Norwegian Meteorological Institute

# A megfigyelések hatása az AROME-Arctic mezoskálájú numerikus időjárás előrejelző modellre az északi sarkkör térségében

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OMSZ – 25.02.2016

# outline

- Motivation of the research study;

- The AROME-Arctic assimilation and forecast system;

- OSE
    - Impact of observations on the analysis system;
    - Impact of observations on the forecast model;
    - Case study;

- OSSE
    - OSSE design and observing network scenarios;
    - Impact study;

- Concluding remarks;

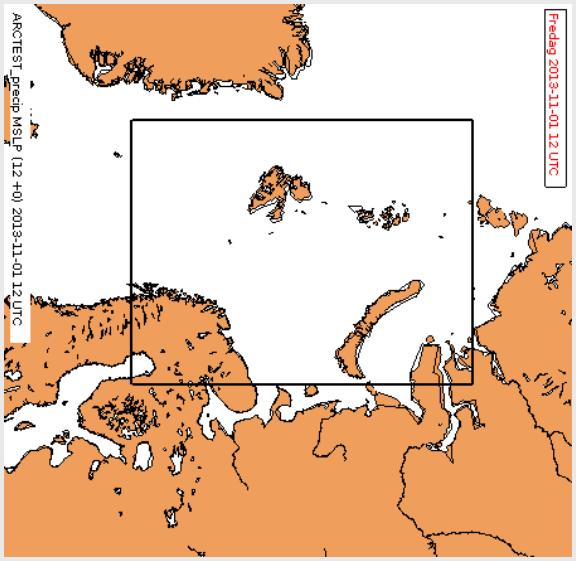
~~- AROME-Arctic operational system (IT infrastructure)~~

# ACCESS: Arctic Climate Change, Economy and Society
# Task 1.8:

1. Describe present *short-range* monitoring and forecasting capabilities in the Arctic
   ==> Observing System Experiments – OSE

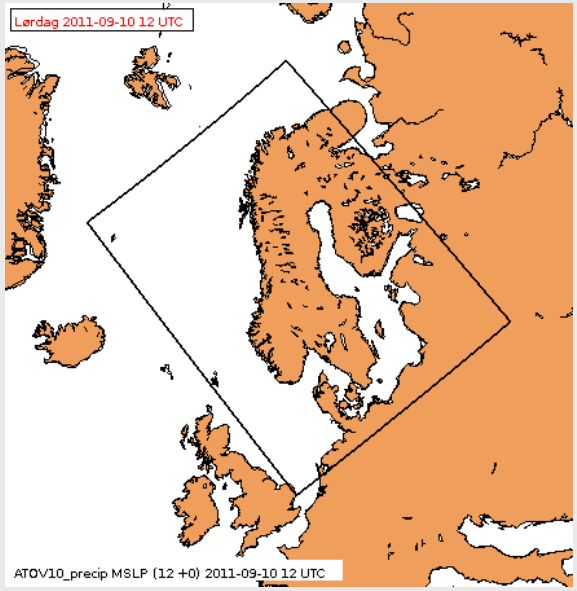
2. Identify key factors limiting the monitoring and forecasting capabilities, and give recommendations for key areas to improve the capabilities
   ==> Obsering System Simulation Experiments – OSSE

# Experimental Arctic HARMONIE (AROME) a convection-permitting 2,5 km model




ARCTIC 750x960

same size:



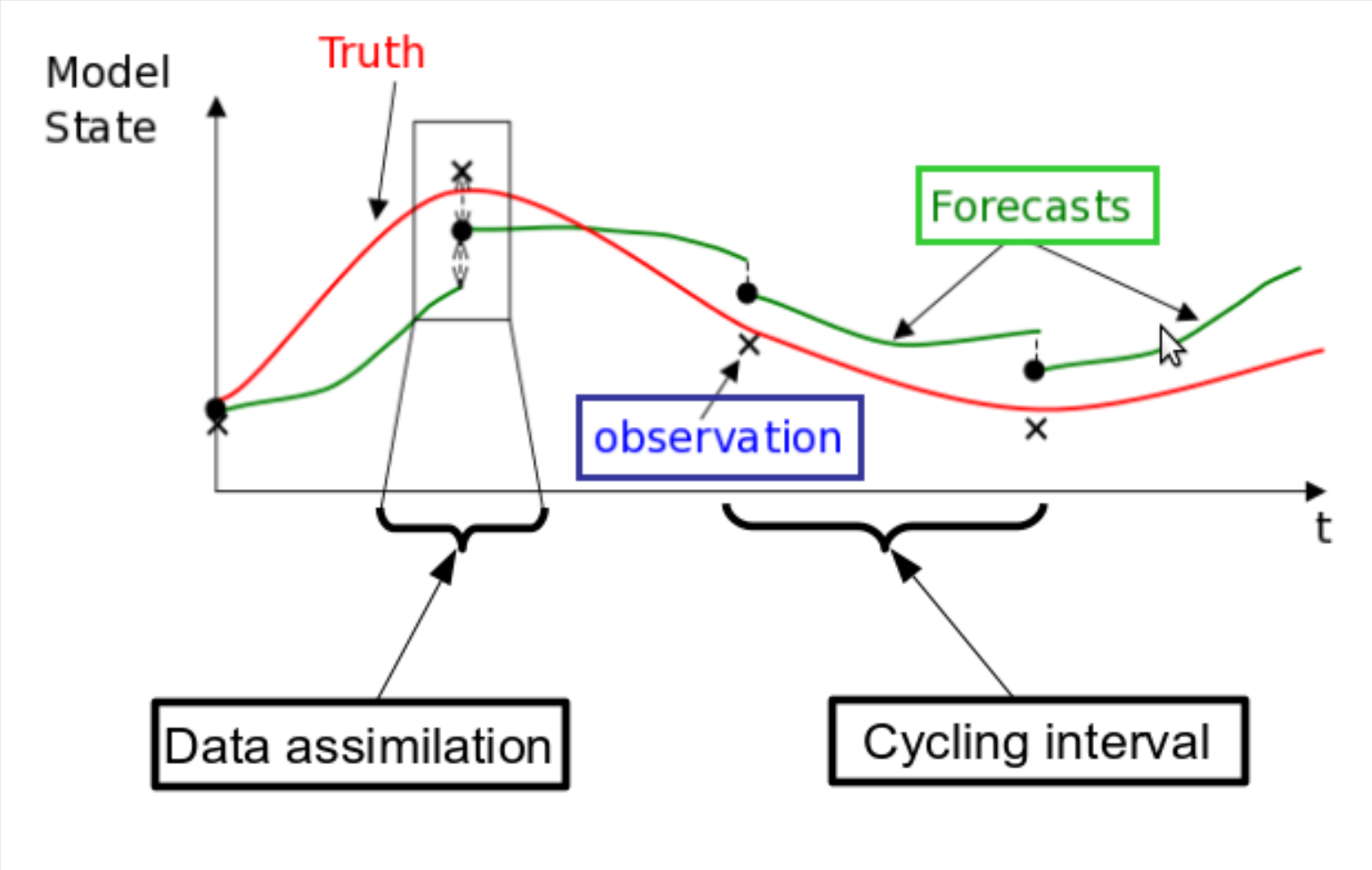

METCOOP

**System setup: (**Harmonie cycle 38h1.1)

- Domain: Same size as METCOOP (750x960)
- Model level definition: 65 level
- Horizontal resolution 2.5 km
- Non-hydrostatic dynamic
- Physical parametrisation: AROME
- Data assimilation: 3D-VAR

  OI for surface
- 3-hourly cycling
- Lateral boundary conditions: ECMWF
- Using all observations from MARS archive
- Background error statistics computed as mean over 4 seasons

# Need for data assimilation in NWP
# Principle of assimilation cycling




We do 3-hourly cycling

# OSE: Observing System Experiments

# OSE – The performed experiments

**ARCREF** – Downscaling of the ECMWF fields without assimilation;

**ARCSURF** – Only surface analysis is used;

**ARCAIREP** – Surface and upper-air assimilation with conventional observations without aircraft data;

**ARCCONV** – Surface and upper-air assimilation with full conventional observations;

**ARCAMSUAN** – System with added ATOVS-AMSU-A radiances;

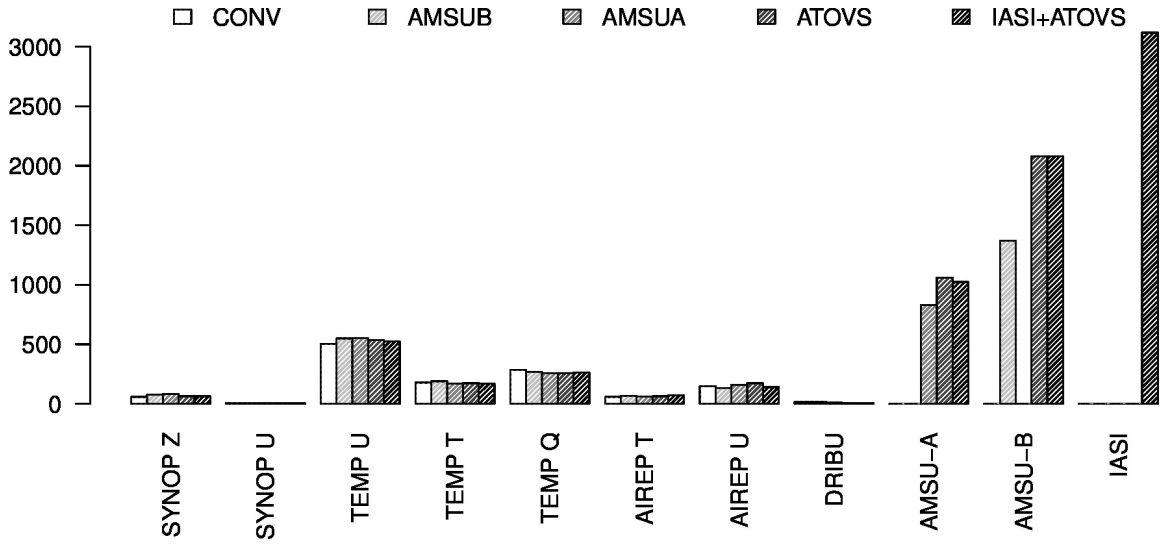
**ARCAMSUB** – System with added ATOVS-AMSU-B/MHS radiances;

**ARCATOVN** – System with added both ATOVS radiances;

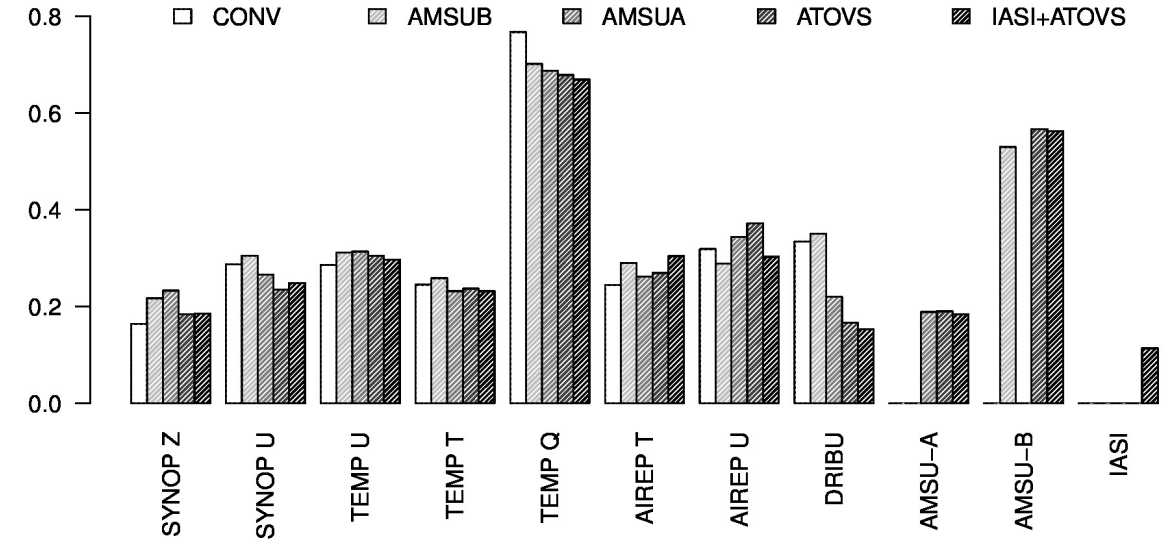
**ARCIASI** – System with further added IASI radiances.

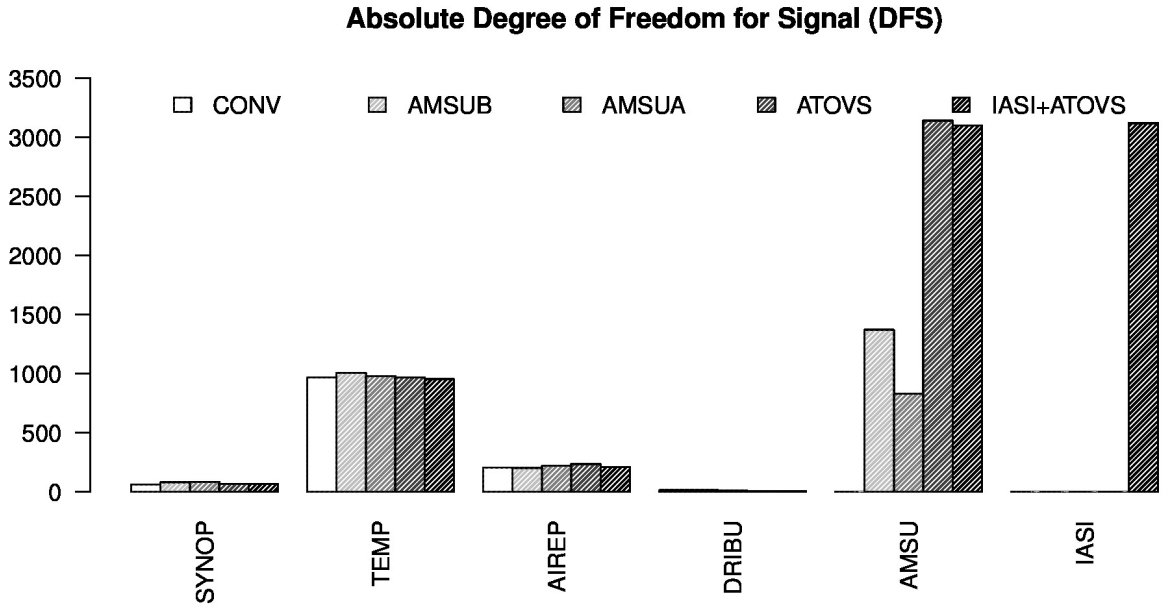
# Impact of observations on the analyses using DFS – Degrees of Freedom for Signals

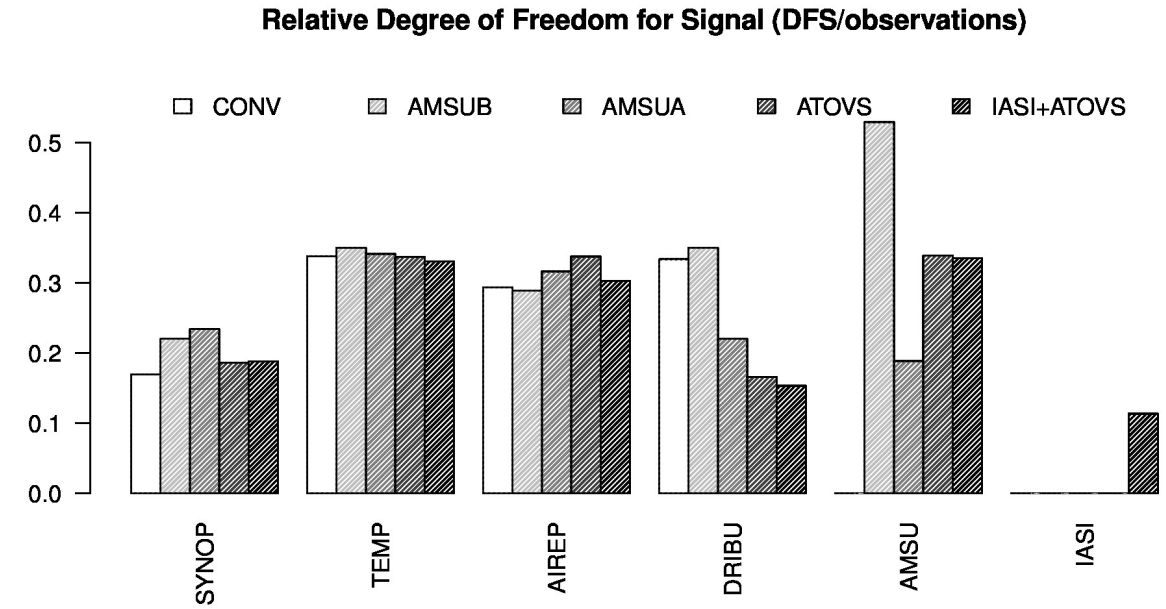
## Absolute Degree of Freedom for Signal (DFS)




