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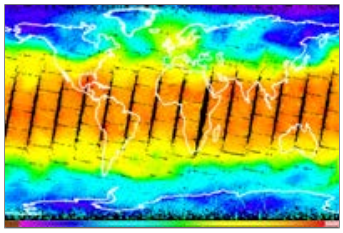
STAR / SMCD / OPDB (Polar Products)

Purpose

This project provides research and development for the Advanced TOVS (ATOVS) system which derives Temperature and Moisture sounding products and Cloud and Radiation products, such as Cloud Top Temperature and Outgoing Longwave Radiation. Product images of the latest 24 hours can be viewed.

ATOVS Soundings


500 mb Temperature

The ATOVS series of NOAA weather satellites has three "atmospheric" sounders, the High-Resolution Infrared Sounder (HIRS), the Advanced Microwave Sounder Unit (AMSU) and the Microwave Humidity Sounder (MHS). These sensors are used to derive operational Advanced TOVS (ATOVS) global sounding products for Temperature and Moisture.

Currently, the ATOVS is generating products from the NOAA-19 and MetOp-2 polar orbiting satellites. ATOVS derives global Temperature and Water Vapor profiles at 42 atmospheric pressure levels (1025 to 0.1 mb) levels.

Click the image to the right or use the left hand navigation bar to access global product images for 17 levels of temperature and 8 levels for moisture.

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ATOVS Sounding Products

The Advanced TIROS Operational Vertical Sounder (ATOVS) consists of High Resolution Infrared Radiation Sounder (HIRS), the Advanced Microwave Sounding Unit-A (AMSU-A) and Microwave Humidity Sounder (MHS) for retrieving temperature and water vapor soundings in all weather conditions (except heavy precipitation).

Currently, the ATOVS is generating products from the NOAA-19, MetOp-B and MetOp-A polar orbiting satellites. ATOVS derives global Temperature and Water Vapor profiles at 40 atmospheric pressure levels (1000 to 0.1 mb) levels. A subset of these levels for the most recent 24 hour period are available below for NOAA-19 and MetOp satellites.

The cloud products (Effective Cloud Amount, Cloud Top Pressure and Cloud Top Temperature) as shown with the Ancillary parameters are at the ATOVS sounding location (~ 1/4 resolution). Full resolution (at each HIRS/4 Field-of-View) are shown on the ATOVS Aerosol, Cloud and Radiation Products Page.

Operational soundings product system can be seen on the OSDPD soundings website.

Satellite: NOAA-19 **Product Type:** Temperature **Parameter:** Temp 500mb **Node:** Ascending Prev Next

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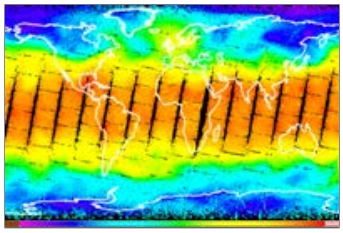
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ATOVS Documentation

Online Documents:

Documentation Links	Description
ATOVS Validation & Evaluation Online / PDF, (PDF, 0 KB)	A paper which discusses the programs used to evaluate the ATOVS system.
NOAA-16 Mirror Misalignment Online / PDF, (PDF, 1.37 MB)	A paper discussing the misalignment of the HIRS/3 scan mirror onboard NOAA-16.

Slideshow Presentations:

Documentation Links	Description
NESDIS Sounding Products Download, (PDF, 13.03 MB)	This slideshow provides an overview of the ATOVS Processing System.
ATOVS Evaluation Systems Download, (PDF, 1.79 MB)	A description of the graphical tools used to evaluate the ATOVS system.
ATOVS Sounding Products (ITSC) Download, (PDF, 709 KB)	A slideshow presented at the 12th International TOVS Study Conference (ITSC). Lorne, Australia, February 2002.

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Reale, A. L., and F. Tilley, 2009: ATOVS derived soundings using NOAA products validation system (NPROVS) datasets for computing first guess and sensor bias adjustments independent of NWP. *16th Conference on satellite Meteorology,* 89 th AMS Annual Meeting, Phoenix, AZ, 11-15 Jan.

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STAR / SMCD / OPDB - Related Links

Internal related links to STAR:

- GOES Soundings
  http://www.star.nesdis.noaa.gov/smcd/opdb/goes/soundings/
- Operational ATOVS Soundings
  http://www.osdpd.noaa.gov/soundings/html/soundings.html

External related links to STAR:

- The International TOVS User Group
  http://cimss.ssec.wisc.edu/itwg/
- POES Status
  http://www.oso.noaa.gov/poesstatus/

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STAR / SMCD / OPDB - Soundings

Operational Polar Satellite Validation and Evaluation Systems

Tony Reale

NOAA/NESDIS
Washington, DC

Michael Pettey and Charles Brown

Raytheon Corporation
Landover, MD

1. Introduction

During the past 25 years of NOAA operational polar satellites, the problem of providing reliable and timely monitoring and scientific validation of operational measurements and derived meteorological products has been an ongoing issue. The systems to provide this function have significantly evolved from hardcopy printouts of software system diagnostics and statistical summaries to elaborate in-house and web based protocols allowing NESDIS scientists and national and international users alike to analyze operational data using enhanced graphical illustrations of real-time data using a variety of geographical orientations and display options

The following report provides a system summary of the current Environmental Data Graphics and Evaluation (EDGE) (Brown *et al*., 1992) system which provides the bulk of operational monitoring at NESDIS for polar orbiting satellites. The EDGE system is comprised of three basic functions:

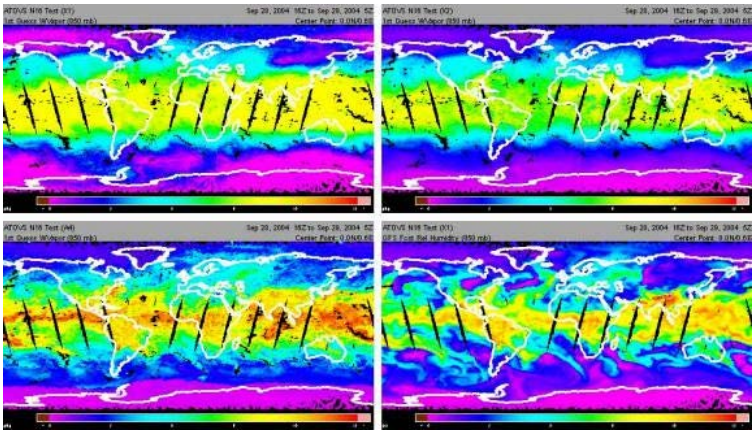
1. EDGEIS, the horizontal field display system,
2. PDISP, the vertical profile display system, and
3. VSTATS, the vertical statistics compilation and display system.

Another important component of the NESDIS operational monitoring protocol is the Polar Orbiting Satellite Sounding Evaluation (POSSE) system, which is web based and available to national and international users for real-time evaluation of NESDIS data and products. POSSE allows remote users to access and analyze operational sounder data and associated products in a horizontal graphical display scenario similar to EDGE.

NESDIS also provides a more basic validation function through its official web site poes.nesdis.noaa.gov but without the numerous options provided by POSSE. However, the POES site does include current and past statistical analysis (similar to VSTAT) capability and up to date system and scientific documentation concerning operational products and plans.

The EDGE system was recently delivered to EUMETSAT to assist that agency in the development and deployment of METOP scheduled in 2006, and will provide the benchmark capability for in support of next generation NPP and NPOES systems planned by NOAA (Aumann *et al*., 2003).

2. System Architecture



The data used by the EDGE graphical programs are generated on the same computer that the NOAA operational ATOVS sounding processing system (Reale *et al*., 2002) resides on, currently and IBM SP. Selected data are extracted and sent to either a file server or a local computer. That data is then read by one of the graphical programs. All graphical programs are written in platform-independent Java, making them available on most major operating systems.

As mentioned, the three main system components of EDGE are:

1. *EDGEIS,* providing horizontal field, vertical cross-section and limited vertical profile analysis,
2. *PDISP*, providing detailed vertical

display of collocated satellite, radiosonde and nwp profiles, and

3. *VSTATS*, providing vertical statistics of collocated satellite and radiosonde observations and archive.

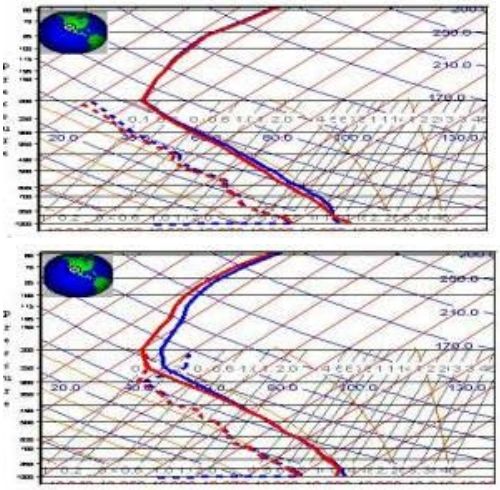


Figure 1: Examples of EDGEIS capability illustrating horizontal fields of 850mb water vapor mixing ration from individual satellite test processing systems (upper two panels), current operation (lower left panel) and NWP (lower right panel, and corresponding vertical profiles of temperature and moisture over the southwest US coast from the lower left and upper right fields.

The primary function of EDGEIS is to provide a user interface for horizontal field analysis of satellite measurements and products and comparable data platforms, for example, NOAA operational numerical weather prediction (NWP) (Kalnay *et al*. 1990). The layout of the programs and most program functions were designed using these horizontal images as the starting point for providing a variety of user functions to manage and manipulate the extensive volumes of data available in a given session. EDGEIS also provides several additional meteorological analytical tools such as

- vertical cross-sections of the atmosphere,
- individual vertical profiling
- the scanning of the complete observational data files
- differencing of selected images and/or data parameters on selected files
- blinking function that highlight data within a specified range of values, and
- image manipulation functions to display multiple images at a time.

The EDGEIS vertical cross section function allows meteorological analysis through active features such as weather fronts. These cross-sections can cut though the atmosphere between any two points on the Earth. When this is done, the vertical cross-sections will show all available profile data (i.e., satellite, NWP, etc).

EDGEIS provides the ability to display any parameter stored on an operational data file, including the vertical profiling of sounding and available ancillary profile data, for example, first guess and NWP profiles.

The Profile Display (PDISP) system allows for the display of individual profiles of collocated satellite and other conventional observations most notably the radiosondes and NWP data These collocations are accessed from datasets that are routinely compiled during the processing of operational satellite sounding products (Tilley *et.al*. 2000). Plotted data include annotation on the radiosonde and satellite observation times, location, distance and geographic location.

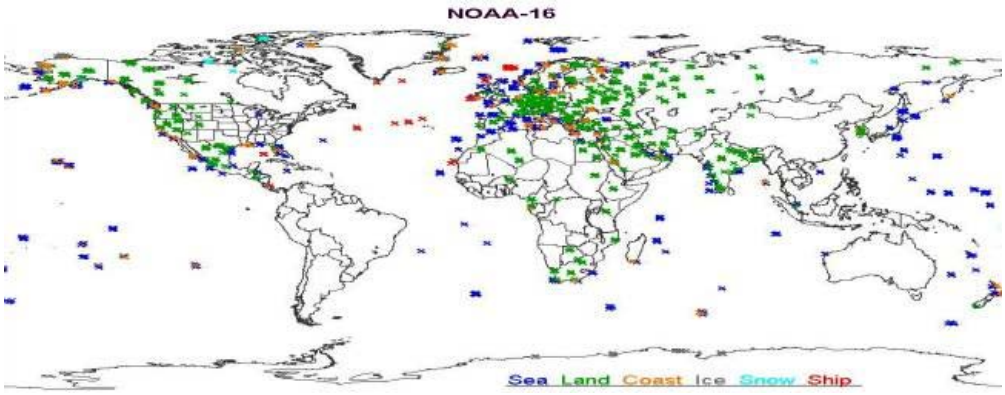


Figure 2: Example of global distribution of collocated radiosonde and satellite observations from PDISP

PDISP has many individual

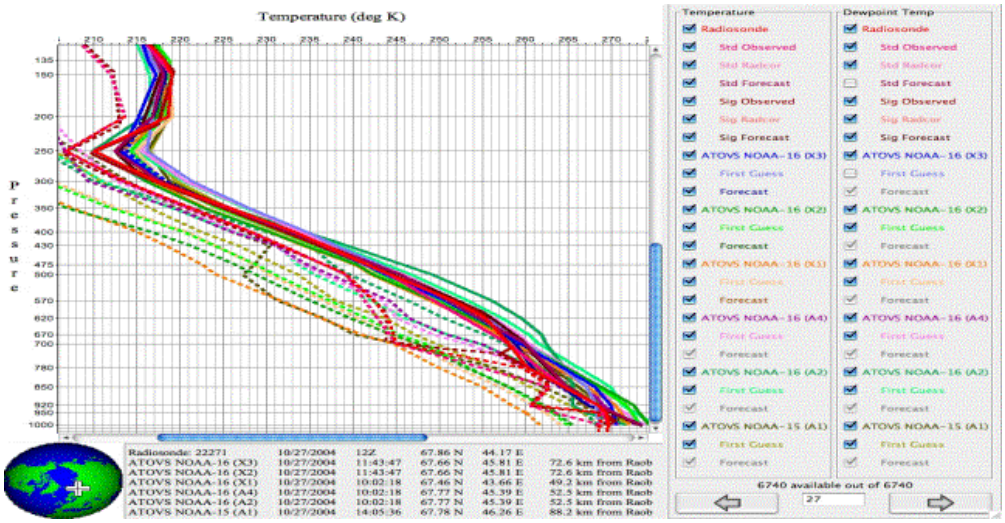


Figure 3: Examples of vertical temperature (solid) and moisture (dashed) profiles available from a single collocation of satellite and radiosonde observations available using PDISP.

functions which allow user to specify the satellite and collocation data sets to be plotted, the plot type (i.e. skew-T, log-linear, etc),.view the global distribution of collocation available, and sub-sample the collocations to plot, for example, based on location, time-window, radiosonde type, radiosonde site, satellite, sounding type.

Similar to EDGEIS, users can interrogate the complete data record associated with the collocation(s) being viewed. An important feature of PDISP is the concept of creating internal file structures capable of storing the multiple collocations of satellite (and NWP) observations typically available for a given radiosonde observation, and the available options to view any combination of the multiple profiles typically available for each collocation.

The Vertical Statistics (VSTAT) system accesses input files that are similar to PDISP, and provides a thorough capability to view pre-computed sets of ensemble statistics comparing collocated radiosonde and satellite derived products data. An important feature of the VSTAT system is that it allows users to compare statistics from multiple satellite product systems, including statistics generated from a common data base of radiosondes. The statistics computed are the mean, standard deviation and root-mean square of the satellite minus radiosonde differences for temperature and water vapor mixing ratio, with user options to also view layer mean temperature and geopotential height differences.

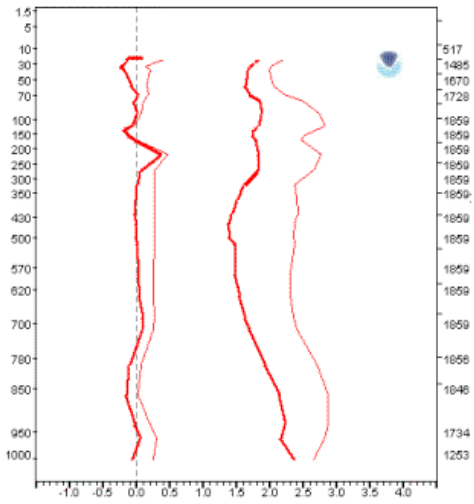
The VSTATS system provides multiple options of viewing statistics for selected satellite systems, geographic regions, and satellite sounding types, and time periods. Selected statistics for a year or more are stored on a weekly basis and are available for viewing by users.

The Polar Orbiting Satellite Sounding Evaluator is basically a web- based version of EDGEIS. It was originally designed to allow users outside of NOAA/NESDIS to access most of the data that is available in EDGEIS. However, recent security issues have mitigated this capability restricting in to more of an in house capability for NOAA/NESDIS scientists to access the latest ATOVS orbital data in real-time.

3. Scientific Analysis

The use of EDGE graphical capabilities to routinely monitor and evaluate the NESDIS operational sounding products is pivotal for maintaining and improving scientific product integrity. Examples of using each of the EDGE subsystems in this respect are illustrated in Figures 1 through 4.

The six panels of Figure 1 illustrate graphical capabilities from EDGEIS. The top four panels show global fields of water vapor mixing ratio at 850mb. The two upper panels are for two different parallel processing systems being used to test a new retrieval approach, the lower left panel the current operational approach with all three showing first guess values. The lower right panel is the concurrent NWP analysis for 850mb moisture. A quick glance identifies differences and possible deficiencies in the performance of the two test systems. The bottom two panels illustrate vertical profiles of temperature and moisture at the same location from the operational (left) and one of the test systems (right), respectively, with the blue curves indicating the first guess profiles and the red curves the final sounding. As can be seen, the test system moisture is different than the operation particularly in the upper atmosphere (above 300mb) where it is supersaturated, an obvious problem needing correction.



Figures 2 and 3 illustrate graphical capabilities from PDISP. Figure 2 shows a typical plot of the global distribution of collocated radiosonde and satellite observations as routinely compiled in support of NESDIS operational product systems (Tilley *et al.* 2000 and Reale *et al.* 2002), in this case for NOAA-16. As shown, the global distributions are not uniform with more collocations clustered in the western parts of Europe and N. America. This

is a by-product of the 3-hour time windows used when collocating satellite observations with predominantly synoptic radiosonde observations (at 00Z and/or 12Z) over land.

Figure 3 shows the multiple profile data sets of temperature (solid) and moisture (dashed) available from a single collocation data record, with over 6000 records available on a given file. The radiosonde location (northern Europe) and respective data systems are annotated and color coded (i.e., the radiosonde is in red) as indicated on the right. The plots include satellite derived and NWP profiles collocated to the radiosonde report. Although seemingly tedious, a scanning of all (6000) profiles can be very enlightening of difference ranges and problems inherent in the respective data.

Figure 4 illustrates graphical capabilities from VSTAT. The left panel shows vertical statistics of the mean (left curves) and standard deviation (right curves) of first guess (light curves) and final sounding (heavy curves) differences from the radiosondes, respectively. The left panel shows these statistics for clear soundings and the right panel for cloudy soundings from ATOVS for NOAA-16, for the region 60N to 60S. The sample sizes at each pressure level are shown along the right vertical axis. The convergent nature of NESDIS operational soundings is revealed by the smaller differences for the final soundings versus the guess. However the regional skewing of the samples used to compute these statistics (Figure 2) limits there reliability as an indicator of global performance (Reale and Thorne 2004).

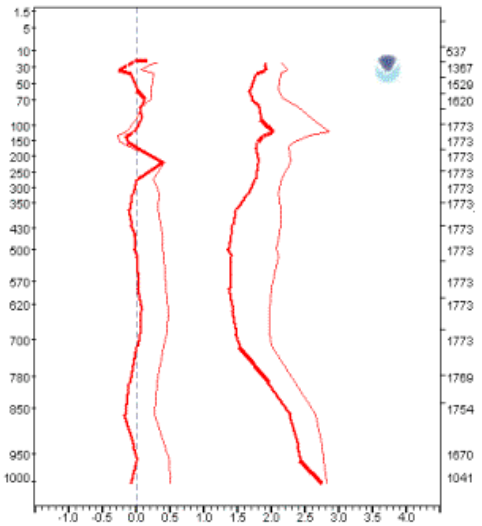


Figure 4: Examples of vertical statistics of radiosonde minus satellite temperature differences for NOAA-16 Clear (left) and Cloudy (right) derived soundings from the 60N to 60S global region; the dark curves are for the final soundings and the lighter curves for the first guess profiles.

4. Future Plans

All graphical systems are being expanded to include research satellites, additional stages of satellite radiometric processing, and calculations of radiometric data from radiosondes, nwp, and derived satellite products. A broadening of all systems to routinely report differences among the various data sources is planned. This would include for example, gridded horizontal datasets of satellite derived minus NWP product differences, and vertical statistics of calculated versus observed satellite radiances. Plans include making these systems and data accessible to users.

5. Acknowledgments

The contents are the opinions of the authors and do not necessarily constitute a statement of policy, decision, or position on behalf of the U.S. Government.

6. References

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Tilley, F.H., M.E. Pettey, M.P.Ferguson, and A.L. Reale, 2000: "Use of Radiosondes in NESDIS Advanced-TOVS (ATOVS) Sounding Products". *10th Conference on Satellite Meteorology and Oceanography*, 9-14 January, Long Beach, CA.

HIRS/3 Scan Mirror Misalignment Onboard NOAA-16

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NOAA/NESDIS
Office of Research and Applications
Washington D.C.

1 BACKGROUND

The National Oceanic and Atmospheric Administration (NOAA)-16 earth orbiting satellite was deployed into polar orbit (ascending, equator, crossover at 1330 LST) on September 21, 2000. Evaluations of the Advanced Microwave Sounding Unit (AMSU) A and B data (Goodrum et al. 2000), received within a few days of orbital deployment indicated that these radiometers were functioning as designed. However, upon the completion of the outgasing of the High resolution Infrared Radiation Sounder (HIRS), marking the onset of routine availability of usable HIRS measurements to users which occurs about 3-weeks after launch, problems with the HIRS measurements began to be noticed. The following report summarizes the series of problems and corrective actions concerning the misalignment of the HIRS scan mirror onboard NOAA-16.

2 PROBLEM IDENTIFICATION

The first reports of problems for the NOAA-16, HIRS data were received from Dr. Pascal Brunel and his co-workers at Centre de Meteorologie Spatiale (CMS), Meteo-France, during November, 2000. Dr. Brunel reported "many troubles" with NOAA-16 HIRS data, "suspecting a (possible) shift of one HIRS spot in the measurements", as "if the instrument (were) not scanning in nominal geometry, or synchronization (was) not on time". The CMS staff suspected the "instrument or the on-board processing" as the source of these problems. The observations were made during routine processing at the CMS direct readout facility (in Lannion, France), using the Advanced-TIROS Operational Vertical Sounder (ATOVS) and Advanced Very High Resolution Radiometer (AVHRR) Processing Package (AAPP) available from EUMETSAT (Klaes et al. 1999).

Meanwhile, National Environmental Satellite, Data, and Information Service (NESDIS) efforts to validate and implement an operational sounding products system (Reale et al. 2000) for NOAA-16 had encountered unusual problems concerning the generation of limb adjustment coefficients (Wark 1993) for the HIRS. Since the HIRS is a cross-track scanner (Goodrum et al. 2000), the path of the atmospheric radiation reaching the HIRS instrument varies with the scan position. Measurements near the center of the scan are comprised of radiation which travel an essentially vertical path to the radiometer, while radiation from scan positions further away from nadir traverse a progressively longer "slant" path. This increase in path results in a gradual lifting of a given channel's vertical sensitivity, with scan positions further from nadir having peak sensitivities which are higher in the atmosphere than those closer to nadir. This is manifested as a systematic difference in the radiance measurements for a given channel across the scan, which is referred to as limb-effect. Typically, the limb effect is symmetric about nadir, since the instrument is designed with symmetric scanning angles with respect to nadir.

Limb effect is removed prior to the derivation of NESDIS operational sounding products through the generation and application of limb adjustment coefficients which normalize all the measurements to (look like) the nadir view (Wark 1993). Such adjustments are typically well-behaved (Goldberg 1999), with a high degree of symmetry in the coefficients applied on either side of nadir. However, for NOAA-16, a distinct lack of symmetry and large residual errors after limb adjustment were being observed for the HIRS, including a highly variable and scan dependent bias (which also changed sign) from one side of the scan to the other. These unusual results led to an initial series of actions by NESDIS to remove the symmetric constraints from the coefficient generation process, sometimes desirable, for example, if systematic differences due to microwave instrument side lobes are a concern. These results were slightly better than the original, but still inferior to results from previous satellites.

During the later part of November (one day after the receipt of CMS results), Dr. Thomas Kleespies of the NESDIS Office of Research and Applications (ORA) provided the first NOAA confirmation of an apparent data mislocation problem for HIRS onboard NOAA-16. These are presented in Figures 1 and 2 which display orbital segments of HIRS observation for channel 19, a surface sensitive channel, in the vicinity of Saudi Arabia and the Red Sea. Figure 1 shows hot, daytime observations corresponding to the ascending orbit node, and Figure 2 the relatively cold, nighttime observations corresponding to the descending orbit node. Geographical coastlines are appended over each image. Normally, these measurements contrast definitively along coastlines, which during the day (Figure 1) mark the boundary between the relatively hot land and cool ocean, and at night (Figure 2) the relatively cold land and warm ocean environments, respectively. As seen in both Figures, the data in the vicinity of coastlines appear to be misaligned by about one pixel to the left, relative to the direction of the satellite.

In early December, Mr. A. Reale of ORA provided additional NOAA results confirming asymmetry in the raw HIRS from NOAA-16. These are presented in the 4 panels of Figure 3 which show color enhanced, ascending (upper panels) and descending (lower panels) node orbit segments of calibrated HIRS measurements for the longwave channel 5 (upper panels), and shortwave channel 15 (lower panels) data from NOAA-16 (left panels) and NOAA-14 (right panels), respectively. Each panel corresponds to a remote, clear ocean region; the upper panels in the tropical Pacific west of South America, the lower panels in the tropical Atlantic west of Africa. The “limb effect” in these raw, calibrated measurements is seen as a darkening (cooling) from the center to outer portions of the scan, as expected for these mid-tropospheric sensitive channels. As seen for the NOAA-14 (right side panels), the limb darkening pattern is symmetric; that is, the same color shades appear on each side of the scan. The NOAA-16 measurements, however, are decidedly non-symmetric, with measurements on the right side (in the direction of the satellite) notably colder than on the left.

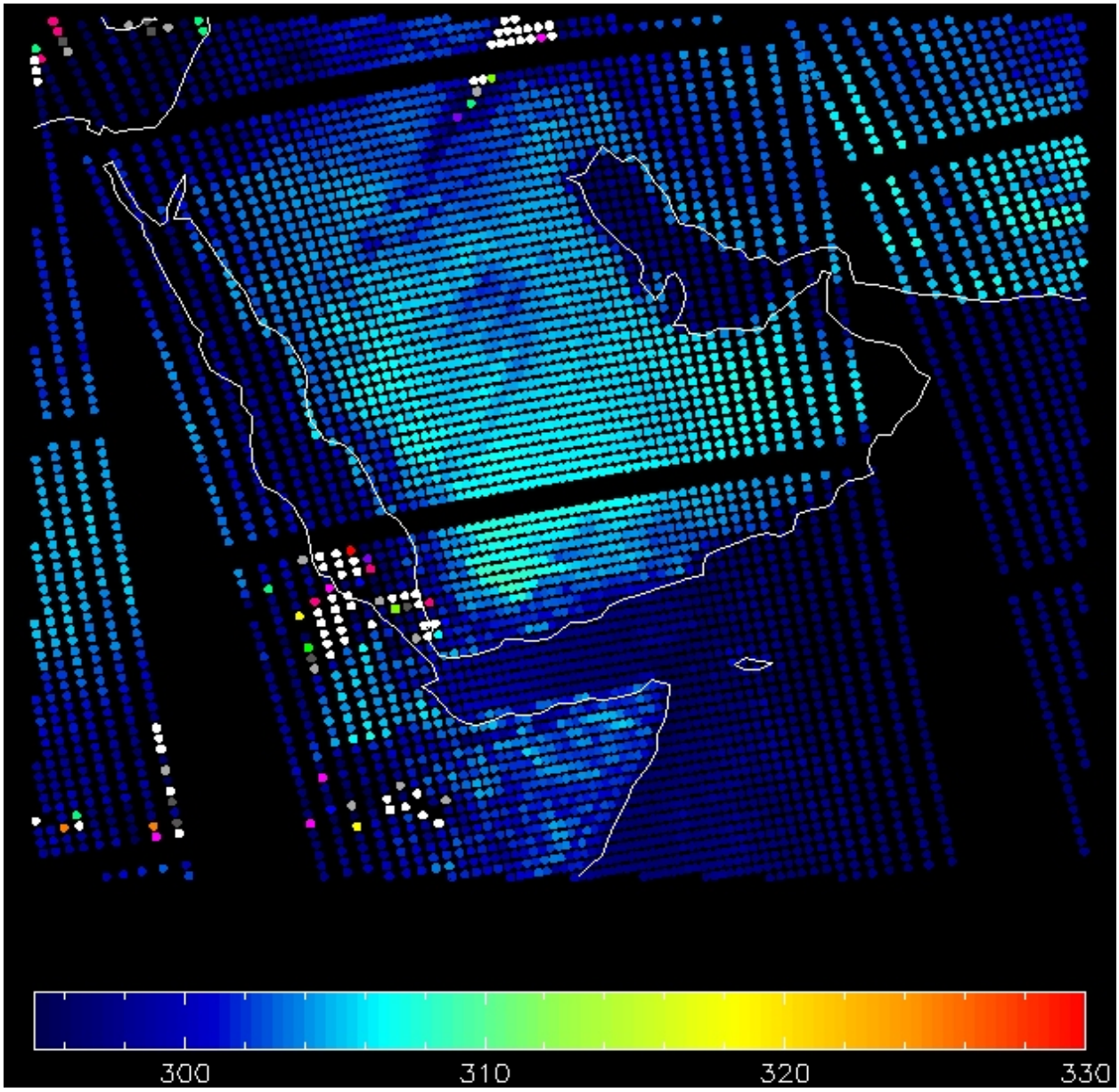


FIGURE 1: Original NOAA-16 measurements for HIRS channel 19 (sensitive at the surface) for an ascending node orbit segment (daytime) in the vicinity of the Red Sea, illustrating the approximately one pixel mislocation (to the left in the direction of the orbit track) along north/south coastal zones.

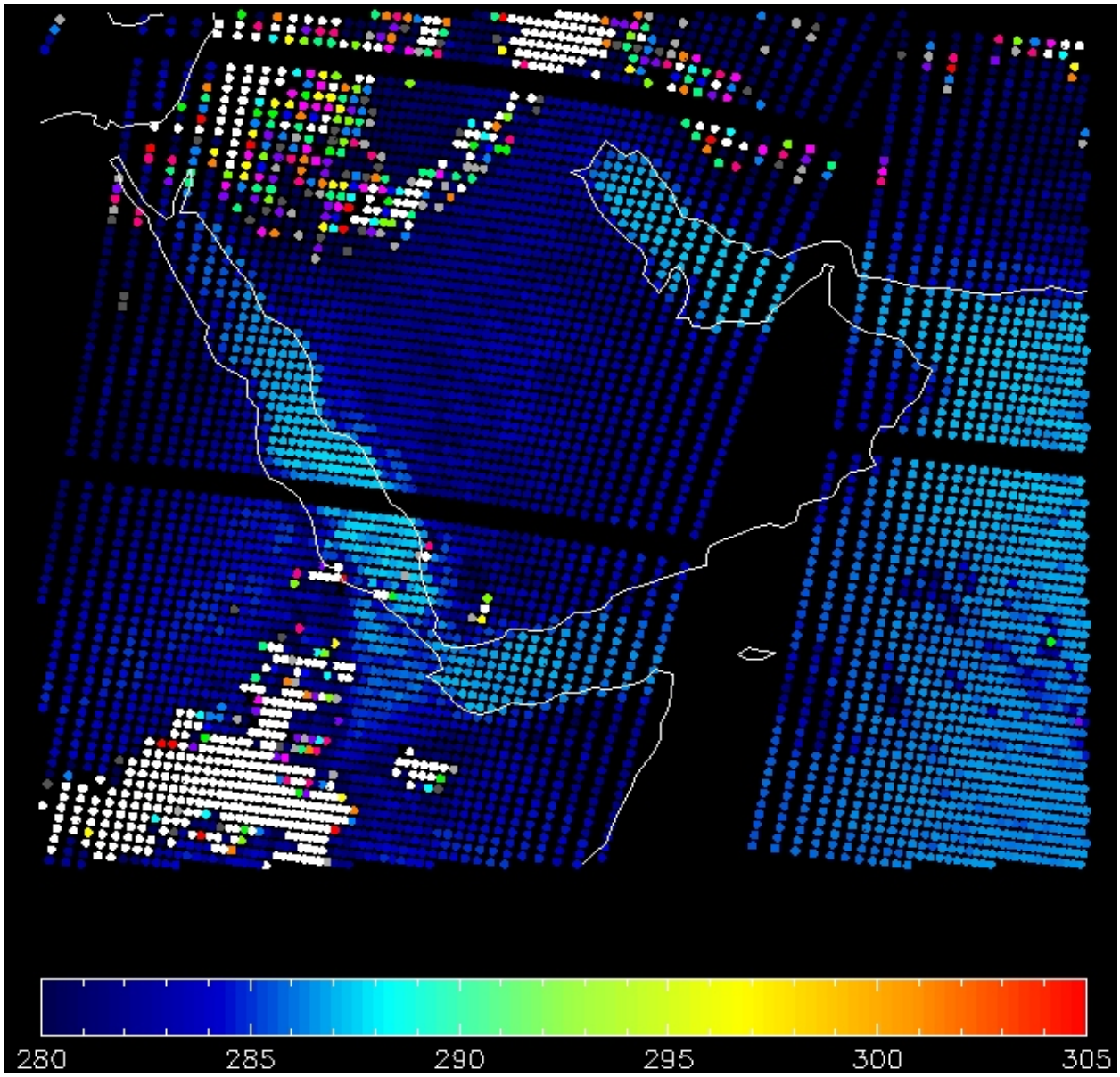


FIGURE 2: Original NOAA-16 measurements for HIRS channel 19 (sensitive at the surface) for a descending node orbit segment (nighttime) in the vicinity of the Red Sea, illustrating the approximately one pixel mislocation (to the left in the direction of the orbit track) along north/south coastal zones.

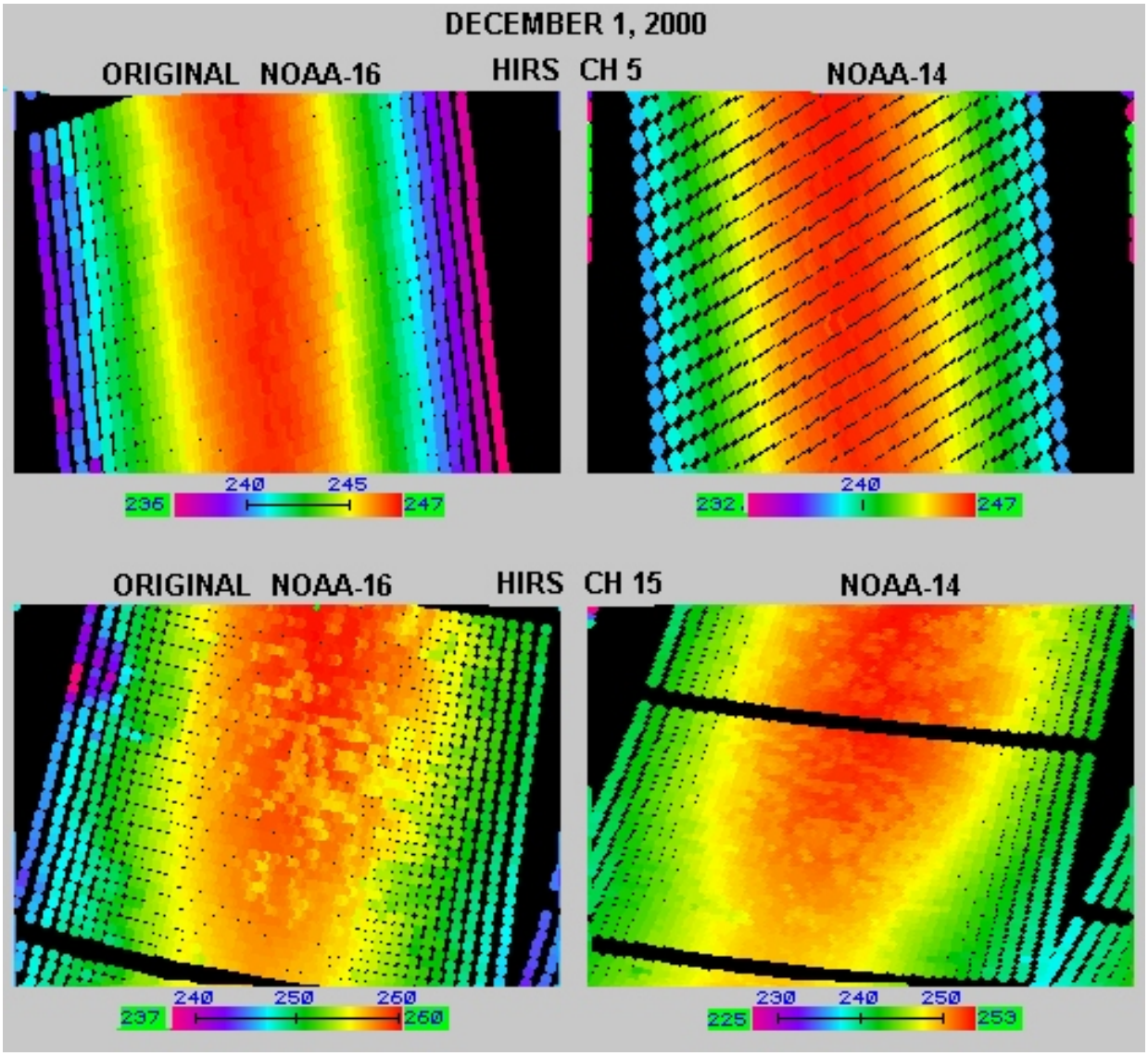


FIGURE 3: Measurements for tropospheric HIRS channels 5 (upper panels) and 15 (lower panels) corresponding to original NOAA-16 (left side panels) and comparative NOAA-14 (right side panels) data for ascending (upper panels) and descending (lower panels) node orbit segments from remote, oceanic, predominantly clear regions, illustrating the asymmetry of the original NOAA-16 HIRS data.

Combining the results from Figure 1, 2 and 3, two manifestations of the same problem are identified. Figures 1 and 2 show the navigational component; that is, the approximately one pixel offset to the left resulting in data mislocation measured against known geographical (coastline) landmarks, and Figure 3, the asymmetric scanning component, that is, the pixels on the right side of the scan appear to be measuring at a systematically higher scanning angle than corresponding pixels on the left. It appears that the HIRS is not scanning in a symmetric geometry from one side of the scan to another, and as reported by CMS, no other instrument data are similarly affected. The HIRS sensor does not appear to be operating as designed, nor consistent with ground navigation and processing software systems.

3 CORRECTIVE ACTION

Given the results from CMS and NOAA internal investigations, together with the fact that NESDIS front-end software is different than that used by direct readout users, Mr. Chalfant deduced that the problem must be instrument related. He then designed, developed and evaluated ATOVS product processing software to test this hypothesis. This was done using the NESDIS operational processing environment, in particular, the NOAA-16 parallel processing systems operated by the Forecast Products Development Team (FPDT). Meanwhile, instrument engineers from NOAA and NASA, headed by Dr. Katherine Richardson (NASA), began a detailed study of the data coming from the satellite, including ground test results and actions undertaken prior to launch, to try and piece together exactly what was going on with the HIRS on NOAA-16.

The initial software modification designed by FPDT for the NESDIS operational sounding products system, was to shift the HIRS measurements one pixel to the right, relative to the orbit track. Since the HIRS scans from left to right, this meant a shifting of HIRS pixel 1 to the pixel 2 position, and likewise across the scan, with pixel 56 shifted to a new, 57th position. It was ultimately decided to remove this 57th pixel, since it was no longer collocatable with other ATOVS radiometer data, resulting in a final shifted scan comprised of 55 pixels, populating the original pixel positions 2 through 56.

Figures 4 and 5 illustrate the result of these initial set of modifications, which were implemented into the NOAA-16 parallel processing during December, 2000. Figure 4 illustrates corrections with respect to data mislocation, and Figure 5 with respect to raw data asymmetry. Each Figure shows the original NOAA-16 HIRS measurements in the right side panels, and the corrected, shifted, measurements in the left side panels.

The orbit segments in each of the two (2) panels of Figure 4 are in the vicinity of the Persian Gulf, illustrating ascending node (daytime) measurements for HIRS channel 19. The gray pixels along the left side of the scan for the “shifted” measurements illustrate the original pixel position 1, which was shifted to the right (relative to the satellite track), leaving the original pixel-1 locations missing (gray). Notice how much better the boundary between the relatively cold ocean and warm land measurements (during the day) aligns with the coastline in the shifted measurements compared to the original data.

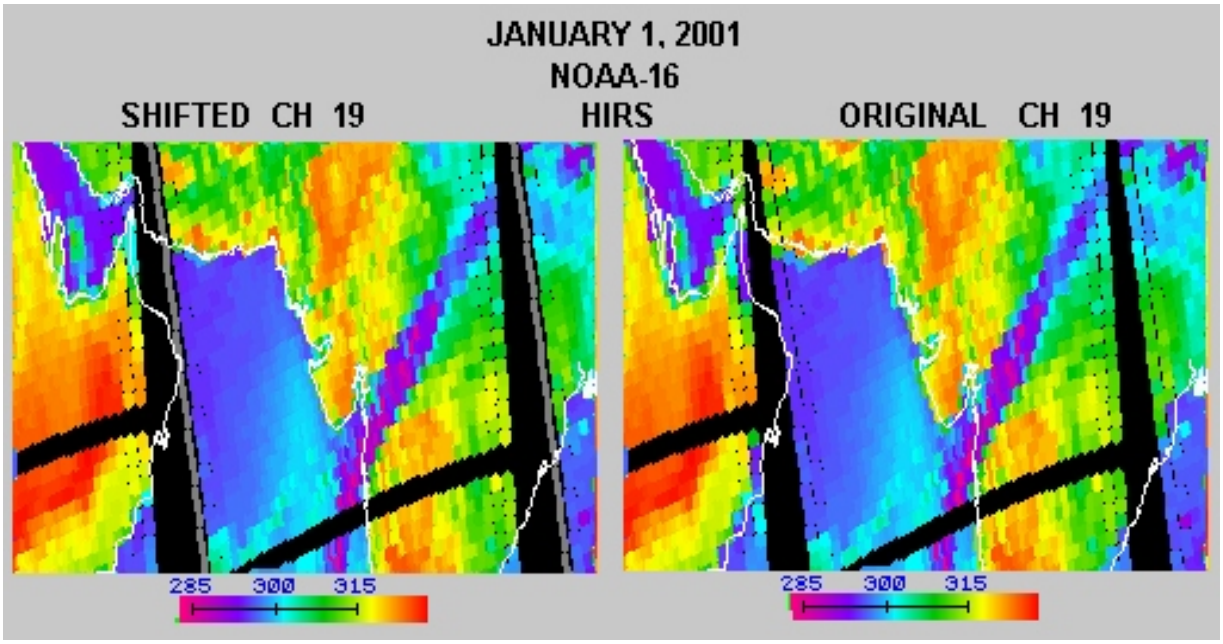
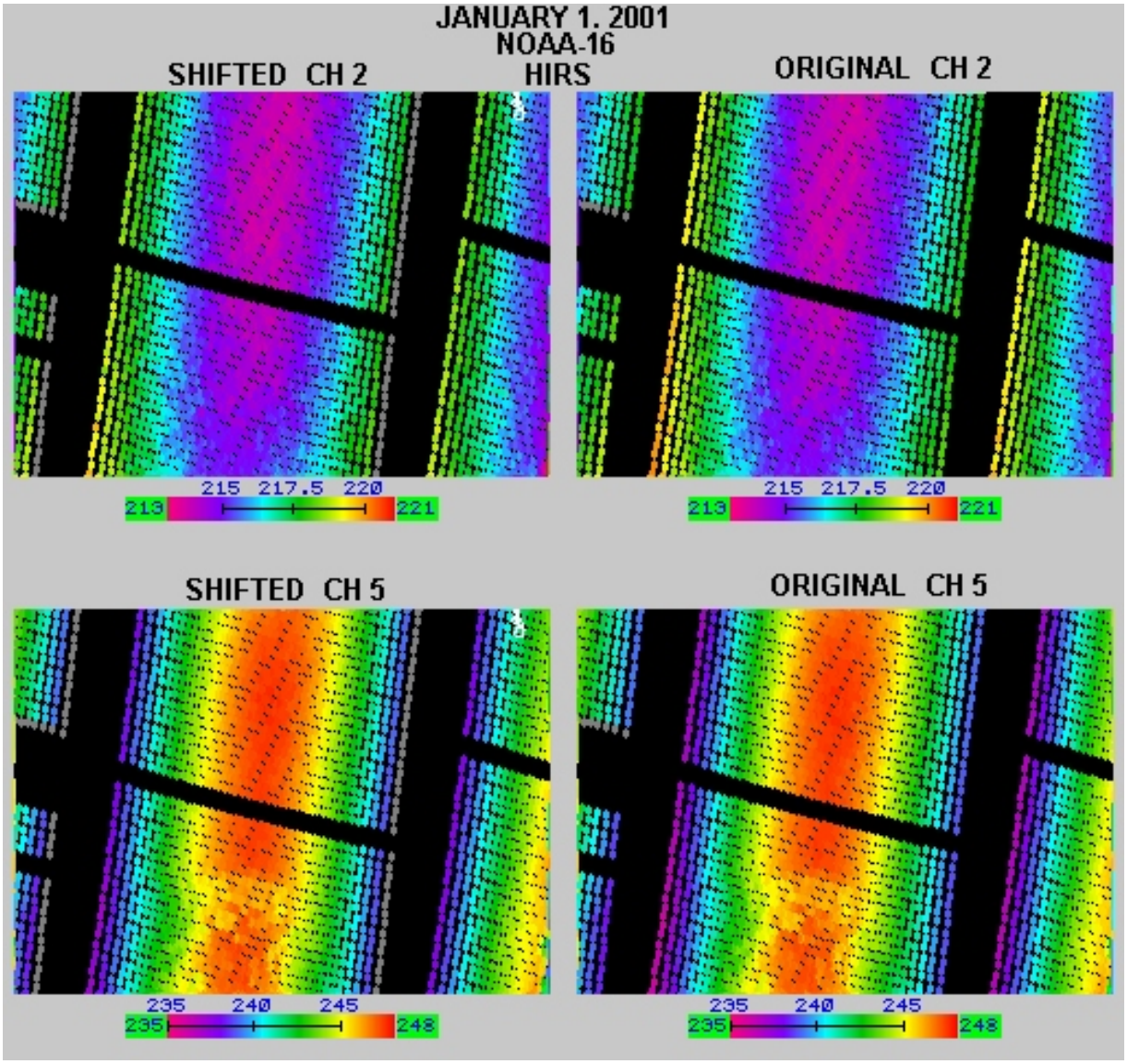


FIGURE 4: Original NOAA-16 measurements for HIRS channel 19 (right) and shifted measurements (left) exhibiting the better alignment with known coastline locations in the vicinity of the Persian Gulf.

The orbit segments shown in the four (4) panels of Figure 5 are from a predominantly clear region in the remote Pacific, west of South America. The two upper panels illustrate descending node data for HIRS channel 2, sensitive in the lower stratosphere, and the two lower panels show HIRS channel 5, sensitive in the middle troposphere. The right side panels for each channels show the original, unshifted observations, and the left side panels the corrected, shifted, data. Notice that the limb effect for each channel is different, with a limb-darkening (cooling) pattern for channel 5, and a brightening (warming) pattern for channel 2. This is as expected since temperature generally decreases with height in the troposphere (channel 5), but increases with height in the stratosphere (channel 2). The grey (missing) pixels which appear to be on the right are actually on the left side relative to the orbit track (similar to Figure 4). Notice the improved symmetry of the shifted versus unshifted limb effect.

A close inspection of the shifted data, however, still indicates a slight asymmetry in the shifted measurements. This is accounted for by the fact that after shifting, the rightmost (relative to the direction of the satellite, left in the picture) pixel (56) is offset by one scan position relative to the leftmost (non-missing), which is now in the pixel-2 position. Although the shifted data remain asymmetric, they are now being processed consistent with the actual path of the radiation through



the atmosphere, with the expected symmetry among pixels 2 through 55. Properly accounting for this shift in the generation of limb correction coefficients resulted in a reduction of residual errors to expected levels (Allegrino et al 1999).

FIGURE 5: Original NOAA-16 measurements for tropospheric HIRS channels 5 (upper left) and 15 (lower left), and comparative NOAA-14 measurements (right) for ascending (upper) and descending (lower) node orbit sections from remote, ocean, predominantly clear regions illustrating the asymmetry of the NOAA-16 HIRS data.

Although the modifications deployed by NESDIS in the parallel operating system for NOAA-16 appeared successful, there was still no clear indication from instrument engineers concerning a HIRS specific problem onboard the satellite. Nonetheless, given the convincing results from CMS and NOAA, subsequent actions were undertaken by NESDIS to modify the earth location software for the NOAA-16 HIRS to include a one pixel offset to the right. This was done by introducing a "Roll" bias of +1.8 degrees (corresponding to a 1.0 pixel shift to the right) in the NESDIS front-end processing systems which generate the raw, level "1b" datasets distributed to users and archived by NOAA/National Climatic Data Center (Goodrum et al. 2000).[1] The result of this was an appropriate shift in the satellite zenith angle computed for each pixel and stored on the 1b-level file. These procedures were implemented by NESDIS for NOAA-16 processing on February 14, 2001. This action included tests at various pixel sub-increments, varying for 1.7 to 2.0 scan angle degrees, which indicated the best results at 1.8 degrees (equivalent to one pixel length).

The introduction of the roll bias as described above essentially reconfigured the HIRS pixels across the scan, so that:

- pixel position 1 (the leftmost pixel) actually contains a satellite zenith angle that would normally be associated with position 2 (and similarly across the scan),
- nadir remains between scan positions 27 and 28,
- pixel position 55 contains a zenith angle normally associated with position 56 and with no symmetric counterpart on the left side of the scan, and
- scan position 56 contains a zenith angle for scan angle "57", with no symmetric counterpart on the left[2].

4 USER CONFIRMATION

In early February, 2001, a series of results were received from the NOAA, Environmental Modeling Center which further confirmed asymmetry problems for the raw HIRS measurements from NOAA-16, with additional validation that a correction of one pixel length was optimal. Figure 6 provides two (2) plots which illustrate mean differences between HIRS measurements which were calculated (McMillin 1995) from NOAA, numerical weather prediction (NWP) forecast model data, and collocated NOAA-16 observations. Each plot illustrates unshifted (solid lines) and shifted (dashed lines) HIRS measurements, respectively, as a function of the scan position (horizontal axis). The shifted HIRS measurements simulated by EMC correspond to a one pixel shift to the right. The curves for each plot illustrate the variation in mean bias across the scan for HIRS channels 5 (left) and 15 (right).

---

[1] However, direct readout users need to introduce a Roll bias to correctly account for the HIRS misalignment.

[2] This position is not processed operationally since it is only collocatable with Advanced Very High Resolution Radiometer (AVHRR), Local Area Coverage (LAC) data (Goodrum et al 2000).

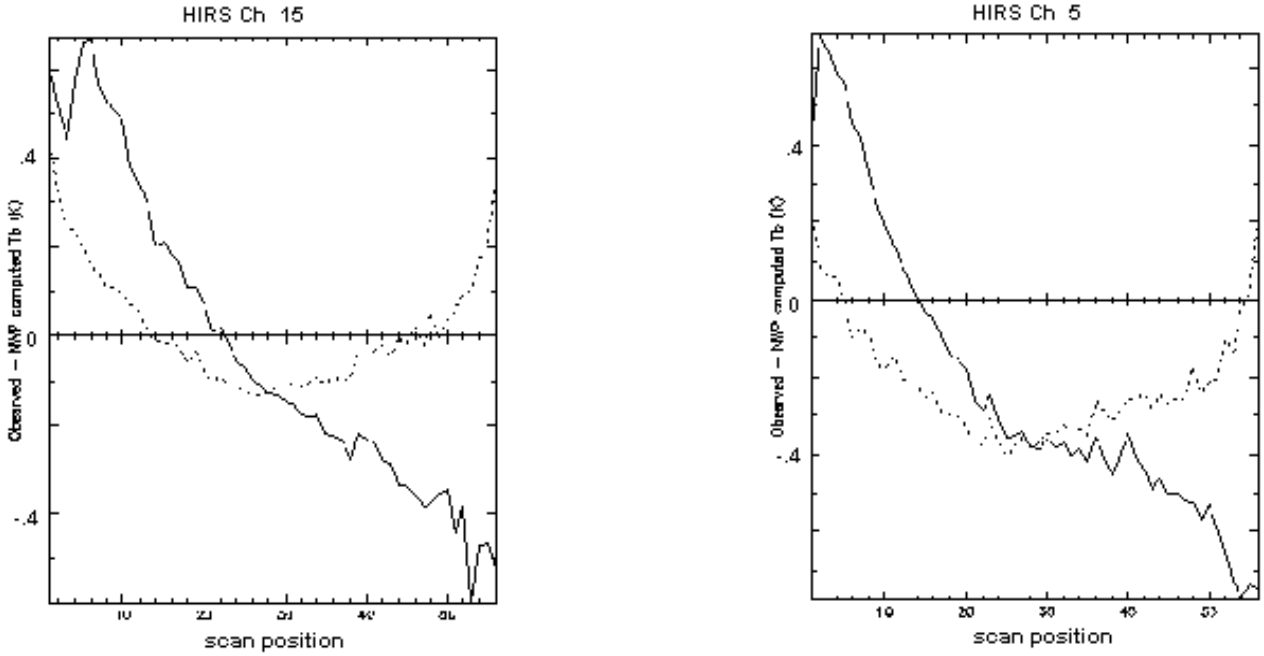


Figure 6: Observed minus NWP-based simulated radiance temperature as a function of the satellite scan position (1-56) for original, non-shifted HIRS (solid), and HIRS observations shifted one pixel to the right (dashed) for channels 15 (left) and 5 (right onboard NOAA-16.

As can be seen, the solid curves representing the original, non-shifted data show a more definitive bias which changes from positive to negative across the scan, whereas the dashed curves representing the shifted data show the expected symmetry about nadir. The magnitude of differences are not important since there are uncertainties in the nwp data and radiative transfer calculations used to compute HIRS measurements, the later varying per scan position as well. These results are conclusive since the nwp is not expected to exhibit systematic differences across the satellite scan.

5 ROOT SOURCE

Confirmation of a unique problem for HIRS onboard NOAA-16 was received in a report from the Lincoln Laboratory, Massachusetts Institute of Technology (MIT) on 16 February 2001, based on a study of a possible NOAA-16, HIRS misalignment with respect to AVHRR data (Meroth 2001). The report cites the most probable cause for a one-pixel shift as seen on-orbit to be a scan mirror shifting (or misalignment) on the motor shaft. A specific failure investigation found that after acceptance vibration testing, two set screws used to secure the scan mirror to the motor shaft were loose. The scan mirror was re-secured to the motor shaft and staked in place, however, it is likely that the mirror was not staked in the original alignment position. The report discusses the need to electronically verify the mechanical relationship between the scan mirror/motor and the NADIR cube mounted in the HIRS instrument on the alignment fixture to

insure that the electrical and mechanical nadir agree. Apparently, this was not done, but has been incorporated into the normal instrument acceptance testing procedure for future satellites.

The MIT report concluded a likely misalignment of the HIRS, and based on collocation studies with respect to the AVHRR, further concluded that the HIRS was misaligned by approximately 1.5 +/- .4 degrees, or .8 +/- .2 HIRS pixels.

Another inconsistency, this time concerning software documentation, was also identified during the HIRS misalignment and troubleshooting exercise, which at first appeared relevant, but later could only be interpreted as an interesting coincidence. It was determined that the HIRS/3 encoder positions for the earth views for NOAA-16 range from 0-55, which contradicts "NESS107", and the "Technical Description for the HIRS/3", VOL 1 (pg 28 and 50), which states that the earth views are 1-56. While this discrepancy is in the correct direction to explain the NOAA-16 shift, it does not explain why there is no apparent shift with NOAA-15 data. The level-1b data report delineating earth scene encoder positions for NOAA-15 and 16 also indicates a range of 0-55, which are out of sync by one position with NOAA-14 which indicates a (correct) range of 1-56.

