On the use of BUOY observations in the Numerical Weather Prediction data assimilation systems at Météo-France

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Outline

1. The global model ARPEGE
2. The limited area models ALADIN
3. Use of BUOY data for atmospheric and surface analyses (data monitoring and diagnostics)
4. Forecast sensitivity to observations with ARPEGE
5. Conclusions

The global model ARPEGE

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Global model ARPEGE (1)

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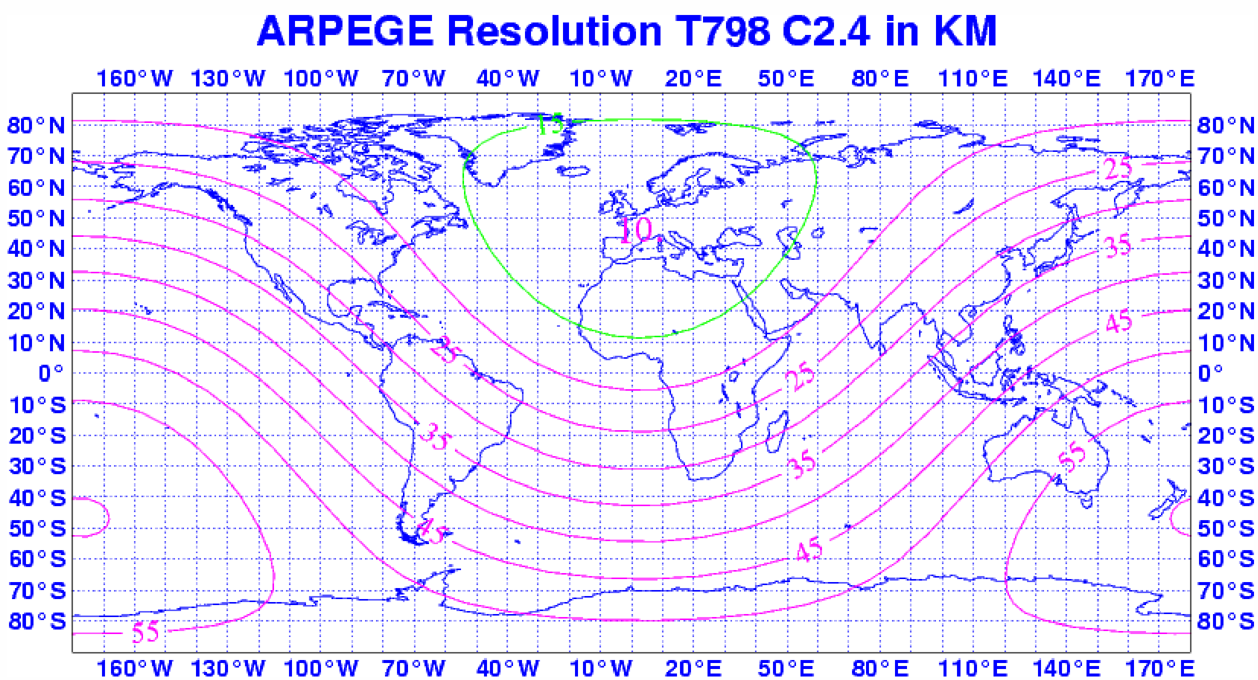
- Spectral model with variable resolution : T_L798C2.4L70
  - o Resolution from 10 km to 60 km, 70 levels from 17m to 0.05 hPa



Forecast cut-offs at 00 UTC :

Long cut-off (assimilation) : **7h30** – Short cut-off (production) : **2h15** – Very short cut-off : **1h10**

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Global model ARPEGE (2)

- 4D-Var assimilation (6h window) :

  o 2 loops of minimization : T107C1L70 (25 iterations) + T323C1L70 (25 iterations) – 2nd inner loop with simplified physics (including large scale condensation)

  o Variational bias correction scheme since 2008

  o Background error variances from an Ensemble Data Assimilation system (4D-Var at lower resolution) since 2008

  o Assimilation time slots : 1 hour

- Data used :

  o SYNOP, SHIP, **BUOY**, AIREP, AMDAR, ACARS, TEMP, PILOT

  o AMV GOES + Meteosat + MTSAT-1R, MODIS (Terra, Aqua), AVHRR/NOAA

  o HIRS, AMSU-A, AMSU-B/MHS, NOAA 15, 16, 17, 18, 19, MetOp and Aqua

  o SSMI/S DMSP F16, 17, 18, AIRS/AQUA, IASI/MetOp, GPS-RO, GPS-ZTD

  o Sea surface winds from scatterometer ASCAT/MetOp

  o Meteosat CSR

  o *SST analysis from OI scheme using SHIP and **BUOY** reports*

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Type of observations over oceans

- **Conventional observations** :

1. BUOY : surface meteorological observations from moored and drifting buoys
2. SHIP : surface meteorological observations from ships (similar to SYNOP reports over land)
3. BATHY : sea surface and below soundings
4. TESAC : Argo profiling floats

  - Measurements : Surface pressure (geopotential height), wind components, sea surface temperature, screen-level temperature and relative humidity.

- **Satellite observations** informative about the ocean surface : scatterometer derived winds (ASCAT), skin temperature (AVHRR, MODIS)

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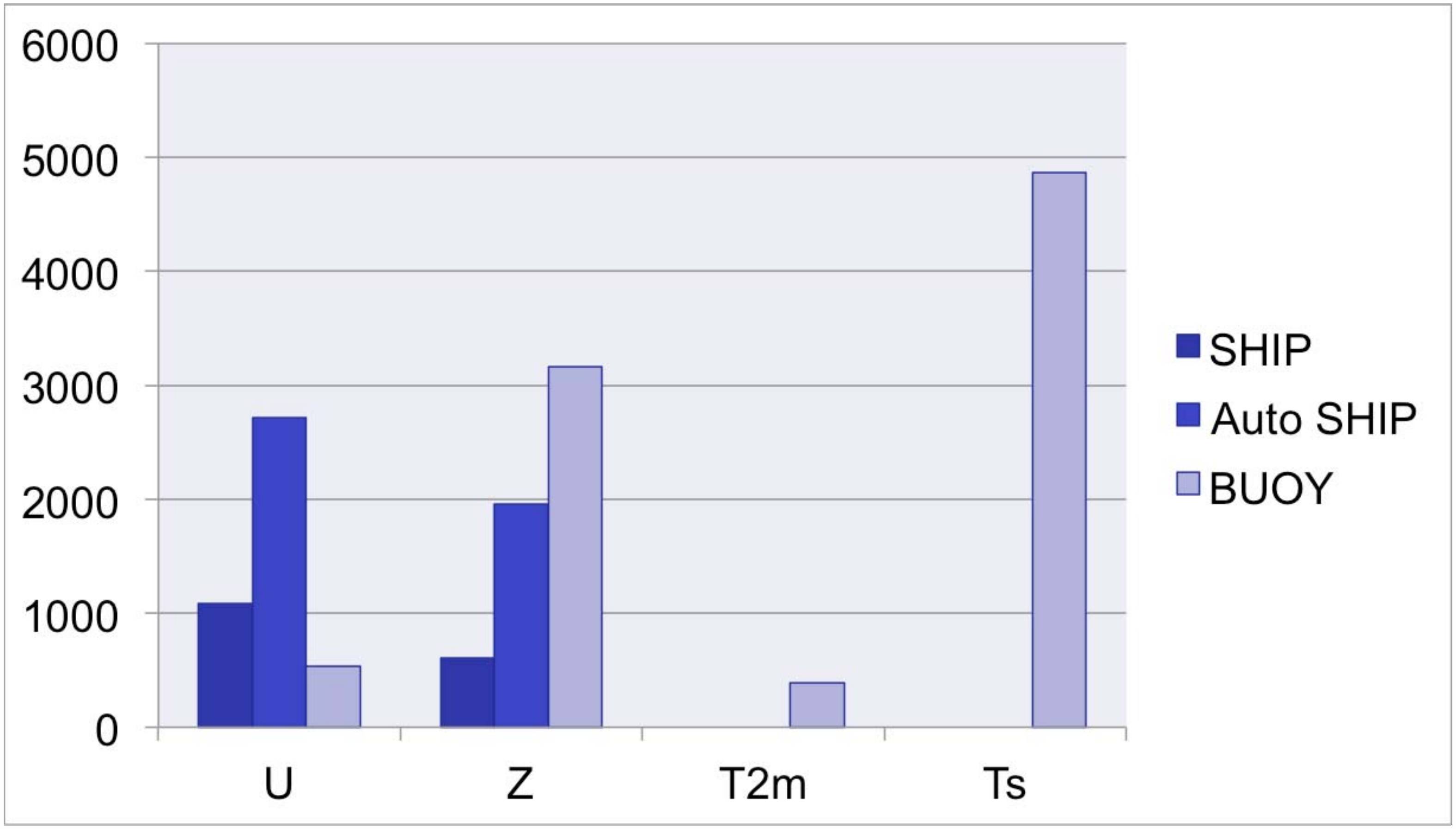
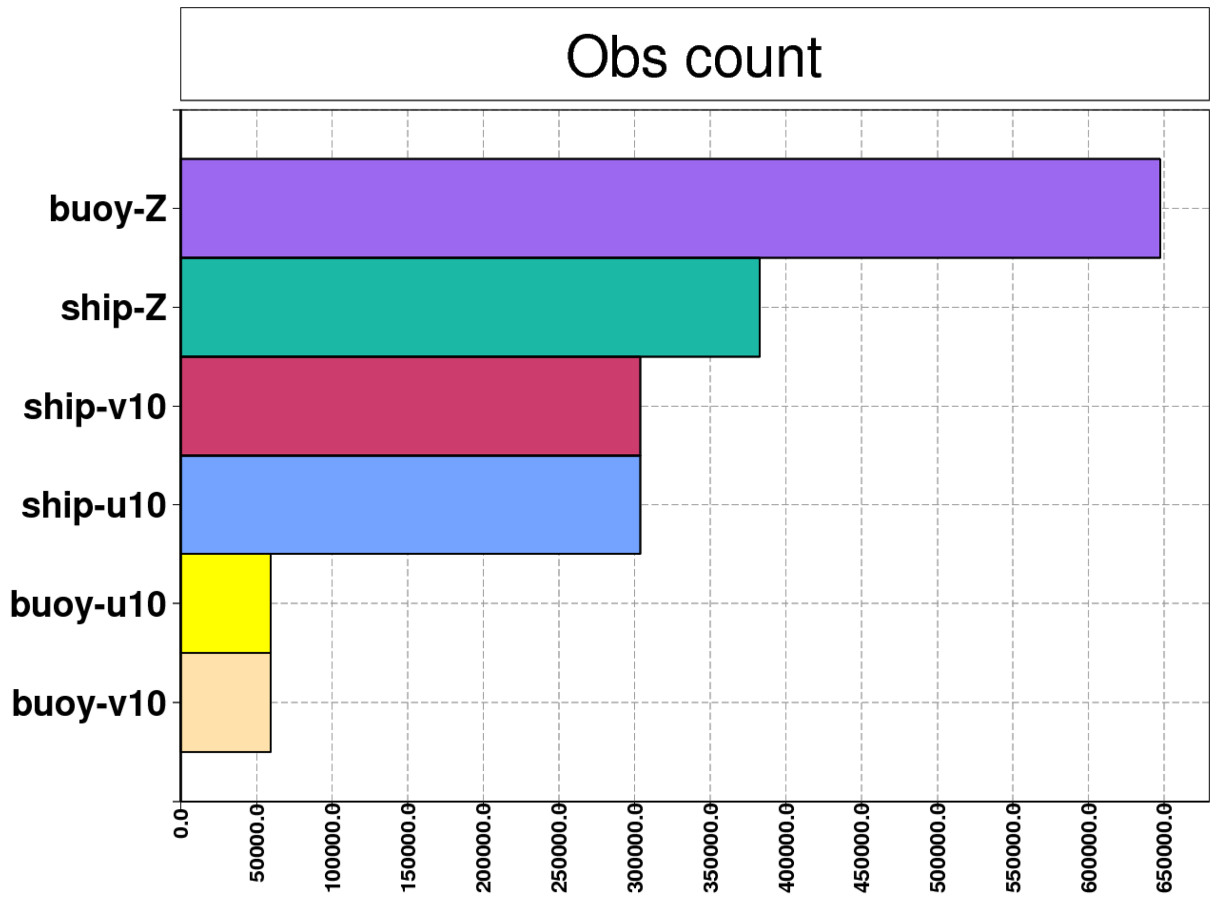
Measured parameters according to data type



Global data available over a 6 hour time window

Measured parameters according to data type



2010/12/02 to 2011/01/15 : assimilated in ARPEGE 4D-Var system

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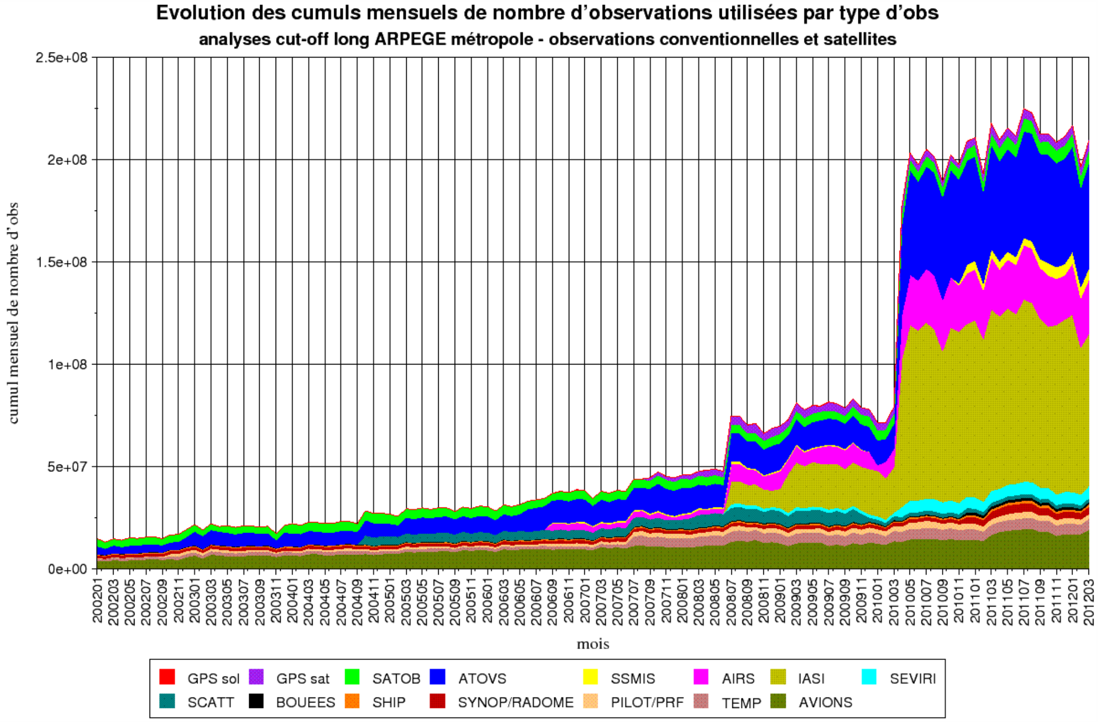
Number of observations assimilated in ARPEGE



