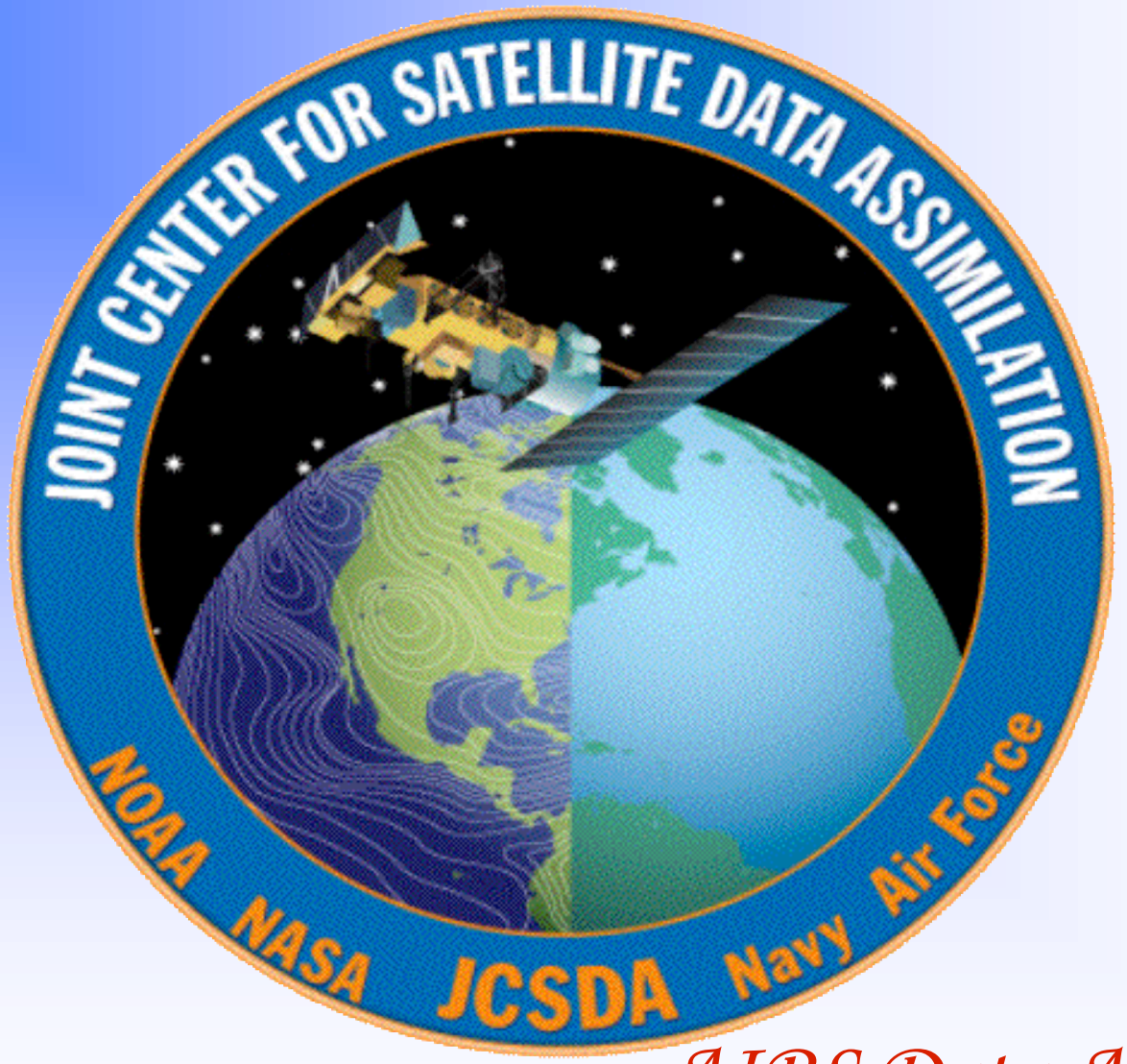
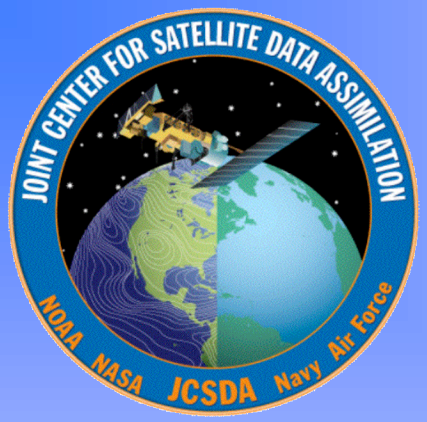


AIRS Data Assimilation

- Status and Future -



Overview

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

The Joint Center for Satellite Data Assimilation

John Le Marshall
Director, JCSDA

Deputy Directors:
Stephen Lord – NWS /NCEP
Jim Yoe - NESDIS
Lars Peter Riishogjaard – GSFC, GMAO
Pat Phoebus – DoD,NRL

November, 2004

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

Goals – Longer Term

- Provide the "bridge" for the integrated use of GEOSS data within numerical models
- Develop the tools for effective integration of GEOSS observations into environmental models

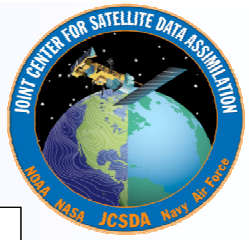
- Expand assimilation system to provide input to models of:
  - environmental hazards
  - air and water quality and resources
  - terrestrial, coastal, and marine ecosystems
  - climate variability and change
  - agricultural productivity
  - energy resources
  - human health
  - biodiversity

Short Term Priorities

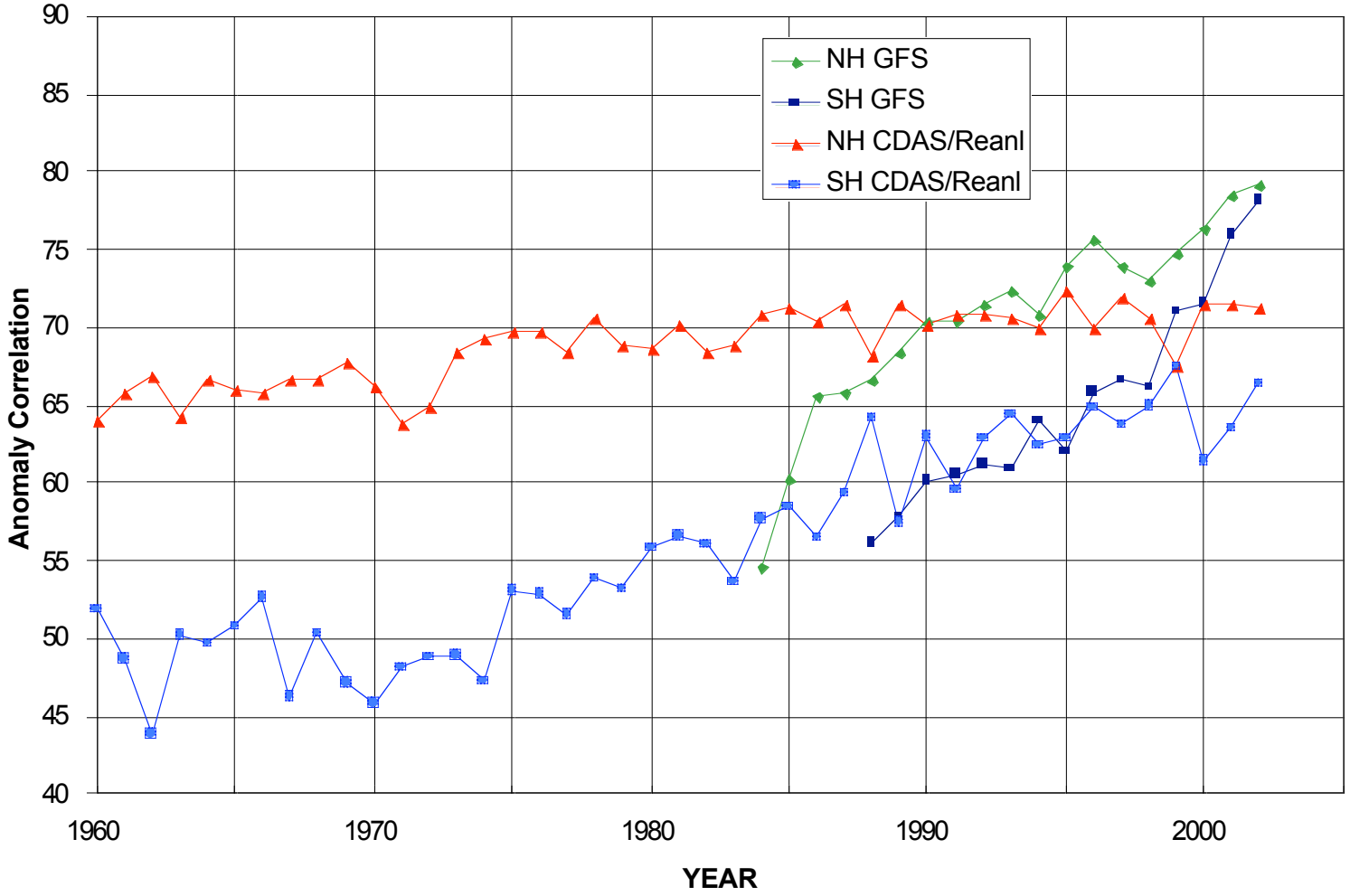
- **SSMIS:** Collaborate with the SSMIS CALVAL Team to jointly help assess SSMIS data. Accelerate assimilation into operational model as appropriate

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

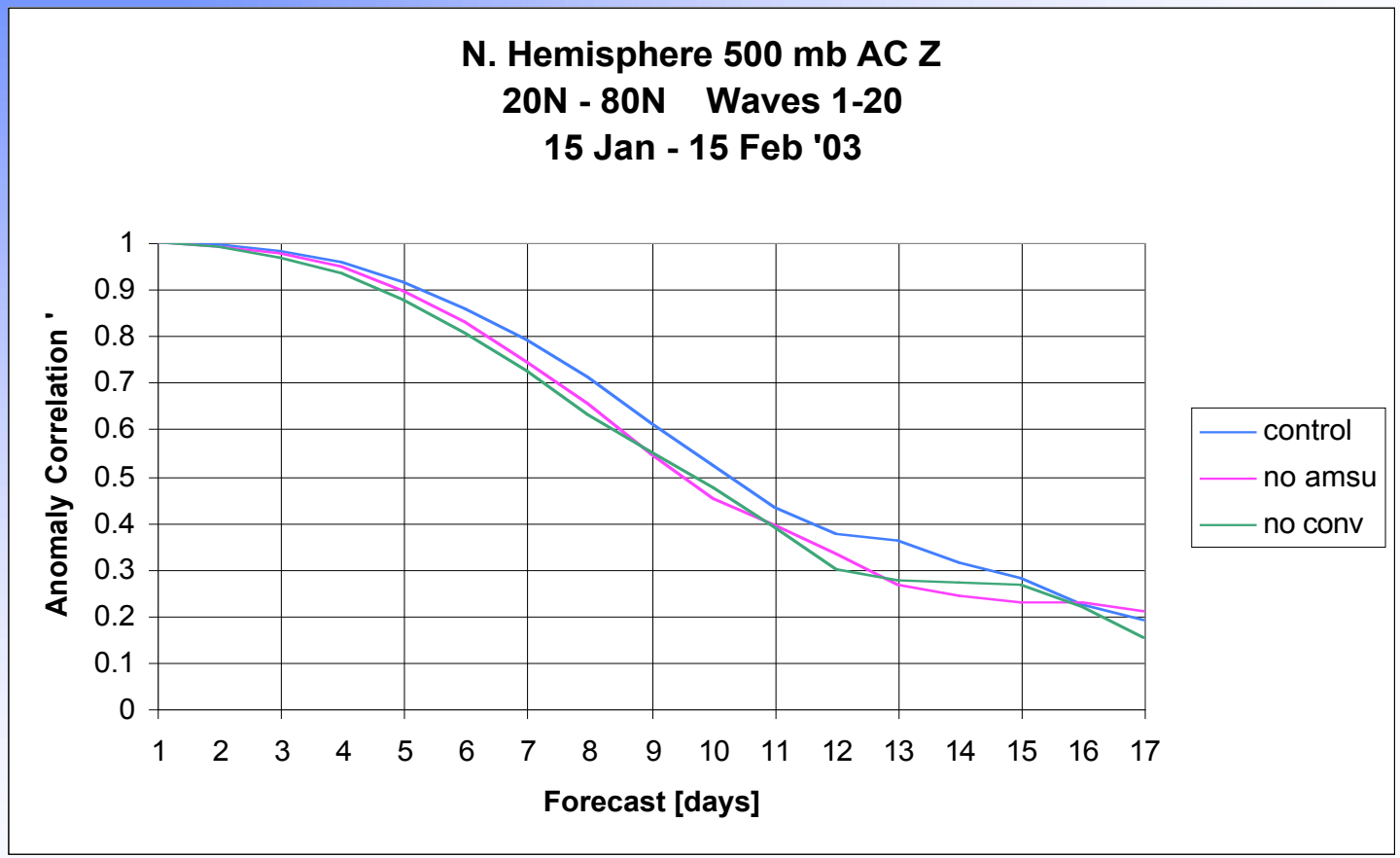
- **AIRS:** Improved utilization of AIRS
  - Improve information content of assimilated data. Improve spatial coverage, spectral content of assimilated data.
  - Improve QC using other satellite data (e.g. MODIS, AMSU)
  - Investigate using cloudy scene radiances and cloud clearing options
  - Reduce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



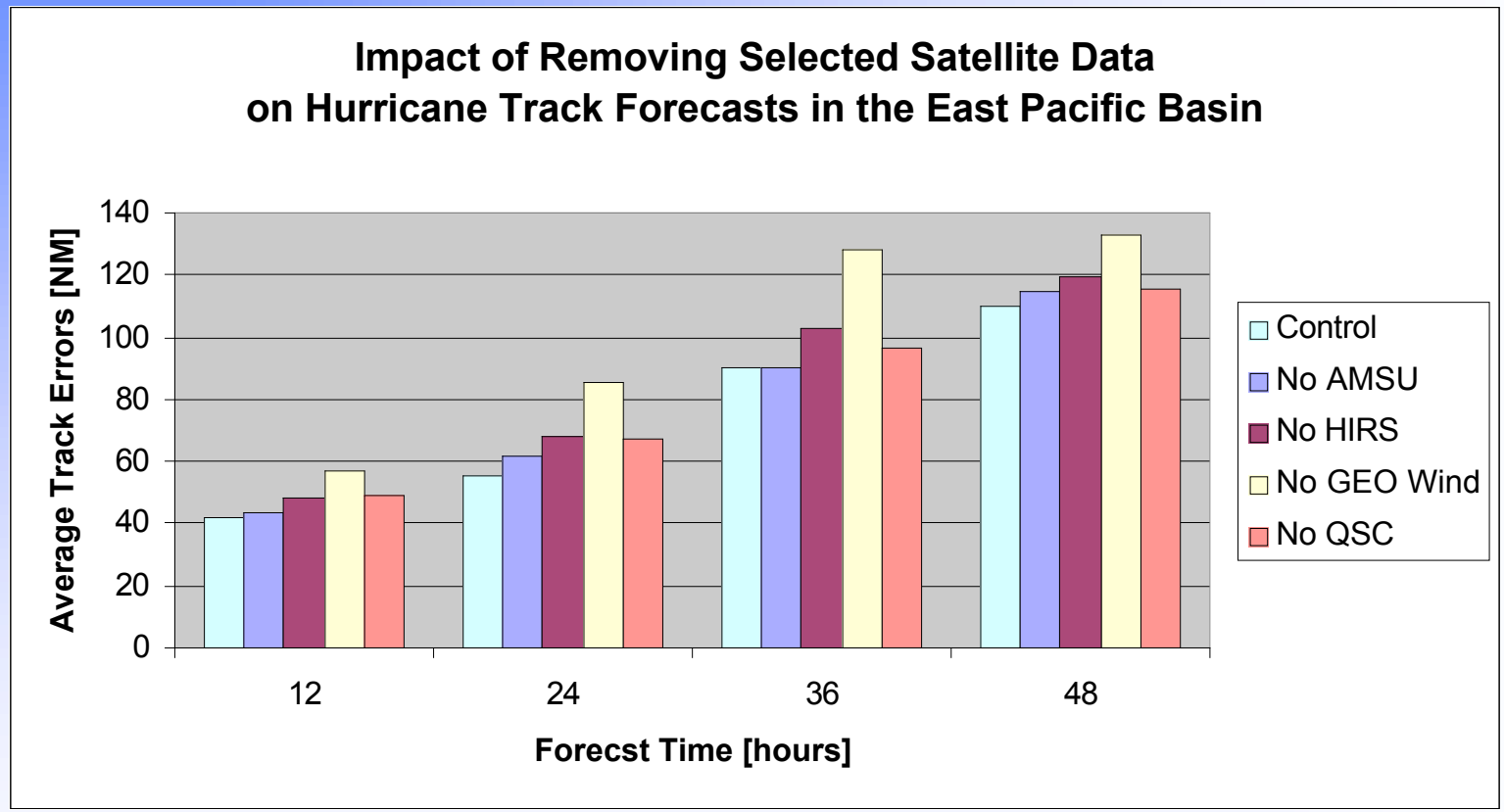
CDAS/Reanl vs GFS
NH/SH 500Hpa day 5
Anomaly Correlation (20-80 N/S)



Data Assimilation Impacts in the NCEP GDAS

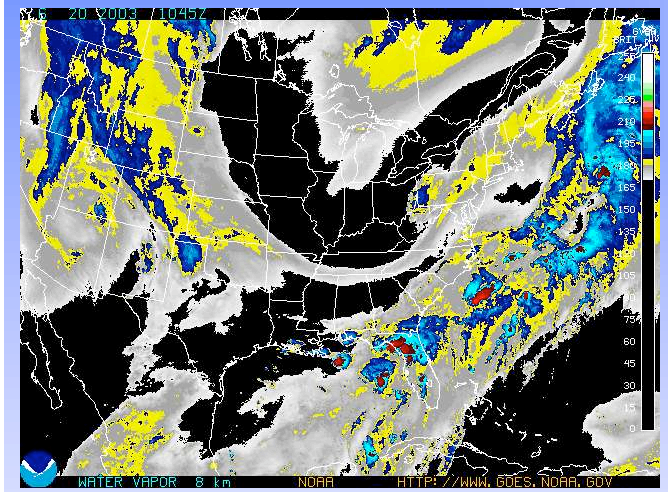


AMSU and "All Conventional" data provide nearly the same amount of improvement to the Northern Hemisphere.

