The NOAA PROducts Validation System (NPROVS)

Summary of the Working Paper

NPROVS provides NOAA STAR with a centralized validation protocol for the routine monitoring and inter-comparing derived atmospheric weather products from polar orbiting and GOES 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. As described, 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 GOE Conus) designation and more. Analysis on real-time weather (daily, weekly) and climate scales (monthly, seasonal, annual) are facilitated. Plans for expanded access and validation against GCOS Reference Upper Air Network (GRUAN) reference radiosonde and selected ground observations are outlined.

The <u>N</u>OAA <u>PRO</u>ducts <u>V</u>alidation <u>S</u>ystem (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) (Reale *et al.* 2010), initially deployed at the Center for Satellite Applications and Research (STAR) in April, 2008, provides centralized, routine compilation of satellite and radiosonde collocation datasets among the multiple satellite derived sounding product systems operated by NOAA, including respective observation screening.

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

- Collocation strategy
- Data screening, and
- Satellite products validation

Validation results are generated using the NPROVS analytical interface which includes basic utilities for:

- display of collocation global distributions
- display of collocated observations and short-term statistical analysis, and
- longer-term trend analysis

The report concludes with future plans and the goal of integrating Global Climate Observing System (GCOS) reference Upper Air Network (GRUAN) into NPROV.

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) and Microwave Integrated Retrieval System (MIRS) (Boukabara *et al.* 2007) and hyper-spectral soundings for AIRS and MetOp-IASI (Goldberg *et al.* 2003). Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) (Kuo et al 2004) sounding products processed by UCAR are also included in NPROVS

Figure-1 shows a schematic diagram of NPROVS and multiple satellite platforms and processing suites that are routinely collocated with the ground-truth radiosonde. Radiosonde observations include spatially interpolated numerical weather prediction (NWP) data from NOAA operational Global Forecast System (GFS) 6-hr forecast forecasts. In addition, NWP observations collocated to satellite product systems are also for selected systems.

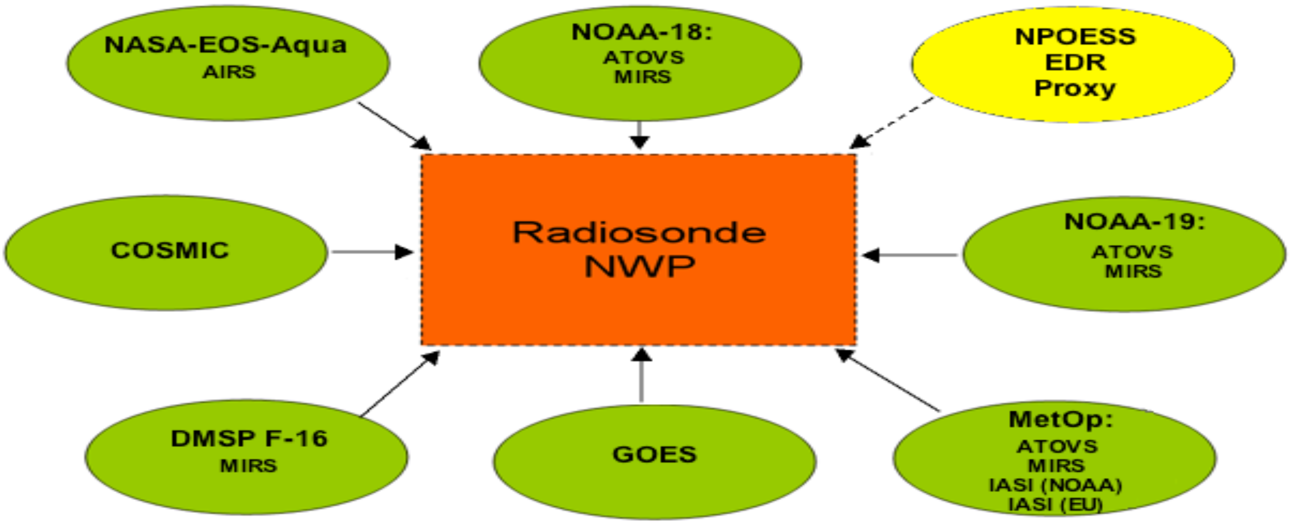

Figure 1: Diagram of satellites and derived product systems (green) accessed by NPROVS and collocated with radiosonde and NWP data

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 March 2010 and January, 2009, respectively.

