JCSDA, May 2006 to May 2007

Lars Peter Riishojgaard

Acting Director

The year in review

- JCSDA context and partners
- Management and budget
- Sensors and impact experiments
- Radiative transfer modeling
- System development
- OSSE capability

JCSDA partners

- NASA
  - GSFC (GMAO and HSB)
- NOAA
  - EMC
  - STAR
  - ESRL
- DoD
  - AFWA
  - NRL/Monterey

Management

- Leadership transition
  - New acting director
  - Two new deputies (Fuzhong Weng, Michele Rienecker)
  - NESDIS senior scientist assigned to JCSDA for ocean DA planning activities (Eric Bayler)
- Memorandum of Agreement appears close to signing
- First JCSDA Executive Retreat June 2007

JCSDA budget

- JCSDA budget is stable; substantial growth requested from FY2010 onward to support NPOESS and GOES-R
- FFO budget ~$1.8M/year
- JCSDA computing ~$2.0M/year
- Directed research/in kind support ~$10M/year

Satellite Data used in NWP

- HIRS sounder radiances
- AMSU-A sounder radiances
- AMSU-B sounder radiances
- GOES sounder radiances
- GOES, Meteosat, GMS winds
- GOES precipitation rate
- SSM/I precipitation rates
- TRMM precipitation rates
- SSM/I ocean surface wind speeds
- ERS-2 ocean surface wind vectors
- Quikscat ocean surface wind vectors
- AVHRR SST
- AVHRR vegetation fraction
- AVHRR surface type
- Multi-satellite snow cover
- Multi-satellite sea ice
- SBUV/2 ozone profile and total ozone
- Altimeter sea level observations (ocean data assimilation)
- AIRS
- MODIS Winds
- COSMIC

~33 instruments

Sensors and impact experiments

- AIRS
- MODIS
- Windsat
- Quikscat
- SSMI/S
- COSMIC
- *METOP (IASI, ASCAT, GRAS, ATOVS ..)*

Table 2: AIRS Data Usage per Six Hourly Analysis Cycle

Data Category	Number of AIRS Channels
Total Data Input to Analysis	~200×10^6 radiances (channels)
Data Selected for Possible Use	~2.1×10^6 radiances (channels)
Data Used in 3D VAR Analysis(Clear Radiances)	~0.85×10^6 radiances (channels)

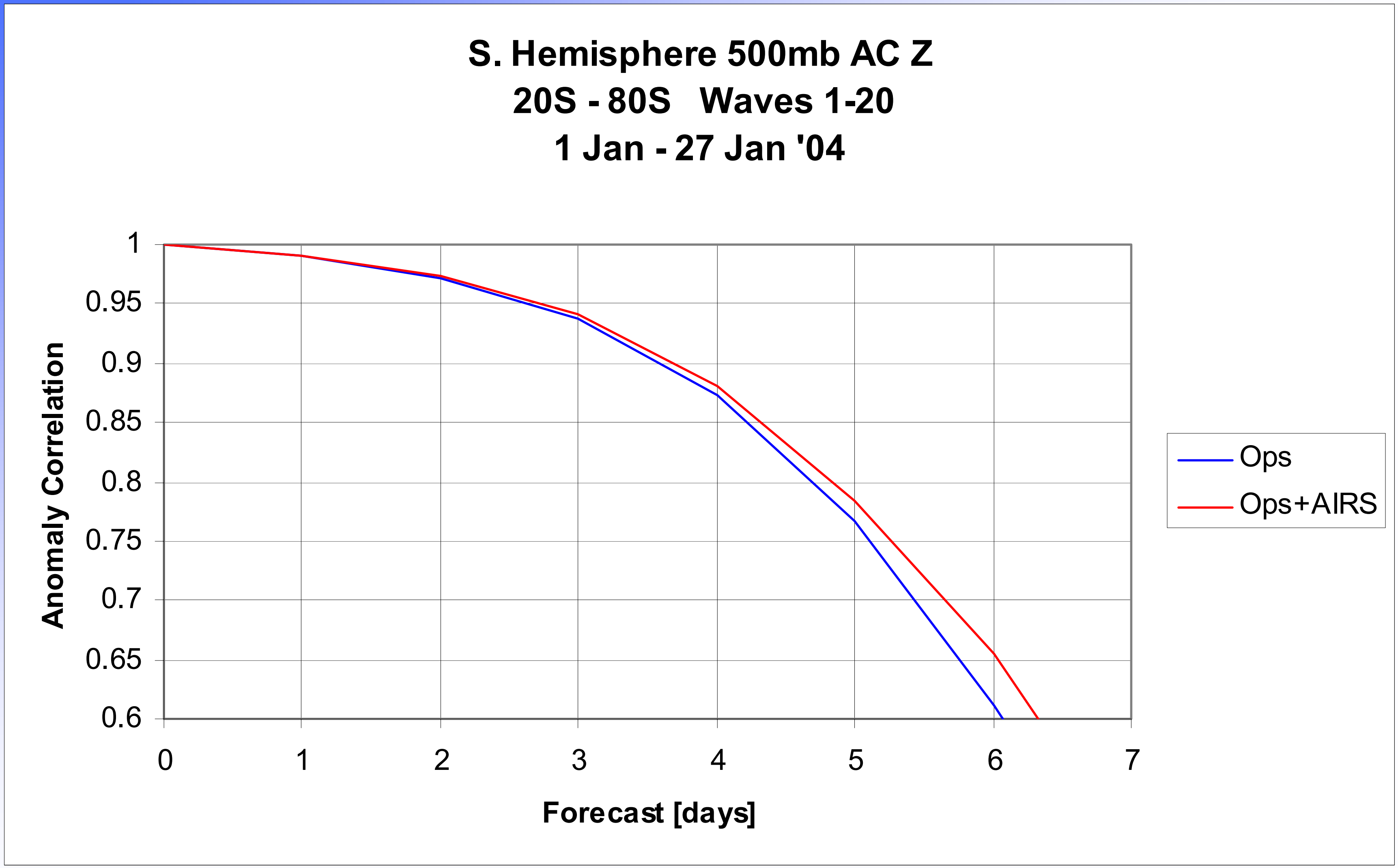


Figure 1(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004

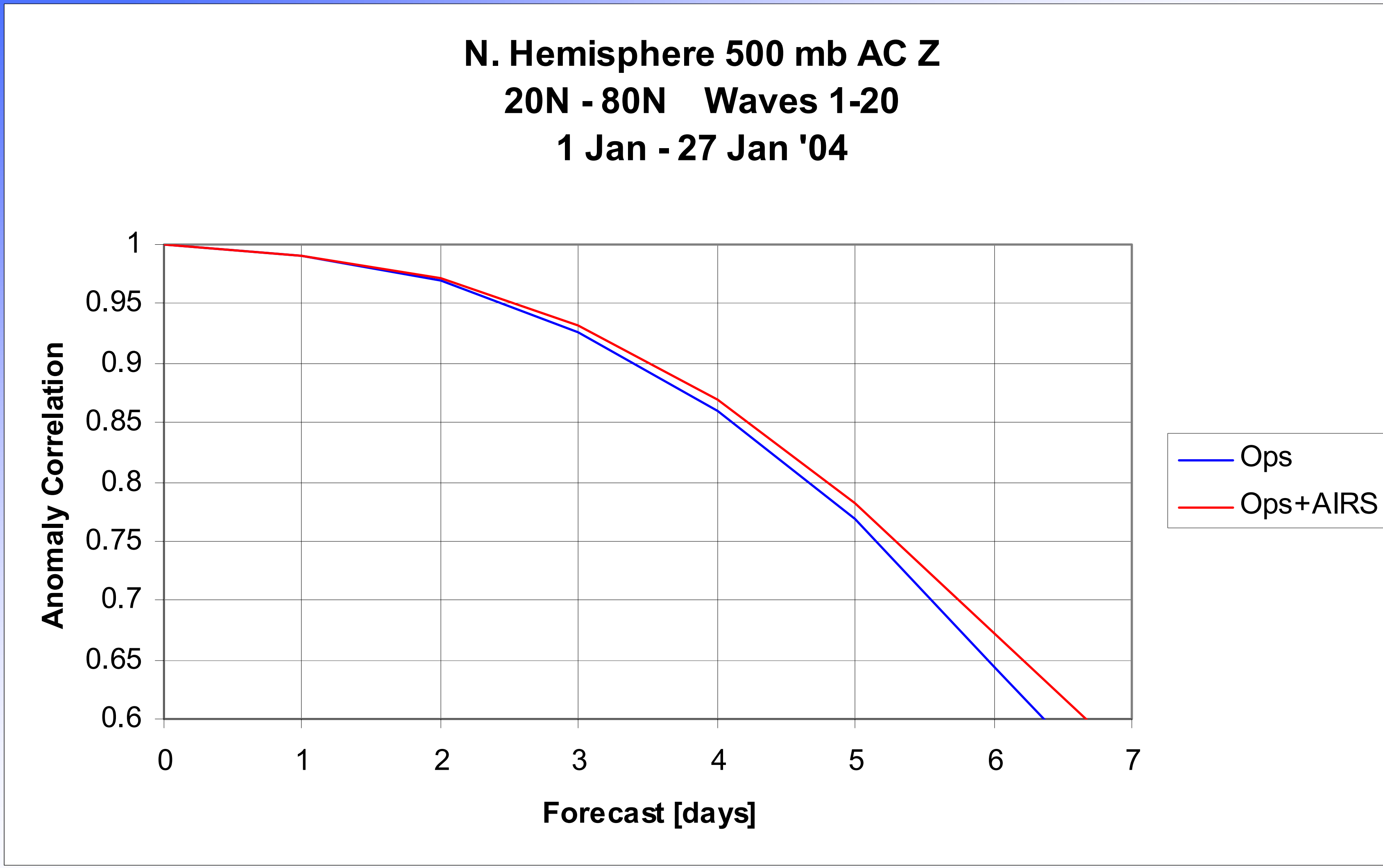


Figure 3(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004

Maps of Ice Polar Stratospheric Clouds from Assimilation of Atmospheric Infrared Sounder

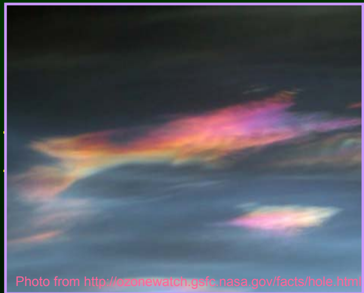


Photo from http://ozonewatch.gsfc.nasa.gov/facts/hole.html

Ivanka Stajner, Craig Benson, Hui-Chun Liu, Steven Pawson, Lang-Ping Chang, and Lars Peter Riishojgaard

Global Modeling and Assimilation Office, NASA/Goddard Space Flight Center, Greenbelt, Maryland

Abstract

A novel technique is presented for detection of ice polar stratospheric clouds (PSCs) that form at extremely low temperatures in the lower polar stratosphere during winter. Temperature is a major factor in determining abundance of PSCs, which in turn provide surfaces for heterogeneous chemical reactions leading to ozone loss and radiative cooling. The technique infers the presence of ice PSCs using radiances from the Atmospheric Infrared Sounder (AIRS) in the Goddard Earth Observing System version 5 (GEOS-5) data assimilation system. Brightness temperatures are computed from short-term GEOS-5 forecasts for several hundred AIRS channels, using a radiation transfer module. The differences between collocated AIRS observations and these computed values are the observed-minus-forecast (O-F) residuals in the assimilation system. Because the radiation model assumes clear-sky conditions, we hypothesize that these O-F residuals contain quantitative information about PSCs. This is confirmed using sparse data from the Polar Ozone and Aerosol Measurement (POAM) III occultation instrument. The analysis uses O-F residuals for the 6.79μm AIRS moisture channel. At coincident locations, when POAM III detects ice clouds, the AIRS O-F residuals for this channel are lower than –2K. When no ice PSCs are evident in POAM III data, the AIRS O-F residuals are larger. Given this relationship, the high spatial density of AIRS data is used to construct maps of regions where O-F residuals are lower than –2K, as a proxy for ice PSCs. The spatio-temporal variations of PSCs in the Antarctic are discussed on the basis of these maps.