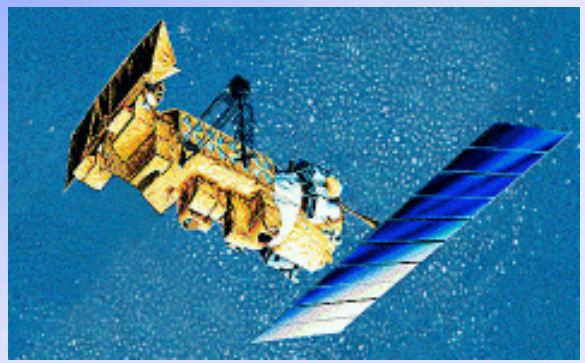

Impact of Removing Selected Satellite Data
on Hurricane Track Forecasts in the East Pacific Basin
Average Track Errors [NM]
140
120
100
80
60
40
20
0
12
24
36
48
Forecst Time [hours]
Control
No AMSU
No HIRS
No GEO Wind
No QSC

Satellite Data Received at NCEP

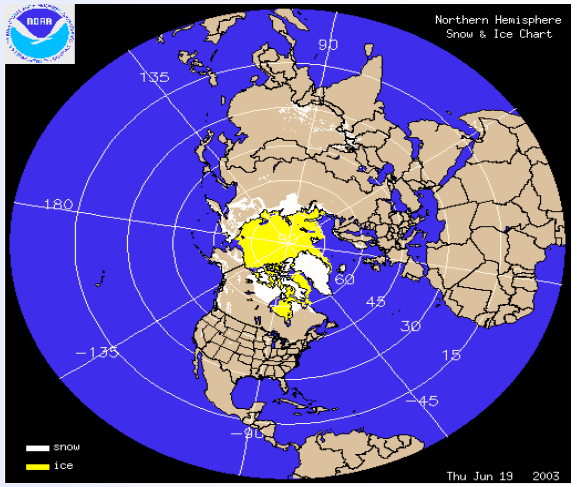
GOES imagery & products



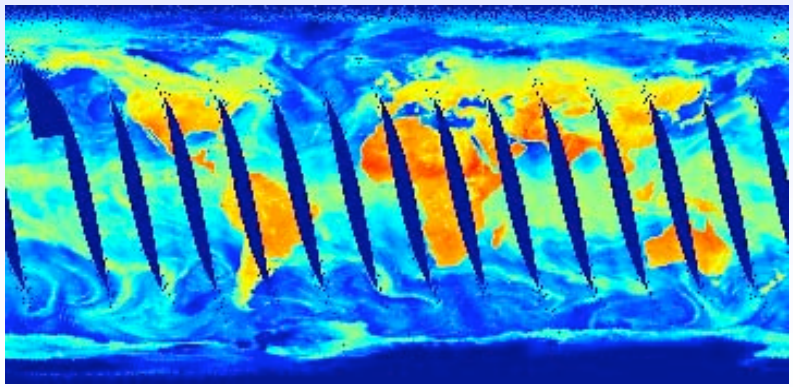
POES radiances

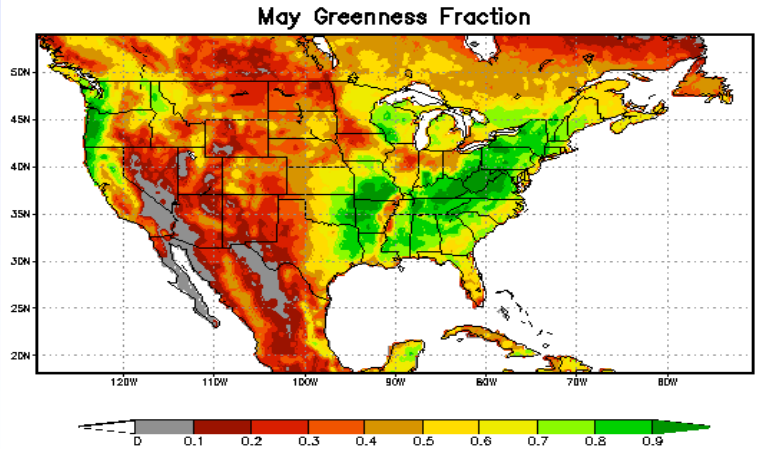


Snow & Ice Products



AIRS radiances

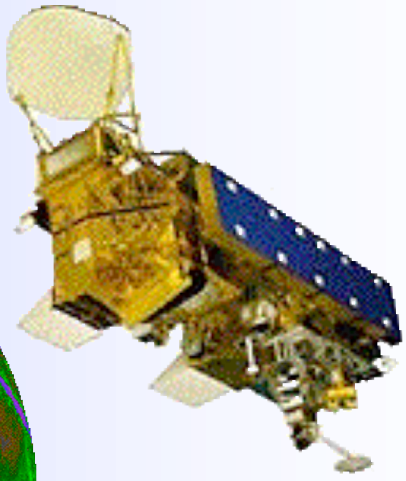




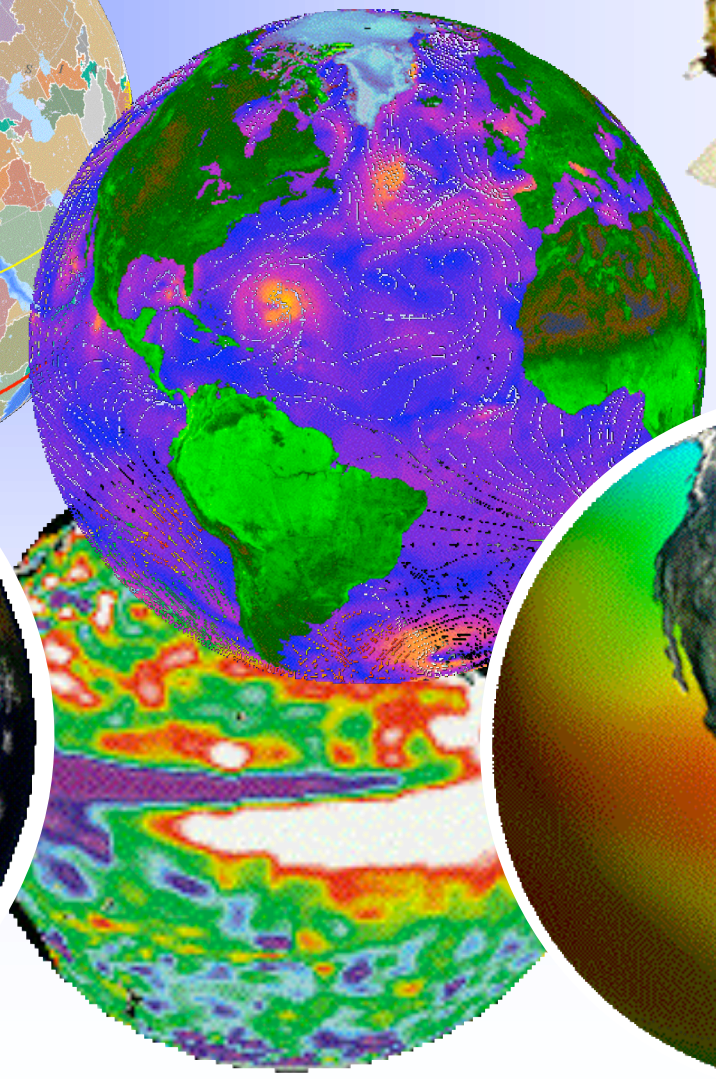
Satellite Data used in NWP

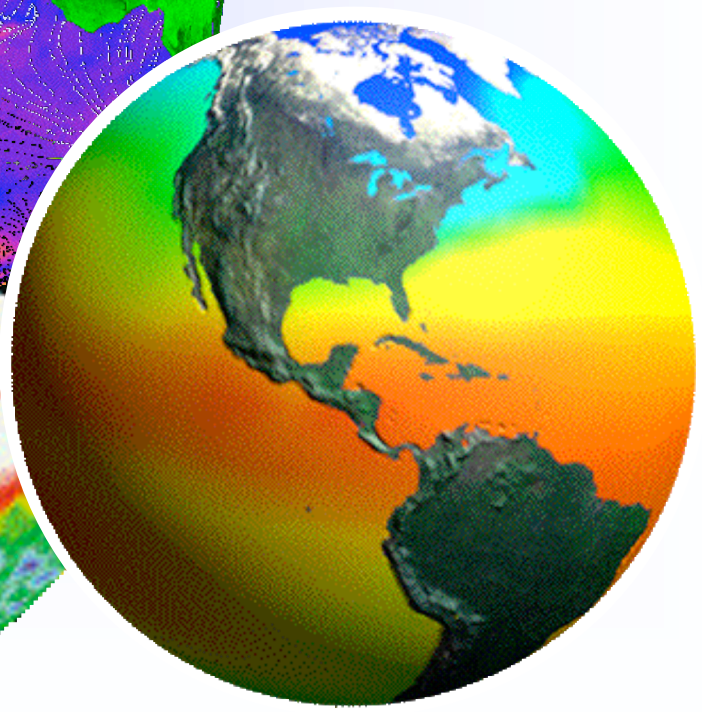
- HIRS sounder radiances
- AMSU-A sounder radiances
- AMSU-B sounder radiances
- GOES sounder radiances
- GOES, Meteosat, GMS winds
- GOES precipitation rate
- SSM/I ocean surface wind speeds
- SSM/I precipitation rates
- ERS-2 ocean surface wind vectors
- Quikscat ocean surface wind vectors
- AVHRR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

AIRS/AQUA/Global Measurements



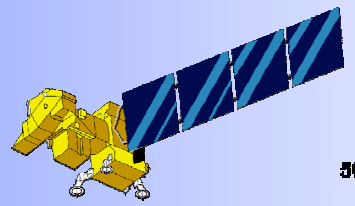
Aqua

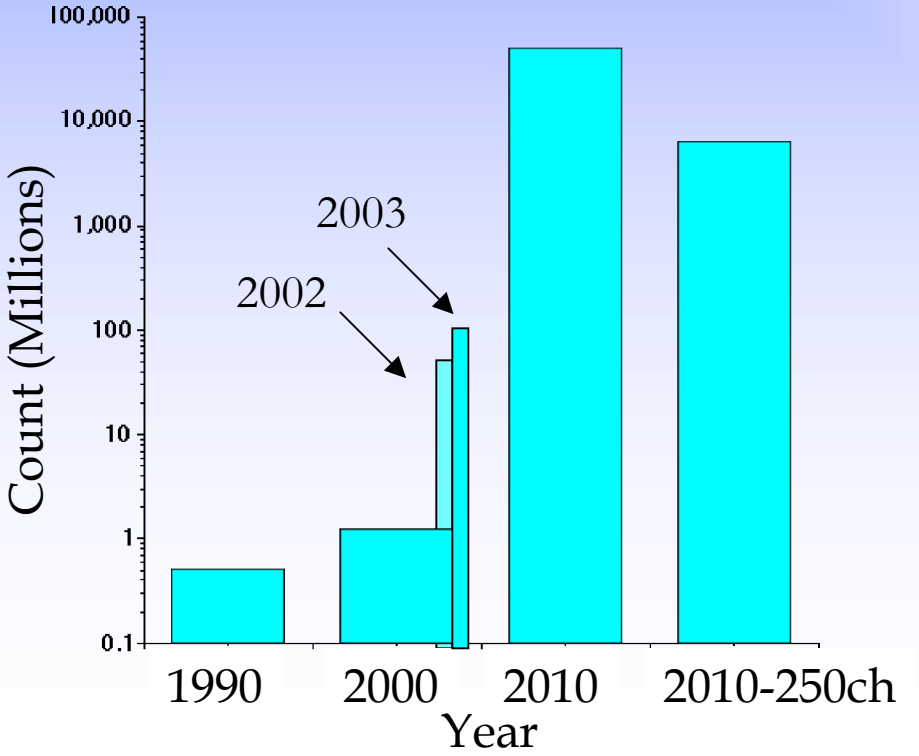




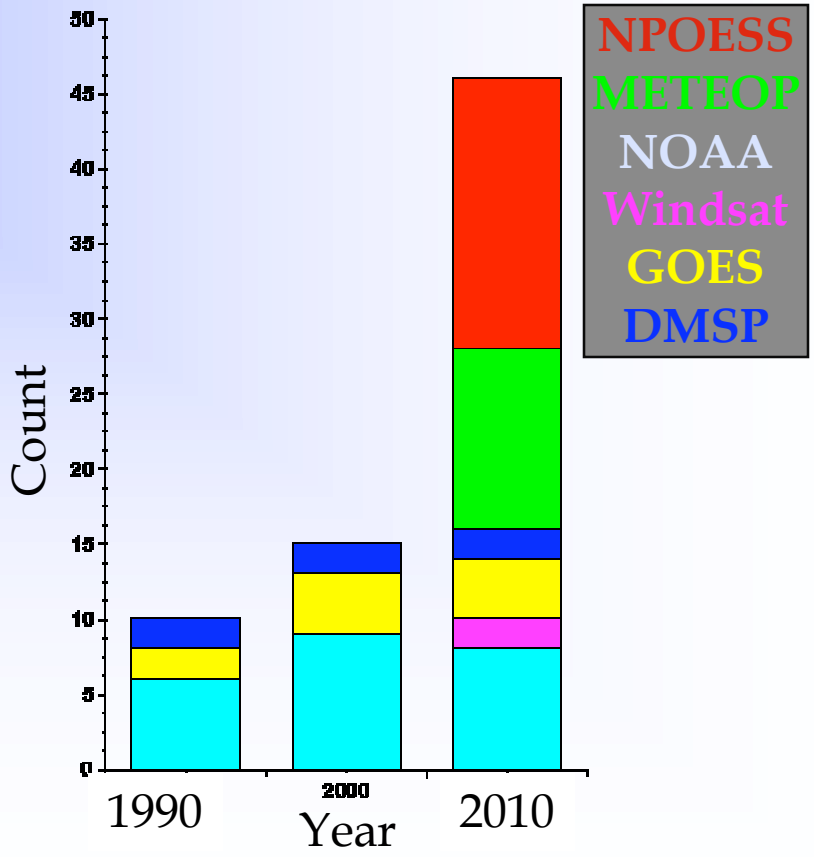
5-Order Magnitude Increase in Satellite Data Over 10 Years

