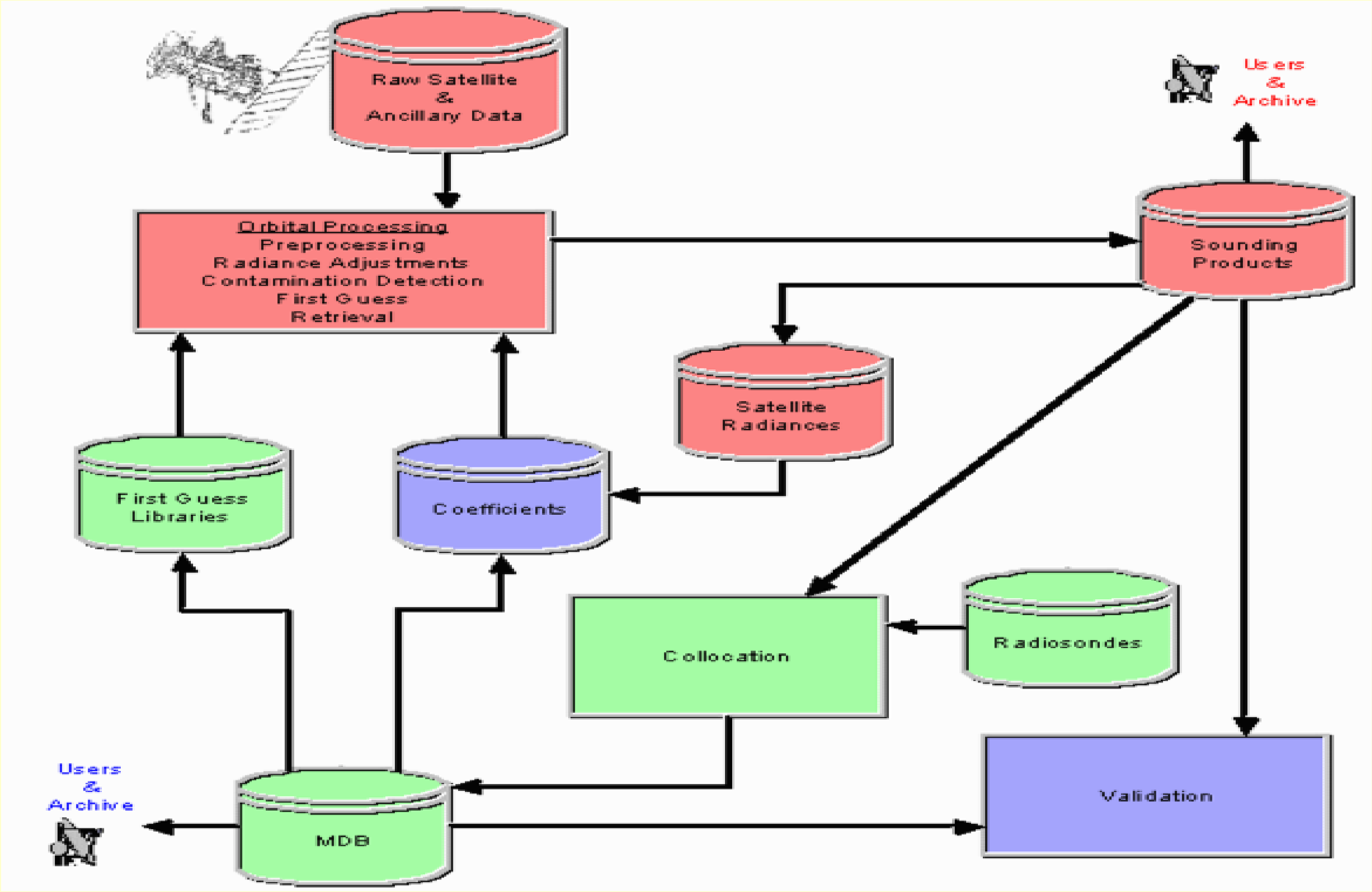
ATOVS POES PROCESSING 2005

Tony Reale

FPDT

March 21, 2005

ATOVS Processing Diagram … Orbital, Daily, Weekly



Orbital Processing

- Earth-location/Calibration
- Append SST, Terrain, Ice/Snow, NWP
- Limb Adjustment
- Interpolate to HIRS
- Microwave Products (CLW, TPW … MSPPS)
- Contamination Detection
  - Precipitation
  - Cloud
- First Guess
- Retrieval

Offline Support Processing

- Limb Correction Coefficients
- Cloud Detection Coefficients
- Collocated Radiosonde and Satellite Observations
  - Unified Radiosonde File
  - Collocated Radiosonde and Satellite Observations (MDB)
  - First Guess Libraries (w/ PCS)
- First Guess Eigenvectors
- Retrieval Operator Components
  - S, A and N matrices
- Validation (EDGE)

New ATOVS System-2004 Science

- ***Incorporate AMSU-B***

- Regression Guess replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)

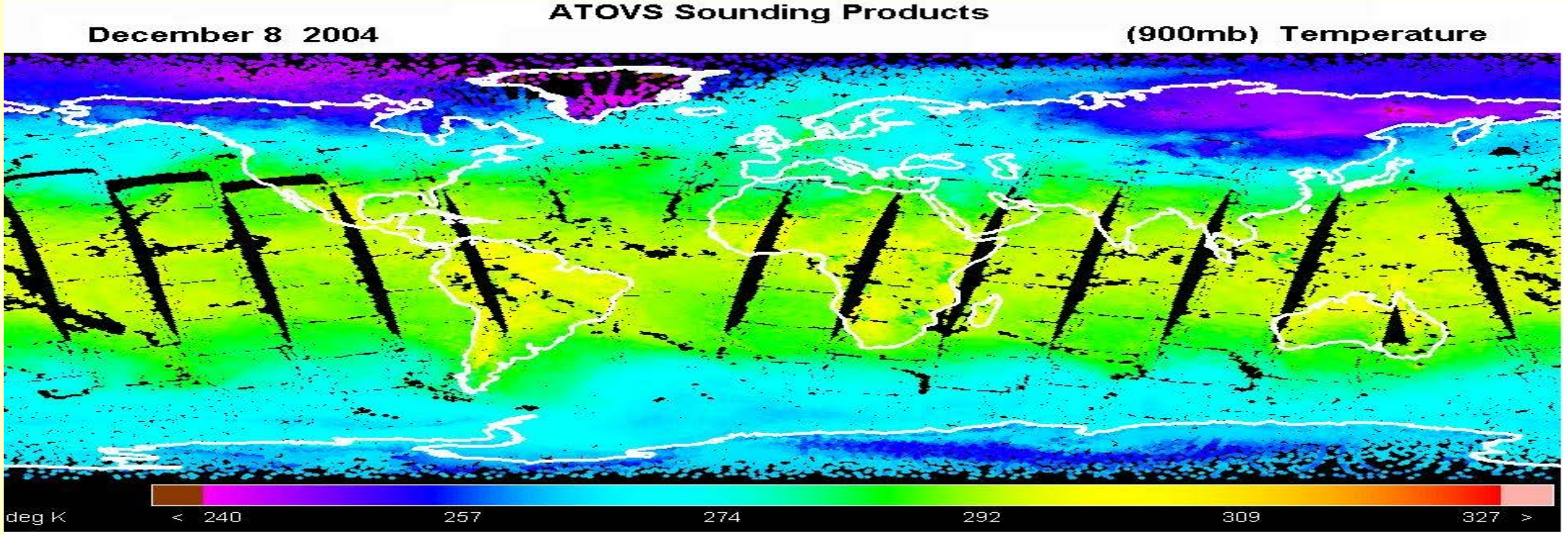
- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS

- Analytical Retrieval Solution (OPTRAN) per sounding (Paul Van-delst, Tom Kleespies, Yong Han)
  - based on Guess Temp and Moisture

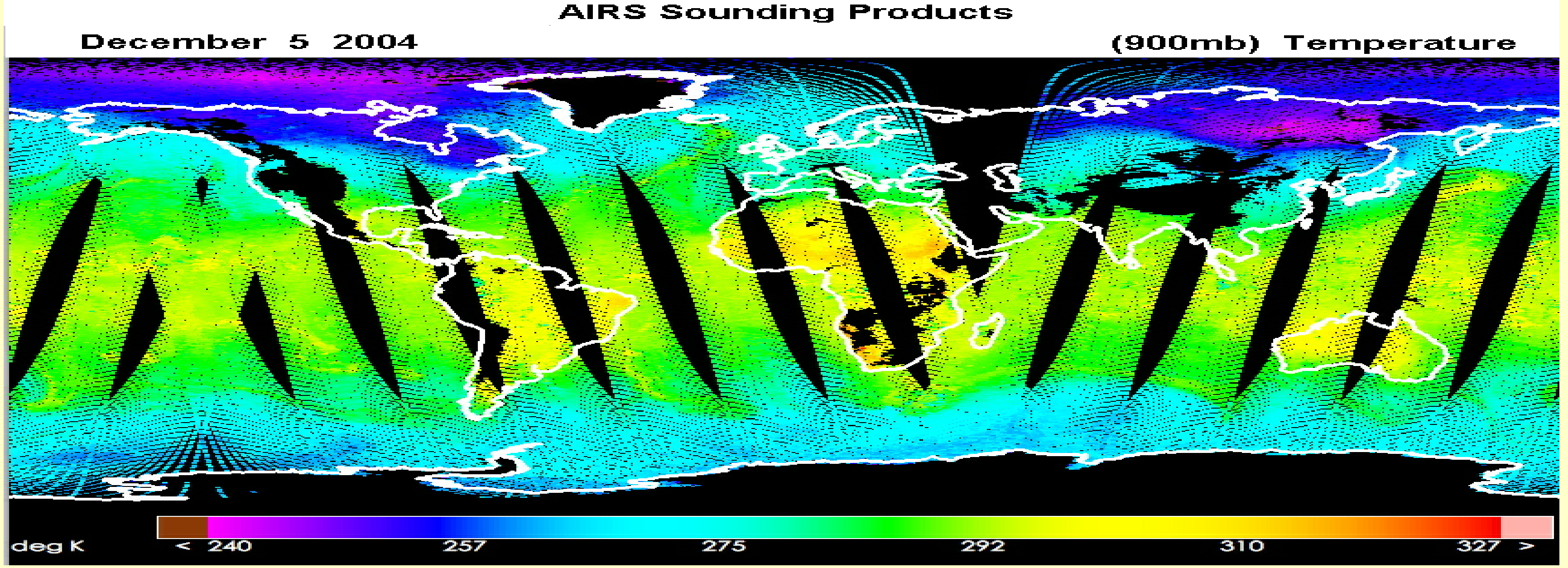
- Peripheral Upgrades
  - Limb-adjustment
  - MSPPS Products
  - Expanded Validation

Environmental Data Graphic and Evaluation System (EDGE)

- **Three (3) Major Sub-systems:**
  - ***EDGEIS:*** Horizontal Fields of Orbital Products
  - ***Profile Display (PDISP):*** Collocated Radiosonde and Satellite Observations
  - ***Vertical Statistics (VSTAT):*** Collocations
- AQUA/AIRS vs. ATOVS Comparisons (Walter Wolf, Chris Barnet, Tom King and Murty Divakarla)
- ***Provided to EUMETSAT (Eamonn McKernan support of Collaborations for METOP …***



ATOVS (top) as benchmark for AIRS (bottom)



SOUNDING USERS (short list)

- NWP
  - DOD (NRL)
  - Germany (DWD)
  - Canada (AES)
  - Japan (JMA)
  - Brazil (INPE)

- Climate
  - NCEP (CDAS),
  - Germany (DWD)

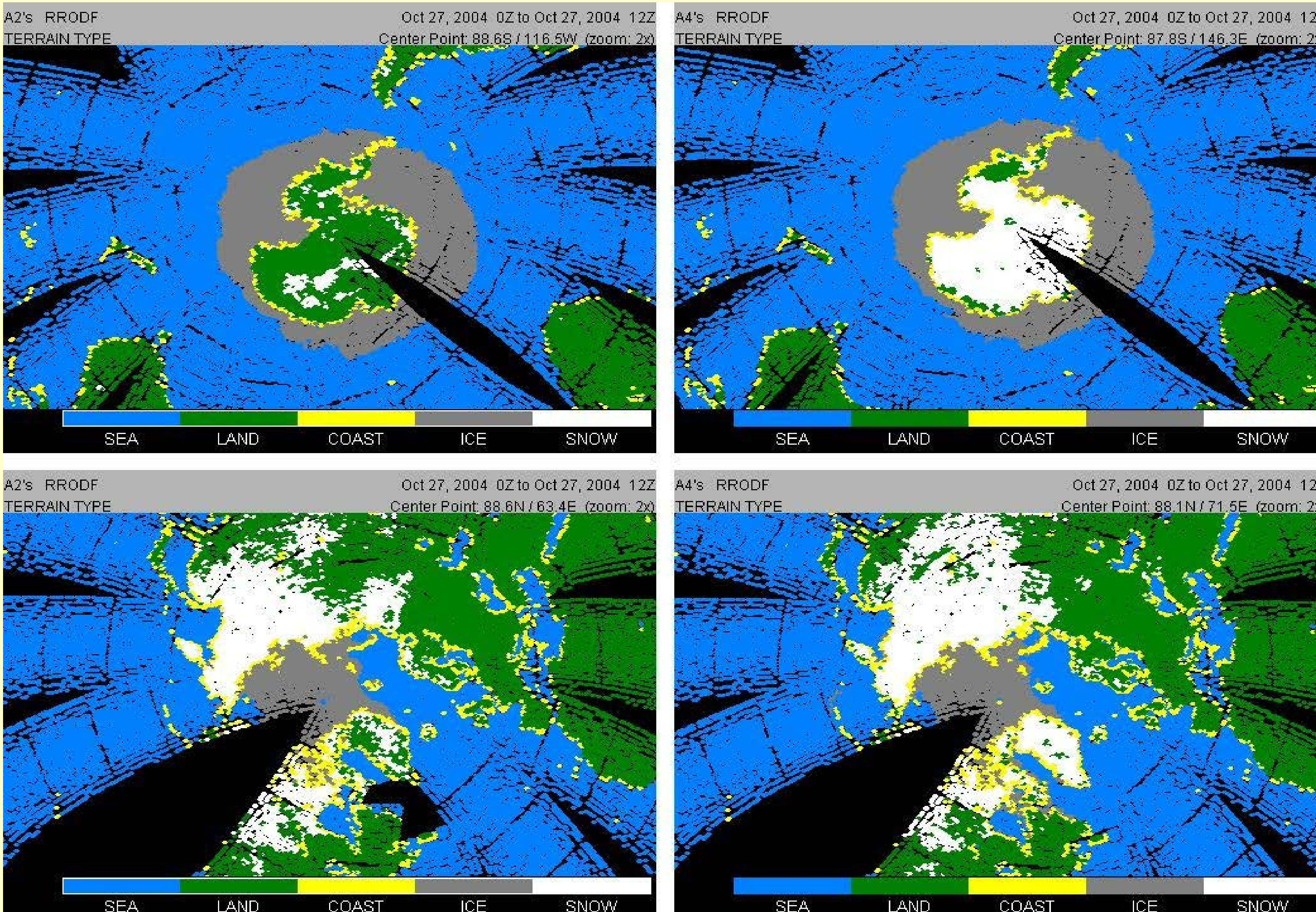
- NOAA
  - AWIPS (NWS)
  - Cloud Products (NESDIS) …

- Others …

Orbital Processing

- Earth-location/Calibration
- Append SST, Terrain, Ice/Snow, NWP
- Limb Adjustment
- Interpolate to HIRS
- Microwave Products (CLW, TPW … MSPPS)
- Contamination Detection
  - Precipitation
  - Cloud
- First Guess
- Retrieval

Sea Ice and Snow from SSM/I (left) vs. MSPPS (right)



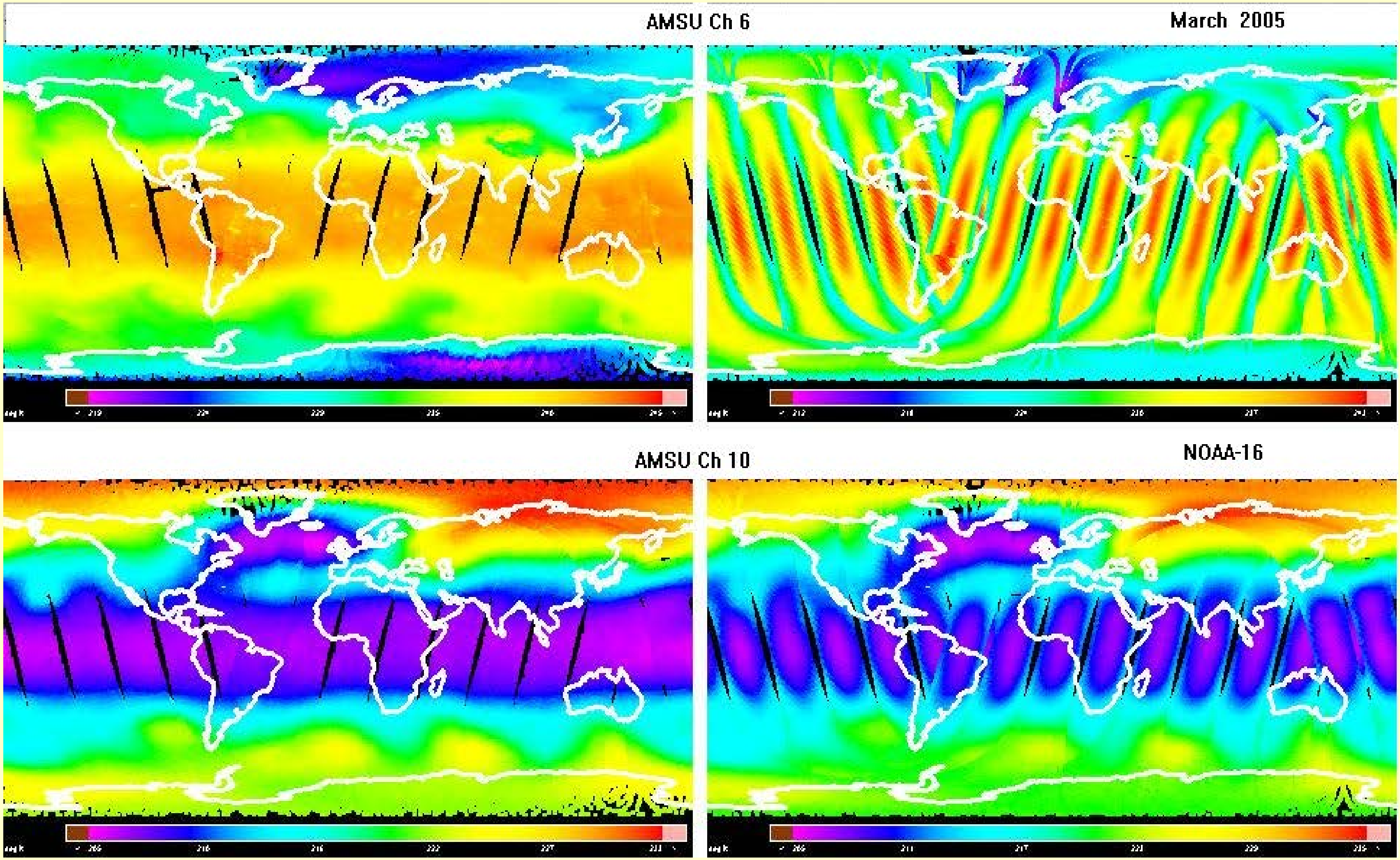
Orbital Processing

- Earth-location/Calibration
- Append SST, Terrain, Ice/Snow, NWP
- Limb Adjustment
- Interpolate to HIRS
- Microwave Products (CLW, TPW … MSPPS)
- Contamination Detection
  - Precipitation
  - Cloud
- First Guess
- Retrieval

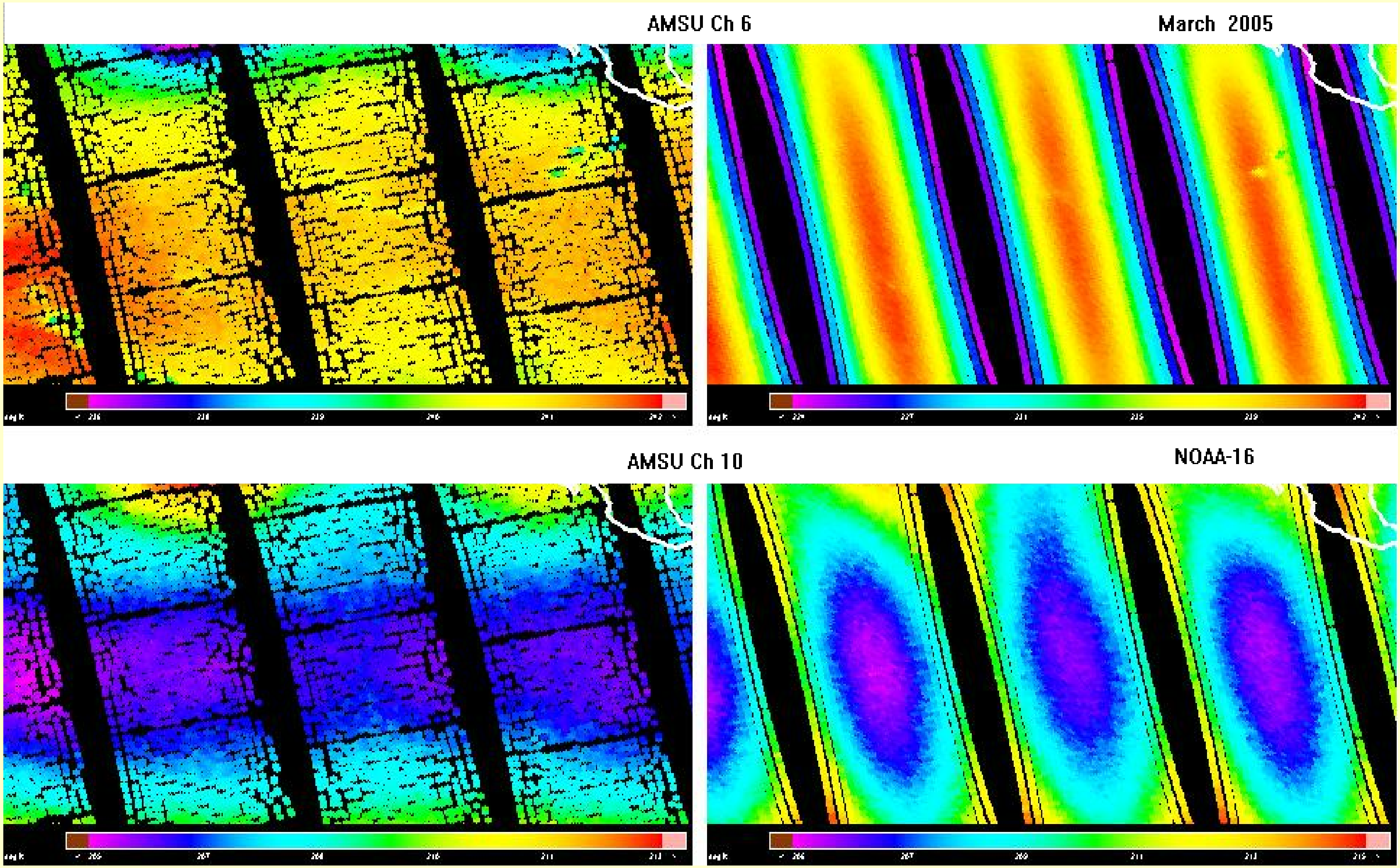
Limb Adjustments

- Dave Wark; NOAA Tech Re NESDIS 64, 1993
- 5-day Level 1b (per sounder) samples in Radiance Temperature
- 2-degree latitude belts (82), Sea vs. Nonsea, and Scan L
- 3 predictors least square regression (i=channel, j=scan)
  - $T_{i,0} = a_{i,j} + a_{i-1,j} T_{i-1,j} + a_{i,j} T_{i,j} + a_{i+1,j} T_{i+1,j}$
- Symmetric vs. Asymmetric option
- Update as Necessary

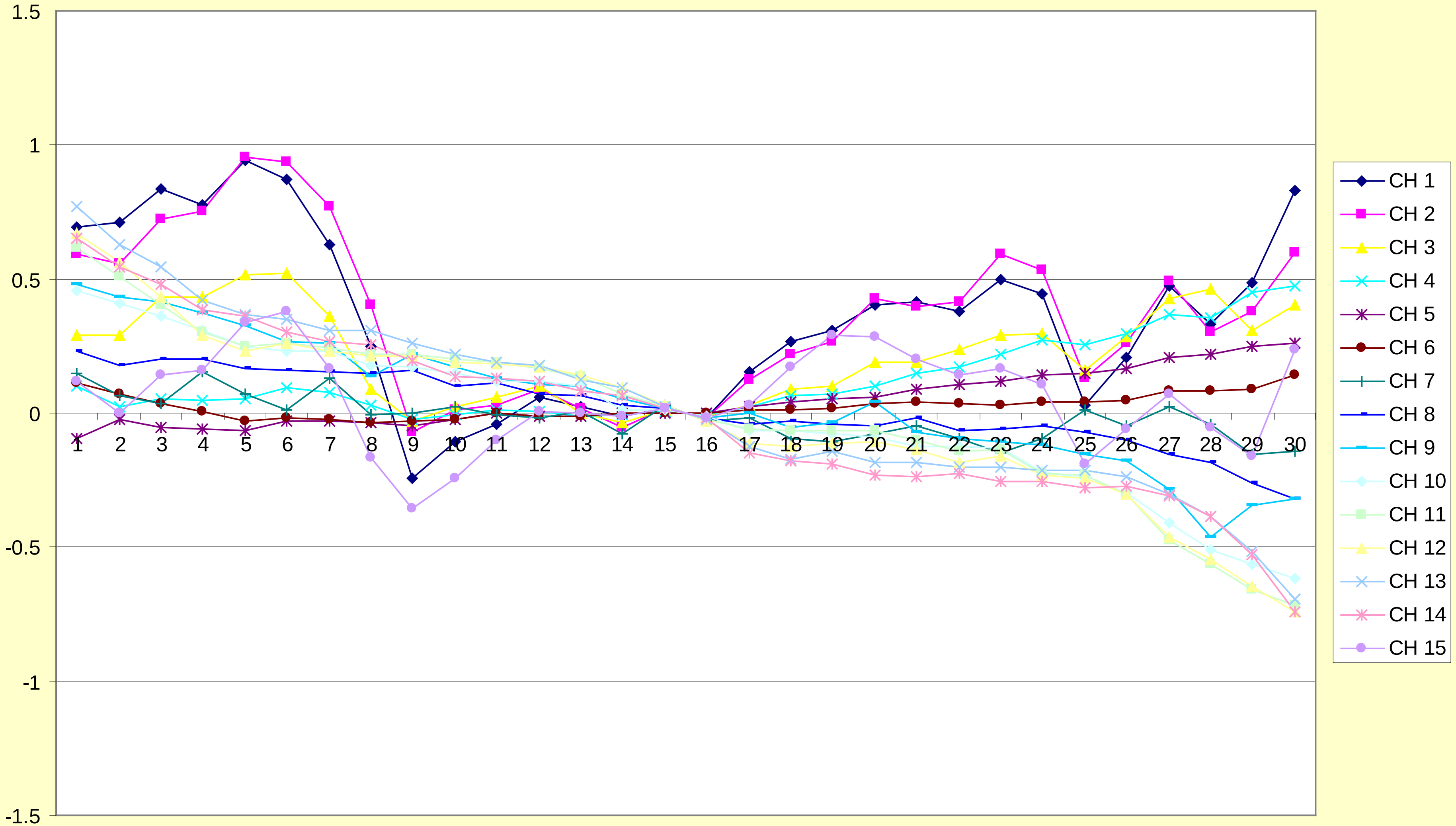
Limb Adjustment
(Wark, NOAA Tech Re. NESDIS 64' 1993)



Limb Adjustment
(Wark, NOAA Tech Re. NESDIS 64' 1993)



A2 AMSU-A Sea Residuals Nov 25-29, 2004



New ATOVS System-2004 Science

- ***Incorporate AMSU-B***

- Regression Guess replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)

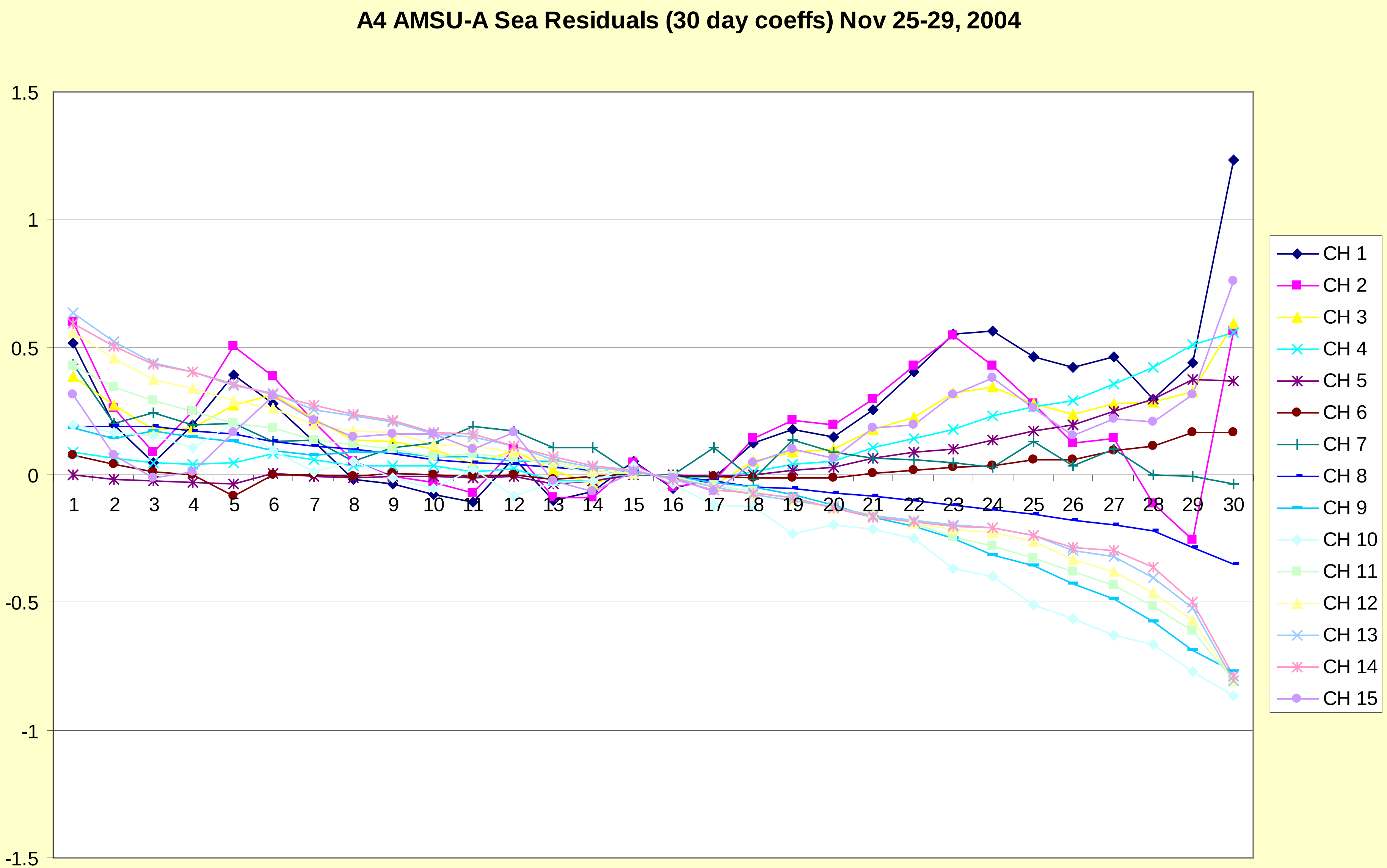
- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS

- Analytical Retrieval Solution (OPTRAN) per sounding (Paul Van-delst, Tom Kleespies, Yong Han)
  - based on Guess Temp and Moisture

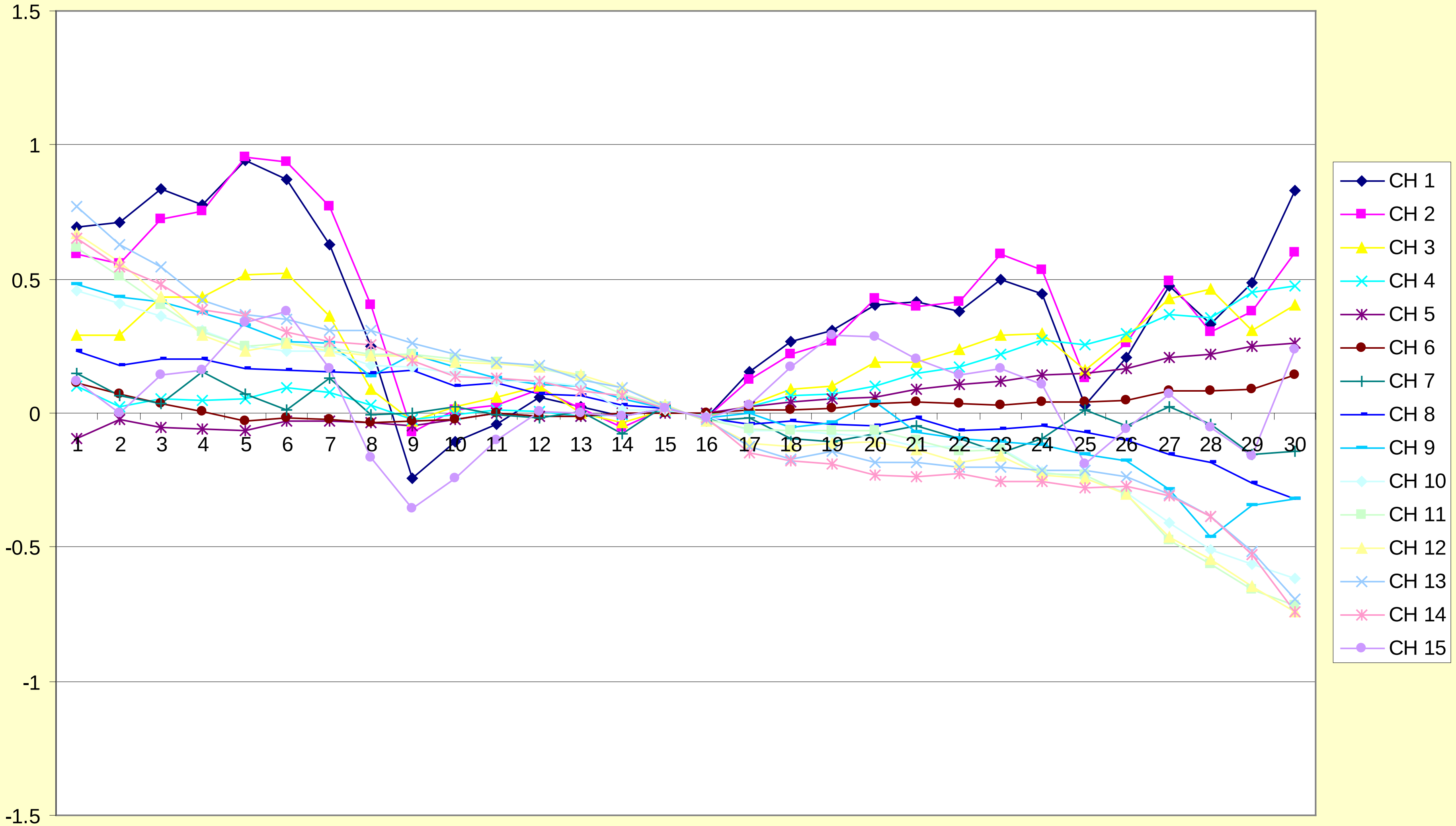
- Peripheral Upgrades
  - Limb-adjustment
  - MSPPS Products
  - Expanded Validation

Proposed Changes to Limb Adjustment (New System-2005)

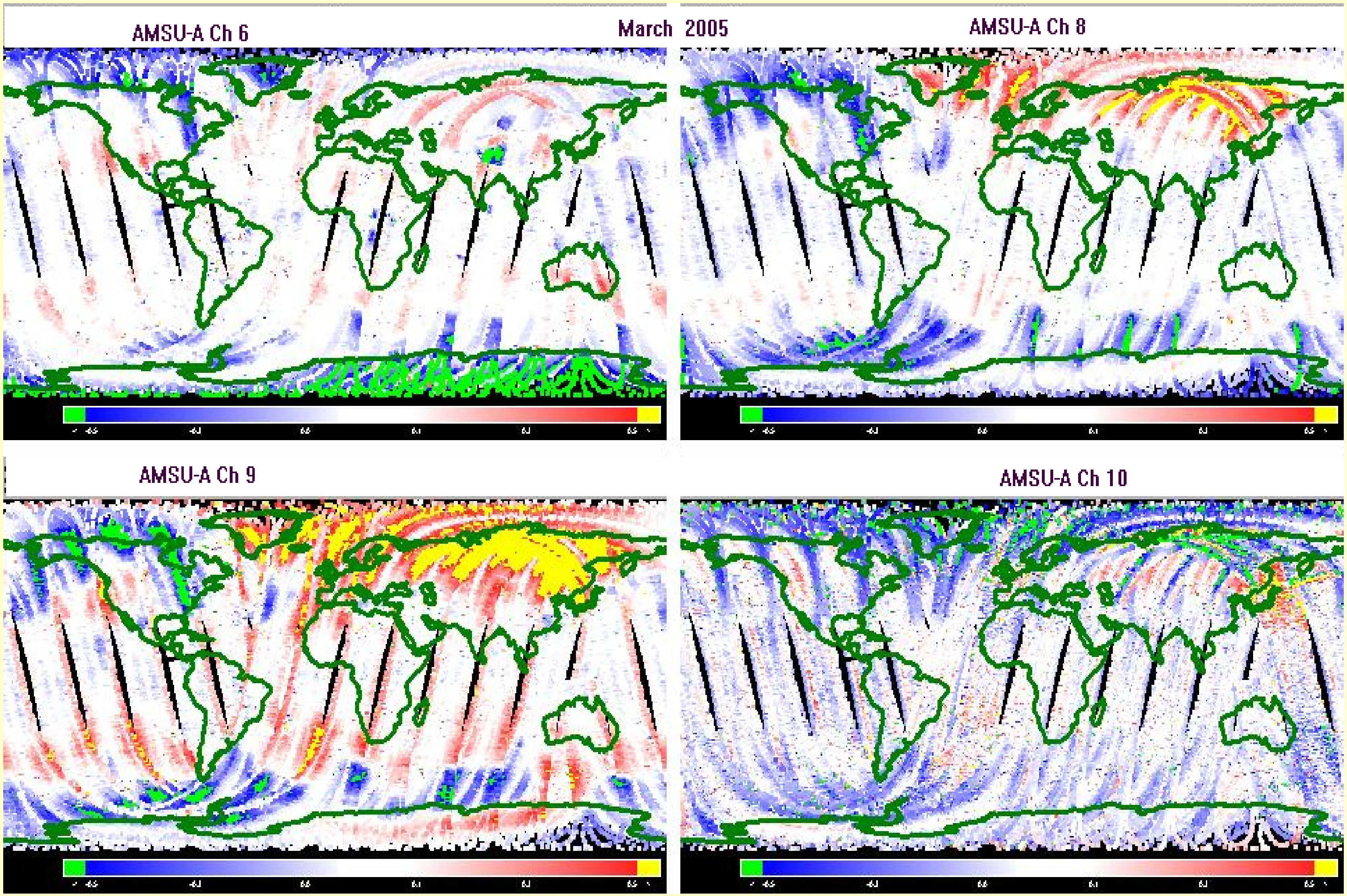
- Retain the basic Wark approach, but:
  - Replace 5-day with 30-day files for generating coefficients
  - Routinely collect radiance temperature samples (daily)
  - Store covariance matrices of measurements for 30-day periods over operational satellite lifetime
    - may have to retain matrices consistent with Wark approach, (i.e., per latitude band?)
  - Routinely arbitrate based on residual plots (weekly, monthly?)
    - May include NWP based residual
  - Archive