6 SUMMARY

An international cooperative effort of European direct readout users (CMS) of NOAA polar orbiting data, NESDIS scientists responsible for the scientific integrity of measurements and derived products from polar satellite systems, and instrument engineers (NOAA and NASA) responsible for monitoring radiometer performance onboard the spacecraft, resulted in the timely identification of a misalignment problem impacting the HIRS/3 radiometer onboard NOAA-16. NESDIS modifications of operational front-end ground software systems to account for the misalignment when processing NOAA-16, HIRS/3 data, were deployed beginning in February, 2001. The importance of the post-launch validation process, particularly the feedback provided by the global user community (CMS, Lannion, France), to identify this problem that otherwise would have significantly compromised the use of these data in global weather and climate applications, is keenly illustrated. The diligence and cooperative spirit of the agencies involved is applauded. The primary benefit of Mr. Chalfant's incorporation of NOAA-16 unique software into the ATOVS product processing system in early December provided:

- the capability to check out changes to NESDIS' front-end "1B" processing related to HIRS unique scanning geometry as well as a calibration problem,
- the capability to generate and apply HIRS limb adjustment coefficients,
- the capability to check out a second geo-location problem associated with HIRS TIP frame time which produced an along track error, and
- the capability to check out the ATOVS temperature and moisture soundings as well as the HIRS atmospheric cloud, ozone and radiation products several months earlier than would have otherwise been possible.

7 REFERENCES

Allegrino, A., A.L. Reale, M.W. Chalfant and D.Q.Wark, 1999: Application of limb adjustment techniques for polar orbiting sounding data. Technical Proceedings of the 10th International TOVS Study Conference, Jan 26- Feb 2, Boulder, Colorado, USA., 1-10.

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McMillin, L.M., L. Crone and T.J. Kleespies, 1995: Atmospheric transmittances of an absorbing gas. 5.Improvements to the OPTRAN approach. Appl. Opt., 34, 8396-8399

Reale, A.L., M.W. Chalfant, and L.M. Wilson, 2000: NESDIS advanced TOVS sounding products. 10th Conference on Satellite Meteorology and Oceanography, 9-14 January, Long Beach, Ca.

Wark, D.W., 1993: Adjustment of TIROS operational vertical sounder data to a vertical view. NOAA Technical Report NESDIS-64, U.S. Dept. Of Comm., Washington D.C., 36 pp.

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4.	USER CONFIRMATION	9
5.	ROOT SOURCE	10
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NESDIS Operational Sounding Products

Tony Reale, AK Sharma, Michael Chalfant,

NOAA/NESDIS, Camp Springs, land, Md.

(tony.reale@noaa.gov)

Frank Tilley, Gene Kratz, Americo Allegrino, Mike Ferguson, Michael Pettey,

Raytheon-ITSS

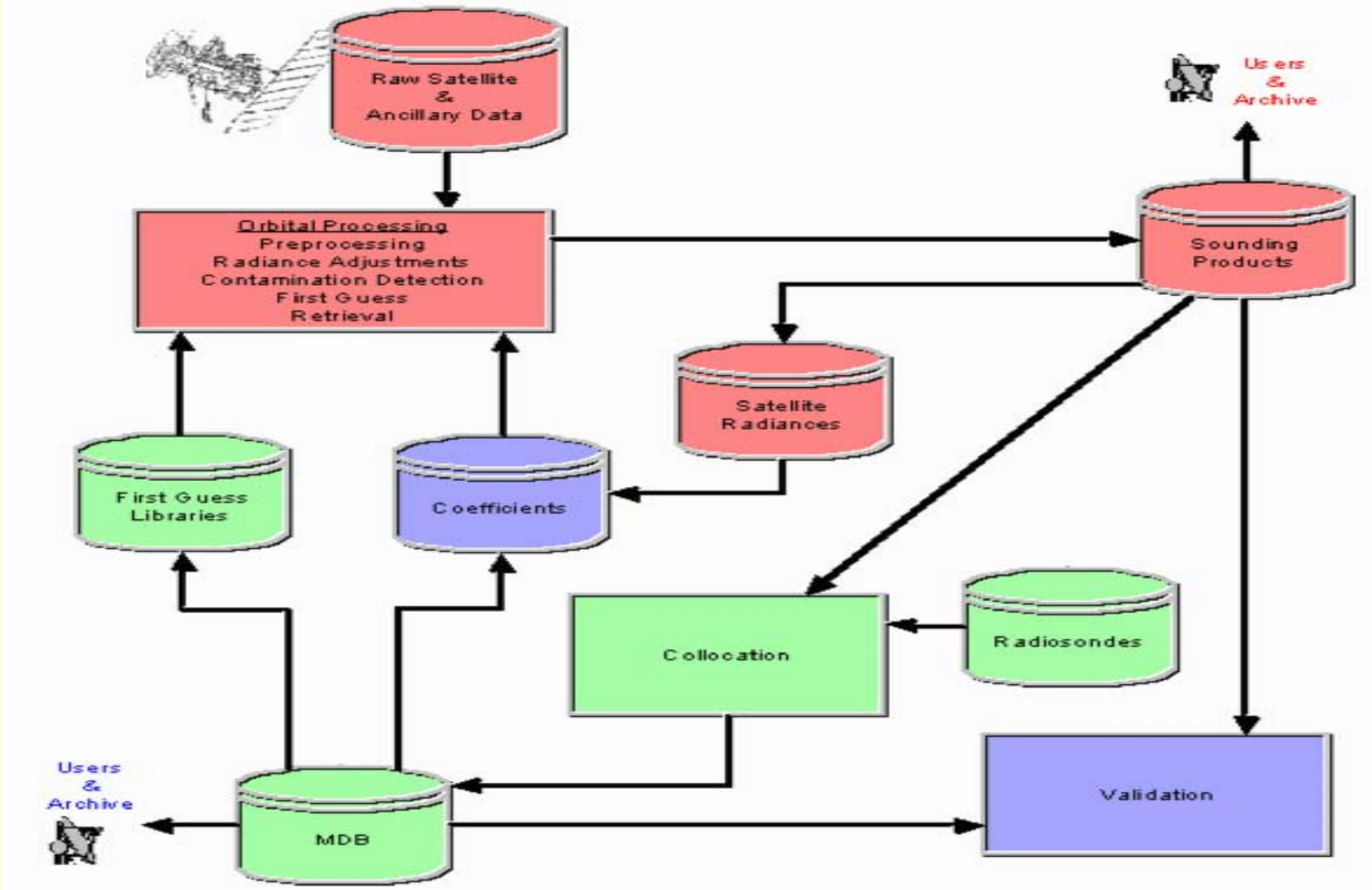
Summary

- **Current POES ATOVS Products Presented**

- **New ATOVS Sys-200X 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 planned**

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-200X Science

- ***Incorporate AMSU-B***

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

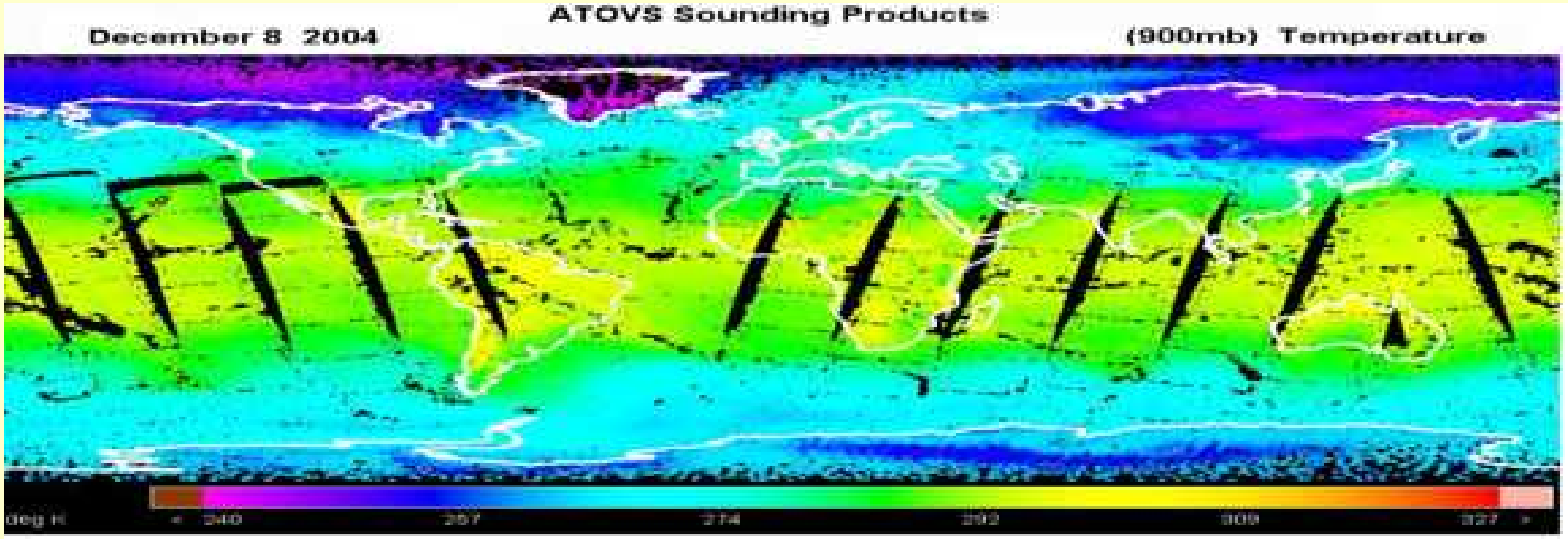
- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS

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

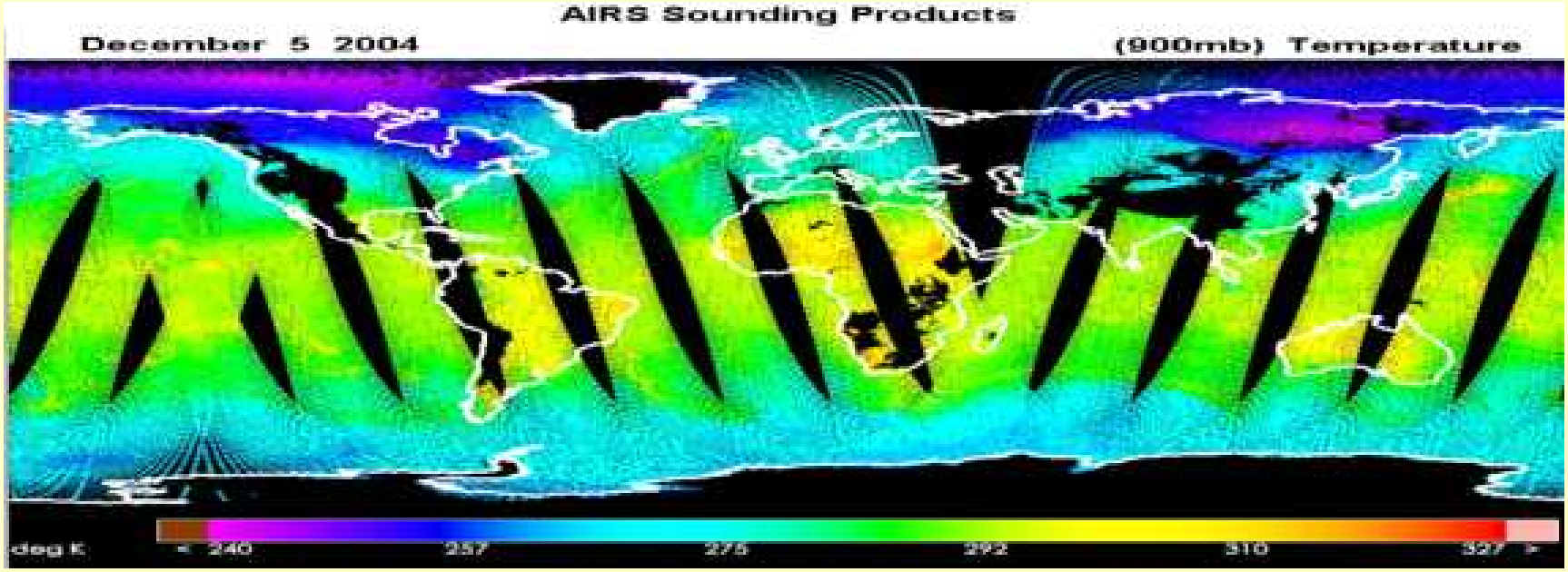
- Peripheral Upgrades
  - Limb-adjustment
  - MSPPS Products
  - Expanded Validation

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 …

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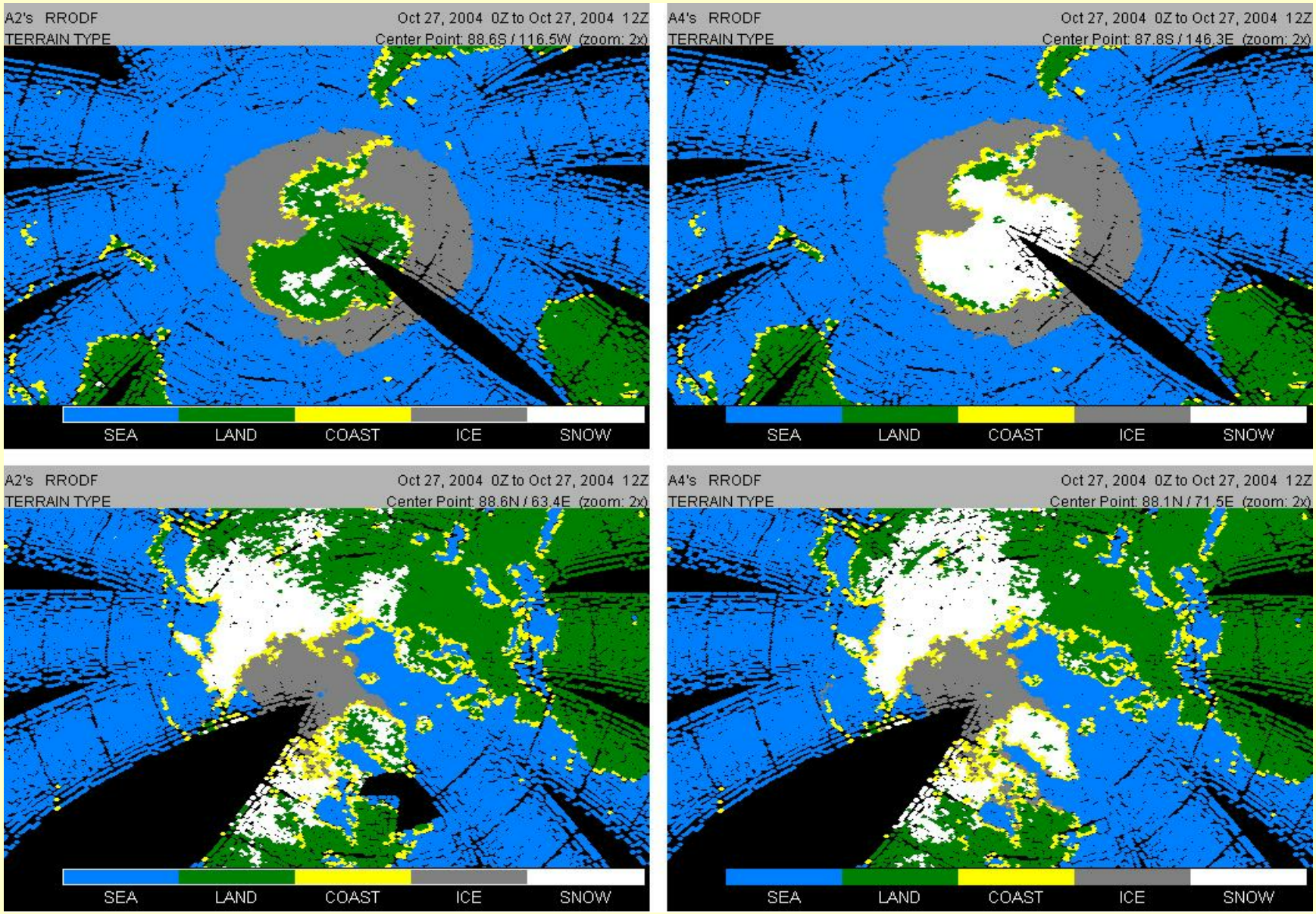
- Retrieval

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



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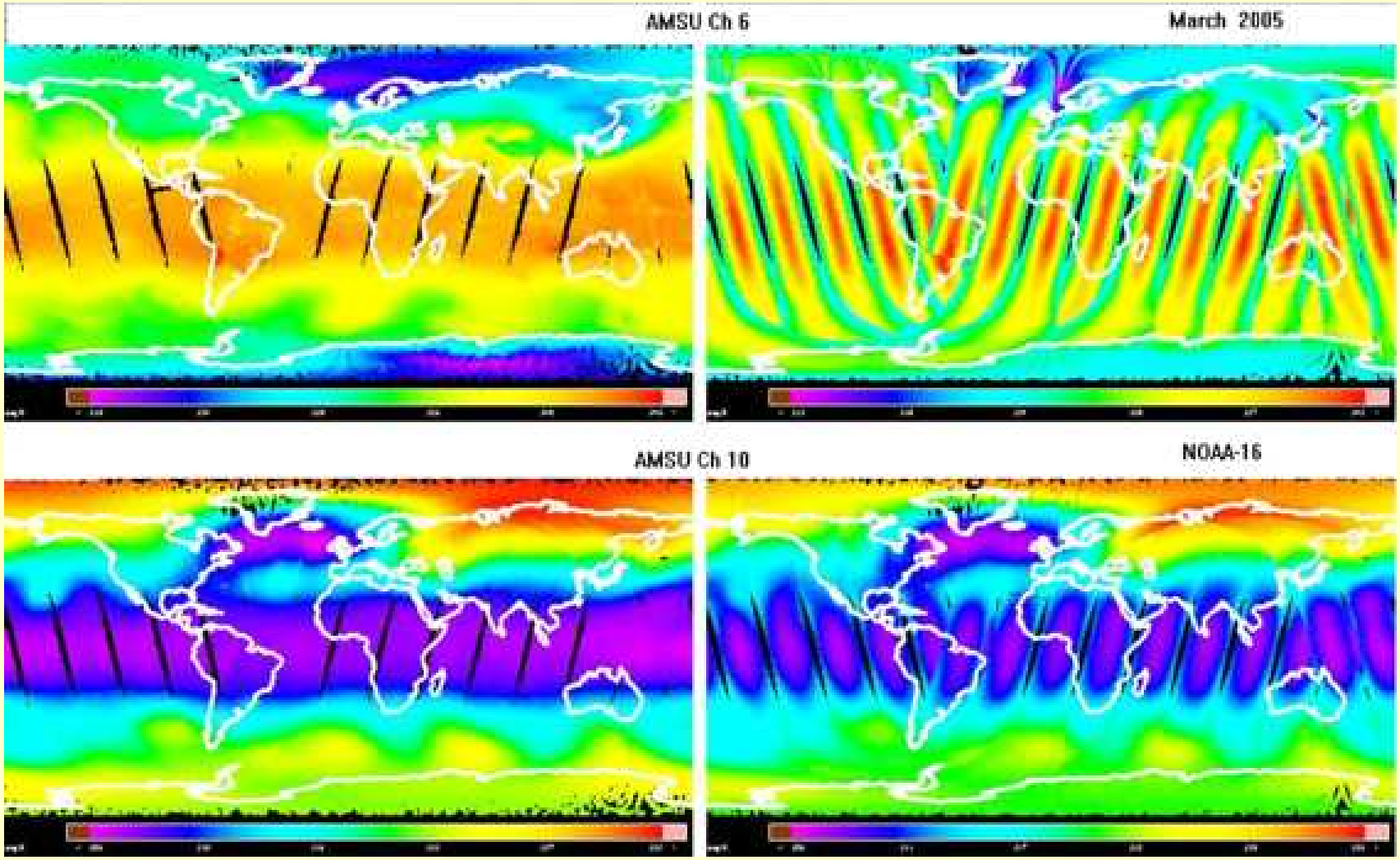
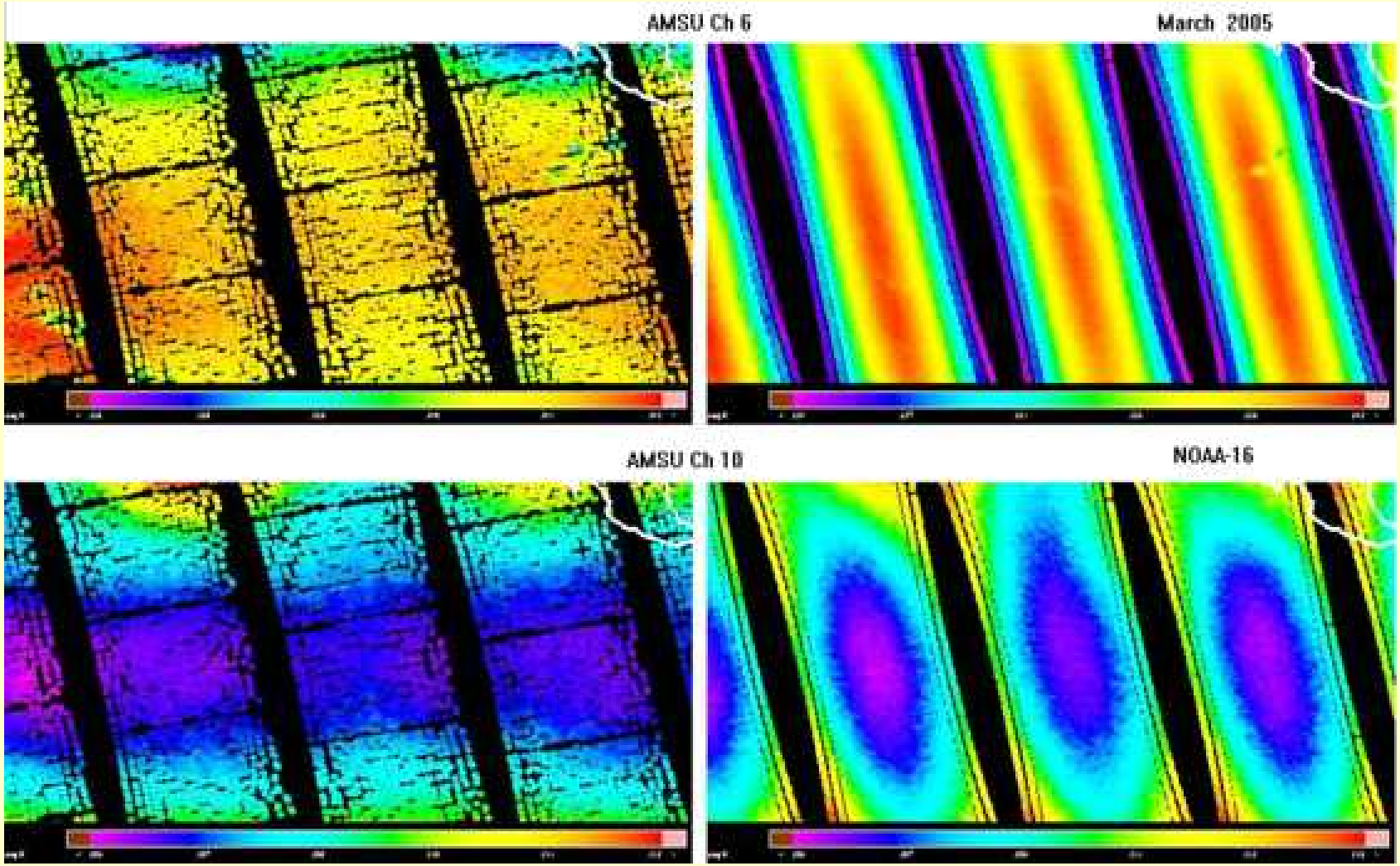
Limb Adjustments

- 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

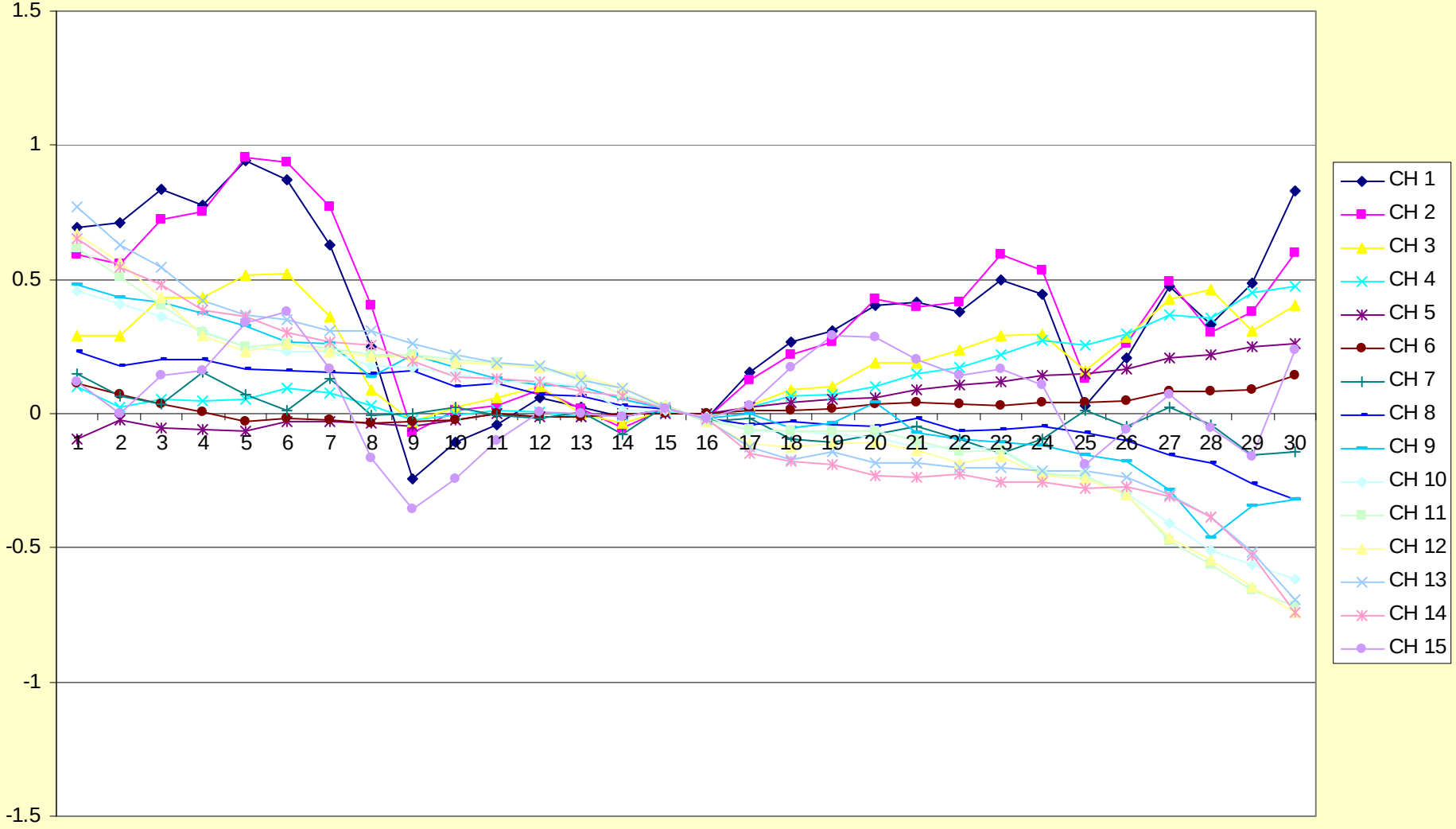
Limb Adjustment
(Wark, NOAA Tech Re. NESDIS 64' 1993)



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



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



New ATOVS System-200X Science

- ***Incorporate AMSU-B***

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

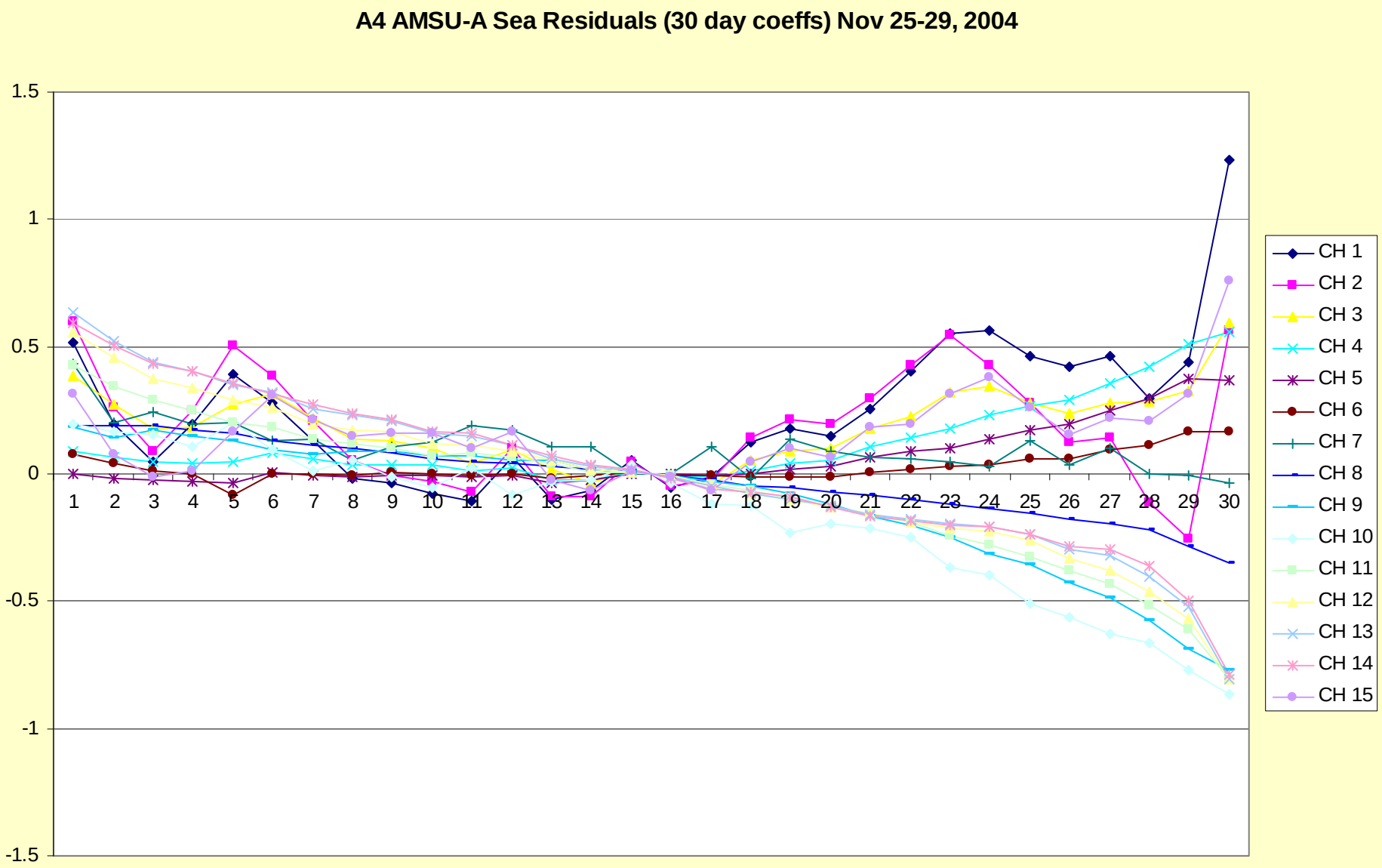
- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS

- 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-200X)

- 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
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CH 11
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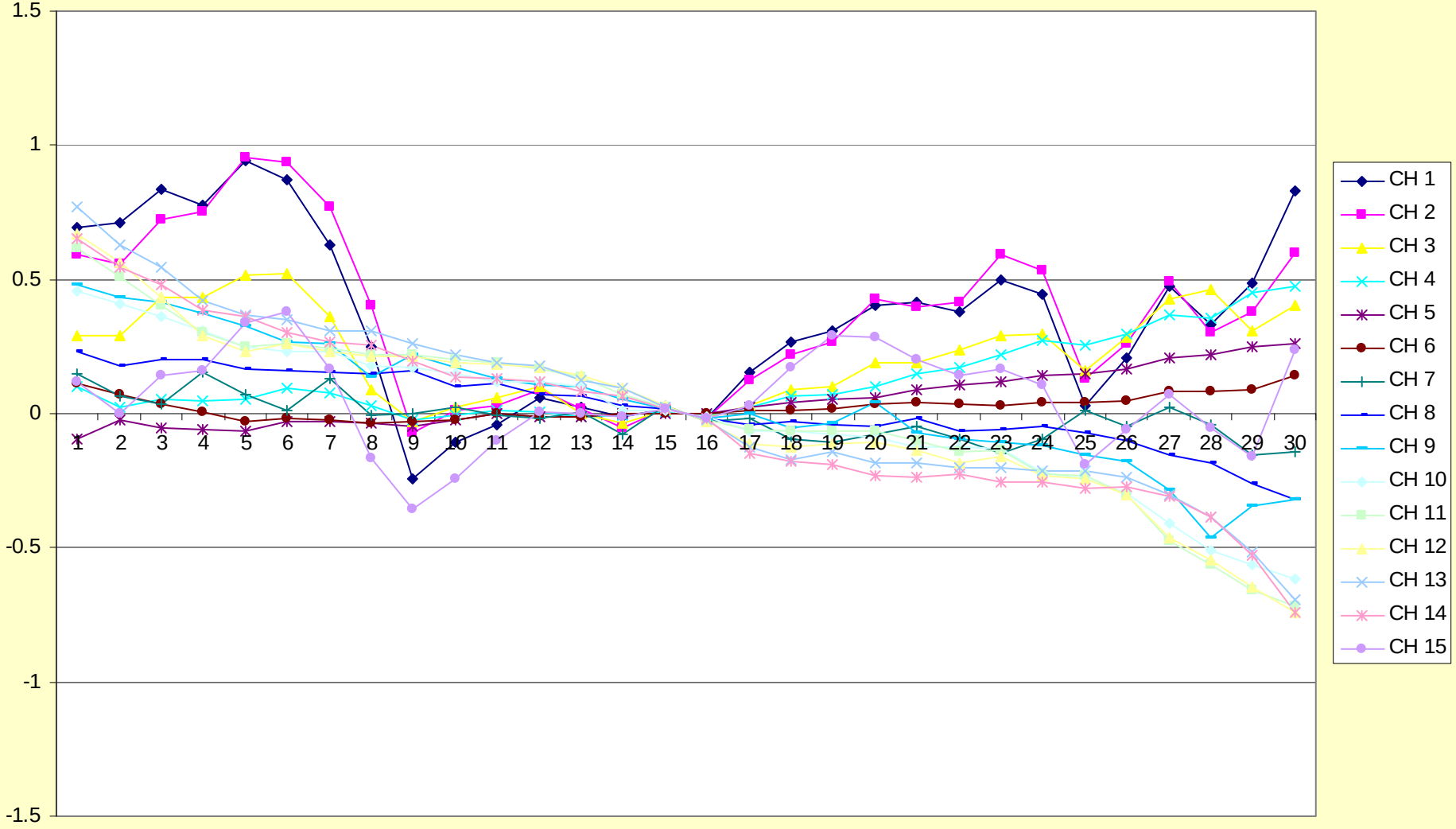
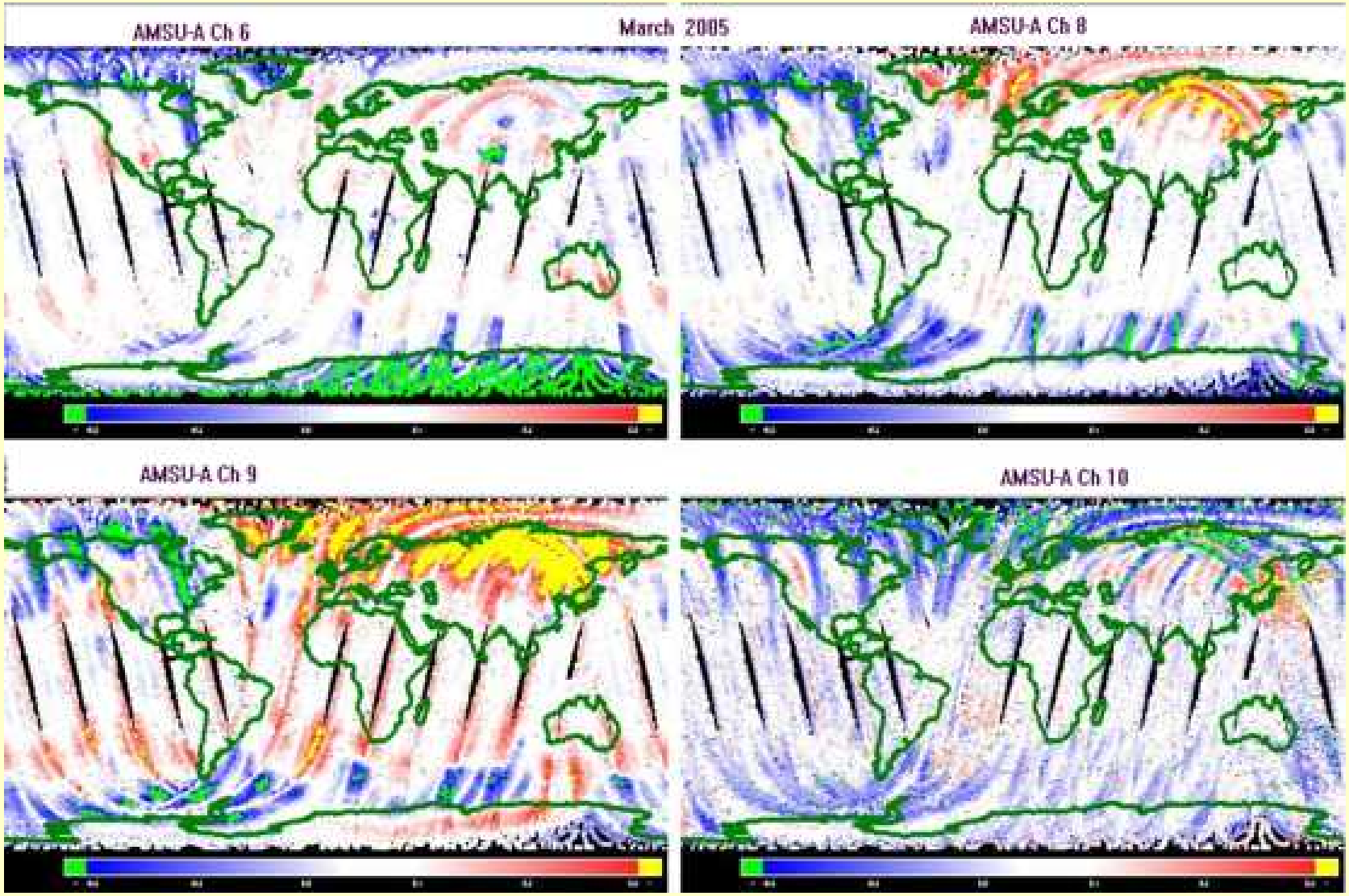
CH 15

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



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



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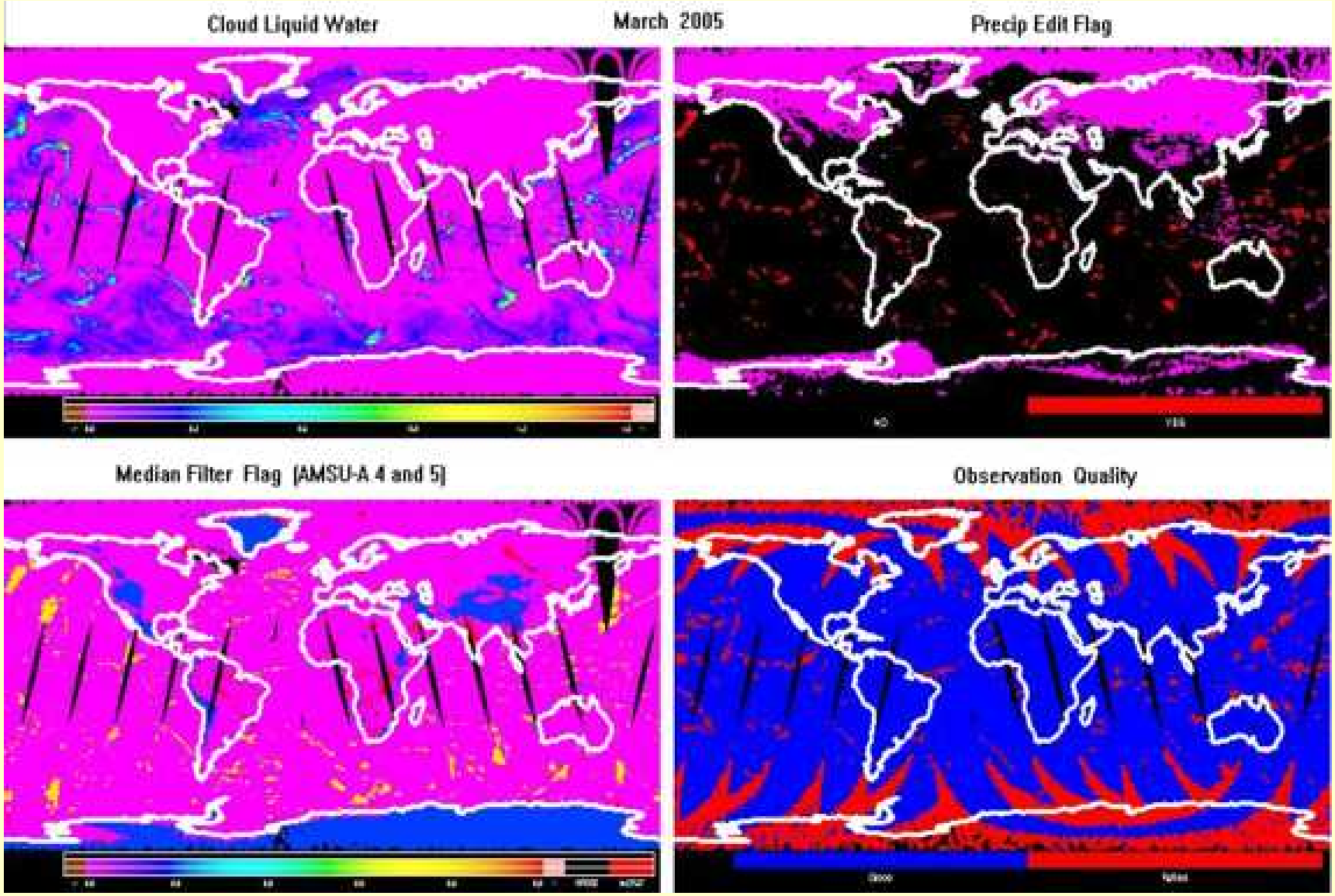
Product Quality Indicators

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

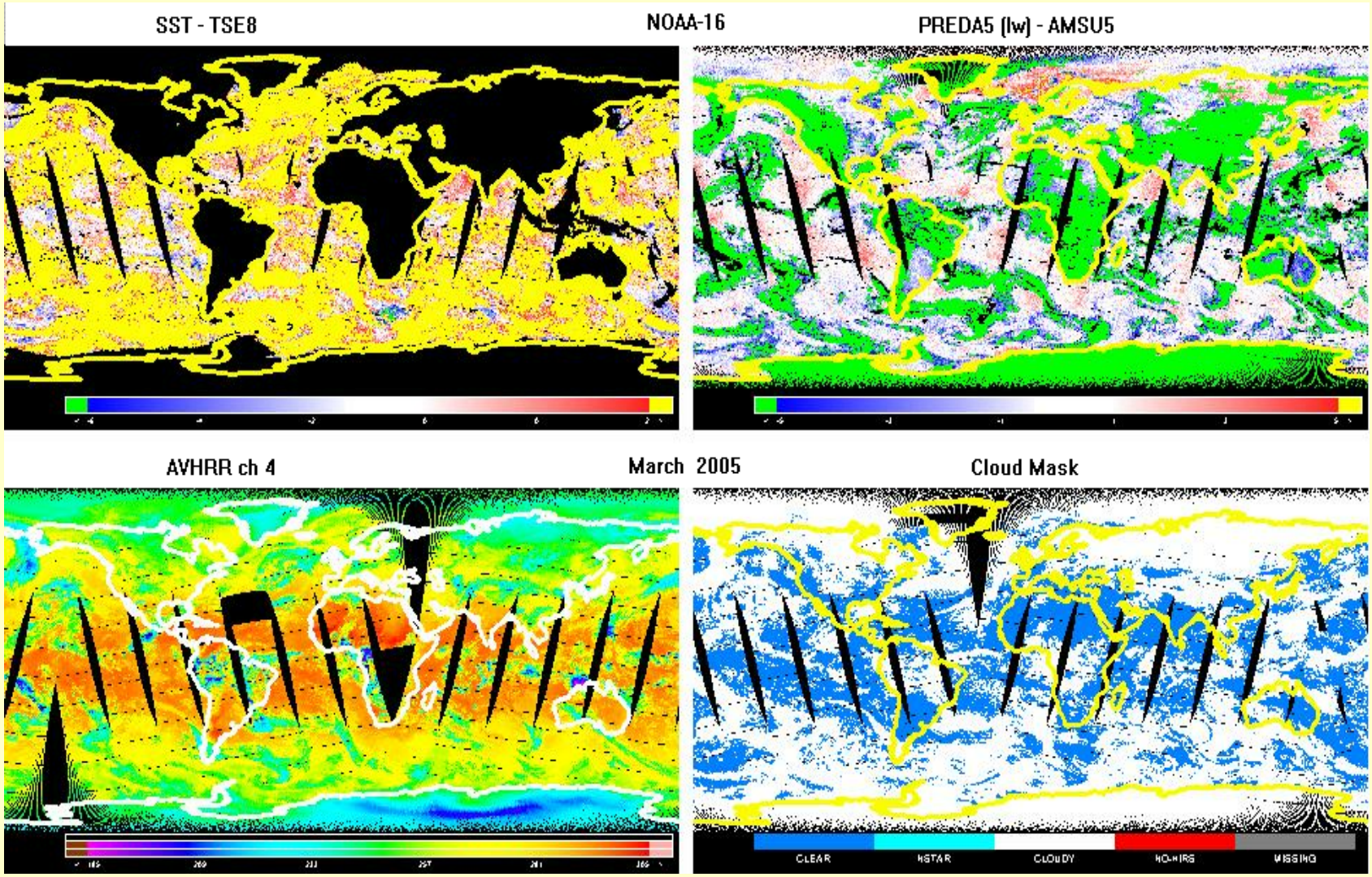
Miscellaneous Quality Control



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

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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

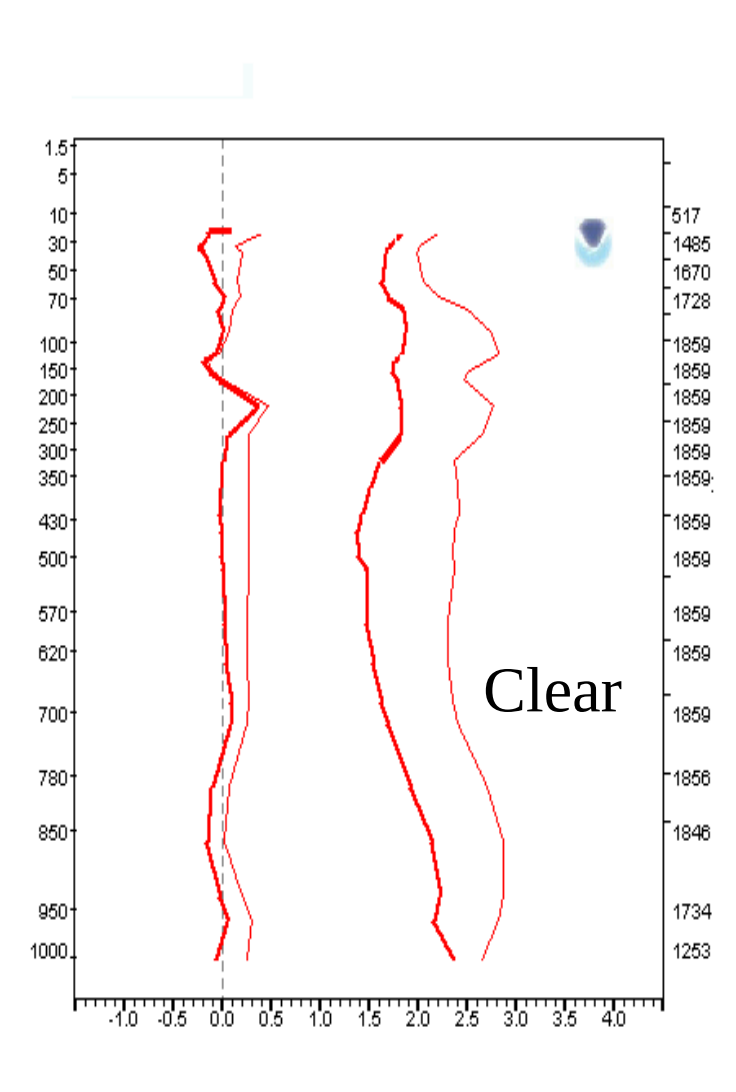
- Libraries are updated daily; eigen coefficients are updated weekly

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

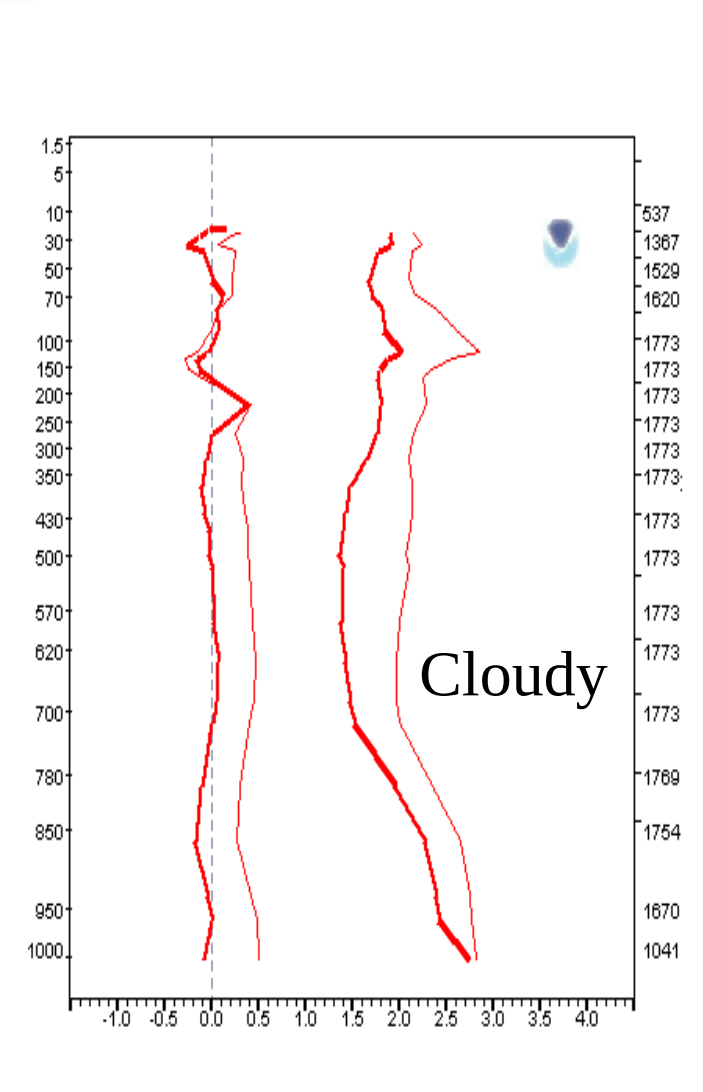
(*Guess (light)* **vs.** ***Retrieval (heavy)***)



First Guess Temperature Minus Radiosonde (light)

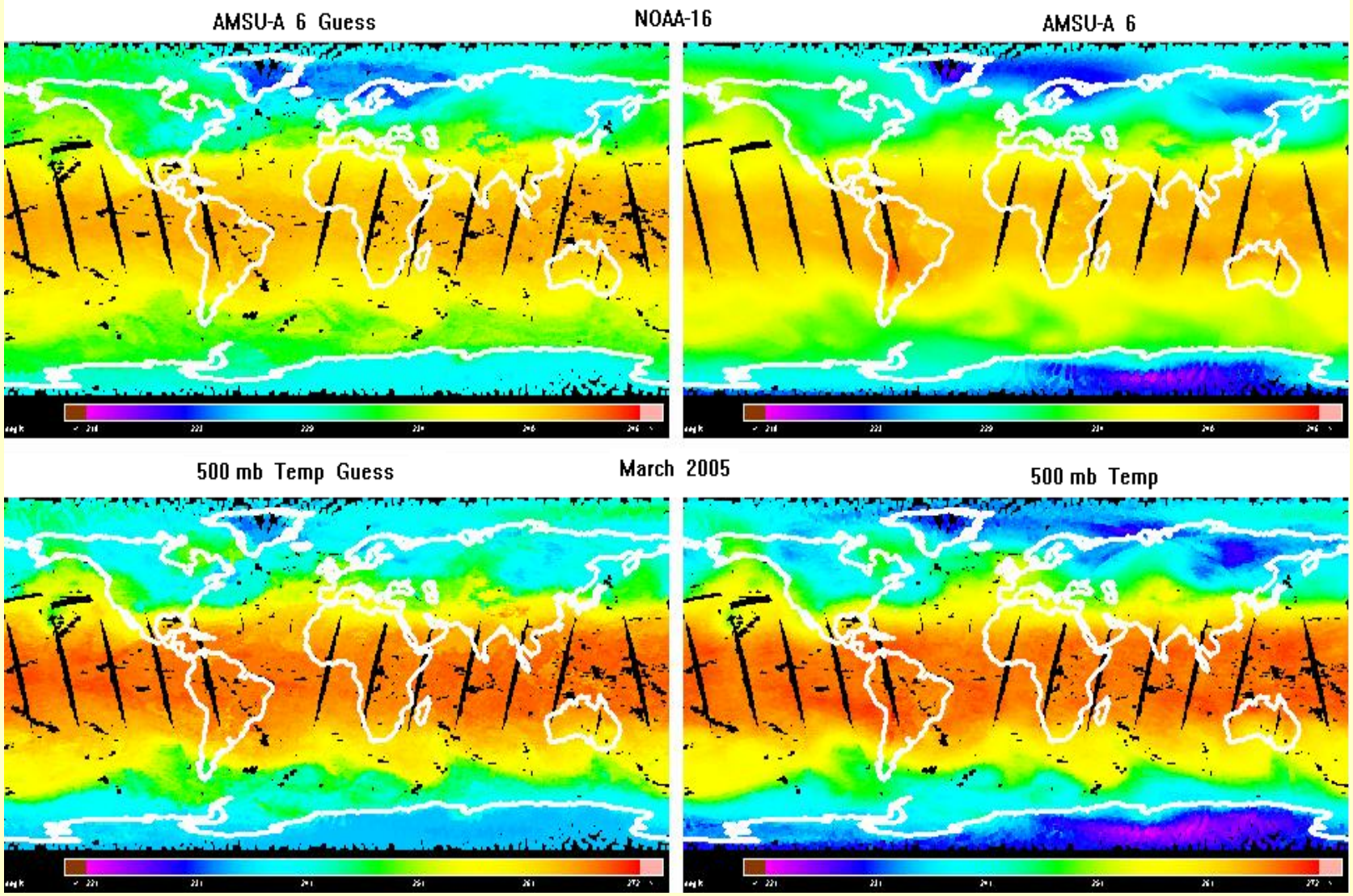
Sounding Temperature Minus Radiosonde (dark)

NOAA-16 (60N to 60S)



