NWC SAF Winds Intercomparison Study Report: 2018

Second Final Report

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1. Abstract

Previous Atmospheric Motion Vector (AMV) intercomparison studies, conducted from 2007 to 2014, 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 compared in terms of coverage, speed, direction, and cloud height (Genkova et al. 2008; Genkova et al. 2010, Santek et al. 2014).

In this continuation, AMVs calculated with JMA's Himawari-8/AHI satellite data were compared to address two main goals:

- To verify the advantages of the calculation of AMVs with the new generation of geostationary satellites that began in 2014 with Himawari-8, continuing with GOES-R over the past two years, and the expected launch of the MTG-I series in the early 2020s, as compared to those calculated with MSG series.
- To determine the best options for the calculation of AMVs with MTG-I with NWC/GEO-HRW algorithm, considering the options taken by the different satellite centres for their AMV calculation.

Also, a Common Quality Index (QI) was computed to determine if better agreement in the winds would result if the Quality Index was computed similarly.

Note: This report replaces the original version dated 25 May 2018, as corrected datasets from EUMETSAT and the Korea Meteorological Administration are now included in the analysis. As a result, the majority of the tables and figures have been updated.

2. Motivation

From the 2017 AMV Intercomparison Study Call for Proposals:

JMA's Himawari-8/AHI satellite data will be used in the processing. This way, improvements of the different AMV algorithms respect to AMVs calculated with MSG satellite data will be shown. Additionally, a verification will be done of the best options available for the processing of AMVs with the new generation of geostationary satellites (Himawari-8/9, GOES-R, MTG-I, etc.), with higher spatial resolution, higher temporal resolution, and more spectral channels. The new spectral channels, bearing new information on cloud microphysics and with a higher temporal resolution, should allow to better understand the characteristics of the tracked features.

The study will act as an input for the development of all AMV algorithms, for their optimal use with this new generation of geostationary satellites. The corresponding conclusions will be taken into account during the scientific developments of "NWC/GEO vMTG day-1 and day-2" versions, to which this Visiting Scientist Activity (VSA) will contribute with its Final Report.

3. Case Study

There were two cases processed from 21 July 2016 (day 203), using several different configurations.

The primary case study for the AMV experiments is a triplet of infrared (10.4μ; band 13) Himawari-8, full–disk images at 1200, 1210, 1220 UTC (Figure 3-1).

A second equivalent dataset was processed for the times 0530, 0540, 0550 UTC, which is coincident with an overpass from CALIPSO, for comparison to CALIPSO cloud heights.

The experiments are numbered, thusly:

Table 3-1: Experiment numbering

Experiment	Configuration	Time	Participants
1	Common (21)	1200-20	All
2	Own (22)	1200-20	All
3	Own (52)	0530-50	All

An example of Himawari 10.4µ image for 1200 UTC is shown in Figure 3-1. The day was selected for the variability of meteorological features found in the different regions. It is also noted that the case was selected in agreement with the International Cloud Working Group, to increase the synergies between both "AMV Intercomparison study" and "Cloud Intercomparison study".

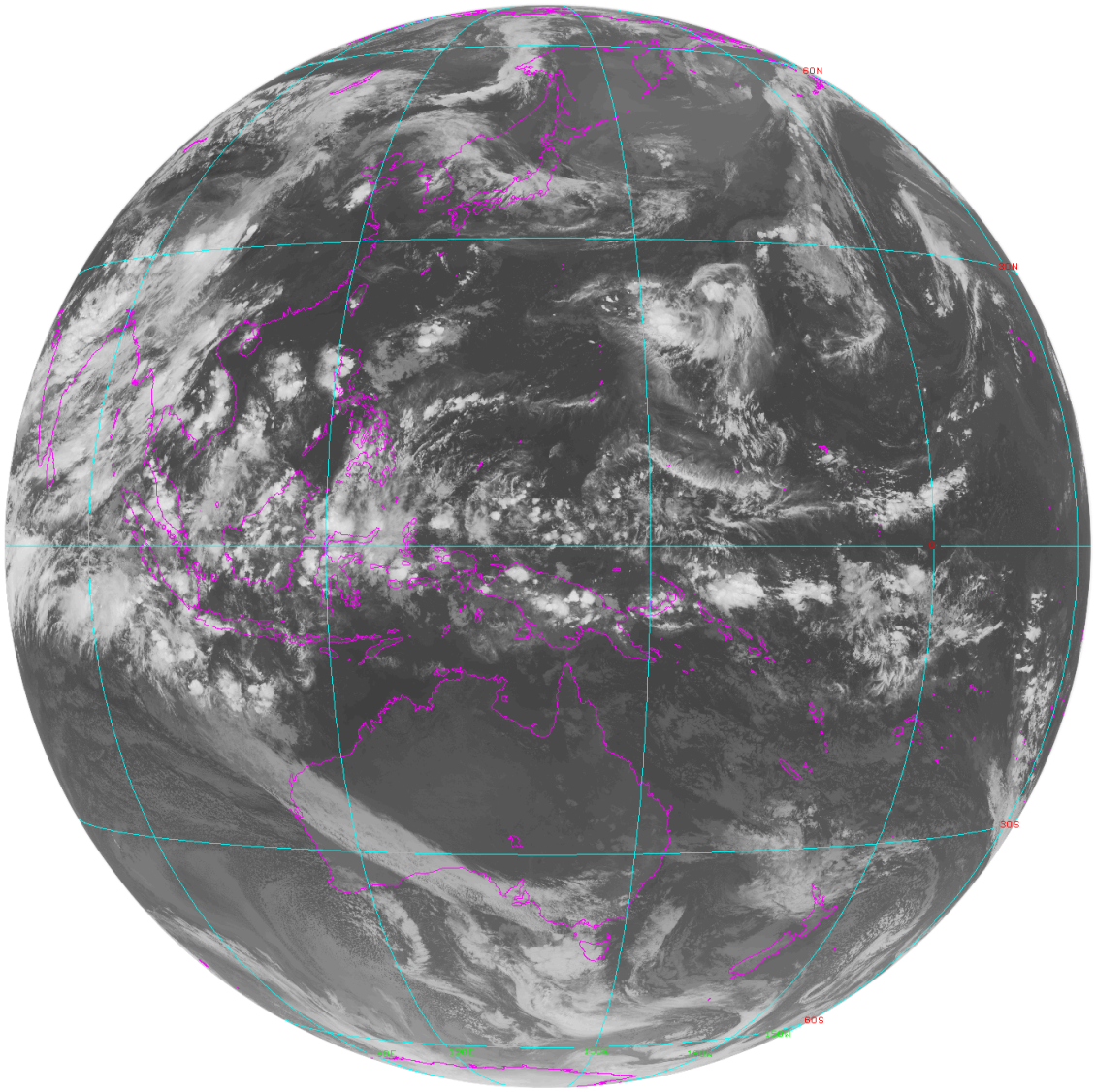


Figure 3-1: Himawari-8 10.4 µm (band 13) from 21 July 2016 at 1200 UTC.

4. Overview

The output provided by the AMV producers was analyzed for three primary 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 announcement or 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; Santek et al. 2014). This includes using the paired t-test, which was first used in the 2014 study:

> *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 was 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 were 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 AMV producer provided files containing the results of the experiments with the same parameters using a text file format.

The AMV producers are:

1. BRZ: CPTEC (Brazil Weather Forecast and Climatic Studies Center)
2. EUM: EUMETSAT (European Organization for the Exploitation of Meteorological Satellites)
3. JMA: Japan Meteorological Agency
4. KMA: Korea Meteorological Administration
5. NOA: NOAA (National Oceanic and Atmospheric Administration)
6. 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 are in the same order as described by the header from NWC:

1	ID	Identification number
2	LAT[DEG]	Latitude
3	LON[DEG]	Longitude
4	TS[PIX]	Target box size
5	SS[PIX]	Search box size
6	SPD[MPS]	AMV speed
7	DIR[DEG]	AMV direction
8	PRES[HPA]	AMV pressure
9	L	Low-level correction
10	NWSSPD[MPS]	Background guess wind speed
11	NWSDIR[DEG]	Background guess wind direction
12	ALB[%]	Albedo
13	CORR[%]	Correlation
14	T	Brightness temperature
15	PRESSERR[HPA]	AMV pressure error
16	H	Height assignment method
17	QIN[%]	QI without forecast
18	QIF[%]	QI with forecast
19	QIC[%]	Common QI

Table 5-1: Reported Variables

The data for the AMV processing consisted of:

- Himawari-8 datasets for the given six time slots (05:30, 05:40, 05:50, 12:00, 12:10 and 12:20 UTC of 21 July 2016), formatted as flat binary files per slot (8-byte reals), corresponding to each pixel of Himawari-8's 2 km resolution full disk imagery (5,500 x 5,500 lines/columns). Individual files are provided

for the different following variables: latitude, longitude, time, satellite and sun zenith angles, radiance, brightness temperature.

- ECMWF ERA-Interim analysis NWP grid fields for the day, 21 July 2016, with fields every six hours and for 37 vertical levels, on a regular latitude/longitude grid, with a resolution of 0.5°. The provided parameters in these fields are: geopotential, temperature, relative humidity, ozone mixing ratio, wind components, land-sea mask, sea-ice cover, surface pressure, snow depth, mean sea level, 10m wind components, 2m temperature and dewpoint temperature, skin temperature and total column ozone.
- Auxiliary binary files contain the Sea and Land mask, Land cover and Elevation for each Himawari-8 pixel.
- Cloud products provided in netCDF format by NOAA/NESDIS, including the following parameters for each Himawari-8 pixel: land class, surface type, surface elevation, cloud probability, cloud mask, cloud type, cloud phase, cloud top pressure.

Noted anomalies: The following errors or anomalies were discovered after the initial data analysis was complete, in the 25 May 2018 Final Intercomparison Report.

- The Common QI reported by EUM in the original dataset was incorrect; a corrected dataset was sent in early April 2018.
- KMA reported that they found an error in the AMV height assignment. A corrected dataset was provided in early April 2018.

All relevant tables, figures, and analyses have been updated in this report, using these corrected datasets.

6. Wind Retrieval Algorithms

Please refer to the 2014 Intercomparison Report for details on the algorithms for each of the AMV producers, as provided to us at that time.

The few changes in the AMV processing by the different centres for this new Intercomparison study, defined by the different producers, are as follows:

1. EUM reports they have changed the tracking scheme, using now the MTG prototype: they have used the central image of each triplet as reference and tracked backward for the first intermediate component, then forward for the second. In the previous study all tracking was performed forward starting at the first image.
2. BRZ reports they have removed an old routine from the tracking module (which caused the error in speed and direction found in the last Intercomparison), added the CO_2 Slicing height assignment method, and changed the target selection to find the targets with maximum contrast.
3. JMA reports that all processes in the JMA AMV algorithm have changed. Considering the tracer search, tracers are preassigned depending on the number of pixels (using the target size of 16x16 pixels for the common setting and using 31x31 and 7x7 pixels in the JMA specific configuration). Considering the tracking, four cross-correlation surfaces are used in the new process. The quality control has also changed. Finally, the height assignment process is completely new: optimal estimation method using observed radiance and NWP vertical profile. As later seen in the study, this is clearly the main difference in all of their AMV processes with respect to the previous Intercomparison.

7. Experiment 1

AMV producers extract infrared channel AMVs considering a prescribed AMV algorithm configuration, but only using the Himawari-8/AHI IR10.4μ images. The NOAA/NESDIS cloud product could be used if possible, for the height assignment. However, only EUM, NOA and NWC used this cloud height product for the height assignment. This experiment was used to test all AMV calculation processes ("target definition", "tracking", "height assignment" and "quality control") in all AMV algorithms, considering similar targets as input.

The prescribed AMV configuration defines target box size, search box size and target locations to be the same for all AMV producers, which is similar to Experiment 4 in the previous study (Santek et al. 2014); however, the use of a cloud height product was not used by all centres making direct comparisons between the different experiments tenuous and difficult.

In the 2nd study (Genkova et al. 2010) it was found that:

> *Winds datasets 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.*

In the 3rd study (Santek et al. 2014):

> *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.*

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

Collocated AMVs from the different algorithms are 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 are used for verification.

Experiment 1 Highlights

The design of the first experiment included a cloud height product along with a prescribed configuration for the wind algorithm settings (target box size, search box size, target locations), to be used if possible, for the height assignment. However, only EUM, NOA and NWC used this cloud height product for the height assignment. This resulted in the AMV height comparison being more variable for collocated vectors, compared to any of the experiments in the 2014 Study. This indicates that the cloud height method is the main driver in variability, over prescribed vs. standard configurations of target box location, size, search box size, etc.

Generally, there were more AMVs compared to Experiment 4 in the 2014 Study, due in part to the higher resolution of AHI imager (2km) vs SEVIRI (3 km), more oceanic regions, and fewer deserts.

When the AMVs are compared to rawinsondes and the model background grids, JMA has the lowest deviation of speed and vector RMS, followed by NOA and NWC, with BRZ having the largest deviation. In fact, JMA's AMVs vary so little from the ECMWF analysis compared to the other AMV producers, it may indicate their cloud height method has a stronger dependence on the background grids.

The use of the Common QI (CQI) results in better statistical agreement for collocated AMVs from the different centres, especially for the AMV direction with the QINF and CQI greater than 80%.

Both BRZ and NWC had a peak in the distribution of AMV direction at 90°, which may indicate an issue with how subpixel tracking is done.

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) and Study 4 (Santek et al. 2014):

- Prescribed target (16x16) and search box (54x54) sizes were used.
- ECMWF ERA-Interim analysis grids were used as NWP data.
- A cloud height product from NOAA/NESDIS was included in the dataset, to be used if possible for the AMV height assignment. However, only EUM, NOA and NWC used this cloud height product for

this. EUM and NWC used this besides the same "CCC method" giving them the more similarities in the height assignment.
- A 55 km distance to define collocation was used.
- 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.

b) Parameter distributions

The bulk statistics in this section are presented as tables for QINF (Quality Index without forecast) >= 50 and 80, and CQI (Common Quality Index) >=50 and 80.

The values of the different parameters among the centres are approximately the same, with these notable exceptions:

- The total number of AMVs generally ranges from 60,000 to 75,000, except for NOA (38,000), EUM (30000) and NWC (14,000). For NWC, this is due to a reduced sampling of targets in this prescribed configuration mode. This total number of AMVs is much larger than Experiment 4 in the 2014 Study, which found approximately 10,000 matches (3,000 for NOA and NWC). This is due, in part, to the higher resolution AHI (2km) vs. SEVIRI (3 km), more oceanic regions, and fewer deserts.
- The maximum speed ranges from 66 ms^{-1} (BRZ) to 92 ms^{-1} (NOA), with an outlier of 145 ms^{-1} for EUM.
- The minimum pressure is approximately 100 hPa, except for EUM which is at 60 hPa.
- The percentages by level (low, medium, high) are 24 % to 36%, 9% to 21%, and 43% to 67%. The main outlier of these is NOA at mid levels with only 2%.

Table 7-1: Experiment 1 statistical summary of AMV datasets for QINF>=50.

	EUM	BRZ	JMA	NOA	KMA	NWC
Total AMVs	30868	70312	76075	38242	58479	14602
QI>=50	26310	61806	57586	36172	49894	12511
SPD_min	2.51	3.01	2.50	3.00	2.50	2.56
SPD_max	145.00	66.05	79.06	92.29	91.32	68.77
SPD_mean	14.08	11.66	13.36	14.06	13.87	13.96
P_min	60.62	100.00	100.00	102.05	102.08	104.00
P_max	1004.00	1000.00	1013.81	977.82	997.66	965.50
P_mean	426.84	530.88	488.55	432.19	412.25	391.90
Low_winds	25.50	36.49	29.63	33.77	23.56	24.64
Mid_winds	13.49	20.94	21.40	2.63	13.38	8.61
High_winds	61.01	42.56	48.97	63.59	63.06	66.75
Low_SPD_min	2.51	3.01	2.50	3.00	2.50	2.78
Low_SPD_max	103.32	38.08	41.20	40.52	70.19	28.57
Low_SPD_mean	9.38	9.58	9.66	10.21	9.77	10.11
Low_P_min	700.23	700.00	700.01	700.06	700.00	700.00
Low_P_max	1004.00	1000.00	1013.81	977.82	997.66	965.50
Low_P_mean	822.03	872.68	883.51	837.59	819.05	781.64
Mid_SPD_min	2.58	3.07	2.50	3.06	2.50	2.82
Mid_SPD_max	123.63	66.05	69.25	78.86	70.08	48.12
Mid_SPD_mean	15.21	13.36	13.53	22.14	14.68	17.44
Mid_P_min	400.01	400.02	400.01	400.01	400.03	400.50
Mid_P_max	699.77	699.98	699.99	449.96	699.90	699.50
Mid_P_mean	526.77	536.15	525.92	425.91	522.20	536.58
High_SPD_min	2.51	3.05	2.50	3.00	2.50	2.56
High_SPD_max	145.00	62.47	79.06	92.29	91.32	68.77
High_SPD_mean	15.80	12.61	16.08	15.77	15.22	14.92
High_P_min	60.62	100.00	100.00	102.05	102.08	104.00
High_P_max	399.94	400.00	399.98	399.99	399.97	400.00
High_P_mean	239.59	235.22	233.19	217.14	236.94	229.36

Table 7-2: Experiment 1 statistical summary of AMV datasets for CQI >= 50

	EUM	BRZ	JMA	NOA	KMA	NWC
Total AMVs	30868	70312	76075	38242	58479	14602
QI>=50	27097	57613	33717	36172	52685	14283
SPD_min	2.51	2.56	2.50	3.00	2.50	2.50
SPD_max	139.93	66.05	69.97	92.29	97.01	68.77
SPD_mean	13.64	11.81	13.29	14.06	13.66	13.64
P_min	57.11	100.00	125.00	102.05	102.08	101.00
P_max	1004.00	1000.00	994.32	977.82	997.66	965.50
P_mean	437.37	533.19	496.89	432.19	408.80	386.40
Low_winds	26.66	37.10	31.43	33.77	23.05	23.61
Mid_winds	14.56	20.33	19.34	2.63	13.29	8.96
High_winds	58.78	42.57	49.23	63.59	63.66	67.43
Low_SPD_min	2.52	2.56	2.50	3.00	2.50	2.57
Low_SPD_max	99.02	35.67	41.20	40.52	70.19	28.57
Low_SPD_mean	9.33	9.61	9.06	10.21	9.67	9.95
Low_P_min	700.23	700.00	700.01	700.06	700.00	700.00
Low_P_max	1004.00	1000.00	994.32	977.82	997.66	965.50
Low_P_mean	823.71	874.49	888.89	837.59	820.21	782.70
Mid_SPD_min	2.53	2.61	2.50	3.06	2.50	2.51
Mid_SPD_max	94.60	66.05	69.25	78.86	70.08	48.12
Mid_SPD_mean	14.58	13.61	14.03	22.14	14.53	17.05
Mid_P_min	400.03	400.02	400.01	400.01	400.03	400.05
Mid_P_max	699.77	699.98	699.99	449.96	699.90	699.50
Mid_P_mean	531.56	536.33	528.20	425.91	521.45	536.54
High_SPD_min	2.51	2.58	2.50	3.00	2.50	2.50
High_SPD_max	139.93	62.47	69.97	92.29	97.01	68.77
High_SPD_mean	15.37	12.88	15.69	15.77	14.92	14.47
High_P_min	57.11	100.00	125.00	102.05	102.08	101.00
High_P_max	399.94	400.00	399.98	399.99	399.97	400.00
High_P_mean	238.80	234.17	234.32	217.14	236.29	227.70

Table 7-3: Experiment 1 statistical summary of AMV datasets for QINF>=80.

	EUM	BRZ	JMA	NOA	KMA	NWC
Total AMVs	30868	70312	76075	38242	58479	14602
QI>=80	19897	41304	34036	30376	35775	7285
SPD_min	2.51	3.01	2.50	3.00	2.50	2.75
SPD_max	139.93	66.05	70.45	92.29	76.09	68.77
SPD_mean	14.50	11.37	14.35	14.77	15.11	15.70
P_min	64.81	100.00	100.00	102.05	102.08	104.50
P_max	1004.00	1000.00	1012.82	976.20	997.66	922.50
P_mean	437.23	552.18	488.37	439.29	425.33	412.39
Low_winds	27.69	40.23	30.64	34.93	26.02	27.60
Mid_winds	12.54	19.92	18.78	2.48	12.64	8.72
High_winds	59.77	39.85	50.58	62.60	61.35	63.68
Low_SPD_min	2.55	3.01	2.50	3.01	2.50	2.86
Low_SPD_max	72.74	35.46	41.20	39.11	33.70	28.57
Low_SPD_mean	9.56	9.57	9.48	10.50	10.29	10.88
Low_P_min	700.23	700.00	700.01	700.08	700.00	700.00
Low_P_max	1004.00	1000.00	1012.82	976.20	997.66	922.50
Low_P_mean	821.40	875.45	889.28	838.05	815.03	779.27
Mid_SPD_min	2.58	3.10	2.50	3.37	2.51	3.11
Mid_SPD_max	94.60	66.05	69.25	60.21	70.08	48.12
Mid_SPD_mean	15.82	13.05	15.41	23.70	16.19	18.97
Mid_P_min	400.03	400.05	400.03	400.01	400.07	400.50
Mid_P_max	699.77	699.97	699.99	449.96	699.90	699.50
Mid_P_mean	526.75	537.17	527.88	425.27	524.05	549.54
High_SPD_min	2.51	3.05	2.50	3.00	2.50	2.75
High_SPD_max	139.93	62.47	70.45	92.29	76.09	68.77
High_SPD_mean	16.51	12.35	16.90	16.79	16.93	17.35
High_P_min	64.81	100.00	100.00	102.05	102.08	104.50
High_P_max	399.84	400.00	399.98	399.99	399.97	400.00
High_P_mean	240.47	233.34	230.85	217.36	239.73	234.57

Table 7-4: Experiment 1 statistical summary of AMV datasets for CQI>=80.

	EUM	BRZ	JMA	NOA	KMA	NWC
Total AMVs	30868	70312	76075	38242	58479	14602
QI>=80	21532	37137	29740	30376	44555	11919
SPD_min	2.51	2.57	2.50	3.00	2.50	2.51
SPD_max	94.60	61.35	69.97	92.29	76.09	68.77
SPD_mean	14.26	11.76	13.68	14.77	14.33	14.02
P_min	63.49	100.00	125.00	102.05	102.08	104.50
P_max	1004.00	1000.00	994.32	976.20	997.66	917.50
P_mean	433.03	553.83	500.37	439.29	410.75	386.93
Low_winds	28.57	41.54	32.13	34.93	24.13	24.25
Mid_winds	12.76	17.60	18.96	2.48	12.01	8.03
High_winds	58.67	40.86	48.91	62.60	63.86	67.72
Low_SPD_min	2.52	2.57	2.50	3.01	2.50	2.70
Low_SPD_max	73.69	35.46	41.20	39.11	40.97	28.57
Low_SPD_mean	9.53	9.69	9.27	10.50	9.95	10.22
Low_P_min	700.23	700.00	700.01	700.08	700.00	700.00
Low_P_max	1004.00	1000.00	994.32	976.20	997.66	917.50
Low_P_mean	822.89	880.02	887.95	838.05	817.93	780.25
Mid_SPD_min	2.58	2.61	2.50	3.37	2.51	2.51
Mid_SPD_max	94.60	60.84	69.25	60.21	70.08	48.12
Mid_SPD_mean	15.82	13.80	14.66	23.07	15.61	17.76
Mid_P_min	400.03	400.09	400.03	400.01	400.03	400.50
Mid_P_max	699.77	699.82	699.99	449.96	699.90	699.50
Mid_P_mean	533.06	534.75	531.09	425.27	521.73	540.48
High_SPD_min	2.51	2.76	2.50	3.00	2.50	2.53
High_SPD_max	91.38	61.35	69.97	92.29	76.09	68.77
High_SPD_mean	16.22	12.99	16.19	16.79	15.74	14.94
High_P_min	63.49	100.00	125.00	102.05	102.08	104.50
High_P_max	499.94	400.00	399.98	399.99	399.97	400.00
High_P_mean	238.49	230.40	233.92	217.36	236.03	227.91

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

- BRZ (Figure 13-1): The QI and pressure distributions are in better agreement with the other centres as compared to the 2014 study: Now, the QI distribution tends toward many more high QI values and the pressure shows a much higher peak in the high levels. However, the direction distribution is quite different than the other centres, with possible anomalous peaks at 90° and 270°.
- EUM (Figure 13-2): The AMV pressure distribution closely matches those in the previous study, and those of NWC now, due to both using the "CCC method" for the height assignment.
- JMA (Figure 13-3): The AMV pressure distribution is improved over what was observed in previous studies, as it more closely matches the other centres which use a variety of cloud height methods. The comparisons to rawinsondes and model background (documented in the following sections) have substantially improved the statistics. This is likely entirely due to the updated cloud height method at JMA and provides evidence that the AMV heights have the biggest impact in the statistics, over other differences such as target size, search box size, tracking method, QI computation, etc.
- KMA (Figure 13-4): The AMV pressure and QI distributions more closely match the other centres, compared to the previous study. This indicates that changes were made to height assignment method and calculation of QI.
- NOA (Figure 13-5): The AMV pressure and QI distribution are in much better agreement to other centres, compared to the previous studies.
- NWC (Figure 13-6): The distributions of parameters closely match those from the other centres, except the QINF that was nearly linearly increasing, compared to the highly exponential curves from the other centres. However, the CQI (Figure 13-12) was exponential. This indicates that the QINF calculation by NWC differs from the CQI more than the difference at the other centres. Also, there is a possible anomalous peak at 90° in the direction distribution. This peak is seen with Himawari AMVs now, but was not present in the previous study with MSG AMVs.

c) Collocation plots

AMVs are first quality controlled, retaining only those with a QINF >= 50 for the first series of plots. For collocation the distance threshold was 55 km. 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.

These collocated plots are quite different than Experiment 4 in the 2014 Study:

- There are substantially more collocated AMVs, which is explained by the higher resolution AHI vs. SEVIRI (2 vs. 3km) data, and more clouds (less desert and more oceanic coverage).
- The top plot in Figure 7-1 is speed, sorted by increasing speed for NWC. Generally, this is in agreement with the 2014 Study Experiment 4 except for these, for which we have no explanation:
    - EUM has many high-speed outliers (blue dots),
    - BRZ has a cluster of low speed outliers (green dots) on the far right of the plot.
- The 2nd graph from the top (direction) has more easterlies even at high speeds, which was not evident in the previous study. This is likely due to higher speed jets in the southern hemisphere during mid-winter (July) compared to September for the 2014 Study.
- The 3rd graph from the top (pressure) appears to be quite different than the 2014 Study, but the axes scales are different. For example, in both cases there are very few low-level AMVs with speeds greater than 20 ms^{-1}. On the other hand, a notable difference is the larger number of slow AMVs at high levels, for which we cannot offer an explanation.

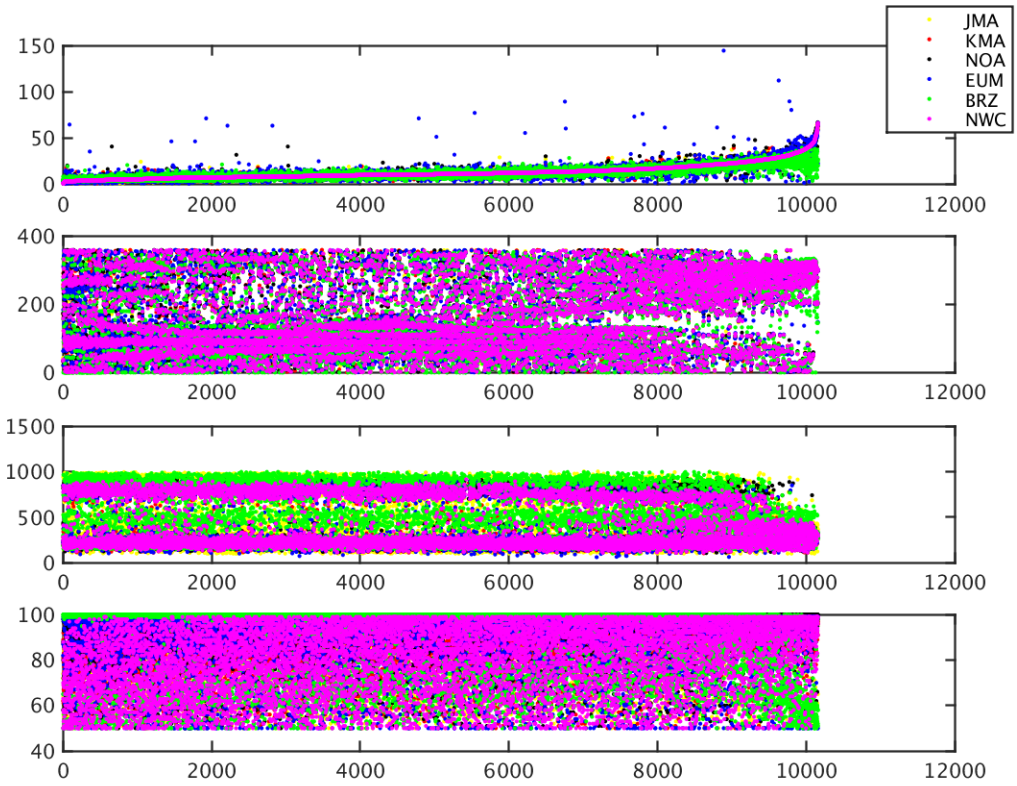


Figure 7-1: Experiment 1 (QINF >= 50) Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.

The maximum pressure difference between any two collocated AMVs is shown in Figure 7-2. This shows more variability compared to the similar Experiment 4 figure in the 2014 Study, in which a prescribed configuration was also used and each centre used its own height assignment method.

More differences seem to exist now between the different height assignment methods in the different centres. Three of these were based on the Cloud products (NOA, EUM, NWC; these two last ones using "CCC method" giving them the most similarities). The remainder used methods which were not based on a cloud top product. This observation is substantiated in Figure 7-3, where there is excellent agreement between EUM and NWC (magenta clusters), many points plotted away from the diagonal (from the other centres), and large clusters of green dots (BRZ) away from the diagonal.

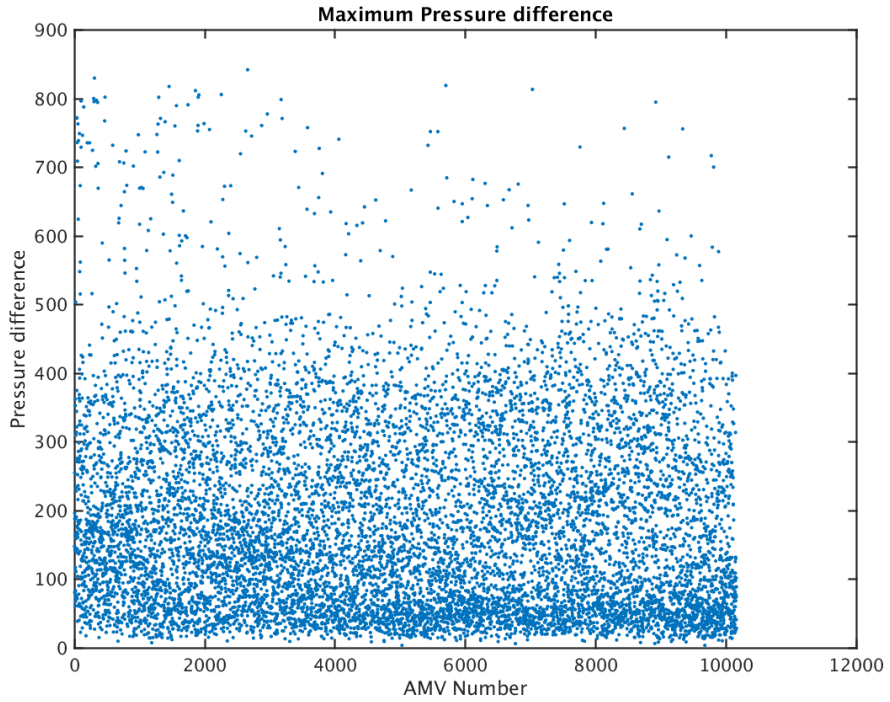


Figure 7-2: Experiment 1 (QINF >= 50) The maximum pressure difference between any two collocated AMVs.

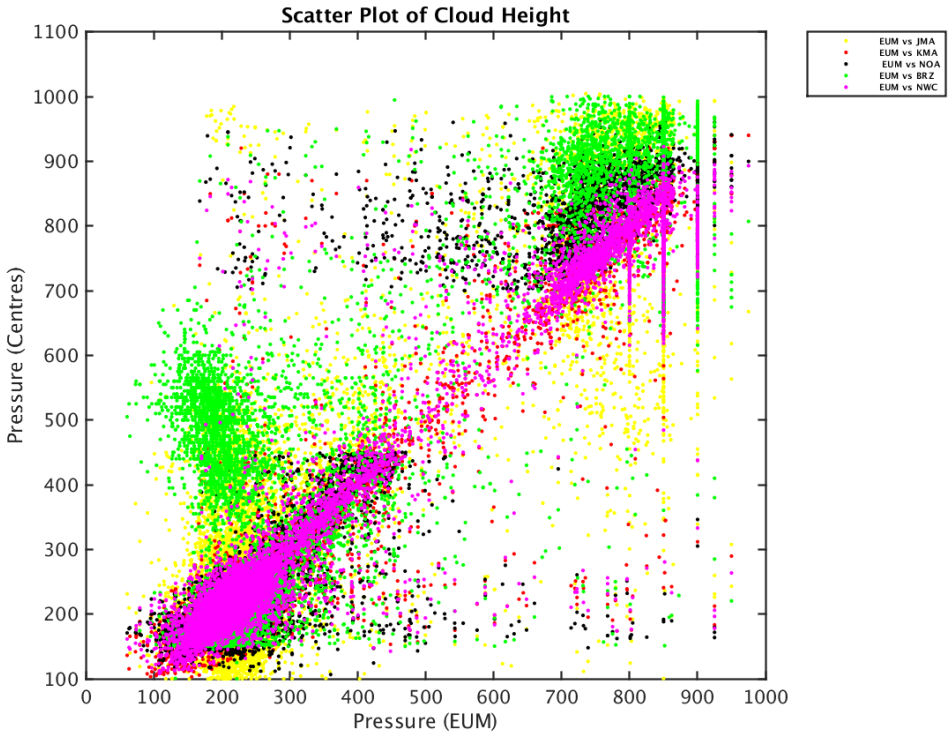


Figure 7-3: Experiment 1 (QINF >= 50) Scatter plot of AMV pressure for each center vs. EUM pressure.

The following three plots are similar to the above, except they are based on the CQI, with the same threshold of 50. The one important exception is that the QI plot (lower graph in Figure 7-4) has fewer lower QI values than in Figure 7-1, as evident by fewer magenta dots in the lower part of the graph. This provides some evidence that the common QI gives better agreement in the AMVs, with a tendency to retain higher QI values.

The CQI from BRZ (green dots) may be related to height assignment differences, resulting in the corresponding lower CQI values in the figure.

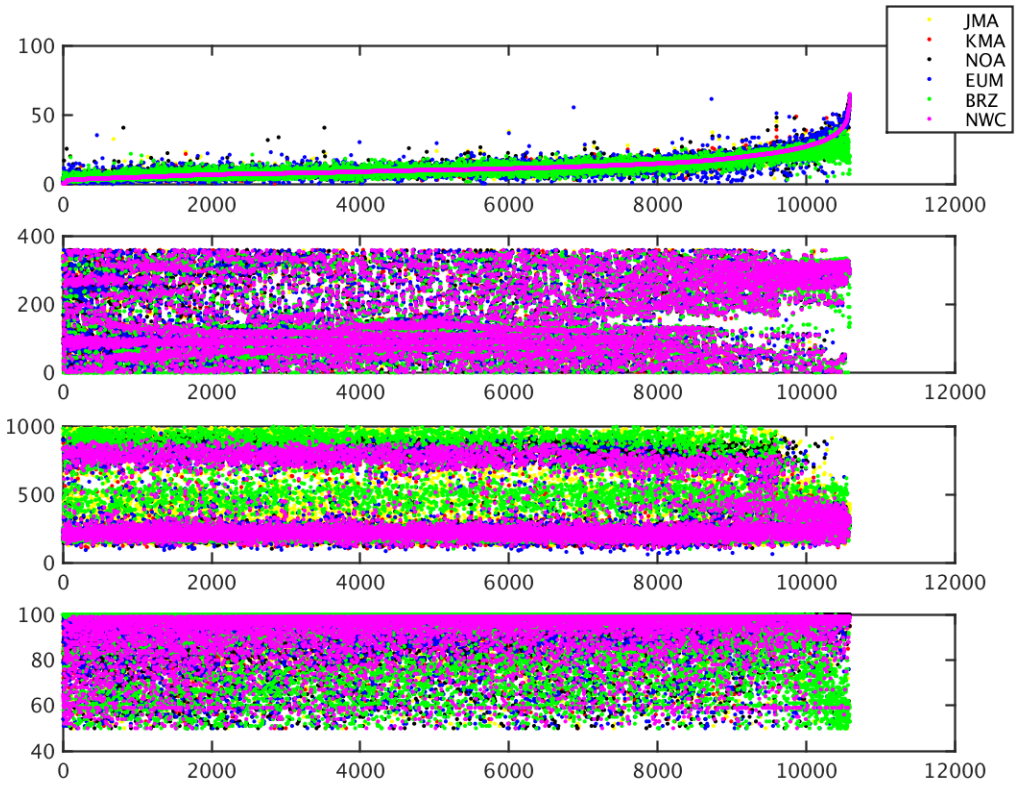


Figure 7-4: Experiment 1 (CQI >= 50) Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.

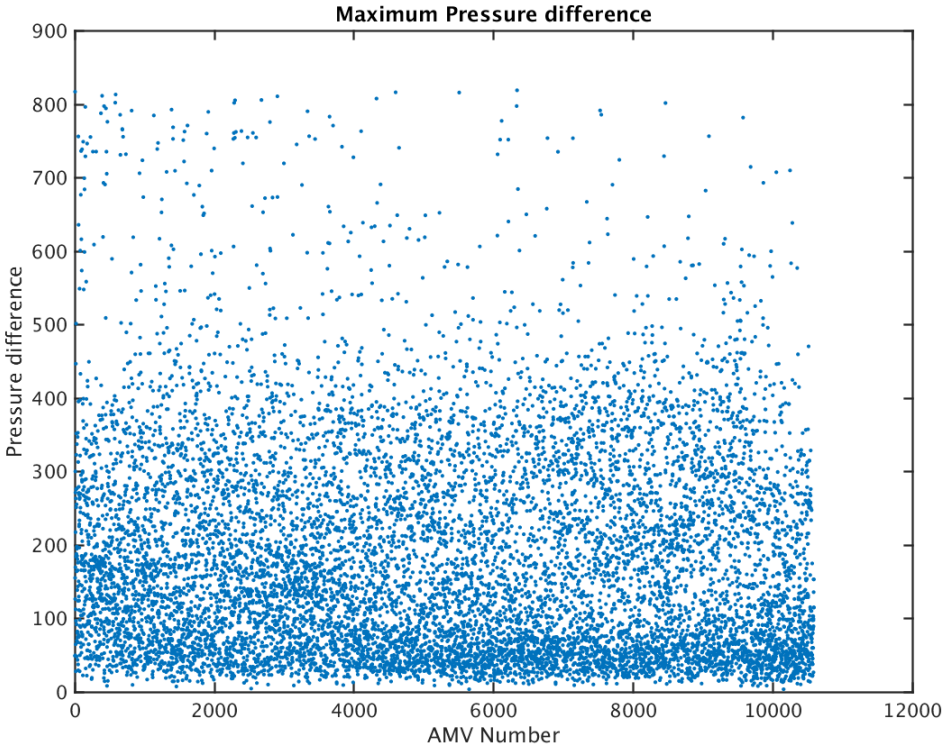


Figure 7-5: Experiment 1 (CQI >= 50) The maximum pressure difference between any two collocated AMVs.

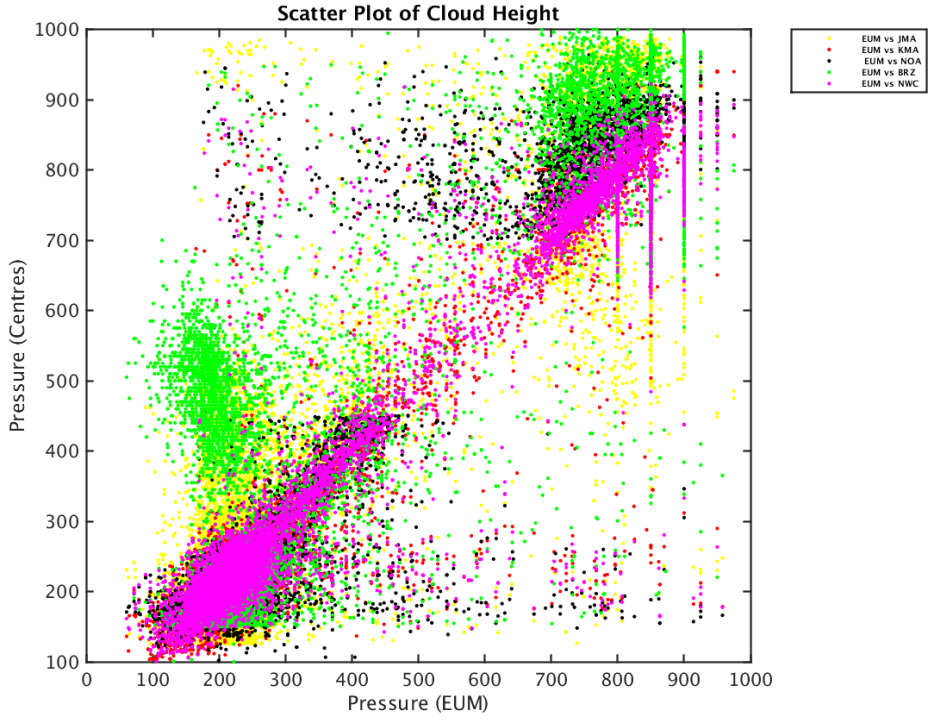


Figure 7-6: Experiment 1 (CQI >= 50) Scatter plot of AMV pressure for each center vs. EUM pressure.

d) Rawinsonde comparison

The comparison of all AMVs to nearby rawinsondes is summarized in the following tables for QINF >= 50 (same threshold as the one used in the previous Intercomparison study) and QINF, CQI >= 80 (giving better results in agreement between centres). Collocated AMVs for all levels have also been compared for QINF, CQI >= 50.

The QINF >=50 vector RMS ranges from 5.5 ms^{-1} (JMA) to 6-7 ms^{-1} (NOA, NWC) to greater than 12 ms^{-1} (BRZ, EUM). The speed RMS ranges from 4 ms^{-1} (JMA) to 5-7 ms^{-1} (KMA, NOA, NWC) to greater than 10 ms^{-1} (BRZ, EUM). Results from EUM improve substantially using the higher QI threshold. The large RMS differences are probably due to the substantial variation in height assignment methods used.

There are less differences between centres when collocated data are considered for both QINF and CQI.

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 (not shown), or collocated winds. However, JMA has generally the best overall stats.

An additional analysis in summarized in Table 7-10 that compares the 'best' AMVs for each centre with nearby rawinsondes, where 'best' is defined by a minimum CQI threshold that results in at least 10,000 AMVs. The CQI threshold ranges from 98 to 100 for all the centres, except it is 90 for NWC as the total number of AMVs for NWC is much smaller than the other centres for this experiment. Despite the use of the highest quality AMVs, the variability in the bias and RMS is similar to the other QI thresholds in Table 7-5 to Table 7-9. However, NOA performed the best in 3 out of the 6 statistics.

Table 7-5: Experiment 1: All AMVs (QINF >= 50) comparison to rawinsondes within 150 km. N= number of matches; P bias = pressure bias; P RMS = pressure RMS; Spd bias = speed bias; Spd RMS= speed RMS; Dir bias = wind direction bias; Vec RMS = 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	**834**	**0.57**	**14.51**	**-1.23**	**10.19**	**-11.72**	**12.60**
EUM	**463**	**-1.42**	**16.56**	**-1.64**	**11.16**	**7.70**	**19.06**
JMA	**807**	**-0.36**	**13.53**	**-0.93**	**4.08**	**-0.26**	**5.66**
KMA	**794**	**-0.87**	**15.67**	**-1.61**	**6.81**	**4.66**	**9.48**
NOA	**511**	**-1.03**	**14.16**	**-0.71**	**5.26**	**0.93**	**7.38**
NWC	**132**	**-0.75**	**15.21**	**-0.88**	**5.05**	**-4.68**	**6.85**

Table 7-6: Experiment 1: Collocated AMVs (QINF >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; Spd bias = speed bias; Spd RMS = speed RMS; Dir bias = wind direction bias; Vec RMS = 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	102	1.13	16.11	-1.72	9.94	-33.90	12.67
EUM	100	-0.84	12.99	-1.15	9.51	-5.32	12.44
JMA	101	1.73	12.24	-1.51	3.75	-3.86	5.35
KMA	103	-2.16	14.09	-0.91	4.33	-3.20	5.72
NOA	100	-3.05	12.08	-0.34	4.30	-4.91	5.60
NWC	100	-0.82	14.12	-1.02	5.09	-5.05	6.34

Table 7-7: Experiment 1: All AMVs (CQI >= 50) comparison to rawinsondes within 150 km. N= number of matches; P bias = pressure bias; P RMS = pressure RMS; Spd bias = speed bias; Spd RMS= speed RMS; Dir bias = wind direction bias; Vec RMS = 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	774	0.90	14.68	-1.28	10.00	-13.13	12.61
EUM	473	-1.63	16.52	-1.74	7.86	8.69	12.67
JMA	400	0.50	13.81	-0.91	3.95	1.30	5.74
KMA	859	-0.55	15.16	-1.88	7.61	5.46	10.10
NOA	512	-1.05	14.15	-0.86	6.29	1.10	8.16
NWC	163	-0.69	15.11	-1.14	4.99	-1.47	6.80

Table 7-8: Experiment 1: All AMVs (CQI >= 80) comparison to rawinsondes within 150 km. N= number of matches; P bias = pressure bias; P RMS = pressure RMS; Spd bias = speed bias; Spd RMS= speed RMS; Dir bias = wind direction bias; Vec RMS = 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	448	0.02	13.97	0.31	6.07	-14.61	8.62
EUM	312	-0.83	16.54	-1.79	6.54	8.31	8.56
JMA	344	0.78	13.77	-1.07	4.07	1.09	5.93
KMA	666	-0.79	15.51	-1.56	6.42	2.78	8.97
NOA	427	-1.49	13.96	-0.89	5.42	0.45	7.52
NWC	132	-0.41	15.08	-0.97	5.01	-5.98	6.94

Table 7-9: Experiment 1: Collocated AMVs (CQI >= 50) comparison to rawinsondes within 150 km. N = number of matches; P bias = pressure bias; P RMS = pressure RMS; Spd bias = speed bias; Spd RMS = speed RMS; Dir bias = wind direction bias; Vec RMS = 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	107	1.12	14.93	-1.36	9.93	-31.67	13.90
EUM	107	-1.69	12.40	-1.57	5.88	-3.01	7.43
JMA	109	2.32	13.22	-1.48	3.77	-1.20	5.35
KMA	109	-0.83	13.39	-0.99	4.44	-2.98	6.22
NOA	110	-3.57	13.13	-0.54	4.35	-3.56	5.76
NWC	110	-0.14	14.17	-0.84	5.09	-3.94	6.65

Table 7-10: Experiment 1: Best AMVs (CQI set for at least 10,000 AMVs) comparison to rawinsondes within 150 km. Total= number of best AMVs; N= number of matches; P bias = pressure bias; P RMS = pressure RMS; Spd bias = speed bias; Spd RMS= speed RMS; Dir bias = wind direction bias; Vec RMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	CQI	Total	N	P bias	P RMS	Spd bias	Spd RMS	Dir bias	Vec RMS
BRZ	**100**	**18355**	**174**	**0.87**	**12.94**	**-0.13**	**4.59**	**-18.86**	**8.03**
EUM	**98**	**11120**	**133**	**0.81**	**14.21**	**-1.59**	**6.54**	**2.79**	**8.95**
JMA	**99**	**11805**	**109**	**2.54**	**14.73**	**-1.14**	**4.53**	**1.49**	**6.95**
KMA	**99**	**19170**	**275**	**-0.68**	**14.89**	**-1.50**	**5.81**	**2.10**	**8.36**
NOA	**99**	**14086**	**180**	**0.55**	**12.04**	**-1.81**	**5.44**	**1.28**	**8.23**
NWC	**90**	**10117**	**102**	**-1.00**	**14.83**	**-0.99**	**4.82**	**-7.08**	**6.72**

e) Model Grid comparison

The Python scripts used to determine the Best fit height analysis also define the comparison of all AMVs to the NWP background model grid winds. This comparison was based on ECMWF ERA-Interim analysis using QINF and CQI >= 80. The tables are for all AMVs, all AMVs by height range (high, medium, and low), and collocated AMVs for all levels. Note: The total number of AMVs for each centre in Table 7-11 will not equal the sum of the three layers found in Table 7-12 through Table 7-14 (high, medium, low), because some of the AMVs provided are outside the pressure ranges for the layers.

The results are very consistent and do not show the variability seen in the rawinsonde comparisons above, which is similar to what was found in the 2014 Study, with the following notable differences:

- In the 2014 Study, NWC had the best statistics except for the collocated AMVs where JMA had the best statistics. In this study, JMA has significantly the best agreement to the background grid for all AMVs, discretized by level, collocated, and using both QINF and CQI.
- As in the 2014 Study, BRZ had the largest deviation from the background grid, except for the low-level AMVs when BRZ, KMA, and EUM have similar large deviations.

An additional analysis in summarized in Table 7-21 that compares the 'best' AMVs for each centre with background model winds, where 'best' is defined by a minimum CQI threshold that results in at least 10,000 AMVs. The CQI threshold ranges from 98 to 100 for all the centres, except it is 90 for NWC as the total number of AMVs for NWC is much smaller than the other centres for this experiment. Despite the use of the highest quality AMVs, the variability in the bias and RMS is similar to the other QI thresholds in Table 7-16, although the largest deviations (highlighted in yellow) are consistently smaller for the best AMVs. As with the other CQI thresholds, JMA has the best

statistics. However, the largest devitations are now split between BRZ and EUM.

Table 7-11: Experiment 1: All AMVs (QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	41304	8805	6.20	8.69	5.54	8.31
EUM	20540	6564	5.04	7.30	4.04	6.55
JMA	34160	12656	2.53	3.13	2.26	2.92
KMA	36310	12482	4.72	6.46	3.69	5.60
NOA	30377	10965	3.98	5.24	3.10	4.48
NWC	7286	2646	4.26	5.30	3.28	4.38

Table 7-12: Experiment 1: High level AMVs (100-400 hPa, QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	16360	5809	7.18	9.66	5.92	8.94
EUM	12104	5212	5.76	8.12	4.40	7.14
JMA	17217	9031	2.93	3.63	2.58	3.35
KMA	22171	10048	5.26	6.91	3.89	5.78
NOA	19002	8880	4.91	6.18	3.73	5.24
NWC	4636	2277	4.69	5.77	3.39	4.59

Table 7-13: Experiment 1: Mid level AMVs (400-700 hPa, QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	8196	683	9.65	12.25	9.38	12.15
EUM	2514	476	6.03	8.19	5.36	7.79
JMA	6389	1463	2.65	3.09	2.46	2.94
KMA	4565	964	5.74	7.52	5.05	7.10
NOA	752	306	5.10	6.50	4.15	5.88
NWC	633	138	5.39	6.41	4.72	5.96

Table 7-14: Experiment 1: Low level AMVs (700-1000 hPa, QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	16649	2311	3.50	4.53	3.24	4.36
EUM	5906	871	3.11	4.63	2.73	4.32
JMA	10526	2151	1.79	2.12	1.63	1.99
KMA	9555	1464	2.99	4.56	2.57	4.19
NOA	10609	1775	2.22	2.69	1.91	2.36
NWC	2013	229	2.93	3.46	2.57	3.13

Table 7-15: Experiment 1: Collocated AMVs (QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	4930	1191	5.90	8.47	5.27	8.16
EUM	4930	1625	3.96	4.93	3.19	4.28
JMA	4930	1793	2.48	2.96	2.24	2.77
KMA	4930	1732	3.69	4.61	2.85	3.79
NOA	4930	1757	3.45	4.30	2.76	3.73
NWC	4930	1763	3.95	4.70	3.09	3.95

The same as the above tables, except for CQI >=80.

Table 7-16: Experiment 1: All AMVs (CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	37180	8522	5.85	8.28	5.16	7.87
EUM	22105	7020	5.01	7.14	4.03	6.40
JMA	29740	10482	2.63	3.26	2.37	3.07
KMA	45566	15587	4.91	6.67	3.85	5.81
NOA	30377	10965	3.98	5.24	3.10	4.48
NWC	11960	4289	4.29	5.24	3.32	4.34

Table 7-17: Experiment 1: High level AMVs (100-400 hPa, CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	15093	5697	6.78	9.10	5.48	8.31
EUM	12831	5530	5.69	7.78	4.33	6.77
JMA	14527	7397	3.06	3.79	2.71	3.54
KMA	28970	12664	5.44	7.12	4.06	6.01
NOA	19002	8880	4.91	6.18	3.73	5.24
NWC	8083	3723	4.63	5.60	3.41	4.49

Table 7-18: Experiment 1: Mid level AMVs (400-700 hPa, CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	6511	591	9.78	12.47	9.50	12.38
EUM	2763	526	5.91	7.93	5.25	7.54
JMA	5622	1185	2.75	3.19	2.57	3.05
KMA	5401	1149	5.74	7.52	5.06	7.12
NOA	752	306	5.10	6.50	4.15	5.88
NWC	956	186	5.24	6.27	4.66	5.88

Table 7-19: Experiment 1: Low level AMVs (700-1000 hPa, CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	15482	2230	3.24	4.13	2.98	3.94
EUM	6496	959	3.29	5.20	2.91	4.93
JMA	9571	1891	1.91	2.28	1.75	2.16
KMA	11168	1766	3.14	4.75	2.71	4.40
NOA	10609	1775	2.22	2.69	1.91	2.36
NWC	2914	377	3.03	3.55	2.62	3.18

Table 7-20: Experiment 1: Collocated AMVs (CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	8076	2122	5.54	7.53	4.85	7.13
EUM	8076	2655	4.04	4.97	3.24	4.28
JMA	8076	2860	2.59	3.10	2.33	2.89
KMA	8076	2802	3.80	4.73	2.97	3.94
NOA	8076	2854	3.54	4.36	2.82	3.74
NWC	8076	2791	3.99	4.74	3.17	4.03

Table 7-21: Experiment 1: Best AMVs (CQI set for at least 10,000 AMVs) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	CQI	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	100	18355	3946	4.71	6.62	4.14	6.21
EUM	98	11120	3712	4.80	6.90	3.83	6.19
JMA	99	11805	4353	2.52	3.19	2.27	3.02
KMA	99	19170	7166	4.74	6.57	3.63	5.65
NOA	99	14086	5342	3.78	5.07	2.89	4.27
NWC	90	10117	3669	4.25	5.21	3.28	4.31

f) Best fit height

The Best Fit height analysis was 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 NWP model analysis wind is at a minimum.

It does this by first determining the model pressure level of the minimum vector difference between the AMV and the model background. Then, the actual minimum is calculated by using a parabolic fit to the vector difference for this model level and the levels directly above and below, 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 was generally about 30% of the AMVs (Salonen et al. 2012).

The following figures 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).

Most of the plots are in agreement that in the northern hemisphere, only high-level clouds are adjusted, while in the south both high and low level clouds are moved due to the best fit. The distribution of high, mid, and low-level clouds (upper left plots) are very similar between the different centers with a spread of +/- 200 hPa for the high clouds, except JMA with a much tighter and smoother distribution (+/- 100 hPa). This further confirms that the JMA AMVs vary little from the ECMWF analysis compared to the other AMV producers and may indicate their cloud height method has a stronger dependency on the background grids.