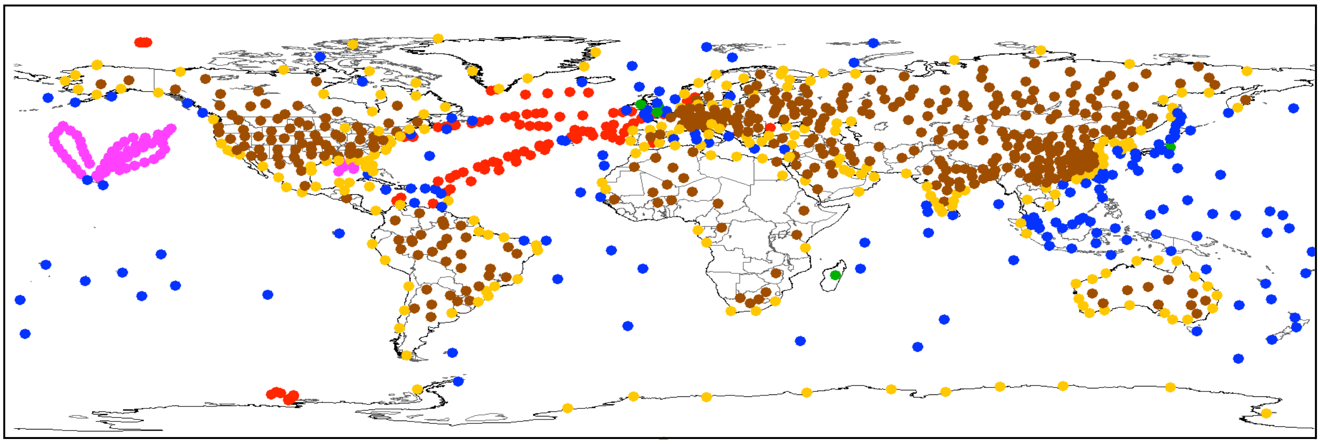

Figure 2: Global location of ground reports collocated with at least one satellite observation platform for a 7-day period during March, 2010; colors indicate whether a dropsonde or radiosonde over land, mainland coast, island, inland island or ship.

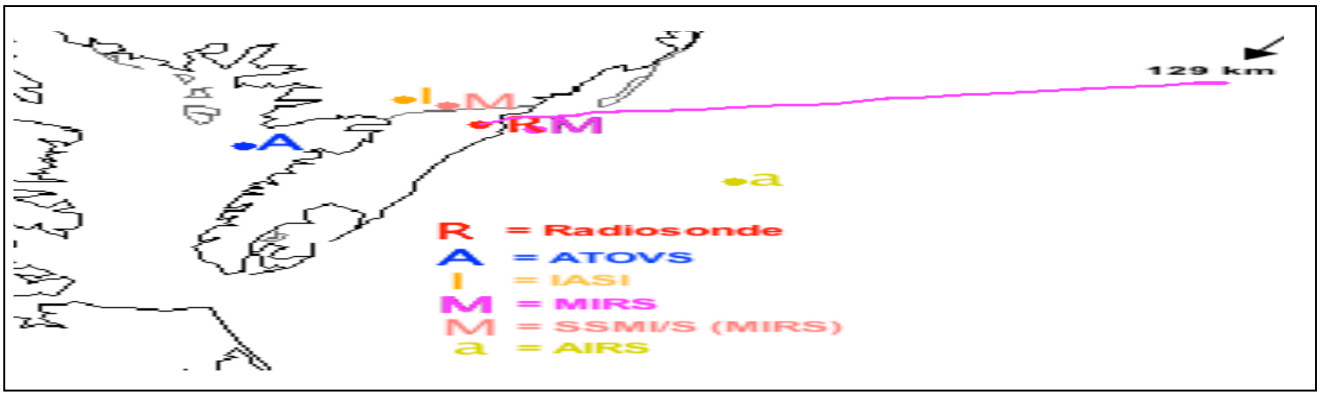

Figure 3: Example of individual set of collocated radiosonde (red) and respective satellite products (other colors) and the associated drift (pink) of the radiosonde during flight in vicinity of Ocean City, Md. on January 2, 2009

