2014 AMV Intercomparison Study Report (Comparison of NWC SAF/HRW AMVs with AMVs from other producers)

4 July 2014

David Santek[1], Javier García-Pereda[2], Chris Velden[1], Iliana Genkova[3], Steve Wanzong[1], Dave Stettner[1], Max Mindock[1]

[1]Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin-Madison
Madison, Wisconsin, USA

[2]NWC SAF/AEMET
Madrid, Spain

[3]IMSG
NOAA/NCEP
Washington, D.C., USA

Table of Contents

1. Abstract

Previous Atmospheric Motion Vector (AMV) intercomparison studies, conducted from 2007 to 2009, compared the operational AMV algorithms of various satellite-derived wind producers using a common set of MSG/SEVIRI images and ancillary data. The studies assessed how the cloudy AMVs from the unique wind producers compared in terms of coverage, speed, direction, and cloud height (Genkova et al. 2008; Genkova et al. 2010).

The goal of this new study is to:

- Include the NWC SAF/HRW algorithm in the intercomparison study in order to quantify its performance relative to the other AMV algorithms.
- Update the results of the previous AMV intercomparison studies because many of the operational AMV algorithms have changed since the last study.
- Perform follow up studies as identified in the previous intercomparison work, such as considering specific characteristics of the input data and AMV output.

2. Motivation

This project seeks to quantify the quality and identify unique attributes of the NWC SAF/HRW (High Resolution Winds) product with respect to AMVs provided by other operational centers. The results will guide new developments and enhancements for future updates to the NWC SAF/HRW algorithm.

3. Case Study

The case study for the AMV experiments is a triplet of infrared (10.8μ) Meteosat-9, full–disk images from 17 September 2012 at 1200, 1215, 1230 UTC (Figure 3-1).

Additionally, both 6.3μ, 7.2μ, 12.0μ and 13.4μ images and MPEF output products "Scene Type and Quality" and "Cloud Analysis" for the same slots were also provided in case AMV producers would like to use them for the AMV Height assignment procedure in Experiment 4.

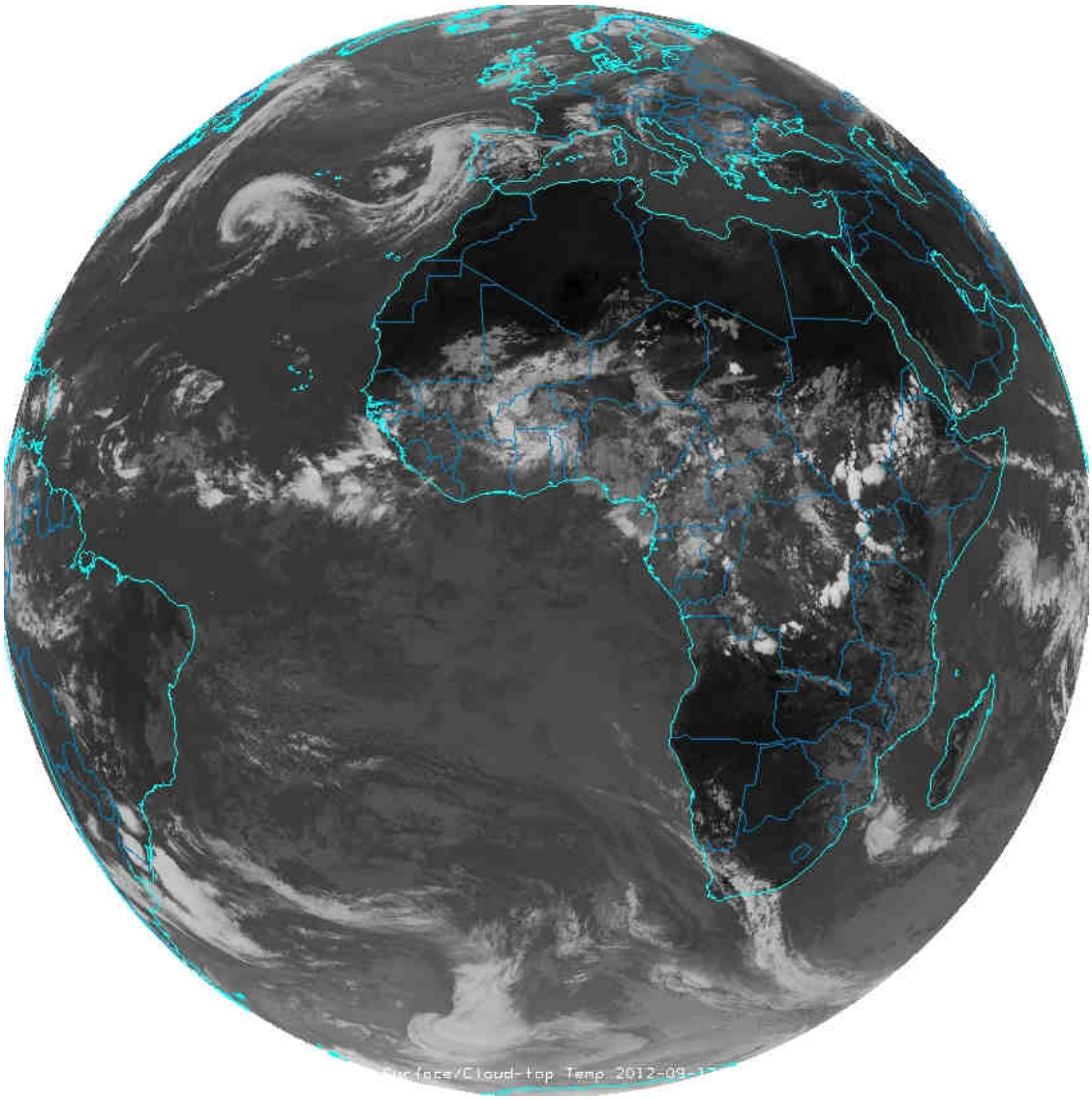


Figure 3-1: Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

4. Overview

The output provided by the winds producers has been analyzed for four experiments, each of which is located in a separate section, including text from the proposal describing the experiment, the approach used in the analysis, highlights of the results, and figures and tables supporting the results. Text that is in *italics* is extracted directly from the CIMSS proposal.

The approach taken began with the scripts used in the previous intercomparison studies, resulting in plots and statistics that can be compared and contrasted with the previous work (Genkova et al. 2008, 2010).

In this new effort, an additional analysis has been performed with a goal to quantify the differences in terms of statistical significance. This has been done using a paired t-test. While the Standard (Student's) t-test determines the likelihood a statistically significant difference exists between two datasets, a paired t-test assumes data points from the two different datasets are related. For example, a paired t-test is often used to compare before-and-after datasets because each "before" data point is paired with a specific "after" data point. In our case, each data point from center X has been paired, by having both latitude and longitude coordinates within a specified distance, with its corresponding data point from center Y. For each of the comparisons, paired t-tests have been calculated for several variables in each experiment in order to compare every combination of centers, with a 95% confidence setting.

5. Input Data Files

Each wind producer provided files containing the results of the experiments with the same parameters using a text file format. The text files contained 'semicolon' separated values, which were converted to 'space' separated values for easier reading by Matlab, Python, and bash scripts. The wind producers are:

- BRZ: Brazil Weather Forecast and Climatic Studies Center
- CMA: China Meteorological Administration
- EUM: EUMETSAT (European Organization for the Exploitation of Meteorological Satellites)
- JMA: Japan Meteorological Agency
- KMA: Korea Meteorological Administration
- NOA: National Oceanic and Atmospheric Administration
- NWC: NWC SAF (Satellite Application Facility on Support to Nowcasting & Very Short Range Forecasting)

The three-letter abbreviations above are used throughout the remainder of this report. The variables reported by the centers were identical:

Table 5-1: Reported Variables

1	IDN	Identification number
2	LAT[DEG]	Latitude
3	LONG[DEG]	Longitude
4	TBOX[PIX]	Target box size
5	SBOX[PIX]	Search box size
6	SPD[MPS]	AMV speed
7	DIR[DEG]	AMV direction
8	P[hPa]	AMV pressure
9	LOWL	Low-level correction
10	GSPD[MPS]	Background guess wind speed
11	GDIR[DEG]	Background guess wind direction
12	ALB[%]	Albedo
13	CORR[%]	Correlation
14	TMET	Brightness temperature
15	PERR[hPa]	AMV pressure error
16	HMET	Height assignment method
17	QINF[%]	QI without forecast
18	QIF[%]	QI with forecast
19	HDISP1	Horizontal pixel displacement for first pair
20	VDISP1	Vertical pixel displacement for first pair
21	HDISP2	Horizontal pixel displacement for second pair
22	VDISP2	Vertical pixel displacement for second pair

with three exceptions:

- BRZ did not report QI with forecast (QIWF).
- CMA did not report QI without forecast (QINF).
- JMA did not report speed for Experiment 1.

The decimal precision of the values varied from centre to centre and is summarized in Table 5-2.
Note: Even though the *precision* reported is not same for all centers, they should be within the expected *accuracy* in the measurements.

Table 5-2: The precision of values in the text files. The last column (Min.) is the minimum precision across all winds producers, for each parameter. This was updated 29 January 2014.

Variable	BRZ	CMA	EUM	JMA	KMA	NOA	NWC	Min.
Latitude	2	2	4+	7+	5	2	4	2
Longitude	2	2	4+	7+	5	2	4	2
Speed	2	2	3+	6+	5	2	2	2
Direction	2	2	3+	6+	5	2	2	2
Height	2	0	3+	6+	5	2	2	0
Model speed	-	-	3	6+	5	2	2	2
Model direction	-	-	3	6+	5	2	2	2
Correlation	2	3	6	8	5	2	2	2
Height error	-	-	0+	-	-	2	2	0

The ancillary data consisted of two ECMWF forecast grids for the 12- and 18-hour forecast from 0000 UTC on 17 September 2012. It was subsected and reformatted by EUMETSAT to the Meteosat-9 domain with the following specifications:

- 135x135 grid centered at 0°N/O°E
- Domain: 67° S to 67° N; 67° E to 67° W
- 1° spatial resolution
- 40 vertical levels
- Parameters: pressure, geopotential height, temperature, water vapor mixing ratio, ozone mixing ratio, wind speed, wind direction, and dew point temperature.

Note: The NOAA AMV processing software requires additional parameters. See the NOAA (NOA) section in the Summary of Wind Retrieval Algorithms for more details on the grids used.

6. Summary of Wind Retrieval Algorithms

The descriptions and configurations of the individual wind retrieval algorithms were extracted from information provided by each producer, in response to a questionnaire and follow up questions.

Questionnaire Questions

Question 1:
Which of these situations occurs in your AMV algorithm:
1) The "reference image" is the first in the triplet (the initial one), and the algorithm tries to track the tracers found here forward to the second image, and once again forward to the third image, to calculate the corresponding pair of winds.
2) The "reference image" is the second in the triplet (the middle one), and the algorithm tries to track the tracers found here backwards to the first image and forward to the third image, to calculate the corresponding pair of winds.
3) The "reference image" is the third in the triplet (the last one), and the algorithm tries to track the tracers found here backwards to the second image, and once again backwards to the first image, to calculate the corresponding pair of winds.

Question 2:
What does the AMV latitude/longitude given in the output files mean?
- The lat/lon position of the tracer in the initial, intermediate or final image?
- The mean position of the tracer between the first and the second image, between the second and third image, or between the first and third image?
- Any other possibility?

Question 3:
A positive longitude is located East or West of Meridian 0º?

Question 4:
The speed of the AMV and the speed of the Wind guess have been provided in meters per second?

Question 5:
The AMV intercomparison study asked you to provide the direction of the AMV and the direction of the Wind guess in degrees, considering 0º as a wind blowing from the North, 90º as a wind blowing from the East, 180º as a wind blowing from the South and 270º as a wind blowing from the West. Is this the way you have provided the data?

Question 6:
What does the NWP guess speed/direction in the output files mean? The one, which corresponds to:
- The lat/lon position of the tracer in the initial, intermediate or final image?
- The mean position of the tracer between the first and the second image, between the second and third image, or between the first and third image?
- Any other possibility?

Question 7:
What does the AMV speed and direction in the output files correspond to?
- The speed and direction of the mean vector calculated with the two contributing vectors (the one displacing from the first to the second image, and the displacing from the second to the third image)?
- The speed and direction of the first or second contributing vector?
- Any other possibility?

Question 8:
What does the pressure, pressure error, and correlation in the output files correspond to?
- The mean value of the pressure/pressure error/correlation, considering the two contributing vectors?
- The pressure/pressure error/correlation related to the first or second contributing vector?
- Any other possibility?

Question 9:
In the horizontal displacements in pixels (defined basically for dataset one), does a positive value mean a displacement from the West to the East?

Question 10:
In the vertical displacements in pixels (defined basically for dataset one), does a positive value mean a displacement from the South to the North?

Questionnaire Response Key

Table 6-1: Questionnaire Response Key

Question	Key
1	1=The "reference image" is the first in the triplet (the initial one), and the algorithm tries to track the tracers found here forward to the second image, and once again forward to the third image, to calculate the corresponding pair of winds. 2=The "reference image" is the second in the triplet (the middle one), and the algorithm tries to track the tracers found here backwards to the first image, and forward to the third image, to calculate the corresponding pair of winds. 3=The "reference image" is the third in the triplet (the last one), and the algorithm tries to track the tracers found here backwards to the second image, and once again backward to the first image, to calculate the corresponding pair of winds.
2	1(a,b,c)= The lat/lon position of the tracer in (a) the initial, (b) the intermediate, or (c) the final image. 2(a,b,c)= The mean position of the tracer between (a) the first and the second image, between (b) the second and third image, or between (c) the first and third image. *= Any other possibility.
3	0=East, 1=West
4	1=Yes, *=Any other possibility
5	1=Yes, *=Any other possibility.
6	1(a,b,c)= The lat/lon position of the tracer in (a) the initial, (b) the intermediate, or (c) the final image. 2(a,b,c)=The mean position of the tracer between (a) the first and the second image, between (b) the second and third image, or between (c) the first and third image. *=Any other possibility.
7	1=The speed and direction of the mean vector calculated with the two contributing vectors (the one displacing from the first to the second image, and then displacing from the second to the third image). 2(a,b)=The speed and direction of the first (a) or second (b) contributing vector.
8	1= The mean value of the pressure/pressure error/correlation, considering the two contributing vectors. 2(a,b)= The pressure/pressure error/correlation related to (a) the first or (b) the second contributing vector. *=Any other possibility.
9	0=No, 1=Yes
10	0=No, 1=Yes

Questionnaire Responses

Table 6-2: Questionnaire Responses. Cells marked with * have the centers answer quoted below.

Question	BRZ	CMA	EUM	JMA	KMA	NOA	NWC
1	2	2	1	2	2	2	1
2	1b	2b	2c	1b	1b	1b	1b
3	0	0	0	0	0	0	0
4	1	*	1	1	1	1	1
5	1	*	1	1	1	1	1
6	*	*	1b	*	1b	1b	1b
7	2b	2b	1	2b	1	1	1
8	2b	2b	*	*	*	*	1
9	1	1	1	1	1	1	1
10	1	0	1	1	1	0	1

Question 4:

CMA: "The speed of the AMV has been provided in meters per second. The speed of the wind guess was not provided. As a matter of fact, in our AMV derivation algorithm, the wind guess is not used at all."

Question 5:

CMA: "Yes, but we only provided the direction of the AMV."

Question 6:

BRZ: "Our algorithm did not use NWP first guess."

CMA: "We didn't provide the NWP guess speed/direction in the output files."

JMA: "We did not use the wind guess for the tracking."

Question 8:

EUM: "These values are, again, the average of those in the two intermediate products."

JMA: "Pressure: just pressure in hPa; Pressure error: we have handled pressure error; Correlation: maximum correlation on matching surface."

KMA: "Pressure was given from target in reference image. Correlation in output file is mean value from two fields."

NOA: "I will only speak to the pressure that we report when our full processing is turned on. This is the median pressure associated with the pixels in both sets of vectors that contribute to the tracking solution. Same with the height assignment pressure error. However, the pressure error is an upstream product that we carry along, but don't compute. We output an individual correlation coefficient for each vector. For this study, we simply averaged the two together to report one value."

Additional follow up questions were used to update the configuration settings and to document how the Quality Indicator (QI) was computed. These are summarized in Table 6-3 to Table 6-5.

Table 6-3: Summary of winds algorithm configuration settings.

AMV Provider	Steps Subsequence	Target Box	Search Box	Target Selection
BRZ	Target, track, height assign.	32X32 pix	50X50 pix	No Threshold
CMA	Target, track, height assign.	32X32 pix	96X96 pix	No Threshold
EUM	Target, height assign., track	24X24 pix	80X80 pix	No Threshold
JMA	Target, track, height assign.	16X16 pix	64X64 pix	No Threshold
KMA	Target, track, height assign.	24X24 pix	30X30 pix	5 Kelvin
NOA	Target, height assign., track	19X19 pix	39X39 pix	7 bright. Units
NWC	Target, track, height assign.	24X24 pix	72X72 pix	Two methods: - Gradient (using BT value and contrast thresholds) - Tr. Characteristics (based on the definition of a frontier in the BT histogram and a test on BT variability inside the tracer)

Table 6-4: Summary of winds height algorithm, the use of NWP wind guess, and whether image scan time is used.

AMV Provider	Height	Wind Guess?	Image scan time?
BRZ	10% coldest pixels Average of intermediate products	No	Yes
CMA	CCij averaged values When using IR: 5% coldest pixels Middle image considered only	No	Yes
EUM	CCC method with MPEF/CLA product When using IR: Target area divided into scenes; coldest scenes used to define EBBT as an arithmetic mean. Average of intermediate products	No	No, nominal image time used.
JMA	10% coldest pixels Average of intermediate products	No	Yes
KMA	15% coldest pixels Average of intermediate products	Yes	No, nominal image time used.
NOA	25% coldest pixels Middle image considered only	Yes	No, nominal image time used.
NWC	CCC method with MPEF/CLA or NWC SAF/Cloud products When using IR: BT of coldest class in temp; histogram with at least 3 pixels after histogram smoothing Average of intermediate products	No	No, nominal image time used.

Table 6-5: Summary of winds algorithm QI calculation settings.

<table>
<tr><th>AMV Provider</th><th>QI Implementation</th><th>QI Consistency Tests</th><th>QI Weights</th></tr>
<tr><td>BRZ</td><td>Single band, average interm. prod.</td><td>Forecast, height, temporal vector, and spatial vector.</td><td>FCST=1, Vector(T)=2, Vector(S)=2. Then, weighted average is multiplied by height to give the final QI.</td></tr>
<tr><td>CMA</td><td colspan="3">Based on formula:
$$B_{m,k} = \frac{1}{6}\left\{\left(\frac{U_m - U_{i,j}}{W_U}\right)^2 + \left(\frac{V_m - V_{i,j}}{W_V}\right)^2 + \left(\frac{T_m - T_{i,j}}{W_T}\right)^2 + \left(\frac{P_m - P_{i,j}}{W_P}\right)^2 + \left(\frac{S_m - S_{i,j}}{W_S}\right)^2 + \left(\frac{D_m - D_{i,j}}{W_D}\right)^2\right\}$$
where U,V : wind component (m/s)
T: temperature (degree)
P: pressure (hPa)
S: wind speed (m/s)
D: wind direction (degree)
W: weights
m: AMV index
i,j: NWP grid index; interpolation of NWP data to AMV level, and selection of nearest index

<table>
<tr><th rowspan="2">AREA</th><th colspan="6">WEIGHTS</th></tr>
<tr><th>WU (m/s)</th><th>Wv (m/s)</th><th>Wt (℃)</th><th>Wp (hPa)</th><th>Ws (m/s)</th><th>Wd (o)</th></tr>
<tr><td>NH</td><td>4.1</td><td>3.8</td><td>10.0</td><td>150</td><td>4.0</td><td>30</td></tr>
<tr><td>TR</td><td>2.2</td><td>2.0</td><td>10.0</td><td>80</td><td>3.2</td><td>40</td></tr>
<tr><td>SH</td><td>3.6</td><td>3.0</td><td>10.0</td><td>150</td><td>4.2</td><td>25</td></tr>
</table></td></tr>
<tr><td>EUM</td><td>Single band, average interm. prod</td><td>Forecast, height, temporal vector, and spatial vector.</td><td>FCST=1, Vector(T)=2, Vector(S)=2. Then, weighted average is multiplied by height to give the final QI.</td></tr>
<tr><td>JMA</td><td>Single band, second interm. prod.</td><td>Forecast, temporal vector, temporal direction, temporal speed, and spatial vector</td><td>FCST=1, Vector(T)=1 Direction(T)=1, Speed(T)=1, Vector(S)=2.</td></tr>
<tr><td>KMA</td><td>Single band, average interm. prod.</td><td>Forecast, temporal vector, temporal direction, temporal speed, and spatial vector.</td><td>FCST=1, Vector(T)=1, Vector(S)=1</td></tr>
<tr><td>NOA</td><td>All bands, one final QI.</td><td>Temporal vector, temporal direction, temporal speed, and spatial vector.</td><td>Vector(T)=1, Direction(T)=1, Speed(T)=1, Vector(S)=2</td></tr>
<tr><td>NWC</td><td>Single band, average interm. prod</td><td>Forecast, height, temporal vector, and spatial vector</td><td>FCST=1, Vector(T)=3, Vector(S)=3. Then, weighted average is multiplied by height to give the final QI.</td></tr>
</table>

All AMV producers are using EUMETSAT Quality Control except CMA, which uses a specific procedure. The Quality Control tests and weights are nevertheless different for each center.

The following algorithm descriptions provide additional information that did not fit into the above tables.

a) EUMETSAT (EUM)

The 'standard' configuration (Exp. 2) and 'prescribed' configuration (Exp. 3) for EUMETSAT were identical.

b) China Meteorological Administration (CMA)

Subpixel interpolation: *We activated the "subpixel tracking" in experiment 1. Our algorithm for the "subpixel tracking" is defined as: A pixel(col,row) with maximum correlation coefficient in search box is found. In column direction of pixel(col,row), a parabolic fitting is calculated with five pixels: (col,row-2), (col,row-1), (col,row), (col,row+1), (col,row+2). The position of the parabola vertex is the "subpixel tracking" result of column. In row direction five pixels: (col-2,row), (col-1,row), (col,row), (col+1,row), (col+2,row) are used to calculate.*[1]

c) Japan Meteorological Agency (JMA)

Subpixel interpolation: This is done *by using polynomial fitting (f(x,y) = a x^2 + b y^2 + c x + d y + e) for subpixel estimation. Five cross-correlation values locating at center and 4 neighboring grid points are used for determining five coefficients.*[2]

d) NOAA (NOA)

The new algorithm designed for GOES-R, Motion Cluster Tracking (MCtrack), was used to derive AMVs instead of the operational winds package that runs in the NOAA/National Environmental Satellite, Data, and Information Service (NESDIS) operations. MCtrack requires additional parameters over what was provided in the standard grid. Due to the required background grids for MCtrack, grids from ECMWF and NCEP's Global Forecast System (GFS) were combined. The additional grids from the GFS were: surface snow, total ozone, tropopause temperature, tropopause pressure, and the depth of the Planetary Boundary Layer (PBL). The resulting grids were at 25 levels, instead of the 40 levels used by the other providers.

[1] Provided by CMA 24 March 2014

[2] Provided by JMA 23 March 2014

e) Korea Meteorological Administration (KMA)

1. We are using the following multiple linear regression for sub-pix el tracking

$$f(x, y) = \beta_1 + \beta_2 x + \beta_3 y + \beta_4 x^2 + \beta_5 xy + \beta_6 y^2$$

2. As shown in below figure, we are using 8 correlation values neighboring at center which is the location of maximum correlation.

(i-1, j-1)의 corr 값		
	max corr 좌표(i, j)	
		(i+1, j+1)의 corr 값

3. This is example. We can get the final displacement (0.4, 0.2) from this method.

f(-1,-1)=-0.3622	f(0,-1)=0.1178	f(1,-1)=0.0644
f(-1,0)=0.0111	f(0,0)=0.4911	f(1,0)=0.4378
f(-1,1)=-0.1489	f(0,1)=0.3311	f(1,1)=0.2778

$$f(x,y)=0.4911+0.2133x+0.1067y-0.2667x^2+0.0000xy-0.2667y^2$$ [3]

f) NWC SAF (NWC)

Subpixel interpolation: *It is based on a quadratic (second order) interpolation in both lines and columns. In each one of the cases the correlation of three pìxels is taken into account:*

- *In the line fitting: (col,row-1), (col,row), (col,row+1) are taken into account.*
- *In the column fitting: (col-1,row), (col,row), (col+1,row) are taken into account.*[4]

g) Brazilian Meteorological Center (BRZ)

No subpixel technique information was provided.

[3] Provided by KMA 14 April 2014

[4] Provided by NWC SAF 25 March 2014

7. Experiment 1

AMV producers extract IR10.8 channel AMVs considering a triplet of images with a known displacement. This experiment will be used to test the Tracking step in all AMV algorithms.

Since the triplet of images is identical, this experiment will give insight to the behavior of the various tracking algorithms. Each AMV producer has unique code to pattern-match each feature in the target image with the same feature in the other two images. With all the images being identical, the pattern match will be perfect. However, the speed and direction of the feature may not be the same from the different AMV producers, for the following reasons:

a) The differing methods used to identify the target and subsequent best match in the other images. For example, are the target and search boxes even or odd dimensioned; how does that impact identifying the 'center' pixel?

b) The implementation of the image geolocation (line/element => latitude/longitude) may not be exactly the same and could introduce a small difference or bias in tracking.

c) Determining latitude/longitude displacements is usually done using a great circle computation, but some centers may use an approximation to the great circle. This may result in small differences in the speed and direction.

For collocated targets, we will not only examine these 'artificial' AMVs to quantify differences in the tracking algorithms (a), but also attempt to identify differences due to factors (b) and (c)

Experiment 1 Highlights

A fixed displacement of four elements and two lines was applied to a single image in order to create an artificial triplet. This tests the tracking differences between the data producers.

There were two positive results:

- All AMV algorithms detected this shift correctly, generally with no more than 0.1-pixel difference (related to subpixel tracking turned on). See Figure 7-1 to Figure 7-7.
- There were 10876 collocated vectors when using a distance threshold of 35 km. The differences of horizontal and vertical displacements between EUM and each of the other centers were not statistically significant (Table 7-1 and Table 7-2).

Two sites, BRZ and CMA, appear to have an AMV speed dependence on distance from satellite subpoint (Figure 7-10 and Figure 7-14), which may be due to the way to compute distance (BRZ) or to truncation in speed (CMA). Both centers are investigating this behaviour.

a) Approach

The text files contained line and element displacements of the tracked features. Since the images were artificially displaced by a constant of four elements and two lines, it was expected that the text files would contain the constant shift. Generating histograms of the line and element displacements and computing the mean of the displacements from each producer verified this.

To further quantify, collocated AMVs were examined with the expectation that the speed and direction of the collocated AMVs would be nearly the same. Any differences noted would most likely have been due to (b) and (c) above, and/or how the final vector was determined (average of two intermediate vectors, second vector, etc.). Differences due to computing the distance from latitude/longitude displacements (c) can be explained if the producers use different methods (great circle vs. an approximation). Differences due to geolocation computation (b) would be difficult to determine since we do not have the image line/element position corresponding to the latitude/longitude of the AMV.

A statistical analysis of the differences for collocated AMVs of pixel displacement, speed, and direction was performed to determine if the differences were significant. Any significant differences found here were used to help explain findings in the subsequent experiments.

b) Pixel displacement distributions

Each center reported pixel displacement for tracking the artificially shifted images in terms of a horizontal and vertical displacement. This was done for each image pair of the triplet. In the following figures, HDISP1 and HDISP2 are the horizontal displacements and VDISP1 and VDISP2 are the vertical displacements for image pair one and two. The sign of the displacements is dependent on which image was used for targeting: first image vs. middle image, or middle image vs. third image, and on how the line and element scheme is defined in each algorithm (South to North or vice versa, West to East or vice versa).

The images were shifted by four elements and two lines, for a total displacement of eight elements and four lines between images one and three. Histograms of each displacement are shown in Figure 7-1 through Figure 7-7. Three centers (EUM, CMA, BRZ) reported all displacements exactly as shifted.

NOA and NWC also detected the shift correctly; however they had a very small percentage of outliers. For NOA, the outliers were due to a software error, which has since been corrected. For NWC, the outliers were due to the "Quick correlation method" used by HRW algorithm (Xu and Zhang 1996), in which the correlation is initially calculated for only one of every eight pixels, and later refined to all pixels around the correlation maxima. This method substantially reduces the algorithm running time, which is necessary for running in minimal computing environments, while only causing incorrect tracking for approximately 0.05% of all AMVs.

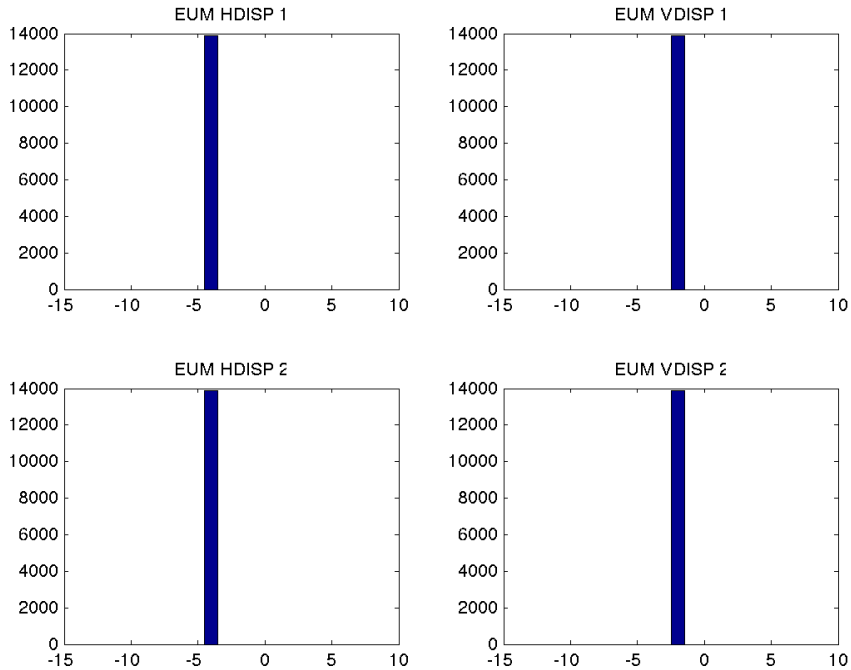


Figure 7-1: EUM: 13890 AMVs. Shift detected correctly for all.

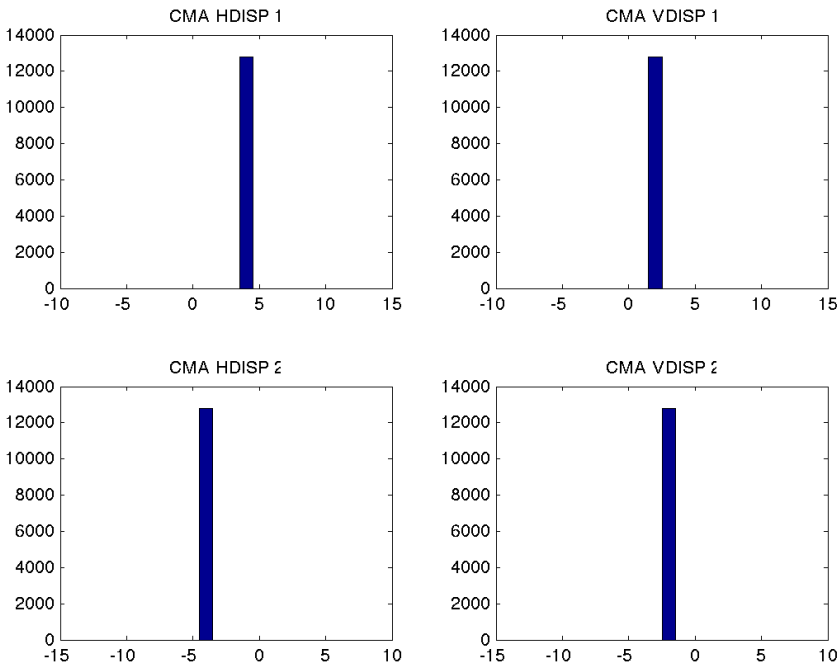


Figure 7-2: CMA: 12769 AMVs. Shift detected correctly for all.

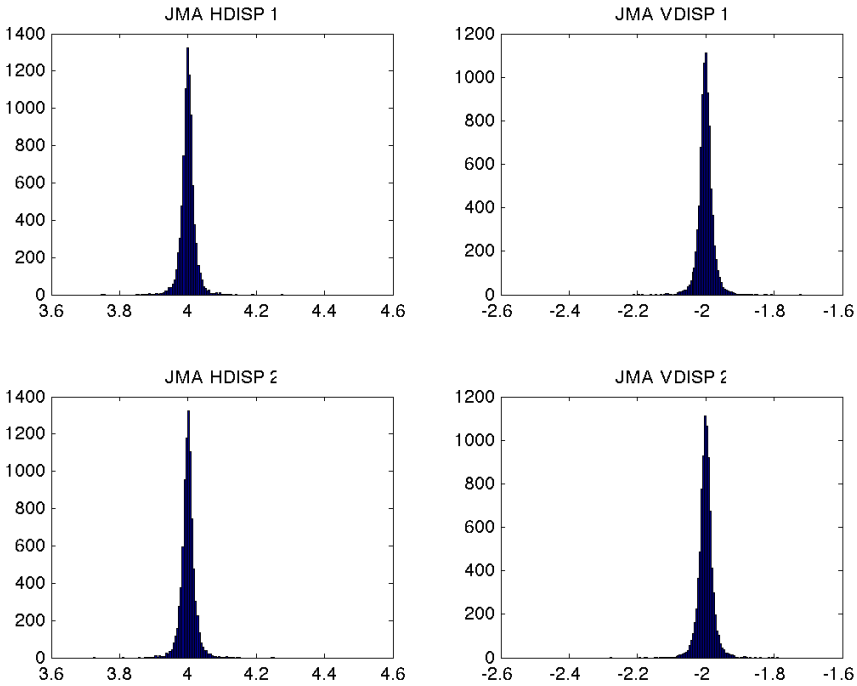


Figure 7-3: JMA: 8540 AMVs. Subpixel variations are nearly all within 0.1 pixels of the mean.

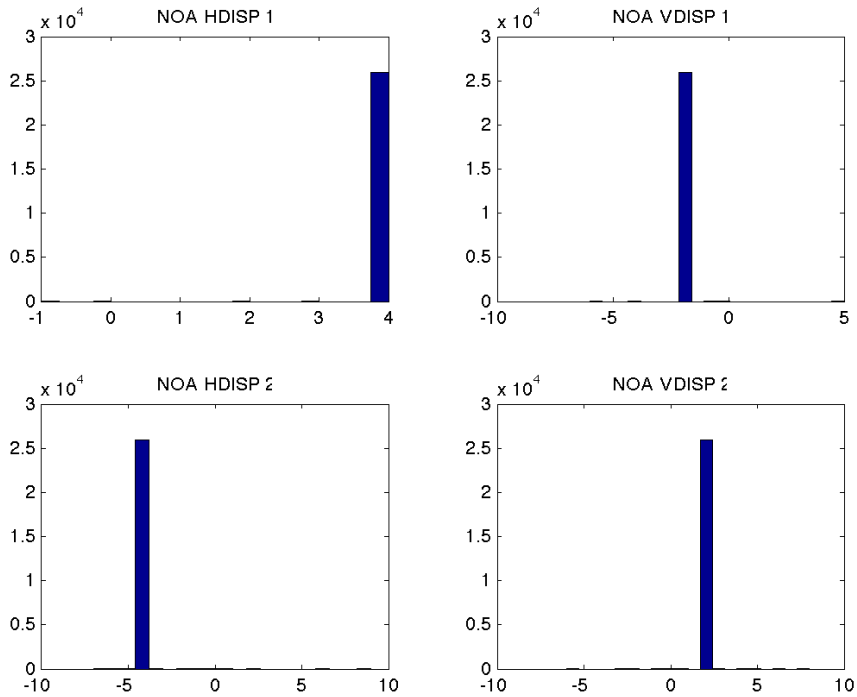


Figure 7-4: NOA: 25958 AMVs. Nearly all displacements are correct, however, there are some outliers

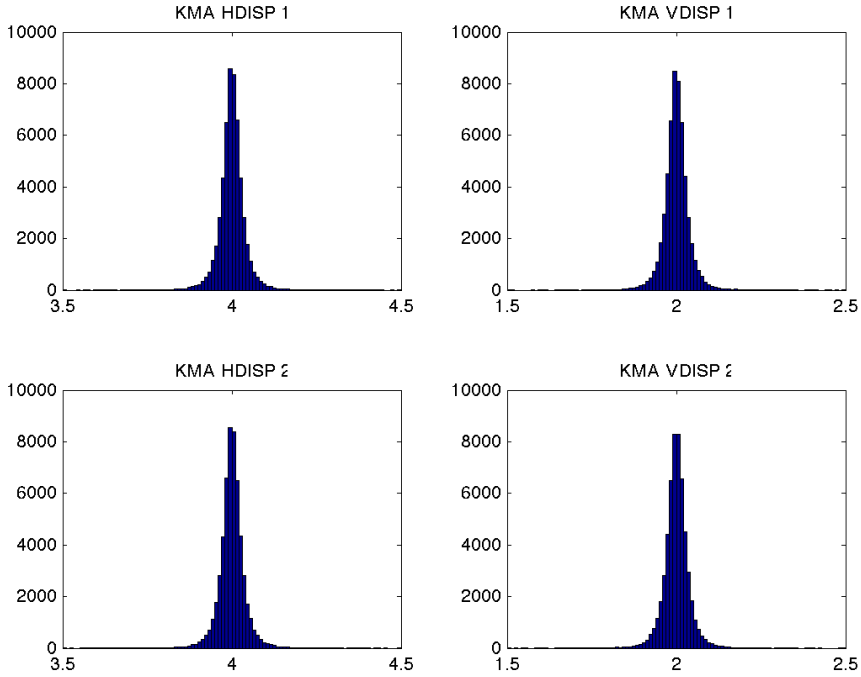


Figure 7-5: KMA: 55200 AMVs. Subpixel variations are all within 0.1 pixels of the mean.

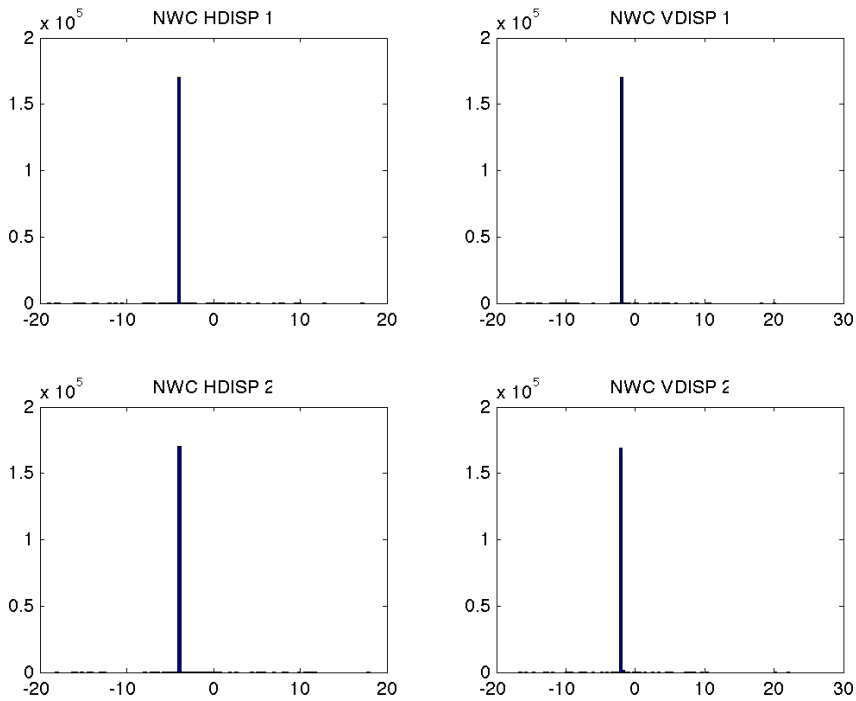


Figure 7-6: NWC: 170775 AMVs. Nearly all displacements are correct, however, there are some outliers.

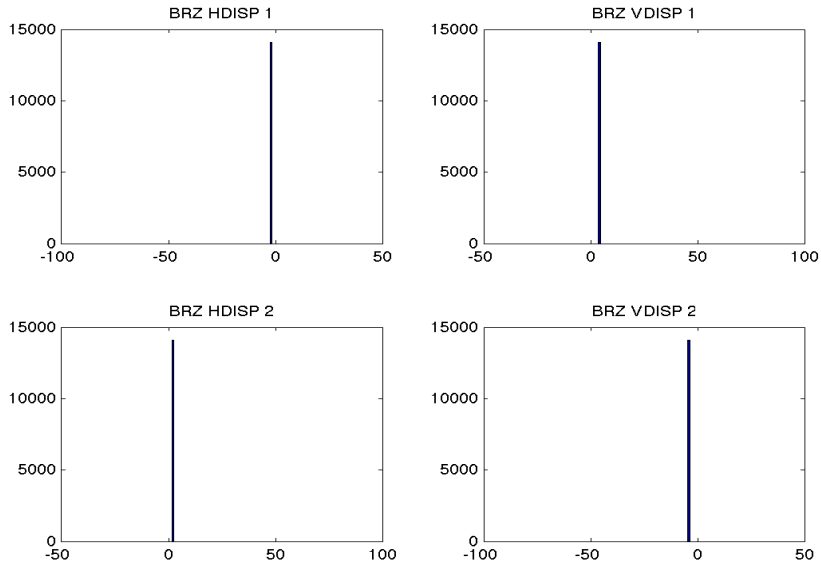


Figure 7-7: BRZ: 14116 AMVs. Shift detected correctly for all

c) Collocation differences

The distribution of pixel displacements in the previous section found only very small deviations (generally less than 0.1 pixel) from the true displacement. But, how does a 0.1 pixel shift translate into velocity? For Meteosat-9, a one-pixel shift, as measured using the Man computer Interactive Data Access System (McIDAS), is:

- 3 km at the satellite subpoint.
- 12 km at 50°N 50°W.
- 33 km at 60°N 60°W .

To convert km/(15 minutes) to ms^{-1}, multiply by: 1.11. Therefore, a 0.1 pixel shift is:

- 0.3 ms^{-1} at the satellite subpoint.
- 1.3 ms^{-1} at 50°N 50°W.
- 3.6 ms^{-1} at 60°N 60°W.

This implies that precise tracking, accurate geolocation, and the computation of distance are essential as even 0.1 pixel error will result in a 0.3 to 3.6 ms^{-1} error in the wind speed, depending on the distance from the satellite subpoint.

Histograms of speed (Figure 7-8) and direction (Figure 7-9) differences (as compared to EUM) were generated for all centers, except JMA, which did not report wind speed. Utilizing a distance threshold of 35 km to define collocation while not filtering QI resulted in 10876 AMVs.

Speed differences between EUM and NOA, KMA, NWC had a zero bias and a range within ±0.2 ms^{-1} (Figure 7-8). However, differences were noted between EUM with CMA and BRZ:

- CMA: There was a 0.5 ms^{-1} slow bias in the CMA AMV speed compared to EUM (upper-left Figure 7-8) and a broader wind direction difference (compared to the other centers) shown in the upper-left of Figure 7-9. Since EUM and CMA reported exactly the same pixel displacements, this speed bias may be due a truncation in the distance calculation.
- BRZ: The frequency plot of AMV speed difference of BRZ-EUM (lower-left Figure 7-8) shows a peak at 0.0 ms^{-1}, however there are two smaller peaks: at +2 ms^{-1} and -2.5 ms^{-1}. As with CMA, the pixel displacements for BRZ are the same as EUM, so this speed (and direction) difference implies an error in calculating distance.

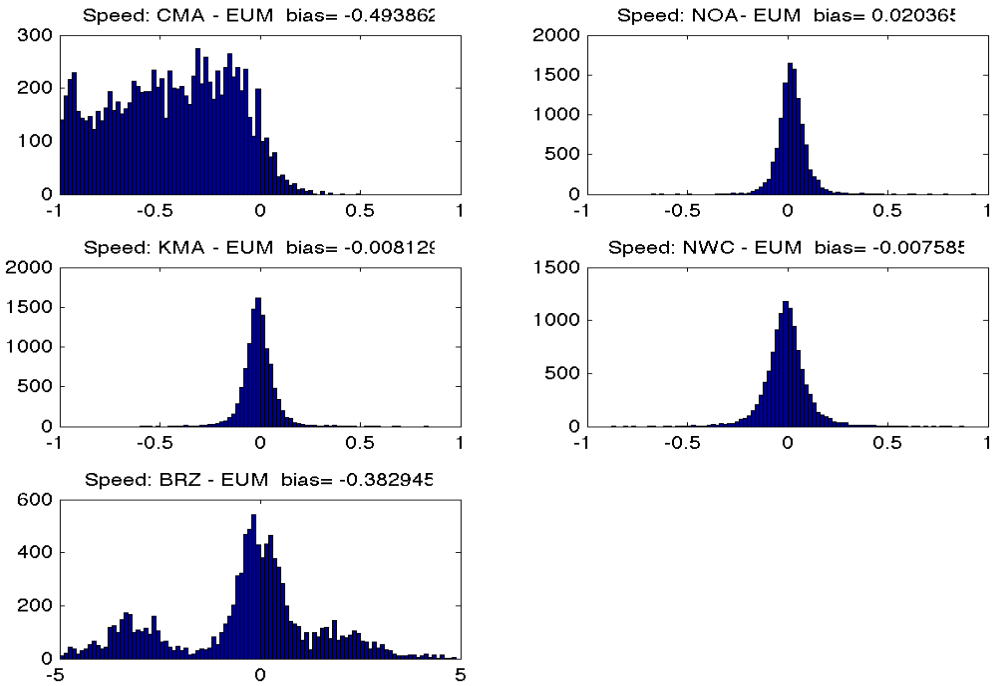


Figure 7-8: Experiment 1 speed difference distribution as compared to EUM. JMA did not provide speed.

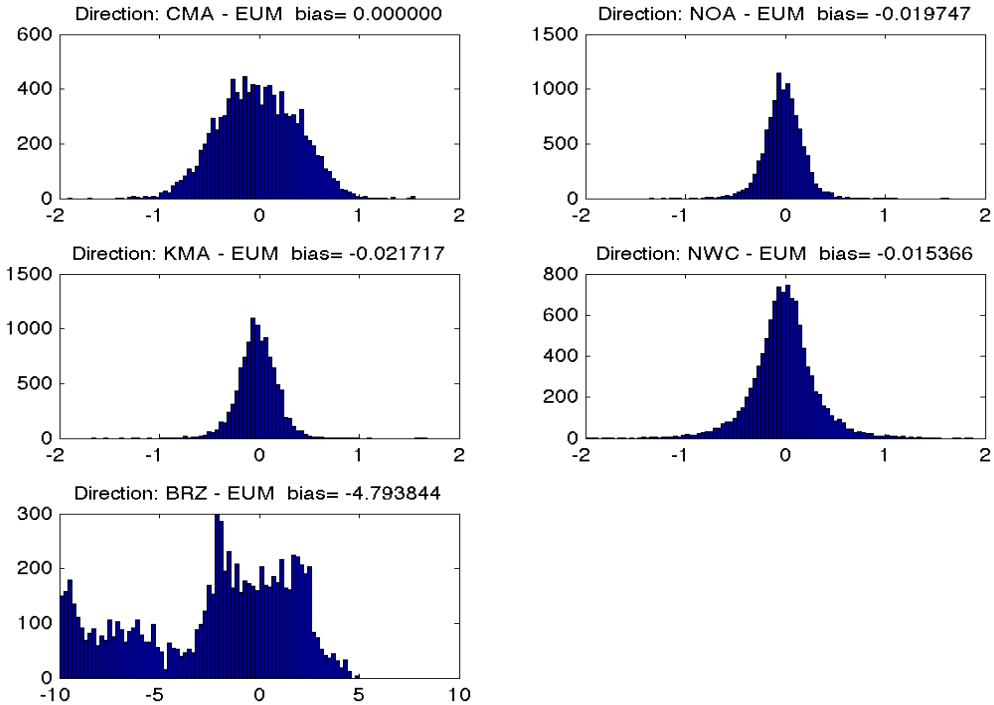


Figure 7-9: Experiment 1 distribution of direction difference as compared to EUM. JMA was not included.

To further investigate reasons for the differences in the speed for BRZ and CMA, scatter plots of the wind speed and direction differences (*centre*-EUM) as a function of latitude and longitude were examined. There was no evidence of latitude or longitude dependency on the speed or direction difference for NWC, NOA, KMA (Figure 7-11, Figure 7-12, and Figure 7-13). However, Figure 7-10 depicts a significant dependence of the speed and direction difference on latitude and longitude between EUM and BRZ. AMV producers at the BRZ centre are investigating the cause of this behavior. Also, the speed difference of CMA-EUM does show some correlation to latitude and longitude (Figure 7-14). Since the difference is nearly all negative values, it may be due to truncation in the distance calculation. CMA is checking on possible reasons for this observation.

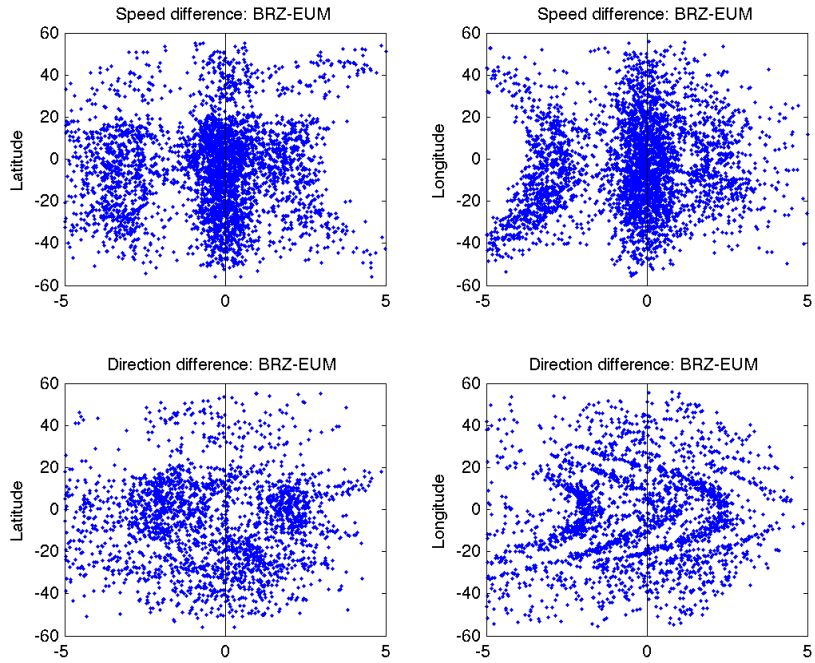


Figure 7-10: Experiment 1: BRZ-EUM differences. Latitude vs. Speed difference (upper-left). Longitude vs. Speed difference (upper-right), Latitude vs. Direction difference (lower-left), Longitude vs. Direction difference (lower-right).

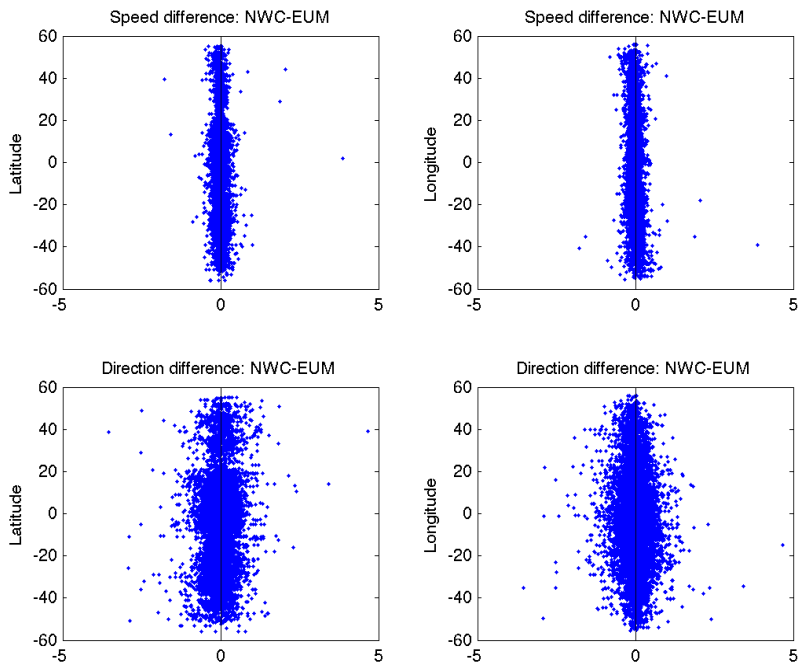


Figure 7-11: Experiment 1: NWC-EUM differences. Latitude vs. Speed difference (upper-left). Longitude vs. Speed difference (upper-right), Latitude vs. Direction difference (lower-left), Longitude vs. Direction difference (lower-right).

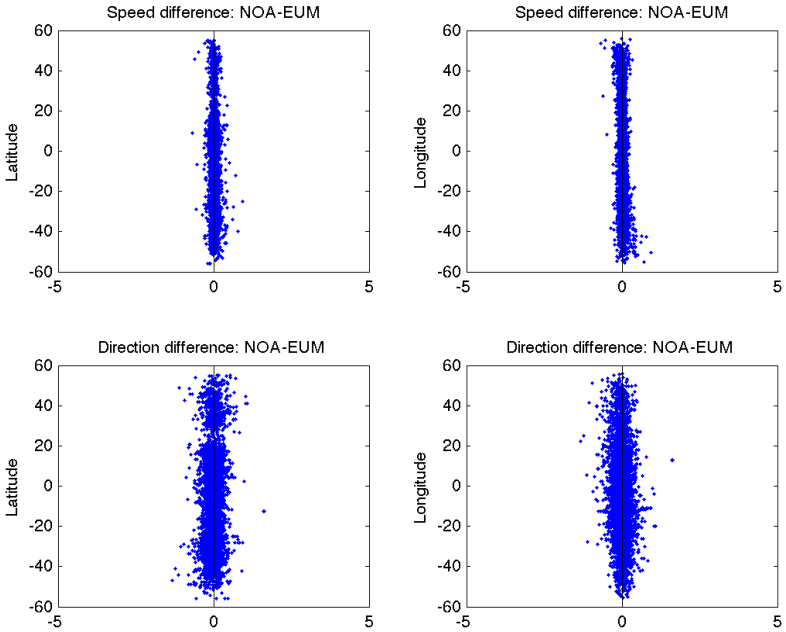


Figure 7-12: Experiment 1: NOA-EUM differences. Latitude vs. Speed difference (upper-left). Longitude vs. Speed difference (upper-right), Latitude vs. Direction difference (lower-left), Longitude vs. Direction difference (lower-right).

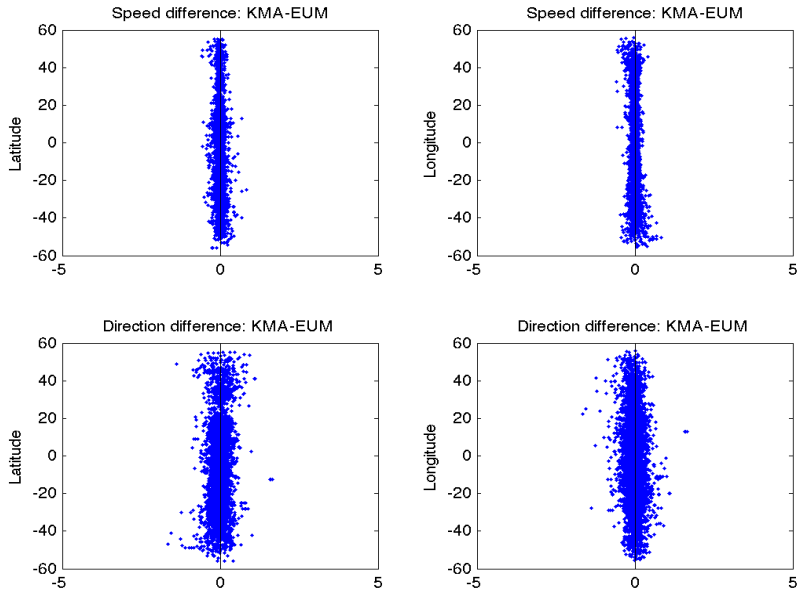


Figure 7-13: Experiment 1: KMA-EUM differences. Latitude vs. Speed difference (upper-left). Longitude vs. Speed difference (upper-right), Latitude vs. Direction difference (lower-left), Longitude vs. Direction difference (lower-right).

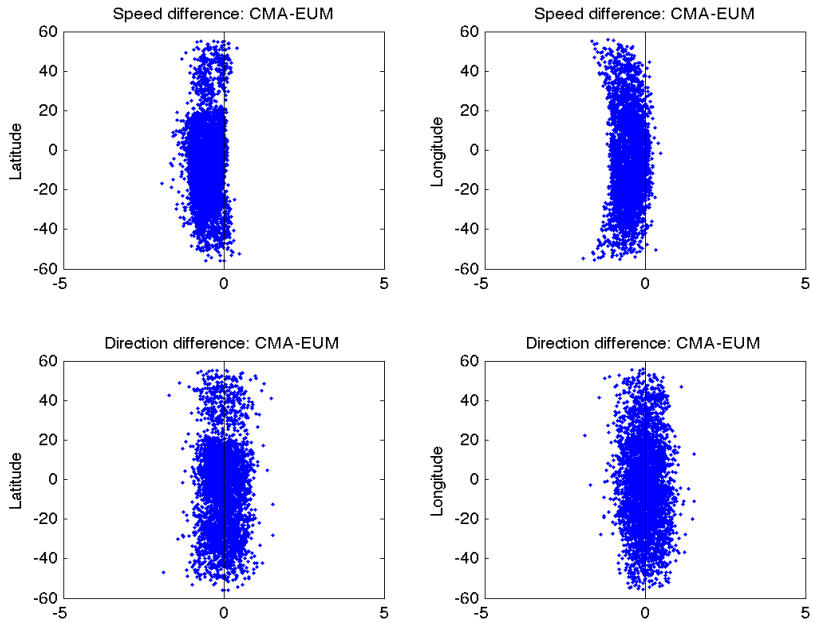


Figure 7-14: Experiment 1: CMA-EUM differences. Latitude vs. Speed difference (upper-left). Longitude vs. Speed difference (upper-right), Latitude vs. Direction difference (lower-left), Longitude vs. Direction difference (lower-right).

d) Statistical comparison

To quantify the observed differences in the previous plots, a paired t-test was used with all combinations of producers and parameters to determine if the differences were statistically significant for collocated AMVs. This was done because there is no 'ground truth' for AMVs and one of the goals of the project is to determine the similarity in the AMVs from the different centers.

The statistics were computed using the Matlab "*ttest*" function, which performs a t-test of the hypothesis that the data come from a distribution with mean zero (see Appendix C: t-test Results for more details). The data in this case were differences between the parameters from each pair of data producers; therefore, a mean of zero is expected. In the following tables, green indicates no statistical difference between the centers at the 95% confidence level and red symbolizes a statistical difference.

All AMVs were considered; there was no filtering based on QI. The distance threshold was 35 km, resulting in 10876 collocated vectors.

For the horizontal and vertical displacements all the algorithms detected the shift correctly (Table 7-1 and Table 7-2): There was no statistical difference between the different centers.

The speed was statistically different between all centers, except for NWC compared to EUM and NOA (Table 7-3). Table 7-4 shows that direction was not statistically different between NWC with EUM, KMA, CMA, NOA and CMA with NOA. Complete output from the t-test can be found in Appendix C: t-test Results: Experiment 1 t-test Results.

Note: NWC SAF provided results for this experiment with subpixel tracking switched on and off. The statistical results were exactly the same between the two. The t-test output with subpixel tracking off is listed at the end of the Experiment 1 t-test Results section.

Table 7-1: Experiment 1 horizontal displacement t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA	BRZ
EUM							
KMA							
CMA							
NOA							
NWC							
JMA							
BRZ							

Table 7-2: Experiment 1 vertical displacement t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA	BRZ
EUM							
KMA							
CMA							
NOA							
NWC							
JMA							
BRZ							

Table 7-3: Experiment 1 speed t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different. JMA did not report speed.

	EUM	KMA	CMA	NOA	NWC	JMA	BRZ
EUM							
KMA							
CMA							
NOA							
NWC							
JMA							
BRZ							

Table 7-4: Experiment 1 direction t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different. JMA was not included.

	EUM	KMA	CMA	NOA	NWC	JMA	BRZ
EUM							
KMA							
CMA							
NOA							
NWC							
JMA							
BRZ							

8. Experiment 2

AMV producers extract IR10.8 channel AMVs considering their standard AMV algorithm configuration, but only using the MSG/SEVIRI IR10.8 images and the ECMWF model data for the Height assignment. This experiment will be used to test the Target selection, Tracking and Quality control steps in all AMV algorithms.

The standard AMV configuration defines target scene size, search scene size, etc. to be the typical settings used by each AMV producers.

For each one of the AMV producer's datasets, a distribution of AMV speed, direction, vector height, and QI will be generated. Differences of these quantities between AMV producers will be made. Also, differences in AMV coverage and number of vectors will be presented as bulk statistics and geographic plots.

Collocated AMVs from the different algorithms will be used to measure the differences. Also, a comparison of the AMVs with the NWP model winds and height assignment investigations using NWP model best fit pressure will be used for verification.

Experiment 2 Highlights

The bulk distribution of AMV height was highly variable among the different centers, which was surprising since they are required to use only the IR brightness temperature. This indicates the variability is likely due to how the representative T_B was determined.

There are 7050 collocated AMVs (QI no forecast > 50). EUM was not statistically different with NWC and JMA and differences among all other centers are usually 0.3 to 1.0 ms^{-1}. Assigned pressures are all statistically different with differences ranging from 30 to 80 hPa. However, the largest differences appear when compared to EUM: up to 130 hPa.

When the AMVs are compared to rawinsondes, NWC has the lowest error while BRZ and EUM have the highest: Vector RMS ranges from 6 ms^{-1} (NWC) to 9 ms^{-1} (BRZ, EUM) and the speed RMS ranges from 4.5 ms^{-1} (NWC) to 7 ms^{-1} (EUM).

For EUM:

- The distribution of AMV heights (high-level winds are too low; low-level winds are too high),
- The large differences of heights compared to other centers, and
- Large errors compared to rawinsondes,

all point to the IR brightness temperature height assignment as not performing well.

Considering collocated data there are not significant changes in the validation statistics. NWC, JMA and KMA show the best results while EUM shows again the worst results.

a) Approach

This experiment tested the target selection and tracking from the different winds producers. The AMVs should have been the best in terms of speed and direction from each producer, as the standard configuration for target and search boxes was used. However, only a single channel was used for cloud height.

This test was similar to Study 1 in many ways (Genkova et al. 2008):

- Only SEVIRI 10.8 µm channel was used for the height assignment.
- Producers used their algorithm and operational settings.
- ECMWF grids were used (although, in the first part of Study 1 the producers used their usual grids).
- Collocated AMVs in Study 1 were within 0.5° of latitude and longitude; in this study the distance was 55 km. Distance provides a more precise collocation, especially in high latitudes.

The Genkova scripts, now including NWC SAF, were used to do similar comparison and analysis as before.

In addition, two new analysis methods were used to quantify any observed differences between producers:

- The best fit analysis was used to further analyze differences in cloud heights.
- Computed paired t-tests were used to determine if the observed differences in collocated AMVs were statistically significant.

b) Parameter distributions

The bulk statistics are presented in both tables and histograms, for QINF >= 50 and QIWF >= 50 (because not all centers reported both QINF and QIWF). Note: Since there were little differences in filtering based on QINF or QIWF, QINF >= 50 will be used for the following discussions (except for CMA which only reported QIWF).

Table 8-1 and Table 8-2 list basic Experiment 2 statistics for the AMVs for each winds producer, without and with forecast quality respectively. The largest variation is in the number of AMVs, ranging from 5000 (CMA) to 91000 (NWC).

Table 8-1: Experiment 2 statistical summary of AMV datasets for QINF >= 50.

	EUM	BRZ	JMA	KMA	NOA	NWC
Total AMVs	12053	7126	6219	48046	11651	90816
QI>=50	9074	2170	5465	40823	10615	75888
SPD_min	2.51	3.06	2.51	2.50	3.00	2.50
SPD_max	78.59	63.00	74.22	60.59	67.30	75.12
SPD_mean	12.50	12.17	11.35	11.90	12.86	12.10
P_min	127.56	19.00	208.68	110.00	138.93	57.41
P_max	1015.02	1000.00	995.88	1000.00	998.35	995.92
P_mean	696.32	591.30	676.19	620.50	508.37	574.97
Low_winds	57.43	47.14	57.31	45.89	21.31	38.68
Mid_winds	32.35	19.12	24.96	32.29	44.58	34.45
High_winds	10.23	33.73	17.73	21.82	34.11	26.88
Low_SPD_min	2.51	3.06	2.51	2.50	3.00	2.50
Low_SPD_max	78.59	39.96	54.92	58.38	27.77	52.05
Low_SPD_mean	9.70	7.75	8.87	9.20	8.55	8.28
Low_P_min	700.04	700.16	850.00	700.01	700.09	700.00
Low_P_max	1015.02	1000.00	995.88	1000.00	998.35	995.92
Low_P_mean	846.41	813.13	866.68	825.78	778.17	785.40
Mid_SPD_min	2.51	3.27	2.51	2.50	3.01	2.50
Mid_SPD_max	77.62	42.78	74.22	60.59	58.15	70.63
Mid_SPD_mean	15.81	10.18	14.43	13.16	11.95	12.17
Mid_P_min	400.08	400.21	400.18	400.01	400.07	400.01
Mid_P_max	699.95	699.94	643.92	699.99	699.80	699.98
Mid_P_mean	546.02	601.94	489.21	552.15	529.06	570.45
High_SPD_min	2.55	3.46	2.51	2.50	3.02	2.50
High_SPD_max	71.68	63.00	60.07	56.96	67.30	75.12
High_SPD_mean	17.73	19.48	15.06	15.70	16.75	17.50
High_P_min	127.56	19.00	208.68	110.00	138.93	57.41
High_P_max	399.92	399.63	399.93	400.00	399.98	399.99
High_P_mean	328.90	275.26	323.72	289.91	312.80	277.99

Table 8-2: Experiment 2 statistical summary of AMV datasets for QIWF >= 50.

	EUM	CMA	JMA	KMA	NOA	NWC
Total AMVs	12053	4920	6219	48046	11651	90816
QI>=50	9260	4915	5161	39215	10276	75055
SPD_min	2.51	3.19	2.51	2.50	3.00	2.50
SPD_max	78.59	76.58	74.22	60.59	67.30	75.12
SPD_mean	12.37	19.79	11.29	12.02	12.86	12.20
P_min	127.56	150.00	208.68	110.00	138.93	57.41
P_max	1015.02	949.00	995.12	1000.00	998.35	995.92
P_mean	695.49	477.82	680.19	620.83	510.56	574.35
Low_winds	57.22	14.73	58.52	45.90	21.78	38.66
Mid_winds	32.42	43.93	23.89	32.35	44.30	34.25
High_winds	10.36	41.34	17.59	21.75	33.92	27.09
Low_SPD_min	2.51	3.19	2.51	2.50	3.00	2.50
Low_SPD_max	78.59	28.51	54.92	42.63	27.77	52.05
Low_SPD_mean	9.65	8.98	8.75	9.24	8.54	8.32
Low_P_min	700.04	700.00	850.00	700.01	700.09	700.00
Low_P_max	1015.02	949.00	995.12	1000.00	998.35	995.92
Low_P_mean	846.30	787.30	866.28	825.61	777.38	786.49
Mid_SPD_min	2.51	3.19	2.51	2.50	3.01	2.50
Mid_SPD_max	77.62	76.58	74.22	60.59	55.56	70.63
Mid_SPD_mean	15.60	17.52	14.52	13.28	11.90	12.27
Mid_P_min	400.08	401.00	400.18	400.01	400.07	400.01
Mid_P_max	699.95	699.00	643.92	699.99	699.80	699.98
Mid_P_mean	546.69	546.19	487.68	551.93	530.59	569.12
High_SPD_min	2.54	3.31	2.51	2.50	3.02	2.50
High_SPD_max	71.68	75.48	60.07	56.96	67.30	75.12
High_SPD_mean	17.33	26.06	15.36	16.01	16.88	17.63
High_P_min	127.56	150.00	208.68	110.00	138.93	57.41
High_P_max	399.92	400.00	399.93	400.00	399.98	399.99
High_P_mean	327.97	294.91	322.69	291.22	313.12	278.18

Appendix A: Parameter Distribution Histograms shows the bulk histograms for each center. Major observations of the AMVs for each centre are listed below:

- BRZ (Figure 14-1): The wind direction (lower-left) is not a smooth distribution. Conversely, it has two very sharp peaks. The AMV pressure distribution (lower-right) has peaks at 300 and 770 hPa. Upper-level winds at 300 hPa are reasonable, but the peak at 770 hPa is most likely too high for low-level clouds.
- EUM (Figure 14-2 and Figure 14-8): The AMV pressure distribution has a peak at 500 and 800 hPa. The upper level winds are too low, while the low-level winds are too high.
- JMA (Figure 14-3 and Figure 14-9): The AMV pressure distribution has a peak at 500 and 850 hPa. The upper level winds are too low, while the low-level winds are placed well. There is also a noticeable gap in mid-level winds.
- KMA (Figure 14-4 and Figure 14-10): The AMV pressure distribution has a peak at 450 and 800 hPa. The upper level winds are too low, while the low-level winds are too high.
- NOA (Figure 14-5 and Figure 14-11): The AMV pressure distribution has a peak at 400 and 780 hPa. The upper level winds are too low, while the low-level winds are too high.
- NWC (Figure 14-6 and Figure 14-12): The AMV pressure distribution has a peak at 400 and 780 hPa. The upper level winds are too low, while the low-level winds are too high.
- CMA (Figure 14-7): The AMV pressure distribution has a peak at 380 and 760 hPa. The upper level winds are too low, while the low level winds are too high. Also, there are many mid-level clouds compared to other centers.

Since only the IR brightness temperature was used in this experiment, the wide variation in cloud heights can be attributed to different techniques and thresholds in determining a representative T_B

c) Collocation plots

AMVs are first quality controlled, retaining only those with a QINF >= 50. For collocation the distance threshold was 55 km, resulting in 7050 AMVs. The following three figures depict the collocated vectors in terms of parameters (from top to bottom: speed direction, pressure, QI, maximum pressure difference between collocated AMVs, and a scatter plot of AMV pressure from each centre pressure vs. EUM AMV pressure).

Note: There are points plotted on the y-axis in Figure 8-3 and Figure 8-6, indicating zero pressure values for EUM AMVs. These zero values are also in the original text files from EUMETSAT.

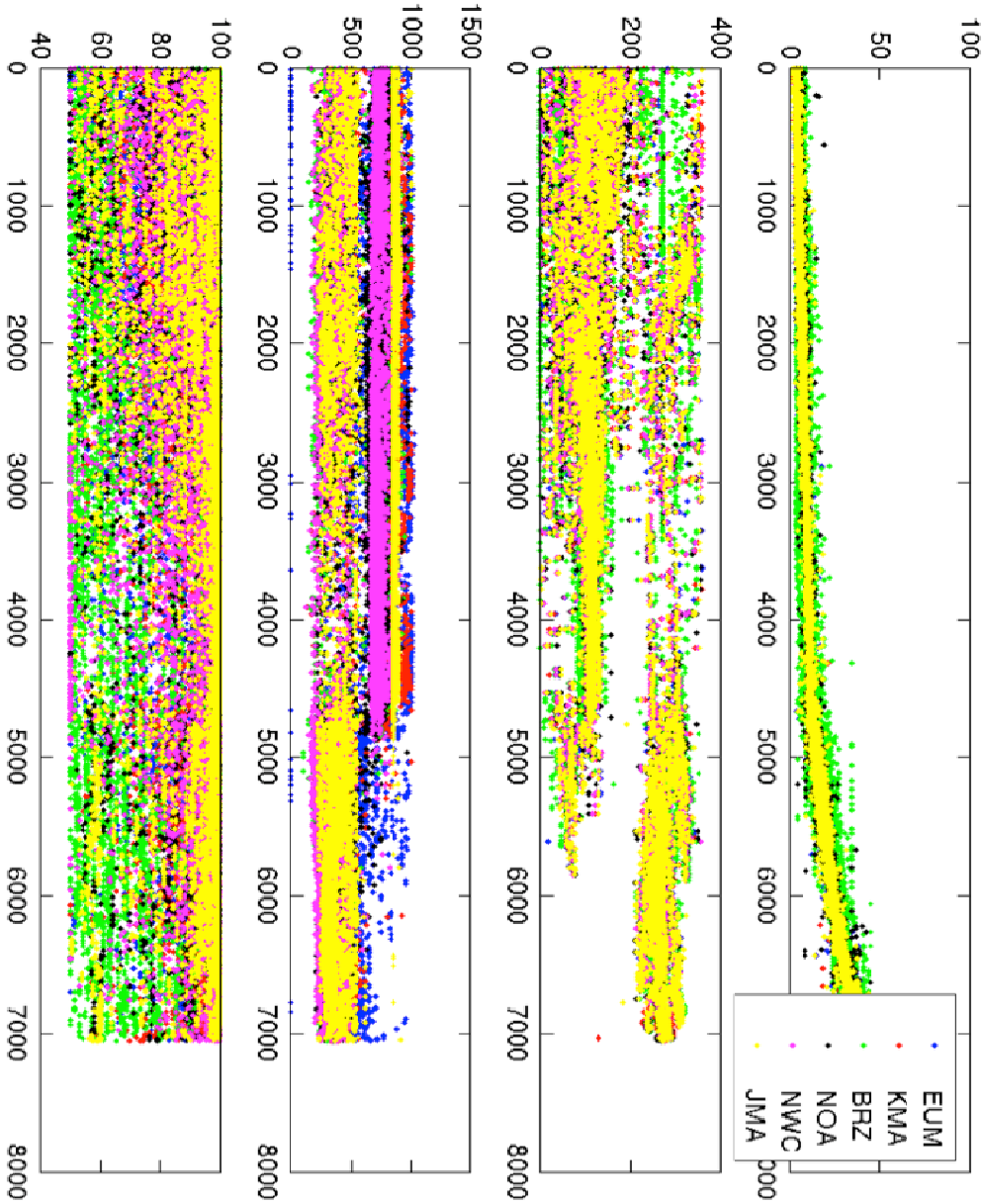


Figure 8-1: Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.

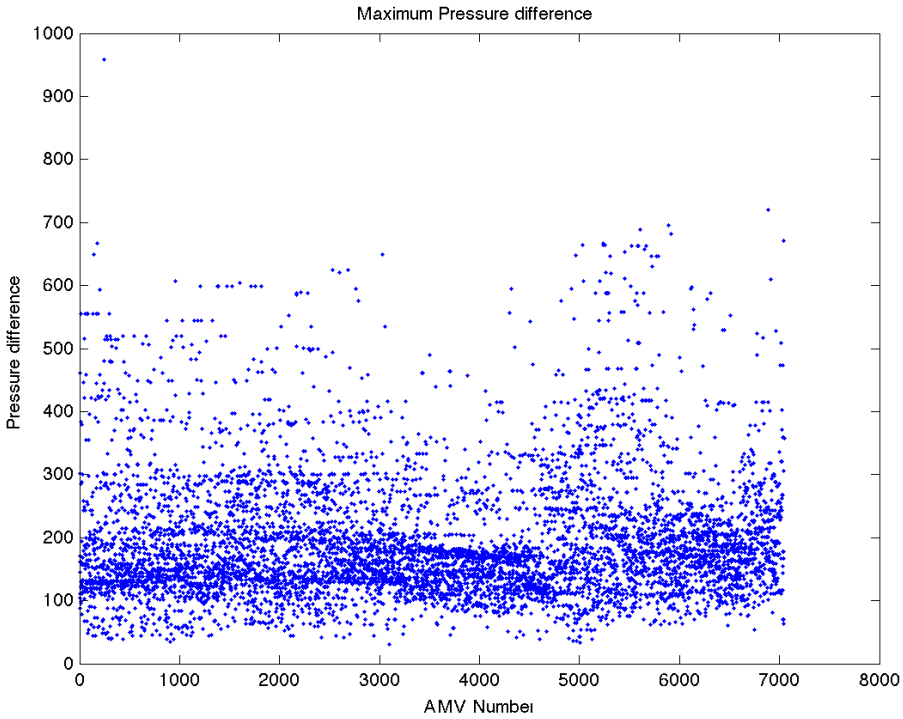


Figure 8-2: The maximum pressure difference between any two collocated AMVs.

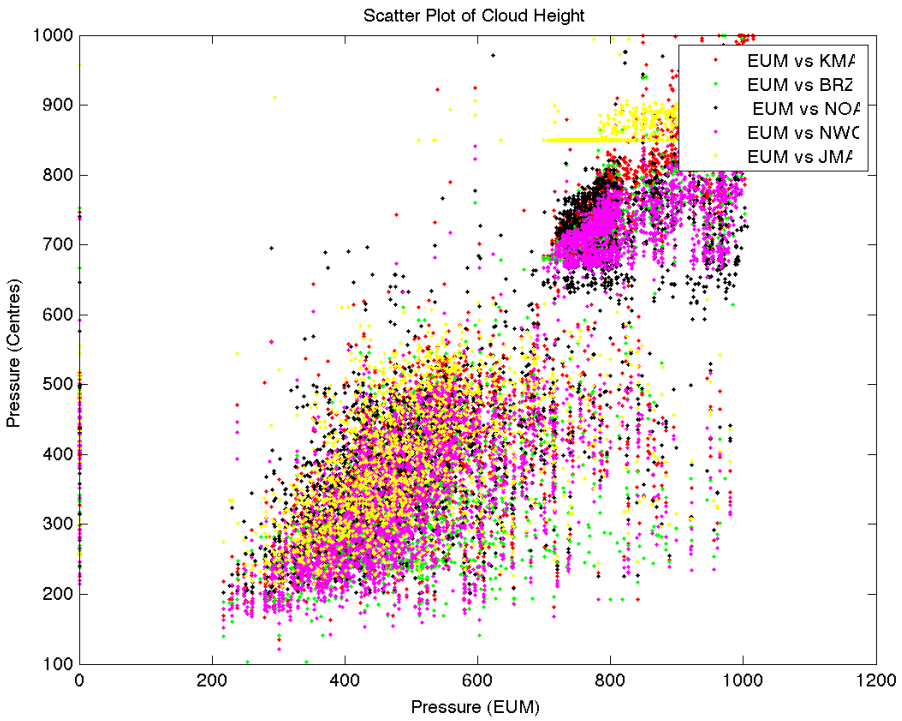


Figure 8-3: Scatter plot of AMV pressure for each center vs. EUM pressure.

A similar comparison was done for AMVs with QI with forecast, retaining only those with a QIWF >= 50. Again, the collocation distance threshold was set to 55 km, resulting in 7050 AMVs.

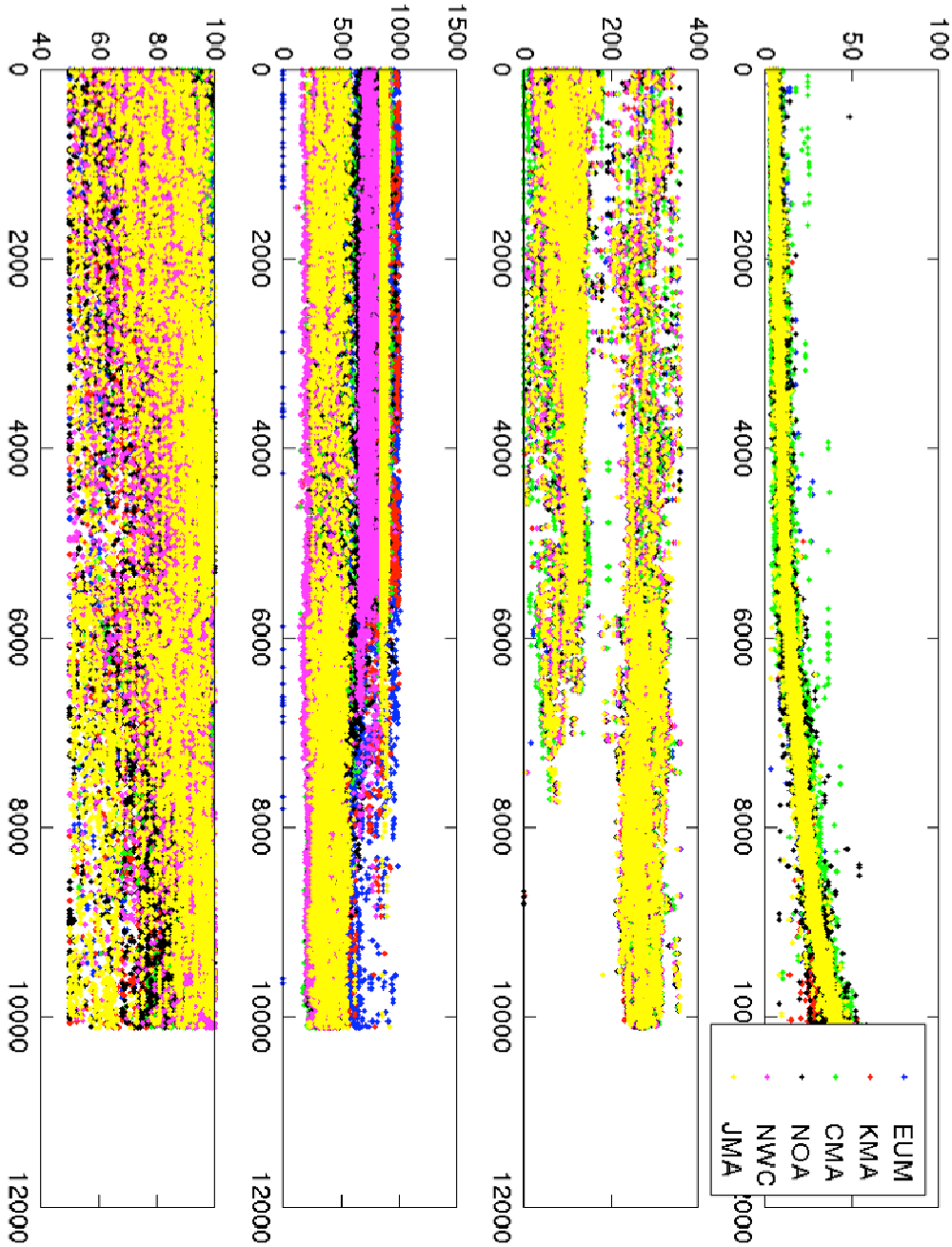


Figure 8-4: Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.

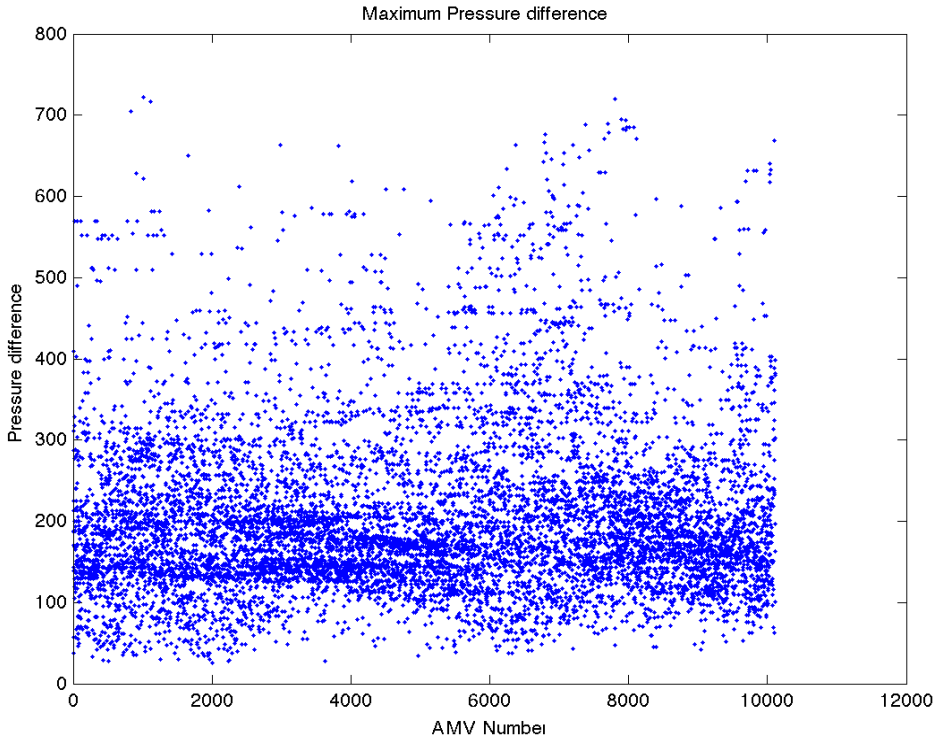


Figure 8-5: The maximum pressure difference between any two collocated AMVs.