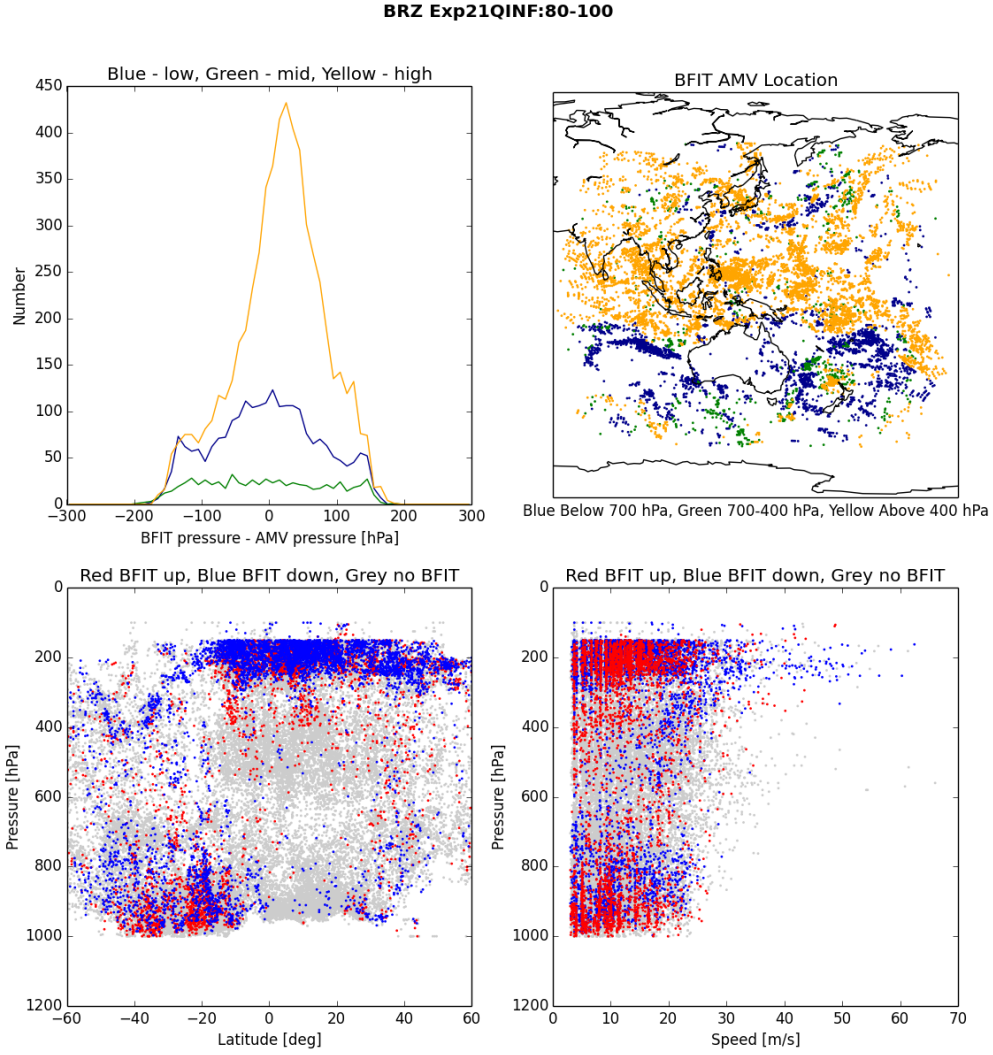


Figure 7-7: BRZ (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

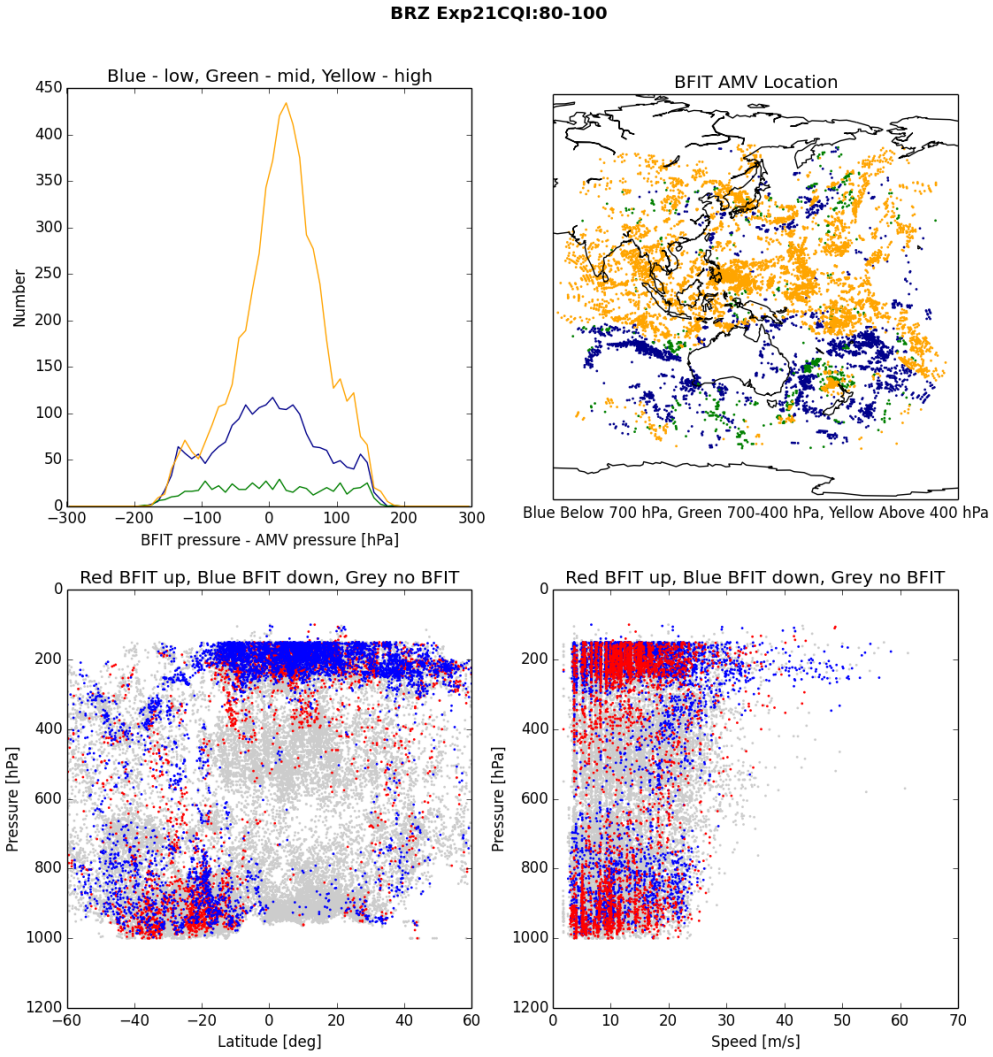


Figure 7-8: BRZ (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

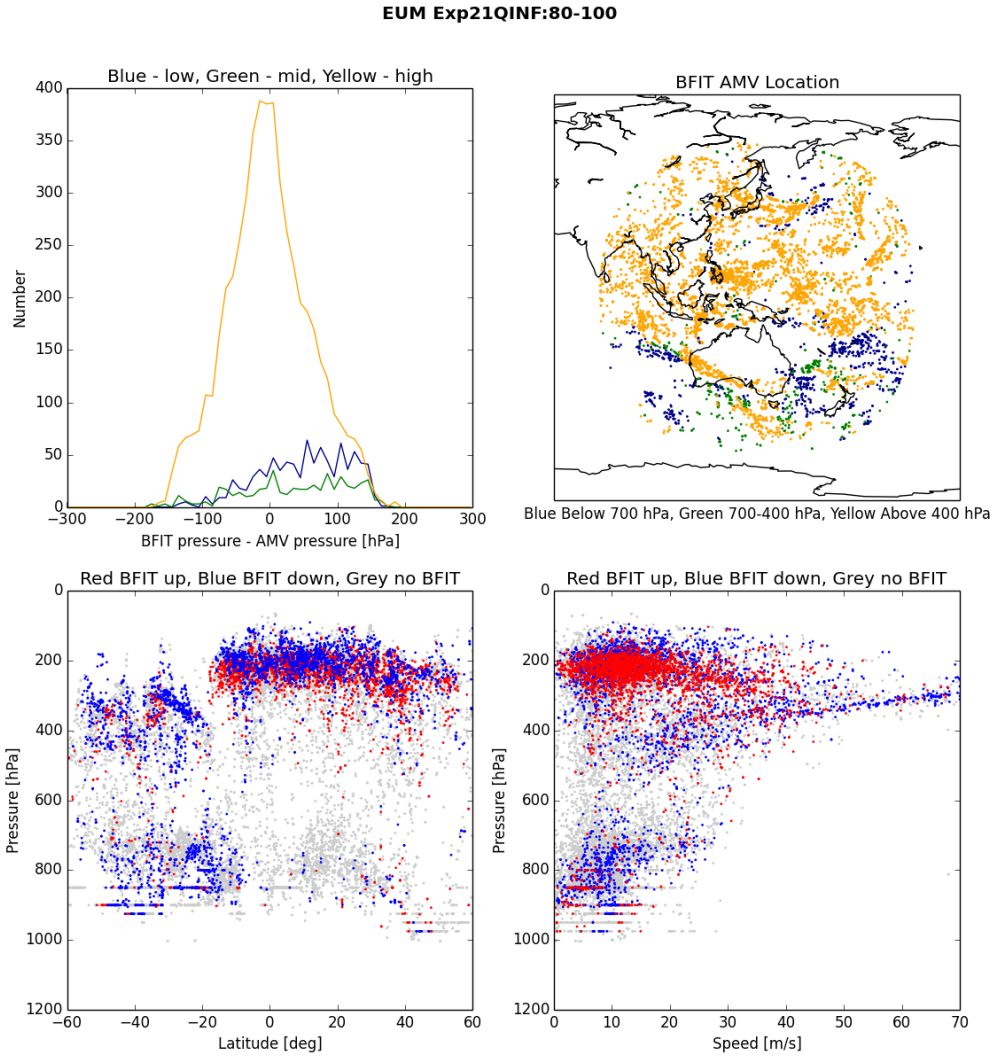


Figure 7-9: EUM (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

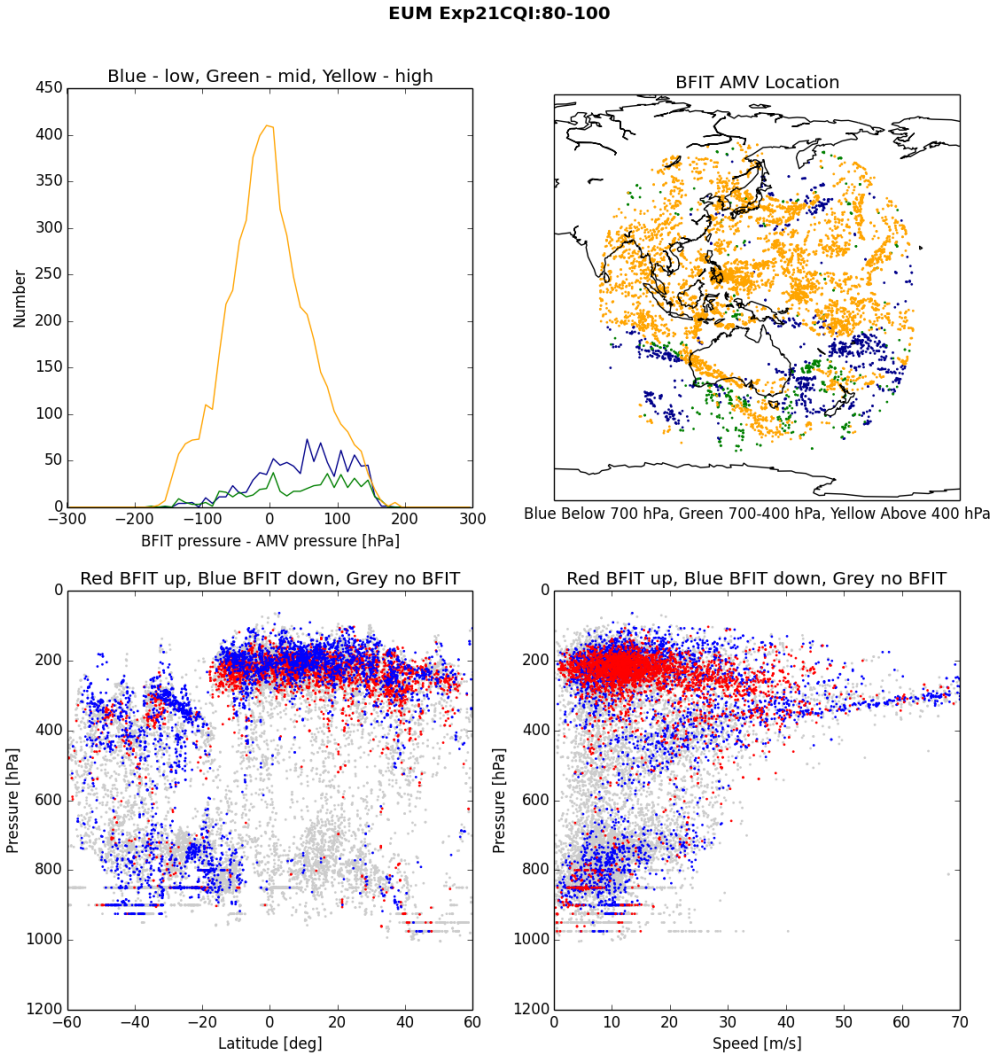


Figure 7-10: EUM (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

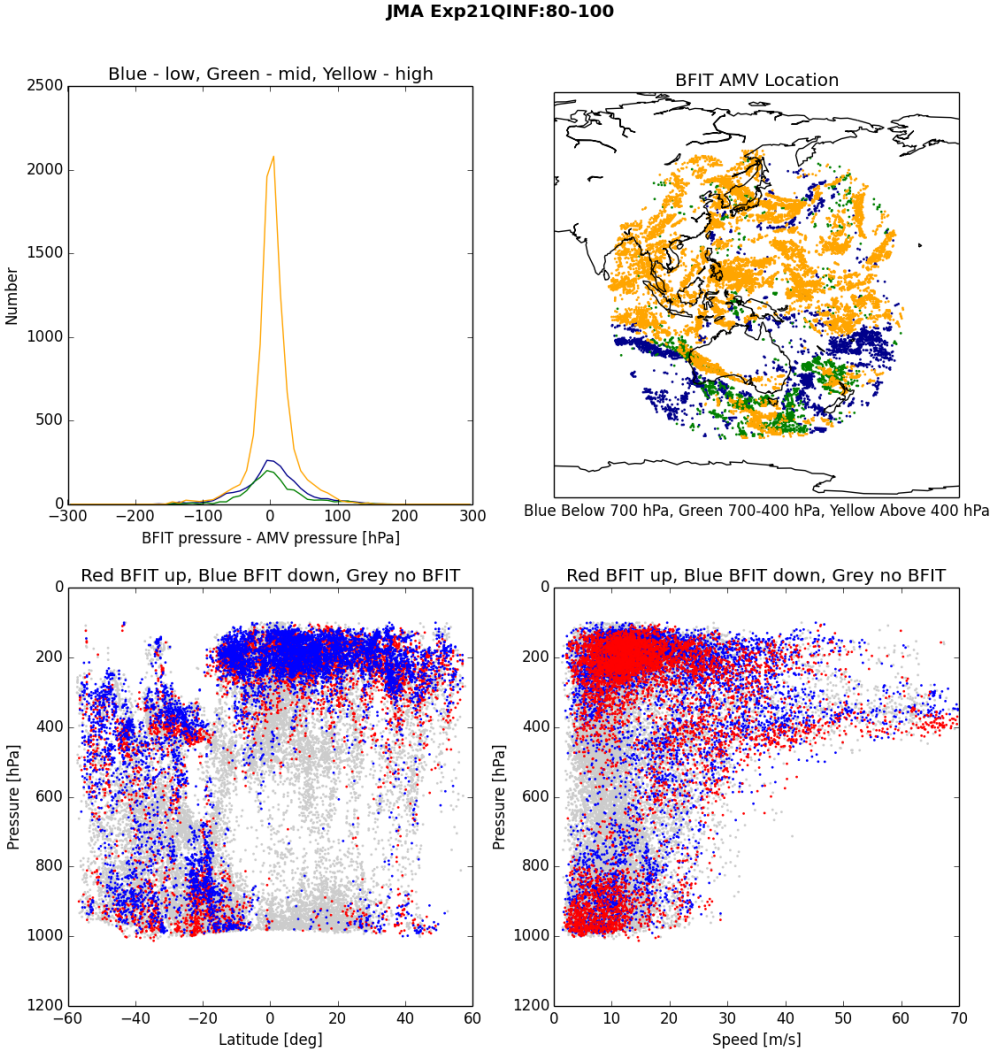


Figure 7-11: : JMA (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

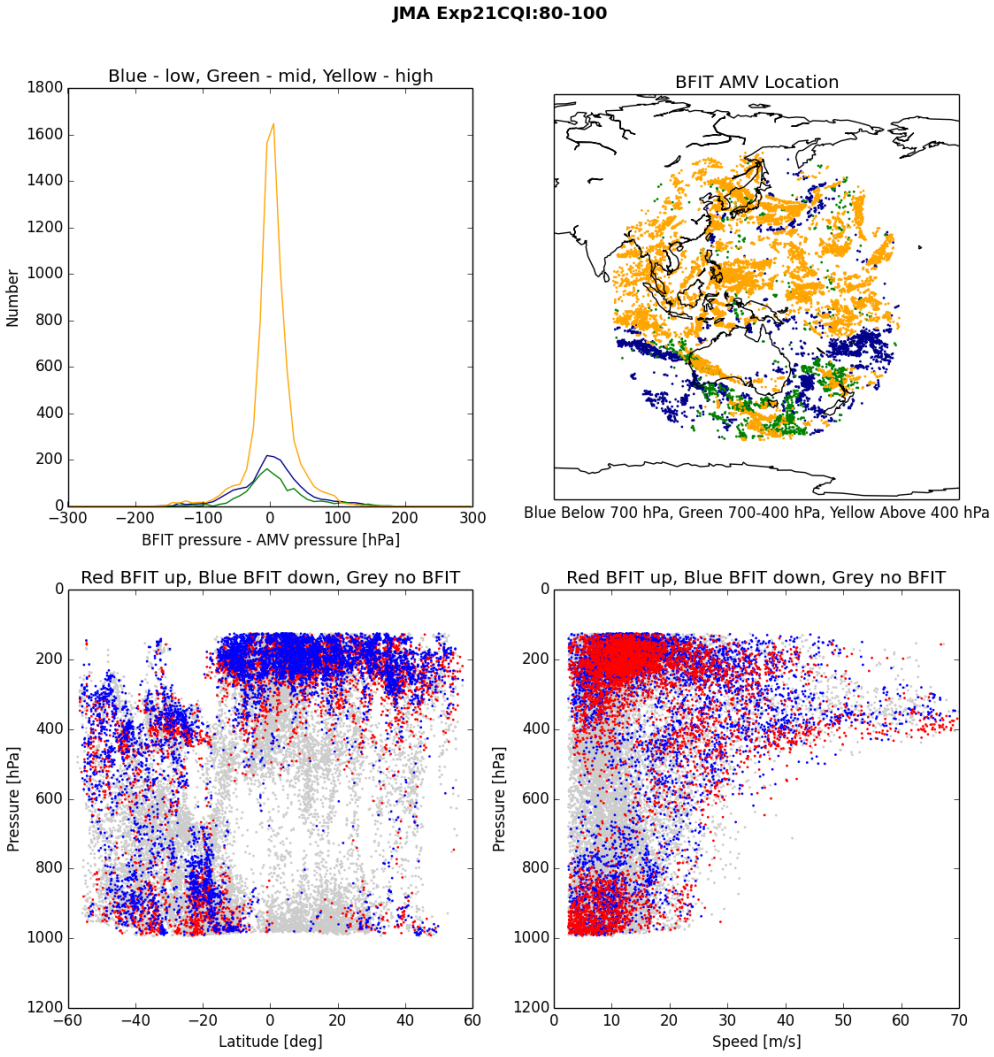


Figure 7-12: JMA (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

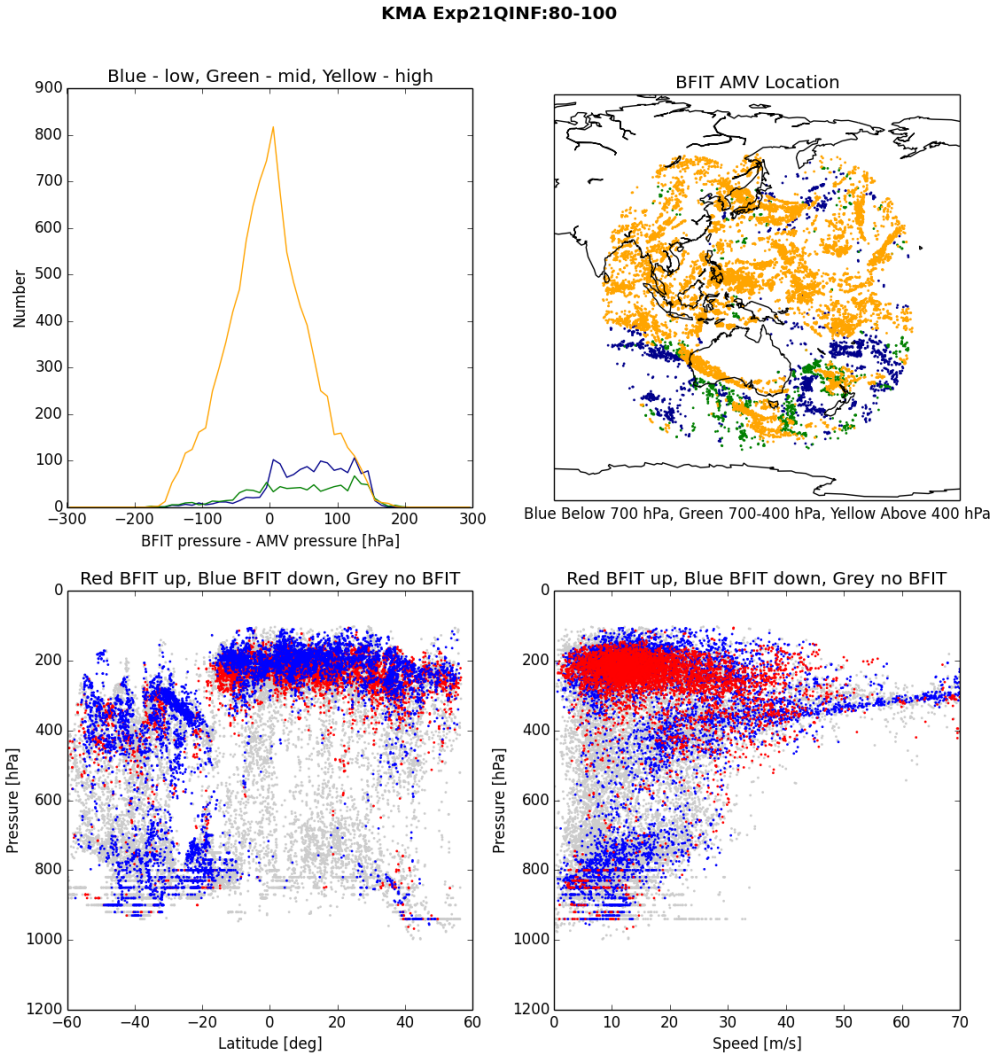


Figure 7-13: KMA (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

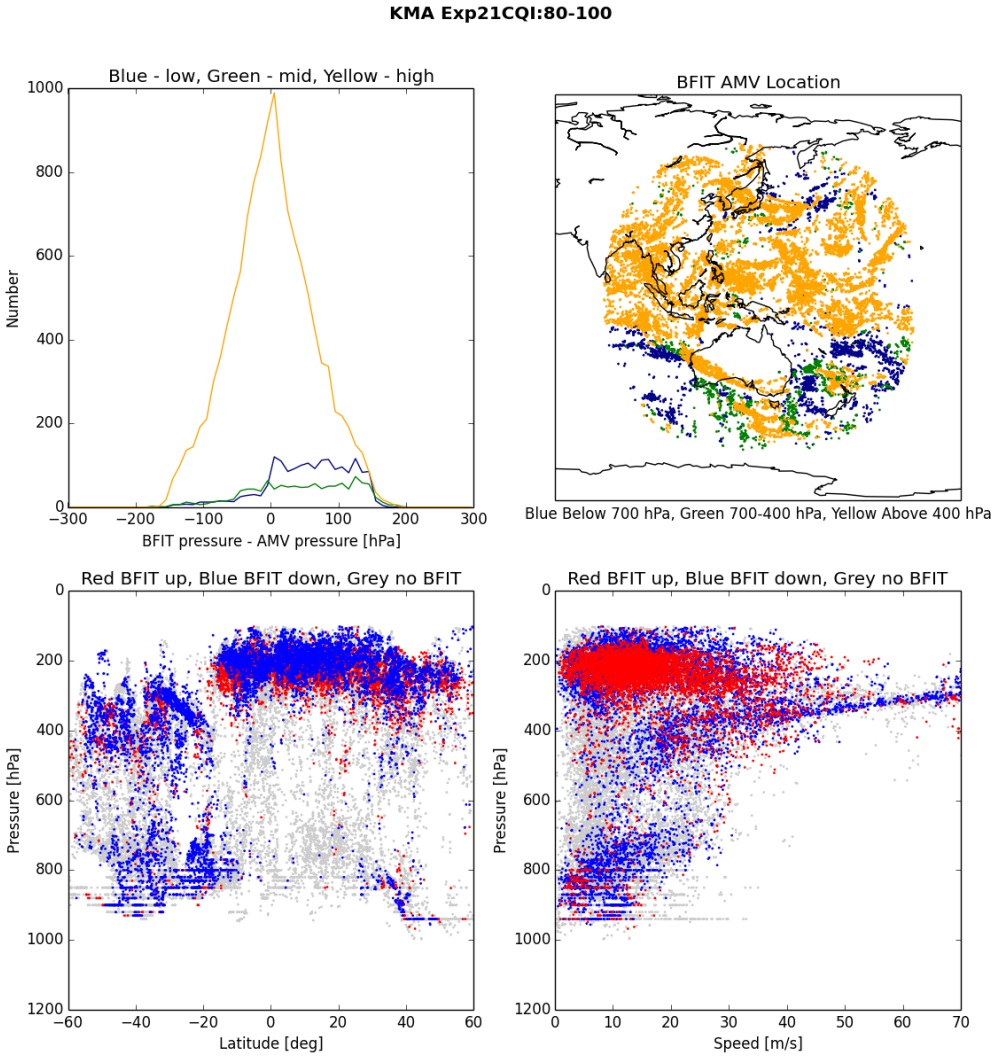


Figure 7-14: KMA (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

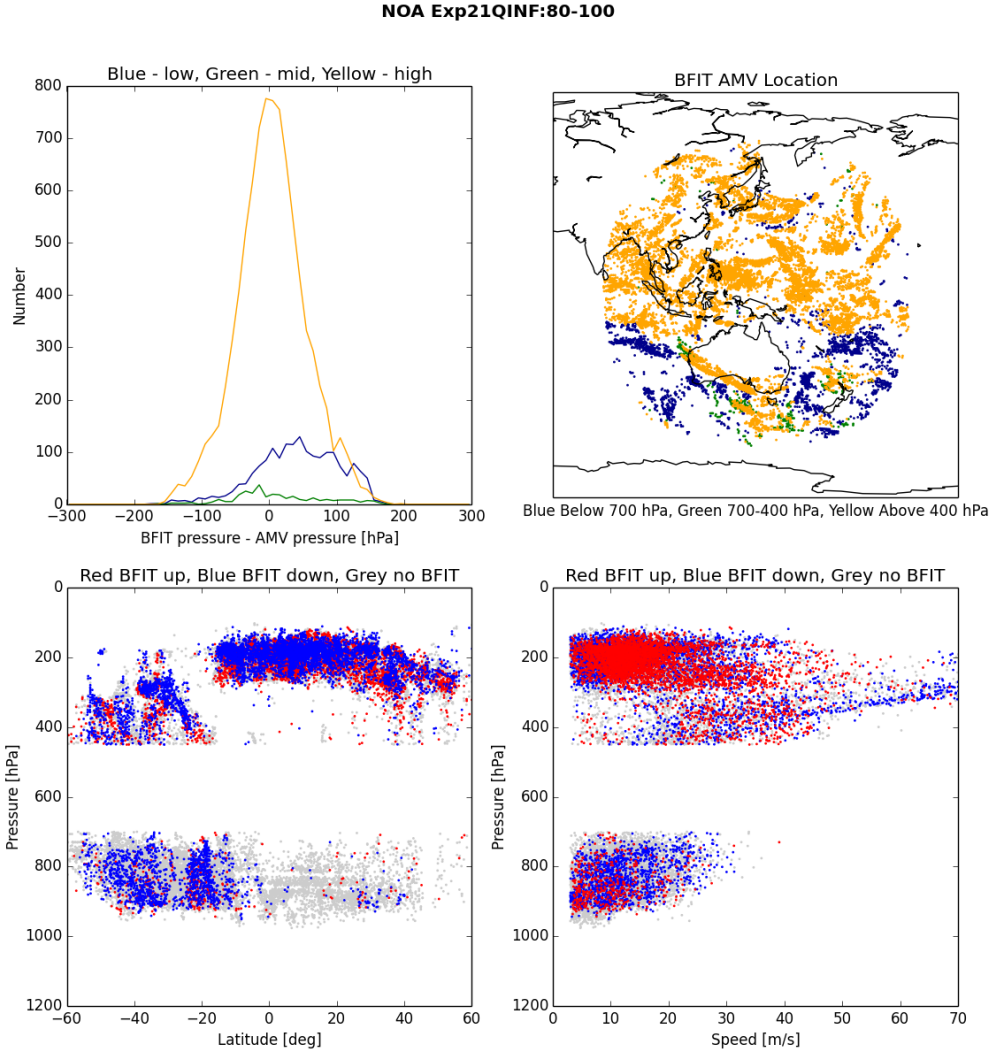


Figure 7-15: NOA (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

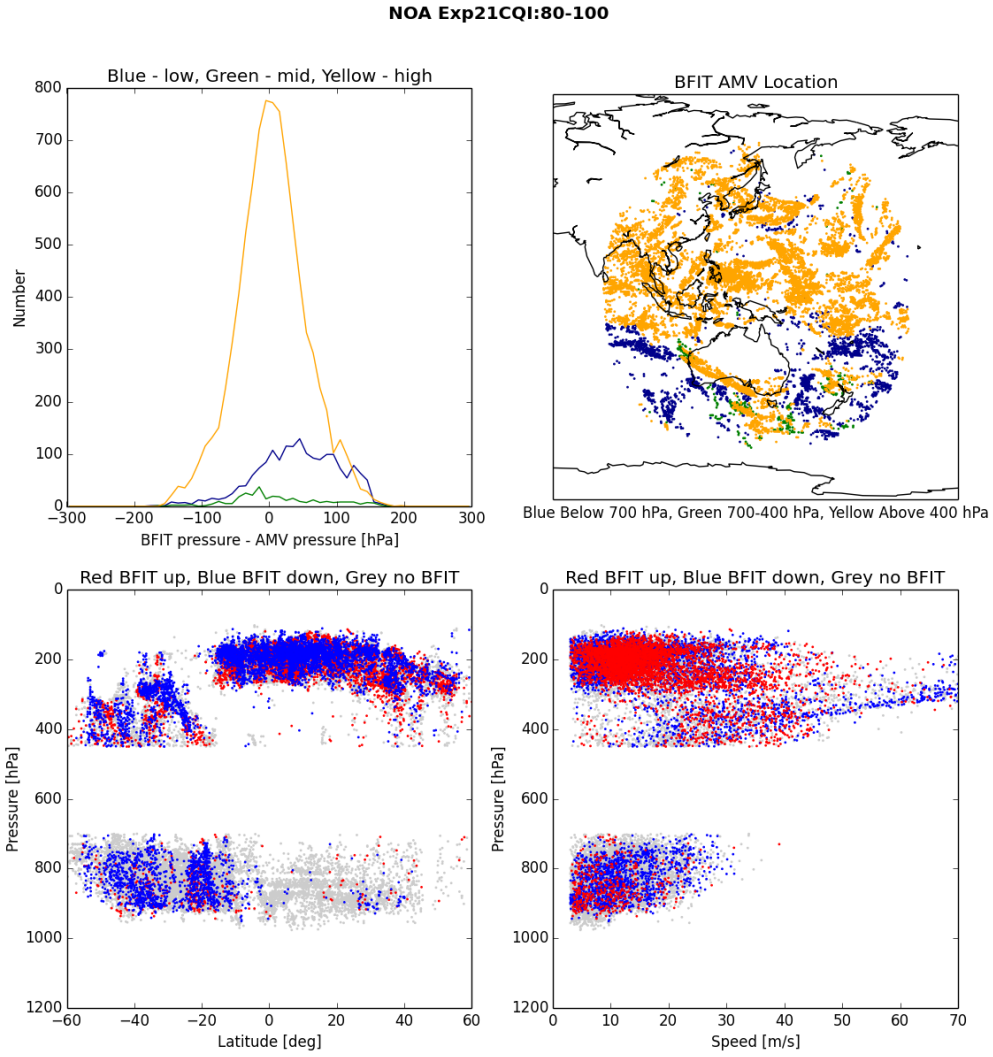


Figure 7-16: NOA (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

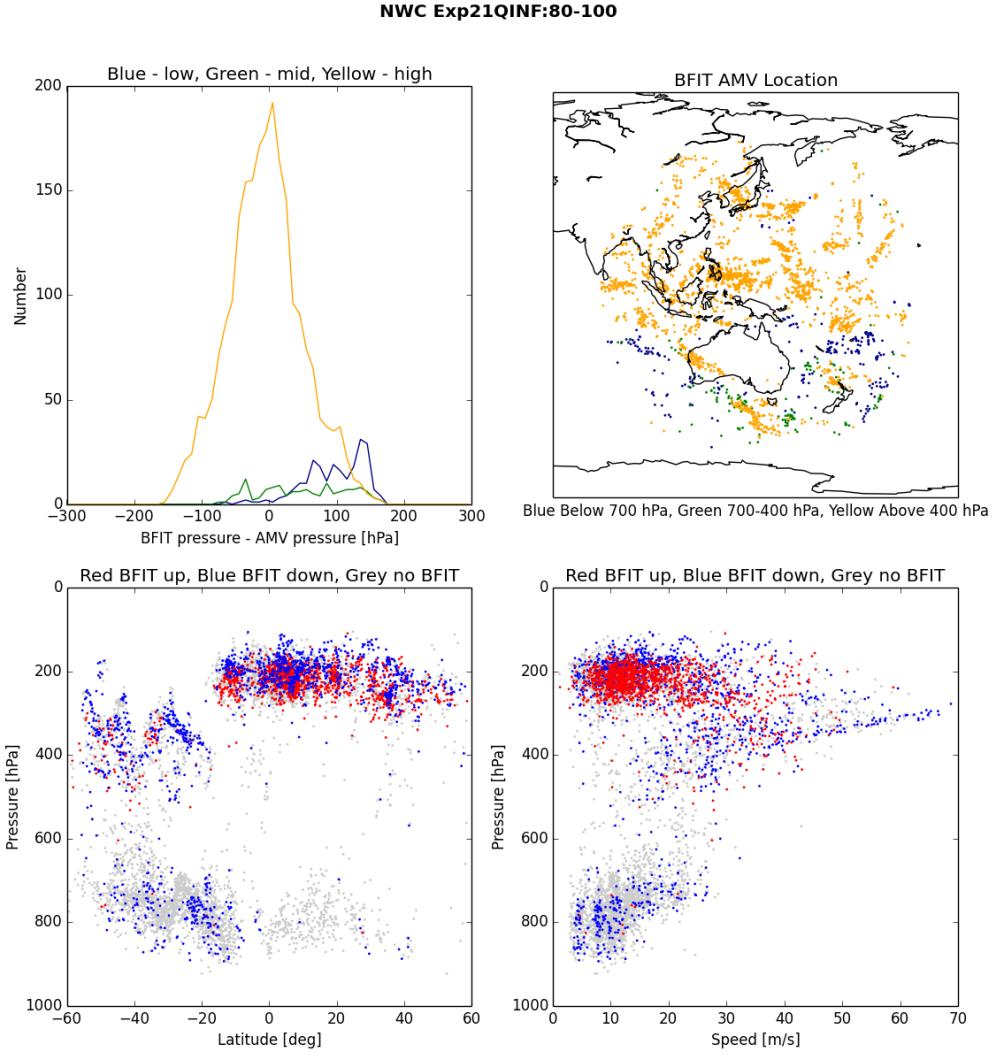


Figure 7-17: NWC (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

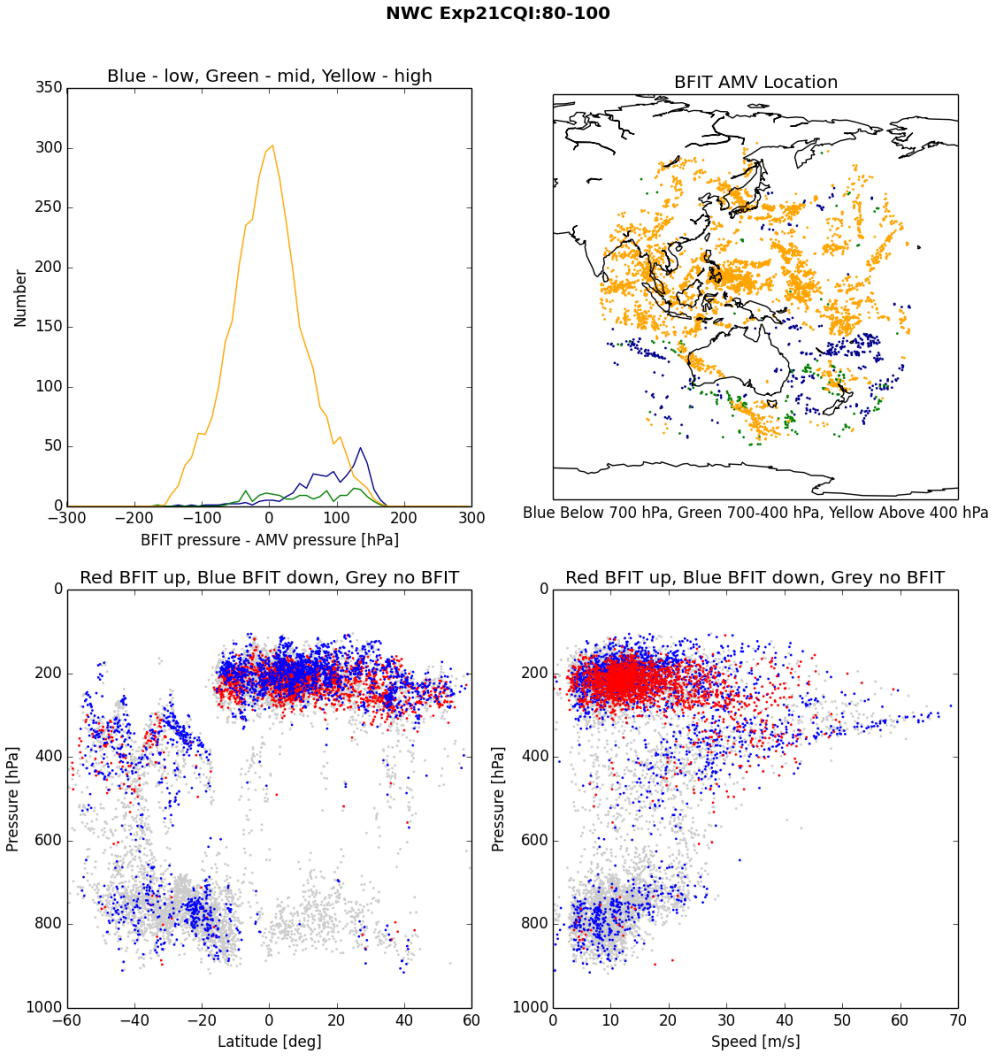


Figure 7-18: NWC (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

The depiction of the distribution of Best Fit statistics is located in the following series of figures. Depending on the site, 21% to 36% of the AMVs are adjusted to a Best Fit pressure (lower-left in each figure). This is on average about a 10% improvement over Experiment 4 in the 2014 Study. 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 for all centres (which was not as consistent in the 2014 Study) of the pressure difference centered near zero (upper-right panel in figures) extending ±200 hPa. The one exception is JMA, where the deviation is ±100 hPa.