A4 AMSU-A Sea Residuals (30 day coeffs) Nov 25-29, 2004
1.5
1
0.5
0
-0.5
-1
-1.5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
CH 1
CH 2
CH 3
CH 4
CH 5
CH 6
CH 7
CH 8
CH 9
CH 10
CH 11
CH 12
CH 13
CH 14
CH 15

A2 AMSU-A Sea Residuals Nov 25-29, 2004



Limb Adjustment
(Comparison of 5-day vs 30-day coefficients)



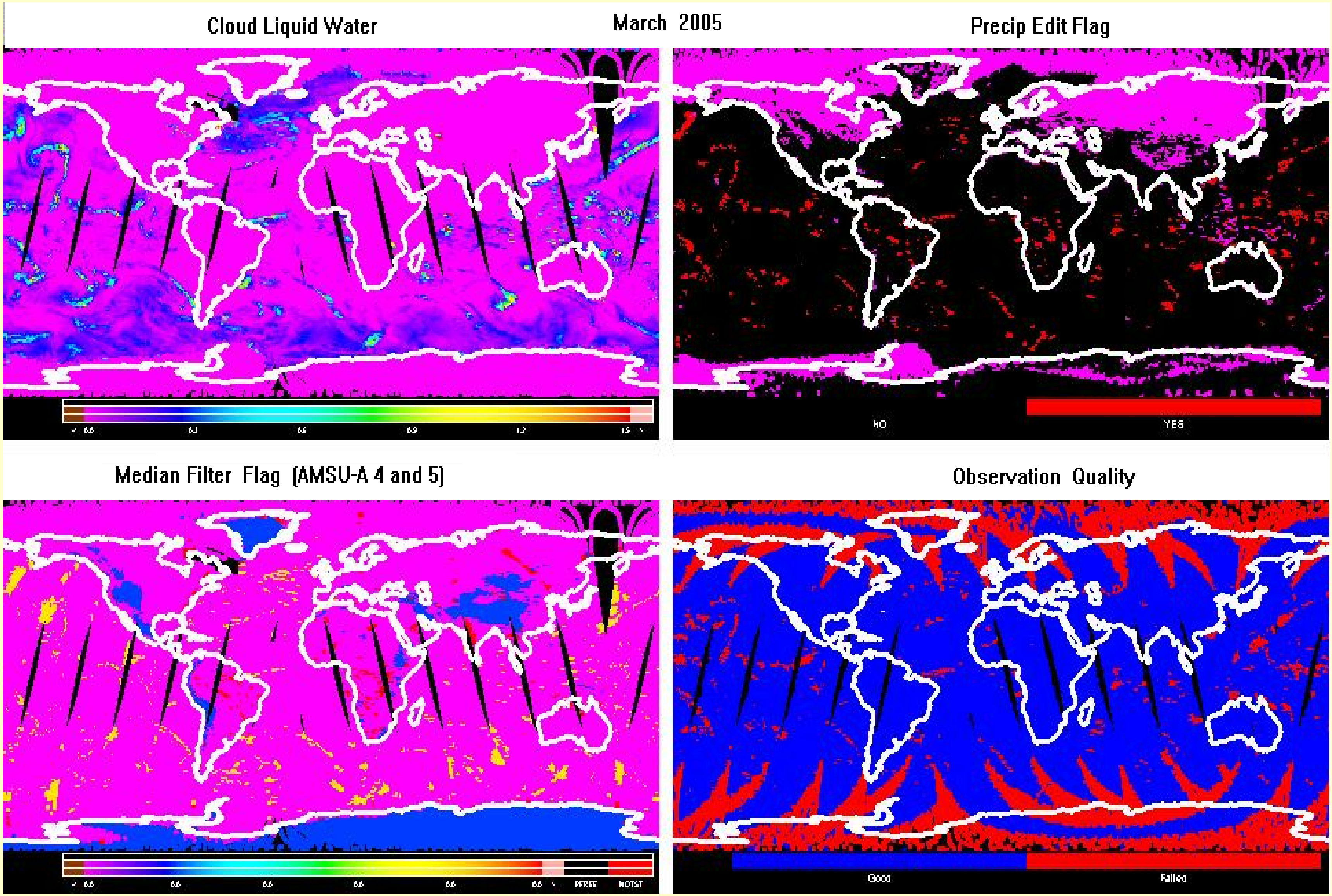
Orbital Processing

- Earth-location/Calibration
- Append SST, Terrain, Ice/Snow, NWP
- Limb Adjustment
- Interpolate to HIRS
- Microwave Products (CLW, TPW … MSPPS)
- Contamination Detection
  – Precipitation
  – Cloud
- First Guess
- Retrieval

Product Quality Indicators

- Measurement Gross Error
- No Interpolation (gaps)
- Precipitation
  - CLW over sea
  - (includes median filter over land)
- Polar Redundant

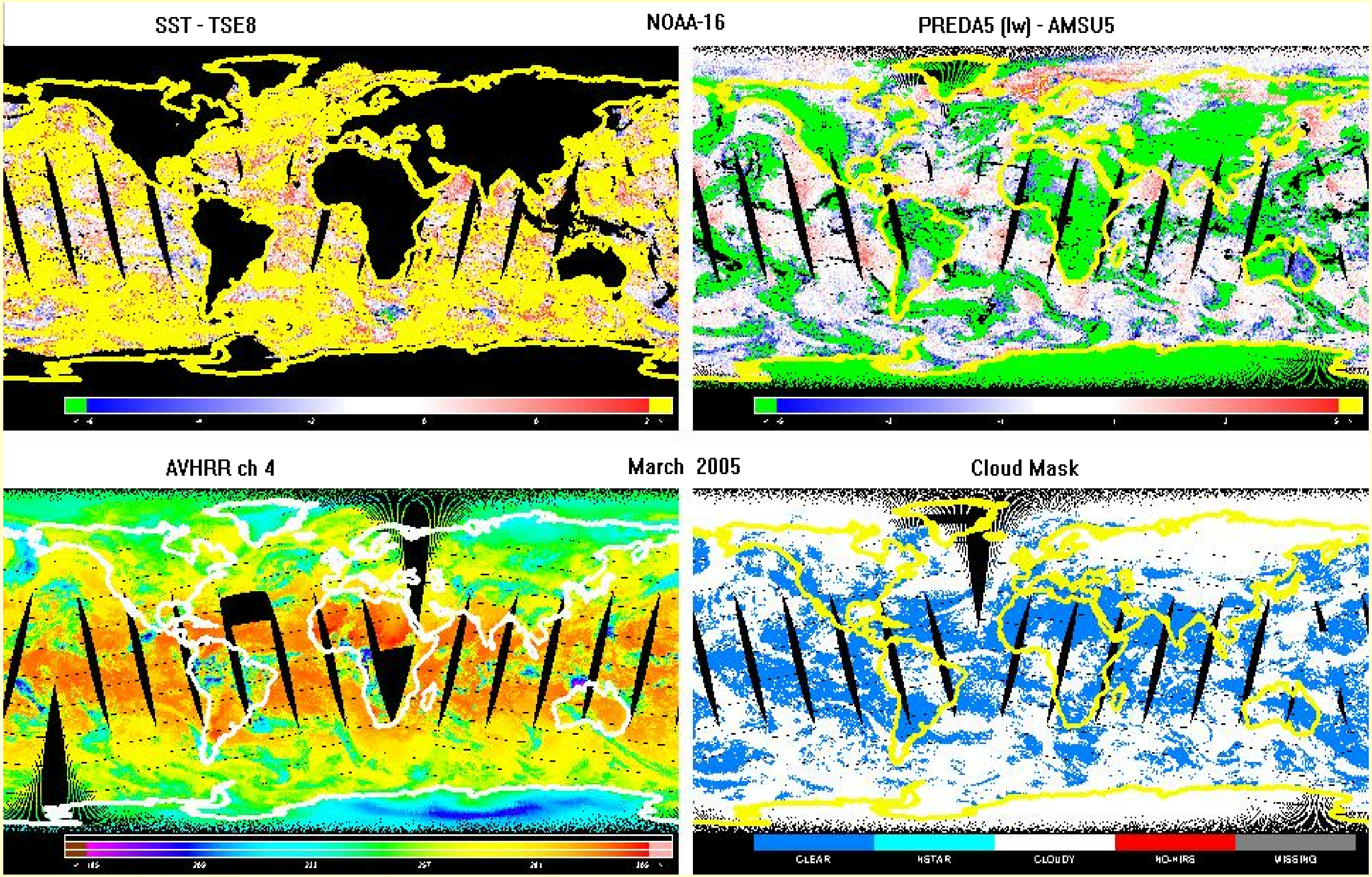
Miscellaneous Quality Control



Cloud Detection

- Reale, NOAA Tech Re. NESDIS 102
- 15 combined physical parameter and inter-channel regression tests
  - HIRS
  - AVHRR
  - AMSU-A
- Sea vs. non-sea tests with some latitude dependence
- Clear vs. cloudy indicator
- Hi-terrain (.gt. 1500m) treated as cloudy

Cloud Detection Tests



Orbital Processing

- Earth-location/Calibration
- Append SST, Terrain, Ice/Snow, NWP
- Limb Adjustment
- Interpolate to HIRS
- Microwave Products (CLW, TPW … MSPPS)
- Contamination Detection
  - Precipitation
  - Cloud
- First Guess
- Retrieval

First Guess Library Search

- First guess uniquely determined for each retrieval by a library search technique

- The method uses discriminate analysis to compute a closeness measure “d” based on principle component score (PCS) differences between observed (pcsmeas) and library (pcslib) based sounder measurements

$$d = [\sum_{i=1,neig} (pcslib_i - pcsmeas_i)\lambda^{-1}{}_i (pcslib_i - pcsmeas_i)]^{1/2}$$

λ is the eigenvalue

- The eigenvectors and values used to compute PCS and specific library (neighbors) searched are segregated for:
  - *1)clear, sea; 2) clear, nonsea; 3) cloudy, sea; and 4) cloudy nonsea*

- The number of PCS used is set (flexible) to the number of channels used

- The 10 neighbors with smallest “d” are averaged for the first guess temperature and water vapor and the associated 10 brightness temperatures (BTs) are averaged for the first guess BT

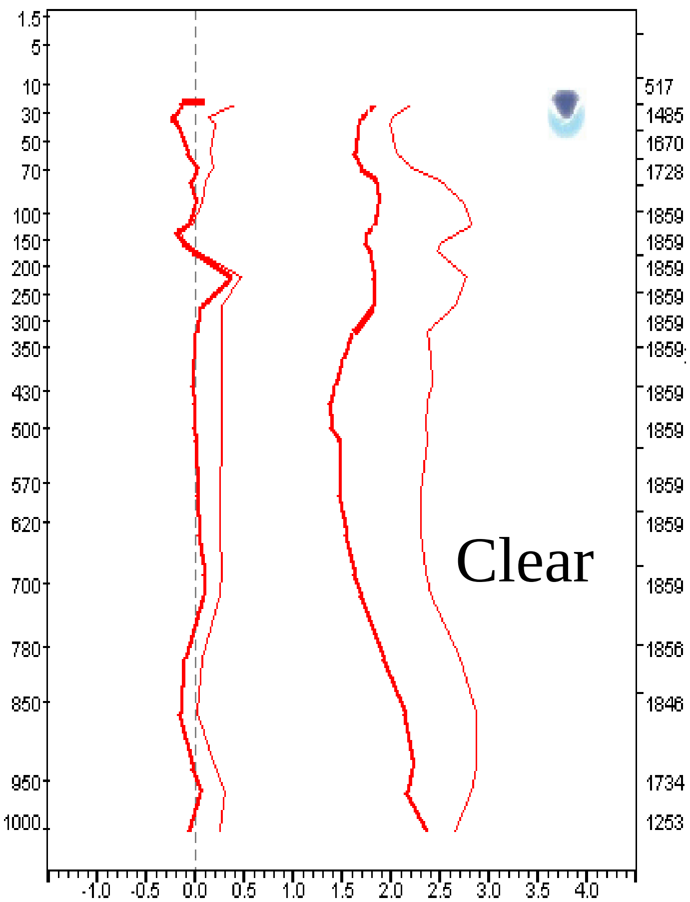
- Libraries are updated daily; eigen coefficients are updated weekly

First Guess Channel Combinations (NOAA-16)

Clear, Sea	**11 Channels**	
HIRS	**(3)**	**7 11 12**
AMSU -A	**(8)**	**1 5 6 7 8 10 11 12**
Clear, Non-sea	**10 Channels**	
HIRS	**(3)**	**7 11 12**
AMSU-A	**(7)**	**5 6 7 8 10 11 12**
Cloudy, Sea	**8 Channels**	
HIRS	**(0)**	
AMSU-A	**(8)**	**1 5 6 7 8 10 11 12**
Cloudy, Non-sea	**7 Channels**	
HIRS	**(0)**	
AMSU-A	**(7)**	**5 6 7 8 10 11 12**

Accuracy Statistics vs Radiosondes

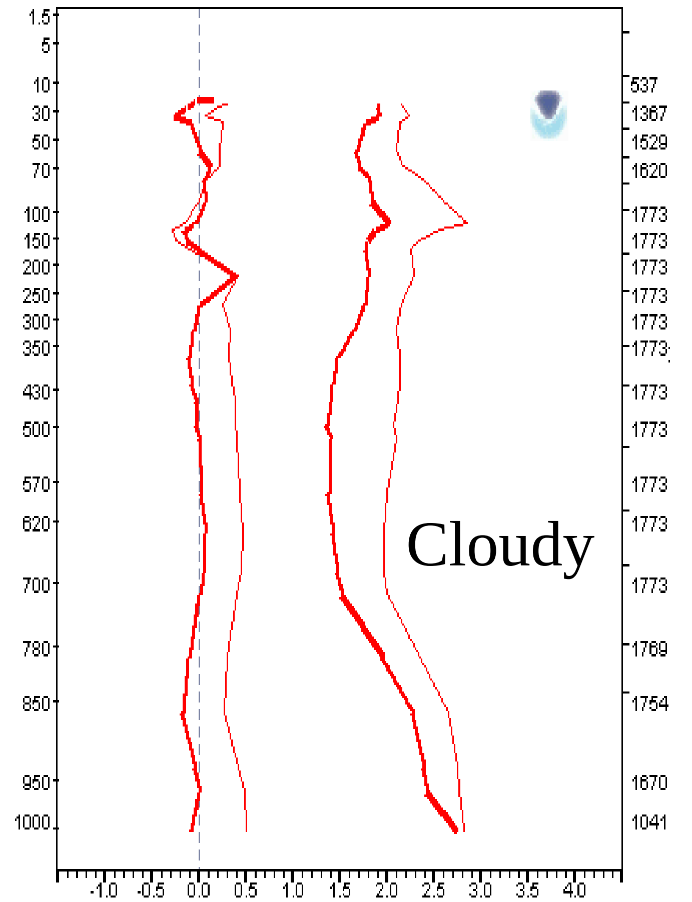
(*Guess (light)* **vs.** ***Retrieval (heavy)***)



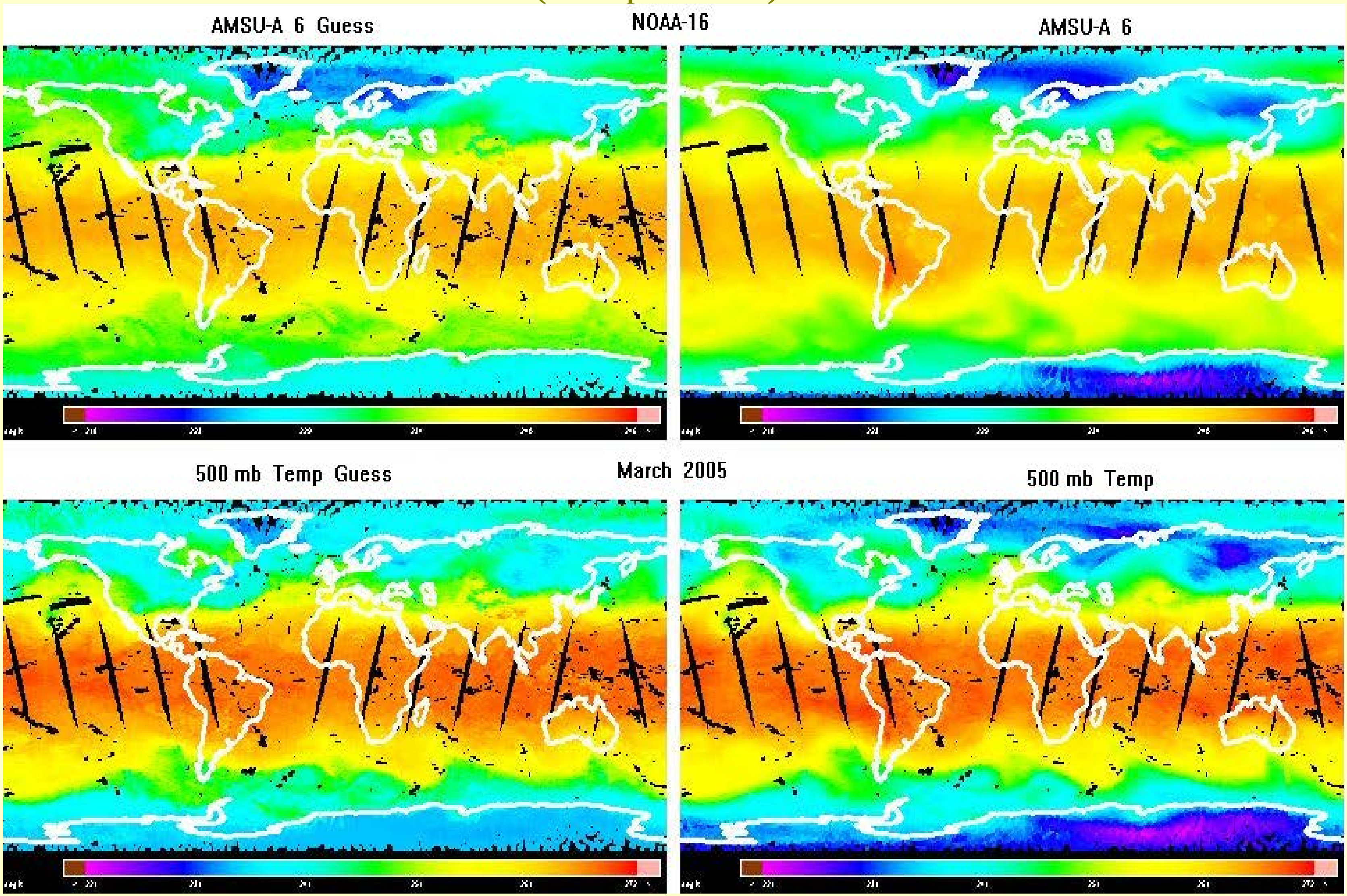
First Guess Temperature Minus Radiosonde (light)

Sounding Temperature Minus Radiosonde (dark)

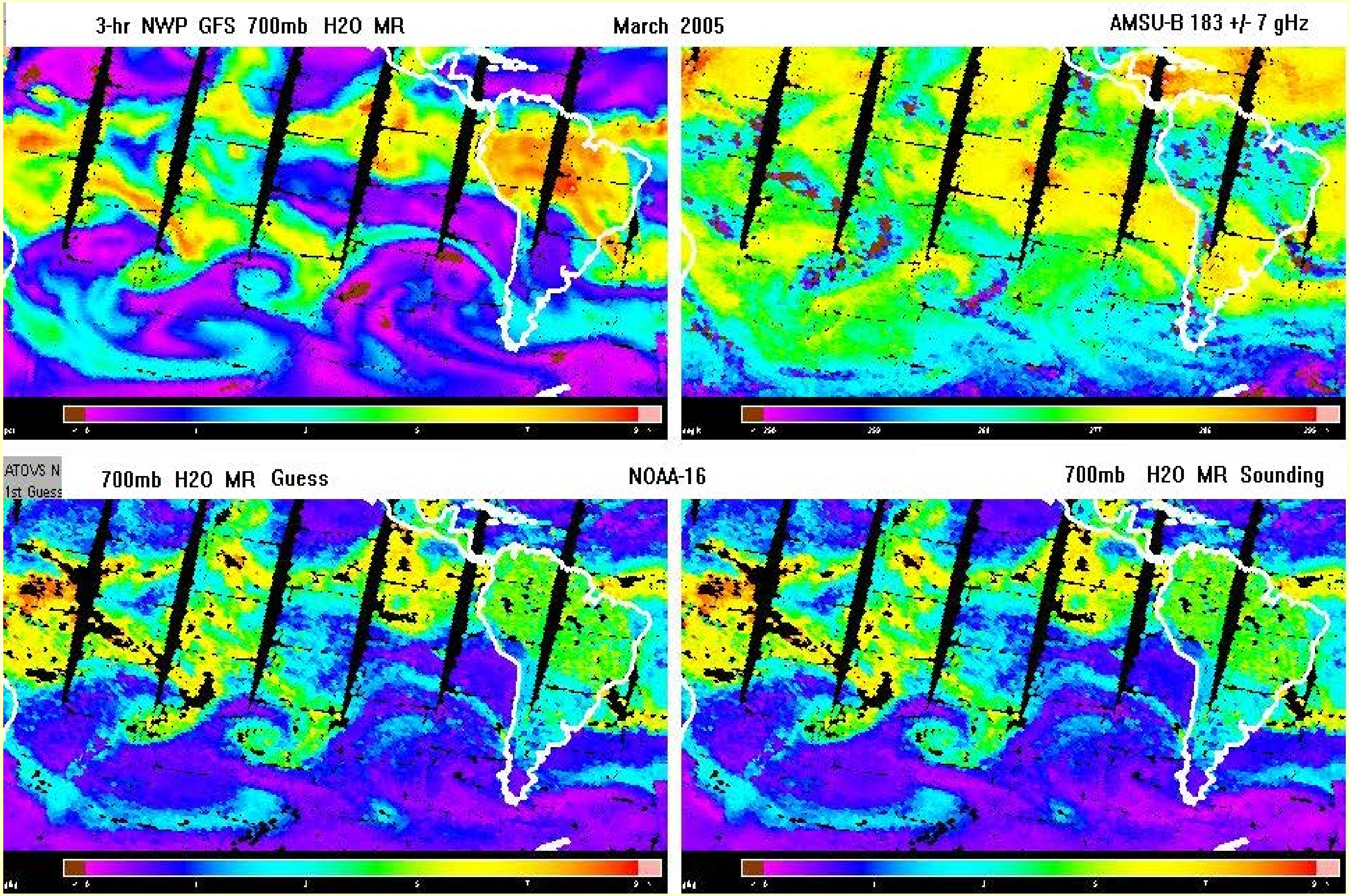
NOAA-16 (60N to 60S)



Observation …. Guess …. Sounding
(Temperature)



Observation … NWP … Guess … Sounding
(H2O Vapor Mixing Ratio)



ATOVS System-2004 Science

- Incorporate AMSU-B
- Regression Guess replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)
- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS
- Analytical Retrieval Solution (OPTRAN) per sounding (Van-delst, Kleespies, Han)
  - based on Guess temp and Moisture
- Peripheral Upgrades
  - Limb-adjustment
  - Expanded validation

First Guess Regression

$$C_{fgcoef} = (S_{yx})\,(S_{xx}+q_{*}I)^{-1}$$

where:

I	- identity matrix
q	- stabilization factor
-1	- matrix inversion
S_{yx}	- covariance (predictand/predictor)
S_{xx}	- covariance (predictor/predictor)
q	-0.5 for temperature
q	-0.0005 for water vapor

First Guess Regression (cont)

$$C_{fgcoef}=(S_{yx})(S_{xx}+q_{*}I)^{-1}$$

4 Sets of Coefficients:

- sea temperature predictors: AMSU-A 4 -14
- sea temperature predictands: @ 40 TOVS 1000 to .1 mb

- sea moisture predictors: AMSU-A 1, 4 – 8; AMSU-B 3 - 5
- sea moisture predictands: ln (q) g/kg @ 17 TOVS 1000 to 200mb

- land temperature predictors: AMSU-A 5 - 14
- land temperature predictands: @ 40 TOVS 1000 to .1 mb

- land moisture predictors: AMSU-A 5 - 8; AMSU-B 3 - 5
- land moisture predictands: ln (q) g/kg @ 17 TOVS 1000 to 200 mb

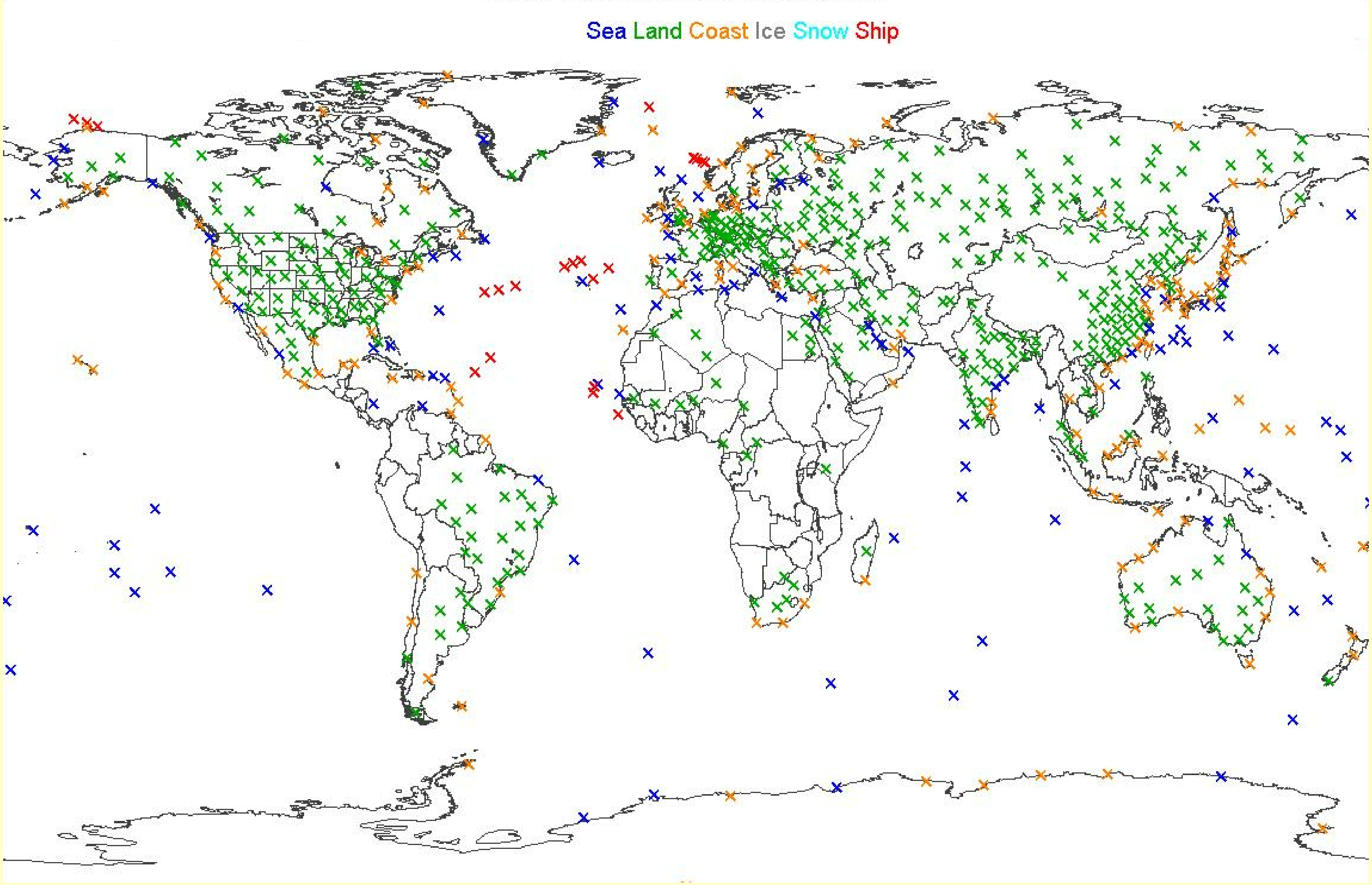
First Guess Regression (cont)

$$C_{fgcoef}=(S_{yx})(S_{xx}+q_{*}I)^{-1}$$

- Land and Sea MDB Collocations used to generate land coefficients
- Sea-only MDB Collocations used to generate sea coefficients

- MDB used is combined from consecutive datasets 21-days apart with duplicate observations removed
  - Sample size for sea 8630
  - Sample size for Non-sea 15,209

- Coefficient update ?



MDB … for all Radiosonde types

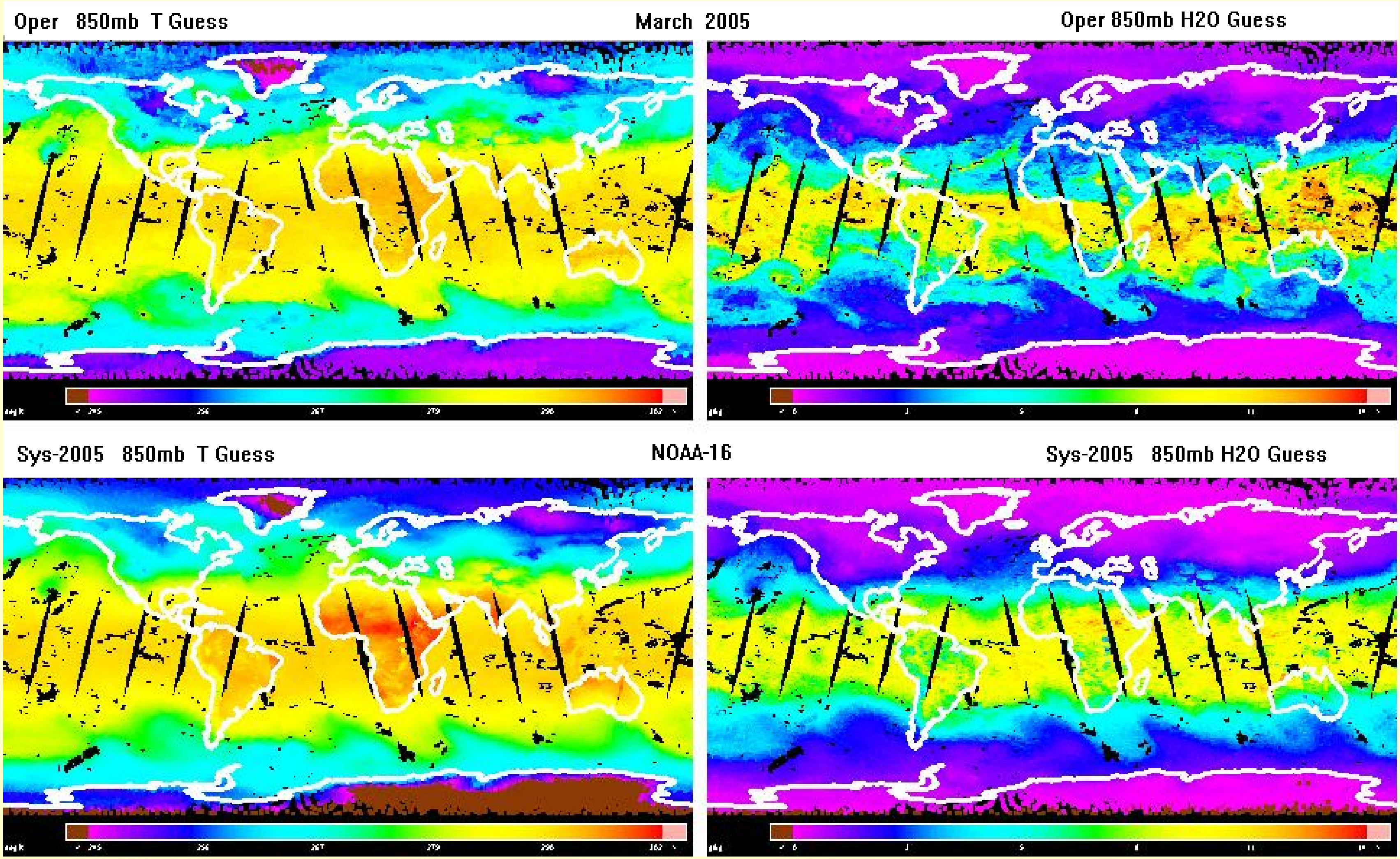
First Guess Regression (cont)

Online:

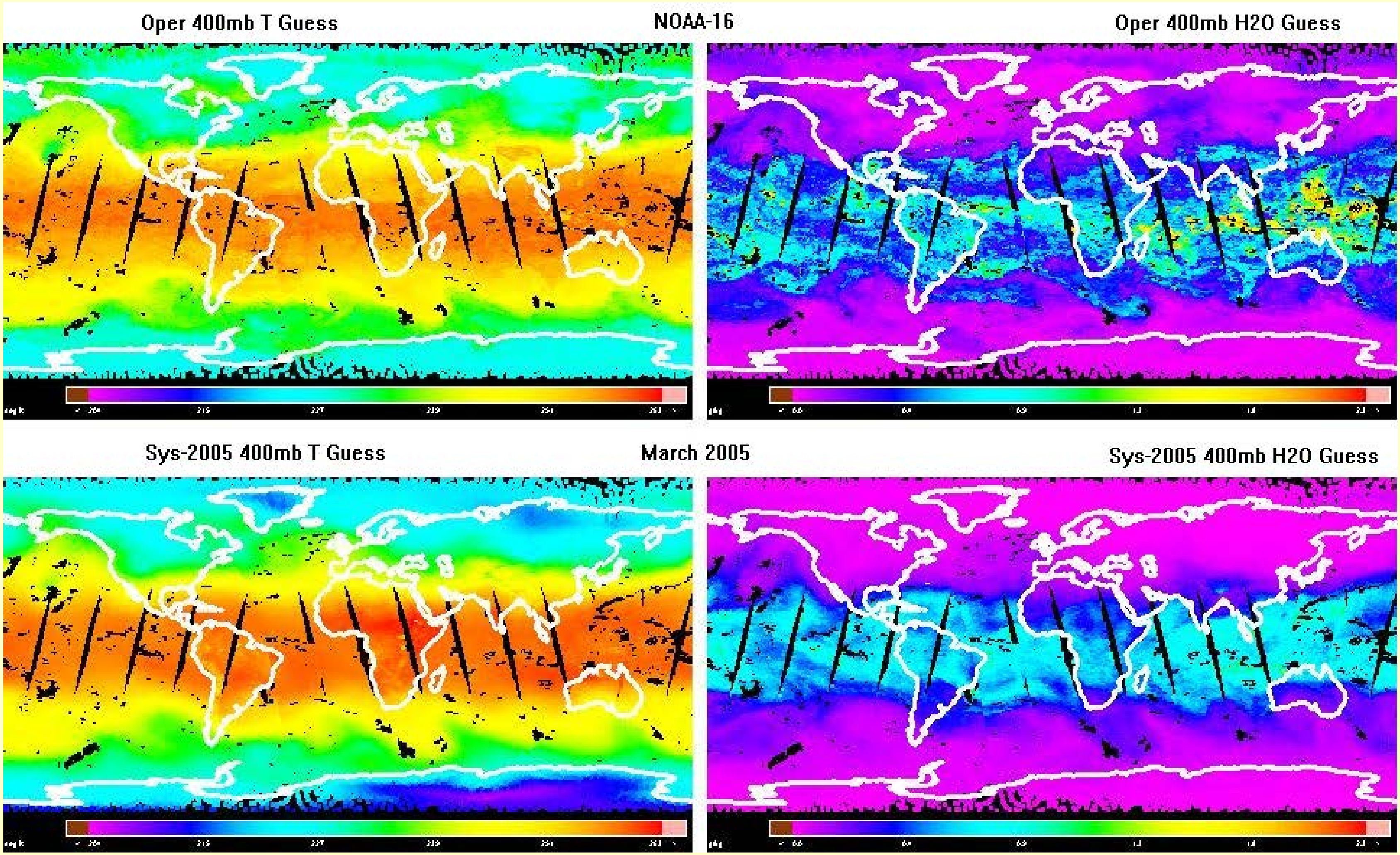
- Coefficients applied to obtain first guess temperature (T) and water vapor mixing ratio (q)

- New OPTRAN used to calculate first guess radiance from first guess T, q, and Tsfc

