École Doctorale des Sciences de l'Environnement d'Île-de-France
Année 2007-2008

Modélisation Numérique de l'Écoulement Atmosphérique et Assimilation d'Observations

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Cours 3
29 Avril 2008

Centre Européen pour les Prévisions Météorologiques à Moyen Terme (CEPMMT, Reading, GB)

(European Centre for Medium-range Weather Forecasts, ECMWF)

Troncature triangulaire T799 (résolution horizontale ≈ 28 kilomètres)

91 niveaux dans la direction verticale (0 - 80 km)

Dimension du vecteur d'état correspondant ≈ $2{,}3\ 10^8$

Pas de discrétisation temporelle : 12 minutes

Résultats extraits de

Richardson *et al.*, 2008, *Verification statistics and evaluations of ECMWF forecasts in 2006-2007*, Memorandum Technique 547, CEPMMT, Reading, GB.

Disponible à l'adresse

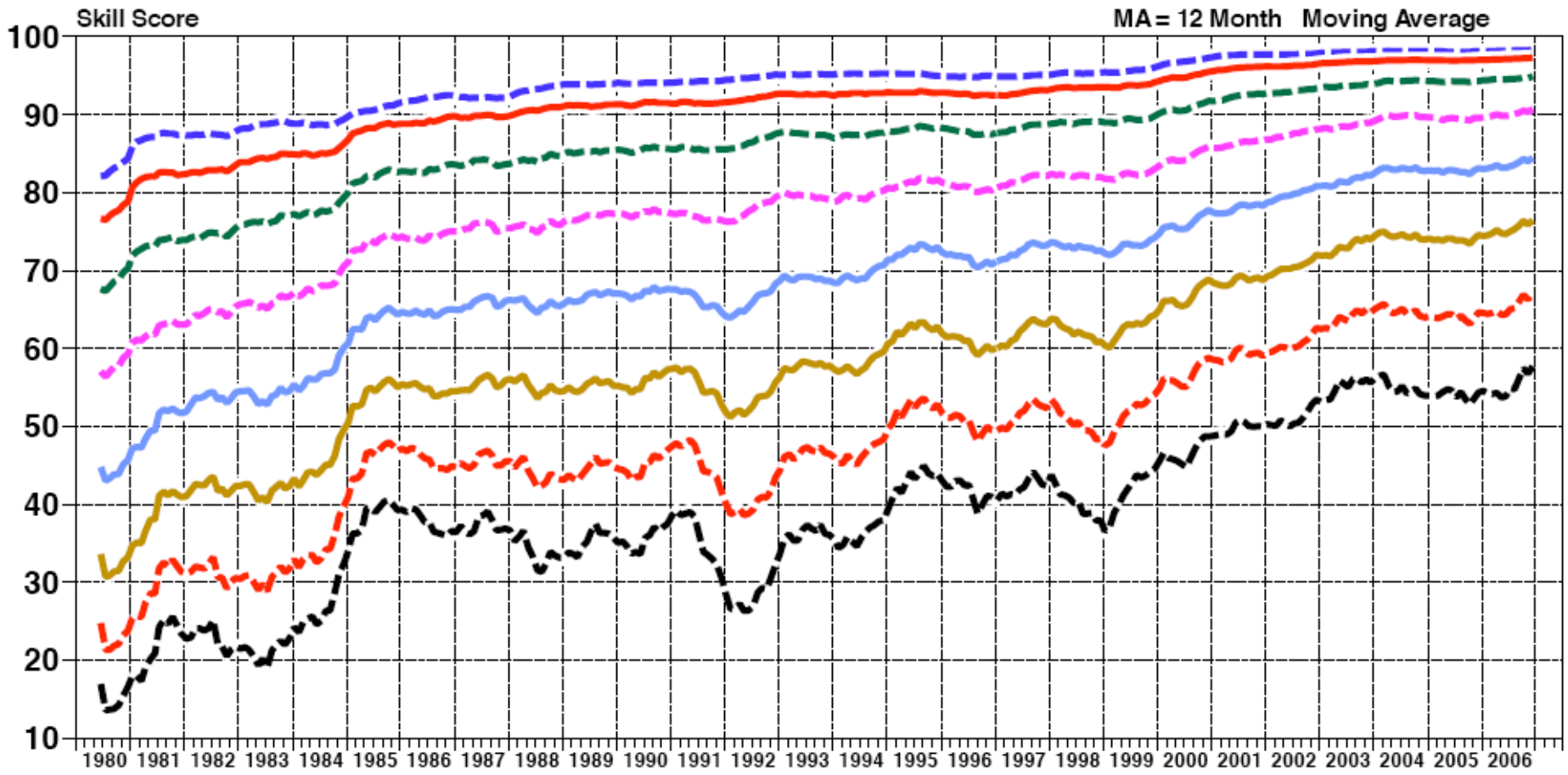
http://www.ecmwf.int/publications/library/do/references/list/14

ECMWF FORECAST VERIFICATION 12UTC

500hPa GEOPOTENTIAL

POS. ORIENTATED SKILL SCORE - RMS NORMALISED BY PERSISTENCE

N.HEM LAT 20.000 TO 90.000 LON -180.000 TO 180.000



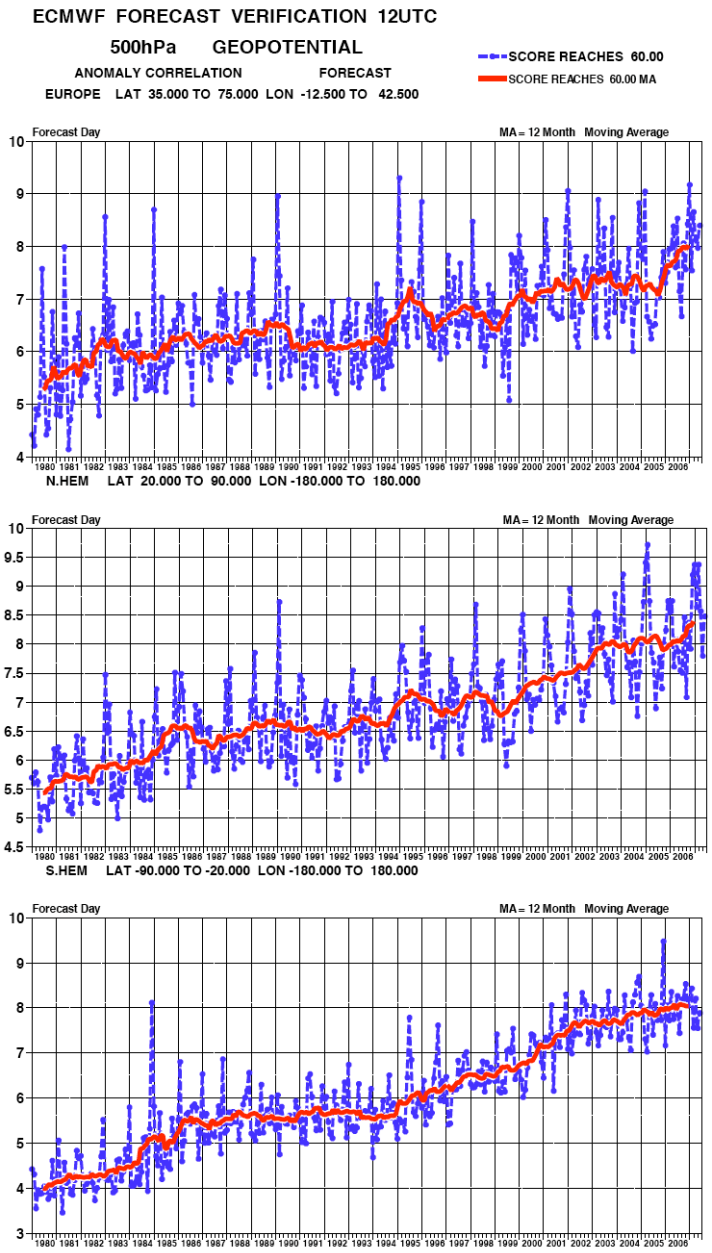


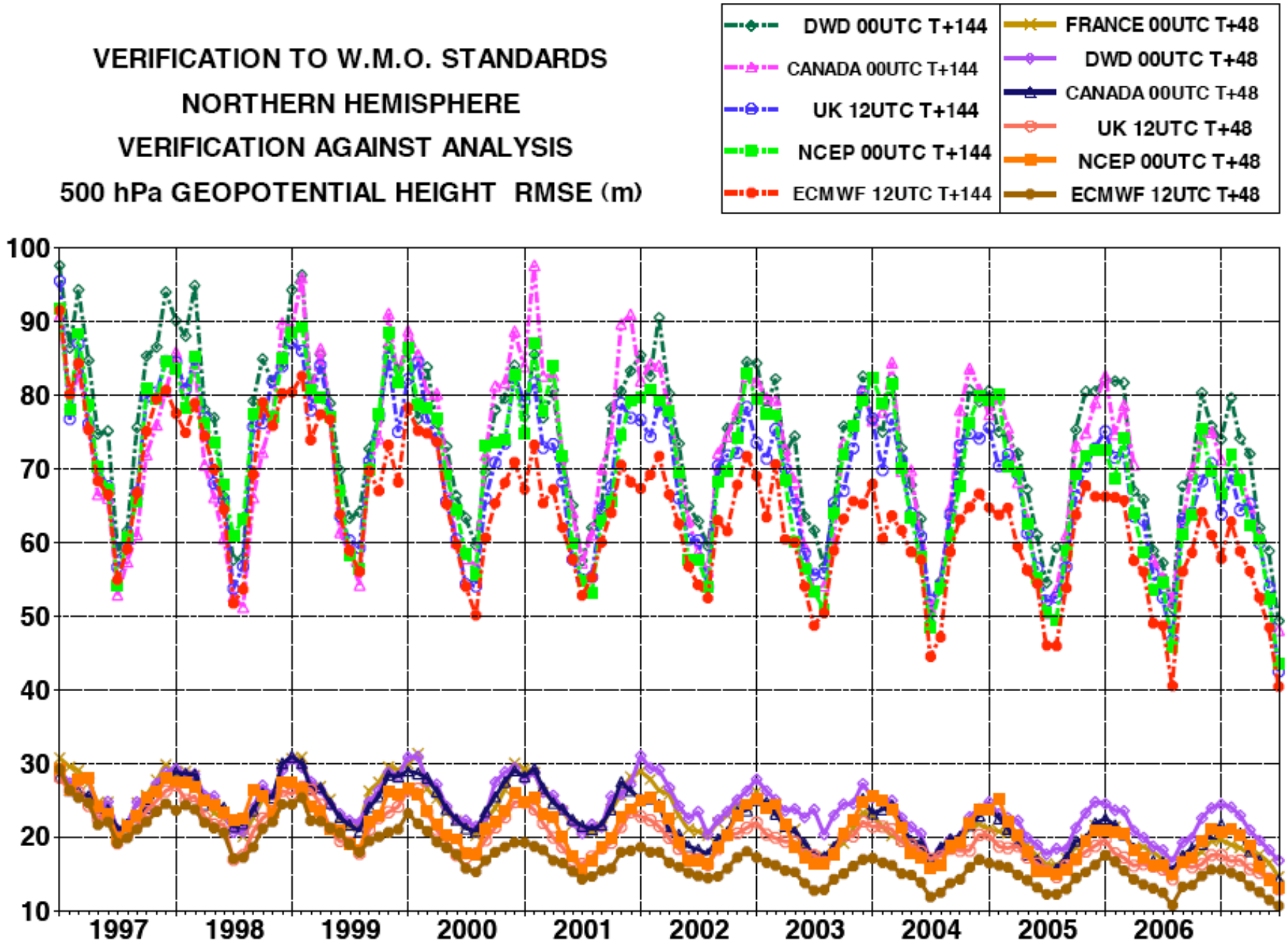
Figure 2: Evolution with time of the 500hPa height forecast performance – each point on the blue curves is the forecast range at which the monthly average of the forecast anomaly correlation with the verifying

