Satellite Assimilation Activities for the NRL Atmospheric Variational Data Assimilation (NAVDAS) and NAVDAS-AR (Accelerated Representer) Systems

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Outline of Presentation

- Who are we?
- Operational NWP Systems
- Status of ATOVS assimilation at NRL
  - AIRS (Ruston et al., 7.2)
  - SSMIS (Campbell et al., 8.4 and A12)
- Observation impact using adjoint techniques
- Current and future research

Naval Research Laboratory (NRL)

- ***Monterey – Marine Meteorology Division***
  - **Research and development of global, mesoscale and shipboard atmospheric analysis and prediction systems**
- ***Washington, D.C. – Remote Sensing and Space Sciences Divisions***
  - **Designed and built WindSat and POAM**
  - **Upper atmosphere assimilation and modeling**
- ***Stennis Space Center, MS – Ocean Division***
  - **Ocean data assimilation and modeling**
- **Primary customer is Fleet Numerical Meteorology and Oceanography Command (FNMOC)**
  - Provides weather support for Navy and Marine Corps, Air Force and other DoD activities
  - Produces and distributes products from numerical prediction models of the ocean and atmosphere

NRL/FNMOC Forecast Suite

- **NOGAPS** - Navy Operational Global Atmospheric Prediction System
  - Spectral T239, L30 with effective model top at 4 hPa
  - Operational forecasts out to 6 days
  - Provides input/boundary conditions for
    - mesoscale, ocean, wave and ice prediction models,
    - ensemble forecasting system
    - Aircraft and ship routing programs
    - tropical cyclone forecast model (GFDN)
  - Used for basic research predictability studies, adjoint sensitivity studies, adaptive observation-targeting

- **COAMPS®*** - Coupled Ocean/ Atmosphere Mesoscale Prediction System
  - nonhydrostatic; globally relocatable, nested grids; explicit prediction of moisture variables
  - 5-10 different operational areas

* COAMPS® is a registered trademark of the Naval Research Laboratory, Monterey CA

NRL/FNMOC Analysis Systems

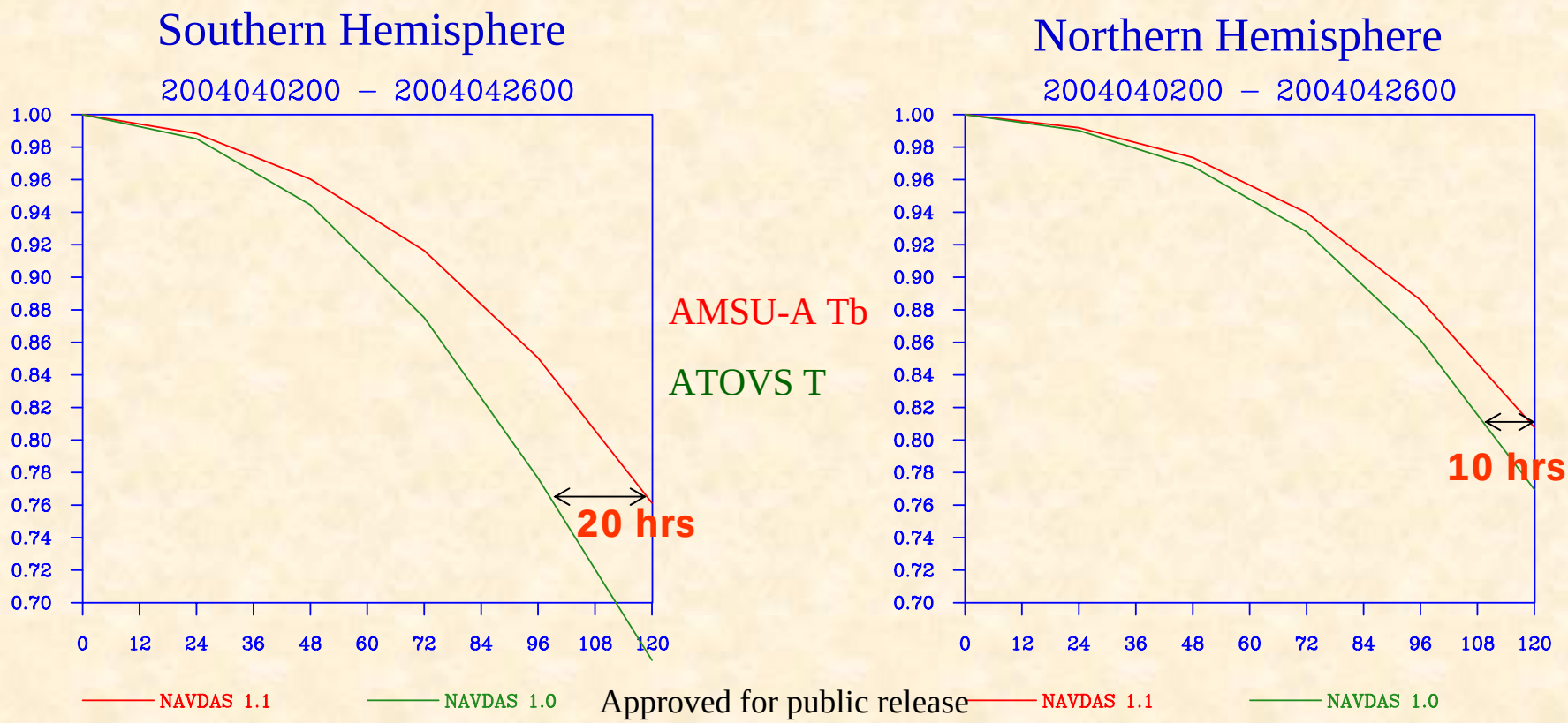
- **NAVDAS** – NRL Atmospheric Variational Data Assimilation System
  - 3dvar observation space algorithm
  - Designed to be precursor for NAVDAS-AR, our 4d accelerated representer assimilation system
  - Unified code for both global and mesoscale NWP systems
    - Operational for NOGAPS on October 1, 2003
    - Operational for COAMPS® October, 2006
  - Adjoint of NAVDAS is used for observation impact studies

