Operational implementation of AIRS and SSM/I assimilation at MSC

Data Assimilation and Satellite Meteorology Division

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Contents of planned implementation

Context: New NWP model configuration (to become OPE in Nov. 2006):
800 X 600 (~35 km), 58 levels, top 10 hPa

- 100 AIRS channels
- 7 SSM/I channels
- Added extreme scans for AMSU-A-B
- Quickscat (from KNMI)
- RTTOV-8 (major change to code structure)
- New vertical interpolator (from NWP to RTTOV coordinate)
- Revised background and observation errors
- Automated radiance bias correction (ATOVS, AIRS, SSM/I, GOES)
- Added levels for RAOBS, added AIREPS, SATWIND from GOES 3.9 μm
- GPS RO (CHAMP, COSMIC) possible

Assimilation cycles strategy

- Need of 2-month assimilation cycles for winter and summer periods + forecasts up to 5 days

Strategy:

- 3Dvar FGAT (first guess interpolated at time of observation), 1 month for each component (turn around: ~2-3 days per day)
- 1 month 4D-var (turn around ~1day per day) for major components
- Incremental adding of components (partial packages of several elements)
- Full 2 month 4Dvar on combined package only

Planned parallel run at CMC: mid March 2007

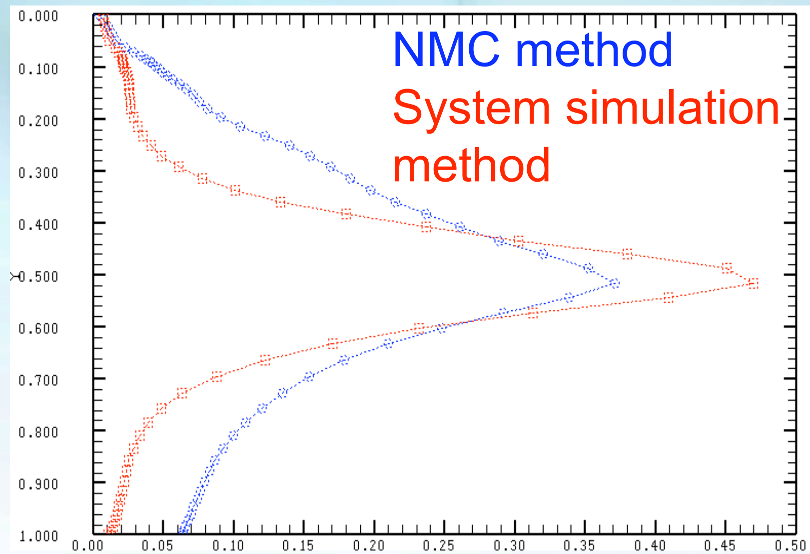
Planned operational: April 2007

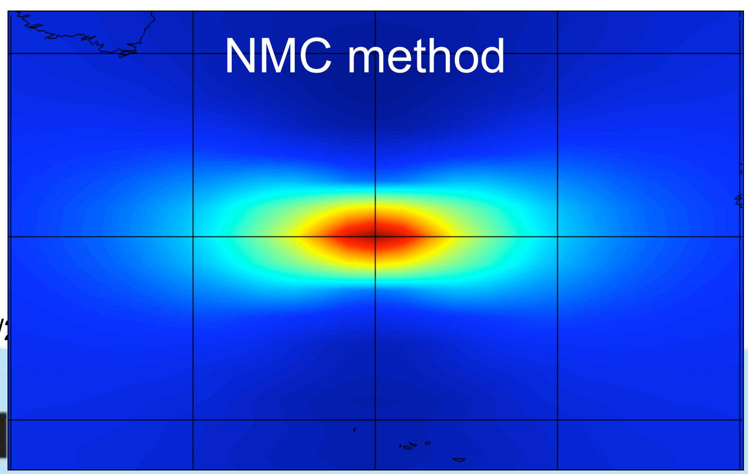
New approach for background and observation error determination

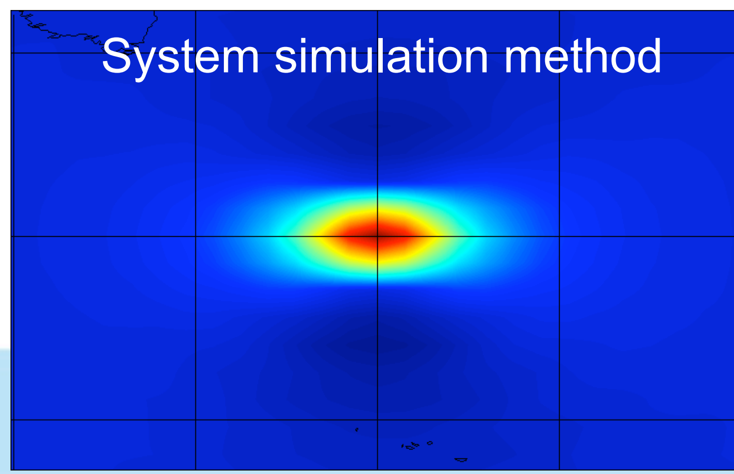
- **Observation error statistics**
  - –Desroziers method which uses assimilation system and optimality criteria to tune variances
  - –used for all obs types (except GOES, Profiler, SatWind ◊ kept as in operational system)
  - –results in large reductions for AMSU data, slight increase for radiosonde
- **Background error statistics** (replaces NMC method):
  - –system simulation approach applied to lower resolution version of model with 3D-FGAT analysis
  - –perfect model assumption (i.e. only obs perturbed) therefore variances underestimated ◊ must be inflated
  - –2 months, 2 perturbed members ◊ total of ~480 realizations of background error (correlations still homogeneous/isotropic)
- **Tuning of background error variances**:
  - –Computed cov(O-P) and HBH^T (background error) for all obs types
  - –Similar to Hollingsworth-Lonnberg approach: compare cov(O-P) with HBH^T+R

Background error spatial correlations

- Analysis increment from single zonal wind observation at 500hPa over Atlantic ocean
- New approach gives sharper spatial correlations for all variables
- Sharper vertical correlations for temperature results in smaller background error variance in space of AMSU observations, partly compensates reduction in σ_{obs}





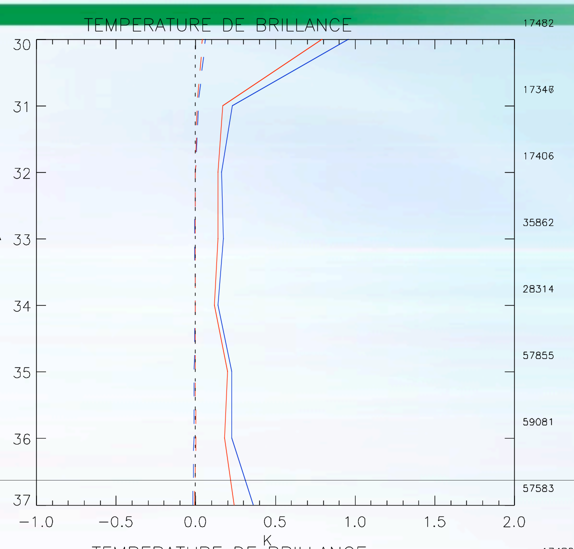


Impact of new statistics on fit to AMSU data

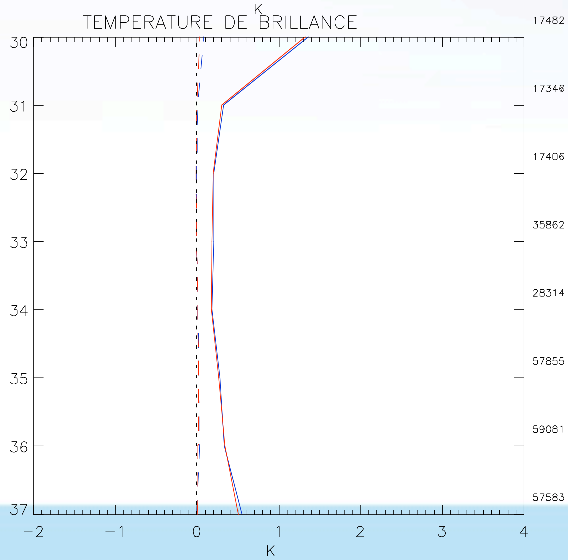
(K4H5F1R4(current) vs K4H5STR4 (new))

Vertical axis: channel number from low to high peaking

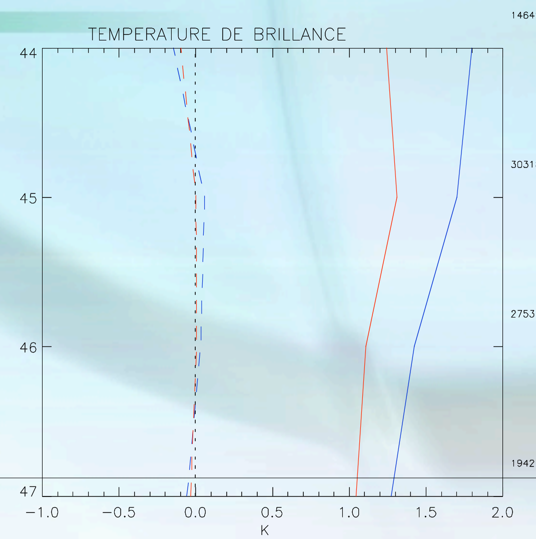
O-A
AMSU-A
World



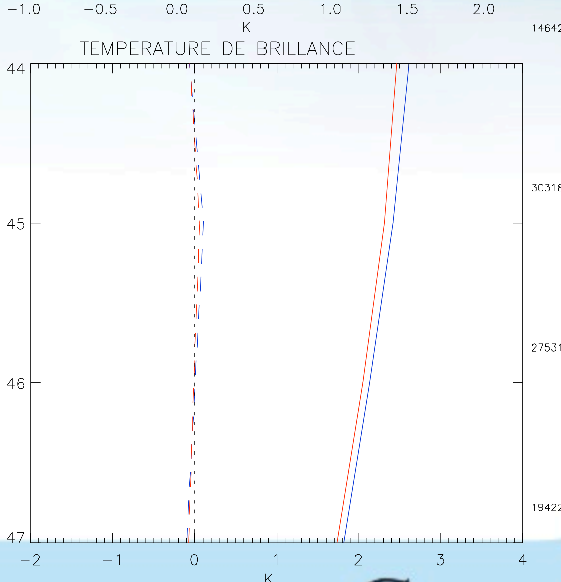
O-P6h
AMSU-A
World



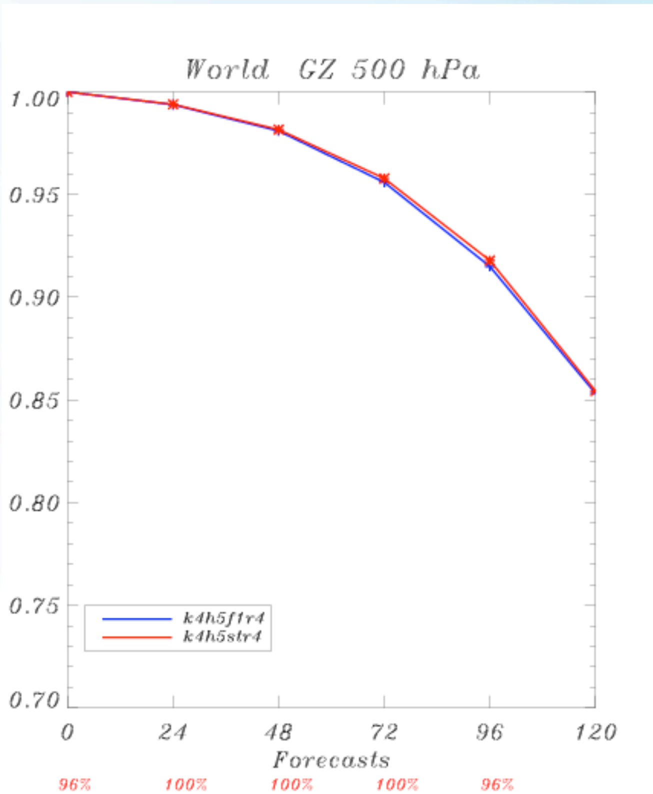
O-A
AMSU-B
World

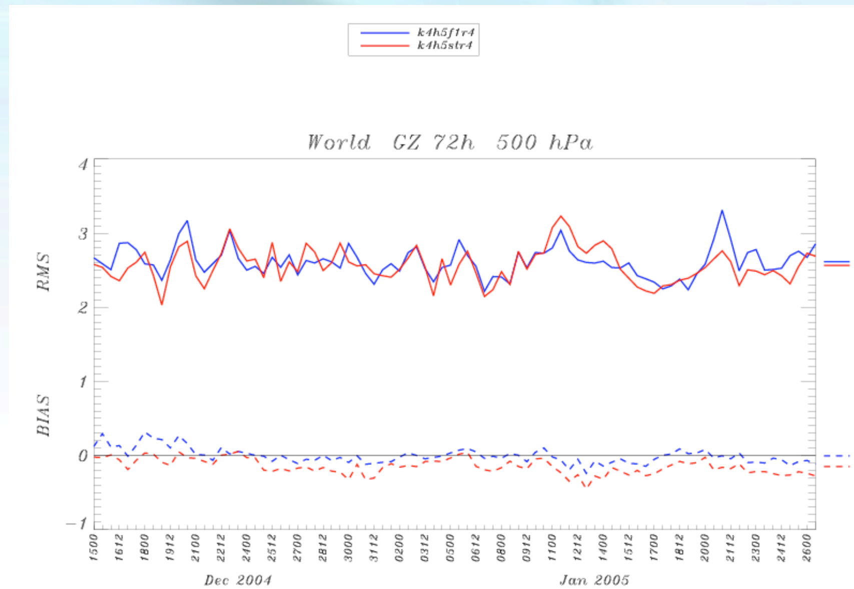


O-P6h
AMSU-B
World



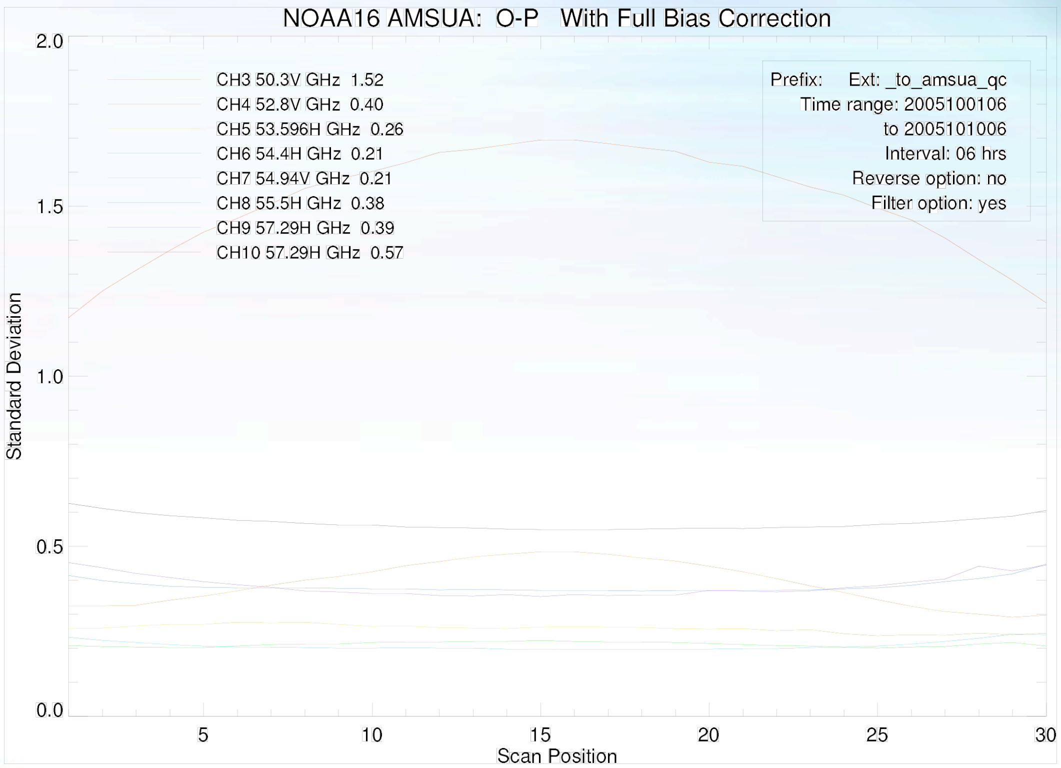
Impact of new statistics vs old





ATOVS: end of scans are no more eliminated

AMSU-A: BT (O-P) std vs scan position



BT (O_P) STD vs scan does not justify elimination of end of scan pixels. For AMSU-A, 6 pixels out of 30 were not used.