## Relative Degree of Freedom for Signal (DFS/observations)



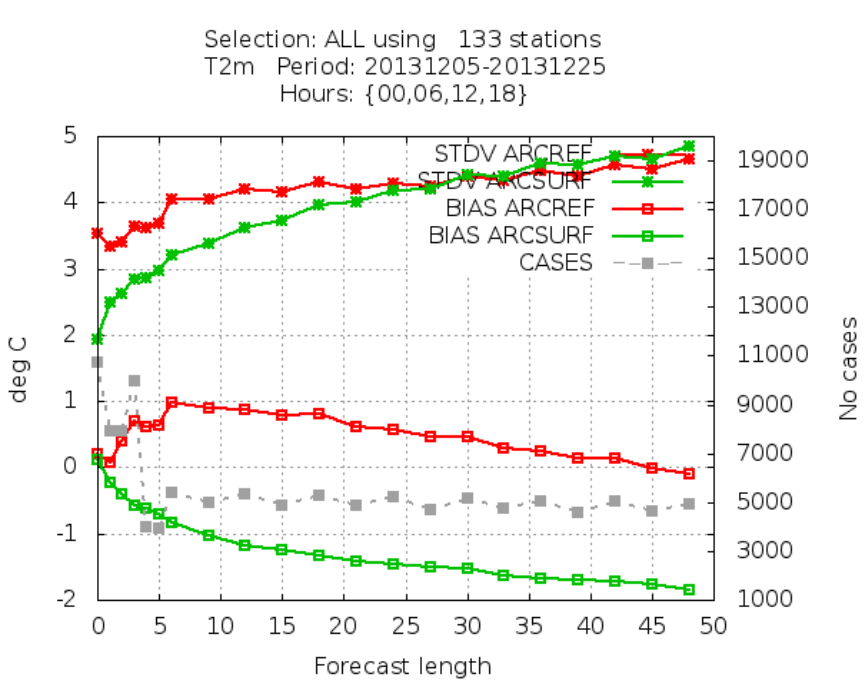


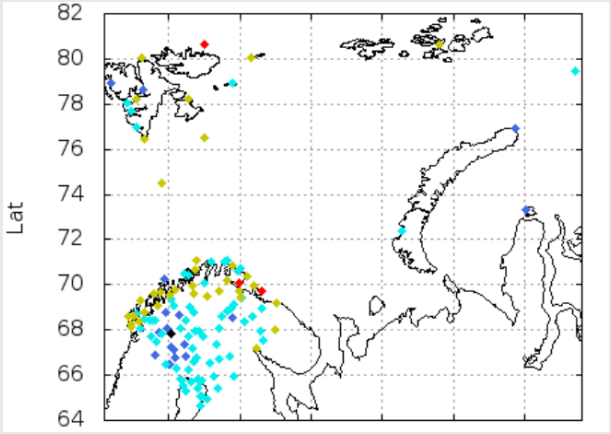



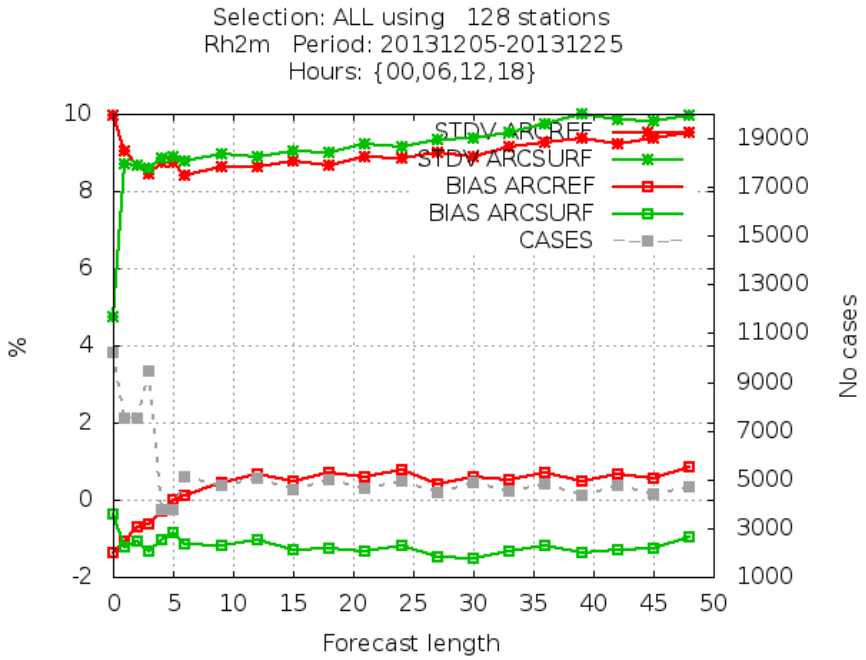
# Impact of observations on the forecast using comparison against observations

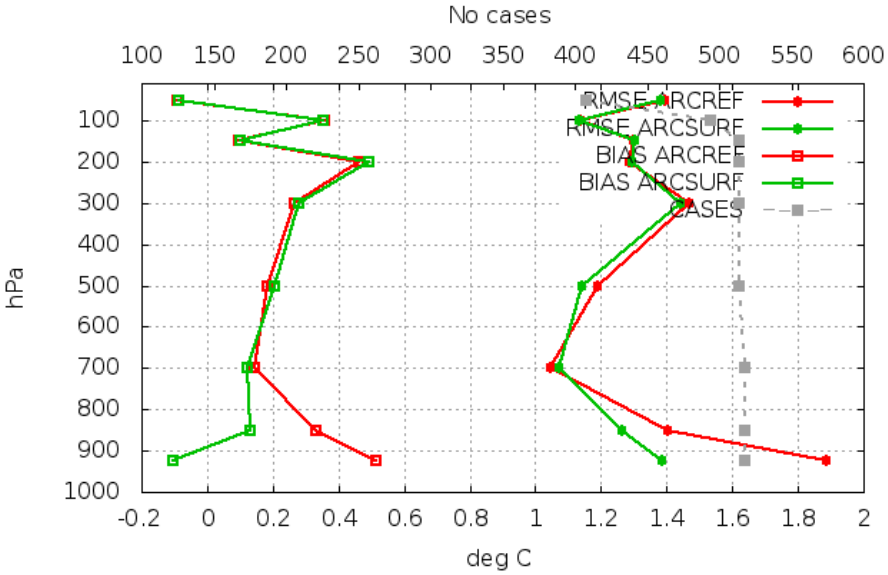
Red line – no assimilation, downscaling of ECMWF fields (ARCREF);

Green line – system with surface assimilation (ARCSURF)

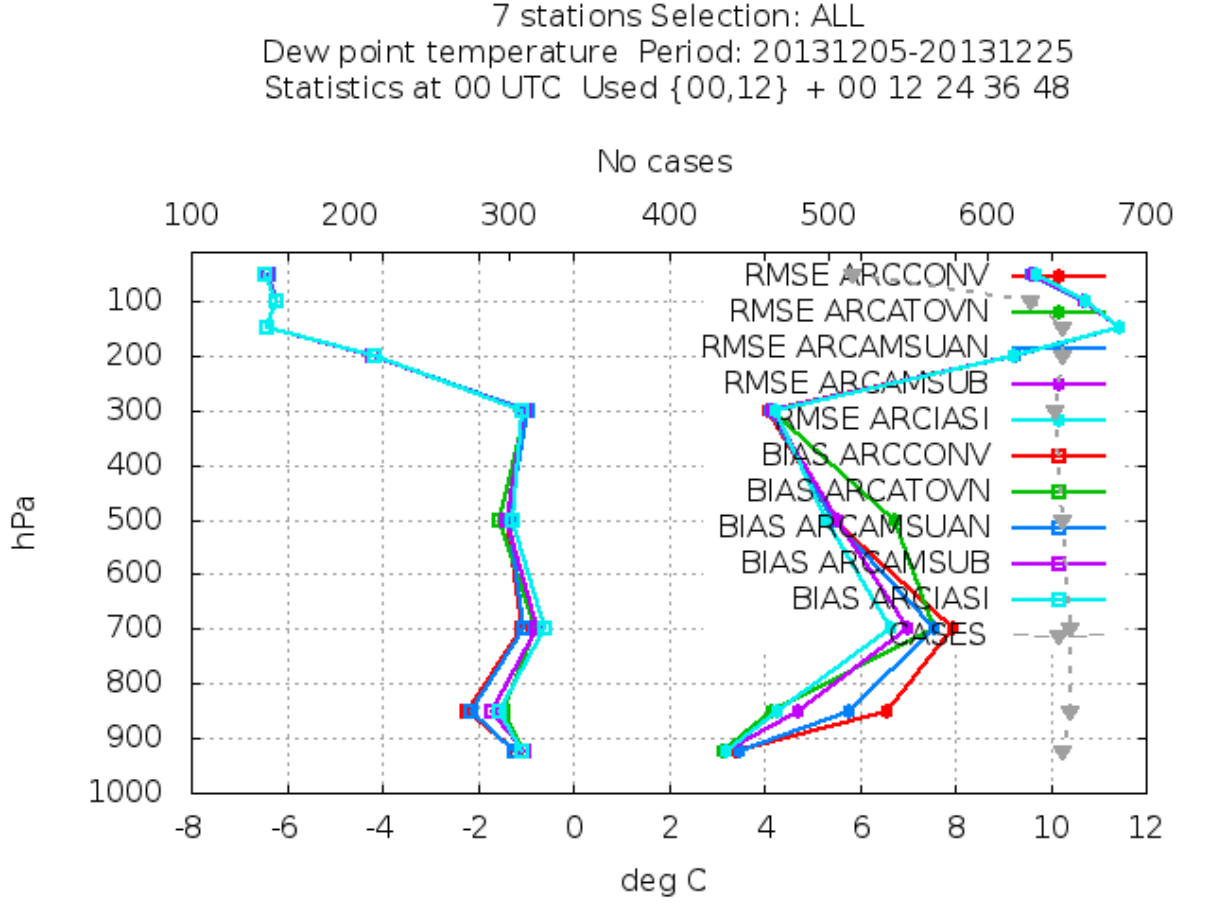


Red line – system with full conventional data (ARCCONV)
Green line – system with ATOVS instruments (ARCATOVN)
Blue line – system with AMSU-A radiance (ARCAMSUAN)
Violet line – system with AMSU-B/MHS radiance (ARCAMSUB)
Light blue – system with ATOVS and IASI radiances (ARCIASI)



# Sensitivity of the forecasts to the used observations using Moist Total Energy Norm (MTEN) *(Storto and Randriamampianina, 2010)*

wants to be evaluated. The impact of the observations is evaluated by means of a cost function, given as

$$J = \left\langle M_t(\mathbf{x}^a_{ctr}) - M_t(\mathbf{x}^a_i),\quad M_t(\mathbf{x}^a_{ctr}) - M_t(\mathbf{x}^a_i) \right\rangle, \qquad (2)$$

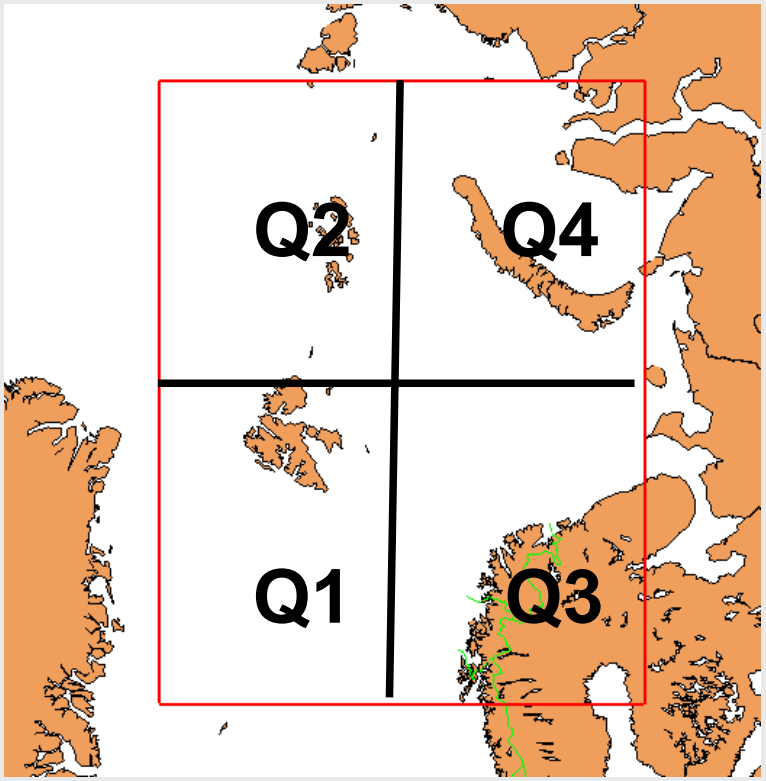
where $\mathbf{x}^a_{ctr}$ and $\mathbf{x}^a_i$ are the analysis from the "all-observation" experiment and that with the withholding of the *i*-th observing group, respectively, $M_t$ is the (fully non-linear) forecast model operator and $\langle \ldots, \ldots \rangle$ stands for the moist total energy norm, defined as in Ehrendorfer *et al.* (1999):

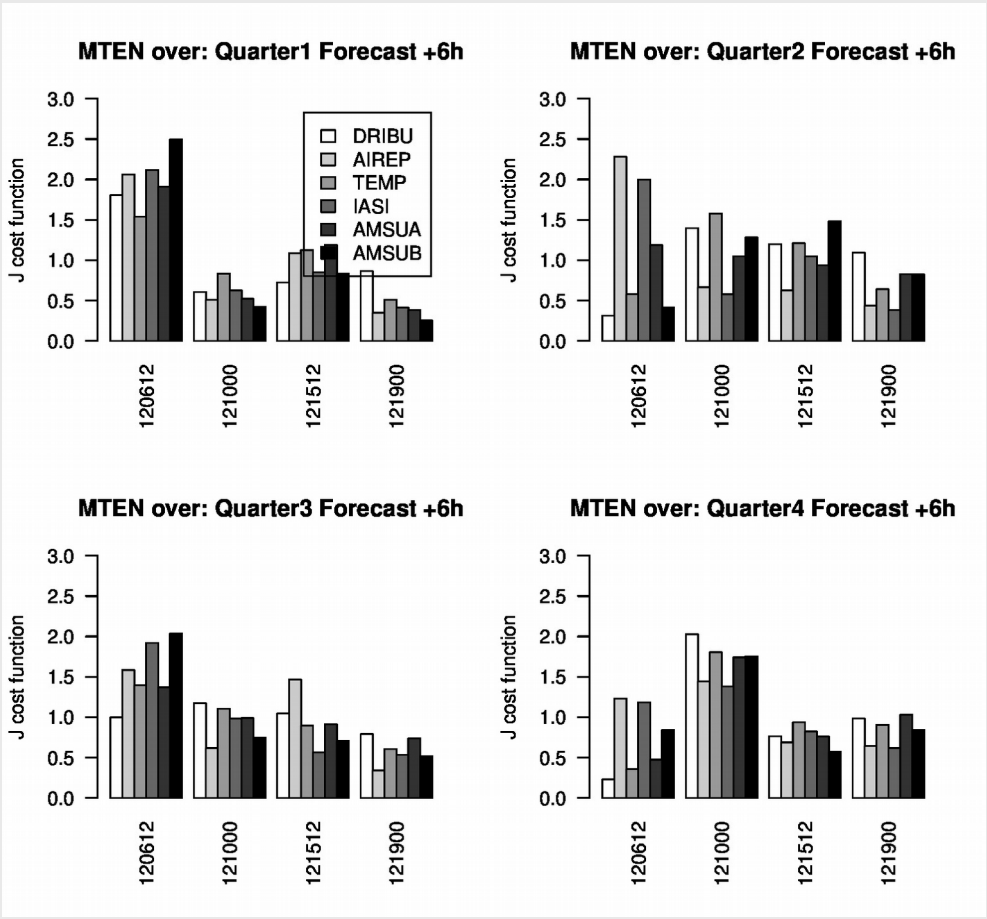
$$\left\langle \mathbf{x}^i_t - \mathbf{x}^{ctr}_t, \mathbf{x}^i_t - \mathbf{x}^{ctr}_t \right\rangle = \int_{\eta_0}^{\eta_1}\int_D \left( u^2 + v^2 + \frac{c_p}{T_r}T^2 + \frac{RT_r}{p_r^2}p^2 + \frac{L^2}{c_p T_r}q^2 \right) \frac{\partial p_r}{\partial \eta} d\eta\, dD \qquad (3)$$