All observations

Time series since 2002

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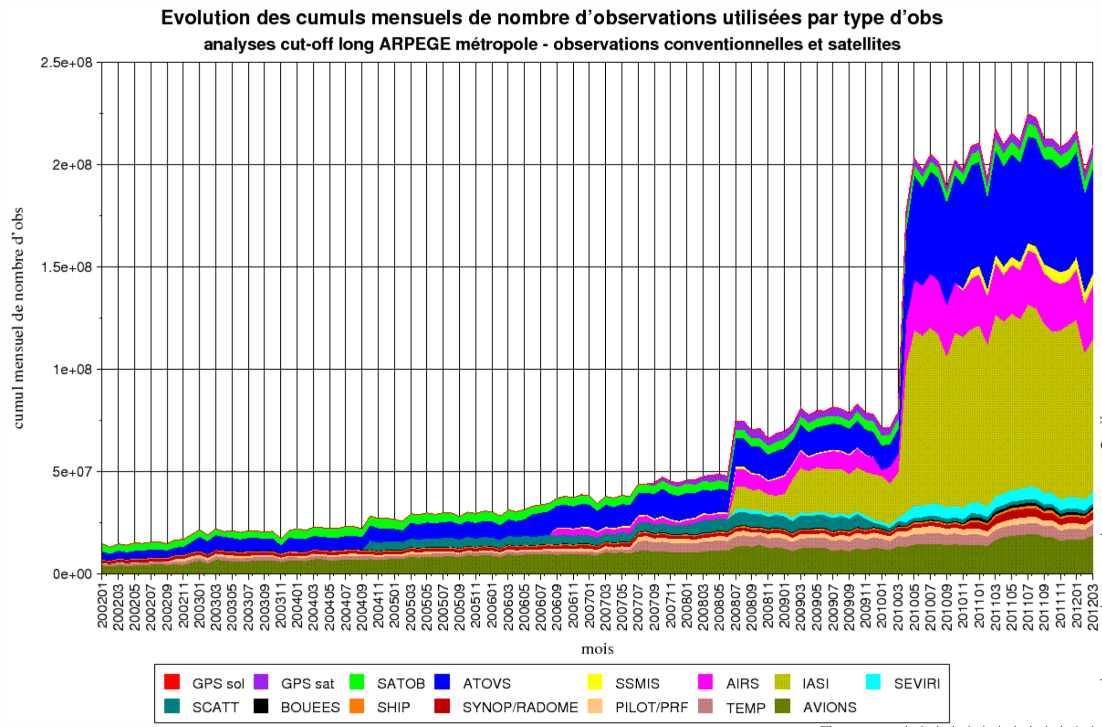
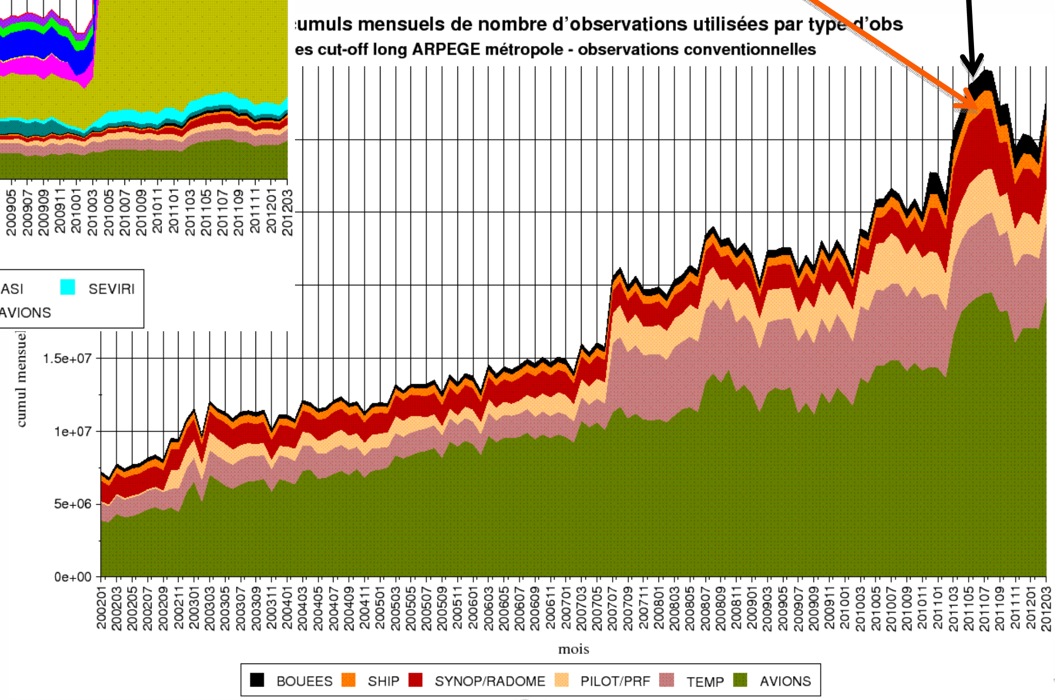
Number of observations assimilated in ARPEGE



All observations

2.7 % SHIP

1.7 % BUOY



Only conventional

Time series since 2002

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Degrees of Freedom for Signal

1. Degrees of freedom of an assimilation system are controlled by the observations assimilated :

$$DFS = Tr\left(\frac{\partial(H\mathbf{x}^a)}{\partial(\mathbf{y}^o)}\right)$$

$$= Tr\left(\mathbf{HK}\right)$$

Under linear assumption

- Sum of impacts of a given observation on its analyzed equivalent : self-sensitivity of an observation on the analysis

- When **R** is block-diagonal, the DFS can be derived for each observation type :

$$DFS_i = Tr\left(\Pi_i \mathbf{HK} \Pi_i^{\mathrm{T}}\right)$$

2. References : Chapnik et al. (2004), Fourrié et al. (2005)

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Degrees of Freedom for Signal (DFS)

1. Sensitivity of the analysis to a perturbation of a particular subset of observations : weight of these observations in the analysis

$$DFS = Tr\left(\frac{\partial(H\mathbf{x}^a)}{\partial(\mathbf{y}^o)}\right)$$

$$= Tr\left(\mathbf{HK}\right)$$

Under linear assumption

When **R** is block-diagonal, DFS can be computed for each observational dataset

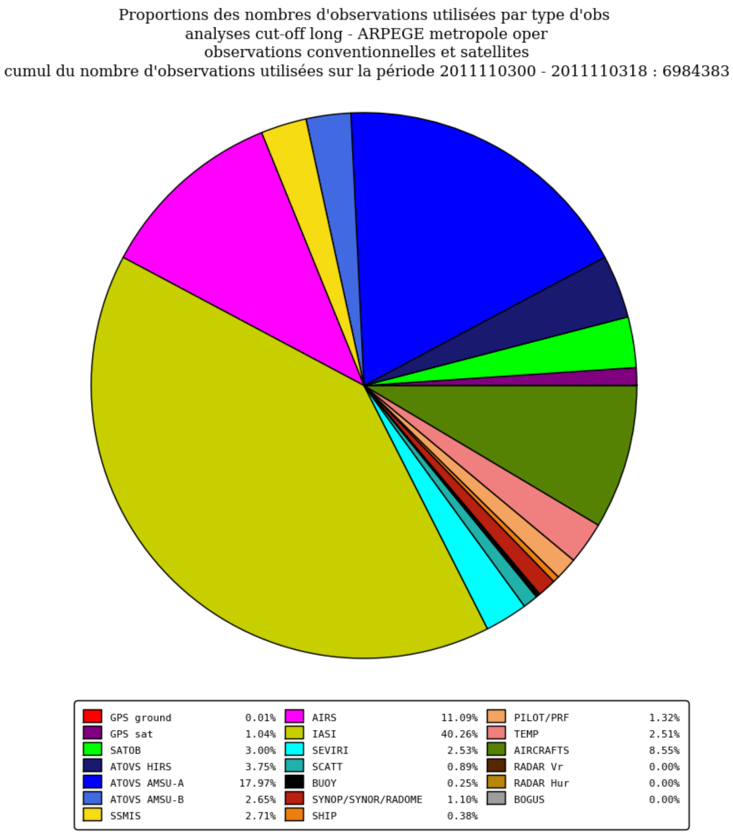
1. Estimation from a randomization technique (Desroziers and Ivanov, 2001)

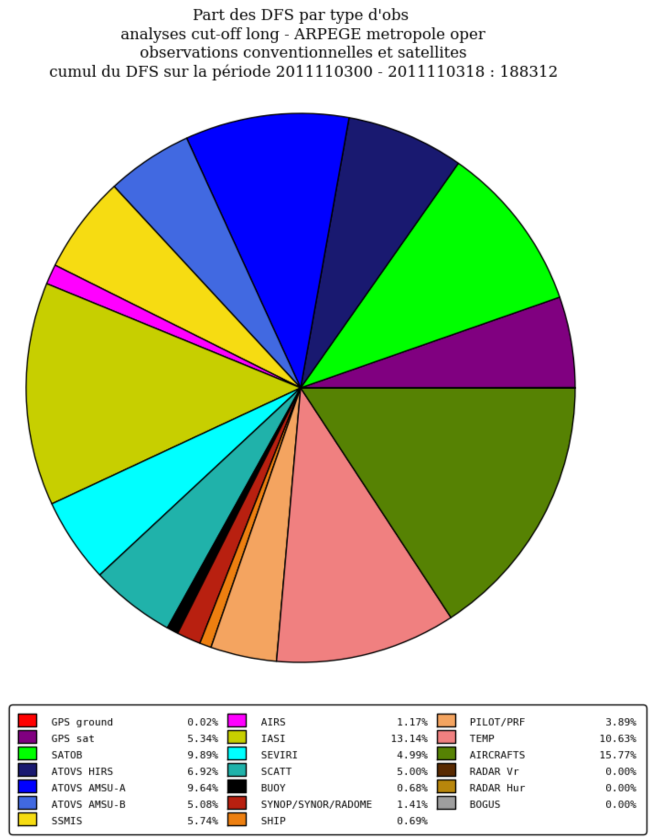
$$Tr(\mathbf{C}) \approx \eta^T \mathbf{C}\, \eta$$

Reference analysis (x_a)
Analysis with perturbed obs (x_a*)

$$Tr(\mathbf{HK}) \approx (\mathbf{R}^{-1/2}\eta)^T (\mathbf{H}\delta x_a^* - \mathbf{H}\delta x_a)$$

Information content of observations in ARPEGE





Number of observations

BUOYS = 0.25 %

SHIP = 0.38 %

Degrees of Freedom for Signal

BUOYS = 0.68 %

SHIP = 0.69 %

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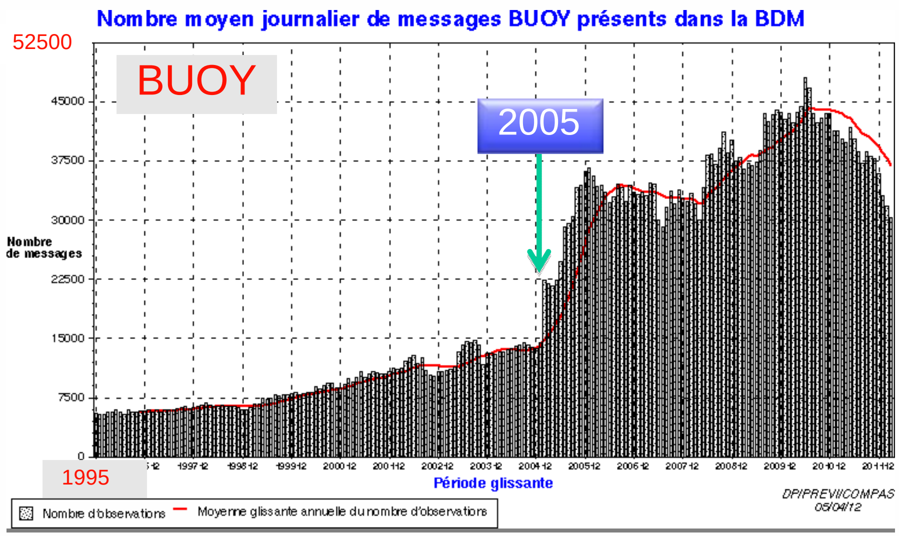
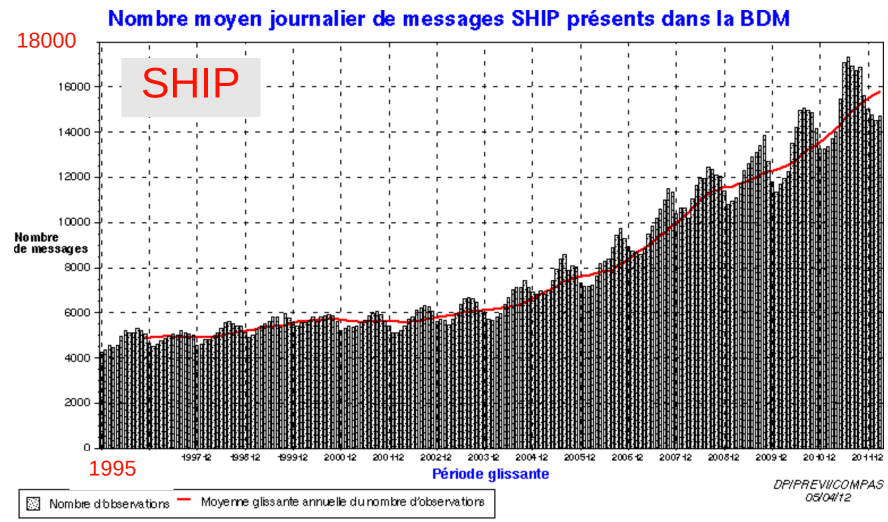
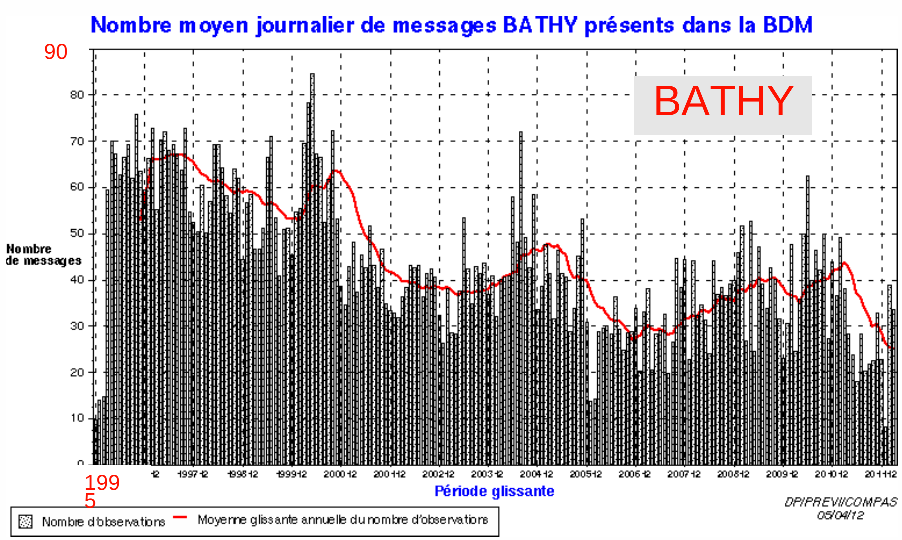
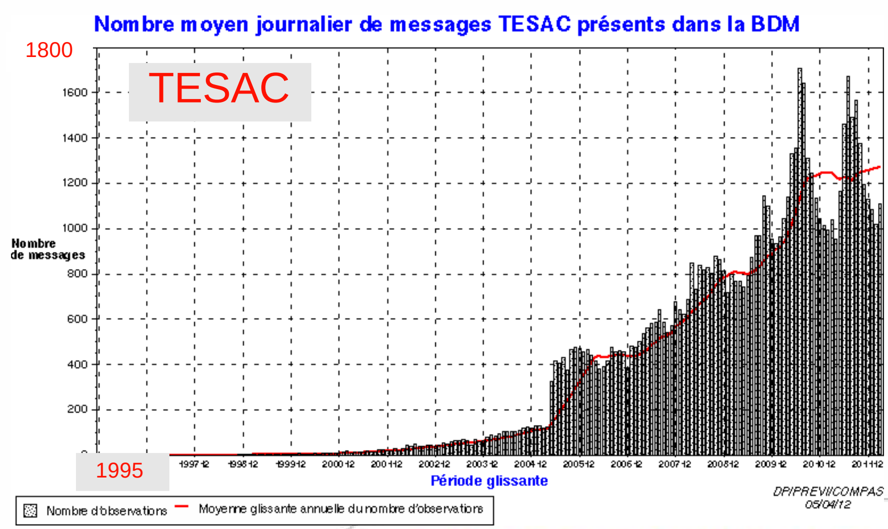
Number of daily archived messages in the MF data base









