Improving the use of satellite winds at the Deutscher Wetterdienst (DWD)

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- Introduction
- Atmospheric motion vector winds (geo and polar)
- AMV height correction using lidar observations
- Use of scatterometer data

The *deterministic* NWP-System of DWD

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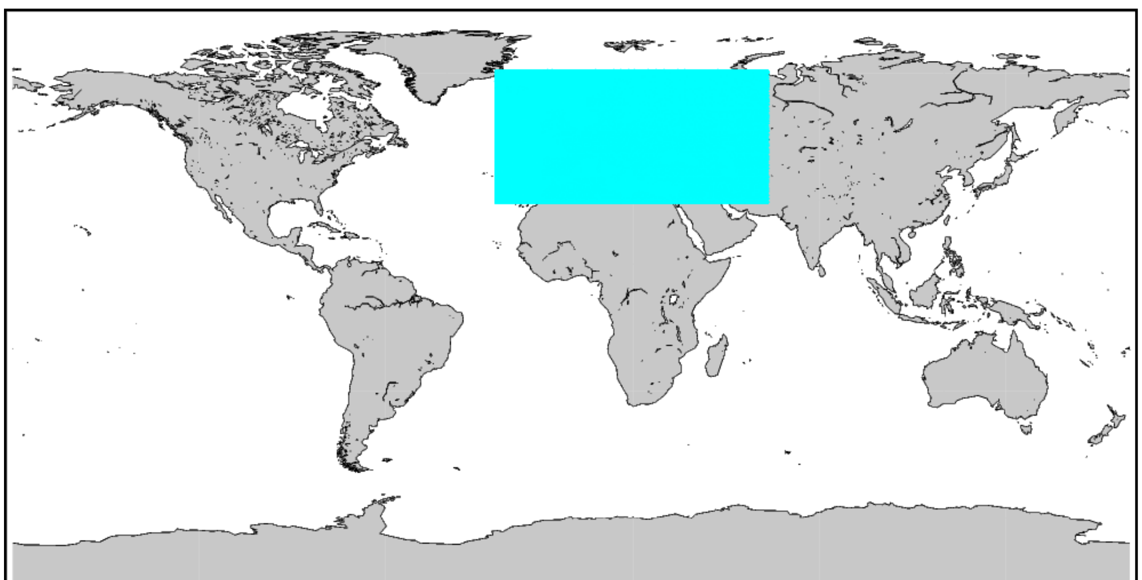
Global-Modell ICON

grid size: 13 km
vertical levels: 90
forecasts:
180 h von 00 und 12 UTC
120 h von 06 und 18 UTC
30 h von 03, 09, 15 und 21UTC
Grid area: 173 km^2

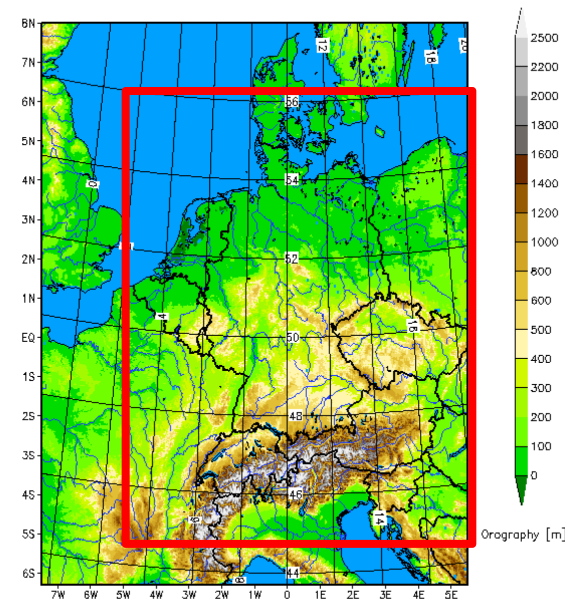
ICON-EU Nest over Europa

grid size: 6.5 km
Vertical levels: 60
forecasts:
120 h von 00, 06, 12 und 18 UTC
30 h von 03, 09, 15 und 21UTC
Grid area: 43 km^2



COSMO-DE (convection resolving)

grid size: 2.8 km
vertical levels: 50
forecasts:
27/45 h von 00, 03, 06, 09, 12, 15, 18, 21 UTC
421x461 grid size



The *probabilistic* NWP-System of DWD

ICON-EPS; M40

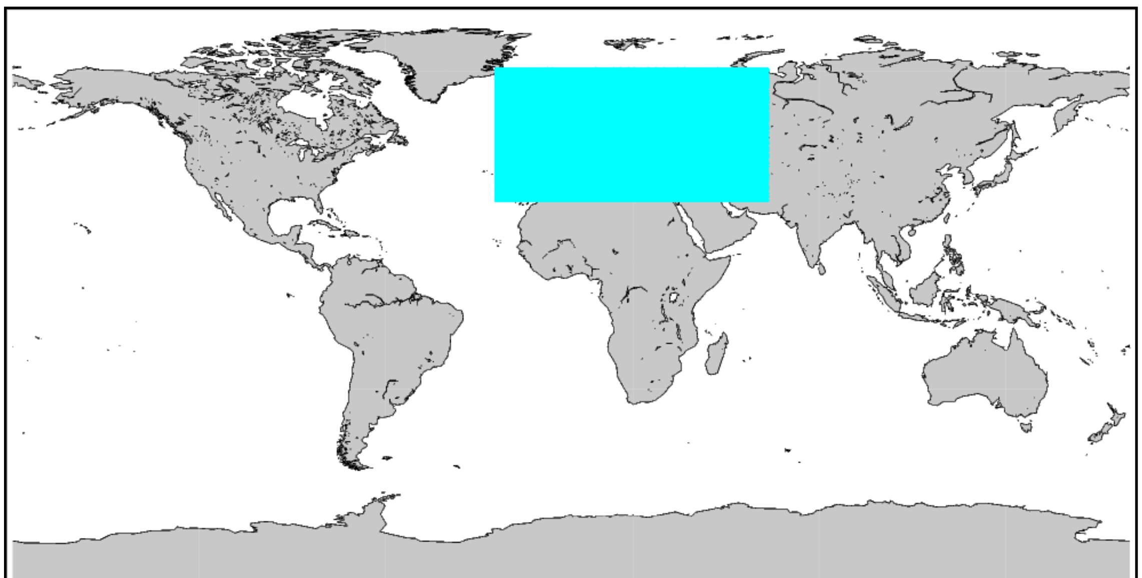
grid size: 40 km
vertical levels: 90
forecasts:
180 h von 00 und 12 UTC
120 h von 06 und 18 UTC
30 h von 03, 09, 15 und 21UTC
grid area: 1638 km²

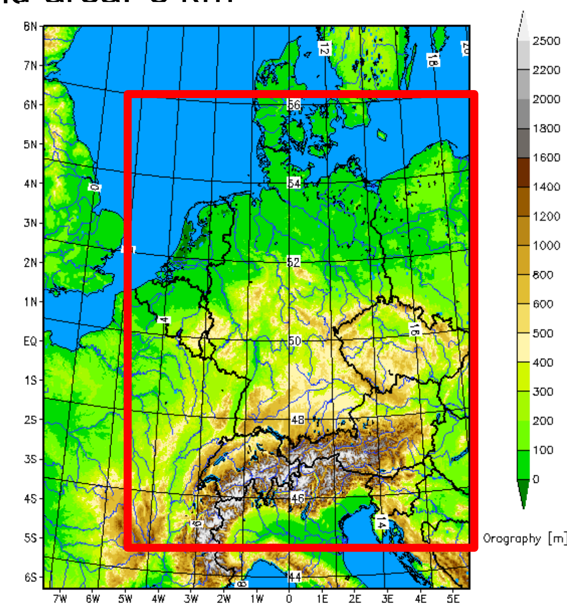
ICON-EU Nest over Europa

grid size: 20 km
vertical levels: 60
forecasts:
120 h von 00, 06, 12 und 18 UTC
30 h von 03, 09, 15 und 21 UTC
grid area: 407 km²

COSMO-DE-EPS; M20

Grid size: 2.8 km
Vertical levels: 50
forecasts:
27 h von 00, 03, 06, 09, 12, 15, 18, 21 UTC
421x461 grid points
grid area: 8 km²





Global and local Ensemble Data Assimilation (EDA)

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- Implementation following the LETKF method based on Hunt et al. (2007).
- VarEnKF. Flow dependent B: $B_{VarEnKF} = \alpha B_{LETKF} + (\alpha\text{-}1)B_{3DVAR}$
- Boundary conditions for KENDA-COSMO.
- Natural initialization for global and local EPS.
- Prior for particle filters.
- Using a variety of conventional and satellite based observing systems

Deterministic DA

- 13km 3D-VAR.
- SST, SMA and snow ana.
- Incremental analysis update.