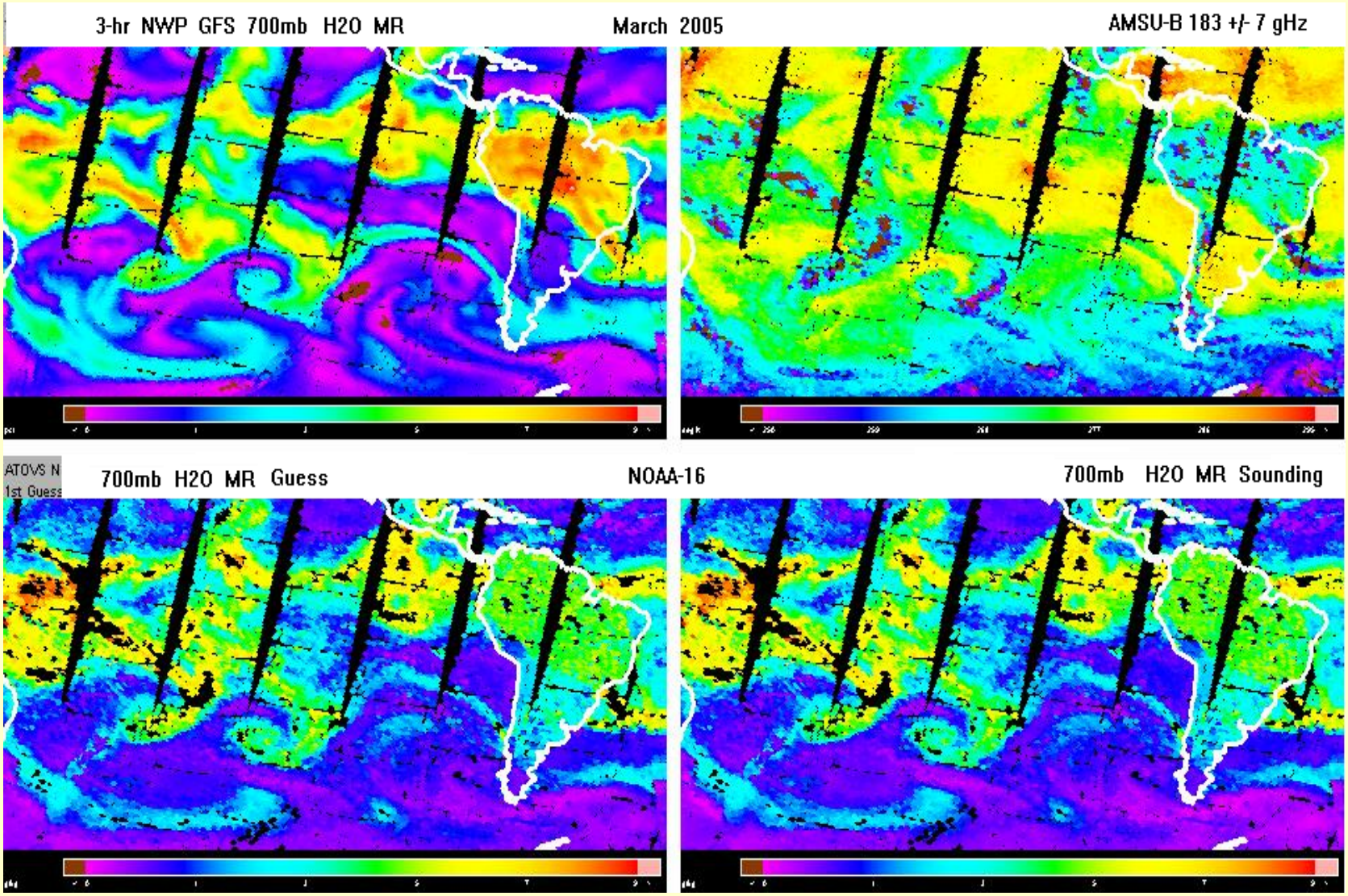
Observation …. Guess …. Sounding

(Temperature)



Observation … NWP … Guess … Sounding

(H2O Vapor Mixing Ratio)



ATOVS System-200X 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

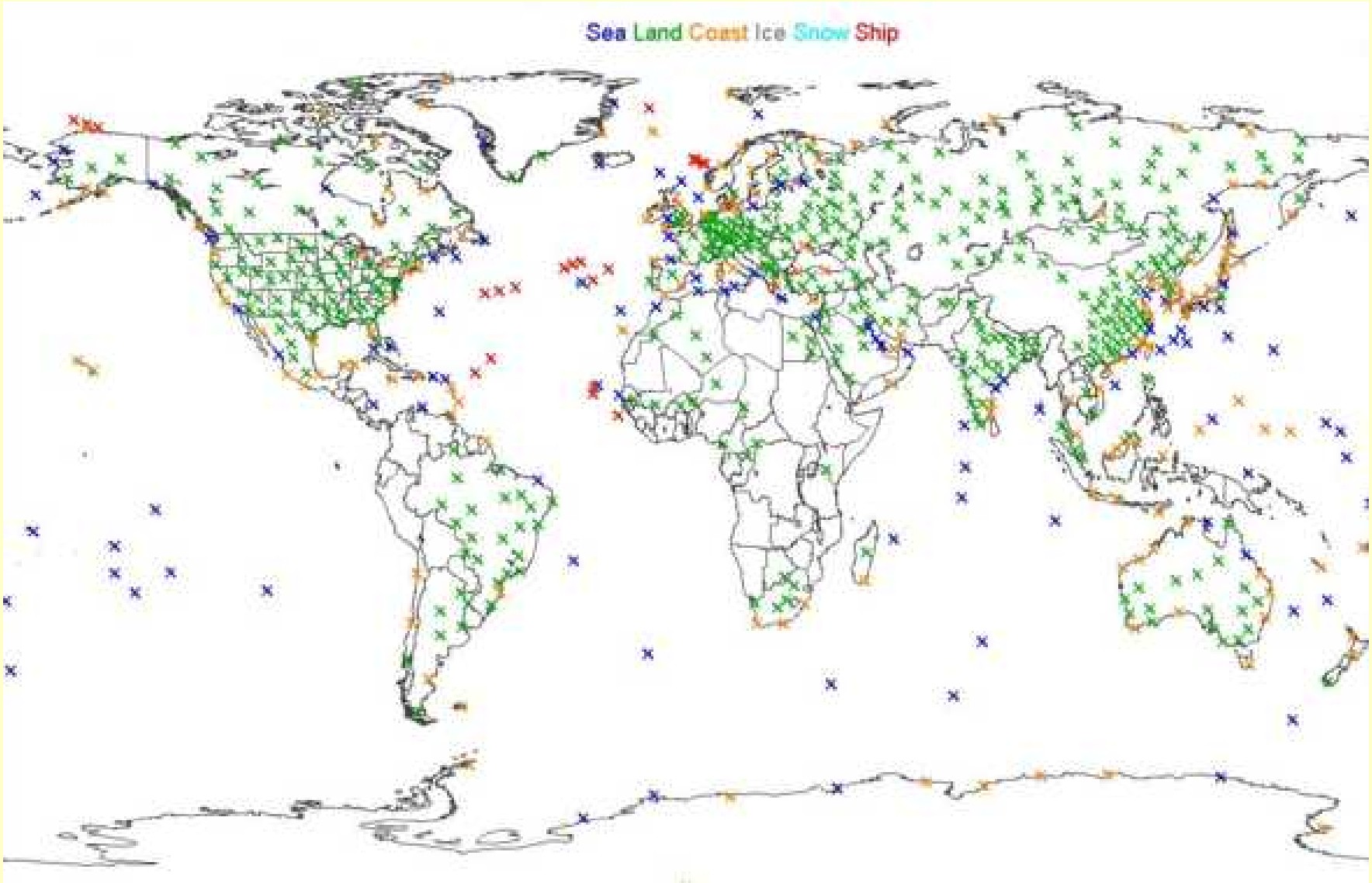
First Guess Regression (cont)

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

- 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

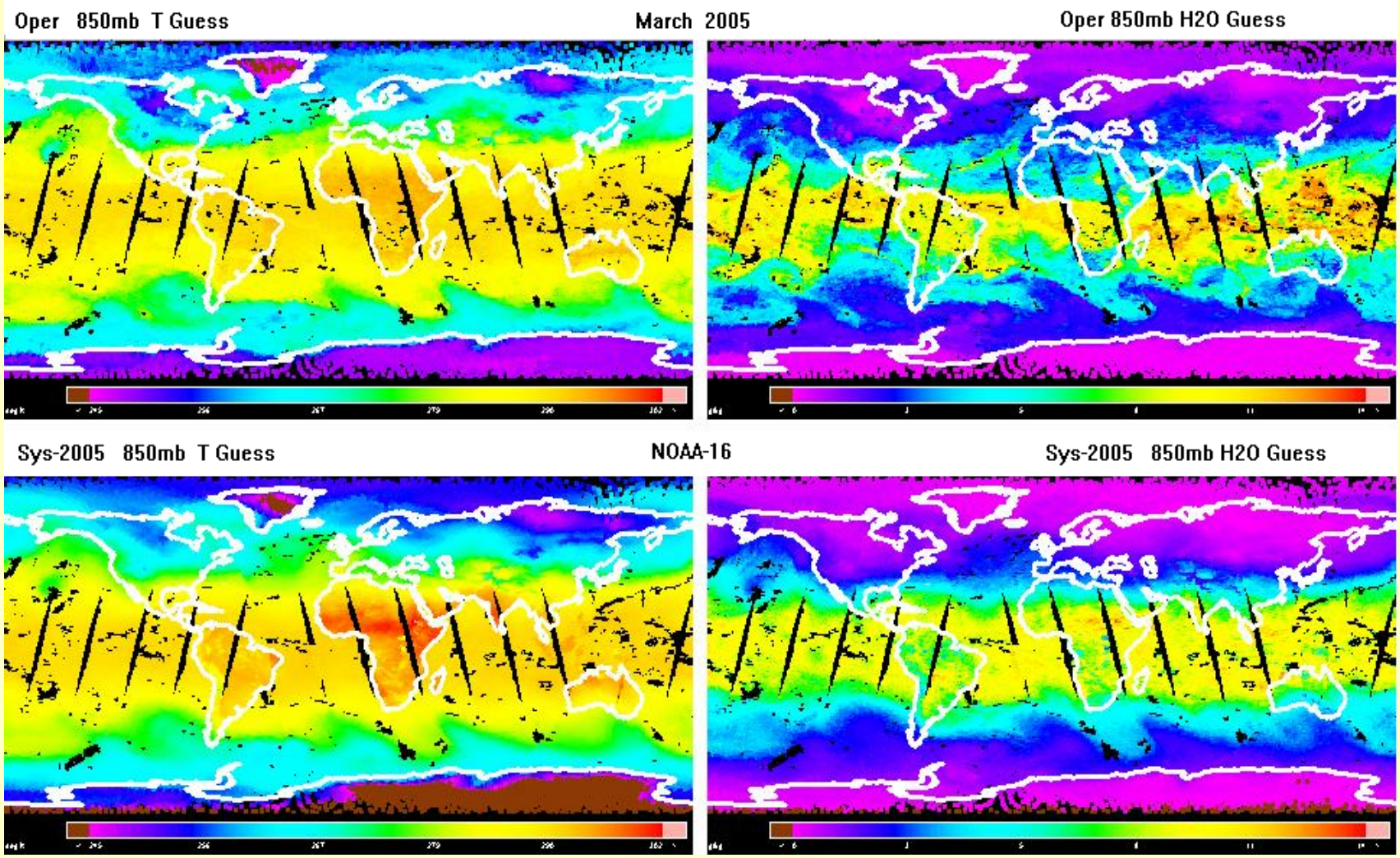
First Guess Regression (cont)

Online:

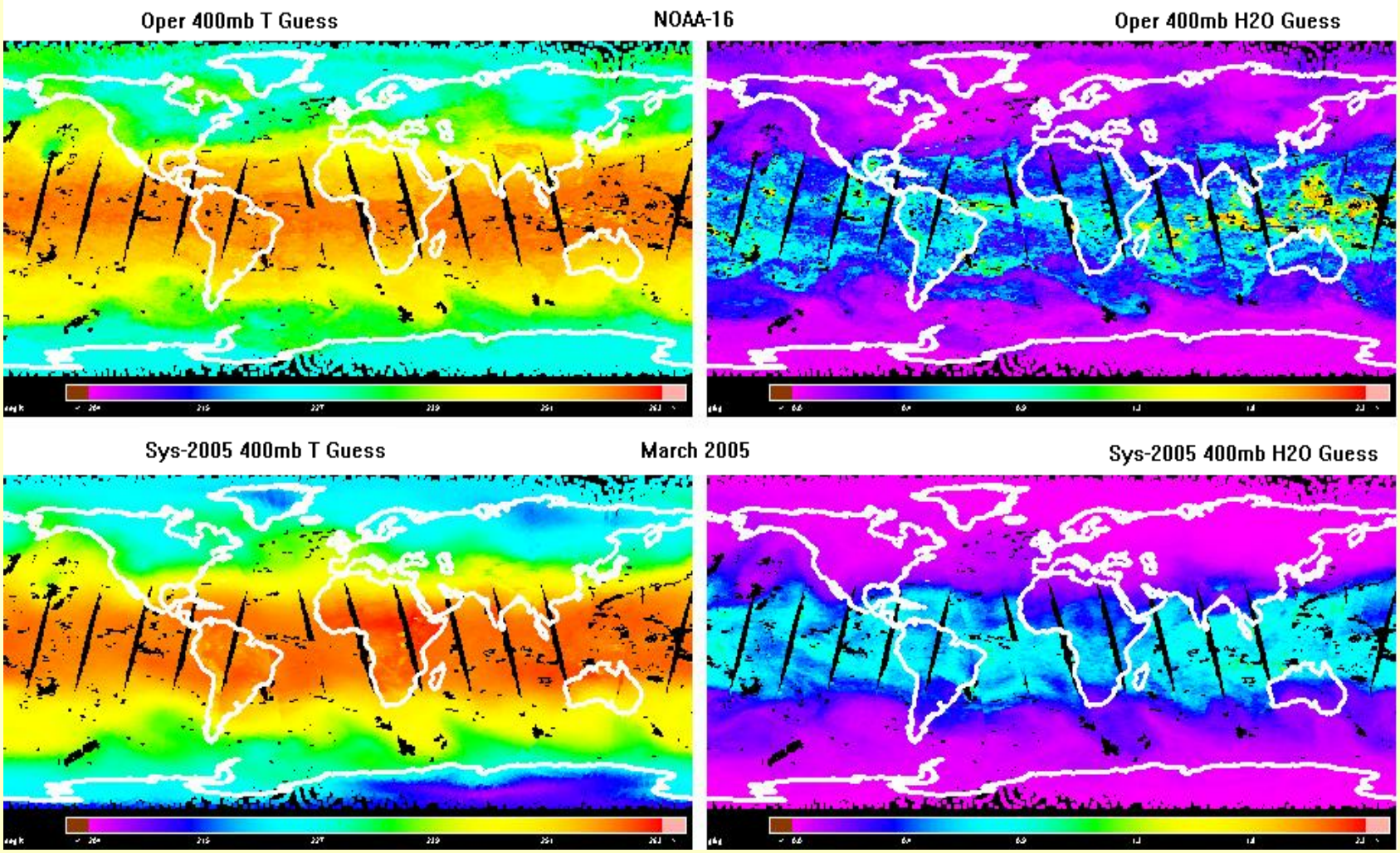
- –Coefficients applied to obtain first guess temperature (T) and water vapor mixing ratio (q)

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

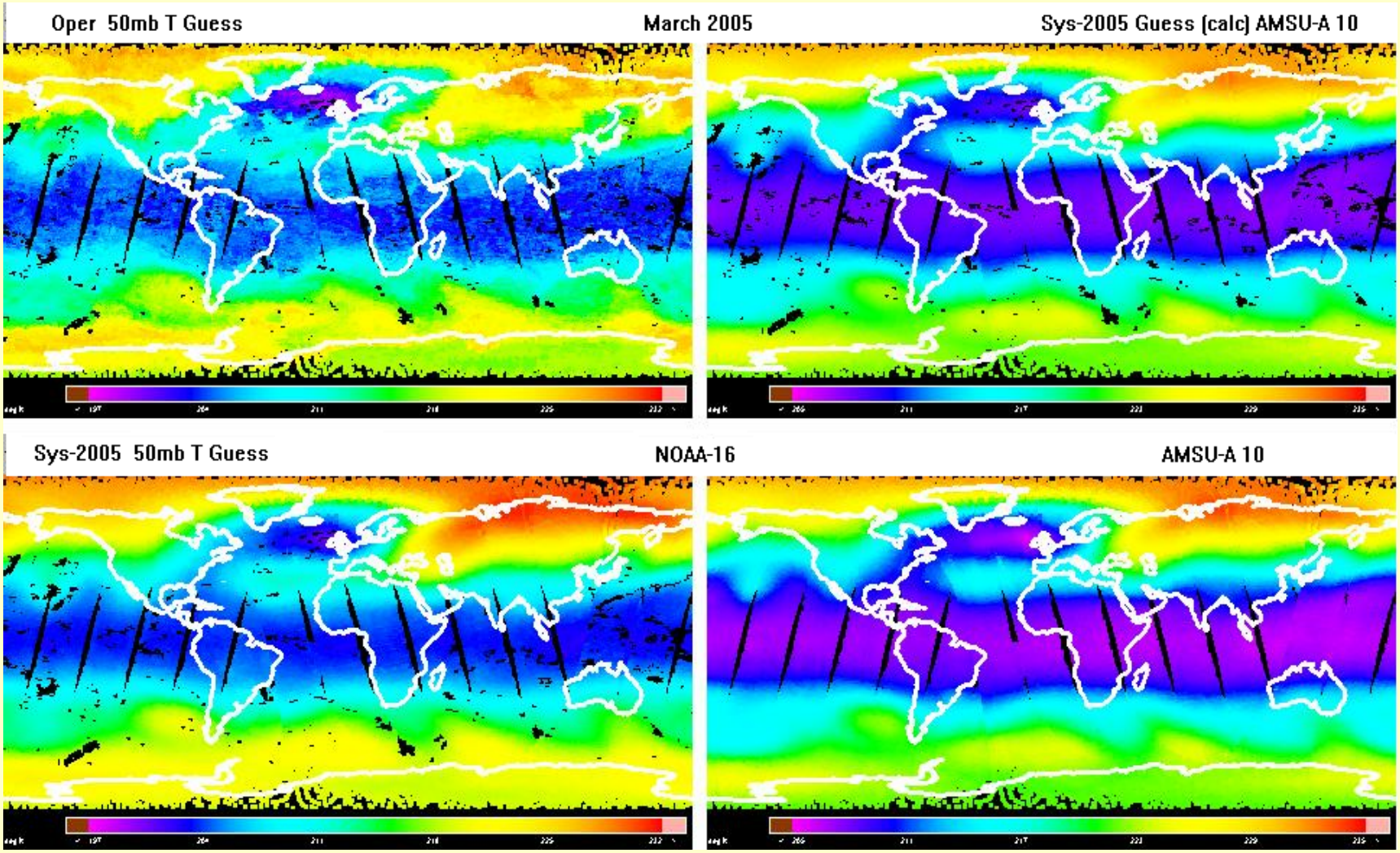
Regression vs. Library Search Guess



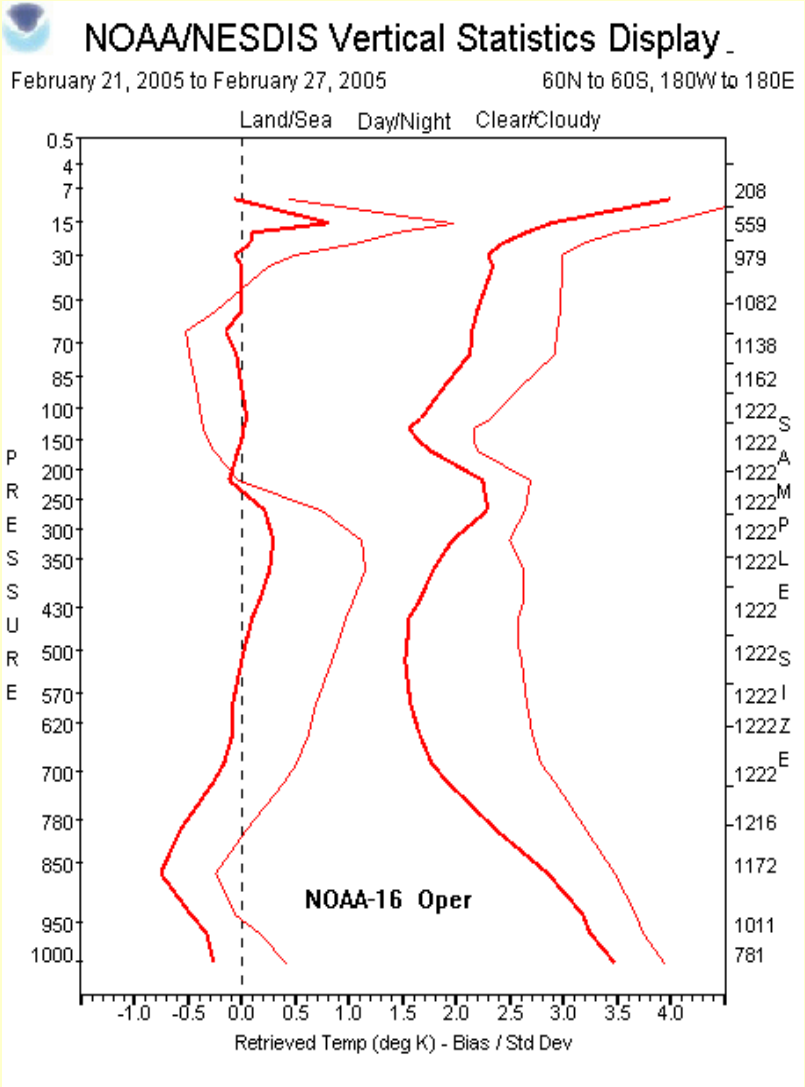
Regression vs. Library Search Guess

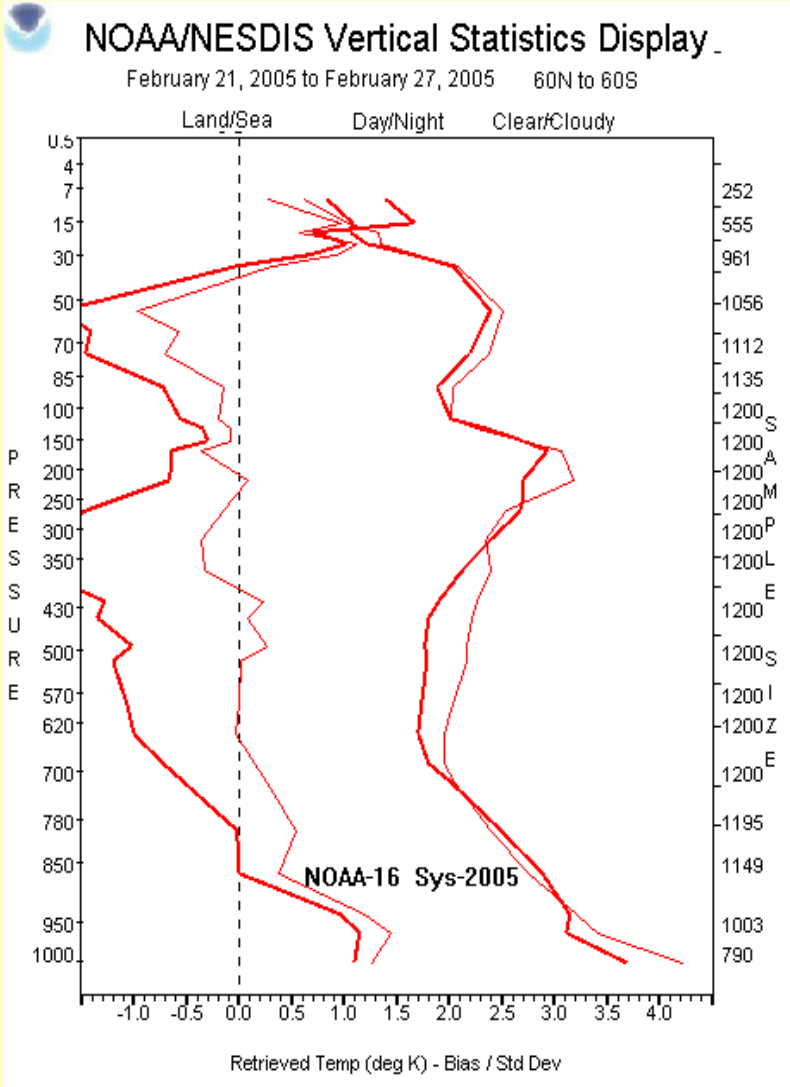


Regression vs. Library Search Guess

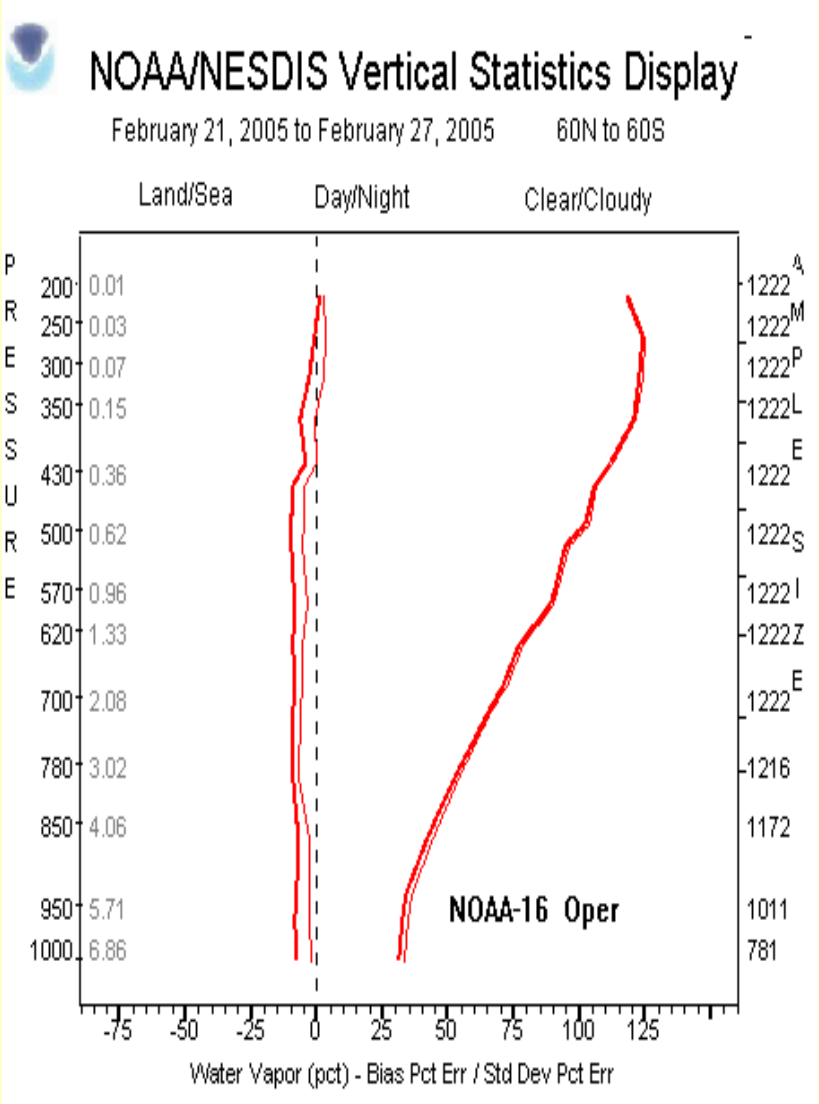


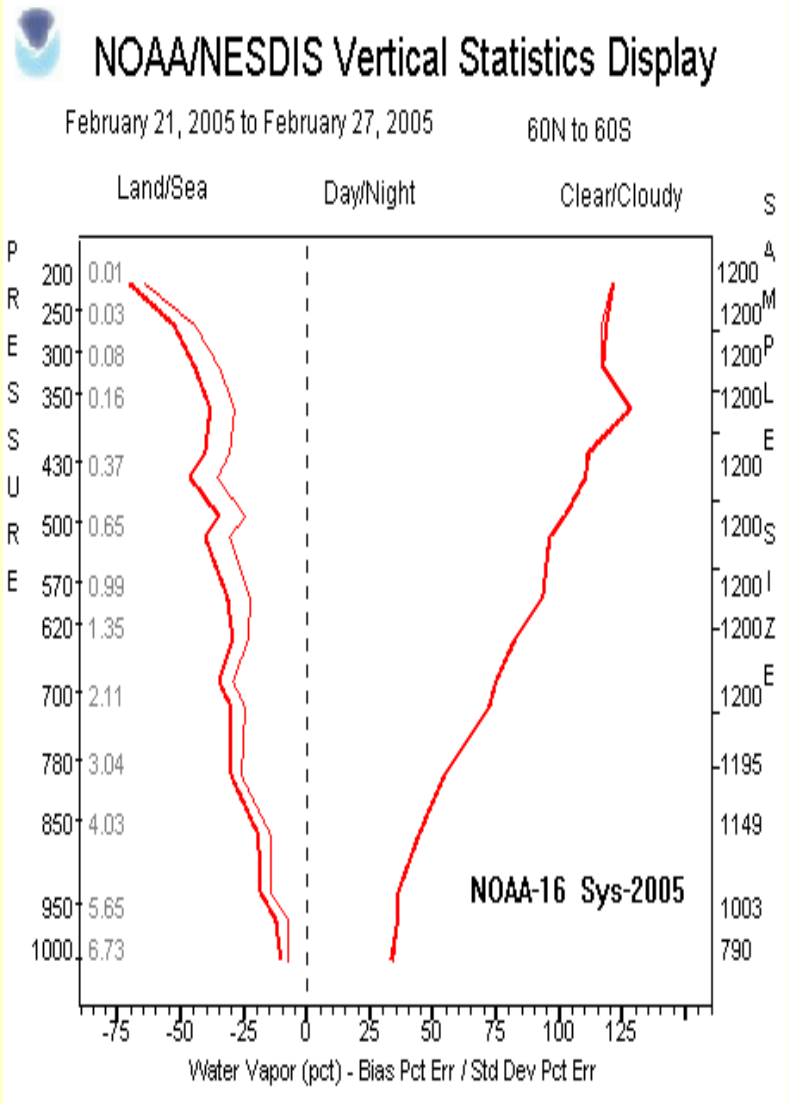
Vertical Statistics - Temperature





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 (MVS) Physical Retrieval Method

- 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

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

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 kth 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)	$A_1S_{ns}N_1$
• 45N to Ice (60N)	Sea and (Nonsea) (2)	$A_2S_sN_2$, $A_2S_{ns}N_2$
• 30N to 45N	Sea and Nonsea (3)	$A_3S_sN_3$, $A_3S_{ns}N_3$
• 15N to 30N	Sea and Nonsea (4)	$A_4S_sN_4$, $A_4S_{ns}N_4$
• 15S to 15N	Sea and Nonsea (5)	$A_5S_sN_5$, $A_5S_{ns}N_5$
• 15S to 30S	Sea and Nonsea (6)	$A_6S_sN_6$, $A_6S_{ns}N_6$
• 30s to 45S	Sea and Nonsea (7)	$A_7S_sN_7$, $A_7S_{ns}N_7$
• 45S to Ice (60N)	Sea and (Nonsea) (8)	$A_8S_sN_8$, $A_8S_{ns}N_8$
• 60S to 90S	Sea-ice and Nonsea (9)	$A_9S_{ns}N_9$

* 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)

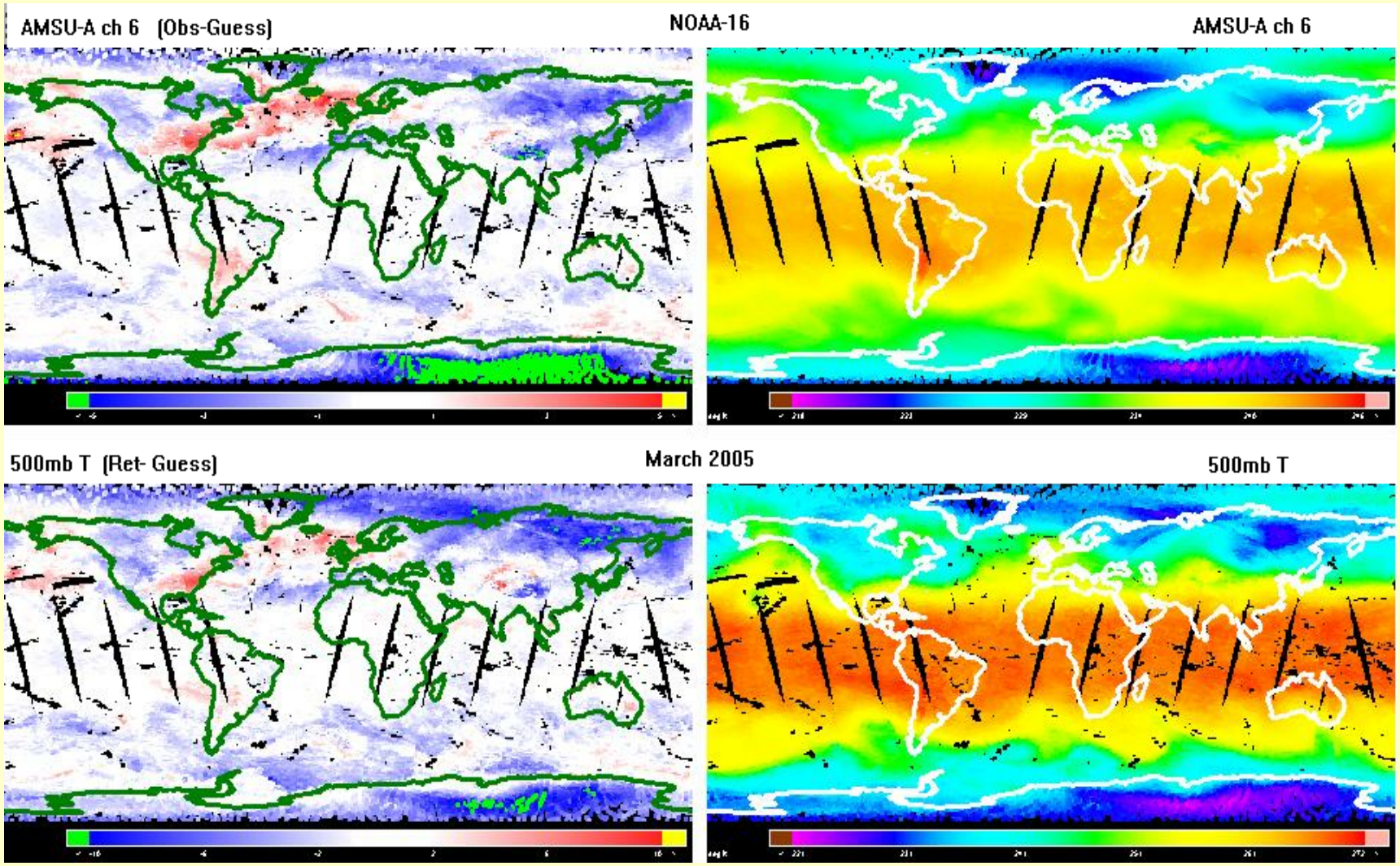
$$(T - Tg)_j = S A^t (A S A^t + N)^{-1} (R - Rg)_i$$

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-200X Science

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- Regression Guess replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)
- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS
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  - based on Guess temp and Moisture
- Peripheral Upgrades
  - Limb-adjustment
  - Expanded validation

Forward-Jacobian Models

Forward Model

- Community Radiative Transfer Model (CRTM) 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. CRTM)

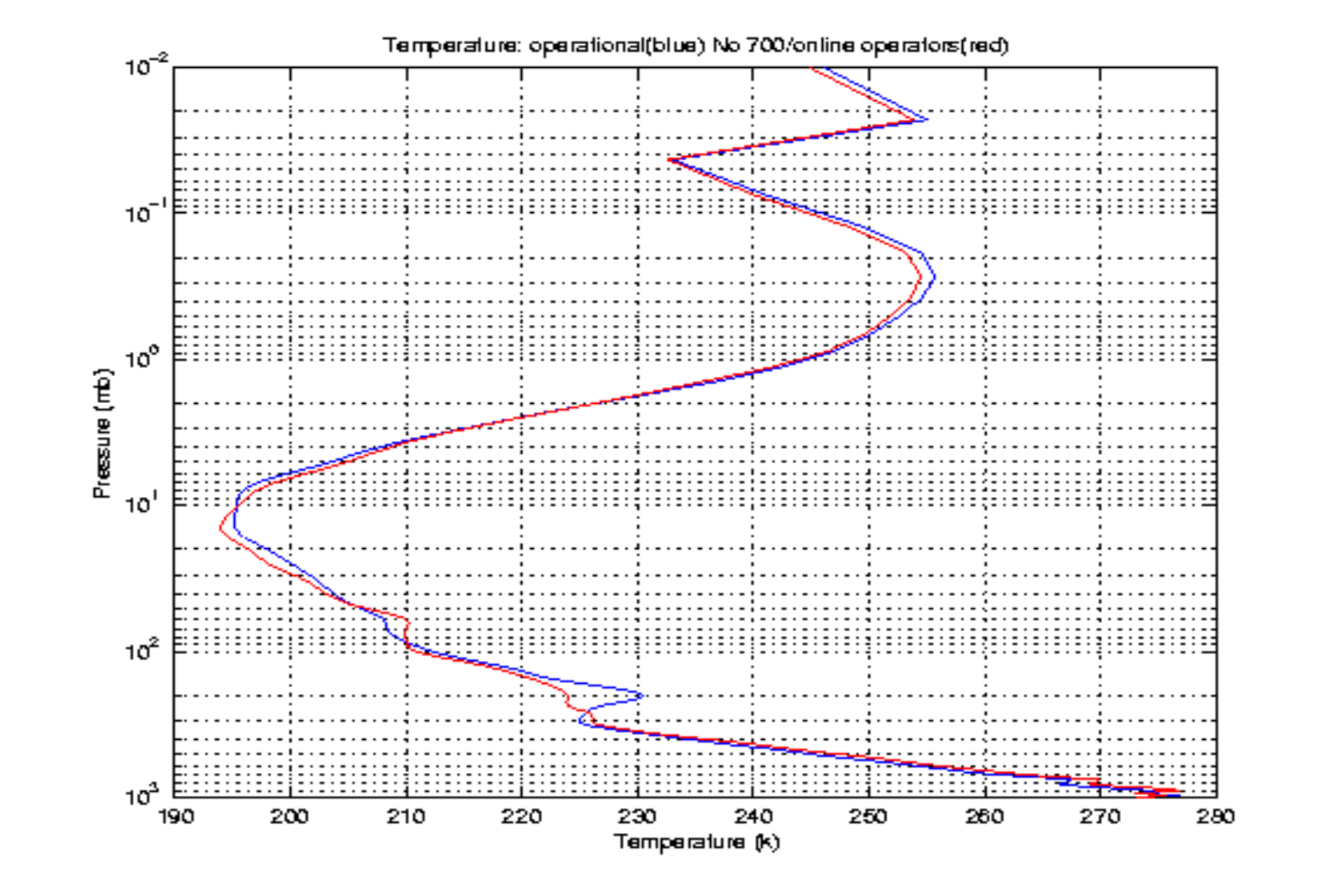
- Hosted as a subroutine in the Offline radiance bias coefficient generation sub-system and in the Online first guess radiance temperature calculations

- *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:

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

- **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

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

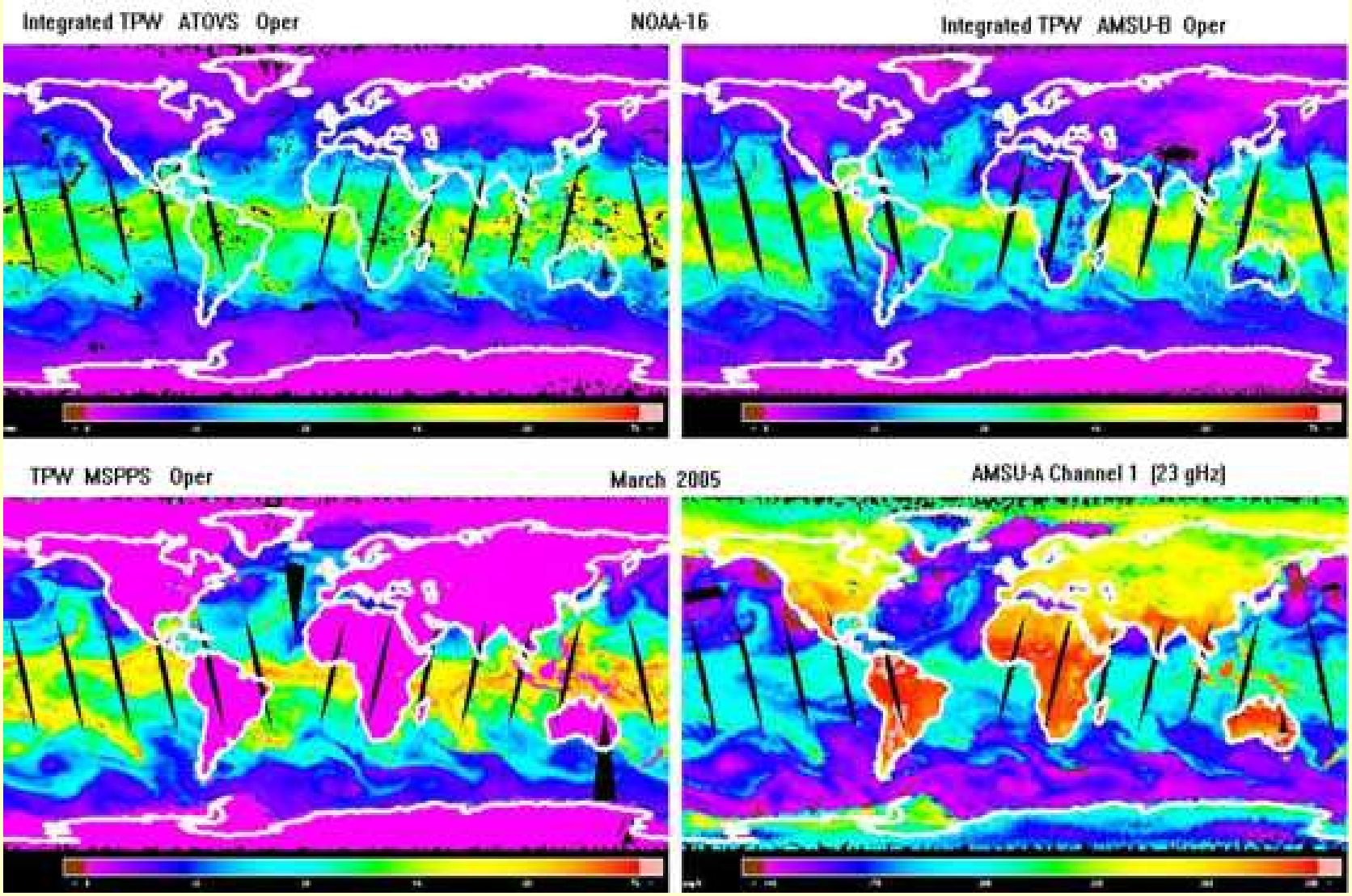
… *there are many questions and much potential for improvement* ***once the basic capability is installed and operating as designed:***

- 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

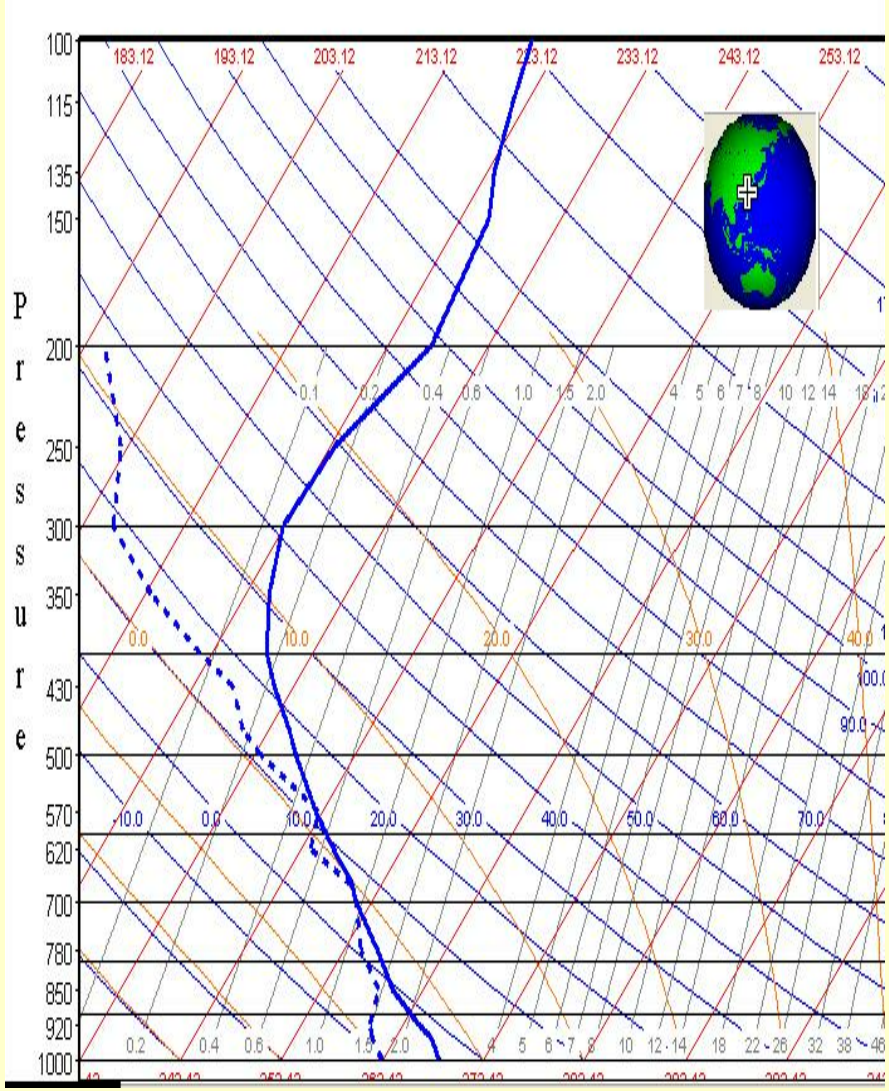
- Retrieval on slant path
  - RT bias adjustment?
- Iteration
  - convergence testing?
  - S and N matrix adjustment?

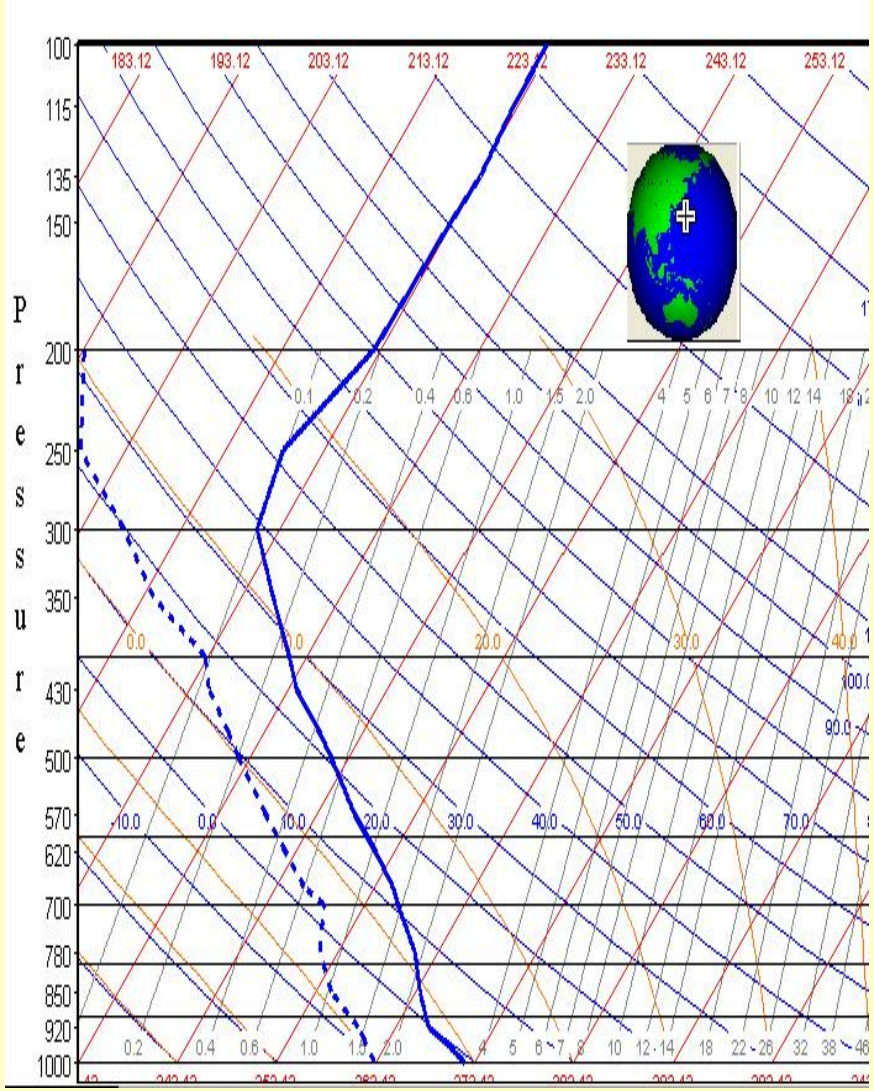
MSPPS TPW as Constraint for Moisture Retrieval

(NESDIS internal product inconsistency)



Which is the Clear, Which is the Cloudy ?





ATOVS System-200X Science

- Incorporate AMSU-B
- Regression Guess replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)
- Measurement (Radiance) Bias Adjustment (Shrink)
  - 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 200X - 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: 2-7,10-16, 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

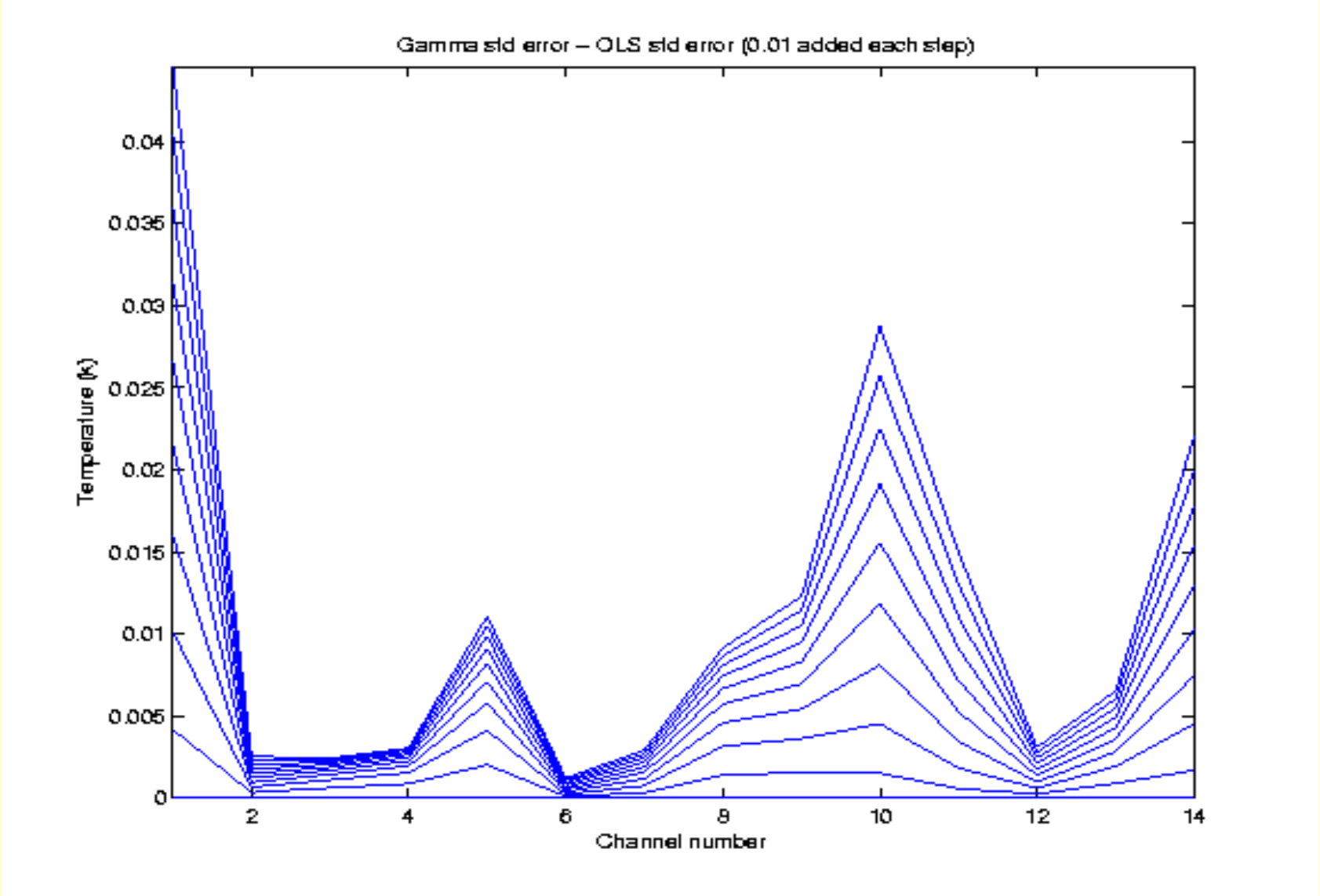
- Shrinkage estimator requires “tuning of gamma” as trade between stable coefficients and increasing residual variances.