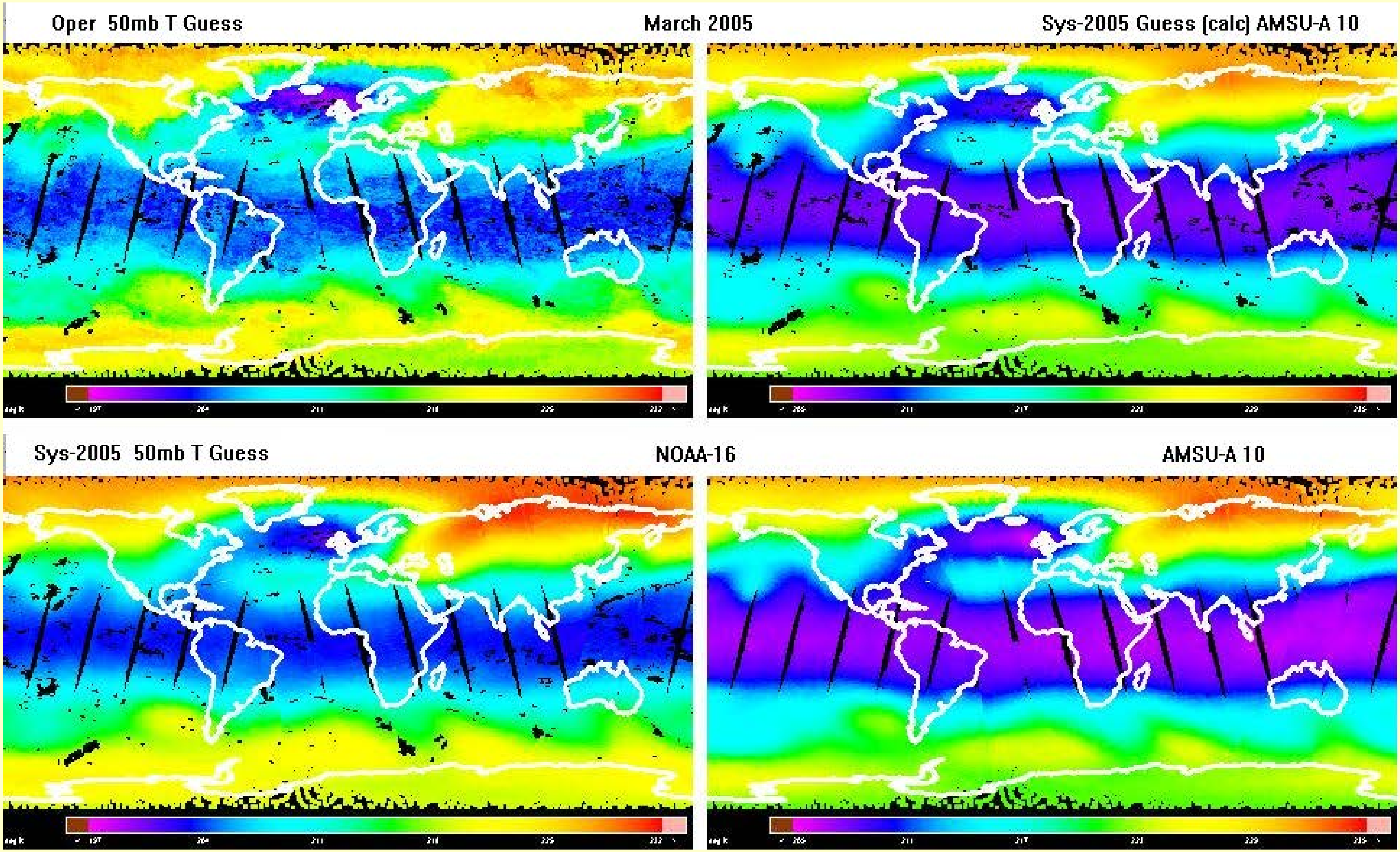
Regression vs. Library Search Guess



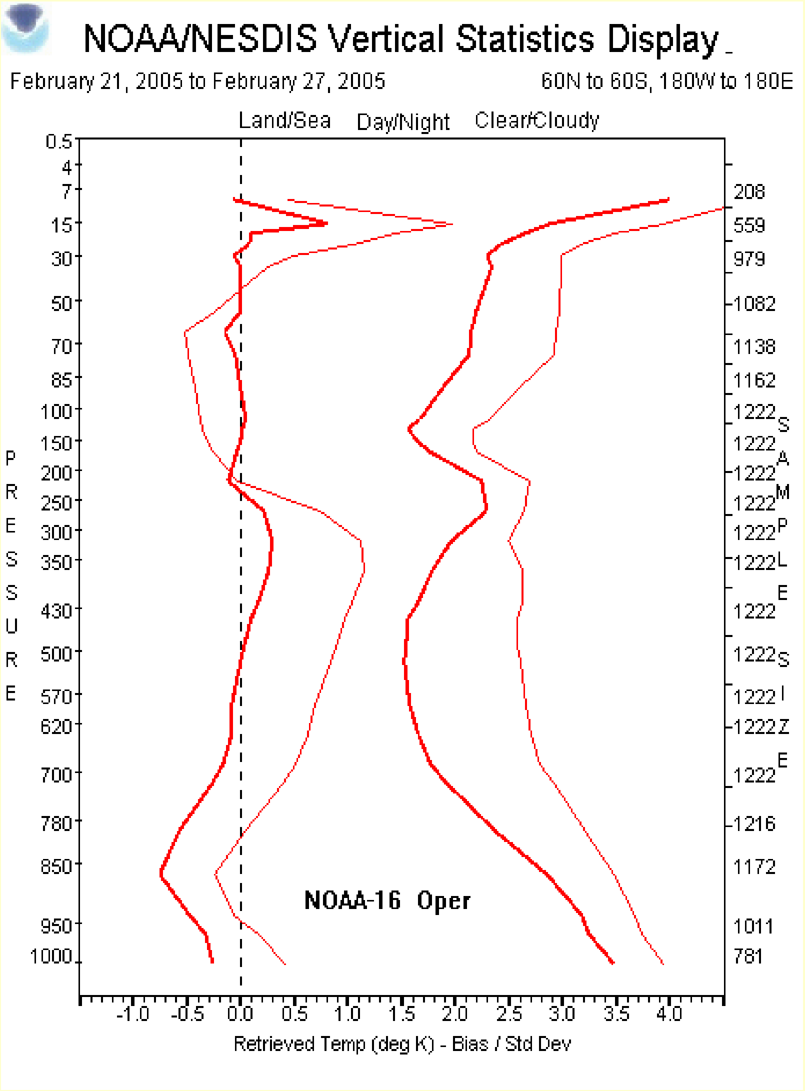
Regression vs. Library Search Guess

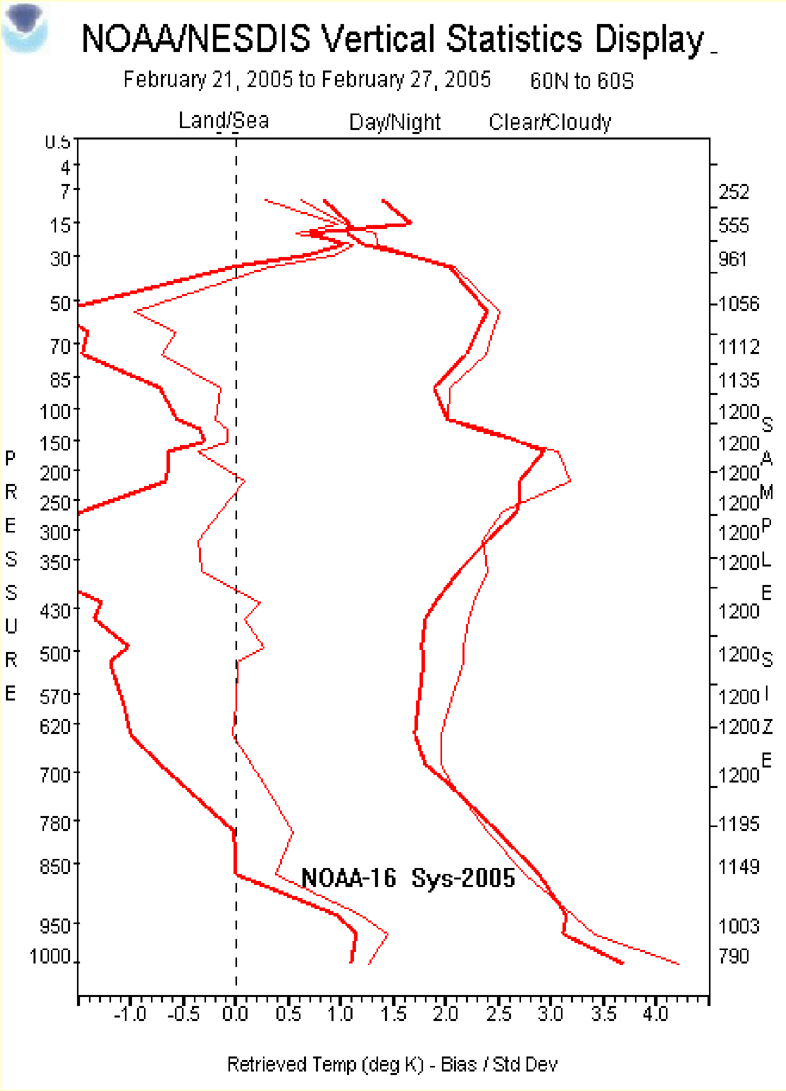


Regression vs. Library Search Guess

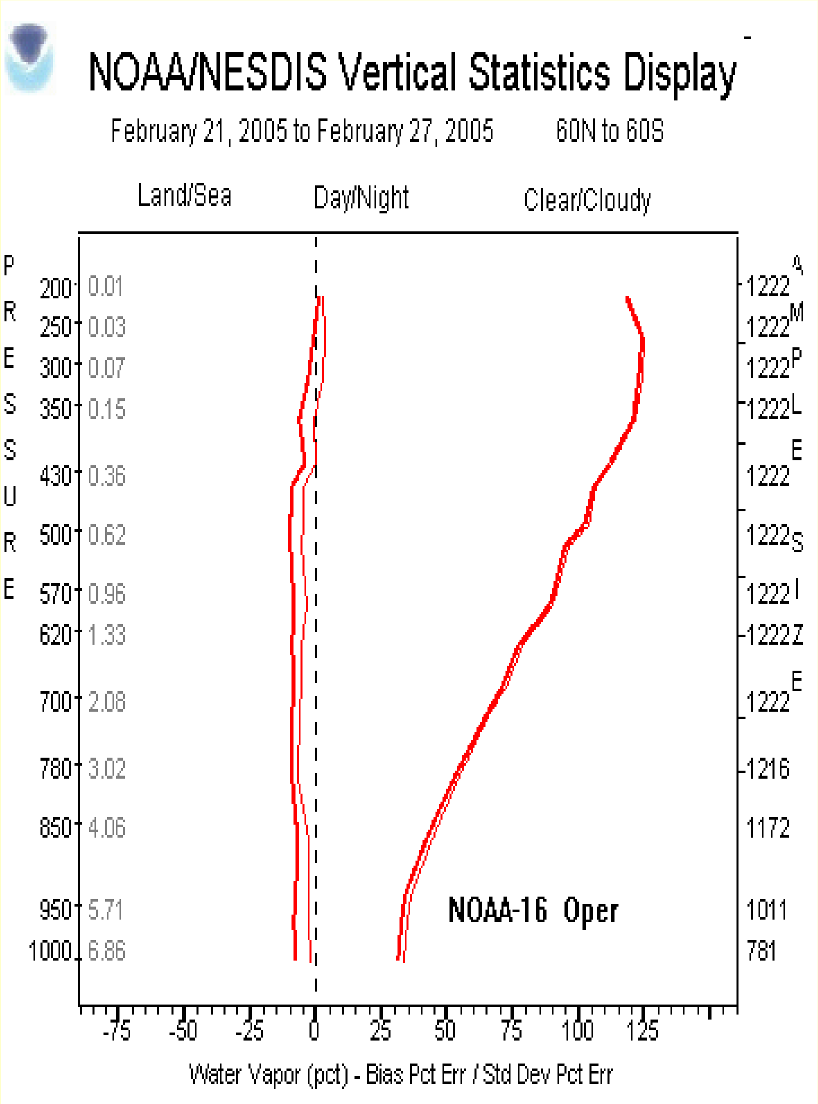


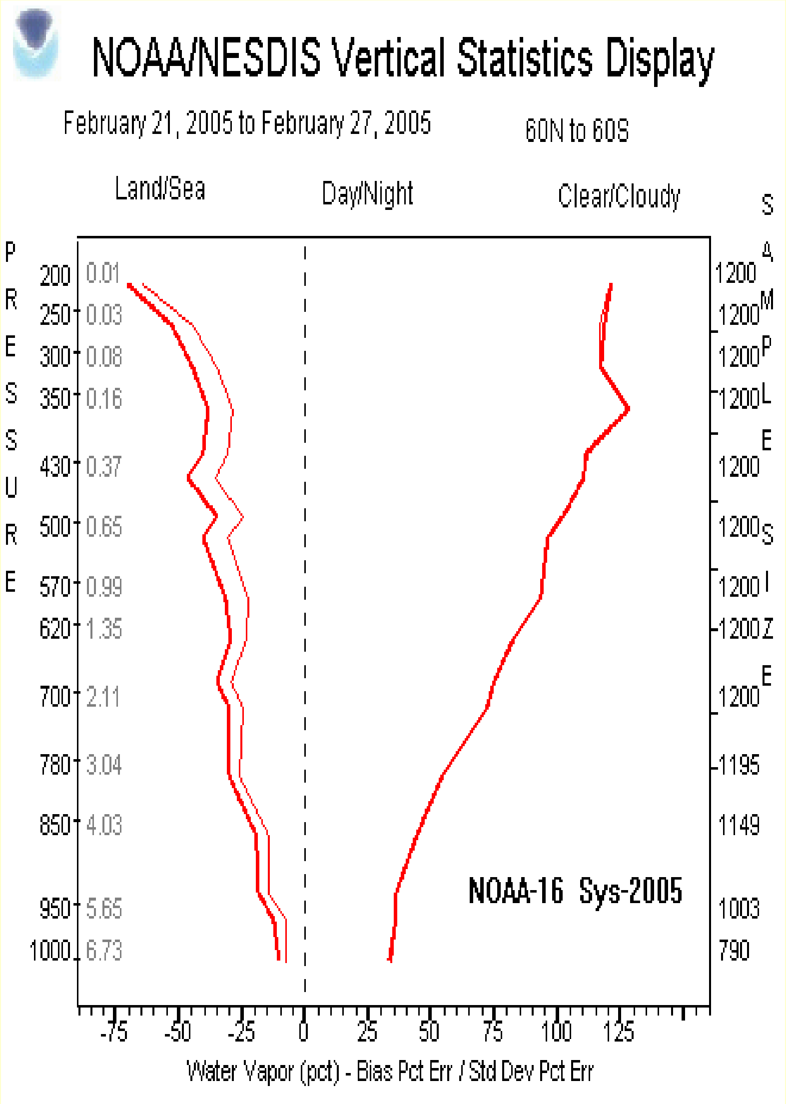
Vertical Statistics - Temperature





Vertical Statistics - Moisture





Orbital Processing

- Earth-location/Calibration
- Append SST, Terrain, Ice/Snow, NWP
- Limb Adjustment
- Interpolate to HIRS
- Microwave Products (CLW, TPW … MSPPS)
- Contamination Detection
  - Precipitation
  - Cloud
- First Guess
- Retrieval

Minimum-Variance Simultaneous Physical Retrieval Method (MVS)

- Theory and derivation from Rodgers, 1976 (Retrieval of atmospheric temperature … Rev. Geophys. Space Phys.

- Physical in that relationship between temperature, moisture and radiance as modeled by RT model is inverted to obtain atmospheric profiles from satellite measurements

- Simultaneous in that temperature and moisture are retrieved in a single solution vector

Retrieval equations for the Operational System*

First guess temperature/water vapor from library search[1]

Measured radiances

Noise covariance matrix[4]

$$T = T_g + S\,A^t\,(A\,S\,A^t + N)^{-1} c\,(R - R_g)$$

Weighting function matrix[2]

First guess radiance from library search[1]

Background covariance S matrix[3]

Radiance bias correction matrix[5]

Updated weekly - Green

Updated with each retrieval - Red

* The operational system currently utilizes HIRS and AMSU-A only

$$T - T_g = S A^t (A S A^t + N)^{-1} (R - R_g)$$

t	matrix transpose	
-1	matrix inverse	
T	product vector	(151)
T_g	guess vector	(151)
S	background error	(151 x 151)
A	channel weighting	(35 x 151)
N	noise	(35 x 35)
R	obs. radiance temp	(j)
R_g	guess radiance temp	(j)

100 levels temperature	(.1 to 1000)mb
50 levels moisture	(103.8 to 1000)mb
1 level surface	
20 HIRS channels	
15 AMSU-A channels	

1: Weighting Function A-Matrix

- A-matrices are *Radiosonde* based and uniquely pre-computed (Offline) for 9 latitudinal "bins" combining both clear and cloudy conditions

- The individual elements of A are products of:
  - a weighting (or Tau) function,
  - a Planck linearization factor,
  - a radiance scaling (700cm-1) factor,
  - a numerical quadrature weight, and
  - for moisture a derivative of the Planck function with respect to temperature.

- A-matrices used for retrieval are composed by averaging the individual sub-matrices for temperature, surface temperature and water vapor that are constructed from each collocation on MDB within a given "Bin"

- They are updated weekly

1: Weighting Function Matrix (Temperature)

- The Temperature portion of the A matrix is computed as follows where $A_t=[(a_t)_{ij}]$ for i channels and j levels and tau is computed using the class profiles and old OPTRAN;
  - For the top temperature level (for j=1);

$$(a_t)_{i,j} = 0.5 * \alpha_i * \beta_{i,j} [2.0 - \tau_{i,1} - \tau_{i,2}]$$

  - For the intermediate temperature levels (for j =2, …, 99);

$$(a_t)_{i,j} = 0.5 * \alpha_i * \beta_{i,j} [\tau_{i,j_{-1}} - \tau_{i,j_{+1}}]$$

  - For the lowest temperature level (for j =100);

$$(a_t)_{i,j} = 0.5 * \alpha_i * \beta_{i,j} [\tau_{i,99} - \tau_{i,100}]$$

  - For the surface temperature level (for j=101)

$$a_i = \alpha_i \beta_i \tau_{i,100}$$

α are the radiance scaling (700cm-1) factors for the bin

β are the Planck function linearization factors for the bin

1: Weighting Function Matrix (Temperature)

- The Water Vapor portion of the A matrix is computed as follows where $A_q=[(a_q)_{ij}]$ for i channels and j levels;
  - For the top water vapor level (for j=1);

$$(a_q)_{i,j} = g^{-1} * (dp/dx)_j * [y_{i,j} - 0.75 * W_{i,j} - 0.5 * W_{i,31}]$$

  - For the intermediate water vapor levels (for j =2, …, 29);

$$(a_q)_{i,j} = g^{-1} * (dp/dx)_j * [y_{i,j} - 0.50 * W_{i,j} - 0.5 * W_{i,31}]$$

  - For the second lowest water vapor level (for j =30);

$$(a_q)_{i,j} = g^{-1} * (dp/dx)_j * [0.5 * y_{i,j}]$$

  - For the lowest water vapor level (for j =31);

$$(a_q)_{i,j} = g^{-1} * (dp/dx)_j * [0.25 * y_{i,j}]$$

1: Weighting Function Matrix (Moisture)

where $$y_{i,j} = \sum_{j=1}^{31} W_{i,j}$$

and $$W_{i,j} = \varepsilon_{i,j} * \alpha_i * \beta_{i,j} * (\partial\bar{\tau} / \partial u)_{i,j}$$

ε is a transmittance factor computed using Fleming(1986)
((dtau/dT)(dtau/du)) dtau/dx per channel, level

α are the radiance scaling factors for the class (700cm-1)

β are the Planck function linearization factors for the class

$\partial\bar{\tau} / \partial u$ is computed from the mean profiles for the class
(Taylor expansion … Fleming, 1986 ?)

1: Weighting Function Matrix (Moisture)

and

$$dp/dx = (7/(2*\kappa))*p^{5/7}$$

where

κ is a pressure coordinate transformation factor (buried in a CDB, origin unknown) and g is the gravitational constant

1: Weighting Function Matrix Linearization

$$A = [A_t \mid a_{ts} \mid A_q]$$

The linearization of the A-matrix proceeds by using all the individual “bin” temperature/moisture vectors (that were used to generate “bin” means) and computing a mean matrix A for each.

The linearized A-matrix used for retrieval is obtained from the average of the individual matrices.

The actual software procedure to assemble the mean A-matrix for a given “bin” with k collocations (for the k^{th} A matrix added) is

$$\overline{A}_k = (1 - 1/k) * \overline{A}_{k-1} + (1/k) * A_k$$

2: The Background Covariance "S" matrix

$$S = E[(X-u)(X-u)^T]$$

where

$u=E[X]$ is the mean vector

T is the transpose

E is the expected value … (Fleming, 1986, Eq 17)

- The X vector contains the Raob minus First Guess data from the MDB for;
  - (a) 100 pressure levels (0.01 mb to 1000 mb) of temperature converted to Planck radiances at 700 cm-1
  - (b) surface temperature converted to Planck radiances at 700 cm-1
  - (c) 50 pressure levels of water vapor mixing ratios (g/kg)

- There are four distinct S matrices from the following library collocations:
  - Sea, Clear $S_{s,c}$
  - Non-sea, Clear $S_{ns,c}$
  - Sea, Cloudy $S_{s,cd}$
  - Non-sea, Cloudy $S_{ns,cd}$

3: The Noise (N) Covariance Matrix

- The Noise (N) covariance matrix is uniquely computed for 9 bins similar to A-matrices and updated weekly
- Values are based on front-end calibration uncertainties (X_i) for each channel obtained
- The channel uncertainty vector is constructed for each channel in the following manner:
  - Convert the mean class radiance (Rbar700) at 700 cm-1 to the central frequency for each channel (Rbar)
  - Remove the band correction for each of the HIRS channels
  - Compute the mean radiance uncertainty deviation (Rbarud) as follows

$$Rbarud_i = Rbar_i + X_i$$

  - Convert Rbarud back to 700cm-1 (band correction coefficients re-applied for the HIRS channels)
  - $CU_i = [Rbarud_i - Rbar700_i]^{1/2}$
  - A tri-diagonal Noise Covariance (N) matrix is then constructed as follows;

$$N_{i,i} = [CU_i]^2$$

$$N_{i,i+1} = [Cu_i * Cu_{i+1}]/4.0 \quad ; i < \text{number of channels}$$

$$N_{i+1,i} = N_{i,i+1} \quad ; i < \text{number of channels}$$

Bin Definitions and Operator Components

• 90N to 60N	Sea-ice and Nonsea (1)	$A_1 S_{ns} N_1$
• 45N to Ice (60N)	Sea and (Nonsea) (2)	$A_2 S_s N_2$, $A_2 S_{ns} N_2$
• 30N to 45N	Sea and Nonsea (3)	$A_3 S_s N_3$, $A_3 S_{ns} N_3$
• 15N to 30N	Sea and Nonsea (4)	$A_4 S_s N_4$, $A_4 S_{ns} N_4$
• 15S to 15N	Sea and Nonsea (5)	$A_5 S_s N_5$, $A_5 S_{ns} N_5$
• 15S to 30S	Sea and Nonsea (6)	$A_6 S_s N_6$, $A_6 S_{ns} N_6$
• 30s to 45S	Sea and Nonsea (7)	$A_7 S_s N_7$, $A_7 S_{ns} N_7$
• 45S to Ice (60N)	Sea and (Nonsea) (8)	$A_8 S_s N_8$, $A_8 S_{ns} N_8$
• 60S to 90S	Sea-ice and Nonsea (9)	$A_9 S_{ns} N_9$

* Non-sea also segregated by ascending and descending node on MDB but this segregation not used

Retrieval Operator Components

$$S\,A^{t}$$

$$(A\,S\,A^{t} + N)^{-1}$$

32 unique sets of retrieval operator components :

7 sea, clear

9 non-sea, clear

7 sea, cloudy

9 non-sea, cloudy

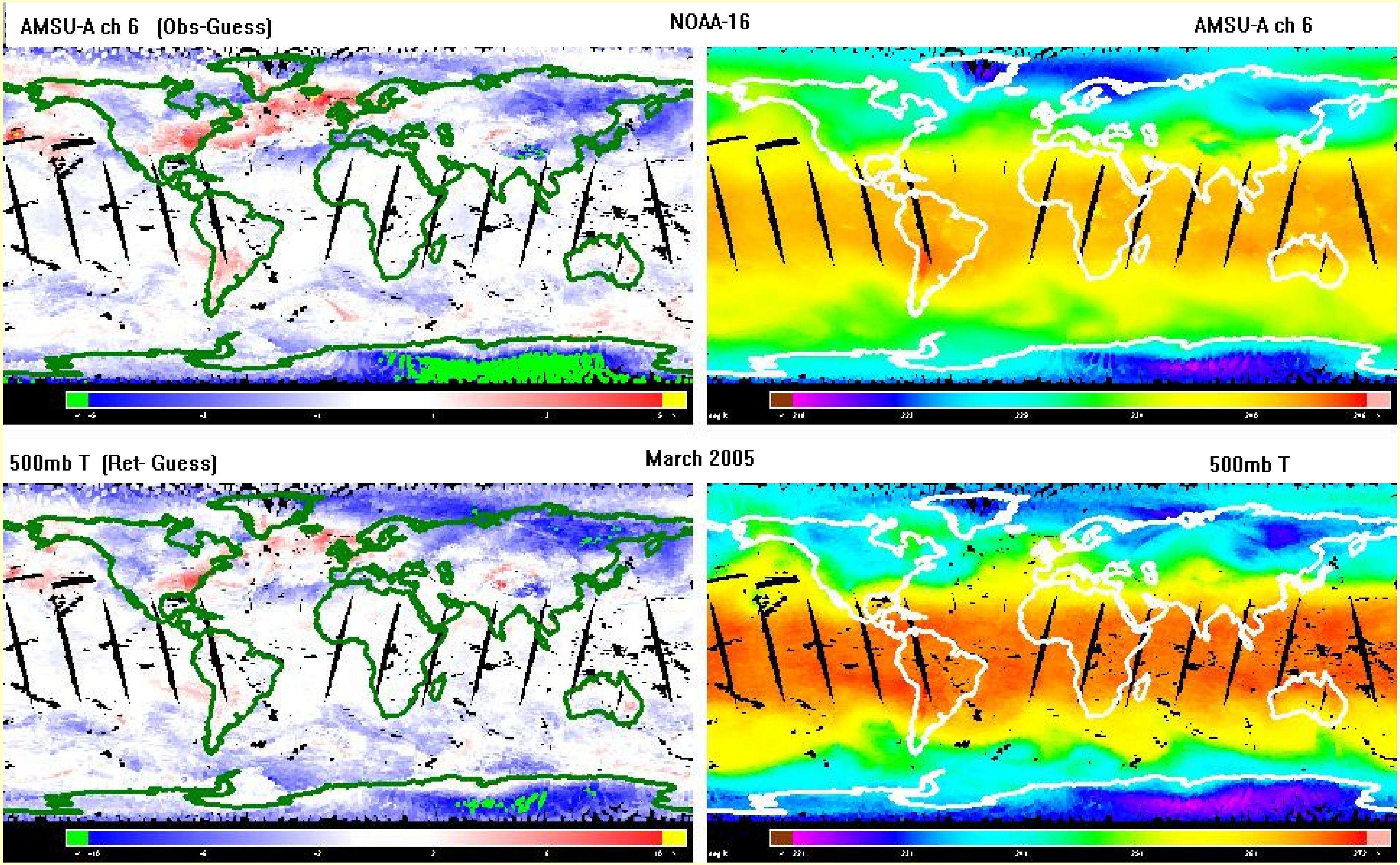
Retrieval Channel Combinations (R_i)

$$(T - Tg)_j = S A^t (A S A^t + N)^{-1} (R - Rg)_i$$

Clear, Sea;	**i = 23 Channels**	
HIRS	**(12)**	**2-7, 10, 12-16**
AMSU -A	**(11)**	**4-14**
Clear, Non-sea	**i =10 Channels**	
HIRS	**(12)**	**2-7, 10, 12-16**
AMSU-A	**(10)**	**5-14**
Cloudy, Sea	**i = 10 Channels**	
HIRS	**(0)**	
AMSU-A	**(10)**	**5-14**
Cloudy, Non-sea	**i = 10 Channels**	
HIRS	**(0)**	
AMSU-A	**(10)**	**5-14**

High terrain above 1500m use cloudy, nonsea w/o AMSU-5; i = 9
High terrain above 2500m use cloudy, nonsea w/o AMSU 5 and 6; i = 8

Delta-R and Delta-T



ATOVS System-2004 Science

- Incorporate AMSU-B

- Regression Guess replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)

- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS

- Analytical Retrieval Solution (OPTRAN) per sounding (Van-delst, Kleespies, Han)
  - based on Guess temp and Moisture

- Peripheral Upgrades
  - Limb-adjustment
  - Expanded validation

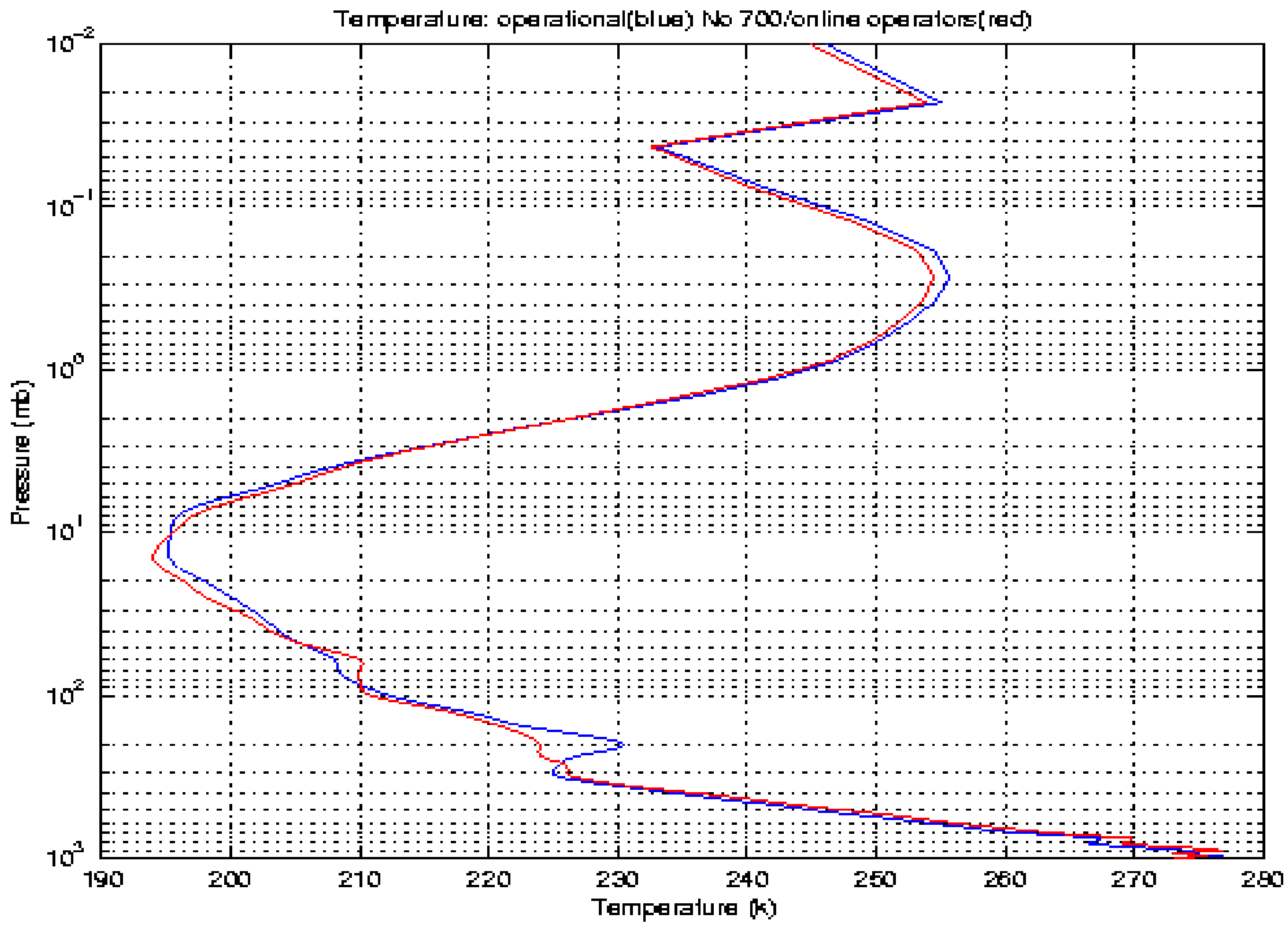
Forward-Jacobian Model s for System 2005

Forward Model

- OPTRAN (original Beta 1.3 version) from Dr Paul Van-delst's webpage (coefficient data files for NOAA 16, HIRS, AMSU-A, and AMSU-B instruments)
- Later Version (Yong Han) received which makes it easier to input new coefficients per satellite, etc
- Brightness temperatures match those in the baseline data set to ***7 decimal places*** ... (comparing Old OPTRAN (used in AMSU-B Oper) vs. Beta 1.3 OPTRAN)
- Hosted as a subroutine in the Offline radiance bias coefficient generation sub-system and in the Online first guess radiance temperature calculations
- *To be hosted as a subroutine in the online retrieval operator*
- Analytic versus Brute-force Jacobian computational agreement ***to 5 decimal places*** confirmed proper installation into operational environment (with support from Tom Kleespies)

First Analytical Retrieval

(achieved in ATOVS operational environment)



First Analytical Retrieval

… it may not seem like much, but represents a significant achievement in manipulating a very large, cumbersome, poorly understood and at times poorly documented operational system:

$$\mathbf{(T - Tg)_j = S\,A^t\,(A\,S\,A^t + N)^{-1}\,(R - Rg)_i}$$

- **700 cm-1 scaling removed**
- Global S-matrix
- SA ^{t} (ASA ^{t}) performed online based on first guess T and q
  - "A" from new Analytic approach
  - Layer Jacobians to Level Jacobians
- N matrix global

- Conversion back to 40 TOVS levels removed ?
- Surface T, P and other boundary conditions (emissivity …)?
- Levels or Layers ?

First Analytical Retrieval

$$(T - Tg)_j = S A^t (A S A^t + N)^{-1} (R - Rg)_i$$

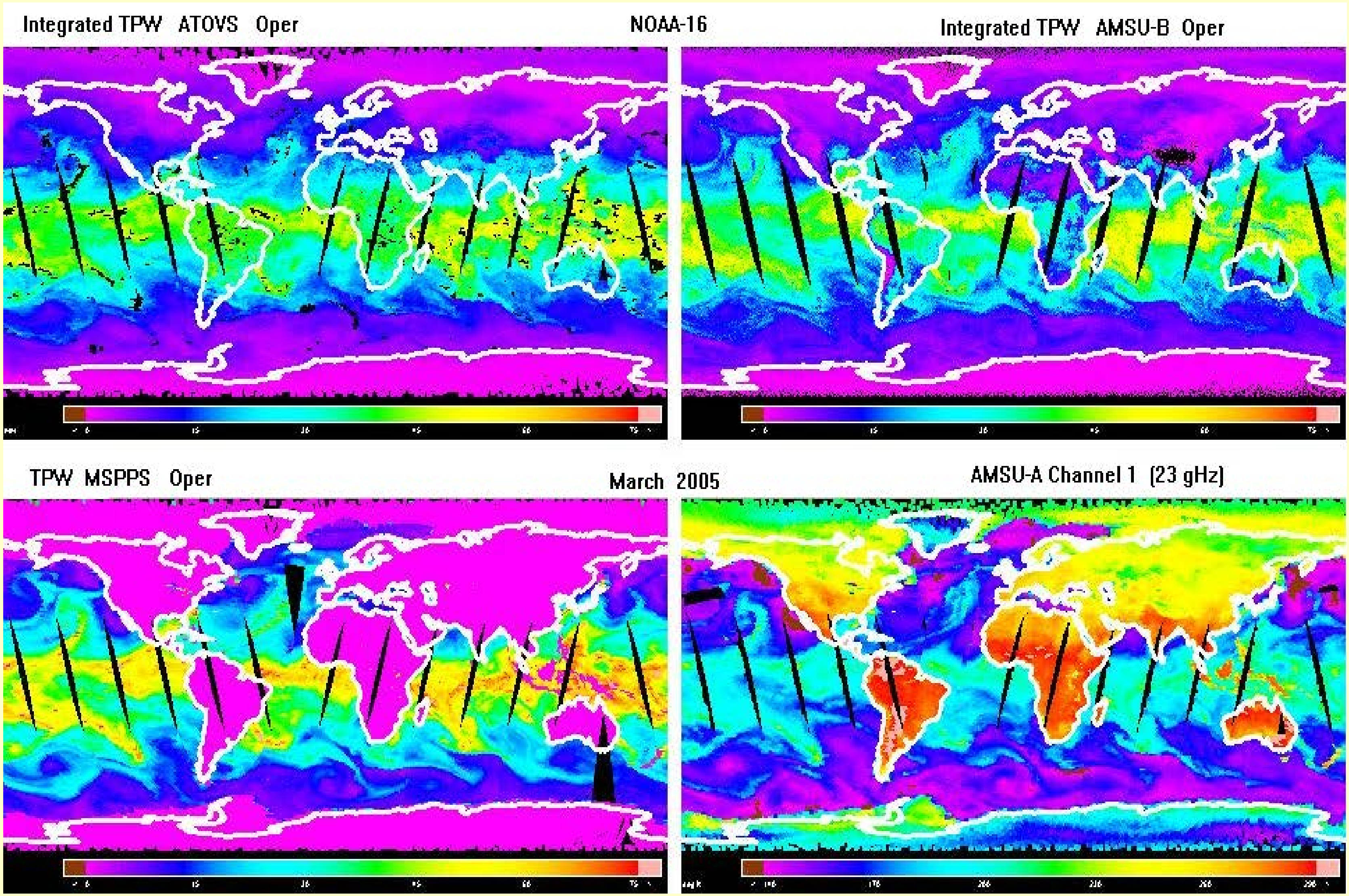
… *there are many questions and much potential for improvement* ***once the basic capability is installed and operating as designed:***

- MVS approach
- N matrix as scene dependent …
- Pressure levels versus layers (40 TOVS levels ???)
  - Also affects radiosonde interpolation
- Surface T, P, TPW and other boundary conditions (emissivity …)
- Others

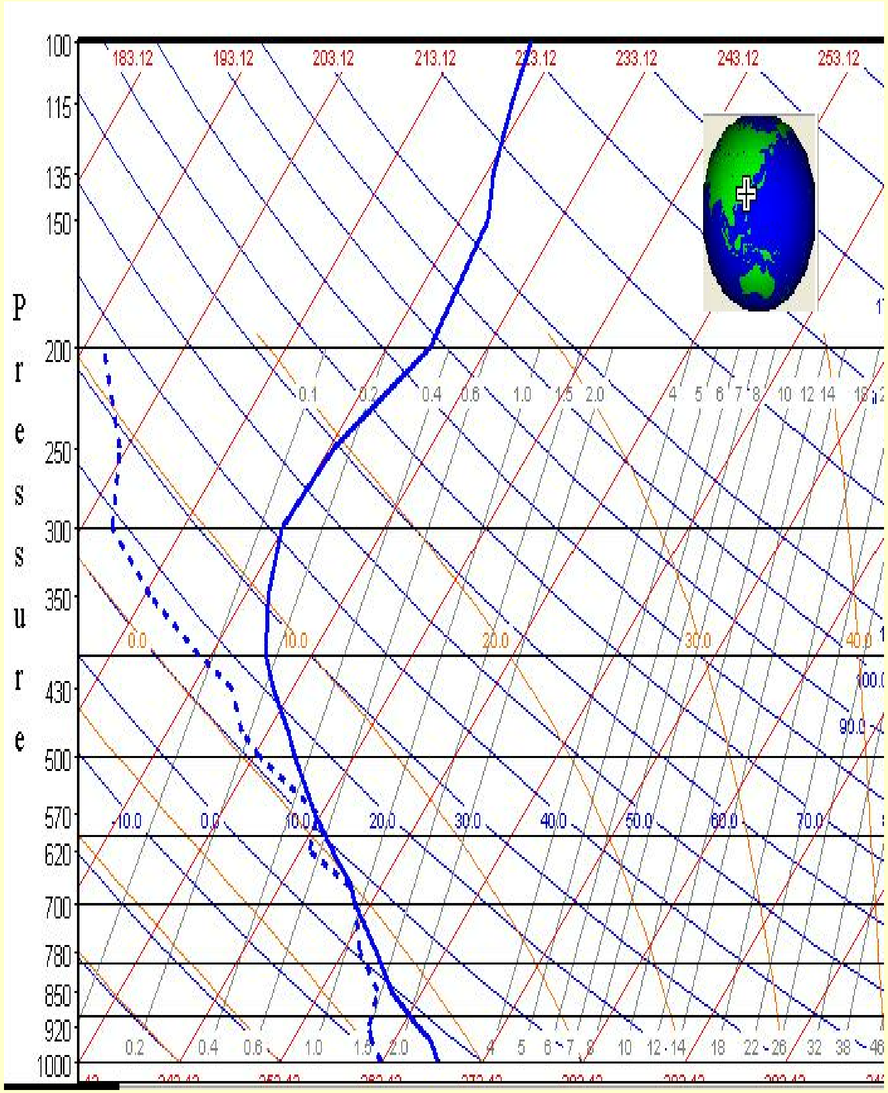
- Retrieval on slant path
  - RT bias adjustment?
- Iteration
  - convergence testing?
  - S and N matrix adjustment?

