JOINT CENTER FOR SATELLITE DATA ASSIMILATION

NOAA NASA JCSDA Navy Air Force

AIRS Related Advances at the JCSDA -ITCS14-

Overview

- JCSDA
- Background
- Data Base
- The Assimilation System
- Results to Date.
- Imminent Activity
- Summary

Joint Center for Satellite Data Assimilation

JOINT CENTER FOR SATELLITE DATA ASSIMILATION

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NASA/Goddard

Global Modeling & Assimilation Office

NOAA/NCEP

Environmental Modeling Center

NOAA/OAR

Office of Weather and Air Quality

NOAA/NESDIS

Office of Research & Applications

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NOAA: NESDIS, NWS, OAR
DoD: Navy, Air Force

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JCSDA Mission and Vision

- Mission: Accelerate and improve the quantitative use of research and operational satellite data in weather and climate analysis and prediction models
- Near-term Vision: A weather and climate analysis and prediction community empowered to effectively assimilate increasing amounts of advanced satellite observations
- Long-term Vision: An environmental analysis and prediction community empowered to effectively use the integrated observations of the GEOSS

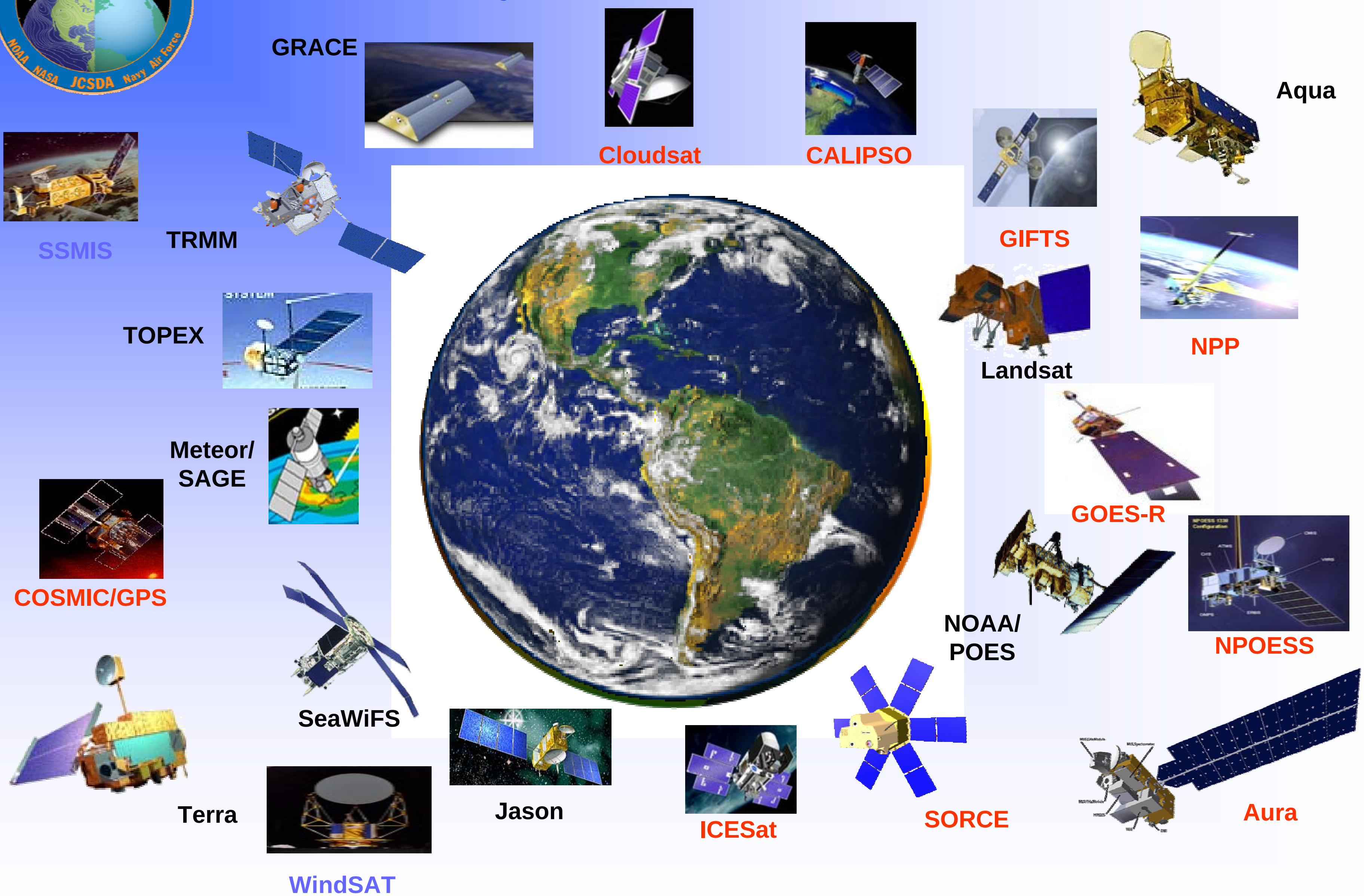
Goals – Short/Medium Term

- Increase uses of current and future satellite data in Numerical Weather and Climate Analysis and Prediction models
- Develop the hardware/software systems needed to assimilate data from the advanced satellite sensors
- Advance the common NWP models and data assimilation infrastructure
- Develop common fast radiative transfer system
- Assess the impacts of data from advanced satellite sensors on weather and climate analysis and prediction
- Reduce the average time for operational implementations of new satellite technology from two years to one

Required Capabilities to Achieve Goals

- A satellite data assimilation infrastructure
- A directed research and development program
- A grants program for long-term research
- An education and outreach program

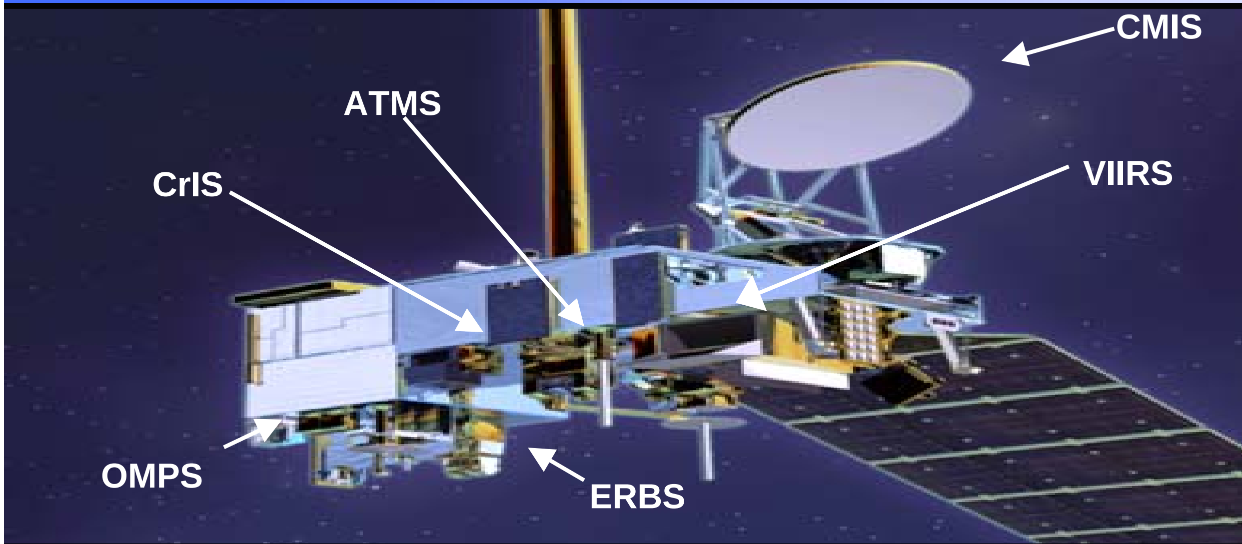
The Challenge
Satellite Systems/Global Measurements



Draft Sample Only

	A	B	C	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	**Satellite Instruments and Their Characteristics (* = currently assimilated in NWP)**																	
2				**Primary Information Content**										**Priority**				
3	**Platform**	**Instrument**	**Status**	**Temper-ature**	**Humidity**	**Cloud**	**Precip-itation**	**Wind**	**Ozone**	**Land Surface**	**Ocean Surface**	**Aerosols**	**Earth Radiation Budget**	**NOAA**	**NAVY**	**NASA**	**AIR FORCE**	**NAVY NON - ASSIM**
4	**DMSP**	SSM/I *	Current		v	v	v	v		v	v			1	1	1	3	1
5		SSM/T*		v										3	3	3	1	2
6		SSM/T-2			v		v							3	3	3	1	2
7		SSMI/S	Current											2	1	2	3	1
8		OLS				v				v				3	2	3	3	2
9	**POES**	AMSU-A *	Current	v	v	v	v			v	v			1	1	1	3	1
10		AMSU-B *			v		v							1	1	1	3	1
11		HIRS/3 *		v	v	v			v	v	v			1	1	1	3	1
12		AVHRR *				v				v	v	v			1		3	2
13		SBUV *							v					1	1	1	3	2
14	**GOES**	Imager *	Current		v	v	v	v		v	v	v		2	1	2	3	1
15		Sounder *		v	v	v		v		v	v			3	1	3	3	2
16	**GFO**	Altimeter*	Current					v			v			1	1	1	1	1
17	**GMS (GOES-9)**	Imager *	Current		v	v		v		v	v	v		3	1	3	3	1
18	**Terra**	MODIS*	Current	v	v	v	v	v		v	v	v		2	1	2	1	1
19	**TRMM**	TMI	Current		v	v		v		v	v			2	2	2	1	1
20		VIRS				v					v	v		3	2	3	1	2
21		PR					v							3	2	3	1	1
22		CERES											v	3	3	3	1	3
23	**QuikSCAT**	Scatterometer *	Current					v		v				1	1	1	3	1
24	**TOPEX**	Altimeter *	Current		TPW			v			v			1	1	1	2	1
25	**JASON-1**	Altimeter*	Current		TPW			v			v			1	1	1	1	1
26	**Aqua**	AMSR-E	Current		v	v	v	v		v	v			1	1	1	2	1
27		AMSU		v	v	v	v			v	v			1	1	1	1	1
28		HSB			v		v				v			3	n/a	3	1	2
29		AIRS		v	v	v			v	v	v			1	1	1	1	1
30		MODIS*		v	v	v	v	v		v	v	v		2	1	1	1	1
31	**Envisat**	Altimeter*	Current				v	v			v			1	1	1	2	1
32		MWR			v	v								2	1	2	2	1
33		MIPAS		v					v					2	2	2	2	2
34		AATSR									v			2	1	2	1	2
35		MERIS				v				v	v	v		2	2	2	2	1
36		SCIAMACHY			v	v			v			v		3	3	3	2	3
37		GOMOS							v					2	1	2	1	2

NPOESS Satellite



CMIS- µwave imager
VIIRS- vis/IR imager
CrIS- IR sounder
ATMS- µwave sounder
OMPS- ozone
GPSOS- GPS occultation
ADCS- data collection
SESS- space environment
APS- aerosol polarimeter
SARSAT - search & rescue
TSIS- solar irradiance
ERBS- Earth radiation budget
ALT- altimeter
SS- survivability monitor

The NPOESS spacecraft has the requirement to operate in three different sun synchronous orbits, 1330, 2130 and 1730 with different configurations of fourteen different environmental sensors that provide environmental data records (EDRs) for space, ocean/water, land, radiation clouds and atmospheric parameters.

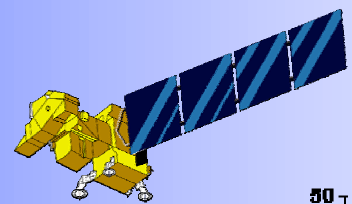
In order to meet this requirement, the prime NPOESS contractor, Northrop Grumman Space Technology, is using their flight-qualified NPOESS T430 spacecraft. This spacecraft leverages extensive experience on NASA's EOS Aqua and Aura programs that integrated similar sensors as NPOESS.

As was required for EOS, the NPOESS T430 structure is an optically and dynamically stable platform specifically designed for earth observation missions with complex sensor suites.

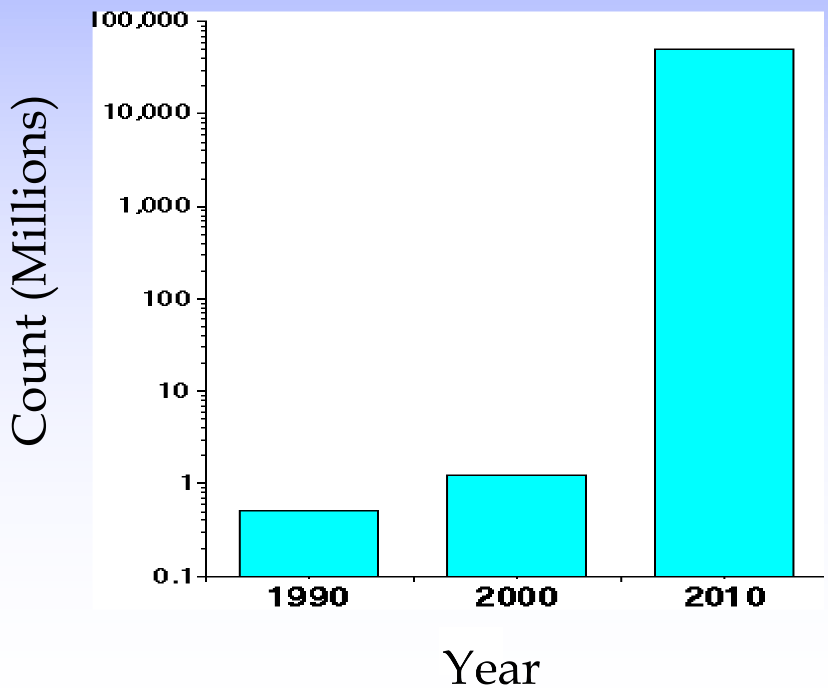
In order to manage engineering, design, and integration risks, a single spacecraft bus for all three orbits provides cost-effective support for accelerated launch call-up and operation requirement changes. In most cases, a sensor can be easily deployed in a different orbit because it will be placed in the same position on the any spacecraft. There are ample resource margins for the sensors, allowing for compensation due to changes in sensor requirements and future planned improvements.

The spacecraft still has reserve mass and power margin for the most stressing 1330 orbit, which has eleven sensors. The five panel solar array, expandable to six, is one design, providing power in the different orbits and configurations.