- **NAVDAS-AR** is under development
  - Observation space 4D-Var using cycling representer method
  - "AR" stands for accelerated representer
  - Targeting late 2008 for implementation into NOGAPS

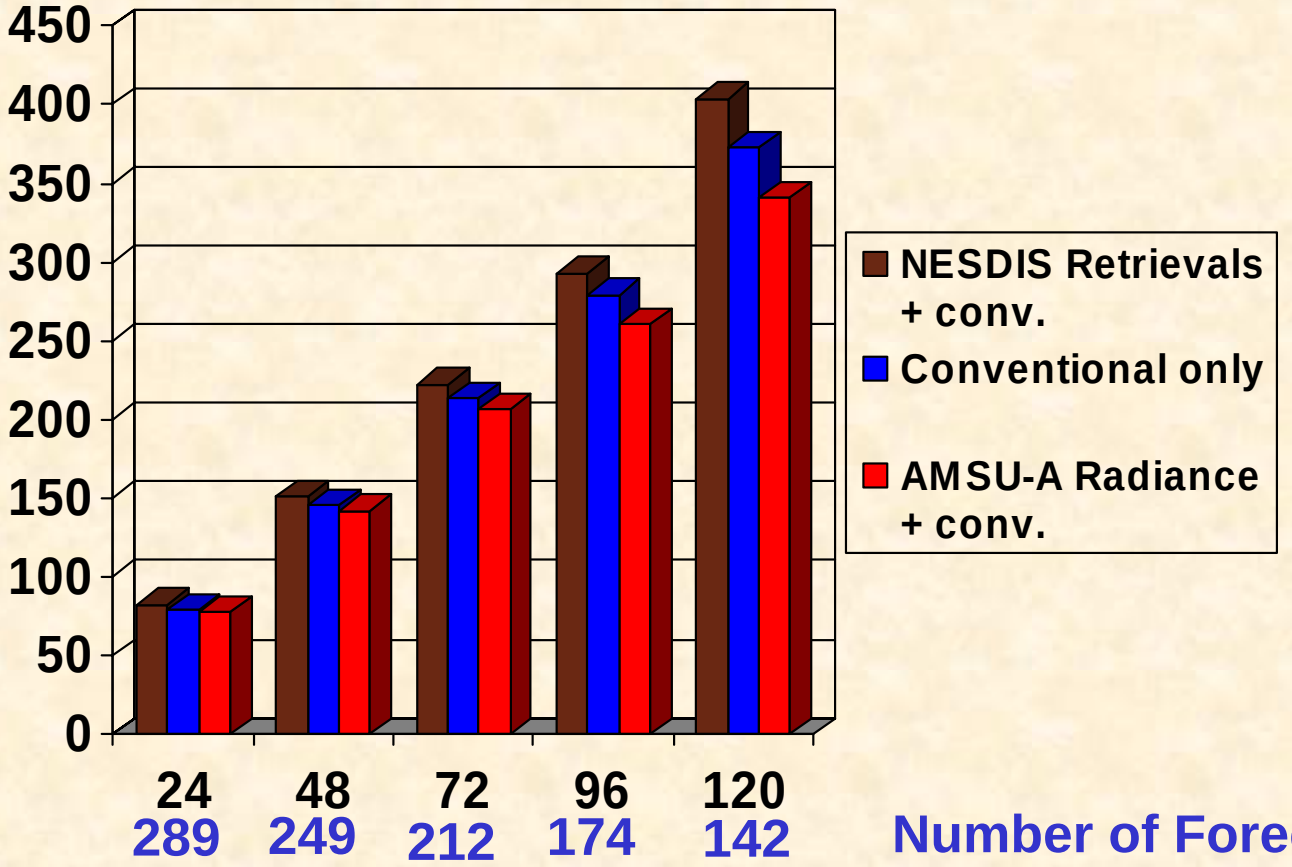
AMSU-A Radiance Assimilation

- Operational June 9, 2004 for NOGAPS
- One of the most significant improvements to NOGAPS forecast skill in the past decade