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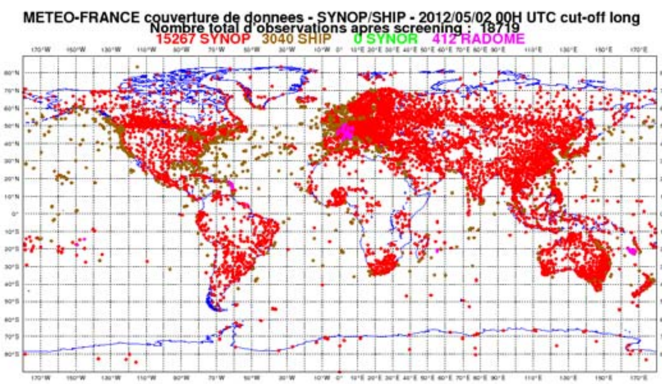
Number of observations assimilated in ARPEGE

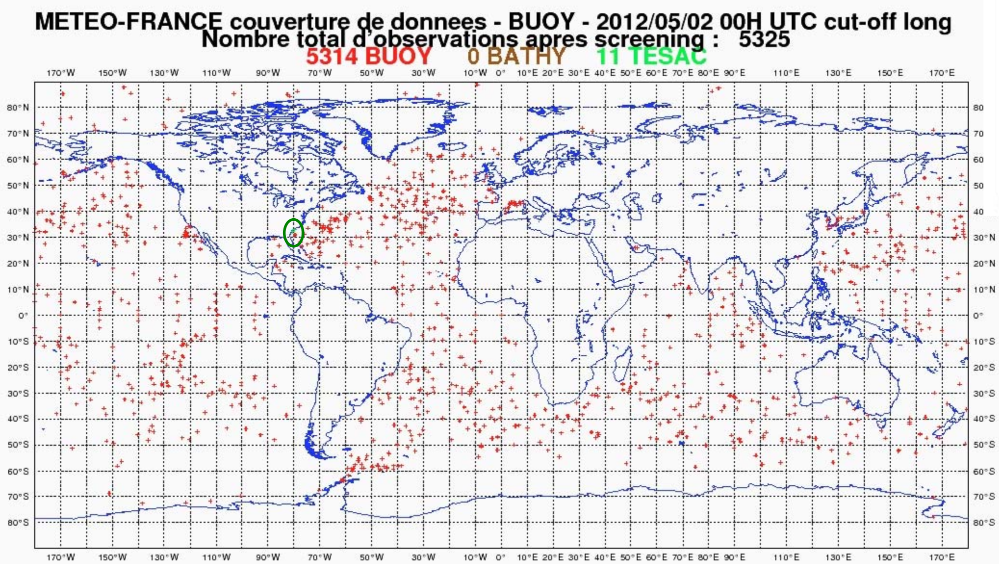
80 % of available data are used

SHIP = 3040



80 % of available data are used

BUOY = 5314



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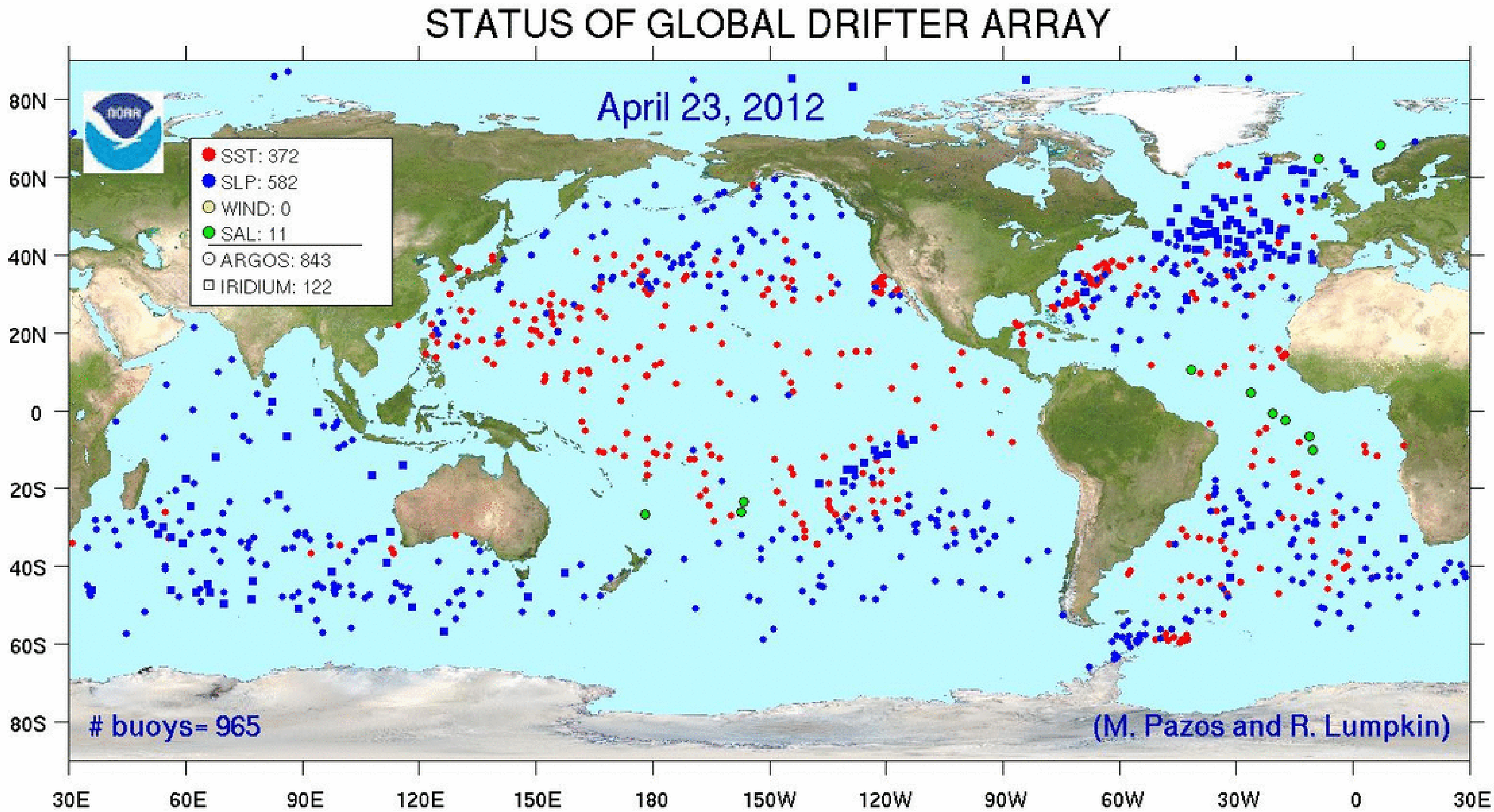

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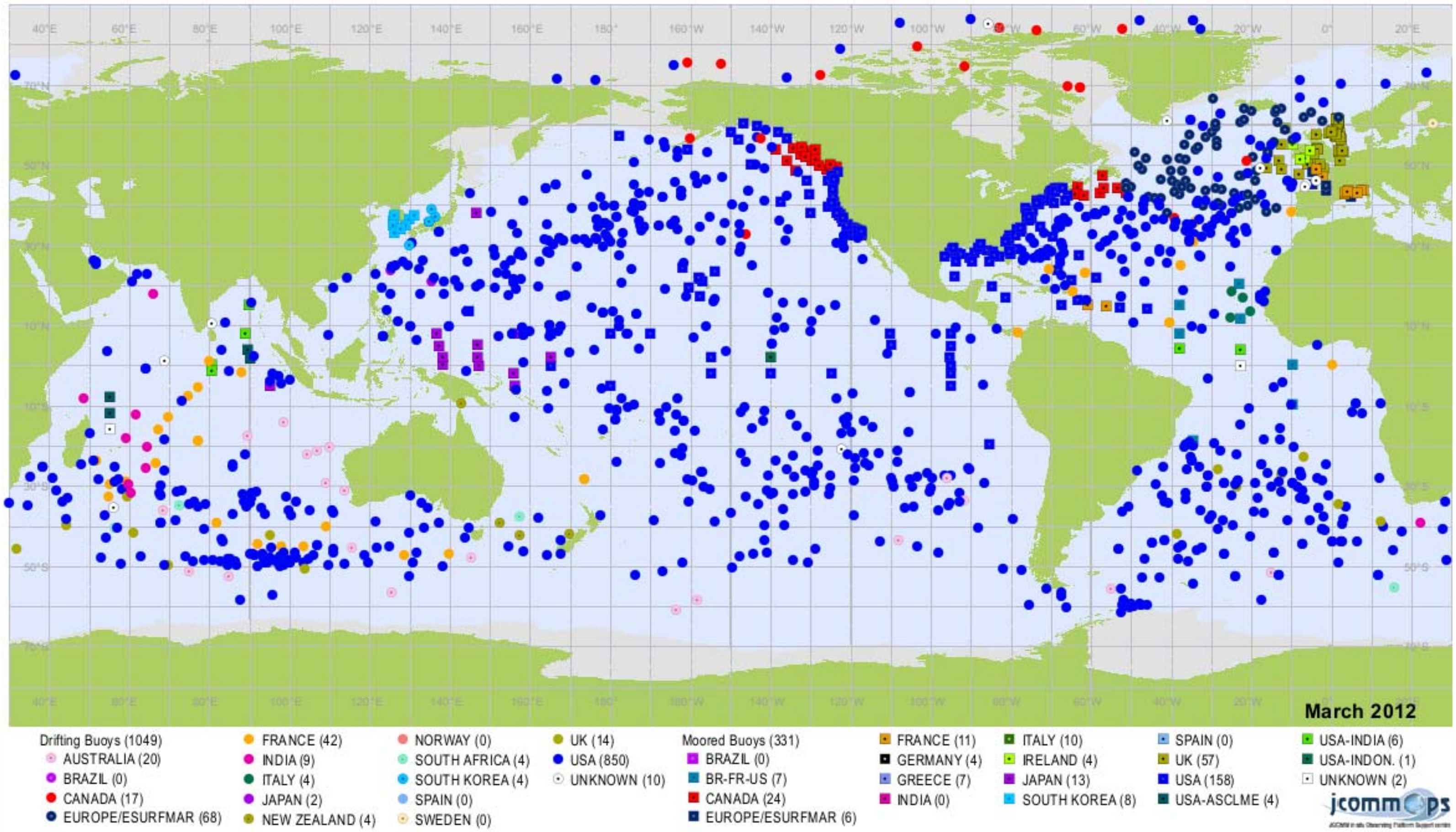
Global network of ocean buoys



- Drifting buoys (1049)
- Moored buoys (331)

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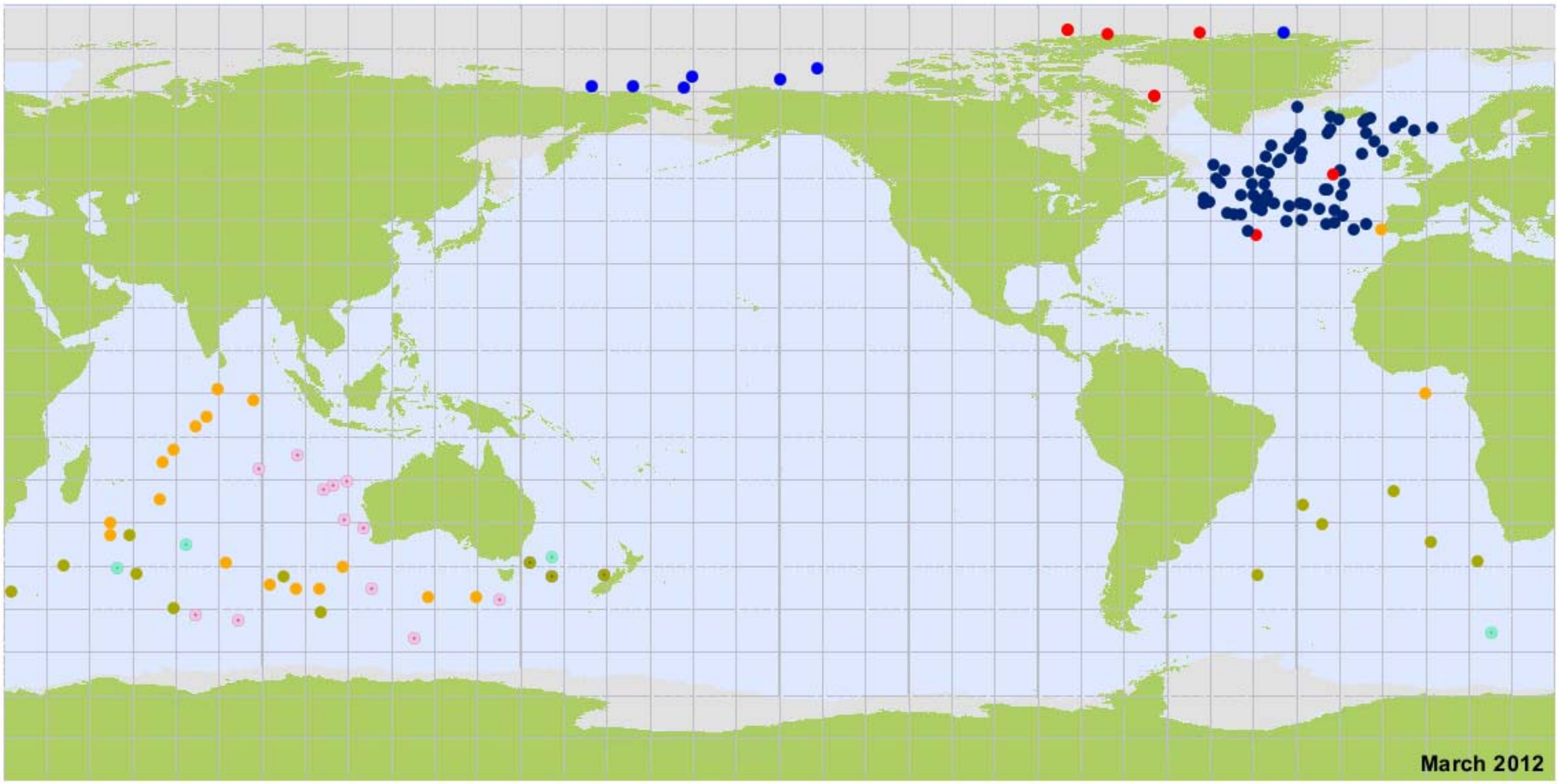
Improved transmission mode (133 buoys)



