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Scatterometer winds in rapidly developing storms (SCARASTO) – First experiments on data assimilation of scatterometer winds

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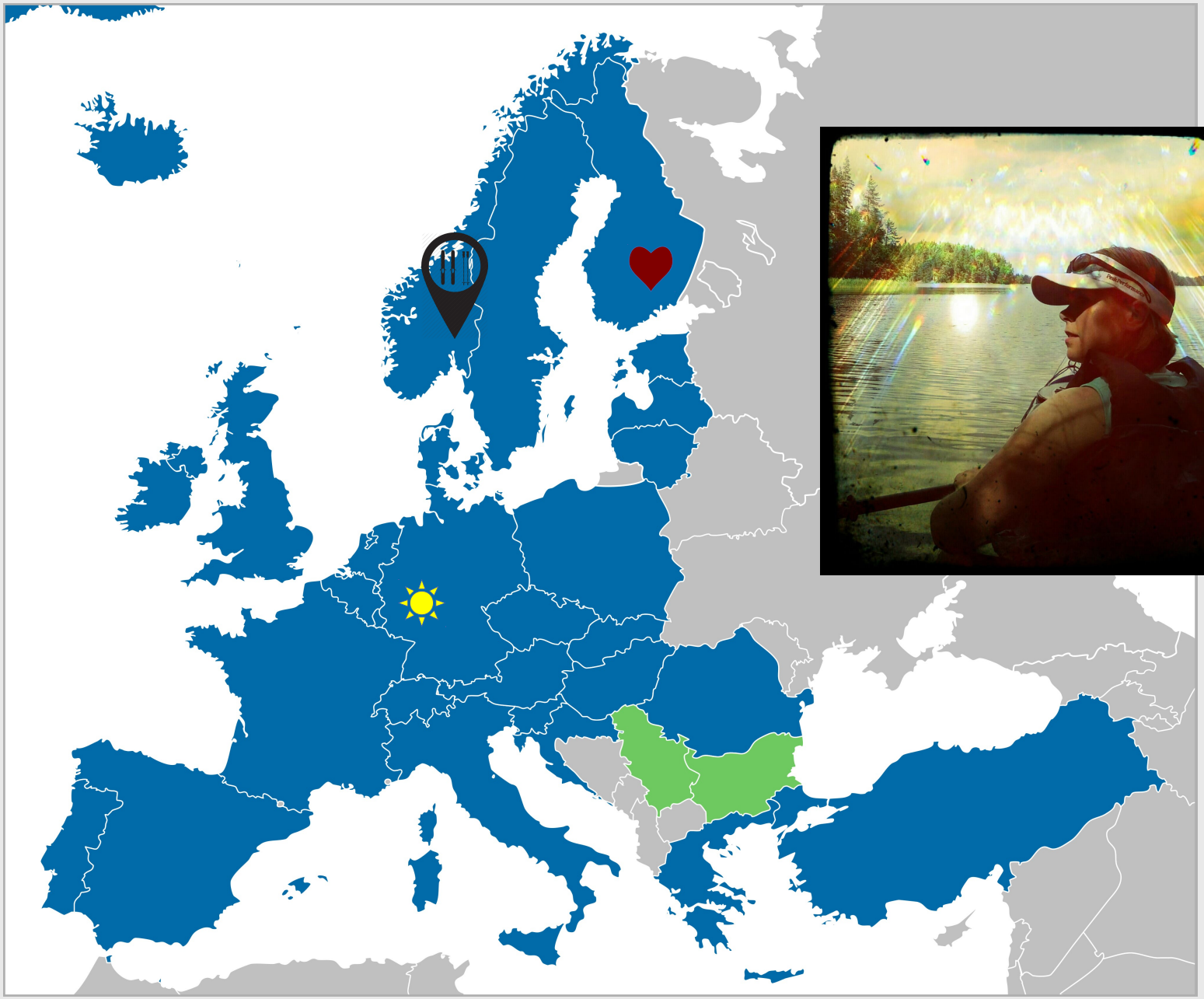
Norwegian Meteorological Institute

17/03/2014

Outline

- Introduction: SCARASTO project
- Scatterometer winds
- HARMONIE model
- Results: Experiments on data assimilation of scatterometer winds
  - Data usage
  - Observation departure statistics
  - Verification
- Summary
- Outlook



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SCARASTO – Scatterometer winds in rapidly developing storms

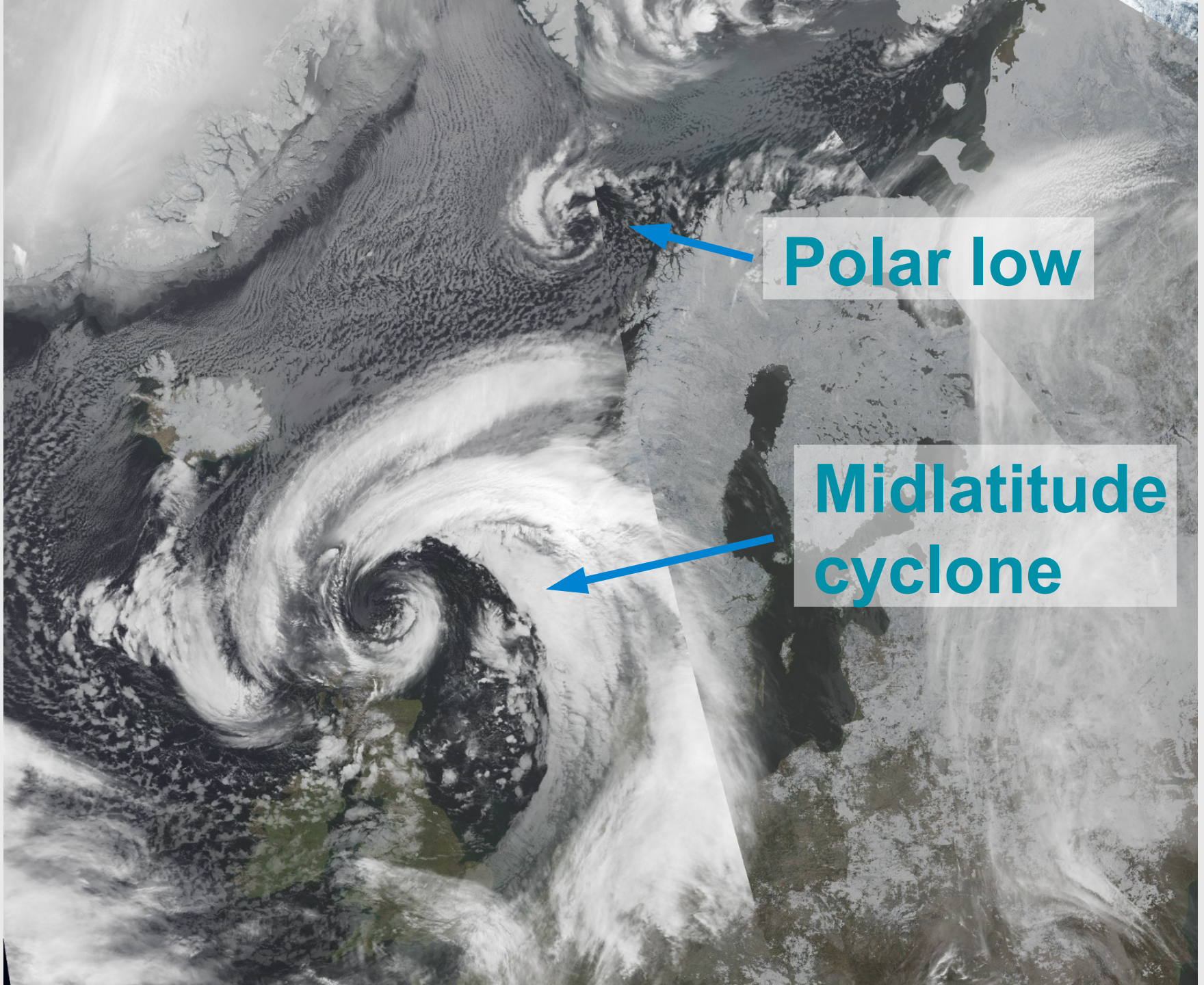
- EUMETSAT fellowship project started May 2013
- The project aims to take better benefit of scatterometer winds in the numerical weather prediction
- The goal of the project is to improve extreme weather forecasting by data assimilation of scatterometer winds

Rapidly developing storms

1. **Extreme weather events**
   - National extreme weather warnings are sent when human life and property are in danger
   - Typically a strong mid-latitude cyclone from the Northern Atlantic

2. **Polar lows**
   - Small but intense short-living meso-scale cyclones
   - Forms when cold polar air is advected over relatively warm water
   - On average 12 per winter in Norwegian area
   - Operational detecting and archiving system at MET Norway

3. **Other high impact weather events**
   - Cases pointed out by forecasters


Polar low
Midlatitude cyclone

Scatterometer winds

- Advanced Scatterometer (ASCAT) is an active microwave instrument on-board satellites MetOp-A and MetOp-B.
  - MetOp-A, launched in October 2006
  - MetOp-B, launched in September 2012
- The ASCAT instrument was designed to measure wind speed and wind direction over the oceans
- The ASCAT system covers two 550 km-wide swaths, which are separated by 670 km.
- The satellites orbit at 837 km altitude. The nominal MetOp orbit repeat cycle is 29 days. The orbit period is approximately 100 minutes.

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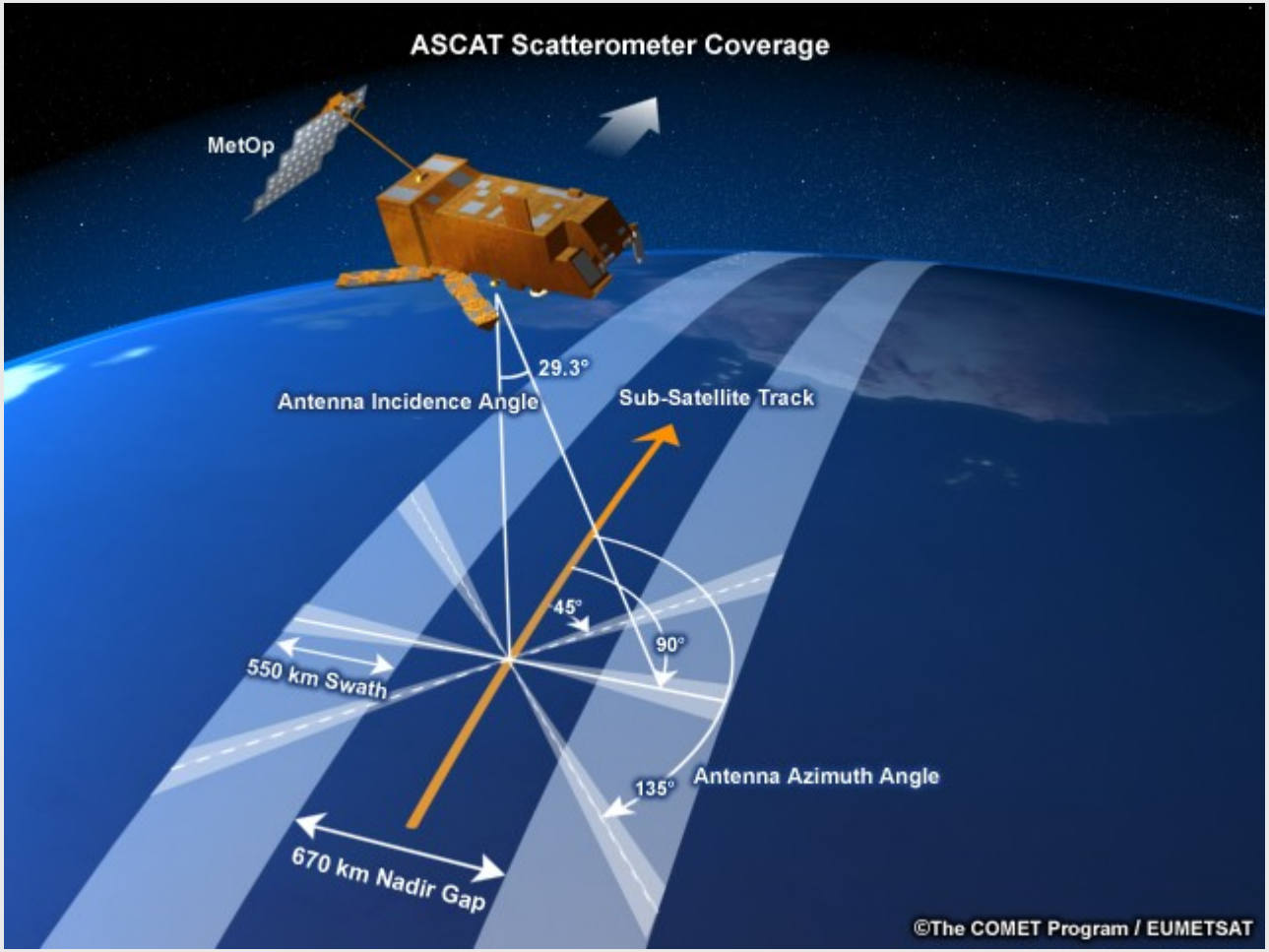
http://www.youtube.com/watch?v=kdwWdLE-2eI



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Scatterometer wind retrieval

- ASCAT operates at a frequency of 5.255 GHz (C-band). Quite insensitive to rain.
- ASCAT makes 3 independent backscatter measurements using the 3 different viewing directions
- The backscatter depends on the sea surface roughness as a function of the wind speed and direction at the ocean surface.
- That makes possible to calculate the surface wind speed and direction using Geophysical Model Function (GMF)
- 4 ambigous wind solutions are retrieved

