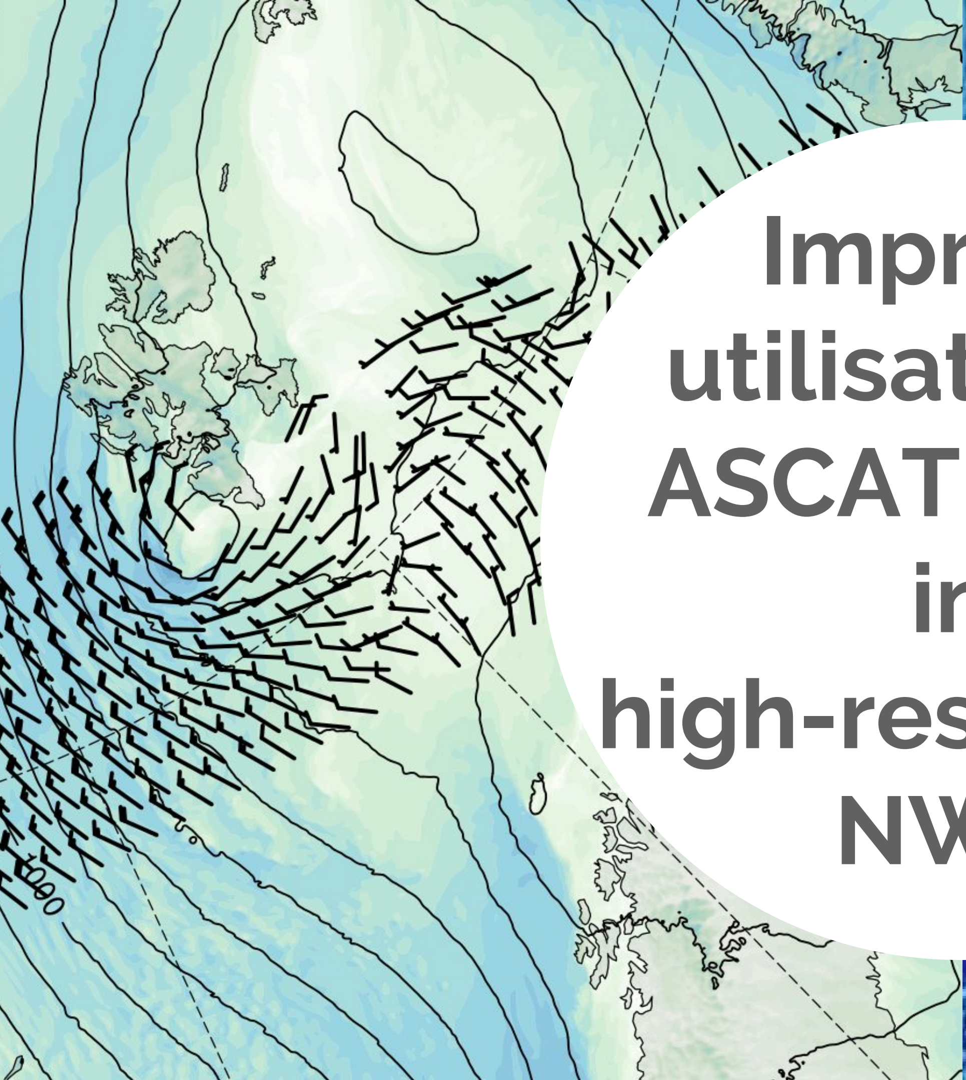
Scatterometer winds in the Arctic model system at MET Norway

Teresa Valkonen

Norwegian Meteorological Institute

The 17th Fellow Day, EUMETSAT Headquarters, Darmstadt, 6 March 2017



Improve utilisation of ASCAT winds in high-resolution NWP

SCARASTO - Scatterometer winds in rapidly developing storms

1st year report

The impact of ASCAT wind in storm cases using the HARMONIE model system. MET report 2/2015

3rd year report

ASCAT winds in the Arctic weather prediction system at MET Norway

01.04.2013

31.01.2017

2nd year report

Assimilating advanced scatterometer winds in a high-resolution limited area model over northern Europe. Manuscript to IEEE JSTARS. Accepted and published online.

Overview

1. **Observing system experiments in the Arctic system**
   Model set up, spatial impact, forecast impact

2. **ASCAT in the AROME-Arctic operational system**
   Operational data monitoring

3. **ASCAT winds in the wave-atmosphere coupled model system**
   Description of wave-coupling, further work

1. Observing system experiments

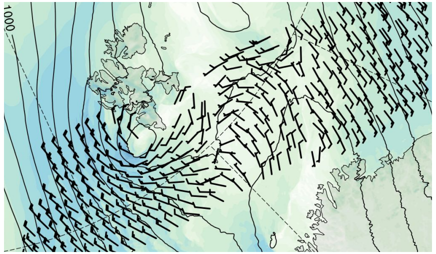
Procedure

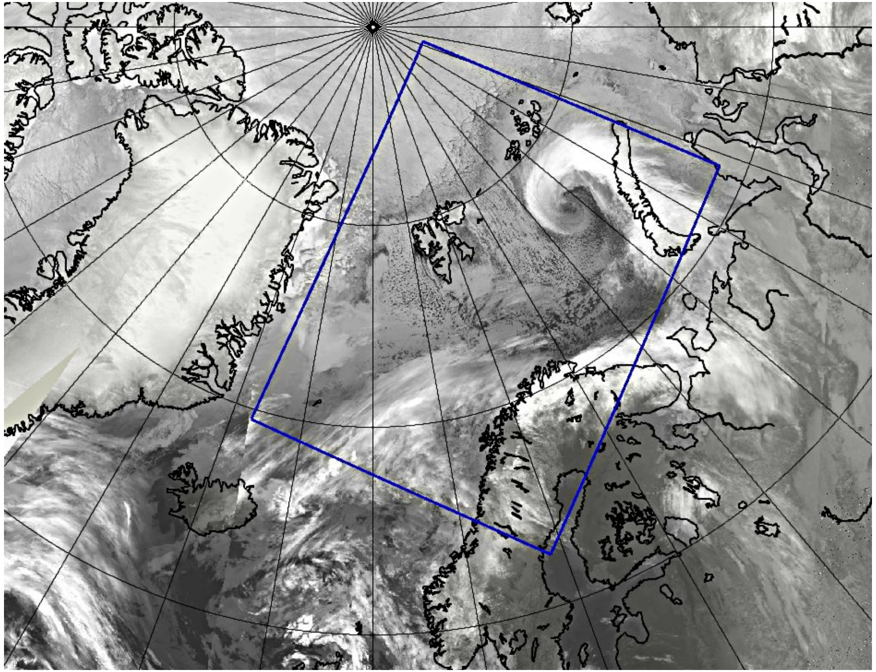
1. The HARMONIE-AROME model system cy38h1.2 over the Arctic domain

2. The model system were selected to mimic the operational model system over Scandinavia: 3DVar with 3-hourly cycling

3. ASCAT coastal product on a 12.5 km grid provided by the EUMETSAT OSI SAF was used, thinned to 100km

4. Two experiments for March 2013: AA-SCAT & AA-REF





Spatial impact of ASCAT

Mean-sea-level pressure

- Over the open Barents sea (region of cold air mesocyclones), AA-SCAT had lower MSLP on average.
- Over the ice-covered region, AA-SCAT had higher MSLP on average.
- The mean differences in MSLP are largest at the analysis time and decrease from there.

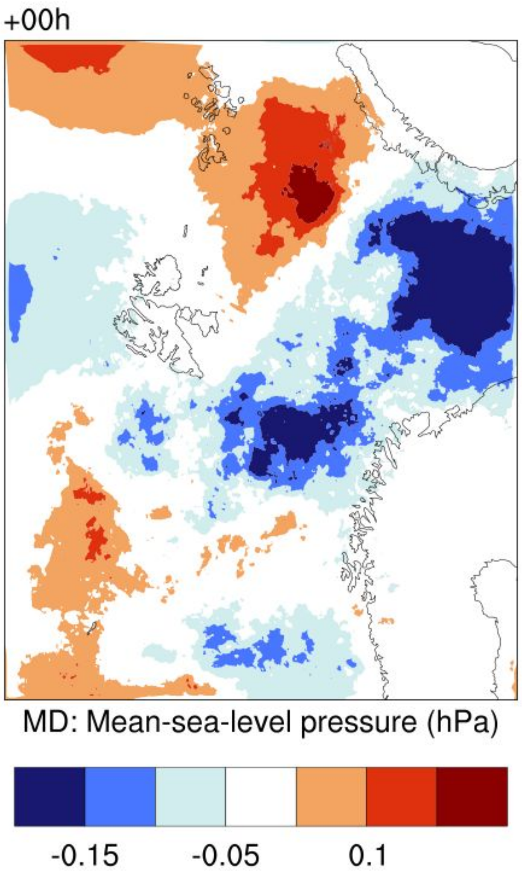
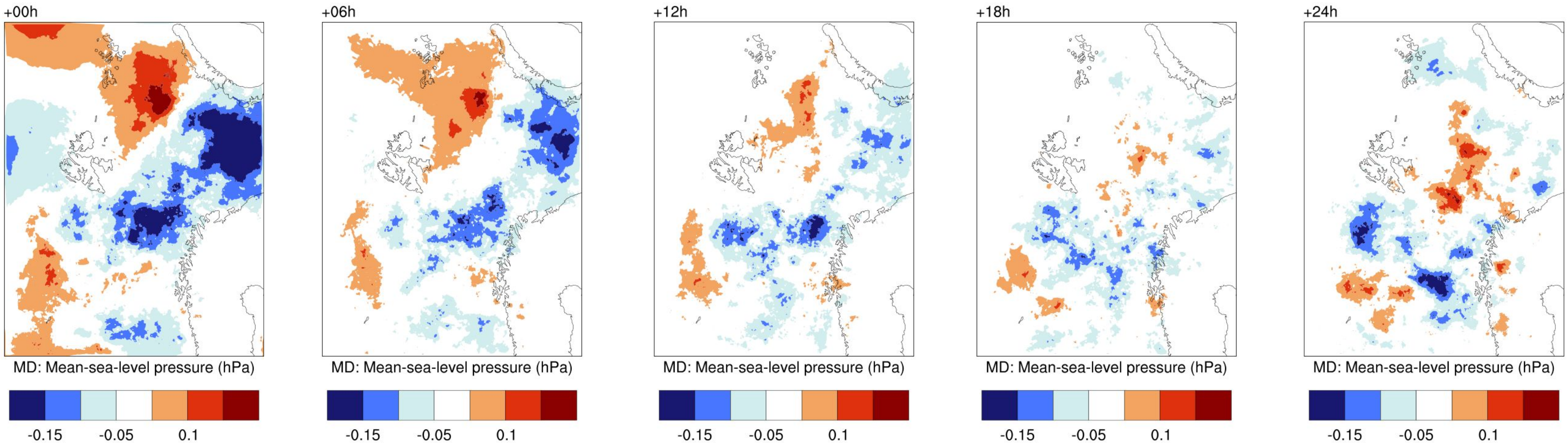


Figure:
Mean difference of MSLP between AA-REF and AA-SCAT experiments in the analysis (+00h forecast) averaged over the study period March 2013.