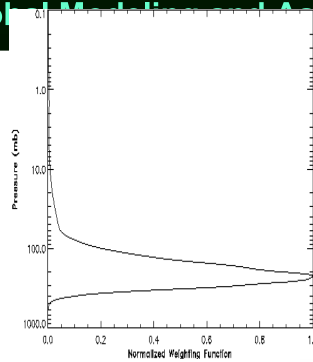


Figure 1. Normalized weighting function for the AIRS moisture channel near 6.79μm for an Antarctic location in September under cloud free conditions.

AIRS provides high resolution infrared spectra, which contain information about atmospheric temperature, moisture and composition (Aumann et al. 2003). Various wavelengths are sensitive to different parts of the atmospheric profiles.

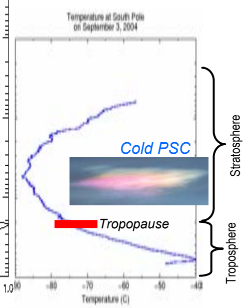


Figure 2. AIRS measured brightness temperature at 6.79μm is colder if emission is coming from a PSC than in a profile without PSCs, where the emission comes from the warmer upper troposphere.

In a typical profile during Antarctic winter temperature continues decreasing with increasing altitude in the lower stratosphere.

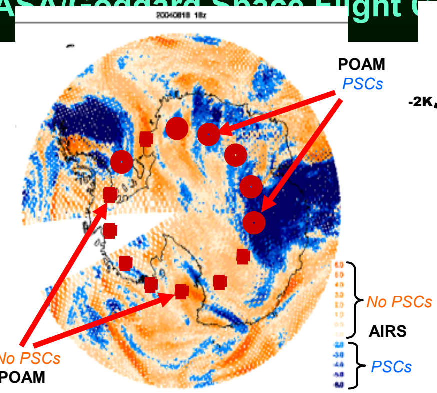


Figure 3. Map of differences in brightness temperature between AIRS observations and the GEOS-5 forecast under cloud-free conditions (O-F residuals) for the 6.79μm channel.

AIRS provides global coverage of the Earth every 12 hours. Regions where AIRS observations are lover by more than –2K are shaded blue. Locations of sparse solar occultation measurements from **POAM** on the same day are marked (o for ice PSCs, + for no ice PSCs, ⊕ for a cloud near the tropopause, possibly tropospheric cirrus) (Fromm et al. 1997). Region south of 60°S is shown.

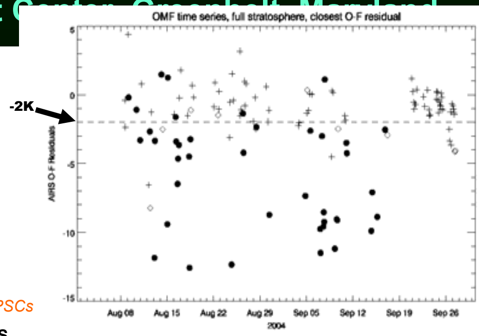


Figure 4. Timeseries comparison of POAM measurements with the closest AIRS O-F residuals (for 6.79μm channel). POAM profiles that detected ice PSCs (•) are collocated with typically lower O-F residuals, than the profiles in which ice PSCs were not detected (+).

Collocation between AIRS and POAM is within 200km and 6 hours. Time difference between POAM and AIRS measurements, and smaller scale features likely contribute to the scatter. POAM observations of clouds near the tropopause (◇) are scattered across the –2K line.

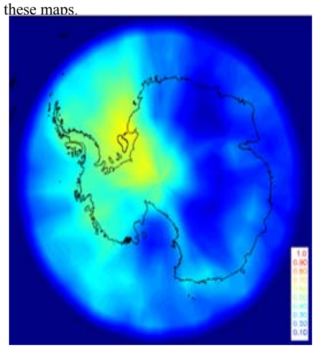


Figure 5. Map of relative frequency of AIRS O-F residuals lower than –2K for the channel at 6.79μm in September 2004.

Highest frequency of PSCs is east of the Antarctic peninsula, which is in agreement with the PSC climatologies from POAM and earlier instruments (Fromm et al. 1997). Topographic gravity waves originating from the Antarctic peninsula are know to contribute to PSC formation in this region.

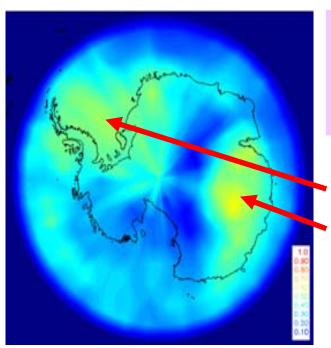
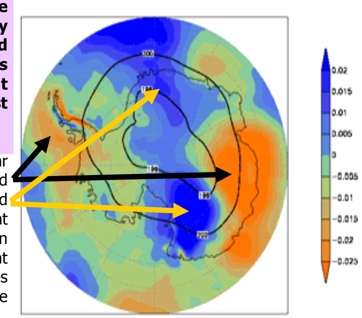


Figure 6. Map of relative frequency of AIRS O-F residuals lower than –2K for the channel at 6.79μm in August 2004.

This indicates high frequency of clouds to the East of the Antarctic peninsula, and the highest frequency over the high terrain near 100°E. Even though high frequency of PSCs near 100°E is not seen in seasonal climatologies, a similar bimodal distribution was observed by POAM II in August of 1995 (Fromm et al. 1997).

Figure 7. Map of the mean vertical velocity ω in Pa/s (color) and temperature (contours of 196K and 200K) at 200 hPa in August 2004 from GEOS-5.

There is upwelling near 90°E and 290°E, and downwelling near 0°E and 140°E. This is consistent with the cloud distribution in Fig. 6. Note also that some topographic waves seem resolved near the Antarctic peninsula.



Conclusions

- AIRS moisture channel at 6.79 μm is affected by ice PSCs.
- AIRS O-F residuals from GEOS-5 provide maps of ice PSCs (Fig.3).
- Comparison with POAM data shows AIRS O-F < -2K for ice PSCs (Fig. 4).
- Frequency of AIRS O-F < -2K in September agrees with PSC climatology (Fig. 5).
- Bimodal distribution in August (Fig. 6) is unusual, but consistent with large scale dynamics (Fig. 7).
- Further studies of PSC distribution, variability and additional comparisons with independent PSC data are planned.

References

Aumann, H. H., et al. (2003), AIRS/AMSU/HSB on the Aqua mission: Design, science objectives, data products, and processing systems, IEEE Trans. Geosci. Remote Sens., 41, 253–264.

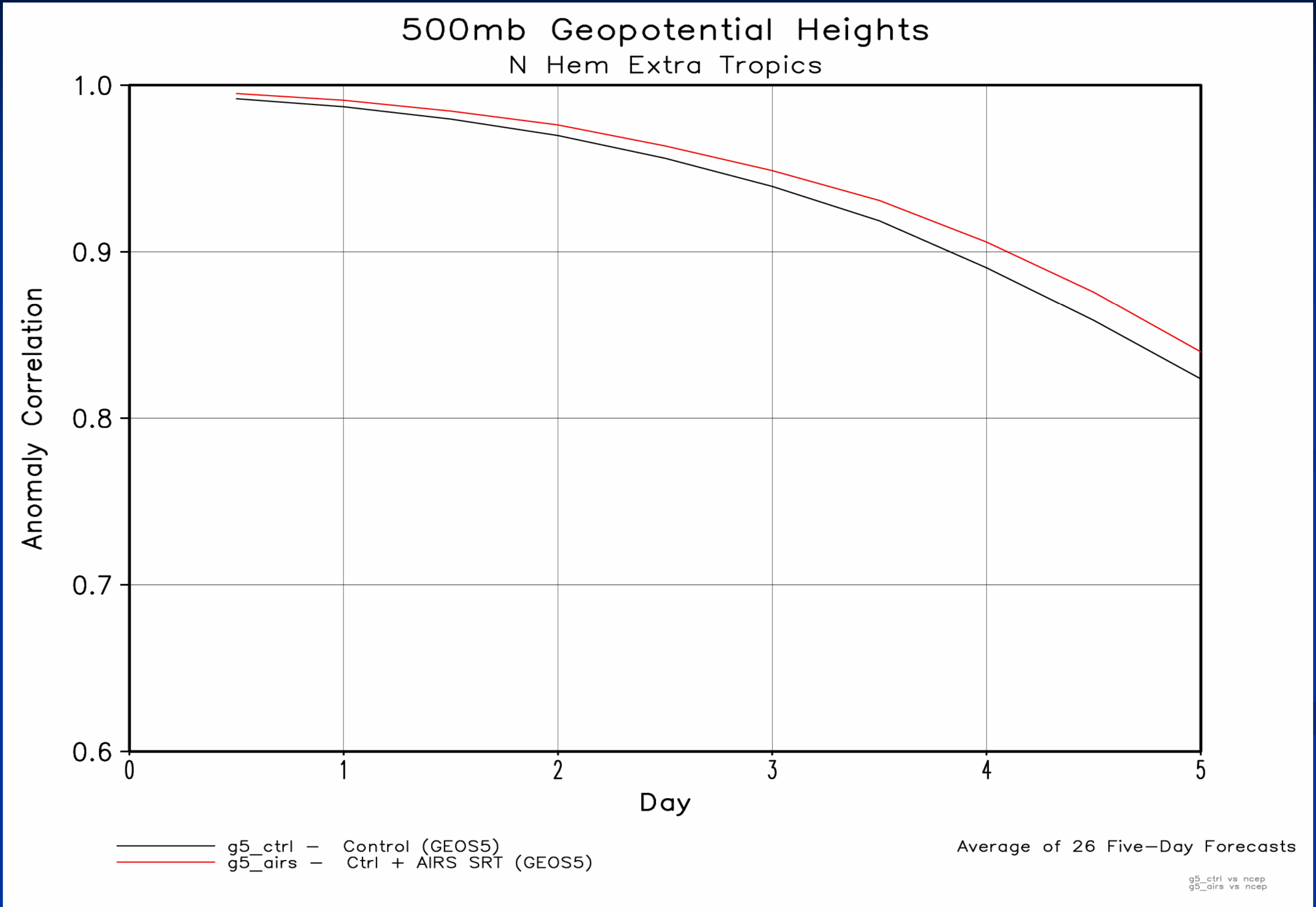
Fromm, M. D., J. D. Lumpe, R. M. Bevilacqua, E. P. Shettle, J. Hornstein, S. T. Massie, and K. H. Fricke (1997), Observations of Antarctic polar stratospheric clouds by POAM II: 1994–1996, *J. Geophys. Res.*, 102(D19), 23,659–23,673.