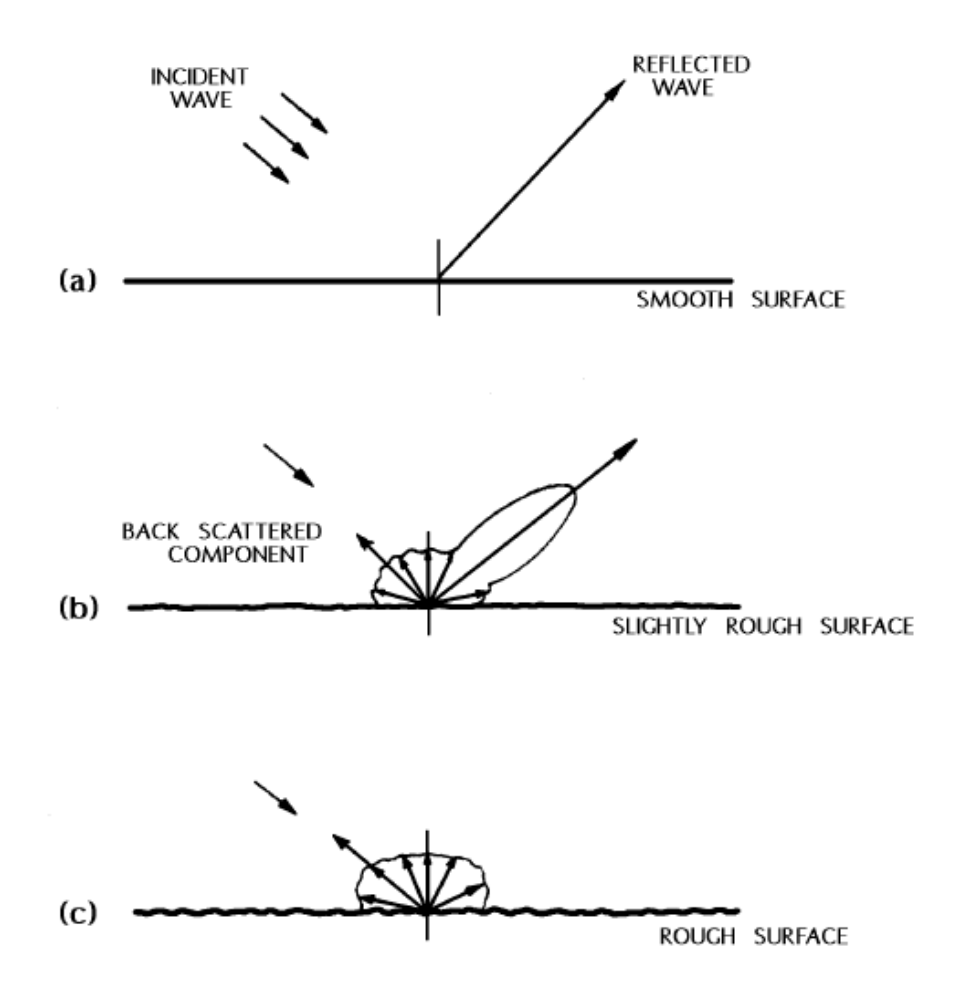


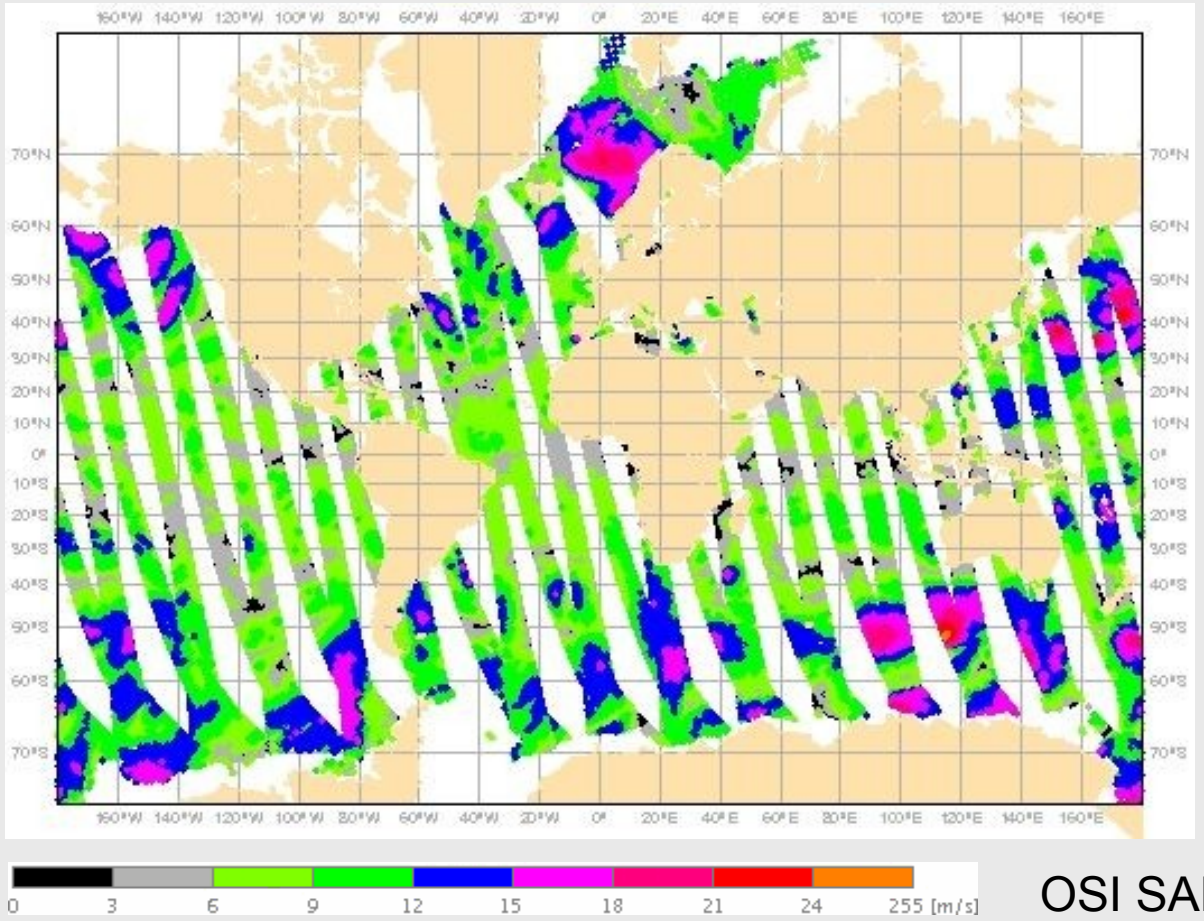
Figure: Stoffelen 1998

Scatterometer wind products

- There are 5 different ASCAT scatterometer wind products available
  - Global OSI SAF 25-km wind product (contains soil data)
  - Global OSI SAF 12.5-km wind product (contains soil data)
  - Global OSI SAF coastal wind product
  - Regional EARS 25-km wind product
  - Regional EARS 12.5-km wind product
- The data are distributed through EUMETCast and archived at EUMETSAT Data Center Archive

Global ASCAT data coverage

OSI SAF ASCAT-A 25-km product

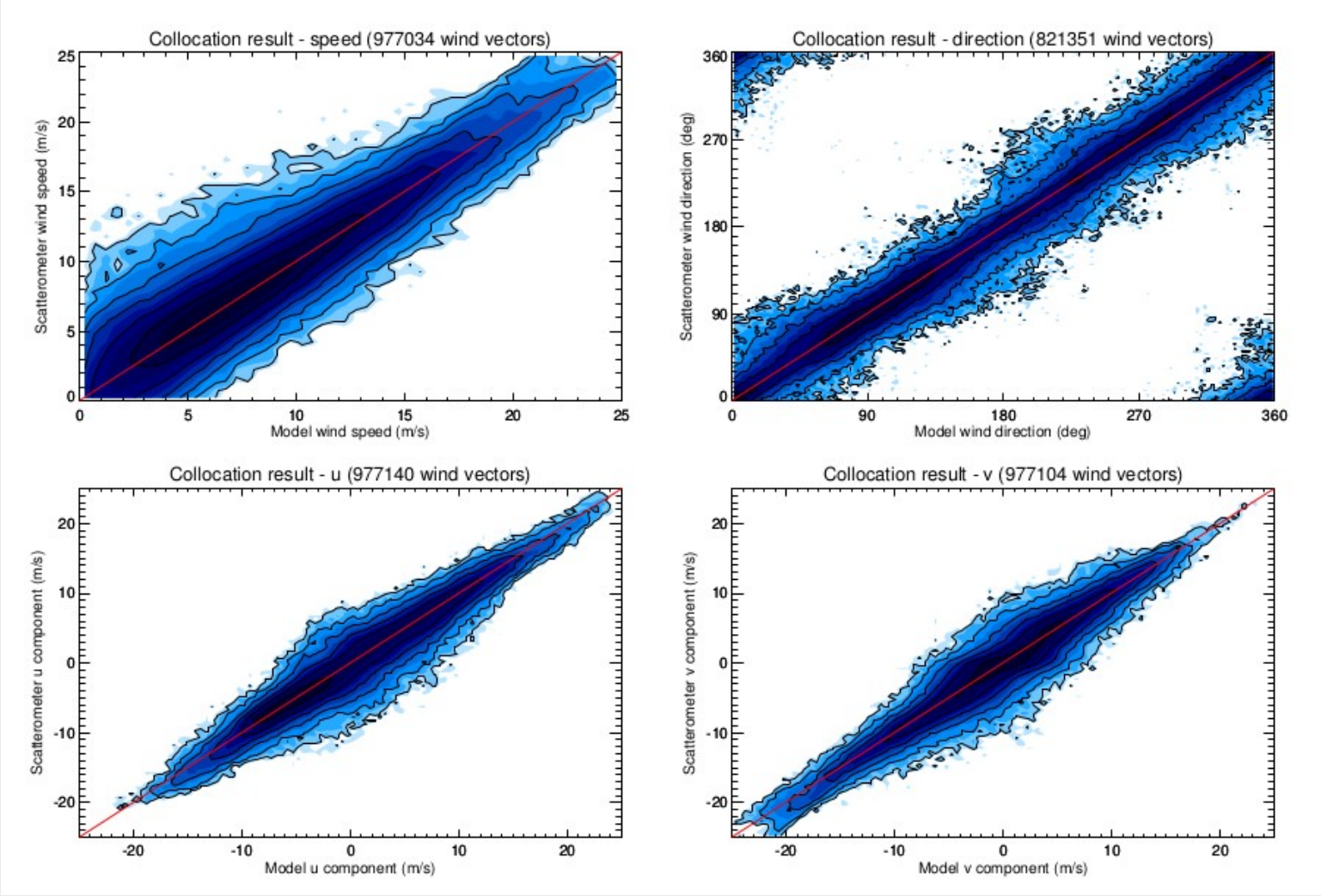


OSI SAF / KNMI

Scatterometer wind quality

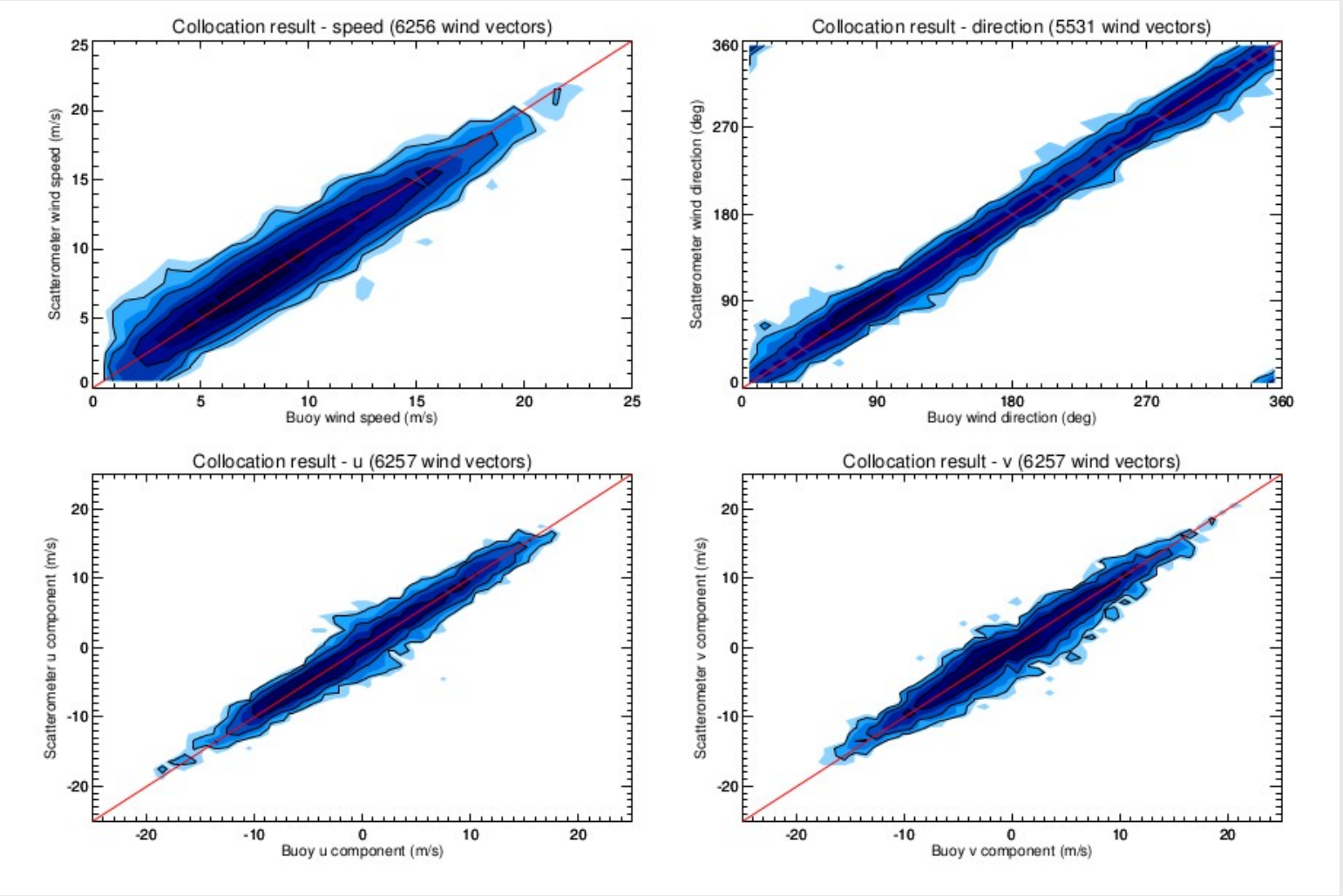
- ASCAT data well calibrated versus the ECMWF forecasts and buoy measurements
- ASCAT vs. ECMWF forecasts
  - Wind speed biases are ~0.20 m/s
  - Std 1.44 m/s in u and 1.49 m/s in v directions, both for Metop-A and Metop-B.
- ASCAT vs. buoy measurements
  - wind speed bias of -0.02 m/s for Metop-A and 0.05 m/s for Metop-B.
  - Standard deviations of u and v wind components are 1.72 m/s and 1.76 m/s for Metop-A and 1.78 m/s and 1.80 m/s for Metop-B, respectively.

25-km ASCAT-A vs. ECMWF forecast



ASCAT Wind Product User Manual

25-km ASCAT-A vs. Buoy



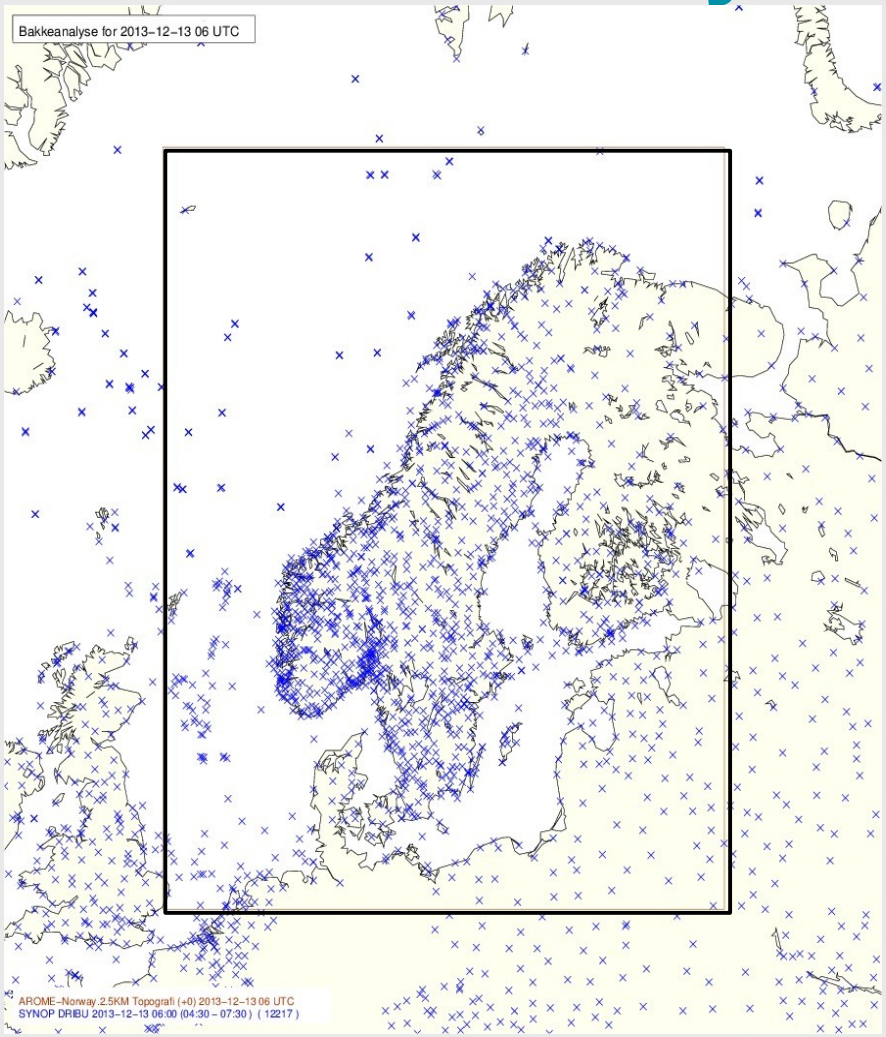
ASCAT Wind Product User Manual

The HARMONIE model

- High-resolution non-hydrostatic convection permitting spectral model
- HIRLAM (**HI**gh **R**esolution **L**imited **A**rea **M**odel) consortium develops the model in a close cooperation with ALADIN (**A**ire **L**imitée **A**daptation dynamique **D**éveloppement **I**nter**N**ational) consortium and Météo-France
- The forecast model and analysis system are mainly those of the AROME model from Météo-France
- The default upper air data assimilation scheme in HARMONIE is the 3DVAR scheme developed in ALADIN
- Exact implementation of the model differs between institutes

Operational setup at MET Norway

- MetCoOp, joint NWP system of Sweden and Norway (From 12 March 2014)
- Grid size 2.5 km
- ECMWF as boundaries
- Data assimilation: 3DVar
- 3-hour assimilation cycle
- Cut off time: 1 h 15 min
- Forecast length
  - +66 h every 6 hours (00, 06, 12, 18 UTC)
  - +03 h (03, 09, 15, 21 UTC)



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Data assimilation of scatterometer winds in Harmonie

- Data assimilation in Harmonie assimilates wind components of retrieval product (not raw measurements)
- Data thinning by factor of 4 is performed to avoid correlated errors.
- The observation error for ASCAT winds is set 2.0 m/s
- Observation operator is model vector wind at 10-m height
- Two wind ambiguities are used
- The 3D-Var cost function is expressed in such a way that one ambiguity is finally used for minimasation.
- Not operational setup in Harmonie yet

Experiment: Case Hilde

- Strong low pressure system that hit Norway 16-17/11/2013. Continued over Sweden and Finland (called Eino).

