GOBIERNO DE ESPAÑA

MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE

AEMet Agencia Estatal de Meteorología

Use of AMDAR Data in NWP at AEMET

Carlos Geijo Guerrero, 27th May 2016, Madrid

NWP is about forecasting the weather in an objective way

$$\frac{D\vec{V}}{Dt} + 2\,\vec{\Omega} \times \vec{V} = -\vec{\nabla}p/\rho - \vec{g} + \vec{F}$$

$$\frac{D\rho}{Dt} + \rho\,\vec{\nabla}\,\vec{V} = 0$$

$$\frac{Ds}{Dt} = \frac{\dot{Q}}{T}$$

$$\frac{Dq_i}{Dt} = \dot{F}_i - \dot{S}_i$$

We need (*among other things*) to specify the initial state:

$$\vec{V}(0,\vec{x}), \rho(0,\vec{x}), s(0,\vec{x}), qi(0,\vec{x})$$

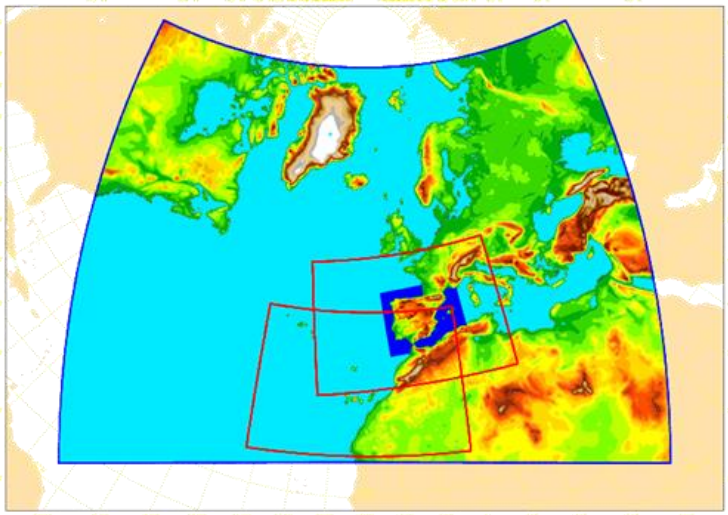
Different methods are commonly used for this purpose:

- Statistical interpolation methods (e.g., 3D-Var)
- Nudging
- Variational methods with constraints
- Adjoint methods (e.g., 4D-Var)
- Kalman Filters from ensembles

AEMET runs LAM (Limited Area Models) NWP systems

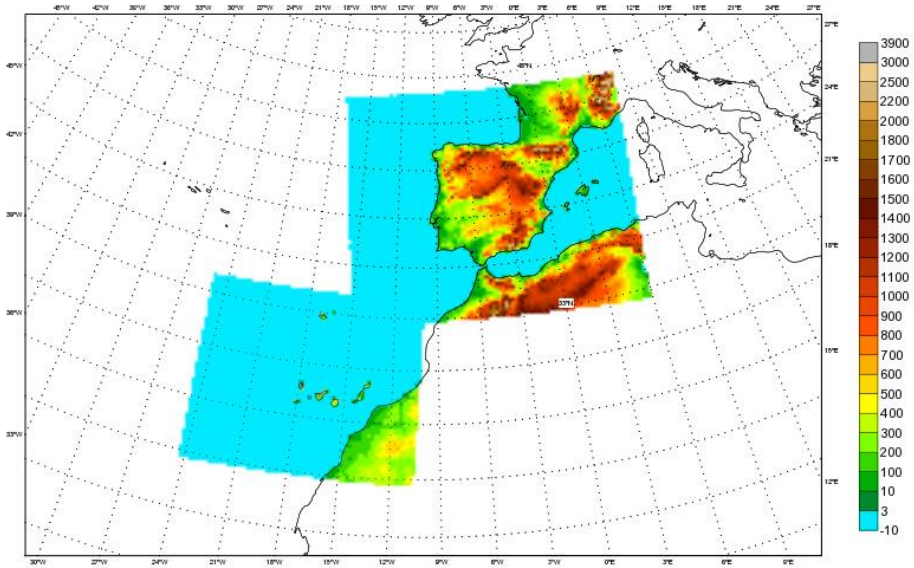
- More affordable than Global NWP
- Adds value to Global NWP by increasing forecast precision
- Aims at filling important gaps in Weather Forecasting (e.g. hazardous situations) some of which would be difficult to manage with Global NWP systems

In “determinisc mode”, AEMET currently counts with two operational LAM NWP systems,



HIRLAM v7.4 , Synoptic NWP system

HARMONIE-AROME v40 , Mesoscale NWP system



GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE
AEMet Agencia Estatal de Meteorología

Courtesy of M.V.Díez

The most important products generated with the NWP models in Aemet with aeronautical information are:

GAMET BULLETIN:

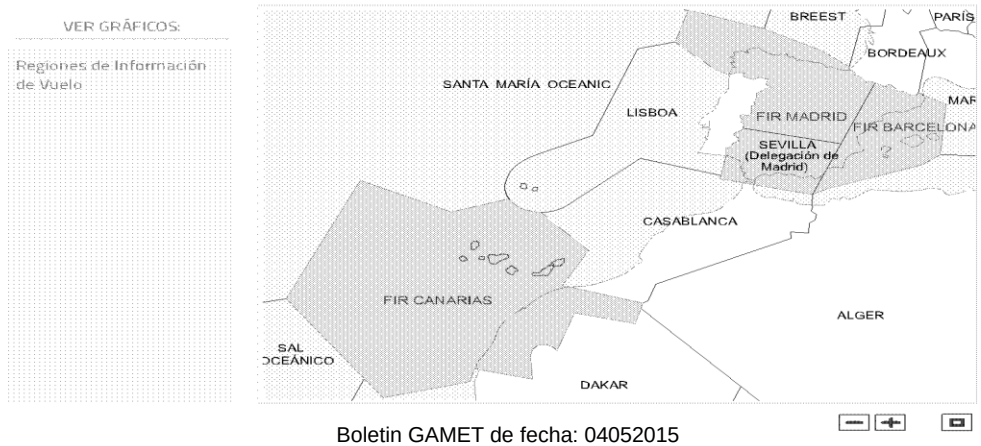
One per FIR (flight information region) Area:

- Madrid, Seville, Barcelona & Canary Islands.

The information given are:

- Wind and Temperature for different heights
- The isozero heights
- The QNH minimum and the coordinates of the location.

One example of Bacelona product:



Boletin GAMET de fecha: 04052015
==========

Zona FIR: BARCELONA
==========

PREVISTO H + 12

WND/T: BARCELONA P.MALLORCA MURCIA

020Hft 061/022kt PS07 059/026kt PS07 047/037kt PS07
050Hft 047/014kt PS02 039/008kt PS02 071/024kt PS02
100Hft 062/018kt MS08 053/017kt MS09 082/023kt MS08
150Hft 060/018kt MS19 057/016kt MS19 070/018kt MS17
200Hft 073/017kt MS30 080/012kt MS30 044/007kt MS30
300Hft 096/027kt MS52 096/014kt MS53 075/005kt MS54

FZLVL: 60 Hft AMSL 61 Hft AMSL 59 Hft AMSL

MNM QNH:1007 hpa
LAT: 4125 LONG: -10

GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE
AEMet Agencia Estatal de Meteorología

Courtesy of M.V.Díez

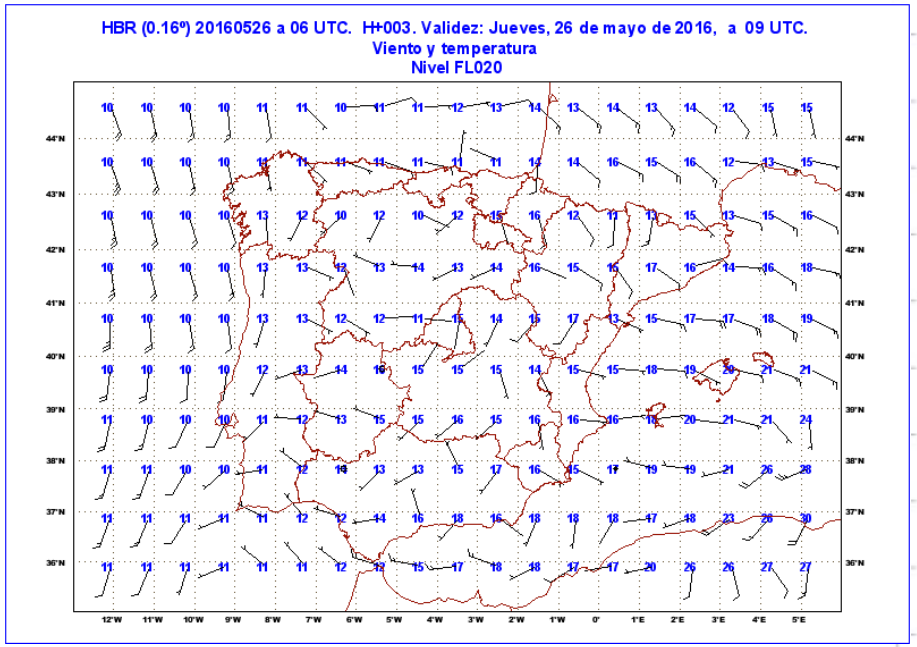
Aeronautical Maps:

Wind and Temperature and Humidity for

Flight Levels:

- 20, 50, 100, 150, 180 & 300.

