NESDIS Contributions to JCSDA Program

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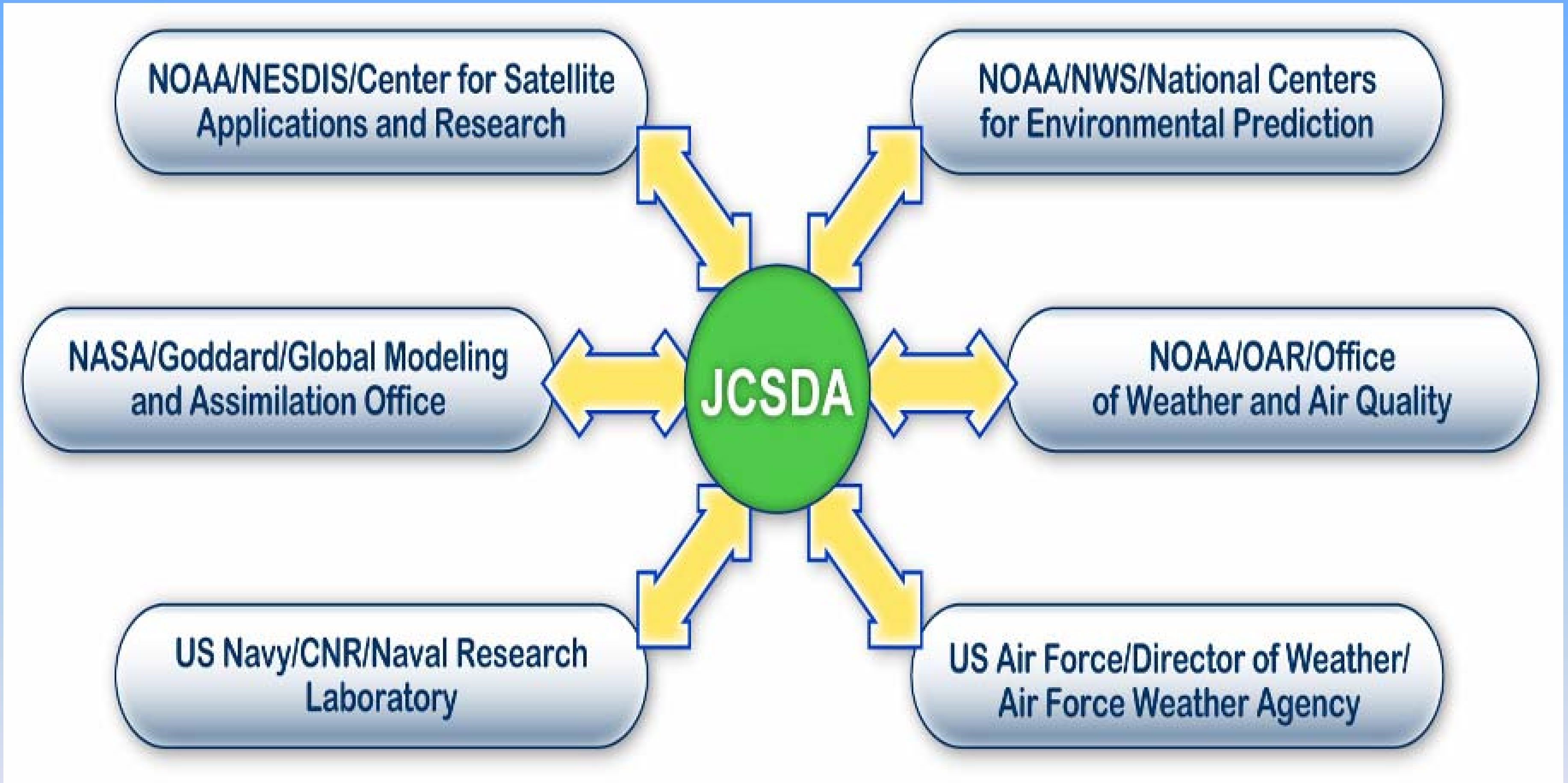
NOAA/NESDIS/Center for Satellite Applications and Research

Presented at the Workshop on Applications of Remotely Sensed Observations in Data Assimilation, University of Maryland, July 31, 2007

Overview

- **NESDIS/STAR Contributions**
  - JCSDA organizational developments
  - Science development and implementation
- **NESDIS/STAR Accomplishments**
  - Community Radiative Transfer Model
  - Improve AIRS data assimilation with full spectral/fovs
  - SSMIS cloudy radiance/UAS channels
  - GPS/RO-COSMIC data assimilation
  - Assimilation using satellite derived air quality products
  - Peer Reviewed Publications
- **Scientific Challenges**

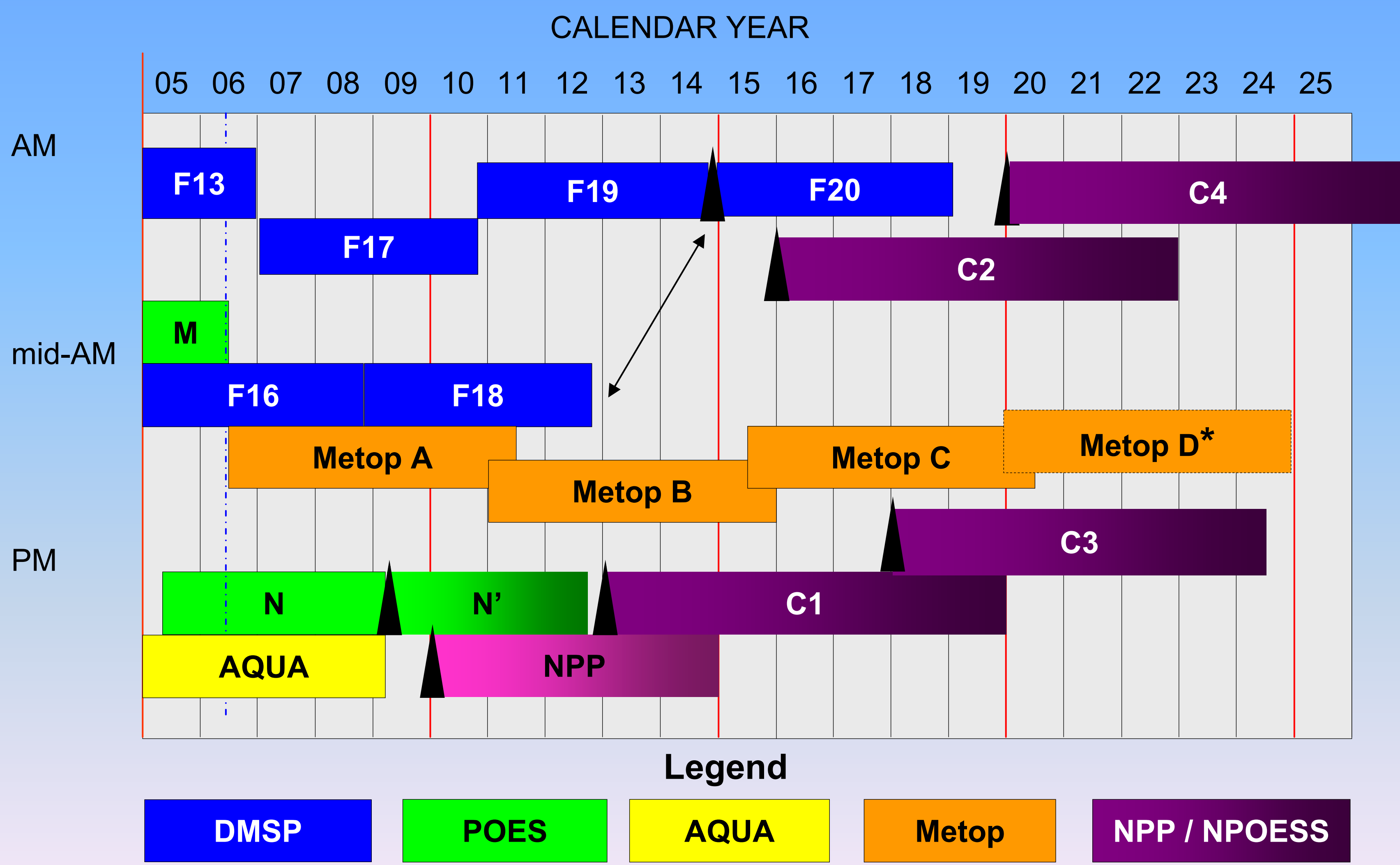
JCSDA Partners



In 2001 the Joint Center was established[2] by NASA and NOAA and in 2002, the JCSDA expanded its partnerships to include the U.S. Navy and Air Force weather agencies.

[2] *Joint Center for Satellite Data Assimilation: Luis Uccellini, Franco Einaudi, James F. W. Purdom, David Rogers: April 2000.*

Polar Satellites Fly-out Schedule



* Metop D is not funded.

NESDIS Supports to the JCSDA Organizational Developments

- Provide annual funding of $3.3M thru NOAA base appropriation
- Leverage JCSDA program through GOES-R, POES, NDE, R2O and other Cal/Val programs
- Provide essential staffs for program planning, JCSDA newsletters, monthly/quarterly highlights, seminars, website, funding transfer, and travel orders
- Recruit 3 new FTEs and train more contractors to work closely with EMC on various data assimilation projects
- Provide centralized offices for visitors and contractors
- Manage the federal funding opportunity (FFO) proposal selection with NOAA grant program
- Provide timely access to POES/GOES/Metop operational satellite data

NESDIS/STAR Personnel Supports

Mitch Goldberg – Administrative/AIRS Science

Fuzhong Weng – JCSDA Deputy Director/Program Manager/MW Science

Mark Liu – CRTM/Transfer scheme, clouds and aerosols

Yong Han – CRTM/OPTRAN/Zeeman splitting

Yong Chen – CRTM/validation

Tom Kleespies – Radiative transfer

Banghua Yan – Surface emissivity/MW impacts studies

Min-Jeong Kim – Cloudy radiance assimilation

Shobha Kondragunta – Air quality data assimilation

Sid Boukabara – Cloudy 1Dvar

Tong Zhu – OSSE

Jim Jung – AIRS/MODIS impacts studies

Lidia Cucurrul – GPS/RO

Haibin Sun – OSSE

Andy Harris – SST analysis

Jerry Zhan – Soil moisture analysis

Chengzhi Zou – NDVI impact assessments

Jaime Daniels – GOES/MODIS winds

Ron Vogal – IR emissivity

Water Wolf – AIRS/MODIS data dissemination

Creg Krawoski – Satellite data BUFRing

Geoge Ohring – JCSDA Quarterly

Ada Armstrong – Adminstrative Assistance

Ken Carey – Program planning support

Eric Baylor – Ocean data assimilation planning

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

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

What is Data Assimilation?

Data assimilation is an analysis technique in which the observed information is accumulated into the model state by taking advantage of consistent constraints with laws of time evolution and physical properties

Satellite Radiance Assimilation and Physical Retrieval – Variational Technique

- **Require forward models and Jacobians**
- **Quantify error covariances**
  - Background
  - Forward model
  - Observations
- **Remove biases**
  - Background
  - Forward model
  - Observations

$$J = \frac{1}{2}\left(\mathbf{x}-\mathbf{x}^b\right)^T \mathbf{B}^{-1}\left(\mathbf{x}-\mathbf{x}^b\right) + \frac{1}{2}\left[\mathbf{I}(\mathbf{x})-\mathbf{I}^o\right]^T (\mathbf{E}+\mathbf{F})^{-1}\left[\mathbf{I}(\mathbf{x})-\mathbf{I}^o\right]$$

where

x is a vector including all possible atmospheric and surface parameters.

I is the radiance vector

B is the error covariance matrix of background

E is the observation error covariance matrix

F is the radiative transfer model error matrix

Radiative Transfer Theory

$$\mu \frac{d\mathbf{I}(\tau,\Omega)}{d\tau} = -\mathbf{I}(\tau,\Omega) + \frac{\omega}{4\pi}\int_0^{4\pi} \mathbf{M}(\tau,\Omega,\Omega')\mathbf{I}(\tau,\Omega')d\Omega' + (1-\omega)\mathbf{S}_t$$

where $\mathbf{I} = [I,Q,U,V]^T$

$$\mathbf{I}(0,\Omega) = \mathbf{S}_t, \Omega(\mu < 0)$$

$$\mathbf{I}(\tau_0,\Omega) - \int_0^{2\pi} \mathbf{A}(\Omega,\Omega')\mathbf{I}(\tau_0,\Omega')d\Omega' = \boldsymbol{\varepsilon}\mathrm{B}(\mathrm{T_s}), \Omega(\mu > 0)$$

Pre-JCSDA Program Approach

- **No scattering**
- **Constant emissivity over land and for sea ice**
- **Fixed CO2, O3 and other trace gases**

JCSDA Program Approach

- **Scattering from clouds, precip and aerosols**
- **Variable land emissivity, sea ice and sea ice**
- **Variable trace gases**

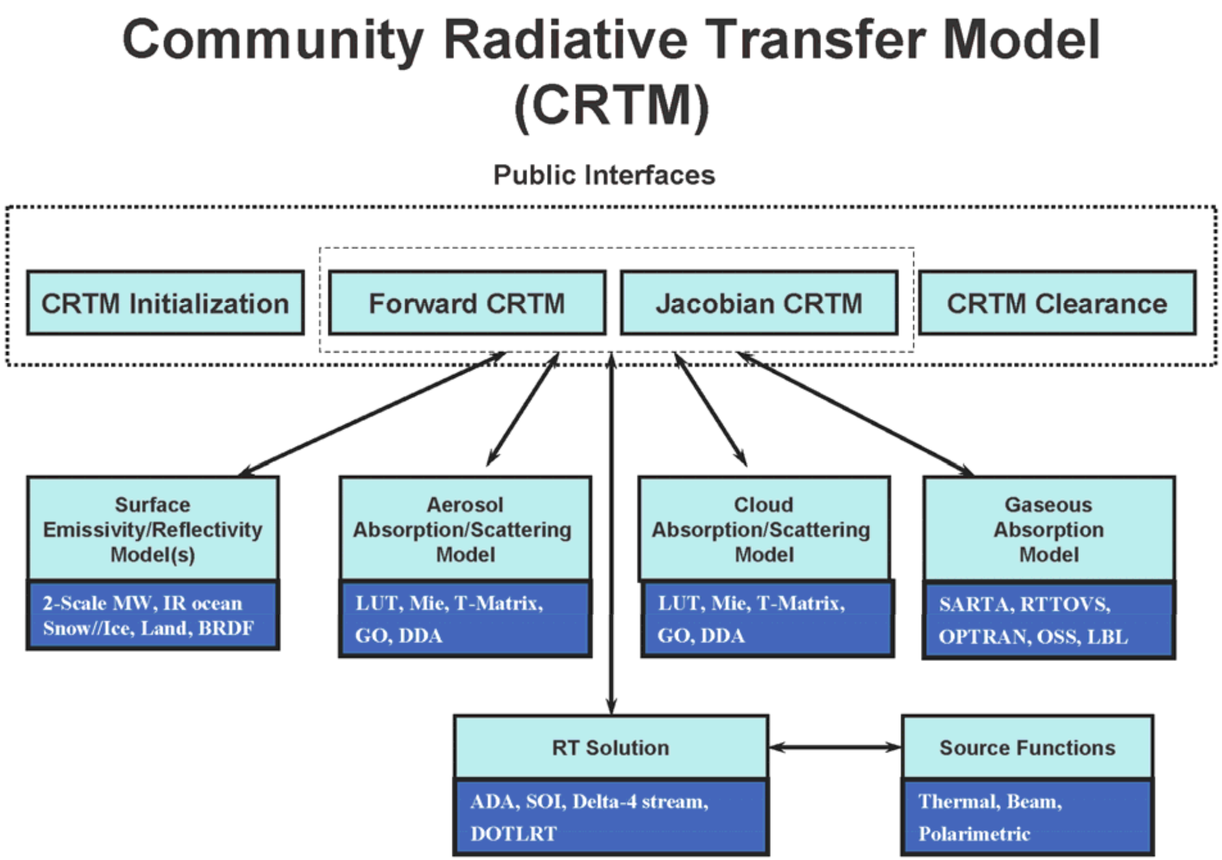
Community Contributions

- **Community Research: Radiative transfer science**
  - UWisc – Successive Order of Iteration
  - University of Colorado –DOTLRT
  - UCLA – Delta 4 stream vector radiative transfer model
  - Princeton Univ – snow emissivity model improvement
  - NESDIS – Advanced doubling and adding scheme, surface emissivity models, LUT for aerosols, clouds, precip
  - AER – Optimal Spectral Sampling (OSS) Method
  - UMBC – SARTA
- **Core team (ORA/EMC): Smooth transition from research to operation**
  - Maintenance of CRTM
  - CRTM interface
  - Benchmark tests for model selection
  - Integration of new science into CRTM

CRTM Capability

Supported Instruments

- GOES-R ABI
- Metop IASI
- TIROS-N to NOAA-18 AVHRR
- TIROS-N to NOAA-18 HIRS
- GOES-8 to 13 Imager channels
- GOES-8 to 13 sounder channel 08-13
- Terra/Aqua MODIS Channel 1-10
- METEOSAT-SG1 SEVIRI
- Aqua AIRS
- Aqua AMSR-E
- Aqua AMSU-A
- Aqua HSB
- NOAA-15 to 18 AMSU-A
- NOAA-15 to 17 AMSU-B
- NOAA-18 MHS
- TIROS-N to NOAA-14 MSU
- DMSP F13 to15 SSM/I
- DMSP F13,15 SSM/T1
- DMSP F14,15 SSM/T2
- DMSP F16 SSMIS
- NPP ATMS
- Coriolis Windsat



Significance: CRTM framework is designed to accelerate transition of new radiative transfer science for assimilation of operational and research satellite data in NWP models and to improve the retrieval technology in satellite remote sensing system

Hyperspectral Satellite Sensors Requires Fast RT Simulators

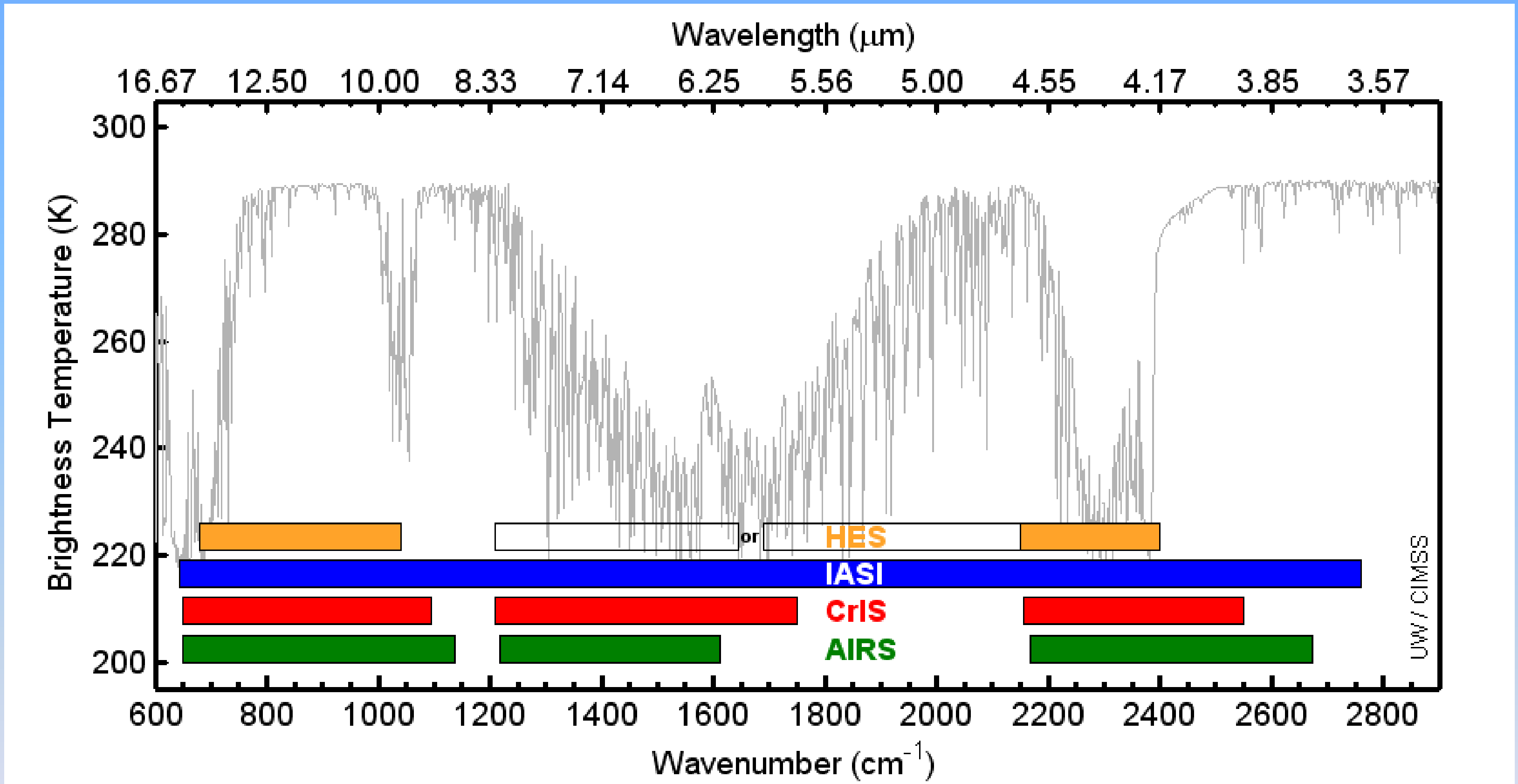
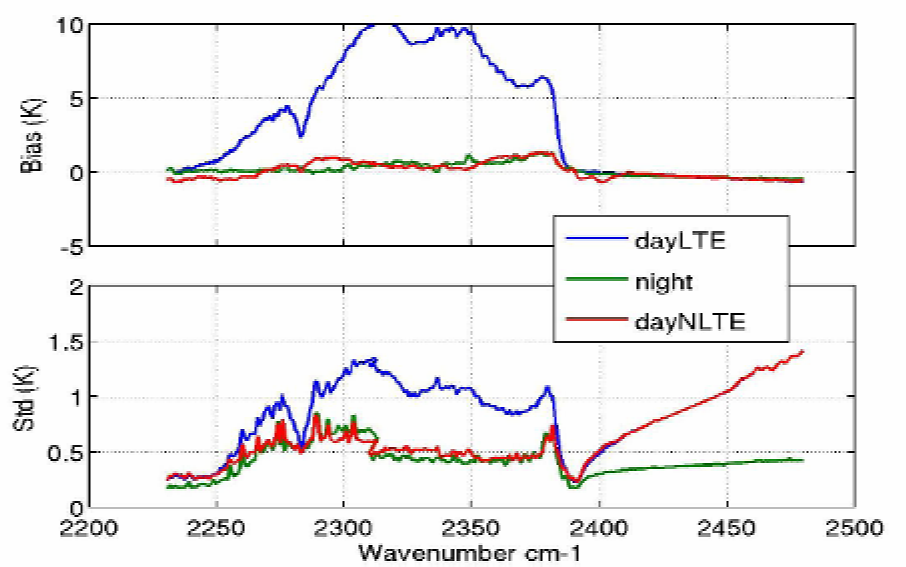
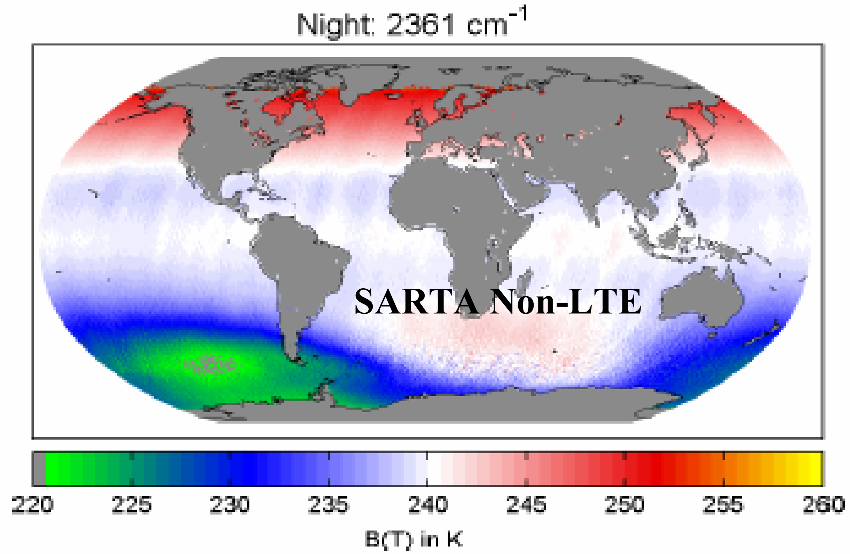


Figure. The whole IR spectral region (gray line) could be covered via a single high-spectral and temporal resolution measurements.

Radiative Transfer Process including non-LTE Process

1. SARTA is a forward model developed by University Maryland at Baltimore County (UMBC).
2. A fast gas absorption model fitted with AIRS observations with the best accuracy comparing with all other fast models in the IR wavelengths, with about 0.2 K accuracy in mid- to lower-tropospheric temperature and water vapor sounding channels.
3. The model allows the user to vary mixing ratios of H20, O3, CH4, and CO. It also includes minor gas mixing ratios of CO2, SO2, HNO3 and N2O.
4. Non-LTE is incorporated .





Significance: In CRTM framework, the original SARTA program is re-coded to meet the CRTM standard. In addition, the SARTA tangent-linear and adjoint models have been also completed. This implementation for the forward and Jacobian computation is very useful for operational applications and for the consistency between forward and adjoint calculations in satellite data assimilation.

CRTM Including Zeeman Splitting Effects

Energy level splitting:

In the presence of an external magnetic field, each energy level associated with the total angular momentum quantum number J is split into 2J+1 levels corresponding to the azimuthal quantum number M = -J, …, 0, …,J

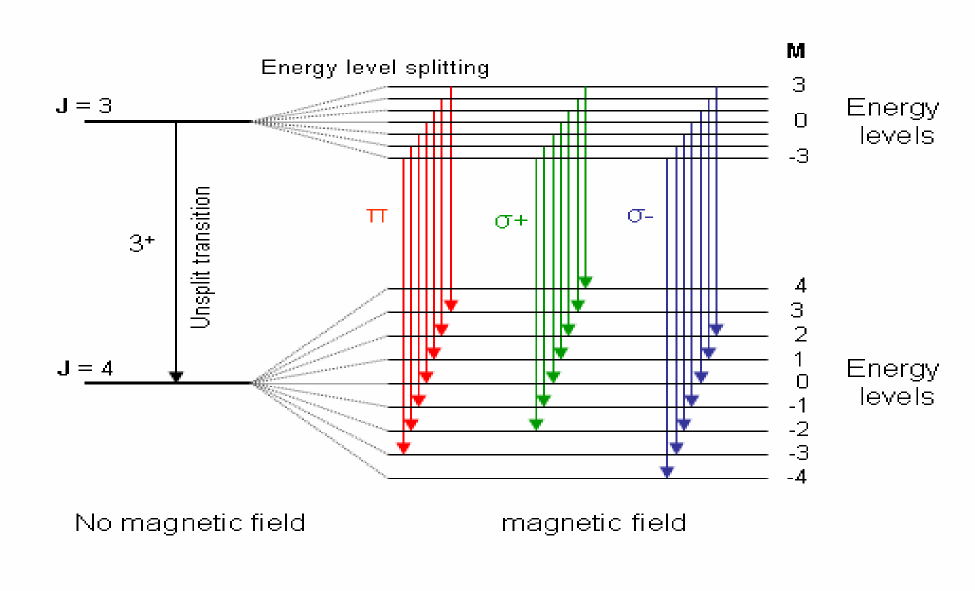
Transition lines (Zeeman components) :

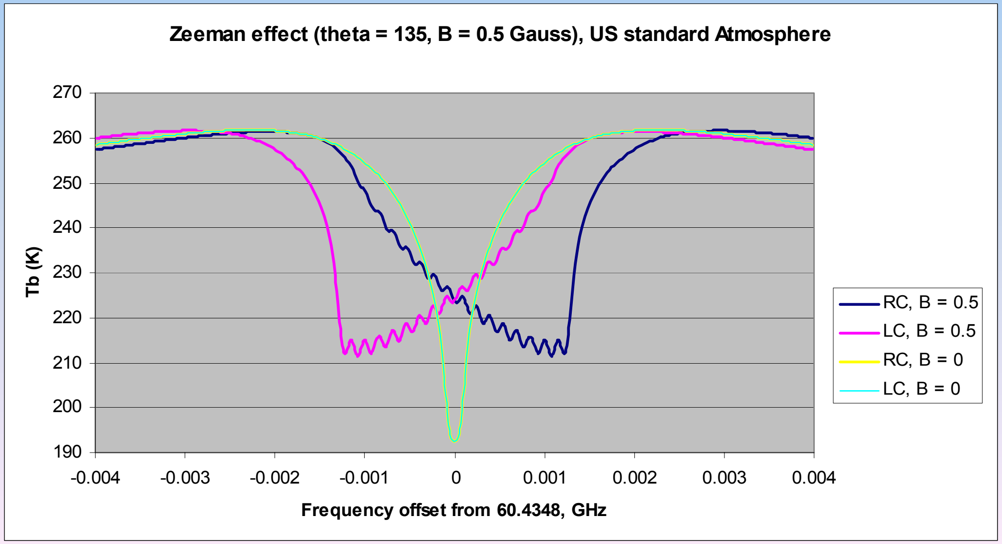
The selection rules permit transitions with $\Delta J = \pm 1$ and $\Delta M = 0, \pm 1$. For a change in J (i.e. J=3 to J=4, represented by 3^+), transitions with

$\Delta M = 0$ are called π components,
$\Delta M = 1$ are called σ+ components and
$\Delta M = -1$ are called σ- components.