500 mb geopotential height anomaly correlation



Retrieval vs. Radiance Assimilation TC Forecast Error (nm)



Same observations; assimilated as either retrievals or radiances
⇒ Illustrates the importance of ***how*** the observations are assimilated

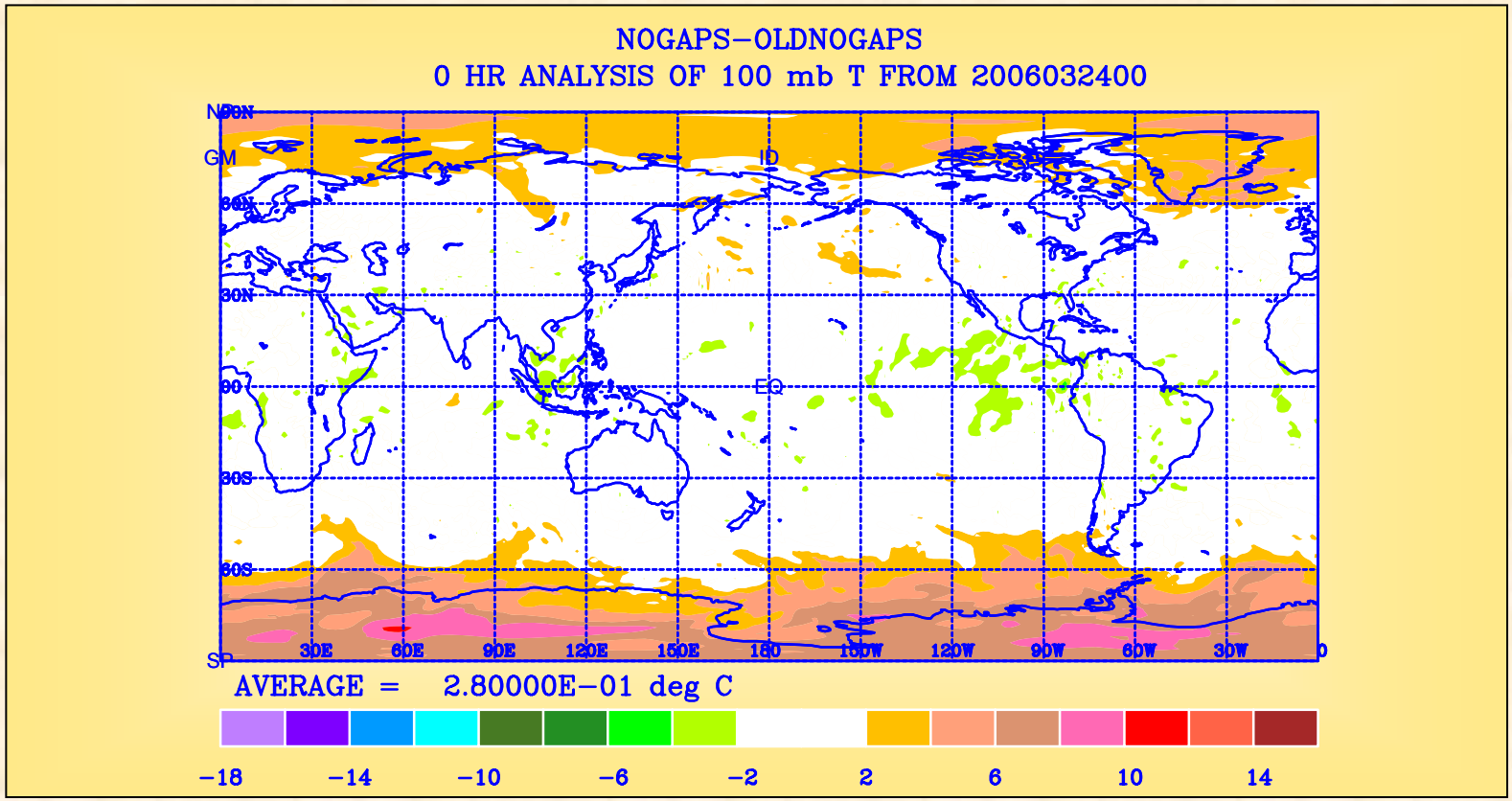
Recent upgrades to AMSU-A Radiance Assimilation

