Observing system needs for global NWP in terms of information content and forecast impact in the tropics

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Overview

- The Rolling Requirements Review (WMO)
- Observations available for global NWP – the gaps
- Supporting evidence
  - Adjoint-based sensitivity
  - Recent OSE
- Summary

The Rolling Requirements Review (WMO)

- Maintained by the Expert Team on the Evolution of the Global Observing Systems
- Has a section for SPARC, expressing requirements for
  - Aerosol profiles
  - Ozone profiles
  - Temperature profiles
  - Horizontal wind profiles
  - Specific humidity profile
  - Long-wave and shortwave radiation

  For the LT / HT / LS / HS & Mesosphere
- Last updated 28 October 1998
- Merge with Global NWP / Atm. Chemistry / GCOS ?

The Rolling Requirements Review (WMO)

- **Example for SPARC, ozone profiles**

Physical variable	Accuracy Goal/Bk/Threshold			Horizontal resolution Goal/Bk/Threshold			Vertical resolution Goal/Bk/Threshold		
Ozone profile - Higher stratosphere & mesosphere (HS & M)	5 %	6.3 %	10 %	50 km	107.7 km	500 km	0.5 km	0.794 km	2 km
Ozone profile - Higher troposphere (HT)	5 %	6.3 %	10 %	50 km	107.7 km	500 km	0.5 km	0.794 km	2 km
Ozone profile - Lower stratosphere (LS)	5 %	6.3 %	10 %	50 km	107.7 km	500 km	0.5 km	0.794 km	2 km
Ozone profile - Lower troposphere (LT)	5 %	6.3 %	10 %	50 km	107.7 km	500 km	0.5 km	0.794 km	2 km

Global NWP - 3D temperature field

- Profiles available from radiosondes and aircraft over populated land areas; there, horizontal and temporal resolution is acceptable and vertical resolution and accuracy are good.
- Over most of the Earth – ocean and sparsely-inhabited land – coverage of in situ data is marginal or absent.
- Single-level data from aircraft along main air routes
- Polar satellites provide T information with global coverage, good horizontal resolution and high accuracy. Vertical resolution is marginal/acceptable.
- RO: high accuracy and vertical resolution
- In the lower stratosphere: Satellite sounders, RO, radiosondes
- In the tropics: lack of temperature profiling data over land
- Prospects: radiance utilisation over land, RO, aircraft

3D humidity field

- **Trop. profiles available from radiosondes over populated land areas. Hor. and temporal resolution is acceptable / marginal.**
- **Over most of the Earth coverage is marginal or absent.**
- **Polar satellites (and Geo) provide humidity information with global coverage, good horizontal resolution and acceptable accuracy. Vertical resolution is marginal/acceptable.**
- **RO provides good information on the humidity profile in the lower troposphere.**
- **Important TCWV info over ocean from microwave imagers.**
- **<u>In the lower stratosphere</u>: Satellite sounders**
- **<u>In the tropics:</u> lack of humidity profiling data over land, TCWV OK over ocean + MODIS/MERIS over land**
- **<u>Prospects</u>: radiance utilisation over land, RO, GPS, aircraft**

3D wind field (horizontal component)

- Profiles available from radiosondes, pilot balloons, aircraft, wind profilers and radars over populated land areas
- In these areas, horizontal and temporal coverage is acceptable and vertical resolution is good; elsewhere poor
- Single-level data from aircraft, satellite winds (AMVs). Horizontal and temporal resolution is acceptable or good, but vertical coverage is marginal.
- <u>In the lower stratosphere</u>: only radiosondes provide wind information.
- <u>In the tropics:</u> severe lack of wind profile data
- <u>Prospects</u>: DWL, aircraft, AMVs from adv. GEO imagers

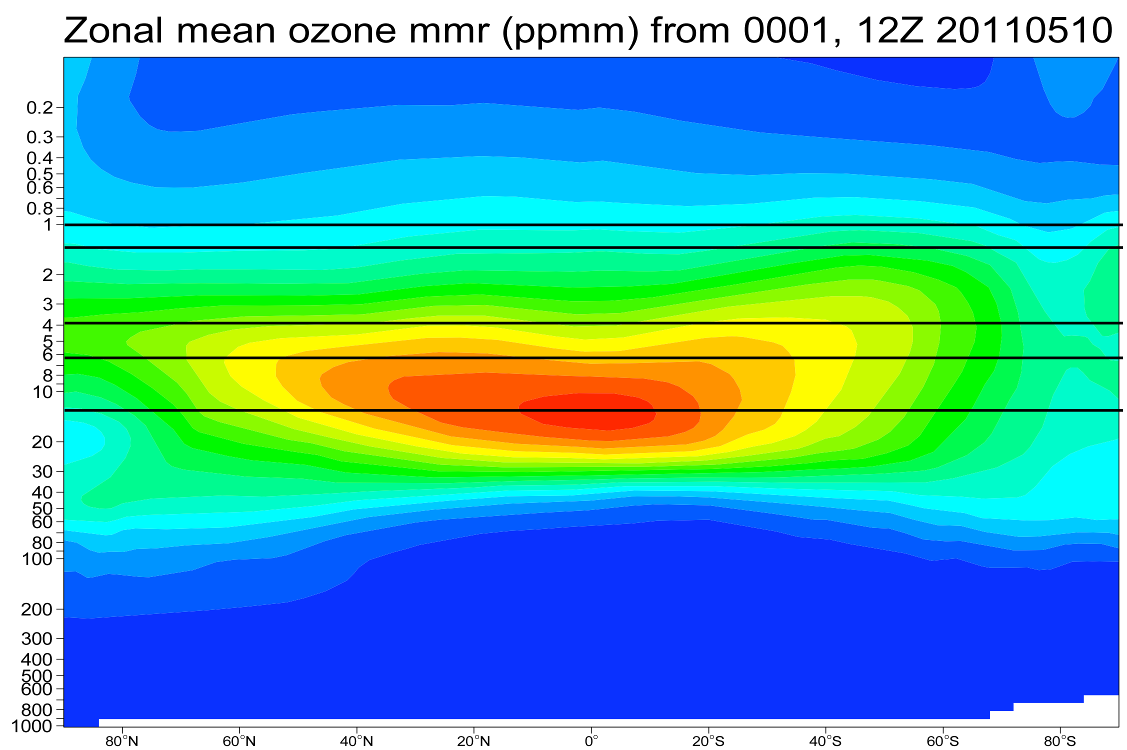
3D ozone field

- Profiles available from ozone sondes, once a week, widely spaced, in non-real time
- Satellite instruments provide total column ozone with acceptable accuracy.

- In the lower stratosphere: IR satellite sounders and solar backscatter instruments
- In the tropics: as above
- Prospects: Microwave limb sounders offering good vertical resolution and accuracy.

Optimization of the assimilation of the SBUV ozone data: 6 vs. 21 layers

- The V8 SBUV are available on 21 levels (Δz ~ 6km in the troposp., and 3km in the stratosp.), then combined into 6 layer product (Vertical correlations).
- T511 L91 (CY36R4)
- Dec 2010 – Jan 2011



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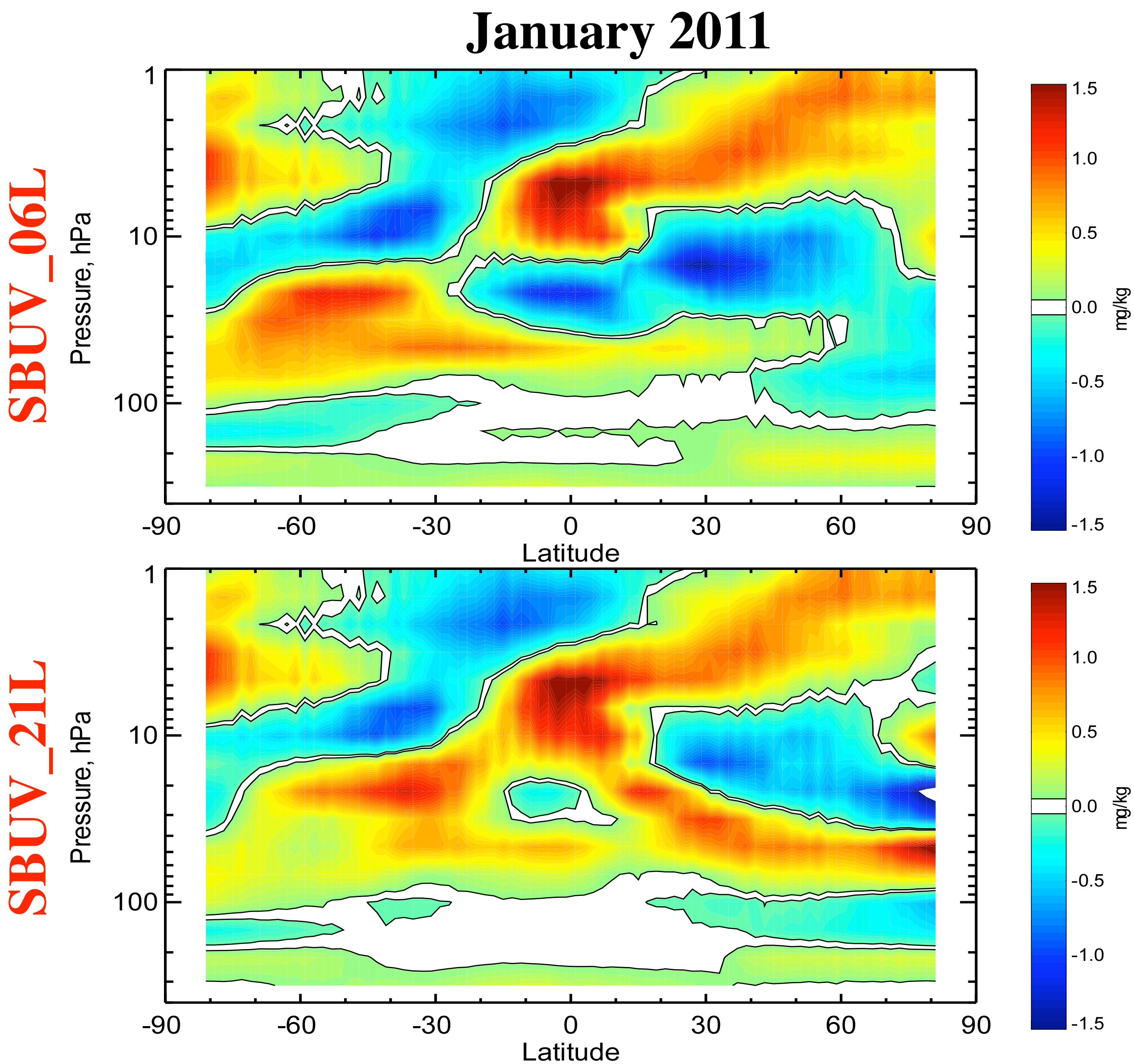
Comparisons with indep data: MLS$^{(v2.2)}$- An



