Global and regional impact studies at the German Weather Service (DWD)

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- **Introduction**
- **Impact studies with the global model GME**
- **Impact studies with the local model COSMO EU/DE**
- **Conclusions and Outlook**

Numerical Weather Prediction at DWD

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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 km^2

COSMO-DE EPS

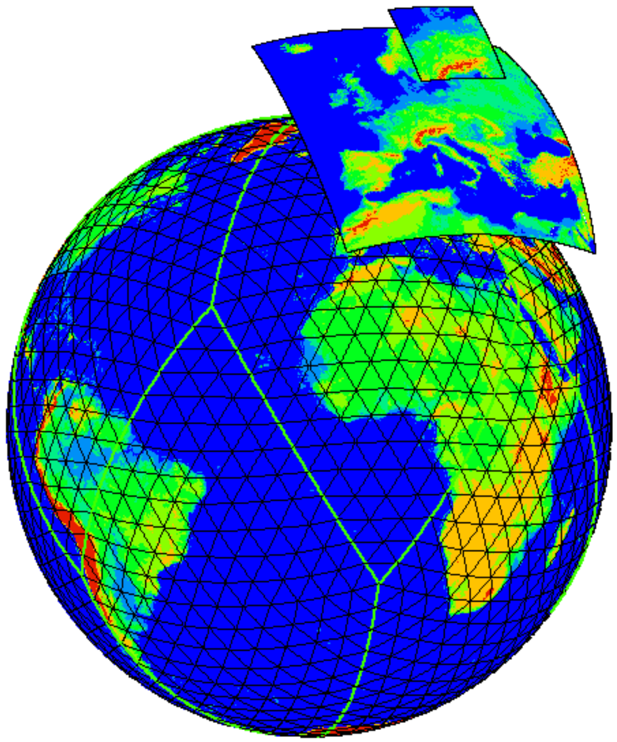
Pre-operational

20 members

Grid spacing: 2.8 km

Variations in:

lateral boundaries, initial conditions, physics



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 km^2

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 km^2

Assimilation schemes

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- **Global: 3DVAR PSAS**
  - **Minimzation in observation space**
  - **Wavelet representation of B-Matrix**
    - **seperable 1D+2D Approach**
    - **vertical: NMC derived covariances**
    - **horizontal: wavelet representation**
  - **Observation usage:** *Synop, Temp/Pilot, Dropsonde, Windprofiler AMV, Buoy, Scatterometer, Aircraft AMUSU-A/B (RARS Service and central) , 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*

Impact of radiosonde and aircraft observations

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- Experiment no using Radiosonde data (NoRS)
- Experiment not using Radiosonde temperature data (NoRS/T)
- Experiment not using Radiosonde wind observations (NoRS/W)
- Experiment not using Radiosonde humidity observations (NoRS/RH)
- Experiment not using Aircraft data (NoAir)
- Experiment not using Aircraft temperature data (NoAir/T)
- Experiment not using Aircraft wind data (NoAir/W)
- Control experiment including all available observations (CRTL)
- 2 month period: 15 Dez. 2010 – 15 Feb. 2011

Impact of radiosonde and aircraft
Normalized forecast error differences
Northern Hemisphere

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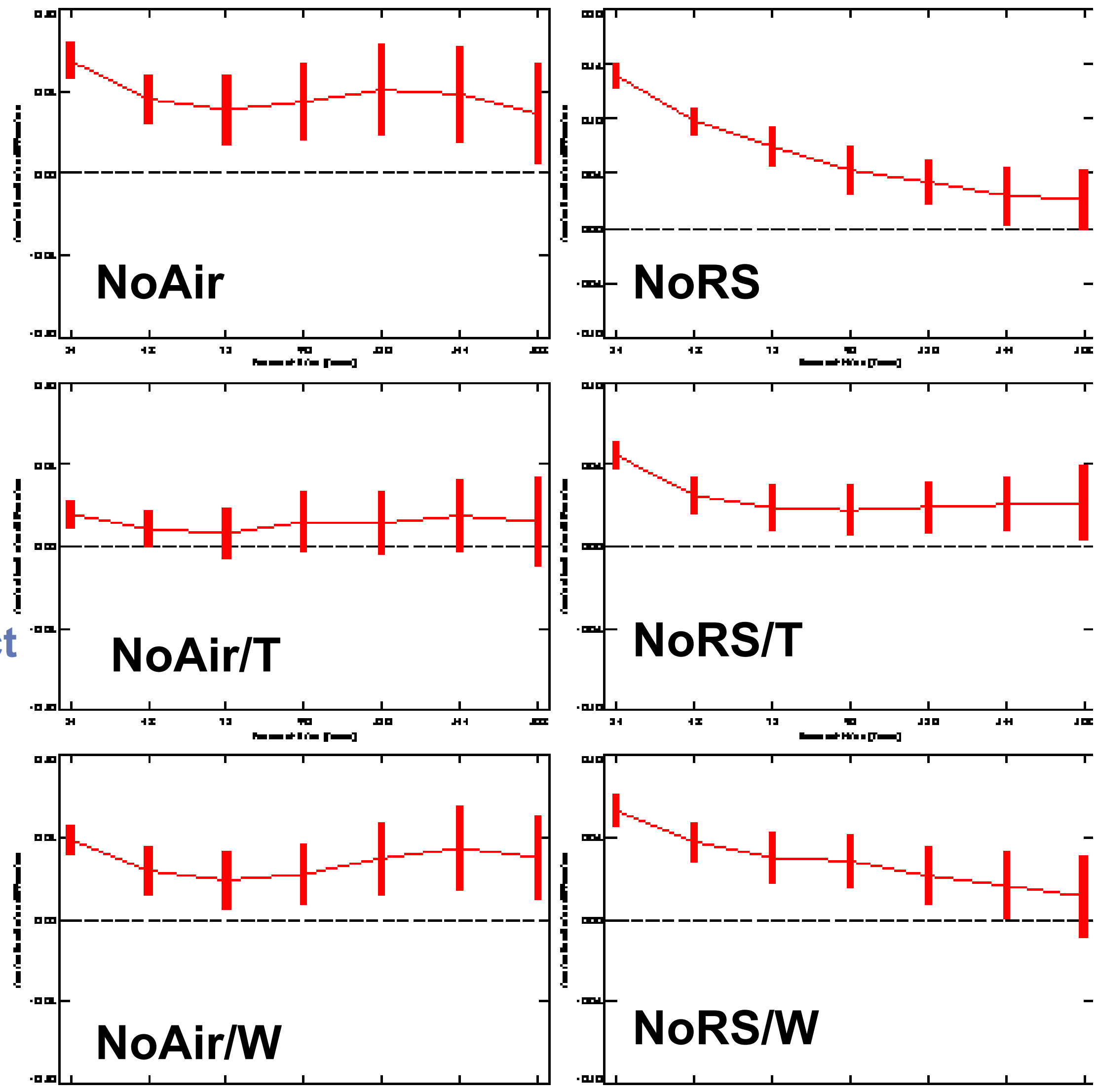
- 2 month period
- Verified against Crtl analyses
- Impact of Air consisted through forecast period
- Imapct of RS decreasing with forecast length
- Impact of RS large in first 3 days
- Impact of Air large > 3 days
- Wind Impact larger than Tem. Impact
- RS Temp. Impact higher than Air Temp Impact
- RS Wind Impact high in first 4 days
- Air Wind Impact consistend and high > 3 days



Impact of radiosonde and aircraft
Normalized forecast error differences

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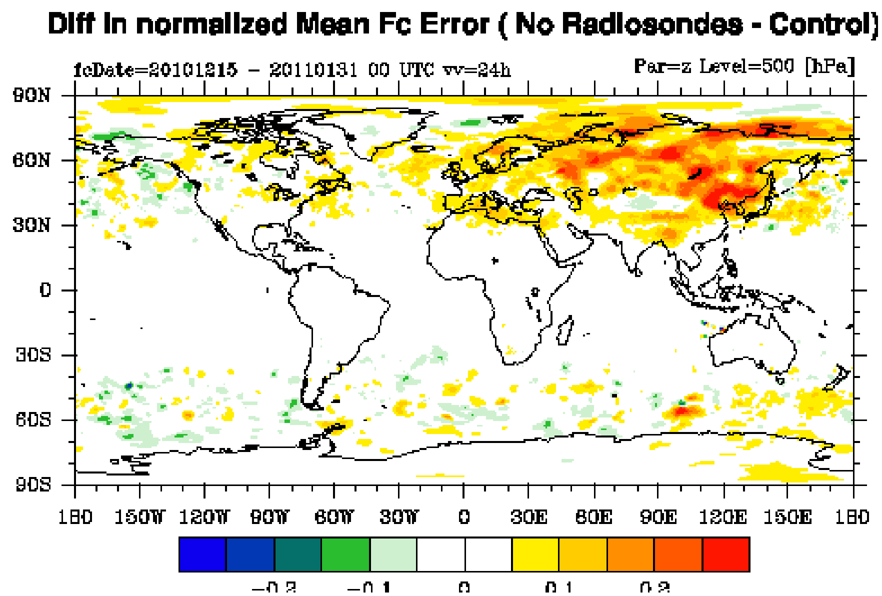

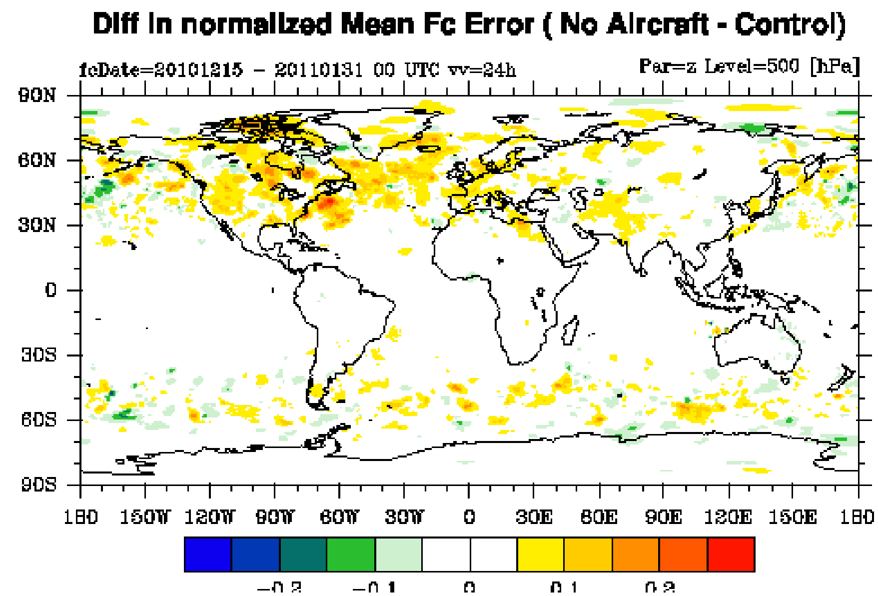

- Large impact of radiosondes over the eurasien continent
- Impact of aircraft strong over North America,North Atlantic and smaller over Europe
- Impact on the southern hemisphere small (signal for RS over Antartica)
- Impact in the tropcis very small compared to the Northern Hemisphere

Impact of radiosonde and aircraft
Temperatur verification against radiosondes
20101215 – 20110215 VV=24h