Stajner I., C. Benson, H.-C. Liu, S. Pawson, N. Brubaker, L.-P. Chang, and L. P. Riishojgaard, Ice Polar Stratospheric Clouds from Assimilation of Atmospheric Infrared Sounder Data, *in preparation.*

Contact: ivanka@gmao.gsfc.nasa.go

Result – average of 26 GEOS-5 AIRS forecasts vs. 26 GEOS-5 Control forecasts

Slide by Reale et al.

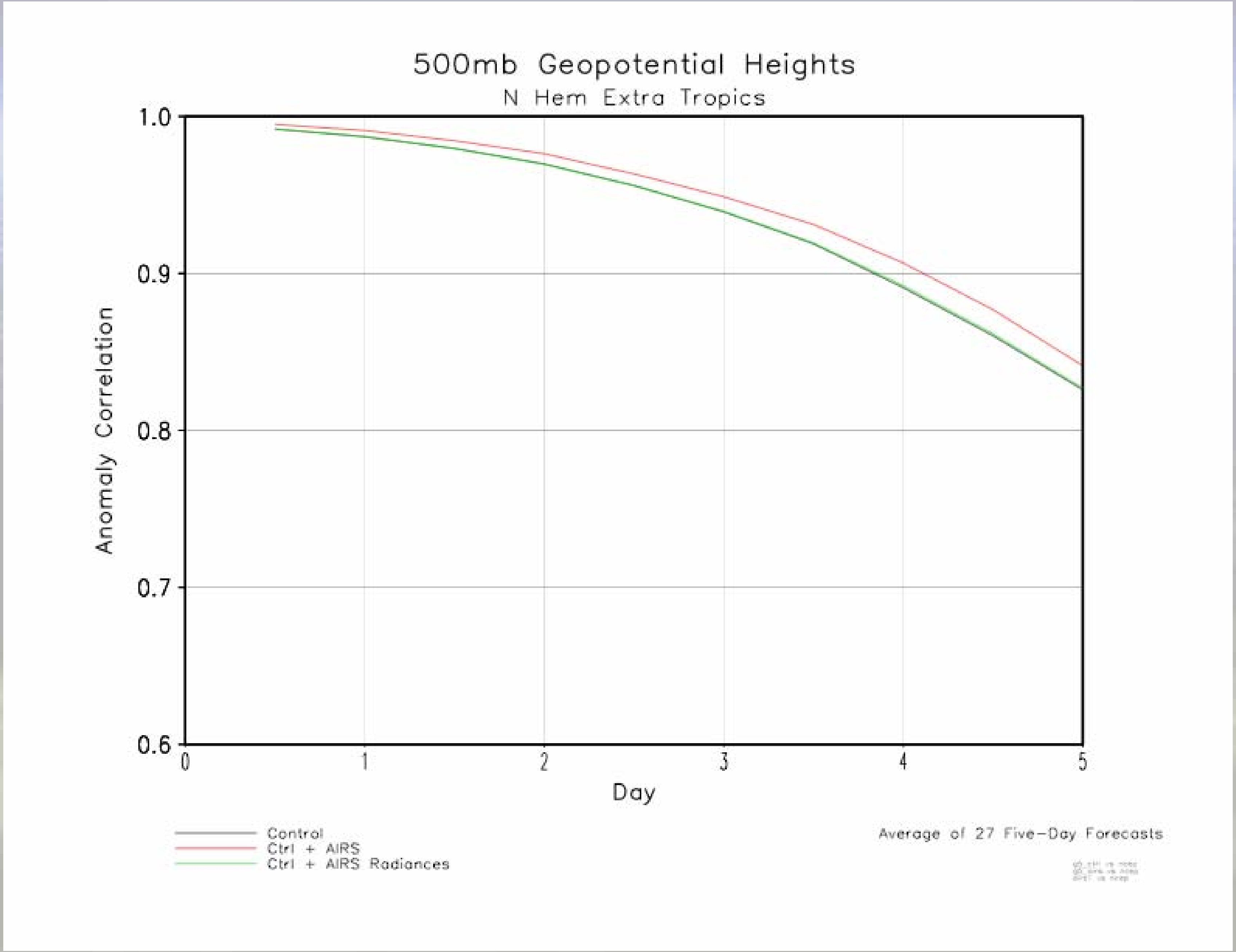


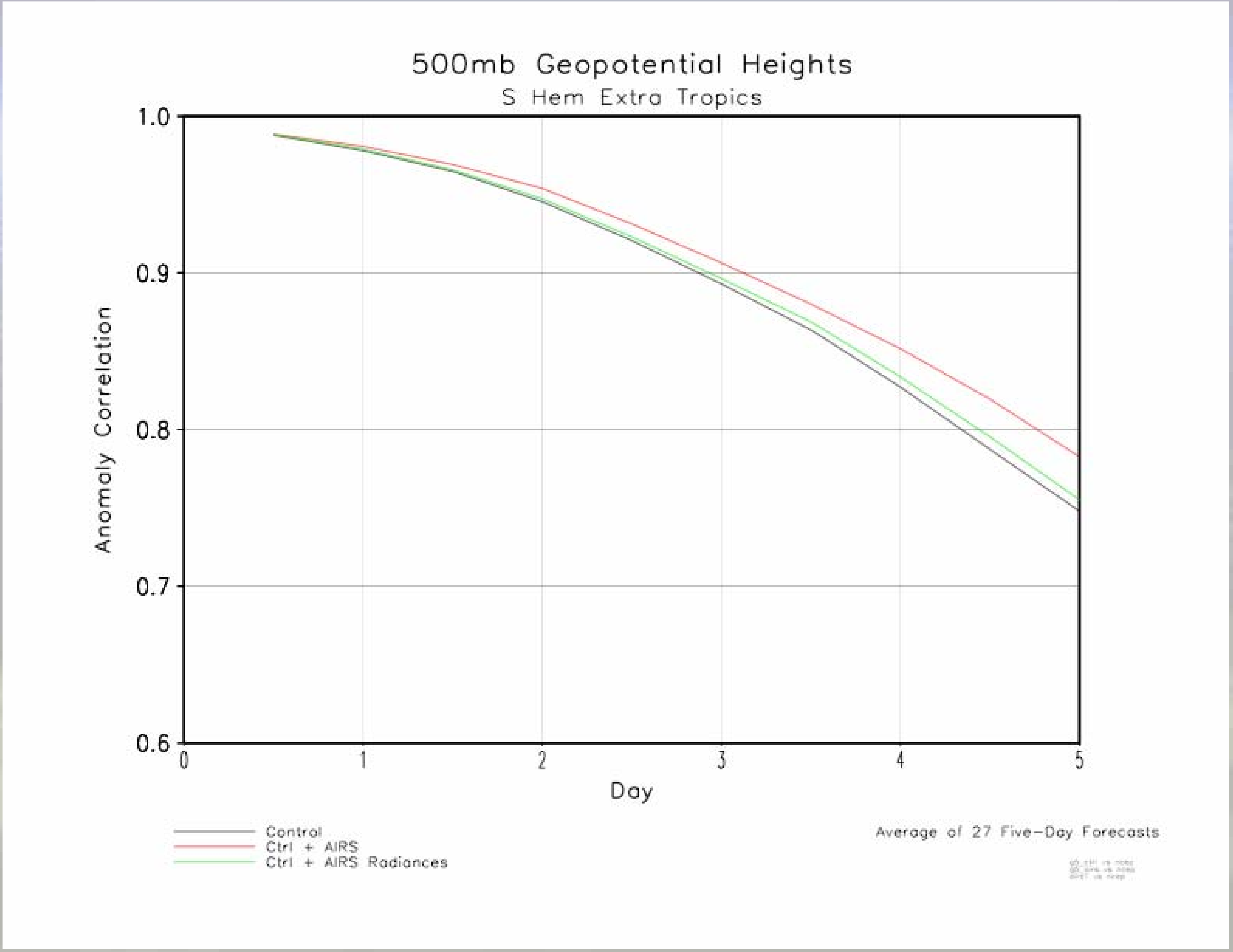
AIRS radiance vs. retrievals comparison

- One period (January 2003), three experiments:
  - Control; including all observations used for routine operations: radiosonde, surface, aircraft and satellite measurements
  - AIRS-1; control + AIRS clear radiances (251 channels)
  - AIRS-2; control + AIRS Science Team temperature retrievals (v. 4.7);

- Assimilation system is GEOS-5, beta7p4; horizontal resolution 1 by 1 ¼ degrees
  - fv-model
  - GSI analysis
    - radiance-based system; AIRS retrievals assimilated as if they were radiosondes

- 27 cases: five-day forecast every day at 00Z; verification carried out against self and NCEP operational analysis (only NCEP shown here)


500mb Geopotential Heights
N Hem Extra Tropics
Anomaly Correlation
1.0
0.9
0.8
0.7
0.6
0
1
2
3
4
5
Day
Control
Ctrl + AIRS
Ctrl + AIRS Radiances
Average of 27 Five-Day Forecasts