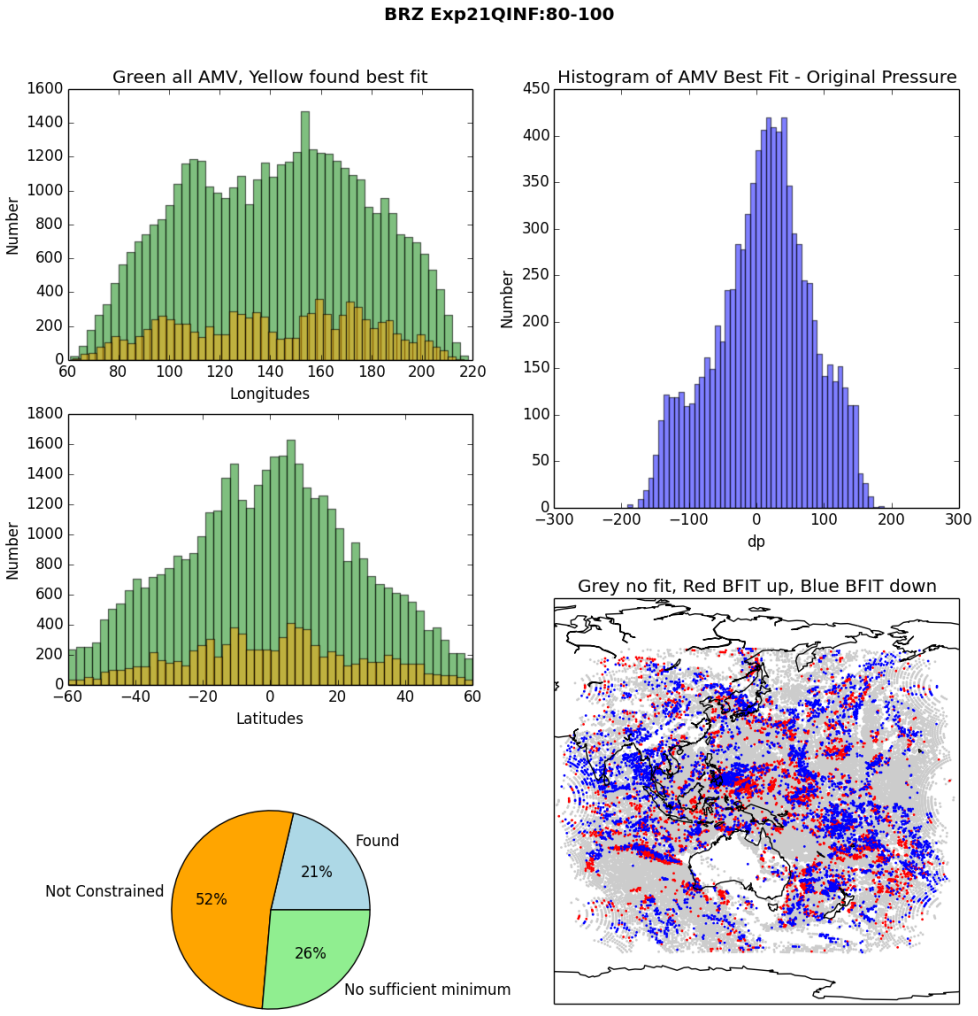


Figure 7-19: BRZ (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

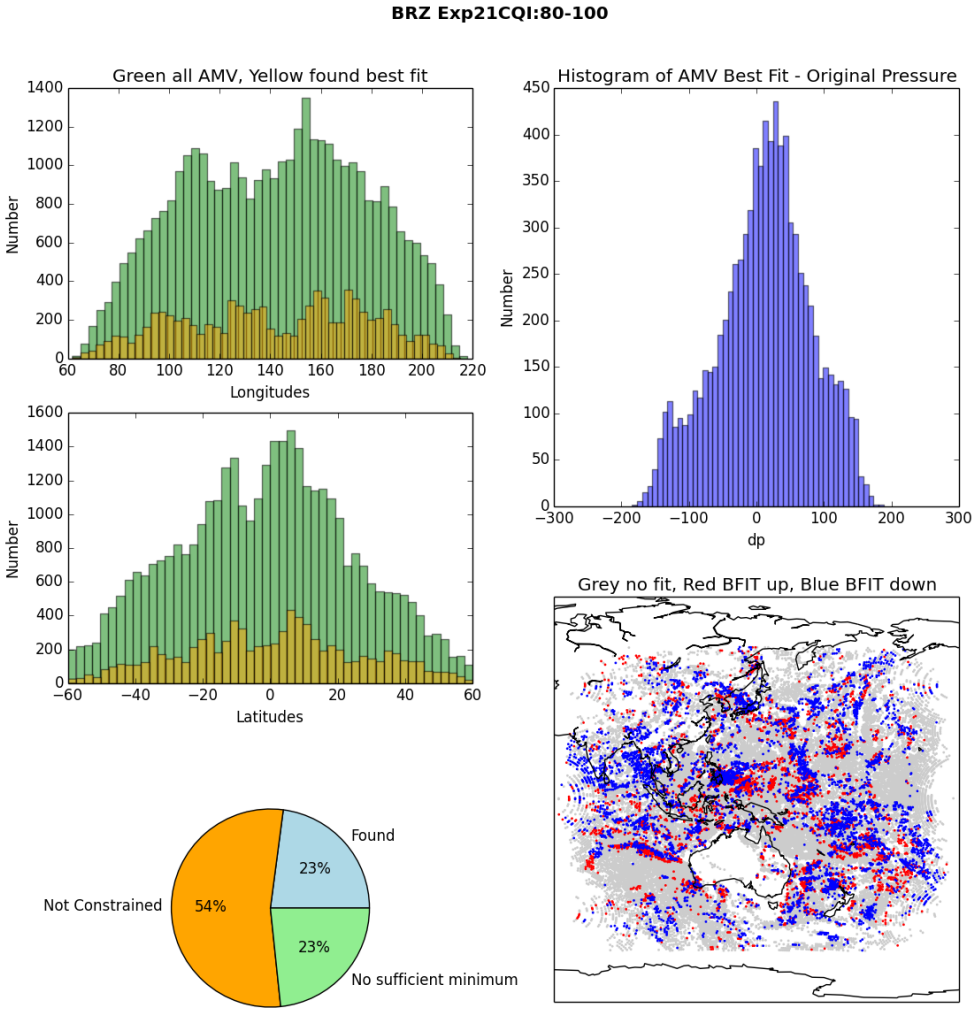


Figure 7-20: BRZ (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

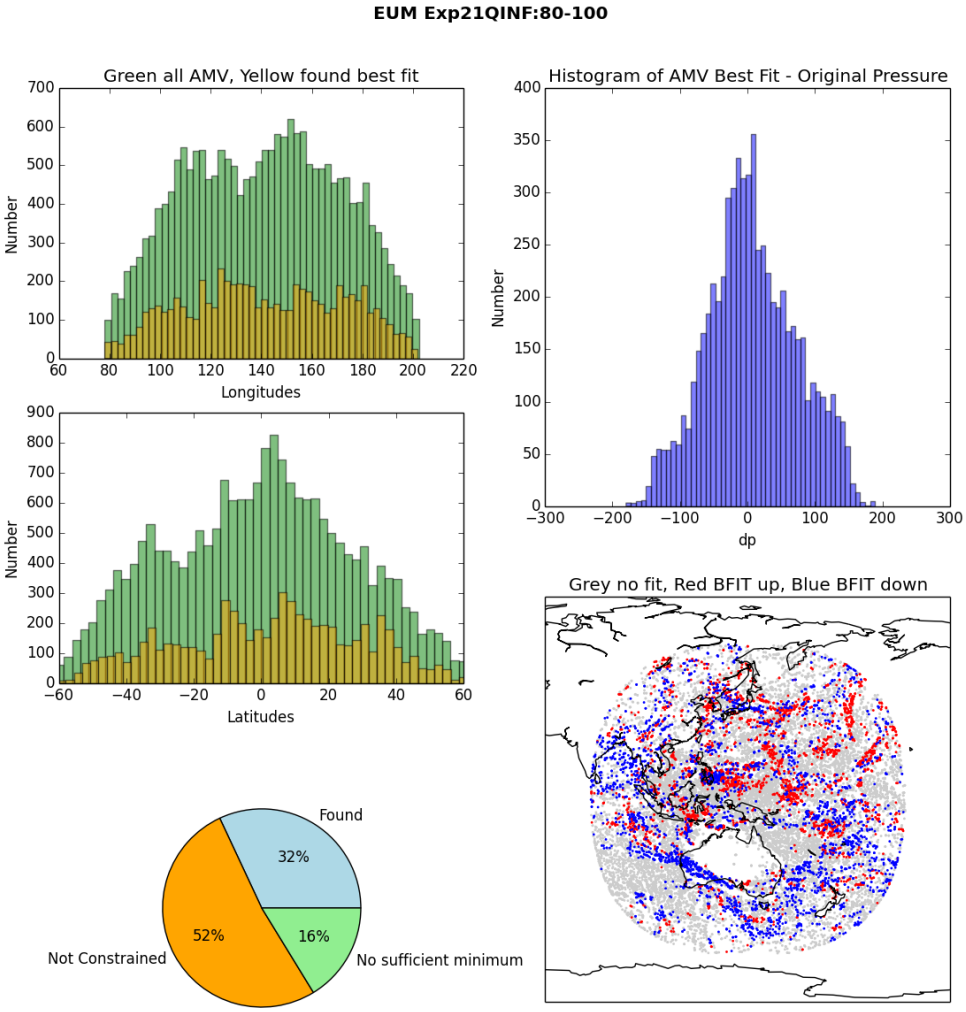


Figure 7-21: EUM (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

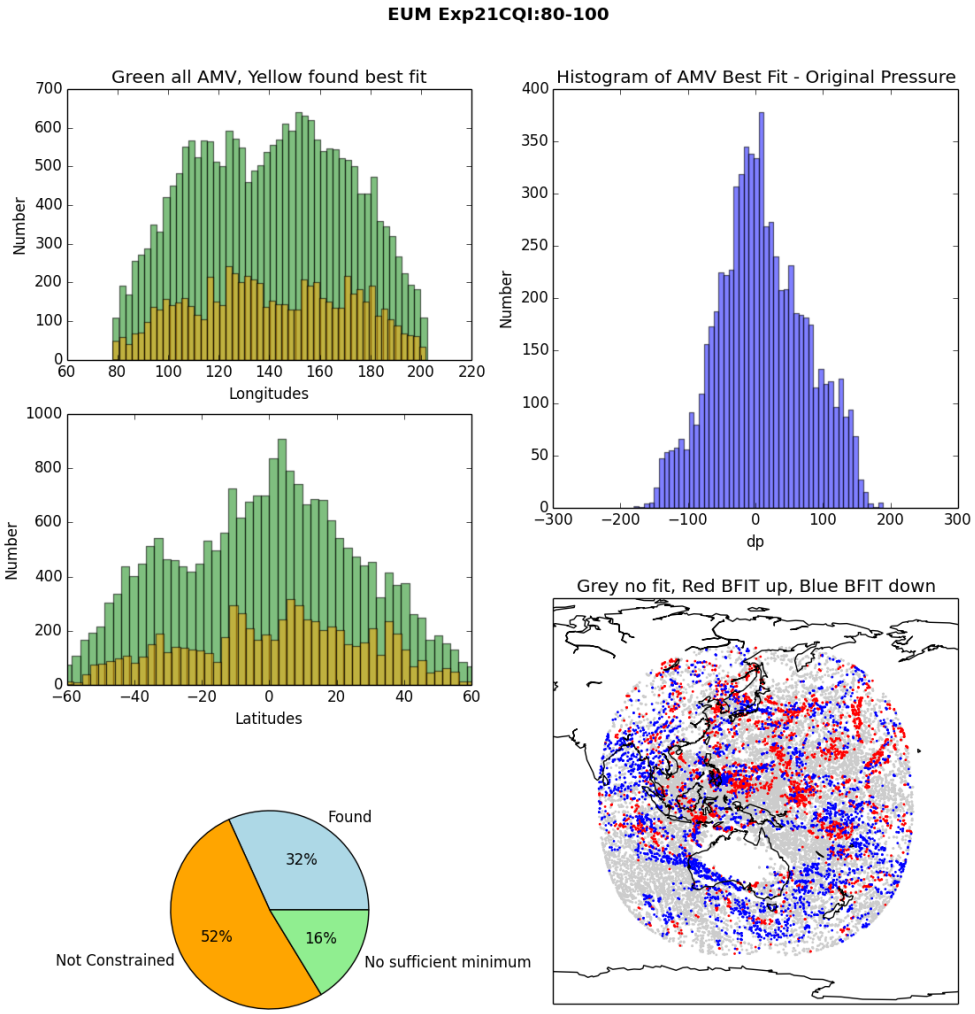


Figure 7-22: EUM (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

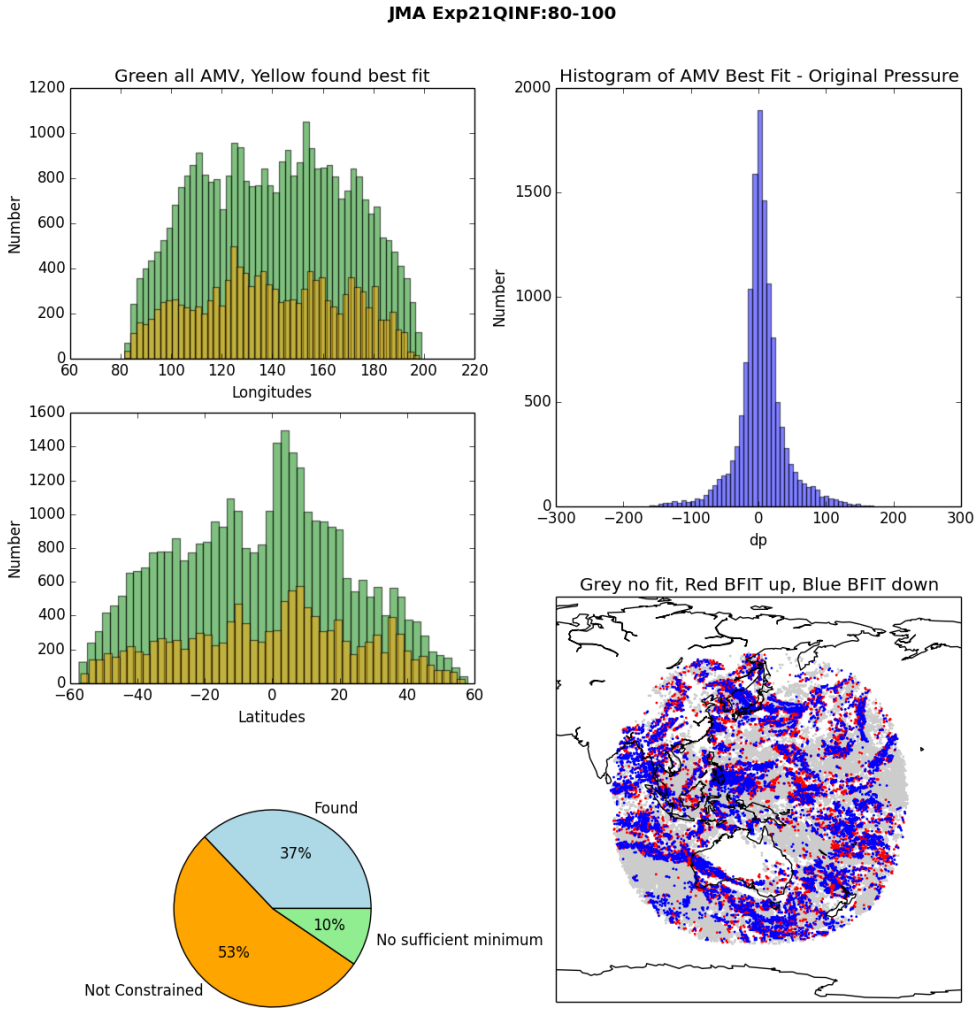


Figure 7-23: JMA (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

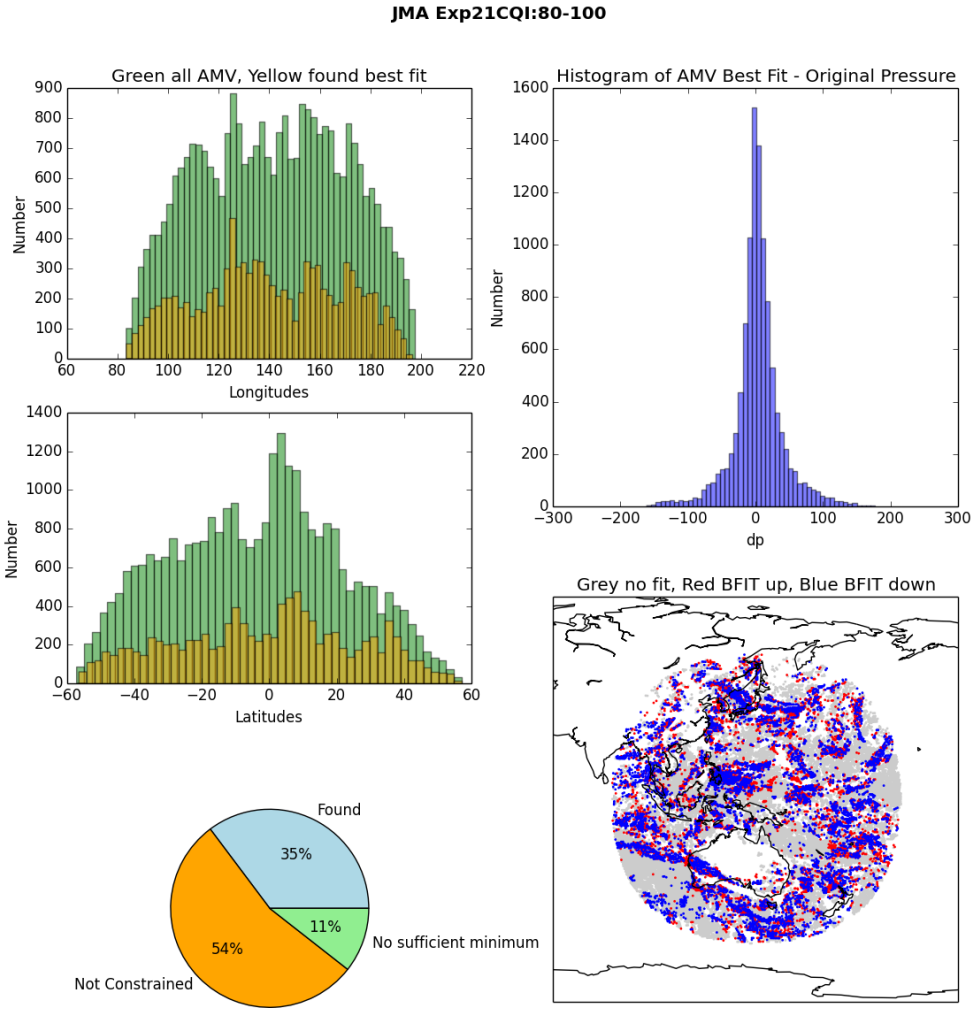


Figure 7-24: JMA (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

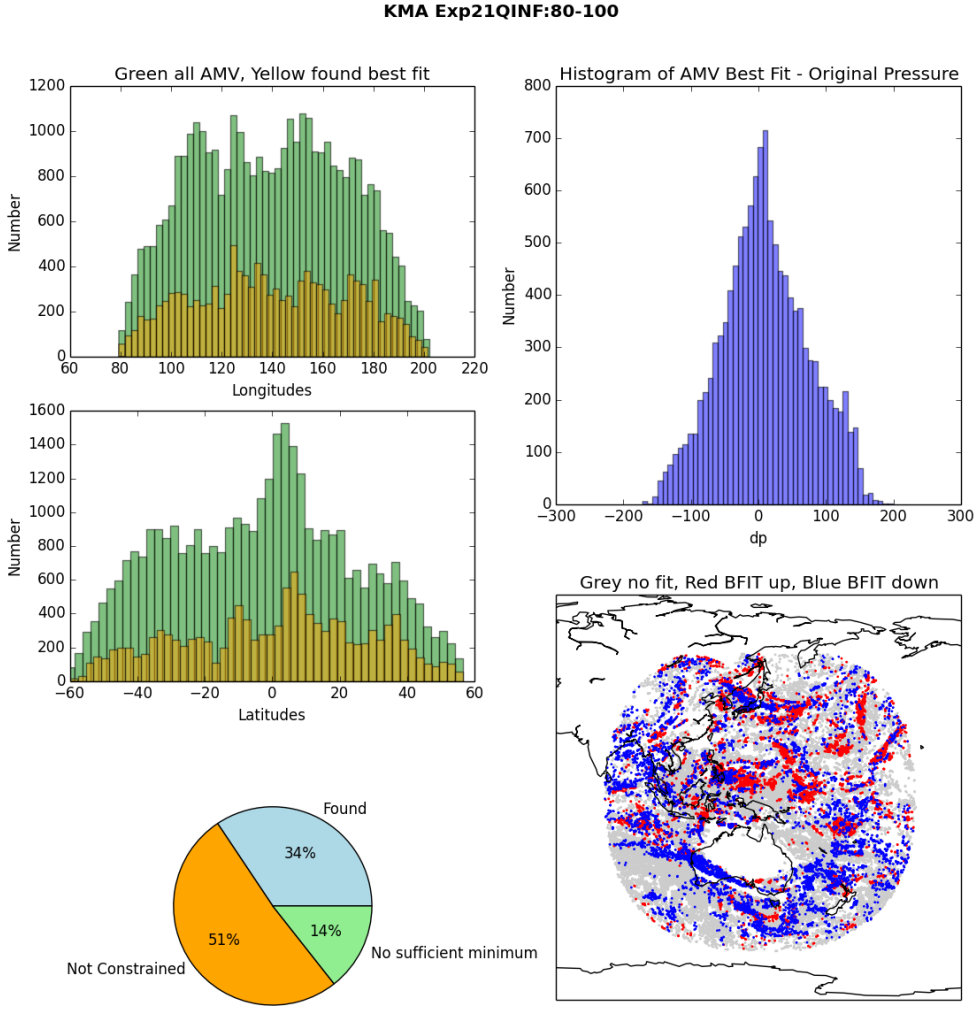


Figure 7-25: KMA (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

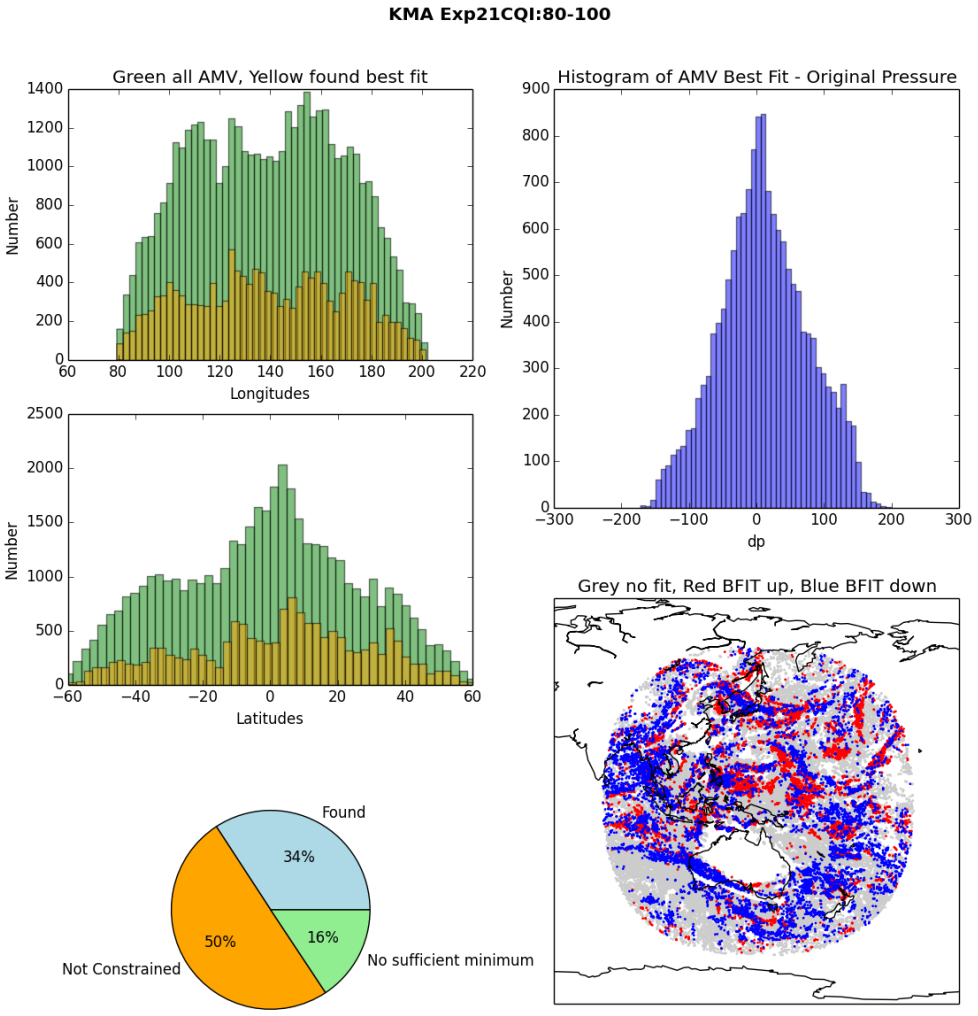


Figure 7-26: KMA (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

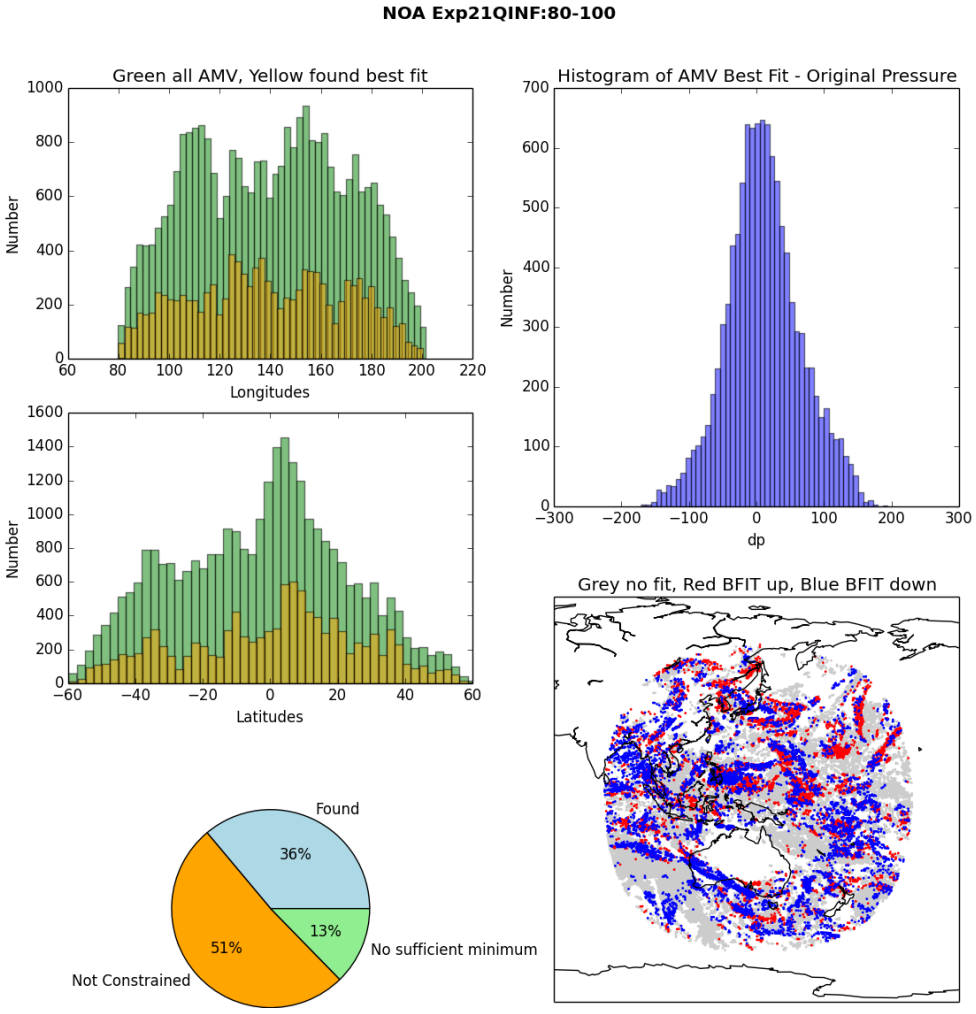


Figure 7-27: NOA (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

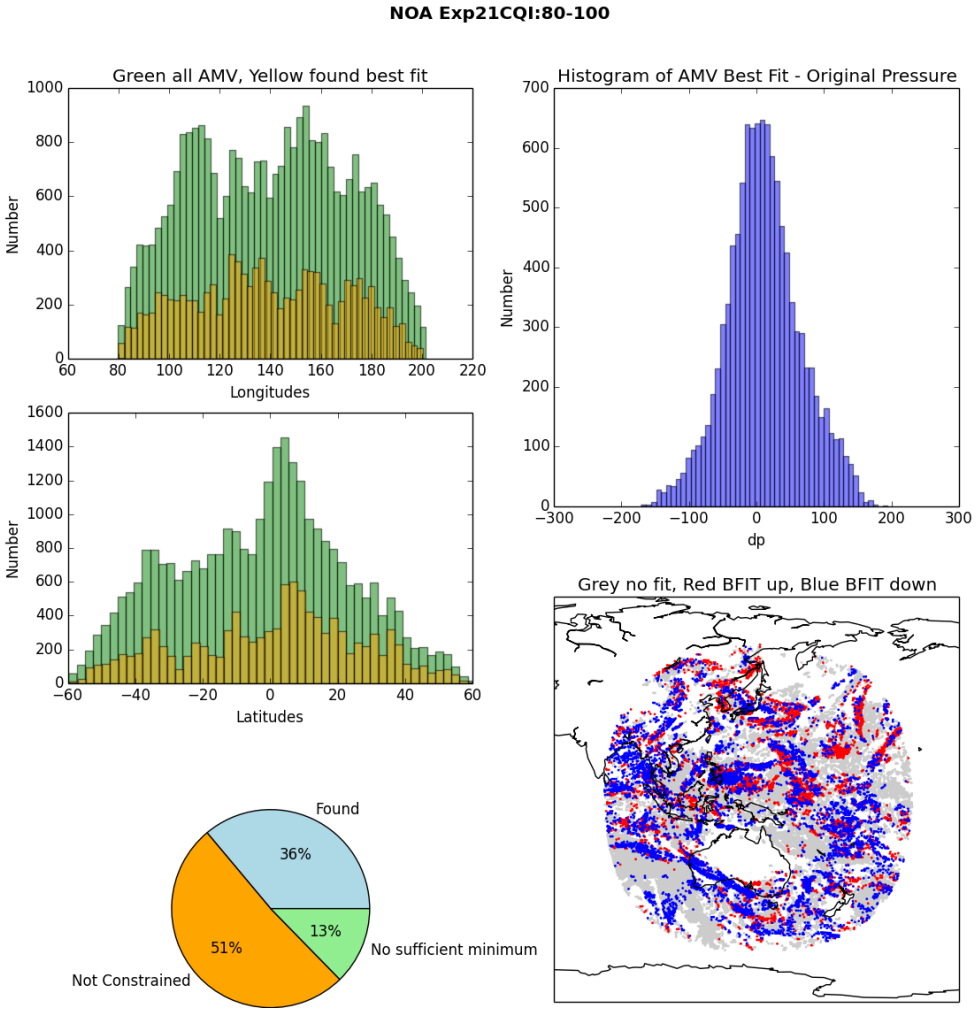


Figure 7-28: NOA (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

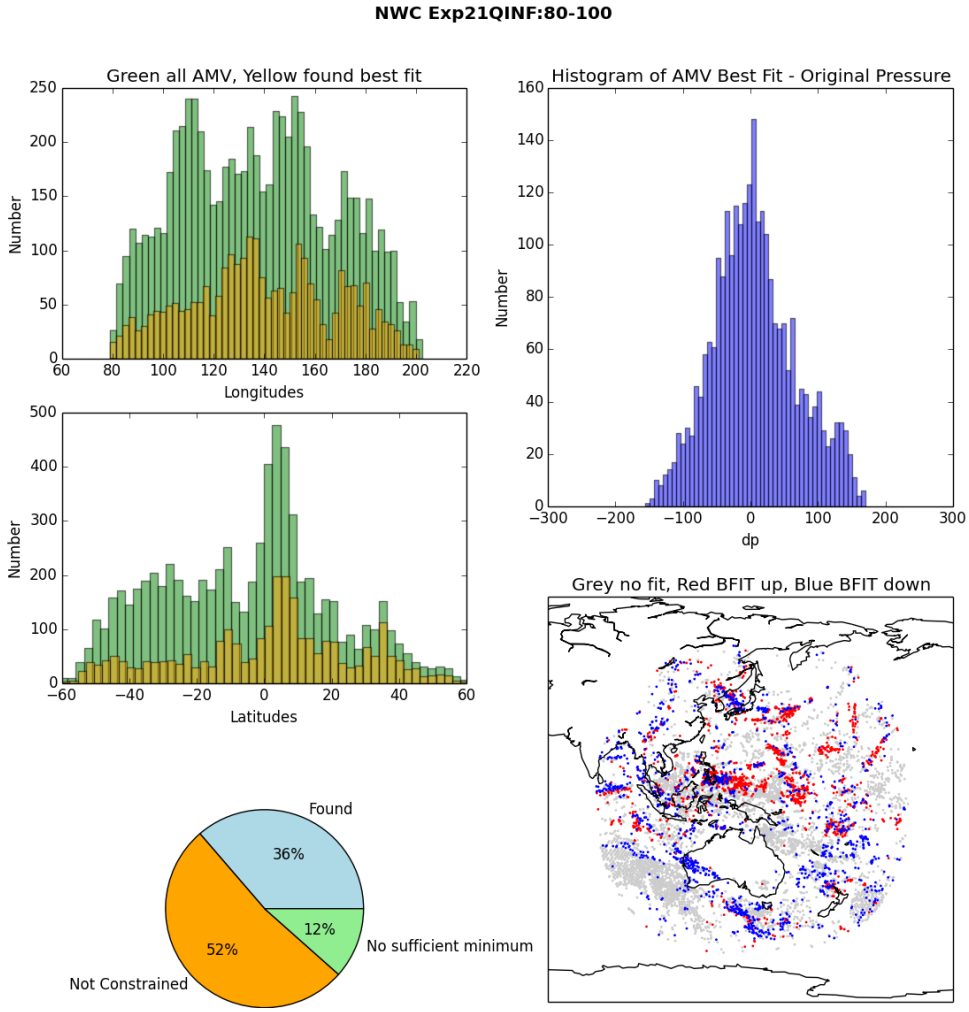


Figure 7-29: NWC (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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).

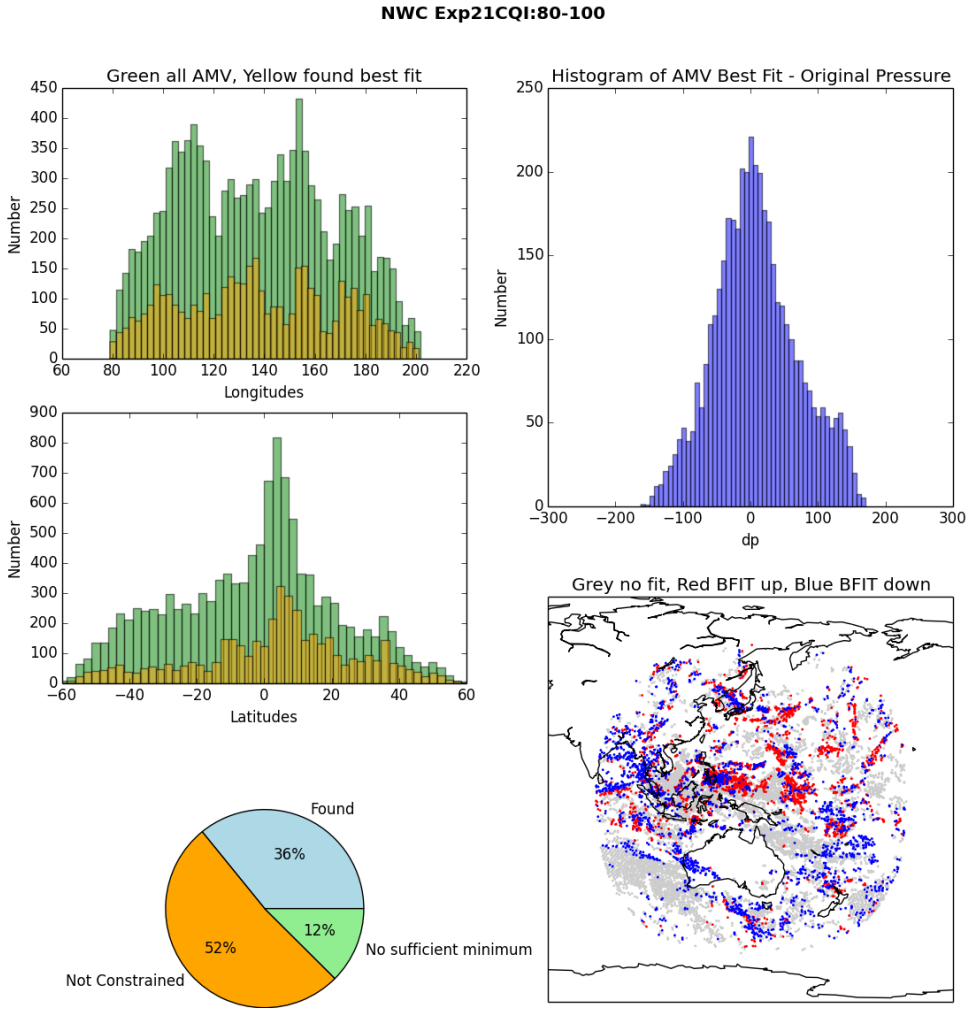


Figure 7-30: NWC (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, No sufficient 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 in Appendix D: Best Fit Speed and Vector Difference to show the distribution of the differences between the AMVs and the background grid, before and after applying the Best Fit algorithm. The lower half of Figure 16-1 to Figure 16-12 shows the change in the *speed difference* distribution before (left) and after (right) Best Fit adjustment. As expected, the speed bias is usually reduced, and the standard deviation is reduced by a factor of 3 to 4. The one exception is JMA, where the improvement in the standard deviation is only on the order of 30%, as the JMA standard deviation before the Best Fit is nearly as good as the other centres *after* the Best fit.

g) 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 *t-test* 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.

To quantify the observed differences in the plots, a paired t-test is once again used with all combinations of producers and parameters. Table 7-22 to Table 7-37 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 and 80, and CQI >=50 and 80. For collocation the distance threshold here is 35 km.

The most consistent agreement was for direction for both the QINF thresholds of 50% (Table 7-23) and 80% (Table 7-27), and the higher CQI threshold of 80% (Table 7-35). The lack of agreement was most evident for AMV pressure, likely due to the lack of commonality in the cloud height algorithms. Even though NWC and EUM both used the CCC method, there were still significant differences for this experiment.

In general, more homogeneity between variables in different datasets is seen using a higher QI threshold (which can be a significant output from this study), and even more using the Common QI threshold of 80% for the filterings (which also can be a significant output from this study).

Table 7-22: Experiment 1, QINF>=50. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 7-23: Experiment 1, QINF>=50. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 7-24: Experiment 1, QINF>=50. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 7-25: Experiment 1, QINF>=50. QI 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 7-26: Experiment 1, QINF>=80. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 7-27: Experiment 1, QINF>=80. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 7-28: Experiment 1, QINF>=80. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 7-29: Experiment 1, QINF>=80. QI 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 7-30: Experiment 1, CQI>=50. 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 was not included.

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

Table 7-31: Experiment 1, CQI>=50. 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 was not included.

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

Table 7-32: Experiment 1, CQI>=50. 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 was not included.

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

Table 7-33: Experiment 1, CQI>=50. QI 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 was not included.

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

Table 7-34: Experiment 1, CQI>=80. 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 was not included.

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

Table 7-35: Experiment 1, CQI>=80. 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 was not included.

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

Table 7-36: Experiment 1, CQI>=80. 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 was not included.

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

Table 7-37: Experiment 1, CQI>=80. QI 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 was not included.

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

8. Experiment 2

AMV producers extract infrared channel AMVs considering their standard AMV algorithm configuration, using the Himawari-8/AHI IR10.4μ images. The NOAA/NESDIS cloud product could be used if possible, for the height assignment. But again, only EUM, NOA and NWC used this cloud height product for the height assignment. This experiment was used to test differences in the AMV calculation process for the different centres, between the prescribed and their standard configurations.

The standard AMV configuration is defined by the individual producers as their typical settings for target box size, search box size and target locations. There was not a specific similar experiment in the 2014 Intercomparison study to be compared with, although it could be considered as a mixed version of Experiments 2 and 4 in the previous study (Santek et al. 2014). However, because of this, direct comparisons with those experiments in the 2014 Study are tenuous.

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

Collocated AMVs from the different algorithms are 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 are used for verification.

Experiment 2 Highlights

The results for Experiment 2 are similar to Experiment 1, above.

As said before, the design of the second experiment included a cloud height product along with the producer's standard configuration for the wind algorithm settings (target box size, search box size, target locations), to be used if possible for the height assignment. However, only EUM, NOA and NWC used this cloud height product for the height assignment. This resulted again in the AMV height comparison being more variable for collocated vectors, compared to any of the experiments in the 2014 Study. This indicates that the cloud height method is the main driver in variability, over prescribed vs. standard configurations of target box location, size, search box size, etc.

Generally, comparing the number of AMVs with the previous experiment prescribed configuration, the main difference is the number of AMVs for some centres (NWC around 15 times more AMVs; EUM around half number of AMVs). There are also in general more AMVs for all cases compared to Experiment 2 and 4 in the 2014 Study, due in part to the higher resolution of AHI imager (2km) vs SEVIRI (3 km), more oceanic regions, and fewer deserts.

When the AMVs are compared to rawinsondes and the model background grids, JMA has again the lowest deviation of speed and vector RMS, followed by NOA and NWC, with BRZ having the largest deviation. EUM AMVs are much better in general than those calculated with the prescribed configuration. JMA's AMVs vary so little from the ECMWF analysis compared to the other AMV producers, it may indicate their cloud height method has a stronger dependence on the background grids.

Compared to Experiment 1, there are fewer instances of statistical agreement for collocated AMVs from the different centres, in terms of speed, direction, pressure and QI. This is likely due to the variability in the wind algorithm settings among the different producers.

Both BRZ and NWC had a peak in the distribution of AMV direction at 90°, which may indicate an issue with how subpixel tracking is done.

a) Approach

By using the standard 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 experiment is to be compared with results in Experiment 1 of this Study (respect to the prescribed configuration), and to Experiments 2 and 4 in the 2014 Study (Santek et al. 2014), in which the specific height assignment method of each centre, and the specific algorithm configuration of each centre, were considered:

- Producers used their algorithm and typical settings.
- ECMWF ERA-Interim analysis grids were used as NWP data.
- A cloud height product from NOAA/NESDIS was included in the dataset, to be used if possible for the AMV height assignment. However, only EUM, NOA and NWC used this cloud height product for this. EUM and NWC used besides the same "CCC method" giving them the more similarities in the height assignment.
- A 55 km distance to define collocation was used.
- 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 experiment tested the differences in each AMV algorithm between the prescribed configuration and their standard configuration. The AMVs should have been the best in terms of number of AMVs, speed and direction from each producer, as their standard configuration for target and search boxes was used.

b) Parameter distributions

The bulk statistics in this section are presented as tables for QINF >= 50 and 80, and CQI >=50 and 80.

The values of the different parameters among the centres are approximately the same, with these important exceptions:

- The total number of AMVs varied widely from 30,000 (EUM) to 50,000 (NOA, KMA) to 70,000 (BRZ, JMA) to 146,000 (NWC). This total number of AMVs is much larger than Experiment 1 in this study, and for Experiment 2 in the 2014 Study, which found approximately 10,000 matches (50,000 for KMA and 90,000 for NWC). The differences are primarly due to the uniqueness of the algorithm by each data producer.

- The maximum speed ranges from 70 ms^{-1} (BRZ) to 95 ms^{-1} (EUM, NOA).
- The percentages by level (low, medium, high) is 25% to 34%, 11% to 22%, and 49% to 64%. However, at mid levels NOA has only 2%.

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

	EUM	BRZ	JMA	NOA	KMA	NWC
Total AMVs	30806	74100	67324	47320	53171	146780
QI>=50	26011	67930	47232	45782	45214	136999
SPD_min	2.50	3.00	2.50	3.00	2.50	2.50
SPD_max	95.22	70.06	85.94	94.16	91.32	84.03
SPD_mean	13.64	11.86	14.29	13.97	14.10	13.14
P_min	57.58	100.00	100.00	105.72	106.81	101.00
P_max	1009.80	1000.00	1016.04	987.20	1000.00	971.00
P_mean	432.39	486.23	493.32	432.01	452.07	407.66
Low_winds	26.87	29.71	30.80	33.55	24.95	25.75
Mid_winds	13.04	21.50	20.09	2.56	21.82	10.86
High_winds	60.09	48.79	49.11	63.89	53.22	63.38
Low_SPD_min	2.50	3.00	2.50	3.01	2.50	2.50
Low_SPD_max	38.52	46.46	44.40	37.59	70.27	36.22
Low_SPD_mean	8.90	9.38	9.70	9.77	10.64	8.82
Low_P_min	700.06	700.00	700.04	700.08	700.00	700.00
Low_P_max	1009.80	1000.00	1016.04	987.20	1000.00	971.00
Low_P_mean	818.82	870.10	883.95	835.02	818.00	787.16
Mid_SPD_min	2.51	3.07	2.50	3.04	2.50	2.54
Mid_SPD_max	69.67	69.46	72.05	69.25	78.19	68.28
Mid_SPD_mean	14.39	13.51	13.86	21.30	15.45	15.32
Mid_P_min	400.06	400.03	400.04	400.06	400.02	400.50
Mid_P_max	699.73	699.97	699.97	449.98	699.98	699.50
Mid_P_mean	526.94	528.13	527.57	426.70	514.90	534.10
High_SPD_min	2.50	3.04	2.51	3.00	2.50	2.50
High_SPD_max	95.22	70.06	85.94	94.16	91.32	84.03
High_SPD_mean	15.60	12.65	17.35	15.88	15.17	14.53
High_P_min	57.58	100.00	100.00	105.72	106.81	101.00
High_P_max	399.94	400.00	400.00	399.97	400.00	400.00
High_P_mean	239.10	234.05	234.31	220.57	254.74	231.78

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

	EUM	BRZ	JMA	NOA	KMA	NWC
Total AMVs	30806	74100	67324	47320	53171	146780
QI>=50	28174	65673	27057	45782	47411	146496
SPD_min	2.50	2.55	2.51	3.00	2.50	2.50
SPD_max	145.55	70.06	85.94	94.16	97.01	84.03
SPD_mean	13.37	12.02	14.00	13.97	13.89	12.97
P_min	57.58	100.00	125.02	105.72	106.81	101.00
P_max	1009.80	1000.00	996.47	987.20	1000.00	972.50
P_mean	438.03	487.06	497.74	432.01	450.50	409.12
Low_winds	27.15	29.96	32.27	33.55	24.56	25.63
Mid_winds	14.14	21.19	17.51	2.56	22.02	11.52
High_winds	58.71	48.85	50.22	63.89	53.42	62.86
Low_SPD_min	2.50	2.55	2.51	3.01	2.50	2.50
Low_SPD_max	54.21	46.46	32.67	37.59	70.27	36.22
Low_SPD_mean	8.89	9.39	9.14	9.77	10.54	8.76
Low_P_min	700.06	700.00	700.04	700.08	700.00	700.00
Low_P_max	1009.80	1000.00	996.47	987.20	1000.00	972.50
Low_P_mean	820.69	870.56	887.37	835.02	817.99	788.38
Mid_SPD_min	2.51	2.55	2.51	3.04	2.50	2.51
Mid_SPD_max	69.67	69.46	72.05	69.25	80.01	62.00
Mid_SPD_mean	13.95	13.73	14.46	21.30	15.11	14.95
Mid_P_min	400.06	400.03	400.00	400.06	400.02	400.50
Mid_P_max	699.73	699.97	699.97	449.98	699.98	699.50
Mid_P_mean	529.96	528.14	533.05	426.70	514.73	535.47
High_SPD_min	2.50	2.59	2.52	3.00	2.50	2.50
High_SPD_max	145.55	70.06	85.94	94.16	97.01	84.03
High_SPD_mean	15.31	12.88	16.97	15.88	14.92	14.33
High_P_min	57.58	100.00	125.02	105.72	106.81	101.00
High_P_max	399.94	400.00	399.98	399.97	400.00	400.00
High_P_mean	238.96	233.99	235.09	220.57	255.08	231.35

Table 8-3: Experiment 2 statistical summary of AMV datasets for QINF >= 80.

	EUM	BRZ	JMA	NOA	KMA	NWC
Total AMVs	30806	74100	67324	47320	53171	146780
QI>=80	20435	48916	26409	40476	32082	104553
SPD_min	2.50	3.00	2.51	3.00	2.50	2.54
SPD_max	95.22	70.06	85.66	94.16	76.09	83.89
SPD_mean	14.71	11.49	15.57	14.51	15.35	13.97
P_min	59.63	100.00	100.00	107.49	106.81	101.00
P_max	997.16	1000.00	1011.73	970.34	1000.00	971.00
P_mean	441.08	501.47	491.41	439.04	456.37	414.05
Low_winds	28.74	32.53	31.71	34.66	27.40	27.12
Mid_winds	12.06	20.71	17.03	2.45	19.02	10.14
High_winds	59.20	46.76	51.26	62.89	53.58	62.74
Low_SPD_min	2.50	3.00	2.54	3.01	2.50	2.54
Low_SPD_max	31.42	46.46	32.67	36.03	62.63	36.22
Low_SPD_mean	9.20	9.32	9.67	9.93	11.01	9.03
Low_P_min	700.06	700.00	700.04	700.40	700.00	700.00
Low_P_max	997.16	1000.00	1011.73	970.34	1000.00	971.00
Low_P_mean	816.96	872.41	888.71	835.62	818.49	785.81
Mid_SPD_min	2.54	3.07	2.51	3.04	2.50	2.60
Mid_SPD_max	66.96	69.46	72.05	69.25	74.59	68.28
Mid_SPD_mean	15.67	13.11	16.26	22.34	17.95	16.56
Mid_P_min	400.06	400.40	400.13	400.06	400.02	400.50
Mid_P_max	699.73	699.97	699.97	449.94	699.97	699.50
Mid_P_mean	527.93	528.95	529.52	426.37	509.16	534.20
High_SPD_min	2.51	3.07	2.52	3.00	2.50	2.60
High_SPD_max	95.22	70.06	85.66	94.16	76.09	83.89
High_SPD_mean	17.19	12.28	18.99	16.73	16.64	15.68
High_P_min	59.63	100.00	100.00	107.49	106.81	101.00
High_P_max	399.94	400.00	400.00	399.97	399.96	400.00
High_P_mean	240.92	231.28	232.98	221.02	252.40	233.94

Table 8-4: Experiment 2 statistical summary of AMV datasets for CQI >= 80.

	EUM	BRZ	JMA	NOA	KMA	NWC
Total AMVs	30806	74100	67324	47320	53171	146780
QI>=80	23041	46166	22823	40476	39246	139290
SPD_min	2.50	2.55	2.51	3.00	2.50	2.50
SPD_max	95.22	70.06	85.66	94.16	76.09	84.03
SPD_mean	14.03	11.89	14.64	14.51	14.61	13.11
P_min	57.58	100.00	125.02	107.49	107.58	101.00
P_max	1006.00	1000.00	996.47	970.34	1000.00	971.00
P_mean	443.45	498.29	500.55	439.04	448.69	411.08
Low_winds	29.08	32.53	32.94	34.66	25.80	26.10
Mid_winds	12.22	19.51	16.96	2.45	19.51	11.28
High_winds	58.70	47.96	50.10	62.89	54.69	62.62
Low_SPD_min	2.50	2.58	2.54	3.01	2.50	2.50
Low_SPD_max	44.37	43.42	32.67	36.03	70.08	36.22
Low_SPD_mean	9.04	9.45	9.43	9.93	10.77	8.79
Low_P_min	700.06	700.00	700.04	700.40	700.00	700.00
Low_P_max	1006.00	1000.00	996.47	970.34	1000.00	971.00
Low_P_mean	819.12	875.54	886.68	835.62	818.35	787.77
Mid_SPD_min	2.54	2.55	2.51	3.04	2.50	2.52
Mid_SPD_max	66.96	69.46	72.05	69.25	74.59	62.00
Mid_SPD_mean	15.03	13.73	15.46	22.34	16.66	15.26
Mid_P_min	400.06	400.26	400.13	400.06	400.02	400.50
Mid_P_max	699.73	699.97	699.97	449.94	699.93	699.50
Mid_P_mean	530.61	526.36	534.75	426.37	509.85	535.79
High_SPD_min	2.50	2.79	2.52	3.00	2.50	2.50
High_SPD_max	95.22	70.06	85.66	94.16	76.09	84.03
High_SPD_mean	16.30	12.80	17.79	16.73	15.68	14.53
High_P_min	57.58	100.00	125.02	107.49	107.58	101.00
High_P_max	399.94	400.00	399.98	399.97	400.00	400.00
High_P_mean	239.23	230.95	235.05	221.02	252.52	231.63

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

- BRZ (Figure 13-13): The pressure and QI distributions are in better agreement with the other centres as compared to the 2014 study: Now, the QI distribution tends toward many more high QI values and the pressure shows a much higher peak in the high levels. As with Exp. 1, the direction distribution is quite different than the other centres, with possible anomalous peaks at 90° and 270°.
- EUM (Figure 13-14): The AMV pressure distributions closely match those in the previous study, and those of NWC now, due to both using "CCC method for the height assignment".
- JMA (Figure 13-15): The AMV pressure distribution is improved over what was observed in previous studies, as it more closely matches the other centres which use a variety of cloud height methods. The comparisons to rawinsondes and model background (documented in the following sections) have substantially improved statistics. This is likely entirely due to the updated cloud height method at JMA and provides evidence that the AMV heights has the biggest impact in the statistics, over other differences such as target size, search box size, tracking method, QI computation, etc. However, the QI distribution shows larger counts in the 60-80% range, which is not typical for the other centres.
- KMA (Figure 13-16): The AMV pressure and QI distributions more closely match the other centres, compared to the previous study. This indicates that changes were made to height assignment method and calculation of QI. However, there is a noticeable low number of highest QI values; most other centres have a peak near the 100% mark.
- NOA (Figure 13-17): The AMV pressure and QI distribution are in much better agreement to other centres, compared to the previous studies.
- NWC (Figure 13-18: The distributions of parameters closely match those from the other centres, except the QINF that was nearly linearly increasing, compared to the highly exponential curves from the other centres. However, the CQI (Figure 13-24) was exponential. This indicates that the QINF calculation by NWC differs from the CQI more than the difference at the other centres. Also, there is a possible anomalous peak at 90° in the direction distribution. This peak is seen with Himawari AMVs now, but was not present in the previous study with MSG AMVs.

c) Collocation plots

AMVs are first quality controlled, retaining only those with a QINF >= 50 for the first series of plots. For collocation the distance threshold was 55 km. 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.

These collocated plots are quite different than Exp. 2 and 4 in the 2014 Study:

- There are substantially more collocated AMVs, which is explained by the higher resolution AHI vs. SEVIRI (2 vs. 3km) data and more clouds (less desert and more oceanic coverage).
- The top plot in Figure 8-1 is speed, sorted by increasing speed for NWC. Generally, this is in agreement with Experiment 1 of this Study. The next features also occur:
    - EUM has high speed outliers (blue dots),
    - BRZ has a cluster of low speed outliers (green dots) on the far right of the plot.
- The remainder of the graphs in this figure are dominated by the nearly 150,000 AMVs from NWC, therefore additional information can not be extracted.

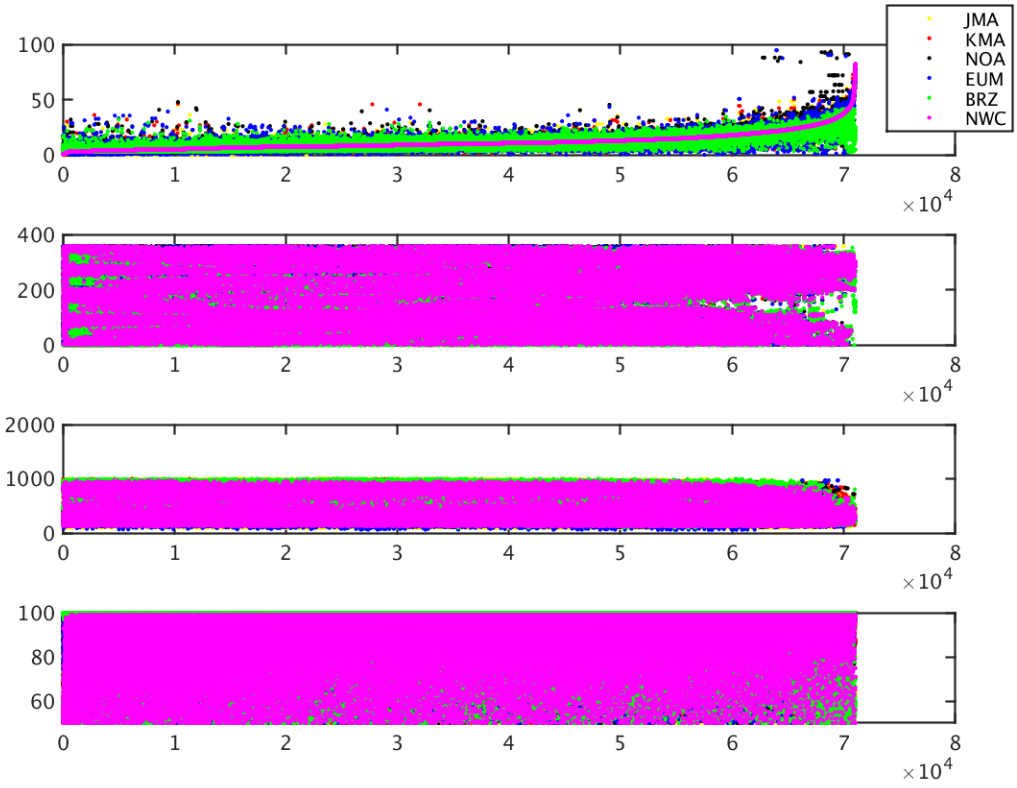


Figure 8-1: Experiment 2 (QINF >= 50). Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.

The maximum pressure difference between any two collocated AMVs is shown in Figure 8-2. This shows the same variability as in Experiment 1 in this Study, for a much larger number of collocations.

Considering the height assignment process shown in Figure 8-3, there is again an excellent agreement between EUM and NWC (magenta clusters), many points plotted away from the diagonal (from the other centres), and large clusters of green dots (BRZ) away from the diagonal, based on the different height assignment methods used.

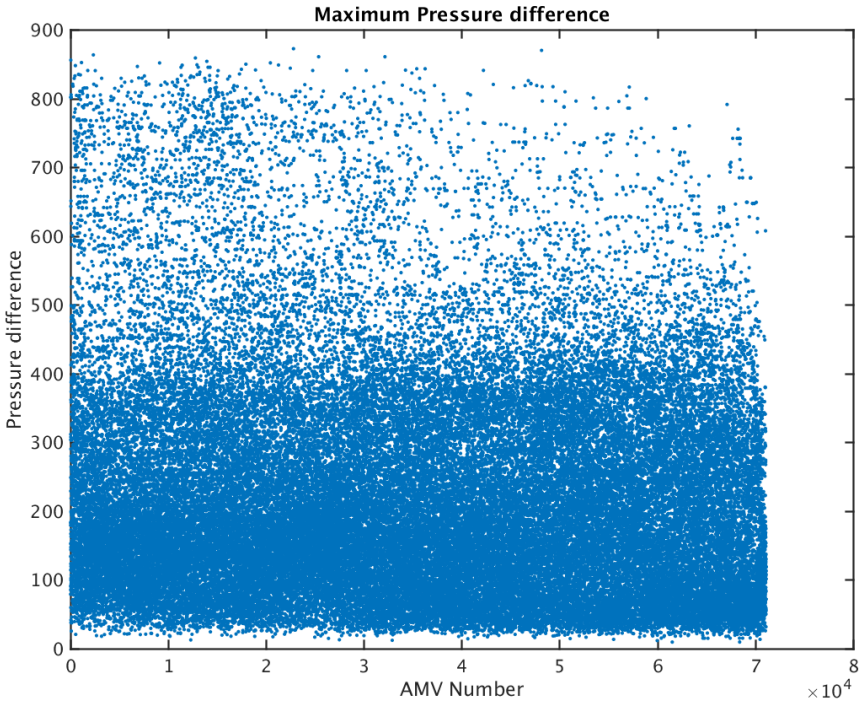


Figure 8-2: Experiment 2 (QINF >= 50). The maximum pressure difference between any two collocated AMVs.

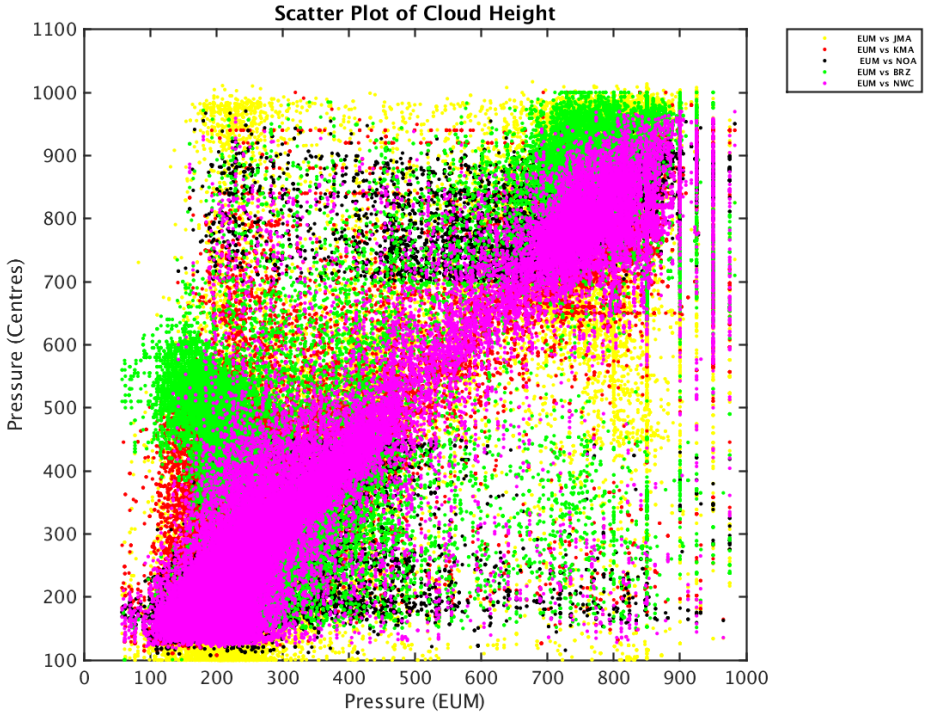


Figure 8-3: Experiment 2 (QINF >= 50). Scatter plot of AMV pressure for each center vs. EUM pressure.

The following three plots are similar to those above, except they are based on the CQI, with the same threshold of 50. The one important exception is the that QI plot (lower graph in Figure 8-4) has fewer lower QI values than in Figure 8-1, as evident by fewer magenta dots in the lower part of the graph. This provides some evidence that the common QI gives better agreement in the AMVs, with a tendency to retain higher QI values.

The CQI from BRZ (green dots) may be related to height assignment differences, resulting in the lower CQI values in the figure.

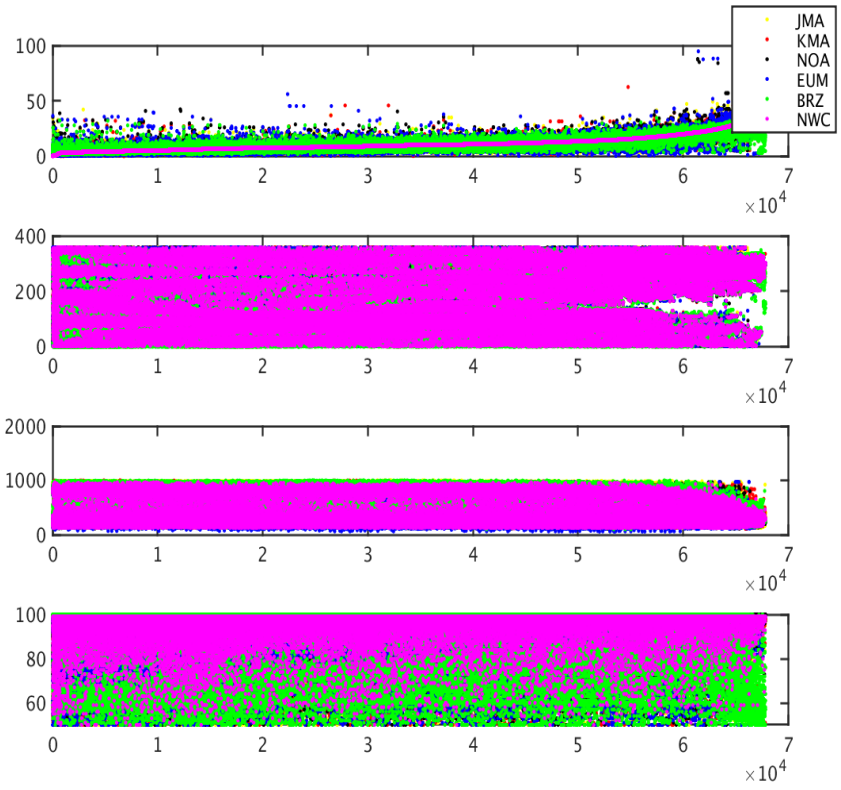


Figure 8-4: Experiment 2 (CQI >= 50). Plots of collocated AMVs of speed (top), direction (2nd), pressure (3rd), and QI (bottom) are color-coded based on legend in upper-right. The x-axis is AMV number.

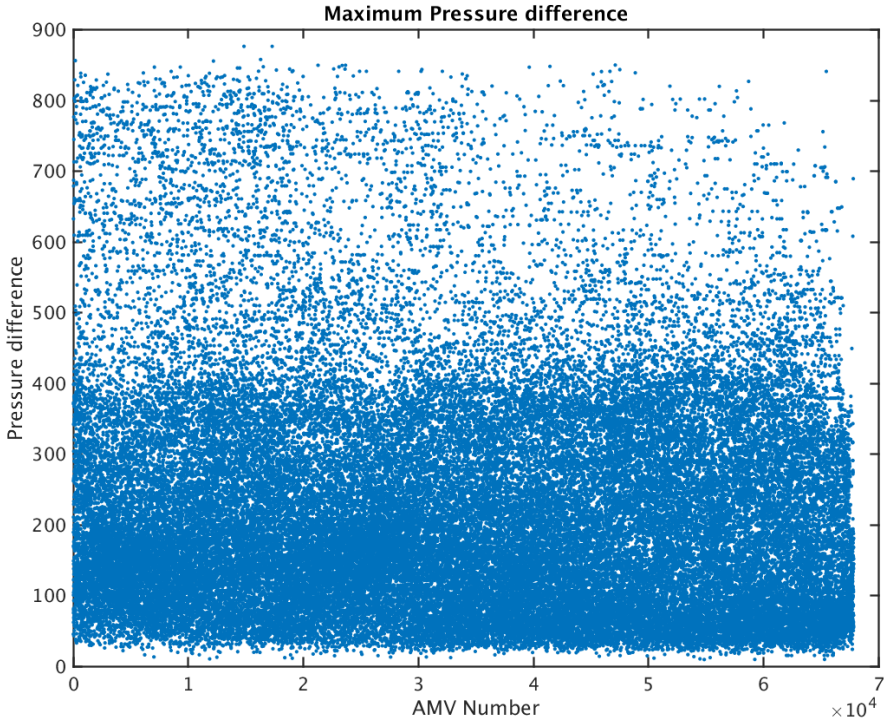


Figure 8-5: Experiment 2 (CQI >= 50). Maximum pressure difference between any two collocated AMVs.

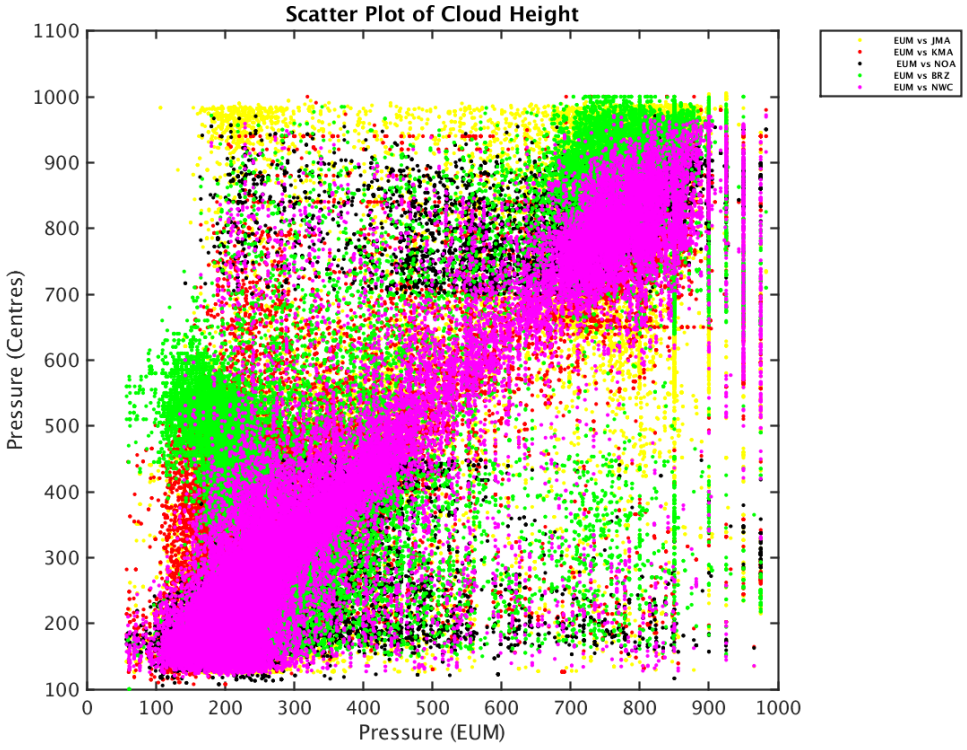


Figure 8-6: Experiment 2 (CQI >= 50). Scatter plot of AMV pressure for each center vs. EUM pressure.

d) Rawinsonde comparison

The comparison of all AMVs to nearby rawinsondes is summarized in the following tables for QINF, CQI >= 50 (same threshold as the one used in the previous Intercomparison study) and for QINF, CQI >= 80 (giving better results in agreement between centres). Collocated AMVs for all levels have also been compared.

The QINF >=50 vector RMS ranges from 6 ms^{-1} (JMA) to 7 ms^{-1} (NOA, NWC) to greater than 8 ms^{-1} (BRZ, EUM, KMA). The speed RMS ranges from 4.5 ms^{-1} (JMA) to 5 ms^{-1} (NOA, NWC) to greater than 7 ms^{-1} (BRZ, EUM, KMA). Results from EUM are much better with respect to those used with the prescribed configuration. In other cases, they are relatively similar to those found for Experiment 1 in this study. The large RMS differences are probably due to the substantial variation in height assignment methods used.

There are less differences between centres when collocated data are considered for both QINF and CQI.

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 (not shown), or collocated winds. However, JMA has again generally the best overall statistics.