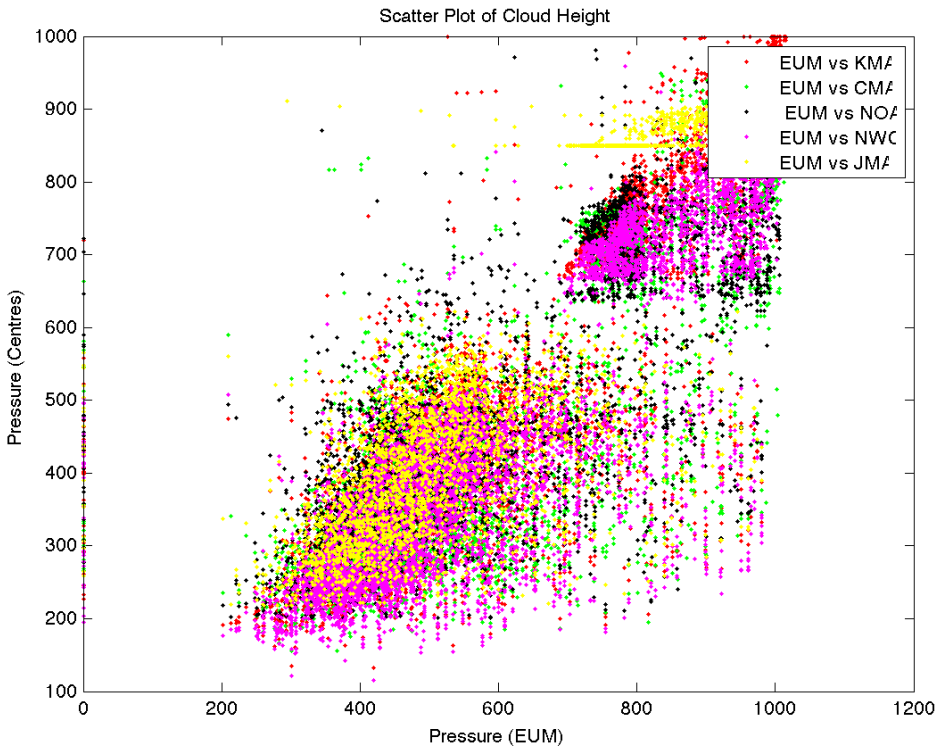


Figure 8-6: Scatter plot of AMV pressure for each center vs. EUM pressure.

d) Rawinsonde comparison

The comparison of all AMVs to nearby rawinsondes is summarized in Table 8-3 (QINF >= 50) and Table 8-7 (QIWF >= 50). Also, the AMVs are grouped into three layers (high, medium, low) for both QINF (Table 8-4 to Table 8-6) and QIWF (Table 8-8 to Table 8-10), and as collocated AMVs for all levels (Table 8-11 and Table 8-12).

Note: The sample is rather small for some AMV producers (the range was from 60 to 2500 AMV matches to rawinsondes).

The vector RMS ranges from 6 ms^{-1} (NWC) to 9 ms^{-1} (BRZ, EUM, CMA) and the speed RMS ranges from 4 ms^{-1} (NWC) to 7 ms^{-1} (EUM, CMA). Since the tracking differences in Experiment 1 were small, these large RMS differences are probably due to the substantial variation in height assignment (see Figure 8-2 and Figure 8-5). This height variation can be explained by the technique used to determine a representative brightness temperature, which is detailed in Table 6-3. The coldest temperature is computed by NWC, followed by CMA, JMA, BRZ, KMA, and NOA. We do not have enough detail of the technique used by EUM to define the brightness temperature used in the height assignment.

There are not substantial differences when collocated data are considered. Vector RMS ranges from 6 ms^{-1} (with NWC, JMA, KMA showing the best results) to 9 ms^{-1} (with EUM showing the worst results). Correspondingly, the speed RMS ranges from 3-4 ms^{-1} (for NWC, JMA, KMA) to 6 ms^{-1} (for EUM). This ranking agrees with the coldest temperatures found for NWC, JMA, and KMA. At the same it might also show issues in the AMV extraction at BRZ and CMA centers which could be related to those discovered in Experiment 1. Meanwhile NOA has the warmest (therefore, the lowest) high-level clouds. EUM also has a very warm temperature based on the comparison statistics and histogram of heights.

Because this is a small sample of data (only one time period), the centers with the best and worst comparison to rawinsondes vary depending on considering all AMVs, grouped by height, or collocated winds. However, closer examination reveals some consistency. For example, JMA has a very good speed bias as compared to rawinsondes in all categories in the tables below, except for the mid-level winds due to a very low count in AMVs. Similarly for EUM, which has very good direction bias, except in cases of very few AMVs.

Table 8-3: Experiment 2: All AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N= number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS= speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	63	0.67	18.81	0.14	5.27	-11.12	9.59
EUM	268	-0.53	26.57	3.09	7.24	0.05	9.43
JMA	177	-2.20	26.26	0.36	6.04	6.07	8.04
KMA	1346	1.19	24.98	-0.02	5.94	9.04	7.91
NOA	361	-1.59	27.14	3.08	6.30	12.84	8.94
NWC	2410	-1.86	26.03	-0.78	4.75	1.53	6.14

Table 8-4: Experiment 2: High-level AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N= number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS= speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	37	2.68	16.58	1.49	5.41	4.39	8.21
EUM	30	-6.20	27.38	2.70	6.60	6.44	7.53
JMA	63	-7.21	25.90	-0.22	4.22	6.40	6.74
KMA	449	-2.69	23.81	-0.94	4.94	3.96	6.64
NOA	119	-0.58	25.67	1.43	4.76	4.19	7.11
NWC	863	-2.01	23.22	-1.23	5.01	0.92	6.57

Table 8-5: Experiment 2: Mid-level AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N= number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS= speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	7	-5.12	24.30	-0.70	3.62	-30.95	7.57
EUM	122	2.08	28.54	3.42	7.15	-2.55	9.01
JMA	42	11.17	30.10	2.84	6.34	-0.04	7.39
KMA	439	5.29	27.13	1.73	6.23	6.01	7.39
NOA	193	-4.23	28.71	4.26	7.07	11.76	9.87
NWC	441	-4.43	29.23	-0.26	4.61	6.09	6.03

Table 8-6: Experiment 2: Low-level AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N= number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS= speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	19	-1.10	20.51	-2.18	5.51	-34.00	12.33
EUM	116	-1.81	24.09	2.86	7.49	1.13	10.26
JMA	72	-5.63	24.08	-0.59	7.12	9.34	9.34
KMA	458	1.07	23.94	-0.80	6.51	16.92	9.39
NOA	49	6.33	24.06	2.46	6.31	38.10	9.07
NWC	328	2.16	26.03	-1.95	3.63	1.46	4.93

Table 8-7: Experiment 2: All AMVs (QI with forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	241	3.60	26.33	0.17	7.51	5.05	8.99
EUM	283	-0.71	26.15	2.74	7.07	0.57	9.46
JMA	169	-2.50	26.81	0.14	5.09	3.52	7.04
KMA	1266	1.24	24.92	0.18	5.81	8.35	7.79
NOA	342	-1.23	27.27	3.17	6.18	14.21	8.87
NWC	2410	-1.89	25.97	-0.72	4.68	1.52	6.06

Table 8-8: Experiment 2: High-level AMVs (QI with forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	119	1.24	25.17	0.29	6.29	5.89	7.85
EUM	30	-6.20	27.38	2.70	6.60	6.44	7.53
JMA	61	-8.23	26.24	0.13	4.16	4.96	6.40
KMA	439	-2.21	23.74	-0.84	4.75	3.04	6.45
NOA	118	-0.79	25.69	1.45	4.78	4.13	7.14
NWC	860	-1.88	23.21	-1.24	5.08	0.86	6.62

Table 8-9: Experiment 2: Mid-level AMVs (QI with forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	105	7.50	27.03	0.55	9.05	6.30	10.50
EUM	129	1.64	28.05	3.24	7.04	-2.61	8.89
JMA	40	11.93	30.70	2.46	5.64	2.80	6.48
KMA	413	5.16	27.19	1.99	6.13	6.44	7.19
NOA	178	-3.18	29.06	4.49	7.00	14.49	9.85
NWC	439	-4.23	29.13	-0.15	4.54	6.62	5.93

Table 8-10: Experiment 2: Low-level AMVs (QI with forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	17	-4.00	29.72	-3.06	4.06	-8.51	5.69
EUM	124	-1.82	23.67	2.24	7.21	2.47	10.40
JMA	68	-5.84	24.79	-1.21	5.48	2.64	7.86
KMA	414	1.00	23.77	-0.53	6.47	15.89	9.48
NOA	46	5.20	23.85	2.48	5.93	38.97	8.88
NWC	337	1.65	25.92	-1.88	3.52	2.64	4.81

Table 8-11: Experiment 2: Collocated AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	277	2.82	18.61	-0.04	3.76	4.34	7.02
EUM	258	0.46	26.94	3.36	6.22	5.70	8.85
JMA	294	0.90	25.98	0.22	3.45	6.07	6.24
KMA	287	2.15	21.00	-0.05	3.55	2.28	5.81
NOA	297	0.47	26.63	1.91	5.16	9.34	8.56
NWC	275	-1.47	19.60	-0.69	3.64	2.59	5.18

Table 8-12: Experiment 2 collocated AMVs with QI >= 50 (with forecast) compared to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	Pbias	PRMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	496	7.52	24.39	-0.03	5.27	4.20	7.36
EUM	488	0.22	27.61	4.24	6.95	3.11	8.97
JMA	534	-1.11	28.36	0.26	4.08	3.87	6.22
KMA	551	0.76	23.70	-0.20	4.15	4.32	5.83
NOA	531	-1.28	27.71	2.85	5.60	6.79	8.06
NWC	551	-0.39	22.92	-0.78	4.29	2.66	5.85

e) Model Grid comparison

Python scripts are used to find the comparison of all AMVs to the background grid. This comparison is based on 12-hour forecast using QINF >= 80. The tables are for all AMVs (Table 8-13), all AMVs by height range (high, medium, and low) (Table 8-14 to Table 8-16), and collocated AMVs for all levels (Table 8-17).

The results are very similar to what was found with the rawinsonde comparisons: NWC and JMA have the lowest error, while BRZ and EUM have the highest errors. Considering collocated data, NWC, JMA, KMA show again the best results while EUM shows again the worst results.

Table 8-13: Experiment 2 all AMVs compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error.

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	743	113	7.51	8.89	7.05	8.64
CMA	3964	755	7.07	8.22	6.44	7.81
EUM	5378	1003	6.88	9.73	6.47	9.54
JMA	3498	955	4.50	6.05	3.71	5.52
KMA	26427	5189	5.95	7.88	5.49	7.61
NOA	8180	1640	6.87	8.79	6.22	8.37
NWC	43626	10413	4.76	5.68	4.17	5.20

Table 8-14: Experiment 2 high-level AMVs (<400 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	195	67	8.03	9.81	6.98	9.24
CMA	1615	567	7.42	8.63	6.13	7.78
EUM	536	188	6.04	8.15	4.85	7.31
JMA	562	196	5.52	6.93	4.29	5.95
KMA	5536	1987	6.10	8.00	4.97	7.23
NOA	2924	1132	6.81	9.16	5.42	8.24
NWC	13277	5329	5.12	6.21	4.03	5.30

Table 8-15: Experiment 2 mid-level AMVs (400-700 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	146	8	7.77	9.15	7.69	9.11
CMA	1678	113	7.65	8.73	7.47	8.63
EUM	1715	198	9.81	12.08	9.40	11.89
JMA	609	101	6.45	8.19	5.96	7.92
KMA	8332	1018	7.34	9.27	7.07	9.12
NOA	3445	388	7.45	9.19	7.16	9.02
NWC	13678	1836	5.15	6.13	4.85	5.89

Table 8-16: Experiment 2 low-level AMVs (>700 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	402	38	7.12	8.22	6.81	8.87
CMA	677	76	4.81	5.44	4.62	5.33
EUM	3127	617	5.43	8.46	5.14	8.34
JMA	2327	658	3.73	5.08	2.98	4.56
KMA	12559	2184	4.96	6.75	4.67	6.60
NOA	1811	120	5.85	7.27	5.72	7.22
NWC	16671	3248	4.16	4.79	3.72	4.47

Table 8-17: Experiment 2 collocated AMVs compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast)

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	2560	515	5.84	6.79	5.26	6.38
CMA	9405	2219	5.71	6.60	4.94	6.00
EUM	5244	927	5.96	7.61	5.48	7.30
JMA	5624	1627	4.20	5.31	3.40	4.58
KMA	5937	1415	4.79	5.66	4.18	5.16
NOA	5999	1223	5.74	6.90	5.11	6.40
NWC	5847	1496	4.95	5.69	4.33	5.19

f) Best fit height

The Best Fit height analysis is completed for each wind producer according to the method described by Salonen et al. (2012). This technique finds the background model best fit pressure associated with the AMV, which is where the vector difference between the observed AMV and model background is at a minimum.

It does this by first locating the model pressure levels within the troposphere up to 150 hPa, which is a tunable parameter, above and below the AMV. Using a parabolic fit, it then analyzes the located model pressure levels and detects the single model pressure level which has the minimum vector difference, which must be both less than or equal to 4 ms^{-1} and at least 2 ms^{-1} smaller than the vector differences +/- 100 hPa from the best fit pressure level. Therefore, this method is dependent on the model vertical resolution. It is possible using a requirement of at least 2 ms^{-1} smaller than the vector differences +/- 100 hPa from the best fit pressure level is too demanding of a requirement.

Similar to previous studies, the number of best fit matches is generally less than 30% of the AMVs (Salonen et al. 2012).

Figure 8-7 to Figure 8-13 show the:

- Distribution of Best Fit minus AMV pressure differences, color-coded by low, medium, and high clouds (upper-left),
- Spatial distribution with same color coding (upper-right),
- Relationship between AMV pressure and latitude, color-coded to indicate if the Best fit moved the AMV higher (red) or lower (blue) (lower-left),
- Relationship between AMV pressure and speed, color-coded to indicate if the Best fit moved the AMV higher (red) or lower (blue) (lower-right).

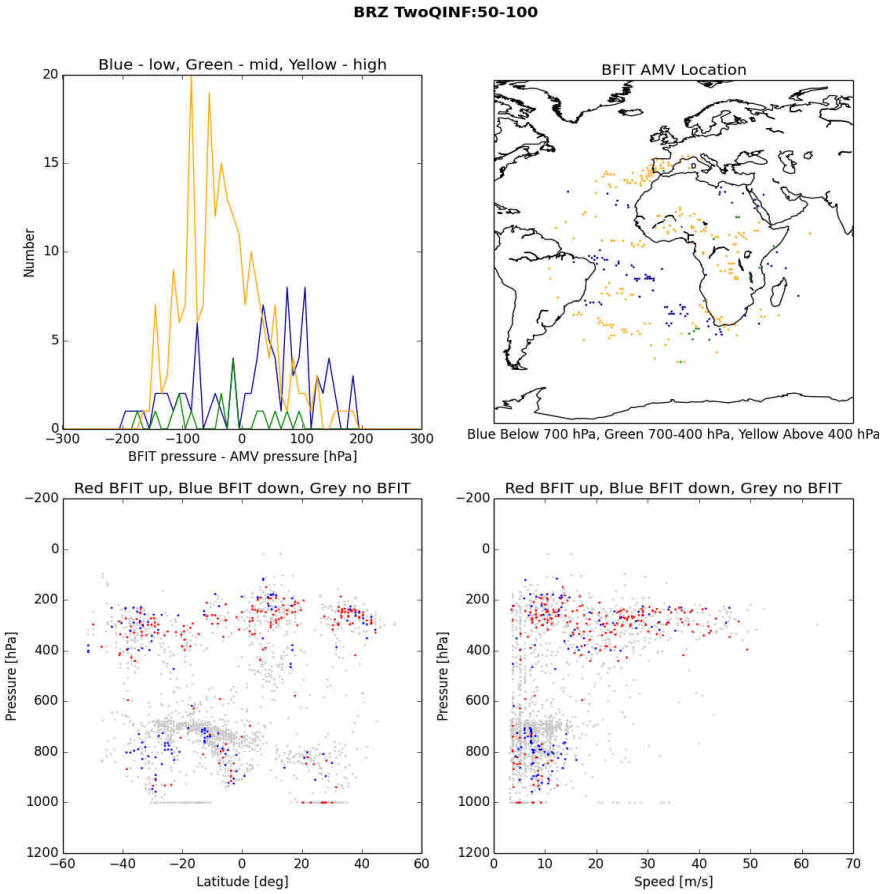


Figure 8-7: BRZ: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

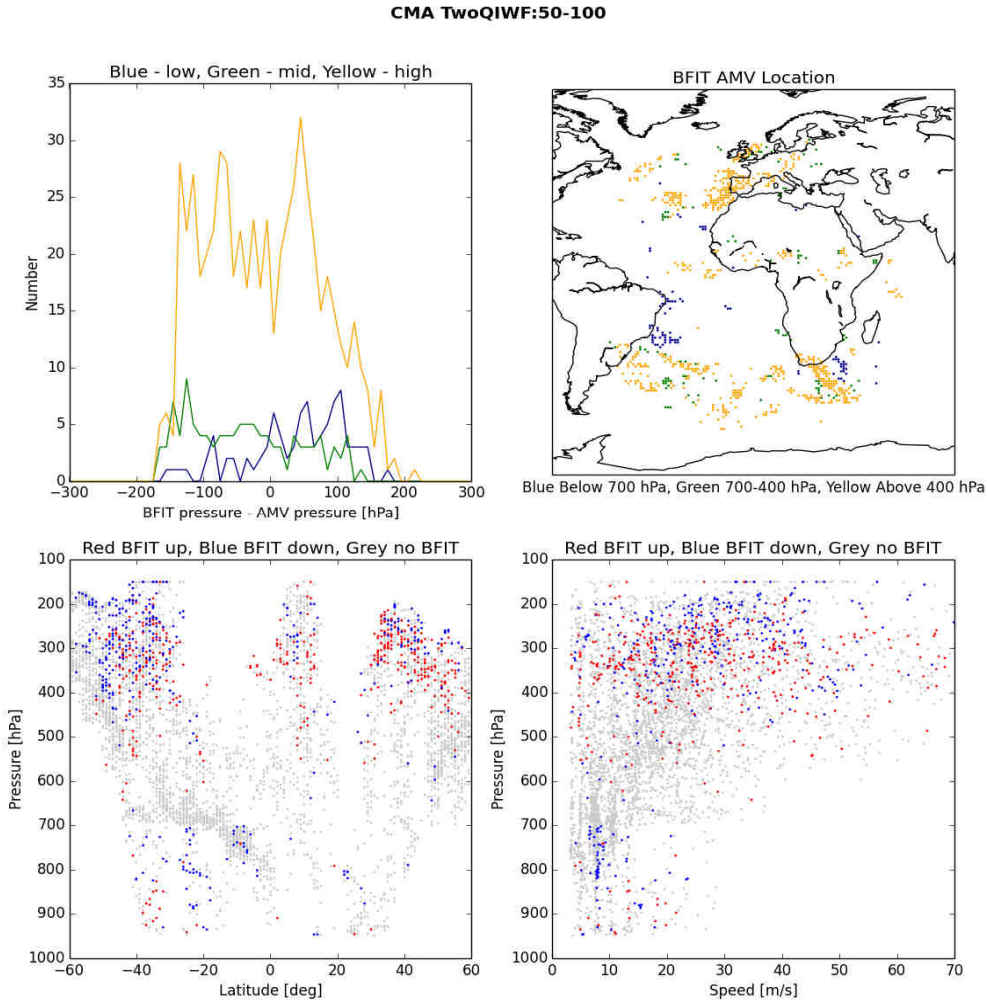


Figure 8-8: CMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

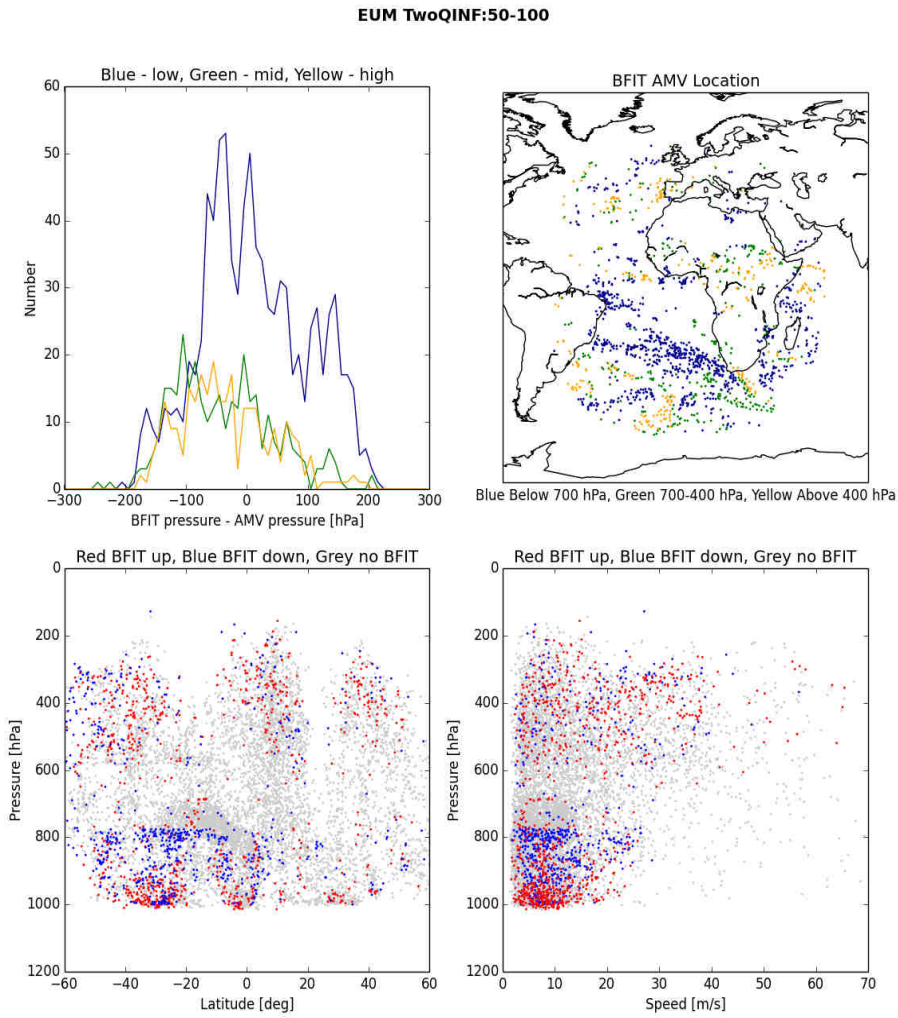


Figure 8-9: EUM: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

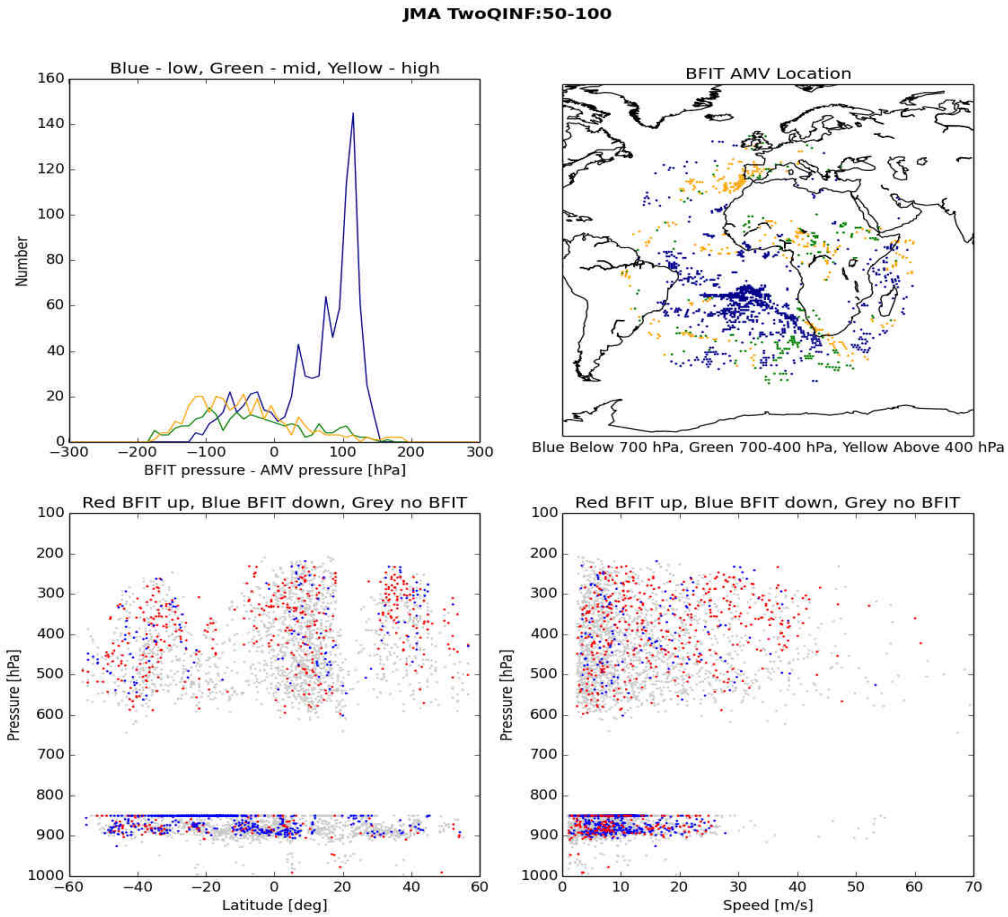


Figure 8-10: JMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

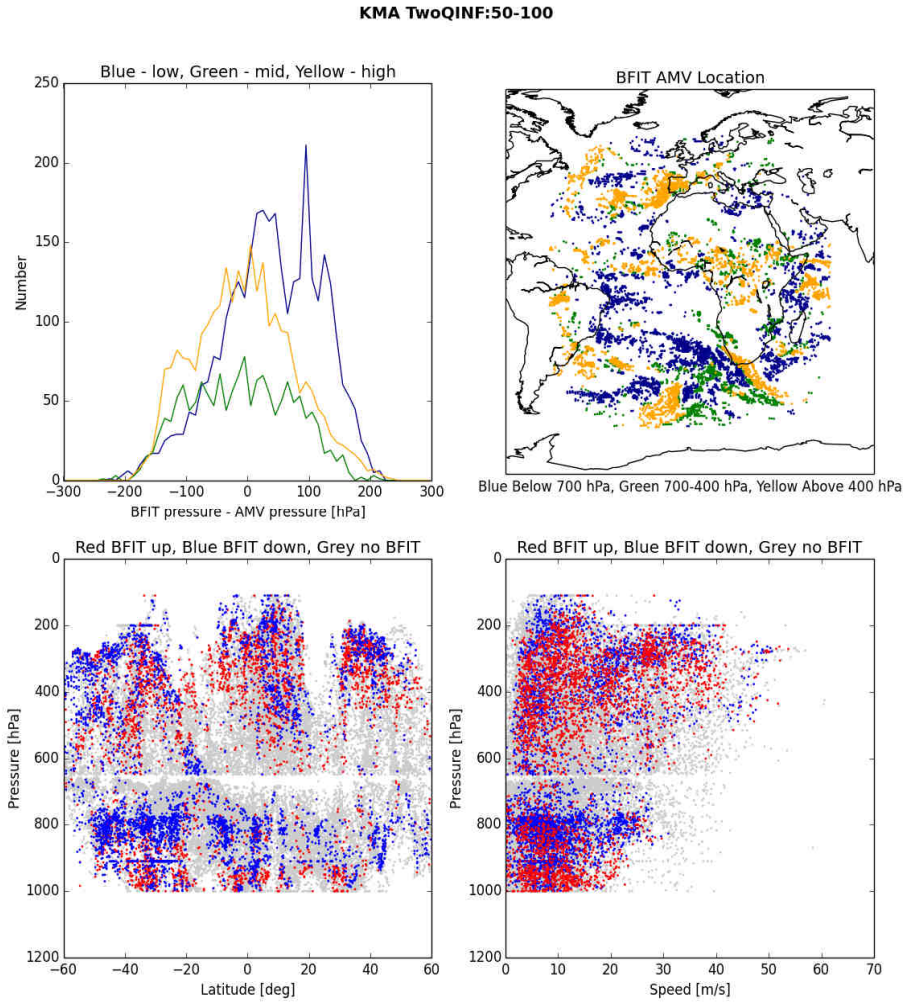


Figure 8-11: KMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

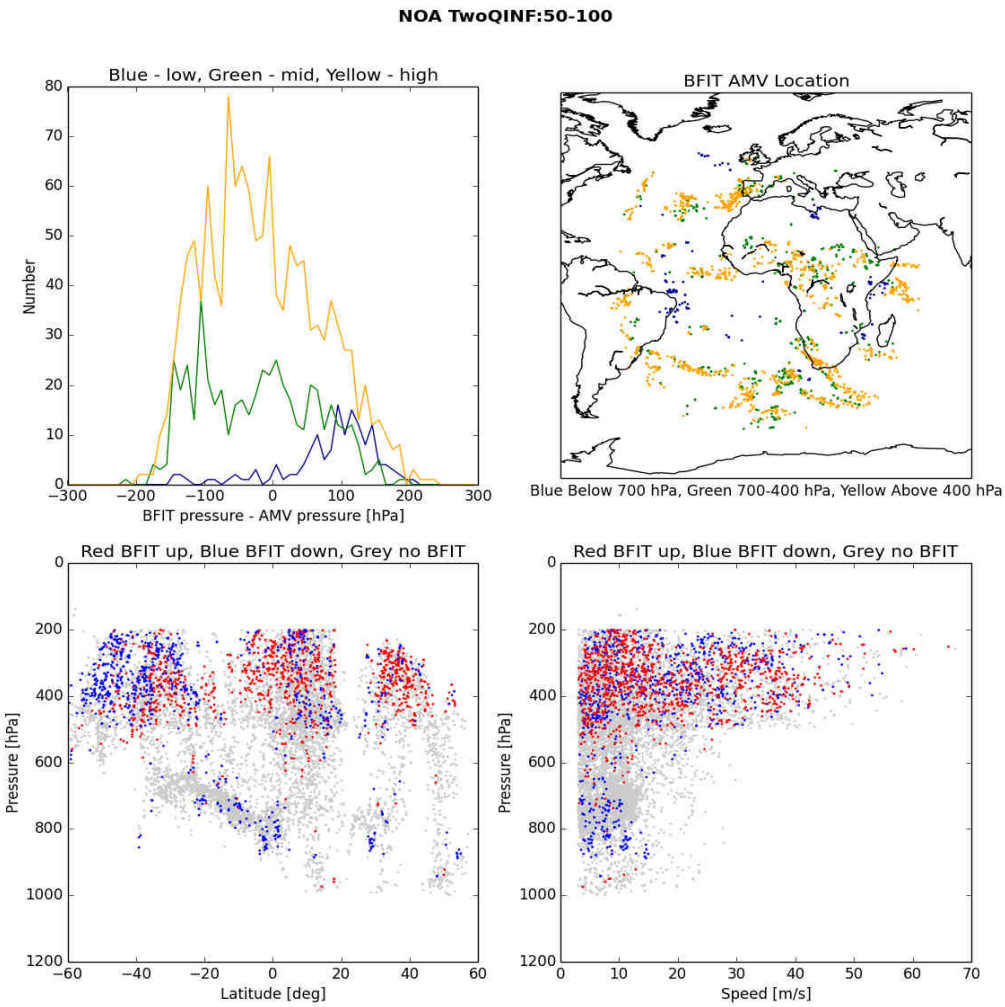


Figure 8-12: NOA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

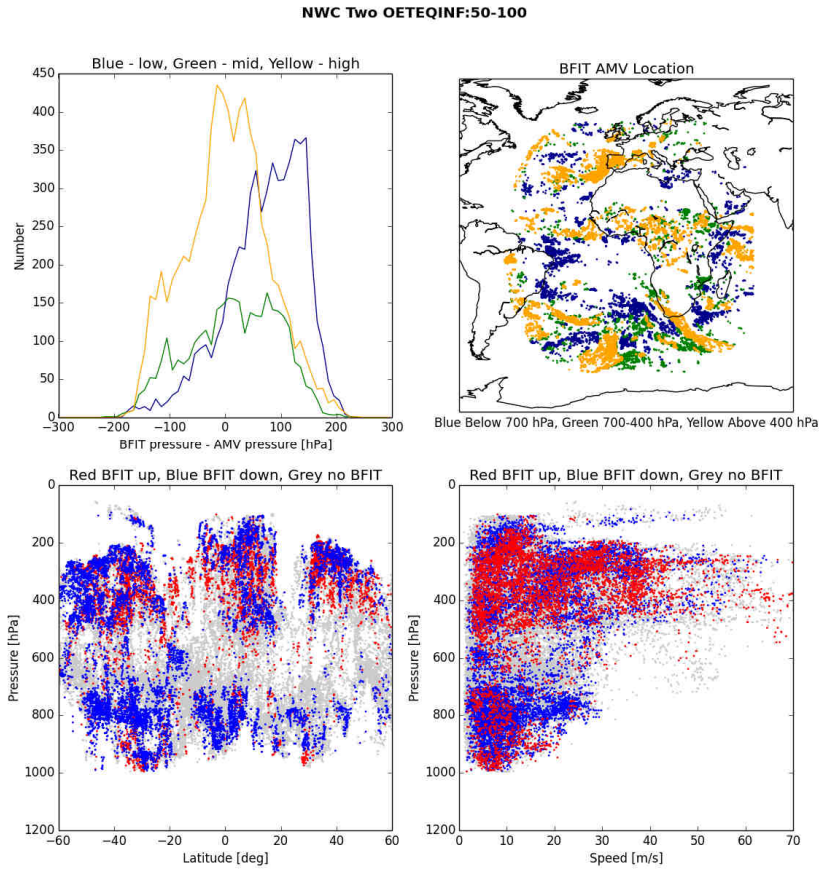


Figure 8-13: NWC: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

The depiction of the distribution of Best Fit statistics is located in Figure 8-14 through Figure 8-20. Depending on the site, 16% to 24% of the AMVs are adjusted to a Best Fit pressure (lower-left in each figure). This pie chart shows the fraction of AMVs with found best fit, not constrained (another minimum was found close by), or did not meet minimum vector difference limits (which was 4 ms^{-1}). Results of the Best Fit algorithm show an approximate Gaussian distribution of the pressure difference centered near zero (upper-right panel in figures) extending ±200 hPa. There does not appear to be a relationship between latitude or longitude and adjusted pressure (upper-left and middle-left panels in figures).

The lower-right panels depict the geographic distribution where red dots indicate the AMV should be higher and blue where it should be lower in the atmosphere. JMA for example (Figure 8-17) shows a spatial pattern in the Best Fit shift of the AMVs: high clouds are moved higher (cyclone northwest of Africa) and low clouds are moved lower (marine stratus) in the mid-South Atlantic Ocean.

In the upper-right corner of the figures is the distribution of the pressure difference (AMV Best Fit pressure minus the Original Pressure). For sites BRZ, CMA, EUM, NOA, and KMA the pressure difference is centered near zero. However, JMA has two peaks (-50 and +100) with a minimum near zero and NWC is slightly skewed to the right of zero. For experiment 2, since the AMV heights were assigned using only the IR brightness temperature, these offset and skewed distributions may be the result of the specific implementation of the IR brightness temperature height assignment.

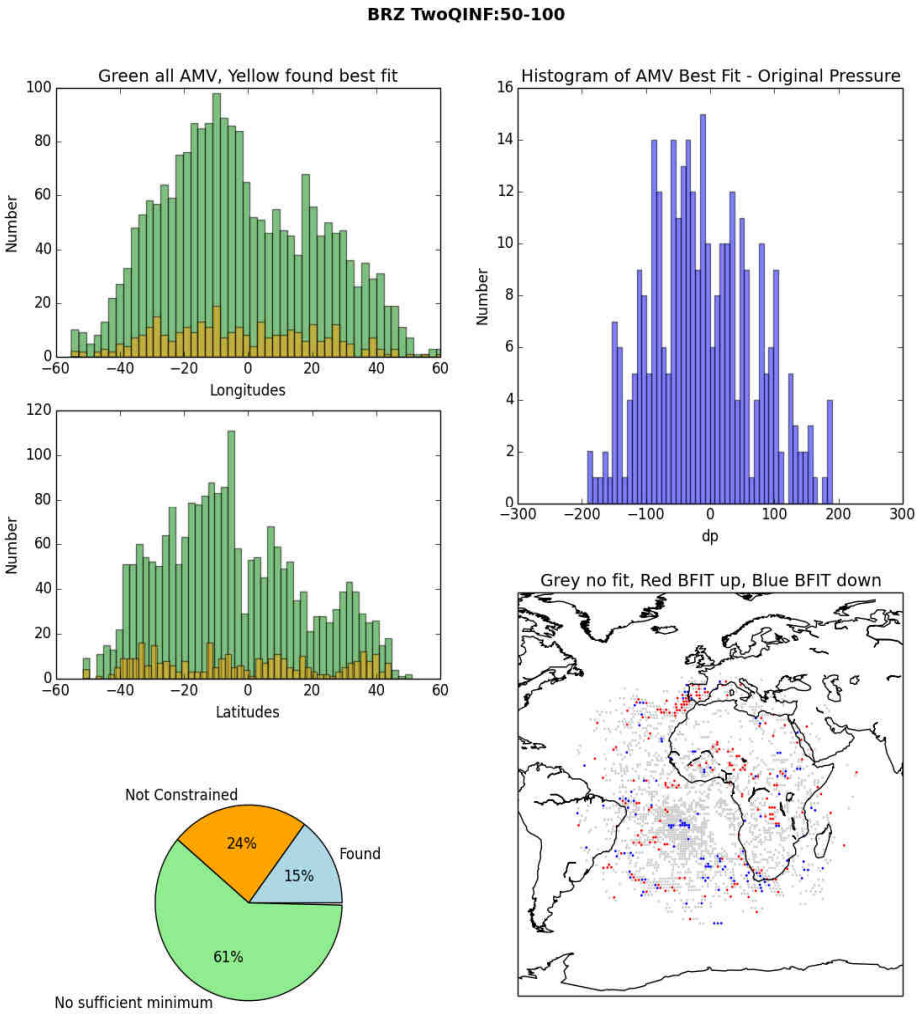


Figure 8-14: BRZ: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

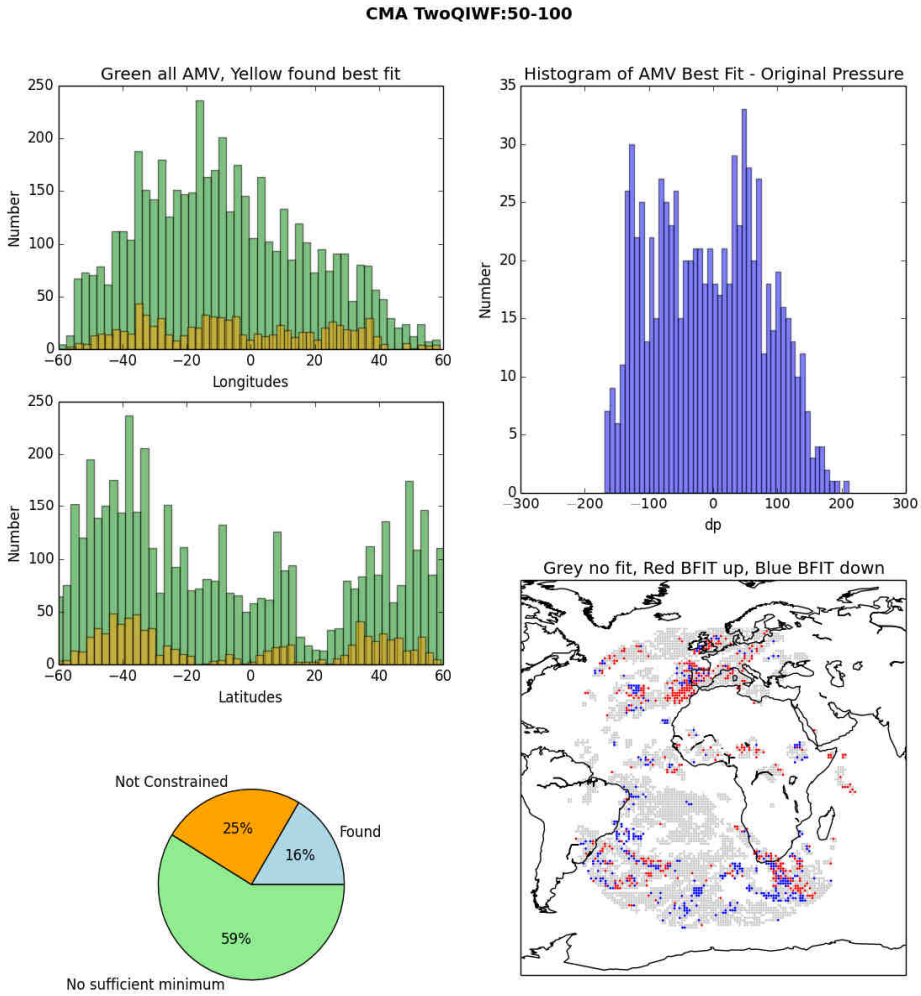


Figure 8-15: CMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

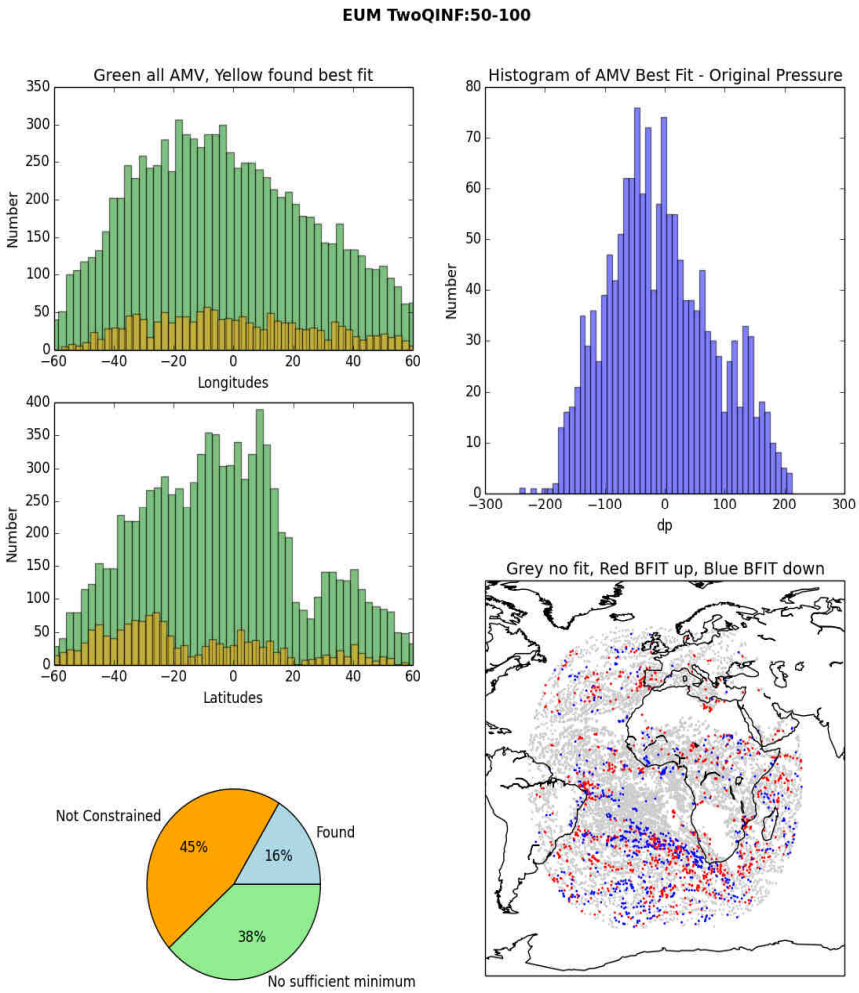


Figure 8-16: EUM: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

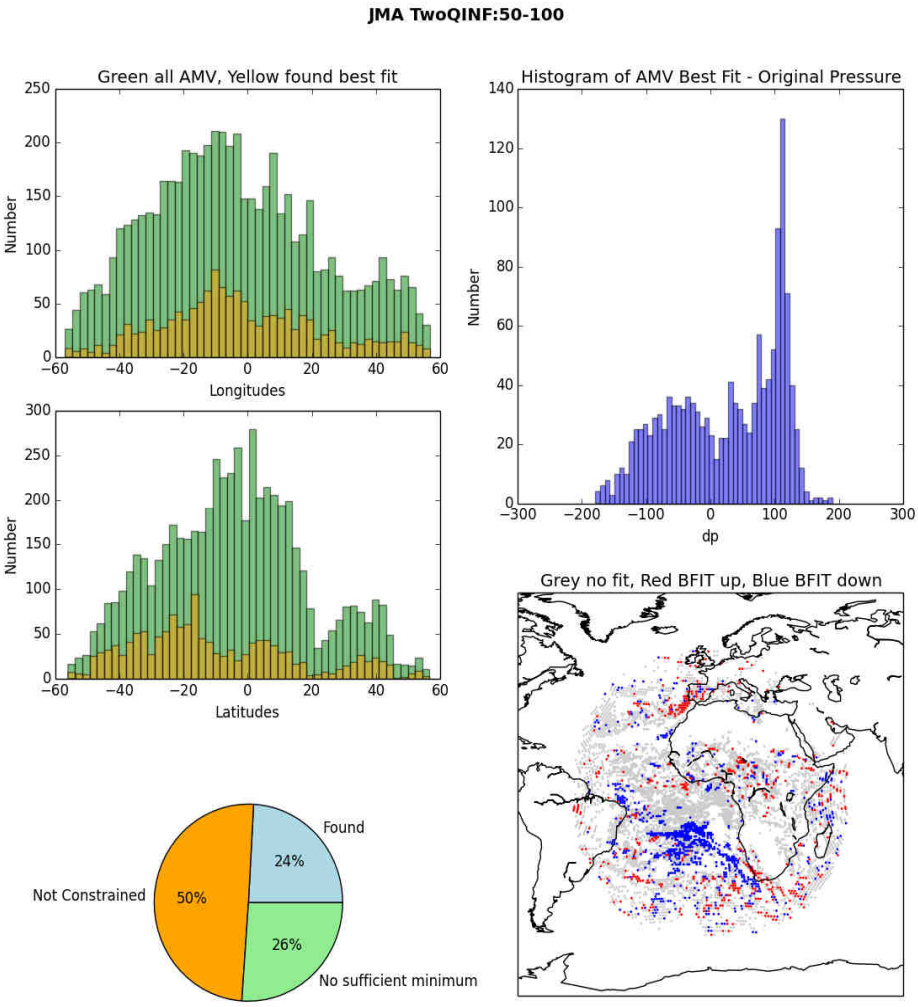


Figure 8-17: JMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

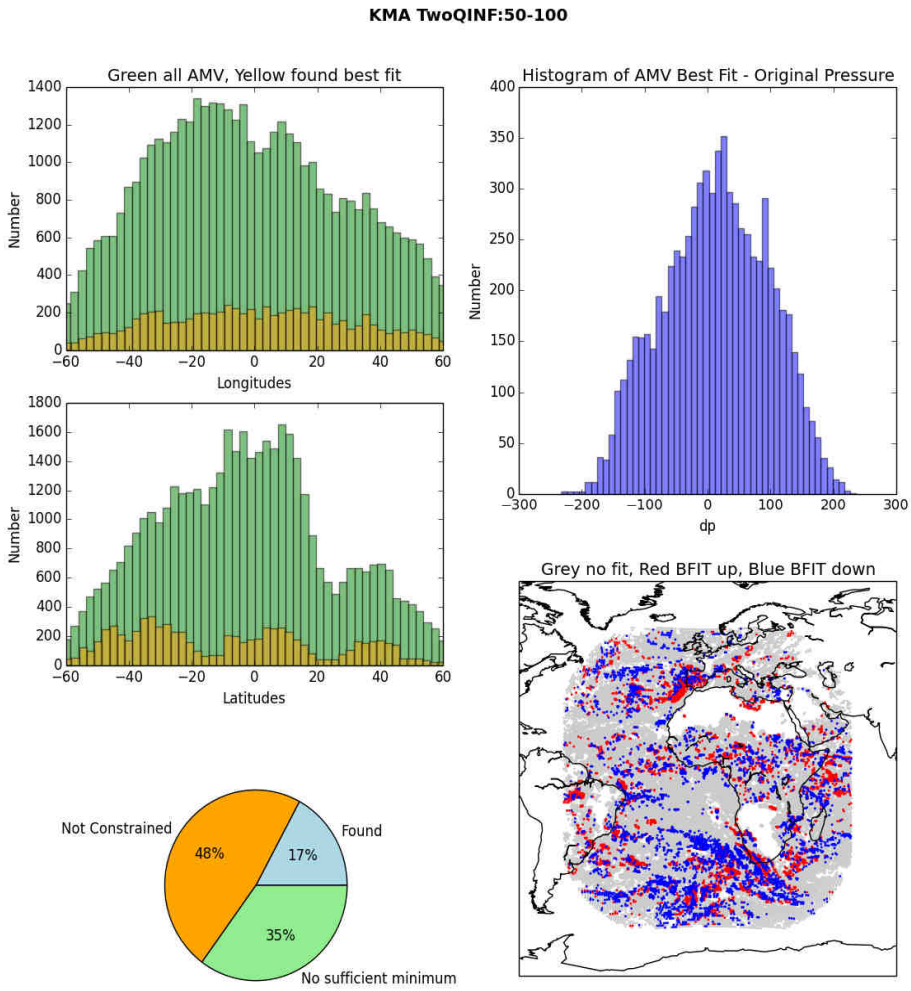


Figure 8-18: KMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

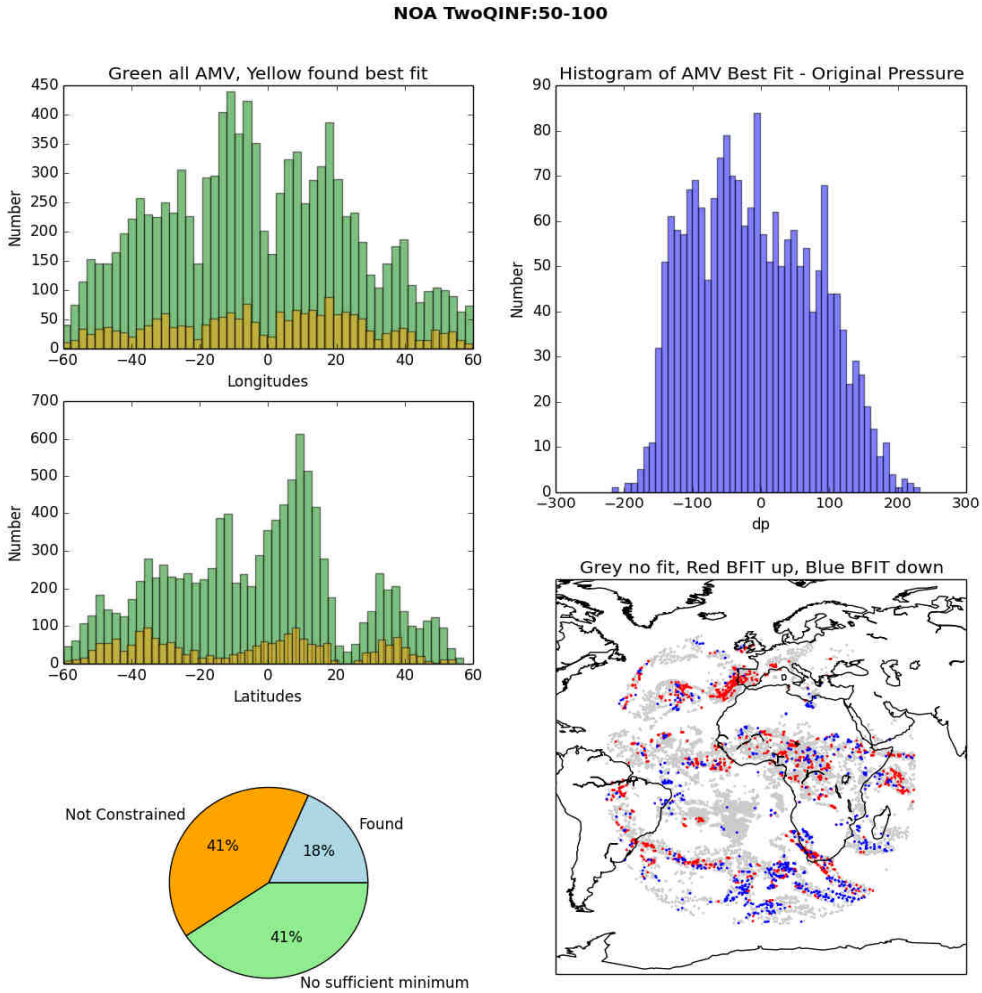


Figure 8-19: NOA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

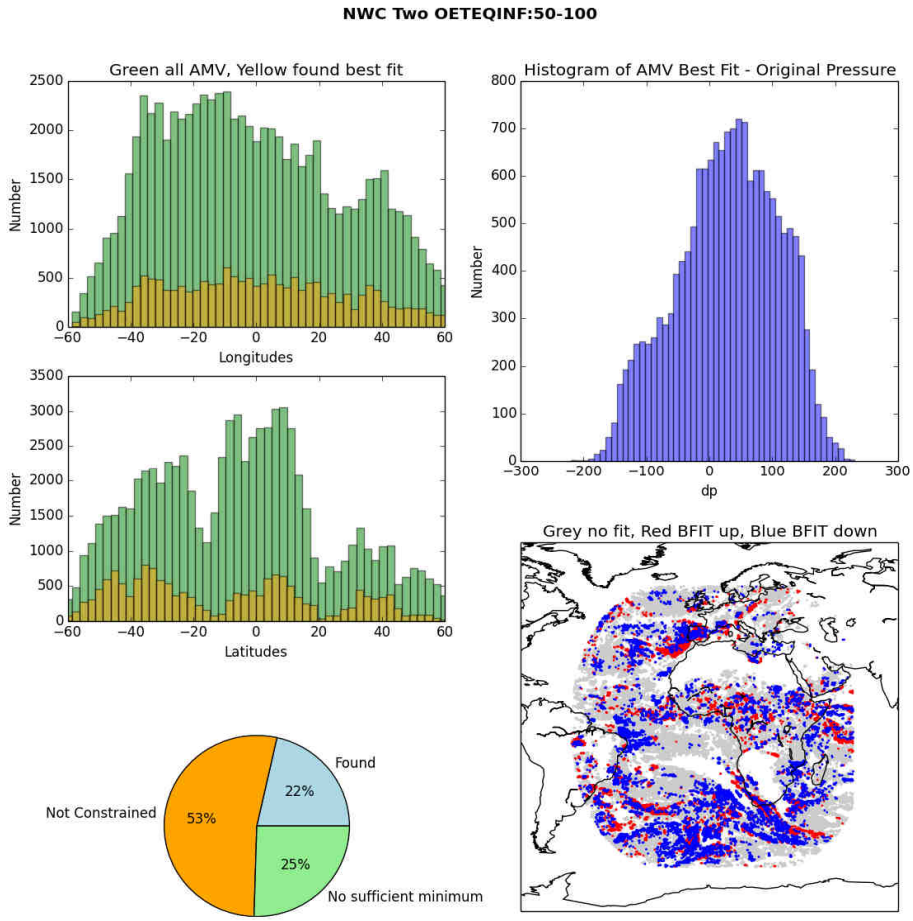


Figure 8-20: NWC: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

Additional figures were generated to show the distribution of the differences between the AMVs and the background grid, before and after applying the Best Fit algorithm. The lower halves of Figure 17-1 to Figure 17-7 shows the change in the speed difference distribution before (left) and after (right) Best Fit adjustment. As expected, the speed bias is usually reduced, as the standard deviation.

Similarly, the lower half of Figure 17-8 to Figure 17-14 shows the change in the vector difference distribution before (left) and after (right) Best Fit adjustment and as expected, the vector difference and standard deviation is usually reduced. BRZ and CMA have the largest deviation before the best fit, with a vector difference of over 7 ms^{-1}, as compared to the background grid. NWC has the smallest deviation before the best fit, with a vector difference of less than 4 ms^{-1}.

g) Statistical comparison

To quantify the observed differences in the previous plots, a paired t-test is once again used with all combinations of producers and parameters. Further information about the test is located in the section for Experiment 2 Statistical comparison. Table 8-18 to Table 8-25 summarize the results in terms of statistical significance for each of the five variables; green signifies not statistically different while red is statistically different.

AMVs were first quality controlled, retaining only those with a QINF >= 50. For collocation the distance threshold is 35 km, resulting in 7050 AMVs.

NWC SAF and EUMETSAT are the only combinations very close in terms of both speed and direction, despite having a cloud height bias of 130 hPa.

Table 8-18: Experiment 2 speed t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 8-19: Experiment 2 direction t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 8-20: Experiment 2 pressure t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 8-21: Experiment 2 QI without forecast t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

A similar comparison was completed for AMVs with QI with forecast, retaining only those with a QIWF >= 50. For collocation the distance threshold was 35 km, resulting in 10113 AMVs.

Table 8-22: Experiment 2 speed t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

Table 8-23: Experiment 2 direction t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

Table 8-24: Experiment 2 pressure t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

Table 8-25: Experiment 2 QI with forecast t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

9. Experiment 3

AMV producers extract IR10.8 channel AMVs considering a prescribed AMV algorithm configuration, but only using the MSG/SEVIRI IR10.8 images and the ECMWF model data for the height assignment. This experiment will be used to test the Tracking and Quality control steps in all AMV algorithms, considering similar targets.

The prescribed AMV configuration defines target scene size, search scene size, etc. to be the same for all AMV producers. Something similar was done in the 2nd study and it was found that:
"Winds data sets retrieved using common target and search box sizes revealed that each producer's algorithm is finely tuned to a specific imagery temporal and spatial resolution, as well as target and search box sizes (Genkova et al. 2010)."

For each one of the AMV producer's datasets, a distribution of AMV speed, direction, vector height, and QI will be generated. Differences of these quantities between AMV producers will be made. Also, differences in AMV coverage and number of vectors will be presented as bulk statistics and geographic plots.

Collocated AMVs from the different algorithms will be used to measure the differences. Also, a comparison of the AMVs with the NWP model winds and height assignment investigations using NWP model best fit pressure will be used for verification.

Experiment 3 Highlights
Graphs of bulk distributions are similar to Experiment 2, since the height assignment options are restricted to IR B_T.

Collocated vectors only number 370, due to the lower overall numbers of AMVs when using prescribed target and search box sizes. Considering this configuration, there are more similarities between centers: speed and direction differences are not statistically different, although, pressure and QI values are significantly different.

a) Approach

By using a prescribed AMV configuration, we were able to better quantify differences in AMV density between the producers. In cases with similar densities among producers, the QI can also be compared quantitatively.

This was similar to Study 2 by Genkova et al. (2010):

- Only SEVIRI 10.8 µm channel was used for the height assignment.
- Producers used their algorithm.
- Prescribed target and search box sizes were used.
- ECMWF grids were used as NWP data.
- A 55 km distance to define collocation was used, while Genkova et al. (2010) used 0.5°.

Genkova's scripts were used to do same comparison and analysis as done before, but now including NWC SAF.

In addition:

- The best fit analysis was used to further analyze differences in cloud heights.
- The paired t-test was computed to determine if the observed differences in collocated AMVs were statistically significant.

This was also an opportunity to compare AMVs from Experiments 2 and 3 from the same producer and quantify differences in AMVs between the standard and the prescribed configuration.

EUMETSAT's 'standard' configuration was the same as their 'prescribed' one.

b) Parameter distributions

The bulk statistics are presented in tables and histograms for QINF >= 50 and QIWF >= 50 (because not all centers reported both QINF and QIWF).

Table 9-1 and Table 9-2 list basic Experiment 3 statistics for the AMVs for each winds producer, without and with forecast quality respectively. The biggest difference is in the number of AMVs: Ranging from 3000 (NWC) to 12000 (EUM).

Table 9-1: Experiment 3 statistical summary of AMV datasets for QI without forecast >= 50.

	EUM	BRZ	JMA	KMA	NOA	NWC
Total AMVs	12053	11371	6219	11986	3881	3169
QI>=50	9074	4510	5465	9605	3169	2349
SPD_min	2.51	3.11	2.51	2.50	3.01	2.51
SPD_max	78.59	72.13	74.22	54.81	78.43	60.85
SPD_mean	12.50	13.41	11.35	12.11	13.77	12.31
P_min	127.56	19.00	208.68	110.00	190.78	83.47
P_max	1015.02	1000.00	995.88	1000.00	992.58	984.15
P_mean	696.32	633.51	676.19	620.92	505.92	553.03
Low_winds	57.43	48.80	57.31	46.00	21.77	38.10
Mid_winds	32.35	30.80	24.96	32.08	43.74	28.99
High_winds	10.23	20.40	17.73	21.93	34.49	32.91
Low_SPD_min	2.51	3.11	2.51	2.50	3.01	2.51
Low_SPD_max	78.59	43.61	54.92	41.09	29.02	28.36
Low_SPD_mean	9.70	8.73	8.87	9.32	8.87	8.74
Low_P_min	700.04	700.00	850.00	700.01	700.13	700.02
Low_P_max	1015.02	1000.00	995.88	1000.00	992.58	984.15
Low_P_mean	846.41	816.54	866.68	826.02	765.86	780.92
Mid_SPD_min	2.51	3.28	2.51	2.51	3.02	2.52
Mid_SPD_max	77.62	64.35	74.22	51.95	78.43	60.56
Mid_SPD_mean	15.81	15.98	14.43	13.48	12.89	10.80
Mid_P_min	400.08	400.01	400.18	400.01	400.01	400.17
Mid_P_max	699.95	699.94	643.92	699.99	699.91	699.97
Mid_P_mean	546.02	573.32	489.21	552.37	529.91	573.72
High_SPD_min	2.55	3.45	2.51	2.51	3.03	2.65
High_SPD_max	71.68	72.13	60.07	54.81	75.37	60.85
High_SPD_mean	17.73	20.74	15.06	15.97	17.99	17.80
High_P_min	127.56	19.00	208.68	110.00	190.78	83.47
High_P_max	399.92	399.38	399.93	399.94	399.91	399.76
High_P_mean	328.90	286.51	323.72	290.97	311.40	270.94

Table 9-2: Experiment 3 statistical summary of AMV datasets for QI with forecast >= 50.

	EUM	CMA	JMA	KMA	NOA	NWC
Total AMVs	12053	5331	6219	11986	3881	3169
QI>=50	9260	5328	5161	8965	2810	2297
SPD_min	2.51	3.16	2.51	2.50	3.01	2.51
SPD_max	78.59	82.64	74.22	54.81	78.43	60.85
SPD_mean	12.37	16.57	11.29	12.30	13.57	12.58
P_min	127.56	150.00	208.68	110.00	190.78	83.47
P_max	1015.02	947.00	995.12	1000.00	992.58	984.15
P_mean	695.49	516.77	680.19	620.65	514.56	550.90
Low_winds	57.22	21.98	58.52	46.11	23.24	37.48
Mid_winds	32.42	44.16	23.89	31.78	43.02	29.21
High_winds	10.36	33.86	17.59	22.11	33.74	33.30
Low_SPD_min	2.51	3.19	2.51	2.50	3.01	2.51
Low_SPD_max	78.59	33.87	54.92	41.09	29.02	28.36
Low_SPD_mean	9.65	8.34	8.75	9.32	8.81	8.86
Low_P_min	700.04	700.00	850.00	700.01	700.13	700.02
Low_P_max	1015.02	947.00	995.12	1000.00	992.58	984.15
Low_P_mean	846.30	778.34	866.28	825.48	764.66	783.50
Mid_SPD_min	2.51	3.16	2.51	2.52	3.02	2.52
Mid_SPD_max	77.62	72.97	74.22	48.37	78.43	60.56
Mid_SPD_mean	15.60	15.53	14.52	13.74	12.73	11.03
Mid_P_min	400.08	401.00	400.18	400.01	400.01	400.17
Mid_P_max	699.95	699.00	643.92	699.99	699.91	699.97
Mid_P_mean	546.69	559.62	487.68	552.48	538.24	571.60
High_SPD_min	2.54	3.19	2.51	2.51	3.03	2.69
High_SPD_max	71.68	82.64	60.07	54.81	75.37	60.85
High_SPD_mean	17.33	23.26	15.36	16.44	17.91	18.13
High_P_min	127.56	150.00	208.68	110.00	190.78	83.47
High_P_max	399.92	400.00	399.93	399.94	399.91	399.76
High_P_mean	327.97	291.08	322.69	291.43	312.08	270.95

Figure 14-13 to Figure 14-24 in Appendix A: Parameter Distribution Histograms show bulk histograms and unique characteristics of the AMVs for each centre, which are very similar to Experiment 2 since the height assignment method was unchanged. The AMV wind direction and pressure distributions for each center (lower-left and lower-right respectively) have peaks in the same locations as in Experiment 2:

- BRZ (Figure 14-13): The wind direction (lower-left) is not a smooth distribution. Conversely, it has two very sharp peaks. The AMV pressure distribution (lower-right) has peaks at 300 and 770 hPa. Upper-level winds at 300 hPa are reasonable, but the 770 hPa peak is most likely too high for low-level clouds.
- EUM (Figure 14-14 and Figure 14-20): The AMV pressure distribution has a peak at 500 and 800 hPa. The upper level winds are too low, while the low-level winds are too high.

- JMA (Figure 14-15 and Figure 14-21): The AMV pressure distribution has a peak at 500 and 850 hPa. The upper level winds are too low, while the low-level winds are placed well. There is also a noticeable gap in mid-level winds.
- KMA (Figure 14-16 and Figure 14-22): The AMV pressure distribution has a peak at 450 and 800 hPa. The upper level winds are too low, while the low-level winds are too high.
- NOA (Figure 14-17 and Figure 14-23): The AMV pressure distribution has a peak at 400 and 780 hPa. The upper level winds are too low, while the low-level winds are too high.
- NWC (Figure 14-18 and Figure 14-24): The AMV pressure distribution has a peak at 400 and 780 hPa. The upper level winds are too low, while the low-level winds are too high.
- CMA (Figure 14-19): The AMV pressure distribution has a peak at 380 and 760 hPa. The upper level winds are too low, while the low level winds are too high. Also, there are many mid-level clouds compared to other centers.

As in Experiment 2, since only the IR brightness temperature was used in this experiment, the wide variation in cloud heights can be attributed to different techniques and thresholds in determining a representative T_B.

c) Collocation plots

AMVs were first quality controlled, retaining only those with QINF >= 50. For collocation the distance threshold was 55 km, resulting in only 370 AMVs.

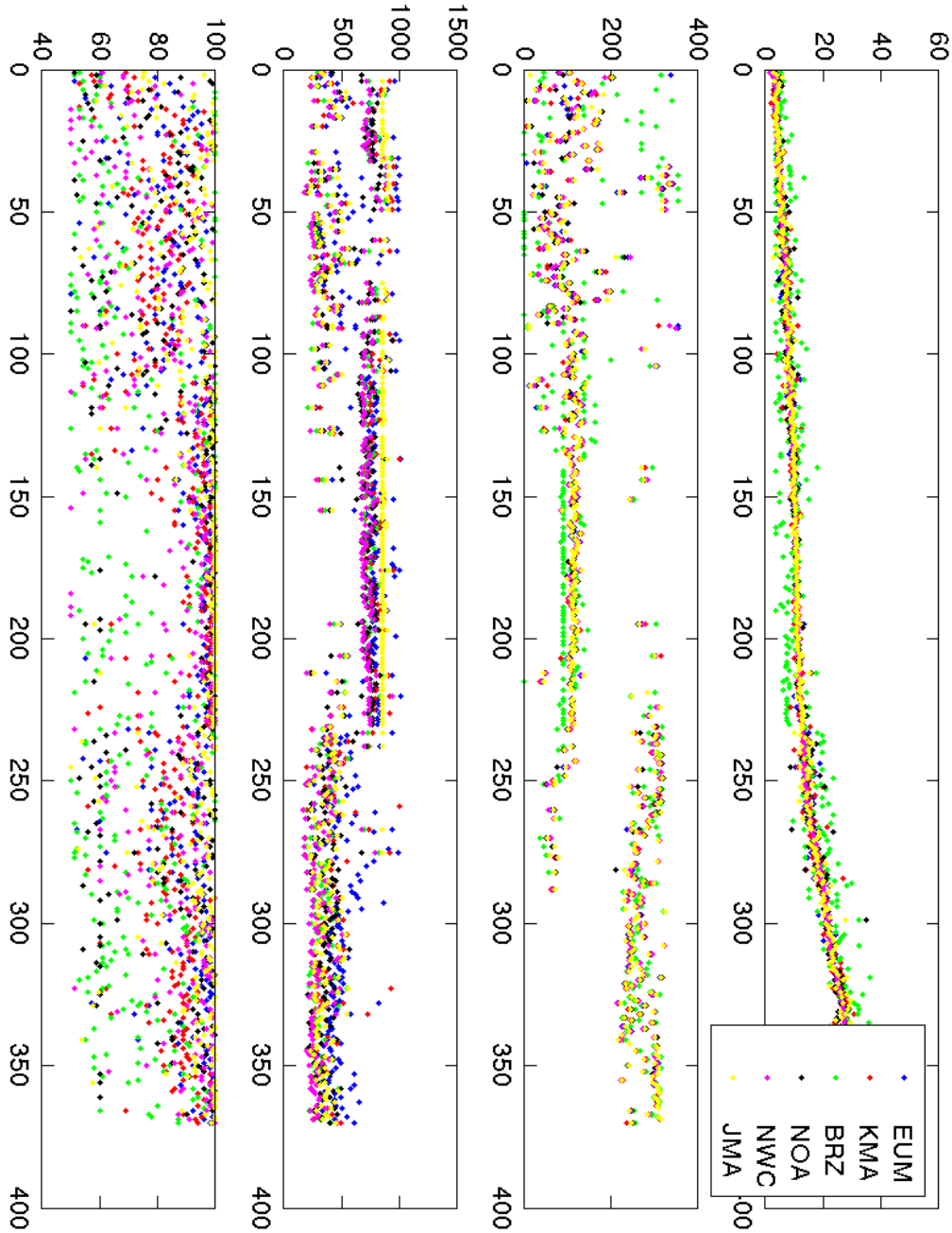


Figure 9-1: Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.

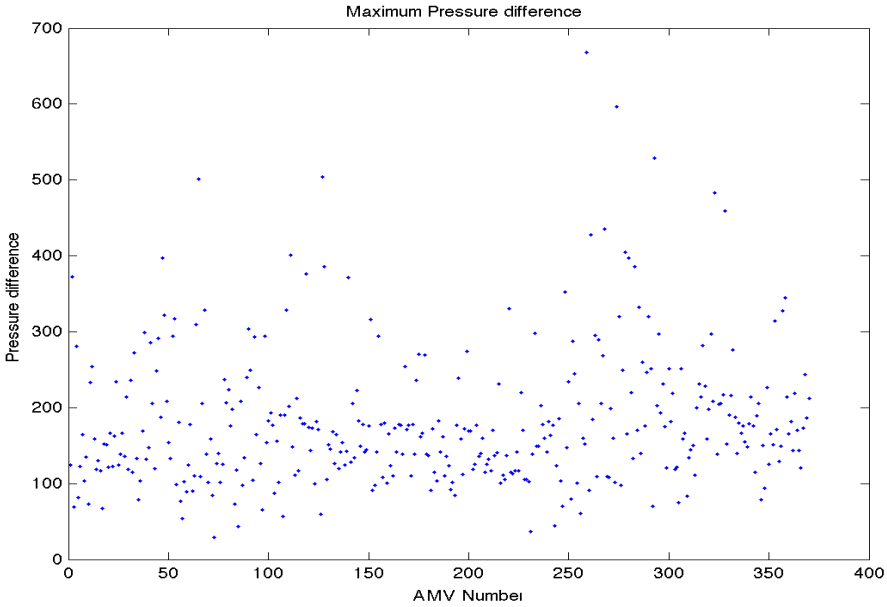


Figure 9-2: The maximum pressure difference between any two collocated AMVs.

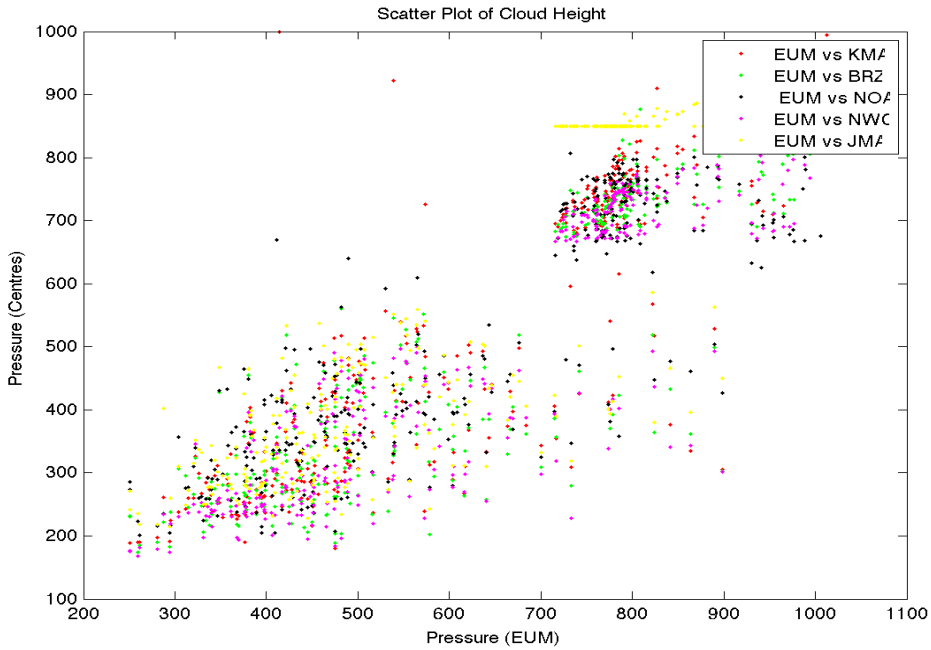


Figure 9-3: Scatter plot of AMV pressure for each center vs. EUM pressure.

A similar comparison was done for AMVs with QI with forecast, retaining only those with a QIWF >= 50. For collocation the distance threshold was 55 km, resulting in 409 AMVs.

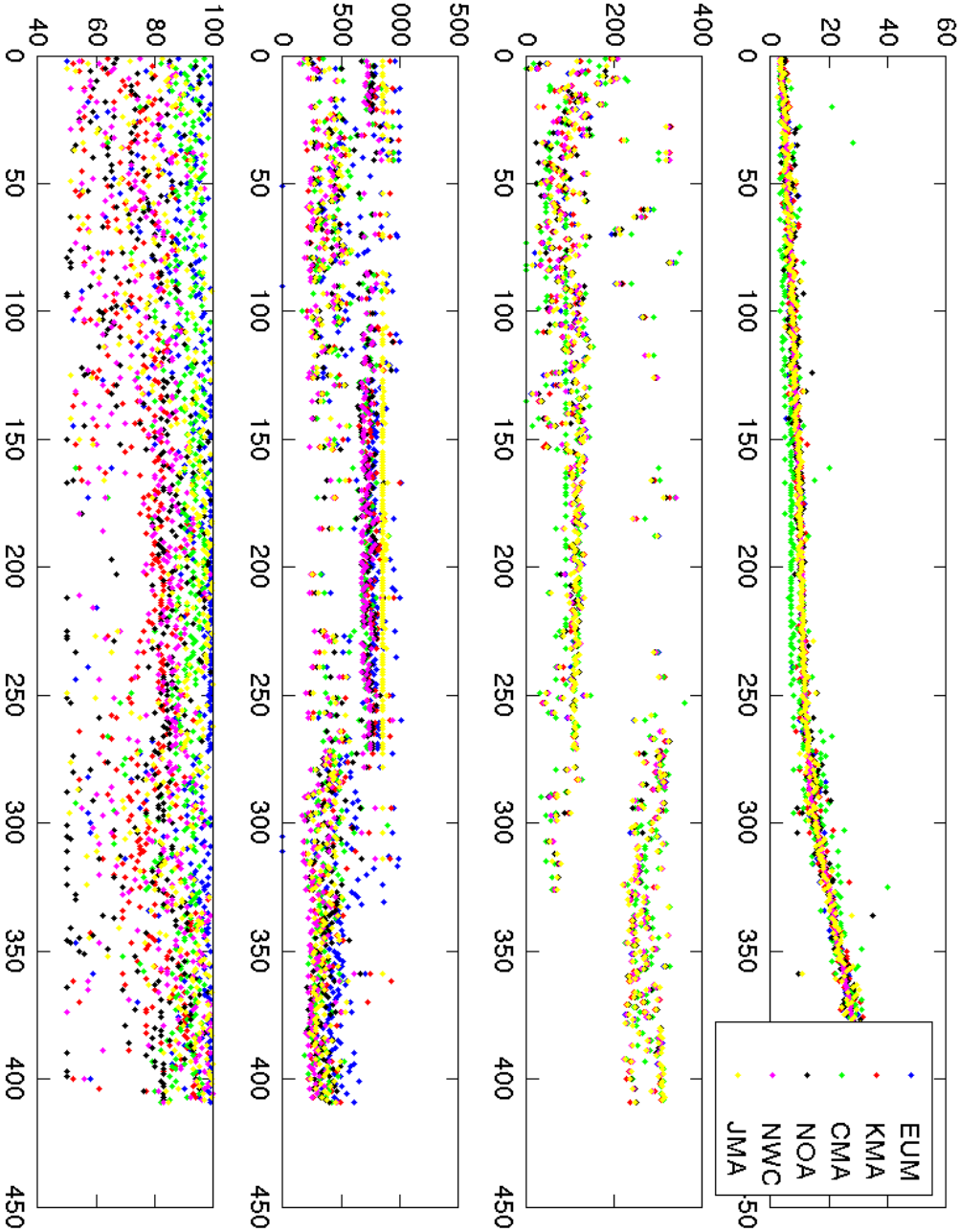


Figure 9-4: Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.

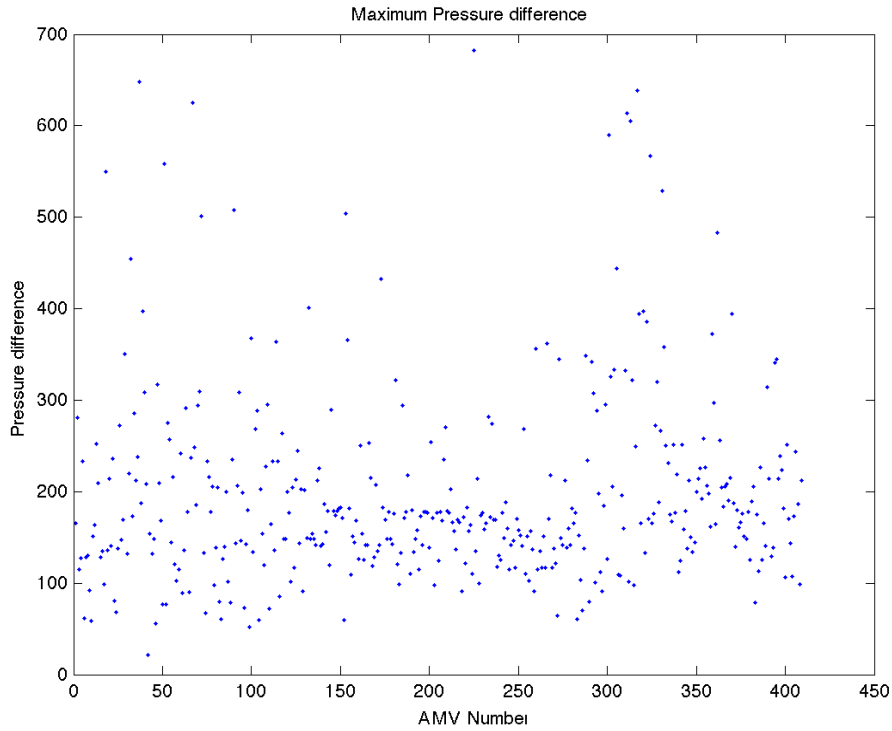


Figure 9-5: The maximum pressure difference between any two collocated AMVs.

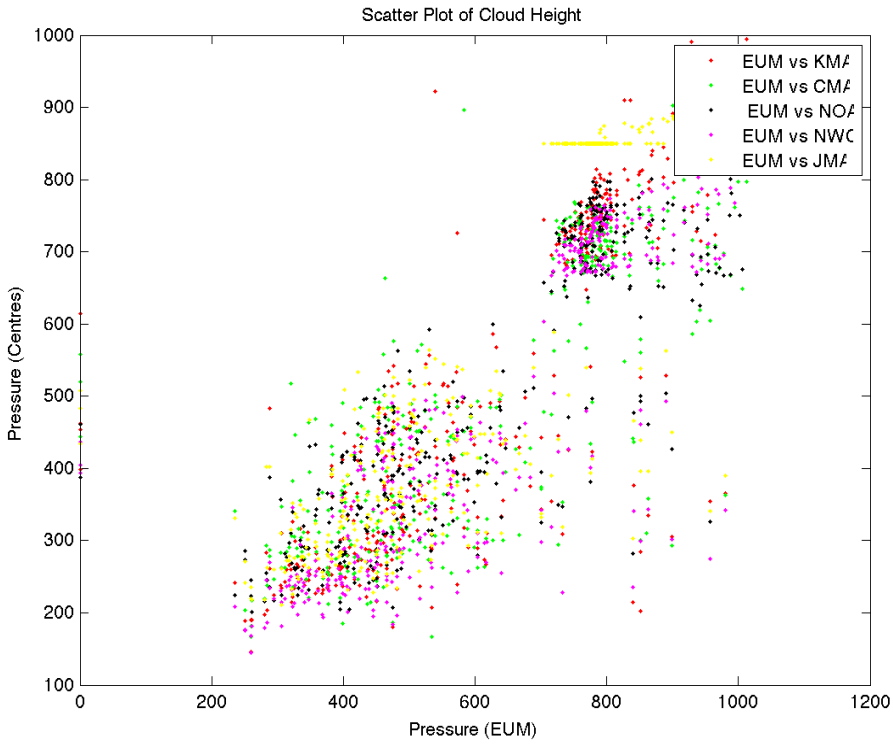


Figure 9-6: Scatter plot of AMV pressure for each center vs. EUM pressure.

d) Rawinsonde comparison

The comparison of Experiment 3 AMVs to collocated rawinsondes is summarized in Table 9-3 (QINF >= 50) and Table 9-4 (QIWF >= 50).

The vector RMS ranges from 6 ms^{-1} (NWC, KMA) to 9-10 ms^{-1} (BRZ, CMA, EUM); the speed RMS ranges from 5 ms^{-1} (NWC, JMA, KMA) to 7 ms^{-1} (BRZ, EUM). These results are basically similar to Experiment 2, which was expected, as there is not a change in the cloud height assignment method.

Note: Because the sample is small, no layer statistics and collocated statistics are calculated for Experiment 3, to avoid problems of representativity caused by the small amount of data.

Table 9-3: Experiment 3 AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	144	0.03	23.90	1.61	6.32	-3.21	10.54
EUM	268	-0.53	26.57	3.09	7.24	0.05	9.43
JMA	177	-2.20	26.26	0.36	6.04	6.07	8.04
KMA	309	0.16	24.85	-0.02	5.36	4.25	7.13
NOA	101	5.13	24.19	2.37	5.57	22.25	9.32
NWC	75	-3.60	22.36	-1.81	5.13	-3.19	6.44

Table 9-4: Experiment 3 AMVs (QI with forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	201	0.97	28.15	1.25	7.30	5.50	9.12
EUM	283	-0.71	26.15	2.74	7.07	0.57	9.46
JMA	169	-2.50	26.81	0.14	5.09	3.52	7.04
KMA	287	0.80	24.72	0.12	5.07	6.05	6.73
NOA	96	4.89	24.10	2.28	5.57	25.82	9.30
NWC	73	-3.17	21.93	-1.95	5.16	0.44	6.29

e) Model Grid comparison

Table 9-5 through Table 9-9 show the output comparison of all AMVs to the NWP background grid, considering the Python scripts discussed in the corresponding section of Experiment 2. They are very similar to the results in Experiment 2, with NWC and JMA having the best fit to the background while BRZ having the highest errors.