We are working for the update of these maps with Harmonie information.
Both products are available in ama webpage.
http://ama.aemet.es/en/busquedas-basicas

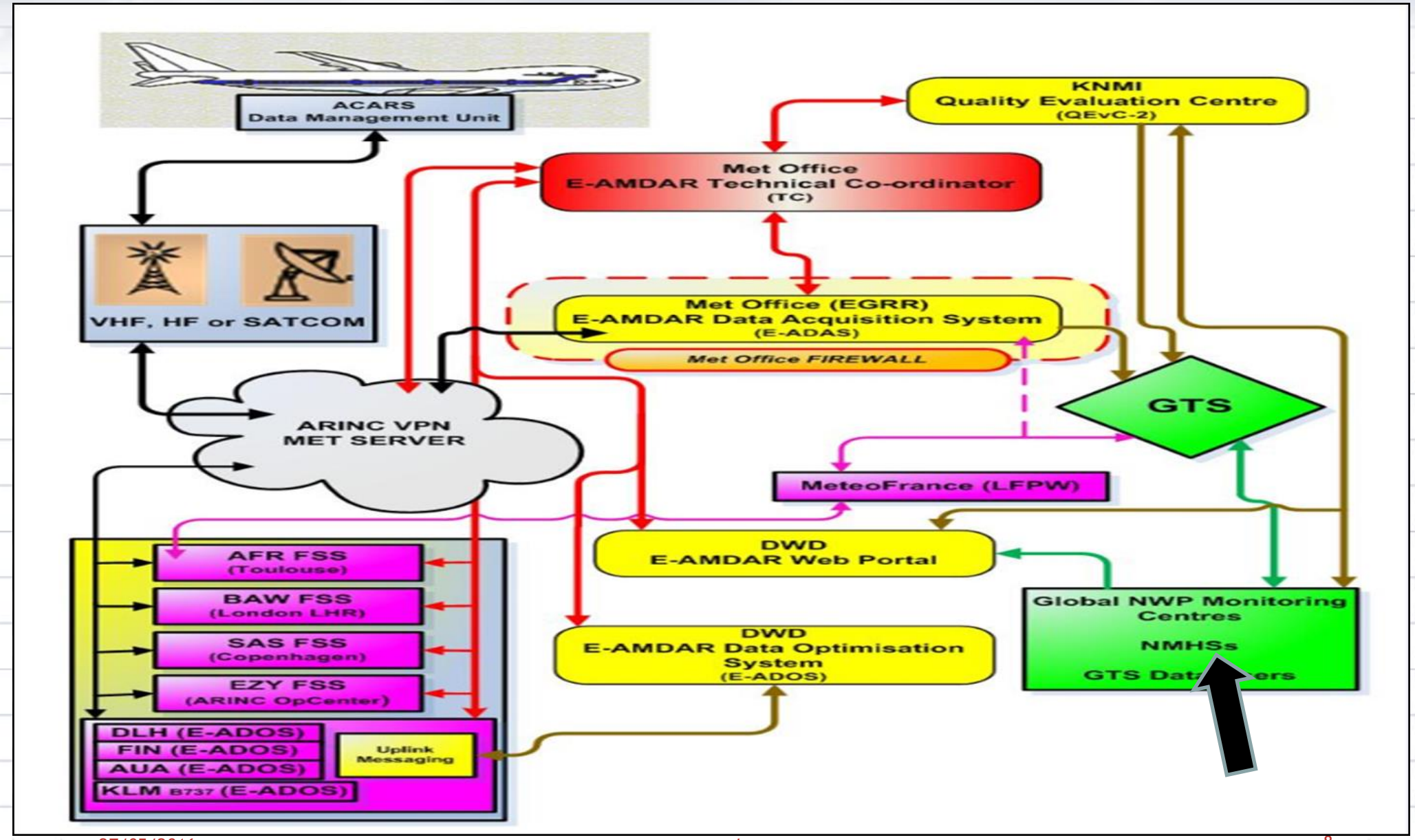


GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE
AEMet Agencia Estatal de Meteorología

When running routinely NWP systems, some aspects are of paramount importance regarding the utility of observations

- Access and availability in time (Timeliness)
- What (and how) is measured and what confidence can be given to these measurements (Quality)
- Coverage (including the commitment to mantain the system to avoid discontinuities)

How AMDAR data get to AEMET ?



GOBIERNO DE ESPAÑA | MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE | AEMet Agencia Estatal de Meteorología

How AMDAR data get to AEMET ?

- ✓ AMDAR data is received in **FM 94 BUFR** format
- ✓ Bulletin headers are identified as **IUA [A-Z] <originatingcentre>**
- ✓ From the Data Description Section (section 3), we use **the descriptor sequence 3 11 001 :**

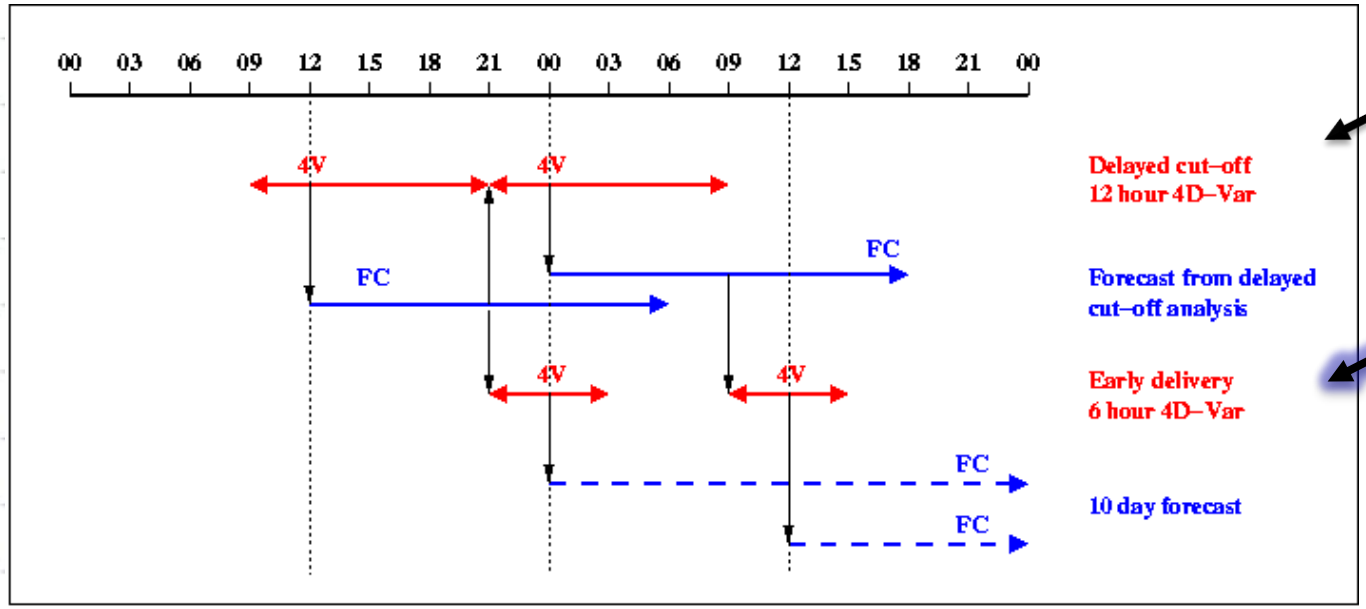
Therefore no humidity data or QC parameters used at the moment !

```
001006 AIRCRAFT FLIGHT NUMBER           CCITTIA5
002061 AIRCRAFT NAVIGATIONAL SYSTEM     CODE TABLE 2061
004001 YEAR                             YEAR
004002 MONTH                            MONTH
004003 DAY                              DAY
004004 HOUR                             HOUR
004005 MINUTE                           MINUTE
005001 LATITUDE (HIGH ACCURACY)         DEGREE
006001 LONGITUDE (HIGH ACCURACY)        DEGREE
008004 PHASE OF AIRCRAFT FLIGHT         CODE TABLE 8004
007002 HEIGHT OR ALTITUDE               M
012001 TEMPERATURE/DRY-BULB TEMPERATURE K
011001 WIND DIRECTION                   DEGREE TRUE
011002 WIND SPEED                       M/S
011031 DEGREE OF TURBULENCE             CODE TABLE 11031
011032 HEIGHT OF BASE OF TURBULENCE     M
011033 HEIGHT OF TOP OF TURBULENCE      M
020041 AIRFRAME ICING                   CODE TABLE 20041
```

Timeliness

Which timeliness requirements meet NWP AEMET needs ?