DBCP Pilot Projects (Iridium and Argos-3 Drifters by Country)

Iridium Drifting Buoys (133) CANADA (8) FRANCE (18) SOUTH AFRICA (4) USA (7)
AUSTRALIA (12) EUROPE/ESURFMAR (68) NEW ZEALAND (3) UK (13)

jcommops

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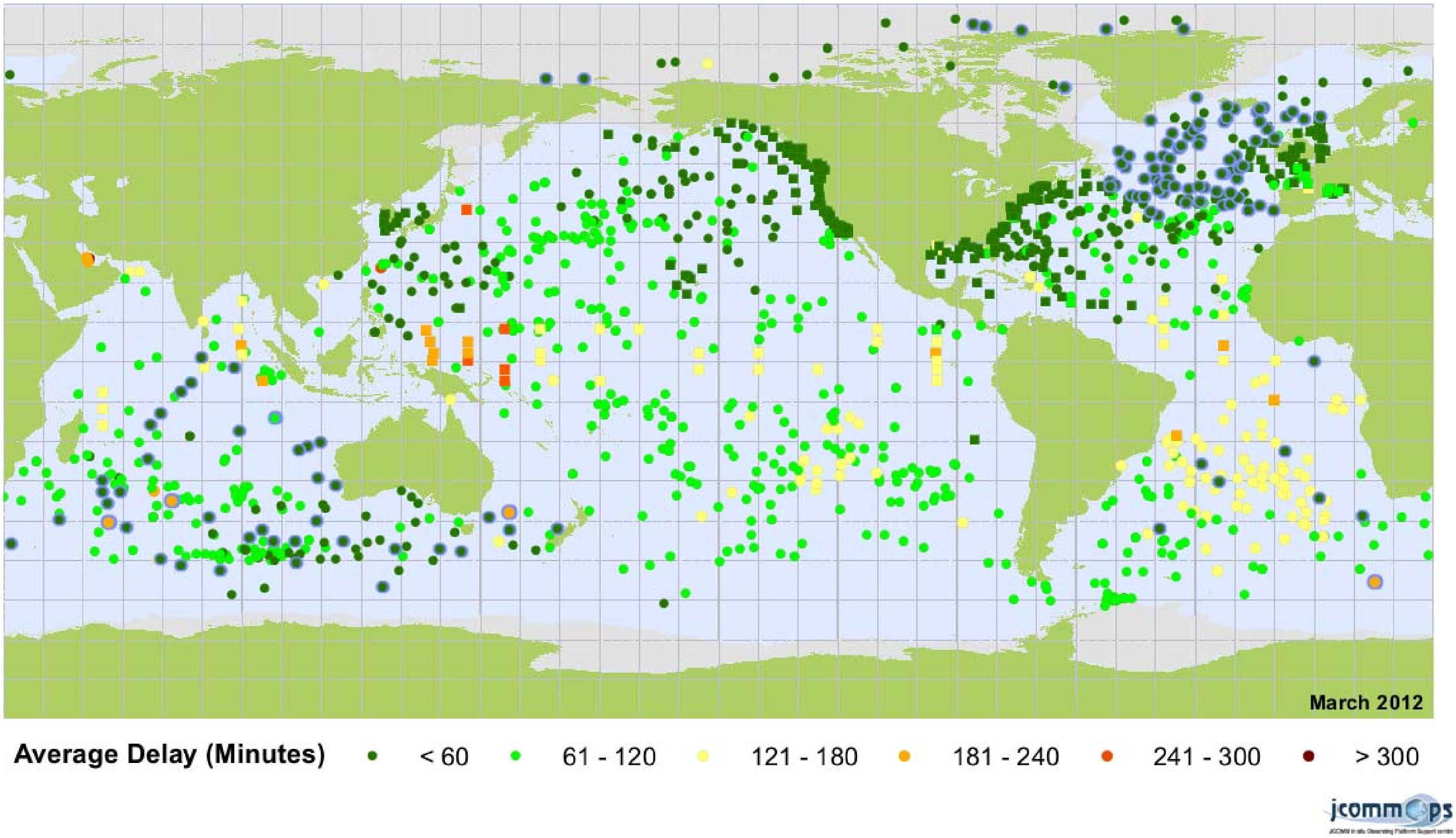
Retransmission delays



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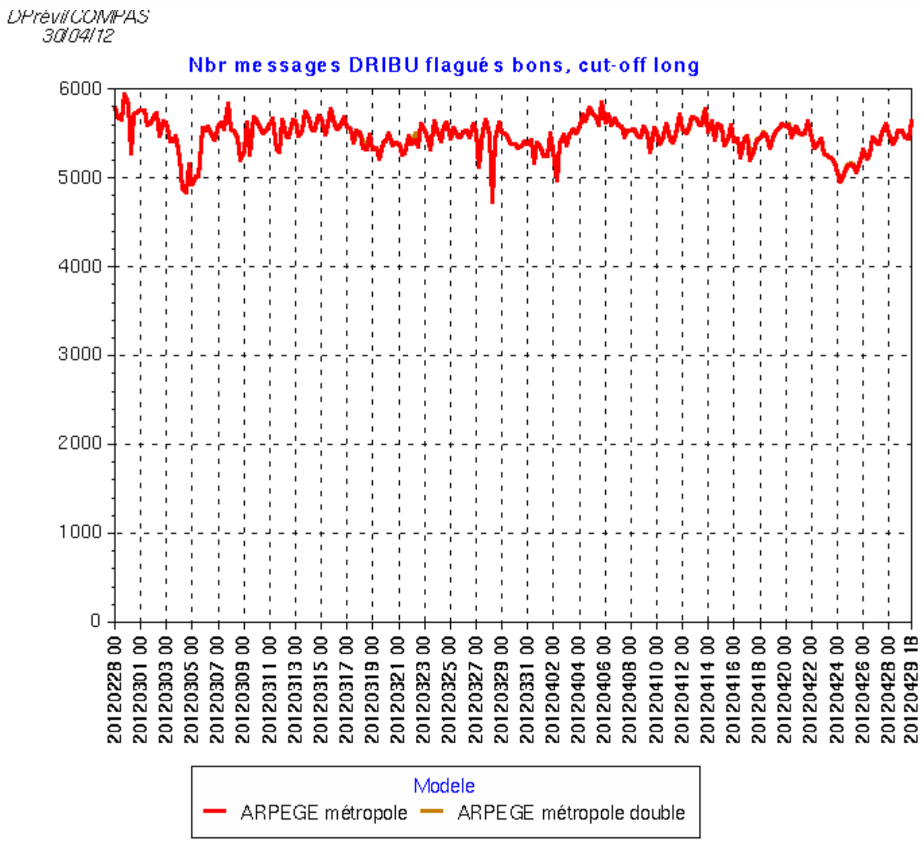
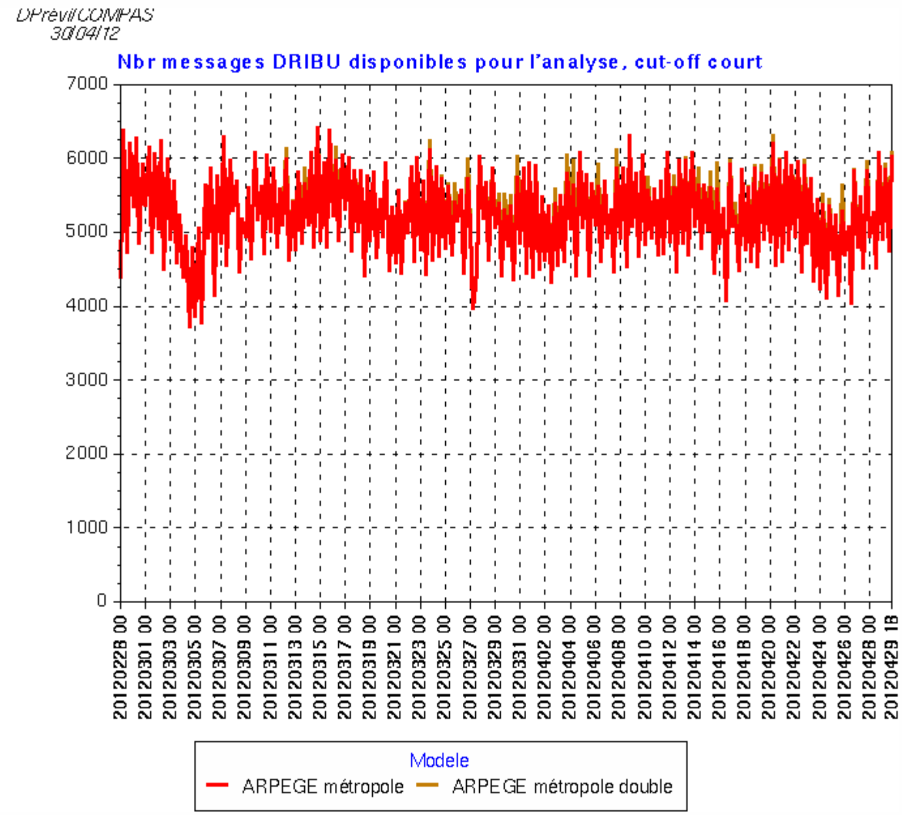
Number of « good quality » messages



Long cut-off



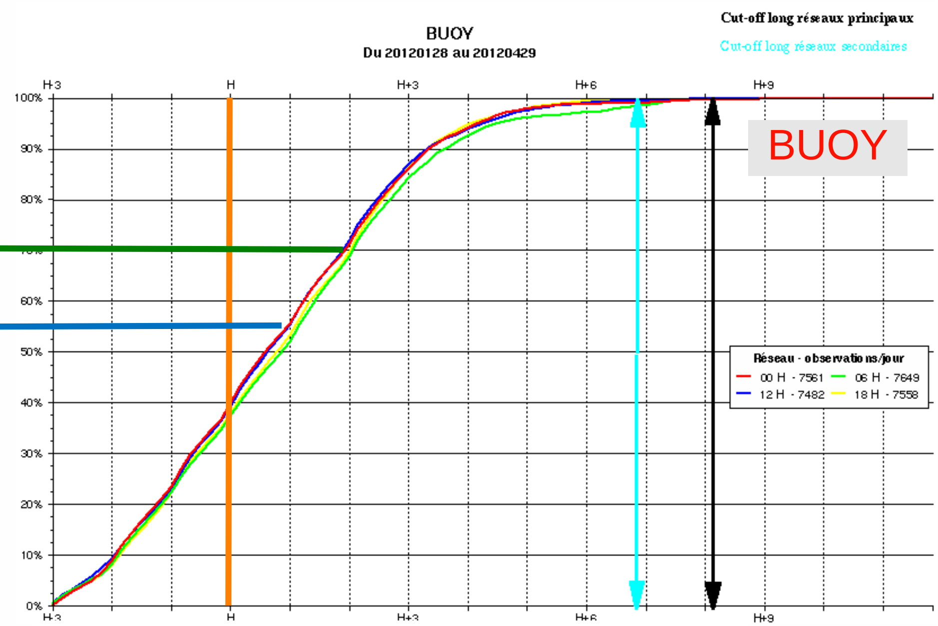
Short cut-off

March-April 2012

Timeliness of observations

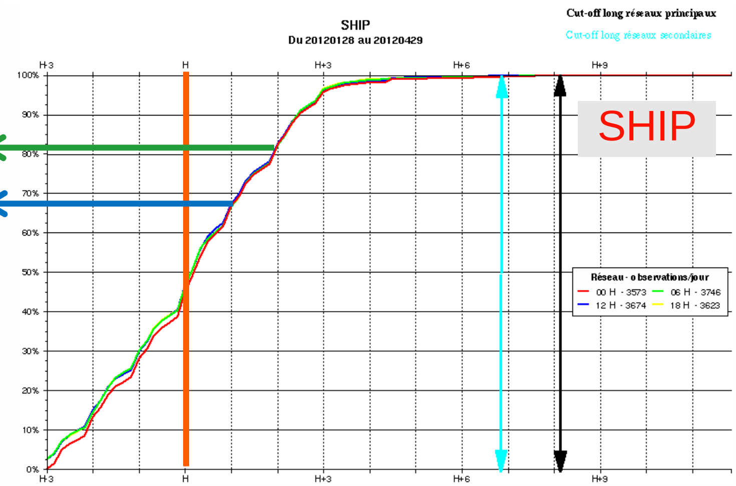
H+2 =>**70** %

H+1 =>**55** %



H+2 =>**82** %

H+1 =>**67** %



Comparison of BUOY data with other data types

Wind intensity at 10 m : comparison against ARPEGE 6h-forecasts (FG) and analyses (AN) – 31 days (20/08/2011 – 19/09/2011)

Data type	BUOY	ASCAT	SHIP
Number	43159	**1118889**	225564
Bias (O-FG)	-0.32	**-0.08**	-0.15
Std (O-FG)	1.68	**1.27**	2.4
Bias (O-AN)	-0.16	**0.04**	-0.13
Std (O-AN)	1.34	**0.73**	2.0