☑ **Improve fit to MLS:**

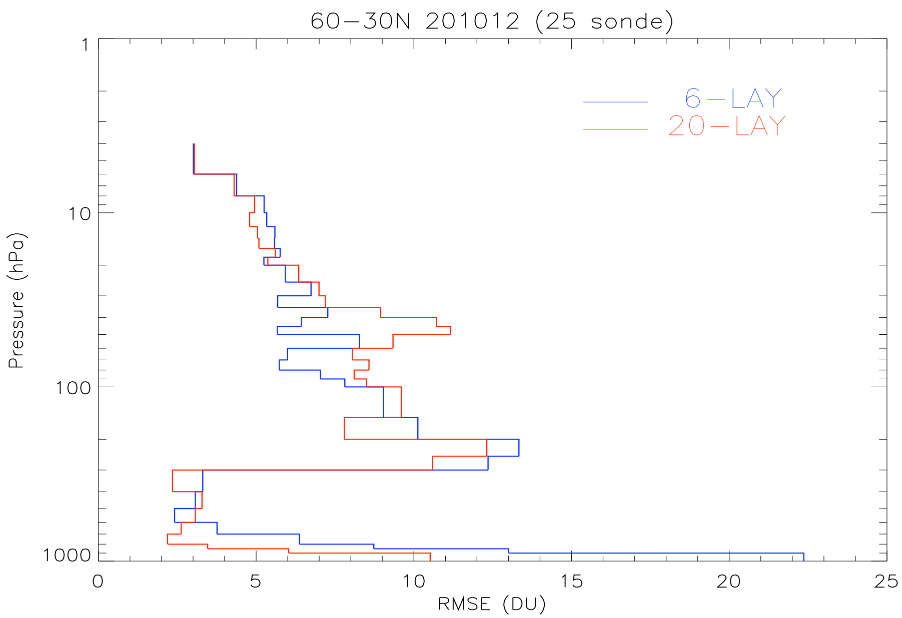
- **Lower tropical stratosphere**
- **In the summer hemisphere (SH)**
- **Upper stratosphere in the NH**

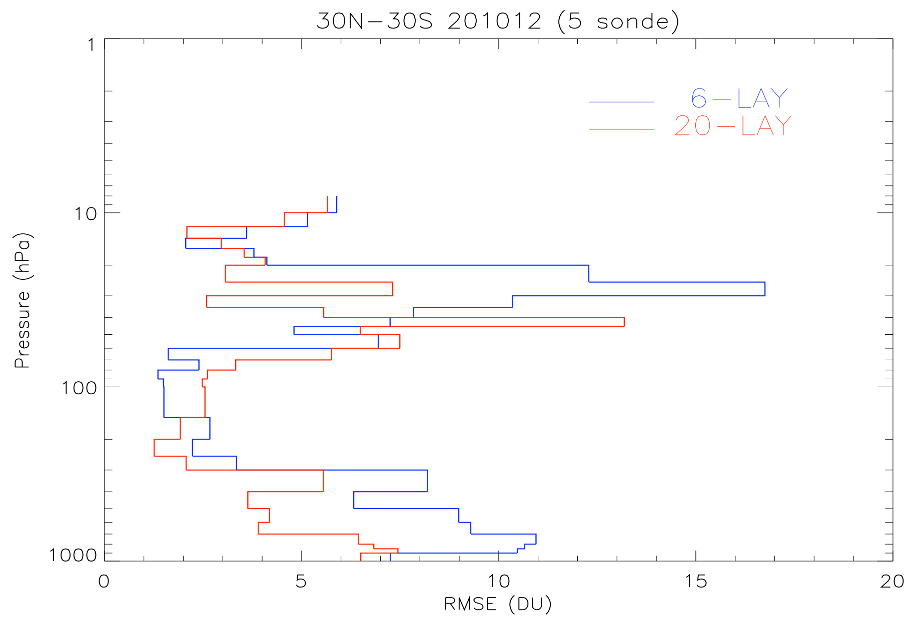
❑ **Neutral in the upper tropical stratosphere**

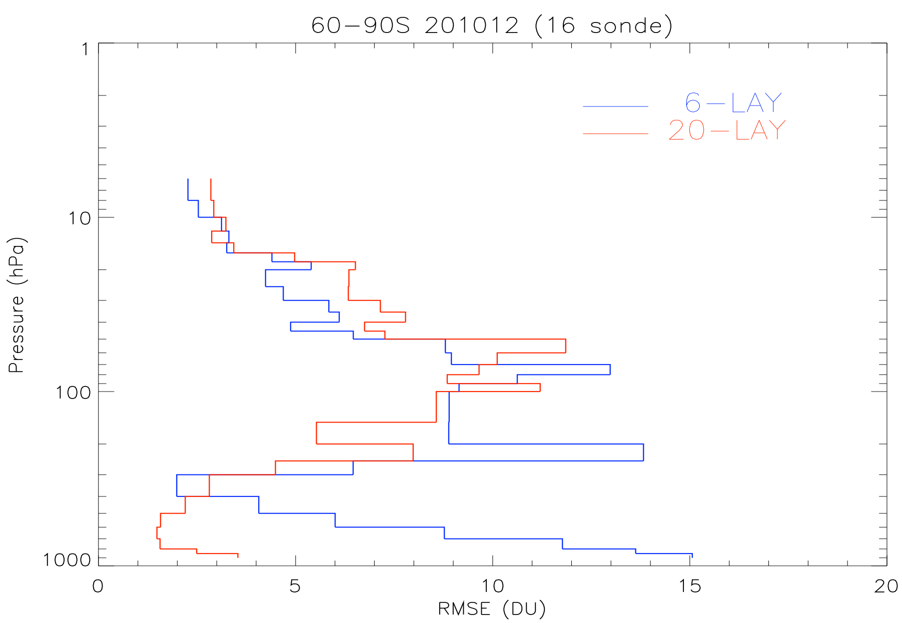
☒ **Reduce fit to MLS:**

- **Lower and mid stratosphere at HL NH.**

Comparisons with independent data: sondes







- ☑ **Improve fit to sondes:**
  - **Lower tropical stratosphere (=MLS)**
  - **In the summer hemisphere (HL SH)**
- ☐ **Neutral at most levels at midlatitudes in the NH.**
- ☒ **Reduce fit to sondes in the lower strat. at HL SH and ML NH.**

Other important quantities for global NWP

- Surface wind: Scatterometers
- SST: Microwave and IR radiances
- Clouds: Good observations, poor assimilation

- Precipitation: Rain gauges, radar, microwave imagers
- Soil moisture: ASCAT (SMOS/SMAP)
- Aerosol: MODIS
- Snow: Surface stations, Microwave and visible imagery

Global NWP – main identified gaps

- The critical atmospheric variables that are not adequately measured by current or planned systems are (in order of priority):
  1. wind profiles at all levels;
  2. temperature and humidity profiles of adequate vertical resolution in cloudy areas, and over land in the tropics
  3. precipitation;
  4. vertically resolved ozone;
  5. (snow mass.)

