# 11A.4 The Development And Use Of Graphical Programs for Real-time and Long-term Monitoring of Environmental Satellite Products With The NOAA Products Validation System (NPROVS)

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## 1. INTRODUCTION

The National Oceanic and Atmospheric Administration / National Environmental Satellite Data and Information Service (NOAA/NESDIS) produces operational global temperature and moisture soundings from several polar-orbiting and geostationary satellites. Within the NESDIS Office of SaTellite Applications and Research (STAR), the function of centralized scientific monitoring and validation of operational atmospheric derived product systems for Advanced-TOVS (ATOVS), Atmospheric Infrared Sounder (AIRS), Microwave Integrated Retrieval System (MIRS), GOES, Infrared Atmospheric Sounding Interferometer (IASI) and Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC) is provided by the NOAA Products Validation System (NPROVS). As part of the NPROVS effort, a suite of graphical programs has been created to allow users to monitor the NPROVS system and to evaluate the data produced by the system.

The following report summarizes the NPROVS graphical programs. An overview of the basic capabilities of each program is presented with an emphasis on changes and additions made over the past year. One important addition is a new tool, the NPROVS Archive Summary System (NARCS), which was created to provide a long-term trending overview of the quality of data produced by all satellite systems in NPROVS. Other changes, including the display of radiosonde balloon drift patterns, are also summarized and their importance to NPROVS is discussed.

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In addition to the overview of the graphical programs, this report describes how each program is used to provide different viewpoints of the NPROVS data including long-term statistical trends, daily comparisons of individual satellite collocations, and global images of all satellite-produced parameters. Also discussed is the manner in which the individual graphical programs are used in combination to quickly identify and assess potential problems in both the NPROVS system and in the quality of the satellite data.

## 2. NPROVS

Satellite derived sounding products are routinely produced by NOAA for a number satellite platforms including GOES, NOAA-18, MetOp, NASA–EOS-AIRS and DMSP and a number of processing approaches including operational Advanced TIROS Operational Vertical Sounder (ATOVS) (Reale et al. 2008), Microwave Integrated Retrieval System (MIRS) (Boukabara et al 2007) and hyper-spectral sounder approaches for AIRS and MetOp-IASI (Barnet). Although not currently used at most of the NWP centers, derived soundings remain a mainstay of NOAA ground processing systems and may yet play a key role as an efficient data compression mechanism for assimilating hyper-spectral observations and in climate.

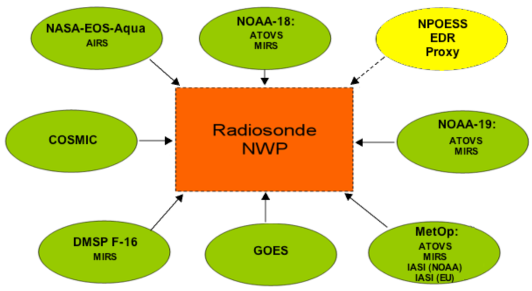


**Figure 1: Diagram of current NPROVS satellite data (green) access, future data (yellow) and collocation with ground truth (red).**

Figure 1 shows a schematic diagram of NPROVS and multiple satellite platforms and processing suites including NWP that are routinely collocated with the ground-truth (primarily radiosondes) observations.

The NPROVS collocation system runs once per day. A file containing all available radiosondes for a given day is processed. This file contains a variable number of records, each of which contains data for a single collocation.

The collocation process begins with a file of radiosondes for a given day that have been pre-screened for data quality. Each radiosonde in the file is used as a baseline for collocation with the satellite data. After the radiosonde data is copied to the record in the NPROVS daily collocation file, the system begins to search each available satellite system for a sounding footprint that is closest to the radiosonde in space and time. If an acceptable sounding is located, the data from the footprint are copied to the collocation file.

After the collocations have been made for every radiosonde, the resulting file contains the collocations for a single day. This file is then stored in the NPROVS Collocation Archive, which currently contains two years of collocated data. Data from the archive are used by scientists within NOAA / NESDIS / STAR to analyze the quality of radiosonde and satellite data and to directly compare the quality of data between different satellite systems.

## 3. NPROVS Graphical Programs

When viewing NPROVS data, scientists from NOAA/NESDIS/STAR look for answers to several questions:

- Is the collocation system working correctly?
- What is the quality of the satellite data?
- If problems exist, what is the cause?

To help provide answers to these questions, several graphical programs were created. These programs provide users with a variety of views of the NPROVS data.