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. The use of NPROVS collocations and drift parameter to estimate the sensitivity of collocations to space and time mismatch is discussed in Section 3.2.

The compilation of radiosondes includes special procedures to identify:

- radiosonde terrain (figure 2)
- superadiabatic layer(s)
- 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 $H_2 0$ vapor changes and subsequent impacts on validation.

Figure 4 summarizes the moisture scoring technique.

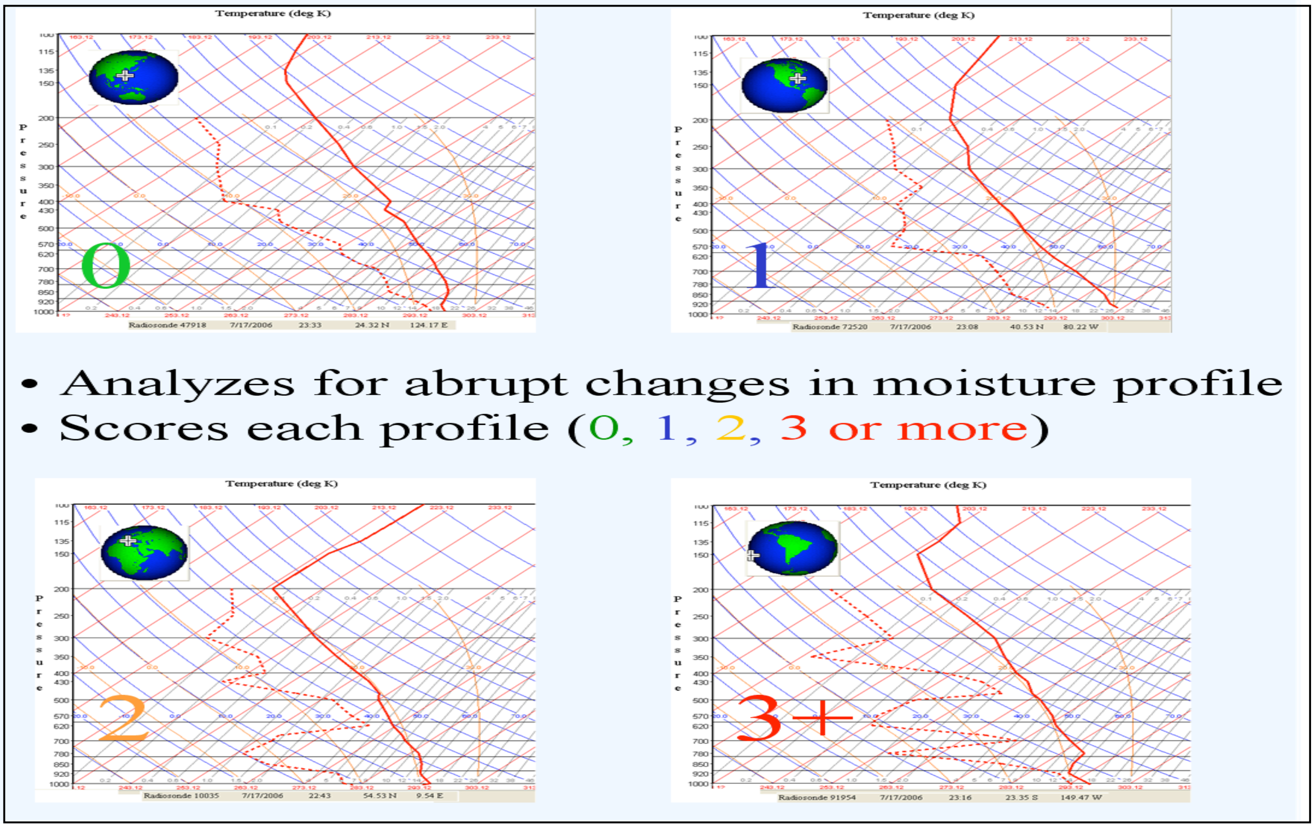

Figure 4: Raob moisture profile (dashed) scores.