VERIFICATION TO W.M.O. STANDARDS

NORTHERN HEMISPHERE

VERIFICATION AGAINST ANALYSIS

500 hPa GEOPOTENTIAL HEIGHT RMSE (m)

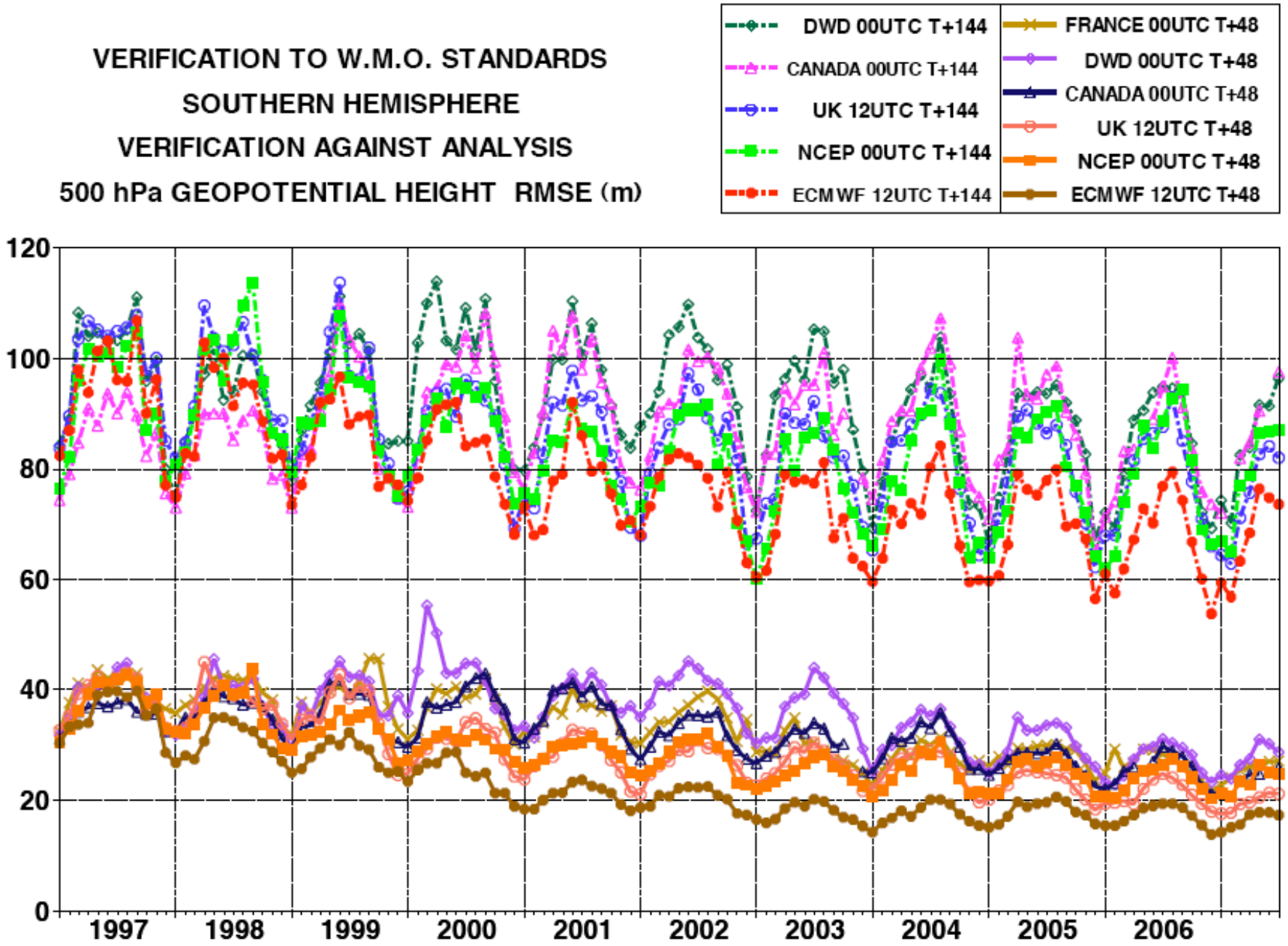


VERIFICATION TO W.M.O. STANDARDS

SOUTHERN HEMISPHERE

VERIFICATION AGAINST ANALYSIS

500 hPa GEOPOTENTIAL HEIGHT RMSE (m)



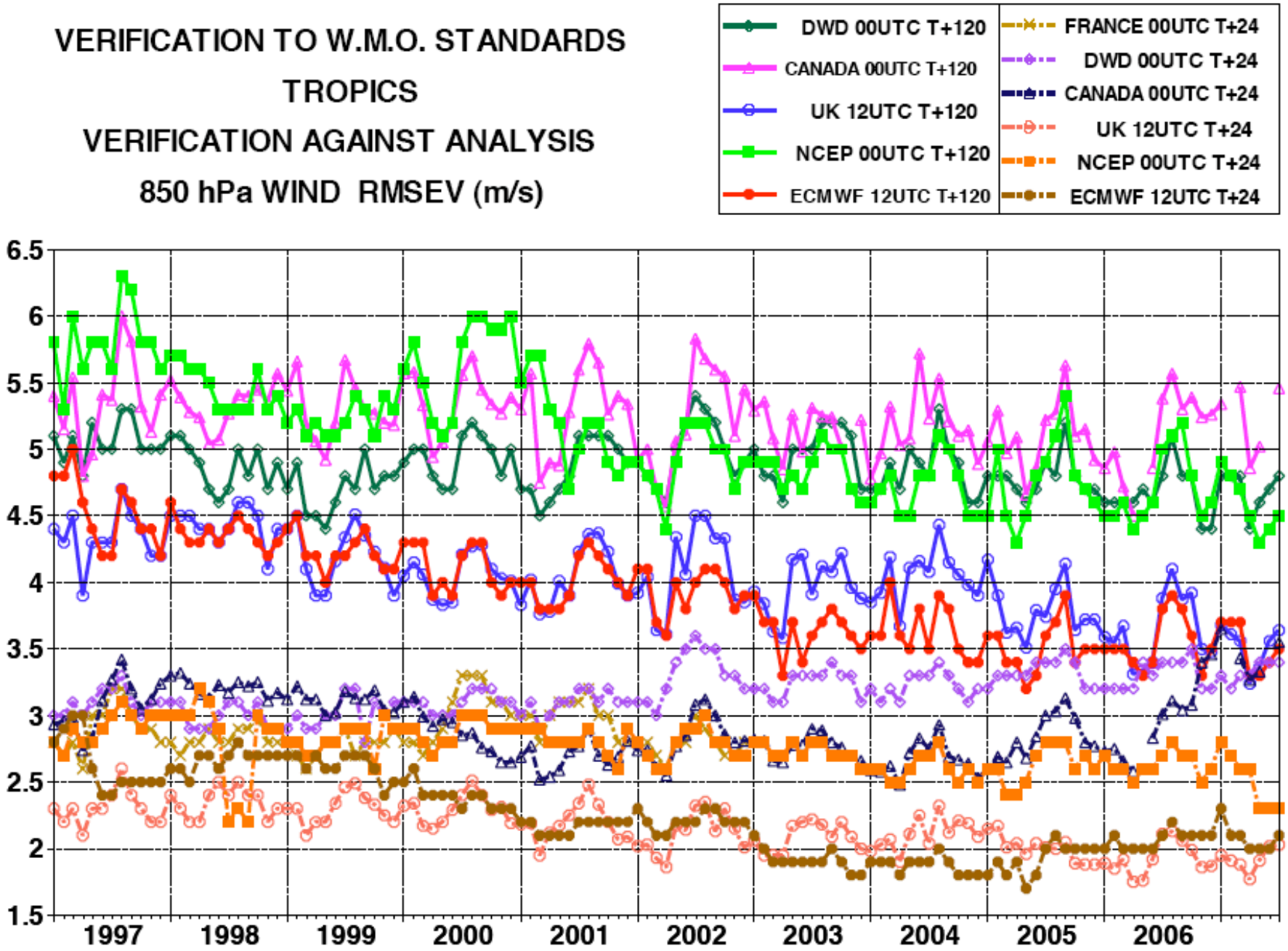


Figure 14: WMO/CBS exchanged scores (RMS vector error over the tropics, 250hPa and 850hPa wind forecast for day 1 and day 5).

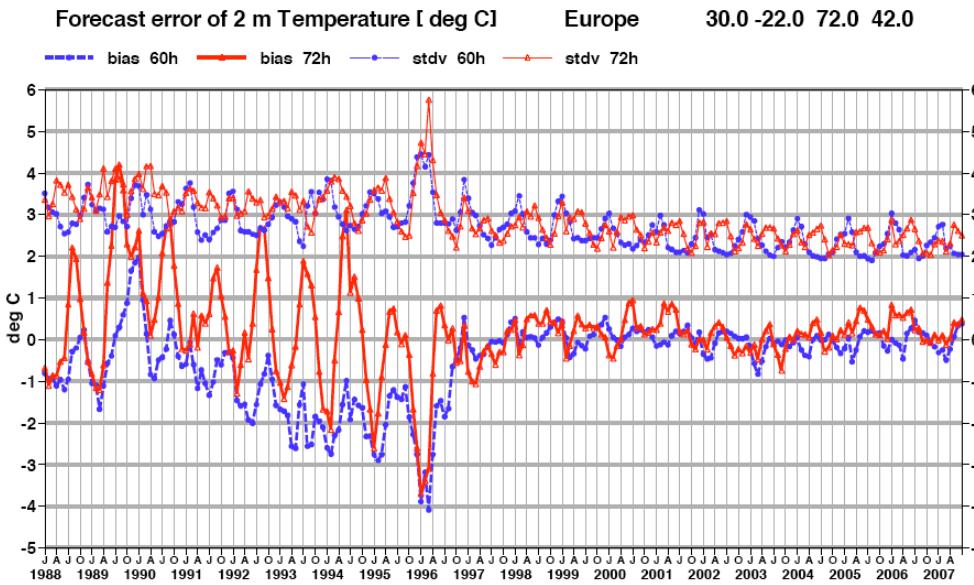


Figure 15: Verification of 2 metre temperature forecasts against European SYNOP data on the GTS for 60-hour (nighttime) and 72-hour (daytime) forecasts. Lower pair of curves are bias, upper curves are standard deviation of error.

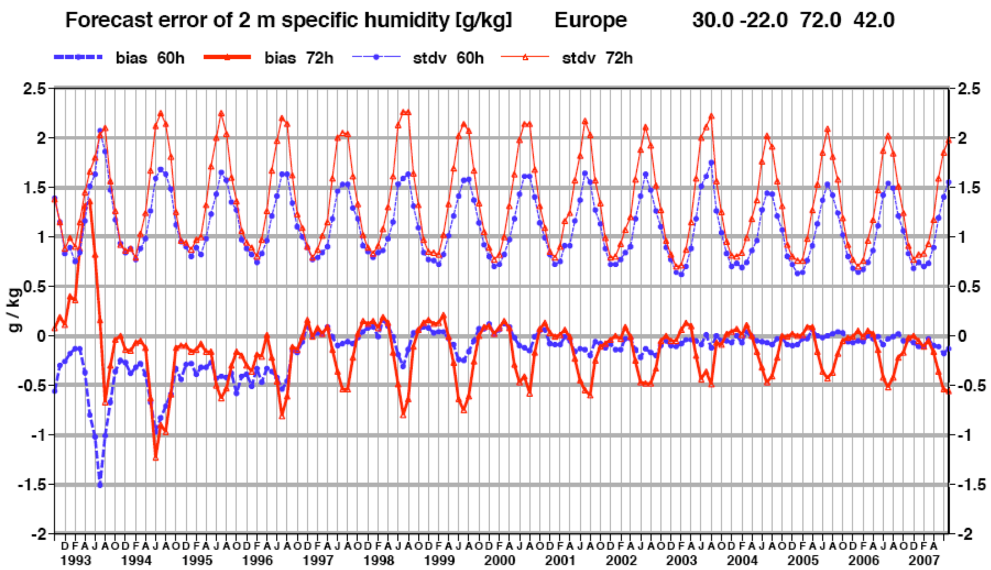


Figure 16: Verification of 2 metre specific humidity forecasts against European SYNOP data on the GTS for 60-hour (nighttime) and 72-hour (daytime) forecasts. Lower pair of curves are bias, upper curves are standard deviation of error.