Pictures:NRK

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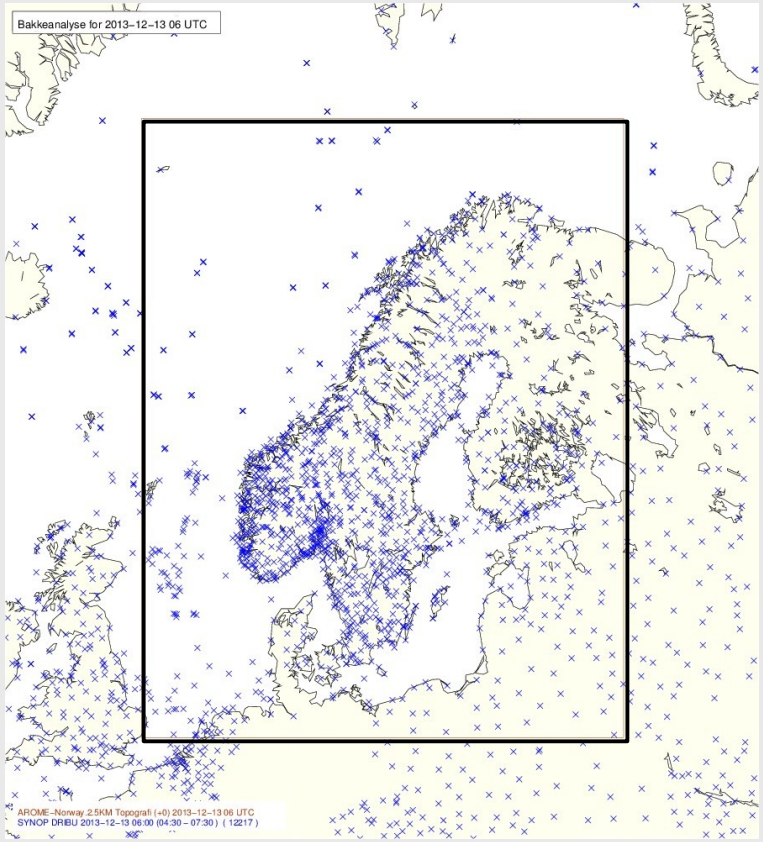
Experimental setup

- 1-week period 11/11/2013 – 18/11/2013
- Harmonie Cy37h1.2
- Domain METCOOP25B
- Grid size 2.5 km
- Model runs at ecgate at ECMWF
- ECMWF forecast used as boundary conditions
- 3-hour assimilation cycle
- Forecast length 66 hours
- 2 experiments
  - 3DVar – CONV
  - 3DVar – CONV + ASCAT



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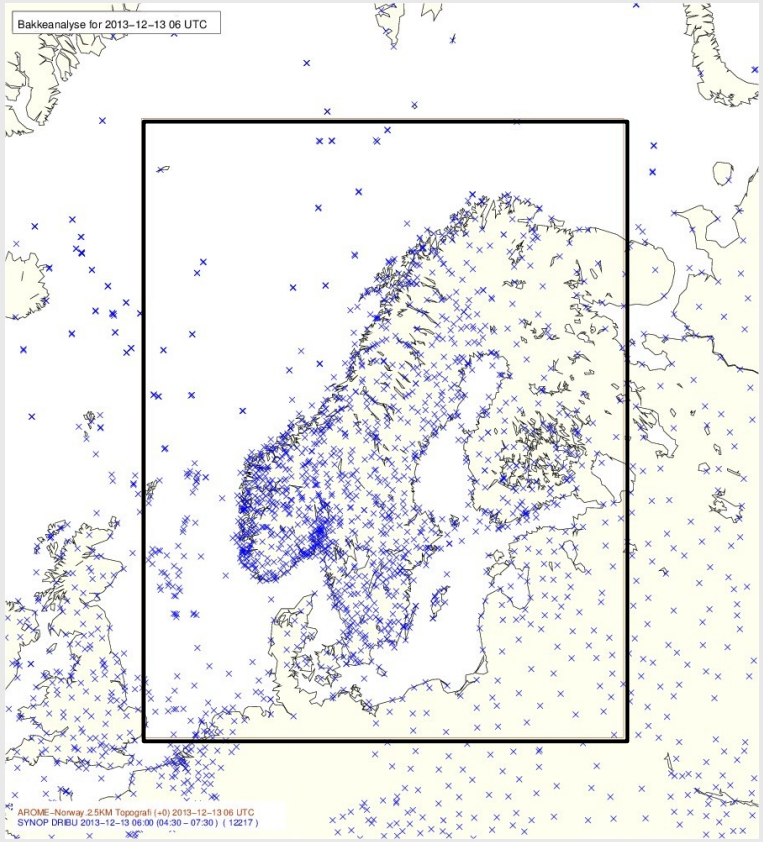

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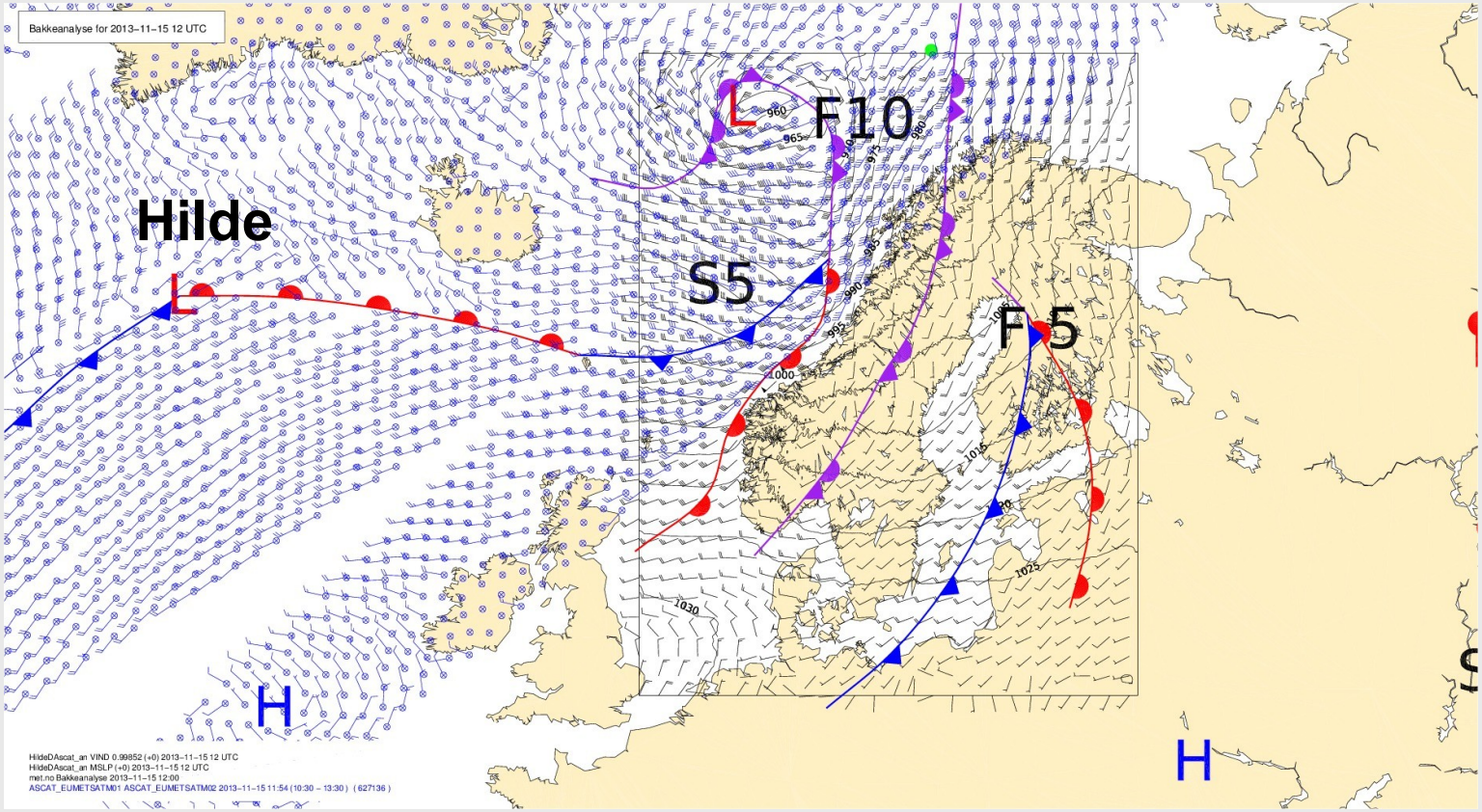

ASCAT-A and ASCAT-B winds

HARMONIE 3DVar with ASCAT winds analysis – PMSL & U10

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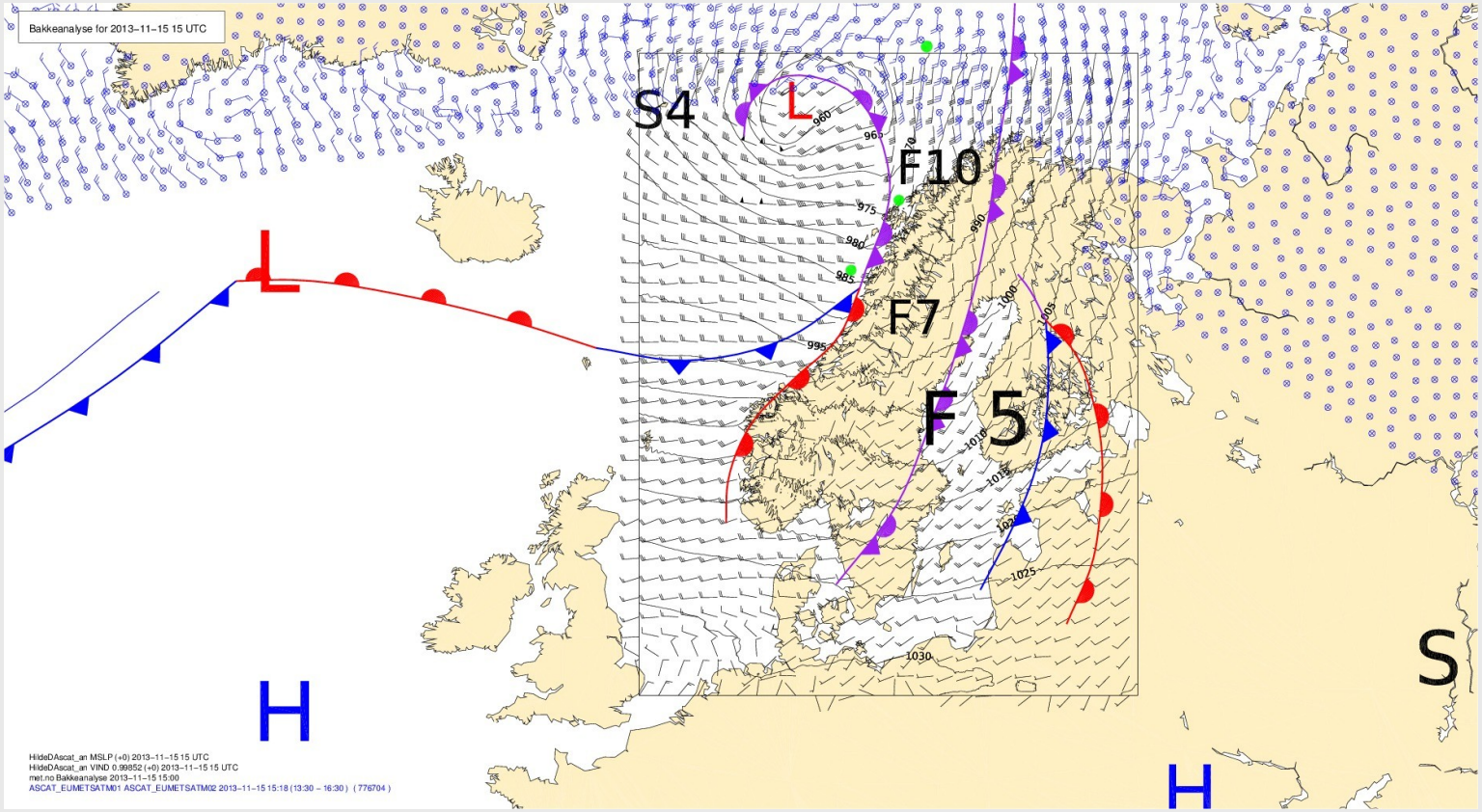

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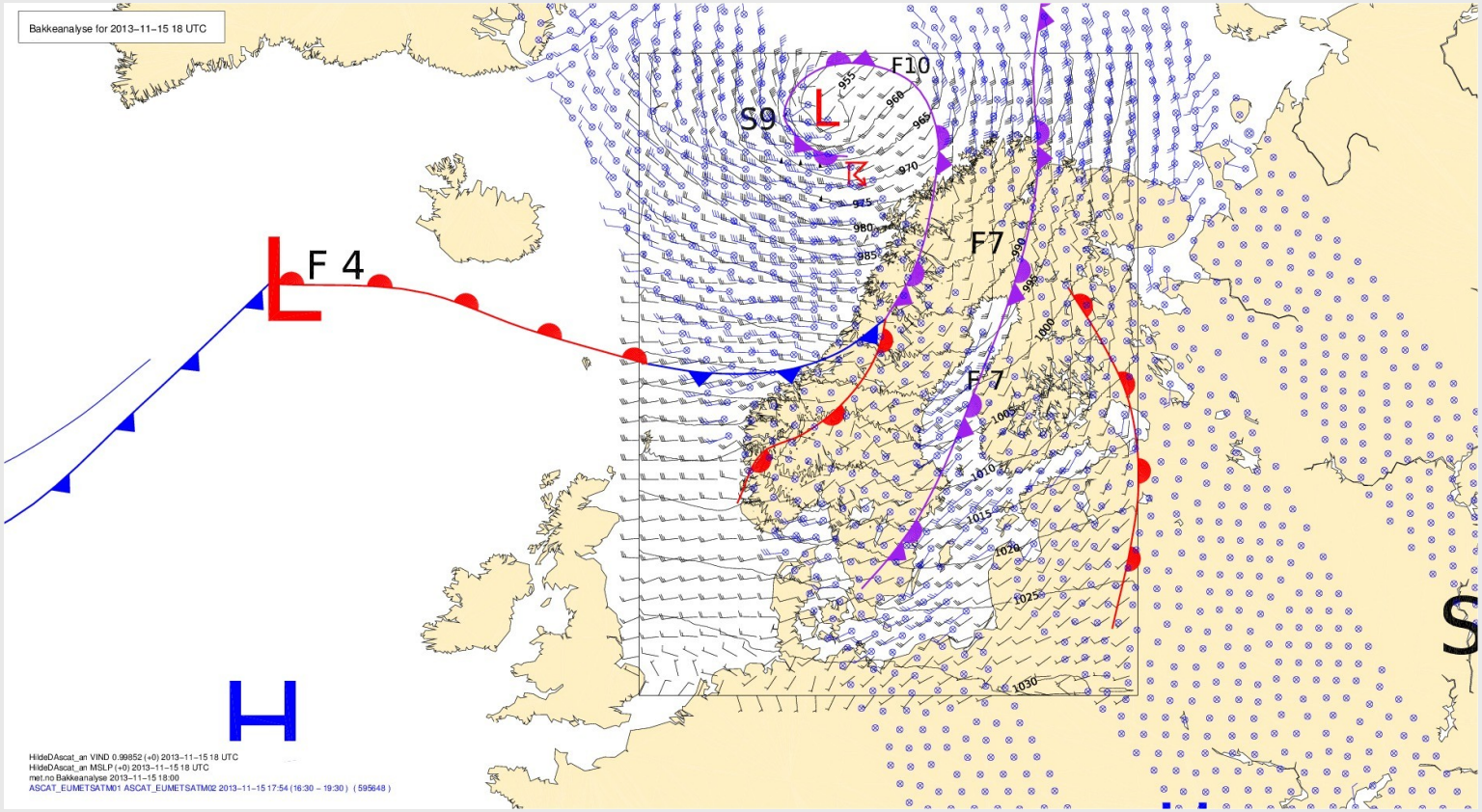

