OSE and OSSE with the AROME model over the Arctic

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Introduction

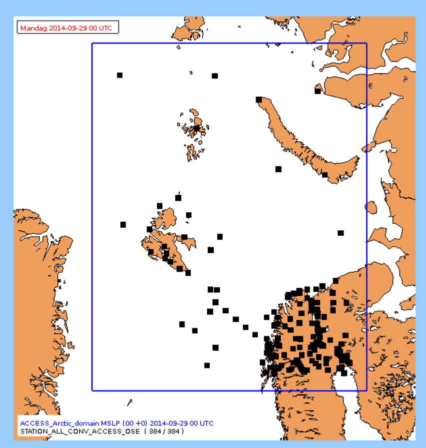
This study was done in frame of an EU-funded project ACCESS (Arctic Climate Change, Economy and Society), where MET Norway, among other tasks have to deal as well with the following: 1) to describe the present *short-range* monitoring and forecasting capabilities in the Arctic; and 2) Identify the key factors limiting the monitoring and forecasting capabilities, and give recommendations for key areas to improve the forecasting capabilities.

Regarding the task 1) described above, the performance of both the ECMWF and the HIRLAM (operational at study time) have been monitored. As results of such a monitoring, a decrease of NWP model accuracy was found towards the north Pole. As results taken from the monitoring study, the following hypotheses can take place: 1) Deficiency in description of the physical process in the NWP model; 2) Predictability issues related to the initial condition; 3) The observing network available in Arctic. The network of conventional observations, in particular coverage of aircraft and radiosonde, is sparse in the Arctic. It is important to describe the full 3-D initial state of the atmosphere to provide good forecasts, and the lack of conventional upper-air observations over the Arctic is essential compared to the observing system over land at mid-latitudes. There is good coverage of satellite data from polar-orbiting satellites at high latitudes, where for instance sensors with temperature and moisture sounding capabilities are available. While for task 1) above, we performed observing system experiments (OSE) with conventional and satellite observations, for the task 2) observing system simulation experiments (OSSE) were conducted to study the effect of enhanced network in the region.

We have chosen to do our studies with the HARMONIE-AROME NWP model (AROME-Arctic), which is a version of the operational regional NWP model at MET Norway.

The experimental AROME-Arctic model

System setup: (Harmonie cycle 38h1.1)
Domain: 750x960 grid points; **Horizontal resolution:** 2.5 km; **Model level definition:** 65 level; Non-hydrostatic dynamic; **Physical parametrisation:** AROME/mezo-NH; **Assimilation strategy:** 3-hourly cycling; **Lateral boundary conditions:** hourly ECMWF; **Surface data assimilation:** Optimum interpolation; **Upper-air data assimilation:** 3D-VAR; Background error statistics computed as mean over 4 seasons.
Tested observations: Surface (SYNOP, DRIBU), Radiosondes, Aircraft, ATOVS (AMSU-A, AMSU-B/MHS) and IASI



Radiances assimilation:
– AMSU-A : Channels 5 -10;
– AMSU-B/MHS: Channels 3 - 5;
– IASI : 65 Active channels
38, 51, 63, 85, 87, 104, 109, 167, 173, 180, 185, 193, 199, 205, 207, 212, 224, 230, 236, 239, 242, 243, 249, 252, 265, 275, 294, 296, 306, 333, 337, 345, 352, 386, 389, 432, 2701, 2819, 2910, 2919, 2991, 2993, 3002, 3008, 3014, 3027, 3069, 3087, 3098, 3207, 3228, 3281, 3309, 3322, 3339, 3438, 3442, 3484, 3491, 3499, 3506, 3575, 3582, 3658, 4032

The experimental AROME-Arctic domain with all conventional observations in. This is a case of 12 UTC, December 2013.