An additional analysis in summarized in Table 8-11 that compares the 'best' AMVs for each centre with nearby rawinsondes, where 'best' is defined by a minimum CQI threshold that results in at least 10,000 AMVs. The CQI threshold ranges from 98 to 100 for all the centres. Despite the use of the highest quality AMVs, the variability in the bias and RMS is similar to the other QI thresholds in Table 8-8 to Table 8-10.

Table 8-5: Experiment 2: All AMVs (QINF >= 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	**971**	**1.40**	**14.43**	**-2.58**	**11.60**	**-11.31**	**13.47**
EUM	**459**	**-0.53**	**15.70**	**-2.48**	**7.05**	**8.42**	**8.71**
JMA	**701**	**-0.53**	**14.38**	**-1.08**	**4.43**	**-0.28**	**6.20**
KMA	**740**	**-0.63**	**14.87**	**-1.43**	**7.88**	**-2.64**	**10.13**
NOA	**691**	**-1.58**	**13.93**	**-0.90**	**5.44**	**1.89**	**7.62**
NWC	**1954**	**-1.17**	**16.16**	**-1.96**	**5.85**	**-0.75**	**7.82**

Table 8-6: Experiment 2: All AMVs (QINF >= 80) 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	676	0.72	13.34	-0.09	6.82	-12.06	9.36
EUM	333	-0.77	15.07	-2.39	6.28	7.87	7.89
JMA	355	0.21	13.94	-1.71	4.64	2.38	6.42
KMA	463	-0.98	13.62	-1.13	7.74	-3.97	9.81
NOA	599	-1.69	13.98	-0.88	5.25	0.39	7.48
NWC	1450	-1.04	16.06	-2.03	6.01	-0.88	8.07

Table 8-7: Experiment 2: Collocated AMVs (QINF >=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	1022	1.05	14.86	-2.24	11.27	-20.77	13.18
EUM	1015	-0.56	14.74	-1.73	5.93	-3.11	7.57
JMA	1009	1.26	14.17	-0.86	3.55	-0.70	5.04
KMA	1049	-1.46	13.46	-1.57	5.46	-3.63	7.00
NOA	1003	-4.55	14.34	-0.76	4.72	-3.86	6.25
NWC	1028	-3.12	15.88	-1.54	4.92	-8.54	6.34

Table 8-8: Experiment 2: All AMVs (CQIs > 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	942	1.46	14.44	-2.69	11.65	-9.48	15.22
EUM	508	-0.62	15.92	-2.17	7.03	10.08	8.87
JMA	313	-2.94	18.33	-1.36	4.64	-0.83	6.34
KMA	797	-0.64	14.80	-1.55	7.78	-1.41	10.03
NOA	691	-1.58	13.93	-0.90	5.44	1.89	7.62
NWC	2204	-1.02	16.30	-2.17	6.03	0.40	7.85

Table 8-9: Experiment 2: All AMVs (CQIs > 80) 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	619	1.16	13.44	-0.40	7.36	-14.65	9.80
EUM	366	-0.66	14.74	-2.20	6.15	8.43	8.05
JMA	270	-3.43	18.67	-1.40	4.64	-0.83	6.42
KMA	628	-0.84	14.30	-1.21	7.39	-2.66	9.49
NOA	599	-1.69	13.98	-0.88	5.25	0.39	7.48
NWC	2063	-1.19	16.19	-2.11	5.99	0.79	7.85

Table 8-10: Experiment 2: Collocated AMVs (CQI >= 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	1013	1.58	14.46	-1.13	9.26	-19.30	13.30
EUM	1009	-0.12	13.44	-1.28	5.21	-2.79	7.18
JMA	978	0.68	13.35	-0.86	3.42	0.36	5.21
KMA	1032	-1.18	12.39	-0.92	5.04	-2.52	7.06
NOA	1001	-4.27	14.05	-0.77	4.38	-3.12	6.41
NWC	1014	-3.22	15.24	-1.23	4.33	-7.69	6.17

Table 8-11: Experiment 2: Best AMVs (CQI set for at least 10,000 AMVs) comparison to rawinsondes within 150 km. Total= number of best AMVs; N= number of matches; P bias = pressure bias; P RMS = pressure RMS; Spd bias = speed bias; Spd RMS= speed RMS; Dir bias = wind direction bias; Vec RMS = vector RMS. The extreme for each category is highlighted: Yellow = high value; cyan = low value.

Site	CQI	Total	N	P bias	P RMS	Spd bias	Spd RMS	Dir bias	Vec RMS
BRZ	100	26341	293	0.15	12.66	-0.19	5.69	-18.81	8.62
EUM	98	12407	170	0.11	13.46	-2.27	5.54	-1.31	7.39
JMA	98	10595	119	0.72	15.22	-1.96	5.12	1.79	6.79
KMA	99	16721	249	-0.57	13.66	-0.44	7.65	-0.80	9.53
NOA	100	14484	215	-0.22	13.22	-1.24	5.45	0.11	8.19
NWC	99	80625	1115	-0.69	16.58	-2.11	6.15	-2.07	8.27

e) Model Grid comparison

The Python scripts used to determine the Best fit height analysis also define the comparison of all AMVs to the NWP background model grid winds. This comparison was based on ECMWF ERA-Interim analysis using QINF and CQI >= 80. The tables are for all AMVs, all AMVs by height range (high, medium, and low), and collocated AMVs for all levels. Note: The total number of AMVs for each centre in Table 8-12 will not equal the sum of the three layers found in Table 8-13 through Table 8-15 (high, medium, low), because some of the AMVs provided are outside the pressure ranges for the layers.

The results are basically similar to those found in Experiment 1 for the prescribed configuration (not considering the number of AMVs which is very different), and do not show the variability seen in the rawinsonde comparisons above, which is a similar to what was found in the 2014 Study, with the following notable differences:

- In the 2014 Study, NWC had the best statistics except for the collocated AMVs where JMA had the best statistics. In this study, JMA had the best agreement to the background grid for all AMVs, discretized by level, collocated, and using both QINF and CQI.

- As in the 2014 Study, BRZ had the largest deviation from the background grid, except for the low-level AMVs when BRZ, KMA, and EUM have similar large deviations.

An additional analysis in summarized in Table 8-22 that compares the 'best' AMVs for each centre with background model winds, where 'best' is defined by a minimum CQI threshold that results in at least 10,000 AMVs. The CQI threshold ranges from 98 to 100 for all the centres. Despite the use of the highest quality AMVs, the variability in the bias and RMS is similar to the other QI thresholds, although the largest deviations (highlighted in yellow) are consistently smaller for the best AMVs. As with the other CQI thresholds, JMA has the best statistics and BRZ has the largest devitations.

Table 8-12: Experiment 2: All AMVs (QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	48916	10675	6.86	9.66	6.12	9.27
EUM	21083	6755	4.68	6.41	3.69	5.56
JMA	26492	10009	2.51	3.11	2.24	2.90
KMA	32674	10635	4.73	6.65	3.88	6.05
NOA	40472	14180	4.00	5.17	3.12	4.38
NWC	104722	35948	4.24	5.21	3.30	4.37

Table 8-13: Experiment 2: High level AMVs (100-400 hPa, QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	22743	7863	7.64	10.50	6.34	9.81
EUM	12257	5324	5.40	7.13	4.04	6.00
JMA	13535	7228	2.94	3.62	2.58	3.34
KMA	17371	7983	4.86	6.24	3.68	5.30
NOA	25446	11635	4.94	6.09	3.75	5.14
NWC	65575	29434	4.64	5.63	3.45	4.58

Table 8-14: Experiment 2: Mid level AMVs (400-700 hPa, QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	10089	734	10.46	13.08	10.22	13.00
EUM	2473	527	5.83	7.62	5.09	7.19
JMA	4488	1109	2.66	3.13	2.45	2.97
KMA	6131	1327	6.75	9.26	6.01	8.88
NOA	992	387	4.77	5.74	3.79	4.96
NWC	10562	2436	5.14	6.25	4.42	5.76

Table 8-15: Experiment 2: Low level AMVs (700-1000 hPa, QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	15952	2073	3.40	4.36	3.15	4.18
EUM	6338	901	2.82	3.97	2.45	3.63
JMA	8448	1660	1.73	2.05	1.59	1.93
KMA	9133	1315	3.11	5.11	2.80	4.89
NOA	14027	2155	2.22	2.72	1.93	2.43
NWC	28516	4055	2.96	3.48	2.53	3.08

Table 8-16: Experiment 2: Collocated AMVs (QINF >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	43281	9814	5.60	8.20	5.01	7.90
EUM	43281	13270	3.84	4.96	3.05	4.24
JMA	43281	14572	2.20	2.71	1.99	2.52
KMA	43281	12709	3.75	5.05	3.08	4.51
NOA	43281	13765	3.41	4.26	2.74	3.64
NWC	43281	13588	3.45	4.13	2.79	3.54

The same as the above tables, except for CQI >=80:

Table 8-17: Experiment 2: All AMVs (CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	46229	10571	6.79	9.65	6.02	9.24
EUM	23781	7504	4.76	6.49	3.77	5.67
JMA	22823	8130	2.63	3.28	2.37	3.08
KMA	40301	12946	4.90	6.89	4.04	6.29
NOA	40472	14180	4.00	5.17	3.12	4.38
NWC	142279	48491	4.35	5.33	3.37	4.46

Table 8-18: Experiment 2: High level AMVs (100-400 hPa, CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	22055	7900	7.52	10.43	6.18	9.71
EUM	13761	5884	5.47	7.14	4.11	6.02
JMA	11421	5858	3.11	3.85	2.75	3.60
KMA	21850	9764	5.01	6.46	3.82	5.53
NOA	25446	11635	4.94	6.09	3.75	5.14
NWC	88348	39160	4.78	5.78	3.52	4.68

Table 8-19: Experiment 2: Mid level AMVs (400-700 hPa, CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	8979	645	10.79	13.42	10.56	13.34
EUM	2840	580	5.80	7.56	5.08	7.14
JMA	3856	863	2.76	3.23	2.56	3.08
KMA	7752	1607	6.64	9.10	5.94	8.73
NOA	992	387	4.77	5.74	3.79	4.96
NWC	15867	3423	5.03	6.10	4.38	5.66

Table 8-20: Experiment 2: low level AMVs (700-1000 hPa, CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	15070	2022	3.28	4.17	3.02	3.98
EUM	7162	1035	2.98	4.38	2.61	4.08
JMA	7533	1399	1.83	2.18	1.69	2.06
KMA	10654	1565	3.42	5.74	3.10	5.54
NOA	14027	2155	2.22	2.72	1.93	2.43
NWC	37978	5883	3.07	3.59	2.61	3.17

Table 8-21: Experiment 2: Collocated AMVs (CQI >= 80) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	56515	13075	5.73	8.35	5.11	8.02
EUM	56515	17533	4.00	5.17	3.17	4.43
JMA	56515	19208	2.27	2.80	2.06	2.62
KMA	56515	16635	3.92	5.25	3.23	4.72
NOA	56515	18163	3.53	4.42	2.84	3.80
NWC	56515	17860	3.55	4.24	2.87	3.65

Table 8-22: Experiment 2: All AMVs (CQI set for at least 10,000 AMVs) compared to background grid: NWP analysis wind. N = total number of AMVs; BFN = number of AMVs with best fit level; VO = mean vector difference; RMSE = root mean square error; VOAF = mean vector difference after best fit; RMSEAF = root mean square error after best fit.

EXP	CQI	N	BFN	VO	RMSE	VOAF	RMSEAF
BRZ	100	26341	5733	5.90	8.32	5.22	7.91
EUM	98	12407	4056	4.43	6.13	3.46	5.28
JMA	98	10595	3991	2.52	3.20	2.29	3.03
KMA	99	16721	5934	4.66	6.71	3.75	6.06
NOA	100	14484	5484	3.84	5.06	2.91	4.21
NWC	99	80625	28532	4.24	5.24	3.26	4.36

f) Best fit height

The Best Fit height analysis was 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 determining the model pressure level of the minimum vector difference between the AMV and the model background. Then, the actual minimum is calculated by using a parabolic fit to the vector difference for this model level and the levels directly above and below 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 was generally about 30% of the AMVs (Salonen et al. 2012).

The following figures 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).

Most of the plots are in agreement that in the northern hemisphere, only high-level clouds are adjusted, while in the south both high and low level clouds are moved due to the best fit. The distribution of high, mid, and low level clouds (upper left plots) are very similar between the different centers with a spread of +/- 200 hPa for the high clouds, except JMA with a much tighter and smoother distribution (+/- 100 hPa). This further confirms that the JMA AMVs vary little from the ECMWF analysis compared to the other AMV producers, and may indicate their cloud height method has a stronger dependency on the background grids.

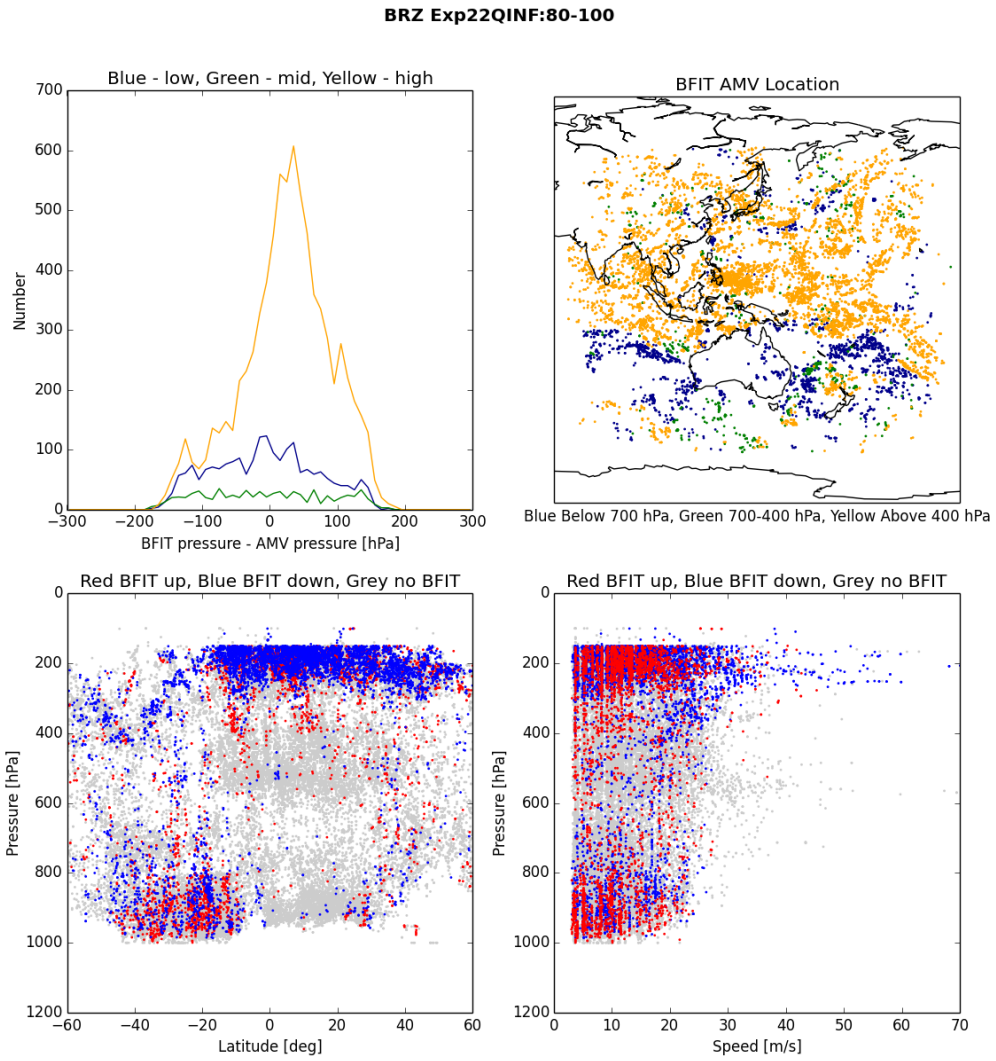


Figure 8-7: Experiment 2. BRZ (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

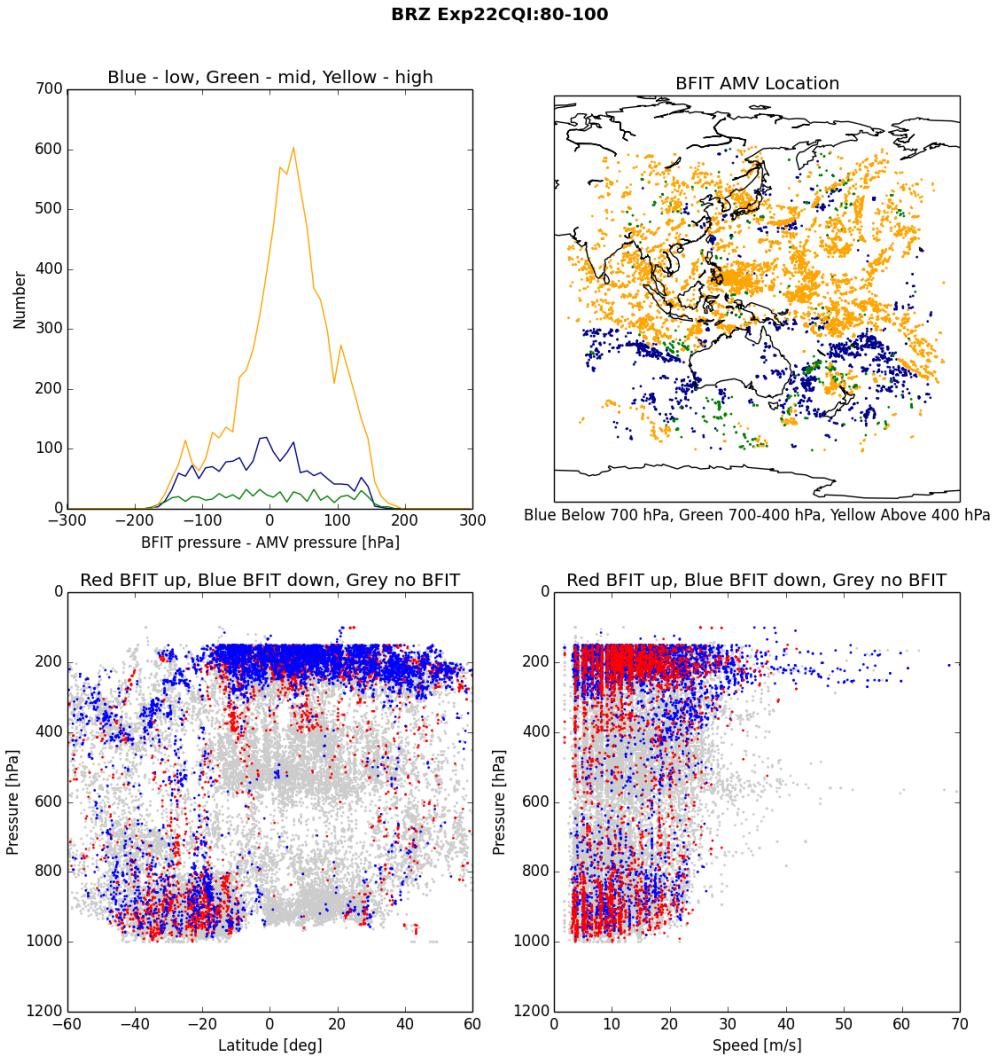


Figure 8-8: Experiment 2. BRZ (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

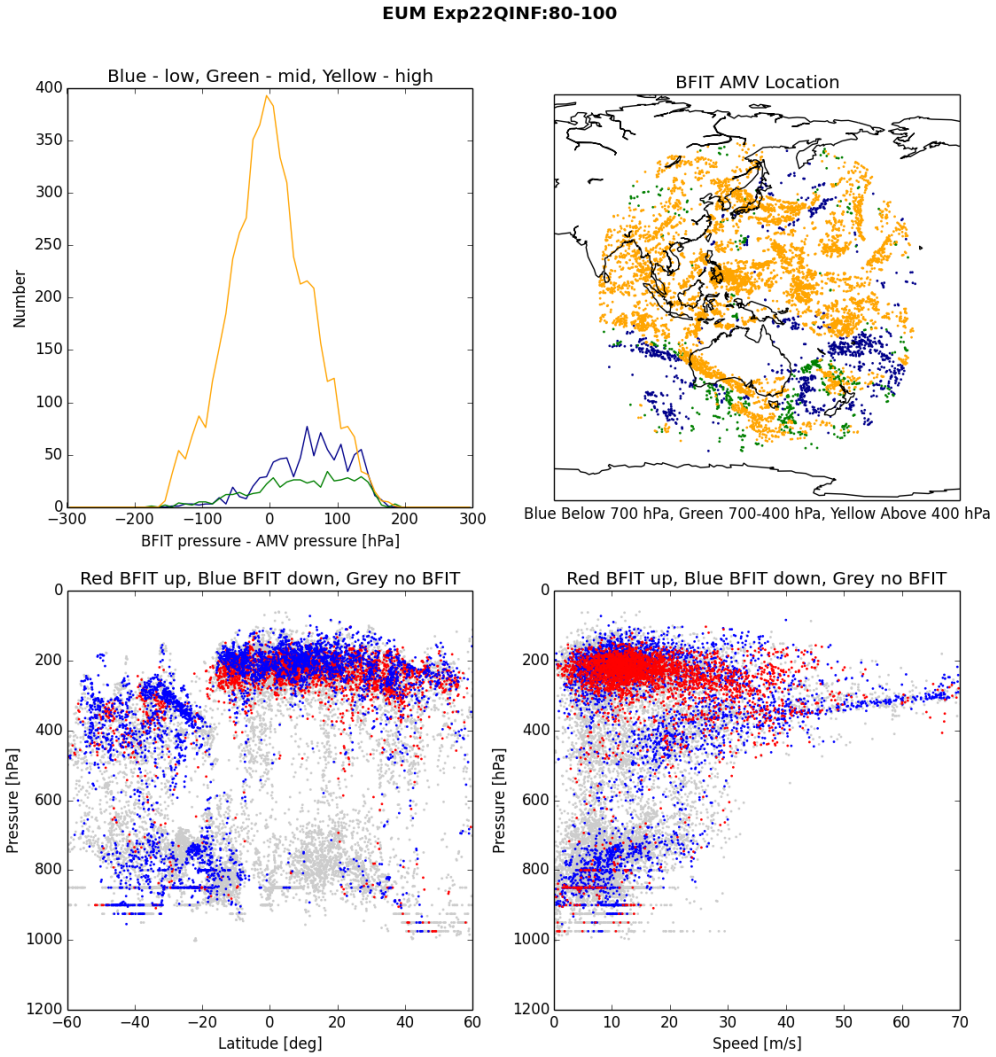


Figure 8-9: Experiment 2. EUM (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

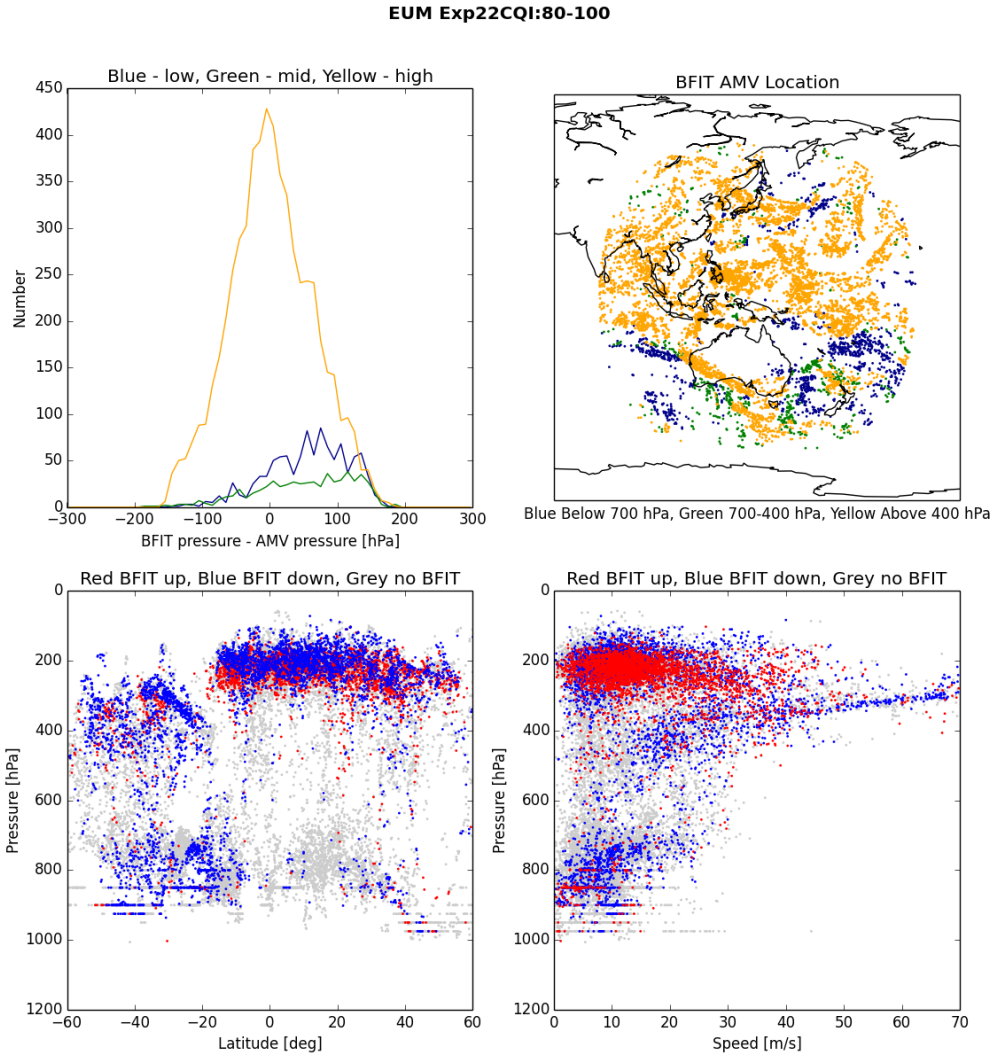


Figure 8-10: Experiment 2. EUM (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

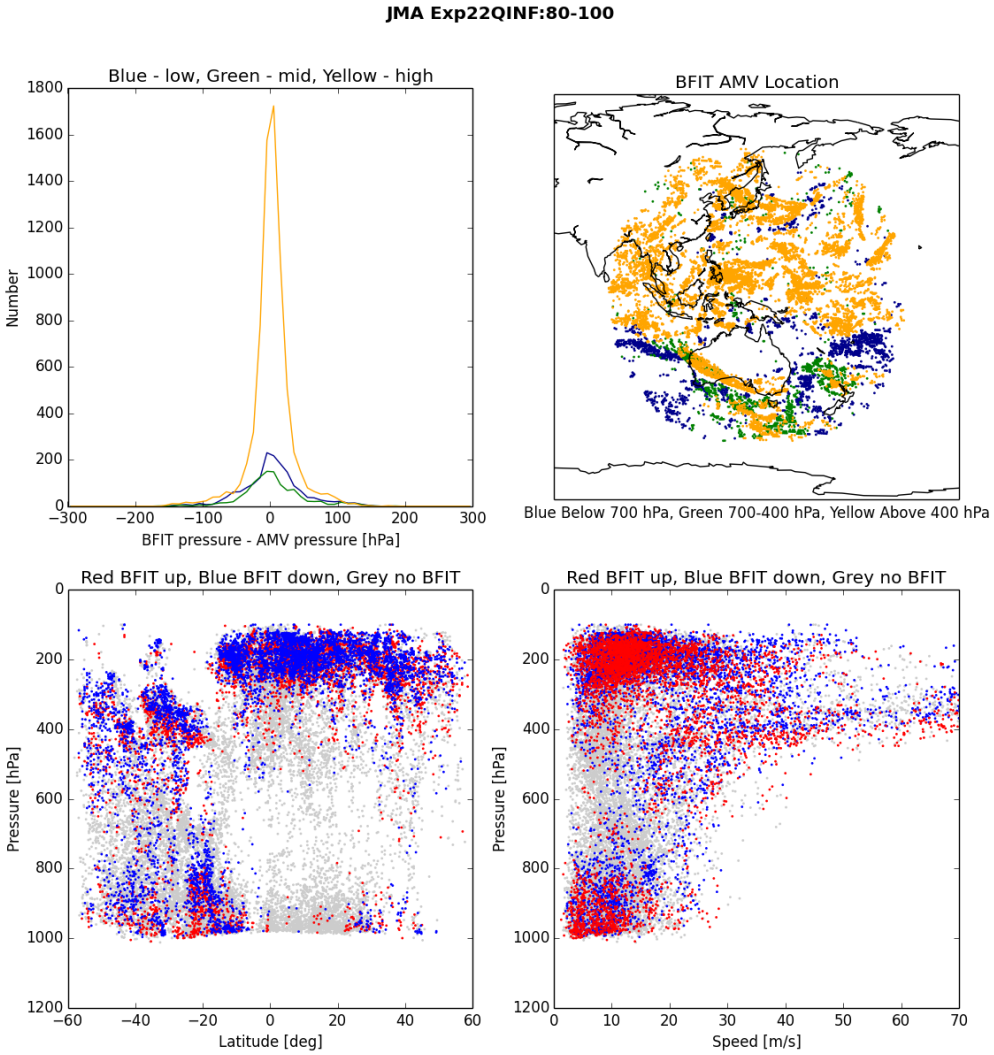


Figure 8-11: Experiment 2. JMA (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

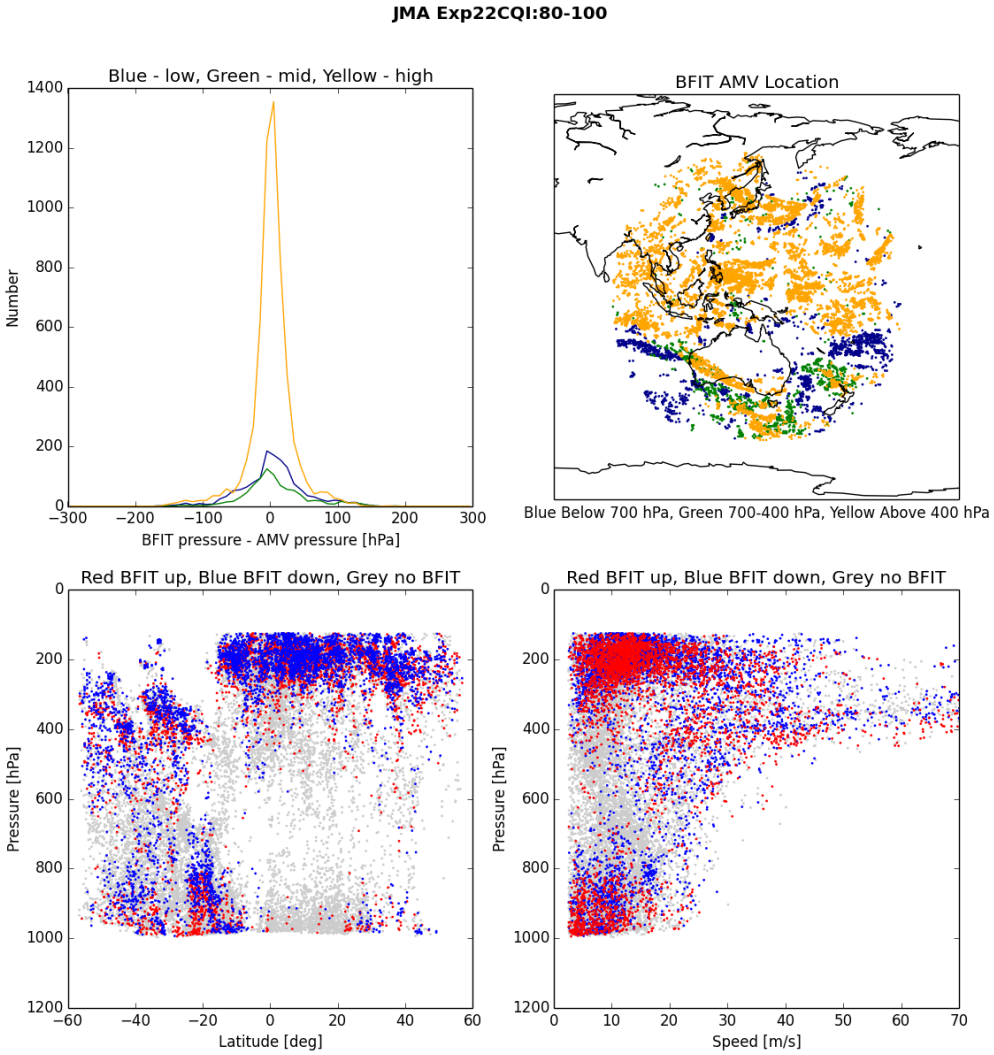


Figure 8-12: Experiment 2. JMA (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

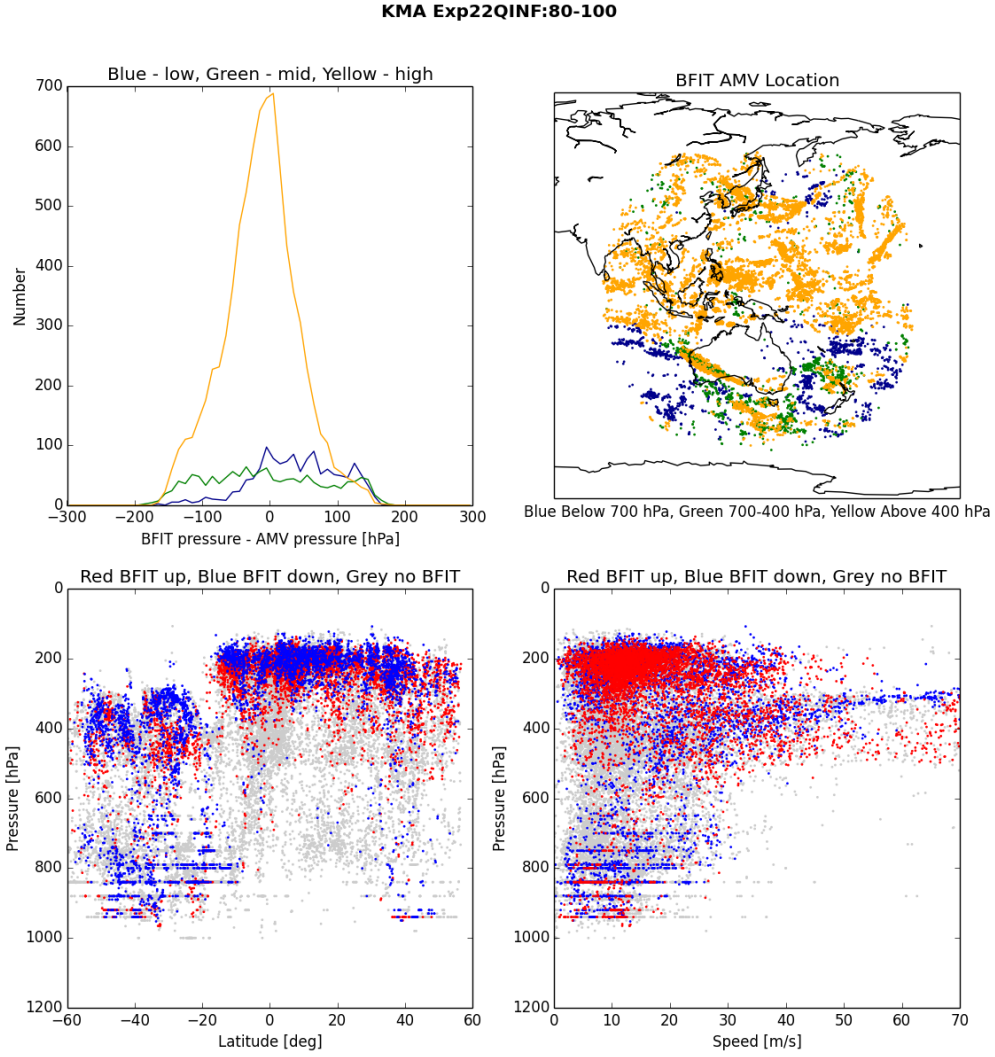


Figure 8-13: Experiment 2. KMA (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

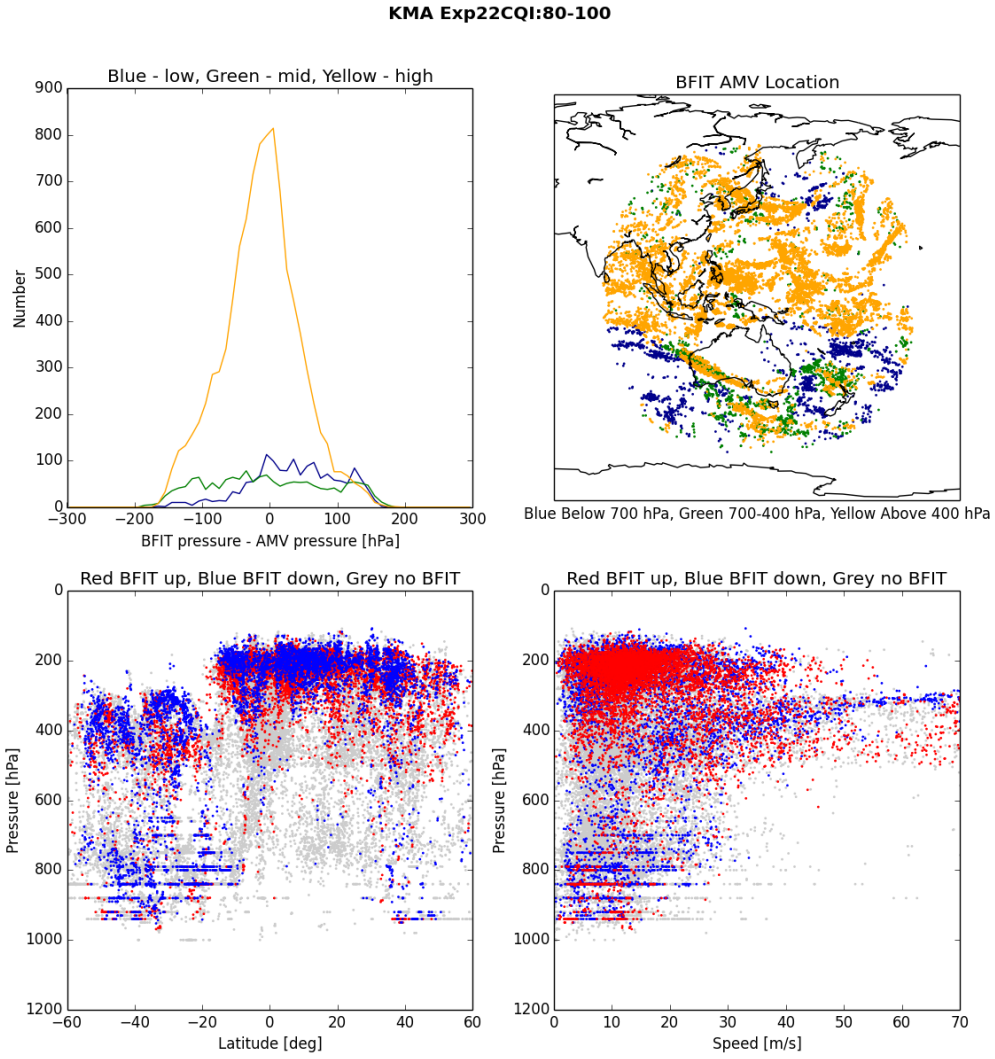


Figure 8-14: Experiment 2. KMA (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

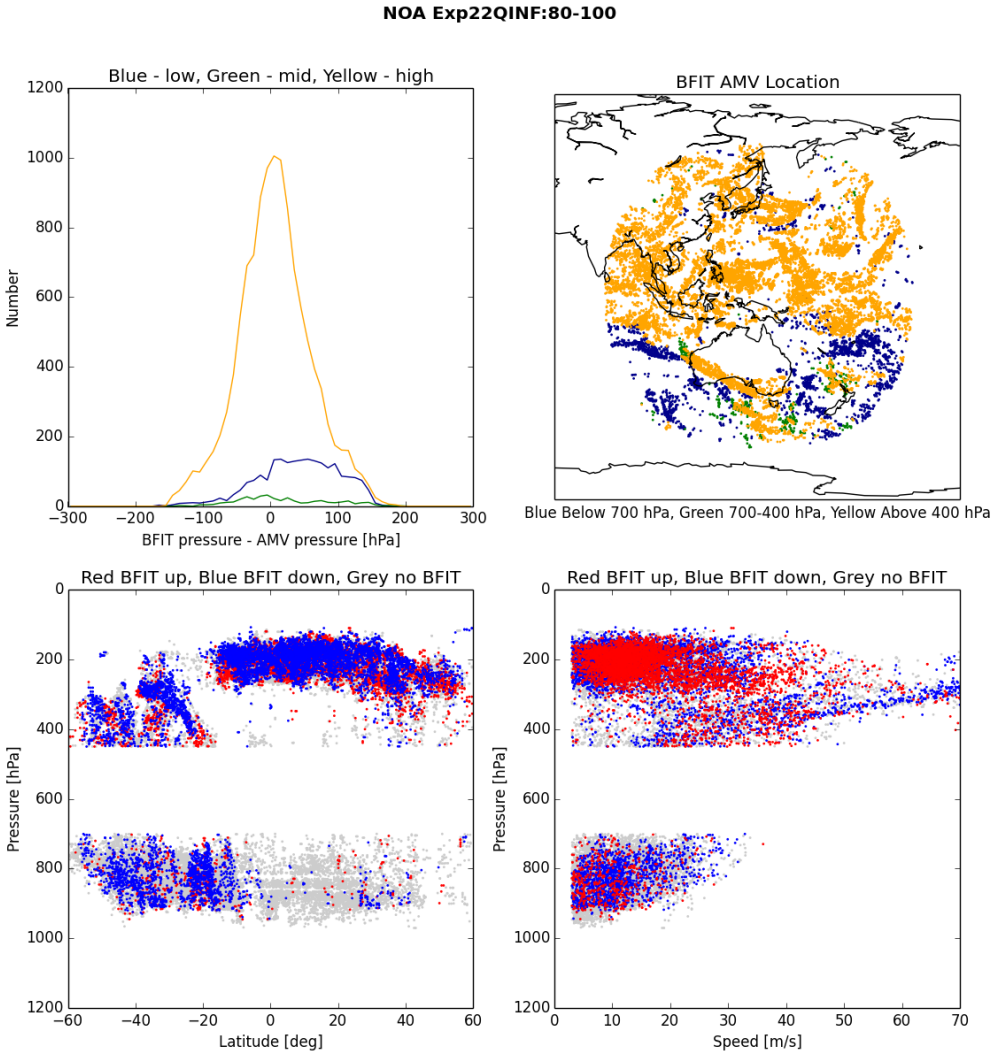


Figure 8-15: Experiment 2. NOA (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

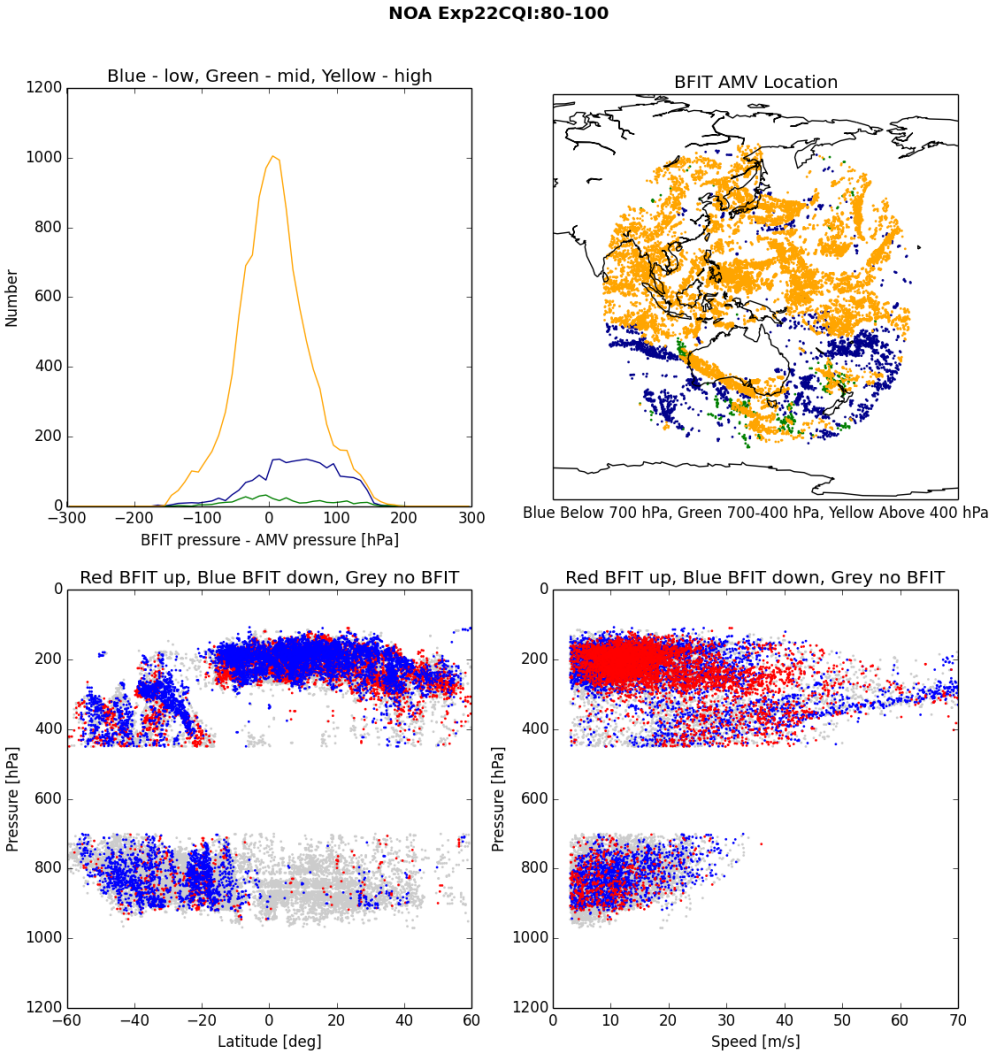


Figure 8-16: Experiment 2. NOA (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

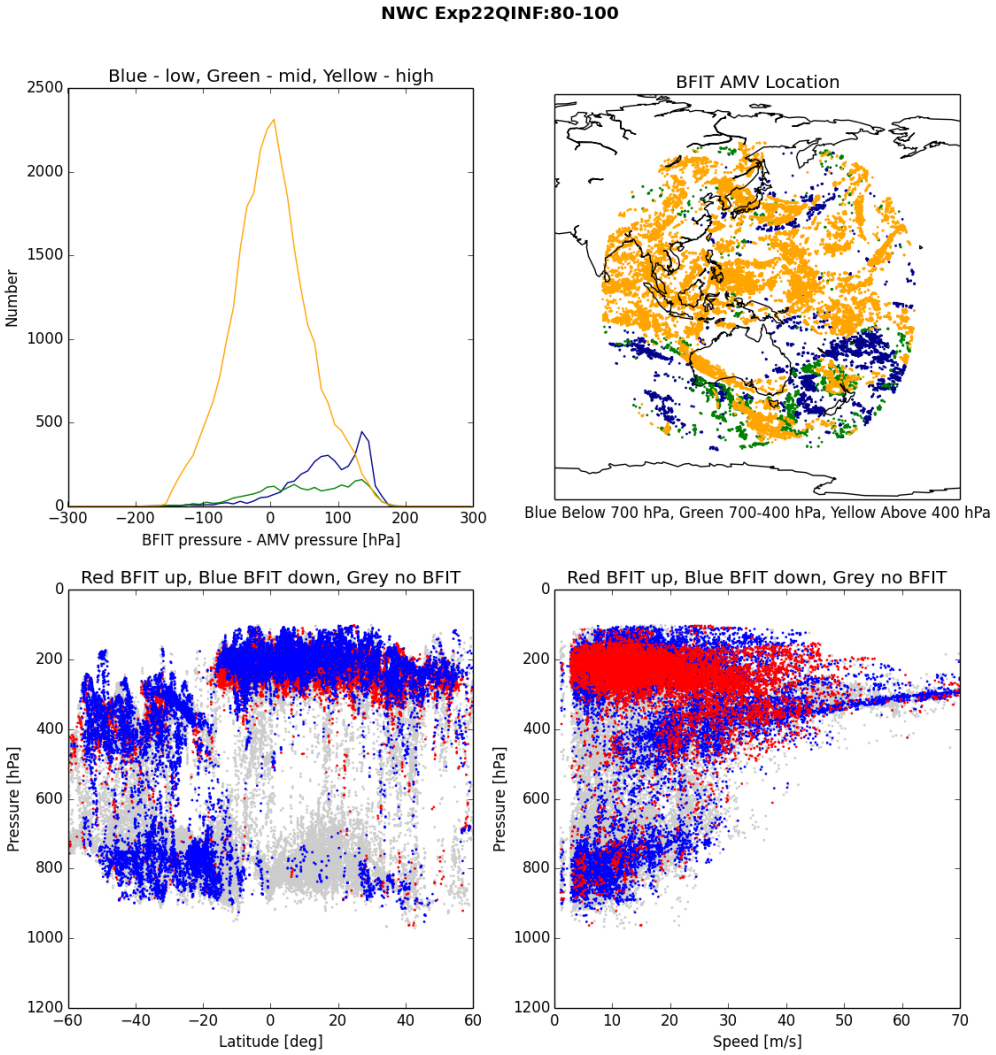


Figure 8-17: Experiment 2. NWC (QINF): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

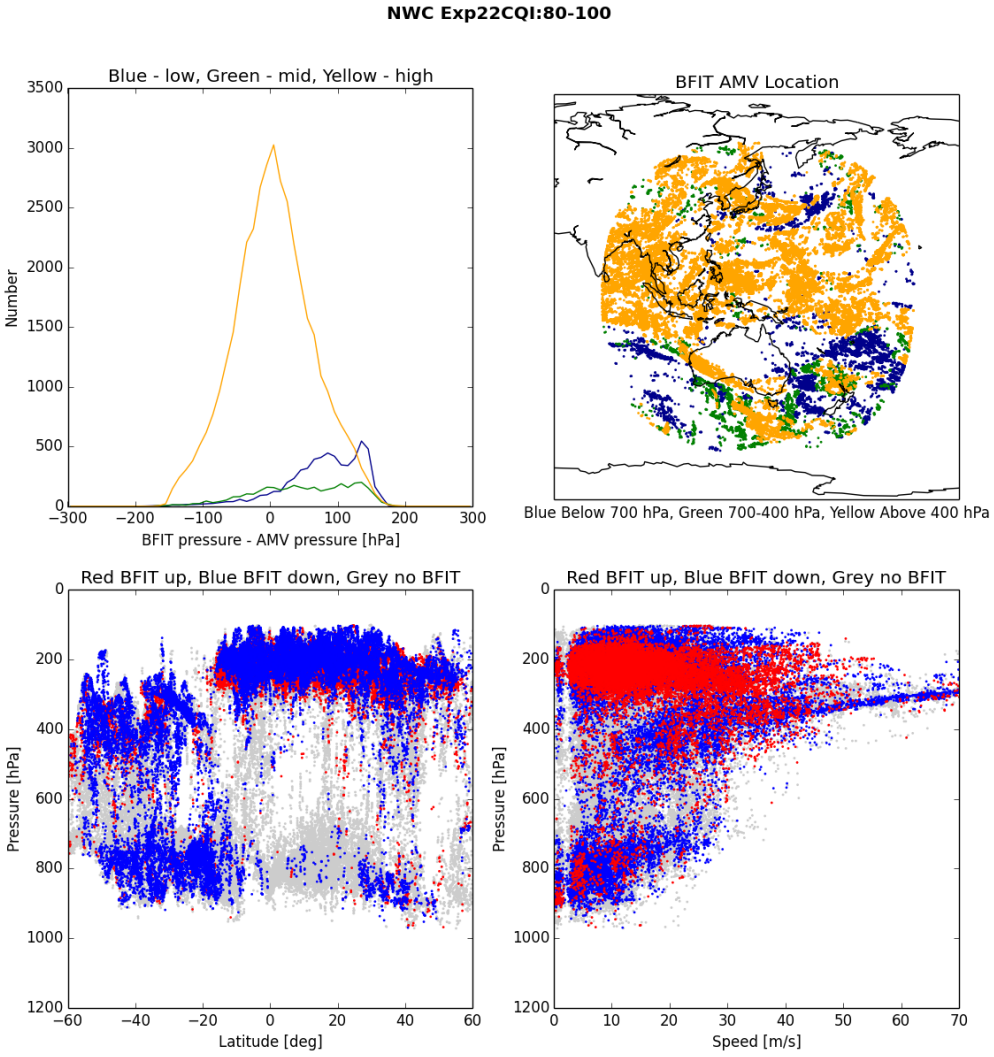


Figure 8-18: Experiment 2. NWC (CQI): Distribution of Best Fit – AMV pressure by height (upper-left); Best Fit AMV location (color coded by height); AMV pressure vs. Latitude (color coded by Best Fit height adjustment); AMV pressure vs. Speed (color coded by Best Fit height adjustment).

The depiction of the distribution of Best Fit statistics is located in the following series of figures. Depending on the site, 21% to 36% of the AMVs are adjusted to a Best Fit pressure (lower-left in each figure). This is on average about a 10% improvement over Experiment 4 in the 2014 Study. 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 for all centres (which was not as consistent in the 2014 Study) of the pressure difference centered near zero (upper-right panel in figures) extending ±200 hPa. The one exception is JMA, where the deviation is ±100 hPa.