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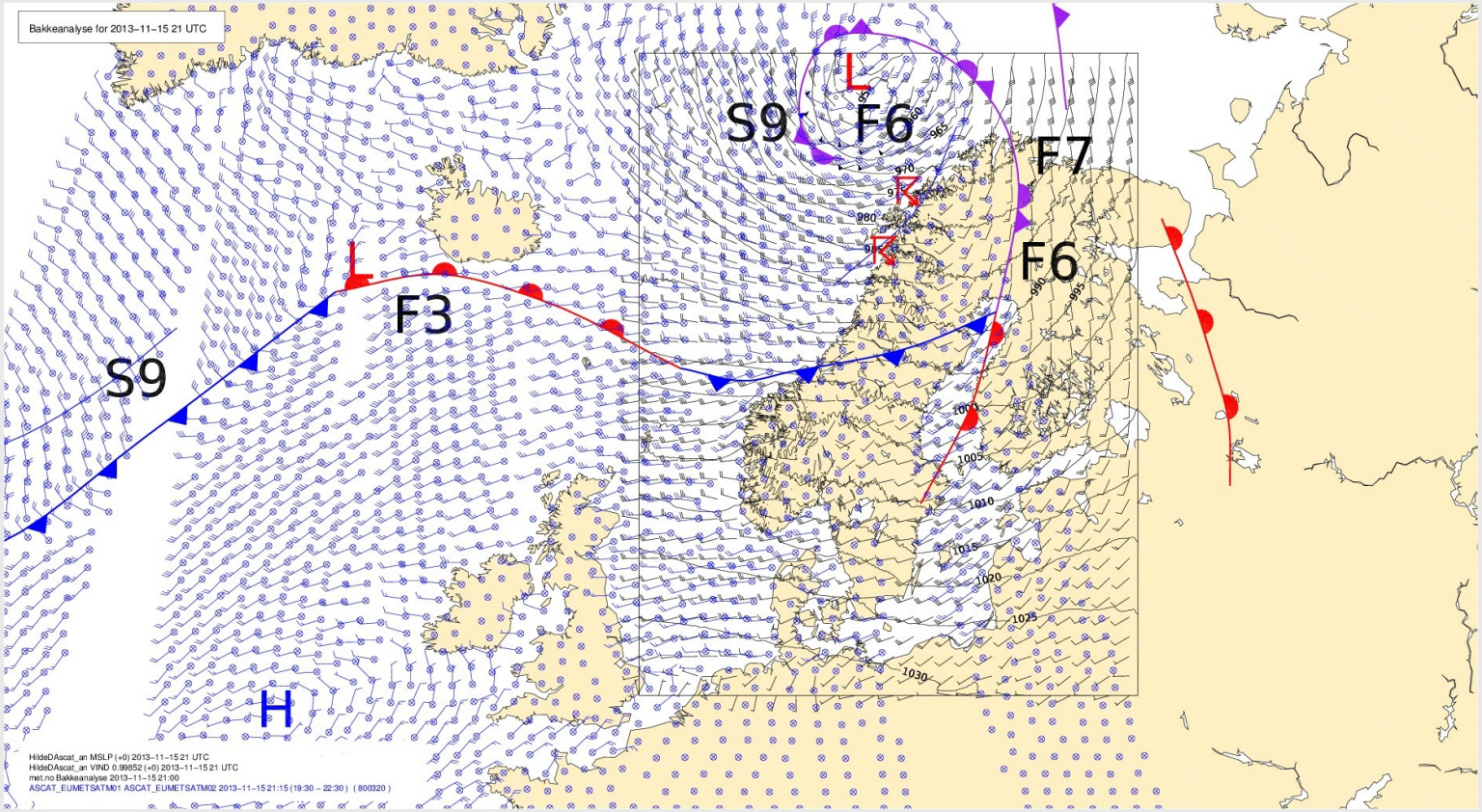

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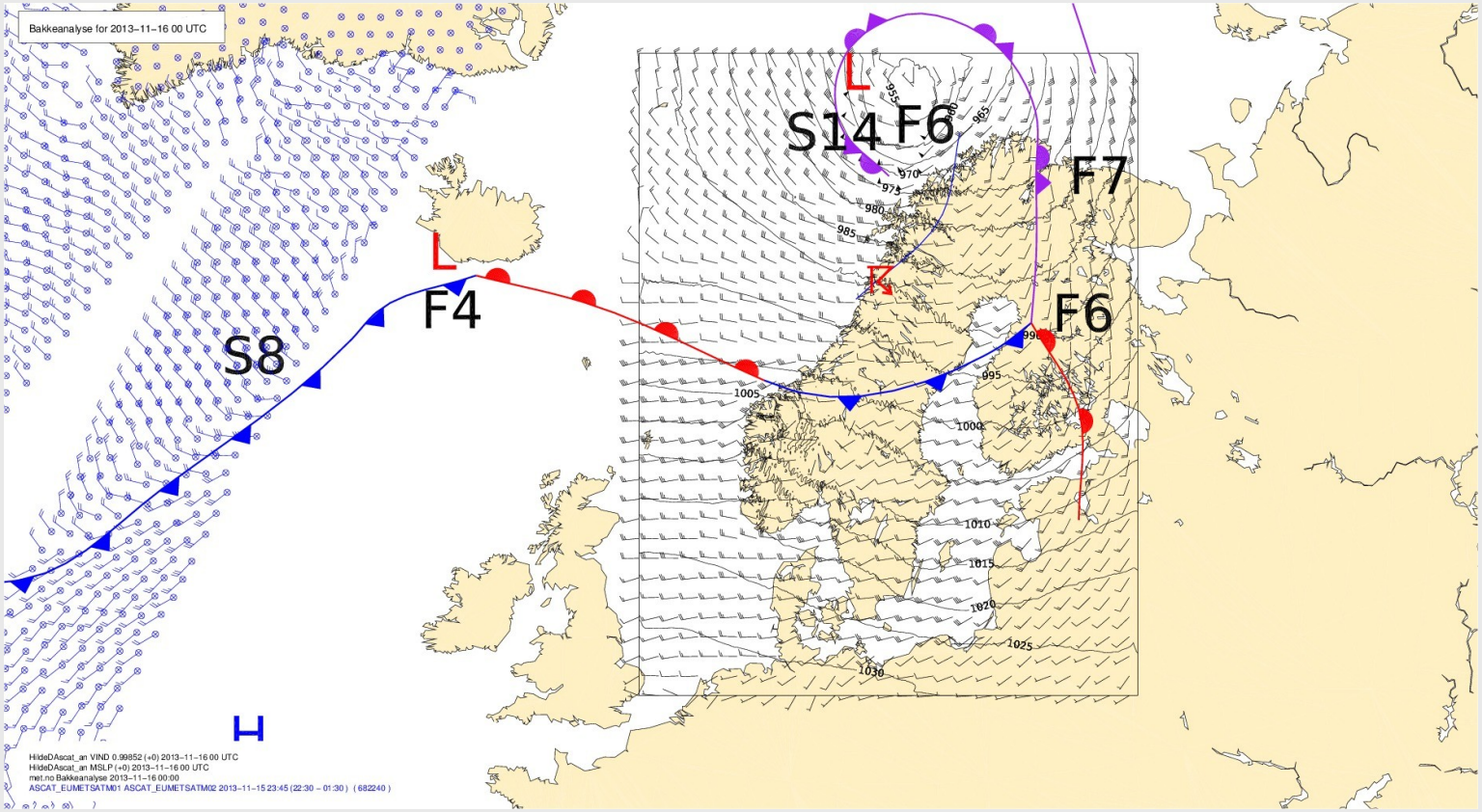

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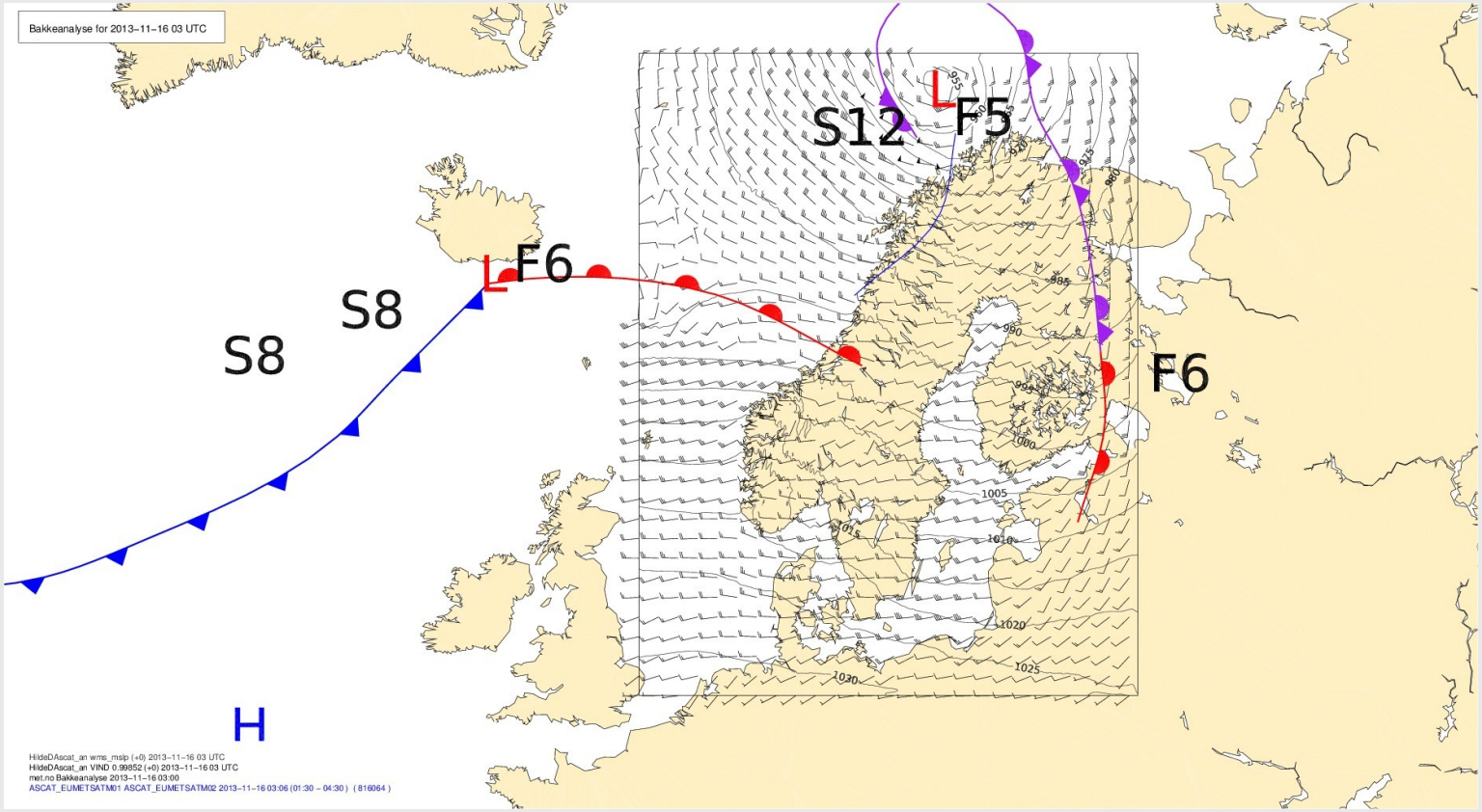

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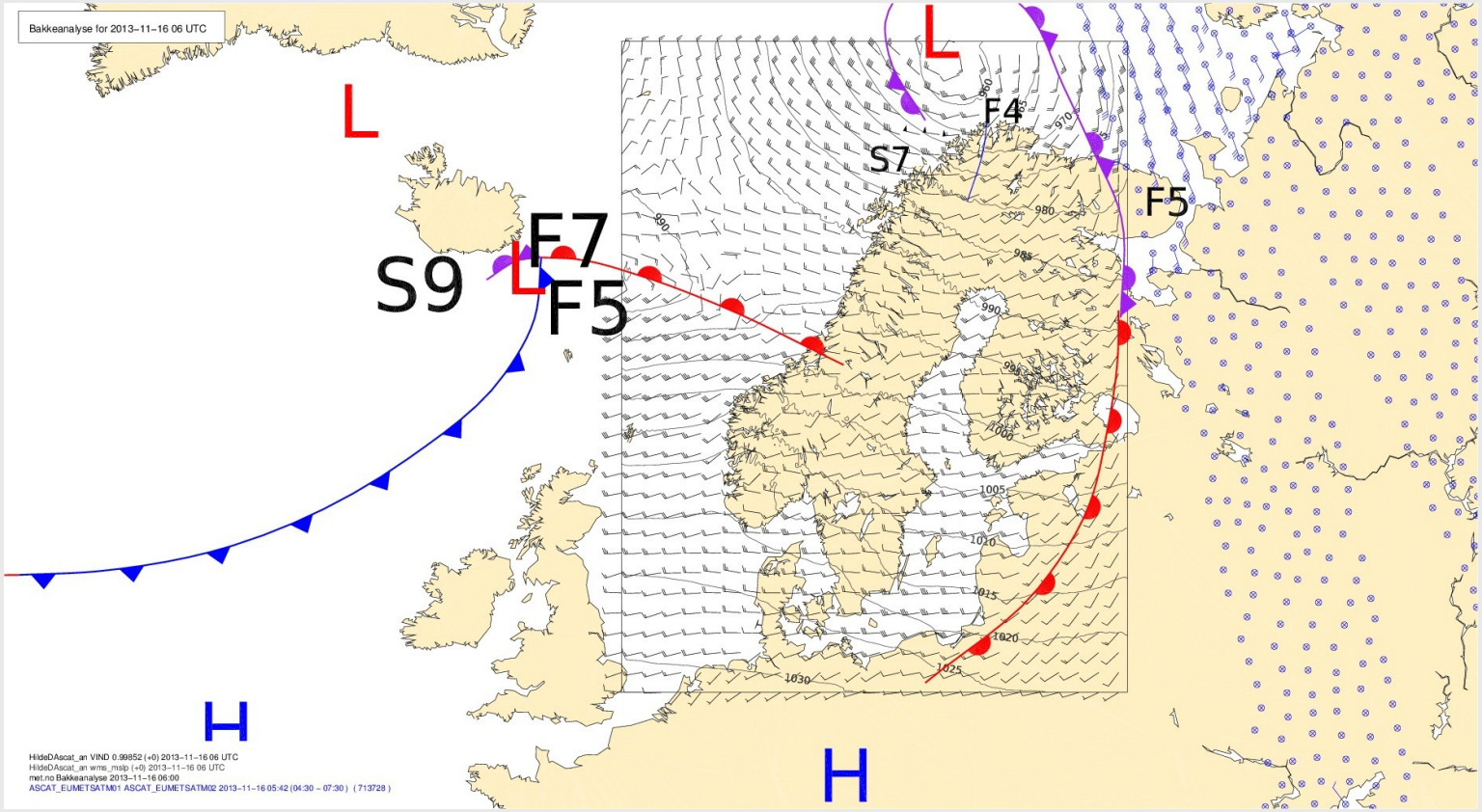