The 25 % increase end up in a ~35 % increase in assimilated data because the thinning eliminates less pixels at large angles. Similar increase for AMSU-B.

New vertical interpolator + TL/AD

Problem: Need of an interpolator from N NWP model levels to M RTM (e.g. RTTOV) levels. If N > M, not all input levels participate if only nearest bracketing levels are used. This introduces distortions when mapping back Jacobians from RTM to NWP coordinate.

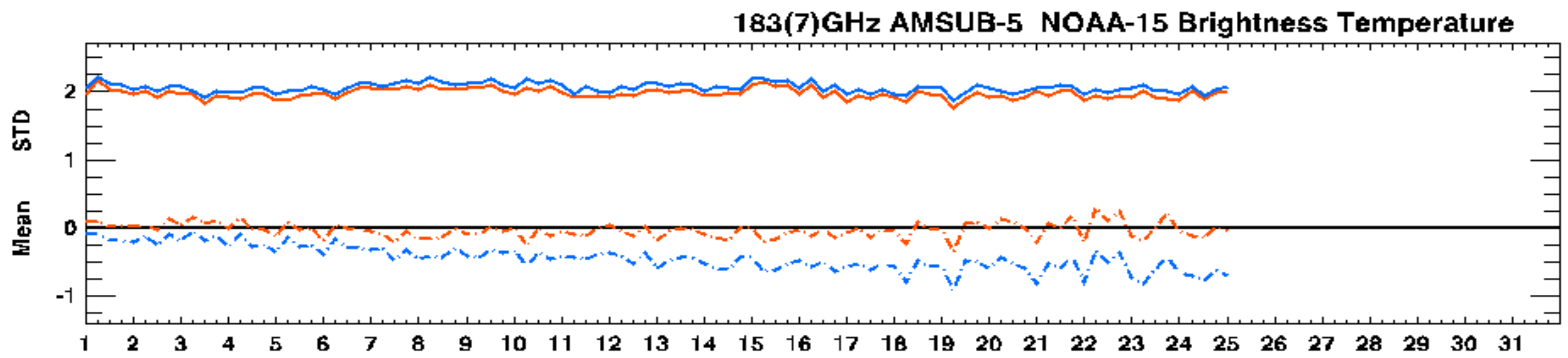
Solution proposed: Interpolator using all input levels with good TL/AD properties (see Y. Rochon's talk next Monday).

- Impact most visible near tropopause and above where density of levels differs the most
- Problem went unnoticed because partially masked by vertical correlation of background errors
- Code (forward/TL/AD) to become available on ITSC site

Example of dynamic (within cycle) bias correction

O-P corrected and uncorrected (January 2005)

Drift in NOAA-15 AMSUB-5 bias

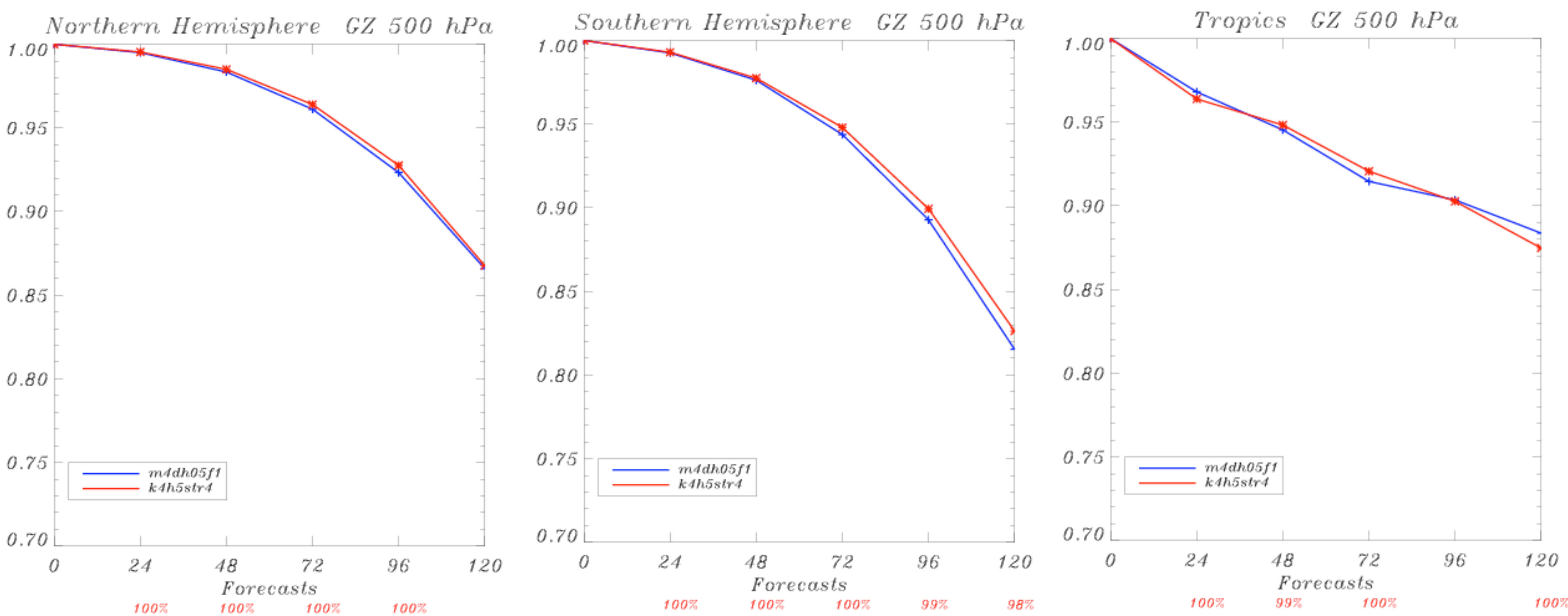


If the drift is relatively slow, the system adapts well to that drift

Correction updated every 6-h based on last 15 days

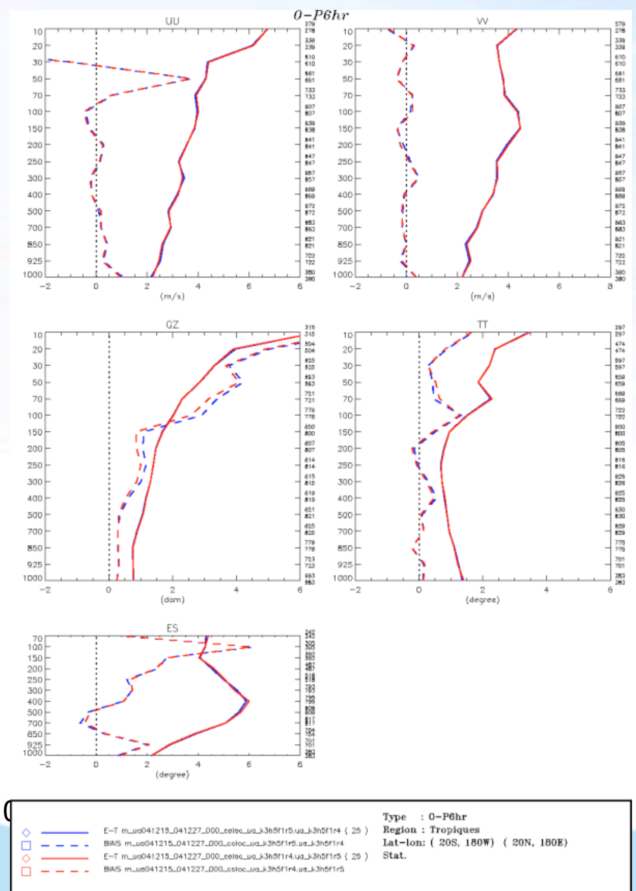
Verifications wrt Analyses CNTL vs EXP
2004121500-2005012612 4D-var

EXP= CNTL +new statistics + added AMSU scans + new interpolator + RTTOV8 + dynamic bias correction

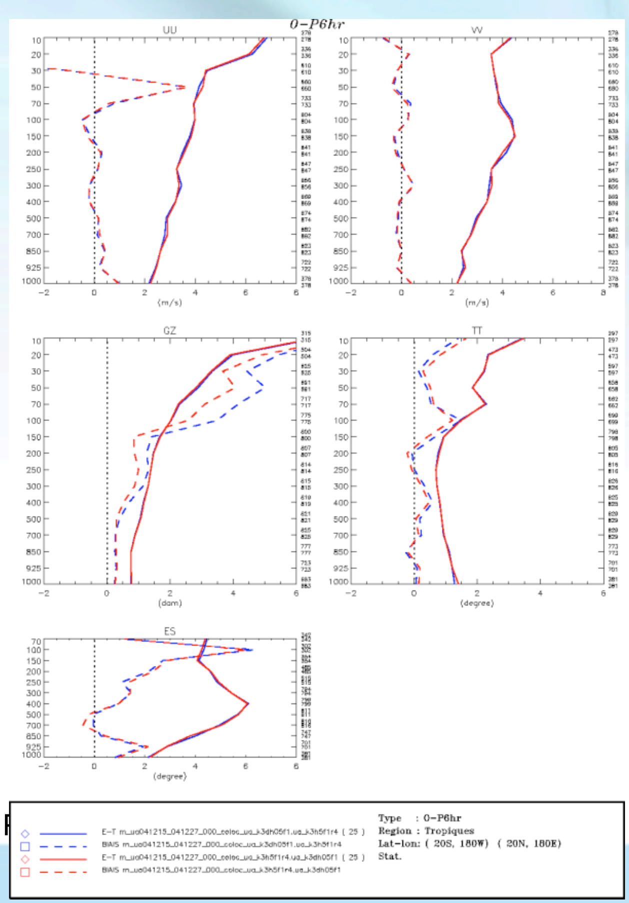


Impact on 6-h forecasts

New interpolator vs old



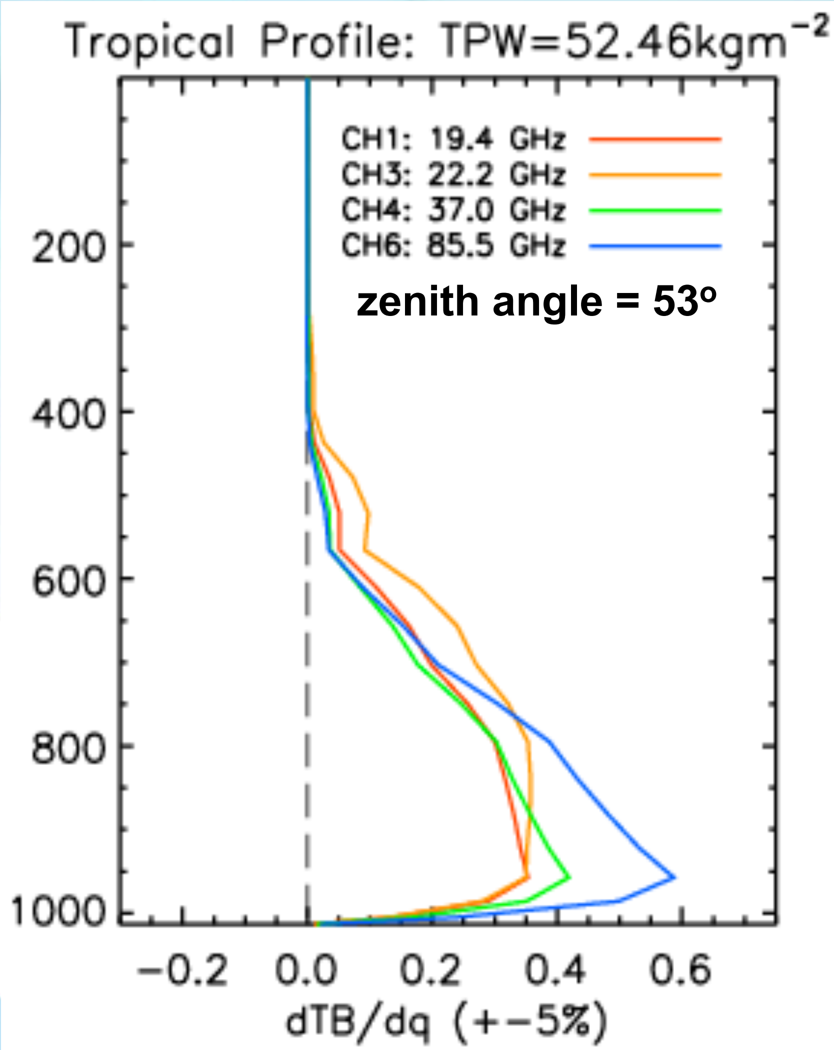
New interpolator+extended AMSU vs CNTL + new stats + RTTOV8 + dynamic bias



Tropics,
13 days
3D-FGAT

SSM/I: Imager: 7 channels

Channel	Frequency (GHz)	Resolution (km)	Assimilation
1	19.35 V	25	Ocean
2	19.35 H	25	Ocean
3	22.235 V	25	Ocean
4	37.0 V	25	Ocean
5	37.0 H	25	Ocean
6	85.5 V	12.5	Ocean
7	85.5 H	12.5	Ocean



SSM/I Data Processing

SSM/I Raw Data
Antenna Temperatures (Ta)

← NOAA/NESDIS

↓

Apply filters (treat DMSP-13,14,15 separately):

1. Remove “stray” scans
2. Remove obs outside T±3h assim. window
3. Remove obs over land/ice/near coast
4. Compute Tb = f(Ta) & remove unphysical Tb
5. Remove precip/cloudy obs

↓

Group remaining data from DMSP-13, 14, 15

↓

Background Check:

1. Compute O-P (3D-Var)
2. Apply bias corrections
3. Remove obs with large O-P

↓

Thinning and sorting:

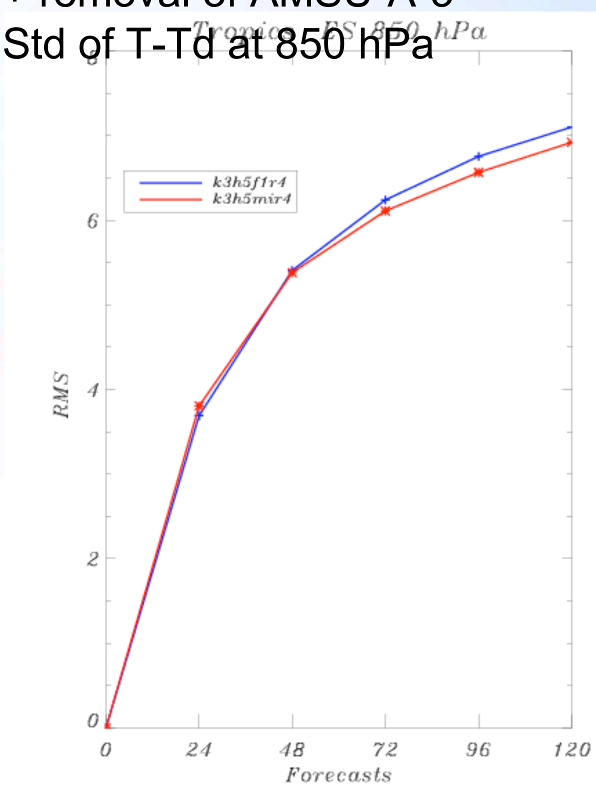
1. Remove overlapping orbits (3D-Var only)
2. Thin data to 200 km resolution