Polarization:

The three groups of Zeeman components also exhibit polarization effects with different characteristics. Radiation from these components received by a circularly polarized radiometer such as the SSMIS upper-air channels is a function of the magnetic field strength |**B**|, the angle θ_B between **B** and the wave propagation direction **k** as well as the state of atmosphere, not dependent on the azimuthal angle of **k** relative to **B**.





Performance of Fast Zeeman Absorption Model

(1) Atmosphere is vertically divided into N fixed pressure layers from 0.000076 mb (about 110km) to 200 mb. (currently N=100, each layer about 1km thick).

(2) The Earth's magnetic field is assumed constant vertically

(3) For each layer, the following regression is applied to derive channel optical depth with a left-circular polarization:

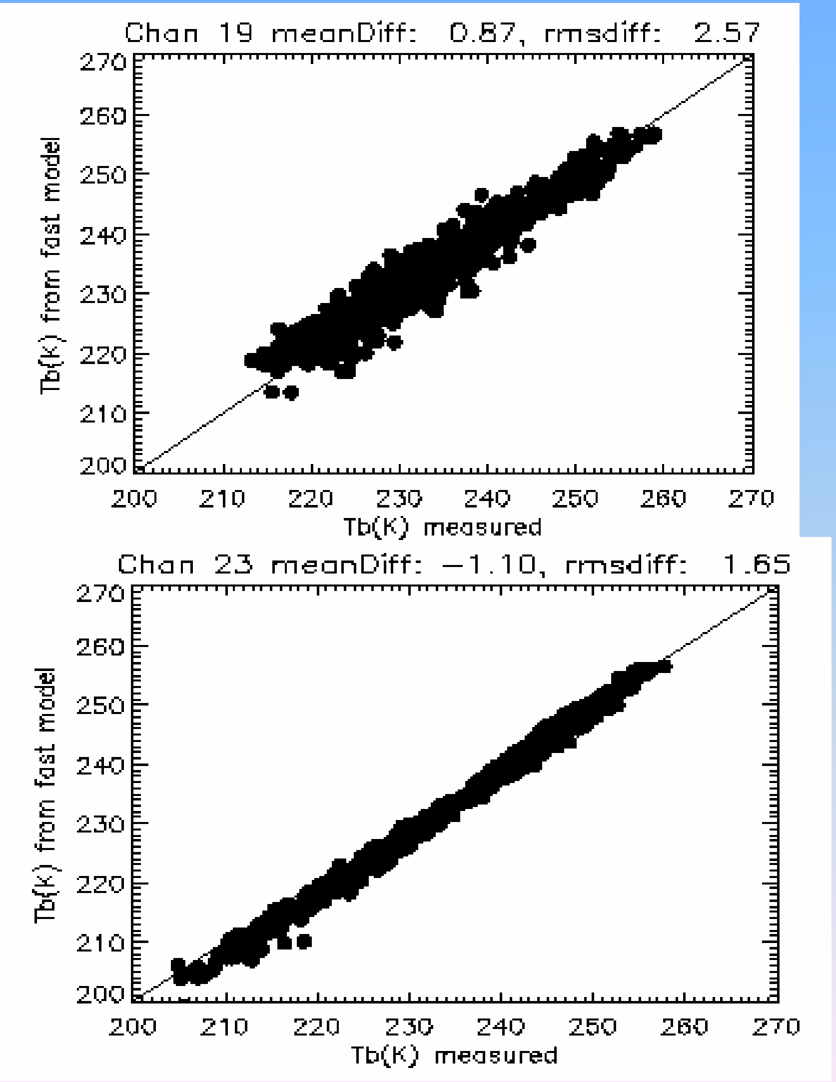
$$T_{b,lc} = \sum_{i=1}^{n} (\tau_{i-1} - \tau_i) T_{air,i}$$

$$\tau_i = \tau_{i-1} \exp(-OD_{lc,i} / COS(\theta)), \quad \tau_0 = 1$$

$$OD_{lc,i} = c_{i,0} + \sum_{j=1}^{m} c_{i,j} x_{i,j}$$

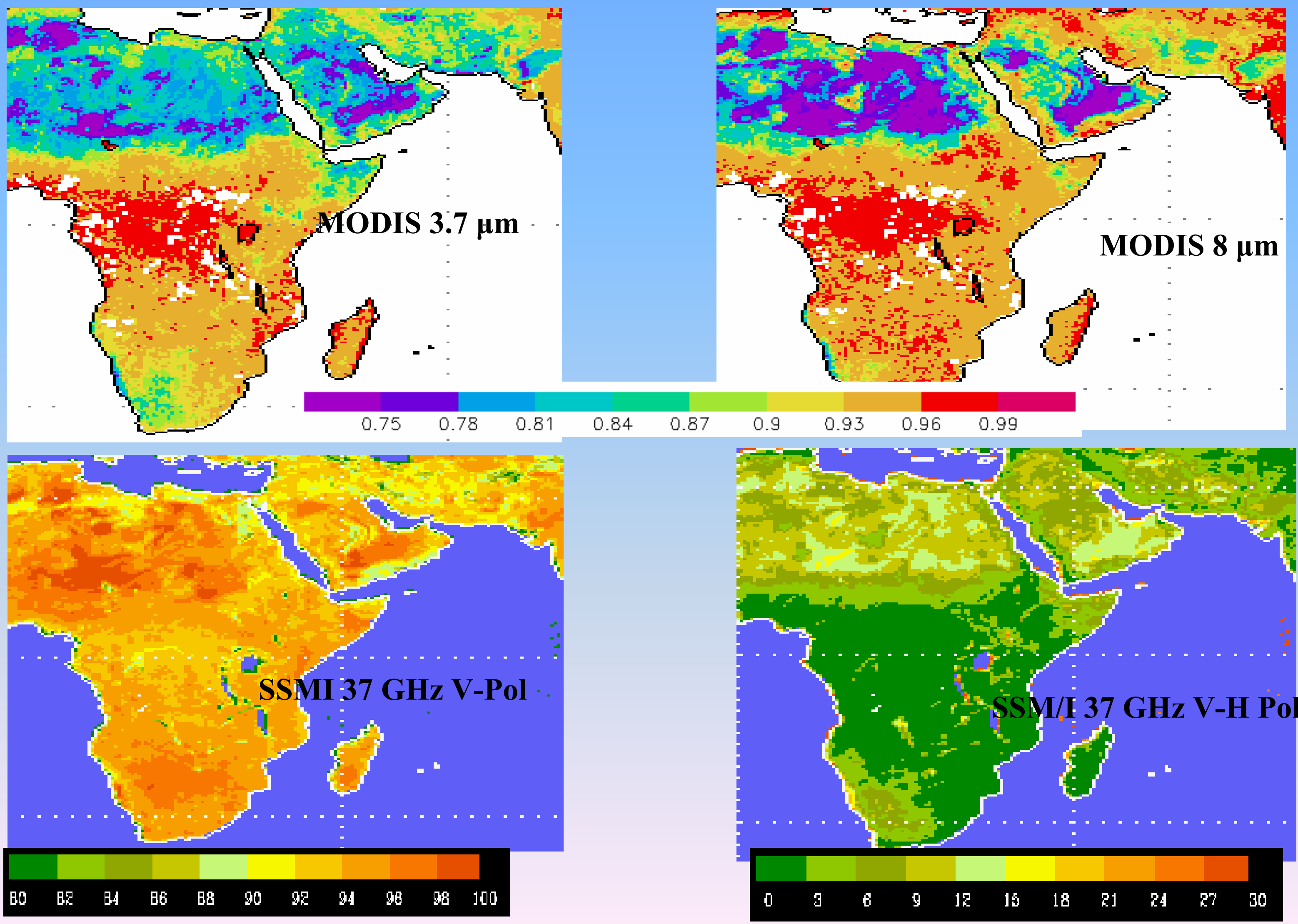
ψ – 300/T; T – temperature
B – Earth magnetic field strength
θ_B – angle between magnetic field and propagation direction

SSMIS UAS Simulated vs. Observed

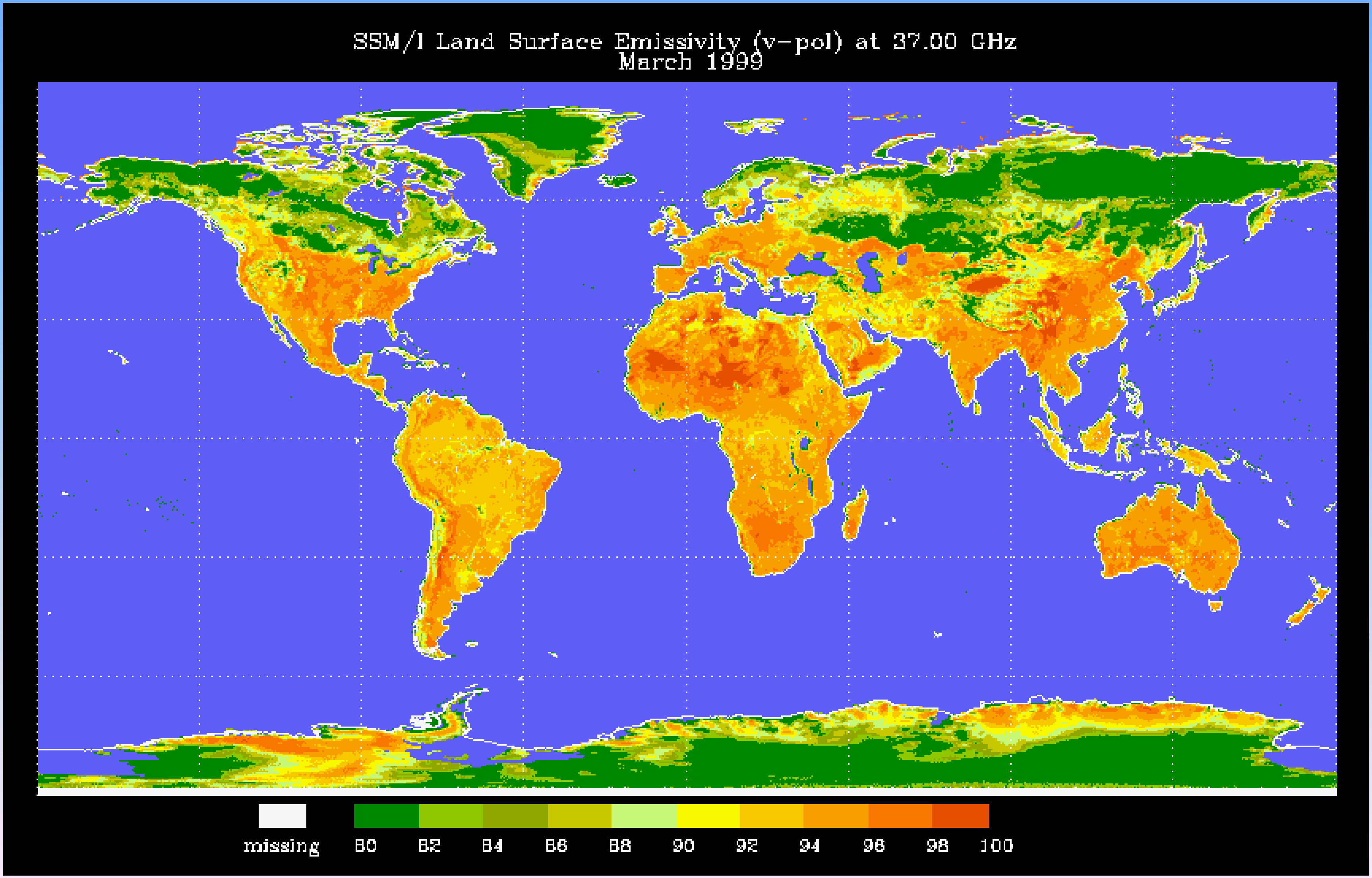


From Han, 2006, 15th ITSC

RT Modeling Handled the Surface Variability through Emissivity



Global Land Emissivity (37V)



Fast Surface Emissivity & Reflectivity Models

Natural Scenes





Optical Theory

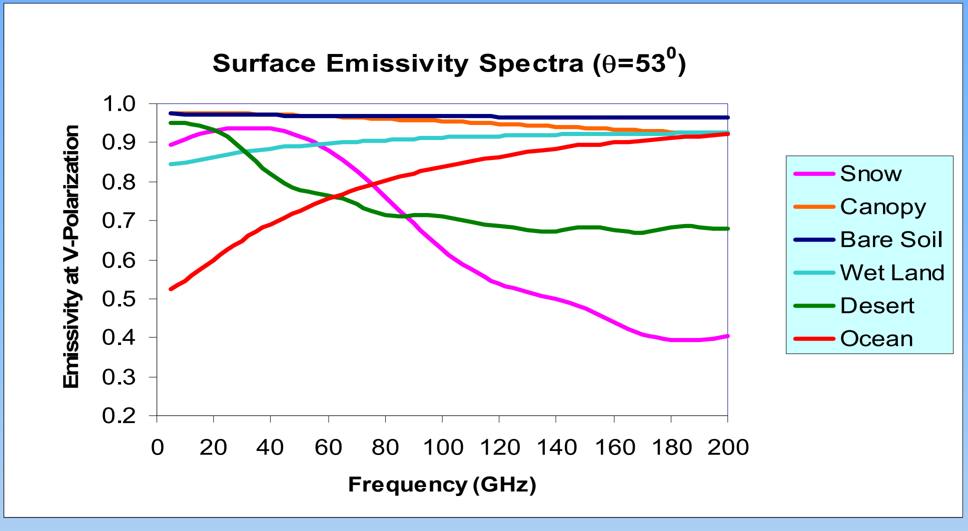
Two-Scale Approx. | **Coherent Reflection** → **Ocean RT Modules**

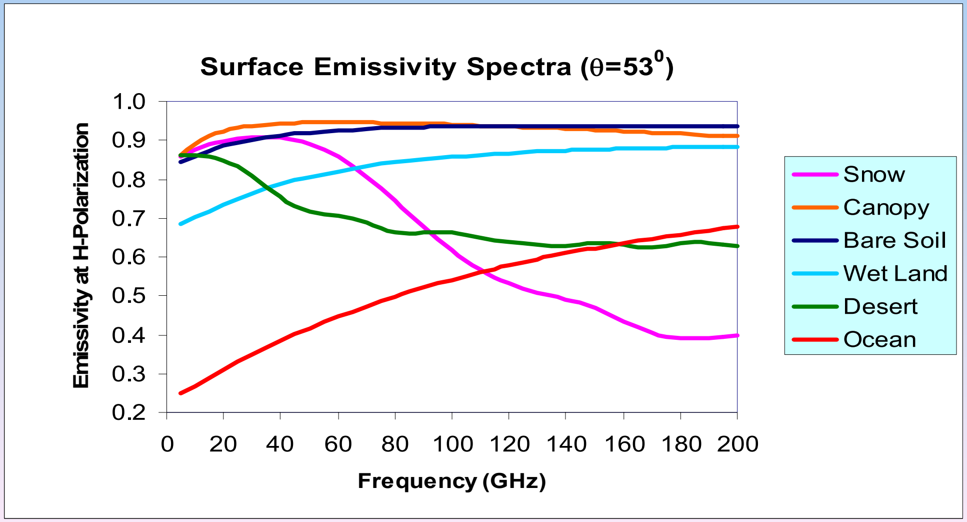
Geometric Optics | **Dense Media Scattering** → **Land RT Modules**

Surface Emissivity Modeling

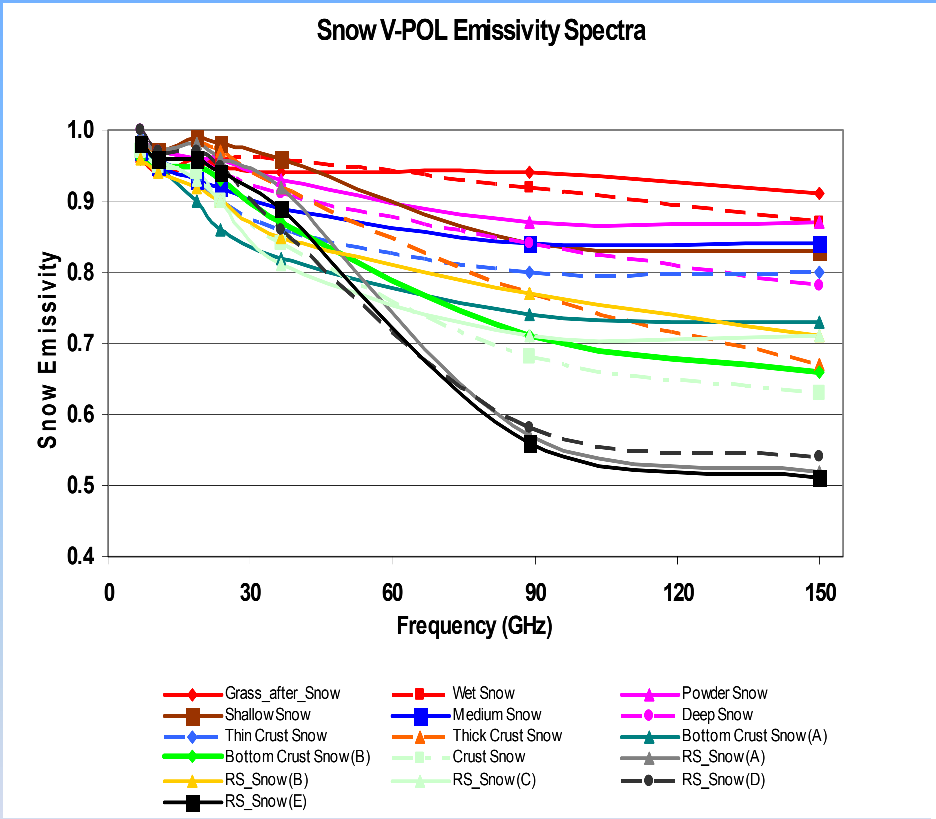
- **Open water** – two-scale roughness theory
- **Sea ice** – Coherent reflection
- **Canopy** – Four layer clustering scattering
- **Bare soil** – Coherent reflection and surface roughness
- **Snow/desert** – Random media

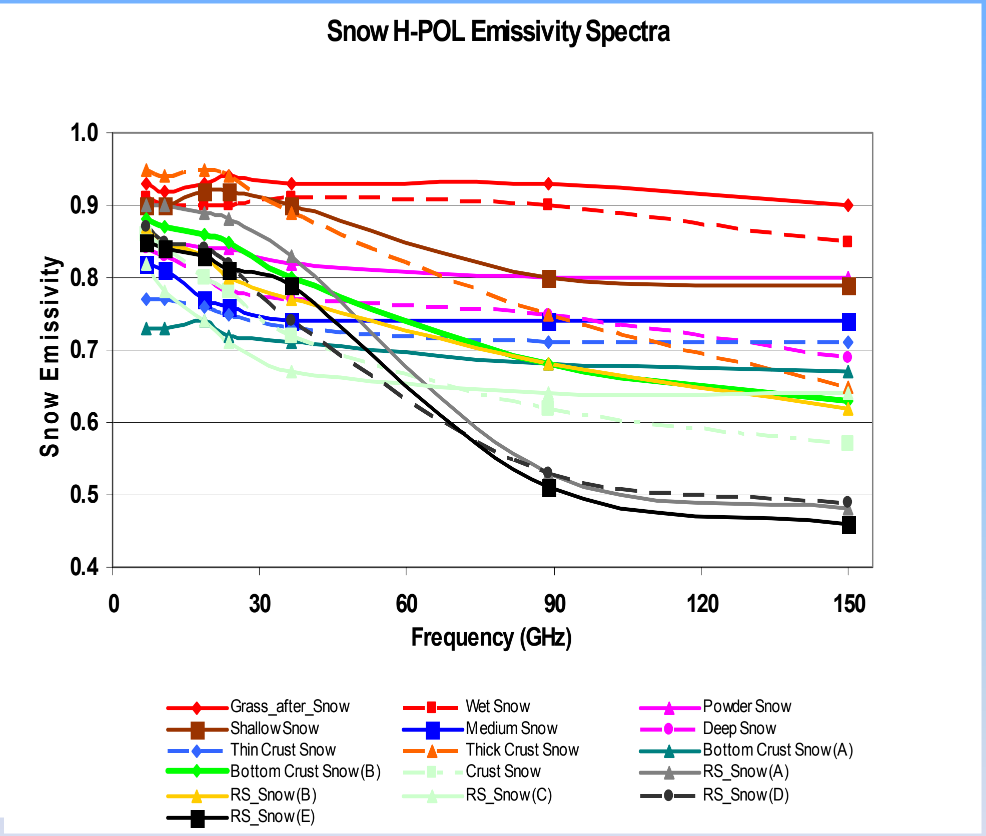
Weng et al (2001, JGR)