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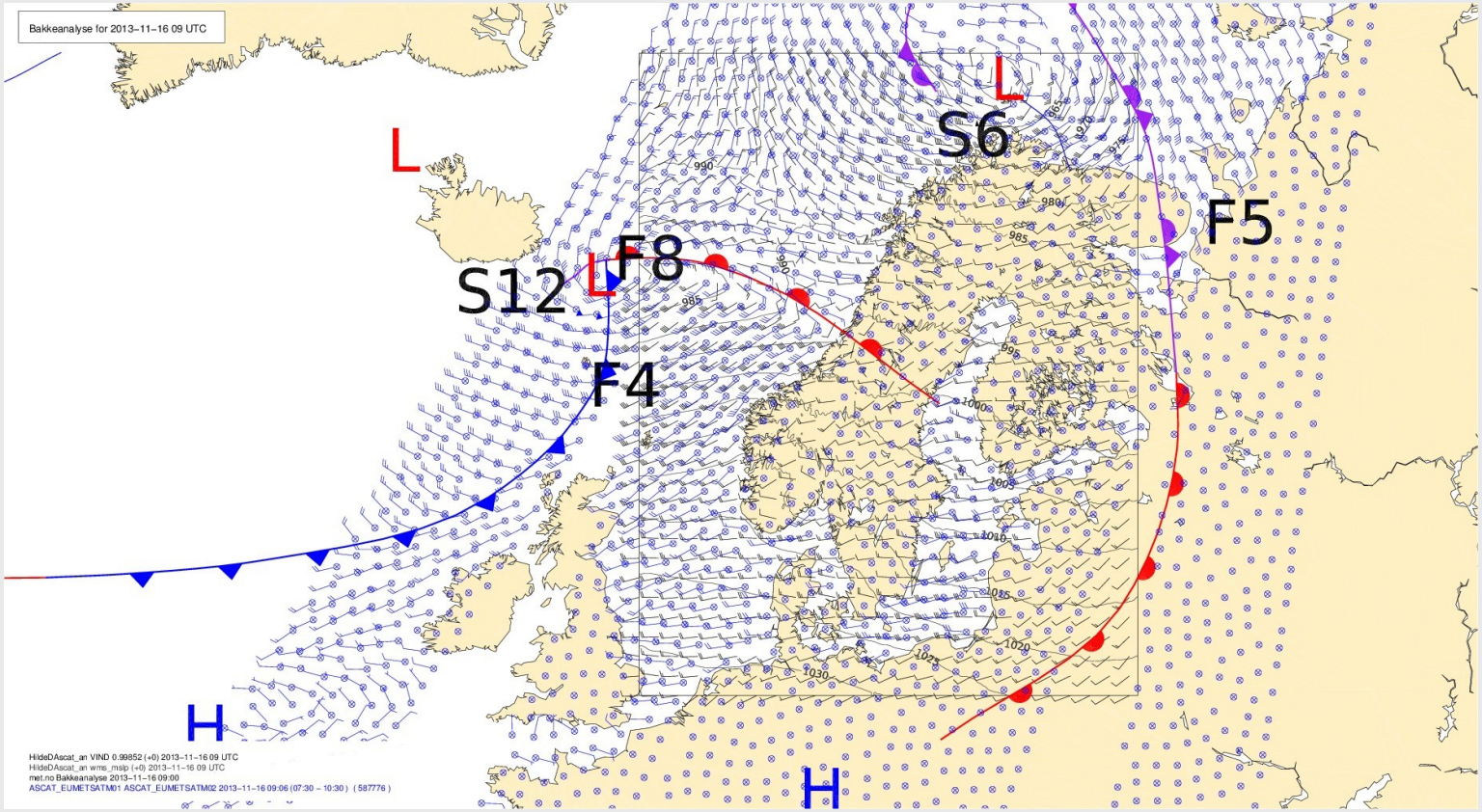

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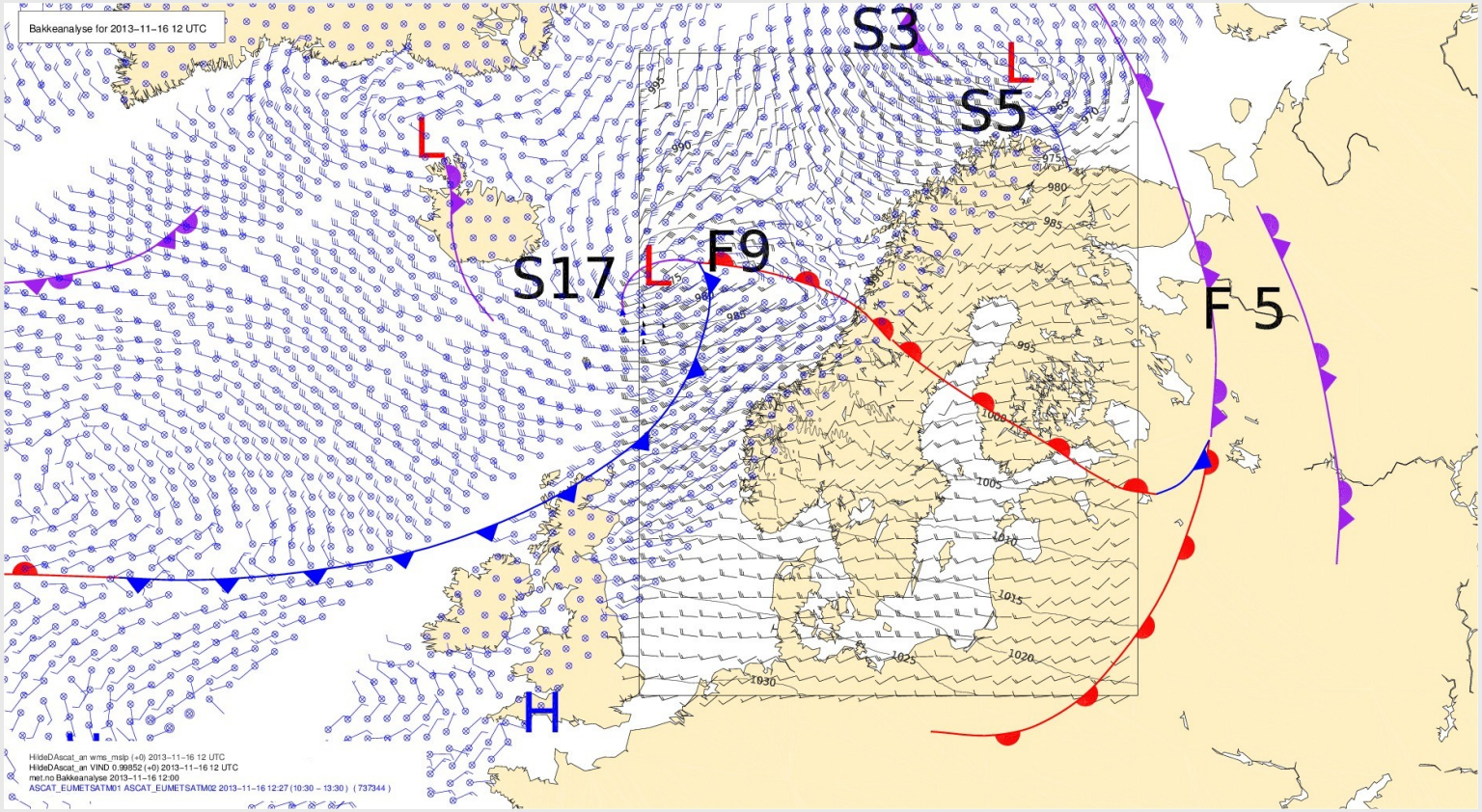

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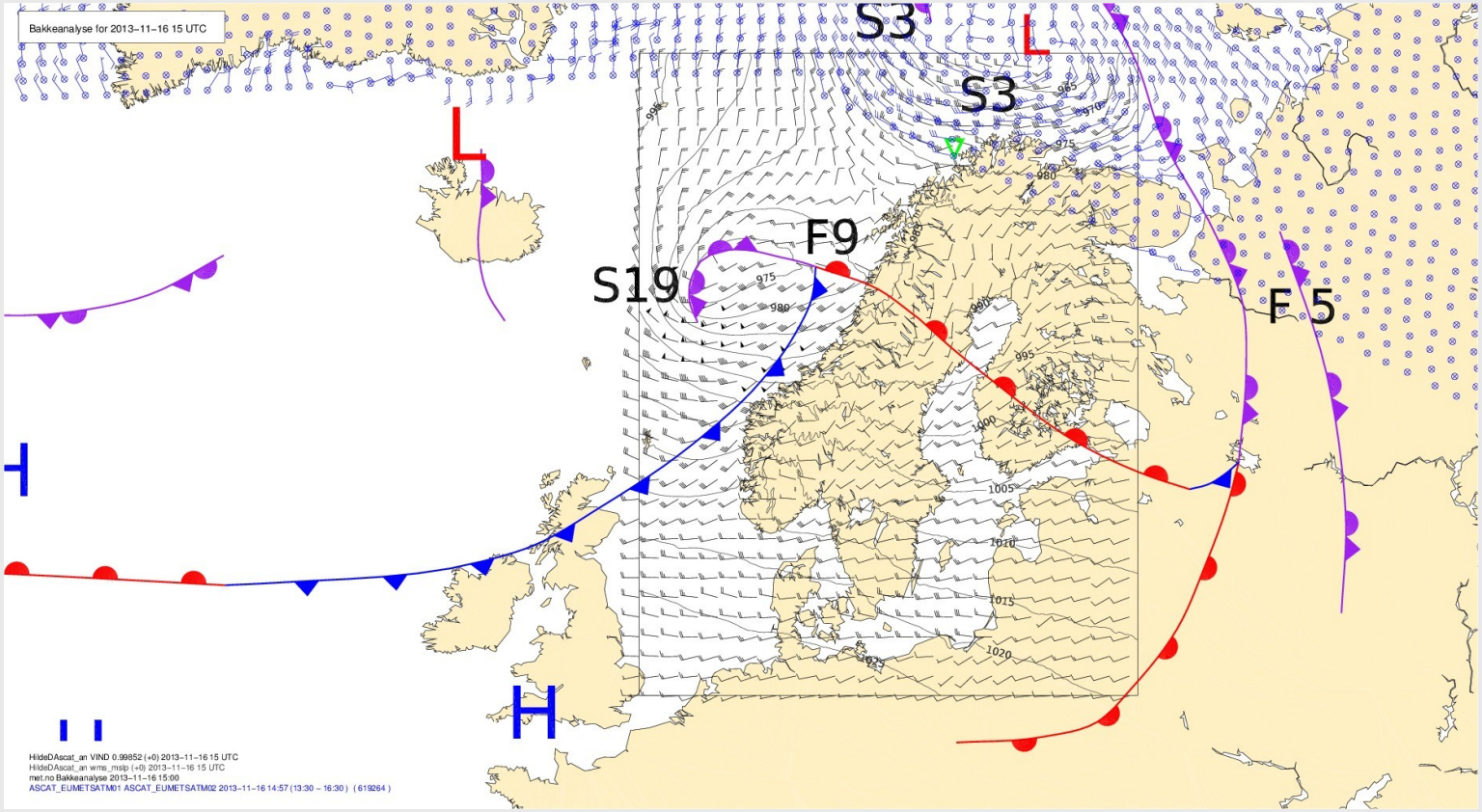

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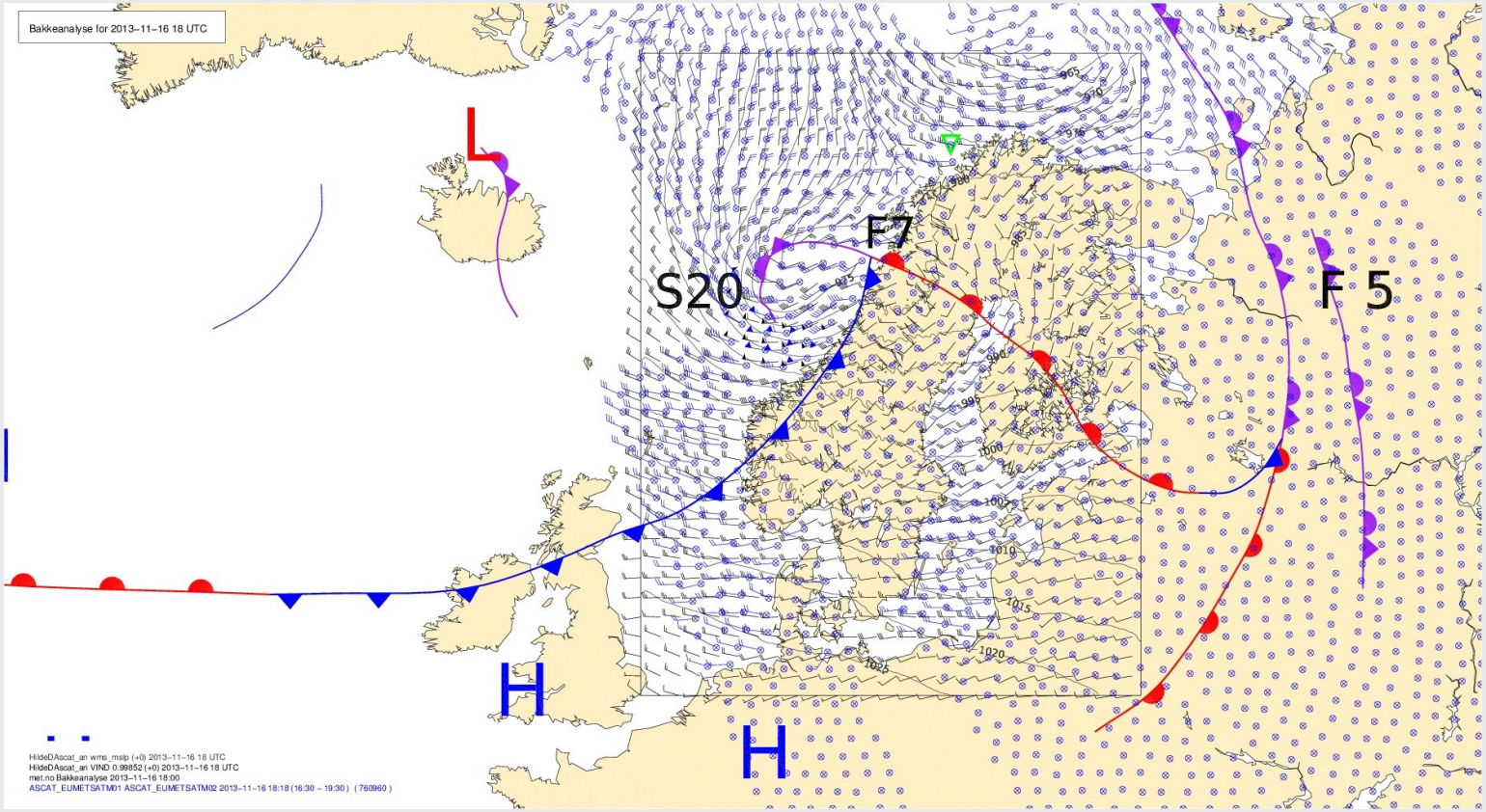