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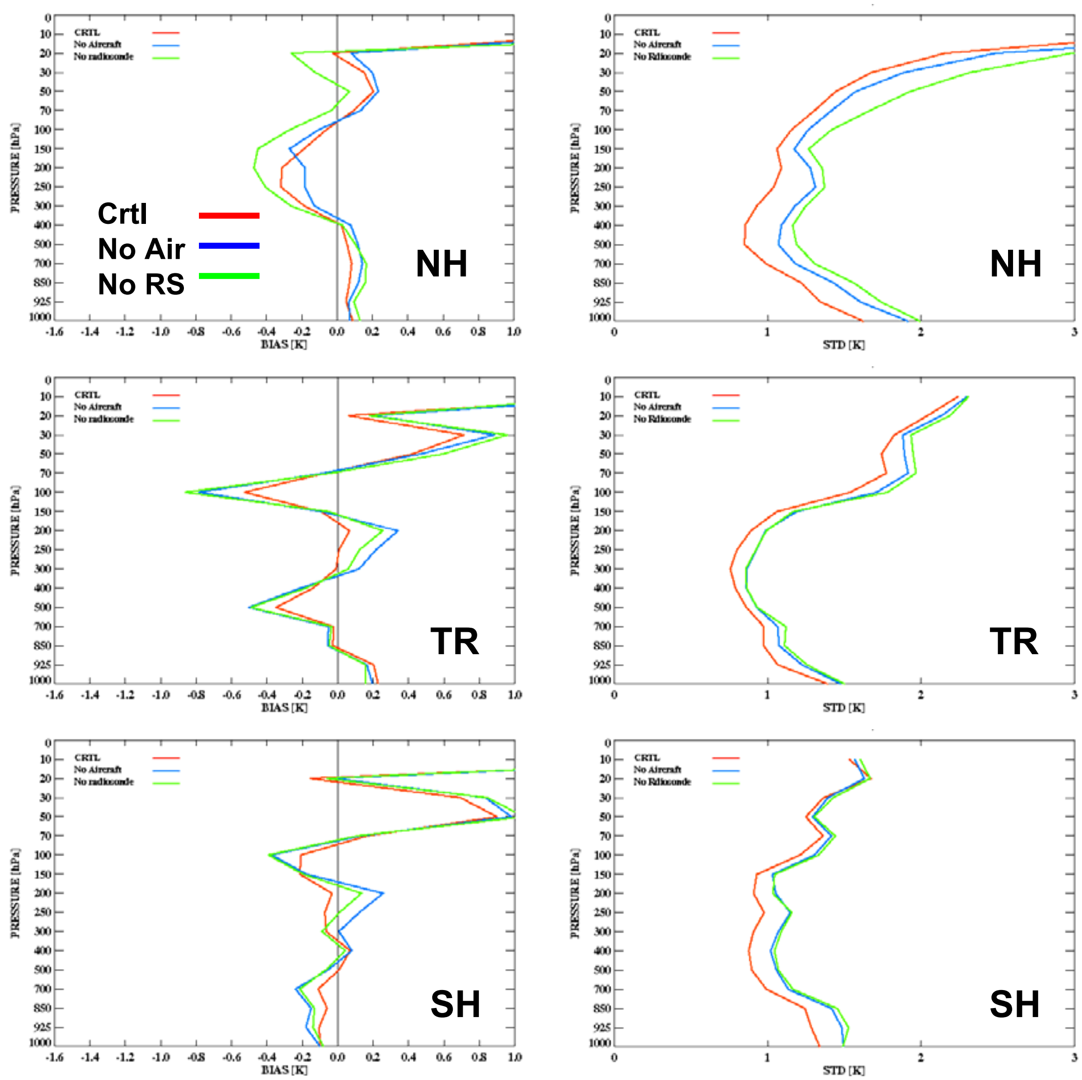
- ❖ Significant impact of both, RS and Air in NH
- ❖ Smaller impacts in SH and Tropics
- ❖ RS impact larger than Air on NH
- ❖ Complemendary impact of RS and Air in SH and Tropics
- ❖ Air Temp Bias visible, mainly at flight level
- ❖ Impact on SH only visible in troposphere
- ❖ Stratospheric impact dominated by satellite radiances



Impact of polar orbiting satellites

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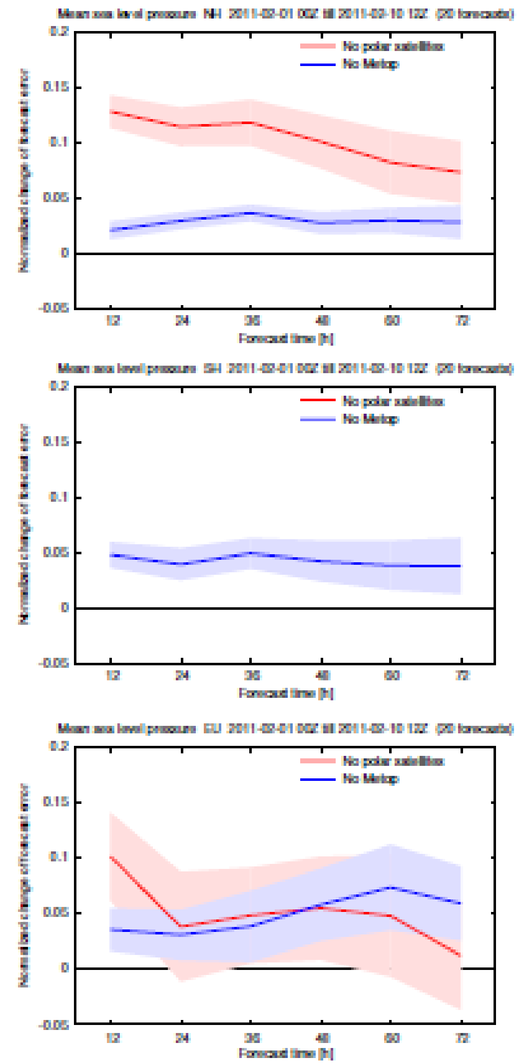
DWD

- Assess the impact of polar orbiting satellites on the short range forecast (up to 72 h) at DWD
- Focussing on Metop-A and Europe
- Period of winterstorms in February 2011
- Performed two data denial experiments
  - ⇨ No data from polar orbiting satellites (AMSU)
  - ⇨ No data from Metop-B (AMSU,ASCAT,GRAS)



Results:

- Metop-A amounts of roughly 20% of data used
- Omitting radiances have a large negative impact on forecast quality for both hemispheres and Europe
- No data from Metop-A has a substantial negative impact on both hemispheres and a relative large impact in Europe.
- Synop verification shows an increase in forecast quality for Europe at day 2 and 3 for surface pressure and wind gusts

Impact of polar orbiting satellites

Case study: Winter storm Nicolas

Effected Germany and Denmark on night from 07 Feb.-08 Feb. 2011

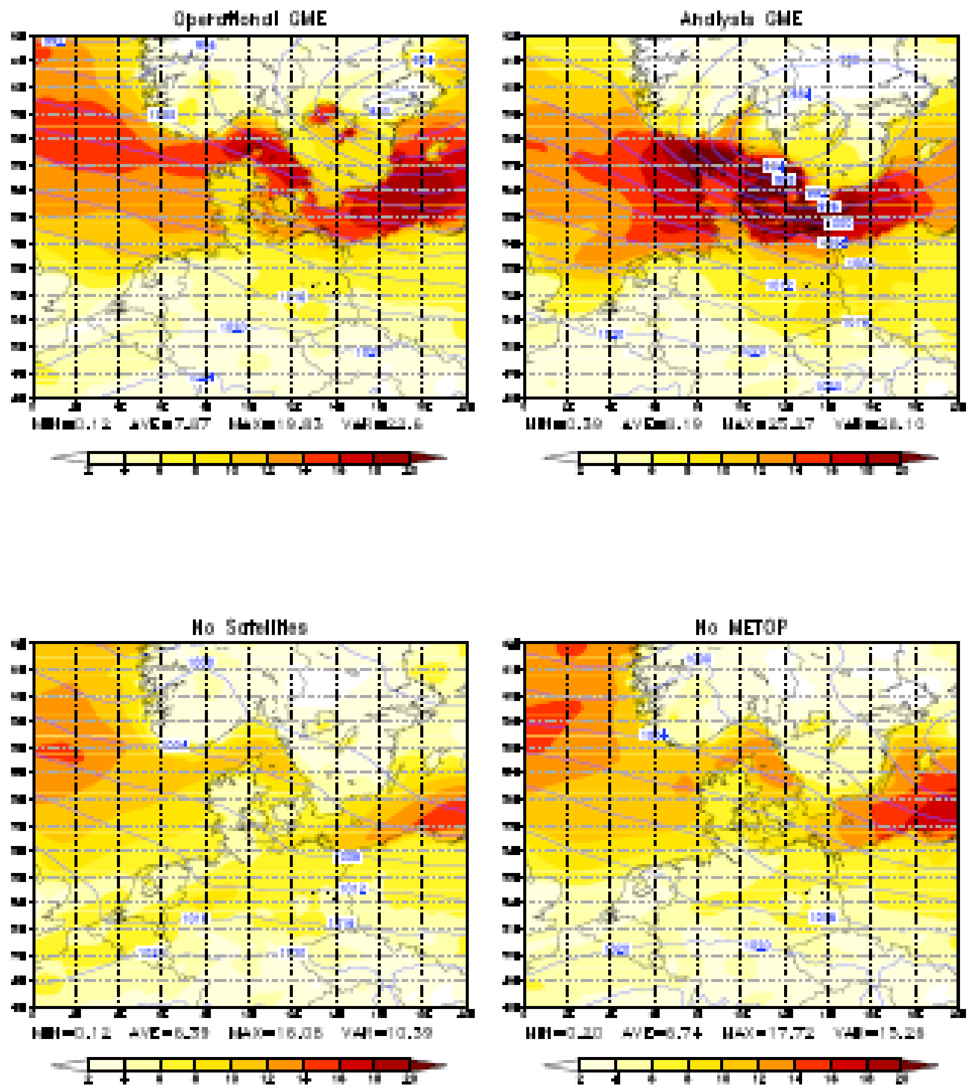
Sea surface pressure and 10m wind

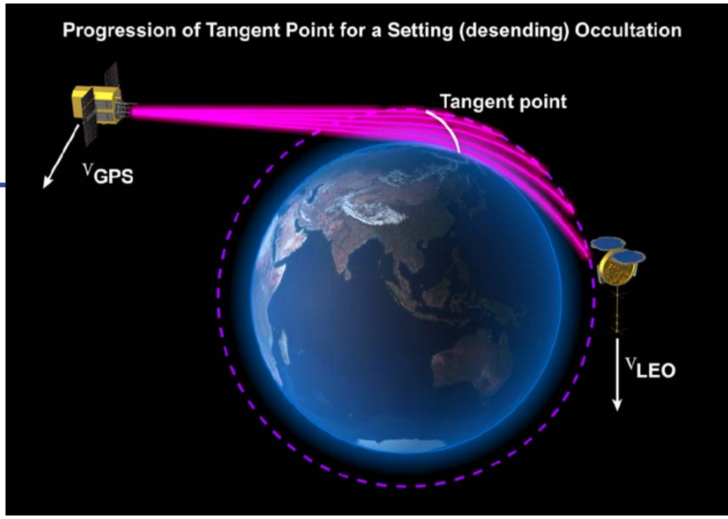
Large negativ impact on 36 to 48 h forecast quality omitting both, Metop-A or all polar obiting satellites