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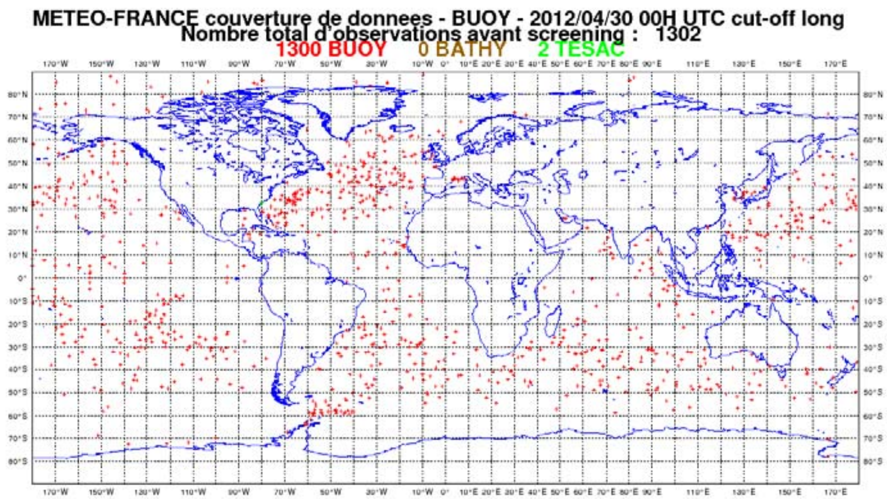
Use of BUOY observations for surface analysis

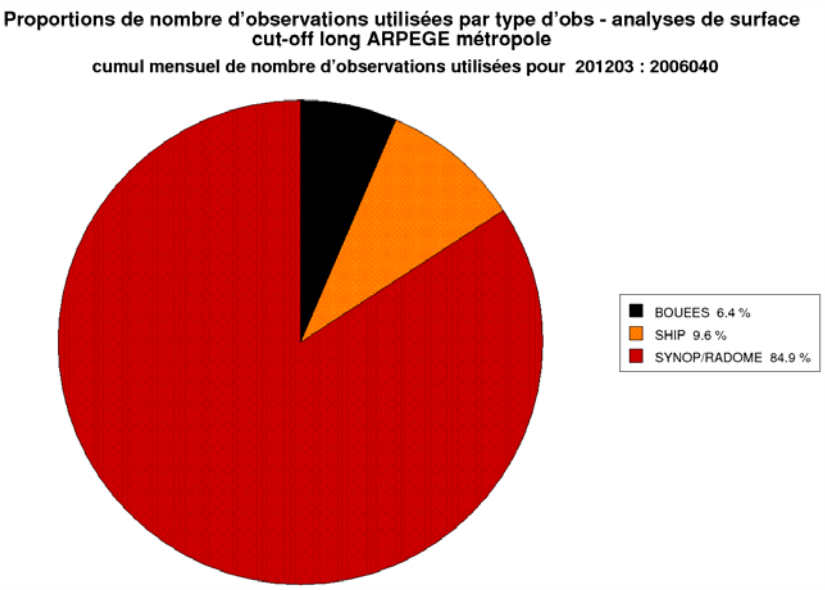
Before screening : **1302**

After screening : **866** (66 %)



Global OI analysis CANARI

SST, T2m, RH2m



BUOYS = 6.4 %

SHIP = 9.4 %

SYNOP = 84.9 %

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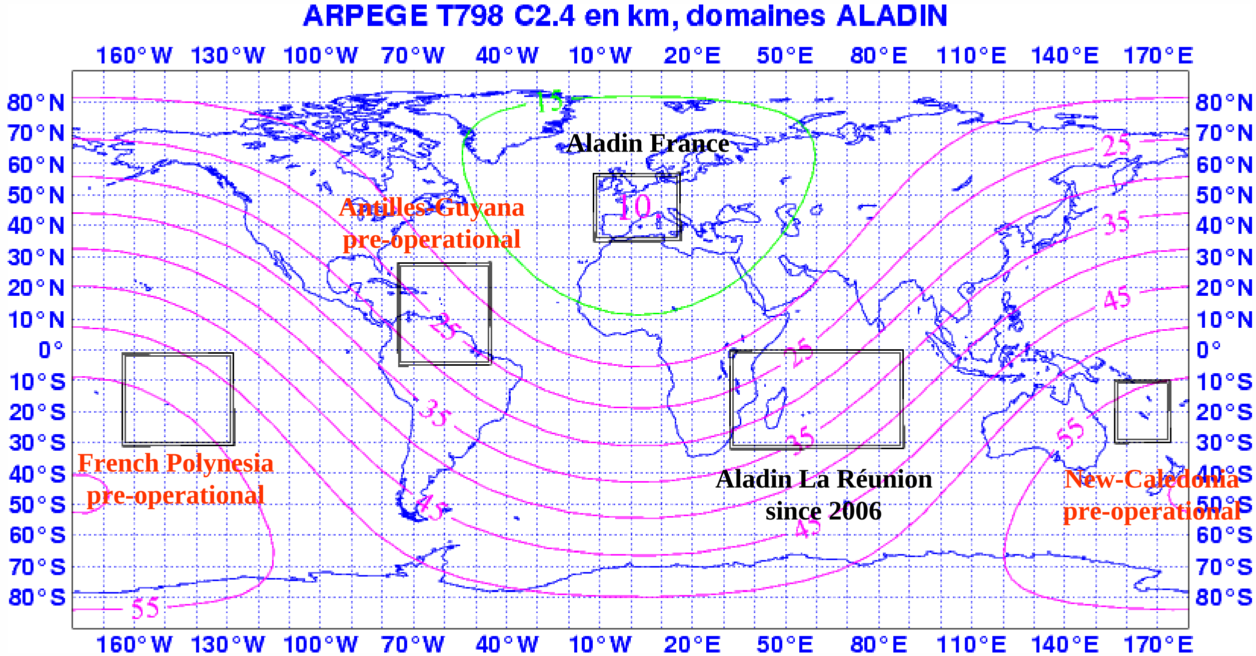
The limited area models ALADIN

Regional model ALADIN

- Spectral limited area model : E199x199L70
  - 70 levels from 17m to 0.05 hPa, horizontal resolution 7.5 km
- 3D-Var assimilation (6h window) :
  - Same data as ARPEGE plus SEVIRI radiances (ALADIN Réunion)
- Current operational domains :



Forecast ranges and cut-offs:

FC+54 (00 UTC) [2h15], FC+48 (06 UTC) [3h],

FC+42 (12 UTC) [1h50], FC+36 (18 UTC) [3h]

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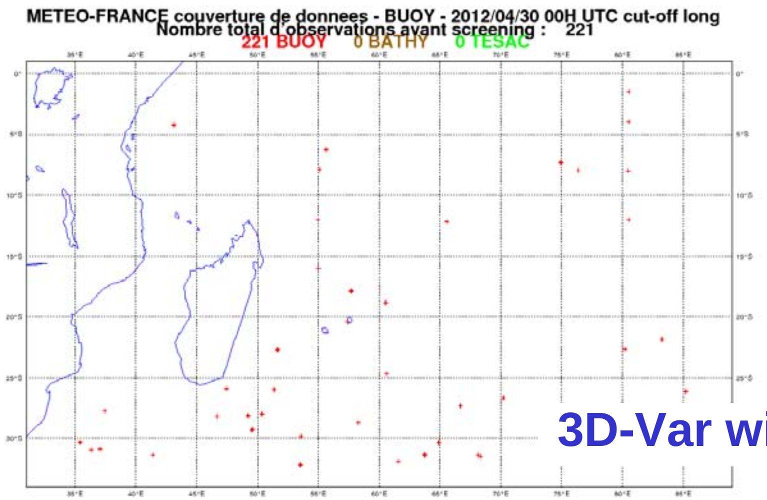
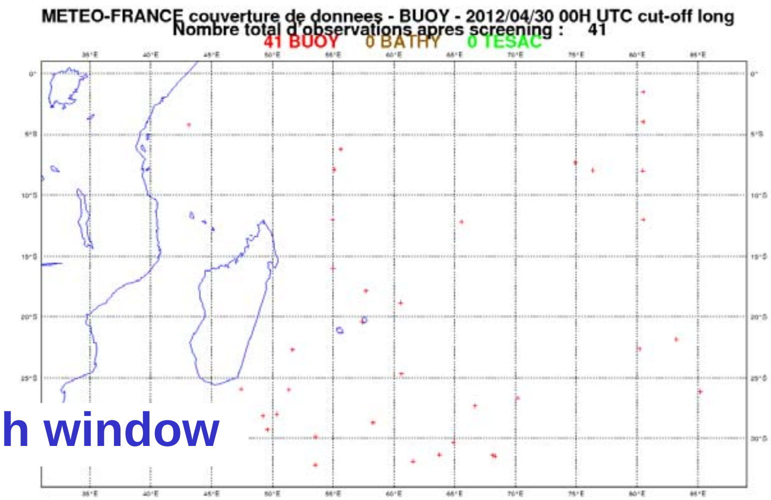
Use of BUOY observations in ALADIN Réunion

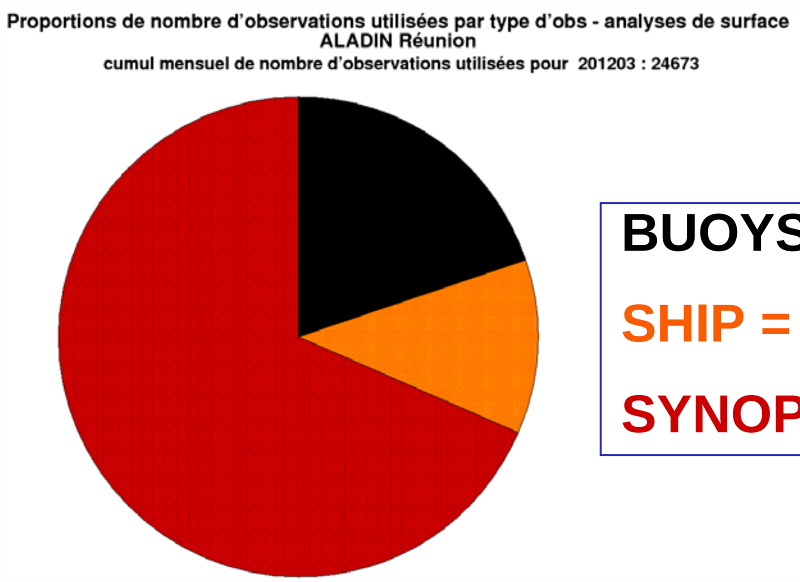
Before screening : **221**



After screening : **41**



3D-Var with 6-h window



BUOYS = 19.9 %

SHIP = 11.5 %

SYNOP = 68.5 %

OI regional surface analysis

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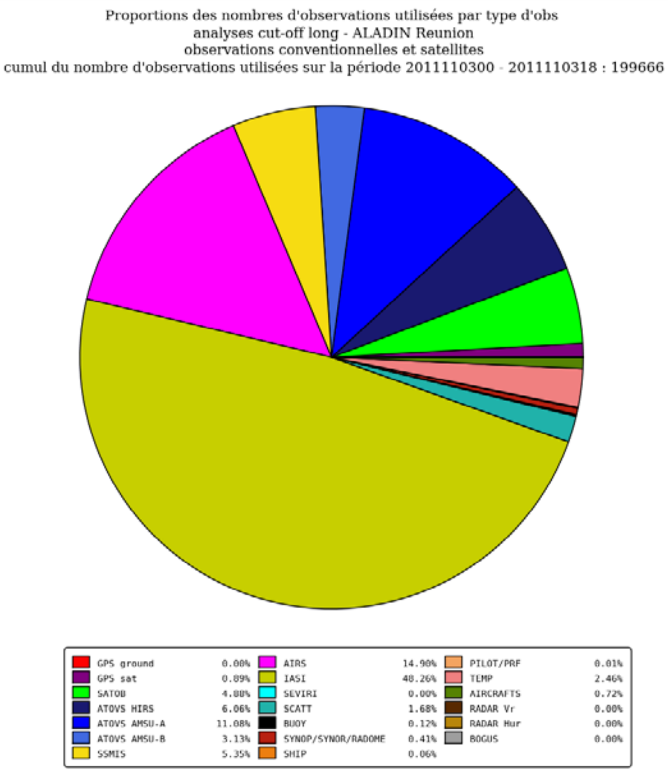
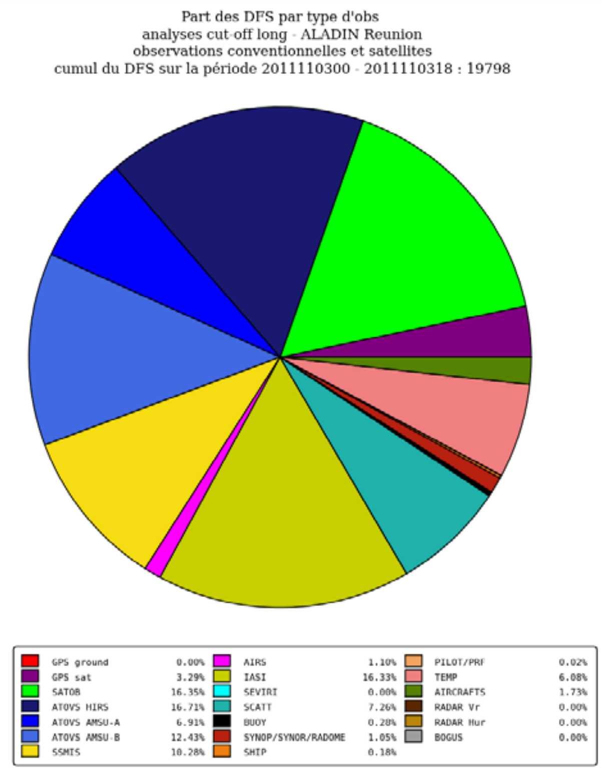
Information content of observations in ALADIN Réunion





Number of observations

Degrees of Freedom for Signal

BUOYS=0.12 %

BUOYS=0.28 %

ALADIN Réunion vs ARPEGE : larger fraction of oceans but less used data (3D-Var vs. 4D-Var)

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Forecast sensitivity to observations with ARPEGE

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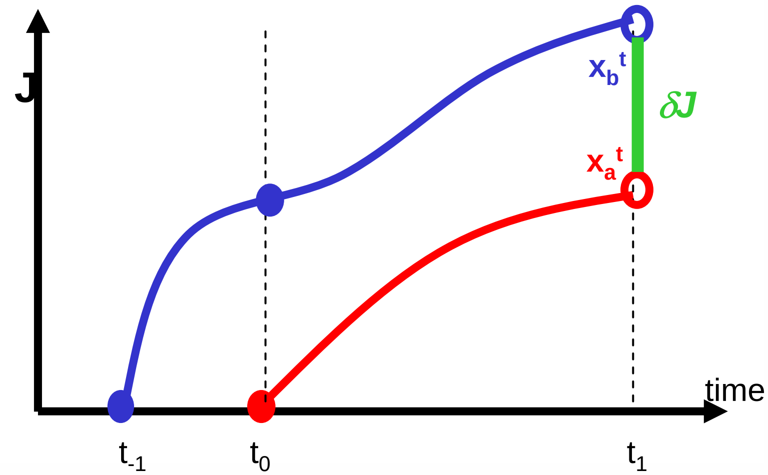
Linear estimate of observation impact

How?