### 3.1 ProfileDisplay

The first of the graphical programs is ProfileDisplay. This cross-platform Java program reads data from the daily collocation files and from the collocation archive. With this program, scientists are able to view temperature and moisture profiles, compute and display vertical accuracy statistics and display scatter plots.

The profile graph window (figure 2) shows the vertical graphs of every available temperature and moisture profile from the radiosonde and collocated satellites. Arrow keys are available to allow for switching between the collocations in the file.

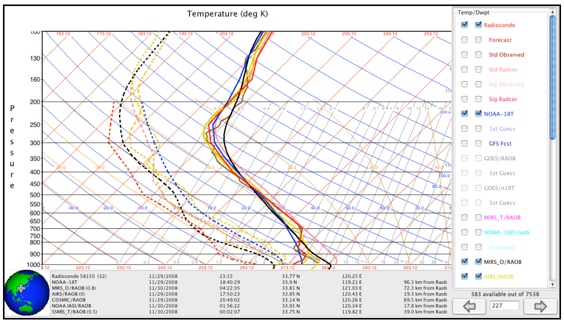


**Figure 2: The main graph window in PDISP showing temperature (solid lines) and moisture (dashed lines) profiles from several satellite systems.**

A sub-selection panel contains a large number of controls that can be used to select very specific subsets of data. These controls give users the ability to focus on selected data. Only collocations that match the selected options are available when viewing profiles and generating statistics.

The quality of data at each pressure level can be viewed by generating vertical accuracy statistics. Statistics are generated from all collocations that match the current sub-selection criteria. As the statistics are being calculated, the profile data at each level is compared to the baseline system (usually the radiosonde). The mean bias and standard deviation of the differences are plotted (figure 3).

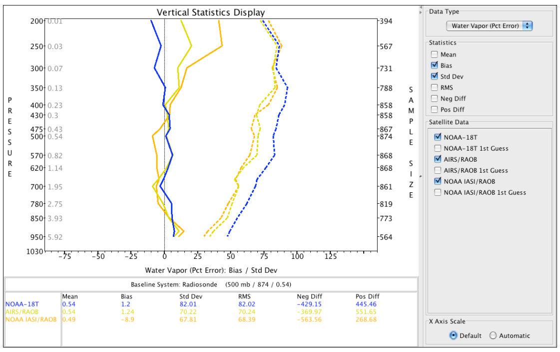


**Figure 3: Vertical accuracy graph showing bias (solid line) and standard deviation (dashed line) for NOAA-18, AIRS and NOAA IASI.**

Like vertical accuracy statistics, scatter plots are used to view the differences between satellite data and the baseline system. When generated, a scatter plot graph is displayed for a selected pressure level. Users can switch between each level to determine whether or not any collocations stray farther from the zero line than is desirable.

If the scatter plot contains outliers, these collocations can be isolated by drawing one or more boxes around them. After switching back to the profile graph, the visible collocations will be those that were selected on the scatter plot. From here, users can take a closer look at the collocation to try to determine why a difference between the satellite and the baseline system exists.

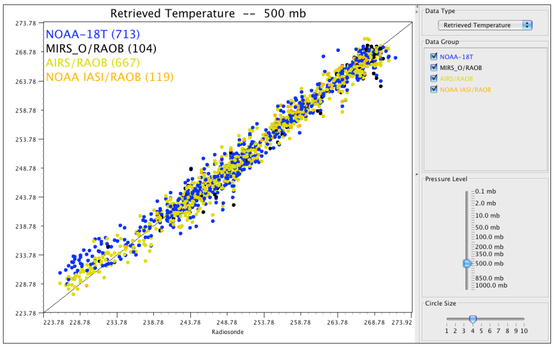


**Figure 4: Scatter plot with ground truth (radiosonde) plotted along X-axis and satellite temperature values plotted along Y-axis.**

### 3.2 NPROVS Archive Summary System (NARCS)

The vertical statistics produced by ProfileDisplay provide a good indication of the quality of the satellite data. But ProfileDisplay is generally limited to handling one month of data or less, making it difficult to view long-term trends. Furthermore, the statistics are mean differences for a single period of time. They do not show changes that occur during the time period.

To solve these problems, the NPROVS Archive Summary System (NARCS) was created. NARCS keeps track of daily, weekly and monthly statistics at selected pressure levels. These statistics are displayed on a single graph (figure 5).