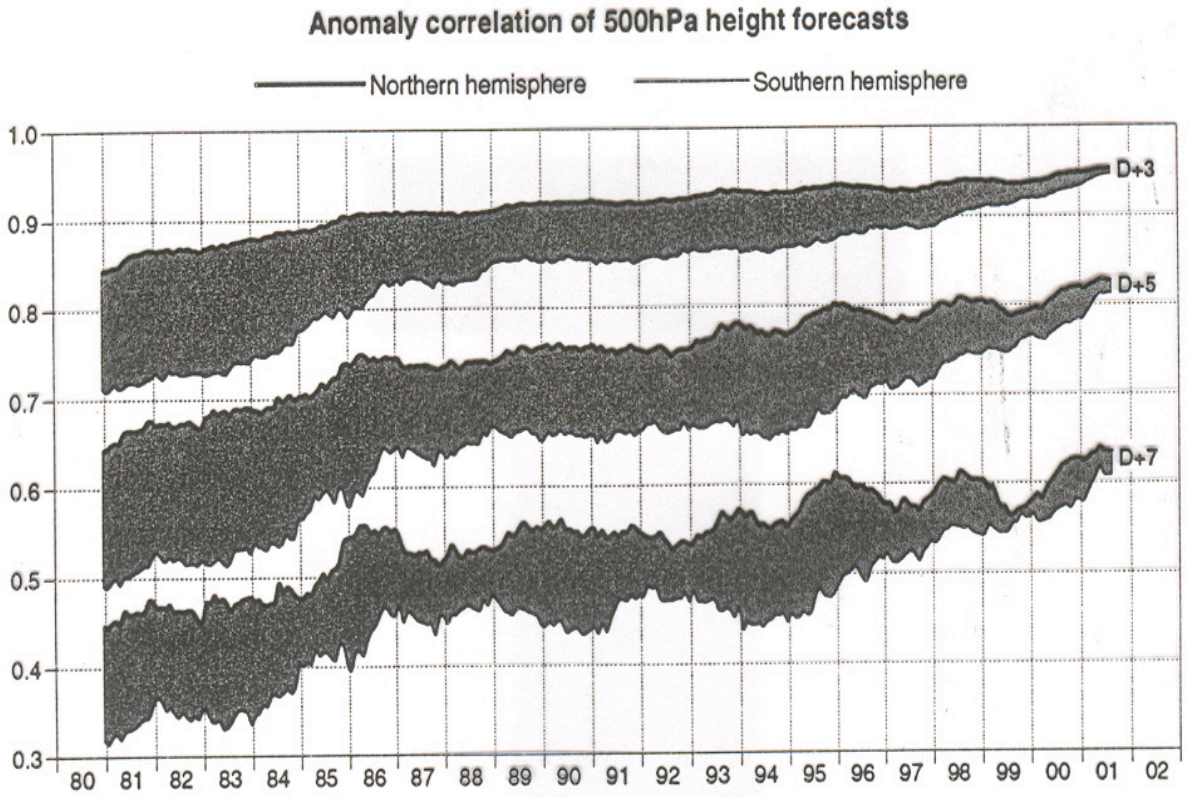


Fig 4. Anomaly correlation coefficients of 3-, 5- and 7-day ECMWF 500hPa height forecasts for the extratropical northern and southern hemispheres, plotted in the form of annual running means of archived monthly-mean scores for the period from January 1980 to August 2001. Values plotted for a particular month are averages over that month and the 11 preceding months. The shading shows the differences in scores between the two hemispheres at the forecast ranges indicated.

Simmons et Hollingsworth, 2002, *Q. J. R. Meteorol. Soc.*, **128**, 647-677

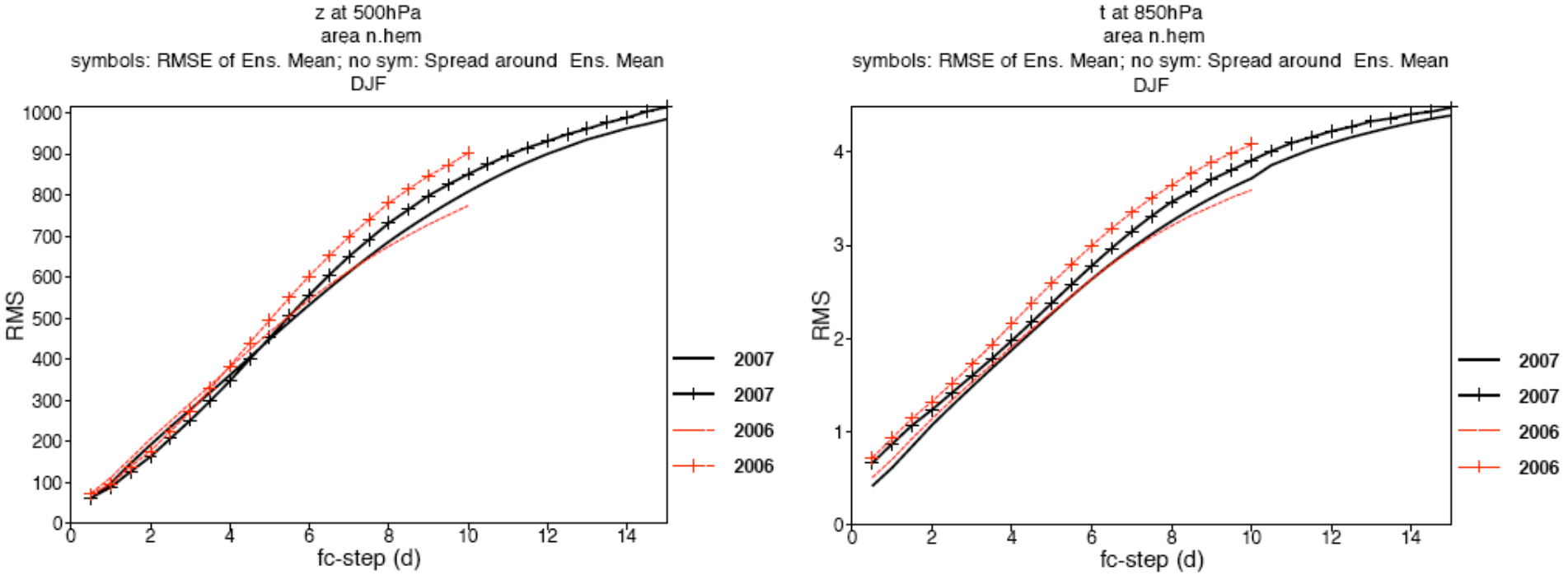


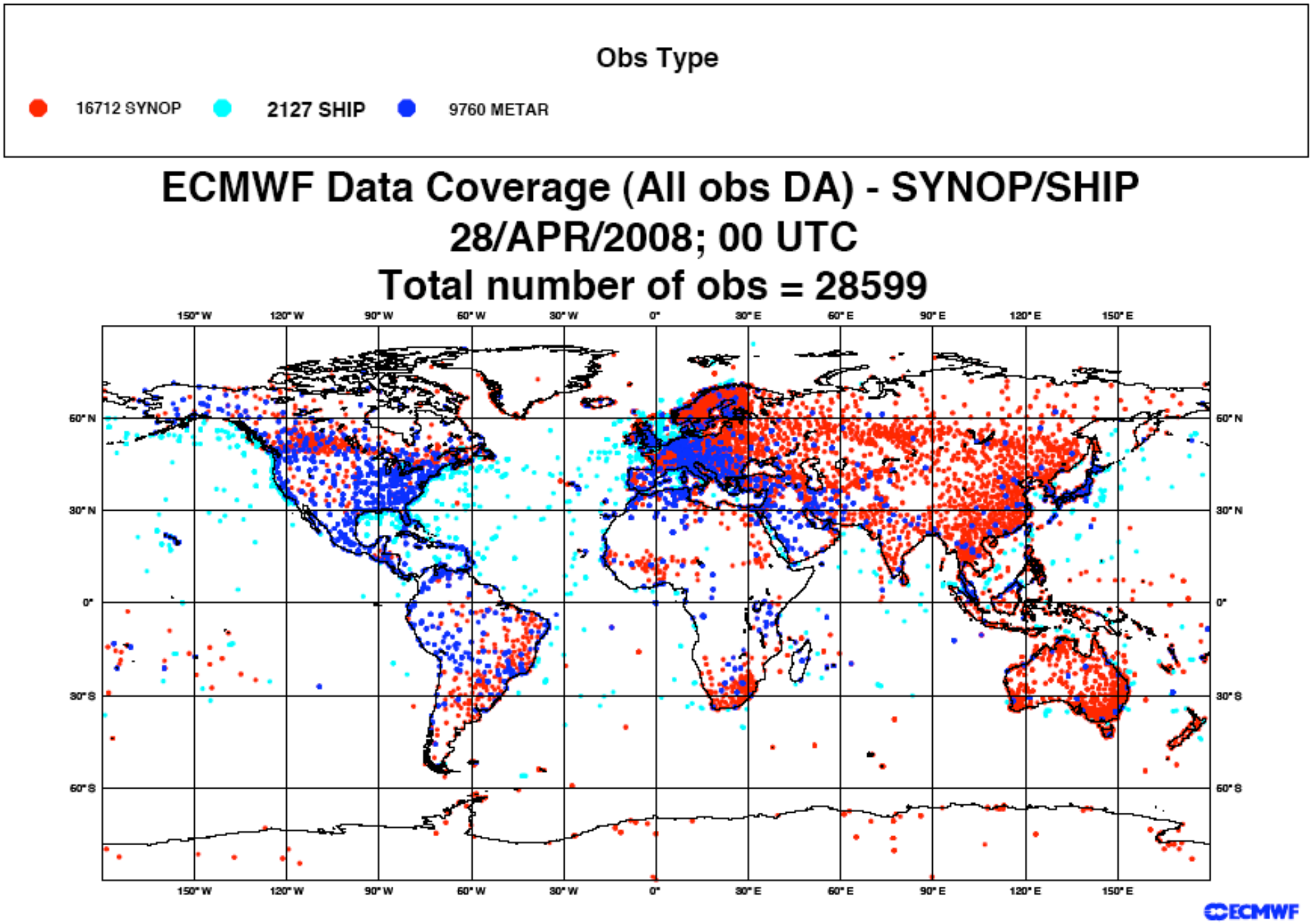
Figure 8: Ensemble spread (standard deviation) and root mean square error of ensemble-mean (lines with crosses) for 500 hPa height (left) and 850 hPa temperature (right) for winter 2006-07 (black) and 2005-06 (red) over the extra-tropical northern hemisphere.