Daily Upper Air Observation Count

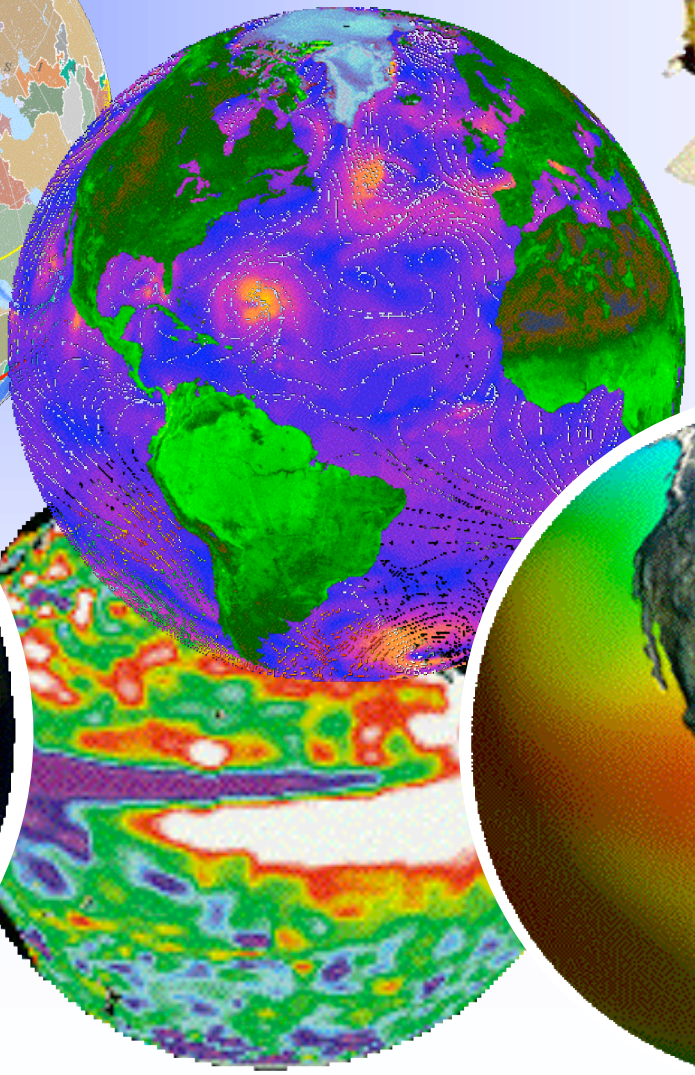


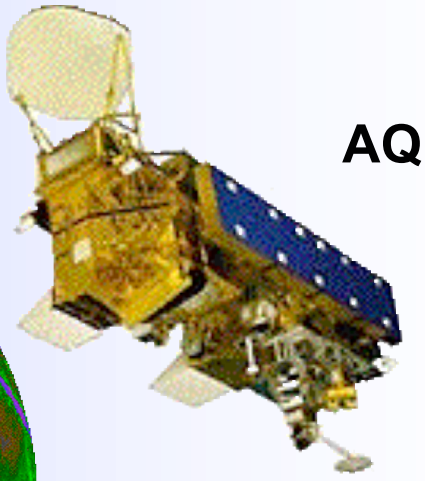


Satellite Instruments by Platform

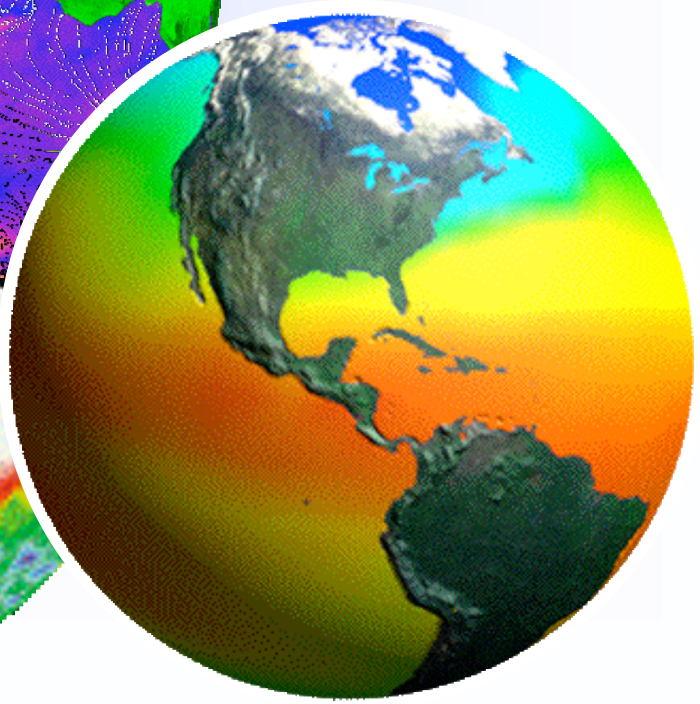


AIRS/AQUA/ Earlier Studies





AQUA

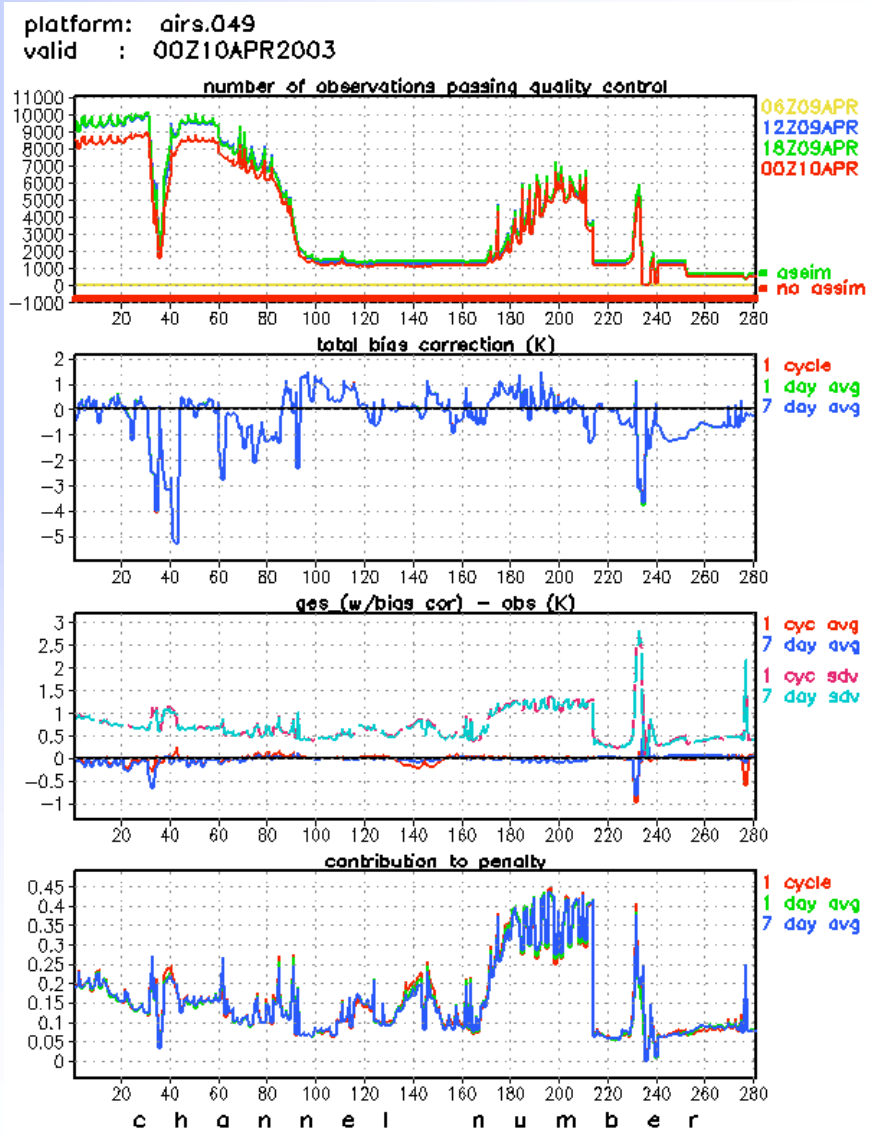


AIRs Targeting Study

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

Project Status at NCEP

- Operational processing
  - ingest: 12 UTC, 16 September 2003
  - dump: 12 UTC, 13 April 2004

- Global analysis code (SSI)
  - more accurate & efficient OPTRAN
  - modify quality control for cloudy IR radiances
  - more flexible horizontal thinning and weighting*
    (* not yet in operational SSI)

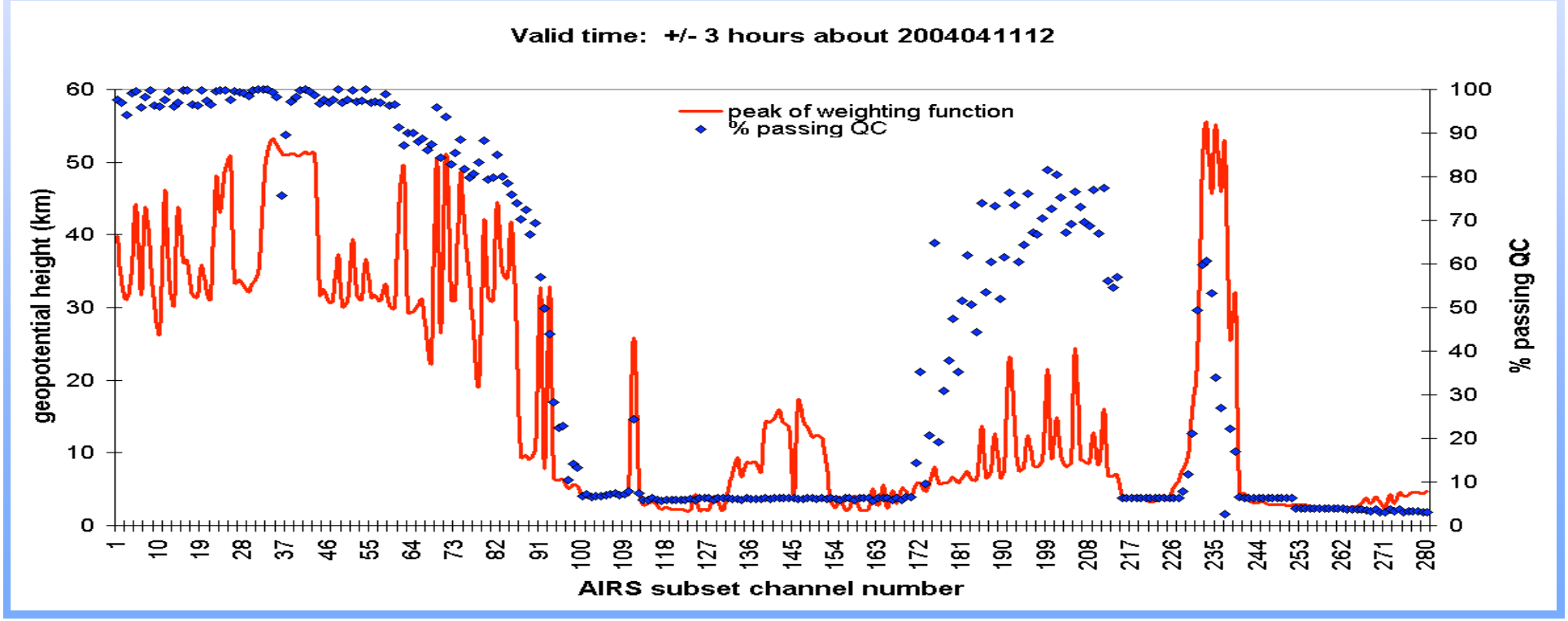
Project Status at NCEP

- Non-operational monitoring/assimilation
  - near real-time monitoring via global parallel (wwwt.emc.ncep.noaa.gov/gmb/gdas/radiance/prx)
  - impact studies ongoing
    - AQUA AMSU: neutral forecast/analysis impact
- Operational monitoring/assimilation
  - increase SSI wall clock time
    - 5 minutes longer for AQUA monitoring
    - 8 minutes longer for AQUA assimilation
  - implementation to follow NCEP CCS upgrade

(CCS = *C*entral *C*omputer *S*ystem)

SSI modifications

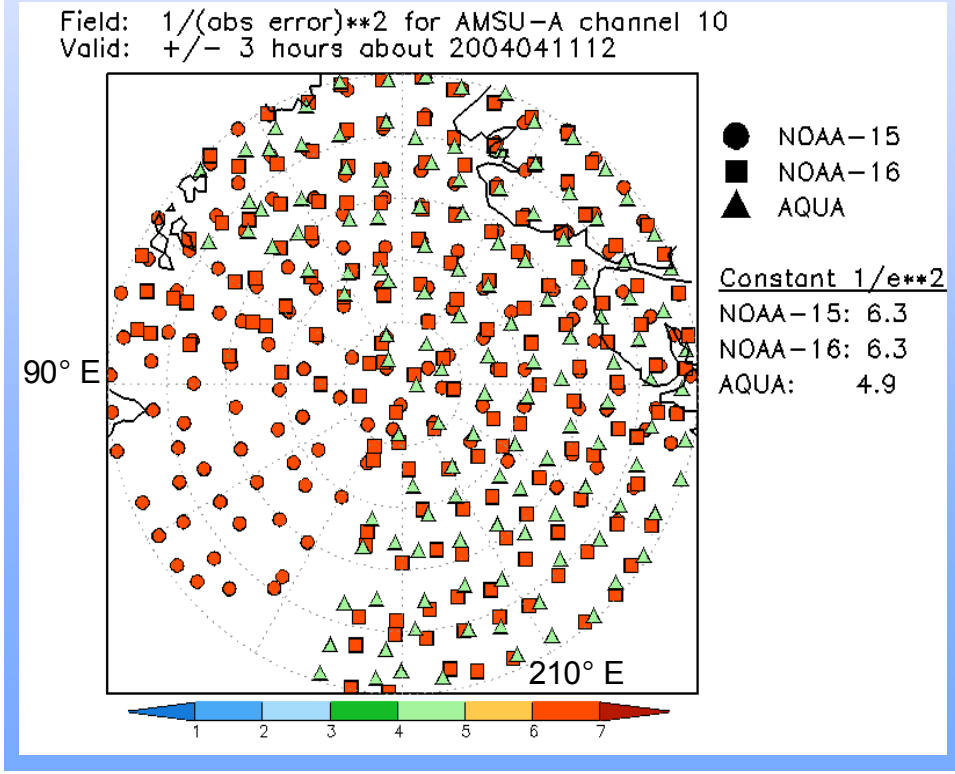
- conservative detection of IR cloudy radiances
  - examine sensitivity, δT_b, of simulated T_b to presence of cloud and skin temperature
  - those channels for which δT_b exceeds an empirical threshold are not assimilated