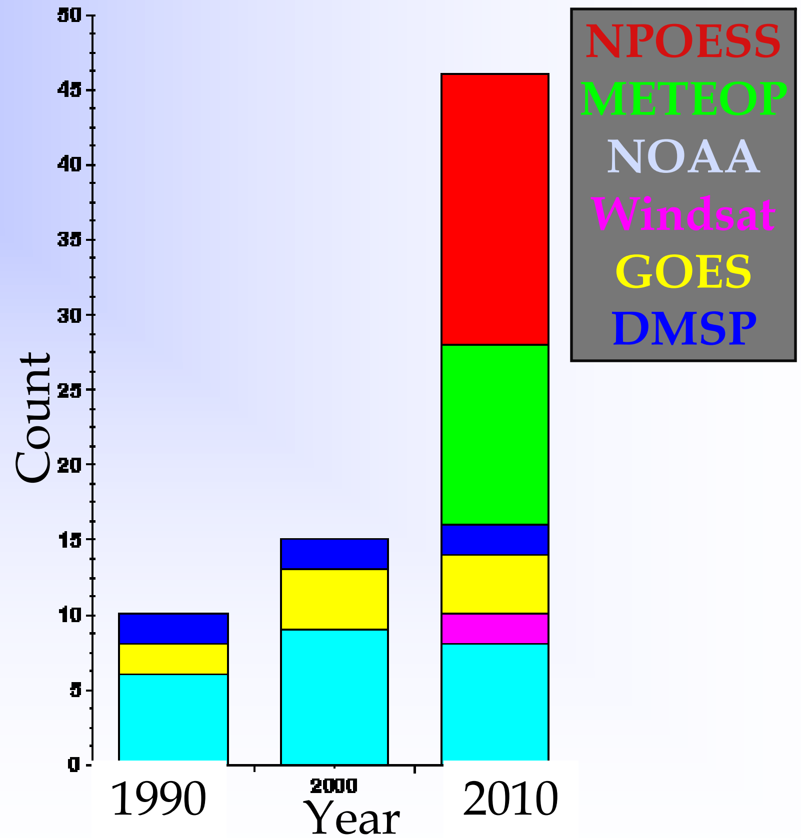
5-Order Magnitude Increase in Satellite Data Over 10 Years



Daily Upper Air Observation Count



Satellite Instruments by Platform



JCSDA Road Map (2002 - 2010)

3D VAR --4D VAR

By 2010, a numerical weather prediction community will be empowered to effectively assimilate increasing amounts of advanced satellite observations

The radiances can be assimilated under all conditions with the state-of-the science NWP models

Resources:

OK

Required

NPOESS sensors (CMIS, ATMS…)
GIFTS, GOES-R

Advanced JCSDA community-based radiative transfer model,
Advanced data thinning techniques

The CRTM include cloud, precipitation, scattering

AIRS, ATMS, CrIS, VIIRS, IASI, SSM/IS, AMSR, WINDSAT, GPS ,more products assimilated

The radiances from advanced sounders will be used. Cloudy radiances will be tested under rain-free atmospheres, more products (ozone, water vapor winds)

Improved JCSDA data assimilation science

A beta version of JCSDA community-based radiative transfer model (CRTM) transfer model will be developed, including non-raining clouds, snow and sea ice surface conditions

AMSU, HIRS, SSM/I, Quikscat, AVHRR, TMI, GOES assimilated

The radiances of satellite sounding channels were assimilated into EMC global model under only clear atmospheric conditions. Some satellite surface products (SST, GVI and snow cover, wind) were used in EMC models

Pre-JCSDA data assimilation science

Radiative transfer model, OPTRAN, ocean microwave emissivity, microwave land emissivity model, and GFS data assimilation system were developed

Science Advance

2002 2003 2004 2005 2006 2007 2008 2009 2010

Short Term Priorities (04)

- **MODIS:** MODIS AMV assessment and enhancement. Accelerate assimilation into operational models.

- **AIRS:** Improved utilization of AIRS
  - Improve data coverage of assimilated data. Improve spectral content in assimilated data.
  - Improve QC using other satellite data (e.g. MODIS, AMSU)
  - Investigate using cloudy scene radiances and cloud clearing options
  - Improve RT Ozone estimates
  - Reduce operational assimilation time penalty (Transmittance Upgrade)

- **SSMIS:** Collaborate with the SSMIS CALVAL Team to jointly help assess SSMIS data. Accelerate assimilation into operational model as appropriate

Some Major Accomplishments

- Common assimilation infrastructure at NOAA and NASA
- Common NOAA/NASA land data assimilation system
- Interfaces between JCSDA models and external researchers
- Community radiative transfer model-Significant new developments, New release June
- Snow/sea ice emissivity model – permits 300% increase in sounding data usage over high latitudes – improved polar forecasts
- ***Advanced satellite data systems such as EOS (MODIS Winds, Aqua AIRS, AMSR-E) tested for implementation***

  -MODIS winds, polar regions - improved forecasts. Current Implementation

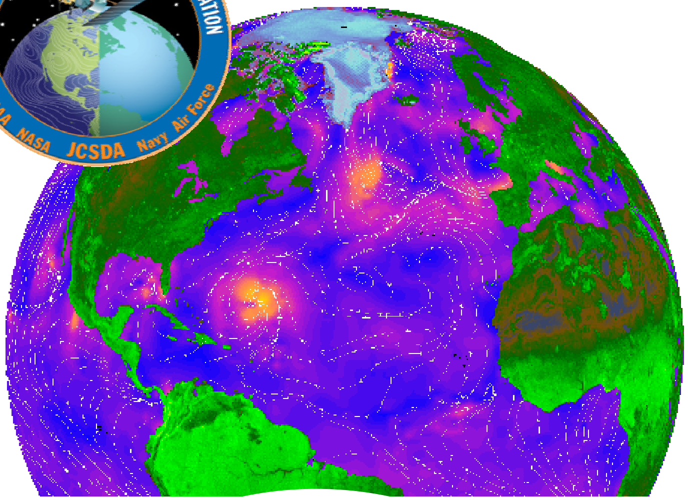
  -***Aqua AIRS - improved forecasts. Current Implementation***
- Improved physically based SST analysis
- Advanced satellite data systems such as

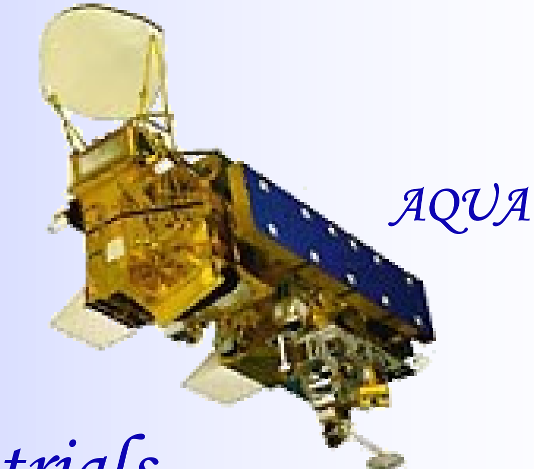
  -DMSP (SSMIS),

  -CHAMP GPS

  being tested for implementation
- Impact studies of POES AMSU, Quikscat, GOES and EOS AIRS/MODIS with JCSDA data assimilation systems completed.

/AQUA/ Assimilation Studies





Targeted studies

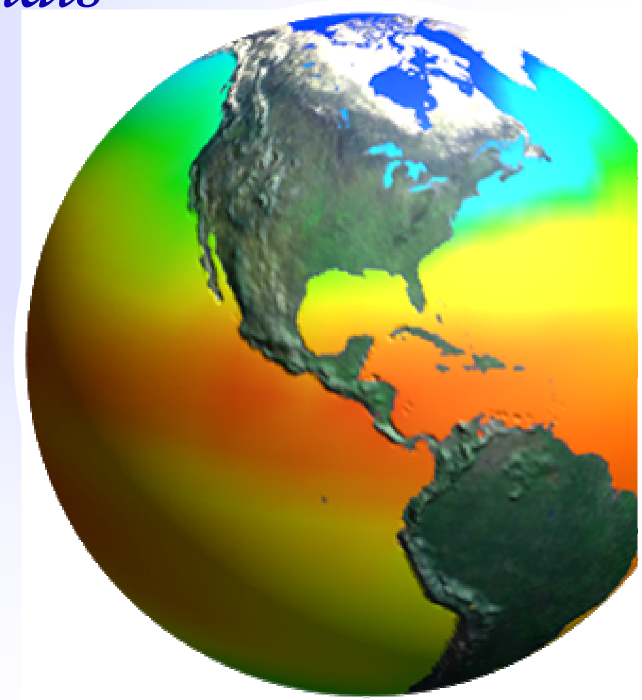
Pre-Operational trials

Initial

First

Second

……….



AQUA

AIRS/AQUA

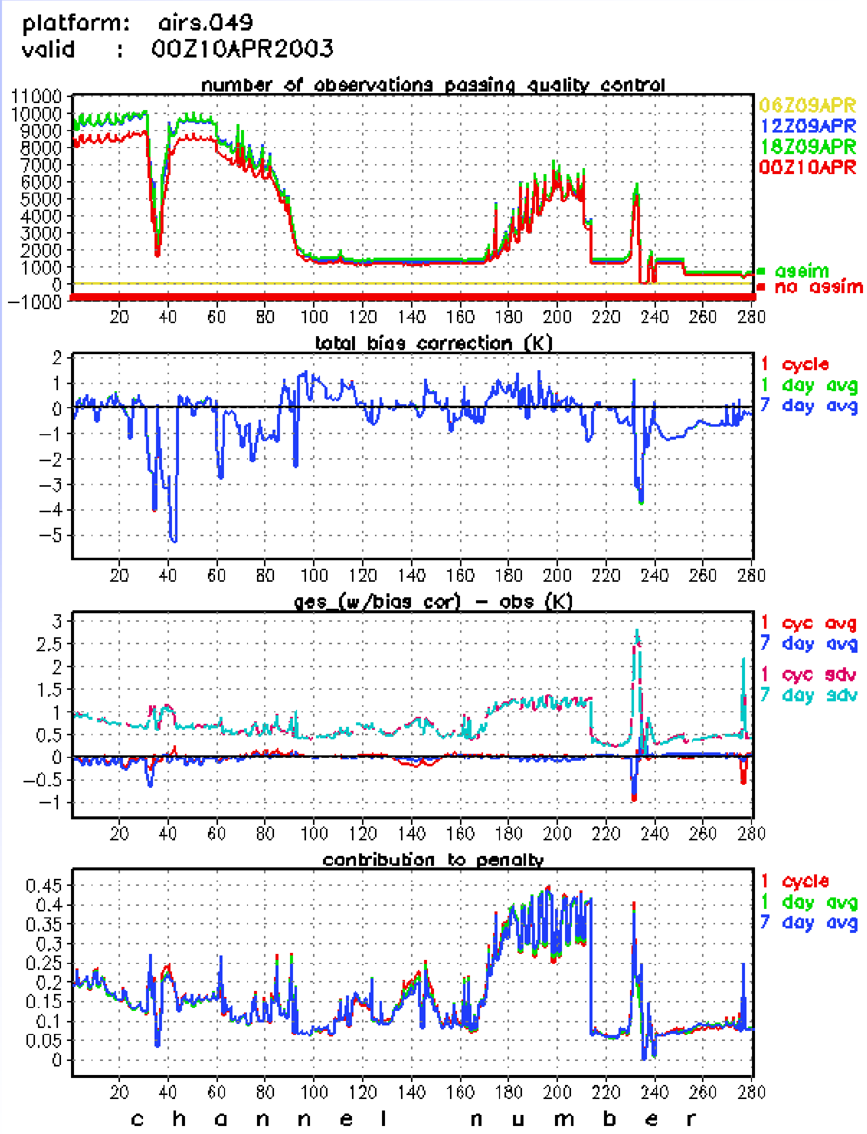
Initial Studies

AIRs Targeting Study

Contributors: GMAO: L.P. Riishojgaard,
EMC: Zoltan Toth,Lacey Holland

Summary of Accomplishments

- GMAO developed a software for stratifying observational data stream that indicates the area having higher background errors
- EMC had some dropsonde data released in the areas found sensitive to Ensemble Kalman Filter technique where high impact events occurs.
- Joint EMC/GMAO have identified 10 winter storm cases in 2003 that have large forecast errors for AIRS studies



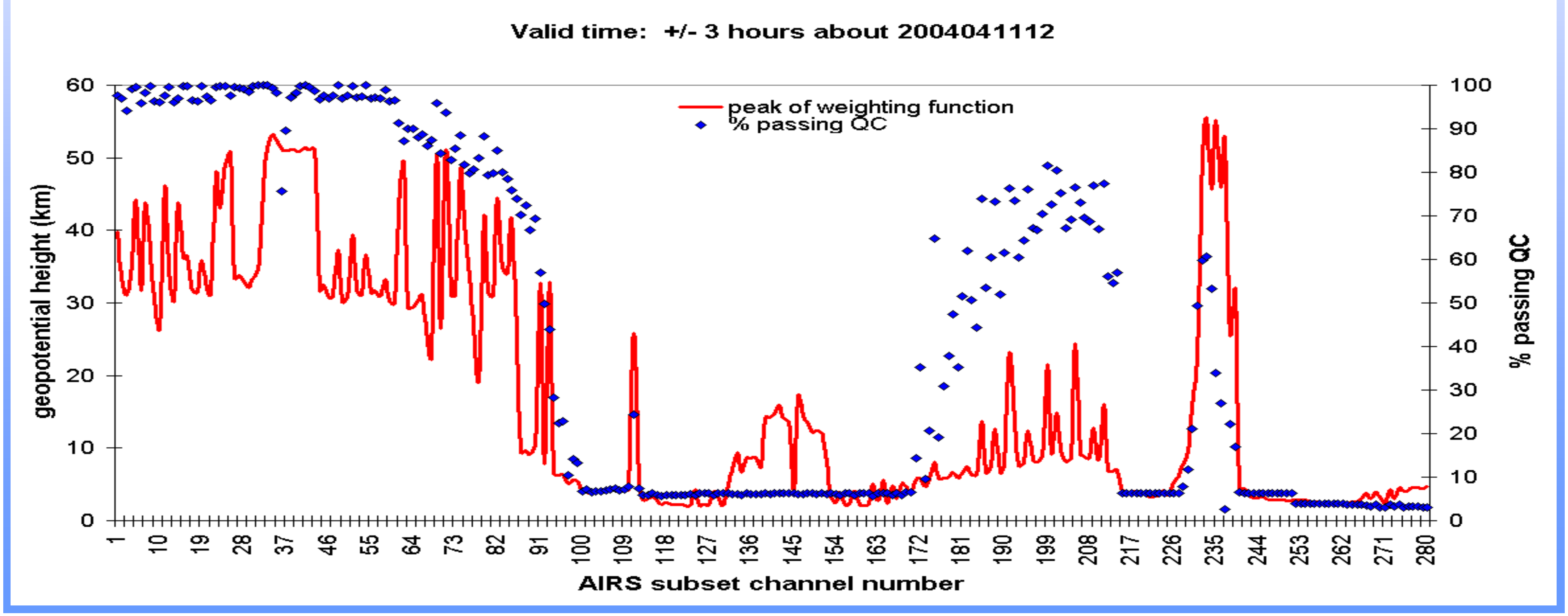
Use of AQUA brightness temperatures in the NCEP GDAS