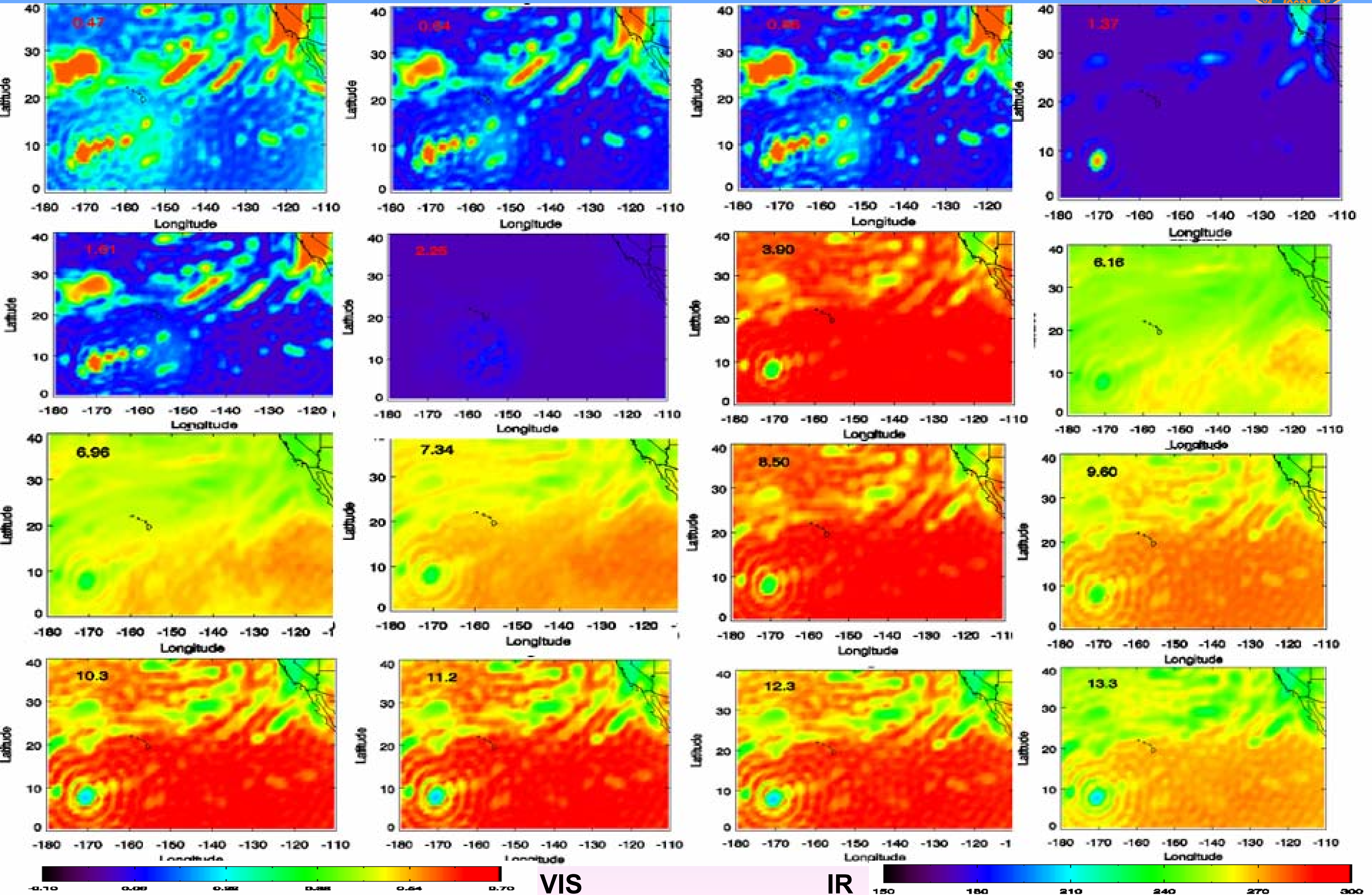


Snow Microwave Emissivity Spectra



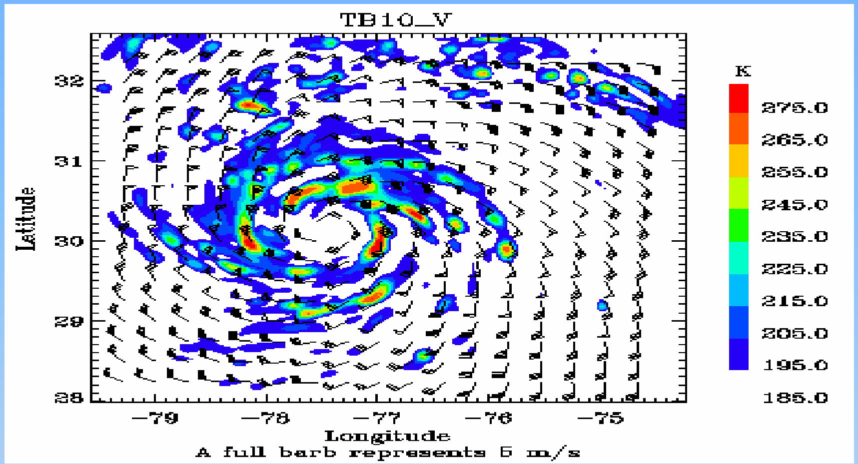


GOES-R ABI Simulations using CRTM

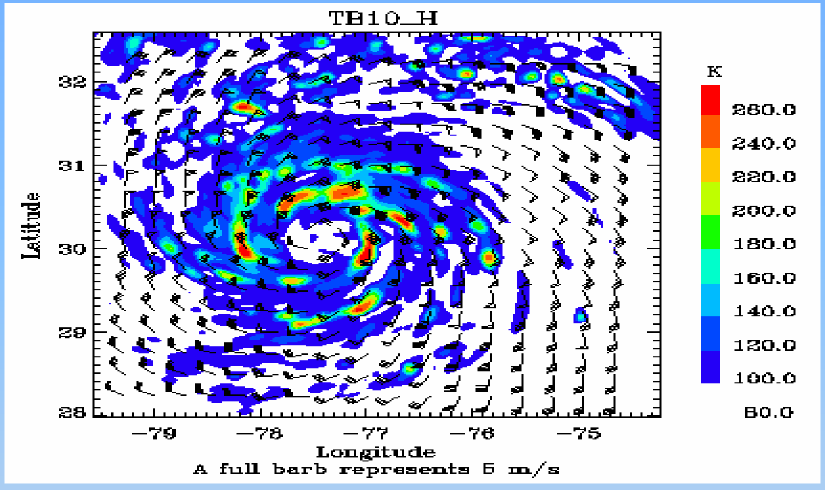


Stokes Radiance Simulations at Microwave Wavelength - Preparation for NPOESS/MIS

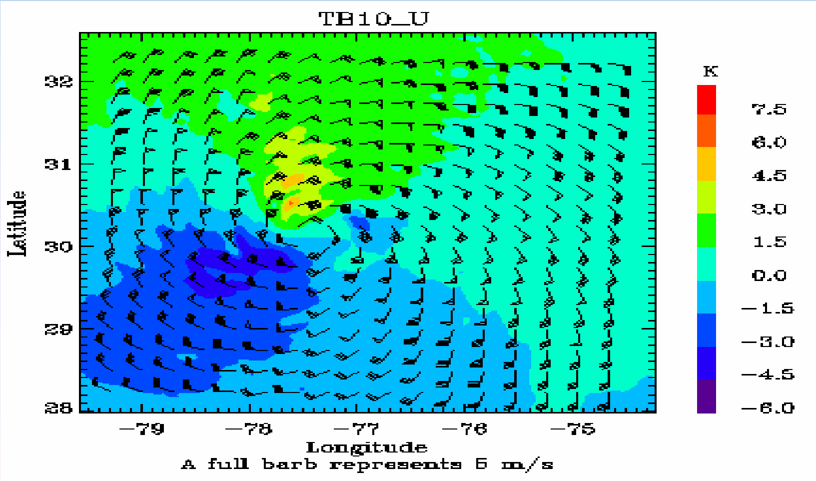
10.7_V



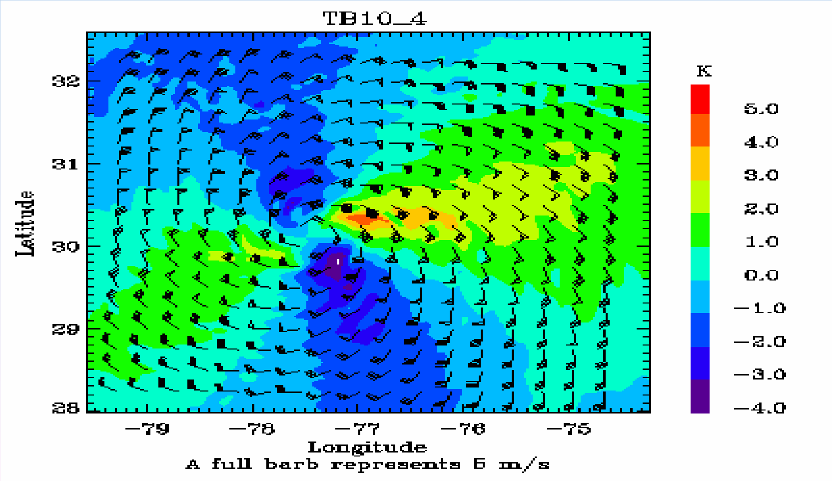
10.7_H



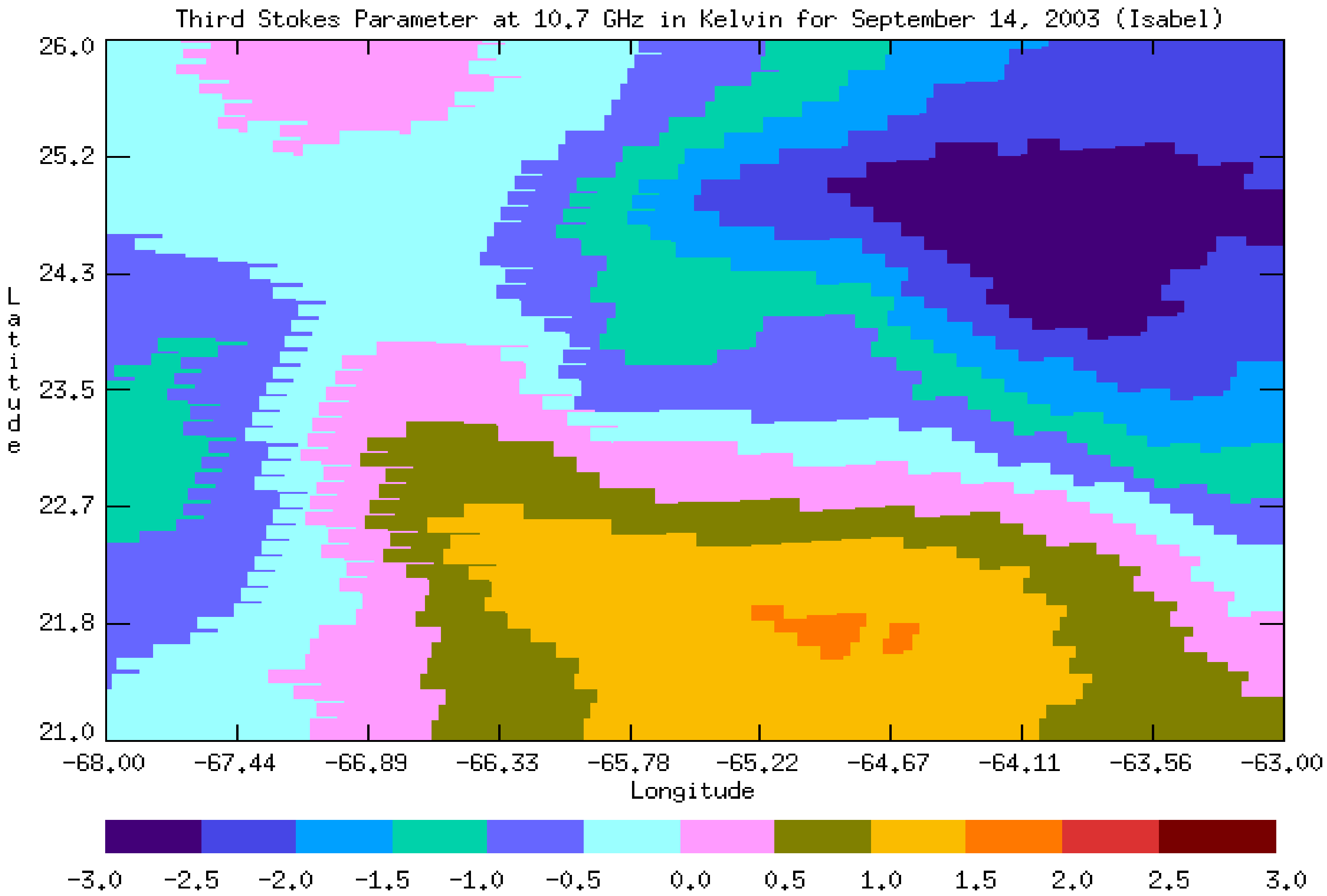
10.7_U



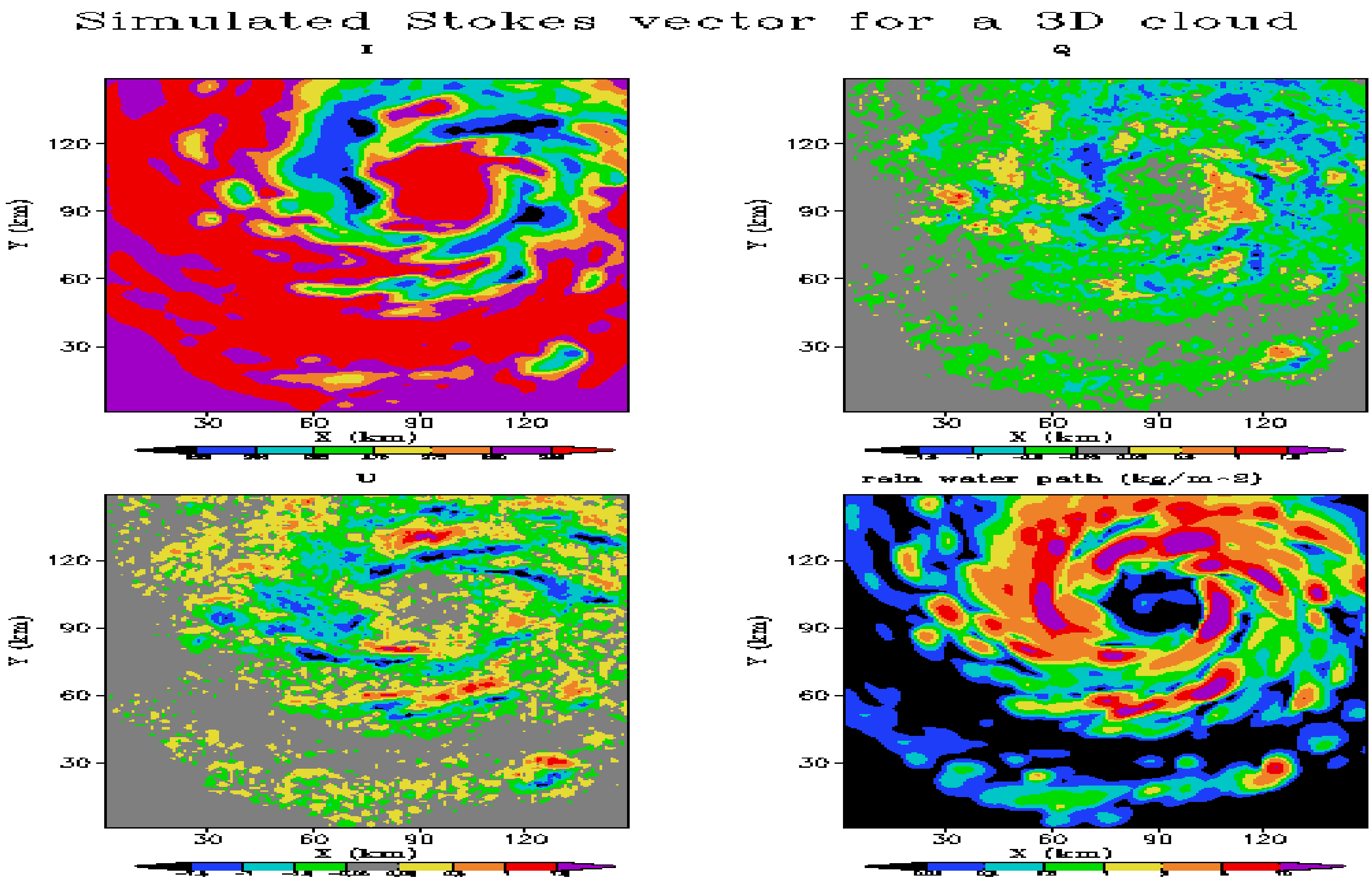
10.7_4



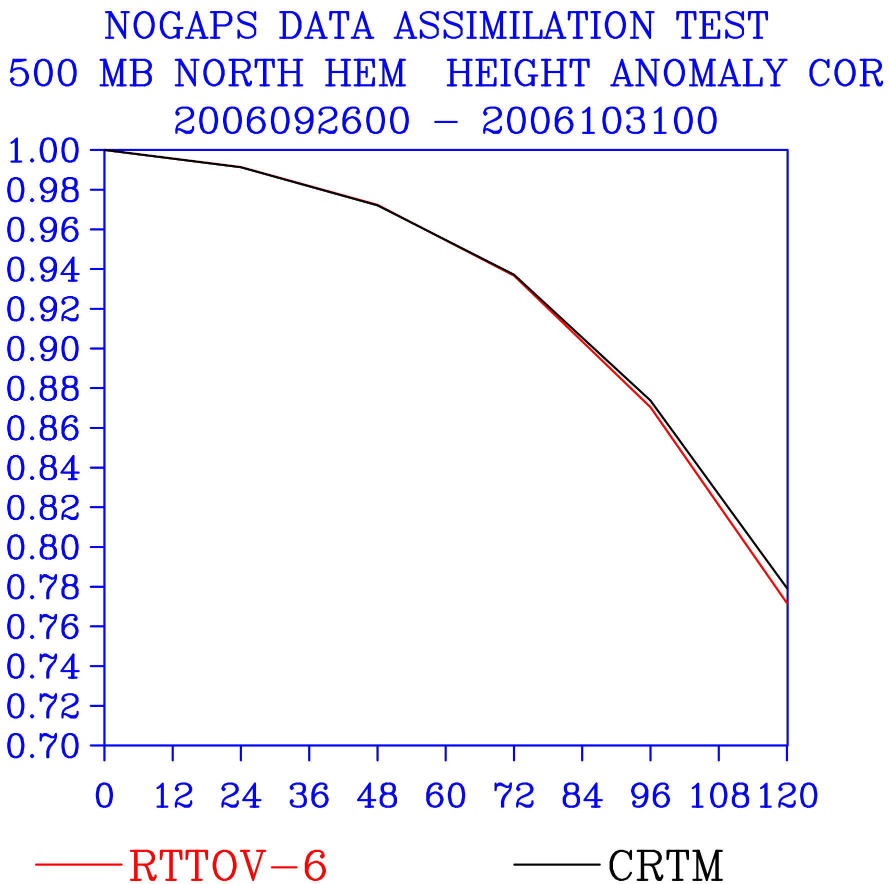
WindSat Measurements for Hurricane Isabel



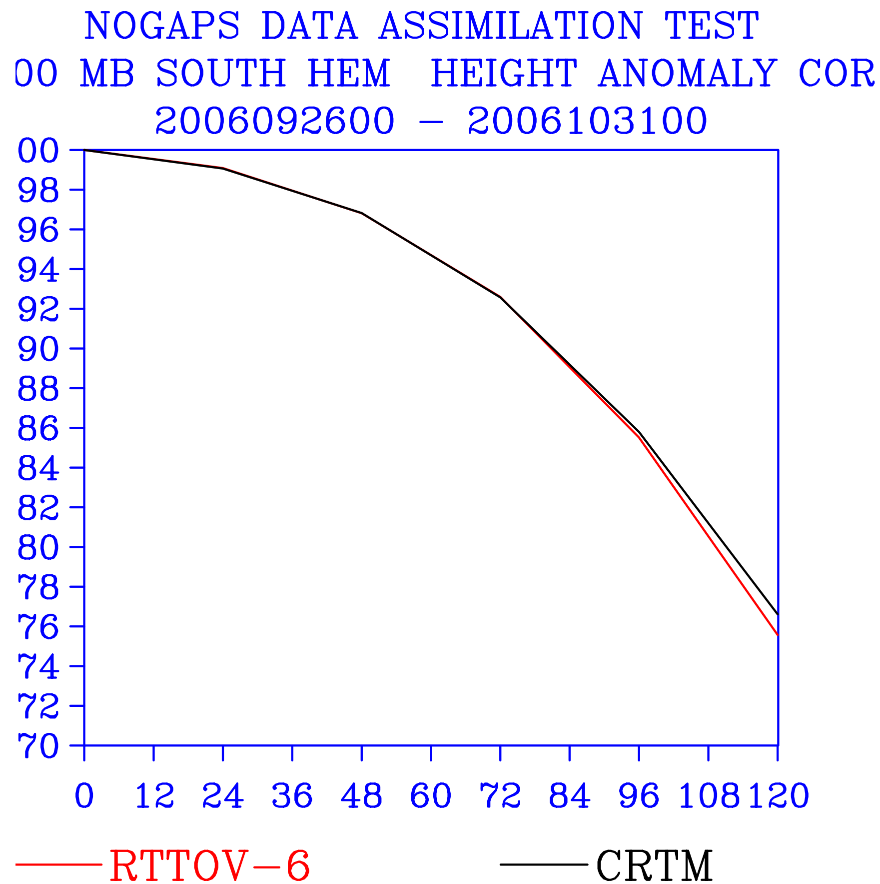
3D Clouds Produce the Third Stokes Component at 10.7 GHz



"CRTM" Impact
500 mb Height Anomaly Correlation (NRL NOGAPS)



Northern Hemisphere



Southern Hemisphere

September 26 - October 19, 2006

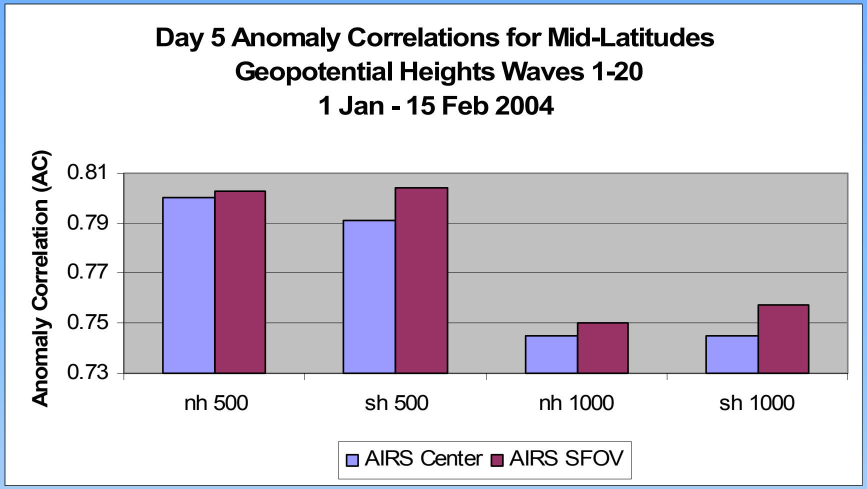
Preparation for Advanced Instruments: Some Recent Advances

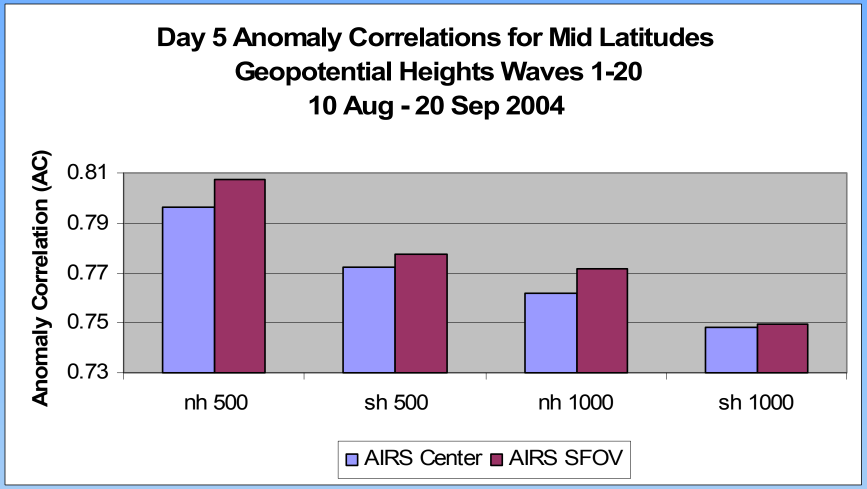
AIRS Data Usage per Six Hourly Analysis Cycle

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	~0.85×10^6 radiances (channels)
Data from all AIRS fovs	~6% more radiances

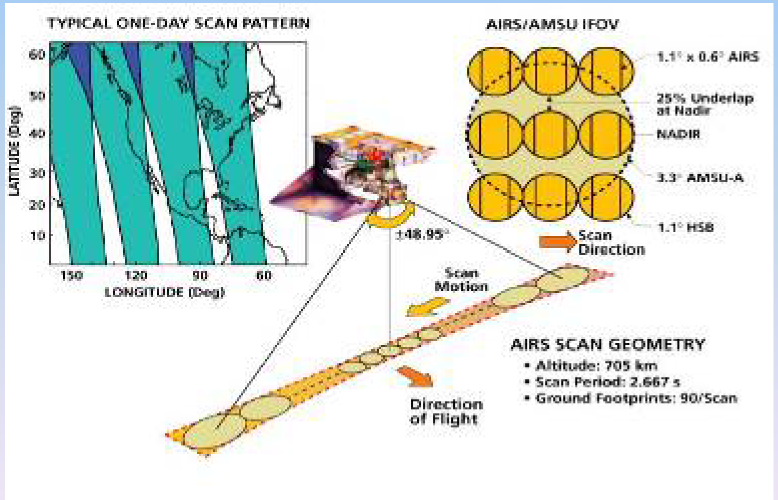
Jim Jung et al., 2007, JCSDA Science Workshop

Full Spatial Resolution Experiment

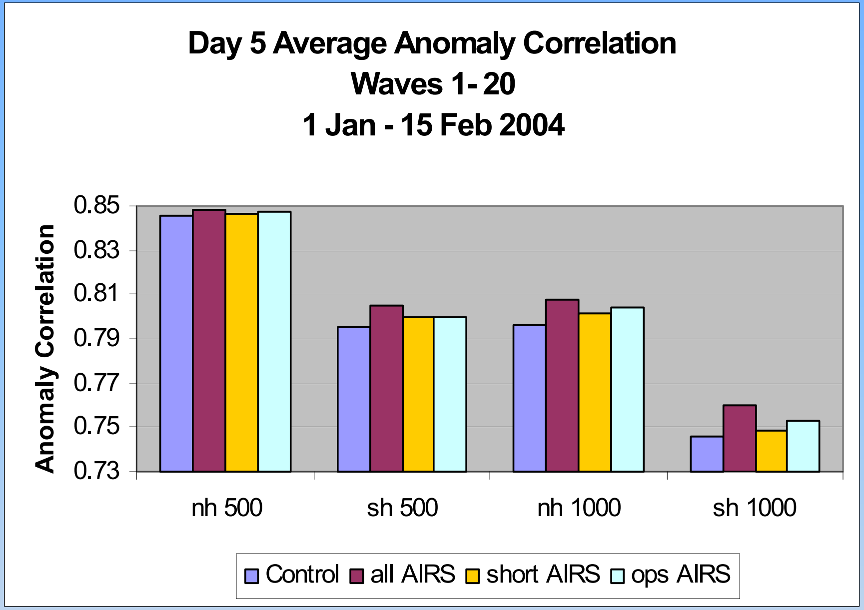


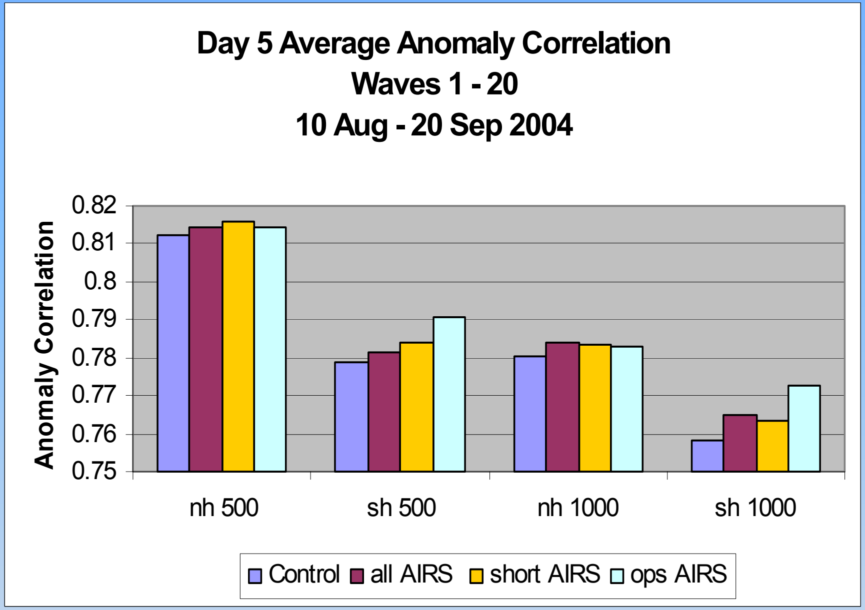


Day 5 Geopotential Height Anomaly Correlations for the GFS with AIRS Center FOV and AIRS SFOV data (AIRS SFOV) at 1000 and 500 hPa for the Northern and Southern Hemispheres.



More AIRS Channel Experiment





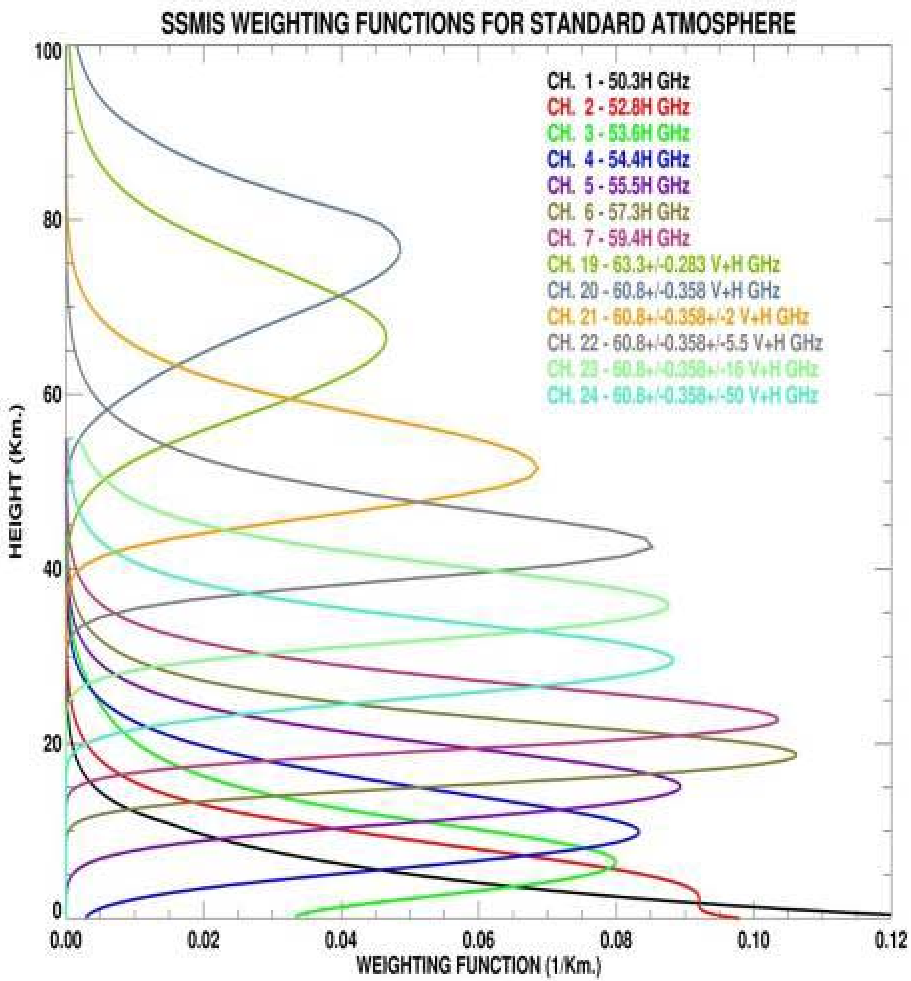
Day 5 Geopotential Height Anomaly Correlations for the GFS for AIRS denied (Control), 251 AIRS data (all AIRS), 115 AIRS water vapor and shortwave (short AIRS), and 152 AIRS data (ops AIRS) at 1000 and 500 hPa for the Northern and Southern Hemispheres.

Using SSMI, SSMIS, WindSat AMSR(E) data in Preparation for a Scanning Imager/Sounder

SSMIS Instrument Characteristics

- **The Defense Meteorological Satellite Program (DMSP) successfully launched the first of five Special Sensor Microwave Imager/Sounder (SSMIS) on 18 October 2003.**
- **SSMIS is a joint United States Air Force/Navy multi-channel passive microwave sensor**
- **Combines and extends the current imaging and sounding capabilities of three separate DMSP microwave sensors, SSM/T, SSM/T-2 and SSM/I, with surface imaging, temperature and humidity sounding channels combined.**
- **The SSMIS measures partially polarized radiances in 24 channels covering a wide range of frequencies (19 – 183 GHz)**
  - conical scan geometry at an earth incidence angle of 53 degrees
  - maintains uniform spatial resolution, polarization purity and common fields of view for all channels across the entire swath of 1700 km.

SSMIS Provides Sounding at Higher Altitudes



SSMIS vs. AMSU-A
Weighting Functions
Oxygen Band Channels

SSMIS 13 Channels Sfc – 80 km

AMSU-A 13 Channels Sfc - 40 km

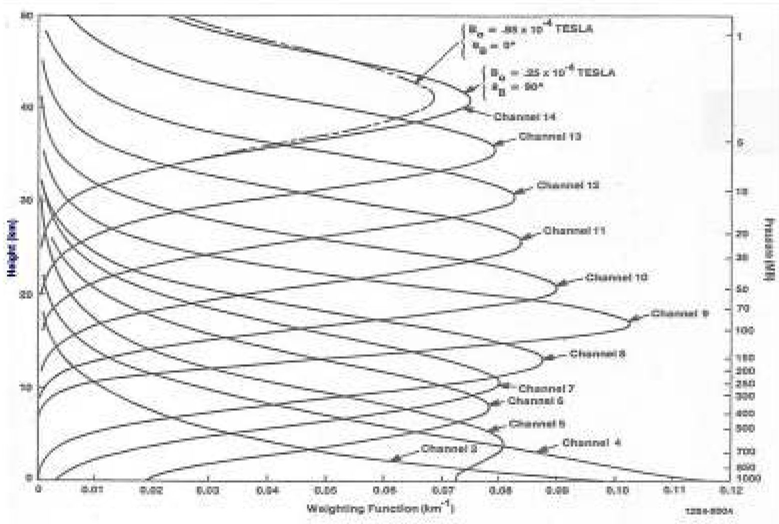
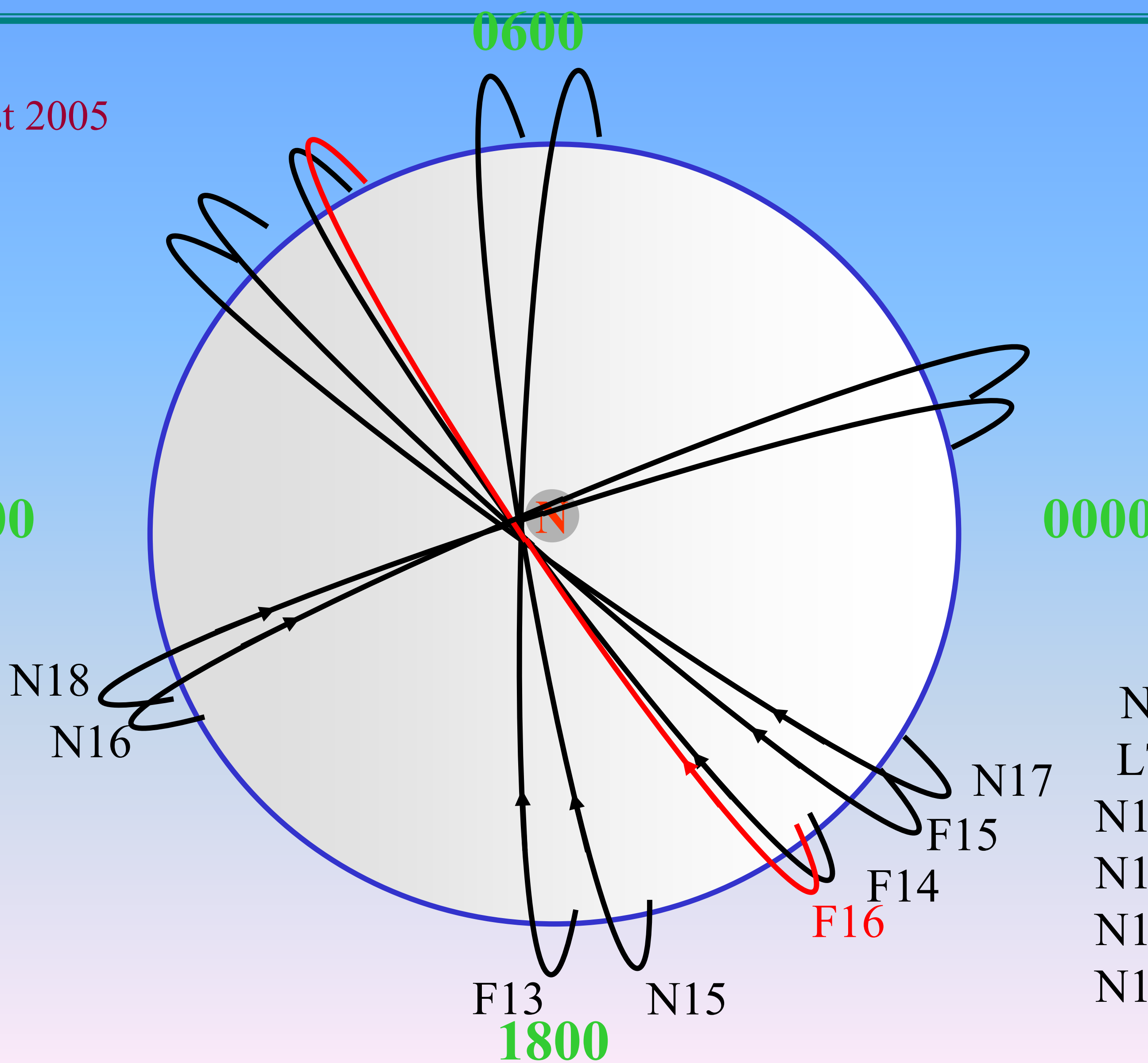