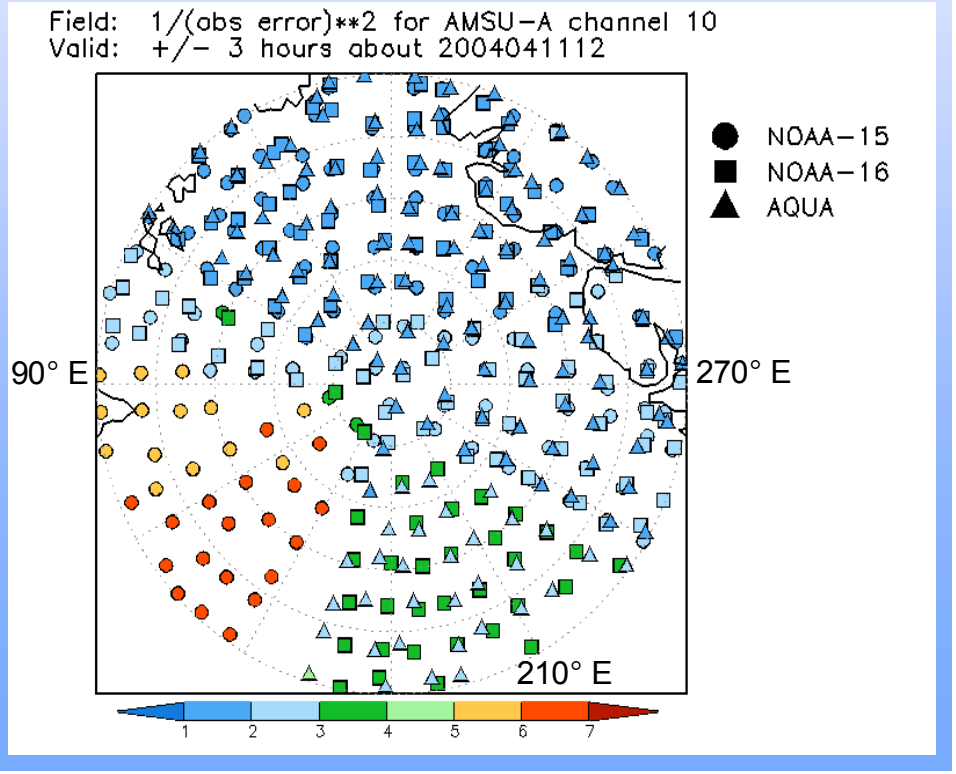
SSI modifications

- 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

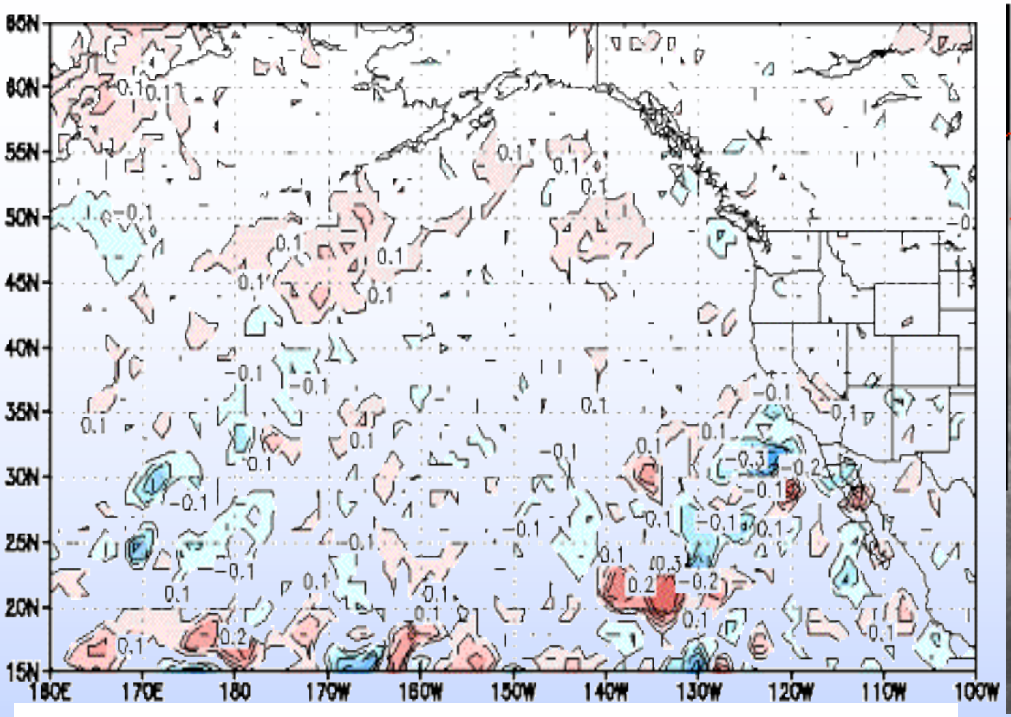


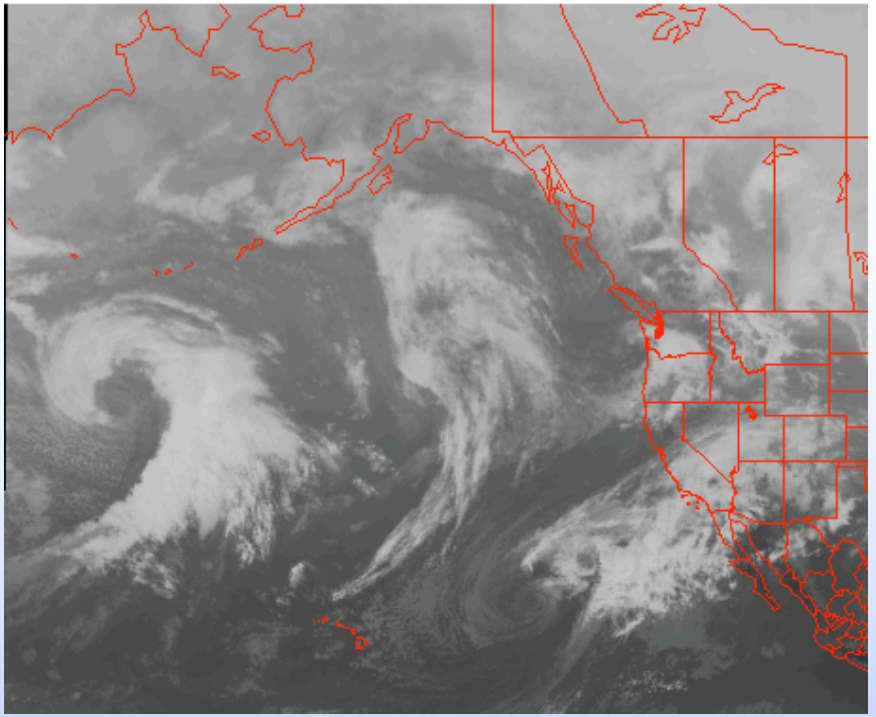
New thinning/weighting

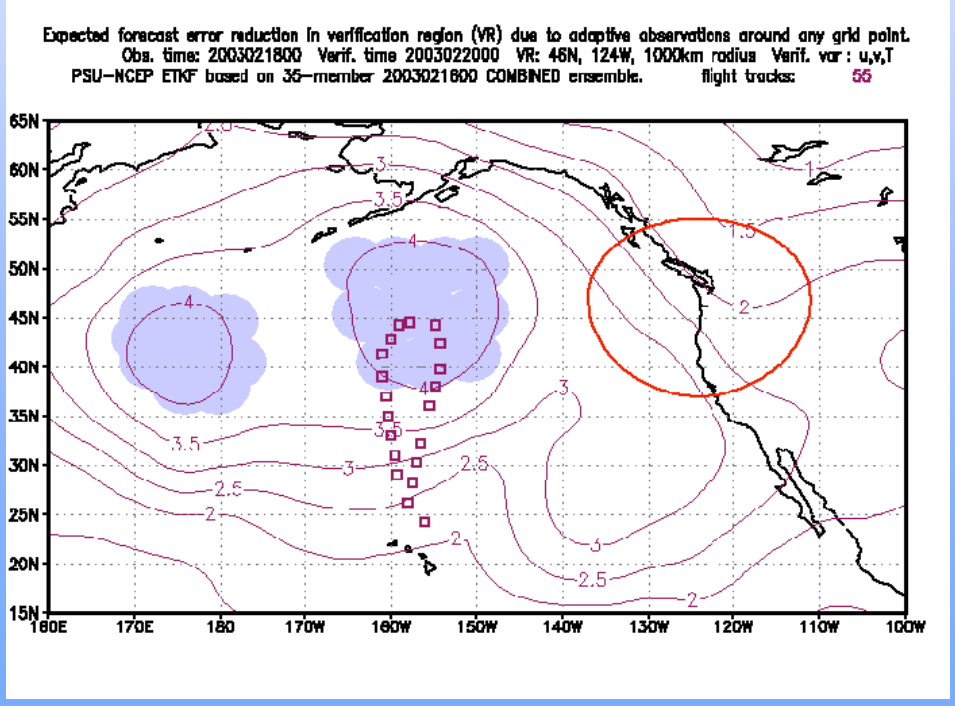


How the impact of AIRS was evaluated

- 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

Summary and Future Work

- Used codes and scripts implemented in NCEP operations (WSR, AIRS)
- Performed case studies using AIRS data over sensitive areas
  - Largely neutral impact
- In future:
  - further expand coverage of sensitive areas included
    - Expand out to 80-75% max value of sensitive regions
    - Expand area based on forecast lead time (larger areas for longer lead times)
  - Other impact studies

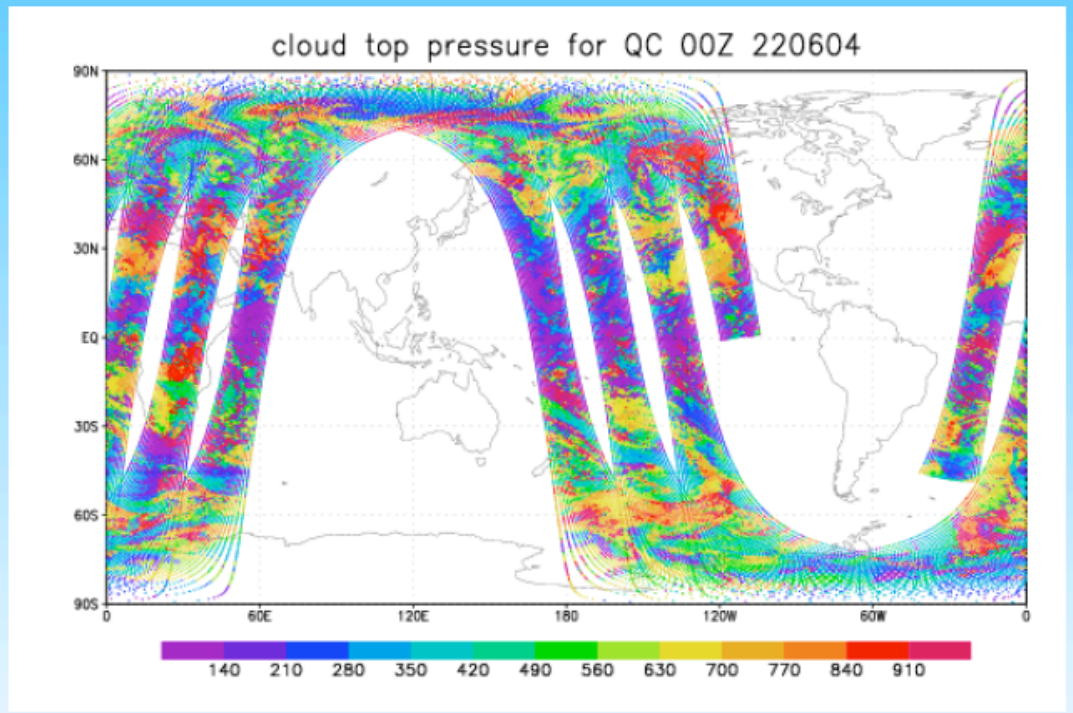
Assimilation of advanced sounders at NCEP

John C. Derber, Russ Treadon, and Paul VanDelst

NOAA/NWS/NCEP/EMC

28 June 2004

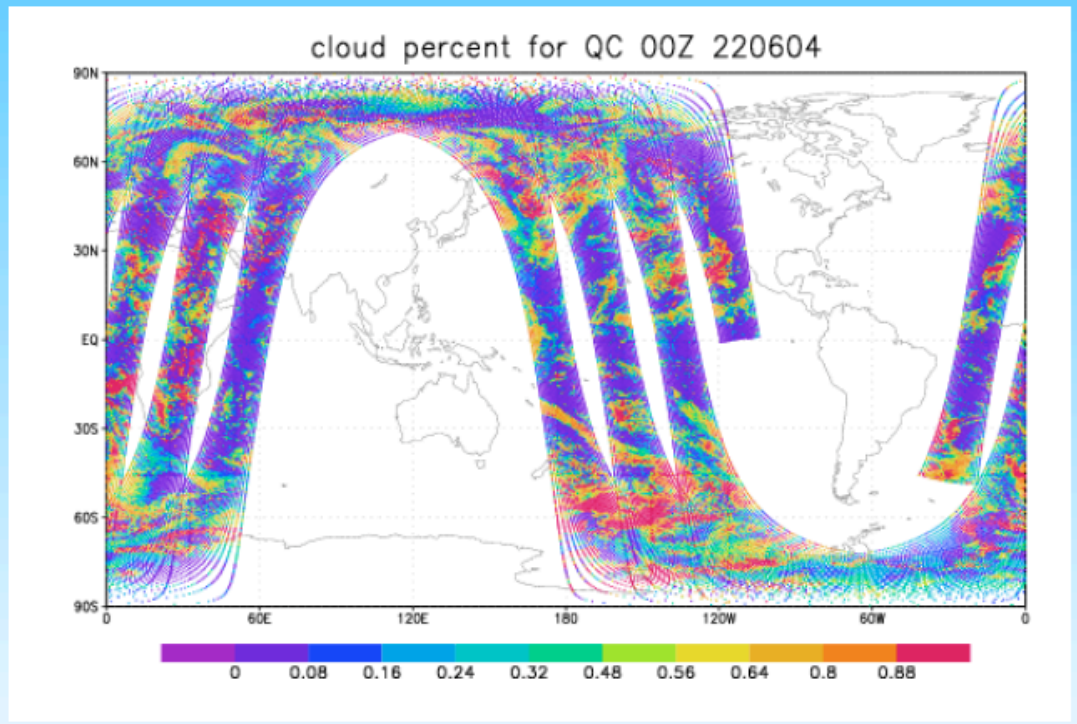
ECMWF workshop on Assimilation of high spectral resolution sounders

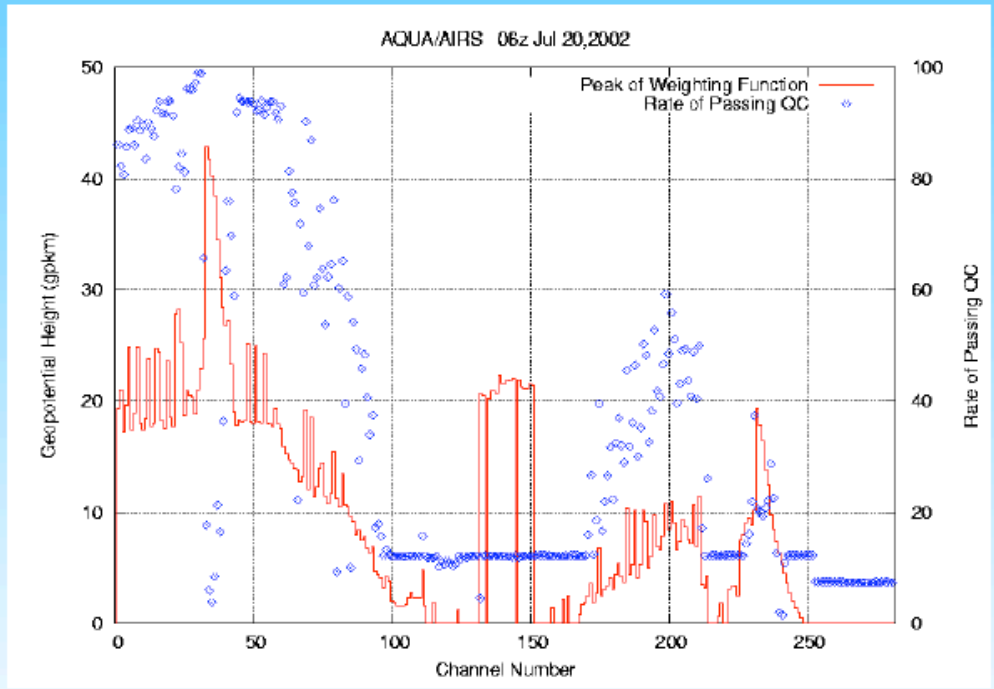


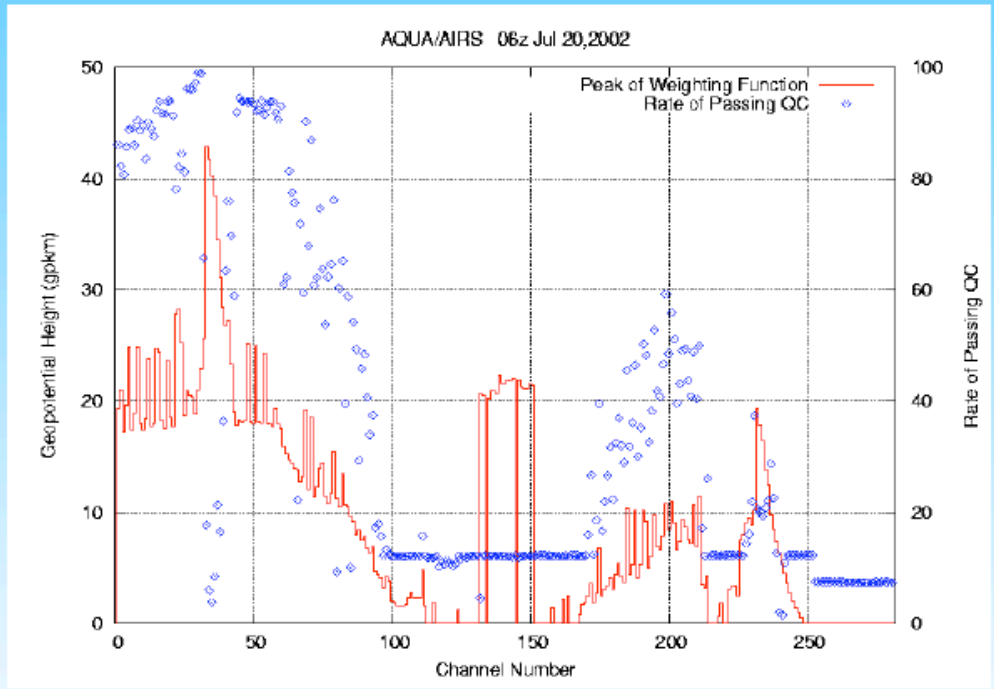
28 June 2004

ECMWF workshop on Assimilation of high spectral resolution sounders

NCEP


cloud percent for QC 00Z 220604
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
0
0.08
0.16
0.24
0.32
0.48
0.56
0.64
0.8
0.88

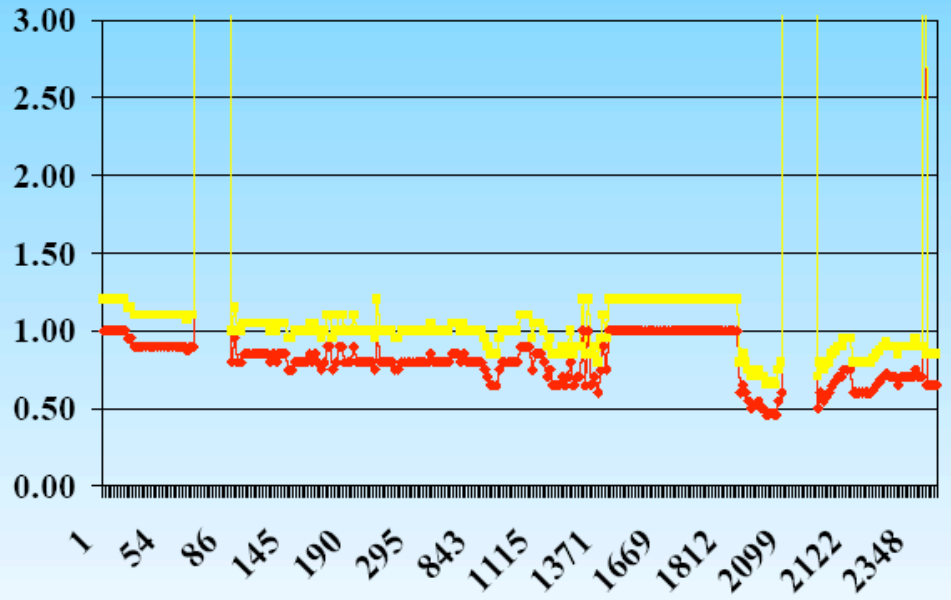

AQUA/AIRS 06z Jul 20,2002
Peak of Weighting Function
Rate of Passing QC
Geopotential Height (gpkm)
Rate of Passing QC
Channel Number
0
10
20
30
40
50
0
20
40
60
80
100
0
50
100
150
200
250


AQUA/AIRS 06z Jul 20,2002
Peak of Weighting Function
Rate of Passing QC
Geopotential Height (gpkm)
Rate of Passing QC
Channel Number
0
10
20
30
40
50
0
20
40
60
80
100
0
50
100
150
200
250

AIRS data

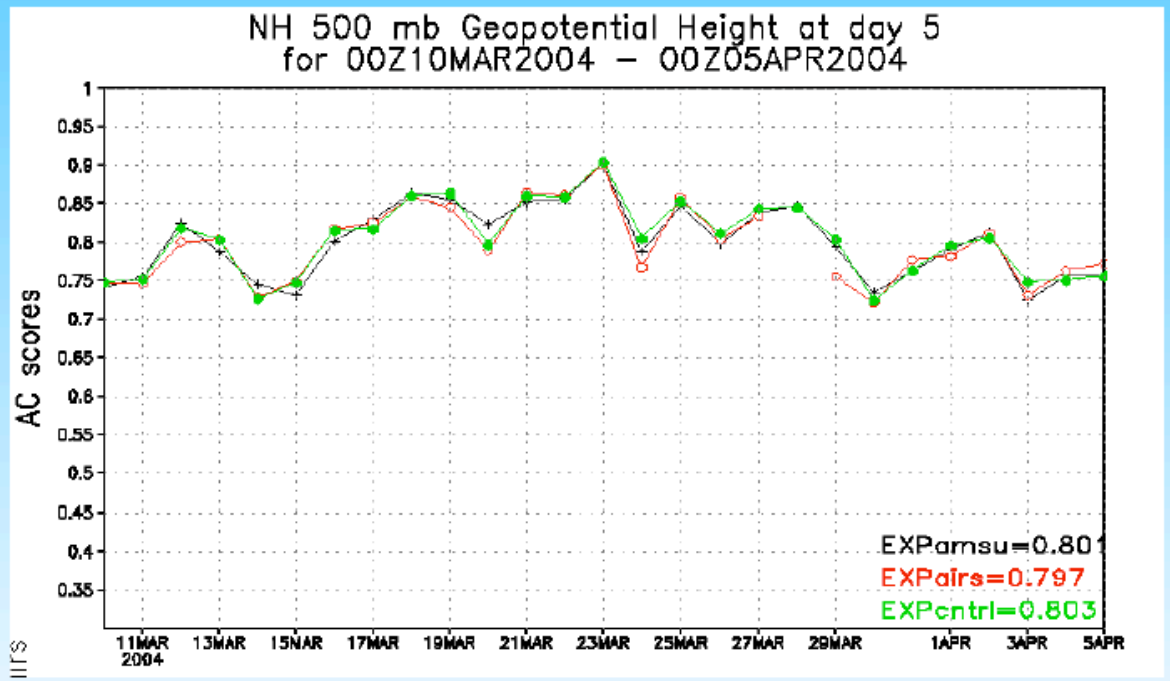
- 254 out of 281 channels used
  - 73-86 removed (channels peak too high)
  - 1937-2109 removed (non-LTE)
  - 2357 removed (large obs-background diff.)
- Shortwave channels during day
  - (wavenumber > 2000) down weighted
  - (wavenumber > 2400) removed

