8.5 Integrated polar-GOES-GPSRO satellite product comparisons using the NOAA PROducts Validation System (NPROVS)

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1. INTRODUCTION

During the past 30 years of NOAA operational polar satellites, the problem of providing reliable and consistent monitoring and scientific validation of operational measurements and derived satellite soundings has been addressed through the compilation and analysis of collocated satellite and radiosonde observation datasets. The NOAA PROducts Validation System (NPROVS) (Pettey *et al.* 2009), recently deployed at the Center for Satellite Applications and Research (STAR), centralized the routine compilation of satellite and radiosonde collocation datasets among the multiple satellite derived sounding product systems operated by NOAA, including respective observation screening. These datasets have also proved useful for characterizing respective platform performance and for computing coefficients in support (tuning) of derived satellite sounding algorithms (Reale and Tilley 2009)

The following report presents an outline of NPROVS and results demonstrating strategies for:

- satellite sounding validation
- screening
- platform error characterization

Results are generated using the Environmental Data Graphical Evaluation (EDGE) interface which includes basic utilities for:

- display of collocation global distributions
- profile display and statistical analysis
- orbital product display (not shown)

The report concludes with an example of longer term trend plots for the recently developed NPROVS ARChive Summary System (NARCSS).

2. NPROVS

Satellite derived sounding products are routinely produced by NOAA for a number of 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 (Goldberg *et al.* 2003). Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) soundings are routinely produced at UCAR-Boulder.

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 shows a schematic diagram of NPROVS and multiple satellite platforms and processing suites, including NWP, that are routinely collocated with the ground-truth (mainly radiosondes) observations. Collocations are processed daily and archived daily. NPOESS EDR Proxy indicates pending collaborations with NOAAA Integrated program Office Government Resource for Algorithm Verification, Independent Testing and Evaluation (GRAVITE) protocols in conjunction with NPOESS.

Figures 2 and 3 show examples of the global distribution of radiosondes (2) and an individual set of collocated radiosonde and satellite locations in the vicinity of Wallops Island, Va., as compiled by NPROVS during January 2009.

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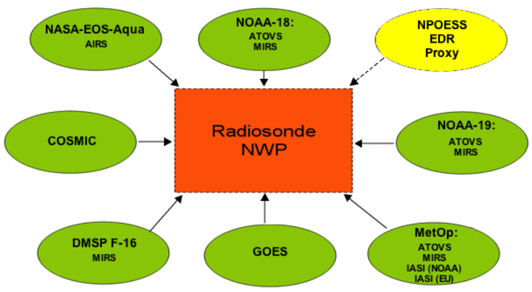

Figure 1: Diagram of current NPROVS satellite data (green) access, future data (yellow) and collocation with ground truth (red).

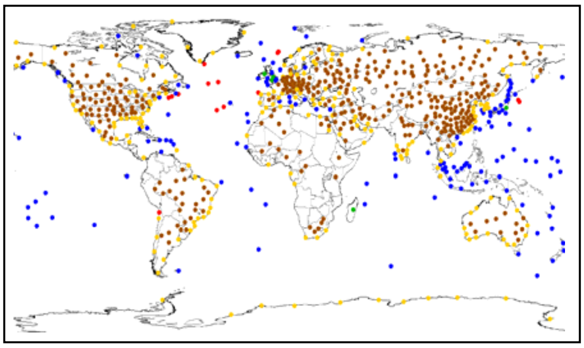

Figure 2: Global location of radiosondes collocated with at least one satellite observation platform for a 2-day period during January 2009; colors indicate the terrain flag of the radiosonde (red, ship; brown, land; yellow, coast; blue, island and green, inland island)

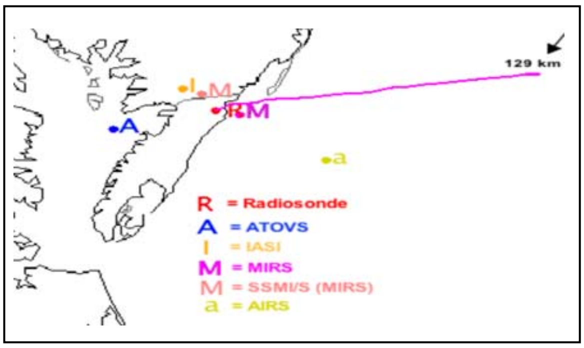

Figure 3: Example of individual set of collocated radiosonde (red) and respective satellite products (other colors) and the associated drift (pink) of the radiosonde during flight in vicinity of Wallops Is, Va.