Stephen Lord

Stacie Bender, John Derber, Lacey Holland, Zoltan Toth, Russ Treadon

SSI modifications

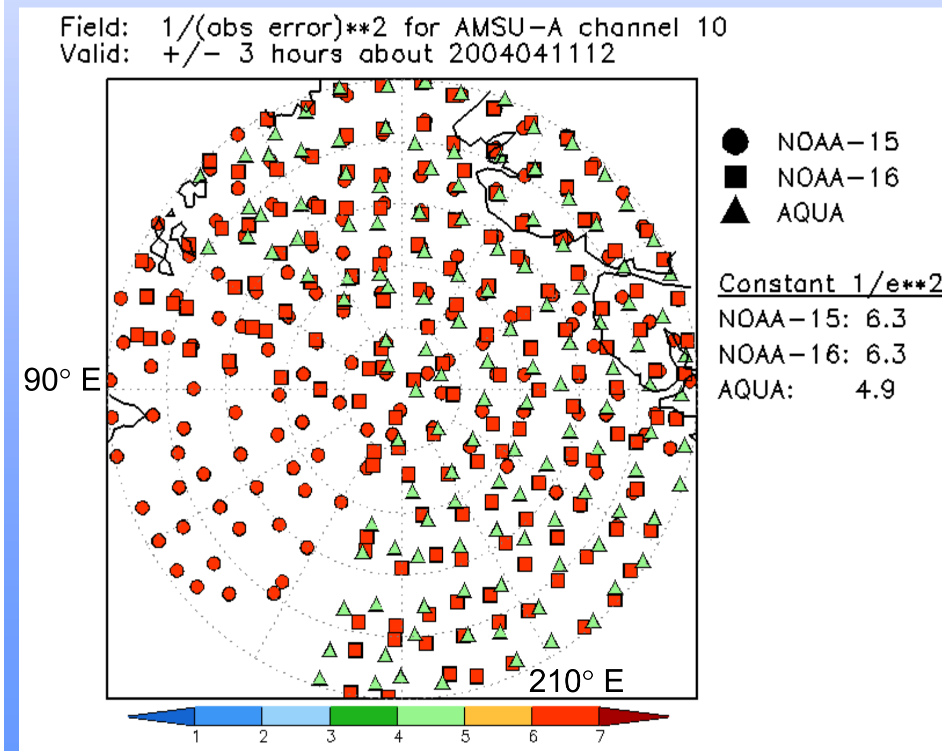
- conservative detection of IR cloudy radiances
  - examine sensitivity, δT_b, of simulated T_b to presence of cloud and skin temperature
  - those channels for which δT_b exceeds an empirical threshold are not assimilated



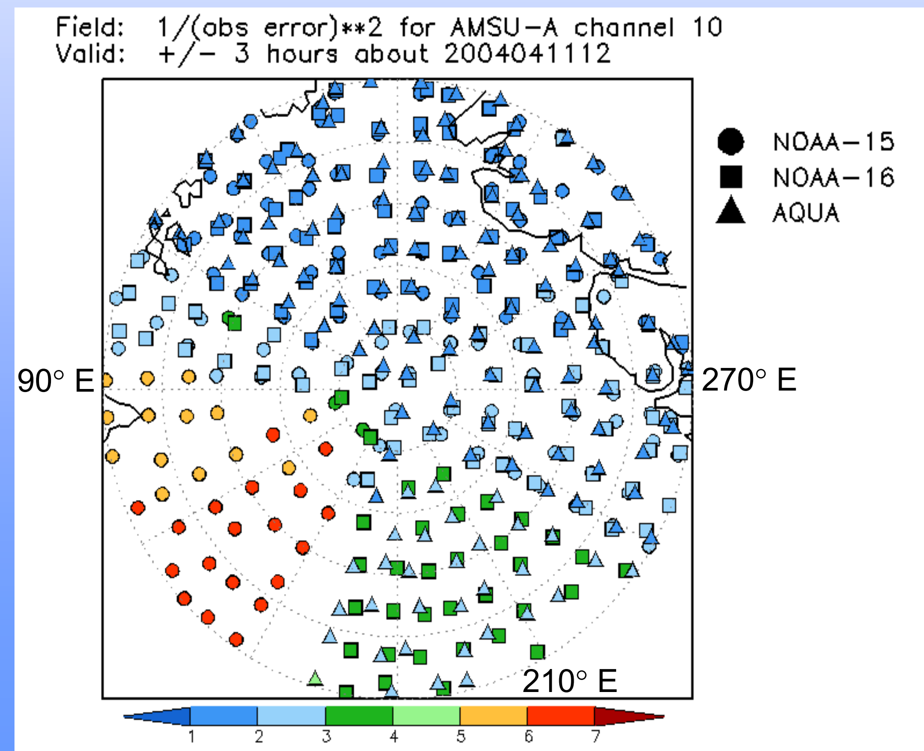
SSI modifications

- more flexible horizontal thinning/weighting
  - account for sensors measuring similar quantities
    - specify sensor groupings (all IR, all AMSU-A, etc)
    - specify relative weighting for sensors within group

Old thinning/weighting

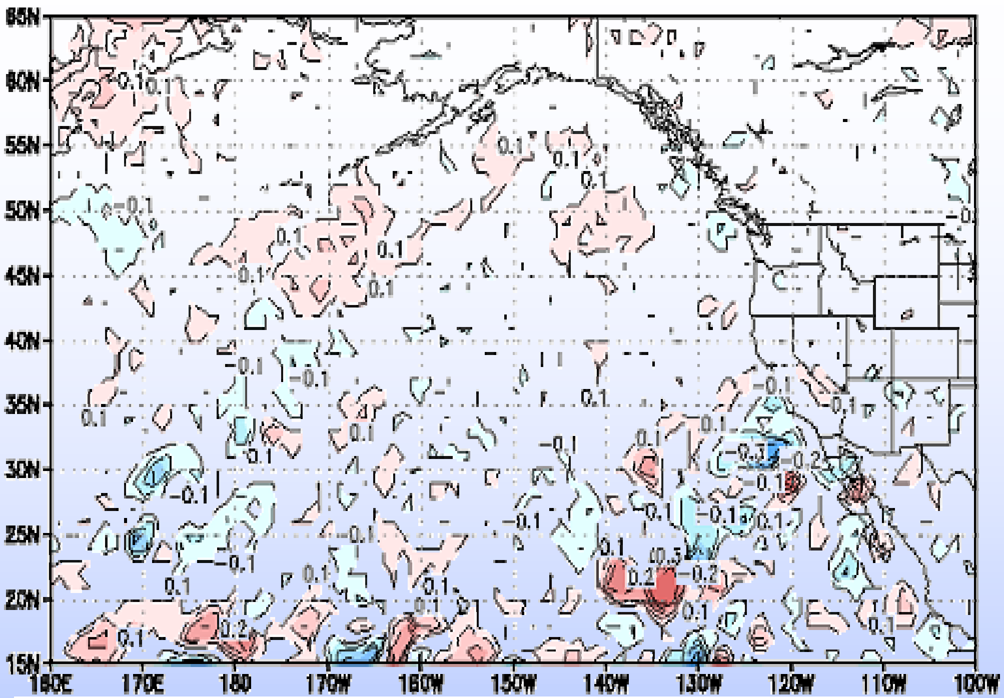


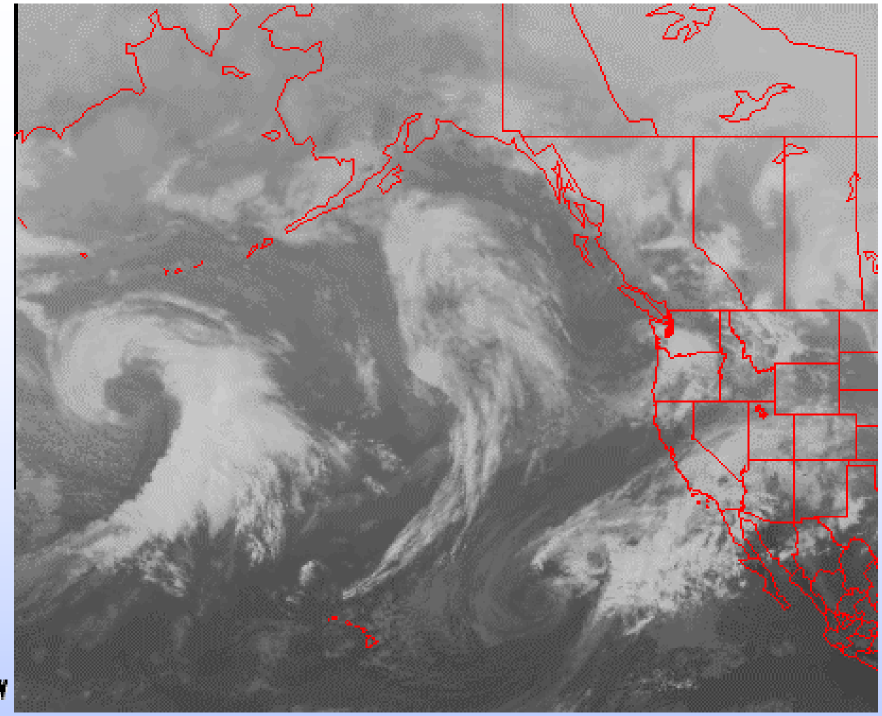
New thinning/weighting

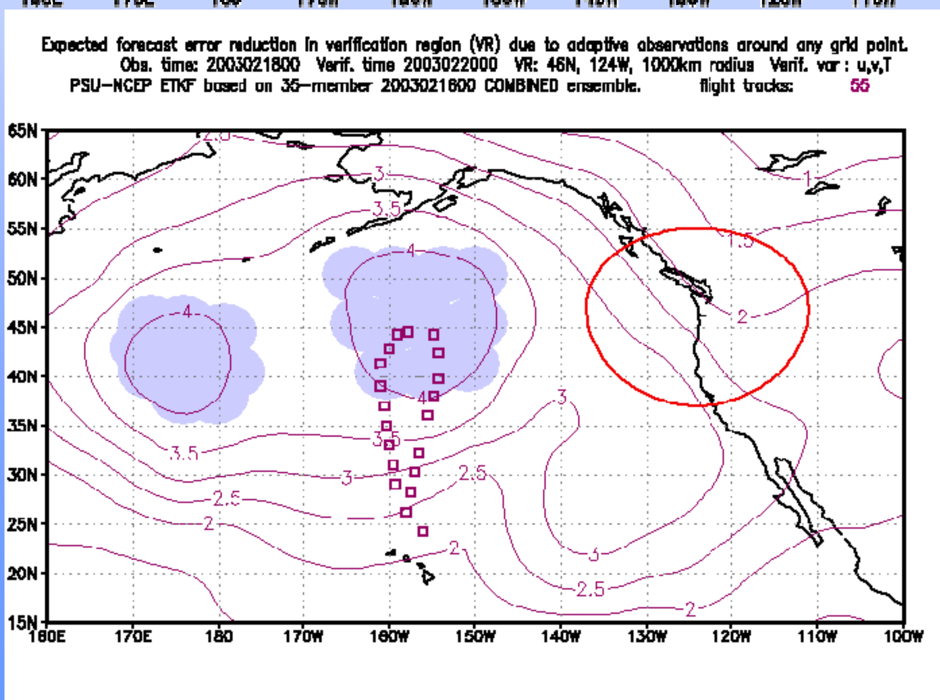


How the impact of AIRS was evaluated

- CASE SELECTION
  - 7 Cases selected from Winter Storm Reconnaissance (WSR) program during 2003
  - Forecasts with high RMSE for given lead time chosen
- DATA SELECTION
  - AIRS data assimilated only in locations identified as having the most potential for forecast improvement as determined through WSR (areas containing 90% or more of maximum sens. value)
  - Somewhat larger area covered by the AIRS data compared to WSR dropsonde coverage
- EVALUATION
  - Impact tested by comparing two forecast/analysis GFS cycles (T126L28), identical except that one contains AIRS data while the other does not
  - Control has all operationally available data (including WSR dropsondes)







Data Impact of AIRS on 500 hPa Temperature (top left), IR Satellite Image (top right), and estimated sensitivity (left) for 18 Feb 2003 at 00 UTC

Impact outside the targeted areas is due to small differences between the first guess forecasts. Sensitive areas show no data impact due to cloud coverage.