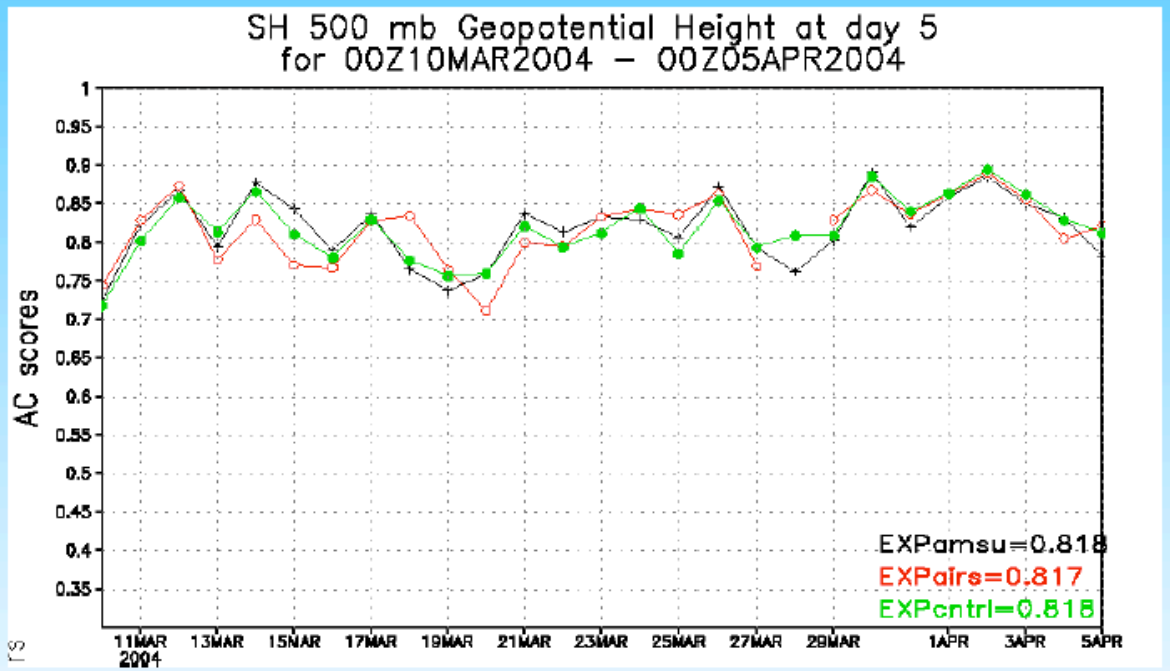
AIRS observational errors



AQUA impact studies

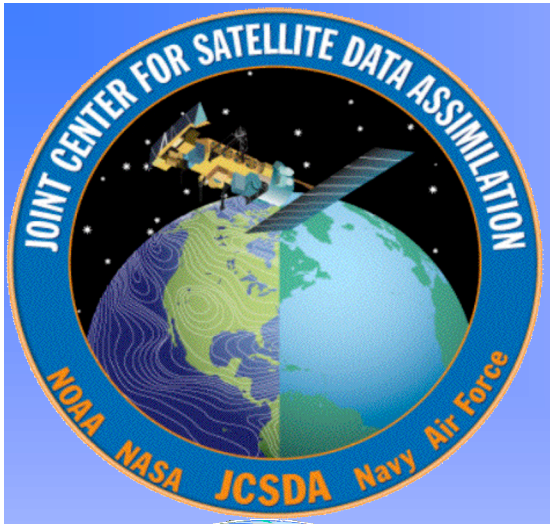
- Test period 10 Mar – 5 Apr 2004
- Uses data operational at time of experiment
- Mass storage problems on our machine, so some incomplete evaluation
- Experiments
  - Current operational
  - Current + AIRS
  - Current + AQUA AMSU
  - Current + AIRS + AQUA AMSU (underway)

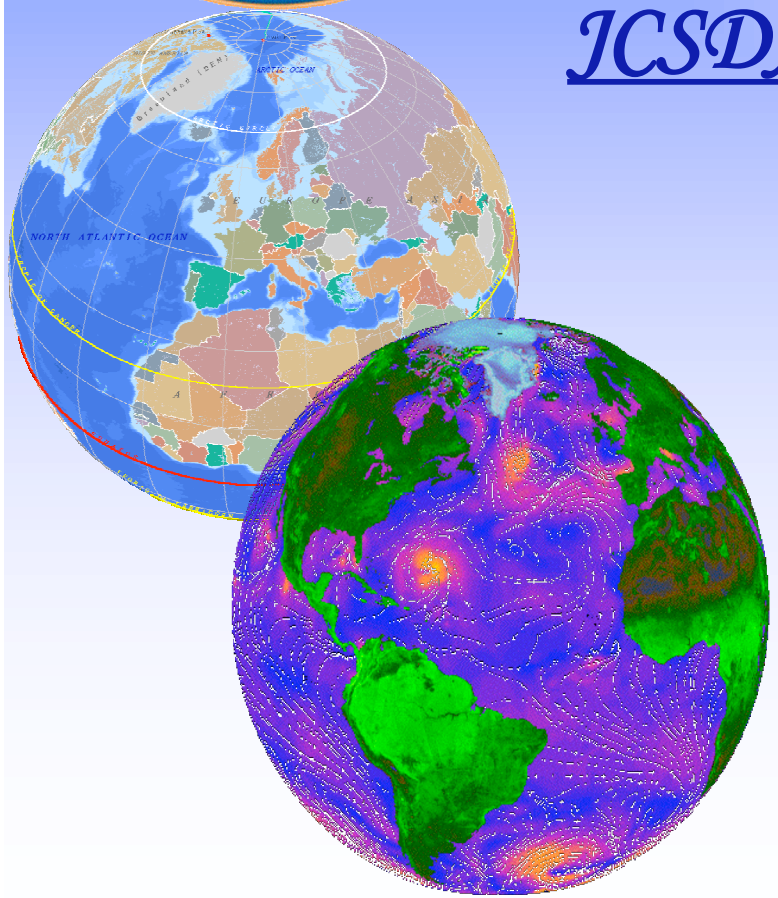

NH 500 mb Geopotential Height at day 5
for 00Z10MAR2004 – 00Z05APR2004
AC scores
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
11MAR 2004
13MAR
15MAR
17MAR
19MAR
21MAR
23MAR
25MAR
27MAR
29MAR
1APR
3APR
5APR
EXPamsu=0.801
EXPairs=0.797
EXPcntrl=0.803


SH 500 mb Geopotential Height at day 5
for 00Z10MAR2004 – 00Z05APR2004
AC scores
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
11MAR 2004
13MAR
15MAR
17MAR
19MAR
21MAR
23MAR
25MAR
27MAR
29MAR
1APR
3APR
5APR
EXPamsu=0.818
EXPairs=0.817
EXPcntrl=0.818

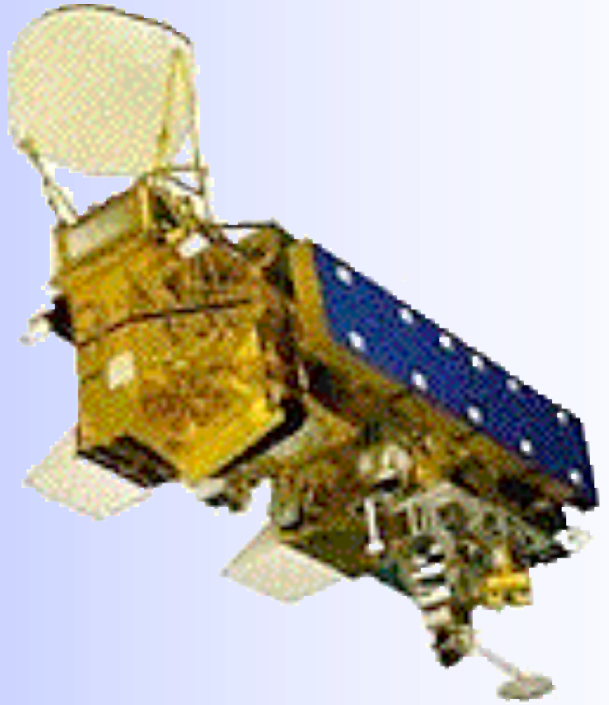
AIRS Comments

- 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

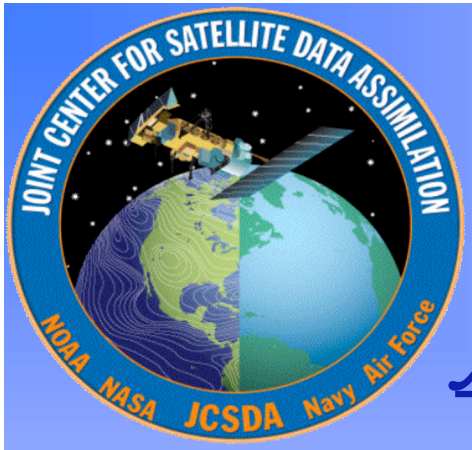




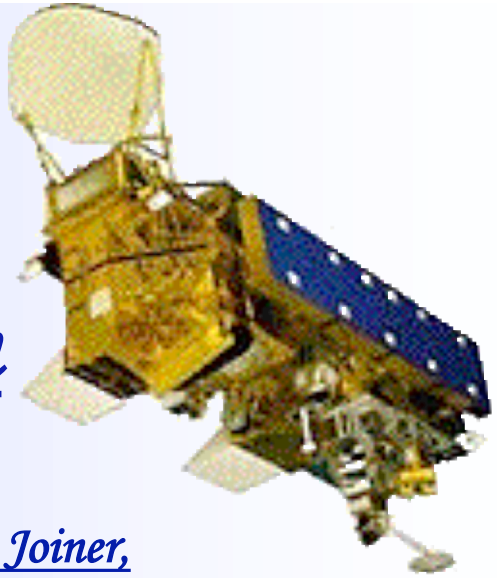
JCSDA



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,
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	TRMM precipitation rates
AMSU-A sounder radiances	ERS-2 ocean surface wind vectors
AMSU-B sounder radiances	Quikscat ocean surface wind vectors
GOES sounder radiances	AVHRR SST
GOES 9,10,12, Meteosat	AVHRR vegetation fraction
atmospheric motion vectors	AVHRR surface type
GOES precipitation rate	Multi-satellite snow cover
SSM/I ocean surface wind speeds	Multi-satellite sea ice
SSM/I precipitation rates	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 cut off

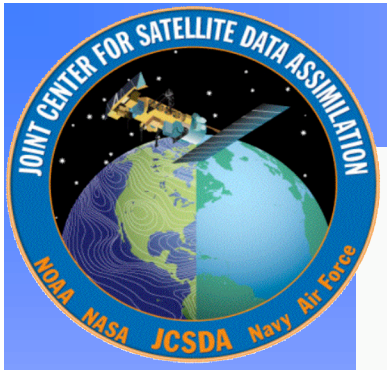
The Trials – Assim1

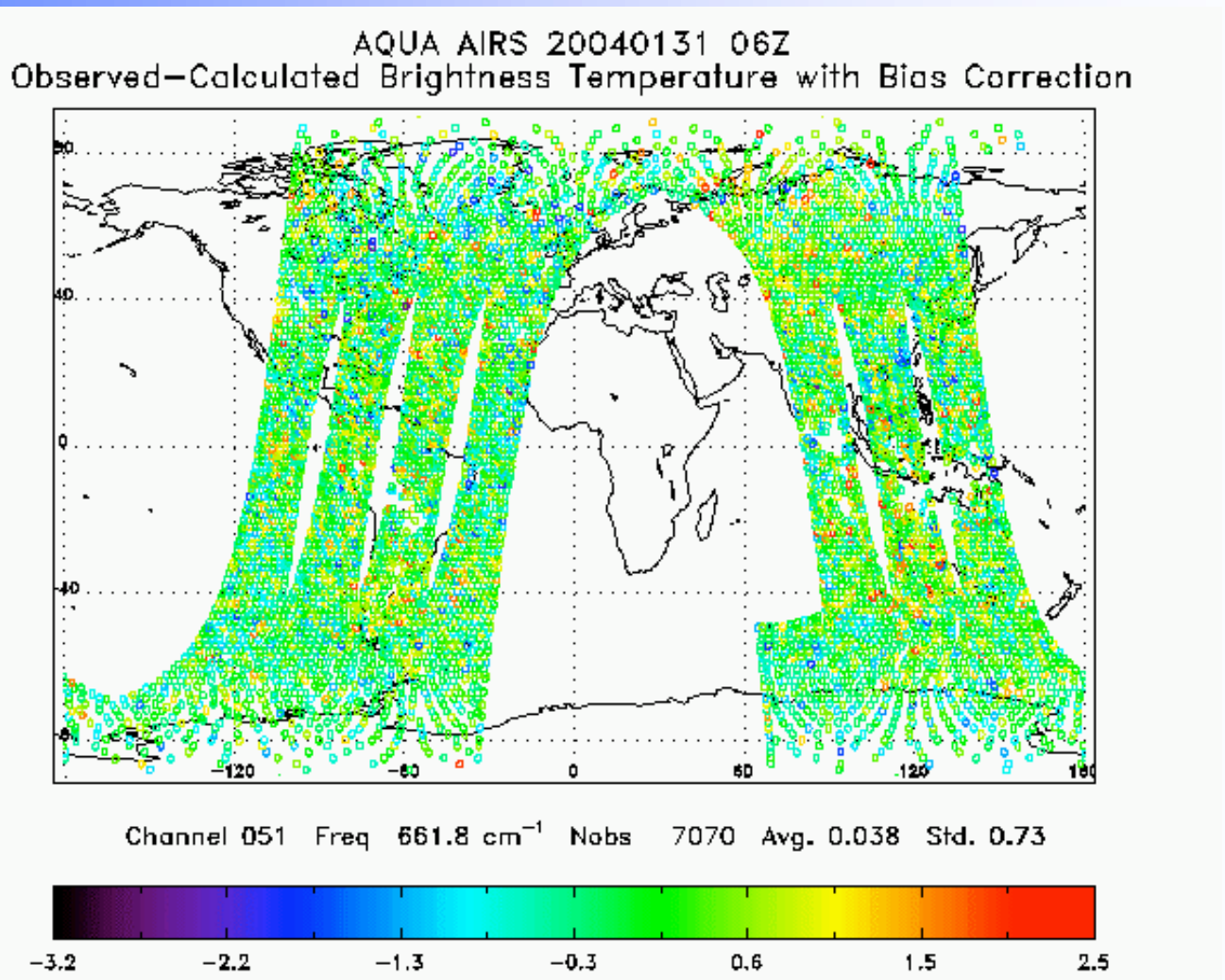
- Used `full AIRS data stream used (JPL)
  - NESDIS (ORA) generated BUFR files
  - All FOVs, 324(281) channels
  - 1 Jan – 15 Feb '04

- 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.





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

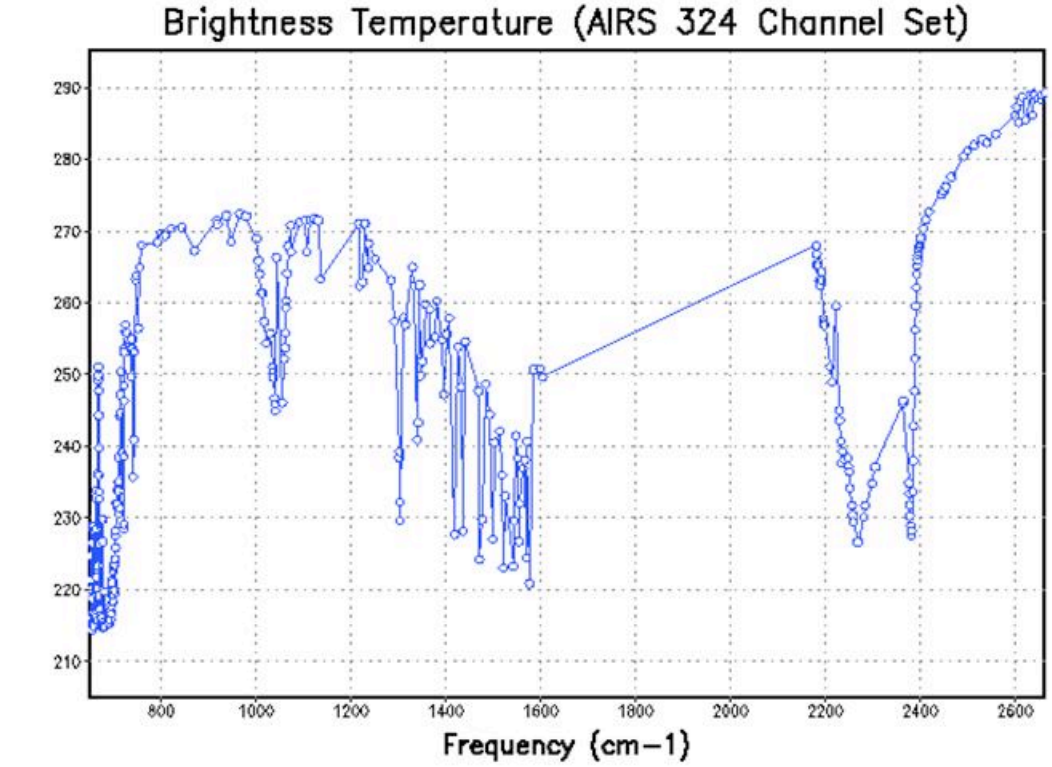


Figure 5.Spectral locations for 324 AIRS thinned channel data distributed to NWP centers.