*where* $u$, $v$, $T$, $p$, $q$ being respectively the difference of $u$- and $v$-component of wind, temperature, surface pressure and specific humidity between the control forecast and the one without the *i*-th set of observations; $c_p$, $R$, $L$ are specific heat at constant pressure, gas constant of dry air, and latent heat condensation; $T_r$ and $p_r$ are reference temperature and reference pressure; $\eta$ is the vertical coordinate. The previous norm is integrated over all the vertical levels between $\eta_0$ and $\eta_1$ and over the domain $D$, which may coincide with the whole model domain depending on the definition of the localisation operator **P**. In our case, for example, the AROME-Arctic domain was divided into four equal sub-domains (*see Fig*

# Sensitivity of the forecasts to the "withdrawn" observations

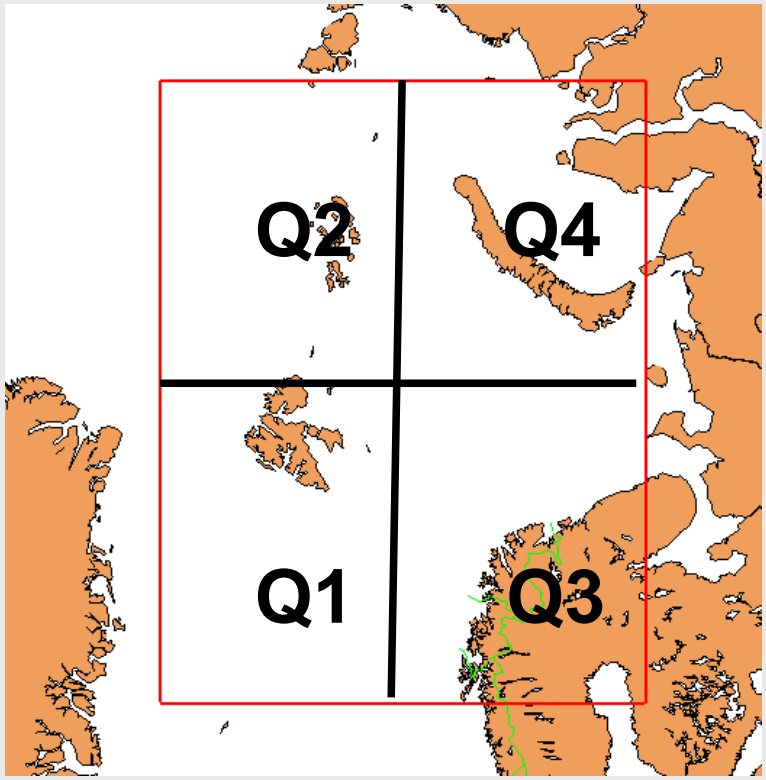
## *6-hour forecasts*

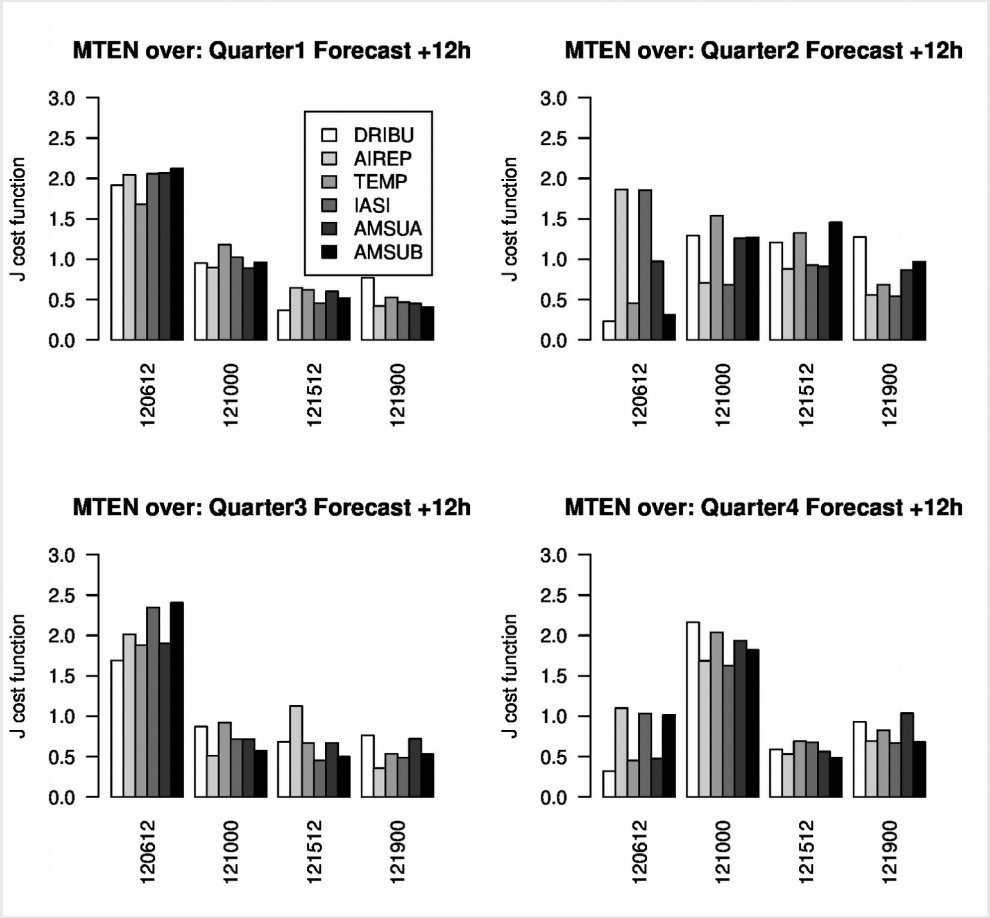


# Sensitivity of the forecasts to the "withdrawn" observations

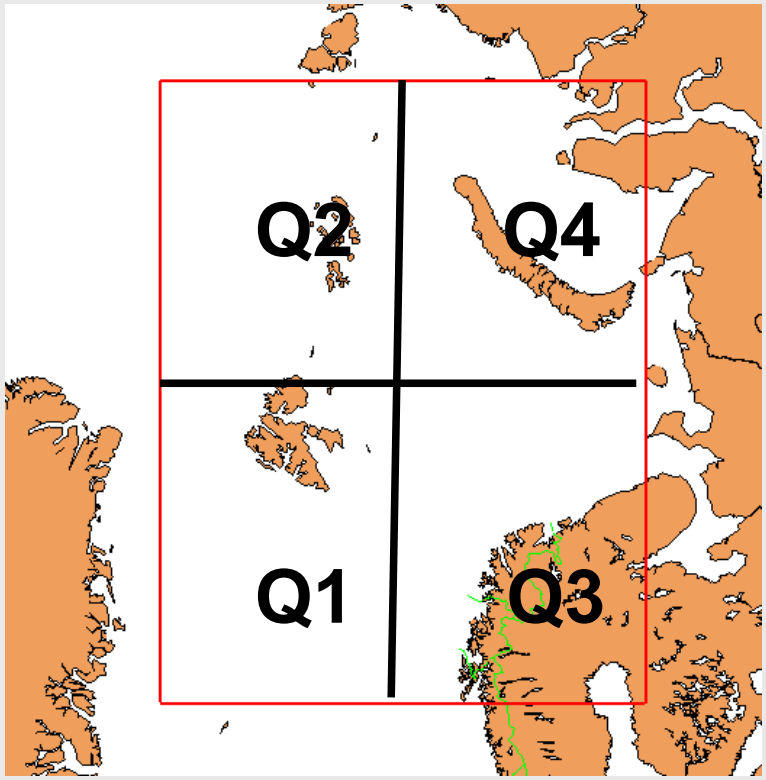
## *12-hour forecasts*

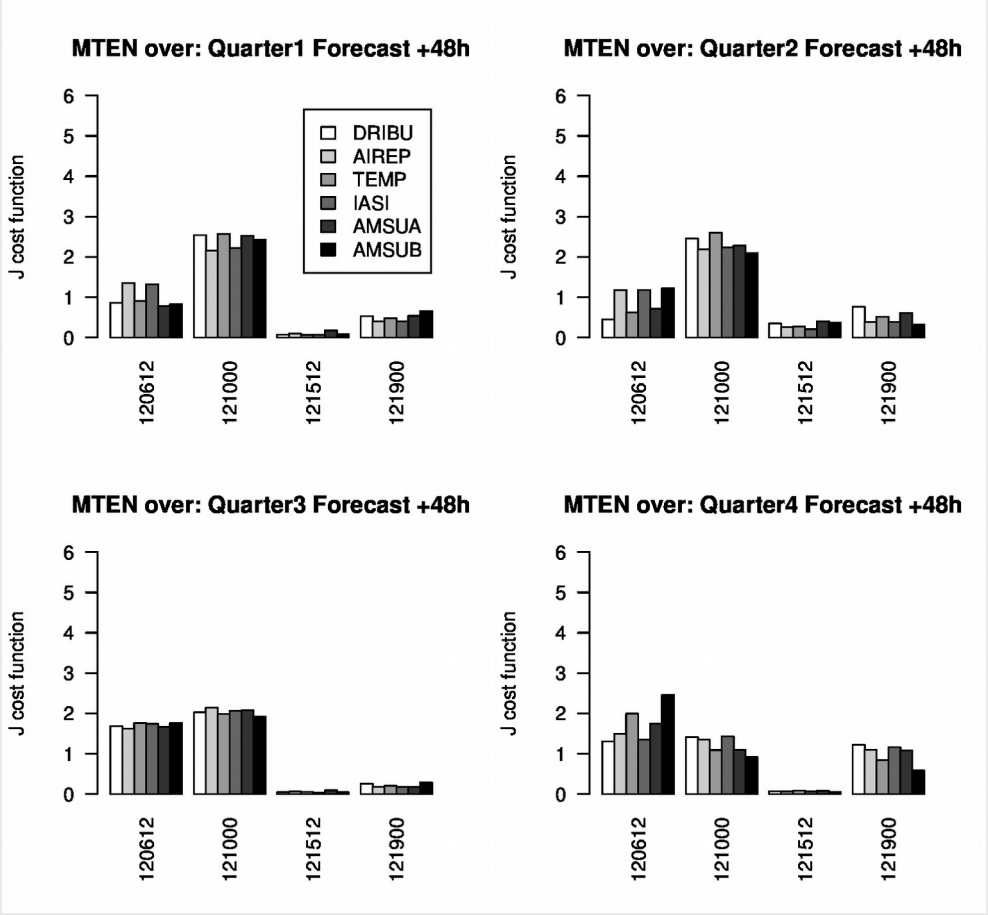


# Sensitivity of the forecasts to the “withdrawn” observations

## *48-hour forecasts*

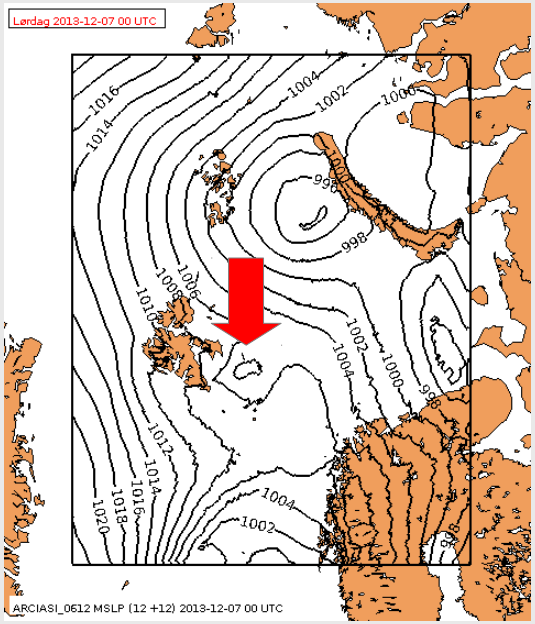


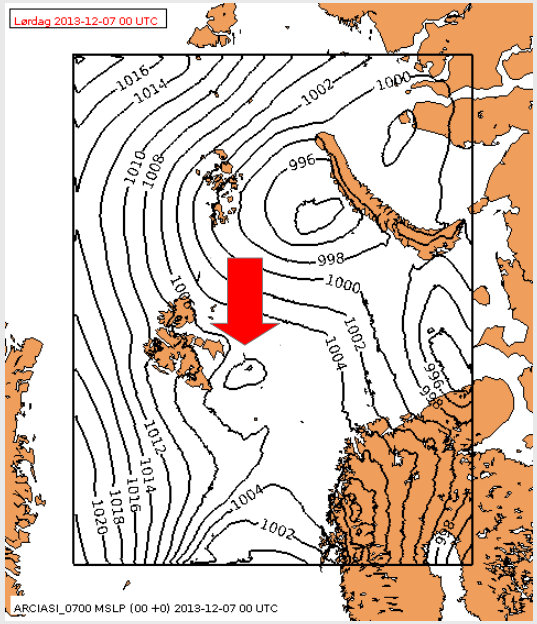
# Case studies

## 1) Polar low (8th of Dec. 2013) and

## ~~2) Fast moving synoptic-scale cyclone 10-12 Dec. 2013~~




2013.12.06 12UTC

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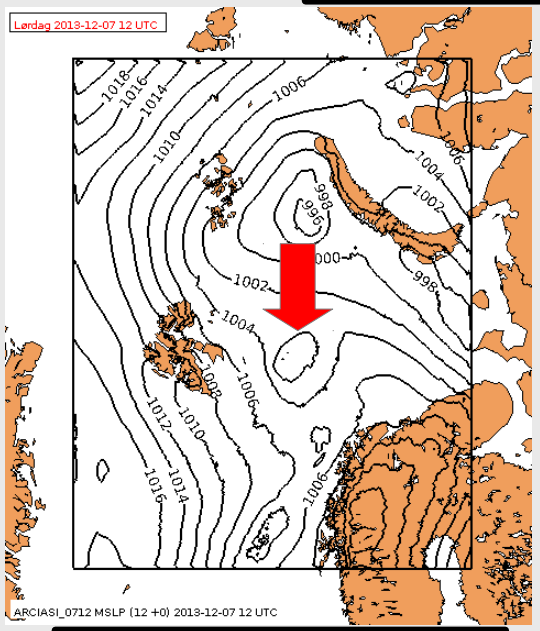


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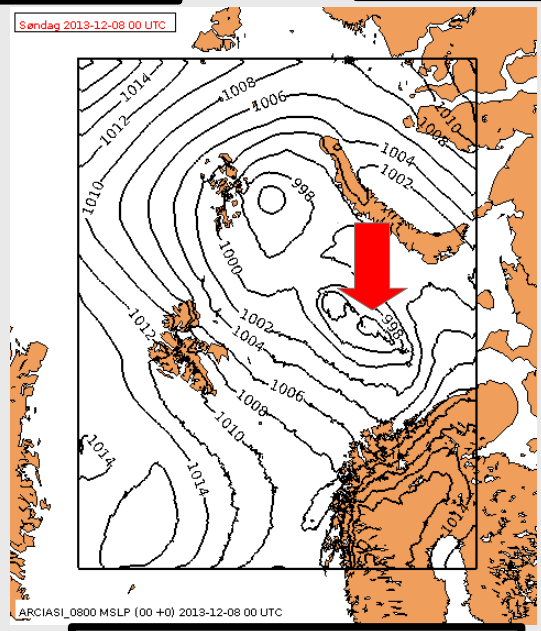


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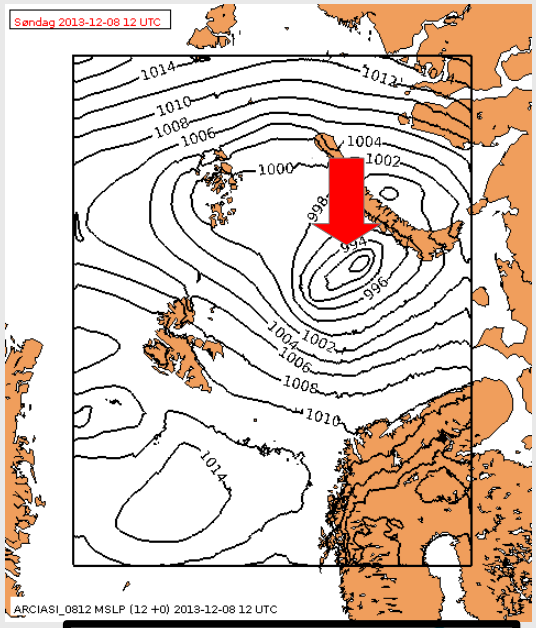


