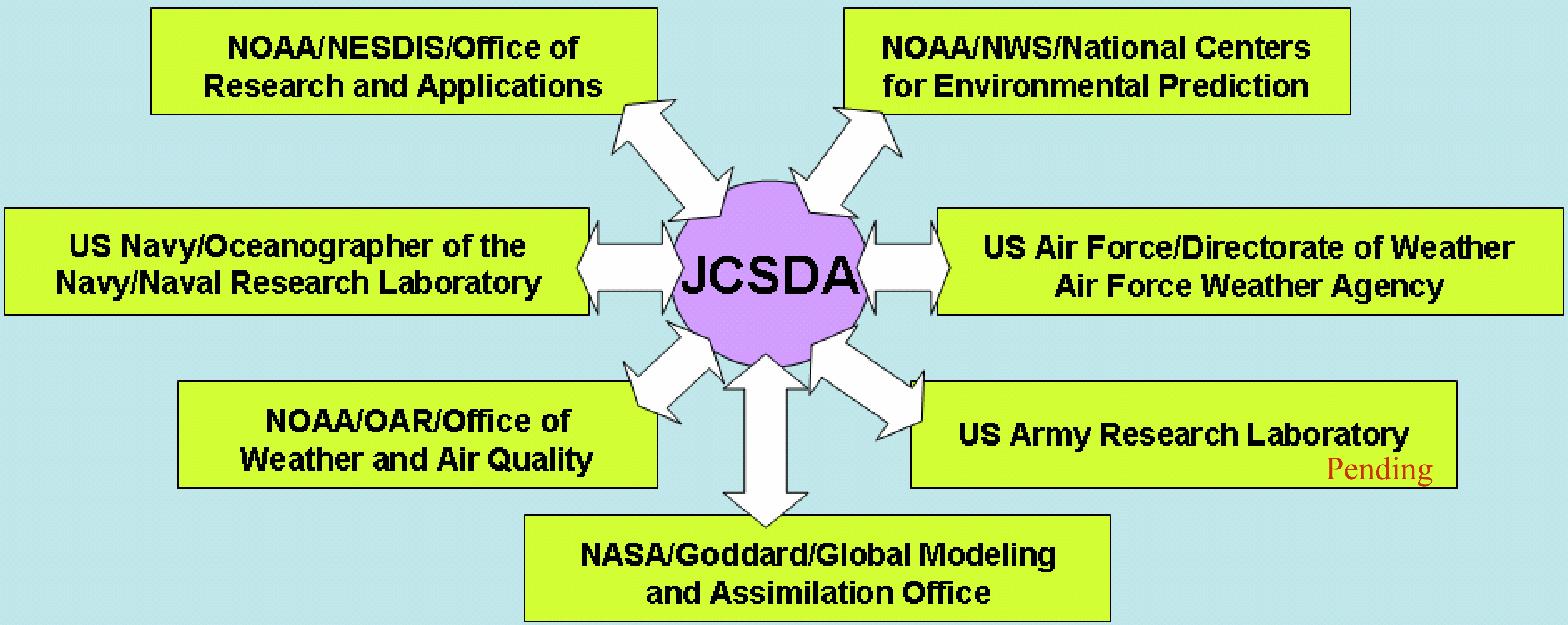
JCSDA EXPERIMENTS IN THE USE OF RADIANCES IN NUMERICAL WEATHER PREDICTION

J. Le Marshall, J. Jung, T. Zapotocny, W. L. Smith, D. Zhou, J. Derber, R. Treadon, S. Lord, M. Goldberg and W. Wolf

JCSDA Partners



JCSDA Mission and Vision

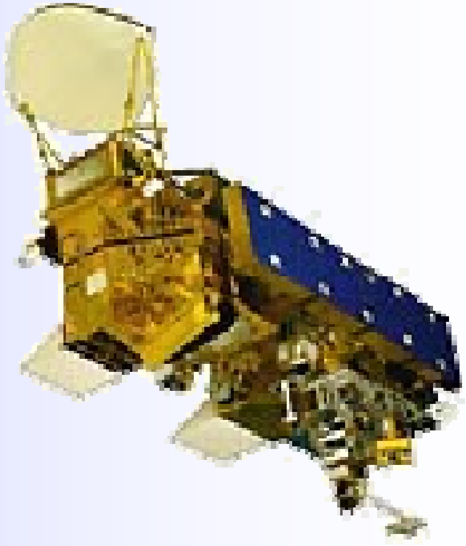
- Mission: Accelerate and improve the quantitative use of research and operational satellite data in weather. ocean, climate and environmental analysis and prediction models

- Vision: A weather, ocean, climate and environmental analysis and prediction community empowered to effectively assimilate increasing amounts of advanced satellite observations and to effectively use the integrated observations of the GEOSS

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
- …

~30 instruments



RECENT ADVANCES

Development and Implementation Progress of Community Radiative Transfer Model (CRTM)

P. van Delst, Q. Liu, F. Weng, Y. Chen, *D. Groff, B. Yan, N. Nalli,*
R. Treadon, J. Derber and *Y. Han .....*

Community Contributions

- Community Research: Radiative transfer science
  - AER. Inc: Optimal Spectral Sampling (OSS) Method
  - NRL – Improving Microwave Emissivity Model (MEM) in deserts
  - NOAA/ETL – Fully polarmetric surface models and microwave radiative transfer model
  - UCLA – Delta 4 stream vector radiative transfer model
  - UMBC – aerosol scattering
  - UWisc – Successive Order of Iteration
  - CIRA/CU – SHDOMPPDA
  - UMBC SARTA
  - Princeton Univ – snow emissivity model improvement
  - NESDIS/ORA – Snow, sea ice, microwave land emissivity models, vector discrete ordinate radiative transfer (VDISORT), advanced double/adding (ADA), ocean polarimetric, scattering models for all wavelengths
- Core team (JCSDA - ORA/EMC): Smooth transition from research to operation
  - Maintenance of CRTM (OPTRAN/OSS coeff., Emissivity upgrade)
  - CRTM interface
  - Benchmark tests for model selection
  - Integration of new science into CRTM

Development and Implementation Progress of Community Radiative Transfer Model (CRTM)

See Poster by Y. Han .....

SSMIS Radiance Assimilation

- NRL – JCSDA development
- NCEP – JCSDA development

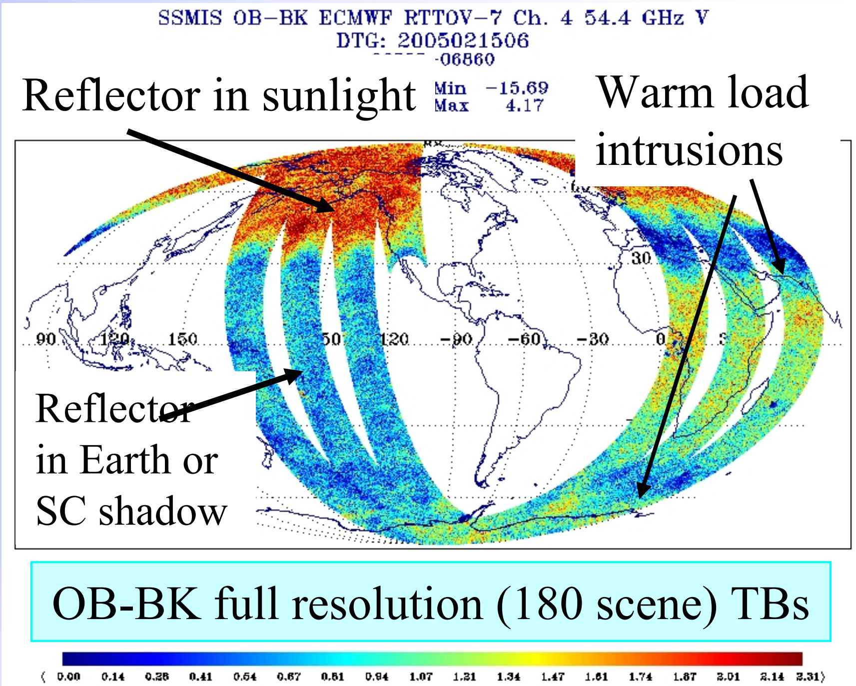
SSMIS Brightness Temperature Evaluation in a Data Assimilation Context

Collaborators: NRL: Nancy Baker (PI), Clay Blankenship, Bill Campbell. Contributors: Steve Swadley (METOC Consulting), Gene Poe (NRL)

Summary of Accomplishments

- Worked closely with Cal/Val team to understand assimilation implications of the sensor design and calibration anomalies, and to devise techniques to mitigate the calibration issues.
- Completed code to read, process, and quality control observations, apply scan non-uniformity and spillover corrections, perform beam cell averaging of footprints, and compute innovations and associated statistics.
- Developed flexible interface to pCRTM and RTTOV-7.
- Initial results indicate that pCRTM is performing well.