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)

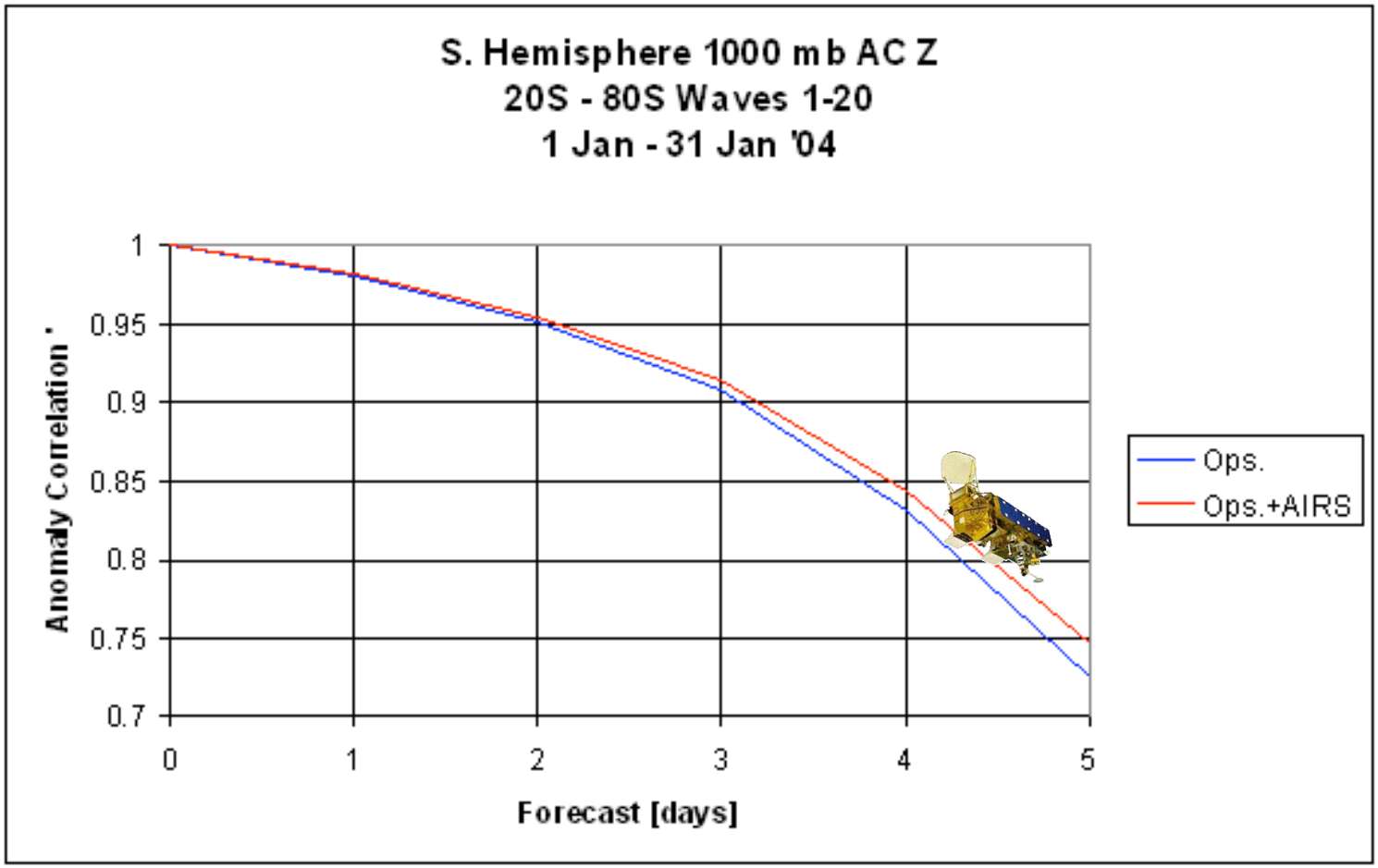
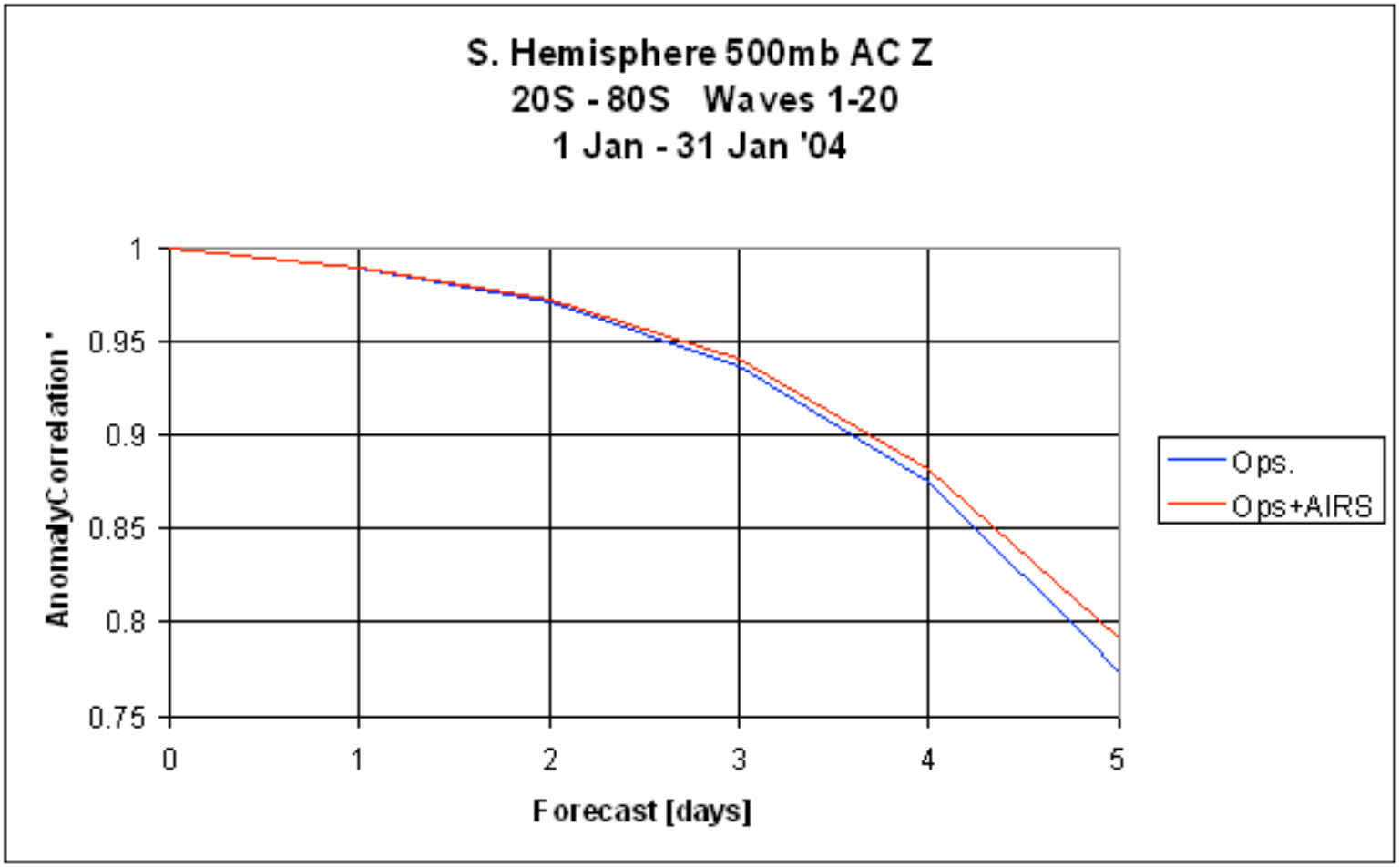


Figure1(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004- Assim1



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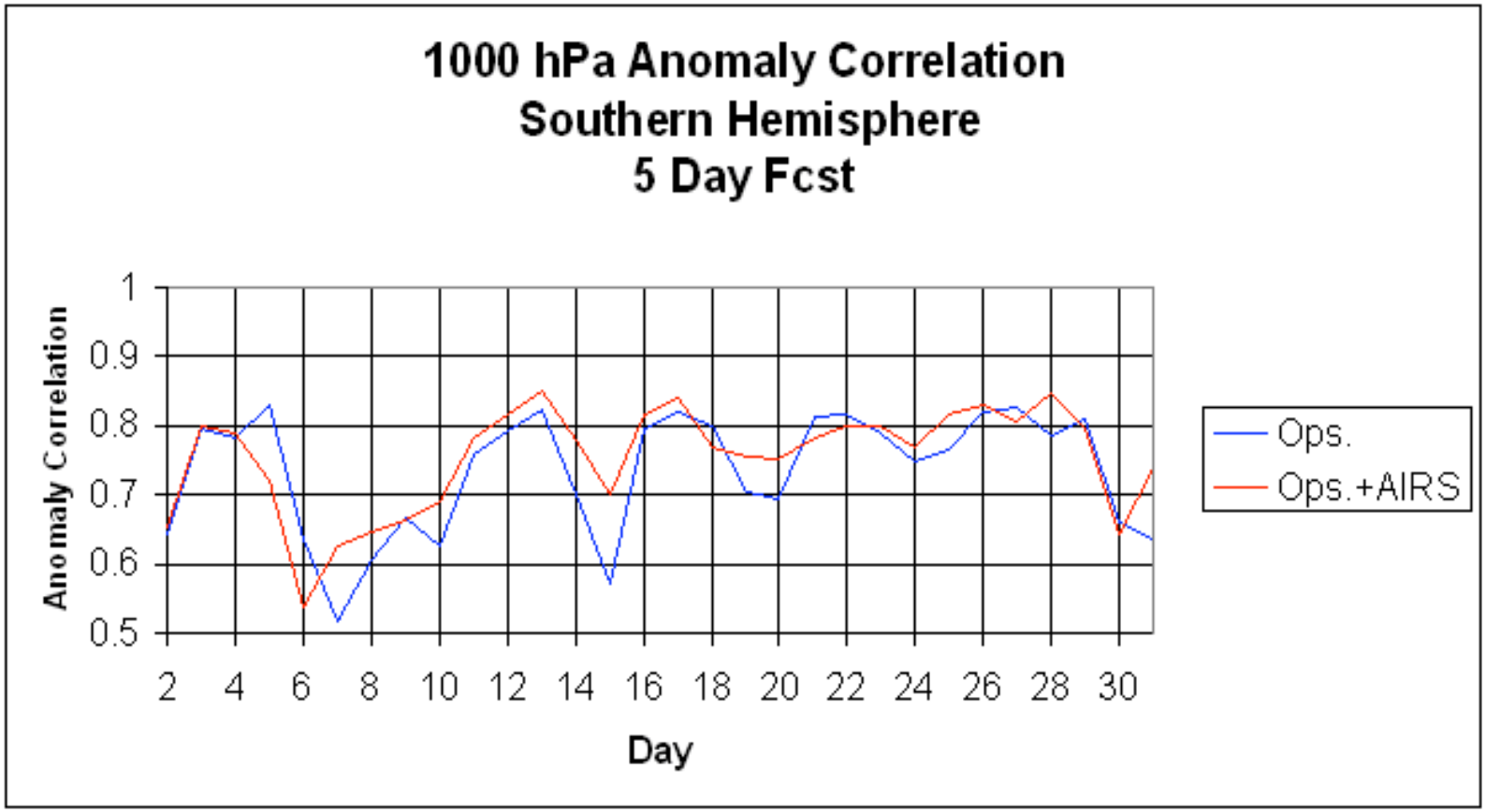

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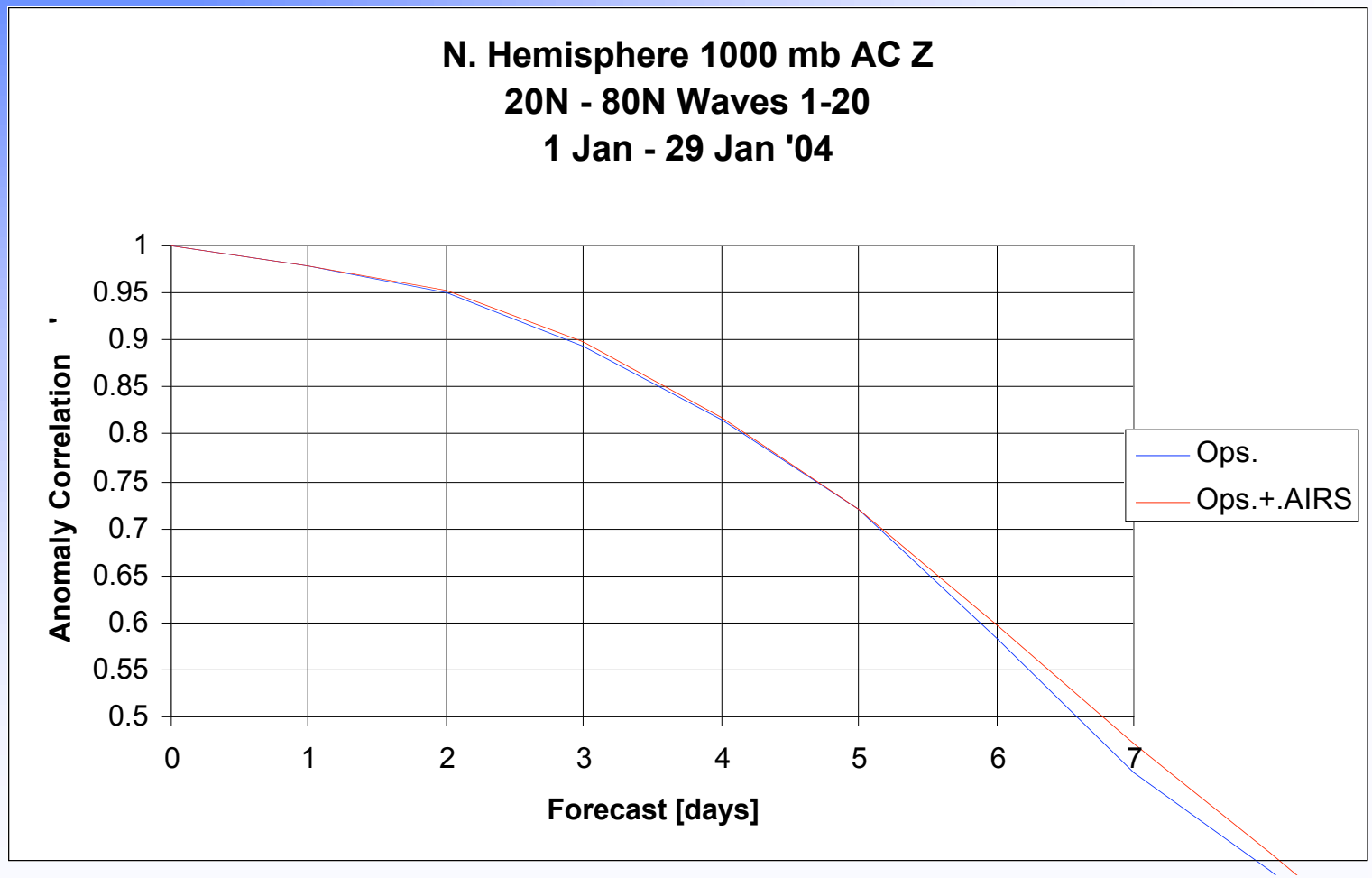
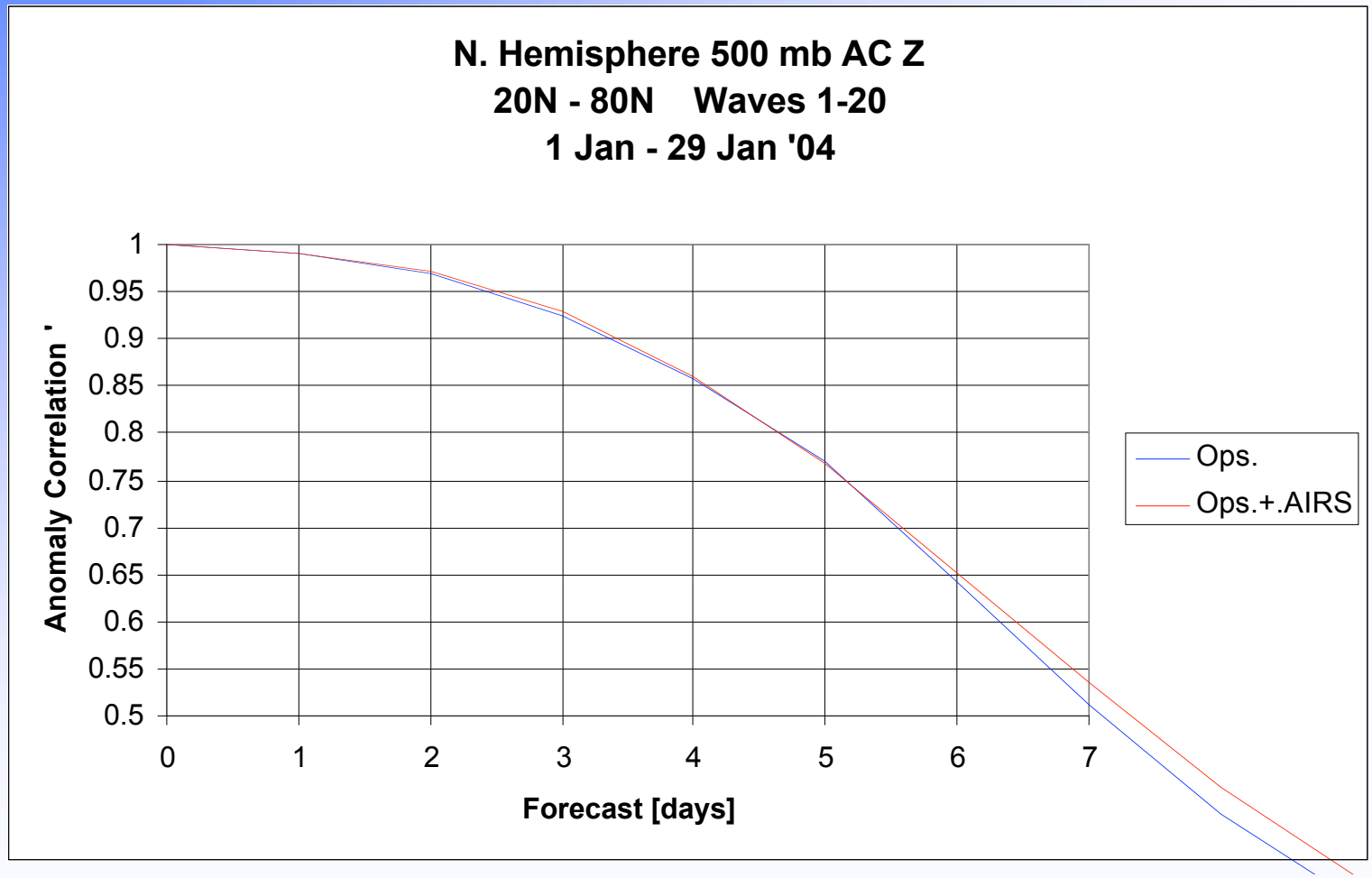