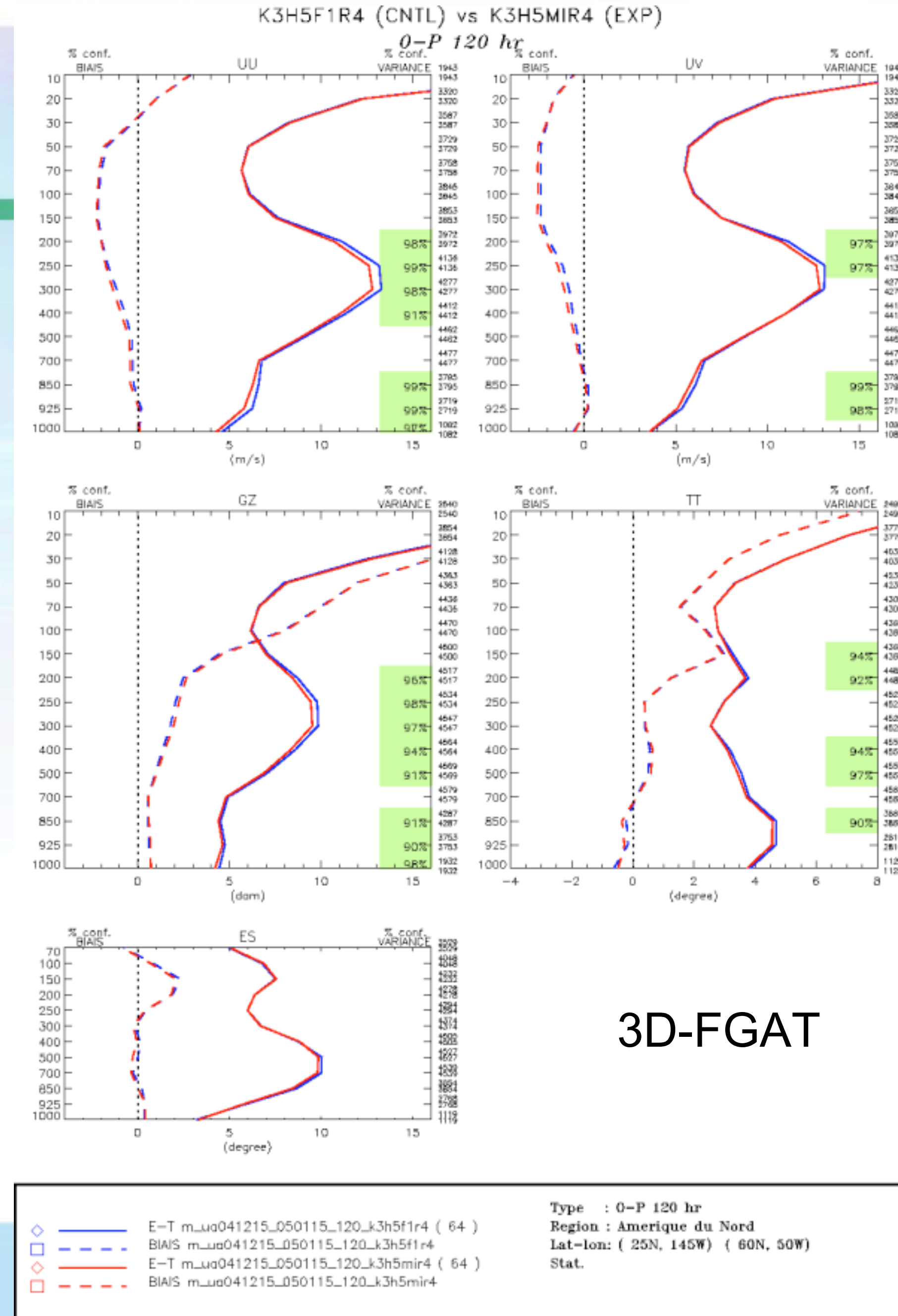
→ Assimilation-ready SSM/I brightness temperatures (Tb)

Impact of SSM/I

7 channels (ocean only)
+ removal of AMSU-A-3

Std of T-Td at 850 hPa



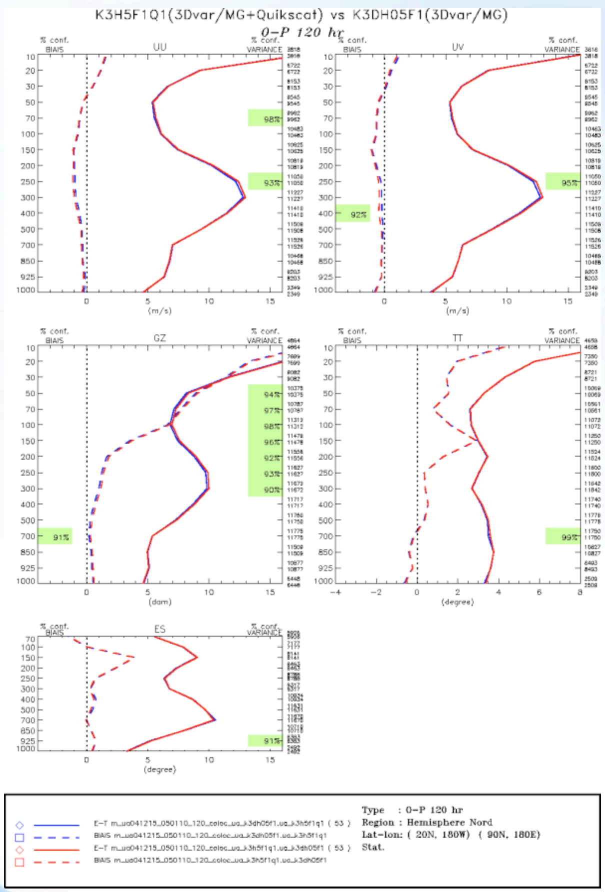


3D-FGAT

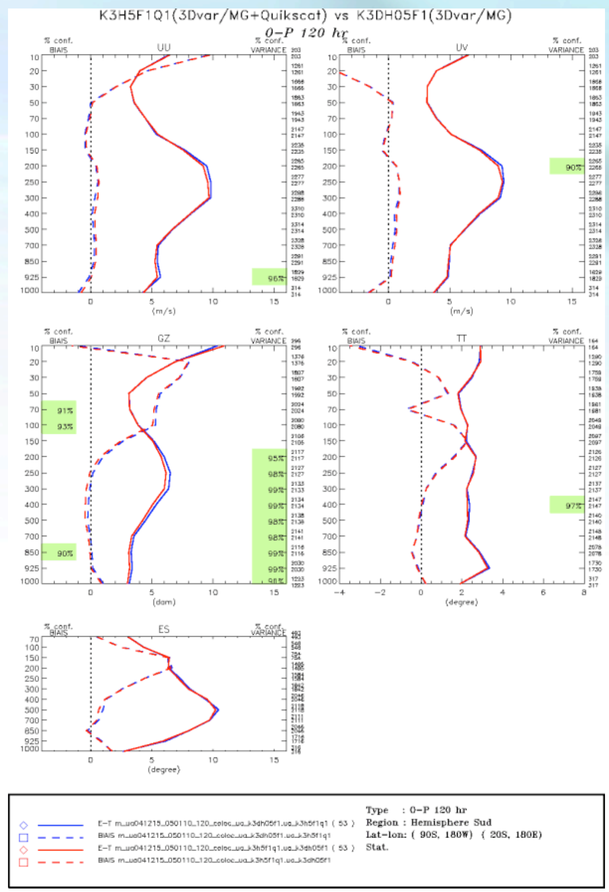
See poster A02, Anselmo et al.

Impact of Quickscat (ocean winds)

NH 120h



SH 120h



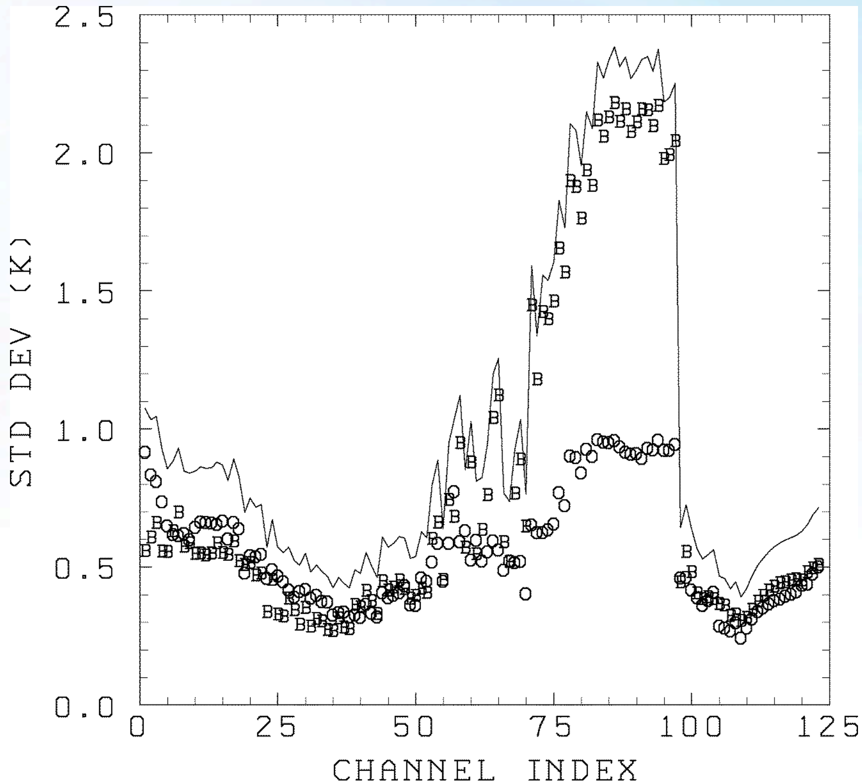
~8000 obs per 6h
3D-FGAT 26 days

AIRS processing

- 100 channels considered for assimilation
- Uses warmest pixel within 3X3 array
- CO_2 slicing for cloud height and emissivity
- Land emissivity based on CERES land types + spectral interpolation
- Ocean emissivity from Masuda
- Ozone background from monthly climatology (19 latitudes)
- RTTOV8 (variable CO2 capability)
- Dynamic bias correction based on previous 15 days
- 250 km thinning (~80,000 radiances per 6h, ~3500 locations)

See poster AO2, Beaulne et al.

Separation of observation and background errors



15.5µ 13.5µ 6.7µ 4.1µ

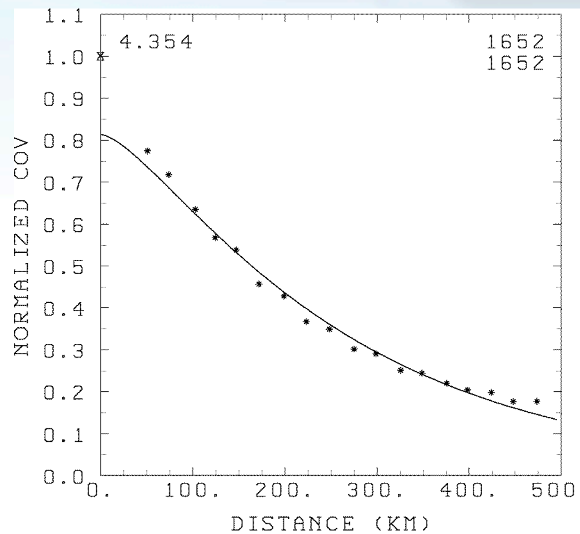
Total (O-P) std: full line

B: backgound (P) error std

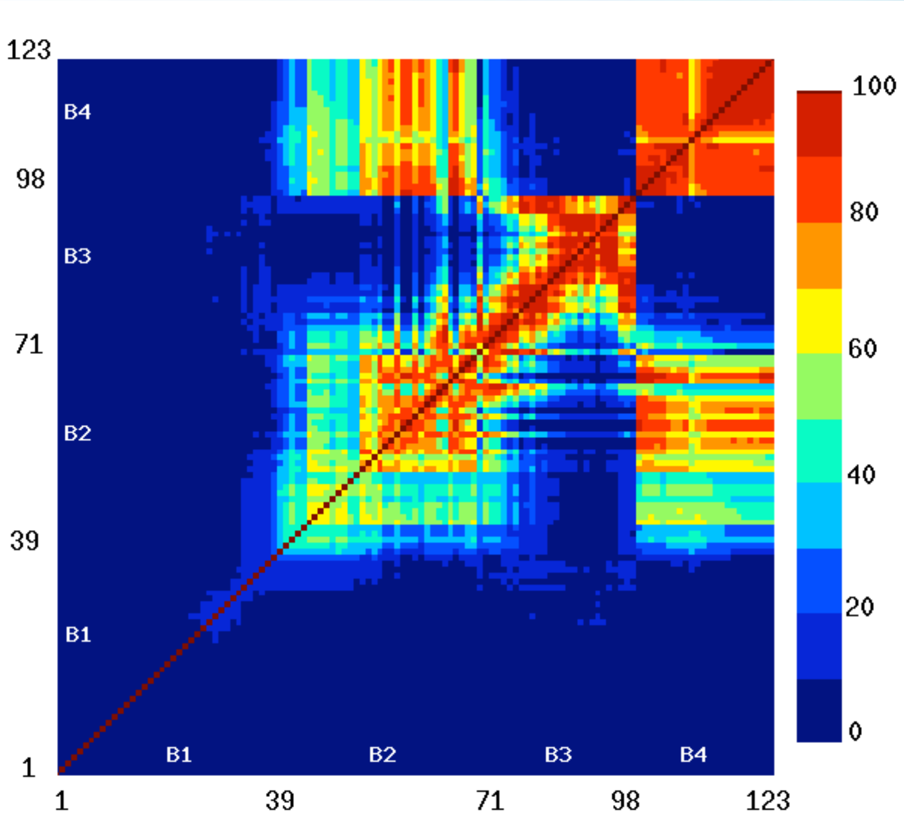
O: observation error std

Hollingsworth-Lonnberg method:

(O-P) vs pixel separation



AIRS inter-channel obs. error correlation (IOEC)



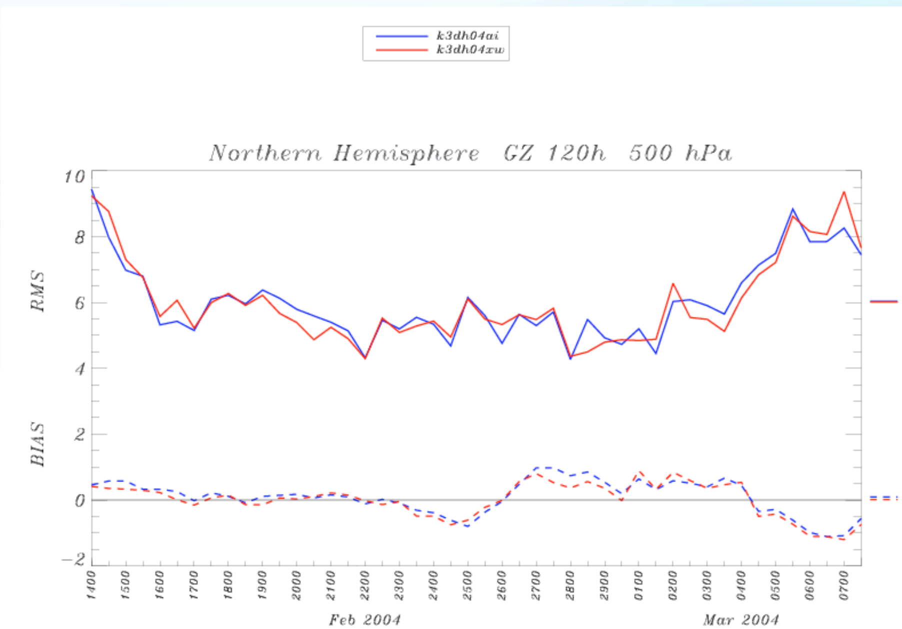
15.5μ 13.5μ 6.7μ 4.1μ

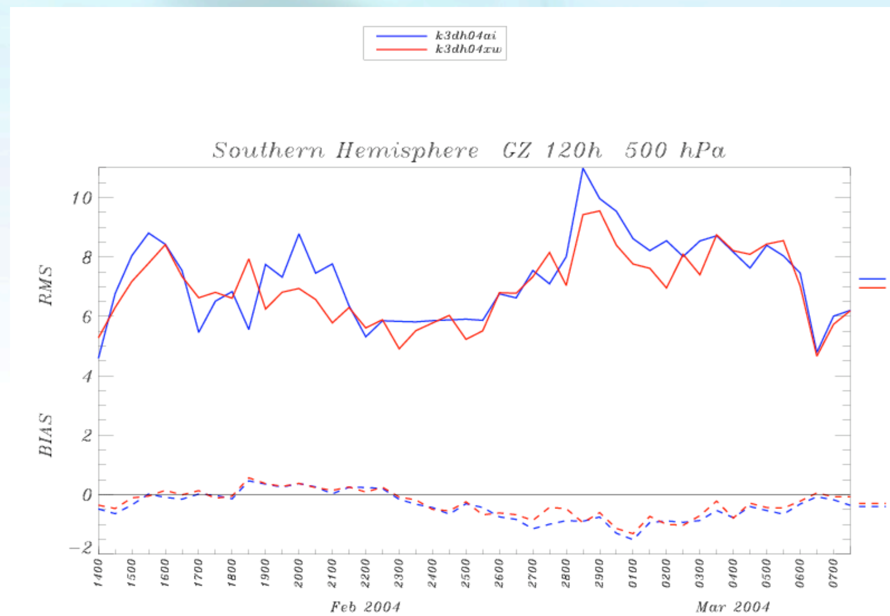
Highest IOEC found in surface-sensitive channels, notably 4-4.5μ and water vapor channels.