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

where :

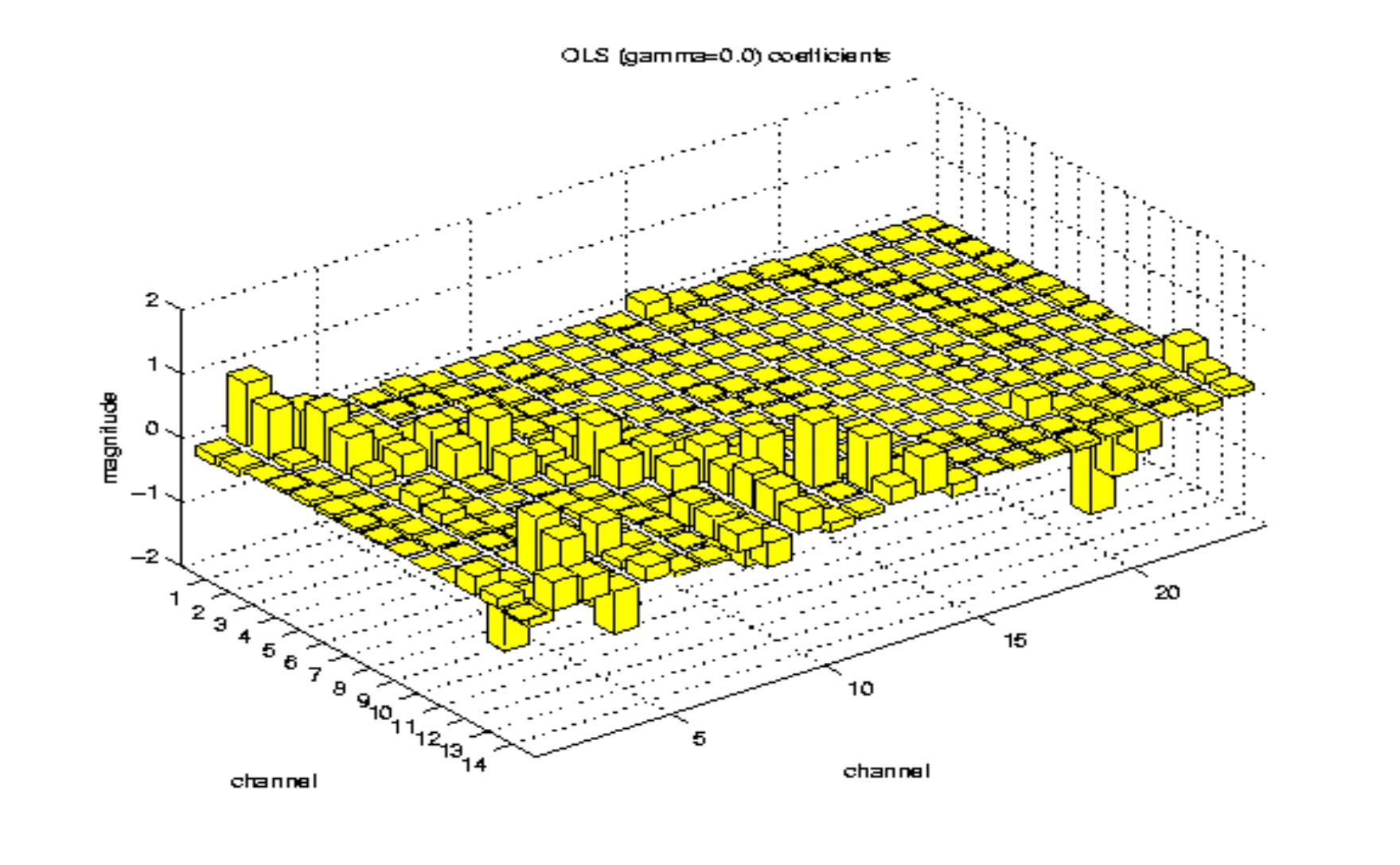
I	identity matrix
C_0	initial estimate of C (identity matrix)
S_{yx}	covariance (predictand/predictor)
S_{xx}	covariance (predictor/predictor)

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



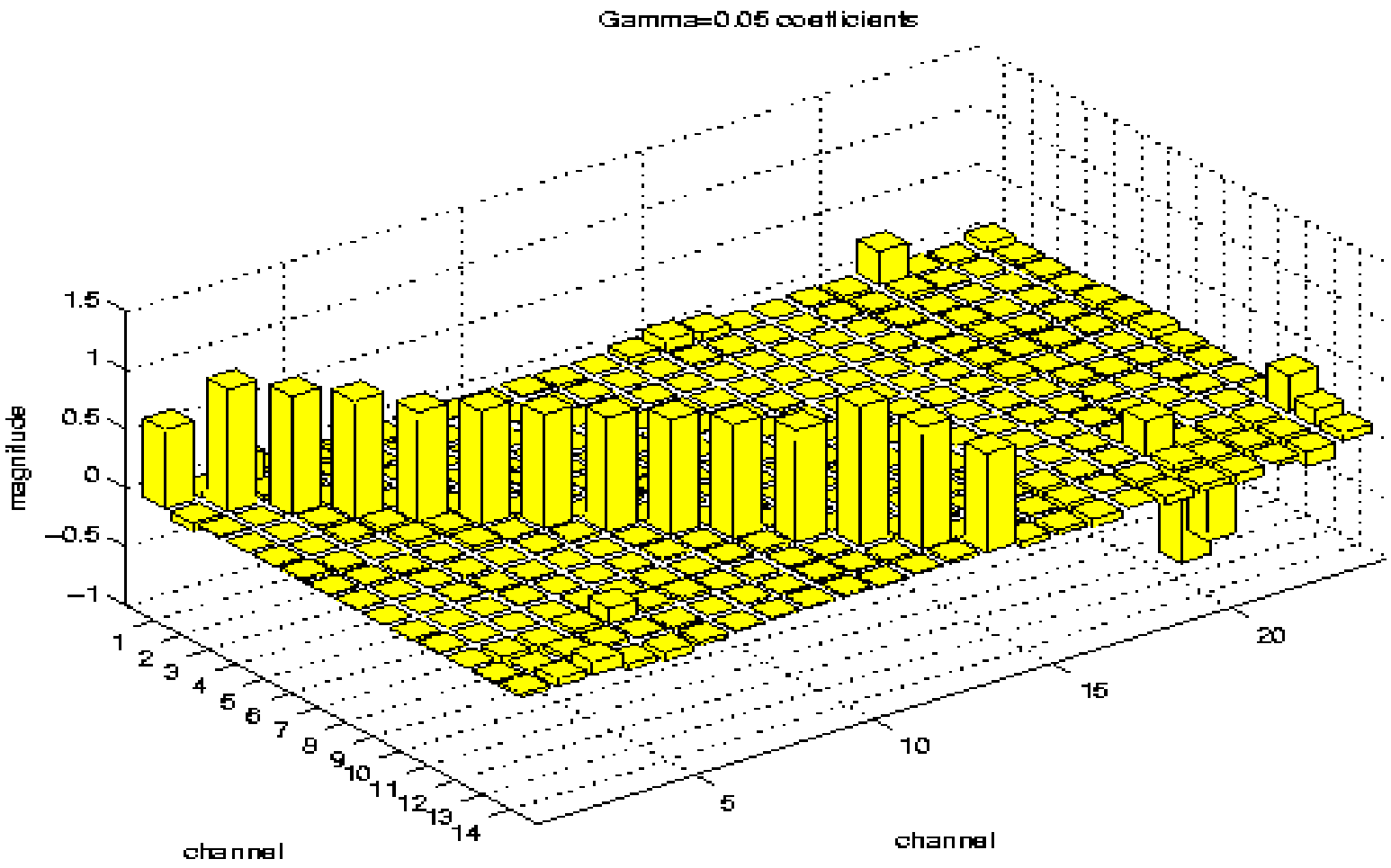
RT Bias Coefficients

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



RT Bias Coefficients

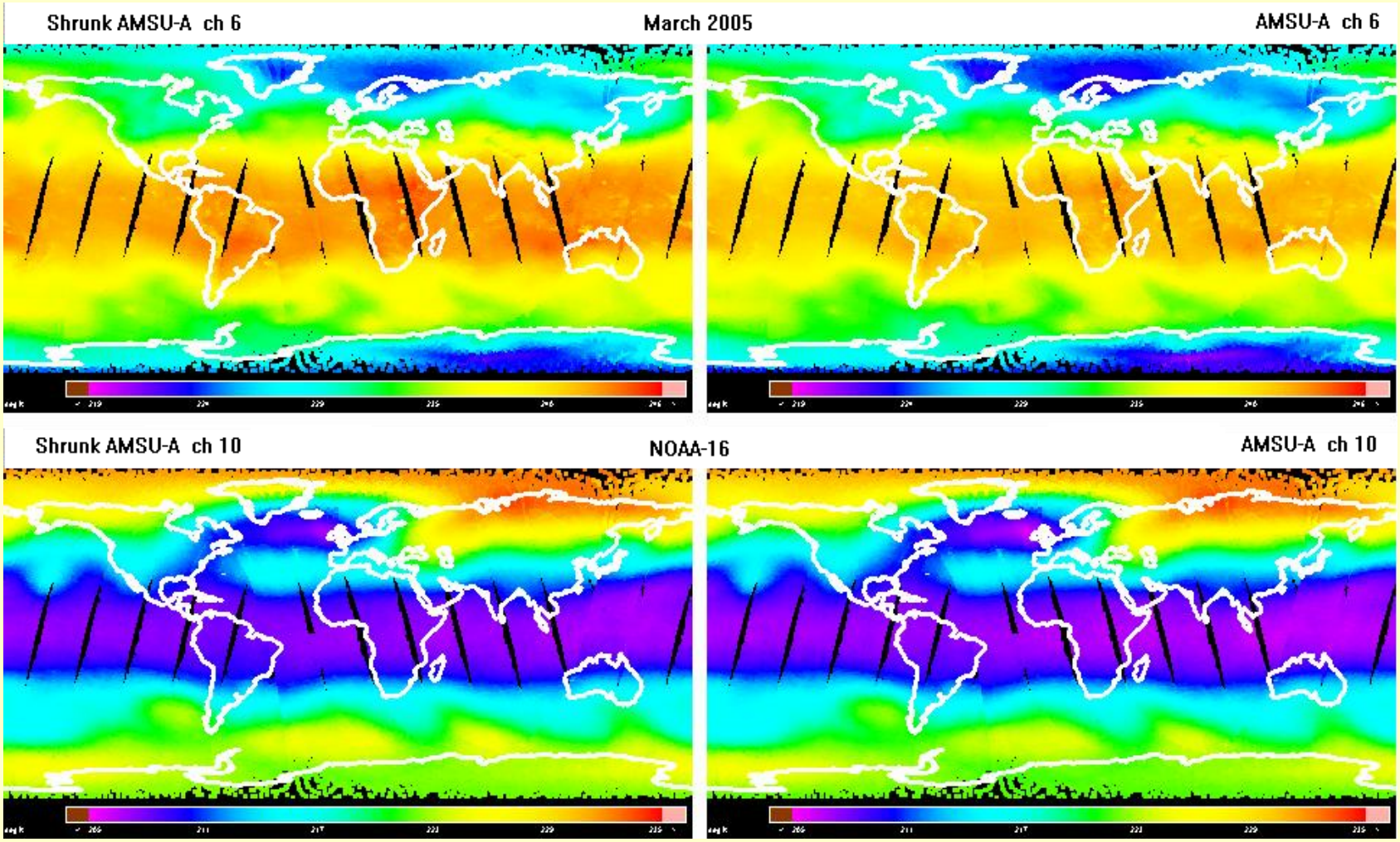
(Gamma=0.05 ; AMSU-A ch 4-14; AMSU-B ch 3,4,and 5)



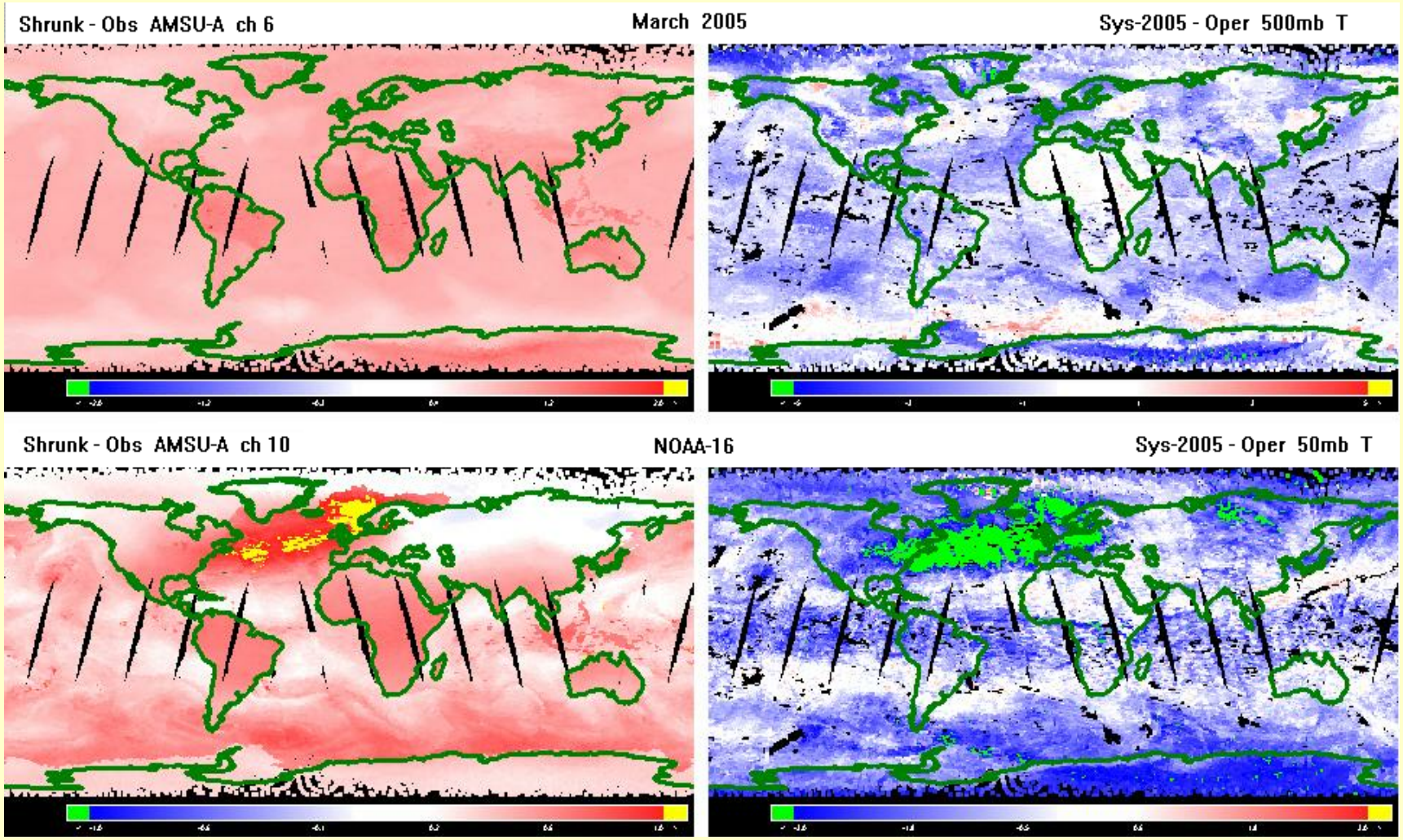
Radiance Bias Correction

Results

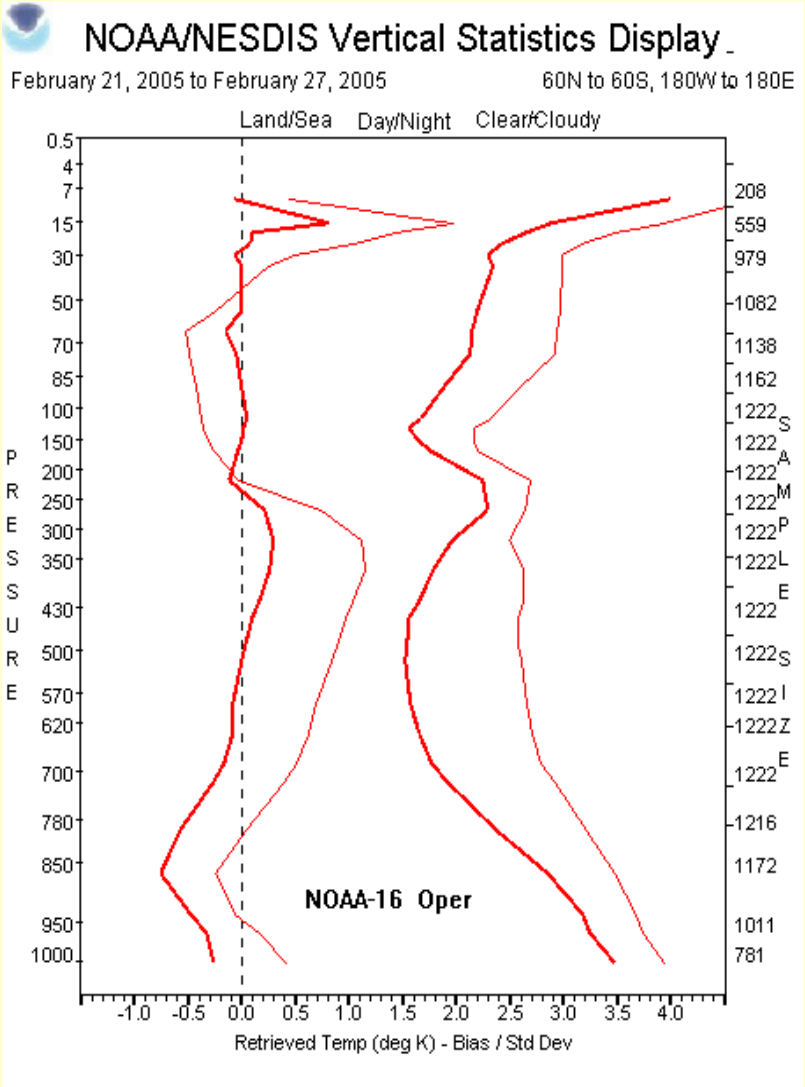
Bias Adjusted (Shrunk) AMSU-A

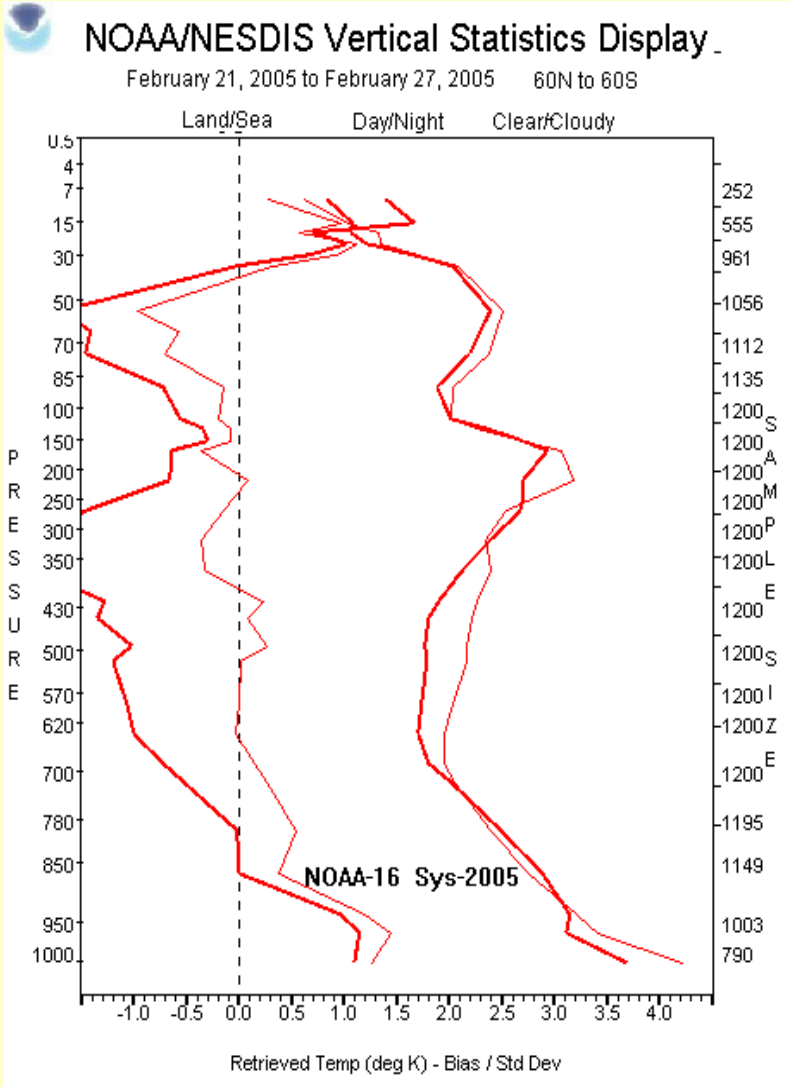


Potential Positive Impacts of Bias Adjustments

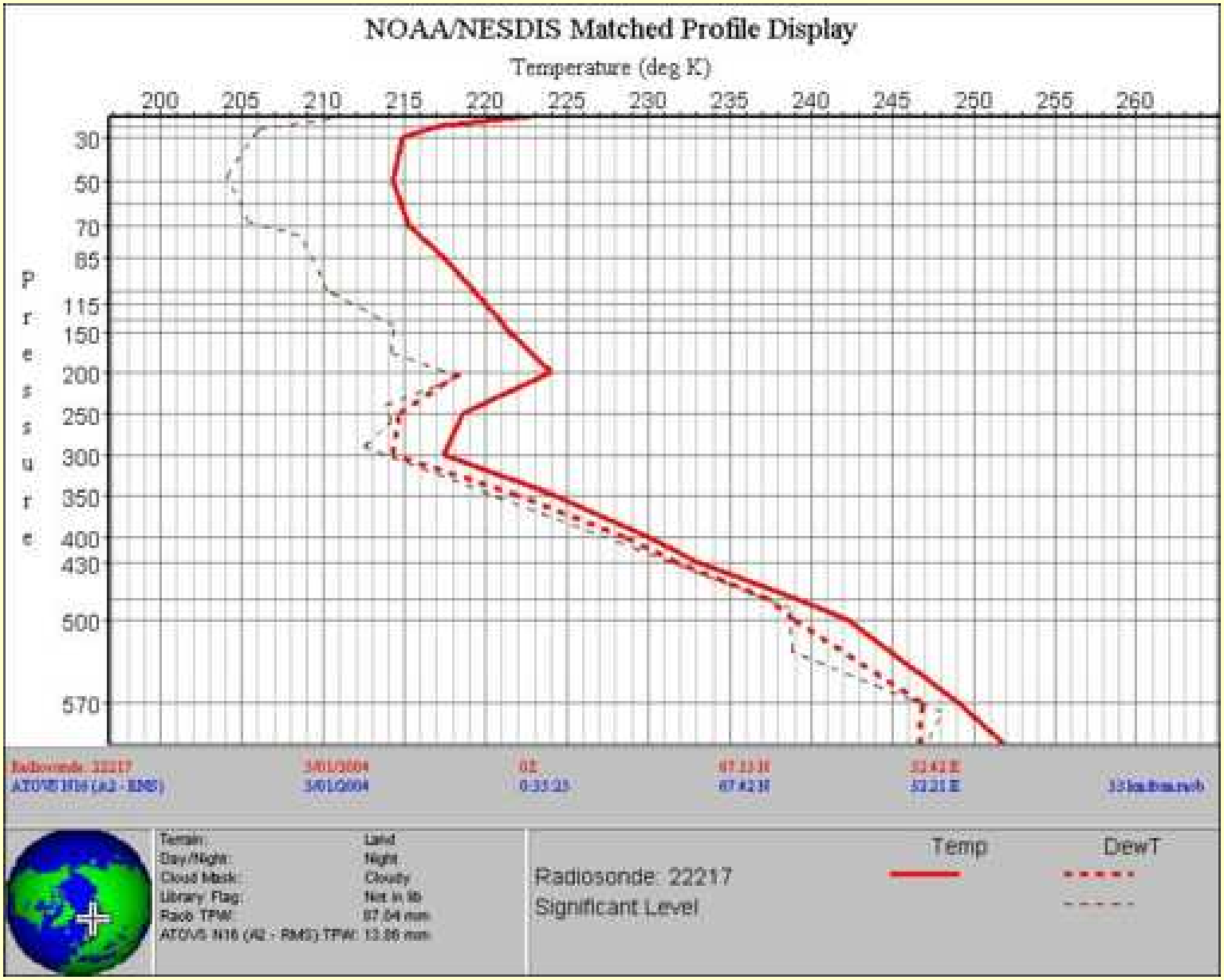


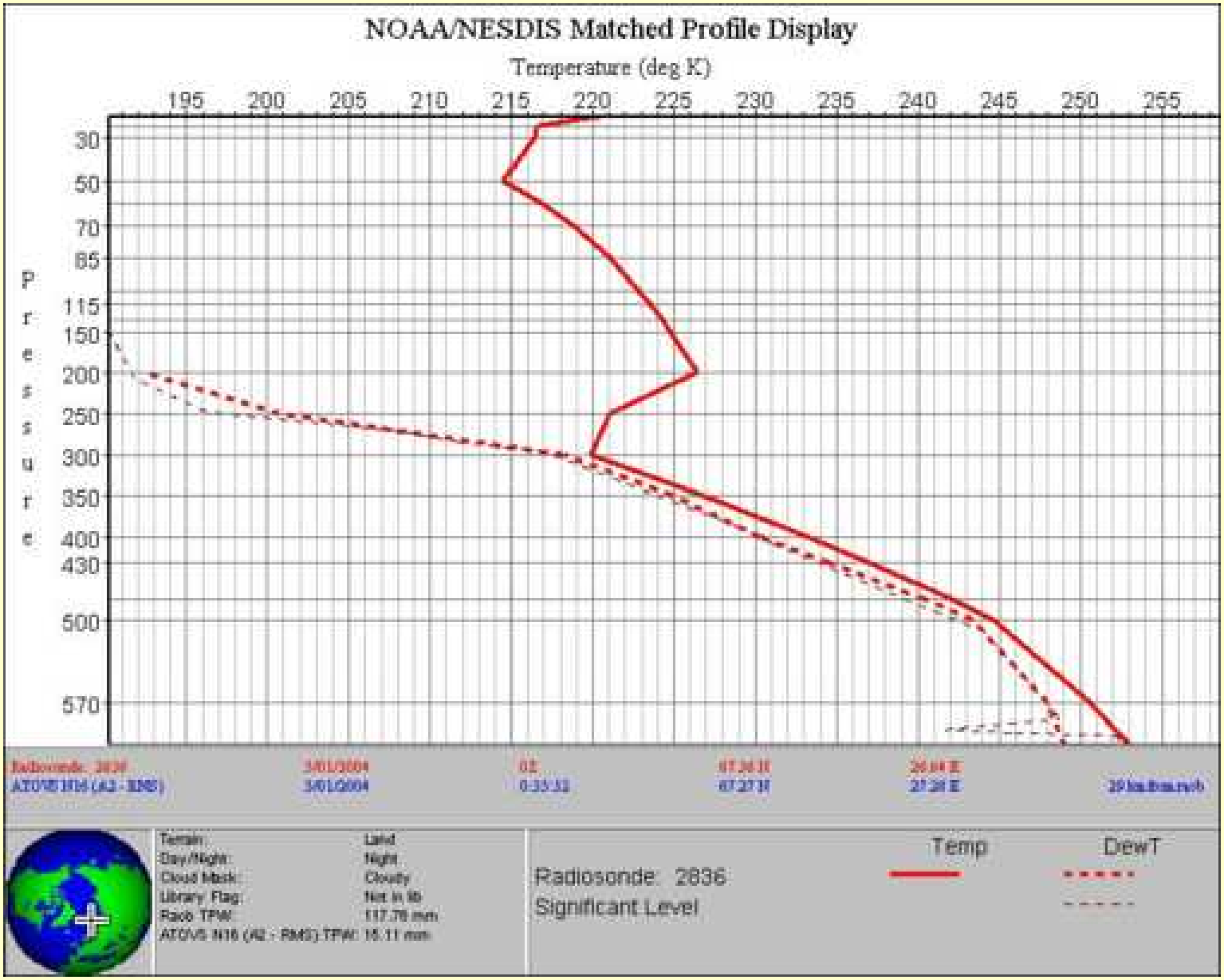
Vertical Statistics - Temperature

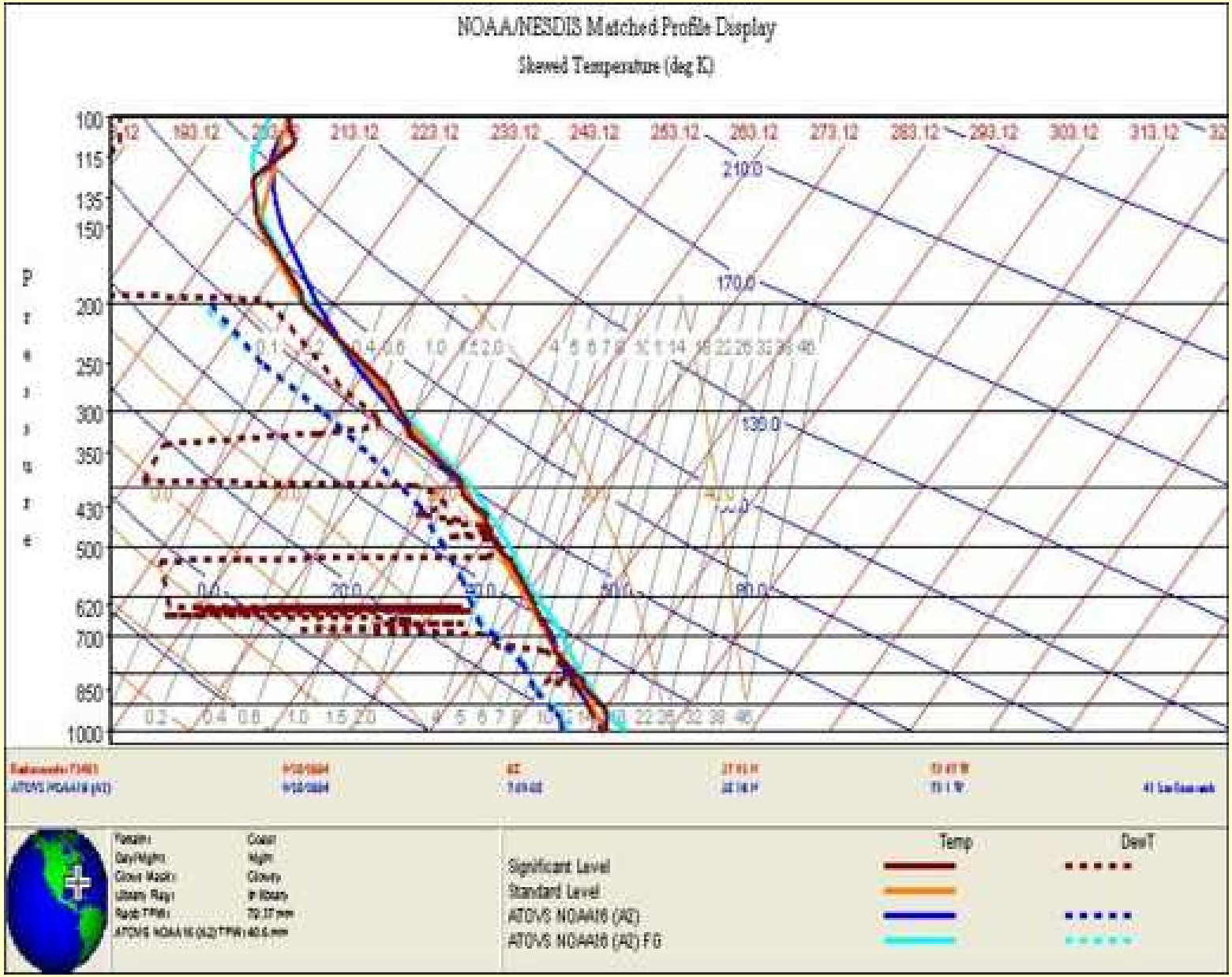




Radiosonde Moisture Profile Errors


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
Terrain: Land
Day/Night: Night
Cloud Mask: Cloudy
Library Flag: Not in lib
Raob TPW: 07.04 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
Terrain: Land
Day/Night: Night
Cloud Mask: Cloudy
Library Flag: Not in lib
Raob TPW: 117.78 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
Temp
DewT
Significant Level
Standard Level
ATOVS NOAA16 (AD)
ATOVS NOAA16 (AD) FG

ATOVS System-200X 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-200X Data Capture and Validation

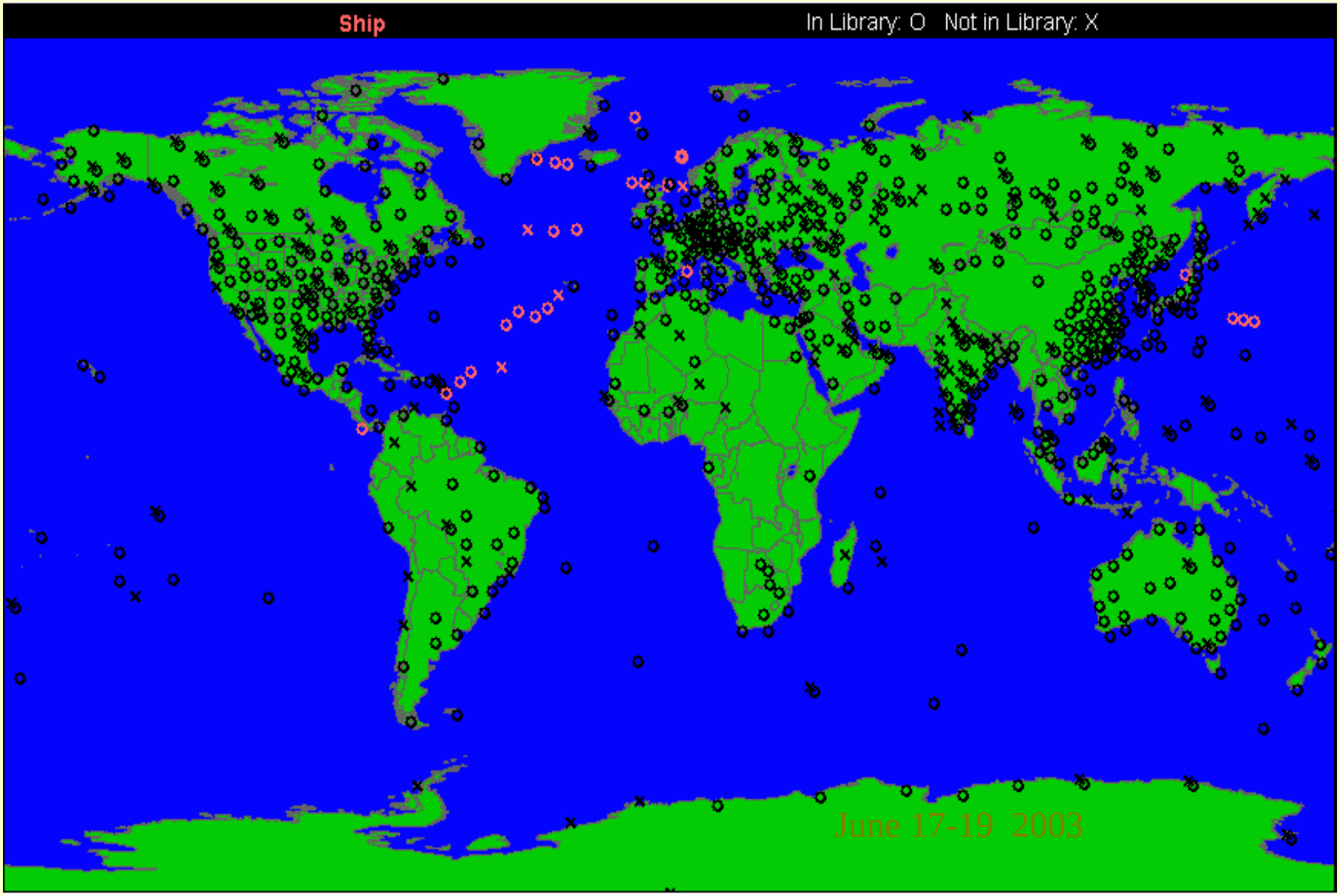
- Sys-2005 expanded to access operationally supported NCEP PREPBUFR Radiosondes
- Sys-2005 expanded to store complete collocated NWP
  - 3-hr GFS @ 100km (+/- 90 minutes)
- Enhanced suite of validation (measurement and product) planned … EDGE
- Possible framework for inter-satellite and product comparisons

Collocated Radiosonde and Satellite Observations provide basis for

Monitoring
Validating and
Tuning

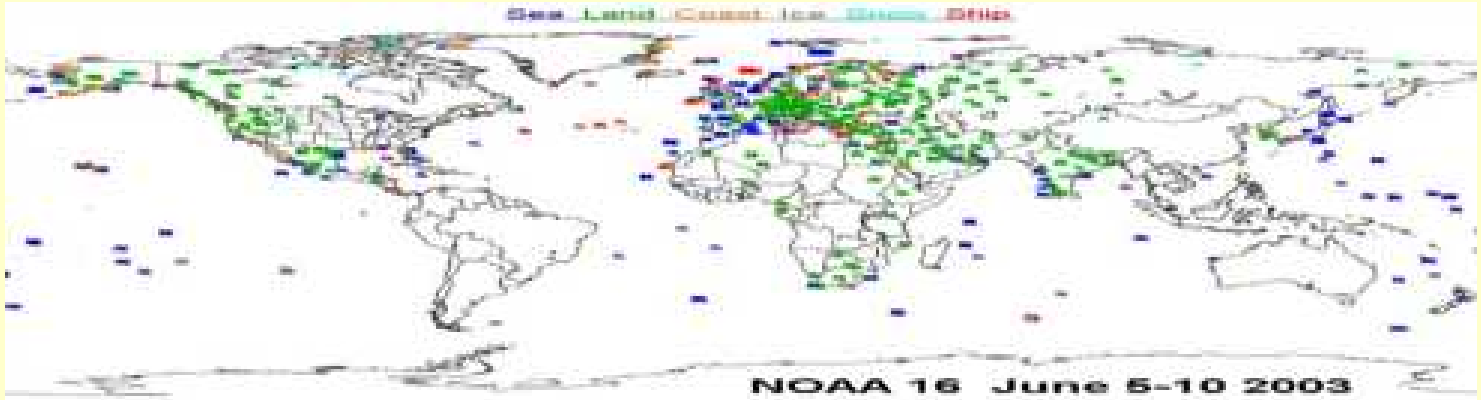
Operational Satellite Data Systems
(ATOVS)

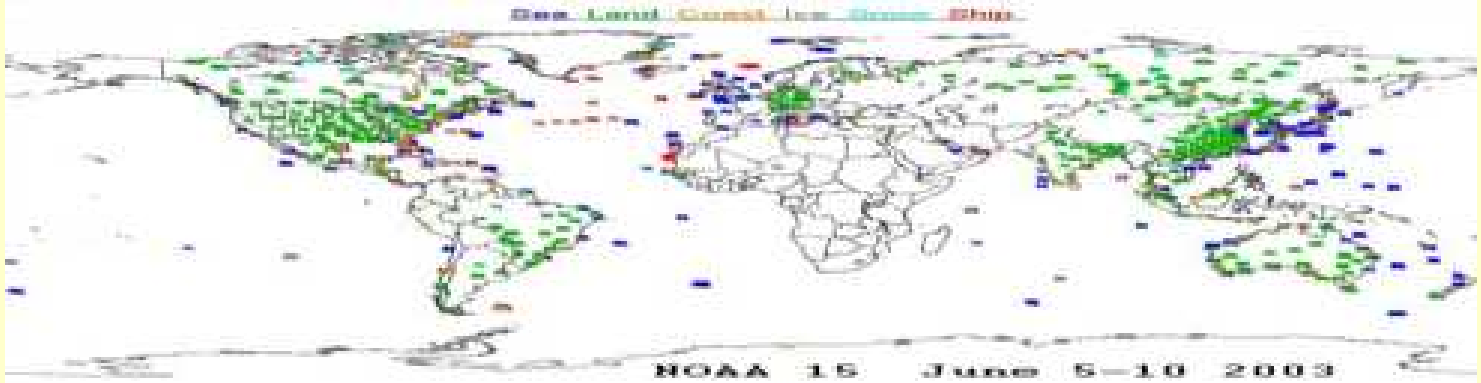
Global Radiosondes

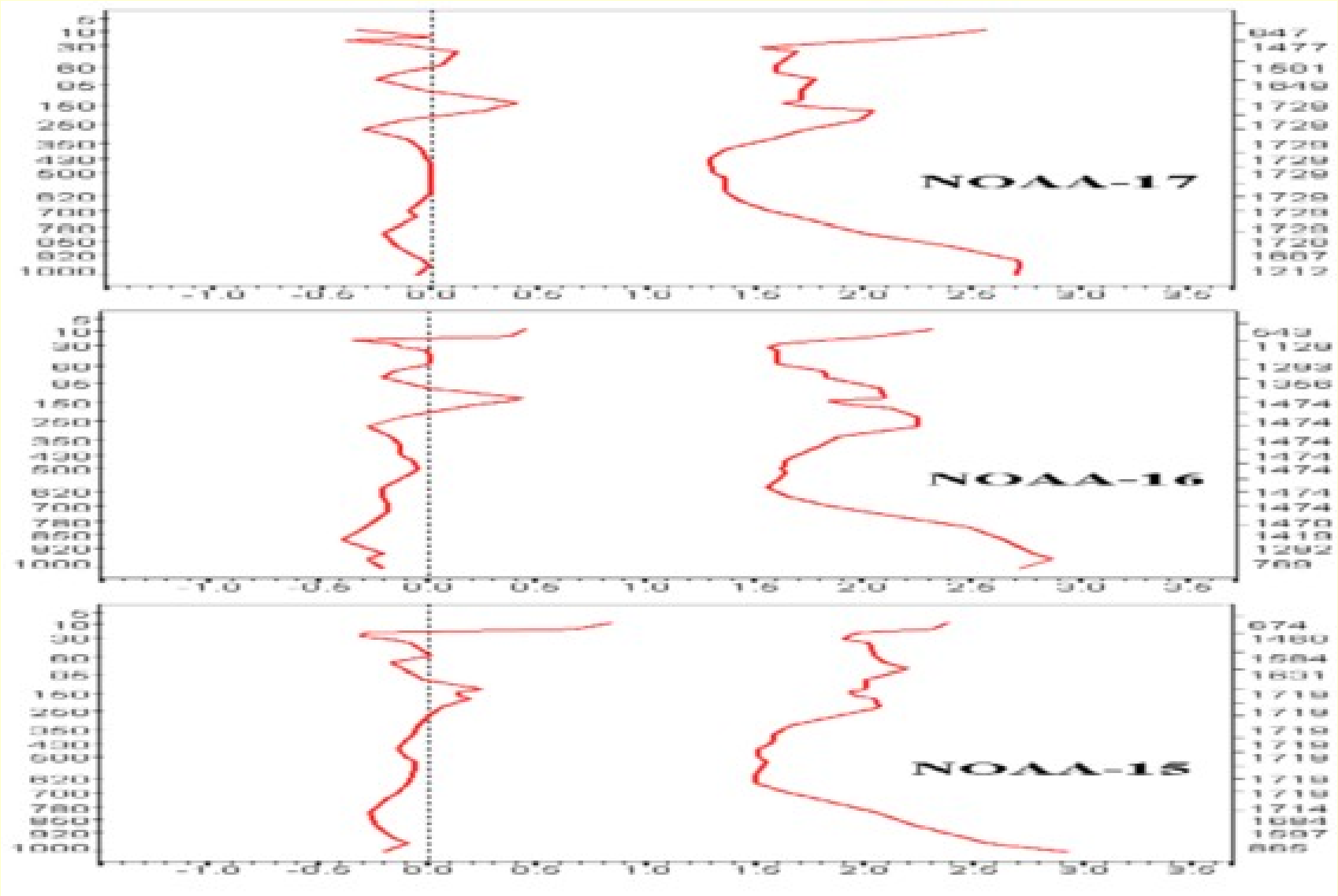


SATELLITE COLLOCATIONS (+/- 3hrs, land; +/- 5hrs, sea)

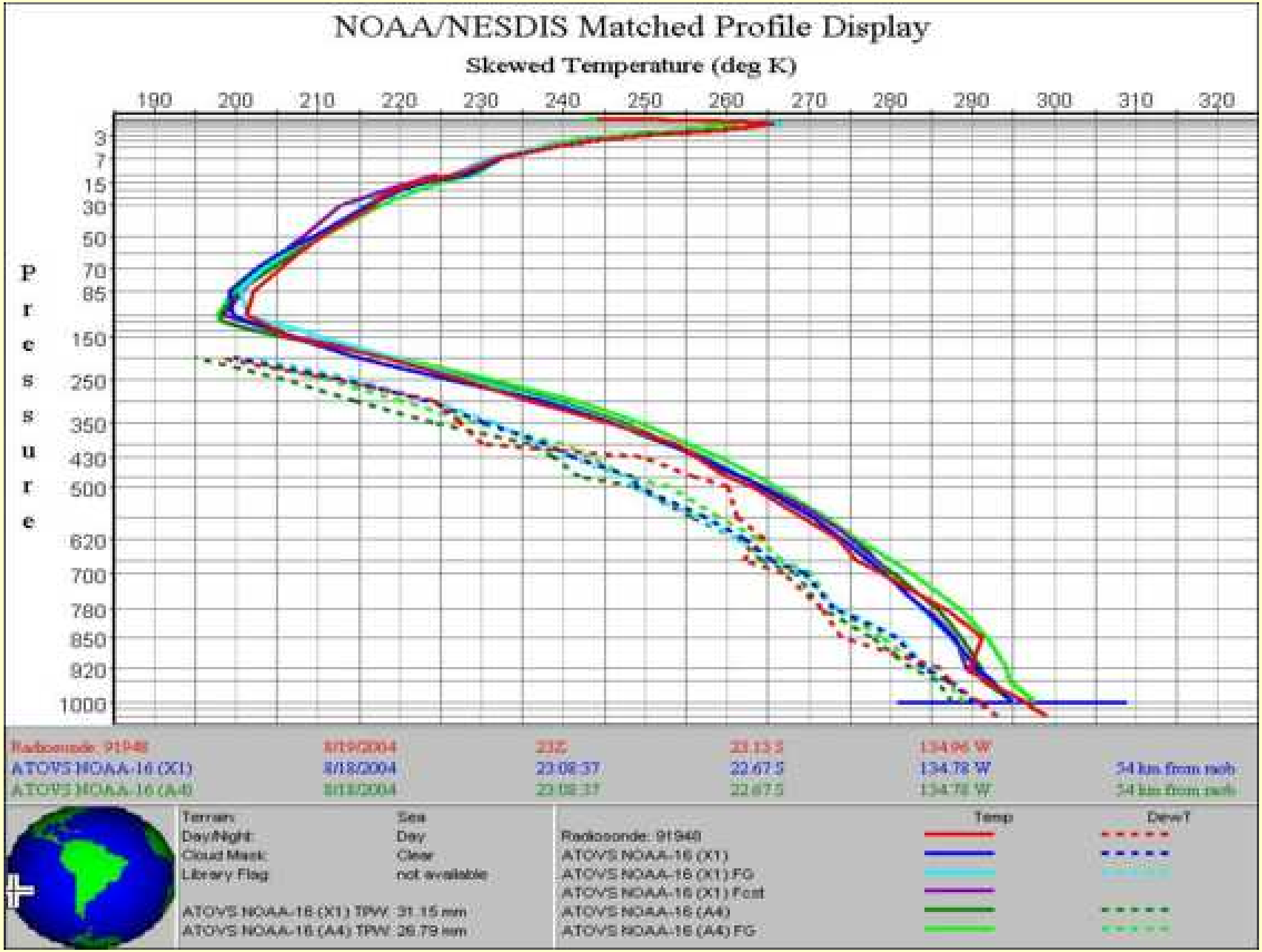
(used operationally at NESDIS)







60N to 60S

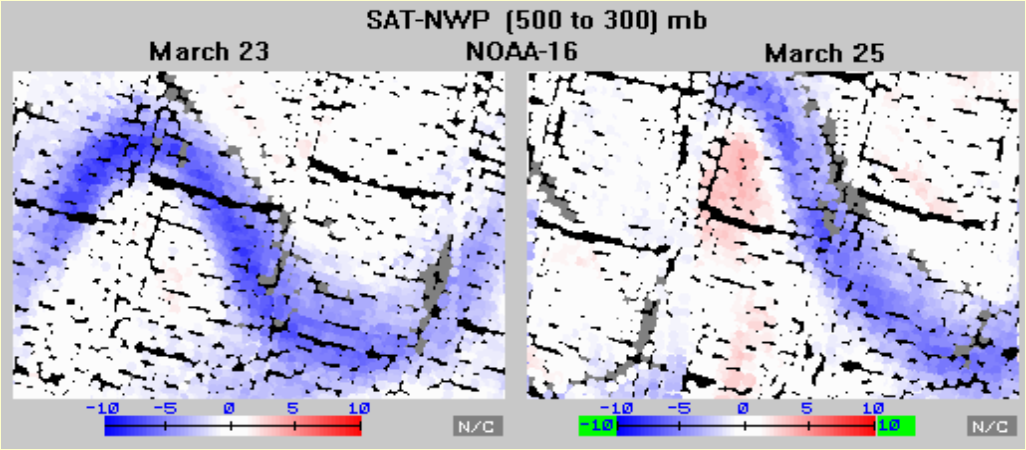

NOAA/NESDIS Matched Profile Display
Skewed Temperature (deg K)
190 200 210 220 230 240 250 260 270 280 290 300 310 320
Pressure
3 7 15 30 50 70 85 150 250 350 430 500 620 700 780 850 920 1000
Radiosonde: 91948 8/19/2004 23Z 33.13 S 134.96 W
ATOVS NOAA-16 (X1) 8/18/2004 23:08:37 22.67 S 134.78 W 54 km from rad
ATOVS NOAA-16 (A4) 8/18/2004 23:08:37 22.67 S 134.78 W 54 km from rad
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
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
Temp
DewT

Uniform Protocols for Radiosonde Screening and Use

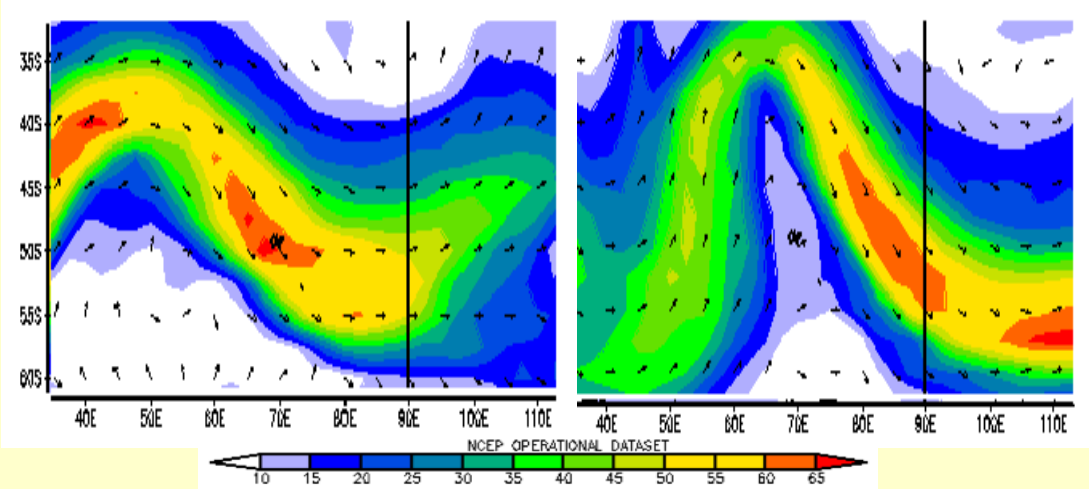
- Interpreting quality marks
- Radiation correction
- Radiosonde interpolation and extension
- Moisture screening
- Radiosonde manufacturer bias
- Collocation criteria
- Multiple satellite/product capture and validation strategies
- ARM and “Special” radiosonde observations
- Other

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

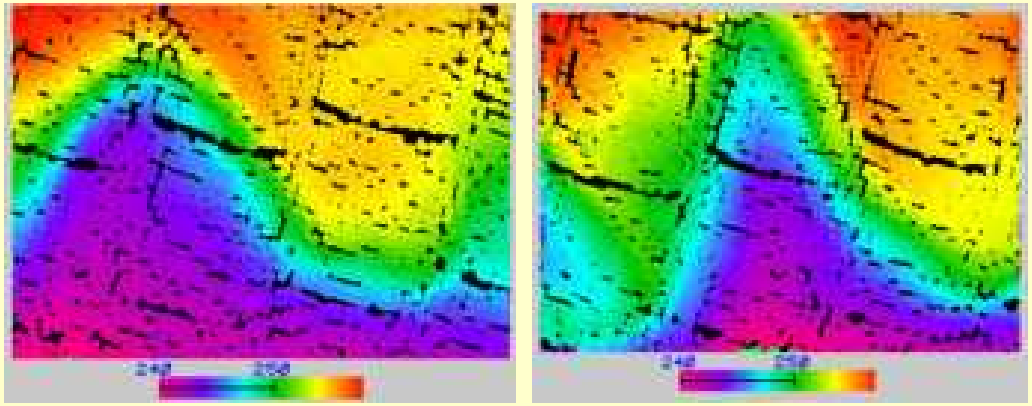


< **DIFFERENCES** between NESDIS Satellite Soundings and NWP

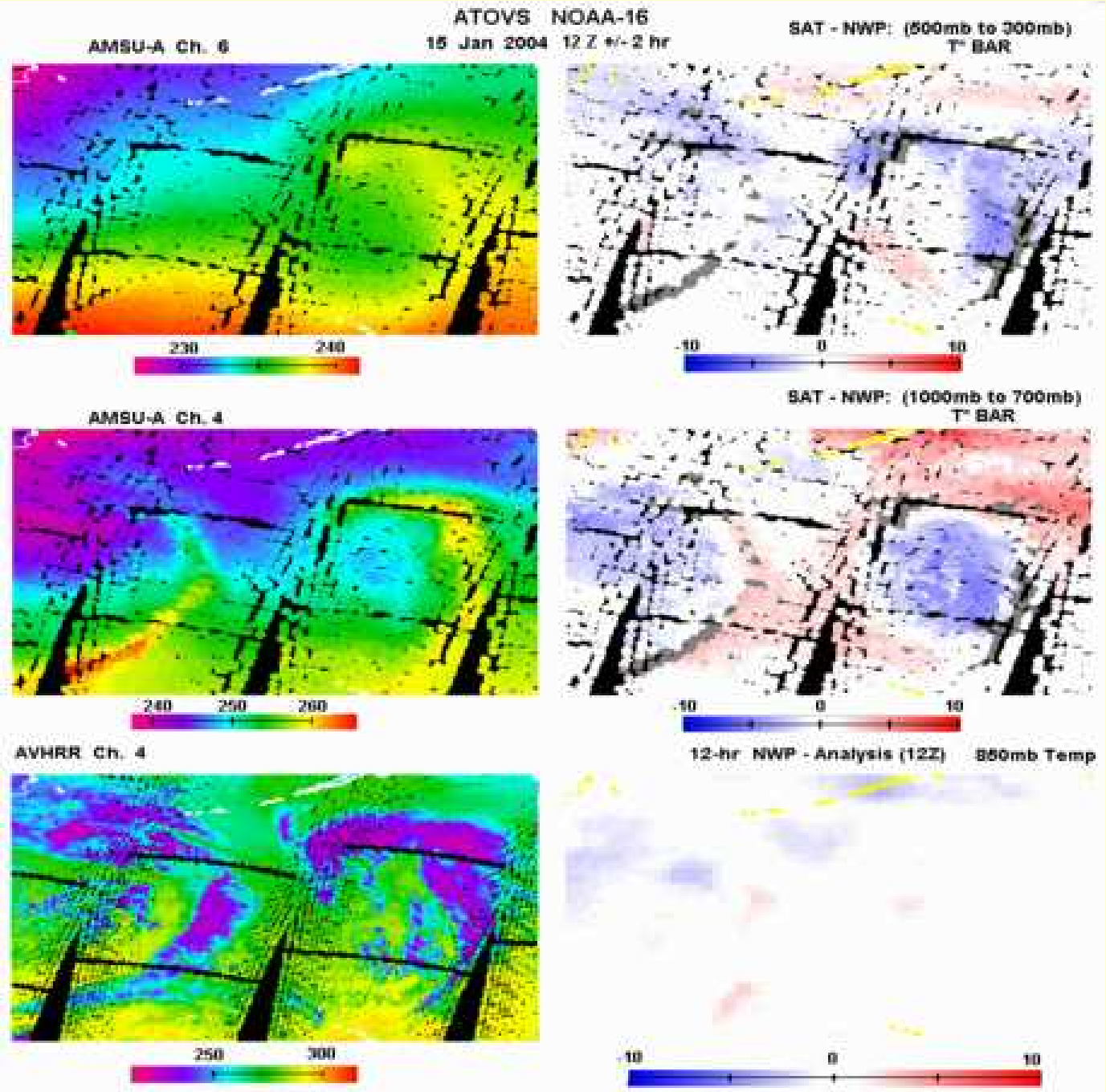


Pinpoint the Location of the **JET STREAM**

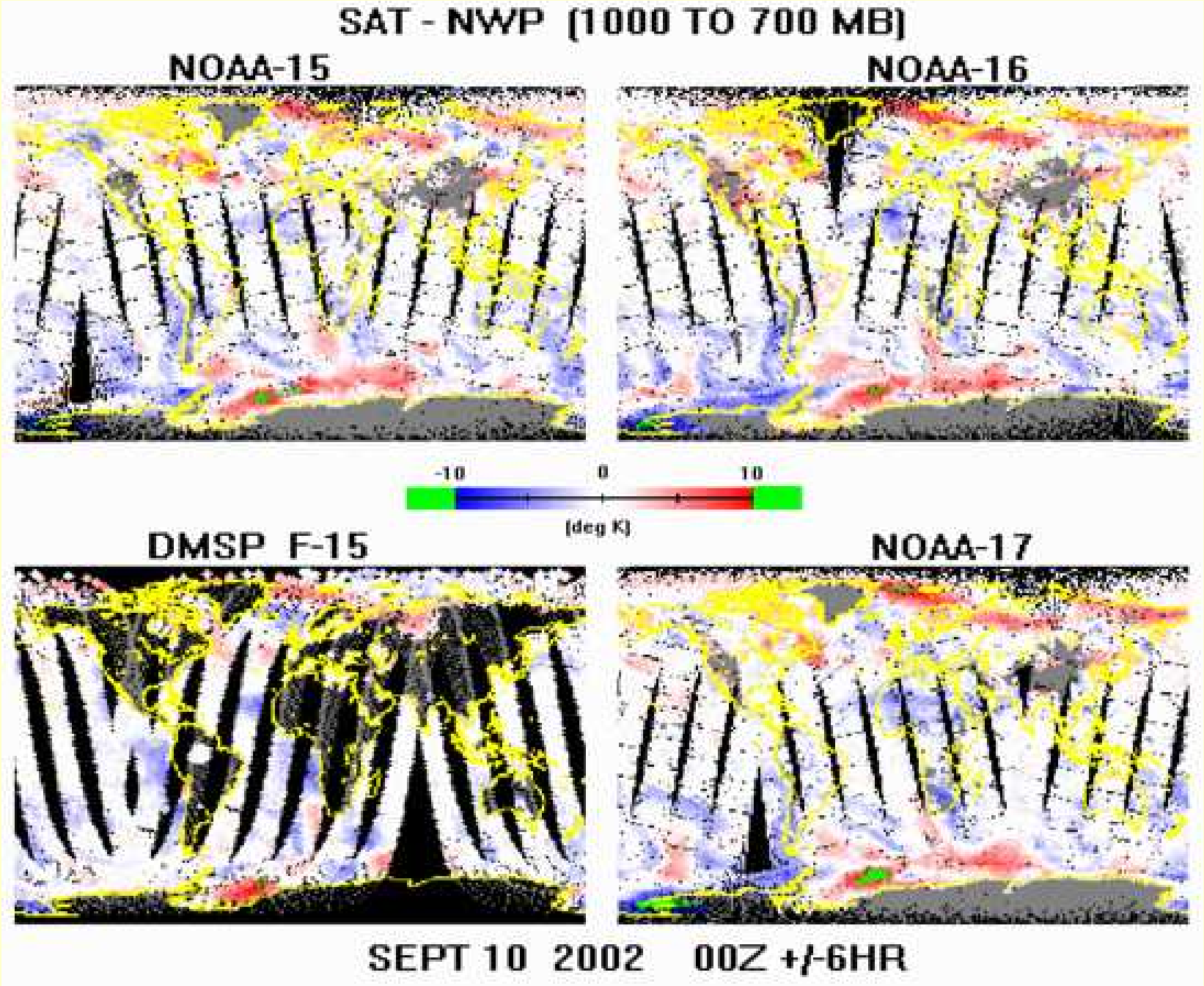
< (EMC 400mb Wind)