Figure A-5 Channel 3-14 Weighting Functions (Beam Positions 15 and 16, Calm Ocean Background)

Critical Operational Constellation from DMSP and NOAA Satellites

•As of August 2005



DMSP
LTANs
F13 1818
F14 2012
F15 2130
F16 2000

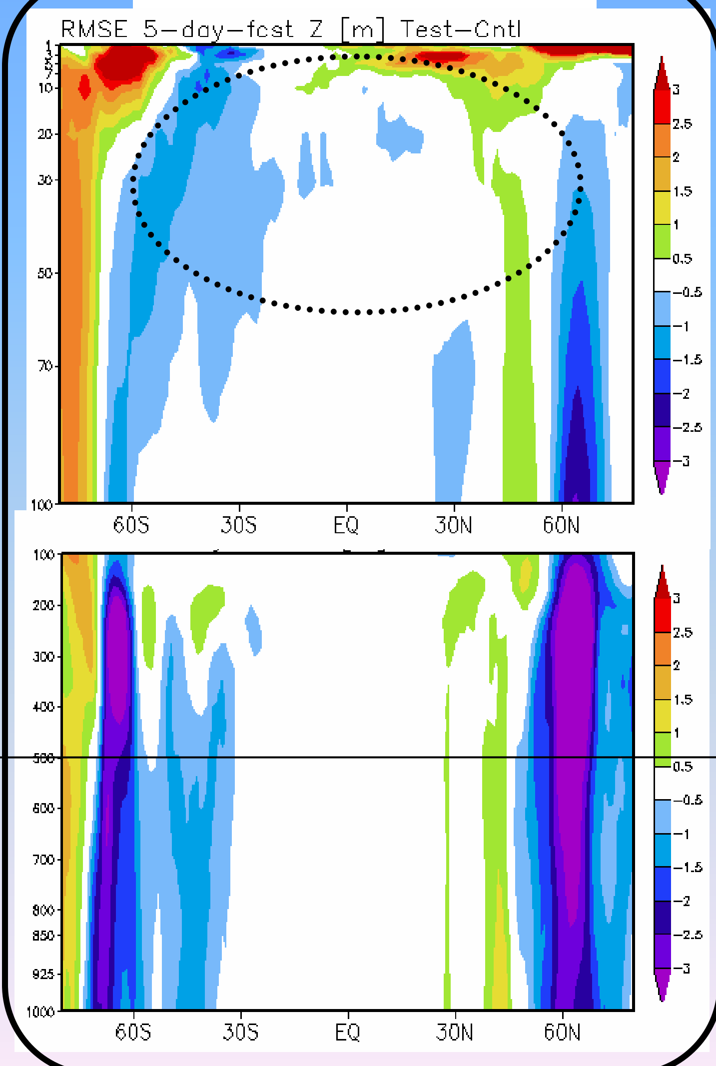
NOAA
LTANs
N15 1903
N16 1430
N17 2204
N18 1359

5day Z forecast zonal averaged RMSE difference (Test-Cntl)

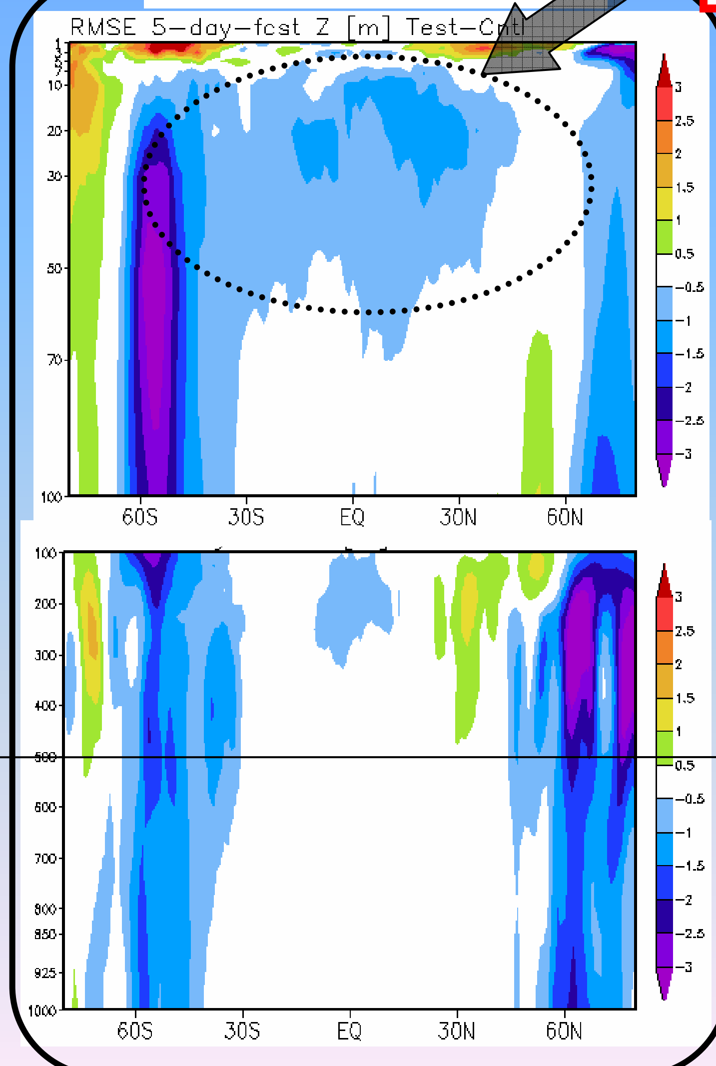
Blue color means improvement.

Much improvement in the stratosphere

UKMO SSMIS



NESDIS SSMIS



10hPa

100hPa

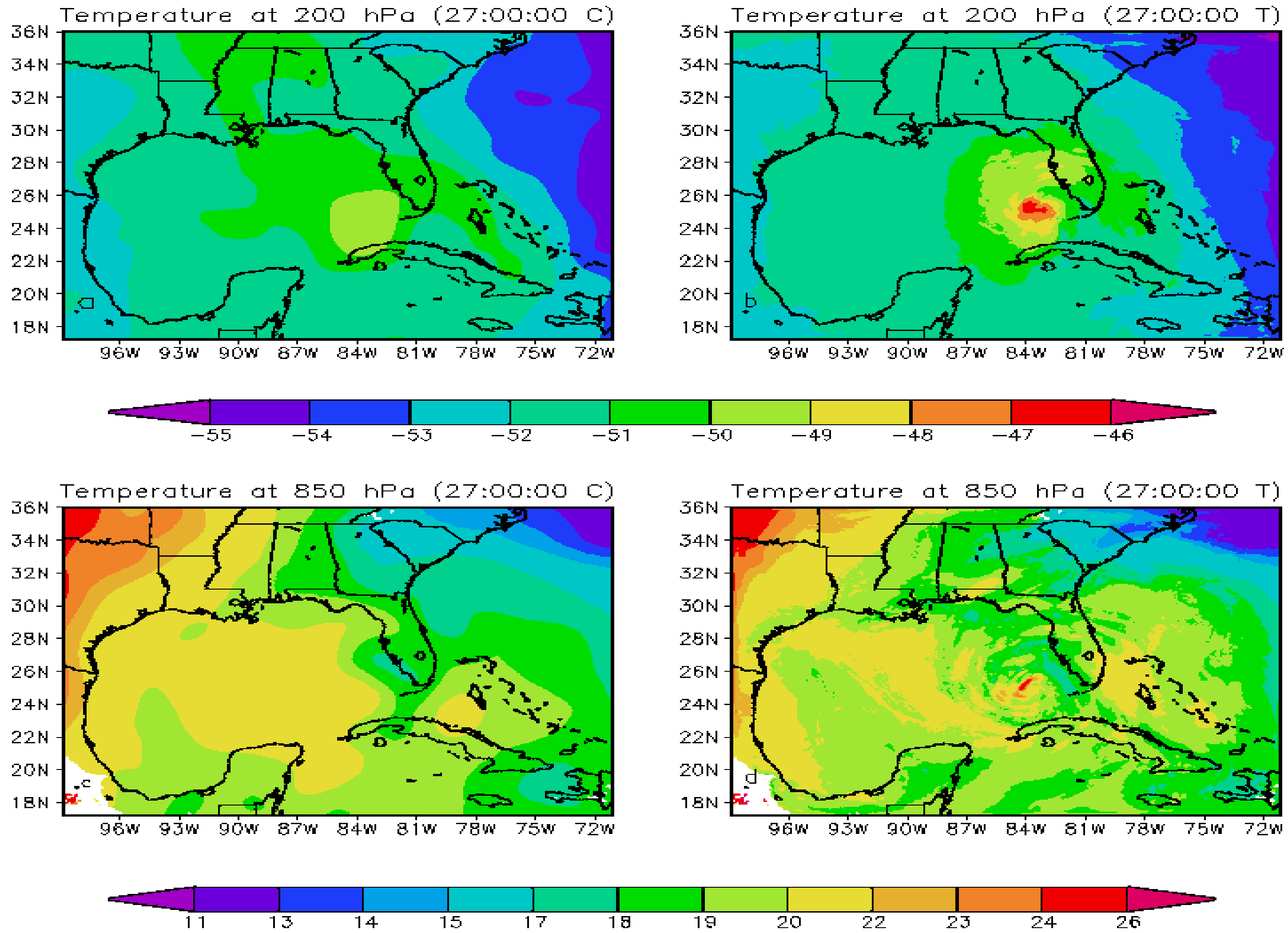
500hPa

1000hPa

Impacts of SSMIS LAS on Hurricane Temperature Analysis

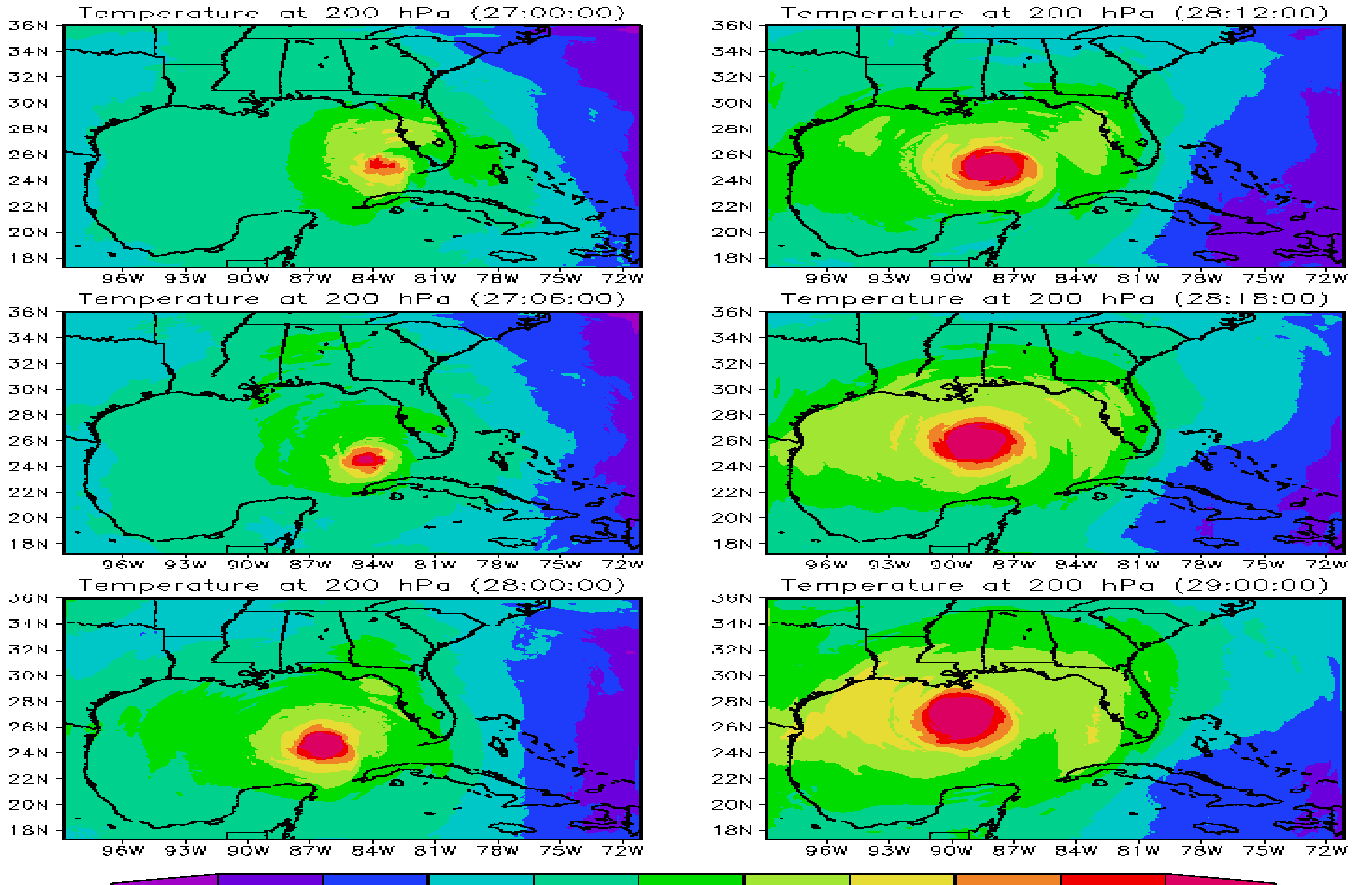
Control

Test



Liu and Weng, GRL, 2007

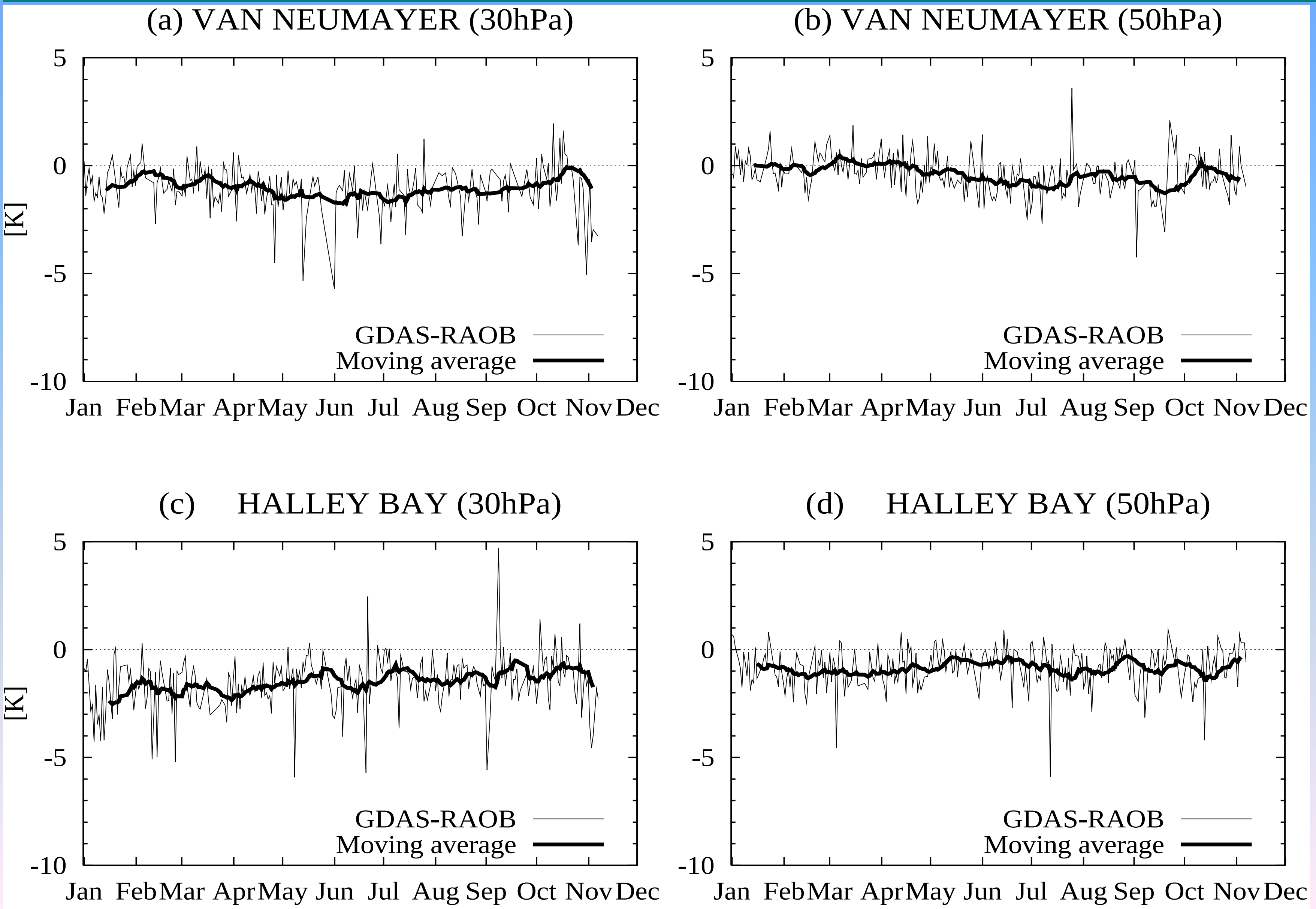
Katrina Warm Core Evolution



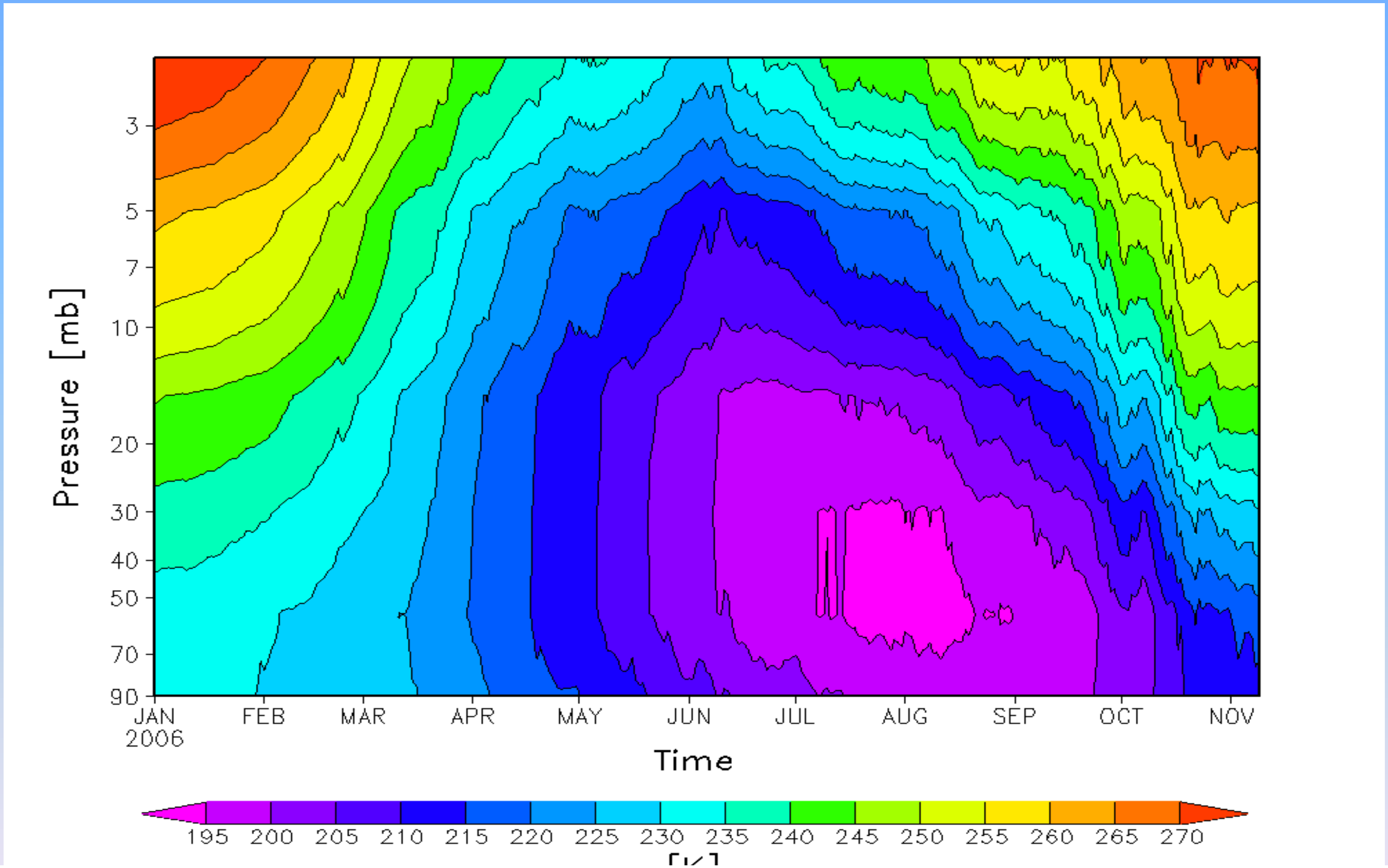
Impacts from SSMIS UAS Data on Global Upper-Air Analysis

- **Innovation vectors are computed from**
  - Global Forecast System (GFS) 6 hour forecasts
  - GSI with SSMIS Channels 5,6,7, 22, 23, 24

GDAS Biases in Stratosphere

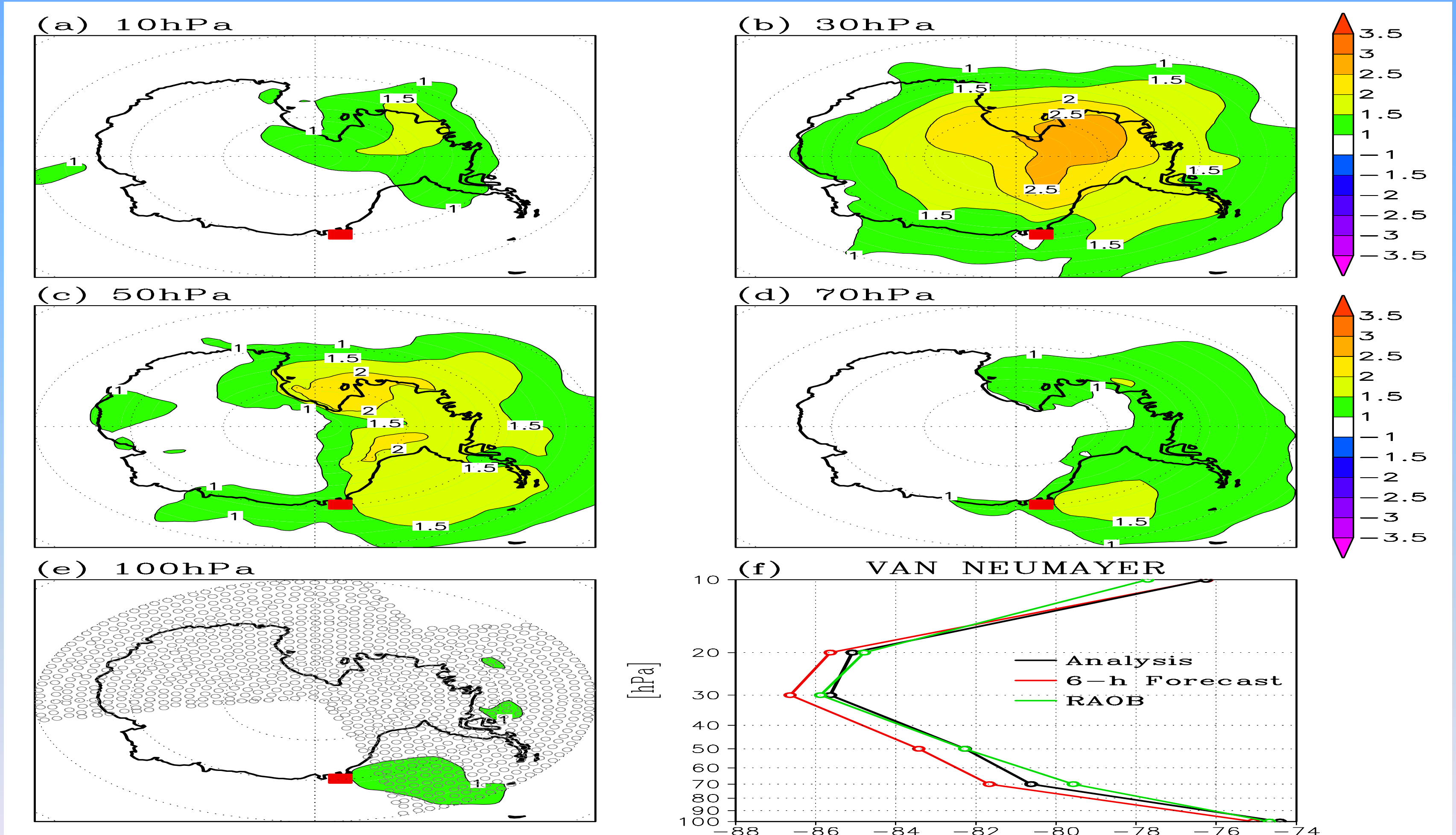


SSMIS Interpolated to Various Pressure Levels



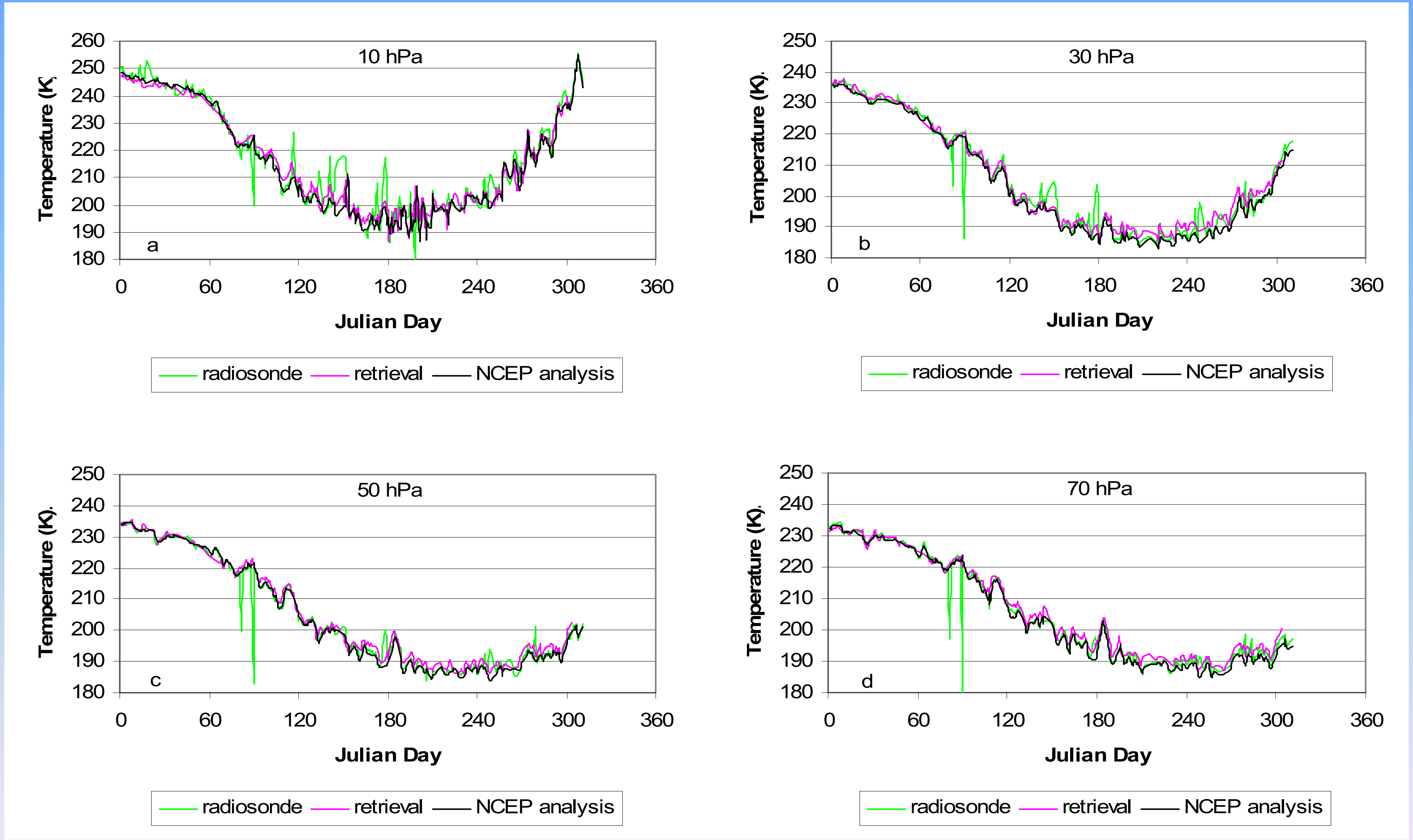
A snapshot of a time series of the interpolated brightness temperatures at SSMIS channels 22, 23, 24, 7, 6, and 5 averaged over 60º South and South Pole for 2006.

SSMIS UAS Innovations to GFS 6 Hour Forecasts



Differences of stratospheric temperatures between new analyses and 6-hour forecast for 12 UTC June 29, 2006. The red colored square indicates the Van Neumayer station. The black circles are footprints of the SSMIS measurements. The stratospheric temperature profiles from 6-hour forecast, radiosonde, and new analysis for the time are given in (f).