500mb Geopotential Heights
S Hem Extra Tropics
Anomaly Correlation
1.0
0.9
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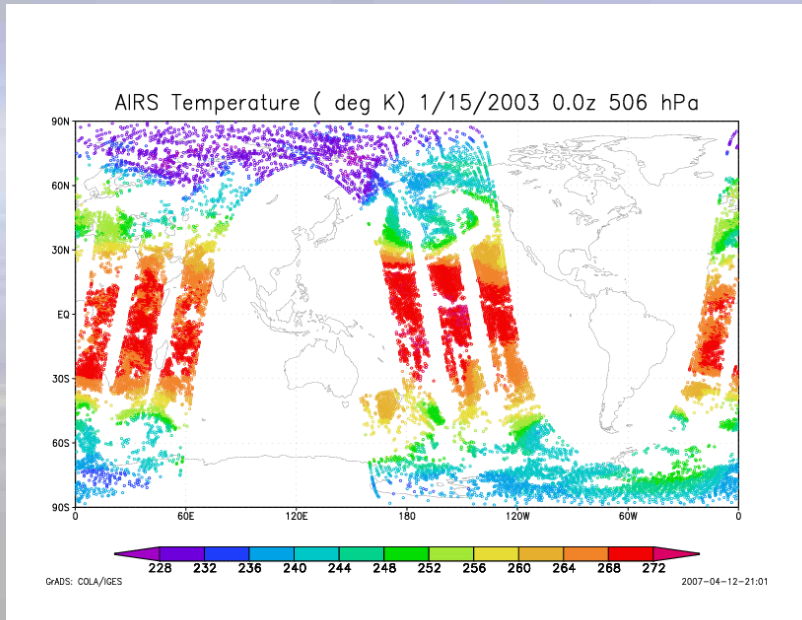
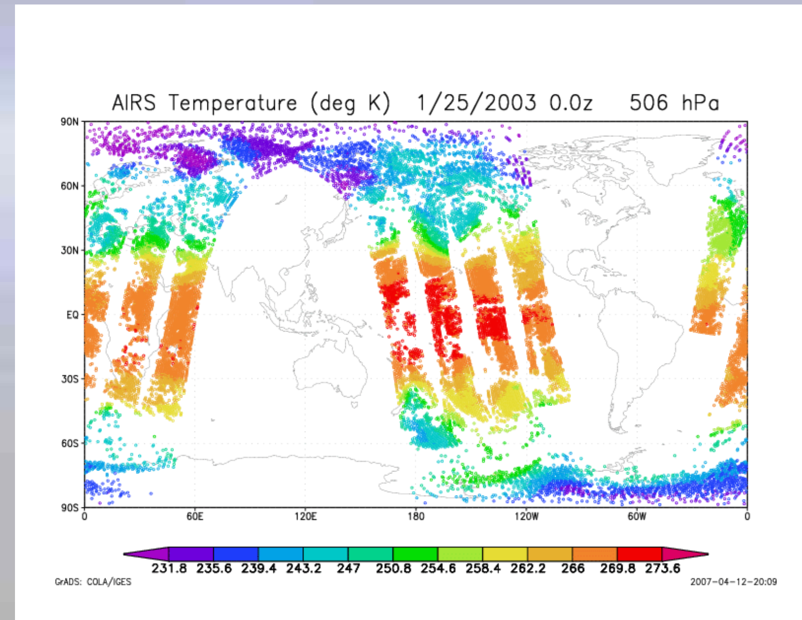
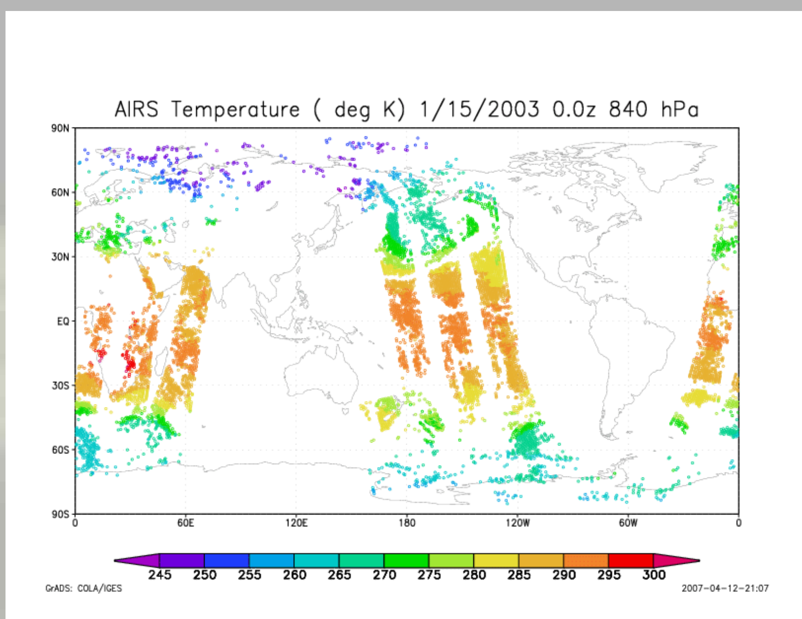
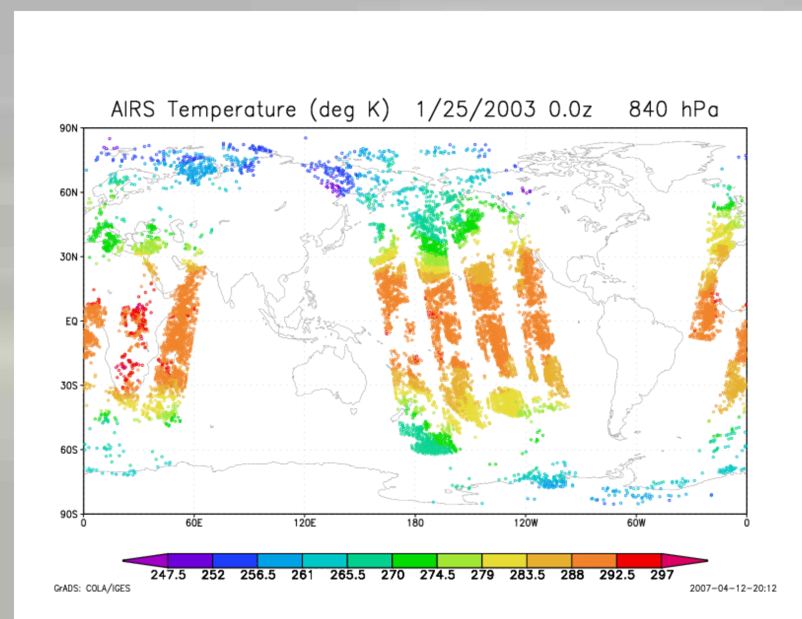
Average of 27 Five-Day Forecasts

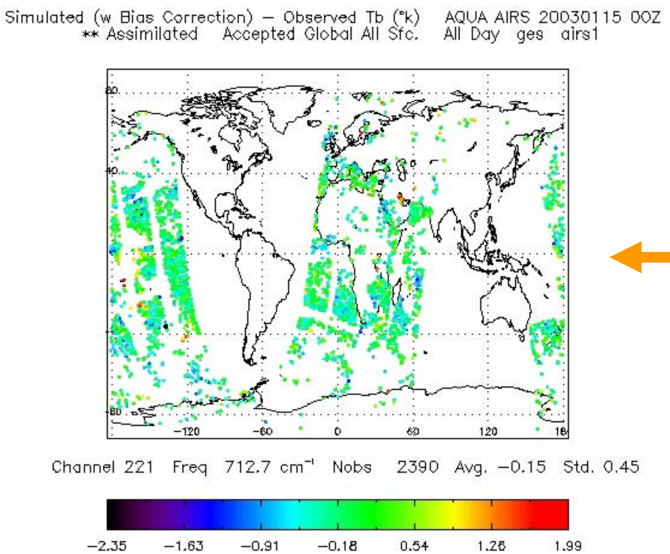

AIRS Temperature (deg K) 1/15/2003 0.0z 506 hPa
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
228 232 236 240 244 248 252 256 260 264 268 272
GrADS: COLA/IGES
2007-04-12-21:01

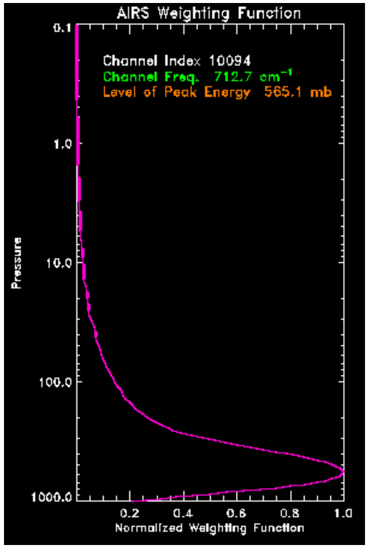

AIRS Temperature (deg K) 1/25/2003 0.0z 506 hPa
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
231.8 235.6 239.4 243.2 247 250.8 254.6 258.4 262.2 266 269.8 273.6
GrADS: COLA/IGES
2007-04-12-20:09

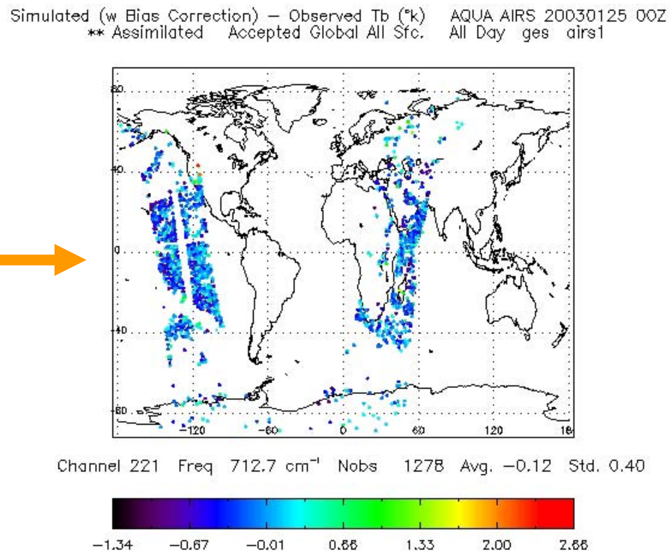

AIRS Temperature (deg K) 1/15/2003 0.0z 840 hPa
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
245 250 255 260 265 270 275 280 285 290 295 300
GrADS: COLA/IGES
2007-04-12-21:07

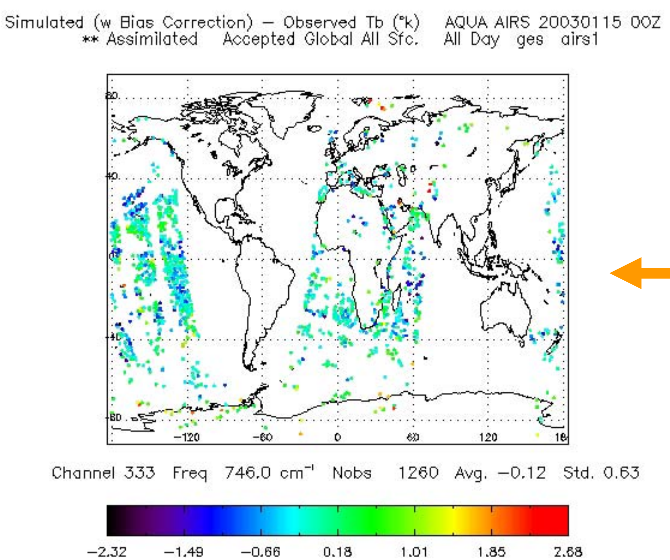

AIRS Temperature (deg K) 1/25/2003 0.0z 840 hPa
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
247.5 252 256.5 261 265.5 270 274.5 279 283.5 288 292.5 297
GrADS: COLA/IGES
2007-04-12-20:12

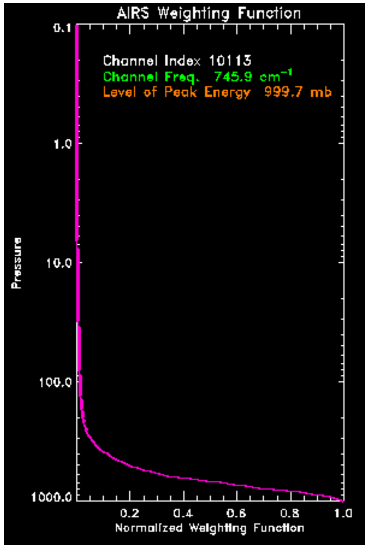
Radiances Used in Analysis for Two Low Peaking Tropospheric AIRS Channels