Large phase errors for the fast evolving trough

Smaller pressure gradients resulting in reduced wind speed maxima

Large effects on severe weather warning





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Use of GPS - radio occultation (bending angles) in the 3DVar-Assimilation of GME (since 03. Aug. 2010)

Advantages of GPS radio occultations (bending angles)

- high vertical resolution → even vertical thinning of data required!
- globally accessible, approximately equally spaced
- not influenced by clouds
- measurement of the bending angle is almost bias free, temporally stable, independent from the instrument
- number of profiles is proportional to the product of the sending GNSS-satellites (GPS, Galileo, GLONASS) and receiving LEOs:
  - CHAMP, GRACE-A (research satellites)
  - FORMOSAT-3 / COSMIC (6 research satellites)
  - GRAS (Metop-A)
  - TerraSar, C/NOFS,SAC-C

(H. Anlauf, DWD)

Use of GPS - radio occultation in the 3DVar-Assimilation of GME (~2000 Obs/day)

geopotential in 500 hPa: anomaly correlation of southern hemisphere for July 2010

Strong impact on the SH

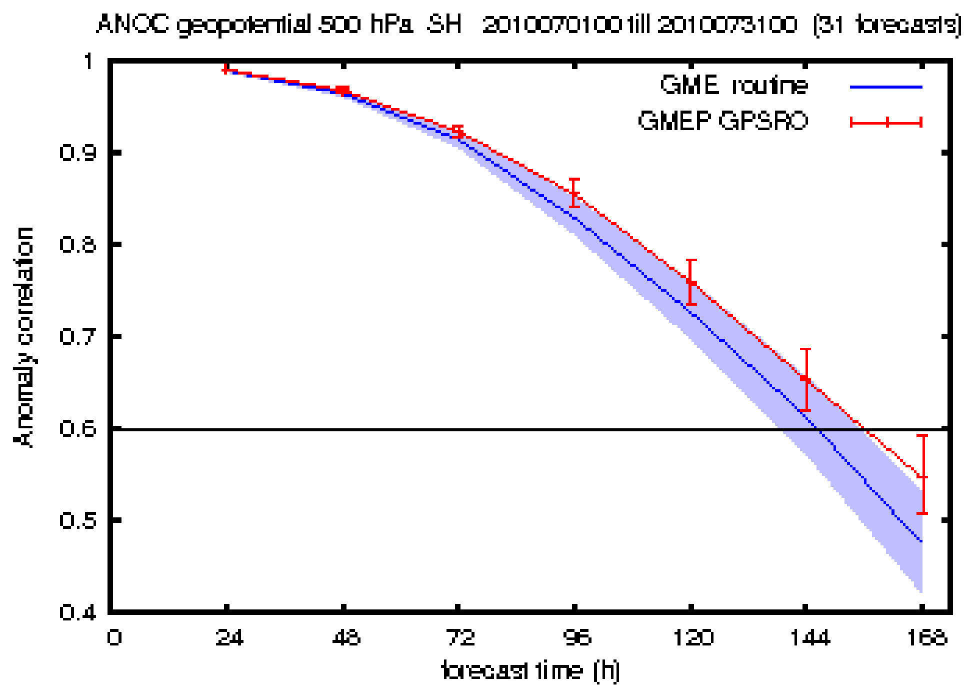
Smaller impact on the NH

Impact strongest in the stratosphere

Large impact on temperature

Minor impact on humidity,
strongest in the upper troposhere

Visible impact also on sea level pressure



AMV impact study

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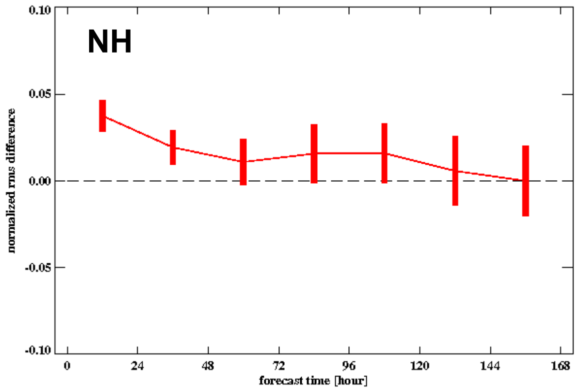
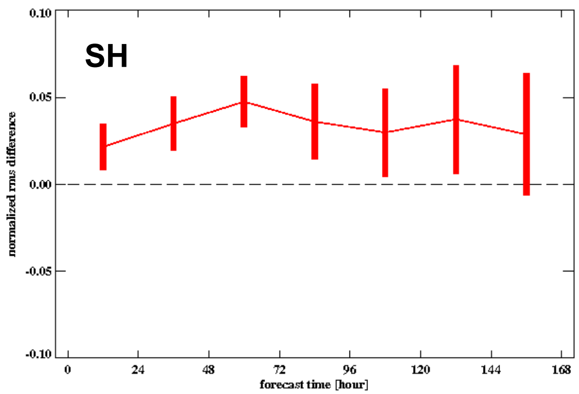
- ➔ Summer and winter period
- ➔ Exp. NoAMV/NoPolarAMV
- ➔ AMV Impact larger for summer than winter
- ➔ Impact highest in Tropics and SH
- ➔ Impact is smaller on NH
- ➔ Impact higher in upper troposhere
- ➔ Impact detectable up to 5 days in summer and up to 3 days in winter on NH
- ➔ On SH impact is 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 regio





Scatterometer impact study

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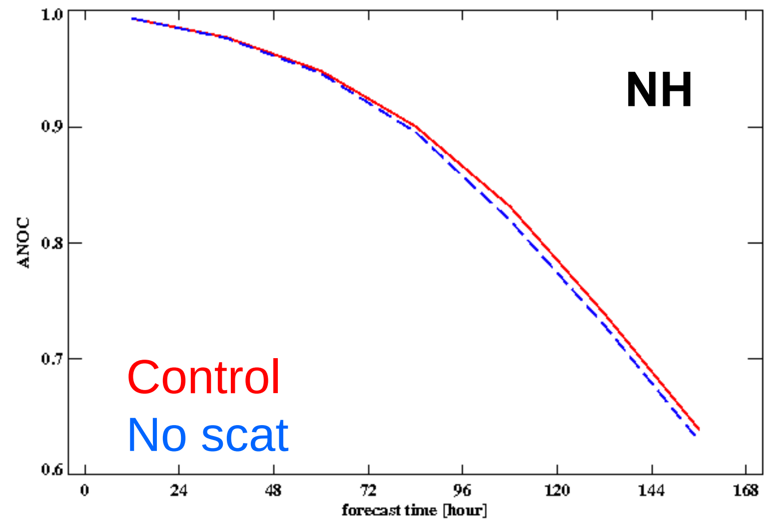
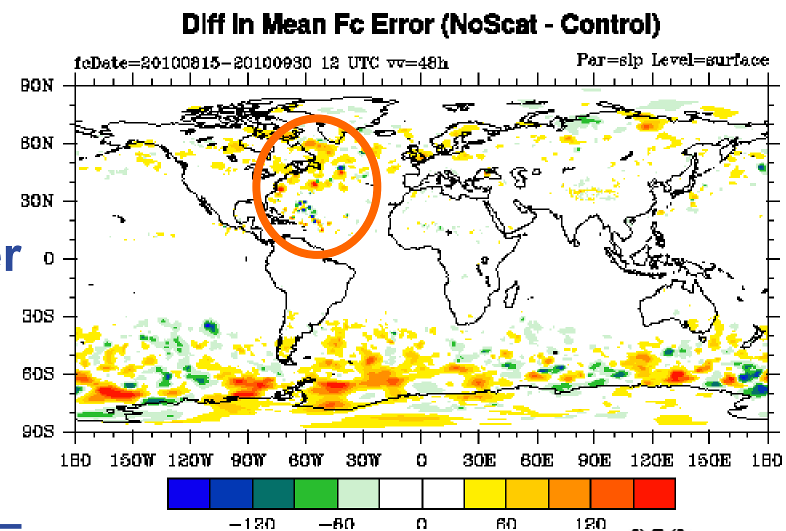
- Experiment: No scatterometer (ASCAT)
- Period: 15 Aug to 30 Sep 2010 (45 forecasts)
- Same summer period as AMV impact study during 2010 Hurricane season
- Consistent positive impact of scatterometer on Northern Hemisphere and Europe for sea surface pressure and wind vector in 850 hPa
- Reduced short range forecast error in North Atlantic off the US east coast
- Positive impact in the tropics up to 72 h
- Neutral impact on the southern hemisphere
- Data quality of Ku-band Seawind scatterometer onboard Oceansat-2 comparable to ASCAT data
- Positive impact up to 72 h forecasts

Sea level pressure





Aircraft humidity sensor

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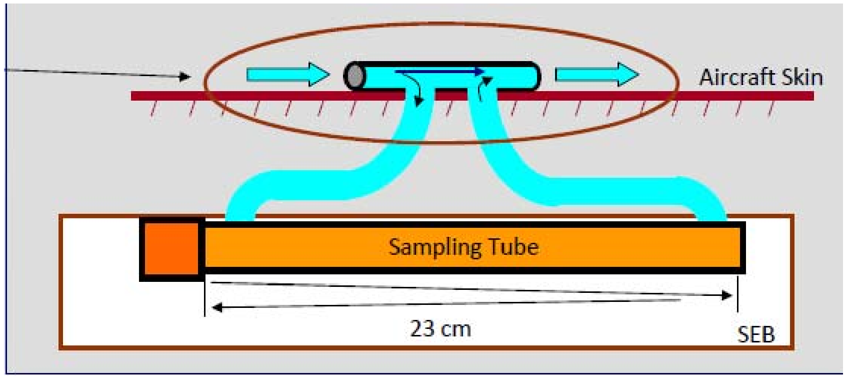
- Humidity sensor name: WVSS-II
- Manufacturer: Spectra Sensors Inc. (USA)
- Sensor principle is based on Beers Law:
  Transmittance (T) is a function of absorption $T=I/I_o = e^{-\sigma lN}$
  where I and I_o are the intensity (power) of the incident light and the transmitted light, respectively; σ is cross section of light absorption by a single particle, N is the density of absorbing particles
- Infrared Absorption Spectrometry "2f-Method by use of Tunable Diode Laser (TDL)
- TDL scans a water vapor absorption band near 1.37 um
- Path length: 23 cm
- Generates every 2 seconds a measurement
- Measures the water vapor mixing ration