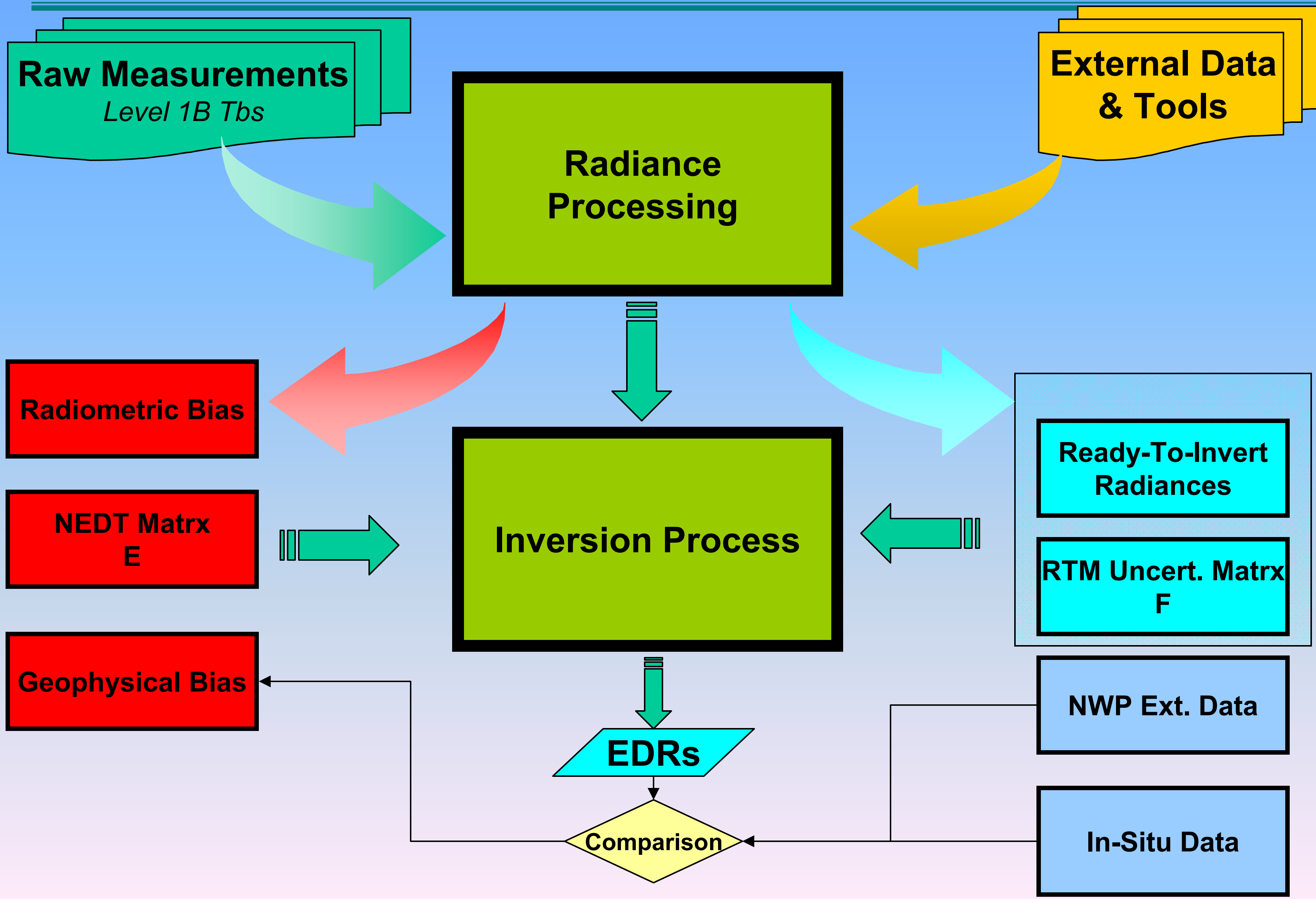
GDAS Analysis vs. SSMIS Retrievals, Roabs



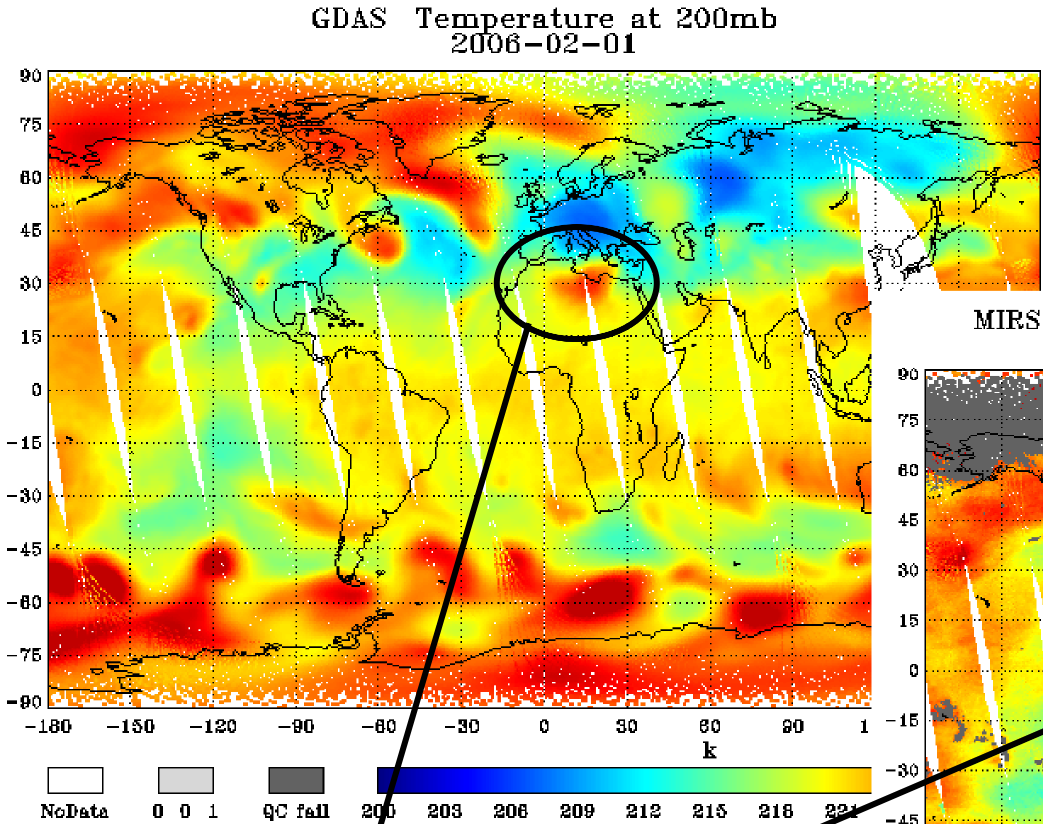
Comparisons of times series of the stratospheric temperatures in 2006 at Van Neumayer station. The Green, red, and black lines represent radiosondes, retrievals using real SSMIS measurements, and NCEP

Hybrid Scheme: 1dvar plus 4dvar

NESDIS 1DVAR (working for Cloudy Radiances)

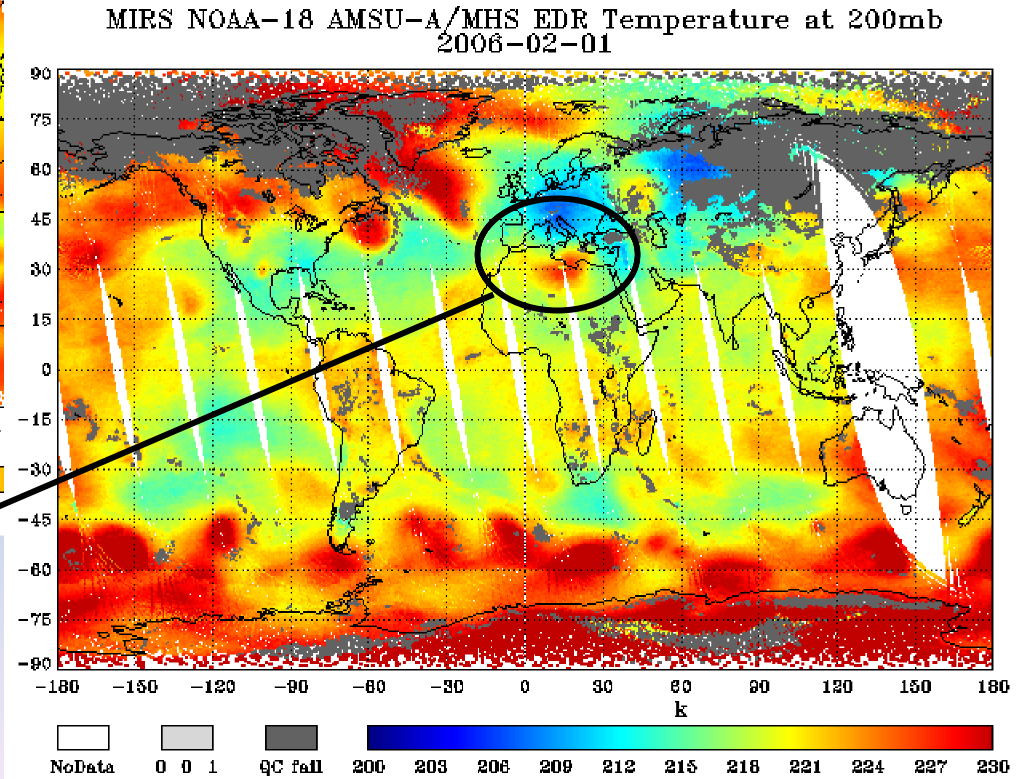


Global Temperature Profiling



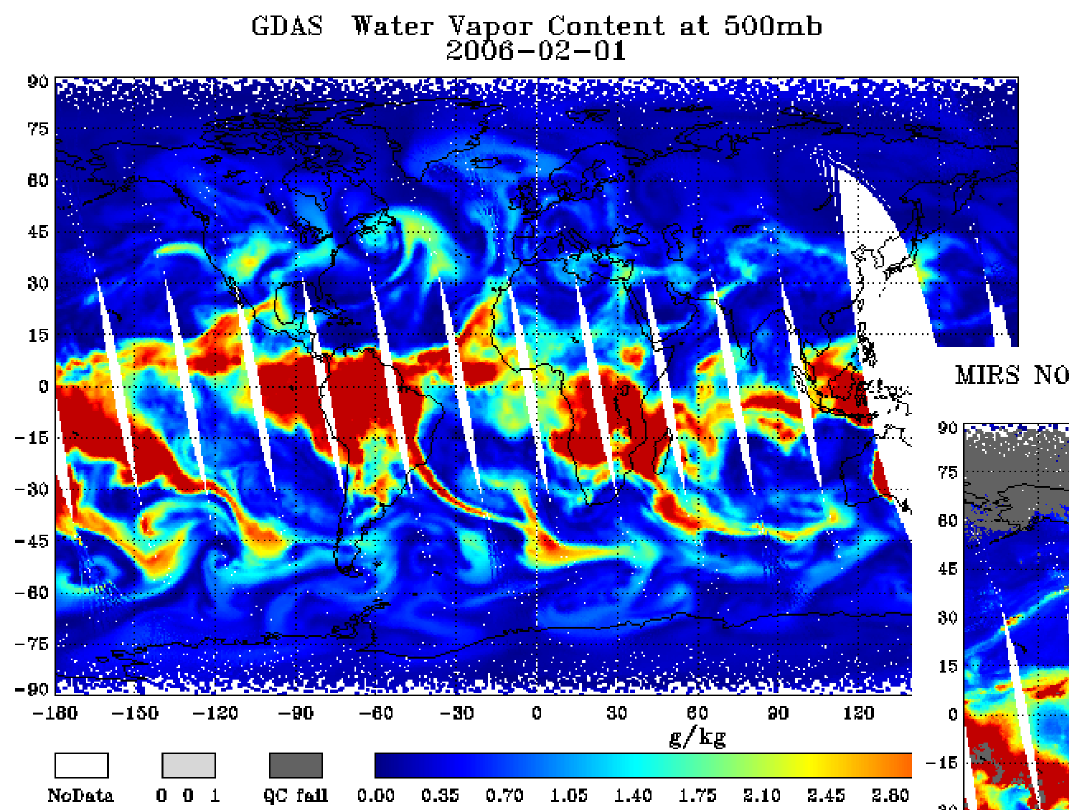
No Scan-Dependence in retrieval
Smooth Transition Land/Ocean

QC-failure is based on convergence:
Focus of on-going work

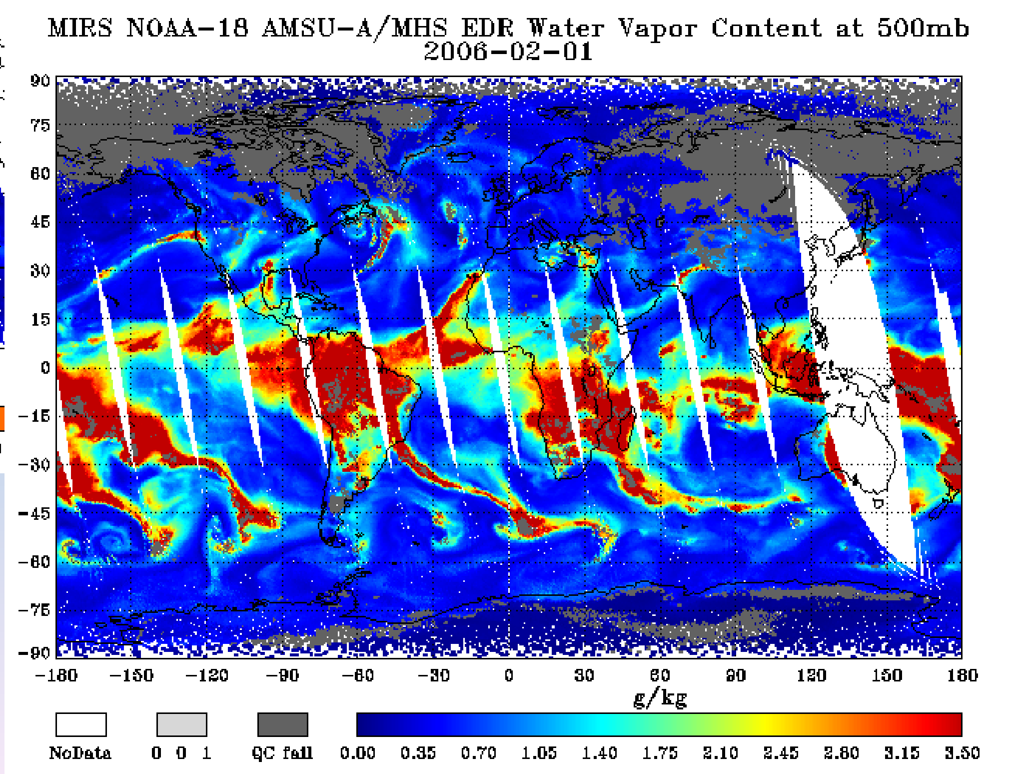


Similar Features Captured

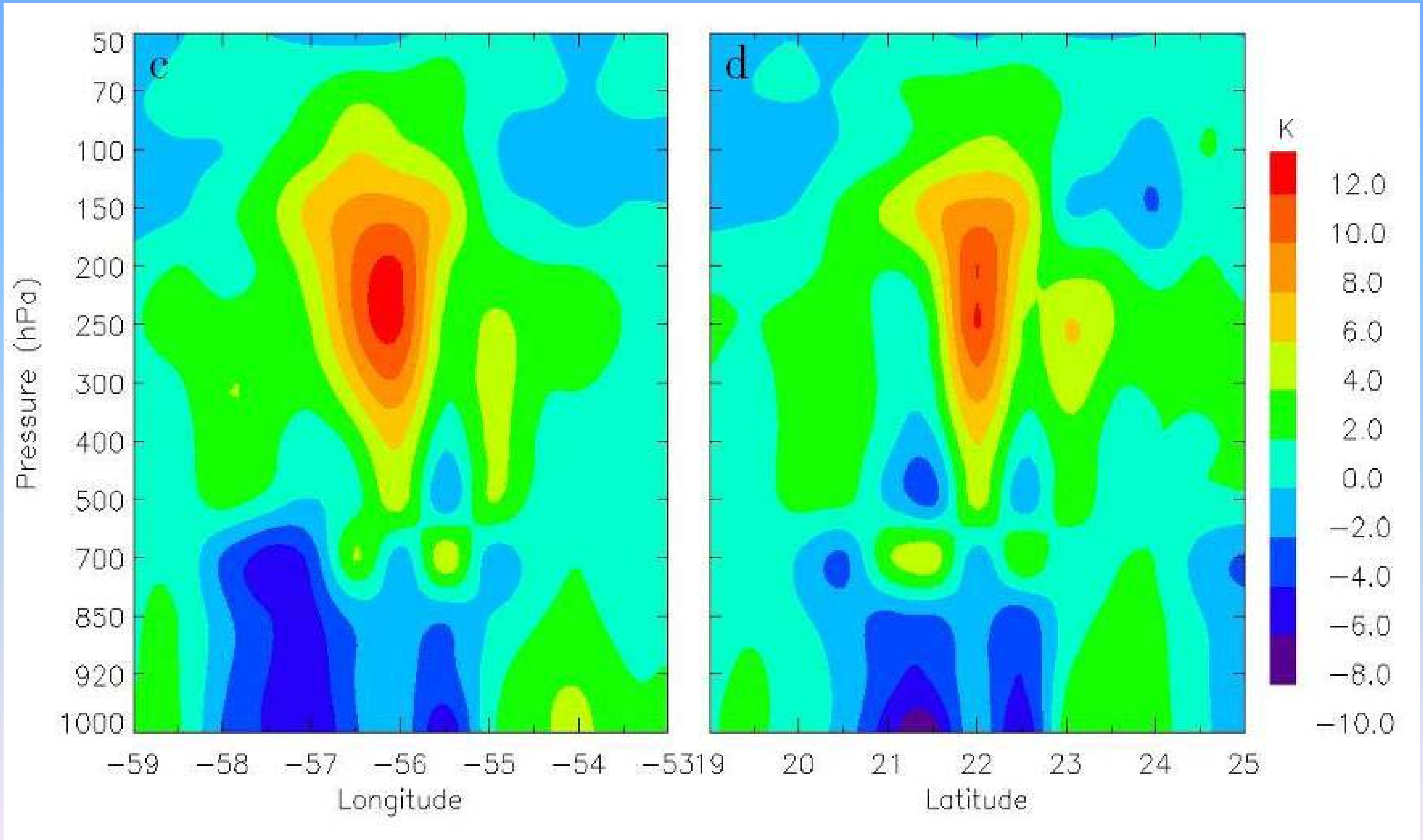
Global Humidity Profiling



No Scan-dependence noticed: Angle dependence properly accounted for



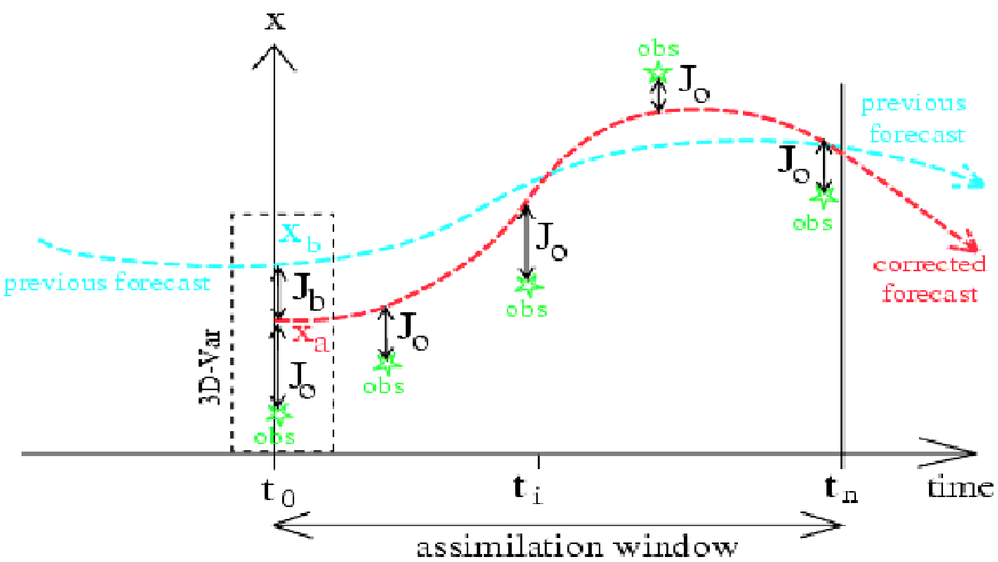
Hurricane Bonnie Warm Core from AMSU



Four Dimension Variational Analysis (4DVAR)

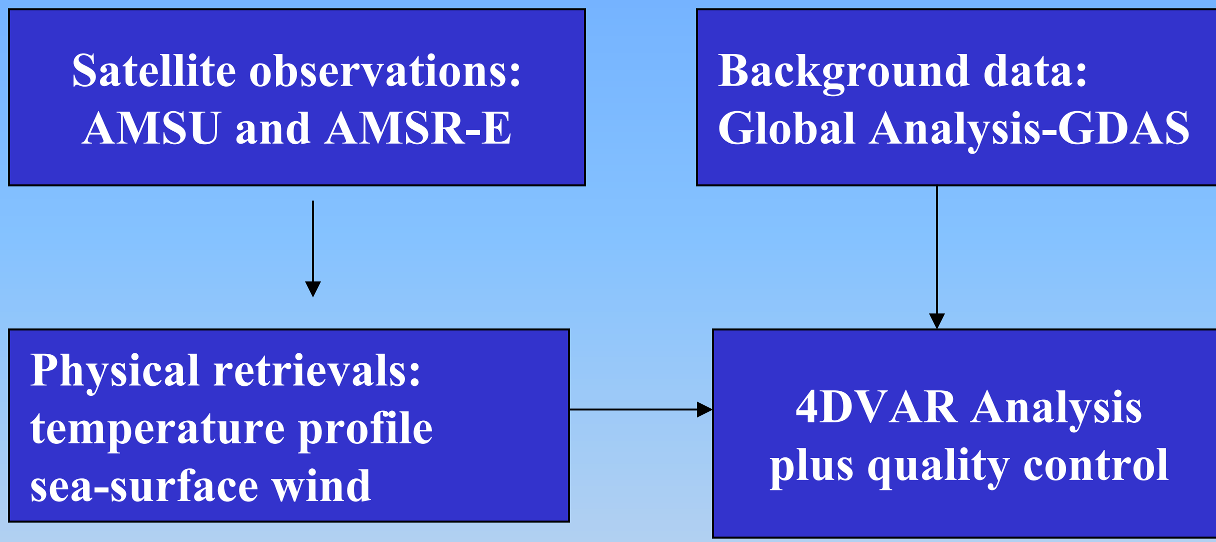
- **Example of 4D-Var intermittent assimilation in a numerical forecasting system. Every 6 hours a 4DVar is performed to assimilate the most recent observations, using a segment of the previous forecast as background. This updates the initial model trajectory for the subsequent forecast**

- **Difficulties:**
  - Adjoint in temporal domain can be non-linear
  - Huge computational requirements and storage



$$J(x) = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \frac{1}{2}\sum_{i}^{n}[y_i - H_i(x_i)]^T R_i^{-1}[y_i - H_i(x_i)]$$

Hybrid Variational Scheme



Cost function:

Weng et al, JAS, 2007

$$J(X) = (X_0 - X_b)^T W_b (X_0 - X_b) + \sum_{i=1}^{2} \left[X(t_i) - X_{obs}(t_i)\right]^T \times W_X \left[X(t_i) - X_{obs}(t_i)\right]$$

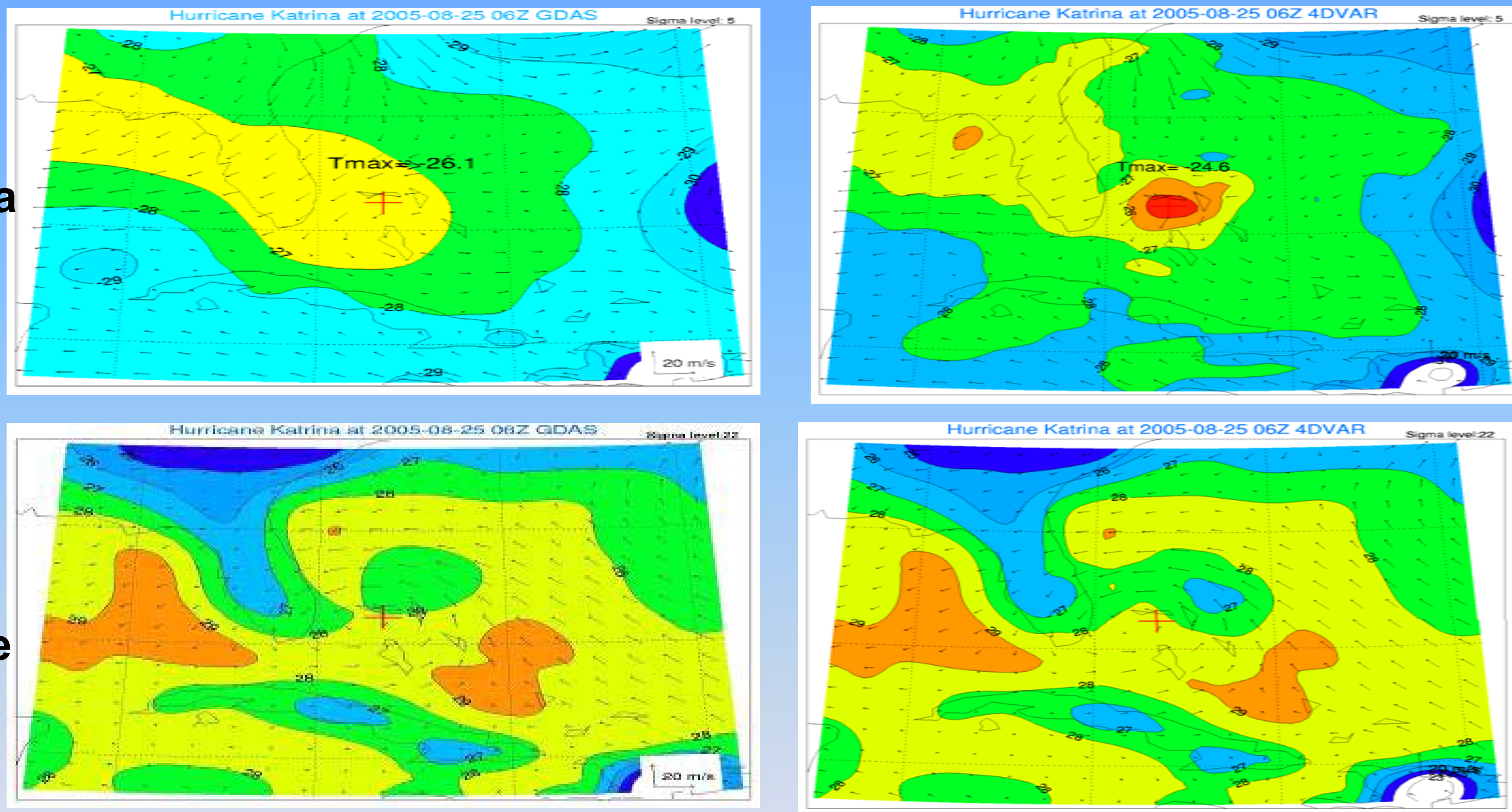
where $X(t_i)$ is observed atmospheric temperature and SSW; W_b and W_x are the error covariance for ackground and satellite measurements

Katrina Analysis

GDAS | 4DVAR

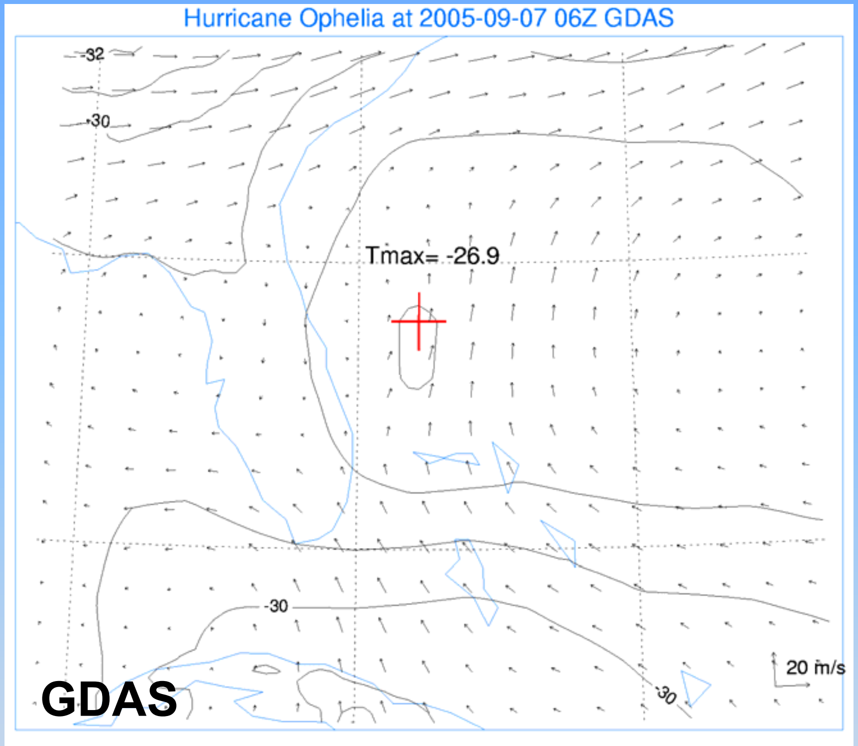
250 hPa

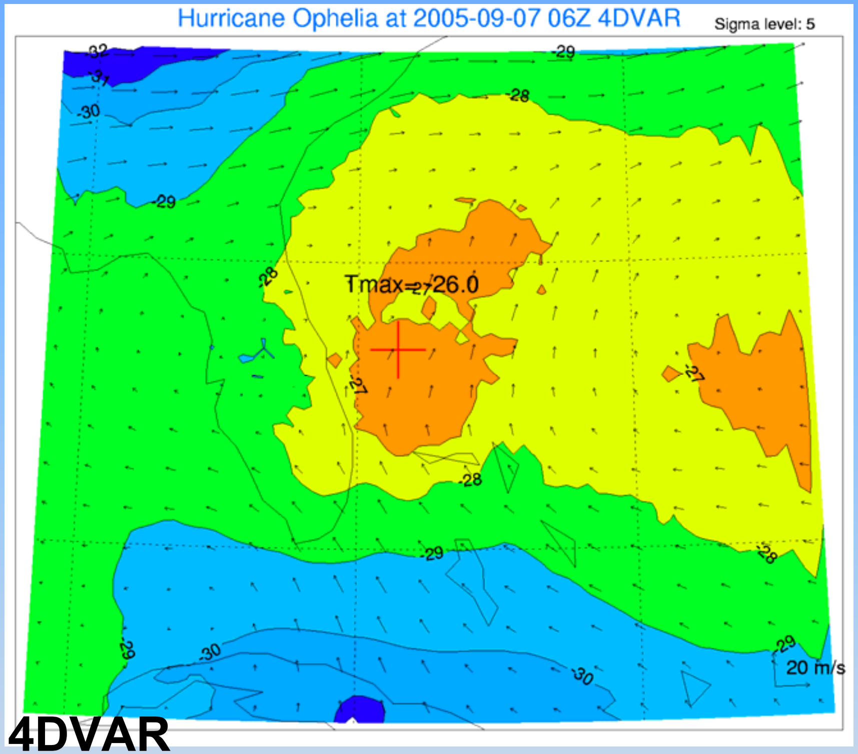
Surface



Above figures compare GDAS analysis temperature fields near 250 hPa and surface with 1DVAR retrievals and 4DVAR analysis. The temperature field from analysis shows hurricane warm core is about 2 degree warmer than GDAS analysis. Uses of cloudy radiances under storm conditions dramatically improve warm core structure. At 0600 UTC August 25, 2005, Katrina was at tropical storm intensity, with the minimum central pressure of 1000 hPa.