Hybrid DA

- 13km VarEnKF(hyprid)
- Operational since January 2016

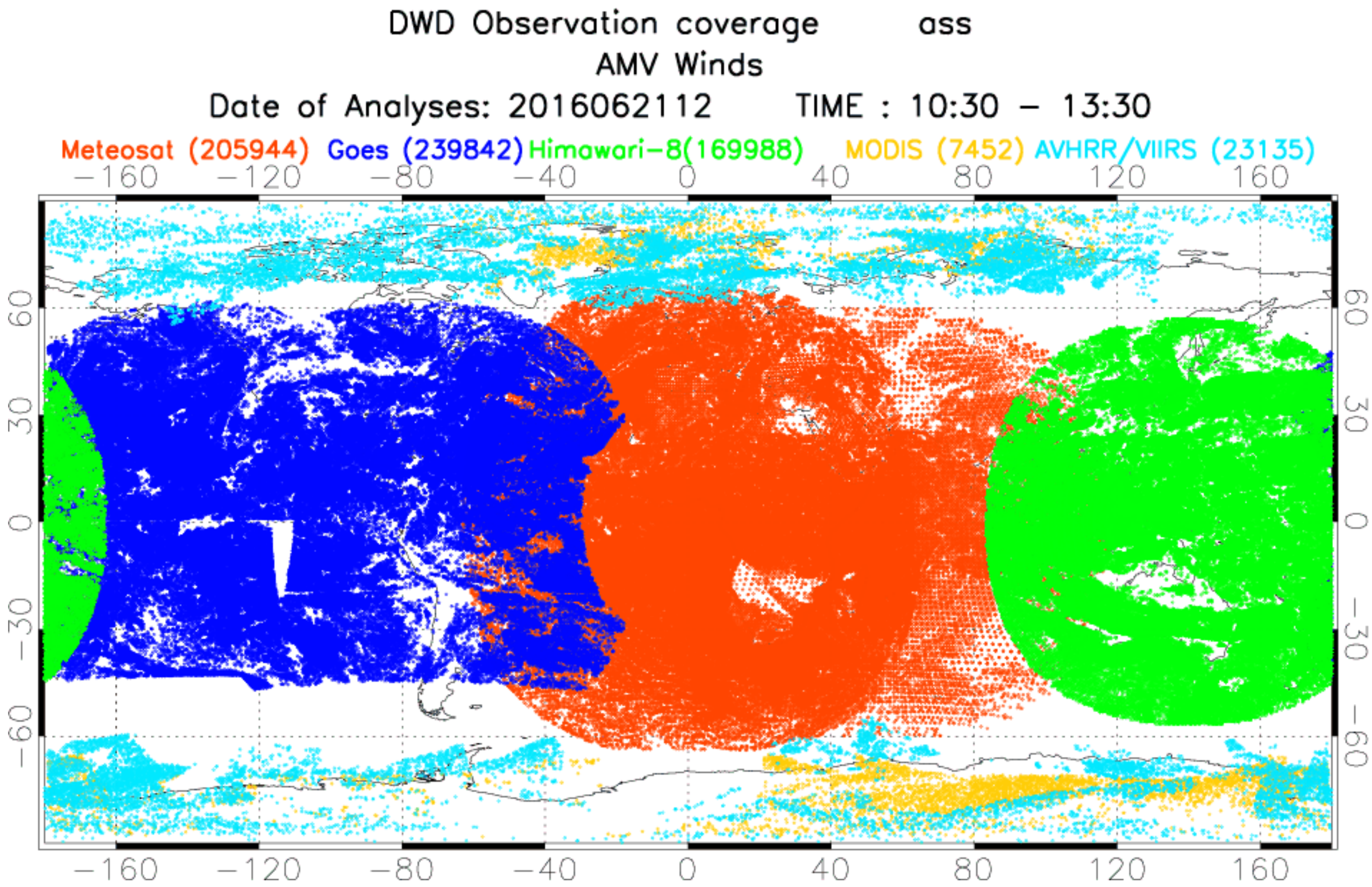
Ensemble DA

- 40 member 40/20 km and 2.8 km LETKF.
- Horizontal localization radius 300km.
- Relaxation to prior perturbations (0.75).
- Adaptive inflation (0.9 - 1.5).
- SST perturbations.
- Soil moisture perturbations

Usage of AMV winds at DWD

- Geostationary satellites (GOES 13/15; Eumetsat 7/10; Himawari-8)
  - extratropics and tropics over oceans and land
  - IR above 1000 hPa
  - WVcloudy above 400 hPa; WVclear is not used
  - VIS below 700 hPa
  - QI threshold blacklisting
  - FG check: asymmetric to remove negative OBS-FG bias
  - Thinning: 1 wind per pre-defined thinning box (200 km;15 vertical layers).
    data selection by highest noFirst Guess QI in a box

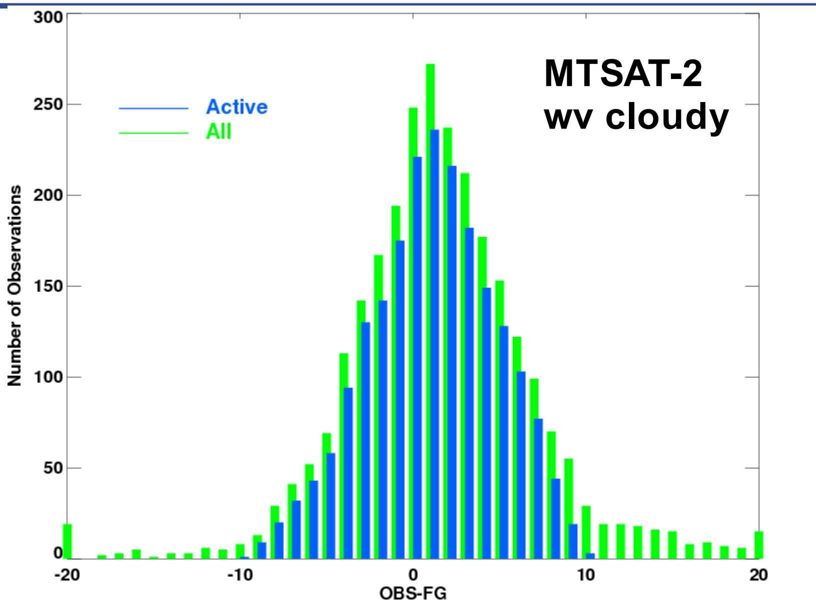
- Polar orbiting satellites (MODIS, AVHRR, DB MODIS, DB AVHRR, NPP/VIIRS)
  - over land and oceans
  - IR above 1000 hPa, over Antartica over 600 hPa
  - WVcloudy above 600 hPa
  - QI threshold blacklisting
  - FG check: asymmetric to remove negative OBS-FG bias
  - Thinnig: 1 wind per thinning box (~60 km; 15 vertical layers)


DWD Observation coverage ass
AMV Winds
Date of Analyses: 2016062112 TIME : 10:30 – 13:30
Meteosat (205944) Goes (239842) Himawari-8(169988) MODIS (7452) AVHRR/VIIRS (23135)
-160 -120 -80 -40 0 40 80 120 160
60 30 0 -30 -60

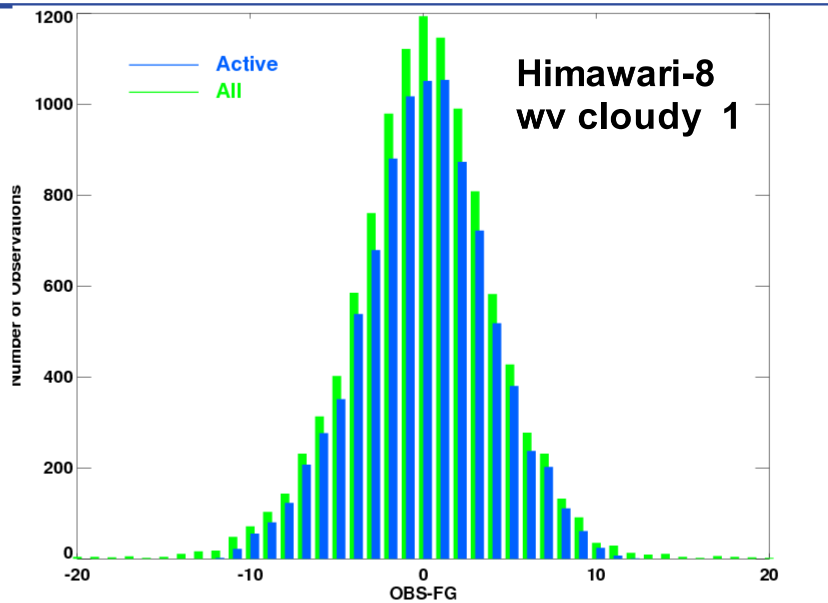
Himawari-8

- Himawari-8 replaces MTSAT-2
- New instrument (AHI) on board
- Higher spatial and temporal resolution
  - better tracking and more and higher quality winds
- More channels
  - 3 water vapour channels (MTSAT only 1)
- Derived AMVs available since mid of July 2015
- Himawari-8 AMV data monitoring started