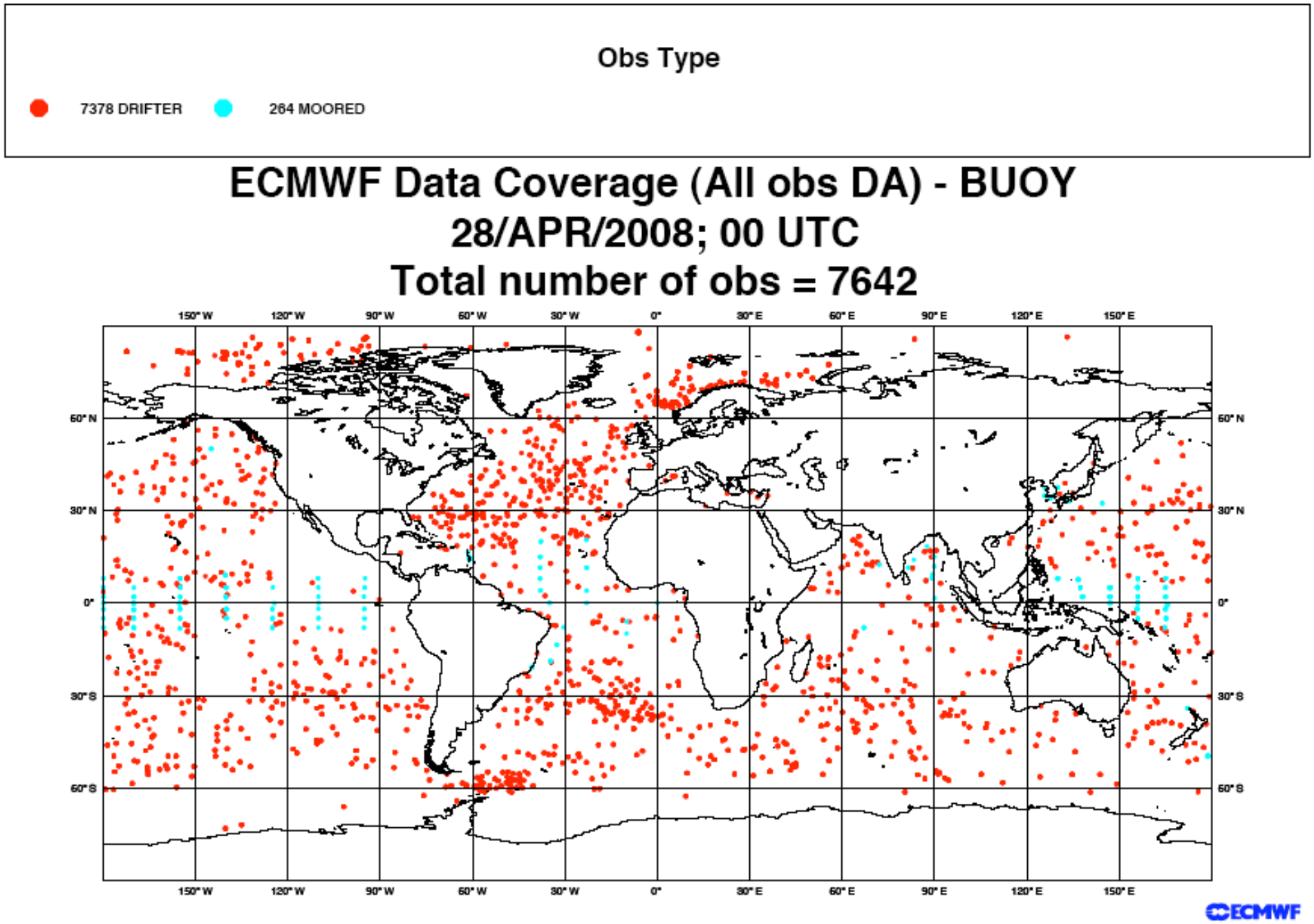
Problèmes restants

- Cycle de l'eau (évaporation, condensation, influence sur le rayonnement absorbé ou émis par l'atmosphère)

- Échanges avec l'océan ou la surface continentale (chaleur, eau, quantité de mouvement, …)

- …

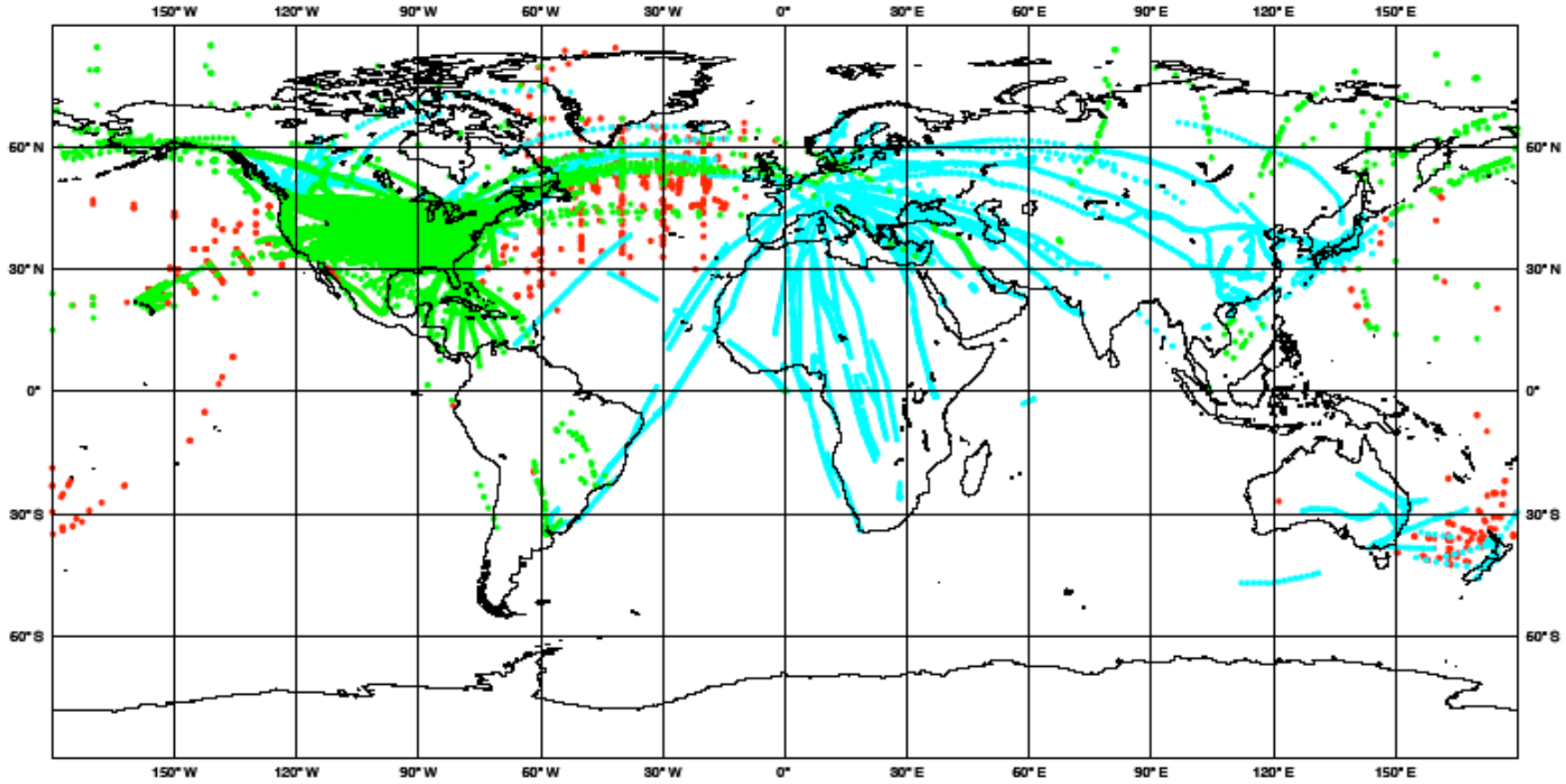

Obs Type
16712 SYNOP
2127 SHIP
9760 METAR
ECMWF Data Coverage (All obs DA) - SYNOP/SHIP
28/APR/2008; 00 UTC
Total number of obs = 28599
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF


Obs Type
7378 DRIFTER
264 MOORED
ECMWF Data Coverage (All obs DA) - BUOY
28/APR/2008; 00 UTC
Total number of obs = 7642
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF