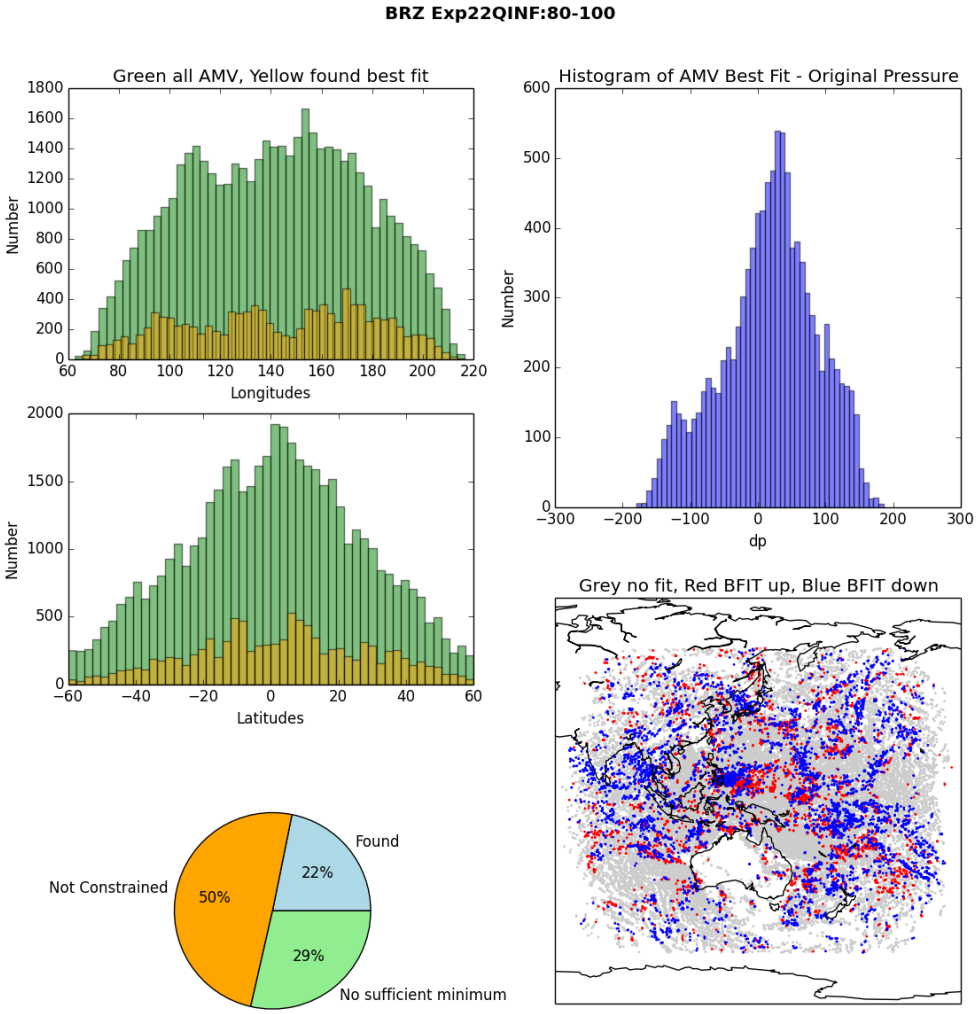


Figure 8-19: Experiment 2. BRZ (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

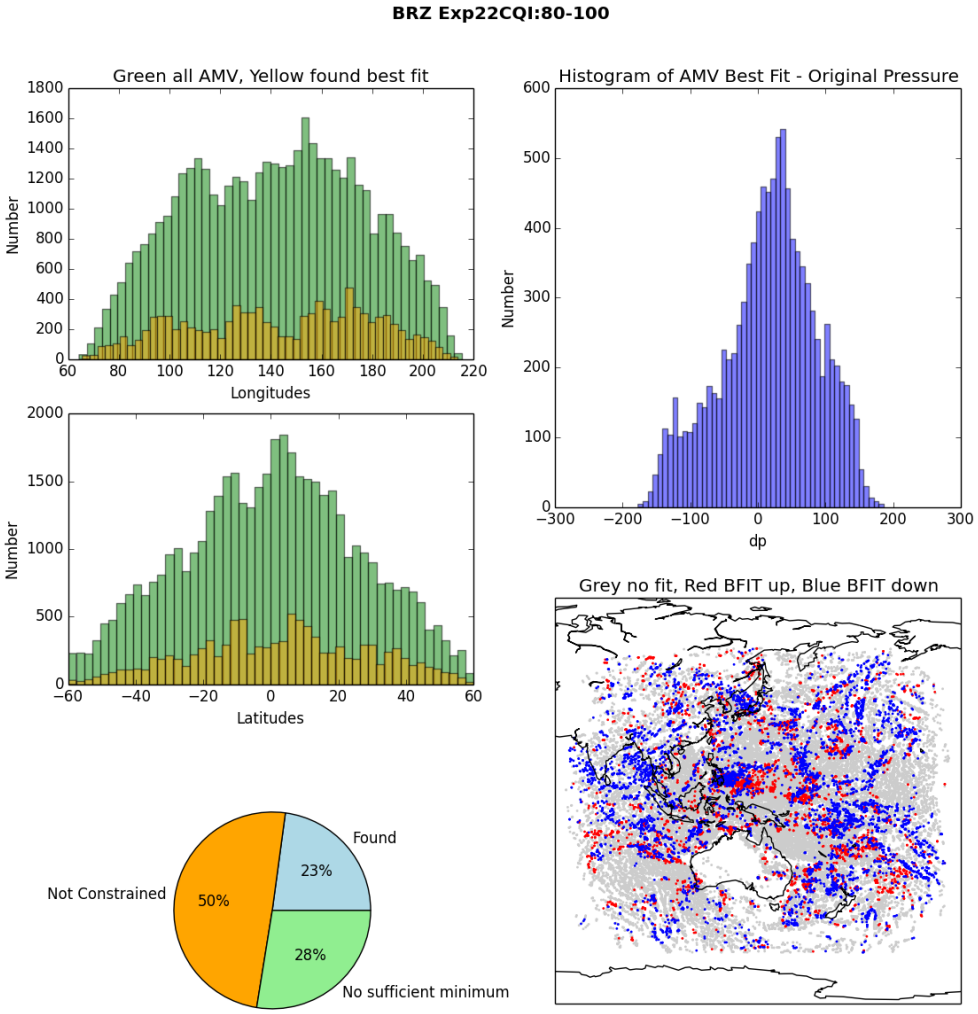


Figure 8-20: Experiment 2. BRZ (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

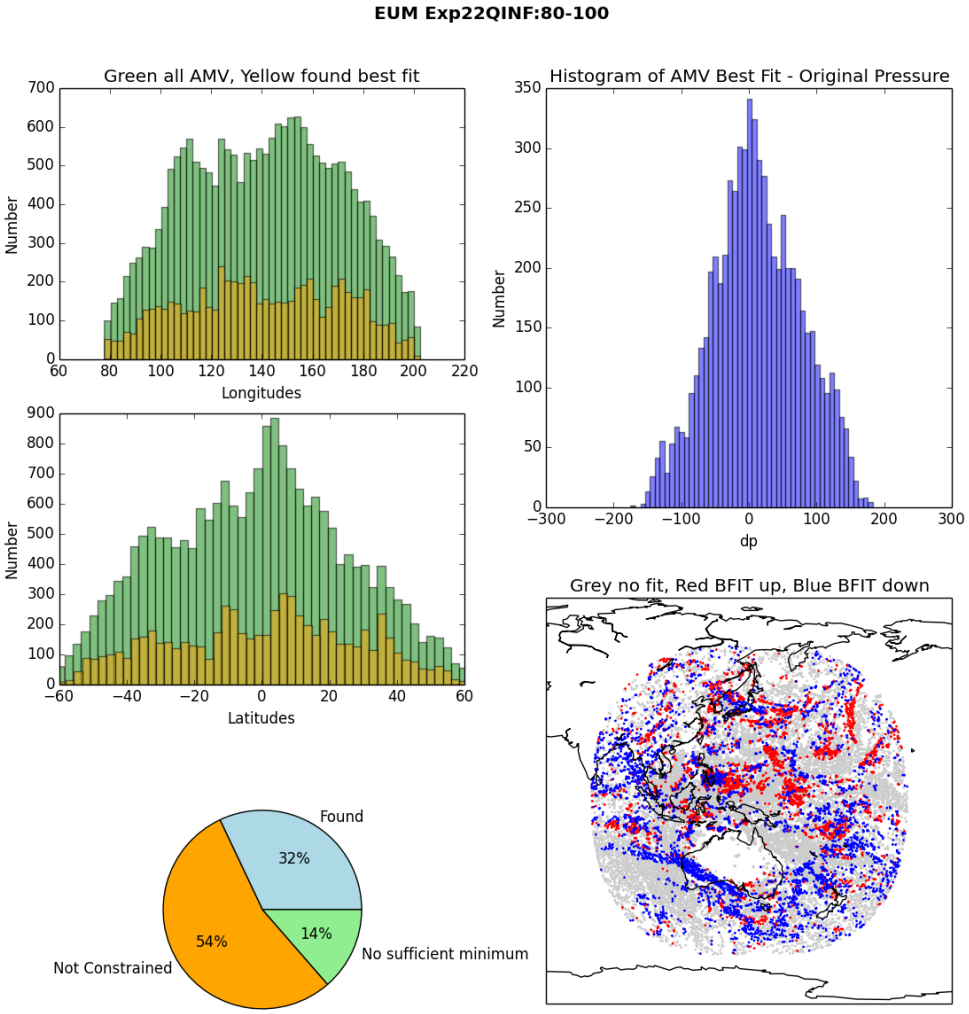


Figure 8-21: Experiment 2. EUM (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

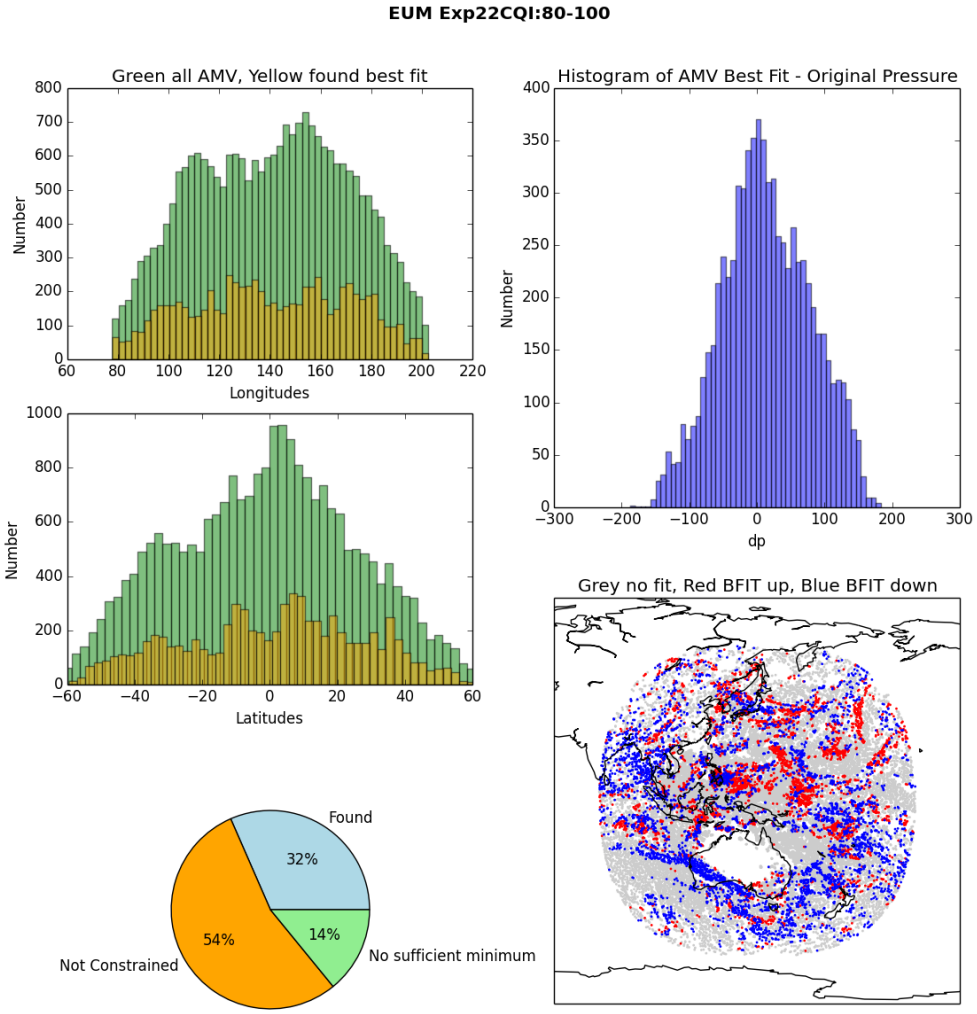


Figure 8-22: Experiment 2. EUM (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

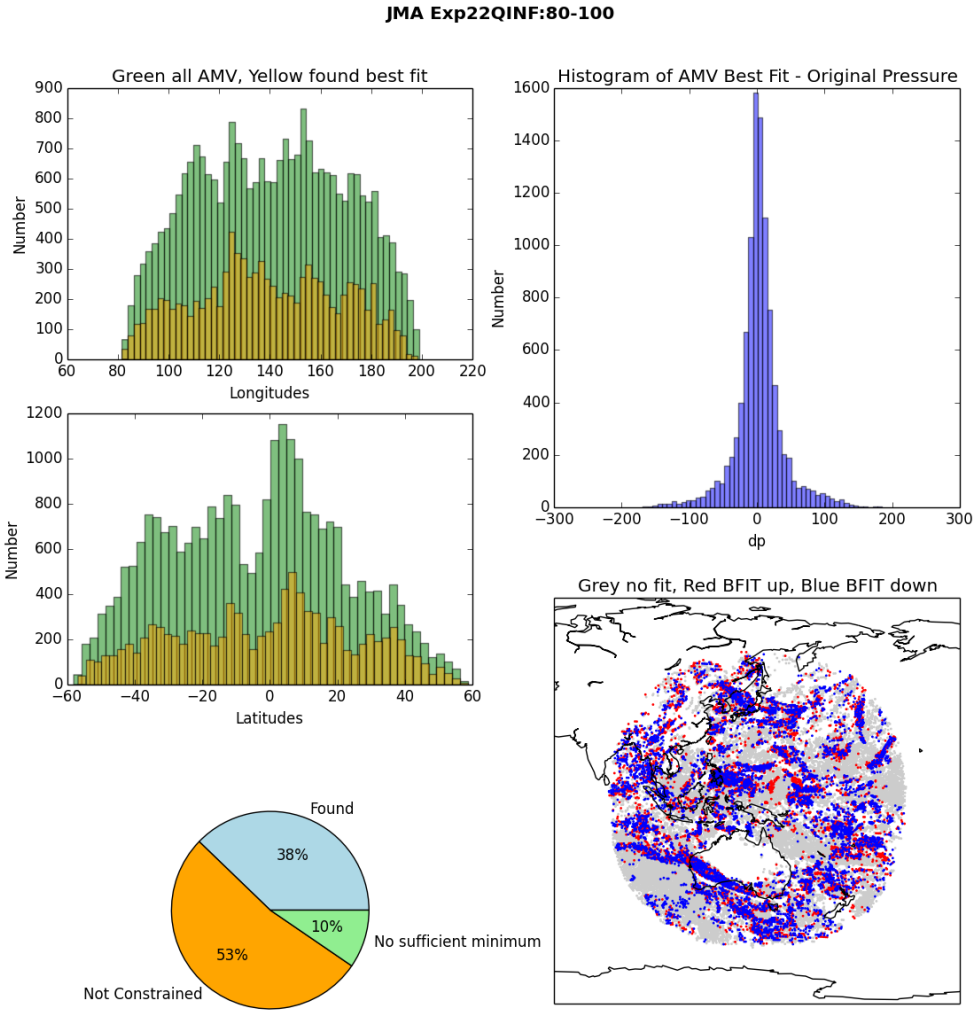


Figure 8-23: Experiment 2. JMA (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

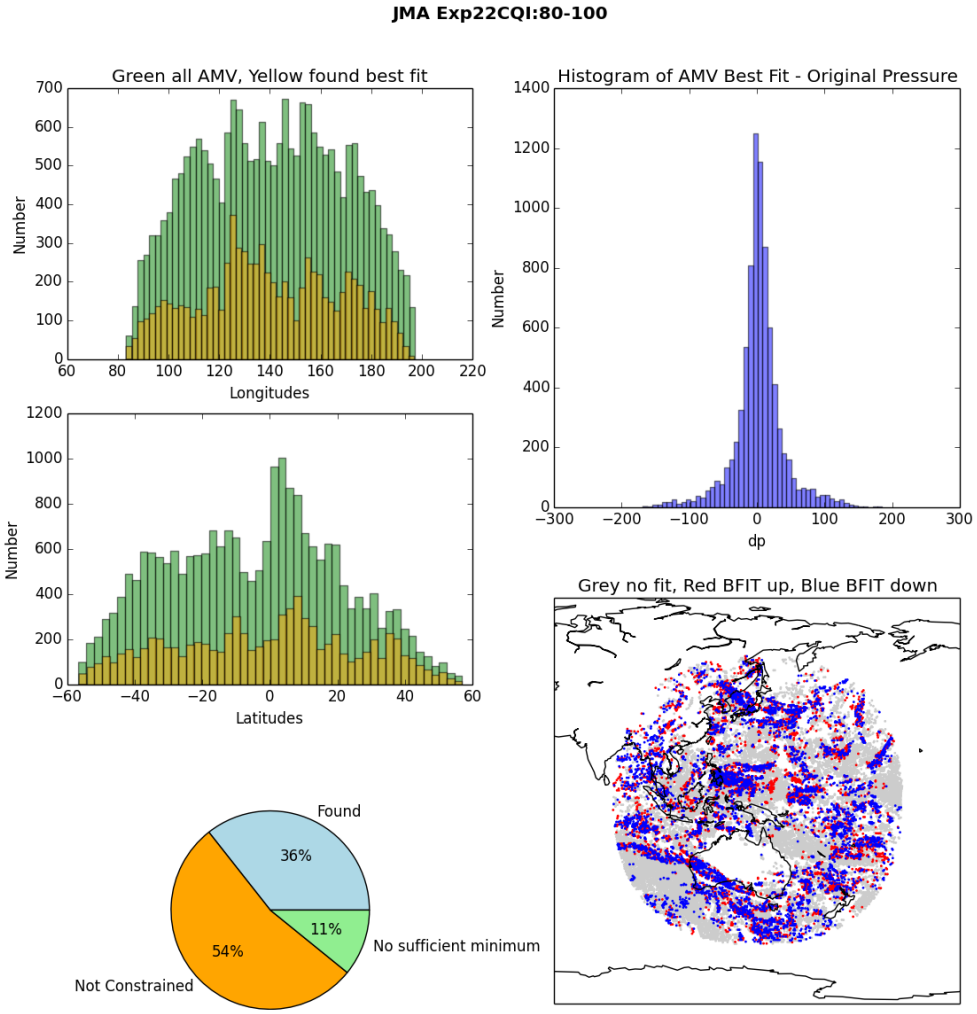


Figure 8-24: Experiment 2. JMA (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

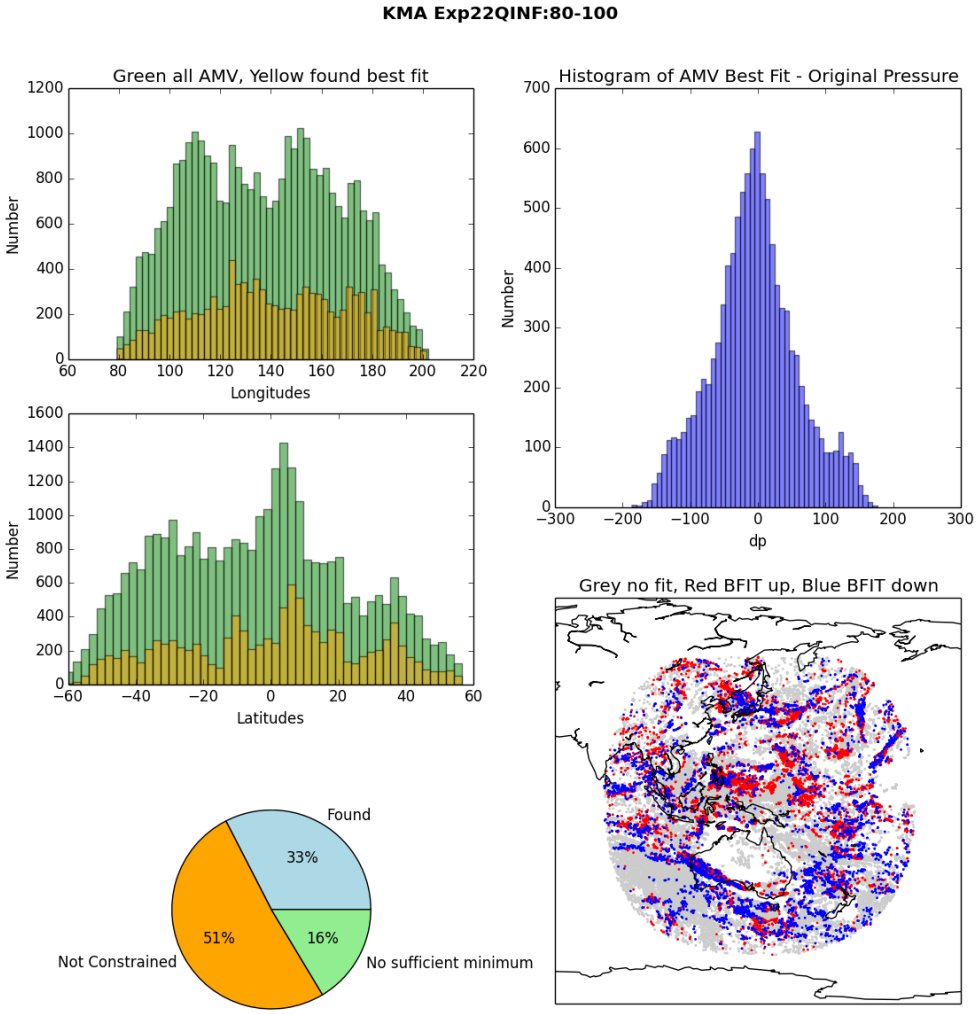


Figure 8-25: Experiment 2. KMA (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

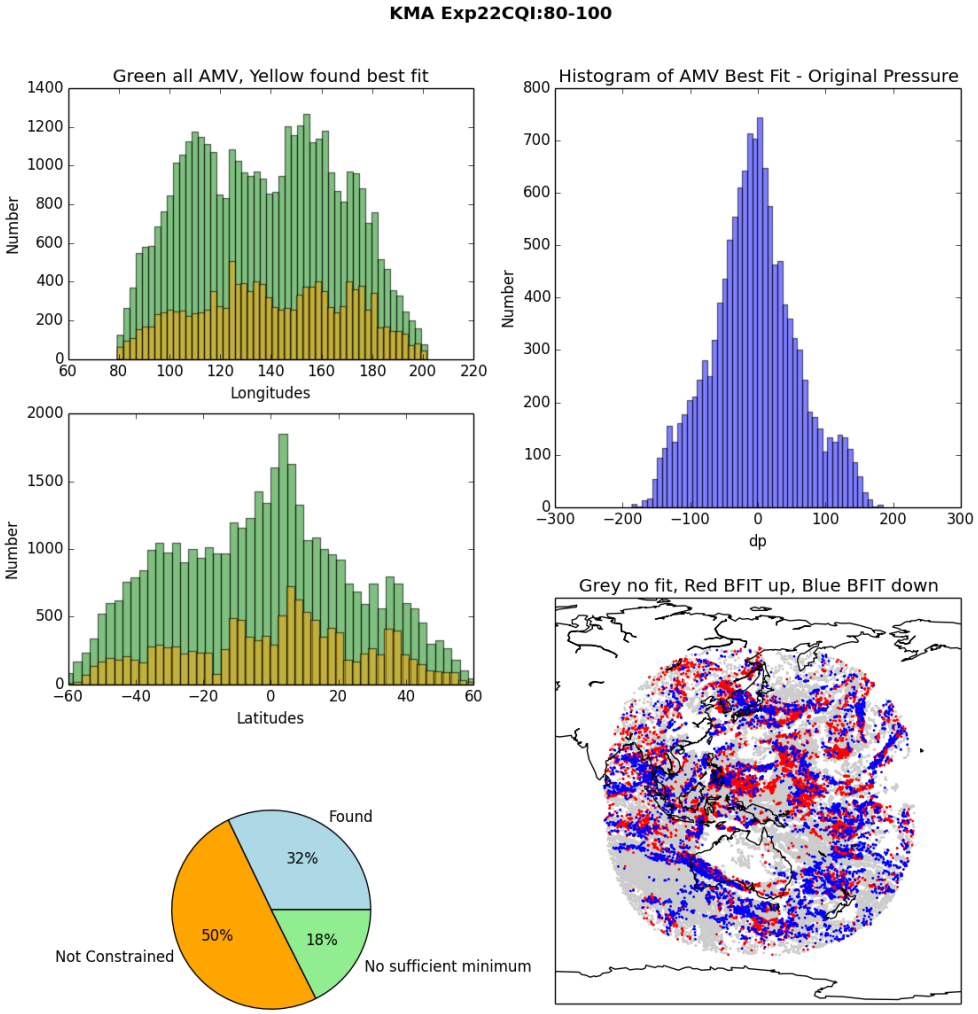


Figure 8-26: Experiment 2. KMA (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

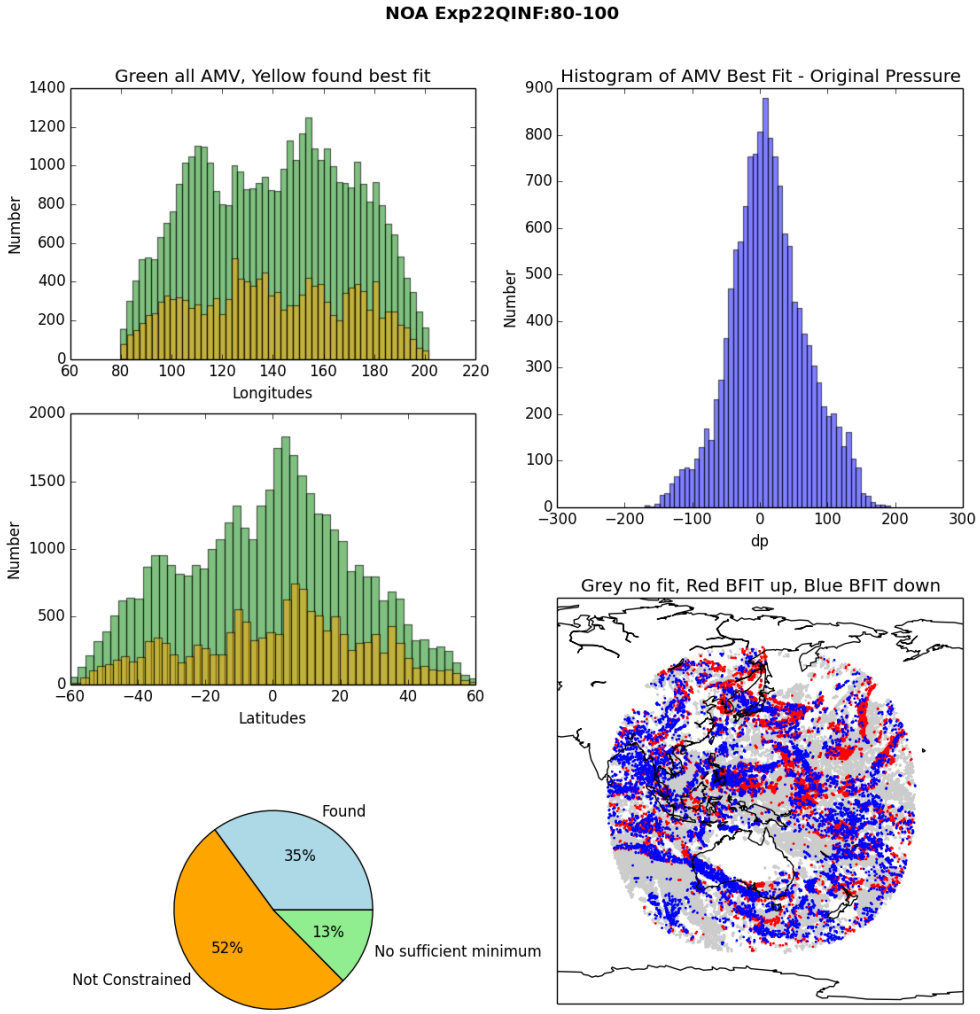


Figure 8-27: Experiment 2. NOA (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

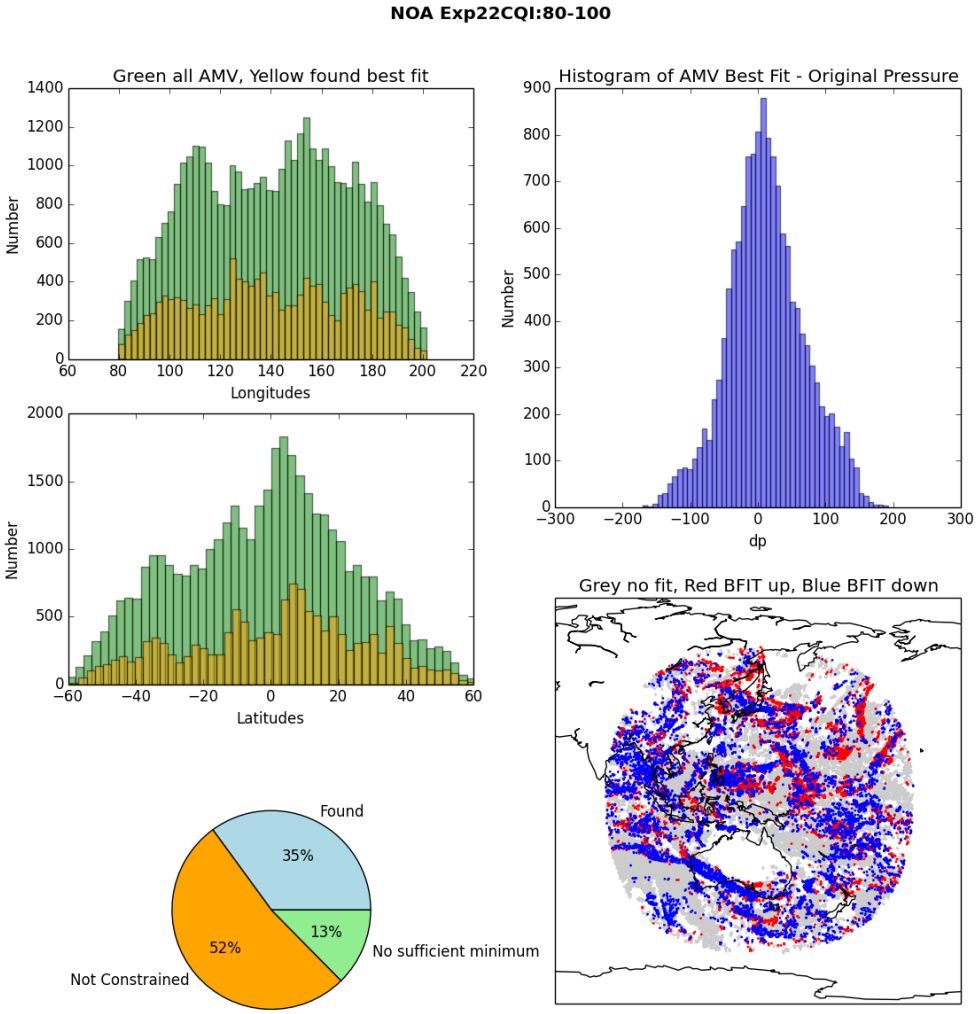


Figure 8-28: Experiment 2. NOA (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

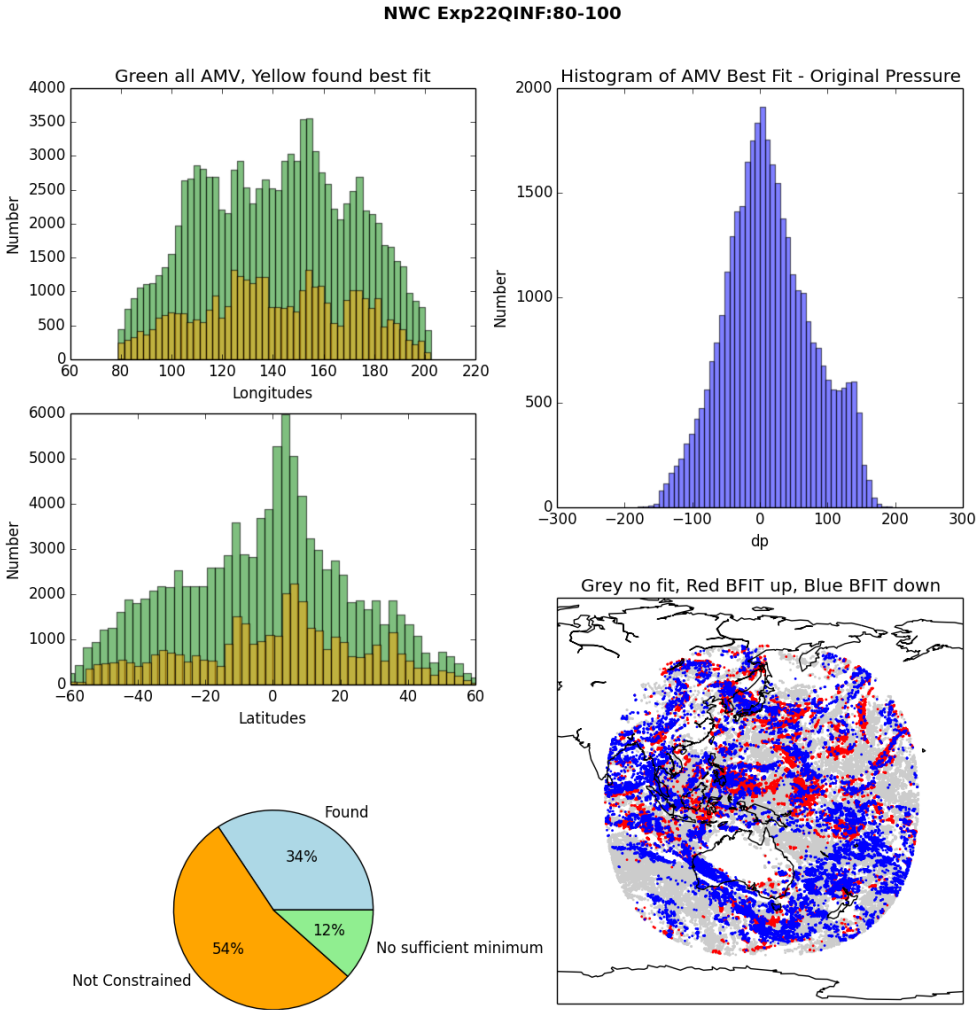


Figure 8-29: Experiment 2. NWC (QINF): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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).

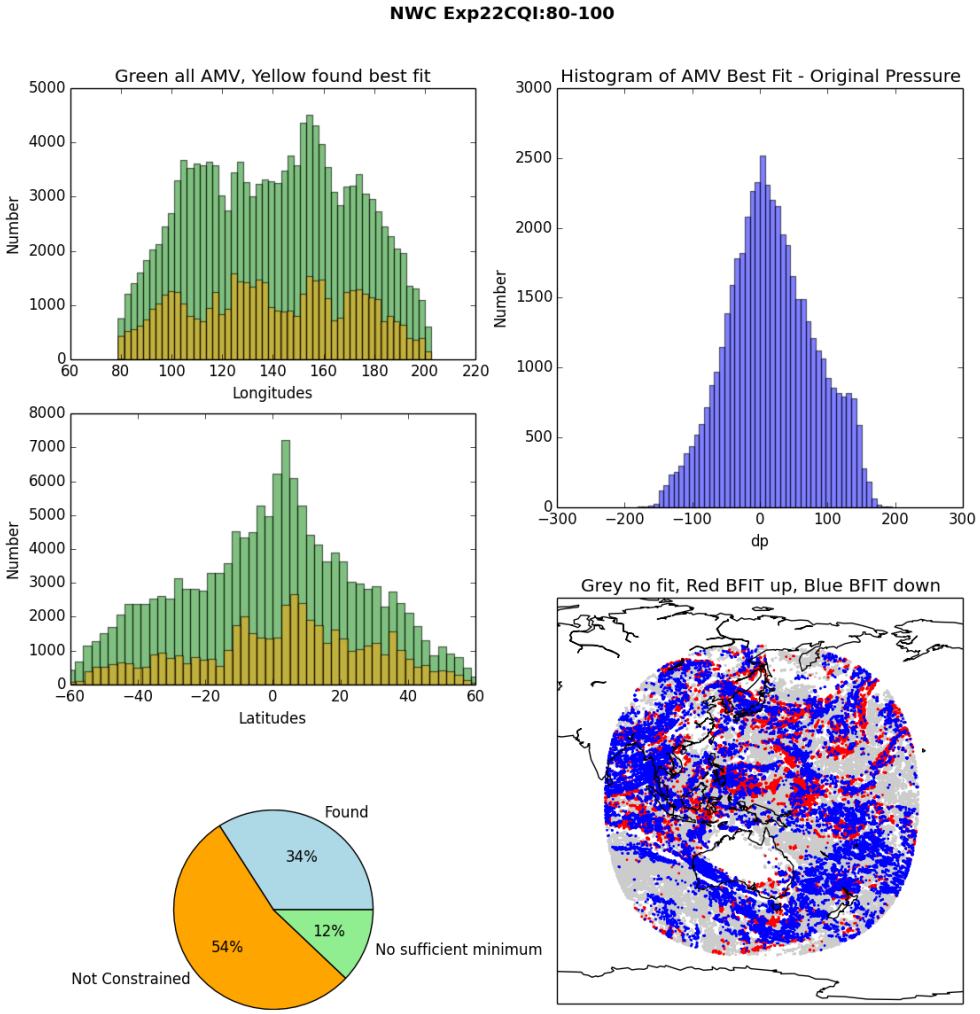


Figure 8-30: Experiment 2. NWC (CQI): Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Latitude (upper-left); Distribution of all AMVs (green) and Best Fit AMVs (gold) vs. Longitude (middle left); Percent of AMVs used in Best Fit (Found) and those that didn't meet criteria (Not Constrained, 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 in Appendix D: Best Fit Speed and Vector Difference to show the distribution of the differences between the AMVs and the background grid, before and after applying the Best Fit algorithm. The lower half of Figure 16-13 to Figure 16-24 shows the change in the *speed difference* distribution before (left) and after (right) Best Fit adjustment. As expected, the speed bias is usually reduced, and the standard deviation is reduced by a factor of 3 to 4. The one exception is JMA, where the improvement in the standard deviation is only on the order of 30%, as the JMA standard deviation before the Best Fit is nearly as good as the other centres *after* the Best fit.

g) 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 *t-test* 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.

To quantify the observed differences in the plots, a paired t-test is once again used with all combinations of producers and parameters. Table 8-23 to Table 8-38 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 and 80, and CQI >=50 and 80. For collocation the distance threshold is 35 km.

Compared to Experiment 1, there was very little agreement between the centers in terms of speed, direction, and QI. The lack of agreement was most evident for AMV pressure, likely due to the lack of commonality in the cloud height algorithms. Even though NWC and EUM both used the CCC method, there were still significant differences for this experiment.

In general, more homogeneity between variables in different datasets is seen using a higher QI threshold (which can be a significant output from this study), and even more using the Common QI threshold of 80% for the filterings (which also can be a significant output from this study).

Comparing with Experiment 1, it is also seen that there is more homogeneity using the prescribed configuration (in Experiment 1), than not using it (in Experiment 2).

Table 8-23: Experiment 2, QINF>=50. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 8-24: Experiment 2, QINF>=50. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 8-25: Experiment 2, QINF>=50. 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. JMA did not report speed.

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

Table 8-26: Experiment 2, QINF>=50. QI 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 8-27: Experiment 2, QINF>=80. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 8-28: Experiment 2, QINF>=80. 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 8-29: Experiment 2, QINF>=80. 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. JMA did not report speed.

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

Table 8-30: Experiment 2, QINF>=80. QI 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	NOA	NWC	JMA	BRZ
EUM						
KMA						
NOA						
NWC						
JMA						
BRZ						

Table 8-31: Experiment 2, CQI>=50. 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 was not included.

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

Table 8-32: Experiment 2, CQI>=50. 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 was not included.

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

Table 8-33: Experiment 2, CQI>=50. 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 was not included.

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

Table 8-34: Experiment 2, CQI>=50. QI 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 was not included.

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

Table 8-35: Experiment 2, CQI>=80. 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 was not included.

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

Table 8-36: Experiment 2, CQI>=80. 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 was not included.

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

Table 8-37: Experiment 2, CQI>=80. 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 was not included.

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

Table 8-38: Experiment 2, CQI>=80. QI 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 was not included.

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

9. Experiment 3

This experiment has the same configuration as Experiment 2, except the use of image data from 0530 to 0550 UTC, 21 July 2016, which corresponds to the time of a CALIPSO overpass.

AMV producers extract infrared channel AMVs considering their standard AMV algorithm configuration, using the Himawari-8/AHI IR10.4 μ images and the height assignment of their choice. The standard AMV configuration is defined by the individual producers as using their typical settings for target selection, target box size, and search box size.

This experiment was used to provide an assessment of the AMV heights as compared to CALIPSO data. All previous analysis of variables, validation against rawinsonde data and model data, and best fit analysis done for Experiment 2 for all AMV datasets are not repeated again here, as both experiments are as said equivalent.

Experiment 3 Highlights

The objective of this experiment was to evaluate the AMV heights as compared to an independent measurement: Cloud heights derived from CALIPSO.

From a qualitative perspective, the results are:

- AMVs are generally near the cloud base for the high-level and thin cirrus clouds, and
- AMVs are near the cloud top for low- and mid-level clouds.

Interestingly, the AMV heights in this small sample are in good agreement among the different centres, which is apparently contrary to the scatter plots of collocated AMV heights in the other experiments. However, this is a very small sample and no attempt was made to ensure that the AMVs are collocated; data from each centre were plotted independently from the others.

a) Approach

By using their standard AMV configuration, this experiment gives the producers a best-case evaluation of their AMV height assignment algorithm, as compared to an independent measurement of cloud height from CALIPSO.

The configuration is the same as Experiment 2:

- Each centre used their own height assignment method. EUM and NWC both used the CCC method; NOA used the provided Cloud datasets with a different procedure. The rest of the centres did not use the Cloud datasets for the height assignment.
- Producers used their algorithm with typical settings.
- ECMWF ERA-Interim analysis grids were used as NWP data.

For each one of the AMV producer's datasets, AMVs are collocated with CALIPSO measurements of cloud top. The thresholds for determining collocation are a distance of 0.1 degree for latitude and longitude, and within one hour.

b) Comparison to CALIPSO

Observations from NASA's Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) provide and independent measurement of cloud top heights, which can be used to validate and compare to the satellite-derived AMVs.

Since CALIPSO is a line-of-site measurement, considering the match thresholds defined above, there are very few collocated observations with AMVs. Therefore, this evaluation is qualitative as illustrated in the following figures.

The figures contain the following plots, graphs, and information, starting with the upper left panel:

- The first panel shows the groundtrack (red line) over a map of the west Pacific,
- The 2nd panel is the same groundtrack superimposed over an RGB image of the corresponding Himawari image,
- The 3rd panel is similar to panel 2, except the underlying image is the Himawari-derived cloud top height product,
- The last panel on the top half of the graph contains statistics on the CALIPSO data.

The lower half of the figure depicts the clouds as detected by CALIPSO (color-coded from gray to red by emissivity). The tropopause height is designated by the black line across the top of the graph (near the top of the cirrus clouds). The topography of the Earth's surface is the light blue line in the lower part of the graph. The collocated AMVs are the black asterisk symbols, primarily located

near the base of the cirrus cloud feature in the middle of the graph and at the top the low level and mid level clouds located in the central and right side of the graph.

From a qualitative perspective, the results are as expected as the AMV heights are generally near the cloud base for the high-level and thin cirrus clouds, and near the cloud top for low- and mid-level clouds. Interestingly, the AMV heights in this small sample are in very good agreement among the different centres, which is apparently contrary to the scatter in collocated AMV heights in Figure 8-2, for example.

Again, this is a very small sample (tens of matches out of tens of thousands of AMVs), and no attempt was made to identify or verify that the AMV heights shown in these figures are collocated with AMVs from the other centres.

Overall, the results are in general agreement with the Best Fit analysis in Experiment 2 (Best fit height), as the high-level AMVs need to be adjusted higher in the atmosphere. And, with these encouraging results, it is recommended that a longer case study is examined in order to quantify the results, which could lead to better height error estimates for AMVs.

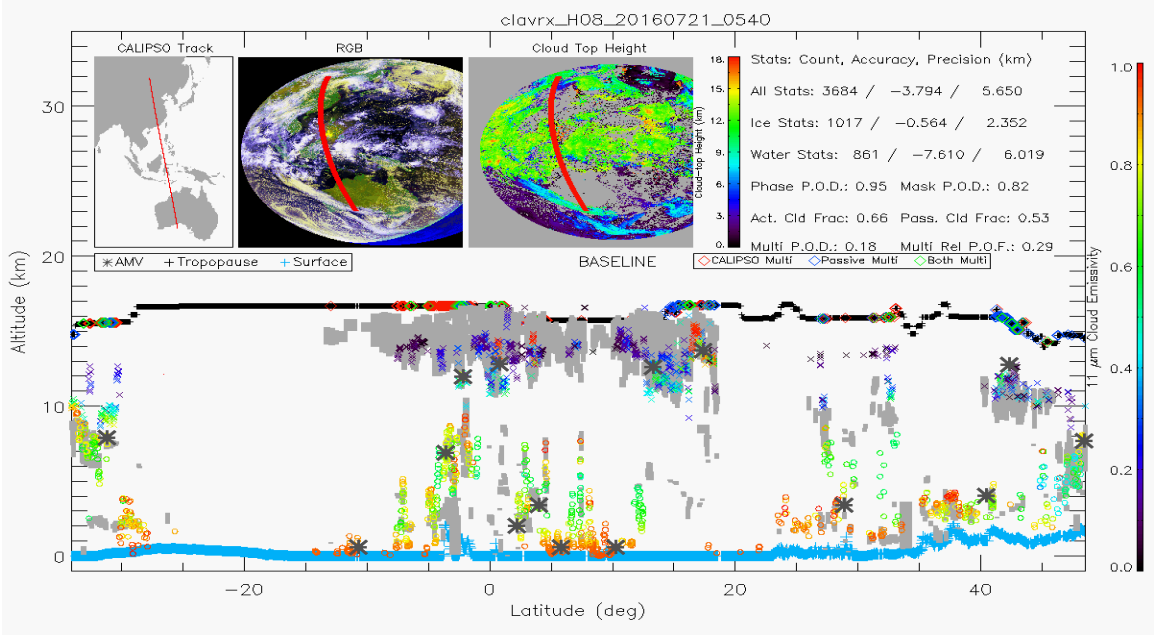


Figure 9-1: BRZ: CALIPSO comparison with collocated AMVs at 0540 UTC on 21 July 2016. Asterisks represent the AMV heights.

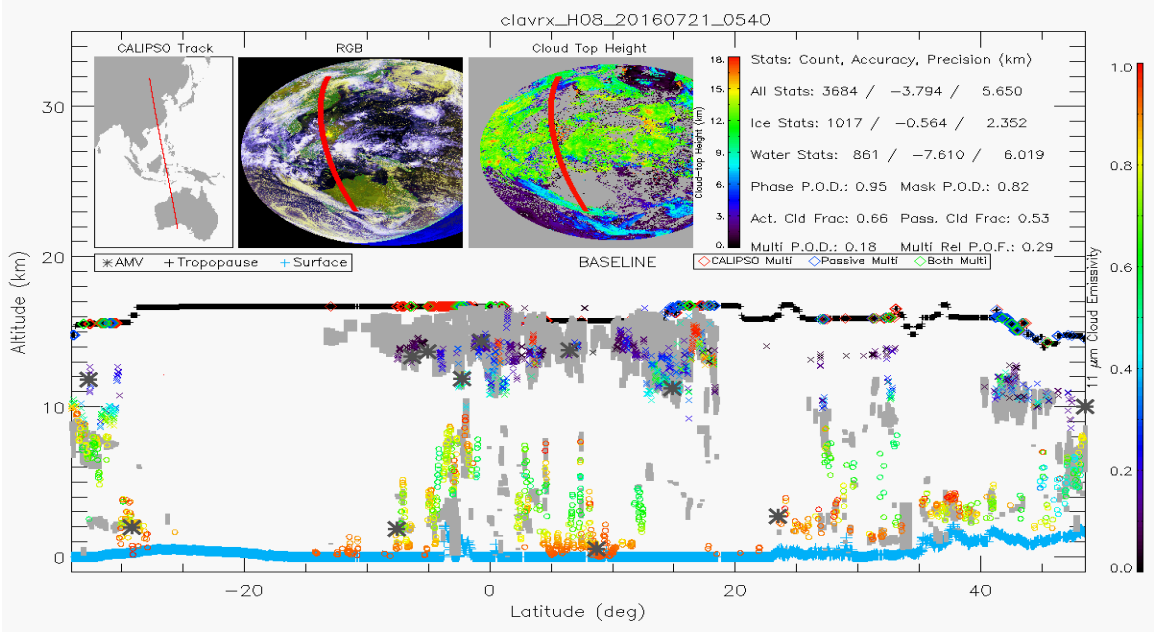


Figure 9-2: EUM: CALIPSO comparison with collocated AMVs at 0540 UTC on 21 July 2016. Asterisks represent the AMV heights.

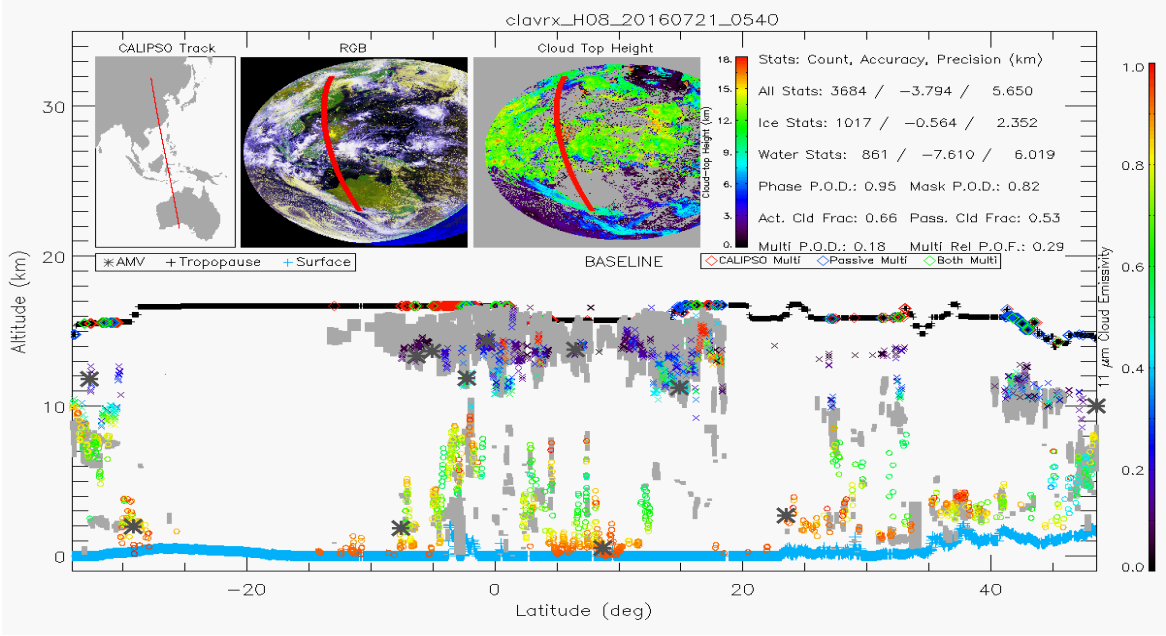


Figure 9-3: JMA: CALIPSO comparison with collocated AMVs at 0540 UTC on 21 July 2016. Asterisks represent the AMV heights.

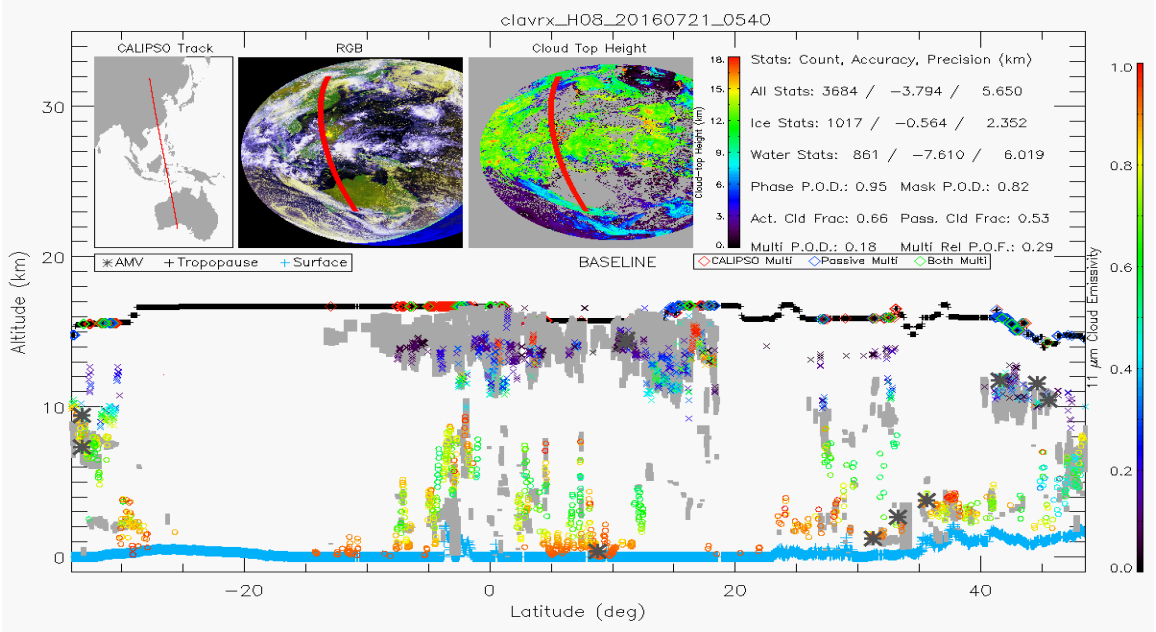


Figure 9-4: KMA: CALIPSO comparison with collocated AMVs at 0540 UTC on 21 July 2016. Asterisks represent the AMV heights.

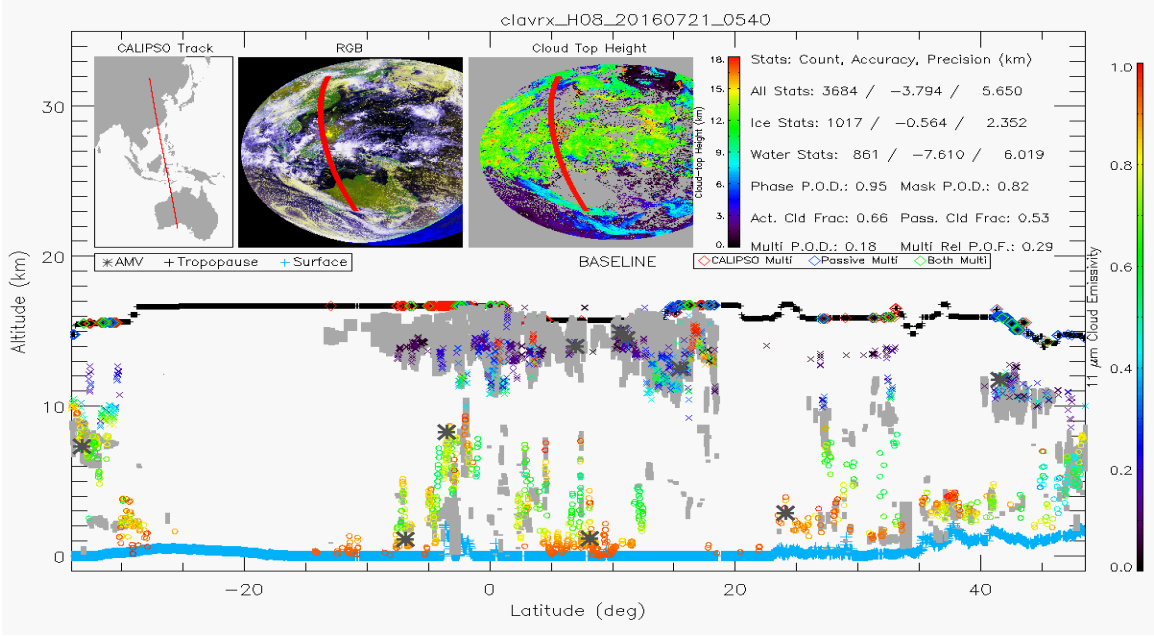


Figure 9-5: NOA: CALIPSO comparison with collocated AMVs at 0540 UTC on 21 July 2016. Asterisks represent the AMV heights.

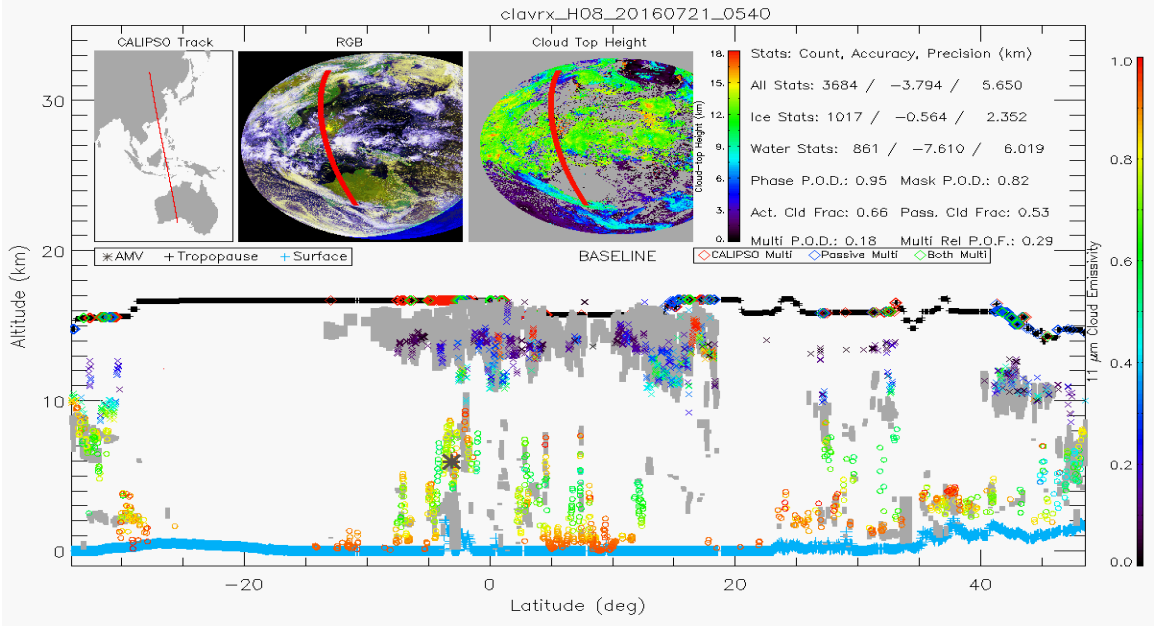


Figure 9-6: NWC: CALIPSO comparison with collocated AMVs at 0540 UTC on 21 July 2016. Asterisks represent the AMV heights.