AMDAR relative humidity statistics

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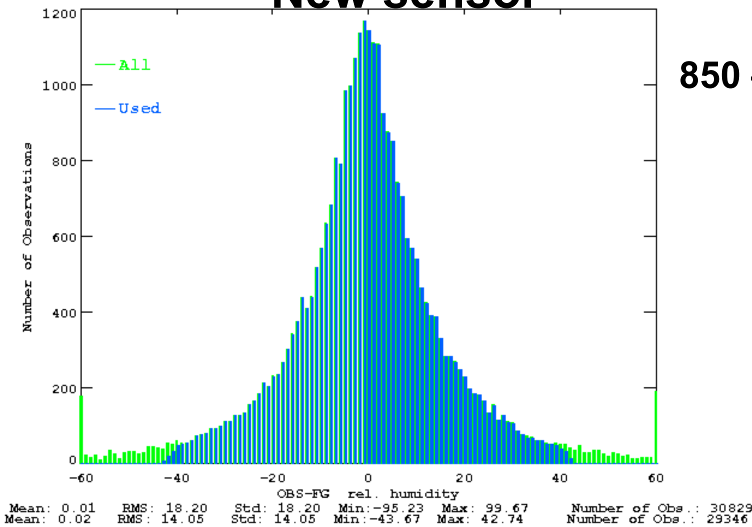
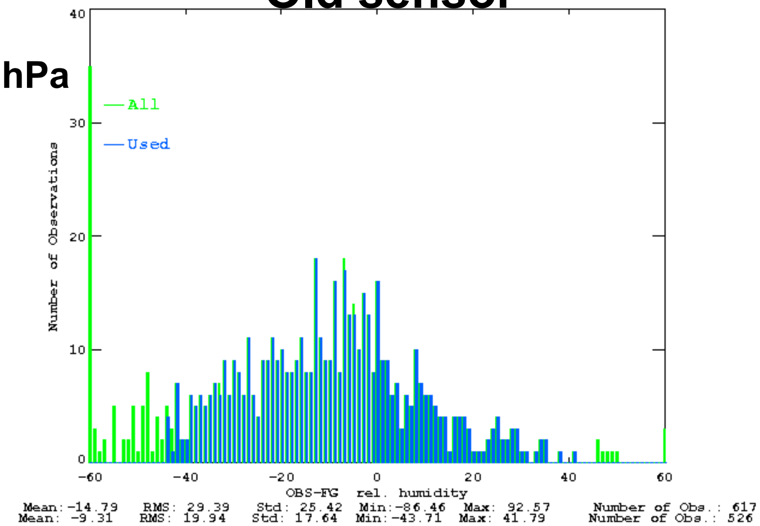
DWD