Table 9-5: Experiment 3 all AMV compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast)

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	1586	188	8.61	10.25	8.25	10.42
CMA	4399	672	6.75	7.47	6.27	7.80
EUM	5378	1003	6.88	9.54	6.47	9.73
JMA	3498	955	4.50	5.52	3.71	6.05
KMA	4486	921	6.09	7.72	5.60	8.00
NOA	1639	312	6.74	7.89	6.16	8.26
NWC	1198	321	4.73	5.52	4.12	5.01

Table 9-6: Experiment 3 high-level AMVs (<400 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	270	83	8.45	10.66	7.36	10.10
CMA	1472	473	7.24	8.36	6.06	7.55
EUM	536	188	6.04	8.15	4.85	7.31
JMA	562	196	5.52	6.93	4.29	5.95
KMA	881	363	6.10	7.99	4.73	7.04
NOA	515	217	6.59	8.40	5.14	7.39
NWC	473	208	4.69	5.65	3.68	4.77

Table 9-7: Experiment 3 mid-level AMVs (400-700 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	475	32	10.55	12.50	10.43	12.46
CMA	1844	126	7.39	8.42	7.24	8.34
EUM	1715	198	9.81	12.08	9.40	11.89
JMA	609	101	6.45	8.19	5.96	7.92
KMA	1413	168	7.90	9.76	7.63	9.63
NOA	653	68	7.63	9.14	7.39	9.02
NWC	337	49	5.21	5.96	4.89	5.72

Table 9-8: Experiment 3 low-level AMVs (>700 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	841	73	7.39	8.67	7.14	8.56
CMA	1096	74	5.01	5.62	4.90	5.56
EUM	3127	617	5.43	8.46	5.14	8.34
JMA	2327	658	3.73	5.08	2.98	4.56
KMA	2192	390	4.91	6.62	4.65	6.50
NOA	471	27	5.66	6.69	5.56	6.65
NWC	396	66	4.41	4.97	4.01	4.68

Table 9-9: Experiment 3 collocated AMVs compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast)

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	164	27	6.21	7.20	5.72	6.95
CMA	380	74	5.38	6.17	4.71	5.58
EUM	308	59	5.64	6.89	5.09	6.53
JMA	310	114	3.79	4.68	2.97	3.96
KMA	272	82	4.92	5.73	4.10	5.08
NOA	280	69	5.54	6.36	4.94	5.93
NWC	261	78	4.93	5.74	4.20	5.07

f) Best fit height

The Best Fit height analysis is completed using the same method as in Experiment 2, described in section Experiment 2 Best fit height.

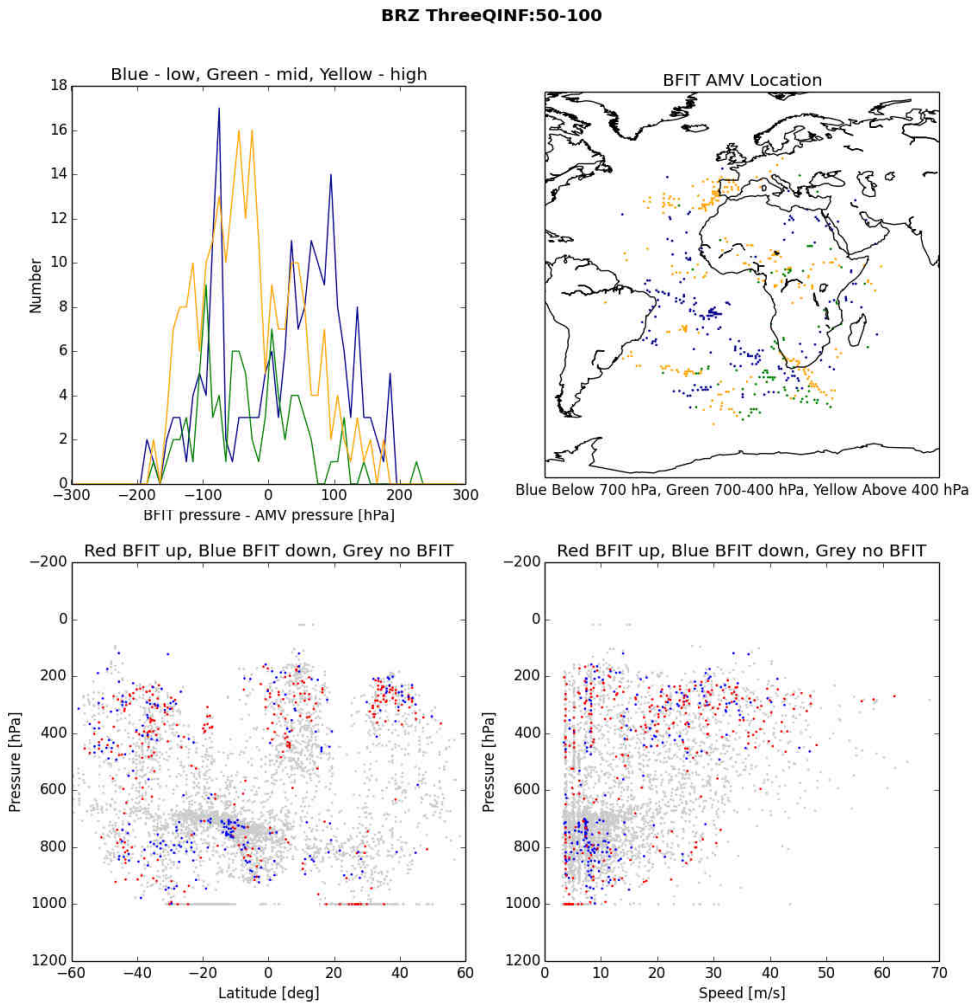


Figure 9-7: BRZ: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

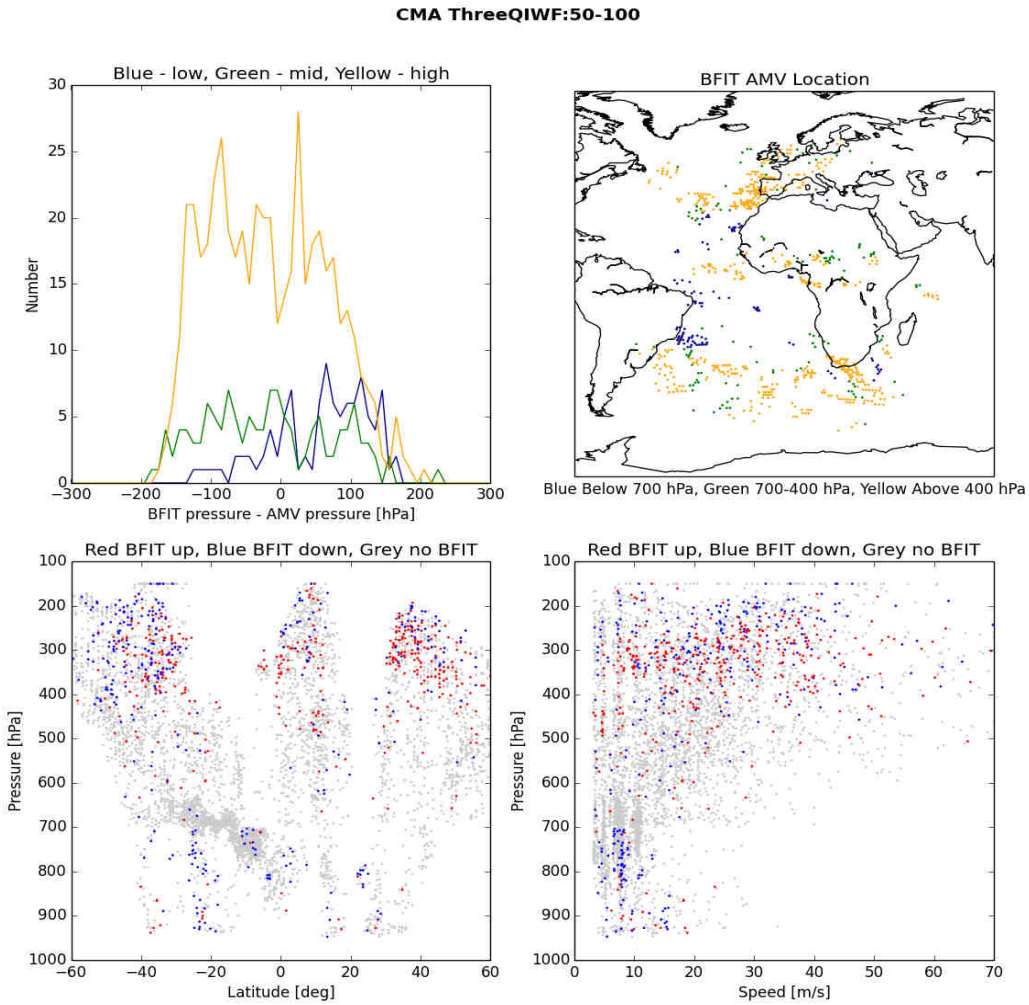


Figure 9-8: CMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

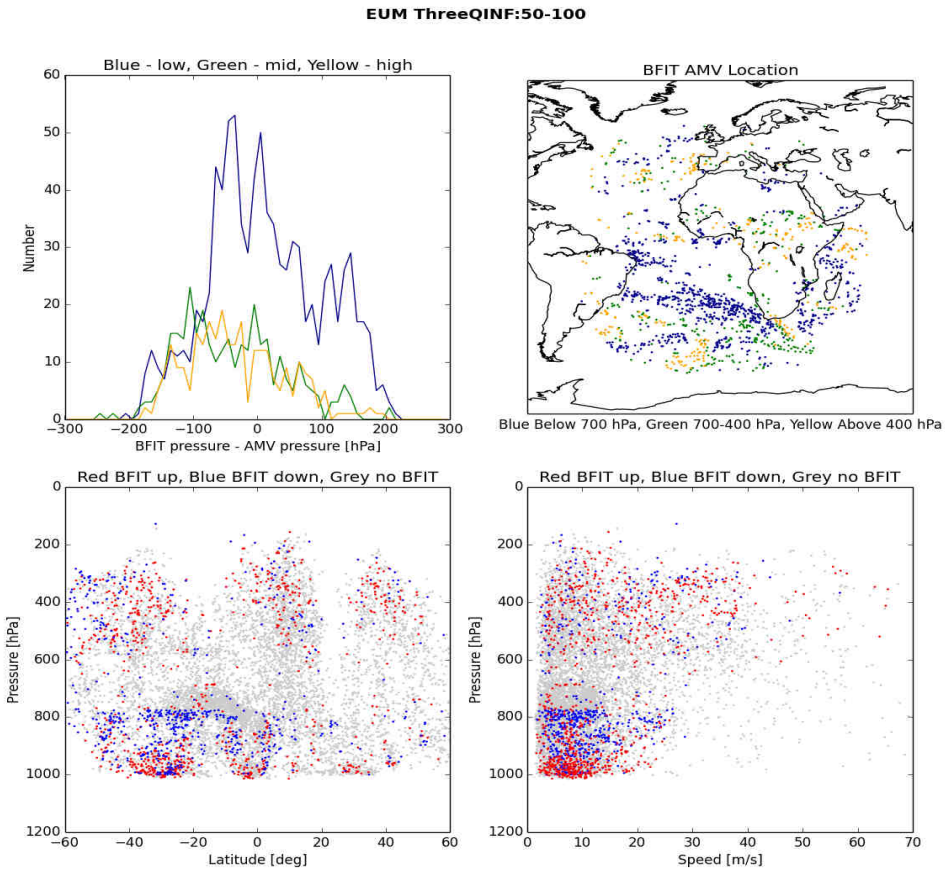


Figure 9-9: EUM: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

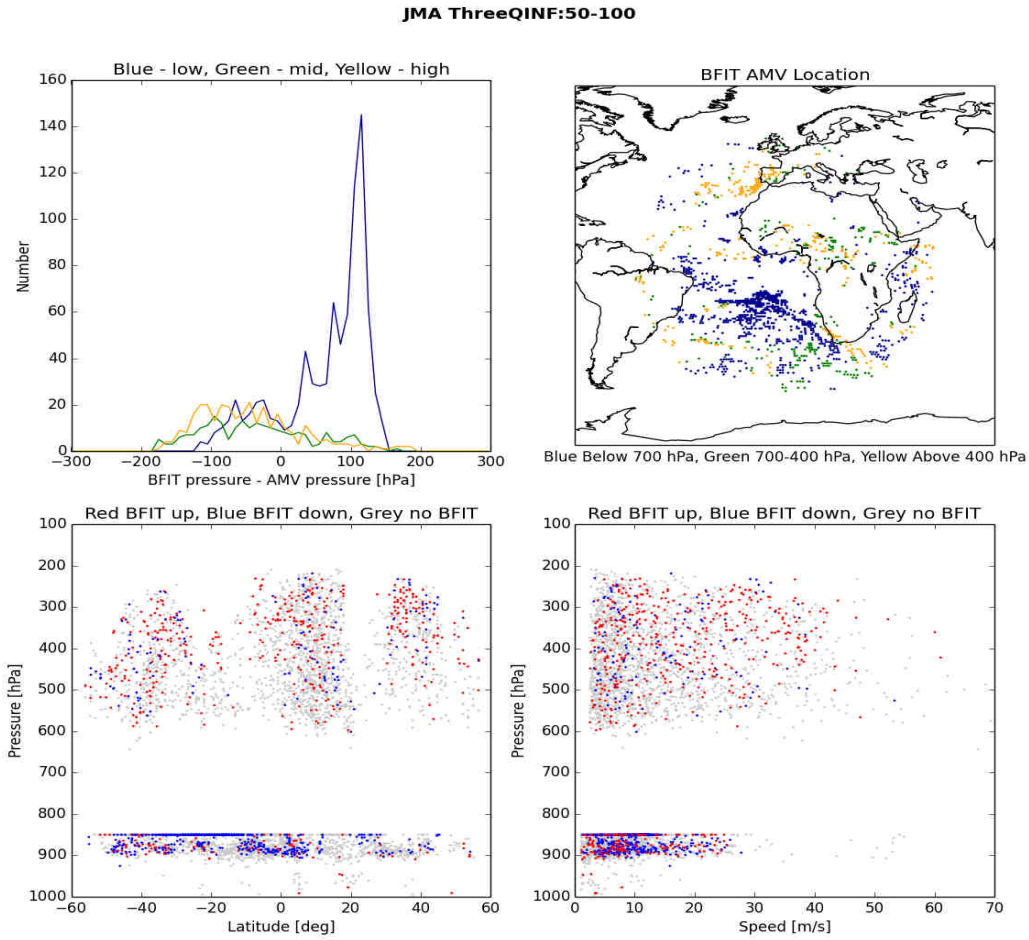


Figure 9-10: JMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

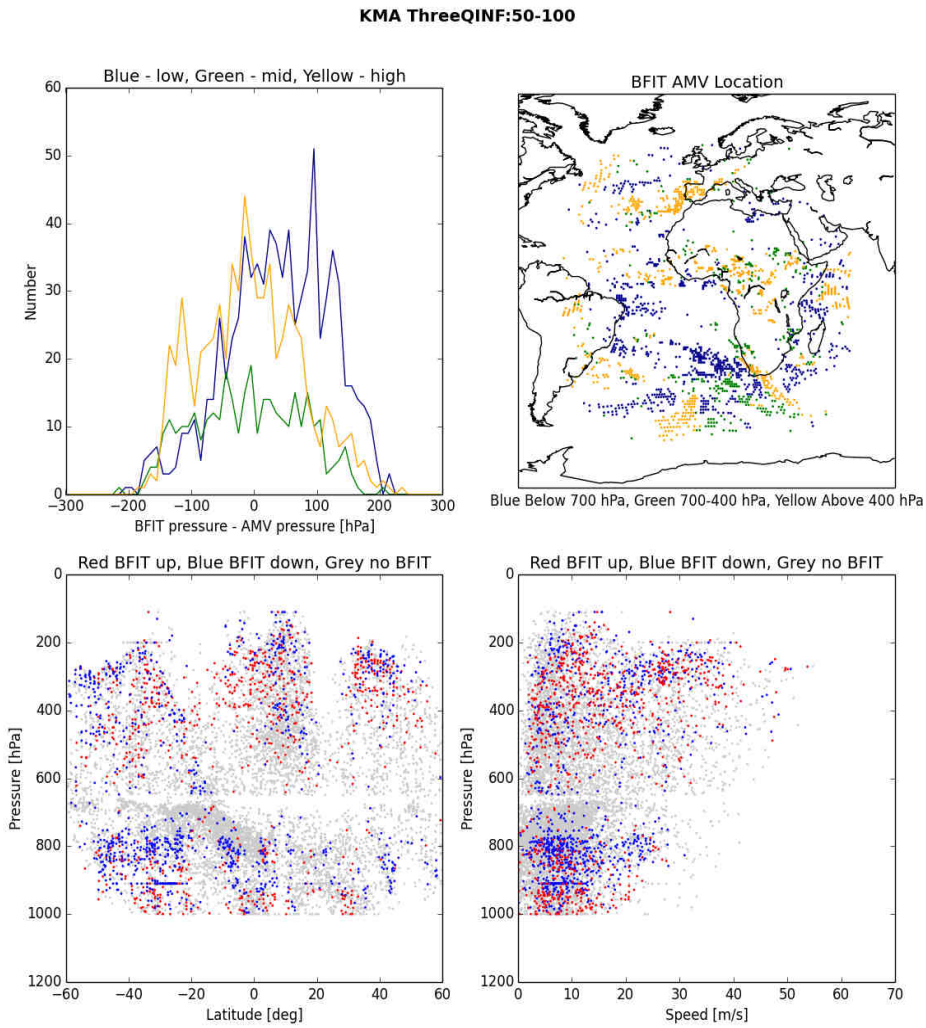


Figure 9-11: KMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

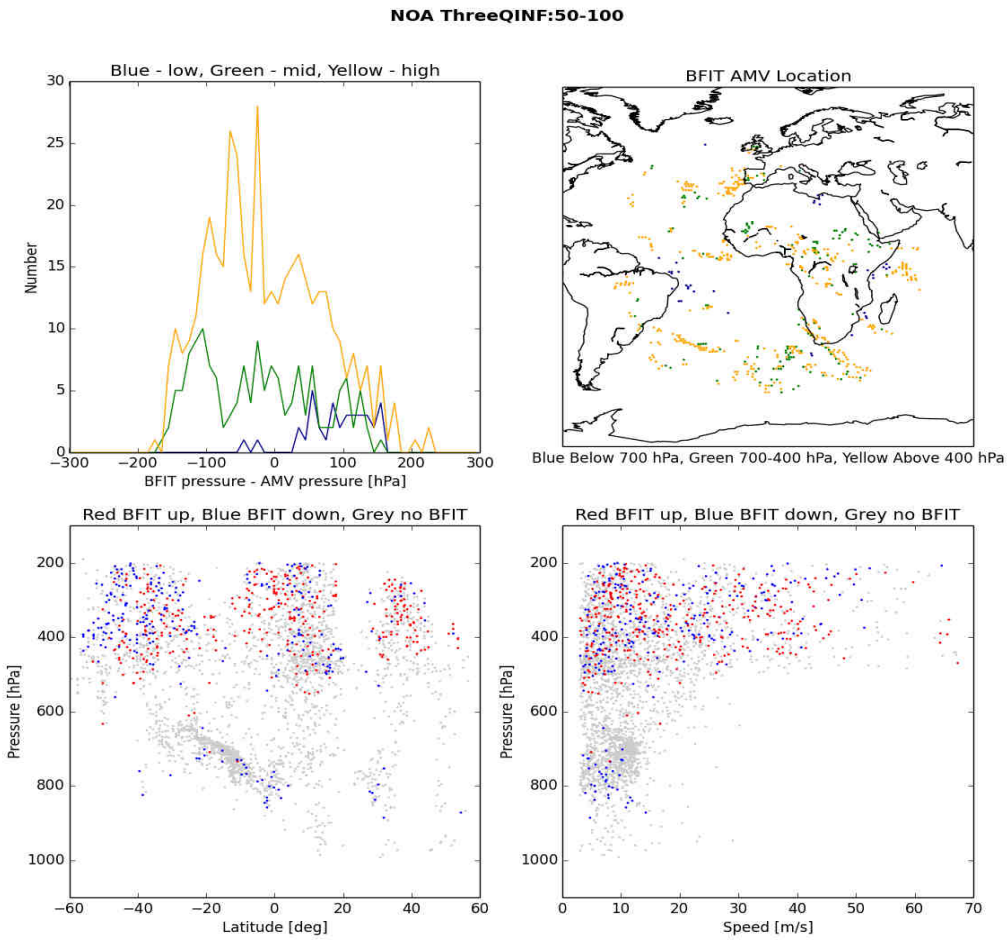


Figure 9-12: NOA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

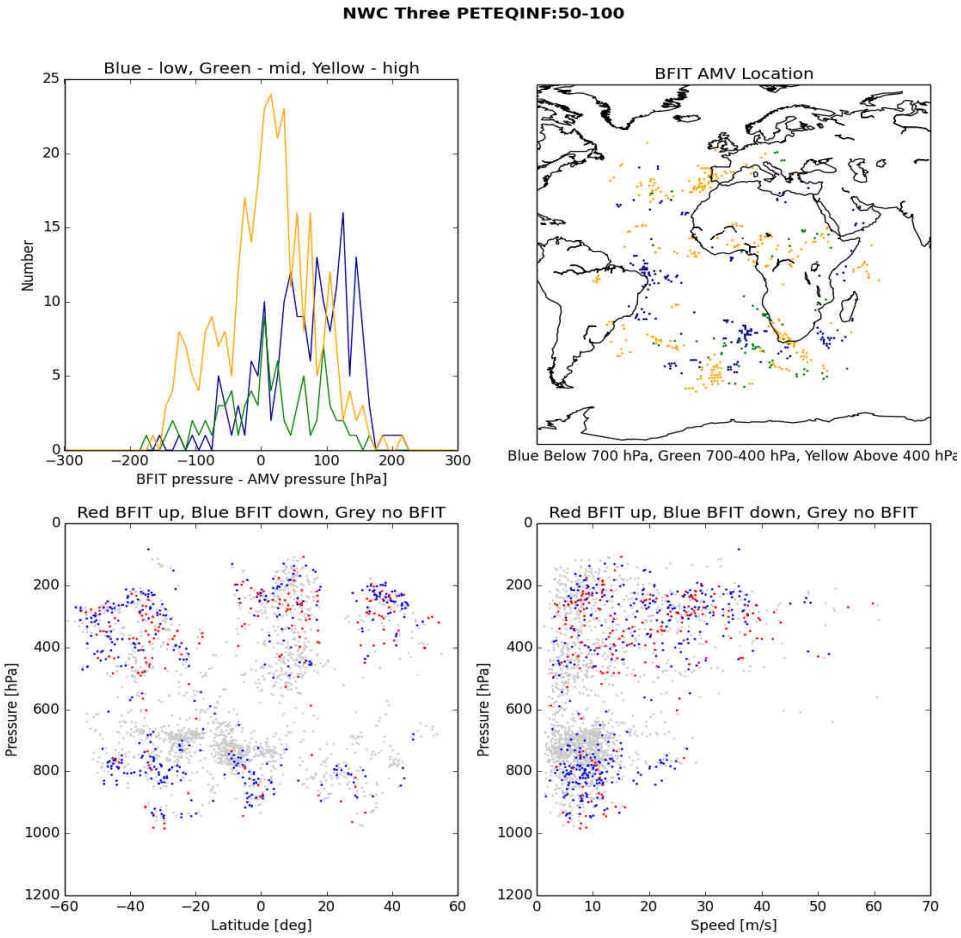


Figure 9-13: NWC: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

The depiction of the distribution of Best Fit statistics is in Figure 9-14 through Figure 9-20. Depending on the site, 12% to 28% (lower-left in each figure) of the AMVs are adjusted to a Best Fit pressure. There does not appear to be a relationship between latitude or longitude and adjusted pressure (upper-left and middle-left in figures).

In the upper-right corner of the figures is the distribution of the pressure difference (AMV Best Fit pressure minus the Original Pressure), all of which are extremely similar to Experiment 2. For sites BRZ, CMA, EUM, NOA, and KMA the pressure difference is centered near zero, JMA had two peaks (-50 and +100) with a minimum near zero, and NWC is slightly skewed to the right of zero. As similar to Experiment 2, since the AMV heights are assigned using only the IR brightness temperature, these offset and skewed distributions may be the result of the specific implementation of the IR brightness temperature height assignment.

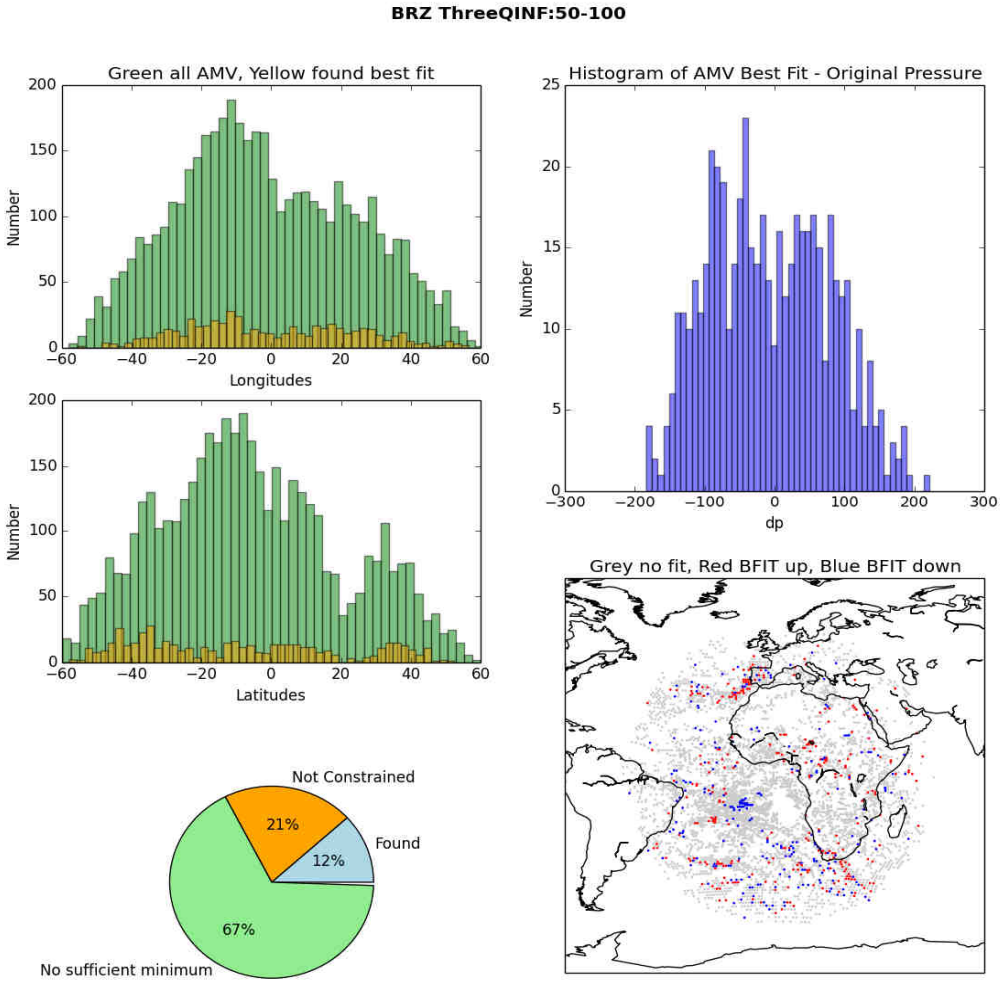


Figure 9-14: BRZ: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle-left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

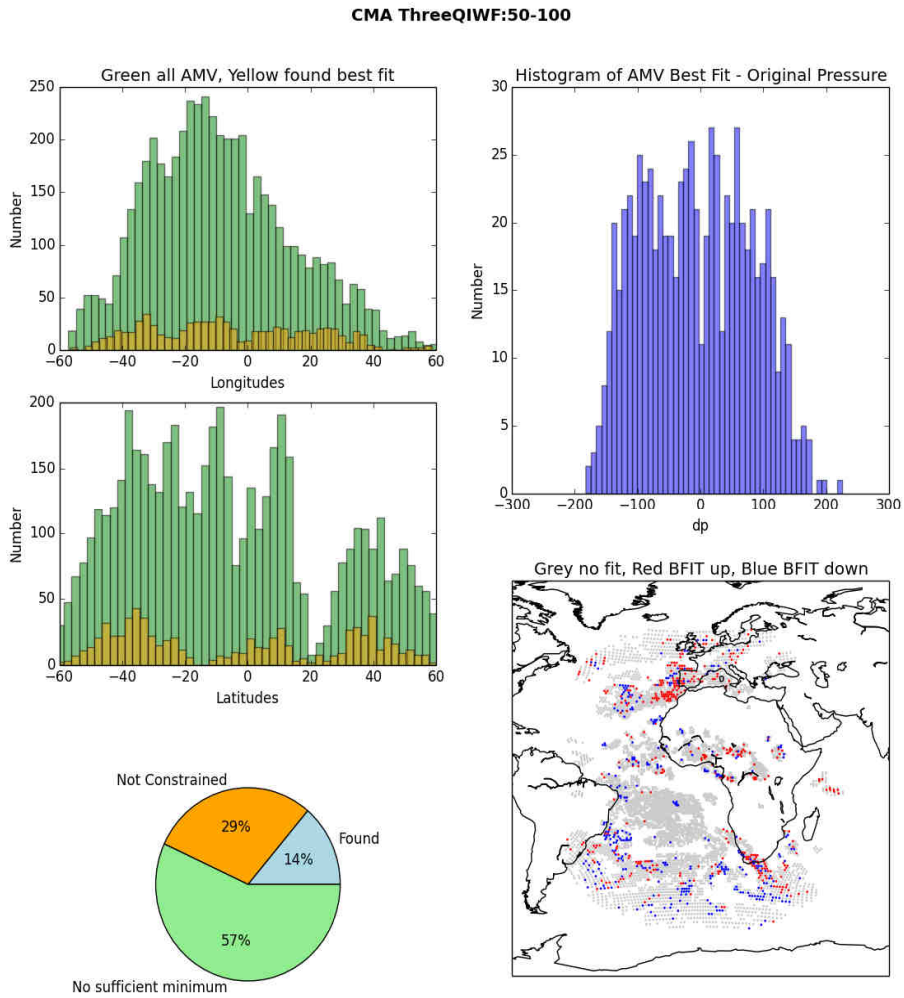


Figure 9-15: CMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle-left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

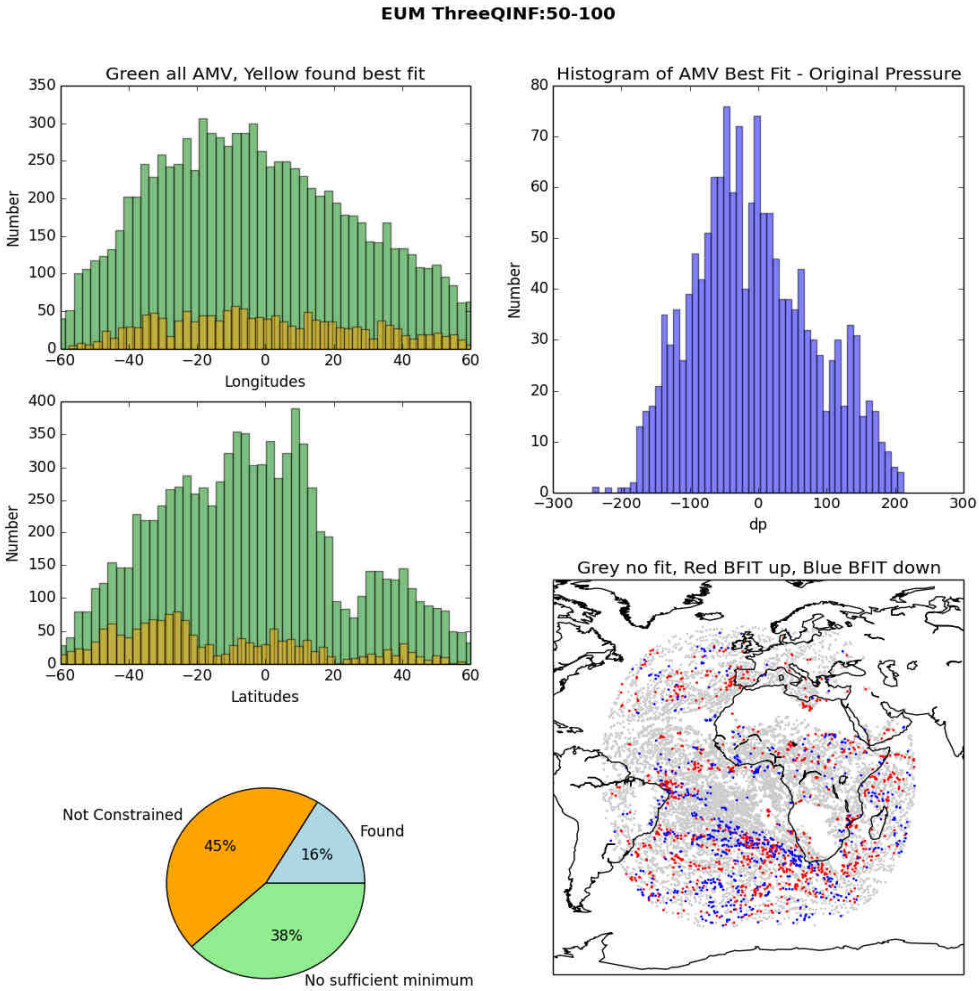


Figure 9-16: EUM: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle-left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

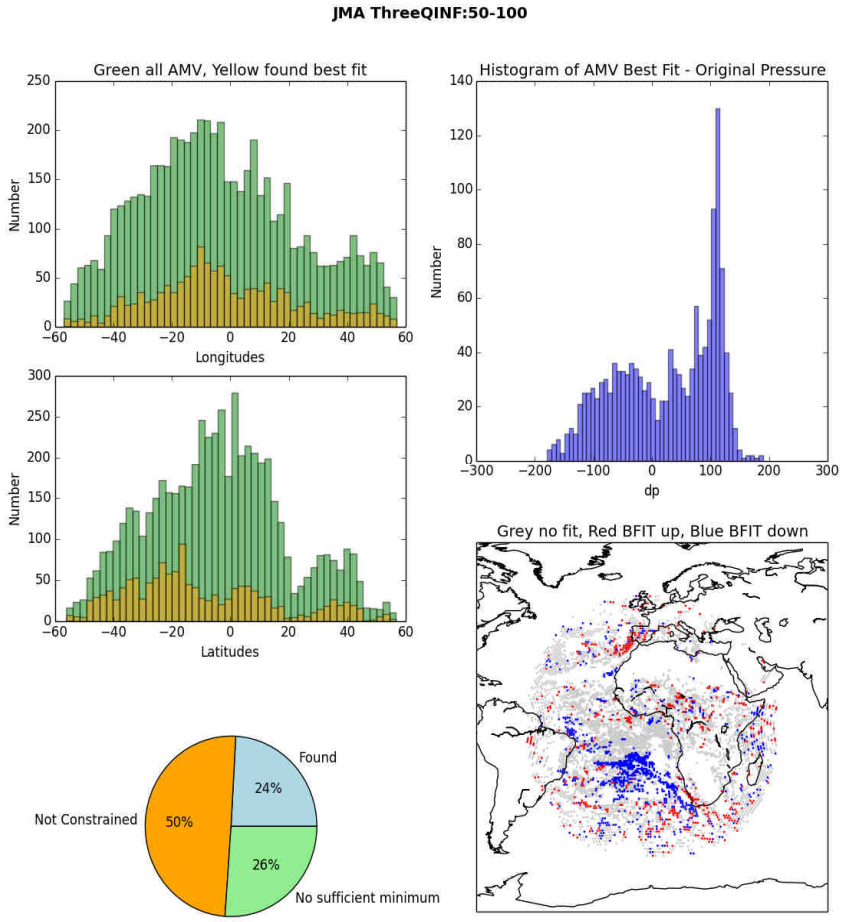


Figure 9-17: JMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle-left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

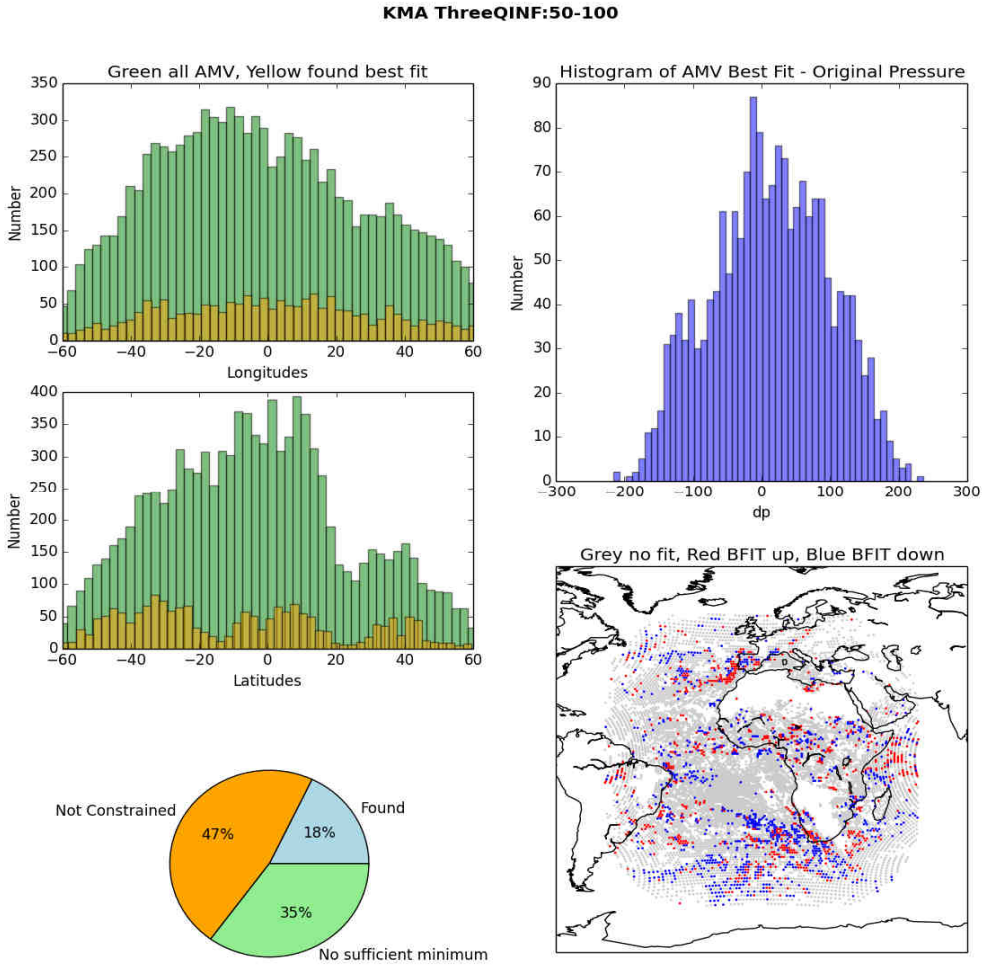


Figure 9-18: KMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle-left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

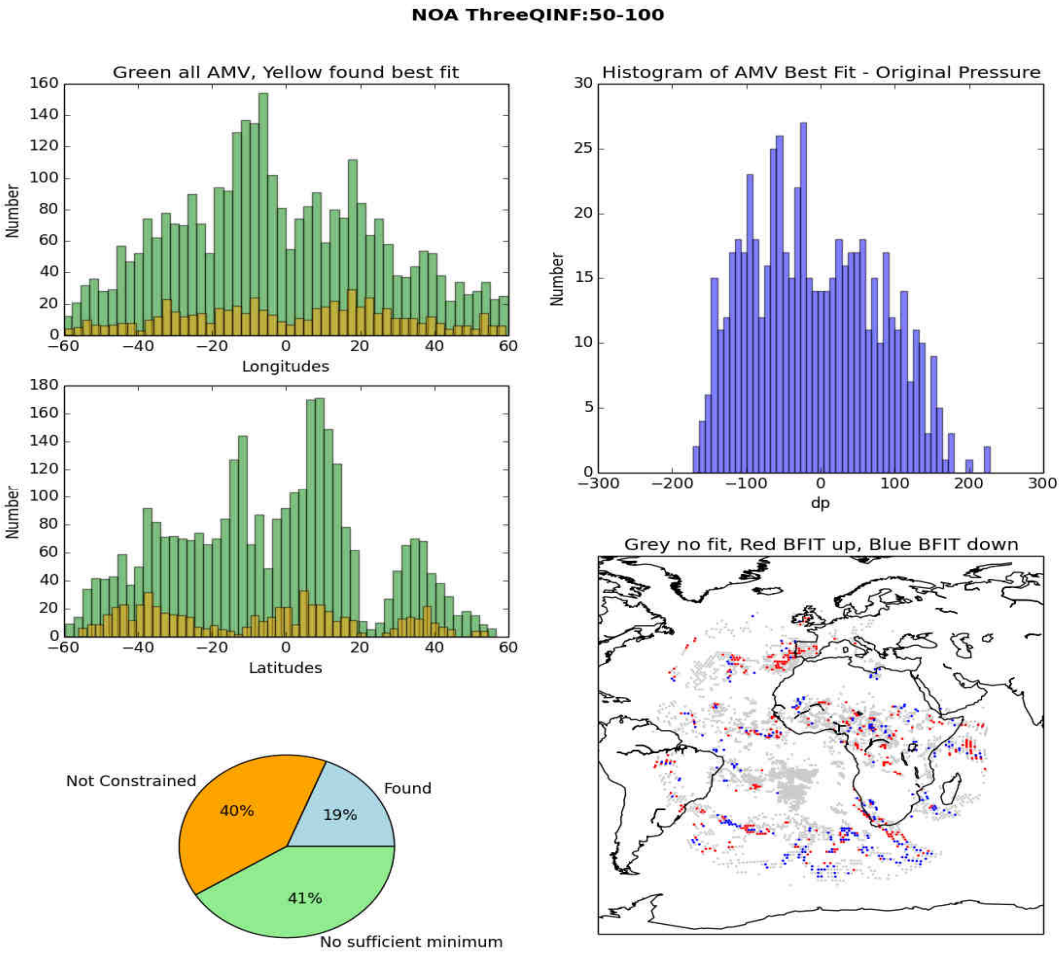


Figure 9-19: NOA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle-left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

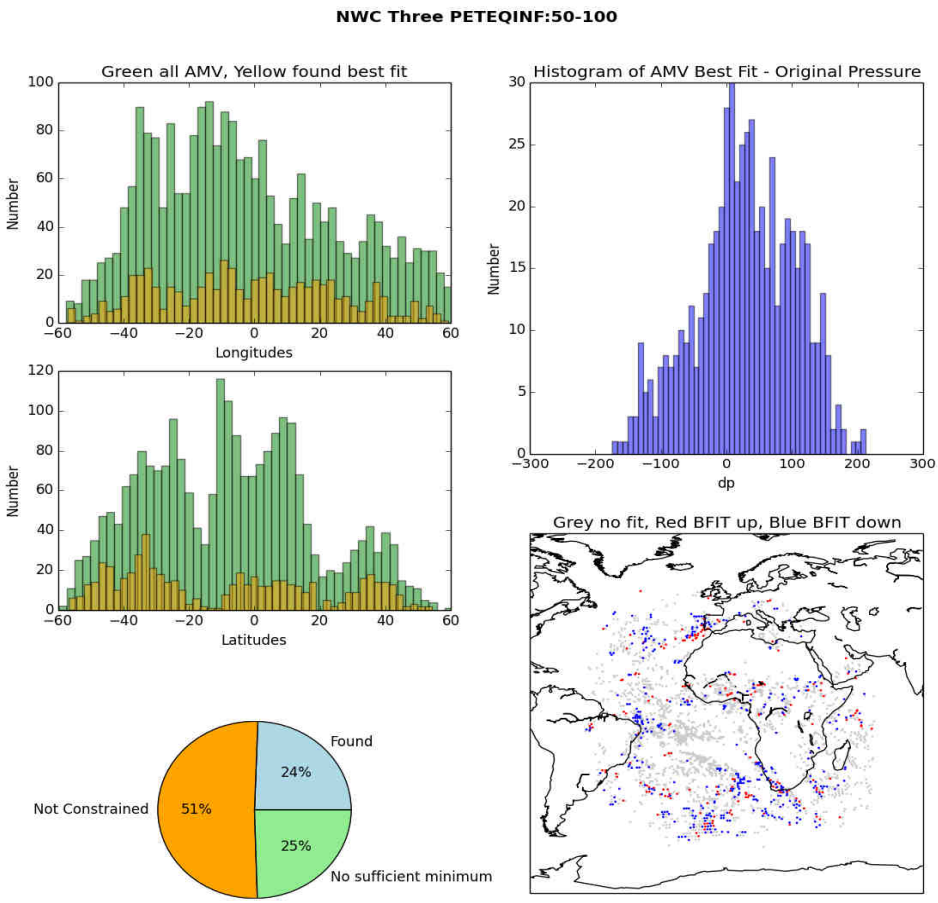


Figure 9-20: NWC: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle-left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

Ancillary figures were generated, located in Appendix D: Best Fit Speed and Vector Difference, to show how the statistics improved when the AMV height was adjusted to the Best Fit level.

The lower half of Figure 17-15 to Figure 17-22 shows the change in the speed difference distribution before (left) and after (right) Best Fit adjustment. As expected, the speed bias and standard deviation is usually reduced. Likewise, the lower half of Figure 17-22 to Figure 17-28 shows the change in the vector difference distribution before (left) and after (right) Best Fit adjustment with the same result: the vector difference and standard deviation are reduced. BRZ and CMA have the largest deviation before the best fit, with a vector difference of about 8 ms^{-1}, as compared to the background grid, and NWC has the smallest deviation before the best fit, with a vector difference of about 4 ms^{-1}, s compared to the background grid. These results are very similar to Experiment 2.

g) Statistical comparison

Paired t-tests are used between all combinations of producers and parameters to determine if the differences are statistically significant in collocated AMVs. Using a QI no forecast >= 50 and distance threshold of 55 km, the number of collocations is very low at 370.

As compared to Experiment 2, there are many more instances of agreement between the winds producers in terms of wind speed (Table 9-10) and wind direction (Table 9-11). In fact, for direction, differences between all centers are not statistically significant. Table 9-10 to Table 9-17 summarize the results in terms of statistical significance for each of the five variables; green signifies not statistically different while red is statistically different.

As with Experiment 2, there is very little similarity in AMV pressure and QI values, at least as measured by the paired t-test.

The output from the paired t-test for this experiment can be found in Appendix C: t-test Results Experiment 3.

Table 9-10: Experiment 3 speed t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 9-11: Experiment 3 direction t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 9-12: Experiment 3 pressure t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 9-13: Experiment 3 QI without forecast t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

The paired t-tests are also used between all combinations of producers and parameters using a QIWF >= 50 and a distance threshold 55 km; the number of collocations is also low at 245.

There is no statistical difference in direction (Table 9-15) and many speed differences are also not statistically different (Table 9-14).

Although many differences between AMV pressure and QI values are still statistically different, the similarities between AMV pressures are noticeably improved when compared to the t-tests completed on the data with QI without forecast.

The output from the paired t-test for this experiment can be found in Appendix C: t-test Results Experiment 3.

Table 9-14: Experiment 3 speed t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

Table 9-15: Experiment 3 direction t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

Table 9-16: Experiment 3 pressure t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

Table 9-17: Experiment 3 QI with forecast t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

10. Experiment 4

AMV producers extract IR10.8 channel AMVs considering a prescribed AMV algorithm configuration, but using the height assignment method of their choosing. This experiment will be used to test the Height assignment and Quality control steps in all AMV algorithms, considering similar targets. The prescribed configuration is a 24 x 24 target box; 80 x 80 search box.

This is the same as Experiment 3, except the AMV producers can use additional height assignment methods, such as CO_2 slicing, H_2O-Intercept, Cloud Base, etc.

For each one of the AMV producer's datasets, a distribution of AMV speed, direction, vector height, and QI will be generated. Differences of these quantities between AMV producers will be made. Also, differences in AMV coverage and number of vectors will be presented as bulk statistics and geographic plots.

Collocated AMVs from the different algorithms will be used to measure the differences. Also, a comparison of the AMVs with the NWP model winds and height assignment investigations using NWP model best fit pressure will be used for verification.

Experiment 4 Highlights

Using additional height assignment methods results in a shift in the distributions of AMV pressure, for both high- and low-level clouds. This is especially noted for EUM, NOA and NWC, which result in a substantial improvement in the vector RMS in the rawinsonde comparisons (for EUM from 9 to 6 ms^{-1}; for NOA from 9 to 7 ms^{-1}; for NWC from 6 to 4 ms^{-1}).

Other centers (BRZ, CMA, KMA, JMA) have very few AMVs shifted in height, resulting in little change in the rawinsonde and model grid comparison RMS errors. It is important to note that the impact of the additional height assignment methods is positive in all cases except JMA, for which statistics degrade in Experiment 4. JMA developers should verify the reasons for this.

For the collocated vectors (numbering 9942), nearly all speed, direction, pressure, and QI differences are significant between all centers. The only exception is direction for EUM, NOA, NWC, and JMA. Pressure differences are smaller than in Experiment 3, although the mean difference for collocated vectors has a range from 20 to 100 hPa. BRZ and JMA have the largest vector RMS values, while EUM and NWC show the smallest ones, so showing the similarities provided by their common height assignment method (CCC method).

a) Approach

A similar comparison and analysis as Experiments 2 and 3 is used, but with additional opportunities to compare cloud heights. An attempt to determine if the new cloud heights have improved best fit statistics over the B_T technique in Experiment 3 was also used.

b) Parameter distributions

The bulk statistics are presented in tables and histograms, for QINF >= 50 and QIWF >= 50 (because not all centers reported both QINF and QIWF).

Table 10-1 and Table 10-2 list basic Experiment 4 statistics for the AMVs for each winds producer, without and with forecasting respectively. The filter of QIWF >= 50 or QINF >= 50 is applied in these tables.

Table 10-1: Experiment 4 statistical summary of AMV datasets for QI without forecast >= 50.

	EUM	BRZ	JMA	KMA	NOA	NWC (O, EUM CL)
Total AMVs	12182	11371	5648	11986	4449	92512
QI>=50	9147	4480	4996	9594	3773	79609
SPD_min	2.51	3.11	2.51	2.50	3.01	2.50
SPD_max	78.59	72.13	67.77	54.81	78.41	76.30
SPD_mean	12.46	13.38	10.69	12.10	14.28	11.73
P_min	123.86	19.00	100.49	105.05	110.17	123.00
P_max	995.20	1000.00	995.88	1000.00	999.47	998.94
P_mean	576.89	594.51	638.54	580.17	377.32	656.12
Low_winds	44.62	46.81	62.73	43.96	18.39	58.87
Mid_winds	17.82	19.80	4.82	23.92	11.90	12.40
High_winds	37.56	33.39	32.45	32.11	69.71	28.73
Low_SPD_min	2.51	3.11	2.51	2.50	3.02	2.50
Low_SPD_max	64.94	43.61	54.92	41.09	23.33	49.96
Low_SPD_mean	8.76	8.43	8.87	9.15	8.95	9.02
Low_P_min	700.11	700.00	707.57	700.04	700.02	700.00
Low_P_max	995.20	1000.00	995.88	1000.00	999.47	998.94
Low_P_mean	861.96	818.49	866.58	826.96	823.59	872.98
Mid_SPD_min	2.51	3.29	2.57	2.51	3.01	2.50
Mid_SPD_max	78.59	55.25	41.13	48.37	66.92	73.30
Mid_SPD_mean	12.69	12.63	10.90	12.22	12.34	13.61
Mid_P_min	400.02	400.05	400.37	400.16	400.41	400.03
Mid_P_max	699.90	699.94	672.61	699.99	699.76	699.95
Mid_P_mean	524.48	592.69	507.67	565.62	533.89	532.31
High_SPD_min	2.54	3.45	2.51	2.51	3.02	2.51
High_SPD_max	71.68	72.13	67.77	54.81	78.41	76.30
High_SPD_mean	16.75	20.76	14.18	16.06	16.02	16.48
High_P_min	123.86	19.00	100.49	105.05	110.17	123.00
High_P_max	399.81	399.58	399.55	399.94	399.54	399.93
High_P_mean	263.17	281.64	217.10	253.14	232.83	265.27

Table 10-2: Experiment 4 statistical summary of AMV datasets for QI with forecast >= 50.

	EUM	CMA	JMA	KMA	NOA	NWC (O, EUM CL)
Total AMVs	12182	5498	5648	11986	4449	92512
QI>=50	9339	5496	4790	9008	3416	79839
SPD_min	2.51	3.16	2.51	2.50	3.02	2.50
SPD_max	78.59	82.64	67.77	54.81	78.41	76.30
SPD_mean	12.33	16.58	10.73	12.27	14.18	11.79
P_min	123.86	150.00	100.49	105.05	110.17	123.00
P_max	995.20	947.00	995.12	1000.00	999.47	998.94
P_mean	575.60	436.74	639.95	578.15	379.93	657.32
Low_winds	44.24	19.71	63.05	43.86	19.17	59.10
Mid_winds	18.19	24.07	4.72	23.56	11.62	12.26
High_winds	37.56	56.22	32.23	32.58	69.20	28.63
Low_SPD_min	2.51	3.19	2.51	2.50	3.03	2.50
Low_SPD_max	64.94	33.87	54.92	41.09	22.60	49.96
Low_SPD_mean	8.74	8.18	8.75	9.14	8.91	9.06
Low_P_min	700.11	700.00	850.00	700.04	700.02	700.00
Low_P_max	995.20	947.00	995.12	1000.00	999.47	998.94
Low_P_mean	861.85	780.36	866.28	826.30	819.85	873.26
Mid_SPD_min	2.51	3.19	2.57	2.52	3.02	2.50
Mid_SPD_max	78.59	71.49	45.11	48.37	66.92	73.30
Mid_SPD_mean	12.46	12.97	11.36	12.42	11.49	13.73
Mid_P_min	400.02	401.00	400.37	400.16	400.58	400.03
Mid_P_max	699.90	699.00	672.61	699.99	699.76	699.95
Mid_P_mean	526.21	583.12	505.20	566.15	538.71	531.70
High_SPD_min	2.54	3.16	2.51	2.51	3.02	2.51
High_SPD_max	71.68	82.64	67.77	54.81	78.41	76.30
High_SPD_mean	16.50	21.07	14.52	16.38	16.09	16.57
High_P_min	123.86	150.00	100.49	105.05	110.17	123.00
High_P_max	399.91	400.00	399.55	399.94	399.54	399.93
High_P_mean	262.37	253.62	216.98	252.76	231.38	265.40

Figure 14-25 to Figure 14-36 show histograms with unique characteristics of the AMVs for each centre, with QIWF >= 50 or QINF >= 50:

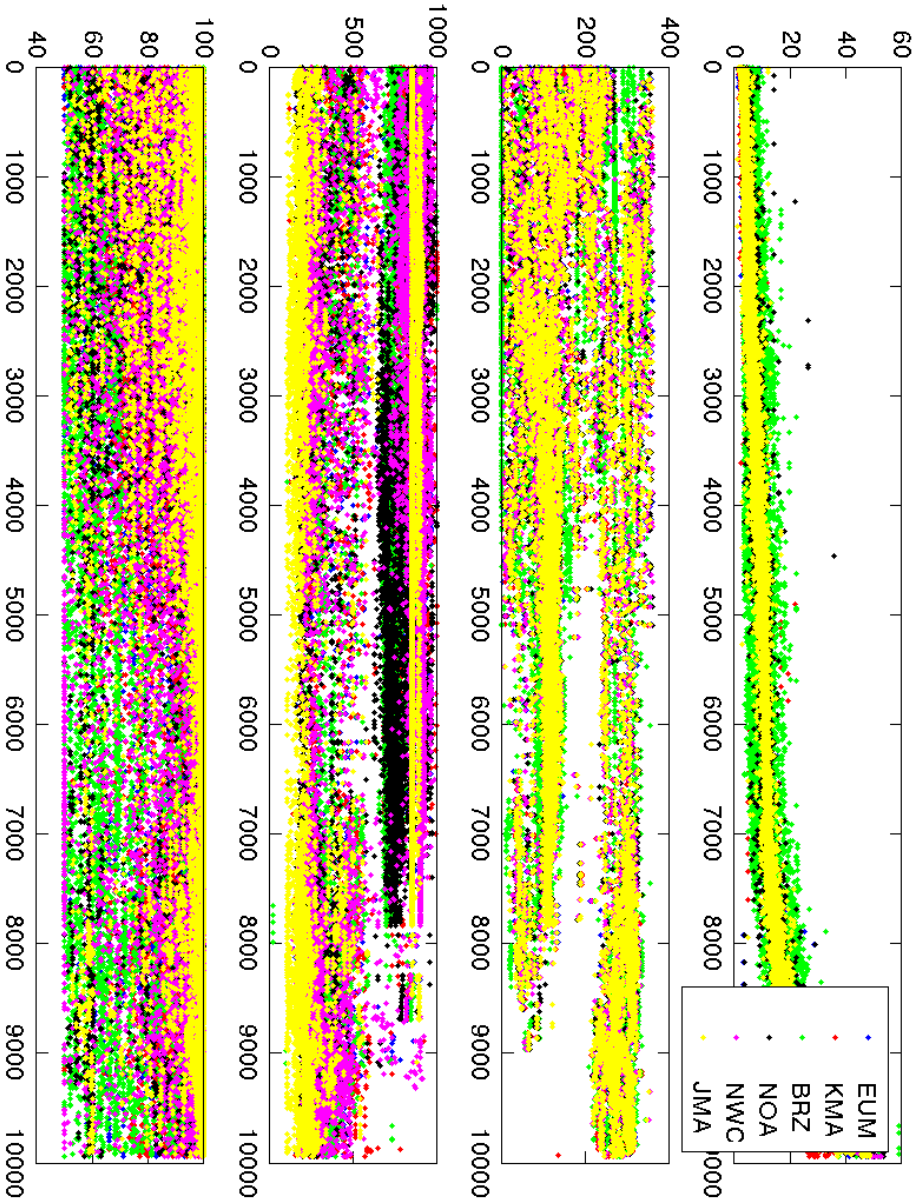
- BRZ (Figure 14-25): The wind direction (lower-left) continues to have two very sharp peaks. The AMV pressure distribution has peaks at 300 and 770 hPa and while the upper-level winds at 300 hPa are reasonable, the 770 hPa peak is likely too high for low-level clouds.
- EUM (Figure 14-26 and Figure 14-32): The AMV pressure distribution has a peak at 250 and 870 hPa.
- JMA (Figure 14-27 and Figure 14-33): The AMV pressure distribution has a peak at 220 and 850 hPa.
- KMA (Figure 14-28 and Figure 14-34): The AMV pressure distribution has a peak at 220 and 850 hPa.
- NOA (Figure 14-29 and Figure 14-35): The AMV pressure distribution has a peak at 220 and 790 hPa. The upper-level winds are placed well, while the low-level winds are too high.
- NWC (Figure 14-30 and Figure 14-36): The AMV pressure distribution has a peak at 220 and 860 hPa.
- CMA (Figure 14-31): The AMV pressure distribution has a peak at 220 and 780 hPa. The upper-level winds are placed well, while the low-level winds are too high.

The distributions from EUM, KMA and NWC are much improved over Experiment 2 and 3.

c) Collocation plots

AMVs are first quality controlled, retaining only those with a QINF >= 50. For collocation the distance threshold is 55 km, resulting in 9942 AMVs.

Figure 10-1: Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.



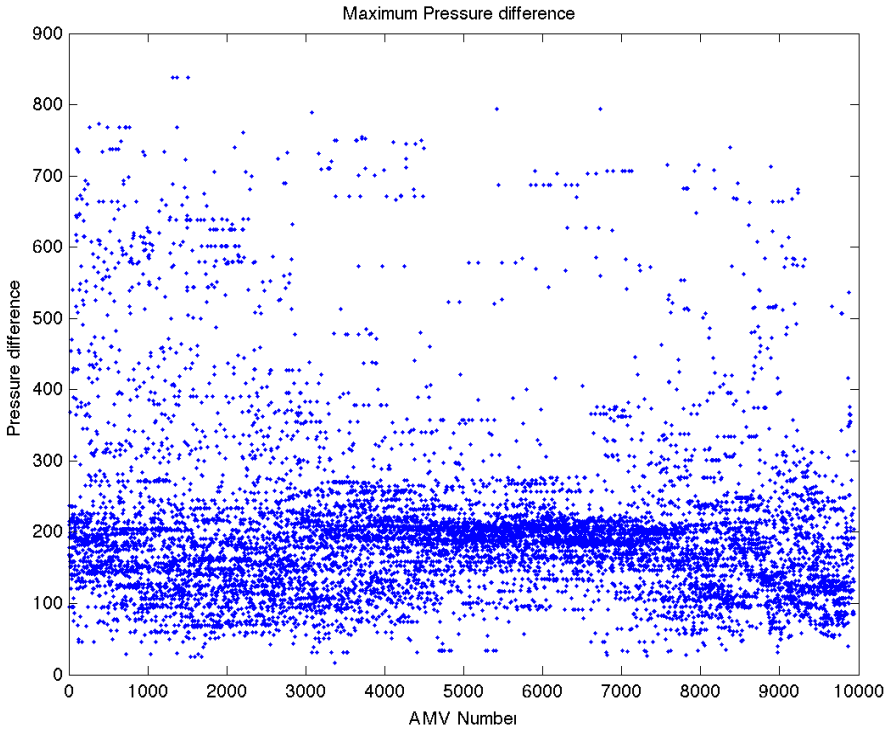


Figure 10-2: The maximum pressure difference between any two collocated AMVs.

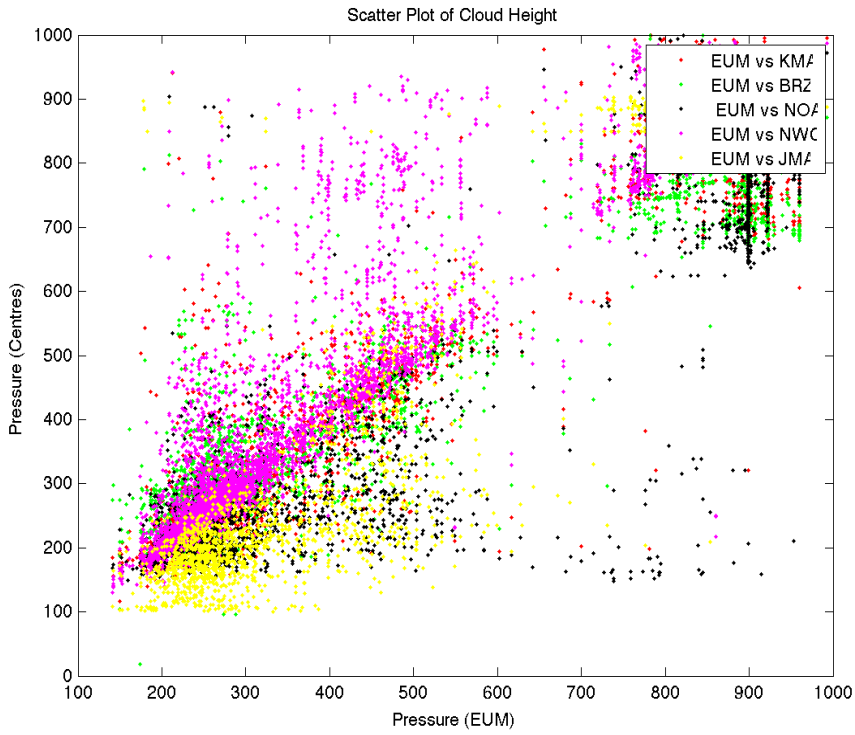
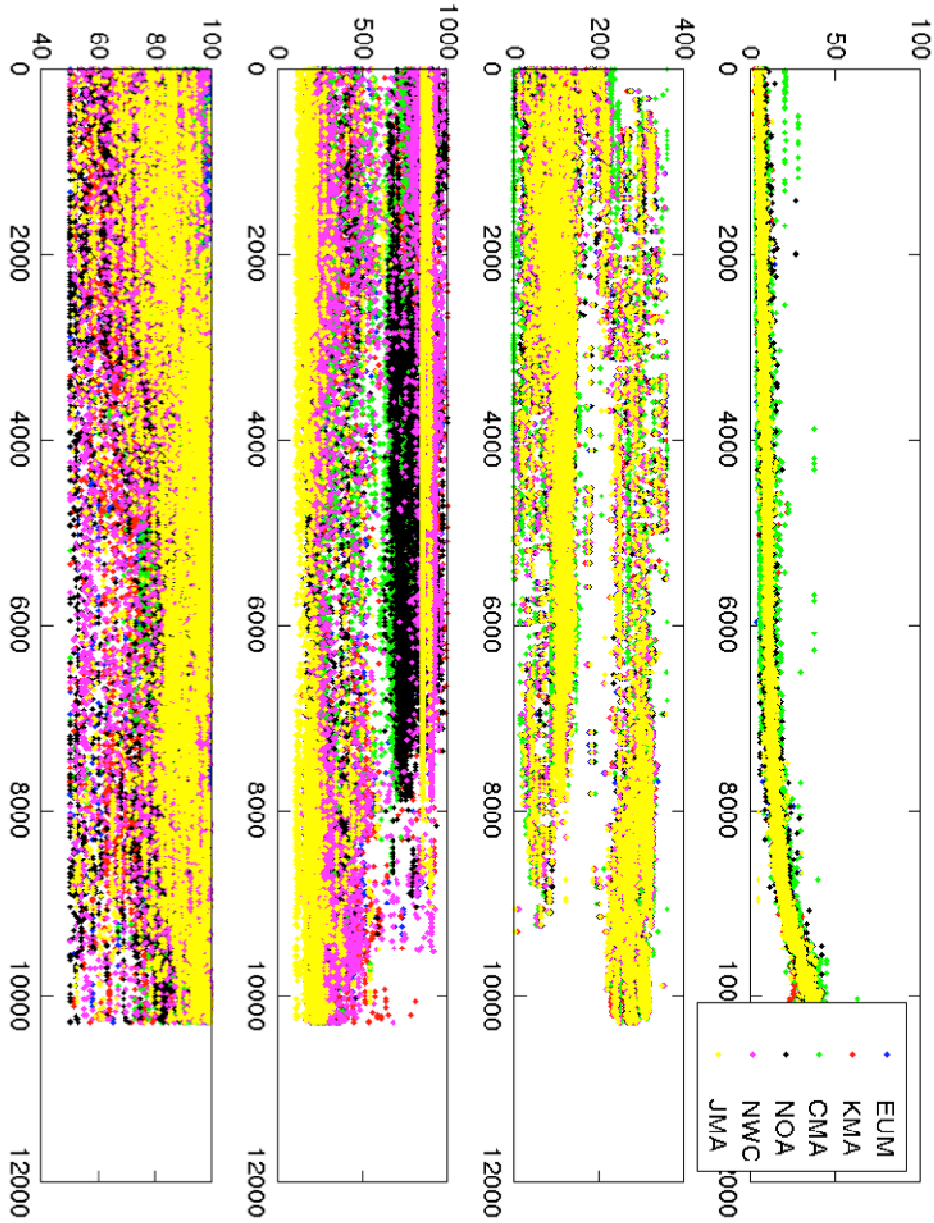


Figure 10-3: Scatter plot of AMV pressure for each center vs. EUM pressure.

A similar comparison is done for AMVs with QI with forecast, retaining only those with a QIWF >= 50. For collocation the distance threshold is 55 km, resulting in 10285 AMVs.

Figure 10-4: Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.



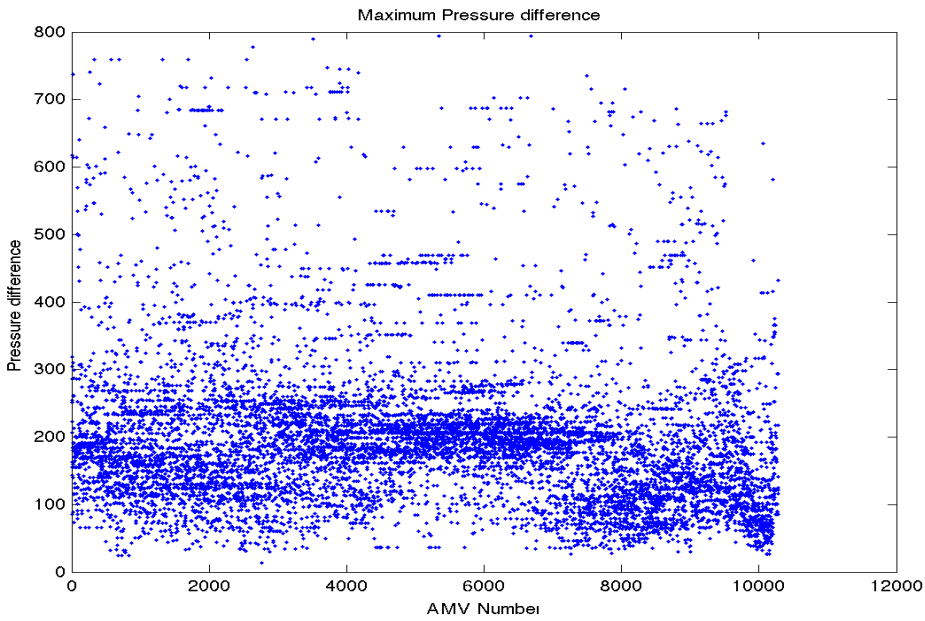


Figure 10-5: The maximum pressure difference between any two collocated AMVs.

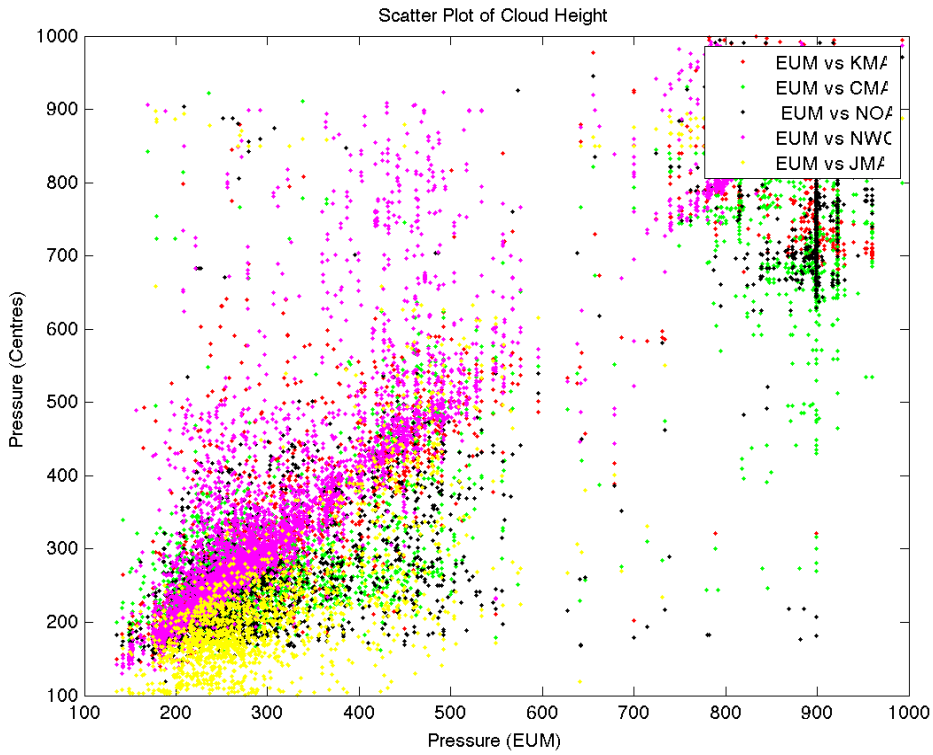


Figure 10-6: Scatter plot of AMV pressure for each center vs. EUM pressure.

d) AMV spatial plots

Two sets of figures are generated to show the spatial distribution of the AMVs along with the satellite images they were derived from. The first set depicts the AMVs over a hemispheric satellite image (Figure 10-7 through Figure 10-13). The AMVs are color-coded by height: Above 375 hPa (cyan); below 850 hPa (magenta).

The coverage from EUM is the most complete, compared to the other centers for this study, for high- and low-level winds (Figure 10-7). Note especially the density of AMVs for the two mid-latitude cyclones to the northwest of Africa (cyan) and the marine stratus to the southeast of southern Africa (magenta). Since EUM's algorithm is tuned for this satellite, the remainder of the discussion in this section will be relative to EUM's results.

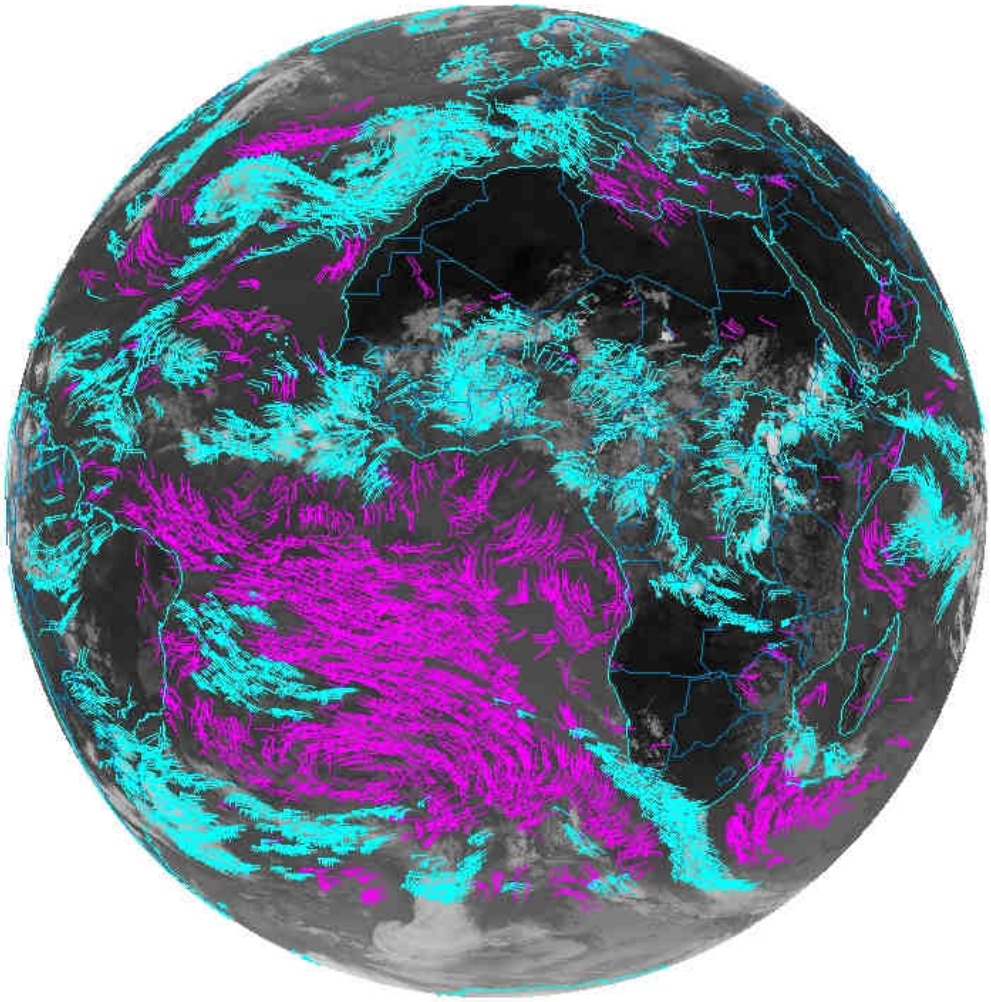


Figure 10-7: EUM high-level (cyan, above 375 hPa) and low-level (magenta, below 850 hPa) AMVs overlaid on the Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

The coverage for BRZ is good for the high-level clouds, however very few low-level vectors are detected over the South Atlantic Ocean (Figure 10-8). The few low-level AMVs are due to height being assigned higher than 850 hPa (Figure 14-25).

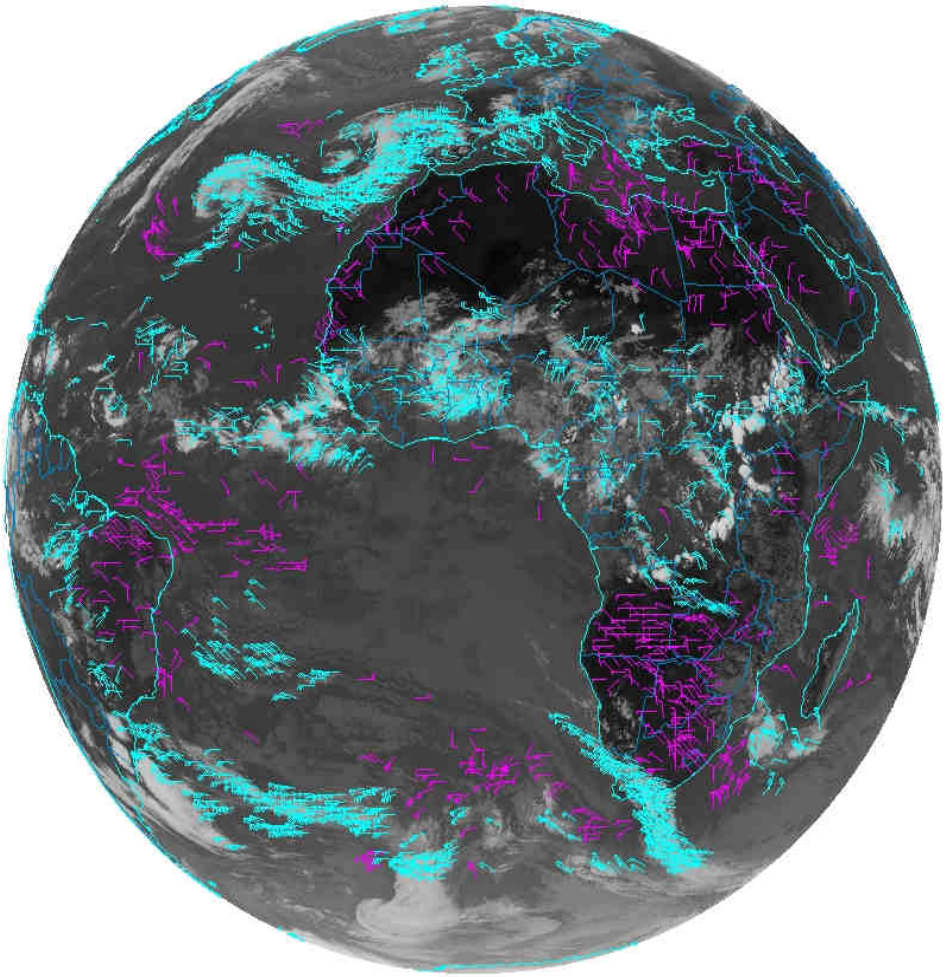


Figure 10-8: BRZ high-level (cyan, above 375 hPa) and low-level (magenta, below 850 hPa) AMVs overlaid on the Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

The CMA processing detects many clouds in the high-levels (Figure 10-9), which visually is comparable to EUM. However, very few low-level clouds are tracked. This lack of low-level winds is due to assigning the heights higher than 850 hPa (Figure 14-31).

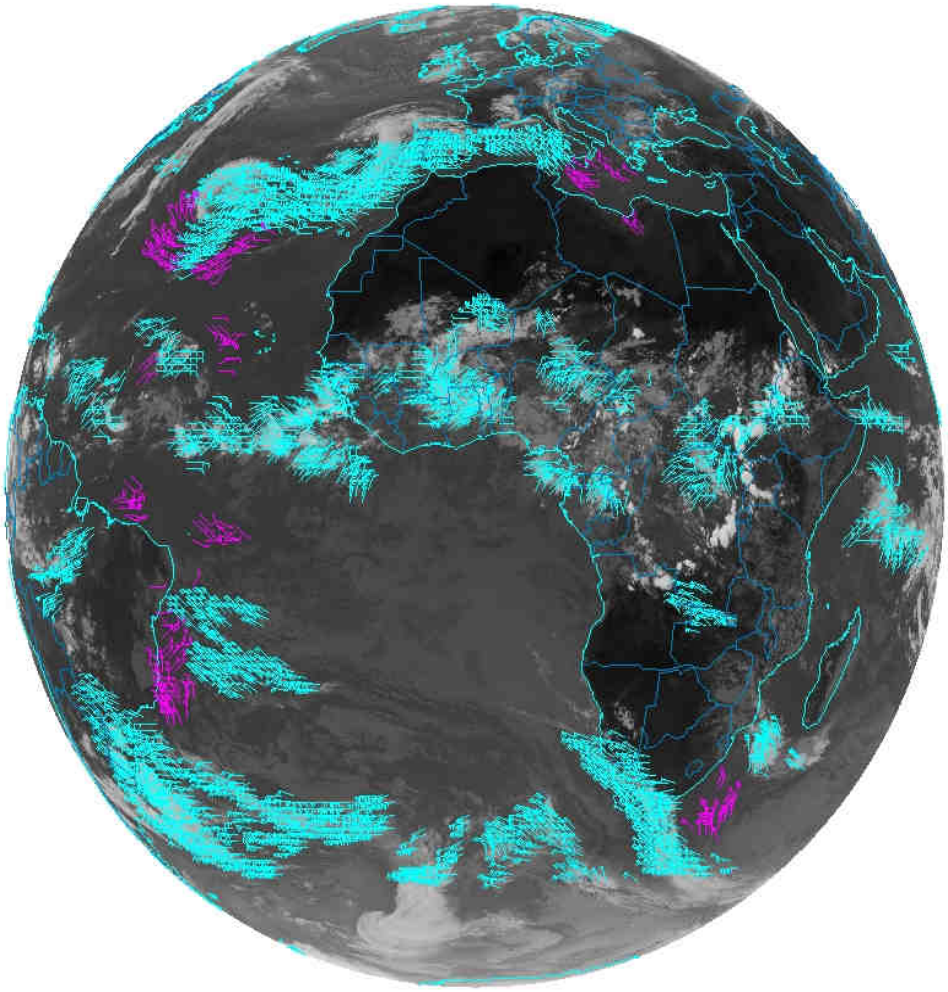


Figure 10-9: CMA high-level (cyan, above 375 hPa) and low-level (magenta, below 850 hPa) AMVs overlaid on the Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

The JMA algorithm captures the low-level winds, similar to EUM, however the coverage at high-levels (above 375 hPa) is not as complete, especially for the mid-latitude cyclone northwest of Africa (Figure 10-10, Figure 10-17). The reason for the fewer high-level AMVs is not known, but it is not due to an incorrect height assignment (Figure 14-27).

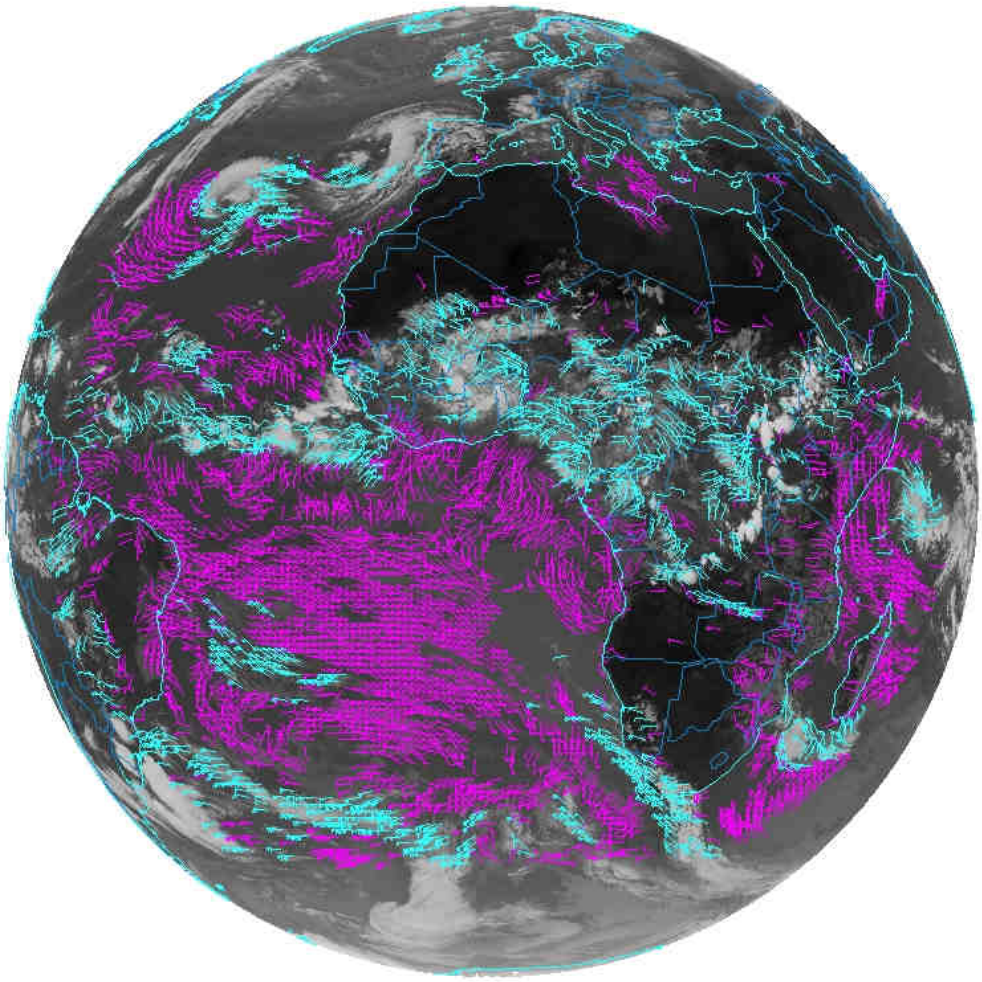


Figure 10-10: JMA high-level (cyan, above 375 hPa) and low-level (magenta, below 850 hPa) AMVs overlaid on the Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

The KMA processing detects many clouds in the high-levels, which visually is comparable to EUM. However, very few low-level clouds are tracked. This lack of low-level winds is due to assigning the heights higher than 850 hPa (Figure 14-28).