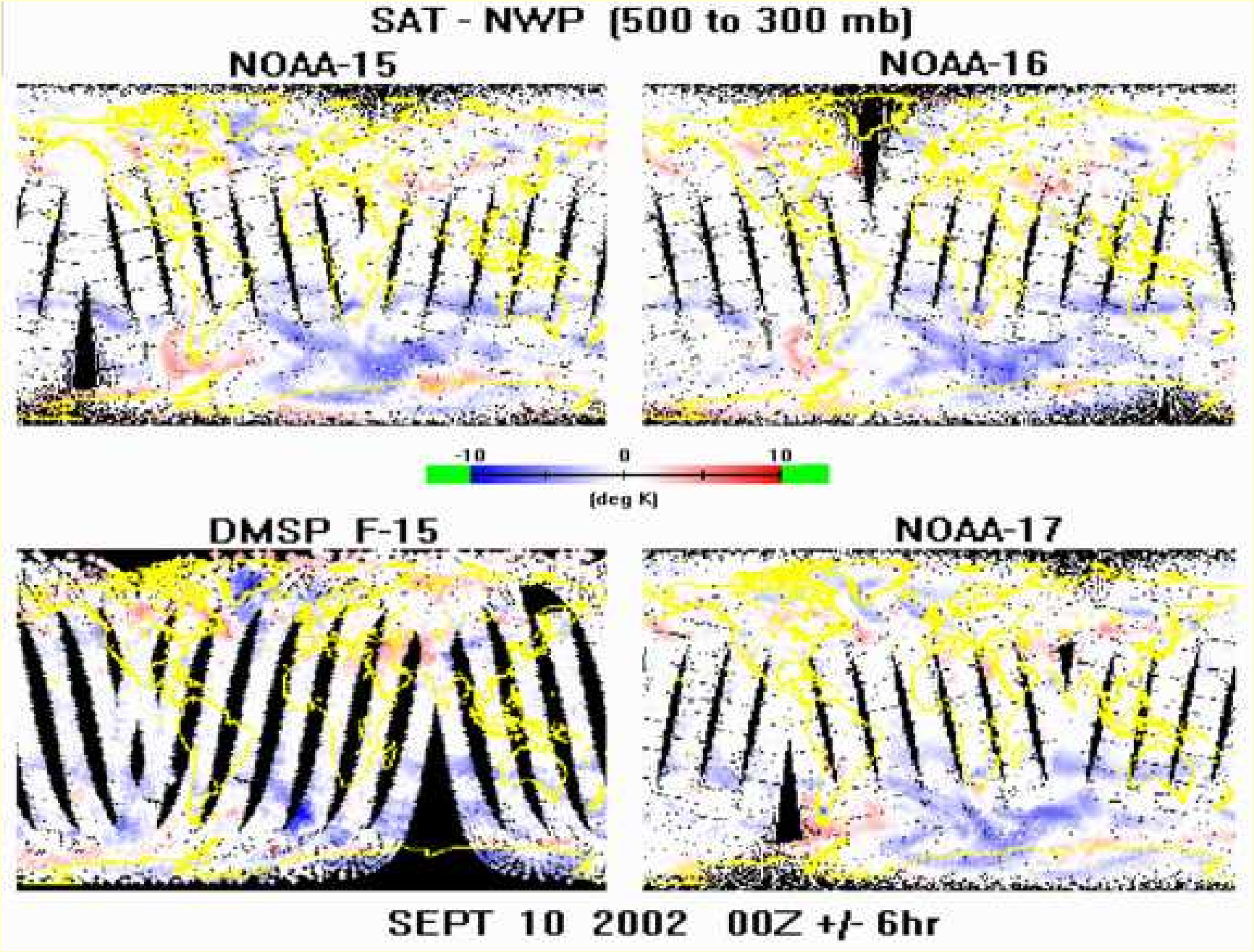


< (AMSU-A Ch 5)

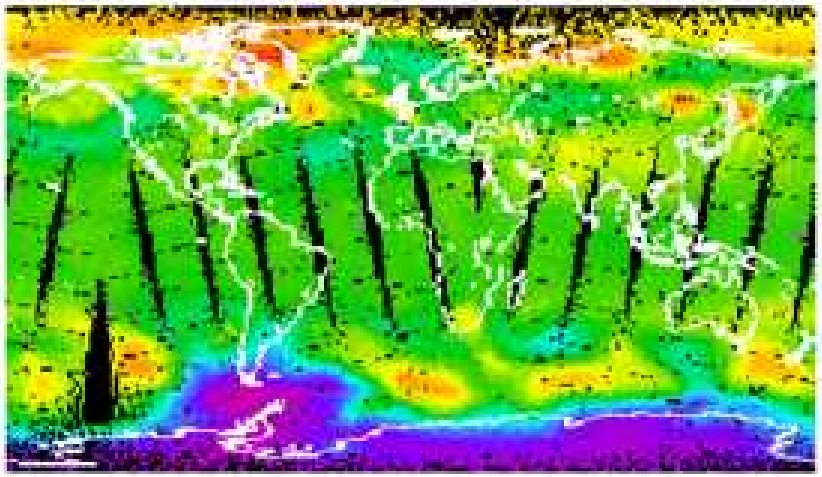


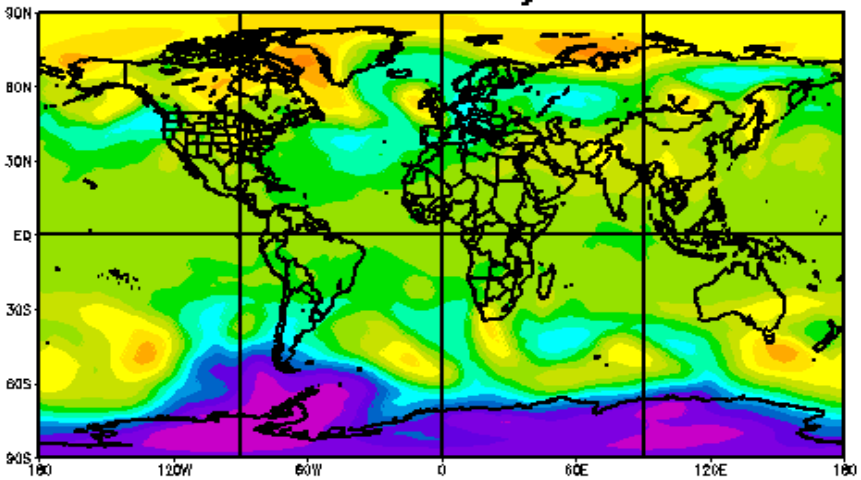
… can serve as baseline for inter-satellite product comparisons

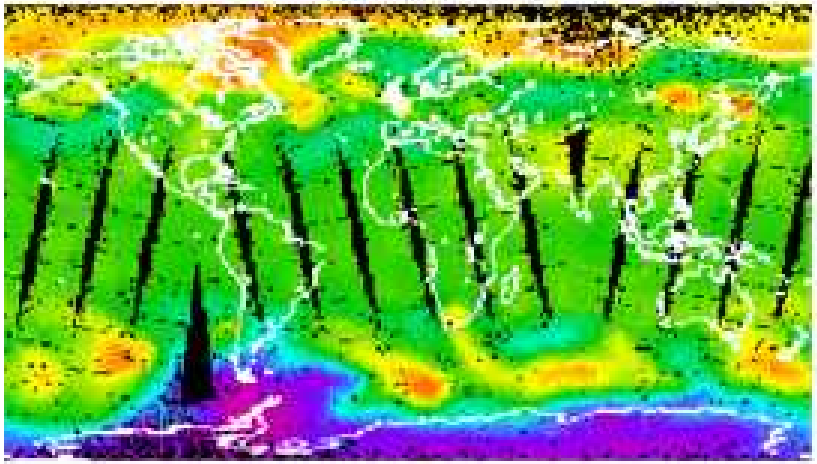

SAT - NWP (1000 TO 700 MB)
NOAA-15
NOAA-16
-10
0
10
(deg K)
DMSP F-15
NOAA-17
SEPT 10 2002 00Z +/-6HR


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)

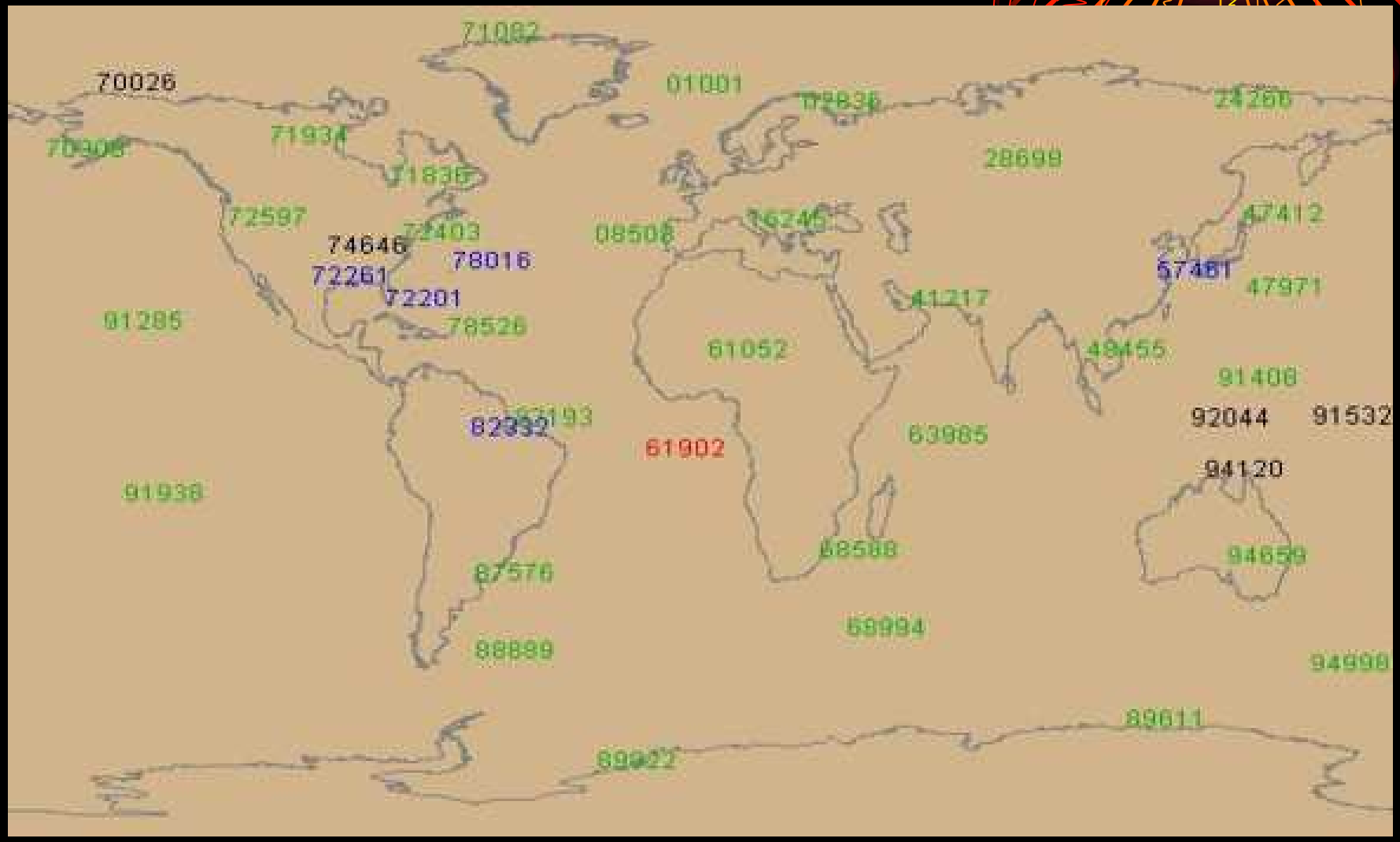
to serve as input for

"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-200X 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 planned**

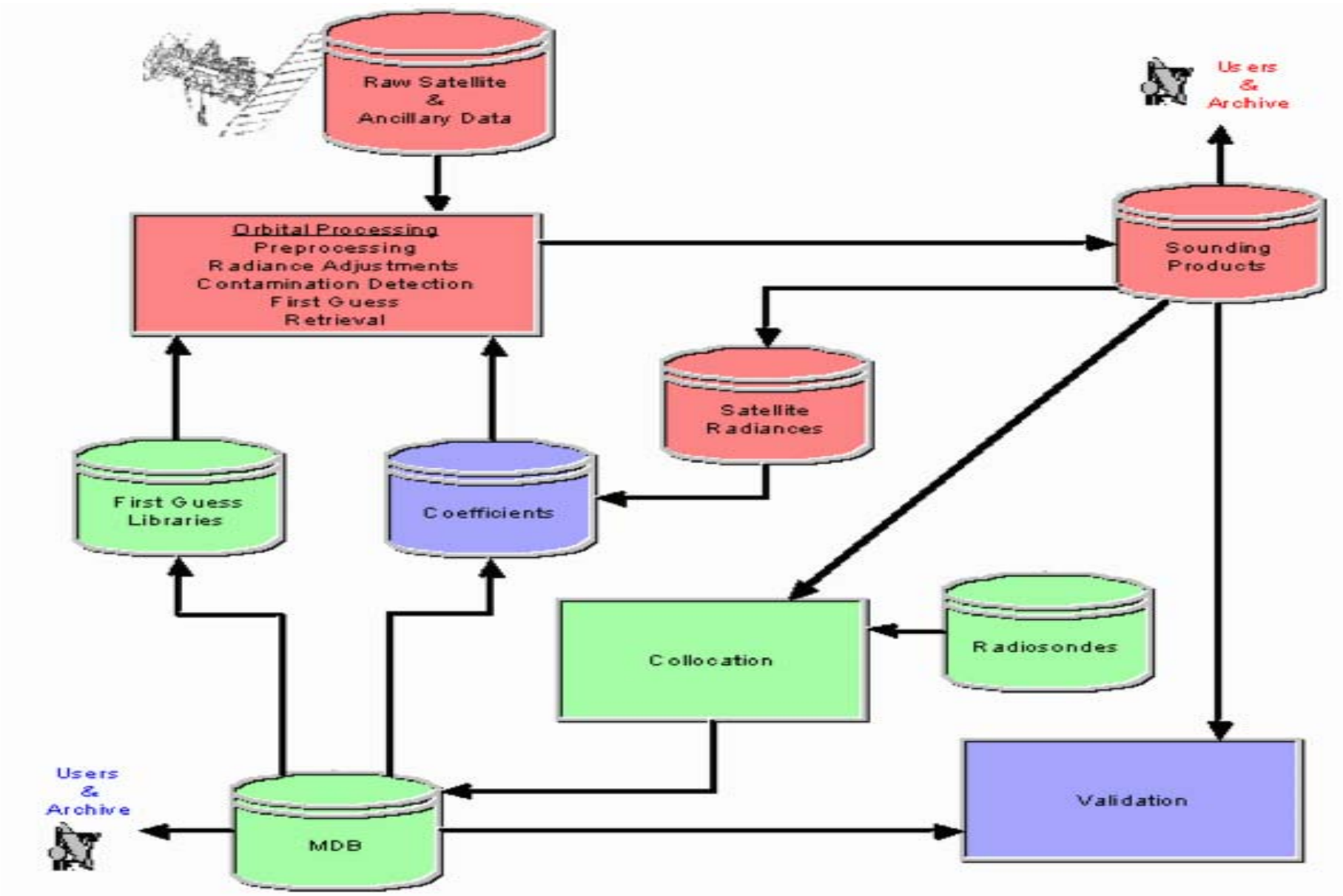
Operational Polar Satellite Validation and Evaluation Systems

Tony Reale
NOAA/NESDIS, Suitland, Md.
(tony.reale@noaa.gov)

Michael Pettey and Charles Brown
Raytheon Corporation, Landover Md.

21st International Conference on Interactive Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology
AMS- San Diego
January 9-15 2005

ATOVS Processing Diagram … Orbital, Daily, Weekly



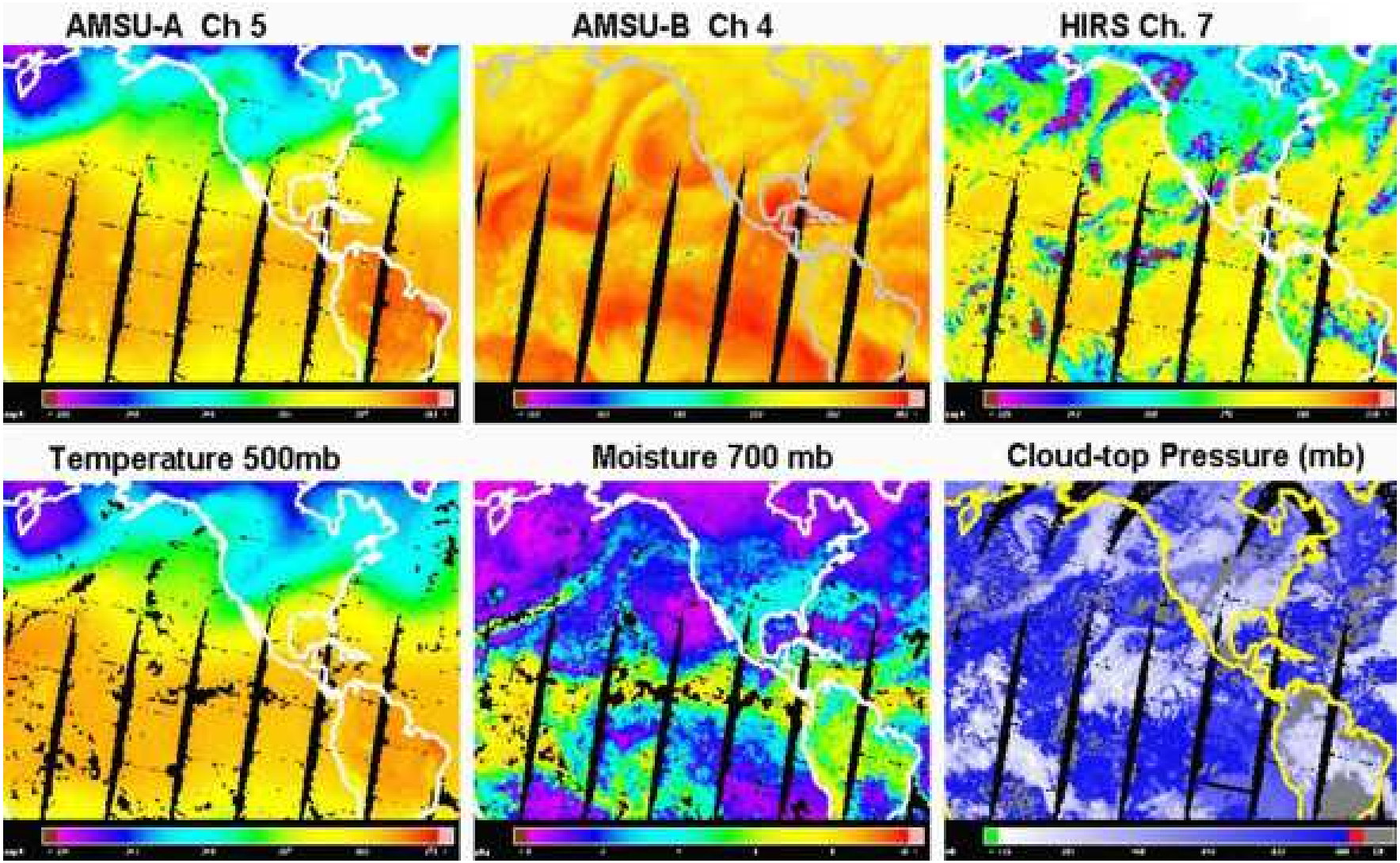
Environmental Data Graphic and Evaluation System

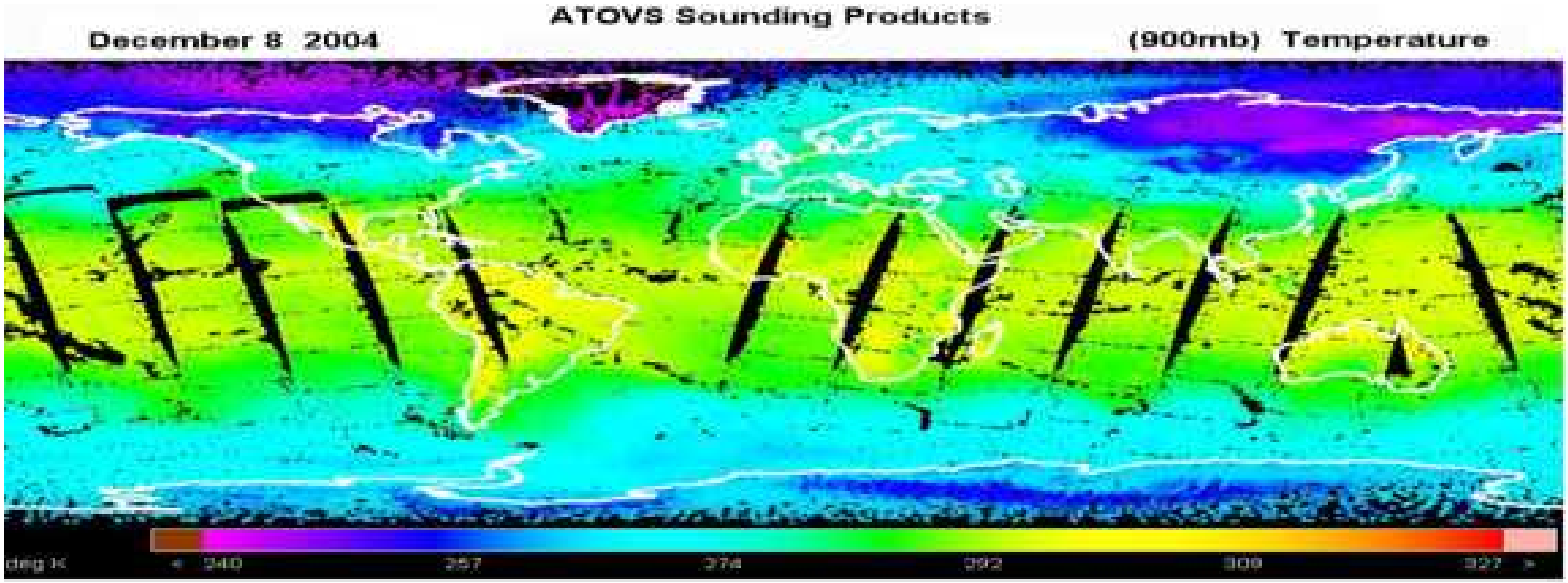
(EDGE)

- **Three (3) Major Sub-systems:**
  - ***EDGEIS:*** Horizontal Fields of Orbital Products
  - ***Profile Display (PDISP):*** Collocated Radiosonde and Satellite Observations
  - ***Vertical Statistics (VSTAT):*** Collocations
- JAVA based … reads operational files … all data
- Provided to EUMETSAT during January, 2004
  - Dr Eamonn McKernan
- ***Vehicle for EUMETSAT/NOAA Collaboration for METOP …***

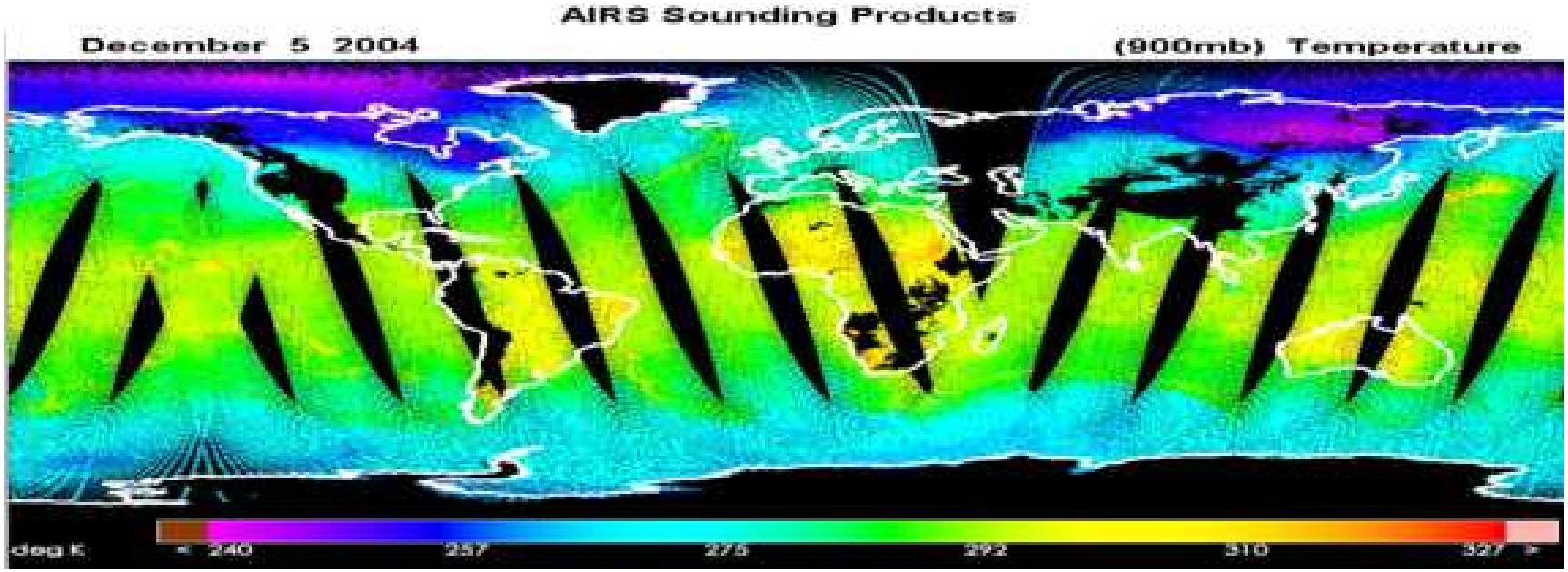
Orbital Products

(EDGEIS)





ATOVS (top) as benchmark for AIRS (bottom)



Panel 1

☑ Change current image

		Math Function
◉ Local File ○ Data Server		◉ Local File ○ Data Server
Select File	rodf_time2_a1.dat	Select File — No File Selected
Retrieved Temp (920 mb)		No Difference

Orbital Node:	◉ Both	○ Ascending	○ Descending
Time Window:	Show All Data	Dec 27, 2004 16 Z	Dec 28, 2004 6 Z
Map Projection:	Cartesian	Center Lat: 0.0	Southern
	Zoom 1.0	Center Lon: 0.0	Extent: 0.0
Data Range:	Manual	Low: 180.0	High: 320.0
Display Type:	◉ Sequential	○ Gridded	X/Y 1.0 1.0
Smoothing:	None	Smooth	Contour: 240
Map Type/Color:	☑ Coastline	☐ Political	Default
Color Ramp:			Default
Grid Lines:	☐ On	Lat: 30.0	Lon: 15.0
Label File:		None	

Panel 2

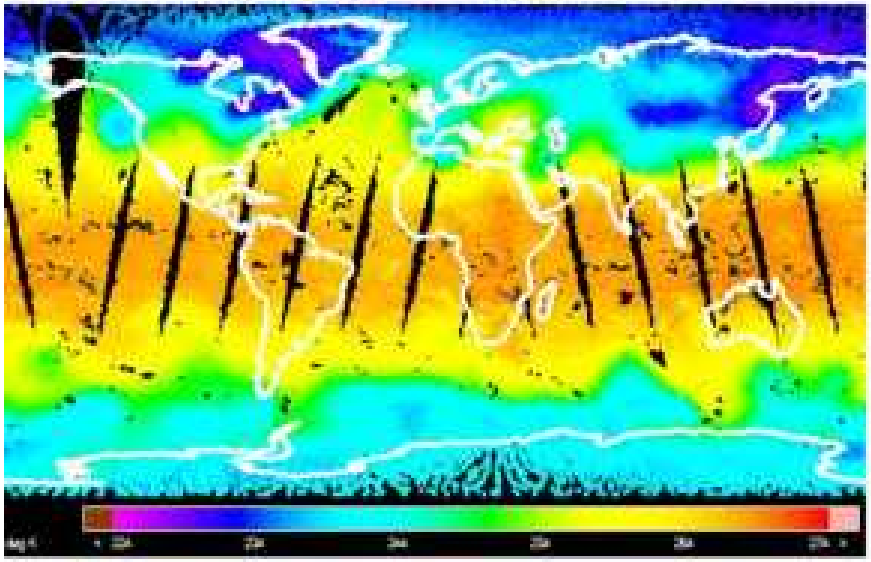
☐ Change current image

		Math Function
◉ Local File ○ Data Server		◉ Local File ○ Data Server
Select File	rodf_time2_a2.dat	Select File — rodf_time2_a2.dat
Retrieved Temp (500 mb)		1st Guess Temp (500 mb)

Orbital Node:	◉ Both	○ Ascending	○ Descending
Time Window:	Show All Data	Dec 27, 2004 16 Z	Dec 28, 2004 6 Z
Map Projection:	Cartesian	Center Lat: 0.0	Southern
	Zoom 1.0	Center Lon: 0.0	Extent: 0.0
Data Range:	Manual	Low: -10.0	High: 10.0
Display Type:	◉ Sequential	○ Gridded	X/Y 1.0 1.0
Smoothing:	None	Smooth	Contour: 240
Map Type/Color:	☑ Coastline	☐ Political	Default
Color Ramp:			Default
Grid Lines:	☐ On	Lat: 30.0	Lon: 15.0
Label File:		None	

(EDGEIS)

NOAA-15 500mb T



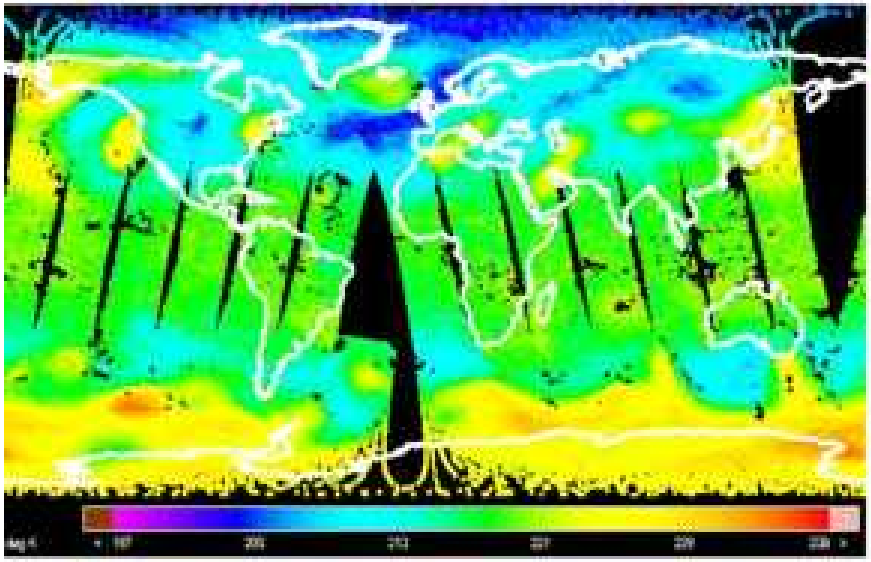
NOAA-16 (Test-Oper) 500mb T

NOAA-16 500mb T

NCEP Analysis 500mb T

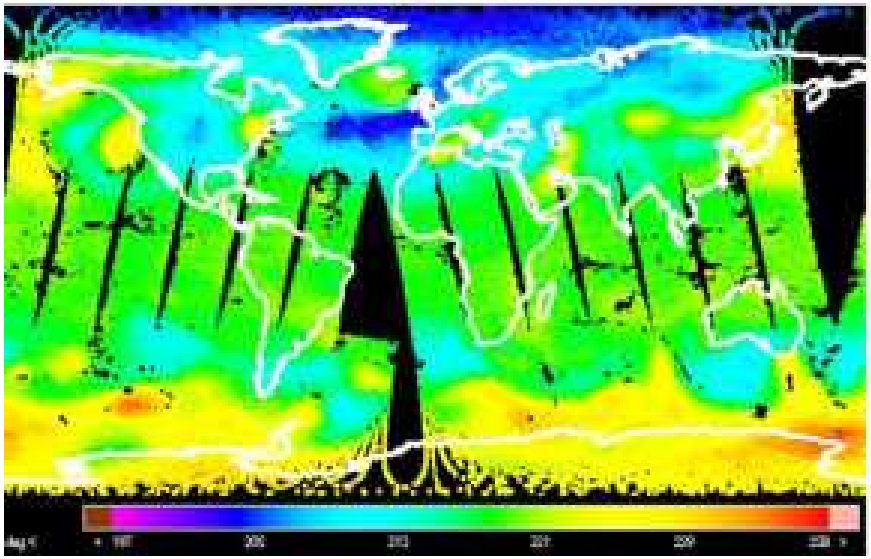
(EDGEIS)

NOAA-16 (Test) 200mb T



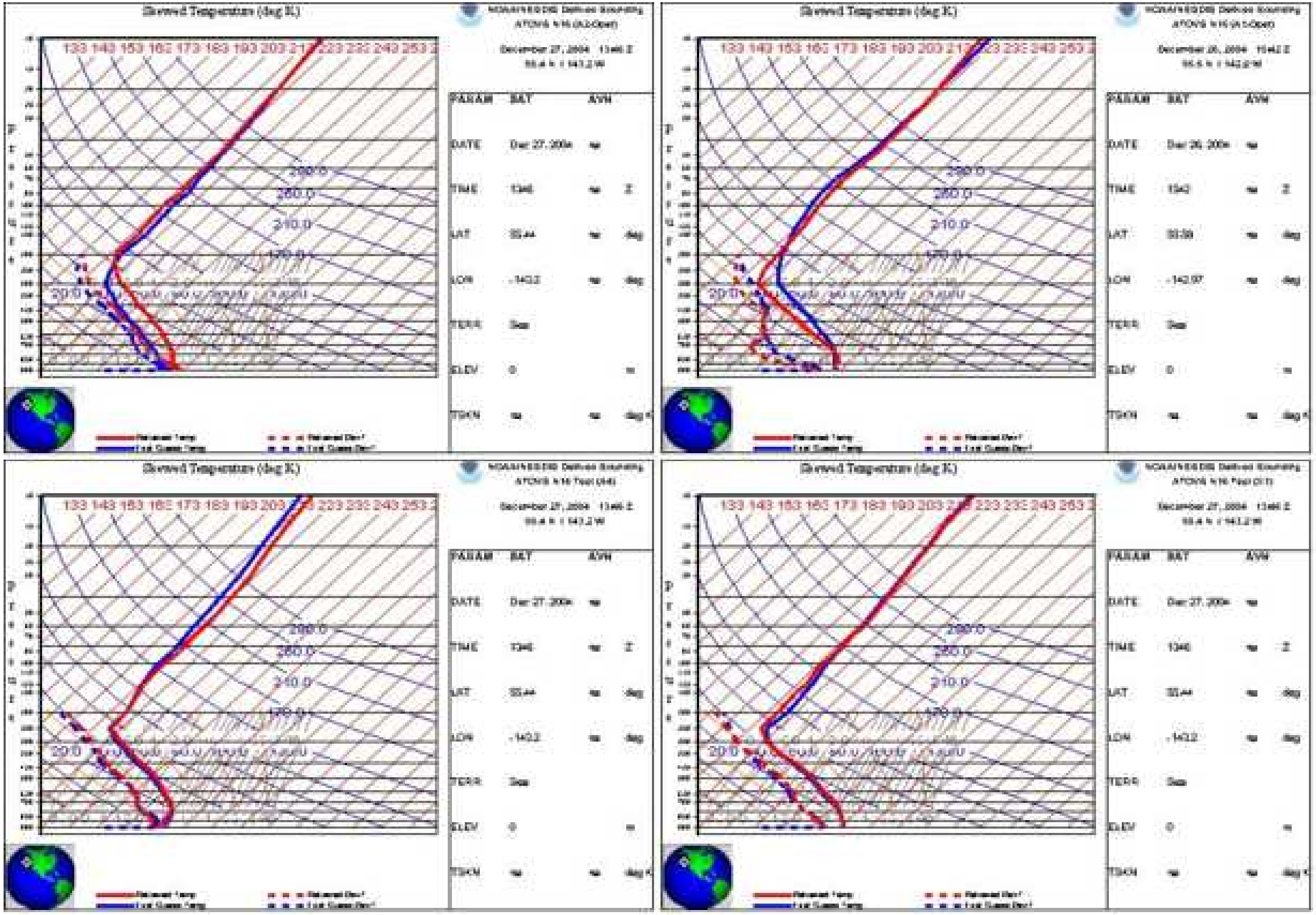
NOAA-16 (Test-Oper) 200mb T

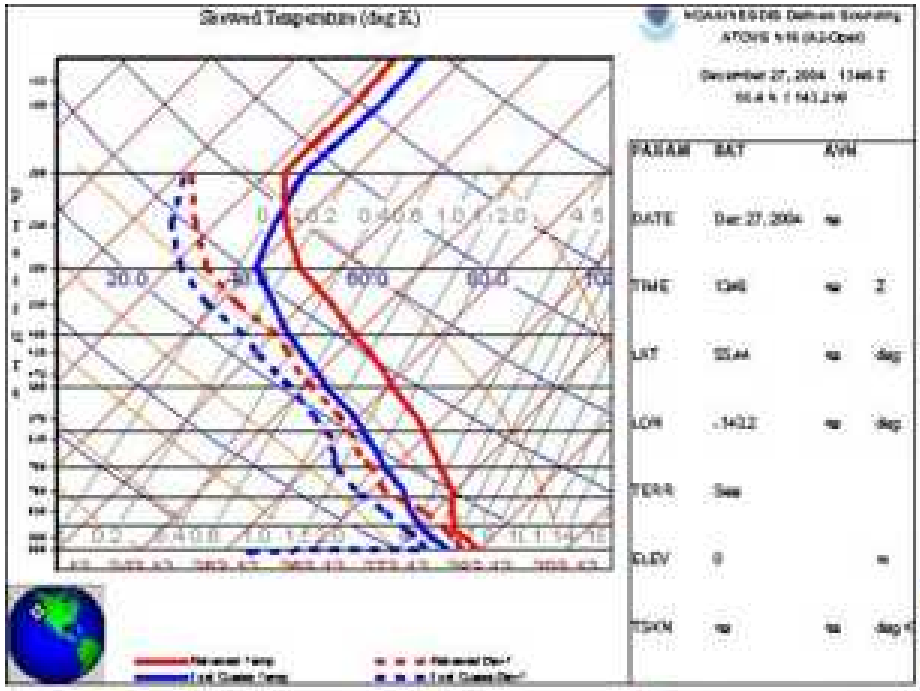
NOAA-16 (Oper) 200mb T

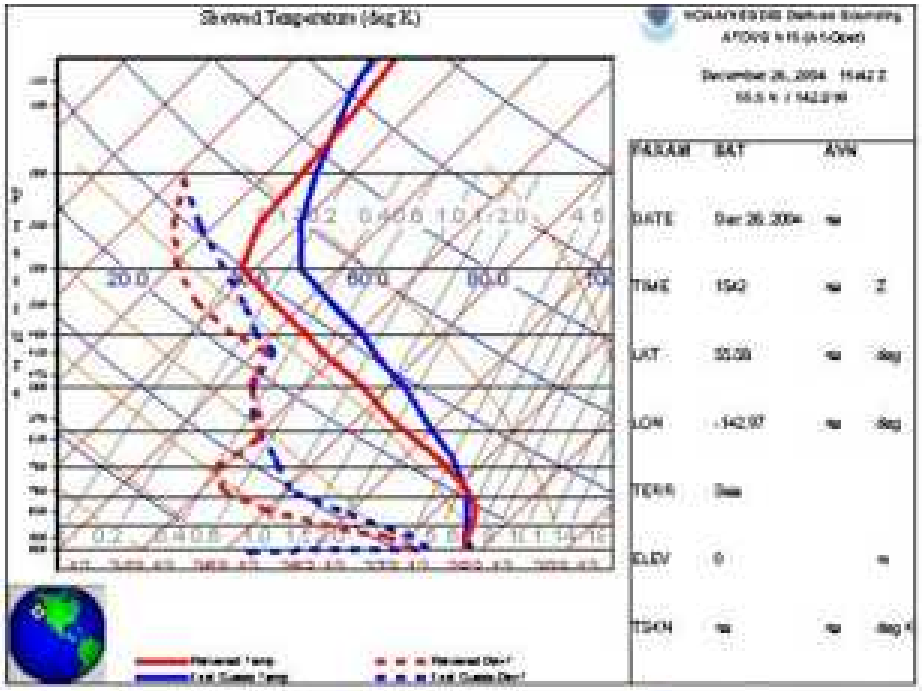


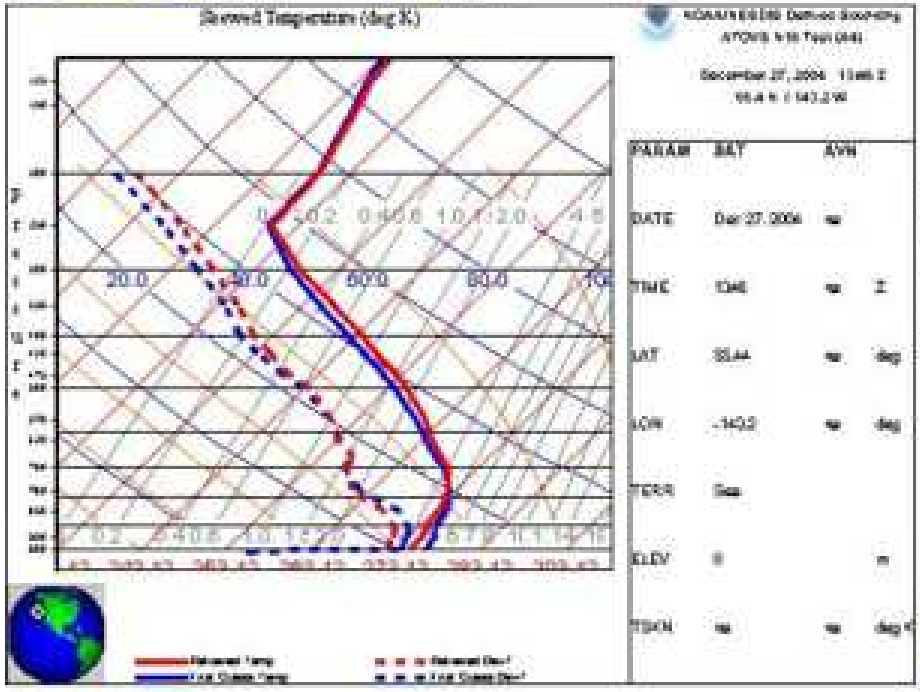
NCEP Analysis 200mb T

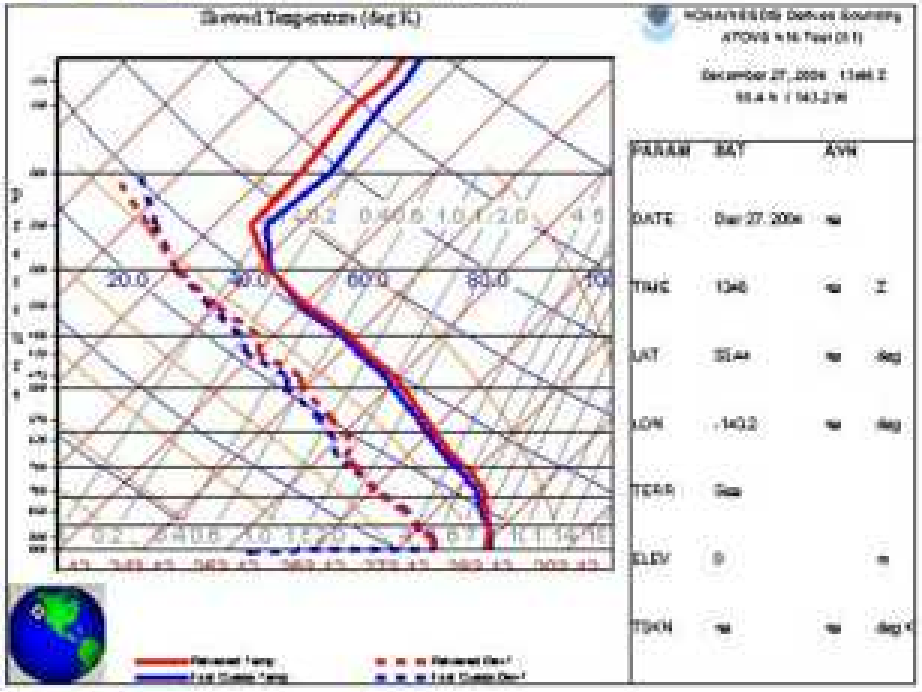
(EDGEIS)

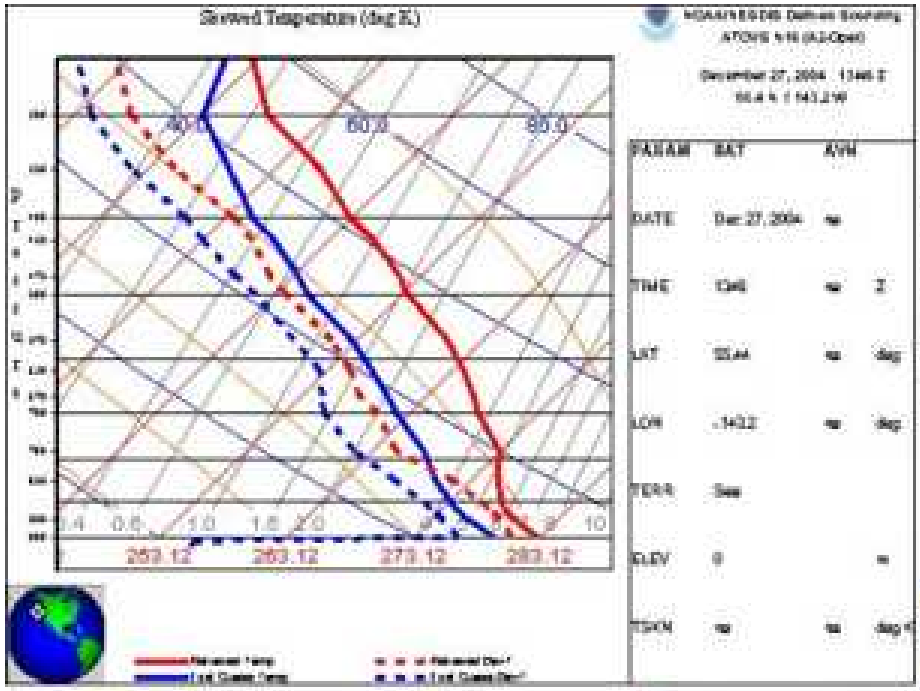

Skewed Temperature (deg K)
PARAM
BAT
AVH
DATE
TIME
LAT
LON
TERR
ELEV
TSKN

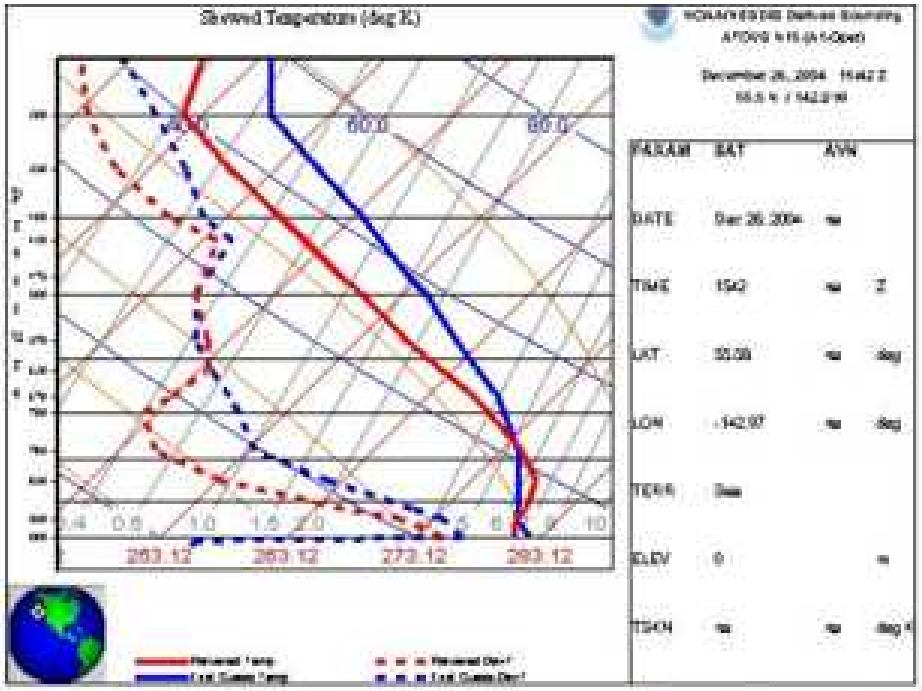

Skewed Temperature (deg K)
NOAA/NESDIS Dalhousie Sounding
ATOVS N16 (A2-Clear)
December 27, 2004 1346 Z
55.4 N / 143.2 W
PARAM BAT AVN
DATE Dec 27, 2004 na
TIME 1346 na Z
LAT 55.44 na deg
LON -143.2 na deg
TERR Sea
ELEV 0 m
TSKN na na deg K

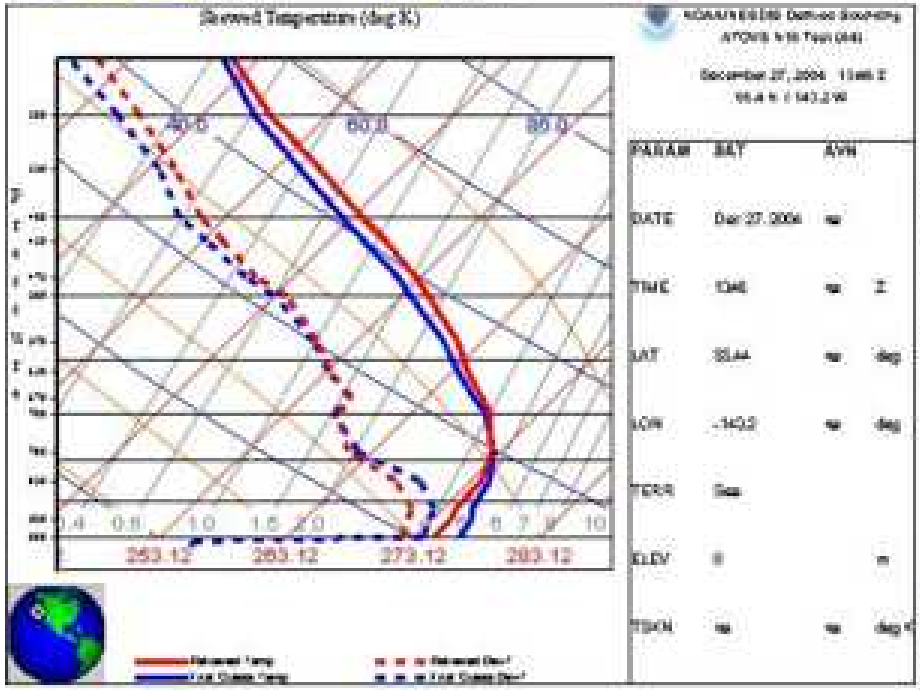

Skewed Temperature (deg K)
NOAA/NESDIS Dalhousie Sounding
ATOVS N16 (A1-Clear)
December 26, 2004 1542 Z
55.5 N / 142.2 W
PARAM BAT AVN
DATE Dec 26, 2004 na
TIME 1542 na Z
LAT 55.55 na deg
LON -142.97 na deg
TERR Sea
ELEV 0 m
TSKN na na deg K

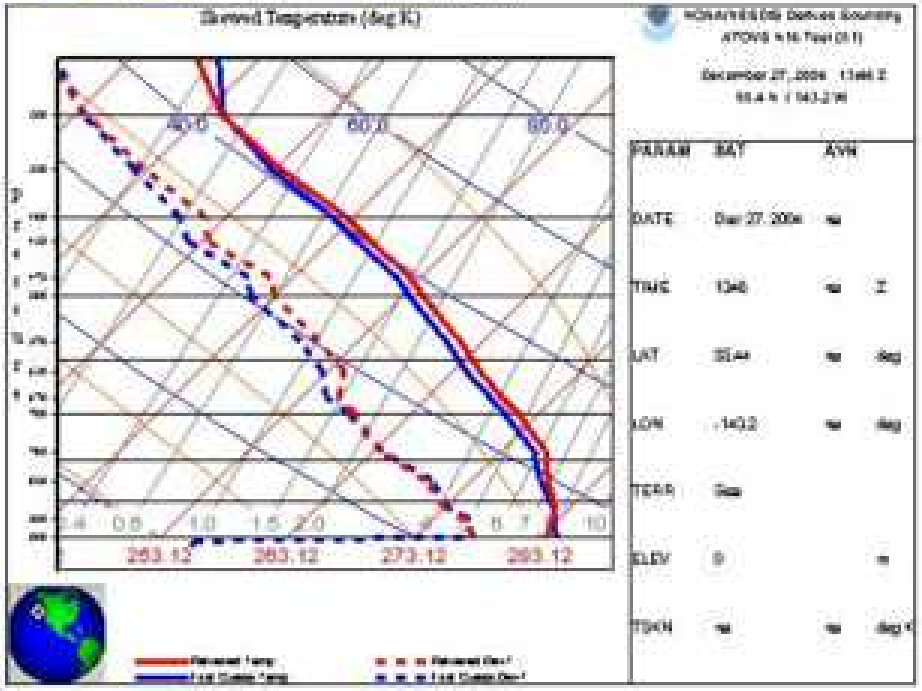

Skewed Temperature (deg K)
NOAA/NESDIS Dalhousie Sounding
ATOVS N16 Test (A4)
December 27, 2004 1346 Z
55.4 N / 143.2 W
PARAM BAT AVN
DATE Dec 27, 2004 na
TIME 1346 na Z
LAT 55.44 na deg
LON -143.2 na deg
TERR Sea
ELEV 0 m
TSKN na na deg K


Skewed Temperature (deg K)
NOAA/NESDIS Dalhousie Sounding
ATOVS N16 Test (S1)
December 27, 2004 1346 Z
55.4 N / 143.2 W
PARAM BAT AVN
DATE Dec 27, 2004 na
TIME 1346 na Z
LAT 55.44 na deg
LON -143.2 na deg
TERR Sea
ELEV 0 m
TSKN na na deg K

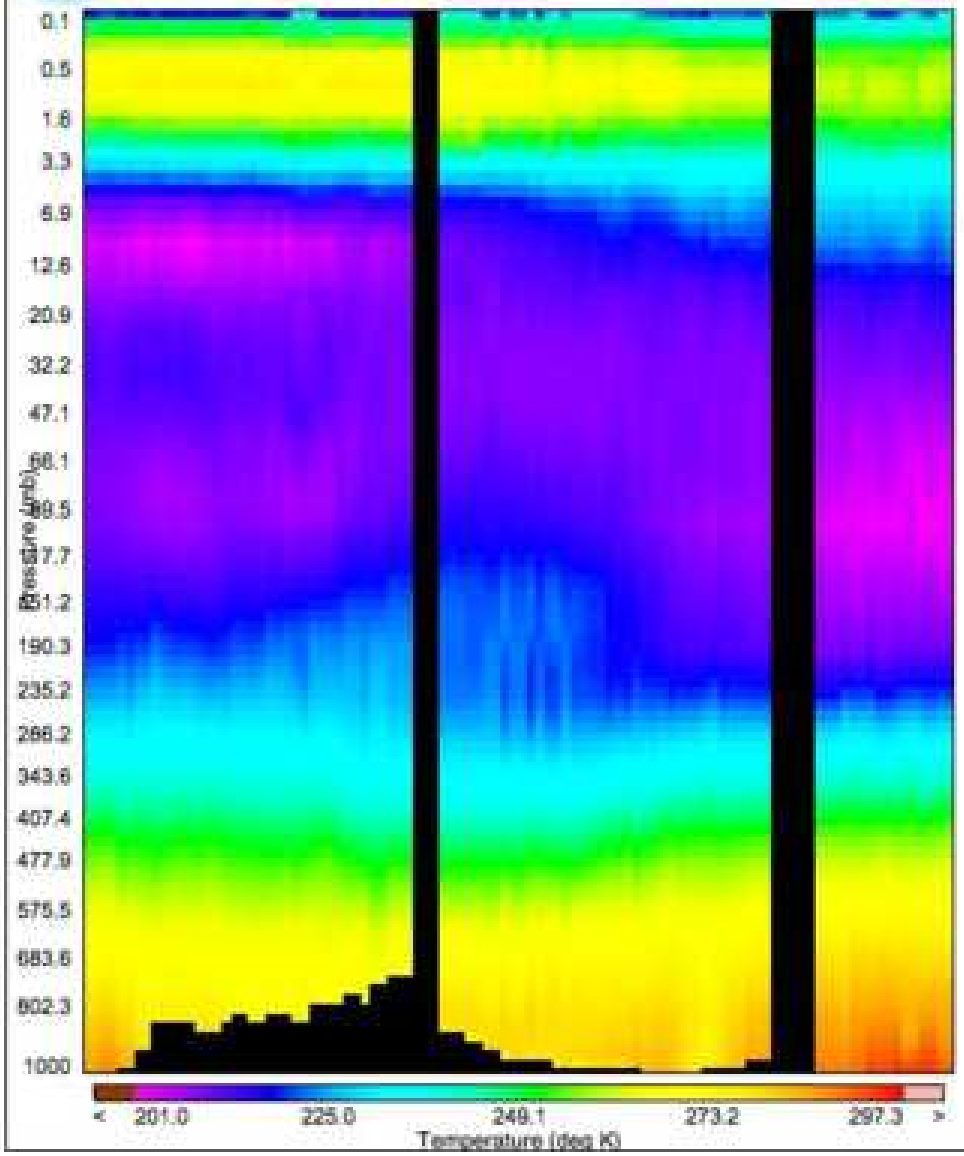

Skewed Temperature (deg K)
40.0
60.0
80.0
0.4 0.6 1.0 1.5 2.0 5 6 7 8 10
253.12 263.12 273.12 283.12
PARAM BAT AVN
DATE Dec 27, 2004 na
TIME 1346 na Z
LAT 55.44 na deg
LON -143.2 na deg
TERR Sea
ELEV 0 m
TSKN na na deg K