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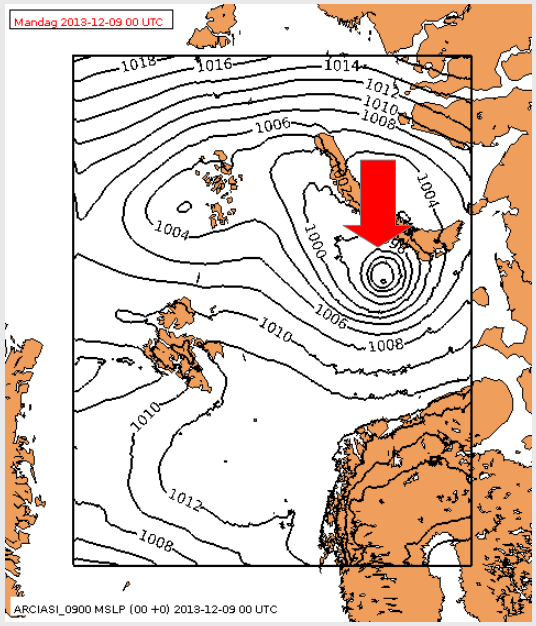
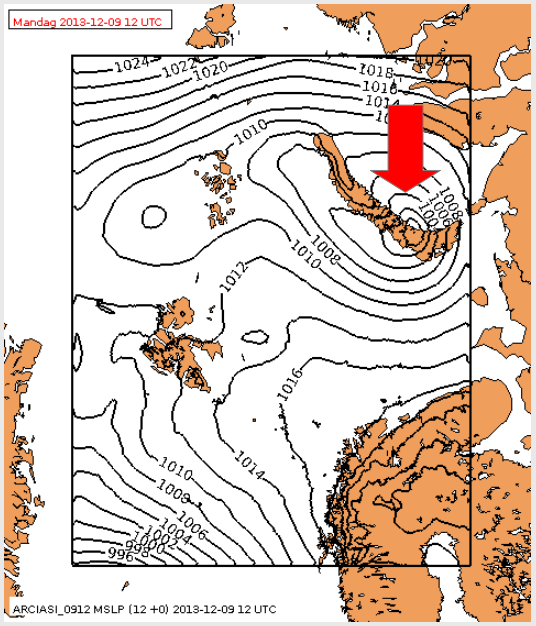



2013.12.09 00UTC

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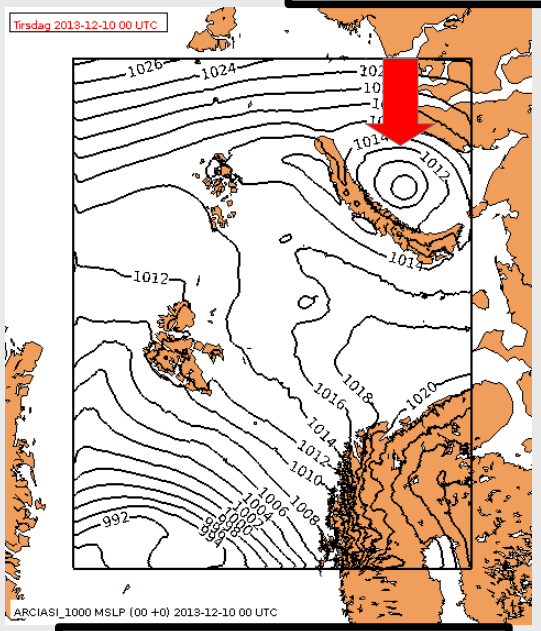
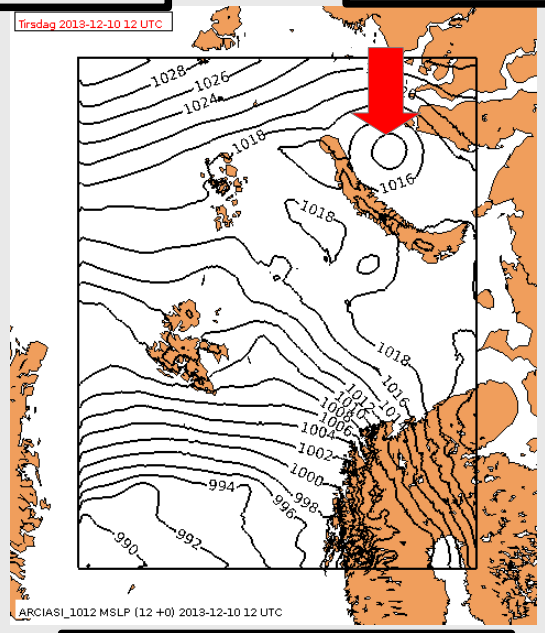
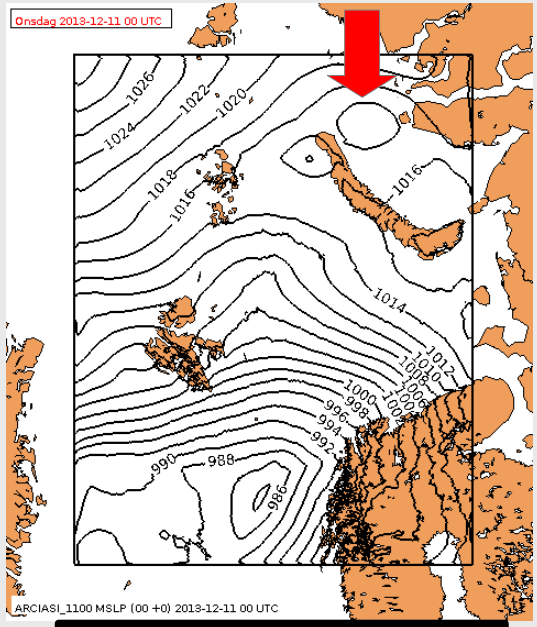



2013.12.10 00UTC




2013.12.10 12UTC




2013.12.11 00UTC

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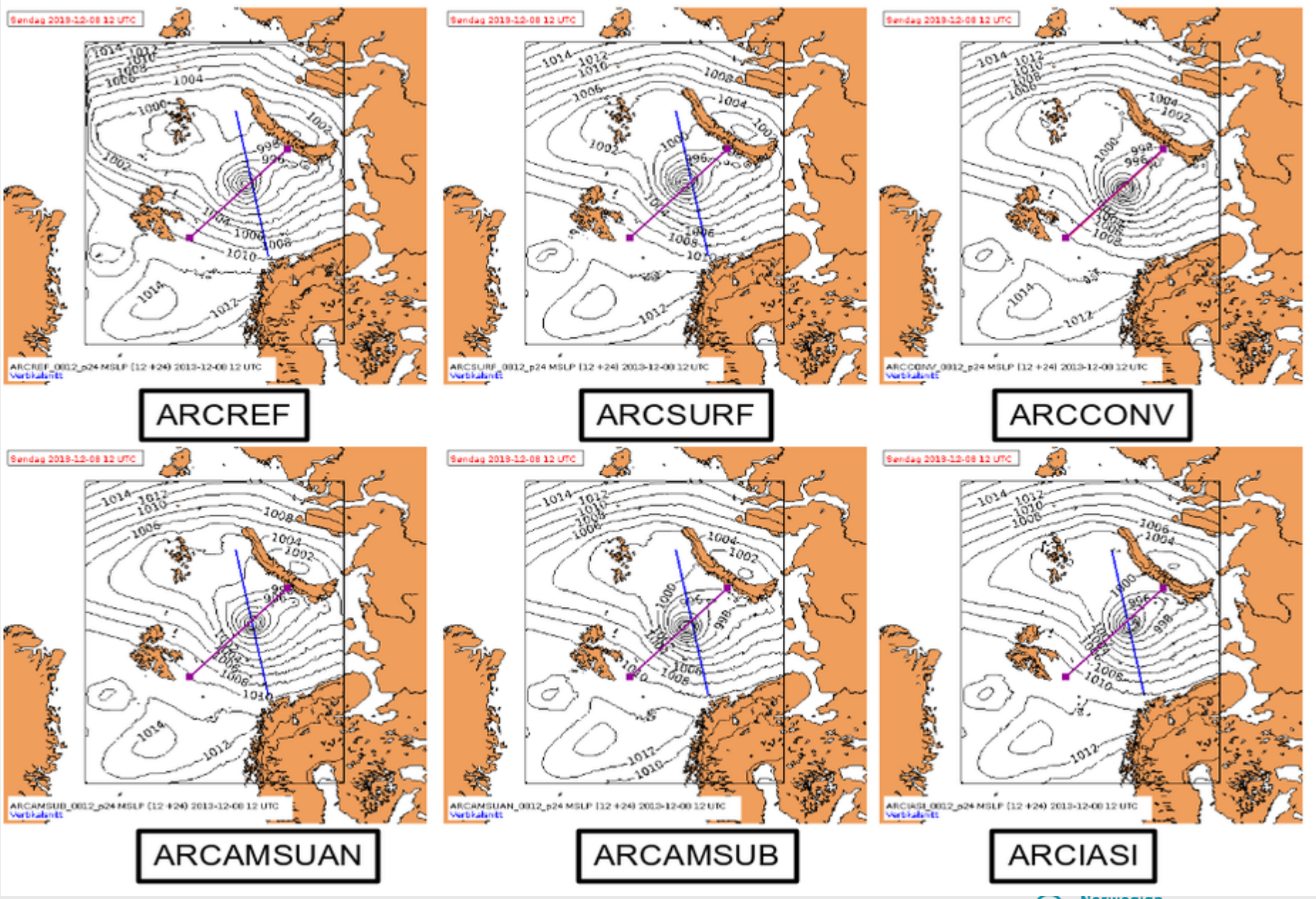


24 hour forecast, valid for 08.12.2015, 12 UTC

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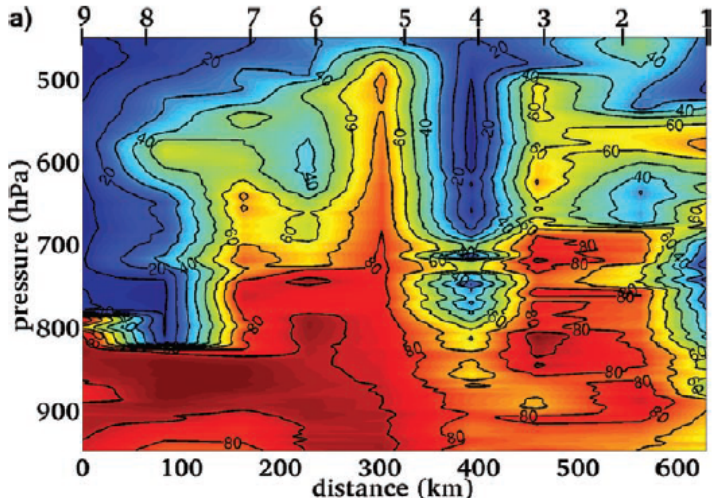
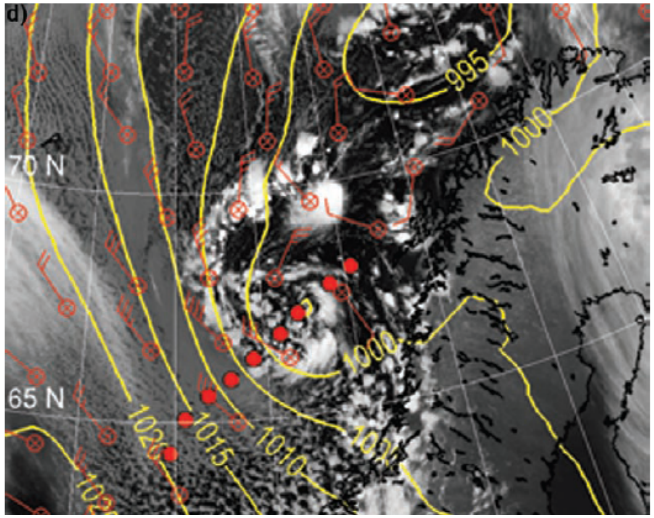
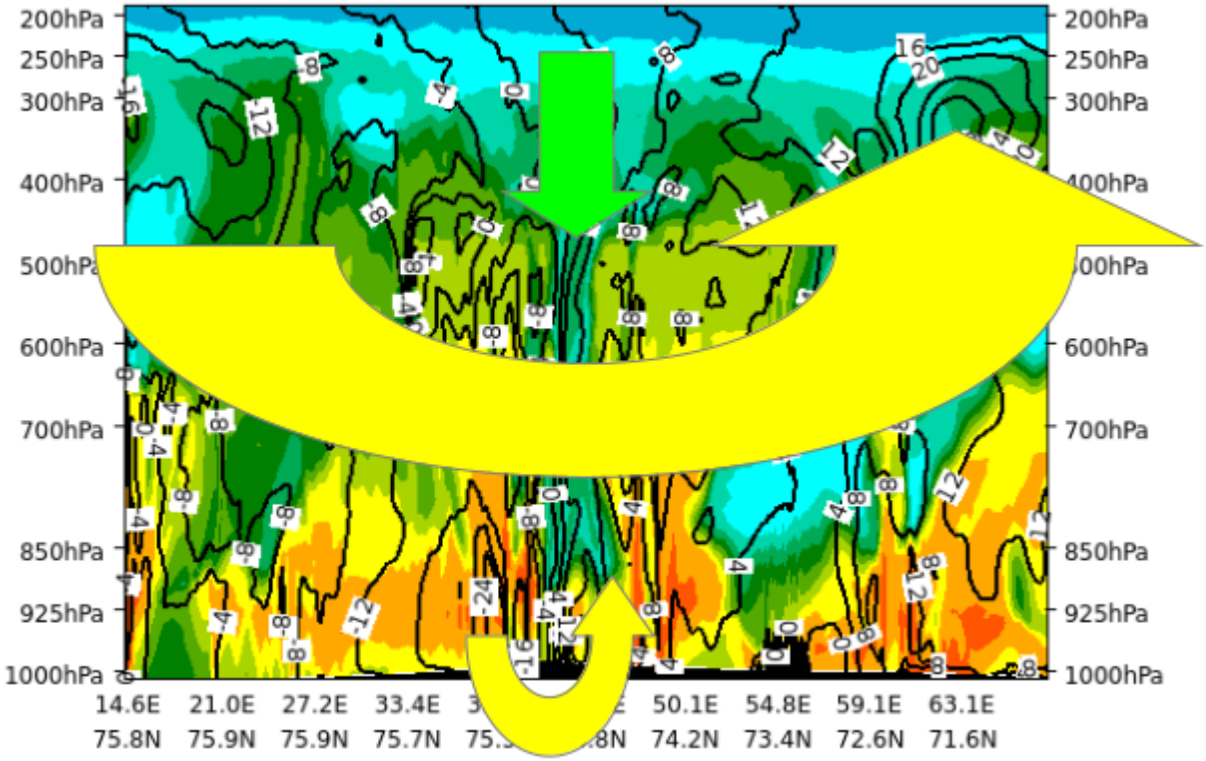
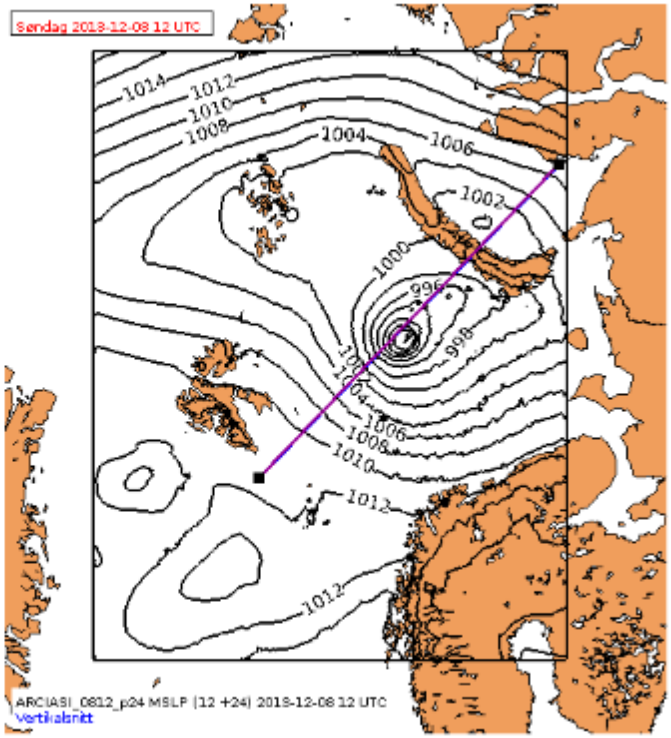
# The polar low case – 8th of Dec. 2013