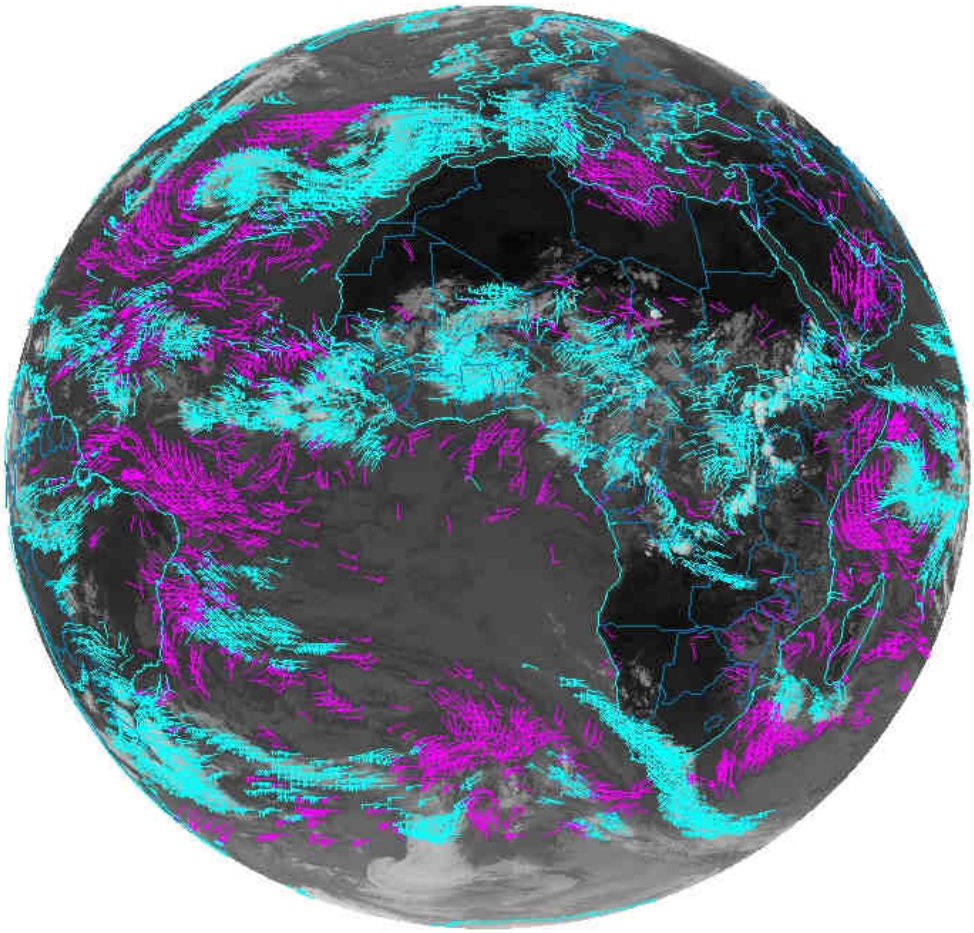


Figure 10-11: KMA high-level (cyan, above 375 hPa) and low-level (magenta, below 850 hPa) AMVs overlaid on the Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

The NOA processing detects many clouds in the high-levels (Figure 10-12), which visually is comparable to EUM. However, very few low-level clouds are tracked. This lack of low-level winds is due to assigning the heights higher than 850 hPa and few low-level winds, as evident by the histogram in Figure 14-29.

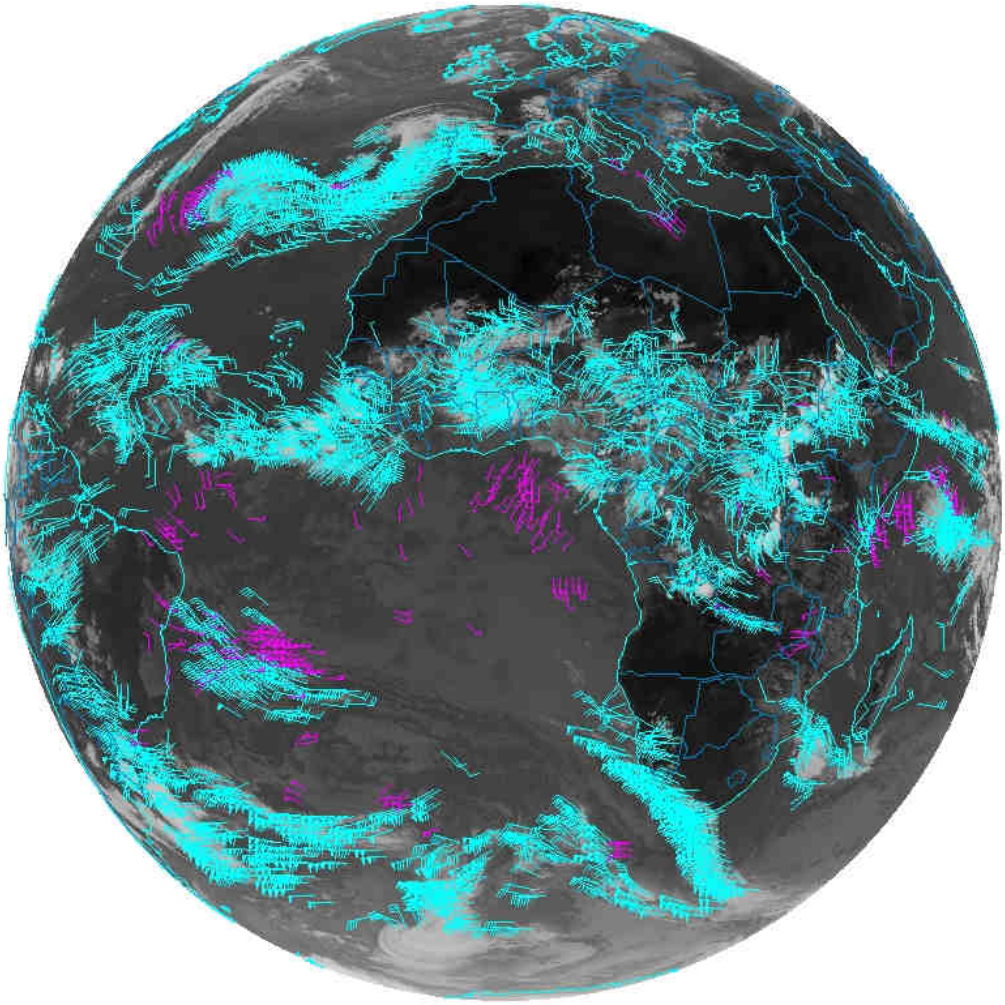


Figure 10-12: NOA high-level (cyan, above 375 hPa) and low-level (magenta, below 850 hPa) AMVs overlaid on the Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

The NWC algorithm captures the low-level winds, similar to EUM, however the coverage at high-levels (above 375 hPa) when the prescribed configuration is used is fewer, especially for the mid-latitude cyclone northwest of Africa (Figure 10-13, Figure 10-20). The reason for the fewer high-level AMVs is not due to a low height assignment (Figure 14-30), as a majority of the high-level winds are above 375 hPa, but to the way NWC defines its tracers.

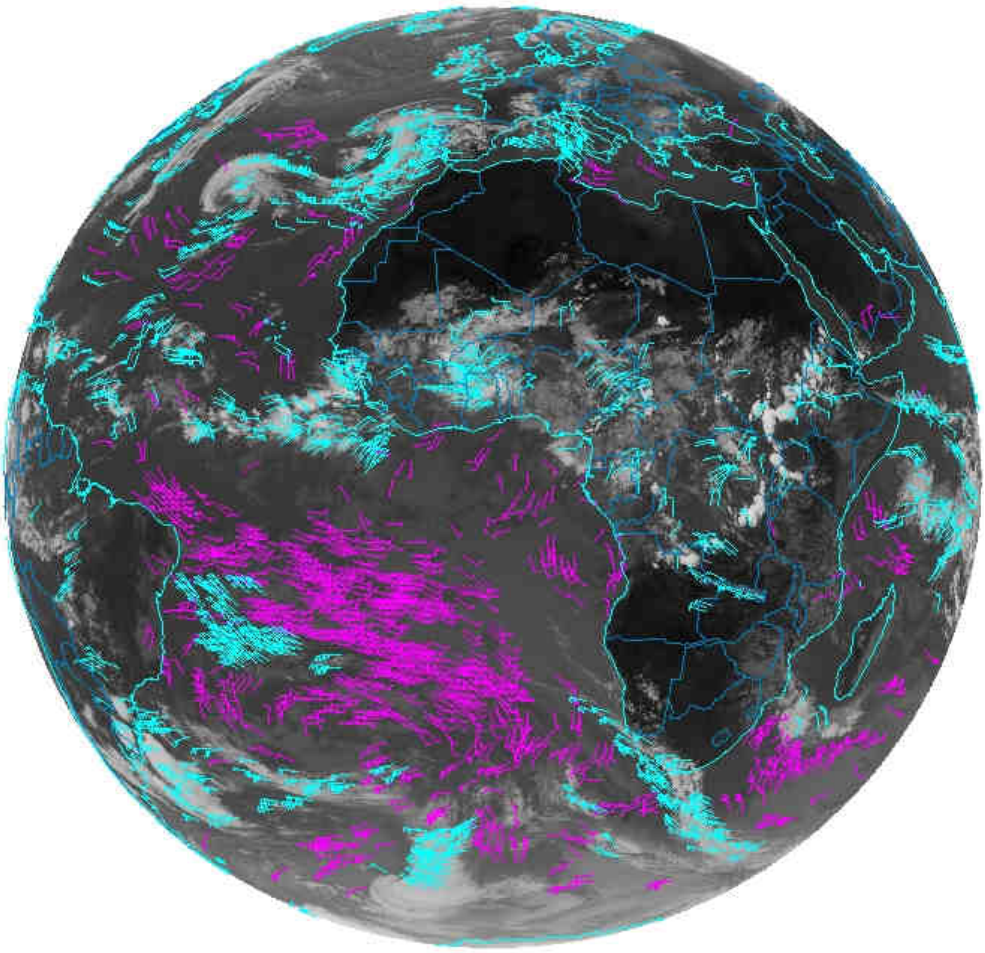


Figure 10-13: NWC high-level (cyan, above 375 hPa) and low-level (magenta, below 850 hPa) AMVs overlaid on the Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

When NWC uses its operational configuration with a higher density of data, the chance of coverage holes is much less significant. It results in a very high-resolution coverage of AMVs at both high- and low-levels (Figure 10-14).

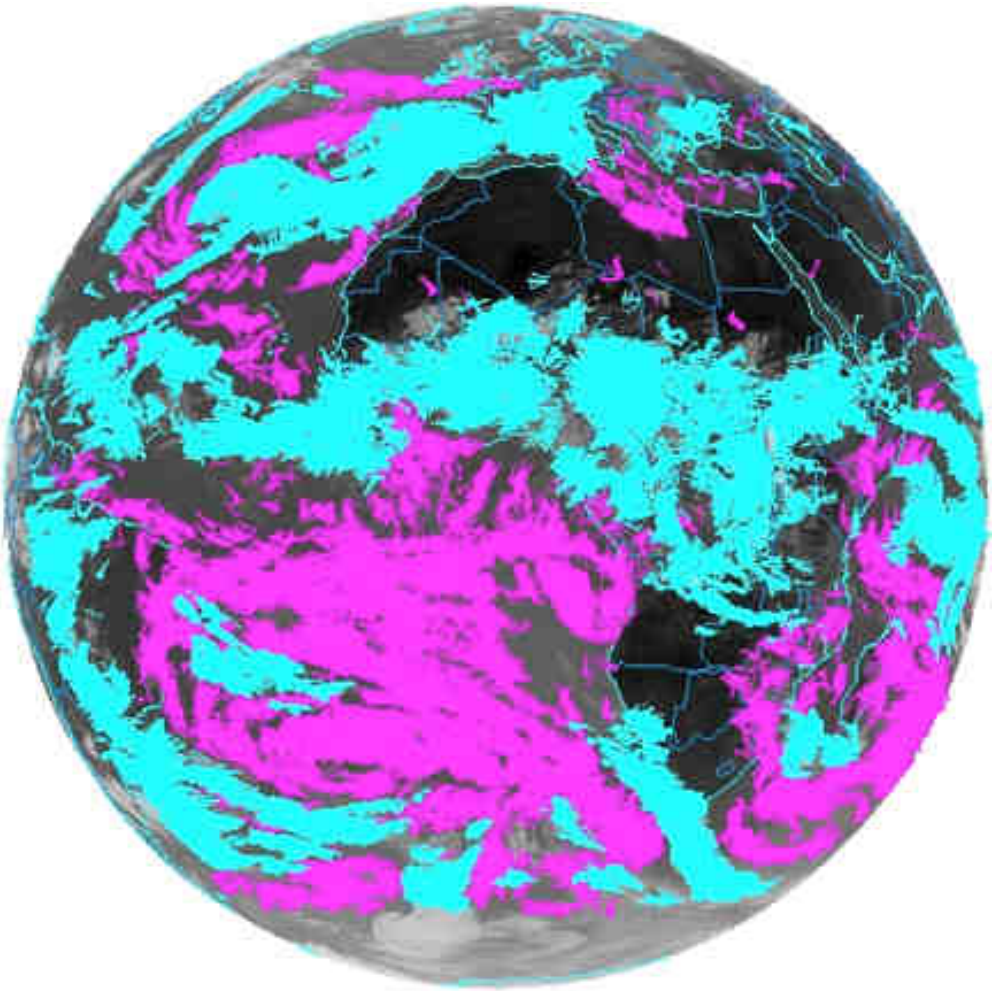


Figure 10-14: NWC Operational configuration with NWCSAF clouds: high-level (cyan, above 375 hPa) and low-level (magenta, below 850 hPa) AMVs overlaid on the Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC.

The following figures have wind vectors from Experiment 4 overlaid on storm systems in the mid-Atlantic Ocean: EUM in magenta; the other centers in cyan (in individual figures).

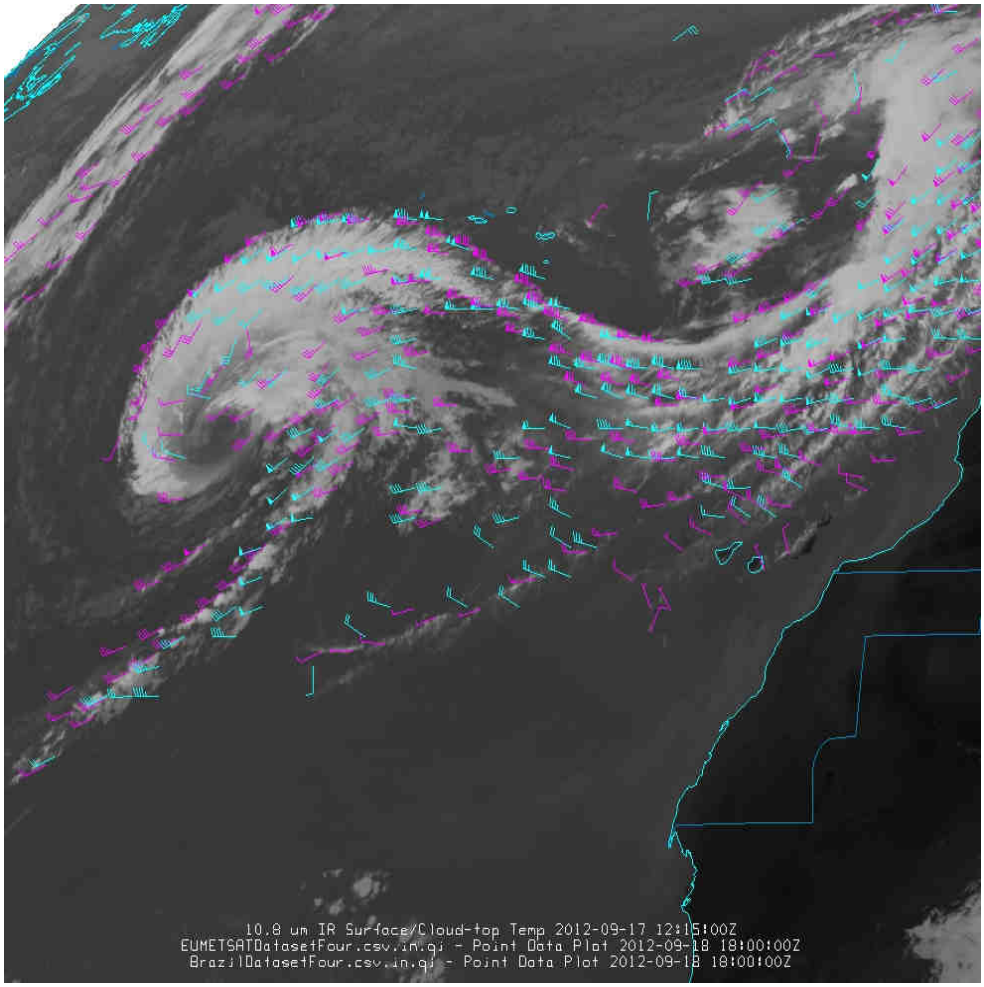


Figure 10-15: Experiment 4: EUM (magenta) and BRZ (cyan) AMVs over Central Atlantic (Africa in lower-right). QI >= 50 and pressure above 375 hPa.

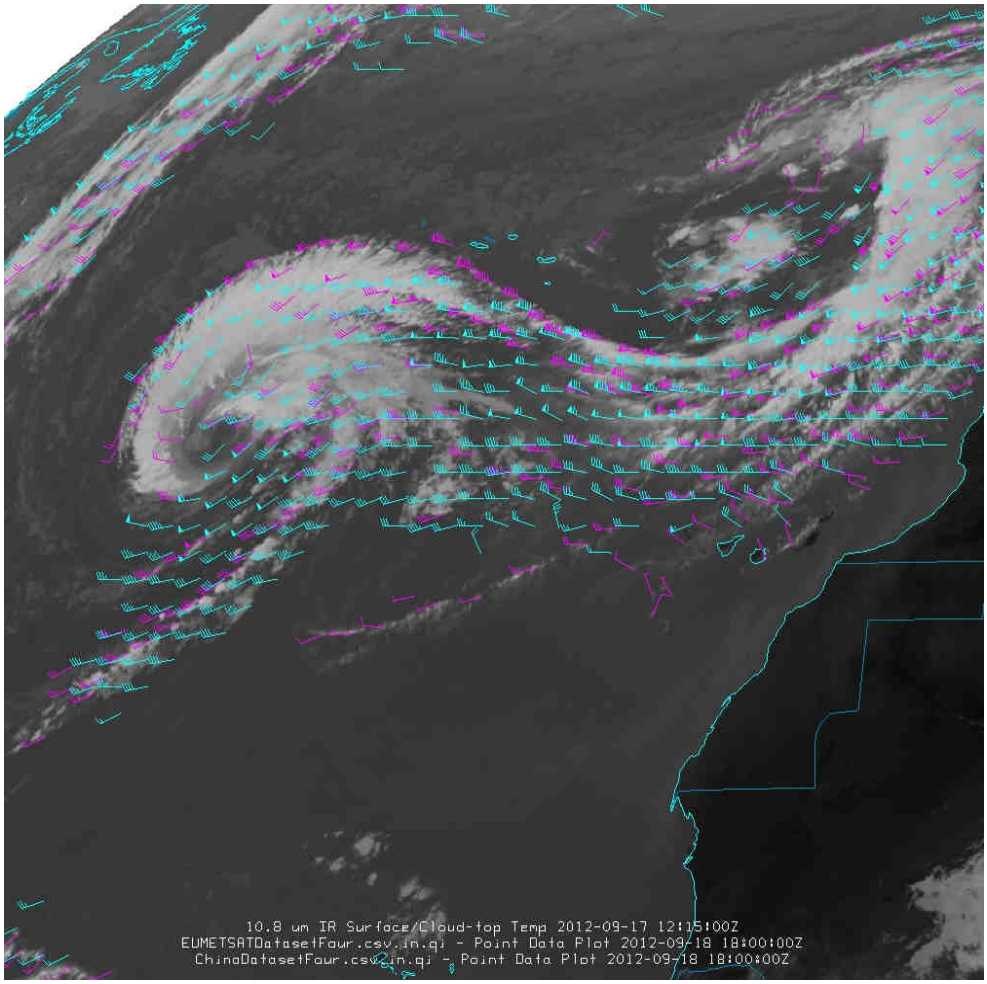


Figure 10-16: Experiment 4: EUM (magenta) and CMA (cyan) AMVs over Central Atlantic (Africa in lower-right). QI >= 50 and pressure above 375 hPa.

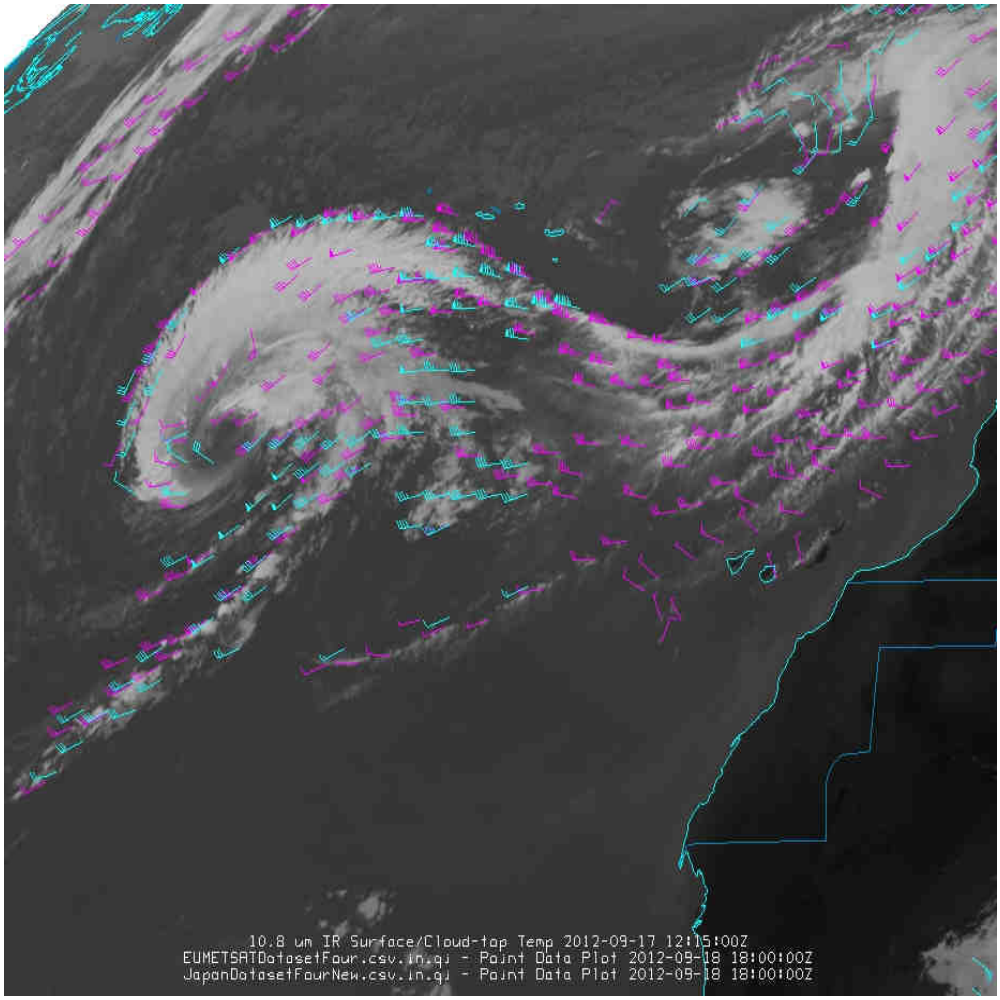


Figure 10-17: Experiment 4: EUM (magenta) and JMA (cyan) AMVs over Central Atlantic (Africa in lower-right). QI >= 50 and pressure above 375 hPa.

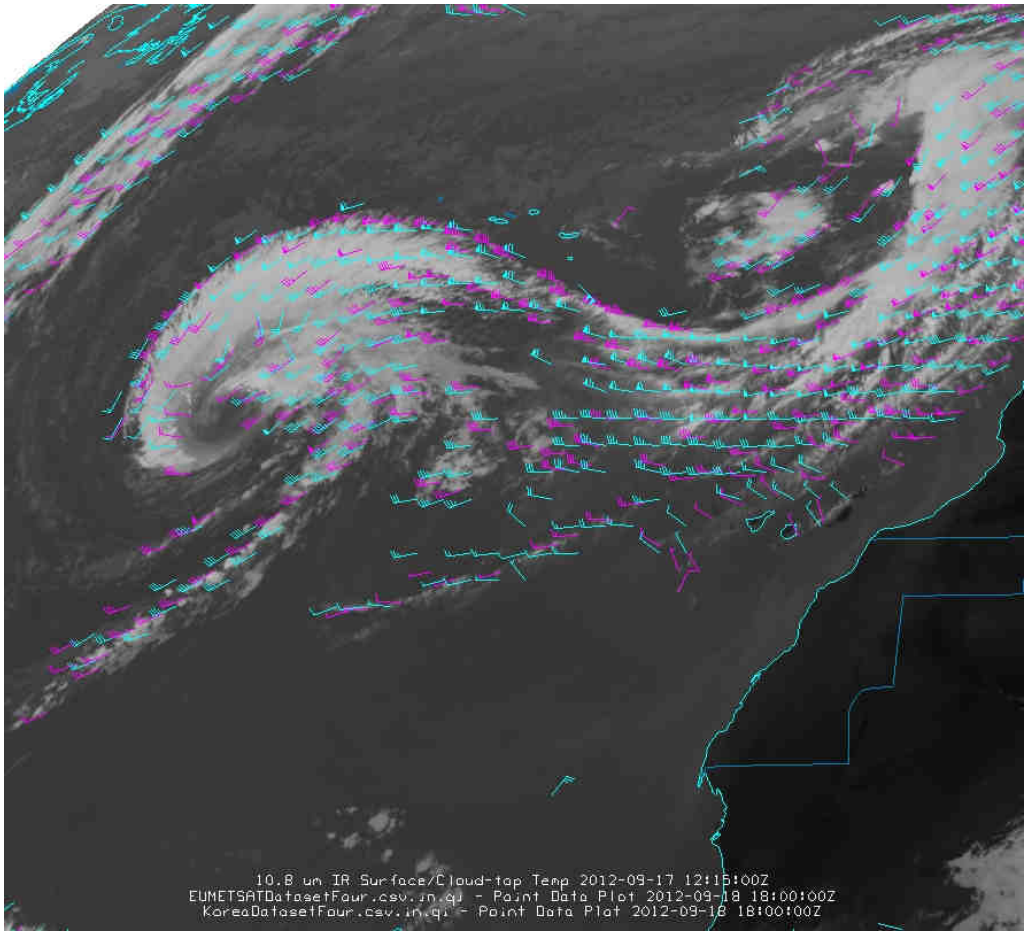


Figure 10-18: Experiment 4: EUM (magenta) and KMA (cyan) AMVs over Central Atlantic (Africa in lower-right). QI >= 50 and pressure above 375 hPa.

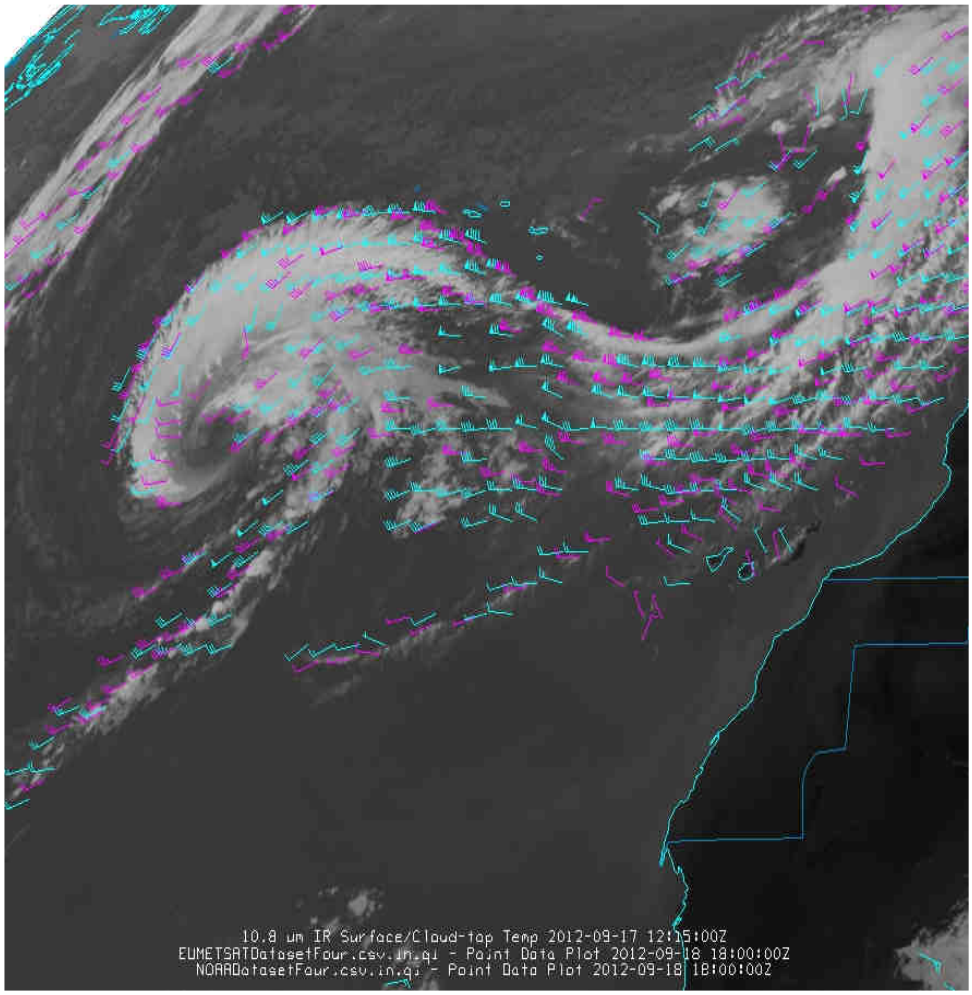


Figure 10-19: Experiment 4: EUM (magenta) and NOA (cyan) AMVs over Central Atlantic (Africa in lower-right). QI >= 50 and pressure above 375 hPa.

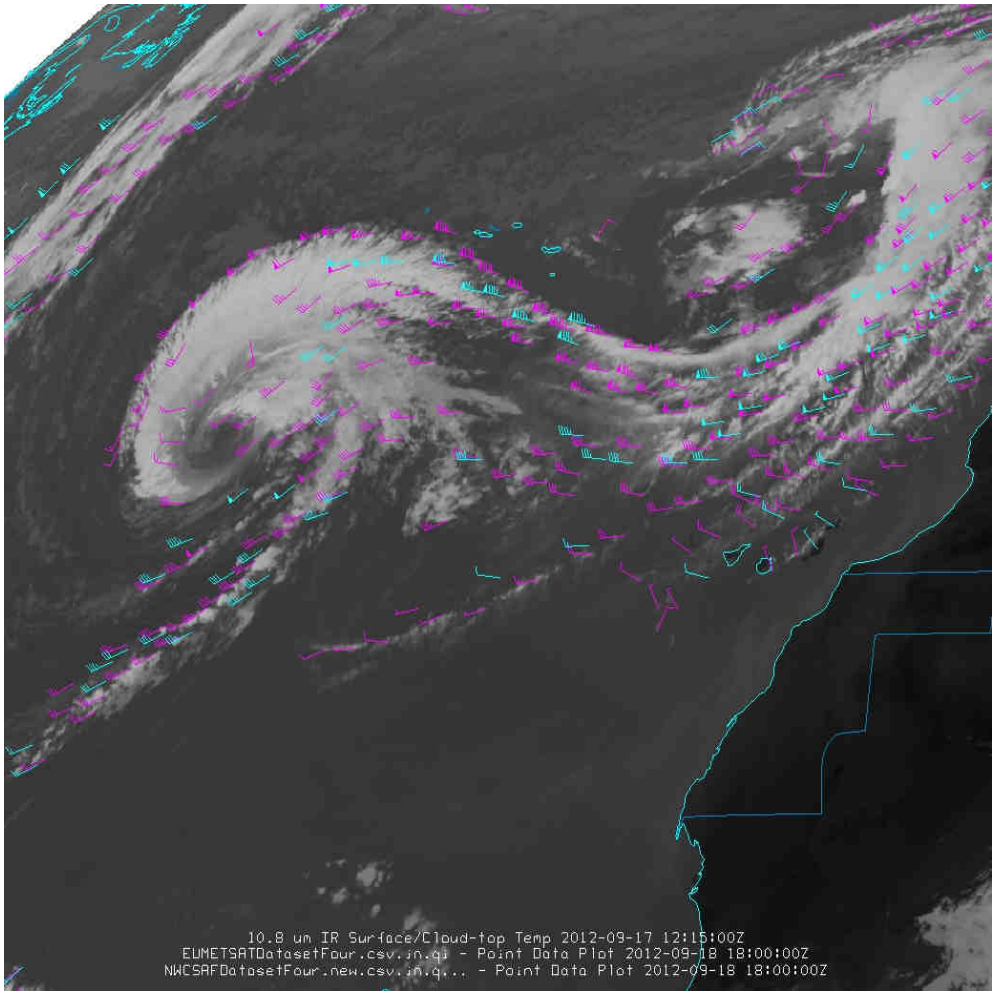


Figure 10-20: Experiment 4: EUM (magenta) and NWC (cyan) AMVs over Central Atlantic (Africa in lower-right). QI >= 50 and pressure above 375 hPa.

e) Rawinsonde comparison

The comparison of Experiment 4 AMVs to collocated rawinsondes is summarized in Table 10-3 (QINF >= 50) and Table 10-7 (QIWF >= 50). Centers with less than 20 AMVs are colored gray and not considered when finding the extreme values for each category, because of the low amount of data.

The vector RMS ranges from 4-5 ms^{-1} (NWC) to 9-10 ms^{-1} (BRZ, JMA) and the speed RMS ranges from 3 ms^{-1} (NWC) to over 7 ms^{-1} (JMA). In general, all sites improve statistically with respect to Experiment 3, and several sites such as EUM, NOA and NWC improve substantially. An exception occurs with JMA, for which statistics degrade in Experiment 4. AMV producers at JMA should verify this issue.

Considering the statistics for the different layers, the sample is often very small and no conclusion seems clear; better conclusions for the layers can be extracted comparing against the NWP background in the following section.

Considering the collocated AMVs, BRZ and JMA have again the largest vector RMS values, while EUM and NWC show the smallest ones, so showing the similarities provided by their common height assignment method (CCC method).

Table 10-3: Experiment 4 all AMVs with QI >= 50 (no forecast) compared to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P Bias	P Rms	SpdBias	Spd Rms	Dir Bias	Vec Rms
BRZ	153	0.63	9.77	0.55	5.61	-3.07	10.05
EUM	307	0.22	22.87	-0.61	4.73	1.99	6.07
JMA	154	-3.00	21.50	-2.26	7.64	8.89	9.60
KMA	326	-0.63	21.91	-0.73	4.72	2.68	6.38
NOA	131	0.35	22.75	1.48	5.79	9.01	7.70
NWC (Prescribed conf., EUM Clouds)	73	-0.76	17.53	-0.60	3.48	-3.74	4.67
NWC (Operational conf., EUM Clouds)	2375	-1.06	22.79	-0.39	3.90	0.46	5.12
NWC (Operational conf., NWC Clouds)	2797	-0.65	21.64	-1.23	4.49	-1.55	5.67

Table 10-4: Experiment 4: High-level AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P Bias	P Rms	Spd Bias	Spd Rms	Dir Bias	Vec Rms
BRZ	94	0.42	18.09	0.67	5.79	1.82	8.83
EUM	181	2.02	20.65	-0.98	4.95	-0.33	6.09
JMA	79	-1.88	18.22	-3.84	8.22	8.71	9.98
KMA	164	-3.09	18.68	-0.76	4.07	0.68	5.20
NOA	88	-4.45	20.80	0.49	5.18	8.36	6.84
NWC (Prescribed conf., EUM Clouds)	56	2.00	14.67	-0.75	3.34	-1.98	4.47
NWC (Operational conf., EUM Clouds)	1233	0.47	20.51	-0.48	4.19	1.85	5.28
NWC (Operational conf., NWC Clouds)	1927	-0.65	19.42	-1.59	4.74	-0.35	5.80

Table 10-5: Experiment 4: Mid-level AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	10	8.34	23.91	1.84	6.26	2.88	9.02
EUM	60	0.22	29.17	0.84	5.04	1.39	6.33
JMA	3	30.58	32.59	-0.67	1.39	2.96	2.91
KMA	68	2.58	26.26	-0.07	3.70	2.24	5.12
NOA	38	8.62	25.68	3.21	6.87	-0.81	8.50
NWC (Prescribed conf., EUM Clouds)	6	6.62	21.48	1.86	5.49	-1.87	6.36
NWC (Operational conf., EUM Clouds)	417	4.11	28.19	0.92	4.34	2.68	5.55
NWC (Operational conf., NWC Clouds)	334	-0.28	28.47	-0.48	4.53	-2.73	6.11

Table 10-6: Experiment 4: Low-level AMVs (QI no forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	49	-0.53	21.82	0.05	5.09	-13.66	12.21
EUM	66	-4.72	22.15	-0.91	3.75	8.92	5.77
JMA	72	-5.63	24.08	-0.59	7.12	9.34	9.34
KMA	94	1.33	23.62	-1.14	6.20	6.49	8.67
NOA	5	22.16	30.61	5.87	6.94	95.17	13.44
NWC (Prescribed conf., EUM Clouds)	11	-18.86	26.31	-1.15	2.70	-13.74	4.57
NWC (Operational conf., EUM Clouds)	725	-6.63	22.99	-0.99	3.01	-3.19	4.56
NWC (Operational conf., NWC Clouds)	536	-0.84	24.12	-0.39	3.36	-4.78	4.85

Table 10-7: Experiment 4 all AMVs with QI >= 50 (with forecast) compared to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	Pbias	PRMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	237	-1.11	18.58	-1.30	6.40	5.28	7.74
EUM	320	-0.05	22.85	-0.80	4.90	3.29	6.26
JMA	149	-3.40	21.98	-2.62	7.04	4.76	8.96
KMA	304	-0.59	21.67	-0.67	4.27	4.19	5.83
NOA	125	0.57	23.53	1.29	5.47	8.30	7.36
NWC (Prescribed conf., EUM Clouds)	73	-0.00	17.42	-0.60	3.47	-2.27	4.56
NWC (Operational conf., EUM Clouds)	2378	-0.74	22.76	-0.36	3.86	0.45	5.09
NWC (Operational conf., NWC Clouds)	2789	-0.53	21.65	-1.20	4.44	-1.64	5.61

Table 10-8: Experiment 4: High-level AMVs (QI with forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	202	-0.48	15.88	-0.83	6.39	5.55	7.79
EUM	183	1.91	20.64	-1.07	5.12	-0.52	6.23
JMA	77	-2.20	18.37	-4.03	8.30	6.62	10.01
KMA	160	-2.85	18.82	-0.67	3.87	0.34	4.94
NOA	83	-3.83	21.59	0.50	5.19	5.31	6.68
NWC (Prescribed conf., EUM Clouds)	56	2.89	14.48	-0.76	3.33	-0.46	4.34
NWC (Operational conf., EUM Clouds)	1242	0.44	20.50	-0.45	4.14	1.88	5.24
NWC (Operational conf., NWC Clouds)	1930	-0.57	19.42	-1.54	4.68	-0.69	5.73

Table 10-9: Experiment 4: Mid-level AMVs (QI with forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	15	-0.53	30.67	-5.35	8.64	0.21	9.68
EUM	64	-1.40	29.05	0.46	5.09	2.40	6.52
JMA	4	15.04	32.34	0.56	2.43	4.77	3.65
KMA	62	1.96	25.81	0.13	3.20	6.09	4.39
NOA	38	8.16	26.05	2.16	5.43	0.95	7.19
NWC (Prescribed conf., EUM Clouds)	5	8.10	23.52	2.67	5.94	-0.49	6.83
NWC (Operational conf., EUM Clouds)	418	4.98	28.29	0.94	4.35	2.30	5.56
NWC (Operational conf., NWC Clouds)	326	0.04	28.57	-0.49	4.56	-3.03	6.12

Table 10-10: Experiment 4: Low-level AMVs (QI with forecast >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	20	-7.95	28.98	-2.99	4.20	6.43	5.17
EUM	73	-3.79	21.95	-1.23	4.11	13.63	6.10
JMA	68	-5.84	24.79	-1.21	5.48	2.64	7.86
KMA	82	1.90	23.39	-1.27	5.54	10.27	7.99
NOA	4	19.60	34.41	9.22	9.80	140.08	16.52
NWC (Prescribed conf., EUM Clouds)	12	-16.88	25.23	-1.20	2.64	-11.45	4.41
NWC (Operational conf., EUM Clouds)	718	-6.10	22.87	-0.95	2.95	-3.09	4.50
NWC (Operational conf., NWC Clouds)	534	-0.76	24.22	-0.38	3.29	-3.92	4.77

Table 10-11: Experiment 4 collocated AMVs with QI >= 50 (no forecast) compared to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
BRZ	269	1.13	16.18	2.46	4.33	0.37	8.67
EUM	290	1.33	14.61	-1.52	3.21	0.18	4.21
JMA	210	-5.17	18.71	-1.80	5.96	7.83	7.62
KMA	287	1.73	16.99	1.07	3.69	26.55	7.03
NOA	219	-3.38	21.14	1.85	5.11	16.32	7.76
NWC	284	1.11	17.47	-1.20	3.64	0.34	4.49

Table 10-12: Experiment 4 collocated AMVs with QI >= 50 (with forecast) compared to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; SpdBias = speed bias; SpdRMS = speed RMS; DirBias = wind direction bias; VecRMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	N	P bias	P RMS	SpdBias	SpdRMS	DirBias	VecRMS
CMA	248	-1.49	15.93	0.70	7.12	5.57	7.69
EUM	297	4.57	20.49	-0.67	2.96	3.38	4.09
JMA	214	-2.46	21.42	-3.10	6.97	4.05	8.94
KMA	269	-3.06	18.77	0.46	2.85	6.84	4.25
NOA	247	-2.59	22.07	1.56	4.42	5.96	5.98
NWC	288	0.84	20.51	-0.18	3.30	2.92	4.41

f) Model Grid comparison

Table 10-13 through Table 10-17 show the output comparison of all AMVs to the background grid from the Python scripts discussed in Experiment 2.

NWC fits the background the best considering all AMVs together and the different layers (except at mid-level in which JMA gives slightly better results), and BRZ has the largest deviation.
Considering the collocated statistics, BRZ again has the largest deviation, and NWC and EUM provide the best statistics with very similar numbers, showing the equivalence of the height assignment method both centers use (CCC method).

Comparing statistics with Experiment 3, and the impact of the change in the height assignment method, EUM statistics improve significantly due to the better height assignment method (with RMSE reducing from 9 to 5 ms^{-1}). Other centers like NWC and KMA also show visible improvements in their RMSE values, with reductions larger than 10%. The rest of the centers generally also show a positive impact with the change of height assignment method, except JMA, for which RMSE values degrade in Experiment 4 (as also seen in the comparison against rawinsondes).

However, JMA has the best results for the mid-level AMVs (Table 10-15), but with a low number of matches (80 AMVs).

Table 10-13: Experiment 4 all AMVs compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast)

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	1590	220	8.02	9.67	7.54	9.43
CMA	4743	1090	6.38	7.44	5.77	7.02
EUM	6583	2301	3.91	5.36	3.29	4.84
JMA	3514	1056	4.91	6.59	3.94	5.88
KMA	4574	1221	5.16	6.83	4.66	6.52
NOA	2274	807	5.90	7.54	4.84	6.83
NWC (Pres.conf., EUM Clouds)	1419	605	3.05	4.01	2.45	3.40
NWC (Oper.conf., EUM Clouds)	53010	18115	3.23	4.15	2.71	3.65
NWC (Oper.conf., NWC Clouds)	52464	18732	3.77	4.65	3.05	4.04

Table 10-14: Experiment 4 high-level AMVs (<400 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	464	131	8.63	10.76	7.55	10.18
CMA	2643	970	6.52	7.66	5.49	6.95
EUM	2610	1126	5.04	6.41	3.98	5.58
JMA	1107	372	7.43	9.00	5.96	8.00
KMA	1497	703	5.15	6.92	4.14	6.21
NOA	1610	707	6.08	7.86	4.77	6.98
NWC (Pres.conf., EUM Clouds)	557	286	4.22	5.20	3.25	4.29
NWC (Oper.conf., EUM Clouds)	16578	7461	4.44	5.34	3.47	4.51
NWC (Oper.conf., NWC Clouds)	22167	9532	4.54	5.46	3.66	4.74

Table 10-15: Experiment 4 mid-level AMVs (400-700 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	309	21	8.75	10.41	8.64	10.37
CMA	1085	51	7.41	8.39	7.34	8.36
EUM	965	206	4.85	6.69	4.44	6.34
JMA	80	26	4.20	5.45	3.80	5.21
KMA	938	127	6.32	8.01	6.12	7.92
NOA	187	13	6.47	7.84	6.39	7.81
NWC (Pres.conf., EUM Clouds)	104	28	4.52	5.68	3.96	5.24
NWC (Oper.conf., EUM Clouds)	5625	1269	4.48	5.64	4.05	5.26
NWC (Oper.conf., NWC Clouds)	6137	1350	4.42	5.55	4.03	5.22

Table 10-16: Experiment 4 low-level AMVs (>700 hPa) compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast).

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	817	68	7.28	8.50	7.05	8.41
CMA	1019	69	4.93	5.51	4.82	5.45
EUM	3008	969	2.64	3.59	2.31	3.36
JMA	2327	658	3.73	5.08	2.98	4.56
KMA	2139	391	4.66	6.17	4.38	6.04
NOA	477	87	5.08	6.20	4.46	5.83
NWC (Pres.conf., EUM Clouds)	758	291	1.99	2.41	1.65	2.09
NWC (Oper.conf., EUM Clouds)	30807	9385	2.35	2.92	2.05	2.64
NWC (Oper.conf., NWC Clouds)	24358	7859	2.90	3.44	2.24	2.82

Table 10-17: Experiment 4 collocated AMVs compared to background grid: a 12-hour forecast. N = total number of AMVs; BFN = Best Fit number of AMVs; V_O = VD OMB mean; RAF = RMSE after Best Fit; VAF = Vector difference after Best Fit; RMSE = root mean square error. QI = 80-100, without forecast (except CMA with forecast)

EXP	N	BFN	VO	RMSE	VAF	RAF
BRZ	4341	638	7.13	8.28	6.66	8.00
CMA	9604	2286	5.74	6.49	5.13	6.07
EUM	8721	3684	2.89	3.78	2.33	3.25
JMA	8576	3297	5.05	6.28	3.59	5.06
KMA	7305	1708	5.33	6.40	4.97	6.20
NOA	7925	2146	6.06	7.32	5.14	6.72
NWC	7951	3130	2.91	3.76	2.37	3.25

g) Best fit height

The Best Fit height analysis is completed using the same method as in Experiment 2 and 3, described in section Experiment 2 of Best fit height.

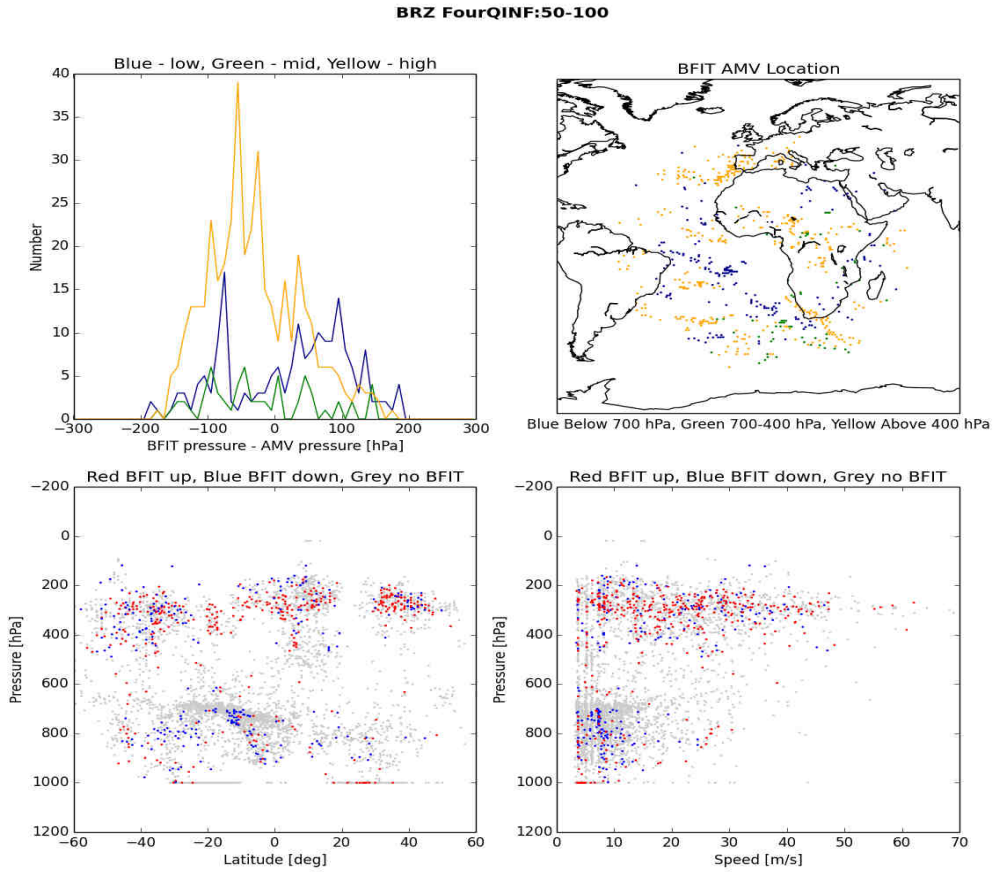


Figure 10-21: BRZ: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

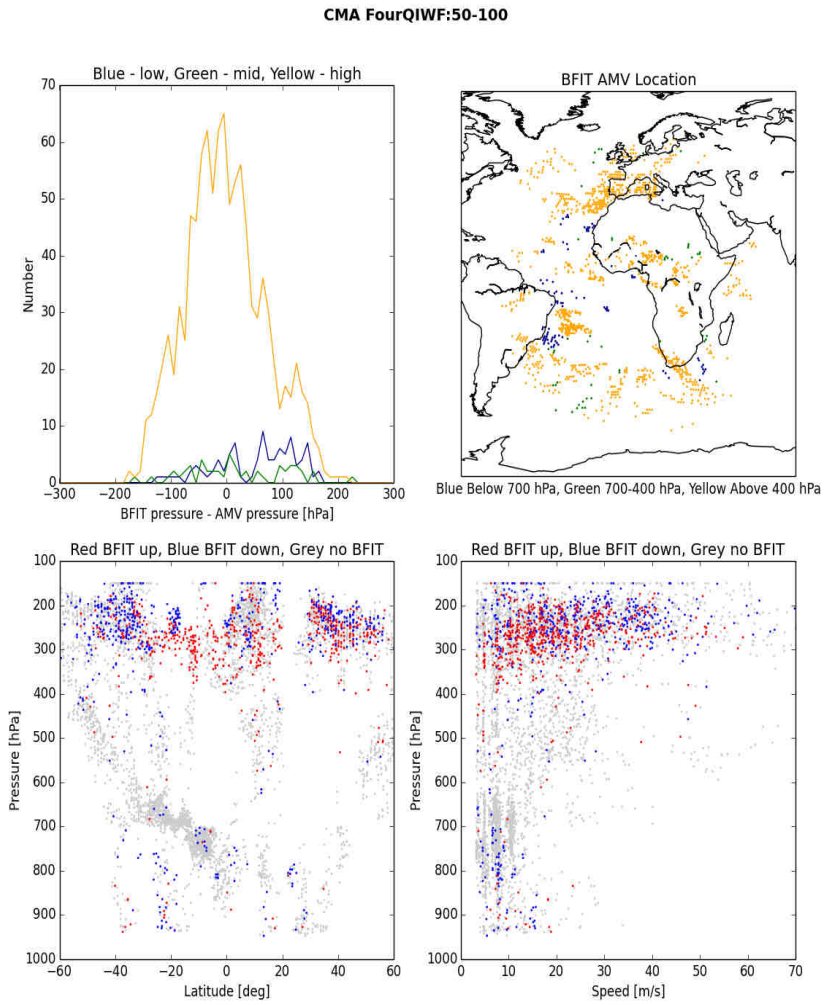


Figure 10-22: CMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

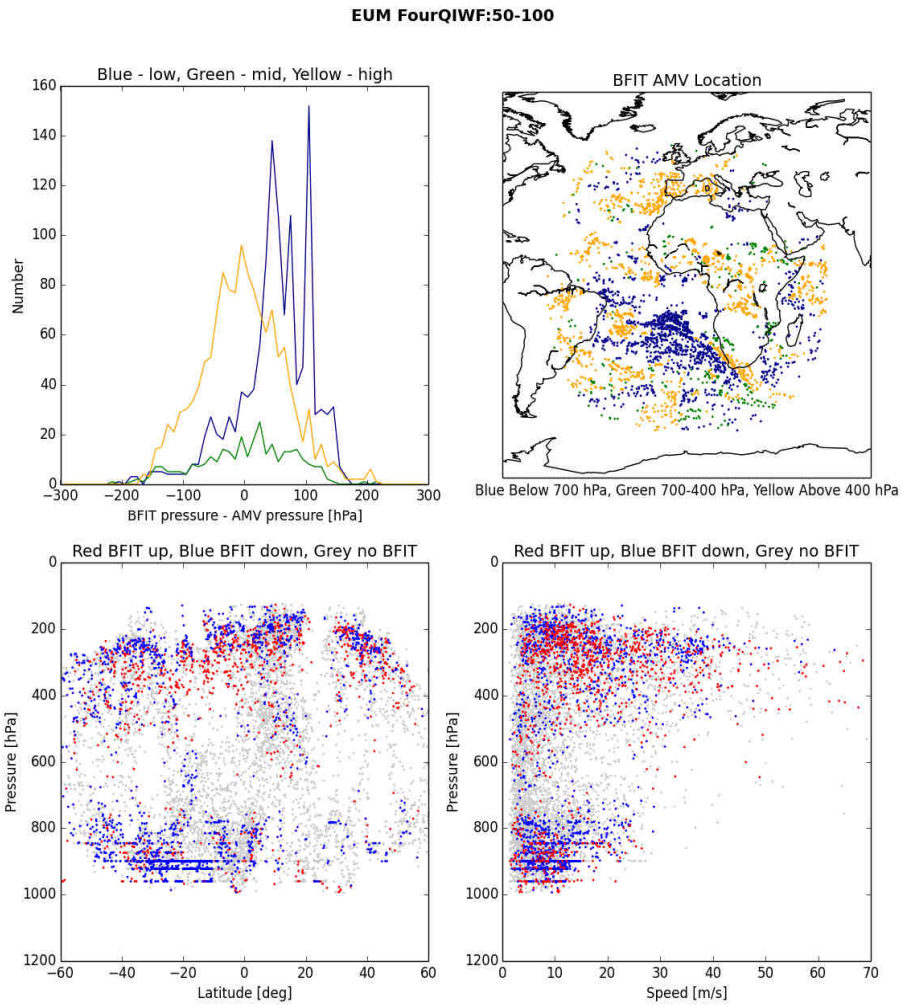


Figure 10-23: EUM: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

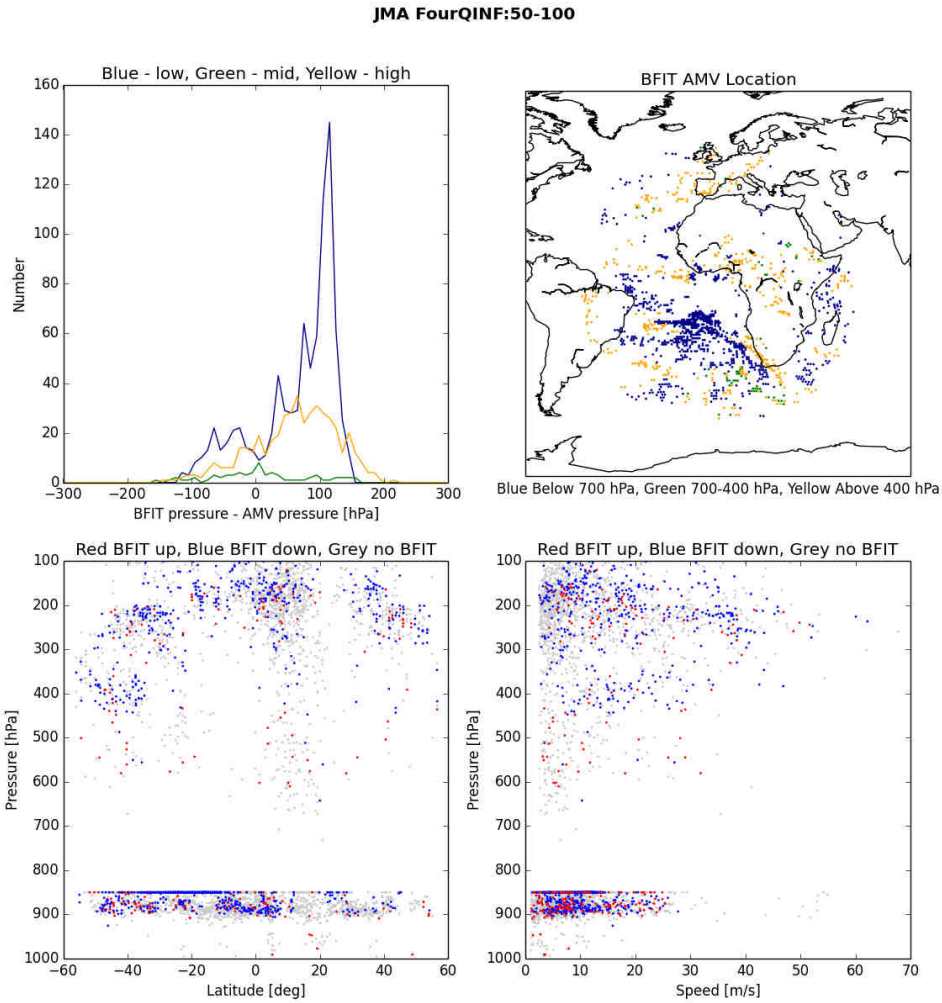


Figure 10-24: JMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

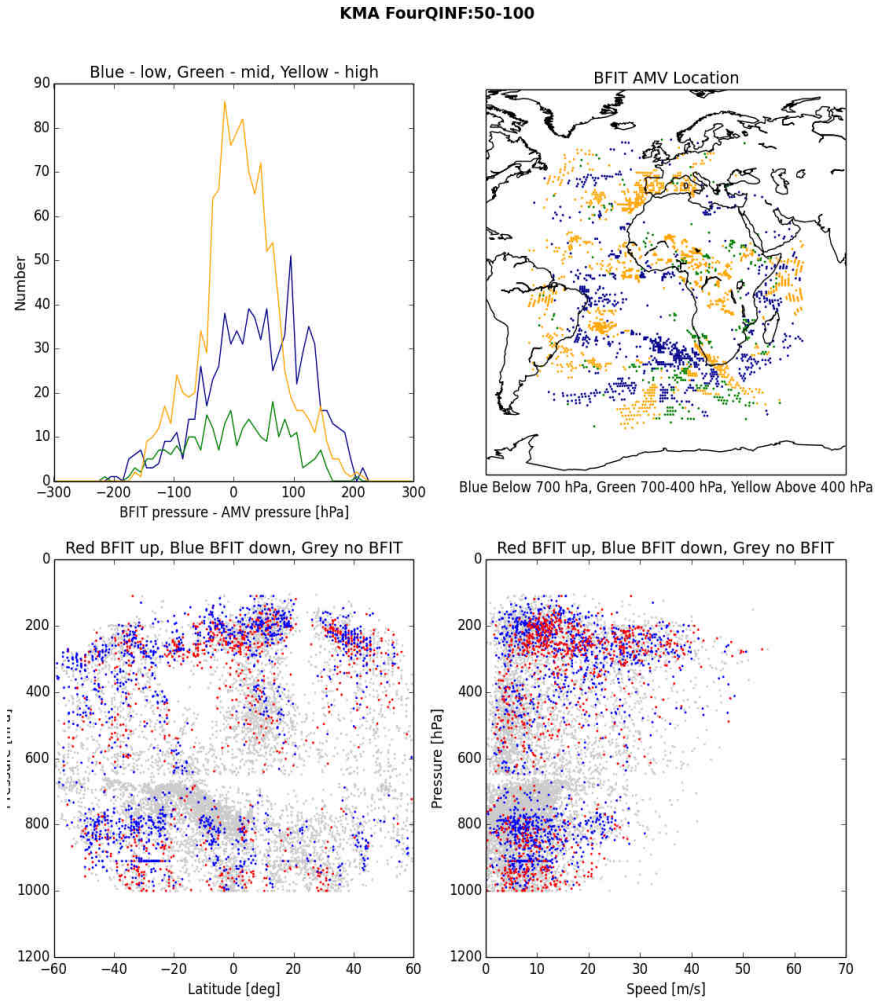


Figure 10-25: KMA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

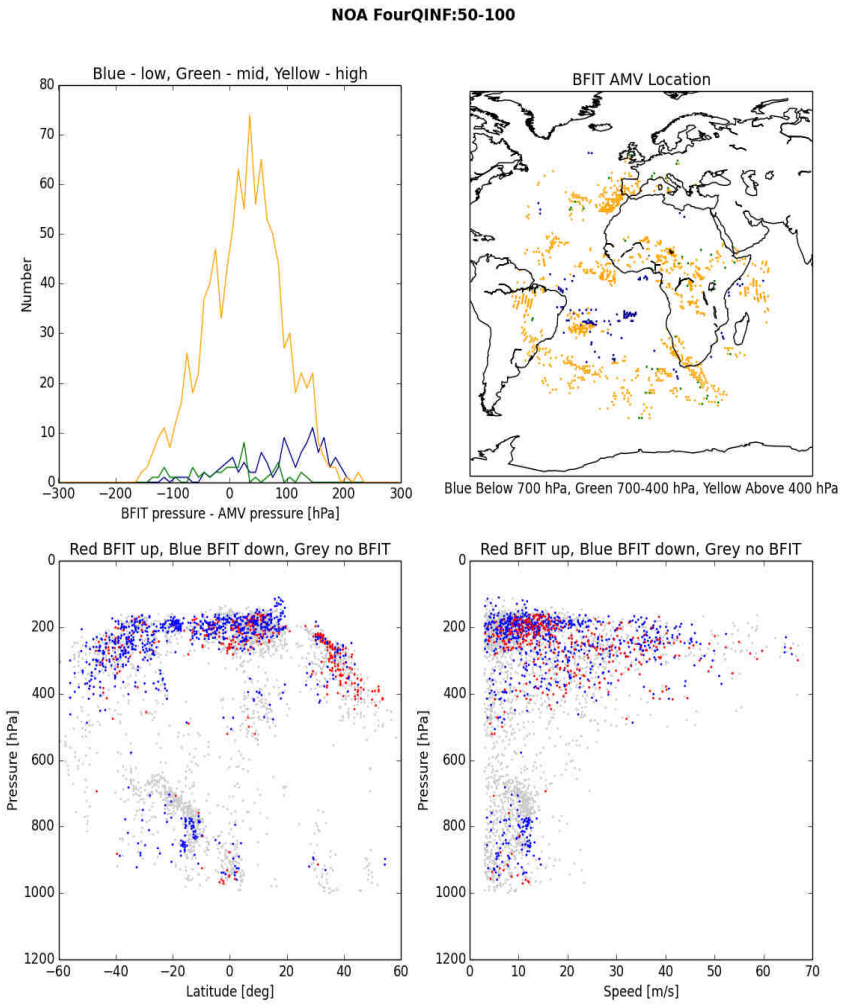


Figure 10-26: NOA: Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

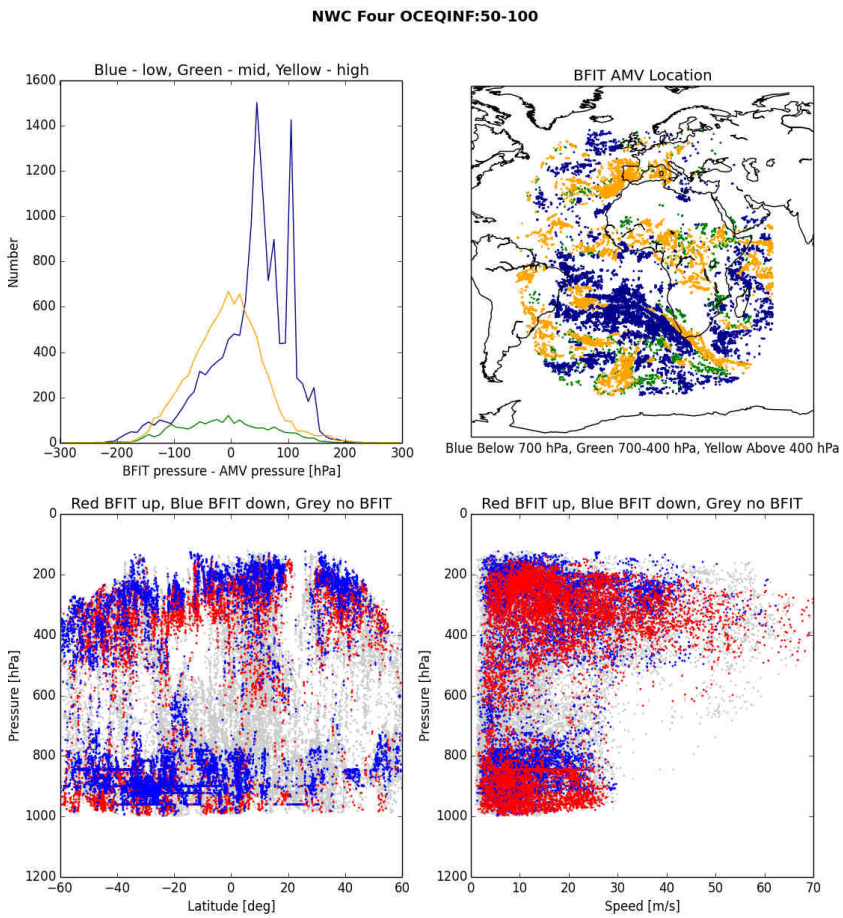


Figure 10-27: NWC (Operational conf., EUM Clouds): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

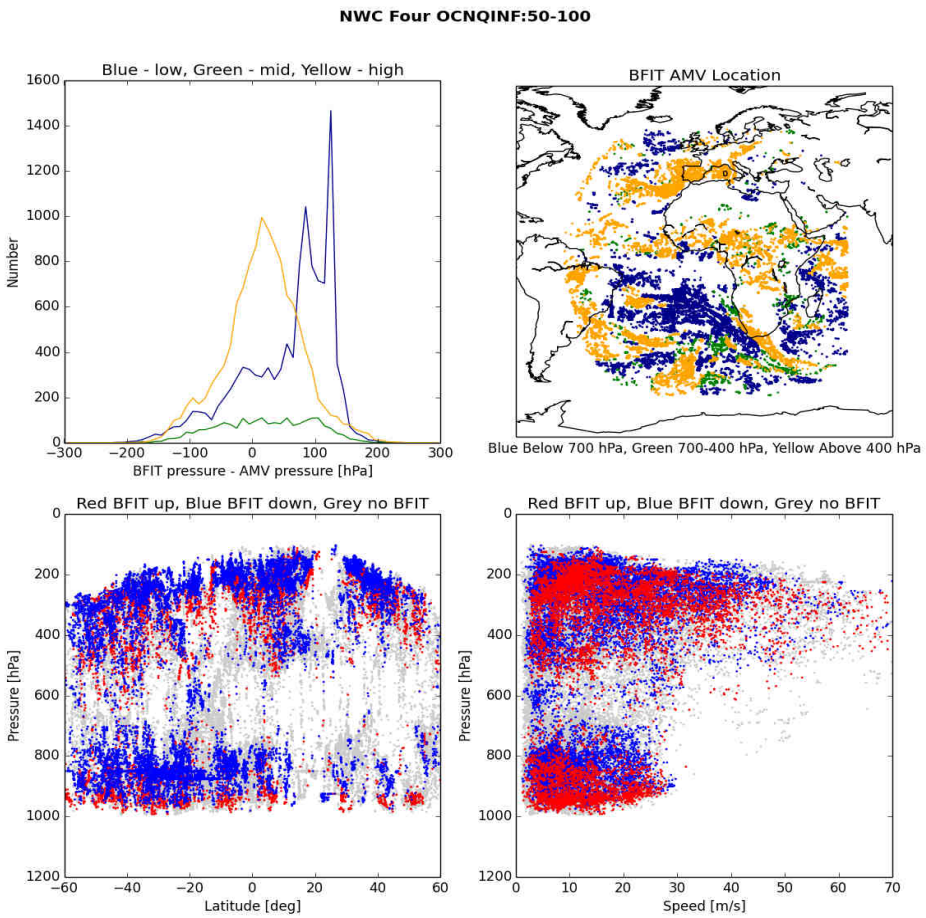


Figure 10-28: NWC (Operational conf., NWC Clouds): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

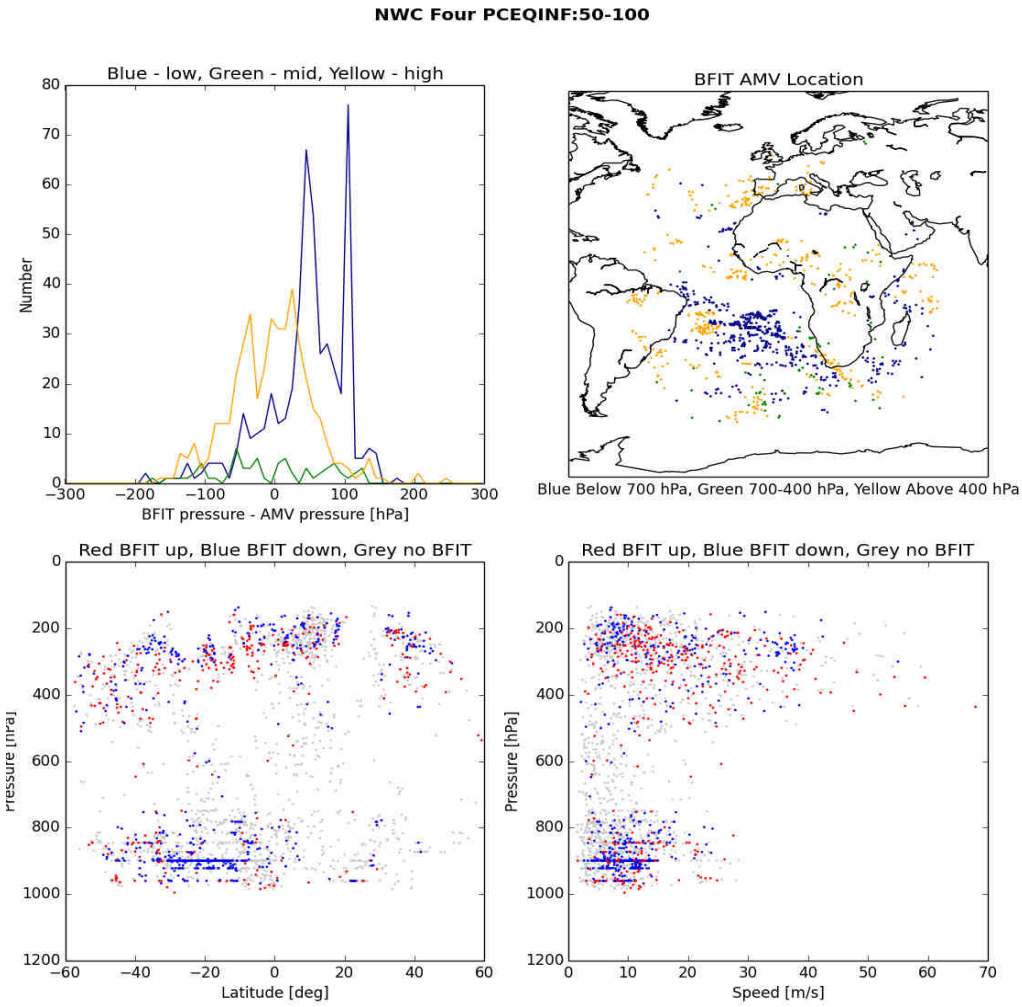


Figure 10-29: NWC (Prescribed conf., EUM Clouds): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

The depiction of the distribution of Best Fit statistics is in Figure 10-30 through Figure 10-38. Depending on the site, 14% to 31% (lower-left in each figure) of the AMVs are adjusted to a Best Fit pressure. There does not appear to be a relationship between latitude or longitude and adjusted pressure (upper-left and middle left in figures). In the upper-right corner of the figures, the distribution of the pressure difference (AMV Best Fit pressure minus the Original Pressure). In the lower-right is the geographic distribution of those AMVs that were moved up (red), down (blue), and unchanged (gray).

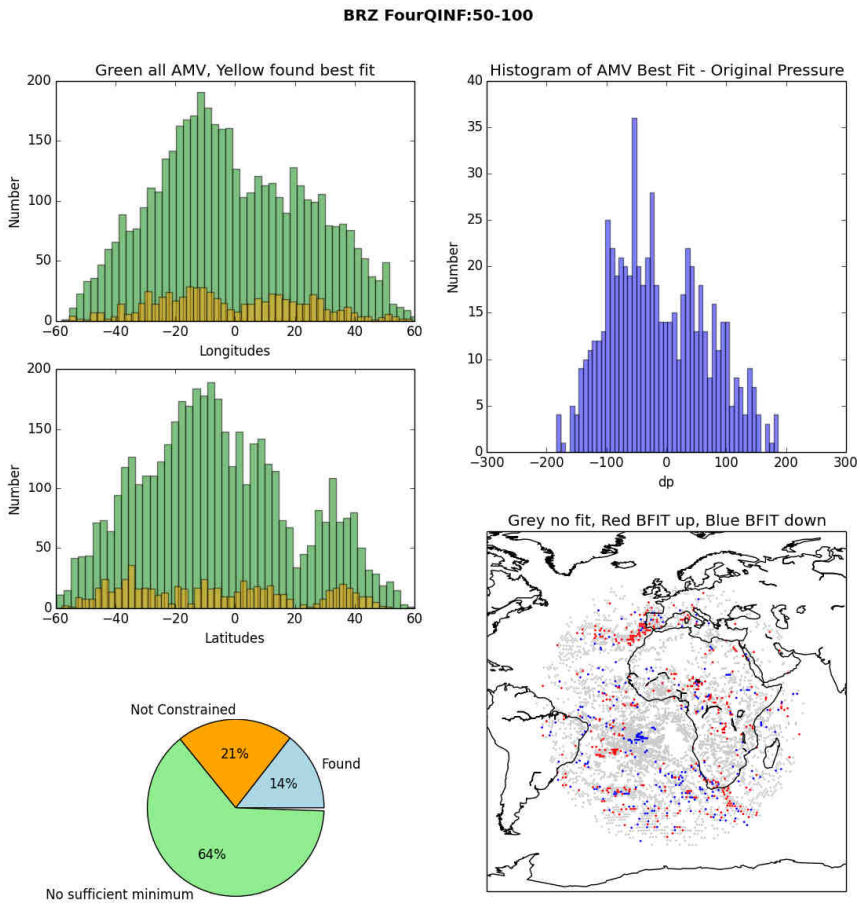


Figure 10-30: BRZ: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

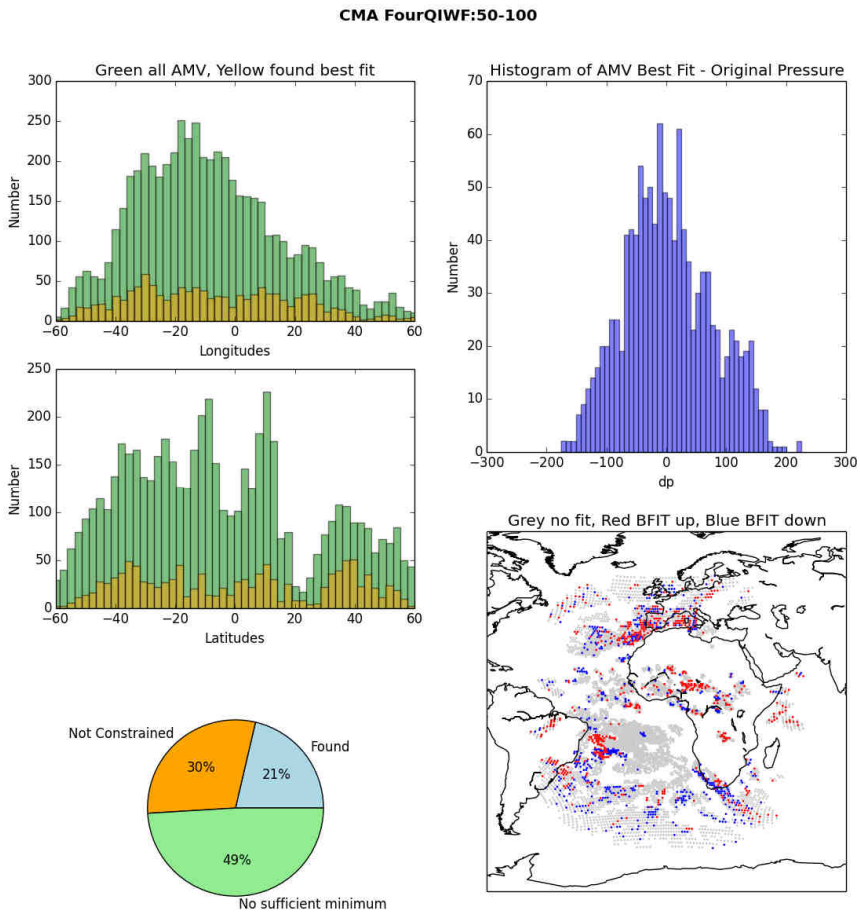


Figure 10-31: CMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

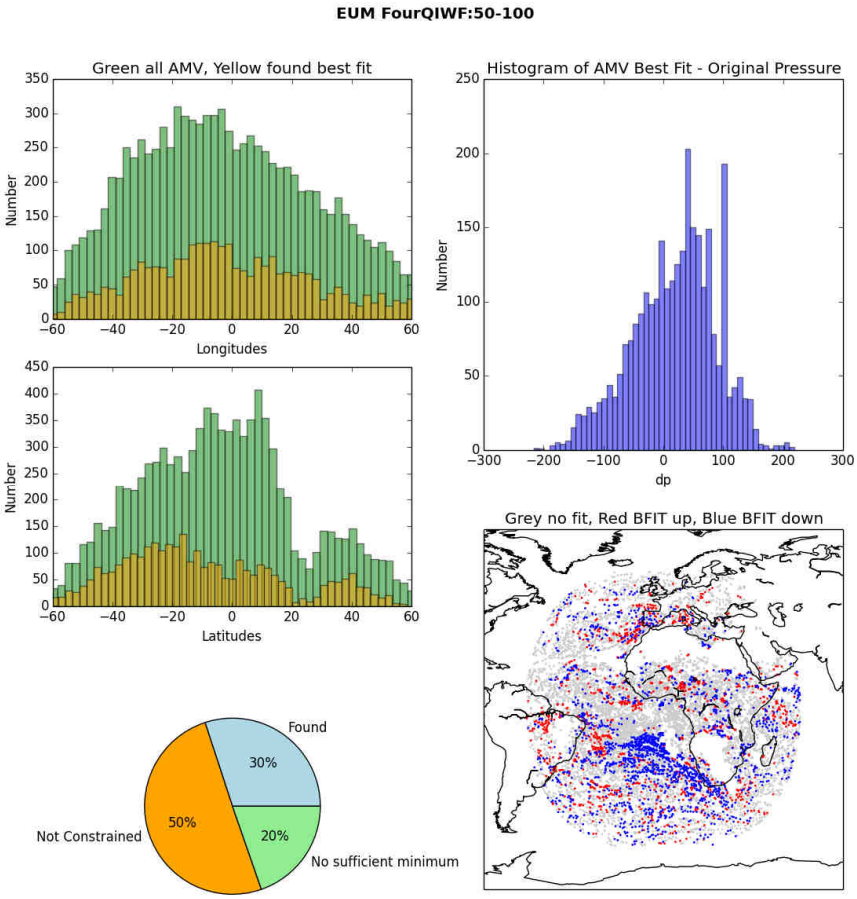


Figure 10-32: EUM: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

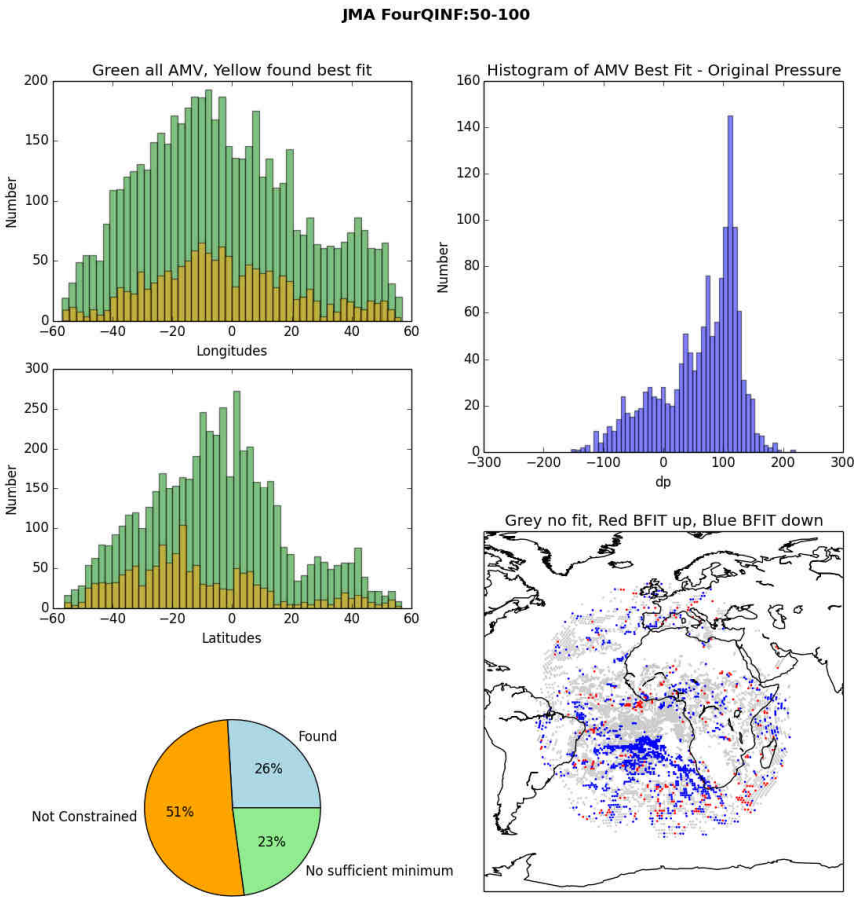


Figure 10-33: JMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

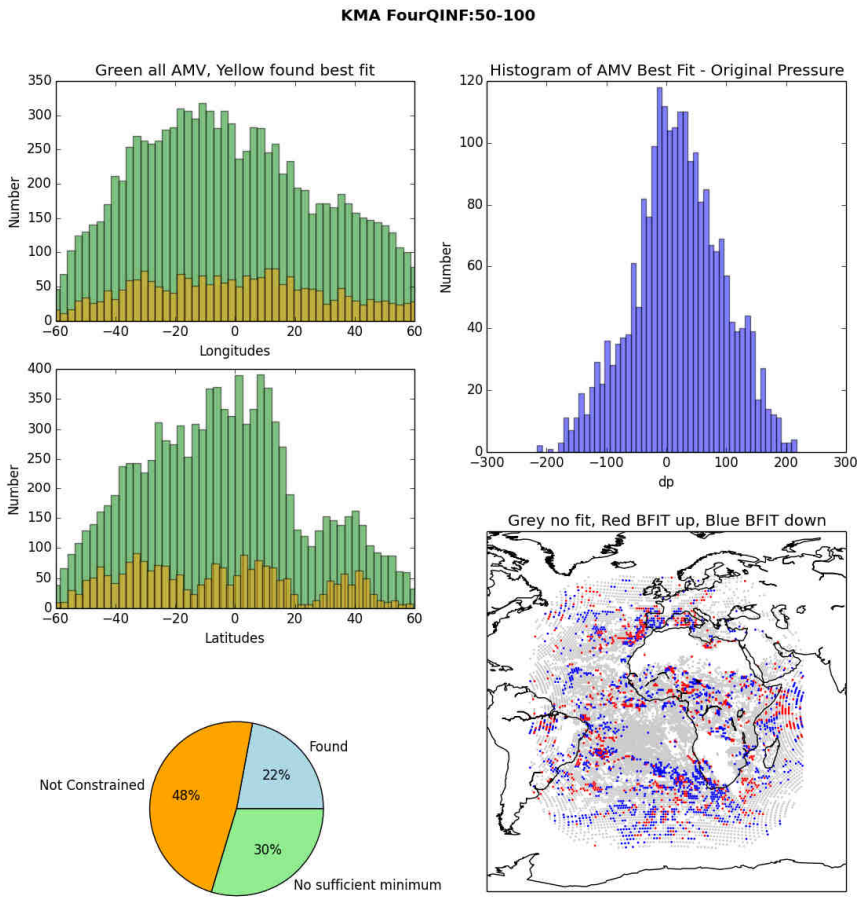


Figure 10-34: KMA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

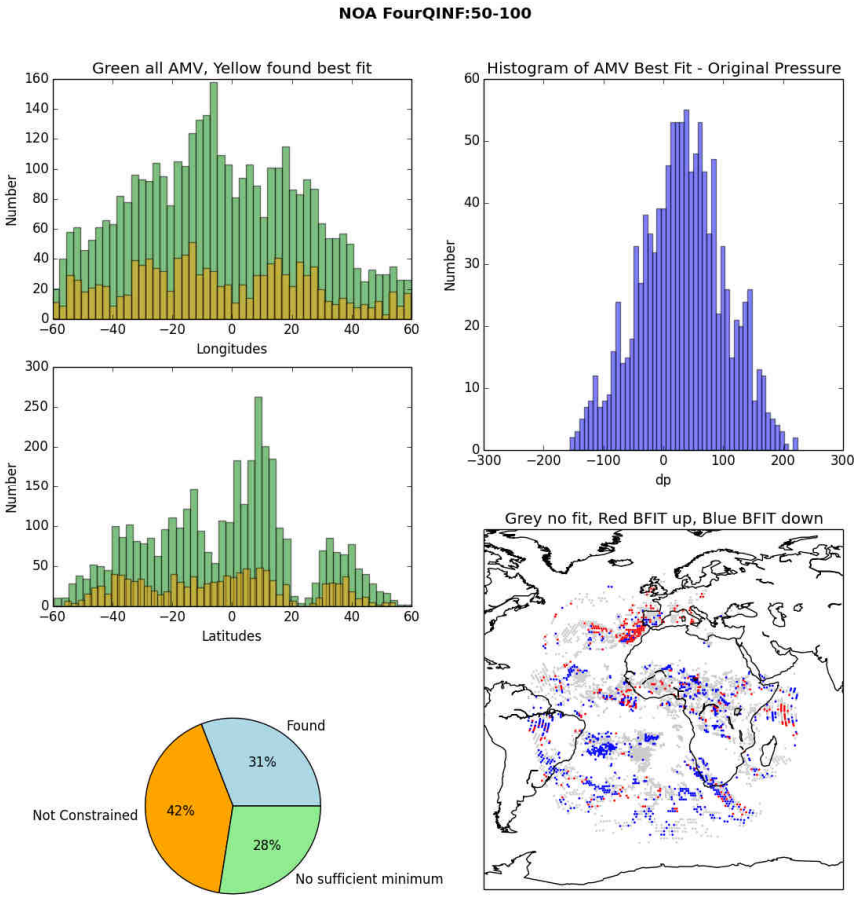


Figure 10-35: NOA: Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

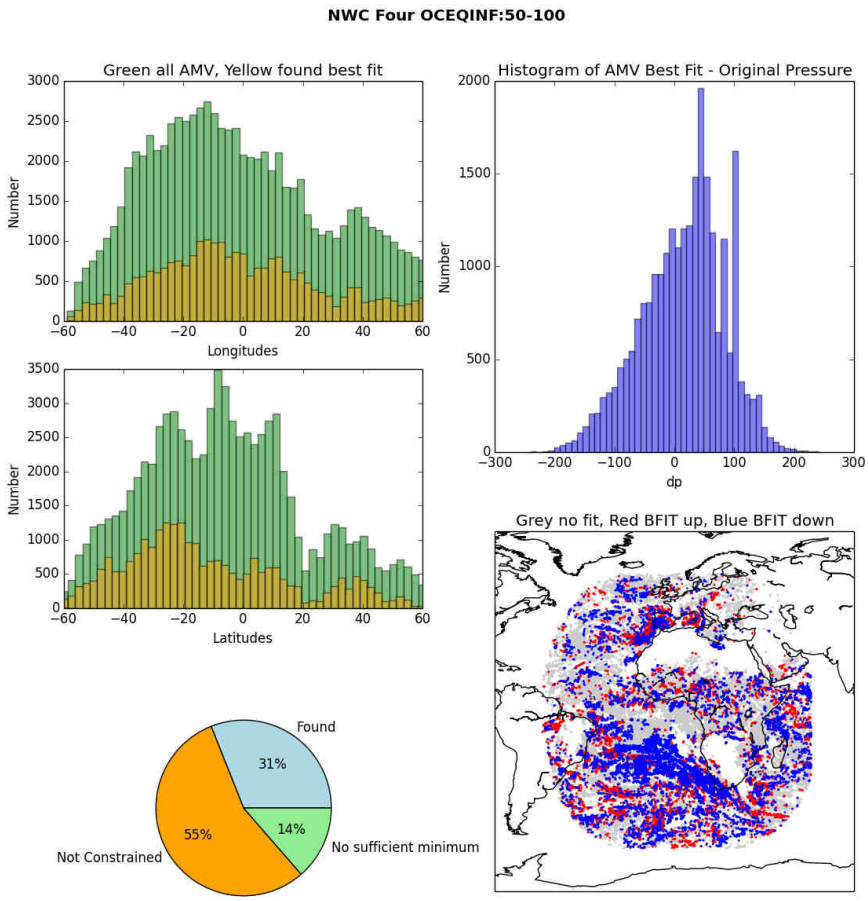


Figure 10-36: NWC (Operational conf., EUM Clouds): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

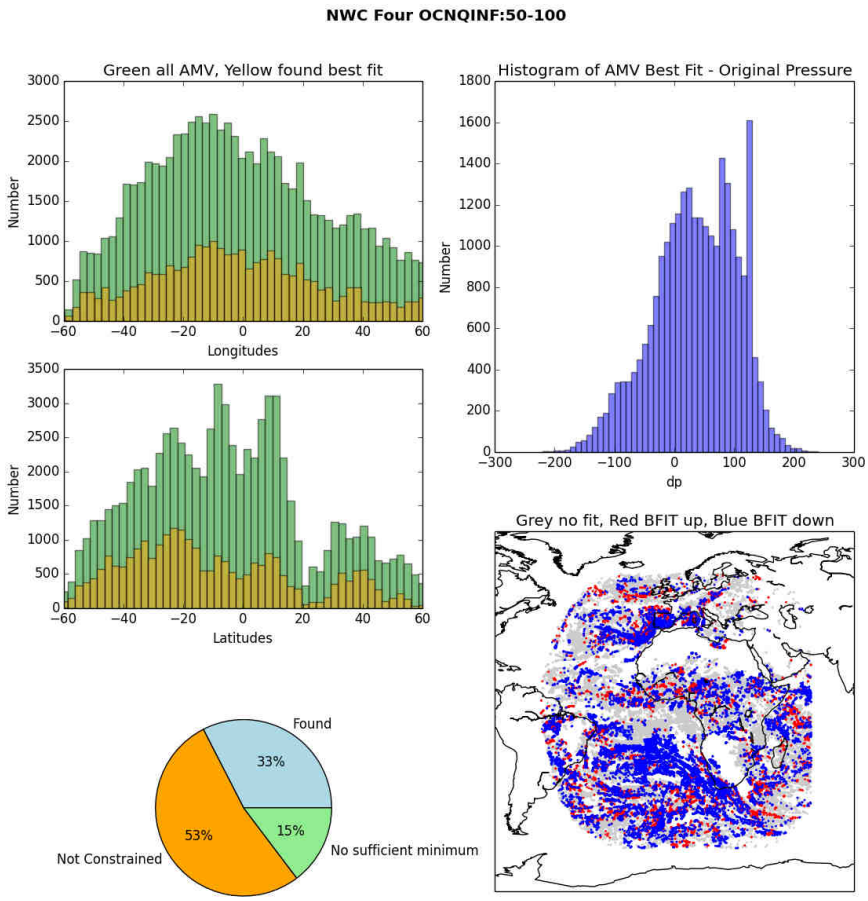


Figure 10-37: NWC (Operational conf, NWC Clouds): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

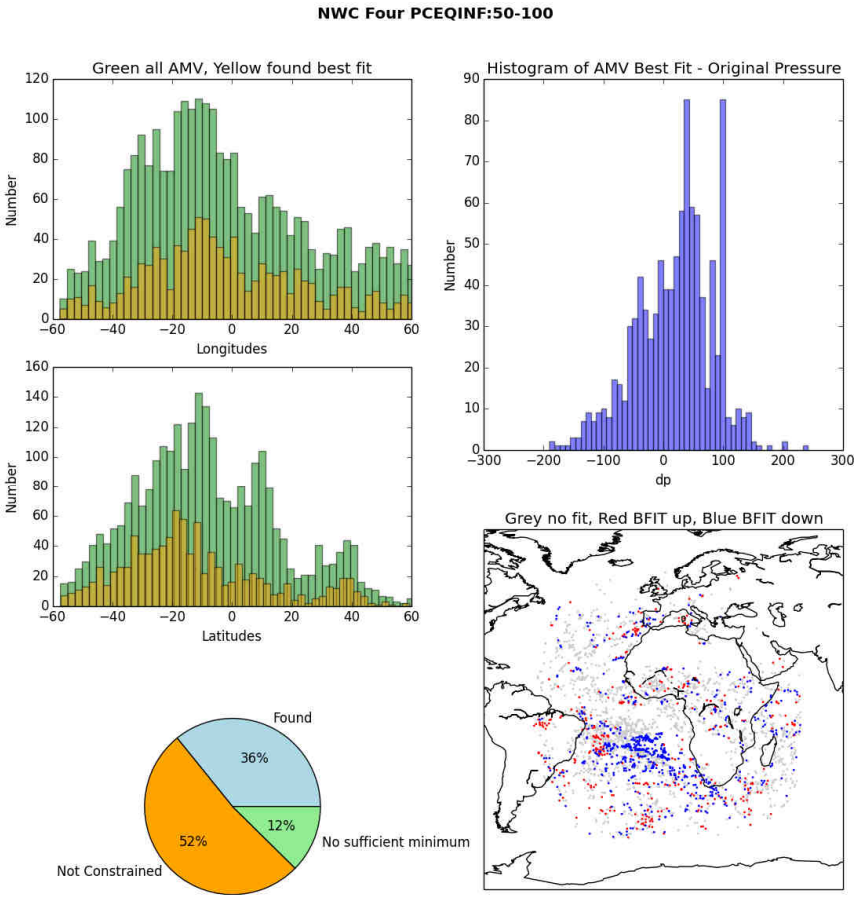


Figure 10-38: NWC (Prescribed conf., EUM Clouds): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient minimum) (lower-left). Frequency of pressure difference, Best Fit – original AMV pressure (upper-right); spatial distribution of Best Fit modified AMVs (color code by Best Fit height adjustment (lower-right).

h) Statistical comparison

The paired t-test between all combinations of producers and parameters has been used to determine if the differences are statistically significant, considering collocated AMVs (with QI without forecast >= 50 and distance threshold 55 km). The number of collocations is 9942. Only in a few combinations of directions, the differences are not statistically significant.