ECMWF **E**arly**D**elivery**S**ervice schedule

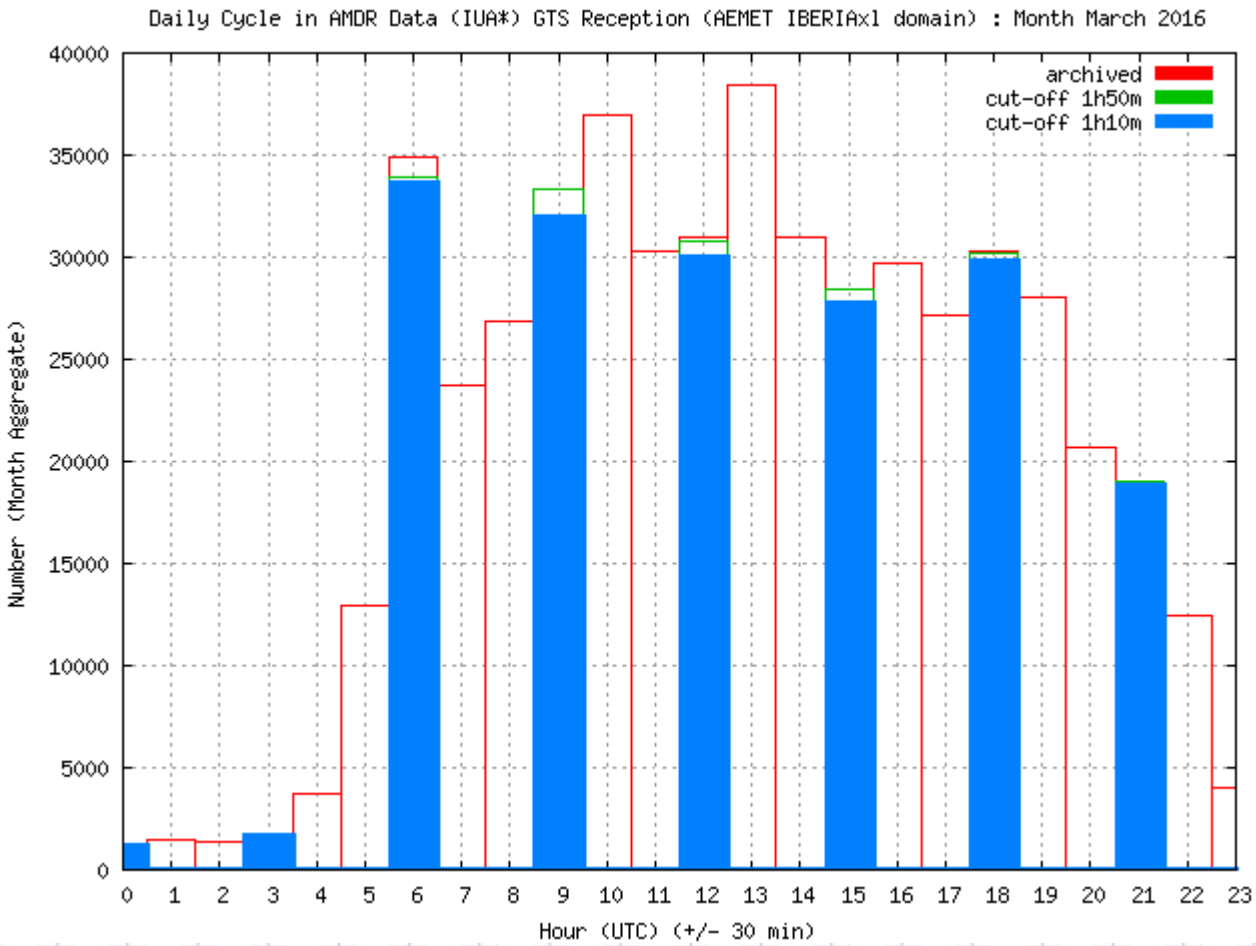


5 Hours Cut-Off Time

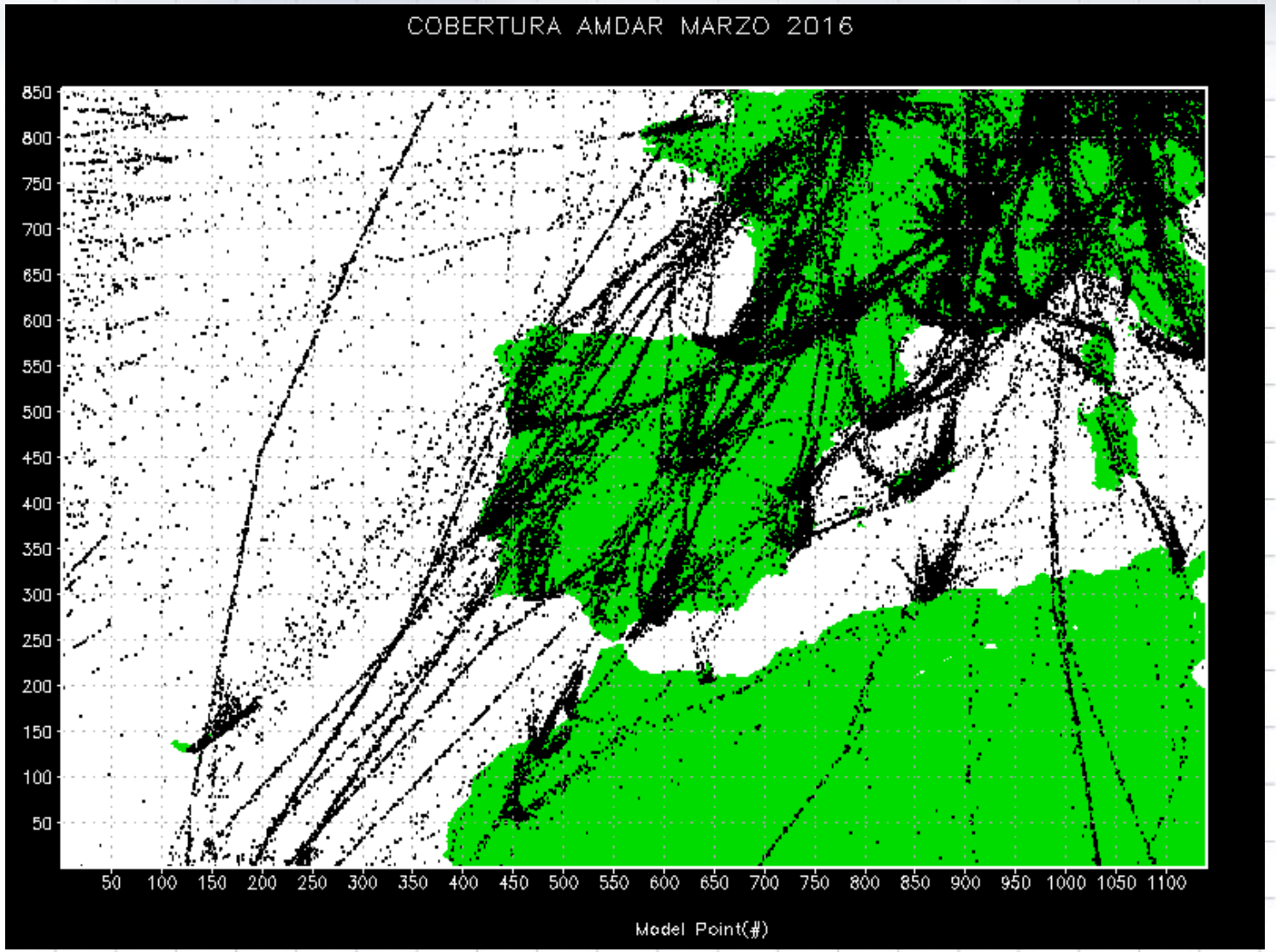
1 Hour COT

"UpateTime" = CyT(6) + COT(1) + DeT (2-3) ~ 9-10 Hours

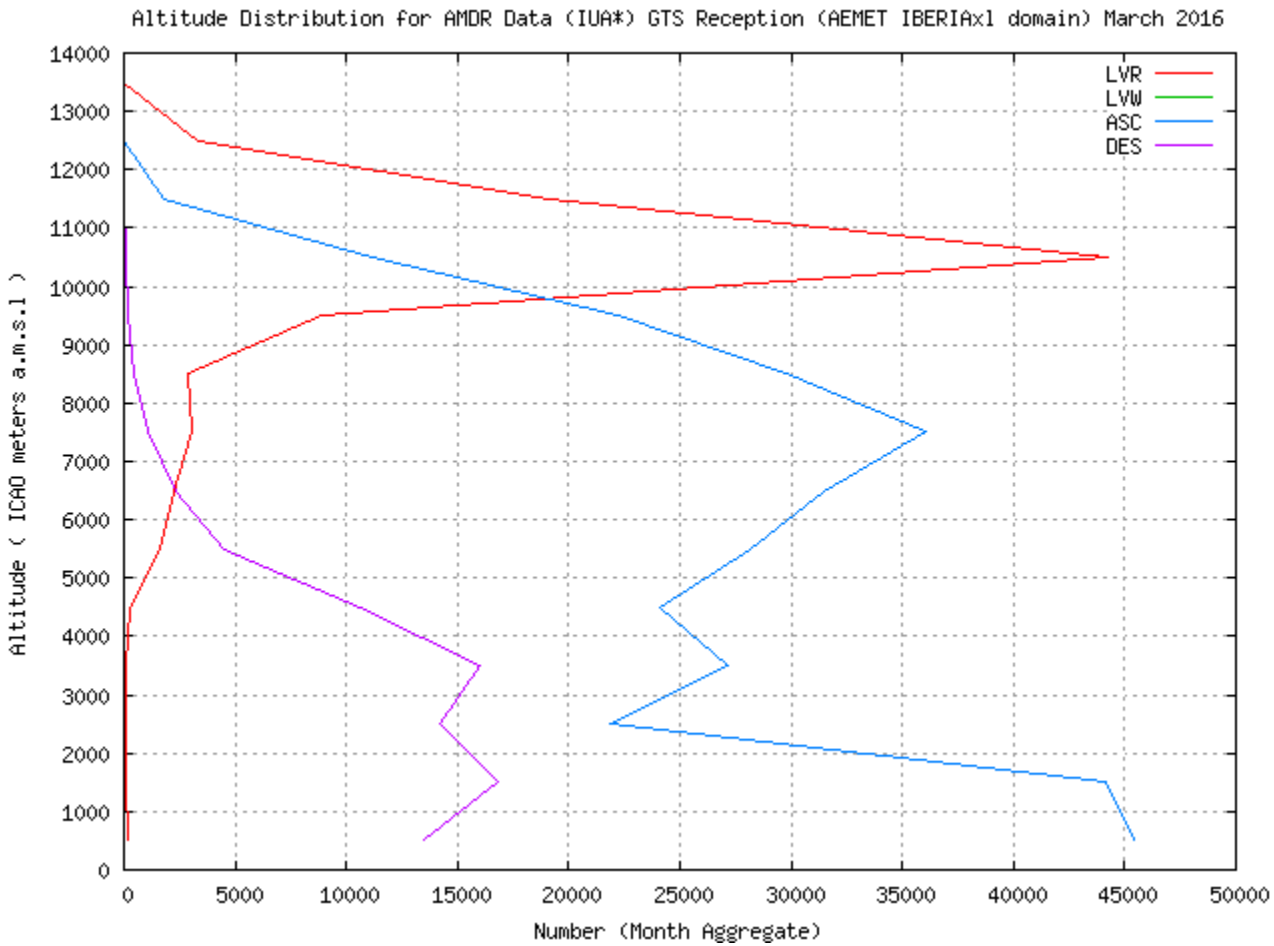
Timeliness


Daily Cycle in AMDR Data (IUA*) GTS Reception (AEMET IBERIAx1 domain) : Month March 2016
archived
cut-off 1h50m
cut-off 1h10m
Number (Month Aggregate)
40000
35000
30000
25000
20000
15000
10000
5000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour (UTC) (+/- 30 min)