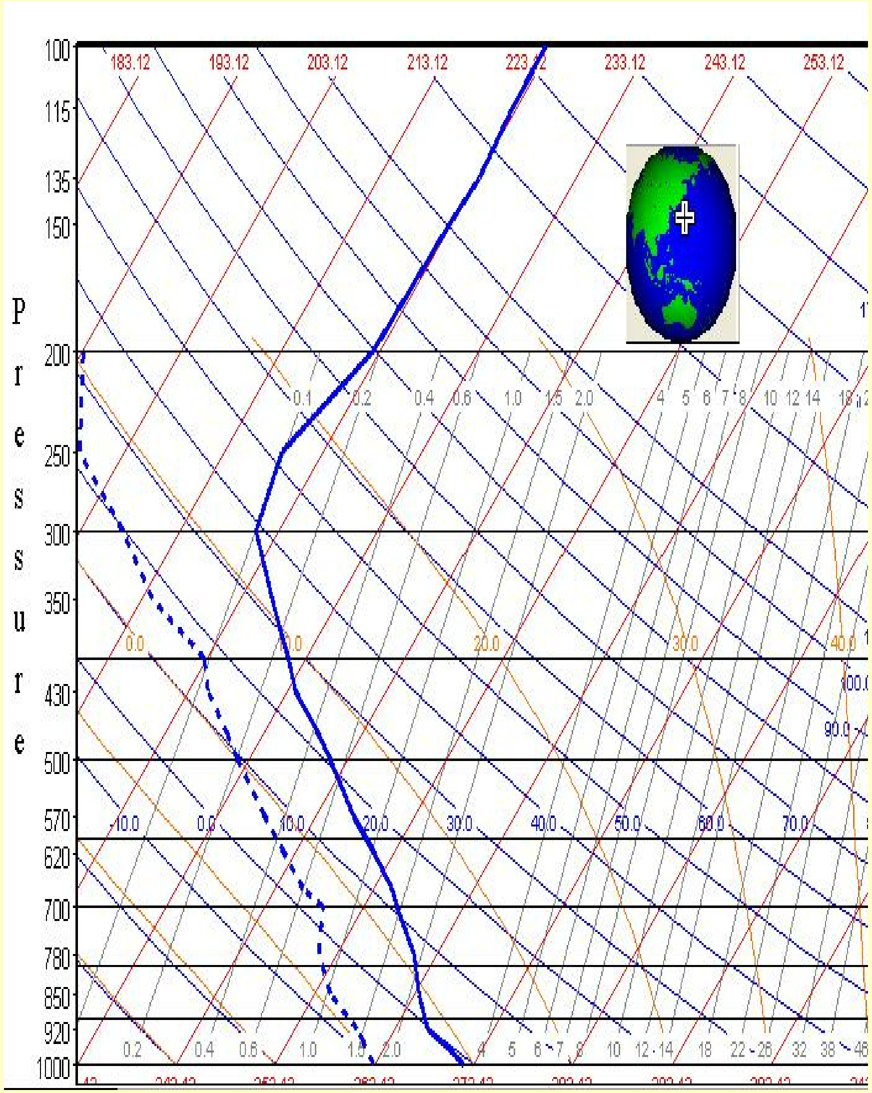
MSPPS TPW as Constraint for Moisture Retrieval

(NESDIS internal product inconsistency)



Which is the Clear, Which is the Cloudy ?





ATOVS System-2004 Science

- Incorporate AMSU-B
- Regression Guess replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)
- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS
- Analytical Retrieval Solution (OPTRAN) per sounding (Van-delst, Kleespies, Han)
  - based on Guess temp and Moisture
- Peripheral Upgrades
  - Limb-adjustment
  - Expanded validation

Radiance Bias Adjustment 2005 - Introduction

- System - 2005 science specifies the adjustment of observed radiance temperatures to compensate for systematic errors in observed minus first guess brightness temperature differences

- Adjustment coefficients are generated Offline and applied at the retrieval step

- Coefficients based on same MDB collocation samples as for First Guess regression Coefficients

- New OPTRAN used for simulations

- Updating ?

Radiance Bias Adjustment Approach

- Co-linearity of satellite measurement and associated errors associated with both the measured and simulated brightness temperatures require some form of constrained regression
- Several approaches will work (ridge, rotated, shrinkage, and orthogonal regressions)
- Shrinkage approach selected consisted with previous DMSP (SSM/T and T2) and current standalone AMSU-B moisture product systems

Radiance Bias Correction (continued)

Let “k” be the number of predictand channels to be corrected.
Let “p” be the number of channels and additional predictors
Let “n” be the number of samples

Let C be the “n x k” matrix of calculated btemps
Let M be the “n x p” matrix of measured btemps and additional predictors
Both C and M are centered (deviations from Cbar and Mbar)

Then the transpose of the radiance bias coefficient matrix R is given by

$$R^T = (M^T M + \alpha I)^{-1}(M^T C + \alpha J)$$

where

I	is the p x p identity matrix
J	is the p x k rectangular matrix with “k” upper rows being the identity matrix I the remaining “p – k” rows being zero
α	the stabilizing parameter
T	the transpose
-1	the inverse.

Radiance Bias Correction (continued)

Additional predictors (if used) require scaling.
The scaling matrix is E, where:
diagonal is the inverse standard deviation of the predictors
off-diagonal elements are zero
D (k upper rows sd-1 of predictands, remaining p-k rows are 0's)

With scaling applied, (1) becomes,

$$R^T = E(EM^T ME^T + \alpha I)^{-1}(EM^T CD + \alpha J)D^{-1}$$

Once the coefficient matrix R has been computed, the estimate of the calculated brightness temperatures ($\hat{c}$) from the measured brightness temperatures is obtained by;

$$\hat{c} = \overline{c} + R(M - \overline{m})$$

References:

Crone, L.J., McMillin, L.M. and Crosby, D.S., "Constrained Regression in Satellite Meteorology", J. Appl. Meteor. 35, 2023-2035, 1996.

Fleming, H.E., et. al., 1991: The forward problem and corrections for the SSM/T satellite microwave temperature sounder. IEEE Transactions on Geoscience and remote Sensing, Vol. 29, No. 4, 571-584.

Radiance Bias Correction Inputs

• Predictands:	AMSU-A channels 4-14; AMSU-B channels 3, 4 and 5 HIRS channels 2-7, 10-17.
• Coefficients Sets:	Sea and Non-sea
• Predictor Sets:	AMSU-A: Sea: 4-14, B? Non-sea: 5-14, B? Additional ? AMSU-B: Sea: 3-5, A? Non-sea: 3-5, A? Additional ? HIRS: Sea: 2-7,10-17, B/A? Non-sea: Same Additional ?
• Inputs:	MDB similar as for first Guess regressions Radiosonde (temperature, water vapor, surface temperature (1st sig) Simulated ATOVS measurements (OPTRAN) Limb-corrected ATOVS measurements Additional predictors
• Forward model:	OPTRAN (latest version from Dr Yong Han) … multiple coefficient data files for per satellite
• Gamma choice:	0.05 ?
• Add Predictor:	SST, NWP (i.e., srfc pressure …), latitude, longitude, cloud liquid water, TPW, solar zenith angle, … ?

Radiance Bias Correction Tuning

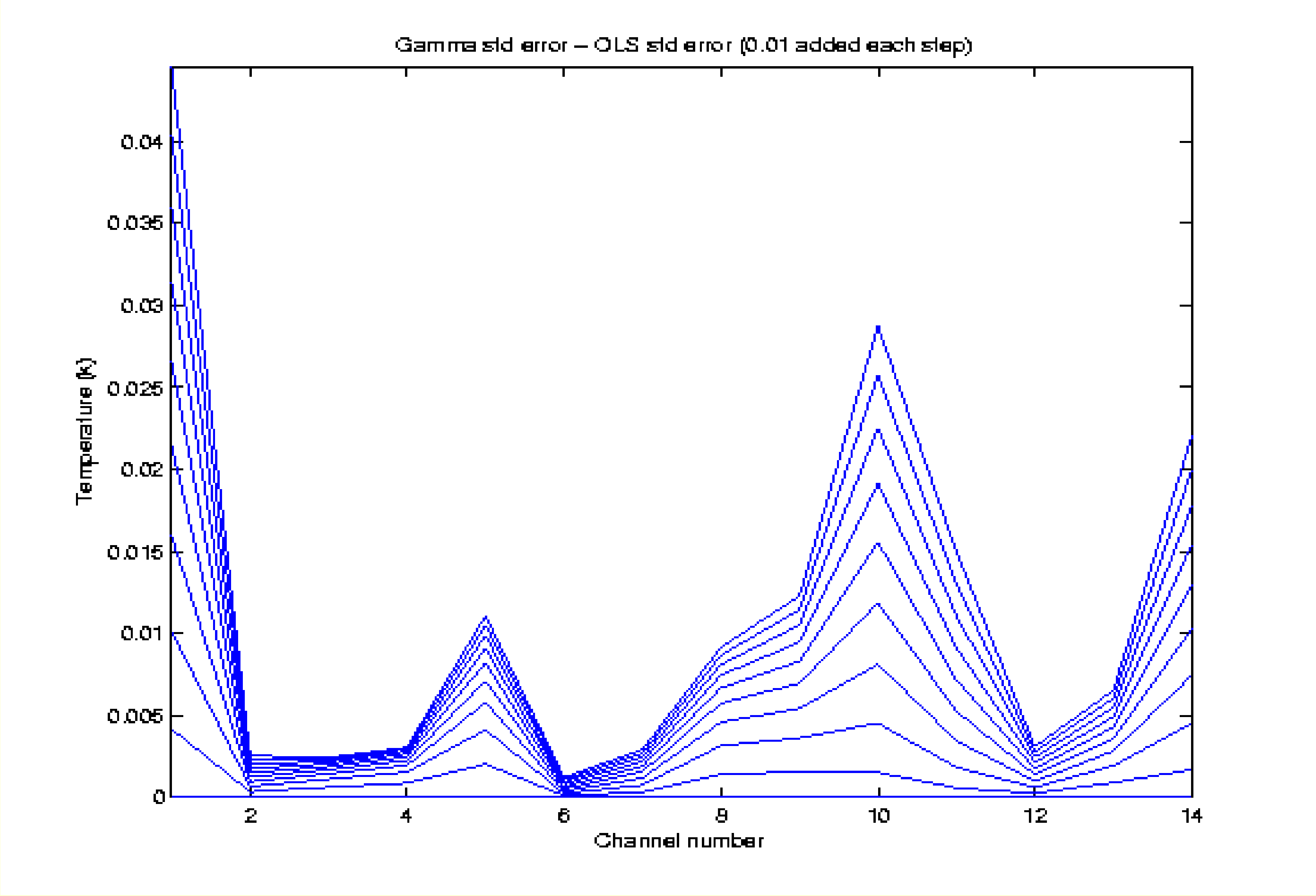
- Shrinkage estimator requires “tuning of gamma” as trade between stable coefficients and increasing residual variances.

$$C_{shrink}=(S_{yx}+gamma*C_0)(S_{xx}+gamma*I)^{-1}$$

where :

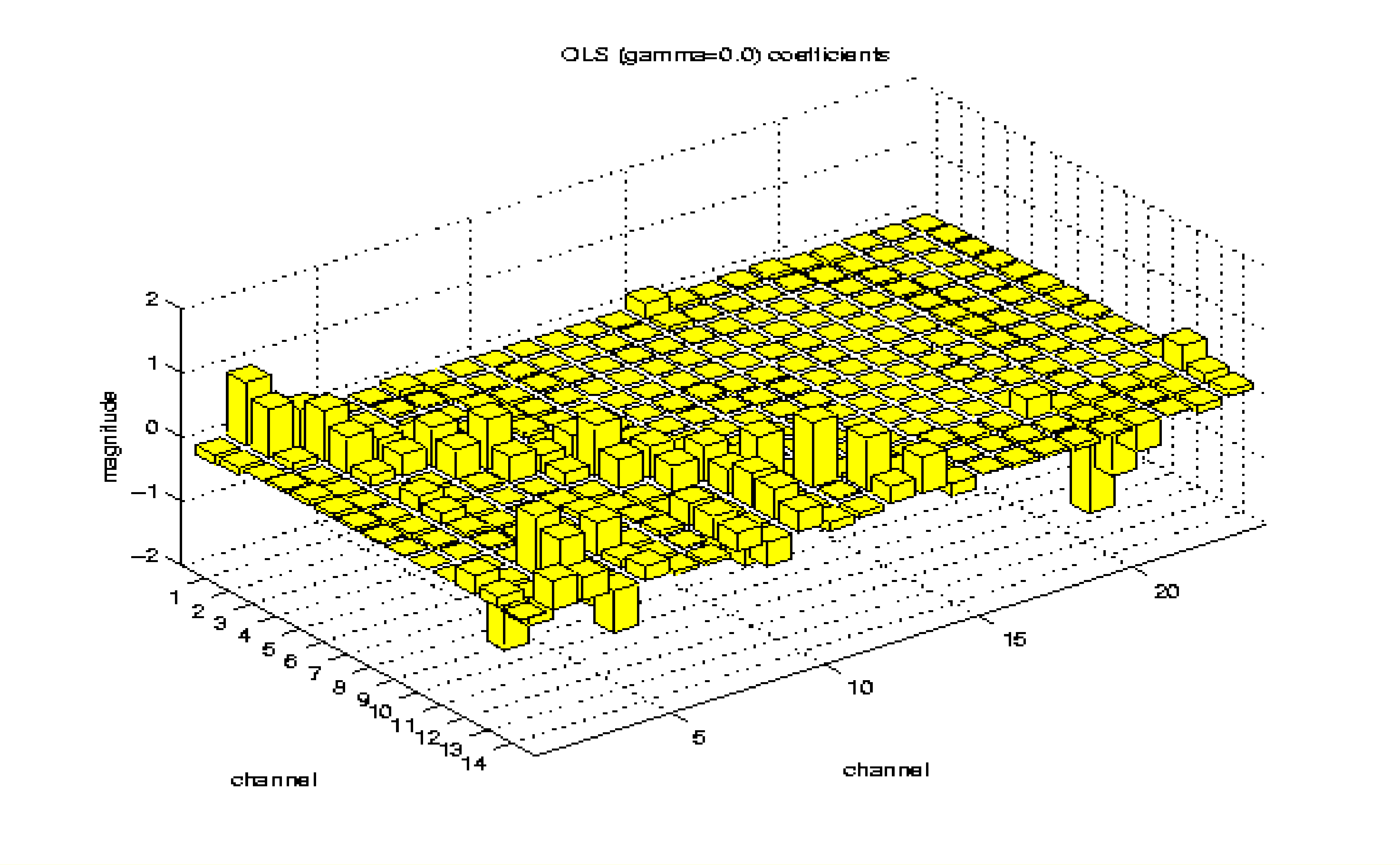
I	identity matrix
C_0	initial estimate of C (identity matrix)
S_{yx}	covariance (predictand/predictor)
S_{xx}	covariance (predictor/predictor)

Increase in residual variances due to increasing Gamma
(AMSU-A 4-14; AMSU-B 3,4, and 5)



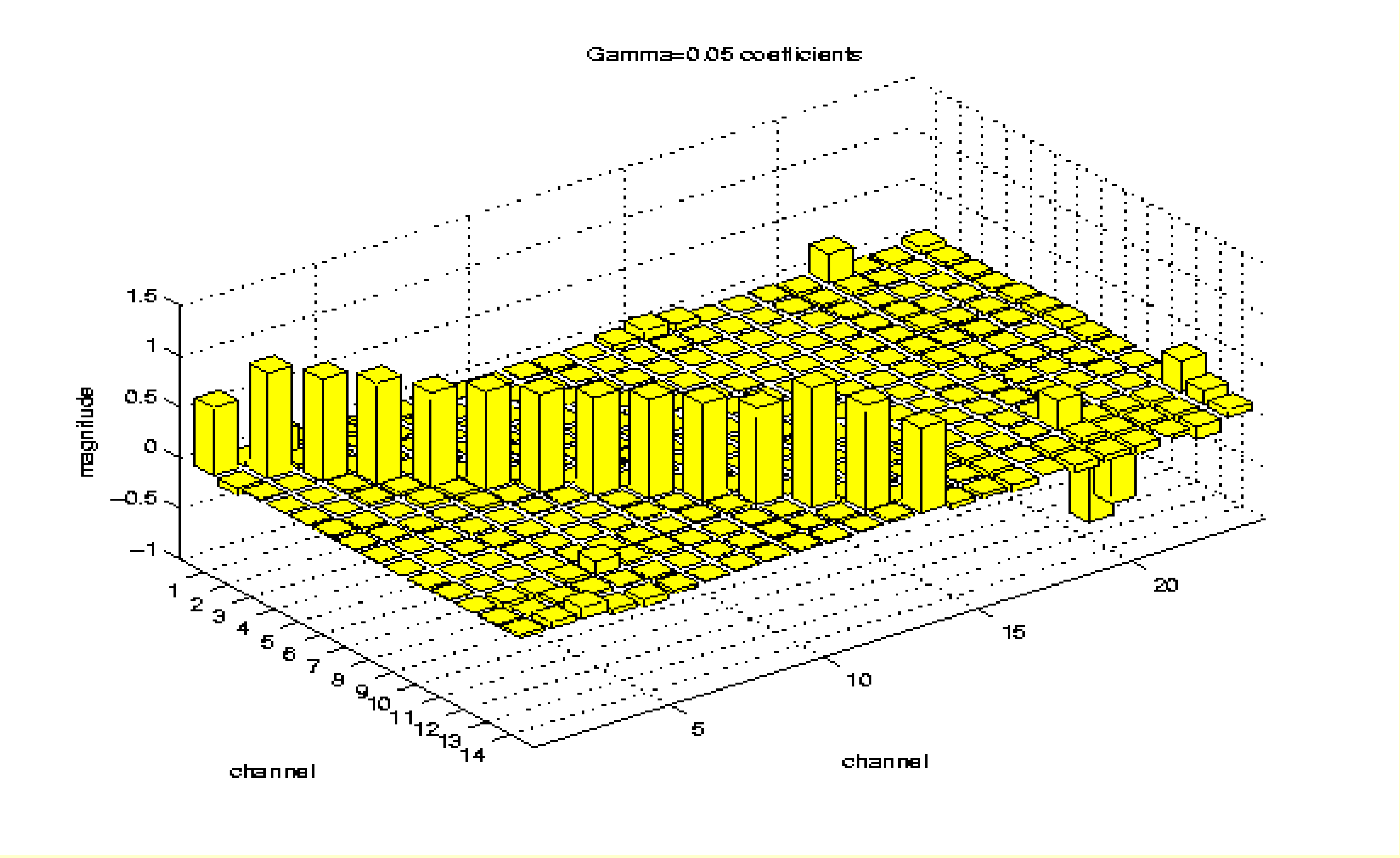
RT Bias Coefficients

(Gamma=0.0 ; AMSU-A ch 4-14; AMSU-B ch 3,4,and 5)



RT Bias Coefficients

(Gamma=0.05 ; AMSU-A ch 4-14; AMSU-B ch 3,4,and 5)

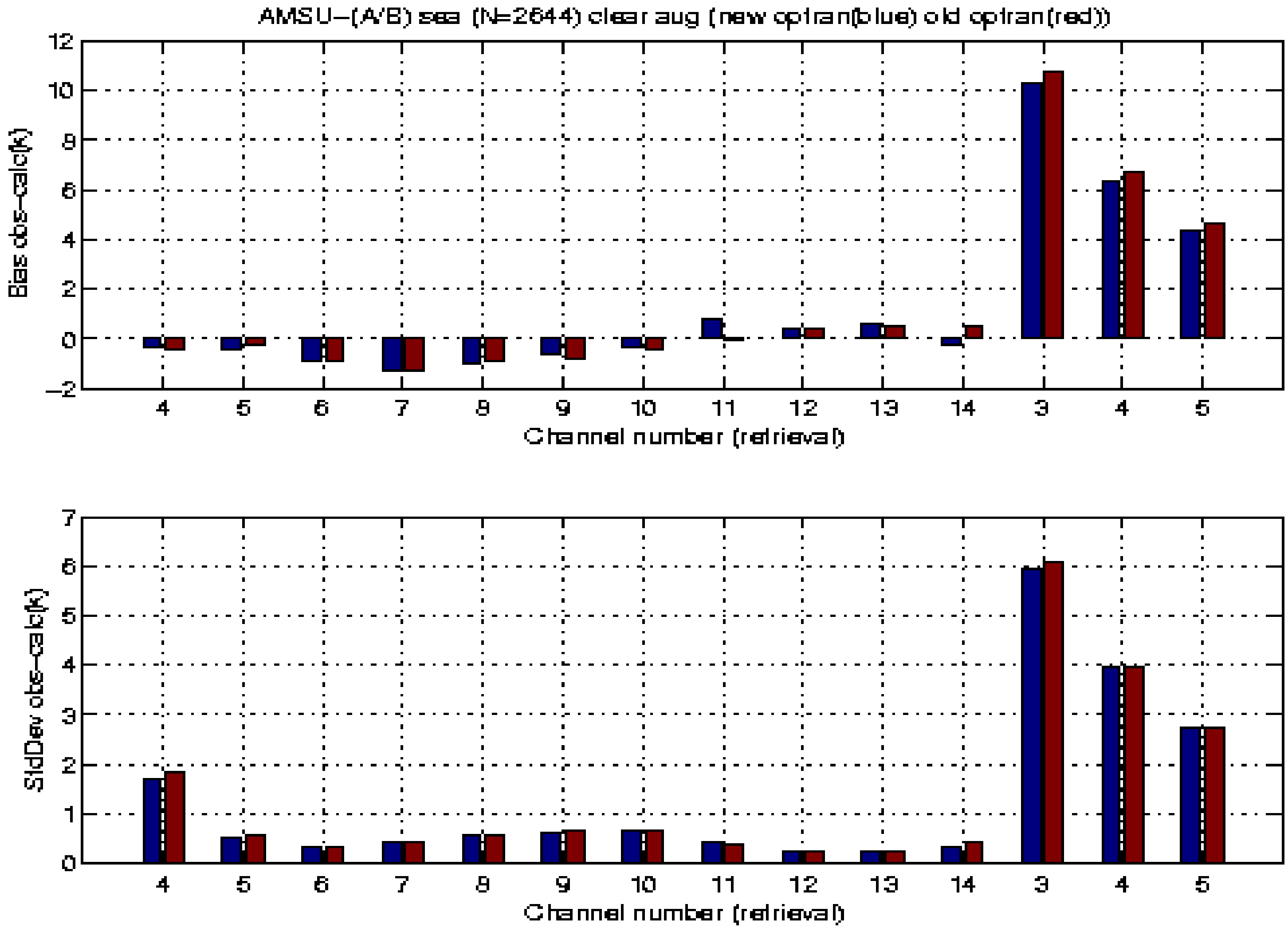


Radiance Bias Correction

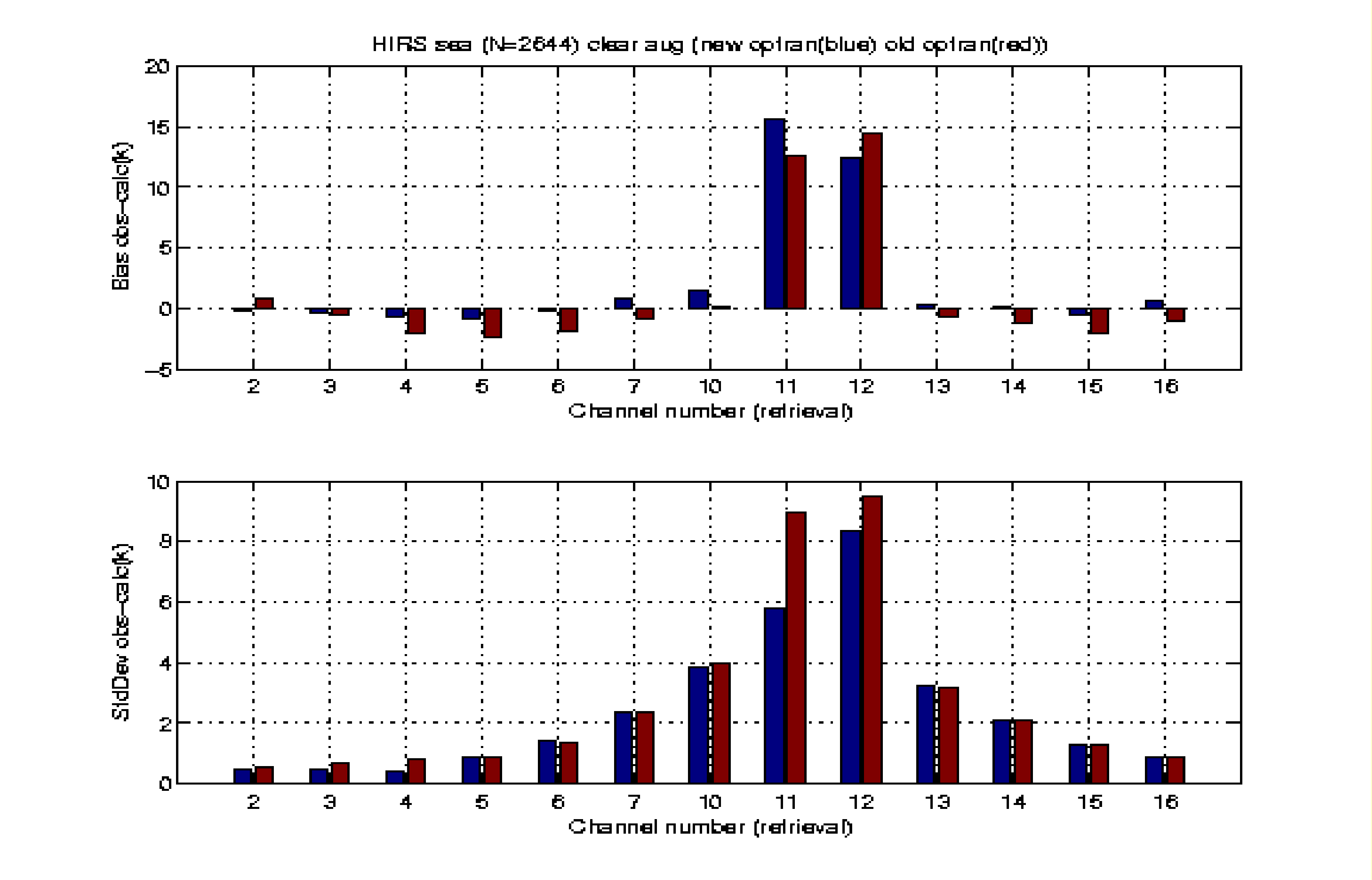
Results

Old/New OPTRAN comparison

AMSU-A/B Retrieval channels



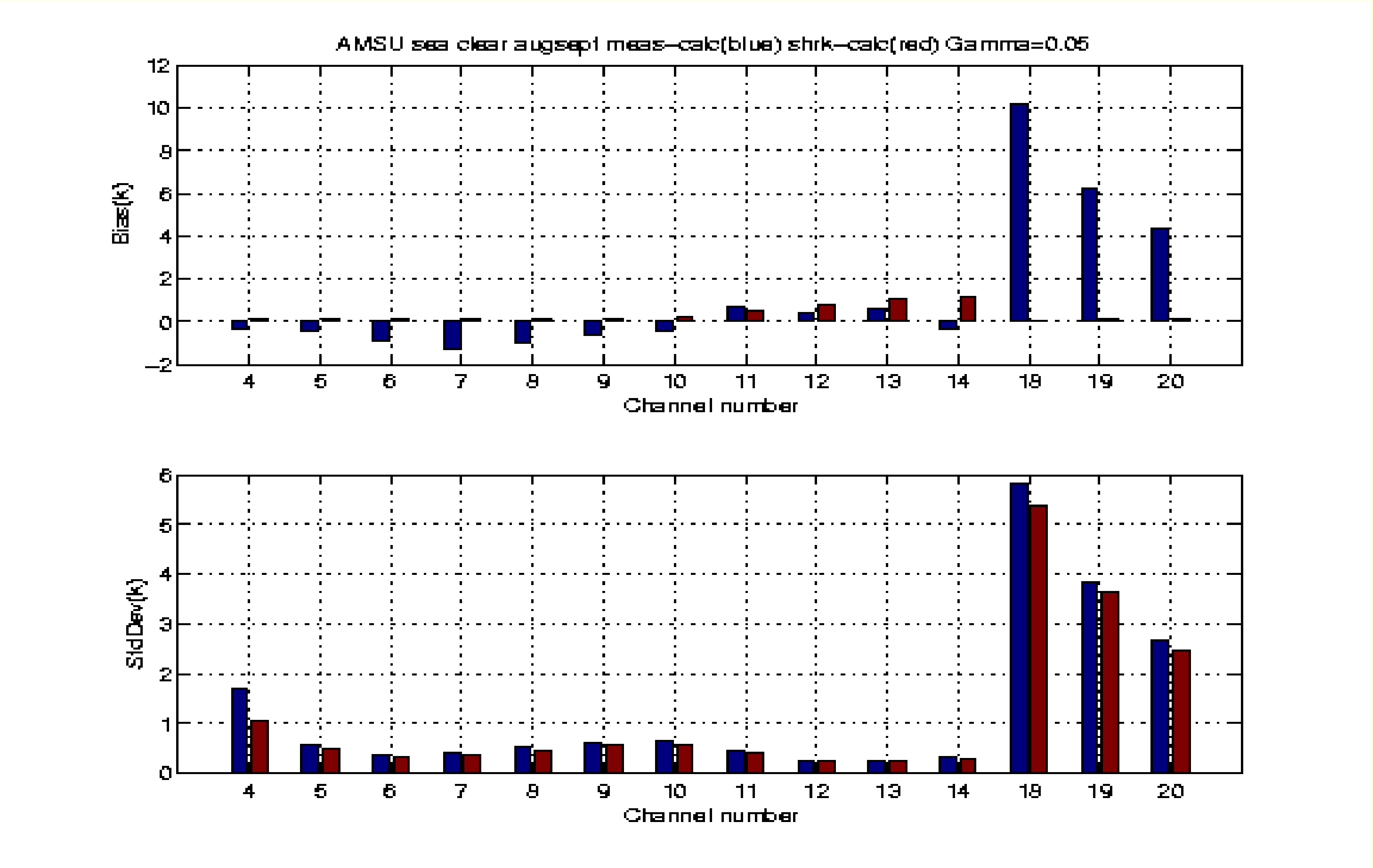
Old/New OPTRAN comparison
HIRS Retrieval channels



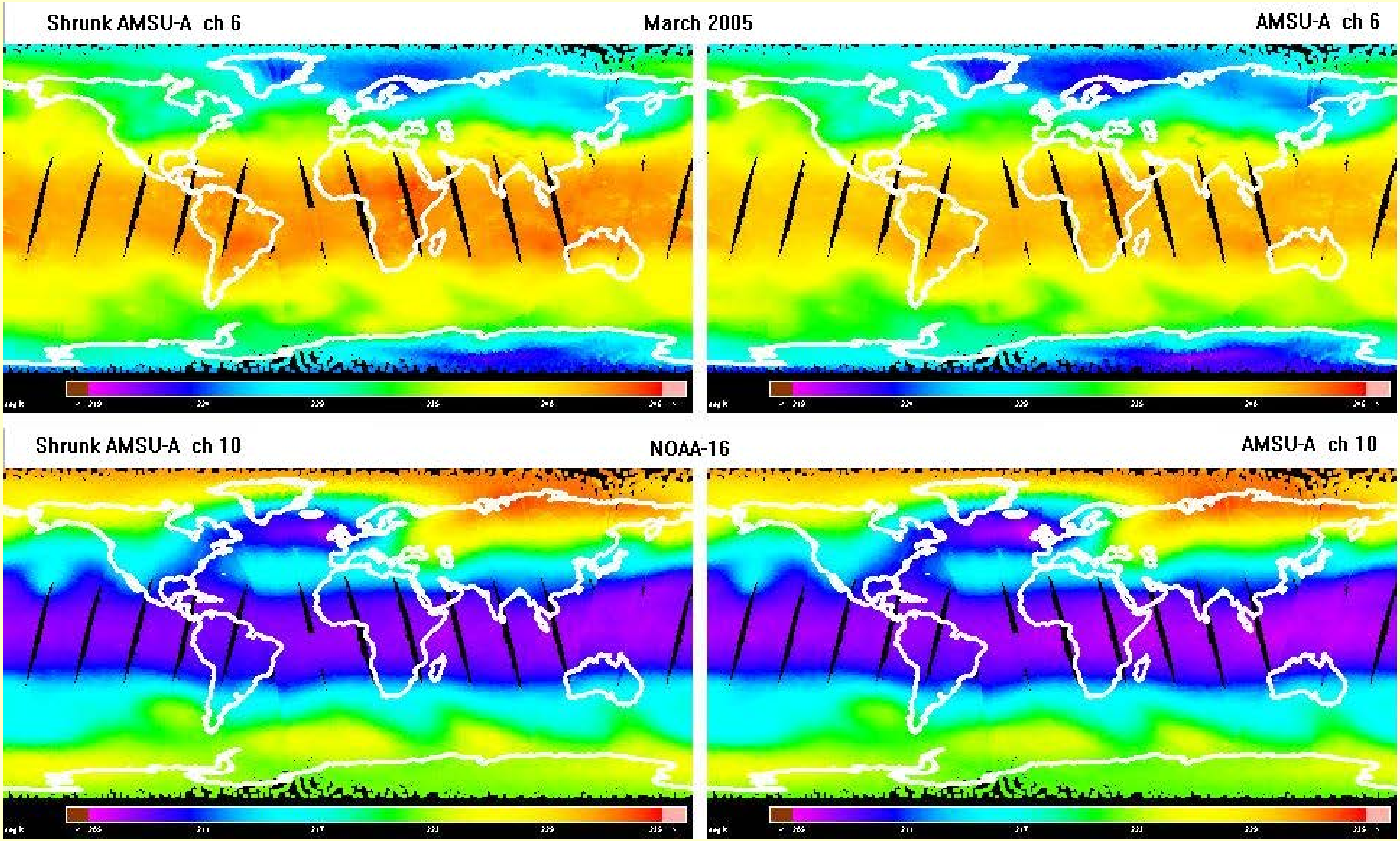
RT Bias Coefficients (Gamma=0.05)