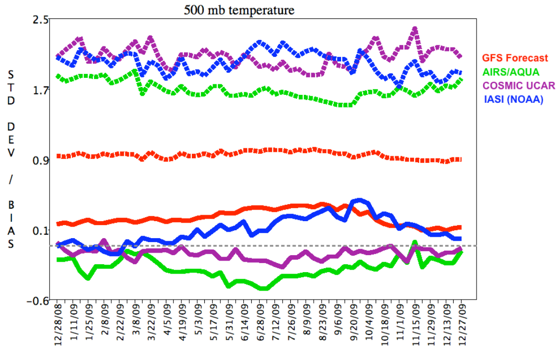


**Figure 5: Weekly bias (solid) and standard deviation (dashed) plots over a one year period.**

NARCS is especially useful when showing seasonal trends. In figure 6, the graph line is the bias of the radiosonde forecast temperature compared to the observed radiosonde temperature. Each data point shows the monthly mean bias for a 21 month period. From the graph, it is easy to see that the forecast has a pronounced seasonal bias.

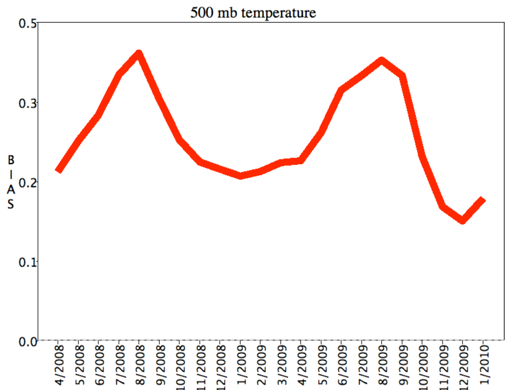


**Figure 6: Radiosonde forecast temperature bias showing a seasonal trend.**

NARCS is also used to identify problems in the NPROVS collocation process. In figure 7, one of the satellites had a bias that was unusually large for one day. An investigation into this revealed that a change in the satellite's data format occurred one orbit later than anticipated. The temperature data from the orbit contained bad values that led to the unusually large bias. Once the problem was identified, the bad data was removed and the orbit was reprocessed.

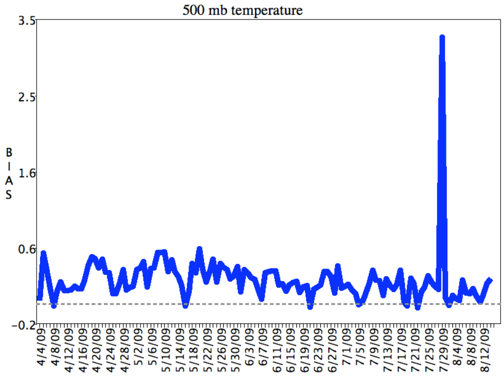


**Figure 7: Satellite temperature bias showing a problem with the collocation process.**

### 3.3 Environmenta Data Graphical Evaluation Imaging System (EDGEIS)

While ProfileDisplay provides STAR scientists with the ability to view satellite data that have been collocated by NPROVS with a radiosonde, it is often useful to view all of the data from a satellite prior to the collocation process. The Environment Data Graphical Evaluation Imaging System (EDGEIS) provides this capability by reading satellite sounding data and creating an image of a chosen parameter (figure 8).

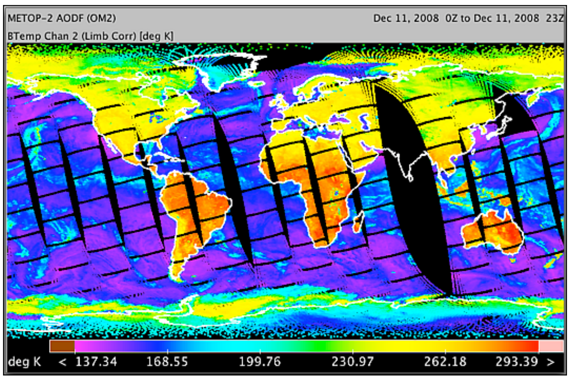


**Figure 8: EDGEIS image of AMSU-A brightness temperature data from the NOAA MetOp-2 satellite system.**

Developed for the ATOVS project, EDGEIS has been expanded to display data from every satellite processed by NPROVS. Many options are available that give users the ability to select which data to display and how to display the data.

EDGEIS has been a useful part of NPROVS. Figure 9 shows the quality flags that are used in deciding whether or not to collocate a sounding footprint. The blue areas are soundings that passed screening criteria while the red areas are soundings that failed screening. Images such as these made it easier to determine why the number of collocations from some satellite systems was lower than expected.