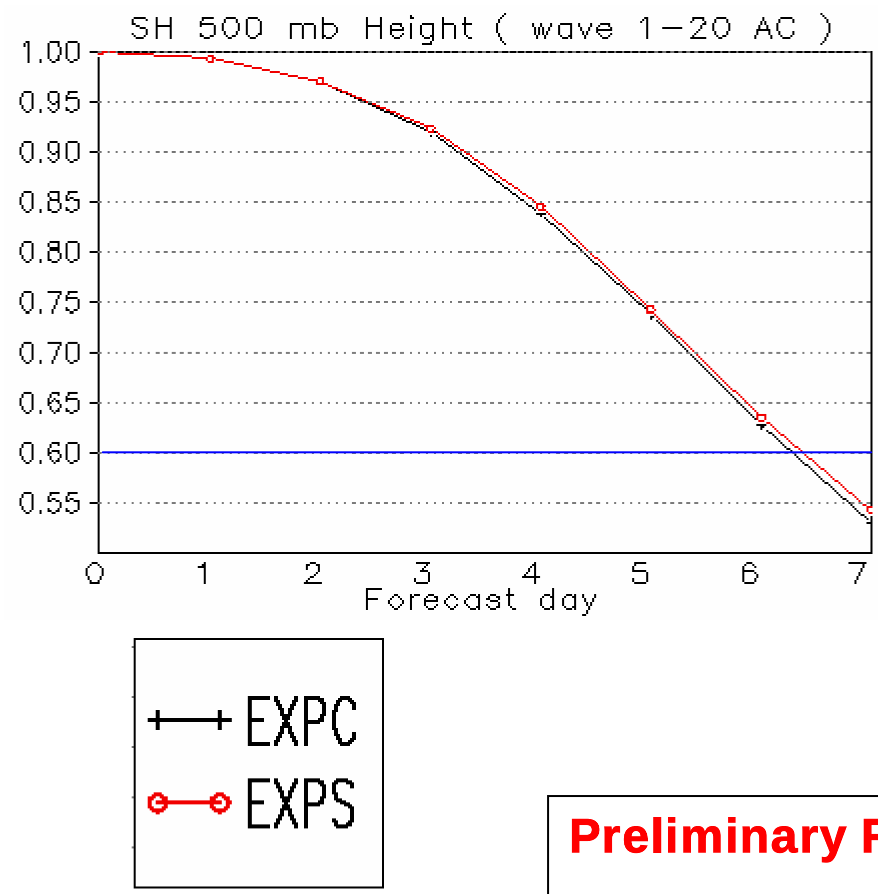
Future: Real time monitoring of SSMIS TBs. Compare pCRTM with RTTOV-7. Assess observation and forward model bias and errors; determine useful bias predictors. Assess forecast impact of SSMIS assimilation.



Chan.	pCRTM Bias	pCRTM s.d.	RTTOV-7 Bias	RTTOV-7 s.d.
4	1.70	0.54	1.68	0.53
5	1.59	1.00	1.64	0.97
6	1.81	1.24	1.83	1.24
7	3.53	1.34	3.55	1.44

SSM/IS radiance assimilation in GSI

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



NCEP SYSTEM – Kazumori

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.

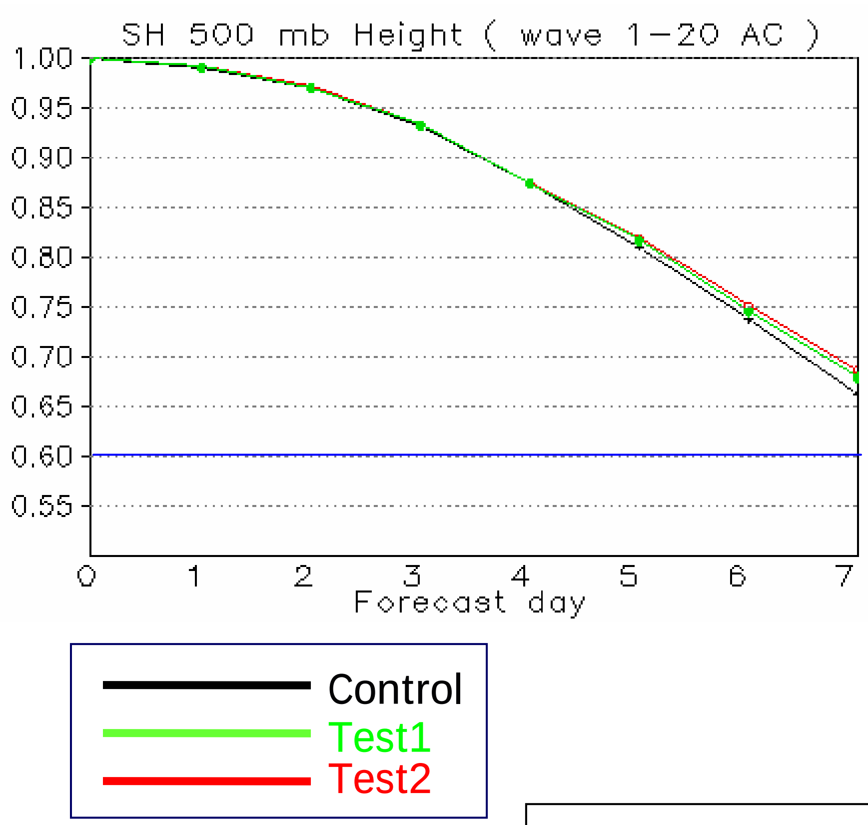
Required further investigation on data quality

NCEP AMSR-E Radiance Assimilation

M. Kazumori

AMSR-E radiance assimilation in GSI

Period:00z 12 Aug.-00z 11 Sep. 2005



M. Kazumori

Assimilation System: GSI 3D-Var

Forecast model: NCEP Operational global model (May.2006)

Resolution: T382L64

Data:

Control: Operational

Test1: Operational + AMSR-E (FASTEM1)

Test2: Operational + AMSR-E (New EM)

Results:

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

Decrease of RMS of surface wind speed analysis increment

AIRS Data Assimilation

The Trial

- Used `full AIRS data stream used (JPL)
  - NESDIS (ORA) generated BUFR files
  - All FOVs, 324(281) channels
  - 1 Jan – 15 Feb '04

- Similar assimilation methodology to that used for operations
- Operational data cut-offs used
- Additional cloud handling added to 3D Var.
- Data thinning to ensure satisfying operational time constraints

The Trial

- AIRS related weights/noise optimised
- Used NCEP Operational verification scheme.