Table 10-18: Experiment 4 speed t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 10-19: Experiment 4 direction t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 10-20: Experiment 4 pressure t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 10-21: Experiment 4 QI without forecast t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	BRZ	NOA	NWC	JMA
EUM						
KMA						
BRZ						
NOA						
NWC						
JMA						

Table 10-22 to Table 10-25 show the results of the paired t-tests with QI with forecast >= 50 and a distance threshold of 55 km; there were 10285 co-locations.

Table 10-22: Experiment 4 speed t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

Table 10-23: Experiment 4 direction t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

Table 10-24: Experiment 4 pressure t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						

Table 10-25: Experiment 4 QI with forecast t-test for each paired combination of winds producers. Green indicates the parameter is not statistically different at the 95% level; red is statistically different.

	EUM	KMA	CMA	NOA	NWC	JMA
EUM						
KMA						
CMA						
NOA						
NWC						
JMA						

i) IR height vs. best height method

The only difference between Experiment 3 and 4 is the option to use any height assignment method (4) over only the IR B_T (3). In the following figures, the change in AMV height between Experiment 3 and 4 is depicted: negative values indicate the AMV is placed to lower pressure (higher altitude); positive values are AMVs moved to higher pressure (lower altitude). Collocated AMVs are determined for each centre if the winds in the two experiments are within 2 km of each other, except for NWC where the distance threshold is 12 km due to the low number of AMVs in Experiment 3.

A histogram of these height differences show that EUM (Figure 10-40), NOA (Figure 10-44), and NWC (Figure 10-45) have a significant change in AMV height when the algorithm uses the preferred height method over only IR B_T. The majority of the winds from EUM and NOA are shifted higher in altitude, which corresponds to the observed shift in the corresponding height histogram. This shift additionally implies a substantial improvement in the vector RMS in rawinsonde comparisons for the three centers: EUM (from 9 to 6 ms^{-1}), NOA (from 9 to 7 ms^{-1}), NWC (from 6 to 4 ms^{-1}).

Other centers (BRZ, CMA, KMA, JMA) have very few AMVs shifted in height, leading in general to smaller changes in the rawinsonde and model grid comparisons errors.

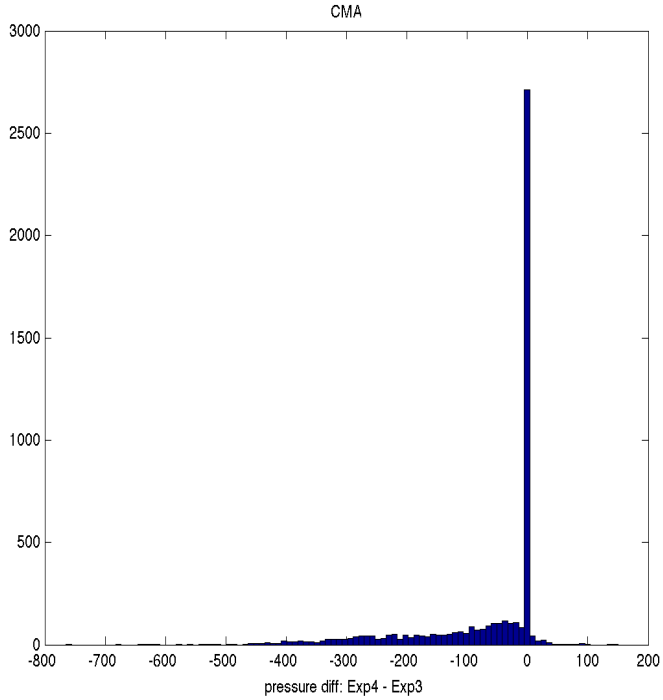


Figure 10-39: CMA collocated pressure differences between Exp. 4 and Exp. 3. 517 matches.

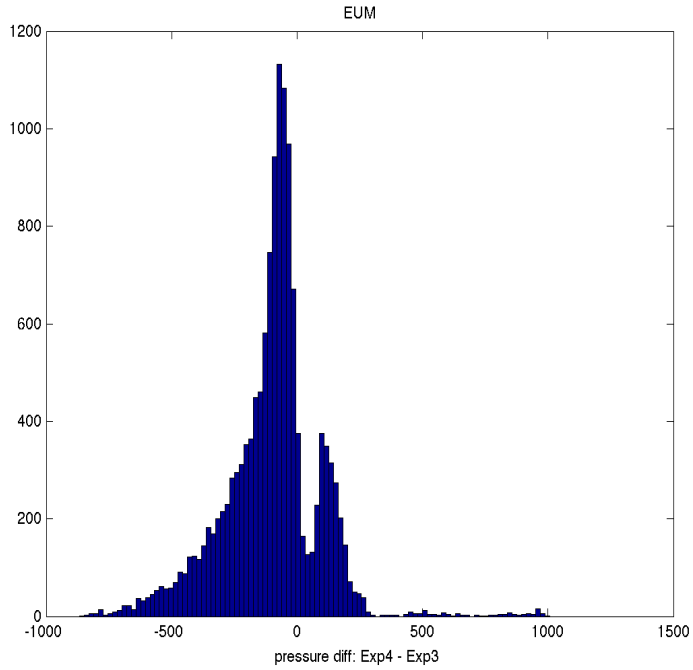


Figure 10-40: EUM collocated pressure differences between Exp. 4 and Exp. 3. 13947 matches.

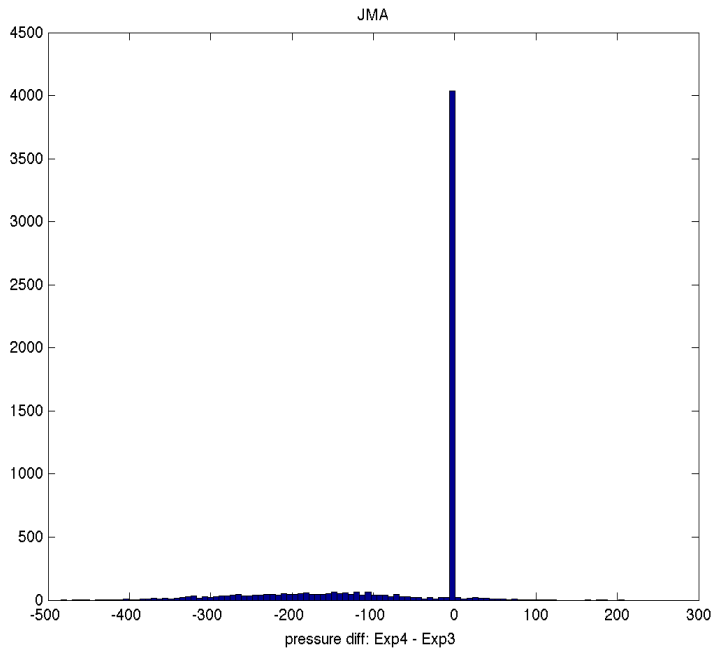


Figure 10-41: JMA collocated pressure differences between Exp. 4 and Exp. 3. 6129 matches.

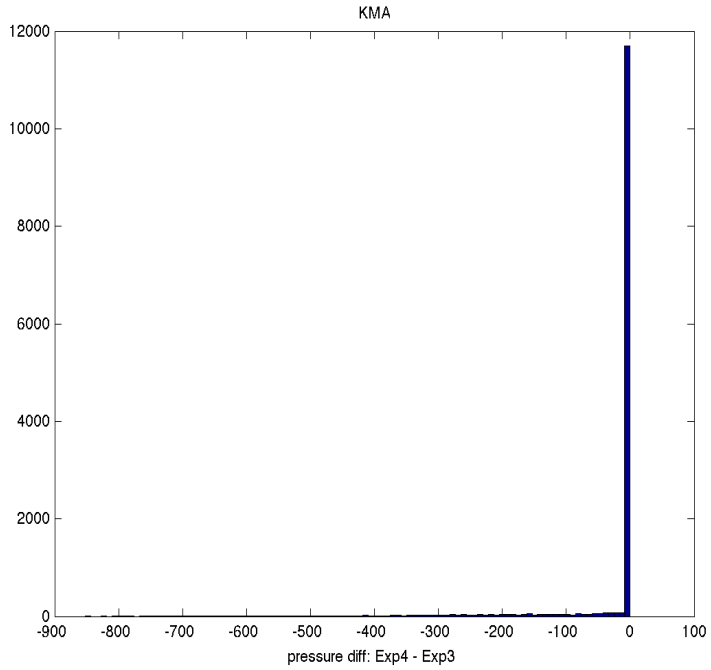


Figure 10-42: KMA collocated pressure differences between Exp. 4 and Exp. 3. 13718 matches.

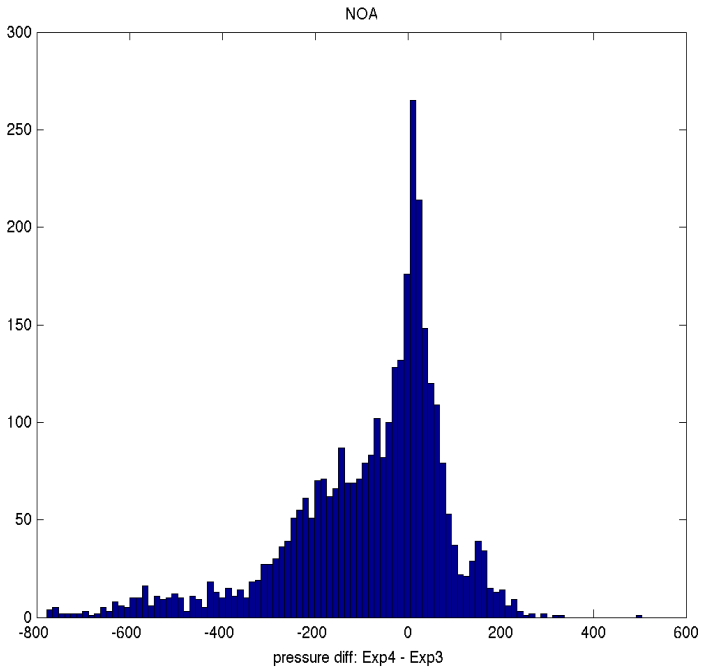


Figure 10-43: NOA collocated pressure differences between Exp. 4 and Exp. 3. 3362 matches.

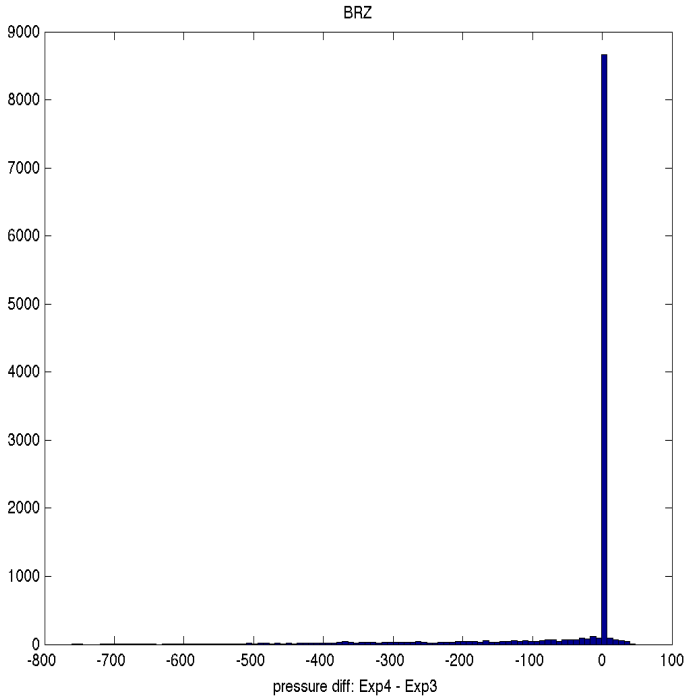


Figure 10-44: BRZ collocated pressure differences between Exp. 4 and Exp. 3. 11371 matches.

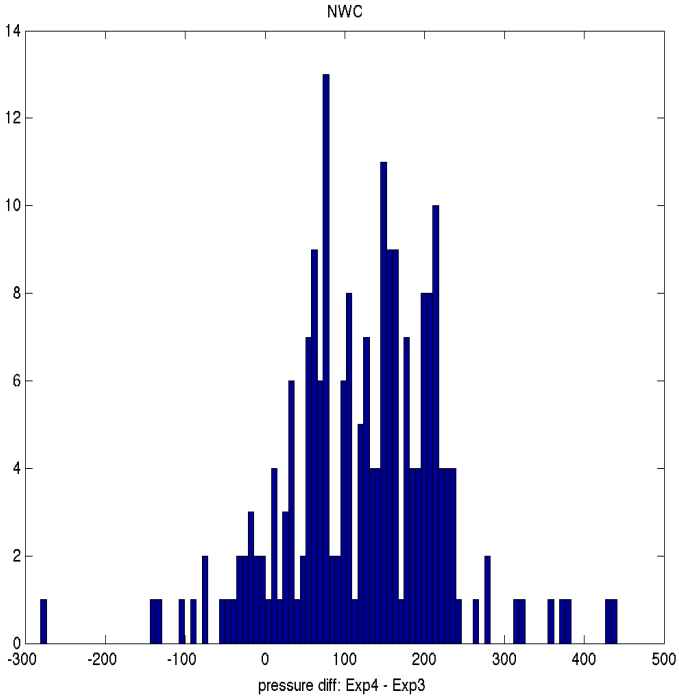


Figure 10-45: NWC collocated pressure differences between Exp. 4 and Exp. 3. 207 matches.

11. Summary and Conclusions

Four experiments have been conducted by each of the AMV producers:

1. AMV producers extract IR 10.8 μ AMVs considering a triplet of images with a known displacement. This experiment tests the tracking step in all AMV algorithms.
2. AMV producers extract IR 10.8 μ AMVs considering their standard AMV algorithm configuration, but only using the MSG/SEVIRI IR 10.8 μ images and the ECMWF model data for the Height assignment. This experiment tests the target selection, tracking and quality control steps in all AMV algorithms.
3. This experiment is the same as Experiment 2, except a prescribed AMV algorithm configuration is used. The experiment is used to test the tracking and quality control steps in all AMV algorithms, considering similar targets.
4. This experiment is the same as Experiment 3, except the AMV producer can use the height assignment method of their choosing. This experiment is used to test the height assignment and quality control steps in all AMV algorithms, considering similar targets.

The following sections detail the findings from the experiments, in terms of each AMV producer, independently. This includes the strengths and weaknesses as determined from the results of the experiments.

a) EUMETSAT

In this study, the EUMETSAT AMVs have been used as the comparison to all the other centers to detect differences in the datasets, as the EUMETSAT algorithm has been specifically developed and tuned for Meteosat data.

The strengths of the algorithm have been especially noted in Experiments 1 and 4. In Experiment 1, all vector displacements are correct. In Experiment 4, the statistical comparison of the EUM AMVs to rawinsondes and the background forecast wind field is performing best together with NWC SAF AMVs. The AMV coverage at high and low levels is very dense in Experiment 4, as evidenced in the spatial plots.

However, the use of only the IR B_T for cloud height (Experiments 2 and 3) results in AMVs being placed several hundred hPa different than when other techniques could be used (Experiment 4). This conclusion is confirmed with the high error in the rawinsonde comparison statistics, and is likely due to a brightness temperature that is too warm.

b) China Meteorological Administration

The CMA algorithm has performed well in Experiment 1, detecting the correct displacement of the artificially moved features in all cases. In the other experiments, the AMV comparison to rawinsondes and the background wind field exhibit larger errors than other centers, which may be due to very extensive use of IR-only B_T in determining AMV heights.

However, the Best Fit analysis indicates that there are good AMVs in this dataset as the Best Fit height adjustment and corresponding improvement in statistics (compared to the background) are very similar to other centers.

The AMV coverage at high levels is dense and visually similar to EUM in Experiment 4. However, low-level AMVs are assigned higher heights than EUM, resulting in degraded statistics compared to rawinsondes and the background grid.

c) Japan Meteorological Agency

JMA algorithm performs very well in Experiments 2 and 3. Results from Experiment 4 show instead a relative degradation of validation statistics when measuring performance with both comparisons to rawinsondes and the background wind field.

More in detail, AMV coverage for JMA is very dense in low levels in Experiment 4, and the comparison to rawinsondes and the background grid is good. However, the upper level winds are few and did not compare well to rawinsondes nor to background grid, while results in Experiment 2 did compare well, likely due to the cold brightness temperature assigned to the cloud features.

JMA developers should verify the reasons because of which Experiment 4 statistics degrade respect to Experiment 2 and 3 statistics.

d) NOAA

The strength of the NOAA algorithm is in its cloud height determination, as evidenced in Experiment 4: A substantial number of heights are adjusted (as compared to IR-only B_T) resulting in an improvement in a statistical comparison to rawinsondes and the background forecast wind field.

The spatial distribution in Experiment 4 is very good at high levels, but very few winds are tracked in low levels. Unfortunately, a high vertical resolution background grid could not be used to better detect temperature inversions and the height of low-level clouds, which may have impacted the low-cloud density.

e) Korea Meteorological Administration

Results from Experiments 2 and 3 show that KMA AMVs perform rather well against many centers.

Results from Experiment 4 show at the same time that the KMA algorithm is in the middle (statistically) when measuring performance, based on comparisons to rawinsondes and the background wind field.

Coverage in Experiment 4 is very good for the high-level winds. However, low-level winds are assigned higher in the atmosphere, compared to EUM.

f) NWC SAF

Among all the centers in this study, the NWC SAF/HRW algorithm has the best statistics as compared to rawinsondes and the background forecast wind field. This is the case for both Experiment 3 (IR B_T only cloud height) and Experiment 4 (any cloud height technique). Moreover, NWC AMVs with IR-only cloud height performs better than several other centers using other cloud height techniques.

The spatial distribution of the low-level winds using the prescribed configuration is dense and with very good comparison to rawinsondes and the background grid. The high-levels winds are less dense that EUM; however the comparison to rawinsondes and the background grid is usually the best among the centers.

There are two areas noted for suggestions to improve the NWC SAF algorithm. First, to investigate increasing the coverage of the high-level winds since it is less dense than several other centers (e.g., EUM, NOA, KMA) when the prescribed configuration is used. Second, the IR BT technique used by NWC SAF will result in the coldest temperature compared to the other centers. This is good for the high-level winds (and the statistics confirm that); however, this may not be the best method for warmer clouds as the low-level clouds are placed too high in Experiment 2.

g) Brazilian Meteorological Center

The performance of the BRZ AMV algorithm could not be evaluated because the results of Experiment 1 indicate an error in determining wind speed up to 10 ms^{-1} depending on the distance from the satellite subpoint.

However, the Best Fit analysis indicates that there are good AMVs in this dataset as the Best Fit height adjustment and corresponding improvement in statistics (compared to the background) are very similar to other centers.

In addition, the coverage in Experiment 4 is very good for the high-level winds. However, low-level winds are assigned higher in the atmosphere, compared to EUM.

12. References

Genkova, I., R. Borde, J. Schmetz, J. Daniels, C. Velden, K. Holmlund, 2008: Global atmospheric motion vectors intercomparison study, *9th Int. Winds Workshop*, Annapolis, MD USA, April 2008.

Genkova, I., R. Borde, J. Schmetz, C. Velden, K. Holmlund, N. Bormann, P. Bauer, 2010: Global atmospheric motion vector intercomparison study, *10th Int. Winds Workshop*, Tokyo, Japan, February 2010.

Salonen, K., J. Cotton, N. Bormann, M. Forsythe**,** 2012: Characterising AMV height assignment error by comparing best fit pressure statistics from the Met Office and ECMWF System, *11th International Winds Workshop*, Auckland, New Zealand, February 2012.

Xu J. and Zhang Q., 1996: Calculation of Cloud motion wind with GMS-5 images in China. *Proceedings 3rd international winds workshop*, EUMETSAT Pub.18, pp.45-52.

13. Acknowledgements

We would like to thank EUMETSAT, the Satellite Application Facility on support to Nowcasting (NWC SAF) and Agencia Estatal de Meteorología (AEMET) for the funding and support of this project.

We would also like to thank Régis Borde and Manuel Carranza at EUMETSAT for their efforts in the preparation of the input datasets for this intercomparison study, without which this report had not been possible, and for their comments and suggestions.

Also, we appreciate the comments and suggestions from the whole International Winds Working Group (IWWG) at the Twelfth International Winds Workshop in Copenhagen, and especially their co-chairs, Jaime Daniels and Mary Forsythe.

14. Appendix A: Parameter Distribution Histograms

Experiment 2: QINF Parameter Distribution Histograms

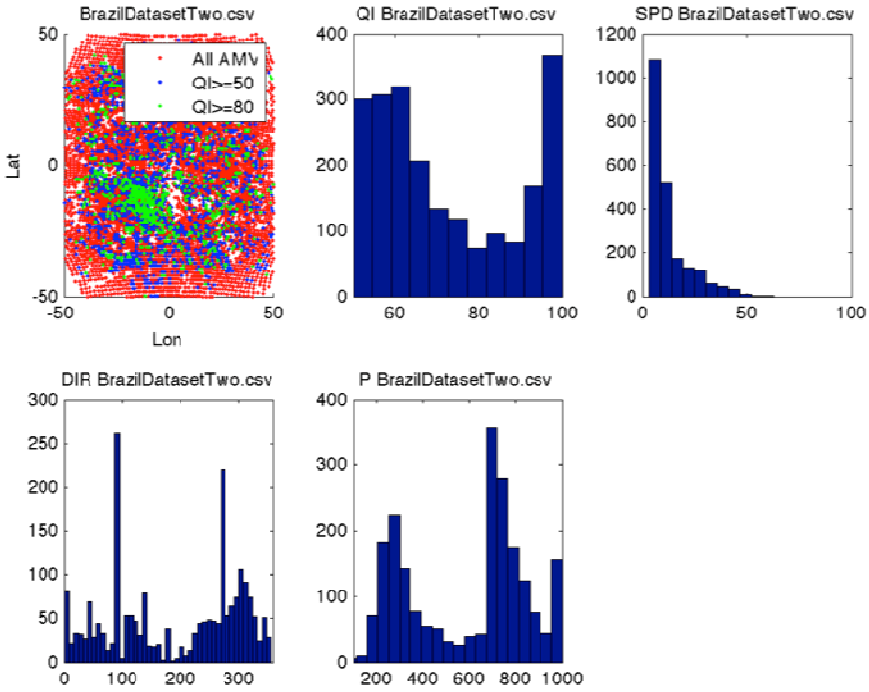


Figure 14-1: Experiment 2 parameter distributions for BRZ: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

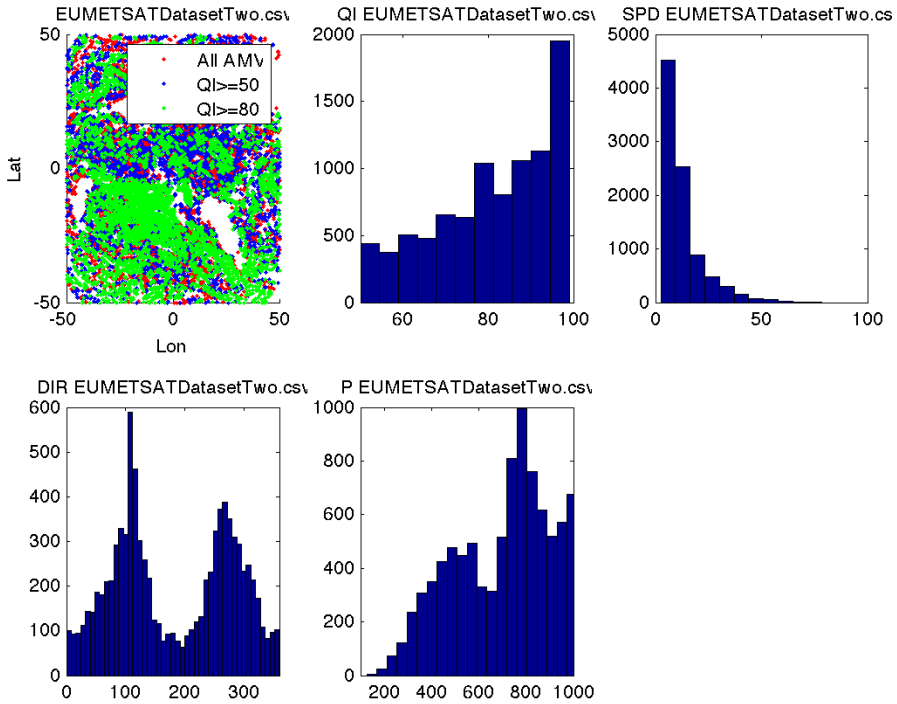


Figure 14-2: Experiment 2 parameter distributions for EUM: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

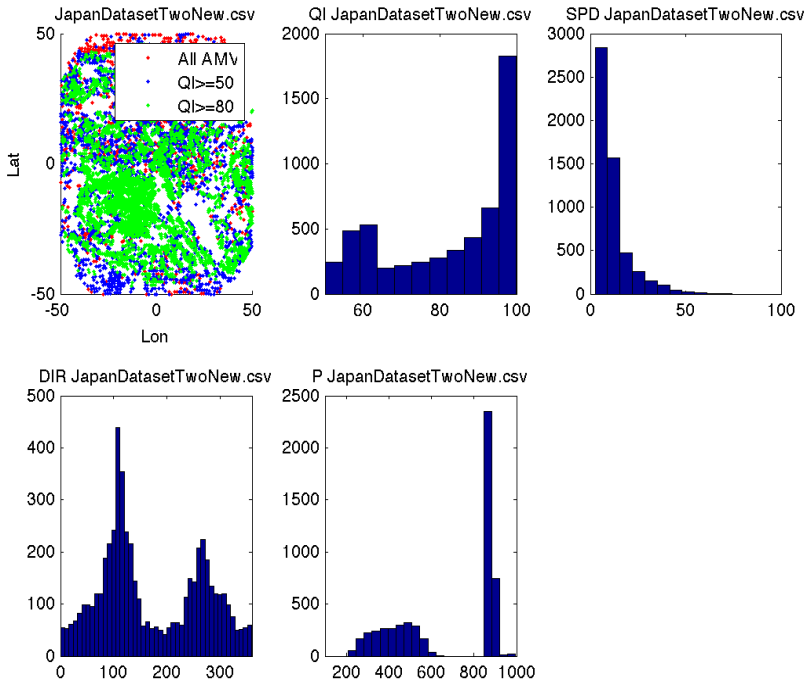


Figure 14-3: Experiment 2 parameter distributions for JMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

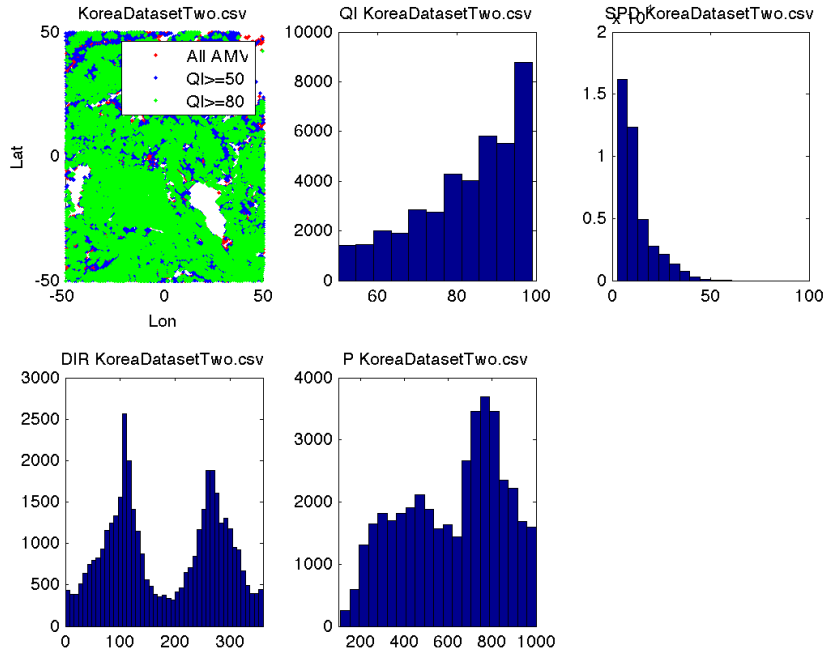


Figure 14-4: Experiment 2 parameter distributions for KMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

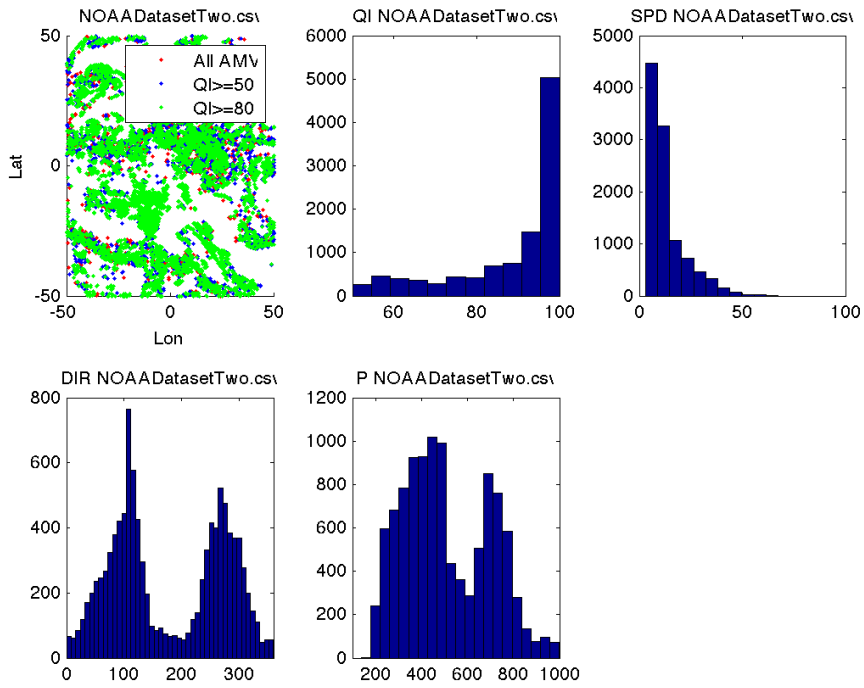


Figure 14-5: Experiment 2 parameter distributions for NOA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

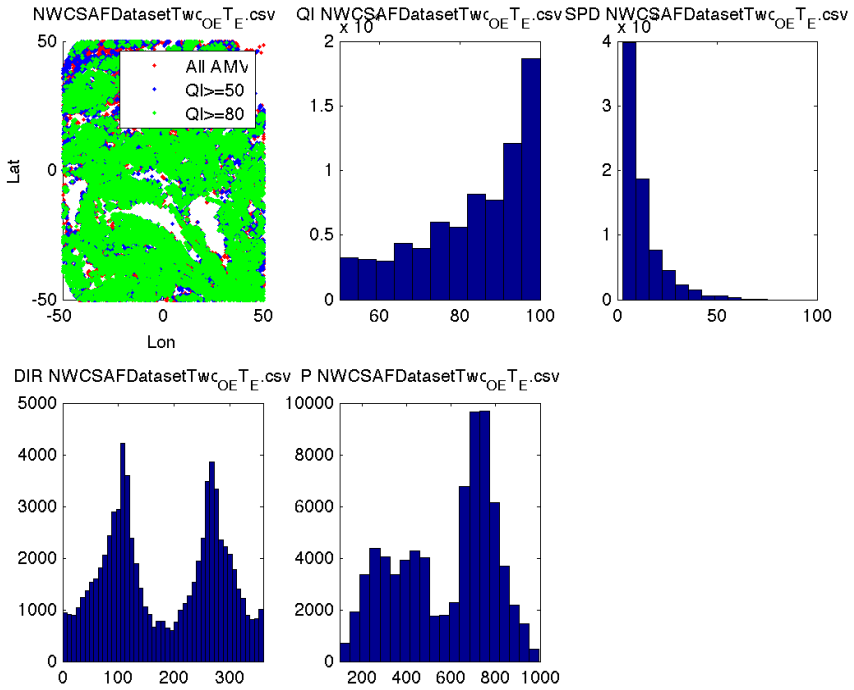


Figure 14-6: Experiment 2 parameter distributions for NWC: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

Experiment 2: QIWF Parameter Distribution Histograms

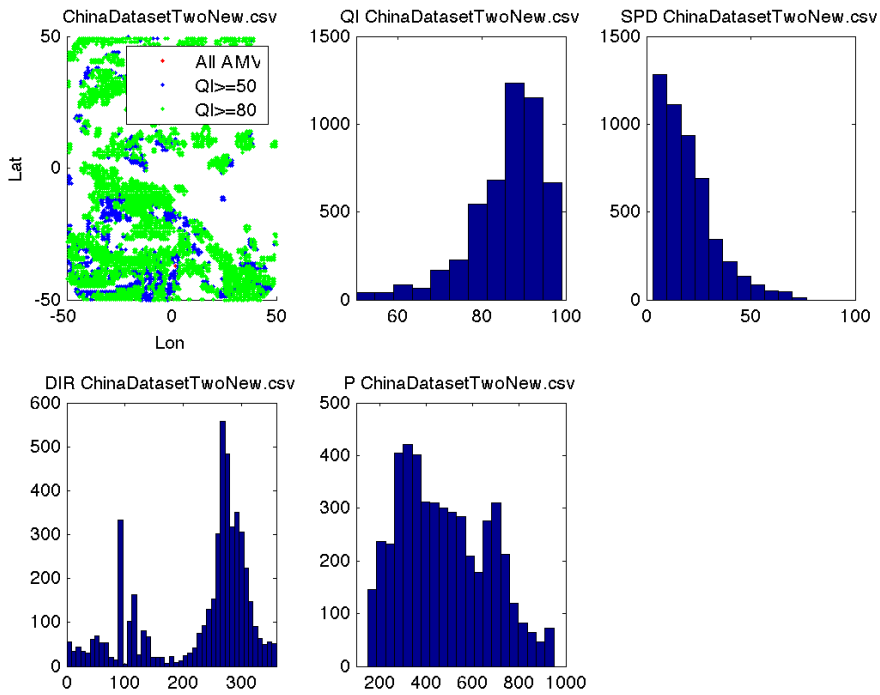


Figure 14-7: Experiment 2 parameter distributions for CMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

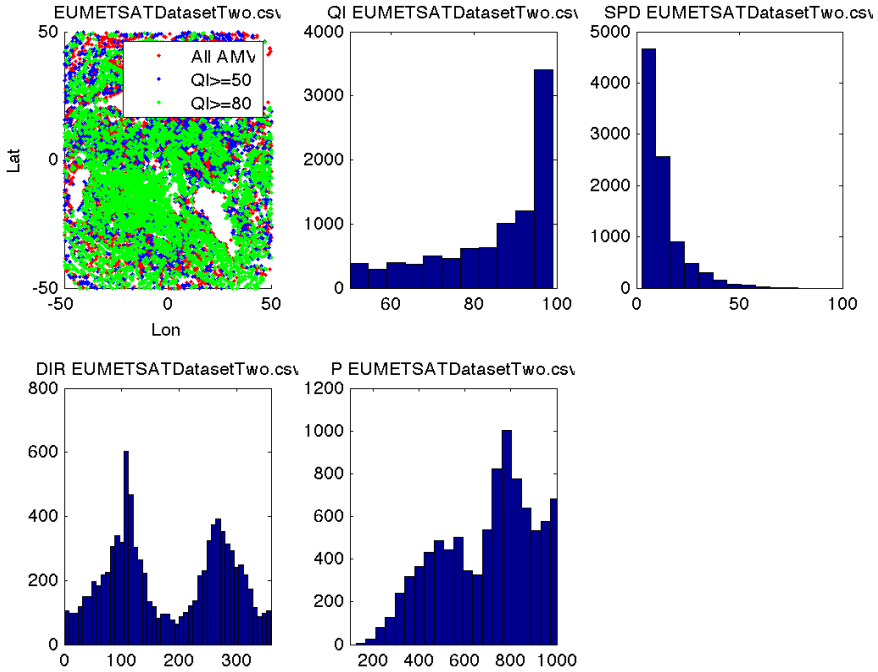


Figure 14-8: Experiment 2 parameter distributions for EUM: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

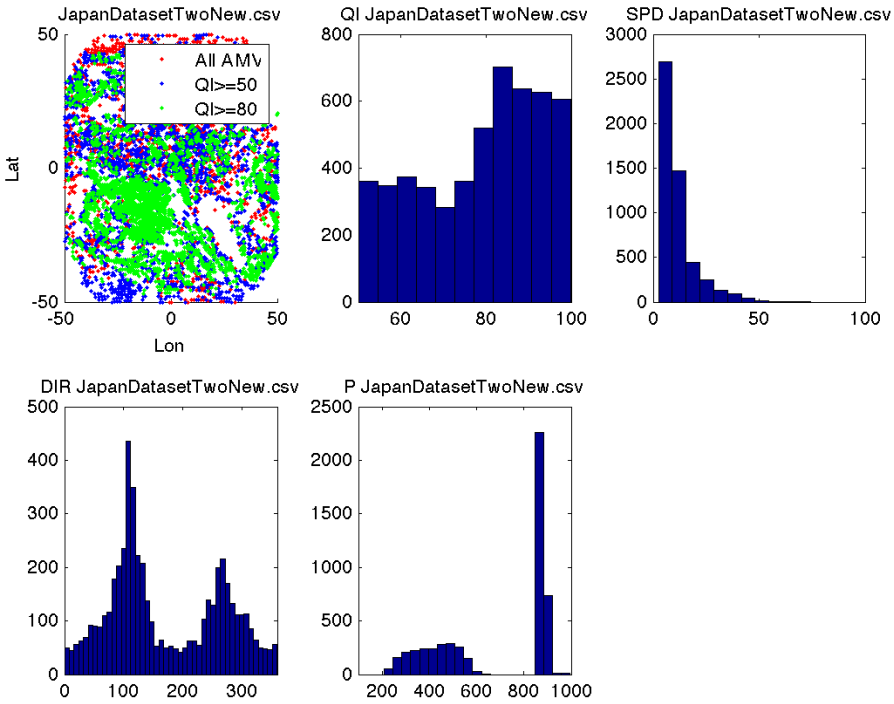


Figure 14-9: Experiment 2 parameter distributions for JMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

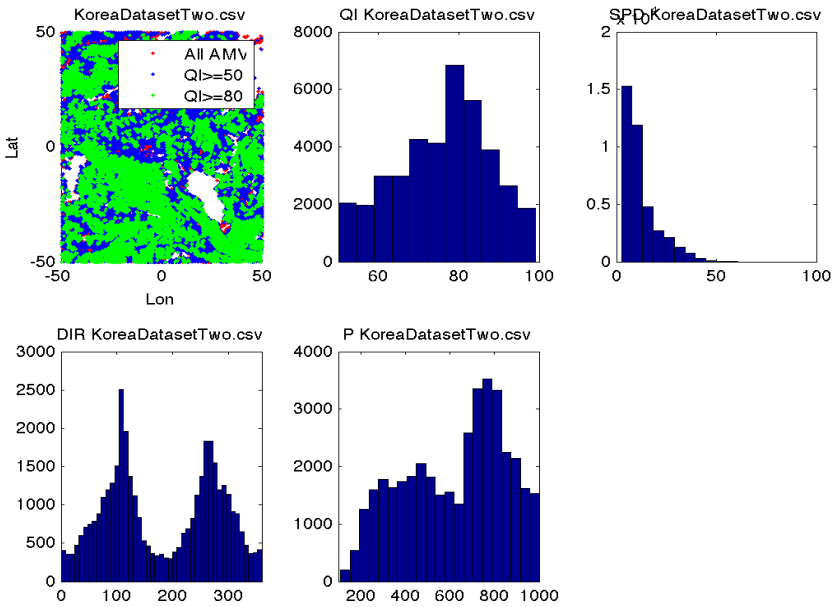


Figure 14-10: Experiment 2 parameter distributions for KMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

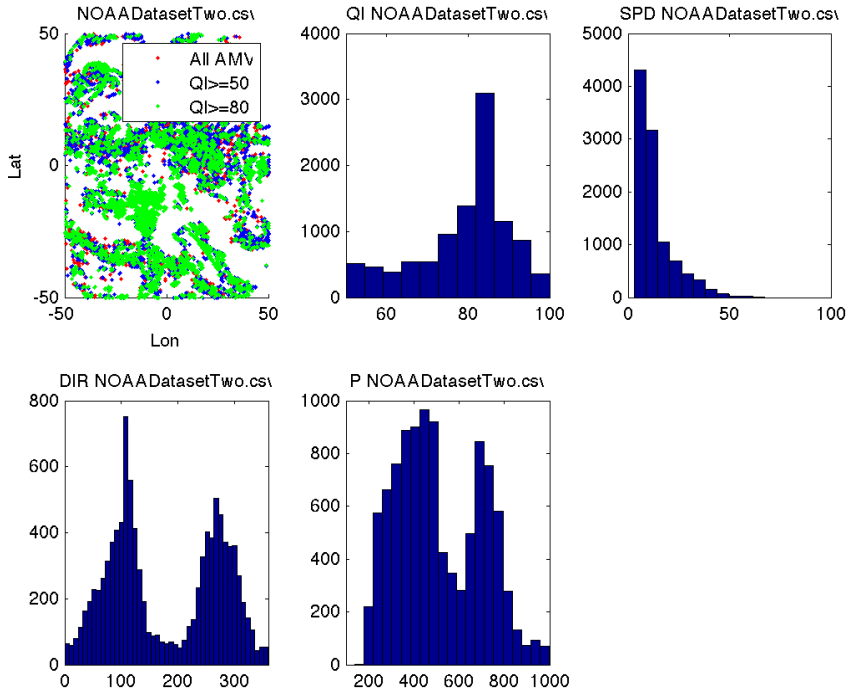


Figure 14-11: Experiment 2 parameter distributions for NOA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

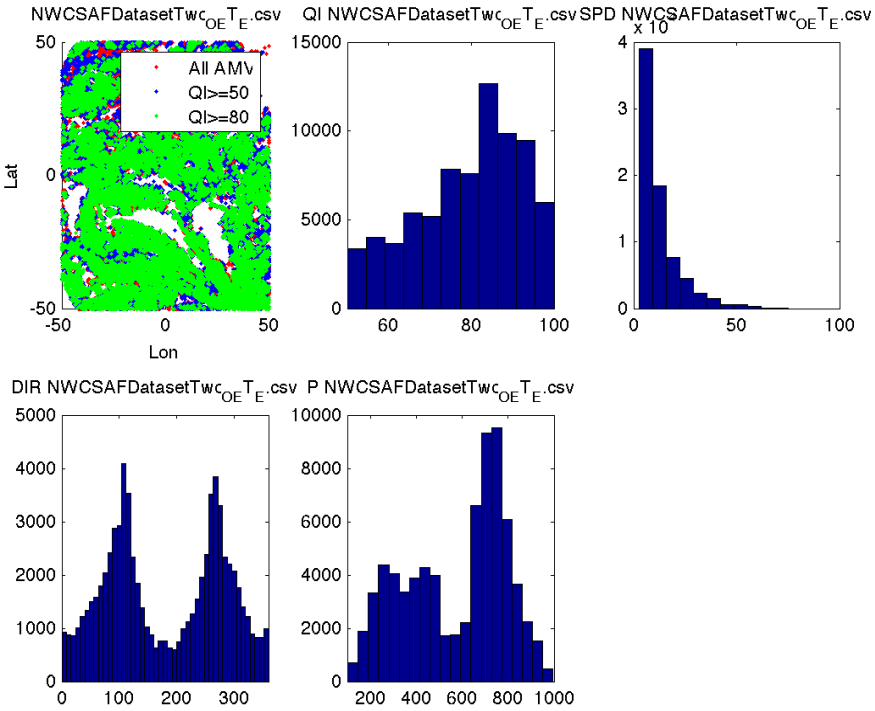


Figure 14-12: Experiment 2 parameter distributions for NWC: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

Experiment 3: QINF Parameter Distribution Histogram

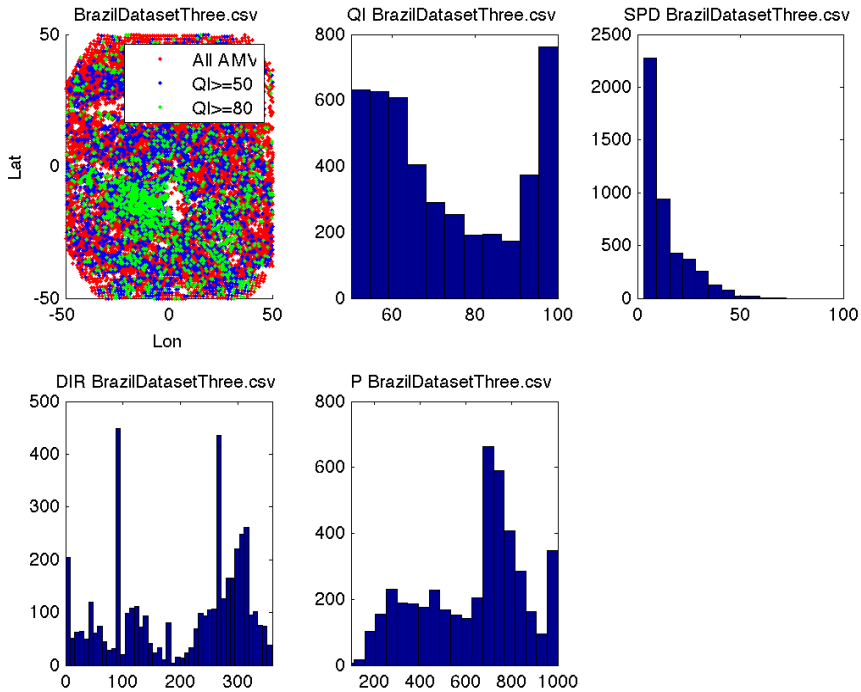


Figure 14-13: Experiment 3 parameter distributions for BRZ: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

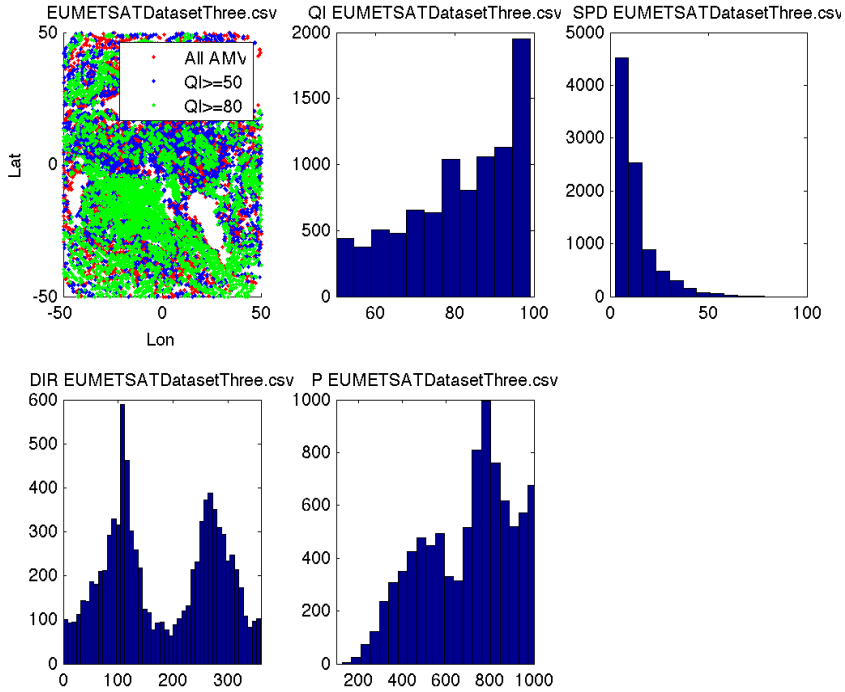


Figure 14-14: Experiment 3 parameter distributions for EUM: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

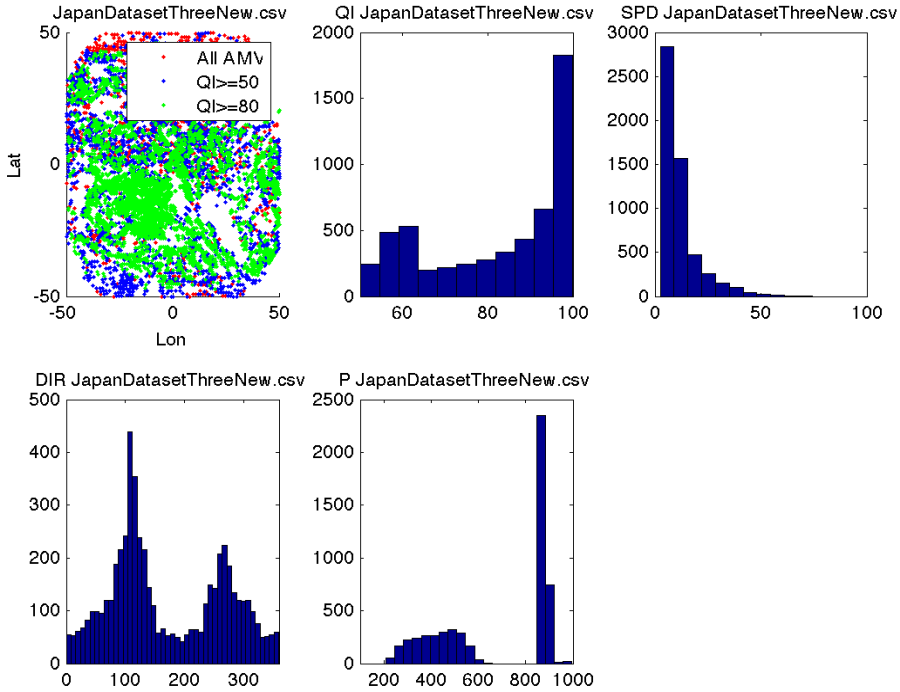


Figure 14-15: Experiment 3 parameter distributions for JMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

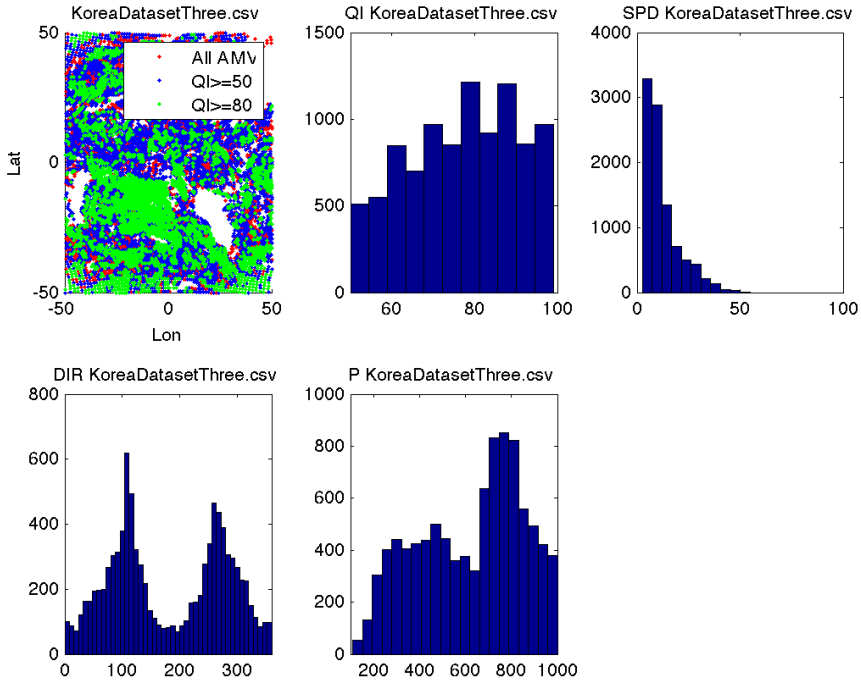


Figure 14-16: Experiment 3 parameter distributions for KMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

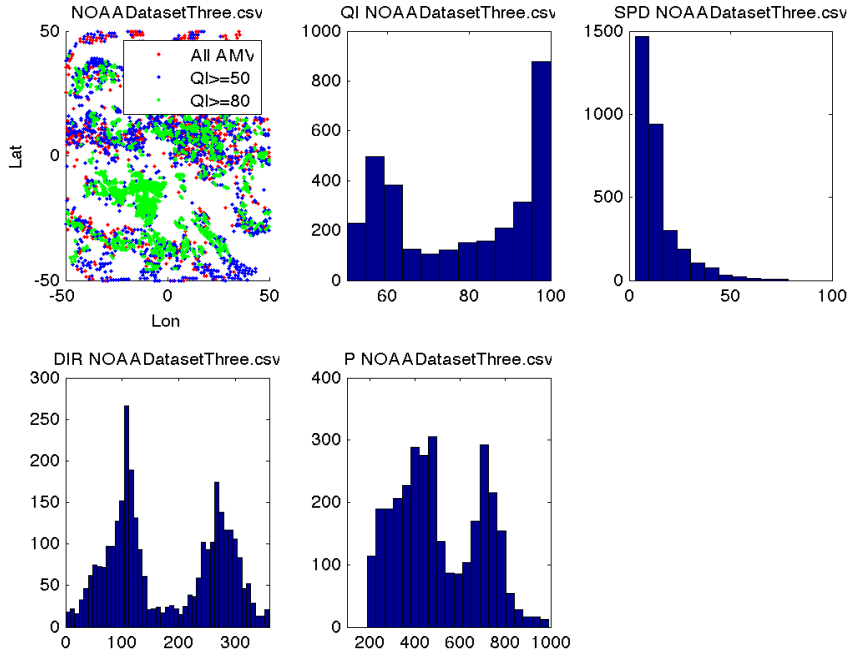


Figure 14-17: Experiment 3 parameter distributions for NOA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

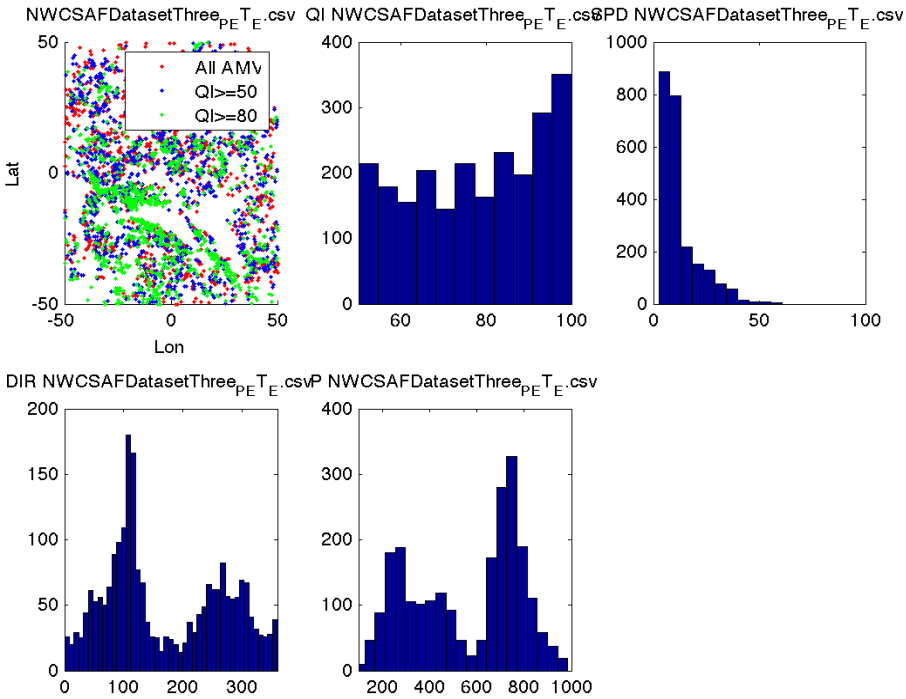


Figure 14-18: Experiment 3 parameter distributions for NWC: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

Experiment 3: QIWF Parameter Distribution Histograms

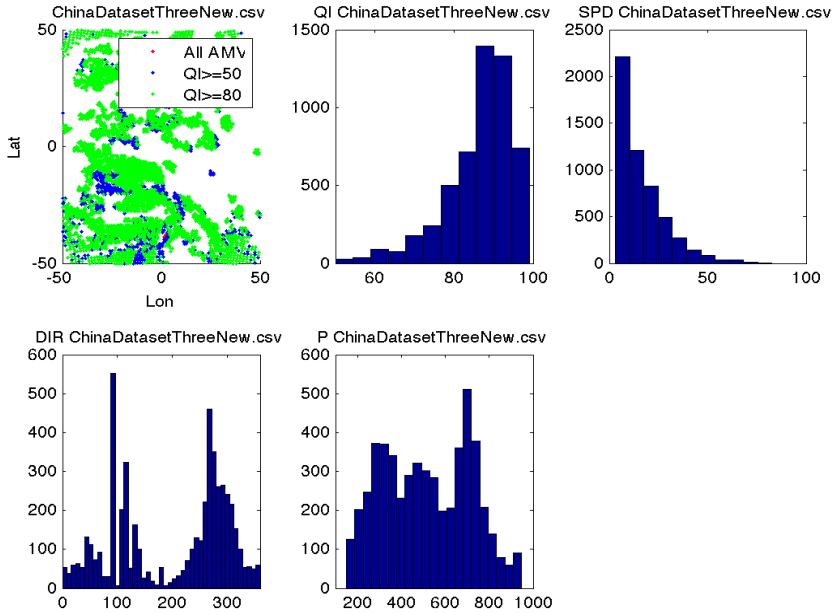


Figure 14-19: Experiment 3 parameter distributions for CMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

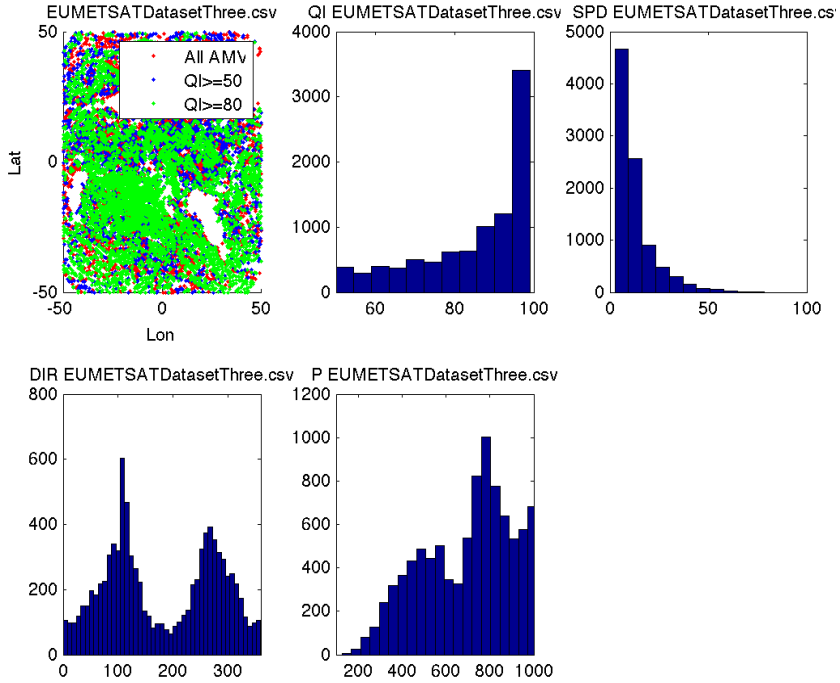


Figure 14-20: Experiment 3 parameter distributions for EUM: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

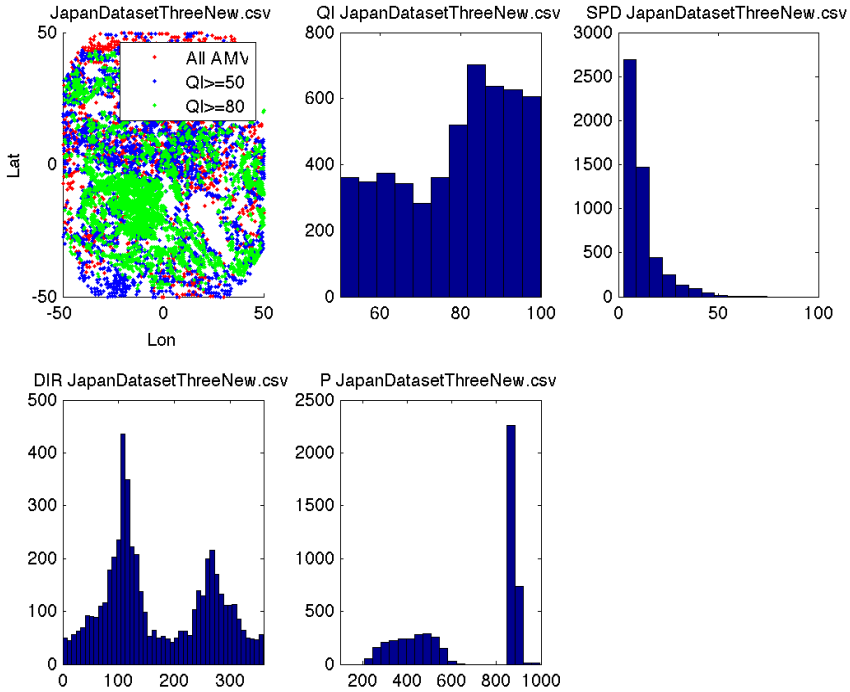


Figure 14-21: Experiment 3 parameter distributions for JMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

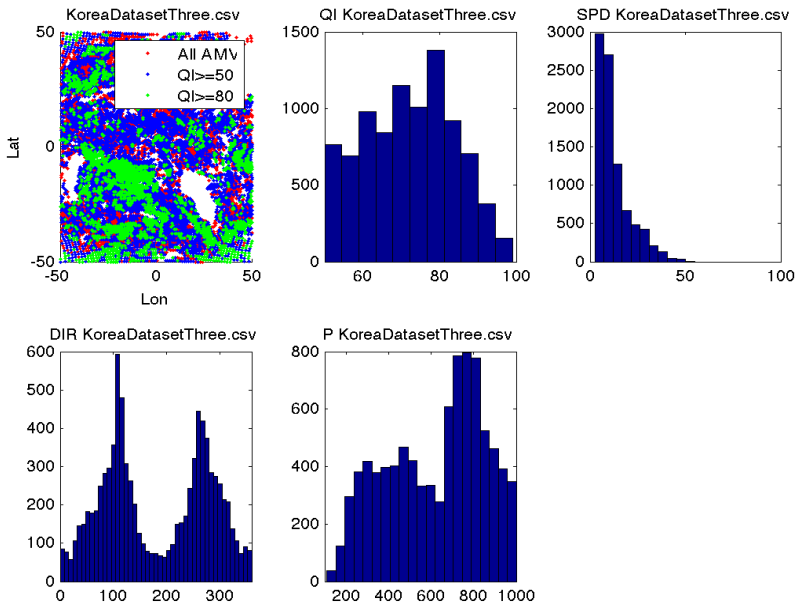


Figure 14-22: Experiment 3 parameter distributions for KMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

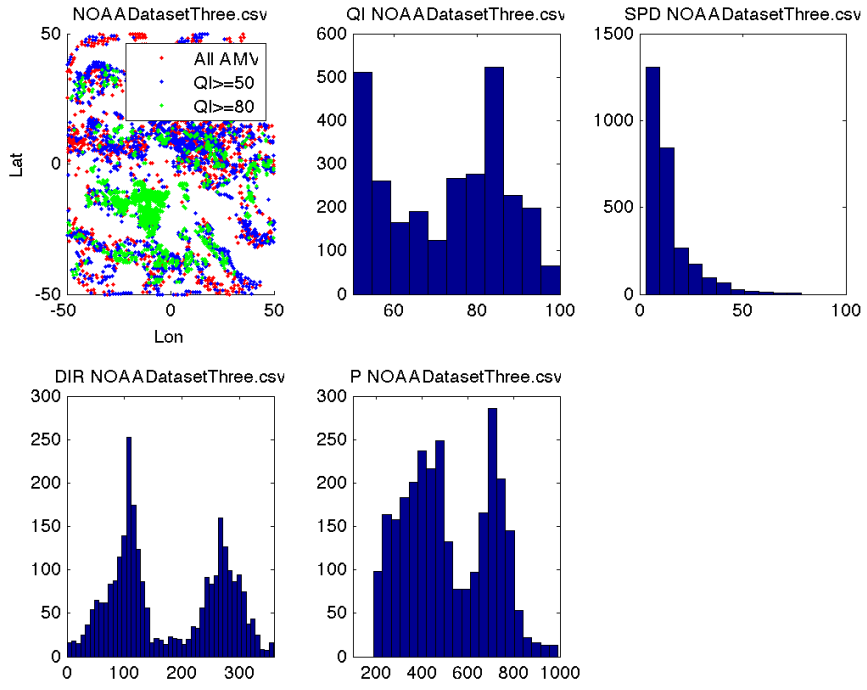


Figure 14-23: Experiment 3 parameter distributions for NOA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

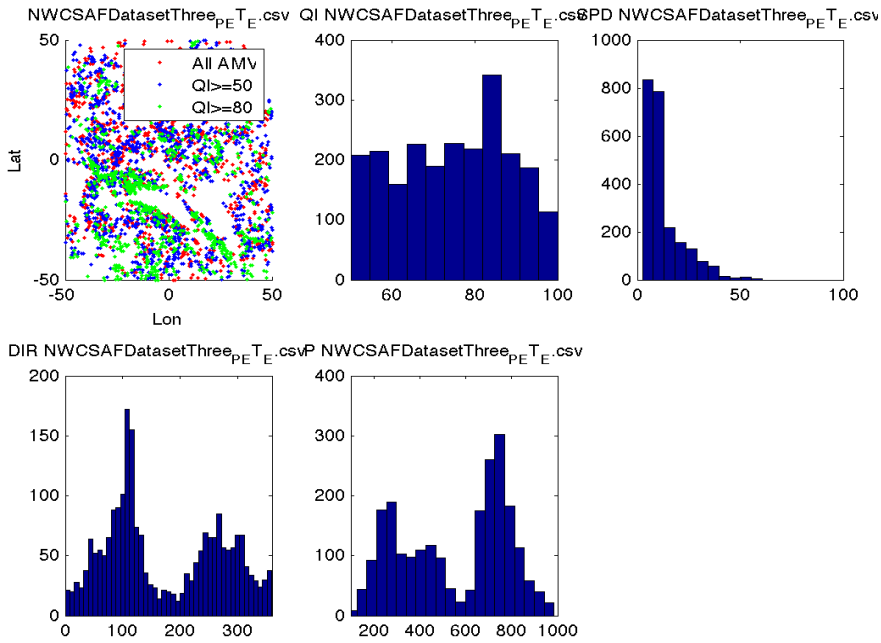


Figure 14-24: Experiment 3 parameter distributions for NWC: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

Experiment 4: QINF Parameter Distribution Histograms

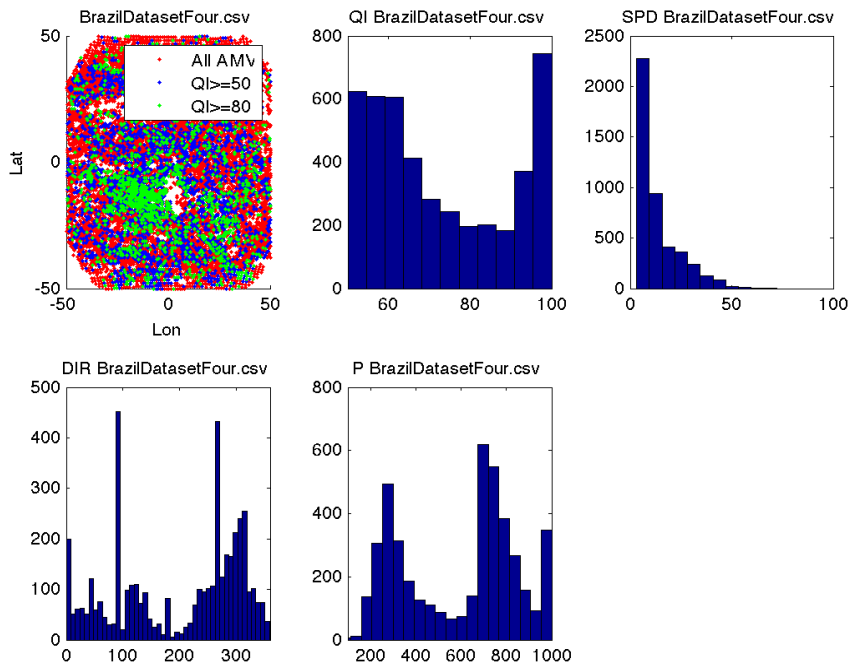


Figure 14-25: Experiment 4 parameter distributions for BRZ: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

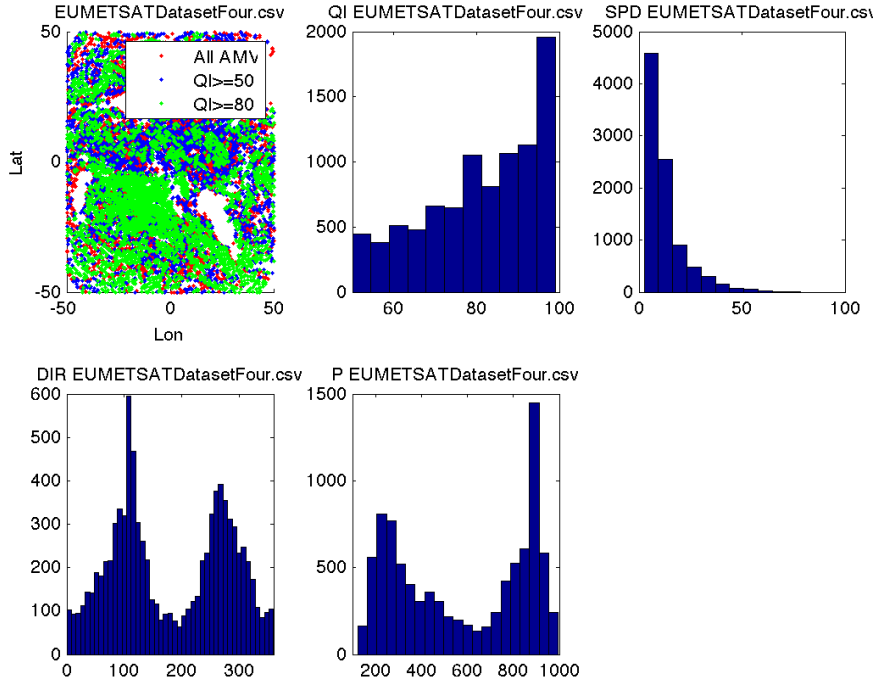


Figure 14-26: Experiment 4 parameter distributions for EUM: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

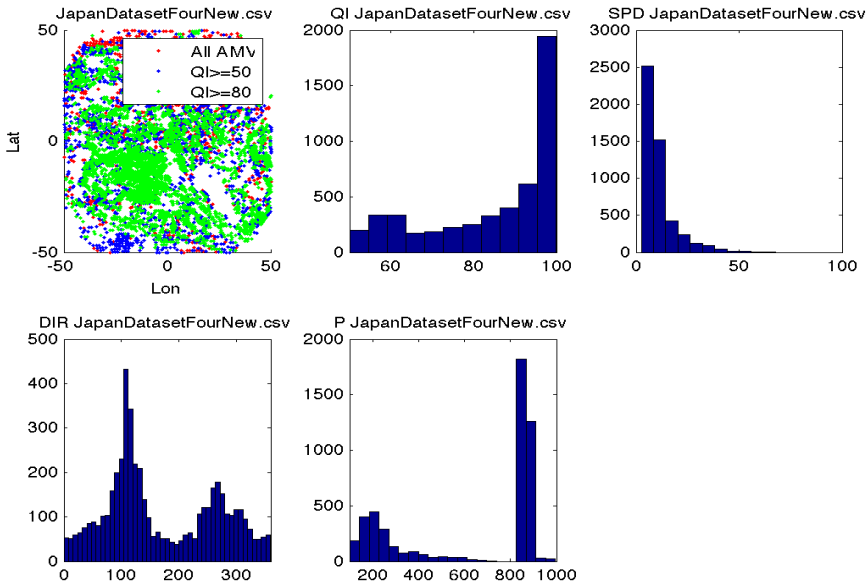


Figure 14-27: Experiment 4 parameter distributions for JMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

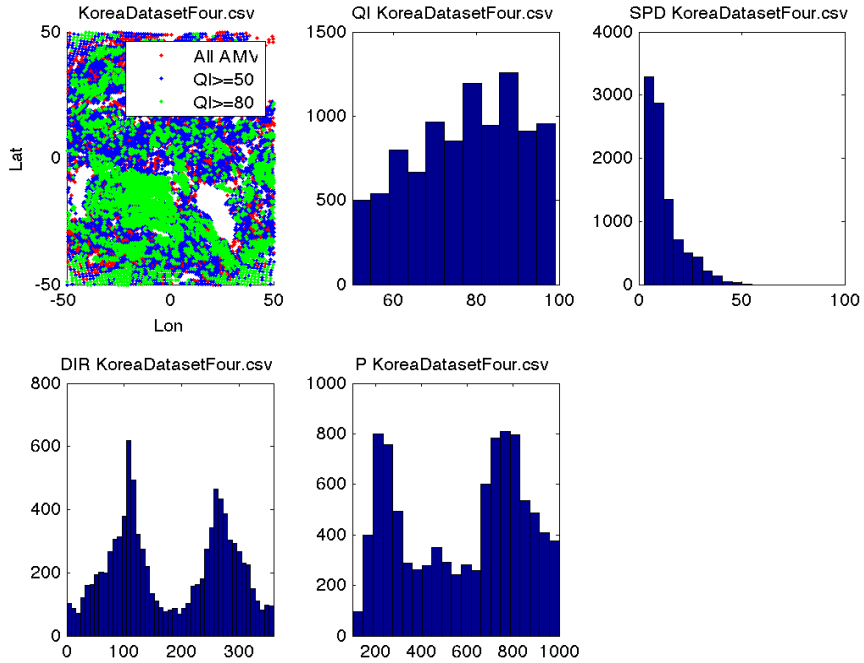


Figure 14-28: Experiment 4 parameter distributions for KMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

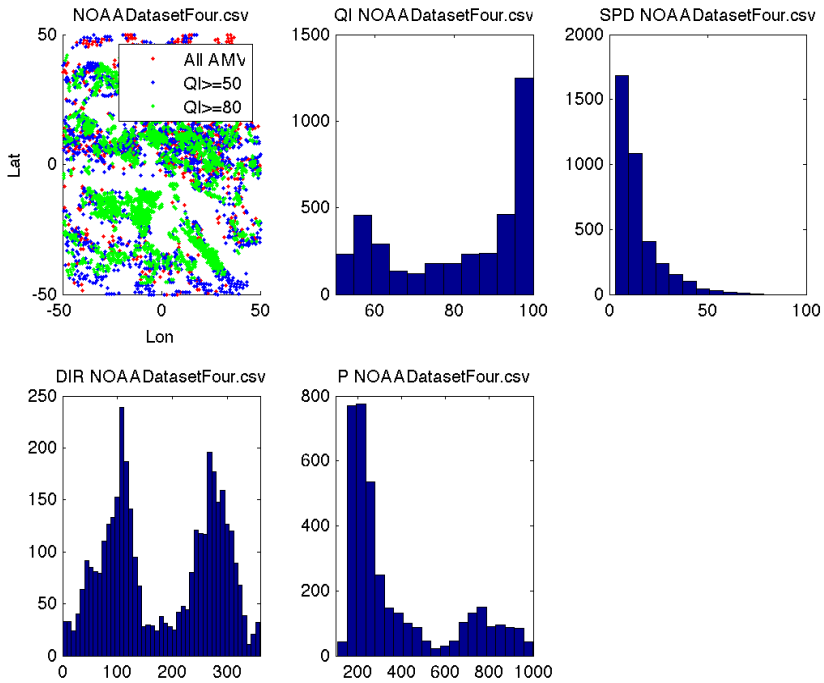


Figure 14-29: Experiment 4 parameter distributions for NOA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