10. Summary and Conclusions

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

1. AMV producers were to extract IR 10.4μ AMVs considering a prescribed AMV algorithm configuration using Himawari-8/AHI IR10.4 μm images at 1200 to 1220 UTC on 21 July 2016, ECMWF ERA-Interim analysis data, and a cloud height product provided by NOAA/NESDIS. However, this cloud product was not used by all centres, as each centre selected their own height assignment method. This experiment tests the target selection, tracking, height assignment and quality control steps in all AMV algorithms, considering similar targets.
2. This experiment is the same as Experiment 1, except the producer's standard AMV algorithm configuration is used. The experiment is used to test the differences in the AMV processing for each centre, considering the prescribed and their standard AMV configuration.
3. This experiment is the same as Experiment 1, except the time period is different: 0530 to 0550 UTC on 21 July 2016. This experiment is used to validate the AMV heights as compared to CALIPSO data.

The following are general observations, conclusions, and recommendations from this Intercomparison Study:

1. Experiments 1 and 2 only differed in terms of a prescribed vs. standard configuration, with the centres using a cloud height method of their choice. Overall, the results between the two experiments were nearly the same in terms of bulk statistics, collocated statistics, comparisons to rawinsondes and grids, and Best Fit analysis. This implies that the cloud height method has the bigger impact in the lack of agreement in the AMVs, over the impact from using a prescribed vs. standard configuration.
2. The Common QI (CQI) was introduced in this Intercomparison, and it showed some skill in filtering collocated AMVs to result in an improved statistical agreement.
3. Another first for these studies is the addition of CALIPSO data to provide an independent measurement of cloud height to be used for comparison and validation of the AMV heights. Due to the small sample of collocated observations for comparison, only a qualitative assessment could be made: AMV heights were generally near the cloud base for the high-level, thin cirrus clouds and near the cloud top for low- and mid-level clouds, as detected by CALIPSO. It is recommended for future Intercomparison studies, that longer case studies are included in order to quantify the results, which could lead to better height error estimates for AMVs.
4. Even though there was a large variation in the AMV heights for collocated winds, the Best Fit analysis and CALIPSO comparison both showed that there are equivalent, high-quality winds produced by all the centres. This may indicate that the independent quality control post-processing by each centre is one of the most important steps in filtering out poor quality AMVs,

resulting in a higher quality product. For future Intercomparison studies, an experiment to substantiate this conjecture should be considered.

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) CPTEC/INPE (Brazil Weather Forecast and Climatic Studies Center)

The performance of the BRZ AMV algorithm has improved with respect to the results in the previous AMV intercomparison. In general, results are more in agreement with the rest of AMV centres, and differences in many of the variables have reduced.

In any case, it is clear that there still exists room for improvement. On one hand, there are still large differences in the height assignment, as compared to all other centres. This results in BRZ often having the largest deviations from rawinsondes and model analysis winds. On the other hand, BRZ has still to verify the differences found in the direction histograms, in which some directions are found to be much more frequent than others.

b) Korea Meteorological Administration (KMA)

The KMA algorithm performed similarly to the results from the previous AMV intercomparison. Overall, the comparisons to rawinsondes and model background were in the middle of the distributions.

c) EUMETSAT

The behavior of EUM algorithm was much better when the QI threshold used was high (80%), and when their standard configuration was used (comparing with the results with the prescribed configuration). In these circumstances, the performance of EUM AMVs is basically similar to that of other centres (NOA, NWC).

The similarities in the height assignment of EUM and NWC centres are also to be noticed, due to the fact of both using the same “CCC method”.

d) NOAA (United States National Oceanic and Atmospheric Administration)

Results for the NOAA AMV algorithm have much improved with respect to the previous Intercomparison study, and now their validation results against rawinsondes and analysis winds are in second position (together with NWC).

In any case, there are still some issues with the NOAA algorithm, like the vertical distribution of the AMVs, for which there are very few AMVs in middle levels, which is in disagreement with the rest of the centres.

e) NWC SAF (Satellite Application Facility on support to Nowcasting)

NWCSAF/HRW algorithm agrees well with other centres in terms of parameter distributions, especially when using the Common QI and their own configuration. Their validation results against rawinsondes and model analysis winds are in second position (together with NOA).

The NWC algorithm is basically the same as the one used for the previous AMV Intercomparison. Due to this stability, its overall performance is similar to what was found in previous AMV Intercomparison study.

However, some elements have been detected that need some analysis by NWC AMV producers: the fact that some AMV directions (like 90º) are more frequent in the direction histogram than others in their vicinity (detected now with Himawari AMVs but not previously with MSG AMVs).

f) Japan Meteorological Agency (JMA)

The JMA algorithm is the one with best performance, considering in general all validation and checking elements, and this reflects the most important change in all AMV algorithms, when compared to the previous Intercomparison study.

Specifically, they have the best overall statistics when compared to rawinsondes and model analysis winds, and their best fit analysis shows that the differences with respect to the best fit level for JMA's AMVs are much smaller than for all other centres.

All this is most likely due to their updated AMV height assignment process: "optimal estimation method using observed radiance and NWP vertical profile". However, it is still to be studied if the small differences between JMA's AMVs and the background model used for their processing, imply a good impact in later applications, like NWP assimilation.

11. 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. Available online at: https://www.eumetsat.int/website/wcm/idc/idcplg?IdcService=GET_FILE&dDocName=PDF_CONF_P51_S4_20_GENKOVA_V&RevisionSelectionMethod=LatestReleased&Rendition=Web

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. Available online at: https://www.eumetsat.int/website/wcm/idc/idcplg?IdcService=GET_FILE&dDocName=PDF_CONF_P56_S4_02_GENKOVA_V&RevisionSelectionMethod=LatestReleased&Rendition=Web

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. Available online at: https://www.eumetsat.int/website/wcm/idc/idcplg?IdcService=GET_FILE&dDocName=PDF_CONF_P60_S5_06_SALONEN_V&RevisionSelectionMethod=LatestReleased&Rendition=Web

Santek, D., J. García-Pereda, C. Velden, I. Genkova, S. Wanzong, D. Stettner, M. Mindock, 2014: 2014 AMV Intercomparison Study, NWCSAF Visiting Scientist Activity Report.
Available online at: http://www.nwcsaf.org/aemetRest/downloadAttachment/225.

Santek, D., J. García-Pereda, C. Velden, I. Genkova, S. Wanzong, D. Stettner, S. Nebuda, M. Mindock, 2014: A new atmospheric motion vector intercomparison study, 12th International Winds Workshop, Copenhagen, Denmark, June 2014.
Available online at: http://www.nwcsaf.org/aemetRest/downloadAttachment/226.

12. Acknowledgements

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We also thank the AMV producers for their efforts in processing these datasets:

BRZ: Renato Galante Negri
EUM: Régis Borde and Manuel Carranza
NWC: Javier García Pereda
JMA: Kenichi Nonaka and Kazuki Shimoji
KMA: Oh Soomin and Lee Byungil
NOA: Wayne Bresky

13. Appendix A: Parameter Distribution Histograms

Experiment 1: QINF Parameter Distribution Histograms

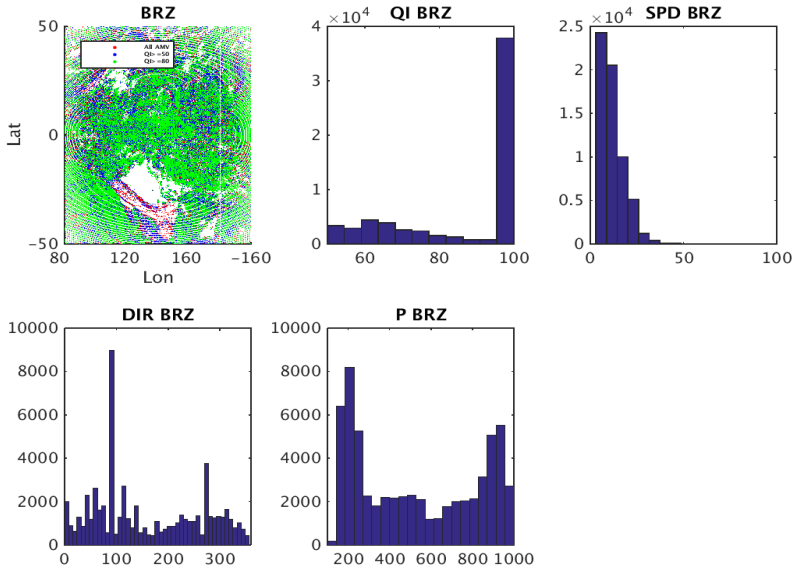


Figure 13-1: Experiment 1, BRZ (QINF>=50). Parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

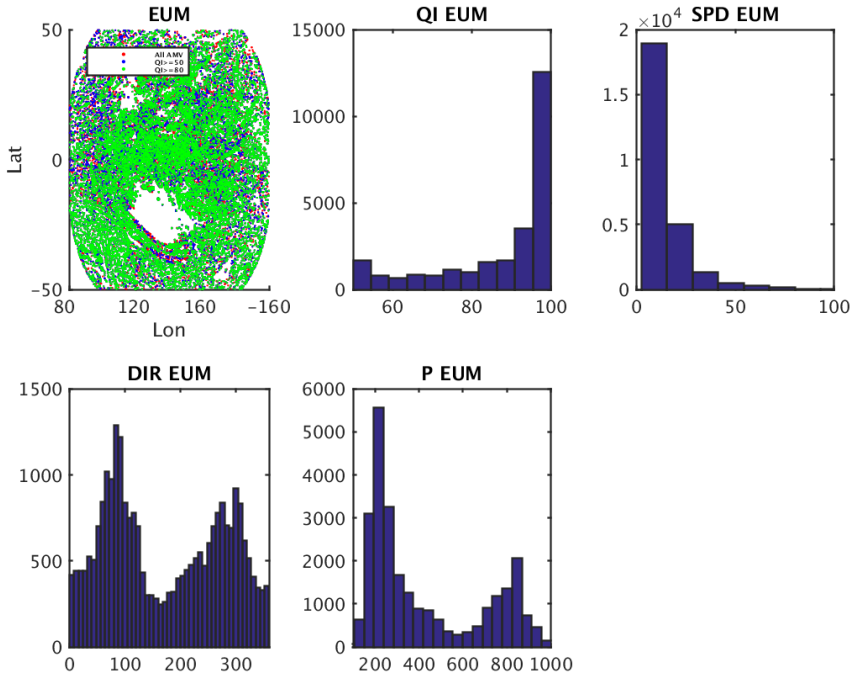


Figure 13-2: Experiment 1, EUM (QINF>=50). Parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

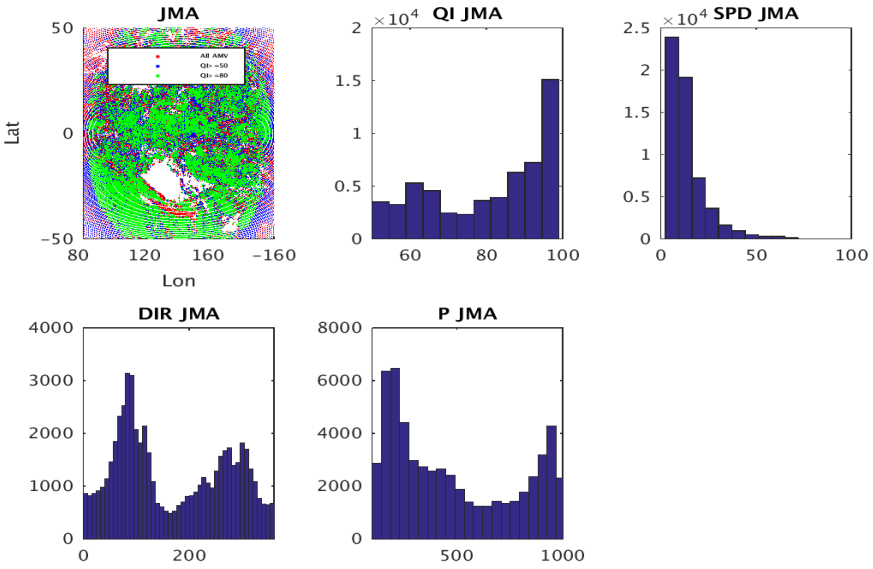


Figure 13-3: Experiment 1, JMA (QINF>=50). Parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

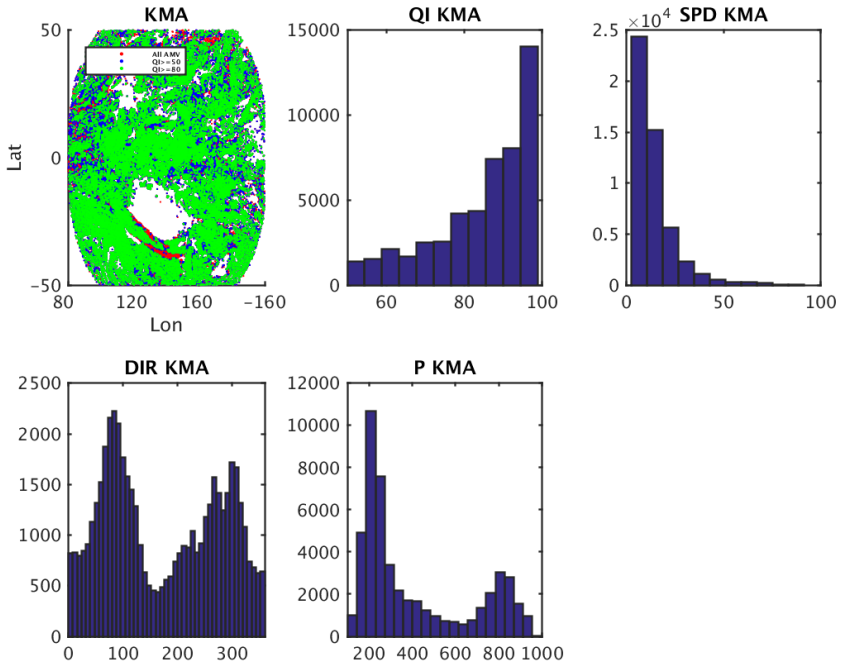


Figure 13-4: Experiment 1, KMA (QINF>=50). Parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

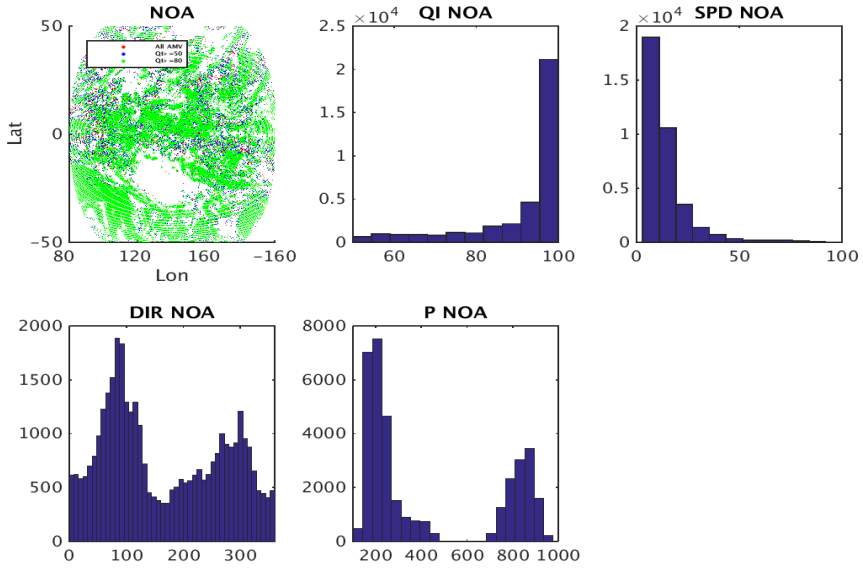


Figure 13-5: Experiment 1, NOA (QINF>=50). Parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

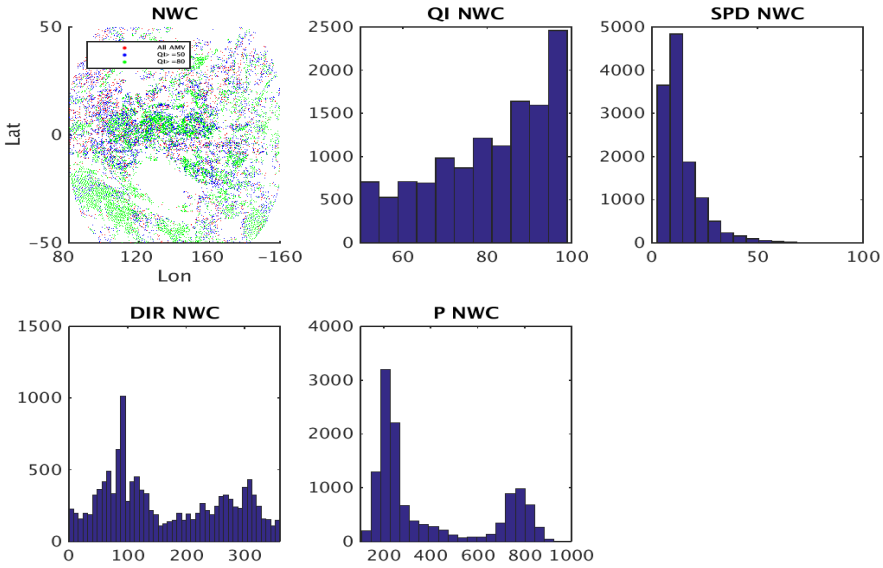


Figure 13-6: Experiment 1, NWC (QINF>=50). Parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

Experiment 1: CQI Parameter Distribution Histograms

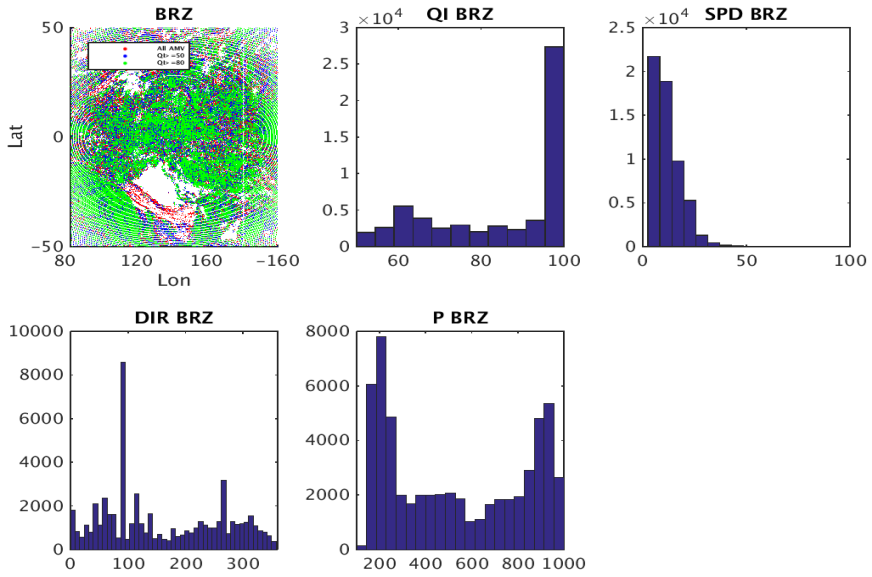


Figure 13-7: Experiment 1 BRZ (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

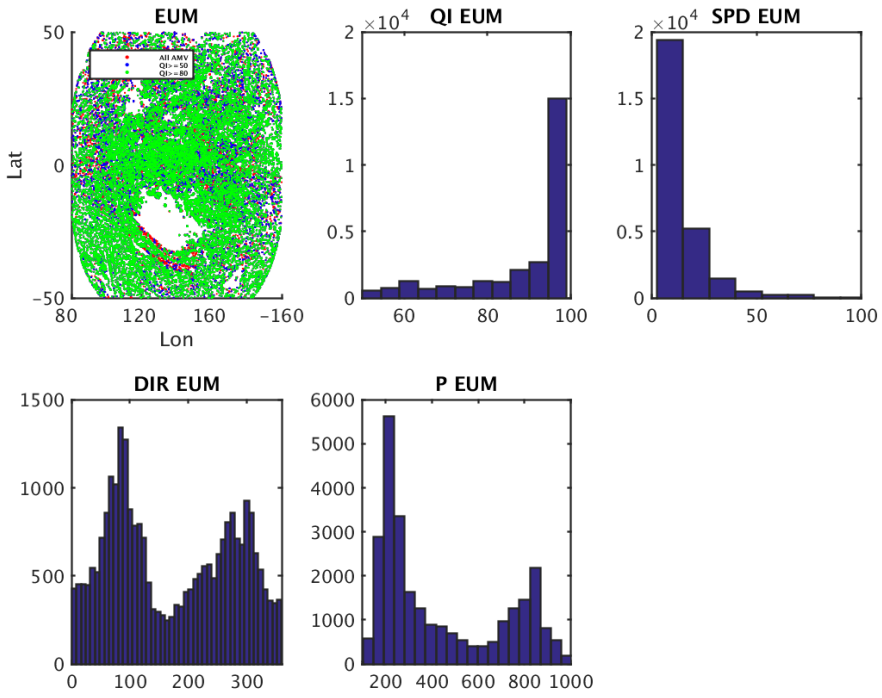


Figure 13-8: Experiment 1 EUM (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

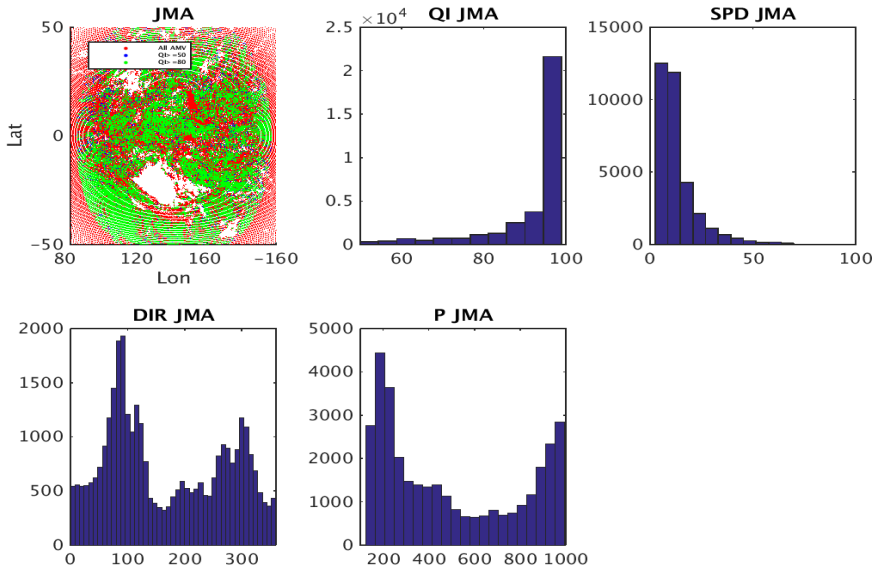


Figure 13-9: Experiment 1 JMA (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

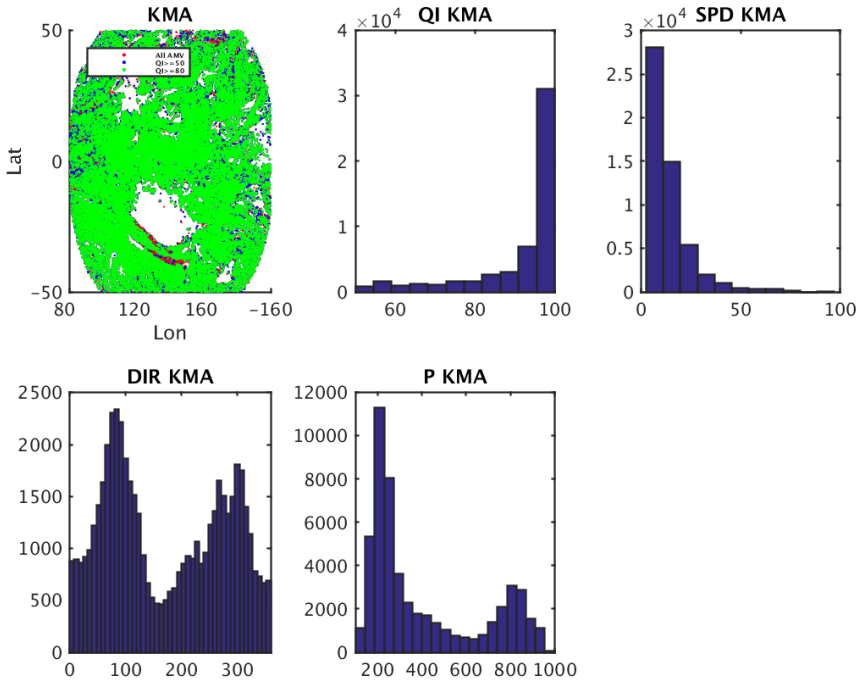


Figure 13-10: Experiment 1 KMA (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

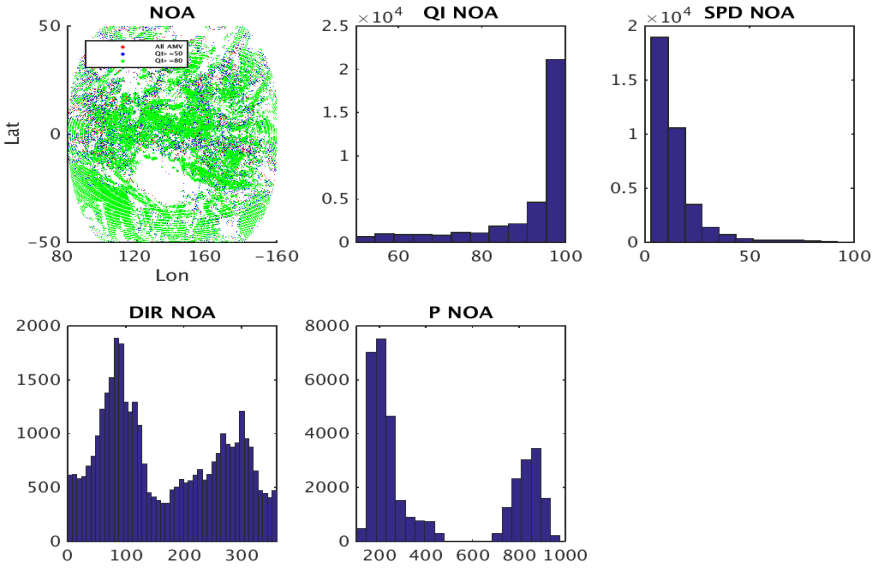


Figure 13-11: Experiment 1 NOA (CQI>=50) NOA parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

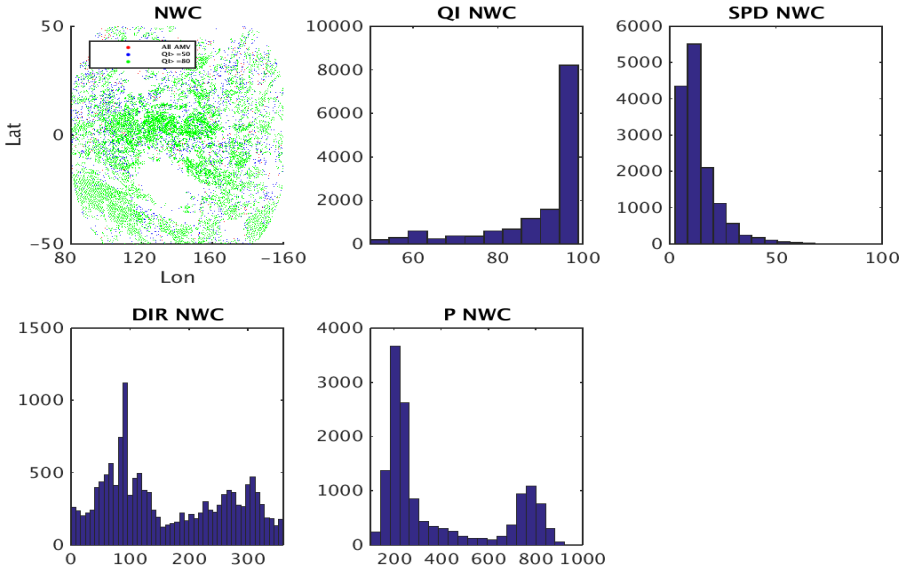


Figure 13-12: Experiment 1 NWC (CQI>=50) NWC parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

Experiment 2: QINF Parameter Distribution Histograms

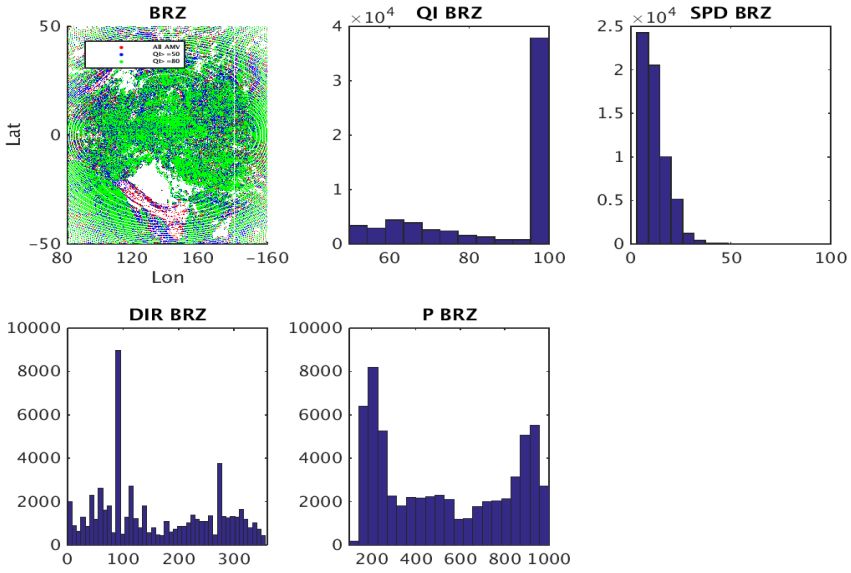


Figure 13-13: Experiment 2 BRZ (QINF>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

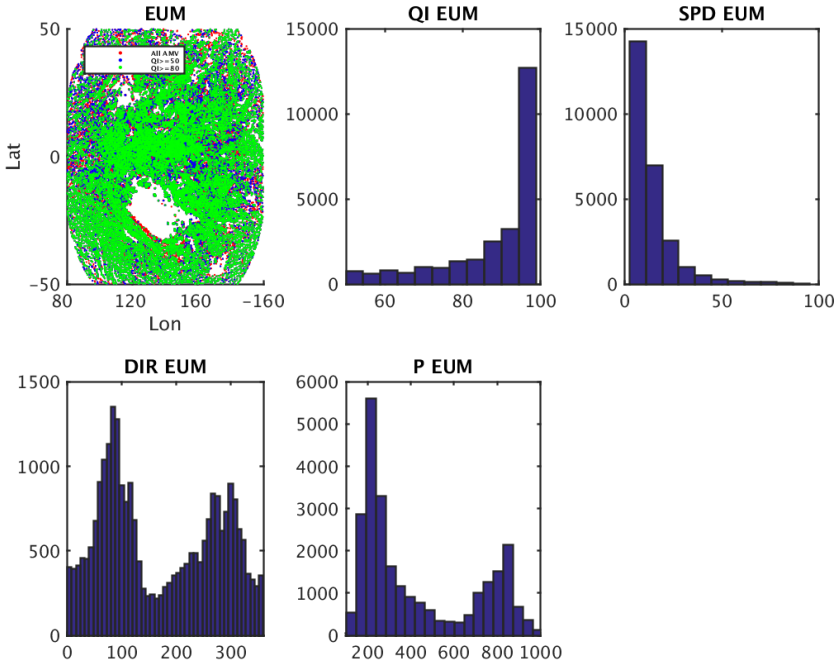


Figure 13-14: Experiment 2 EUM (QINF>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

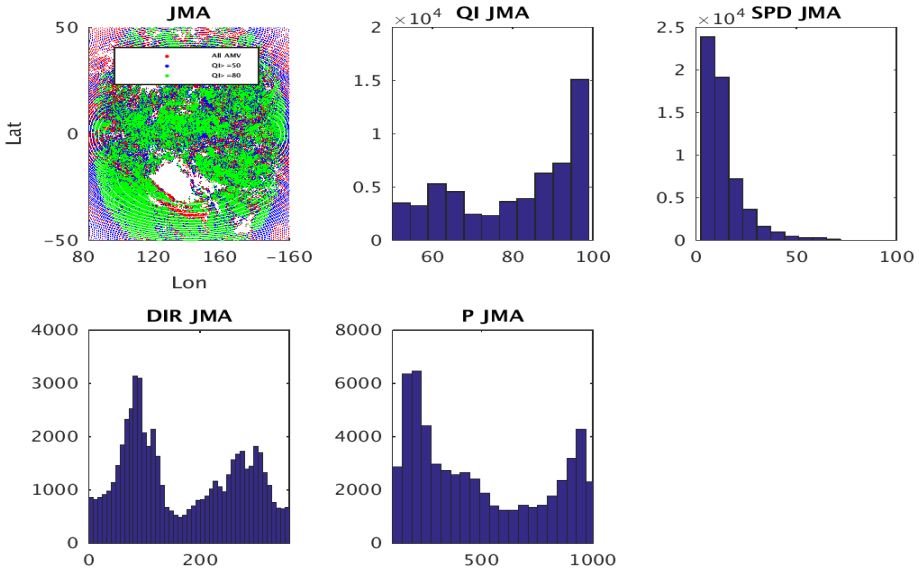


Figure 13-15: Experiment 2 JMA (QINF>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

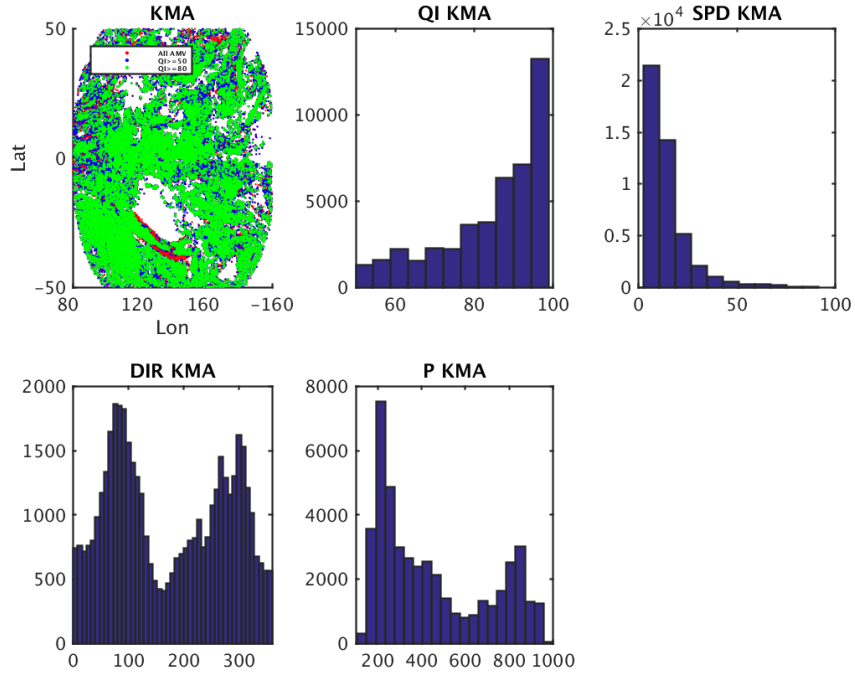


Figure 13-16: Experiment 2 KMA (QINF>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

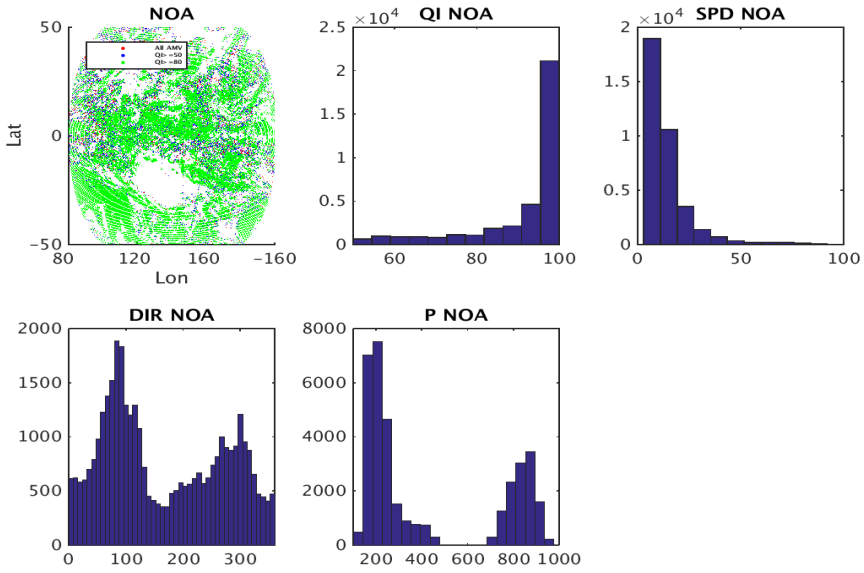


Figure 13-17: Experiment 2 NOA (QINF>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

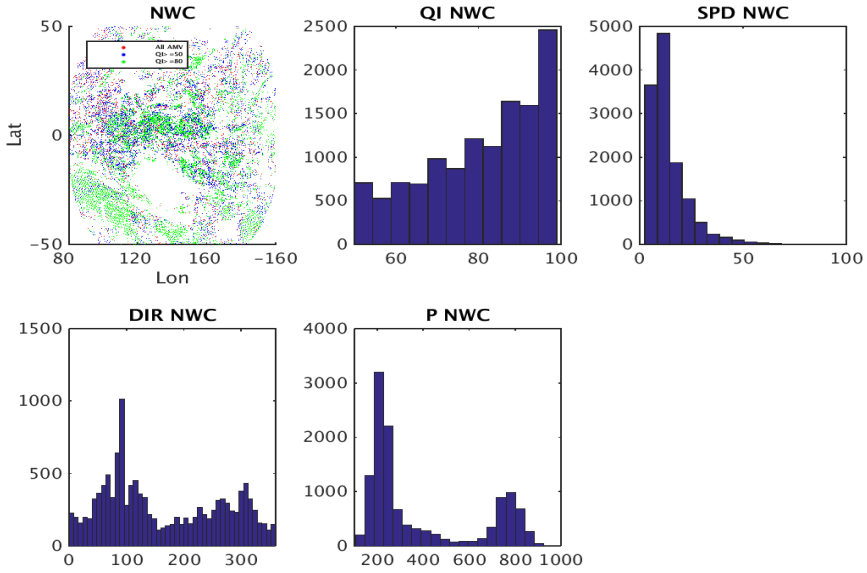


Figure 13-18: Experiment 2 NWC (QINF>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

Experiment 2: CQI Parameter Distribution Histogram

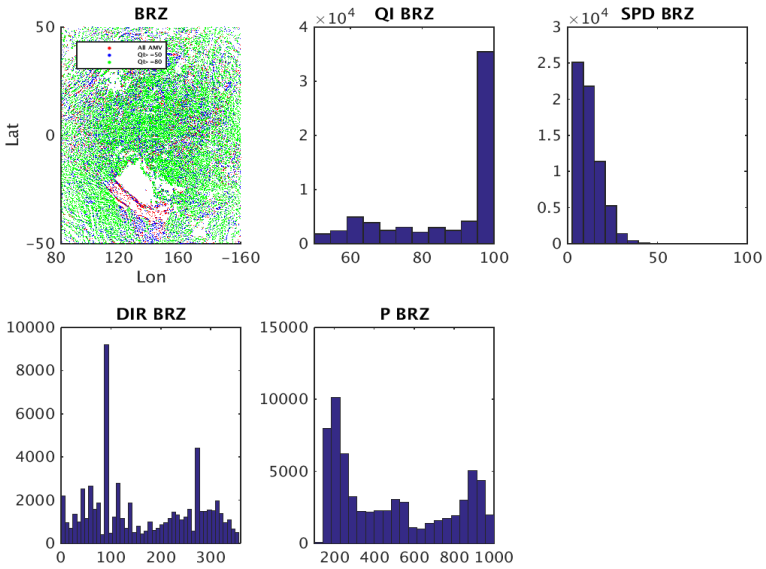


Figure 13-19: Experiment 2 BRZ (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

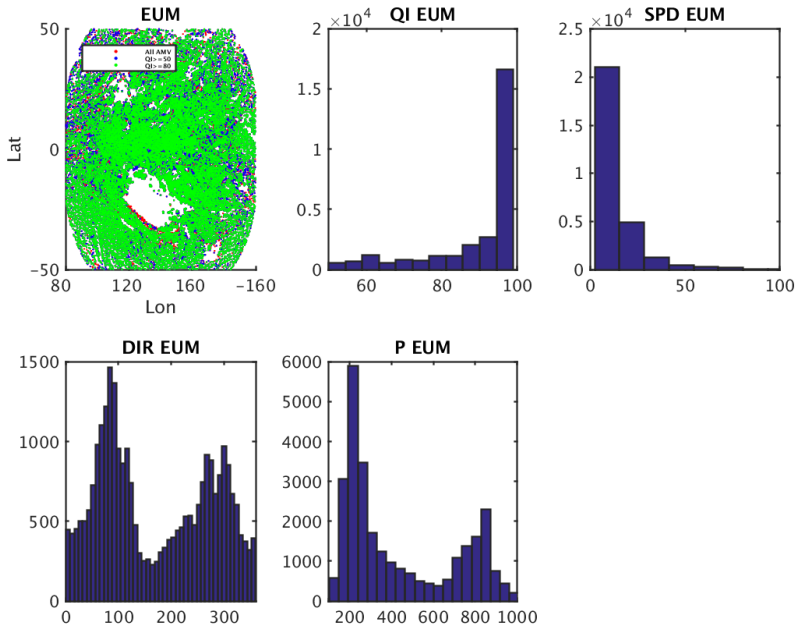


Figure 13-20: Experiment 2 EUM (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

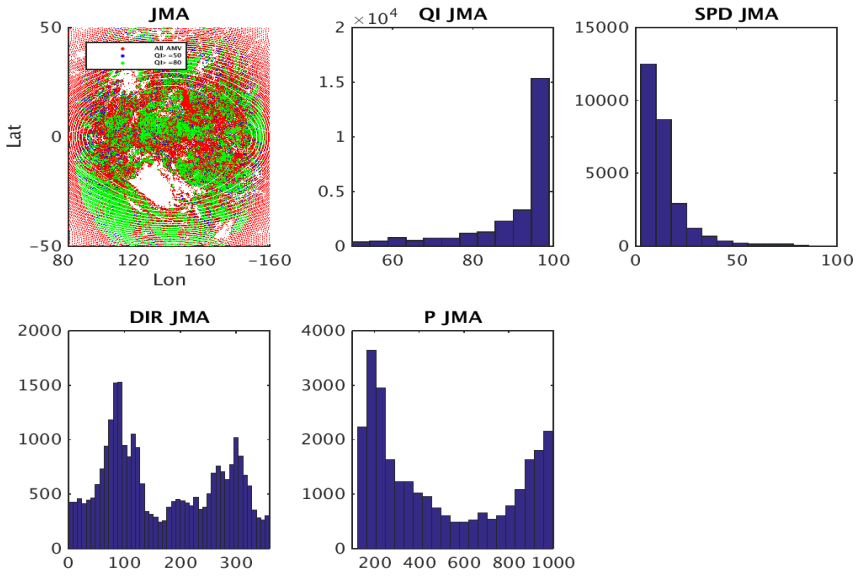


Figure 13-21: Experiment 2 JMA (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

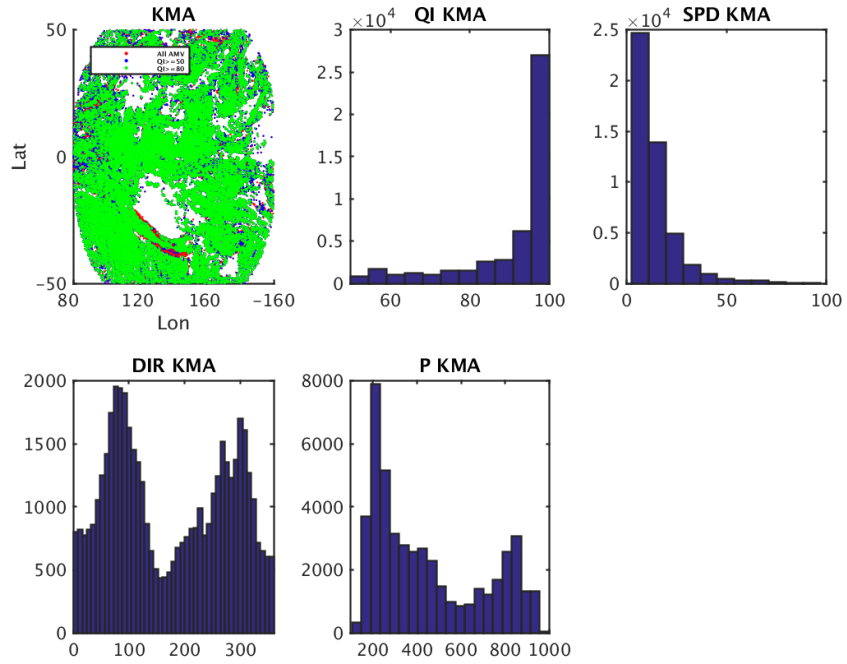


Figure 13-22: Experiment 2 KMA (CQI>=50) KMA parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

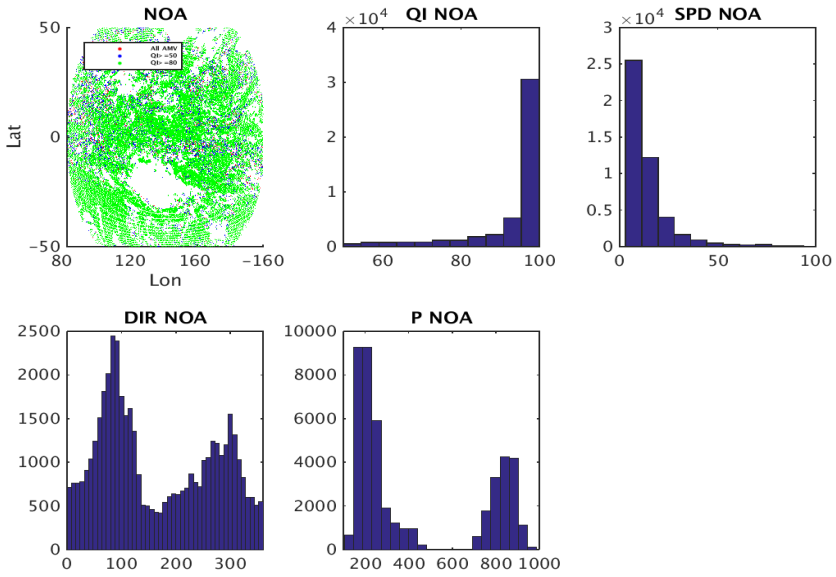


Figure 13-23: Experiment 2 NOA (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

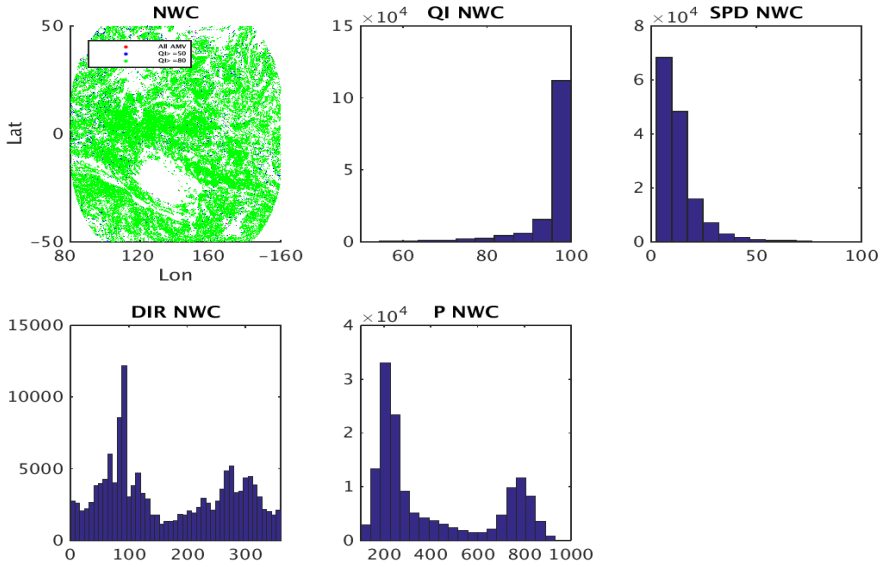


Figure 13-24: Experiment 2 NWC (CQI>=50) parameter distributions: latitude/longitude spatial distribution and histograms of QI, wind speed, direction, and AMV pressure.