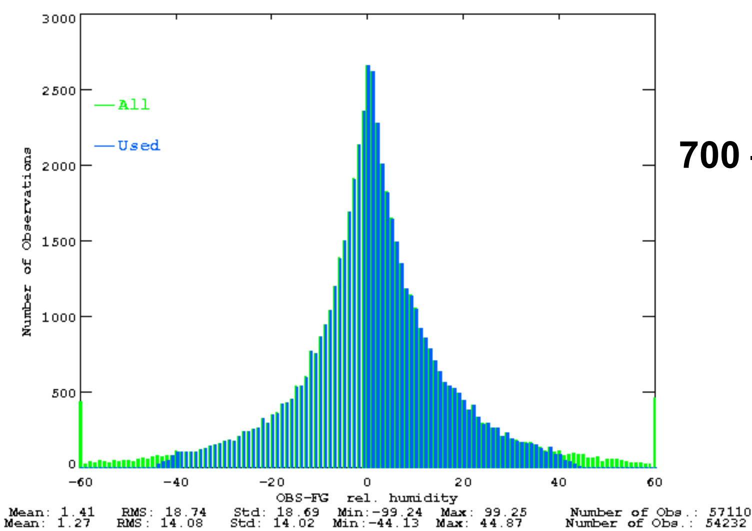
New sensor | **Old sensor**

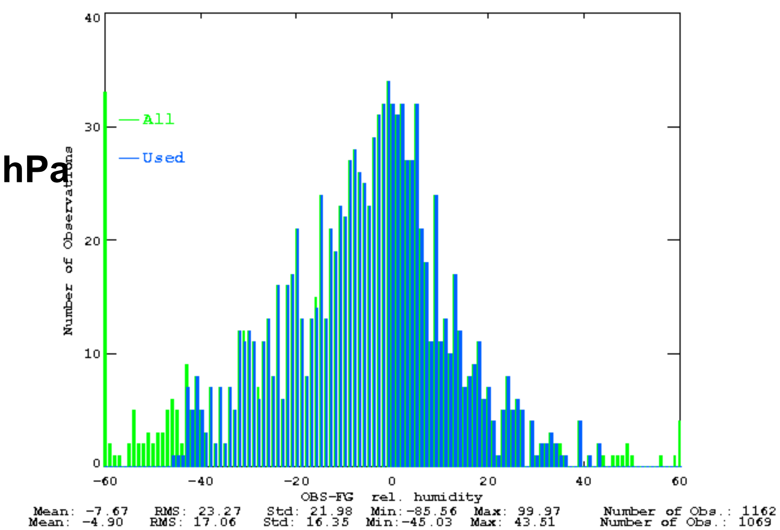
850 – 700 hPa





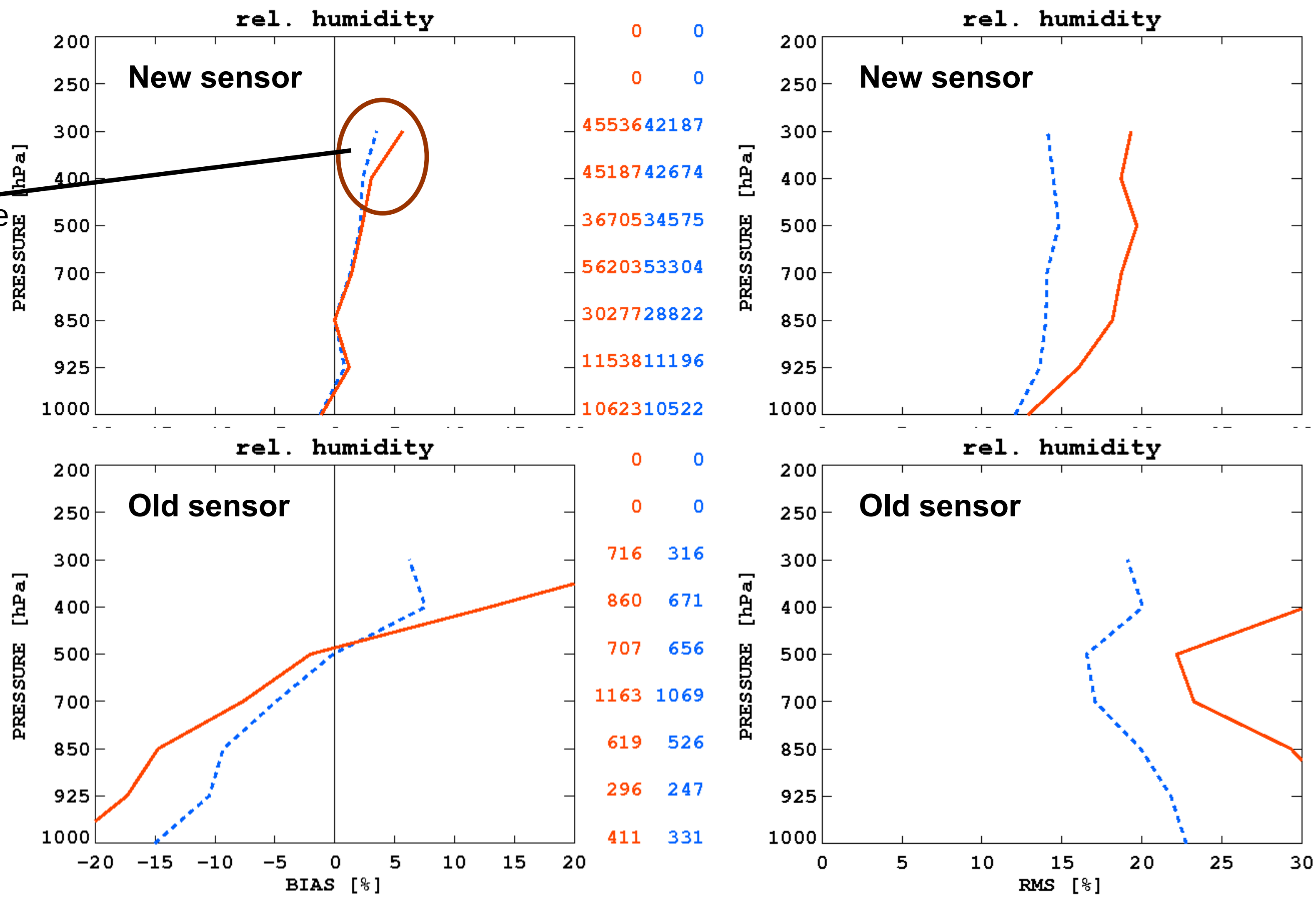
700 – 500 hPa

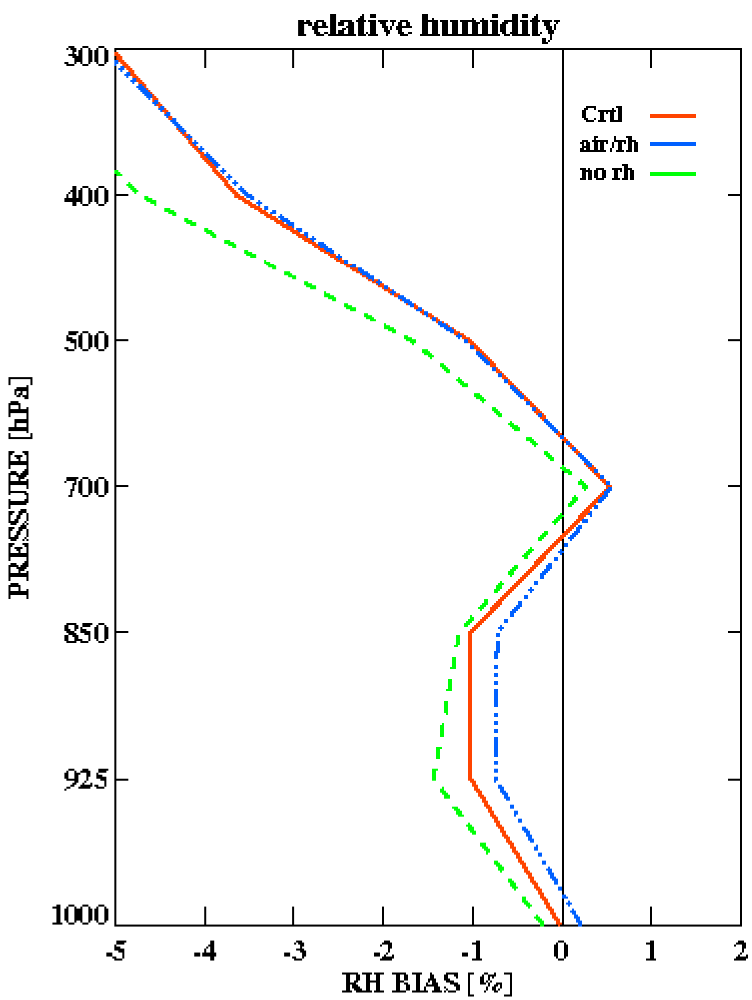


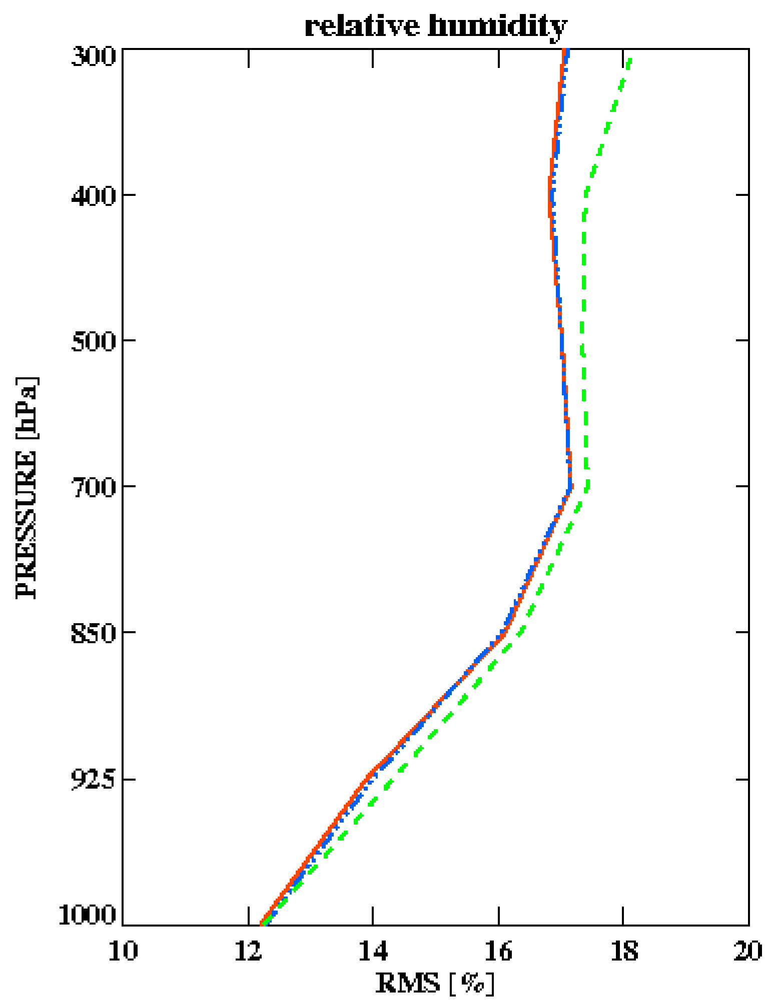


Vertical profiles of Aircraft humidity

Wet Bias in the upper troposphere corresponding to results of serveral reasearch flights by the Met Office




relative humidity
300
400
500
700
850
925
1000
PRESSURE [hPa]
-5
-4
-3
-2
-1
0
1
2
RH BIAS [%]
Crtl
air/rh
no rh


relative humidity
300
400
500
700
850
925
1000
PRESSURE [hPa]
10
12
14
16
18
20
RMS [%]

Forecast Scores N_America
rel. humidity 700 hPa

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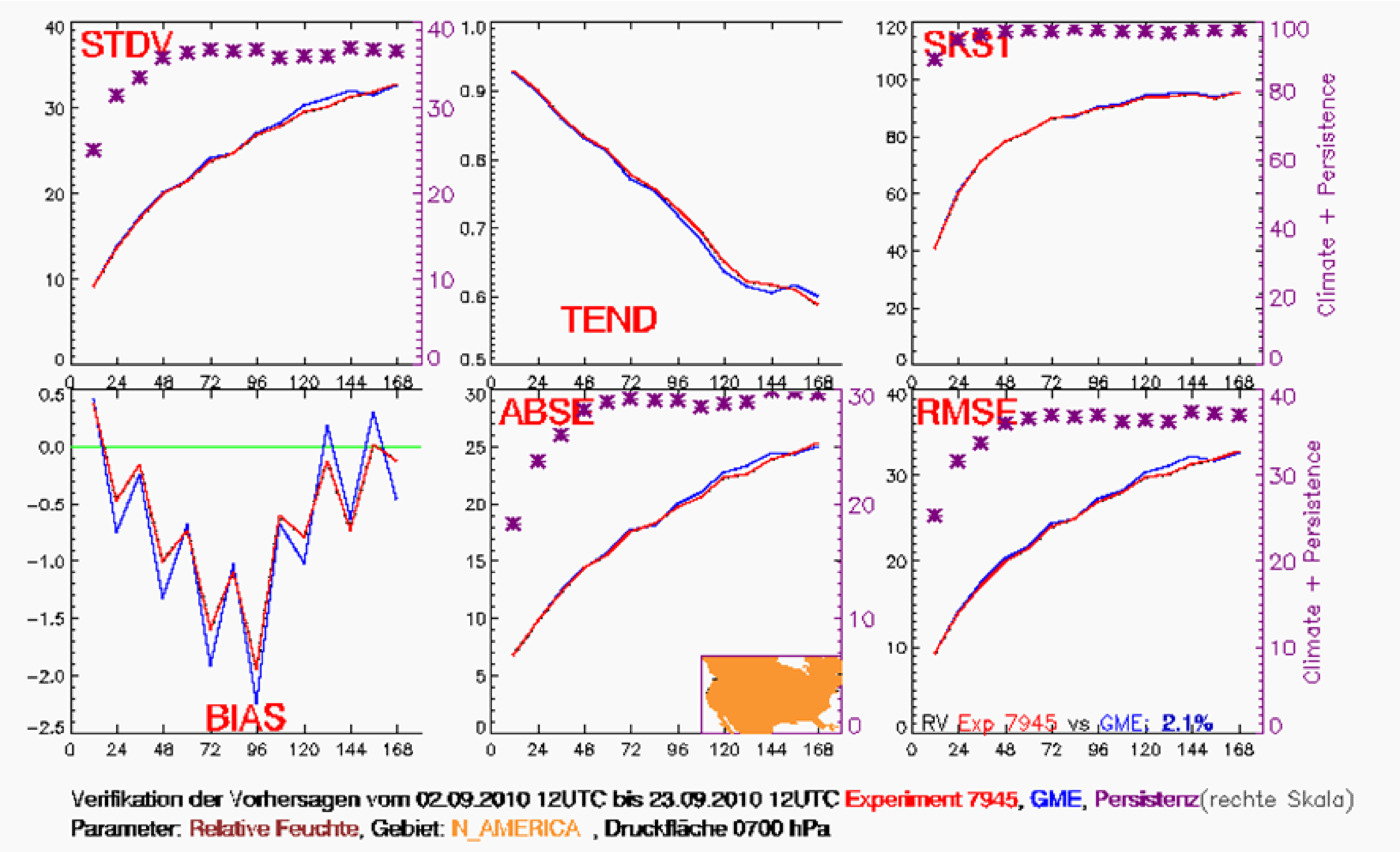

Latent Heat Nudging operational at DWD and MeteoSwiss

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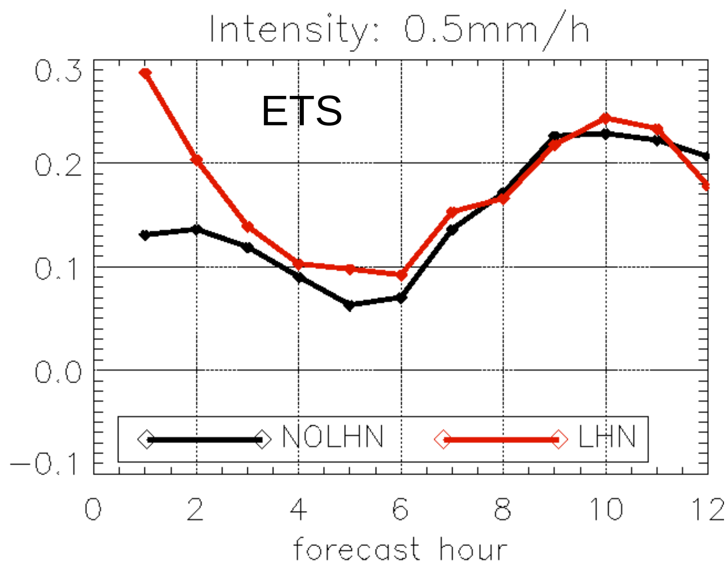
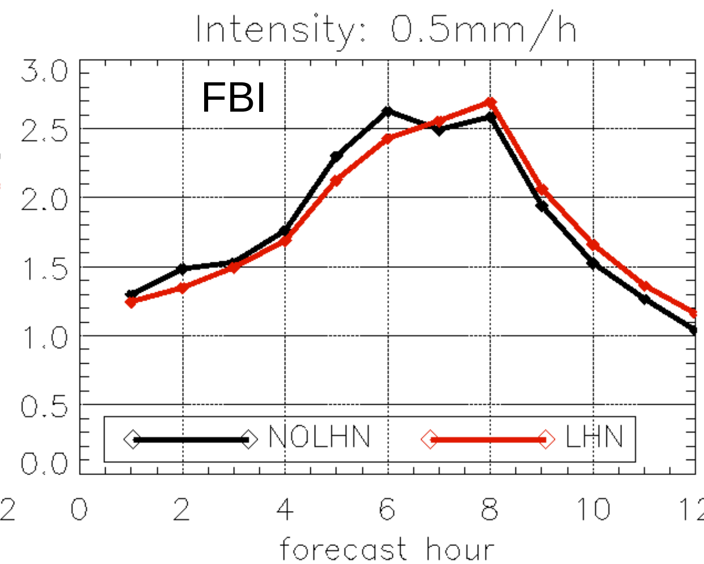
verification of
hourly precipitation
against radar

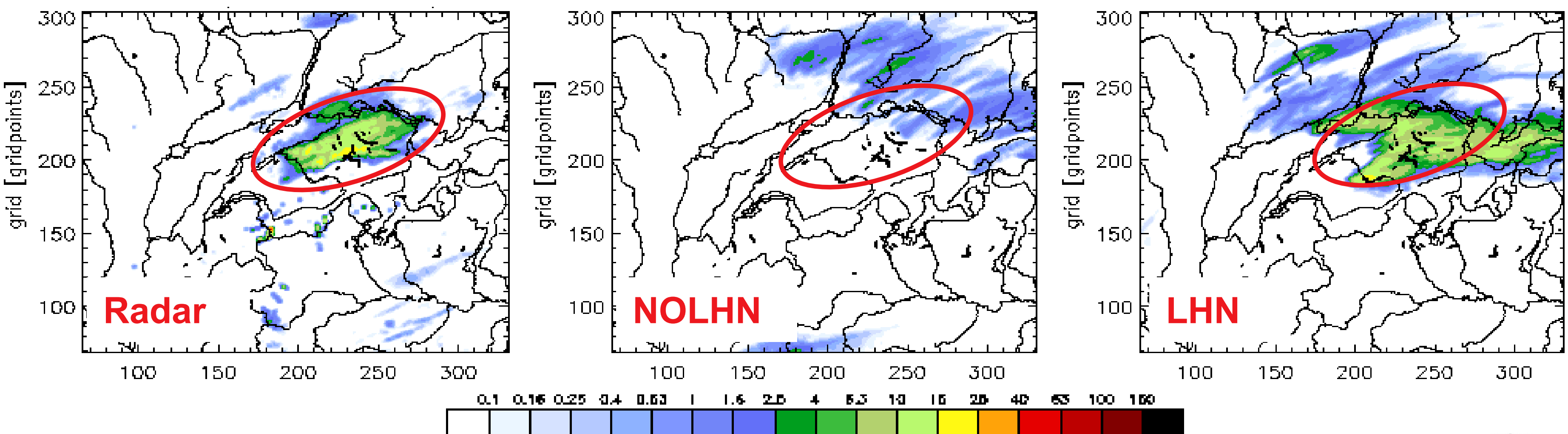
11 – 19 June 2007
(air mass convection)