Skewed Temperature (deg K)
40.0
60.0
80.0
0.4 0.6 1.0 1.5 2.0 5 6 7 8 10
253.12 263.12 273.12 283.12
PARAM BAT AVN
DATE Dec 26, 2004 na
TIME 1542 na Z
LAT 55.00 na deg
LON -142.97 na deg
TERR Sea
ELEV 0 m
TSKN na na deg K


Skewed Temperature (deg K)
40.0
60.0
80.0
0.4 0.6 1.0 1.5 2.0 5 6 7 8 10
253.12 263.12 273.12 283.12
PARAM BAT AVN
DATE Dec 27, 2004 na
TIME 1346 na Z
LAT 55.44 na deg
LON -143.2 na deg
TERR Sea
ELEV 0 m
TSKN na na deg K


Skewed Temperature (deg K)
40.0
60.0
80.0
0.4 0.6 1.0 1.5 2.0 5 6 7 8 10
253.12 263.12 273.12 283.12
PARAM BAT AVN
DATE Dec 27, 2004 na
TIME 1346 na Z
LAT 55.44 na deg
LON -143.2 na deg
TERR Sea
ELEV 0 m
TSKN na na deg K

NOAA/NESDIS Vertical Atmospheric Cross-Section

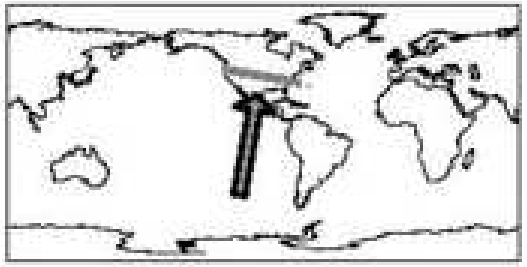


Retrieved Temperature

AIRS GDF Test

Dec 9, 2004 (6:30 Z) to Dec 9, 2004 (9:46 Z)

Starting Position (Lat/Lon): 44.45 / -126.31
Ending Position (Lat/Lon): 34.02 / -70.24



PDISP and VSTATS

Collocated Radiosonde and Satellite Observations provide basis for the

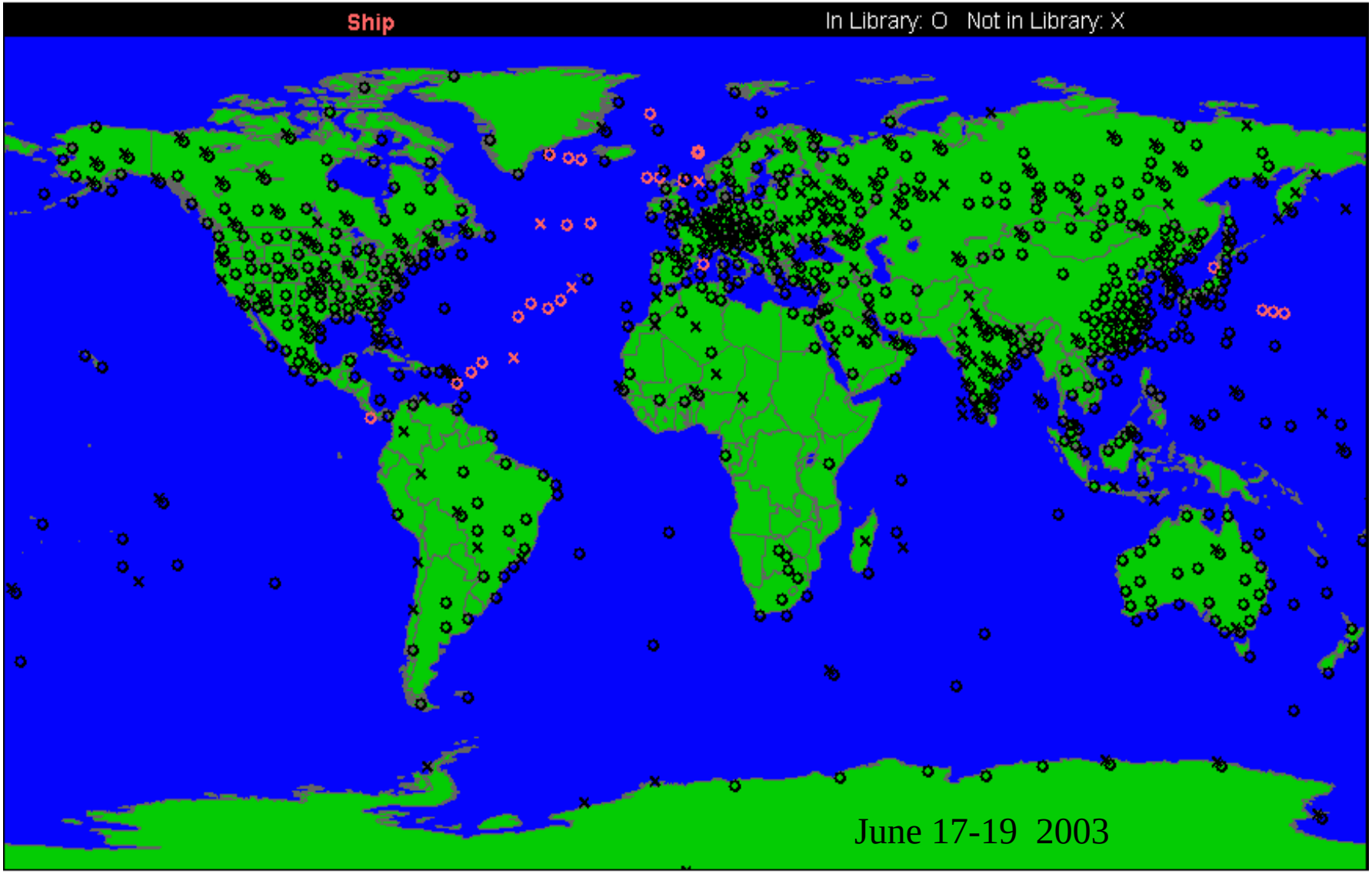
Monitoring
Validation and
Tuning

of ***Operational Satellite Product Systems***

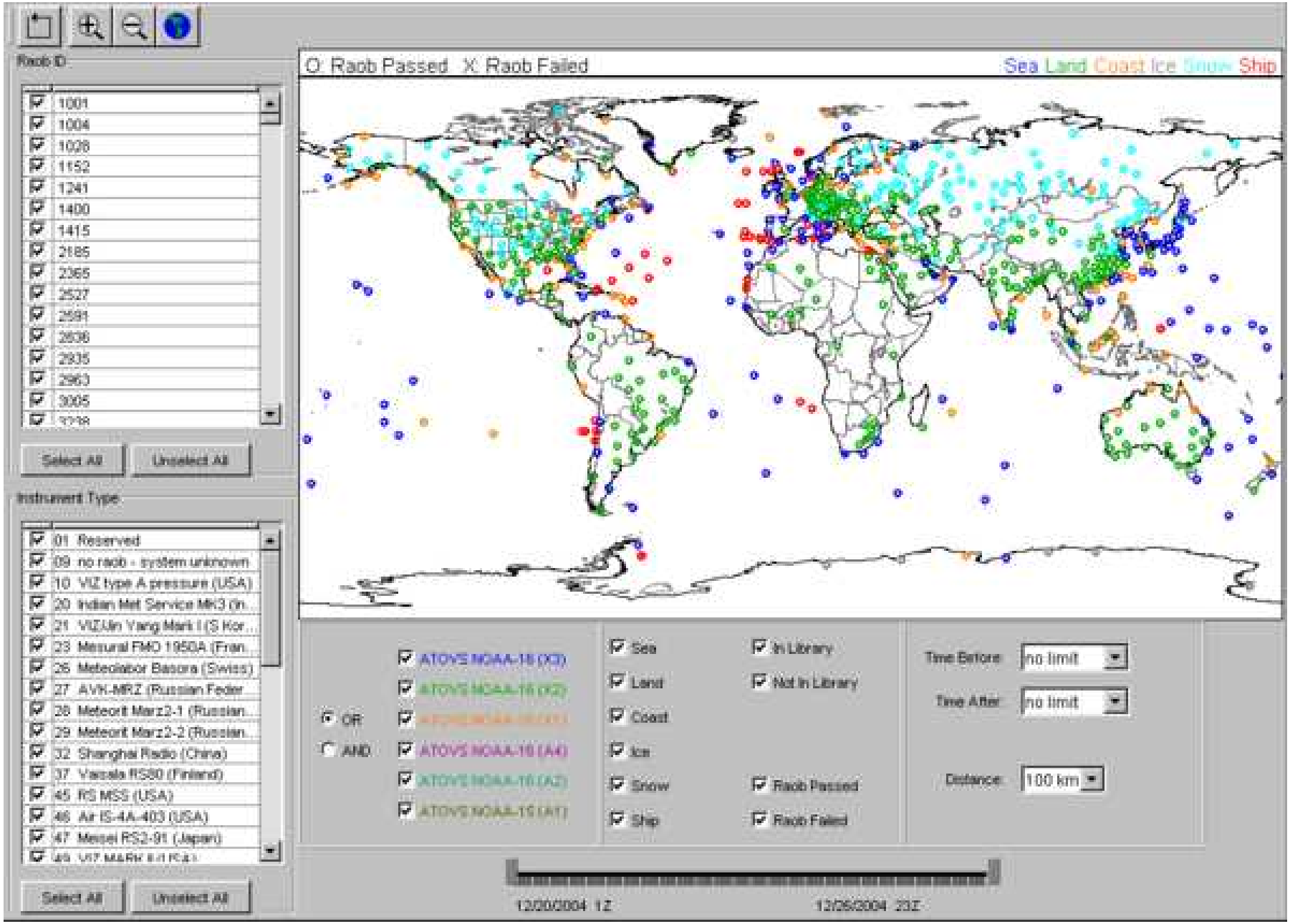
(… *critical data-sets for climate retrieval problem)*

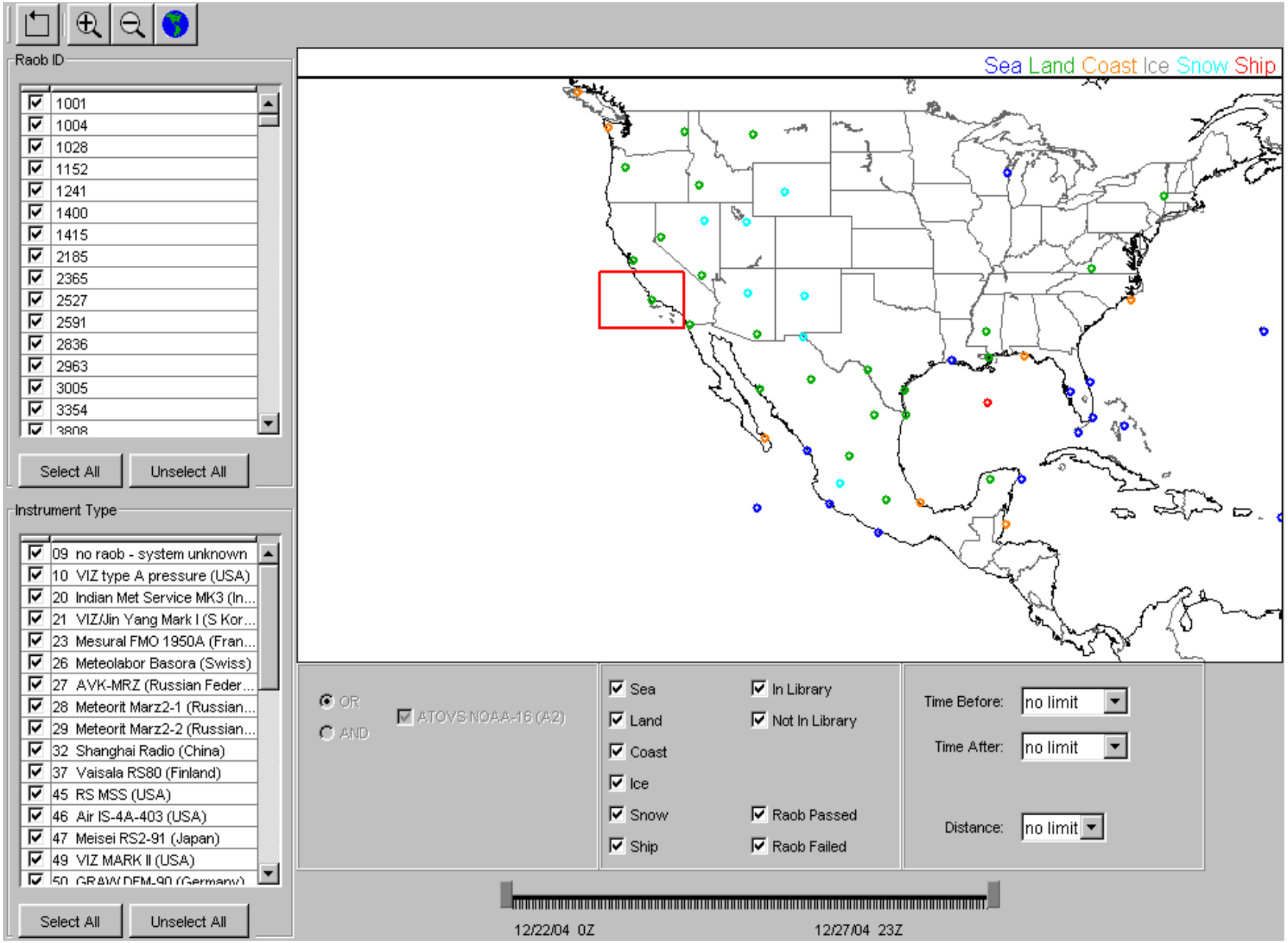
Global Radiosondes

(PDISP)

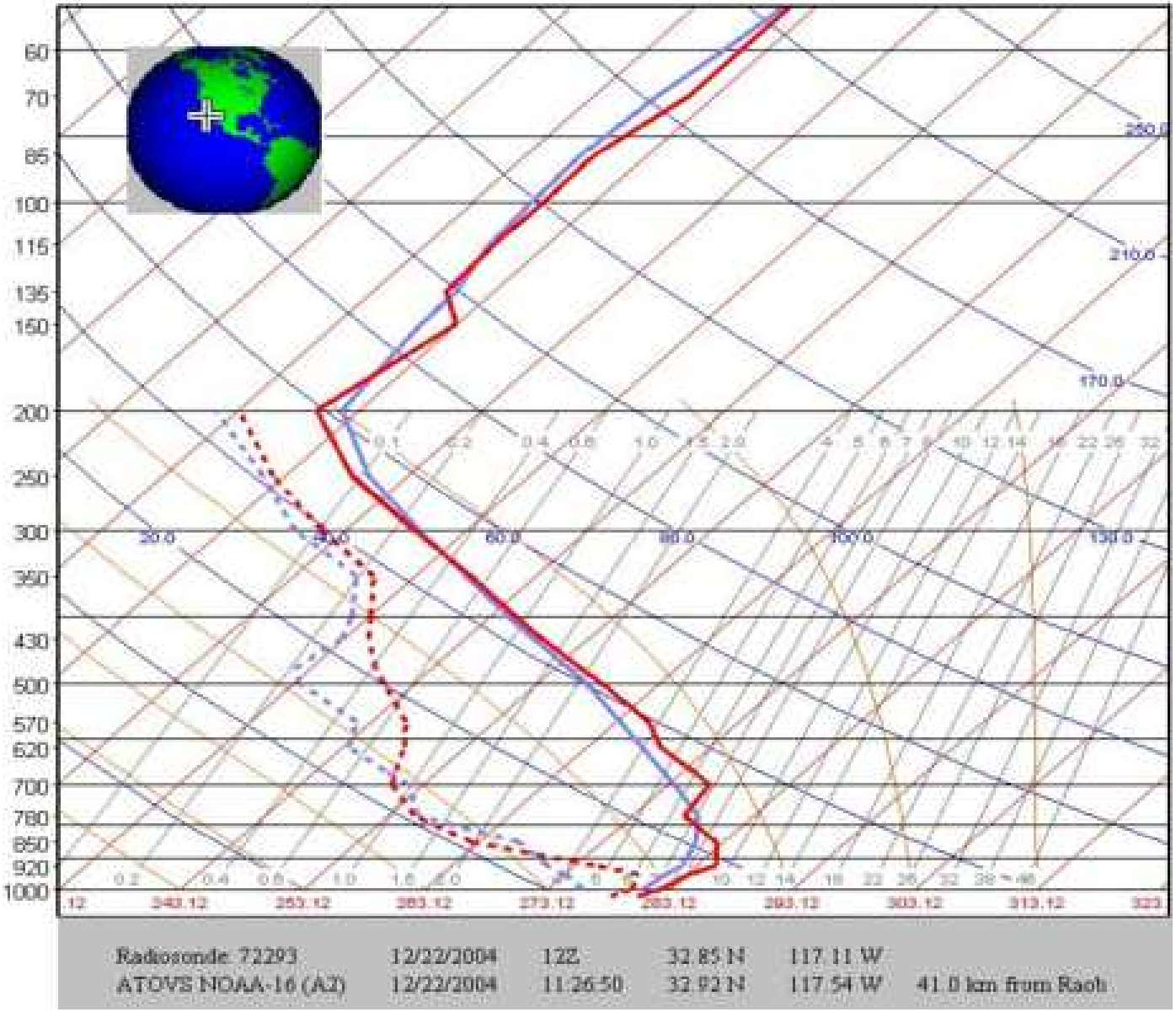


PDISP

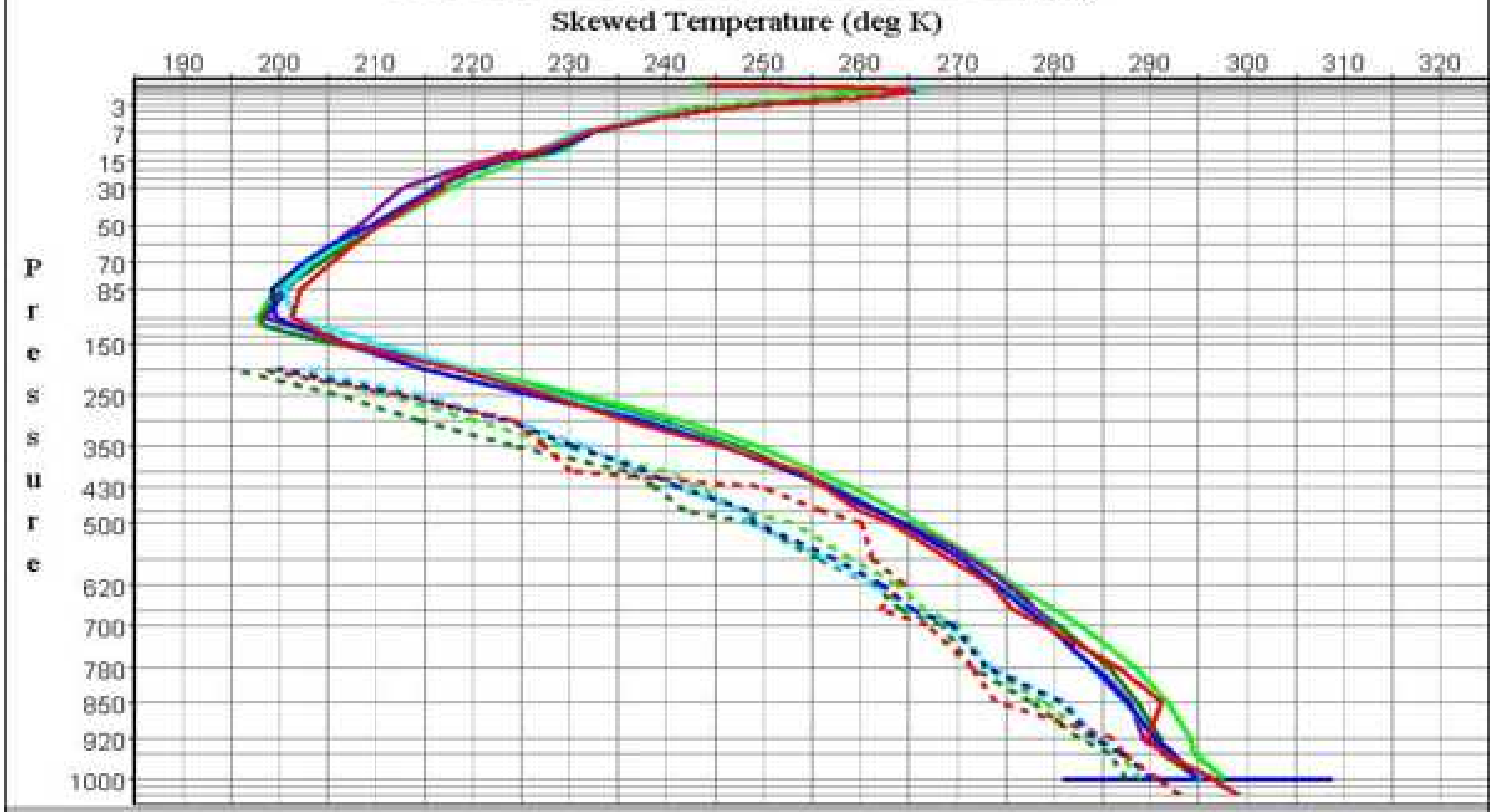

Raob ID
1001
1004
1028
1152
1241
1400
1415
2185
2365
2527
2591
2838
2935
2963
3005
Select All
Unselect All
Instrument Type
01 Reserved
09 no raob - system unknown
10 VIZ type A pressure (USA)
20 Indian Met Service MK3 (In...
21 VIZ/Jin Yang Mark II (S Kor...
23 Mesural FMO 1950A (Fran...
26 Meteolabor Basora (Swiss)
27 AVK-MRZ (Russian Feder
28 Meteorit Marz2-1 (Russian...
29 Meteorit Marz2-2 (Russian...
32 Shanghai Radio (China)
37 Vaisala RS80 (Finland)
45 RS MSS (USA)
46 Air IS-4A-403 (USA)
47 Meisei RS2-91 (Japan)
Select All
Unselect All
O: Raob Passed X: Raob Failed
Sea Land Coast Ice Snow Ship
OR
AND
ATOVS NOAA-15 (X3)
ATOVS NOAA-16 (X2)
ATOVS NOAA-16 (A4)
ATOVS NOAA-15 (A1)
Sea
Land
Coast
Ice
Snow
Ship
In Library
Not In Library
Raob Passed
Raob Failed
Time Before
no limit
Time After
no limit
Distance
100 km
12/20/2004 1Z
12/26/2004 23Z


Raob ID
1001
1004
1028
1152
1241
1400
1415
2185
2365
2527
2591
2836
2963
3005
3354
Select All
Unselect All
Instrument Type
09 no raob - system unknown
10 VIZ type A pressure (USA)
20 Indian Met Service MK3 (In...
21 VIZ/Jin Yang Mark I (S Kor...
23 Mesural FMO 1950A (Fran...
26 Meteolabor Basora (Swiss)
27 AVK-MRZ (Russian Feder...
28 Meteorit Marz2-1 (Russian...
29 Meteorit Marz2-2 (Russian...
32 Shanghai Radio (China)
37 Vaisala RS80 (Finland)
45 RS MSS (USA)
46 Air IS-4A-403 (USA)
47 Meisei RS2-91 (Japan)
49 VIZ MARK II (USA)
Select All
Unselect All
Sea Land Coast Ice Snow Ship
OR
AND
ATOVS NOAA-16 (A2)
Sea
Land
Coast
Ice
Snow
Ship
In Library
Not In Library
Raob Passed
Raob Failed
Time Before:
no limit
Time After:
no limit
Distance:
no limit
12/22/04 0Z
12/27/04 23Z

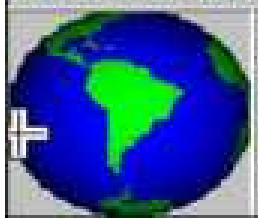
PDISP


60
70
85
100
115
135
150
200
250
300
350
430
500
570
620
700
780
850
920
1000
Radiosonde 72293 12/22/2004 12Z 32.85 N 117.11 W
ATOVS NOAA-16 (A2) 12/22/2004 11:26:50 32.92 N 117.54 W 41.0 km from Raob

NOAA/NESDIS Matched Profile Display



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 rsob
ATOVS NOAA-16 (A4)	8/18/2004	23:08:37	22.67 S	134.78 W	54 km from rsob

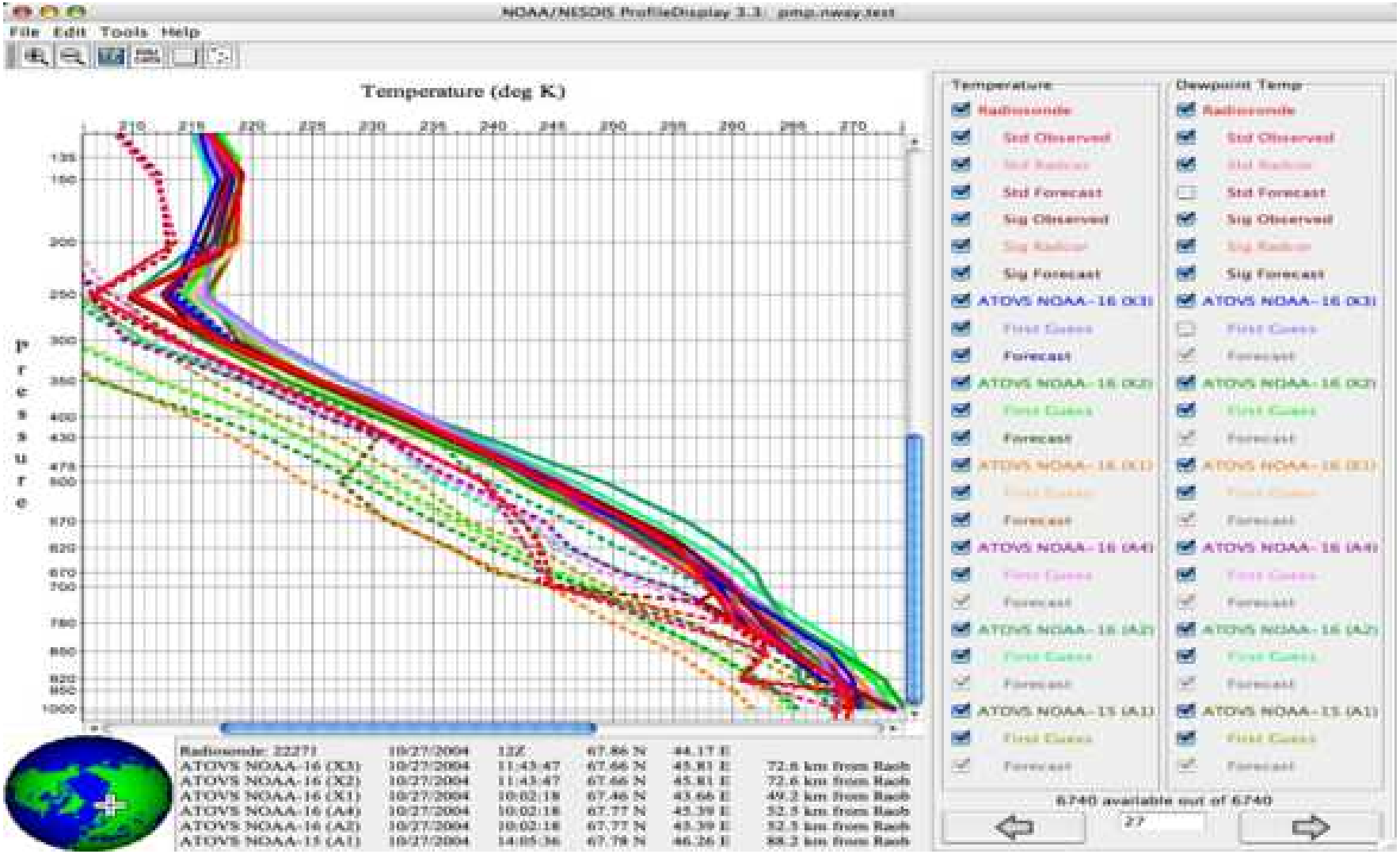


Terrain:	Sea
Day/Night:	Day
Cloud Mask:	Clear
Library Flag:	not available
ATOVS NOAA-16 (X1) TPW:	31.15 mm
ATOVS NOAA-16 (A4) TPW:	26.79 mm

	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		

Compare individual profiles from ***Radiosonde, Satellite*** and ***NWP*** platforms

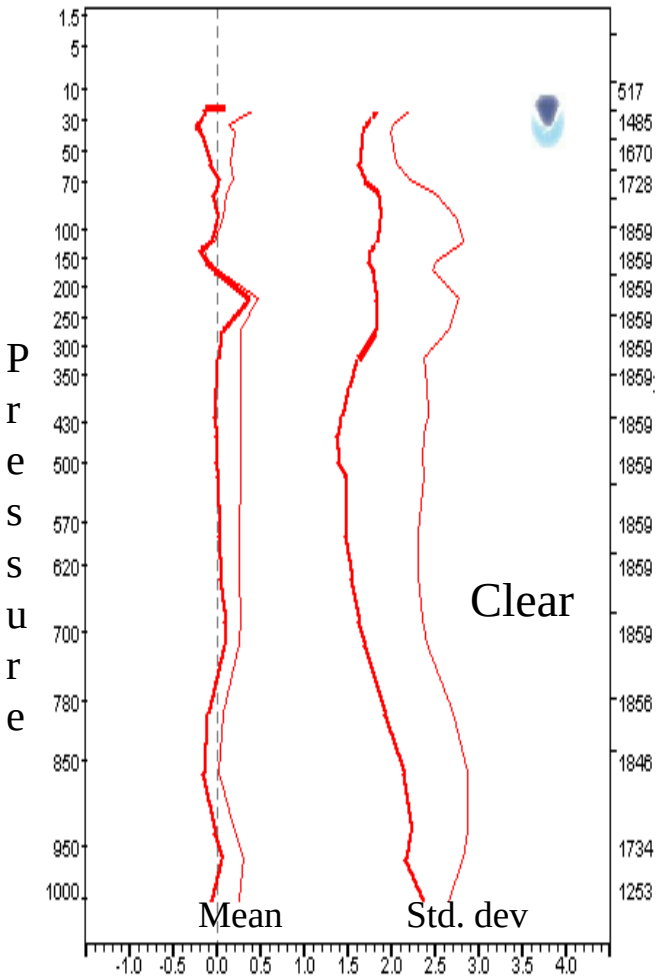
(PDISP)



Vertical Accuracy Statistics

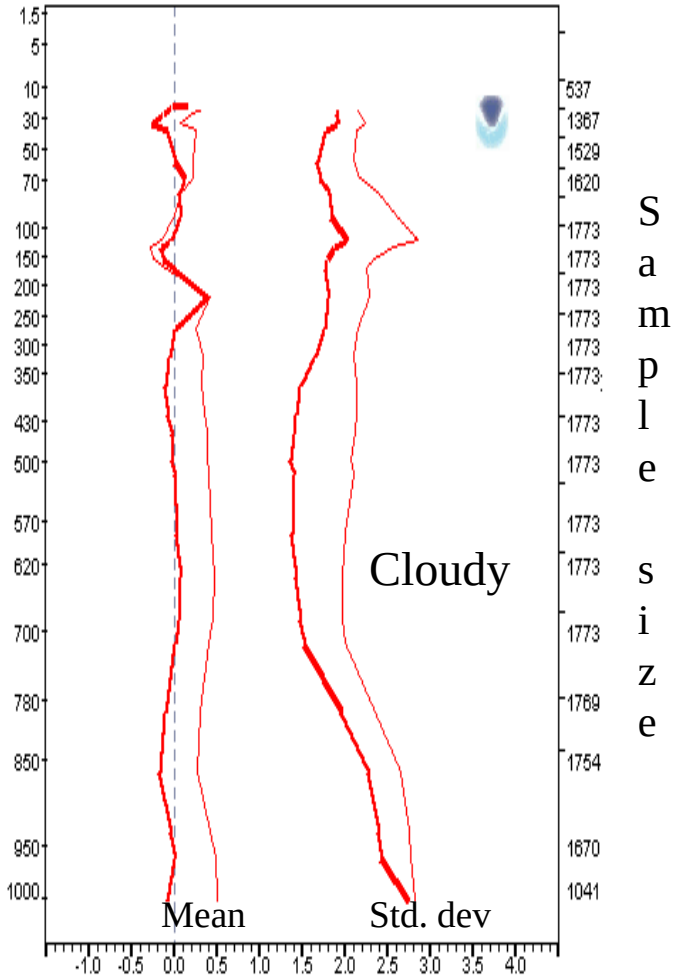
(Sounding Product Error Characteristics)

(VSTATS)



Collocated
Radiosonde versus
Satellite Differences
for ATOVS
First Guess (light)
and
Final Sounding (heavy)
Profiles

NOAA-16
(60N to 60S)



Vertical Stat Display 2.3

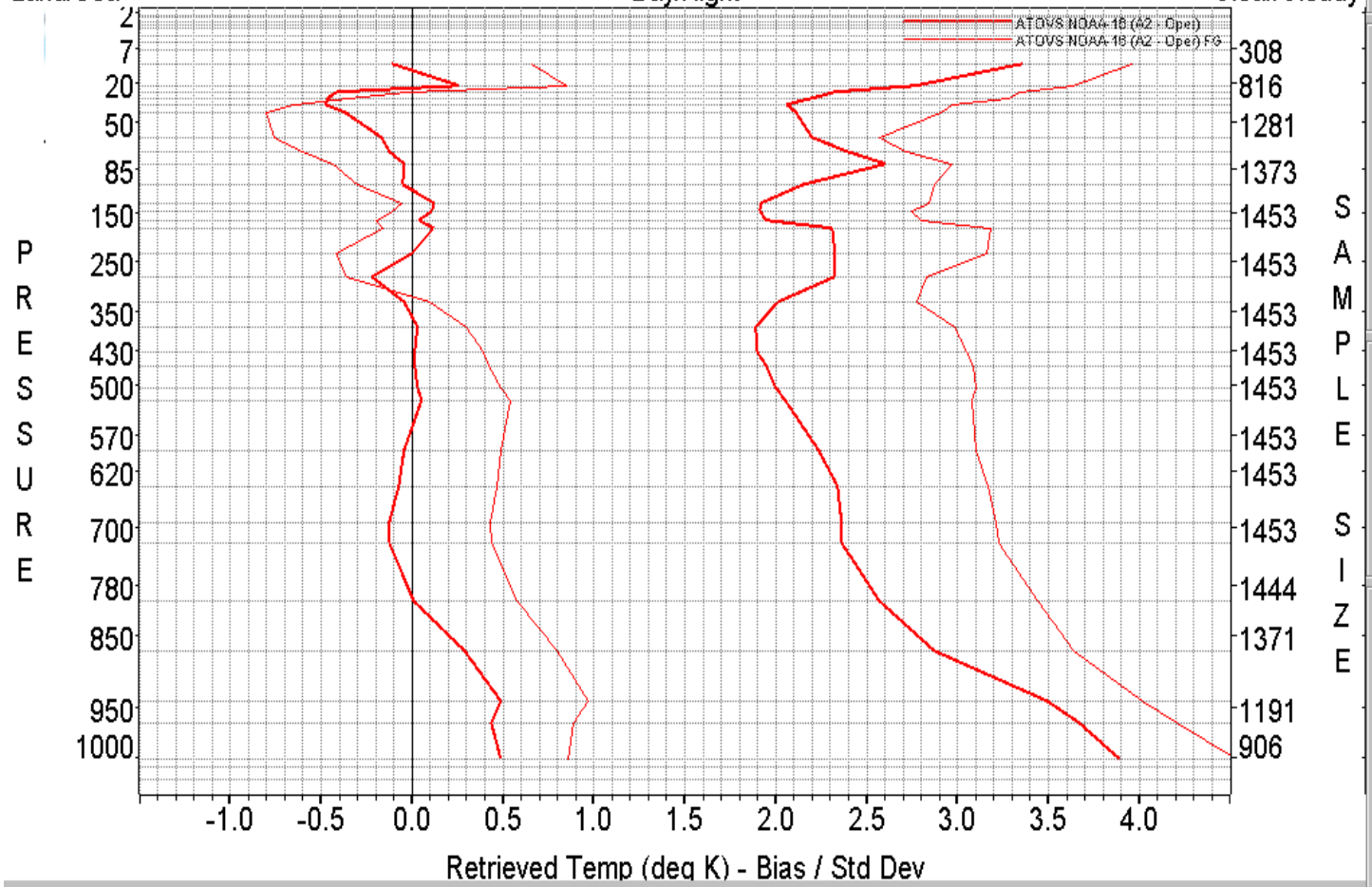
File Edit Modify Stat Sets Help

NOAA/NESDIS Vertical Statistics Display

December 20, 2004 to December 26, 2004

60N to 60S, 180W to 180E

Land/Sea | Day/Night | Clear/Cloudy



VstatDisplay

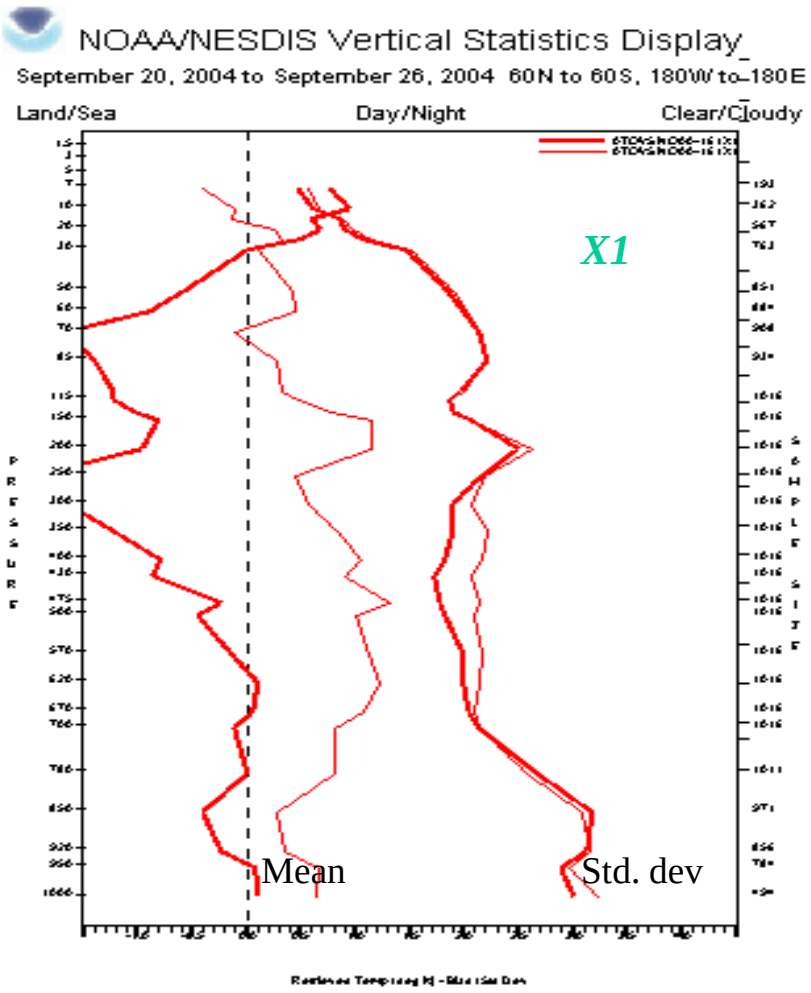
Version 2.3

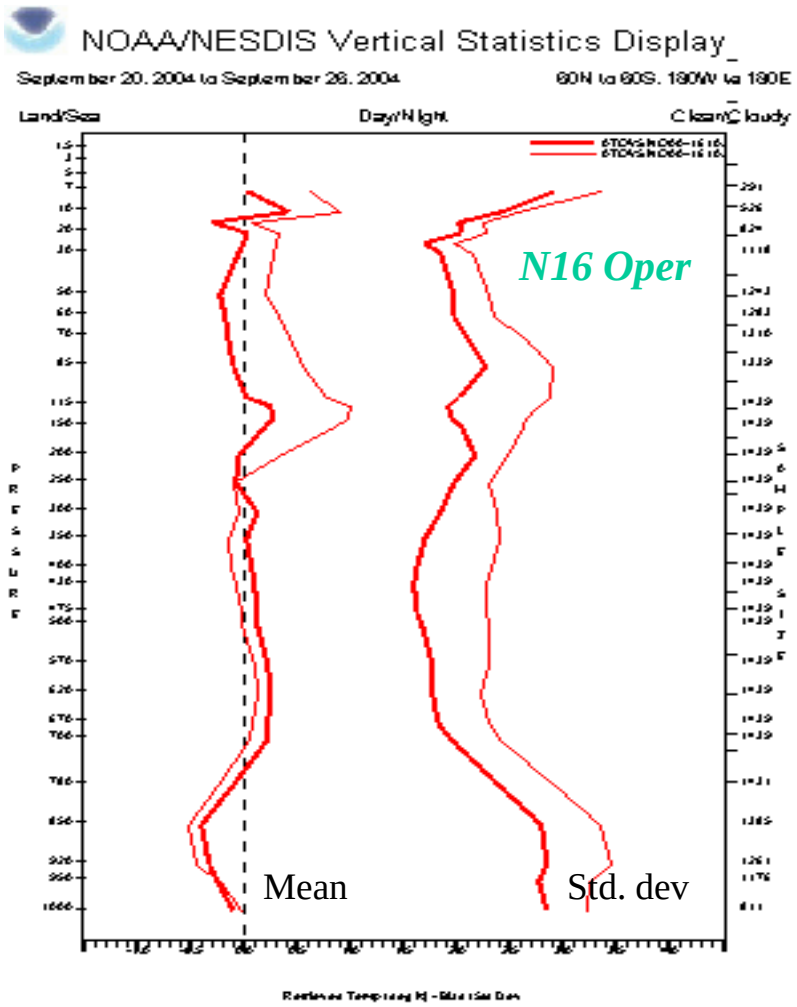
- (•) Retrieved Temp
- ( ) Virtual Temp
- ( ) Water Vapor
- ( ) Layer Thickness

- [x] Bias
- [x] Standard Dev
- [ ] Root Mean Sq.

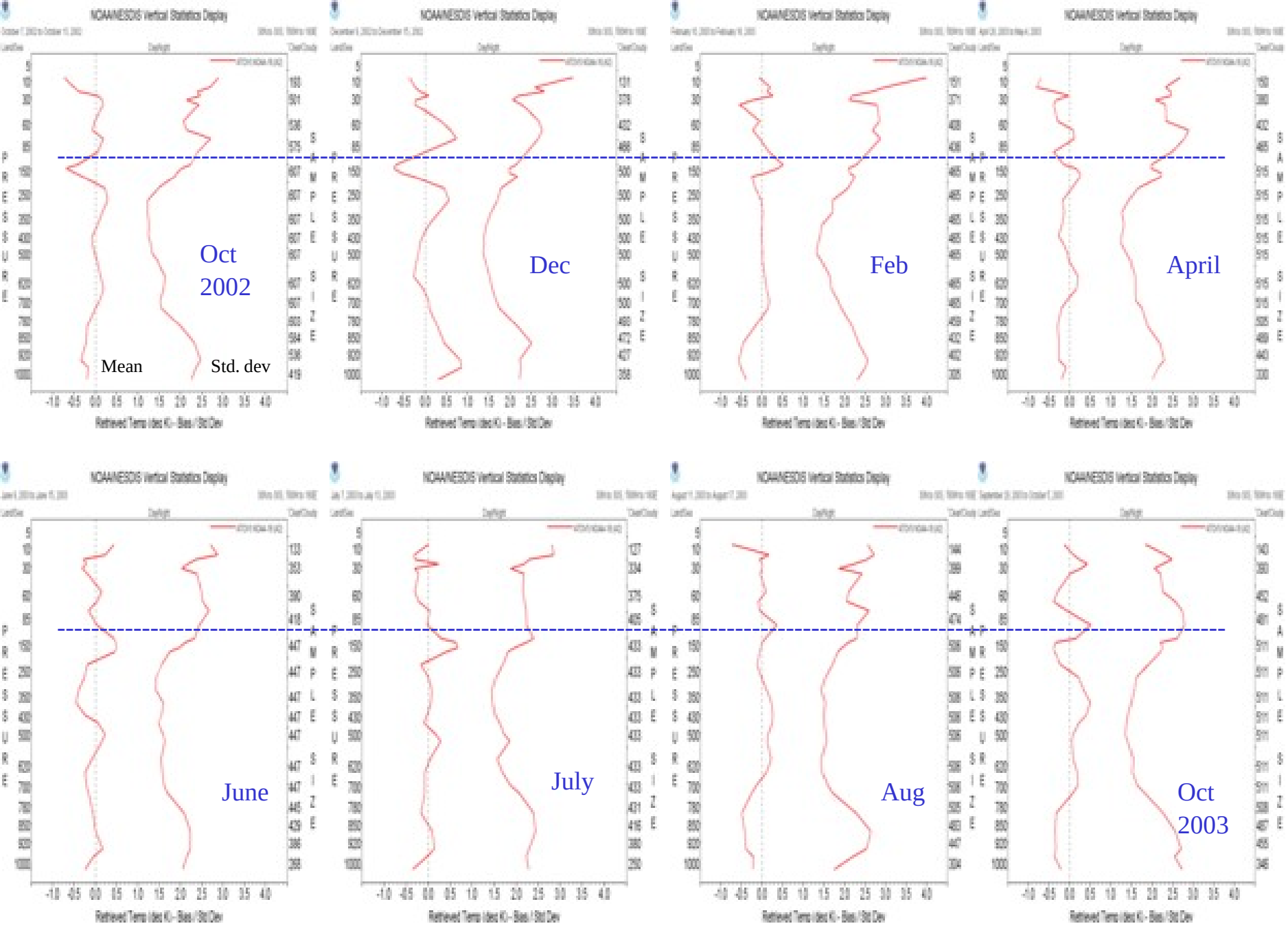
- [x] Primary Sat
- [x] Primary Sat FG
- [ ] Secondary Sat
- [ ] Secondary Sat FG

(1030 mb / 0)	Mean	Bias	Std Dev	RMS	Neg Diff	Pos Diff
Raob	0.00					
ATOVS NOAA-16 (A2 - Oper)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
ATOVS NOAA-16 (A2 - Oper) FG	0.00	0.00	0.00	0.00	0.00	0.00

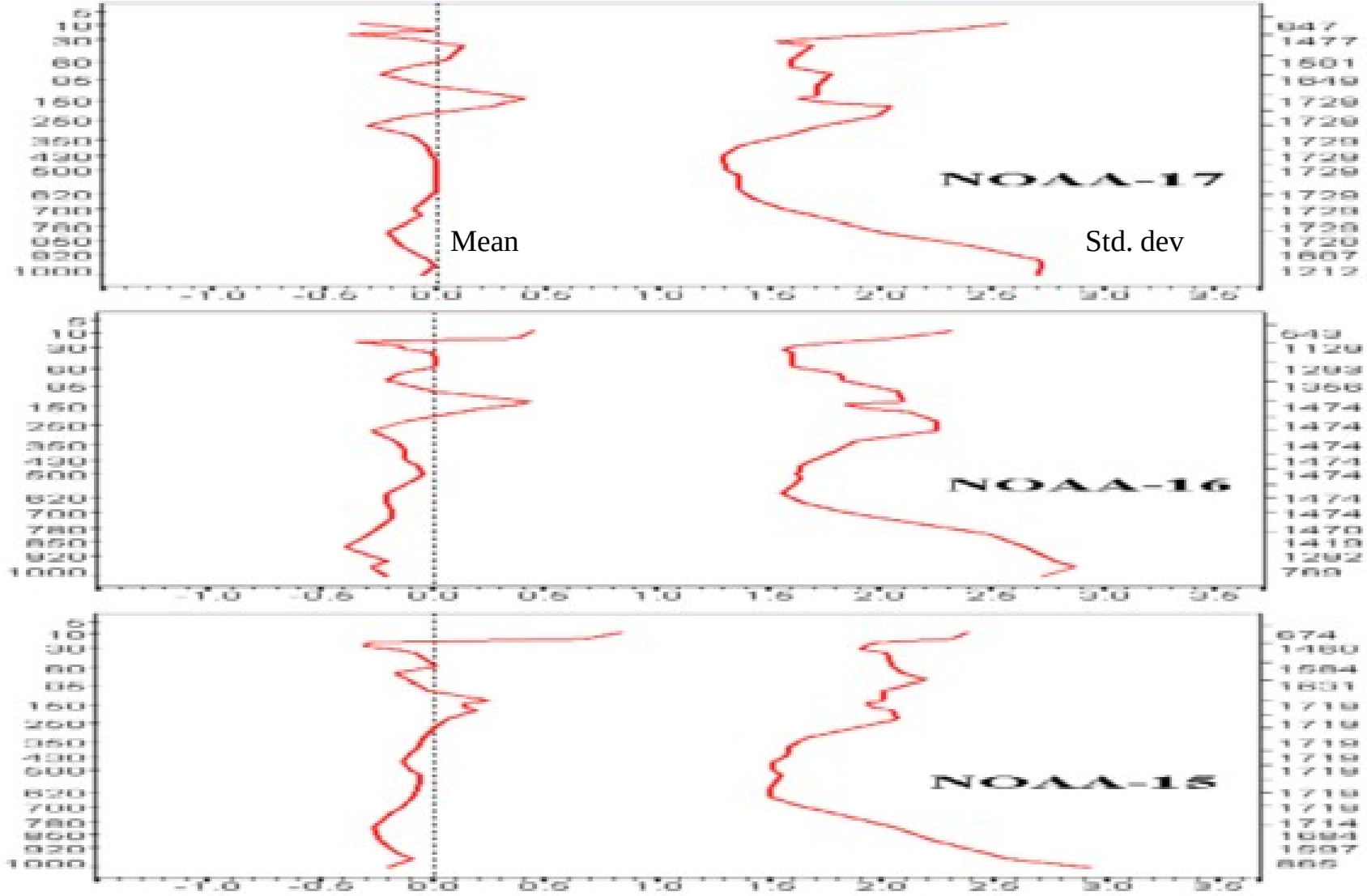




Vertical Statistics Temperature



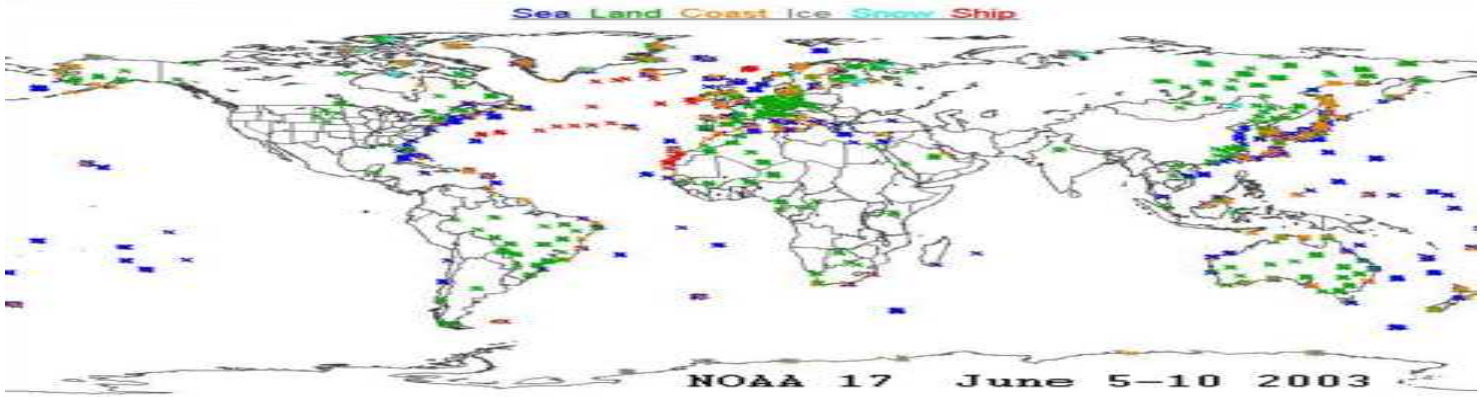
CDAS Investigation NOAA-16 (Temperature)

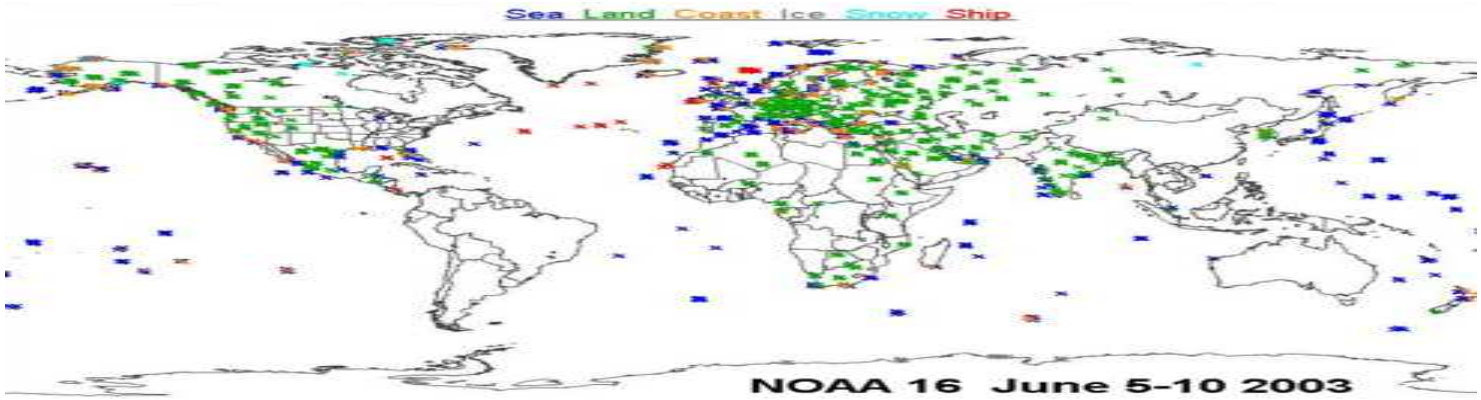


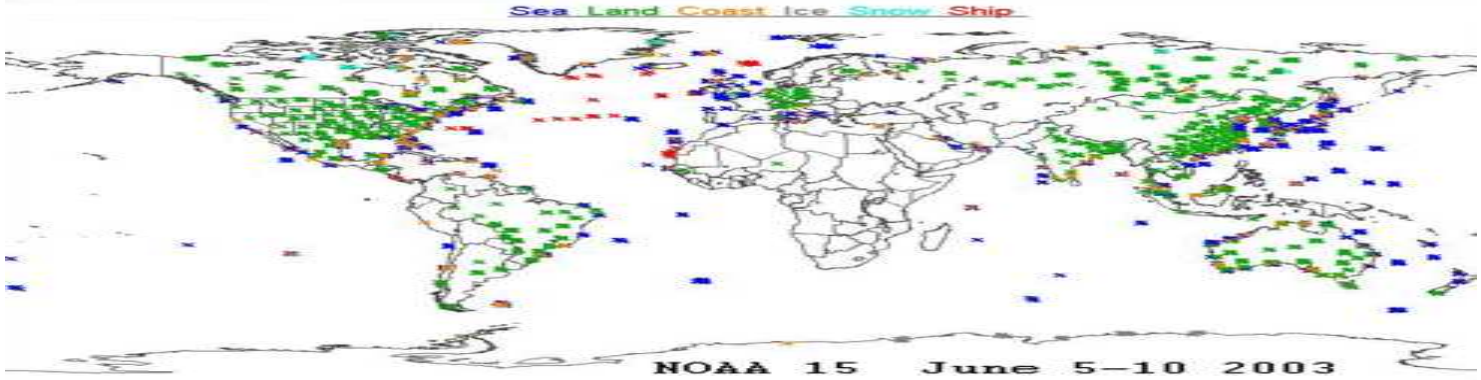
60N to 60S Temperature

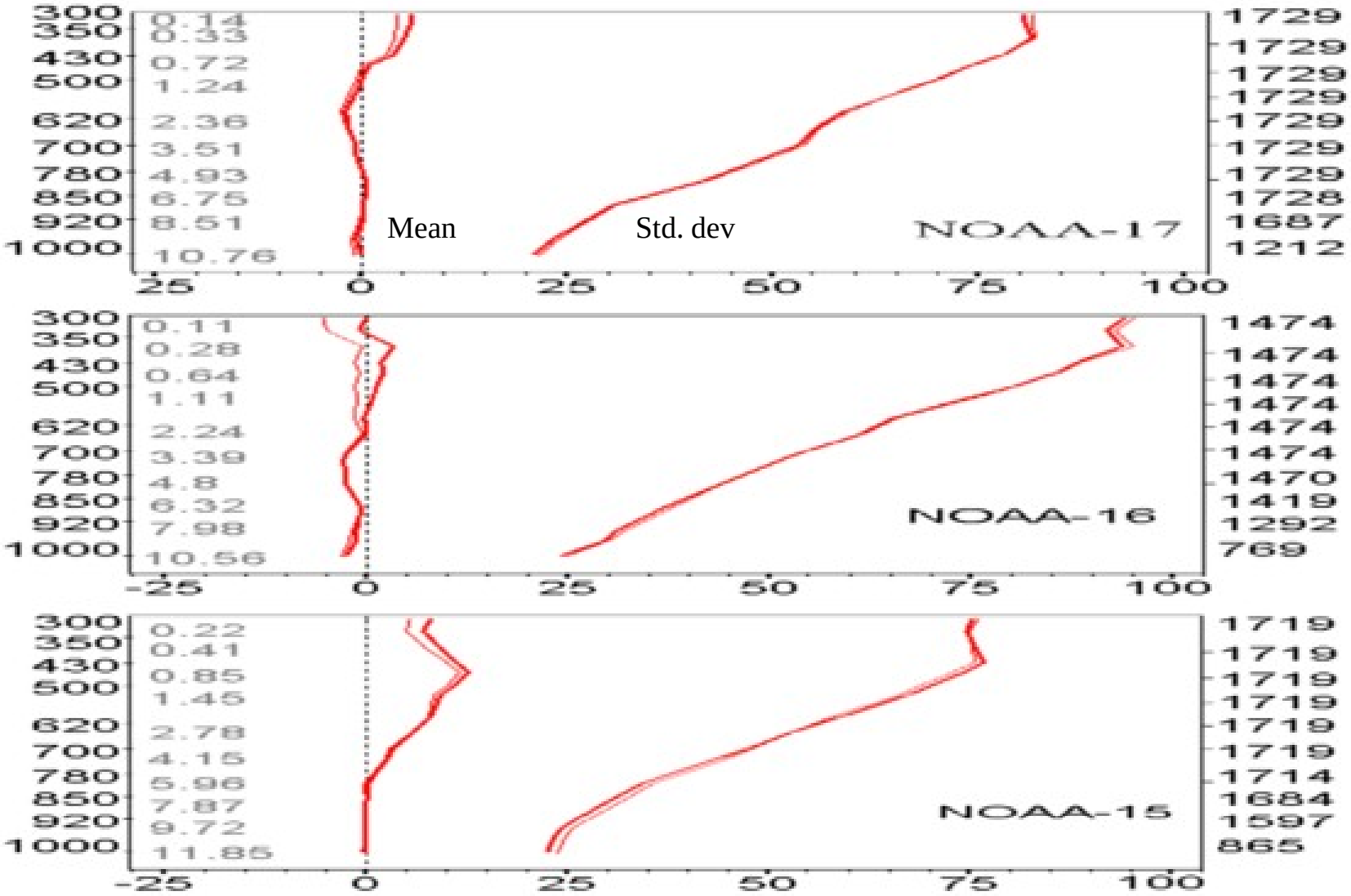
SATELLITE COLLOCATIONS (+/- 3hrs, land; +/- 5hrs, sea)

(PDISP)









60N to 60S Moisture (%) g/kg

Products
- Soundings
- Non Soundings

Vertical Stats
POSSE
Graphic Apps

Documentation
Filter Functions
Limb Corrections
RFI Corrections
Trending Acc Plots
Featured Images

Other related sites:

POES Status(SOCC)
Data Access (IPD)
GOES
Dr. Wark Memorial

Search this site

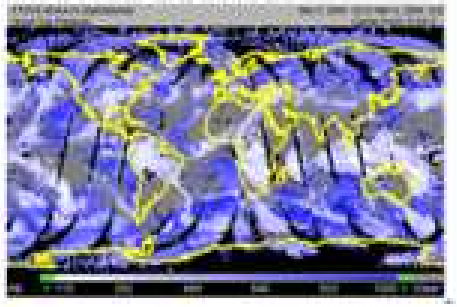
DOC | NOAA | NESDIS | ORA

Primary Polar Products

NOAA's polar orbiting satellites provide measurements from the HIRS/3, AMSU-A and AMSU-B sounder instruments on board NOAA-15 and NOAA-16.