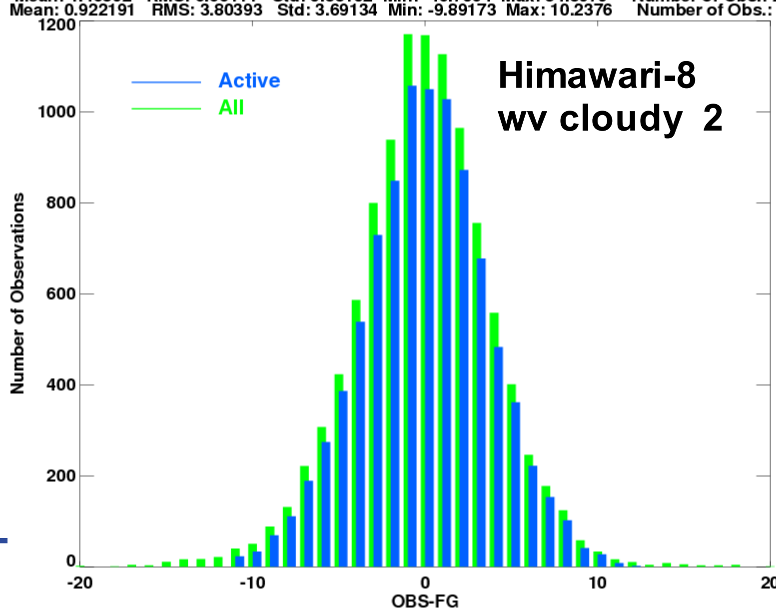
Verification results

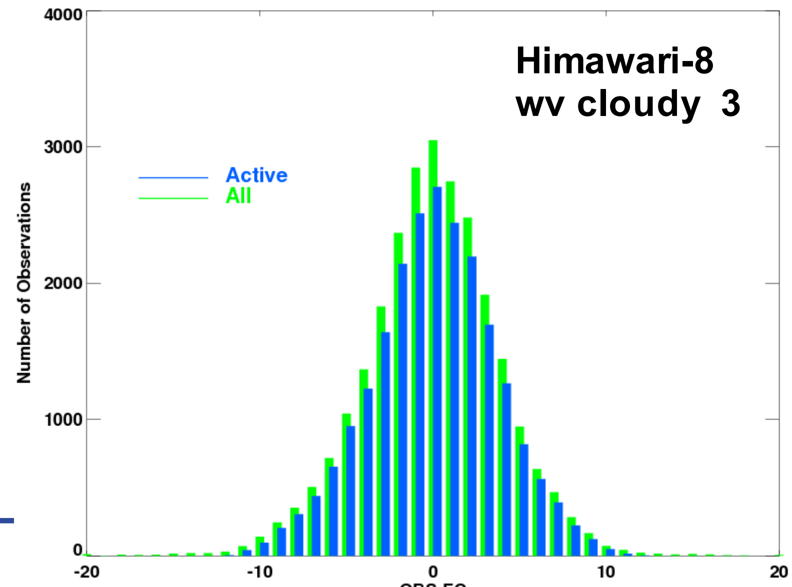


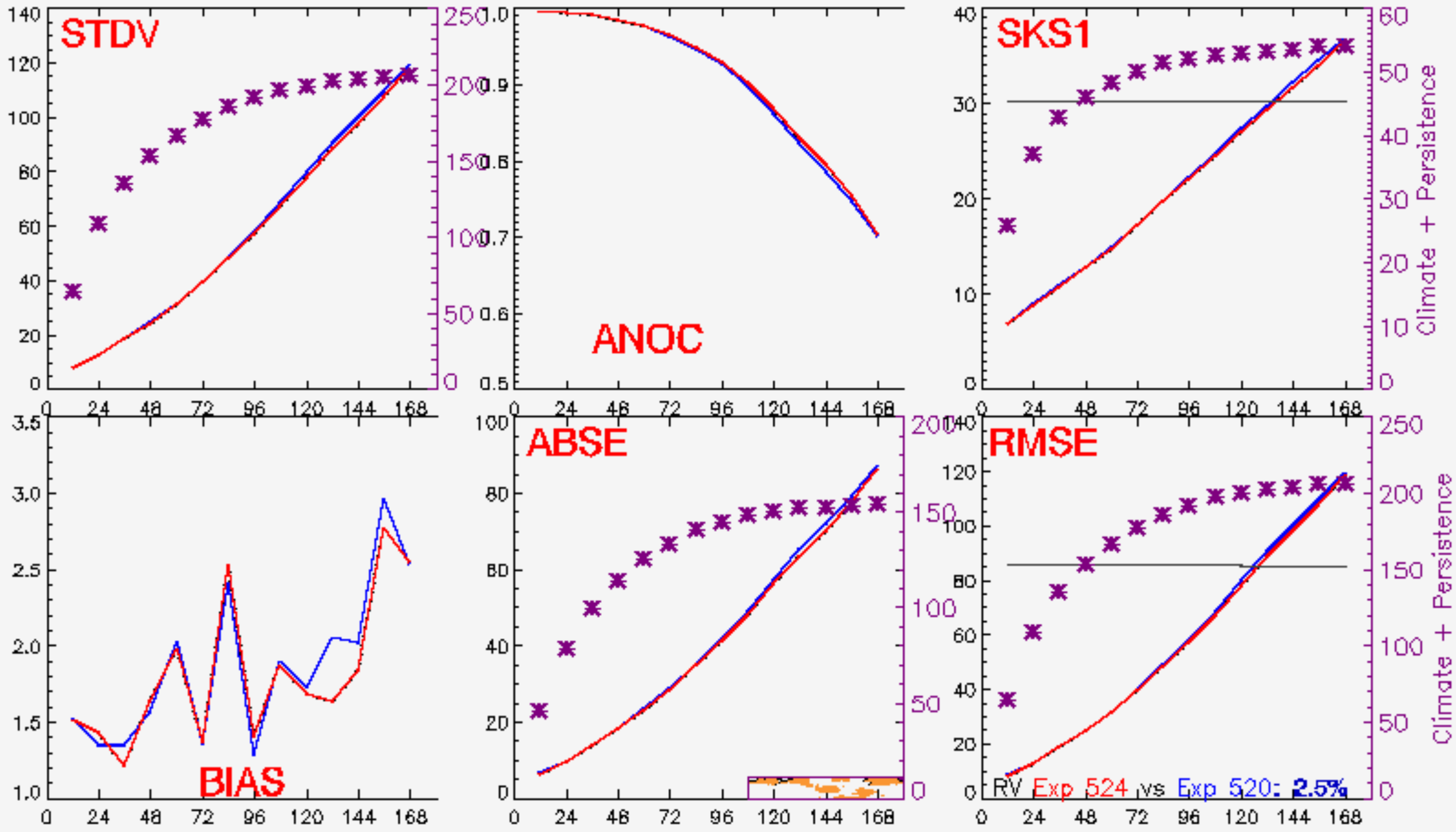
Mean: 1.46892 RMS: 6.06111 Std: 5.88152 Min: -40.7504 Max: 34.8979 Number of Obs.: 2681
Mean: 0.922191 RMS: 3.80393 Std: 3.69134 Min: -9.89173 Max: 10.2376 Number of Obs.: 2082



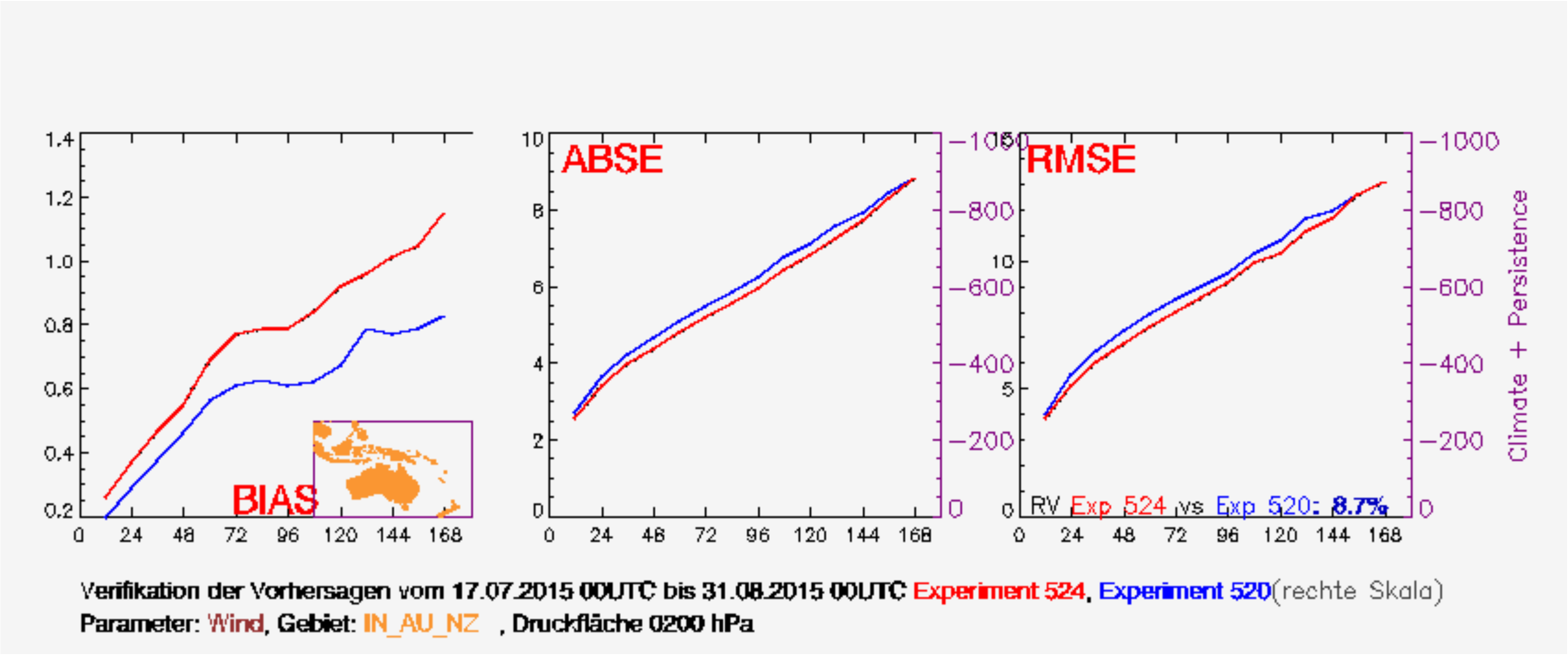
Mean: -0.0772769 RMS: 4.15307 Std: 4.15254 Min: -26.1910 Max: 23.3270 Number of Obs.: 10818
Mean: -0.0851204 RMS: 3.74495 Std: 3.74418 Min: -11.5405 Max: 11.9996 Number of Obs.: 9470







Verifikation der Vorhersagen vom 17.07.2015 12UTC bis 31.08.2015 12UTC Experiment 524, Experiment 520, Persistenz, Linien: Klima
Parameter: Geopotential, Gebiet: SH , Druckfläche 0200 hPa



Positive forecast impact replacing MTSAT-2R AMVs with Himawari-8 AMVs

Comparison between VIIRS, AVHRR and MODIS

VIIRS is a 22-band imaging radiometer that, in terms of features, is a cross between MODIS and AVHRR, with some characteristics of the Operational Linescan System (OLS) on Defense Meteorological Satellite Program (DMSP) satellites. It has several unique characteristics that will have an impact on a VIIRS polar winds product. These include:

- a wider swath (3000 km) compare to MODIS (2320 km) and AVHRR (2500 km),
- higher spatial resolution (750 m for most bands; 375 m for some) MODIS and AVHRR (1 km),
- constrained pixel growth: better resolution at edge of swath implies better feature tracking,
- a day-night band (DNB).

One disadvantage of VIIRS is that, unlike MODIS but similar to AVHRR, it does not have a thermal water vapor band. Therefore, no clear-sky winds can be retrieved.