These results represent the end product of a series of tests which analyze the degree of deviation from a monotonically decreasing H_20 vapor profile. Moisture profiles exhibiting essentially monotonic decreases with height have low scores. Moisture profiles exhibiting multiple layers of abrupt changes in H_20 vapor mixing content have progressively higher scores

The impact of the moisture profile score on validation is shown in Figure 5.

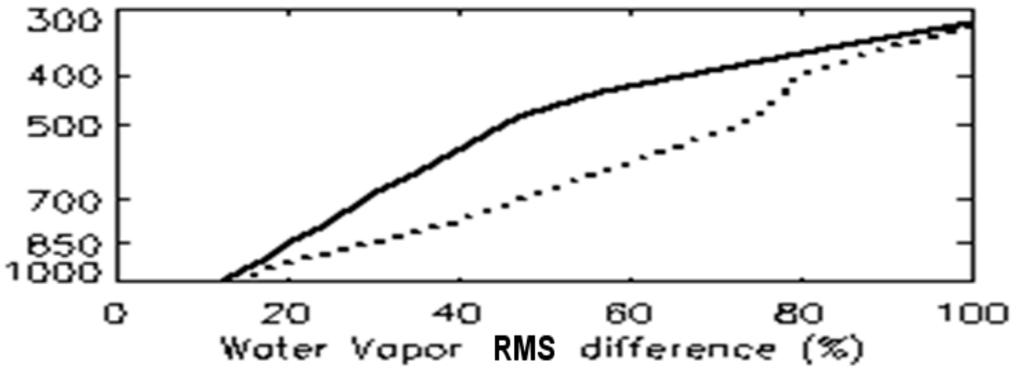

Figure 5: Raob-minus-NWP (collocated to raob) H_20 vapor fraction (%) RMS difference for Raobs with moisture scores 0,1 (solid) versus scores of 2 or more (dashed) .

As seen, the radiosonde-minus-NWP RMS is reduced 20% to 40% in the middle troposphere for profiles with moisture scores of 0 or 1. This underscores potential impacts for satellite validation (and tuning) since most sensors cannot unambiguously discern moisture structures corresponding to higher profile scores.

NPROVS also retains respective satellite observation and associated sounding profile quality control (QC) indicators as available for each satellite product suite. The satellite QC parameters are not considered when compiling collocations are available for utilization in respective products validation as discussed in Section 3.

NPROVS collocation datasets are compiled daily and processed into weekly and monthly datasets for routine validation and archive.

3. RESULTS

3.1 Validation and Screening Strategies

Figures 6a and 6b illustrate the impact of sampling strategy with respect to satellite QC on collocation sample yield and perceived performance. The curves illustrate satellite-minus radiosonde mean and standard deviation differences in temperature for ATOVS operational soundings, NOAA operational 3-hr GFS observations collocated to the ATOVS soundings, and hyper-spectral AIRS and IASI soundings, respectively. The sample used is a common denominator sample of collocations which contained each system and for which the sets of collocated hyper-spectral soundings either passed (6a) or failed (6b) their respective QC (6b) requirements. The original sample size of collocations containing all these systems (regardless of QC) was approximately 7000. The period of record is a 7-day period in July, 2010.