- Operational with NOAA-18, September 2005
  - 3-5 hr improvement in SH 500 hPa anomaly correlation
- Late-arriving AMSU-A data files
  - Delay +3:00 data cut by 5 minutes
  - Delay start of AMSU-A preprocessor by 120 seconds
  - Pick up occasional extra orbits of data
- Improve the assimilation of surface sensitive channels over land
  - Integrated ATOVS pre-processor (AMSU-A, AMSU-B, HIRS/3)
  - Retrieve surface emissivity over bare land; use JCSDA Microwave Emissivity Model as initial guess (and for ice, snow, boreal forests)
  - Retrieve land surface temperature
  - HIRS cloud screening
  - Testing is underway
- **Revised bias correction method**

AMSU-A Radiance Bias Correction

- Operational AMSU-A bias correction reinforces NOGAPS stratospheric temperature bias
  - Over time, led to rejection of polar radiosondes
  - Correlation between model errors and predictors
- Old method – 7 predictors, tropospheric and stratospheric thicknesses, modulated by sin and cos, Skin T, TPW, d(CLW)
- New Method – 2-predictor Harris and Kelly
  - 850-300 mb thickness and 200-50 mb thickness
- Extensively tested revised AMSU-A bias correction (~6 months)
  - New method is stable
  - No rejection of polar raobs
  - Improved fit of analyses and forecasts with other observations
  - Neutral forecast impact in the troposphere

Results of Revised AMSU-A Bias Correction



New bias correction eliminates NOGAPS temperature bias in the polar stratosphere

AMSU-A Radiance Bias Correction

- Revised bias correction is necessary for successful AIRS, SSMIS and GPS assimilation

- **Plan: Implement operationally this fall**

AMSU-B and HIRS Radiance Assimilation

- AMSU-B
  - 150 GHz and 183.31±1, 3, and 7 GHz channels (NOAA-16/17)
  - Screen out land, coast, and sea ice and points with high scattering index (heavy clouds and precipitation)
  - 1dvar (retrieval) approach
- Overall positive impact with NRL tests
  - Occasional poor TC track forecasts have prevented transition to OPS
- Several recent changes to NAVDAS reduced the inherent model/analysis moist bias → redo tests
- We will implement nonlinear radiance assimilation with NAVDAS-AR
- HIRS radiance assimilation
  - Assimilate NOAA-17 ch 2,3,4 to complement AMSU-A for the upper atmosphere
  - Not transitioned yet