Verifying Radar

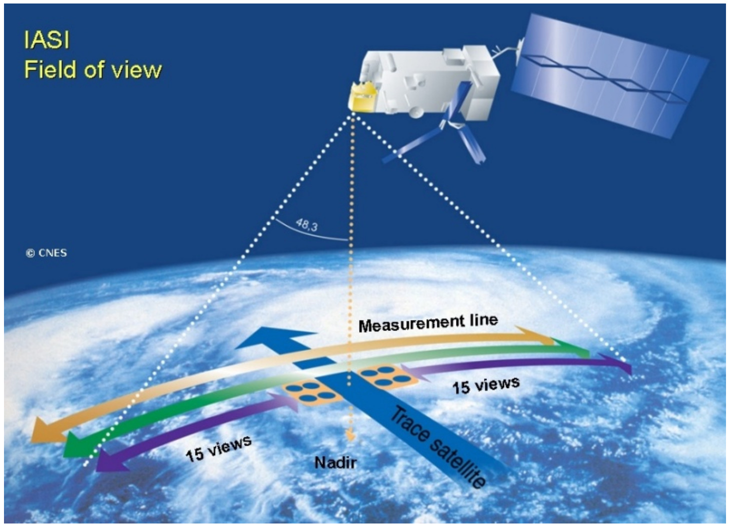
6-12h precipitation forecast (19 June 2007)



Assimilation of IASI Measurements into the COSMO-EU

Michael Schwärz

- Infrared atmospheric sounding interferometer onboard Metop
- IFOV: 3.33° (48 km nadir)
- Swath: +/- 1026 km
- 8461 channels ⇨ 300 channels selected by IC
- Use of RTTOV 9 within 1DVAR
- Bias correction (Harris and Kelly 2001)
- Cloud detection
  a) IASI level 2 cloud flags
  b) after McNelly and Watts (2003)
- Use of temperature and humidity profiles in COSMO EU



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Experiment design

- 215 temperature channels from 15 µm band
- 6.25 µm wv band
- IASI level 2 flags for cloud detection
- COSMO-EU + IASI 1DVAR profiles

Results

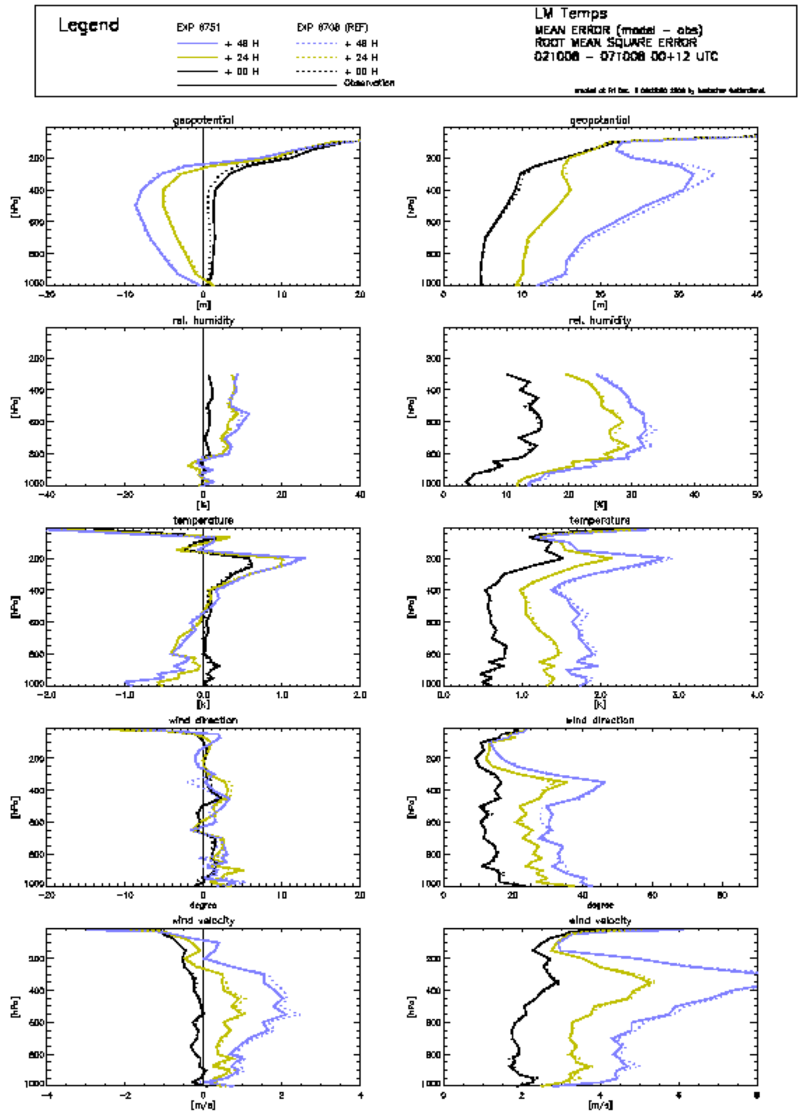
- Data processing and nudging works
- Positive results in upper air verification
- Stronger for RMS than Bias
- Heighest for geopotential height in the upper troposphere and humidity in the middle troposphere

Outlook

Better channel selection

Thinning in COSMO – EU

Use of cloud detection by McNelly and Watts



GNSS humidity observations

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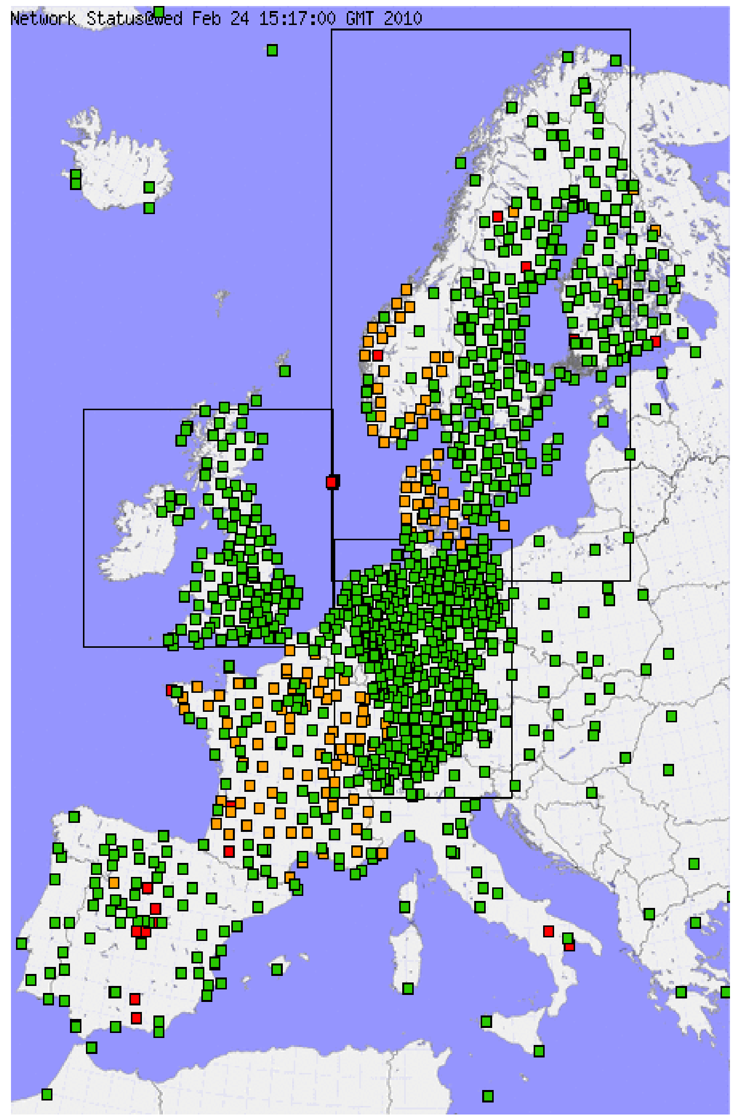
GNSS = Global Navigation Satellite System
- GPS (USA)
- GLONASS (Rusia)
- GALILEO (Europe)
- etc…



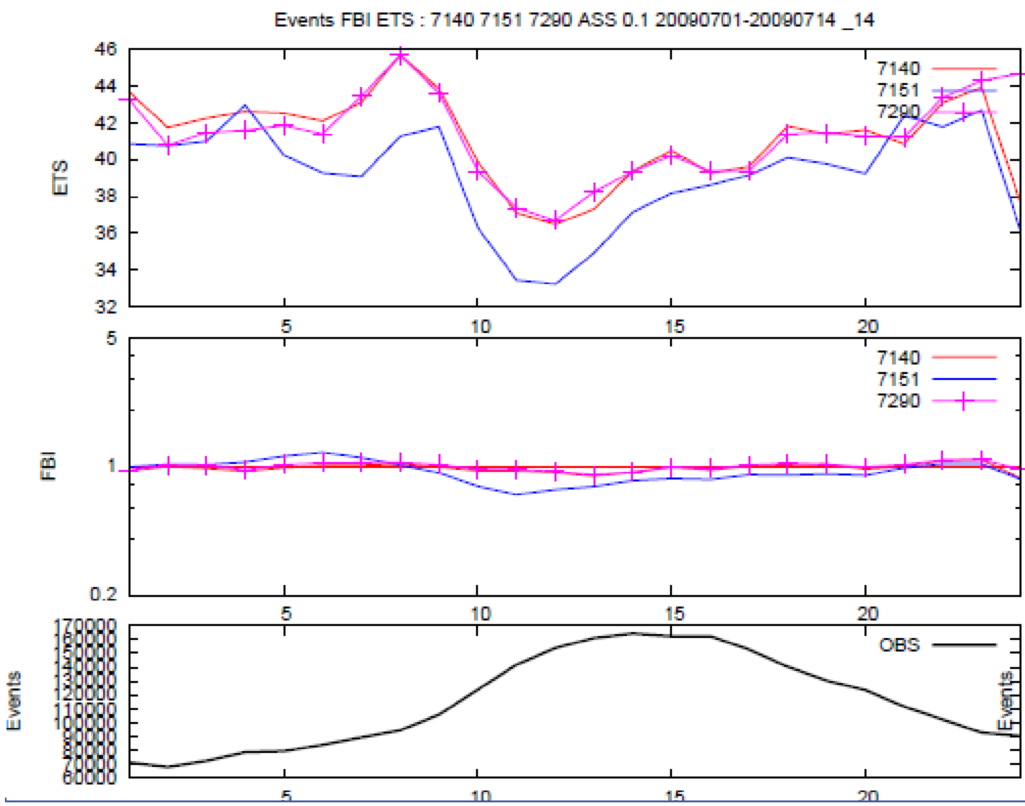
- ➢ Delay in signal due to atmosphere
- ➢ Total Delay (integrated value) can be measured by calculating the time delay between sending and receiving the signal
- ➢ Wet part of the delay is proportional to integrated water vapour (IWV).
- ➢ ZTD is measured and converted to IWV
- ➢ IWV is used by COSMO nudging
- ➢ IWV is converted into humidity by defining an “observed” specific humidity profile
- ➢ Bias correction could be done optionally