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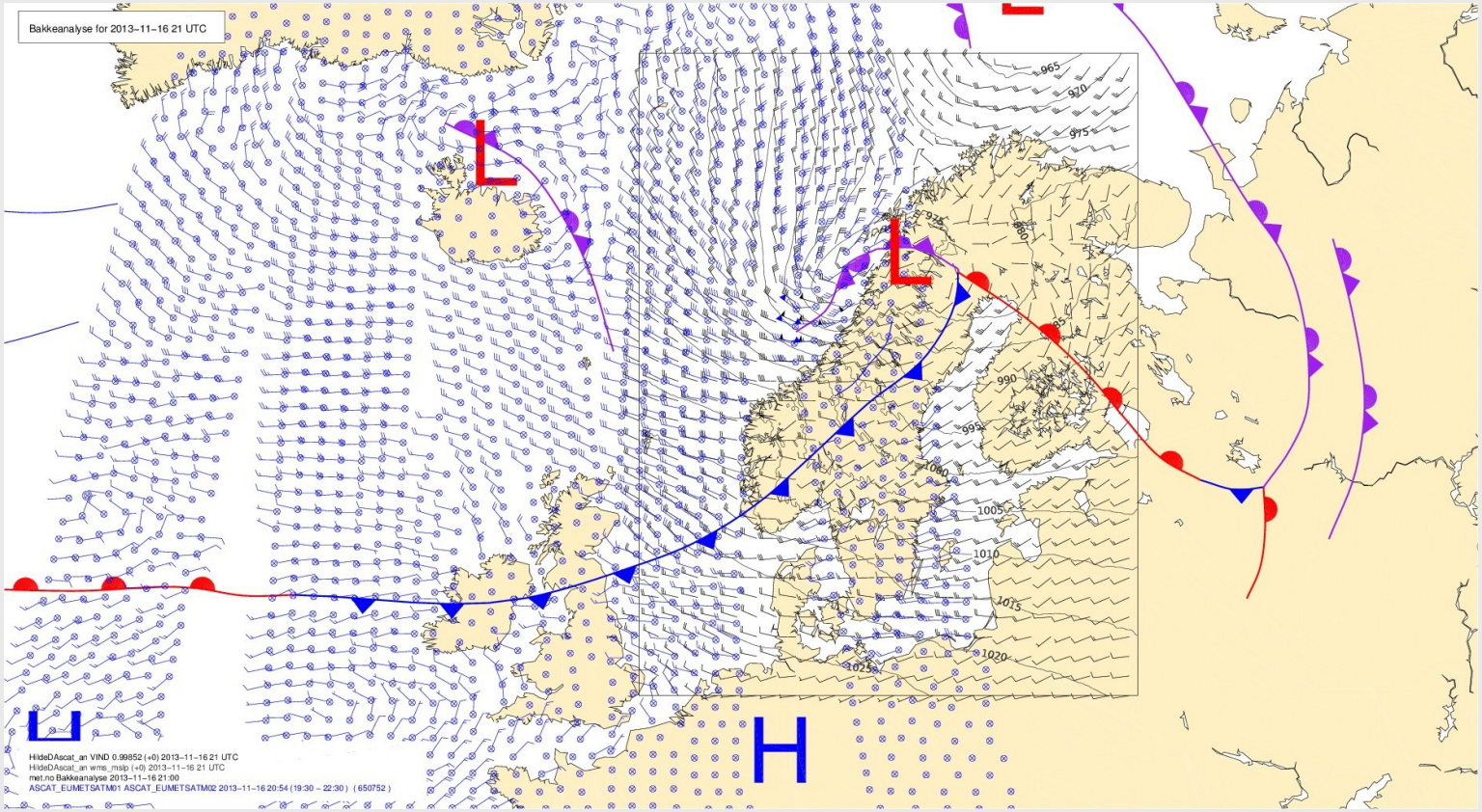

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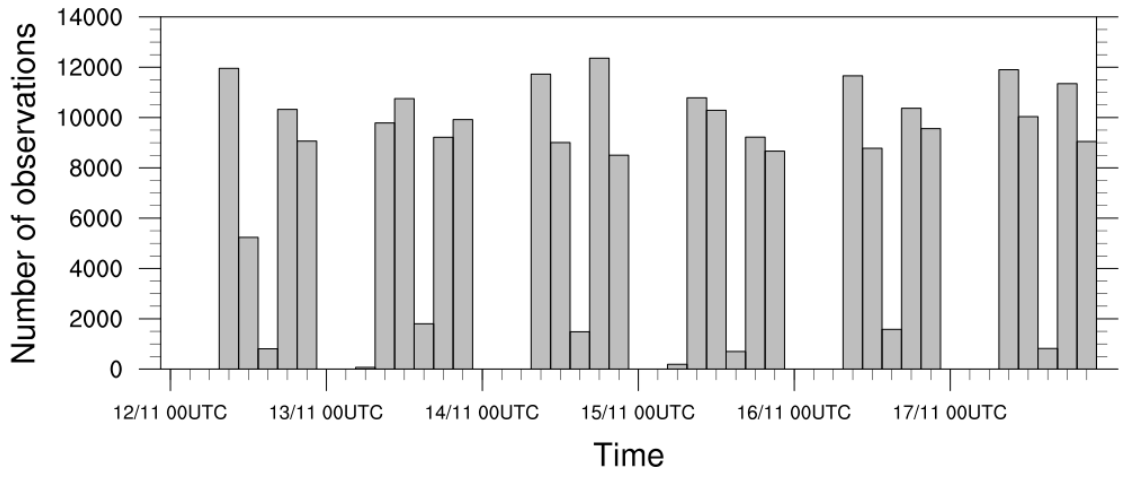
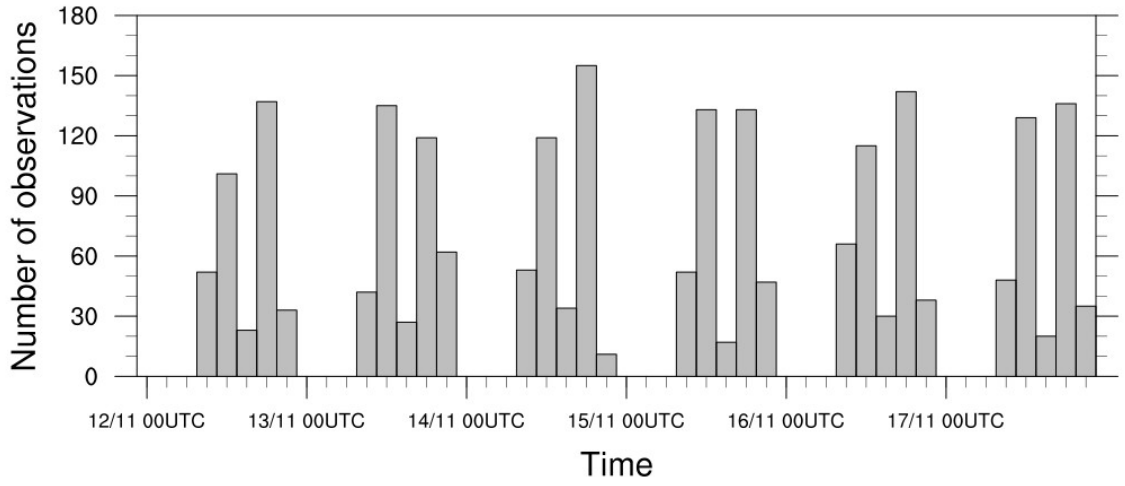
Number of ASCAT wind data

ASCAT data in



ASCAT data used



About **1 %** of data is used

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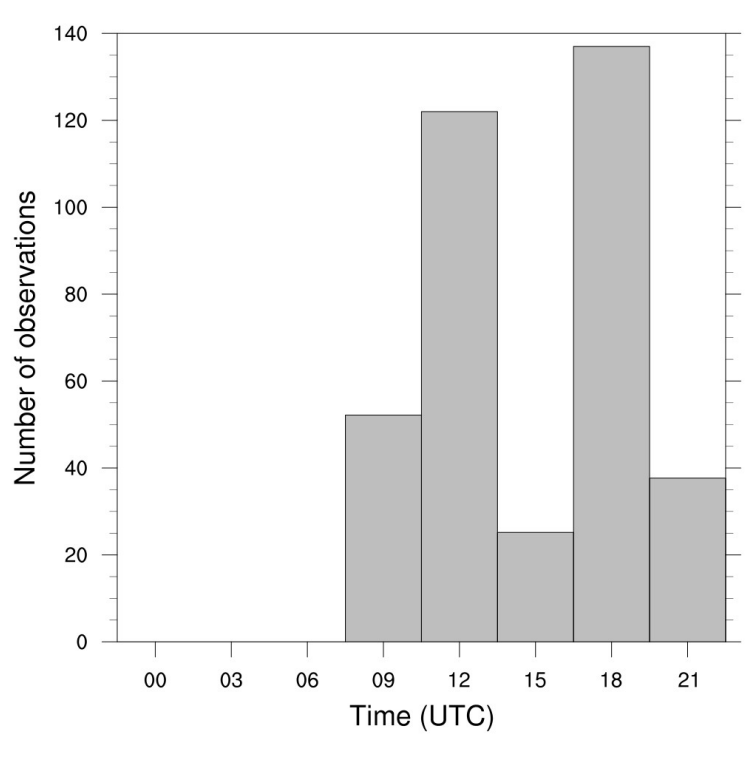
Average number of ASCAT data used for data assimilation



- Number of ASCAT observations used
  - Cycles 12 and 18UTC: very good coverage
  - Cycles 09, 15 and 21UTC: some data
  - Cycles 00, 03 and 06: none!

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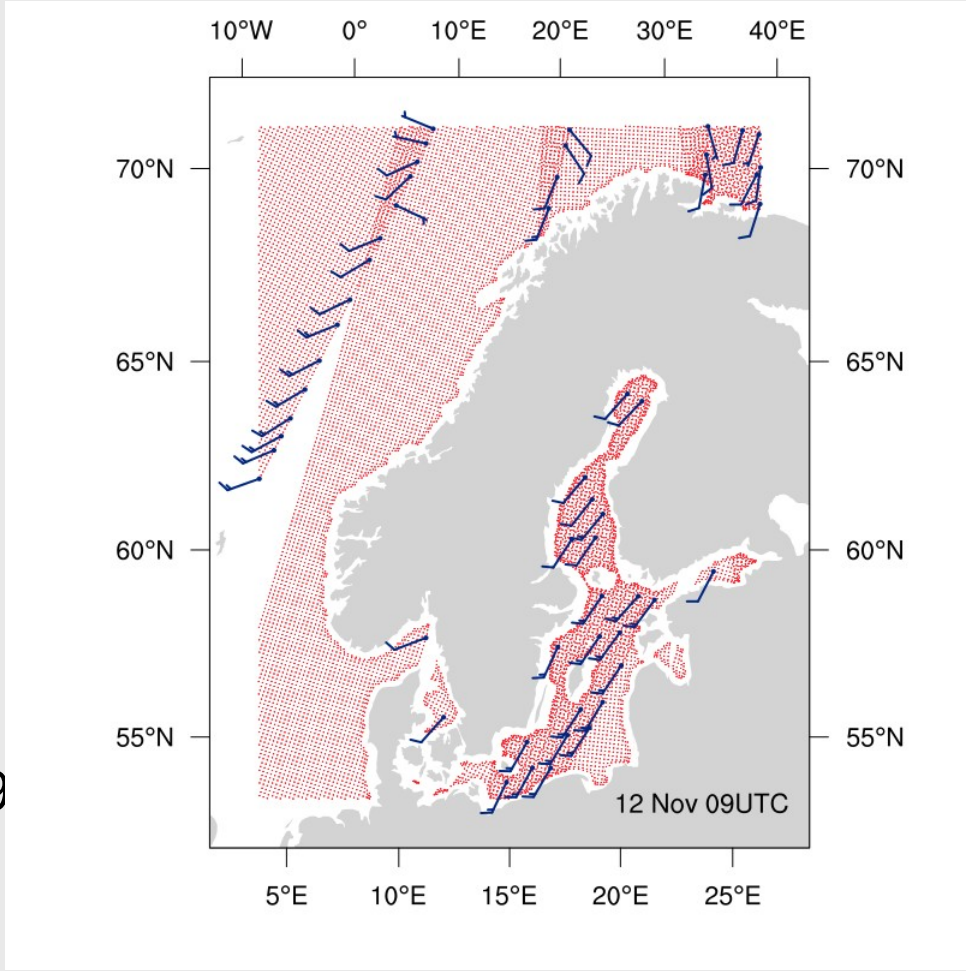
ASCAT coverage

- ASCAT-A and ASCAT-B coastal wind products
- Assimilation window 3 h

- Data points read into the model
- Wind observation used in data assimilation

- Strange data rejection at 09 and 21 UTC



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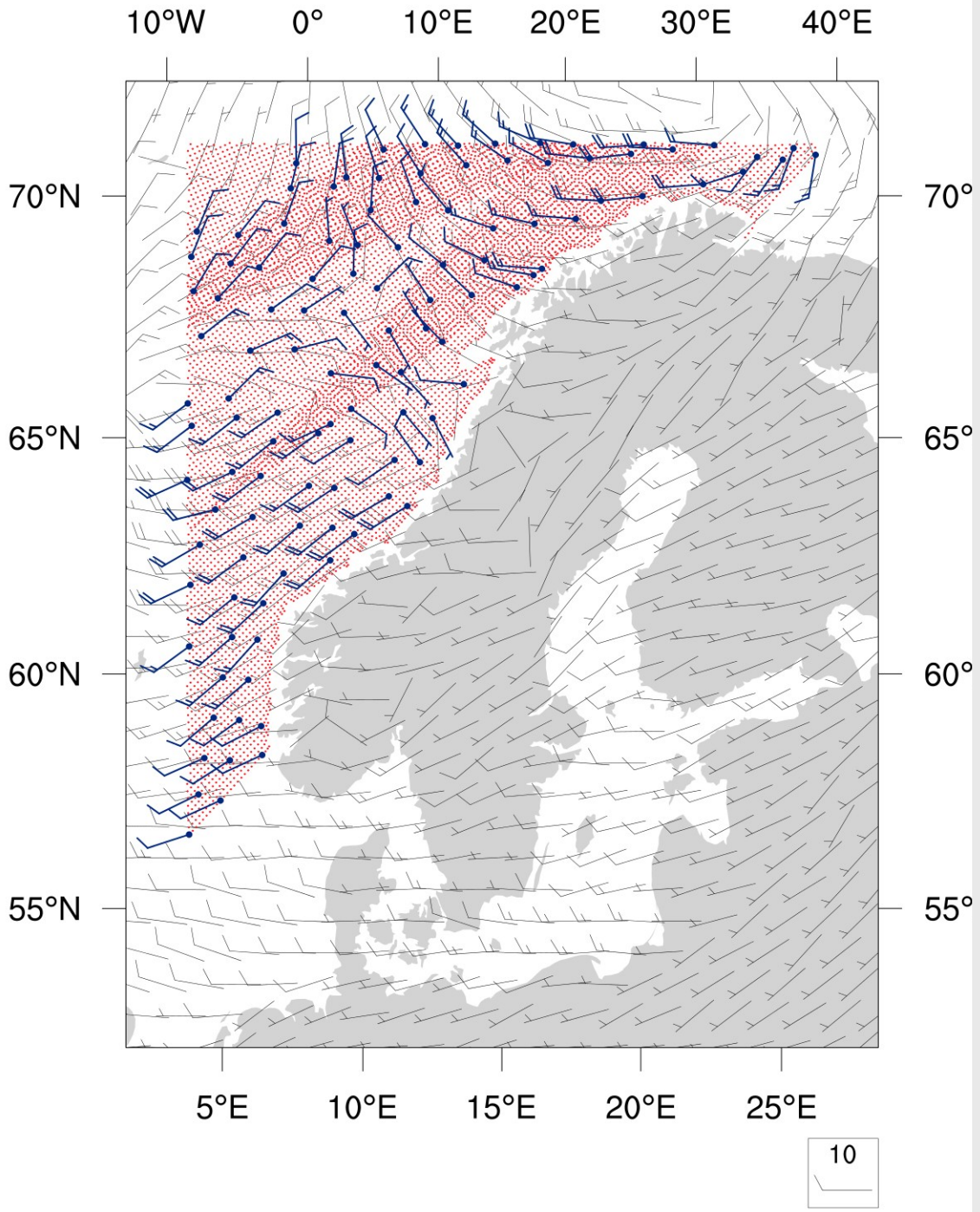
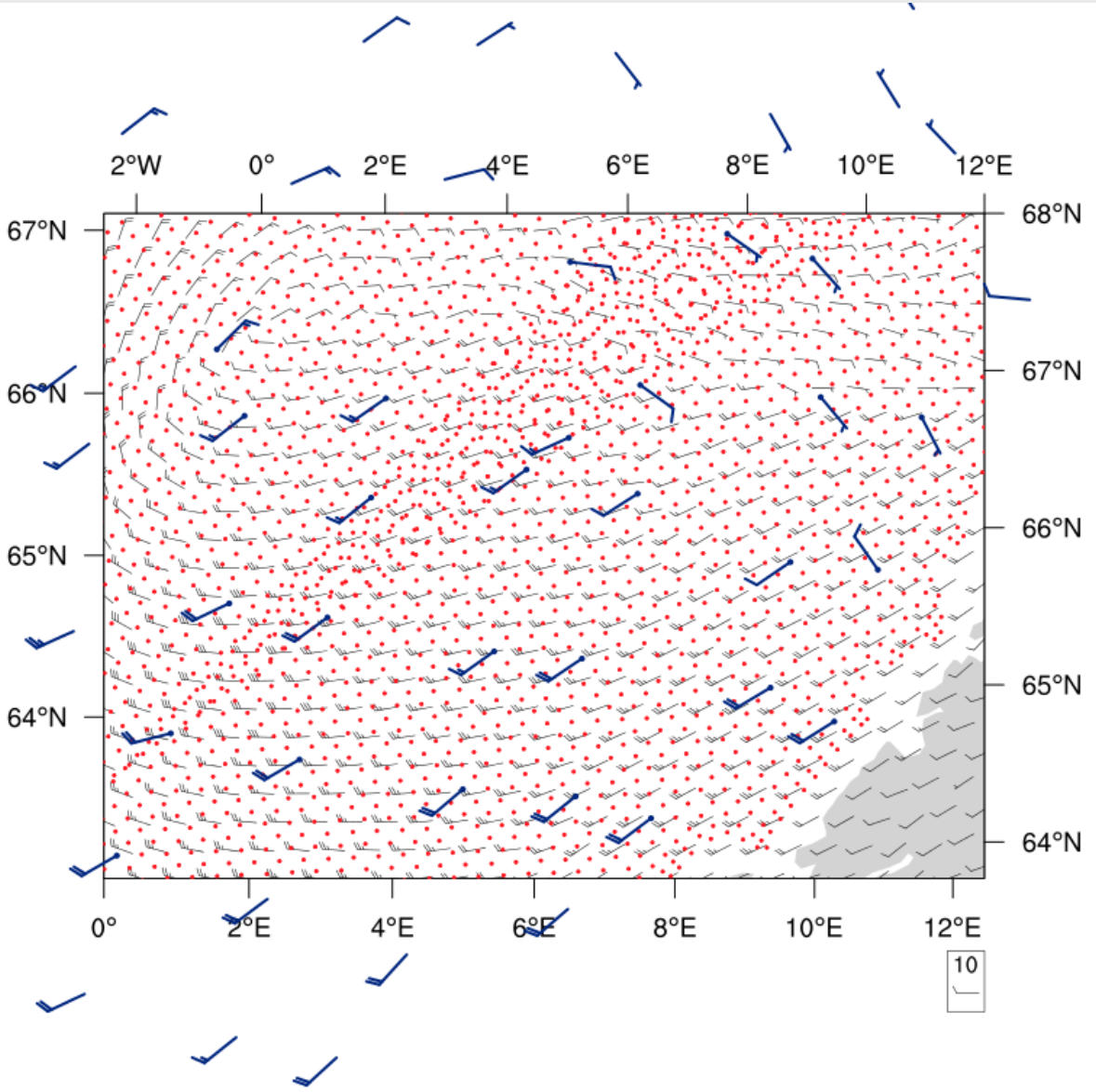
Data thinning and ambiguity selection