NPP/VIIRS assimilation

2015080100 – 2015083121

Control Control+NPP

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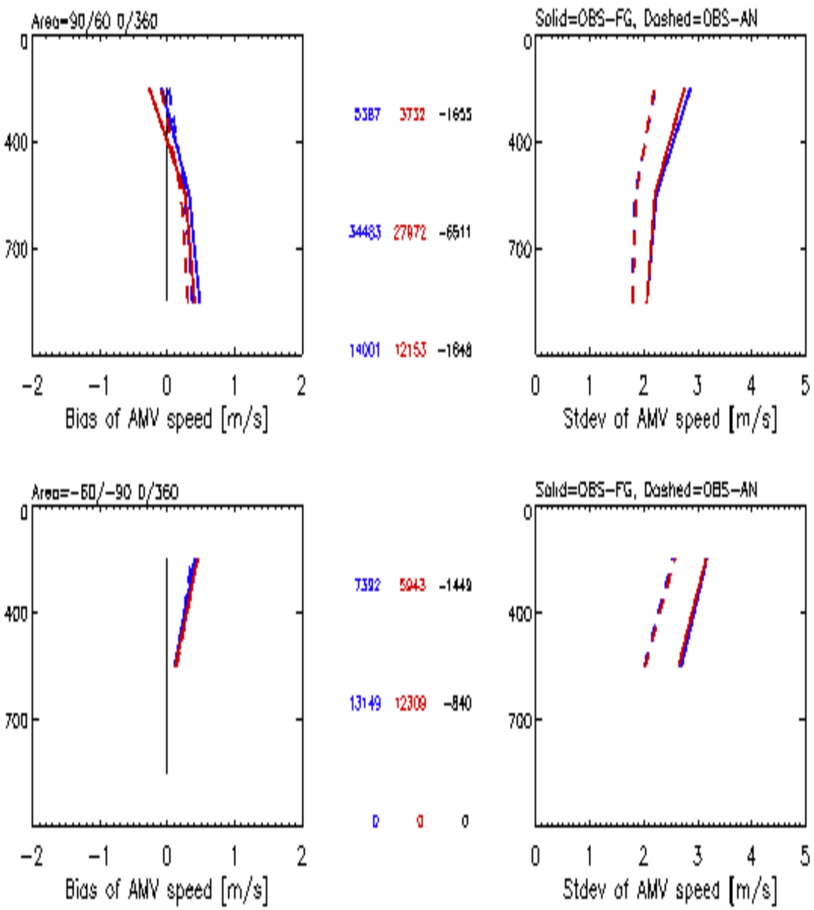
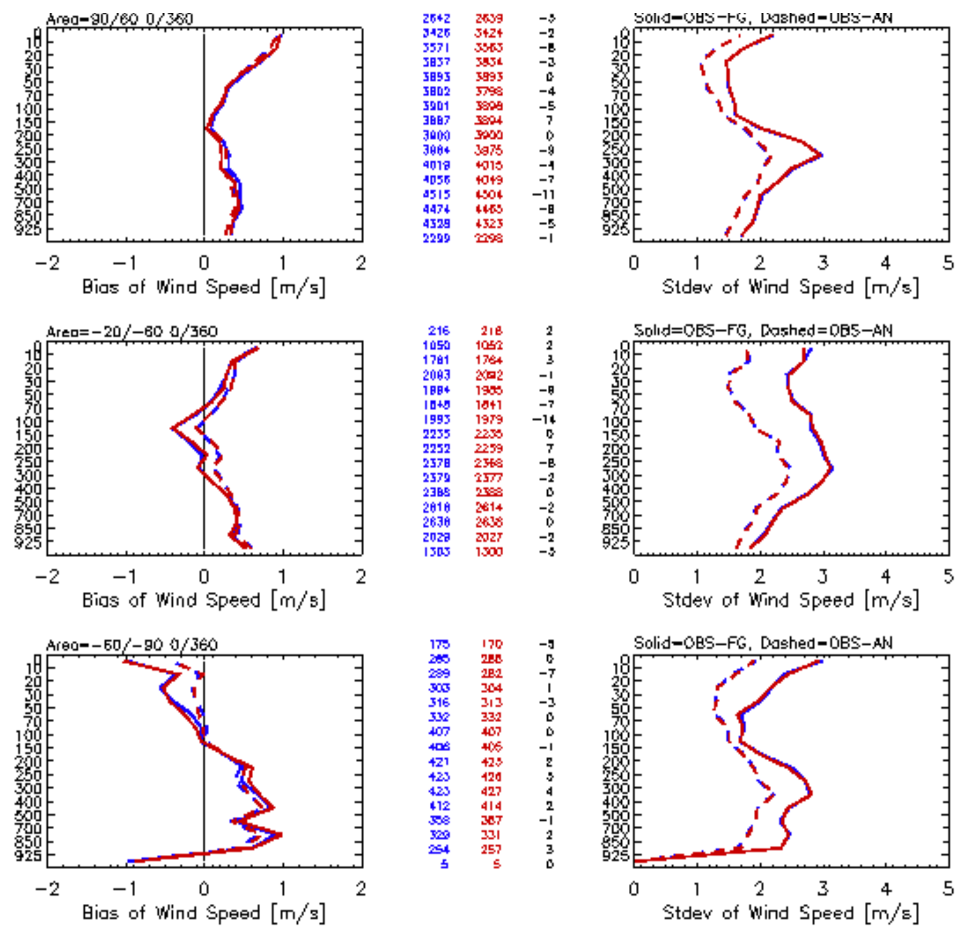
NOAA-19 AVHRR/IR

Radiosonde comparison





Normalized wind vector error scores
Experiment using NPP-VIIRS AMVs

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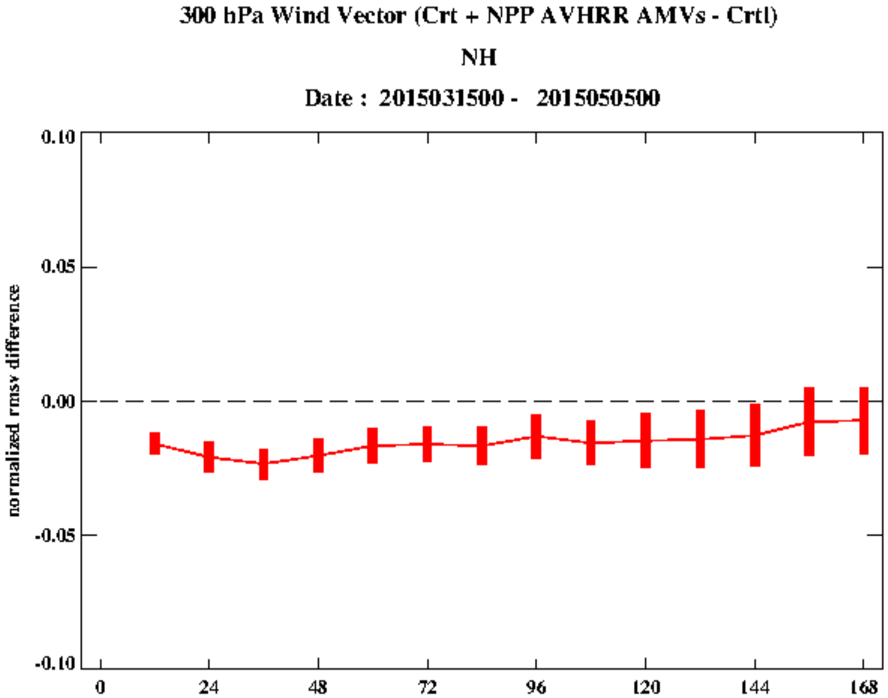

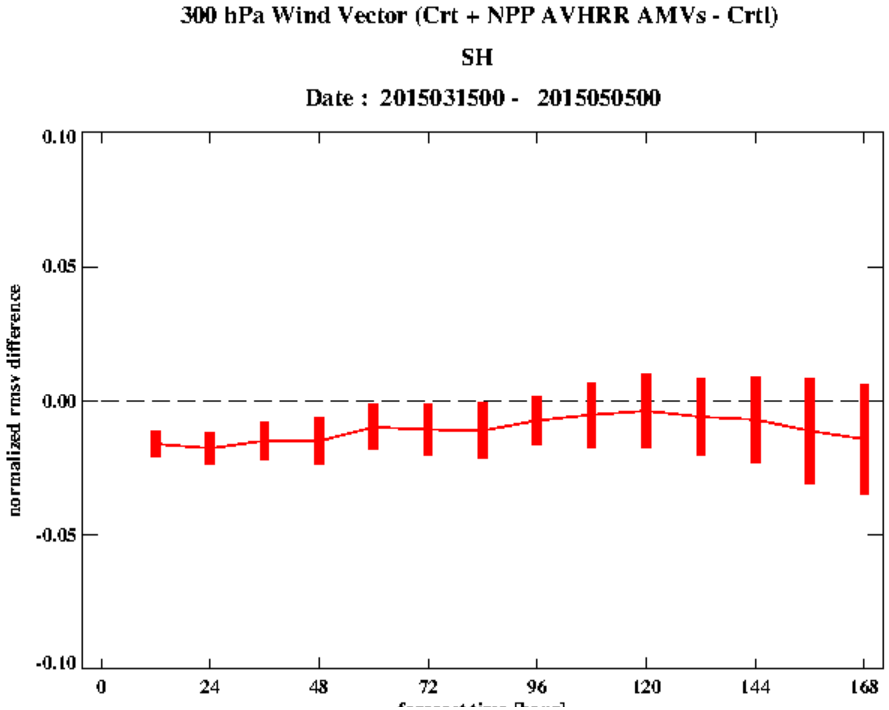

- Quality of NPP/VIIRS polar AMVs comparable to MODIS or AVHRR
- Due to wider swath and and higher resolution more data than AVHRR
- Positive impact and operationell since May 2016

DualMetop
OBS-FG statistics

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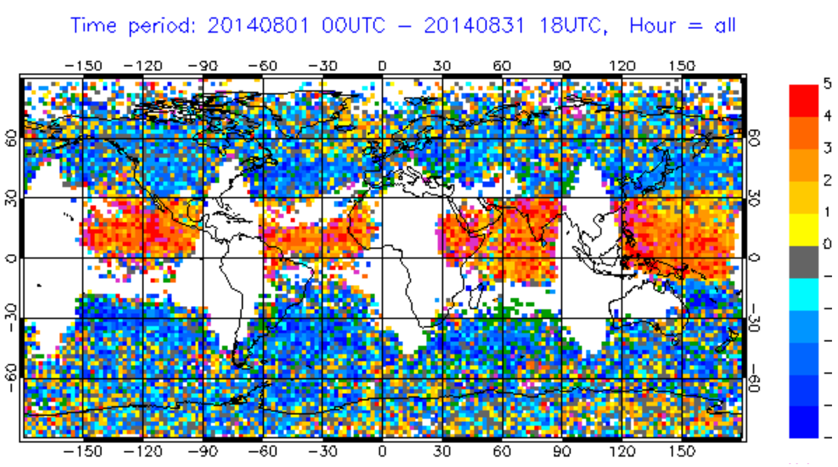
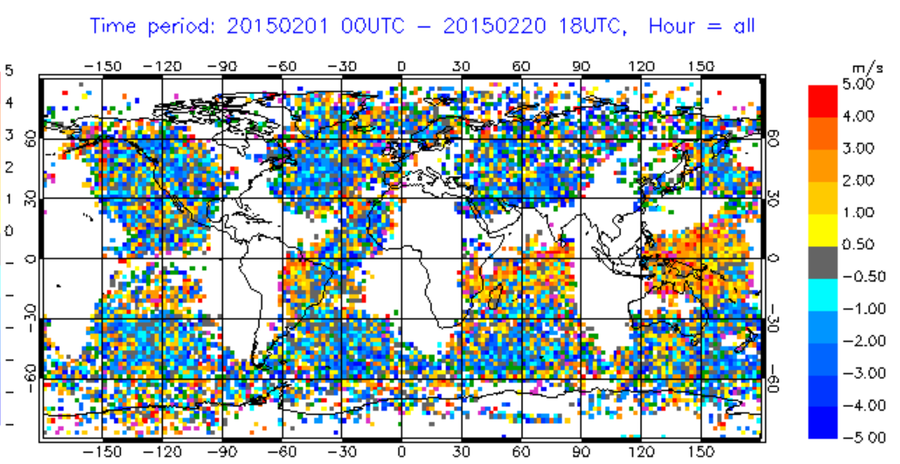
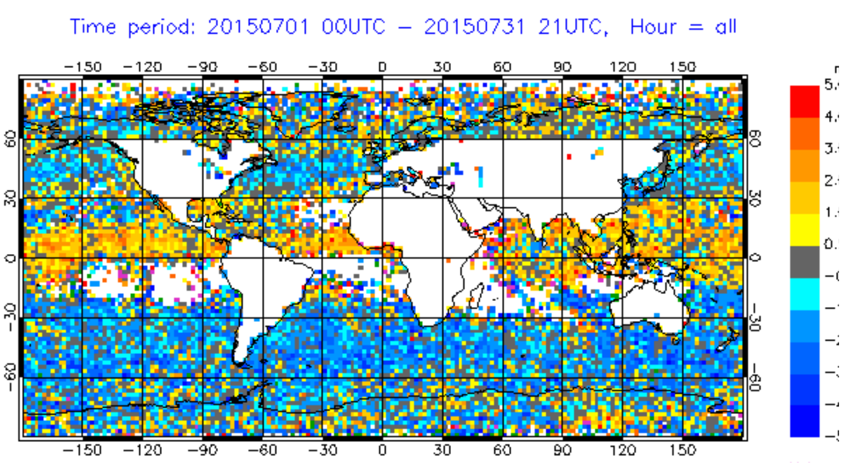
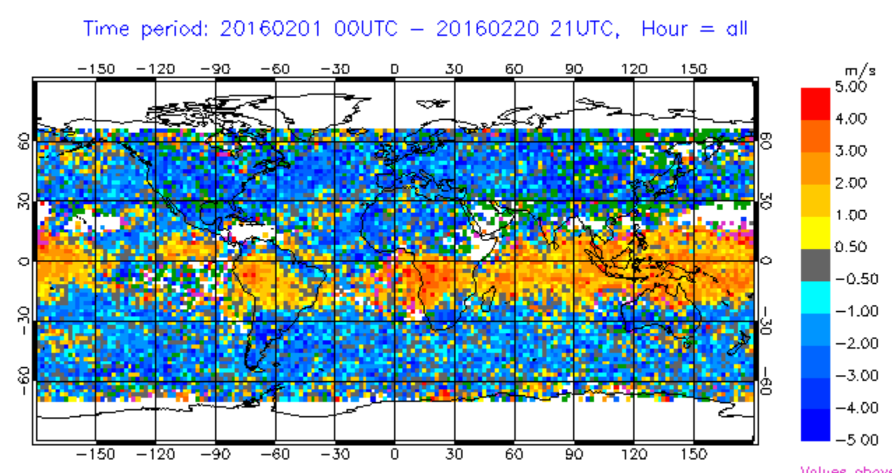