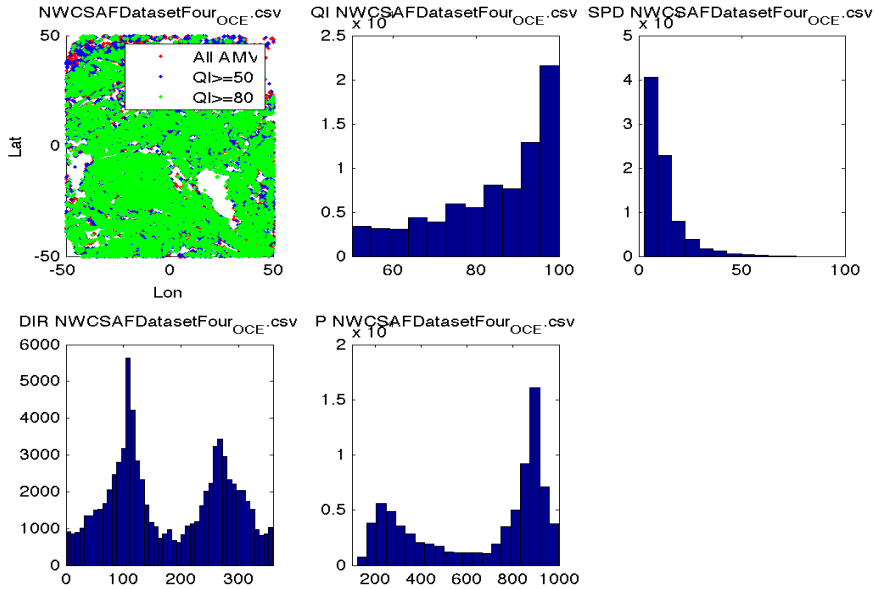


Figure 14-30: Experiment 4 parameter distributions for NWC: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

Experiment 4: QIWF Parameter Distribution Histograms

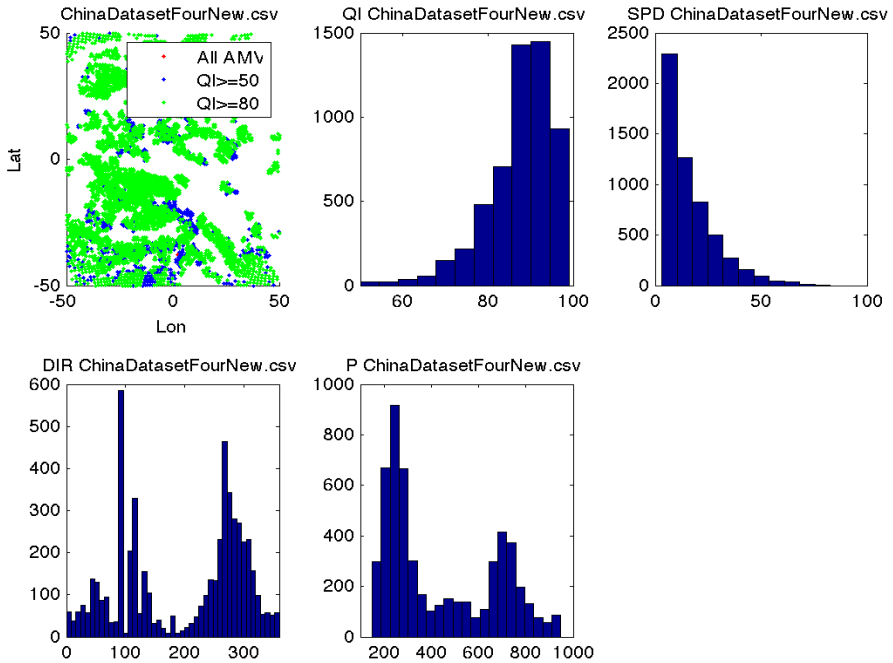


Figure 14-31: Experiment 4 parameter distributions for CMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

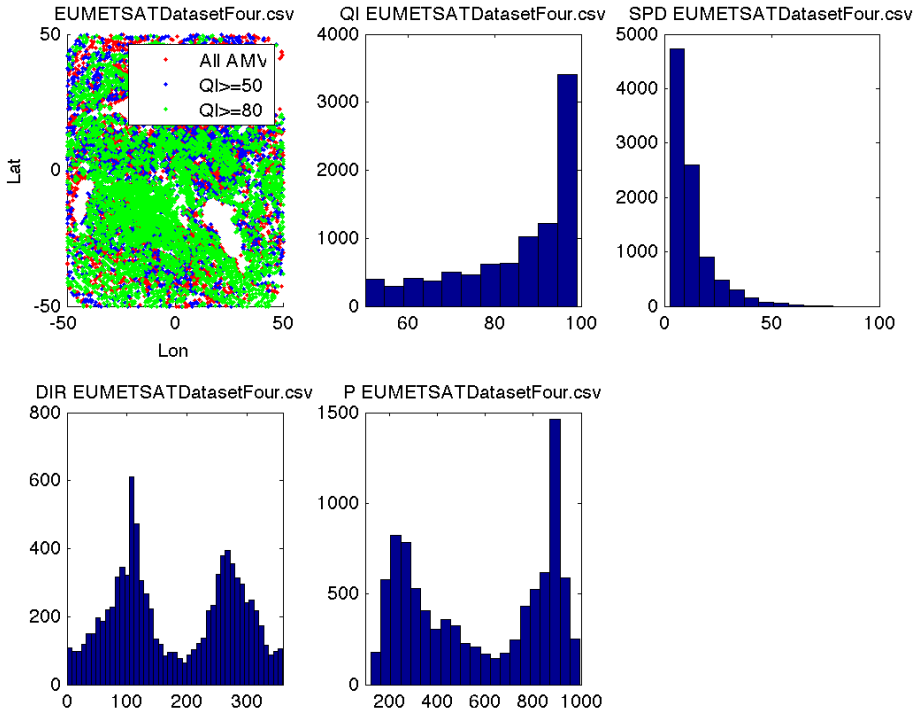


Figure 14-32: Experiment 4 parameter distributions for EUM: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

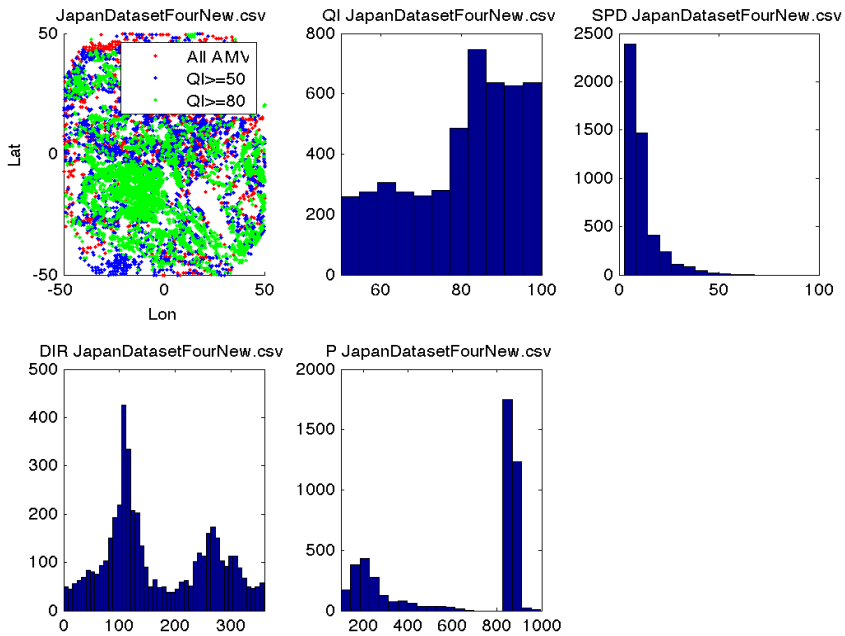


Figure 14-33: Experiment 4 parameter distributions for JMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

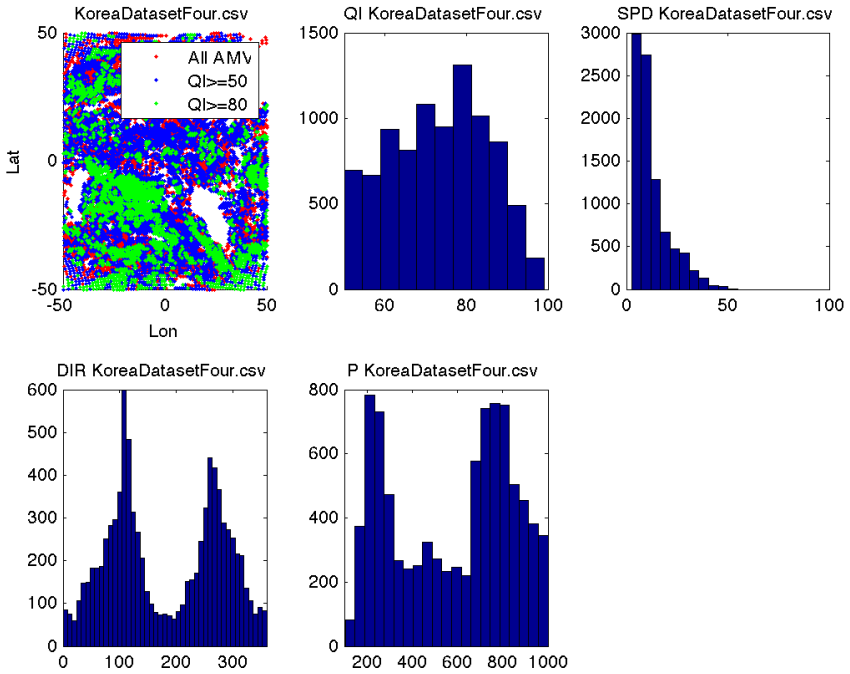


Figure 14-34: Experiment 4 parameter distributions for KMA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

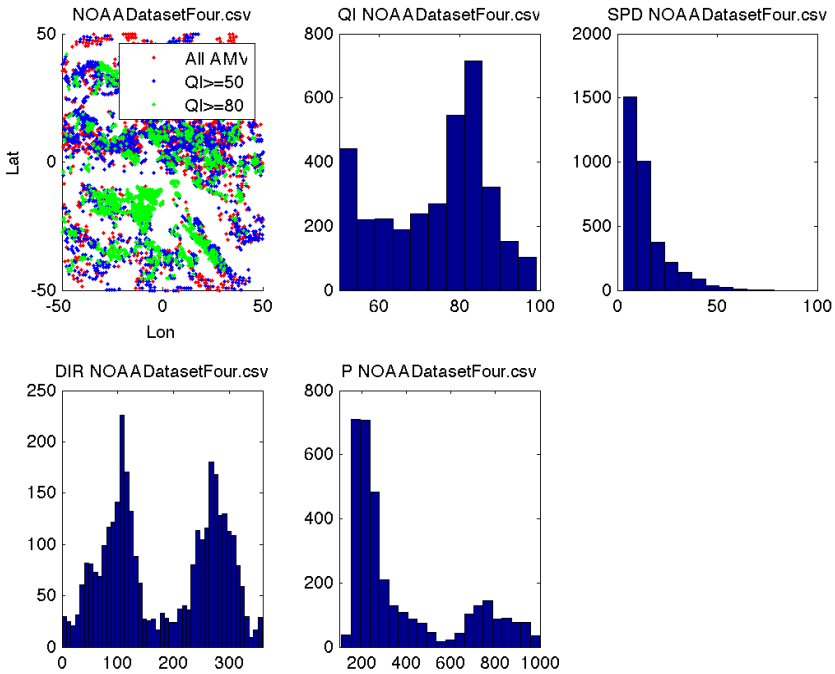


Figure 14-35: Experiment 4 parameter distributions for NOA: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

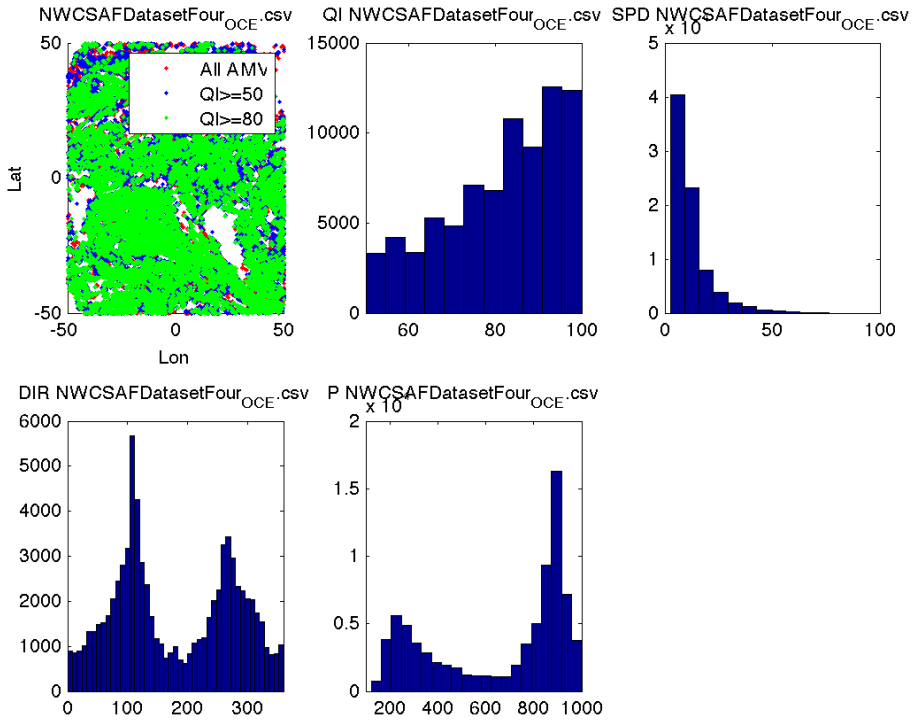


Figure 14-36: Experiment 4 parameter distributions for NWC: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

15. Appendix B: Matlab t-test Documentation

```
ttest  One-sample and paired-sample t-test.

H = ttest(X) performs a t-test of the hypothesis that the data in the
    vector X come from a distribution with mean zero, and returns the
    result of the test in H.  H=0 indicates that the null hypothesis
    ("mean is zero") cannot be rejected at the 5% significance leve
    H=1 indicates that the null hypothesis can be rejected at the 5%
    level. The data are assumed to come from a normal distribution
    with unknown variance.

    X can also be a matrix or an N-D array. For matrices, ttest performs
    separate t-tests along each column of X, and returns a vector of
    results. For N-D arrays, ttest works along the first non-singleton
    dimension of X.

    ttest treats NaNs as missing values, and ignores them.

    H = ttest(X,M) performs a t-test of the hypothesis that the data in
    X come from a distribution with mean M. M must be a scalar.

    H = ttest(X,Y) performs a paired t-test of the hypothesis that two
    matched samples, in the vectors X and Y, come from distributions with
    equal means. The difference X-Y is assumed to come from a normal
    distribution with unknown variance. X and Y must have the same
    length. X and Y can also be matrices or N-D arrays of the same size.

    [H,P] = ttest(...) returns the p-value, i.e., the probability of
    observing the given result, or one more extreme, by chance if the
    null hypothesis is true.  Small values of P cast doubt on the
    validity of the null hypothesis.

    [H,P,CI] = ttest(...) returns a 100*(1-ALPHA)% confidence interval
    For the true mean of X, or of X-Y for a paired test.

    [H,P,CI,STATS] = ttest(...) returns a structure with the following
    fields:
       'tstat' – the value of the test statistic
       'df'    -- the degrees of freedom of the test
       'sd'    -- the estimated population standard deviation.  For a
                  paired test, this is the std. dev. Of X-Y.
```

16. Appendix C: t-test Results

Text output from Matlab script Stats_QIF_One.m; a statistical confidence of 95% was used. See Appendix B: Matlab t-test Documentation for description of h, p, ci, Mean and Appendix G: Matlab Scripts for script Stats_QIF_One.m

Experiment 1 t-test Results

Collocated AMVs: 10876

```
EUMETSAT vs. Korea
  Speed:  h = 1, p = 0.00, ci = 0.01 0.02, Mean: 0.01
  Dir:    h = 1, p = 0.00, ci = 0.02 0.03, Mean: 0.03
  Hdisp1: h = 0, p = 0.54, ci = -0.00 0.00, Mean: 0.00
  Vdisp1: h = 0, p = 0.51, ci = -0 0.00, Mean: 0.00
  Hdisp2: h = 0, p = 0.54, ci = -0.00 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.51, ci = -0.00 0.00, Mean: -0.00
EUMETSAT vs. China
  Speed:  h = 1,   p = 0.00, ci = 0.49 0.51, Mean: 0.50
  Dir:    h = 1,   p = 0.00, ci = 0.01 0.03, Mean: 0.02
  Hdisp1: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp1: h = NaN, p = NaN, ci = 0 0.00, Mean: 0.00
  Hdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
EUMETSAT vs. NOAA
  Speed:  h = 1, p = 0.00, ci = -0.02 -0.01, Mean: -0.01
  Dir:    h = 1, p = 0.00, ci = 0.02 0.03, Mean: 0.02
  Hdisp1: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp1: h = NaN, p = NaN, ci = 0 0.00, Mean: 0.00
  Hdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
EUMETSAT vs. NWCSAF
  Speed:  h = 0, p = 0.60, ci = -0.02 0.01, Mean: -0.00
  Dir:    h = 0, p = 0.85, ci = -0.06 0.05, Mean: -0.01
  Hdisp1: h = 0, p = 0.08, ci = -0.01 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.50, ci = -0 0.01, Mean: 0.00
  Hdisp2: h = 0, p = 0.13, ci = -0.01 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.52, ci = -0.00 0.01, Mean: 0.00
EUMETSAT vs. Japan
  Speed:  h = 1, p = 0.00, ci = 17.21 17.33, Mean: 17.27
  Dir:    h = 1, p = 0.00, ci = -0.12 -0.11, Mean: -0.11
  Hdisp1: h = 0, p = 0.10, ci = -0.00 0.00, Mean: 0.00
  Vdisp1: h = 0, p = 0.92, ci = -0 0.00, Mean: -0.00
  Hdisp2: h = 0, p = 0.10, ci = -0.00 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.92, ci = -0.00 0.00, Mean: 0.00
EUMETSAT vs. Brazil
  Speed:  h = 1, p = 0.00, ci = 0.40 0.47, Mean: 0.43
  Dir:    h = 1, p = 0.00, ci = 4.72 4.96, Mean: 4.84
  Hdisp1: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp1: h = NaN, p = NaN, ci = 0 0.00, Mean: 0.00
  Hdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
Korea vs. China
  Speed:  h = 1, p = 0.00, ci = 0.48 0.49, Mean: 0.49
  Dir:    h = 1, p = 0.02, ci = -0.01 -0.00, Mean: -0.01
  Hdisp1: h = 0, p = 0.54, ci = -0.00 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.51, ci = -0 0.00, Mean: -0.00
```

```
  Hdisp2: h = 0, p = 0.54, ci = -0.00 0.00, Mean: 0.00
  Vdisp2: h = 0, p = 0.51, ci = -0.00 0.00, Mean: 0.00
Korea vs. NOAA
  Speed:  h = 1, p = 0.00, ci = -0.03 -0.03, Mean: -0.03
  Dir:    h = 1, p = 0.01, ci = -0.00 -0.00, Mean: -0.00
  Hdisp1: h = 0, p = 0.54, ci = -0.00 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.51, ci = -0 0.00, Mean: -0.00
  Hdisp2: h = 0, p = 0.54, ci = -0.00 0.00, Mean: 0.00
  Vdisp2: h = 0, p = 0.51, ci = -0.00 0.00, Mean: 0.00
Korea vs. NWCSAF
  Speed:  h = 1, p = 0.01, ci = -0.03 -0.00, Mean: -0.02
  Dir:    h = 0, p = 0.26, ci = -0.09 0.02, Mean: -0.03
  Hdisp1: h = 0, p = 0.07, ci = -0.01 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.56, ci = -0 0.01, Mean: 0.00
  Hdisp2: h = 0, p = 0.14, ci = -0.01 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.47, ci = -0.00 0.01, Mean: 0.00
Korea vs. Japan
  Speed:  h = 1, p = 0.00, ci = 17.20 17.31, Mean: 17.25
  Dir:    h = 1, p = 0.00, ci = -0.14 -0.13, Mean: -0.14
  Hdisp1: h = 0, p = 0.67, ci = -0.00 0.00, Mean: 0.00
  Vdisp1: h = 0, p = 0.51, ci = -0 0.00, Mean: -0.00
  Hdisp2: h = 0, p = 0.67, ci = -0.00 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.51, ci = -0.00 0.00, Mean: 0.00
Korea vs. Brazil
  Speed:  h = 1, p = 0.00, ci = 0.38 0.46, Mean: 0.42
  Dir:    h = 1, p = 0.00, ci = 4.69 4.93, Mean: 4.81
  Hdisp1: h = 0, p = 0.54, ci = -0.00 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.51, ci = -0 0.00, Mean: -0.00
  Hdisp2: h = 0, p = 0.54, ci = -0.00 0.00, Mean: 0.00
  Vdisp2: h = 0, p = 0.51, ci = -0.00 0.00, Mean: 0.00
China vs. NOAA
  Speed:  h = 1, p = 0.00, ci = -0.52 -0.51, Mean: -0.51
  Dir:    h = 0, p = 0.07, ci = -0.00 0.01, Mean: 0.01
  Hdisp1: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp1: h = NaN, p = NaN, ci = 0 0.00, Mean: 0.00
  Hdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
China vs. NWCSAF
  Speed:  h = 1, p = 0.00, ci = -0.52 -0.49, Mean: -0.50
  Dir:    h = 0, p = 0.41, ci = -0.08 0.03, Mean: -0.02
  Hdisp1: h = 0, p = 0.08, ci = -0.01 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.50, ci = -0 0.01, Mean: 0.00
  Hdisp2: h = 0, p = 0.13, ci = -0.01 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.52, ci = -0.00 0.01, Mean: 0.00
China vs. Japan
  Speed:  h = 1, p = 0.00, ci = 16.71 16.82, Mean: 16.77
  Dir:    h = 1, p = 0.00, ci = -0.14 -0.12, Mean: -0.13
  Hdisp1: h = 0, p = 0.10, ci = -0.00 0.00, Mean: 0.00
  Vdisp1: h = 0, p = 0.92, ci = -0 0.00, Mean: -0.00
  Hdisp2: h = 0, p = 0.10, ci = -0.00 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.92, ci = -0.00 0.00, Mean: 0.00
China vs. Brazil
  Speed:  h = 1, p = 0.00, ci = -0.10 -0.03, Mean: -0.07
  Dir:    h = 1, p = 0.00, ci = 4.70 4.94, Mean: 4.82
  Hdisp1: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp1: h = NaN, p = NaN, ci = 0 0.00, Mean: 0.00
  Hdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
NOAA vs. NWCSAF
  Speed:  h = 0, p = 0.19, ci = -0.00 0.02, Mean: 0.01
  Dir:    h = 0, p = 0.29, ci = -0.09 0.03, Mean: -0.03
```

```
  Hdisp1: h = 0, p = 0.08, ci = -0.01 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.50, ci = -0 0.01, Mean: 0.00
  Hdisp2: h = 0, p = 0.13, ci = -0.01 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.52, ci = -0.00 0.01, Mean: 0.00
NOAA vs. Japan
  Speed:  h = 1, p = 0.00, ci = 17.23 17.34, Mean: 17.28
  Dir:    h = 1, p = 0.00, ci = -0.14 -0.13, Mean: -0.14
  Hdisp1: h = 0, p = 0.10, ci = -0.00 0.00, Mean: 0.00
  Vdisp1: h = 0, p = 0.92, ci = -0 0.00, Mean: -0.00
  Hdisp2: h = 0, p = 0.10, ci = -0.00 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.92, ci = -0.00 0.00, Mean: 0.00
NOAA vs. Brazil
  Speed:  h = 1, p = 0.00, ci = 0.41 0.49, Mean: 0.45
  Dir:    h = 1, p = 0.00, ci = 4.70 4.94, Mean: 4.82
  Hdisp1: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp1: h = NaN, p = NaN, ci = 0 0.00, Mean: 0.00
  Hdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
  Vdisp2: h = NaN, p = NaN, ci = 0.00 0.00, Mean: 0.00
NWCSAF vs. Japan
  Speed:  h = 1, p = 0.00, ci = 17.22 17.33, Mean: 17.27
  Dir:    h = 1, p = 0.00, ci = -0.16 -0.05, Mean: -0.11
  Hdisp1: h = 0, p = 0.07, ci = -0.00 0.01, Mean: 0.00
  Vdisp1: h = 0, p = 0.50, ci = -0 0.00, Mean: -0.00
  Hdisp2: h = 0, p = 0.16, ci = -0.00 0.01, Mean: 0.00
  Vdisp2: h = 0, p = 0.52, ci = -0.01 0.00, Mean: -0.00
NWCSAF vs. Brazil
  Speed:  h = 1, p = 0.00, ci = 0.40 0.48, Mean: 0.44
  Dir:    h = 1, p = 0.00, ci = 4.71 4.98, Mean: 4.85
  Hdisp1: h = 0, p = 0.08, ci = -0.00 0.01, Mean: 0.00
  Vdisp1: h = 0, p = 0.50, ci = -0 0.00, Mean: -0.00
  Hdisp2: h = 0, p = 0.13, ci = -0.00 0.01, Mean: 0.00
  Vdisp2: h = 0, p = 0.52, ci = -0.01 0.00, Mean: -0.00
Japan vs. Brazil
  Speed:  h = 1, p = 0.00, ci = -16.90 -16.77, Mean: -16.83
  Dir:    h = 1, p = 0.00, ci = 4.83 5.07, Mean: 4.95
  Hdisp1: h = 0, p = 0.10, ci = -0.00 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.92, ci = -0 0.00, Mean: 0.00
  Hdisp2: h = 0, p = 0.10, ci = -0.00 0.00, Mean: 0.00
  Vdisp2: h = 0, p = 0.92, ci = -0.00 0.00, Mean: -0.00
```

Using NWCSAFDatasetOne_O_C_WO_N.csv (without subpixel tracking), the statistical results are the same:

```
EUMETSAT vs. NWCSAF
  Speed:  h = 0, p = 0.12, ci = -0.05 0.00, Mean: -0.02
  Dir:    h = 0, p = 0.72, ci = -0.08 0.05, Mean: -0.01
  Hdisp1: h = 0, p = 0.14, ci = -0.01 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.61, ci = -0 0.01, Mean: 0.00
  Hdisp2: h = 0, p = 0.16, ci = -0.01 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.72, ci = -0.01 0.01, Mean: 0.00

Korea vs. NWCSAF
  Speed:  h = 1, p = 0.00, ci = -0.06 -0.01, Mean: -0.04
  Dir:    h = 0, p = 0.24, ci = -0.10 0.03, Mean: -0.04
  Hdisp1: h = 0, p = 0.14, ci = -0.01 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.60, ci = -0 0.01, Mean: 0.00
  Hdisp2: h = 0, p = 0.17, ci = -0.01 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.73, ci = -0.01 0.01, Mean: 0.00

China vs. NWCSAF
  Speed:  h = 1, p = 0.00, ci = -0.54 -0.49, Mean: -0.51
```

```
  Dir:    h = 0, p = 0.41, ci = -0.09 0.04, Mean: -0.03
  Hdisp1: h = 0, p = 0.14, ci = -0.01 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.61, ci = -0 0.01, Mean: 0.00
  Hdisp2: h = 0, p = 0.16, ci = -0.01 0.00, Mean: -0.00
  Vdisp2: h = 0, p = 0.72, ci = -0.01 0.01, Mean: 0.00

NWCSAF vs. Japan
  Speed:  h = 1, p = 0.00, ci = 17.20 17.33, Mean: 17.26
  Dir:    h = 1, p = 0.00, ci = -0.16 -0.03, Mean: -0.10
  Hdisp1: h = 0, p = 0.12, ci = -0.00 0.01, Mean: 0.01
  Vdisp1: h = 0, p = 0.61, ci = -0 0.01, Mean: -0.00
  Hdisp2: h = 0, p = 0.19, ci = -0.00 0.01, Mean: 0.00
  Vdisp2: h = 0, p = 0.72, ci = -0.01 0.01, Mean: -0.00

NWCSAF vs. Brazil
  Speed:  h = 1, p = 0.00, ci = 0.41 0.50, Mean: 0.46
  Dir:    h = 1, p = 0.00, ci = 4.71 5.00, Mean: 4.86
  Hdisp1: h = 0, p = 0.14, ci = -0.00 0.01, Mean: 0.00
  Vdisp1: h = 0, p = 0.61, ci = -0 0.01, Mean: -0.00
  Hdisp2: h = 0, p = 0.16, ci = -0.00 0.01, Mean: 0.00
  Vdisp2: h = 0, p = 0.72, ci = -0.01 0.01, Mean: -0.00

Japan vs. Brazil
  Speed:  h = 1, p = 0.00, ci = -16.87 -16.74, Mean: -16.81
  Dir:    h = 1, p = 0.00, ci = 4.83 5.08, Mean: 4.95
  Hdisp1: h = 0, p = 0.09, ci = -0.00 0.00, Mean: -0.00
  Vdisp1: h = 0, p = 0.94, ci = -0 0.00, Mean: 0.00
  Hdisp2: h = 0, p = 0.09, ci = -0.00 0.00, Mean: 0.00
  Vdisp2: h = 0, p = 0.94, ci = -0.00 0.00, Mean: -0.00
```

Experiment 2 t-test Results

QI without forecast collocated AMVs: 7050

```
EUMETSAT "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.29 0.40, Mean: 0.34
  Direction: h = 1, p = 0.05, ci = -1.25 -0.01, Mean: -0.63
  Pressure:  h = 1, p = 0.00, ci = 86.92 92.06, Mean: 89.49
  QI:        h = 1, p = 0.00, ci = -2.46 -2.00, Mean: -2.23

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = -0.82 -0.66, Mean: -0.74
  Direction: h = 1, p = 0.03, ci = -2.44 -0.12, Mean: -1.28
  Pressure:  h = 1, p = 0.00, ci = 128.58 134.20, Mean: 131.39
  QI:        h = 1, p = 0.00, ci = 12.91 13.79, Mean: 13.35

EUMETSAT "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.14 -0.05, Mean: -0.09
  Direction: h = 1, p = 0.00, ci = -1.76 -0.62, Mean: -1.19
  Pressure:  h = 1, p = 0.00, ci = 95.59 101.03, Mean: 98.31
  QI:        h = 1, p = 0.00, ci = -5.04 -4.43, Mean: -4.74

EUMETSAT "VS" NWCSAF
  Speed:     h = 0, p = 0.12, ci = -0.01 0.05, Mean: 0.02
  Direction: h = 0, p = 0.33, ci = -0.85 0.29, Mean: -0.28
  Pressure:  h = 1, p = 0.00, ci = 125.24 130.35, Mean: 127.80
  QI:        h = 1, p = 0.00, ci = -2.94 -2.29, Mean: -2.62

EUMETSAT "VS" Japan
  Speed:     h = 0, p = 0.40, ci = -0.02 0.06, Mean: 0.02
  Direction: h = 1, p = 0.00, ci = -1.78 -0.50, Mean: -1.14
  Pressure:  h = 1, p = 0.00, ci = 37.56 43.63, Mean: 40.59
```

```
  QI:        h = 1, p = 0.00, ci = -2.77 -2.13, Mean: -2.45

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = -1.17 -0.99, Mean: -1.08
  Direction: h = 0, p = 0.29, ci = -1.87 0.56, Mean: -0.66
  Pressure:  h = 1, p = 0.00, ci = 40.46 43.34, Mean: 41.90
  QI:        h = 1, p = 0.00, ci = 15.17 16.00, Mean: 15.58

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.49 -0.38, Mean: -0.44
  Direction: h = 0, p = 0.07, ci = -1.16 0.04, Mean: -0.56
  Pressure:  h = 1, p = 0.00, ci = 7.04 10.60, Mean: 8.82
  QI:        h = 1, p = 0.00, ci = -2.79 -2.23, Mean: -2.51

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.37 -0.27, Mean: -0.32
  Direction: h = 0, p = 0.14, ci = -0.11 0.80, Mean: 0.35
  Pressure:  h = 1, p = 0.00, ci = 37.37 39.25, Mean: 38.31
  QI:        h = 1, p = 0.01, ci = -0.68 -0.09, Mean: -0.39

Korea "VS" Japan
  Speed:     h = 1, p = 0.00, ci = -0.38 -0.27, Mean: -0.33
  Direction: h = 0, p = 0.07, ci = -1.07 0.05, Mean: -0.51
  Pressure:  h = 1, p = 0.00, ci = -50.48 -47.31, Mean: -48.89
  QI:        h = 0, p = 0.14, ci = -0.51 0.07, Mean: -0.22

Brazil "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = 0.56 0.74, Mean: 0.65
  Direction: h = 0, p = 0.87, ci = -1.09 1.28, Mean: 0.10
  Pressure:  h = 1, p = 0.00, ci = -35.07 -31.09, Mean: -33.08
  QI:        h = 1, p = 0.00, ci = -18.55 -17.63, Mean: -18.09

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.68 0.84, Mean: 0.76
  Direction: h = 0, p = 0.10, ci = -0.19 2.19, Mean: 1.00
  Pressure:  h = 1, p = 0.00, ci = -4.93 -2.26, Mean: -3.59
  QI:        h = 1, p = 0.00, ci = -16.44 -15.50, Mean: -15.97

Brazil "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.67 0.84, Mean: 0.76
  Direction: h = 0, p = 0.81, ci = -1.05 1.34, Mean: 0.14
  Pressure:  h = 1, p = 0.00, ci = -92.39 -89.20, Mean: -90.80
  QI:        h = 1, p = 0.00, ci = -16.27 -15.33, Mean: -15.80

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.07 0.16, Mean: 0.12
  Direction: h = 1, p = 0.00, ci = 0.32 1.50, Mean: 0.91
  Pressure:  h = 1, p = 0.00, ci = 27.99 30.99, Mean: 29.49
  QI:        h = 1, p = 0.00, ci = 1.77 2.47, Mean: 2.12

NOAA "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.06 0.16, Mean: 0.11
  Direction: h = 0, p = 0.89, ci = -0.63 0.72, Mean: 0.05
  Pressure:  h = 1, p = 0.00, ci = -59.84 -55.58, Mean: -57.71
  QI:        h = 1, p = 0.00, ci = 1.94 2.64, Mean: 2.29

NWCSAF "VS" Japan
  Speed:     h = 0, p = 0.76, ci = -0.04 0.03, Mean: -0.01
  Direction: h = 1, p = 0.00, ci = -1.44 -0.28, Mean: -0.86
  Pressure:  h = 1, p = 0.00, ci = -88.67 -85.74, Mean: -87.20
  QI:        h = 0, p = 0.39, ci = -0.21 0.54, Mean: 0.17
```

QI with forecast collocated AMVs: 10113

```
EUMETSAT "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.36 0.47, Mean: 0.42
  Direction: h = 0, p = 0.60, ci = -0.23 0.40, Mean: 0.08
  Pressure:  h = 1, p = 0.00, ci = 95.55 99.81, Mean: 97.68
  QI:        h = 1, p = 0.00, ci = 7.38 7.84, Mean: 7.61

EUMETSAT "VS" China
  Speed:     h = 1, p = 0.00, ci = -0.32 -0.19, Mean: -0.26
  Direction: h = 0, p = 0.35, ci = -0.25 0.70, Mean: 0.23
  Pressure:  h = 1, p = 0.00, ci = 134.12 139.11, Mean: 136.61
  QI:        h = 1, p = 0.00, ci = 0.15 0.67, Mean: 0.41

EUMETSAT "VS" NOAA
  Speed:     h = 0, p = 0.09, ci = -0.09 0.01, Mean: -0.04
  Direction: h = 1, p = 0.04, ci = -0.75 -0.01, Mean: -0.38
  Pressure:  h = 1, p = 0.00, ci = 109.33 113.99, Mean: 111.66
  QI:        h = 1, p = 0.00, ci = 9.19 9.69, Mean: 9.44

EUMETSAT "VS" NWCSAF
  Speed:     h = 0, p = 0.60, ci = -0.02 0.04, Mean: 0.01
  Direction: h = 0, p = 0.82, ci = -0.24 0.30, Mean: 0.03
  Pressure:  h = 1, p = 0.00, ci = 135.30 139.49, Mean: 137.39
  QI:        h = 1, p = 0.00, ci = 4.56 5.06, Mean: 4.81

EUMETSAT "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.02 0.09, Mean: 0.06
  Direction: h = 0, p = 0.06, ci = -0.61 0.01, Mean: -0.30
  Pressure:  h = 1, p = 0.00, ci = 55.76 60.57, Mean: 58.17
  QI:        h = 1, p = 0.00, ci = 7.25 7.85, Mean: 7.55

Korea "VS" China
  Speed:     h = 1, p = 0.00, ci = -0.75 -0.60, Mean: -0.67
  Direction: h = 0, p = 0.53, ci = -0.30 0.59, Mean: 0.14
  Pressure:  h = 1, p = 0.00, ci = 37.00 40.87, Mean: 38.93
  QI:        h = 1, p = 0.00, ci = -7.42 -6.99, Mean: -7.21

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.51 -0.40, Mean: -0.46
  Direction: h = 1, p = 0.01, ci = -0.83 -0.09, Mean: -0.46
  Pressure:  h = 1, p = 0.00, ci = 12.18 15.78, Mean: 13.98
  QI:        h = 1, p = 0.00, ci = 1.59 2.06, Mean: 1.83

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.46 -0.36, Mean: -0.41
  Direction: h = 0, p = 0.65, ci = -0.27 0.17, Mean: -0.05
  Pressure:  h = 1, p = 0.00, ci = 38.88 40.55, Mean: 39.72
  QI:        h = 1, p = 0.00, ci = -3.01 -2.60, Mean: -2.80

Korea "VS" Japan
  Speed:     h = 1, p = 0.00, ci = -0.42 -0.31, Mean: -0.36
  Direction: h = 1, p = 0.01, ci = -0.66 -0.11, Mean: -0.38
  Pressure:  h = 1, p = 0.00, ci = -40.82 -38.20, Mean: -39.51
  QI:        h = 0, p = 0.66, ci = -0.34 0.22, Mean: -0.06

China "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = 0.14 0.29, Mean: 0.22
  Direction: h = 1, p = 0.02, ci = -1.13 -0.08, Mean: -0.61
  Pressure:  h = 1, p = 0.00, ci = -26.62 -23.29, Mean: -24.95
```

```
  QI:        h = 1, p = 0.00, ci = 8.80 9.27, Mean: 9.03

China "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.20 0.33, Mean: 0.27
  Direction: h = 0, p = 0.38, ci = -0.63 0.24, Mean: -0.19
  Pressure:  h = 0, p = 0.39, ci = -0.98 2.55, Mean: 0.78
  QI:        h = 1, p = 0.00, ci = 4.16 4.64, Mean: 4.40

China "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.25 0.38, Mean: 0.31
  Direction: h = 1, p = 0.02, ci = -0.98 -0.07, Mean: -0.53
  Pressure:  h = 1, p = 0.00, ci = -80.46 -76.43, Mean: -78.45
  QI:        h = 1, p = 0.00, ci = 6.86 7.42, Mean: 7.14

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.04, ci = 0.00 0.10, Mean: 0.05
  Direction: h = 1, p = 0.02, ci = 0.08 0.75, Mean: 0.41
  Pressure:  h = 1, p = 0.00, ci = 24.19 27.27, Mean: 25.73
  QI:        h = 1, p = 0.00, ci = -4.88 -4.38, Mean: -4.63

NOAA "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.05 0.15, Mean: 0.10
  Direction: h = 0, p = 0.69, ci = -0.31 0.48, Mean: 0.08
  Pressure:  h = 1, p = 0.00, ci = -55.47 -51.52, Mean: -53.49
  QI:        h = 1, p = 0.00, ci = -2.18 -1.60, Mean: -1.89

NWCSAF "VS" Japan
  Speed:     h = 1, p = 0.01, ci = 0.01 0.08, Mean: 0.05
  Direction: h = 1, p = 0.02, ci = -0.60 -0.06, Mean: -0.33
  Pressure:  h = 1, p = 0.00, ci = -80.46 -78.00, Mean: -79.23
  QI:        h = 1, p = 0.00, ci = 2.43 3.05, Mean: 2.74
```

Experiment 3 t-test Results

QI without forecast collocated AMVs: 370

```
EUMETSAT "VS" Korea
  Speed:     h = 0, p = 0.84, ci = -0.15 0.19, Mean: 0.02
  Direction: h = 0, p = 0.17, ci = -0.79 4.46, Mean: 1.83
  Pressure:  h = 1, p = 0.00, ci = 82.56 104.22, Mean: 93.39
  QI:        h = 1, p = 0.00, ci = 2.92 4.90, Mean: 3.91

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = -1.07 -0.32, Mean: -0.69
  Direction: h = 0, p = 0.70, ci = -4.19 6.25, Mean: 1.03
  Pressure:  h = 1, p = 0.00, ci = 106.27 126.87, Mean: 116.57
  QI:        h = 1, p = 0.00, ci = 10.85 14.55, Mean: 12.70

EUMETSAT "VS" NOAA
  Speed:     h = 0, p = 0.37, ci = -0.24 0.09, Mean: -0.08
  Direction: h = 0, p = 0.08, ci = -0.32 5.68, Mean: 2.68
  Pressure:  h = 1, p = 0.00, ci = 91.46 112.30, Mean: 101.88
  QI:        h = 1, p = 0.02, ci = 0.28 3.35, Mean: 1.81

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.01, ci = 0.03 0.23, Mean: 0.13
  Direction: h = 0, p = 0.14, ci = -0.45 3.17, Mean: 1.36
  Pressure:  h = 1, p = 0.00, ci = 122.95 142.70, Mean: 132.82
  QI:        h = 1, p = 0.00, ci = 2.49 5.38, Mean: 3.94

EUMETSAT "VS" Japan
  Speed:     h = 0, p = 0.83, ci = -0.12 0.14, Mean: 0.01
```

```
  Direction: h = 0, p = 0.09, ci = -0.39 5.98, Mean: 2.79
  Pressure:  h = 1, p = 0.00, ci = 36.05 60.81, Mean: 48.43
  QI:        h = 1, p = 0.00, ci = -3.47 -0.99, Mean: -2.23

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = -1.11 -0.32, Mean: -0.71
  Direction: h = 0, p = 0.75, ci = -5.82 4.21, Mean: -0.80
  Pressure:  h = 1, p = 0.00, ci = 16.50 29.87, Mean: 23.18
  QI:        h = 1, p = 0.00, ci = 6.97 10.60, Mean: 8.79

Korea "VS" NOAA
  Speed:     h = 0, p = 0.35, ci = -0.29 0.10, Mean: -0.09
  Direction: h = 0, p = 0.37, ci = -1.01 2.71, Mean: 0.85
  Pressure:  h = 0, p = 0.08, ci = -1.00 17.98, Mean: 8.49
  QI:        h = 1, p = 0.01, ci = -3.64 -0.56, Mean: -2.10

Korea "VS" NWCSAF
  Speed:     h = 0, p = 0.16, ci = -0.05 0.27, Mean: 0.11
  Direction: h = 0, p = 0.63, ci = -2.39 1.45, Mean: -0.47
  Pressure:  h = 1, p = 0.00, ci = 33.70 45.17, Mean: 39.43
  QI:        h = 0, p = 0.97, ci = -1.38 1.43, Mean: 0.02

Korea "VS" Japan
  Speed:     h = 0, p = 0.98, ci = -0.19 0.19, Mean: -0.00
  Direction: h = 0, p = 0.30, ci = -0.85 2.77, Mean: 0.96
  Pressure:  h = 1, p = 0.00, ci = -52.99 -36.93, Mean: -44.96
  QI:        h = 1, p = 0.00, ci = -7.37 -4.91, Mean: -6.14

Brazil "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = 0.25 0.99, Mean: 0.62
  Direction: h = 0, p = 0.48, ci = -2.92 6.23, Mean: 1.65
  Pressure:  h = 1, p = 0.00, ci = -21.13 -8.26, Mean: -14.69
  QI:        h = 1, p = 0.00, ci = -12.90 -8.87, Mean: -10.88

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.45 1.20, Mean: 0.82
  Direction: h = 0, p = 0.90, ci = -5.05 5.72, Mean: 0.34
  Pressure:  h = 1, p = 0.00, ci = 12.56 19.95, Mean: 16.25
  QI:        h = 1, p = 0.00, ci = -10.80 -6.72, Mean: -8.76

Brazil "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.35 1.07, Mean: 0.71
  Direction: h = 0, p = 0.47, ci = -3.02 6.55, Mean: 1.77
  Pressure:  h = 1, p = 0.00, ci = -73.57 -62.71, Mean: -68.14
  QI:        h = 1, p = 0.00, ci = -16.82 -13.04, Mean: -14.93

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.01, ci = 0.05 0.36, Mean: 0.21
  Direction: h = 0, p = 0.33, ci = -3.95 1.31, Mean: -1.32
  Pressure:  h = 1, p = 0.00, ci = 24.00 37.89, Mean: 30.94
  QI:        h = 1, p = 0.02, ci = 0.32 3.93, Mean: 2.12

NOAA "VS" Japan
  Speed:     h = 0, p = 0.20, ci = -0.05 0.23, Mean: 0.09
  Direction: h = 0, p = 0.79, ci = -0.72 0.95, Mean: 0.11
  Pressure:  h = 1, p = 0.00, ci = -62.14 -44.76, Mean: -53.45
  QI:        h = 1, p = 0.00, ci = -5.46 -2.63, Mean: -4.04

NWCSAF "VS" Japan
  Speed:     h = 1, p = 0.05, ci = -0.23 -0.00, Mean: -0.12
  Direction: h = 0, p = 0.28, ci = -1.15 4.01, Mean: 1.43
```

```
  Pressure:  h = 1, p = 0.00, ci = -90.21 -78.57, Mean: -84.39
  QI:        h = 1, p = 0.00, ci = -7.72 -4.61, Mean: -6.17
```

QI with forecast collocated AMVs: 409

```
EUMETSAT "VS" Korea
  Speed:     h = 0, p = 0.79, ci = -0.25 0.32, Mean: 0.04
  Direction: h = 0, p = 0.58, ci = -0.81 1.44, Mean: 0.32
  Pressure:  h = 1, p = 0.00, ci = 103.89 142.39, Mean: 123.14
  QI:        h = 1, p = 0.00, ci = 12.31 15.24, Mean: 13.77

EUMETSAT "VS" China
  Speed:     h = 1, p = 0.01, ci = -1.04 -0.13, Mean: -0.58
  Direction: h = 0, p = 0.69, ci = -5.09 3.37, Mean: -0.86
  Pressure:  h = 1, p = 0.00, ci = 90.82 129.52, Mean: 110.17
  QI:        h = 0, p = 0.52, ci = -1.15 2.25, Mean: 0.55

EUMETSAT "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.58 -0.12, Mean: -0.35
  Direction: h = 0, p = 0.82, ci = -1.01 1.27, Mean: 0.13
  Pressure:  h = 1, p = 0.00, ci = 93.31 127.06, Mean: 110.19
  QI:        h = 1, p = 0.00, ci = 14.32 18.16, Mean: 16.24

EUMETSAT "VS" NWCSAF
  Speed:     h = 0, p = 0.39, ci = -0.09 0.23, Mean: 0.07
  Direction: h = 0, p = 0.31, ci = -0.44 1.38, Mean: 0.47
  Pressure:  h = 1, p = 0.00, ci = 140.12 174.84, Mean: 157.48
  QI:        h = 1, p = 0.00, ci = 6.61 10.02, Mean: 8.32

EUMETSAT "VS" Japan
  Speed:     h = 0, p = 0.08, ci = -0.38 0.02, Mean: -0.18
  Direction: h = 0, p = 0.46, ci = -1.49 0.67, Mean: -0.41
  Pressure:  h = 1, p = 0.00, ci = 88.86 124.32, Mean: 106.59
  QI:        h = 1, p = 0.00, ci = 5.83 9.44, Mean: 7.64

Korea "VS" China
  Speed:     h = 1, p = 0.01, ci = -1.09 -0.15, Mean: -0.62
  Direction: h = 0, p = 0.59, ci = -5.45 3.10, Mean: -1.18
  Pressure:  h = 0, p = 0.05, ci = -26.03 0.09, Mean: -12.97
  QI:        h = 1, p = 0.00, ci = -14.86 -11.58, Mean: -13.22

Korea "VS" NOAA
  Speed:     h = 1, p = 0.01, ci = -0.70 -0.08, Mean: -0.39
  Direction: h = 0, p = 0.78, ci = -1.50 1.12, Mean: -0.19
  Pressure:  h = 1, p = 0.03, ci = -24.42 -1.49, Mean: -12.96
  QI:        h = 1, p = 0.01, ci = 0.54 4.40, Mean: 2.47

Korea "VS" NWCSAF
  Speed:     h = 0, p = 0.80, ci = -0.22 0.28, Mean: 0.03
  Direction: h = 0, p = 0.72, ci = -0.70 1.00, Mean: 0.15
  Pressure:  h = 1, p = 0.00, ci = 26.99 41.68, Mean: 34.34
  QI:        h = 1, p = 0.00, ci = -7.03 -3.88, Mean: -5.45

Korea "VS" Japan
  Speed:     h = 0, p = 0.15, ci = -0.51 0.08, Mean: -0.22
  Direction: h = 0, p = 0.24, ci = -1.95 0.49, Mean: -0.73
  Pressure:  h = 1, p = 0.00, ci = -25.09 -8.02, Mean: -16.55
  QI:        h = 1, p = 0.00, ci = -7.66 -4.61, Mean: -6.14

China "VS" NOAA
  Speed:     h = 0, p = 0.37, ci = -0.28 0.74, Mean: 0.23
```

```
  Direction: h = 0, p = 0.64, ci = -3.15 5.13, Mean: 0.99
  Pressure:  h = 0, p = 1.00, ci = -11.71 11.74, Mean: 0.02
  QI:        h = 1, p = 0.00, ci = 13.66 17.72, Mean: 15.69

China "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.20 1.11, Mean: 0.65
  Direction: h = 0, p = 0.54, ci = -2.90 5.56, Mean: 1.33
  Pressure:  h = 1, p = 0.00, ci = 35.86 58.75, Mean: 47.31
  QI:        h = 1, p = 0.00, ci = 5.94 9.59, Mean: 7.77

China "VS" Japan
  Speed:     h = 0, p = 0.10, ci = -0.08 0.88, Mean: 0.40
  Direction: h = 0, p = 0.84, ci = -3.90 4.80, Mean: 0.45
  Pressure:  h = 0, p = 0.54, ci = -15.16 8.00, Mean: -3.58
  QI:        h = 1, p = 0.00, ci = 5.25 8.92, Mean: 7.08

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.21 0.63, Mean: 0.42
  Direction: h = 0, p = 0.54, ci = -0.76 1.45, Mean: 0.34
  Pressure:  h = 1, p = 0.00, ci = 39.10 55.48, Mean: 47.29
  QI:        h = 1, p = 0.00, ci = -10.04 -5.80, Mean: -7.92

NOAA "VS" Japan
  Speed:     h = 0, p = 0.08, ci = -0.02 0.36, Mean: 0.17
  Direction: h = 0, p = 0.34, ci = -1.64 0.57, Mean: -0.54
  Pressure:  h = 0, p = 0.36, ci = -11.31 4.12, Mean: -3.60
  QI:        h = 1, p = 0.00, ci = -10.39 -6.82, Mean: -8.61

NWCSAF "VS" Japan
  Speed:     h = 1, p = 0.00, ci = -0.41 -0.09, Mean: -0.25
  Direction: h = 0, p = 0.08, ci = -1.87 0.11, Mean: -0.88
  Pressure:  h = 1, p = 0.00, ci = -56.25 -45.53, Mean: -50.89
  QI:        h = 0, p = 0.45, ci = -2.45 1.08, Mean: -0.68
```

Experiment 4 t-test Results

QI without forecast collocated AMVs: 9942

```
EUMETSAT "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.15 0.22, Mean: 0.18
  Direction: h = 0, p = 0.09, ci = -0.06 0.80, Mean: 0.37
  Pressure:  h = 1, p = 0.00, ci = 53.18 57.50, Mean: 55.34
  QI:        h = 1, p = 0.00, ci = 2.09 2.48, Mean: 2.28

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = -0.76 -0.63, Mean: -0.70
  Direction: h = 1, p = 0.00, ci = -4.33 -2.08, Mean: -3.20
  Pressure:  h = 1, p = 0.00, ci = 57.07 61.79, Mean: 59.43
  QI:        h = 1, p = 0.00, ci = 11.61 12.36, Mean: 11.99

EUMETSAT "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.20 -0.14, Mean: -0.17
  Direction: h = 0, p = 0.10, ci = -1.04 0.09, Mean: -0.47
  Pressure:  h = 1, p = 0.00, ci = 77.83 82.45, Mean: 80.14
  QI:        h = 1, p = 0.00, ci = -1.76 -1.21, Mean: -1.49

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.04, ci = -0.05 -0.00, Mean: -0.02
  Direction: h = 0, p = 0.20, ci = -0.76 0.16, Mean: -0.30
  Pressure:  h = 1, p = 0.00, ci = -23.16 -20.38, Mean: -21.77
  QI:        h = 1, p = 0.01, ci = -0.69 -0.10, Mean: -0.39
```

```
EUMETSAT "VS" Japan
  Speed:     h = 1, p = 0.01, ci = 0.01 0.06, Mean: 0.03
  Direction: h = 0, p = 0.18, ci = -0.85 0.16, Mean: -0.34
  Pressure:  h = 1, p = 0.00, ci = 50.07 53.34, Mean: 51.71
  QI:        h = 1, p = 0.00, ci = -4.52 -4.04, Mean: -4.28

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = -0.95 -0.81, Mean: -0.88
  Direction: h = 1, p = 0.00, ci = -4.68 -2.47, Mean: -3.57
  Pressure:  h = 1, p = 0.00, ci = 2.54 5.65, Mean: 4.10
  QI:        h = 1, p = 0.00, ci = 9.34 10.06, Mean: 9.70

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.40 -0.31, Mean: -0.36
  Direction: h = 1, p = 0.01, ci = -1.50 -0.19, Mean: -0.84
  Pressure:  h = 1, p = 0.00, ci = 22.37 27.23, Mean: 24.80
  QI:        h = 1, p = 0.00, ci = -4.03 -3.51, Mean: -3.77

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.24 -0.17, Mean: -0.21
  Direction: h = 1, p = 0.01, ci = -1.17 -0.17, Mean: -0.67
  Pressure:  h = 1, p = 0.00, ci = -79.39 -74.84, Mean: -77.11
  QI:        h = 1, p = 0.00, ci = -2.97 -2.39, Mean: -2.68

Korea "VS" Japan
  Speed:     h = 1, p = 0.00, ci = -0.19 -0.11, Mean: -0.15
  Direction: h = 1, p = 0.01, ci = -1.27 -0.16, Mean: -0.72
  Pressure:  h = 1, p = 0.00, ci = -6.09 -1.17, Mean: -3.63
  QI:        h = 1, p = 0.00, ci = -6.80 -6.33, Mean: -6.57

Brazil "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = 0.45 0.59, Mean: 0.52
  Direction: h = 1, p = 0.00, ci = 1.53 3.93, Mean: 2.73
  Pressure:  h = 1, p = 0.00, ci = 18.14 23.26, Mean: 20.70
  QI:        h = 1, p = 0.00, ci = -13.88 -13.06, Mean: -13.47

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.60 0.74, Mean: 0.67
  Direction: h = 1, p = 0.00, ci = 1.75 4.06, Mean: 2.90
  Pressure:  h = 1, p = 0.00, ci = -83.74 -78.67, Mean: -81.21
  QI:        h = 1, p = 0.00, ci = -12.79 -11.97, Mean: -12.38

Brazil "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.66 0.80, Mean: 0.73
  Direction: h = 1, p = 0.00, ci = 1.67 4.05, Mean: 2.86
  Pressure:  h = 1, p = 0.00, ci = -10.40 -5.06, Mean: -7.73
  QI:        h = 1, p = 0.00, ci = -16.66 -15.88, Mean: -16.27

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.12 0.18, Mean: 0.15
  Direction: h = 0, p = 0.55, ci = -0.39 0.73, Mean: 0.17
  Pressure:  h = 1, p = 0.00, ci = -104.51 -99.31, Mean: -101.91
  QI:        h = 1, p = 0.00, ci = 0.75 1.43, Mean: 1.09

NOAA "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.17 0.23, Mean: 0.20
  Direction: h = 0, p = 0.55, ci = -0.29 0.55, Mean: 0.13
  Pressure:  h = 1, p = 0.00, ci = -31.08 -25.78, Mean: -28.43
  QI:        h = 1, p = 0.00, ci = -3.07 -2.52, Mean: -2.80
```

```
NWCSAF "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.03 0.08, Mean: 0.06
  Direction: h = 0, p = 0.87, ci = -0.55 0.47, Mean: -0.04
  Pressure:  h = 1, p = 0.00, ci = 71.22 75.73, Mean: 73.48
  QI:        h = 1, p = 0.00, ci = -4.19 -3.58, Mean: -3.89
```

QI with forecast collocated AMVs: 10285

```
EUMETSAT "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.17 0.24, Mean: 0.20
  Direction: h = 0, p = 0.40, ci = -0.43 0.17, Mean: -0.13
  Pressure:  h = 1, p = 0.00, ci = 52.03 56.22, Mean: 54.12
  QI:        h = 1, p = 0.00, ci = 13.20 13.62, Mean: 13.41

EUMETSAT "VS" China
  Speed:     h = 1, p = 0.00, ci = 0.26 0.38, Mean: 0.32
  Direction: h = 1, p = 0.00, ci = 0.84 2.05, Mean: 1.44
  Pressure:  h = 1, p = 0.00, ci = 87.20 92.25, Mean: 89.73
  QI:        h = 1, p = 0.00, ci = 3.01 3.46, Mean: 3.24

EUMETSAT "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.14 -0.08, Mean: -0.11
  Direction: h = 0, p = 0.19, ci = -0.12 0.62, Mean: 0.25
  Pressure:  h = 1, p = 0.00, ci = 70.03 74.09, Mean: 72.06
  QI:        h = 1, p = 0.00, ci = 12.50 12.97, Mean: 12.73

EUMETSAT "VS" NWCSAF
  Speed:     h = 0, p = 0.34, ci = -0.01 0.03, Mean: 0.01
  Direction: h = 1, p = 0.01, ci = 0.09 0.68, Mean: 0.39
  Pressure:  h = 1, p = 0.00, ci = -21.86 -19.23, Mean: -20.54
  QI:        h = 1, p = 0.00, ci = 5.67 6.19, Mean: 5.93

EUMETSAT "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.04 0.09, Mean: 0.06
  Direction: h = 0, p = 0.42, ci = -0.44 0.18, Mean: -0.13
  Pressure:  h = 1, p = 0.00, ci = 52.30 55.44, Mean: 53.87
  QI:        h = 1, p = 0.00, ci = 5.45 5.89, Mean: 5.67

Korea "VS" China
  Speed:     h = 1, p = 0.00, ci = 0.05 0.18, Mean: 0.12
  Direction: h = 1, p = 0.00, ci = 1.00 2.14, Mean: 1.57
  Pressure:  h = 1, p = 0.00, ci = 33.69 37.52, Mean: 35.61
  QI:        h = 1, p = 0.00, ci = -10.38 -9.96, Mean: -10.17

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.35 -0.27, Mean: -0.31
  Direction: h = 0, p = 0.05, ci = -0.00 0.76, Mean: 0.38
  Pressure:  h = 1, p = 0.00, ci = 15.92 19.95, Mean: 17.94
  QI:        h = 1, p = 0.00, ci = -0.91 -0.43, Mean: -0.67

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.23 -0.16, Mean: -0.19
  Direction: h = 1, p = 0.00, ci = 0.21 0.82, Mean: 0.51
  Pressure:  h = 1, p = 0.00, ci = -76.87 -72.46, Mean: -74.67
  QI:        h = 1, p = 0.00, ci = -7.73 -7.22, Mean: -7.48

Korea "VS" Japan
  Speed:     h = 1, p = 0.00, ci = -0.18 -0.10, Mean: -0.14
  Direction: h = 0, p = 0.99, ci = -0.34 0.34, Mean: 0.00
  Pressure:  h = 0, p = 0.84, ci = -2.74 2.24, Mean: -0.25
  QI:        h = 1, p = 0.00, ci = -7.96 -7.52, Mean: -7.74
```

```
China "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.49 -0.37, Mean: -0.43
  Direction: h = 1, p = 0.00, ci = -1.83 -0.56, Mean: -1.19
  Pressure:  h = 1, p = 0.00, ci = -19.94 -15.40, Mean: -17.67
  QI:        h = 1, p = 0.00, ci = 9.25 9.75, Mean: 9.50

China "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.37 -0.25, Mean: -0.31
  Direction: h = 1, p = 0.00, ci = -1.64 -0.48, Mean: -1.06
  Pressure:  h = 1, p = 0.00, ci = -112.87 -107.67, Mean: -110.27
  QI:        h = 1, p = 0.00, ci = 2.43 2.96, Mean: 2.69

China "VS" Japan
  Speed:     h = 1, p = 0.00, ci = -0.32 -0.20, Mean: -0.26
  Direction: h = 1, p = 0.00, ci = -2.18 -0.96, Mean: -1.57
  Pressure:  h = 1, p = 0.00, ci = -38.63 -33.08, Mean: -35.86
  QI:        h = 1, p = 0.00, ci = 2.21 2.66, Mean: 2.44

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.09 0.15, Mean: 0.12
  Direction: h = 0, p = 0.39, ci = -0.17 0.44, Mean: 0.14
  Pressure:  h = 1, p = 0.00, ci = -94.89 -90.31, Mean: -92.60
  QI:        h = 1, p = 0.00, ci = -7.08 -6.53, Mean: -6.80

NOAA "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.14 0.19, Mean: 0.17
  Direction: h = 1, p = 0.00, ci = -0.62 -0.13, Mean: -0.38
  Pressure:  h = 1, p = 0.00, ci = -20.52 -15.85, Mean: -18.19
  QI:        h = 1, p = 0.00, ci = -7.29 -6.84, Mean: -7.06

NWCSAF "VS" Japan
  Speed:     h = 1, p = 0.00, ci = 0.02 0.08, Mean: 0.05
  Direction: h = 1, p = 0.00, ci = -0.75 -0.28, Mean: -0.51
  Pressure:  h = 1, p = 0.00, ci = 72.35 76.48, Mean: 74.42
  QI:        h = 0, p = 0.05, ci = -0.52 0.01, Mean: -0.26
```