Global and Mesoscale 4DVAR NAVDAS-AR

- NAVDAS-AR provides a flexible framework
  - Weak constraint formulation allows for model error to be included
  - Other forecast models (and associated components can be used)
  - Adjoint of NAVDAS-AR was readily coded

- NAVDAS vs. NAVDAS-AR
  - NAVDAS Cost → O(obs 2)
  - NAVDAS-AR Cost → O(obs) + M resolution
  - Cost crossover ≈ 1 million observations

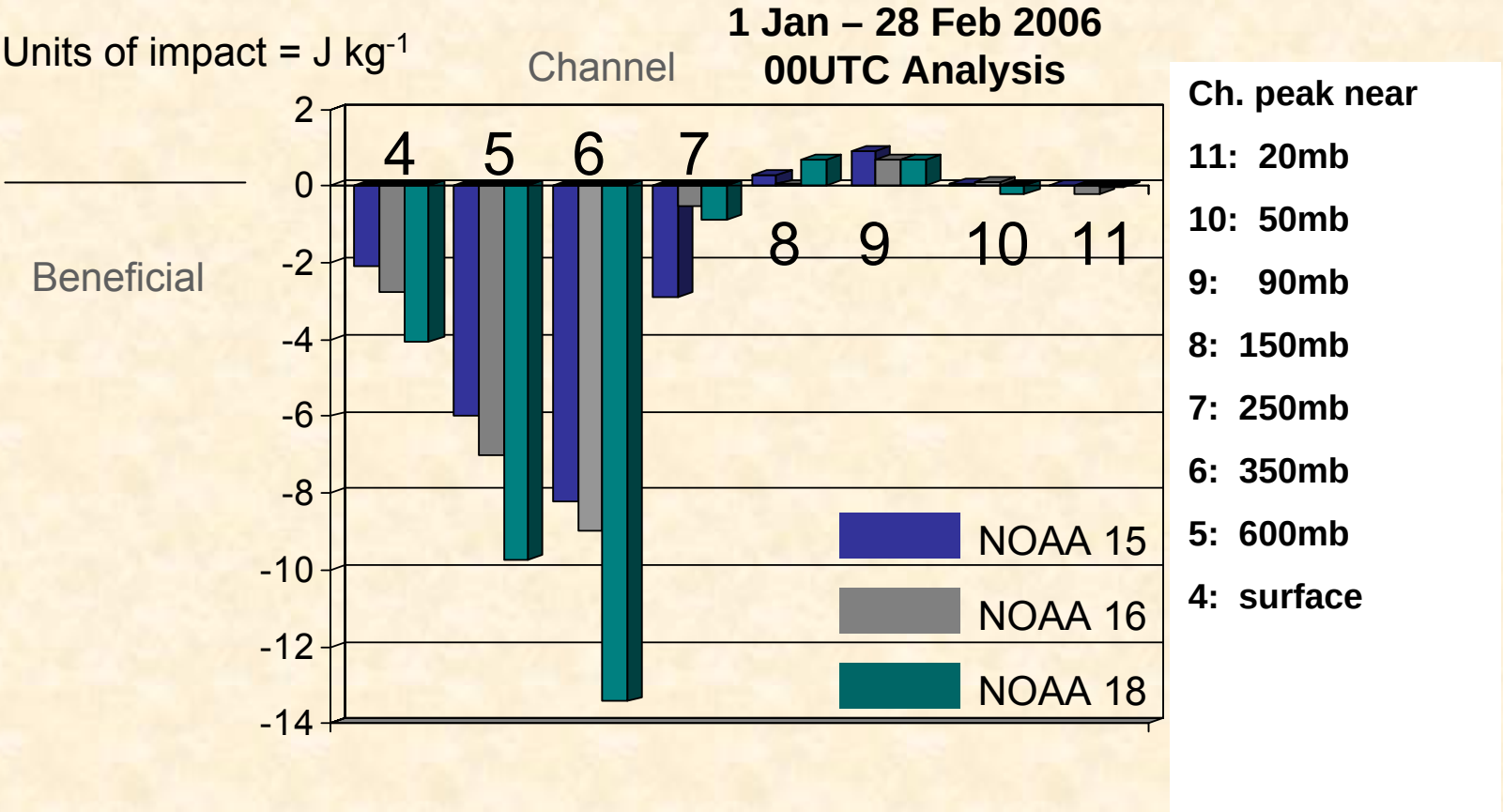
- Status:
  - Implemented AMSU-A radiance assimilation (using JCSDA CRTM)
  - Forecast skill on par with NAVDAS (single outer loop)
  - 2nd outer loop shows significant improvement in forecast skill
  - We still need to optimize code, e.g. observation selection for 4dvar and higher resolution inner loop.