Approximately 1000 collocations (a radiosonde with at least one collocated satellite) are processed daily. The criteria for a candidate collocation are:

- radiosonde temperature and moisture profile extend at least 5 km without gaps
- satellite within 6 hours and 250 km
- single "closest" satellite retained

It is interesting to note the spatial drift of the radiosonde (pink) easily exceeds the spatial domain of the collocated observations. Conventional collocation datasets are compiled using the location and time of the radiosonde at the surface. Available drift parameters (radiosonde and satellites) are retained within NPROVS; their impact on validation is discussed in Section 3.2.

The compilation of radiosondes includes specialized testing of the radiosondes extending at least 5 km. Tests include:

- superadiabatic layer(s)
- tropopause within limits
- supersaturated level(s)
- moisture profile score
- temperature inversion(s)

Flags indicating one or more of the above occurrences are retained on the output radiosonde file. Of particular interest are tests for H_20 vapor changes and subsequent impacts on validation.

Figure 4 summarizes the moisture testing and associated results.

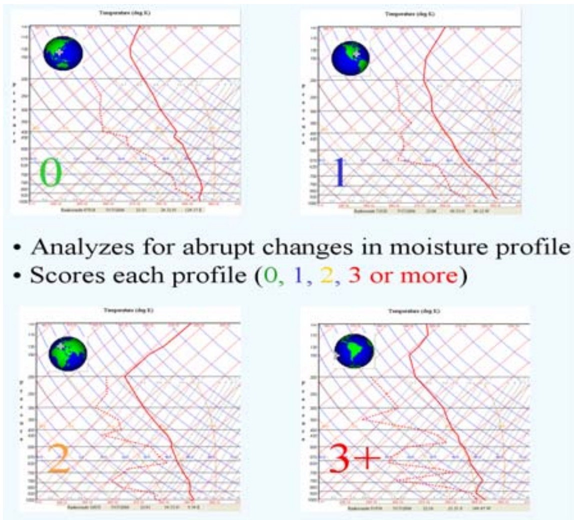

Figure 4: Raob moisture profile (dashed) scores

These results represent the end product of a series of tests which analyze the degree of deviation from a monotonically decreasing H20 vapor mixing ratio profile. Moisture profiles exhibiting essentially monotonic decreases with height have low scores. Moisture profiles exhibiting multiple layers for which the H20 vapor mixing ratio exhibits abrupt changes (increasing followed by decreasing ratios) have progressively higher scores.

NPROVS, and in particular the EDGE analytical interface, also keeps track of the respective satellite observations and sounding profile quality control (QC) indicators as provided for each respective platform. The satellite QC is not considered when compiling collocations but can significantly impact respective validation results as discussed in Section 3.

NPROVS collocation datasets are compiled daily and are processed into weekly and monthly datasets for more meaningful statistical validation and archive.

3. RESULTS

3.1 Validation and Screening Strategies

The EDGE statistical interface includes options for applying QC information to select collocations for validation. QC parameters are available for the respective satellites and ground truth radiosondes.

Figures 5 and 6 illustrate comparative statistics of radiosonde-minus-satellite Mean (solid) and standard deviation (SD dashed) for soundings products which passed their respective satellite product system QC requirements. Figure 5 inter-compares polar hyperspectral (IASI, AIRS), conventional (ATOVS) and COSMIC GPSRO sounding product, Figure 6 includes GOES. Both sets of plots are based on common denominator sampling strategies. The period of record is December (31-days) 2009; GFS is the NOAA operational Global Forecast System 6-hour forecast. The vertical pressure scale ranges from 1000 mb to 10 mb and the horizontal axis ranges from -1.5K to 4.5 K; sample sizes for each pressure level are listed along the right-side axis.

The impact of accepting only QC'd sounding products and including the COSMIC soundings which have a much lower spatial density than for polar satellites results in a common denominator sample size that is reduced by 90%. This sample is reduced another 80% when GOES is included in the common denominator strategy (figure 6).