Observing System Experiments (OSE)

The following experiments were conducted:

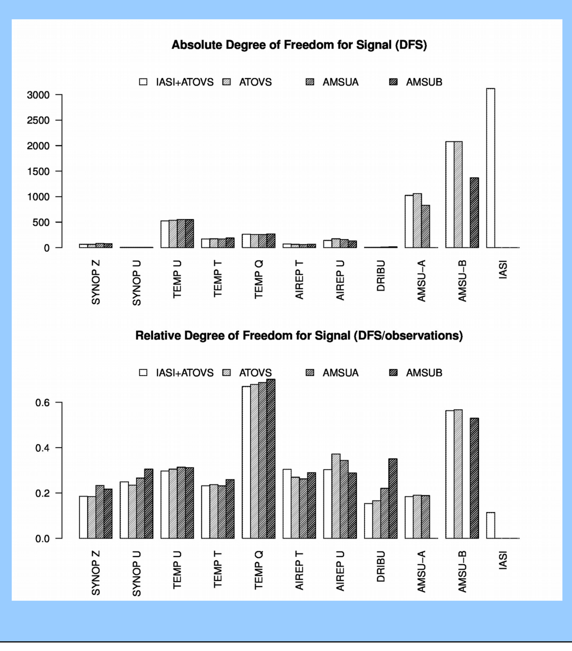
ARCREF – Downscaling of the ECMWF fields without assimilation;
ARCSURF – Only surface analysis is used;
ARCAIREP – Surface and upper-air assimilation with conventional observations without aircraft data;
ARCCONV – Surface and upper-air assimilation with full conventional observations;
ARCAMSUAN – System 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.

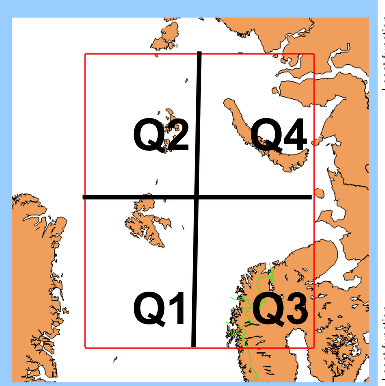
Sensitivity of the AROME-Arctic analyses to the observations

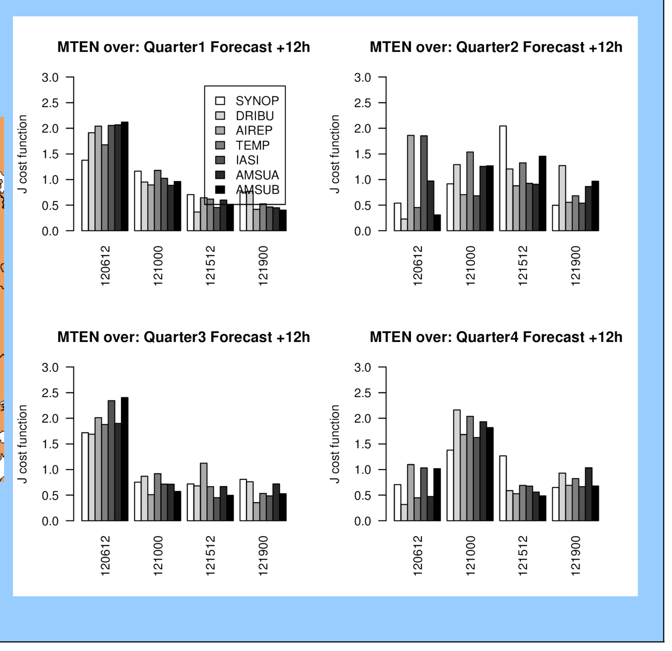
using Degrees of Freedom for Signals (DFS) (*Chapnik et al. 2006*) (left) and

the sensitivity of the forecast model to the observations (right)