Spatial impact of ASCAT

Mean-sea-level pressure - mean difference

+00h   +06h   +12h   +18h   +24h



Figures:
Mean difference of MSLP between AA-REF and AA-SCAT experiments in the successive forecast +00h, +06h, 012h, +18h, +24h averaged over the study period March 2013.

Spatial impact of ASCAT

Mean-sea-level pressure

- The RMS difference indicates the largest variability over the open sea.
- The RMSD values stay approximately at the same level for the longer forecast lengths.

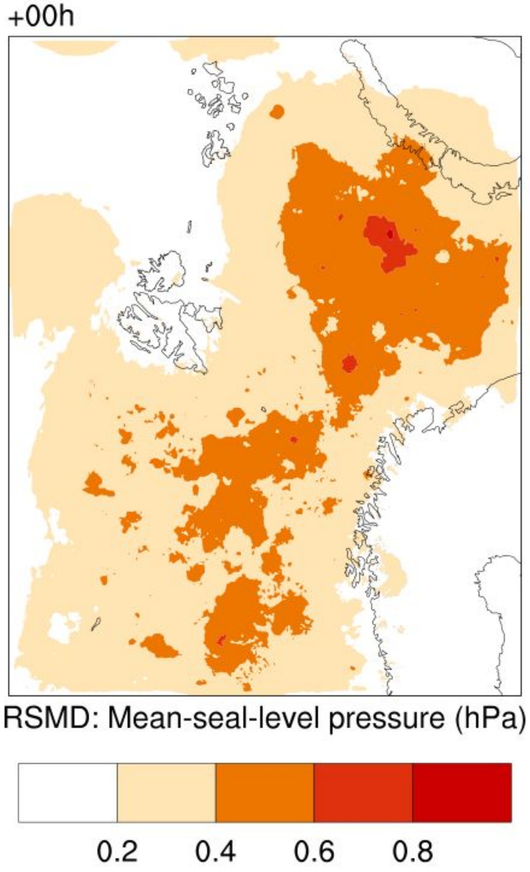
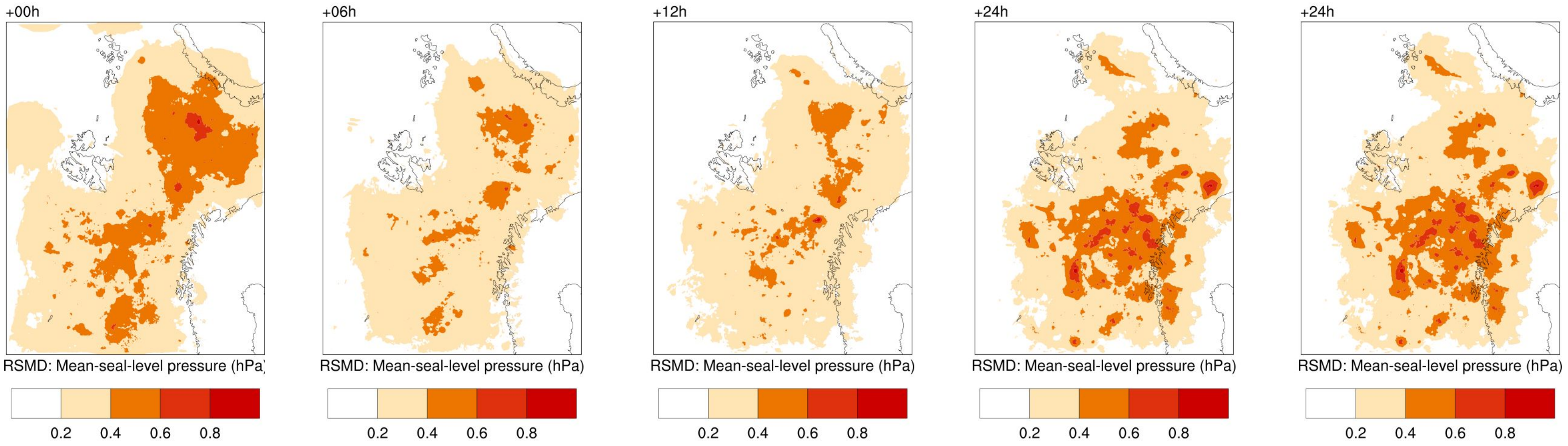


Figure:
Mean RMS difference of MSLP between AA-REF and AA-SCAT experiments in the analysis (+00h forecast) averaged over the study period March 2013.

Spatial impact of ASCAT

Mean-sea-level pressure - root-mean-square difference

+00h   +06h   +12h   +18h   +24h



Figures:
Mean RMS difference of MSLP between AA-REF and AA-SCAT experiments in the successive forecast +00h, +06h, 012h, +18h, +24h averaged over the study period March 2013.

Spatial impact of ASCAT

Wind speed at 10 m

- AA-SCAT had stronger wind speeds at the analysis time
- The differences in wind speed are seen only over the open sea, or close to it
- A lot of small scale variation in the wind field because of the convective nature of the cold-air outbreaks.

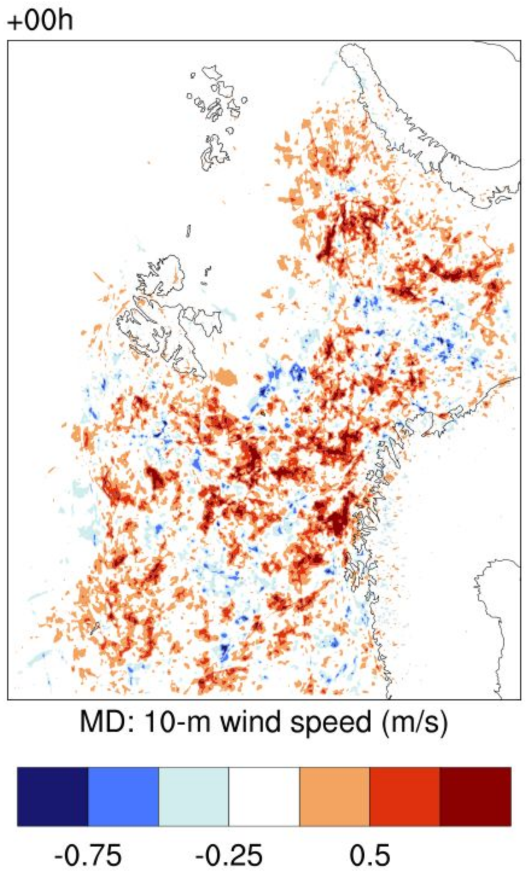


Figure:
Mean difference of wind speed (m/s) between AA-REF and AA-SCAT experiments in the analysis (+00h forecast) averaged over the study period March 2013.

Spatial impact of ASCAT

Wind speed at 10 m

- The RMS difference indicates the largest variability over the open sea.
- The RMSD values stay approximately at the same level for the longer forecast lengths.