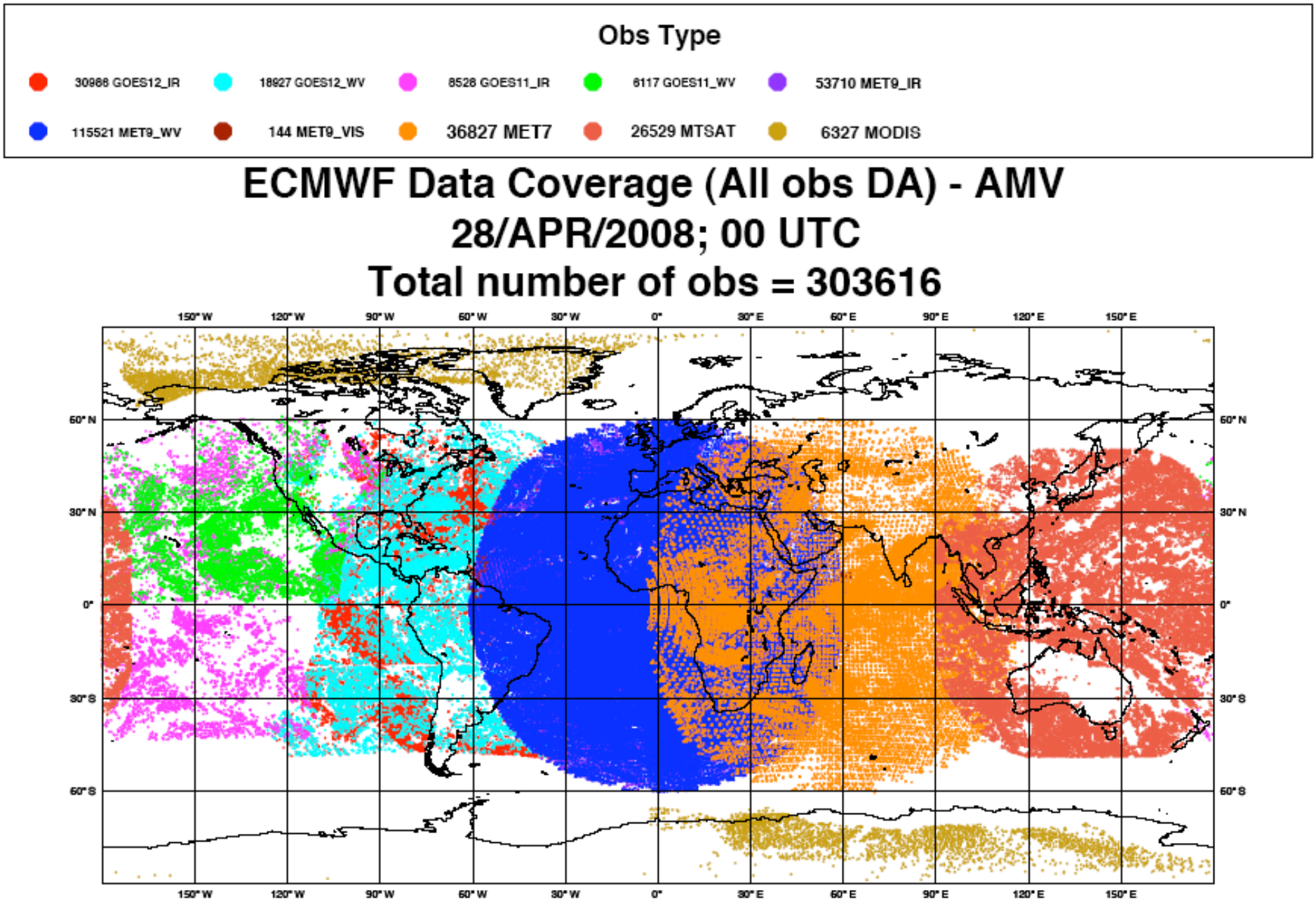
Obs Type

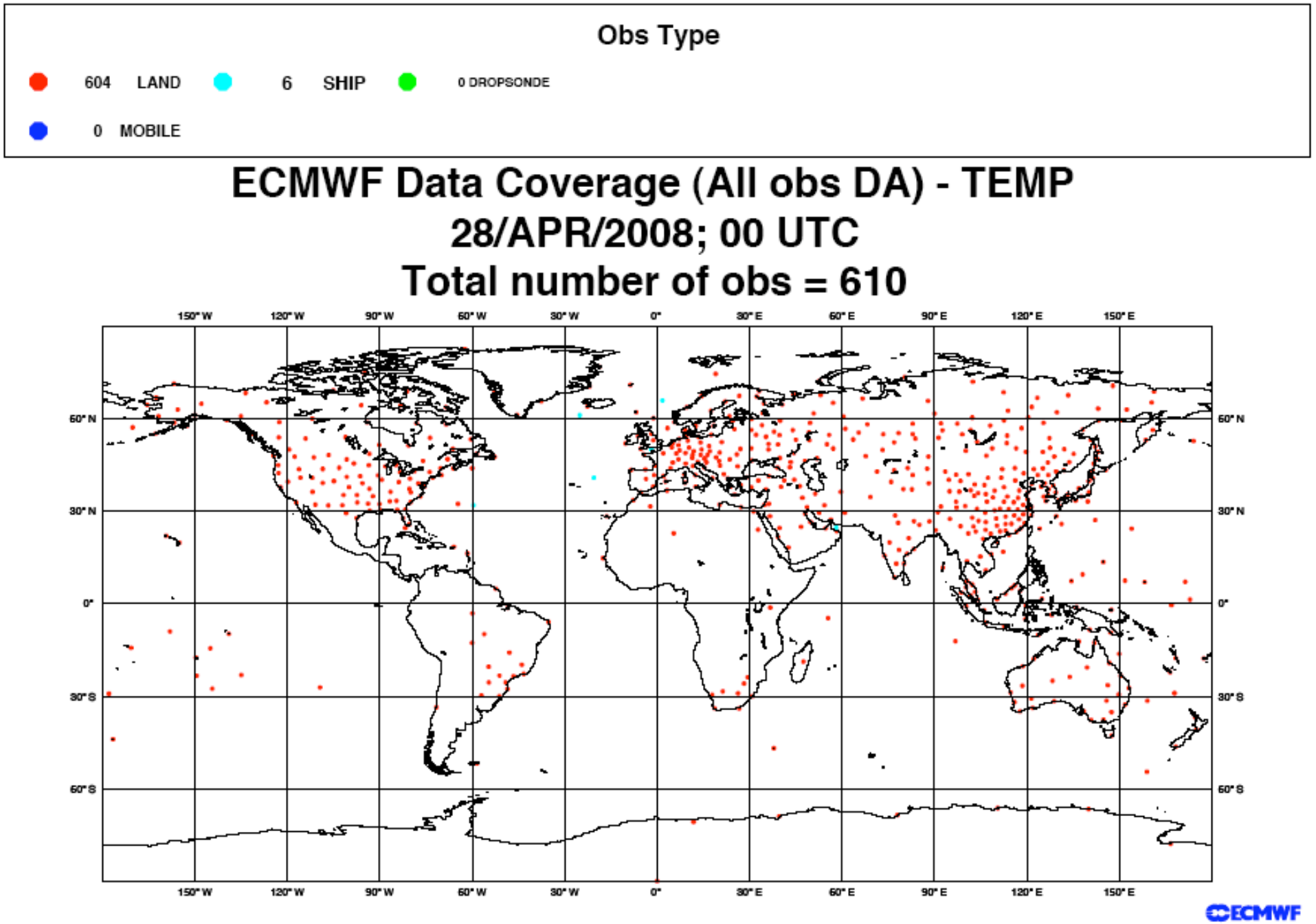
7492 AIREP 21768 AMDAR 28367 ACARS

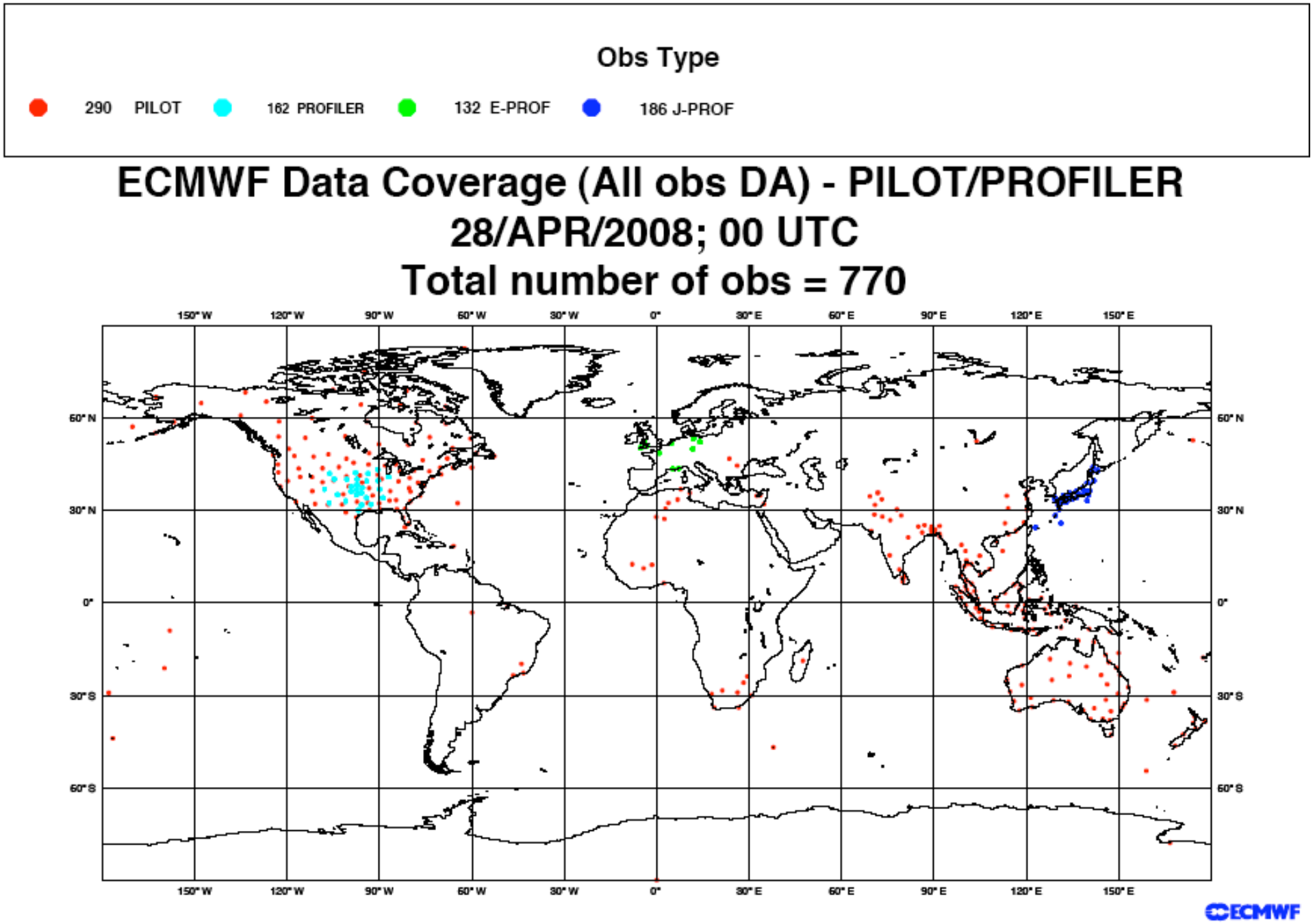
ECMWF Data Coverage (All obs DA) - AIRCRAFT
28/APR/2008; 00 UTC
Total number of obs = 57627