- Light purple shading indicates AIRS data selection
- Violet squares indicate dropsonde locations
- Red ellipse shows verification region

SFC. PRES. (based on RMSE)	AIRS + drops vs. drops only	Drops vs. no drops
Improved	0	4
Neutral	3	2
Degraded	4	1

VECTOR WIND (1000-250 hPa)	AIRS + drops	Drops vs. no drops
Improved	1	1
Neutral	3	1
Degraded	3	5

TEMP (1000-250 hPa)	AIRS + drops vs. drops only	Drops vs. no drops
Improved	1	3
Neutral	5	2
Degraded	1	2

SPECIFIC HUMIDITY (1000-250 hPa)	AIRS + drops vs. drops only	Drops only vs. no drops
Improved	6	4
Neutral	1	1
Degraded	0	2

Improved/Neutral/Degraded classification based on RMSE of forecasts verified against raobs over WSR pre-defined verification area

Overall impact of AIRS on WSR forecasts

- determined by comparing the number of fields (temperature, vector wind, humidity between 1000-250 hPa as well as sfc pressure) that were improved or degraded for each case

OVERALL	AIRS + drops vs. drops only	Drops vs. no drops
Improved	2	4
Neutral	1	0
Degraded	4	3

- While the addition of dropsondes shows a slight positive impact, the addition of AIRS data has no overall benefit

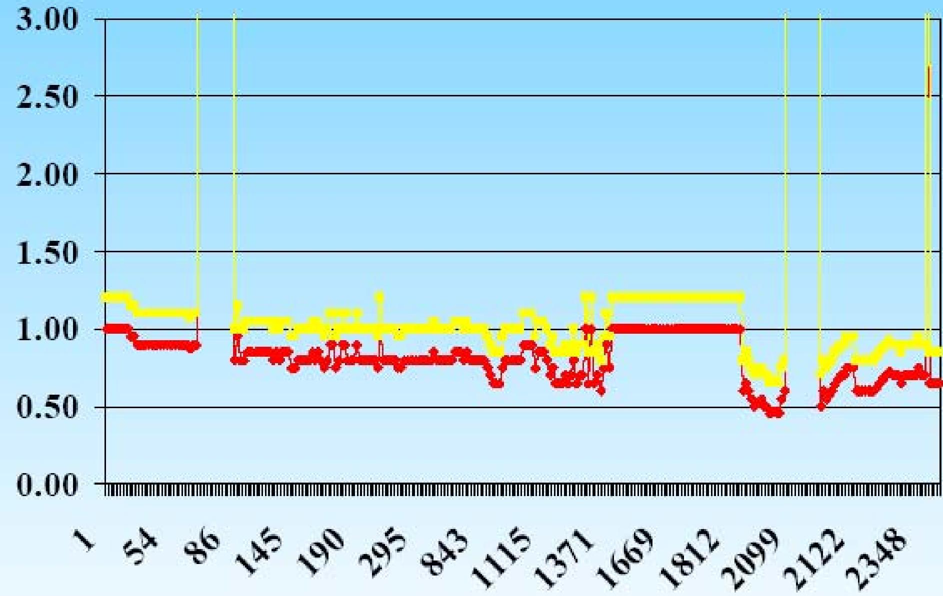
Assimilation of advanced sounders at NCEP

John C. Derber, Russ Treadon, and Paul VanDelst
NOAA/NWS/NCEP/EMC

AIRS data

- 254 out of 281 channels used
  - 73-86 removed (channels peak too high)
  - 1937-2109 removed (non-LTE)
  - 2357 removed (large obs-background diff.)
- Shortwave channels during day
  - (wavenumber > 2000) down weighted
  - (wavenumber > 2400) removed

AIRS observational errors



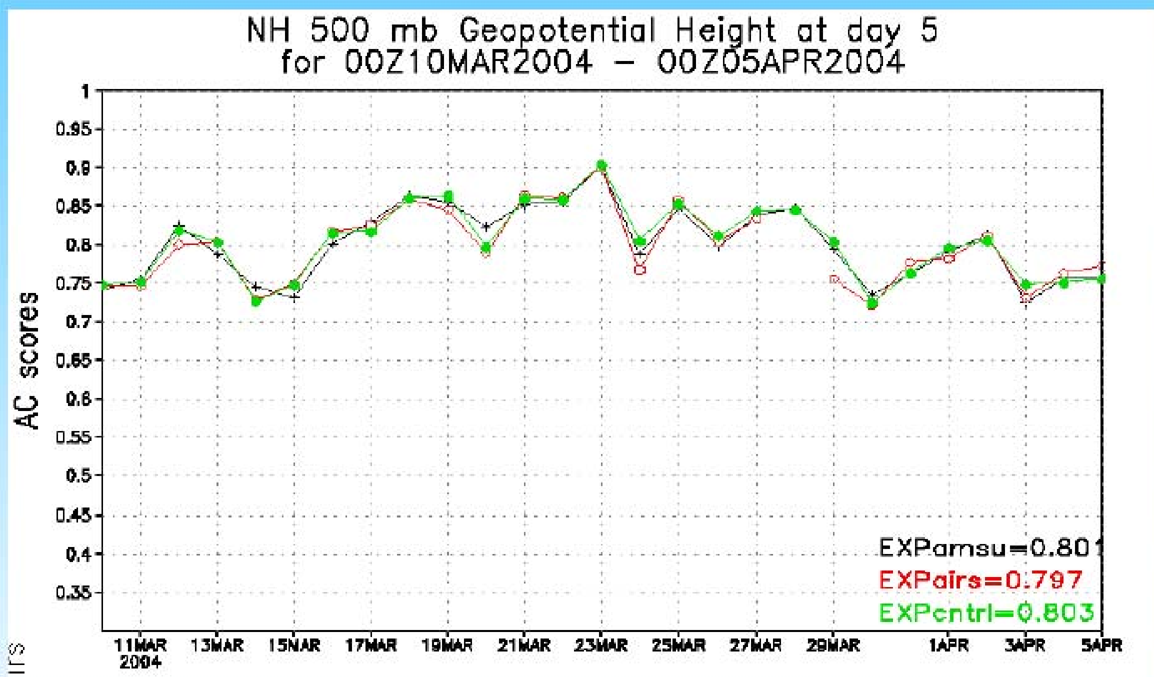
28 June 2004

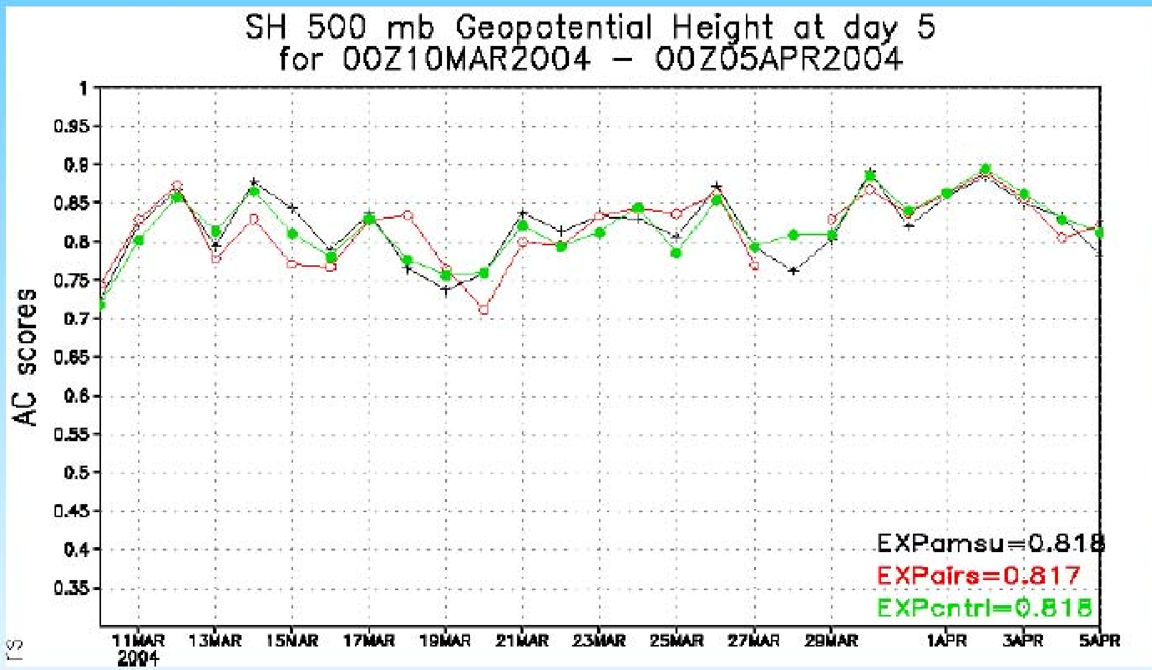
ECMWF workshop on Assimilation of high spectral resolution sounders

NCEP

AQUA impact studies

- Test period 10 Mar – 5 Apr 2004
- Uses data operational at time of experiment
- Mass storage problems on our machine, so some incomplete evaluation
- Experiments
  - Current operational
  - Current + AIRS
  - Current + AQUA AMSU
  - Current + AIRS + AQUA AMSU (underway)


NH 500 mb Geopotential Height at day 5
for 00Z10MAR2004 – 00Z05APR2004
AC scores
EXPamsu=0.801
EXPairs=0.797
EXPcntrl=0.803
11MAR 2004
13MAR
15MAR
17MAR
19MAR
21MAR
23MAR
25MAR
27MAR
29MAR
1APR
3APR
5APR


SH 500 mb Geopotential Height at day 5
for 00Z10MAR2004 - 00Z05APR2004
AC scores
EXPamsu=0.818
EXPairs=0.817
EXPcntrl=0.818
11MAR 2004
13MAR
15MAR
17MAR
19MAR
21MAR
23MAR
25MAR
27MAR
29MAR
1APR
3APR
5APR

AIRS Comments

- Results with both AIRS and AQUA AMSU similar so far
- AIRS data used when radiances clear (above and between clouds) – 38 % of thinned data used
- To date – little impact of AIRS data
- Adds 7-8 minutes to analysis wall time
- Impact studies continuing

AQUA

JCSDA

RECENT ADVANCES

AIRS Data Assimilation

J. Le Marshall, J. Jung, J. Derber, R. Treadon,
S.J. Lord, M. Goldberg, W. Wolf and H-S Liu, J. Joiner,
P. van Delst, R. Atlas and J Woollen……

1 January 2004 – 31 January 2004

Used operational GFS system as Control

Used Operational GFS system Plus Enhanced AIRS Processing as Experimental System

Table 1: Satellite data used operationally within the NCEP Global Forecast System

HIRS sounder radiances AMSU-A sounder radiances AMSU-B sounder radiances GOES sounder radiances GOES 9,10,12, Meteosat atmospheric motion vectors GOES precipitation rate SSM/I ocean surface wind speeds SSM/I precipitation rates	TRMM precipitation rates 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

Global Forecast System
Background

- Operational SSI (3DVAR) version used
- Operational GFS T254L64 with reductions in resolution at 84 (T170L42) and 180 (T126L28) hours.
- 2.5hr data cut off

The Trials – Assim1

- 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 Trials – Assim1

- Used NCEP Operational verification scheme.

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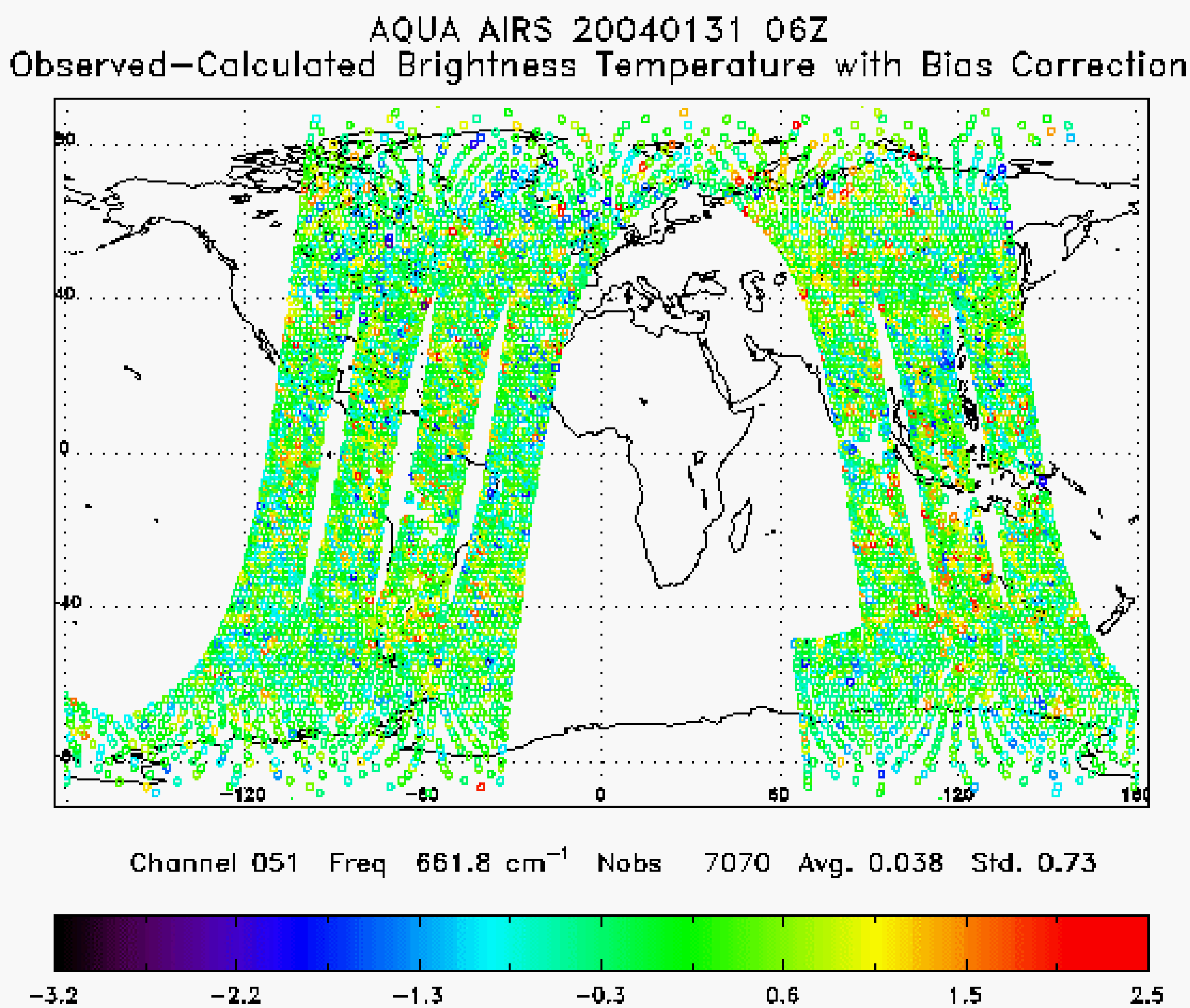
NOAA NASA JCSDA Navy Air Force