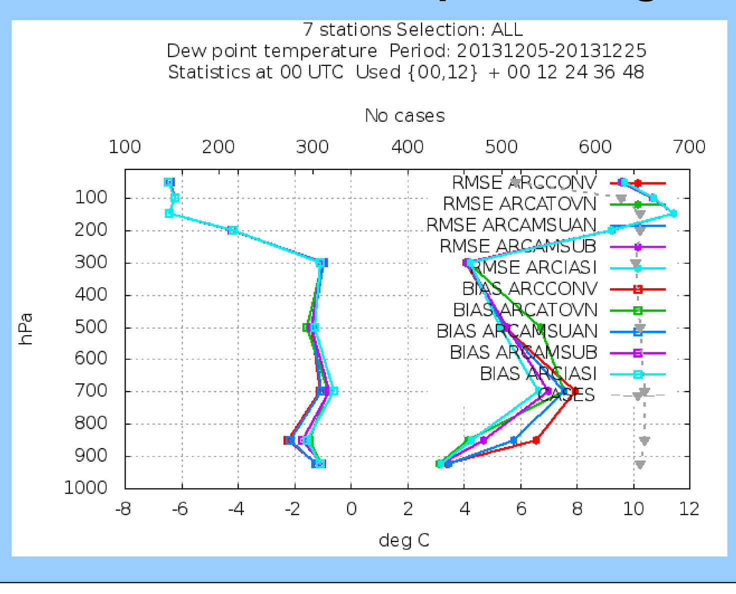
using moist total energy norm (MTEN) (*Storto and Randriamampianina, 2010)*

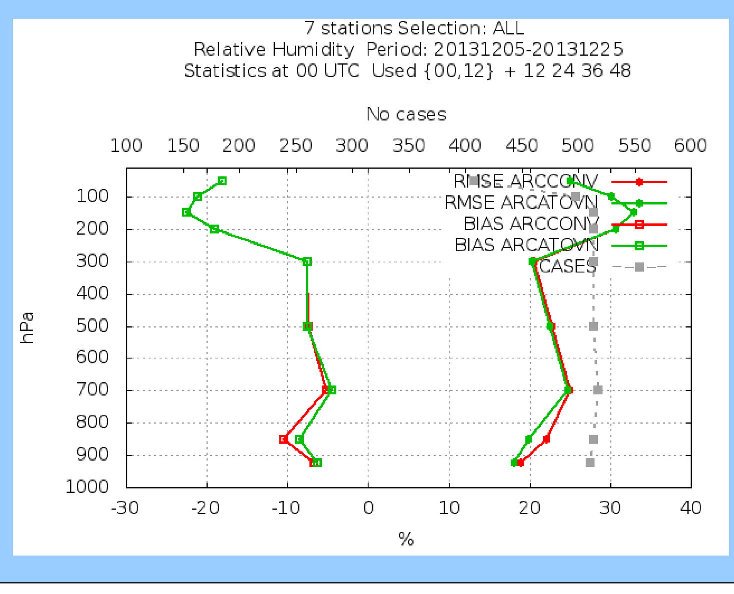






Impact of radiances on the AROME-Arctic forecasts comparison against radiosonde observations





The observing system simulation experiments setup

Simulation of (politically)reasonable network

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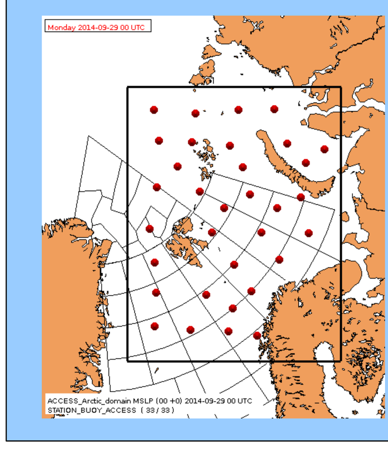


Simulation of 4 scenarios:

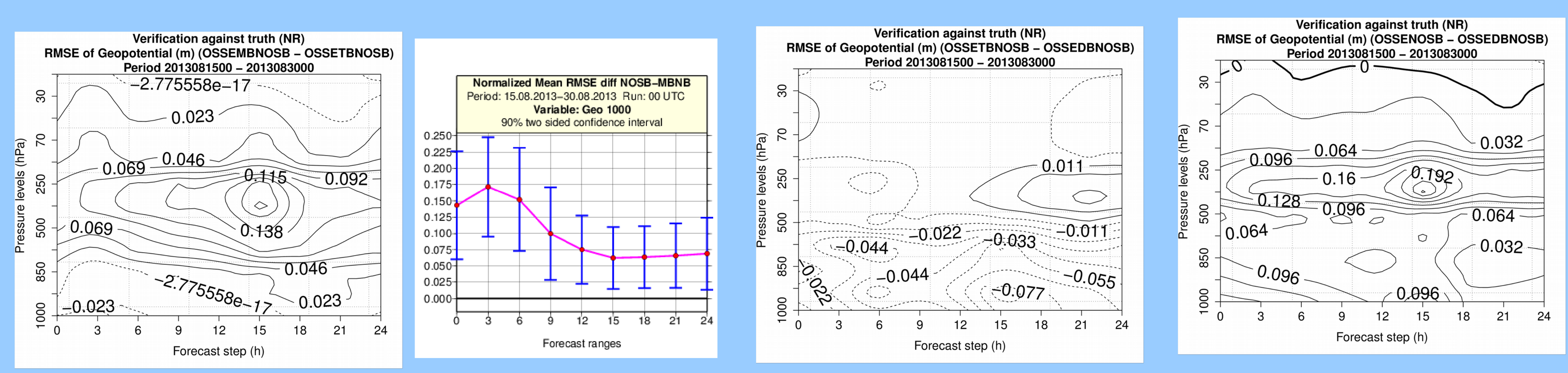
1) **Randomly distributed DRIBU** stations: 45 – ~4x (OSSEMBNOSB); 34 – ~3x (OSSETBNOSB); 24 – ~2x (OSSEDBNOSB) Note: actual network ~ 11 station;

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** (OSSENOSB)