Generated in August, applied to Sept data

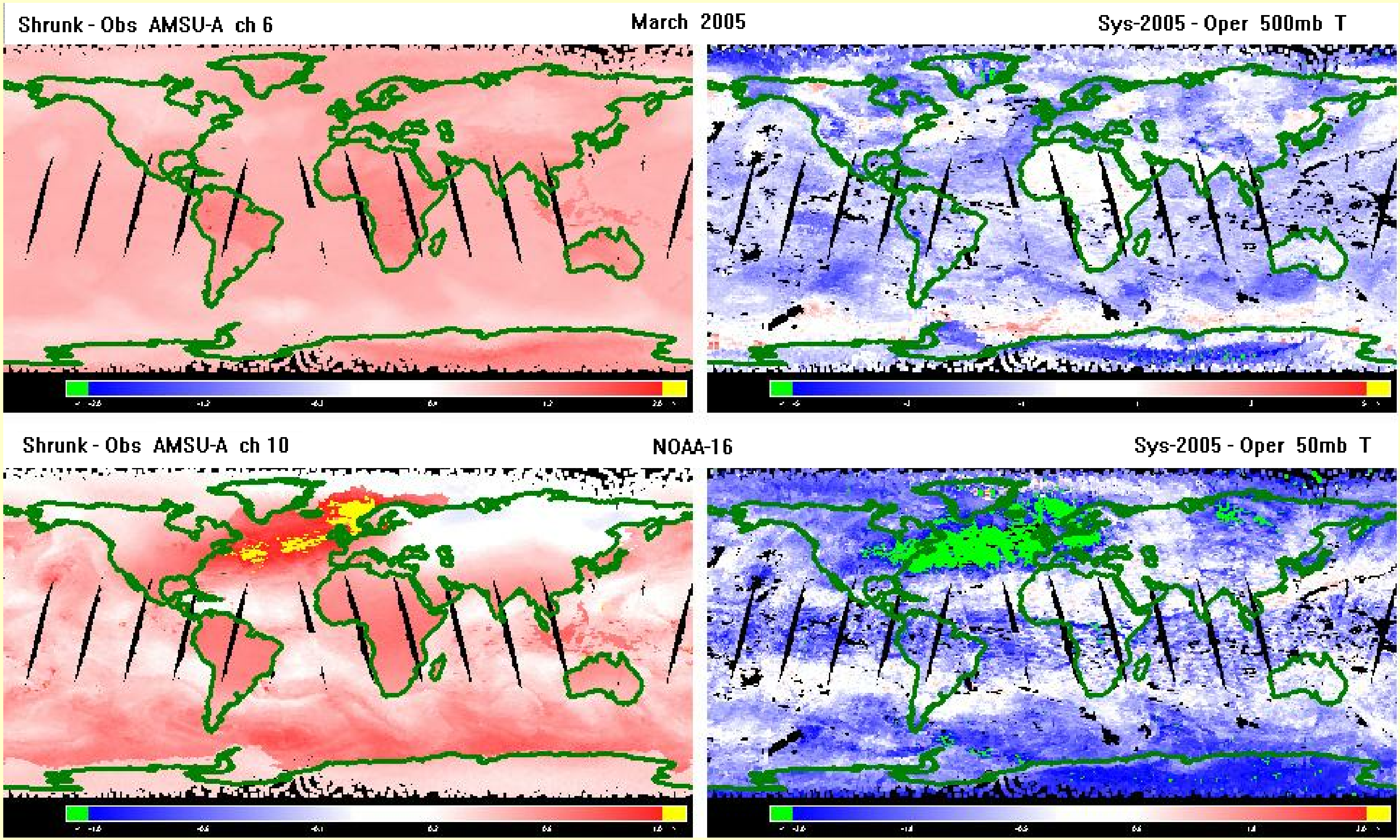
(AMSU-A ch 4-14; AMSU-B ch 3,4,and 5)



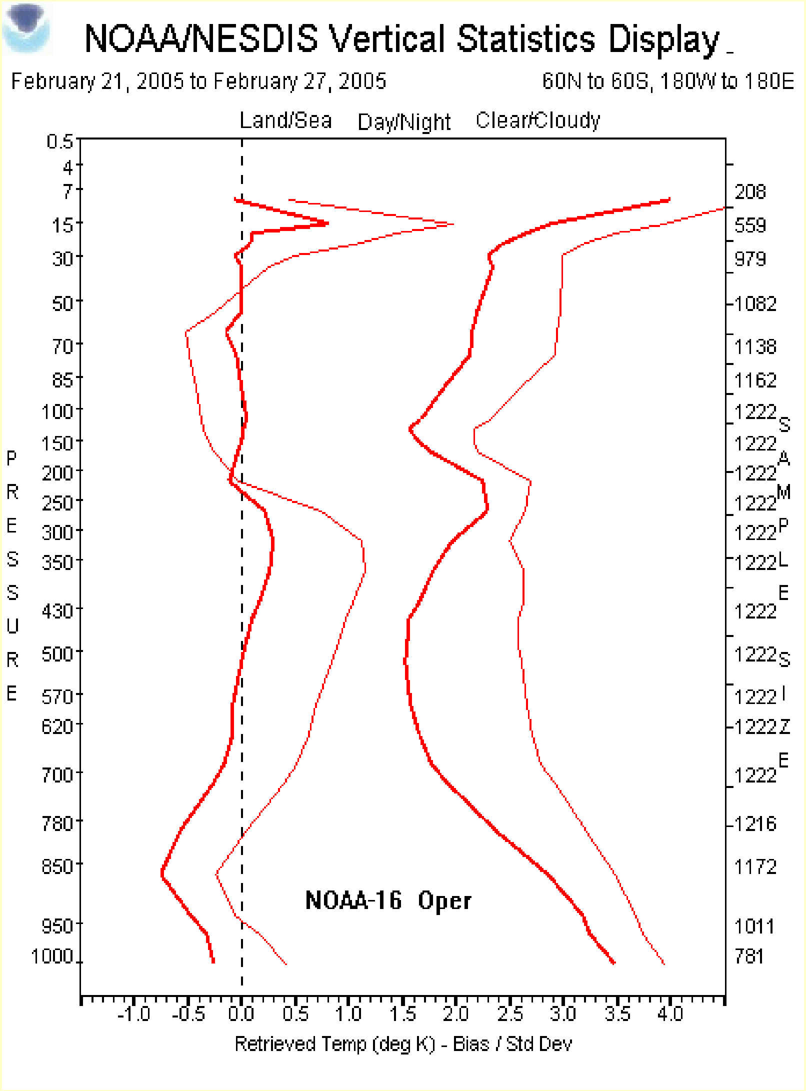
Shrunk AMSU-A

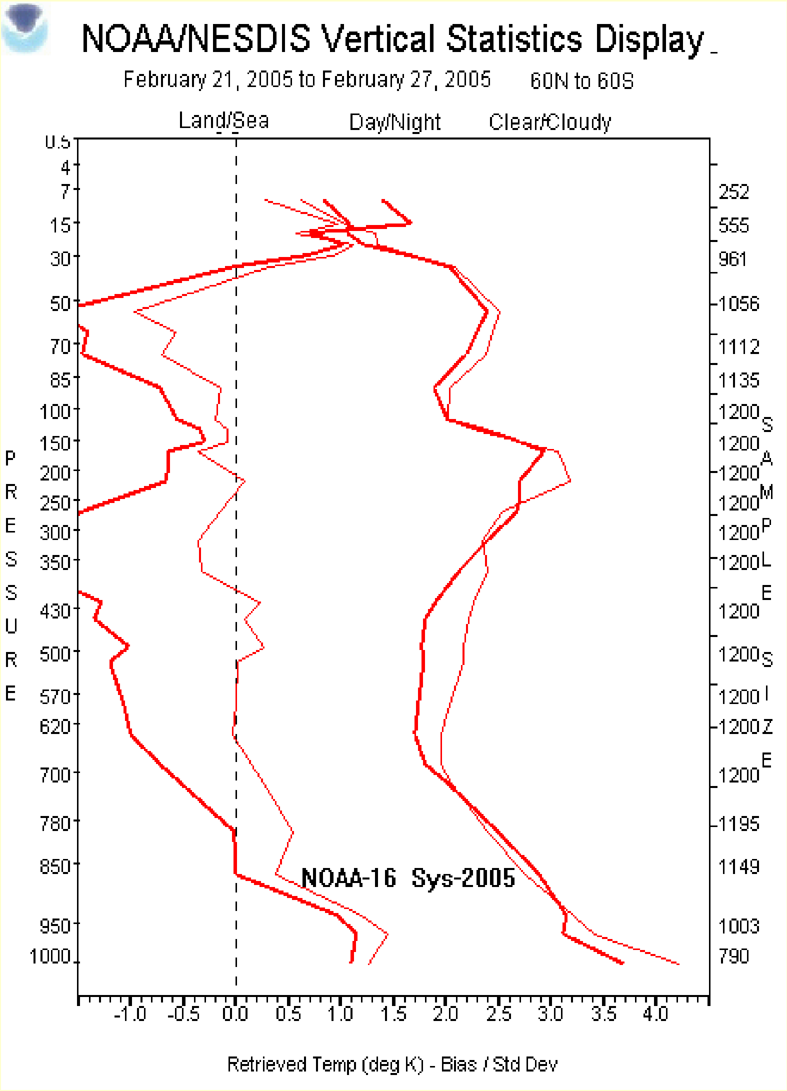


Potential Positive Impacts of Bias Adjustments

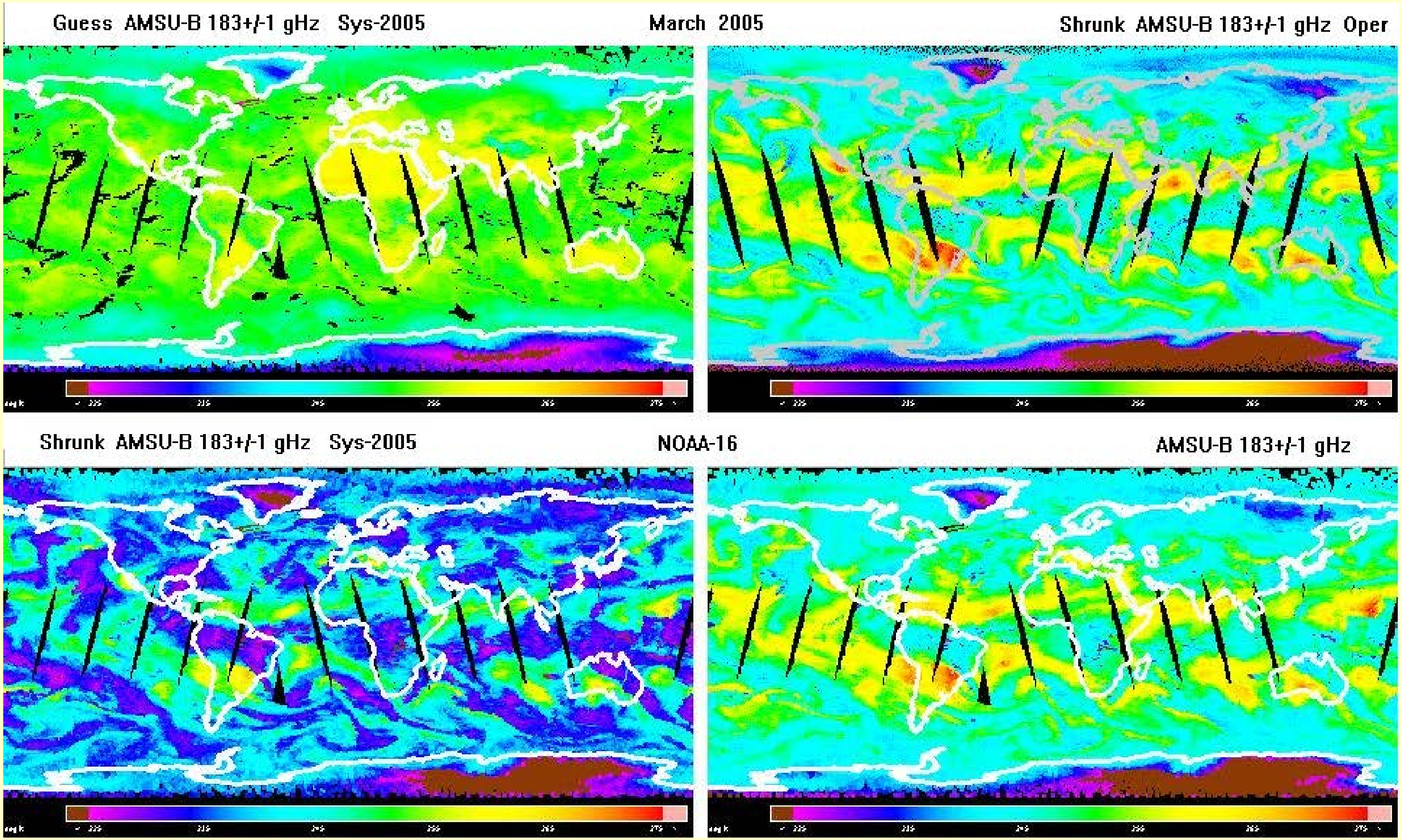


Vertical Statistics - Temperature

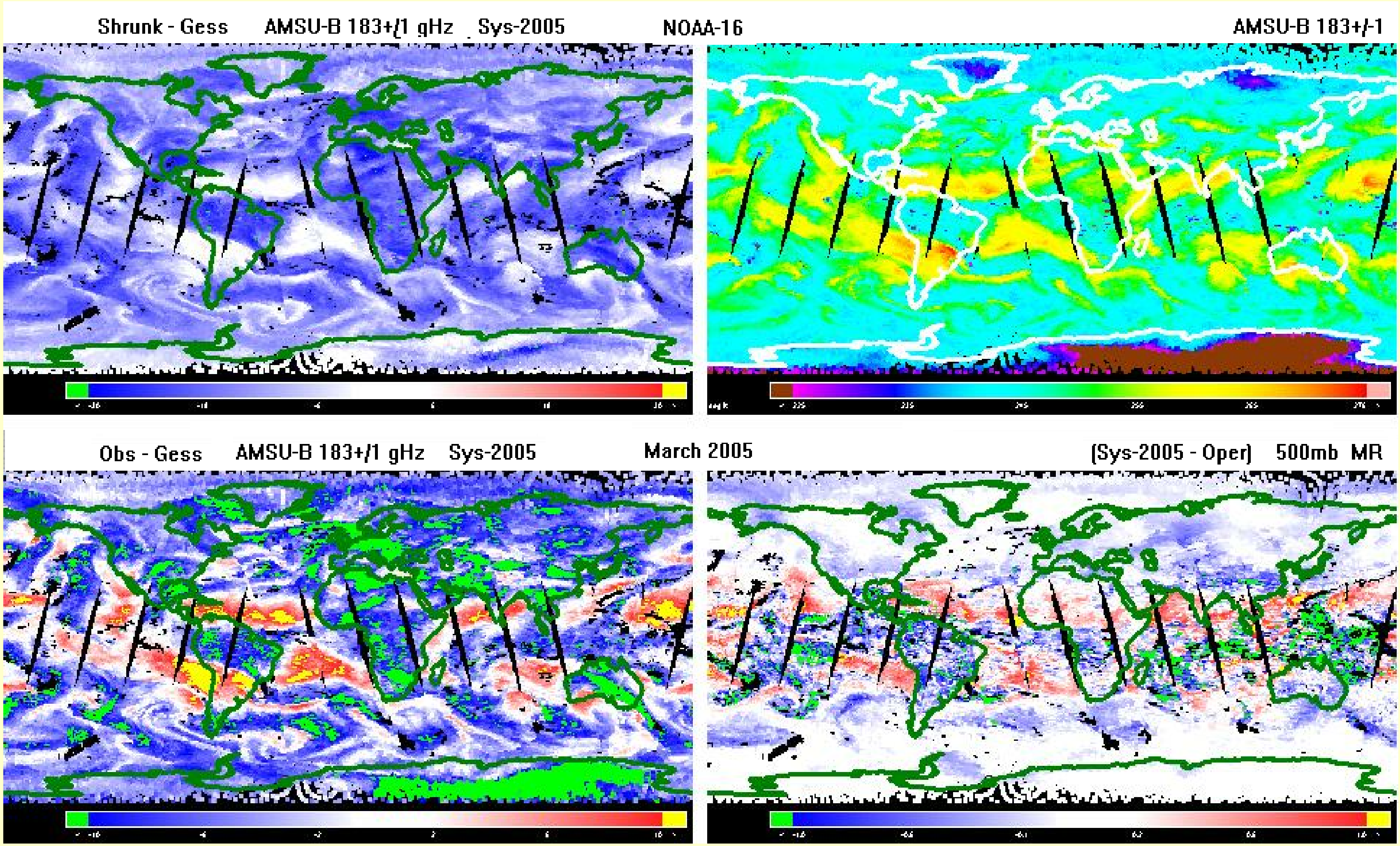




Shrunk AMSU-B

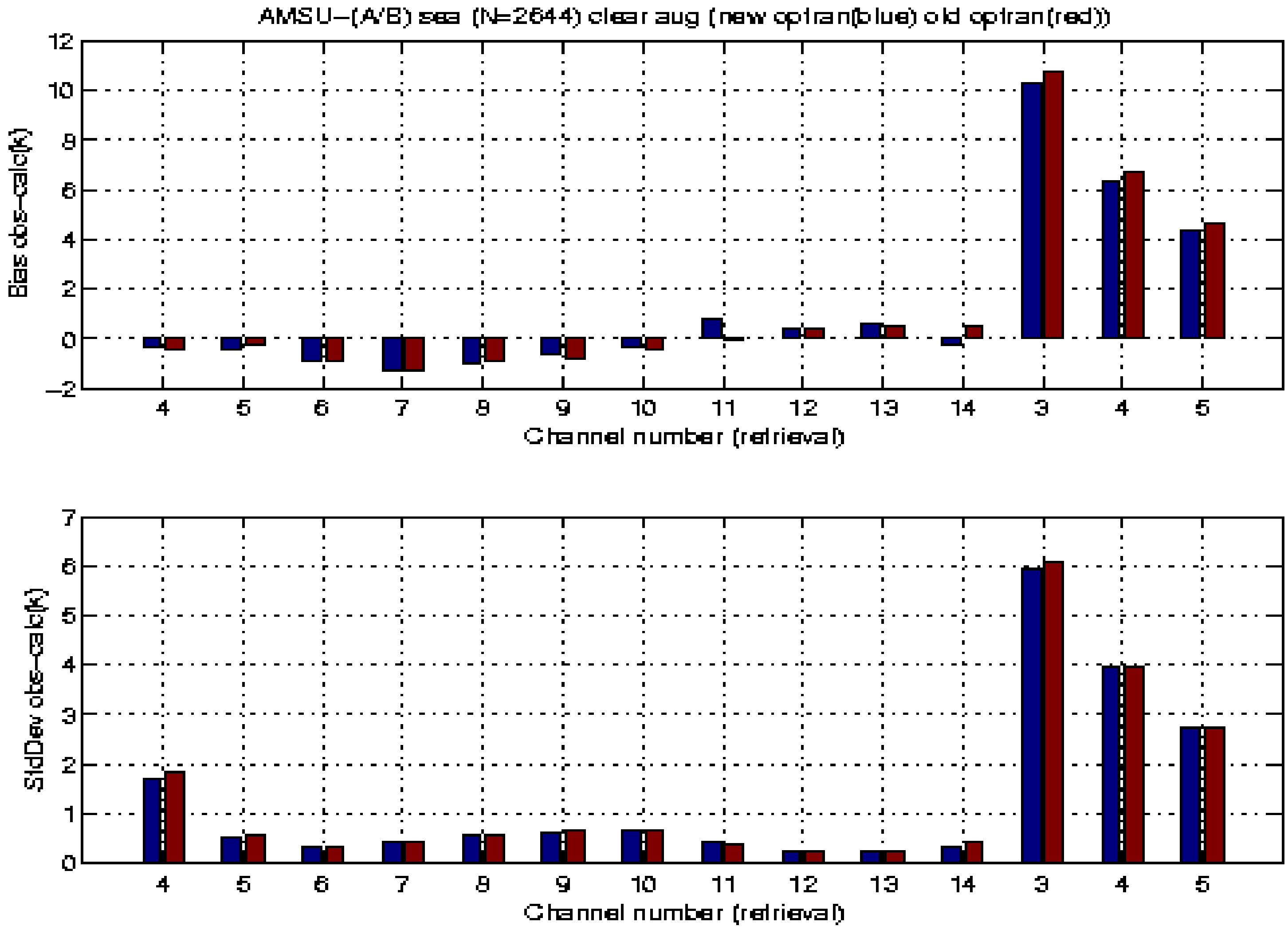


Potential Positive Impacts of Bias Adjustments

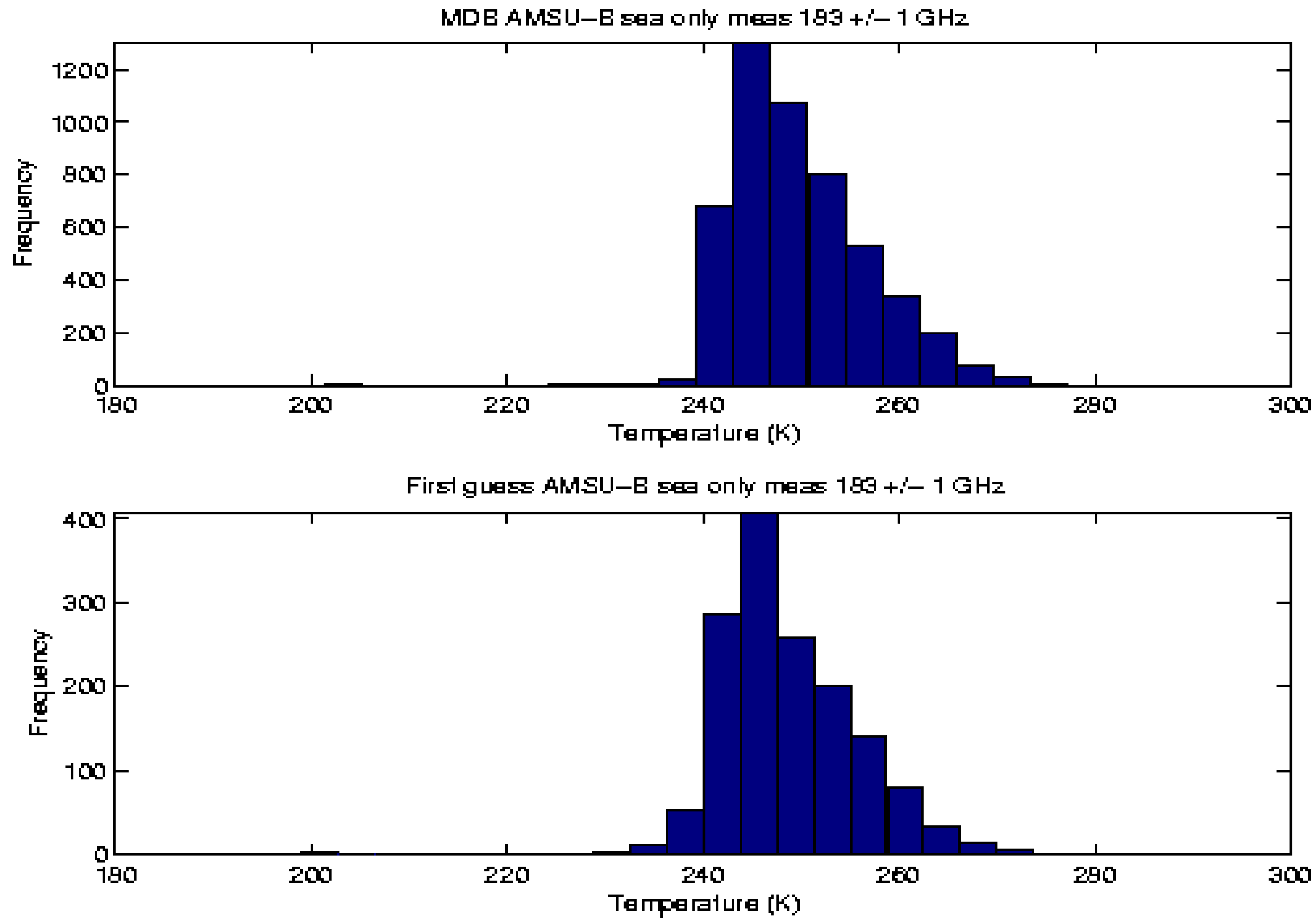


Old/New OPTRAN comparison

AMSU-A/B Retrieval channels

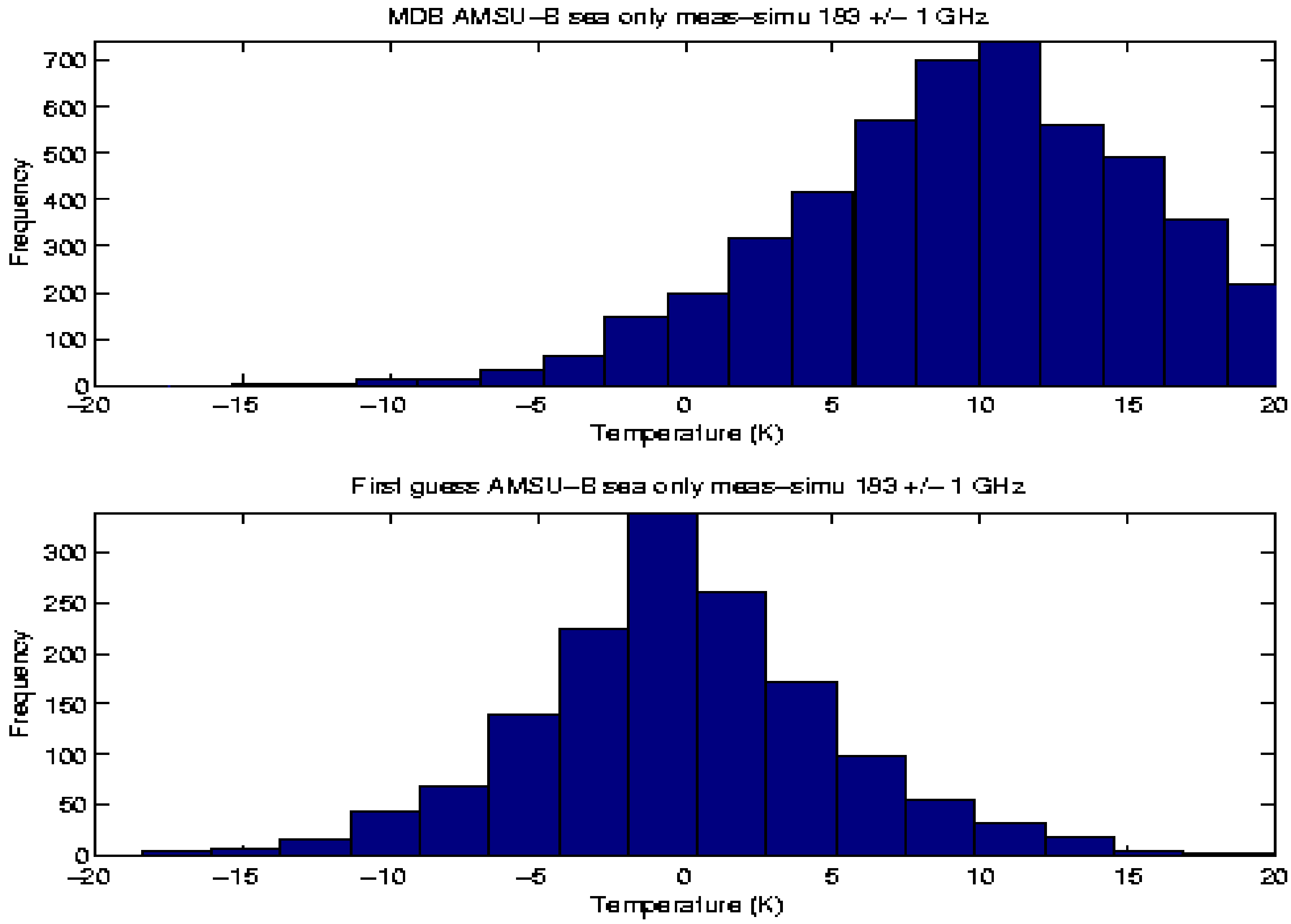


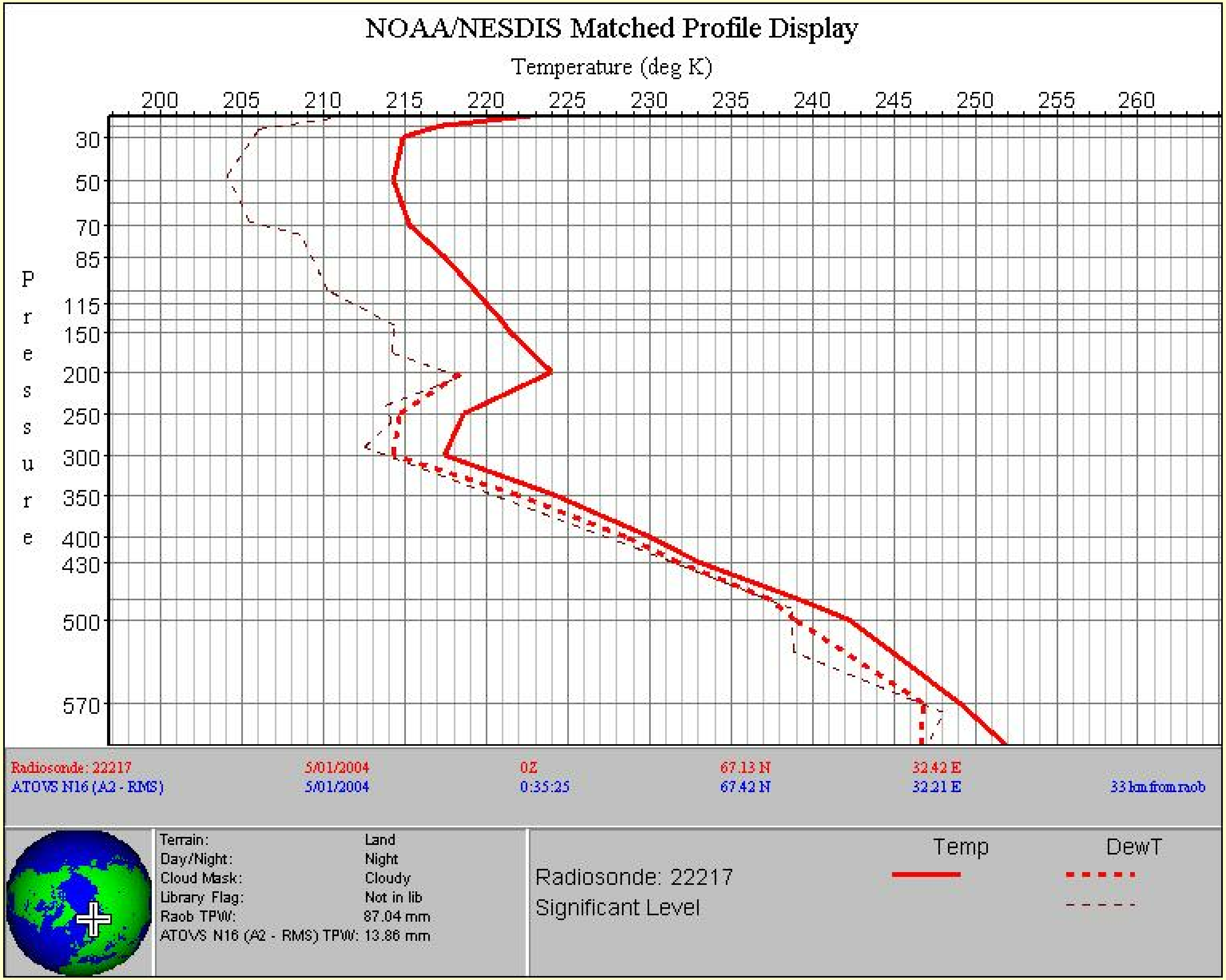
MDB (top) vs. AMSU-B Oper. Library (bottom)
(183 +/- 1 gHz)

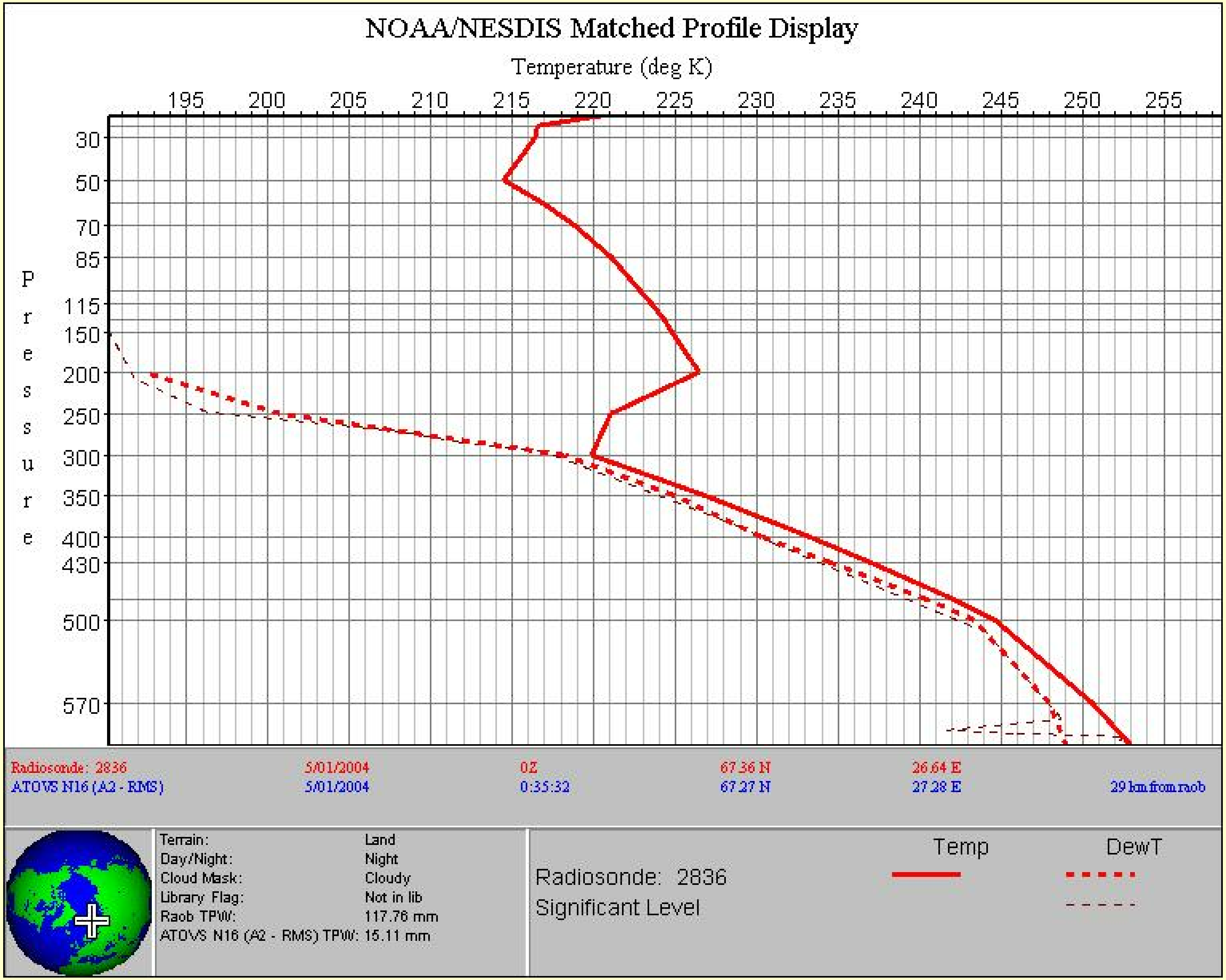


Simulated AMSU-B Cold Bias

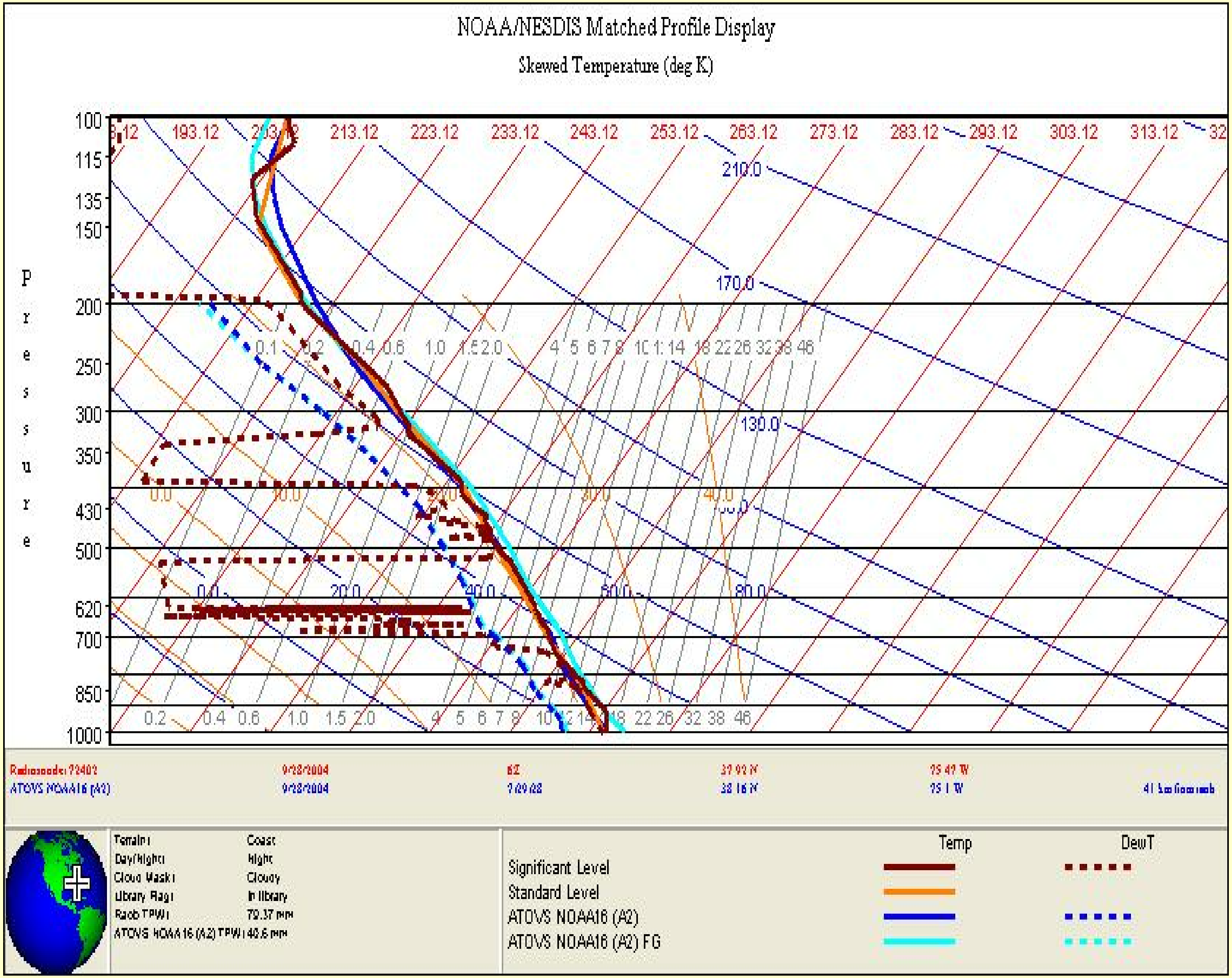
MDB (top) vs. Library (bottom)