Observation Impact Methodology

- New mathematical technique using NAVDAS and NOGAPS adjoint models
- Observation impact generated once per day at 00 UTC
- Uses operational (beta) analysis fields and operational innovation vectors from NAVDAS / NOGAPS
- Results are used to
  - evaluate observation quality
  - tune observation reject lists
  - guidance for modifying assimilation procedures
  - Select AIRS channels for assimilation

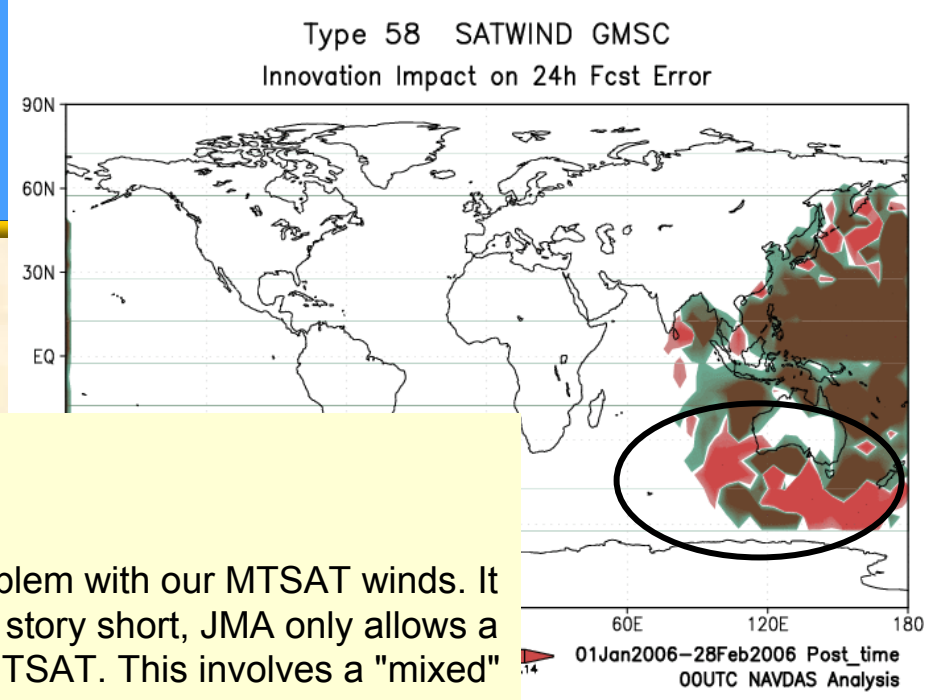
Baker and Daley (QJRMS, 2000)
Langland and Baker (Tellus, 2004)