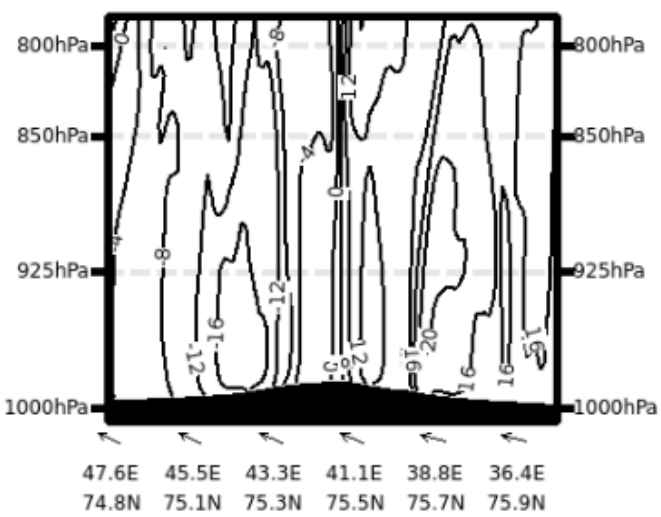



Kristjánsson at al., 2011

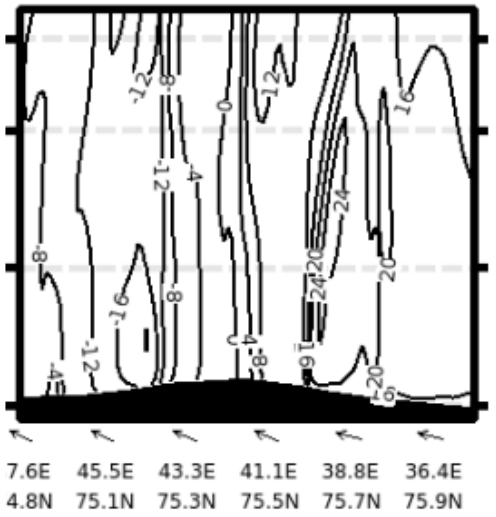


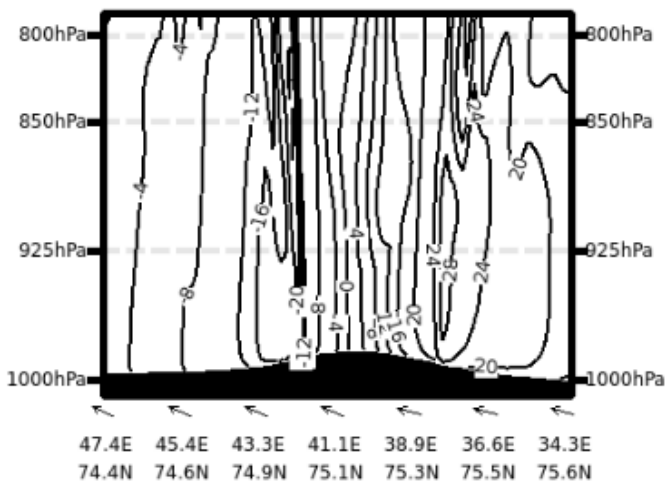





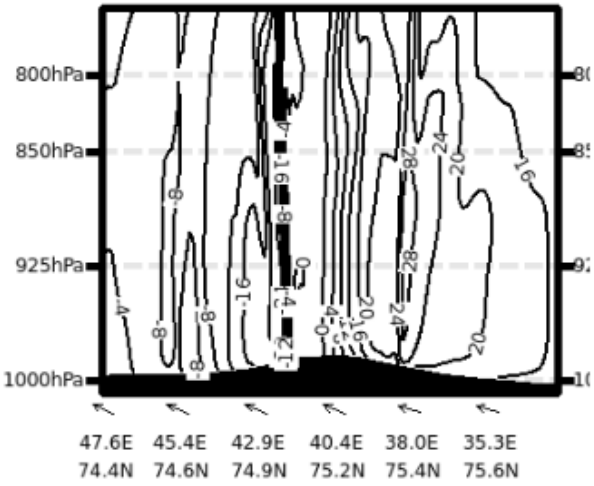

ARCREF



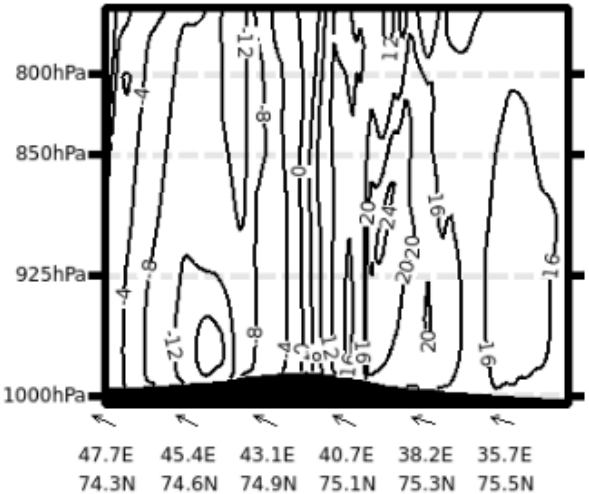

ARCSURF



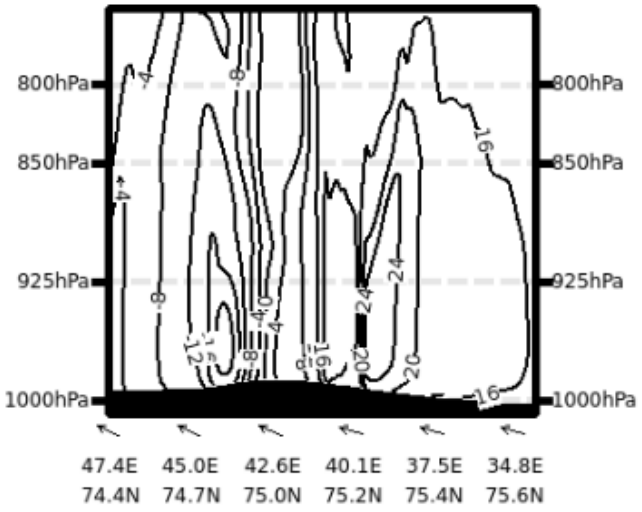

ARCCONV




ARCAMSUAN



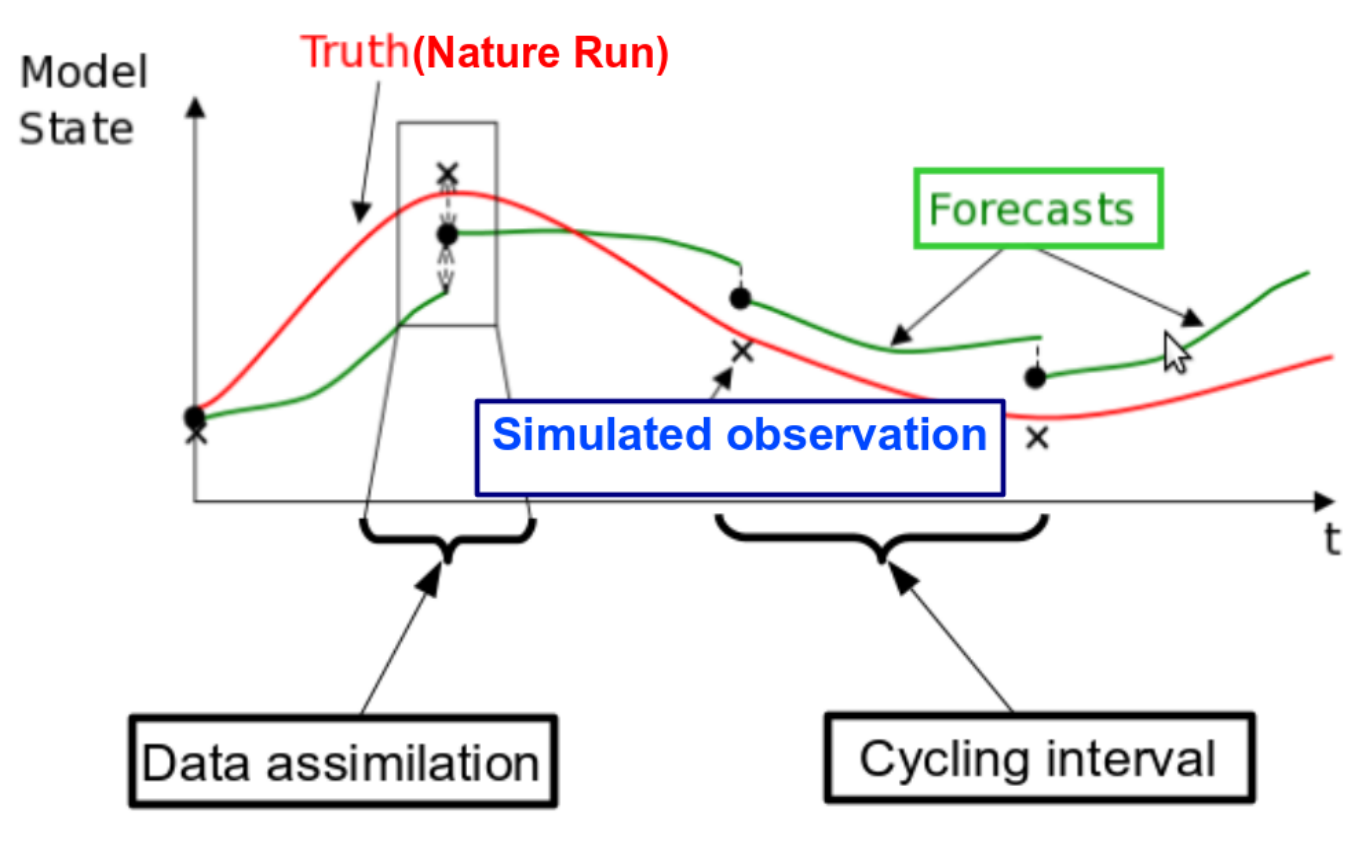

ARCAMSUB




ARCIASI

# OSSE: Observing System Simulation Experiments

# OSSE design



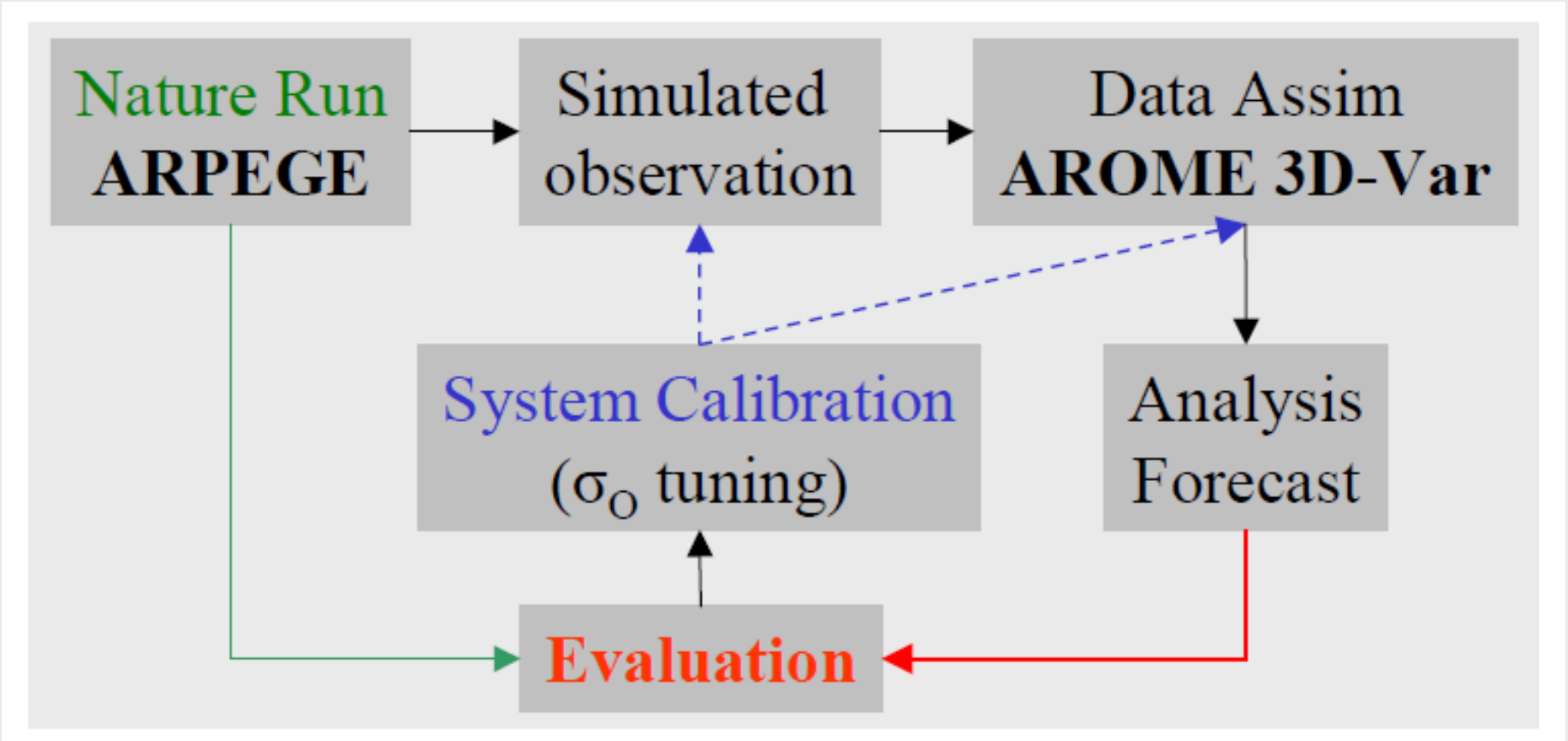

**Nature run (NR):** Using the French ARPEGE global model for August 2013

**Observation simulation:** $y^s = NR + \delta$; $\delta = N(0, \lambda\sigma_o^2)$

$\delta$ – a random number using Gaussian distribution;

$\sigma_o$ – the observation error.

# OSSE experiments design
# Estimation/Tuning of the observation errors



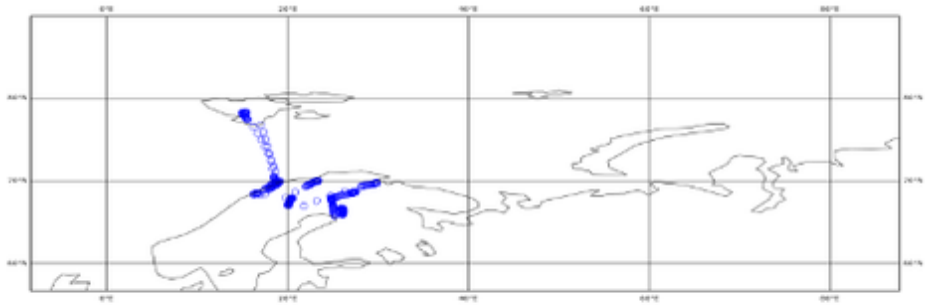

Simulated observation Y= NR + $f(\lambda\ \sigma_o)$ ; λ= 0.2, 0.4, **0.6**, 0.8,1.0 were tested.

Where $\sigma_o$ is the observation error.

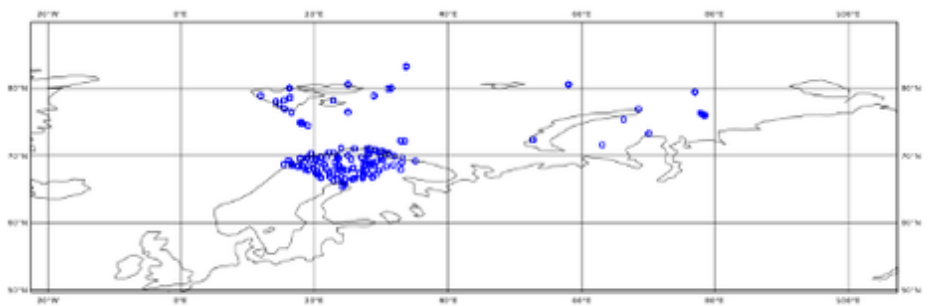
**Evaluation period:** 1-10 August 2013.