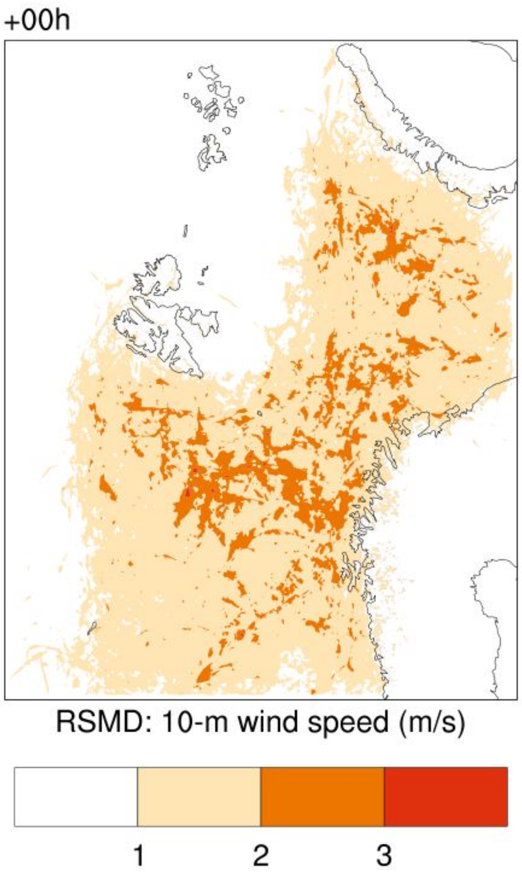
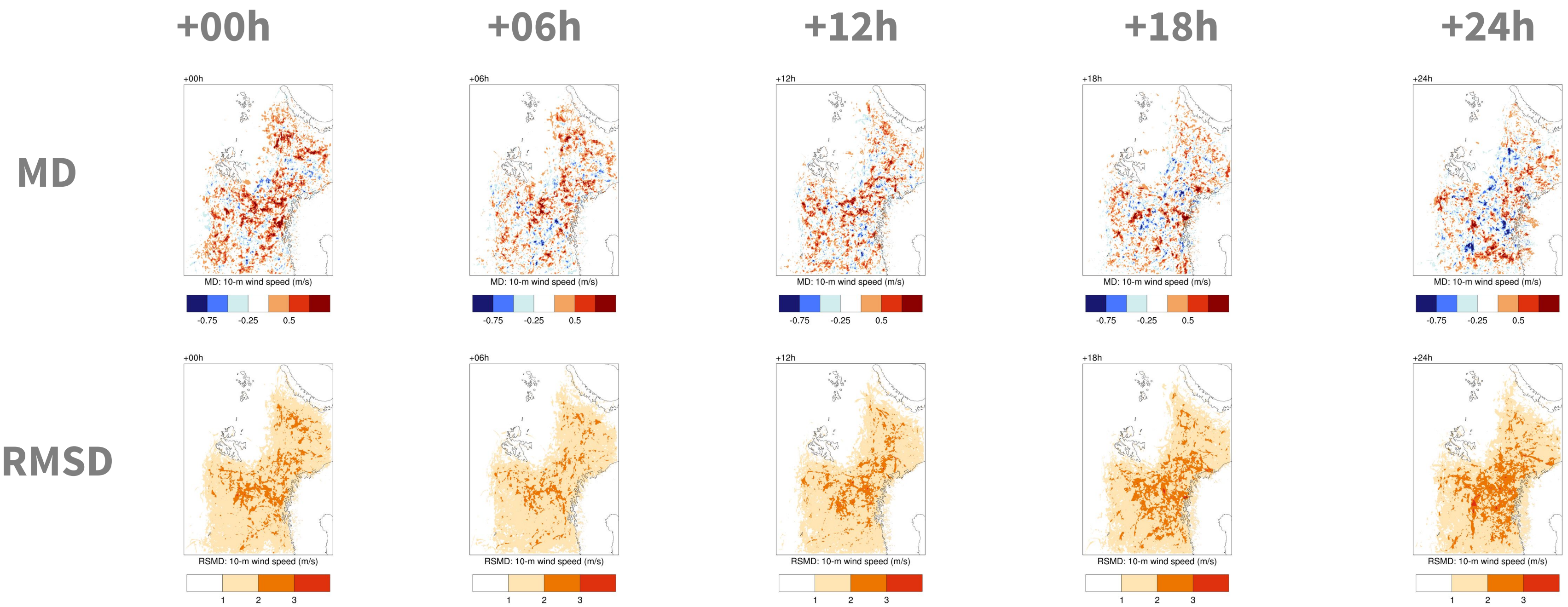


Figure:
Mean RMS difference of wind speed (m/s) between AA-REF and AA-SCAT experiments in the analysis (+00h forecast) averaged over the study period March 2013.

Spatial impact of ASCAT

Wind speed 10m

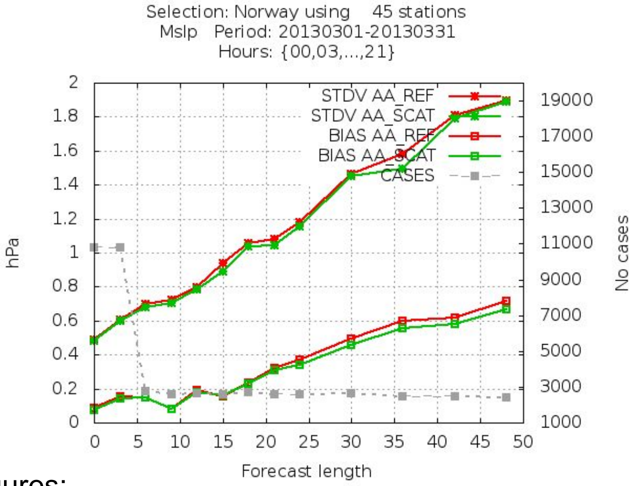


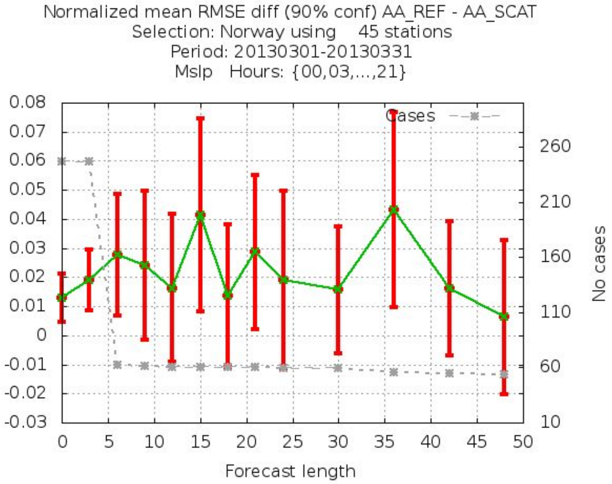
Figures:
Mean difference (MD) and RMS difference of wind speed at 10m between AA-REF and AA-SCAT experiments in the successive forecast +00h, 06h, 012h, +18h, +24h averaged over the study period March 2013.

Local impact of ASCAT

Mean-sea-level pressure

ASCAT assimilation shows improvements on all forecast lengths.





Figures:

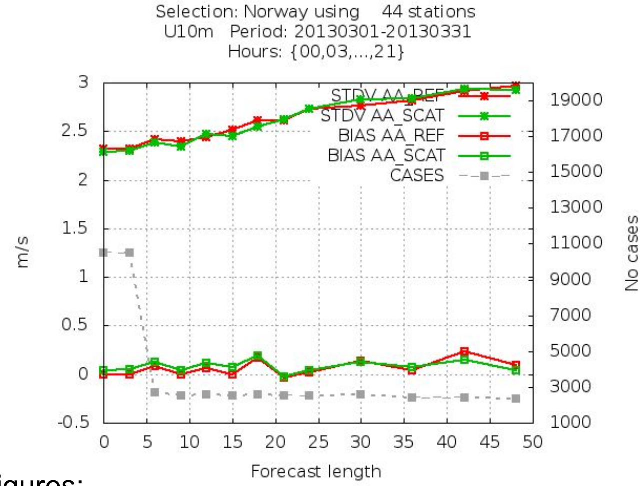
Mean difference (squares) and standard deviation (circles) at the synoptic stations over the whole study period for MSLP in experiments AA-REF (red) and AA-SCAT (green).

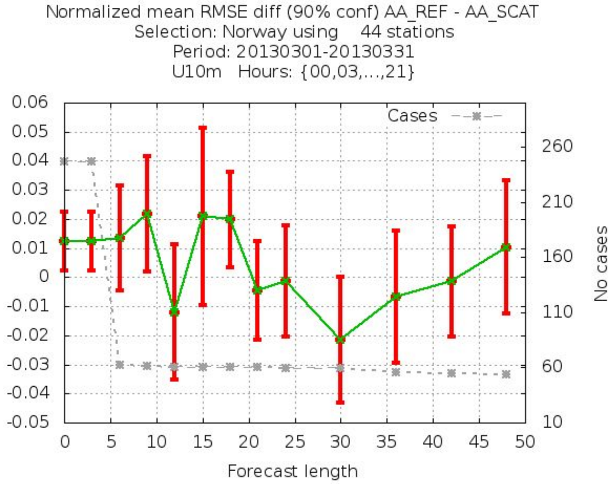
Normalised root-mean-square differences between AA-REF and AA-SCAT for MSLP. Positive values implies that the ASCAT winds have improved the forecasts. The red bars show the 90% confidence levels based on Student t-test.

Local impact of ASCAT

Wind speed at 10 m

ASCAT assimilation shows improvements on the first hours of forecast.





Figures:
Mean difference (squares) and standard deviation (circles) at the synoptic stations over the whole study period for 10m wind speed in experiments AA-REF (red) and AA-SCAT (green).

Normalised root-mean-square differences between AA-REF and AA-SCAT for 10m wind speed. Positive values implies that the ASCAT winds have improved the forecasts. The red bars show the 90% confidence levels based on Student t-test.

Local impact of ASCAT

Other variables

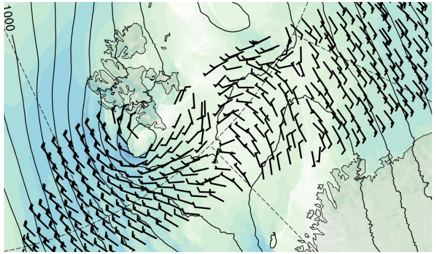
- Surface temperature and relative humidity mostly no significant changes due to the ASCAT data assimilation.
- Precipitation and cloud cover no significant changes due to the ASCAT data assimilation.

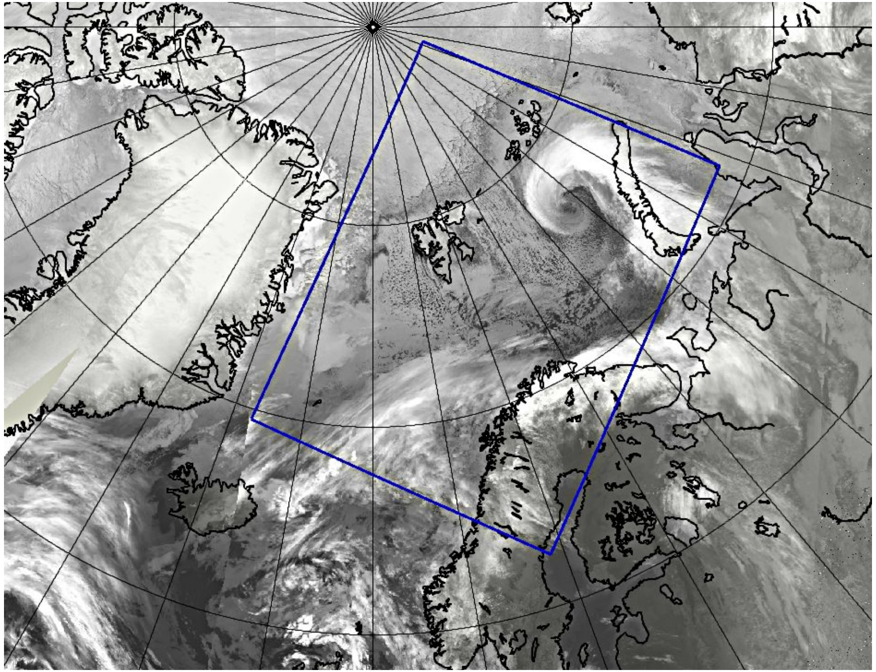
Conclusions - OSEs

1. ASCAT data contribute to deepening the cold air mesocyclones and the strengthening the associated wind speeds

2. The use of ASCAT data in assimilation improves forecasts of MSLP for all forecast lengths, and wind and wind gusts for the first hours of forecasts.