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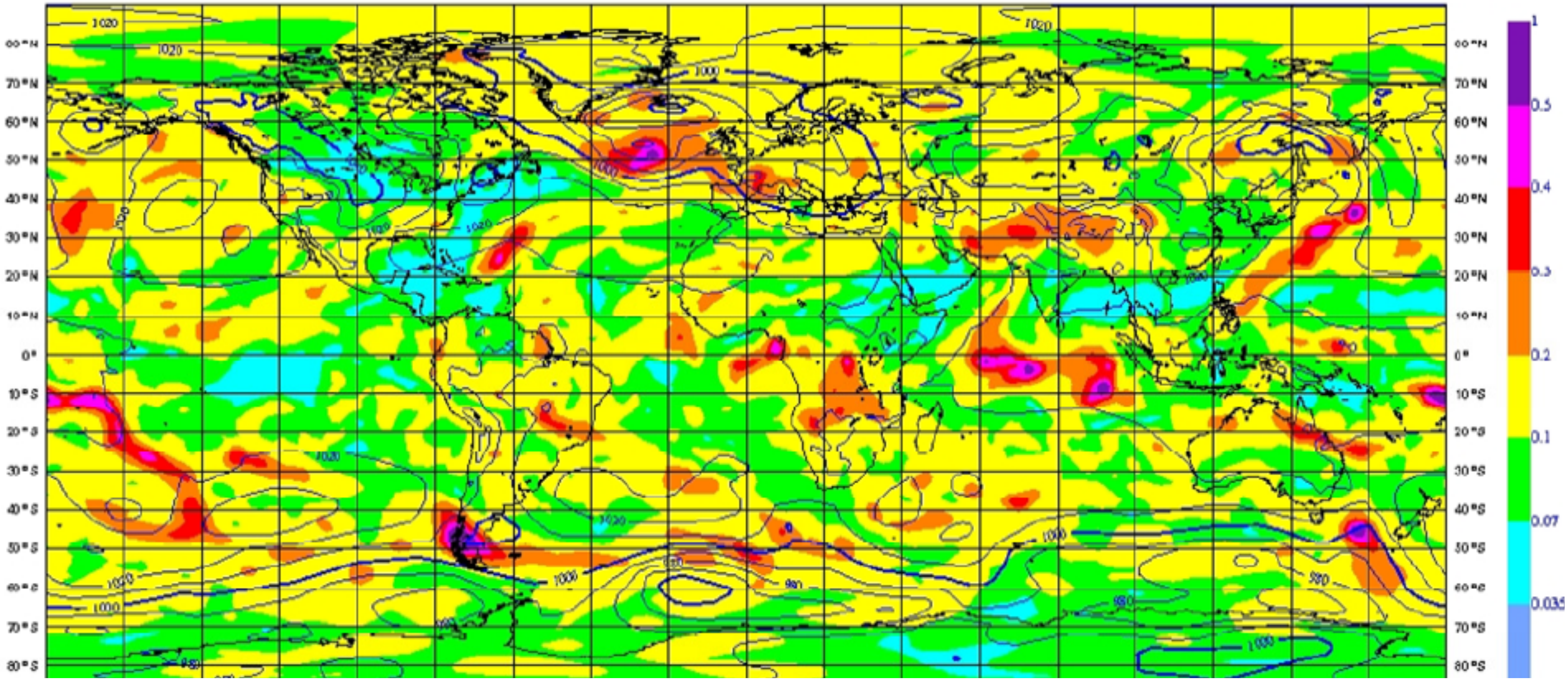
Vorticity St.dev at 500 hPa, 50-member EDA



- 24 January 2009, 09 UTC

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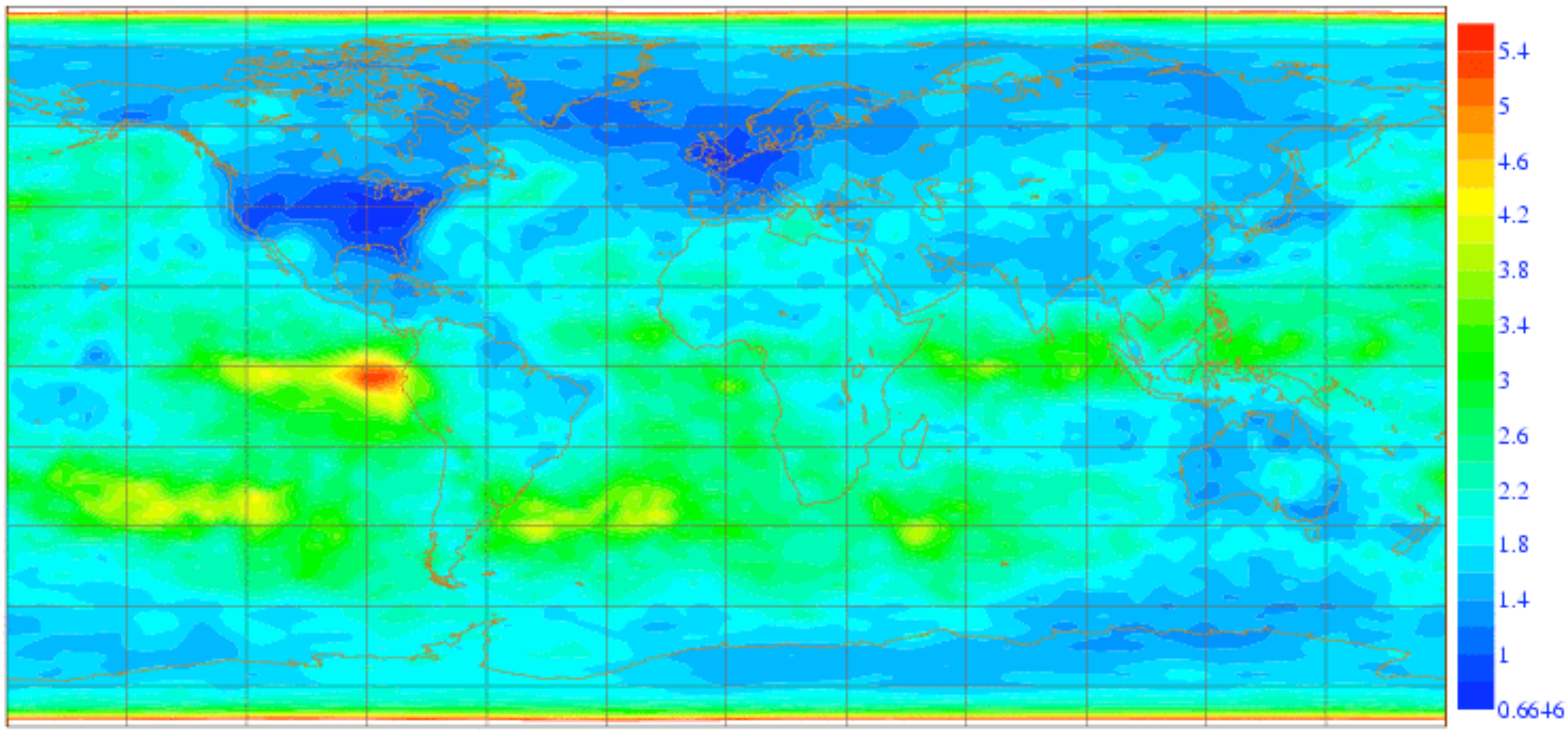
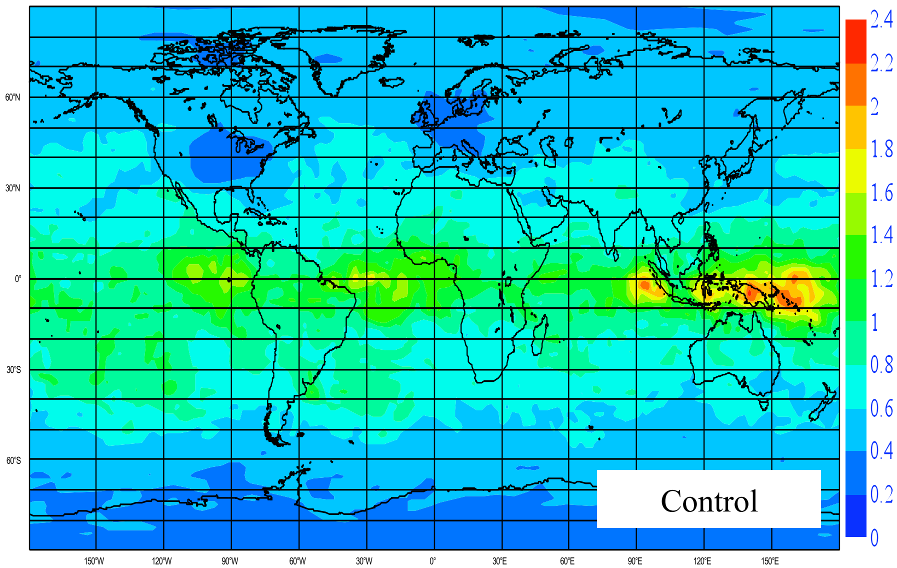
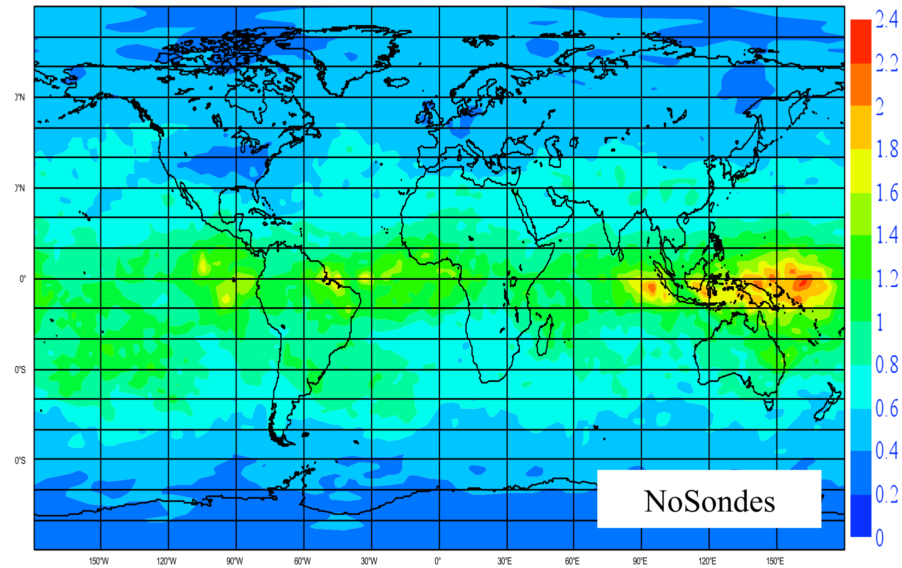
Analysis spread, a measure of analysis uncertainty
200 hPa, u-component wind