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

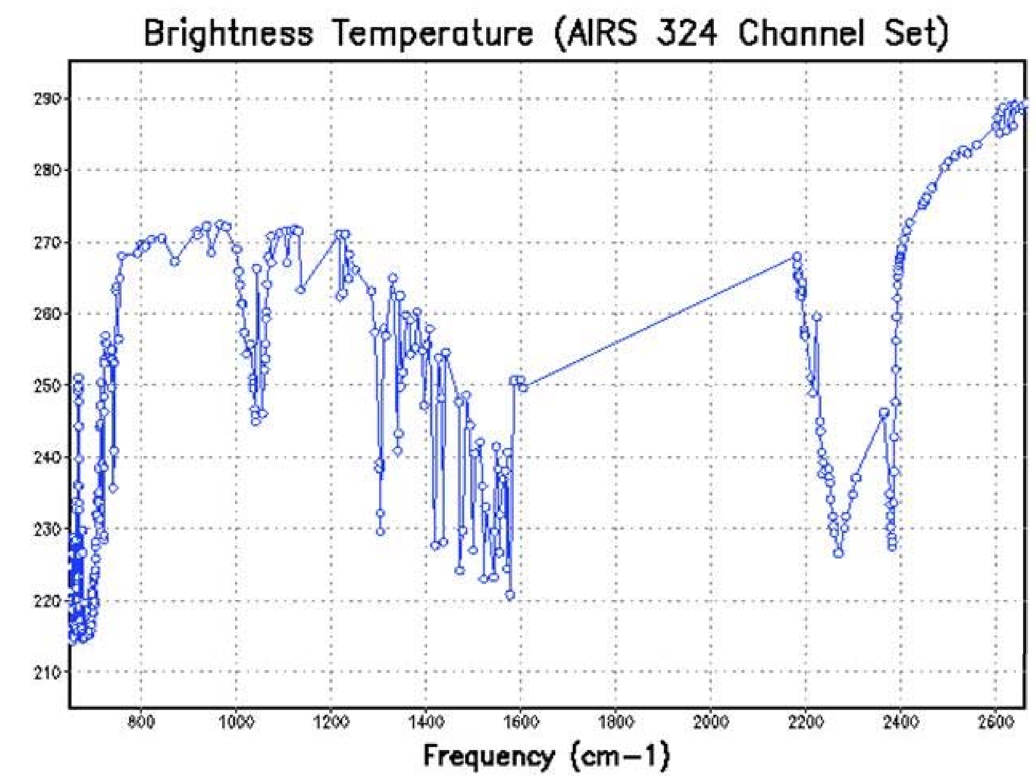


Figure 5.Spectral locations for 324 AIRS thinned channel data distributed to NWP centers.

Table 2: AIRS Data Usage per Six Hourly Analysis Cycle

Data Category	Number of AIRS Channels
Total Data Input to Analysis	~200x10^6 radiances (channels)
Data Selected for Possible Use	~2.1x10^6 radiances (channels)
Data Used in 3D VAR Analysis(Clear Radiances)	~0.85x10^6 radiances (channels)

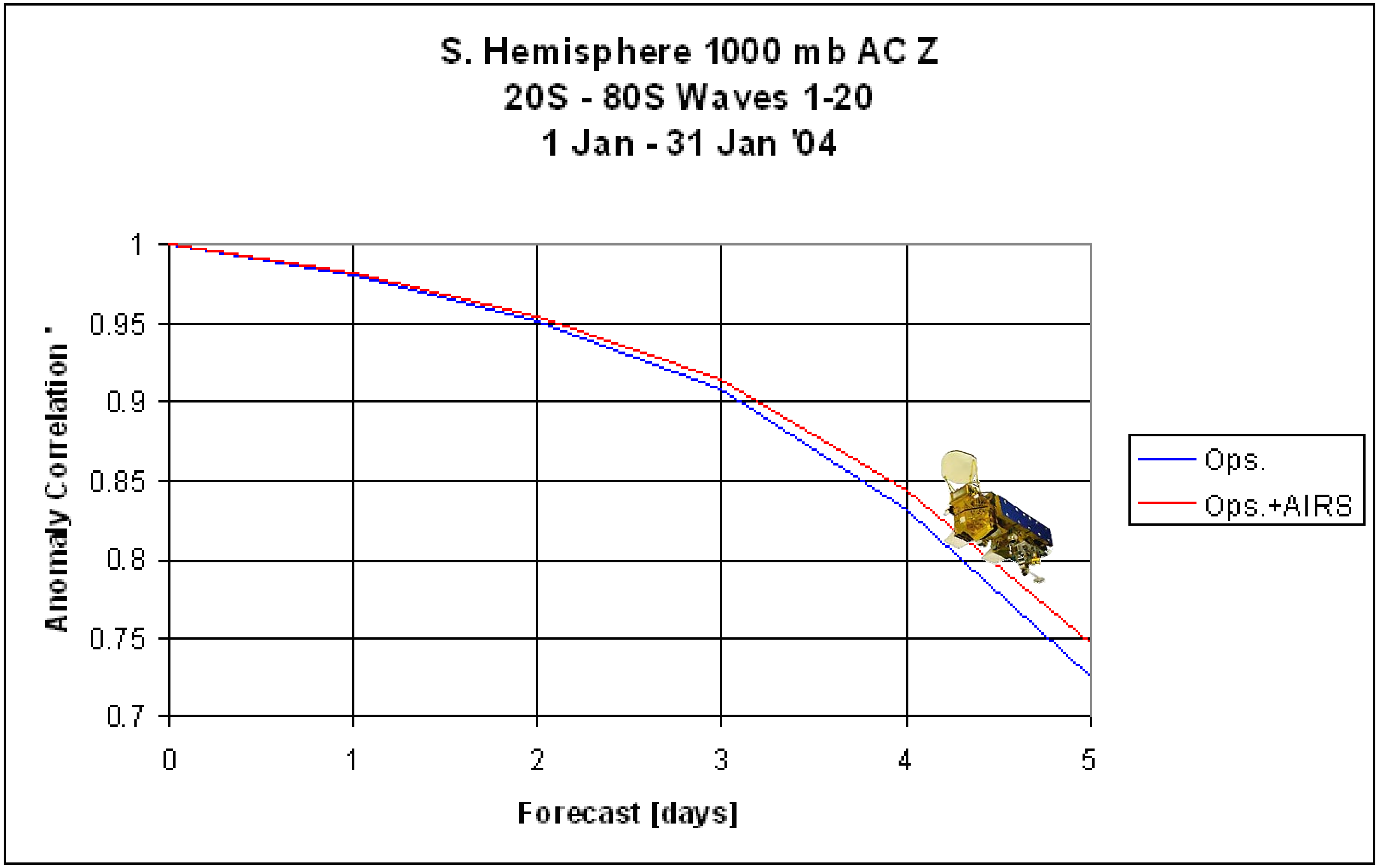


Figure1(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004- Assim1

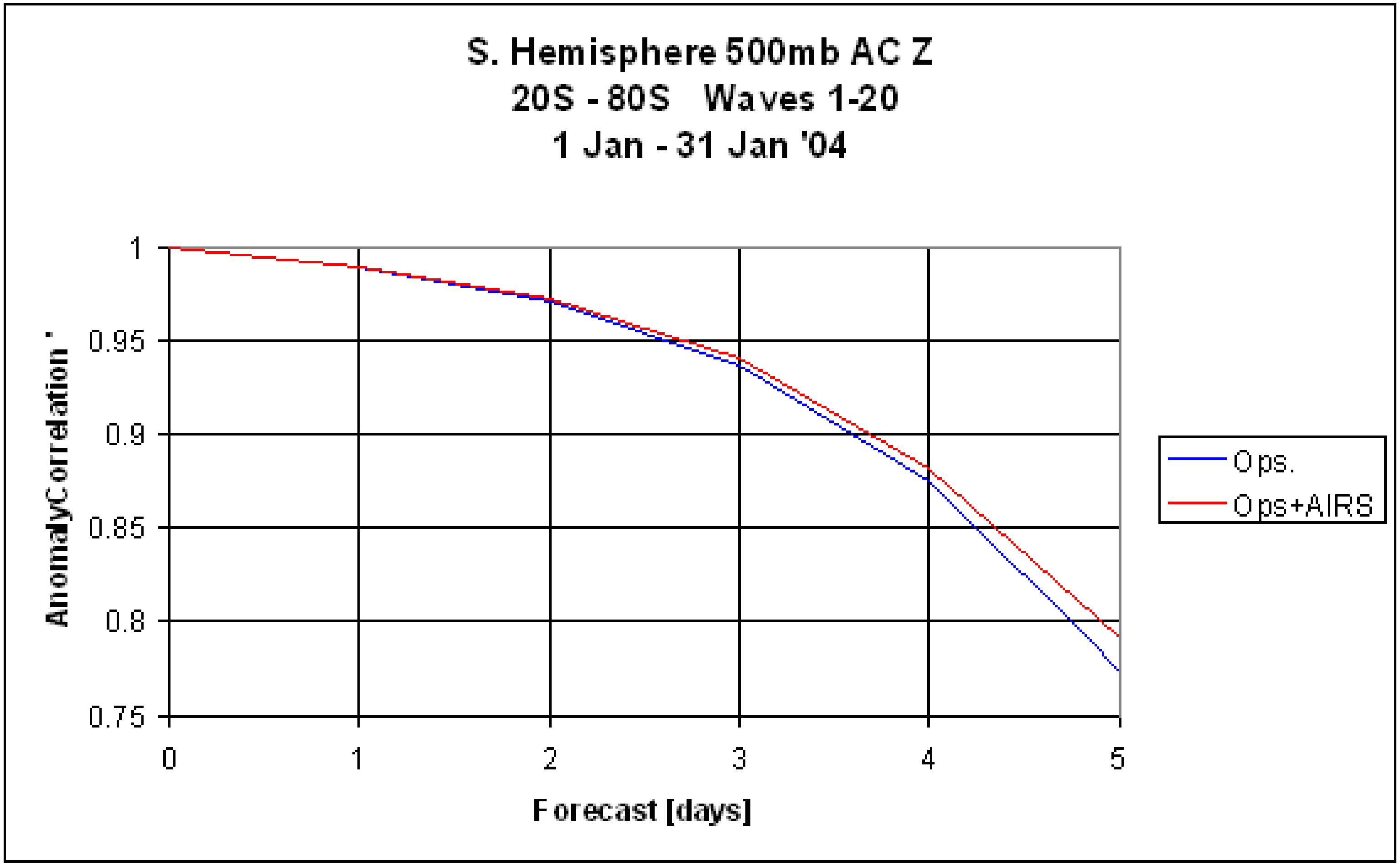


Figure1(a). 500hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004 – Assim1