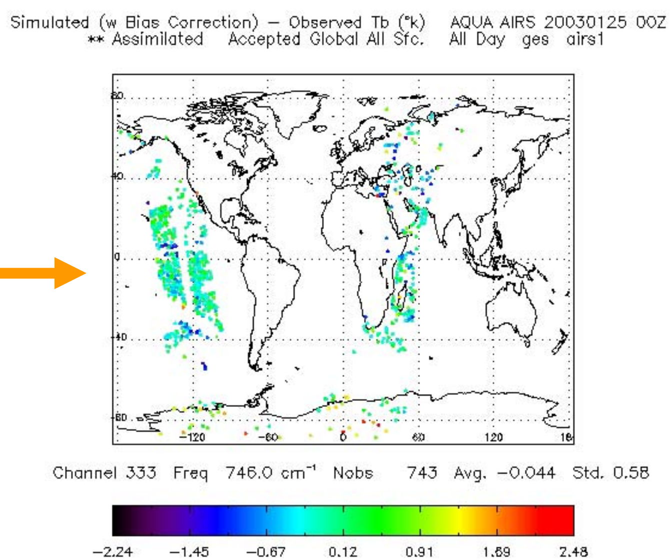










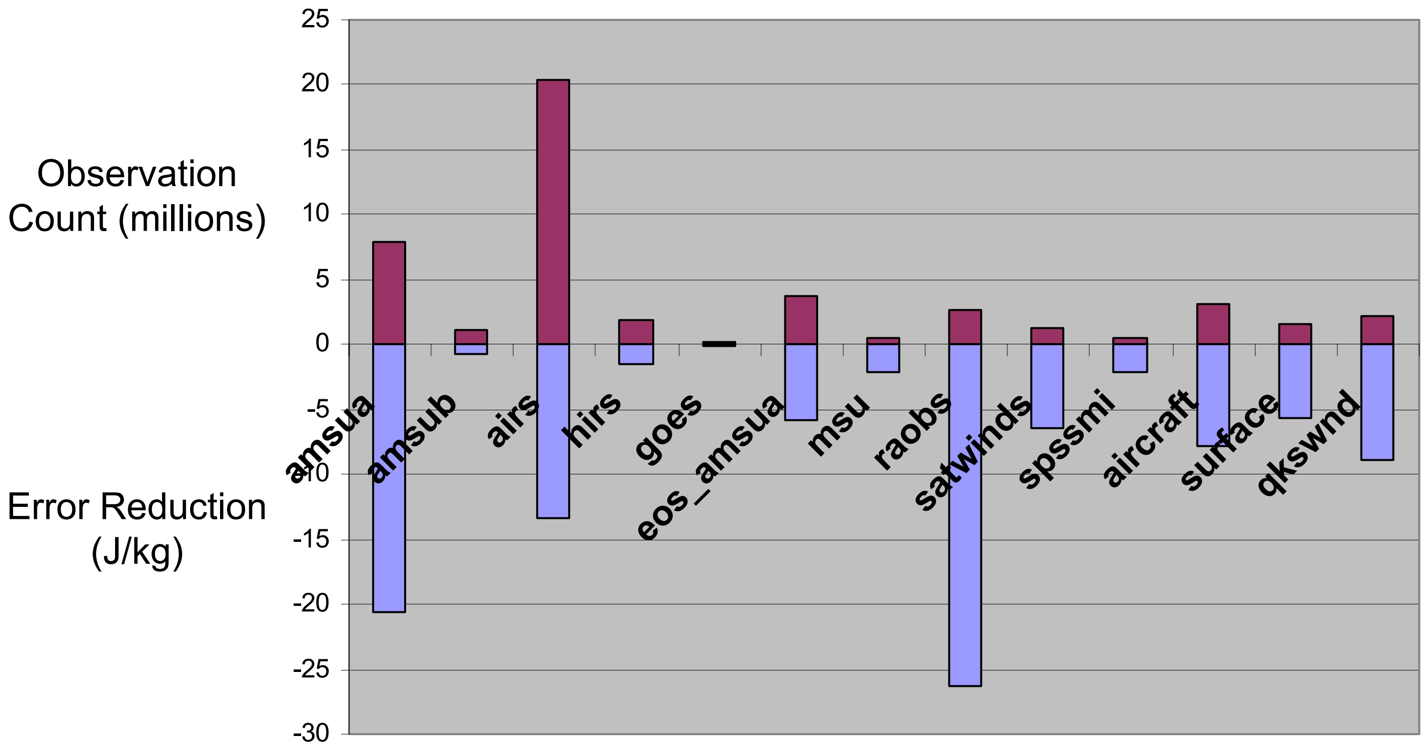


20030115 00z

20030125 00z

Observing system impacts on 24h forecast error

July 2005 00z Totals



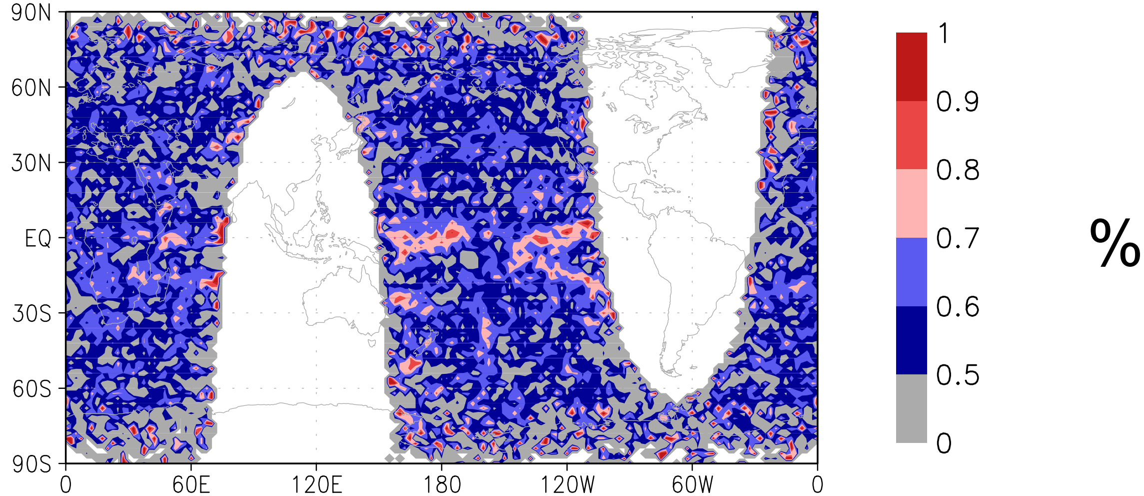
GEOS-5 Adjoint Data Assimilation System

Gelaro and Zhu 2006

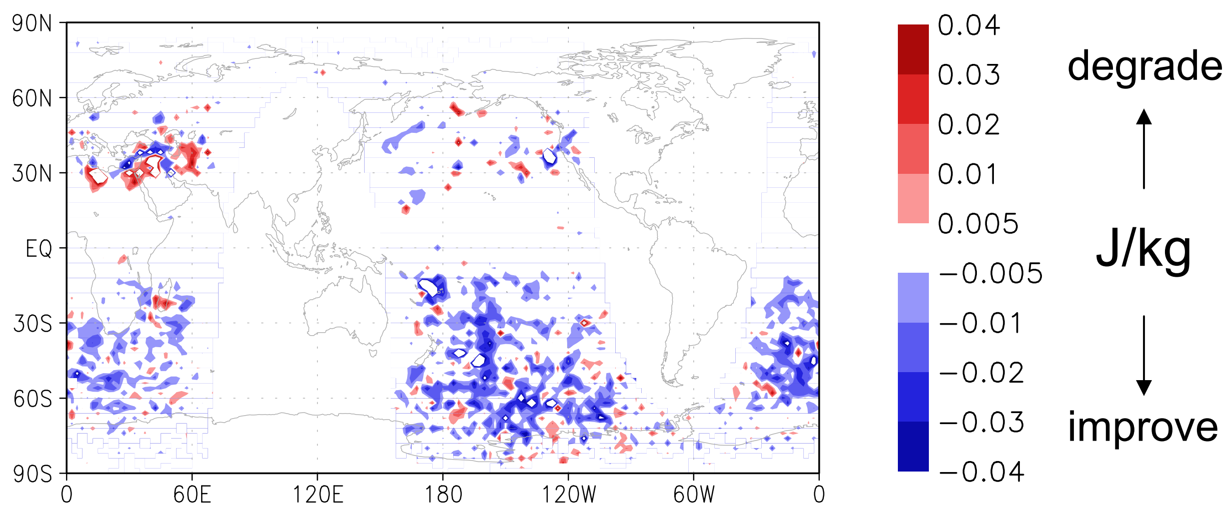
Observing system impacts on 24h forecast error