AIRS Assimilation

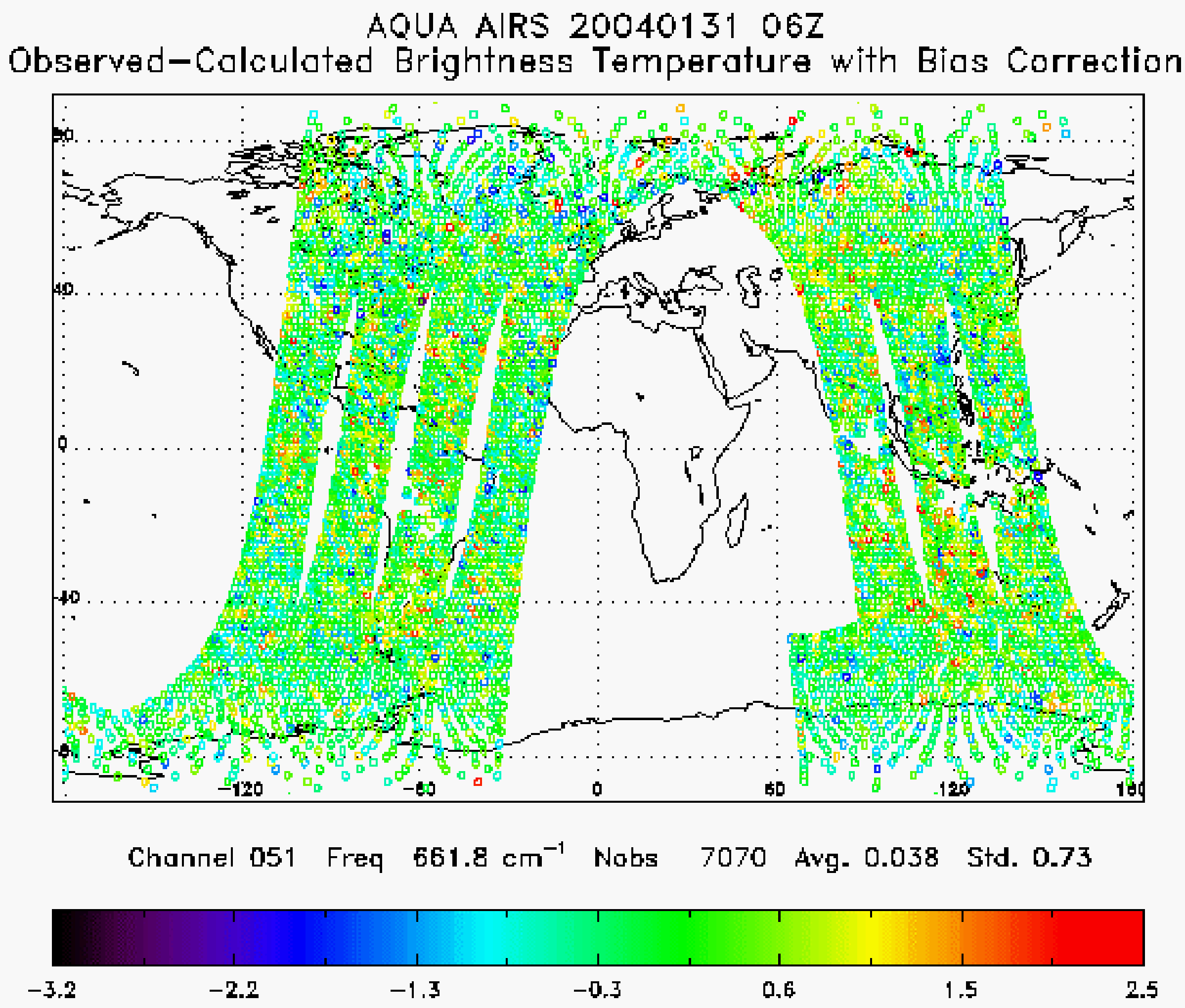
- **<u>Used 251 Out of 281 Channels</u>**

  - 73 - 86 Removed (Channels peak too High)

  - 1937 - 2109 Removed (Non LTE)

  - 2357 Removed (Large Obs – Background Diff.)

- Used Shortwave at Night
  - Wavenumber > 2000 cm^{-1} Downweighted during day
  - Wavenumber > 2400cm^{-1} Removed during day



AIRS data coverage at 06 UTC on 31 January 2004. (Obs-Calc. Brightness Temperatures at 661.8 cm^{-1}are shown)

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)