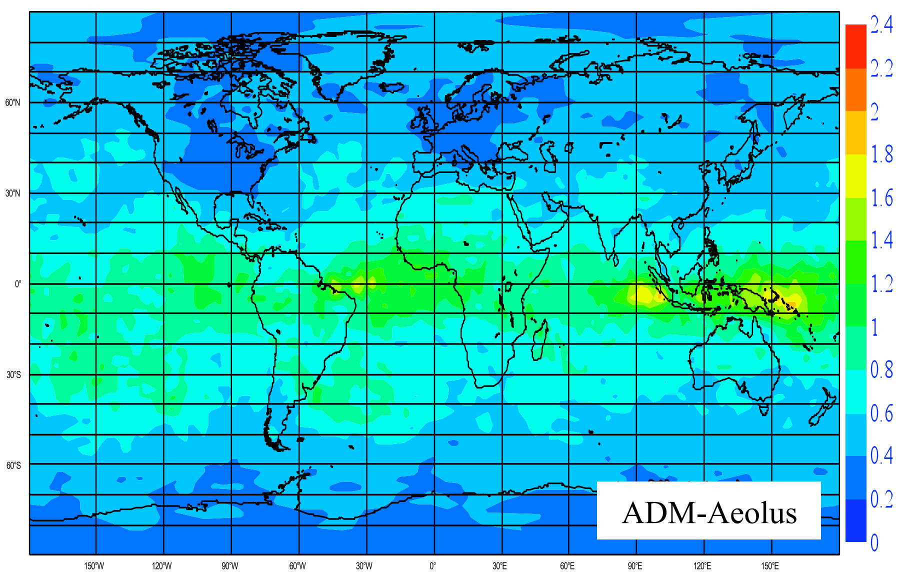


- Ensemble of 10 assimilations, over 31 days of October 2000

ADM impact on ensemble An: U-comp spread at 200 hPa

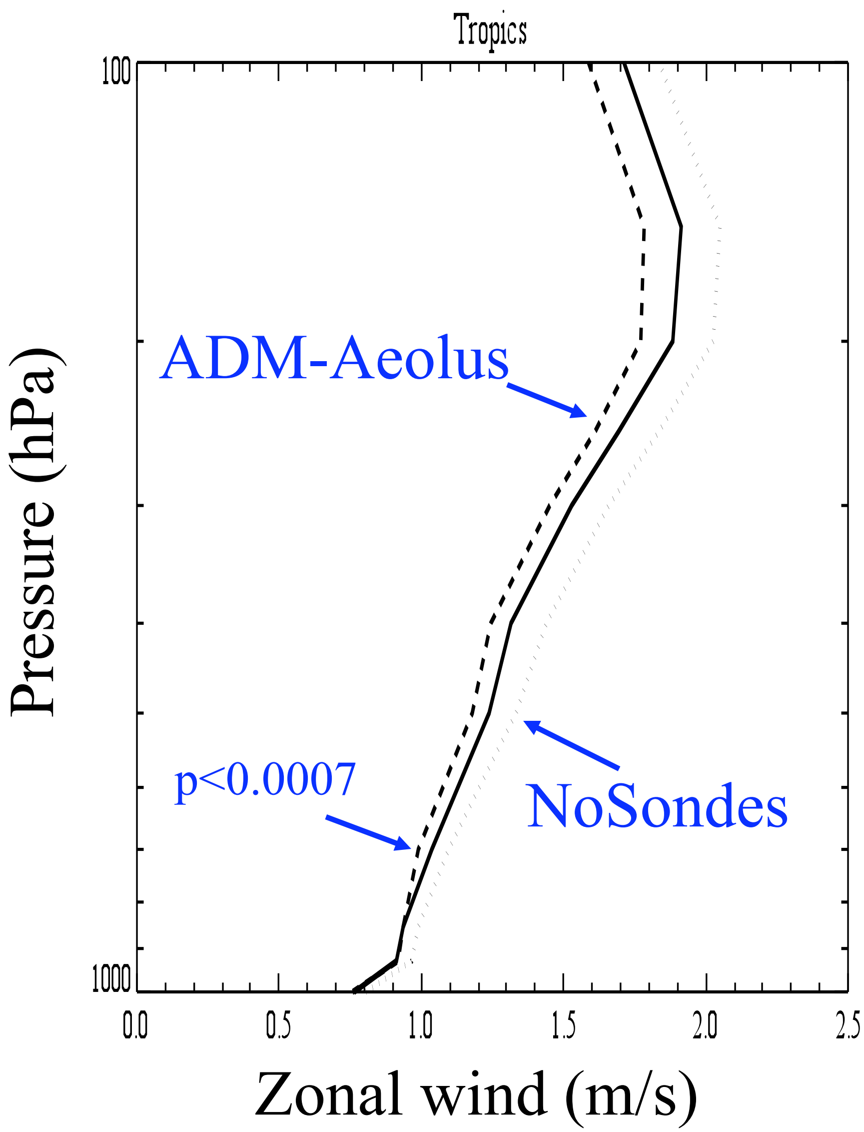






- Radiosondes and wind profilers over N.Amer, Japan, Europe, Australia
- DWL over oceans and tropics

Profiles of 12-hour FC impact, Tropics



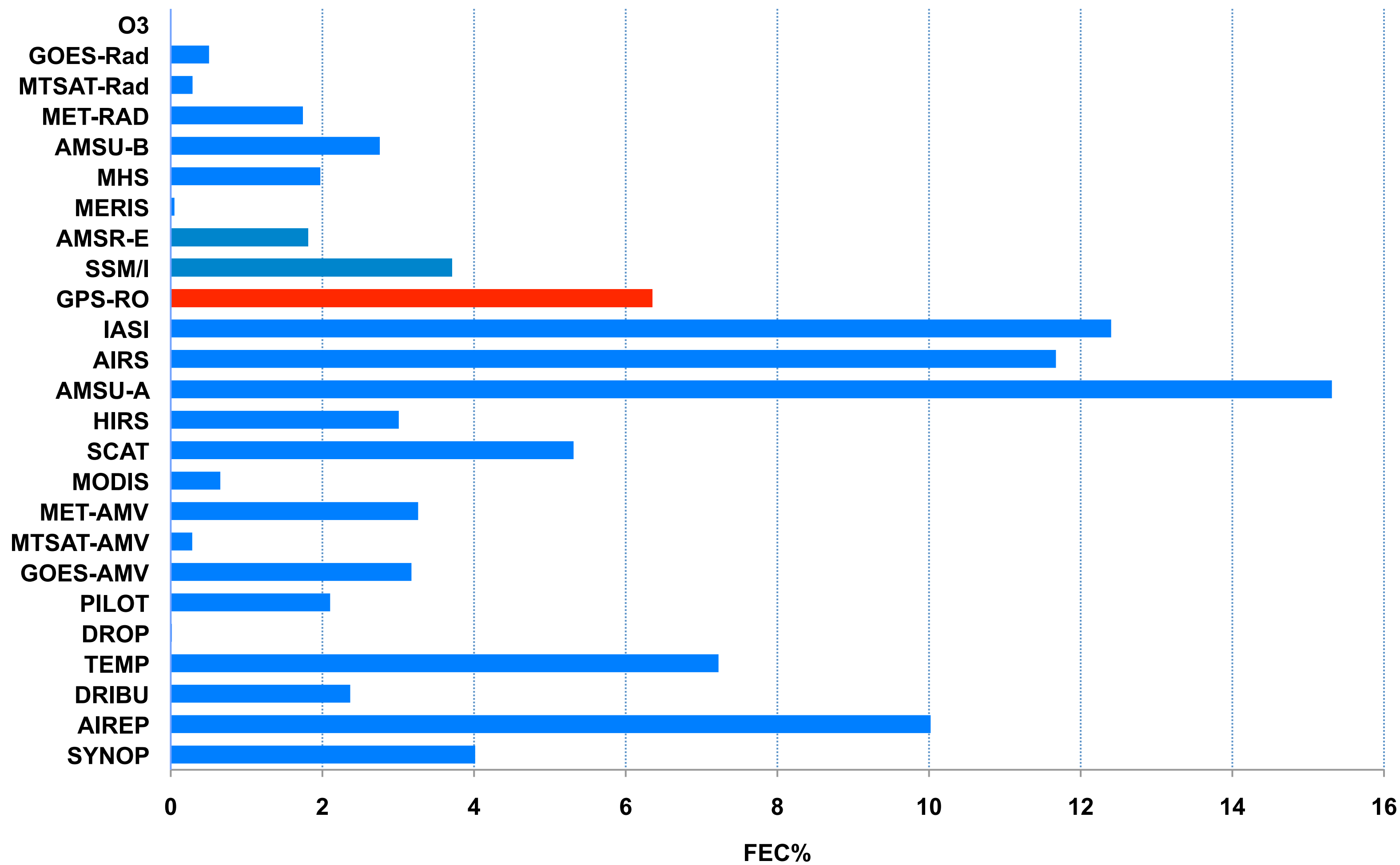
Spread in zonal wind (U, m/s)
Scaling factor ~ 2 for wind error
Tropics, N. & S. Hem all similar