July 2005 00z

Fraction of **AIRS** observations that improve forecast



Total monthly impact of **AIRS** observations

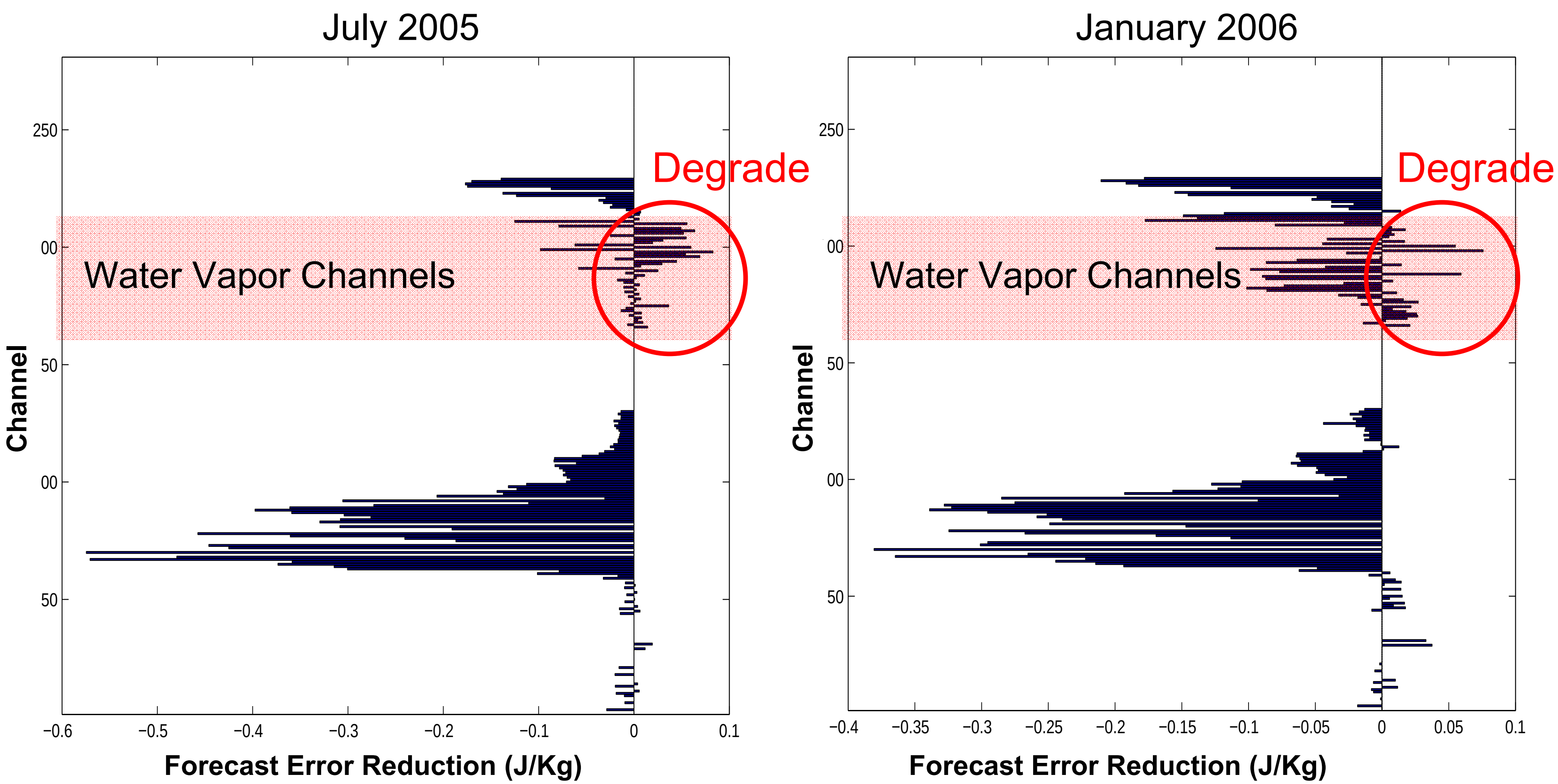


GEOS-5 Adjoint Data Assimilation System

Gelaro and Zhu 2006

Assessing impact of hyper-spectral observing systems: AIRS

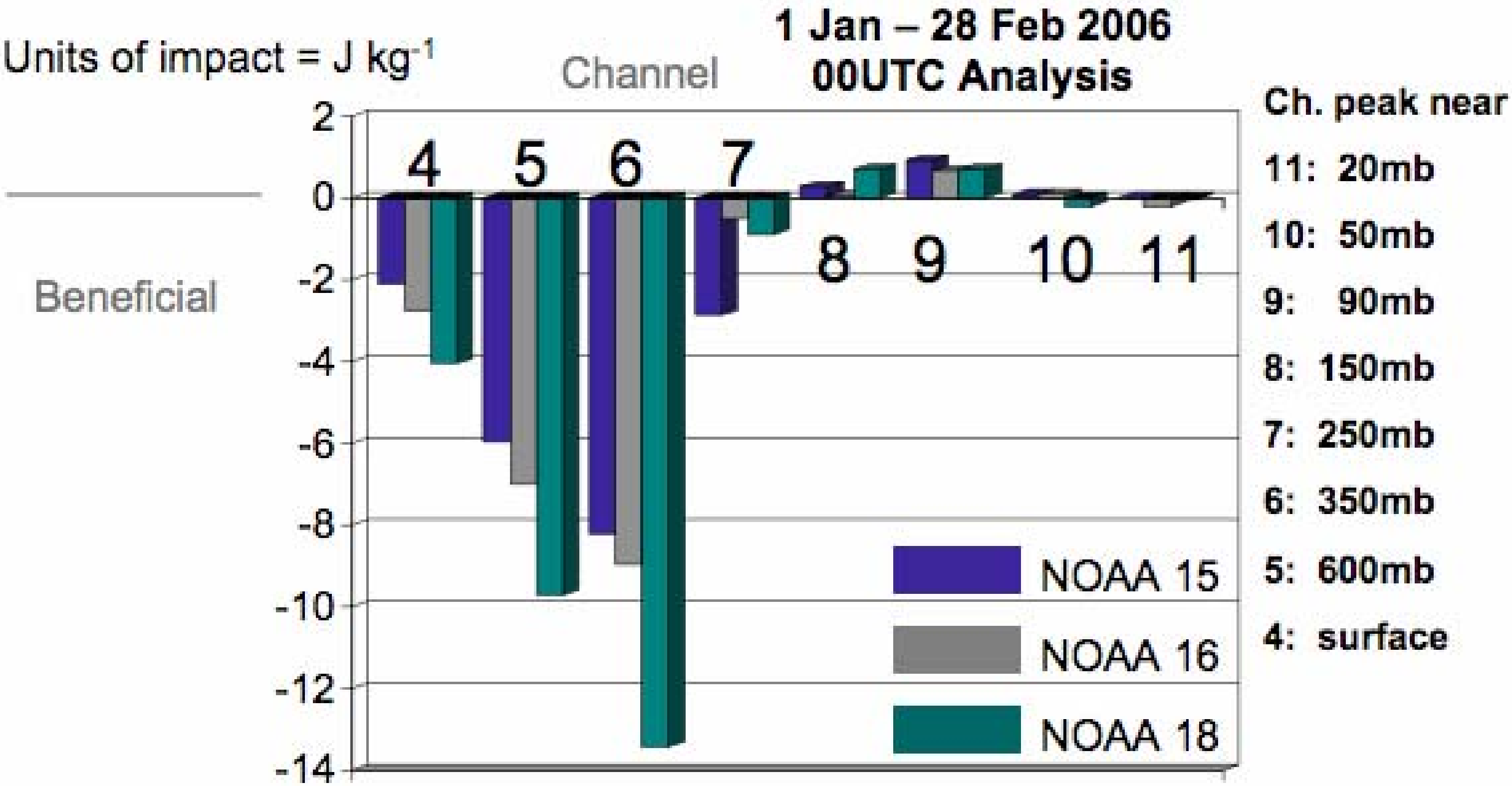
00z Monthly Total 24h Error Reduction



GEOS-5 Adjoint Data Assimilation System

Gelaro and Zhu 2006

Impact for AMSU-A channels

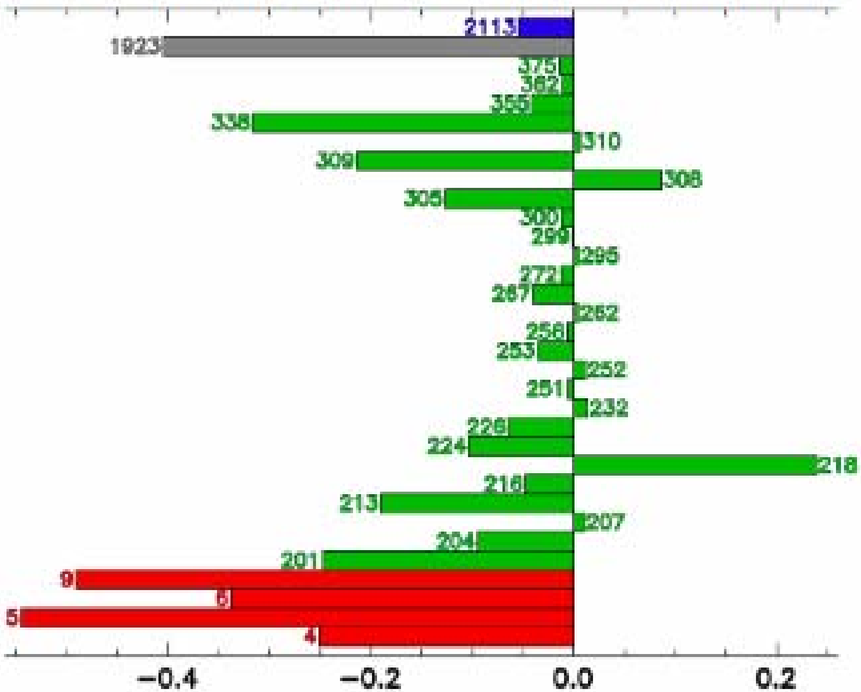


Results suggest a problem with assimilation of ch 8 and 9
Likely sources are the operational bias correction and insufficient model and analysis resolution

Data Assimilation
Use of NAVDAS Adjoint

Assessment of AQUA sensors
AMSU/A, AIRS longwave 14-13µm, AIRS shortwave 4.474µm, AIRS shortwave 4.180µm