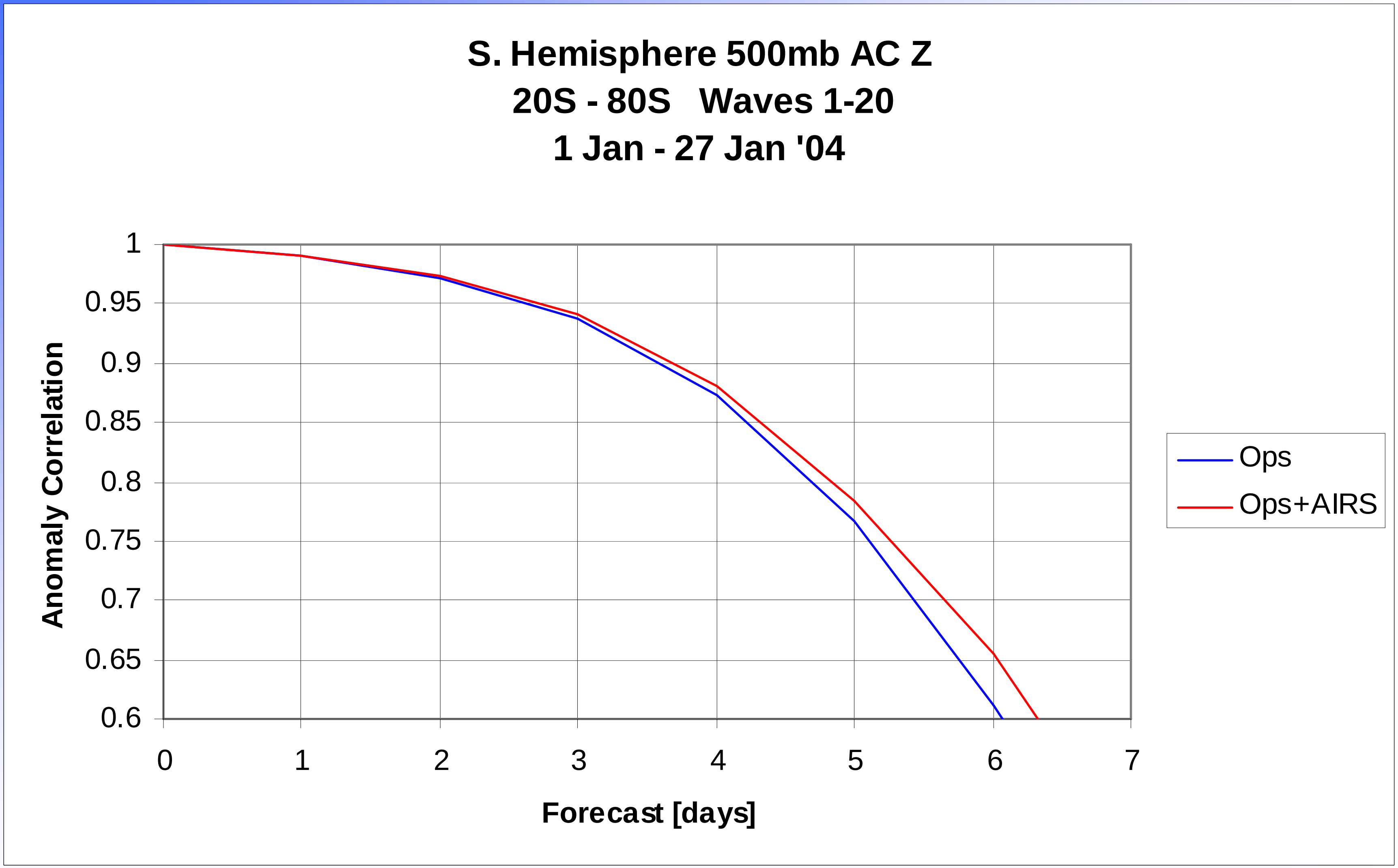


Figure 1(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004

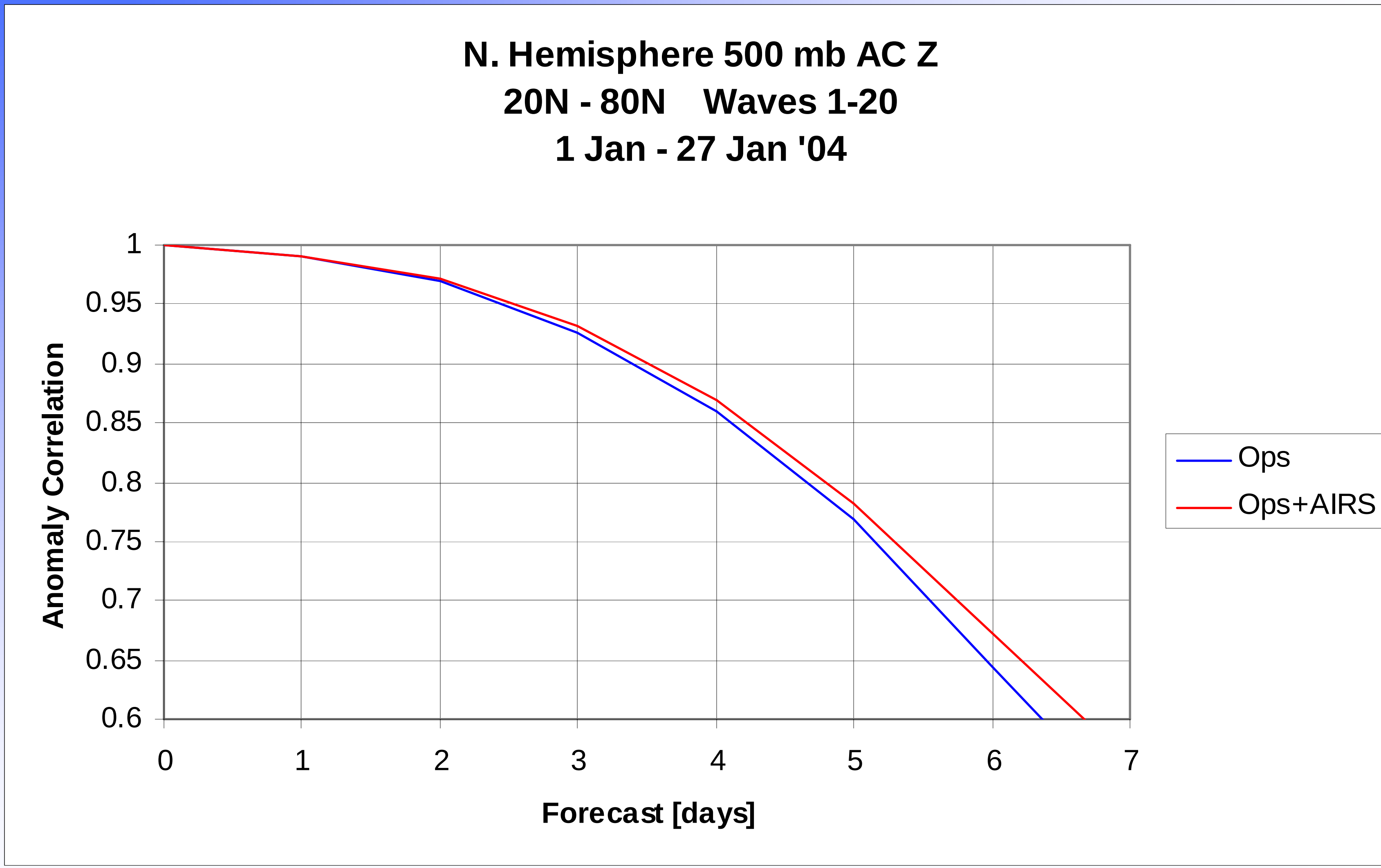
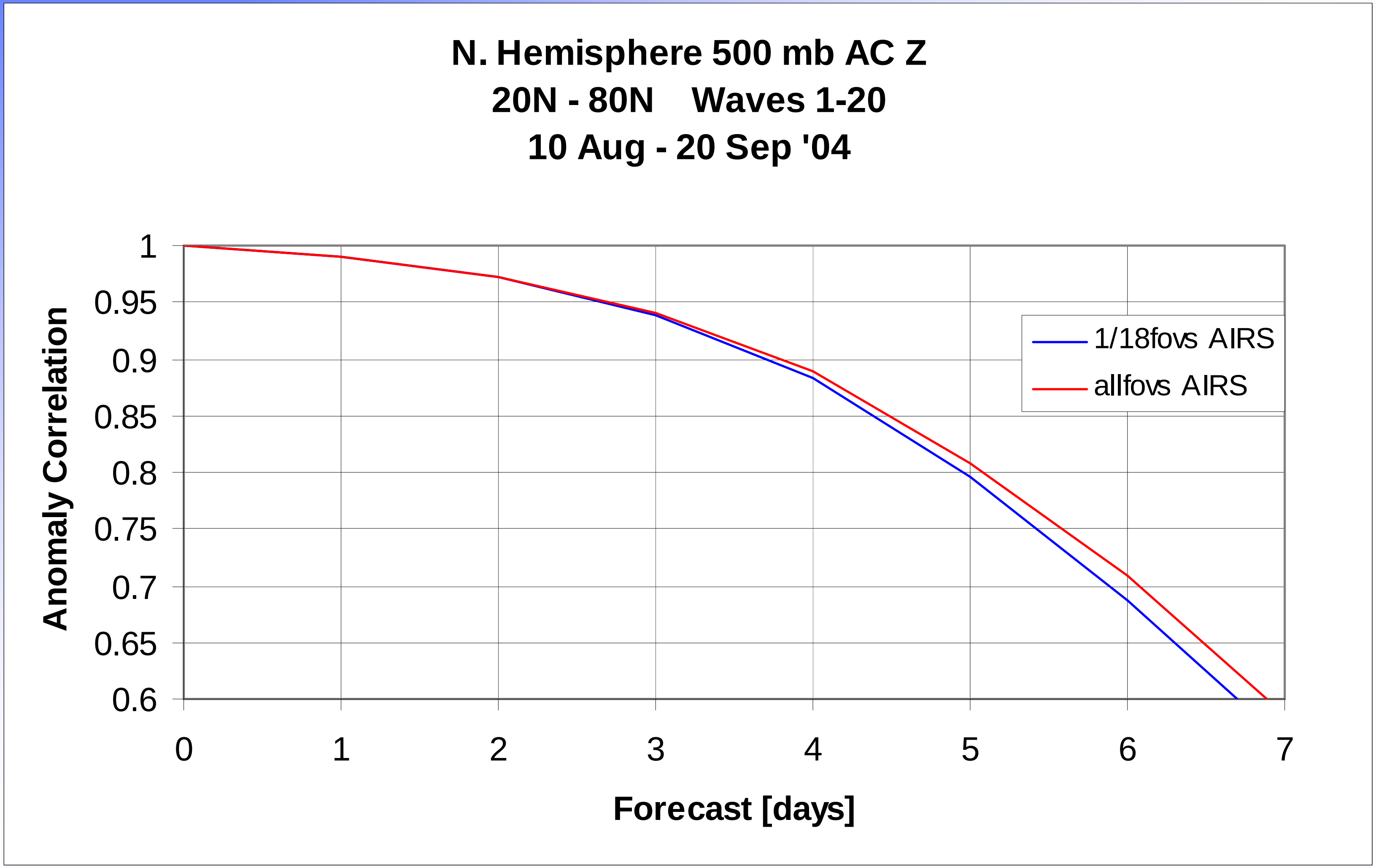