- Implemented in IFS (ECMWF) by C. Cardinali and M. Fisher.

- *J* : short-range forecast error = difference between a 24h forecast and an analysis (dry energy norm)



- Observation impact:

$$\delta J = J(x^t{}_b) - J(x^t{}_a)$$

$$\left(\frac{\partial J}{\partial x_a}\right) = \frac{1}{2}\left[\frac{\partial J(x_a^t)}{\partial x_a} + \frac{\partial J(x_b^t)}{\partial x_b}\right]$$

$$\delta J \approx \frac{\partial J}{\partial y}\delta y = \left(\frac{\partial x_a}{\partial y}\right)\left(\frac{\partial J}{\partial x_a}\right)(y - Hx_b)$$

$$\left(\frac{\partial x_a}{\partial y}\right) = \mathbf{K}^T = \mathbf{R}^{-1}\mathbf{HA}$$

• Contribution of individual observations to the reduction of *J*

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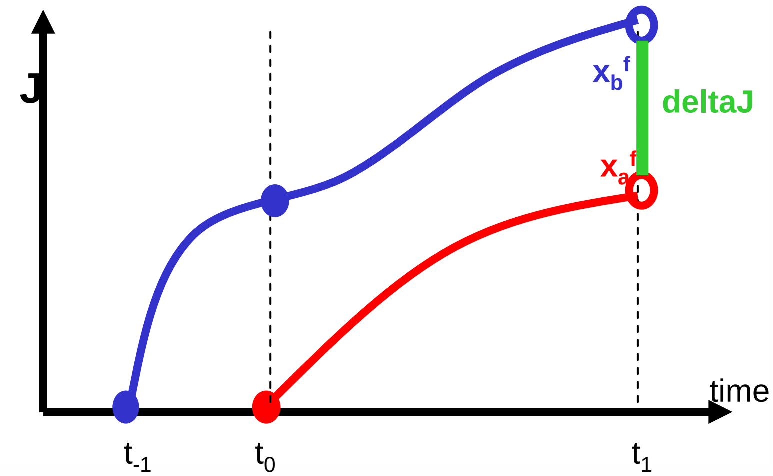
Linear estimate of observation impact

How?

- Implemented in IFS (ECMWF) by C. Cardinali and M. Fisher.
- J : 3D integrated dry total energy of the difference between the 24h forecast and a reference state
- Observation impact:



$$\delta J = \frac{1}{2}(\mathbf{R}^{-1}\mathbf{HA})\left(\mathbf{M}_a^T \frac{\partial J^b}{\partial x_b^f} + \mathbf{M}_b^T \frac{\partial J^a}{\partial x_a^f}\right)(y - Hx_b)$$

• second order approximation (Errico, 2007).

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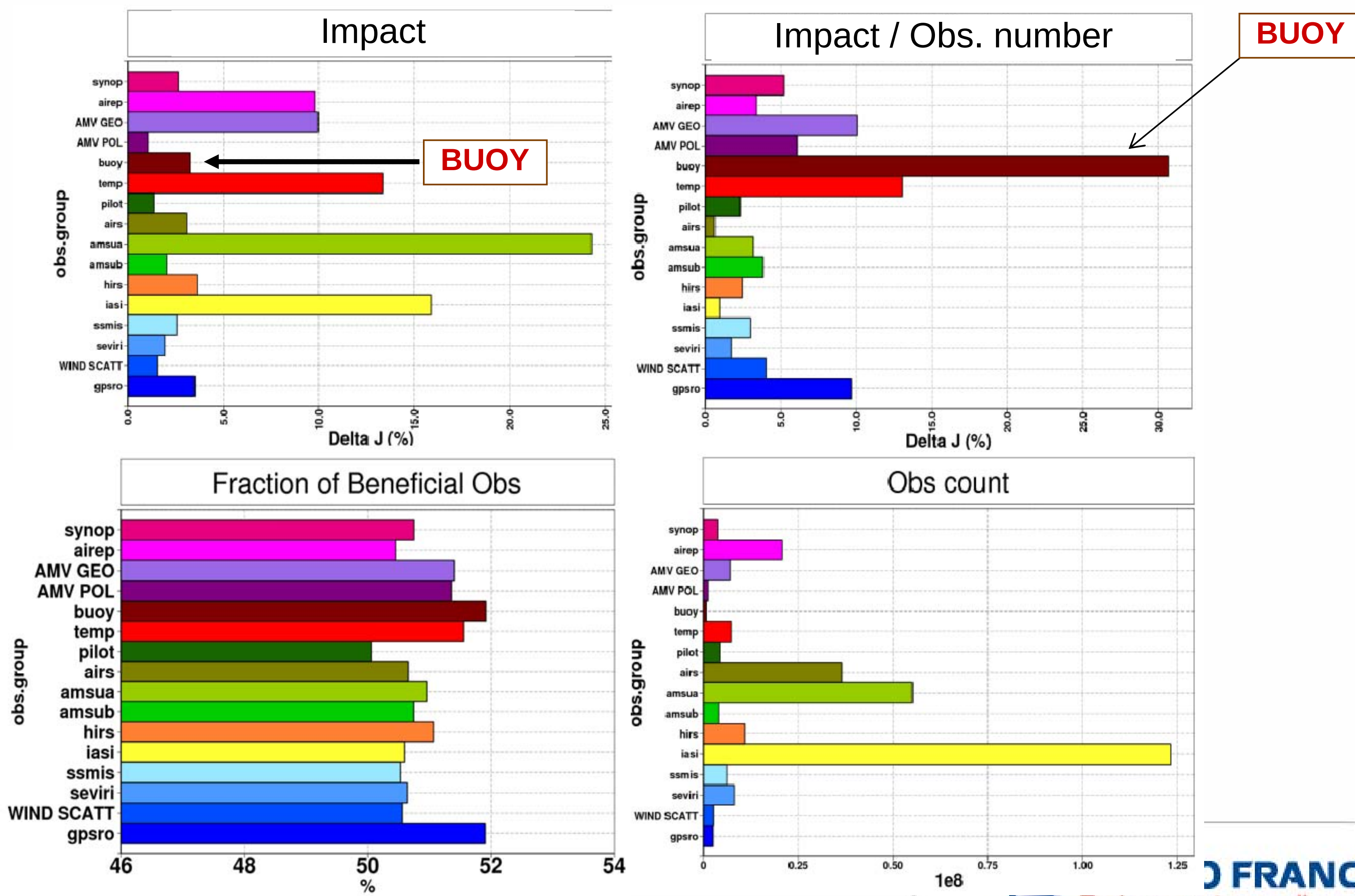
Forecast impact experiment from Dec. 2010 to Jan. 2011



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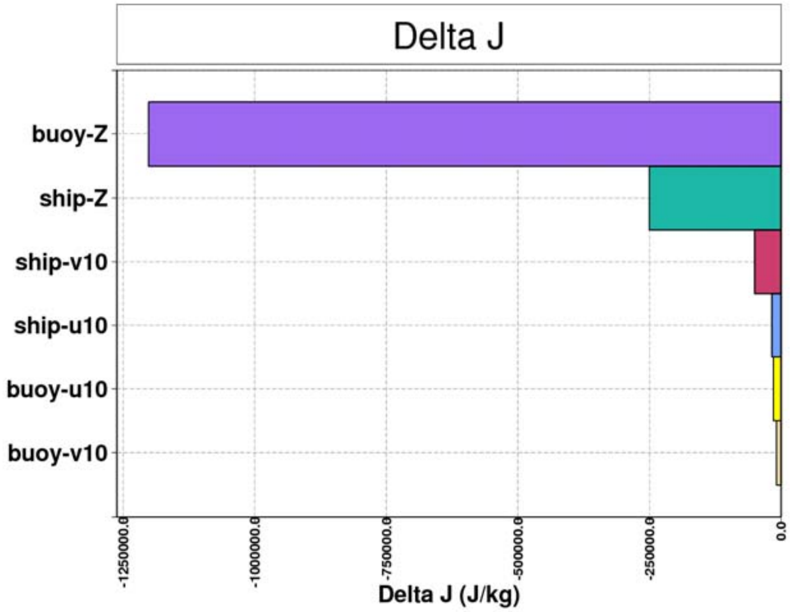
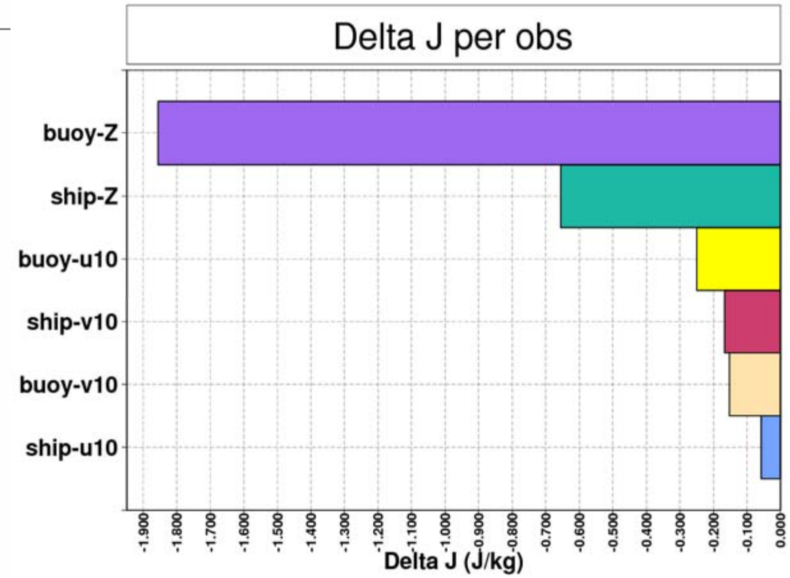
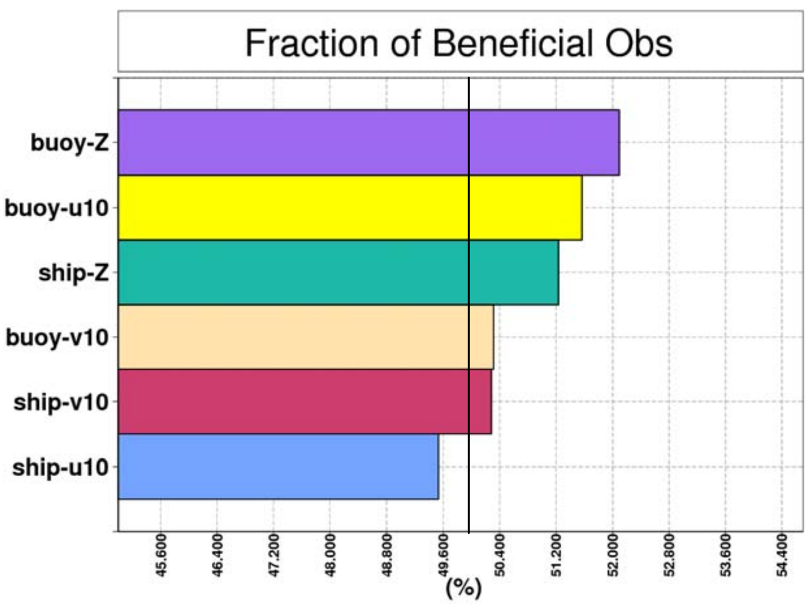
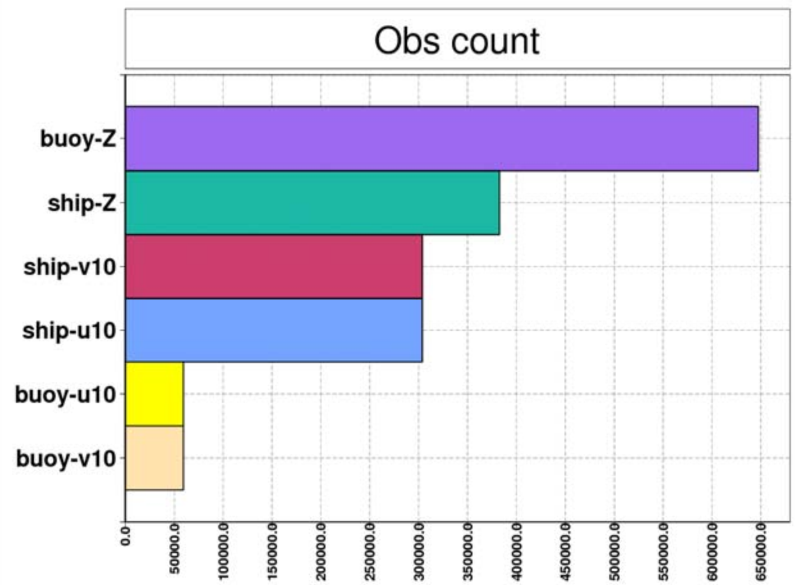

Delta J
buoy-Z
ship-Z
ship-v10
ship-u10
buoy-u10
buoy-v10
-1250000.0
-1000000.0
-750000.0
-500000.0
-250000.0
0.0
Delta J (J/kg)