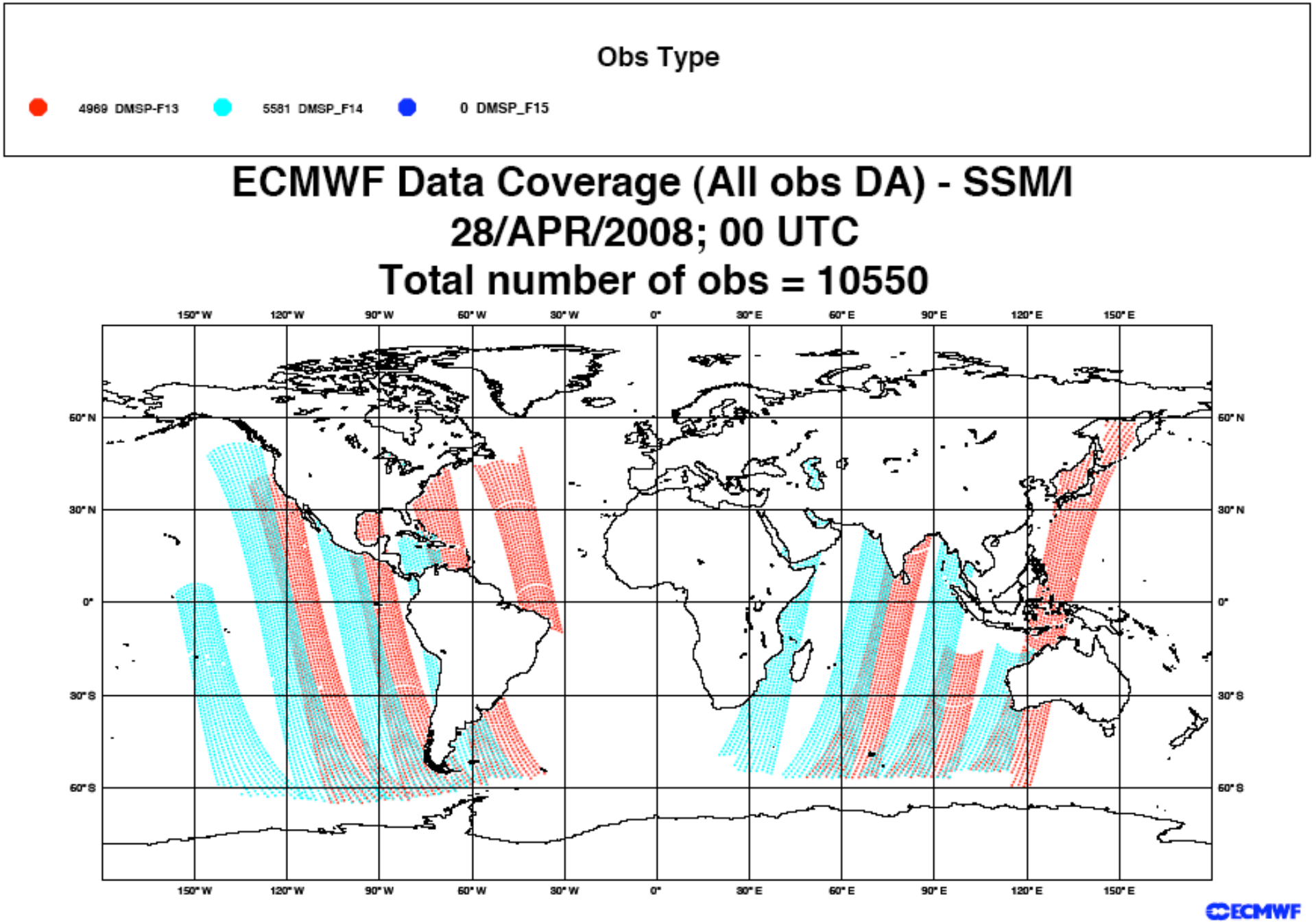


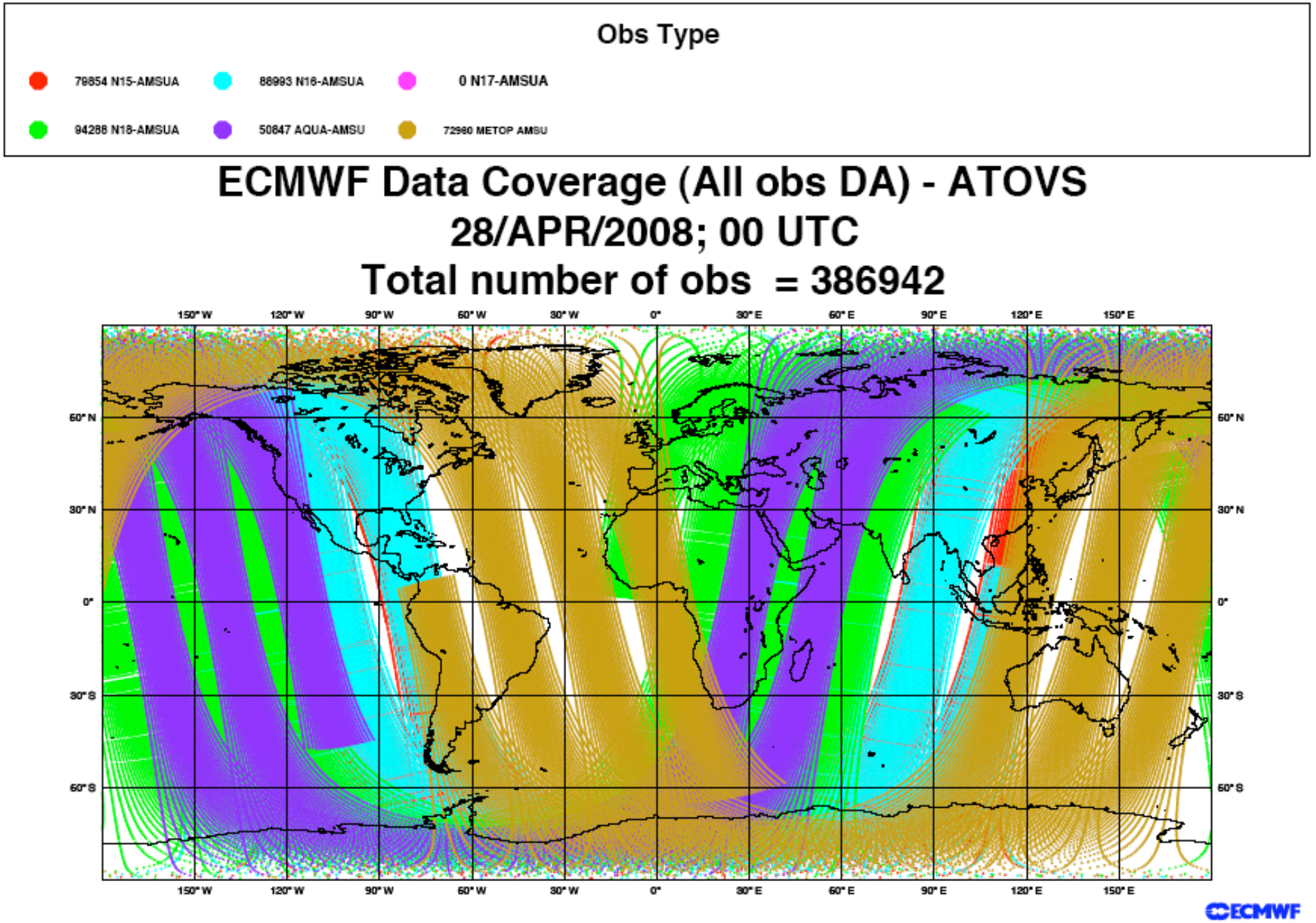
ECMWF


Obs Type
30986 GOES12_IR
18927 GOES12_WV
8528 GOES11_IR
6117 GOES11_WV
53710 MET9_IR
115521 MET9_WV
144 MET9_VIS
36827 MET7
26529 MTSAT
6327 MODIS
ECMWF Data Coverage (All obs DA) - AMV
28/APR/2008; 00 UTC
Total number of obs = 303616
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF


Obs Type
604 LAND
6 SHIP
0 DROPSONDE
0 MOBILE
ECMWF Data Coverage (All obs DA) - TEMP
28/APR/2008; 00 UTC
Total number of obs = 610
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF


Obs Type
290 PILOT
162 PROFILER
132 E-PROF
186 J-PROF
ECMWF Data Coverage (All obs DA) - PILOT/PROFILER
28/APR/2008; 00 UTC
Total number of obs = 770
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF

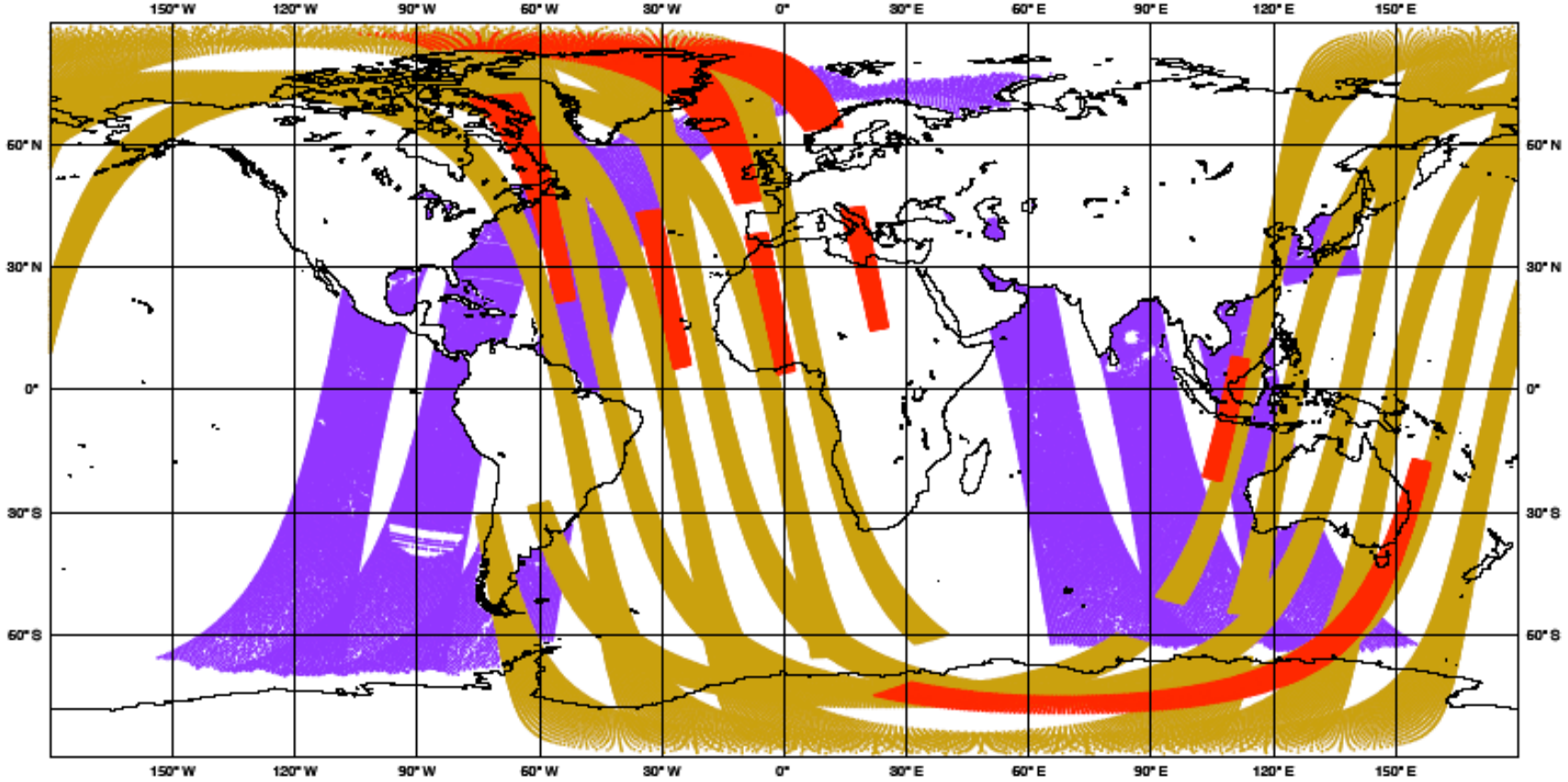

Obs Type
4969 DMSP-F13
5581 DMSP_F14
0 DMSP_F15
ECMWF Data Coverage (All obs DA) - SSM/I
28/APR/2008; 00 UTC
Total number of obs = 10550
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF


Obs Type
79854 N15-AMSUA
88993 N16-AMSUA
0 N17-AMSUA
94288 N18-AMSUA
50847 AQUA-AMSU
72960 METOP AMSU
ECMWF Data Coverage (All obs DA) - ATOVS
28/APR/2008; 00 UTC
Total number of obs = 386942
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF

Obs Type

44916 SCAT 208740 ASCAT 37544 ERS-2

ECMWF Data Coverage (All obs DA) - SCAT
28/APR/2008; 00 UTC
Total number of obs = 291200