3. The results are very similar to the ones found in the Scandinavian domain





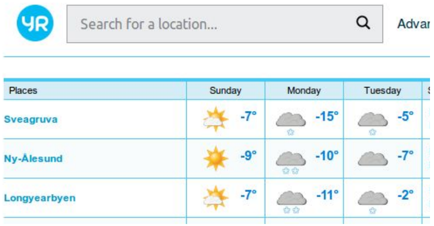
2. ASCAT in the operational Arctic system

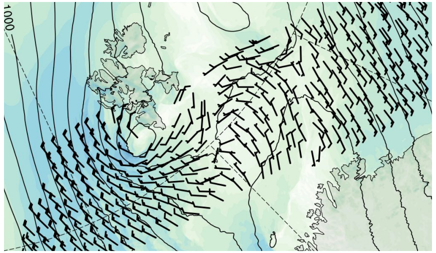
Procedure

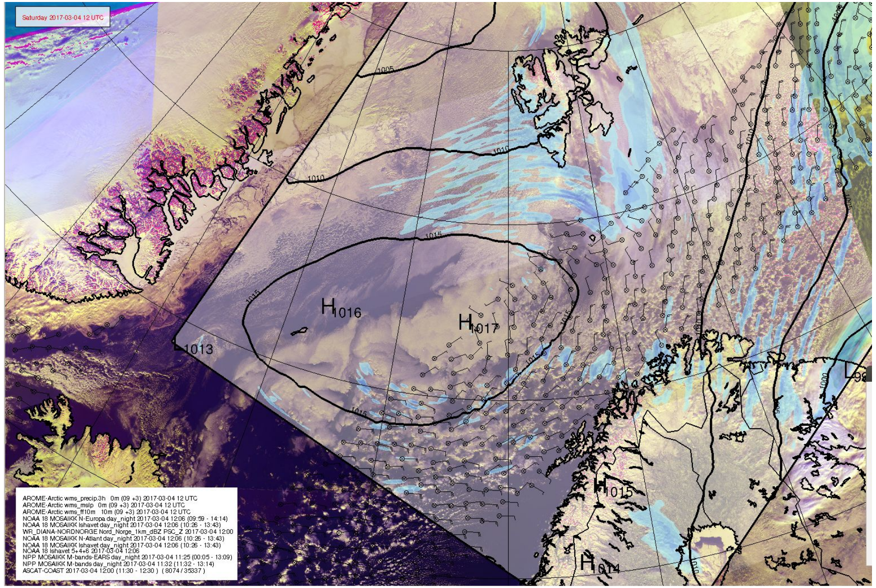
1. The ASCAT data was actively included in the daily runs of AROME-Arctic, started in November 2015 (based on the positive impacts from the OSEs in the Arctic and Scandinavian domain).

2. Data thinning of ASCAT data was decided to be 50 km based on the positive impacts found in the Scandinavian domain.

3. Forecasters got access to the new AROME-Arctic model output right from the beginning







Data usage in the starting phase

Background departures

- The frequency distribution of background departures follow normal distribution
- Biases are small and the standard deviations typical
- The results imply that the Arctic system is well sep up the ASCAT data

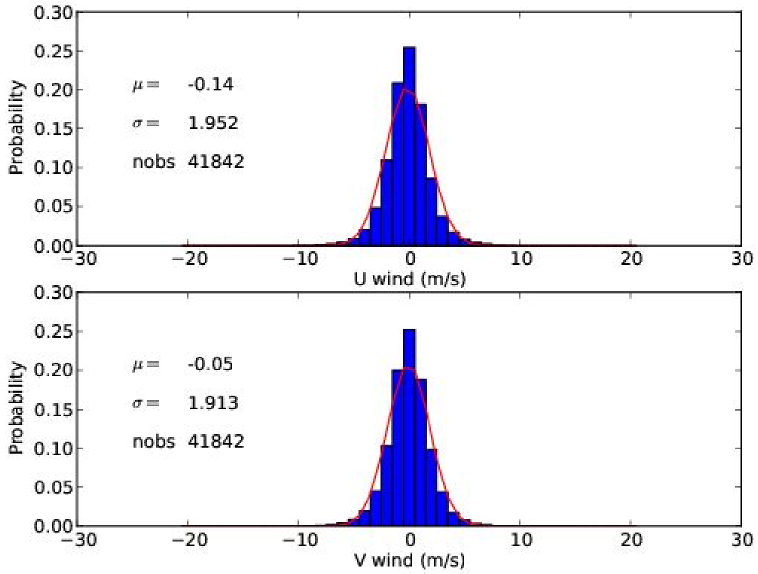


Figure:
Background departure distribution for ASCAT zonal (upper panel) and meridional (lower panel) wind components in the daily runs of AROME Arctic in January 2016.

Data usage in the starting phase

Background departures

- The wind speed in model background is higher than the assimilated ASCAT winds on strong winds
- This difference can originate from several reason, e.g., from the parameterisation of the boundary layer winds

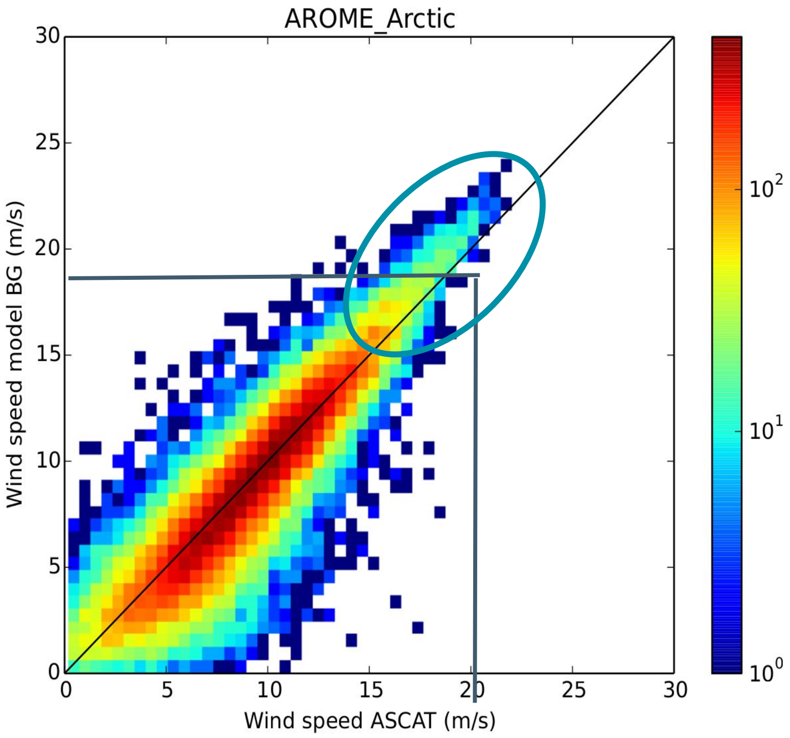


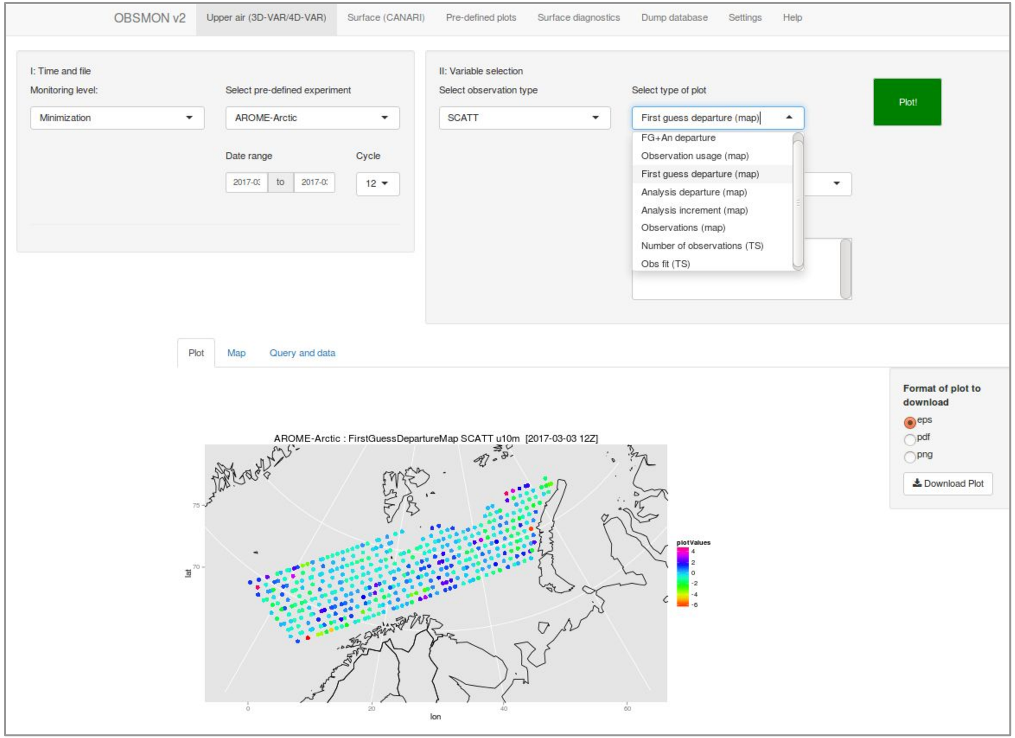
Figure:
Density scatter plot for absolute wind speed (m/s) calculated from the wind components for the assimilated ASCAT data and the background equivalent in the observation space in the AROME-Arctic system in January 2016

Observation monitoring in the operational system (OBSMON)