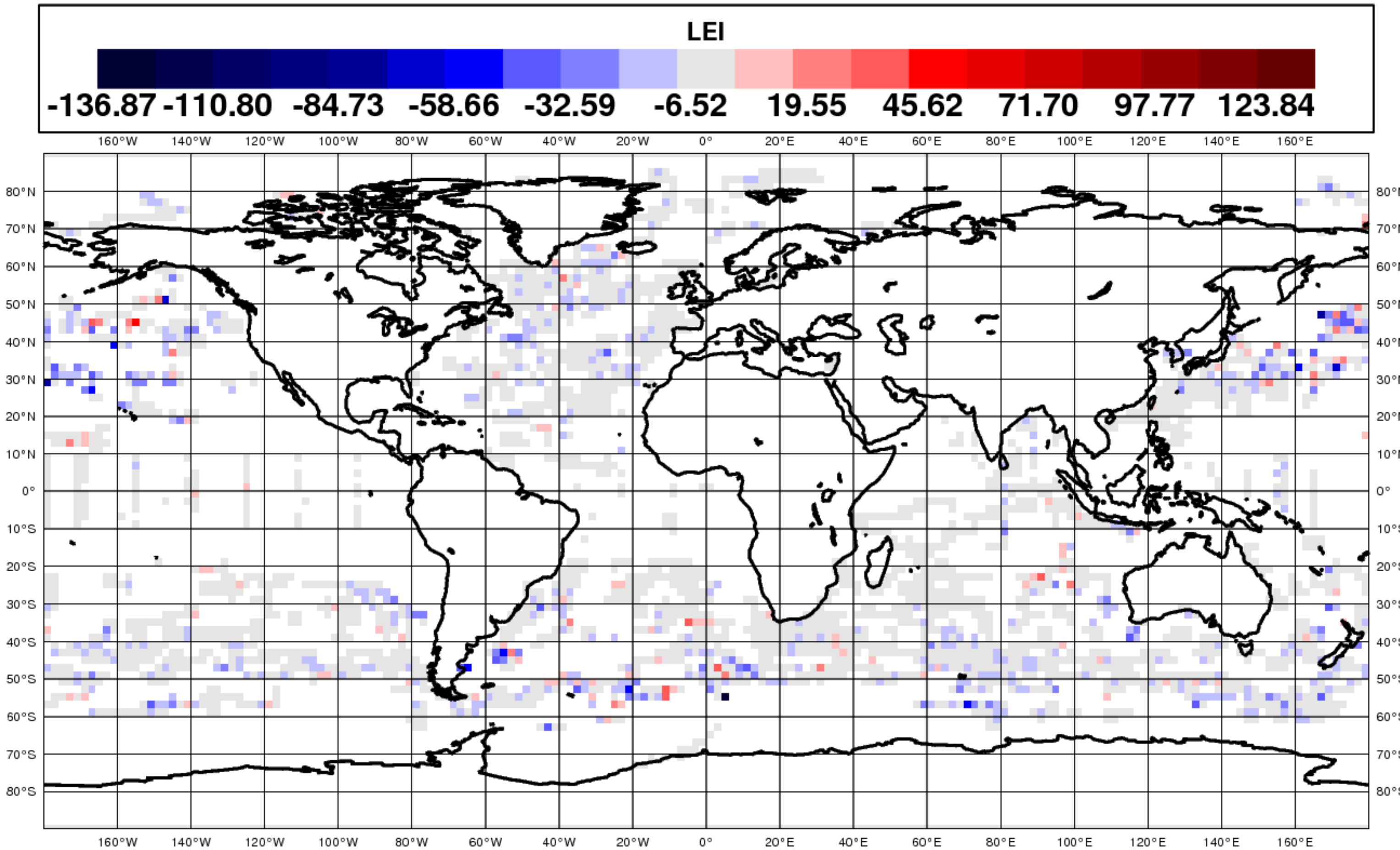

Delta J per obs
buoy-Z
ship-Z
buoy-u10
ship-v10
buoy-v10
ship-u10
-1.900
-1.800
-1.700
-1.600
-1.500
-1.400
-1.300
-1.200
-1.100
-1.000
-0.900
-0.800
-0.700
-0.600
-0.500
-0.400
-0.300
-0.200
-0.100
0.000
Delta J (J/kg)


Fraction of Beneficial Obs
buoy-Z
buoy-u10
ship-Z
buoy-v10
ship-v10
ship-u10
45.600
46.400
47.200
48.000
48.800
49.600
50.400
51.200
52.000
52.800
53.600
54.400
(%)


Obs count
buoy-Z
ship-Z
ship-v10
ship-u10
buoy-u10
buoy-v10
0.0
50000.0
100000.0
150000.0
200000.0
250000.0
300000.0
350000.0
400000.0
450000.0
500000.0
550000.0
600000.0
650000.0

BUOY all parameters

Averaged Linear Estimate of Impact (LEI): -6806.31 J/kg
Experiment: B281 / From 2010/12/02 at 00UTC to 2011/01/15 at 18UTC / H UTC cycles / Grid: 2° × 2°.
Objective function : Total energy of the 24h forecast error.
Observation type: buoy, parameter: All, level : all



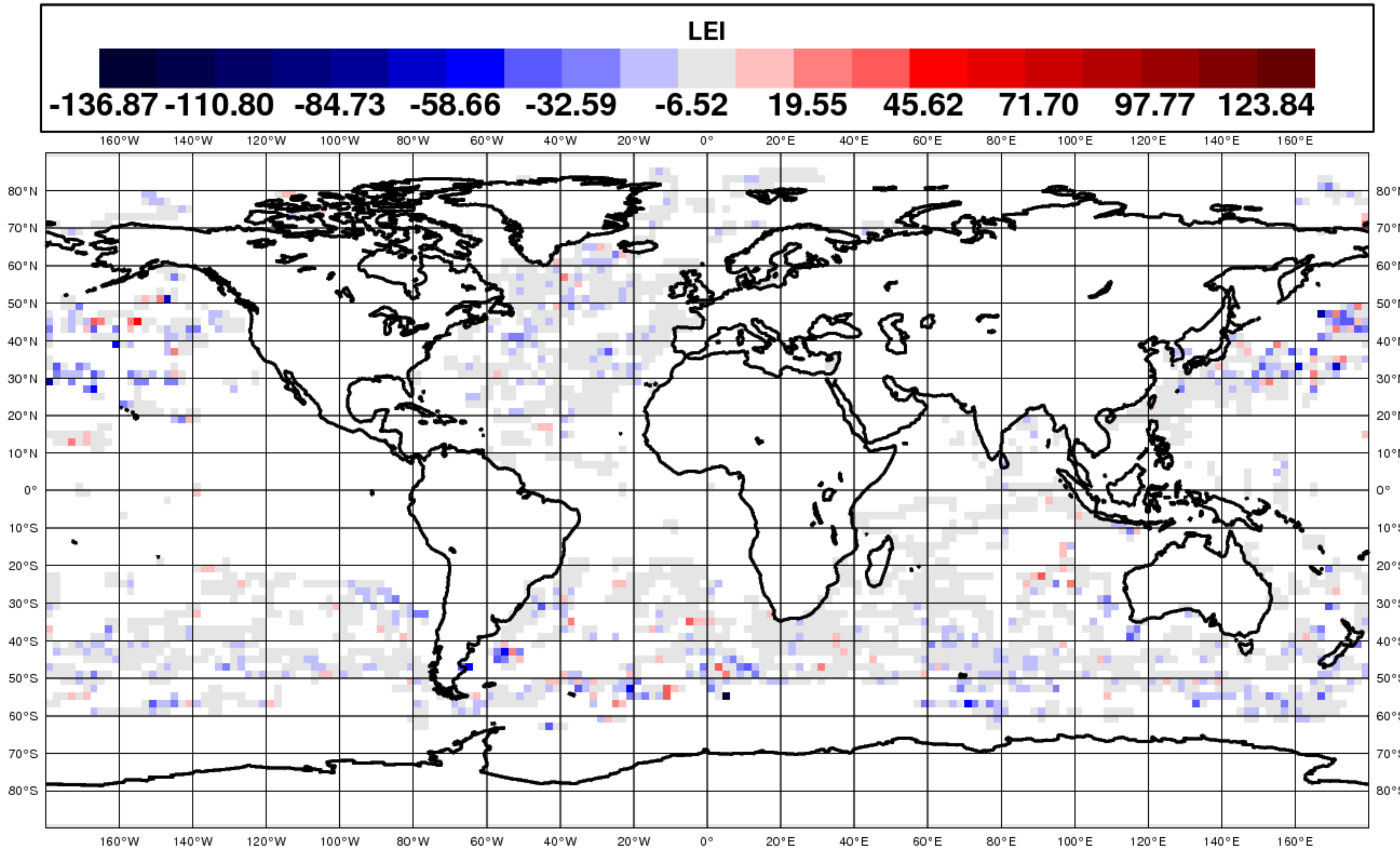
BUOY geopotential

Averaged Linear Estimate of Impact (LEI): -6675.23 J/kg

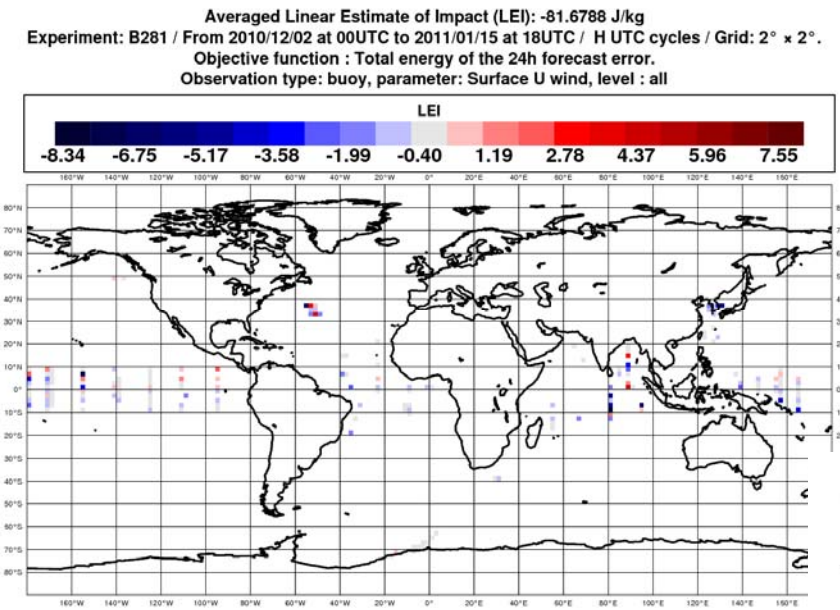
Experiment: B281 / From 2010/12/02 at 00UTC to 2011/01/15 at 18UTC / H UTC cycles / Grid: 2° × 2°.

Objective function : Total energy of the 24h forecast error.