Figure 3(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004

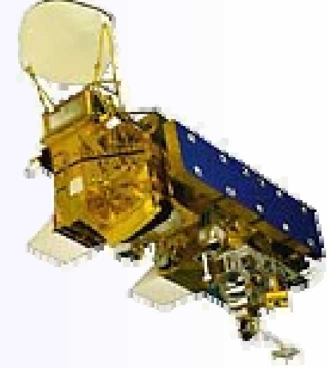
AIRS Data Assimilation

Impact of Data density…

10 August – 20 September 2004



N. Hemisphere 500 mb AC Z
20N - 80N Waves 1-20
10 Aug - 20 Sep '04
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0
1
2
3
4
5
6
7
Forecast [days]
1/18fovs AIRS
allfovs AIRS



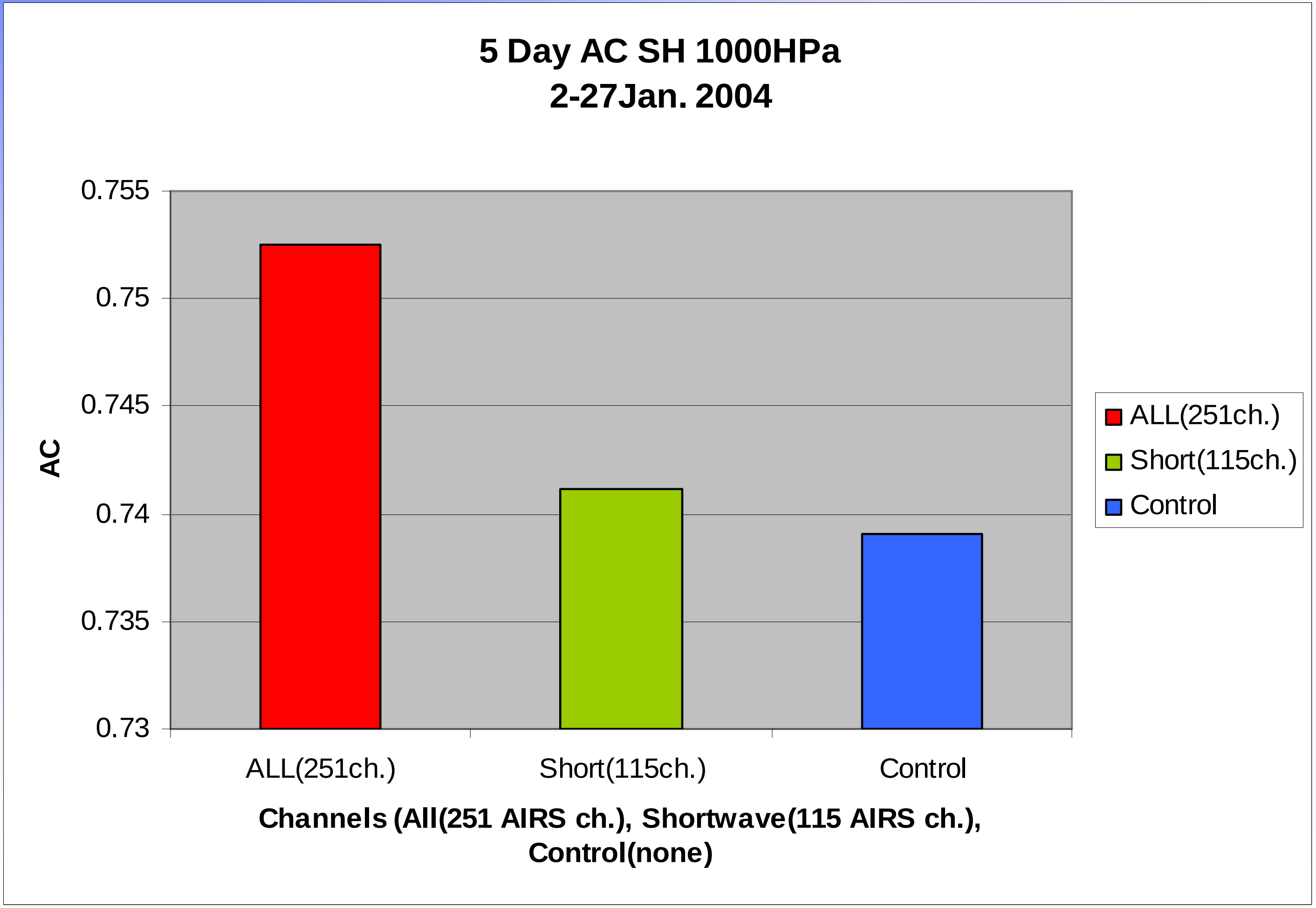
AIRS Data Assimilation

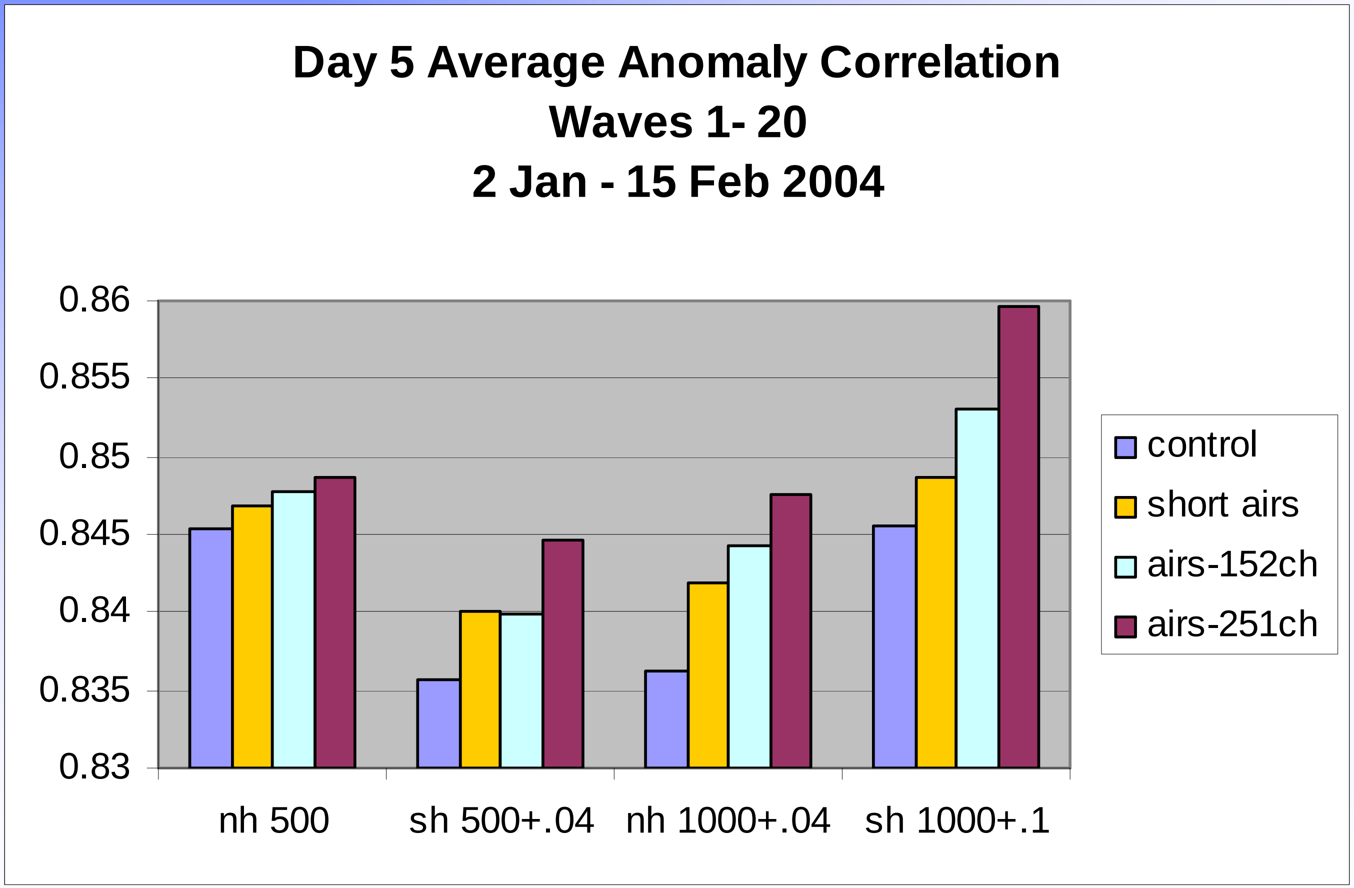
Impact of Spectral density…

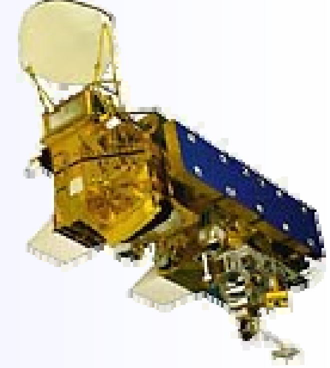