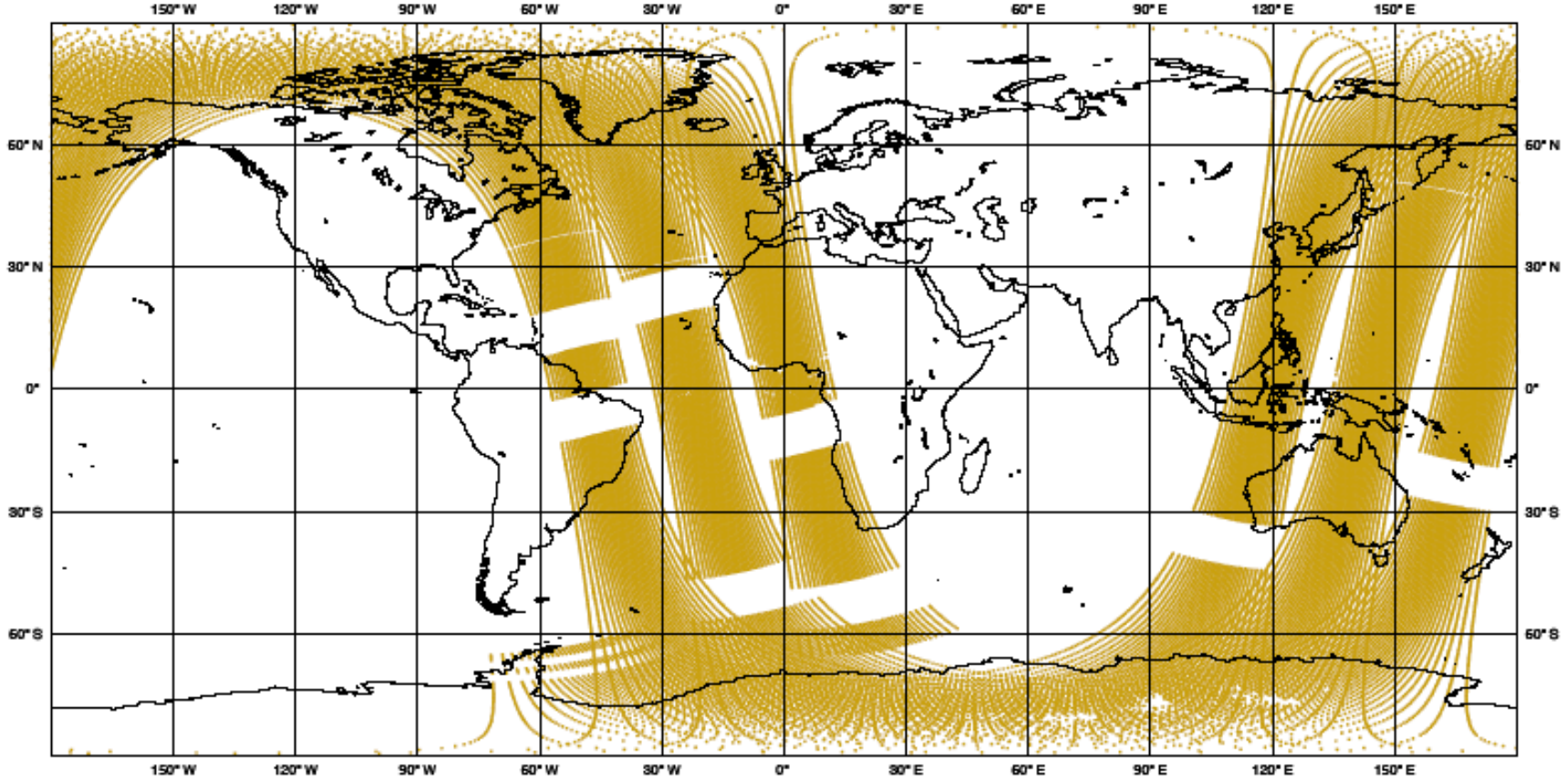


ECMWF

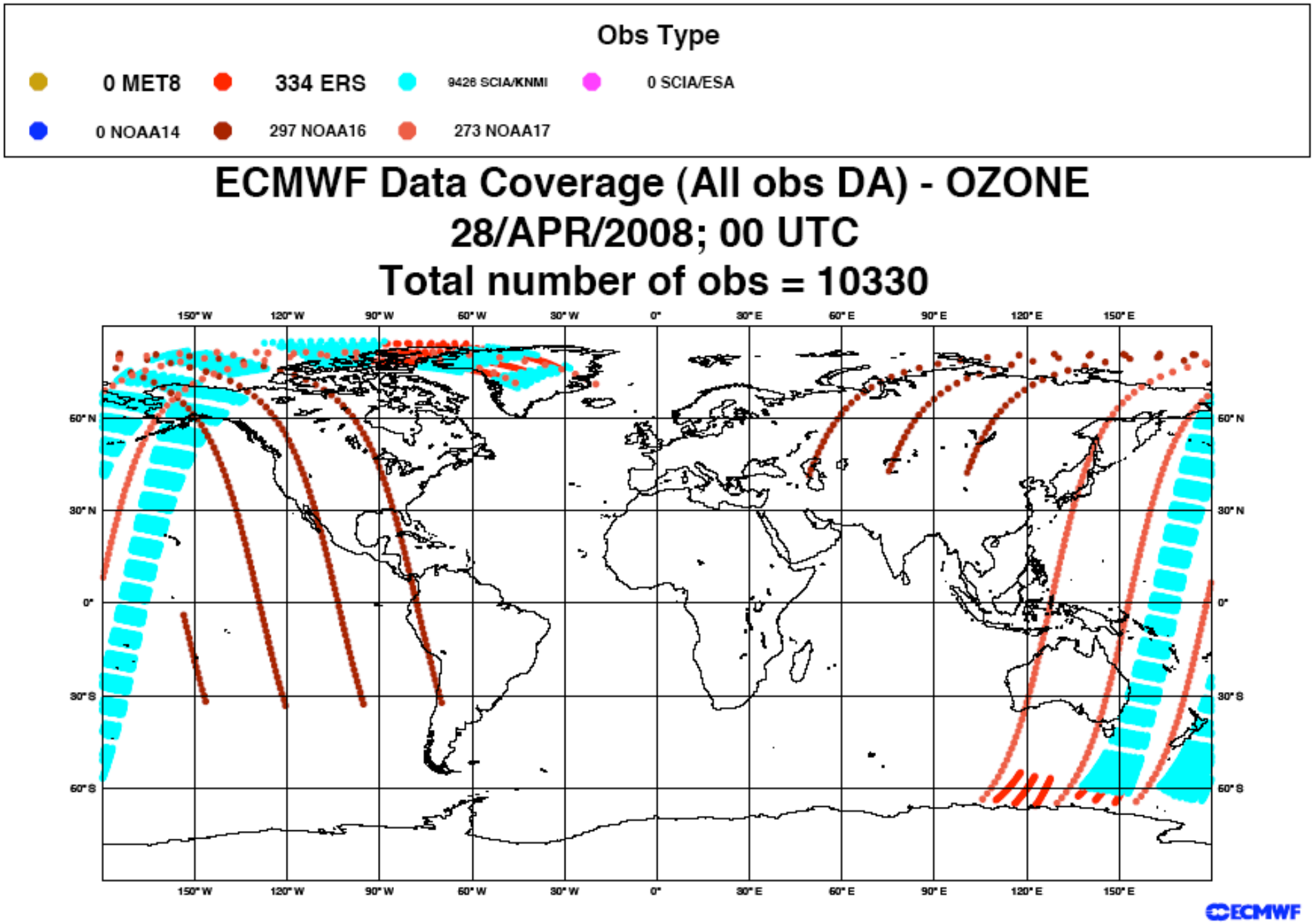
Obs Type

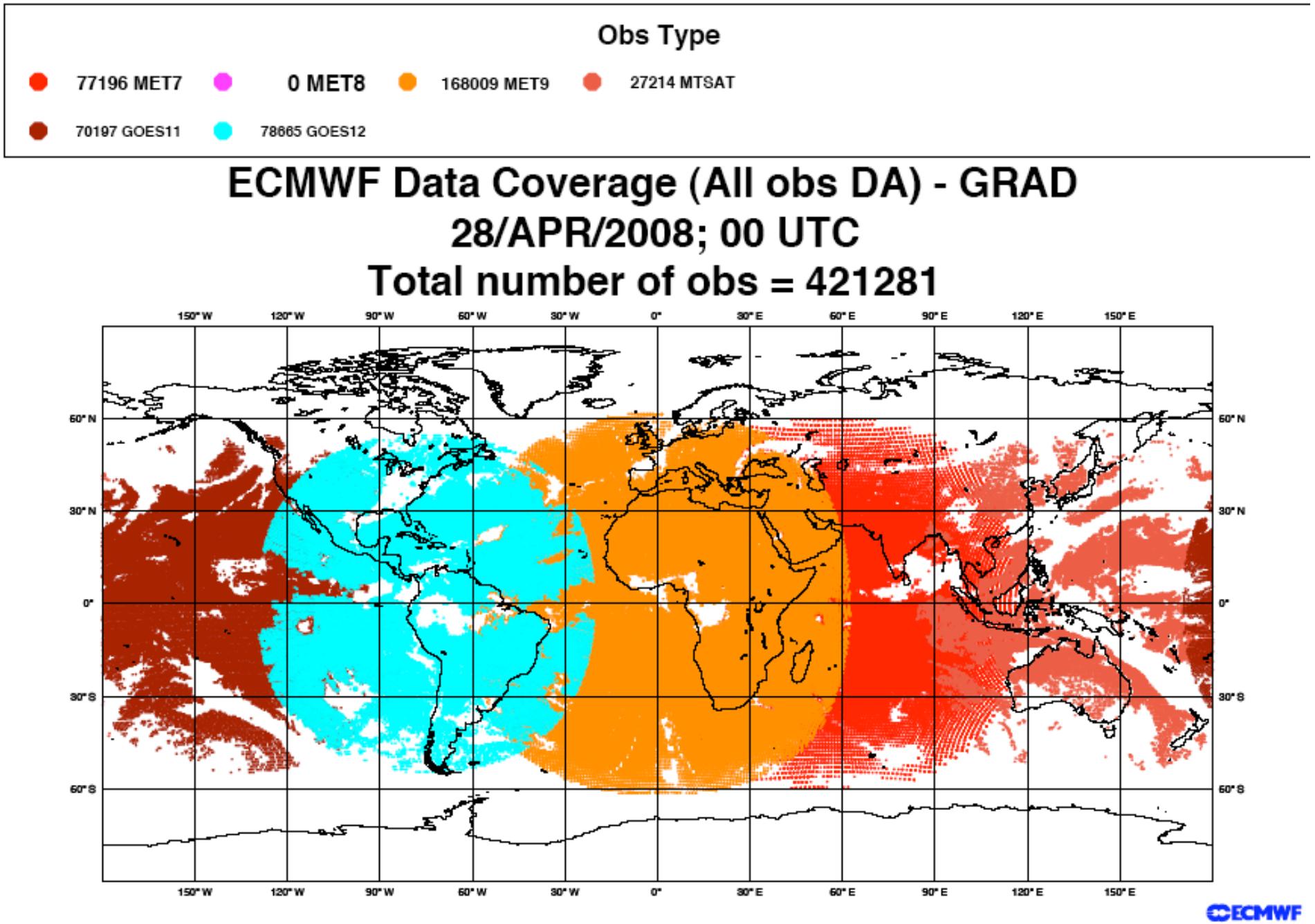
62392 METOP IASI

ECMWF Data Coverage (All obs DA) - METOP
28/APR/2008; 00 UTC
Total number of obs = 62392



ECMWF

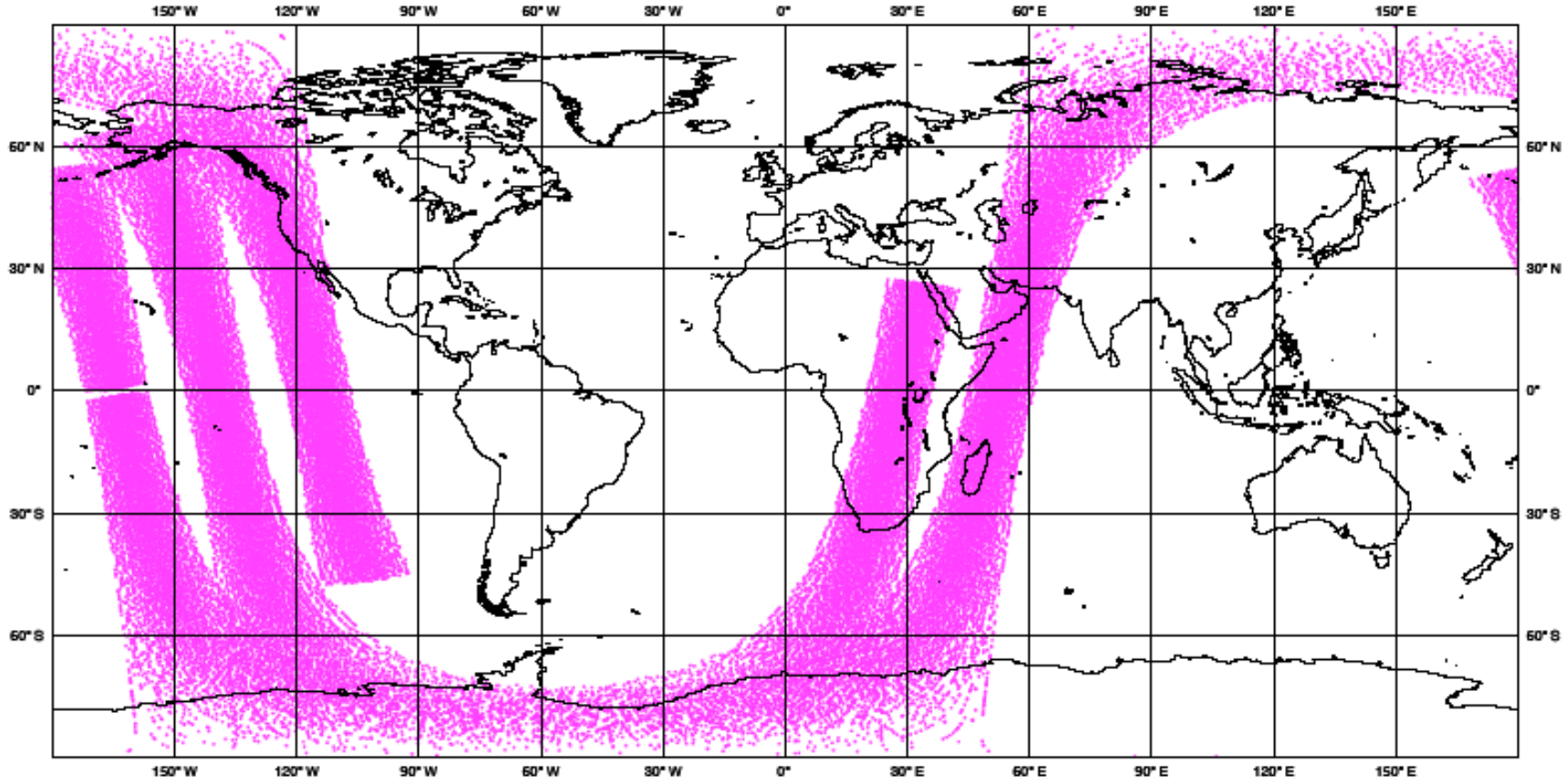

Obs Type
0 MET8
334 ERS
9426 SCIA/KNMI
0 SCIA/ESA
0 NOAA14
297 NOAA16
273 NOAA17
ECMWF Data Coverage (All obs DA) - OZONE
28/APR/2008; 00 UTC
Total number of obs = 10330
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF