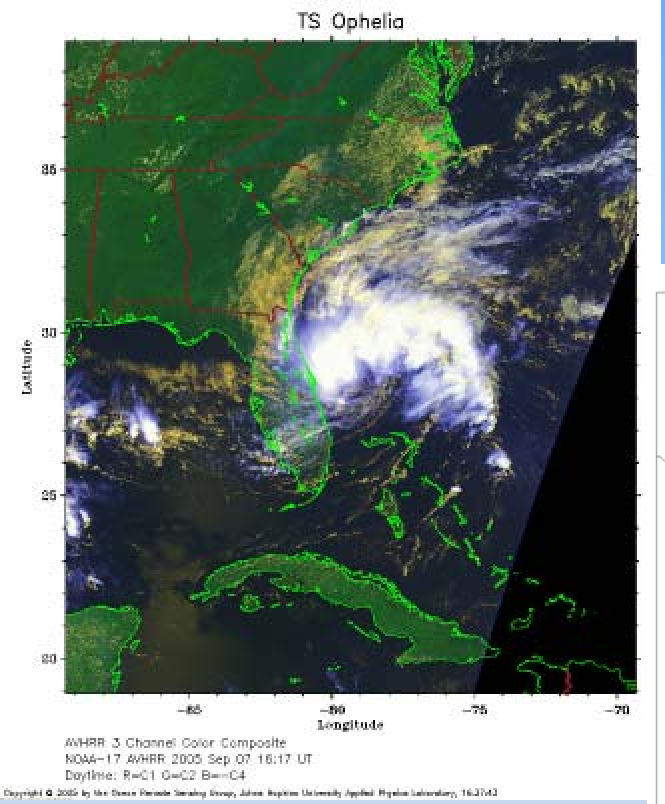
Hurricane Ophelia 2005



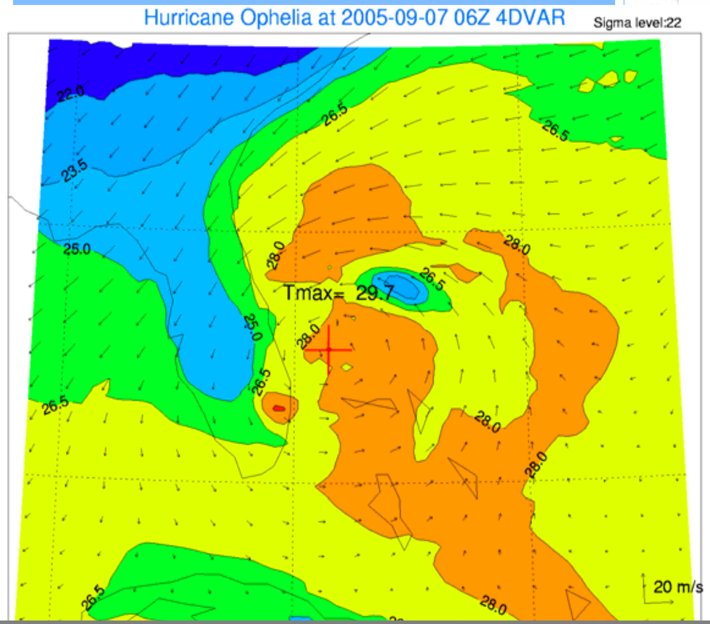


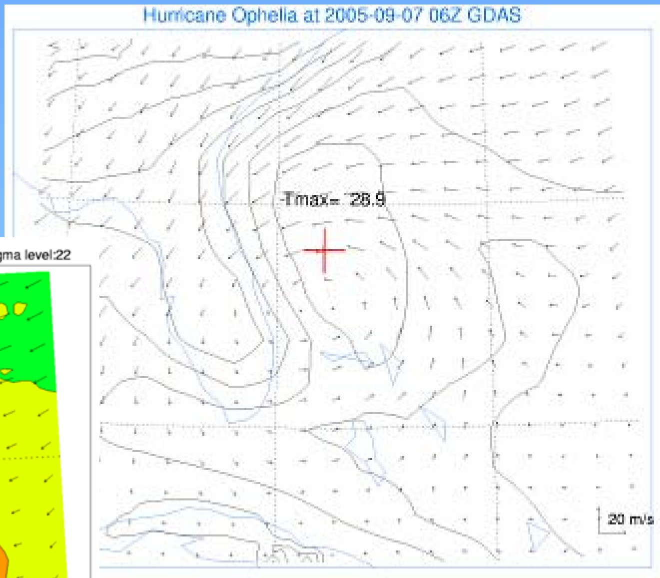
Above two figures compare GDAS analysis temperature field near 250 hPa with 1DVAR retrievals and 4DVAR analysis. The temperature field from analysis shows hurricane warm core is about 2 degree warmer than GDAS analysis. Uses of cloudy radiances under storm conditions dramatically improve warm core structure. At 0600 UTC September 07, 2005, Ophelia was at tropical storm intensity, with the minimum central pressure of 1003 hPa.

Hurricane Ophelia 2005



4DVAR



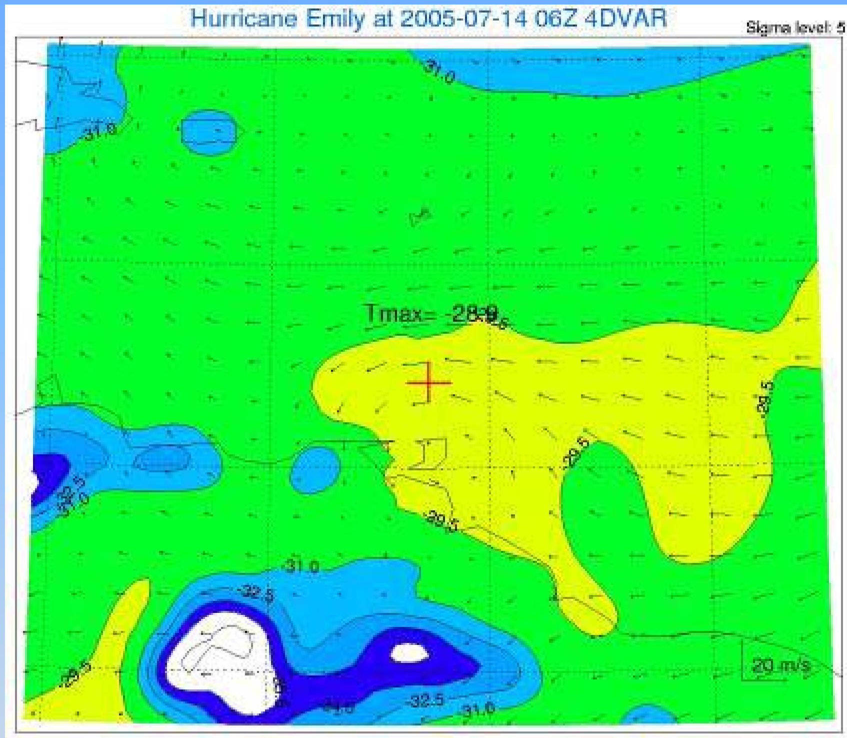


GDAS

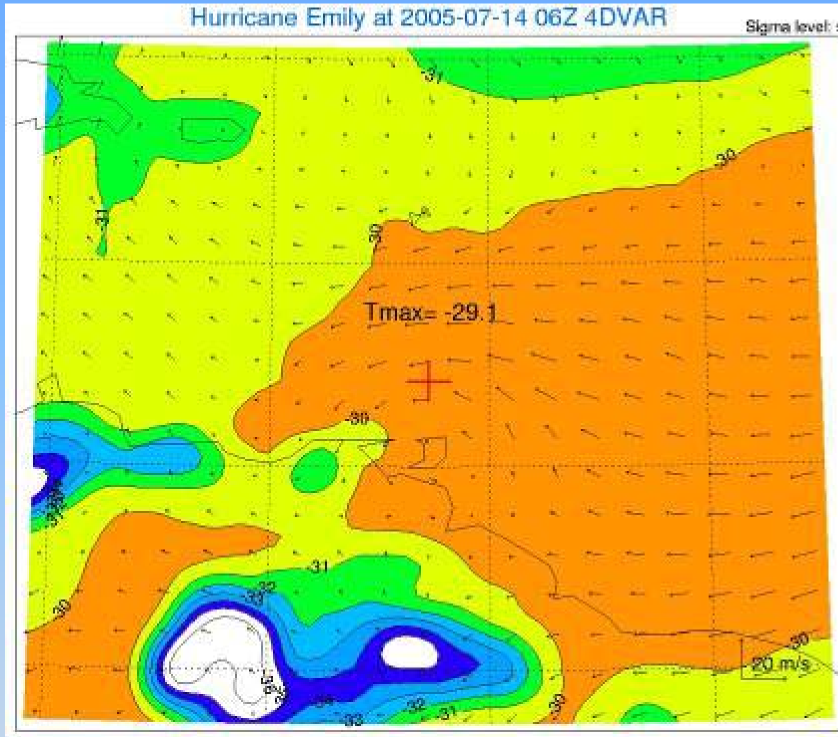
The 1DVAR retrieval plus 4DVAR analysis shows asymmetric surface temperature distribution, with a 2 K cooling rainband at northeastern side, which is consistent with the deep convections shown on NOAA-17 satellite AVHRR channel 4 image. Again, this feature is attributed to uses of more AMSR-E radiances at 6 and 10 GHz which are sensitive to SST

Hurricane Emily 2005

GDAS

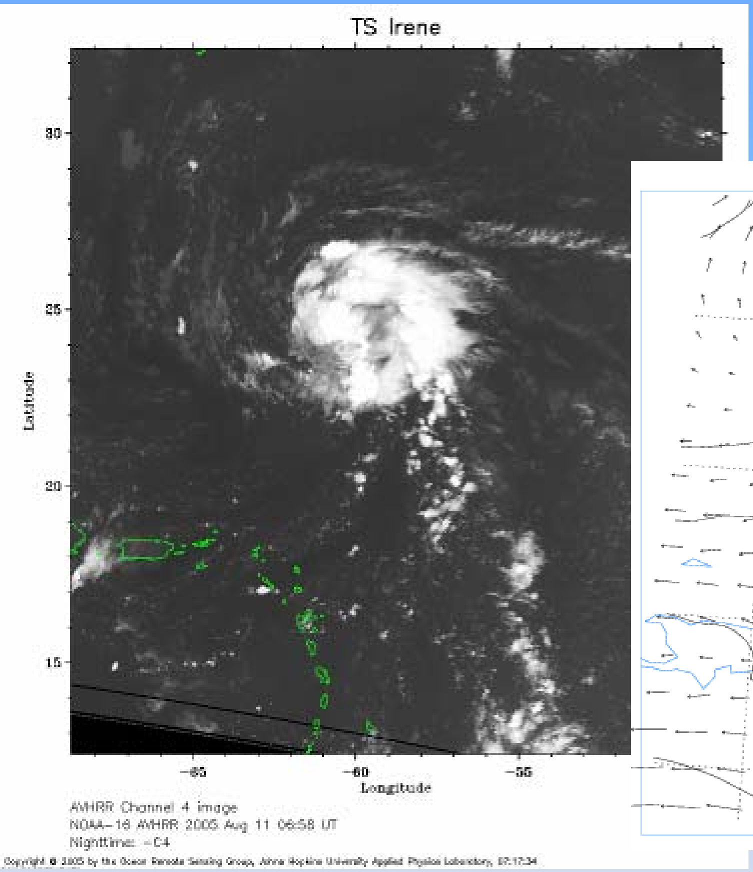


4DVAR

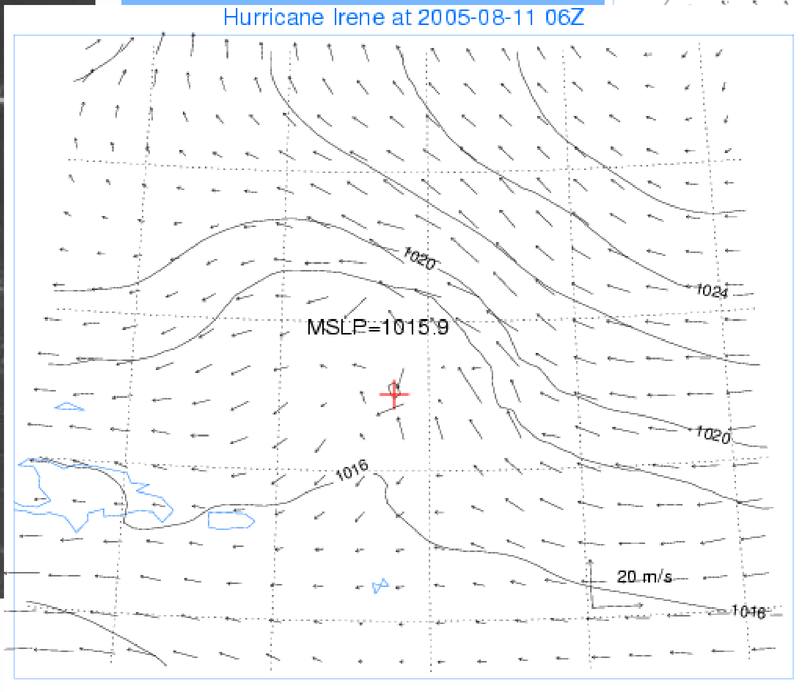


- At 0600 UTC July 14, 2005, Emily was at tropical storm intensity, with the minimum central pressure of 991 hPa.
- Above two figures compare GDAS analysis temperature field near 250 hPa with the 4DVAR results. Hurricane warm core does not change too much after 4DVAR analysis.

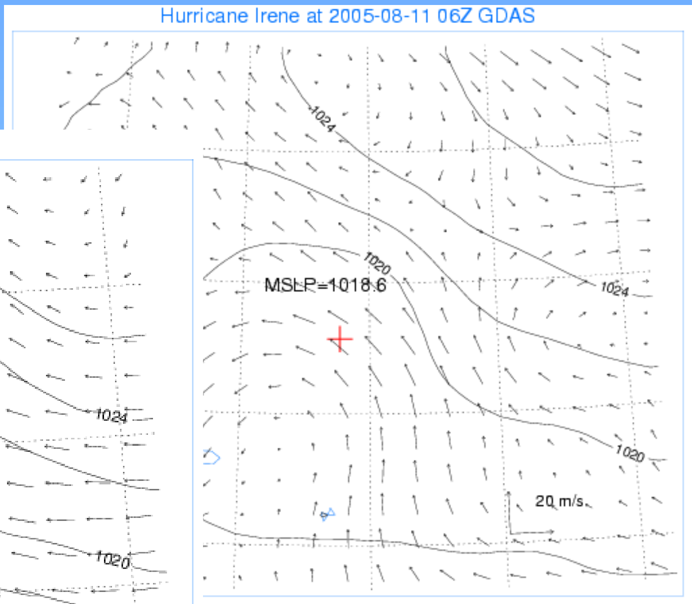
Hurricane Irene 2005



4DVAR



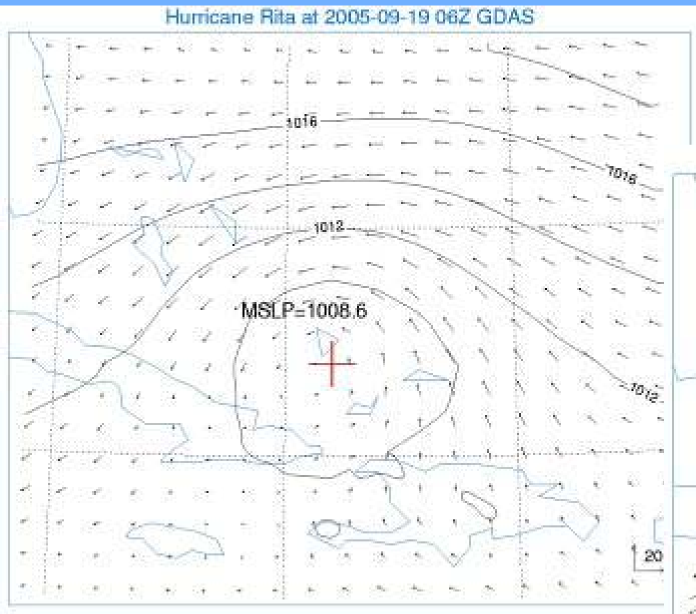
GDAS



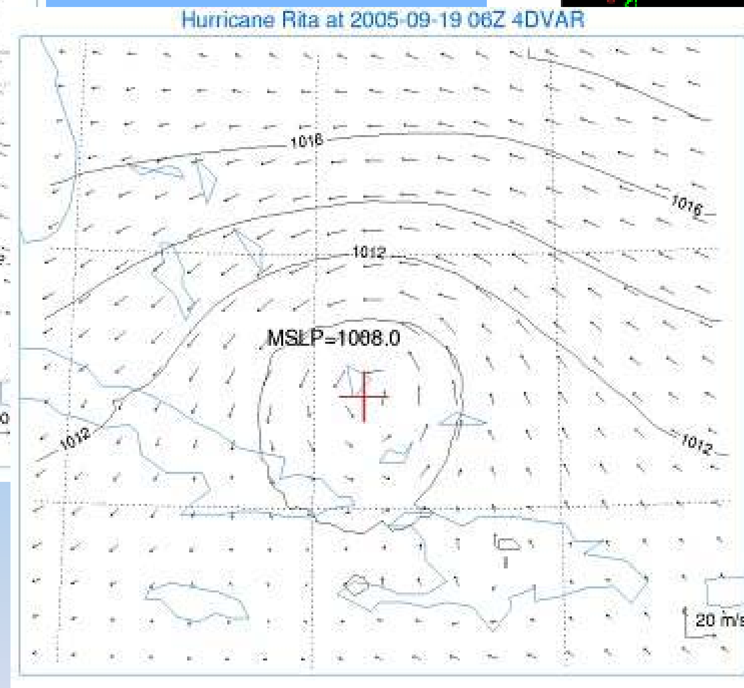
- **At 0600 UTC August 11, 2005, Irene was a tropical storm, with the minimum central pressure of 1006 hPa.**
- **Above two figures compare the SLP and SSW of GDAS analysis with the 4DVAR results. The SLP for 4DVAR analysis is about 3 hPa deeper than that of GDAS analysis.**

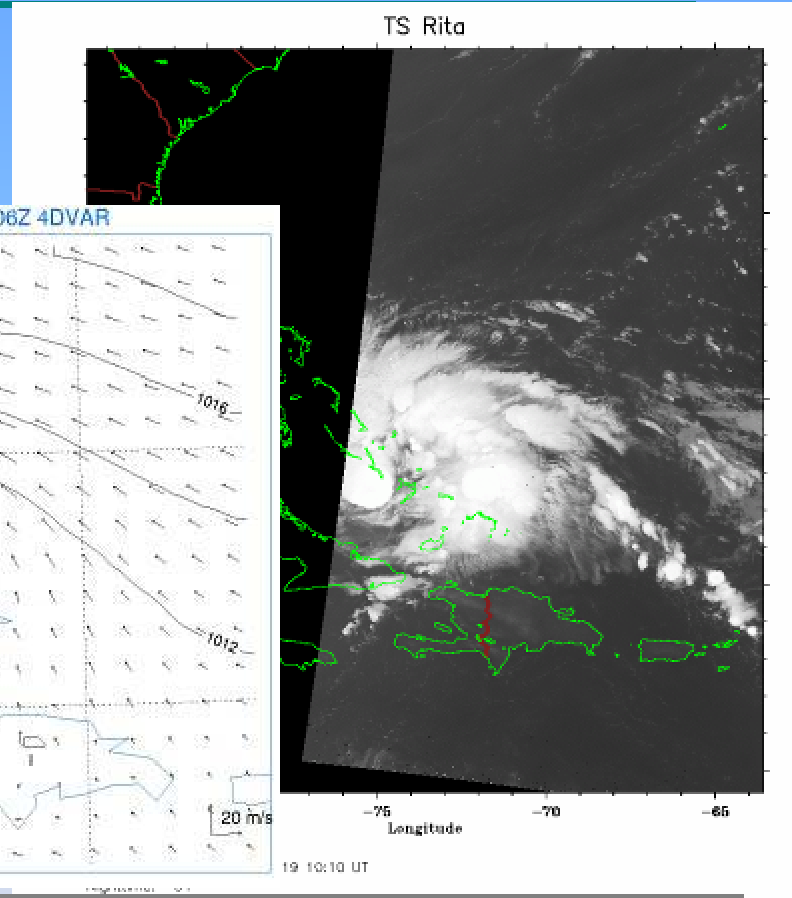
Hurricane Rita 2005

GDAS



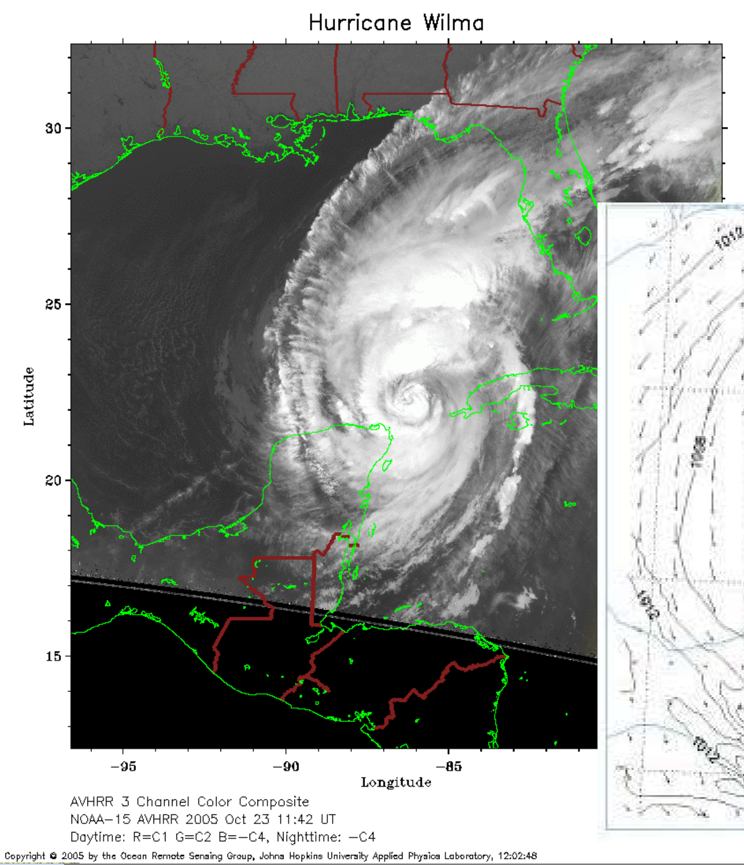
4DVAR



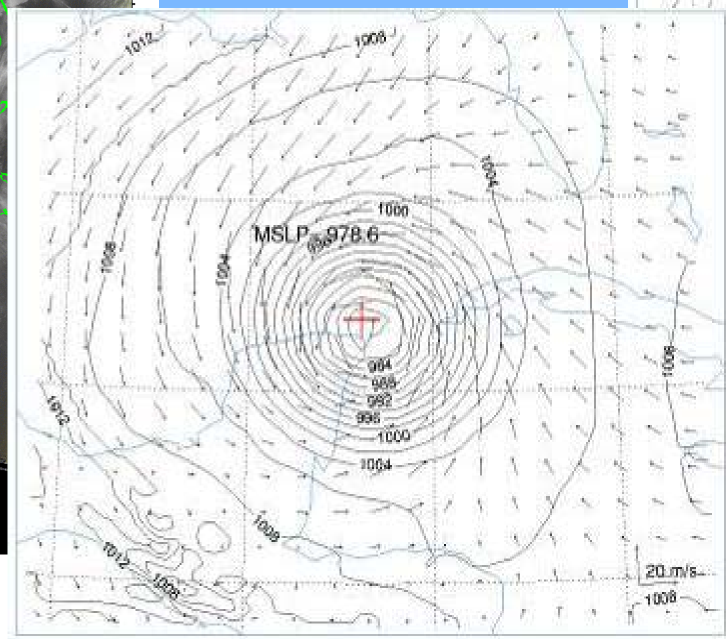


- At 0600 UTC September 19, 2005, Rita was at tropical storm intensity, with the minimum central pressure of 1002 hPa.
- Above two figures compare the SLP and SSW from GDAS analysis with the 4DVAR results. The SLP for 4DVAR analysis is 0.8 hPa deeper than GDAS analysis field. The wind speed is also increased after 4DVAR analysis.

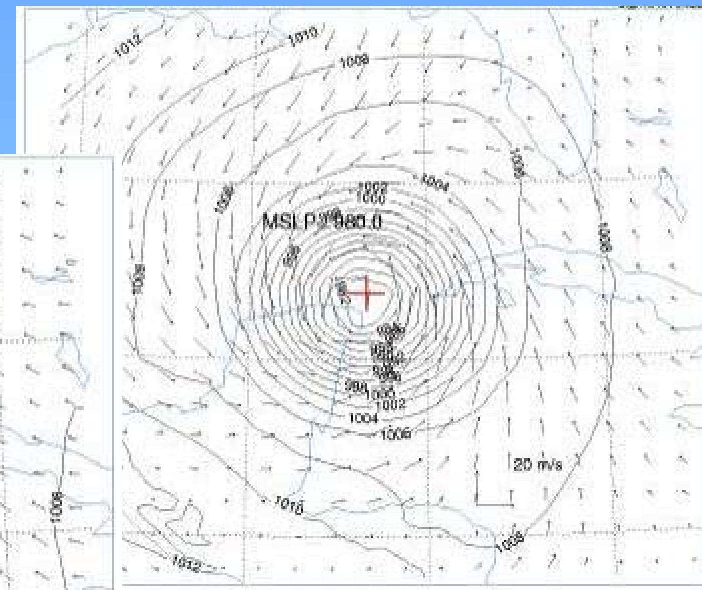
Hurricane Wilma 2005



4DVAR



GDAS



- At 0600 UTC December 23, 2005, Wilma was Category 2 hurricane, with the minimum central pressure of 962 hPa.
- Above two figures compare the SLP and SSW from GDAS analysis with the 4DVAR results. The SLP for 4DVAR analysis is 1.5 hPa deeper than GDAS analysis field.