1. OBSMON is a tool to monitor observation usage in the HARMONIE-AROME model system

2. ASCAT data usage was implemented in the OBSMON system

3. The data usage in AROME-Arctic is regularly monitored (weekly meetings).

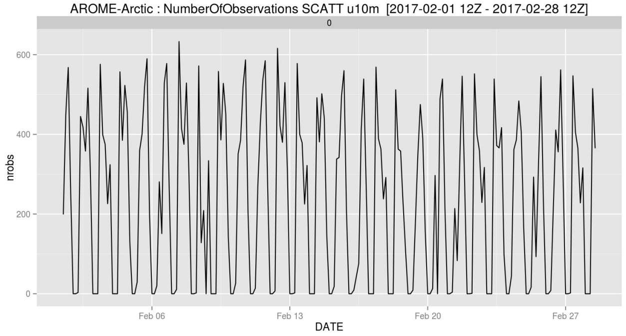


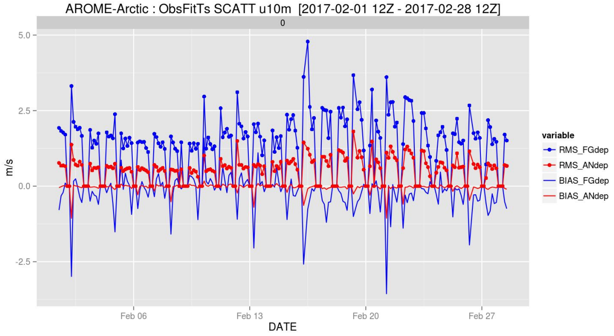
Observation monitoring in the operational system - February 2017

Number of observations

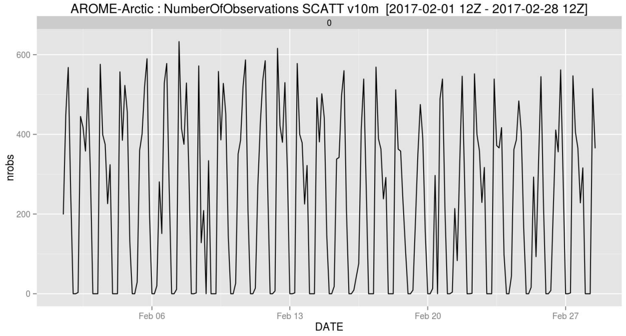
Observation fit

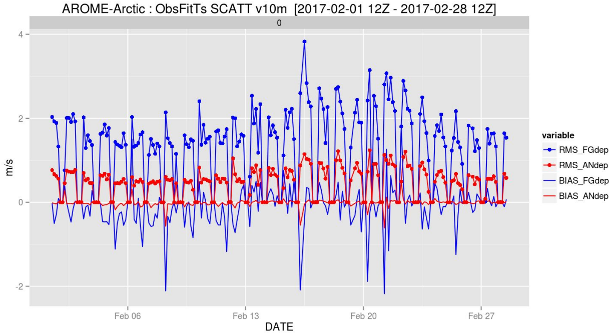
ASCAT U wind





ASCAT V wind



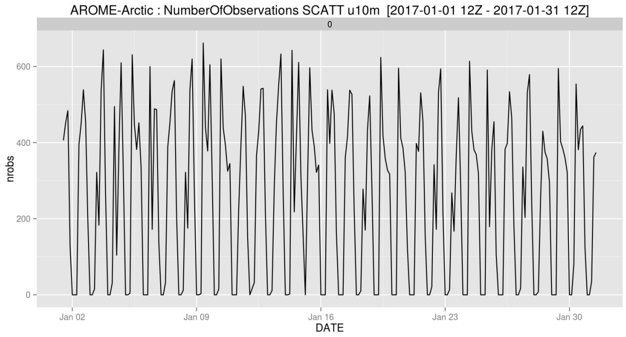


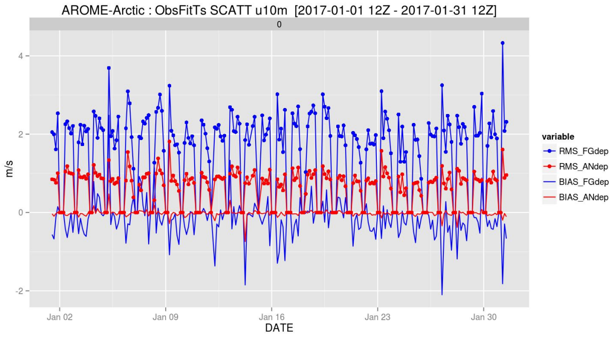
Observation monitoring in the operational system - January 2017

Number of observations

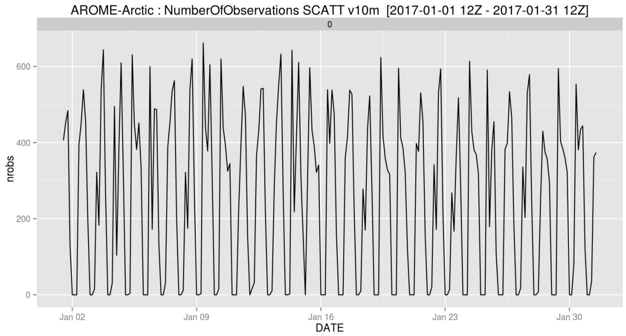
Observation fit

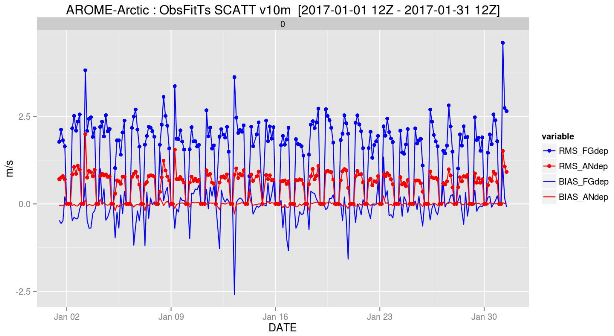
ASCAT U wind





ASCAT V wind



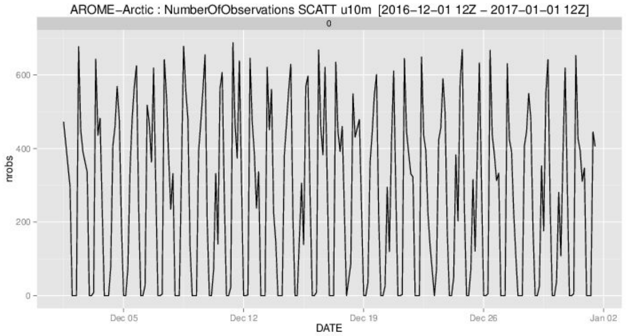


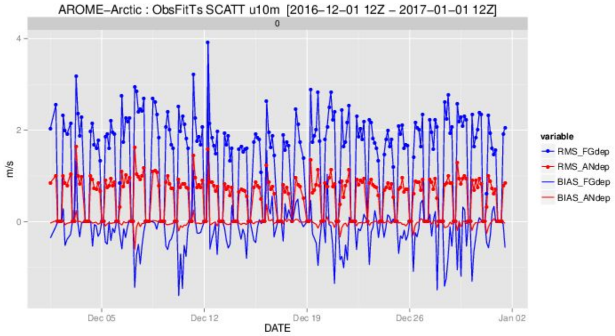
Observation monitoring in the operational system - December 2016