# Observations to be simulated

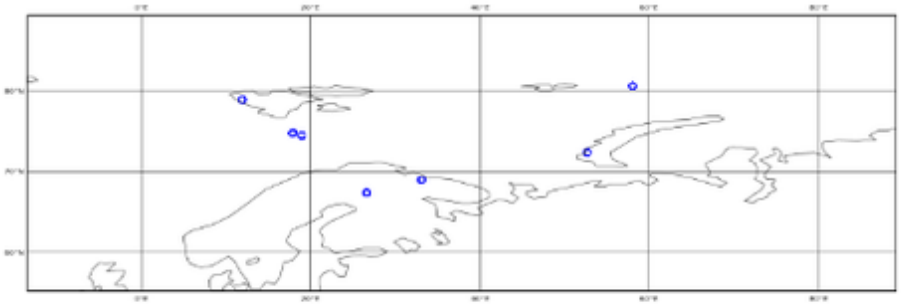
# current observing networks



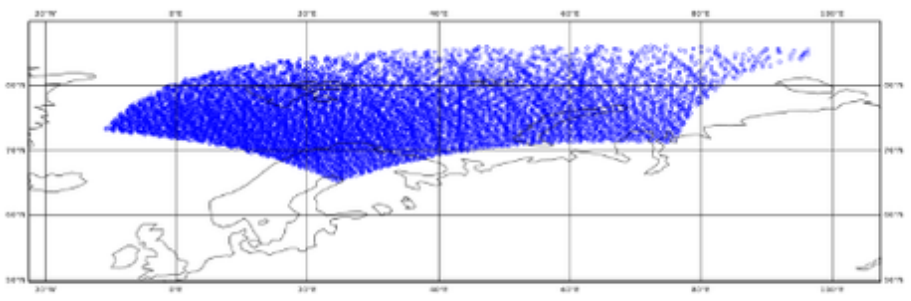
Aircraft



Surface



Radiosonde

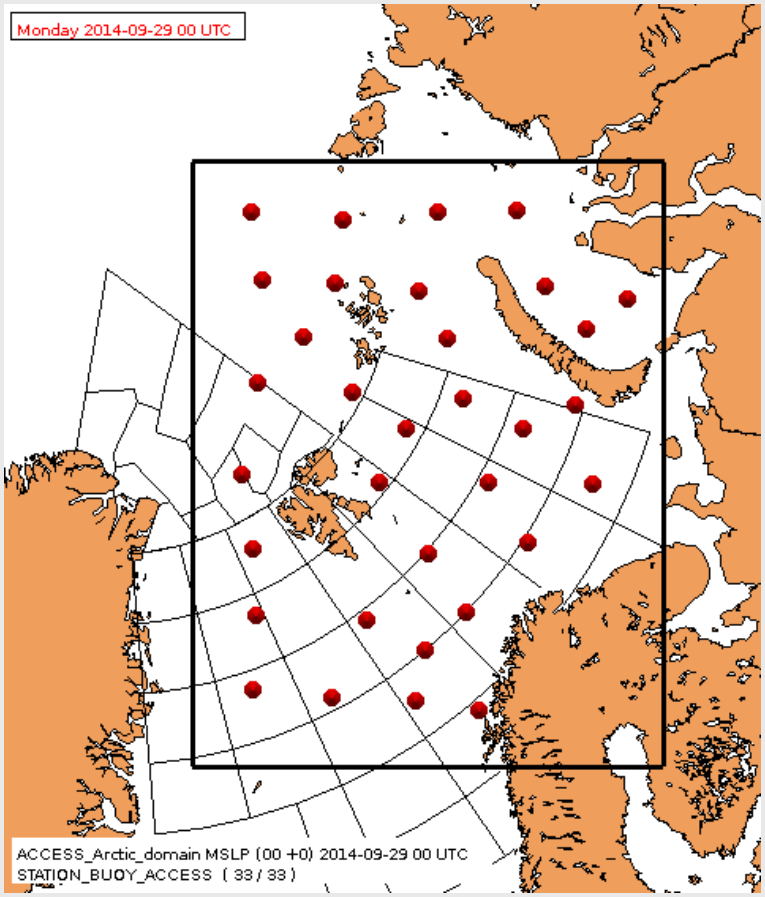


Satellite data

Case of 12 UTC

# Observations to be simulated

## simulation of (politically) reasonable observing networks




## Four scenarios:

1) Randomly distributed BUOY stations
adding 33 BUOYs
(OSSEMBUOY – about 45 active) → 4x

adding 12 (2x) and 22 (3x) BUOYS

2) At least daily 2 launches of the existing (7, 2 RS more at 00 UTC) radiosondes (OSSE2XTEMP)

3) 4 launches per day of the existing (7, 16 RS more per day) radiosondes (OSSE4XTEMP)

4) (Reference) Run with the simulated current observing networks (OSSEREF)

# OSSE impact study

## Verification period: 15-30 August 2013
## with warming period 10-14 August 2013

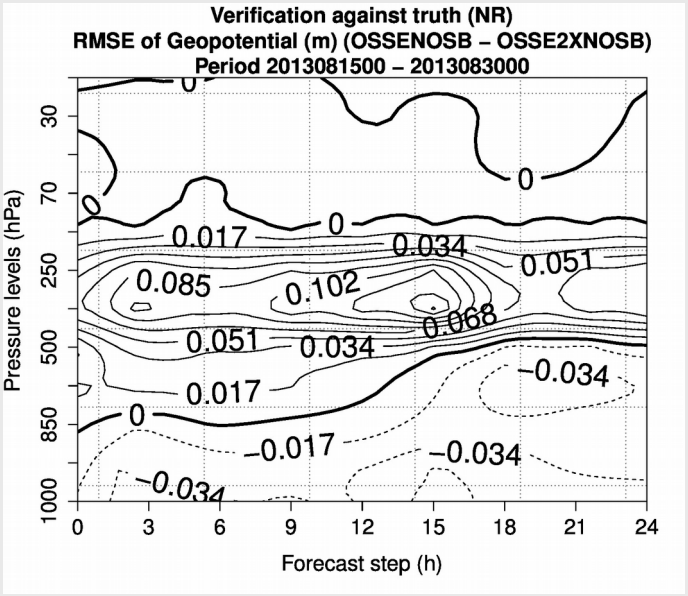
**The large-scale mixing is not used in this study**

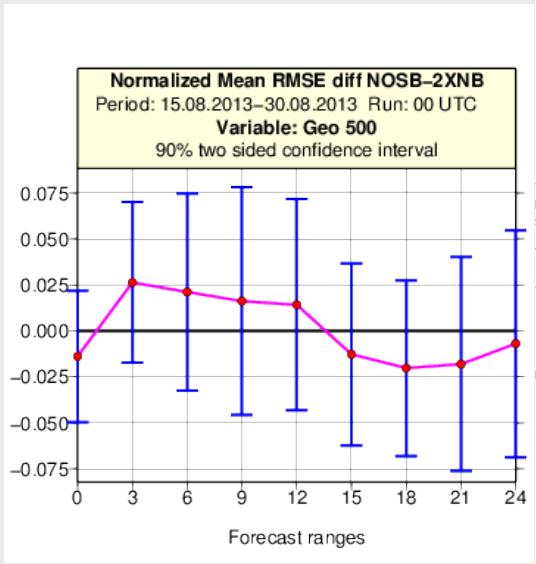
**Fact:**

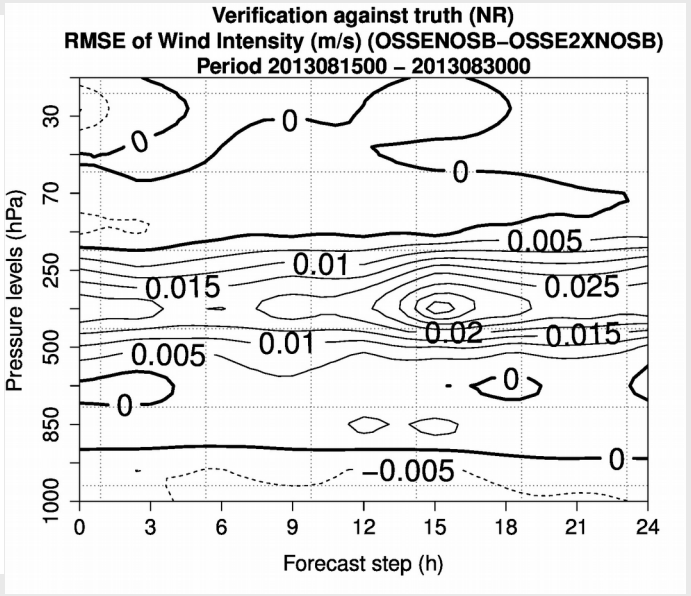
**up to 24 hours of NR ==> *24 h forecasts at 00 UTC***
**12 h forecasts at 12 UTC**

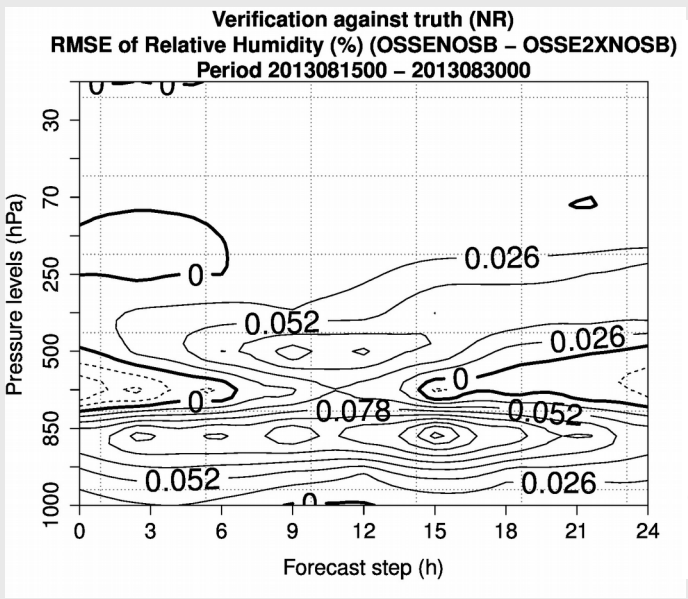
**Verification against the truth – field verification**

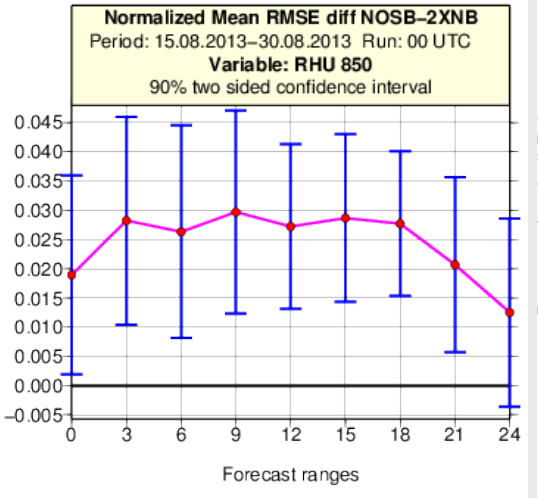
# OSSE – impact of “at least 2 launches” of radiosondes per day

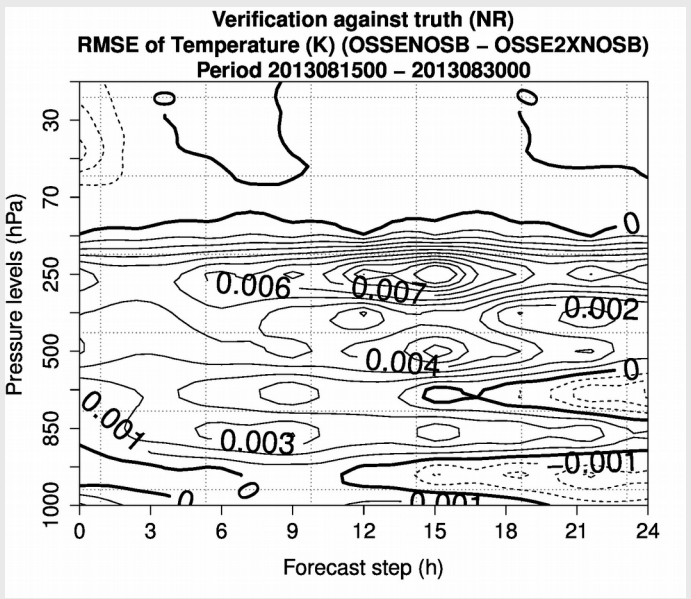


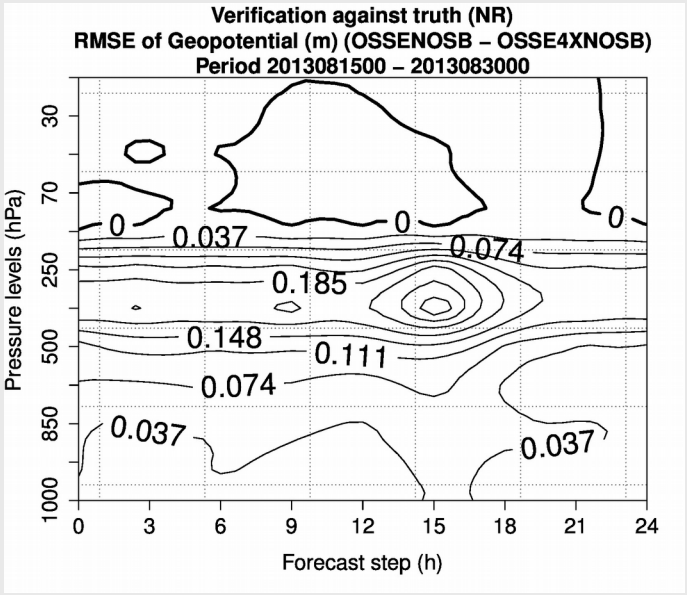



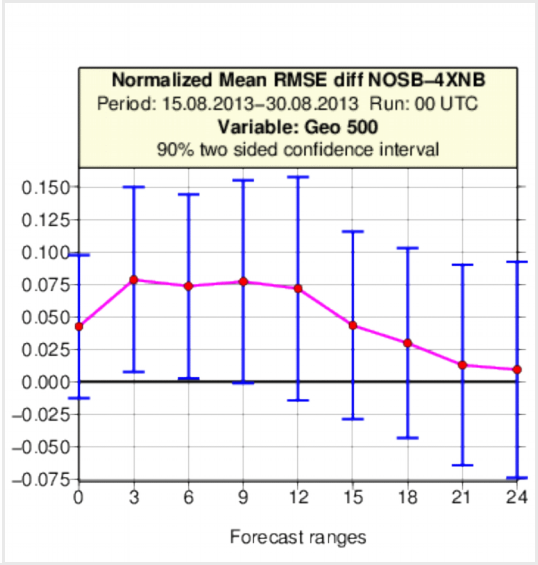



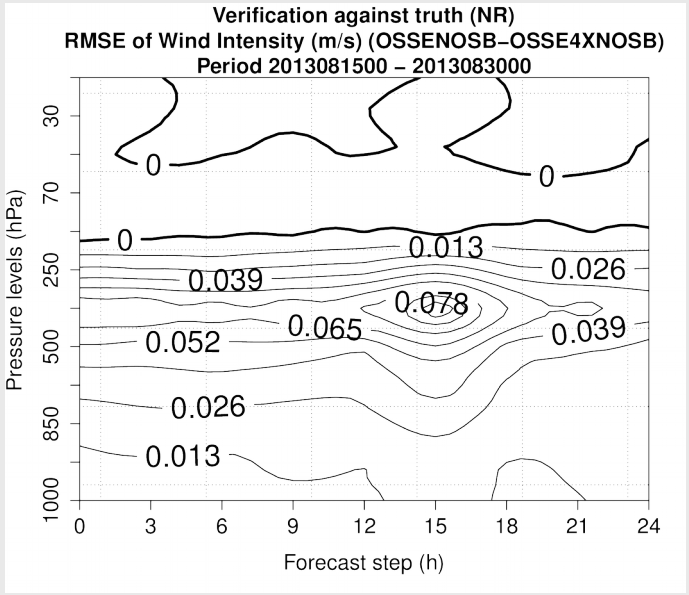



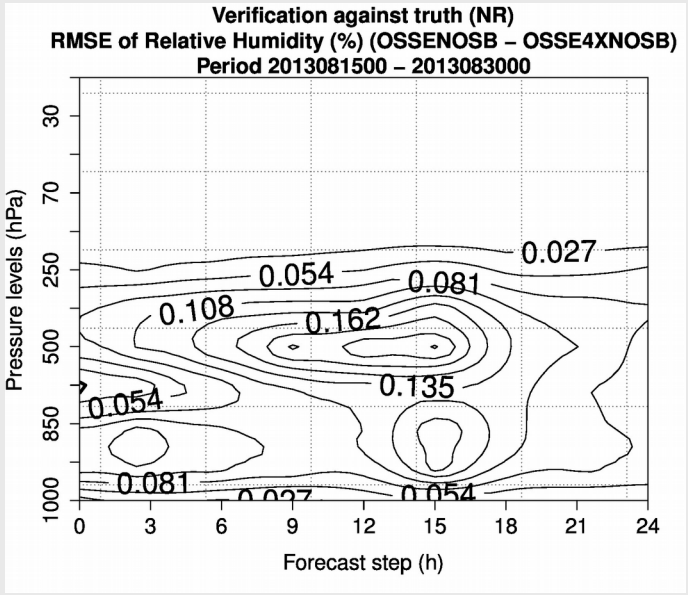



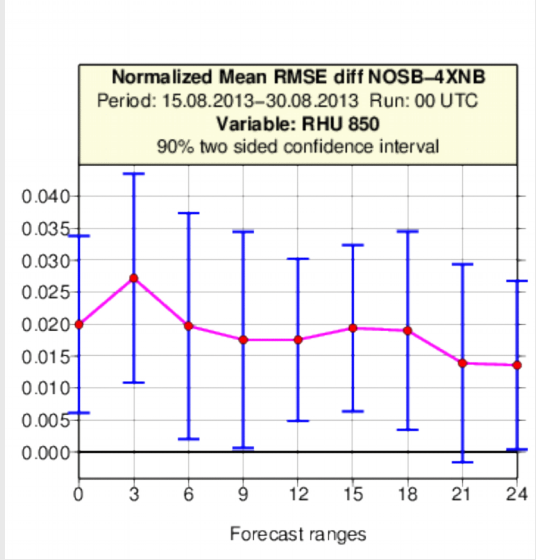
# OSSE – impact of 4 launches of radiosondes per day