- Data thinning by factor of 4 is performed to avoid correlated errors.



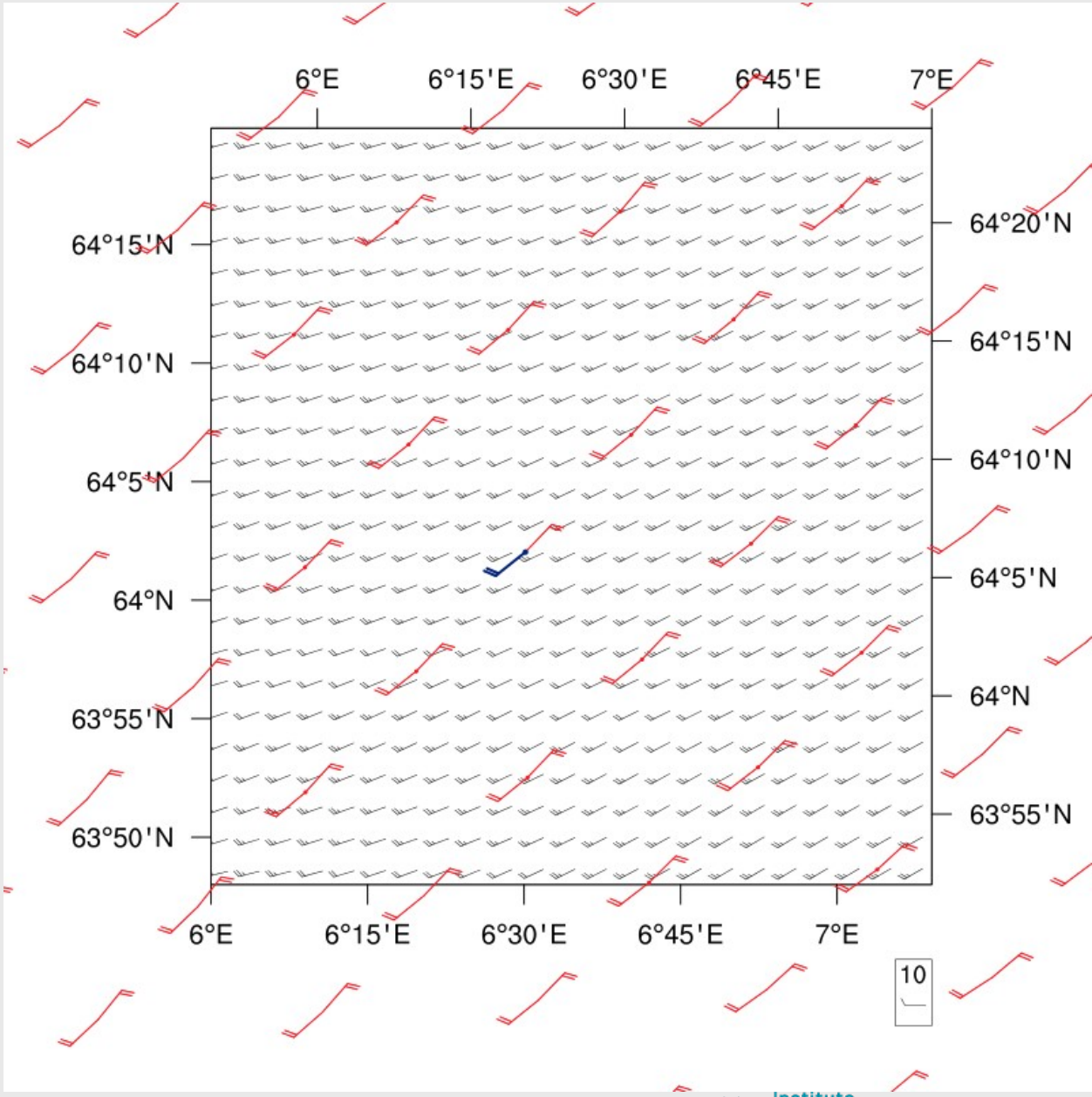
Data thinning and ambiguity selection

- Individual ambiguity selection problems
- Long observation assimilation window.
- Local misplacements of fronts.



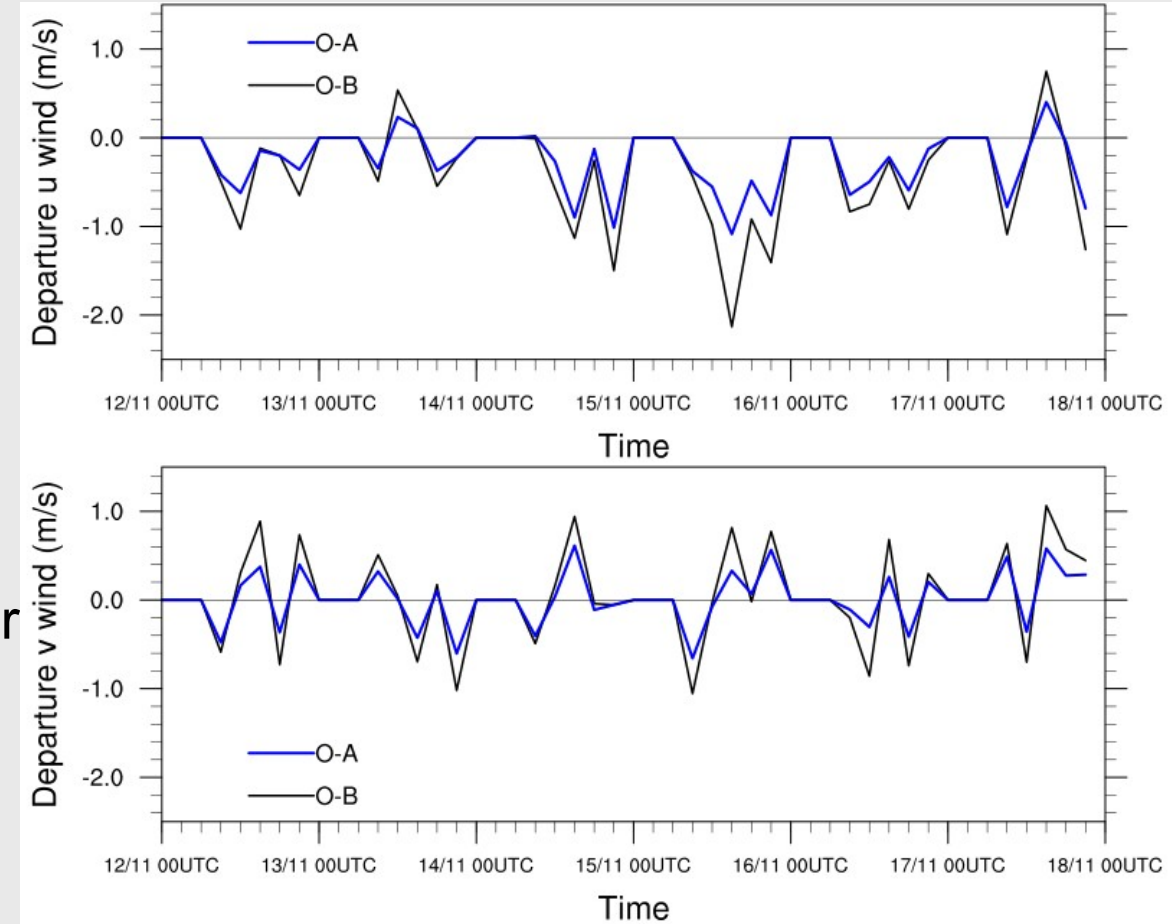
Thinning

- Data thinning by factor of 4 is performed to avoid correlated errors.
- Footprint of ASCAT measurement is larger than model grid size
- Optimal observation operator (?)



Statistics of averaged departures

- Background departure: Observation – background O-B
- Analysis departure: Observation – analysis O-A
- The analysis has been changed closer to the ASCAT wind retrieval



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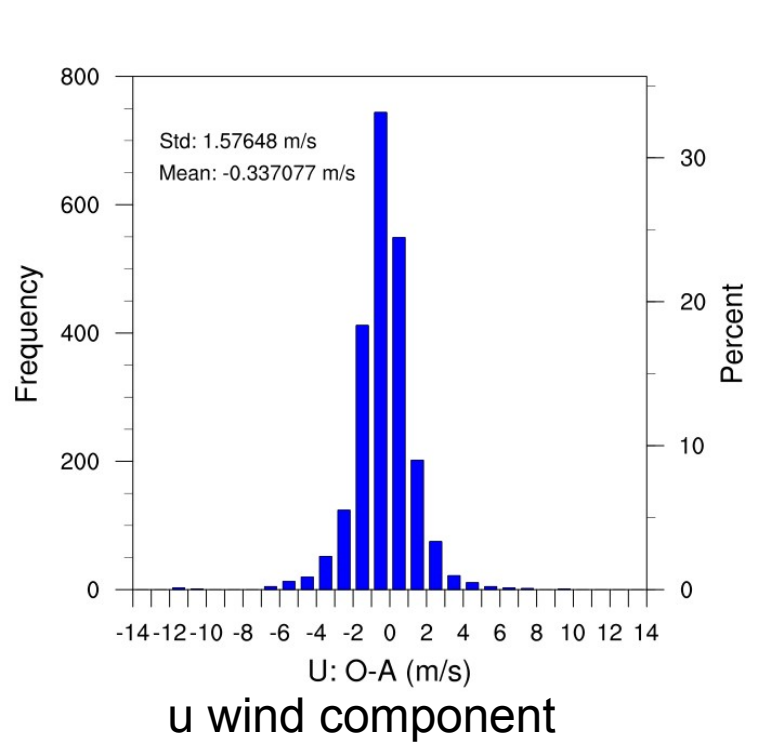
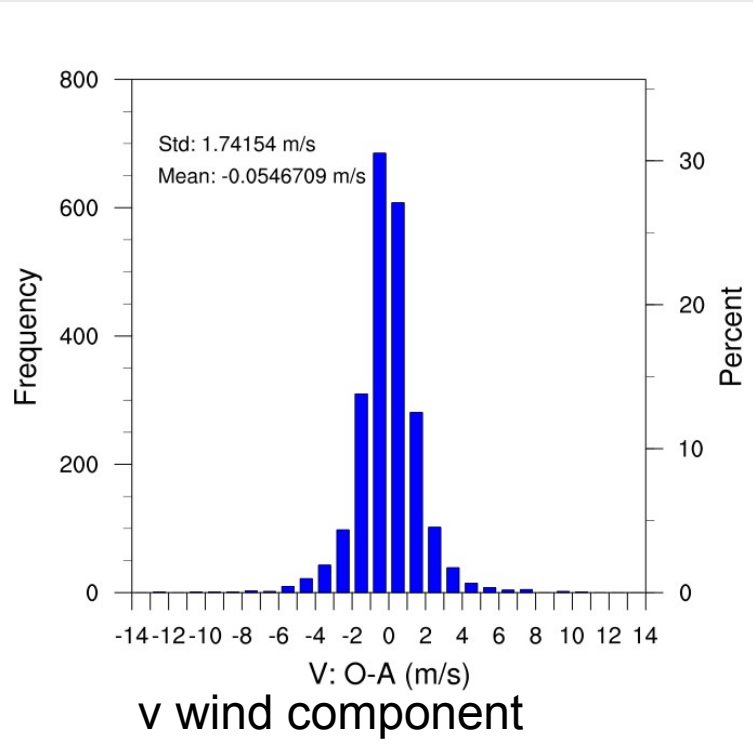
Statistics of departures



u wind component



v wind component

- The standard deviation of the analysis departure is here approximately 30 % smaller than the background departure
- The analysis has been changed closer to the ASCAT wind retrieval
- The standard deviation of background (2.2 m/s, 2.5 m/s) is higher than the observation error set in the system (2.0 m/s)