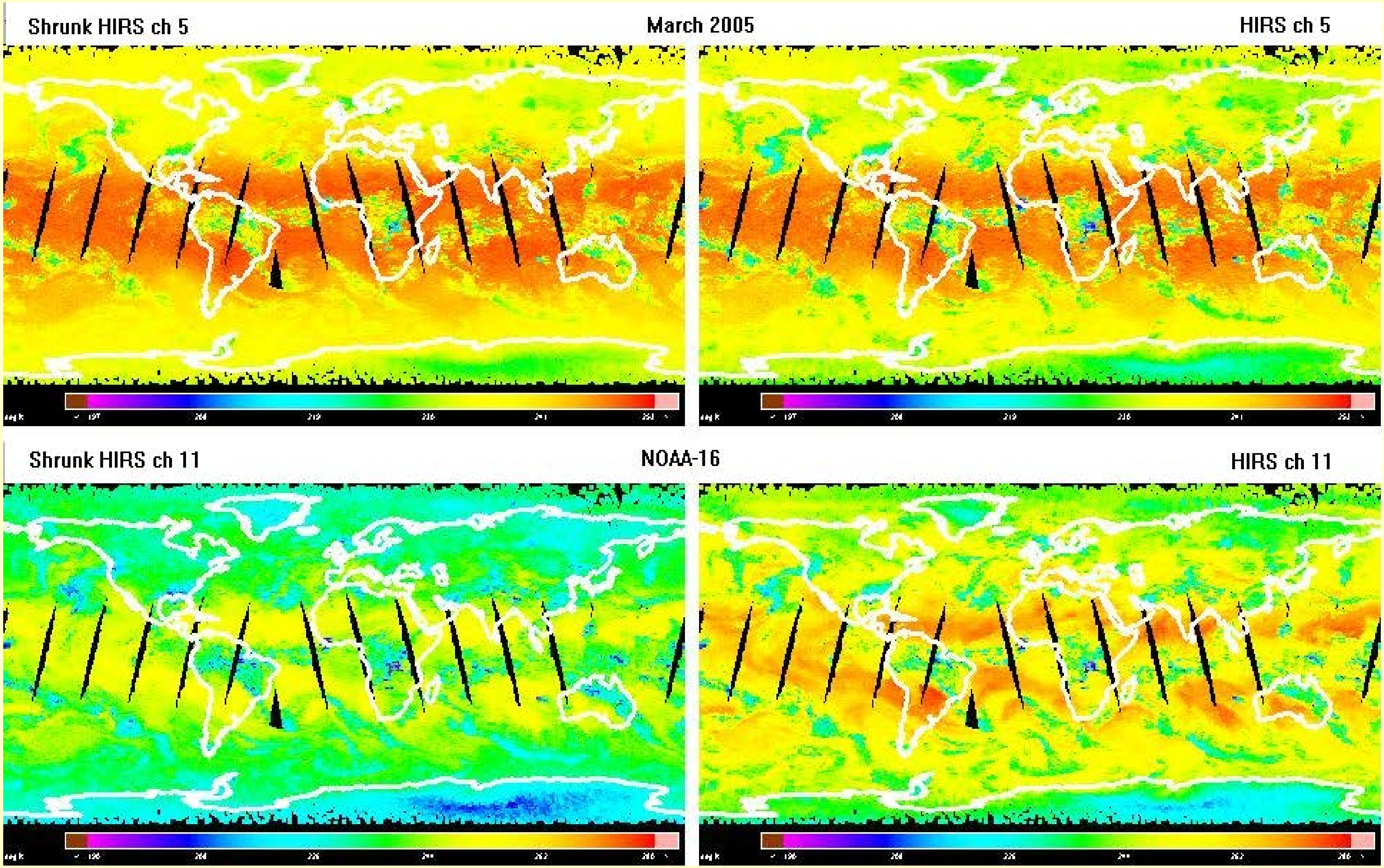

NOAA/NESDIS Matched Profile Display
Temperature (deg K)
200 205 210 215 220 225 230 235 240 245 250 255 260
Pressure
30 50 70 85 115 150 200 250 300 350 400 430 500 570
Radiosonde: 22217 5/01/2004 0Z 67.13 N 32.42 E
ATOVS N16 (A2 - RMS) 5/01/2004 0:35:25 67.42 N 32.21 E 33 km from raob
Terrain: Land
Day/Night: Night
Cloud Mask: Cloudy
Library Flag: Not in lib
Raob TPW: 87.04 mm
ATOVS N16 (A2 - RMS) TPW: 13.86 mm
Radiosonde: 22217
Significant Level
Temp
DewT



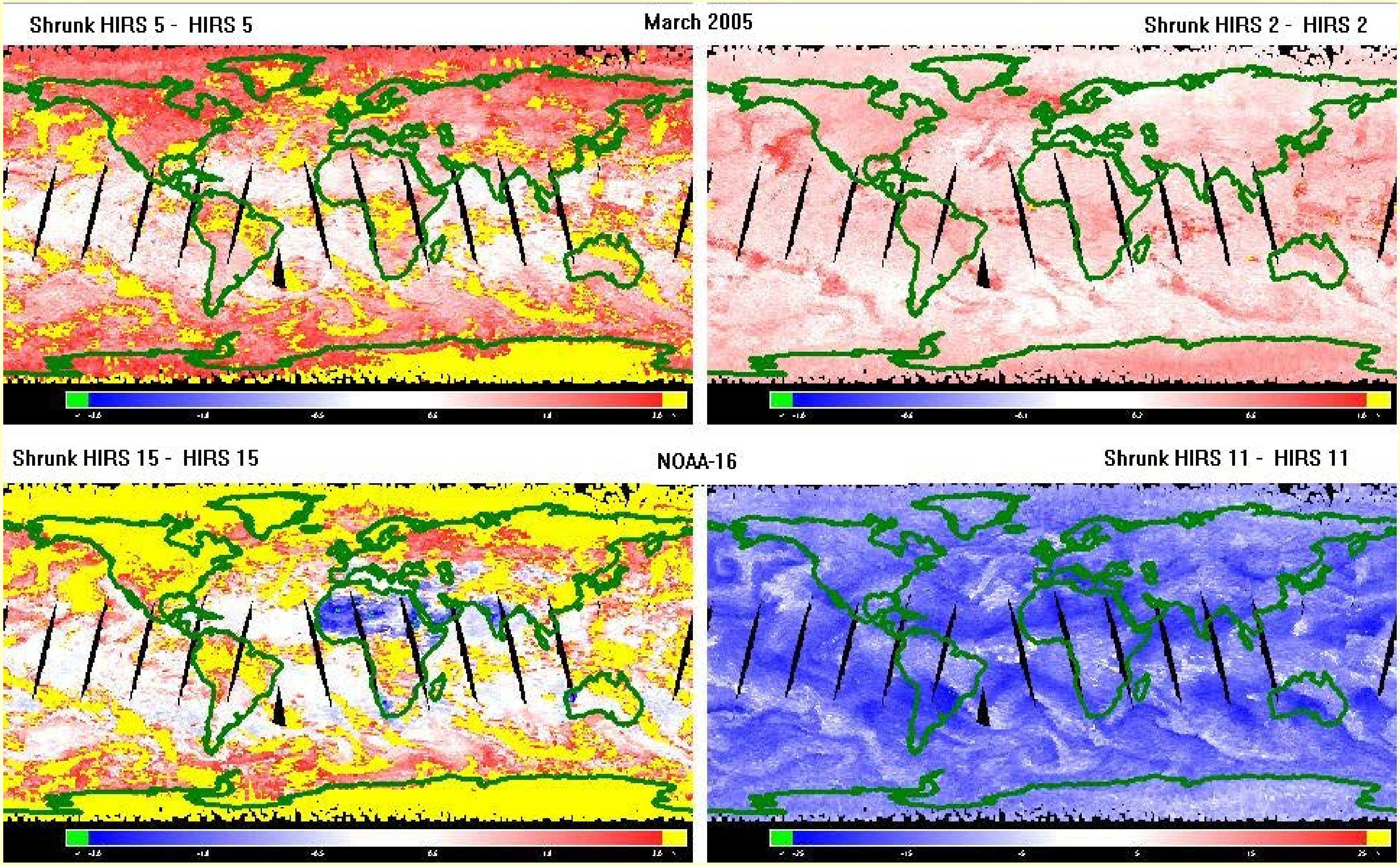
NOAA/NESDIS Matched Profile Display
Temperature (deg K)
195 200 205 210 215 220 225 230 235 240 245 250 255
Pressure
30 50 70 85 115 150 200 250 300 350 400 430 500 570
Radiosonde: 2836 5/01/2004 0Z 67.36 N 26.64 E
ATOVS N16 (A2 - RMS) 5/01/2004 0:35:32 67.27 N 27.28 E 29 km from raob
Terrain: Land
Day/Night: Night
Cloud Mask: Cloudy
Library Flag: Not in lib
Raob TPW: 117.76 mm
ATOVS N16 (A2 - RMS) TPW: 15.11 mm
Radiosonde: 2836
Significant Level
Temp
DewT


NOAA/NESDIS Matched Profile Display
Skewed Temperature (deg K)
Pressure
100
115
135
150
200
250
300
350
430
500
620
700
850
1000
193.12
213.12
223.12
233.12
243.12
253.12
263.12
273.12
283.12
293.12
303.12
313.12
210.0
170.0
130.0
80.0
0.0
20.0
40.0
0.1
0.2
0.4
0.6
1.0
1.5
2.0
4
5
6
7
8
14
18
22
26
32
38
46
Radiosonde: 72402
9/28/2004
37.93 N
ATOVS NOAA16 (A2)
9/28/2004
38.16 N
Terrain: Coast
Day/Night: Night
Cloud Mask: Cloudy
Library Flag: In library
Raob TPW: 79.37 mm
ATOVS NOAA16 (A2) TPW: 40.6 mm
Temp
DewT
Significant Level
Standard Level
ATOVS NOAA16 (A2)
ATOVS NOAA16 (A2) FG

Shrunk HIRS

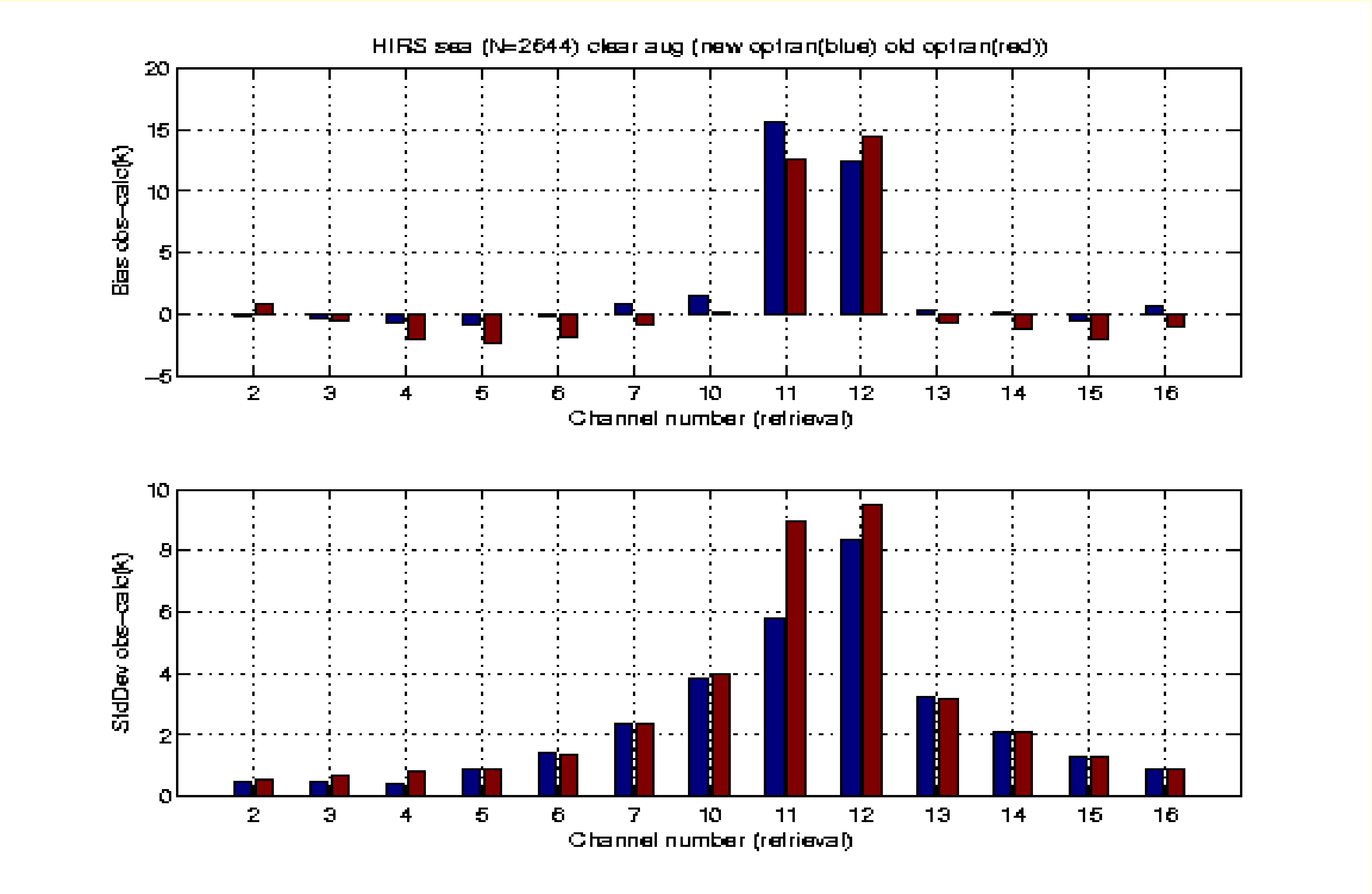

Shrunk HIRS ch 5
March 2005
HIRS ch 5
Shrunk HIRS ch 11
NOAA-16
HIRS ch 11

Shrunk minus Observed for Selected HIRS



Old/New OPTRAN comparison

HIRS Retrieval channels



ATOVS System-2004 Science

- Incorporate AMSU-B

- Regression Guess replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)

- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS

- Analytical Retrieval Solution (OPTRAN) per sounding (Van-delst, Kleespies, Han)
  - based on Guess temp and Moisture

- Peripheral Upgrades
  - Limb-adjustment
  - Expanded validation

Expanded Sys-2005 Data Capture and Validation

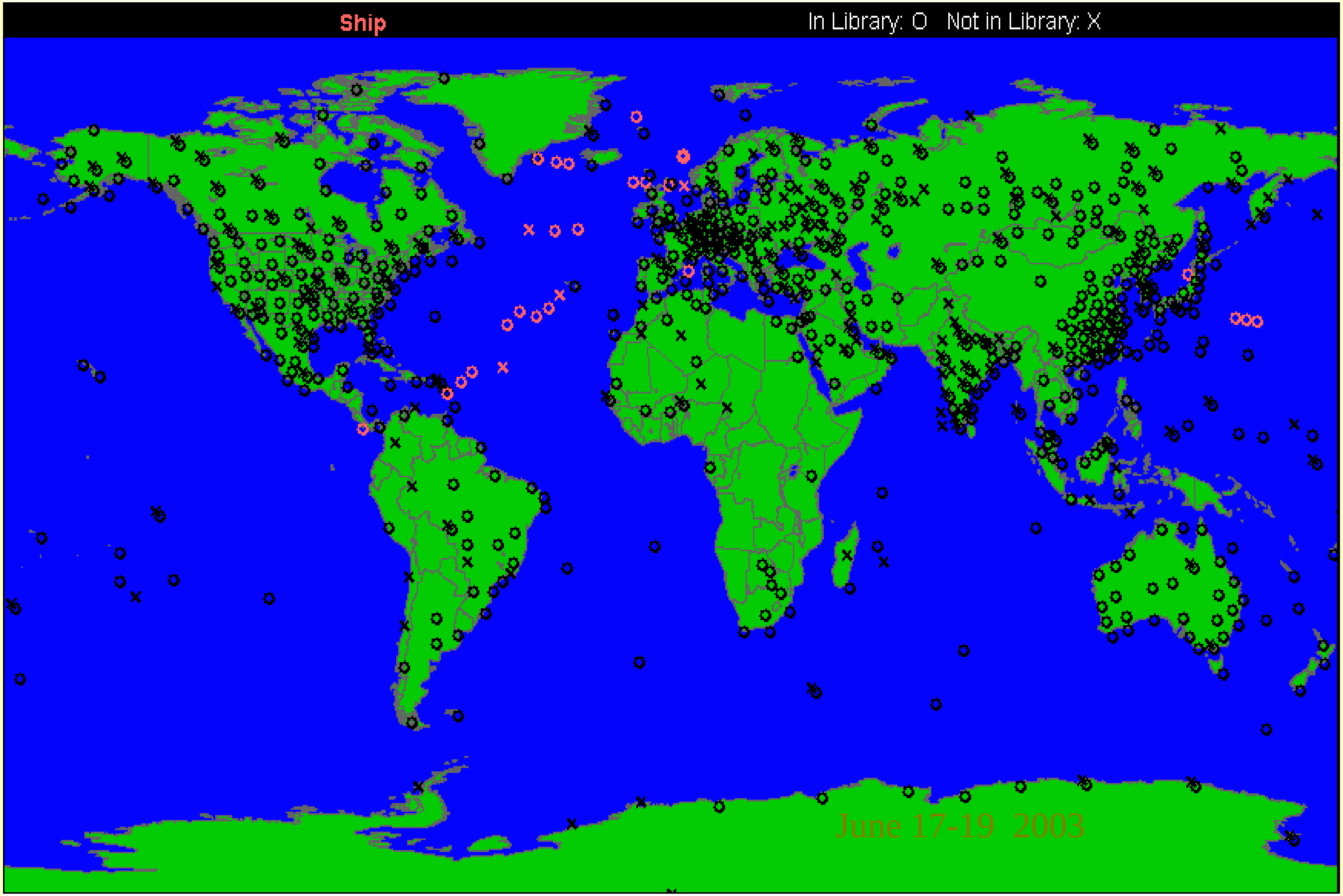
- Sys-2005 expanded to access operationally supported NCEP PREPBUFR Radiosondes
- Sys-2005 expanded to store complete collocated NWP
  - 3-hr GFS @ 100km (+/- 90 minutes)
- Enhanced suite of validation (measurement and product) planned … EDGE
- Possible framework for inter-satellite and product comparisons

Collocated Radiosonde and Satellite Observations
provide basis for

Monitoring
Validating and
Tuning

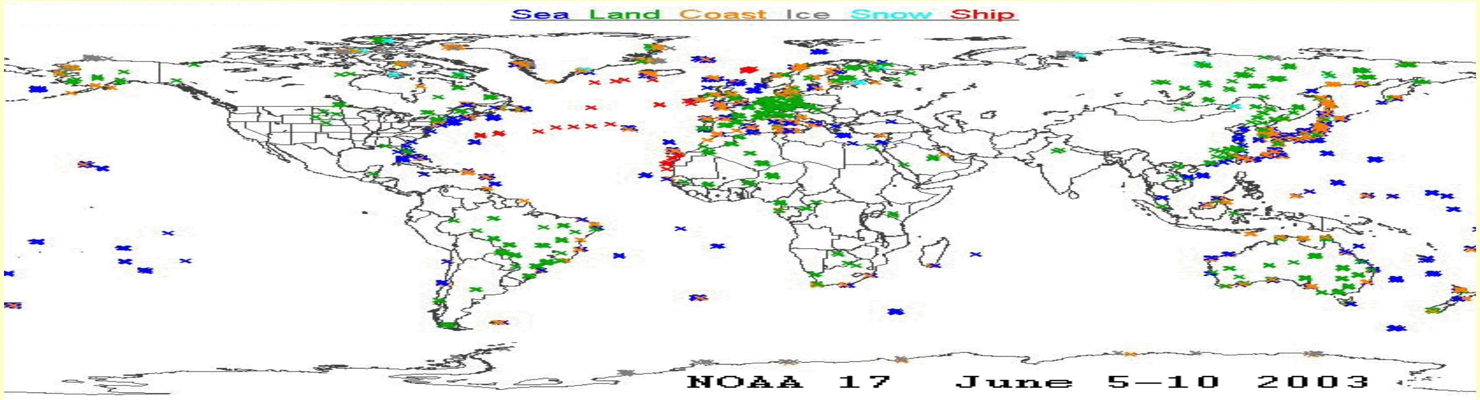
Operational Satellite Data Systems
(ATOVS)

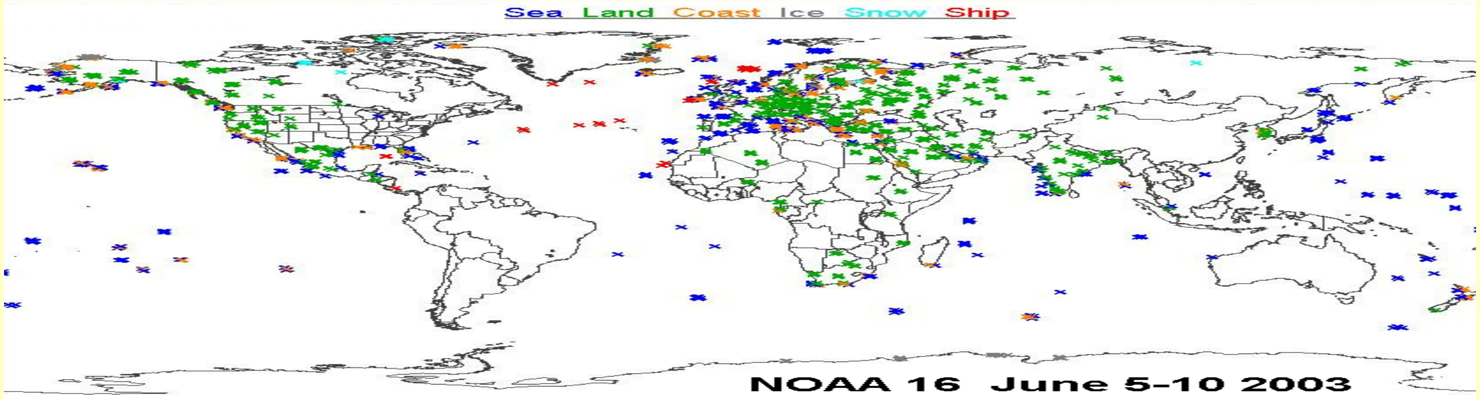
Global Radiosondes

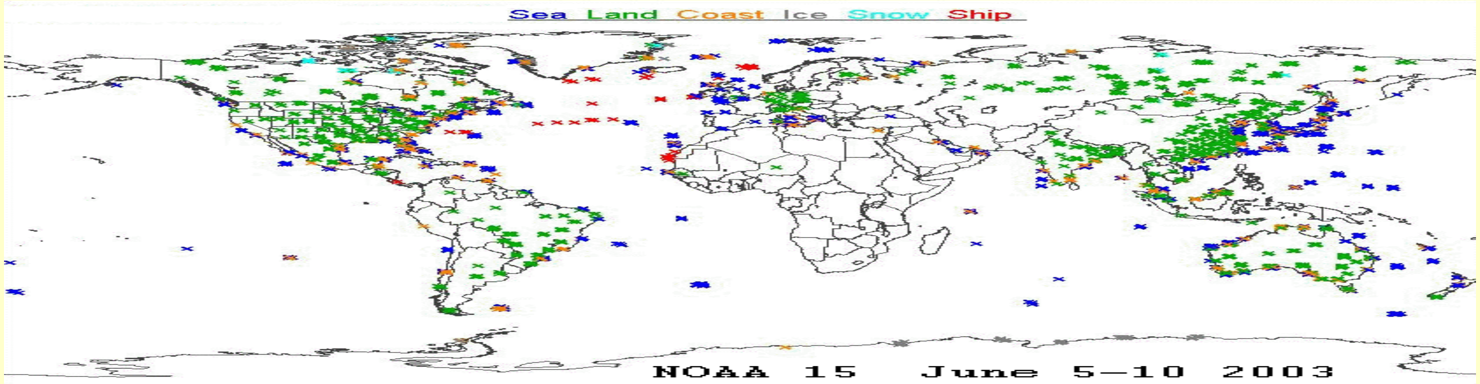


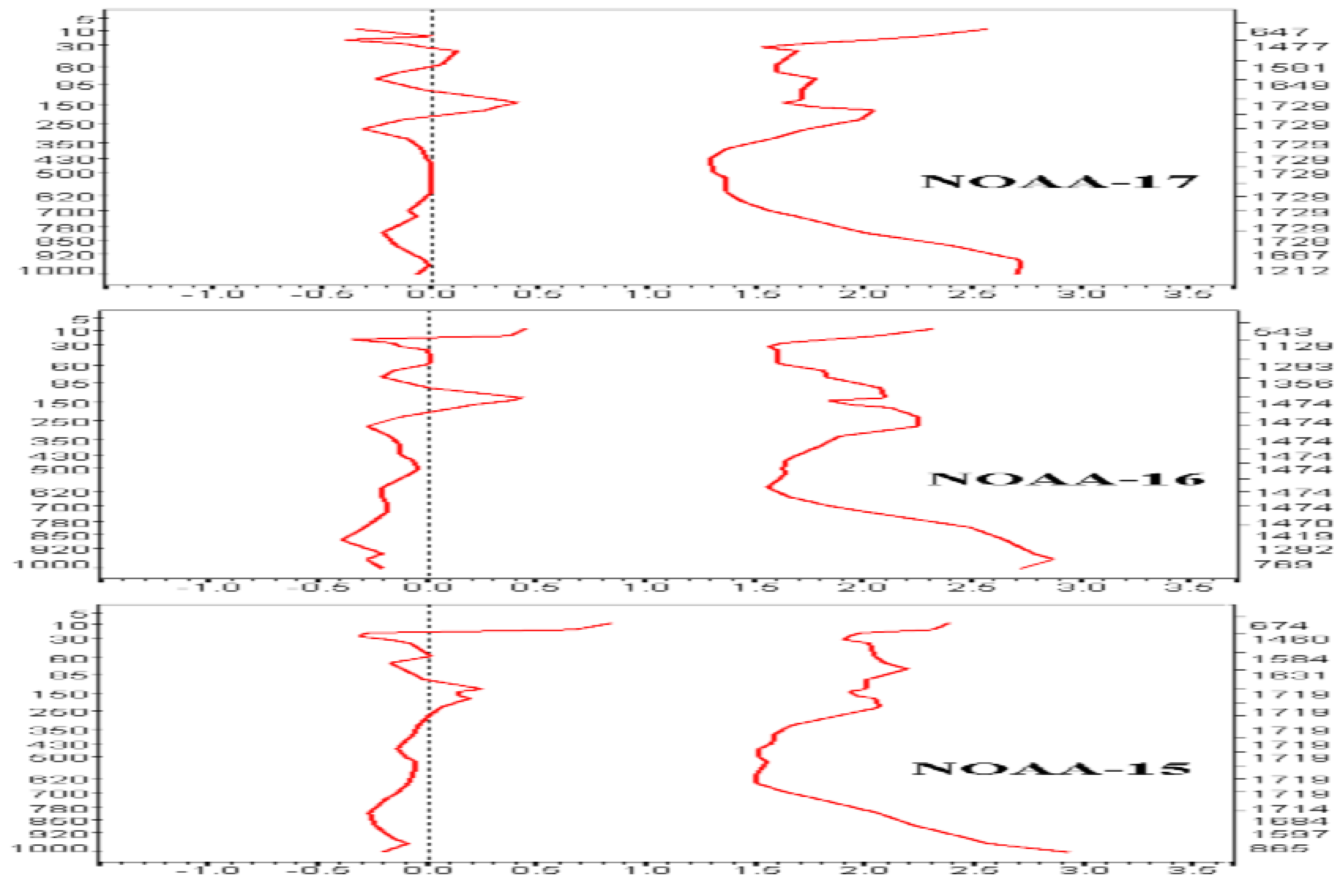
SATELLITE COLLOCATIONS (+/- 3hrs, land; +/- 5hrs, sea)

(used operationally at NESDIS)



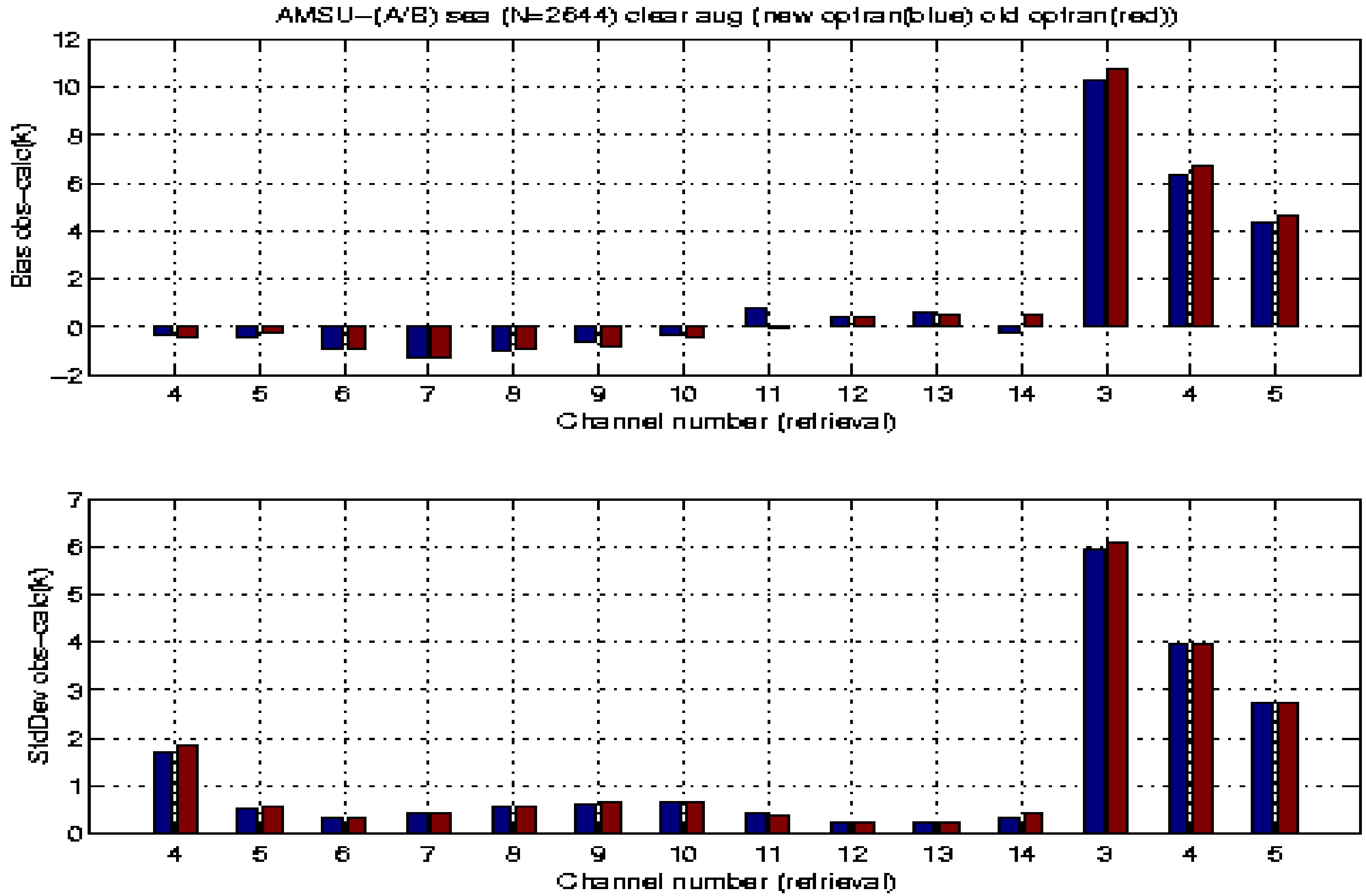


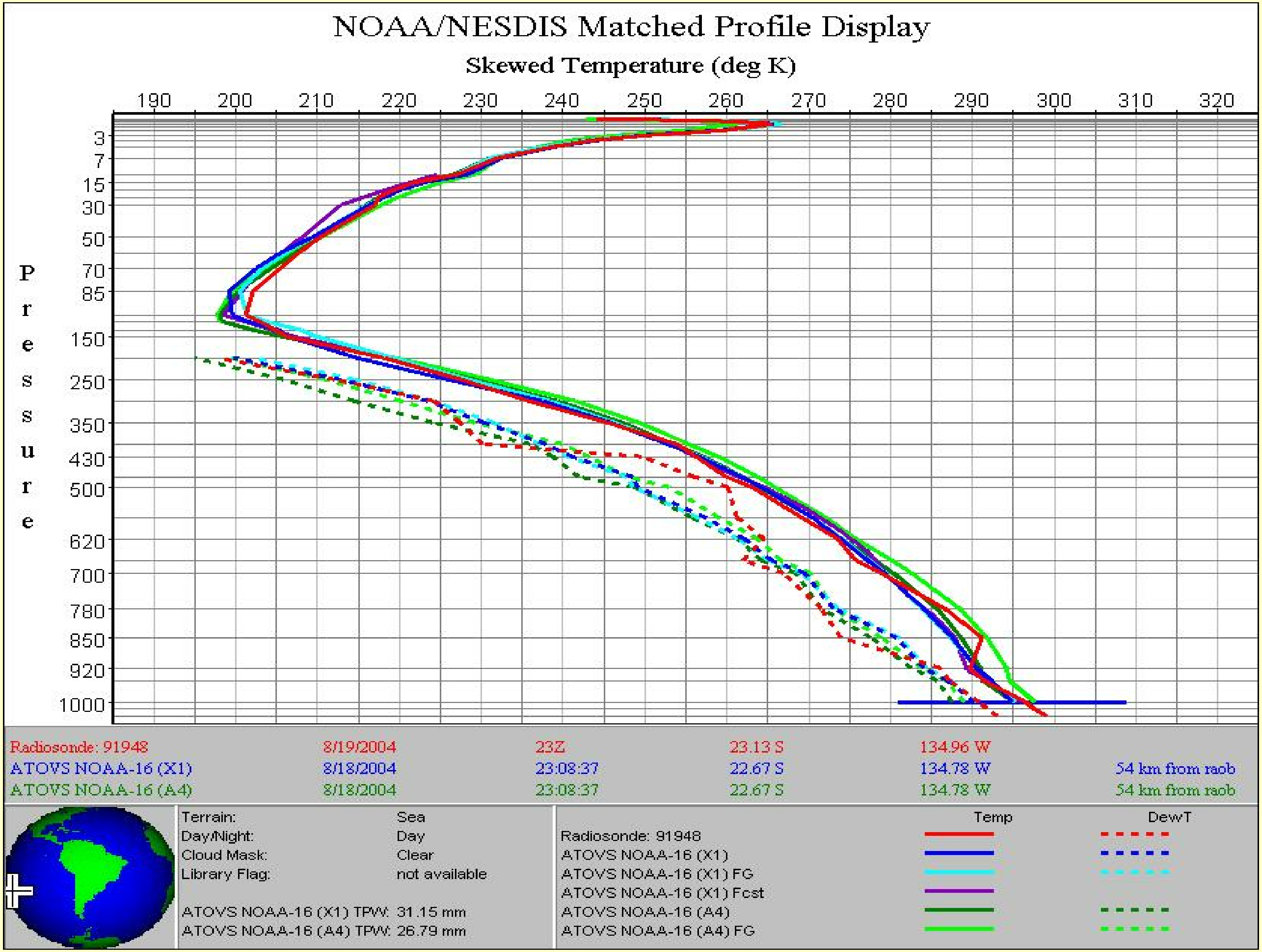




60N to 60S

RT Model Simulations and Comparisons
(AMSU-A/B)



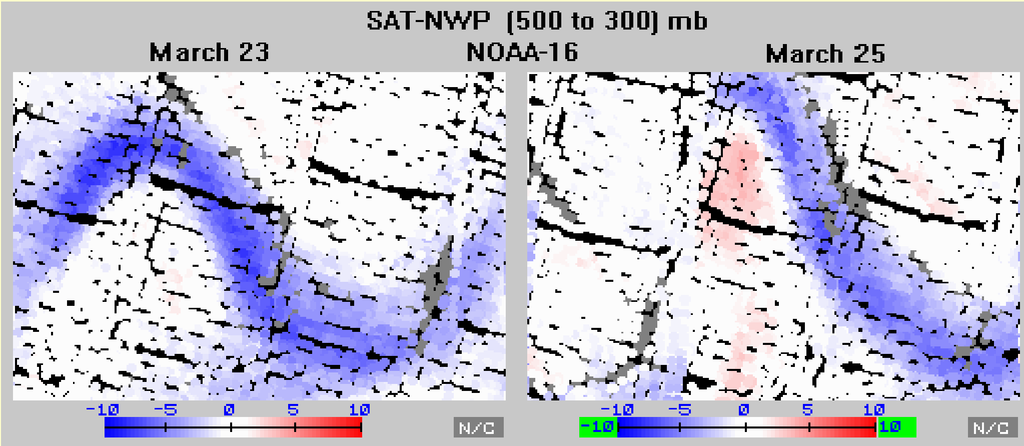

NOAA/NESDIS Matched Profile Display
Skewed Temperature (deg K)
190 200 210 220 230 240 250 260 270 280 290 300 310 320
Pressure
3 7 15 30 50 70 85 150 250 350 430 500 620 700 780 850 920 1000
Radiosonde: 91948 8/19/2004 23Z 23.13 S 134.96 W
ATOVS NOAA-16 (X1) 8/18/2004 23:08:37 22.67 S 134.78 W 54 km from raob
ATOVS NOAA-16 (A4) 8/18/2004 23:08:37 22.67 S 134.78 W 54 km from raob
Terrain: Sea
Day/Night: Day
Cloud Mask: Clear
Library Flag: not available
ATOVS NOAA-16 (X1) TPW: 31.15 mm
ATOVS NOAA-16 (A4) TPW: 26.79 mm
Temp
DewT
Radiosonde: 91948
ATOVS NOAA-16 (X1)
ATOVS NOAA-16 (X1) FG
ATOVS NOAA-16 (X1) Fcst
ATOVS NOAA-16 (A4)
ATOVS NOAA-16 (A4) FG