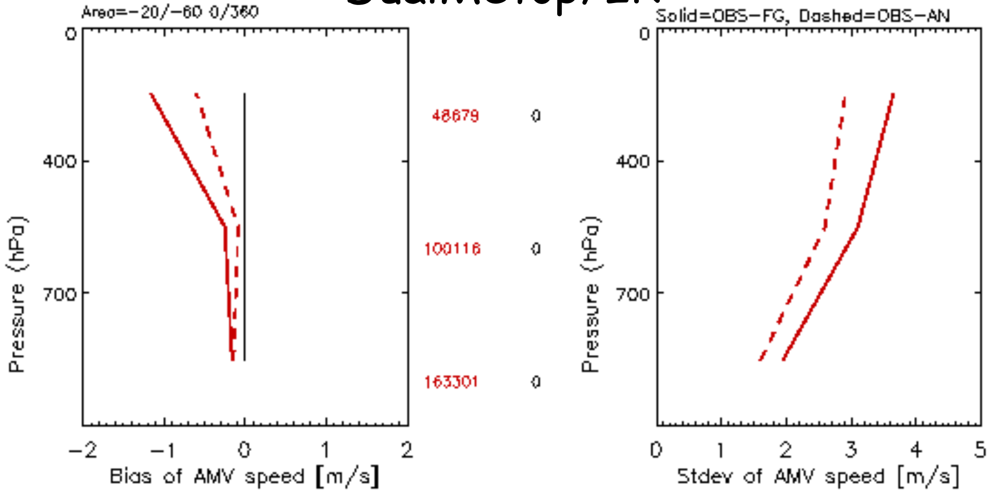




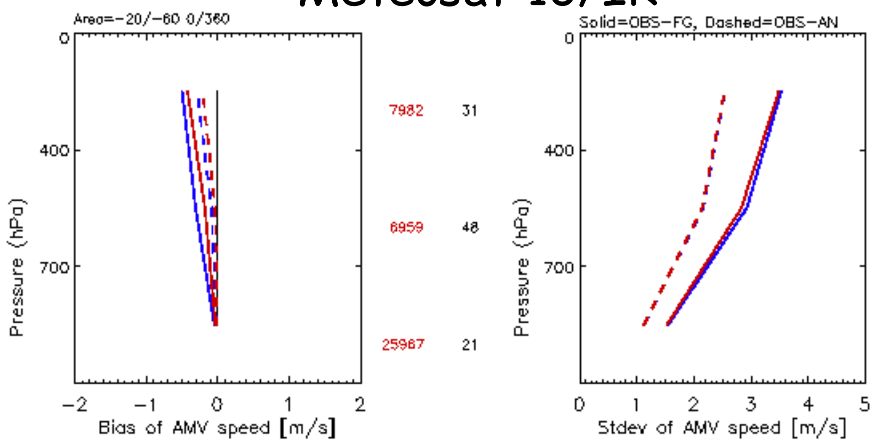


Obs –fg statistics using DualMetop AMVs
July 2015

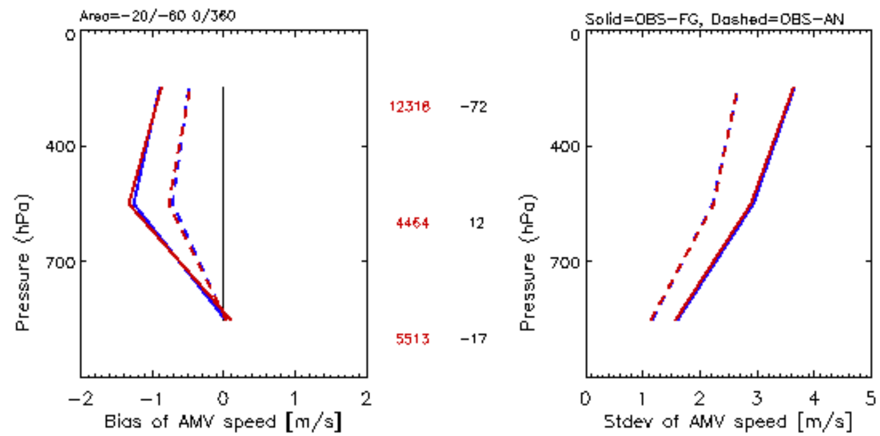
DualMetop/IR



Meteosat 10/IR



GOES 13/IR



Impact of Dual Metop Winds February 2016 (1 month)

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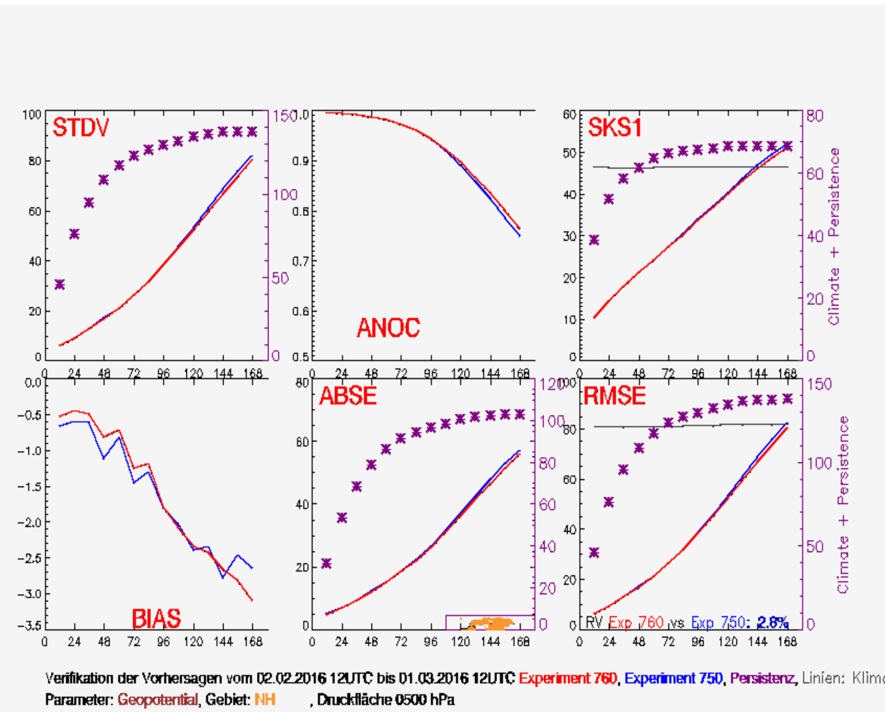

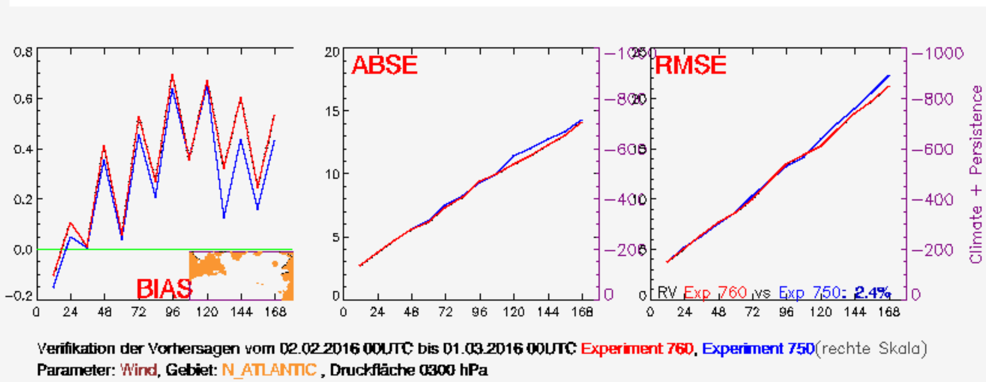

- Use only in the extra-tropics between 30 and 70 Grad north/south
- Fit of other AMVs to model background improved
- Small positive forecast impact
- If impact is stable than routine usage planned for autumn 2016