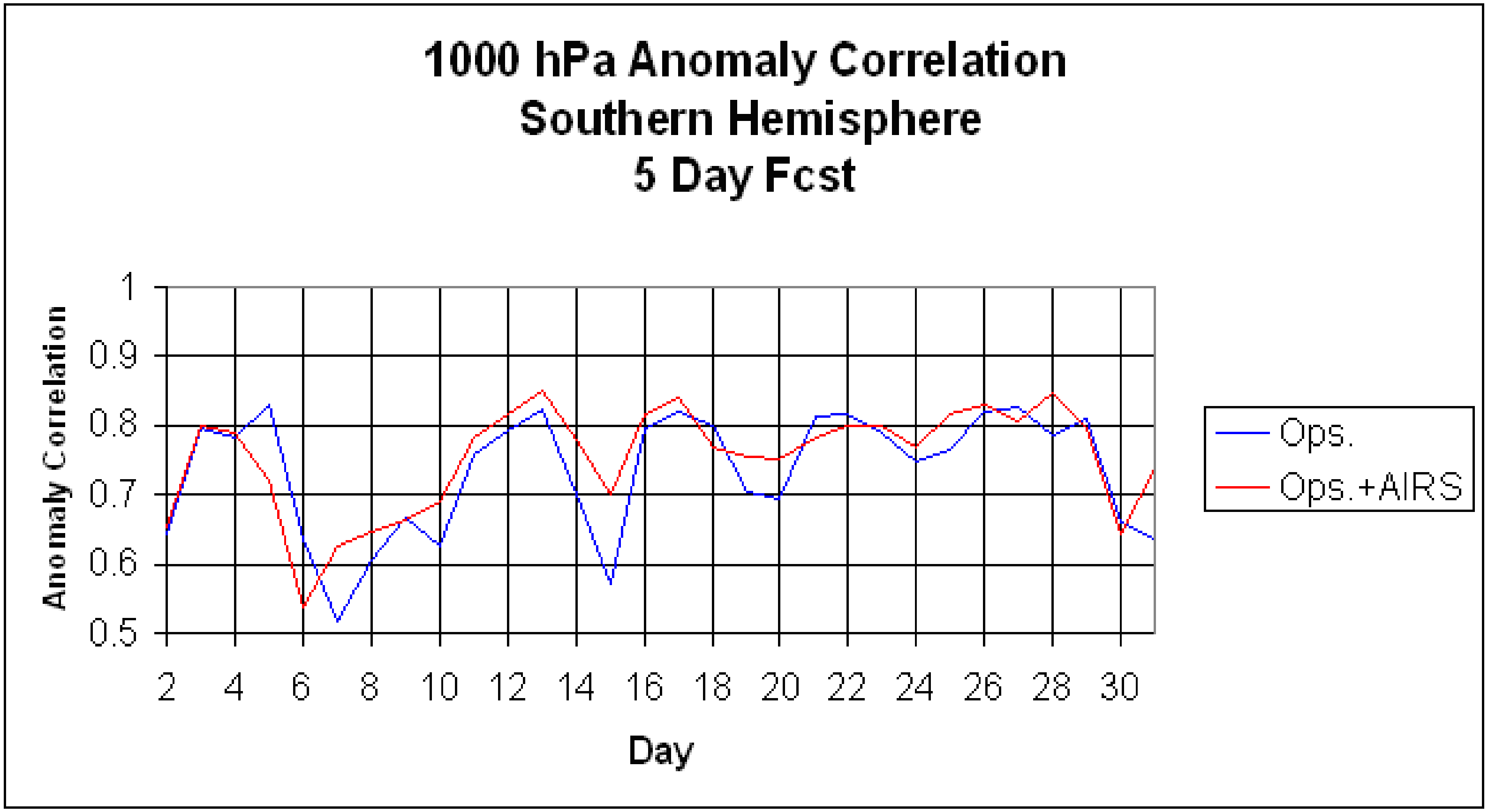


Figure1(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004

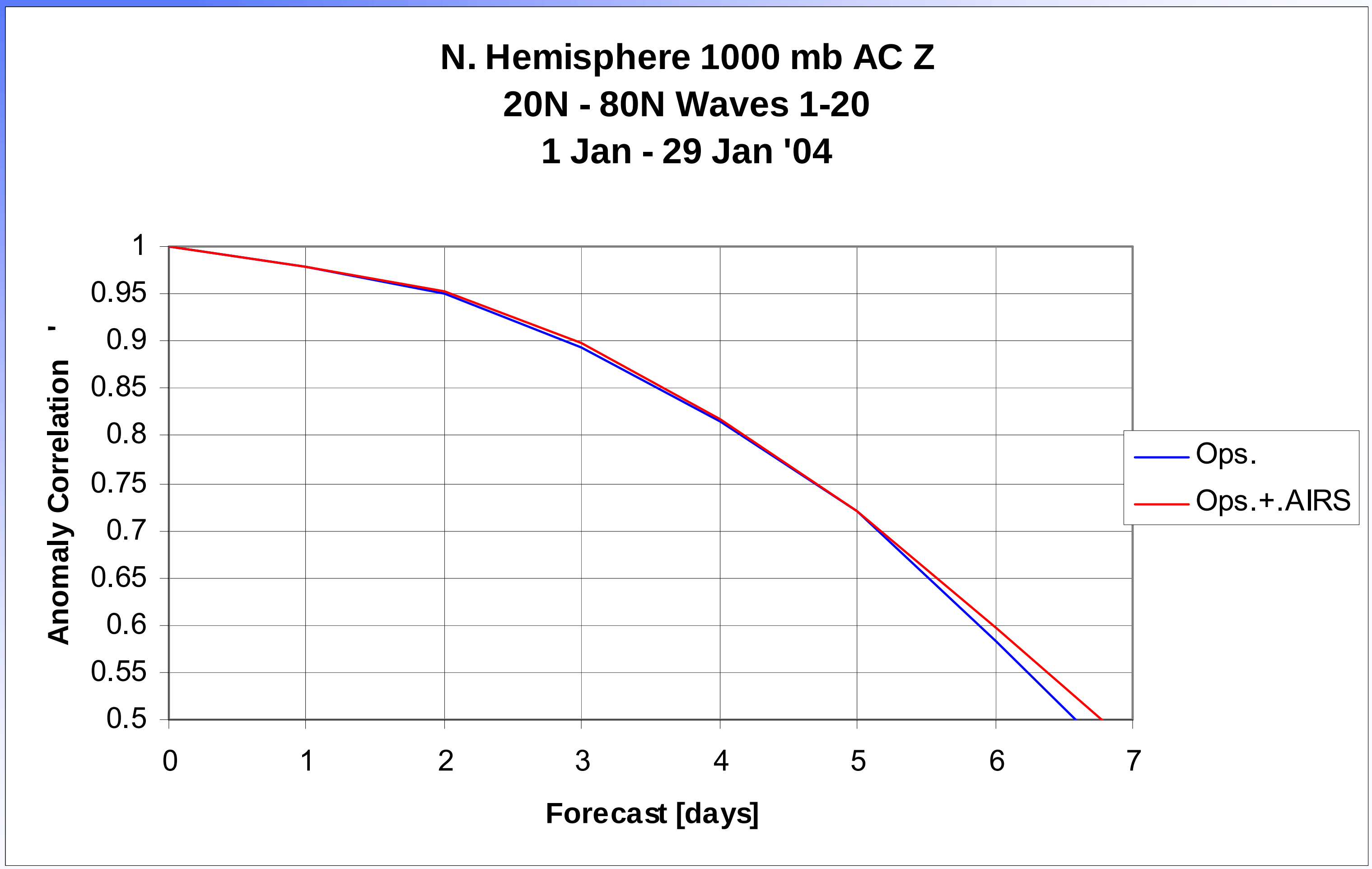


Figure1(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern Hemisphere, January 2004

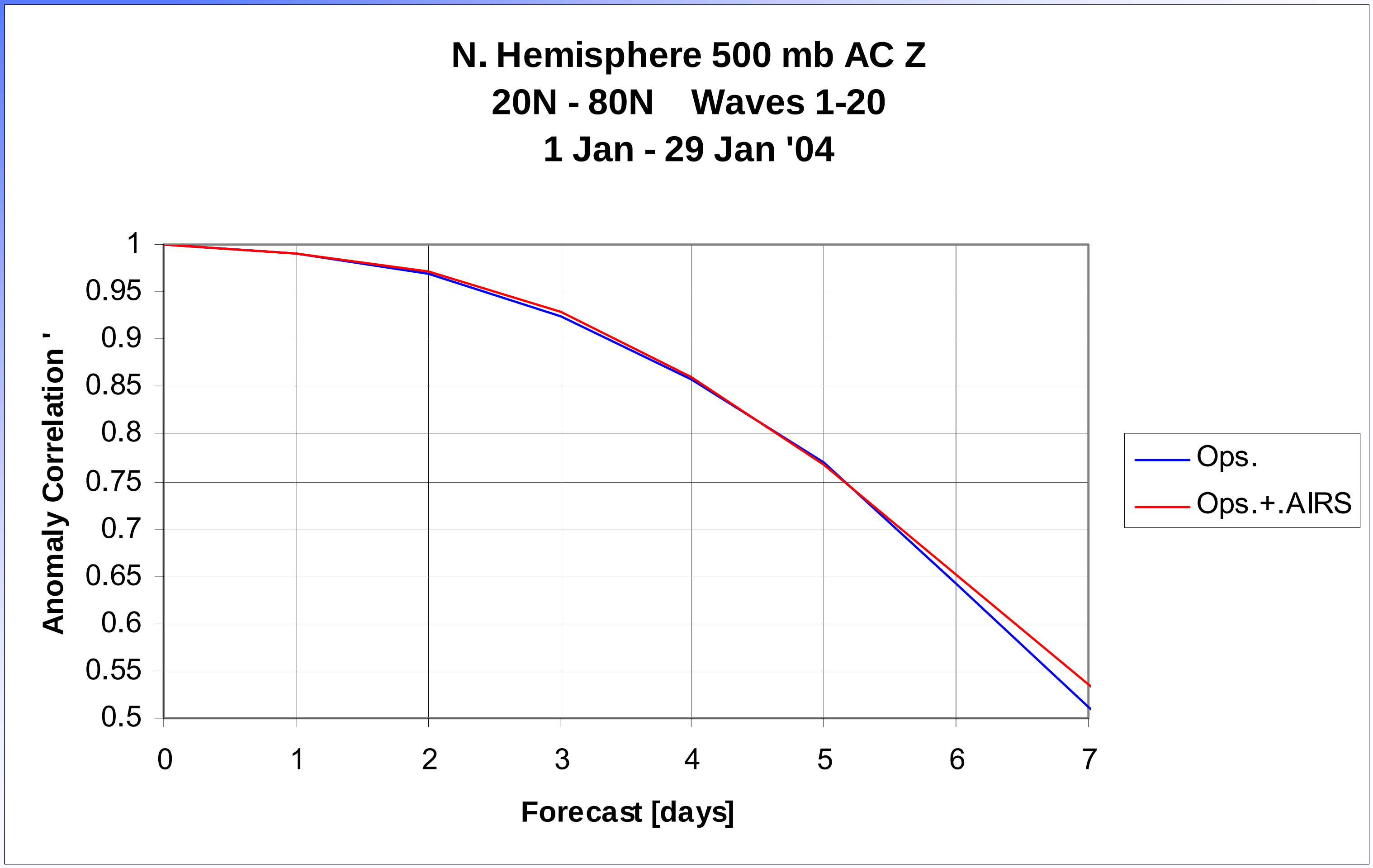
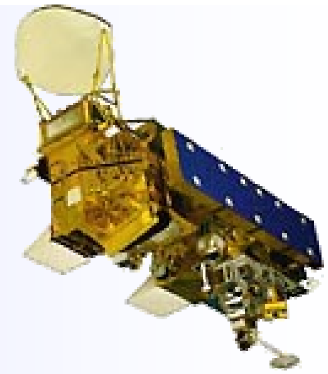


Figure1(a). 500hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern Hemisphere, January 2004



AIRS Data Assimilation

J. Le Marshall, J. Jung, J. Derber, R. Treadon,

S.J. Lord, M. Goldberg, W. Wolf and H-S Liu, J. Joiner,

P. van Delst, R. Atlas and J Woollen……

1 January 2004 – 31 January 2004

Used operational GFS system as Control

Used Operational GFS system Plus Enhanced AIRS Processing as Experimental System

Clear Positive Impact

AIRS Data Assimilation

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1 January 2004 – 27 January 2004

Used operational GFS system as Control

Used Operational GFS system Plus Enhanced AIRS Processing as Experimental System

The Trials – Assim 2

- Used `full AIRS data stream used (JPL)
  - NESDIS (ORA) generated BUFR files
  - All FOVs, 324(281) channels
  - 1 Jan – 27 Jan ’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 Trials – Assim 2