Uniform Protocols for Radiosonde Screening and Use

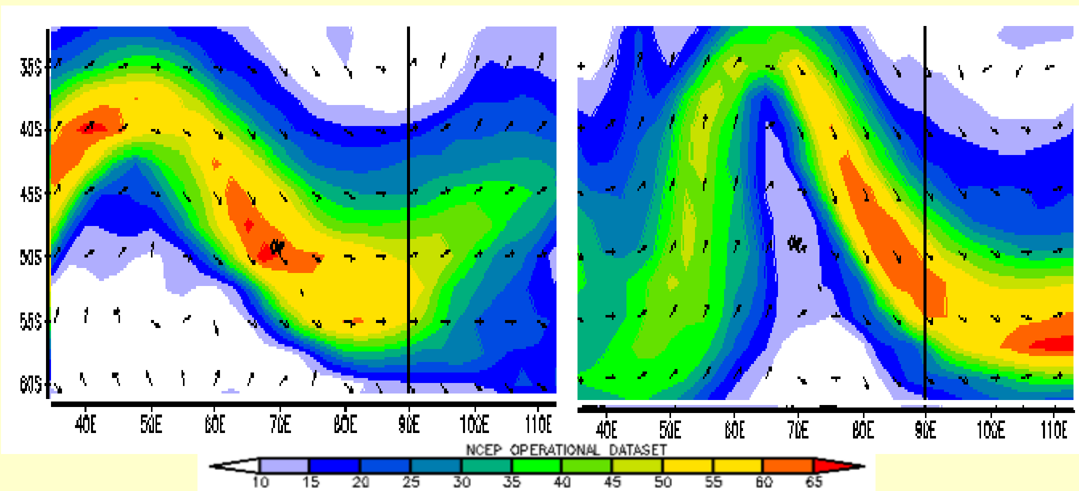
- Interpreting quality marks
- Radiation correction
- Radiosonde interpolation and extension
- Moisture screening
- Radiosonde manufacturer bias
- Collocation criteria
- Multiple satellite/product capture and validation strategies
- ARM and “Special” radiosonde observations
- Other

NWP as Validation Tool

- Global coverage compliments POES data
- Useful for sounder health monitoring
- Can provide product monitoring in remote regions
- Baseline for inter-satellite comparisons
- Need consistent protocols for collocation and use

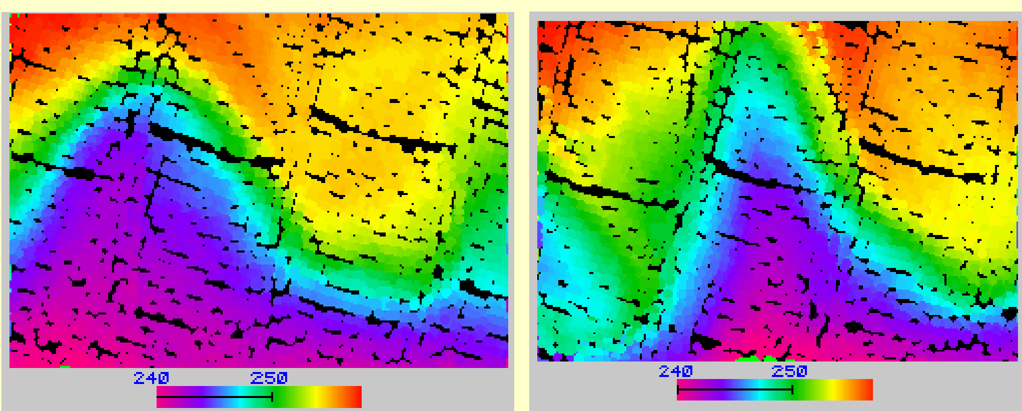


< **DIFFERENCES** between NESDIS Satellite Soundings and NWP

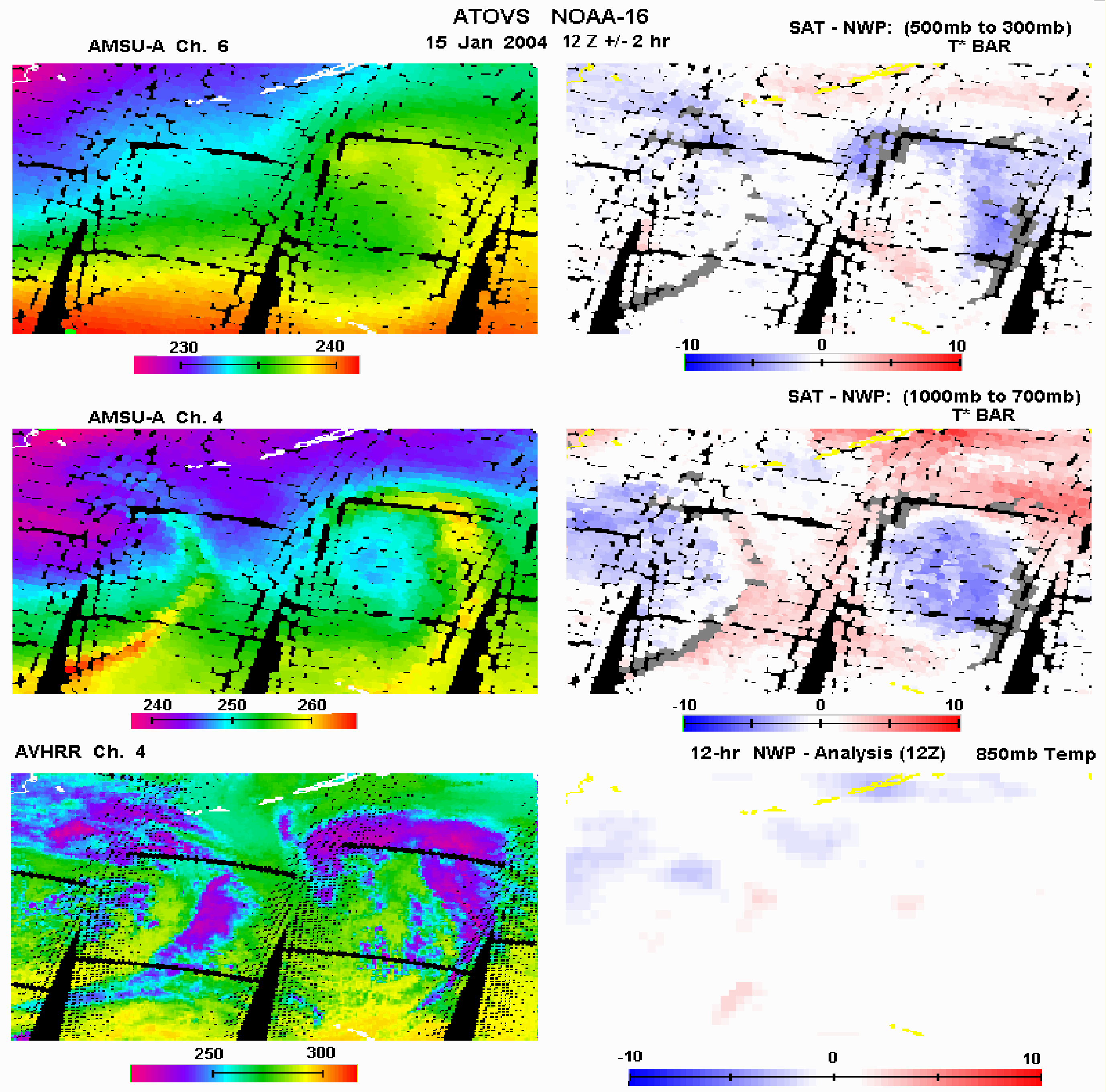


Pinpoint the Location of the **JET STREAM**

< (EMC 400mb Wind)

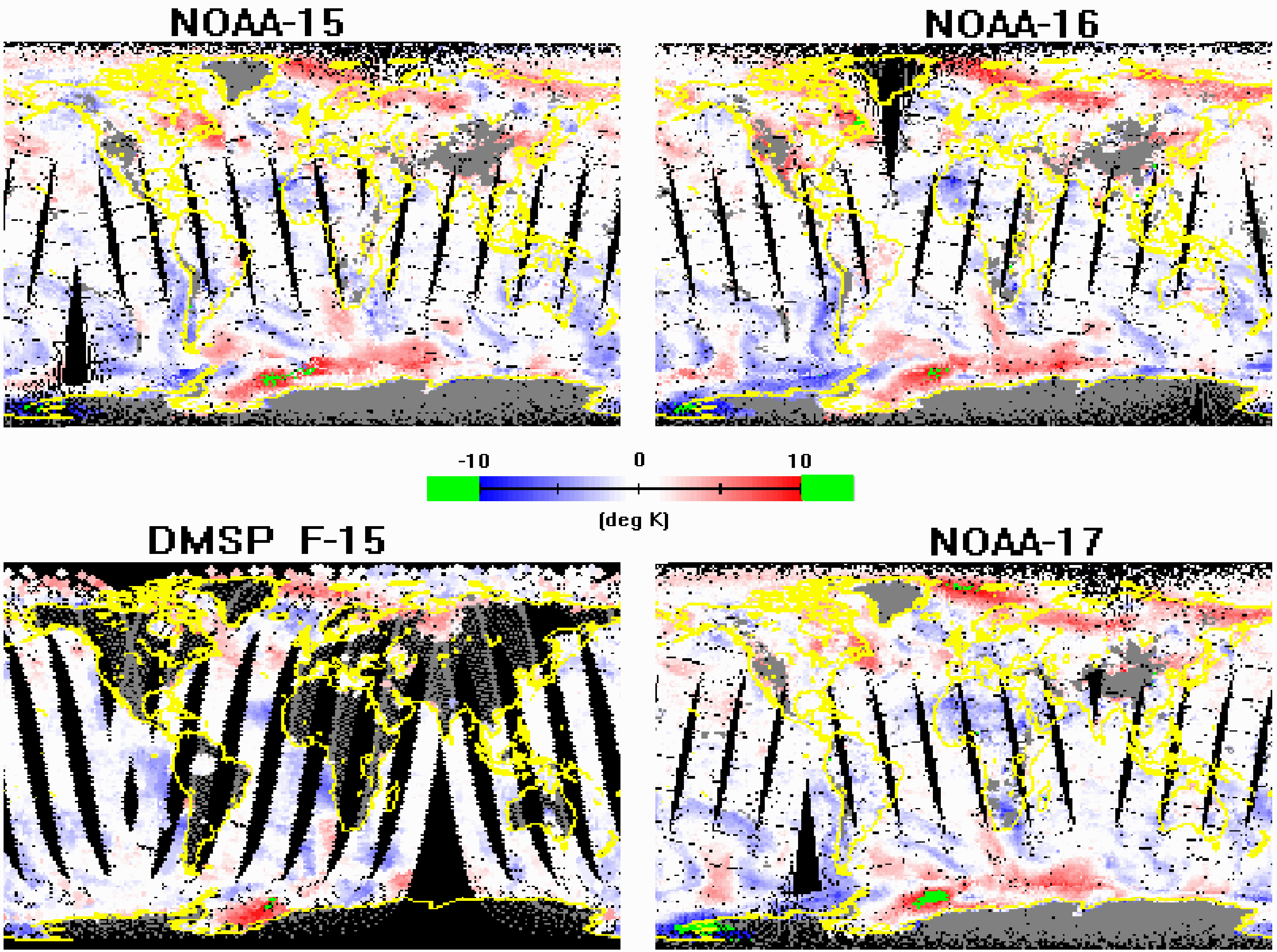


< (AMSU-A Ch 5)

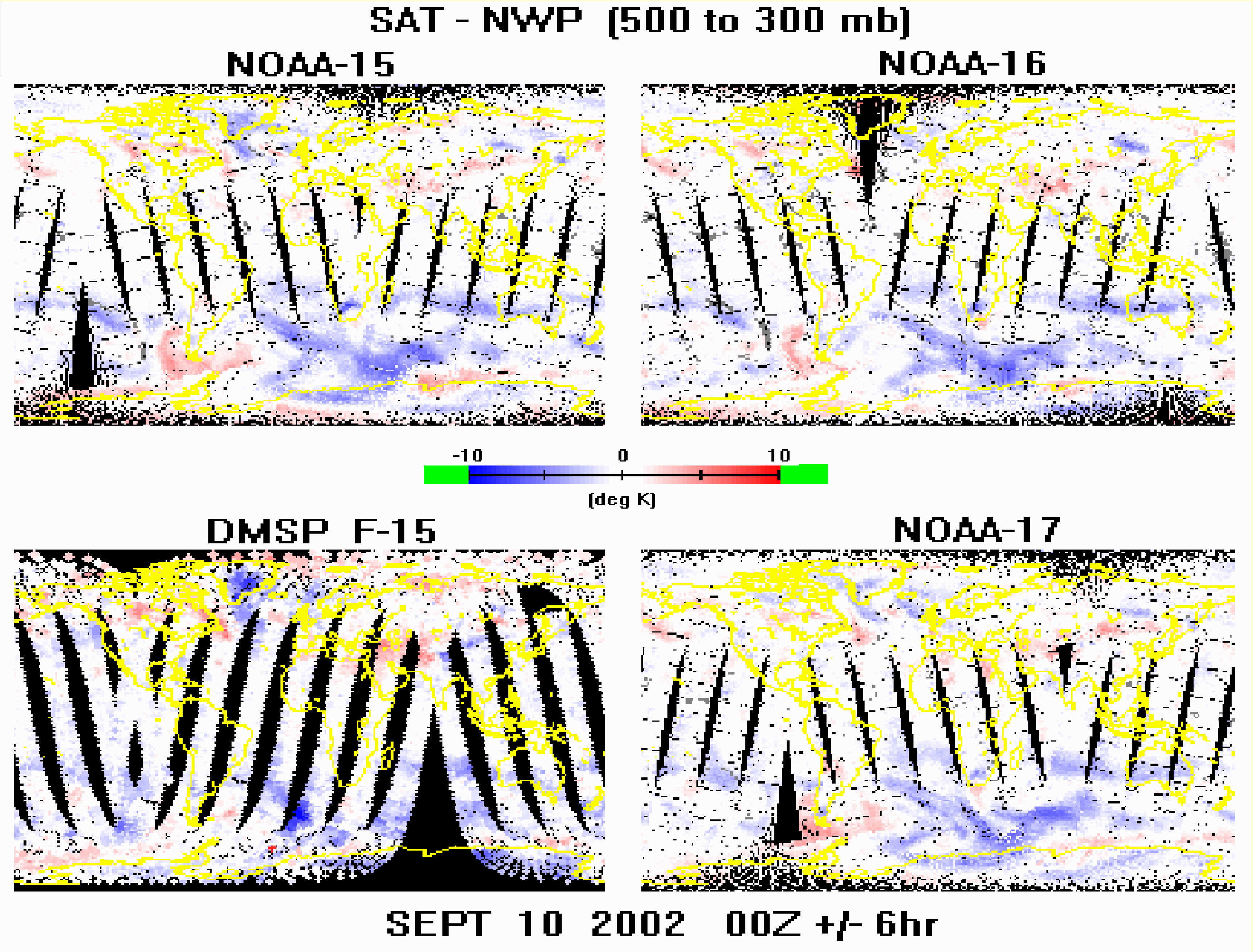


… can serve as baseline for inter-satellite product comparisons

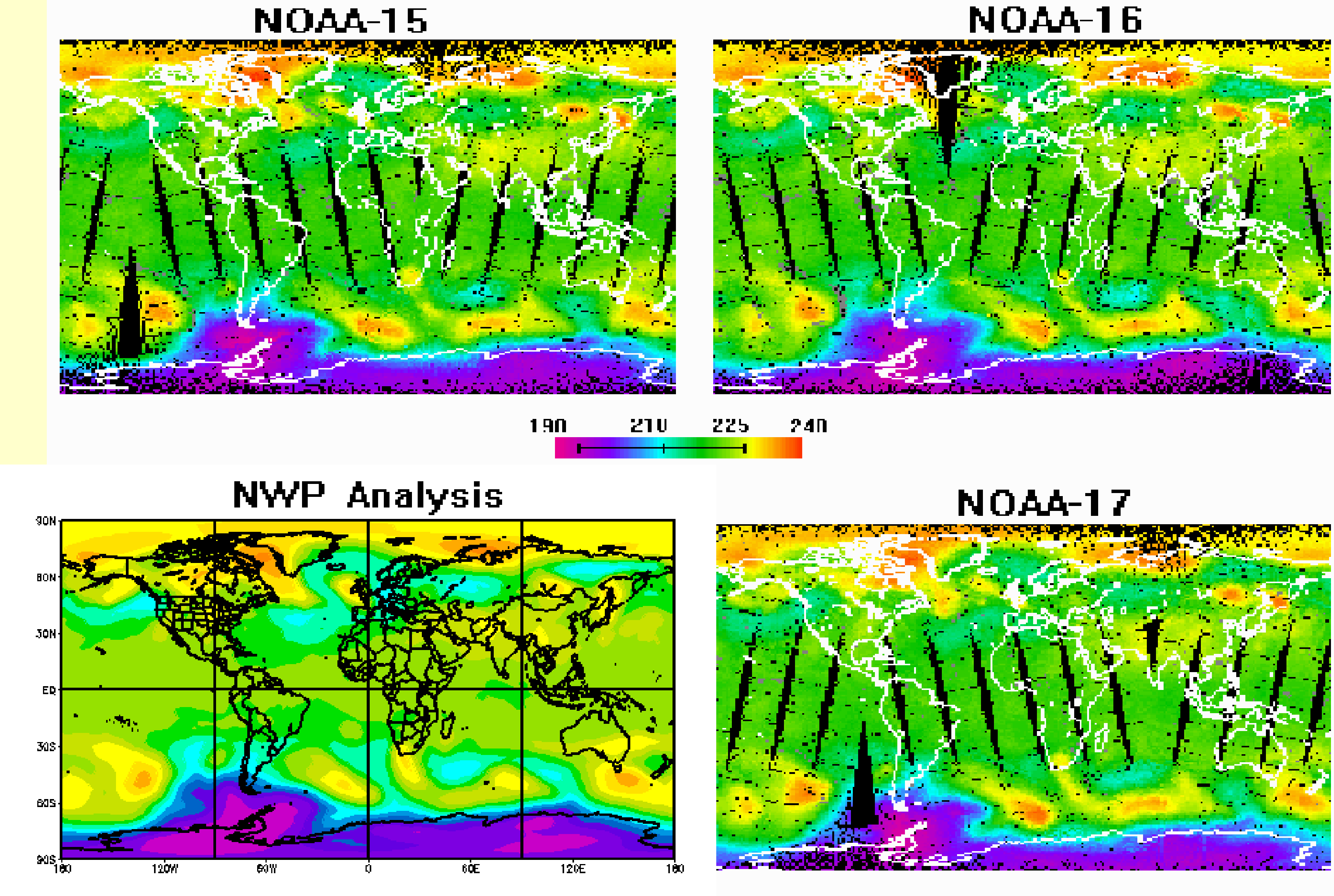
SAT - NWP (1000 TO 700 MB)



SEPT 10 2002 00Z +/-6HR


SAT - NWP (500 to 300 mb)
NOAA-15
NOAA-16
-10
0
10
(deg K)
DMSP F-15
NOAA-17
SEPT 10 2002 00Z +/- 6hr

TEMPERATURE (200 mb)



Sept 10, 2001 0Z +/- 6 hrs

Climate Requirements

"Real-time" Database Compilation Effort

…satellite data, ground truth collocations, NWP …

(during satellite operational lifetime)

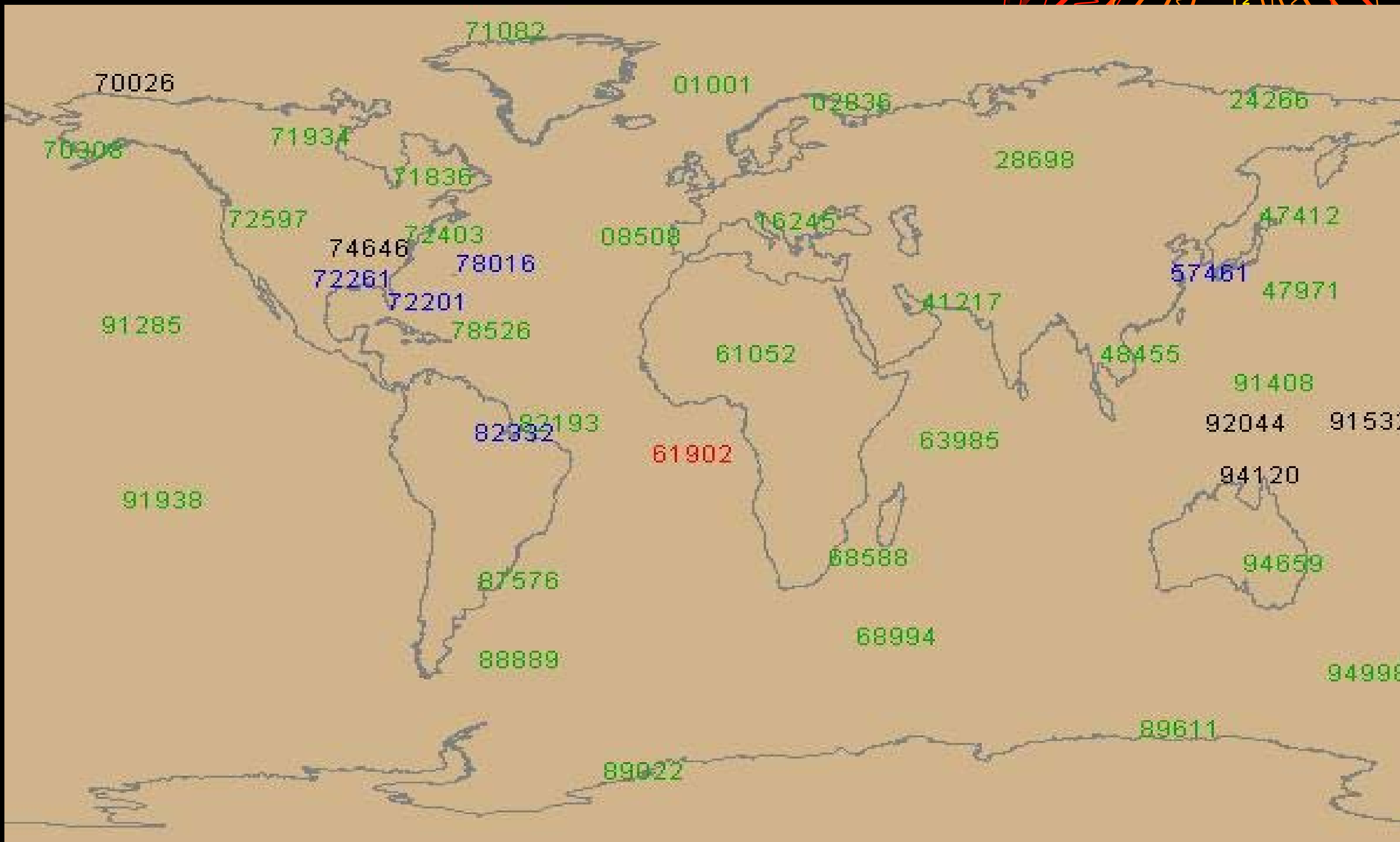
to serve as input for

"Retrospective" Processing Effort

…T, H2O, Clouds, Measurements ...

(at conclusion of satellite operational lifetime)

Reference network of standardized ground truth measurements "coincident" with operational polar satellite overpass to "accurately" monitor sensor and product performance



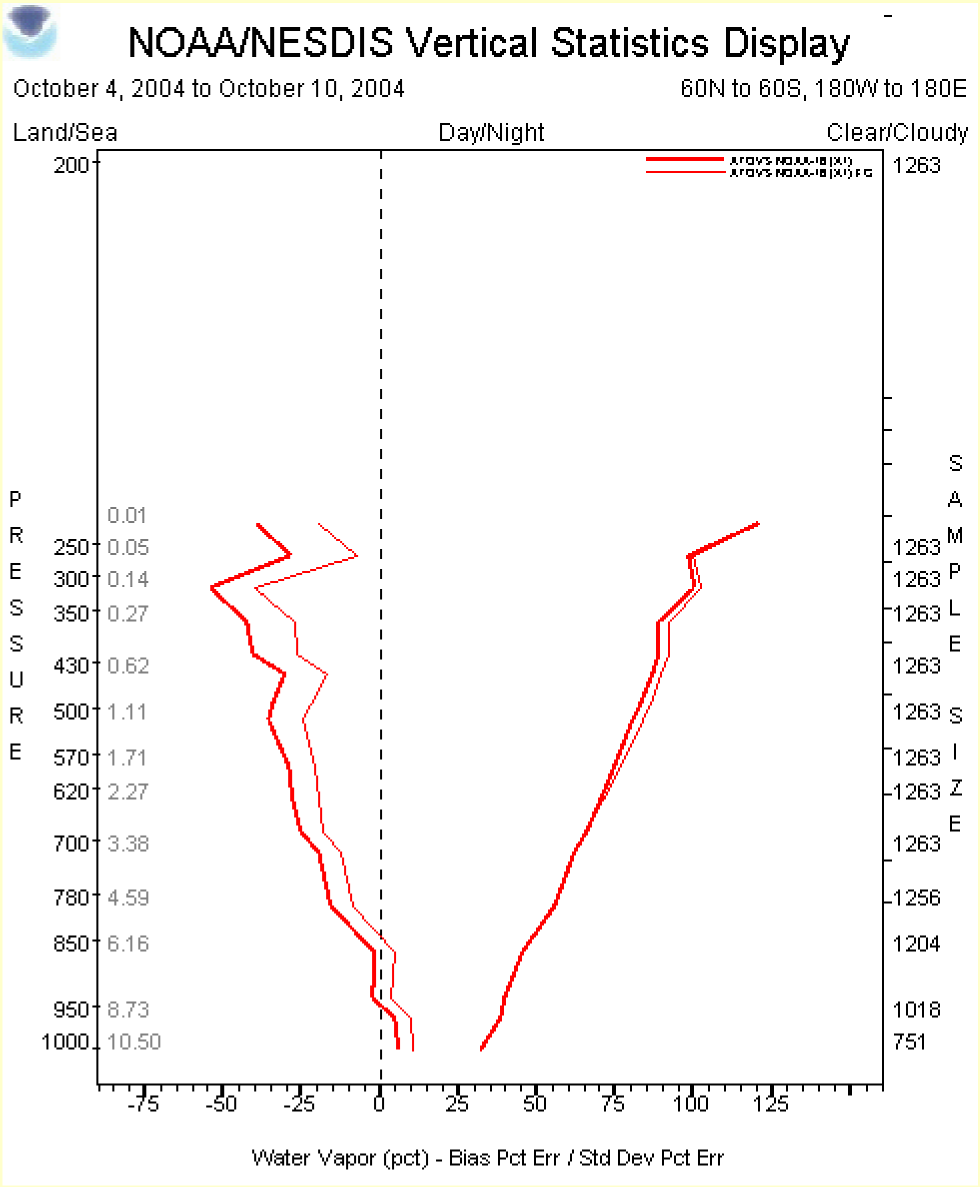
Summary

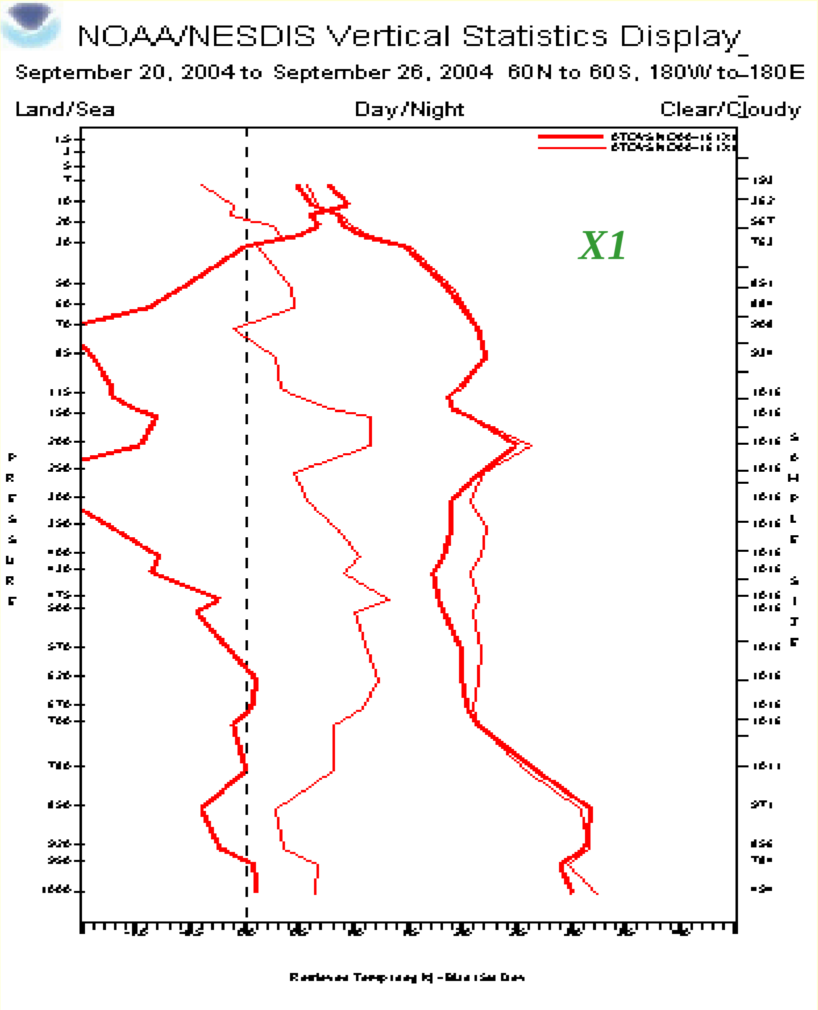
- **Current POES ATOVS Products Presented**

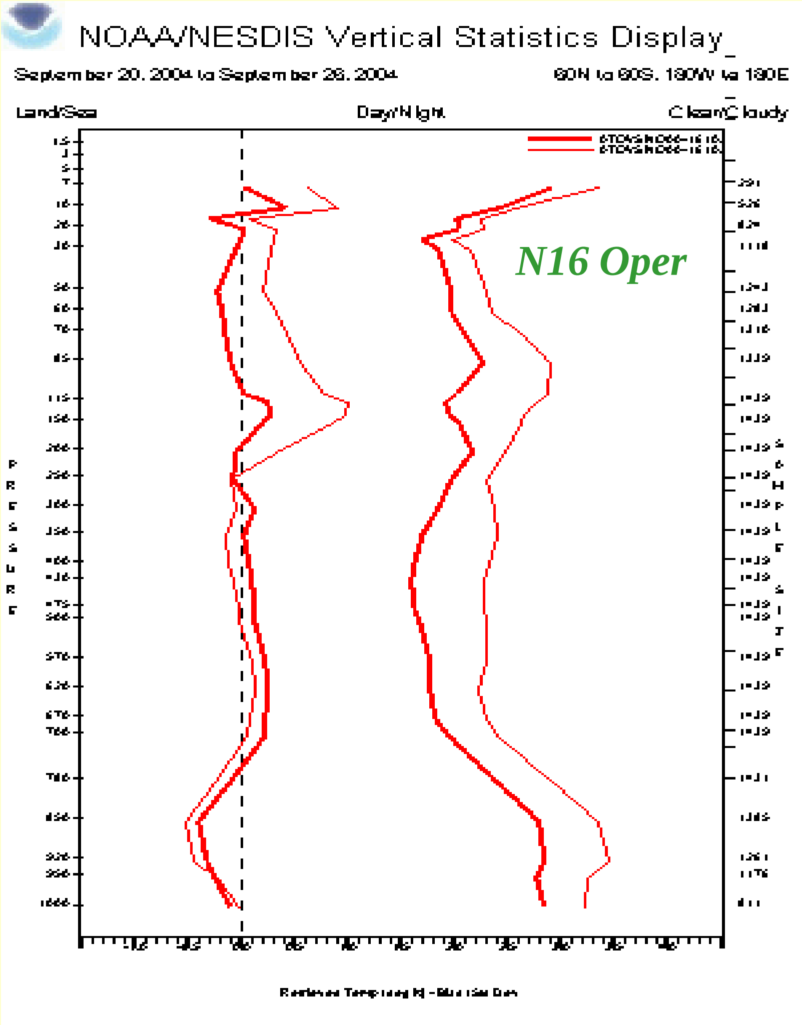
- **New ATOVS Sys-2005 nearing completion:**
  - **new retrieval approach provides suitable framework for expanded algorithm development**
  - **questions and issues raised**
  - **expanded validation**

- **Better internal consistency among NESDIS products and validation protocols needed**

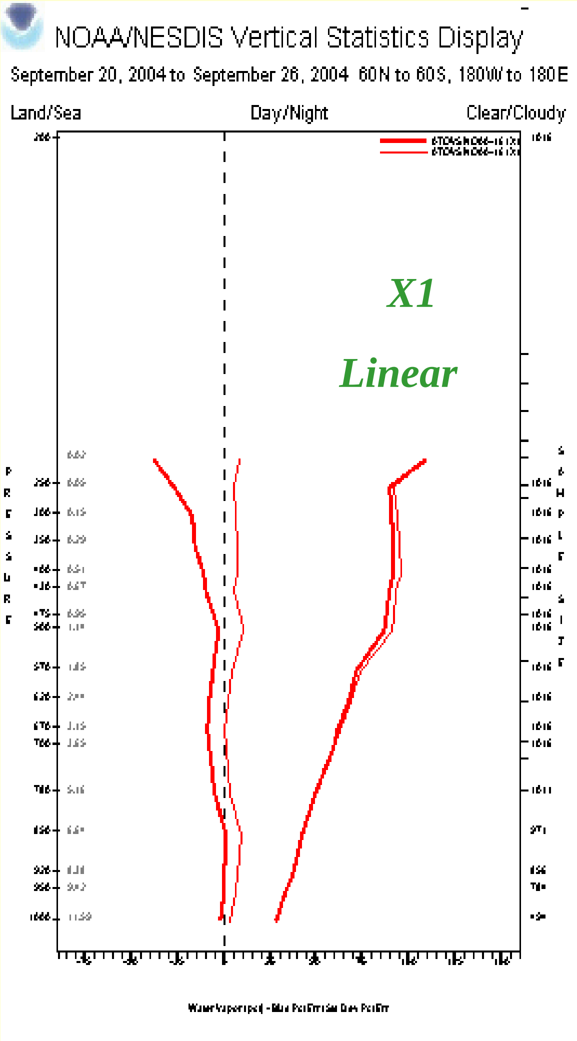
extras

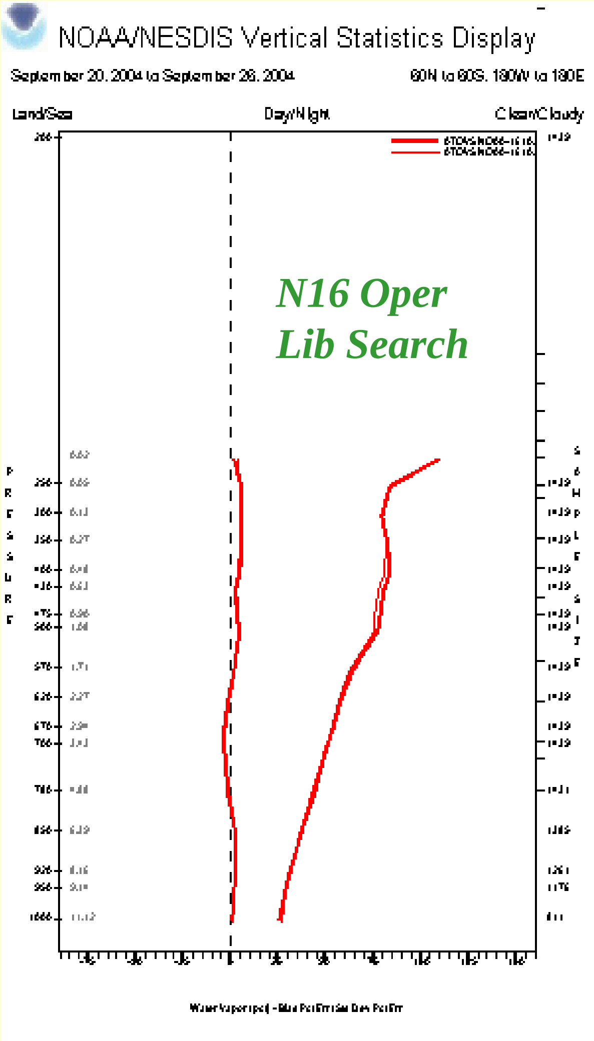

NOAA/NESDIS Vertical Statistics Display
October 4, 2004 to October 10, 2004
60N to 60S, 180W to 180E
Land/Sea
Day/Night
Clear/Cloudy
PRESSURE
SAMPLE SIZE
200
250 0.05
300 0.14
350 0.27
430 0.62
500 1.11
570 1.71
620 2.27
700 3.38
780 4.59
850 6.16
950 8.73
1000 10.50
0.01
1263
1256
1204
1018
751
-75 -50 -25 0 25 50 75 100 125
Water Vapor (pct) - Bias Pct Err / Std Dev Pct Err