Higher amplification of obs. Error is justified in these channels, short of explicitly considering IEOC in AIRS assimilation.

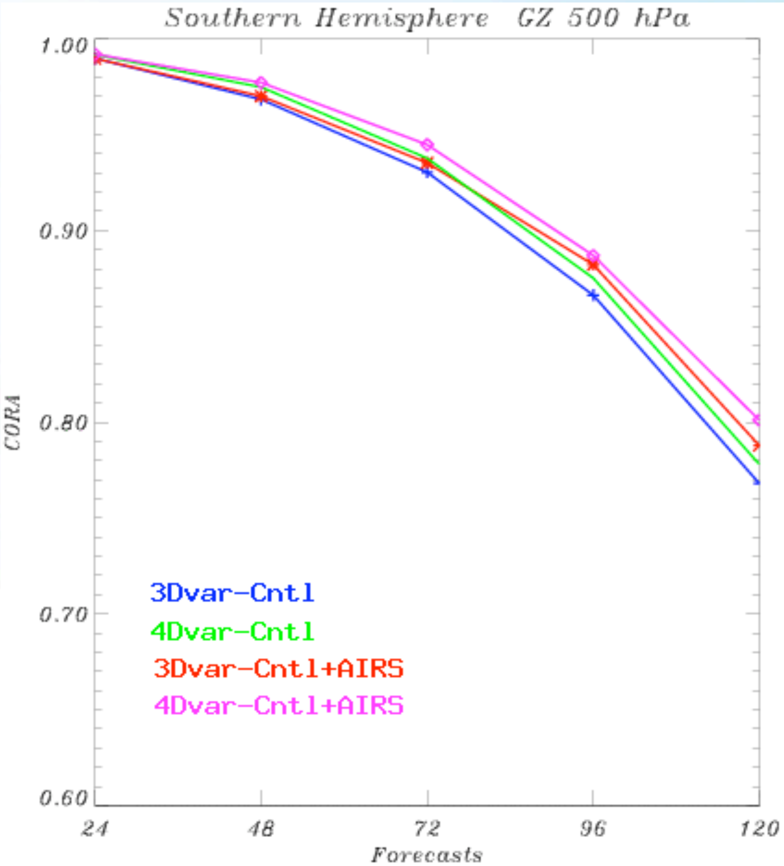
AIRS: temporal series

3D-var, 30 days, in 100 km 28 level system:
AIRS vs NOAIRS





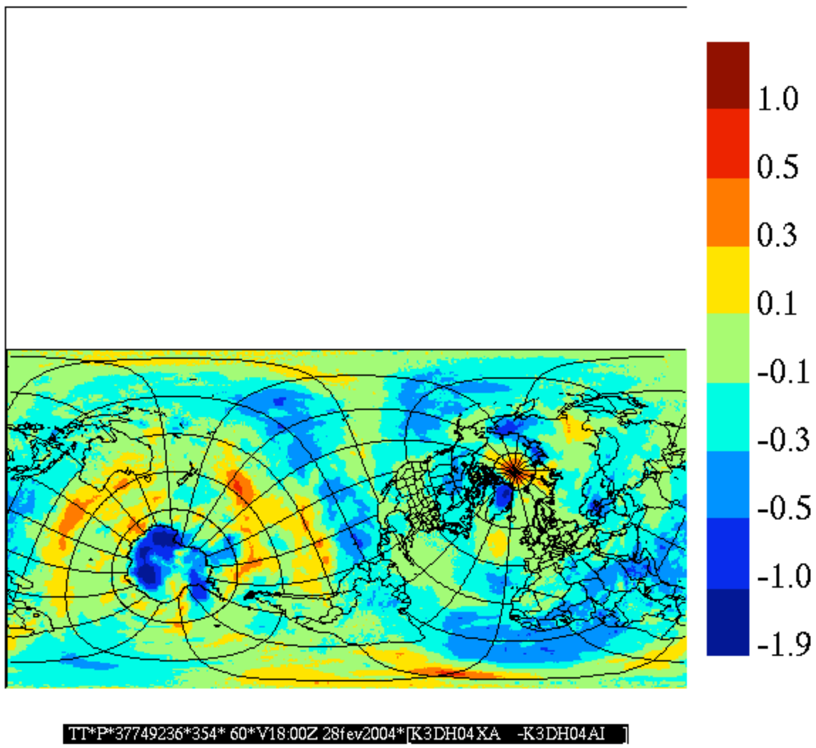
SH 500 hPa Anomaly correlation



Period 14-25 Feb 2004, 100 km res. model

- 4D var larger impact than AIRS up to day 3
- AIRS larger impact than 4D-var for days 4-5
- ~6h predictability gain at day 5

Impact of AIRS on Temperature structure



500 Hpa T difference (AIRS-NOAIRS)

Between the mean analysis over a period of 2 weeks:

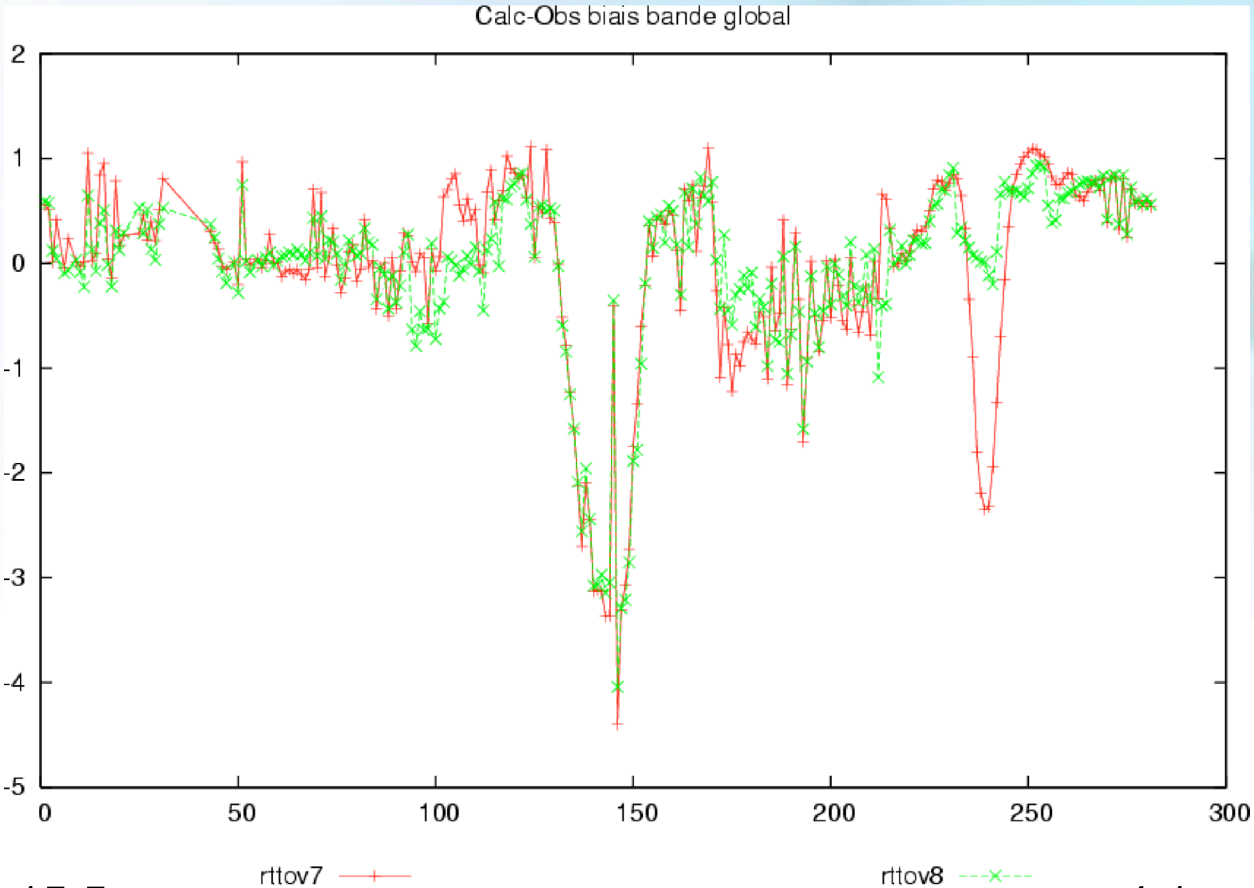
- Colder in tropics
- Warmer in SH extra-tropics

Conclusion

- Major upgrade with new data sources (SSM/I, AIRS, Quickscat, possibly GPS RO) + improved error statistics is planned at MSC (spring 2007)
- Modest, but systematically positive impact from most components.
- Largest impact expected from AIRS in SH based on results obtained in previous model configuration. Adaptation to IASI should be relatively straightforward.
- Validation of forecasts in radiance space is a new feature
- Stratospheric version with top at 0.1 hPa planned in 2008 with added data sources.

GRAZIE!

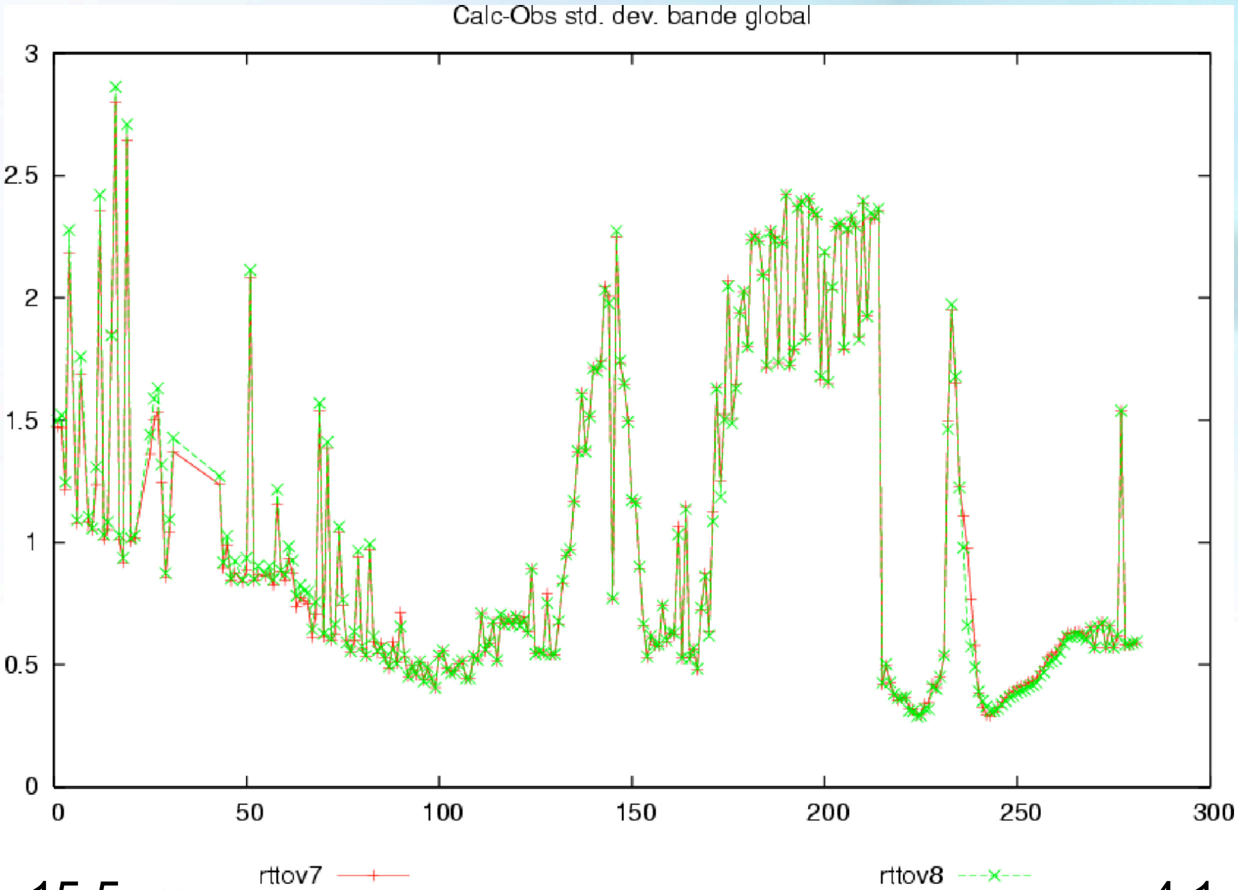
(O-P) bias using R7 and R8 AIRS coefficients