Coverage


COBERTURA AMDAR MARZO 2016
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100
Model Point(#)

Coverage


Altitude Distribution for AMDR Data (IUA*) GTS Reception (AEMET IBERIAx1 domain) March 2016
LVR
LVW
ASC
DES
Altitude (ICAO meters a.m.s.l)
Number (Month Aggregate)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

Wind and Air Temperature Measurements from Aircrafts

- Measurements are dependent upon each other (errors are correlated)
- One fundamental instrument is the Pitot-static probe which permtis measurment of static (free airstream) and dynamical (total) pressures in the air flow, p_o and p_s
- From these two measurements, the Match number is readily calculated according to the theory of stationary adiabatic flows

$$M^2 = \frac{2}{(\gamma-1)}\left[\left(\frac{p_s}{p_o}\right)^{\frac{\gamma-1}{\gamma}} - 1\right], \quad M = \frac{v}{c_o}, \quad \gamma = \frac{c_p}{c_v}$$

- The temperature of the free airstream T_o is then obtained from the aircraft thermometer probe measurement T (accounting for eventual de-icing corrections, etc…) and this Match number using a similar formula. Differences between T_o and T are often around -30 K !
- The true or indicated airspeed a_s (i.e. with respect to the aircraft) is then obtained from M and the air sound speed c_o

Wind and Air Temperature Measurements from Aircrafts

P_o ,P_s ,T → Altitude (ICAO) , M, T_o , a_s

- Accuracy in the determination of the fundamental M measurement is reported (WMO-958, 2003) better than 0.2%

- Conversion (for reporting) of P_o to hundreds of feet introduces a systematic error with height which ranges from 4.5 hPa (zero reference level) to 1.5hPa (cruise level)

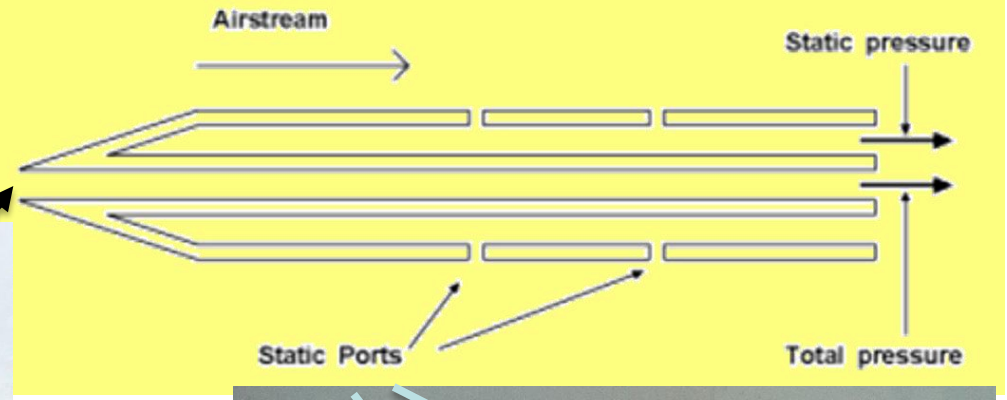
- Accuracy in T_o depends on errors in the determination of M and T, plus other eventual sources of error (de-icing, insuficient air-flow, etc..). Nominally it is reported well below 0.5 ^oC . However, in the event that the sensor is wetted in cloud, the evaporation cooling can generate errors up to a few degrees (-3 ^oC)

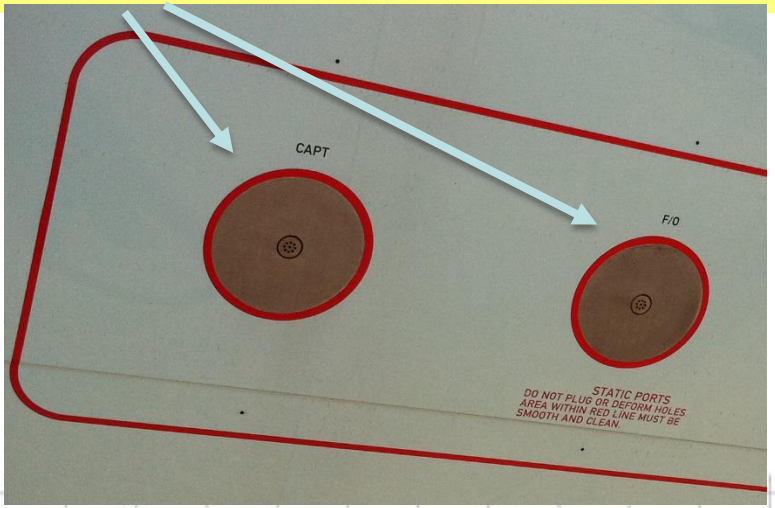
- Accuracy of a_s ,unless gross T_o errors exist, is about 0.5 m/s. From the method of calculation, it is easy to see that, if error in M is negligible, bias in T_o introduces bias in a_s

Wind and Air Temperature Measurements from Aircrafts

1. MEASUREMENT OF PRESSURE ALTITUDE

Static (i.e. free airstream) pressure is measured directly by an electronic barometer connected to static pressure ports in the pitot-static probe (Figure 1).



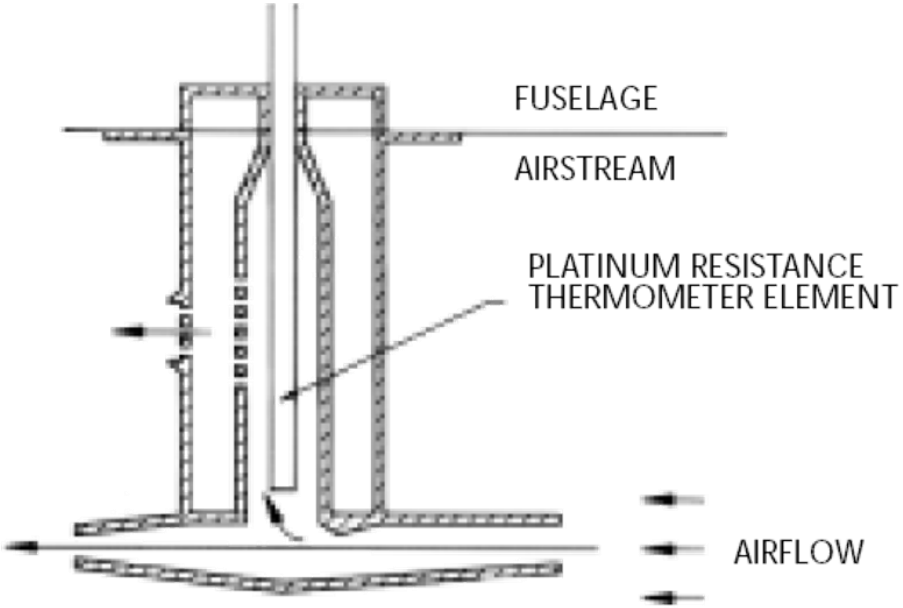


The aircraft is equipped with several pitot-static probes

Wind and Air Temperature Measurements from Aircrafts

Temperature observations are made via small tubes protruding from the front sides of the aircraft

Figure 4
Aircraft thermometer probe



Optimal location of these measurement instruments around the aircraft is “a kind of art”

Wind and Air Temperature Measurements from Aircrafts

- Wind **W** is determined from the difference between ground velocity $\mathbf{V_g}$ and velocity of the air with respect to the aircraft $\mathbf{V_a}$, that is : $\mathbf{W} = \mathbf{V_g} - \mathbf{V_a}$

- The full resolution of the vectors requires measurements of aircraft orientation with respect to the ground (heading, pitch and roll) and airstream (yaw and angle of attack).

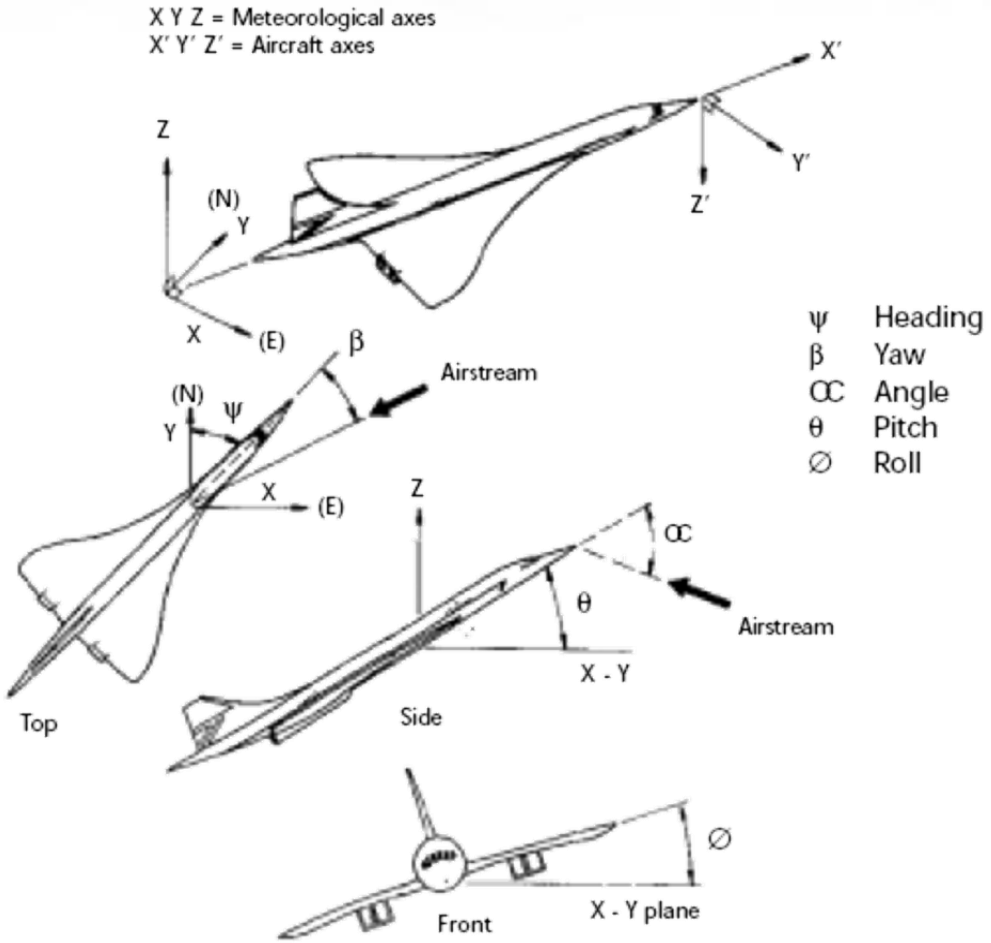
- During manoeuvres (high roll and/or pitch angles) or in sudden changes in the wind field (turbulence) these determinations are difficult and big errors are to be expected

- In normal level flight, pitch, yaw and angle of attack are very small and can be neglected. In this case the horizontal component of the wind is easily computed from $\mathbf{V_g}$ and a_s , ... assuming no cross-winds!

