Recent progress in using satellite winds at the German Weather Service

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• Introduction
• Recent changes in the use of AMV observations
• AMVs over land
• AMV impact study
• Use of Scatterometer data (Ascat, Oceansat-2)
• Height correction of AMVs with airborne lidar and dropsonde observations
• Conclusions and Outlook
Numerical Weather Prediction at DWD

Global model GME
Grid spacing: 30 km
Layers: 60
Forecast range:
174 h at 00 and 12 UTC
48 h at 06 and 18 UTC
1 grid element: 778 km²

COSMO-EU
Grid spacing: 7 km
Layers: 40
Forecast range:
78 h at 00 and 12 UTC
48 h at 06 and 18 UTC
1 grid element: 49 km²

COSMO-DE EPS
Pre-operational
20 members
Grid spacing: 2.8 km
Variations in:
lateral boundaries, initial conditions, physics

COSMO-DE
Grid spacing: 2.8 km
Layers: 50
Forecast range:
21 h at 00, 03, 06, 09, 12, 15, 18, 21 UTC
1 grid element: 8 km²
Assimilation schemes

• Global: 3DVAR PSAS
  ▪ Minimzation in observation space
  ▪ Wavelet representation of B-Matrix
    ❖ separable 1D+2D Approach
    ❖ vertical: NMC derived covariances
    ❖ horizontal: wavelet representation

  ▪ Observation usage: Synop, Temp/Pilot, Dropsonde, AMV, Buoy, Scatterometer, AMUSU-A/B, Aircraft, Radio Occultation

  ▪ Time window: 3 hours

• Local:
  ▪ Continous nudging scheme and latent heat nudging
  ▪ Time windows: 0.5 – 1 hour
  ▪ Observation usage: Synop, Temp/Pilot, Dropsonde, Buoy, Aircraft, Scatterometer, Windprofiler, Radar precipitation
Usage of AMV winds at DWD

• Geostationary satellites (GOES 13/15; Eumetsat 7/9; MTSAT-2R)
  • 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)
  • over land and oceans
  • IR above 1000 hPa, over Antarctica 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)
Motivation

500 hPa Geopotential Height
Northern Hemisphere
Date: 2010080912 - 2010091512

- Ctrl
- No Wind profiles
- No Temp profiles

ANOCA

forecast time [hour]
AMV impact study

- Summer and winter period
- Exp. NoAMV/NoPolarAMV/NoScat
- AMV Impact larger for summer than winter
- Impact highest in Tropics and SH
- Impact is smaller on NH
- Impact higher in upper troposphere
- Impact detectable up to 5 days in summer and up to 3 days in winter on NH
- On SH impact is seen over the whole forecast range
- In tropics strong impact in the first 72 hours
- Strong impact of PolarAMVs seen over Antarctica
- Only small impact of northern polar region
- ASCAT data showed a strong impact on psml and 850 wind vector in the NH but almost no impact on the SH.
Comparision between MTSAT-1R and MTSAT-2R

Test period: June 2010

Compared to First Guess field

No significant difference in quality between MTSAT-1R and MTSAT-2R

Operational use since autumn 2010
• Comparision between GOES 11 and GOES 15

• Test period : Nov 2011

• Compared to First Guess field

• No significant difference in quality

• Operational use since Dez. 2011
Comparison AVHRR Metop
NOAA ⇒ Eumetsat
Dec 11 – Jan 12

Arctic

Bias: -0.01
Rms: 3.90
Cor: 0.92
NN: 34837

Eumetsat

Bias: 1.49
Rms: 6.31
Cor: 0.84
NN: 35191

Antarctica

Bias: 0.68
Rms: 4.29
Cor: 0.90
NN: 25740

Bias: 1.51
Rms: 6.05
Cor: 0.82
NN: 20857
Data quality AMVs over land

Wind speed [m/sec]
Level: 100 – 400 [hPa]
Period: 2011040100 - 2011043118

AMVs over sea

bias = -0.17
rms = 4.27
cor = 0.96

AMVs over land

bias = -0.92
rms = 4.79
cor = 0.93
Data quality AMVs over land

Meteosat 9 wvCloudy
Level: 400 hPa – 100 hPa

- AMVs over land comparable to AMVs over sea for upper troposphere
- For the lower troposphere, AMVs over land above deep orography problematic
- On average bias for AMVs over land 0.5 m/s higher in upper troposphere increasing to 1 m/s in lower troposphere. RMS comparable
AMV over Land Impact