17. Appendix D: Best Fit Speed and Vector Difference

Experiment 2 Best Fit speed difference

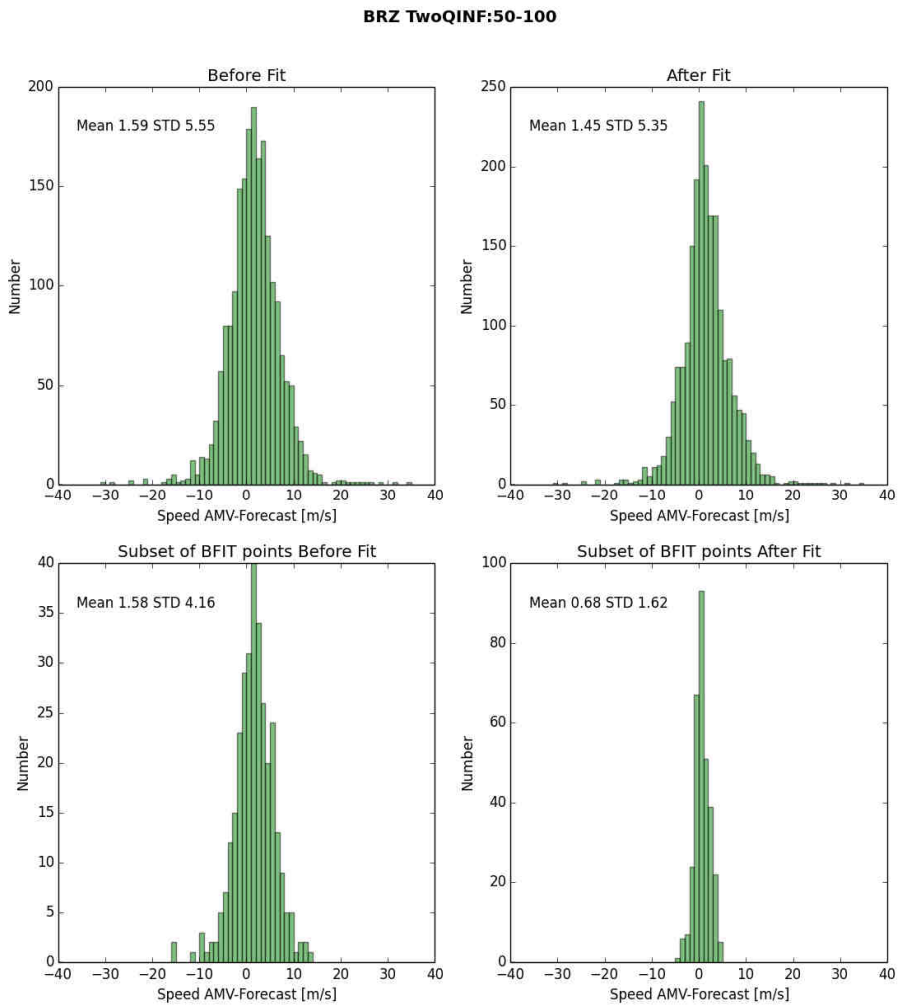


Figure 17-1: BRZ: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

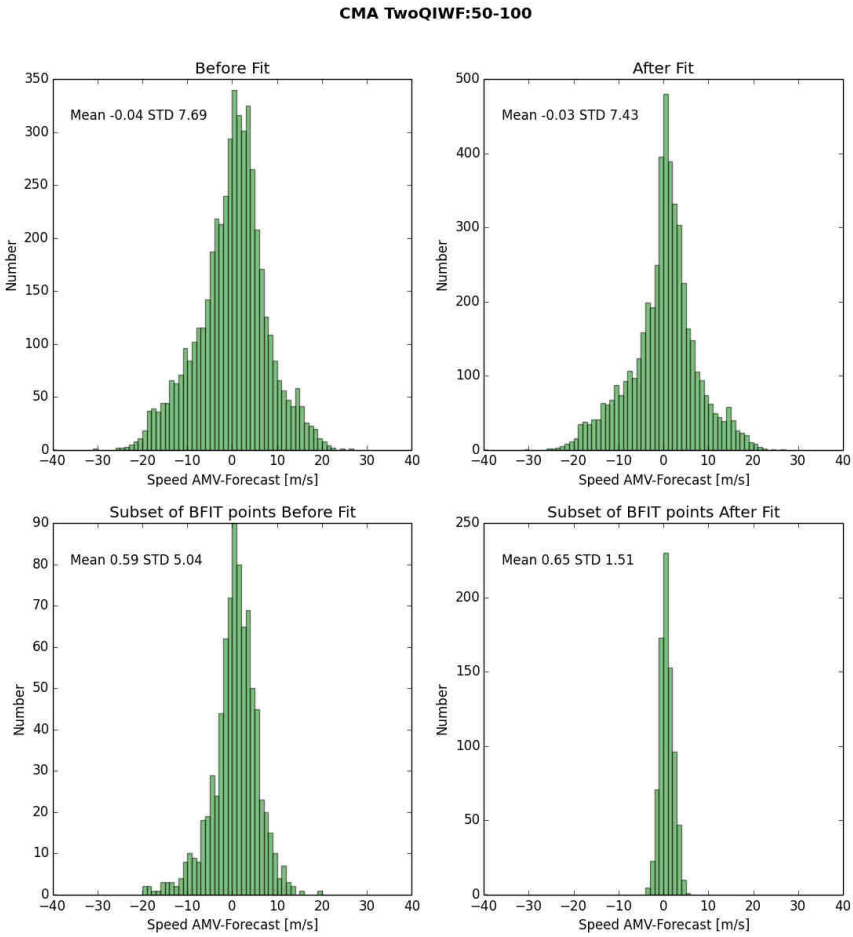


Figure 17-2: CMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

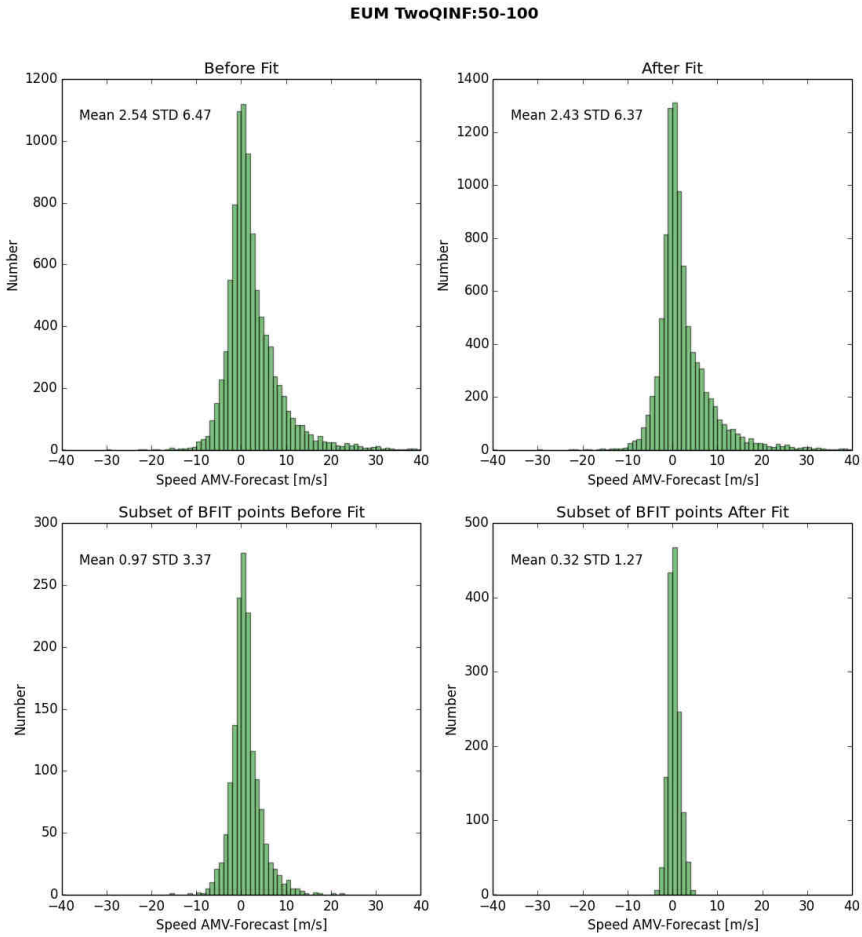


Figure 17-3: EUM: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

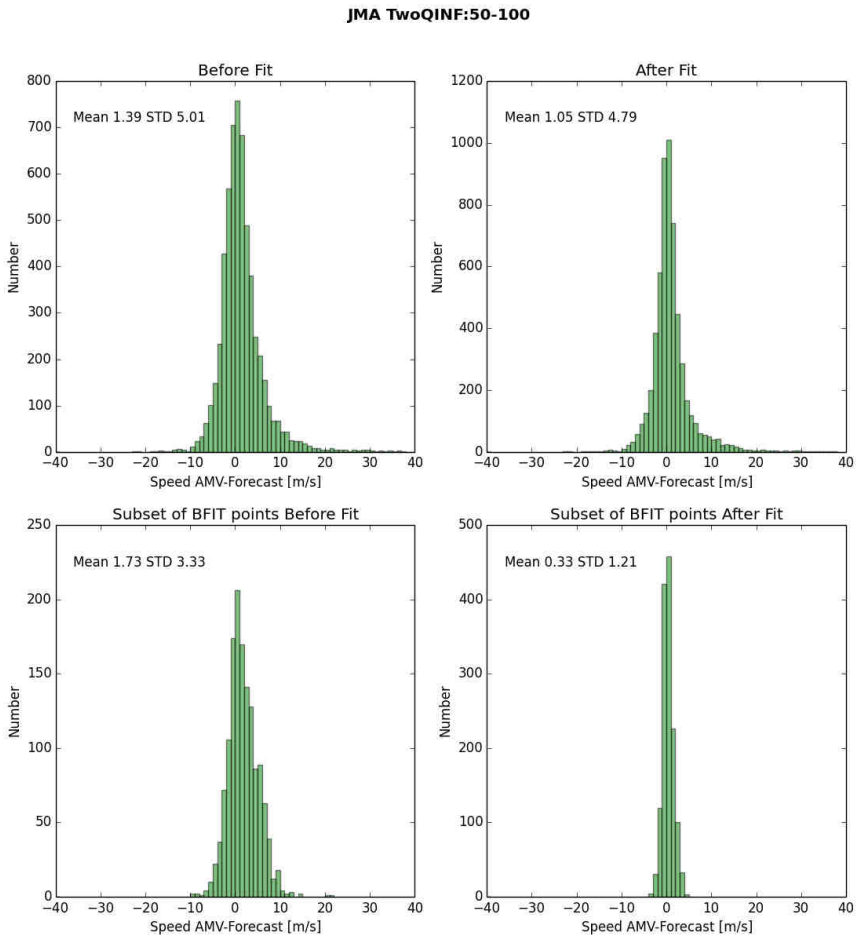


Figure 17-4: JMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

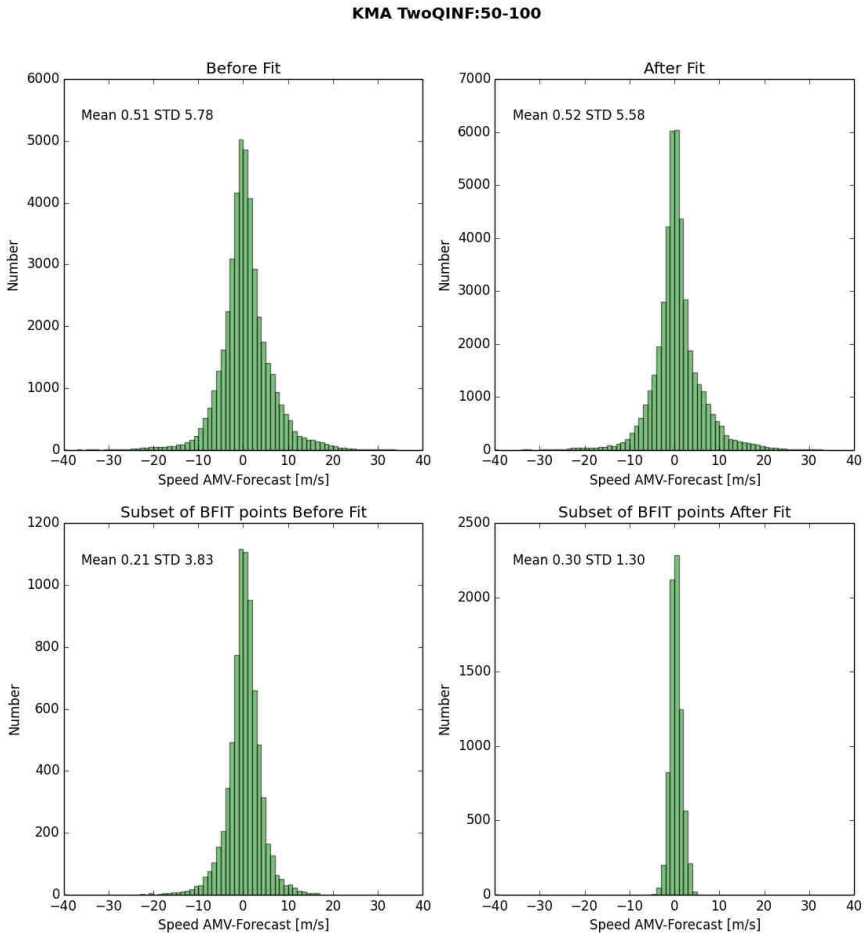


Figure 17-5: KMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

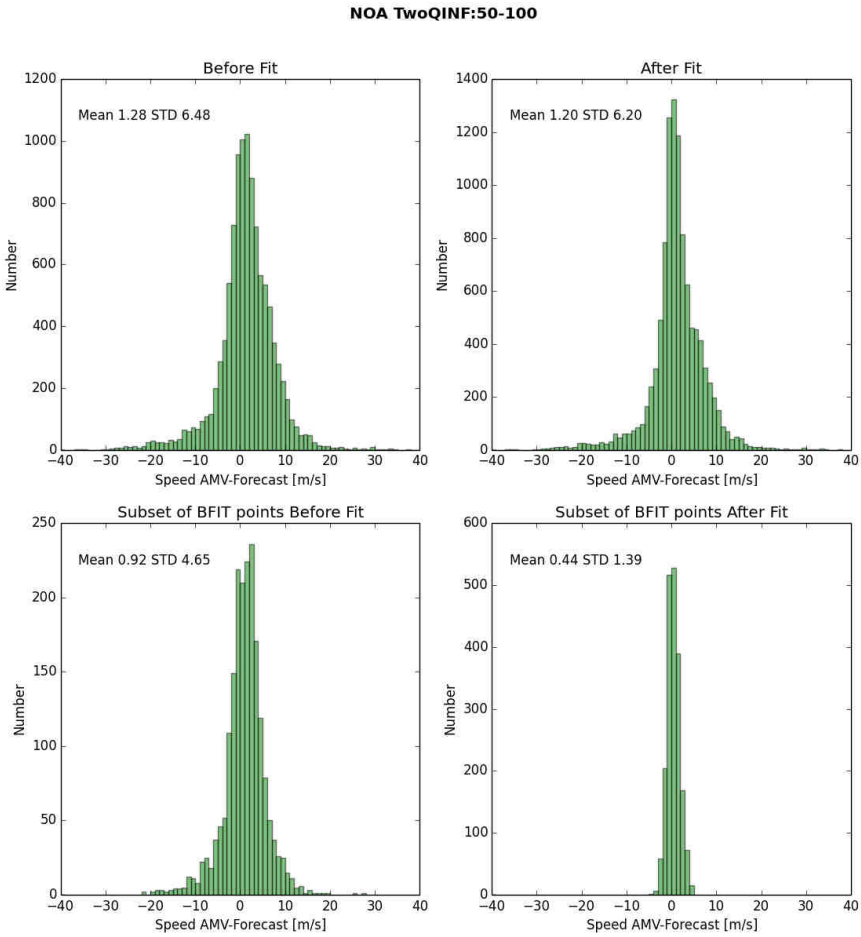


Figure 17-6: NOA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

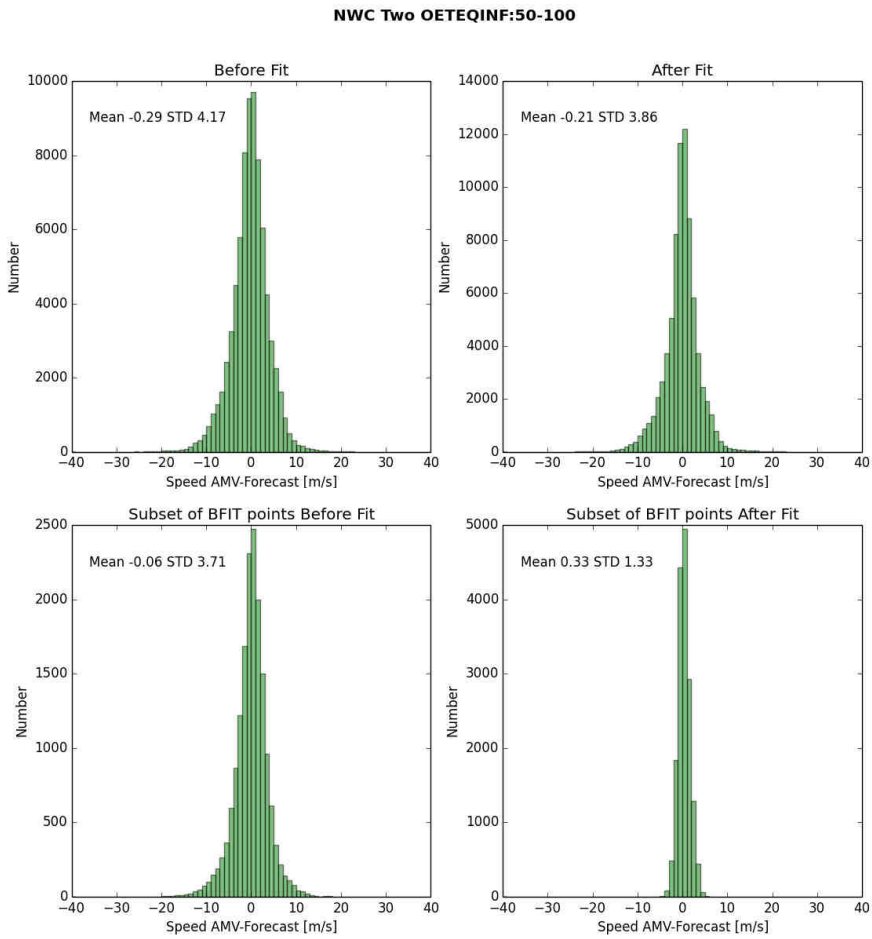


Figure 17-7: NWC: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

Experiment 2 Best Fit vector difference

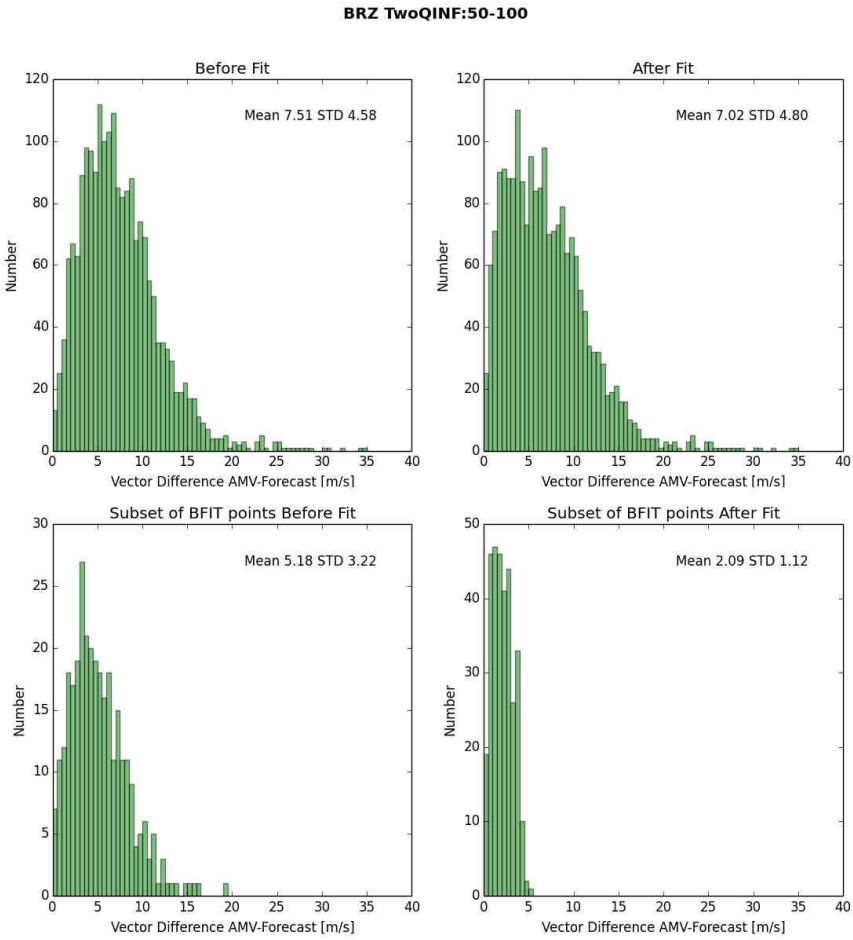


Figure 17-8: BRZ: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

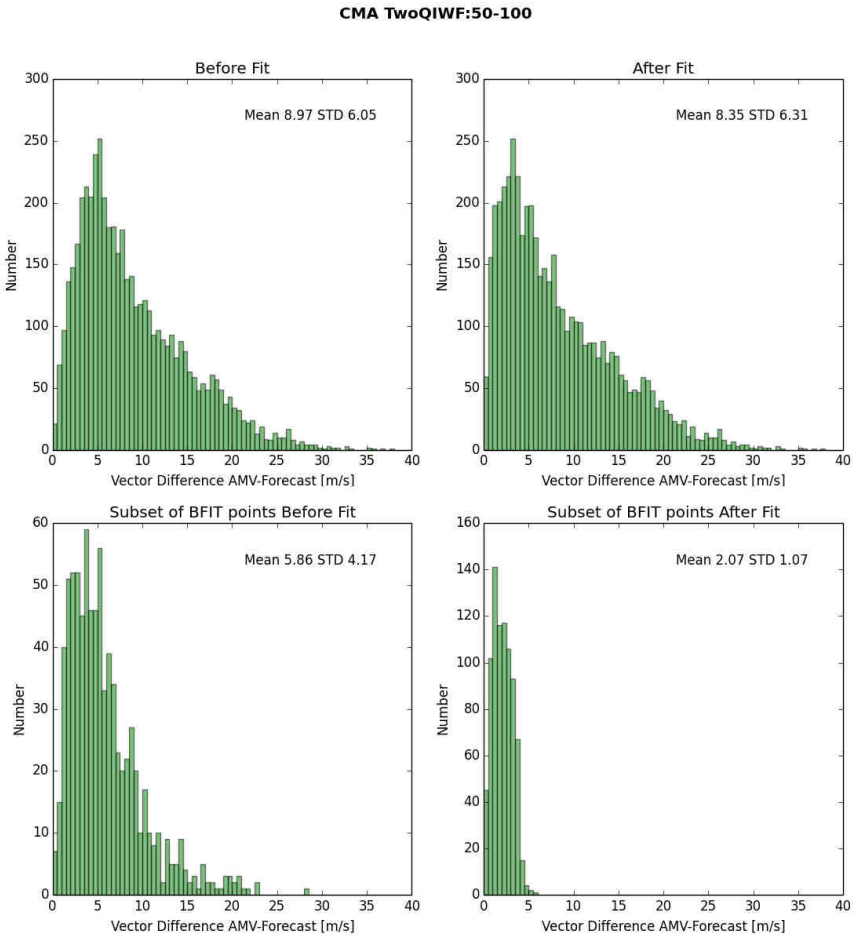


Figure 17-9: CMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

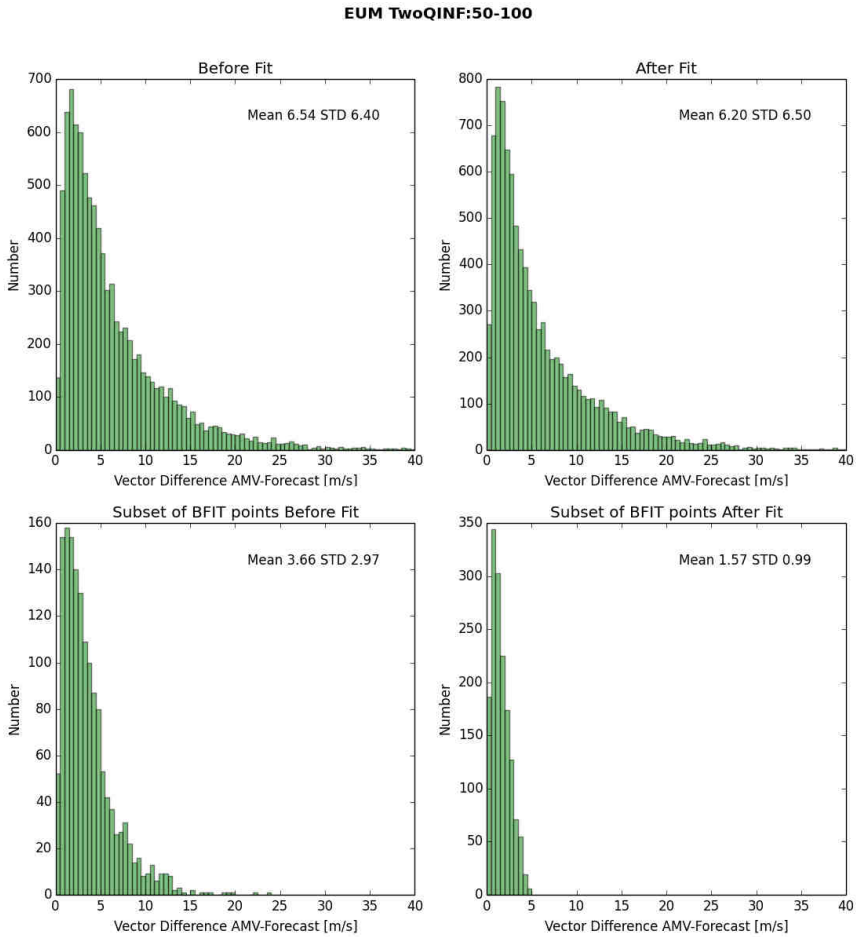


Figure 17-10: EUM: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

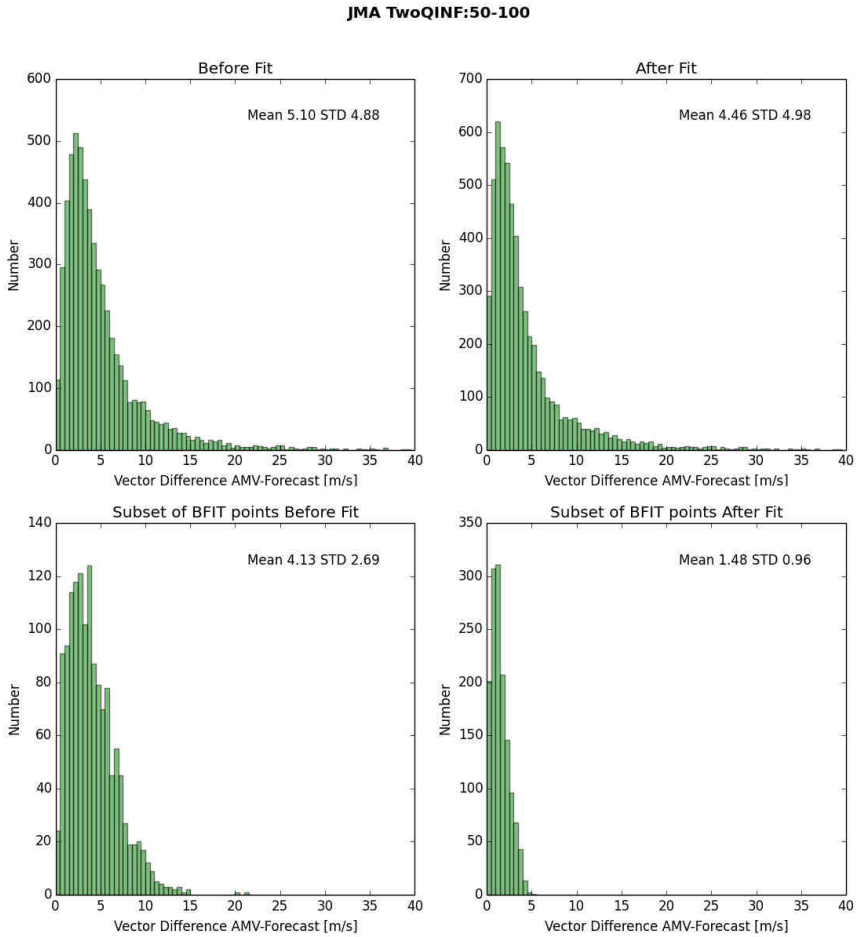


Figure 17-11: JMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

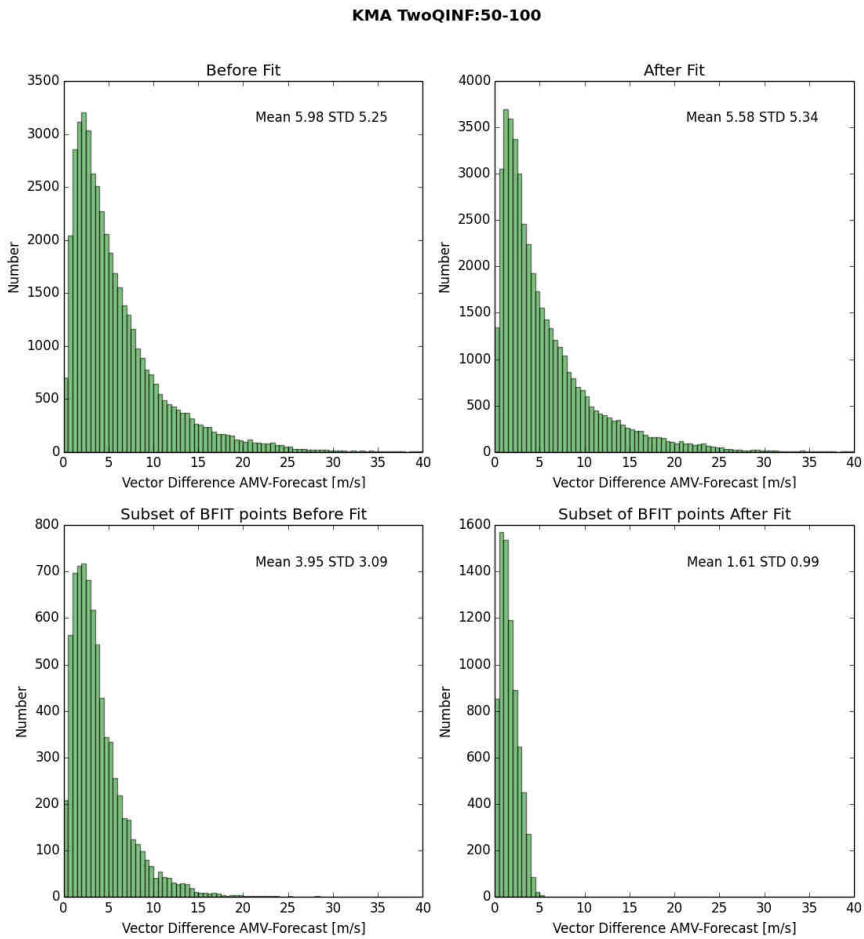


Figure 17-12: KMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

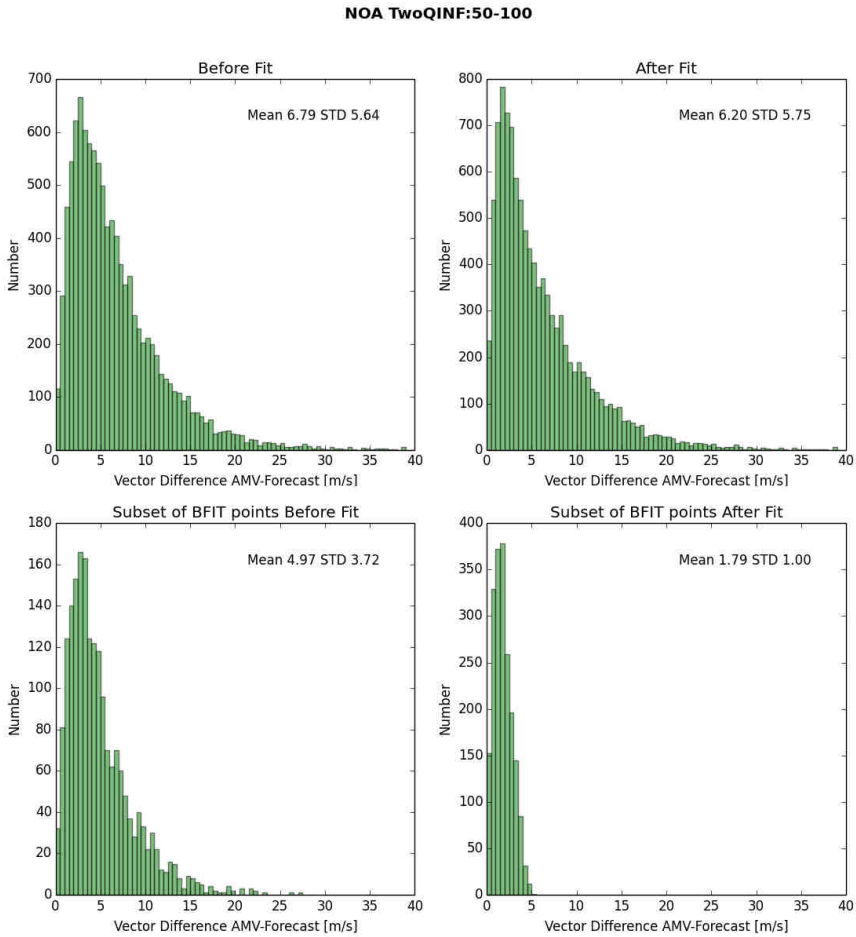


Figure 17-13: NOA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

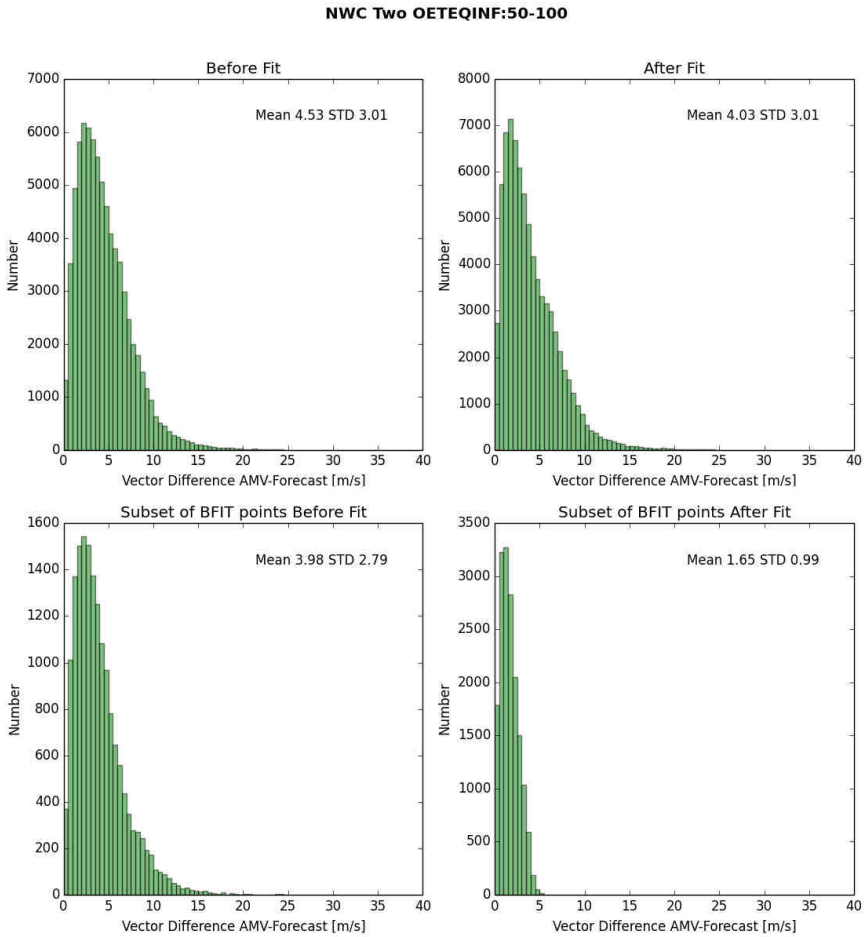


Figure 17-14: NWC: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

Experiment 3 Best Fit speed difference

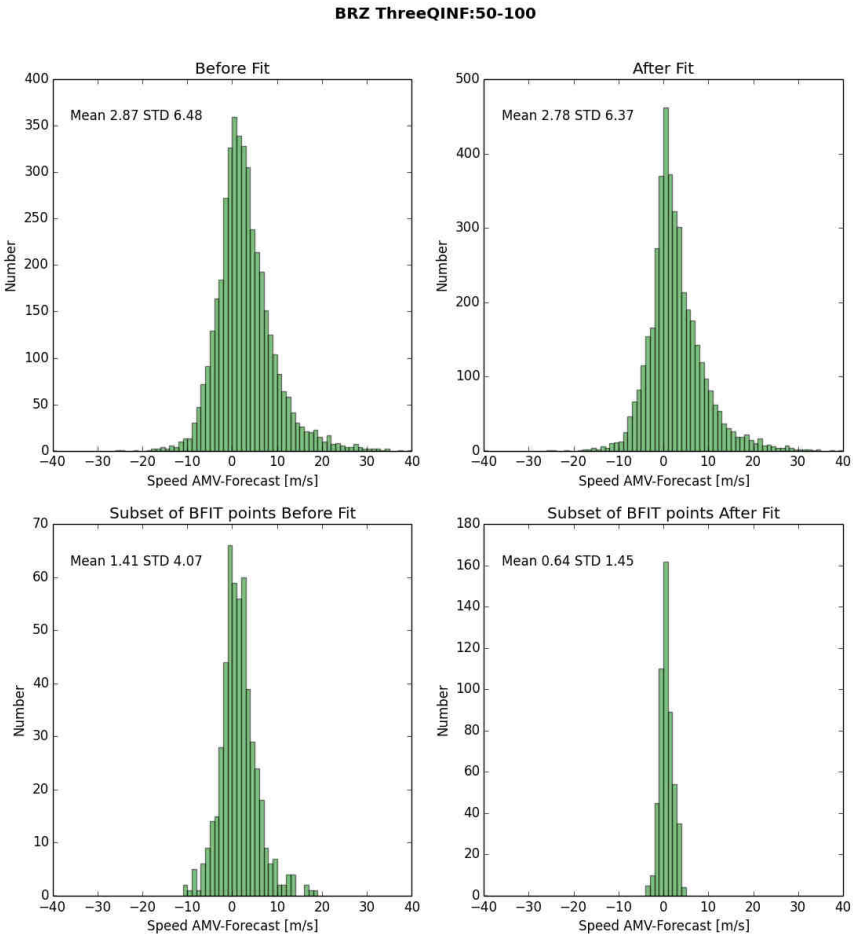


Figure 17-15: BRZ: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

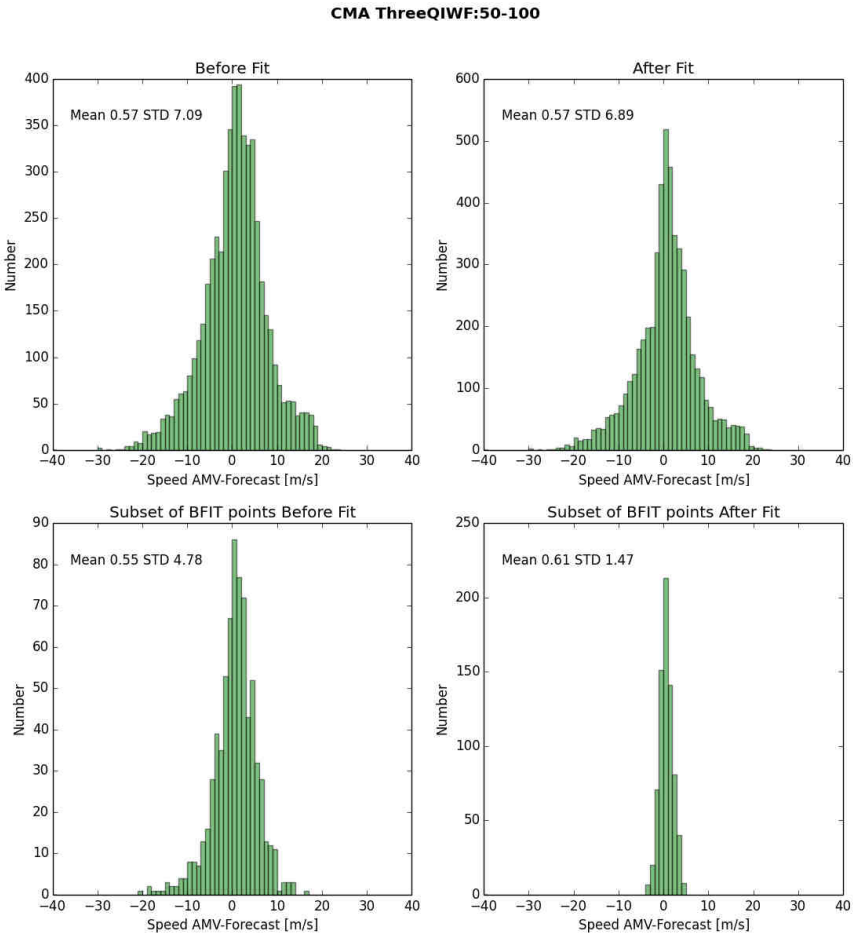


Figure 17-16: CMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

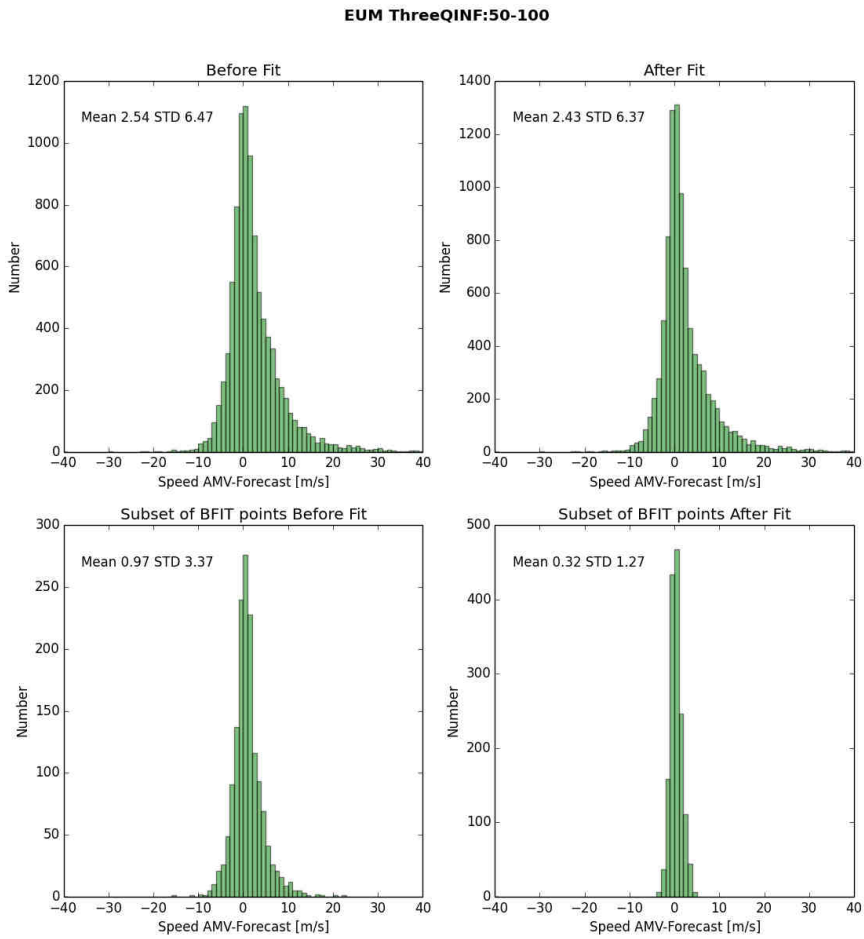


Figure 17-17: EUM: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

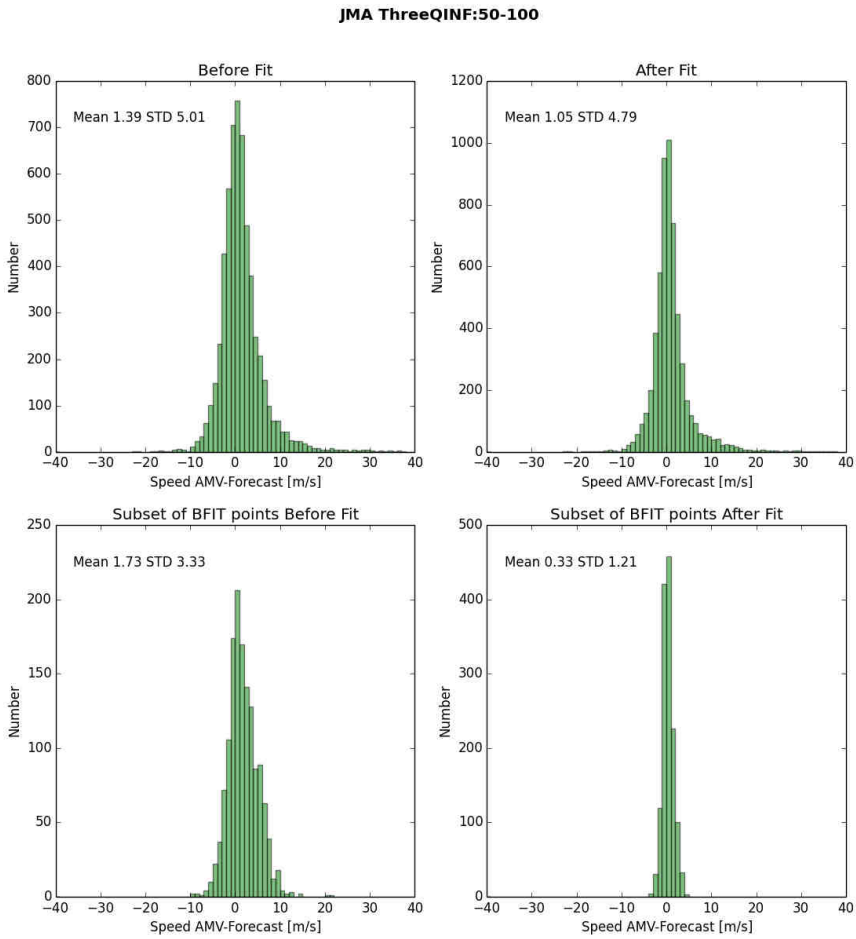


Figure 17-18: JMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

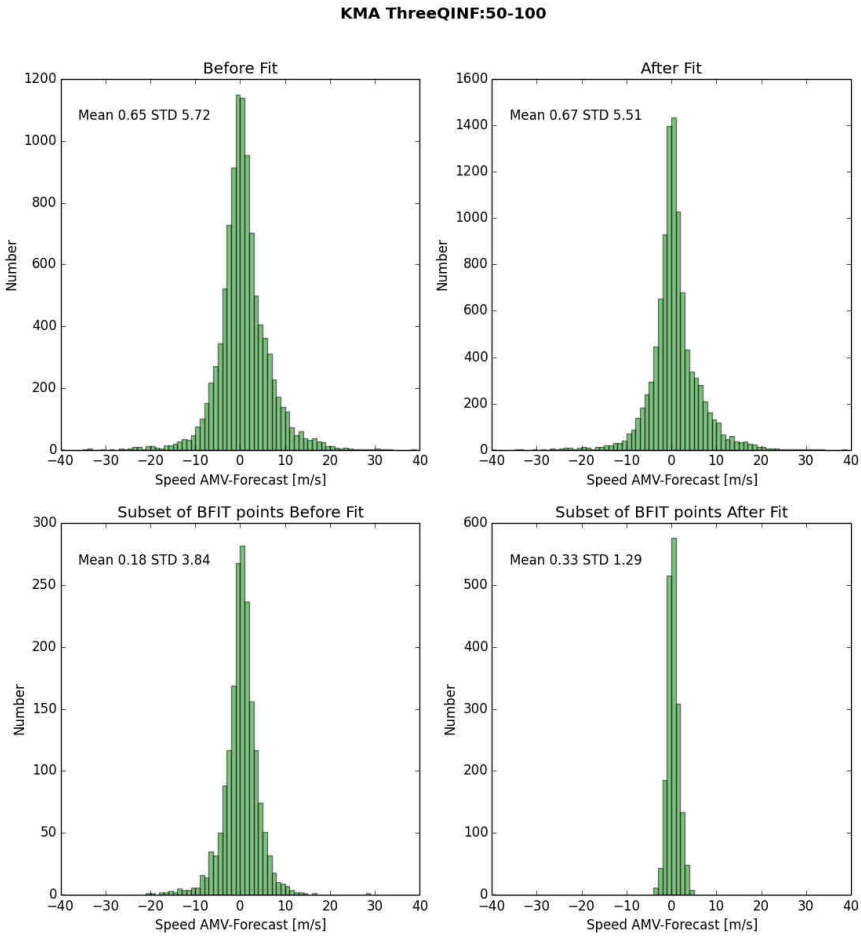


Figure 17-19: KMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

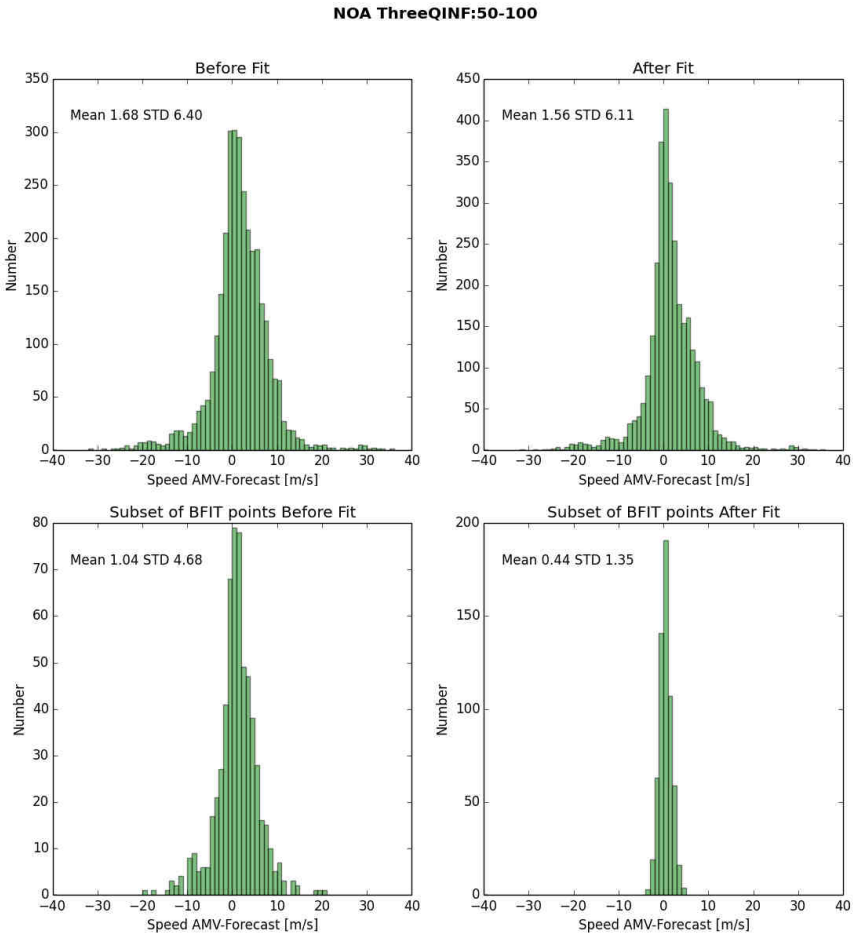


Figure 17-20: NOA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

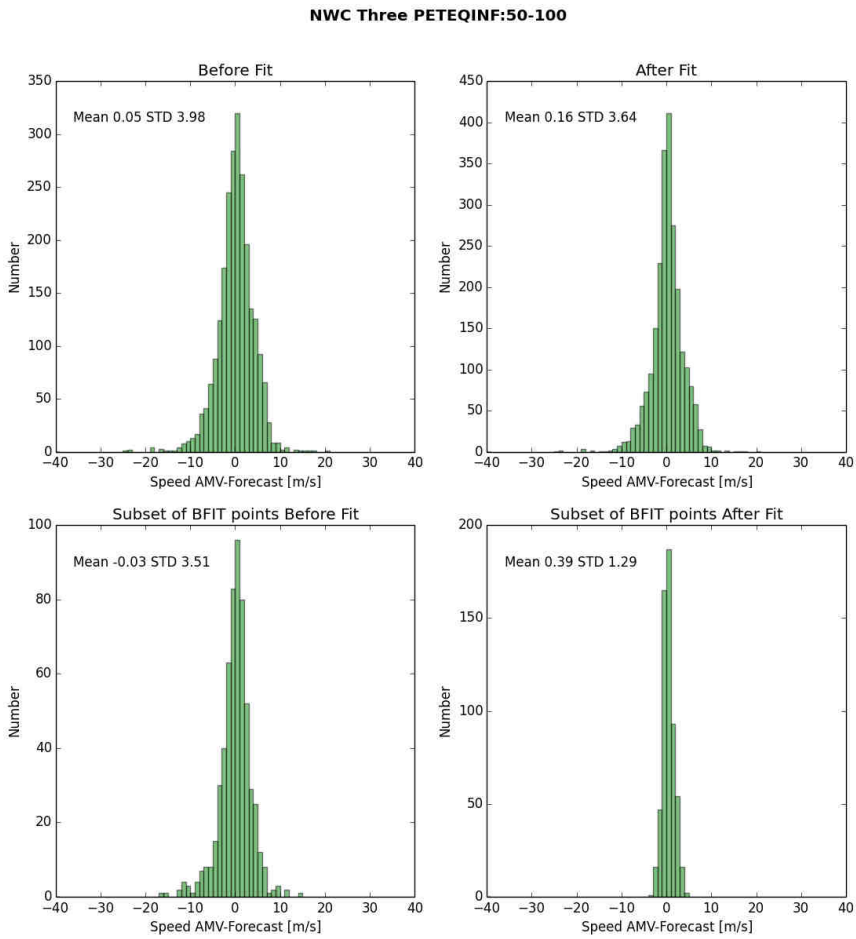


Figure 17-21: NWC: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

Experiment 3 Best Fit vector difference

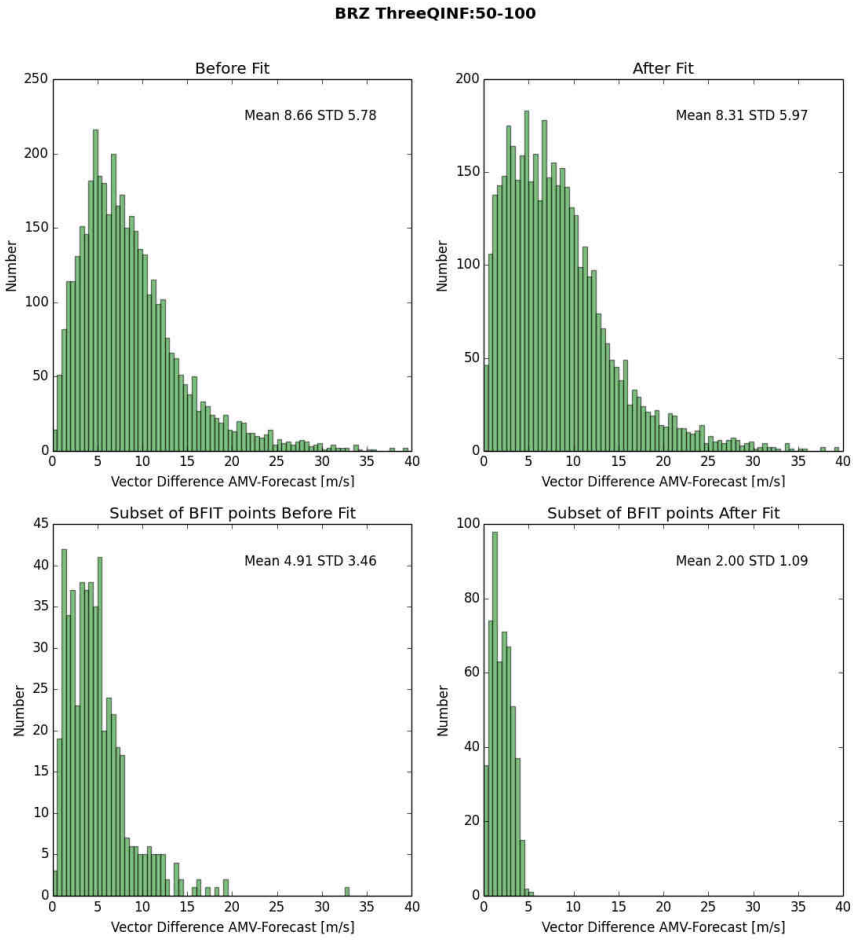


Figure 17-22: BRZ: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

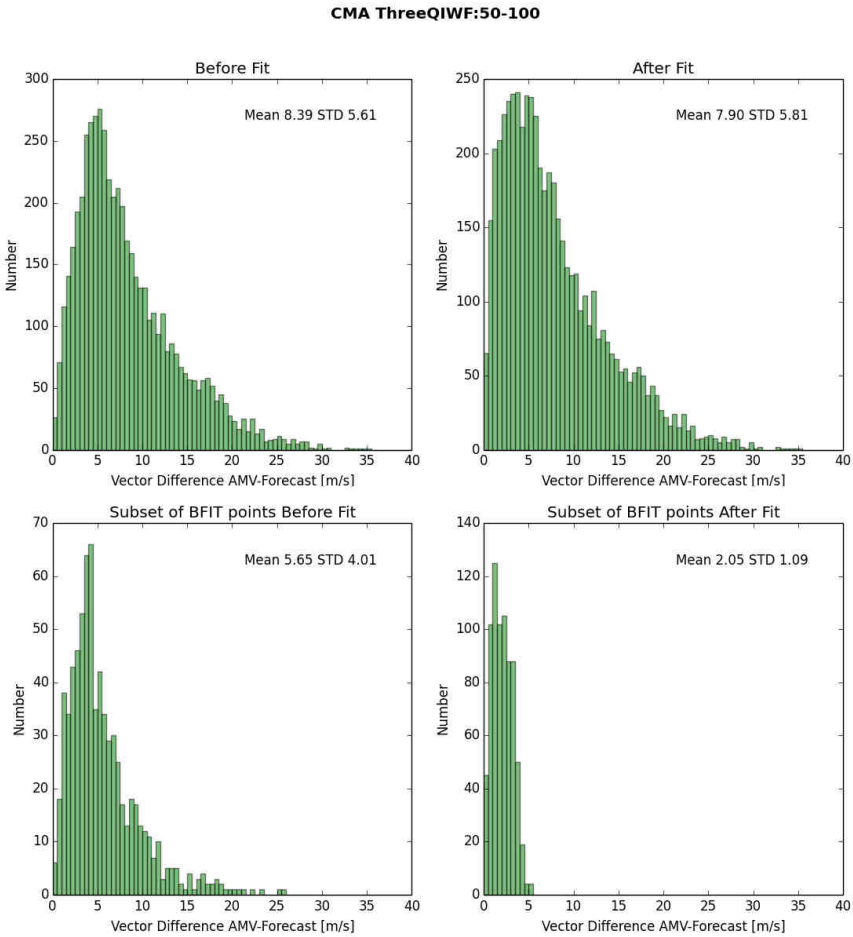


Figure 17-23: CMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

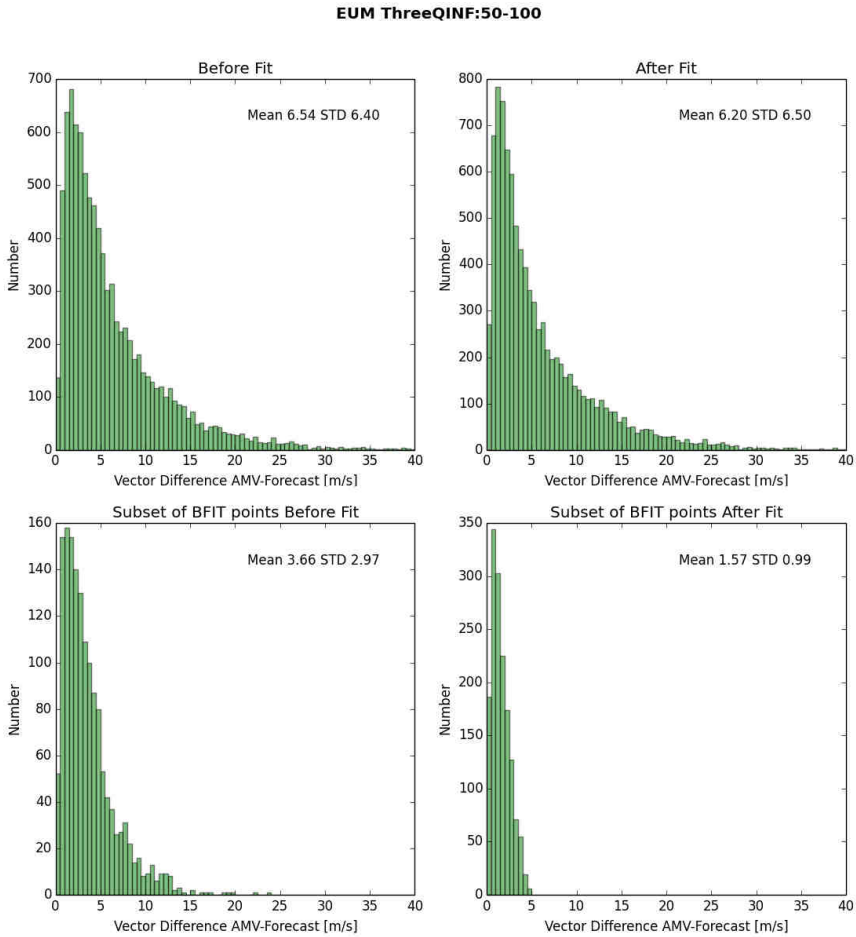


Figure 17-24: EUM: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

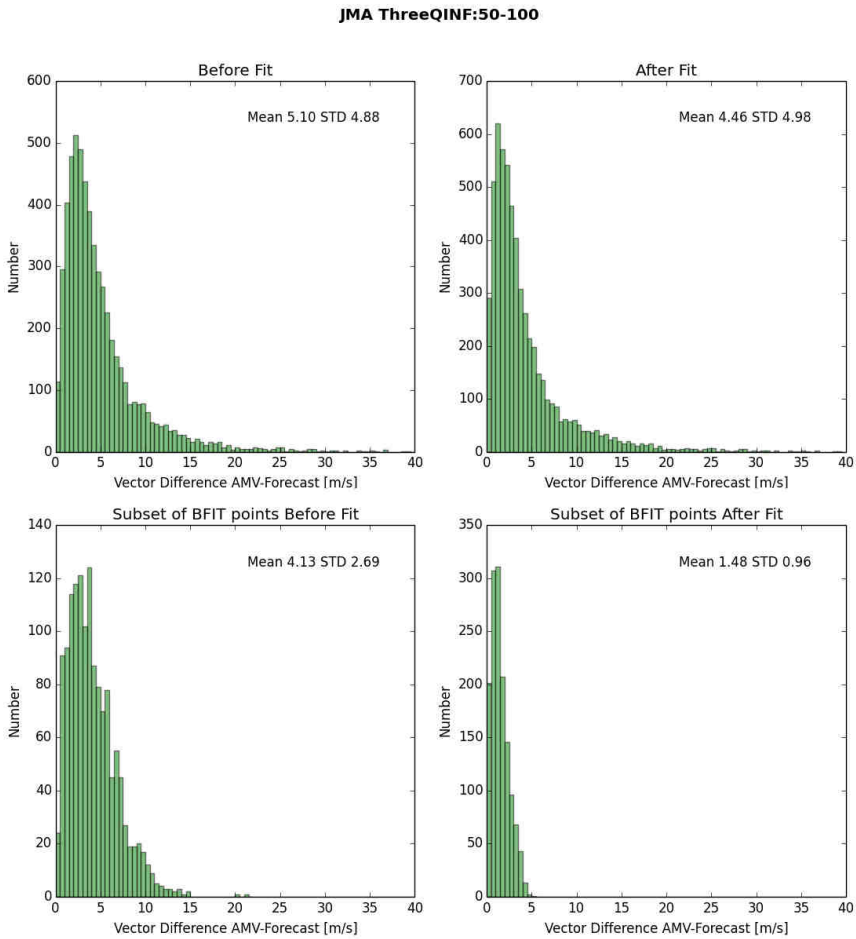


Figure 17-25: JMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

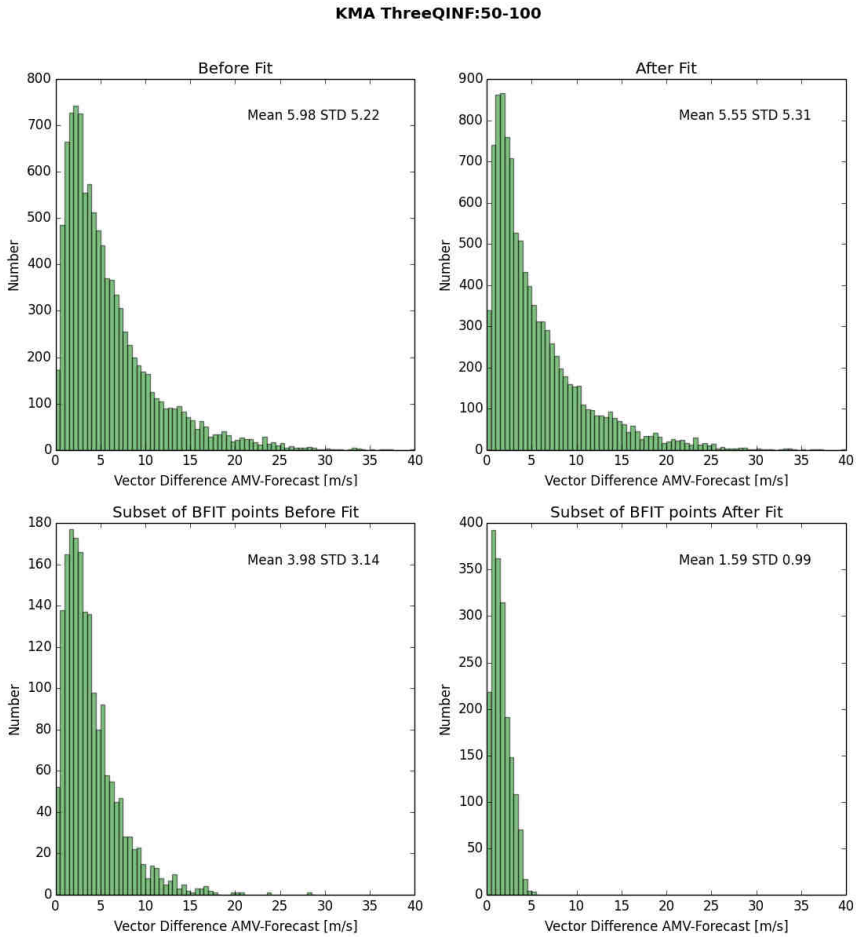


Figure 17-26: KMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

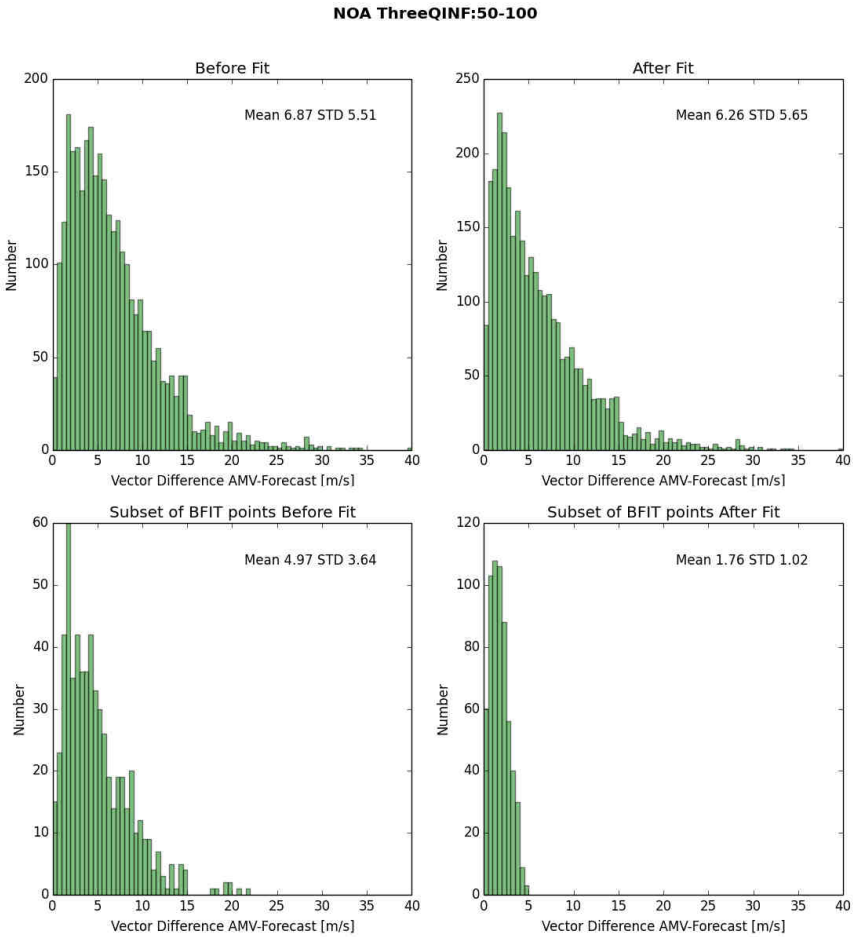


Figure 17-27: NOA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

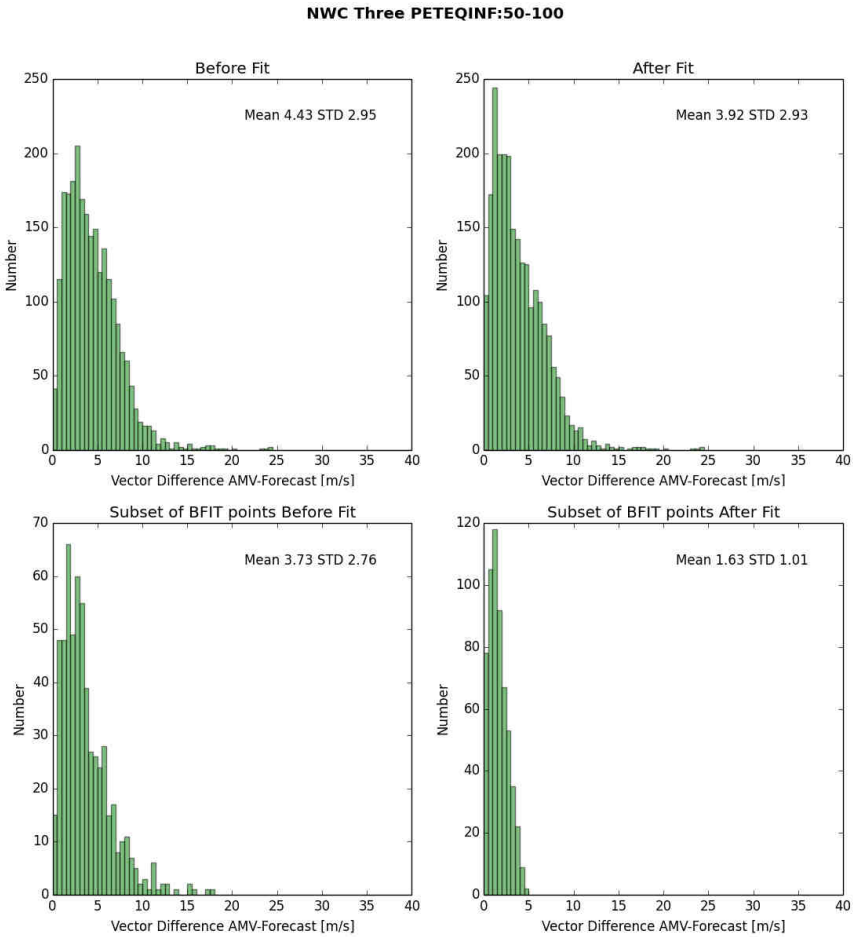


Figure 17-28: NWC: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

Experiment 4 Best Fit speed difference

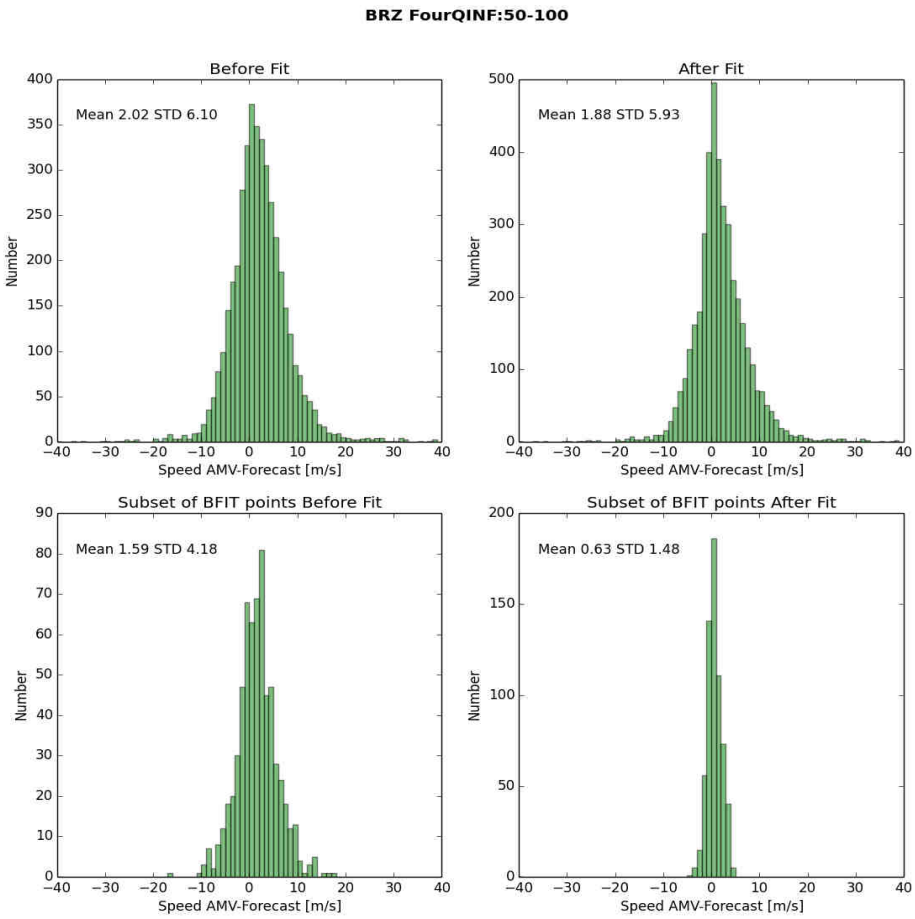


Figure 17-29: BRZ: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

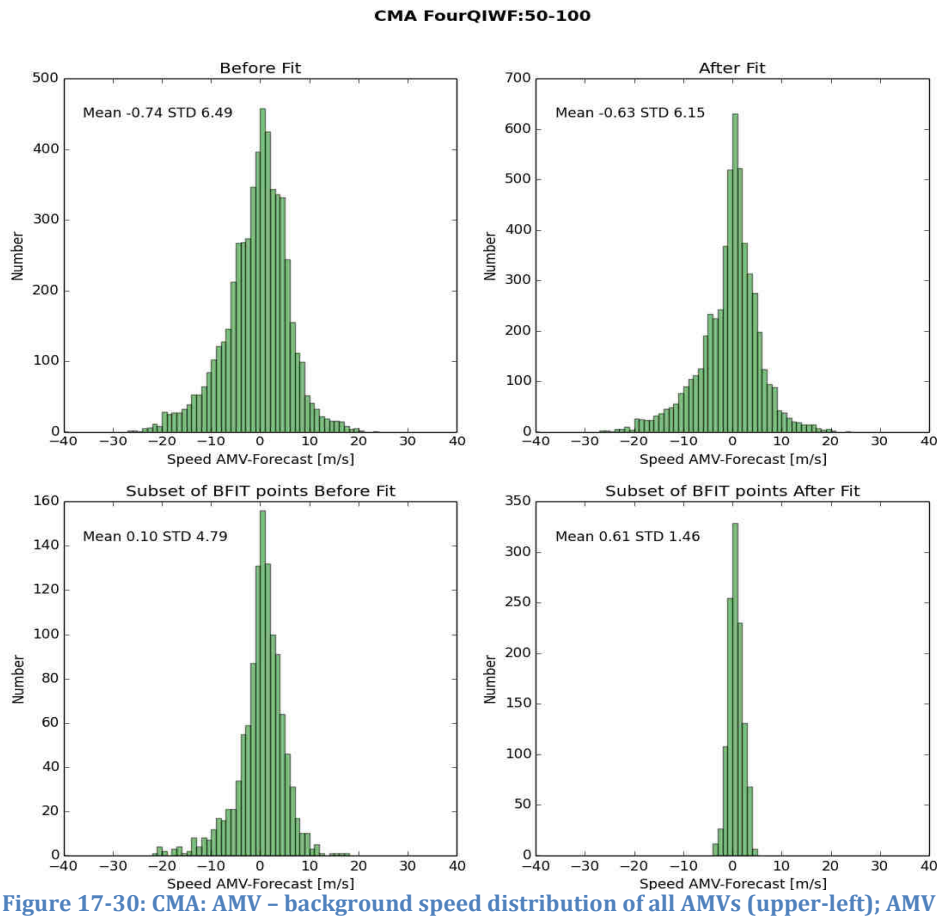


Figure 17-30: CMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

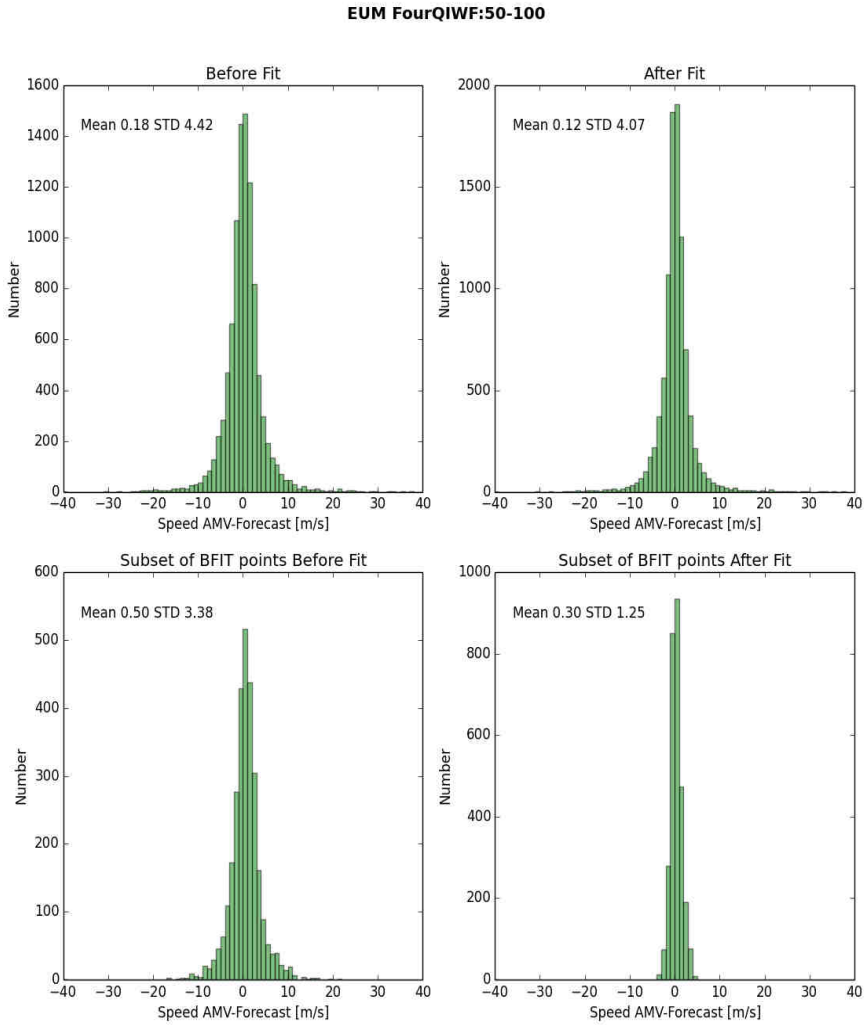


Figure 17-31: EUM: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

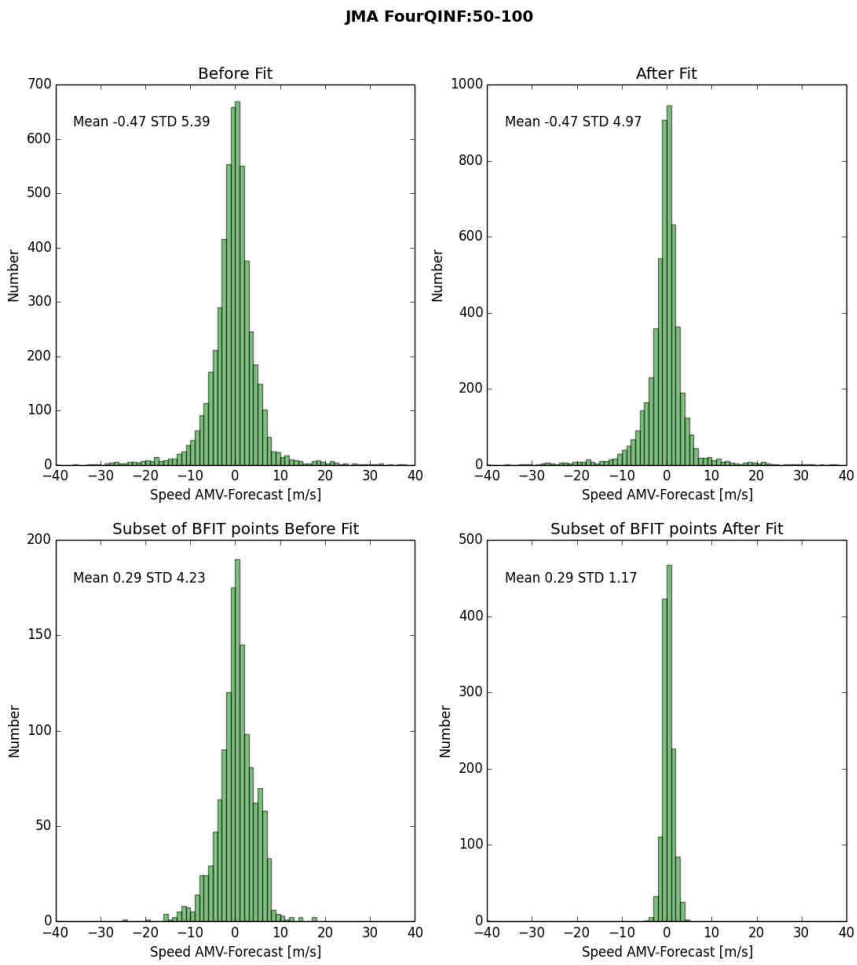


Figure 17-32: JMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

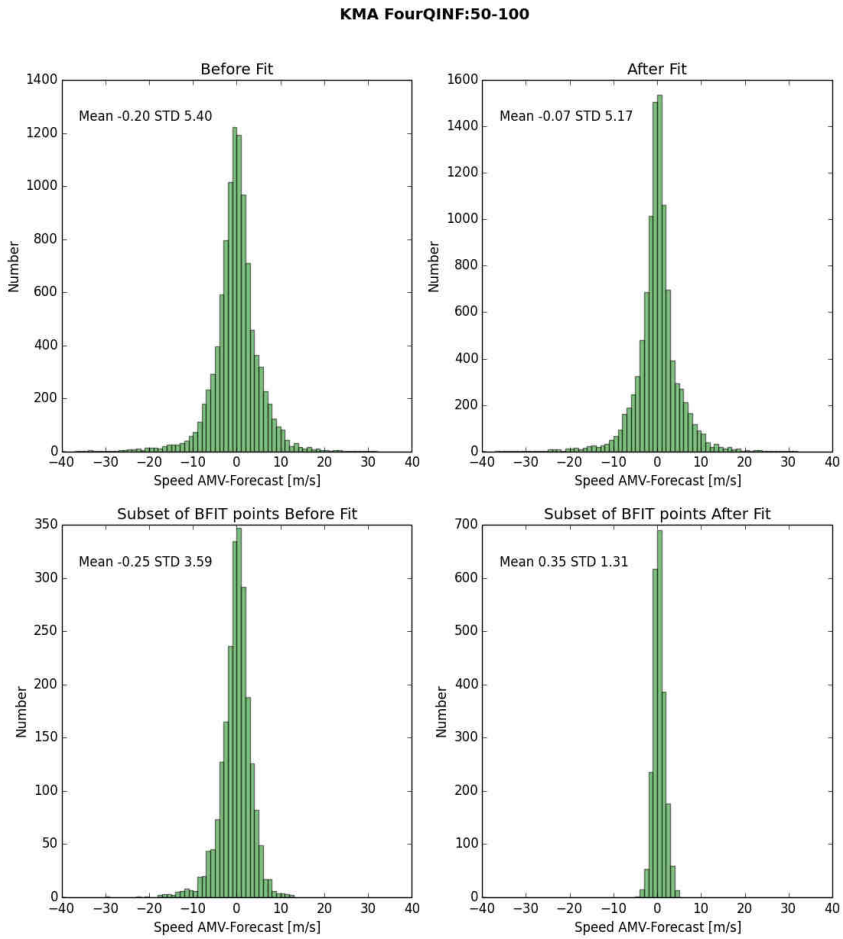


Figure 17-33: KMA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

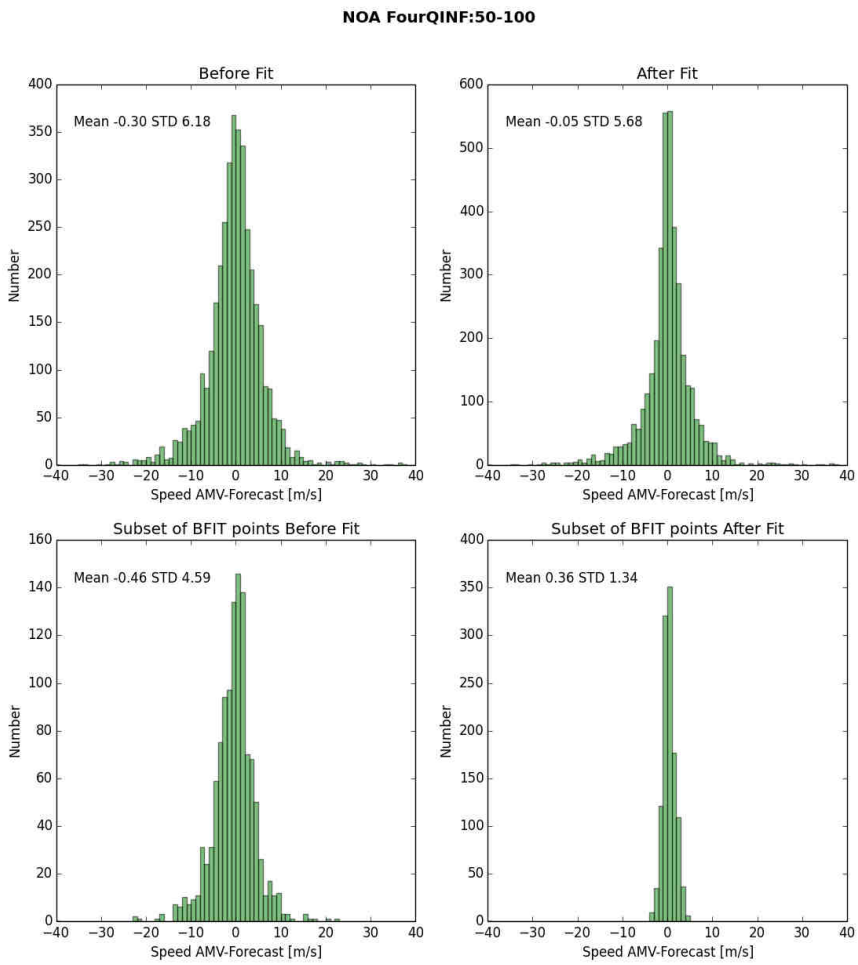


Figure 17-34: NOA: AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

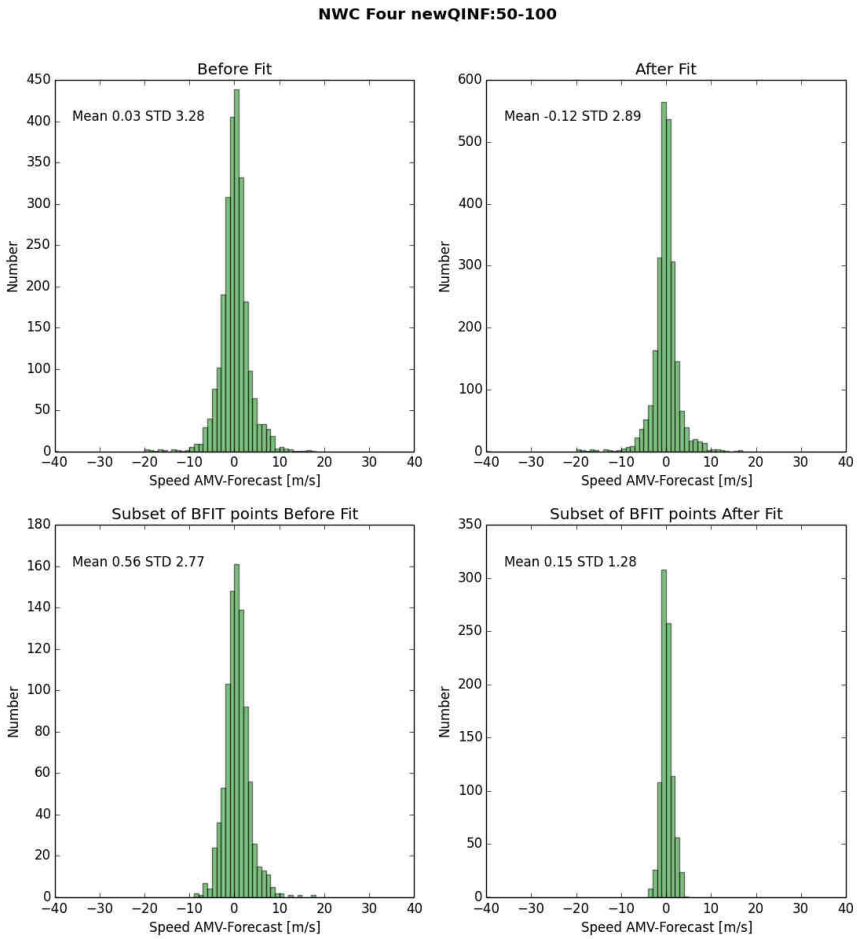


Figure 17-35: NWC (Prescribed conf. - EUM Clouds): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

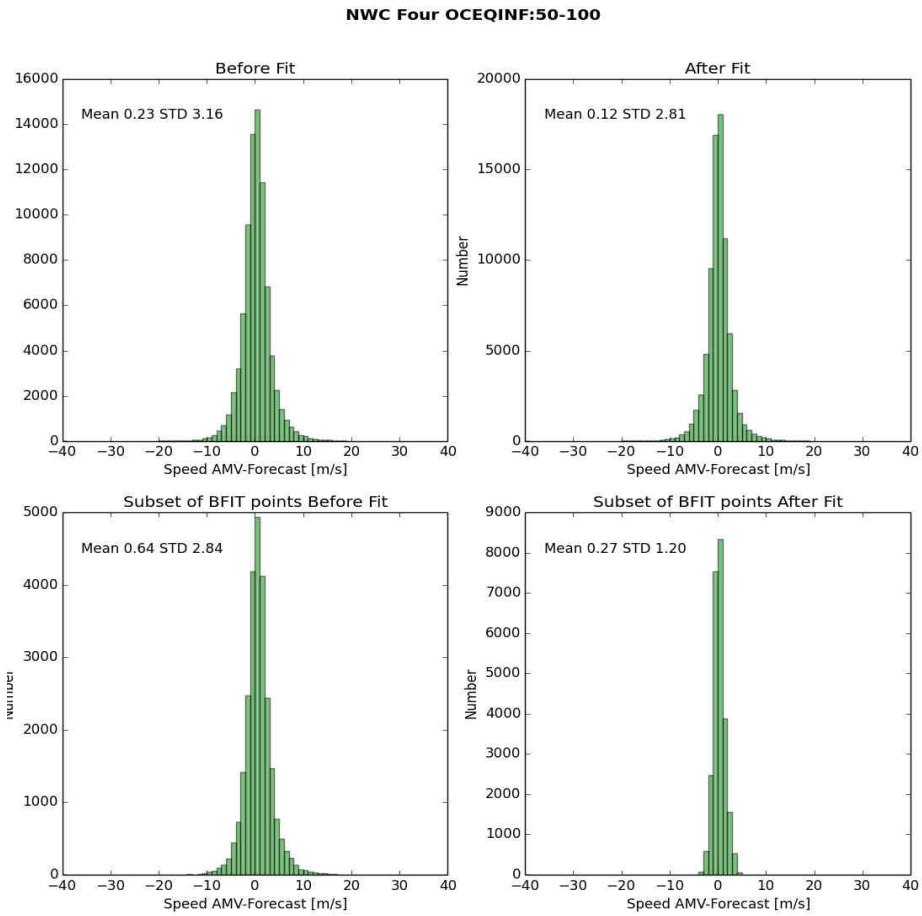


Figure 17-36: NWC (Operational conf. – EUM Clouds): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

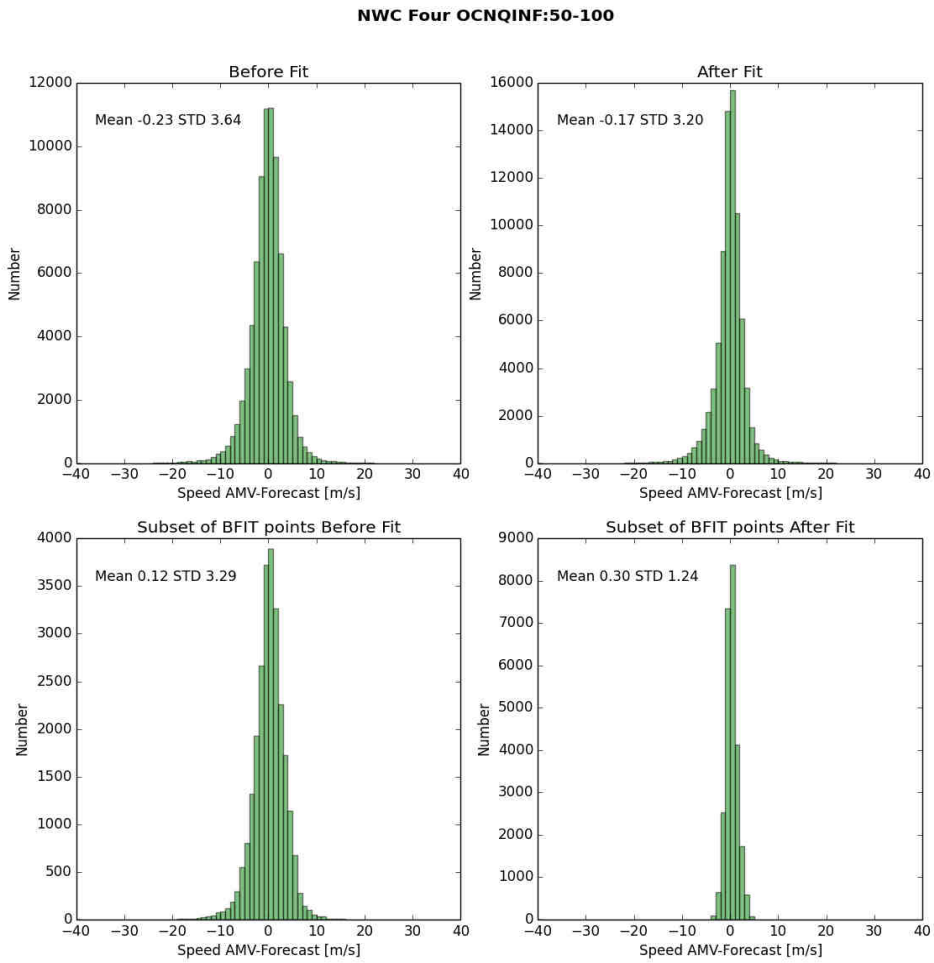


Figure 17-37: NWC (Operational conf. – NWC Clouds): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

Experiment 4 Best Fit vector difference

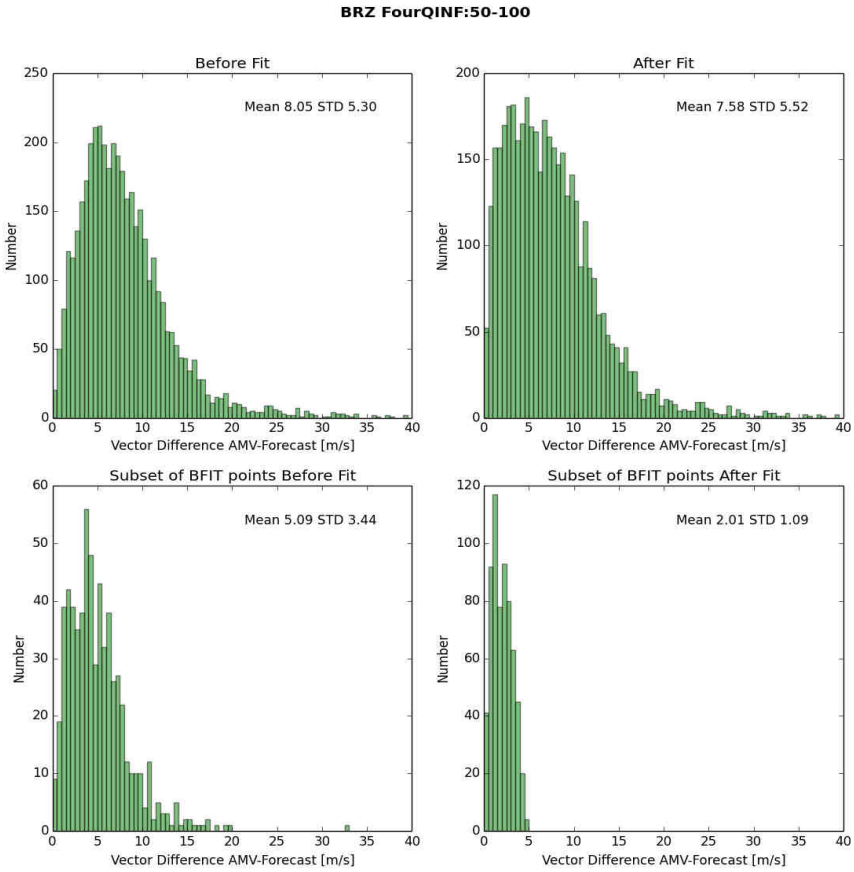


Figure 17-38: BRZ: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

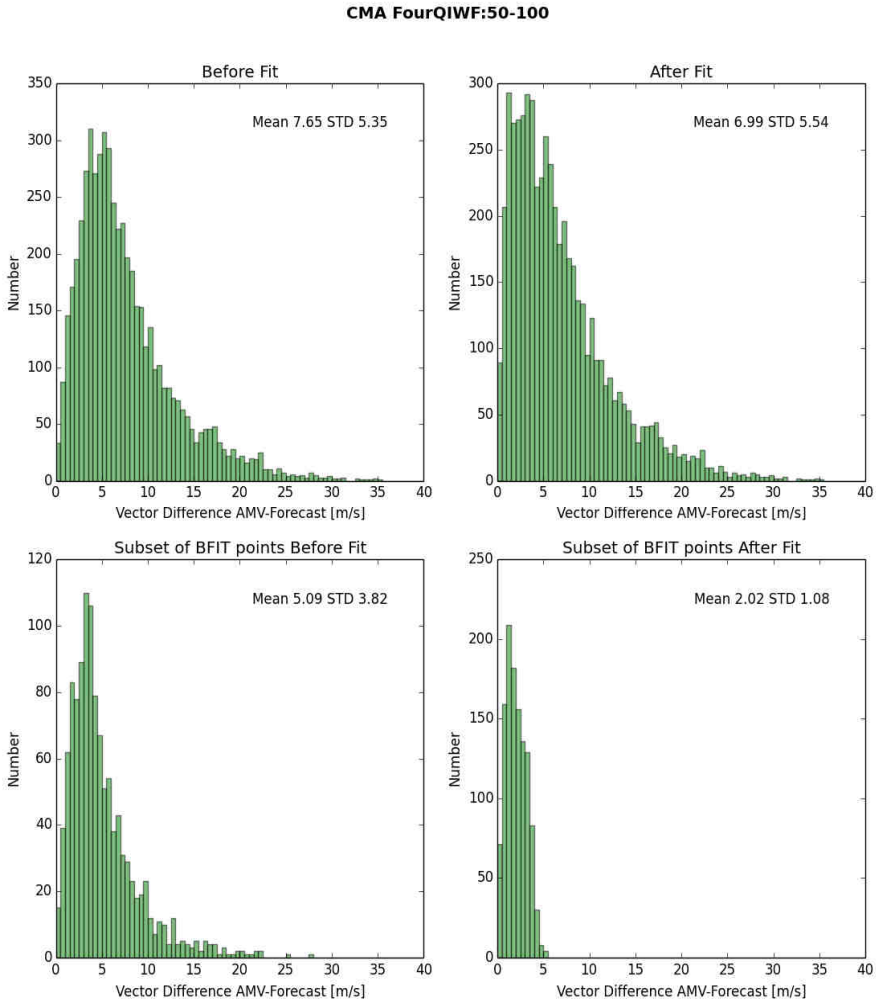


Figure 17-39: CMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

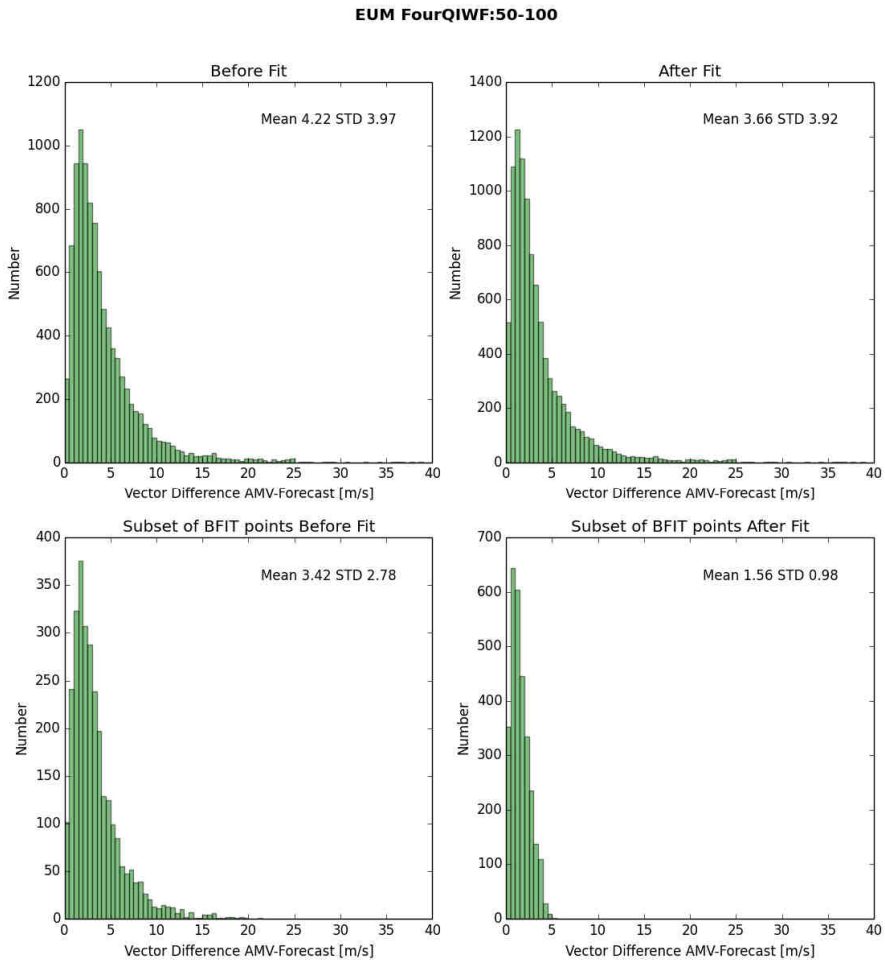


Figure 17-40: EUM: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

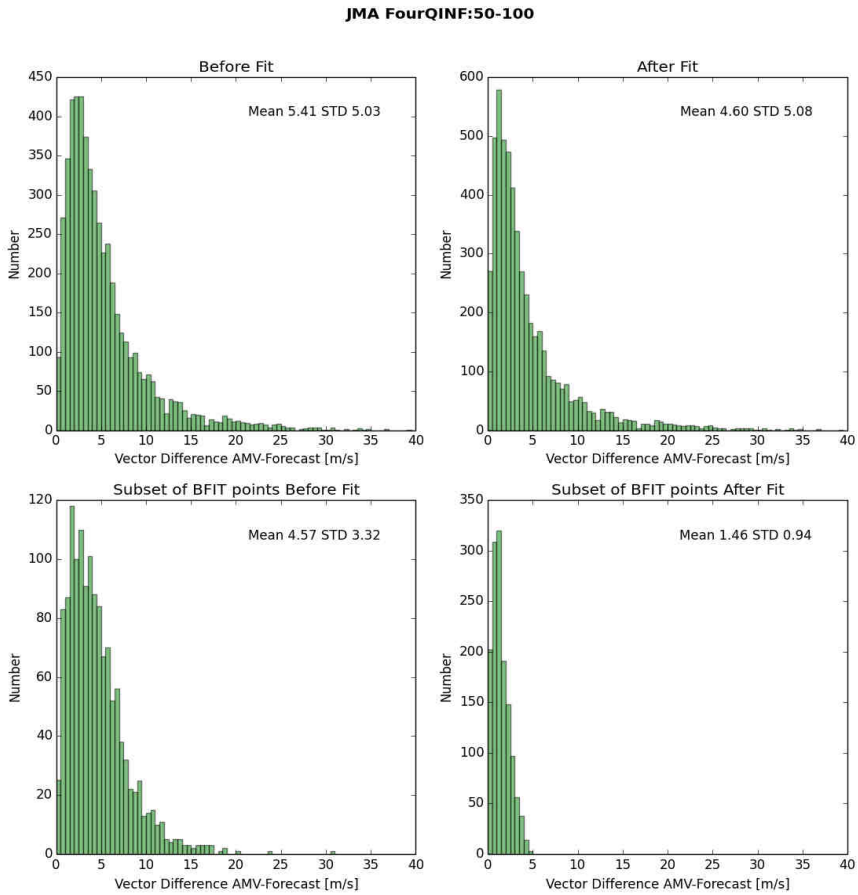


Figure 17-41: JMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

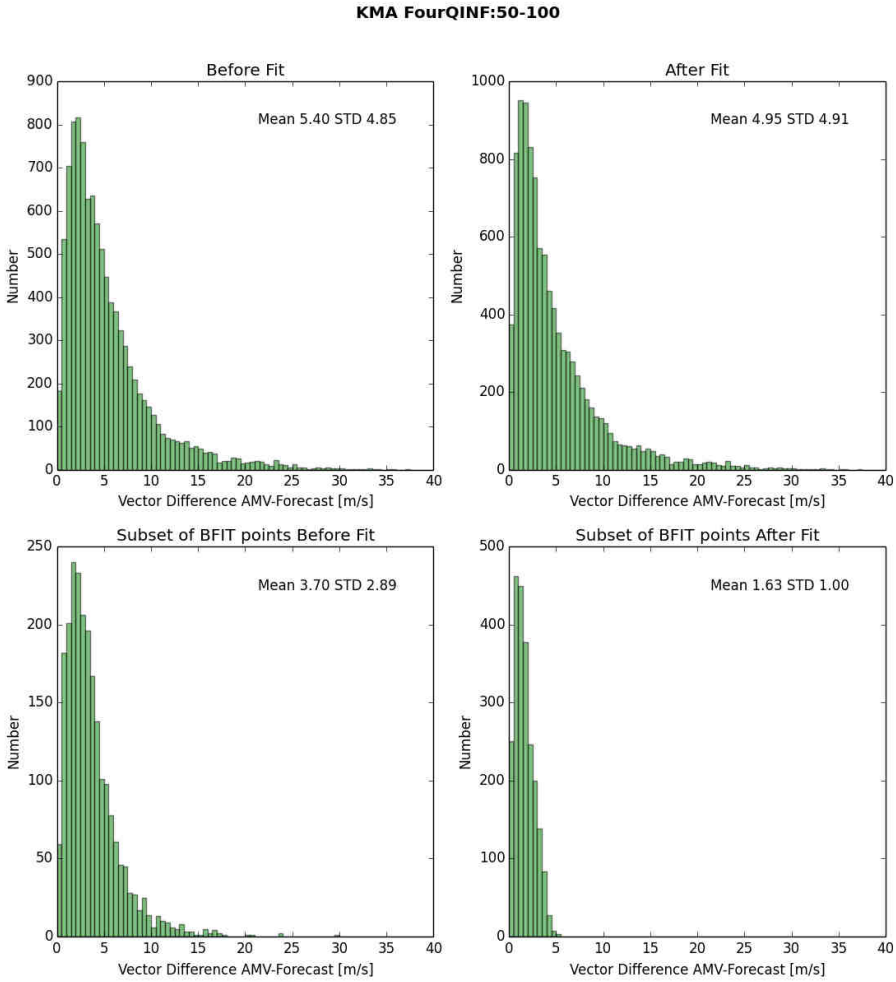


Figure 17-42: KMA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

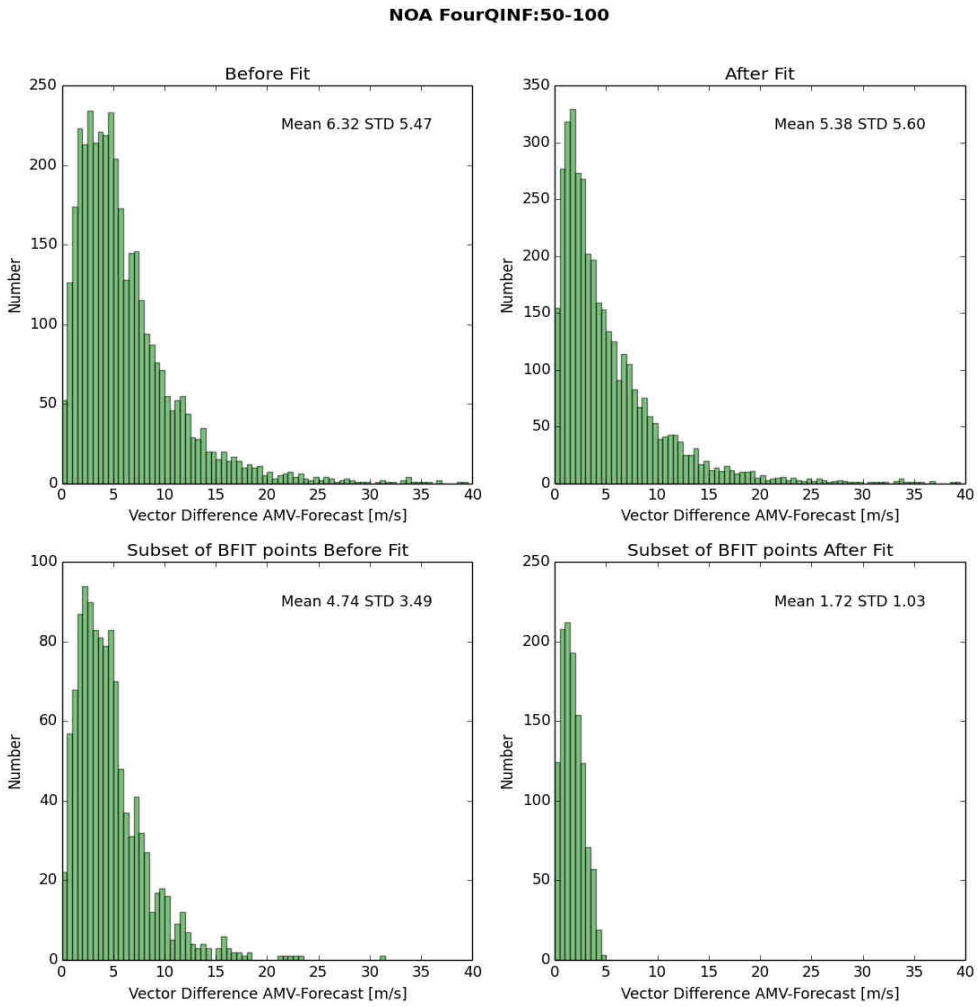


Figure 17-43: NOA: AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

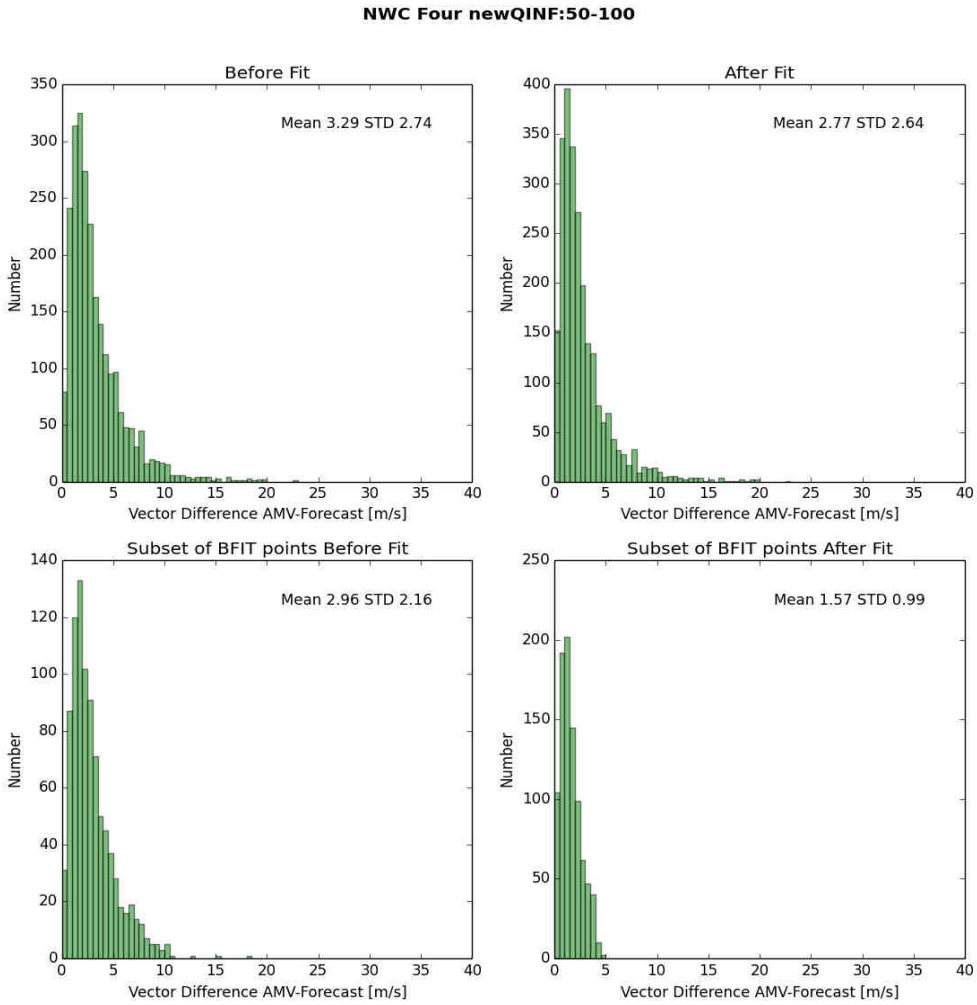


Figure 17-44: NWC (Prescribed conf. – EUM Clouds): AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

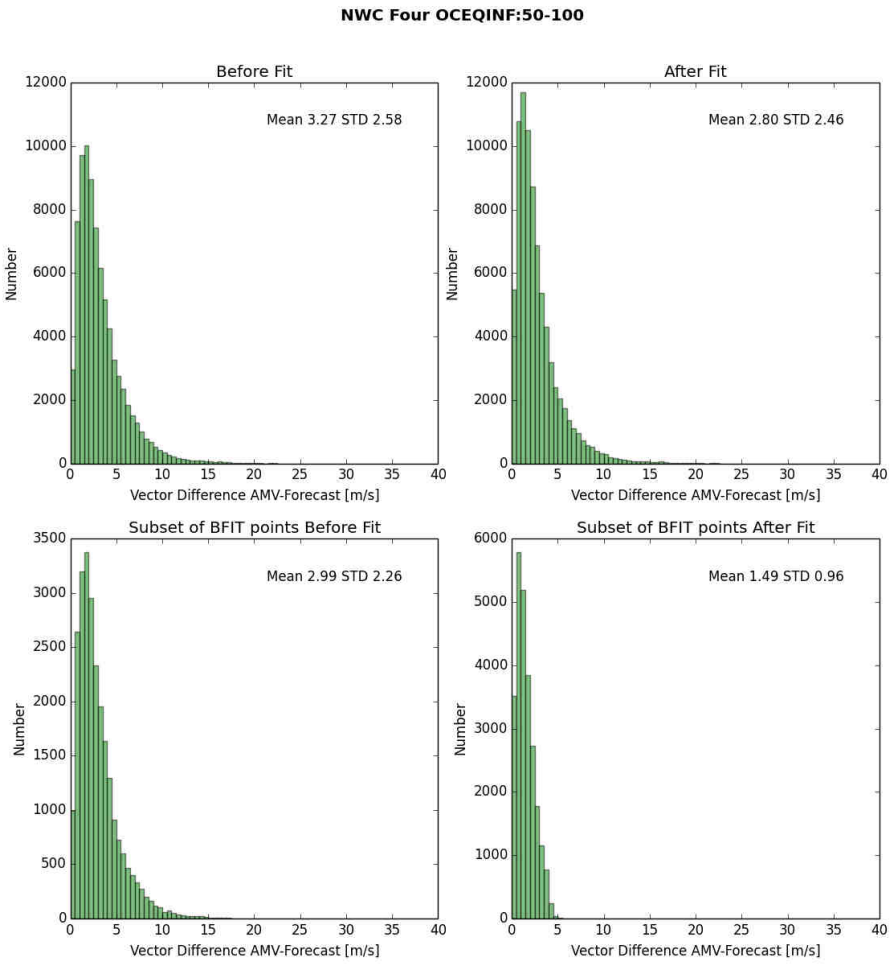


Figure 17-45: NWC (Operational conf. – EUM Clouds): AMV – background vector difference distribution of all AMVs (upper-left); AMV – background vector difference distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background vector difference distribution of Best Fit AMVs (lower-left); AMV – background vector difference distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

18. Appendix E: Shell Scripts

The following scripts were used to preprocess the text files.

input_fix.sh

input_fix.sh replaces semi-colons with 5 spaces in the text files.