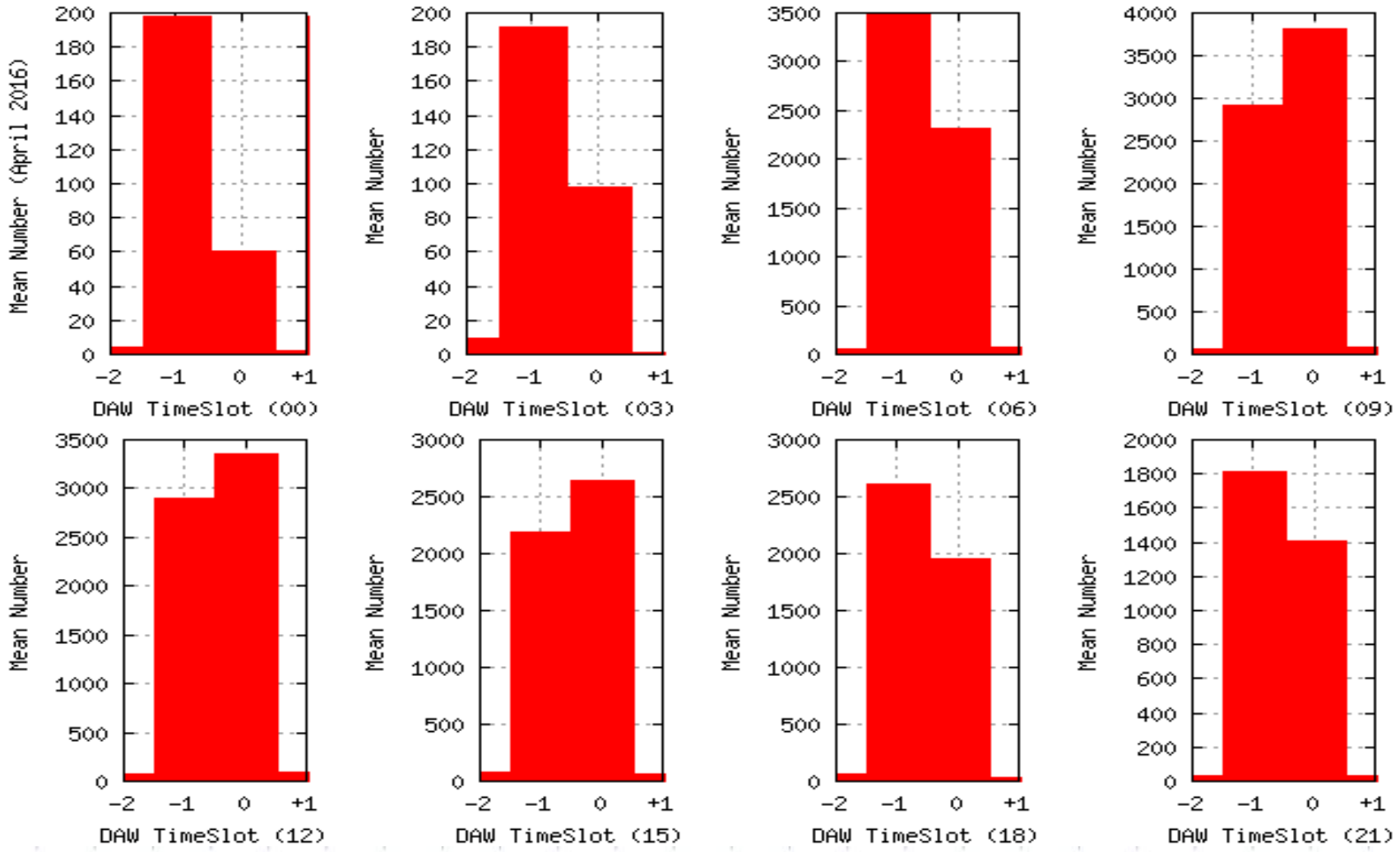
- In spite of the difficulties, nominal reported errors are only between 1-3 m/s depending on several circumstances.