Figure1(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern Hemisphere, January 2004



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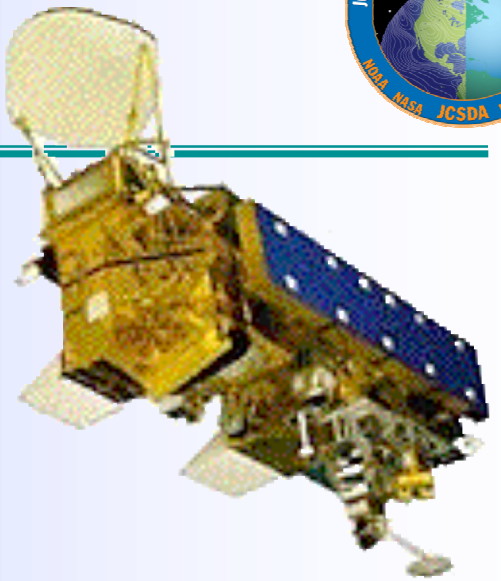

AIRS Data Assimilation

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1-31 January 2004

Used operational GFS system as Control

Used Operational GFS system Plus Enhanced AIRS Processing as Experimental System

Clear Positive Impact

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.

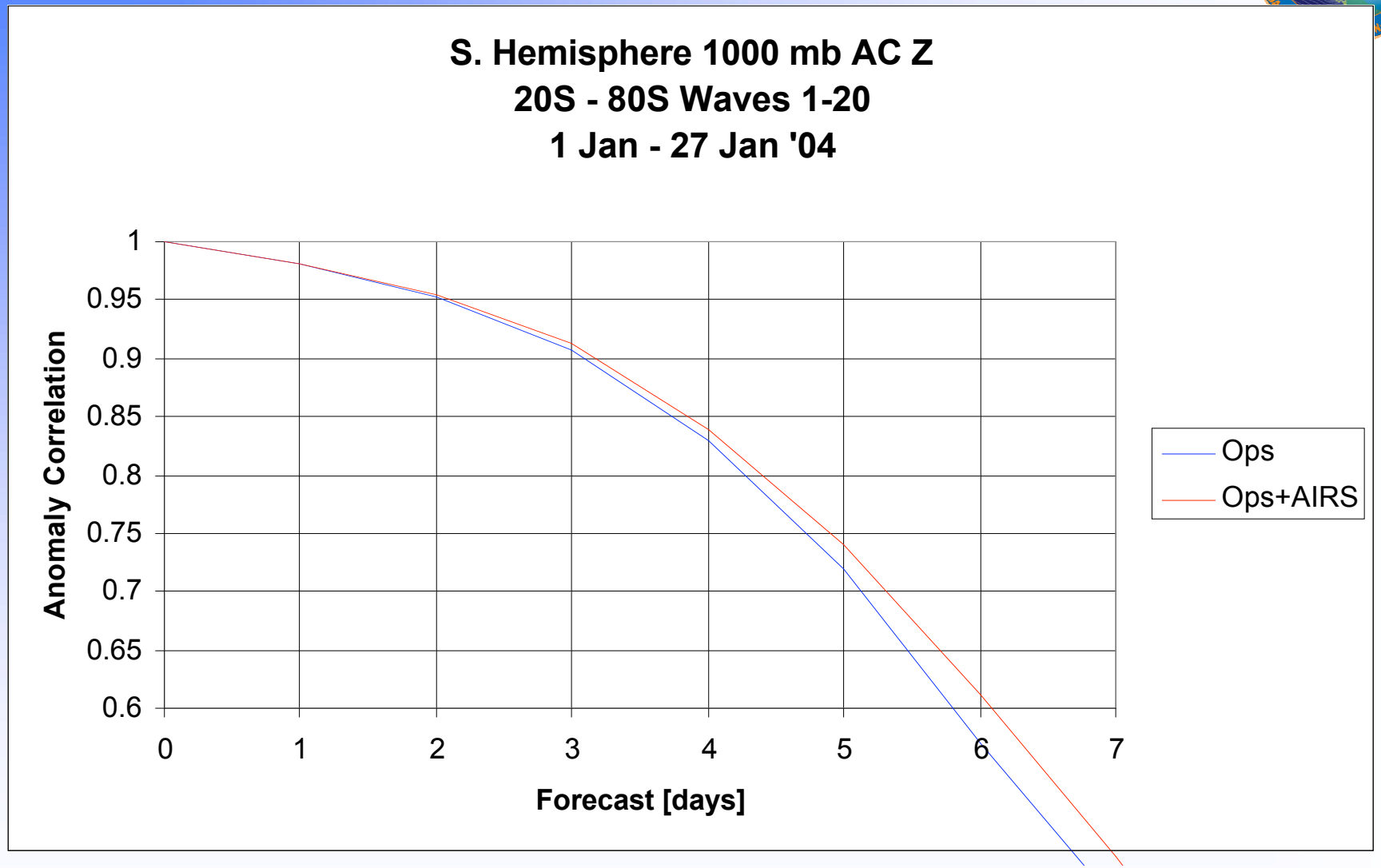


Figure1(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004

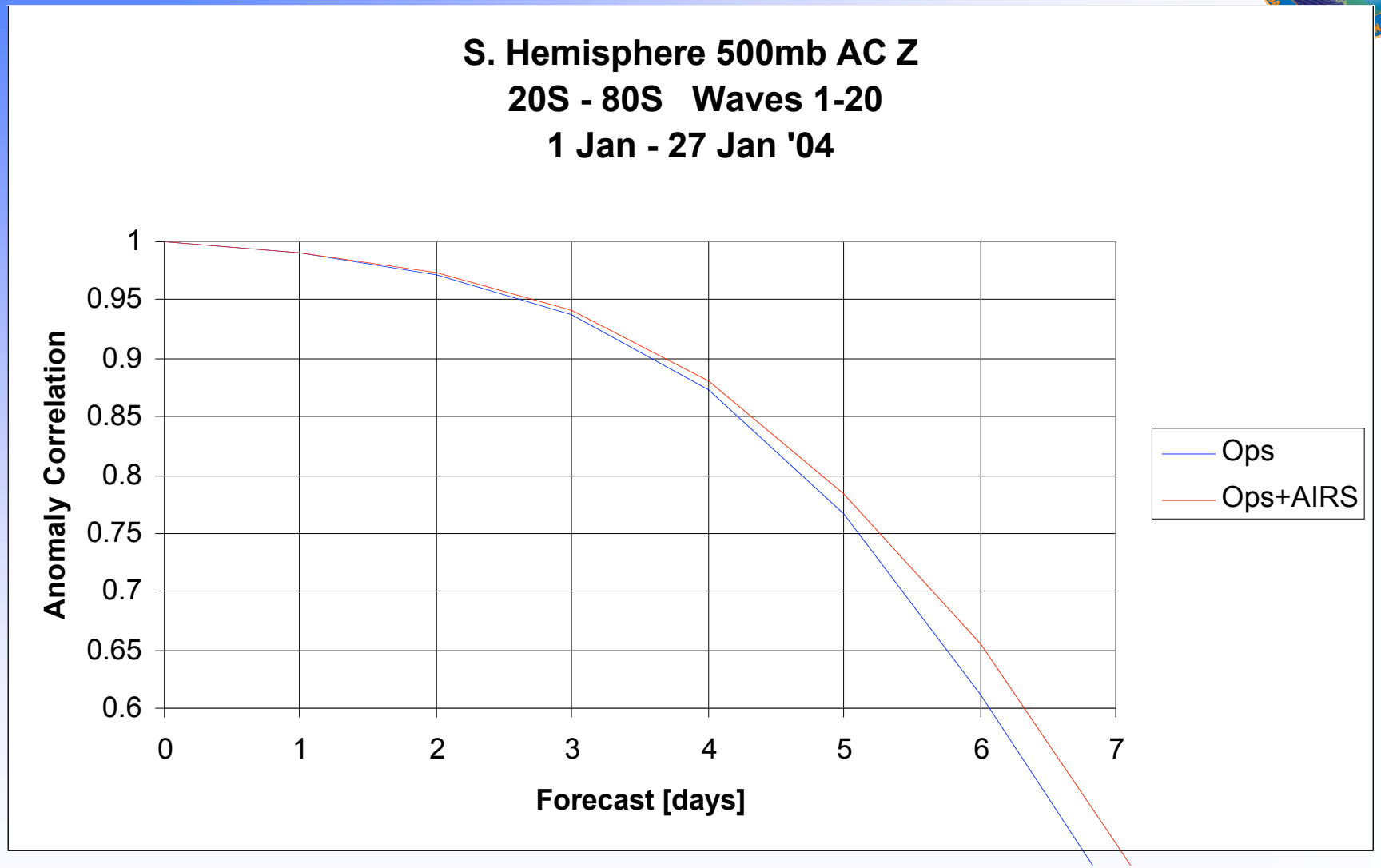


Figure 1(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004

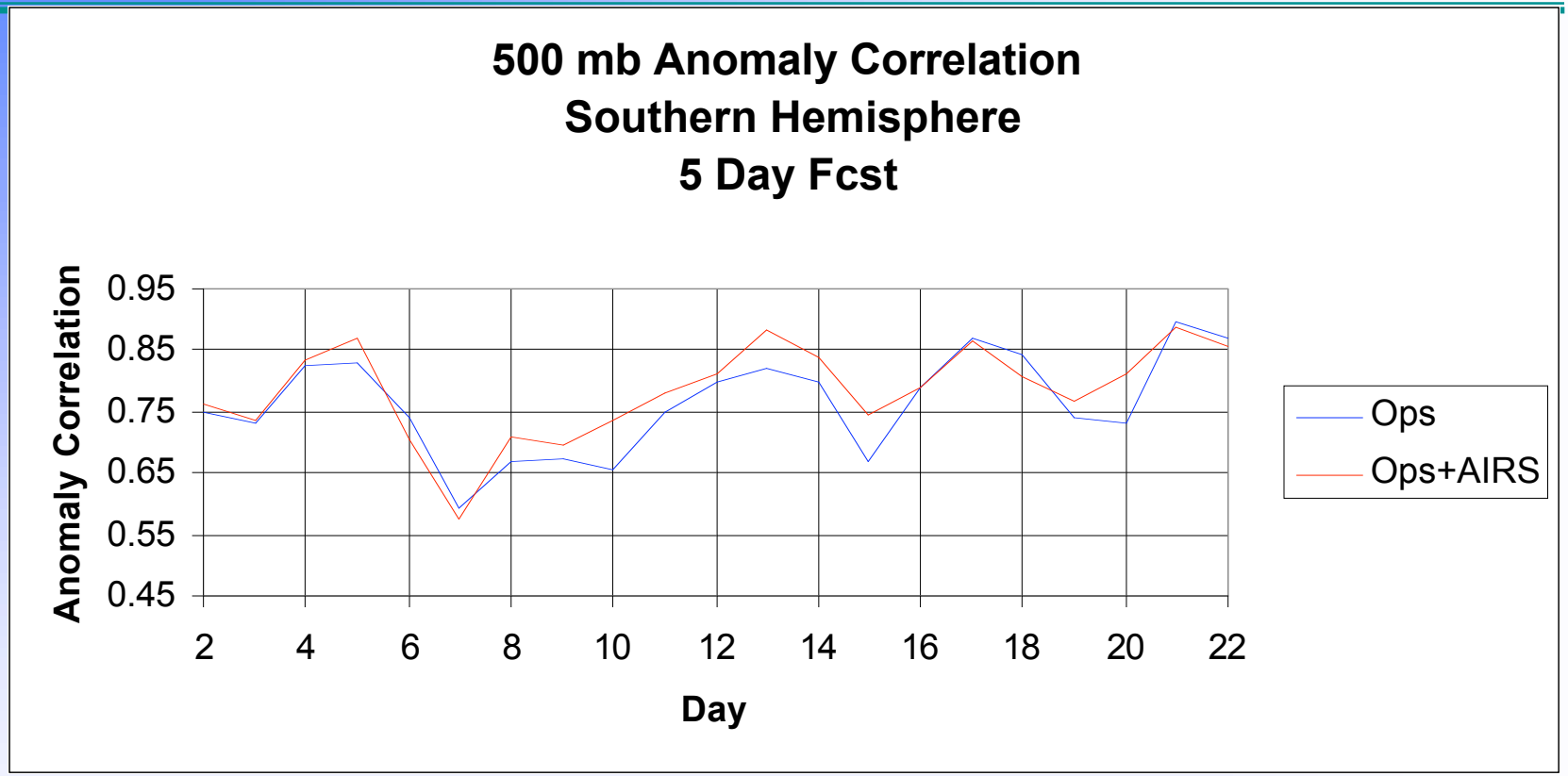


Figure 2. 500hPa Z Anomaly Correlations 5 Day Forecast for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, (1-27) January 2004