10 August – 20 September 2004

GOES – R OSSE

Test of channel frequency selection for HES
Using AIRS hyperspectral radiances




Day 5 Average Anomaly Correlation
Waves 1- 20
2 Jan - 15 Feb 2004
0.86
0.855
0.85
0.845
0.84
0.835
0.83
nh 500
sh 500+.04
nh 1000+.04
sh 1000+.1
control
short airs
airs-152ch
airs-251ch



AIRS Data Assimilation

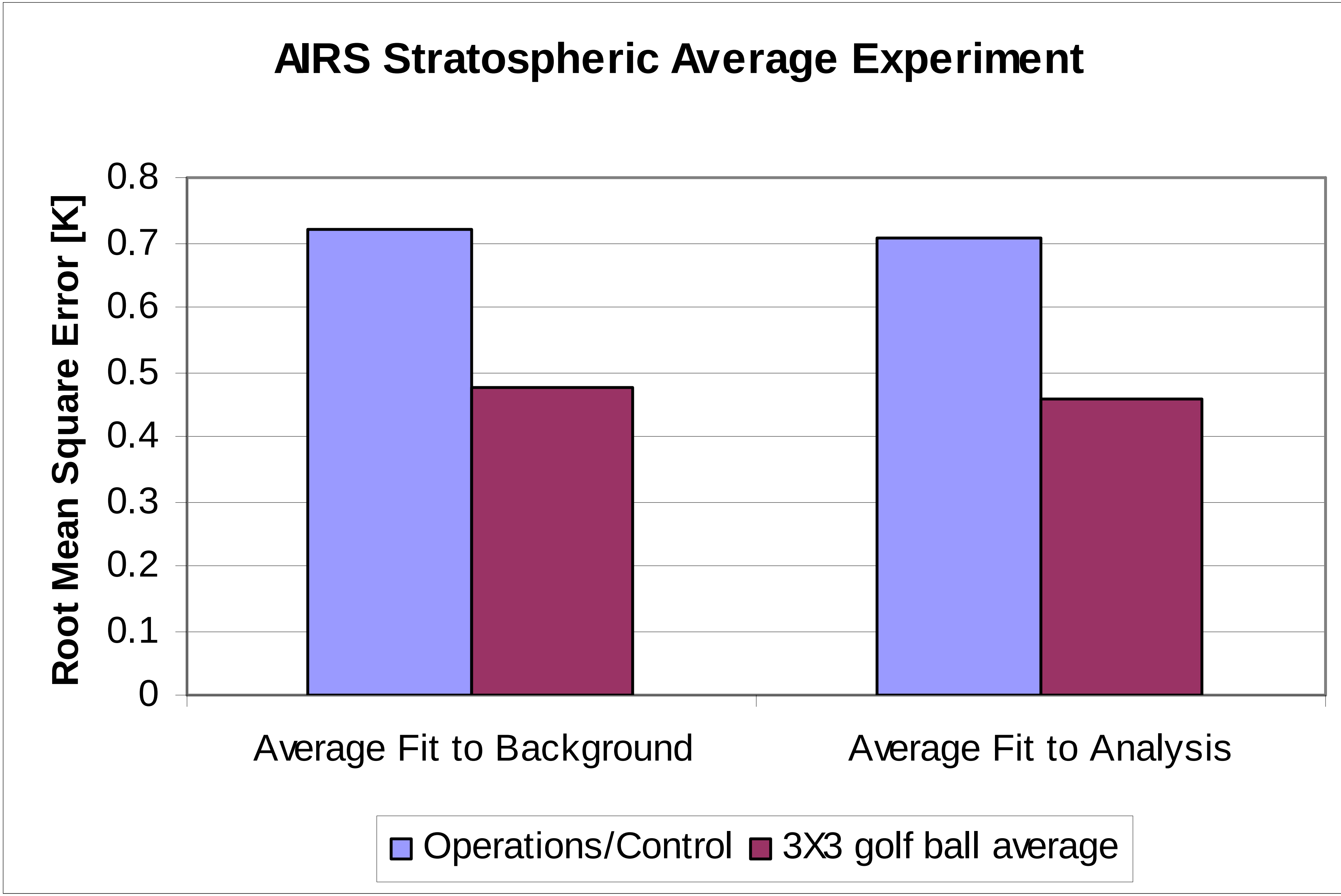
Application of AIRS in the Stratosphere

Use of AIRS for stratospheric Analysis

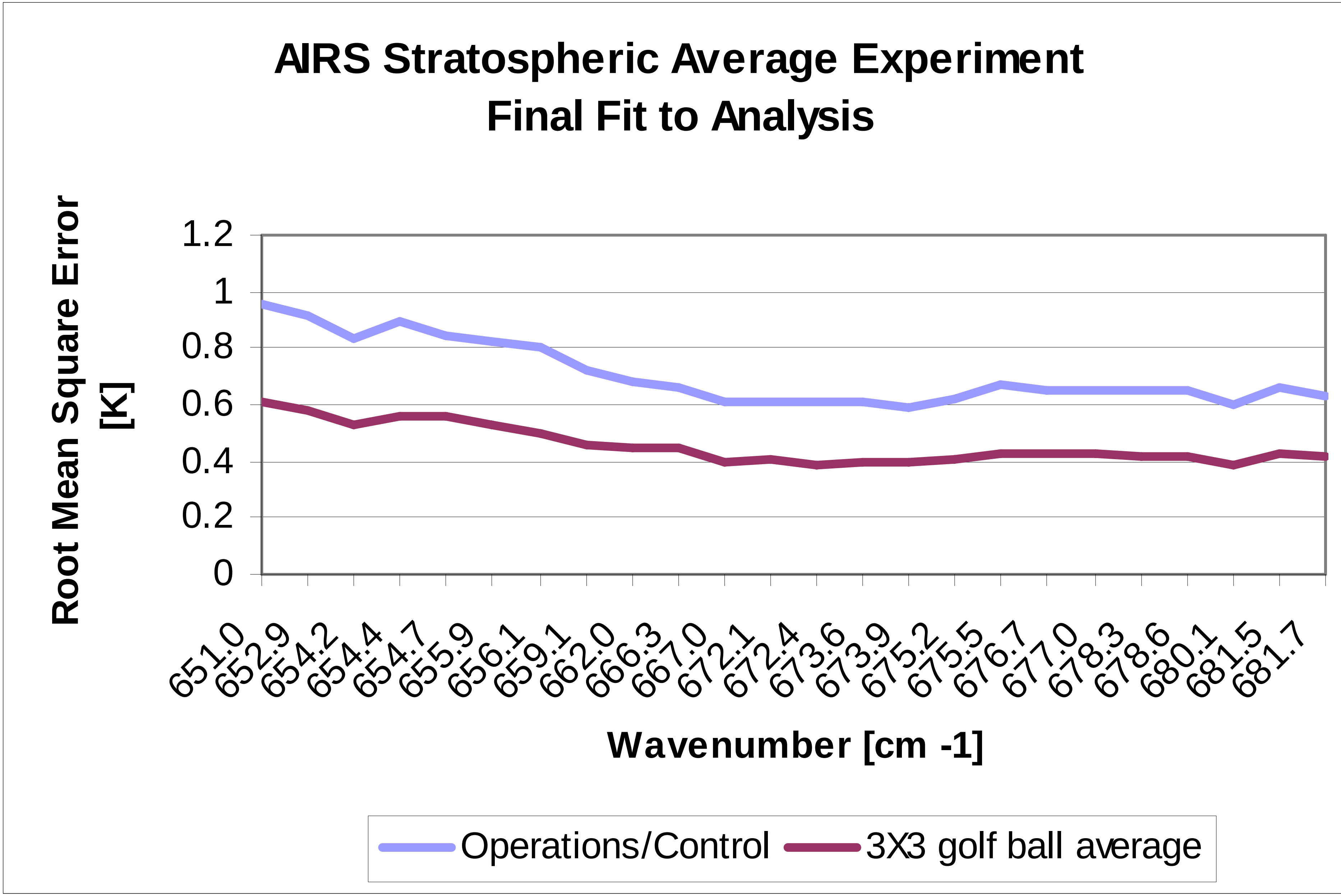
Uses averaging to reduce noise in stratospheric channels