15.5μm

4.1μm

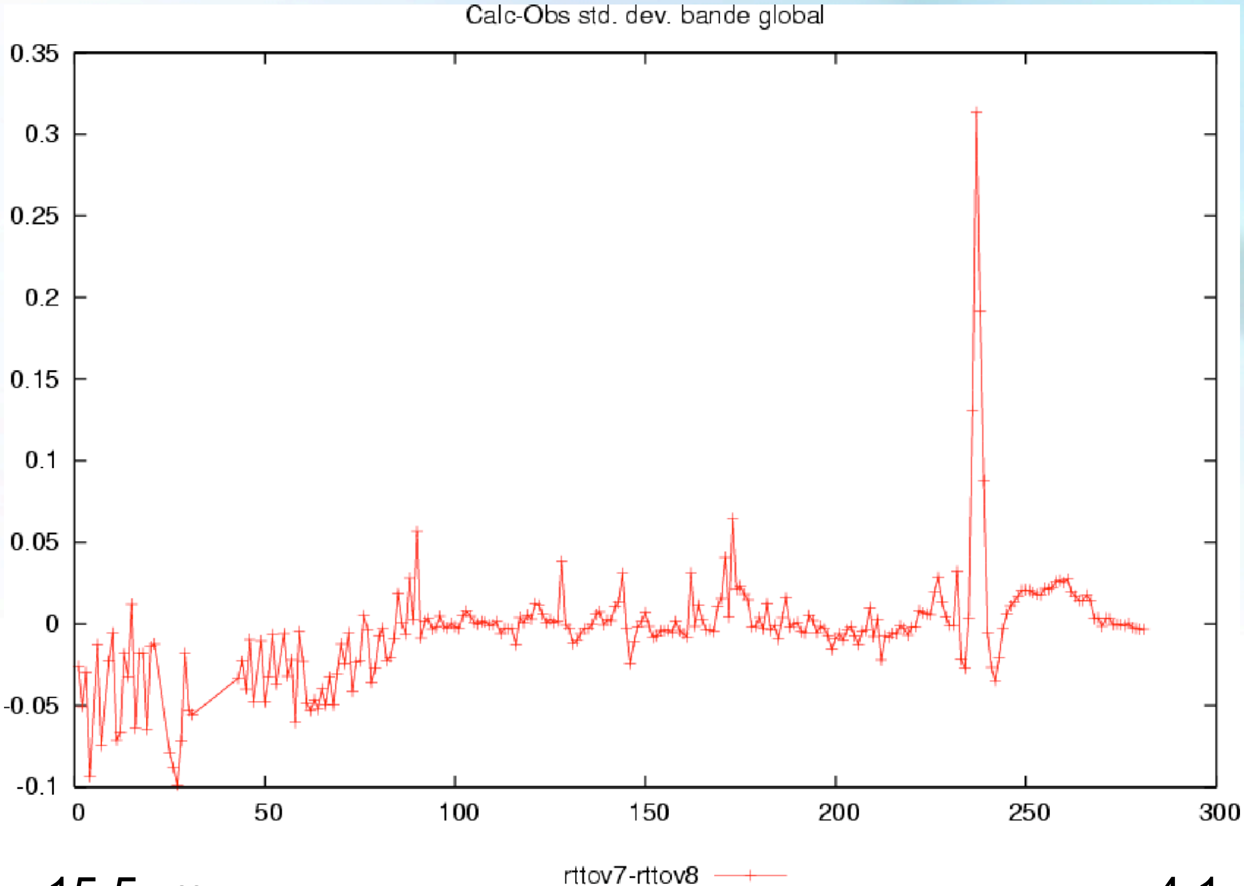
STD for R7 and R8 coefficients



15.5µm

4.1µm

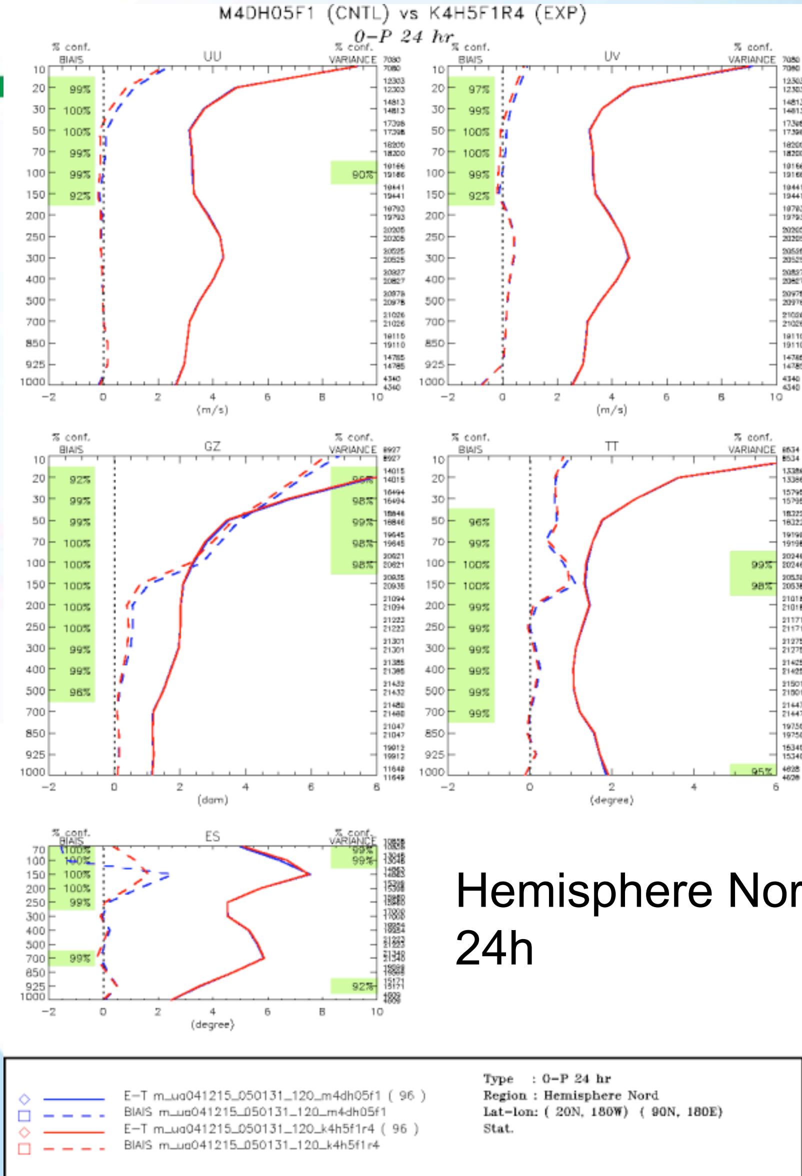
Difference in STD (R7_coef –R8_coef)



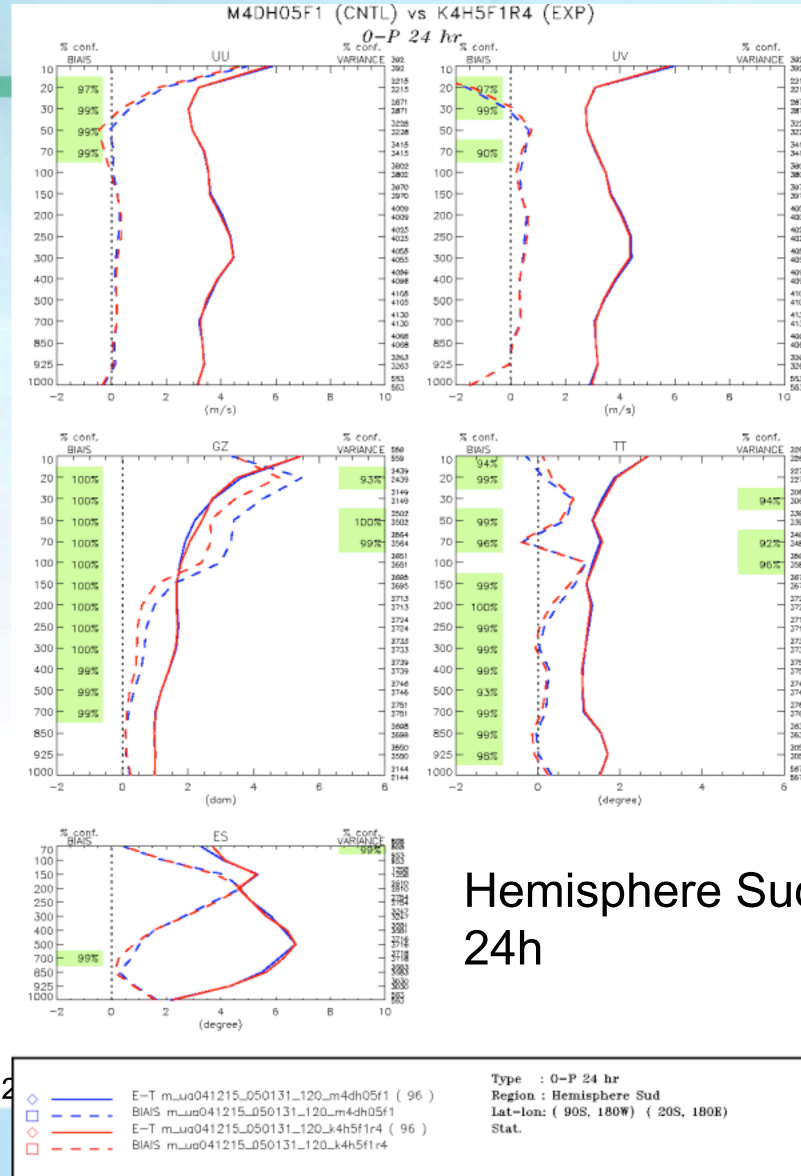
15.5μm

4.1μm

Verifications wrt RAOBS data M4DH05F1 vs K4H5F1R4 2004121500-2005013100



Hemisphere Nord 24h



Hemisphere Sud 24h

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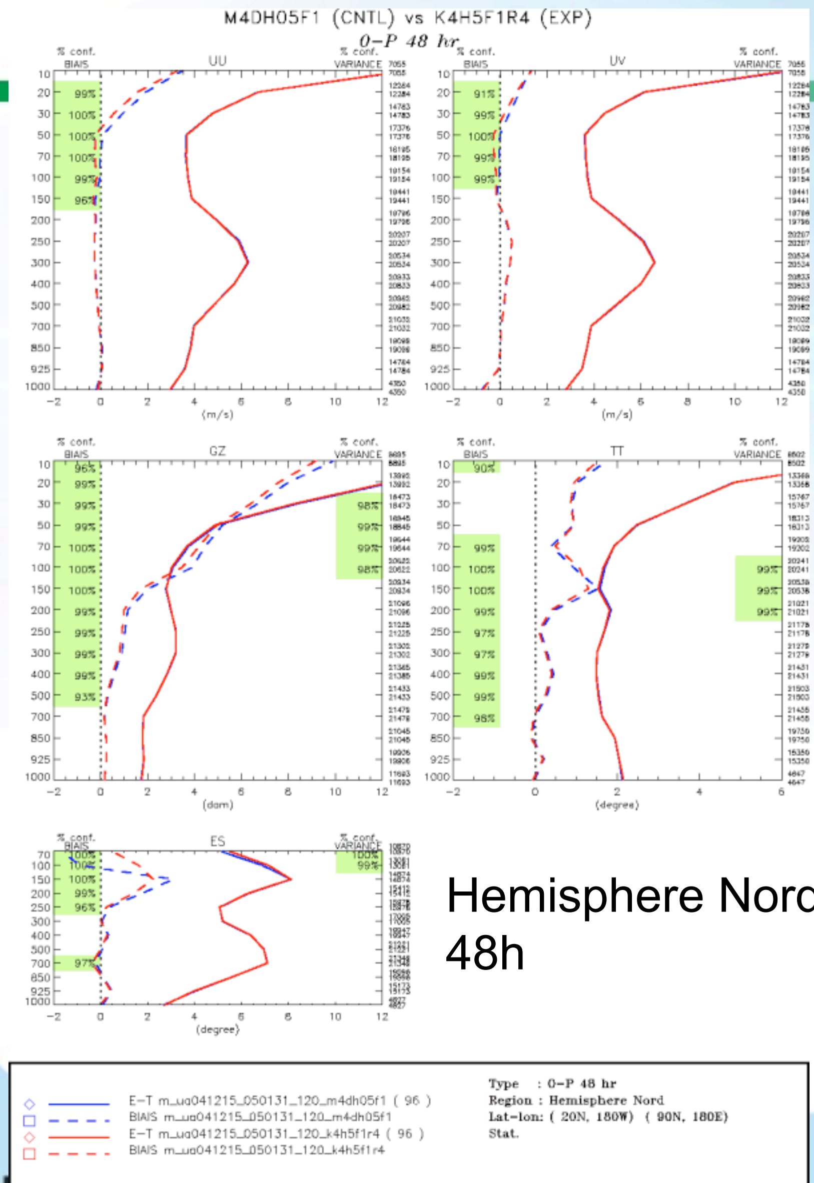
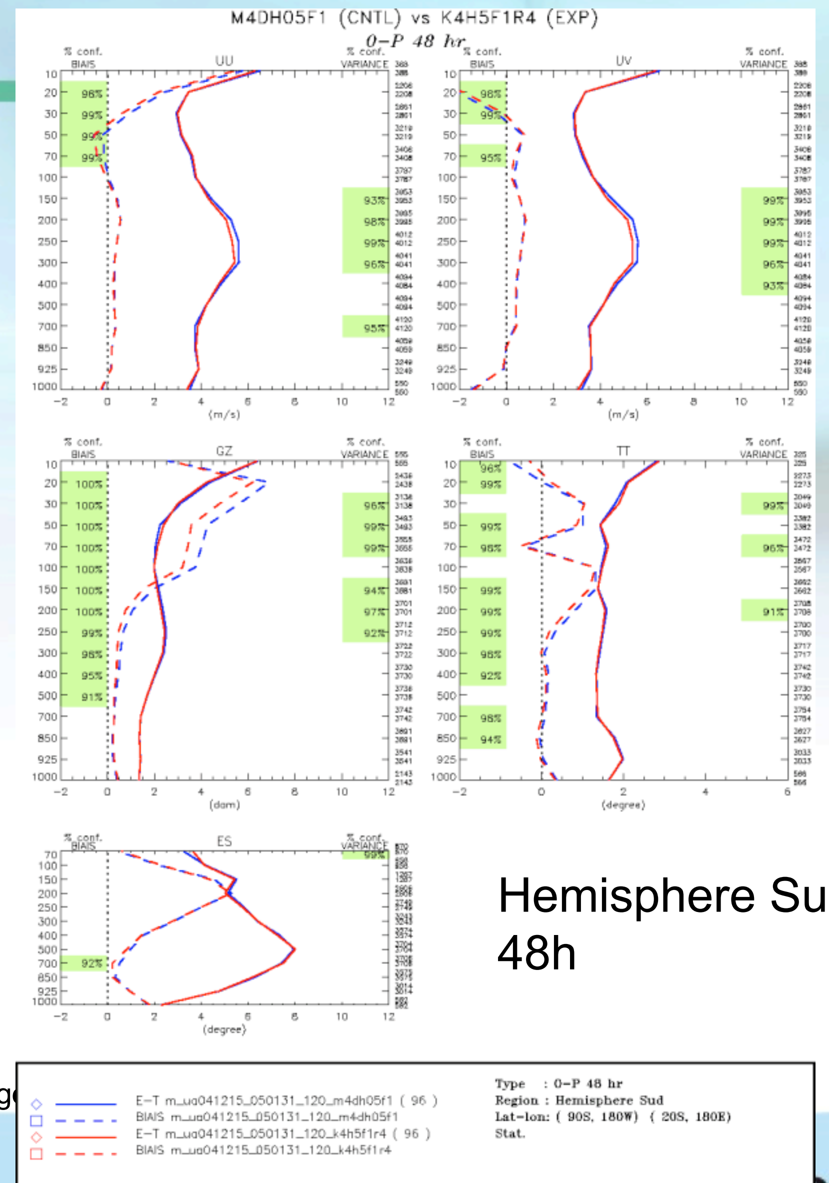