Number of observations

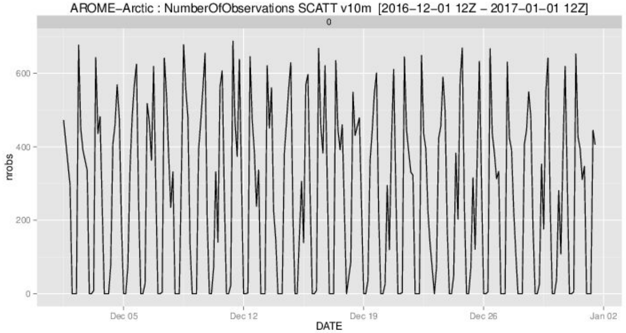
Observation fit

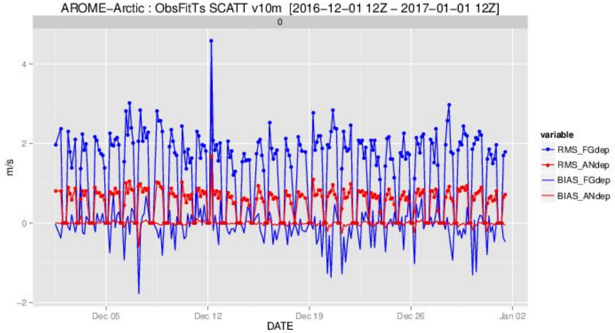
ASCAT U wind





ASCAT V wind



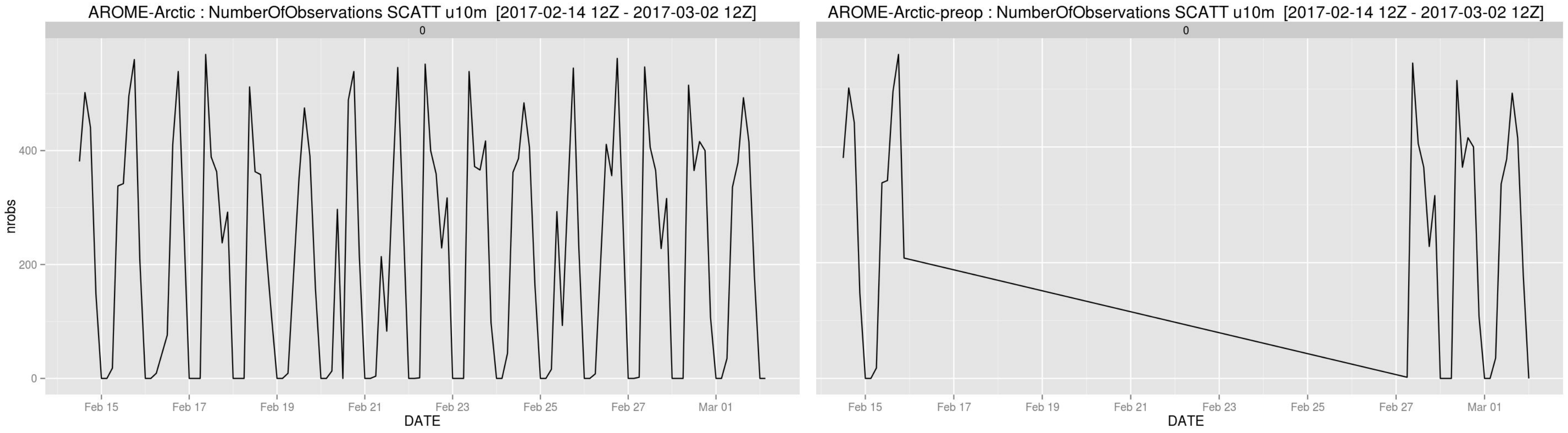


Observation monitoring - an example

Number of used ASCAT observations in the Arctic system

Operational AROME-Arctic cy38

Pre-operational AROME-Arctic preop cy40

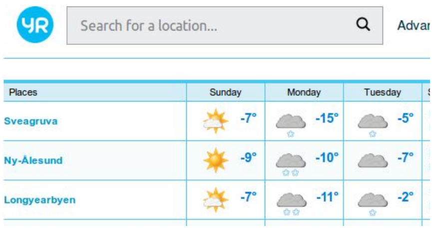


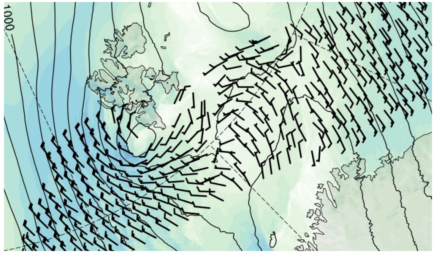
Conclusions - Operational system

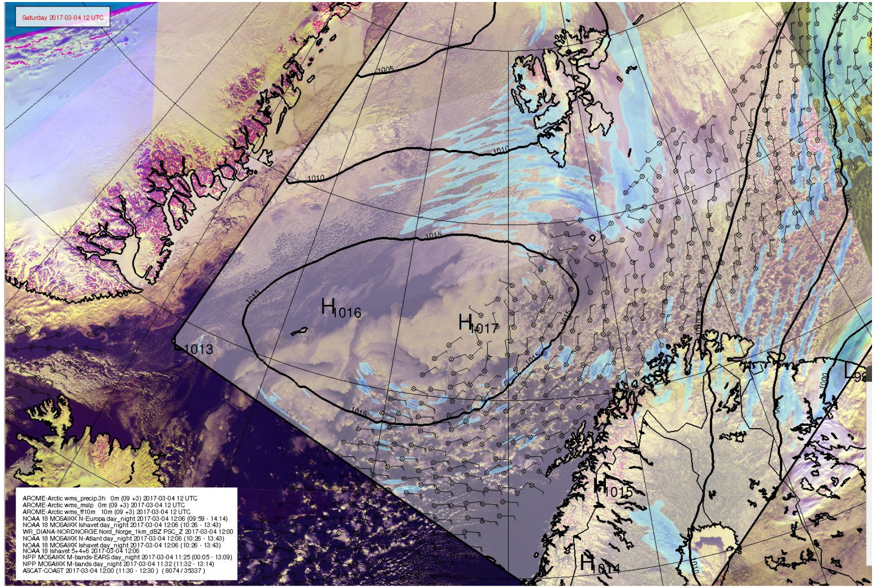
1. The observation usage and model quality of AROME-Arctic are regularly monitored (weekly meetings)

2. The amount of assimilated ASCAT data is regular, the data streams and the observation fit are stable.

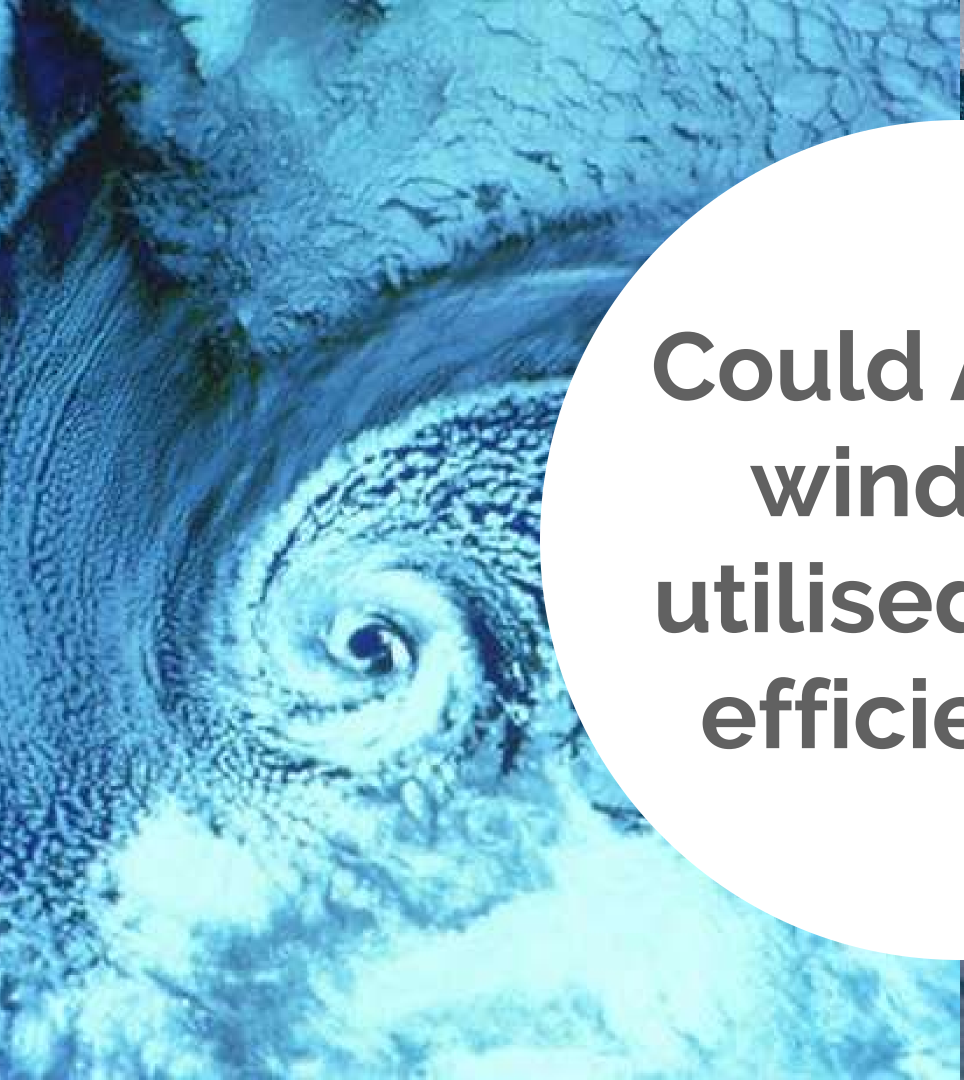
3. The operational observation monitoring system can detect problems at early stage







3. ASCAT winds in the wave-coupled model system



Could ASCAT winds be utilised more efficiently?

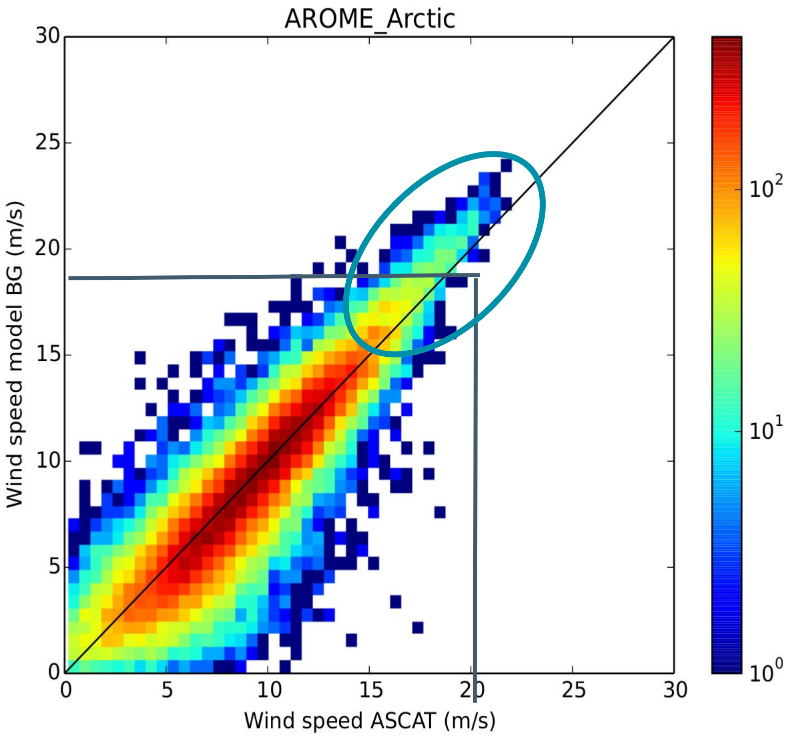
Motivation for wave-coupled system

Wave-coupled model might be able to use satellite winds more efficiently

The bias probably limits the impact of satellite winds in the assimilation.

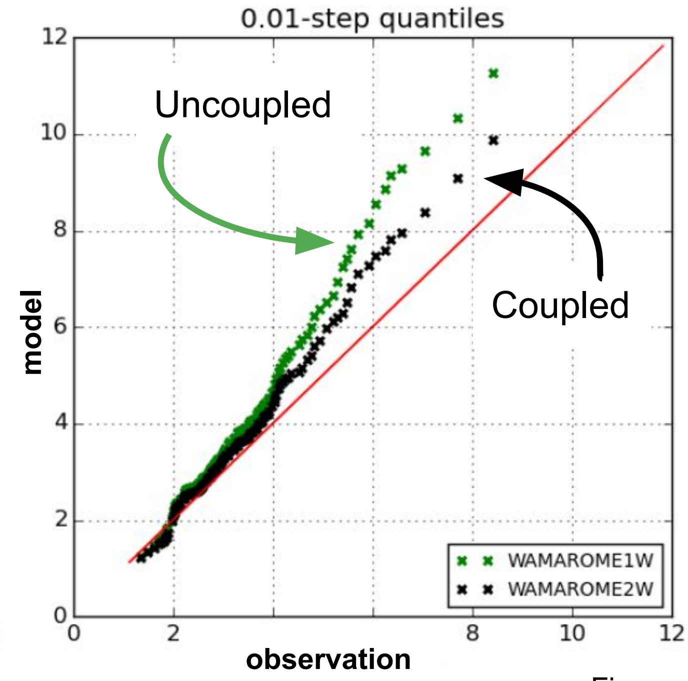
The model bias has been found also against offshore observations.