AMV wind quality comparison between Meteosat 10 and Meteosat 11

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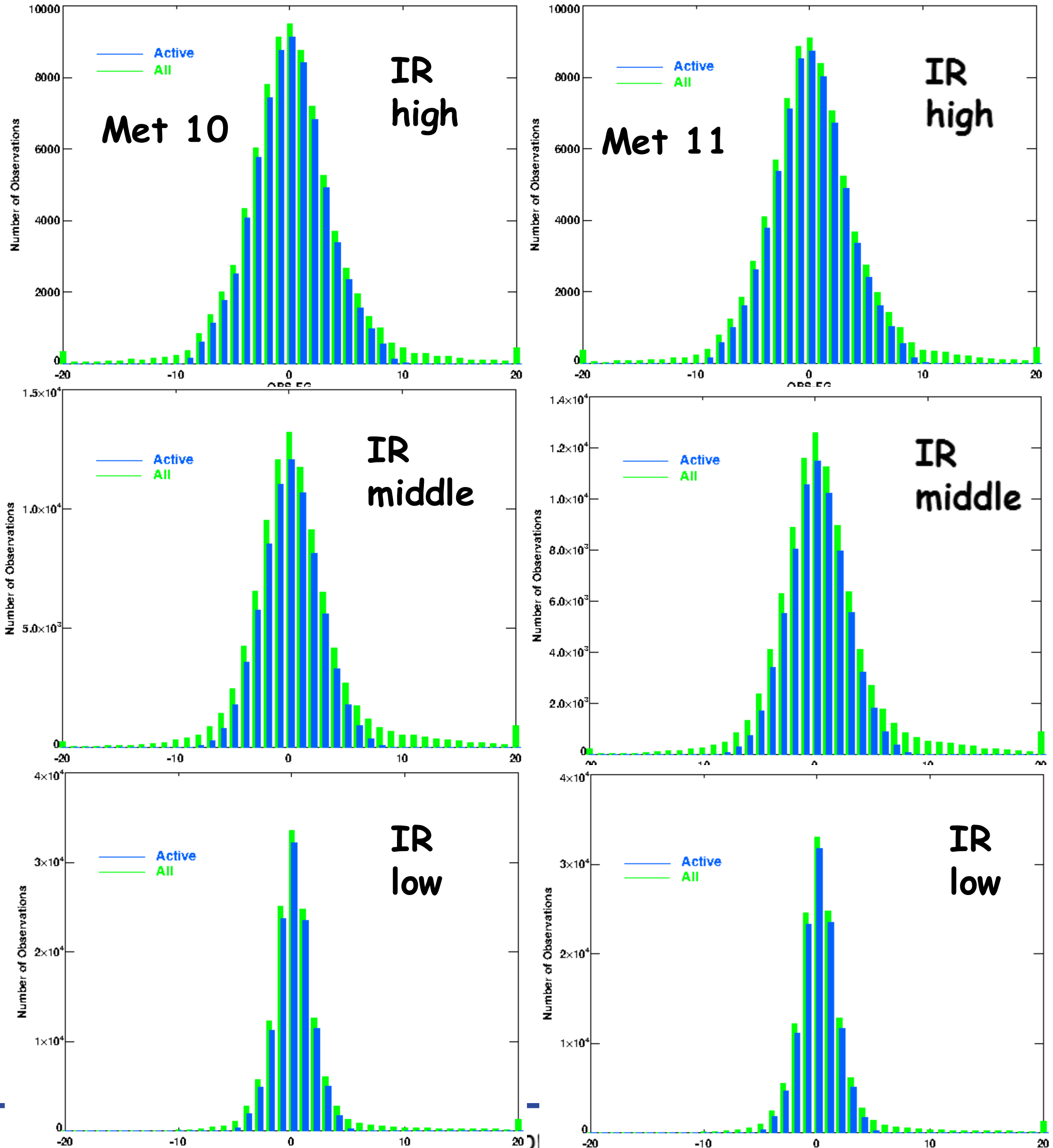

QI > 80

- Comparison based on obs – FG Sta
- Wind speed bias comparable
- No significant wind error differences
- Geographical distribution of wind sp bias and wind error very similar

Height correction of atmospheric motion vectors (AMVs) using lidar observations

Kathrin Folger, Martin Weissmann, Alexander Cress Harald Anlauf
Hans-Ertel-Centre for Weather Research, Data Assimilation Branch; Ludwig-Maximilians-Universität (LMU) München; Deutscher Wetterdienst (DWD)

- **Correct AMV height assignment error**
- **Can lidar observation help ?**
  - ***Indenpendent information***
  - ***Accurate cloud top height***
- **Calipso lidar estimated cloud top height are used**
- **Verification using radiosonde observations and NWP model forecasts (GME)**
- **Represent AMVs as layer winds**
- **Layer averaging observation operator implemented in data assimilation code**

Up to 20% wind error reduction compared to radiosonde and dropsonde Observation using lidar corrected AMV heights and layer averaging

AMV wind error (VRMS) and wind speed bias

10-day-period (1 June – 10 June 2013)

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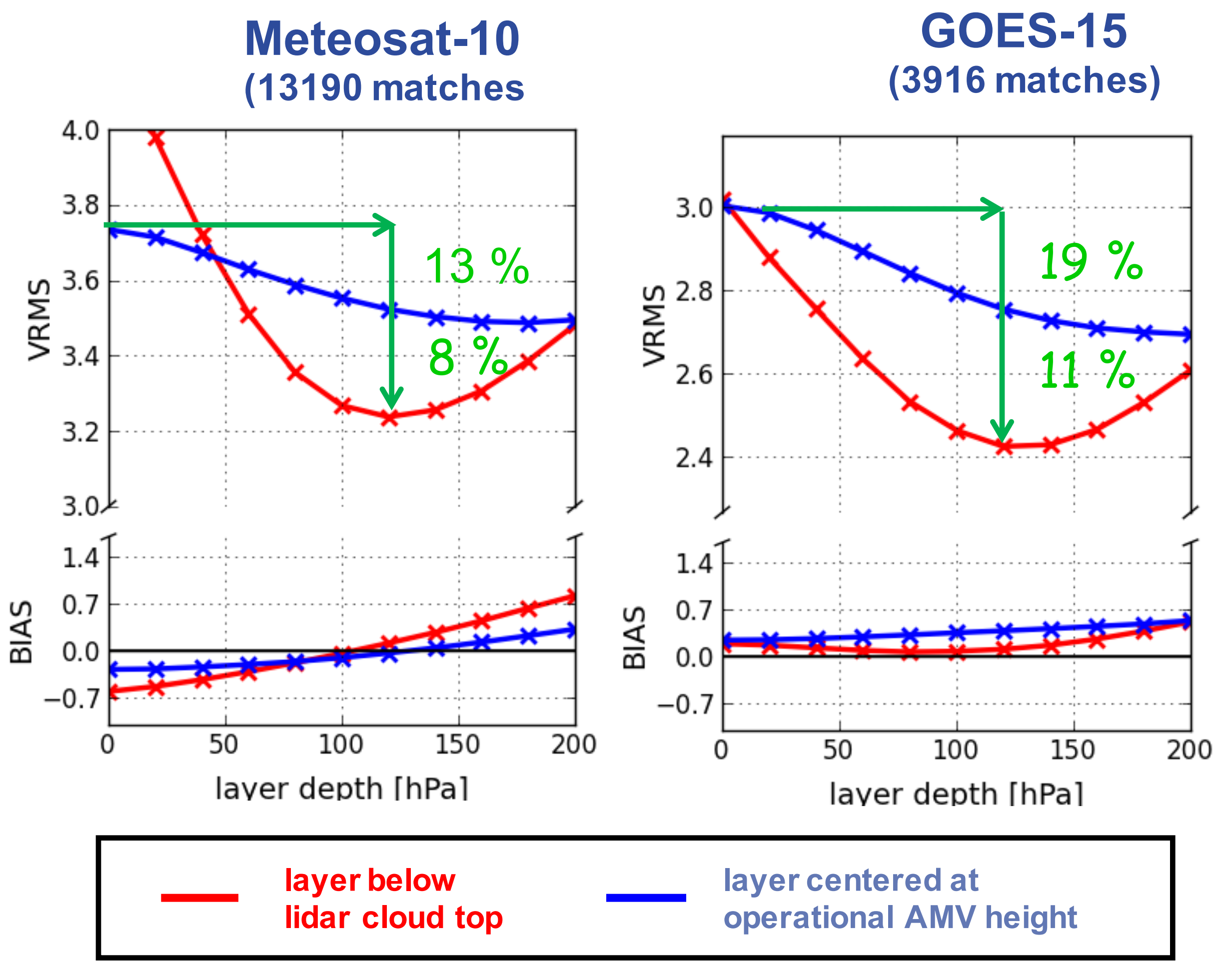
DWD



- **Comparison against NWP model**
- **Fairly robust minimum for lidar layer**
  - **Roughly 100-120 hPa**
- **Minimum for AMV layer more dependent on processing/ satellite or channels**

AMV height correction

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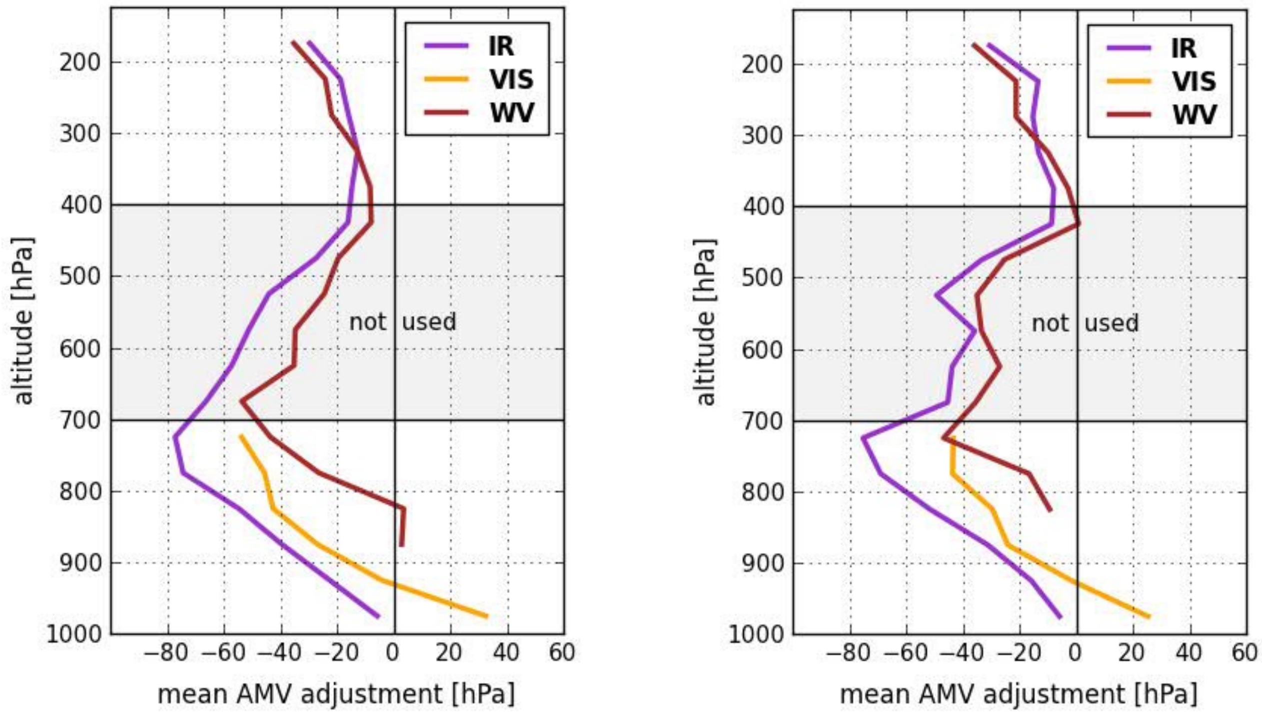
***Idea**: Use CALIPSO cloud heights to derive weekly/monthly correction functions for AMV heights*



Height bias correction functions for Meteosat-10 for a 30-day period (1 April 2013 – 6 May 2013, left panel) and a 10-day period (1 May 2013 – 10 May 2013, right panel) as a function of altitude. Different line styles indicate different satellite channels (cf. legend).