Hemisphere Nord 48h



Hemisphere Sud 48h

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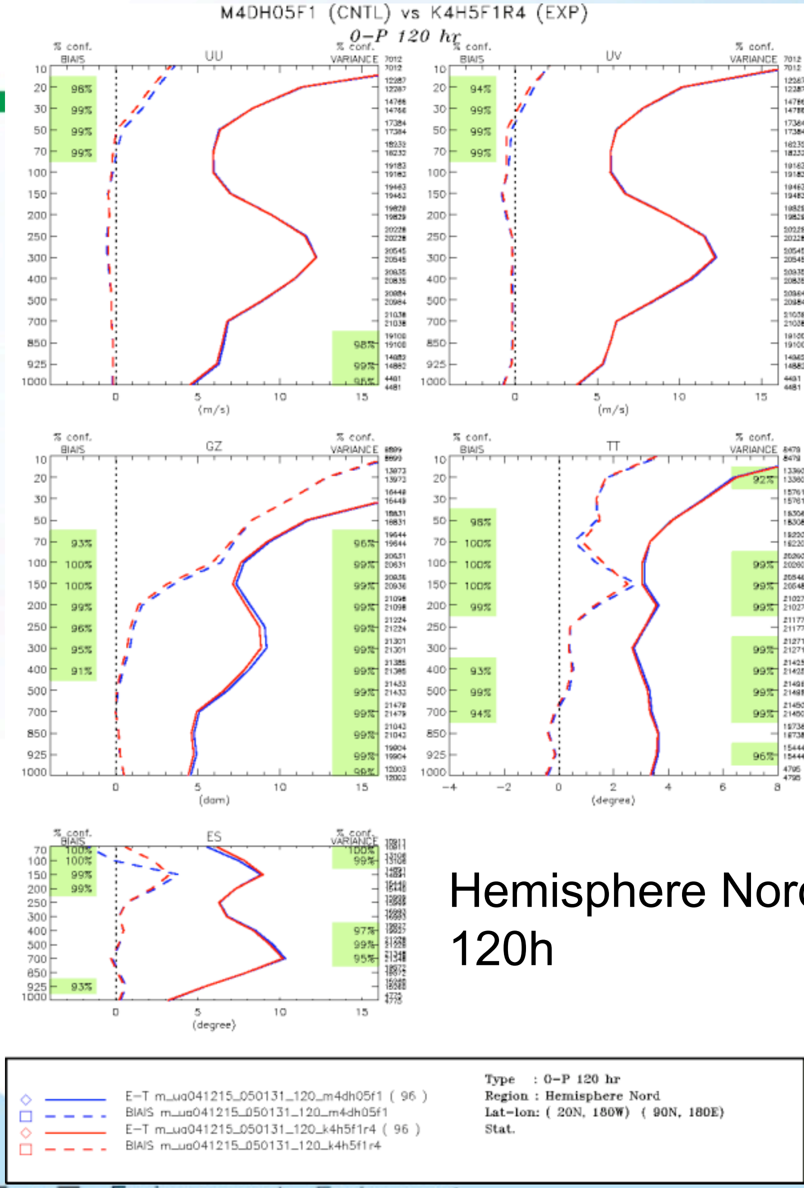
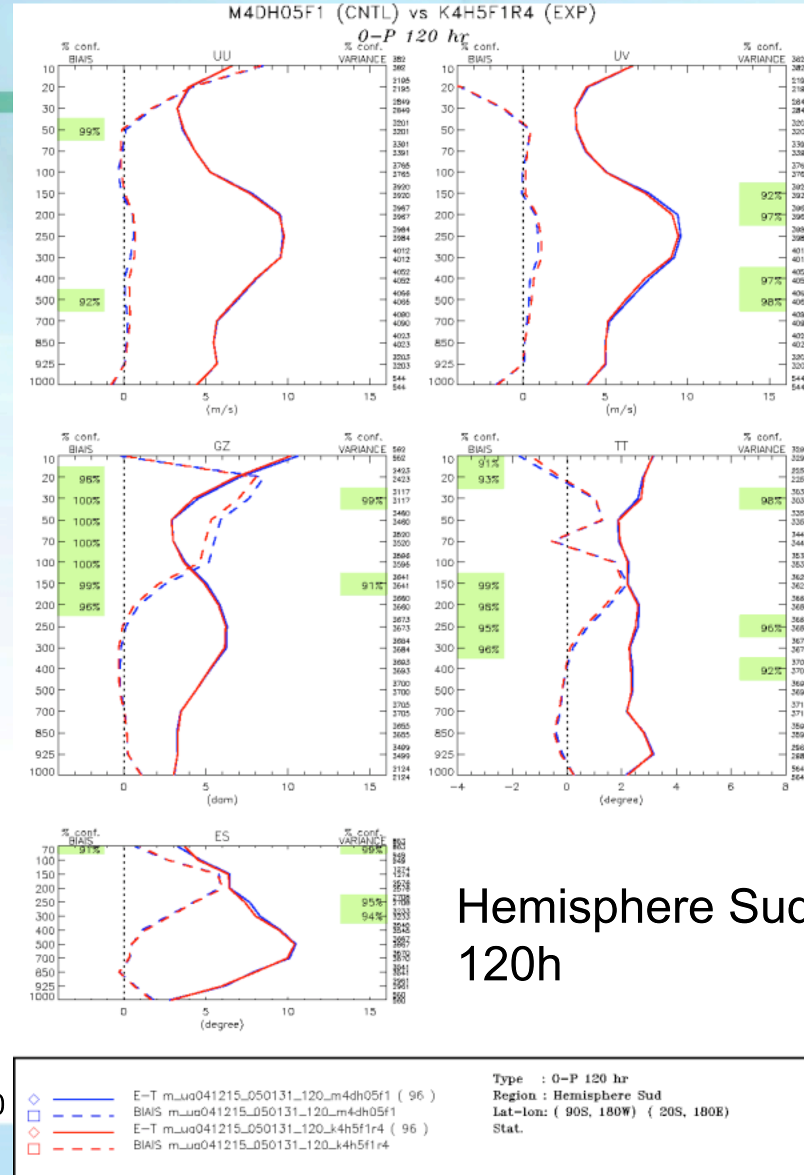


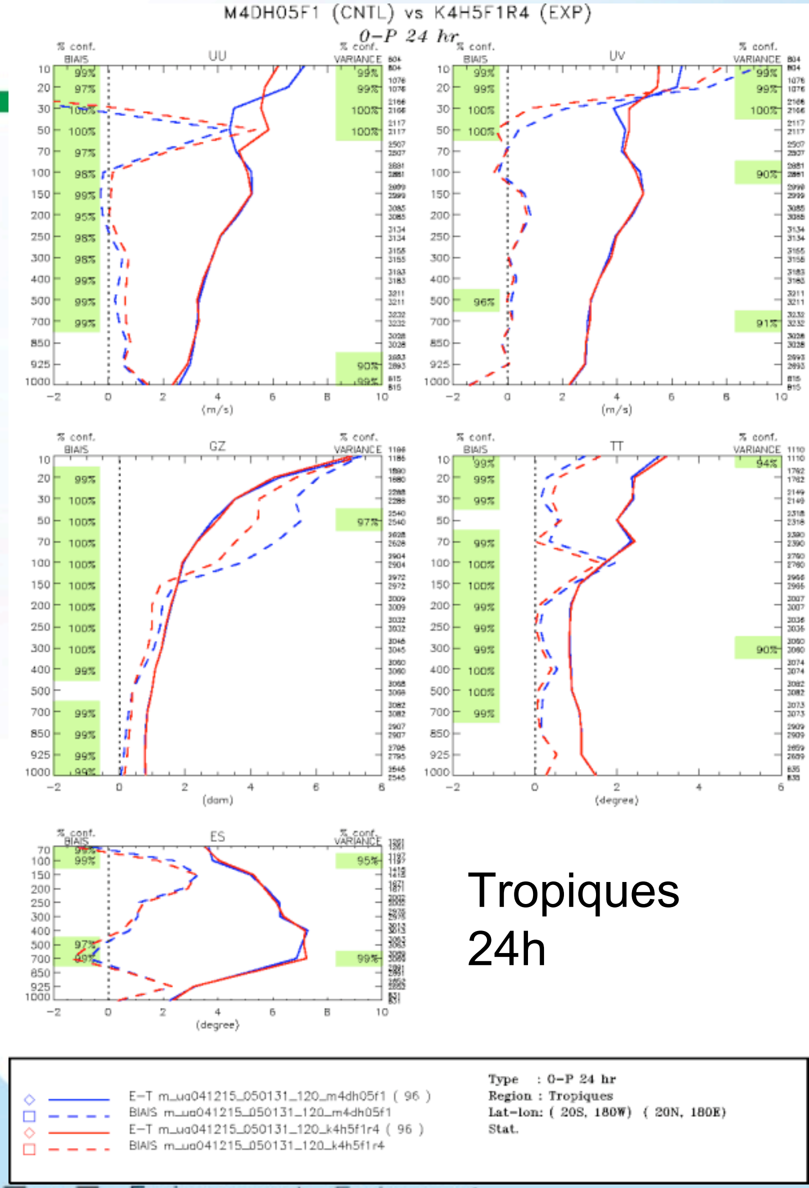
Hemisphere Nord
120h



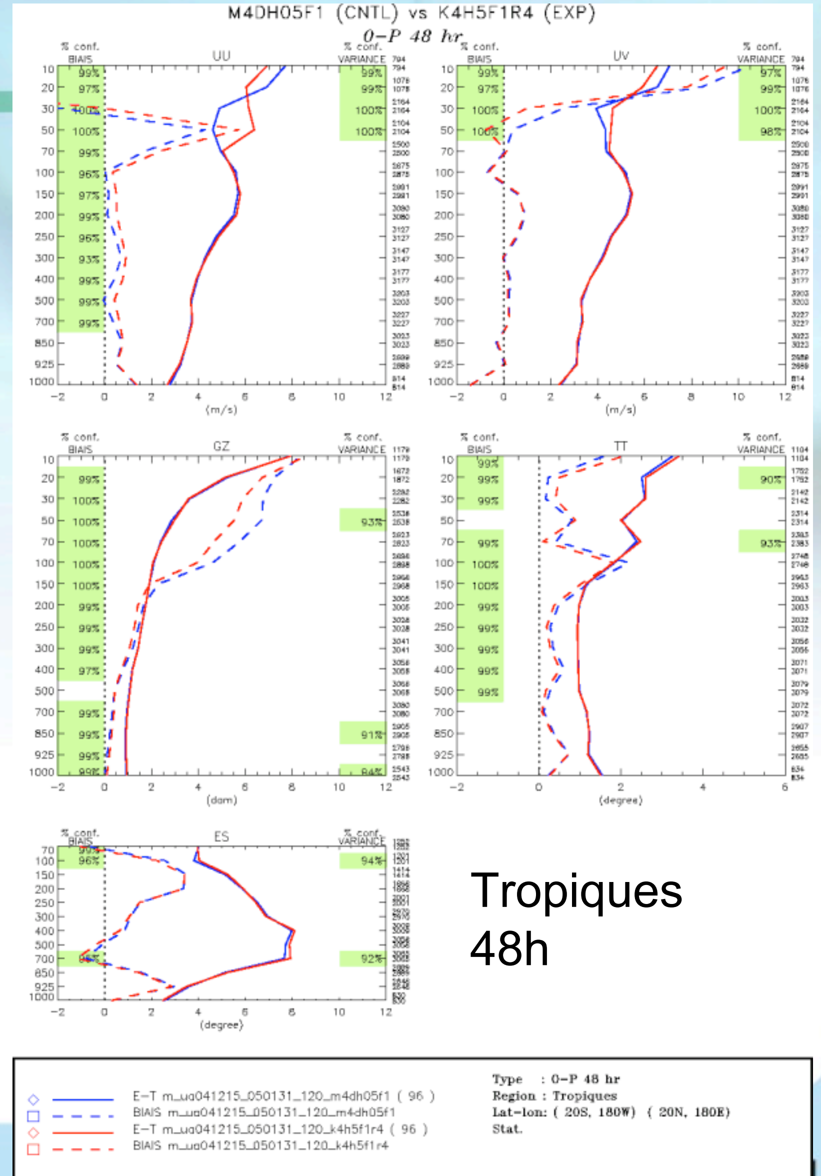
Hemisphere Sud
120h

Verifications wrt RAOBS data M4DH05F1 vs K4H5F1R4

2004121500-2005013100



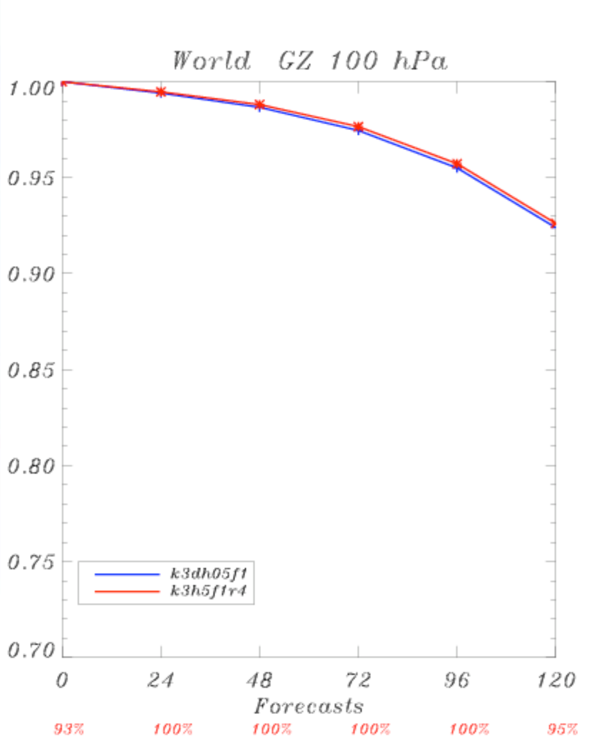
Tropiques 24h

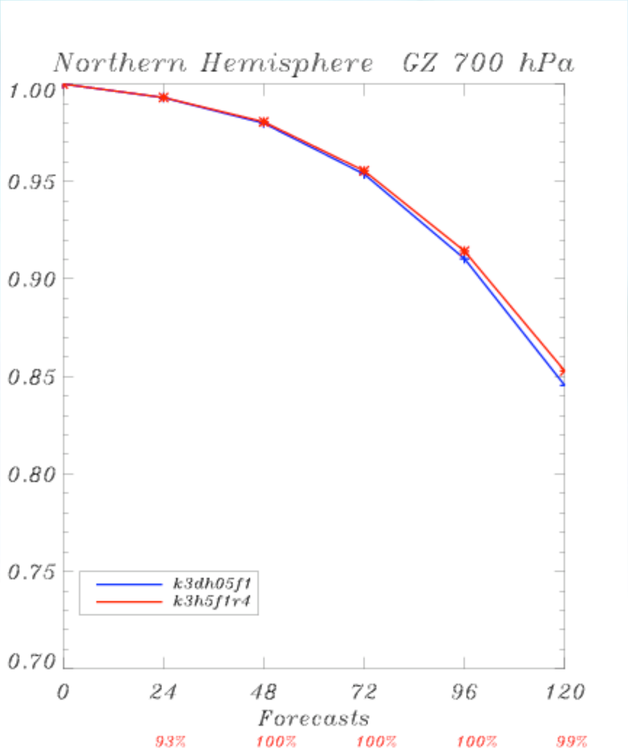


Tropiques 48h

Impact attributed to new interpolator

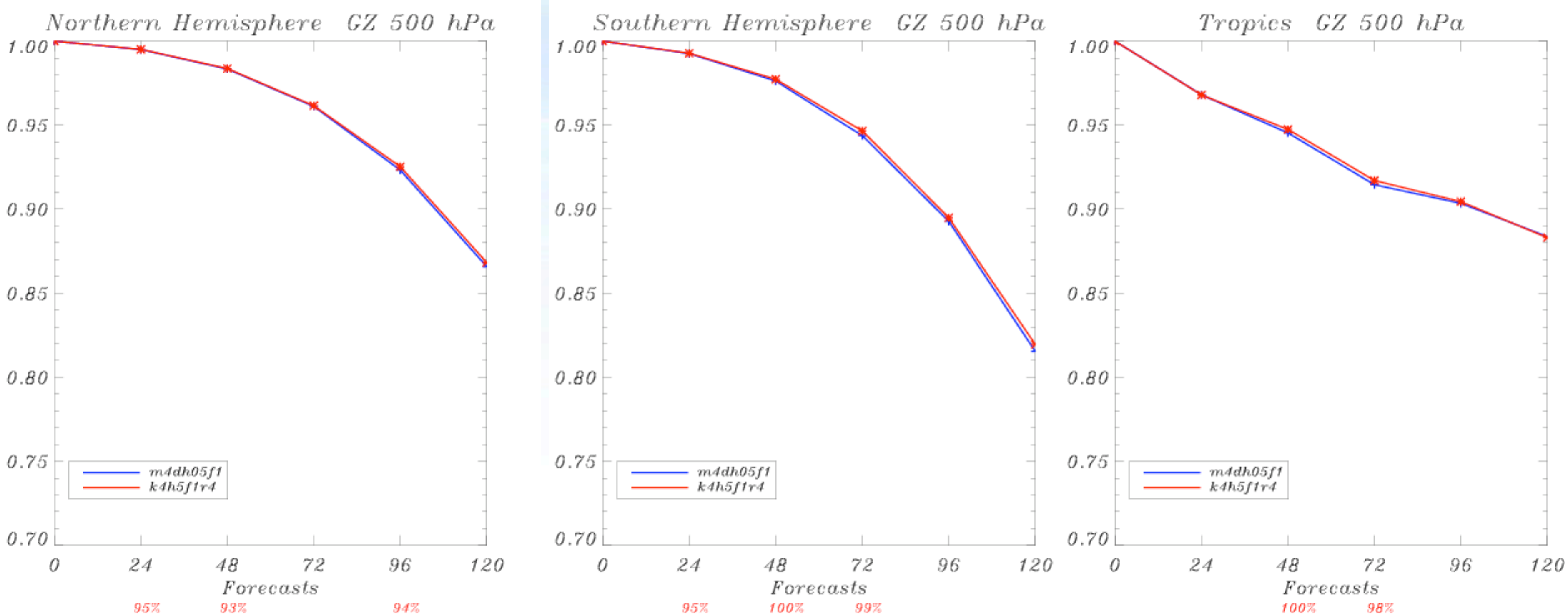
Anomaly correlation versus forecast time