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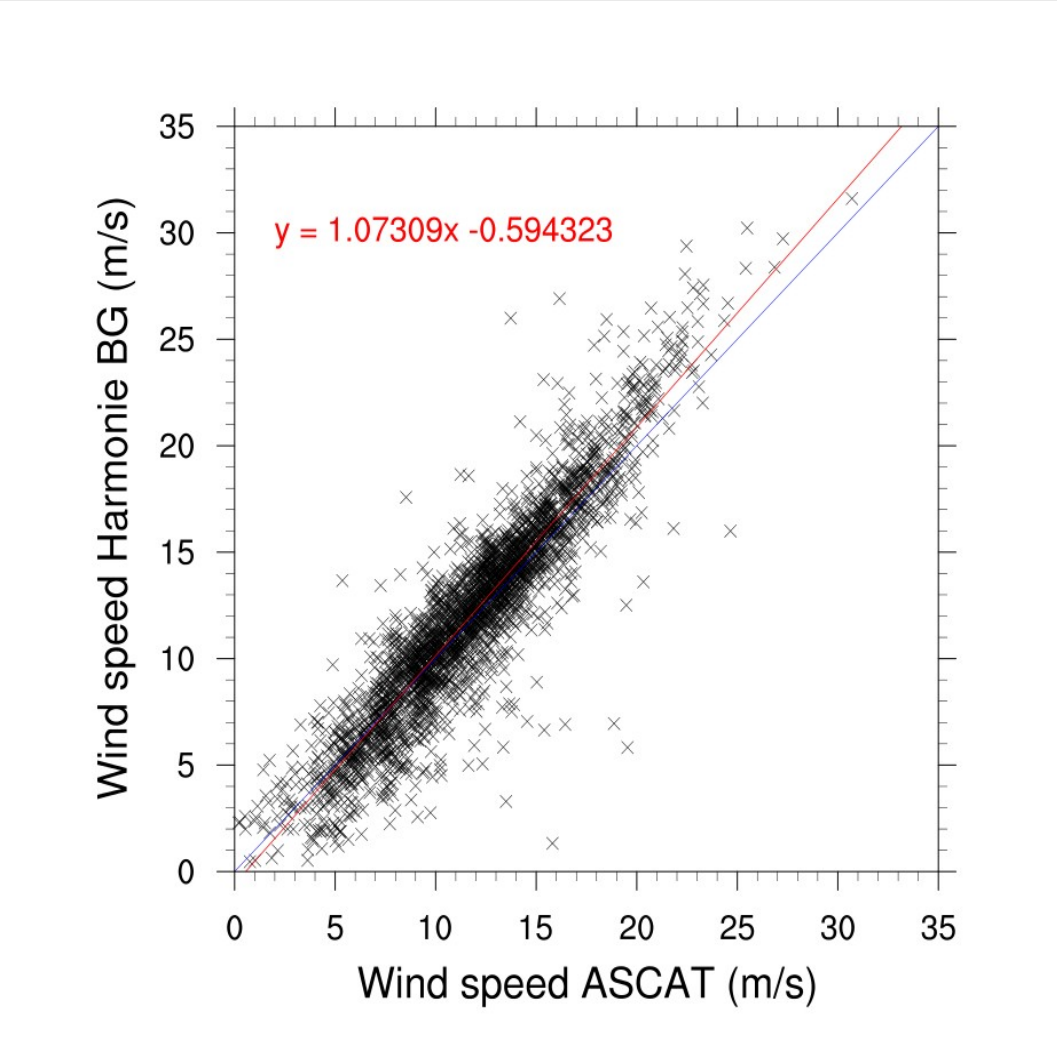
Strong windspeeds



- Model windspeeds are stronger than ASCAT winds
- ASCAT winds do not have such behaviour against ECMWF winds or buoys
- Overestimation of model wind speeds can be due to physical parametrisation schemes

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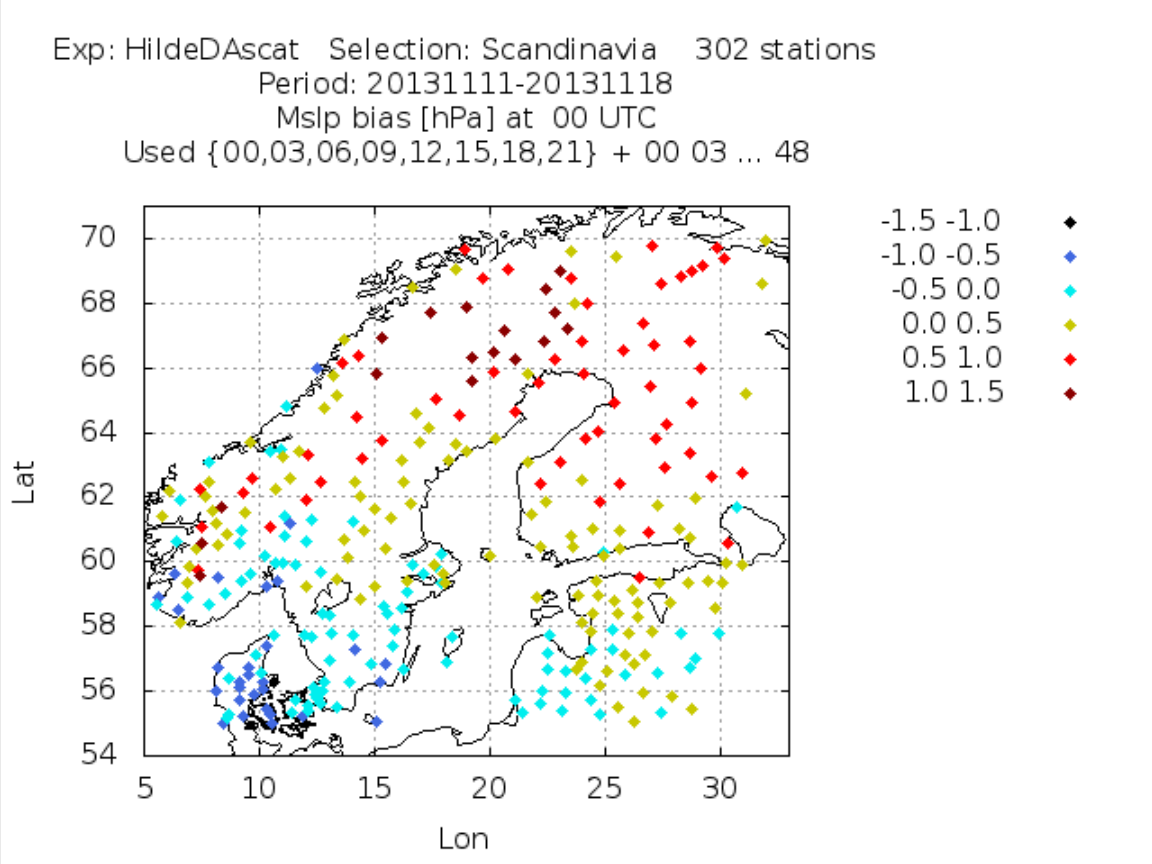
Verification

- Monitor/WebGraf of the HARMONIE system



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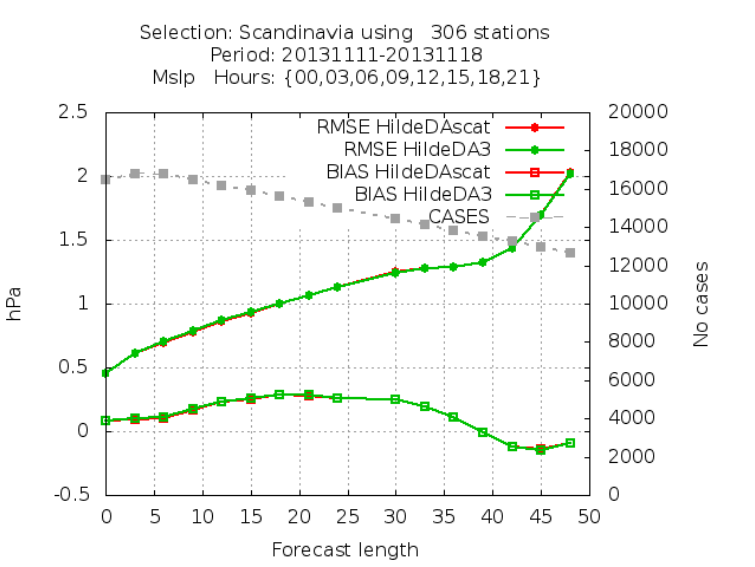
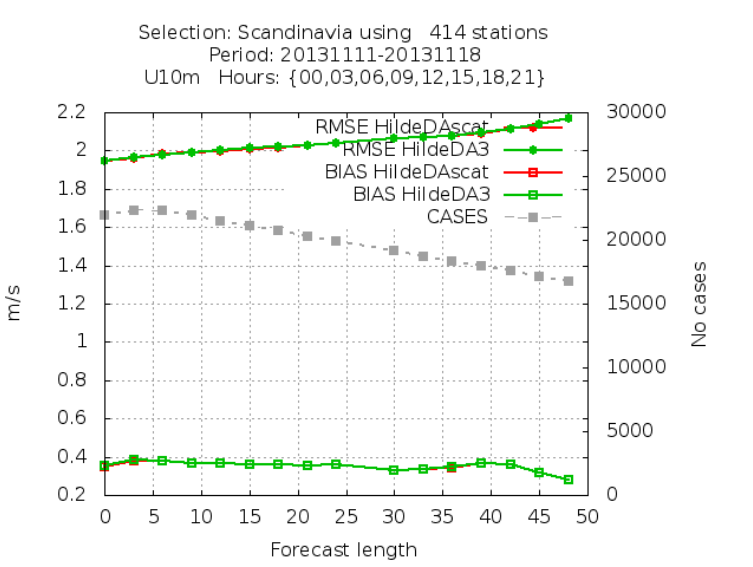
Verification

Forecast length

Mean sea level pressure



Wind speed



RMSE of MSLP grows over time

Slight positive bias in wind speed

Assimilation scatterometer winds cannot show an impact here!

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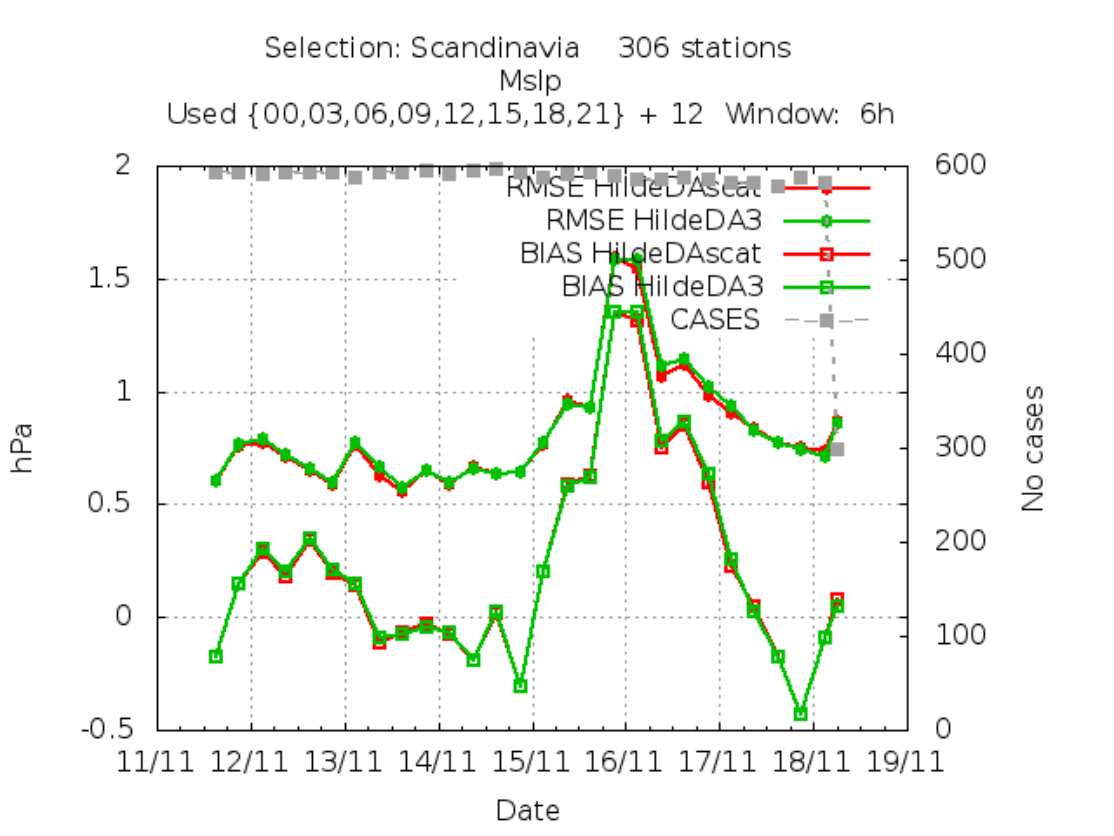
Verification

Timeseries: Mean sea level pressure



There is a weak improvement in RMSE and bias during the most intense development of the storm.

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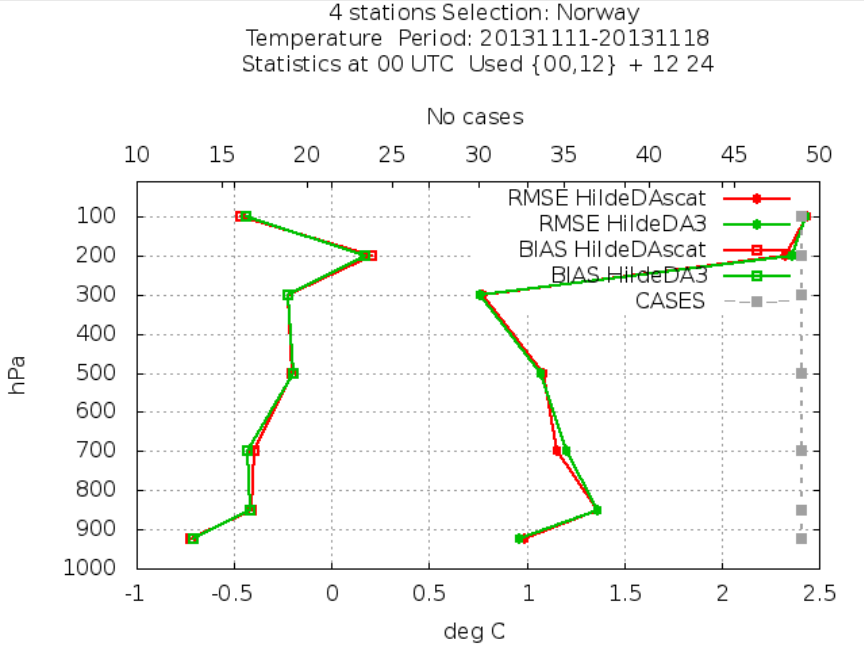
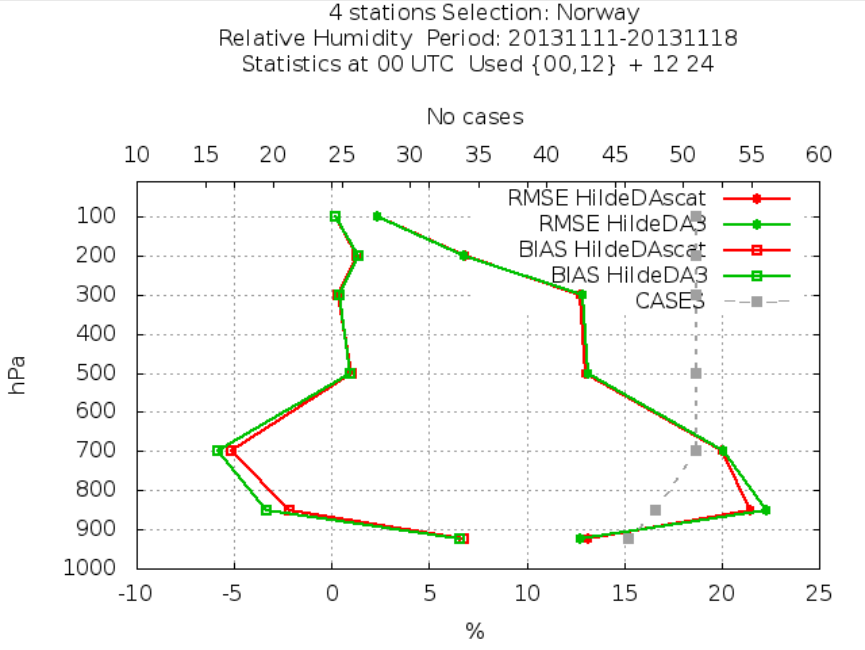
Vertical profiles

Temperature



Relative humidity



- Temperature and humidity bias slightly decreased around 700 hPa
- Impacts are directly seen in upper levels because of improved dynamics. Surface variables (T, U, RH) are locally driven and it is difficult to see impact on them.

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Summary

- The SCARASTO project aims to improve extreme weather forecasting in Norway by data assimilation of scatterometer winds
- ASCAT scatterometer winds have high data quality and spatial coverage is good during daytime.
- Data assimilation of scatterometer winds runs technically in Harmonie system
- Harmonie model wind speeds are overestimated on strong winds over ocean compared to ASCAT winds.
- Verification results from preliminary model experiments show a weak impact of scatterometer winds

Outlook

- Experiences with data assimilation of scatterometer winds call for comparison and development of further approaches for optimal use of scatterometer winds in high-resolution NWP
- Future work
  - Optimal thinning, data rejection and observation weighting methods
  - Impact study on Polar lows and other high impact events
  - Longer simulation periods for robust verification results
  - Operational implementation of scatterometer wind assimilation
- Longer term developments within the NWP consortium
  - Flow dependent methods (4DVar, FGAT, ...)
  - Rapid update cycle

Thank you!

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