Also of interest in Figures 6 and 7 is the fact that the GOES and COSMIC retrieval utilize a NOAA GFS 6-hour and 12-hour forecast, respectively, as the first guess (FG). Each of these FG curves is plotted.

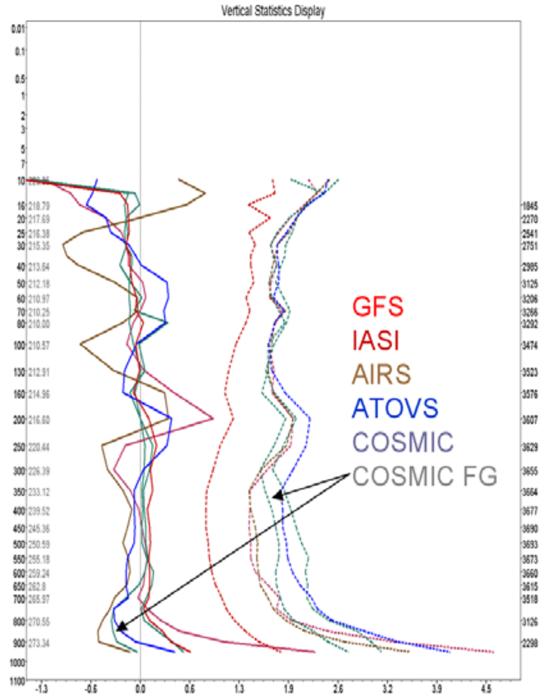

Figure 5: Polar satellite (AIRS, IASI and ATOVS) and COSMIC GPSRO temperature sounding products versus GFS 6-hour forecast and Raob using common denominator sample for satellite products which passed QC.

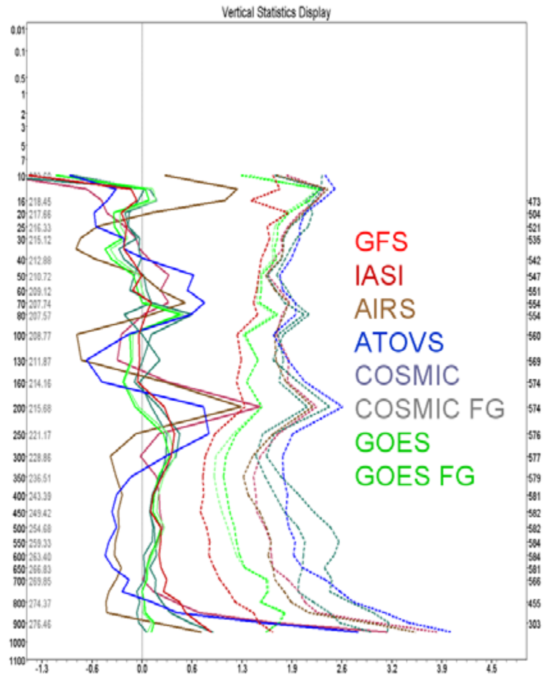

Figure 6: Polar satellite (AIRS, IASI and ATOVS), COSMIC GPSRO and GOES temperature sounding products versus GFS 6-hour forecast and Raob using common denominator sample for satellite products which passed QC.

The point is that care is needed when comparing different satellites to insure compatibility and adequate sample size for a meaningful validation. NPROVS and associated EDGE analytical interface provide a useful user interface in this respect.

3.2 Platform Performance and Sensitivity

One of the potential strengths of the NPROVS collocation dataset is that it can provide feedback to data providers (and managers) concerning the sensitivities and relative performance of the respective satellite and ground truth data platforms, particularly those secured over a continuous long-term record.

Figure 7 illustrates an example using the COSMIC radio occultation (RO) observations to monitor radiosonde upper troposphere relative humidity (RH) for different radiosonde instrument types. Shown are histograms of upper troposphere (300 mb) Radiosonde-minus-COSMIC mean relative humidity differences segregated by specific radiosonde type groupings (Sun *et al.* 2009). Blue indicates daytime differences and gray nighttime differences.