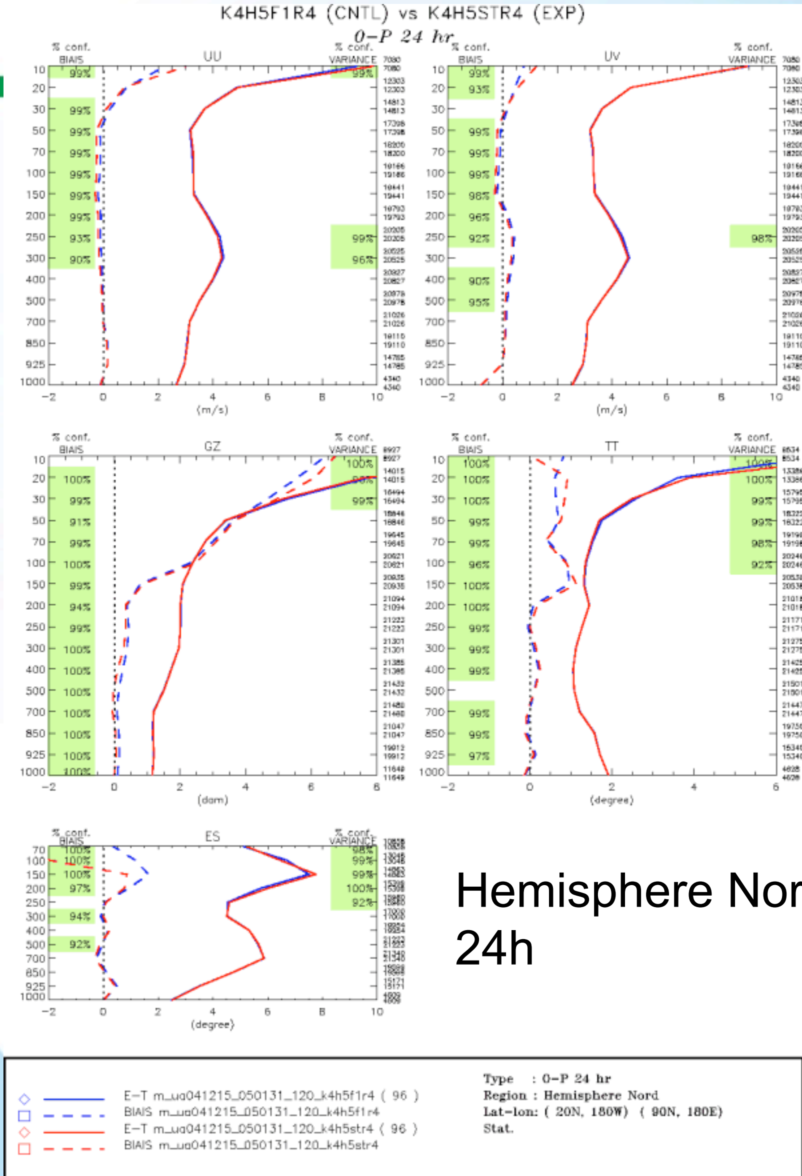
6 weeks of 4D-var cycles: CNTL vs CNTL+RTTOV8 + new interpolator + automated bias cor + ATOVS end of scans included

Verifications wrt Analyses M4DH05F1 vs K4H5F1R4
2004121500-2005012612

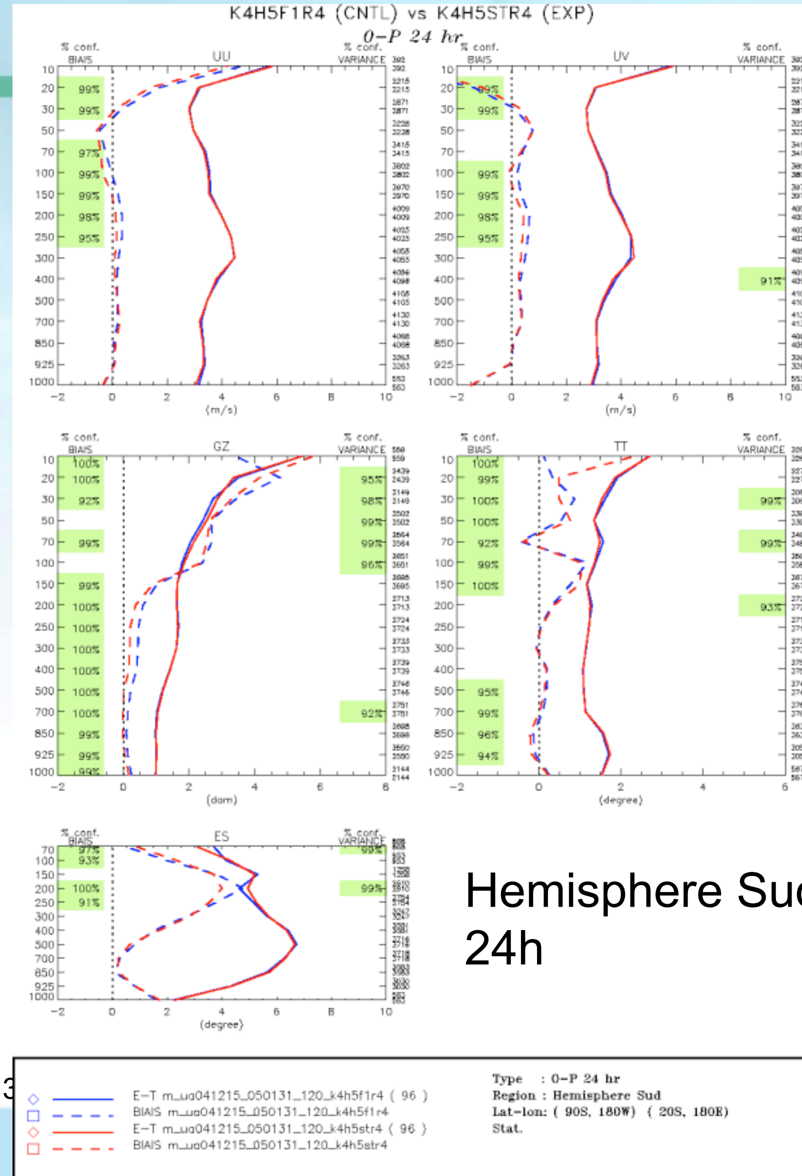


Verifications wrt RAOBS data K4H5F1R4 vs K4H5STR4

2004121500-2005013100



Hemisphere Nord
24h



Hemisphere Sud
24h

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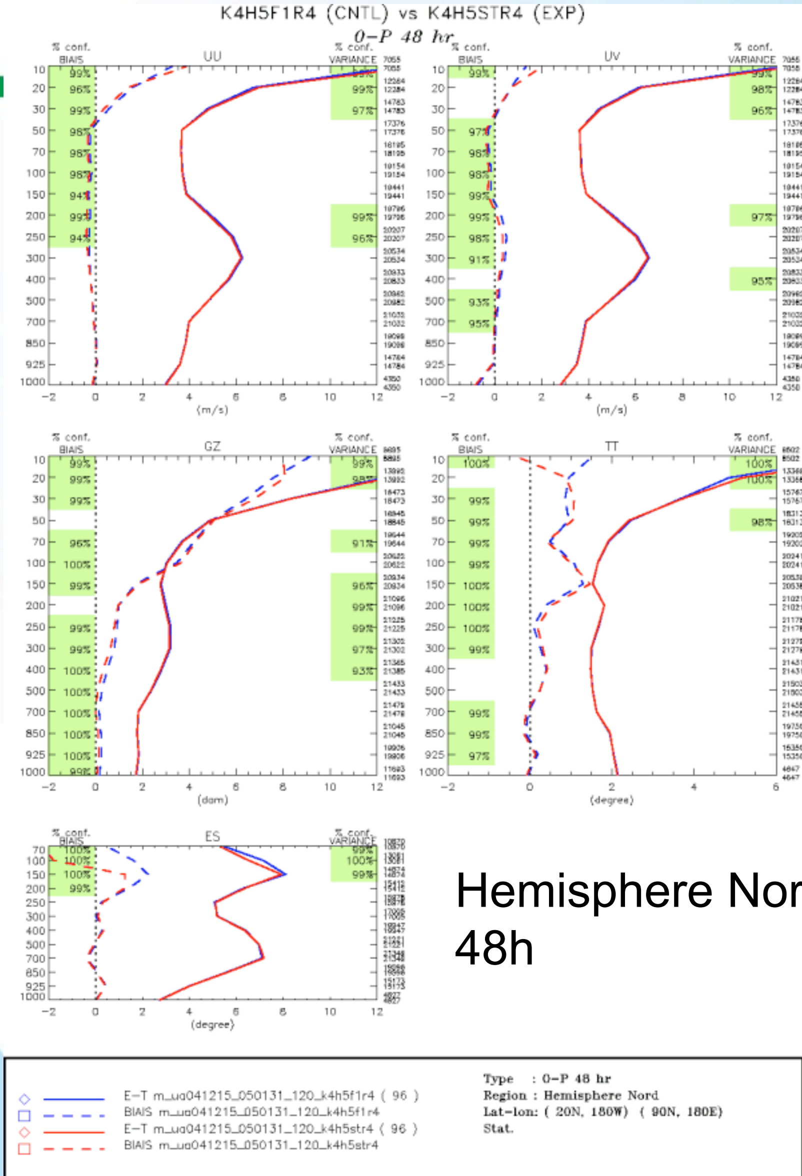
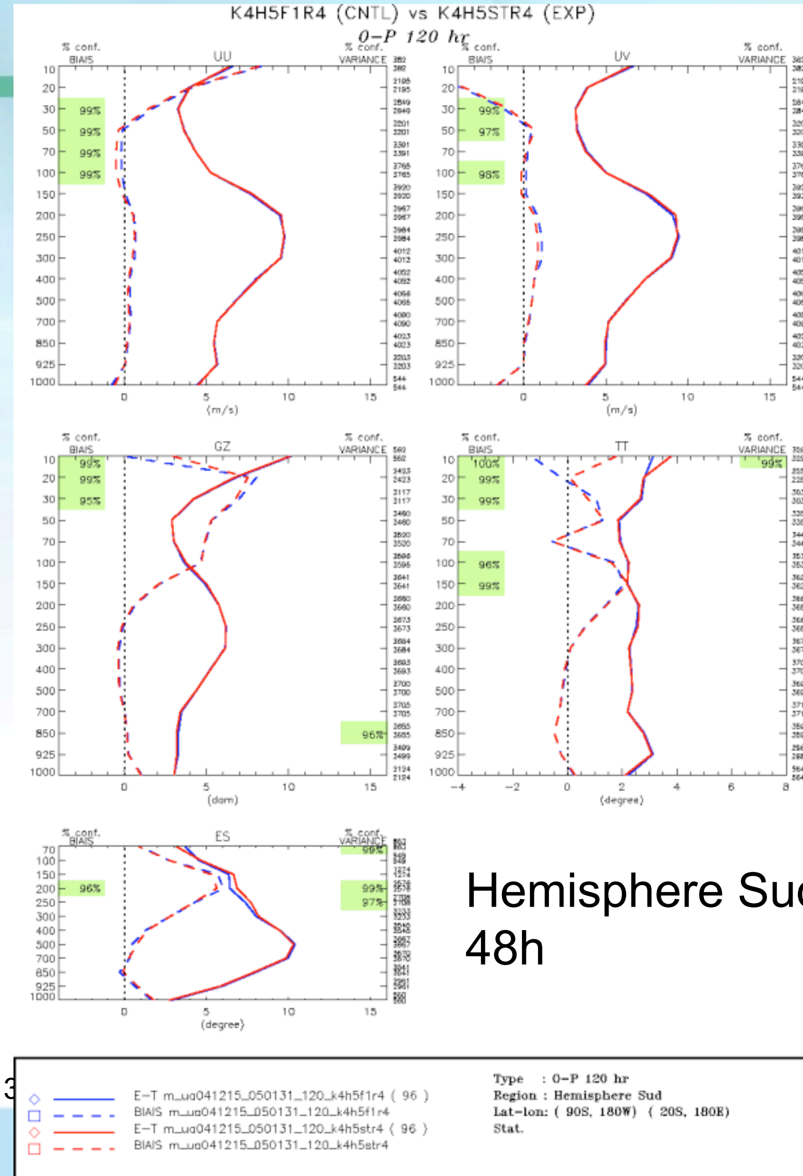
2004121500-2005013100