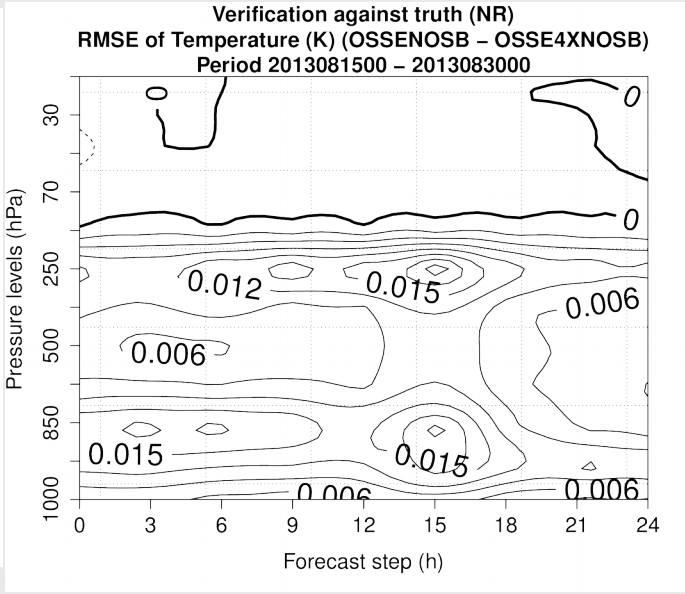


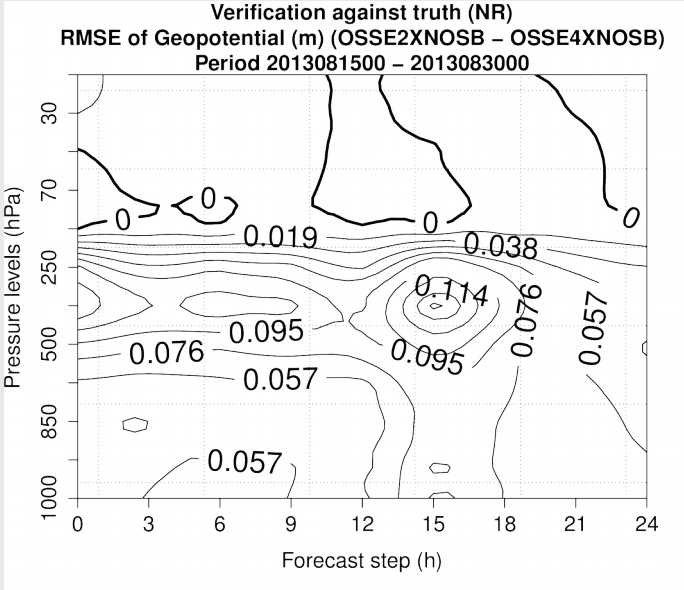



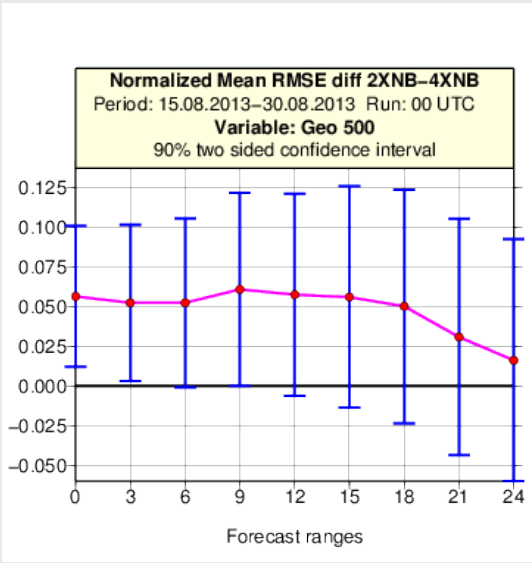



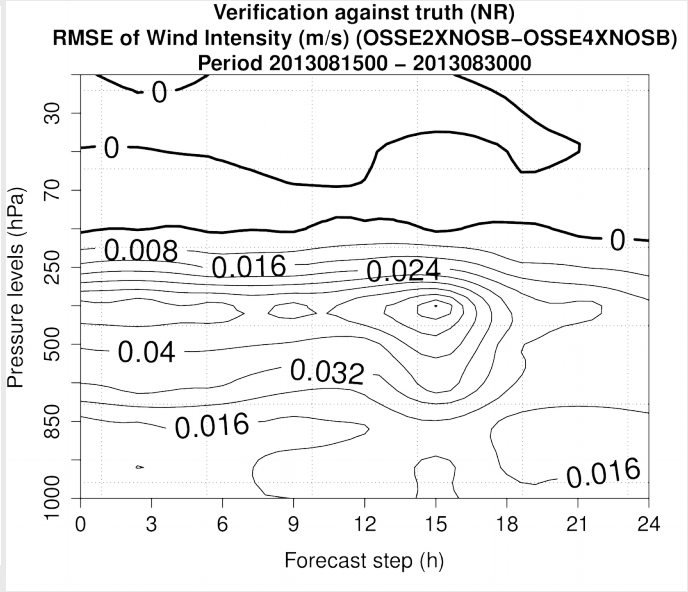



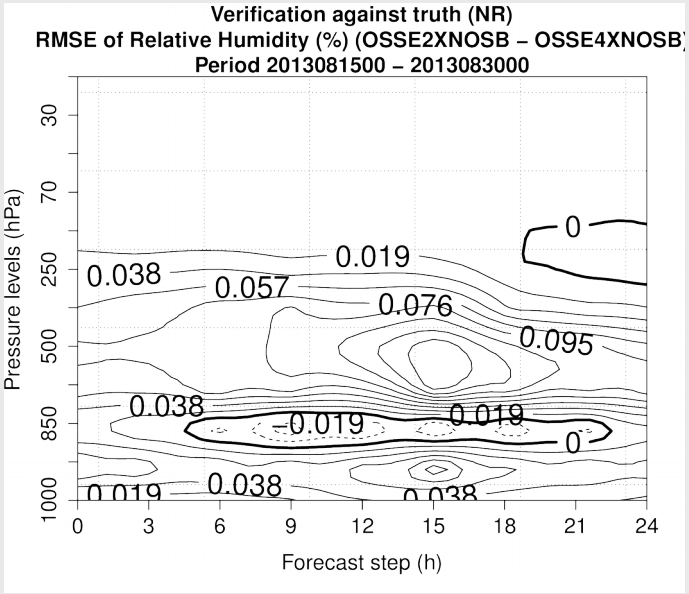



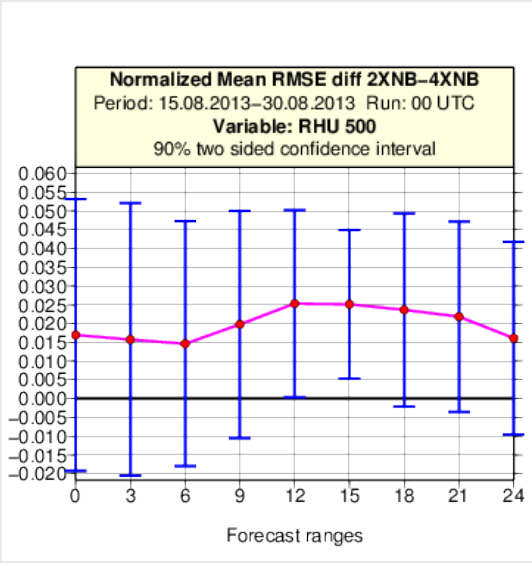
# OSSE – difference between “at least 2 launches” and 4 times radiosondes per day