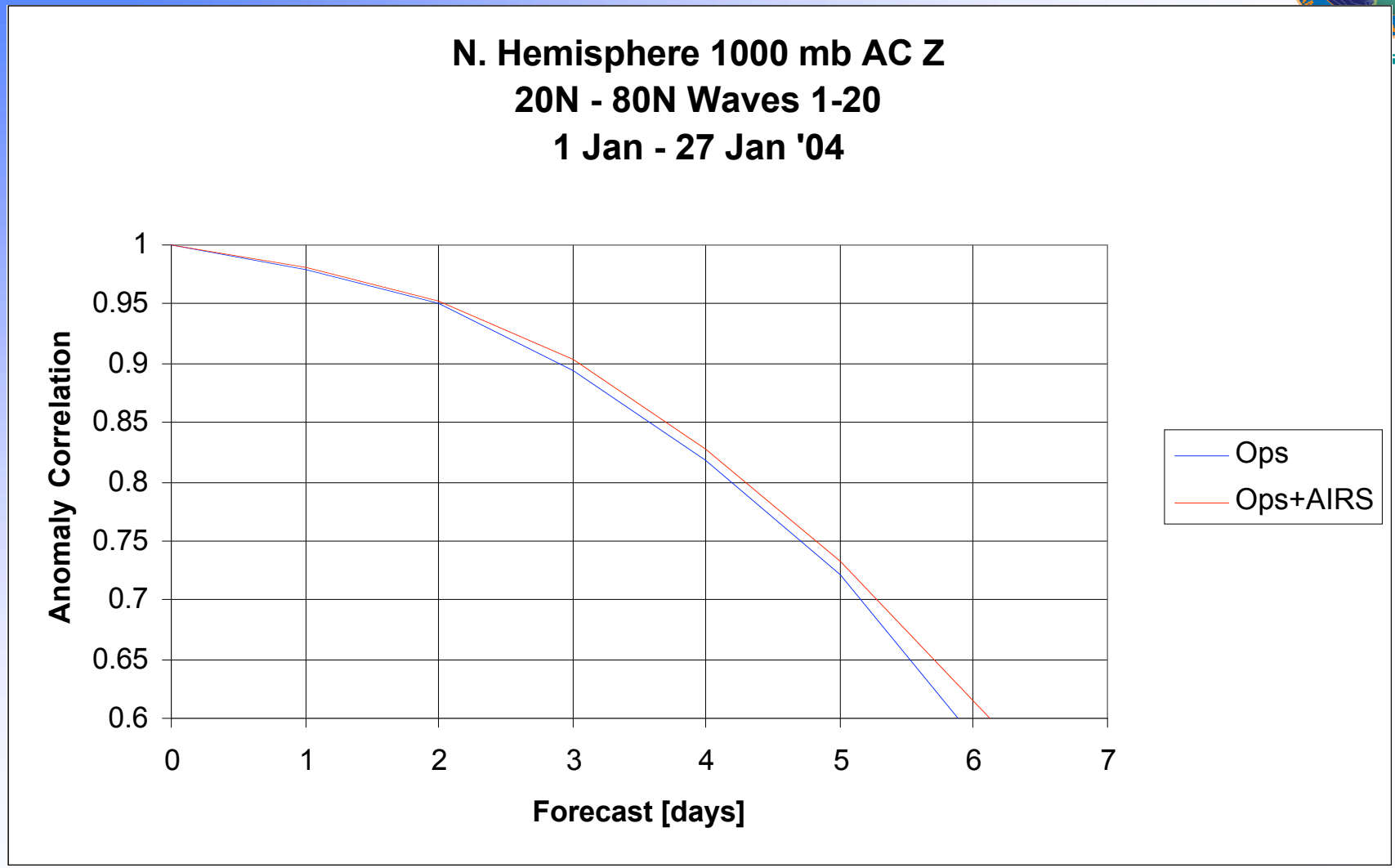


Figure3(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004

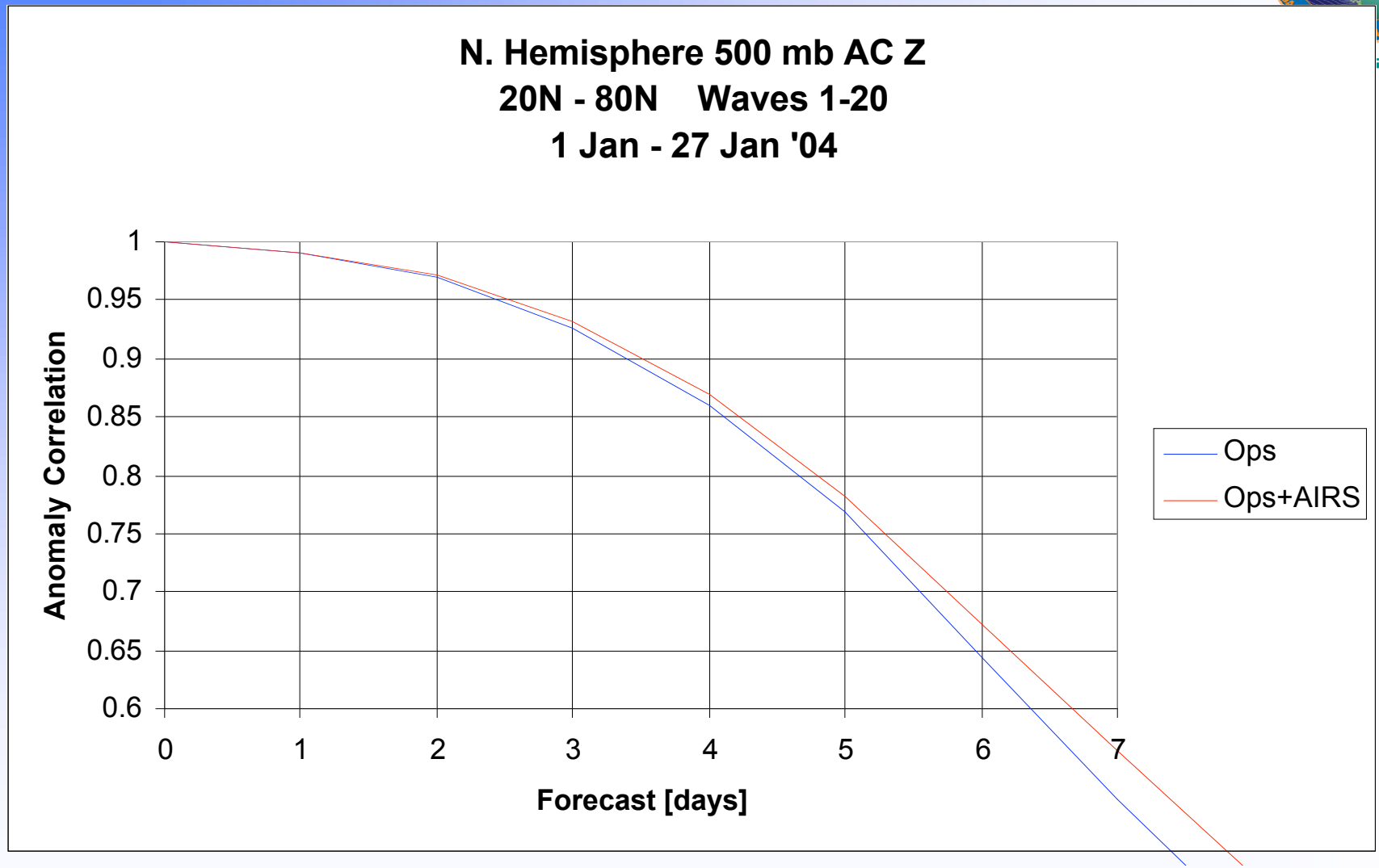
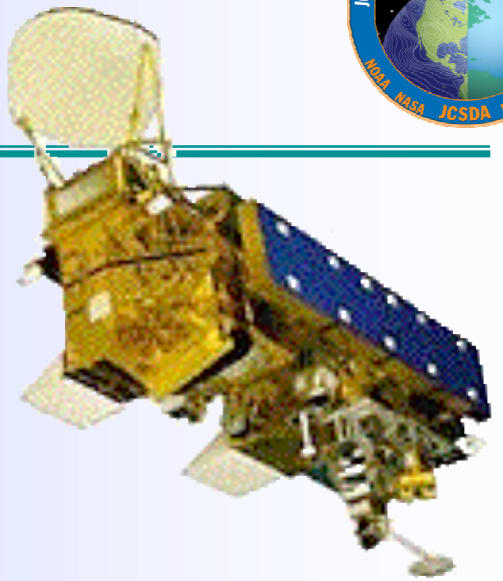


Figure 3(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004



AIRS Data Assimilation

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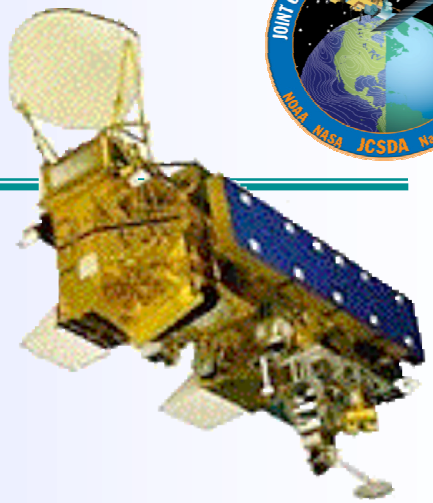
1-27 January 2004

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 GSI system as Control

Used next generation GSI system Plus AIRS as Experimental System

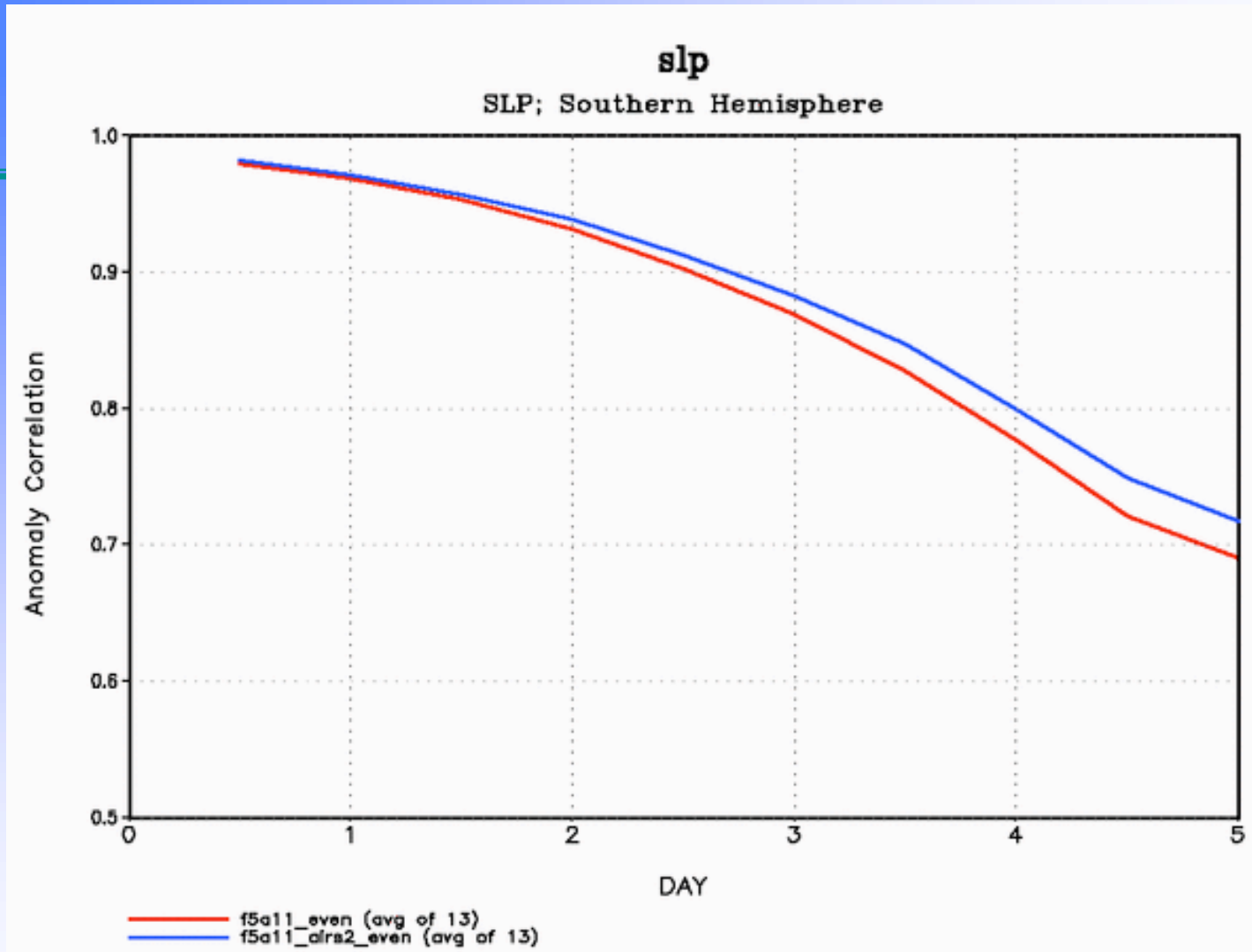
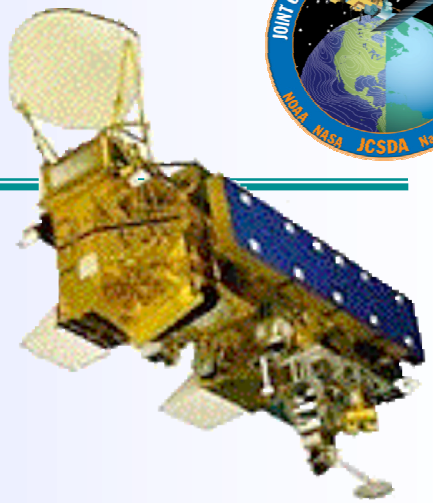


Figure 2(a). 1000hPa Z Anomaly Correlations for the GMAO GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, 1-13 January 2003



AIRS Data Assimilation

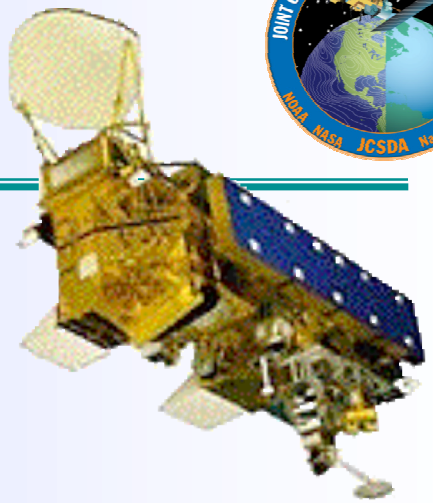
Supporting Studies:

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

Current Studies:

Snow:

1 January – 15 February 2004-Snow/modl.,anl.

10 August – 30 September 2004

Next Op. GDAS – 1 Jan, 04 – 15 Feb

AIRS Data Assimilation

-The Next Steps

Fast Radiative Transfer Modelling (OSS, Superfast RTM)

GFS Assimilation studies using:

full spatial resolution AIRS data (_ _)
full spatial resolution AIRS data with recon. radiances
full spatial res. AIRS with cld. cleared radiances
(_ AMSU/MODIS/MFG use)
full spatial and spectral res. AIRS data
full spatial and spectral res. raw cloudy AIRS
(_ MODIS/AMSU) data
(full cloudy inversion with cloud parameters etc.)

AIRS Assimilation -The Next Steps

(Including AMSU/MODIS…..)

* All data plus data selection / thinning studies plus _

** all channels plus channel selection / noise red. studies

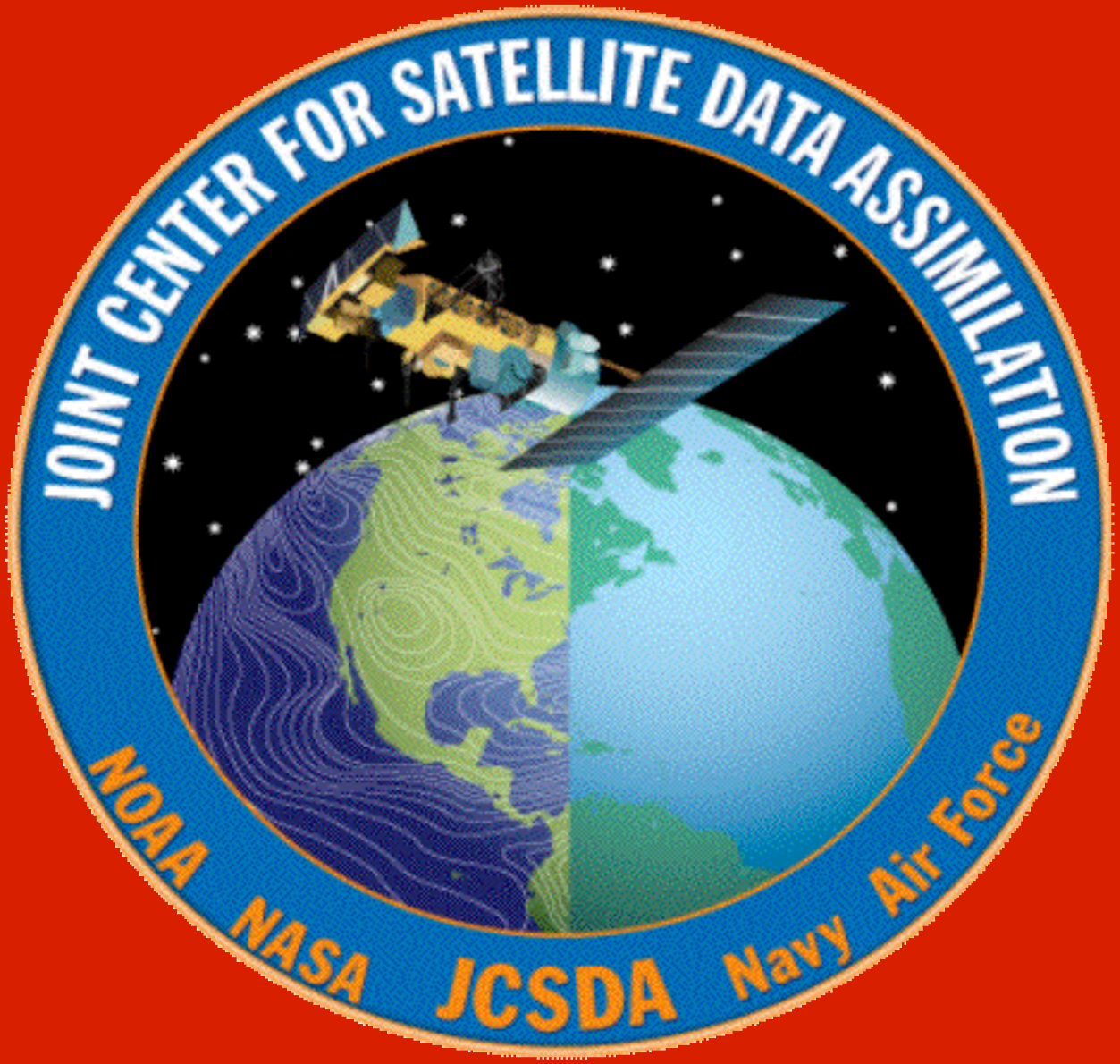
Data utilised (AQUA)	Spatial Res.	Spectral Res.	Comment
AIRS	Full* all data, data selection / thinning studies, Surface chanels with _ calc.	Current 300 Ch.	Current 3DVar CLR Rd assim
AIRS	Full*	Current 300 Ch. Recon.Rads	Current 3DVar CLR Rd assim
AIRS AMSU and MODIS	Full*	300 Cld Cleared Rads.	AMSU/MODIS used in QC
AIRS AMSU and MODIS	Full*	Full** all channels plus channel selection / noise red. studies	Current 3DVar CLR Rd assim
AIRS AMSU MODIS	Full*	Full**	Cloudy Rads Used

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 observations (such as AIRS), 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.


JOINT CENTER FOR SATELLITE DATA ASSIMILATION
NOAA
NASA
JCSDA
Navy
Air Force