AMV height correction

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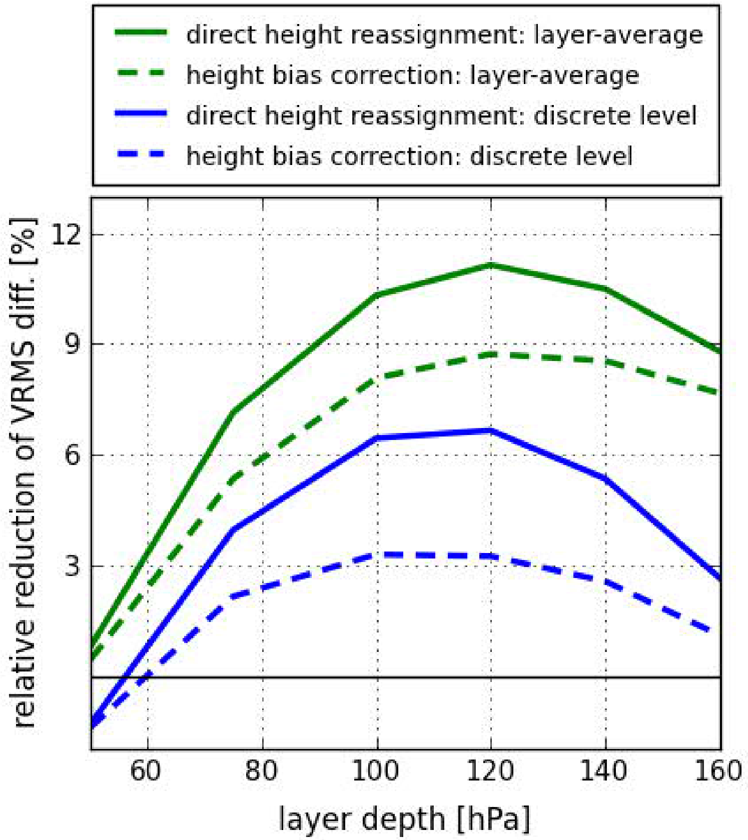
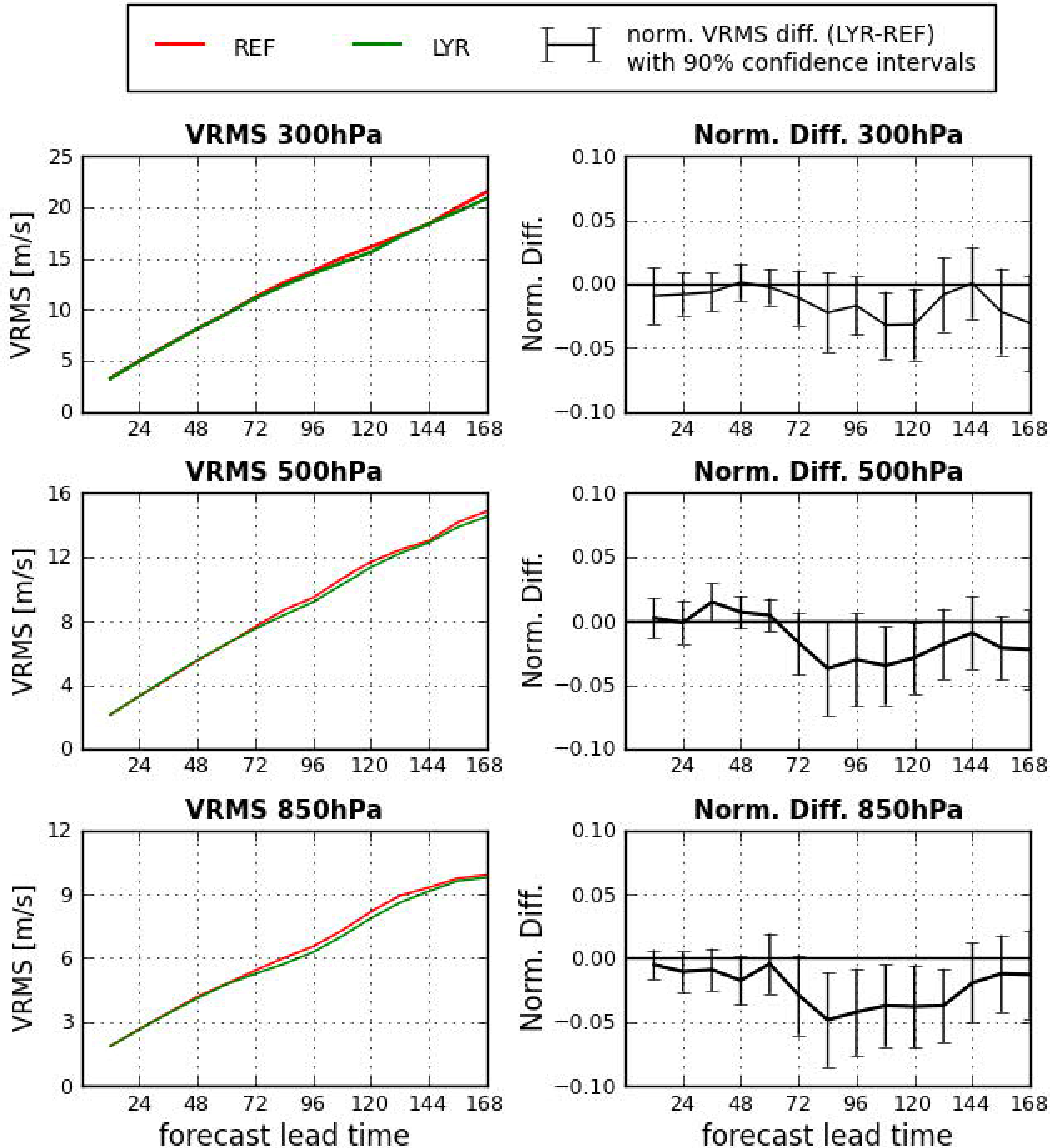


Relative reduction of VRMS differences between AMV and model FG winds for assigning AMVs to layers/levels below the lidar cloud top (solid lines) and to layers/levels based on the 30-day height bias correction (dashed lines) instead of the discrete operational AMV heights. Green lines represent layer-averages and blue lines discrete levels relative to the respective height. Low-level and high-level AMVs are combined. The x-axis denotes the vertical depth of the layers.



- Small forecast improvement Using height correction and Layer averaging
- Impact is higher at lower levels
- Impact is also seen in other variables (Geo 500, 850)
- So far no impact for other periods.
- Future: Compute height correction for longer periods and geographical regions

Use of Scatterometer data

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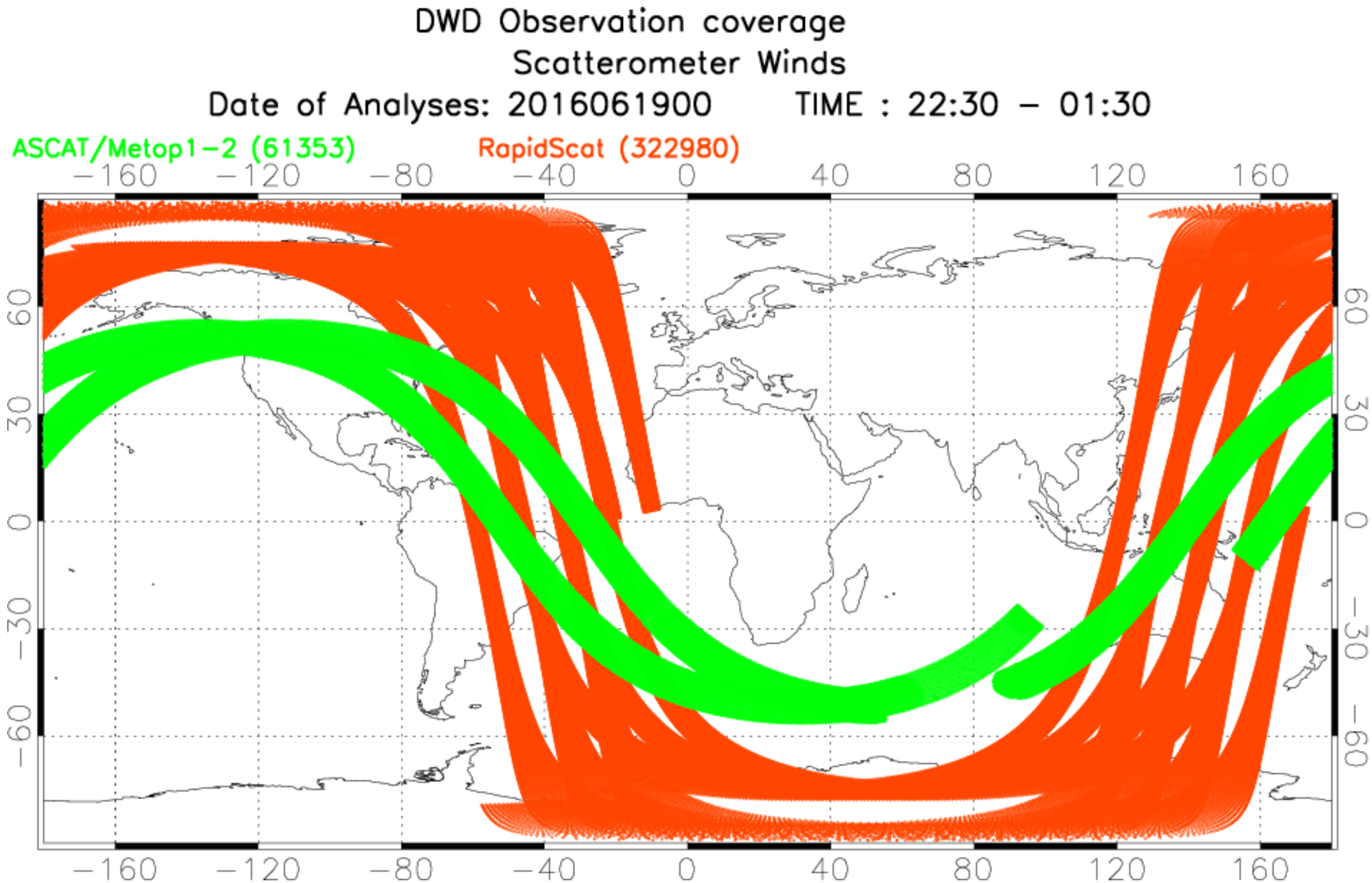