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

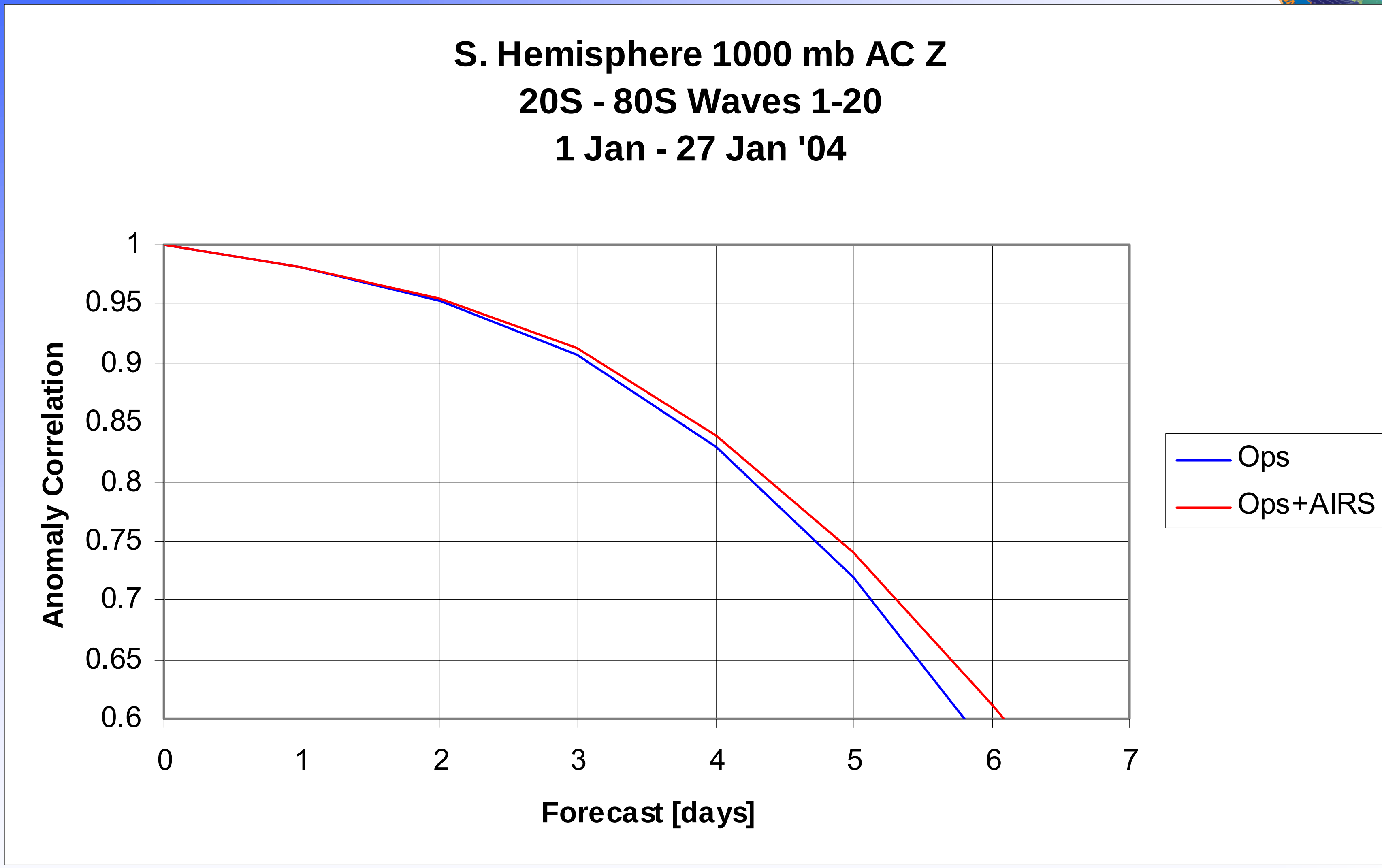


Figure1(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004

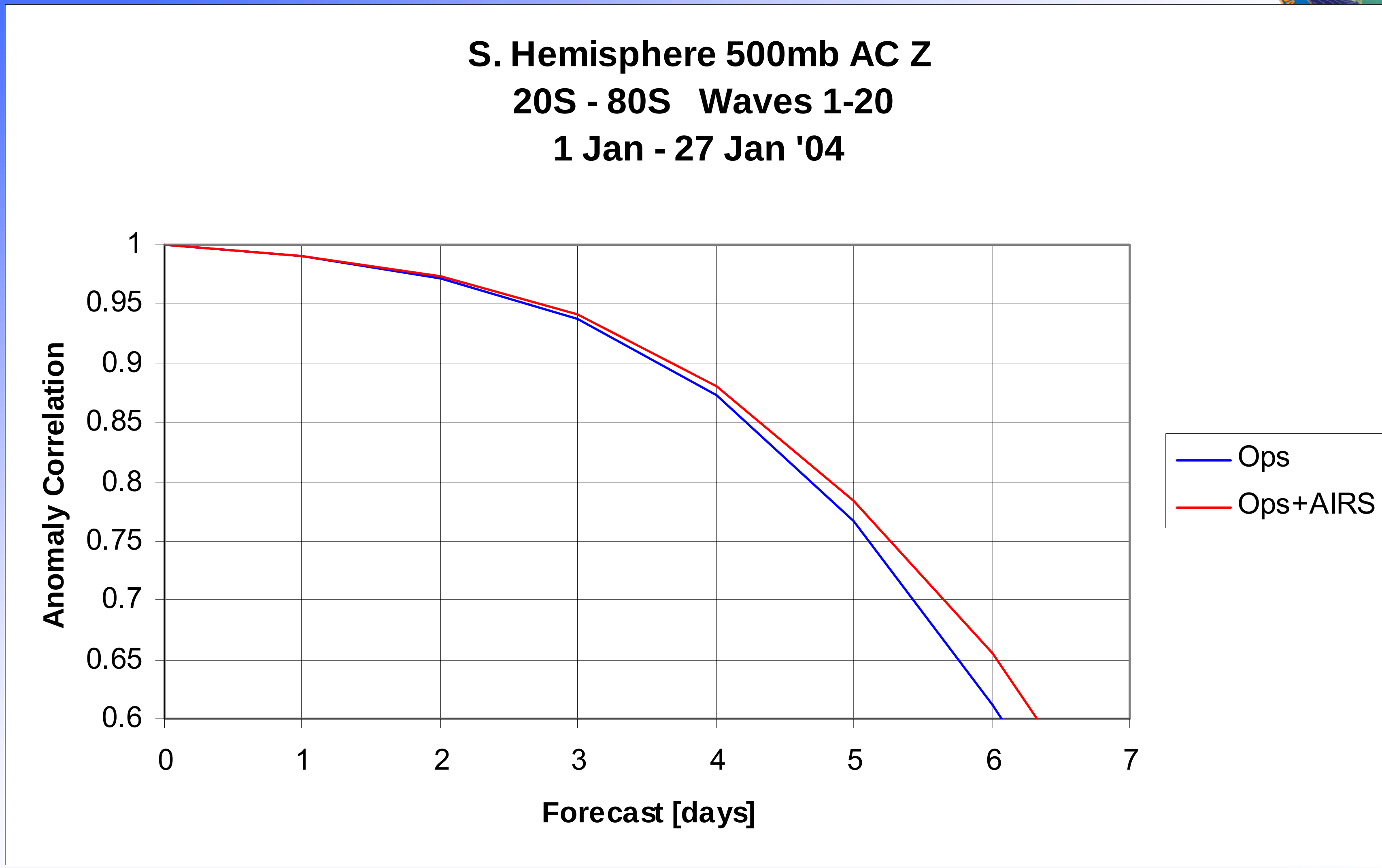


Figure 1(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004

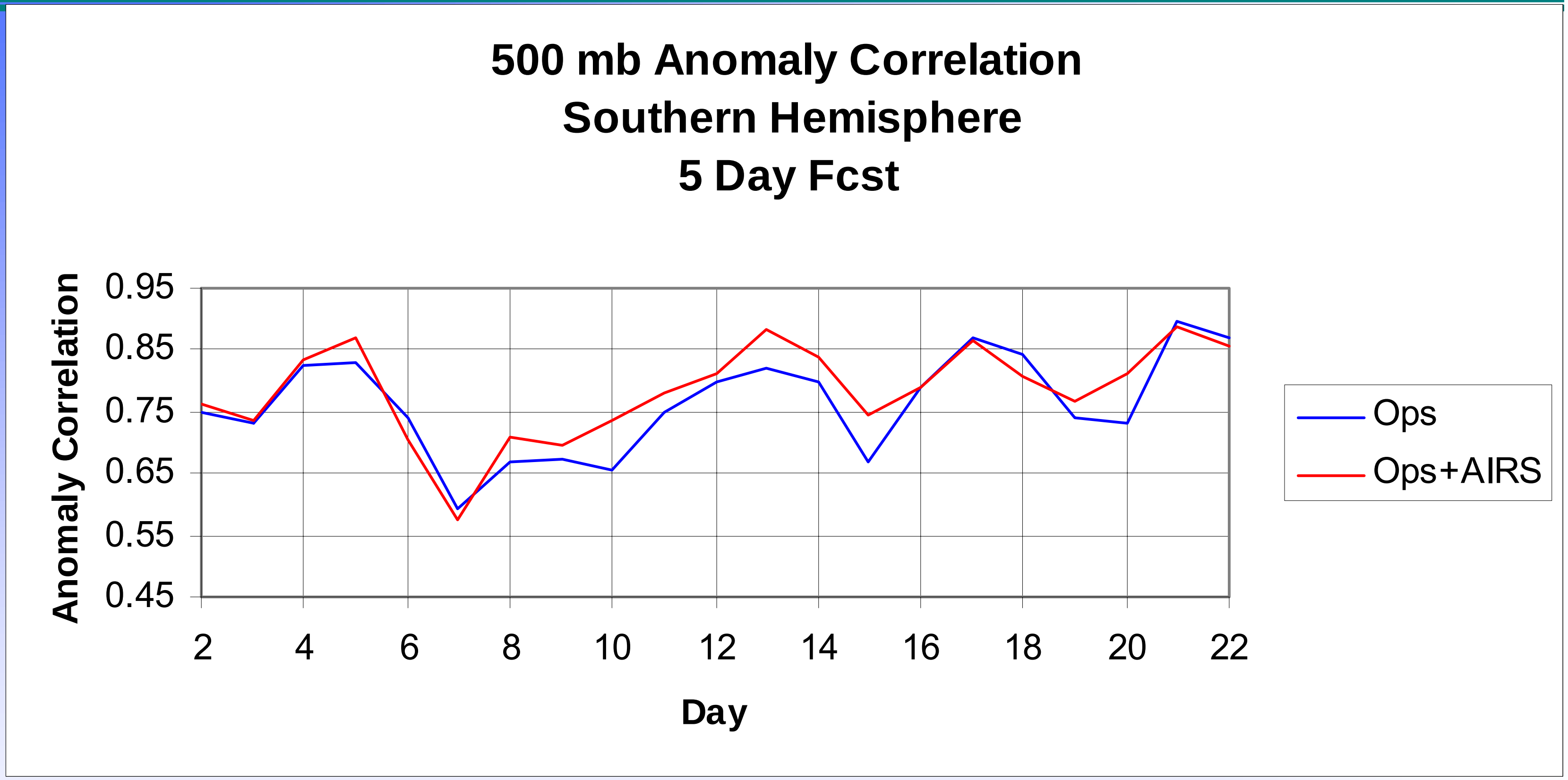


Figure 2. 500hPa Z Anomaly Correlations 5 Day Forecast for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, (1-27) January 2004

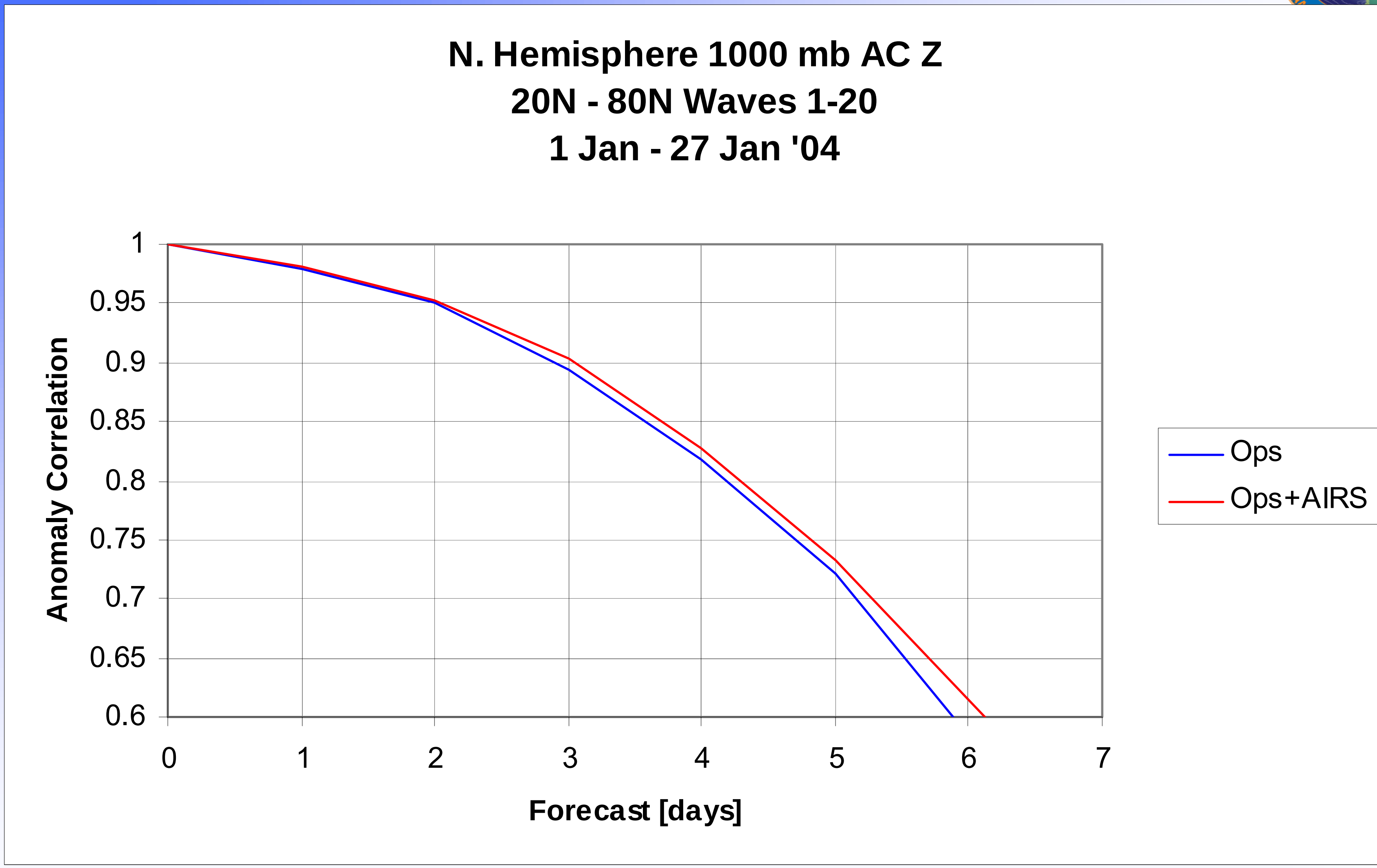


Figure3(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004

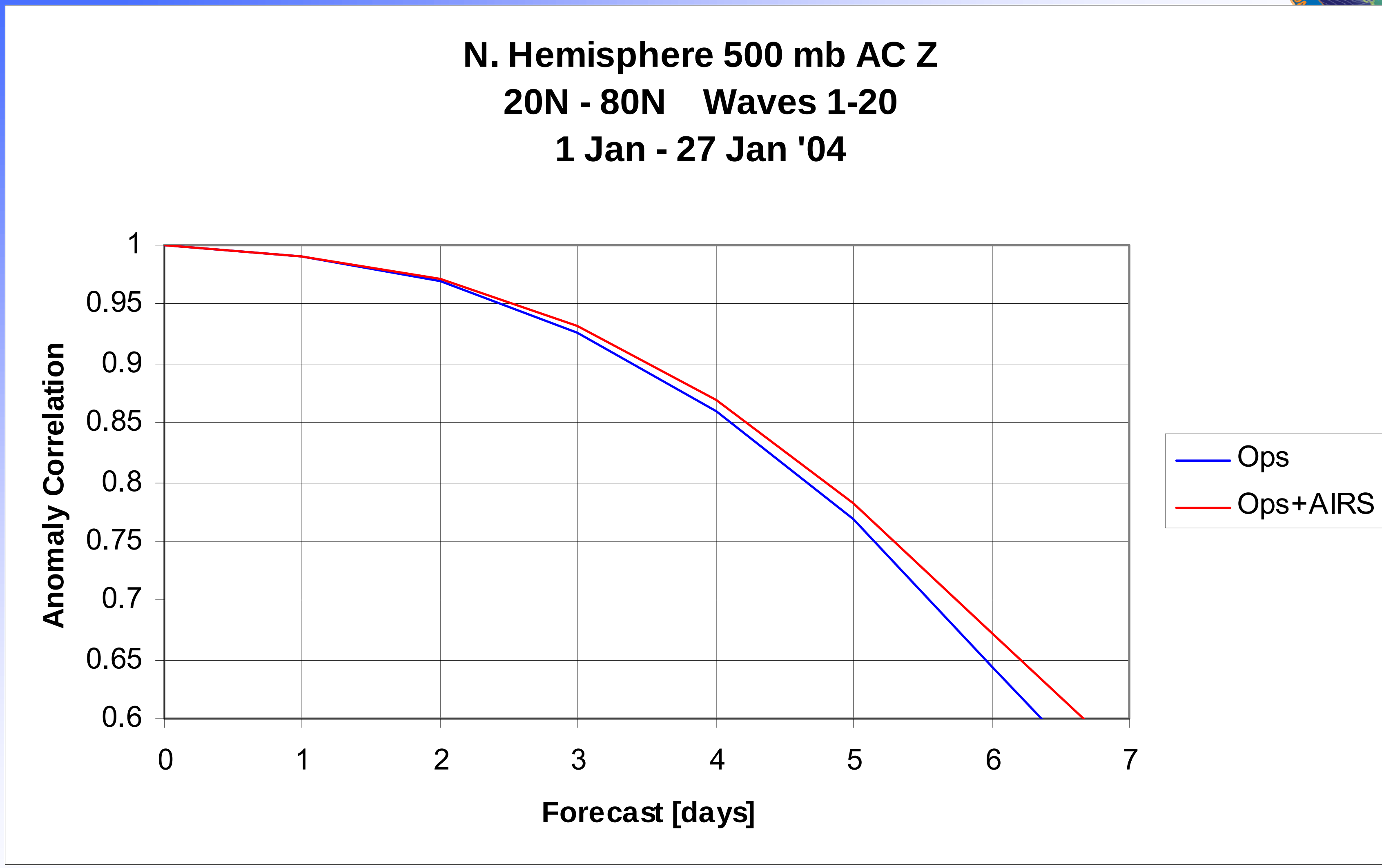
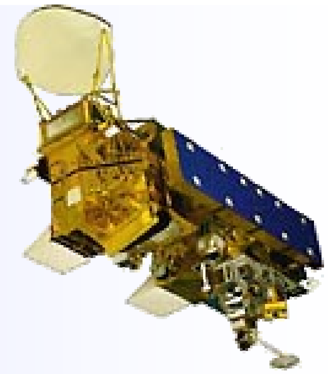