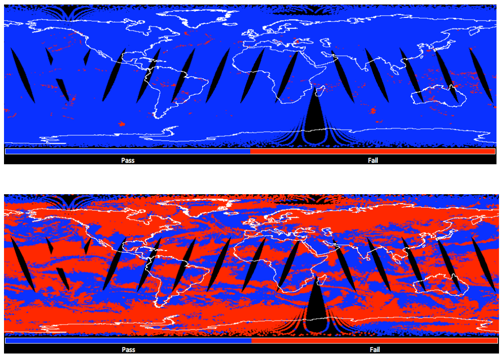


**Figure 9: Data quality comparison of 2 satellite systems. Accepted data (blue). Failed data (red).**

### 4.0 Other Uses Of NPROVS Data

Until this past year, the collocated NPROVS data were used for the comparison of satellite systems. Now that a dataset containing almost 2 years of data is available, the data are starting to be used for other purposes both within NOAA/NESDIS/STAR and by groups outside of STAR. New graphical programs have been created to meet the changing needs of users.

The radiosonde balloon drift is one area that has received increased interest. Within ProfileDisplay, a feature was added to display the balloon drift of each radiosonde (figure 10). Such images of the balloon trajectories, when combined with plots of satellite sounding locations, demonstrate how far the balloons can drift away from the soundings, potentially affecting the quality of satellite versus radiosonde comparisons.

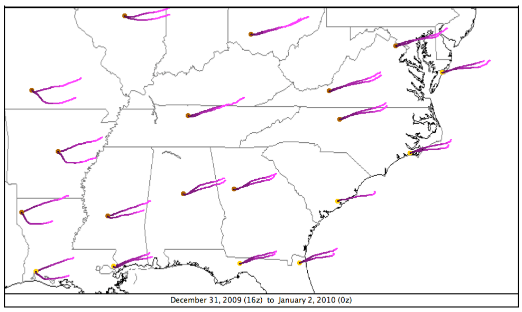


**Figure 10: Radiosonde balloon drift trajectories (purple lines).**

Radiosonde balloon drift data are also being displayed using contour images. In figure 11, data from many radiosonde stations were used to create a contour plot of the maximum distance that balloons drifted during a two year period.

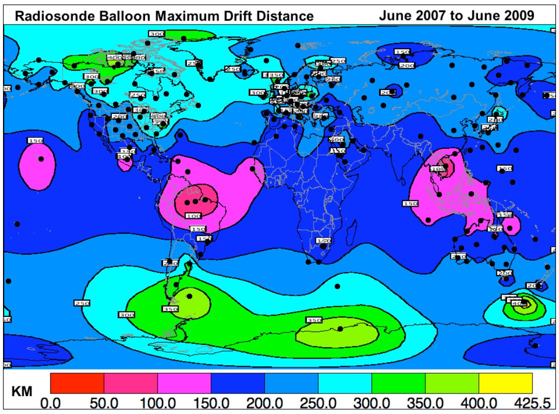


**Figure 11: Maximum distance that radiosonde balloons drifted over a two year period.**

Another way to view balloon drift is shown in figure 12. This image shows the positions of radiosonde balloons at 30 hPa over a two year period for a single radiosonde station. The balloon positions are color coded to show seasonal trends. In the image, balloons that were launched during spring months are plotted in purple, summer launches are in green, autumn launches are red, and winter launches are blue. Using these images, it is easy to determine seasonal trends such as the fact that, for this particular radiosonde station, balloons that are launched in winter months tend to travel farther to the east.

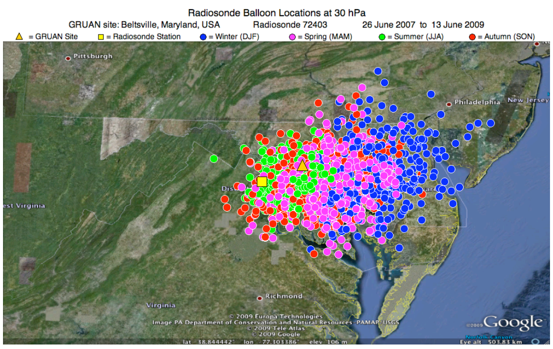


**Figure 12: Radiosonde balloon locations at 30 hPa over a two year period. (purple=spring, green=summer, autumn=red, winter=blue)**

## 5.0 Future Development

Development of the current NPROVS graphical programs will continue in order to increase their usefulness and to meet the changing requirements of NOAA / NESDIS / STAR scientists. As users find new uses for the NPROVS data, the current programs will be modified and new programs will be created.

Another area of focus will involve better access to the NPROVS data. Much of the data will be available from the NOAA / NESDIS / STAR website. The website will also be used to provide users with the latest versions of the various programs.

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