Experiment design

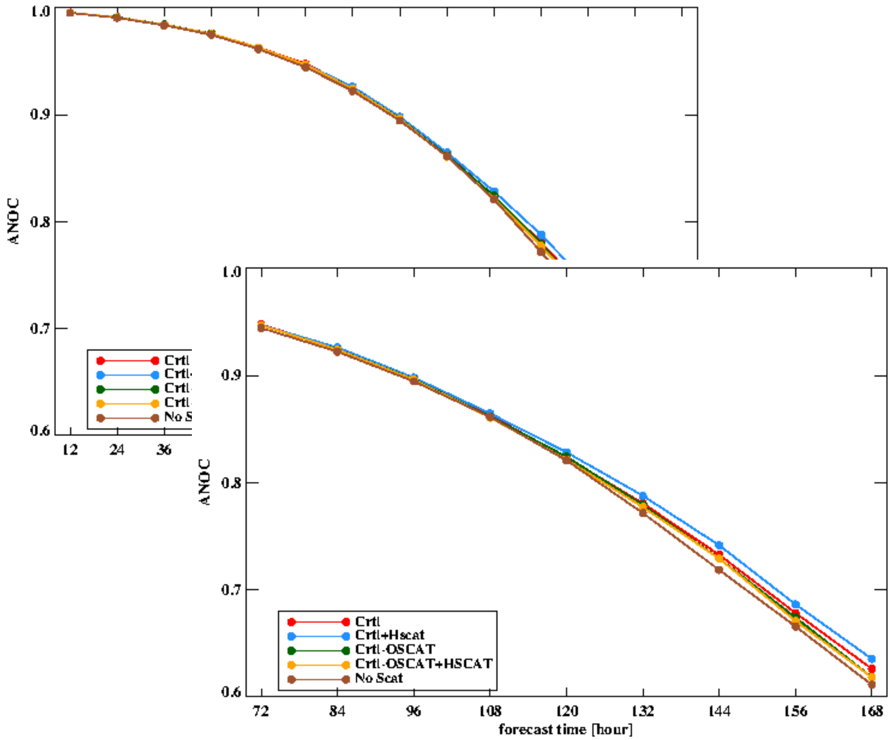
- Control experiment
- Experiment using additionally HY-2A scatterometer data
- Exp: Crtl discarding OceanSat-2 but including HY-2A
- Exp: Crtl without OceanSat-2 data
- Exp: Crtl without any scatterometer data

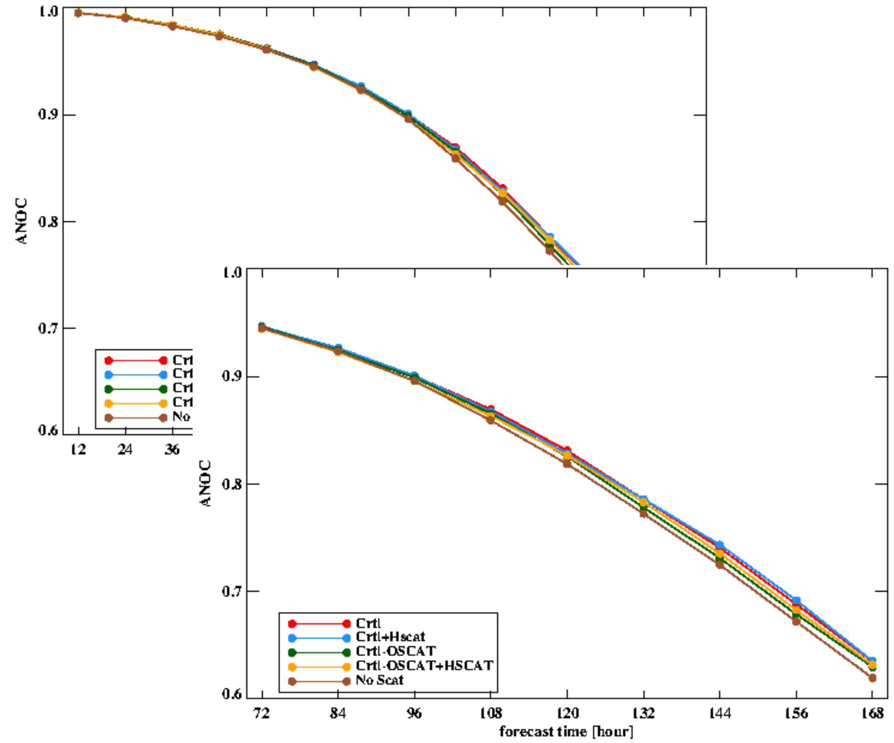
Period: 01.12.2013 –31.12.2014 (winter period)

All experiments use a 40 km resolution 3dvar + ICON

Scatterometer data used in Crt: ASCAT onboard Metop A/B and OceanSat-2

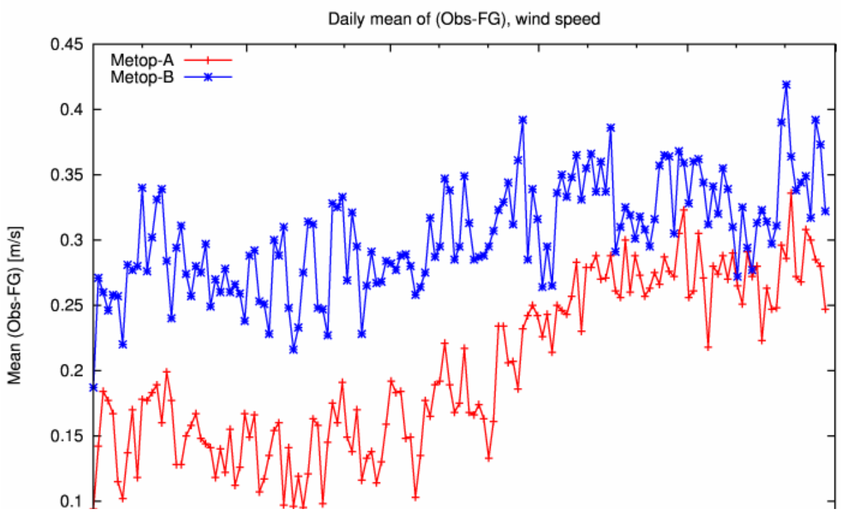
Scatterometer experiments

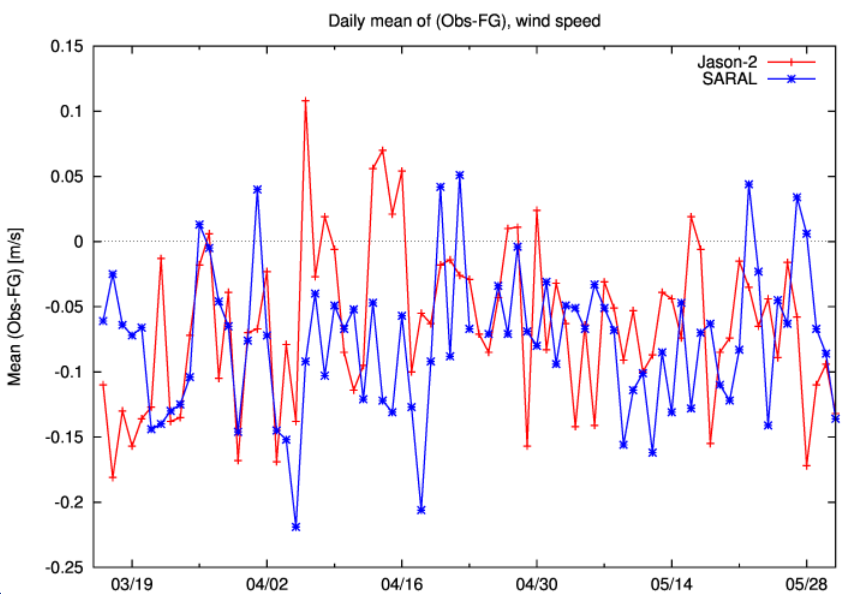




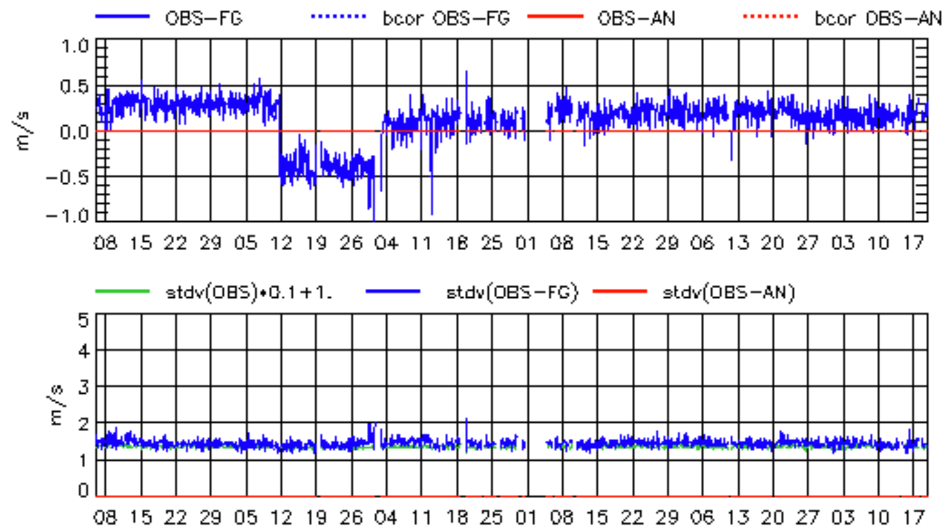
- NoScat shows a clear degration of forecast quality on both hemispheres
- Using a fourth scatterometer (HY-2A) shows some improvements
- Removing the Oceansat-2 scatterometer shows small degration
- Using HY-2A alone can not fully compensate for loss of Oceansat-2

Scatterometer monitoring





RapidScat
20160106-20160619



- ASAT bias larger than 0.25 m/s
- Metop-A significant bias increase
- Altimeter wind speed bias small
- RapidScat bias changes a lot
  - Online bias correction necessary
- RapidScat quality comparable to ASCAT

Summary I

- Himawari-8 shows some benefit compared to the MTSAT series
  - *AMVs operational since January 2016*
- NPP/VIIRS polar wind quality comparable to AVHRR and Modis winds but due to improved instrument configuration more data available
  - *operational since May 2016*
- Quality of Dual Metop winds similar to other AMV wind products in the extra-tropics
- Dual Metop winds show small positive forecast impact
  - *May become operationally this year*
- Meteosat 11 AMV winds similar quality as Meteosat 10 winds
- Operational monitoring of FY-2G and INSAT AMVs

Summary II

- Displacement of AMVs relative to Lidar cloud top heights can reduce the AMV height error and error correlation
- NWP may benefit from assimilating lidar-corrected AMVs and treating them as layer-averaged winds in future
- LIDAR observations may be useful to validate AMV processing algorithms to monitor AMVs and to derive height correction functions
- Scatterometer show a significant positive analysis and forecast impact
- More scatterometer data beneficial
- ASCAT winds show substantial biases. Bias correction necessary
- RapidScat wind quality similar to ASCAT winds, but geographical limitations