500 hPa Geopotential Height
Northern Hemisphere
Date: 2011040200 - 2011053100

500 hPa Geopotential Height
Europe
Date: 2011040200 - 2011053100

ANOC

forecast time [hour]
AMV over land
Normalized rms difference

Experiment period: 2011040200 - 2011052400

- Experiment with AMVs over land but without Asian AMVs
- Verified against own analysis
- Forecast impact positive for all forecast times on Northern Hemisphere and Europe
- Neutral impact on Southern Hemisphere
Scatterometer

- Scatterometer provides ocean wind vectors from backscatter triplets or quadruplets using a geophysical model function

- Ku band (QuikScat, Oceansat-2) or C band radar systems (ERS 2, ASCAT)

- Radar backscatter depends on sea surface waves

- Quality control important (Rain flagging, land/ice flagging etc.)

- How to spread information into the vertical?

- Representation of Boundary layer physics over oceans important

- Several future missions planned (Windsat, Metop-B, CFOSAT, HY-2A, Microwave Temperature and Wind Mission)
Scatterometer

DWD Observation coverage
Scatterometer Winds

Date of Analyses: Time: 22:30 - 01:29

ASCAT (120750) OSCAT (53170)
OSCAT Data Quality

All data

- **windspeed**
  - bias: 0.15
  - rms: 7.37
  - cor: 0.69

- **winddirection**
  - bias: -0.94
  - rms: 28.38
  - cor: 0.77

Flagged data removed

- **windspeed**
  - bias: 0.04
  - rms: 6.77
  - cor: 0.71

- **winddirection**
  - bias: -0.91
  - rms: 25.86
  - cor: 0.78
Oscat data quality

Scatterometer Satellite ID: ASCAT  Exp: 0
Date: 20110900100 - 20110900521
North: 90.00 SOUTH: -90.00 WEST: -180.00 EAST: 180.00
Level Max/Min: 103513.54 / 93477.89

Scatterometer Satellite ID: OSCAT  Exp: 0
Date: 20110900100 - 20110900521
North: 90.00 SOUTH: -90.00 WEST: -180.00 EAST: 180.00
Level Max/Min: 103513.54 / 93477.89

![Histogram of wind speed](image1)

![Histogram of wind speed](image2)
Oscat impact

Mittelwerte der Scores im Zeitraum: 02.09.2011 00 UTC - 31.10.2011 00 UTC
GME r256f 08466
Oscat impact

Scatterdiagramm der Scores im Zeitraum: 02.09.2011 12 UTC - 31.10.2011 12 UTC
Erroneous low pressure system caused
By a malfunctional bouy

(1) 10m MAX. WIND (> 10.8 m/s)  (2) PMSL

(1) Mean: 6.93812  Min: 0.01161  Max: 32.486  Var: 16.0166
(2) Mean: 1013.1  Min: 988.949  Max: 1029.26

(1) Mean: 7.19943  Min: 0.01161  Max: 47.33  Var: 22.4795
(2) Mean: 1012.81  Min: 983.98  Max: 1029.26
36 hour forecast

(1) 10m MAX. WIND (> 10.8 m/s) (2) PMSL

[Weather map showing wind conditions]

(1) Mean: 10.2257, Min: 0.177827, Max: 38.4935, Var: 21.309
(2) Mean: 1013.47, Min: 992.298, Max: 1026.87

(1) Mean: 10.3035, Min: 0.215587, Max: 38.9832, Var: 21.4931
(2) Mean: 1013.4, Min: 992.371, Max: 1025.78
Time series of sea level pressure observation and analysis at bojie (63643) location

01 March – 02 March 2010

[Graph showing time series of sea level pressure observations with different scenarios: OBS, Exp with Scat, Exp without Scat, Routine.]
Goals