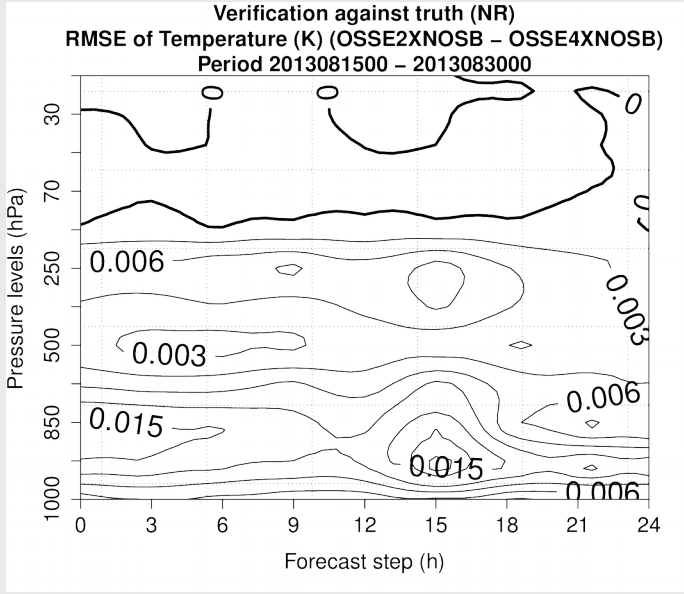


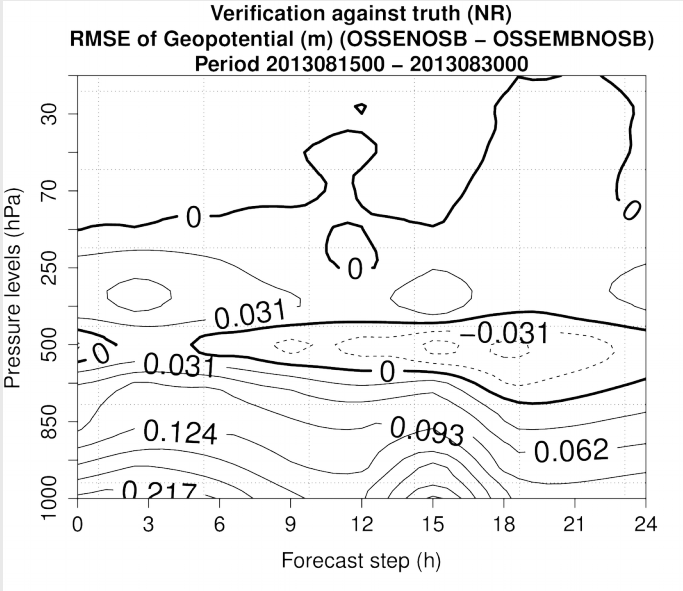



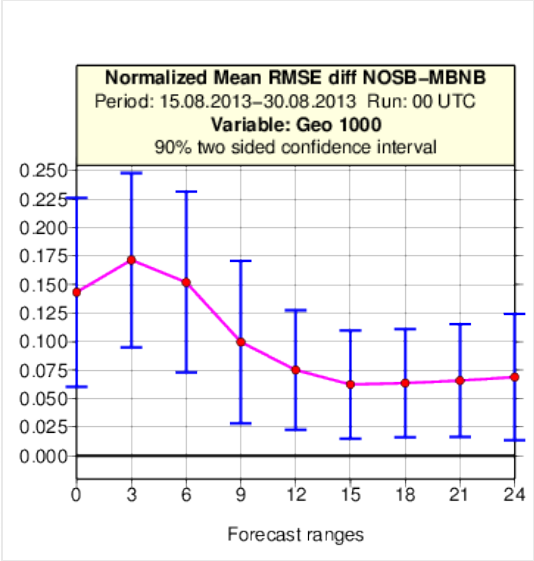



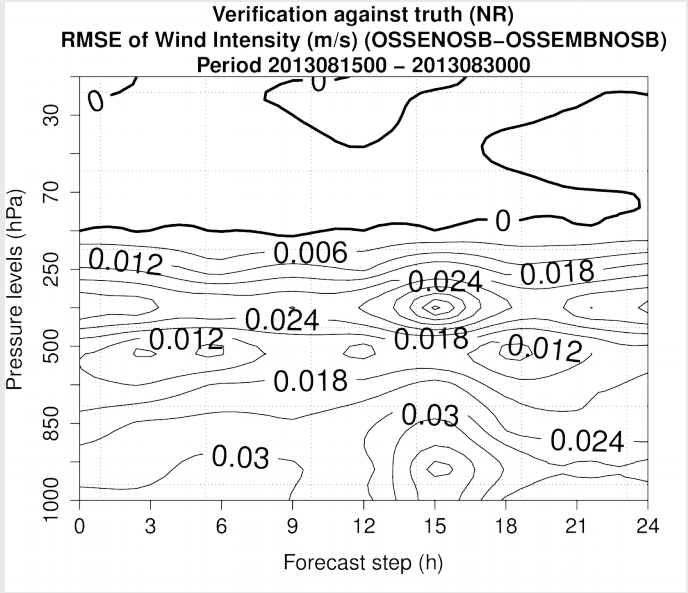



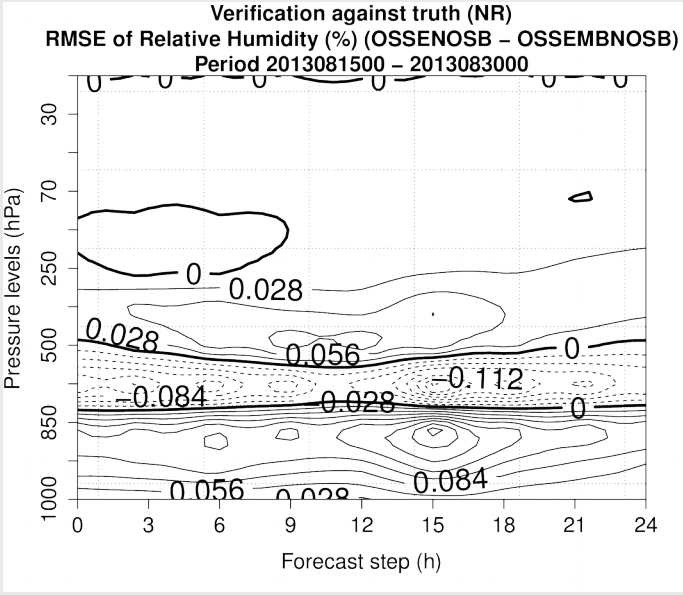



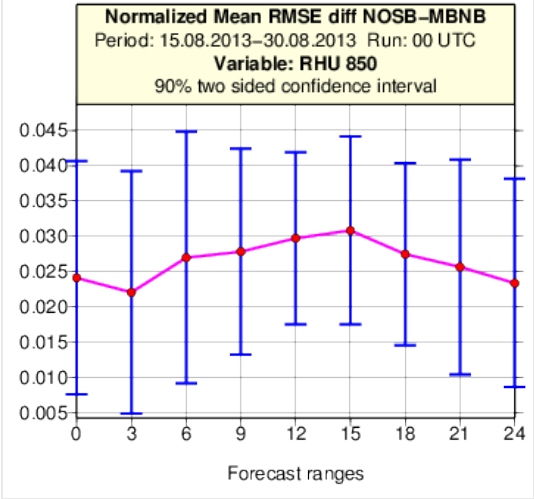
# OSSE – impact of more (~ 45) BUOYs

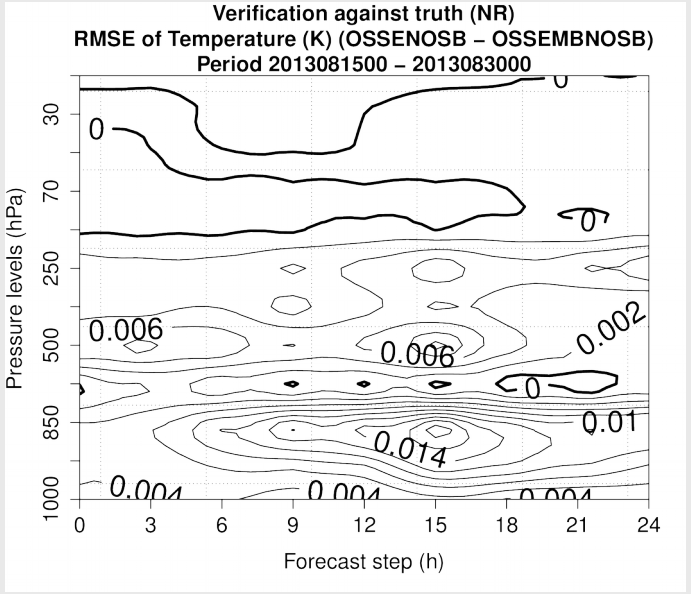


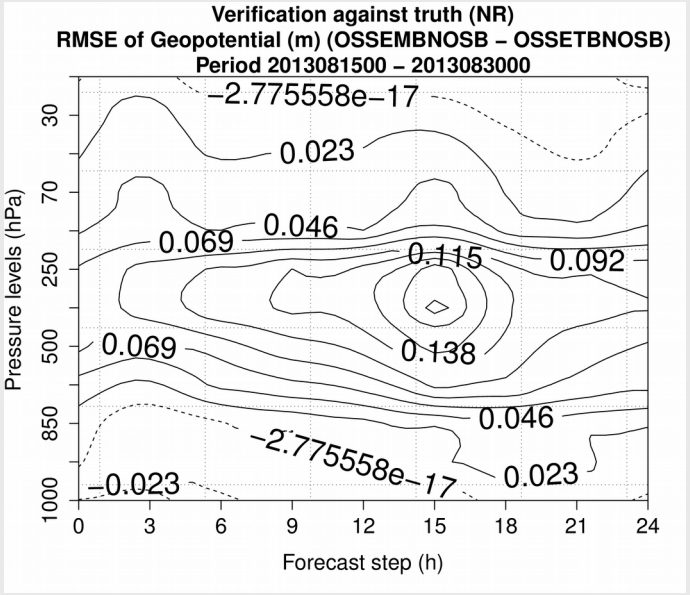



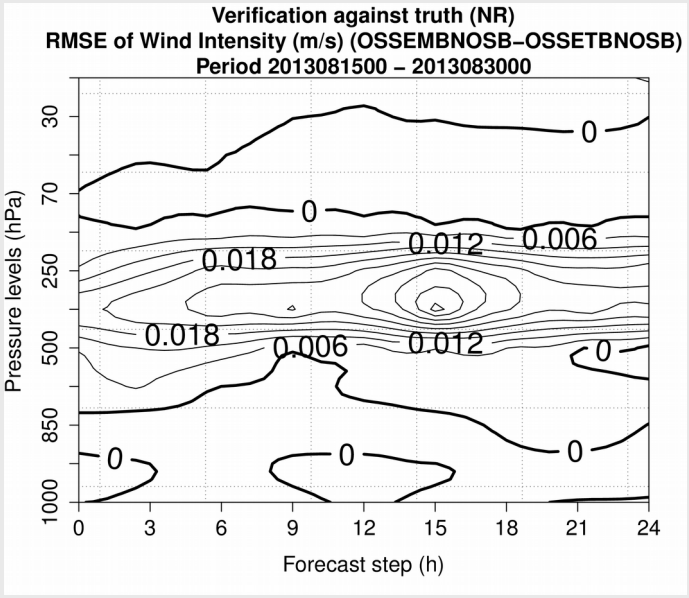



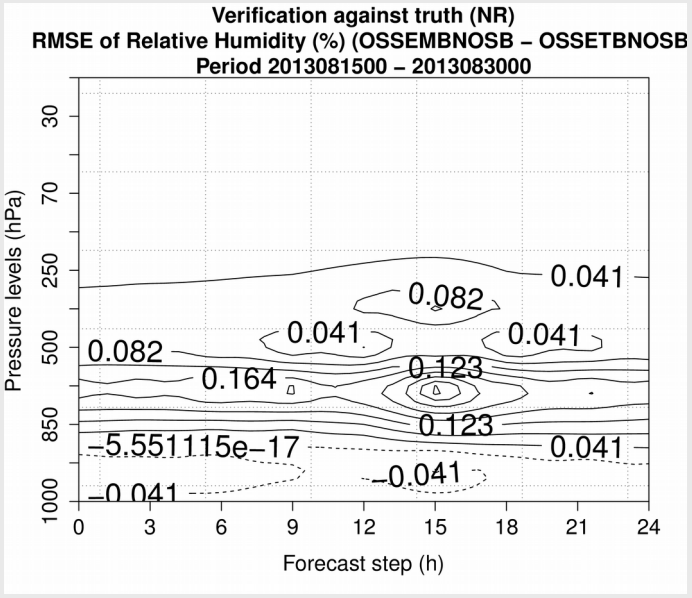



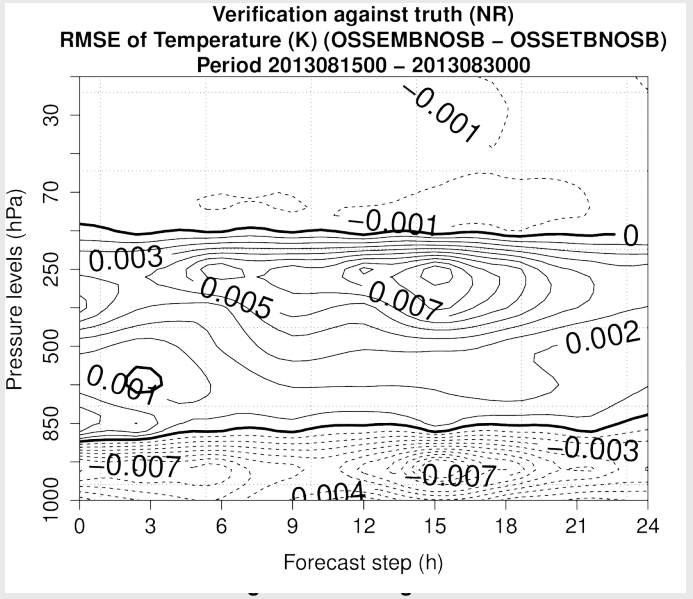



# OSSE – impact of more (~45 (x4) vs ~34 (x3)) BUOYs

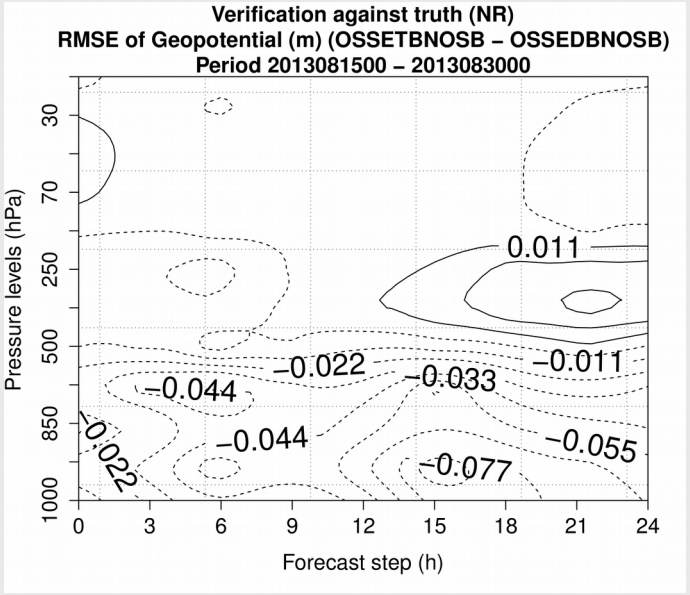


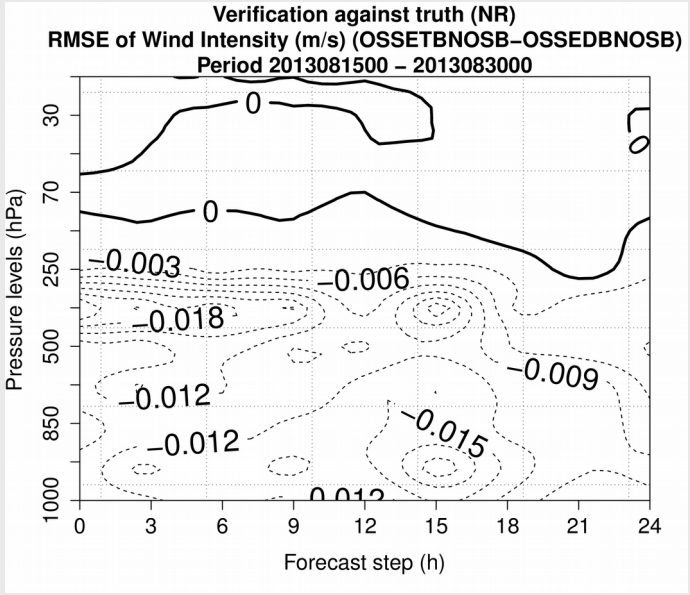



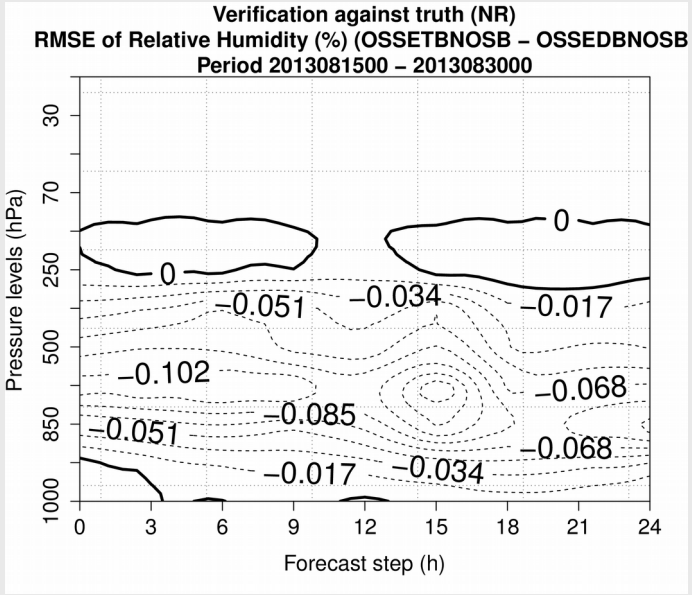



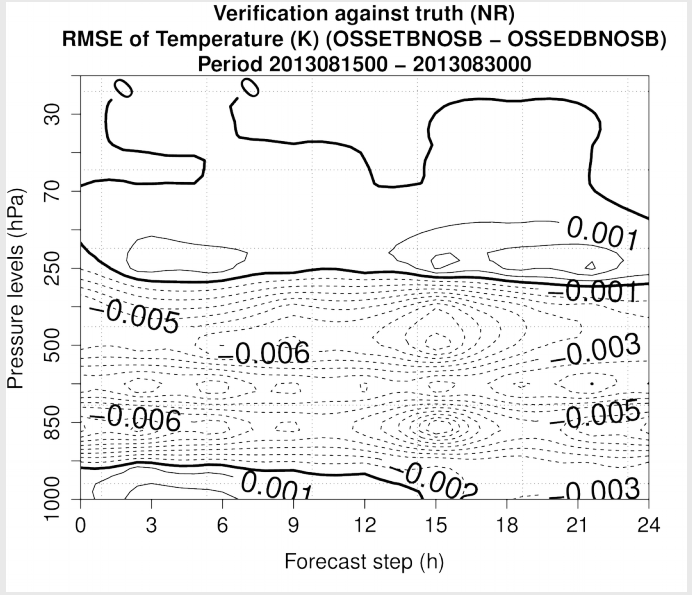



# OSSE – impact of more (~34 (x3) vs ~24 (x2)) BUOYs

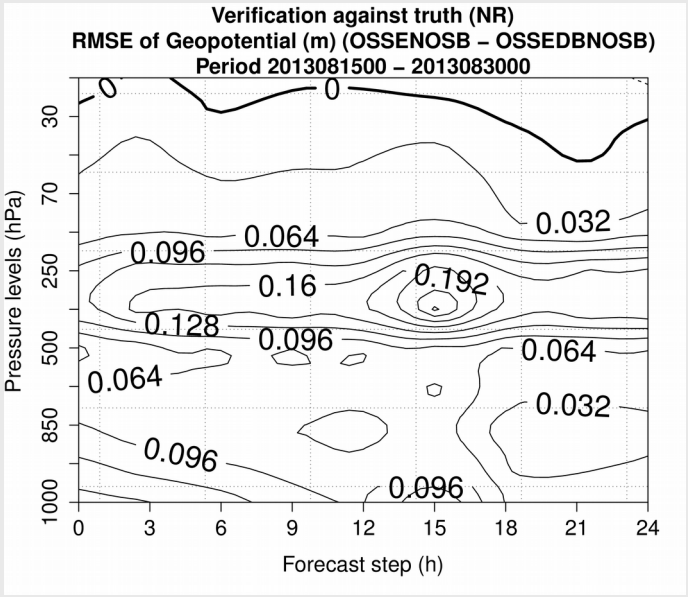


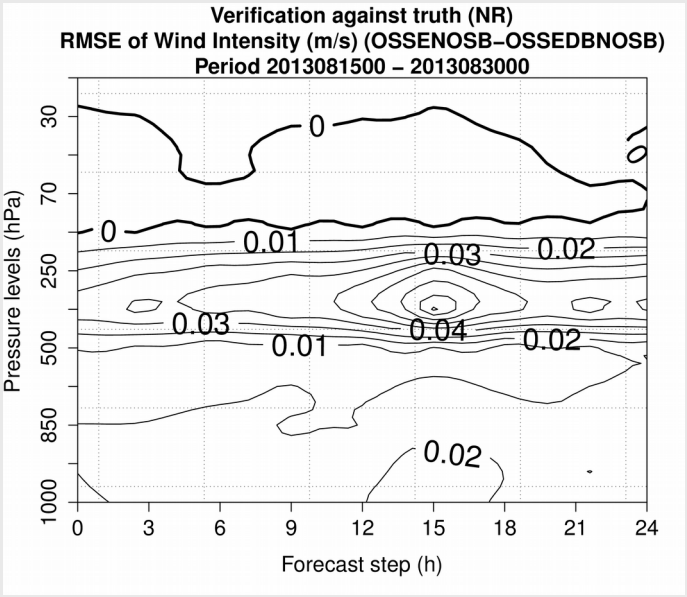



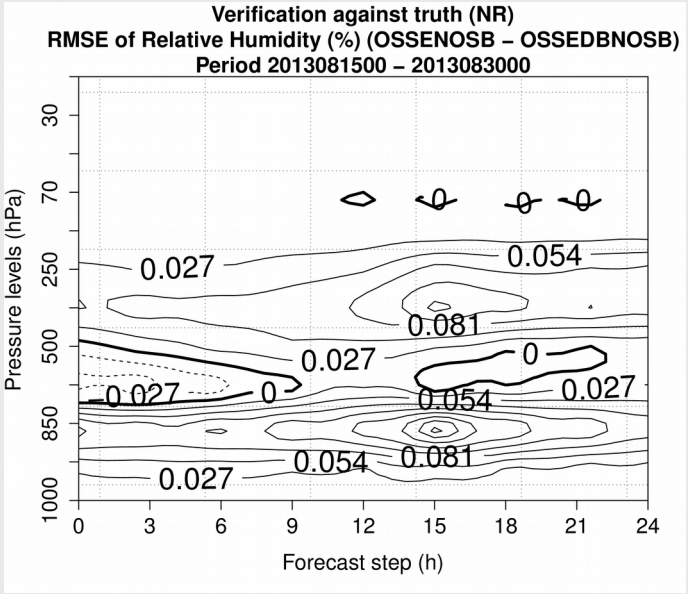



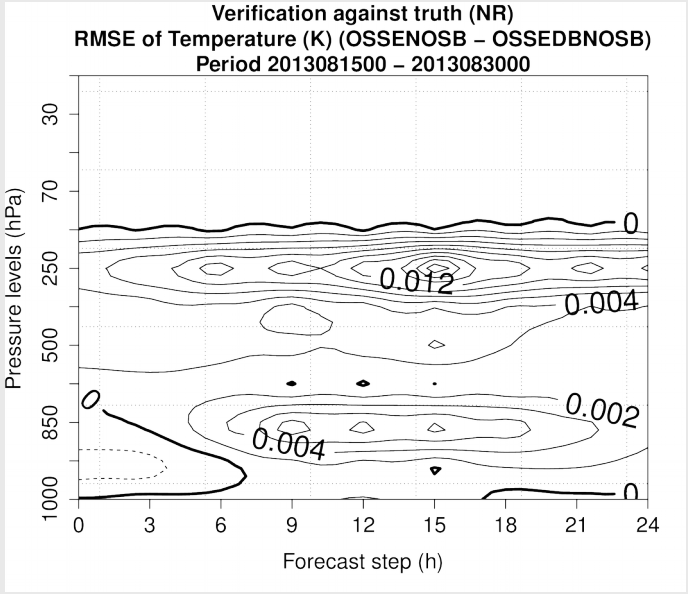



# OSSE – impact of more ~24 (x2) BUOYs



# Concluding remarks for OSE

- Downscaling of global model cannot give reliable forecasts;
- Buoys play important role in adjusting the analyses, and also have considerable influence on the forecasts especially on areas, where conventional observations are sparse;
- Use of satellite observations is important for reliable analyses and forecasts;
- IASI radiances are needed for an efficient forecasting of polar low;
- Using the HARMONIE system, regional data assimilation influences mainly the  tropospheric levels.

# Concluding remarks for OSSE

– Reducing by ~60% the simulated observation error, we could get comparable observations to the real ones;

– Providing at least twice (in fact 2 more RS / day) radiosonde measurements per day significantly improves the forecast of humidity;

– Providing 4 launches (16 RS more / day) per day at the current existing radiosonde stations have significant impact on AROME forecasts.

– Using about 45 BUOYs provides good coverage of studied domain with significant positive impact on the AROME forecasts;

– Overall roughly 34 (x3) BUOYs seems to be optimal for the study domain;

– The impact of twice more BUOYs is positive but less than that of three times more;

**We need to show similar behaviour of these instruments with real cases before publishing these results.**

# Köszönöm szépen a figyelmet