Hemisphere Nord
48h



Hemisphere Sud
48h

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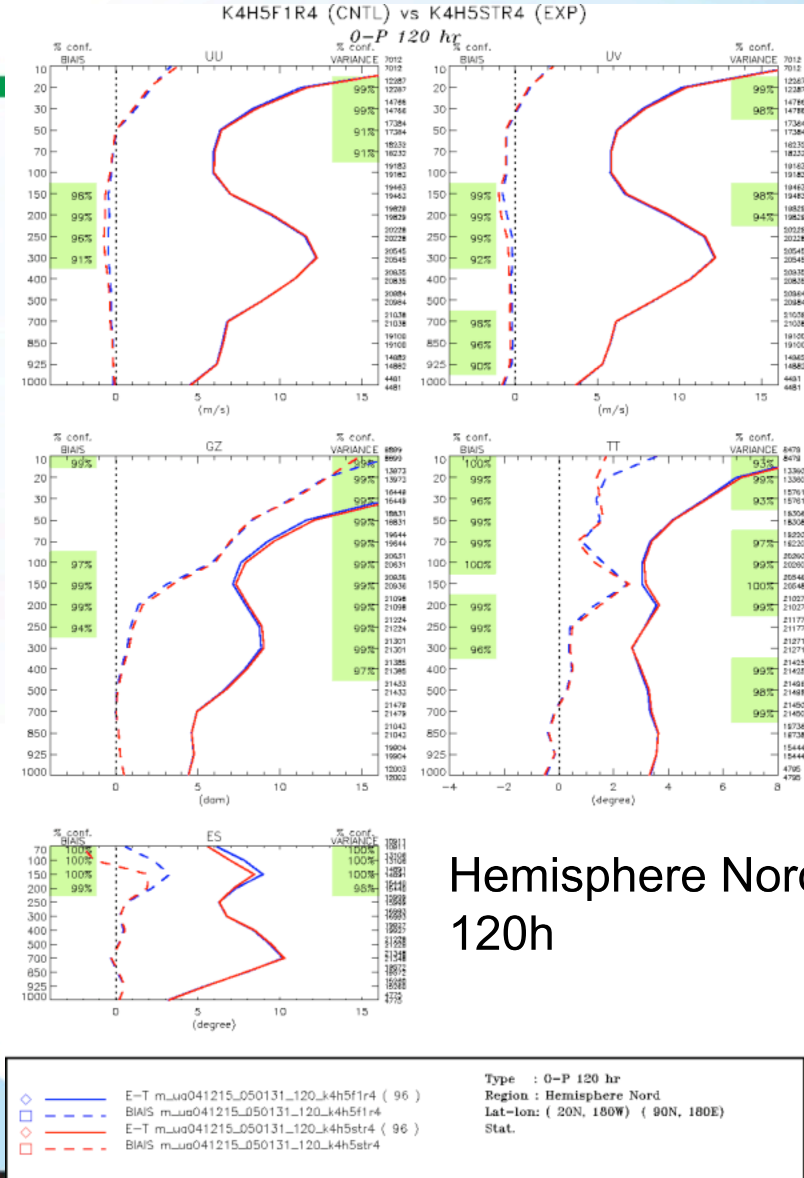
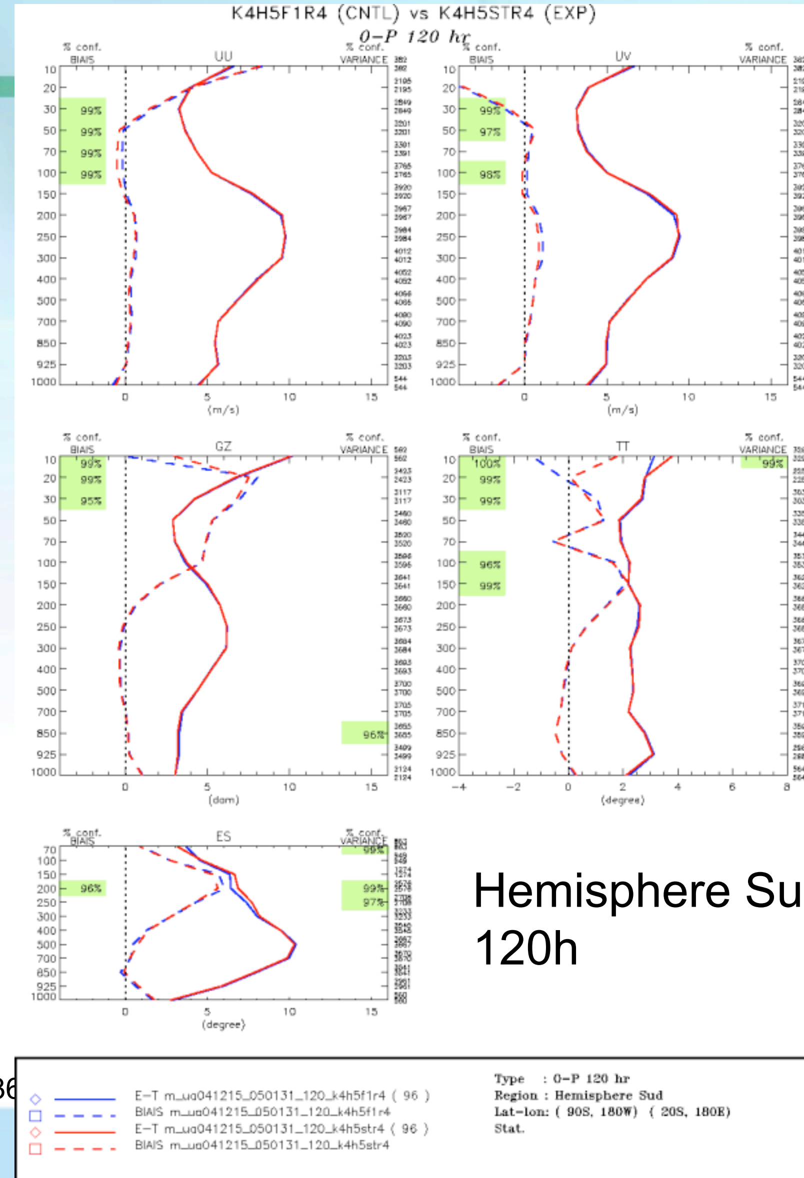


Hemisphere Nord
120h



Hemisphere Sud
120h

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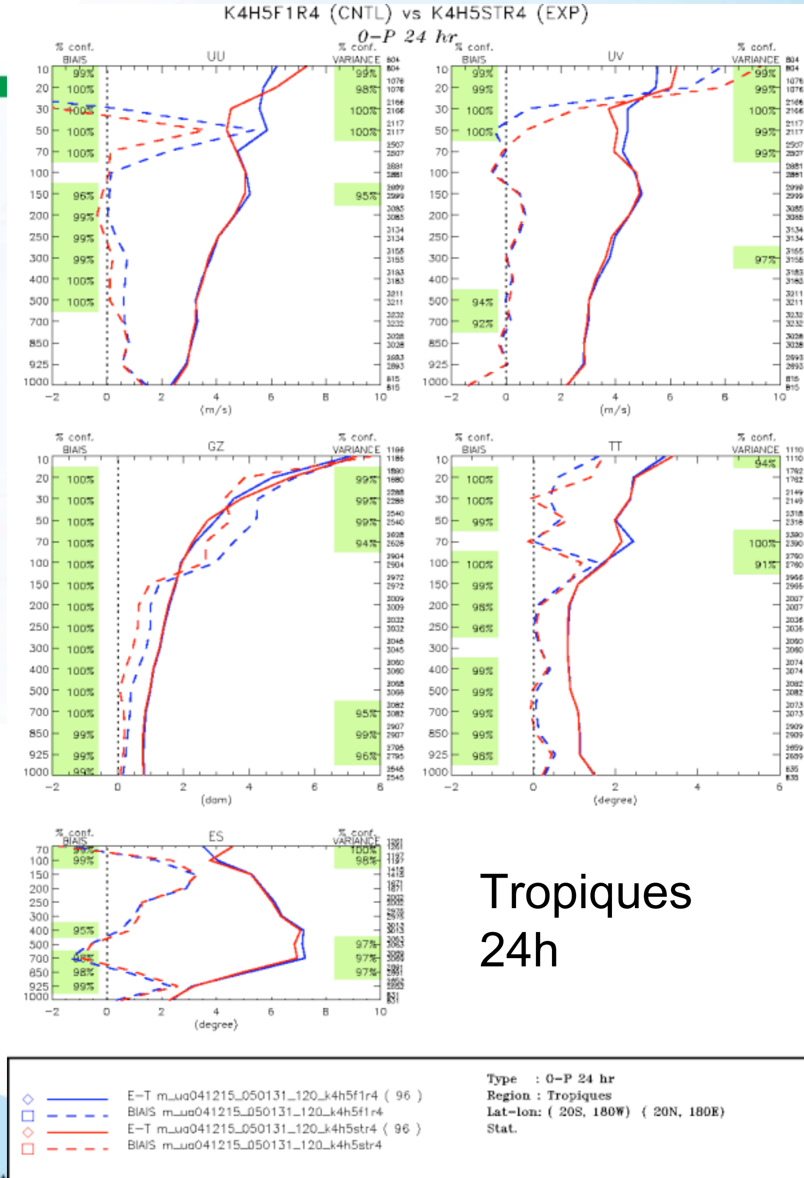
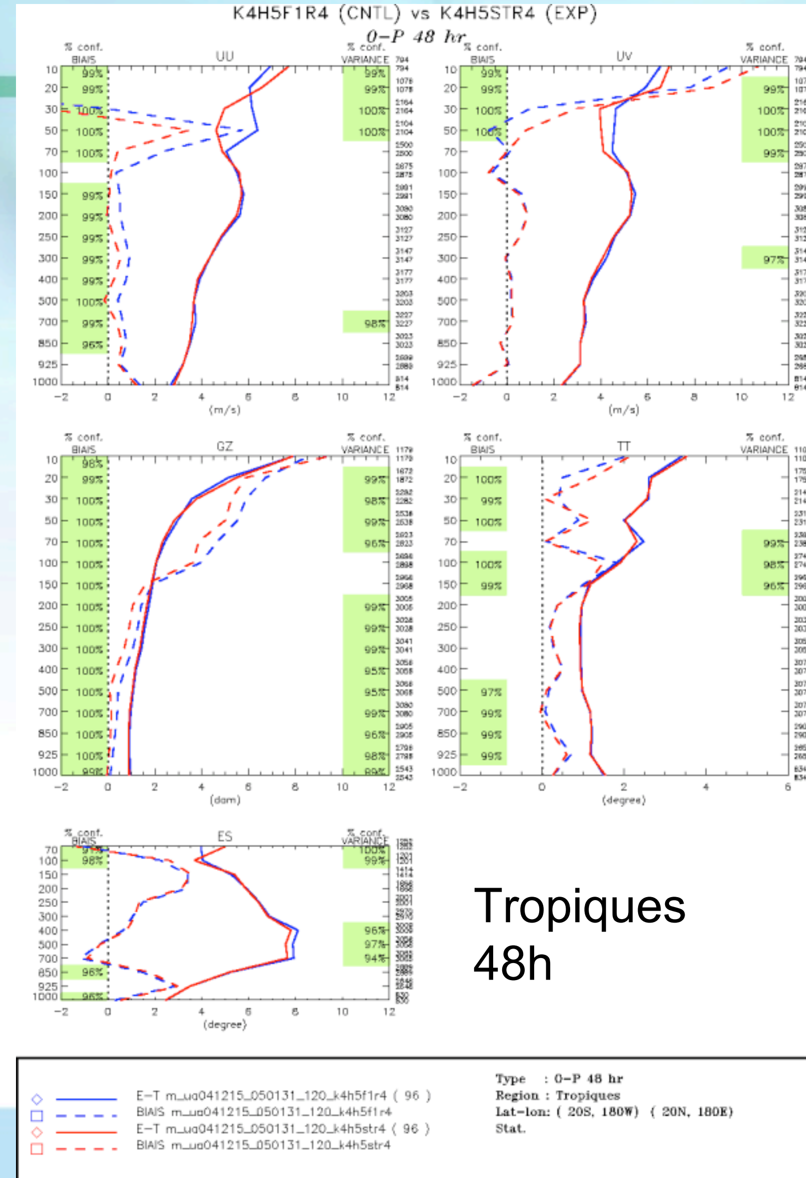


Tropiques 24h

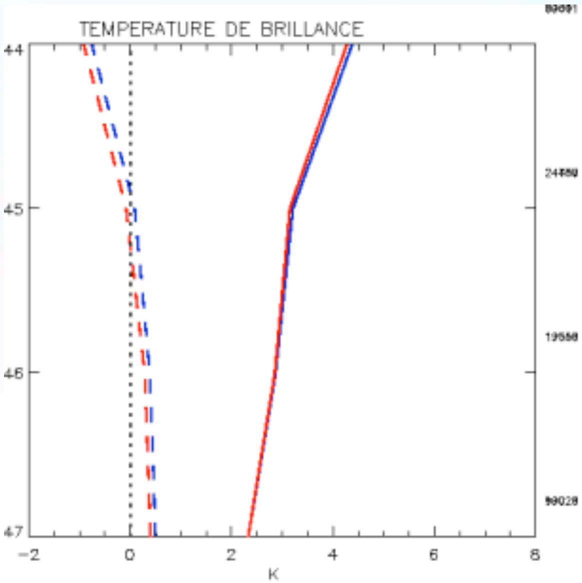


Tropiques 48h

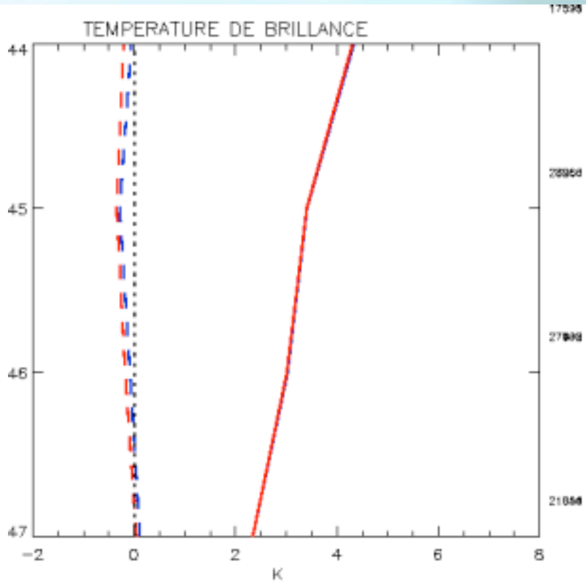
Verifications wrt AMSU data K4H5F1R4 vs K4H5STR4

2004121500-2005011500

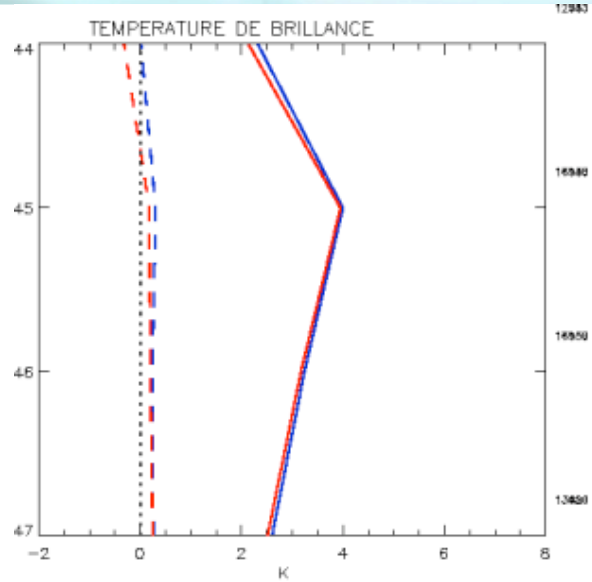
24h AMSU-B
HemisphereNord



24h AMSU-B
HemisphereSud

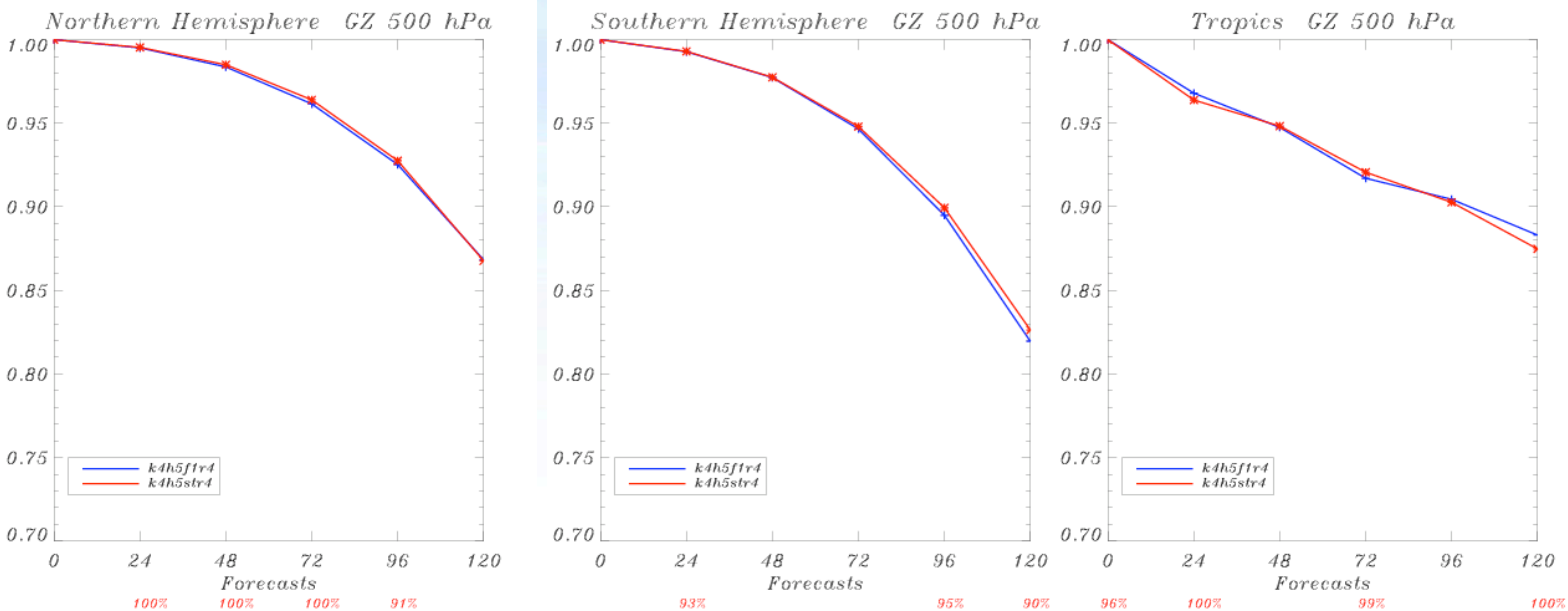


24h AMSU-B
Tropiques



Verifications wrt Analyses K4H5F1R4 vs K4H5STR4
2004121500-2005012612

Impact of new statistics only



SSM/I coverage after thinning