- Fundamental research in the areas of data assimilation (DA) and ensemble forecasting
- Training of young researchers and students
- Methods to assess the analysis and forecast impact of observations in the KENDA-COSMO system
- Methods to use additional satellite observations for NWP
- Methods to improve the representation of forecast uncertainty in the KENDA-COSMO system
- Robust data assimilation methods for strongly non-linear systems with non-Gaussian error statistics

Research areas

Observation impact
- Tools to quantify the analysis and forecast impact of observations in EnDA
- Monitoring of observations
- Optimized use of observations

Satellite observations
- Direct assimilation of MSG SEVIRI VIS+NIR radiances in KENDA
- AMV height correction with lidar observations
- (Lightning) (ADM-Aeolus)

Ensemble forecasts
- Improved representation of forecast uncertainty
- KENDA initial perturbations
- Flow-dependence and impact time of perturbations

DA methods
- Methods for convective-scale DA
- Idealized tests with non-Gaussian error statistics (toy models)
- Robust methods for highly non-linear systems
Height correction of atmospheric motion vectors with airborne lidar observations

Martin Weissmann, Kathrin Folger und Heiner Lange

**Goals:**
- Shifting the height of estimated AMVs to cloud heights detected by an lidar during T-PARC
- Evaluating the reduction of AMV wind error through the height correction with dropsonde observations
- Developing a correction algorithm that could adjust AMV heights with satellite lidar observations in the future

**Data base:** T-PARC ~60 hours, Drops, Lidar Backscatter, CIMMS Geo AMVs

**Steps:** Cloud height detection, correction, verification mit Dropsonde data (for T-PARC AMVs)
Conditions

- less than 100 km distance
- less than 60 min. time difference
- no WV (only IR/SWIR/VIS)
- AMVs 150 hPa below flight height
- dropsonde within 100 km distance
measurement example

Japan T-PARC 2008-09-11
Backscatter ratio at 1064nm (cloudheight 6), threshold 10

height above sea level [km]

0.0 2.0 4.0 6.0 8.0 10.0 12.0

09:30 10:00 10:30 11:00 11:30

time [UTC]

0.1 1.0 10.0 100.0 1000.0

AMVs
Comparable AMV – Lidar clouds

to close to the aircraft

Lidar and satellite see different cloud

Tolerance range [-100, +150]
Comparison of difference between AMV winds and dropsonde layer winds

General approach

• **Assumption:** AMV winds are representative of a layer wind

• **Method:** Compare the AMV wind measurement with dropsonde layer winds

\[
\begin{align*}
X &= \text{AMV wind minus dropsonde layer wind} \\
&= \text{[+75,-75 hPa around AMV height]} \\
Y &= \text{AMV wind minus dropsonde layer wind} \\
&= \text{[+0,-150 hPa below/around lidar cloud]} \\
\text{Compute the relative improvement} : \ (X-Y)/X \times 100 \ [\%]
\end{align*}
\]
Results for all AMVs

- Improvement with Lidar: 5-10%
- Systematic height assignment error
- Improvement 10% if compared layer winds 100-150 hPa below AMV
- Results are dominated by VIS winds
Conclusions I

- Wind information are very important in our assimilation system

- AMVs important contribution to the global observation system

- Impact of AMVs stronger in summer period than in winter

- Impact is high on the Southern Hemisphere and Tropics and smaller on the Northern Hemisphere

- Strong impact of polar AMVs over the southern polar regions

- Use of MTSAT-2R and GOES 15 winds operationally

- Metop AVHRR winds derived from Eumetsat show higher bias and RMS compared to winds derived from NOAA

- Use of AMVs over land show a strong positive impact
Conclusions II

- Quality of Oceansat-2 winds comparable to ASCAT winds
- Small positive impact of Oceansat-2 scatterometer winds
- Scatterometer winds help to stabilize the COSMO analysis and forecasts
- Small positive impact also in COSMO regional model
- Program started to analysis and improve the height assignment of AMVs with the help of lidar and dropsonde cloud height and wind observations
- Assimilation of height corrected AMV winds or AMV winds as layer winds