Temperature and moisture soundings products are generated via the Advanced TOVS (ATOVS) and AMSU-B soundings processing systems.

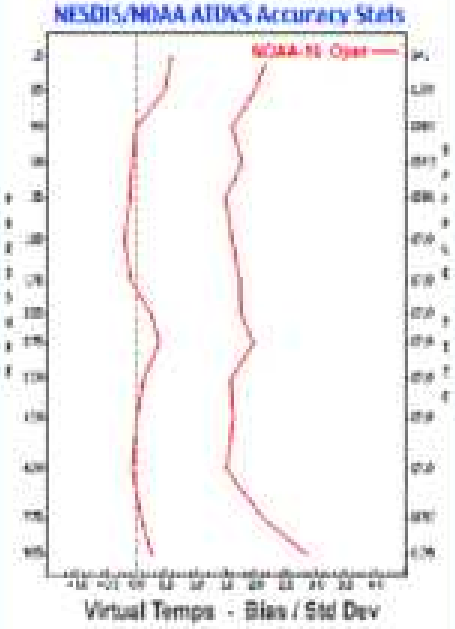
Non-sounding products produced by ATOVS, such as Cloud Amount, Radiation and Ozone:



Vertical Accuracy Plots

FPDT routinely performs vertical accuracy statistics where the soundings are collocated with Radiosondes from NCEP.

Currently, a Java application produces these graphs every week for NOAA-15 and NOAA-16.

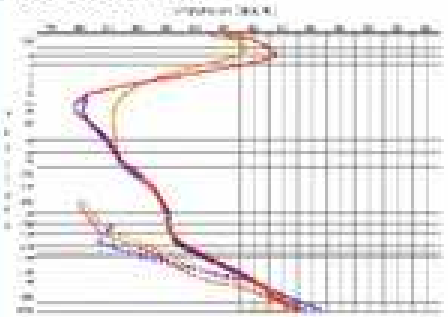


Plots are generated for:

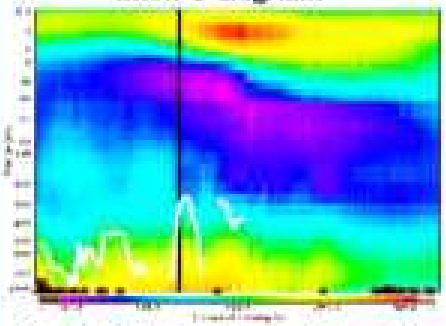
Retrieved Temps (40 Levels)
Virtual Temps (15 Levels)
Water Vapor (15 Levels)

POSSE

The Polar Orbiting Satellite Sounding Evaluation system is a client-server applet that allows a user to select any product at any level from a real-time database with all 40 levels of temperature and moisture satellite soundings and Forecast levels.



Skew-T diagrams

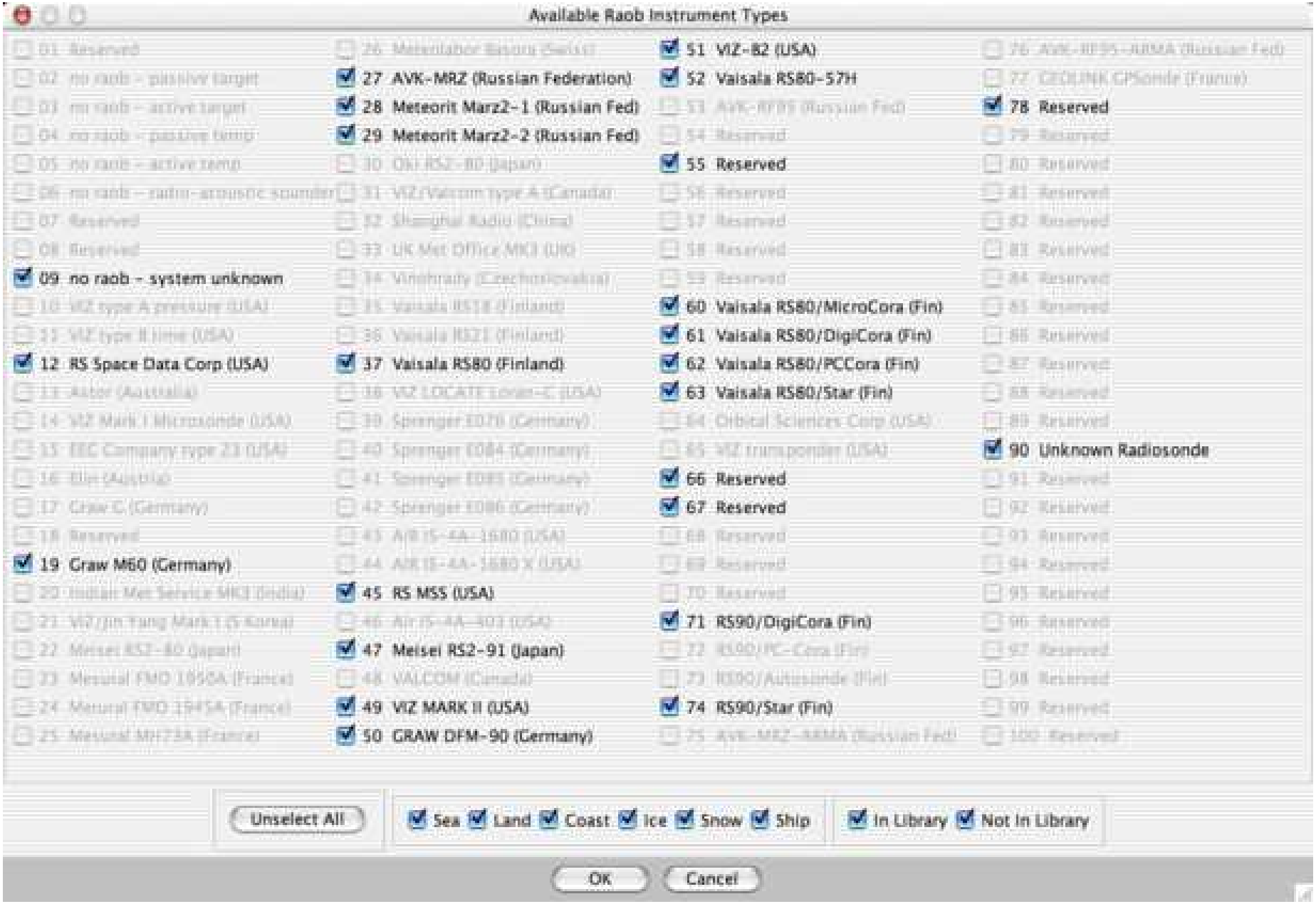


Vertical Slice Diagram (40 levels)

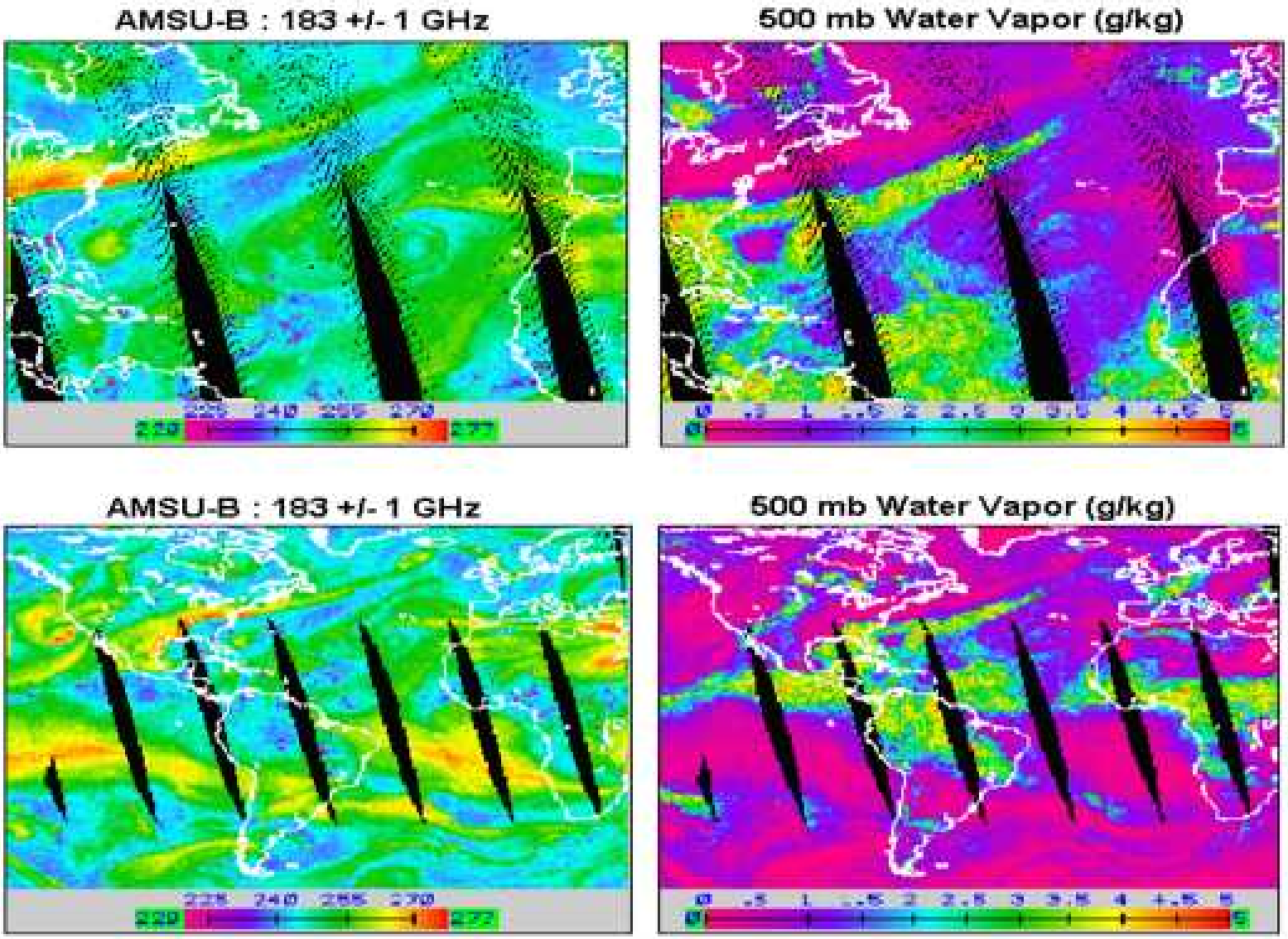
http://www.orbit.nesdis.noaa.gov/smcd/opdb/poes

EXTRAS

NMC Raob Types

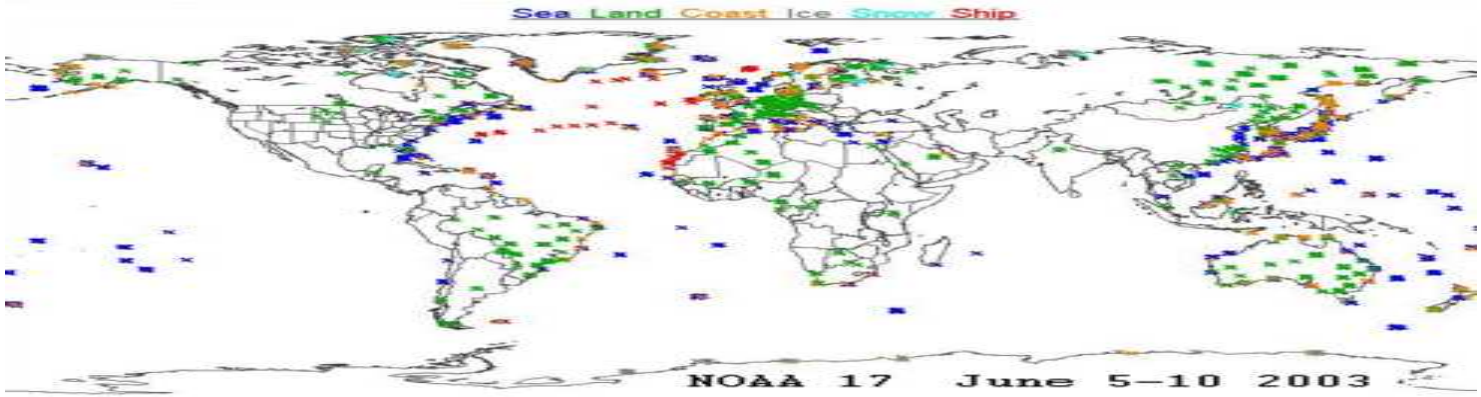


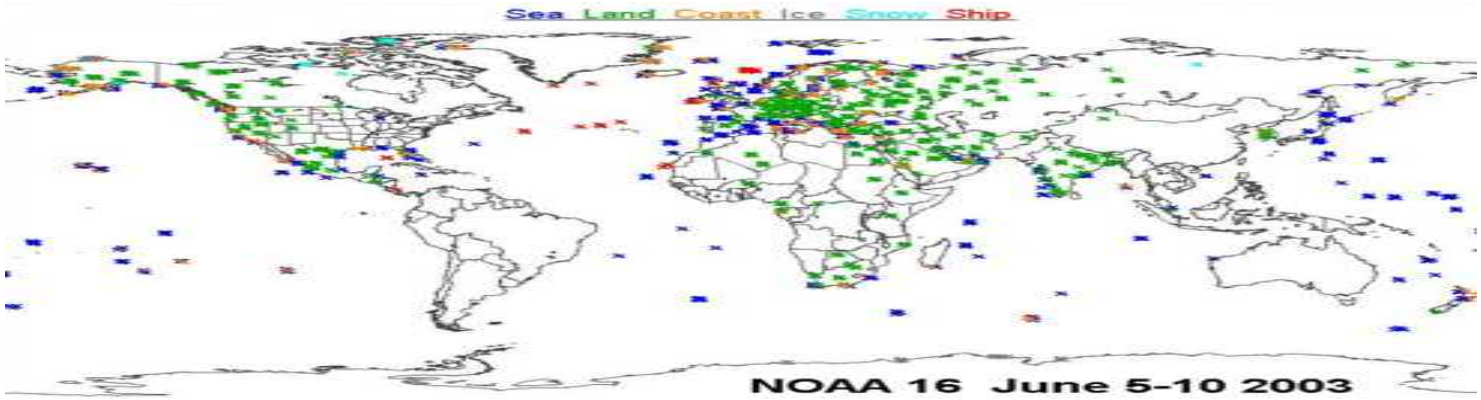
(EDGEIS)

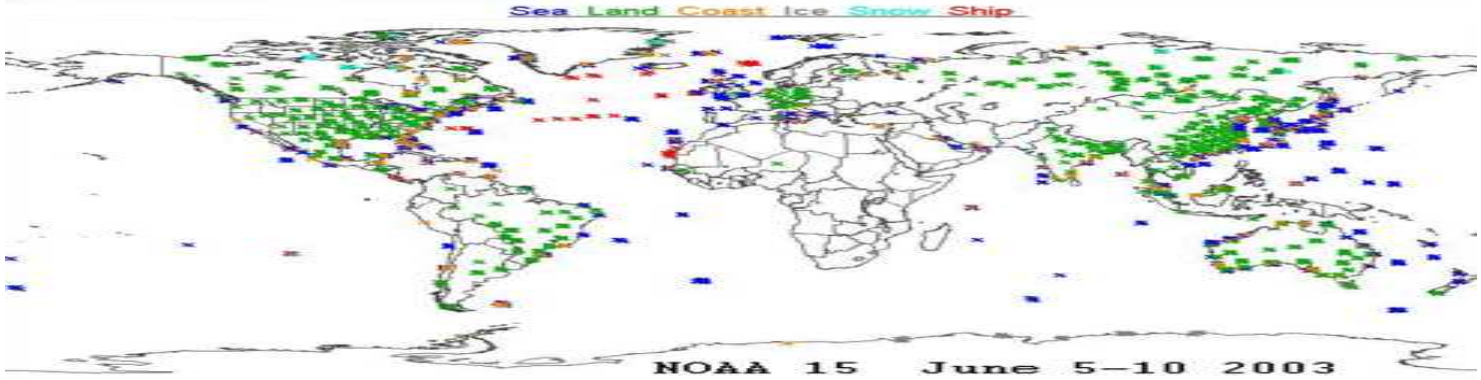

AMSU-B : 183 +/- 1 GHz
500 mb Water Vapor (g/kg)
AMSU-B : 183 +/- 1 GHz
500 mb Water Vapor (g/kg)

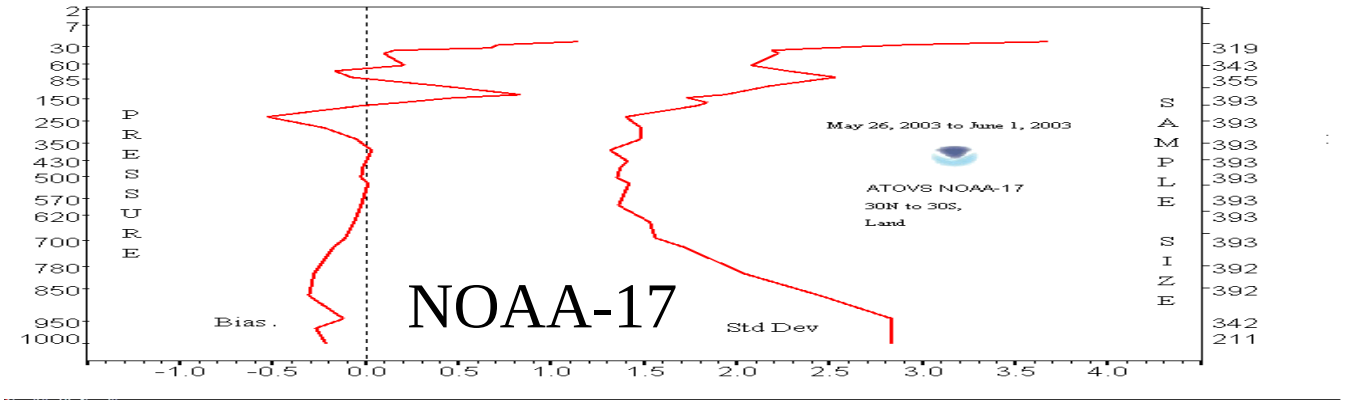
SATELLITE COLLOCATIONS (+/- 3hrs, land; +/- 5hrs, sea)

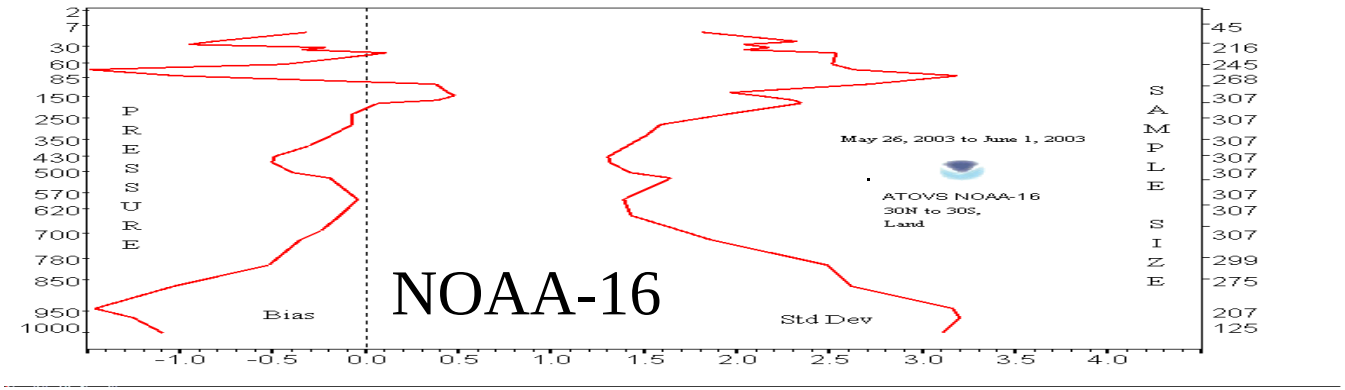
(PDISP)

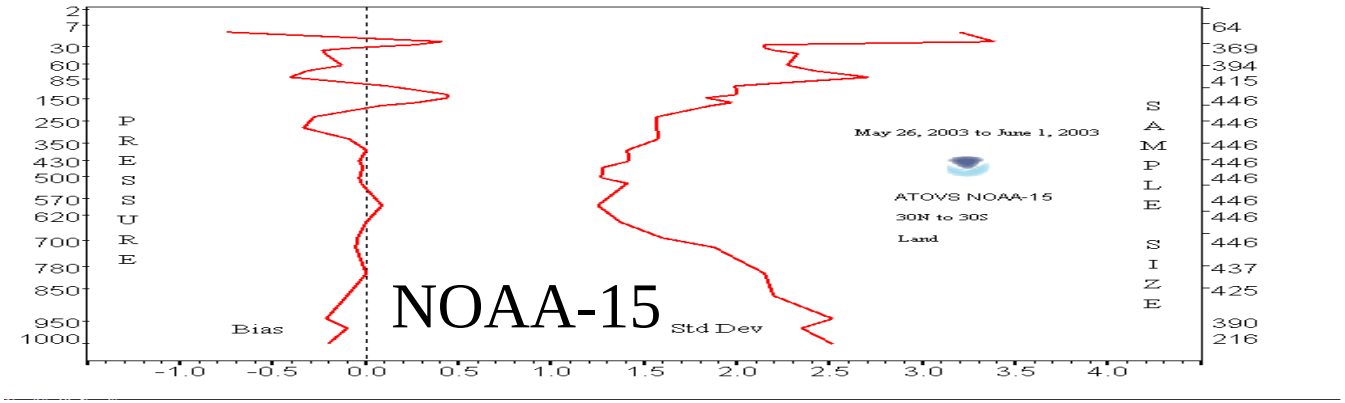












Satellite minus Radiosonde temperature statistics

Tropical land (30N to 30S)

June 7-14, 2003

Results "skewed" by regional sampling differences

ATOVS Science … System-2005

- Incorporate AMSU-B
- Regression Guess Replaces Library Search
  - Calculate First Guess Radiance (OPTRAN)
- Measurement (Radiance) Bias Adjustment
  - AMSU-A
  - AMSU-B
  - HIRS
- Retrieval Solution using “NESDIS/NCEP community OPTRAN” … not pre-computed

Motivation … *for System-2005*

… satisfy the **greatest common denominator** of total user need

… serve as **benchmark** for planned next generation products
(NPP to METOP to NPOESS)

Real-time Products and ***Long-term Data-sets***
for use in
Weather and ***Climate***

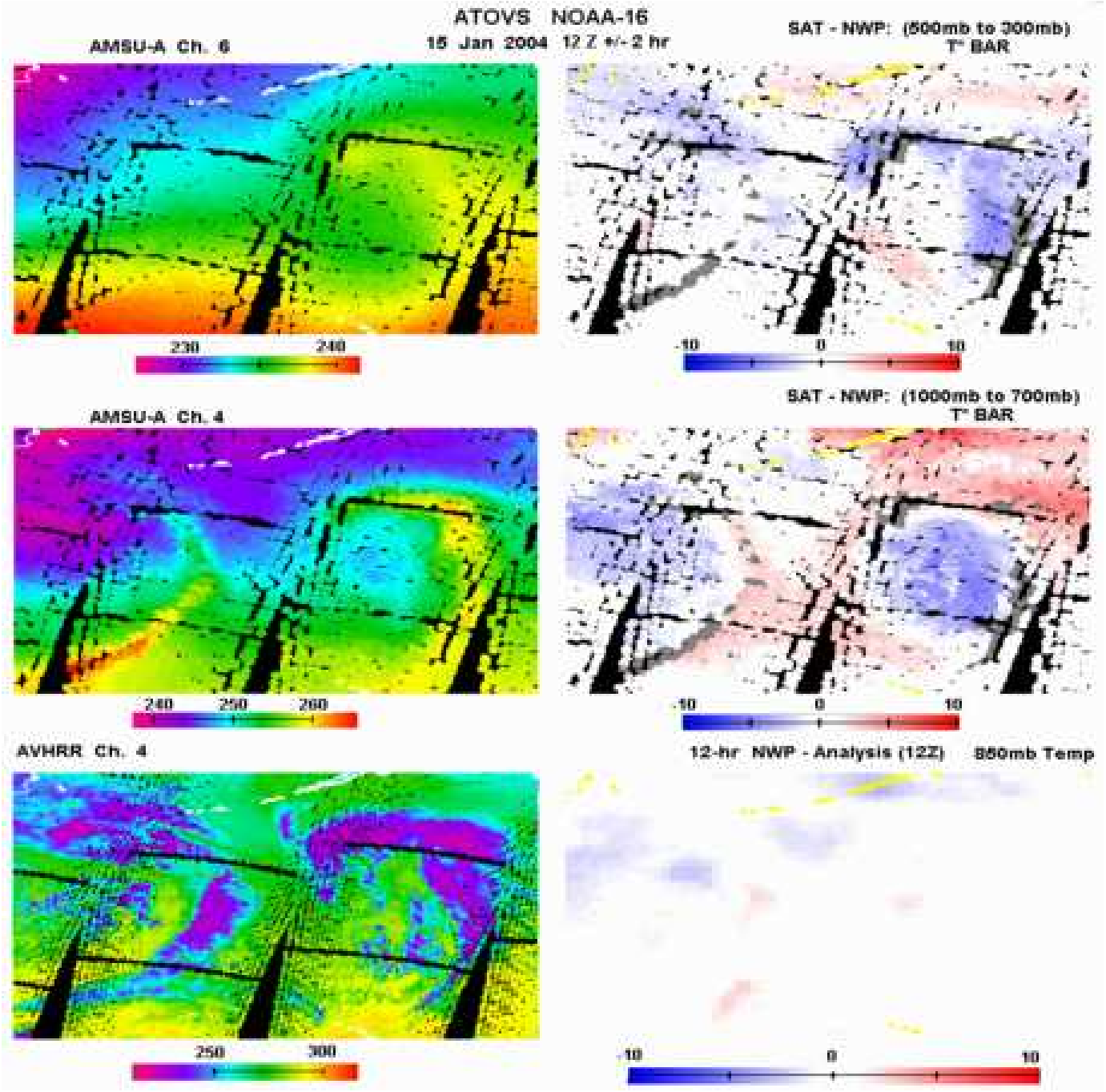
SOUNDING USERS

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

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

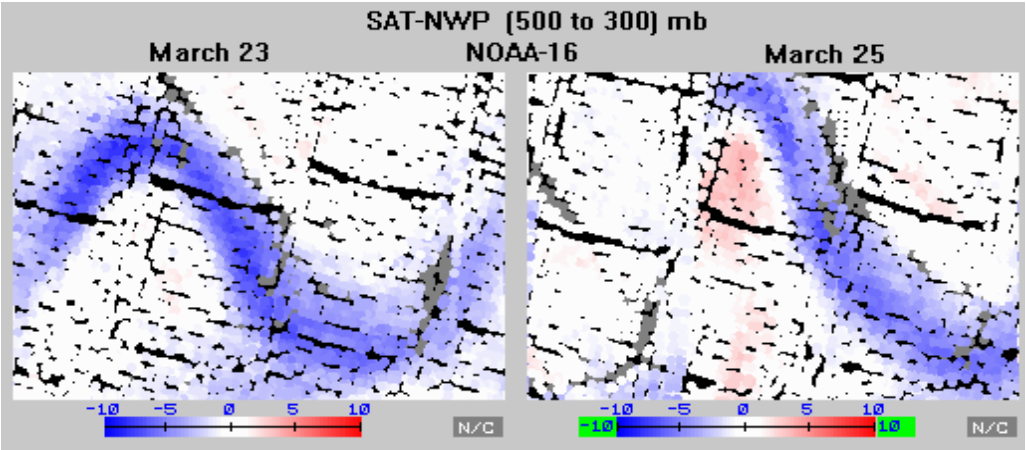
- NOAA
  - AWIPS (NWS)
  - Cloud Products (NESDIS) …

- Others …

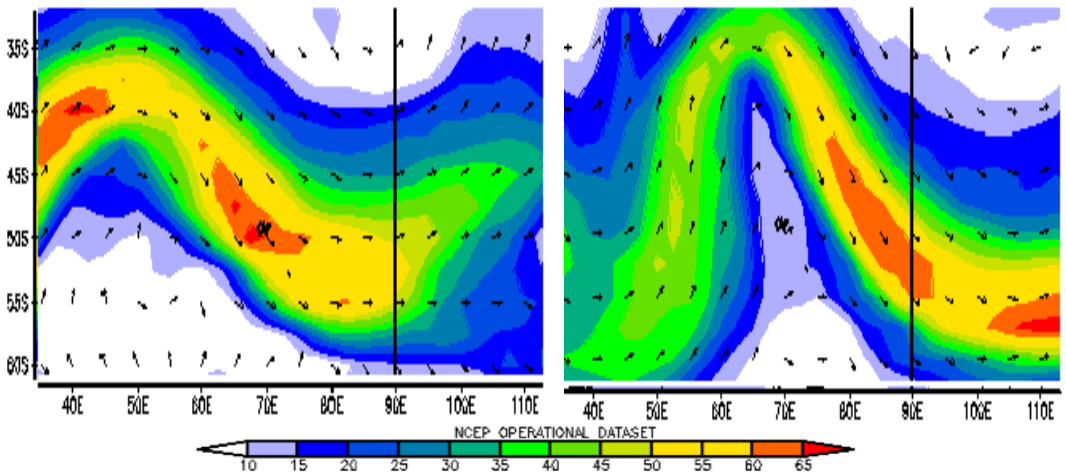


SUAN can provide an NWP independent platform for "bias tuning"

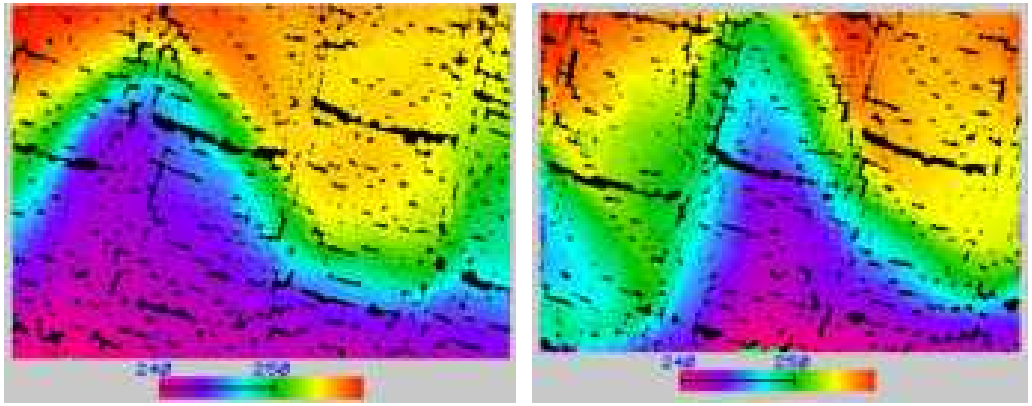
leading to improved satellite data impact in frontal zones?



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

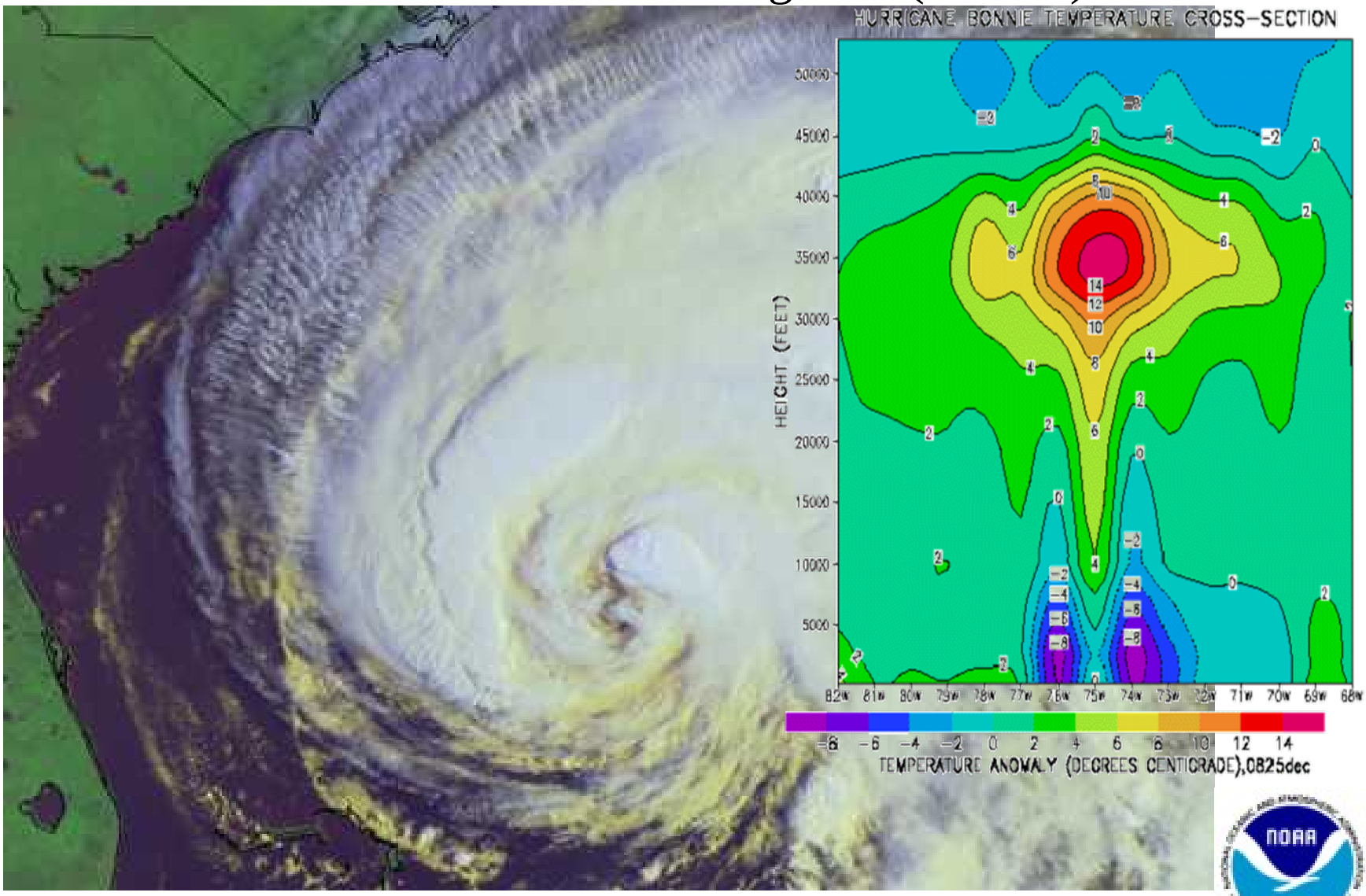


Pinpoint the Location of the **JET STREAM**
< (EMC 400mb Wind)



Provide Information in Addition to **SATELLITE MEASUREMENTS**
< (AMSU-A Ch 5)

Hurricane Bonnie's warm core revealed in temperature anomaly cross section derived using NOAA-15 Advanced Microwave Sounding Unit (AMSU) data



Tony Reale
ATOVS Sounding Products

NOAA NESDIS
Office of Research and Applications
NOAA NESDIS

ATOVS Sounding Products

- AMSU-A/HIRS/AVHHR Measurements, Temperature and Moisture Soundings, Clouds and Radiation
- AMSU-B Moisture Measurements and Soundings
- Collocated Radiosonde and Satellite Observations
- Future Plans
- NOAA Tech. Re. NESDIS 102

ATOVS Upgrades

Phase-1:

- Implemented Oct-01
- Combined CLW and Median Filter for Precip detection
- N-16 HIRS Scan Mirror Misalignment (NOAA Tech Memo NESDIS 46)
- Upper Stratospheric Soundings (NOAA Tech Memo NESDIS 45)

Phase-2:

- Implemented March-02
- More Consistent Retrieval Covariance Matrix (S)
- Selection of Sounding fov based on AMSU Ch.2 instead of HIRS Ch.8
- Improved Terrain Designation (Sea, Coast, Land)

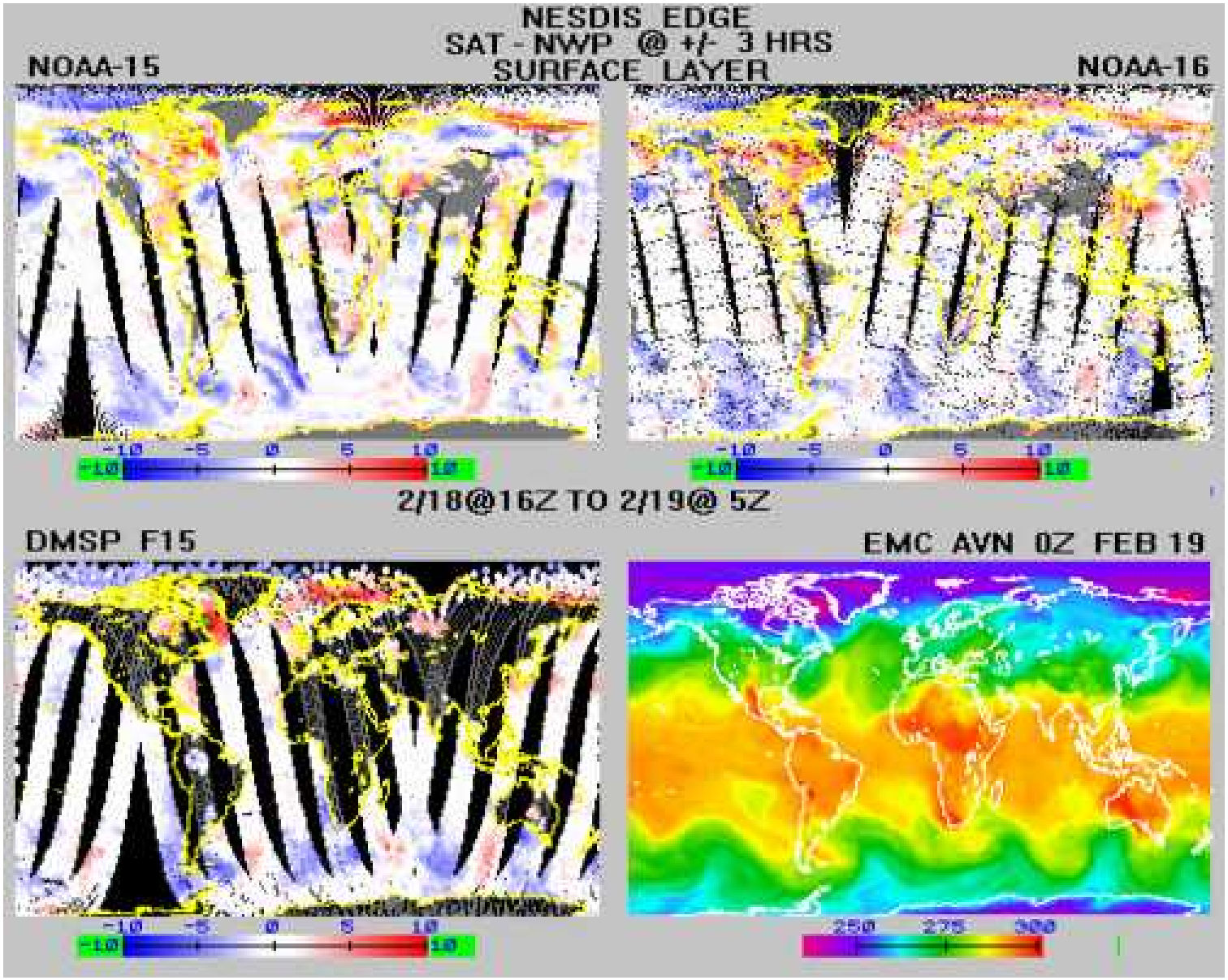
SAT - NWP DEPARTURES

- **LOW**: (1000 to 700) Layer Mean Virtual Temp
- **UP** : (500 to 300) Layer mean Virtual Temp

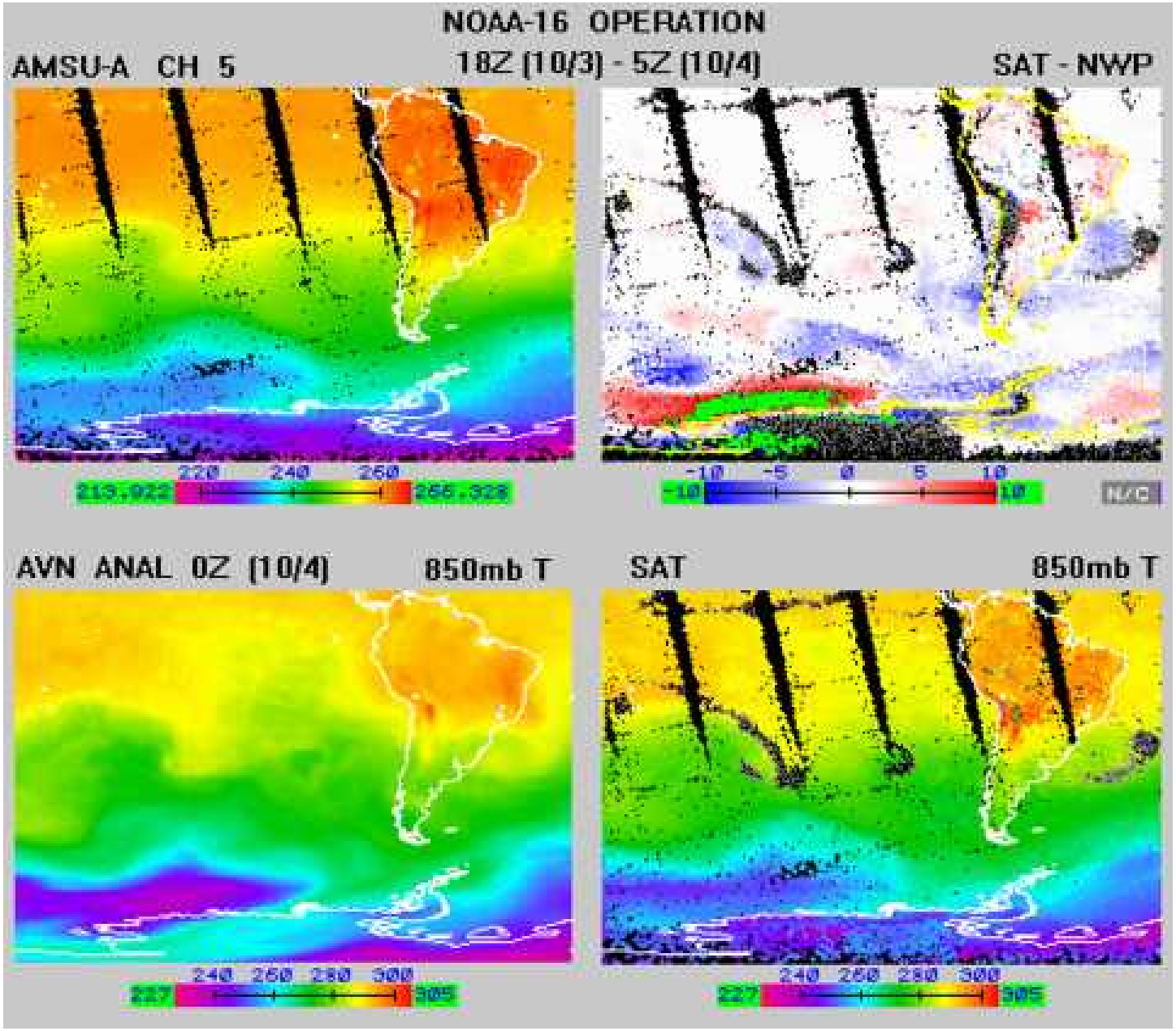
- Powerful **diagnostic tool** for global sounding system validation

- Largest values typically **correlated with thermal advection** (warming/cooling) pattern
- Provides **information in context of NWP**

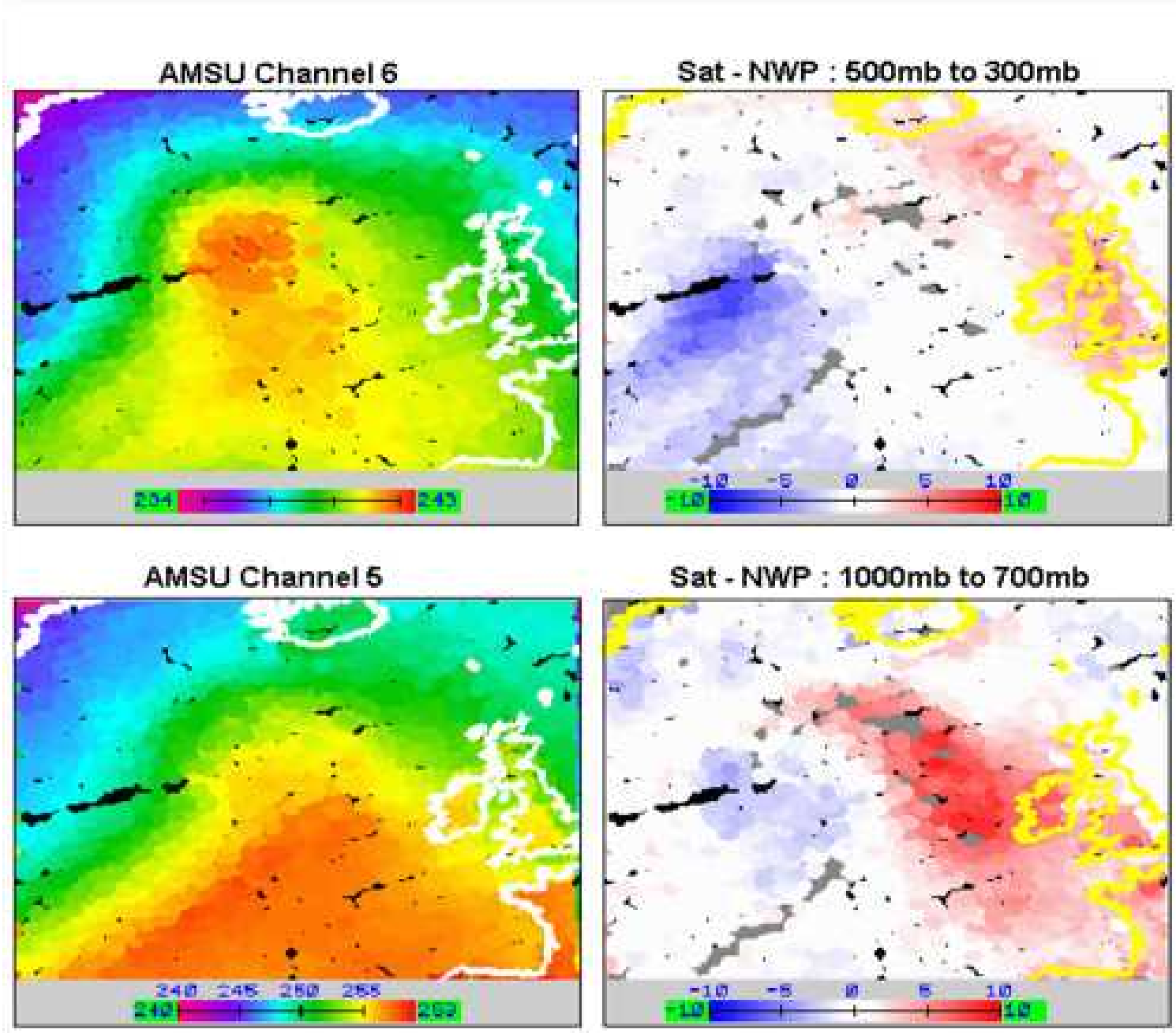
Good Consistency Among NOAA and DMSP Operational Products Systems vs NWP



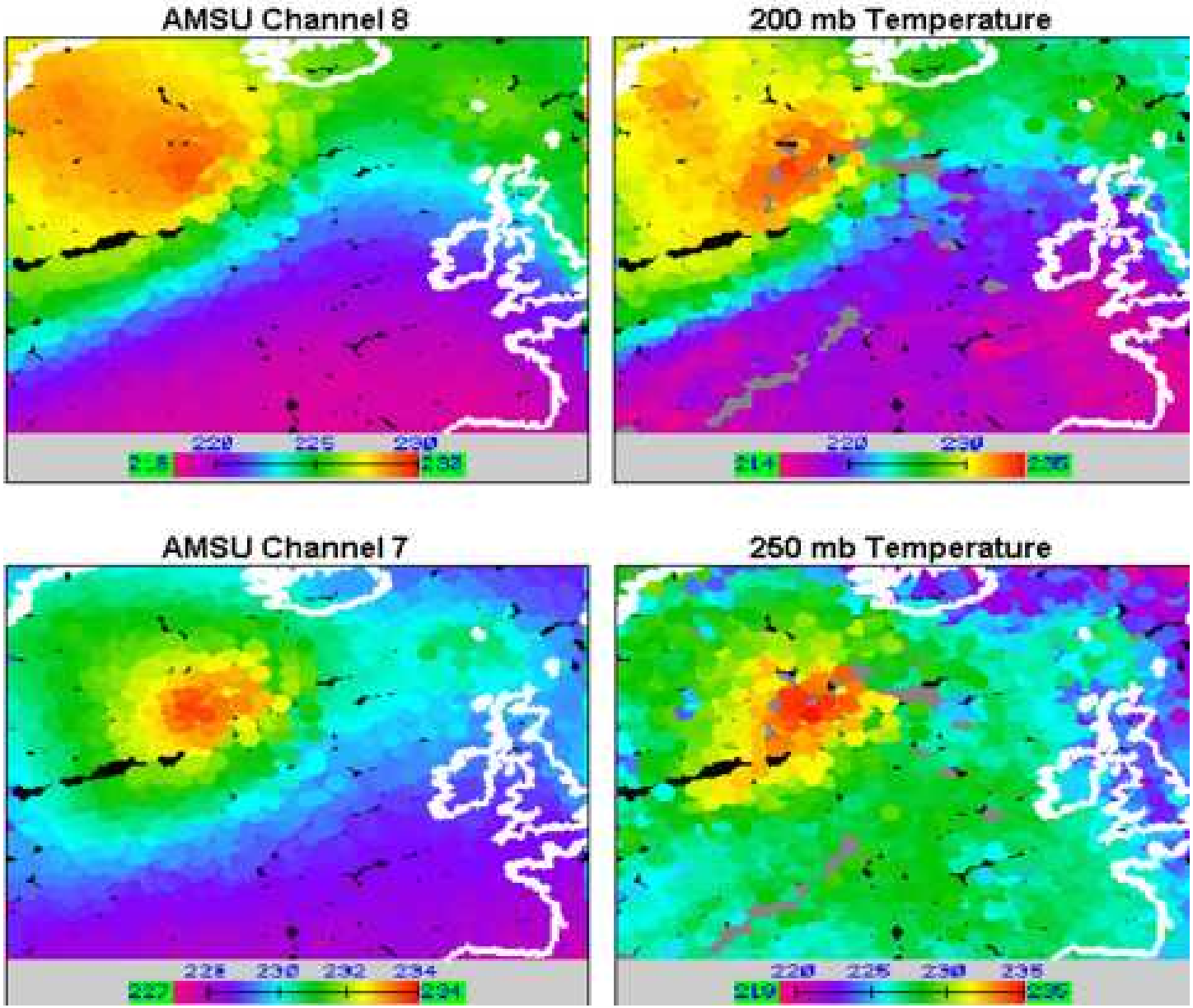
Soundings Provide Information in Data Poor Regions