The overestimation of winds might be caused by problems in the wind stress / roughness calculations, which can be improved by wave-coupling

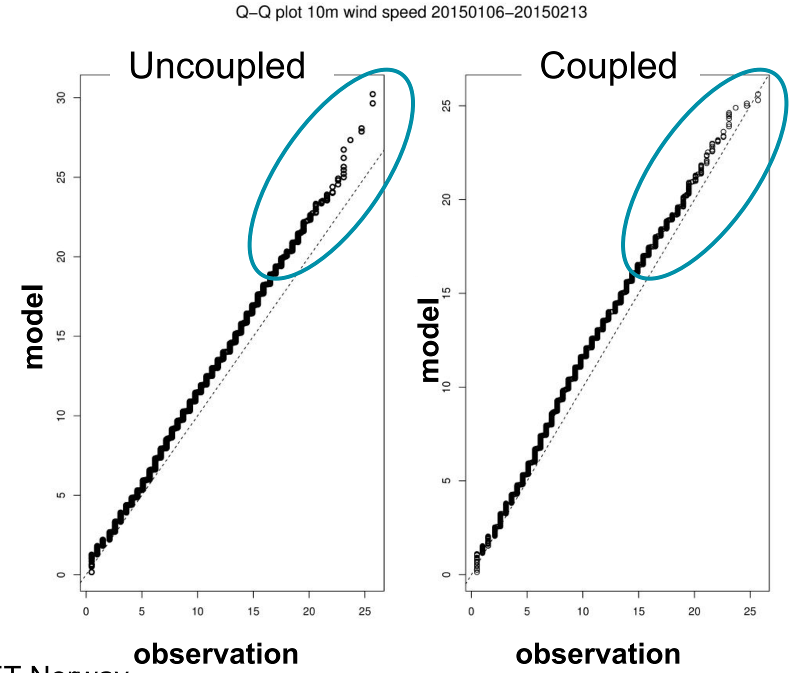


Impact of wave-atmosphere coupling (w/o DA)

Significant wave height (North Sea)

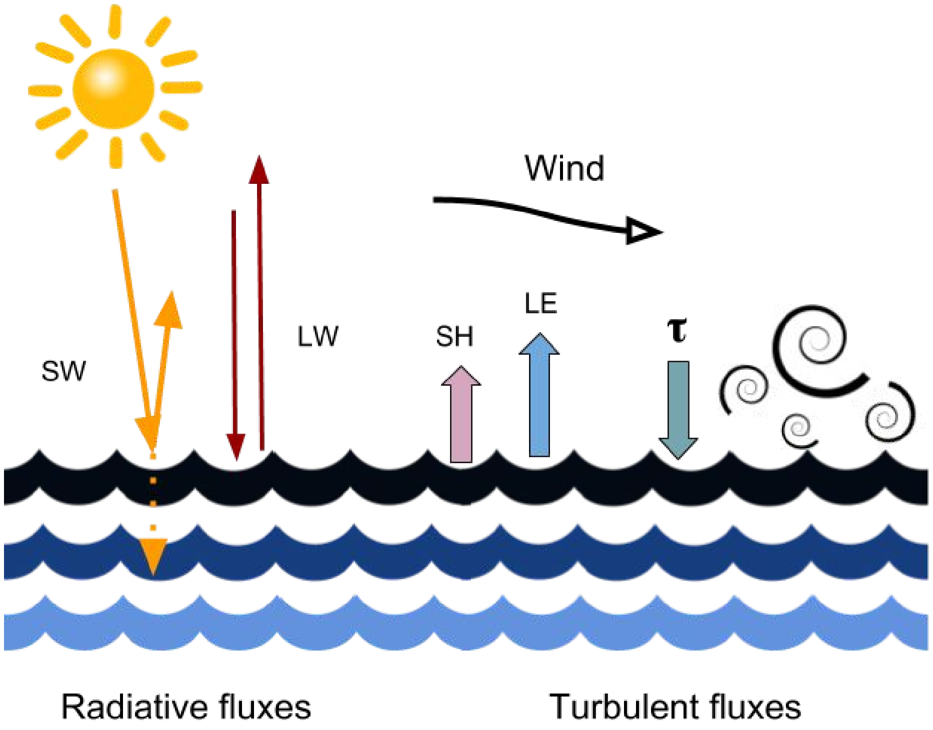


10-m wind speed at ocean stations



Figures: Jakob Süld, MET Norway

Fluxes at the atmosphere-ocean interface

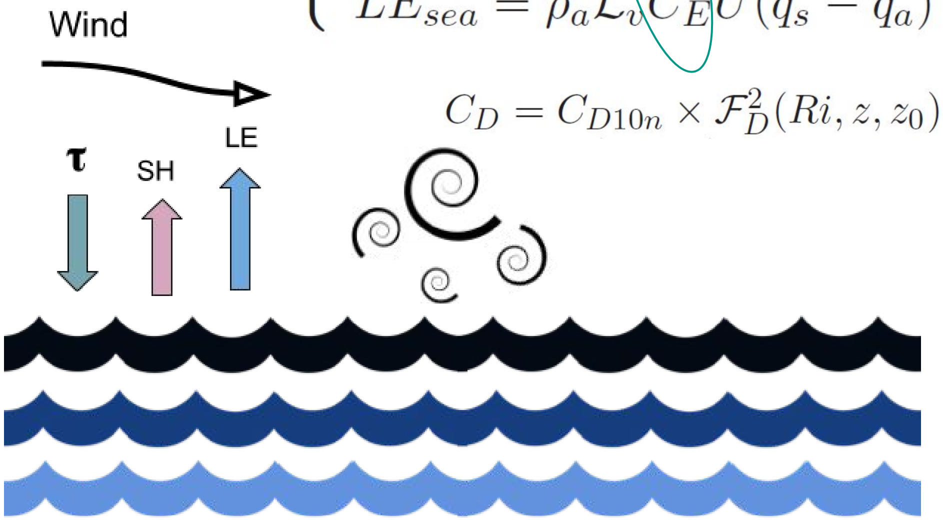


1. Radiative fluxes
2. Turbulent fluxes
   a. Sensible heat flux
   b. Latent heat flux
   c. Wind stress (momentum flux)
3. In the HARMONIE-AROME, the surface fluxes are parameterised in the sea tile of the surface model SURFEX

Turbulent flux parameterisation

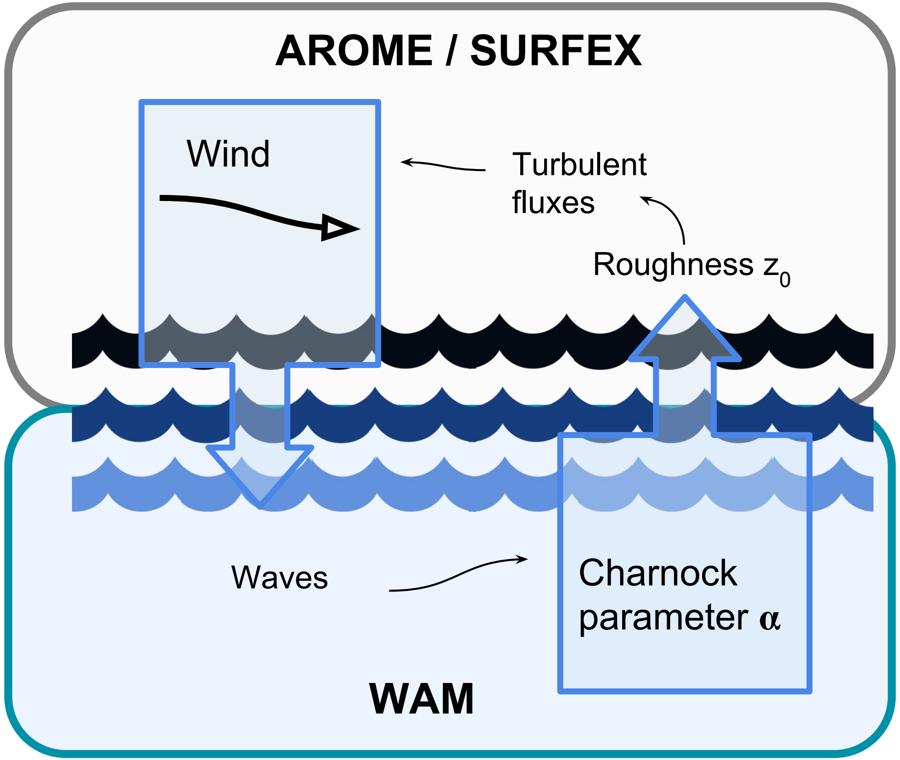
$$
\begin{cases}
|\vec{\tau}|_{sea} = -\rho_a C_D U^2 \\
H_{sea} = \rho_a c_{p_a} C_H U(\theta_s - \theta_a) \\
LE_{sea} = \rho_a \mathcal{L}_v C_E U(q_s - q_a)
\end{cases}
$$

$$C_D = C_{D10n} \times \mathcal{F}_D^2(Ri, z, z_0)$$



1. Turbulent fluxes from the mean meteorological gradients with the use of transfer coefficients C_D, C_H and C_E
2. The transfer coefficients are determined from neutral transfer coefficients C_{10n}, stability functions and roughness length z_0
3. In a wave-coupled system, we would like to have the impact of waves included in the transfer coefficients