Observation type: buoy, parameter: Geopotential, level : all

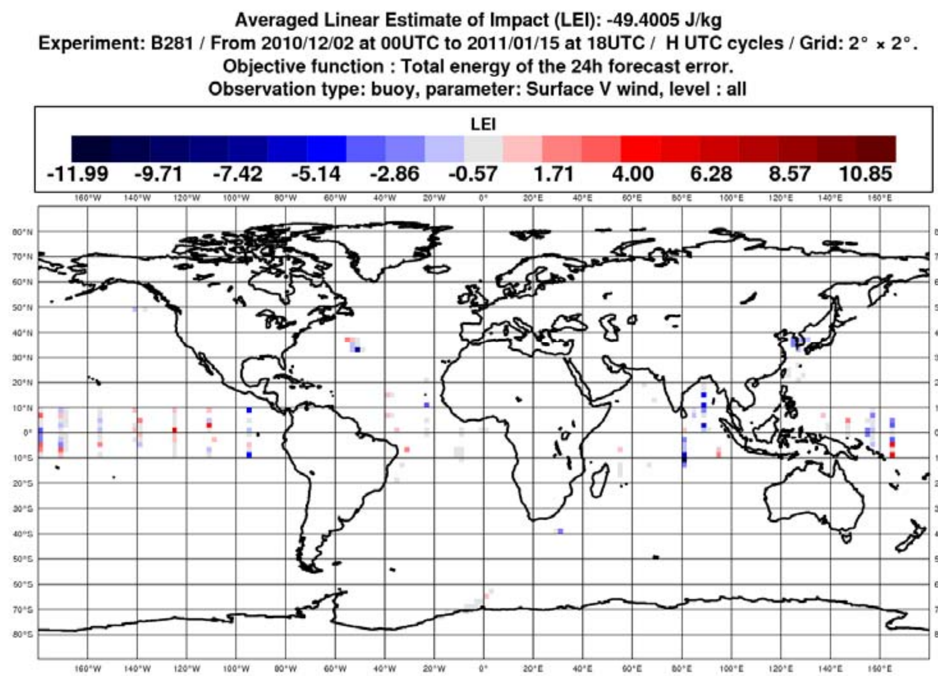


BUOY wind



U component

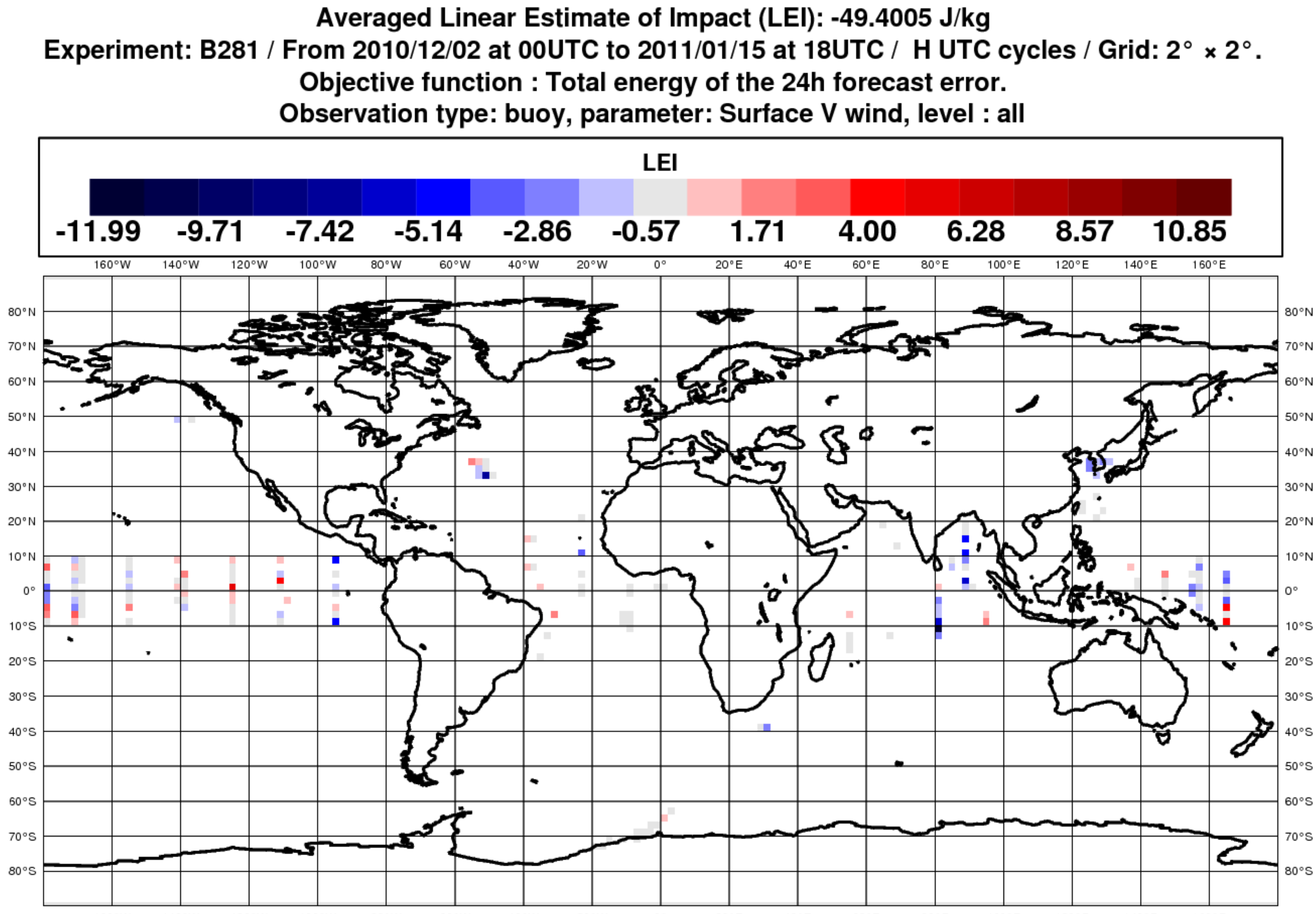
dJ =-61.76 J/kg



V component

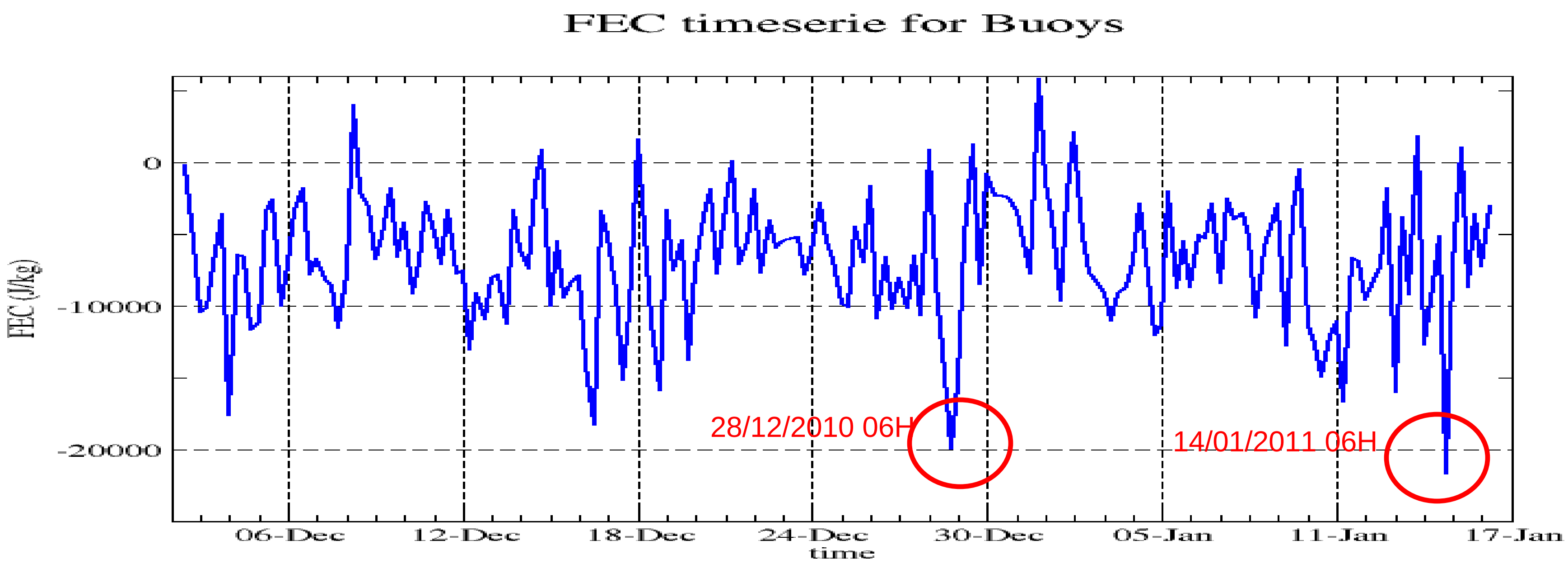
dJ=-49.40 J/kg

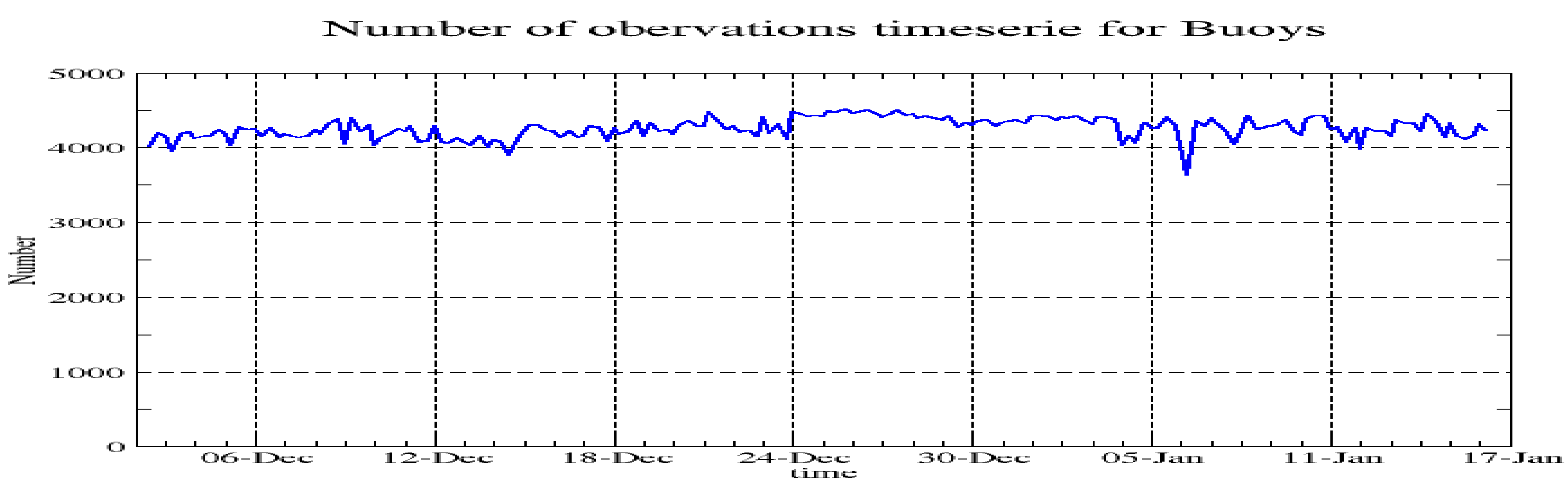
Buoy v wind



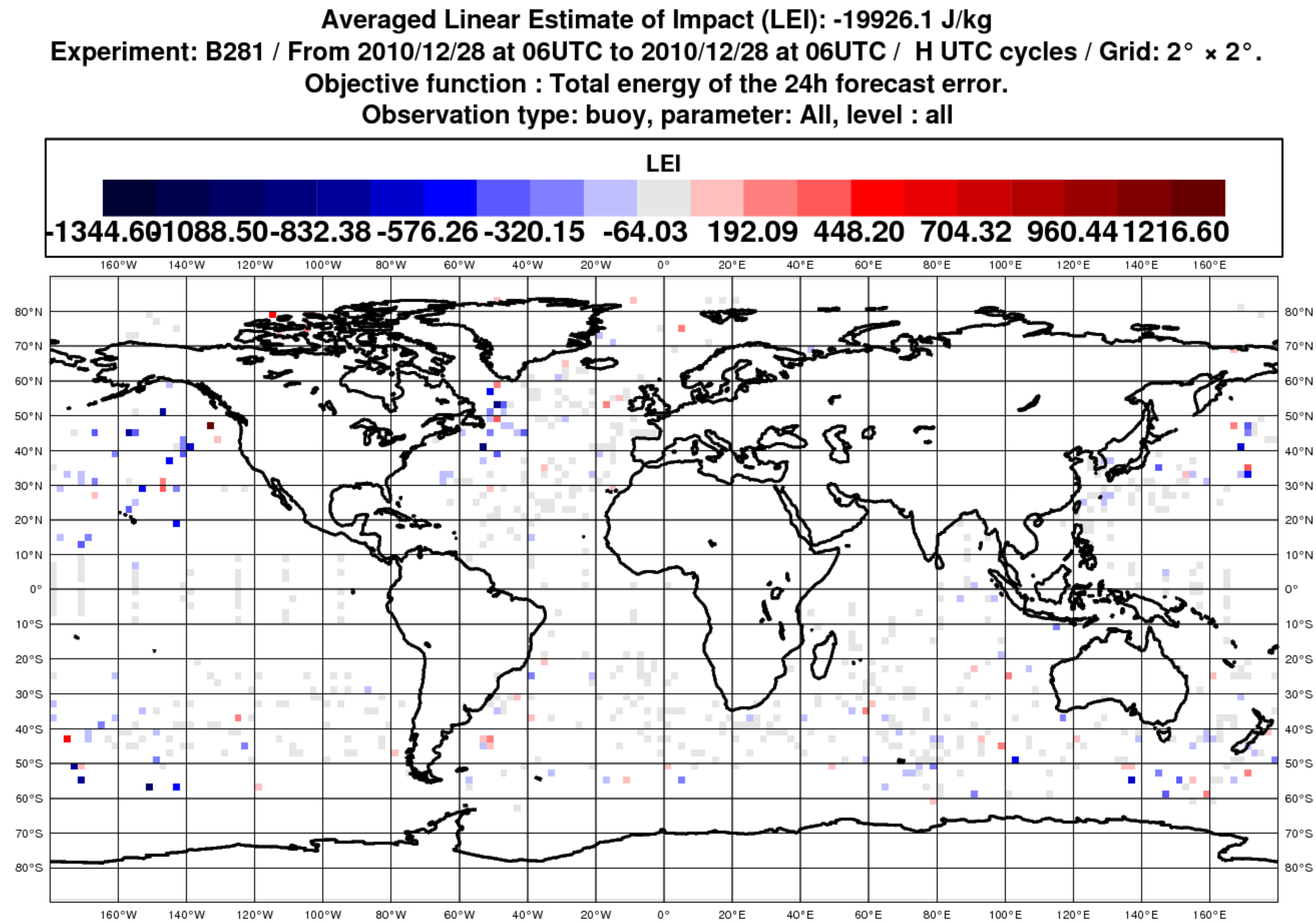
Averaged Linear Estimate of Impact (LEI): -49.4005 J/kg
Experiment: B281 / From 2010/12/02 at 00UTC to 2011/01/15 at 18UTC / H UTC cycles / Grid: 2° × 2°.
Objective function : Total energy of the 24h forecast error.
Observation type: buoy, parameter: Surface V wind, level : all
LEI
-11.99
-9.71
-7.42
-5.14
-2.86
-0.57
1.71
4.00
6.28
8.57
10.85
160°W
140°W
120°W
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S
70°S
80°S

Buoy time series



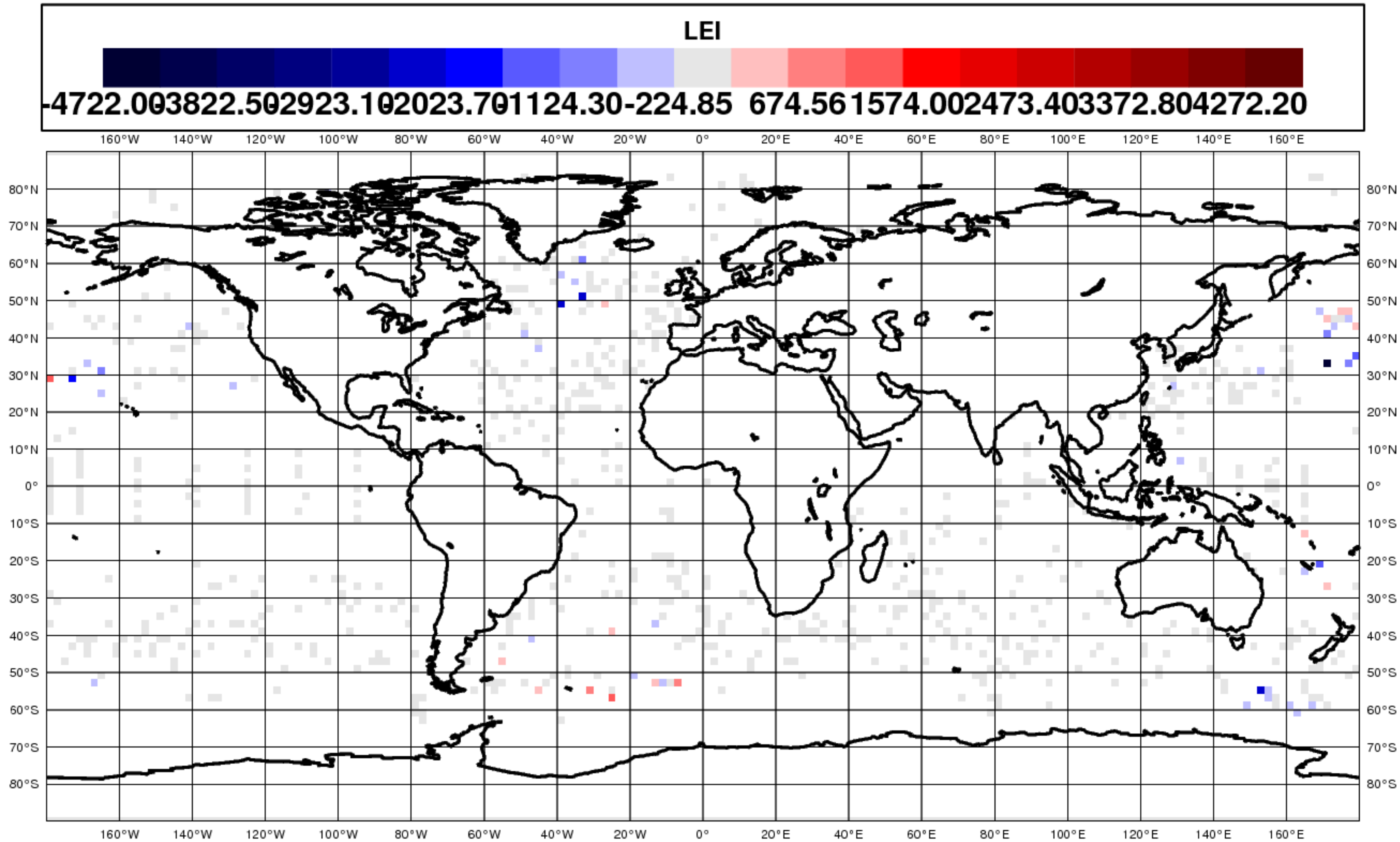


Buoy on the 28/12/2010 06H UTC



Buoy on the 14/01/2011 06H UTC

Averaged Linear Estimate of Impact (LEI): -21635.7 J/kg
Experiment: B281 / From 2011/01/14 at 06UTC to 2011/01/14 at 06UTC / H UTC cycles / Grid: 2° × 2°.
Objective function : Total energy of the 24h forecast error.
Observation type: buoy, parameter: All, level : all



Conclusions

- BUOY observations are used operationally at Météo-France for upper air and surface analyses (global and LAMs)
- Small fraction of observations assimilated in Météo-France models
- Significant fraction of conventional observations over oceans (for surface pressure)
- Wind measurements from BUOY are more accurate than SHIP but less accurate than ASCAT
- Relative information content (DFS) larger than the percentage of observations (lower for most satellite data)
- Largest forecast sensivity to observations (when normalised by the amount of data) => each individual observation is very valuable to reduce short range forecast errors (surface pressure)
- Timeliness of BUOY data could be improved (one hour lag compared to other surface data)

Thank you for your attention

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