Simulated ADM adds value at all altitudes and in longer-range forecasts (T+48,T+96) and analyses

Differences significant (T-test)
Supported by information content diagnostics

Global NWP –main observing systems

Forecast error sensitivity with respect to observations



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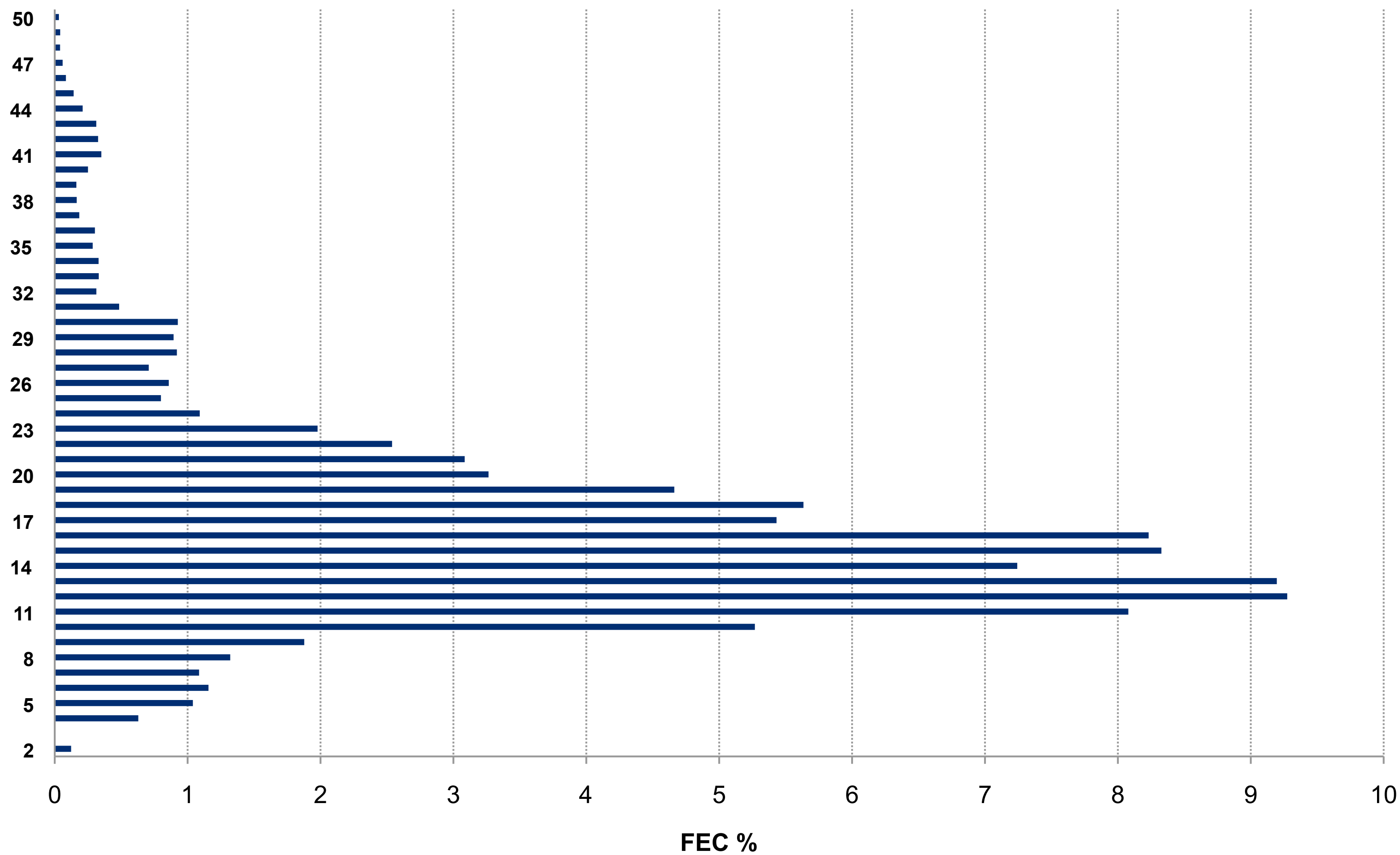
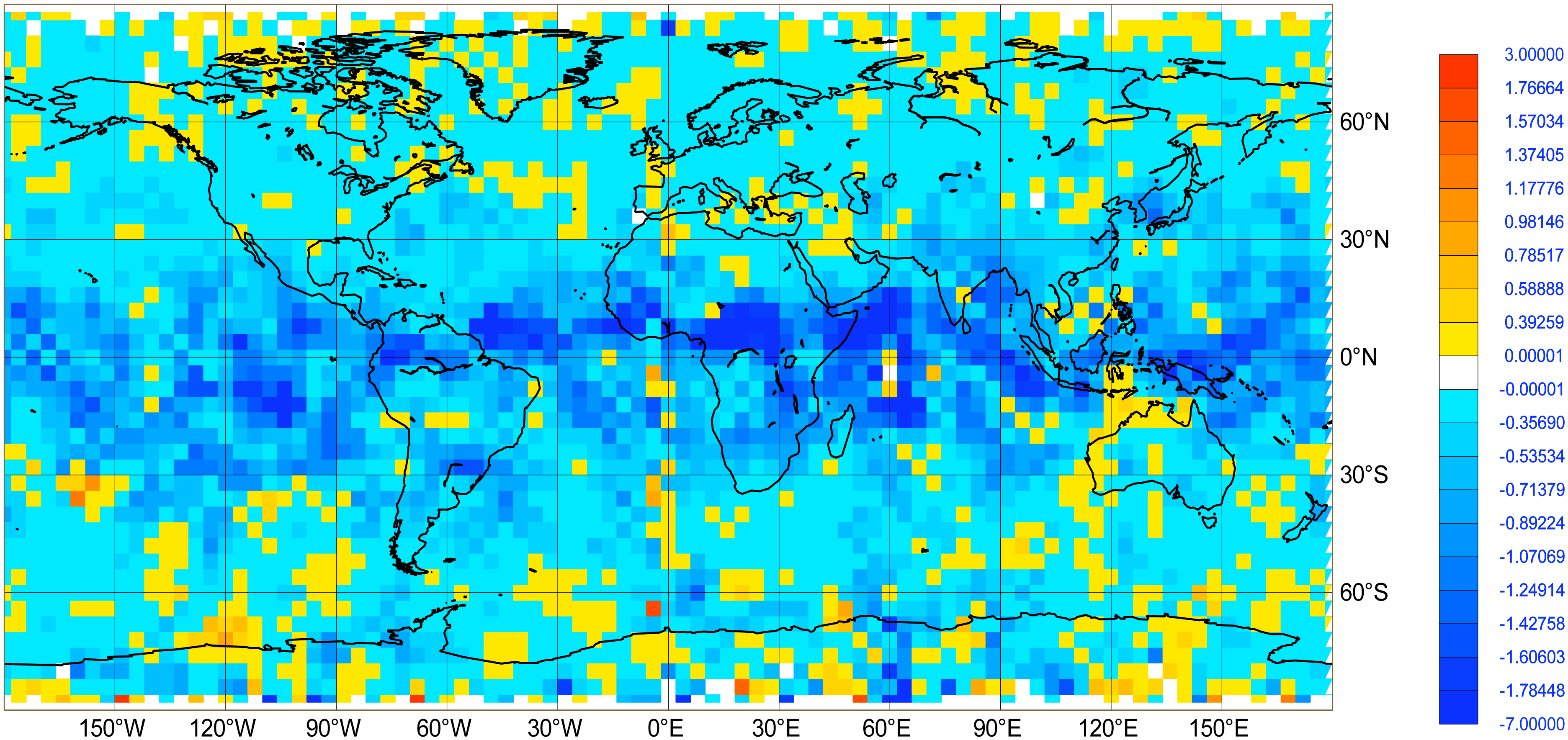
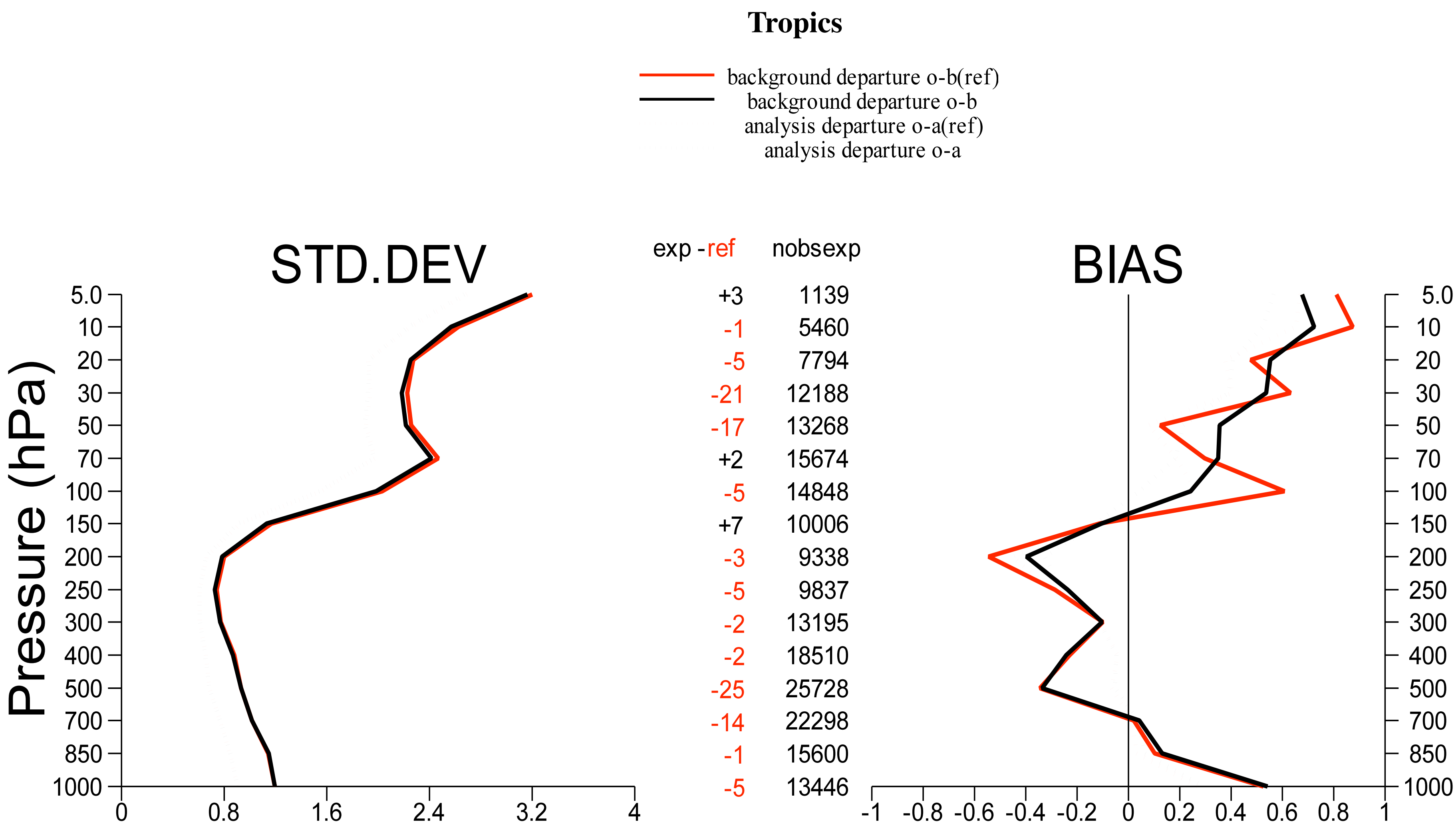
GPS-RO June 2009