Wave-atmosphere coupling



1. The surface roughness z_0 over open sea depends on the Charnock's parameter α

$$z_0 = \frac{\alpha u_*^2}{g} + \frac{\beta \nu}{u_*}$$

2. In an uncoupled system, α is a constant

3. In a coupled system, α depends on the sea state and is calculated in WAM

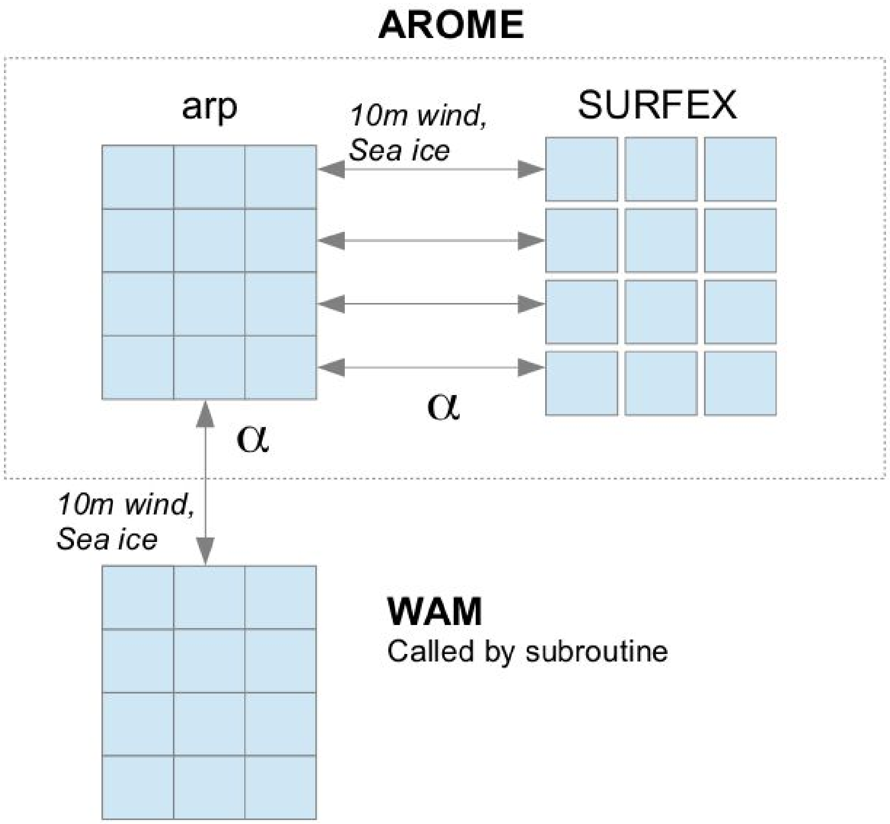
$$\alpha = \hat{\alpha} / \sqrt{1 - \frac{\tau_w}{\tau}}$$

Code changes

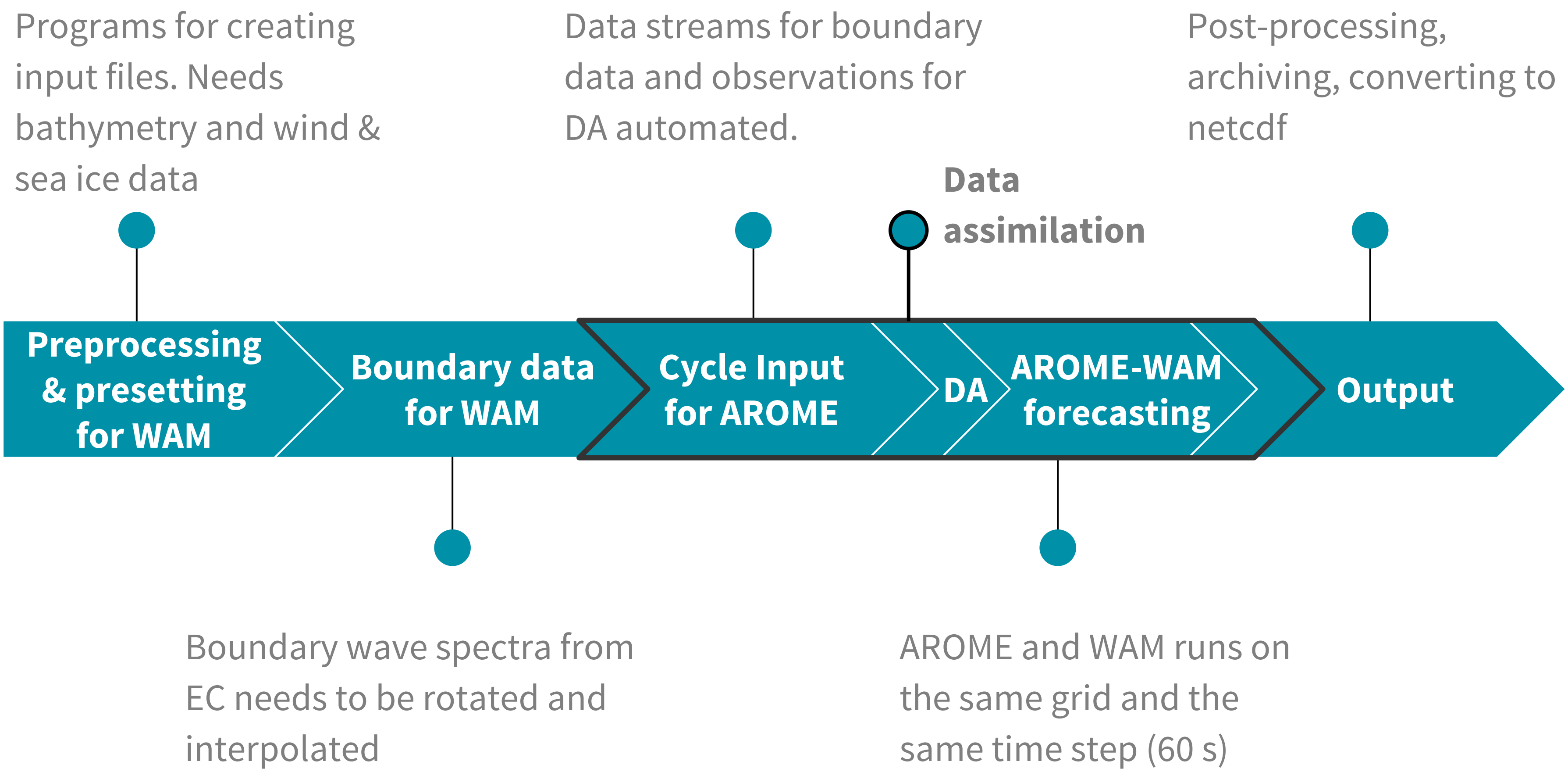
1. ECWAM cy36 is added in out AROME source library under the main model routine arp: src/arp/wam_code

2. The coupling is done outside SURFEX because there is no advection in SURFEX

3. The main source code changes in AROME are the transfer of variables between WAM and SURFEX, and the routines calling WAM



By Jakob Süld, MET Norway


Programs for creating input files. Needs bathymetry and wind & sea ice data
Data streams for boundary data and observations for DA automated.
Post-processing, archiving, converting to netcdf
Data assimilation
Preprocessing & presetting for WAM
Boundary data for WAM
Cycle Input for AROME
DA
AROME-WAM forecasting
Output
Boundary wave spectra from EC needs to be rotated and interpolated
AROME and WAM runs on the same grid and the same time step (60 s)

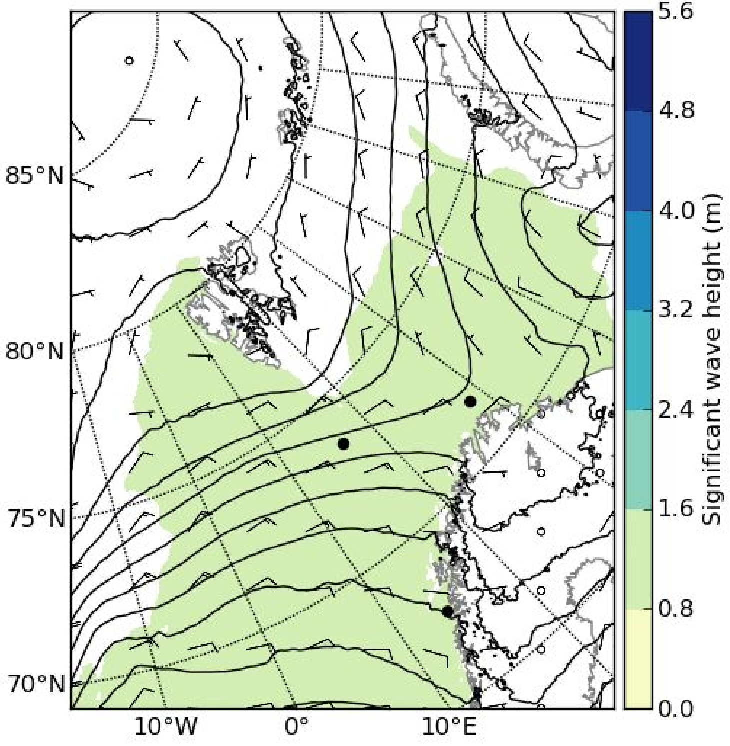
Wave-coupling in the Arctic system

Achievements

- A 4-day wave-coupled experiment with full atmospheric assimilation including ASCAT
- No deficiencies in the assimilation of ASCAT
- The experimental wave-coupled model system with DA is technically available

Longer impact experiments with different observation usage are work in progress.

Ongoing work to update both atmospheric and wave model.



Summary

The impact of ASCAT data in the Arctic system was investigated

ASCAT assimilation shows improvements in forecasting of MSLP and wind. ASCAT data contribute to deepening the cold air mesocyclones and strengthening the associated wind speeds.

Assimilation of ASCAT winds were implemented in the daily runs of the Arctic forecasting system

The data usage is monitored. The amount of assimilated data is regular and the data streams are stable.

The experimental wave-coupled model system was developed to make use of ASCAT winds

Provides an initial base for future work towards a more efficient usage of ASCAT data.

Thank you!