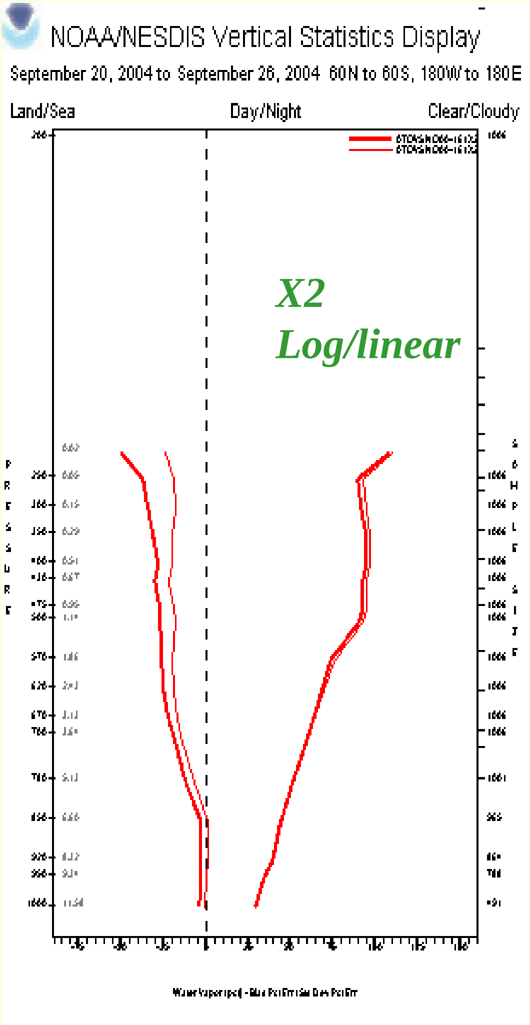




Vertical Statistics Temperature



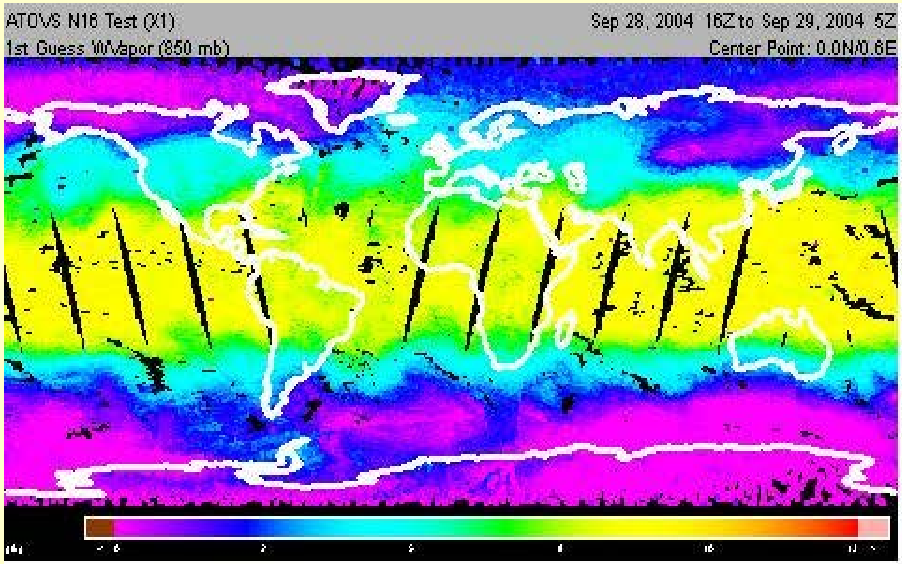




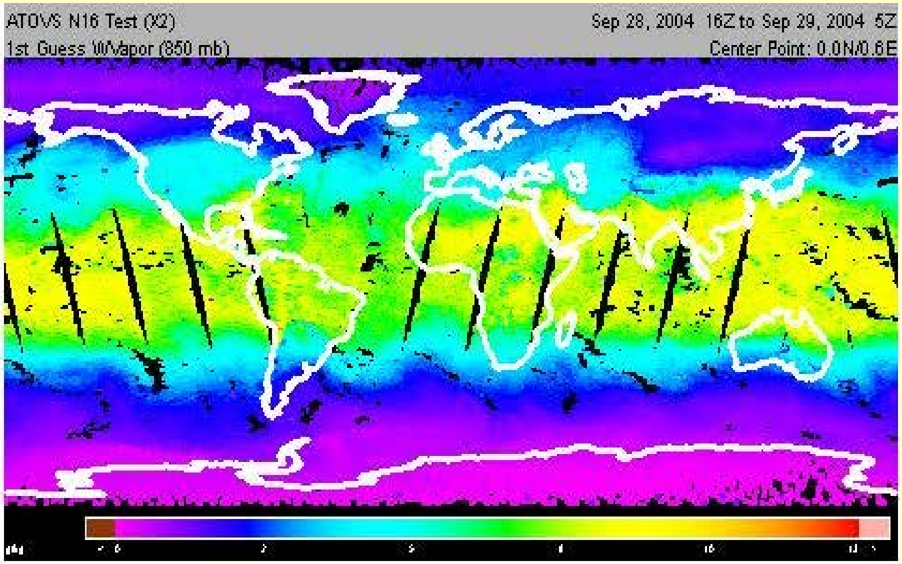
Vertical Statistics % Moisture

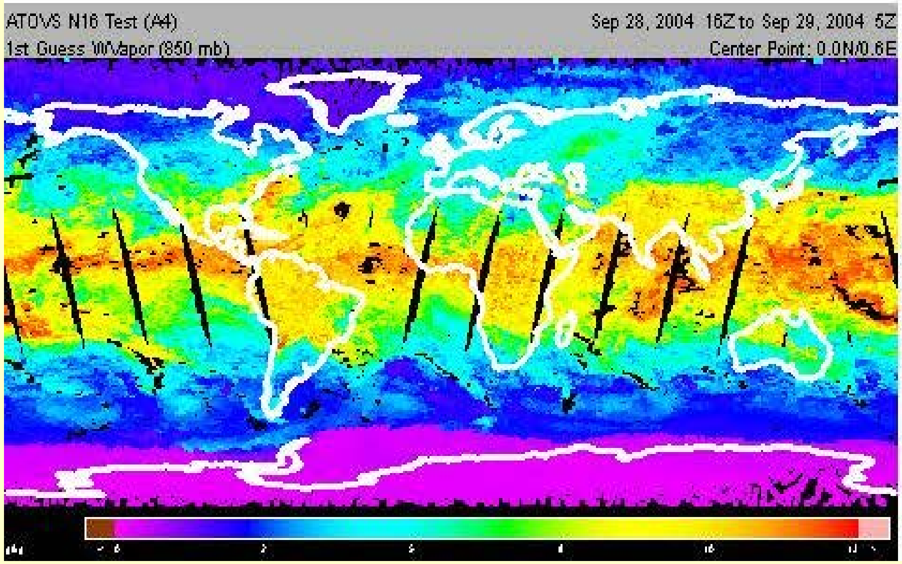
850mb H20MR … 0 to 13.5 g/kg

X1

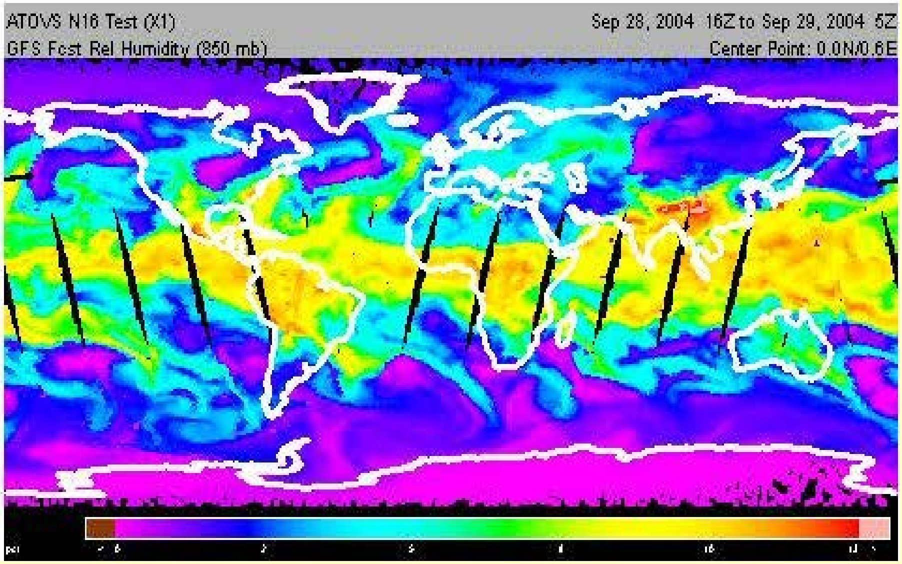


X2

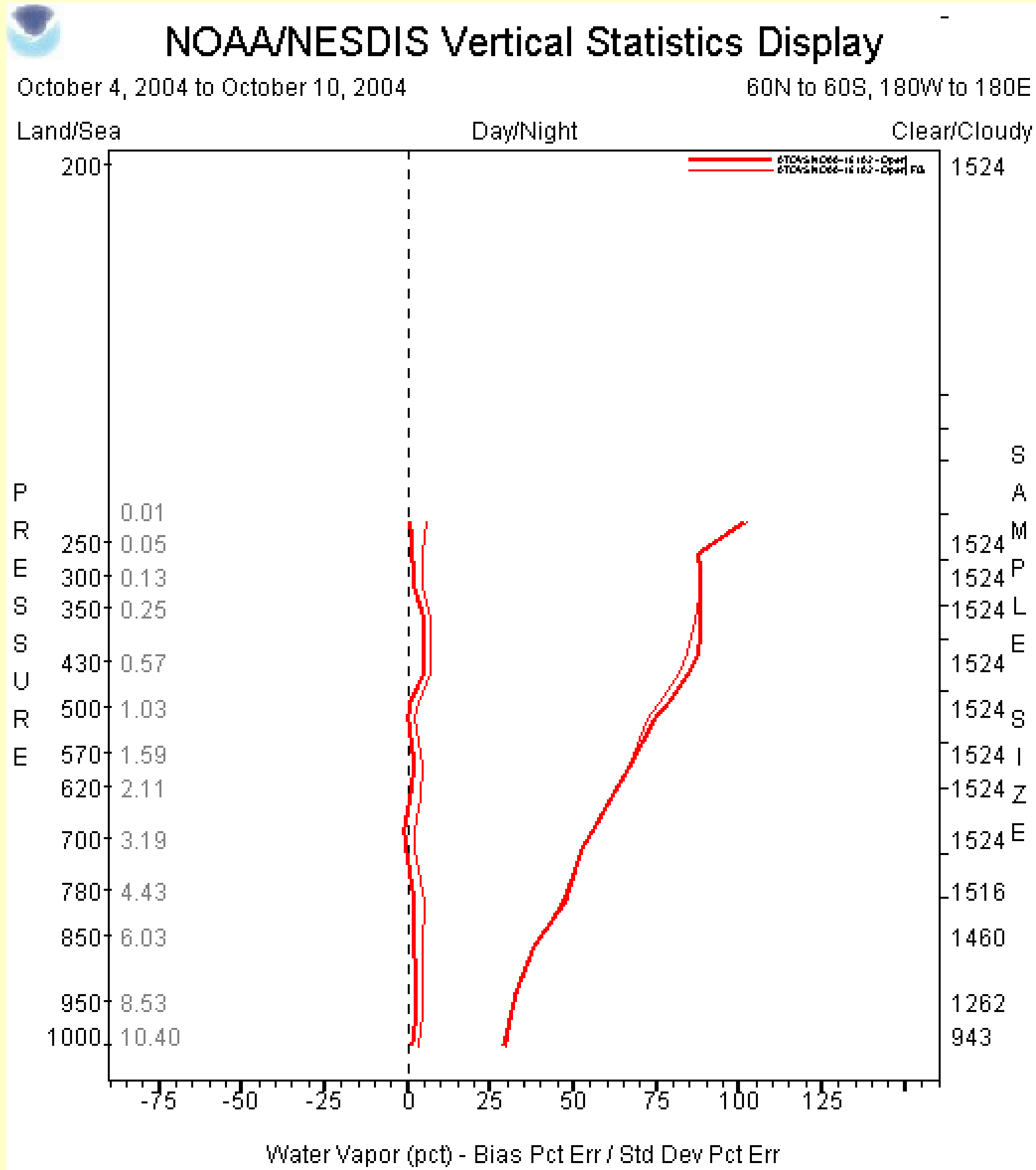


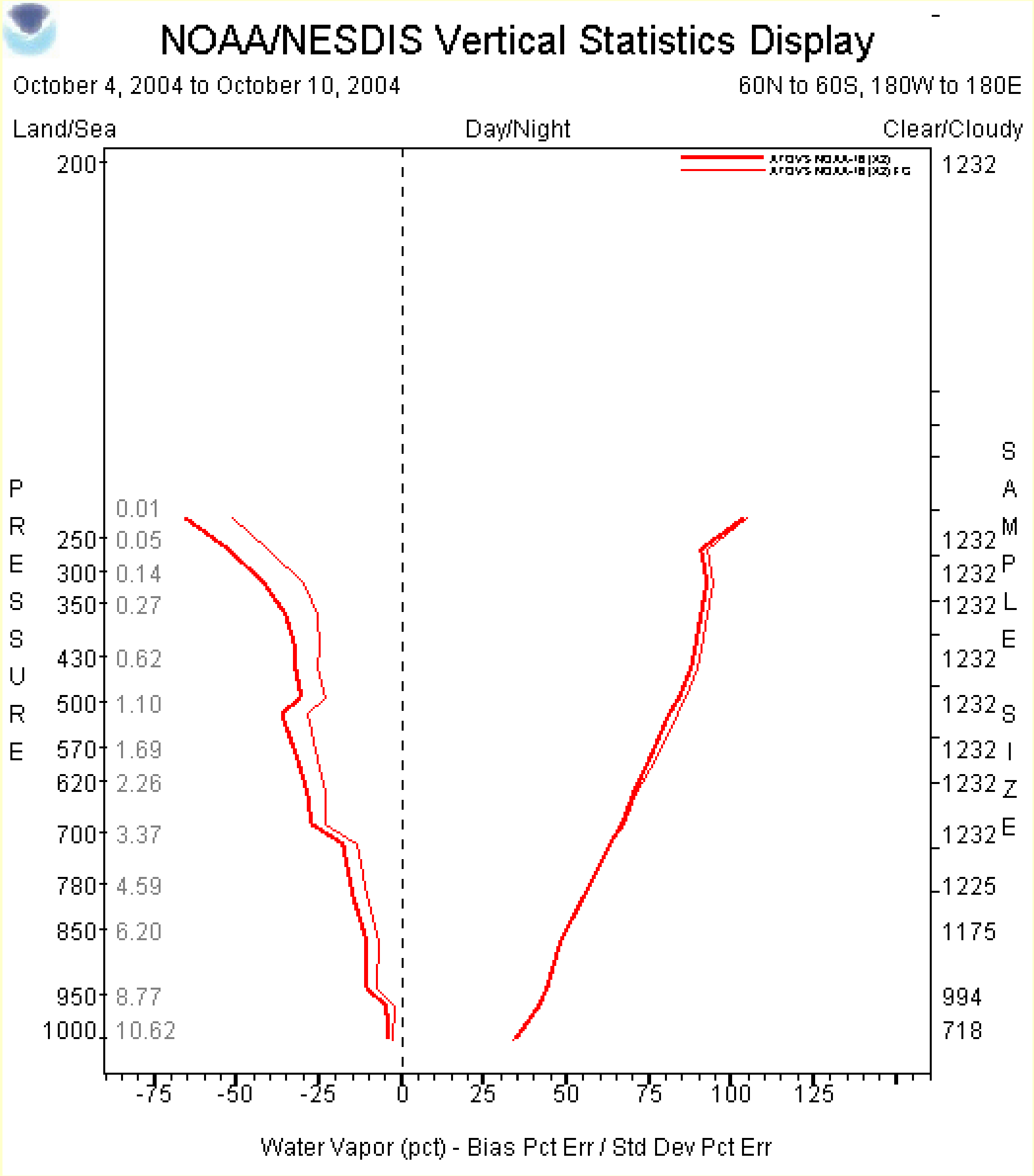


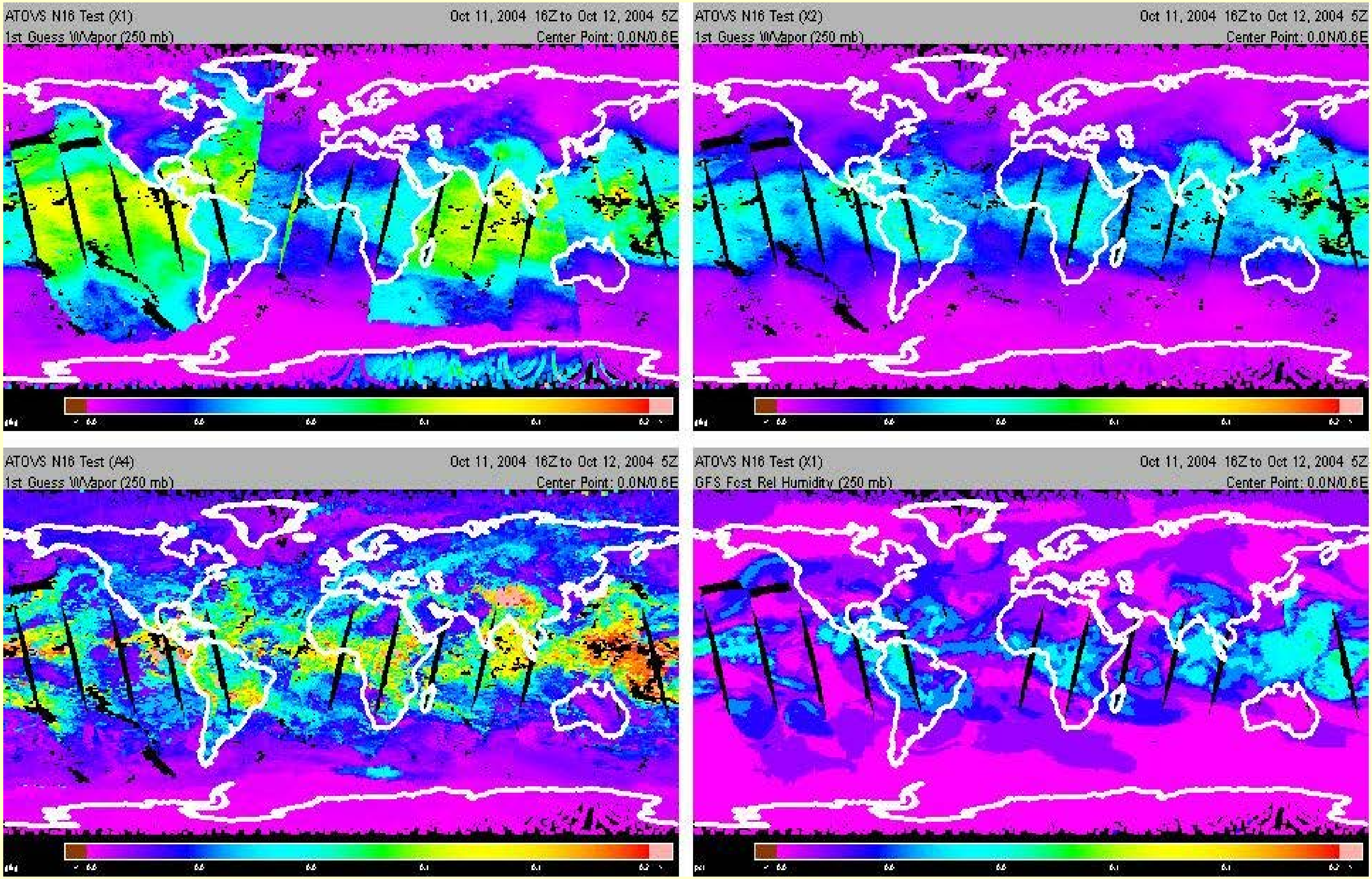
N16 Oper



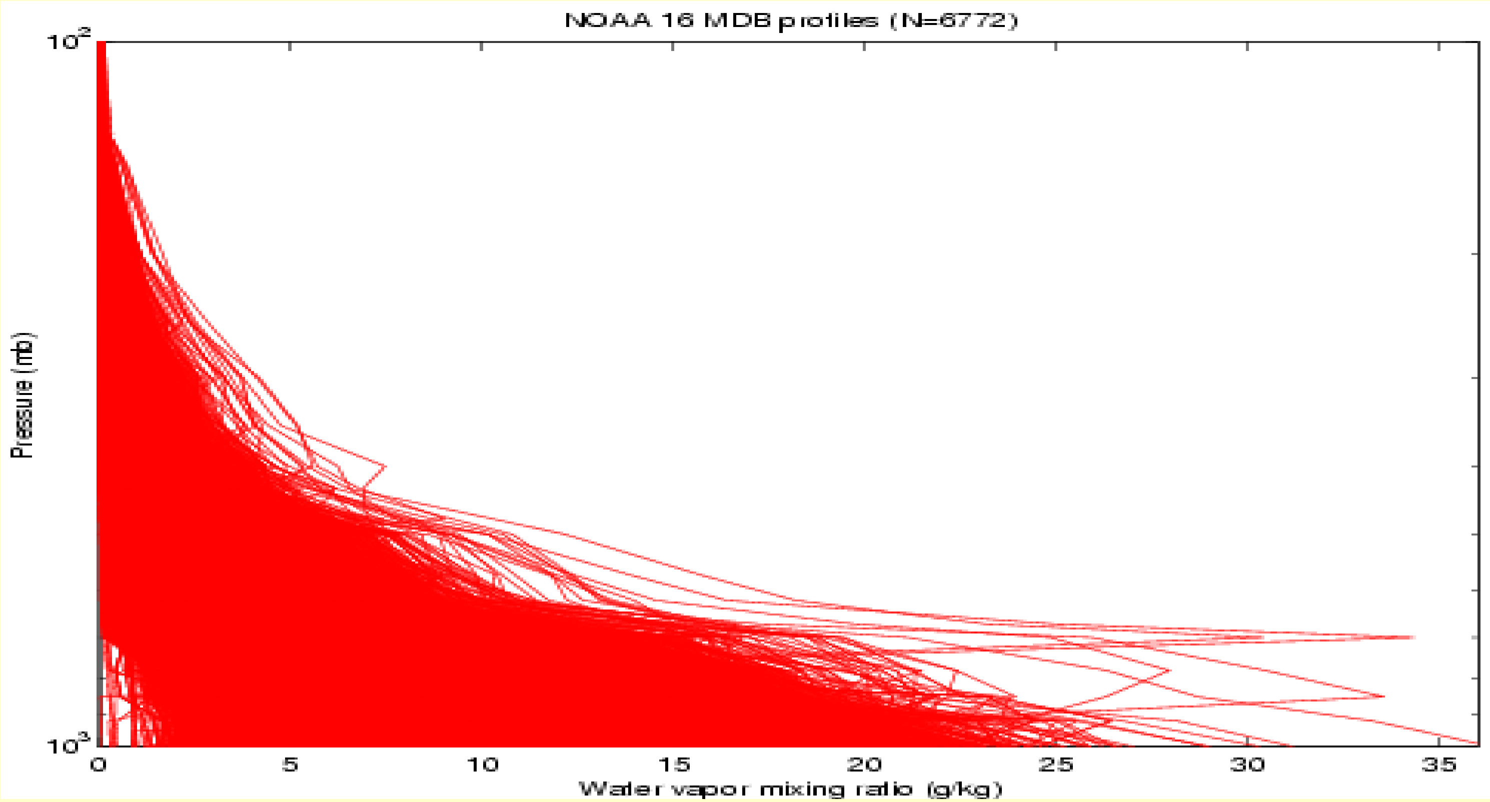
EMC 3-hr NWP


NOAA/NESDIS Vertical Statistics Display
October 4, 2004 to October 10, 2004
60N to 60S, 180W to 180E
Land/Sea
Day/Night
Clear/Cloudy
PRESSURE
200
250 0.05
300 0.13
350 0.25
430 0.57
500 1.03
570 1.59
620 2.11
700 3.19
780 4.43
850 6.03
950 8.53
1000 10.40
0.01
SAMPLE SIZE
1524
1524
1524
1524
1524
1524
1524
1524
1524
1516
1460
1262
943
-75 -50 -25 0 25 50 75 100 125
Water Vapor (pct) - Bias Pct Err / Std Dev Pct Err


NOAA/NESDIS Vertical Statistics Display
October 4, 2004 to October 10, 2004
60N to 60S, 180W to 180E
Land/Sea
Day/Night
Clear/Cloudy
PRESSURE
200
250
300
350
430
500
570
620
700
780
850
950
1000
0.01
0.05
0.14
0.27
0.62
1.10
1.69
2.26
3.37
4.59
6.20
8.77
10.62
SAMPLE SIZE
1232
1232
1232
1232
1232
1232
1232
1232
1232
1225
1175
994
718
-75
-50
-25
0
25
50
75
100
125
Water Vapor (pct) - Bias Pct Err / Std Dev Pct Err


ATOVS N16 Test (X1)
Oct 11, 2004 16Z to Oct 12, 2004 5Z
1st Guess W/Vapor (250 mb)
Center Point: 0.0N/0.6E
ATOVS N16 Test (X2)
Oct 11, 2004 16Z to Oct 12, 2004 5Z
1st Guess W/Vapor (250 mb)
Center Point: 0.0N/0.6E
ATOVS N16 Test (A4)
Oct 11, 2004 16Z to Oct 12, 2004 5Z
1st Guess W/Vapor (250 mb)
Center Point: 0.0N/0.6E
ATOVS N16 Test (X1)
Oct 11, 2004 16Z to Oct 12, 2004 5Z
GFS Fcst Rel Humidity (250 mb)
Center Point: 0.0N/0.6E

MDB Raob Moisture … outliers



NMC Raob Types

Available Raob Instrument Types

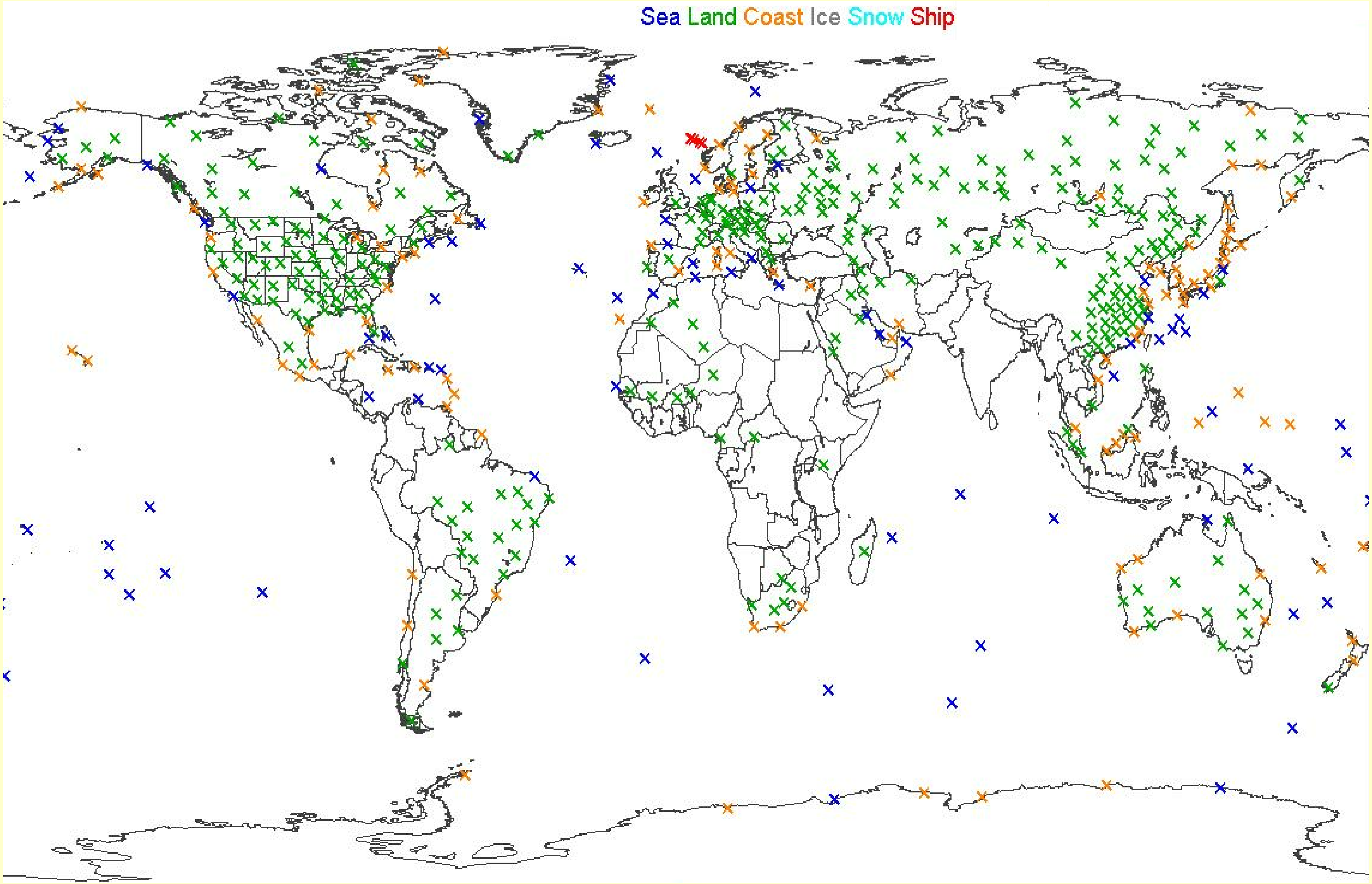
[ ] 01 Reserved	[ ] 26 Meteolabor Basora (Swiss)	[x] 51 VIZ-B2 (USA)	[ ] 76 AVK-RF95-ARMA (Russian Fed)
[ ] 02 no raob – passive target	[x] 27 AVK-MRZ (Russian Federation)	[x] 52 Vaisala RS80-57H	[ ] 77 GEOLINK GPSonde (France)
[ ] 03 no raob – active target	[x] 28 Meteorit Marz2-1 (Russian Fed)	[ ] 53 AVK-RF95 (Russian Fed)	[x] 78 Reserved
[ ] 04 no raob – passive temp	[x] 29 Meteorit Marz2-2 (Russian Fed)	[ ] 54 Reserved	[ ] 79 Reserved
[ ] 05 no raob – active temp	[ ] 30 Oki RS2-80 (Japan)	[x] 55 Reserved	[ ] 80 Reserved
[ ] 06 no raob – radio-acoustic sounder	[ ] 31 VIZ/Valcom type A (Canada)	[ ] 56 Reserved	[ ] 81 Reserved
[ ] 07 Reserved	[ ] 32 Shanghai Radio (China)	[ ] 57 Reserved	[ ] 82 Reserved
[ ] 08 Reserved	[ ] 33 UK Met Office MK3 (UK)	[ ] 58 Reserved	[ ] 83 Reserved
[x] 09 no raob – system unknown	[ ] 34 Vinohrady (Czechoslovakia)	[ ] 59 Reserved	[ ] 84 Reserved
[ ] 10 VIZ type A pressure (USA)	[ ] 35 Vaisala RS18 (Finland)	[x] 60 Vaisala RS80/MicroCora (Fin)	[ ] 85 Reserved
[ ] 11 VIZ type B time (USA)	[ ] 36 Vaisala RS21 (Finland)	[x] 61 Vaisala RS80/DigiCora (Fin)	[ ] 86 Reserved
[x] 12 RS Space Data Corp (USA)	[x] 37 Vaisala RS80 (Finland)	[x] 62 Vaisala RS80/PCCora (Fin)	[ ] 87 Reserved
[ ] 13 Astor (Australia)	[ ] 38 VIZ LOCATE Loran-C (USA)	[x] 63 Vaisala RS80/Star (Fin)	[ ] 88 Reserved
[ ] 14 VIZ Mark I Microsonde (USA)	[ ] 39 Sprenger E076 (Germany)	[ ] 64 Orbital Sciences Corp (USA)	[ ] 89 Reserved
[ ] 15 EEC Company type 23 (USA)	[ ] 40 Sprenger E084 (Germany)	[ ] 65 VIZ transponder (USA)	[x] 90 Unknown Radiosonde
[ ] 16 Elin (Austria)	[ ] 41 Sprenger E085 (Germany)	[x] 66 Reserved	[ ] 91 Reserved
[ ] 17 Graw G (Germany)	[ ] 42 Sprenger E086 (Germany)	[x] 67 Reserved	[ ] 92 Reserved
[ ] 18 Reserved	[ ] 43 AIR IS-4A-1680 (USA)	[ ] 68 Reserved	[ ] 93 Reserved
[x] 19 Graw M60 (Germany)	[ ] 44 AIR IS-4A-1680 X (USA)	[ ] 69 Reserved	[ ] 94 Reserved
[ ] 20 Indian Met Service MK3 (India)	[x] 45 RS MSS (USA)	[ ] 70 Reserved	[ ] 95 Reserved
[ ] 21 VIZ/Jin Yang Mark I (S Korea)	[ ] 46 Air IS-4A-403 (USA)	[x] 71 RS90/DigiCora (Fin)	[ ] 96 Reserved
[ ] 22 Meisei RS2-80 (Japan)	[x] 47 Meisei RS2-91 (Japan)	[ ] 72 RS90/PC-Cora (Fin)	[ ] 97 Reserved
[ ] 23 Mesural FMO 1950A (France)	[ ] 48 VALCOM (Canada)	[ ] 73 RS90/Autosonde (Fin)	[ ] 98 Reserved
[ ] 24 Merural FMO 1945A (France)	[x] 49 VIZ MARK II (USA)	[x] 74 RS90/Star (Fin)	[ ] 99 Reserved
[ ] 25 Mesural MH73A (France)	[x] 50 GRAW DFM-90 (Germany)	[ ] 75 AVK-MRZ-ARMA (Russian Fed)	[ ] 100 Reserved

Unselect All

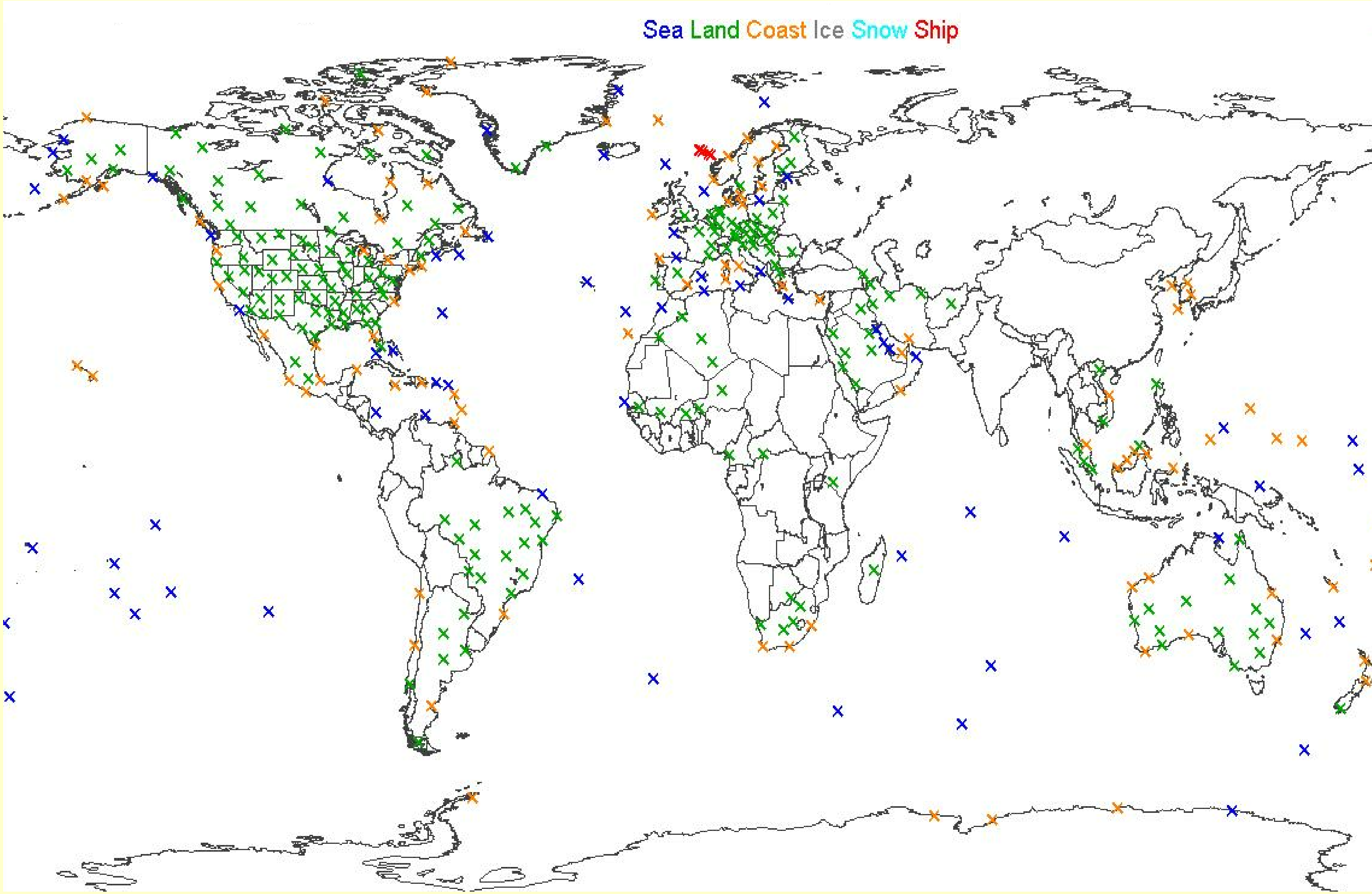
[x] Sea [x] Land [x] Coast [x] Ice [x] Snow [x] Ship

[x] In Library [x] Not In Library

OK Cancel



MBD: ***VIZ B2;*** ***Vaisala RS80: 57H, DIGI-CORA, PC-CORA***
Vaisala RS90: DIGI-CORA, STAR
AVK MRZ (Russia), Shanghai (China), Mesei RS2-91 (Japan)



MBD: VIZ B2; Vaisala RS80: 57H, DIGI-CORA, PC-CORA
Vaisala RS90: DIGI-CORA, STAR

Milestones

- **Parallel baseline on SP** … *early October* … *Feb 04* *(Complete)*
- **Parallel Sys-2004 (X1, X2))** … *November* … *Feb 04* *(Complete)*
  - revised AMSU-B
  - reg guess
  - calc guess rad
  - old retrieval
- **Parallel Sys-2004 (X3)** … *January (04)* … *Apr 04* … *(Complete)*
  - bias adjustment … *Sept -04*
  - *optimized lib. search* … *Oct-04*
  - retrieval with new OPTRAN … *Nov 04*
- **Peripheral Science** … limb adjustment … *January-Feb* … *Apr 04* … *Oct 04*
- **Test and Evaluation** (w/new validation) … *Jan-March* … *Apr - June* … *Fall-04*
- **Initial Operational Capability** … *June 04* … *Fall 04* ... *Winter 04/05*