JCSDA WindSat Testing

- **Coriolis/WindSat data is being used to assess the utility of passive polarimetric microwave radiometry in the production of sea surface winds for NWP**
- **Study accelerates NPOESS preparation and provides a chance to enhance the current global system**
- **Uses NCEP GDAS**

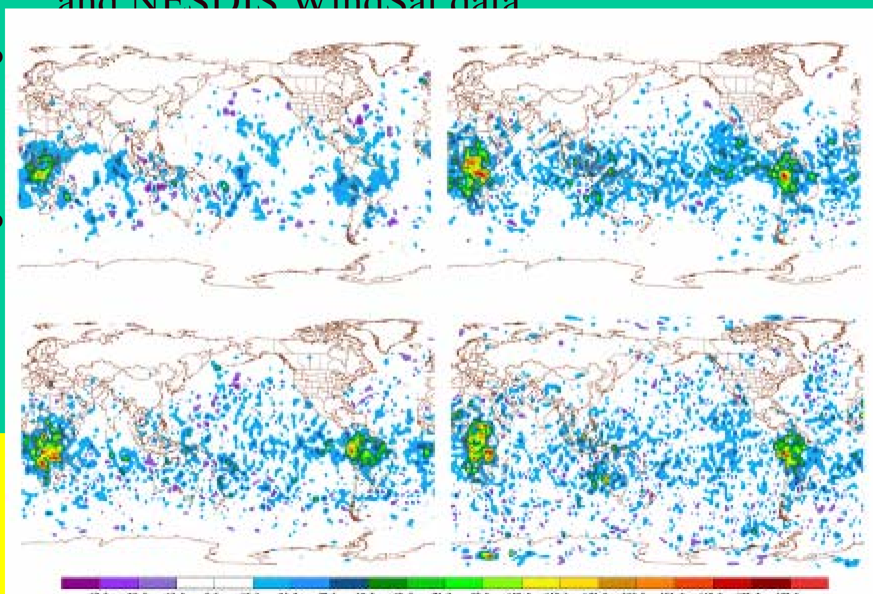
Bi Li and Mike Morgan, CIMSS

Assimilation of WindSat Data in the GFS

Contributors: Li Bi, Tom Zapotocny, Jim Jung (CIMSS) and Michael Morgan

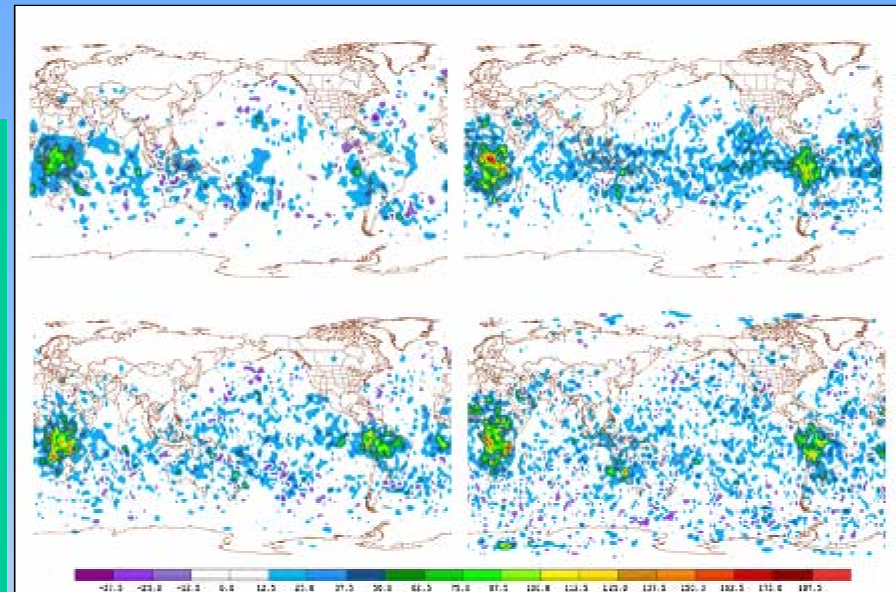
Summary of Accomplishments

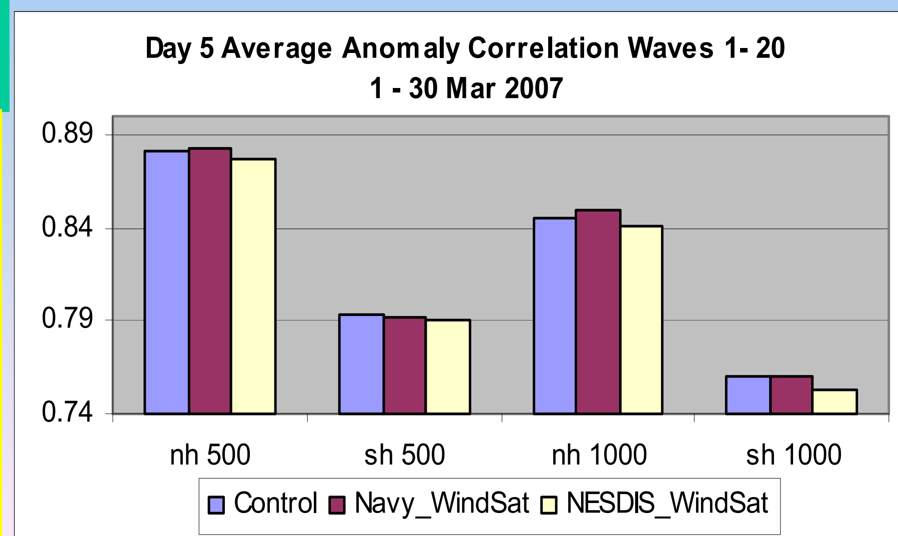
- Developed preliminary quality control for Navy and NESDIS WindSat data



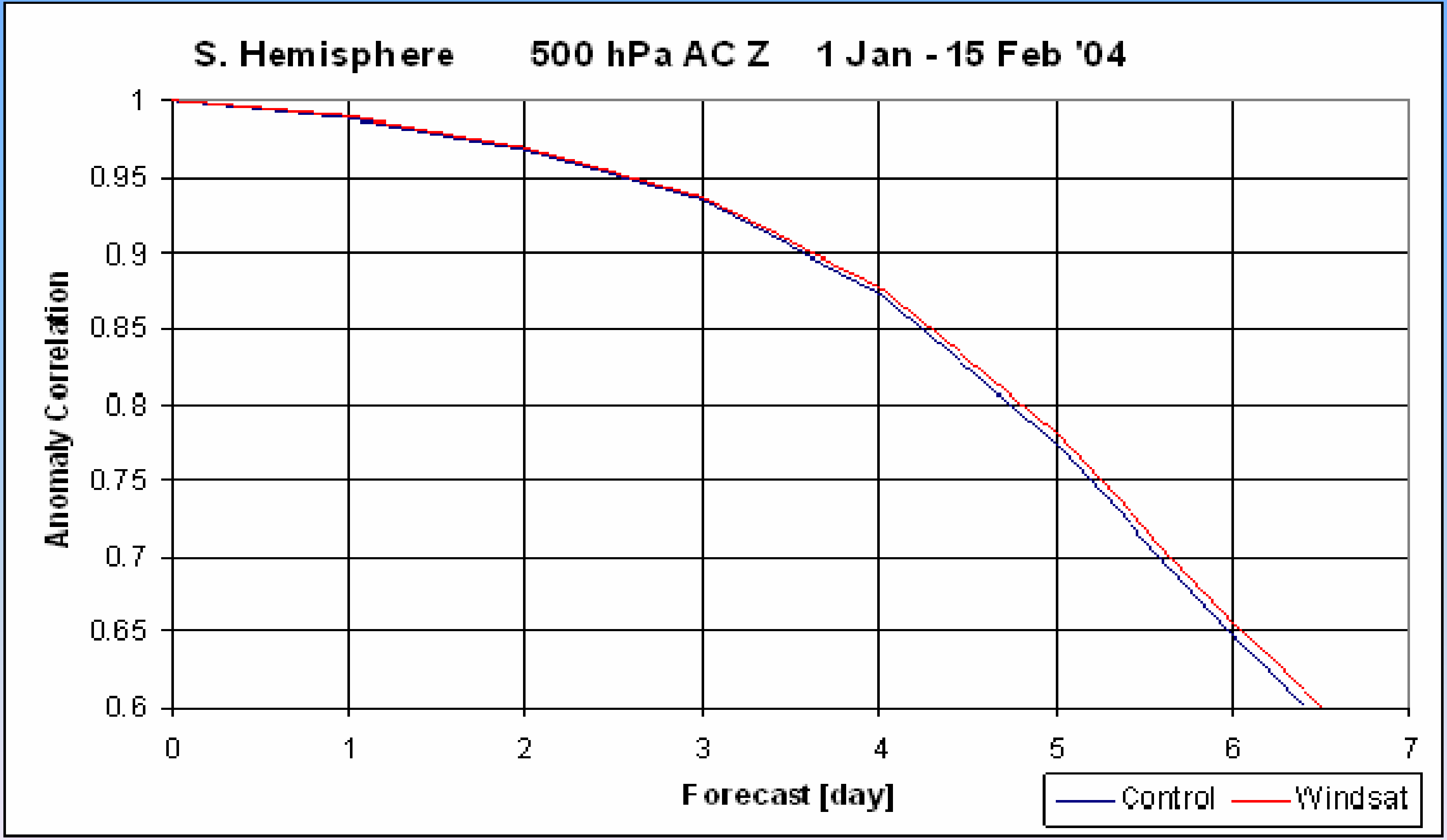
- Develop the direct assimilation of the WindSat radiances into the GFS and compare results obtained from Navy/NESDIS WindSat retrieval.

925 hPa FCST IMPACT 24-HR NAVY WINDSAT MARCH 1 – MARCH 30 2007





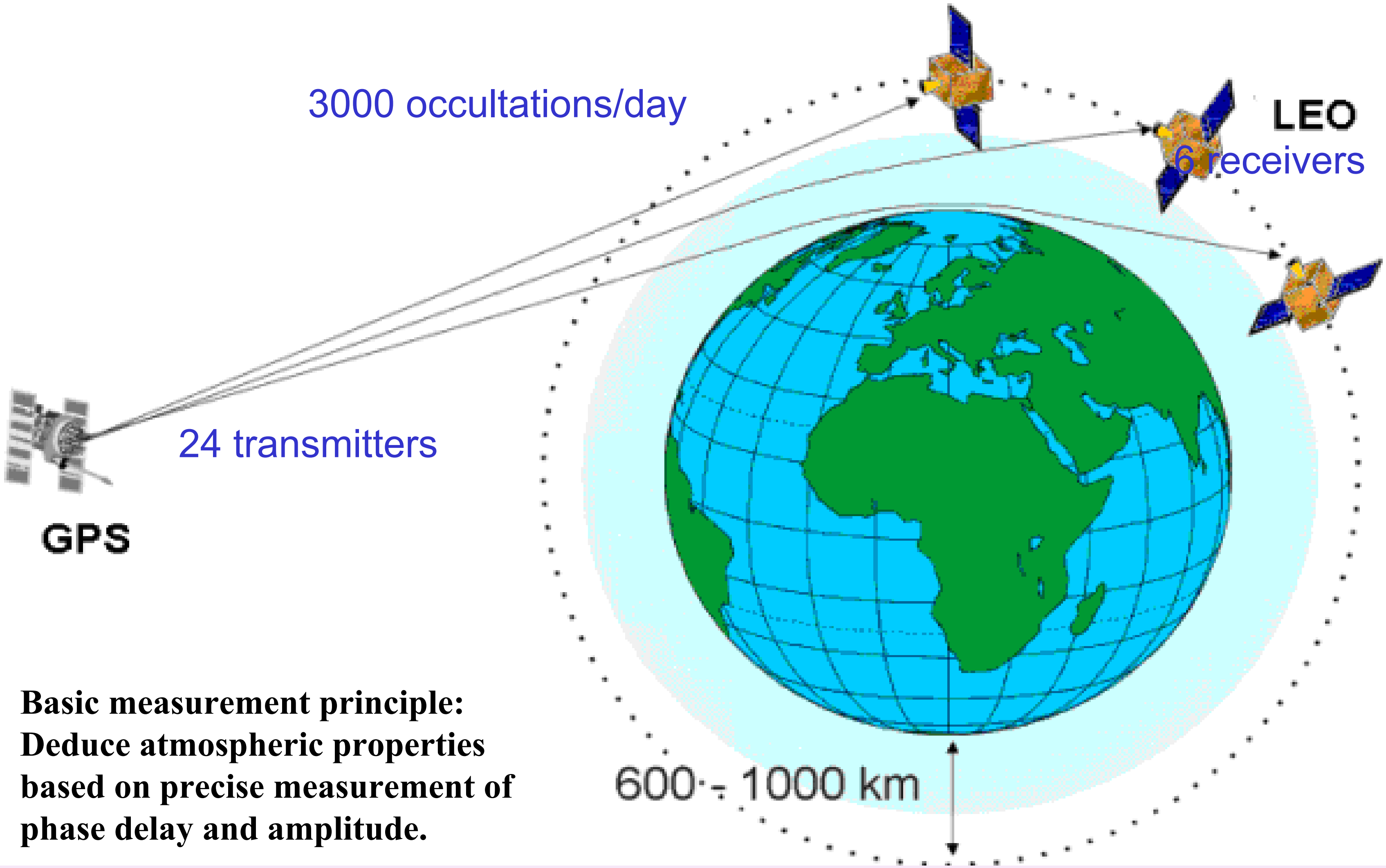
WindSat v Ops - QuikSCAT



Assimilation of GPS RO observations at JCSDA

Lidia Cucurull, John Derber,
Russ Treadon, Jim Yoe…

Global Positioning Satellite/Radio Occultation (GPS/RO)



Basic measurement principle: Deduce atmospheric properties based on precise measurement of phase delay and amplitude.

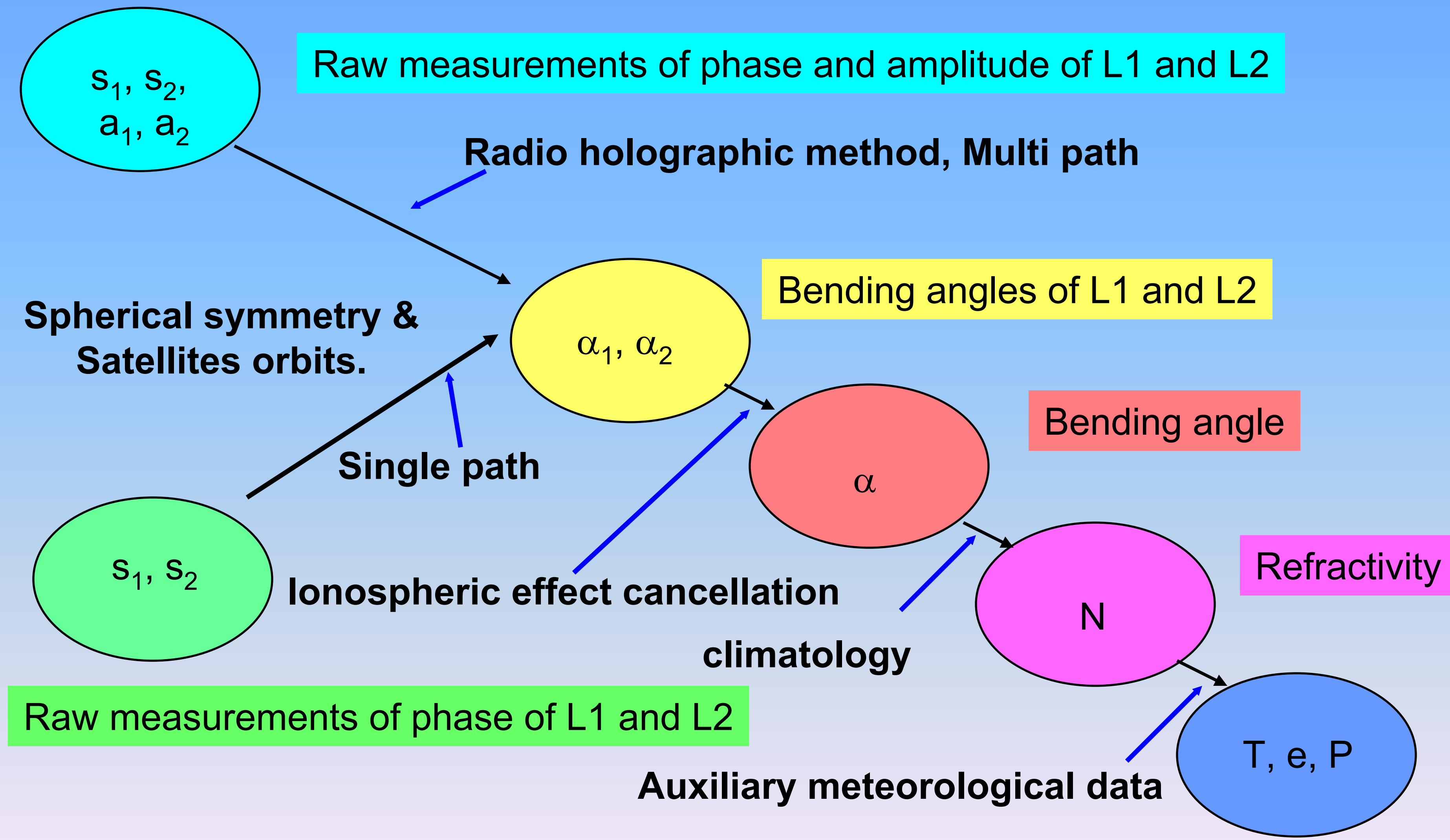
GPS RO /COSMIC:

- **COSMIC: The COnstellation of Satellites for Meteorology, Ionosphere, and Climate**
- **A Multinational Program**
  - Taiwan and the United States of America
- **A Multi-agency Effort**
  - NSPO (Taiwan), NSF, UCAR,
  - NOAA, NASA, USAF
- **Based on the GPS Radio Occultation Method**

GPS RO/COSMIC :

- **Goals are to provide:**
  - Limb soundings with high vertical resolution
  - All-weather operating capability
  - Measurements of Doppler delay based on temperature and humidity variations, convertible to bending angle, refractivity, and higher order products (i.e., temperature/humidity)
  - Suitable for direct assimilation in NWP models
  - Self-calibrated soundings at low cost for climate benchmark

GPS radio occultation measurements & processing



Forward Models:

Refractivity:

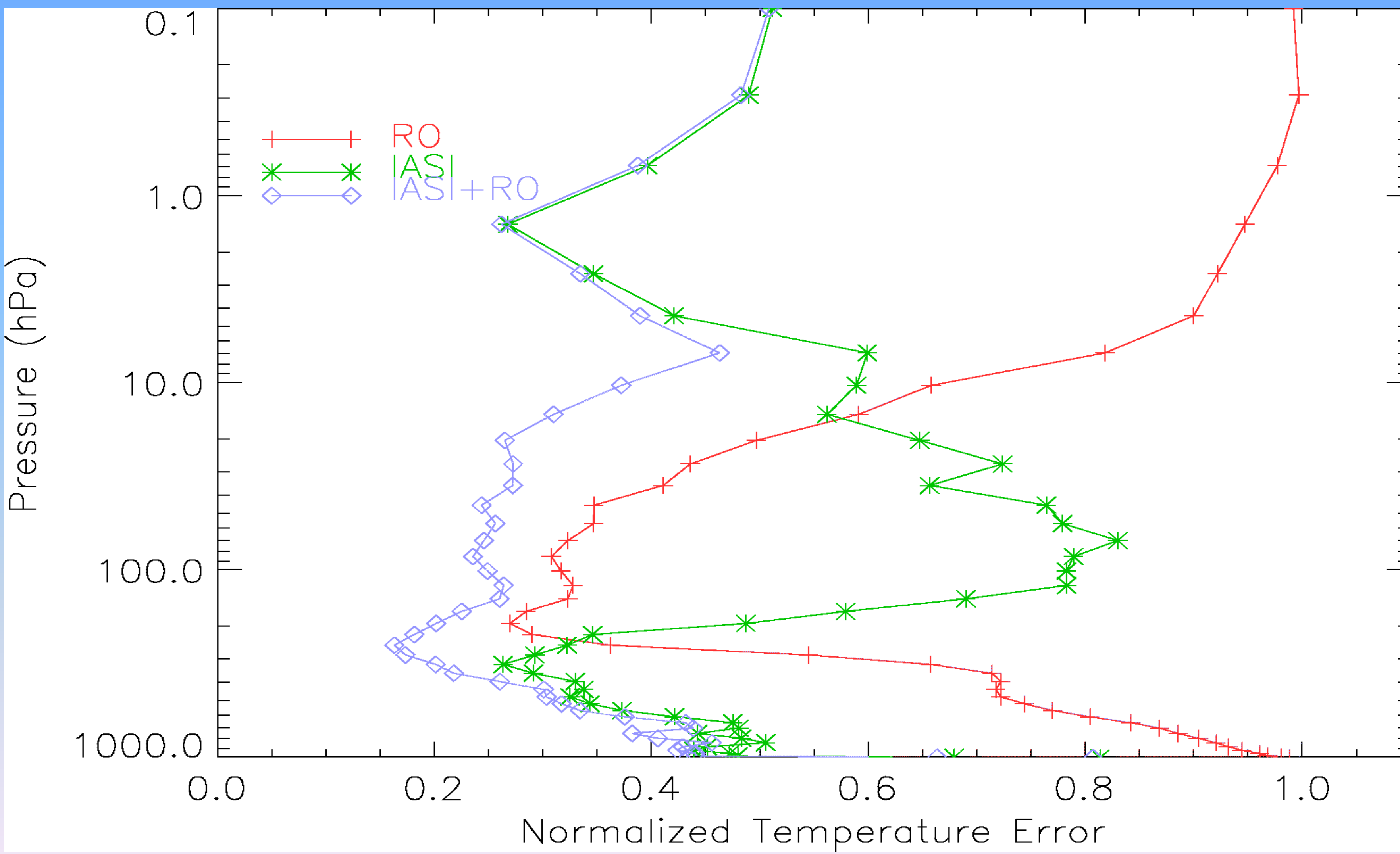
$$N = 77.6\frac{P}{T} + 3.73\times10^{-5}\frac{P_w}{T^2}$$

Bending angle:

$$\alpha(a) = -2a\int_a^\infty \frac{d\ln n / dx}{(x^2 - a^2)^{1/2}}\,dx$$

$$(x = nr)$$

Information content from1D-Var studies
IASI (Infrared Atmospheric Sounding Interferometer)
RO (Radio Occultation) - METOP



(Collard & Healy, QJRMS,2003)

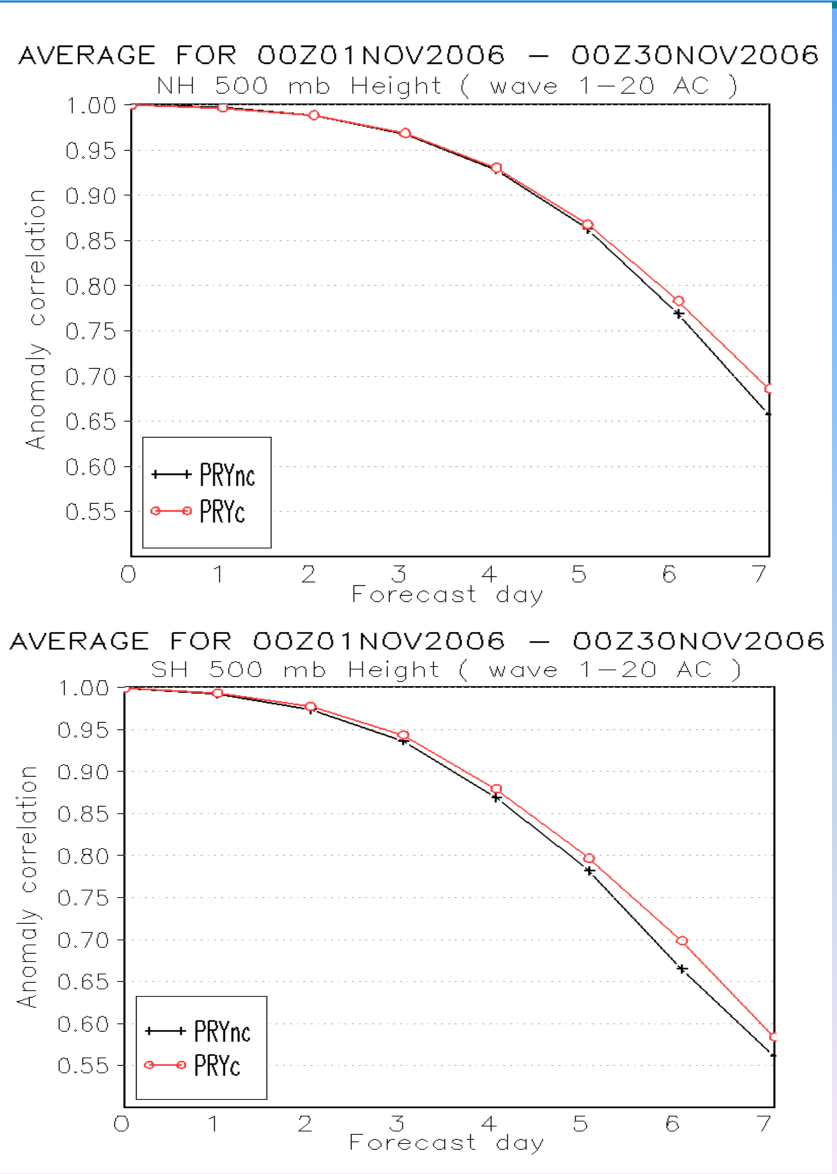
GPS RO / COSMIC (cont'd):

- **COSMIC launched April 2006**
- **Lifetime 5 years**
- **Operations funded through March 08**

COSMIC data was assimilated operationally

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.**



Assimilating satellite observations for Air quality forecasts

S. Kondragunta, X Xhang, Q Zhao, G. Pouliot, R. Mathur, T. . Pierce, J McQueen, P. Lee, L. Flynn, T. Beck, M. Liu, S. Lu

Project Objectives

- To develop a near real time satellite-based biomass burning emissions product for assimilation into NWS air quality forecast model to improve PM2.5 and ozone forecasts

- Other applications include retrospective air quality modeling work, EPA National Emissions Inventory, etc.

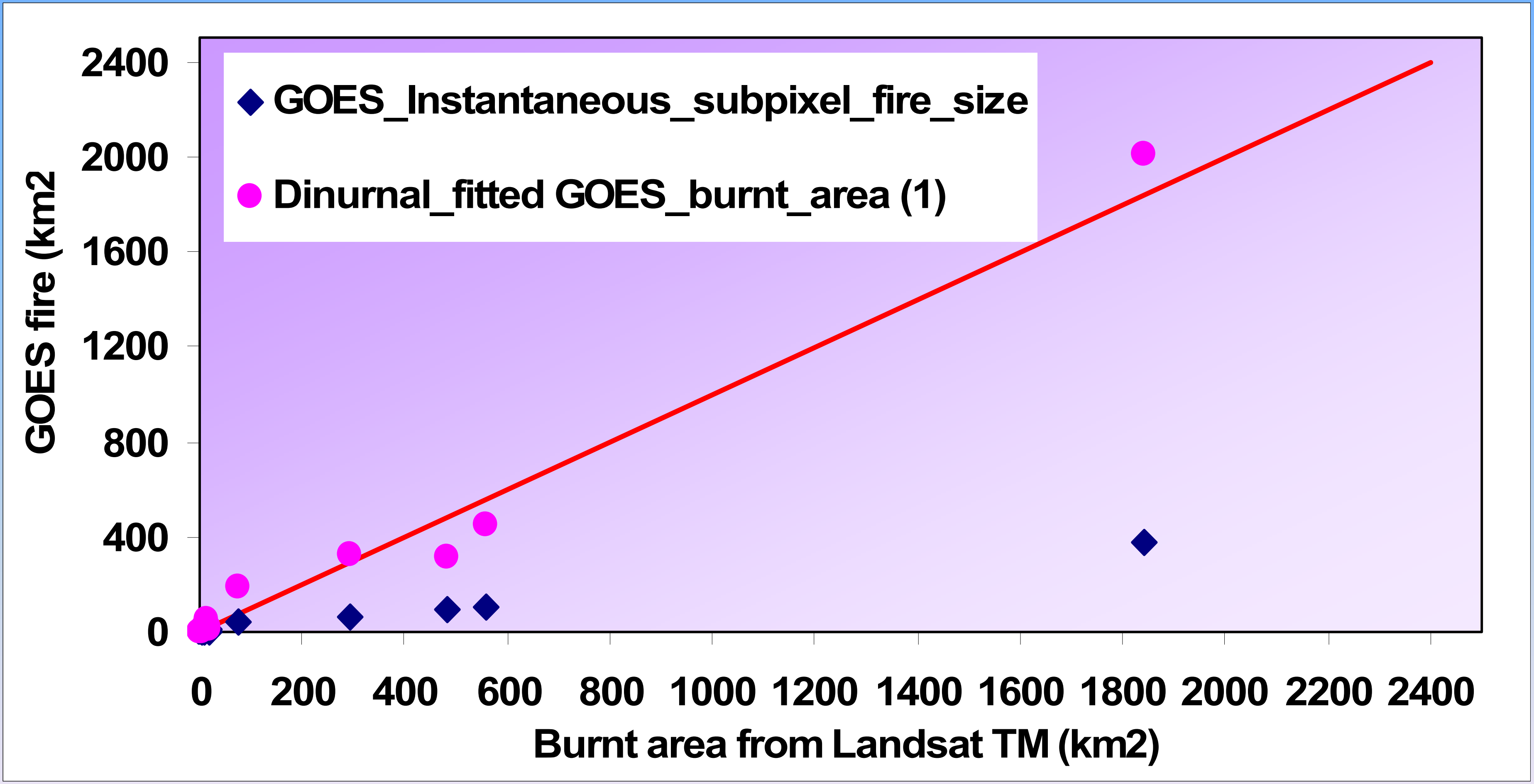
Emissions Algorithm

- **Conventional**
  - Based on burned area, available fuel loading, combustion efficiency, and emissions factors
- **Inputs**
  - MODIS Vegetation Property-based Fuel System (MVPFS) (NASA MODIS) – NESDIS product
  - Fire location and size (NOAA GOES) – NESDIS product
  - Fuel moisture category factor (NOAA AVHRR) – NESDIS product
  - Emissions factors - literature
- **Outputs**
  - PM2.5 emissions in tons/hour in near real time
  - CO, SO2, NOx, CH4, etc. (as required by users)