Wind and Air Temperature Measurements from Aircrafts

Figure 6
Aircraft reference axes and altitude angles

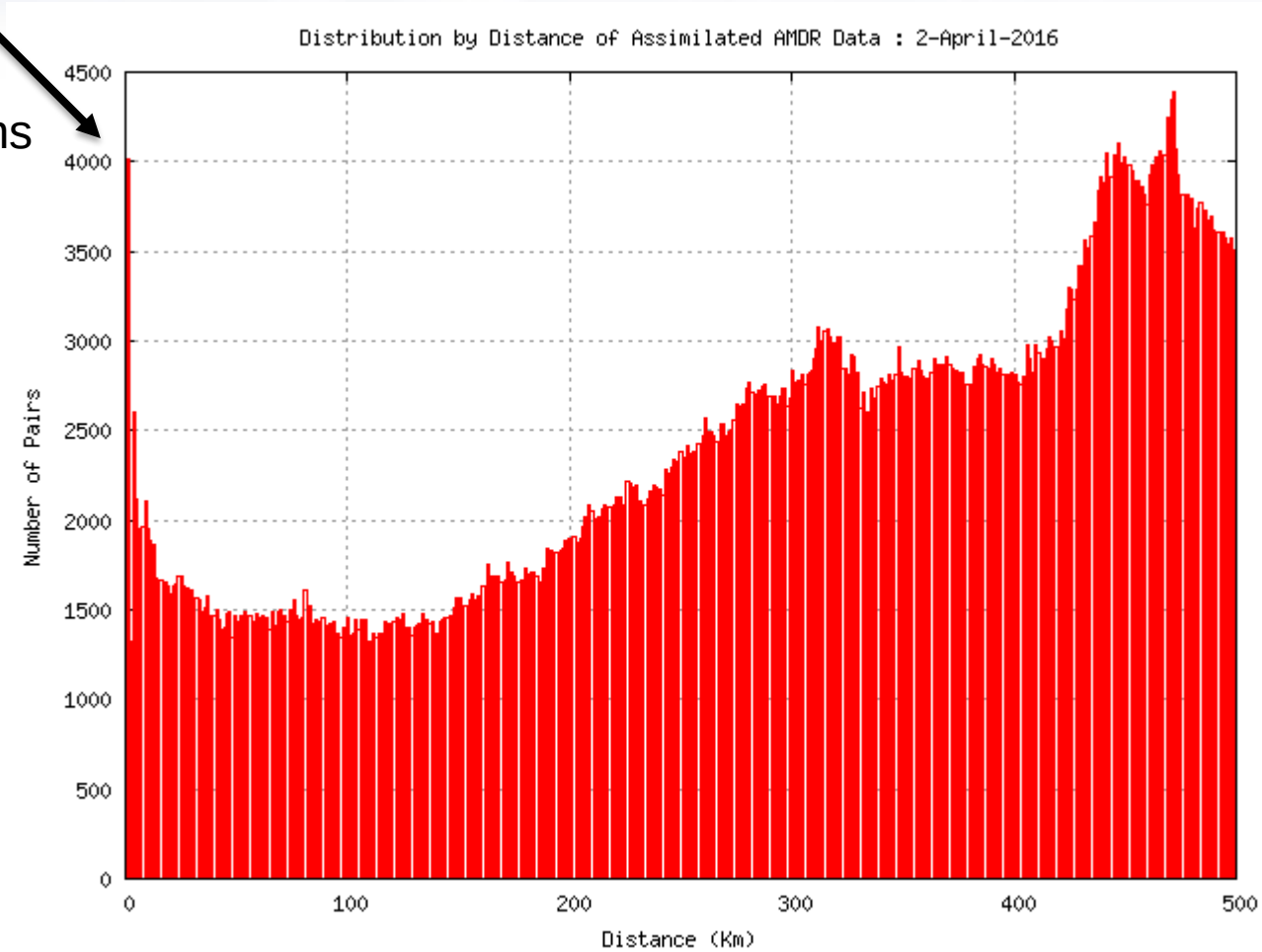


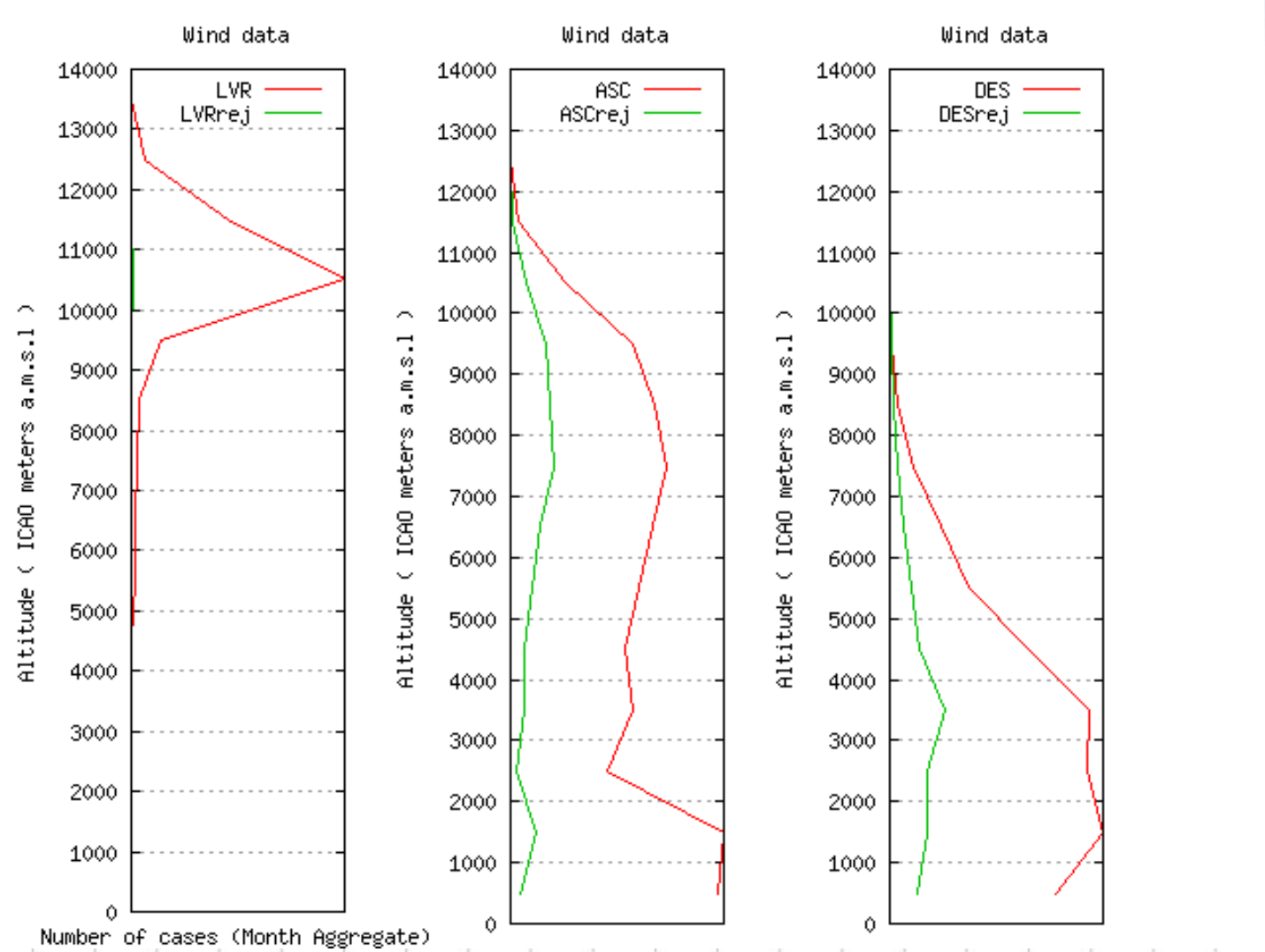
AMDAR Data usage in the 3 x 8 3D-Var AEMET-HARMONIE runs during April 2016 (3hours Data Assimilation Window (DAW) : H-2h30m H+0h30m)

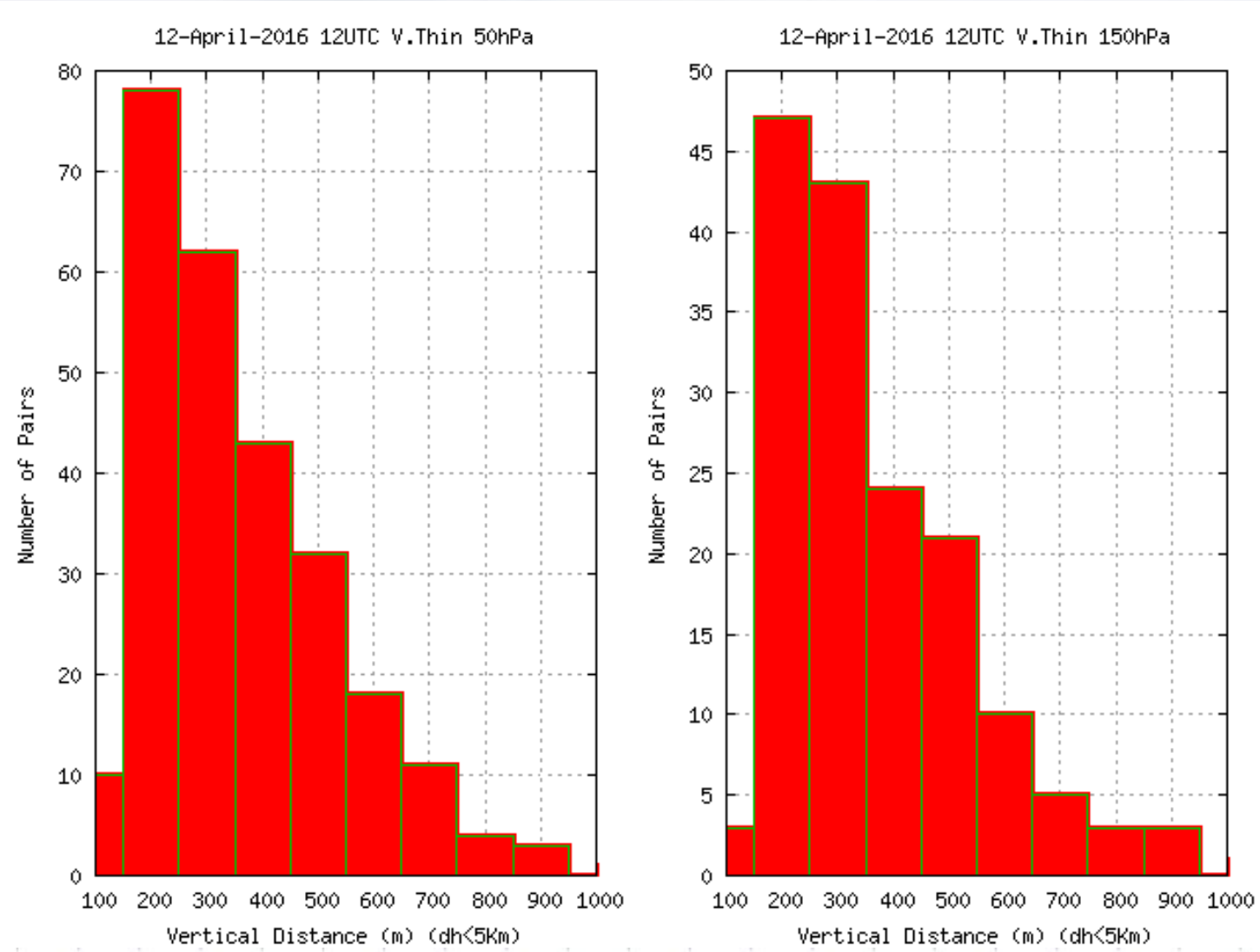


High density of observations in the vecinity of airports.

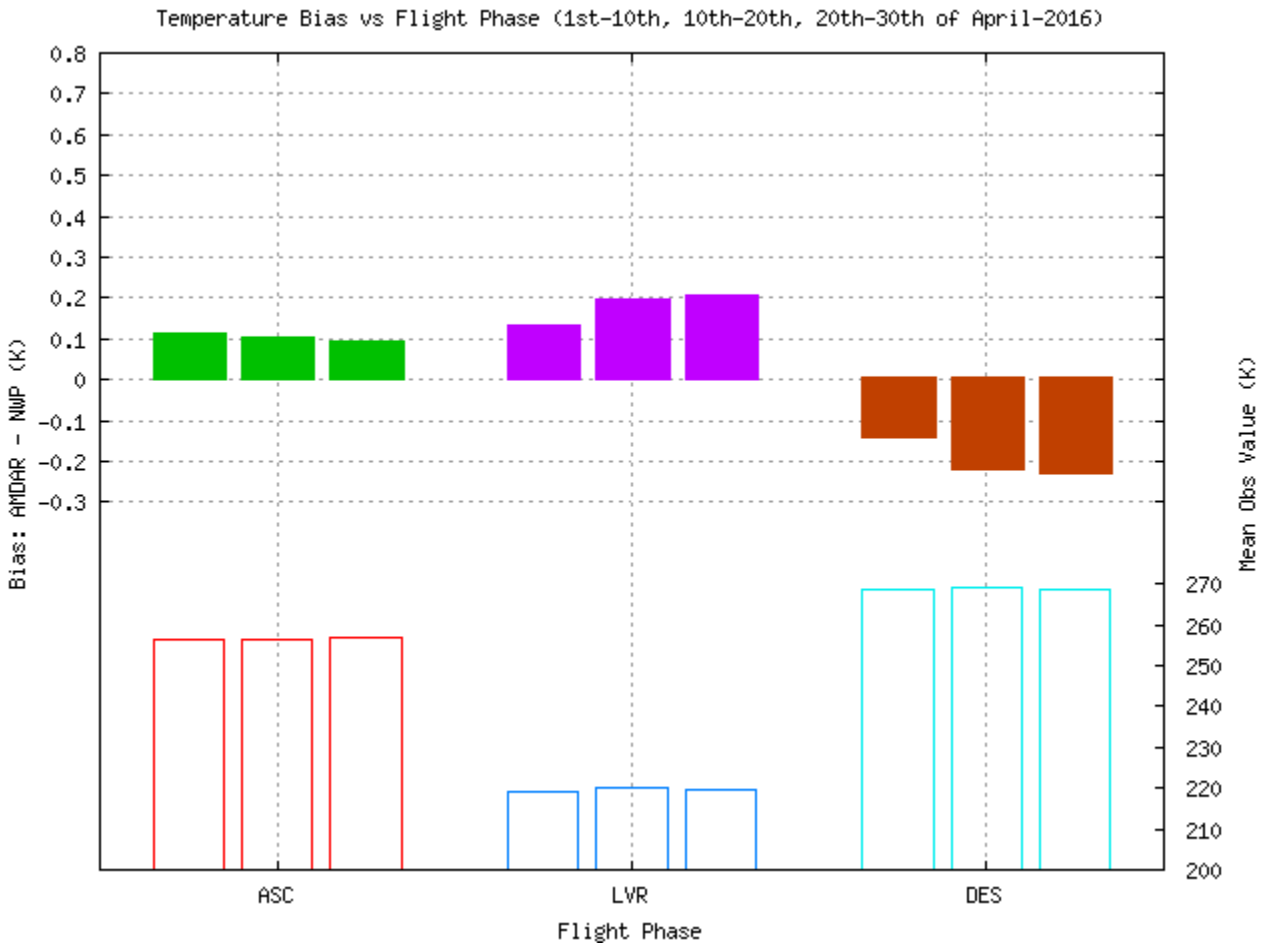
In DA systems like 3D-Var, thinning becomes an issue