AQUA sensitivity specified by channel number: Aug 15-26, 2006



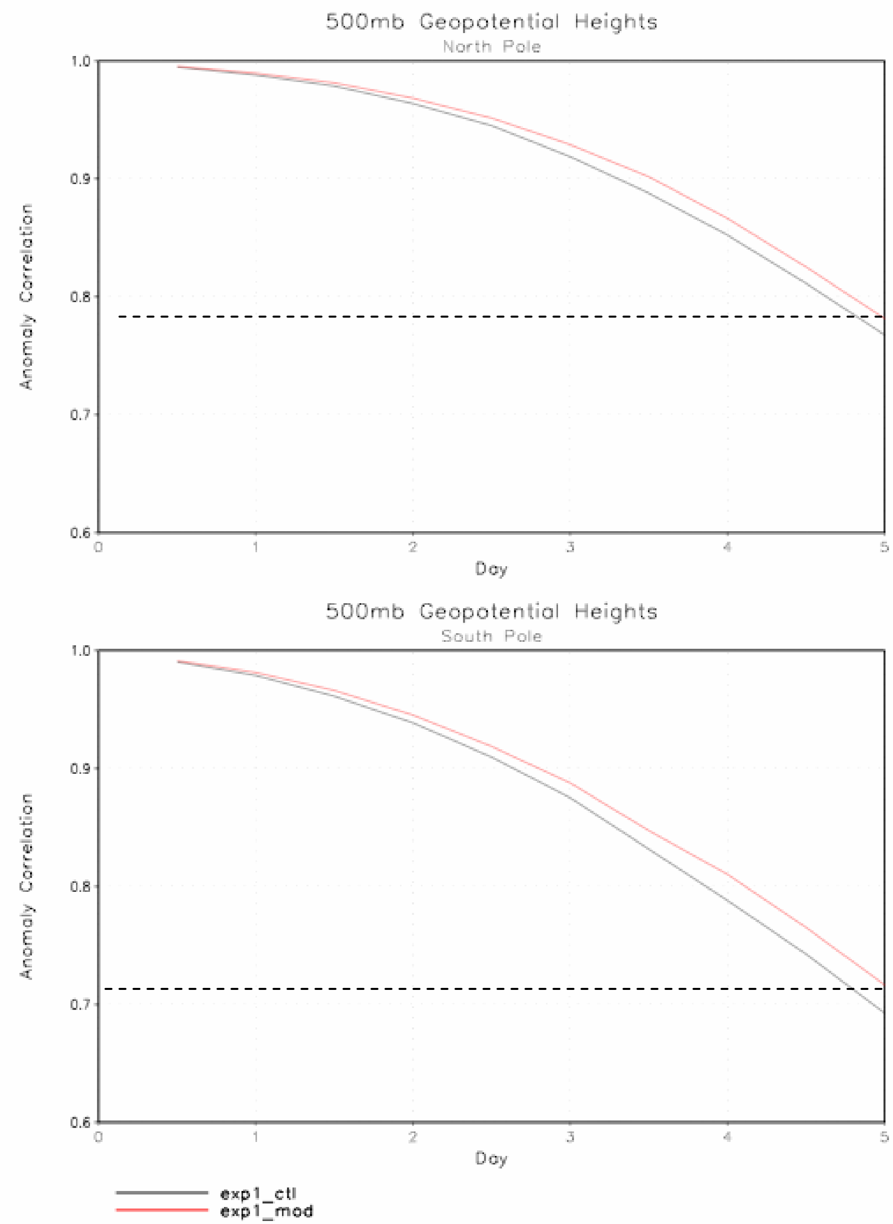
Beneficial **Non-beneficial**

Building the case for a MODIS winds follow-on

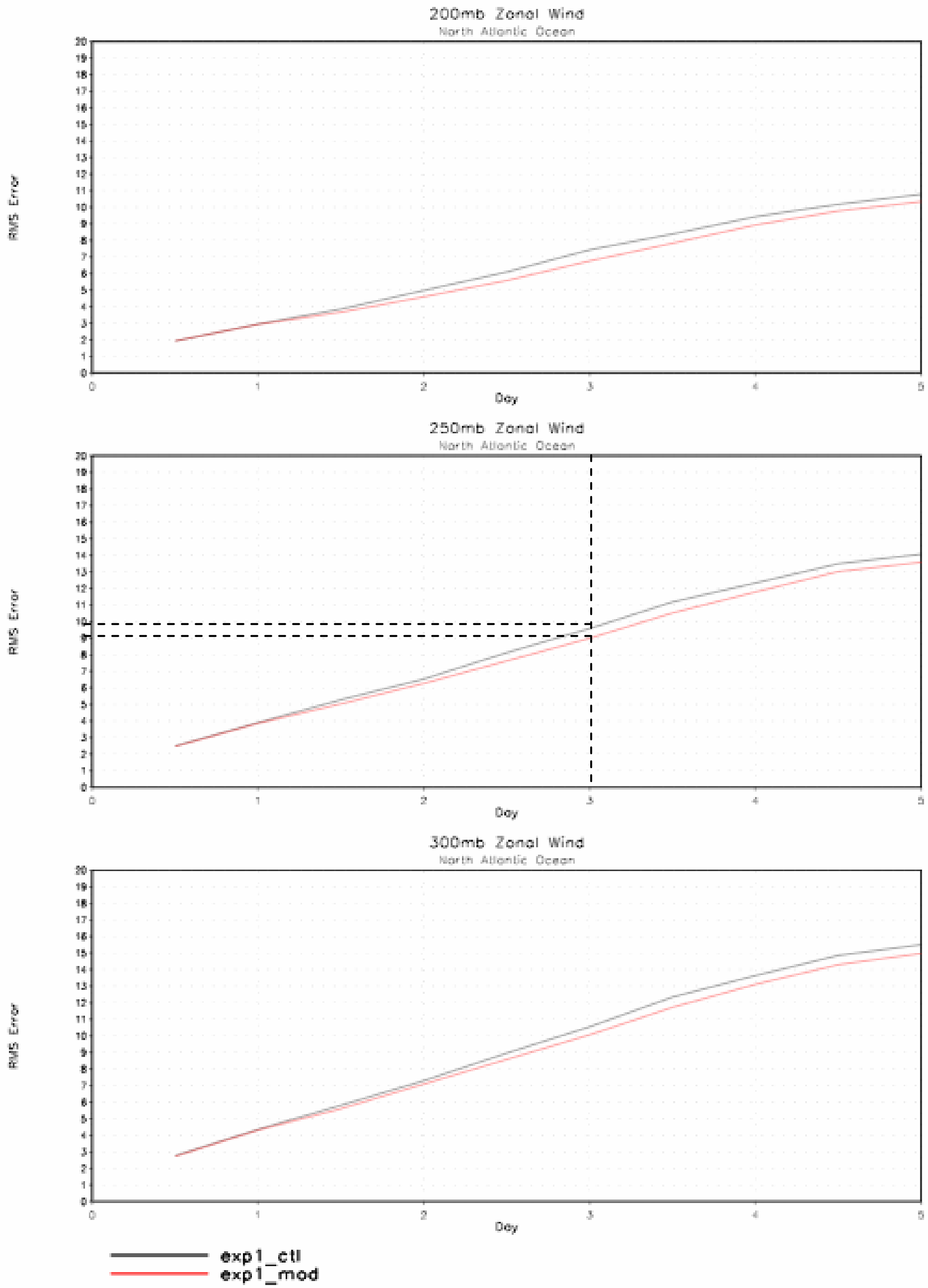
- NESDIS and GSFC collaborating on economic assessment of polar winds impact
  - "Orbit neutral" assessment of the expected economic impact of having feature tracking winds (cloud and water vapor) available over entire NH
  - G. Dittberner, L. P. Riishojgaard, Mitretek
- Since both Molniya and MEO will provide increased coverage over what is possible from LEO, the MODIS winds results can be used to obtain a lower bound on the expected impact
  - Hurricane track forecasting (NCEP/JCSDA diagnostics)
  - Low-level temperature over the lower 48 (this study)
  - Jet-stream forecasts (this study)

2004 ATLANTIC BASIN
AVERAGE HURRICANE TRACK ERRORS (NM)

13.2	43.6	66.5	94.9	102.8	157.1	227.9	301.1	Cntrl
11.4	34.8	60.4	82.6	89.0	135.3	183.0	252.0	Cntrl + MODIS
74	68	64	61	52	46	39	34	Cases (#)
00-h	12-h	24-h	36-h	48-h	72-h	96-h	120-h	Time

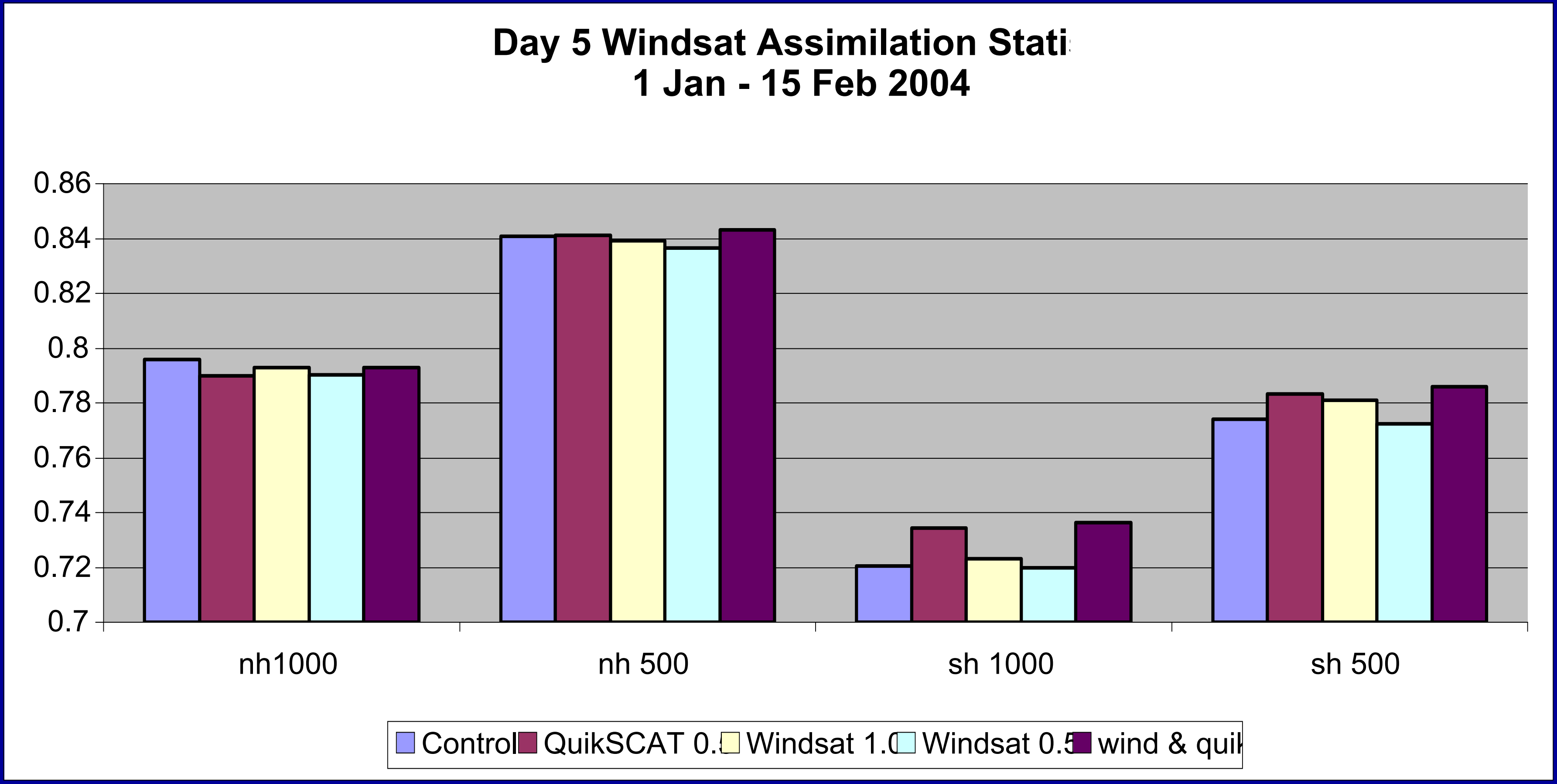


500mb Geopotential Heights
North Pole
Anomaly Correlation
1.0
0.9
0.8
0.7
0.6
0
1
2
3
4
5
Day
500mb Geopotential Heights
South Pole
Anomaly Correlation
1.0
0.9
0.8
0.7
0.6
0
1
2
3
4
5
Day
exp1_ctl
exp1_mod



200mb Zonal Wind
North Atlantic Ocean
RMS Error
Day
250mb Zonal Wind
North Atlantic Ocean
RMS Error
Day
300mb Zonal Wind
North Atlantic Ocean
RMS Error
Day
exp1_ctl
exp1_mod

Windsat impact experiments (Jung, Bi et al.)



SSMIS Radiance Preprocessor

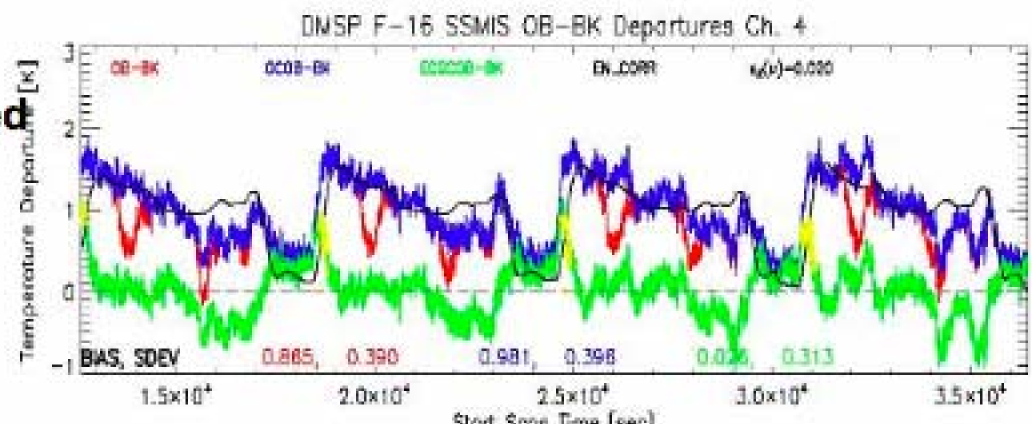
Unified SSMIS Radiance Preprocessor for NWP

Why is it Important ?