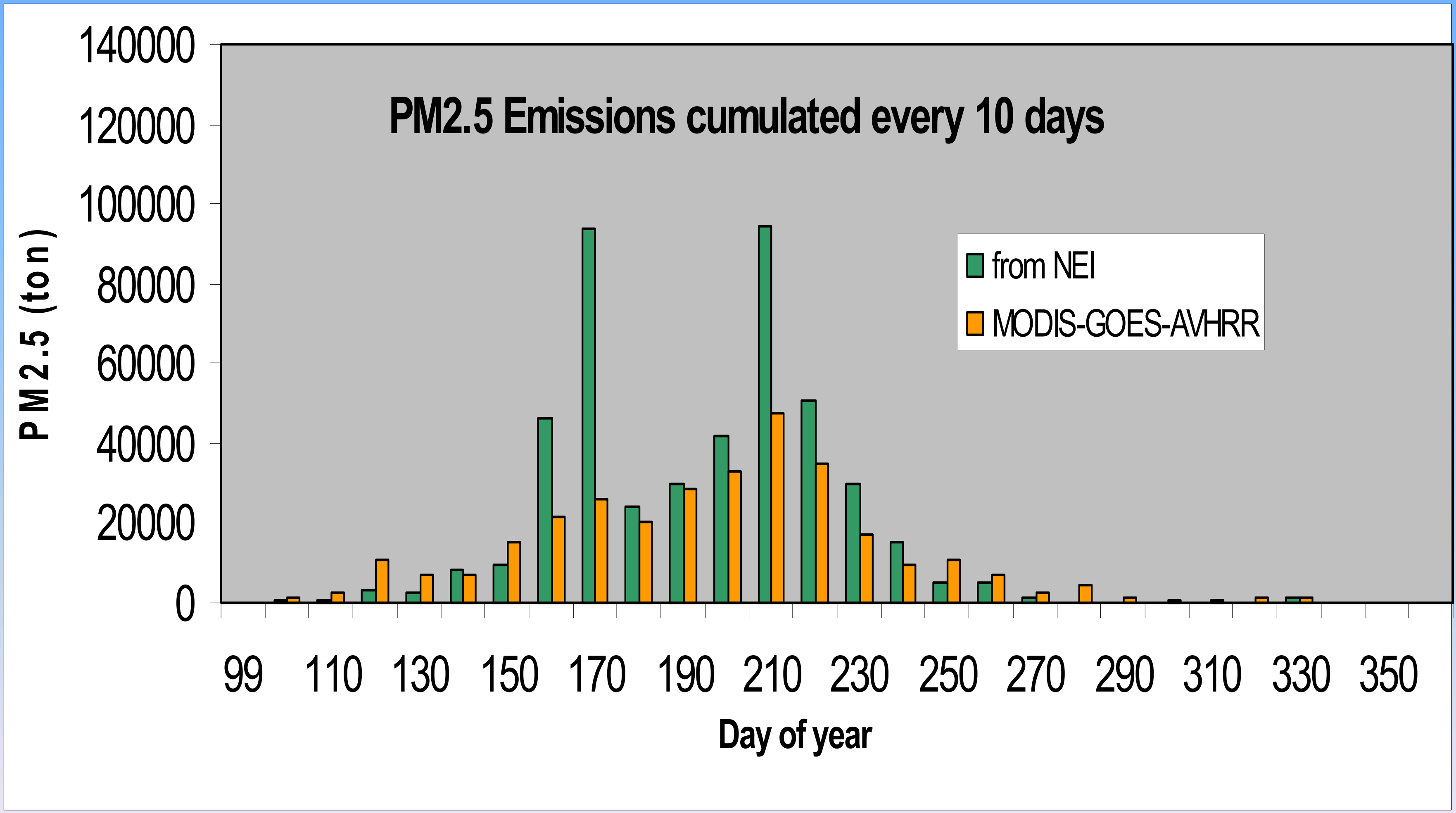
Major Accomplishments

- **Algorithm development to derive aerosol (PM2.5) and trace gas emissions during biomass burning events completed**
  - Algorithm improvements, particularly for determining fire size
  - Data processed: GOES-E 2002 - present
  - Manuscript on the algorithm submitted to a peer-reviewed journal
  - Supported 2006 TEXAQS field campaign
- **Worked with NOAA/OAR to conduct test air quality model simulations using satellite-derived emissions and WRF-CMAQ modeling system. Case study and results presented here**

Evaluation of GOES Fire Size Product



Verification of Satellite-based Biomass Burning PM2.5 Emissions

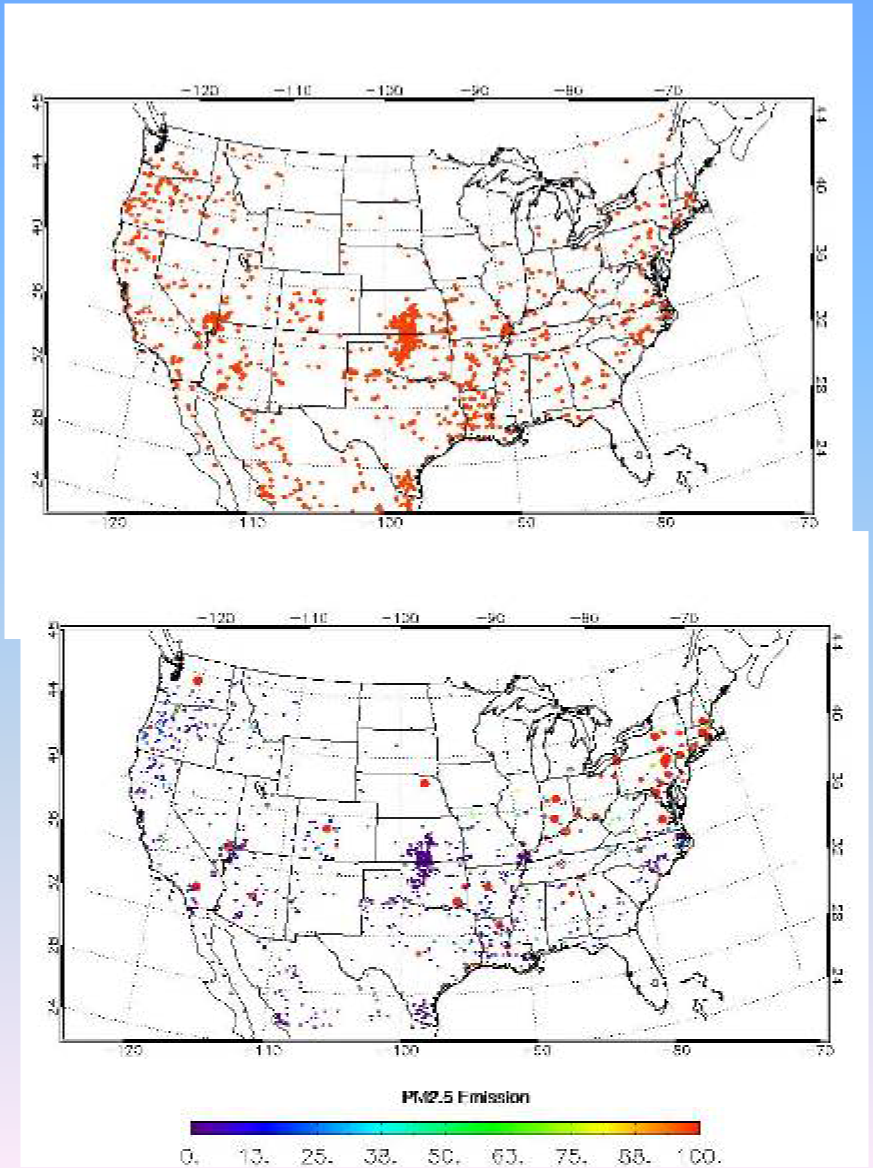


Case Study for June 21 – July 1, 2005

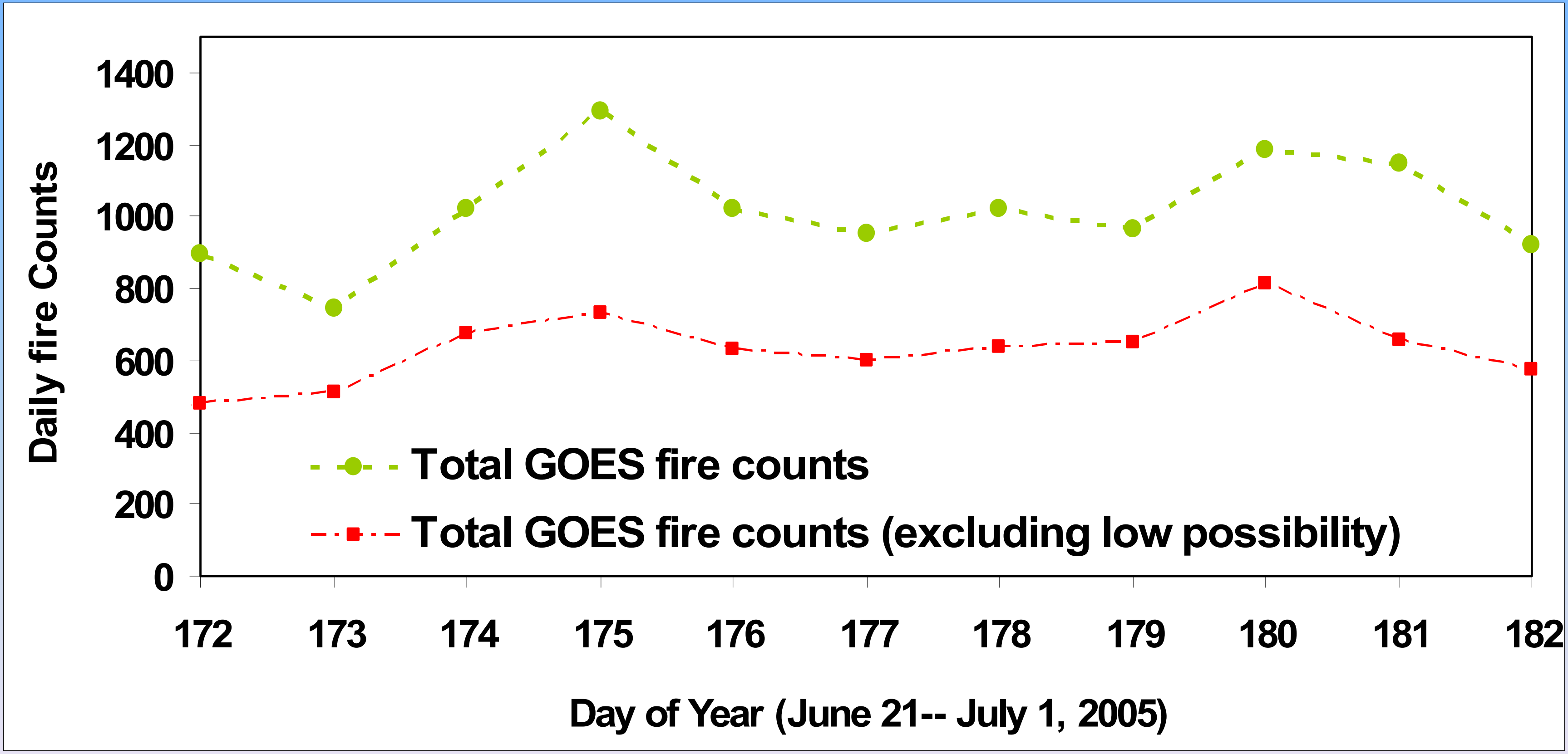
Top panel: Composite of fire occurrence

Bottom panel: Total PM2.5 emissions (tons)

- **Time period corresponded to widespread fire activity over the U.S.**
- **Emissions from most fires low with few fires emitting high amounts of smoke particles**



Temporal Variability in Observed Fire Occurrence



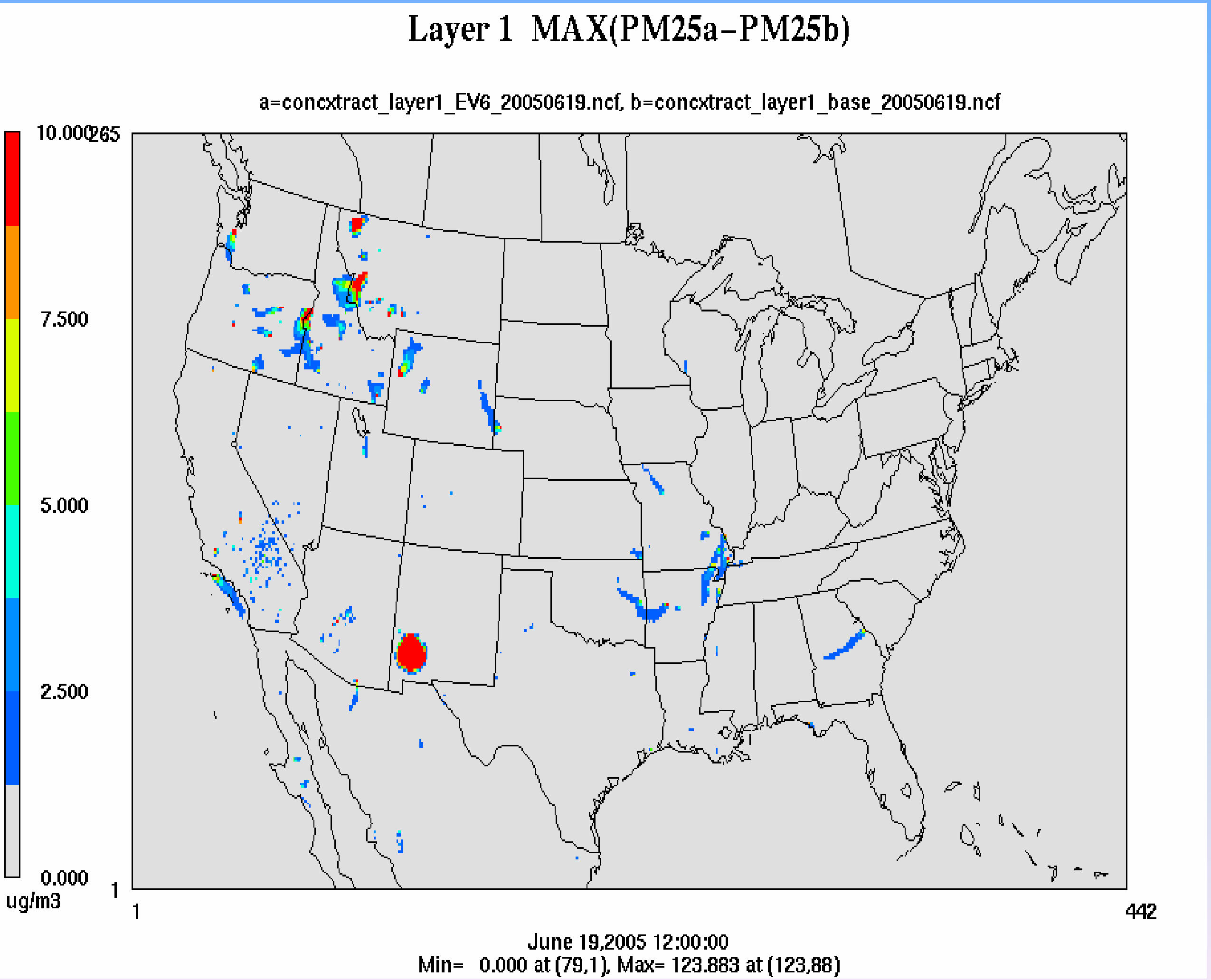
Assimilation Run

- AQF-aerosol version of CMAQ for the CONUS for June 2005
- Model grid was 12 km X 12 km
- Carbon-bond 4 chemistry
- 24-hour cycling period. Hourly forecasts for 48 hours beginning at 12Z
- Assumed emissions for a 24-hour time period persisted for the next 48 hours

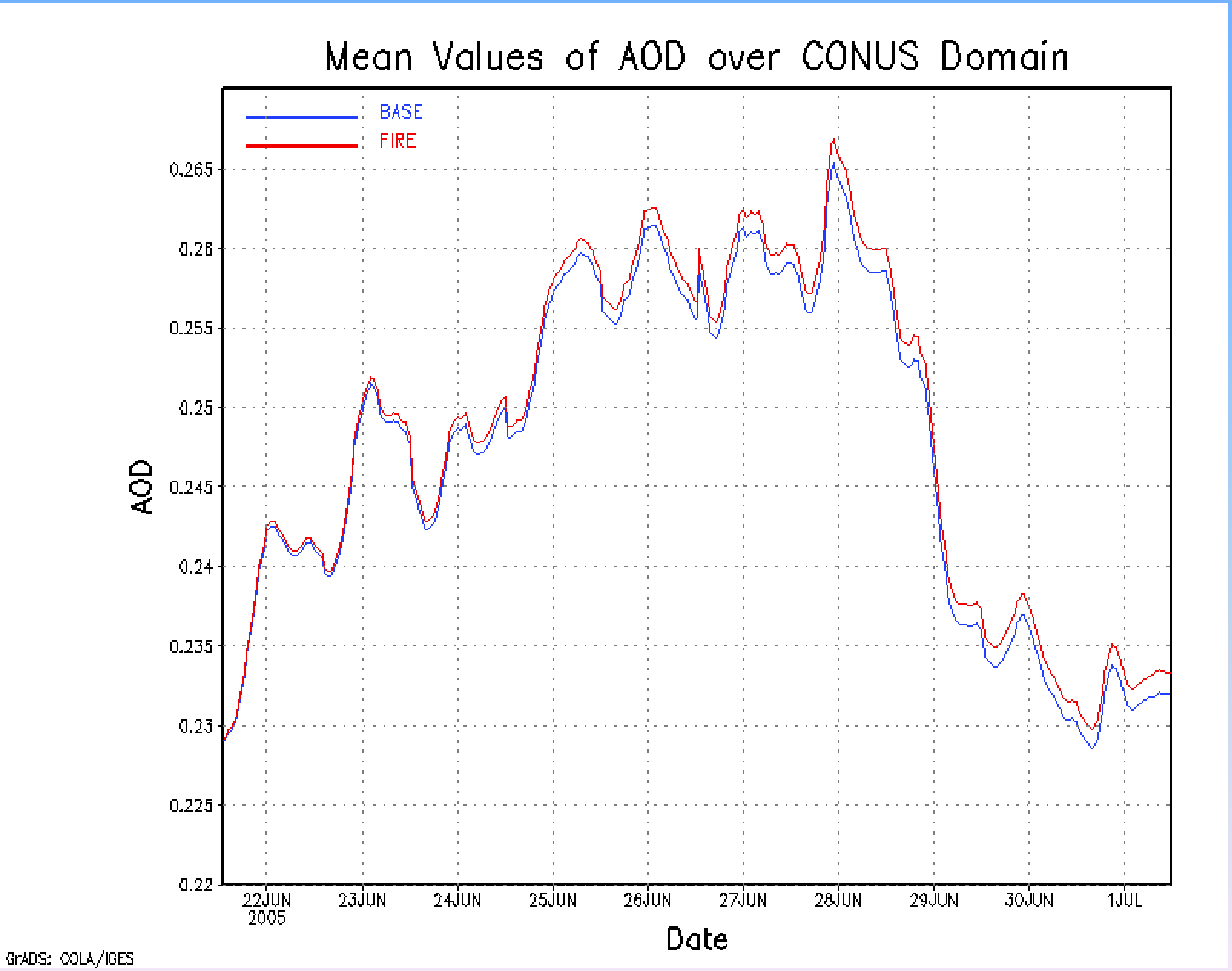
Surface PM2.5 Concentrations (Fire – Control)

Significance:

The new EPA standard for PM2.5 is a daily average of 35 $\mu g/m^3$. Without assimilation of fire emissions, forecast will be biased low for these episodic events



Time Series of Mean AOD



Assimilation of Satellite Observations over Land

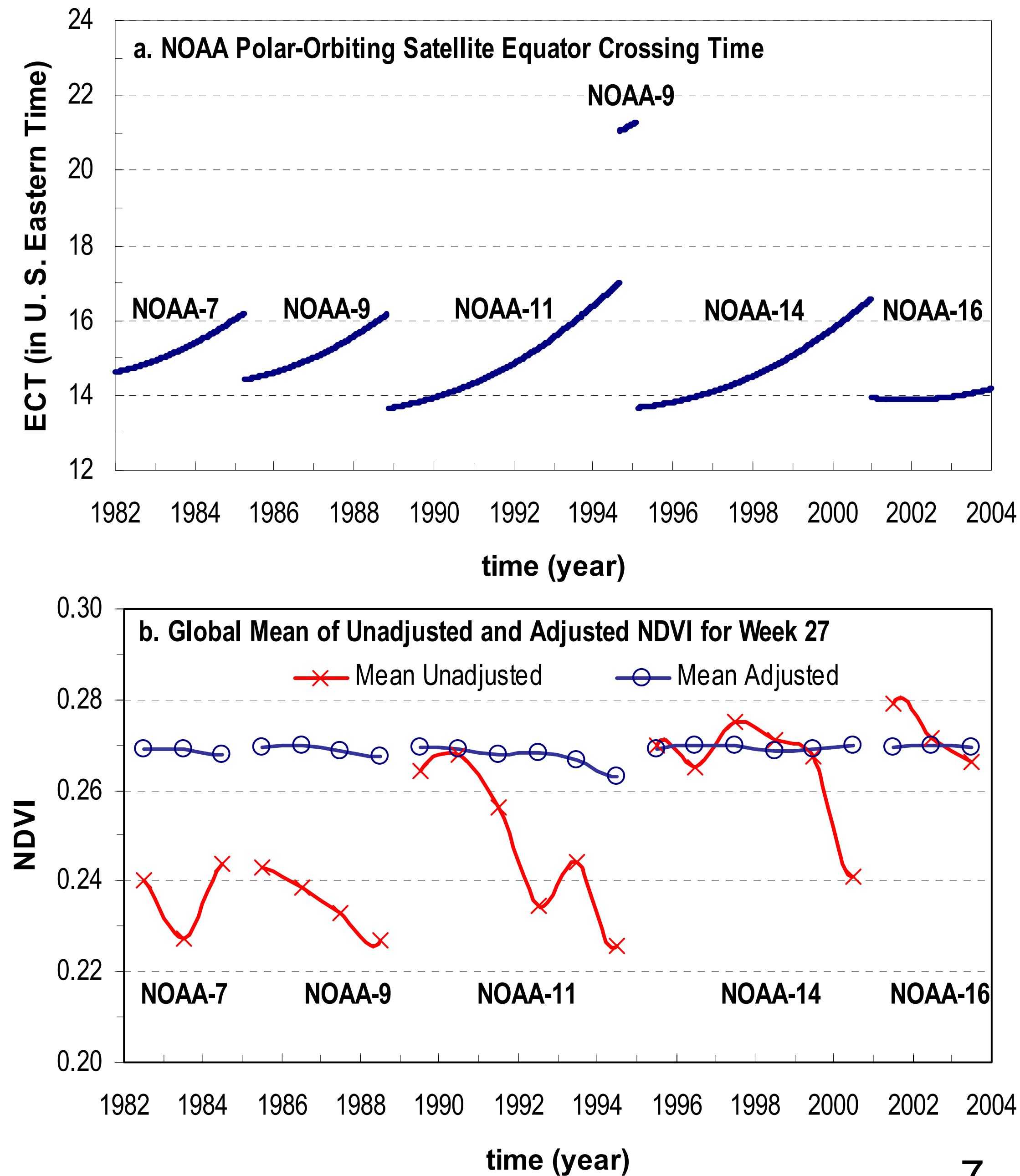
Le Jiang, Dan Tarpley, Wei Guo, Felix Kogan,
and Kenneth Mitchell

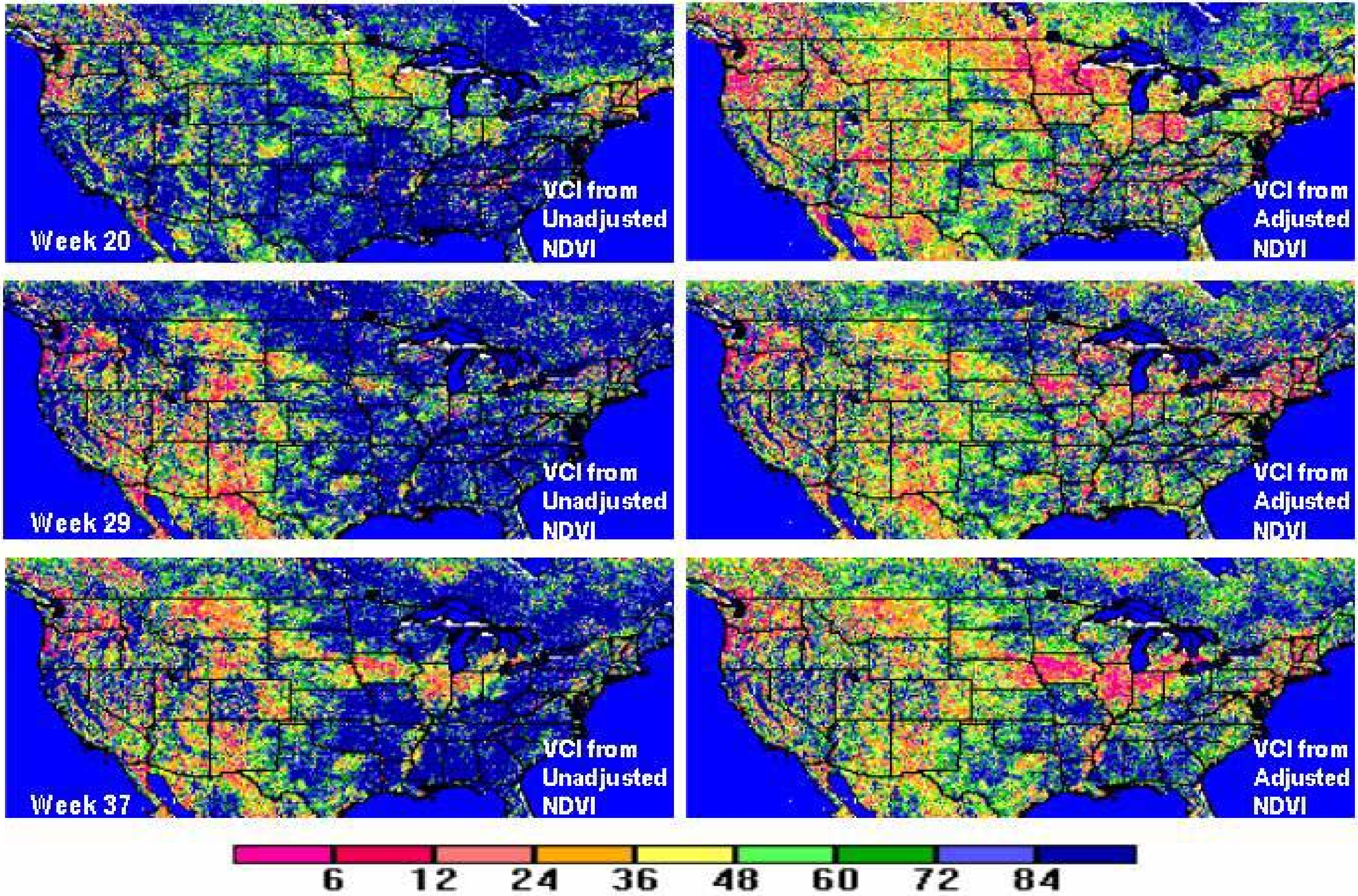
AVHRR-Based Global Vegetation Processing System (GVPS)

- Implementing the adjusted cumulative distribution function (ACDF) method in operational NDVI algorithm to correct the satellite orbital drift
- Producing a consistent and quality improved long-term NDVI dataset
- Operational data availability to NCEP/EMC (expected by June 2007)

Satellite ECTs for the period 1982 to 2003

Global mean of unadjusted and adjusted NDVI for week 27 from 1982 to 2993.





Comparison of Vegetation Condition Index (VCI) resulted from un-adjusted and adjusted NDVI datasets over the CONUS (27N~53N, 127W~67W) in 2005 for weeks 20 (May), 29 (July) and 37 (September)

Assimilation of Satellite Observations over Oceans

Paul Chang, Banghua Yan, Fuzhong Weng, Nick. Nalli

STAR Ocean Projects Supporting JCSDA

- Prepare Quikscat and Windsat ocean wind vectors for assimilation testing
- Fast ocean polarimetric emissivity and sea ice emissivity model
- improve water-leaving radiance calculation through uses of MOREL bi-optical model and directly coupled RT schemes
- GOES SST products
- Beginning a planning of ocean data assimilation program through NOAA IOOS initiative

NESDIS/STAR Publications (2006-2007) Supported through JCSDA

LeMarshall, J, et al., the Joint Center for Satellite Data Assimilation, Bull Amer Meteor, Soc, pp 329-240.

Zapotocny et al., 2007, A Two Season Impact Study of Four Satellite Data Types and Rawinsonde Data in the NCEP Global Data Assimilation System, WAF, (revised)

Jiang, L., J. D. Tarpley, K. E. Mitchell, W. Guo, B. H. Ramsay, and F. N. Kogan, Deriving near real time global green vegetation fraction from AVHRR-based global vegetation indices, to be submitted to JHM, 2007.

Jiang, L., J. D. Tarpley, K. E. Mitchell, S. Zhou, F. N. Kogan, and W. Guo, Adjusting for long term anomalous trends in NOAA's global vegetation index datasets, in review at IEEE Trans. Geosci. Rem. Sens., 2007.

Liu, Q. and F. Weng, 2006: Advanced doubling–adding method for radiative transfer in planetary atmospheres, J. Atmos. Sci., 63, 3459-3465,

Weng, F., T. Zhu, and B. Yang, 2007: Satellite data assimilation in numerical weather prediction models, 2. Uses of rain affected microwave radiances for hurricane vortex analysis, J. Atmos. Sci., (in press).

Weng, F., 2007: Advances in radiative transfer modeling in support of satellite data assimilation, J. Atmos. Sci., (in press).

Han, Y, F. Weng, Q. Liu, and P. van Delst, 2007: A fast radiative transfer model for SSMIS upper-atmosphere sounding channels, J. Geophys. Res, (accepted)

Liu, Q. and F. Weng, 2006, Combined Henyey–Greenstein and Rayleigh phase function, Appl. Opt., 45, 7475-7479

Kondragunta, S., P. Lee, J. McQueen, C. Kittaka, P. Ciren, A. Prados, I. Laszlo, B. Pierce, R. Hoff, J. J. Szykman, Air Quality Forecast Verification using Satellite Data, Journal of Applied Meteorology and Climatology, accepted, 2007

JAS Special volume on assimilation of cloud and precipitation data from satellites

IEEE Special volume on surface remote sensing and property modeling

Concluding Remarks

NESDIS/STAR has provided to JCSDA strong supports in resource, management and science leadership

Challenges in Satellite Data Assimilation

- **Difficult to ingest all hyperspectral sounding data when more trace gases are included**
- **Difficult to use satellite measurements that are affected by surface**
- **Difficult to assimilate satellite radiances that are affected by aerosols and clouds**
- **New initiatives in ocean data assimilation**