14. 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 level
    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.
```

15. Appendix C: t-test Results

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

a) Experiment 1 t-test Results

QINF>=50 collocated AMVs File: Exp_21_statsout.txt

```
Japan "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.05 0.12, Mean: 0.08
  Direction: h = 0, p = 0.74, ci = -0.59 0.84, Mean: 0.12
  Pressure:  h = 1, p = 0.00, ci = 22.59 27.33, Mean: 24.96
  QI:        h = 1, p = 0.00, ci = -1.41 -0.86, Mean: -1.13

Japan "VS" NOAA
  Speed:     h = 0, p = 0.18, ci = -0.07 0.01, Mean: -0.03
  Direction: h = 0, p = 0.09, ci = -0.10 1.33, Mean: 0.61
  Pressure:  h = 1, p = 0.00, ci = 11.88 16.89, Mean: 14.38
  QI:        h = 1, p = 0.00, ci = -6.94 -6.38, Mean: -6.66

Japan "VS" EUMETSAT
  Speed:     h = 1, p = 0.04, ci = 0.00 0.16, Mean: 0.08
  Direction: h = 0, p = 0.10, ci = -1.78 0.14, Mean: -0.82
  Pressure:  h = 1, p = 0.00, ci = 21.60 26.64, Mean: 24.12
  QI:        h = 1, p = 0.00, ci = -3.11 -2.46, Mean: -2.78

Japan "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.88 1.06, Mean: 0.97
  Direction: h = 1, p = 0.00, ci = 2.71 4.54, Mean: 3.63
  Pressure:  h = 1, p = 0.00, ci = -53.42 -46.46, Mean: -49.94
  QI:        h = 1, p = 0.00, ci = -2.65 -1.85, Mean: -2.25

Japan "VS" NWCSAF
  Speed:     h = 0, p = 0.80, ci = -0.03 0.03, Mean: 0.00
  Direction: h = 1, p = 0.01, ci = 0.26 1.59, Mean: 0.93
  Pressure:  h = 1, p = 0.00, ci = 24.88 29.47, Mean: 27.18
  QI:        h = 1, p = 0.00, ci = 5.43 6.04, Mean: 5.74

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.15 -0.07, Mean: -0.11
  Direction: h = 0, p = 0.21, ci = -0.28 1.27, Mean: 0.49
  Pressure:  h = 1, p = 0.00, ci = -11.99 -9.16, Mean: -10.58
  QI:        h = 1, p = 0.00, ci = -5.77 -5.28, Mean: -5.52

Korea "VS" EUMETSAT
  Speed:     h = 0, p = 0.99, ci = -0.08 0.08, Mean: 0.00
  Direction: h = 0, p = 0.06, ci = -1.92 0.04, Mean: -0.94
  Pressure:  h = 0, p = 0.19, ci = -2.09 0.42, Mean: -0.84
  QI:        h = 1, p = 0.00, ci = -1.93 -1.37, Mean: -1.65

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.80 0.97, Mean: 0.89
  Direction: h = 1, p = 0.00, ci = 2.61 4.39, Mean: 3.50
  Pressure:  h = 1, p = 0.00, ci = -77.68 -72.11, Mean: -74.90
  QI:        h = 1, p = 0.00, ci = -1.48 -0.75, Mean: -1.12

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.11 -0.05, Mean: -0.08
  Direction: h = 1, p = 0.03, ci = 0.06 1.55, Mean: 0.80
  Pressure:  h = 1, p = 0.00, ci = 1.35 3.08, Mean: 2.22
```

```
  QI:        h = 1, p = 0.00, ci = 6.60 7.15, Mean: 6.87

NOAA "VS" EUMETSAT
  Speed:     h = 1, p = 0.01, ci = 0.03 0.19, Mean: 0.11
  Direction: h = 1, p = 0.01, ci = -2.46 -0.41, Mean: -1.43
  Pressure:  h = 1, p = 0.00, ci = 8.00 11.48, Mean: 9.74
  QI:        h = 1, p = 0.00, ci = 3.58 4.17, Mean: 3.87

NOAA "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.91 1.09, Mean: 1.00
  Direction: h = 1, p = 0.00, ci = 2.10 3.92, Mean: 3.01
  Pressure:  h = 1, p = 0.00, ci = -67.26 -61.39, Mean: -64.32
  QI:        h = 1, p = 0.00, ci = 4.04 4.77, Mean: 4.40

NOAA "VS" NWCSAF
  Speed:     h = 0, p = 0.15, ci = -0.01 0.07, Mean: 0.03
  Direction: h = 0, p = 0.42, ci = -0.45 1.07, Mean: 0.31
  Pressure:  h = 1, p = 0.00, ci = 11.47 14.11, Mean: 12.79
  QI:        h = 1, p = 0.00, ci = 12.11 12.69, Mean: 12.40

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.78 1.00, Mean: 0.89
  Direction: h = 1, p = 0.00, ci = 3.33 5.55, Mean: 4.44
  Pressure:  h = 1, p = 0.00, ci = -76.96 -71.16, Mean: -74.06
  QI:        h = 1, p = 0.01, ci = 0.13 0.93, Mean: 0.53

EUMETSAT "VS" NWCSAF
  Speed:     h = 0, p = 0.05, ci = -0.16 0.00, Mean: -0.08
  Direction: h = 1, p = 0.00, ci = 0.72 2.77, Mean: 1.74
  Pressure:  h = 1, p = 0.00, ci = 1.78 4.33, Mean: 3.05
  QI:        h = 1, p = 0.00, ci = 8.19 8.85, Mean: 8.52

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -1.05 -0.88, Mean: -0.97
  Direction: h = 1, p = 0.00, ci = -3.54 -1.86, Mean: -2.70
  Pressure:  h = 1, p = 0.00, ci = 74.38 79.85, Mean: 77.11
  QI:        h = 1, p = 0.00, ci = 7.59 8.39, Mean: 7.99
```

QINF>=80 collocated AMVs. File: statsout_exp1.txt

```
Japan "VS" Korea
  Speed:     h = 0, p = 0.05, ci = -0.00 0.07, Mean: 0.04
  Direction: h = 0, p = 0.20, ci = -0.30 1.42, Mean: 0.56
  Pressure:  h = 1, p = 0.00, ci = 11.63 17.83, Mean: 14.73
  QI:        h = 1, p = 0.00, ci = 0.69 1.02, Mean: 0.86

Japan "VS" NOAA
  Speed:     h = 0, p = 0.18, ci = -0.01 0.07, Mean: 0.03
  Direction: h = 1, p = 0.00, ci = 0.37 1.92, Mean: 1.14
  Pressure:  h = 1, p = 0.00, ci = 3.91 10.26, Mean: 7.09
  QI:        h = 1, p = 0.00, ci = -4.02 -3.71, Mean: -3.86

Japan "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.08 0.20, Mean: 0.14
  Direction: h = 0, p = 0.83, ci = -1.21 0.97, Mean: -0.12
  Pressure:  h = 1, p = 0.00, ci = 11.85 18.54, Mean: 15.19
  QI:        h = 1, p = 0.00, ci = -2.07 -1.71, Mean: -1.89

Japan "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.42 0.59, Mean: 0.50
  Direction: h = 1, p = 0.00, ci = 1.71 3.83, Mean: 2.77
```

```
  Pressure:  h = 1, p = 0.00, ci = -63.46 -54.08, Mean: -58.77
  QI:        h = 1, p = 0.00, ci = -5.04 -4.64, Mean: -4.84

Japan "VS" NWCSAF
  Speed:     h = 0, p = 0.91, ci = -0.03 0.04, Mean: 0.00
  Direction: h = 1, p = 0.00, ci = 0.37 1.89, Mean: 1.13
  Pressure:  h = 1, p = 0.00, ci = 18.35 24.38, Mean: 21.36
  QI:        h = 1, p = 0.00, ci = 2.30 2.67, Mean: 2.49

Korea "VS" NOAA
  Speed:     h = 0, p = 0.71, ci = -0.05 0.04, Mean: -0.01
  Direction: h = 0, p = 0.18, ci = -0.28 1.44, Mean: 0.58
  Pressure:  h = 1, p = 0.00, ci = -9.47 -5.82, Mean: -7.64
  QI:        h = 1, p = 0.00, ci = -4.88 -4.56, Mean: -4.72

Korea "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.05 0.17, Mean: 0.11
  Direction: h = 0, p = 0.23, ci = -1.80 0.44, Mean: -0.68
  Pressure:  h = 0, p = 0.57, ci = -1.12 2.05, Mean: 0.46
  QI:        h = 1, p = 0.00, ci = -2.93 -2.56, Mean: -2.75

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.38 0.55, Mean: 0.46
  Direction: h = 1, p = 0.00, ci = 1.14 3.27, Mean: 2.21
  Pressure:  h = 1, p = 0.00, ci = -77.26 -69.74, Mean: -73.50
  QI:        h = 1, p = 0.00, ci = -5.90 -5.50, Mean: -5.70

Korea "VS" NWCSAF
  Speed:     h = 0, p = 0.07, ci = -0.07 0.00, Mean: -0.03
  Direction: h = 0, p = 0.20, ci = -0.30 1.43, Mean: 0.57
  Pressure:  h = 1, p = 0.00, ci = 5.37 7.90, Mean: 6.63
  QI:        h = 1, p = 0.00, ci = 1.44 1.82, Mean: 1.63

NOAA "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.05 0.18, Mean: 0.11
  Direction: h = 1, p = 0.03, ci = -2.43 -0.09, Mean: -1.26
  Pressure:  h = 1, p = 0.00, ci = 5.86 10.35, Mean: 8.11
  QI:        h = 1, p = 0.00, ci = 1.81 2.14, Mean: 1.98

NOAA "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.39 0.56, Mean: 0.47
  Direction: h = 1, p = 0.00, ci = 0.55 2.70, Mean: 1.62
  Pressure:  h = 1, p = 0.00, ci = -69.75 -61.96, Mean: -65.86
  QI:        h = 1, p = 0.00, ci = -1.15 -0.80, Mean: -0.97

NOAA "VS" NWCSAF
  Speed:     h = 0, p = 0.25, ci = -0.07 0.02, Mean: -0.03
  Direction: h = 0, p = 0.97, ci = -0.80 0.77, Mean: -0.01
  Pressure:  h = 1, p = 0.00, ci = 12.48 16.07, Mean: 14.27
  QI:        h = 1, p = 0.00, ci = 6.18 6.53, Mean: 6.35

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.26 0.45, Mean: 0.36
  Direction: h = 1, p = 0.00, ci = 1.54 4.23, Mean: 2.89
  Pressure:  h = 1, p = 0.00, ci = -77.93 -69.99, Mean: -73.96
  QI:        h = 1, p = 0.00, ci = -3.14 -2.76, Mean: -2.95

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.20 -0.08, Mean: -0.14
  Direction: h = 1, p = 0.03, ci = 0.11 2.39, Mean: 1.25
  Pressure:  h = 1, p = 0.00, ci = 4.42 7.92, Mean: 6.17
```

```
  QI:        h = 1, p = 0.00, ci = 4.18 4.57, Mean: 4.38

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.58 -0.42, Mean: -0.50
  Direction: h = 1, p = 0.00, ci = -2.62 -0.66, Mean: -1.64
  Pressure:  h = 1, p = 0.00, ci = 76.41 83.85, Mean: 80.13
  QI:        h = 1, p = 0.00, ci = 7.12 7.54, Mean: 7.33
```

CQI>= 50 collocated AMVs. File: Exp_21_statsout.txt

```
Japan "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.09 0.16, Mean: 0.13
  Direction: h = 0, p = 0.38, ci = -0.44 1.15, Mean: 0.36
  Pressure:  h = 1, p = 0.00, ci = 29.18 33.81, Mean: 31.50
  QI:        h = 1, p = 0.00, ci = -1.65 -1.25, Mean: -1.45

Japan "VS" NOAA
  Speed:     h = 0, p = 0.34, ci = -0.06 0.02, Mean: -0.02
  Direction: h = 1, p = 0.00, ci = 0.41 2.05, Mean: 1.23
  Pressure:  h = 1, p = 0.00, ci = 18.15 22.95, Mean: 20.55
  QI:        h = 1, p = 0.00, ci = 0.39 0.87, Mean: 0.63

Japan "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.18 0.30, Mean: 0.24
  Direction: h = 0, p = 0.11, ci = -1.86 0.18, Mean: -0.84
  Pressure:  h = 1, p = 0.00, ci = 25.53 30.42, Mean: 27.97
  QI:        h = 1, p = 0.00, ci = 1.39 1.89, Mean: 1.64

Japan "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.70 0.85, Mean: 0.77
  Direction: h = 1, p = 0.00, ci = 3.38 5.34, Mean: 4.36
  Pressure:  h = 1, p = 0.00, ci = -42.62 -35.91, Mean: -39.26
  QI:        h = 1, p = 0.00, ci = 5.88 6.53, Mean: 6.21

Japan "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.04 0.11, Mean: 0.07
  Direction: h = 1, p = 0.00, ci = 0.51 2.03, Mean: 1.27
  Pressure:  h = 1, p = 0.00, ci = 30.28 34.74, Mean: 32.51
  QI:        h = 1, p = 0.00, ci = 1.69 2.16, Mean: 1.92

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.19 -0.10, Mean: -0.15
  Direction: h = 1, p = 0.04, ci = 0.04 1.70, Mean: 0.87
  Pressure:  h = 1, p = 0.00, ci = -12.40 -9.49, Mean: -10.94
  QI:        h = 1, p = 0.00, ci = 1.85 2.31, Mean: 2.08

Korea "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.05 0.17, Mean: 0.11
  Direction: h = 1, p = 0.02, ci = -2.21 -0.18, Mean: -1.20
  Pressure:  h = 1, p = 0.00, ci = -4.89 -2.16, Mean: -3.52
  QI:        h = 1, p = 0.00, ci = 2.85 3.33, Mean: 3.09

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.57 0.72, Mean: 0.65
  Direction: h = 1, p = 0.00, ci = 3.09 4.92, Mean: 4.00
  Pressure:  h = 1, p = 0.00, ci = -73.49 -68.04, Mean: -70.76
  QI:        h = 1, p = 0.00, ci = 7.34 7.97, Mean: 7.65

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.09 -0.02, Mean: -0.05
```

```
  Direction: h = 1, p = 0.02, ci = 0.15 1.67, Mean: 0.91
  Pressure:  h = 1, p = 0.03, ci = 0.10 1.93, Mean: 1.02
  QI:        h = 1, p = 0.00, ci = 3.15 3.59, Mean: 3.37

NOAA "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.20 0.32, Mean: 0.26
  Direction: h = 1, p = 0.00, ci = -3.12 -1.02, Mean: -2.07
  Pressure:  h = 1, p = 0.00, ci = 5.64 9.21, Mean: 7.42
  QI:        h = 1, p = 0.00, ci = 0.74 1.28, Mean: 1.01

NOAA "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.72 0.87, Mean: 0.79
  Direction: h = 1, p = 0.00, ci = 2.20 4.06, Mean: 3.13
  Pressure:  h = 1, p = 0.00, ci = -62.70 -56.93, Mean: -59.82
  QI:        h = 1, p = 0.00, ci = 5.24 5.92, Mean: 5.58

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.05 0.14, Mean: 0.09
  Direction: h = 0, p = 0.92, ci = -0.76 0.84, Mean: 0.04
  Pressure:  h = 1, p = 0.00, ci = 10.64 13.29, Mean: 11.96
  QI:        h = 1, p = 0.00, ci = 1.04 1.55, Mean: 1.29

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.45 0.62, Mean: 0.54
  Direction: h = 1, p = 0.00, ci = 4.08 6.32, Mean: 5.20
  Pressure:  h = 1, p = 0.00, ci = -70.11 -64.36, Mean: -67.24
  QI:        h = 1, p = 0.00, ci = 4.21 4.91, Mean: 4.56

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.22 -0.11, Mean: -0.16
  Direction: h = 1, p = 0.00, ci = 1.05 3.16, Mean: 2.11
  Pressure:  h = 1, p = 0.00, ci = 3.17 5.91, Mean: 4.54
  QI:        h = 1, p = 0.04, ci = 0.02 0.54, Mean: 0.28

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.77 -0.62, Mean: -0.70
  Direction: h = 1, p = 0.00, ci = -3.97 -2.21, Mean: -3.09
  Pressure:  h = 1, p = 0.00, ci = 69.09 74.46, Mean: 71.78
  QI:        h = 1, p = 0.00, ci = -4.62 -3.94, Mean: -4.28
```

CQI>=80 collocated AMVs. File: Exp_21_statsout.txt

```
Japan "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.07 0.14, Mean: 0.10
  Direction: h = 0, p = 0.62, ci = -1.07 0.63, Mean: -0.22
  Pressure:  h = 1, p = 0.00, ci = 22.66 27.51, Mean: 25.09
  QI:        h = 1, p = 0.00, ci = -0.91 -0.69, Mean: -0.80

Japan "VS" NOAA
  Speed:     h = 0, p = 0.46, ci = -0.05 0.02, Mean: -0.01
  Direction: h = 0, p = 0.30, ci = -0.37 1.22, Mean: 0.42
  Pressure:  h = 1, p = 0.00, ci = 14.05 19.03, Mean: 16.54
  QI:        h = 1, p = 0.00, ci = -0.55 -0.31, Mean: -0.43

Japan "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.08 0.18, Mean: 0.13
  Direction: h = 0, p = 0.21, ci = -1.67 0.37, Mean: -0.65
  Pressure:  h = 1, p = 0.00, ci = 21.40 26.51, Mean: 23.95
  QI:        h = 1, p = 0.00, ci = 0.28 0.54, Mean: 0.41

Japan "VS" Brazil
```

```
  Speed:     h = 1, p = 0.00, ci = 0.29 0.41, Mean: 0.35
  Direction: h = 1, p = 0.00, ci = 2.67 4.63, Mean: 3.65
  Pressure:  h = 1, p = 0.00, ci = -43.51 -36.26, Mean: -39.88
  QI:        h = 1, p = 0.00, ci = -0.61 -0.29, Mean: -0.45

Japan "VS" NWCSAF
  Speed:     h = 1, p = 0.02, ci = 0.01 0.08, Mean: 0.04
  Direction: h = 1, p = 0.01, ci = 0.20 1.69, Mean: 0.95
  Pressure:  h = 1, p = 0.00, ci = 26.95 31.68, Mean: 29.32
  QI:        h = 1, p = 0.00, ci = 0.51 0.74, Mean: 0.62

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.16 -0.08, Mean: -0.12
  Direction: h = 0, p = 0.13, ci = -0.20 1.48, Mean: 0.64
  Pressure:  h = 1, p = 0.00, ci = -9.94 -7.15, Mean: -8.55
  QI:        h = 1, p = 0.00, ci = 0.25 0.48, Mean: 0.37

Korea "VS" EUMETSAT
  Speed:     h = 0, p = 0.28, ci = -0.02 0.08, Mean: 0.03
  Direction: h = 0, p = 0.40, ci = -1.44 0.57, Mean: -0.43
  Pressure:  h = 0, p = 0.06, ci = -2.32 0.06, Mean: -1.13
  QI:        h = 1, p = 0.00, ci = 1.09 1.33, Mean: 1.21

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.18 0.31, Mean: 0.25
  Direction: h = 1, p = 0.00, ci = 2.90 4.83, Mean: 3.87
  Pressure:  h = 1, p = 0.00, ci = -67.84 -62.09, Mean: -64.97
  QI:        h = 1, p = 0.00, ci = 0.20 0.50, Mean: 0.35

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.09 -0.03, Mean: -0.06
  Direction: h = 1, p = 0.01, ci = 0.34 1.99, Mean: 1.17
  Pressure:  h = 1, p = 0.00, ci = 3.36 5.10, Mean: 4.23
  QI:        h = 1, p = 0.00, ci = 1.31 1.54, Mean: 1.42

NOAA "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.09 0.20, Mean: 0.15
  Direction: h = 1, p = 0.04, ci = -2.12 -0.03, Mean: -1.07
  Pressure:  h = 1, p = 0.00, ci = 5.76 9.08, Mean: 7.42
  QI:        h = 1, p = 0.00, ci = 0.71 0.98, Mean: 0.84

NOAA "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.30 0.43, Mean: 0.36
  Direction: h = 1, p = 0.00, ci = 2.25 4.20, Mean: 3.23
  Pressure:  h = 1, p = 0.00, ci = -59.41 -53.43, Mean: -56.42
  QI:        h = 0, p = 0.81, ci = -0.18 0.14, Mean: -0.02

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.02 0.09, Mean: 0.06
  Direction: h = 0, p = 0.19, ci = -0.26 1.31, Mean: 0.53
  Pressure:  h = 1, p = 0.00, ci = 11.45 14.11, Mean: 12.78
  QI:        h = 1, p = 0.00, ci = 0.93 1.18, Mean: 1.06

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.15 0.29, Mean: 0.22
  Direction: h = 1, p = 0.00, ci = 3.13 5.48, Mean: 4.30
  Pressure:  h = 1, p = 0.00, ci = -66.85 -60.82, Mean: -63.84
  QI:        h = 1, p = 0.00, ci = -1.02 -0.70, Mean: -0.86

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.14 -0.04, Mean: -0.09
```

```
  Direction: h = 1, p = 0.00, ci = 0.54 2.66, Mean: 1.60
  Pressure:  h = 1, p = 0.00, ci = 4.10 6.63, Mean: 5.36
  QI:        h = 1, p = 0.00, ci = 0.08 0.35, Mean: 0.21

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.37 -0.25, Mean: -0.31
  Direction: h = 1, p = 0.00, ci = -3.59 -1.81, Mean: -2.70
  Pressure:  h = 1, p = 0.00, ci = 66.34 72.06, Mean: 69.20
  QI:        h = 1, p = 0.00, ci = 0.92 1.23, Mean: 1.08
```

b) Experiment 2 t-test Results

QINF>=50 collocated AMVs. File: Exp_22_statsout.txt

```
Japan "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.11 0.14,   Mean: 0.13
  Direction: h = 1, p = 0.00, ci = -1.02 -0.37, Mean: -0.70
  Pressure:  h = 1, p = 0.00, ci = -6.83 -4.53, Mean: -5.68
  QI:        h = 1, p = 0.00, ci = -6.85 -6.60, Mean: -6.72

Japan "VS" NOAA
  Speed:     h = 0, p = 0.66, ci = -0.02 0.01,    Mean: -0.00
  Direction: h = 1, p = 0.01, ci = -0.77 -0.11,   Mean: -0.44
  Pressure:  h = 1, p = 0.00, ci = 24.65 26.83,   Mean: 25.74
  QI:        h = 1, p = 0.00, ci = -15.23 -14.99, Mean: -15.11

Japan "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.27 0.31, Mean: 0.29
  Direction: h = 1, p = 0.00, ci = -2.85 -2.05, Mean: -2.45
  Pressure:  h = 1, p = 0.00, ci = 31.39 33.61, Mean: 32.50
  QI:        h = 1, p = 0.00, ci = -10.52 -10.27, Mean: -10.39

Japan "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.79 0.85,     Mean: 0.82
  Direction: h = 1, p = 0.00, ci = 2.65 3.42,     Mean: 3.04
  Pressure:  h = 1, p = 0.00, ci = -30.94 -28.03, Mean: -29.49
  QI:        h = 1, p = 0.00, ci = -11.61 -11.29, Mean: -11.45

Japan "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.20 0.23,   Mean: 0.22
  Direction: h = 0, p = 0.91, ci = -0.32 0.29,  Mean: -0.02
  Pressure:  h = 1, p = 0.00, ci = 21.38 23.37, Mean: 22.37
  QI:        h = 1, p = 0.00, ci = -7.49 -7.24, Mean: -7.36

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.15 -0.11, Mean: -0.13
  Direction: h = 0, p = 0.11, ci = -0.06 0.57, Mean: 0.26
  Pressure:  h = 1, p = 0.00, ci = 30.54 32.29, Mean: 31.41
  QI:        h = 1, p = 0.00, ci = -8.48 -8.29, Mean: -8.39

Korea "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.14 0.18, Mean: 0.16
  Direction: h = 1, p = 0.00, ci = -2.14 -1.37, Mean: -1.76
  Pressure:  h = 1, p = 0.00, ci = 37.38 38.98, Mean: 38.18
  QI:        h = 1, p = 0.00, ci = -3.78 -3.57, Mean: -3.67

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.66 0.72, Mean: 0.69
  Direction: h = 1, p = 0.00, ci = 3.34 4.12, Mean: 3.73
```

```
  Pressure:  h = 1, p = 0.00, ci = -25.03 -22.58, Mean: -23.81
  QI:        h = 1, p = 0.00, ci = -4.87 -4.58, Mean: -4.72

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.08 0.10, Mean: 0.09
  Direction: h = 1, p = 0.00, ci = 0.36 0.99, Mean: 0.68
  Pressure:  h = 1, p = 0.00, ci = 27.37 28.74, Mean: 28.05
  QI:        h = 1, p = 0.00, ci = -0.75 -0.54, Mean: -0.64

NOAA "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.27 0.32, Mean: 0.30
  Direction: h = 1, p = 0.00, ci = -2.40 -1.63, Mean: -2.01
  Pressure:  h = 1, p = 0.00, ci = 6.05 7.48, Mean: 6.77
  QI:        h = 1, p = 0.00, ci = 4.62 4.82, Mean: 4.72

NOAA "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.79 0.86, Mean: 0.83
  Direction: h = 1, p = 0.00, ci = 3.09 3.86, Mean: 3.48
  Pressure:  h = 1, p = 0.00, ci = -56.40 -54.04, Mean: -55.22
  QI:        h = 1, p = 0.00, ci = 3.53 3.79, Mean: 3.66

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.20 0.24, Mean: 0.22
  Direction: h = 1, p = 0.01, ci = 0.10 0.74, Mean: 0.42
  Pressure:  h = 1, p = 0.00, ci = -3.93 -2.79, Mean: -3.36
  QI:        h = 1, p = 0.00, ci = 7.65 7.85, Mean: 7.75

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.50 0.56, Mean: 0.53
  Direction: h = 1, p = 0.00, ci = 5.04 5.94, Mean: 5.49
  Pressure:  h = 1, p = 0.00, ci = -63.16 -60.81, Mean: -61.99
  QI:        h = 1, p = 0.00, ci = -1.19 -0.91, Mean: -1.05

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.09 -0.05, Mean: -0.07
  Direction: h = 1, p = 0.00, ci = 2.05 2.82, Mean: 2.43
  Pressure:  h = 1, p = 0.00, ci = -10.72 -9.53, Mean: -10.13
  QI:        h = 1, p = 0.00, ci = 2.92 3.14, Mean: 3.03

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.63 -0.57, Mean: -0.60
  Direction: h = 1, p = 0.00, ci = -3.44 -2.67, Mean: -3.05
  Pressure:  h = 1, p = 0.00, ci = 50.70 53.01, Mean: 51.86
  QI:        h = 1, p = 0.00, ci = 3.94 4.23, Mean: 4.08
```

QINF>=80 collocated AMVs. File: Exp_22_statsout.txt

```
Japan "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.06 0.09, Mean: 0.07
  Direction: h = 1, p = 0.00, ci = -1.47 -0.78, Mean: -1.13
  Pressure:  h = 0, p = 0.07, ci = -0.08 2.58, Mean: 1.25
  QI:        h = 1, p = 0.00, ci = -0.47 -0.35, Mean: -0.41

Japan "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = 0.05 0.08, Mean: 0.07
  Direction: h = 1, p = 0.00, ci = -1.14 -0.46, Mean: -0.80
  Pressure:  h = 1, p = 0.00, ci = 24.60 27.04, Mean: 25.82
  QI:        h = 1, p = 0.00, ci = -6.05 -5.93, Mean: -5.99

Japan "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.18 0.22, Mean: 0.20
```

```
  Direction: h = 1, p = 0.00, ci = -2.78 -1.98, Mean: -2.38
  Pressure:  h = 1, p = 0.00, ci = 30.20 32.72, Mean: 31.46
  QI:        h = 1, p = 0.00, ci = -3.43 -3.30, Mean: -3.37

Japan "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.36 0.41, Mean: 0.39
  Direction: h = 1, p = 0.00, ci = 2.19 3.02, Mean: 2.61
  Pressure:  h = 1, p = 0.00, ci = -34.31 -30.90, Mean: -32.61
  QI:        h = 1, p = 0.00, ci = -7.37 -7.24, Mean: -7.30

Japan "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.13 0.16, Mean: 0.15
  Direction: h = 1, p = 0.00, ci = -0.86 -0.25, Mean: -0.56
  Pressure:  h = 1, p = 0.00, ci = 23.52 25.86, Mean: 24.69
  QI:        h = 1, p = 0.00, ci = -1.55 -1.41, Mean: -1.48

Korea "VS" NOAA
  Speed:     h = 0, p = 0.49, ci = -0.02 0.01, Mean: -0.01
  Direction: h = 0, p = 0.05, ci = -0.00 0.66, Mean: 0.33
  Pressure:  h = 1, p = 0.00, ci = 23.61 25.53, Mean: 24.57
  QI:        h = 1, p = 0.00, ci = -5.64 -5.53, Mean: -5.58

Korea "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.11 0.15, Mean: 0.13
  Direction: h = 1, p = 0.00, ci = -1.65 -0.85, Mean: -1.25
  Pressure:  h = 1, p = 0.00, ci = 29.32 31.11, Mean: 30.21
  QI:        h = 1, p = 0.00, ci = -3.02 -2.90, Mean: -2.96

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.29 0.34, Mean: 0.31
  Direction: h = 1, p = 0.00, ci = 3.31 4.16, Mean: 3.73
  Pressure:  h = 1, p = 0.00, ci = -35.31 -32.40, Mean: -33.85
  QI:        h = 1, p = 0.00, ci = -6.96 -6.83, Mean: -6.90

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.06 0.09, Mean: 0.07
  Direction: h = 1, p = 0.00, ci = 0.24 0.90, Mean: 0.57
  Pressure:  h = 1, p = 0.00, ci = 22.71 24.17, Mean: 23.44
  QI:        h = 1, p = 0.00, ci = -1.14 -1.01, Mean: -1.07

NOAA "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.11 0.16, Mean: 0.14
  Direction: h = 1, p = 0.00, ci = -1.98 -1.18, Mean: -1.58
  Pressure:  h = 1, p = 0.00, ci = 4.86 6.43, Mean: 5.64
  QI:        h = 1, p = 0.00, ci = 2.57 2.68, Mean: 2.62

NOAA "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.29 0.35, Mean: 0.32
  Direction: h = 1, p = 0.00, ci = 2.98 3.82, Mean: 3.40
  Pressure:  h = 1, p = 0.00, ci = -59.79 -57.06, Mean: -58.43
  QI:        h = 1, p = 0.00, ci = -1.37 -1.26, Mean: -1.31

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.06 0.09, Mean: 0.08
  Direction: h = 0, p = 0.14, ci = -0.08 0.57, Mean: 0.24
  Pressure:  h = 1, p = 0.00, ci = -1.78 -0.48, Mean: -1.13
  QI:        h = 1, p = 0.00, ci = 4.45 4.57, Mean: 4.51

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.15 0.21, Mean: 0.18
  Direction: h = 1, p = 0.00, ci = 4.49 5.48, Mean: 4.98
```

```
  Pressure:  h = 1, p = 0.00, ci = -65.44 -62.69, Mean: -64.07
  QI:        h = 1, p = 0.00, ci = -4.00 -3.88, Mean: -3.94

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.08 -0.04, Mean: -0.06
  Direction: h = 1, p = 0.00, ci = 1.42 2.22, Mean: 1.82
  Pressure:  h = 1, p = 0.00, ci = -7.44 -6.11, Mean: -6.77
  QI:        h = 1, p = 0.00, ci = 1.83 1.95, Mean: 1.89

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.27 -0.21, Mean: -0.24
  Direction: h = 1, p = 0.00, ci = -3.57 -2.75, Mean: -3.16
  Pressure:  h = 1, p = 0.00, ci = 55.91 58.68, Mean: 57.29
  QI:        h = 1, p = 0.00, ci = 5.76 5.89, Mean: 5.82
```

CQI>=50 collocated AMVs. File: Exp_22_statsout.txt

```
Japan "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.14 0.18, Mean: 0.16
  Direction: h = 1, p = 0.00, ci = -0.98 -0.27, Mean: -0.62
  Pressure:  h = 1, p = 0.00, ci = 2.11 4.51, Mean: 3.31
  QI:        h = 1, p = 0.02, ci = 0.02 0.21, Mean: 0.11

Japan "VS" NOAA
  Speed:     h = 0, p = 0.36, ci = -0.01 0.03, Mean: 0.01
  Direction: h = 1, p = 0.00, ci = -1.07 -0.37, Mean: -0.72
  Pressure:  h = 1, p = 0.00, ci = 33.56 35.78, Mean: 34.67
  QI:        h = 1, p = 0.00, ci = -1.57 -1.40, Mean: -1.49

Japan "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.30 0.35, Mean: 0.33
  Direction: h = 1, p = 0.00, ci = -3.21 -2.38, Mean: -2.79
  Pressure:  h = 1, p = 0.00, ci = 38.62 40.91, Mean: 39.76
  QI:        h = 1, p = 0.00, ci = 0.40 0.60, Mean: 0.50

Japan "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.76 0.82, Mean: 0.79
  Direction: h = 1, p = 0.00, ci = 2.78 3.59, Mean: 3.19
  Pressure:  h = 1, p = 0.00, ci = -18.74 -15.75, Mean: -17.24
  QI:        h = 1, p = 0.00, ci = 3.79 4.05, Mean: 3.92

Japan "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.24 0.27, Mean: 0.25
  Direction: h = 0, p = 0.15, ci = -0.56 0.09, Mean: -0.24
  Pressure:  h = 1, p = 0.00, ci = 29.45 31.55, Mean: 30.50
  QI:        h = 1, p = 0.00, ci = -3.46 -3.30, Mean: -3.38

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.17 -0.13, Mean: -0.15
  Direction: h = 0, p = 0.58, ci = -0.42 0.23, Mean: -0.09
  Pressure:  h = 1, p = 0.00, ci = 30.46 32.26, Mean: 31.36
  QI:        h = 1, p = 0.00, ci = -1.69 -1.51, Mean: -1.60

Korea "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.14 0.19, Mean: 0.17
  Direction: h = 1, p = 0.00, ci = -2.59 -1.75, Mean: -2.17
  Pressure:  h = 1, p = 0.00, ci = 35.59 37.31, Mean: 36.45
  QI:        h = 1, p = 0.00, ci = 0.29 0.49, Mean: 0.39

Korea "VS" Brazil
```

```
  Speed:     h = 1, p = 0.00, ci = 0.60 0.66, Mean: 0.63
  Direction: h = 1, p = 0.00, ci = 3.40 4.22, Mean: 3.81
  Pressure:  h = 1, p = 0.00, ci = -21.83 -19.28, Mean: -20.55
  QI:        h = 1, p = 0.00, ci = 3.68 3.94, Mean: 3.81

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.08 0.11, Mean: 0.09
  Direction: h = 1, p = 0.02, ci = 0.05 0.72, Mean: 0.39
  Pressure:  h = 1, p = 0.00, ci = 26.47 27.91, Mean: 27.19
  QI:        h = 1, p = 0.00, ci = -3.58 -3.41, Mean: -3.50

NOAA "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.29 0.34, Mean: 0.32
  Direction: h = 1, p = 0.00, ci = -2.49 -1.67, Mean: -2.08
  Pressure:  h = 1, p = 0.00, ci = 4.33 5.85, Mean: 5.09
  QI:        h = 1, p = 0.00, ci = 1.89 2.08, Mean: 1.99

NOAA "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.75 0.82, Mean: 0.78
  Direction: h = 1, p = 0.00, ci = 3.50 4.30, Mean: 3.90
  Pressure:  h = 1, p = 0.00, ci = -53.15 -50.68, Mean: -51.91
  QI:        h = 1, p = 0.00, ci = 5.28 5.53, Mean: 5.41

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.23 0.26, Mean: 0.24
  Direction: h = 1, p = 0.01, ci = 0.14 0.82, Mean: 0.48
  Pressure:  h = 1, p = 0.00, ci = -4.77 -3.57, Mean: -4.17
  QI:        h = 1, p = 0.00, ci = -1.97 -1.82, Mean: -1.90

EUMETSAT "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.43 0.50, Mean: 0.47
  Direction: h = 1, p = 0.00, ci = 5.51 6.45, Mean: 5.98
  Pressure:  h = 1, p = 0.00, ci = -58.25 -55.76, Mean: -57.00
  QI:        h = 1, p = 0.00, ci = 3.29 3.55, Mean: 3.42

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.09 -0.05, Mean: -0.07
  Direction: h = 1, p = 0.00, ci = 2.14 2.97, Mean: 2.56
  Pressure:  h = 1, p = 0.00, ci = -9.90 -8.62, Mean: -9.26
  QI:        h = 1, p = 0.00, ci = -3.97 -3.80, Mean: -3.88

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.57 -0.51, Mean: -0.54
  Direction: h = 1, p = 0.00, ci = -3.82 -3.02, Mean: -3.42
  Pressure:  h = 1, p = 0.00, ci = 46.53 48.96, Mean: 47.74
  QI:        h = 1, p = 0.00, ci = -7.42 -7.19, Mean: -7.30
```

CQI>=80 collocated AMVs. File: Exp_22_statsout.txt

```
Japan "VS" Korea
  Speed:     h = 1, p = 0.00, ci = 0.09 0.12, Mean: 0.10
  Direction: h = 1, p = 0.00, ci = -1.52 -0.80, Mean: -1.16
  Pressure:  h = 1, p = 0.00, ci = 6.04 8.53, Mean: 7.29
  QI:        h = 1, p = 0.00, ci = -0.52 -0.43, Mean: -0.48

Japan "VS" NOAA
  Speed:     h = 0, p = 0.08, ci = -0.00 0.03, Mean: 0.01
  Direction: h = 1, p = 0.00, ci = -1.26 -0.55, Mean: -0.91
  Pressure:  h = 1, p = 0.00, ci = 32.46 34.76, Mean: 33.61
  QI:        h = 1, p = 0.00, ci = -1.49 -1.40, Mean: -1.44
```

```
Japan "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.21 0.25, Mean: 0.23
  Direction: h = 1, p = 0.00, ci = -3.15 -2.31, Mean: -2.73
  Pressure:  h = 1, p = 0.00, ci = 37.45 39.81, Mean: 38.63
  QI:        h = 1, p = 0.00, ci = -0.44 -0.34, Mean: -0.39

Japan "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.30 0.35, Mean: 0.32
  Direction: h = 1, p = 0.00, ci = 2.67 3.49, Mean: 3.08
  Pressure:  h = 1, p = 0.00, ci = -20.25 -17.10, Mean: -18.68
  QI:        h = 1, p = 0.00, ci = -1.48 -1.36, Mean: -1.42

Japan "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.19 0.22, Mean: 0.21
  Direction: h = 1, p = 0.01, ci = -0.75 -0.09, Mean: -0.42
  Pressure:  h = 1, p = 0.00, ci = 29.67 31.89, Mean: 30.78
  QI:        h = 1, p = 0.00, ci = -1.84 -1.75, Mean: -1.80

Korea "VS" NOAA
  Speed:     h = 1, p = 0.00, ci = -0.10 -0.07, Mean: -0.09
  Direction: h = 0, p = 0.15, ci = -0.09 0.59, Mean: 0.25
  Pressure:  h = 1, p = 0.00, ci = 25.43 27.22, Mean: 26.33
  QI:        h = 1, p = 0.00, ci = -1.01 -0.92, Mean: -0.97

Korea "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.11 0.15, Mean: 0.13
  Direction: h = 1, p = 0.00, ci = -1.99 -1.14, Mean: -1.57
  Pressure:  h = 1, p = 0.00, ci = 30.50 32.18, Mean: 31.34
  QI:        h = 1, p = 0.00, ci = 0.04 0.13, Mean: 0.08

Korea "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.20 0.25, Mean: 0.22
  Direction: h = 1, p = 0.00, ci = 3.82 4.65, Mean: 4.24
  Pressure:  h = 1, p = 0.00, ci = -27.30 -24.63, Mean: -25.96
  QI:        h = 1, p = 0.00, ci = -1.00 -0.89, Mean: -0.95

Korea "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.09 0.12, Mean: 0.10
  Direction: h = 1, p = 0.00, ci = 0.39 1.08, Mean: 0.74
  Pressure:  h = 1, p = 0.00, ci = 22.80 24.18, Mean: 23.49
  QI:        h = 1, p = 0.00, ci = -1.36 -1.28, Mean: -1.32

NOAA "VS" EUMETSAT
  Speed:     h = 1, p = 0.00, ci = 0.19 0.24, Mean: 0.21
  Direction: h = 1, p = 0.00, ci = -2.23 -1.41, Mean: -1.82
  Pressure:  h = 1, p = 0.00, ci = 4.28 5.75, Mean: 5.01
  QI:        h = 1, p = 0.00, ci = 1.00 1.10, Mean: 1.05

NOAA "VS" Brazil
  Speed:     h = 1, p = 0.00, ci = 0.28 0.33, Mean: 0.31
  Direction: h = 1, p = 0.00, ci = 3.58 4.40, Mean: 3.99
  Pressure:  h = 1, p = 0.00, ci = -53.55 -51.03, Mean: -52.29
  QI:        h = 0, p = 0.45, ci = -0.04 0.08, Mean: 0.02

NOAA "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = 0.17 0.21, Mean: 0.19
  Direction: h = 1, p = 0.01, ci = 0.14 0.83, Mean: 0.49
  Pressure:  h = 1, p = 0.00, ci = -3.44 -2.23, Mean: -2.83
  QI:        h = 1, p = 0.00, ci = -0.40 -0.31, Mean: -0.36

EUMETSAT "VS" Brazil
```

```
  Speed:     h = 1, p = 0.00, ci = 0.07 0.12, Mean: 0.10
  Direction: h = 1, p = 0.00, ci = 5.32 6.29, Mean: 5.81
  Pressure:  h = 1, p = 0.00, ci = -58.58 -56.03, Mean: -57.30
  QI:        h = 1, p = 0.00, ci = -1.09 -0.97, Mean: -1.03

EUMETSAT "VS" NWCSAF
  Speed:     h = 1, p = 0.03, ci = -0.04 -0.00, Mean: -0.02
  Direction: h = 1, p = 0.00, ci = 1.89 2.71, Mean: 2.30
  Pressure:  h = 1, p = 0.00, ci = -8.47 -7.22, Mean: -7.85
  QI:        h = 1, p = 0.00, ci = -1.45 -1.36, Mean: -1.41