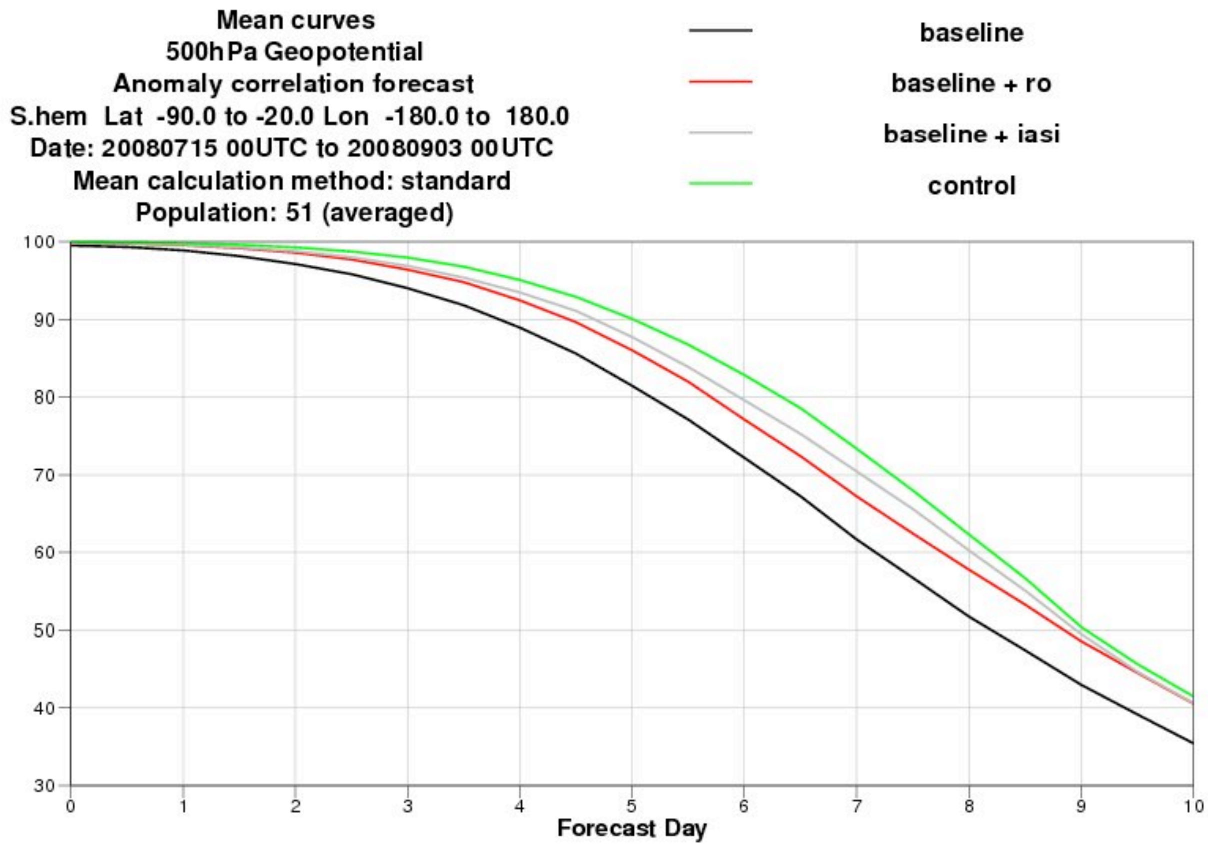
June 2009 GPS-RO, 13-30 km, FC error contribution



OSE With-Without GPS-RO
Radiosonde fit, June 2009



Comparison with IASI, relative to a "poor" no satellite sounder baseline system.