Impact of adding DRIBU stations

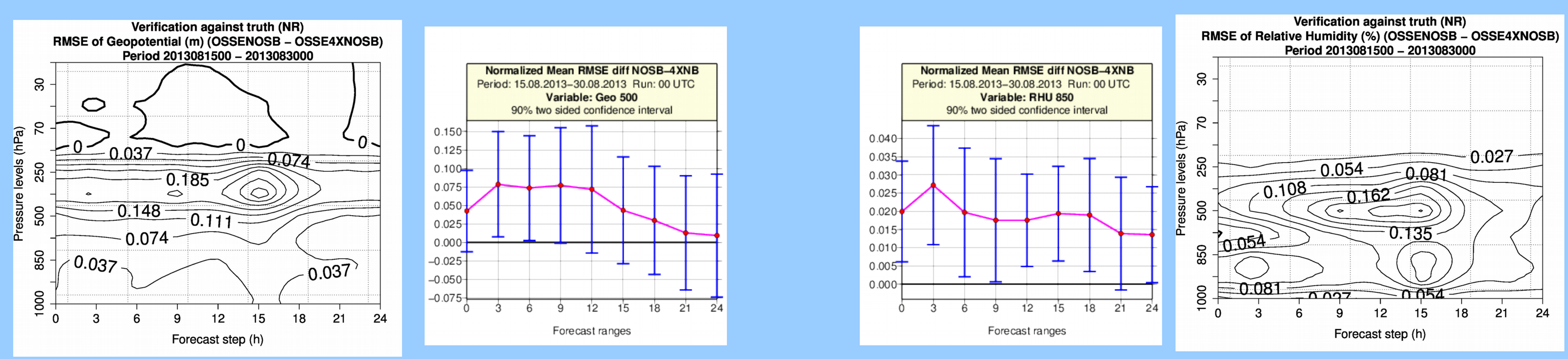


Comparing 4x vs 3x more
3x better than 4x more

Comparing 3x vs 2x more
3x better than 2x more

Impact of 2x more DRIBU
2x more have positive impact

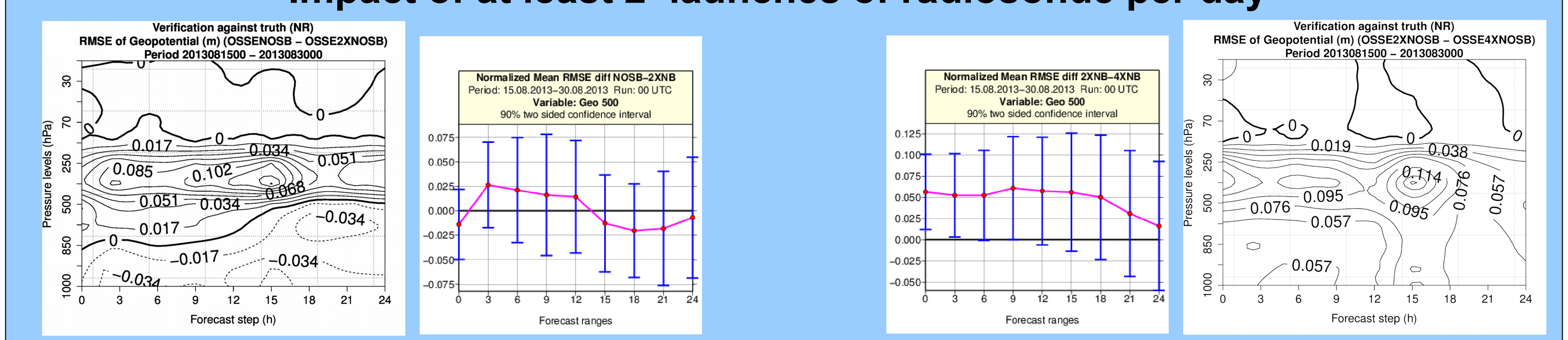
Impact of 4 launches of radiosonde per day



Impact on geopotential, significant up to 9 hours

Impact on humidity, significant up to 24 hours

Impact of at least 2 launches of radiosonde per day



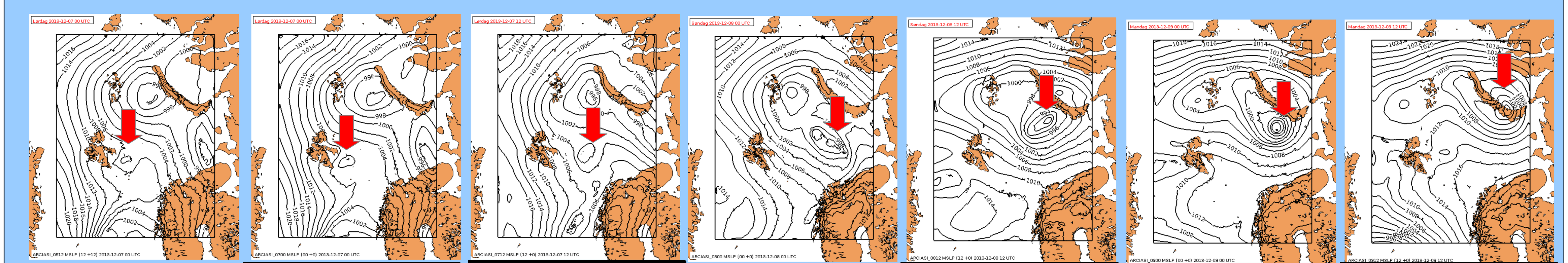
Impact on geopotential, but still significant impact on humidity (not shown)

Comparing impact of 4 times vs 2 times per day

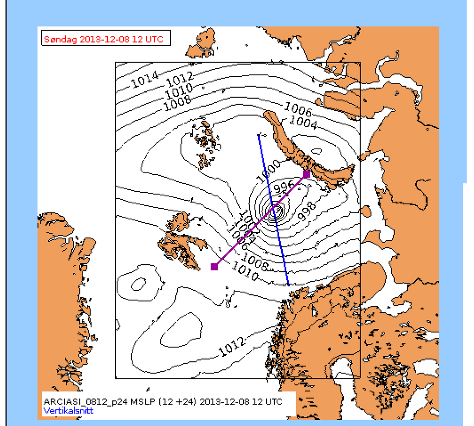
Concluding remarks – OSSE

– 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;