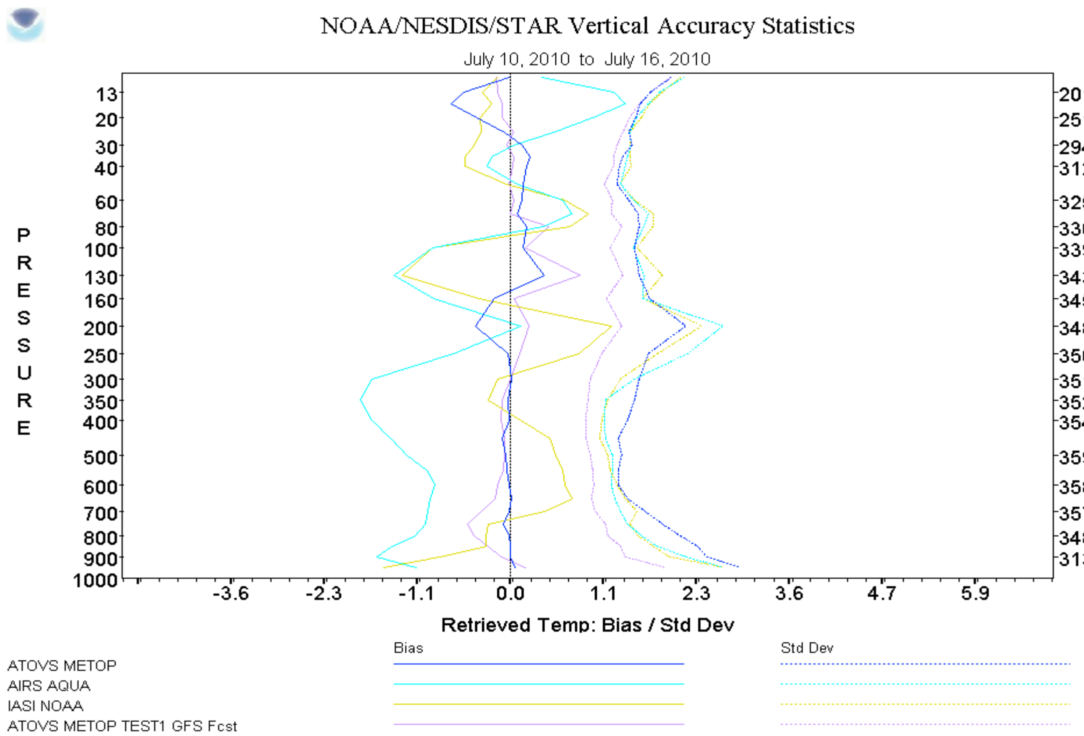

Figure 6a: Sat-minus-Raob mean and standard deviation differences for Temperature at 500mb using common denominator sample of ATOVS operational soundings, GFS 3-hour forecast collocated to the ATOVS soundings, and IASI and AIRS experimental soundings which passed QC.