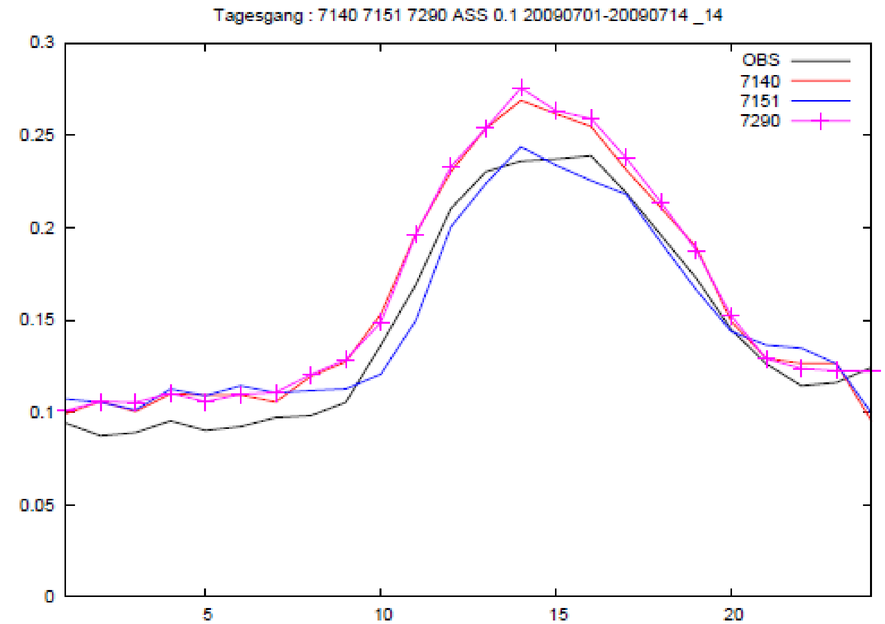
Results Assimilation

Blue = Control run without GPS

Red = Run with `operational` GPS data

Pink = Run with more GPS data (longer store time





Verification of precipitation (14-day-average)

Positiv results in the scores

Still constant bias in diurnal cycle

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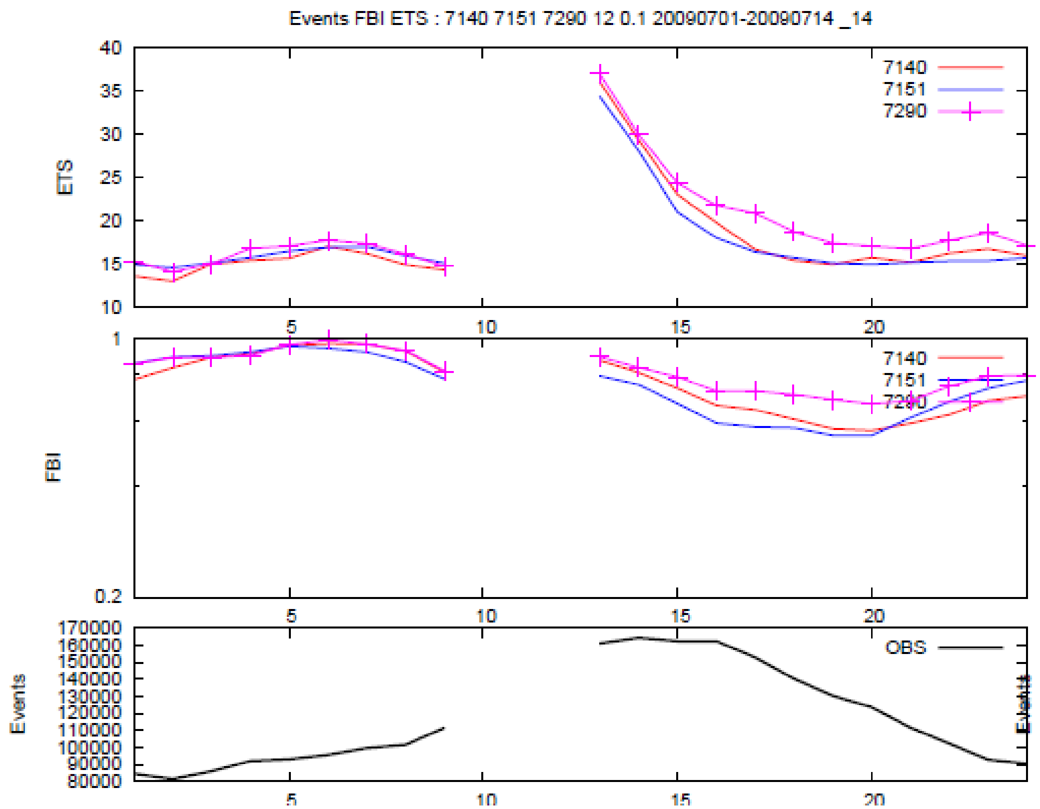
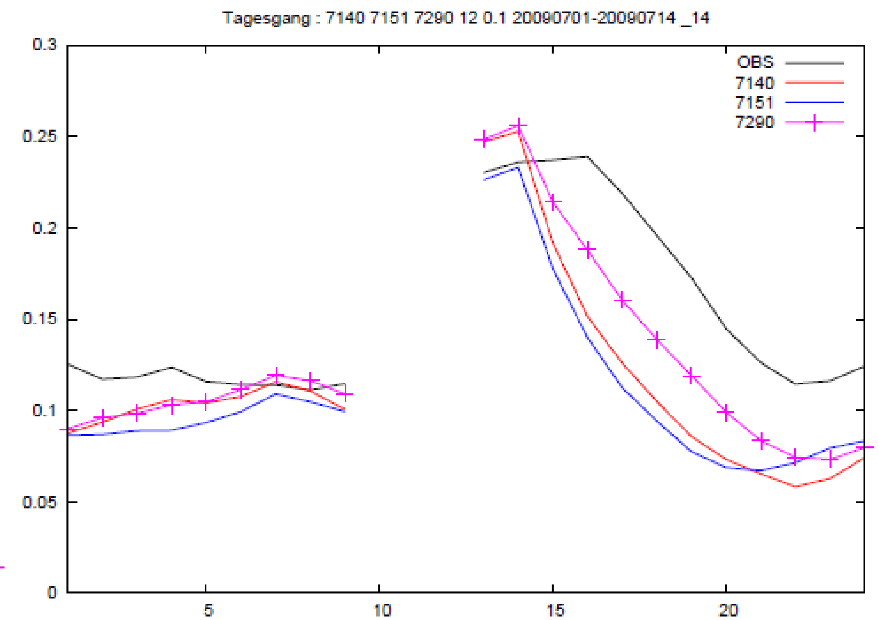
Forecast

Blue = Control run without GPS data

Red = Run with `operational` GPS data

Pink = Run with more GPS data





Verification of precipitation (14-day-average, 21 hour starting at 12 UTC)

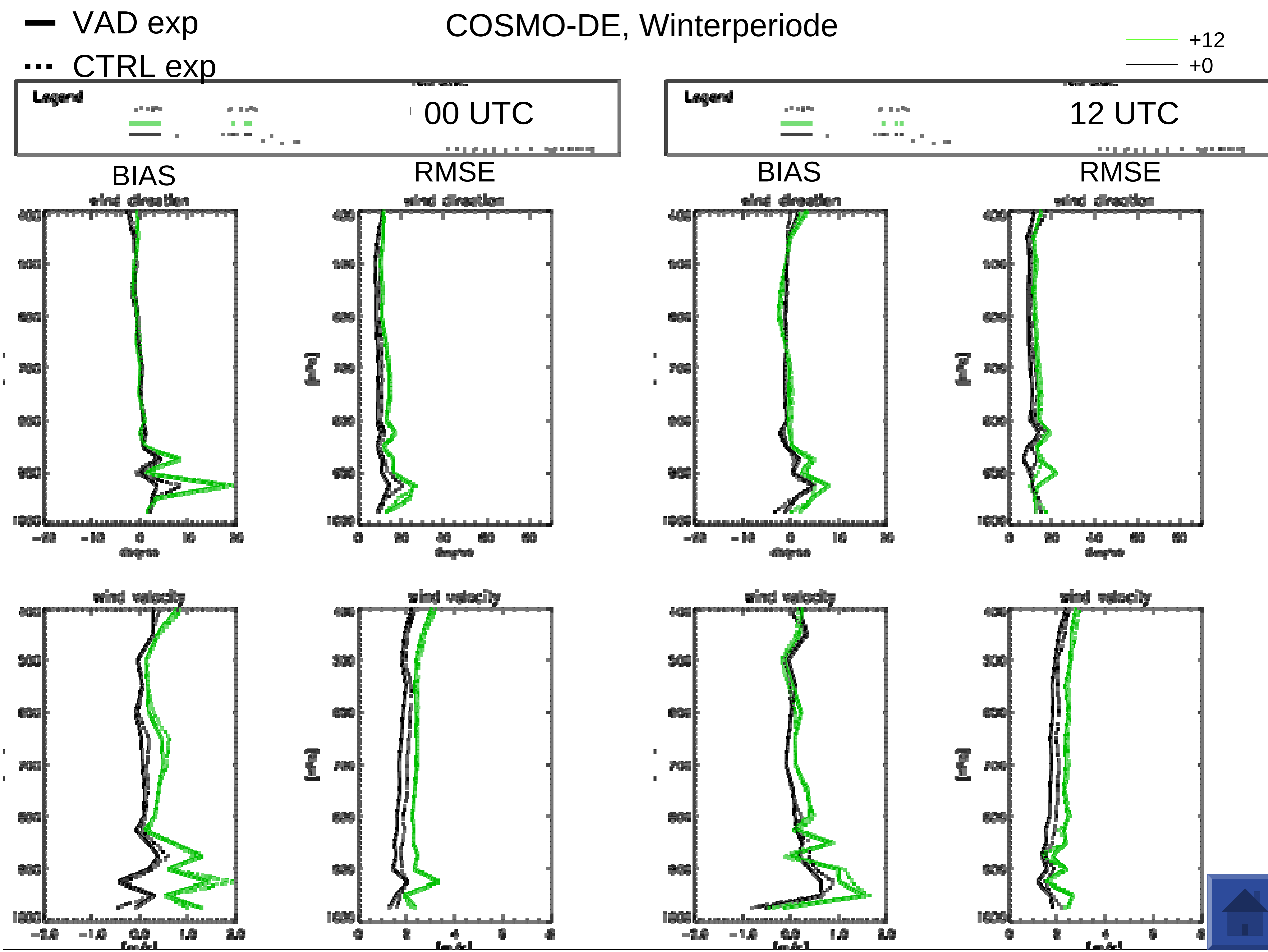
Positiv impact in the scores and the diurnal cycle

Impact of VAD wind profile measurements on the forecast of COSMO-model

Kathleen Helmert (FEZE), Klaus Stephan (FE12)

- VAD stands for Velocity Azimuth Display
- radial wind measured by Doppler radar of a certain elevation is a function of azimuth and range or height
- height will be classified in intervals of about 500 m,
- At each height level a sinus curve is fitted to the measured radial wind components in azimuth
- This gives a value for velocity and direction of the mean wind vector above the radar
- Assumptions behind:
  - homogeneous wind field within the radar domain
  - erroneous measurements have no impact on the fit
    - but clutter (wind miles), aliasing effect the fit!