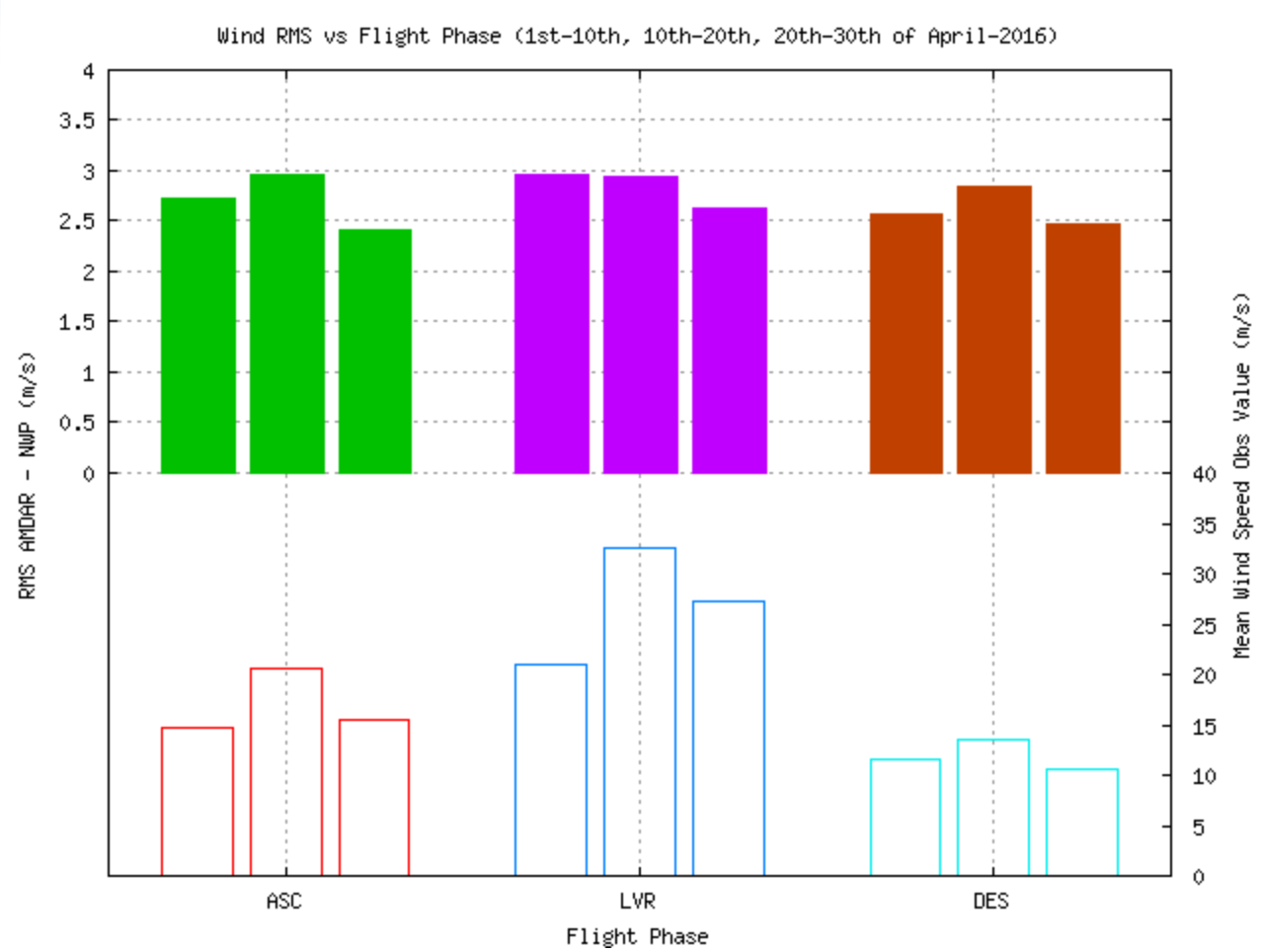

Wind data
LVR
LVRrej
Altitude (ICAO meters a.m.s.l)
Number of cases (Month Aggregate)
Wind data
ASC
ASCrej
Altitude (ICAO meters a.m.s.l)
Wind data
DES
DESrej
Altitude (ICAO meters a.m.s.l)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000


12-April-2016 12UTC V.Thin 50hPa
Number of Pairs
0
10
20
30
40
50
60
70
80
100 200 300 400 500 600 700 800 900 1000
Vertical Distance (m) (dh<5Km)
12-April-2016 12UTC V.Thin 150hPa
Number of Pairs
0
5
10
15
20
25
30
35
40
45
50
100 200 300 400 500 600 700 800 900 1000
Vertical Distance (m) (dh<5Km)