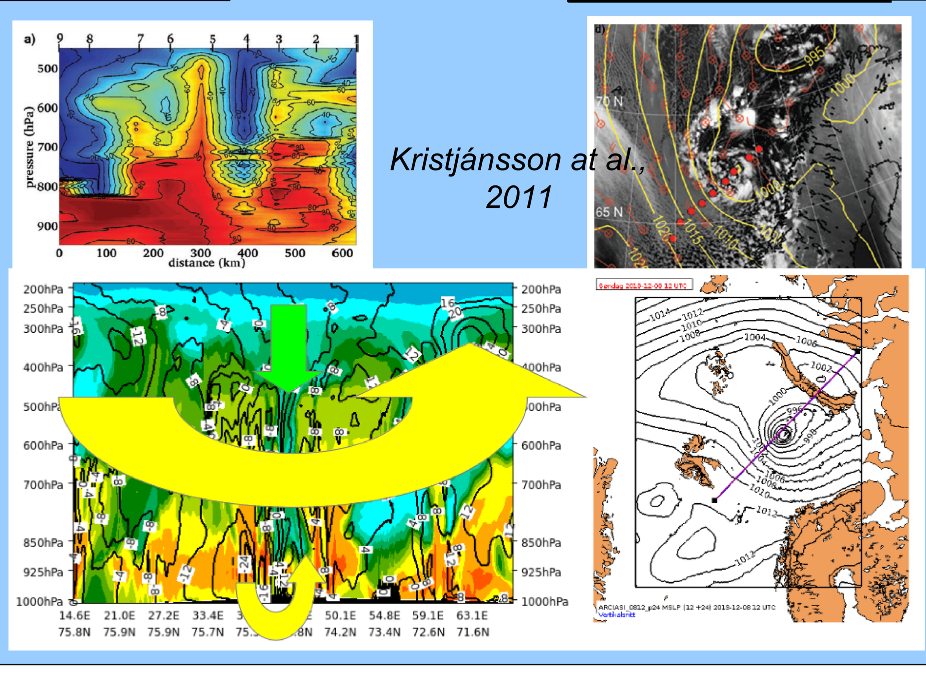
Case study: Polar low Dec. 8th, 2013



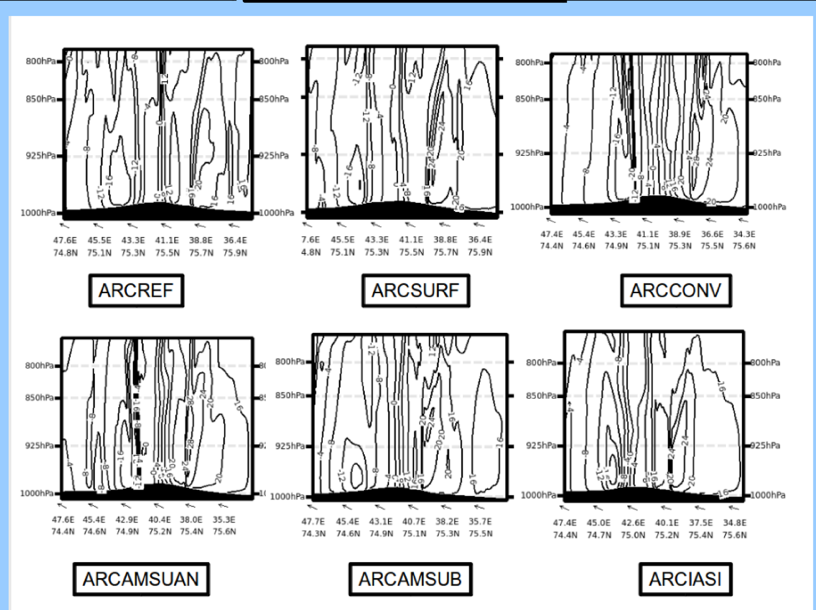
2013.12.06 12UTC | 2013.12.07 00UTC | 2013.12.07 12UTC | 2013.12.08 00UTC | 2013.12.08 12UTC | 2013.12.09 00UTC | 2013.12.09 12UTC



ARCIASI



Kristjánsson at al., 2011



u-wind component, checking the near surface cyclonic system

Concluding remarks – OSE

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

References

http://www.access-eu.org/

Chapnik B, Desroziers G, Rabier F, Talagrand O. 2006. Diagnosis and tuning of observational error in a quasi-operational data assimilation setting. *Q. J. R. Meteorol. Soc.* **132**: 543–565.

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