Impact for AMSU-A channels

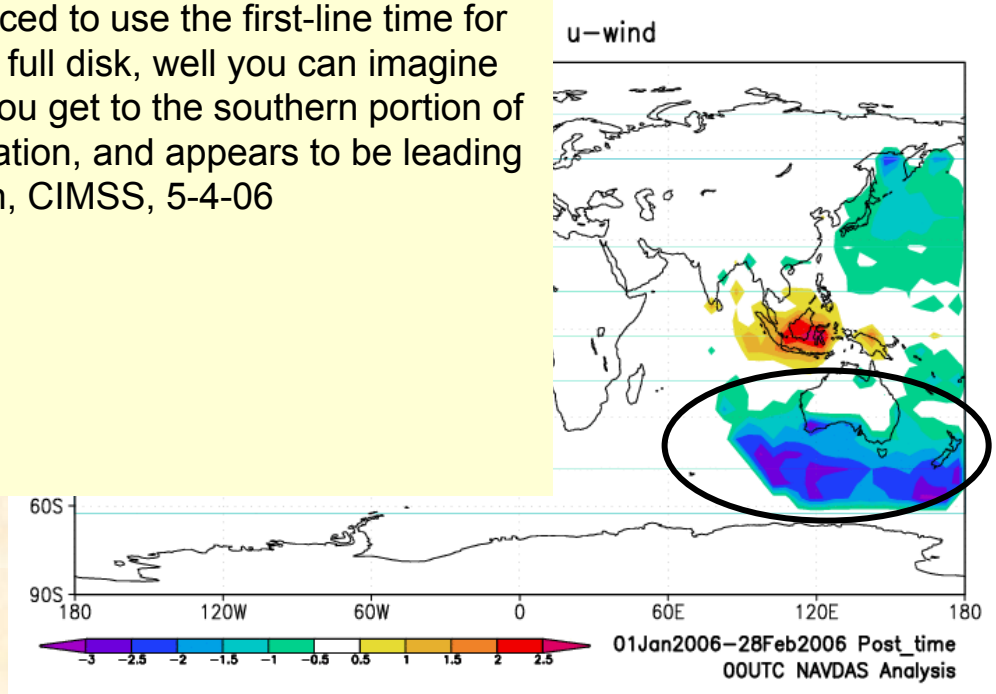


Results suggest a problem with assimilation of ch 8 and 9
Likely sources are the operational bias correction and insufficient model and analysis resolution