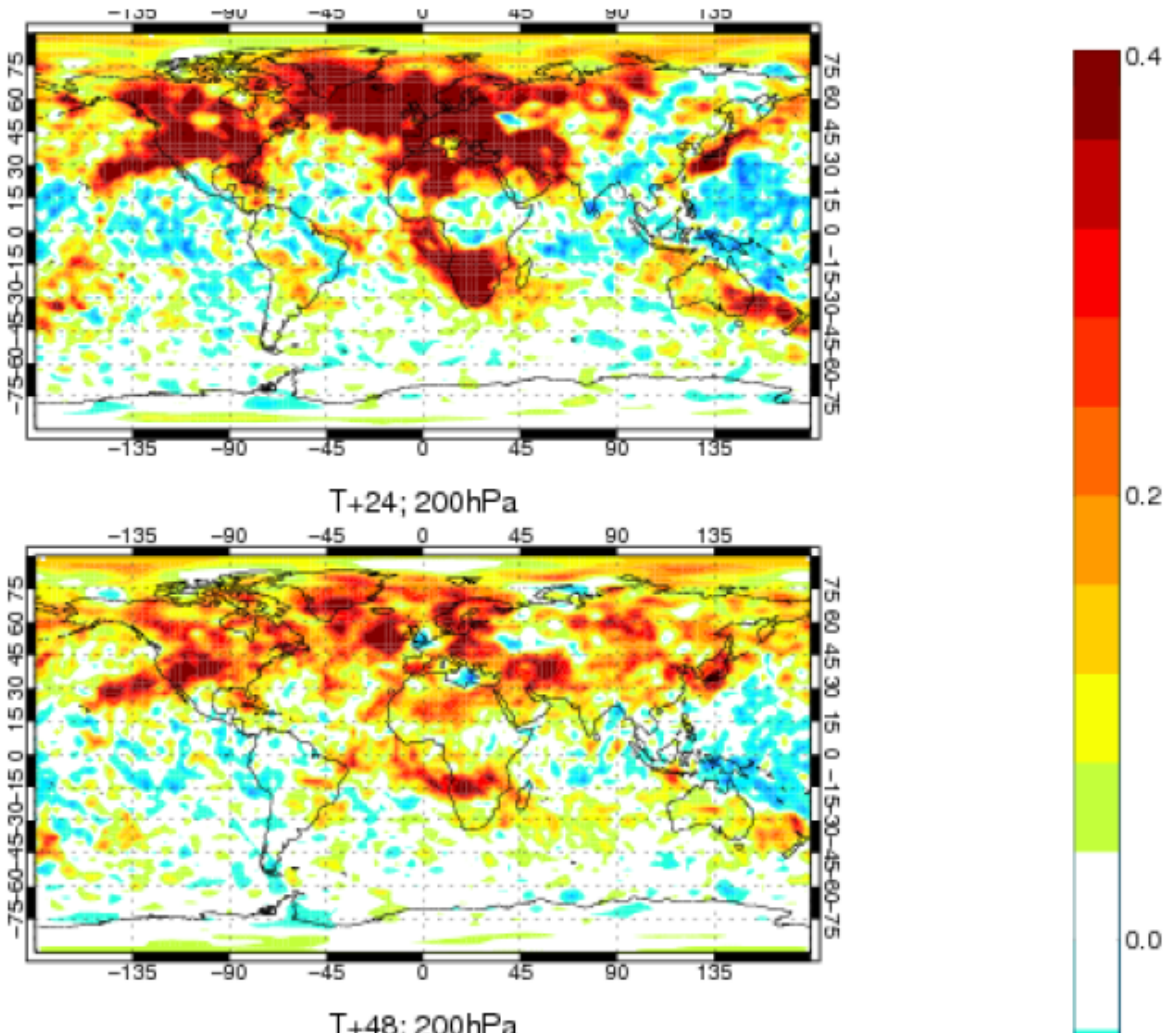
KEY QUESTION: How many GPSRO receivers do we need? Can we increase the number to equal the impact of IASI?

Radio occultation

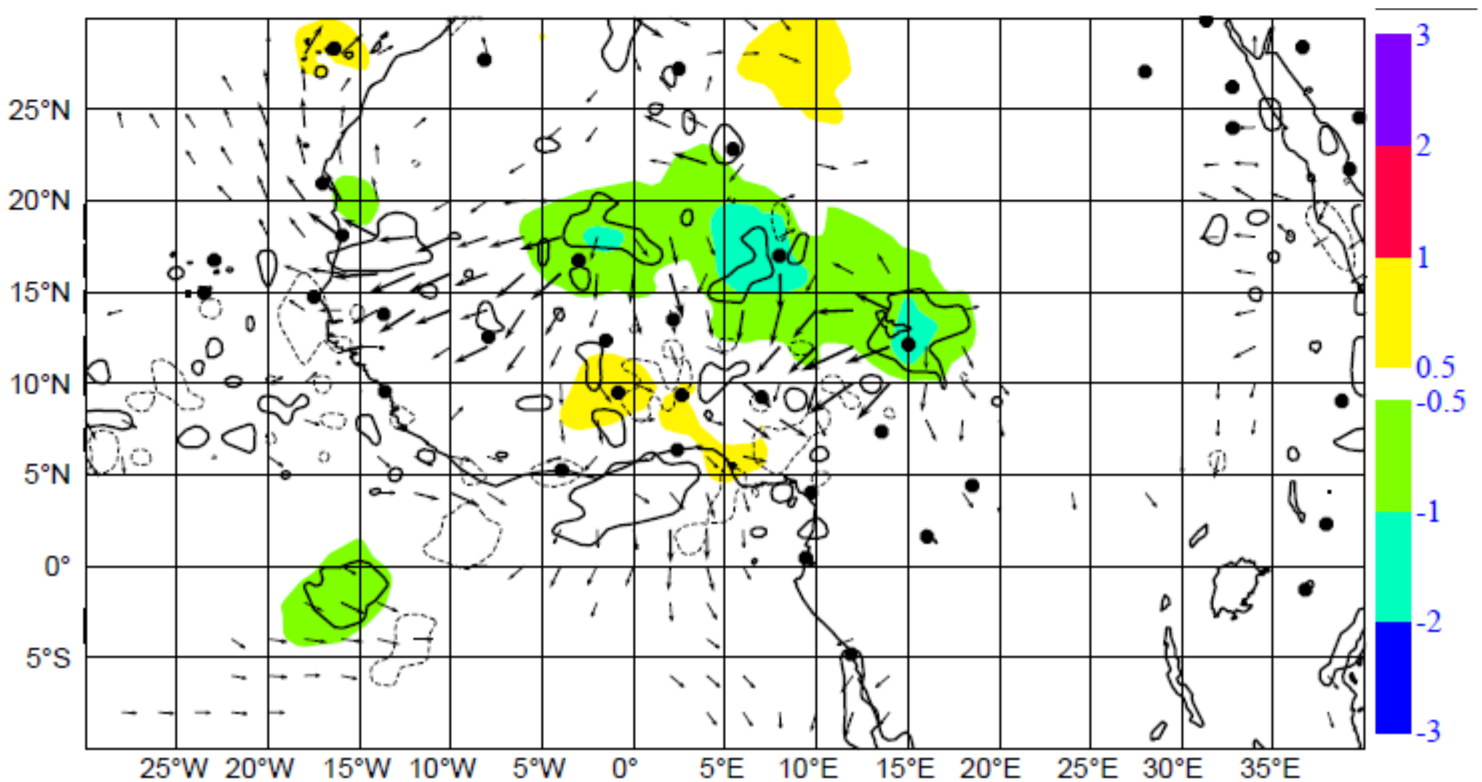
- RO sounding is able to penetrate clouds and precipitation with virtually no impact on its accuracy.
- Over ocean, where there are few traditional observations, GPS RO soundings from COSMIC and other RO missions have demonstrated significant NWP impact.
- GPS RO soundings provide valuable information on the moisture in the tropical lower troposphere, which is crucial for the development of tropical storms.
- Ability to detect biases in aircraft data. and is now very influential in bias correction of satellite sounding data.
- Taiwan and U.S. are planning for the COSMIC follow-on mission, (COSMIC-II), which promises to provide 8,000 to 10,000 GPS RO soundings per day.

Aircraft FC impact, Temperature 200 hPa

RMS error difference
7 July - 29
September 2008.



AMMA radiosonde impact



Mean temperature analysis increments at 925 hPa for August 2006 based on both the 00 UTC 12 UTC analysis from the AMMA experiment;