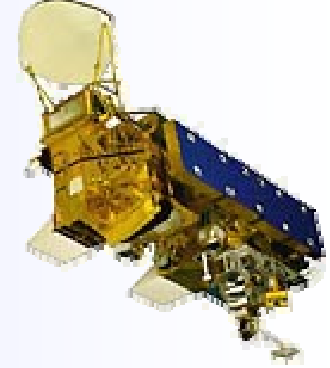
60 Stratospheric channels averaged over each AMSU fov
i.e. 3 x 3 average

Averaging improves fit to six hour forecast/background field.



AIRS Stratospheric Average Experiment
Root Mean Square Error [K]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Average Fit to Background
Average Fit to Analysis
Operations/Control
3X3 golf ball average


AIRS Stratospheric Average Experiment
Final Fit to Analysis
Root Mean Square Error [K]
1.2
1
0.8
0.6
0.4
0.2
0
651.0
652.9
654.2
654.4
654.7
655.9
656.1
659.1
662.0
666.3
667.0
672.1
672.4
673.6
673.9
675.2
675.5
676.7
677.0
678.3
678.6
680.1
681.5
681.7
Wavenumber [cm -1]
Operations/Control
3X3 golf ball average



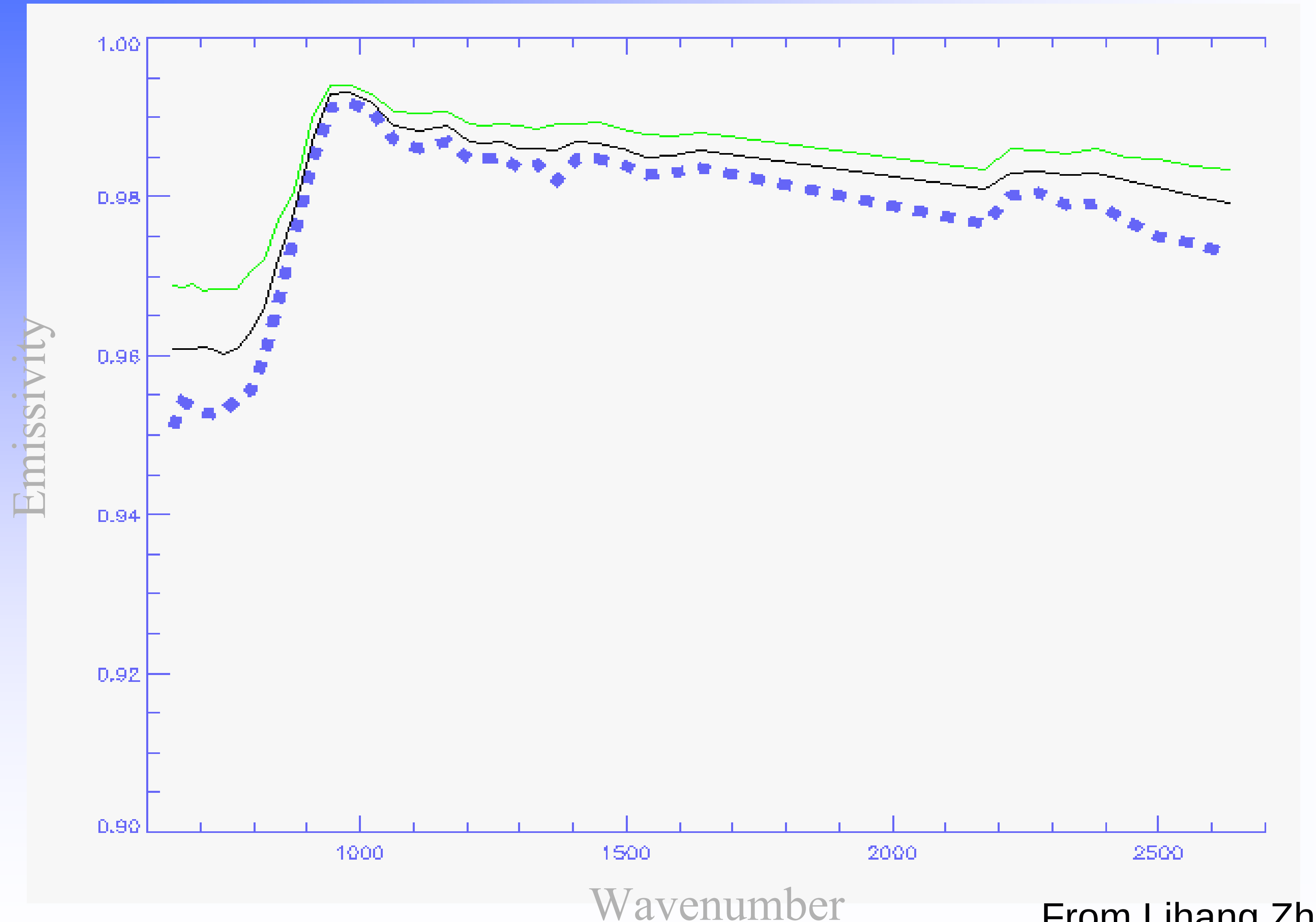
AIRS Data Assimilation

Application of AIRS over land and ice

Surface Emissivity (ε) Estimation Methods

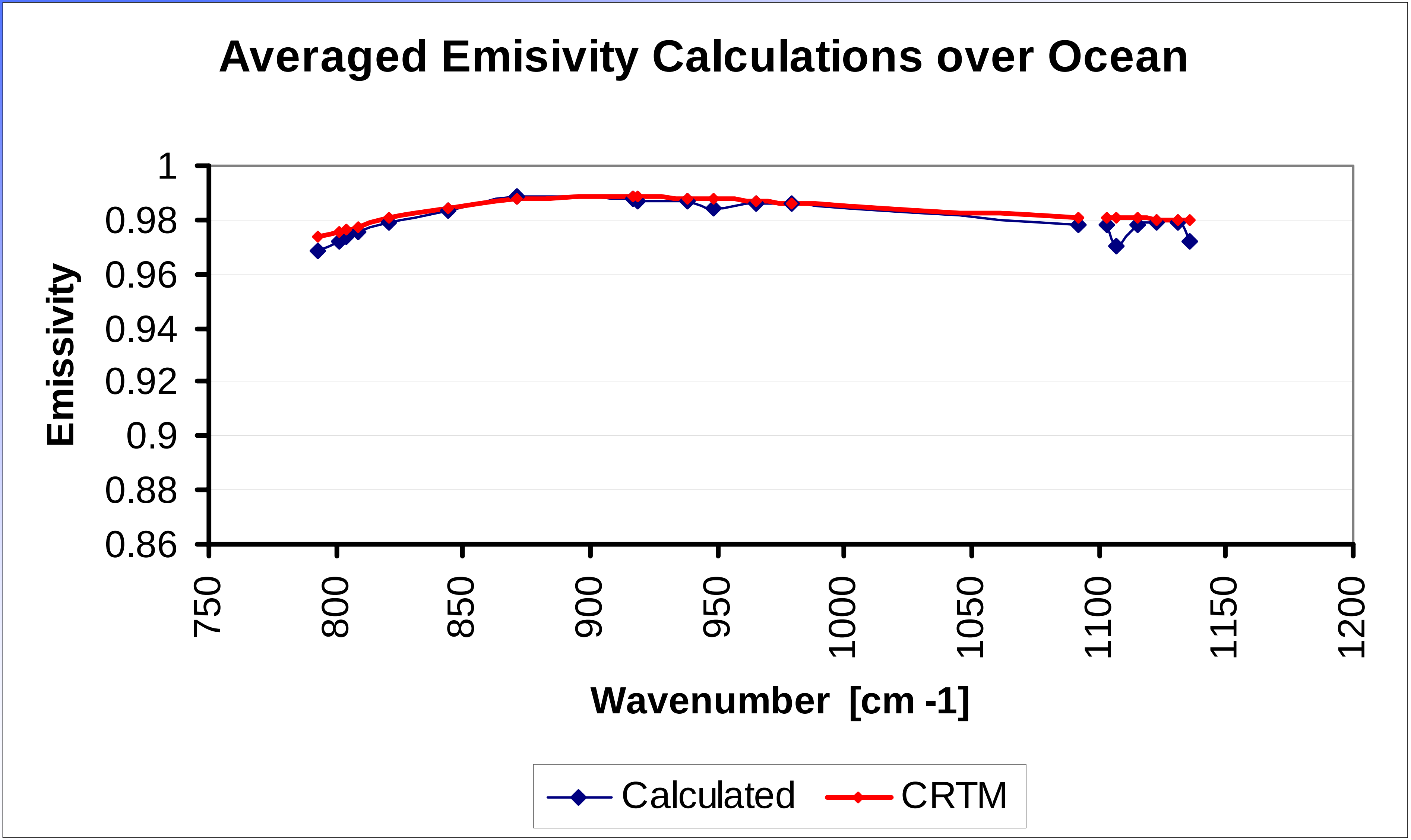
- Geographic Look Up Tables (LUTs) - CRTM
- Regression based on theoretical estimates
  - Lihang Zhou
  - Eva Borbas
- Minimum Variance, provides T_{surf} and ε *
- Eigenvector technique
  - Dan Zhou and Bill Smith
- Variational Minimisation – goal

Regression IR HYPERSPECTRAL EMISSIVITY - ICE and SNOW
Sample Max/Min Mean computed from synthetic radiance sample

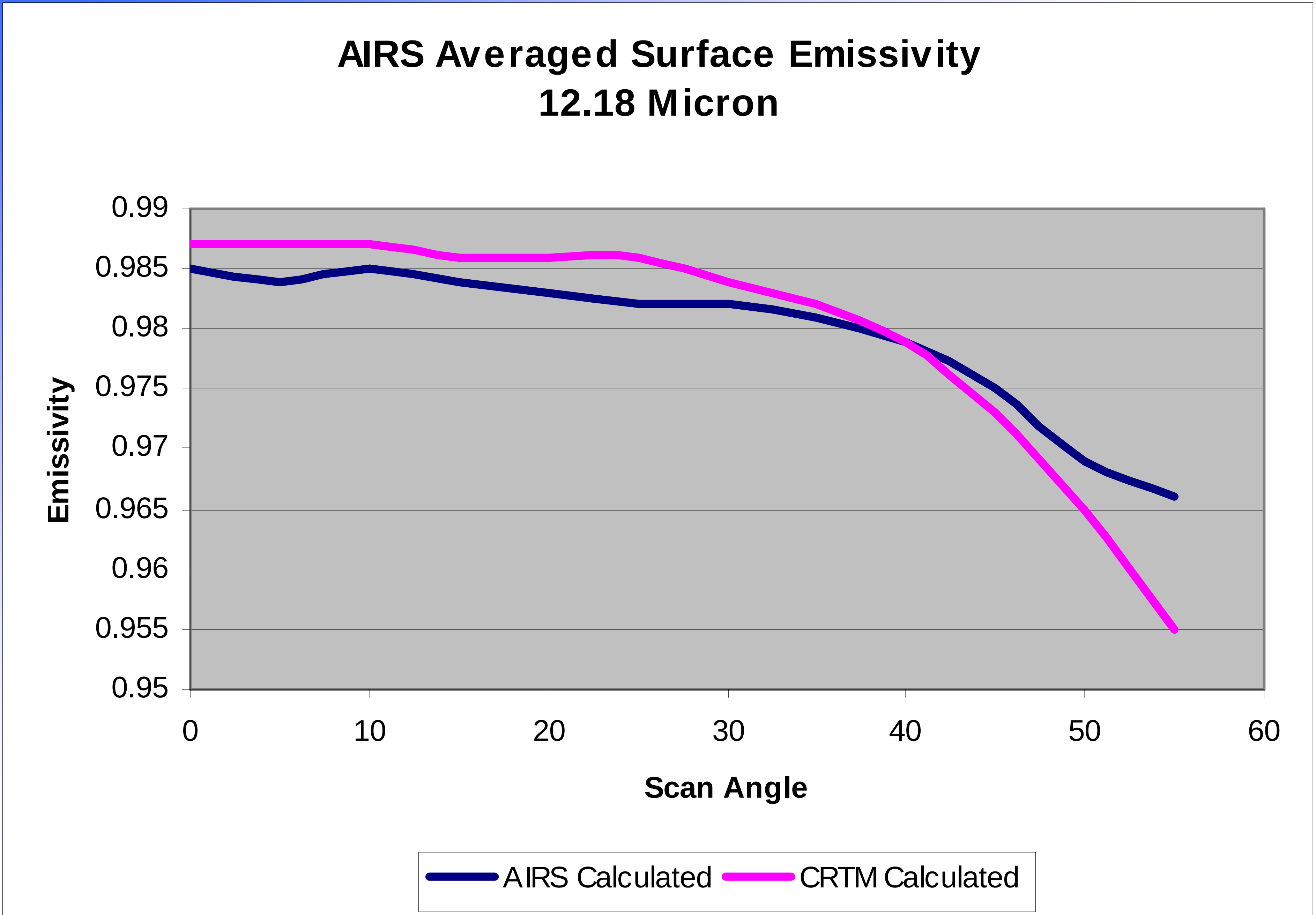


From Lihang Zhou

Minimum Variance IR HYPERSPECTRAL EMISSIVITY - Water



Minimum Variance IR HYPERSPECTRAL EMISSIVITY - Water



Summary:

The introduction of several new types of observational data has been examined by the JCSDA.

There have been positive results using the assimilation of SSM/IS and AMSR-E data.

AIRS hyperspectral data into environmental prognosis centers has provided improvements in forecast skill.

We have also noted the improvement gained from using AIRS at a spatial density greater than that used generally for operational NWP.

Summary:

We have also completed some studies to look at the impact of spectral coverage and found for the period studied, use of a fuller AIRS spectral coverage, namely 3.7 to 15.4 µm, provided superior forecasts.

The modelling of surface emissivity in the CRTM and in a number of related studies have also commenced to improve our use of AIRS data over land and ice

Conclusion

Given the opportunities for enhancement of the assimilation system and the availability of many different types of satellite data, the results here indicate an opportunity to further improve current analysis and forecast systems. The systems can be improved both through the use of additional data and through the enhancement of the use of current data.

Further improvements may also be anticipated through use of data over land, cloudy data and the use of complementary data such as Moderate Resolution Imaging Spectroradiometer (MODIS) radiances to better characterize the AIRS fovs.

JOINT CENTER FOR SATELLITE DATA ASSIMILATION

NOAA NASA JCSDA Navy Air Force

International TOVS Study Conference, 15th, ITSC-15, Maratea,Italy, 4-10 October 2006
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2006.