Figure 3(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004



AIRS Data Assimilation

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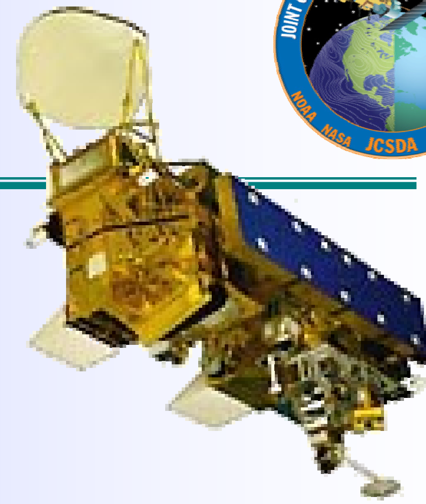
1 January 2004 – 27 January 2004

Used operational GFS system as Control

Used Operational GFS system Plus Enhanced AIRS Processing as Experimental System

Clear Positive Impact



AIRS Data Assimilation

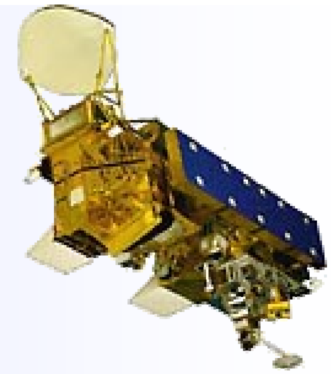
Supporting Studies:

1-13 January 2003

Used next generation GMAO GSI system as Control

Used next generation GMAO GSI system Plus AIRS as Experimental System

Positive Impact



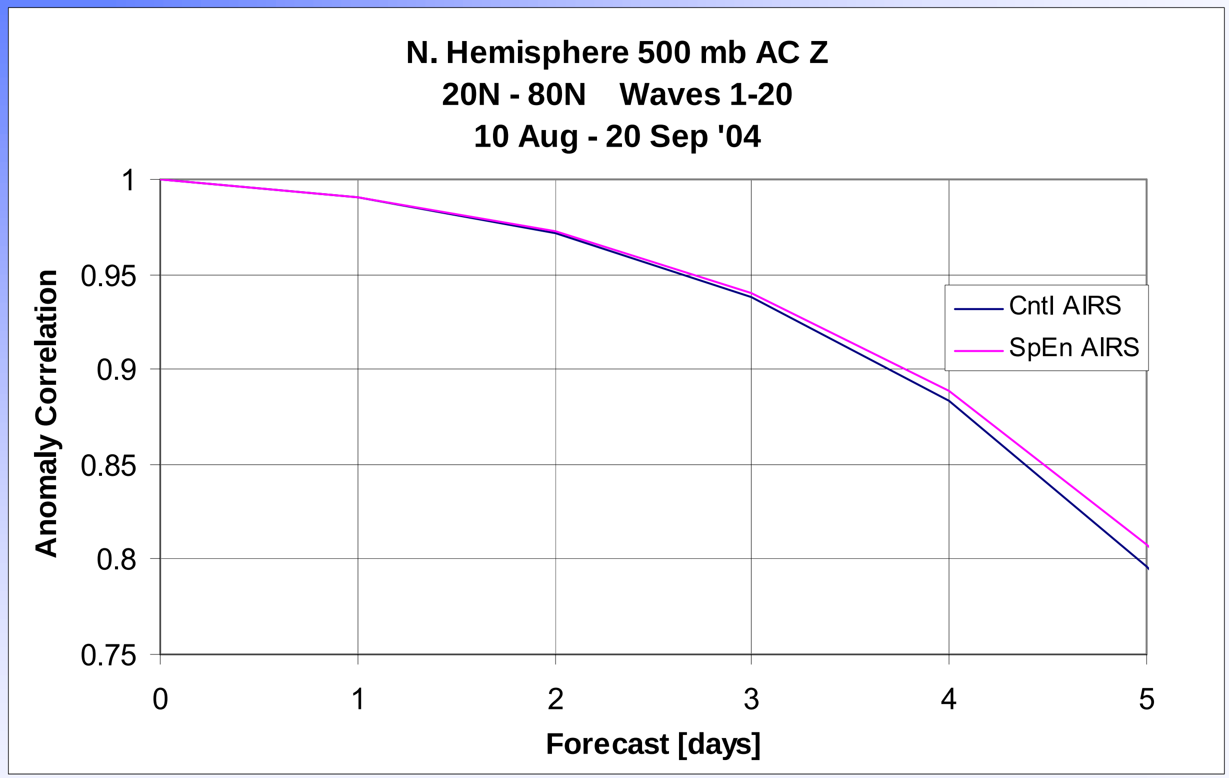
AIRS Data Assimilation

10 August – 20 September 2004

Used operational GFS system as plus AQUA AMSU plus Conv. AIRS as Control

Used operational GFS system as plus AQUA AMSU Plus Enhanced AIRS Sys. as Experimental System

Impact of AIRS spatial data density/QC (Snow, SSI/eo/nw)



AIRS Data Assimilation

-The Next Steps

Fast Radiative Transfer Modelling (OSS, Superfast RTM)

GFS Assimilation studies using:

full spatial resolution AIRS data,MODIS, cld info. & Є

full spatial resolution AIRS data with recon. radiances

full spatial res. AIRS with cld. cleared radiances (ć AMSU/MODIS/MFG use)

full spatial and spectral res. AIRS data

full spatial and spectral res. raw cloudy AIRS (ć MODIS/AMSU) data

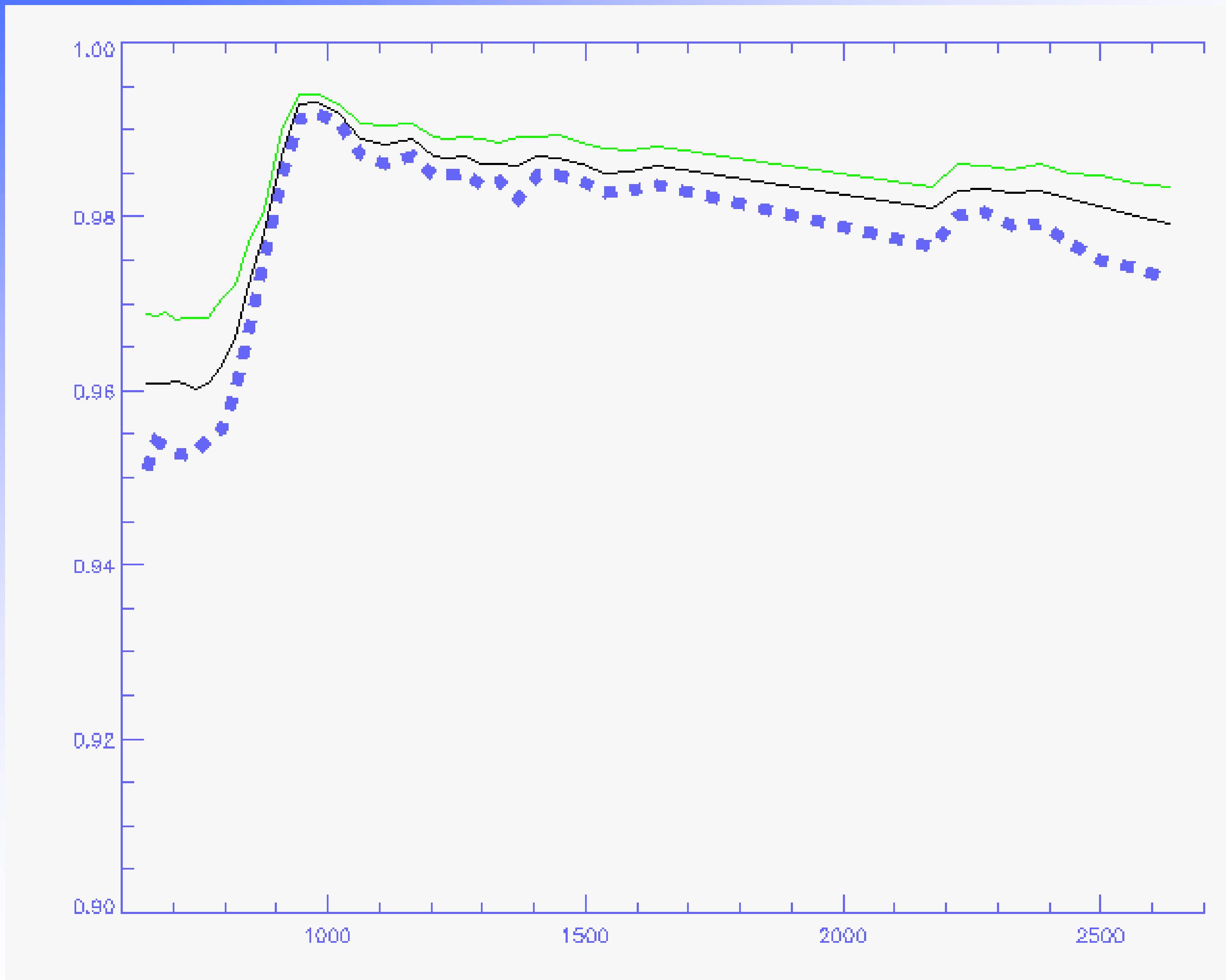
(full cloudy inversion with cloud parameters etc.)

Surface Emissivity Techniques

- *Regression (NESDIS)*
- *Minimum Variance (CIMSS)*
- *Eigenvector (Hampton Univ.)*

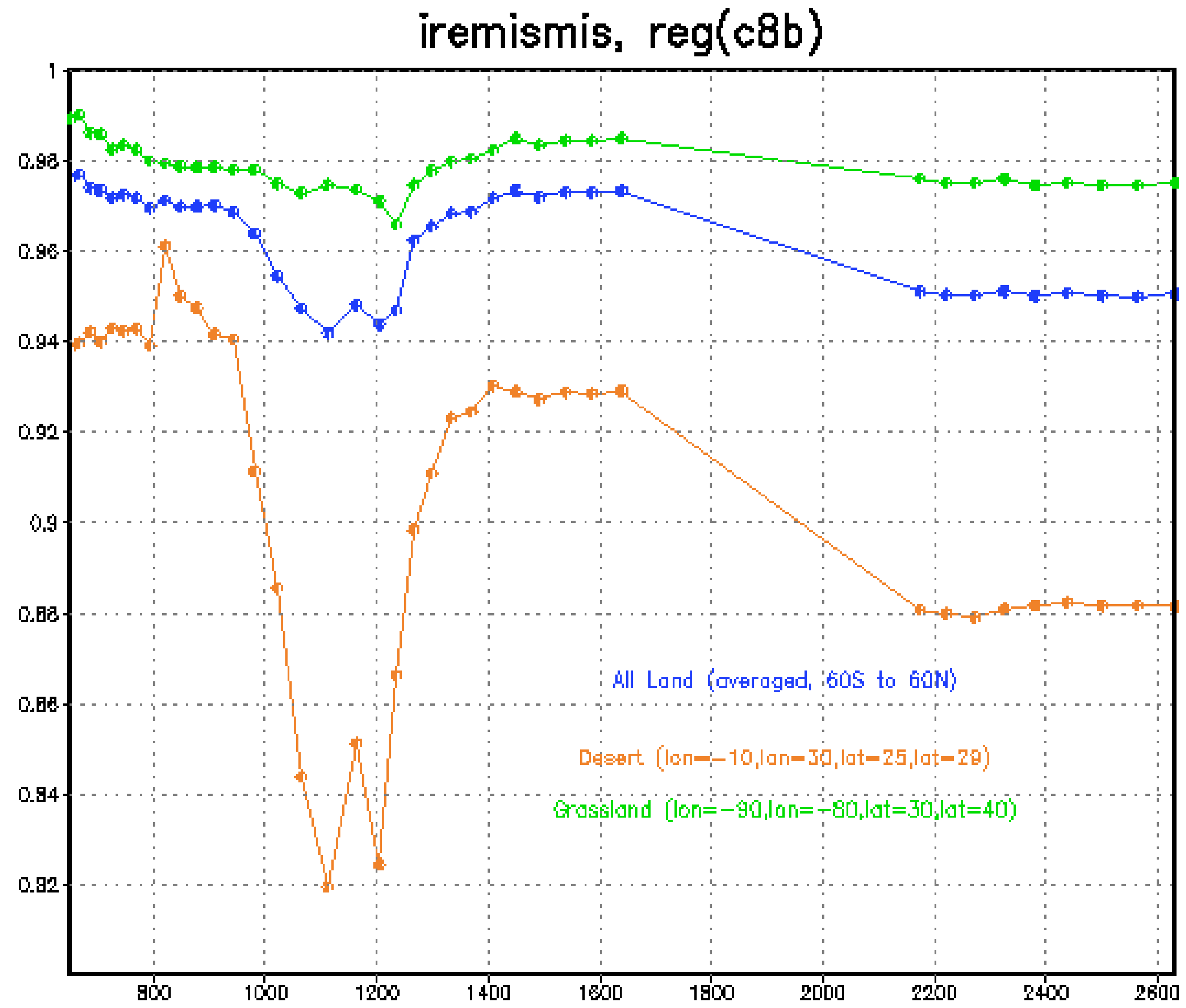
IR HYPERSPECTRAL EMISSIVITY - ICE and SNOW

Sample Max/Min Mean computed from synthetic radiance sample



IR HYPERSPECTRAL EMISSIVITY - LAND

Computed from synthetic radiance sample



Prologue

- JCSDA is well positioned to exploit the AIRS and future Advanced Sounders in terms of
- Assimilation science
- Modeling science.
- Computing power

Generally next decade of the meteorological satellite program promises to be every bit as exciting as the first, given the opportunities provided by new instruments such as AIRS, IASI, GIFTS and CrIS, modern data assimilation techniques, improving environmental modeling capacity and burgeoning computer power.

The Joint Center will play a key role in enabling the use of these satellite data from both current and future advanced systems for environmental modeling.

Summary/Conclusions

Results using AIRS hyperspectral data, within stringent current operational constraints, show significant positive impact.

Given the many opportunities for future enhancement of the assimilation system, the results indicate a considerable opportunity to improve current analysis and forecast systems through the application of hyperspectral data.

It is anticipated current results will be further enhanced through improved physical modeling, a less constrained operational environment allowing use of higher spectral and spatial resolution and cloudy data.

Summary/Conclusions

Effective exploitation of the new IR hyperspectral data about to become available from the Infrared Atmospheric Sounding Interferometer (IASI), Cross-track Infrared Sounder (CrIS), and Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) instruments will further enhance analysis and forecast improvement.

JOINT CENTER FOR SATELLITE DATA ASSIMILATION

NOAA NASA JCSDA Navy Air Force