Date: Jan-Feb 2006

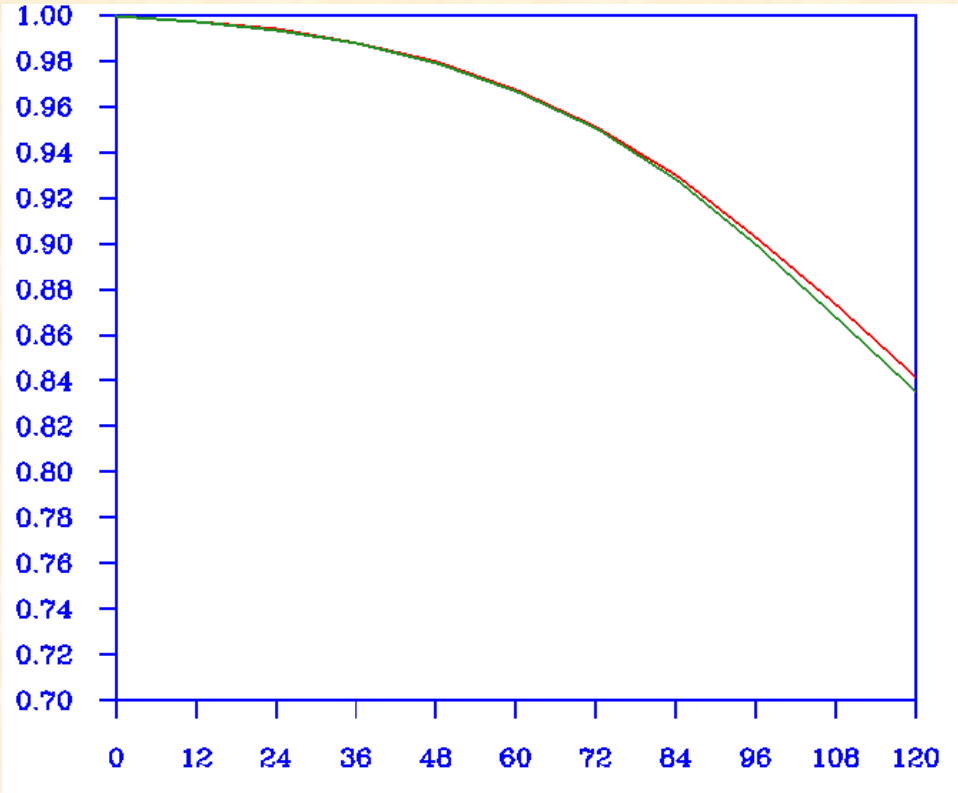


Folks, believe it or not we think we have isolated the problem with our MTSAT winds. It does indeed involve a processing issue. To make a long story short, JMA only allows a certain imaging schedule for producing SH winds from MTSAT. This involves a "mixed" imaging strategy where a full disk is used with two SH-only scans. Problem is they don't provide the scan-line times for us, so we are forced to use the first-line time for the entire image. Since it takes 22 minutes to scan a full disk, well you can imagine there is a significant timing error that develops when you get to the southern portion of the full disk scan. This deltaT affects our speed calculation, and appears to be leading to the slow speed bias. -- Chris Velden, CIMSS, 5-4-06

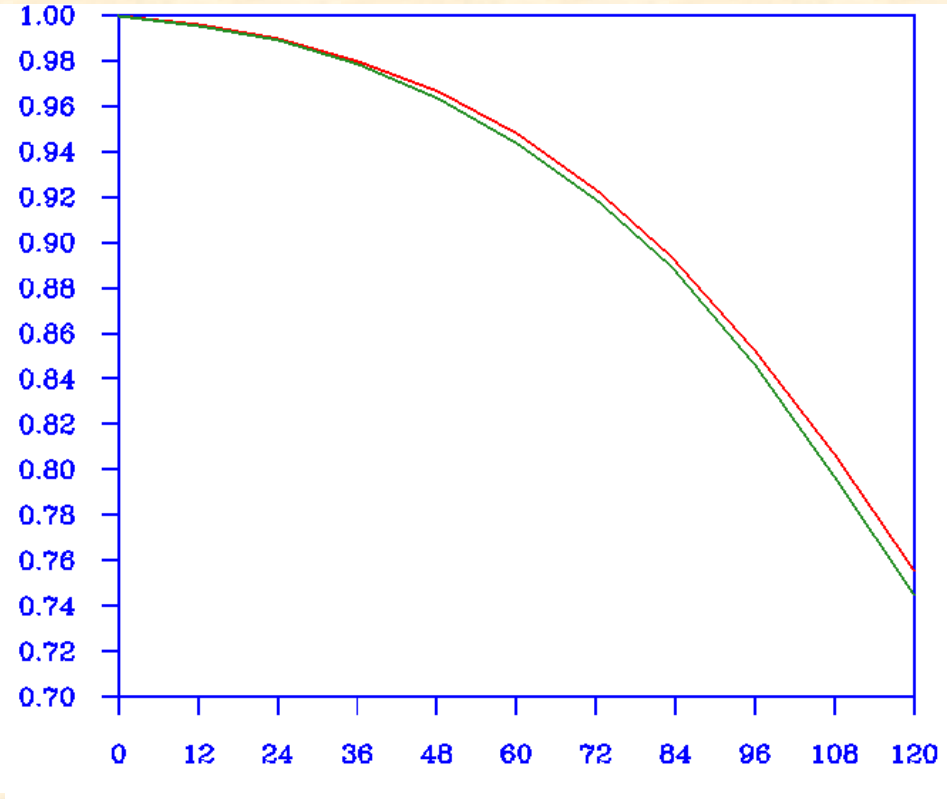


Restricting SSEC MTSAT Winds

500 mb Height Anomaly Correlation



Northern Hemisphere



Southern Hemisphere

Restricted Winds **Control**

February 16 – March 27, 2006

Current And Future Research Efforts

- NRL Aerosol Analysis and Prediction System (NAAPS)
  - Visibility and health risks
  - Assimilate MODIS and AVHRR aerosol optical thickness (AOT)
  - Operational at FNMOC in 2007
- Ocean modeling and assimilation (NRL- Stennis)
  - NAVDAS and NAVDAS-AR will provide framework
- Upper atmosphere assimilation and modeling (NRL-DC)
  - To 120 km and above
  - Ozone and GPS/RO assimilation
  - Higher-peaking SSMIS channels
  - Microwave limb sounder for temperature, humidity and ozone
- Prepare for assimilation of future satellites
  - METOP, NPP and NPOESS
  - Lessons learned from SSMIS

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.