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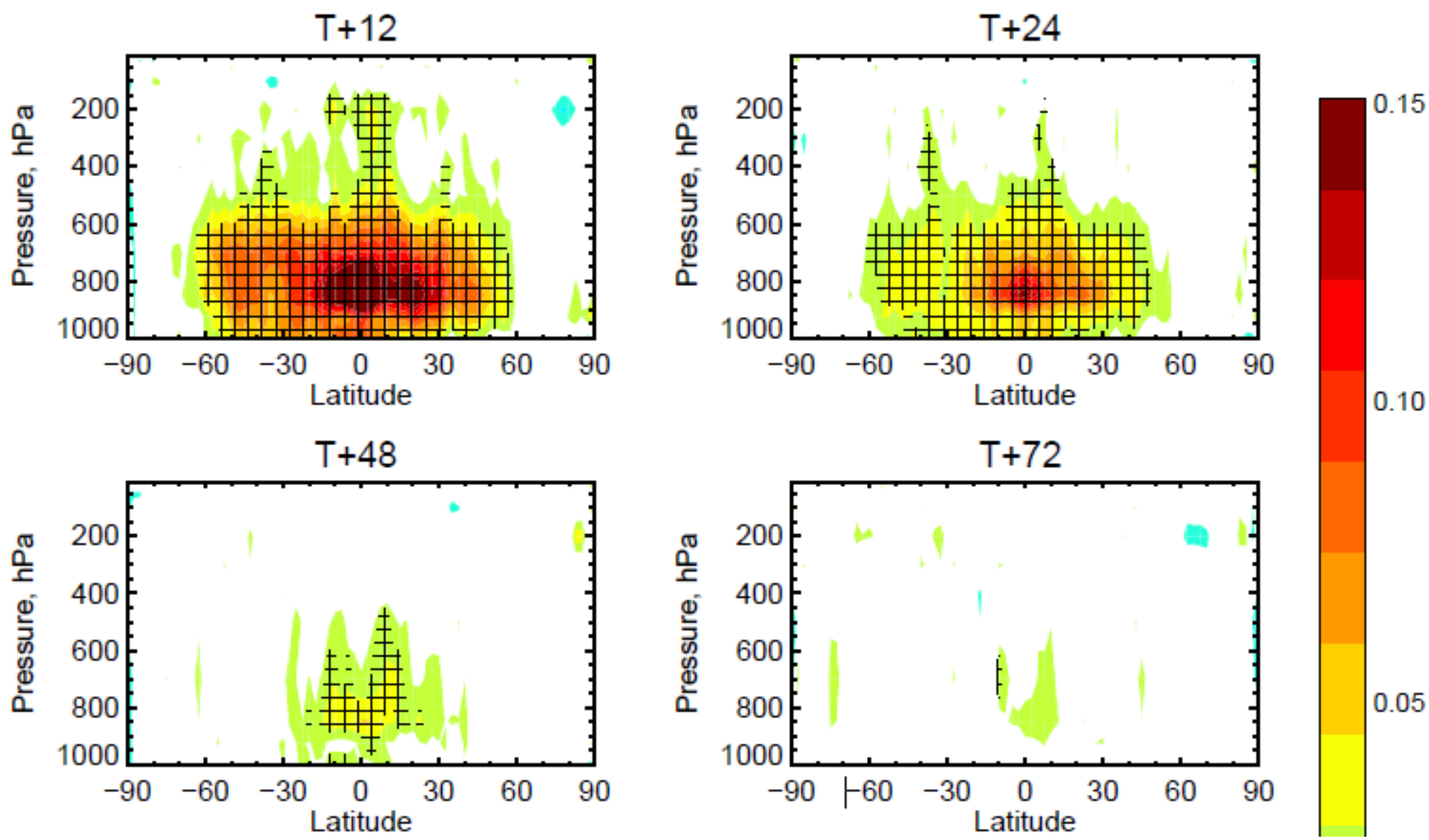
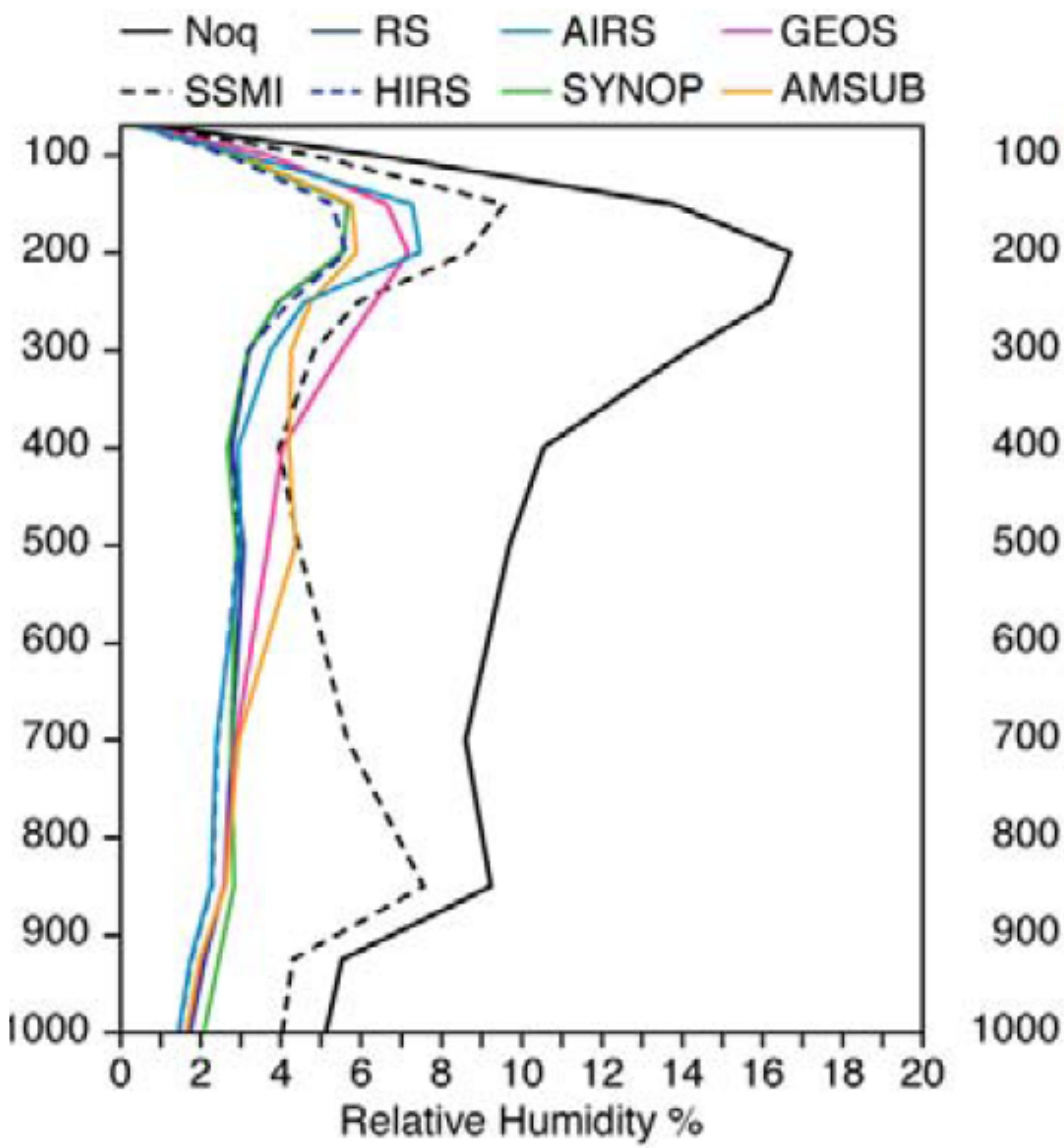
SSMI forecast impact on humidity



Relative humidity impact (normalized RMS) from SSMI data. Crosses indicate where scores are statistically significant at the 95% level, 20/05/2009-31/12/2009.

Humidity analysis impact from satellite data, tropics



The impact of future developments of the space-based observing system on NWP

- T and q sounding from advanced sounders of the AIRS/IASI-type and conventional sounders of the HIRS/AMSU-A/MHS-type: *The information brought by advanced IR sounders is crucial*
- Humidity imaging in clear skies and in areas affected by clouds and precipitation: *Strongest impact from SSMI, due to its contribution in the boundary layer, followed by MHS and HIRS. Forecast impact from humidity data in cloudy areas is stronger than from data in clear skies*
- Soil moisture derived from ASCAT. *Correction of systematic errors in soil moisture in several regions demonstrated.*

The interaction between terrestrial and space-based observing systems

- **Aim: investigate the impact of a terrestrial observing systems on radiance bias correction anchoring**
- **The synergy between radiosondes and GPSRO as anchors (with respect to temperature); *GPSRO currently anchor sufficiently on its own the bias correction for satellite sounders*.**
- **The question of what radiosonde coverage is needed in the stratosphere, to which height, and for which latitude ranges; *Particularly strong impact found in the tropics.***

Wmo 5th workshop on observation impact

- Impact of Various Observing Systems on Numerical Weather Prediction will be organised by the Expert Team on the Evolution of the Global Observing System in Sedona, United States, from 22 to 25 May 2012.
- The previous four workshops in this series took place in Geneva (April 1997), Toulouse (March 2000), Alpbach (March 2004) and Geneva (May 2008).
- The Organizing Committee: Erik Andersson (ECMWF), Carla Cardinali (ECMWF), John Eyre (Met Office, UK), Ron Gelaro (NOAA/GMAO, the US), Florence Rabier (Meteo-France), Lars-Peter Riishojgaard (NOAA/JCSDA, the US) and Yoshiako Sato (JMA, Japan).

Science questions

1. What network of in situ observations is needed in the stratosphere to complement current satellite observations (including radio occultation)? What about the tropics?
2. What is the impact of current AMDAR observations? What are the priorities for expansion of the network?
3. At what level, in terms of profiles per day, does the impact of radio occultation observations start to saturate?
4. What is the impact of new developments in the assimilation of radiance data over land?
5. What benefits are found when data from more than one passive sounder are available from satellite in complementary orbits, e.g. multiple AMSU-As, AIRS + IASI ?

Science questions 2

5. What insights can be gained from more tailored use of adjoint- and ensemble-based measures of observation impact, for example, in the tropics or at the meso-scale where metrics other than global energy may be appropriate?
6. Which observations are particularly important for the 7-14 day forecast range?
7. What impacts/benefits could be expected by sustained components of the AMMA special observing systems?

Summary

- AMSU-A is now the most important data type for Global NWP
- AIRS and IASI have demonstrated significant benefit to NWP
- RO complement the satellite sounders with its high vertical resolution, and small bias

- Lack of wind profile information at all levels is the main shortcoming of the global observing systems, especially in the tropics.
- Radiosondes provide the only source of winds in the stratosphere
- Hence the need for ADM/Aeolus

- The WMO 5th impact workshop, 22-25 May 2012.