This script ran on 'granite'. A copy is stored on 'tinman' 1 Oct 2013: /Users/daves/Desktop/Intercomparison/Max_Mindock/AMVIntercomparisonFinalData16Apr2013/ZMiscellaneous/

```
#*********************************************************************
# input_fix.sh
# This script does a recursive, case sensitive directory search and replace of
files
# To make a case insensitive search replace, use the -i switch in the grep call
# uses a startdirectory parameter so that you can run it outside of specified
directory - else this script will modify itself!
#*********************************************************************

!/bin/bash
# **************** Change Variables Here ************
startdirectory="/Users/mmindock/Desktop/AMVIntercomparisonFinalData16Apr2013/Ja
pan/GoodData/*.csv"
searchterm="N/A"
replaceterm="0"
# ************************************************************

echo "*****************************************"
echo "* Search and Replace in Files Version .1 *"
echo "*****************************************"

        for file in $(grep -l -R $searchterm $startdirectory)
          do
           sed 's/;/     /g' $file > output.txt
           mv output.txt $file
           echo "Modified: " $file
        done

echo " *** Yay! All Done! *** "
```

19. Appendix F: Best fit Python Scripts

These scripts compute the Best fit pressure.

test_amv.py

Determines AMV best fit pressure with respect to model background.
On 'verdandi' 16 Jan 2014: /home/snebuda/icomp/python/save/
On tinman 21 Jan 2014: /Users/daves/Desktop/Intercomparison/BestFit

```
#!/usr/bin/env python

import os, os.path
import sys

import numpy as np
import amv as amv

import matplotlib as mpl
import matplotlib.pyplot as plt
from mpl_toolkits.basemap import Basemap

from matplotlib.colors import LogNorm
from pylab import *

undef = -9999.

# European data
file_amv='EUMETSATDatasetTwo.csv'
file_fig='amv.europe.png'
fig_title='European AMV Data'

# Chinese data
file_amv='ChinaDatasetTwo.csv'
file_fig='amv.china.png'
fig_title='Chinese AMV Data'

print "Reading amv data file: "  + file_amv
amv_data = amv.read_txt(file_amv)

print "Reading forecast file"
file_fcst =
'/home/daves/intercomparison/nominal/DecodedForecast_20120917070613Z_2012091712
0000Z_12_O_MPFS03'
fcst_data = amv.read_DecodedForecast_MSG(file_fcst)

print "Finding grid location"
grid_i,grid_j = amv.locate(amv_data,fcst_data)

print "Finding best fit"
amv_num = amv_data.shape[1]
amv_bfit=np.empty(amv_num)
bfit_flag=np.empty(amv_num)
```

```
print 'Number of AMV {0}'.format(amv_num)

n = 0
while (n < amv_num):
    amv_single = amv_data[:,n]
    fcst_profile = fcst_data[grid_i[n],grid_j[n],:,:]
    amv_bfit[n],bfit_flag[n] = amv.bestfit(amv_single,fcst_profile)
    n += 1

amv_prs = amv_data[4,:]
amv_lat = amv_data[2,:]
amv_lon = amv_data[3,:]

#Compute change in pressure for AMV best fit
dp = amv_bfit[amv_bfit !=undef] - amv_prs[amv_bfit !=undef]
dp_x = amv_lon[amv_bfit != undef]
dp_y = amv_lat[amv_bfit != undef]
dp_x_none = amv_lon[amv_bfit == undef]
dp_y_none = amv_lat[amv_bfit == undef]
dp_x_down = amv_lon[amv_bfit > amv_prs]
dp_y_down = amv_lat[amv_bfit > amv_prs]
dp_x_up = amv_lon[(amv_bfit != undef) & (amv_bfit < amv_prs)]
dp_y_up = amv_lat[(amv_bfit != undef) & (amv_bfit < amv_prs)]

frac = np.empty(4)
flag_title=['Found','Not Constrained','No sufficient minimum','No forecast
pressure match']
for f in range (4):
    frac[f] = float((bfit_flag == f).sum()) / float(amv_num)

x=amv_data[3,:]
y=amv_data[2,:]

fig = plt.figure(figsize=(12,12))

plt.subplot(3,2,1)
num_bins=50
n,bins,patches = plt.hist(x,num_bins,facecolor='green',alpha=0.5)
n,bins,patches = plt.hist(dp_x,num_bins,facecolor='orange',alpha=0.5)
plt.xlim(-60.,60.)
plt.ylim(0.,600.)
plt.xlabel('Longitudes')
plt.ylabel('Number')
plt.title(r'Green all AMV, Yellow found best fit')

plt.subplot(3,2,3)
num_bins=50
n,bins,patches = plt.hist(y,num_bins,facecolor='green',alpha=0.5)
n,bins,patches = plt.hist(dp_y,num_bins,facecolor='orange',alpha=0.5)
plt.xlim(-60.,60.)
plt.ylim(0.,600.)
plt.xlabel('Latitudes')
plt.ylabel('Number')
#plt.title(r'Green all AMV, Yellow found best fit')

plt.subplot(4,2,7)
#not enough flag=3 to plot for these test cases
labels=flag_title[0:3]
sizes=frac[0:3]
colors=['lightblue','orange','lightgreen','red']
```

```
plt.pie(sizes,labels=labels,colors=colors,autopct='%.0f%%')
plt.axis('equal')

plt.subplot(2,2,2)
num_bins=50
n,bins,patches = plt.hist(dp,num_bins,facecolor='blue',alpha=0.5)
plt.xlim(-300.,300.)
plt.ylim(0.,100.)
plt.xlabel('dp')
plt.ylabel('Number')
plt.title(r'Histogram of AMV Best Fit - Original Pressure')

plt.subplot(2,2,4)
plt.scatter(dp_x_none,dp_y_none,s=1,color='0.8')
plt.scatter(dp_x_up,dp_y_up,s=1,color='r')
plt.scatter(dp_x_down,dp_y_down,s=1,color='b')
m = Basemap(projection='cyl',llcrnrlat=-80.,urcrnrlat=80.,llcrnrlon=-
80.,urcrnrlon=80.,resolution='c')
m.drawcoastlines()
plt.title(r'Grey no fit, Red higher, Blue lower ')

plt.figtext(0.5,0.96,fig_title,ha='center',color='black',weight='bold',size='la
rge')

#plt.show()
plt.gcf().set_size_inches(13, 13)
plt.savefig(file_fig)
plt.clf()

print "wrote figure file: "  + file_fig
```

amv.py

```
#!/usr/bin/env python

import os, os.path
import sys
import numpy as np
import math

def read_txt(file):

    undef = -9999.0

# count the valid AMV
    amv_num = 0
    with open(file,'r') as f:
        for line in f:
            try:
                amv_list=parse_amv(line)
                if (amv_list[0] != undef):
                    amv_num +=1
            except:
                continue
    f.closed

# allocate np arrays
    amv_spd = np.empty(amv_num)
    amv_dir = np.empty(amv_num)
```

```
    amv_prs = np.empty(amv_num)
    amv_lat = np.empty(amv_num)
    amv_lon = np.empty(amv_num)

# read again to fill np arrays
    count = 0
    with open(file,'r') as f:
        for line in f:
            try:
                amv_list=parse_amv(line)
                if (amv_list[0] != undef):
                    amv_spd[count] = amv_list[0]
                    amv_dir[count] = amv_list[1]
                    amv_lat[count] = amv_list[2]
                    amv_lon[count] = amv_list[3]
                    amv_prs[count] = amv_list[4]
                    count +=1
            except:
                continue
    f.closed

# place in one variable for convenience
    amv_data = np.vstack((amv_spd,amv_dir,amv_lat,amv_lon,amv_prs))

    return amv_data



def parse_amv(line):

# contain format of text file and data checking in one function

    undef = -9999.0

    tlat = 1 ; vlat=[-61.,61.]
    tlon = 2 ; vlon=[-61.,61.]
    tspd = 5 ; vspd=[0.,150.]
    tdir = 6 ; vdir=[0.,361.]
    tprs = 7 ; vprs=[10.,1020.]

    token=line.split()

    lat=undef
    lon=undef
    spd=undef
    dir=undef
    prs=undef
    #print 'lat {0} lon {1} spd {2} dir {3} prs
{4}'.format(token[tlat],token[tlon],token[tspd],token[tdir],token[tprs])

# basic valid data check, could add QI or other flag check here
    valid=True
    if (float(token[tlat]) < vlat[0]) or (float(token[tlat]) > vlat[1]):
        valid=False
    if (float(token[tlon]) < vlon[0]) or (float(token[tlon]) > vlon[1]):
        valid=False
    if (float(token[tspd]) < vspd[0]) or (float(token[tspd]) > vspd[1]):
        valid=False
    if (float(token[tdir]) < vdir[0]) or (float(token[tdir]) > vdir[1]):
        valid=False
    if (float(token[tprs]) < vprs[0]) or (float(token[tprs]) > vprs[1]):
```

```
        valid=False

    if (valid):
        lat = float(token[tlat])
        lon = float(token[tlon])
        spd = float(token[tspd])
        dir = float(token[tdir])
        prs = float(token[tprs])

    amv_list = [spd,dir,lat,lon,prs]

    return amv_list



def write_txt(file,amv_data):

    amv_num  = np.size(amv_data,axis=1)

    with open(file,'w') as f:
        out_string=file+" spd,dir,lat,lon,prs"
        f.write(out_string)
        f.write("\n")
        i = 0
        while (i<amv_num):
            out_string="{0} {1} {2} {3}
{4}".format(amv_data[0,i],amv_data[1,i],amv_data[2,i],amv_data[3,i],amv_data[4,
i])
            f.write(out_string)
            f.write("\n")

            i +=1
    f.closed

    return

def read_DecodedForecast_MSG(file):

    """Usage: DecFcst = read_DecodedForecast_MSG(file)
    where, e.g.:
    file = '[...]/DecodedForecast_20120503070606Z_20120503120000Z_12_V_MPFS07'
    """

#    Decoded forecast header (4,776 bytes)
#    Decoded_Forecast_Header = BYTARR(4776)

#    Decoded forecast data point (40 bytes)
#    Decoded_Forecast_Point = {Latitude      : FLOAT(0), $
#                              Longitude     : FLOAT(0), $
#                              Pressure      : FLOAT(0), $
#                              Geopotential  : FLOAT(0), $
#                              Temperature   : FLOAT(0), $
#                              WVMixingRatio : FLOAT(0), $
#                              O3MixingRatio : FLOAT(0), $
#                              WindSpeed     : FLOAT(0), $
#                              WindDirection : FLOAT(0), $
#                              DewPointTemp  : FLOAT(0)}
#   Decoded forecast data array (29,160,000 bytes)
#   Decoded_Forecast_Array = REPLICATE(Decoded_Forecast_Point, 40L * 135L *
135L)
```

```
# This could input defined
    num_x = 135
    num_y = 135
    num_var = 10
    num_lev = 40
    num_pt = num_x * num_y
    arrout = np.zeros((num_x,num_y,10,40))

#   Open file and skip header
    fo = open(file)
    fo.seek(4776)

    print "Program is reading decoded forecast data:" + file

#   '>f4' is float which is big-endian
    forecast=np.fromfile(fo,dtype=('>f4'))
    fo.close()
    fore=np.reshape(forecast,(num_pt,num_lev,num_var))

    latitude      = fore[:,:,0]
    longitude     = fore[:,:,1]
    pressure      = fore[:,:,2]
    geopotential  = fore[:,:,3]
    temperature   = fore[:,:,4]
    wvmixingratio = fore[:,:,5]
    o3mixingratio = fore[:,:,6]
    windspeed     = fore[:,:,7]
    winddirection = fore[:,:,8]
    dewpointtemp  = fore[:,:,9]

    for j in range(num_pt):

#hardwired for this input file
        x = np.floor(longitude[j,0] + 67)
        y = np.floor(latitude[j,0] + 67)

        arrout[x,y,0,:] = pressure[j,:]
        arrout[x,y,1,:] = geopotential[j,:]
        arrout[x,y,2,:] = temperature[j,:]
        arrout[x,y,3,:] = wvmixingratio[j,:]
        arrout[x,y,4,:] = o3mixingratio[j,:]
        arrout[x,y,5,:] = windspeed[j,:]
        arrout[x,y,6,:] = winddirection[j,:]
        arrout[x,y,7,:] = dewpointtemp[j,:]
        arrout[x,y,8,:] = latitude[j,:]
        arrout[x,y,9,:] = longitude[j,:]

    return arrout


def locate(amv_data,fcst_data):

    amv_num  = np.size(amv_data,axis=1)
    grid_i = np.zeros(amv_num)
    grid_j = np.zeros(amv_num)
    fcst_lat  = fcst_data[:,:,8,0]
    fcst_lon  = fcst_data[:,:,9,0]
    numx = np.size(fcst_data,axis=0)
    numy = np.size(fcst_data,axis=1)

    n = 0
```

```
    while (n<amv_num):
        amv_lat  = amv_data[2,n]
        amv_lon  = amv_data[3,n]
        grid_diff = (amv_lat-fcst_lat)**2 + (amv_lon-fcst_lon)**2
        indx= np.argmin(grid_diff)
        indx_2d=np.unravel_index(indx,(numx,numy))
        grid_i[n] = indx_2d[0]
        grid_j[n] = indx_2d[1]
        n +=1

    return grid_i,grid_j



def bestfit(amv_data,fcst_data):

    """Finds the background model best fit pressure associated with the AMV.
       The model best fit pressure is the height (in pressure units) where the
       vector difference between the observed AMV and model background is a
       minimum.  This calculation may only work approximately 1/3 of the time.

       Reference:
       Salonen et al (2012), "Characterising AMV height assignment error by
       comparing best fit pressure statistics from the Met Office and ECMWF
       System."  Proceedings of the 11th International Winds Workshop,
       Auckland, New Zealand, 20-24 February 2012.

       Input contained in amv_data and fcst_data:
       amv_spd -  AMV speed m/s
       amv_dir -  AMV direction deg
       amv_prs -  AMV pressure hPa
       fcst_spd - (level) forecast speed m/s
       fcst_dir - (level) forecast direction (deg)
       fcst_prs - (level) forecast pressure (hPa)

       Output:
       amv_bfit - AMV best fit pressure m/s, unconstrained value is undef
       flag - 0 found, 1 not contrained, 2 vec diff minimum not met, 3 failed
to find suitable fcst pressure match

       History:
       10/2012 - Steve Wanzong - Created in Fortran
       10/2013 - Sharon Nebuda - rewritten for python
    """
    undef = -9999.0

    amv_spd = amv_data[0]
    amv_dir = amv_data[1]
    amv_prs = amv_data[4]
    amv_lat = amv_data[2]
    amv_lon = amv_data[3]

    fcst_spd = fcst_data[5,:]
    fcst_dir = fcst_data[6,:]
    fcst_prs = fcst_data[0,:]
    fcst_lat = fcst_data[8,0]
    fcst_lon = fcst_data[9,0]

    fcst_num_levels = fcst_spd.shape[0]

#   verbose = True
```

```
    verbose = False

    SatwindBestFitPress = undef
    SatwindBestFitU = undef
    SatwindBestFitV = undef

    PressDiff = 150.                      # pressure above and below AMV to
look for fit
    TopPress = 50.                        # highest level to allow search

    flag = 3

    #print " AMV location lat,lon,prs
({0},{1},{2})".format(amv_lat,amv_lon,amv_prs)

    if (amv_prs<TopPress):
        if (verbose):
            print " AMV location lat,lon,prs ({0},{1},{2}) is higher than
pressure {3}".format(amv_lat,amv_lon,amv_prs,TopPress)
        return undef

#Calculate the pressure +/- 150 hPa from the AMV pressure.
    PressMax = amv_prs + PressDiff
    PressMin = max((amv_prs-PressDiff),TopPress)

#1d array of indicies to consider for best fit location
    kk = np.where((fcst_prs<PressMax) & (fcst_prs>PressMin))
    if (len(kk[0]) ==0):
        if (verbose):
            print " AMV location lat,lon,prs ({0},{1},{2}) failed to find fcst
prs around AMV".format(amv_lat,amv_lon,amv_prs)
        return undef

#Diagnostic field: Find the model minimum speed and maximum speed within
PressDiff of the AMV.
    if (verbose):
        SatwindMinSpeed = min(fcst_spd[kk])
        SatwindMaxSpeed = max(fcst_spd[kk])

#Compute U anv V for both AMVs and forecast
# fix this
    amv_uwind = -amv_spd * np.sin(math.radians(amv_dir))
    amv_vwind = -amv_spd * np.cos(math.radians(amv_dir))
#   fcst_uwind = -fcst_spd[:] * np.sin(math.radians(fcst_dir[:]))
#   fcst_vwind = -fcst_spd[:] * np.cos(math.radians(fcst_dir[:]))
    dr=0.017453
    fcst_uwind = -fcst_spd * np.sin(dr*fcst_dir)
    fcst_vwind = -fcst_spd * np.cos(dr*fcst_dir)

#Calculate the vector difference between the AMV and model background at all
levels.
    VecDiff = np.sqrt((amv_uwind - fcst_uwind) ** 2 + (amv_vwind - fcst_vwind)
** 2)

#Find the model level of best fit pressure, from the minimum vector difference.
    MinVecDiff = min(VecDiff[kk])
    imin=-1
    for i, item in enumerate(VecDiff):
        if MinVecDiff == VecDiff[i]:
            if i in kk[0]:
                imin = i
```

```
    if (imin ==-1 ):
        if (verbose):
            print " AMV location lat,lon,prs ({0},{1},{2}) failed to find min
vector difference in layers around AMV".format(amv_lat,amv_lon,amv_prs)

        return undef


#Use a parabolic fit to find the best fit pressure.
#p2 - Minimized model pressure at level imin (hPa)
#v2 - Minimized vector difference at level imin (m/s)
#p1 - 1 pressure level lower in atmosphere than p2
#p3 - 1 pressure level above in atmosphere than p2
#v1 - Vector difference 1 pressure level lower than p2
#v3 - Vector difference 1 pressure level above than p2

    p2 = fcst_prs[imin]
    v2 = VecDiff[imin]

# assumes fcst data level 0 at surface and (fcst_num_levels-1) at model top
#if bottom model level
    if imin == 0:
        SatwindBestFitPress = p2
    else:
        p3 = fcst_prs[imin+1]
        p1 = fcst_prs[imin-1]
        v3 = VecDiff[imin+1]
        v1 = VecDiff[imin-1]

#if top of allowed region
        if p3 < TopPress:
            SatwindBestFitPress = p2

#check not collinear
        elif (v1 != v2 and v2 != v3):
            SatwindBestFitPress = p2 - (0.5 *
            ((((p2 - p1) * (p2 - p1) * (v2 - v3)) - ((p2 - p3) * (p2 - p3) *
(v2 - v1))) /
            (((p2 - p1) * (v2 - v3)) - ((p2 - p3) * (v2 - v1)))))
            if (SatwindBestFitPress < p3) or (SatwindBestFitPress > p1):
                if (verbose):
                    print " Best Fit not found between two pressure layers"
                    print " SatwindBestFitPress {0} p1 {1} p2 {2} p3 {3} imin
{4} ".format(SatwindBestFitPress,p1,p2,p3,imin)
                SatwindBestFitPress = p2
        else:
            SatwindBestFitPress = p2

#Find best fit U and V by linear interpolation.
    if (verbose):
        if p2 == SatwindBestFitPress:
            SatwindBestFitU = fcst_uwind[imin]
            SatwindBestFitV = fcst_vwind[imin]
        else:
            if p2 < SatwindBestFitPress:
                LevBelow = imin - 1
                LevAbove = imin
                Prop = (SatwindBestFitPress - p1) / (p2 - p1)
            else:
                LevBelow = imin
```

```
                LevAbove = imin + 1
                Prop = (SatwindBestFitPress - p2) / (p3 - p2)

            SatwindBestFitU = fcst_uwind[LevBelow] * (1.0 - Prop) +
fcst_vwind[LevAbove] * Prop
            SatwindBestFitV = fcst_uwind[LevBelow] * (1.0 - Prop) +
fcst_vwind[LevAbove] * Prop


# Check to see if the best fit pressure is constrained.

    SatwindGoodConstraint = 0
    flag = 2

    if MinVecDiff <= 4.0:

        SatwindGoodConstraint = 1
        flag = 1

        for ilev in range(fcst_num_levels):
            if fcst_prs[ilev] >= TopPress:

                if ((fcst_prs[ilev] < (SatwindBestFitPress - 100.)) or  \
                   (fcst_prs[ilev] > (SatwindBestFitPress + 100.))) and  \
                   (VecDiff[ilev] <= (MinVecDiff + 2.0)):
                   SatwindGoodConstraint = 0

    if SatwindGoodConstraint == 1:
        amv_bfit = SatwindBestFitPress
        flag = 0
    else:
        amv_bfit = undef

    if (verbose):
        print "*** AMV best fit ***"
        print "AMV -> p/minspd/maxspd: {0} {1}
{2}".format(amv_prs,SatwindMinSpeed,SatwindMaxSpeed)
        print "Bestfit -> p1,p2,p3,v1,v2,v3: {0} {1} {2} {3} {4}
{5}".format(p1,p2,p3,v1,v2,v3)
        print "Bestfit -> pbest,bfu,bfv,obu,obv,bgu,bgv: {0} {1} {2} {3} {4}
{5} {6}".format(

SatwindBestFitPress,SatwindBestFitU,SatwindBestFitV,amv_uwind,amv_vwind,fcst_uw
ind[imin],fcst_vwind[imin])
        print "Good Constraint: {0}".format(SatwindGoodConstraint)
        print "Minimum Vector Difference: {0}".format(VecDiff[imin])
        print "Vector Difference Profile: "
        print VecDiff
        print "Pressure Profile: "
        print fcst_prs

        if (abs(SatwindBestFitU - amv_uwind) > 4.0) or  (abs(SatwindBestFitV -
amv_vwind) > 4.0):
            print 'U Diff: {0}'.format(abs(SatwindBestFitU - amv_uwind))
            print 'V Diff: {0}'.format(abs(SatwindBestFitV - amv_vwind))

    return amv_bfit,flag
```

20. Appendix G: Matlab Scripts

The Matlab scripts were similar to the ones used by Iliana Genkova in the earlier AMV intercomparison studies, but were modified to:

- Use distance in kilometers instead of degrees of latitude and longitude for determining collocated AMVs.
- Truncate or round values for better comparison if producers reported values with differing precision.

Winds_Bulk_QINF.m

On 'tinman' 8 June 2014: /Users/daves/Documents/MATLAB/Intercomparison

```
% old data colums - see email to Dave Stettner
% doublecheck.... test with new data, sent away!

% new data columns
% 1. IDN
% 2. LAT[DEG]
% 3. LONG[DEG]
% 4. TBOX[PIX]
% 5. SBOX[PIX]
% 6. SPD[MPS]
% 7. DIR[DEG]
% 8. P[HPA]
% 9. LOWL
% 10.MSPD[MPS]
% 11.MDIR[DEG]
% 12.ALB[%]
% 13.CORR[%]
% 14.TMET
% 15.PERR[HPA]
% 16.HMET
% 17.QINF[%]
% 18.QIF[%]

clear;

% Set exp: 2,3,4
exp=4

qitype=17  % QI with forecast (18) or without (17)

if (exp == 2 )
    fall= {'BrazilDatasetTwo.csv',  'EUMETSATDatasetTwo.csv',
'JapanDatasetTwoNew.csv', 'KoreaDatasetTwo.csv', 'NOAADatasetTwo.csv',
'NWCSAFDatasetTwo_O_ET_E.csv',};
    fsym= {'b.'                  , 'ro'                      , 'y'
, 'g^'                  , 'k+'                  , 'ms'};
    tbsize=[32 24 24 24 19 24];
end

if (exp == 3 )
   fall= {'BrazilDatasetThree.csv', 'EUMETSATDatasetThree.csv',
'JapanDatasetThreeNew.csv', 'KoreaDatasetThree.csv', 'NOAADatasetThree.csv',
'NWCSAFDatasetThree_P_ET_E.csv',};
```

```
   fsym= {'b.'                    , 'ro'                      ,  'y'
, 'g^'                  , 'k+'                  , 'ms'};
   tbsize=[24 24 24 24 24 24];
end

if (exp == 4 )
    fall= {'BrazilDatasetFour.csv', 'EUMETSATDatasetFour.csv',
'JapanDatasetFourNew.csv', 'KoreaDatasetFour.csv', 'NOAADatasetFour.csv',
'NWCSAFDatasetFour_O_C_E.csv',};
    fsym= {'b.'                    , 'ro'                      , 'y'
, 'g^'                  , 'k+'                  , 'ms'};
    tbsize=[24 24 24 24 24 24];
end

%    figure;

for i=1:6
    fname=fall{i};
    a=load(fname);

    %Remove records with invalid pressure
    abad=find(a(:,8)==0);
    a(abad,:)=[];

    %Remove records with invalid latitude
    abad=find(a(:,2) >  90);
    a(abad,:)=[];
    abad=find(a(:,2) < -90);
    a(abad,:)=[];

    spd25=find(a(:,6)>=2.5);
    a=a(spd25,:);

    % Scale JMA QI 0 to 100

    if ( i == 3)
        a(:,qitype)=a(:,qitype)*100.;
    end

    good_50=find(a(:,qitype)>=50);
    good_80=find(a(:,qitype)>=80);
    figure;
    subplot(2,3,1);
    hold on;
    plot(a(:,3),a(:,2),'r.');
    plot(a(good_50,3),a(good_50,2),'b.');
    plot(a(good_80,3),a(good_80,2),'g.');
    legend('All AMV','QI>=50','QI>=80');
    xlabel('Lon');
    ylabel('Lat');
    title(fname);
%     plot(a(good_80,3),a(good_80,2),fsym{i});
     xlim([-50  50])
     ylim([-50  50])
%     hold on;
    disp('*************************');
    disp(fname);
    fprintf('Target box size in pixels: %d \n',tbsize(i));
    fprintf('Total num winds: %d \n',length(a(:,1)));
    fprintf('Winds QI>=50: %d \n',length(good_50));
    fprintf('Winds QI>=80: %d \n',length(good_80));
```

```
fprintf('Lat_min, %6.2f \n', min(a(:,2)));
fprintf('Lat_max, %6.2f \n', max(a(:,2)));
fprintf('Lon_min, %6.2f \n', min(a(:,3)));
fprintf('Lon_max, %6.2f \n', max(a(:,3)));

fprintf(' \n');
fprintf('*** For AMV with QI>=50 ***\n');

alow=find(a(good_50,8)>=700);
amid=find(a(good_50,8)<700 & a(good_50,8)>400);
ahigh=find(a(good_50,8)<=400);

fprintf('SPD_min, %6.2f \n', min(a(good_50,6)));
fprintf('SPD_max, %6.2f \n', max(a(good_50,6)));
fprintf('SPD_mean, %6.2f \n', mean(a(good_50,6)));

fprintf('P_min, %6.2f \n', min(a(good_50,8)));
fprintf('P_max, %6.2f \n', max(a(good_50,8)));
fprintf('P_mean, %6.2f \n', mean(a(good_50,8)));

fprintf('Low_winds, %6.2f \n', 100*length(alow)/length(good_50) );
fprintf('Mid_winds, %6.2f \n', 100*length(amid)/length(good_50) );
fprintf('High_winds, %6.2f \n', 100*length(ahigh)/length(good_50) );

aa=a(good_50,:);
fprintf('Low_SPD_min, %6.2f \n', min(aa(alow,6)));
fprintf('Low_SPD_max, %6.2f \n', max(aa(alow,6)));
fprintf('Low_SPD_mean, %6.2f \n', mean(aa(alow,6)));

fprintf('Low_P_min, %6.2f \n', min(aa(alow,8)));
fprintf('Low_P_max, %6.2f \n', max(aa(alow,8)));
fprintf('Low_P_mean, %6.2f \n', mean(aa(alow,8)));

fprintf('Mid_SPD_min, %6.2f \n', min(aa(amid,6)));
fprintf('Mid_SPD_max, %6.2f \n', max(aa(amid,6)));
fprintf('Mid_SPD_mean, %6.2f \n', mean(aa(amid,6)));

fprintf('Mid_P_min, %6.2f \n', min(aa(amid,8)));
fprintf('Mid_P_max, %6.2f \n', max(aa(amid,8)));
fprintf('Mid_P_mean, %6.2f \n', mean(aa(amid,8)));

fprintf('High_SPD_min, %6.2f \n', min(aa(ahigh,6)));
fprintf('High_SPD_max, %6.2f \n', max(aa(ahigh,6)));
fprintf('High_SPD_mean, %6.2f \n', mean(aa(ahigh,6)));

fprintf('High_P_min, %6.2f \n', min(aa(ahigh,8)));
fprintf('High_P_max, %6.2f \n', max(aa(ahigh,8)));
fprintf('High_P_mean, %6.2f \n', mean(aa(ahigh,8)));

subplot(2,3,2);
hist(a(good_50,qitype),11); % QI
v=axis;
axis([50 100 v(3) v(4)]);
title(['QI' ' ' fname]);

subplot(2,3,3);
hist(a(good_50,6),11); % SPD
v=axis;
axis([0 100 v(3) v(4)]);
title(['SPD' ' ' fname]);
```

```
    subplot(2,3,4);
    hist(a(good_50,7),45); % DIR
    v=axis;
    axis([0 360 v(3) v(4)]);
    title(['DIR' ' ' fname]);

    subplot(2,3,5);
    hist(a(good_50,8),21); % H
    v=axis;
    axis([100 1000 v(3) v(4)]);
    title(['P' ' ' fname]);

    if ( exp == 2)
        saveas(gcf, ['Exp_2_QINF_' fname(1:6)], 'tif');
    end

    if ( exp == 3)
        saveas(gcf, ['Exp_3_QINF_' fname(1:6)], 'tif');
    end

    if ( exp == 4)
        saveas(gcf, ['Exp_4_QINF_' fname(1:6)], 'tif');
    end

% THIS section doesn't make sense with the new data sets, as they don't have
Height Assignment Method. Best to be deleted.
% %     subplot(2,3,6);
% %     aa=a(good_50,:);
% %     if i==1
% %         ind_0=find( a(good_50,26)==1 );
% %         aa(ind_0,26)=0;
% %         ind_1=find( a(good_50,26)==14 );
% %         aa(ind_1,26)=1;
% %         ind_2=find( a(good_50,26)==2 |  a(good_50,26)==3 |
a(good_50,26)==4 |  a(good_50,26)==5 );
% %         aa(ind_2,26)=2;
% %     end;
% %     hist(aa(:,26),0:3); % HAM
% %     title(['HAM' ' ' fname]);

      %saveas(gcf,['bulk_' fname(1:3) '.tif'],'tif');

%     figure;
%     hist(a(good_50,2)); % Lat (zonal distribution)
%     title(['Lat' ' ' fname]);
%     saveas(gcf,['hist_lat_' fname(1:3) '.tif'],'tif');
%
%     figure;
%     hist(a(good_50,3)); % Lon
%     title(['Lon' ' ' fname]);
%     saveas(gcf,['hist_lon_' fname(1:3) '.tif'],'tif');
%

%     pause;
%     keyboard;

end;
```

Winds_Bulk_QIF.m

On 'tinman' 8 June 2014: /Users/daves/Documents/MATLAB/Intercomparison

```
% old data colums - see email to Dave Stettner
% doublecheck.... test with new data, sent away!

% new data columns
% 1. IDN
% 2. LAT[DEG]
% 3. LONG[DEG]
% 4. TBOX[PIX]
% 5. SBOX[PIX]
% 6. SPD[MPS]
% 7. DIR[DEG]
% 8. P[HPA]
% 9. LOWL
% 10.MSPD[MPS]
% 11.MDIR[DEG]
% 12.ALB[%]
% 13.CORR[%]
% 14.TMET
% 15.PERR[HPA]
% 16.HMET
% 17.QINF[%]
% 18.QIF[%]

clear;

% Set exp: 2,3,4
exp=4

qitype=18  % QI with forecast (18) or without (17)

if (exp == 2 )
    fall= {'ChinaDatasetTwoNew.csv',  'EUMETSATDatasetTwo.csv',
'JapanDatasetTwoNew.csv', 'KoreaDatasetTwo.csv', 'NOAADatasetTwo.csv',
'NWCSAFDatasetTwo_O_ET_E.csv',};
    fsym= {'b.'                  , 'ro'                      , 'y'
, 'g^'                  , 'k+'                  , 'ms'};
    tbsize=[32 24 24 24 19 24];
end

if (exp == 3 )
   fall= {'ChinaDatasetThreeNew.csv', 'EUMETSATDatasetThree.csv',
'JapanDatasetThreeNew.csv', 'KoreaDatasetThree.csv', 'NOAADatasetThree.csv',
'NWCSAFDatasetThree_P_ET_E.csv',};
   fsym= {'b.'                   , 'ro'                       ,  'y'
, 'g^'                   , 'k+'                   , 'ms'};
   tbsize=[24 24 24 24 24 24];
end

if (exp == 4 )
    fall= {'ChinaDatasetFourNew.csv', 'EUMETSATDatasetFour.csv',
'JapanDatasetFourNew.csv', 'KoreaDatasetFour.csv', 'NOAADatasetFour.csv',
'NWCSAFDatasetFour_O_C_E.csv',};
    fsym= {'b.'                   , 'ro'                       , 'y'
, 'g^'                   , 'k+'                   , 'ms'};
    tbsize=[24 24 24 24 24 24];
end
```

```
%    figure;
for i=1:6
    fname=fall{i};
    a=load(fname);

    %Remove records with invalid pressure
    abad=find(a(:,8)==0);
    a(abad,:)=[];

    %Remove records with invalid latitude
    abad=find(a(:,2) >  90);
    a(abad,:)=[];
    abad=find(a(:,2) < -90);
    a(abad,:)=[];

    spd25=find(a(:,6)>=2.5);
    a=a(spd25,:);

    % Scale JMA QI 0 to 100

    if ( i == 3)
        a(:,qitype)=a(:,qitype)*100.;
    end

    good_50=find(a(:,qitype)>=50);
    good_80=find(a(:,qitype)>=80);
    figure;
    subplot(2,3,1);
    hold on;
    plot(a(:,3),a(:,2),'r.');
    plot(a(good_50,3),a(good_50,2),'b.');
    plot(a(good_80,3),a(good_80,2),'g.');
    legend('All AMV','QI>=50','QI>=80');
    xlabel('Lon');
    ylabel('Lat');
    title(fname);
%     plot(a(good_80,3),a(good_80,2),fsym{i});
     xlim([-50  50])
     ylim([-50  50])
%     hold on;
    disp('***************************');
    disp(fname);
    fprintf('Target box size in pixels: %d \n',tbsize(i));
    fprintf('Total num winds: %d \n',length(a(:,1)));
    fprintf('Winds QI>=50: %d \n',length(good_50));
    fprintf('Winds QI>=80: %d \n',length(good_80));

    fprintf('Lat_min, %6.2f \n', min(a(:,2)));
    fprintf('Lat_max, %6.2f \n', max(a(:,2)));
    fprintf('Lon_min, %6.2f \n', min(a(:,3)));
    fprintf('Lon_max, %6.2f \n', max(a(:,3)));

    fprintf(' \n');
    fprintf('*** For AMV with QI>=50 ***\n');

    alow=find(a(good_50,8)>=700);
    amid=find(a(good_50,8)<700 & a(good_50,8)>400);
    ahigh=find(a(good_50,8)<=400);

    fprintf('SPD_min, %6.2f \n', min(a(good_50,6)));
```

```
fprintf('SPD_max, %6.2f \n', max(a(good_50,6)));
fprintf('SPD_mean, %6.2f \n', mean(a(good_50,6)));

fprintf('P_min, %6.2f \n', min(a(good_50,8)));
fprintf('P_max, %6.2f \n', max(a(good_50,8)));
fprintf('P_mean, %6.2f \n', mean(a(good_50,8)));

fprintf('Low_winds, %6.2f \n', 100*length(alow)/length(good_50) );
fprintf('Mid_winds, %6.2f \n', 100*length(amid)/length(good_50) );
fprintf('High_winds, %6.2f \n', 100*length(ahigh)/length(good_50) );

aa=a(good_50,:);
fprintf('Low_SPD_min, %6.2f \n', min(aa(alow,6)));
fprintf('Low_SPD_max, %6.2f \n', max(aa(alow,6)));
fprintf('Low_SPD_mean, %6.2f \n', mean(aa(alow,6)));

fprintf('Low_P_min, %6.2f \n', min(aa(alow,8)));
fprintf('Low_P_max, %6.2f \n', max(aa(alow,8)));
fprintf('Low_P_mean, %6.2f \n', mean(aa(alow,8)));

fprintf('Mid_SPD_min, %6.2f \n', min(aa(amid,6)));
fprintf('Mid_SPD_max, %6.2f \n', max(aa(amid,6)));
fprintf('Mid_SPD_mean, %6.2f \n', mean(aa(amid,6)));

fprintf('Mid_P_min, %6.2f \n', min(aa(amid,8)));
fprintf('Mid_P_max, %6.2f \n', max(aa(amid,8)));
fprintf('Mid_P_mean, %6.2f \n', mean(aa(amid,8)));

fprintf('High_SPD_min, %6.2f \n', min(aa(ahigh,6)));
fprintf('High_SPD_max, %6.2f \n', max(aa(ahigh,6)));
fprintf('High_SPD_mean, %6.2f \n', mean(aa(ahigh,6)));

fprintf('High_P_min, %6.2f \n', min(aa(ahigh,8)));
fprintf('High_P_max, %6.2f \n', max(aa(ahigh,8)));
fprintf('High_P_mean, %6.2f \n', mean(aa(ahigh,8)));

subplot(2,3,2);
hist(a(good_50,qitype),11); % QI
v=axis;
axis([50 100 v(3) v(4)]);
title(['QI' ' ' fname]);

subplot(2,3,3);
hist(a(good_50,6),11); % SPD
v=axis;
axis([0 100 v(3) v(4)]);
title(['SPD' ' ' fname]);

subplot(2,3,4);
hist(a(good_50,7),45); % DIR
v=axis;
axis([0 360 v(3) v(4)]);
title(['DIR' ' ' fname]);

subplot(2,3,5);
hist(a(good_50,8),21); % H
v=axis;
axis([100 1000 v(3) v(4)]);
title(['P' ' ' fname]);

if ( exp == 2)
```

```
        saveas(gcf, ['Exp_2_QIF_' fname(1:6)], 'tif');
    end

    if ( exp == 3)
        saveas(gcf, ['Exp_3_QIF_' fname(1:6)], 'tif');
    end

    if ( exp == 4)
        saveas(gcf, ['Exp_4_QIF_' fname(1:6)], 'tif');
    end

% THIS section doesn't make sense with the new data sets, as they don't have
Height Assignment Method. Best to be deleted.
% %     subplot(2,3,6);
% %     aa=a(good_50,:);
% %     if i==1
% %         ind_0=find( a(good_50,26)==1 );
% %         aa(ind_0,26)=0;
% %         ind_1=find( a(good_50,26)==14 );
% %         aa(ind_1,26)=1;
% %         ind_2=find( a(good_50,26)==2 |  a(good_50,26)==3 |
a(good_50,26)==4 |  a(good_50,26)==5 );
% %         aa(ind_2,26)=2;
% %     end;
% %     hist(aa(:,26),0:3); % HAM
% %     title(['HAM' ' ' fname]);

      %saveas(gcf,['bulk_' fname(1:3) '.tif'],'tif');

%     figure;
%     hist(a(good_50,2)); % Lat (zonal distribution)
%     title(['Lat' ' ' fname]);
%     saveas(gcf,['hist_lat_' fname(1:3) '.tif'],'tif');
%
%     figure;
%     hist(a(good_50,3)); % Lon
%     title(['Lon' ' ' fname]);
%     saveas(gcf,['hist_lon_' fname(1:3) '.tif'],'tif');
%

%     pause;
%     keyboard;

end;
```

Winds_Match_QIF.m

On 'tinman' 22 June 2014: /Users/daves/Documents/MATLAB/Intercomparison

```
% collocation of the cgms study datastes - search for a spatial match
% within less than a specified distance

clear;

% Set exp: 2,3,4
exp=4

qitype=18  % QI with forecast (18) or without (17)
dist=55    % Distance in km
qi=50      % QI threshold

if (exp == 2 )
   fall= {'EUMETSATDatasetTwo.csv',  'ChinaDatasetTwoNew.csv',
'JapanDatasetTwoNew.csv', 'NOAADatasetTwo.csv' , 'KoreaDatasetTwo.csv',
'NWCSAFDatasetTwo_O_ET_E.csv'};
   tbsize=[24 32 24 19 24 24];
end

if (exp == 3 )
   fall= {'EUMETSATDatasetThree.csv', 'ChinaDatasetThreeNew.csv',
'JapanDatasetThreeNew.csv', 'NOAADatasetThree.csv' , 'KoreaDatasetThree.csv',
'NWCSAFDatasetThree_P_ET_E.csv'};
   tbsize=[24 32 24 19 24 24];
end

if (exp == 4 )
   fall= {'EUMETSATDatasetFour.csv', 'ChinaDatasetFourNew.csv',
'JapanDatasetFourNew.csv', 'NOAADatasetFour.csv' , 'KoreaDatasetFour.csv',
'NWCSAFDatasetFour_O_C_E.csv'};
   tbsize=[24 24 24 24 24 24];
end

fsym= {'b.'                     ,  'r.'                  , 'g.'
, 'k.'                  , 'm.'                  , 'y.' };

set_eum=load(fall{1});
set_cma=load(fall{2});
set_jma=load(fall{3});
set_noa=load(fall{4});
set_kma=load(fall{5});
set_nwc_temp=load(fall{6});

set_nwc=sortrows(set_nwc_temp,6);

qivar=[];
qivar=find(set_eum(:,qitype)>=qi);
set_eum=set_eum(qivar,:);
qivar=[];
qivar=find(set_kma(:,qitype)>=qi);
set_kma=set_kma(qivar,:);
qivar=[];
qivar=find(set_cma(:,qitype)>=qi);
set_cma=set_cma(qivar,:);
qivar=[];
qivar=find(set_noa(:,qitype)>=qi);
```

```
set_noa=set_noa(qivar,:);
qivar=[];
qivar=find(set_nwc(:,qitype)>=qi);
set_nwc=set_nwc(qivar,:);
qivar=[];
set_jma(:,qitype)=set_jma(:,qitype)*100.;
qivar=find(set_jma(:,qitype)>=qi);
set_jma=set_jma(qivar,:);


i_out=0;

for i_amv=1:length(set_nwc(:,1))
%   disp(i_amv)

    [val1, loc1]=min( deg2km(distance(set_eum(:,2), set_eum(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

    if val1 < dist

            [val2, loc2]=min( deg2km(distance(set_cma(:,2), set_cma(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

            if val2 < dist

                [val3, loc3]=min( deg2km(distance(set_jma(:,2), set_jma(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                if val3 < dist

                    [val4, loc4]=min( deg2km(distance(set_noa(:,2),
set_noa(:,3), set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                    if val4 < dist

                        [val5, loc5]=min( deg2km(distance(set_kma(:,2),
set_kma(:,3), set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                        if val5 < dist

                    i_out=i_out+1;
                    set_out_lat(i_out,:) =[ set_eum(loc1,02) set_kma(loc5,02)
set_cma(loc2,02)  set_noa(loc4,02) set_nwc(i_amv,02) set_jma(loc3,02) ];
                    set_out_lon(i_out,:) =[ set_eum(loc1,03) set_kma(loc5,03)
set_cma(loc2,03)  set_noa(loc4,03) set_nwc(i_amv,03) set_jma(loc3,03) ];
                    set_out_spd(i_out,:) =[ set_eum(loc1,06) set_kma(loc5,06)
set_cma(loc2,06)  set_noa(loc4,06) set_nwc(i_amv,06) set_jma(loc3,06) ];
                    set_out_dir(i_out,:) =[ set_eum(loc1,07) set_kma(loc5,07)
set_cma(loc2,07)  set_noa(loc4,07) set_nwc(i_amv,07) set_jma(loc3,07) ];
                    set_out_pres(i_out,:)=[ set_eum(loc1,08) set_kma(loc5,08)
set_cma(loc2,08)  set_noa(loc4,08) set_nwc(i_amv,08) set_jma(loc3,08) ];
                    set_out_ham(i_out,:) =[ set_eum(loc1,16) set_kma(loc5,16)
set_cma(loc2,16)  set_noa(loc4,16) set_nwc(i_amv,16) set_jma(loc3,16) ];
                    set_out_qi(i_out,:)  =[ set_eum(loc1,qitype)
set_kma(loc5,qitype) set_cma(loc2,qitype)  set_noa(loc4,qitype)
set_nwc(i_amv,qitype) set_jma(loc3,qitype) ];

                    end;
                end;
            end;
        end
```

```
    end;
end;

disp('**************');
disp(i_out);

figure;
x=1:i_out;
subplot(4,1,1);
plot(x,set_out_spd(:,1),fsym{1},x,set_out_spd(:,2),fsym{2},x,
set_out_spd(:,3),fsym{3},x,set_out_spd(:,4),fsym{4},x,set_out_spd(:,5),fsym{5},
x, set_out_spd(:,6), fsym{6} );
legend('EUM', 'KMA', 'CMA', 'NOA', 'NWC', 'JMA');
subplot(4,1,2);
plot(x,set_out_dir(:,1),fsym{1},x,set_out_dir(:,2),fsym{2},x,
set_out_dir(:,3),fsym{3},x,set_out_dir(:,4),fsym{4},x,set_out_dir(:,5),fsym{5},
x, set_out_dir(:,6),fsym{6} );
subplot(4,1,3);
plot(x,set_out_pres(:,1),fsym{1},x,set_out_pres(:,2),fsym{2},x,
set_out_pres(:,3),fsym{3},x,set_out_pres(:,4),fsym{4},x,set_out_pres(:,5),fsym{
5},x, set_out_pres(:,6),fsym{6} );
subplot(4,1,4);
plot(x,set_out_qi(:,1),fsym{1},x,set_out_qi(:,2),fsym{2},x,
set_out_qi(:,3),fsym{3},x,set_out_qi(:,4),fsym{4},x,set_out_qi(:,5),fsym{5},x,s
et_out_qi(:,6),fsym{6} );

if ( exp == 2)
   saveas(gcf,'Exp_2_qif_all.tif','tif');
end

if ( exp == 3)
   saveas(gcf,'Exp_3_qif_all.tif','tif');
end

if ( exp == 4)
   saveas(gcf,'Exp_4_qif_all.tif','tif');
end

figure;
plot(set_out_pres(:,1),set_out_pres(:,2),'r.',set_out_pres(:,1),
set_out_pres(:,3),'g.', set_out_pres(:,1), set_out_pres(:,4),'k.',
set_out_pres(:,1), set_out_pres(:,5),'m.', set_out_pres(:,1),
set_out_pres(:,6),'y.');
legend('EUM vs KMA','EUM vs CMA',' EUM vs NOA','EUM vs NWC', 'EUM vs JMA');
xlabel('Pressure (EUM)');
ylabel('Pressure (Centres)');
title('Scatter Plot of Cloud Height');

if ( exp == 2)
   saveas(gcf,'Exp_2_qif_pres_scat.tif','tif');
end

if ( exp == 3)
   saveas(gcf,'Exp_3_qif_pres_scat.tif','tif');
end

if ( exp == 4)
   saveas(gcf,'Exp_4_qif_pres_scat.tif','tif');
end

figure;
```

```
plot(x,abs(max(set_out_pres')-min(set_out_pres')),'.');
xlabel('AMV Number');
ylabel('Pressure difference');
title('Maximum Pressure difference');

if ( exp == 2)
   saveas(gcf,'Exp_2_qif_pres_hist.tif','tif');
end

if ( exp == 3)
   saveas(gcf,'Exp_3_qif_pres_hist.tif','tif');
end

if ( exp == 4)
   saveas(gcf,'Exp_4_qif_pres_hist.tif','tif');
end

set_out_names = {'EUMETSAT', 'Korea', 'China', 'NOAA', 'NWCSAF', 'Japan'}

set_out_spd1 = [set_out_spd(:,1), set_out_spd(:,2), set_out_spd(:,3),
set_out_spd(:,4), set_out_spd(:,5), set_out_spd(:,6),
((set_out_spd(:,1)+set_out_spd(:,6)+set_out_spd(:,2))/3)];
fall1 = {'EUMETSAT', 'Korea', 'China', 'NOAA', 'NWCSAF', 'Japan', 'Correct'}

set_out_qi1 = [set_out_qi(:,1), set_out_qi(:,2), set_out_qi(:,3),
set_out_qi(:,4), set_out_qi(:,5), set_out_qi(:,6),
((set_out_qi(:,3)+set_out_qi(:,5))/2)];

for i=1:5
    for n=i:5
        fprintf('%s "VS" %s \n', set_out_names{i}, set_out_names{n+1});
        [h,p,ci,stats]=ttest(set_out_spd(:,i),set_out_spd(:,n+1));
        fprintf('  Speed:     h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n',
h, p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_dir(:,i),set_out_dir(:,n+1));
        fprintf('  Direction: h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n',
h, p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_pres(:,i),set_out_pres(:,n+1));
        fprintf('  Pressure:  h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n',
h, p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_qi(:,i),set_out_qi(:,n+1));
        fprintf('  QI:        h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f
\n\n', h, p, ci(1), ci(2), (ci(1)+ci(2))/2);
    end;
end;



%
% %"Correct" Speed Comparison
% for i=1:6
%     fprintf('%s %s \n', 'Speed Correct VS.', fall1{i});
%     [h,p,ci,stats]=ttest(set_out_spd1(:,7),set_out_spd1(:,i));
%     fprintf('Speed "Correct": h = %d, p = %f, ci = %f %f, Mean: %f \n', h, p,
ci(1), ci(2), mean(set_out_spd1(:,7)-set_out_spd1(:,i)));
% end;
% fprintf('\n');
```

```
% "Correct" QI Comparision
for i=1:6
    fprintf('%s %s \n', 'QI Correct VS.', fall1{i});
    [h,p,ci,stats]=ttest(set_out_qi1(:,7),set_out_qi1(:,i));
    fprintf('Speed "Correct": h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n',
h, p, ci(1), ci(2), mean(set_out_qi1(:,7)-set_out_qi1(:,i)));
end;
```

Winds_Match_QINF.m

On 'tinman' 26 June 2014: /Users/daves/Documents/MATLAB/Intercomparison

```
% collocation of the cgms study datastes - search for a spatial match
% within less than a specified distance

clear;

% Set exp: 2,3,4
exp=4

qitype=17  % QI with forecast (18) or without (17)
dist=55    % Distance in km
qi=50      % QI threshold

if (exp == 2 )
   fall= {'EUMETSATDatasetTwo.csv',  'BrazilDatasetTwo.csv',
'JapanDatasetTwoNew.csv', 'NOAADatasetTwo.csv' , 'KoreaDatasetTwo.csv',
'NWCSAFDatasetTwo_O_ET_E.csv'};
   tbsize=[24 32 24 19 24 24];
end

if (exp == 3 )
   fall= {'EUMETSATDatasetThree.csv', 'BrazilDatasetThree.csv',
'JapanDatasetThreeNew.csv', 'NOAADatasetThree.csv' , 'KoreaDatasetThree.csv',
'NWCSAFDatasetThree_P_ET_E.csv'};
   tbsize=[24 32 24 19 24 24];
end

if (exp == 4 )
   fall= {'EUMETSATDatasetFour.csv', 'BrazilDatasetFour.csv',
'JapanDatasetFourNew.csv', 'NOAADatasetFour.csv' , 'KoreaDatasetFour.csv',
'NWCSAFDatasetFour_O_C_E.csv'};
   tbsize=[24 24 24 24 24 24];
end

fsym= {'b.'                    ,  'r.'                  , 'g.'
, 'k.'                 , 'm.'                 , 'y.' };

set_eum=load(fall{1});
set_brz=load(fall{2});
set_jma=load(fall{3});
set_noa=load(fall{4});
set_kma=load(fall{5});
set_nwc_temp=load(fall{6});

set_nwc=sortrows(set_nwc_temp,6);

qivar=[];
qivar=find(set_eum(:,qitype)>=qi);
set_eum=set_eum(qivar,:);
qivar=[];
qivar=find(set_kma(:,qitype)>=qi);
set_kma=set_kma(qivar,:);
qivar=[];
qivar=find(set_brz(:,qitype)>=qi);
set_brz=set_brz(qivar,:);
qivar=[];
qivar=find(set_noa(:,qitype)>=qi);
```

```
set_noa=set_noa(qivar,:);
qivar=[];
qivar=find(set_nwc(:,qitype)>=qi);
set_nwc=set_nwc(qivar,:);
qivar=[];
set_jma(:,qitype)=set_jma(:,qitype)*100.;
qivar=find(set_jma(:,qitype)>=qi);
set_jma=set_jma(qivar,:);


i_out=0;

for i_amv=1:length(set_nwc(:,1))
%   disp(i_amv)

    [val1, loc1]=min( deg2km(distance(set_eum(:,2), set_eum(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

    if val1 < dist

            [val2, loc2]=min( deg2km(distance(set_brz(:,2), set_brz(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

            if val2 < dist

                [val3, loc3]=min( deg2km(distance(set_jma(:,2), set_jma(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                if val3 < dist

                    [val4, loc4]=min( deg2km(distance(set_noa(:,2),
set_noa(:,3), set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                    if val4 < dist

                        [val5, loc5]=min( deg2km(distance(set_kma(:,2),
set_kma(:,3), set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                        if val5 < dist

                    i_out=i_out+1;
                    set_out_lat(i_out,:) =[ set_eum(loc1,02) set_kma(loc5,02)
set_brz(loc2,02)  set_noa(loc4,02) set_nwc(i_amv,02) set_jma(loc3,02) ];
                    set_out_lon(i_out,:) =[ set_eum(loc1,03) set_kma(loc5,03)
set_brz(loc2,03)  set_noa(loc4,03) set_nwc(i_amv,03) set_jma(loc3,03) ];
                    set_out_spd(i_out,:) =[ set_eum(loc1,06) set_kma(loc5,06)
set_brz(loc2,06)  set_noa(loc4,06) set_nwc(i_amv,06) set_jma(loc3,06) ];
                    set_out_dir(i_out,:) =[ set_eum(loc1,07) set_kma(loc5,07)
set_brz(loc2,07)  set_noa(loc4,07) set_nwc(i_amv,07) set_jma(loc3,07) ];
                    set_out_pres(i_out,:)=[ set_eum(loc1,08) set_kma(loc5,08)
set_brz(loc2,08)  set_noa(loc4,08) set_nwc(i_amv,08) set_jma(loc3,08) ];
                    set_out_ham(i_out,:) =[ set_eum(loc1,16) set_kma(loc5,16)
set_brz(loc2,16)  set_noa(loc4,16) set_nwc(i_amv,16) set_jma(loc3,16) ];
                    set_out_qi(i_out,:)  =[ set_eum(loc1,qitype)
set_kma(loc5,qitype) set_brz(loc2,qitype)  set_noa(loc4,qitype)
set_nwc(i_amv,qitype) set_jma(loc3,qitype) ];

                    end;
                end;
            end;
        end
```

```
    end;
end;

disp('**************');
disp(i_out);

figure;
x=1:i_out;
subplot(4,1,1);
plot(x,set_out_spd(:,1),fsym{1},x,set_out_spd(:,2),fsym{2},x,
set_out_spd(:,3),fsym{3},x,set_out_spd(:,4),fsym{4},x,set_out_spd(:,5),fsym{5},
x, set_out_spd(:,6), fsym{6} );
legend('EUM', 'KMA', 'BRZ', 'NOA', 'NWC', 'JMA');
subplot(4,1,2);
plot(x,set_out_dir(:,1),fsym{1},x,set_out_dir(:,2),fsym{2},x,
set_out_dir(:,3),fsym{3},x,set_out_dir(:,4),fsym{4},x,set_out_dir(:,5),fsym{5},
x, set_out_dir(:,6),fsym{6} );
subplot(4,1,3);
plot(x,set_out_pres(:,1),fsym{1},x,set_out_pres(:,2),fsym{2},x,
set_out_pres(:,3),fsym{3},x,set_out_pres(:,4),fsym{4},x,set_out_pres(:,5),fsym{
5},x, set_out_pres(:,6),fsym{6} );
subplot(4,1,4);
plot(x,set_out_qi(:,1),fsym{1},x,set_out_qi(:,2),fsym{2},x,
set_out_qi(:,3),fsym{3},x,set_out_qi(:,4),fsym{4},x,set_out_qi(:,5),fsym{5},x,s
et_out_qi(:,6),fsym{6} );

if ( exp == 2)
   saveas(gcf,'Exp_2_qinf_all.tif','tif');
end

if ( exp == 3)
   saveas(gcf,'Exp_3_qinf_all.tif','tif');
end

if ( exp == 4)
   saveas(gcf,'Exp_4_qinf_all.tif','tif');
end

figure;
plot(set_out_pres(:,1),set_out_pres(:,2),'r.',set_out_pres(:,1),
set_out_pres(:,3),'g.', set_out_pres(:,1), set_out_pres(:,4),'k.',
set_out_pres(:,1), set_out_pres(:,5),'m.', set_out_pres(:,1),
set_out_pres(:,6),'y.');
legend('EUM vs KMA','EUM vs BRZ',' EUM vs NOA','EUM vs NWC', 'EUM vs JMA');
xlabel('Pressure (EUM)');
ylabel('Pressure (Centres)');
title('Scatter Plot of Cloud Height');

if ( exp == 2)
   saveas(gcf,'Exp_2_qinf_pres_scat.tif','tif');
end

if ( exp == 3)
   saveas(gcf,'Exp_3_qinf_pres_scat.tif','tif');
end

if ( exp == 4)
   saveas(gcf,'Exp_4_qinf_pres_scat.tif','tif');
end

figure;
```

```
plot(x,abs(max(set_out_pres')-min(set_out_pres')),'.');
xlabel('AMV Number');
ylabel('Pressure difference');
title('Maximum Pressure difference');

if ( exp == 2)
   saveas(gcf,'Exp_2_qinf_pres_hist.tif','tif');
end

if ( exp == 3)
   saveas(gcf,'Exp_3_qinf_pres_hist.tif','tif');
end

if ( exp == 4)
   saveas(gcf,'Exp_4_qinf_pres_hist.tif','tif');
end

set_out_names = {'EUMETSAT', 'Korea', 'Brazil', 'NOAA', 'NWCSAF', 'Japan'}

set_out_spd1 = [set_out_spd(:,1), set_out_spd(:,2), set_out_spd(:,3),
set_out_spd(:,4), set_out_spd(:,5), set_out_spd(:,6),
((set_out_spd(:,1)+set_out_spd(:,2))/2)];
fall1 = {'EUMETSAT', 'Korea', 'Brazil', 'NOAA', 'NWCSAF', 'Japan', 'Correct'};



for i=1:5
    for n=i:5
        fprintf('%s "VS" %s \n', set_out_names{i}, set_out_names{n+1});
        [h,p,ci,stats]=ttest(set_out_spd(:,i),set_out_spd(:,n+1));
        fprintf('  Speed:     h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n',
h, p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_dir(:,i),set_out_dir(:,n+1));
        fprintf('  Direction: h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n',
h, p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_pres(:,i),set_out_pres(:,n+1));
        fprintf('  Pressure:  h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n',
h, p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_qi(:,i),set_out_qi(:,n+1));
        fprintf('  QI:        h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f
\n\n', h, p, ci(1), ci(2), (ci(1)+ci(2))/2);
    end;
end;
fprintf('\n')
%
%
%"Correct" Speed Comparison
for i=1:6
    fprintf('%s %s \n', 'Speed Correct VS.', fall1{i});
    [h,p,ci,stats]=ttest(set_out_spd1(:,7),set_out_spd1(:,i));
    fprintf('Speed "Correct": h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n',
h, p, ci(1), ci(2), mean(set_out_spd1(:,7)-set_out_spd1(:,i)));
end;
```

Stats_QIF_One.m

On 'tinman' 27 June 2014: /Users/daves/Documents/MATLAB/Intercomparison

```
% collocation of the cgms study datasets - search for a spatial match
% within less than a specified distance in km

clear;

fall= {'EUMETSATDatasetOne.csv', 'ChinaDatasetOneNew.csv',
'JapanDatasetOneNew.csv', 'NOAADatasetOne.csv' , 'KoreaDatasetOne.csv',
'NWCSAFDatasetOne_O_C_WO_N.csv', 'BrazilDatasetOne.csv'};
fsym= {'b+'                    , 'r.'                    , 'g.'
, 'k.'                 , 'm.'                 , 'y.'
, 'b.' };
tbsize=[24 32 24 19 24 24 24];

%Use subpixel
fall{6}='NWCSAFDatasetOne_O_C_S_E.csv'

set_eum_temp=load(fall{1});
gooddir=find(set_eum_temp(:,7) <= 360);
set_eum=set_eum_temp(gooddir,:);

set_kma=load(fall{5});
set_cma=load(fall{2});
set_noa=load(fall{4});
set_nwc_temp=load(fall{6});
set_jma=load(fall{3});
set_brz=load(fall{7});

set_nwc=sortrows(set_nwc_temp,6);

qi=0       % VARIABLE

qivar=[];
qivar=find(set_eum(:,18)>=qi);
set_eum=set_eum(qivar,:);
qivar=[];
qivar=find(set_kma(:,18)>=qi);
set_kma=set_kma(qivar,:);
qivar=[];
qivar=find(set_cma(:,18)>=qi);
set_cma=set_cma(qivar,:);
qivar=[];
qivar=find(set_noa(:,18)>=qi);
set_noa=set_noa(qivar,:);
qivar=[];
qivar=find(set_nwc(:,18)>=qi);
set_nwc=set_nwc(qivar,:);
qivar=[];
qivar=find(set_jma(:,18)>=qi);
set_jma=set_jma(qivar,:);
qivar=[];
qivar=find(set_brz(:,18)>=qi);
set_brz=set_brz(qivar,:);

i_out=0;
dist=35

for i_amv=1:length(set_nwc(:,1))
```

```
%   disp(i_amv)

    [val1 loc1]=min( deg2km(distance(set_eum(:,2), set_eum(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

    if val1 < dist

            [val2 loc2]=min( deg2km(distance(set_cma(:,2), set_cma(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

            if val2 < dist

                [val3 loc3]=min( deg2km(distance(set_jma(:,2), set_jma(:,3),
set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                if val3 < dist

                    [val4 loc4]=min( deg2km(distance(set_noa(:,2),
set_noa(:,3), set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                    if val4 < dist

                        [val5 loc5]=min( deg2km(distance(set_kma(:,2),
set_kma(:,3), set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                        if val5 < dist

                            [val6 loc6]=min( deg2km(distance(set_brz(:,2),
set_brz(:,3), set_nwc(i_amv,2), set_nwc(i_amv,3)))); % lat/lon metrics

                             if val6 < dist

                    i_out=i_out+1;

                    set_out_lat(i_out,:) =[ set_eum(loc1,2) set_kma(loc5,2)
set_cma(loc2,2)  set_noa(loc4,2) set_nwc(i_amv,2) set_jma(loc3,2)
set_brz(loc6,2) ];
                    set_out_lon(i_out,:) =[ set_eum(loc1,3) set_kma(loc5,3)
set_cma(loc2,3)  set_noa(loc4,3) set_nwc(i_amv,3) set_jma(loc3,3)
set_brz(loc6,3) ];

                    set_out_spd(i_out,:) =[ set_eum(loc1,6) set_kma(loc5,6)
set_cma(loc2,6)  set_noa(loc4,6) set_nwc(i_amv,6) set_jma(loc3,6)
set_brz(loc6,6) ];
                    set_out_dir(i_out,:) =[ set_eum(loc1,7) set_kma(loc5,7)
set_cma(loc2,7)  set_noa(loc4,7) set_nwc(i_amv,7) set_jma(loc3,7)
set_brz(loc6,7) ];

                    % set_out_tem(i_out,:) =[ set_eum(loc1,13) set_kma(loc5,13)
set_cma(loc2,13)  set_noa(loc4,13) set_nwc(i_amv,13) set_jma(loc3,13) ];
                    set_out_pres(i_out,:)=[ set_eum(loc1, 8)  set_kma(loc5, 8)
set_cma(loc2, 8)   set_noa(loc4, 8) set_nwc(i_amv, 8)  set_jma(loc3, 8)
set_brz(loc6, 8) ];
                    set_out_ham(i_out,:) =[ set_eum(loc1,16)  set_kma(loc5,16)
set_cma(loc2,16)   set_noa(loc4,16) set_nwc(i_amv,16)  set_jma(loc3,16)
set_brz(loc6,16) ];
                    set_out_qi(i_out,:)  =[ set_eum(loc1,18)  set_kma(loc5,18)
set_cma(loc2,18)   set_noa(loc4,18) set_nwc(i_amv,18)  set_jma(loc3,18)
set_brz(loc6,18) ];
                    set_out_h1(i_out,:) = [ set_eum(loc1,19) -set_kma(loc5,19)
-set_cma(loc2,19)  -set_noa(loc4,19) set_nwc(i_amv,19) -set_jma(loc3,19) -
```

```
set_brz(loc6,20) ];
                    set_out_v1(i_out,:) = [ set_eum(loc1,20) -set_kma(loc5,20)
-set_cma(loc2,20)   set_noa(loc4,20) set_nwc(i_amv,20)  set_jma(loc3,20)
set_brz(loc6,19) ];
                    set_out_h2(i_out,:) = [ set_eum(loc1,21) -set_kma(loc5,21)
set_cma(loc2,21)   set_noa(loc4,21) set_nwc(i_amv,21) -set_jma(loc3,21)
set_brz(loc6,22) ];
                    set_out_v2(i_out,:) = [ set_eum(loc1,22) -set_kma(loc5,22)
set_cma(loc2,22)  -set_noa(loc4,22) set_nwc(i_amv,22)  set_jma(loc3,22) -
set_brz(loc6,21) ];

                              end;
                    end;
                end;
            end;
        end
    end;
end;


set_out_names = {'EUMETSAT', 'Korea', 'China', 'NOAA', 'NWCSAF', 'Japan',
'Brazil'}
i_out

% set_out_spd1 = [set_out_spd(:,1), set_out_spd(:,2), set_out_spd(:,3),
set_out_spd(:,4), set_out_spd(:,5), set_out_spd(:,6), set_out_spd(:,7) ];
% fall1 = {'EUMETSAT', 'Korea', 'China', 'NOAA', 'NWCSAF', 'Japan', 'Brazil'}

% set_out_qi1 = [set_out_qi(:,1), set_out_qi(:,2), set_out_qi(:,3),
set_out_qi(:,4), set_out_qi(:,5), set_out_qi(:,6), set_out_qi(:,7) ];

for i=1:6
    for n=i:6
        fprintf('%s vs. %s \n', set_out_names{i}, set_out_names{n+1});
        [h,p,ci,stats]=ttest(set_out_spd(:,i),set_out_spd(:,n+1));
        fprintf('  Speed:  h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n', h,
p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_dir(:,i),set_out_dir(:,n+1));
        fprintf('  Dir:    h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n', h,
p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_h1(:,i),set_out_h1(:,n+1));
        fprintf('  Hdisp1: h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n', h,
p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_v1(:,i),set_out_v1(:,n+1));
        fprintf('  Vdisp1: h = %d, p = %.2f, ci = %.f %.2f, Mean: %.2f \n', h,
p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_h2(:,i),set_out_h2(:,n+1));
        fprintf('  Hdisp2: h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n', h,
p, ci(1), ci(2), (ci(1)+ci(2))/2);
        [h,p,ci,stats]=ttest(set_out_v2(:,i),set_out_v2(:,n+1));
        fprintf('  Vdisp2: h = %d, p = %.2f, ci = %.2f %.2f, Mean: %.2f \n', h,
p, ci(1), ci(2), (ci(1)+ci(2))/2);

    end;
end;



%
% %"Correct" Speed Comparison
% for i=1:6
```

```
%     fprintf('%s %s \n', 'Speed Correct VS.', fall1{i});
%     [h,p,ci,stats]=ttest(set_out_spd1(:,7),set_out_spd1(:,i));
%     fprintf('Speed "Correct": h = %d, p = %f, ci = %f %f, Mean: %f \n', h, p,
ci(1), ci(2), mean(set_out_spd1(:,7)-set_out_spd1(:,i)));
% end;
% fprintf('\n');



% "Correct" QI Comparision
%for i=1:6
%    fprintf('%s %s \n', 'QI Correct vs.', fall1{i});
%    [h,p,ci,stats]=ttest(set_out_qi1(:,7),set_out_qi1(:,i));
%    fprintf('Speed "Correct": h = %d, p = %f, ci = %f %f, Mean: %f \n', h, p,
ci(1), ci(2), mean(set_out_qi1(:,7)-set_out_qi1(:,i)));
%end;
```

Winds_Height_Diff.m

On 'tinman' 9 June 2014: /Users/daves/Documents/MATLAB/Intercomparison

```
% Experiment 3 & 4 AMV height difference
% collocation of the cgms study datasets - search for a spatial match
% within less than a specified distance, dist

% 1. IDN
% 2. LAT[DEG]
% 3. LONG[DEG]
% 4. TBOX[PIX]
% 5. SBOX[PIX]
% 6. SPD[MPS]
% 7. DIR[DEG]
% 8. P[HPA]
% 9. LOWL
% 10.GSPD[MPS]
% 11.GDIR[DEG]
% 12.ALB[%]
% 13.CORR[%]
% 14.TMET
% 15.PERR[HPA]
% 16.HMET
% 17.QINF[%]
% 18.QIF[%]
% 19.HDISP1
% 20.VDISP1
% 21.HDISP2
% 22.VDISP2

clear;
close all;

kindex=7
dist=2;   % distance in km (set to 2 for most) =12 for NWC (kindex=6)

if (kindex == 1 )
    fall= {'ChinaDatasetThreeNew.csv',  'ChinaDatasetFourNew.csv'};
    fsym= {'b.'                     , 'ro'};
    site= 'CMA';
end

if (kindex == 2 )
    fall= {'EUMETSATDatasetThree.csv',  'EUMETSATDatasetFour.csv'};
    fsym= {'b.'                     , 'ro'};
    site= 'EUM';
end
if (kindex == 3 )
    fall= {'JapanDatasetThreeNew.csv',  'JapanDatasetFourNew.csv'};
    fsym= {'b.'                     , 'ro'};
    site= 'JMA';
end

if (kindex == 4 )
    fall= {'KoreaDatasetThree.csv',  'KoreaDatasetFour.csv'};
    fsym= {'b.'                     , 'ro'};
    site= 'KMA';
end

if (kindex == 5 )
```

```
    fall= {'NOAADatasetThree.csv',  'NOAADatasetFour.csv'};
    fsym= {'b.'                     , 'ro'};
    site= 'NOA';
end

if (kindex == 6 )
    fall= {'NWCSAFDatasetThree_P_ET_E.csv',  'NWCSAFDatasetFour_P_C_E.csv'};
    fsym= {'b.'                     , 'ro'};
    site= 'NWC';
end

if (kindex == 7 )
    fall= {'BrazilDatasetThree.csv',  'BrazilDatasetFour.csv'};
    fsym= {'b.'                     , 'ro'};
    site= 'BRZ';
end

set_three=load(fall{1});
set_four=load(fall{2});

qi=0;

qivar=[];
qivar=find(set_three(:,18)>=qi);
set_three=set_three(qivar,:);
qivar=[];
qivar=find(set_four(:,18)>=qi & set_four(:,2) < 90. );
set_four=set_four(qivar,:);

i_out=0;

for i_amv=1:length(set_four(:,1))
%   disp(i_amv)
    [val1 loc1]=min( deg2km(distance(set_three(:,2), set_three(:,3),
set_four(i_amv,2), set_four(i_amv,3)))); % lat/lon metrics

    if val1 < dist

                      i_out=i_out+1;

                      set_out_lat(i_out,:) =[ set_three(loc1,2) set_four(i_amv,2)
];
                      set_out_lon(i_out,:) =[ set_three(loc1,3) set_four(i_amv,3)
];

                      set_out_spd(i_out,:) =[ set_three(loc1,6) set_four(i_amv,6)
];
                      set_out_dir(i_out,:) =[ set_three(loc1,7) set_four(i_amv,7)
];

                      set_out_pres(i_out,:) =[ set_three(loc1,8)
set_four(i_amv,8)  ];
                      set_out_ham(i_out,:) = [ set_three(loc1,16)
set_four(i_amv,16) ];
                      set_out_qi(i_out,:) =  [ set_three(loc1,18)
set_four(i_amv,18) ];
                      set_out_ind(i_out,:) = [ loc1 i_amv ];

      end;
end;
```

```
disp('**************');
disp(i_out);

figure(1);
%x=1:i_out;
%subplot(2,2,1);
%plot(x,set_out_pres(:,1),fsym{1},x,set_out_pres(:,2),fsym{2});
%legend(site);


%subplot(2,2,2);
%plot(set_out_pres(:,1),set_out_pres(:,2),'k.');

%subplot(2,2,3);
%plot(x,set_out_pres(:,2)-set_out_pres(:,1),'.');

%subplot(2,2,4);
hist(set_out_pres(:,2)-set_out_pres(:,1),100);
title(site);
xlabel('pressure diff: Exp4 - Exp3');

saveas(gcf,['Pdiff_' site],'tif');
```