Brazil "VS" NWCSAF
  Speed:     h = 1, p = 0.00, ci = -0.14 -0.10, Mean: -0.12
  Direction: h = 1, p = 0.00, ci = -3.91 -3.09, Mean: -3.50
  Pressure:  h = 1, p = 0.00, ci = 48.18 50.73, Mean: 49.46
  QI:        h = 1, p = 0.00, ci = -0.43 -0.33, Mean: -0.38
```

16. Appendix D: Best Fit Speed and Vector Difference

a) Experiment 1 Best Fit speed difference

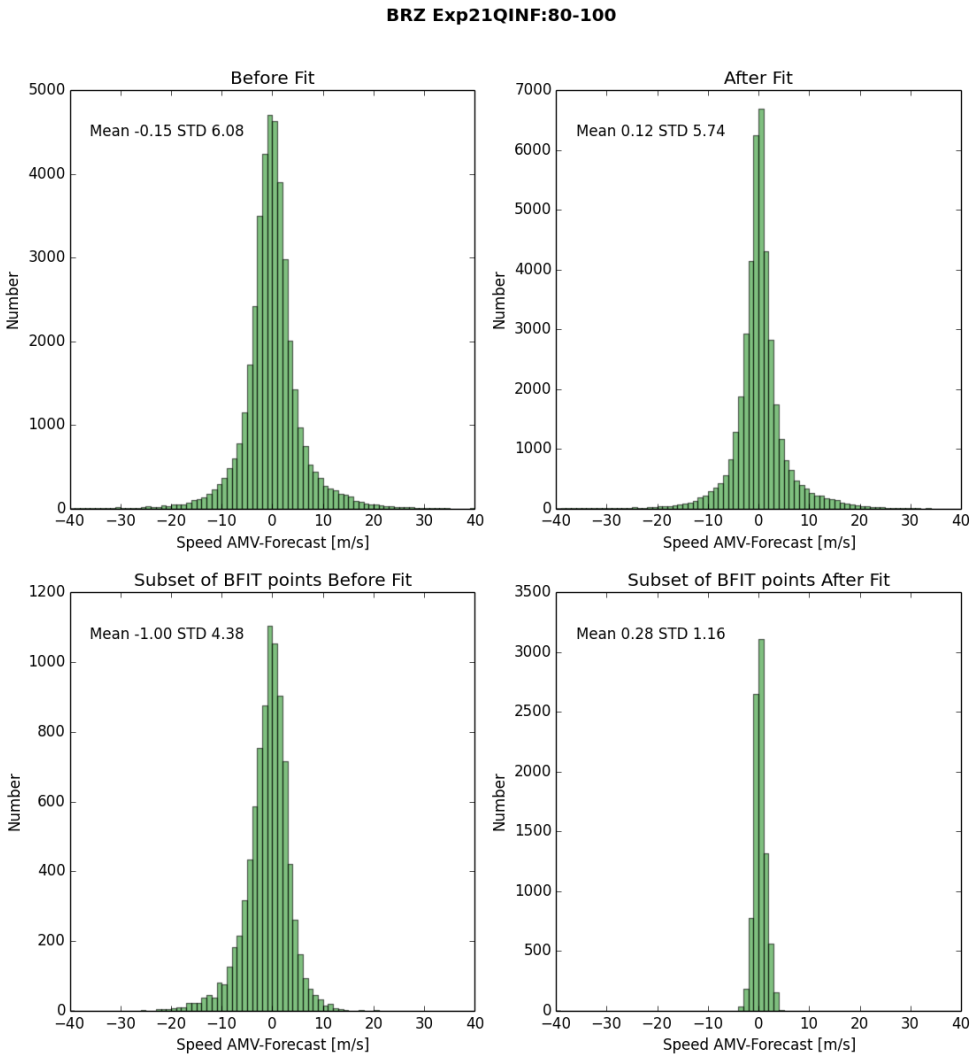


Figure 16-1: Experiment 1, BRZ (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

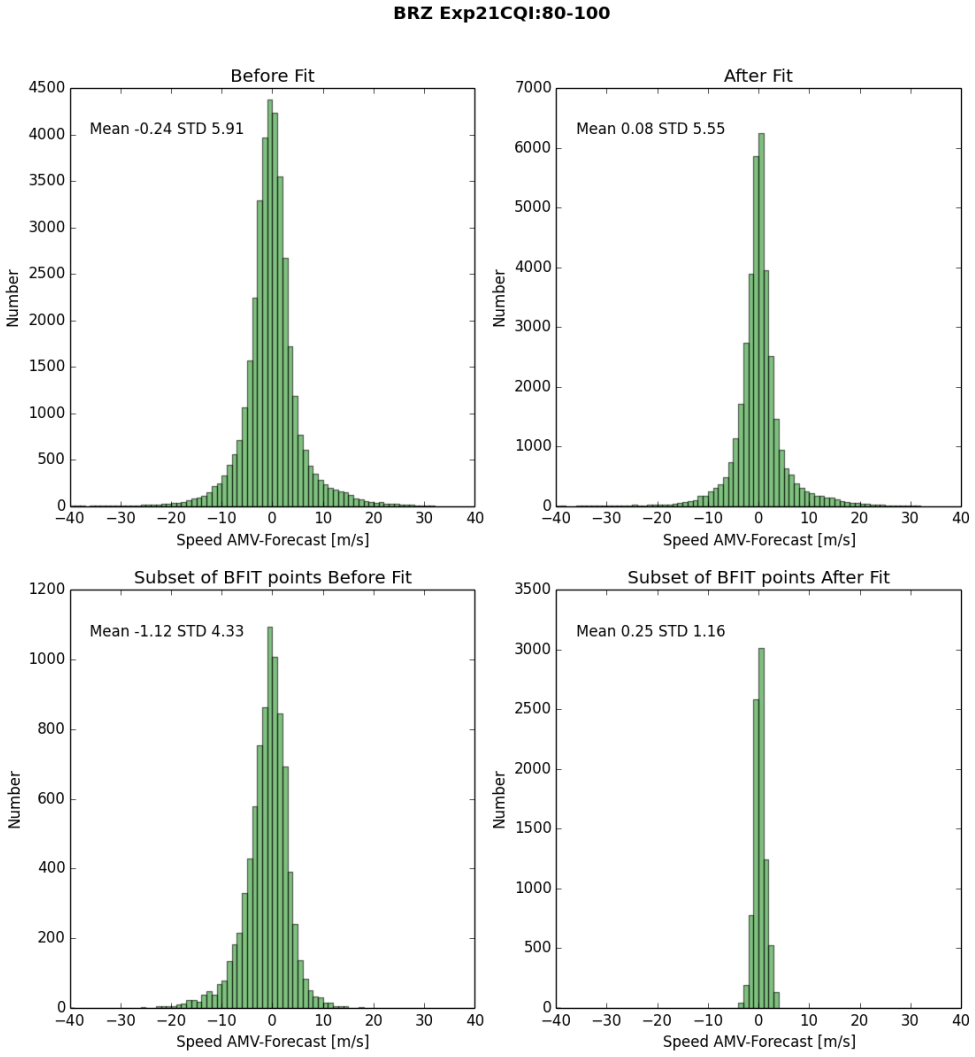


Figure 16-2: Experiment 1, BRZ (CQI>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

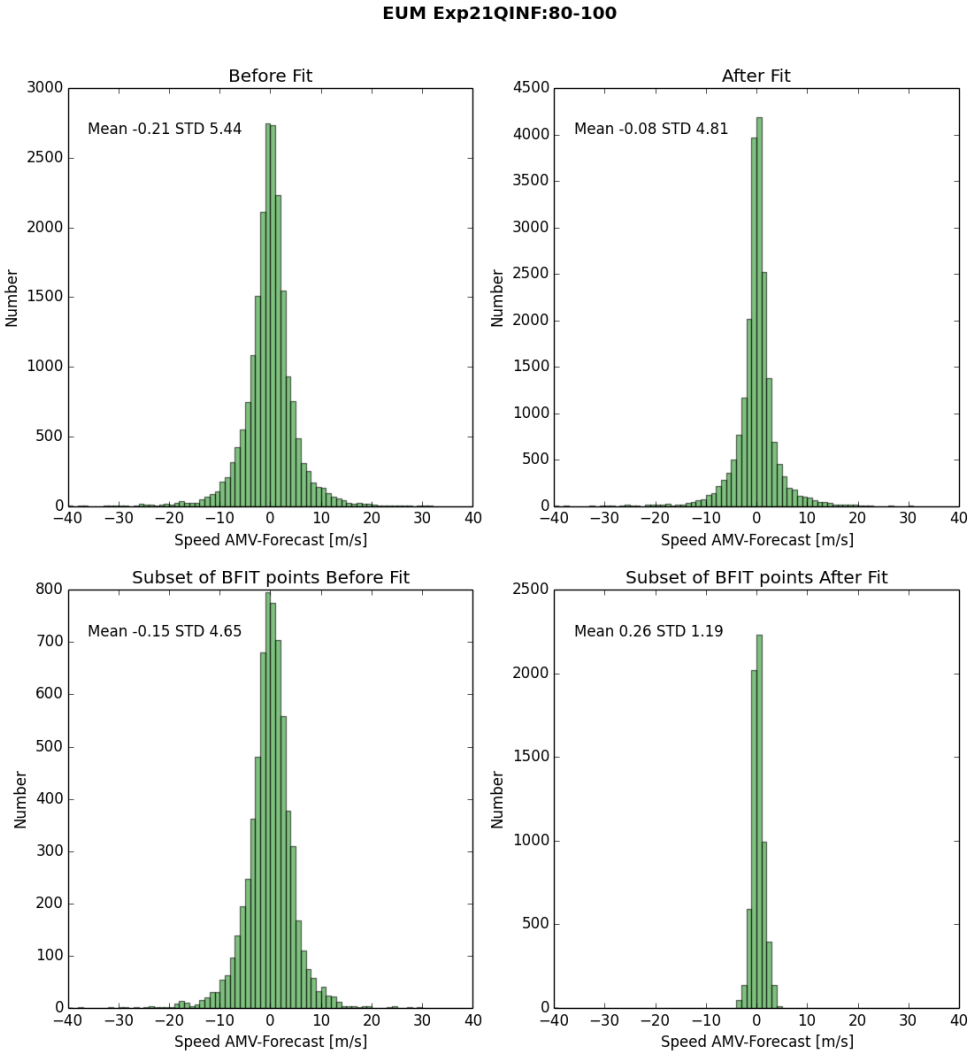


Figure 16-3: Experiment 1, EUM (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

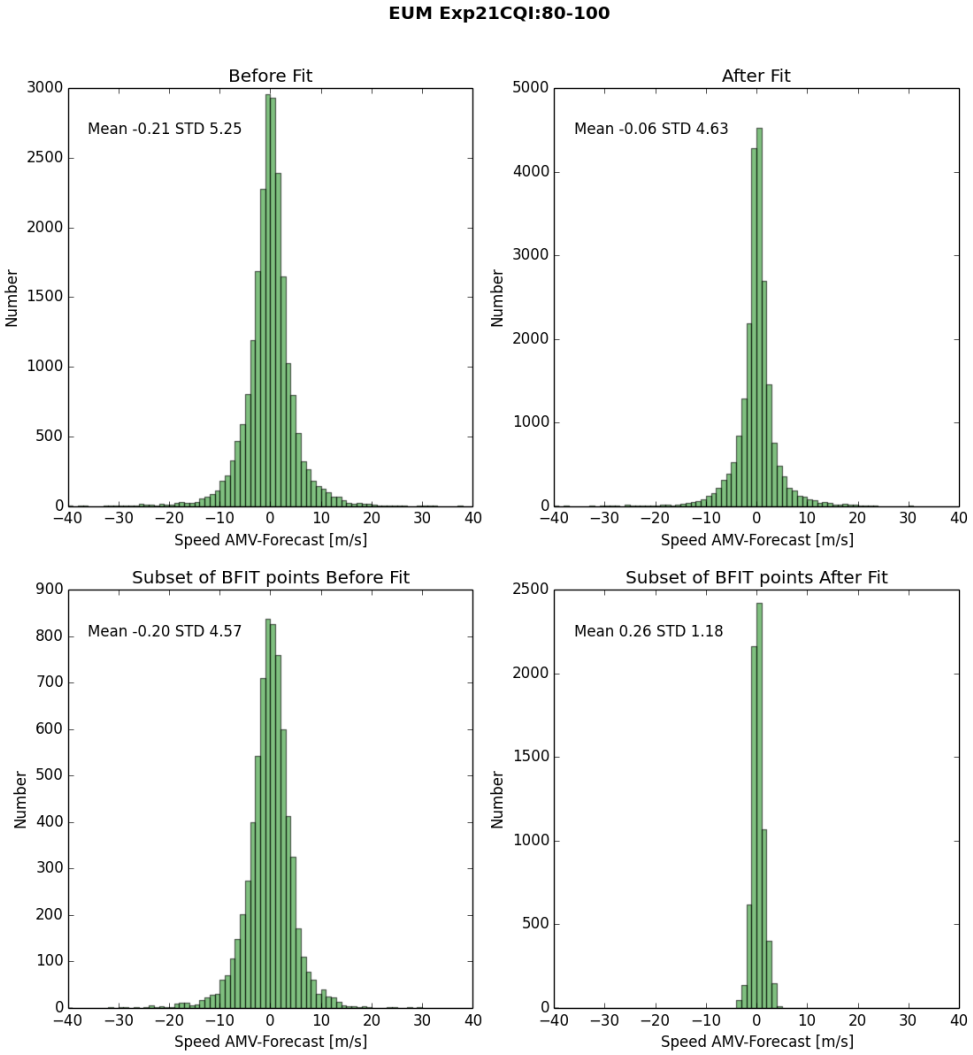


Figure 16-4: Experiment 1, EUM (CQI>= 80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

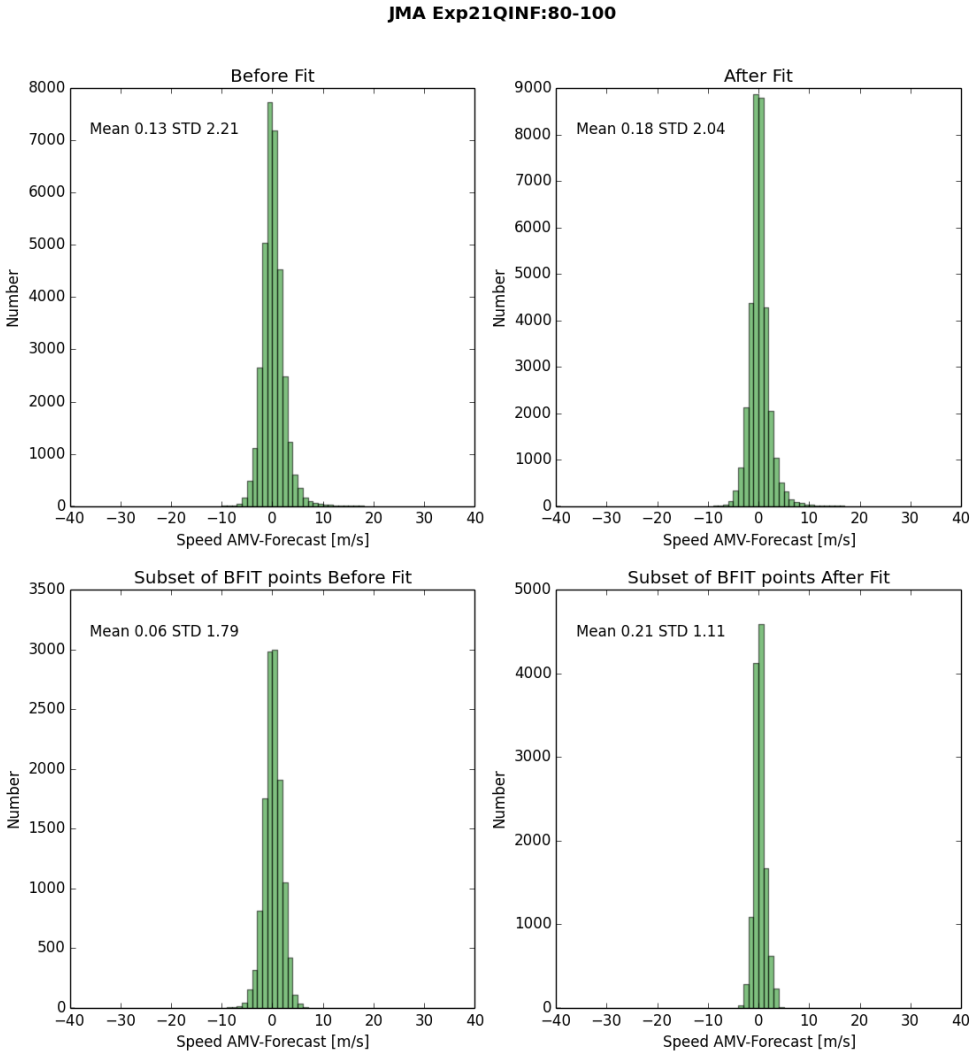


Figure 16-5: Experiment 1, JMA (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

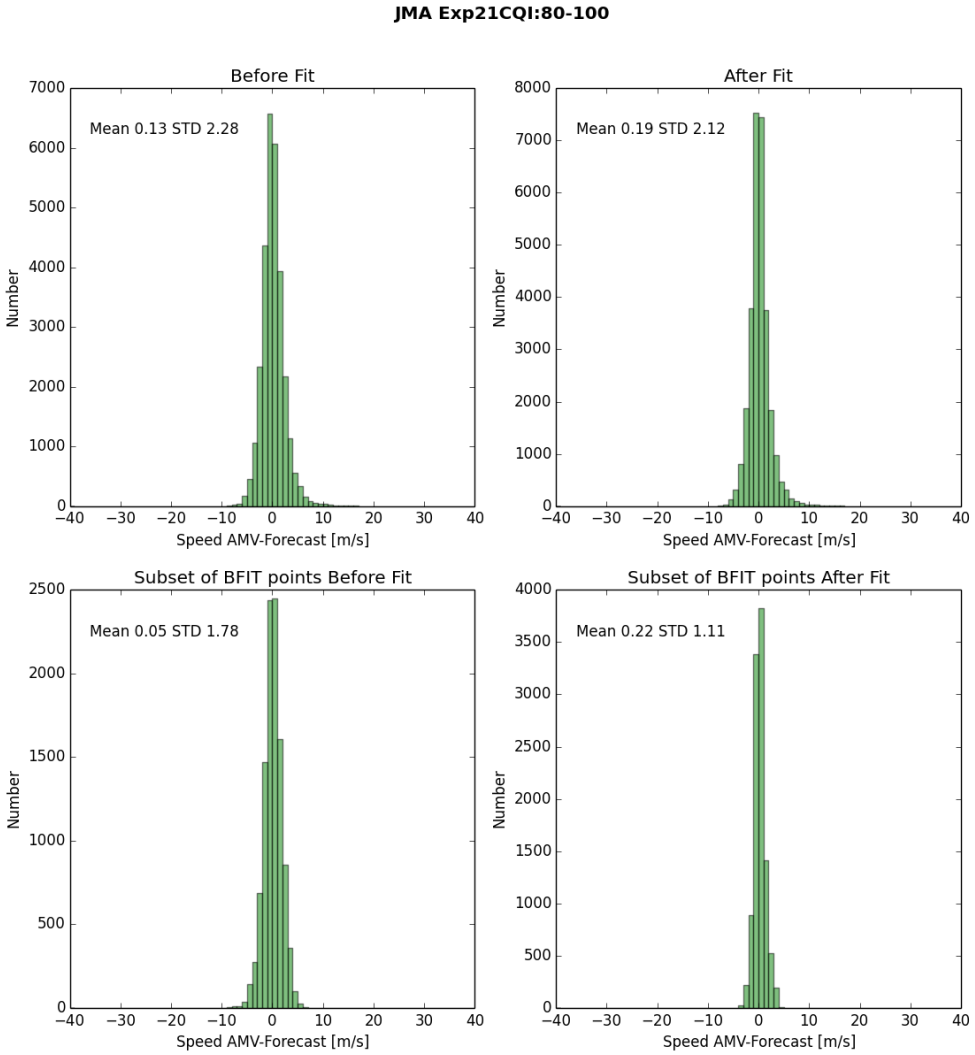


Figure 16-6: Experiment 1, JMA (CQI>= 80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

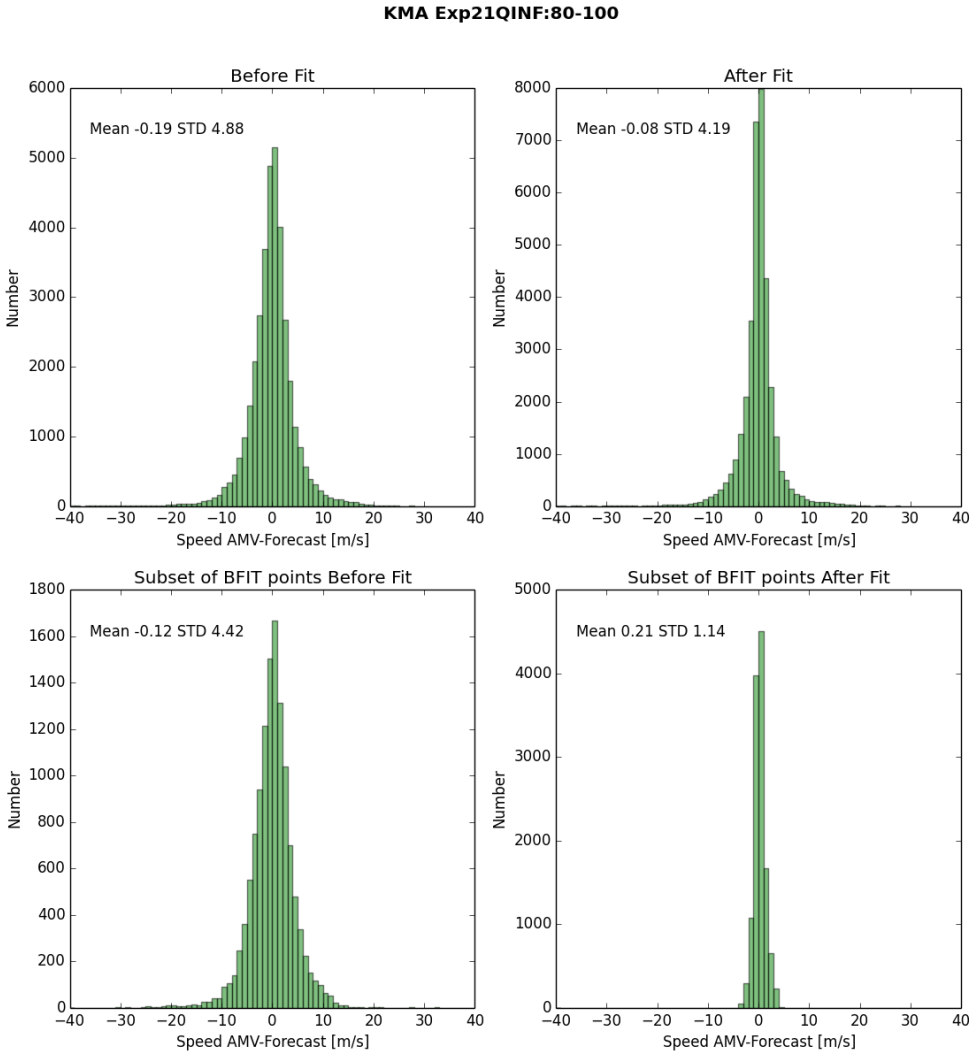


Figure 16-7: Experiment 1, KMA (QINF>= 80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

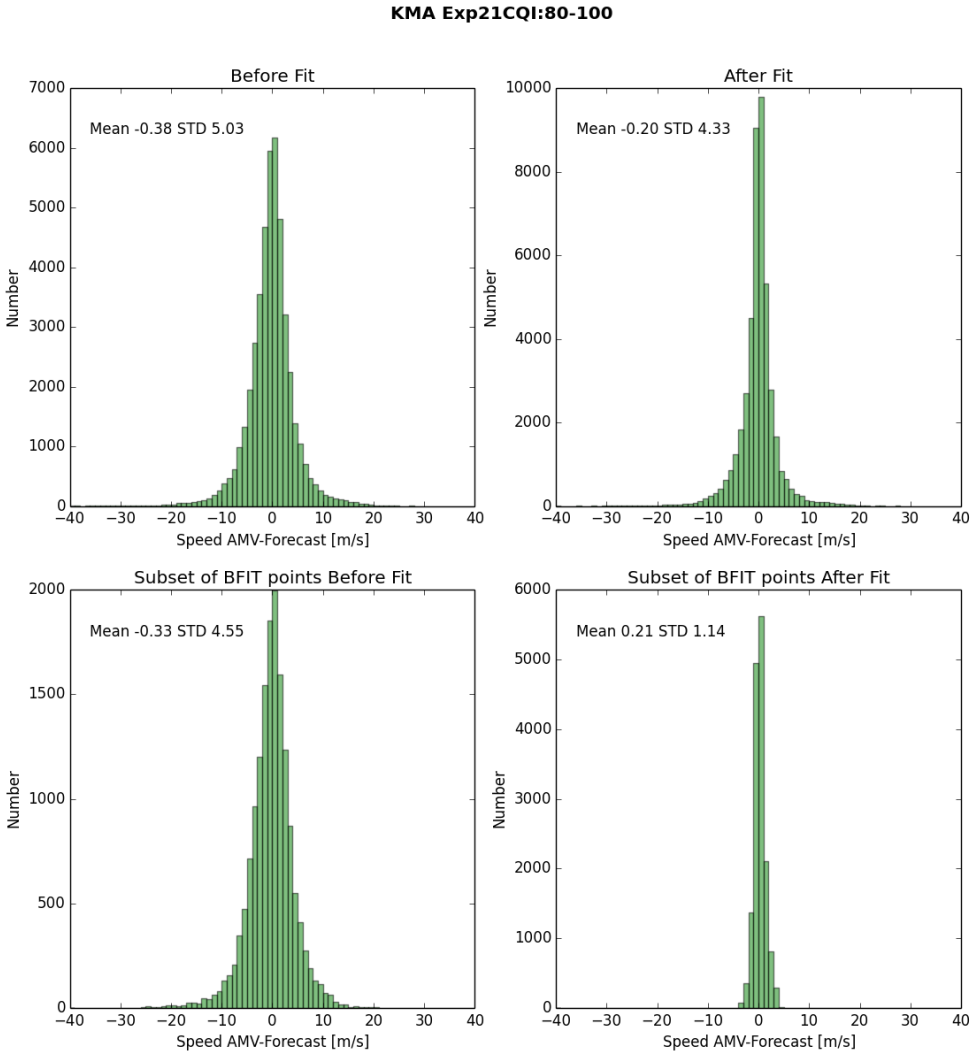


Figure 16-8: Experiment 1, KMA (CQI>= 80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

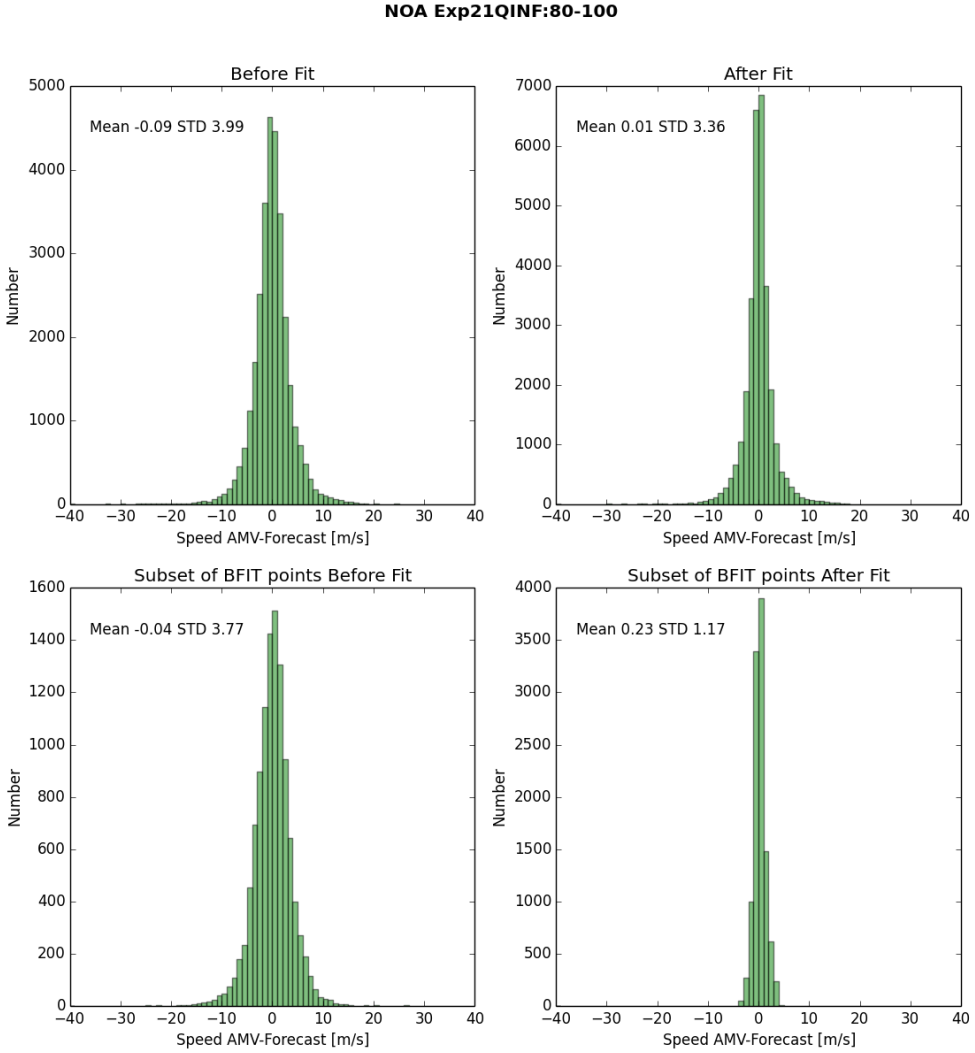


Figure 16-9: Experiment 1, NOA (QINF>= 80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

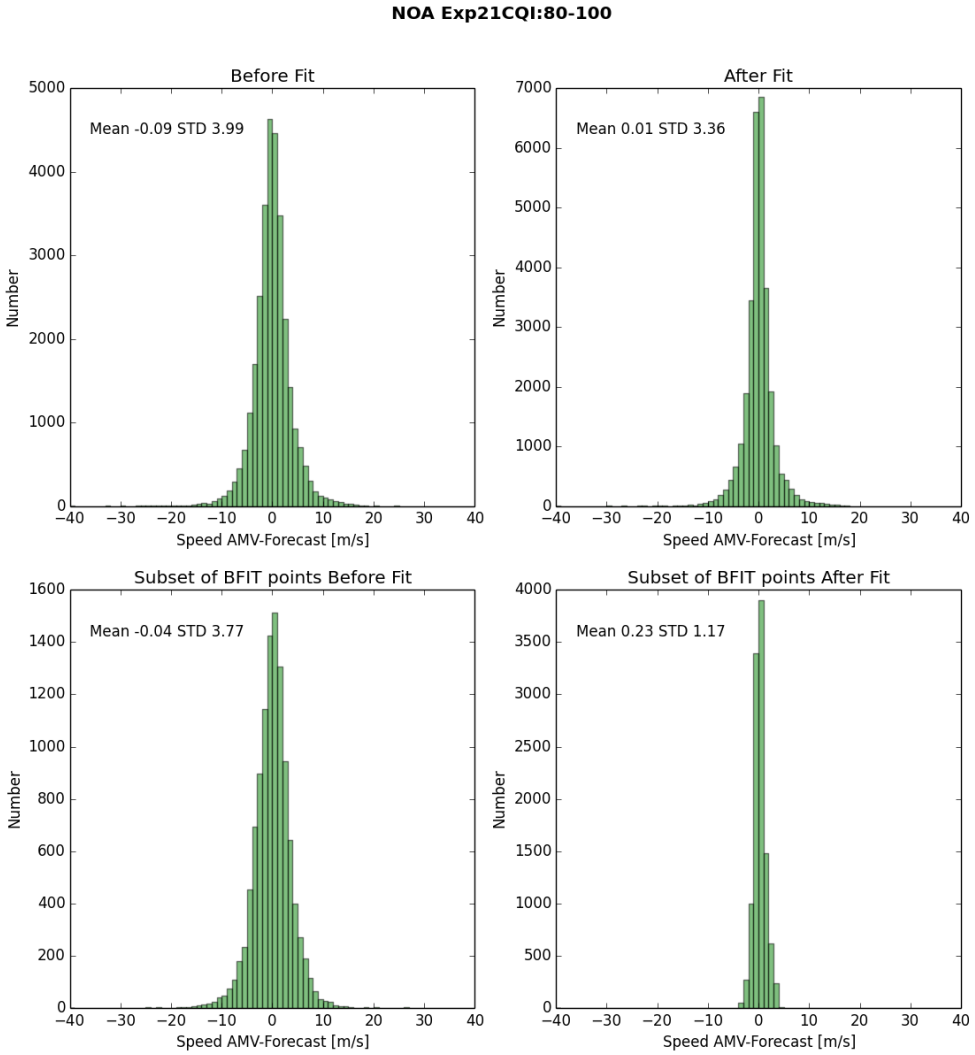


Figure 16-10: Experiment 1, NOA (CQI>= 80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

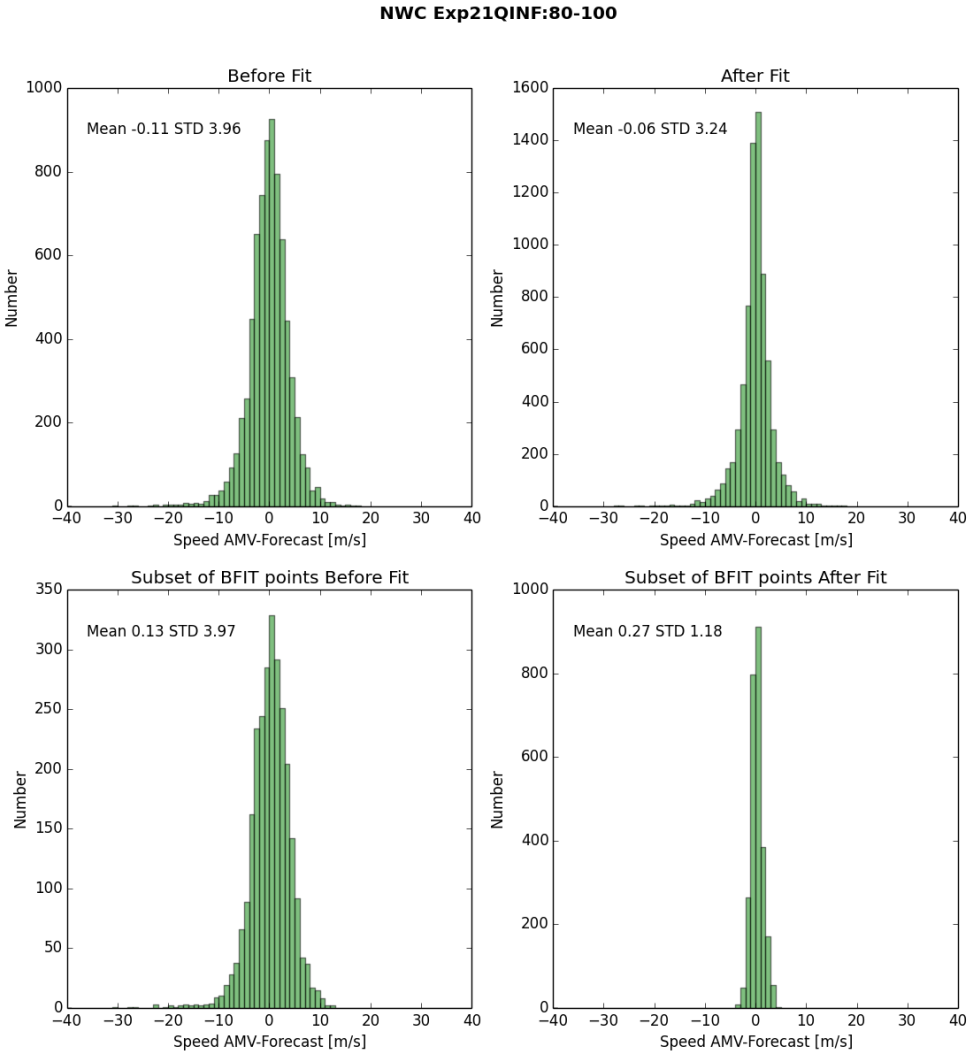


Figure 16-11: Experiment 1, NWC (QINF>= 80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

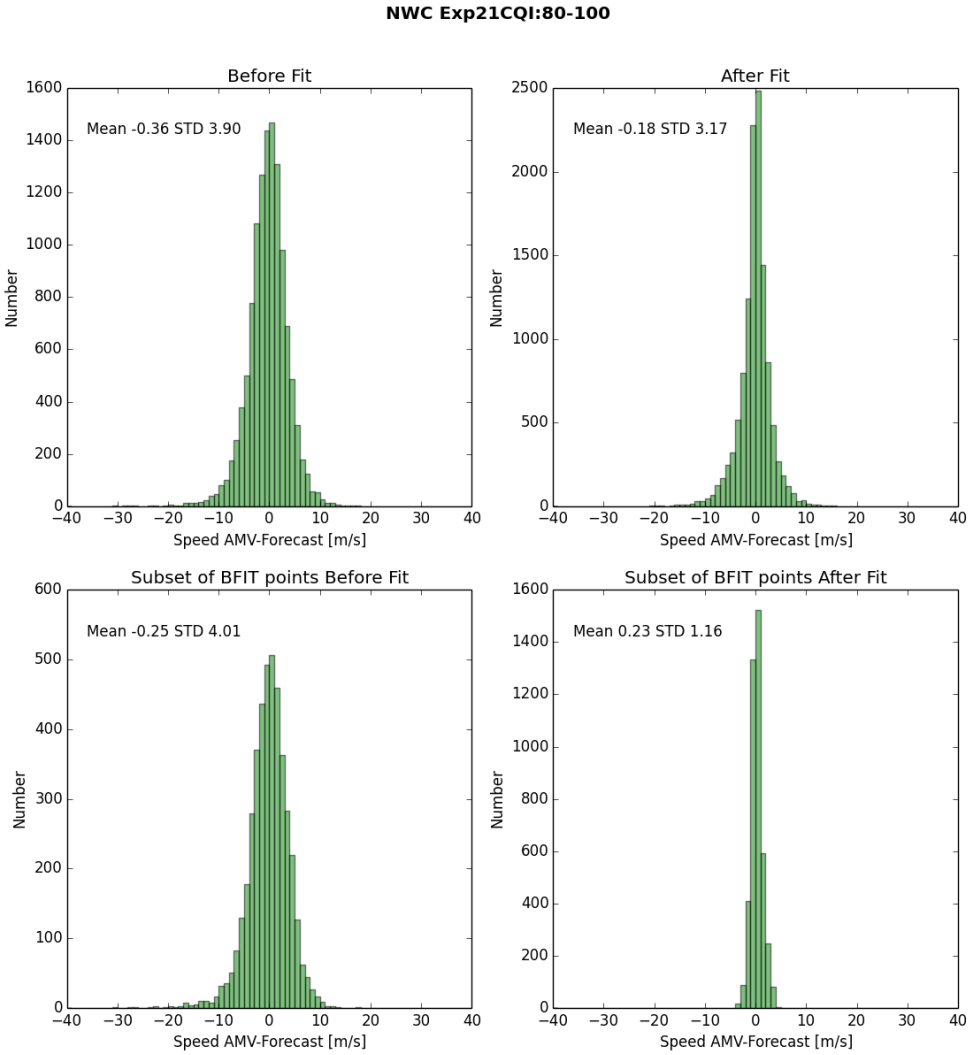


Figure 16-12: Experiment 1, NWC (CQI>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

b) Experiment 2 Best Fit speed difference

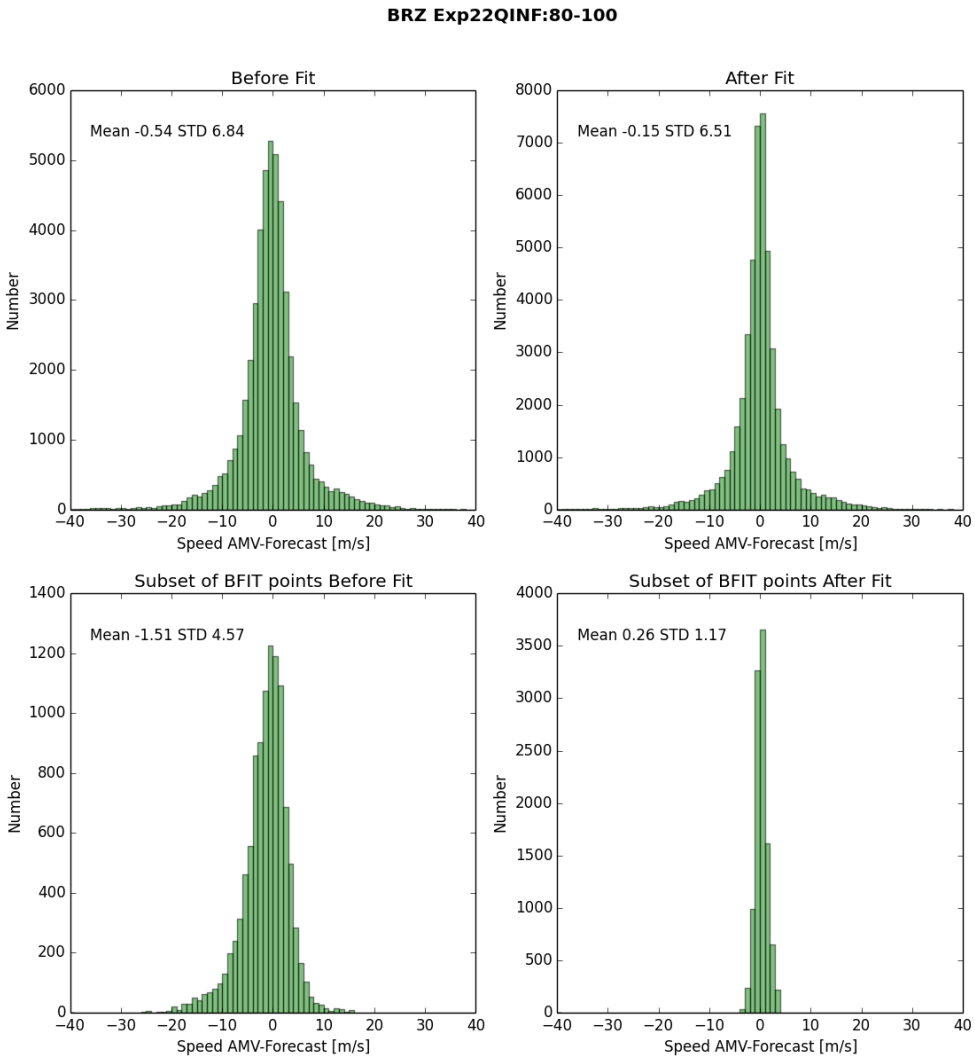


Figure 16-13: Experiment 2, BRZ (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

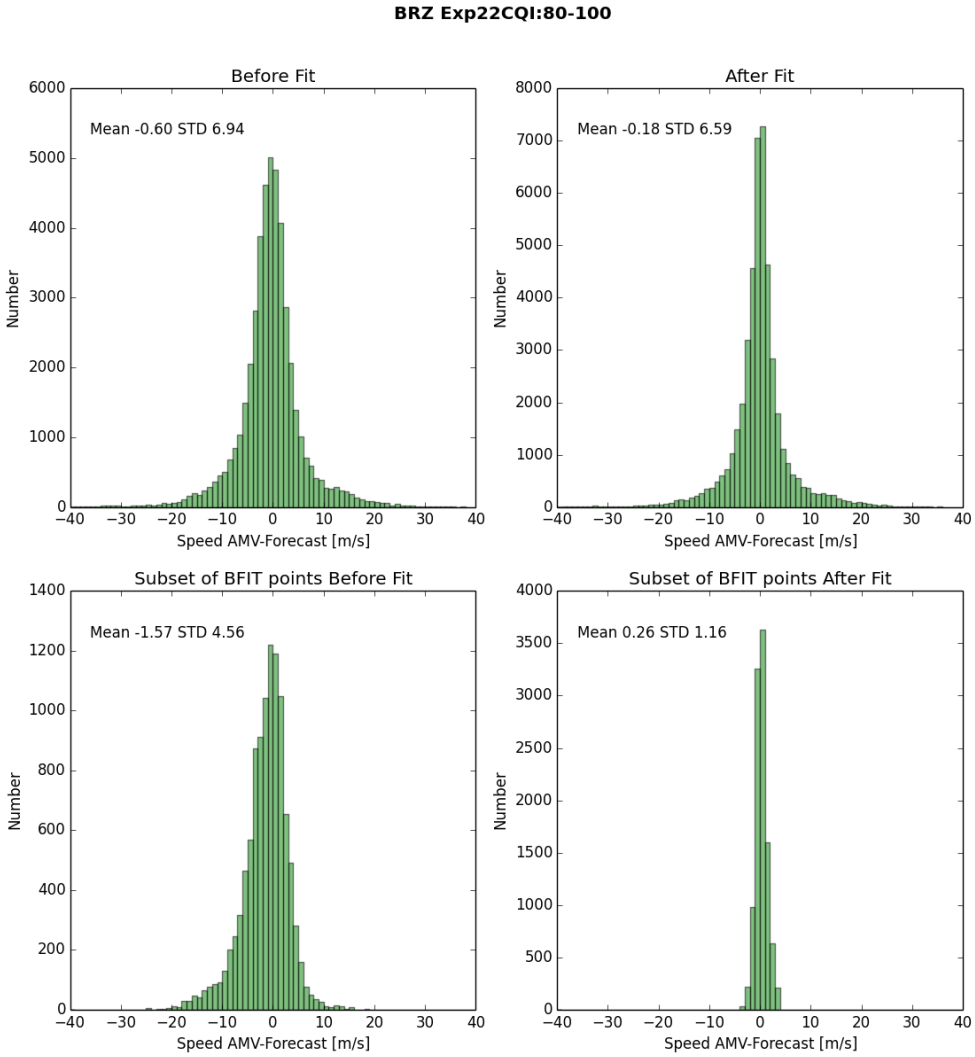


Figure 16-14: Experiment 2, BRZ (CQI>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

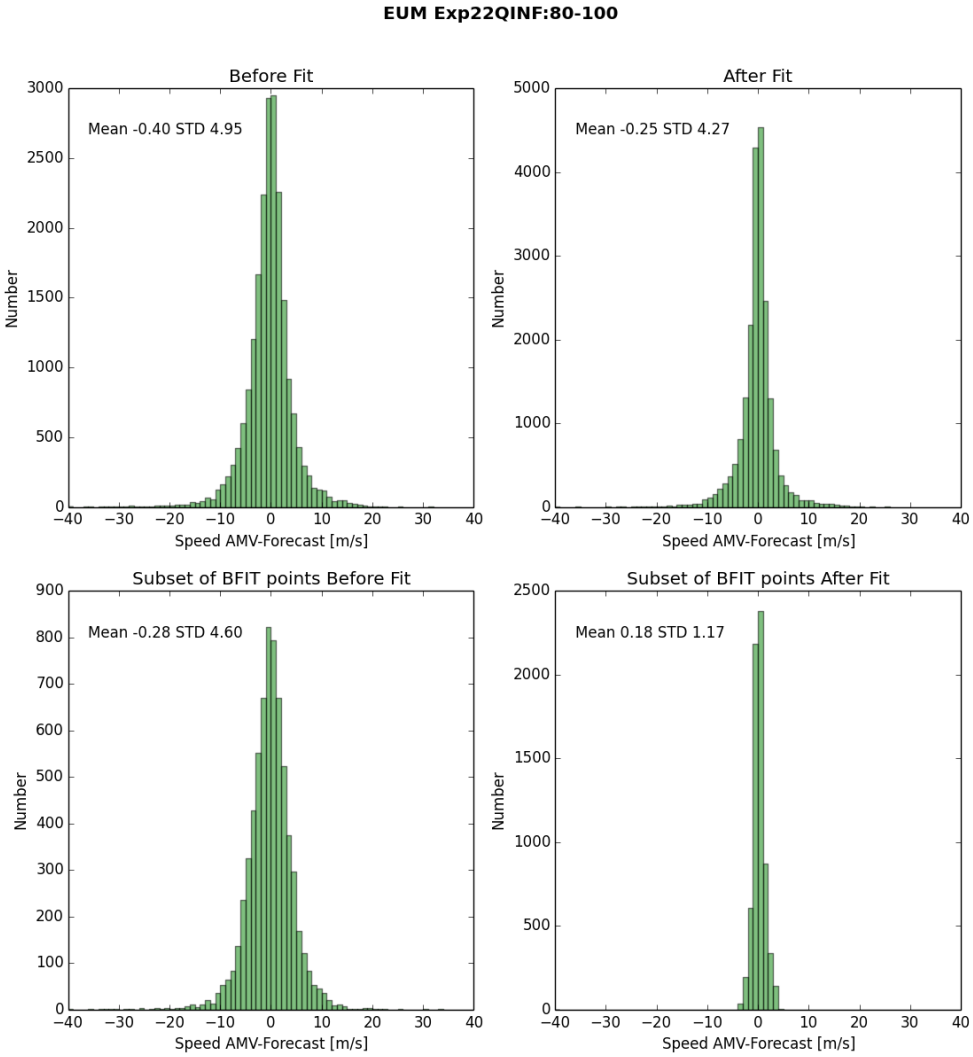


Figure 16-15: Experiment 2, EUM (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

Figure 16-16: Experiment 2, EUM (CQI>=80): 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).

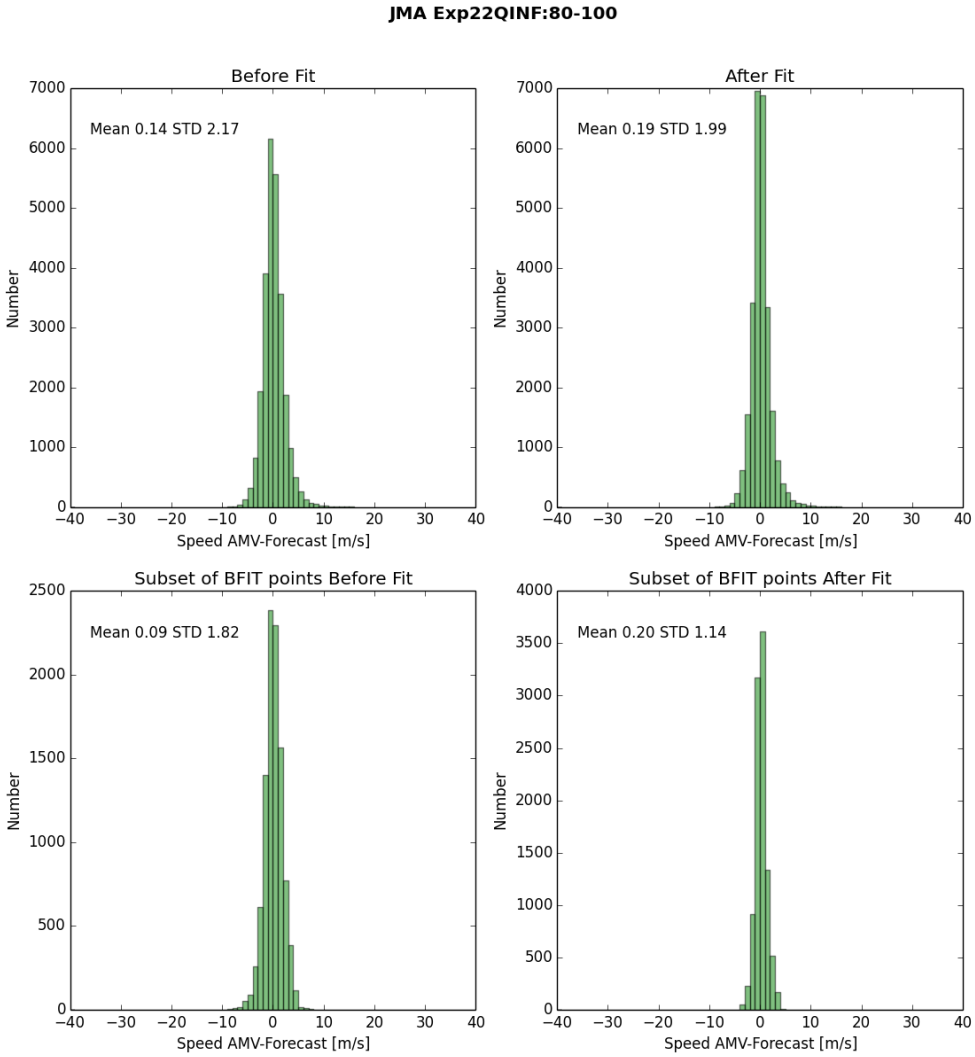


Figure 16-17: Experiment 2, JMA (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

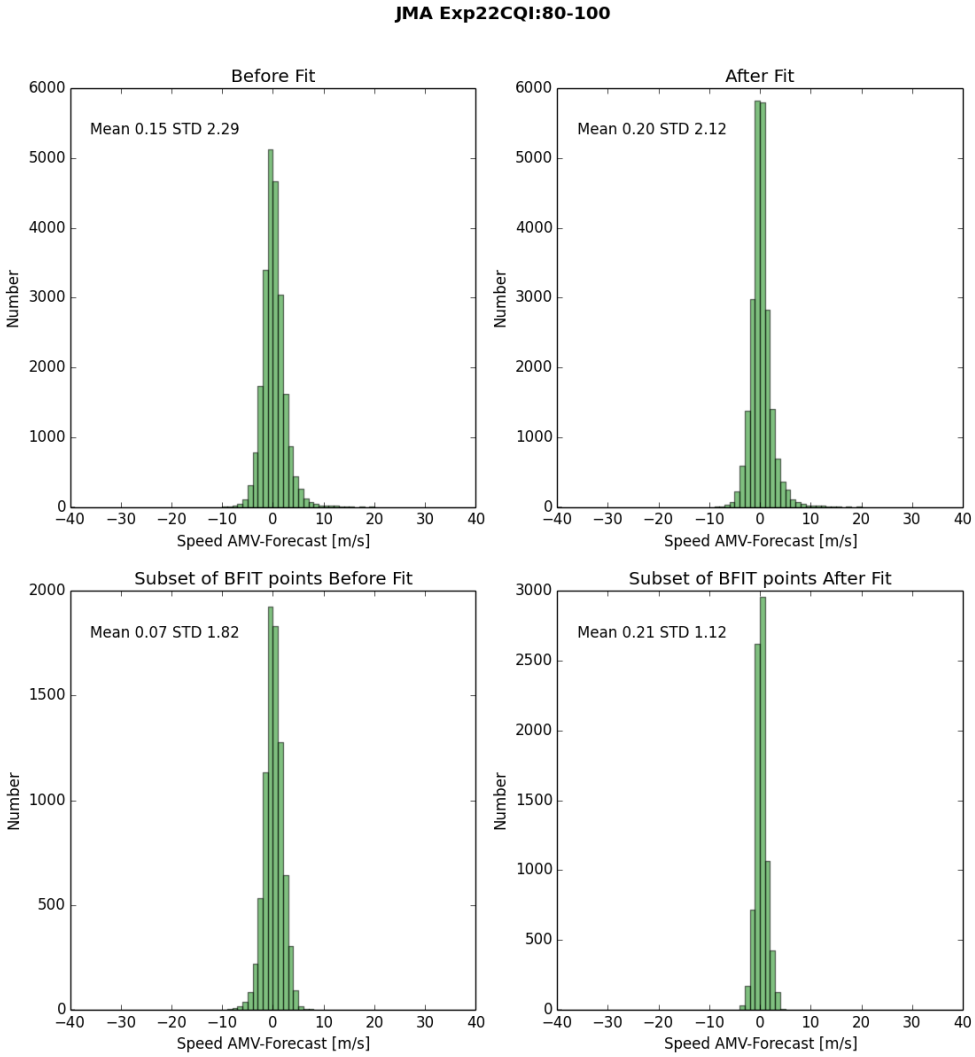


Figure 16-18: Experiment 2, JMA (CQI>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

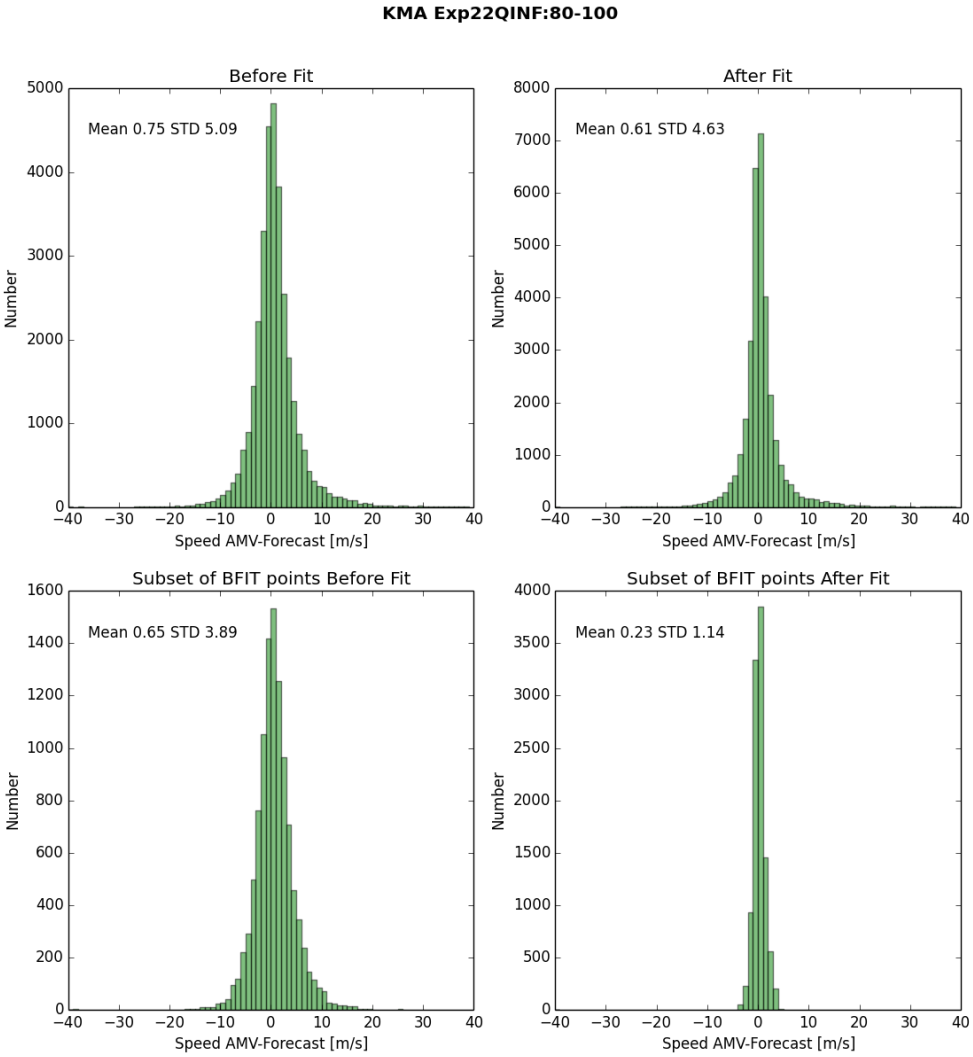


Figure 16-19: Experiment 2, KMA (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

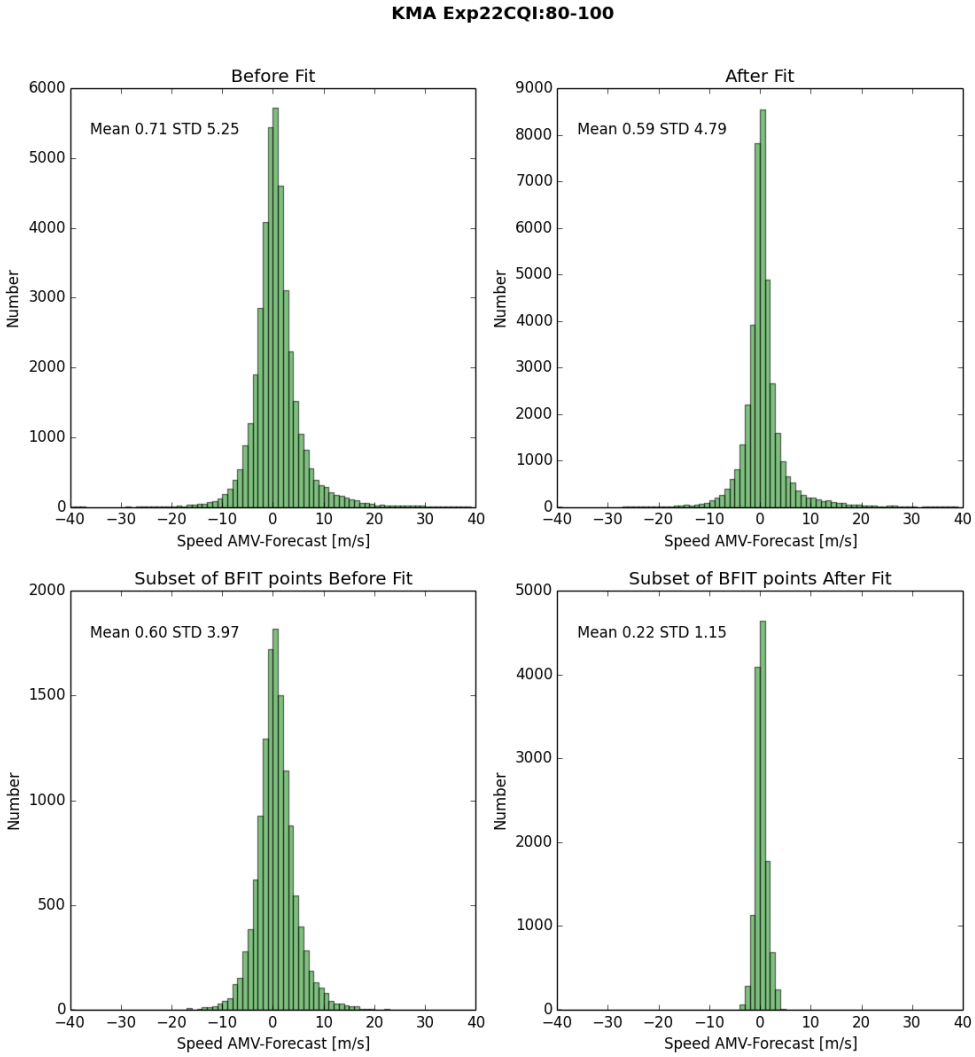


Figure 16-20: Experiment 2, KMA (CQI>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

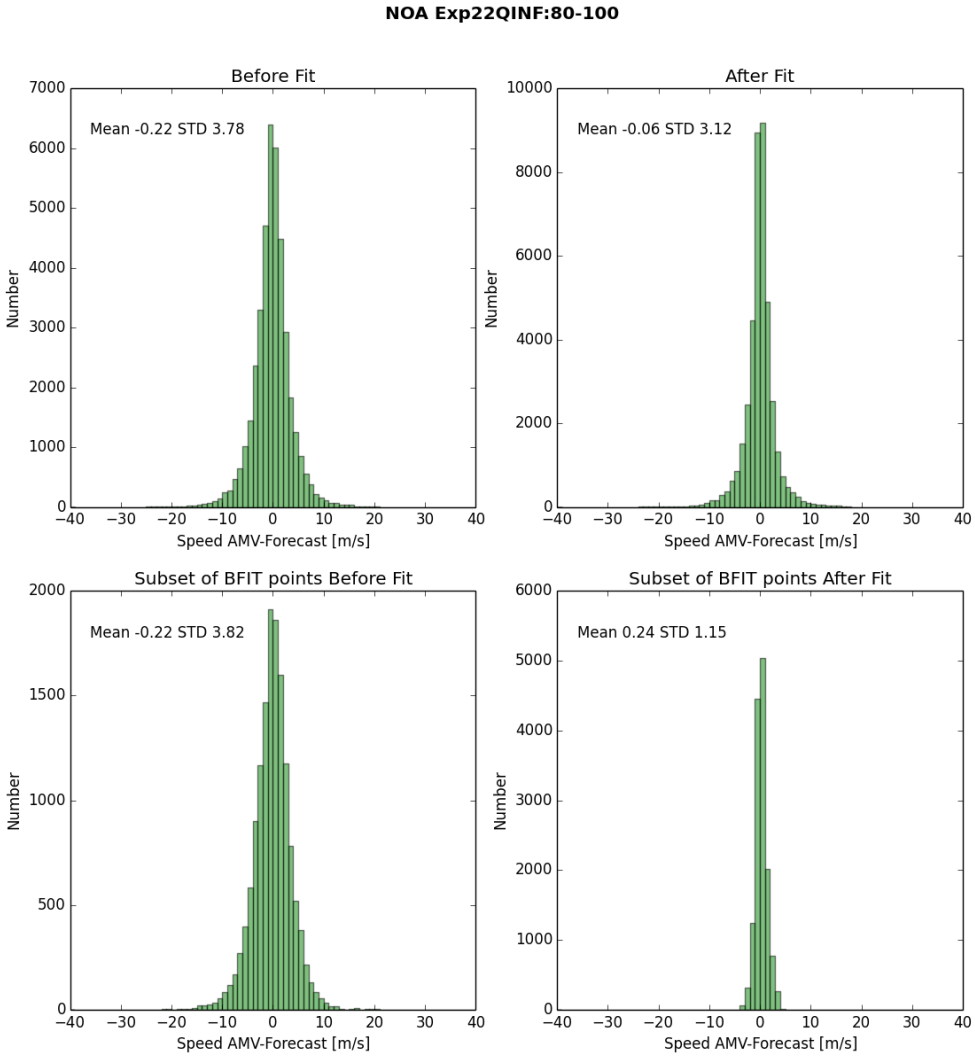


Figure 16-21: Experiment 2, NOA (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

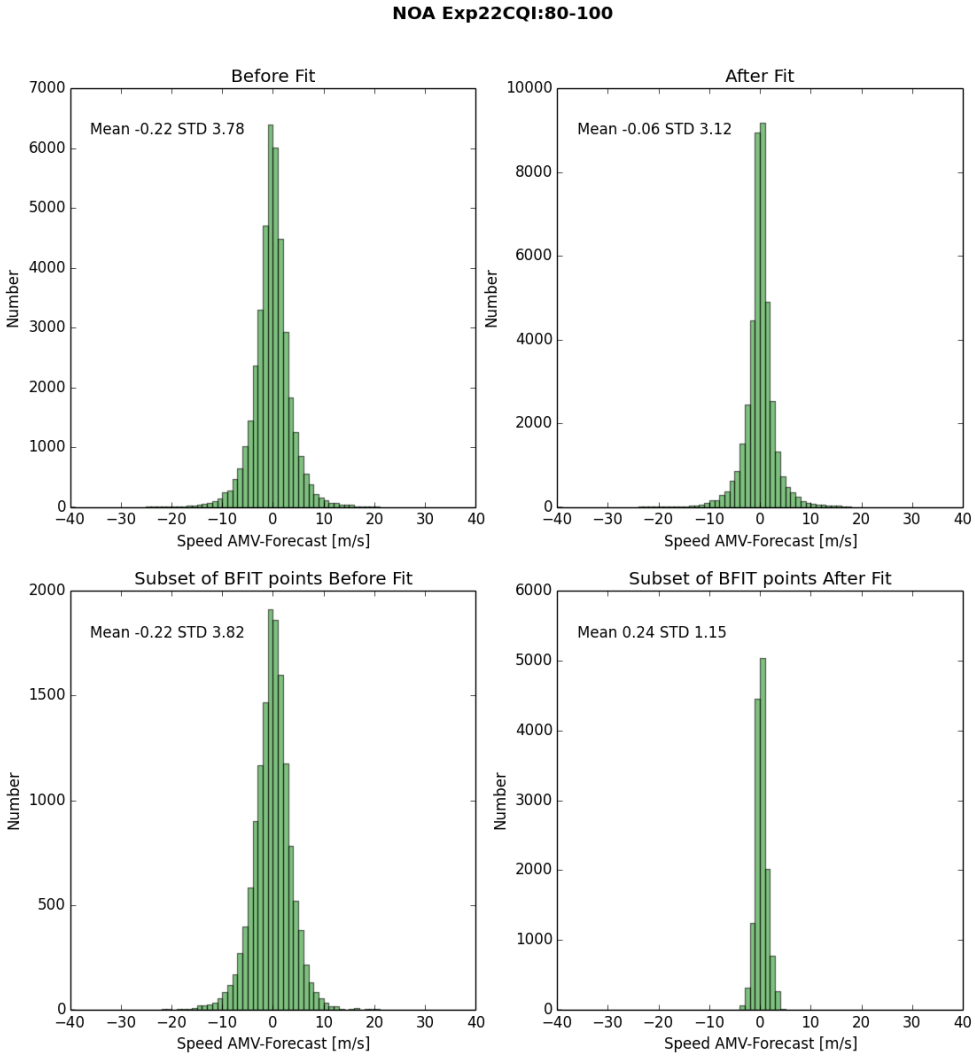


Figure 16-22: Experiment 2, NOA (CQI>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

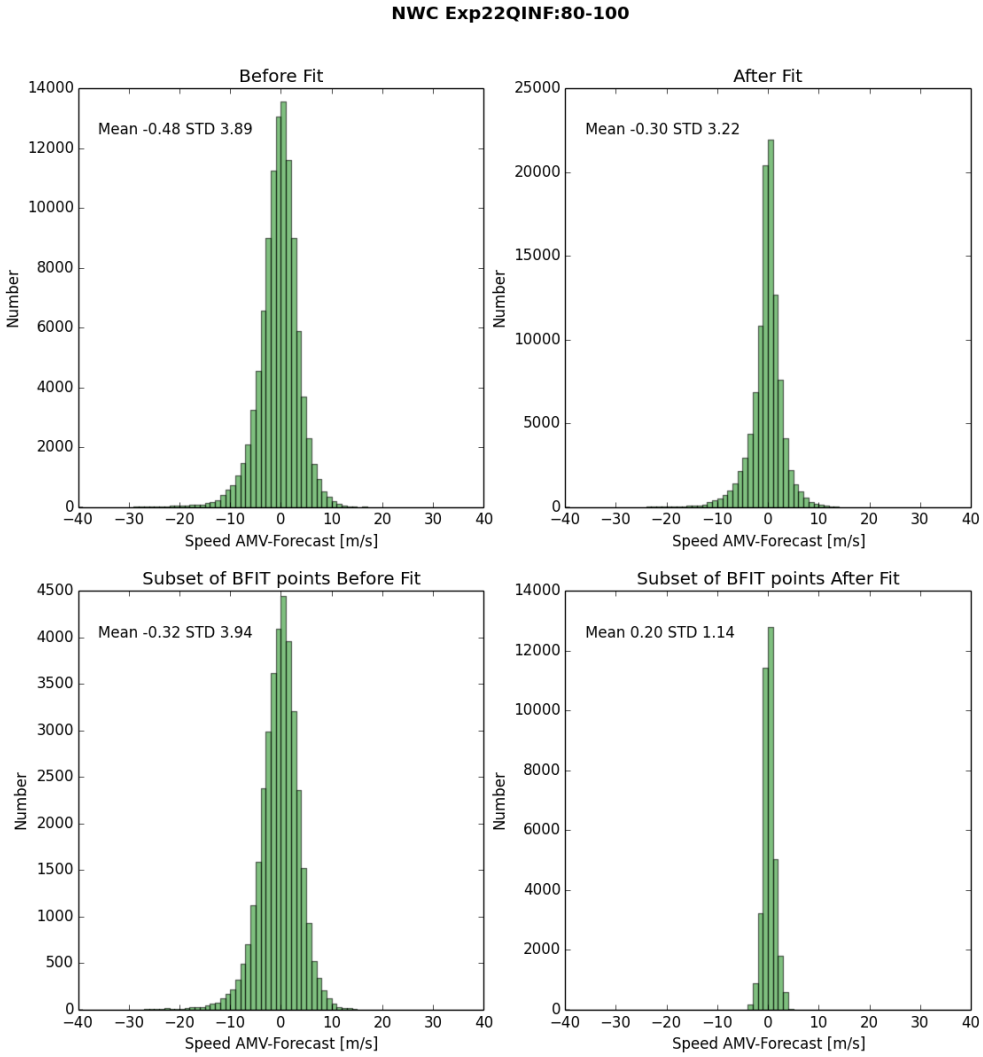


Figure 16-23: Experiment 2, NWC (QINF>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

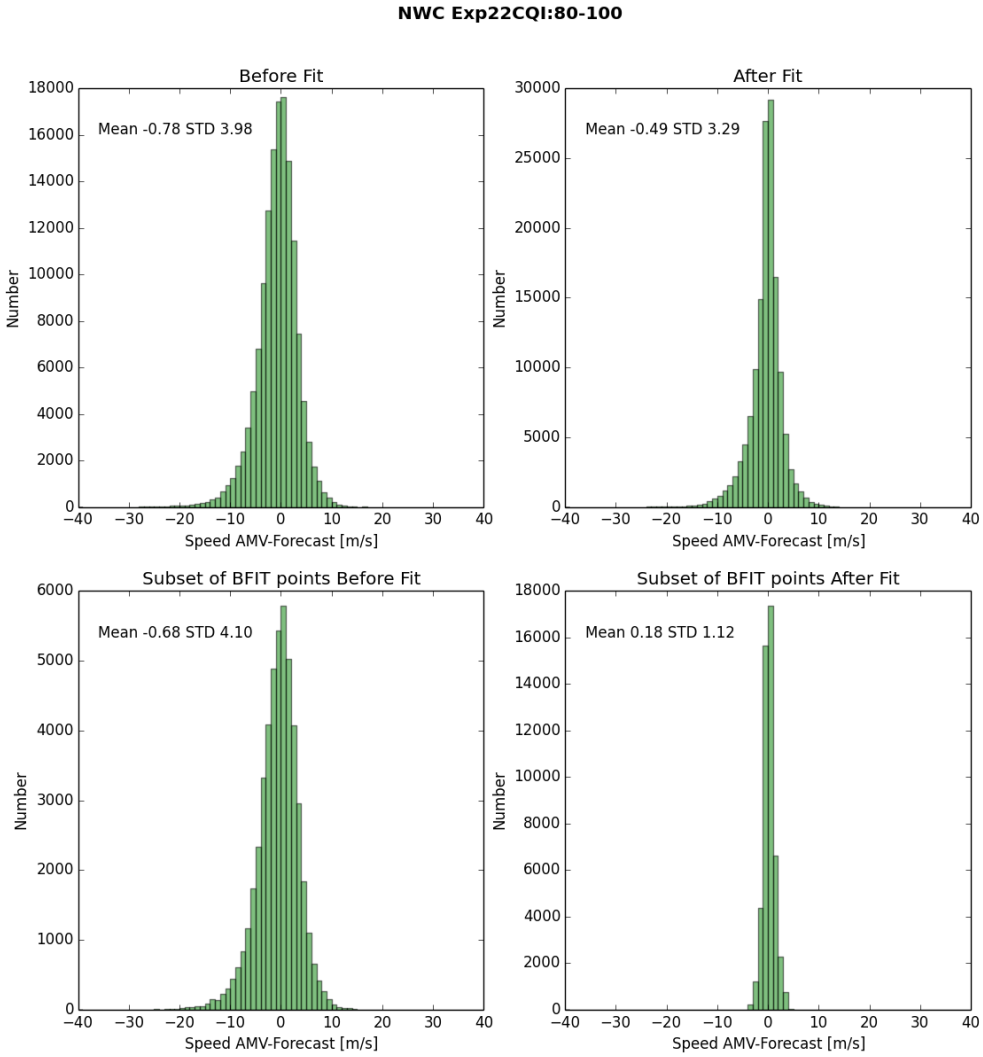


Figure 16-24: Experiment 2, NWC (CQI>=80): AMV – background speed distribution of all AMVs (upper-left); AMV – background speed distribution of all AMVs, including those that are Best Fit adjusted. (upper-right); AMV – background speed distribution of Best Fit AMVs (lower-left); AMV – background speed distribution of Best Fit AMVs, after Best Fit adjustment (lower-right).

Appendix E: Shell Scripts

The following script was used to preprocess the text files.

input_fix.sh

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

```
#**************************************************************************
# 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! *** "
```

17. Appendix F: Best-Fit Python Scripts

These scripts compute the Best-Fit pressure.

test_amv.py

```
#!/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
```

18. 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

```
% 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 datasets, 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

```
% 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 datasets, 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

```
% 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

```
% 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

```
% 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

```
% 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');
```