...and Thermal Advection Zones

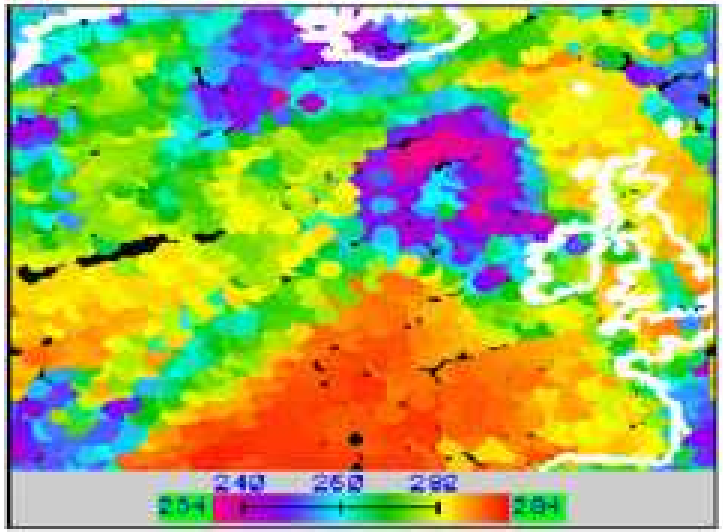


…delineate Jet Stream Core

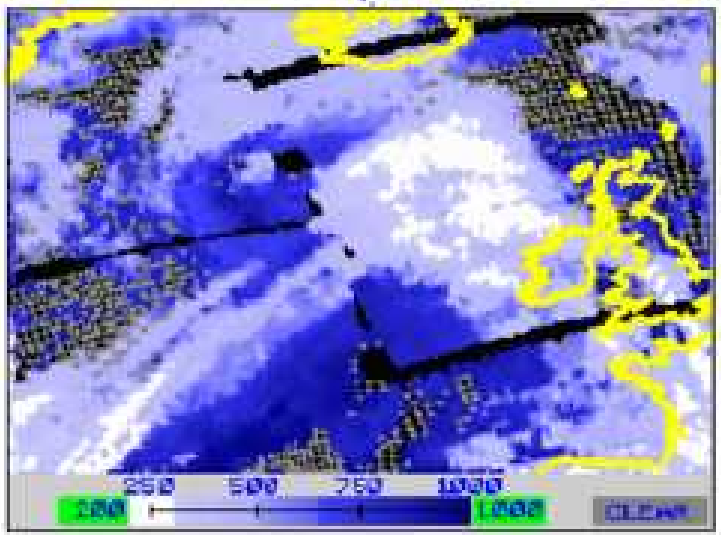


Clouds and Moisture

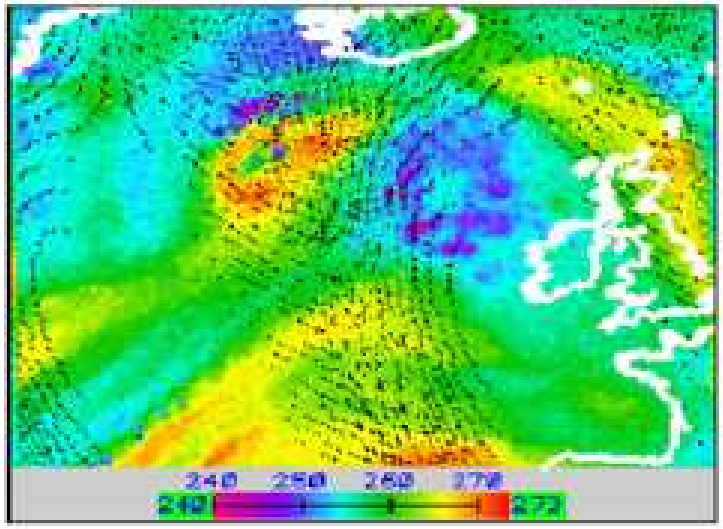
HIRS Channel 8



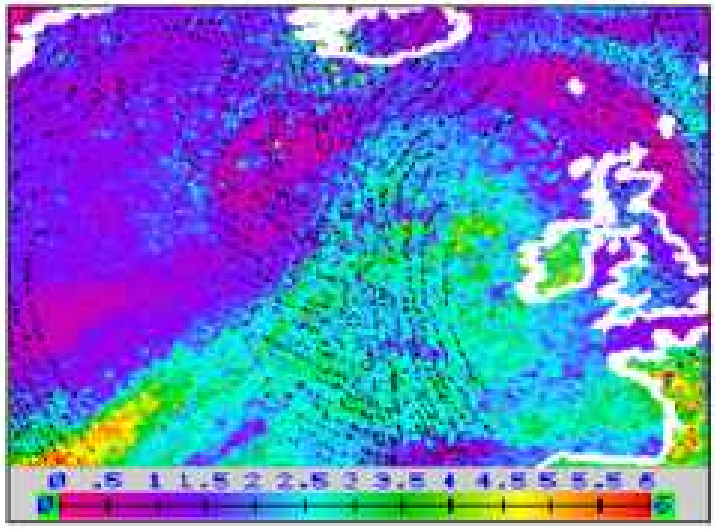
Cloud Top Pressure



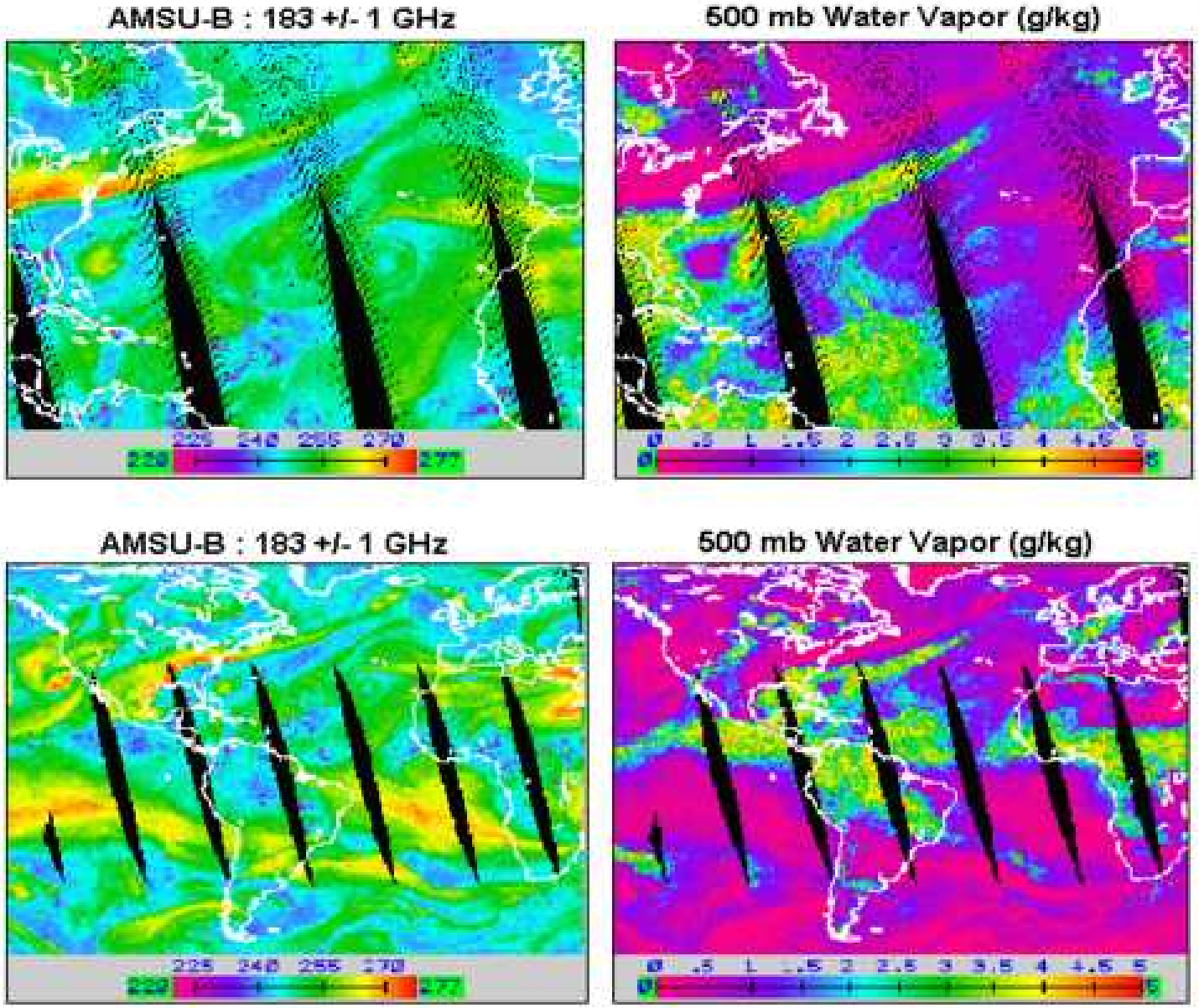
AMSU-B: 183 +/- 3 GHz



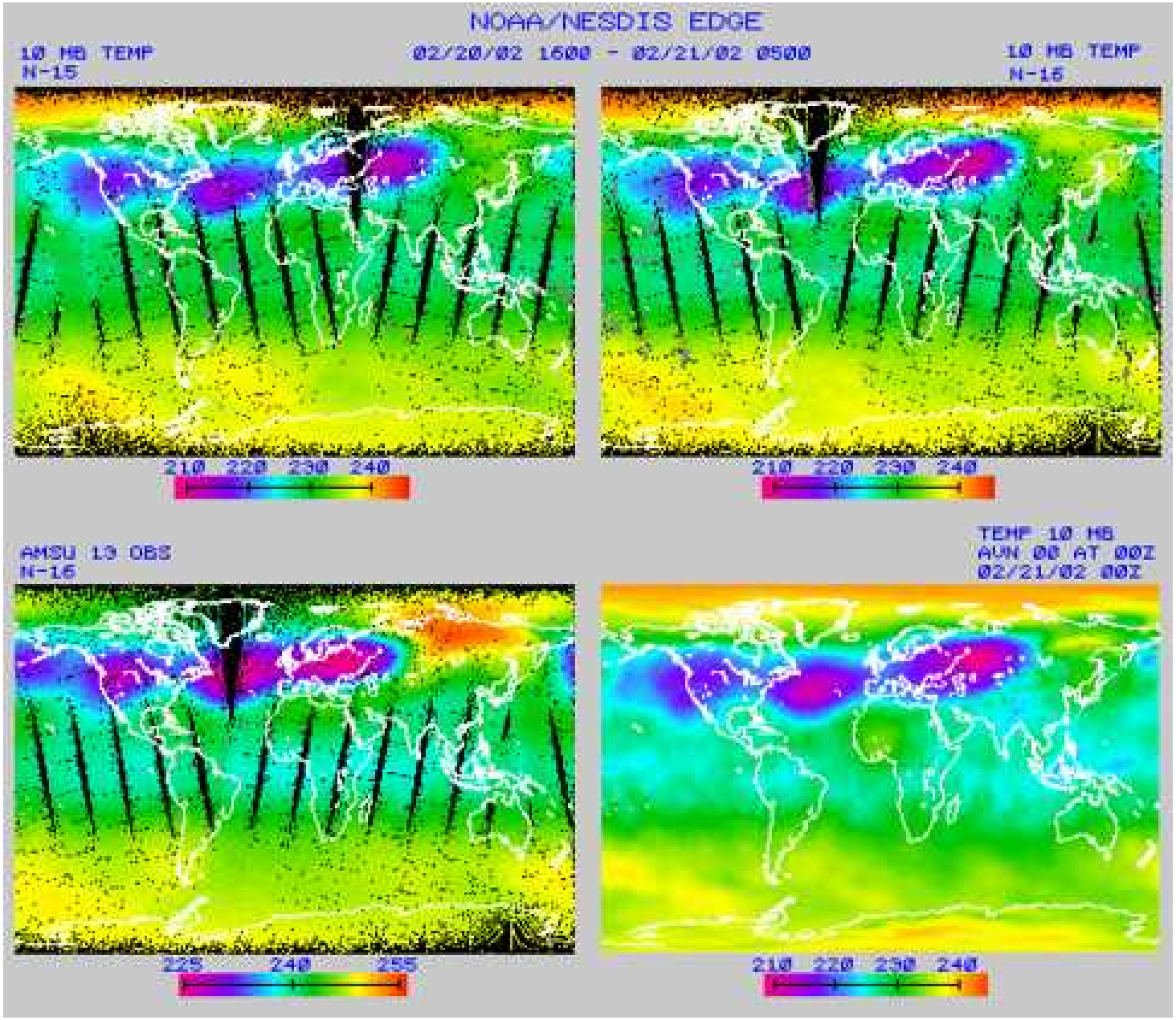
620 mb Water Vapor (g/kg)



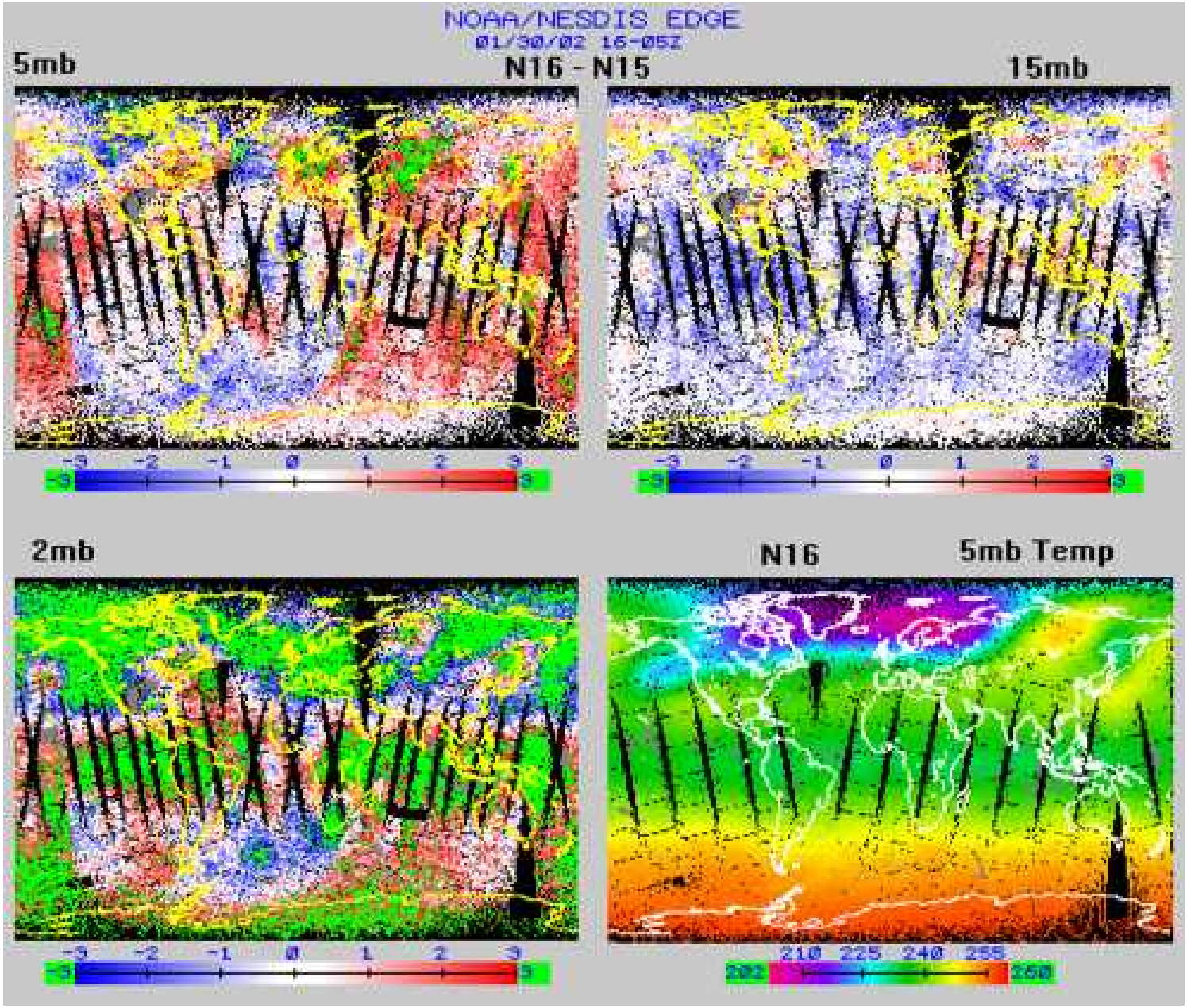
Upper Troposphere Water Vapor



Upper Stratosphere Products vs NWP Analysis



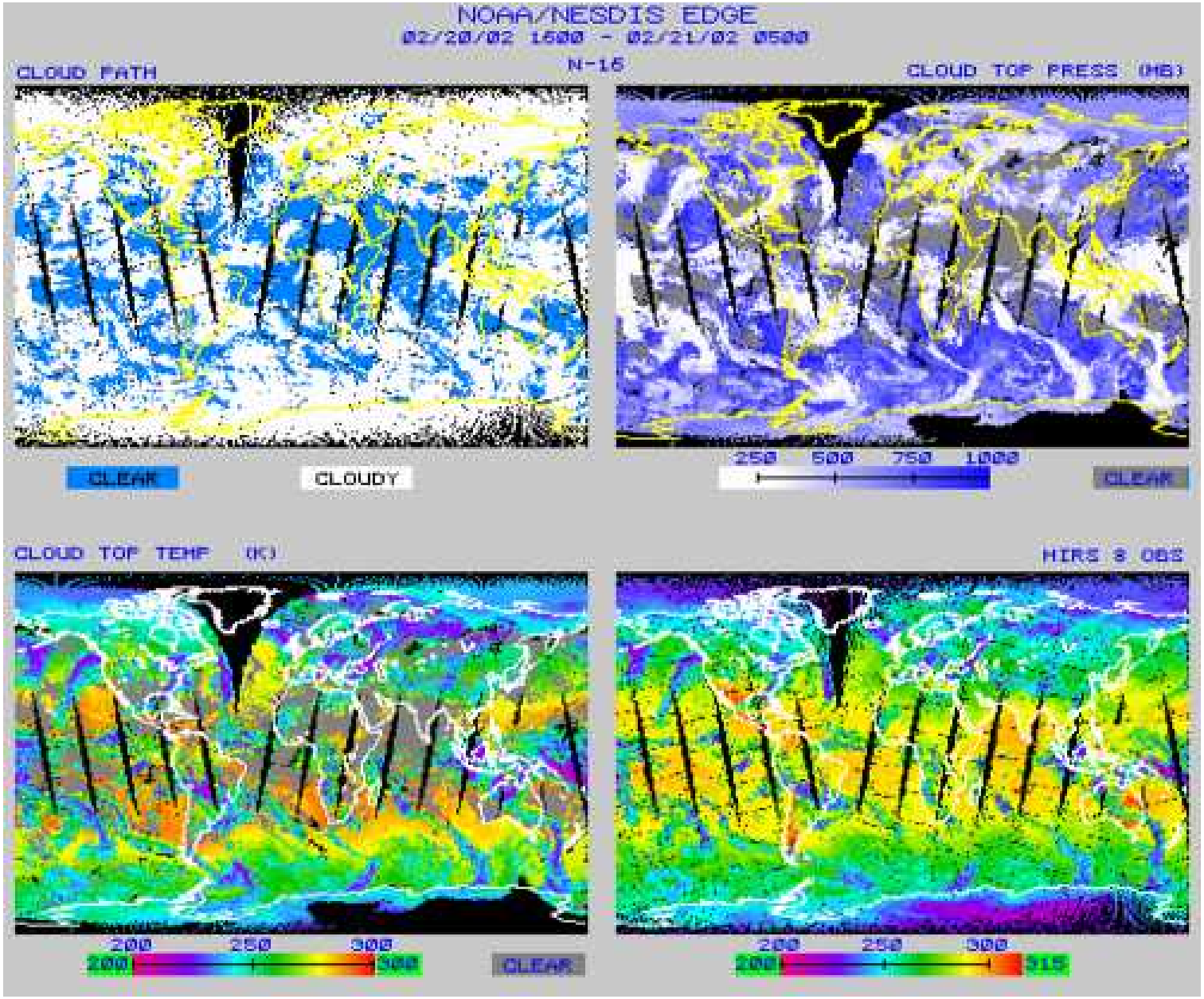
Diurnal vs AMSU Ch 14 Impacts above 15mb



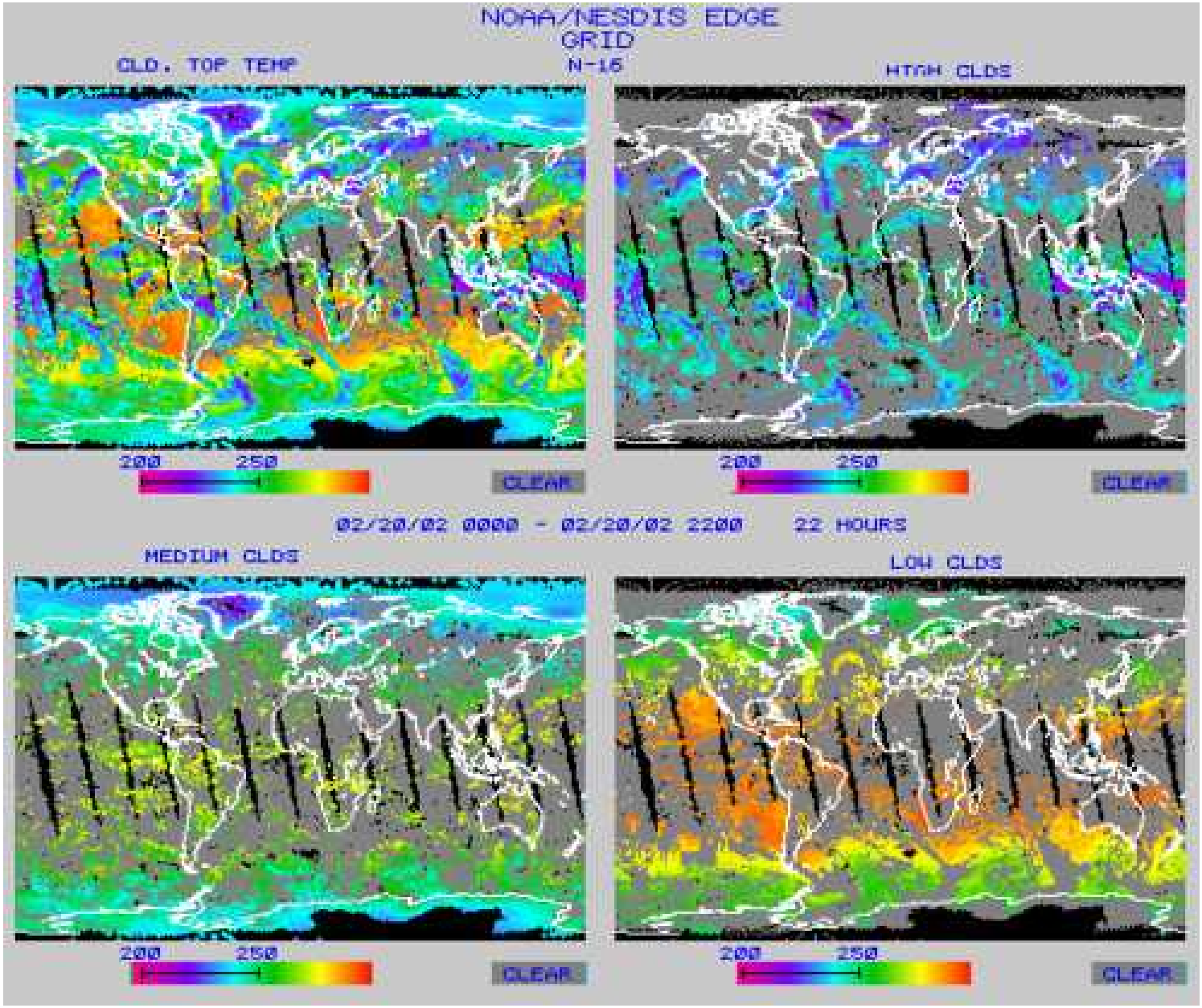
CLOUD AND RADIATION PRODUCTS

- Cloud Mask
- Cloud Top Temperature and Pressure
- Radiation and Layer Cooling Rates

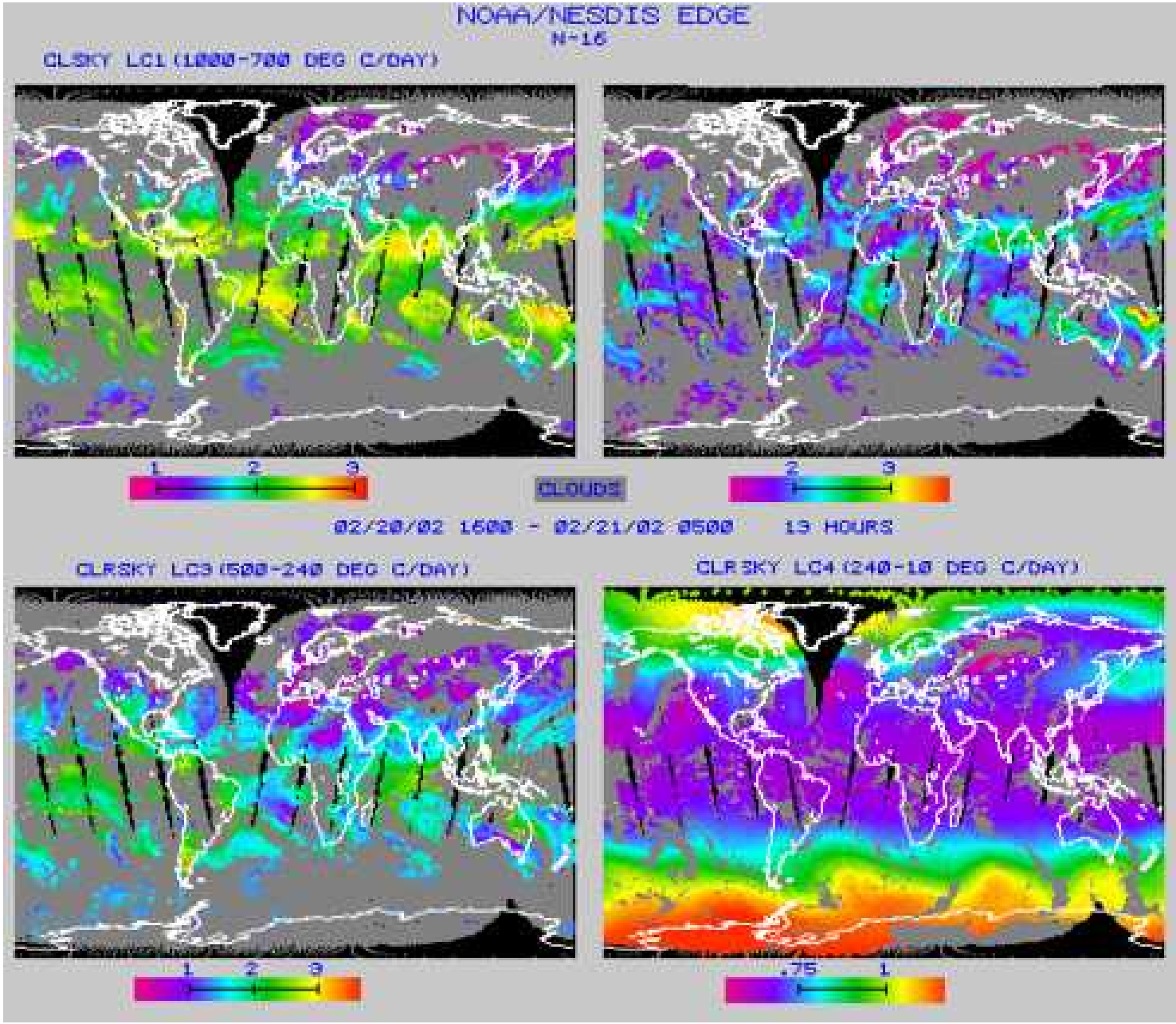
Cloud Mask and Products vs Infrared Measurements



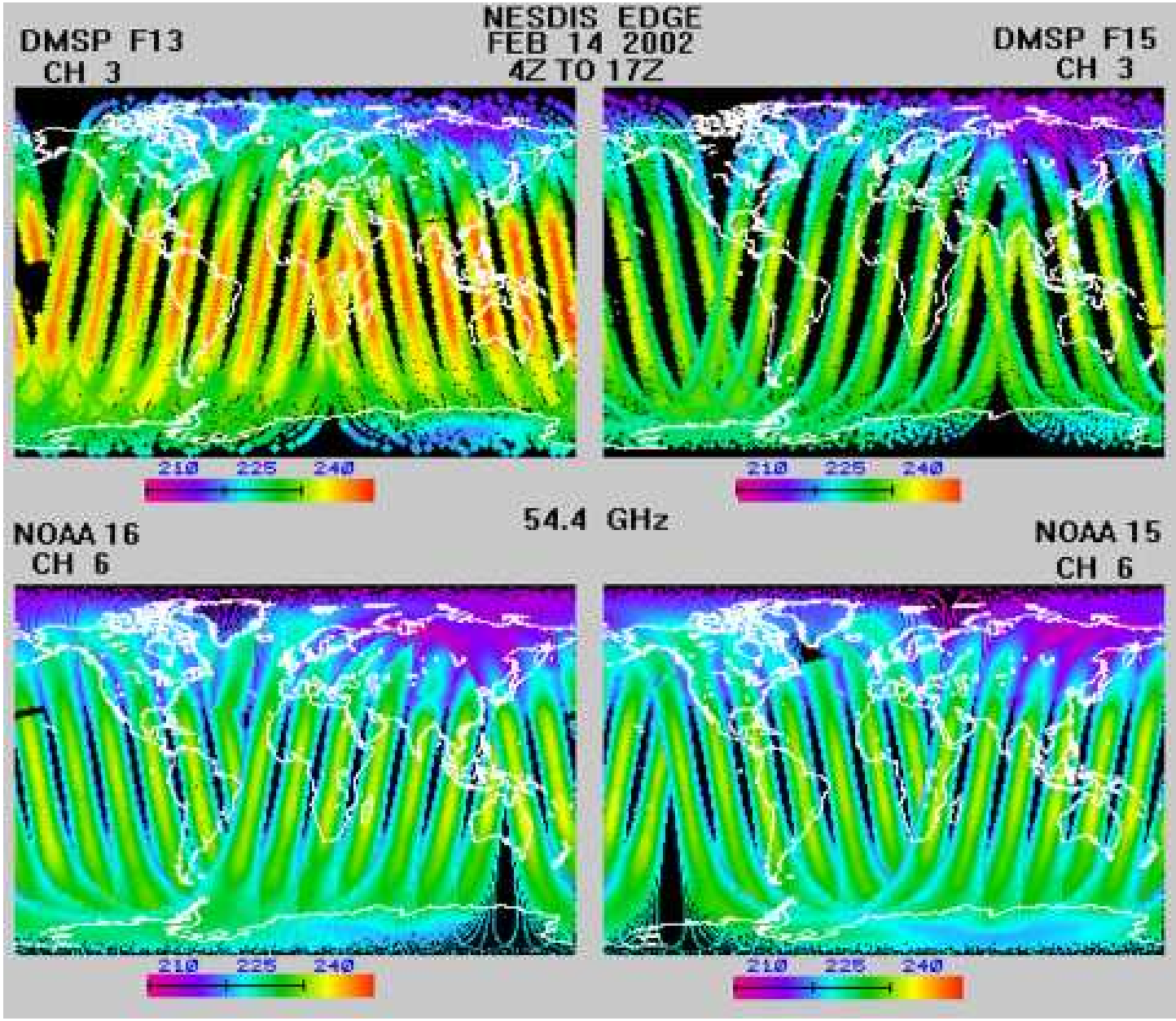
High, Medium and Low Cloud Analysis



Clear Sky Layer Cooling Rates



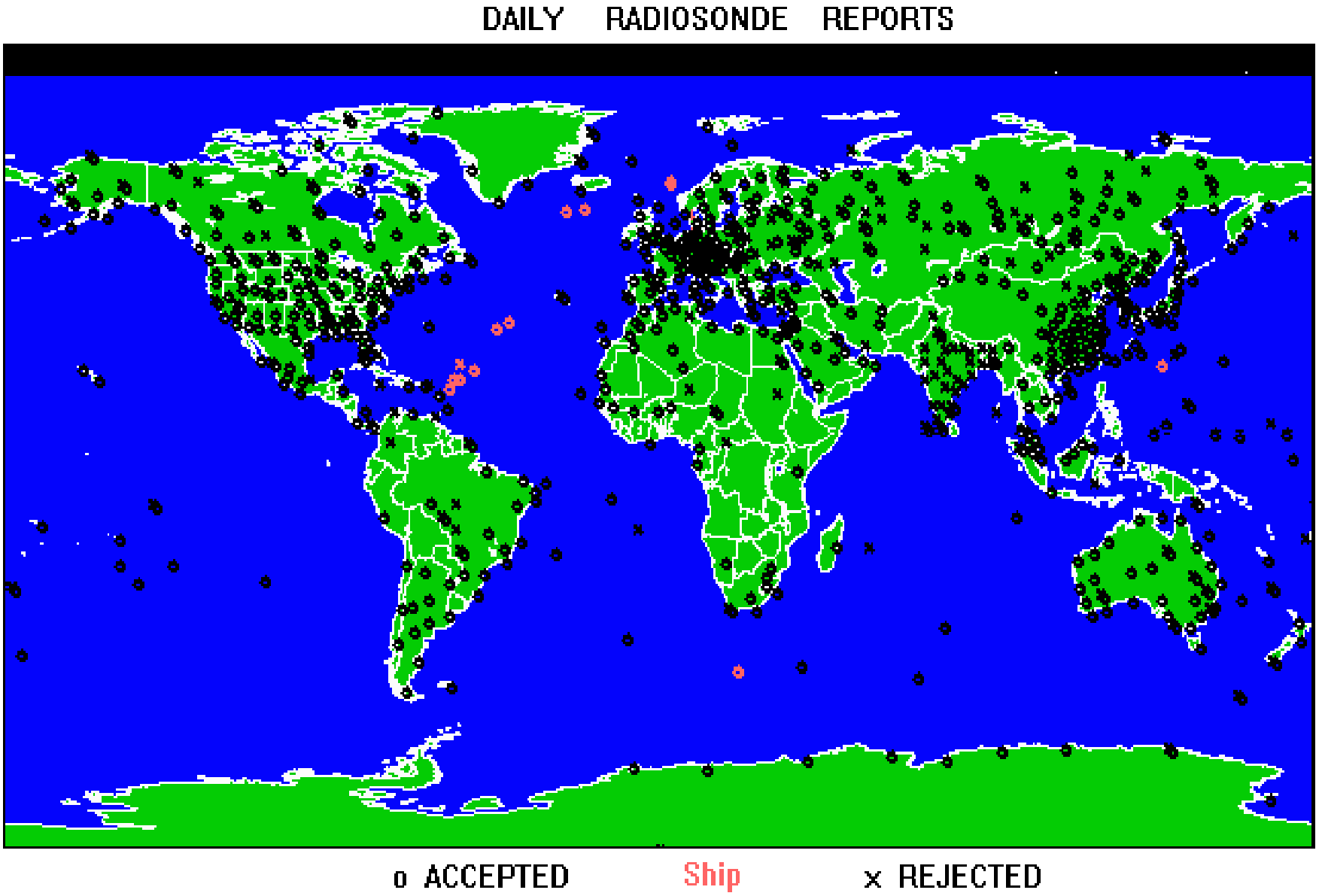
DMSP: Problems for SSM/T1 Onboard F13



Collocated Radiosonde and Satellite Observations

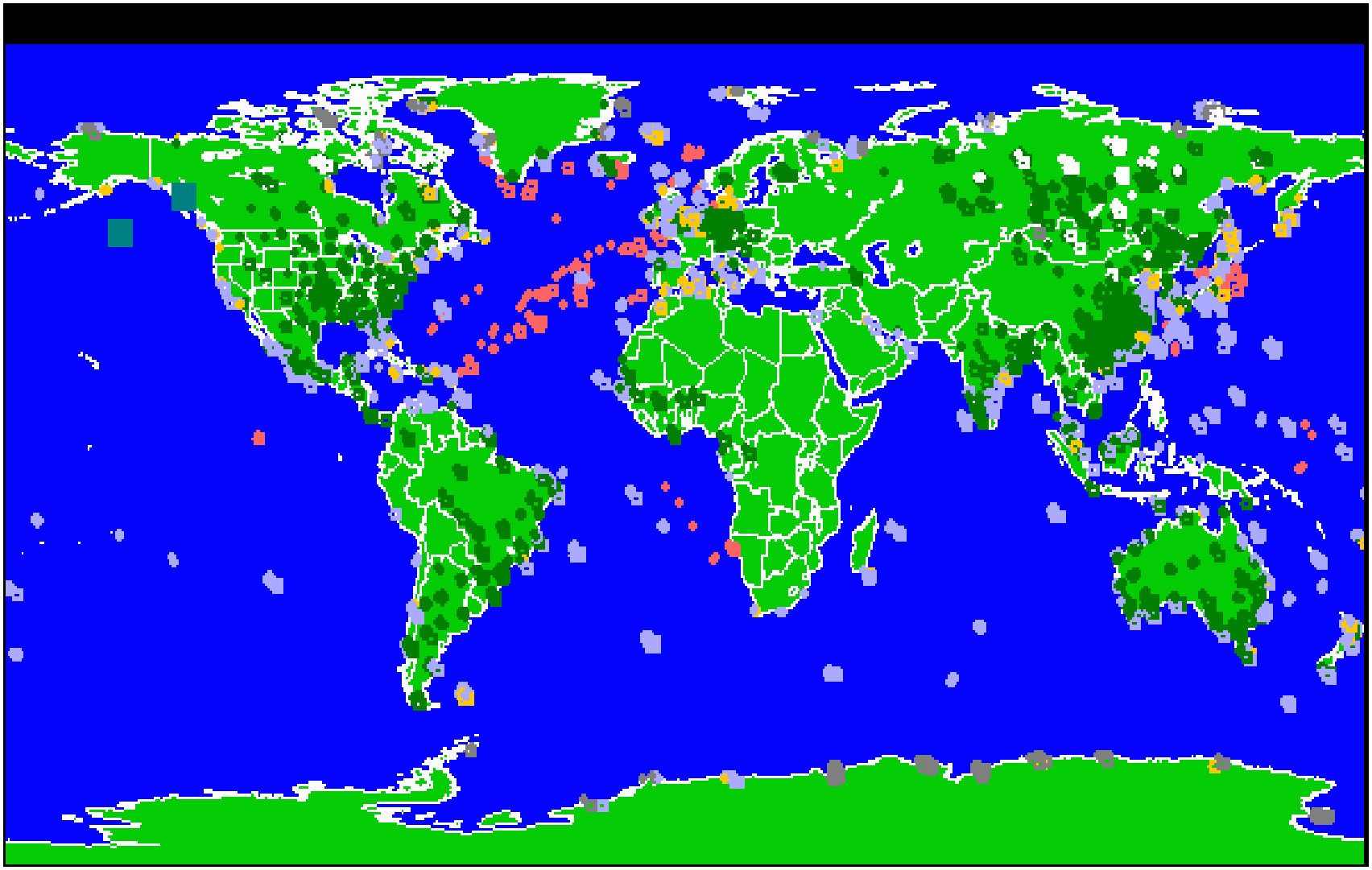
- Radiosondes Provide Critical Ground Truth Information for Polar Satellite Data
- Timely Collocations with Polar Satellites not (always) available globally
- Programs needed to insure global and reliable ground truth in support of operational (and research) satellites
- See Poster

Typical Daily Radiosonde Coverage



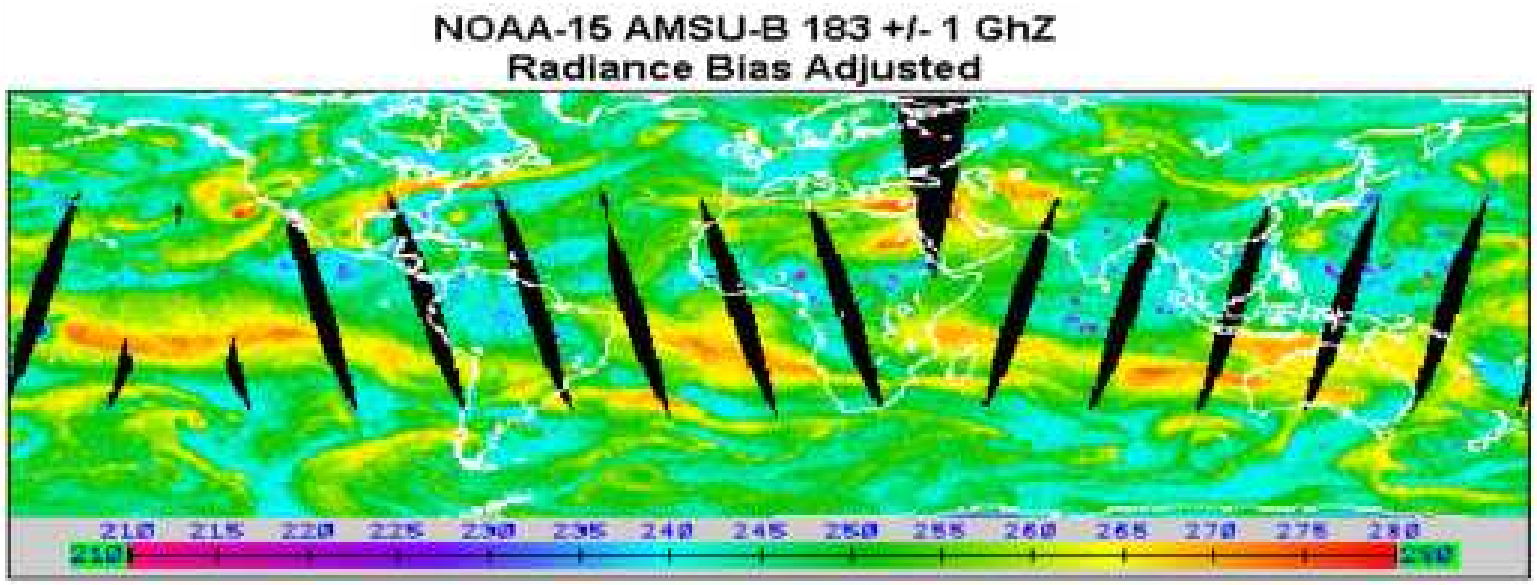
Raob/Satellite Collocations for a Typical 21- day Period

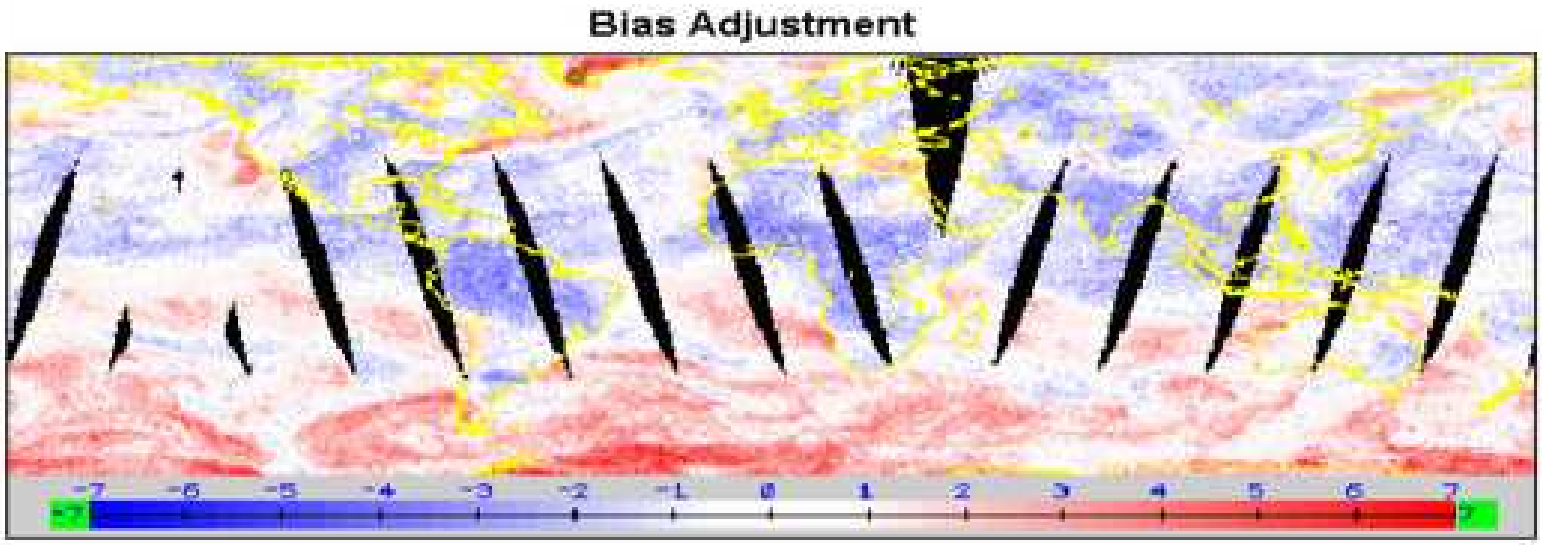
NOAA-15 MDB



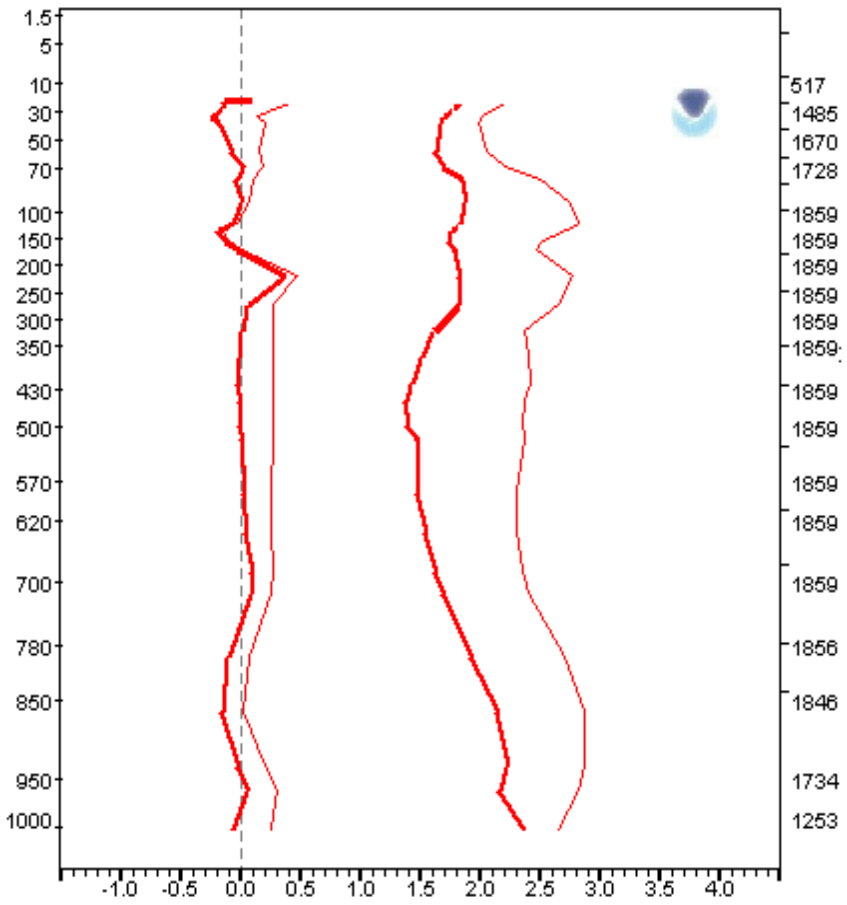
SEA LAND COAST ICE SNOW SHIP

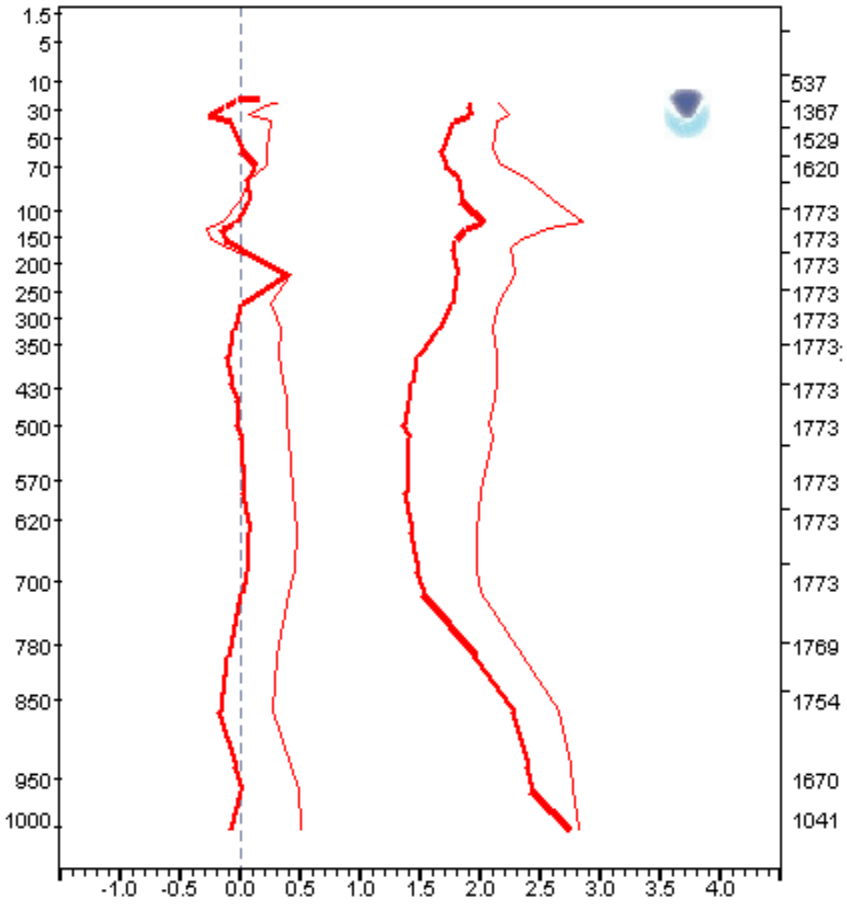
Collocations Provide Information for Radiance Bias Adjustment of Sounder Data





Accuracy Statistics vs **Radiosondes**
for
Clear (left) and **Cloudy** (right) **ATOVS Temperature Sounding** (heavy)
and **First Guess** (light)
Bias and **RMS;** NOAA-16; September 2001





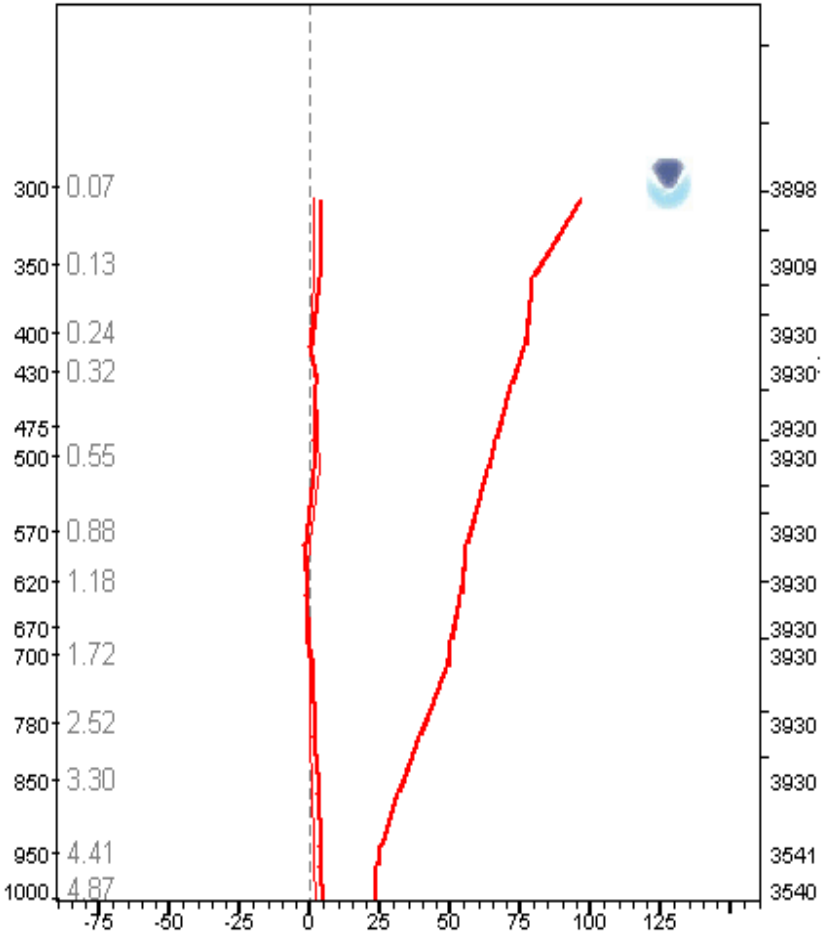
Accuracy Statistics vs **Radiosondes**

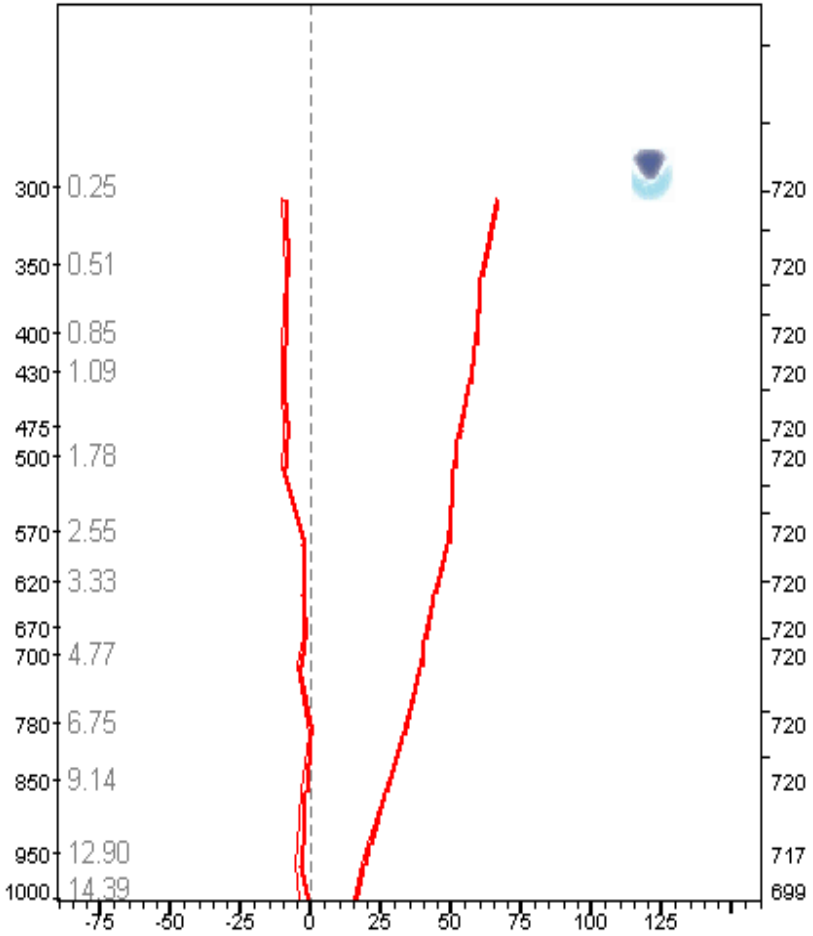
for

90N to 30N (left) and **30N to 30S** (right) **AMSU-B Moisture Soundings (**heavy**)**

and **First Guess** (light)

% Bias and **RMS**; NOAA 16; September 2001





FUTURE PLANS

- NOAA-M (June-02 Launch)
- Transition to SP Computers (Summer/Fall-02)
- ATOVS Tech Memo Including Phase-1 and Phase-2 Upgrades
- Pre-METOP Coordination
- ATOVS System-2003

ATOVS SYSTEM-2003
(Primary Goals)

- Integrate AMSU-B into ATOVS (AMSU-A, HIRS and AVHRR)
- Replace Current First Guess Approach with AMSU-only Regression
- Develop Radiance Bias Adjustment
- Develop Unique Physical Retrieval Solution per Sounding (based on Guess)

ATOVS SYSTEM-2003
(Additional Goals)

- Incorporate/Improve CLW, TPW, Emissivity and other Microwave-based Applications

- Incorporate surface pressure (from NWP?) in Guess and Retrieval steps

- Append complete NWP profile to Satellite Data Record for diagnostic validation and research

ATOVS SYSTEM-2003
(Preliminary Milestones)

- Incorporate AMSU-B …. Spring-02
- Improved Microwave Applications ….Spring/Summer-02
- Regression Guess …. Spring/Summer-02
- Bias Adjustments …. Summer/Fall-02
- Unique Retrieval Solution …. Fall/Winter-02
- Parallel System Processing Begins …. Winter-02/03
- System Validation/Transition …… Spring/Summer-03
- Implementation …. Fall 03

SUMMARY

- Phase-1 and Phase-2 ATOVS Upgrades Implemented into NESDIS Operations during Oct-01 and March-02

- Soundings provide meteorologically consistent global weather analysis in vicinity of fronts, tropopause, and upper stratosphere

- New cloud products available along with radiation and layer cooling rates

- Radiosondes concurrent with satellite overpass are critical for product monitoring and validation

- Plans for ATOVS System-2003 include integration of AMSU-B, a regression based first guess approach, and more explicit use of radiative transfer resulting in better definition of product error characteristics