Obs Type
77196 MET7
0 MET8
168009 MET9
27214 MTSAT
70197 GOES11
78665 GOES12
ECMWF Data Coverage (All obs DA) - GRAD
28/APR/2008; 00 UTC
Total number of obs = 421281
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
60° N
30° N
0°
30° S
60° S
ECMWF

Obs Type

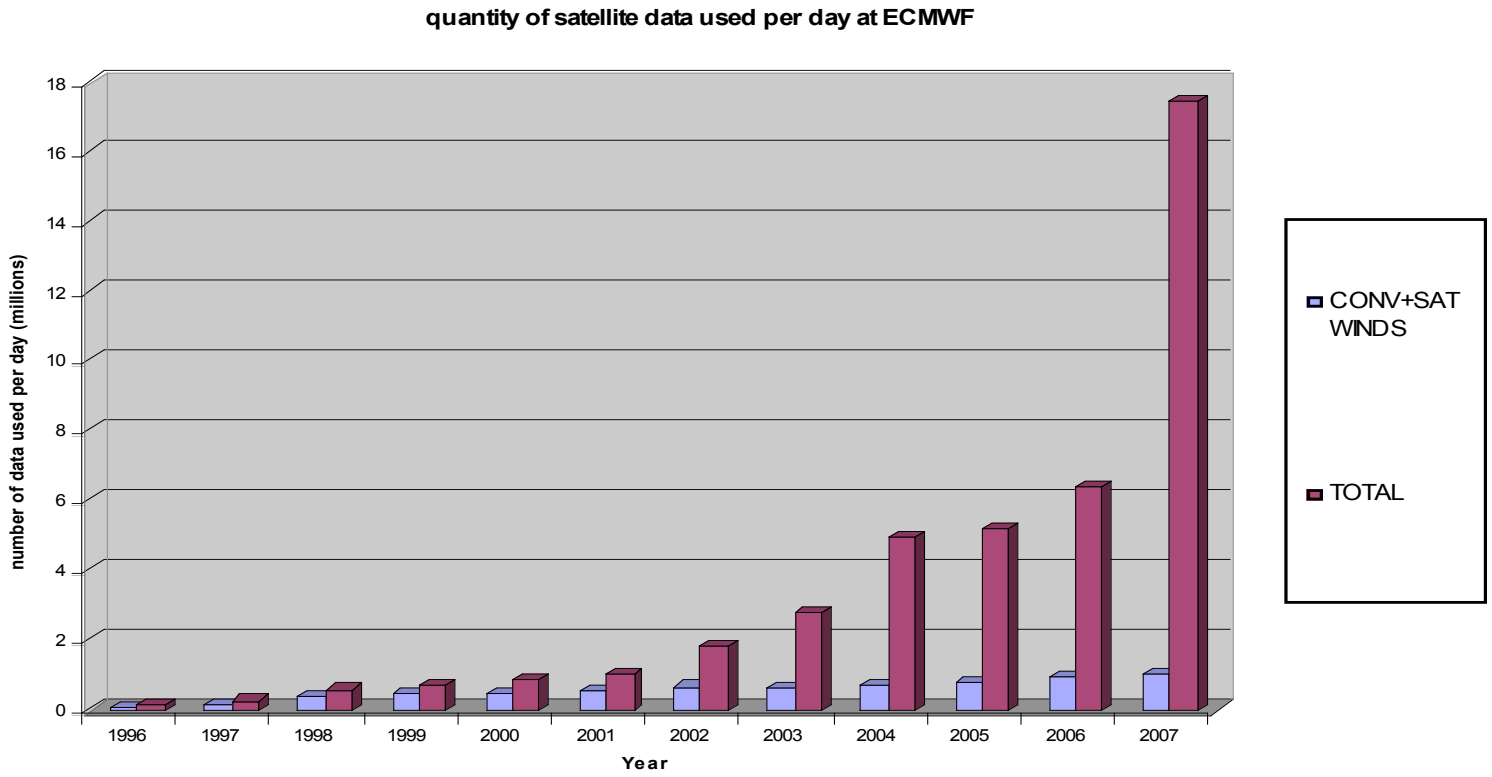
0 TERRA 45347 AQUA

ECMWF Data Coverage (All obs DA) - AIRS
28/APR/2008; 00 UTC
Total number of obs = 45347



ECMWF

December 2007: Satellite data volumes used: around 18 millions per day



- Observations *synoptiques* (observations au sol, radiosondages), effectuées simultanément, par convention internationale, dans toutes les stations météorologiques du globe (00:00, 06:00, 12:00, 18:00 TU)

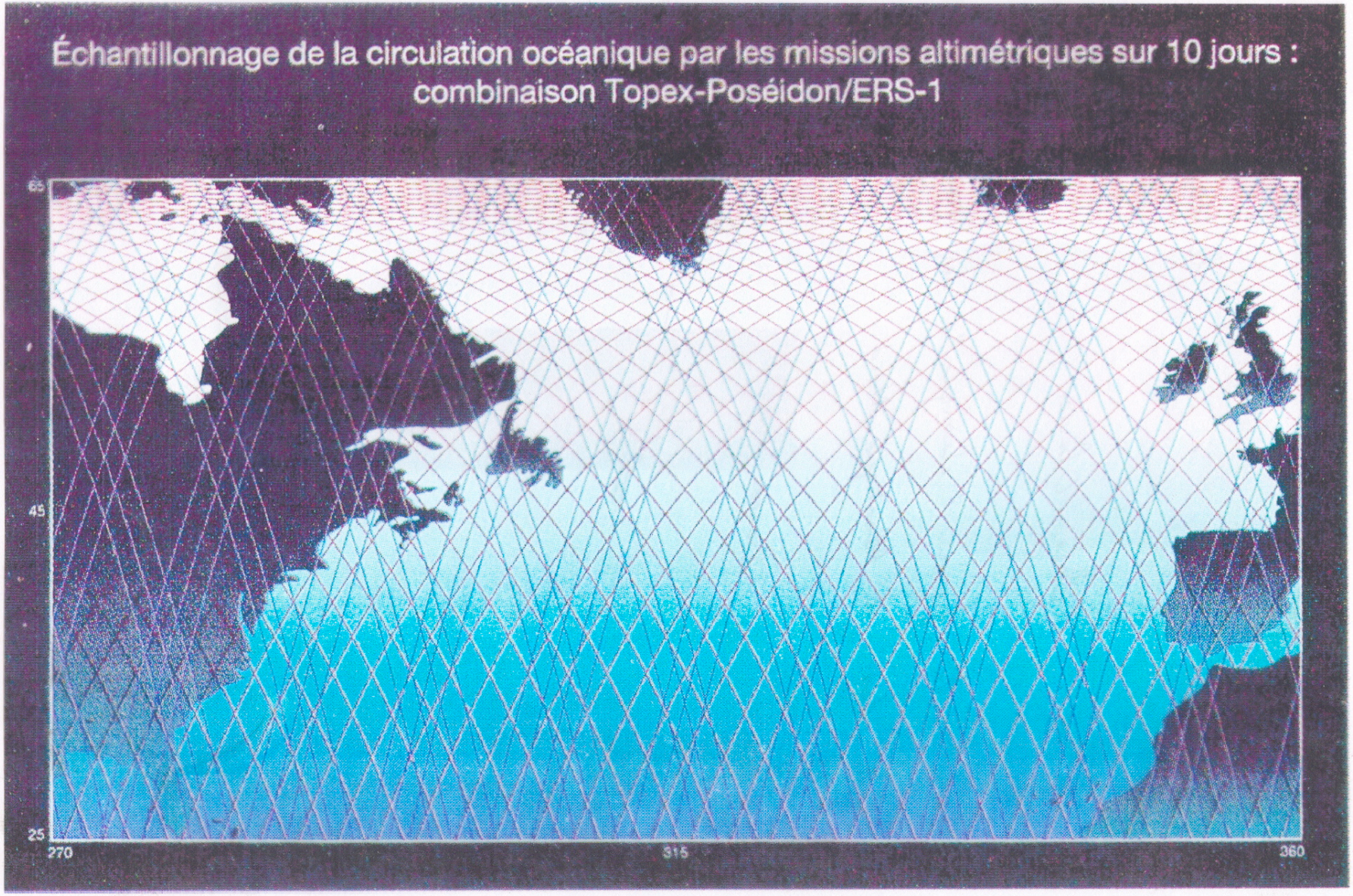
- Observations *asynoptiques* (satellites, avions), effectuées plus ou moins continûment dans le temps.

- Observations *directes* (température, pression, composantes du vent, humidité), portant sur les variables utilisées pour décrire l'état de l'écoulement dans les modèles numériques

- Observations *indirectes* (observations radiométriques, …), portant sur une combinaison plus ou moins complexe (le plus souvent, une intégrale d'espace unidimensionnelle) des variables utilisées pour décrire l'état de l'écoulement

$$y = H(\boldsymbol{x})$$

H : *opérateur d'observation* (par exemple, équation de transfert radiatif)



S. Louvel, Doctoral Dissertation, 1999

Purpose of assimilation : reconstruct as accurately as possible the state of the atmospheric or oceanic flow, using all available appropriate information. The latter essentially consists of

- The observations proper, which vary in nature, resolution and accuracy, and are distributed more or less regularly in space and time.

- The physical laws governing the evolution of the flow, available in practice in the form of a discretized, and necessarily approximate, numerical model.

- 'Asymptotic' properties of the flow, such as, *e*. *g*., geostrophic balance of middle latitudes. Although they basically are necessary consequences of the physical laws which govern the flow, these properties can usefully be explicitly introduced in the assimilation process.

Assimilation is one of many '*inverse problems*' encountered in many fields of science and technology

- solid Earth geophysics
- plasma physics
- 'nondestructive' probing
- navigation (spacecraft, aircraft, ….)
- …

Solution most often (if not always) based on Bayesian, or probabilistic, estimation. 'Equations' are fundamentally the same.

Difficulties specific to assimilation of meteorological and oceanographical observations :

- Very large numerical dimensions ($n \approx 10^6$-10^8 parameters to be estimated, $p \approx 1$-2.10^7 observations per 24-hour period). Difficulty aggravated in Numerical Weather Prediction by the need for the forecast to be ready in time.

- Non-trivial underlying dynamics