- Significant SSMIS Calibration Anomalies uncovered during Cal/Val
- Calibration errors exceed accuracy thresholds for NWP (~0.25K for temperature sounding channels)
- Objective is to develop a unified radiance preprocessor for NWP/JCSDA users to correct for calibration anomalies
- Implementation of unified SSMIS Preprocessor at FNMOC for F-16 planned for late summer 2007
- Data will be distributed via Shared Processing Network

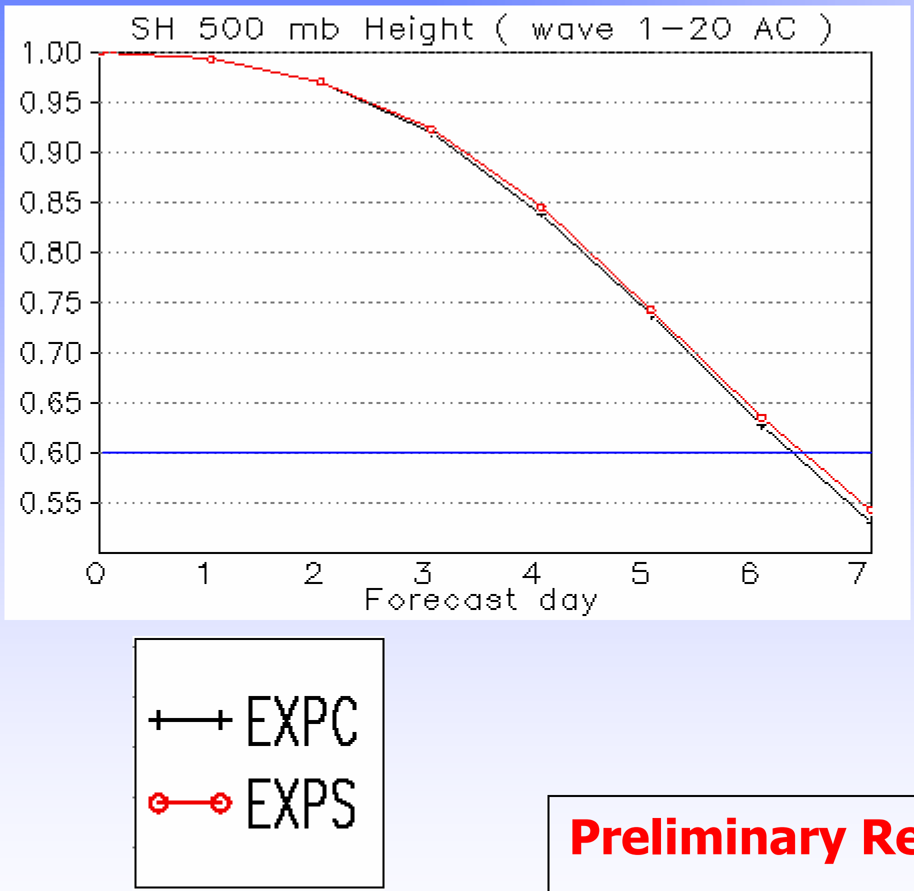
NRL Collaborations

- SSMIS Cal/Val Team – Determined physical mechanisms responsible for SSMIS Calibration Anomalies
- Met Office – SSMIS BUFR Based Preprocessor
- JCSDA – Discussions about alternative NESDIS preprocessor algorithms
- ECMWF – Provides Analyses of T(p) to 0.01 hPa ~ 80 km



SSM/IS radiance assimilation in GSI

Period:00z 10 Aug.-00z 10Sep. 2006



Assimilation System:

GSI 3D-Var

Forecast model:

NCEP Operational global model (Sep.2006)

Resolution:

T382L64

Data:

EXPC: Operational

EXPS: Operational + UKMO SSMIS data

(removed flagged data)

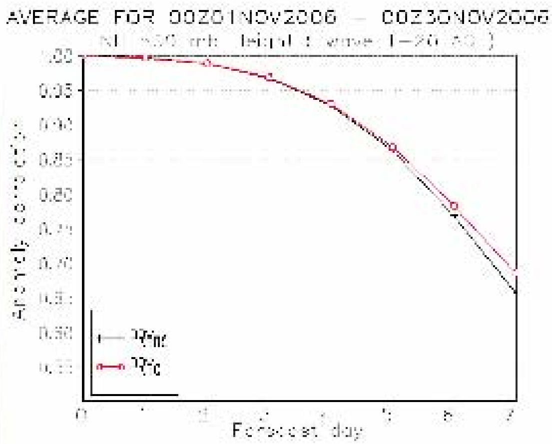
Preliminary Results:

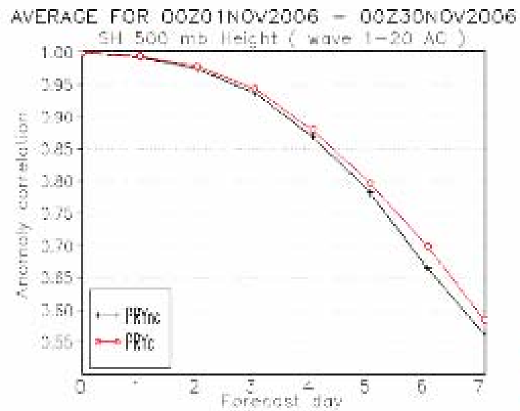
Improved A.C. 500 hPa height in the S.H.

Required further investigation on data quality

GSI/GFS Impact study with COSMIC

- Anomaly correlation as a function of forecast day for two different experiments:
  - PRYnc (assimilation of operational obs),
  - PRYc (PRYnc + COSMIC refractivity)
- We assimilated around 1,000 COSMIC profiles per day
- In general, the impact of the COSMIC data will depend on the meteorological situation, model performance, location of the observations, etc.



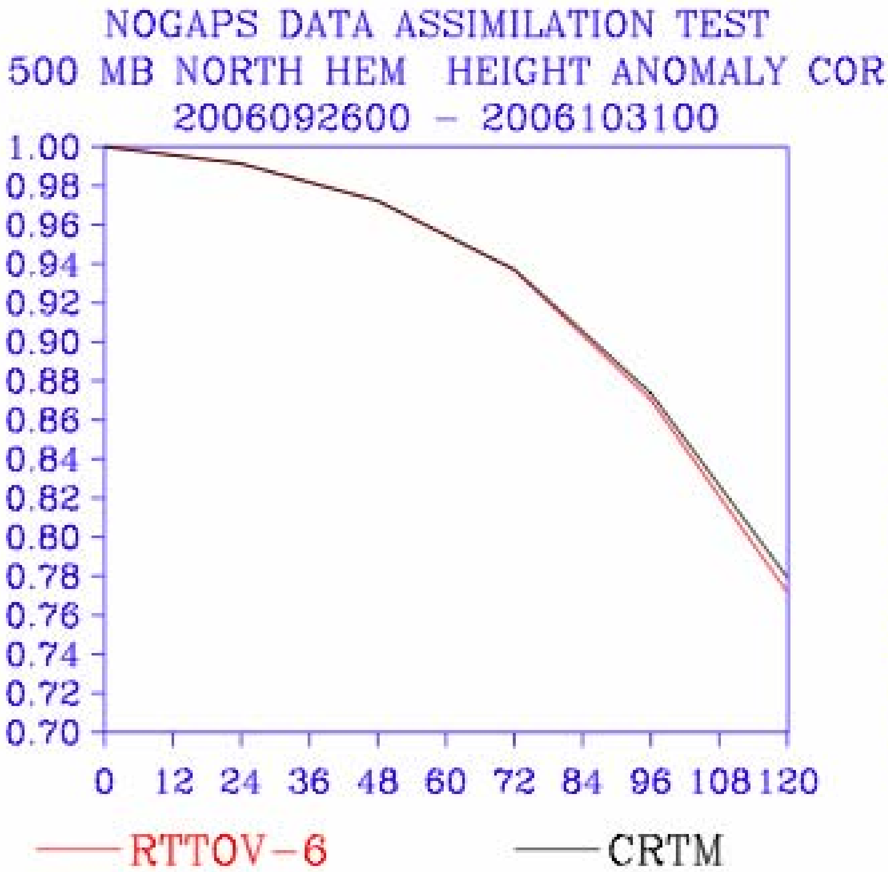


from Cucurull et al.

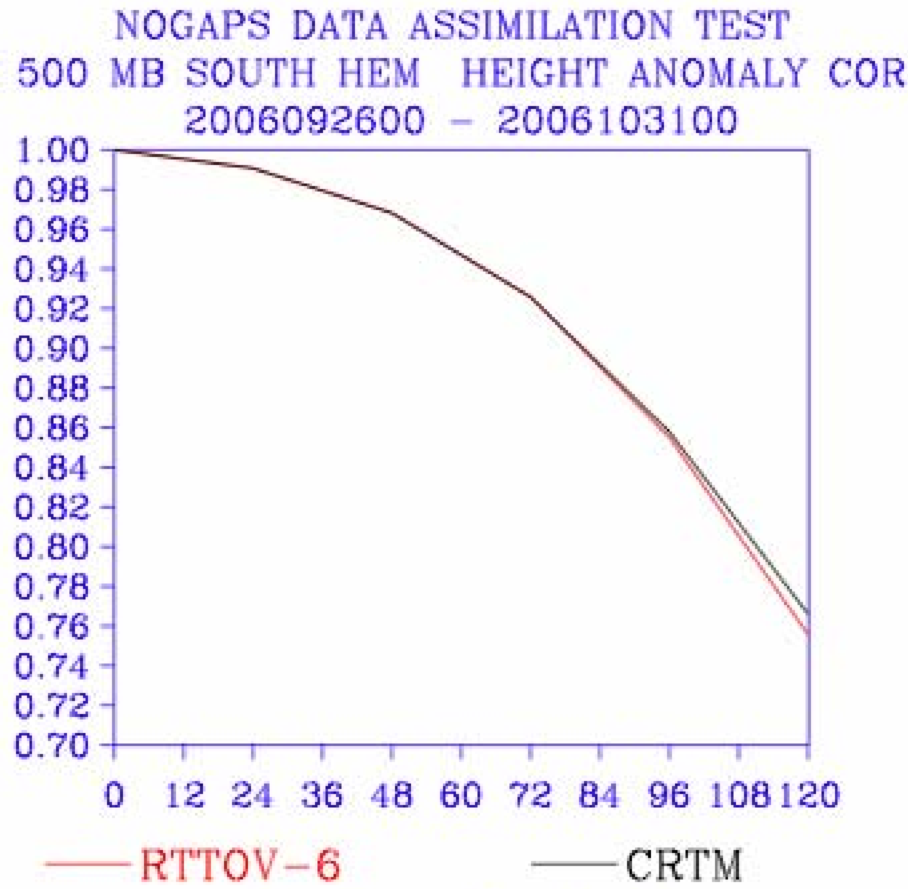
System development

- GSI now operational at NCEP (May 1, 2007)
- GMAO validating GSI-based system for reanalysis; operations will follow shortly
- CRTM used by both EMC and GMAO; tested at NRL/Monterey

"CRTM" Impact
500 mb Height Anomaly Correlation



Northern Hemisphere



Southern Hemisphere

September 26 - October 19, 2006

What about the future?

- NRL/Monterey: NAVDAS-AR
- GMAO developing “classical” 4D-VAR based on GEOS-5 model adjoint
- NCEP/EMC “simplified 4D-VAR”
- Unclear what can and what cannot be merged

NAVDAS-AR*

- NRL developed NAVDAS-AR, an observation space, weak-constraint four-dimensional data assimilation system
- We plan to transition to FNMOC for operational implementation at the end of FY08
- The adjoint of NAVDAS-AR is readily developed, allowing for an assessment of the impact of observations on forecast accuracy to be evaluated
- NASA is considering adapting NAVDAS-AR

* Accelerated Representer

Summary

- JCSDA is growing by almost any applicable measure
  – more than 100 participants in 2007 Workshop
- The number of satellite sensors being tested and studied is growing
- Collaboration expected to be formalized shortly
  – realization is work in progress