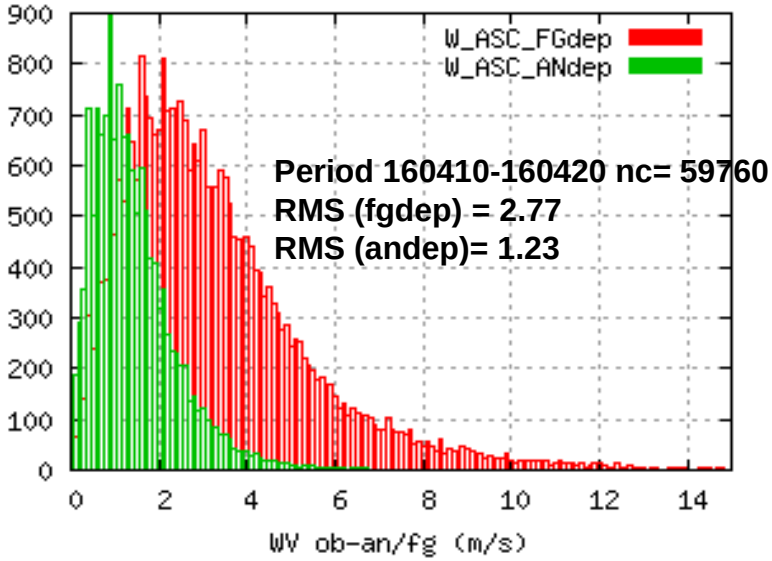
AMDAR DATA EVALUATION

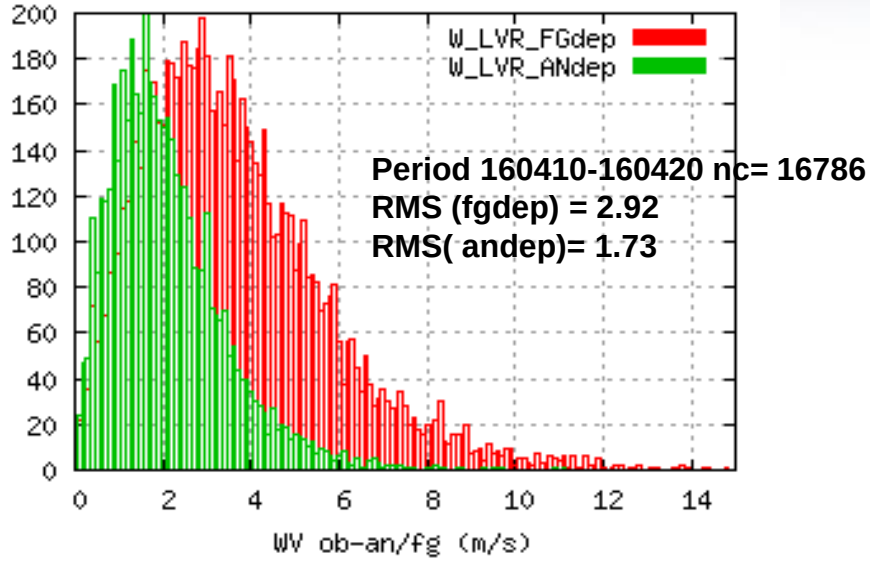


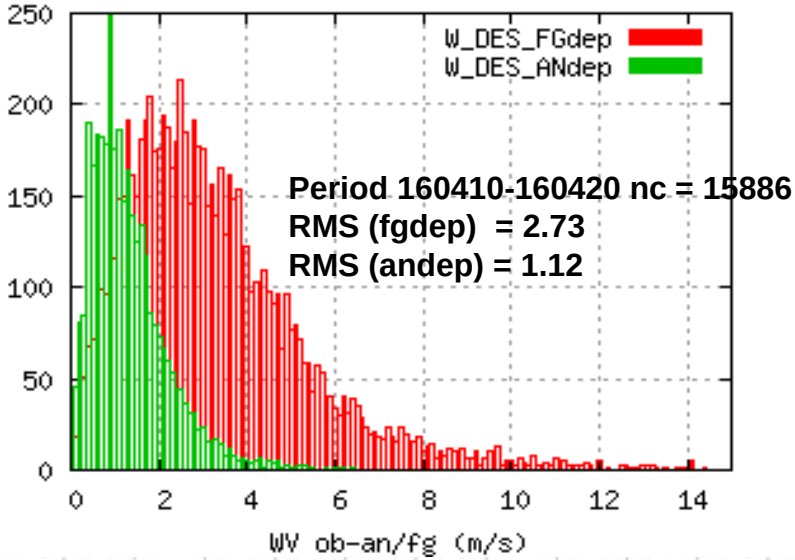
AMDAR DATA EVALUATION



AMDAR DATA EVALUATION

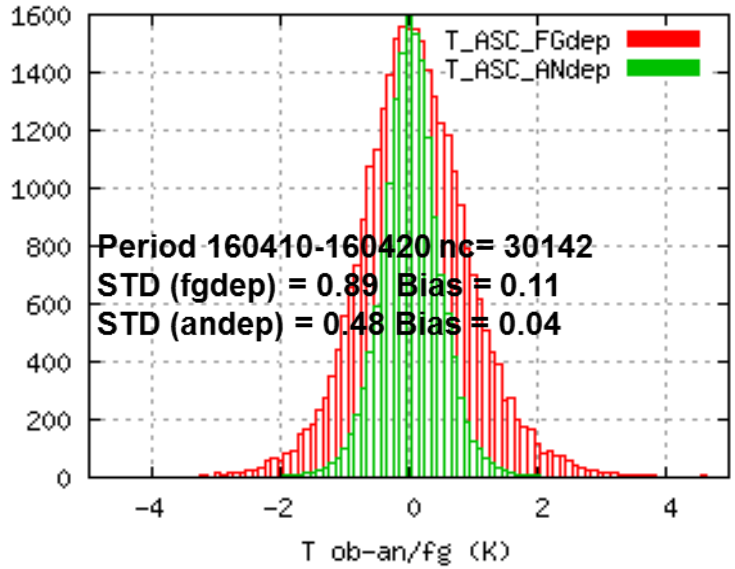


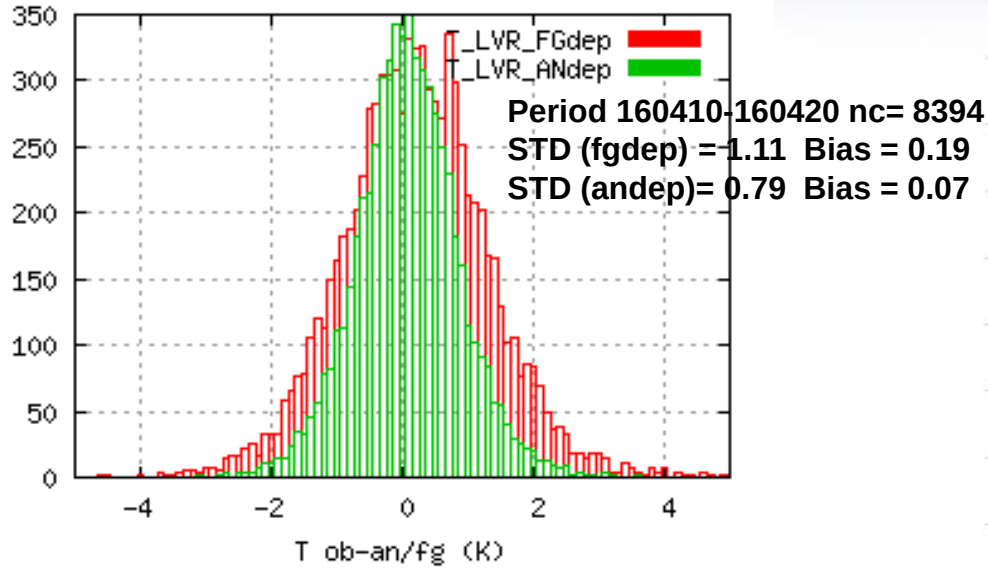


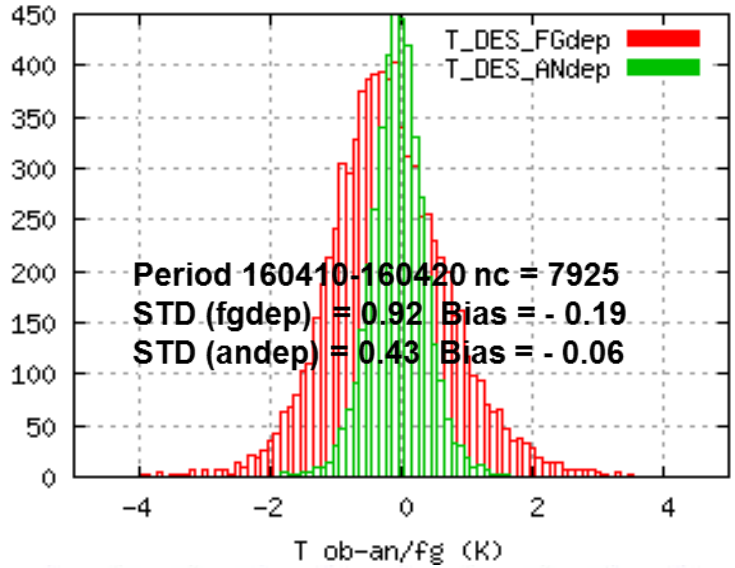


"ob – fg" statistics indicate that AMDAR wind data accuracy is indeed within specifications of ~ 4 kt

AMDAR DATA EVALUATION

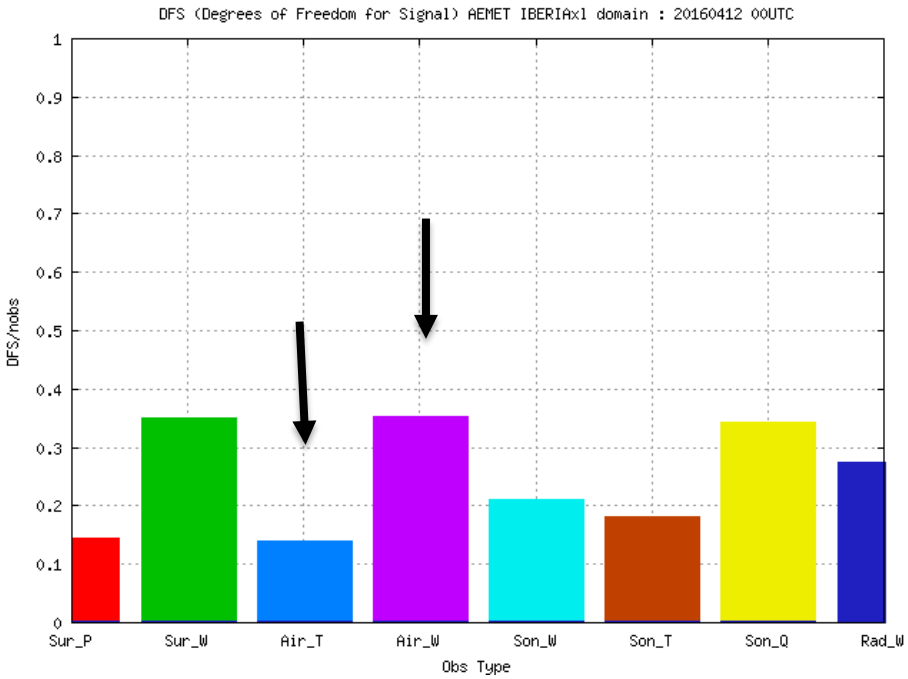
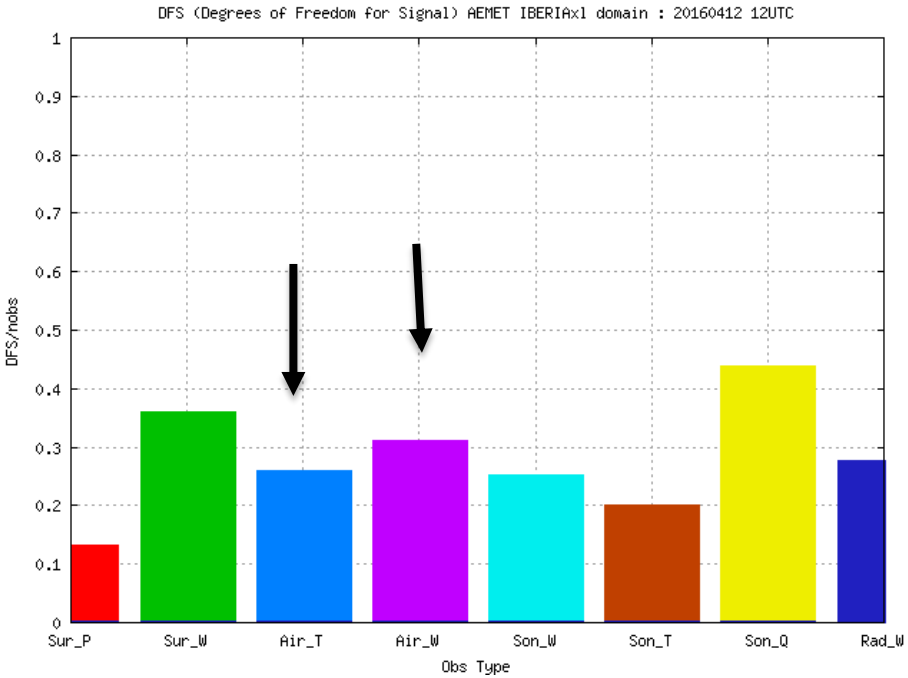






These statistics are also compatible with the specified accuracy for AMDAR T data of 0.5 K

AMDAR DATA IMPACT

Degrees of Freedom for Signal , one Data Assimilation Diagnostic Tool

- ✓ Assimilation of AMDAR data is currently a fundamental component of AEMET upper-air NWP 3D-Var data assimilation system