COSMO-DE, Winterperiode



Time series of sea level pressure observation and analysis at bojie (63643) location

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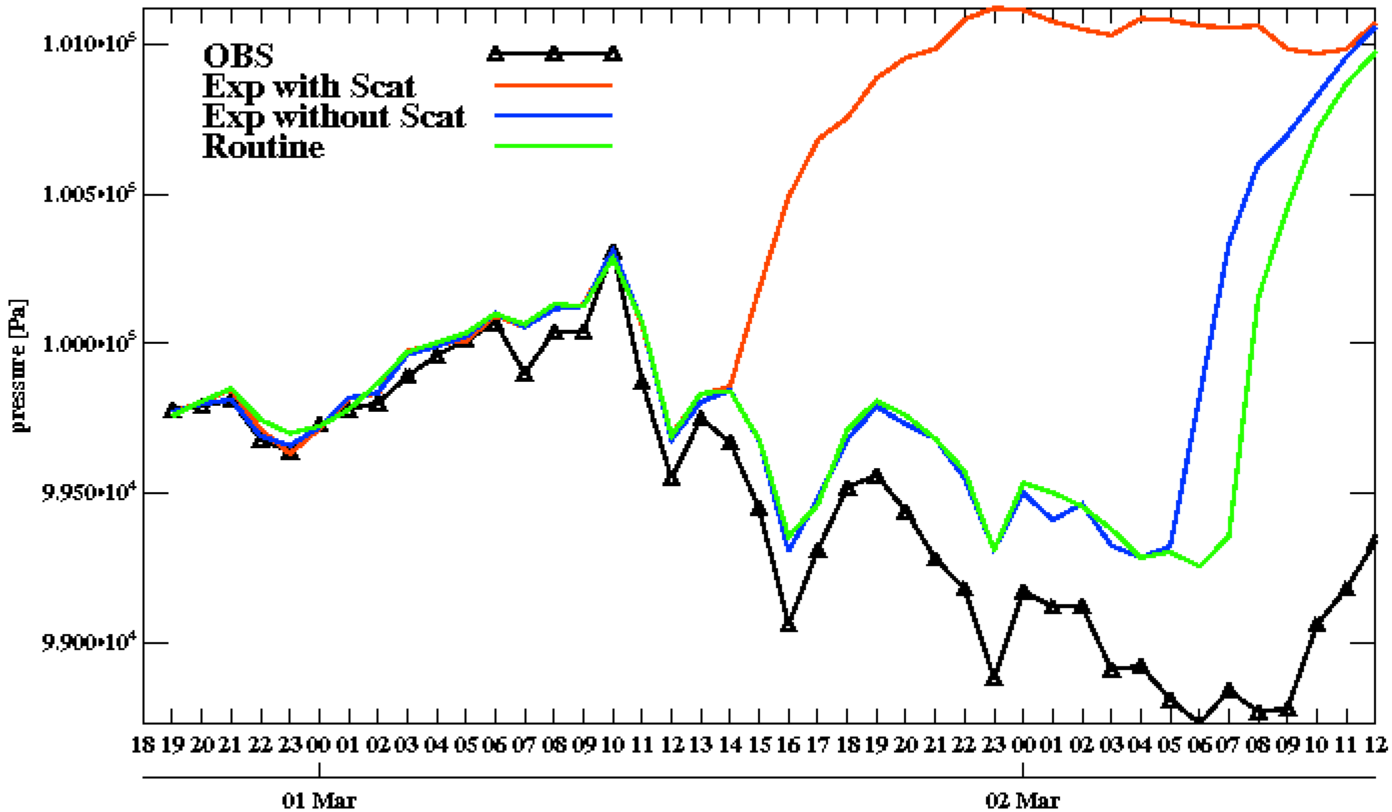
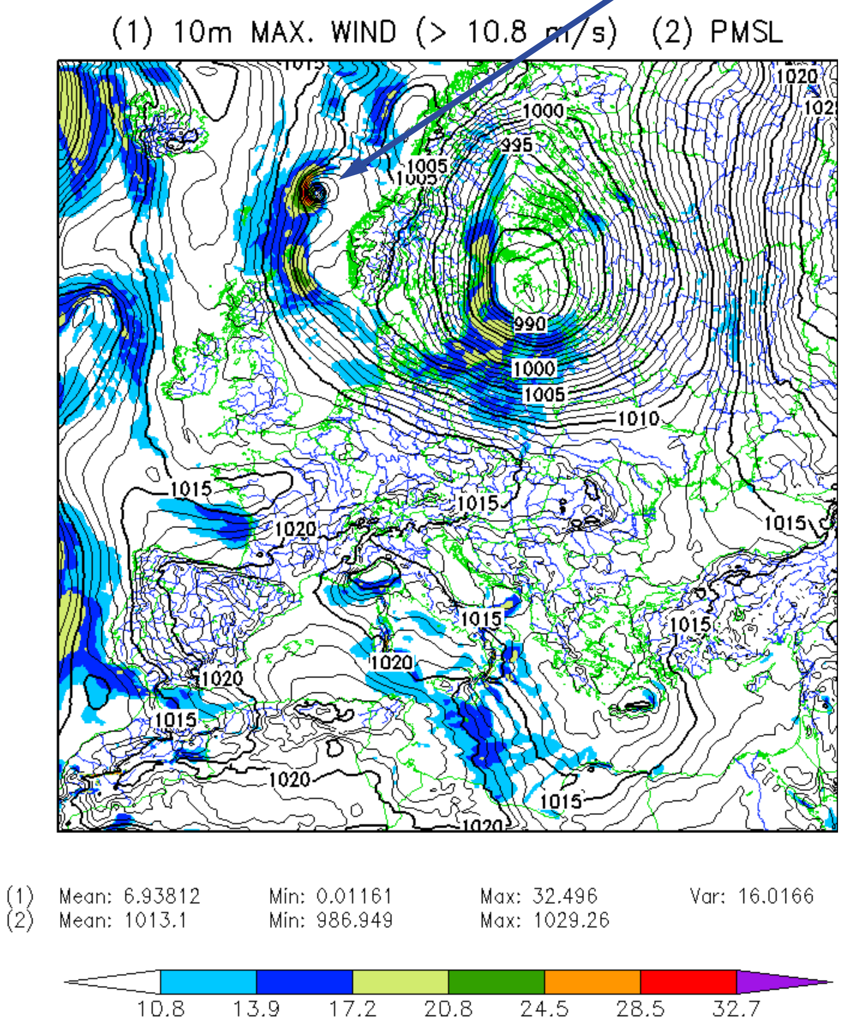
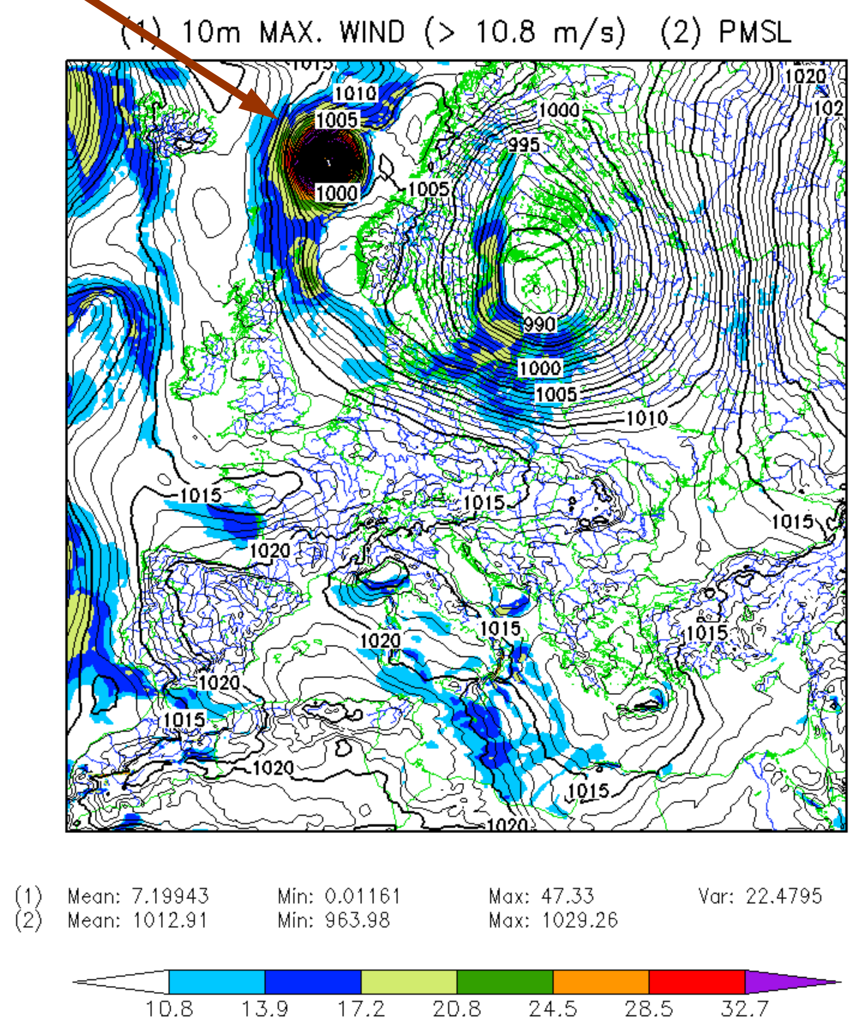
01 March – 02 March 2010



Erroneous low pressure system caused
By a malfunctional bouy





Conclusions I

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- *RS and Aircraft data are very important in our assimilation system*
- *RS more important for short range forecast ~ 3days and aircraft measurements more important for longer range forecasts*
- *Wind information more important than temperature*
- *Impact of wind obs. large around the jet level*
- *Aircraft temperatures have biases*
- *Impact of radiances large on both hemispheres and Europe*
- *Metop-A measurements very important for forecast quality in Europe*
- *Impact of GPS Radio Occultation measurements large on the SH and smaller but consistent on the NH*

Conclusions II

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- ***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***
- ***Positive Impact of scatterometer data in summer hurricane period and also in the limited area model***
- ***Positive impact of radar rain rates up to 6 hours***
- ***General positive impact of GPS ZTD IWV data used (especially in assimilation) in COSMO in summer, still problems in winter***
- ***VAD winds show only small positive impacts but need a careful data selection (data quality is very mixed)***

Recommendation and Questions

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- *Maintain or expand the radiosonde network in remote areas (Siberia, China etc.*
- *Expand aircraft measurements into remote areas (Amdar humidity, TAMDAR over Africa or Eurasian)*
- *Keep at least two polar orbiting satellites with infrared and MW instruments*
- *Operational AMVs over polar regions are required*
- *At least two scatterometer systems on separated orbits are important*
- *Concerning the importance of vertical profiles of wind observations a routine space-borne wind measurement system (lidar) is required*
- *What is the best observations mix concerning humidity observations for convective permitting limited area models ?*
- *What is best mix for wind observations in connection with humidity ?*