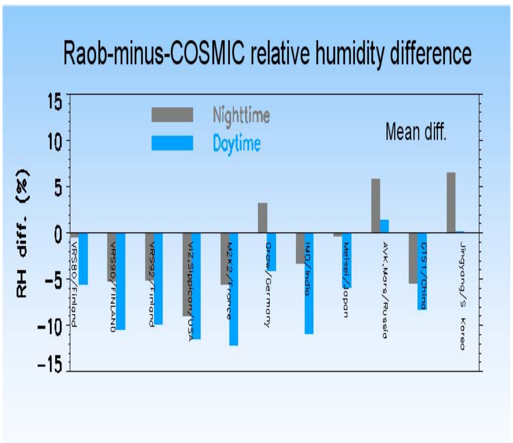

Figure 7: Histogram of COSMIC-minus-Raob daytime versus nighttime upper tropospheric RH for a 6-month period in 2008 for radiosonde instrument type groupings (Sun and Reale 2009)

Results indicate an overall dry bias for the radiosondes (lower relative humidity) except for selected radiosonde types over Russia and that the bias is generally greater during the day than at night. Normally, studies of this nature are obtained through intensive and expensive research field experiments but using NPROVS are achieved through relatively inexpensive data compilation and archive. Results agree with previous publications from such experiments (Wang and Zhang 2008).

The sensitivity of collocated observations with respect to spatial and temporal differences is also a topic of interest. Emerging principles for the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) (World Meteorological Organization 2008) have questioned the importance of synchronized satellite and ground truth observations from GRUAN sites for climate. Preliminary studies using NPROVS estimate spatial and temporal sensitivities on the order of 0.1K per hour and 0.5K per 100 km on the real-time weather scale (Sun 2009). Studies to determine such sensitivities on the climate scale using significantly longer periods than for this study are pending.

Figure 8 illustrates trend statistics for soundings from combined polar, GPSRO and GOES satellite platforms compiled using the recently deployed NARCCS for the period January through July, 2009. Unlike for figures 6 and 7, these curves are based on respective independent samples comprised of QC'd observations from each satellite system.

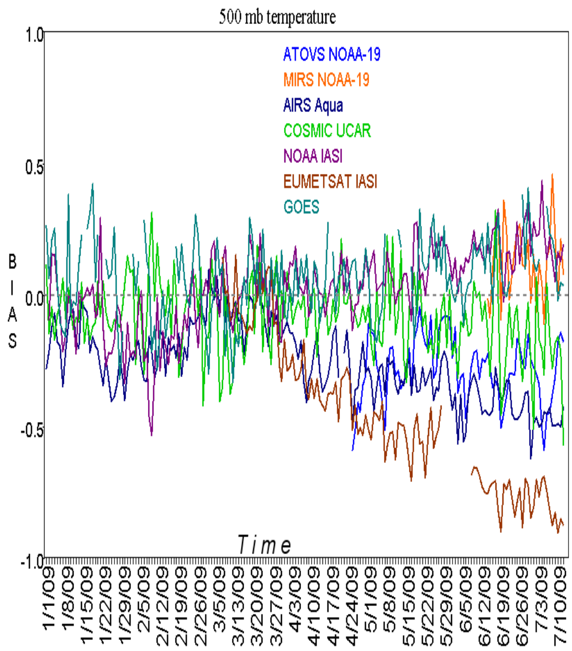

Figure 8: Trend plots of mean Sat-minus-Raob 500mb temperature (+/- 1.0K) for denoted Sat systems during January to July 2009

As seen, most systems collect within +/- 0.5K except for EUMETSAT IASI which gradually drifts out of this range over time. The integrated use of NPROVS collocation datasets and associated EDGE analytical interface provides an effective validation, troubleshooting and product monitoring function at STAR.

5. SUMMARY

NPROVS provides NOAA STAR with a centralized validation protocol for the routine monitoring and inter-comparing derived atmospheric weather products from polar orbiting, GOES and GPSRO environmental satellites. This is primarily achieved through the compilation and analysis of collocated radiosonde, NWP and independently processed satellite product systems; currently 19 operational and experimental products systems are included. NPROVS compiles collocations on a daily basis with all collocations routinely archived at STAR. NPROVS includes a variety of analytical interface and sampling options (EDGE) including satellite and Raob QC, space and time windows, terrain designation, individual and common denominator sampling, radiosonde instrument type selection, regional (ie GOES Conus) designation and more. Analysis on real-time weather (daily, weekly) and climate scales (monthly, seasonal, annual) are facilitated.

6. REFERENCES

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