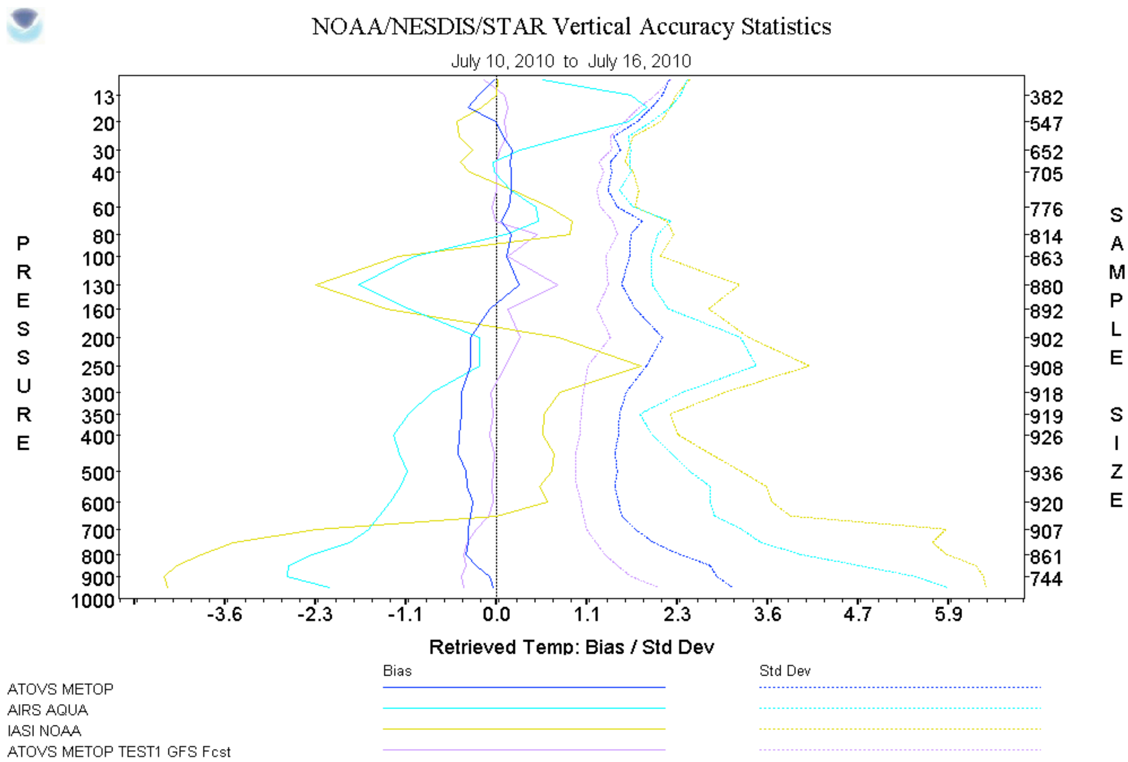

Figure 6b: Sat-minus-Raob mean and standard deviation differences for Temperature at 500mb using common denominator sample of ATOVS operational soundings, GFS 3-hour forecast collocated to the ATOVS soundings, and IASI and AIRS experimental soundings which failed QC.

As seen, requiring collocation samples to contain sets of AIRS and IASI soundings which passed their respective QC reduces the sample size yield by about 50%. By comparison, samples containing collocated AIRS and IASI products which both failed QC is about 900, which means that in approximately 2500 samples (almost 40%) the IASI and AIRS QC indicators were mixed. Clearly and as expected, the satellite-minus radiosonde differences for AIRS and IASI are significantly reduced using QC'd samples, however it is interesting that differences for the ATOVS operational soundings and GFS observations are about the same in both sets. These results suggest inconsistencies in the respective QC approaches for hyper-spectral soundings and the potential for improved performance in areas currently being marked for QC. NPROVS provides a good source of feedback in these areas.

3.2 Platform Performance and Mismatch Sensitivity

One of the potential strengths of the NPROVS is that in addition to providing feedback to satellite data providers (and managers) concerning the relative performance and sensitivities of the satellite products, it can also provide feedback on the performance of ground truth data platforms.

Figure 7 illustrates an example using the Constellation Observing System for Meteorology, Ionosphere and Climate (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.* 2010). Blue indicates daytime differences and gray nighttime differences.

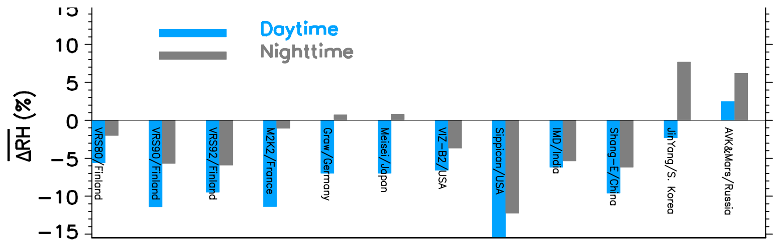

Figure 7: Mean 300 hPa raob-minus-COSMIC relative humidity difference for different radiosonde types for daytime and nighttime, April 2008 to December, from Sun et al (2010).

Results indicate an overall dry bias for the radiosondes (lower relative humidity) except for selected radiosonde types over Russia (AVK) 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).

Figure 8 illustrates trend statistics from January 2009 through July 1 for 500mb mean satellite-minus-radiosonde differences for selected satellite platforms using NPROVS ARChive Summary System (NARCCS).

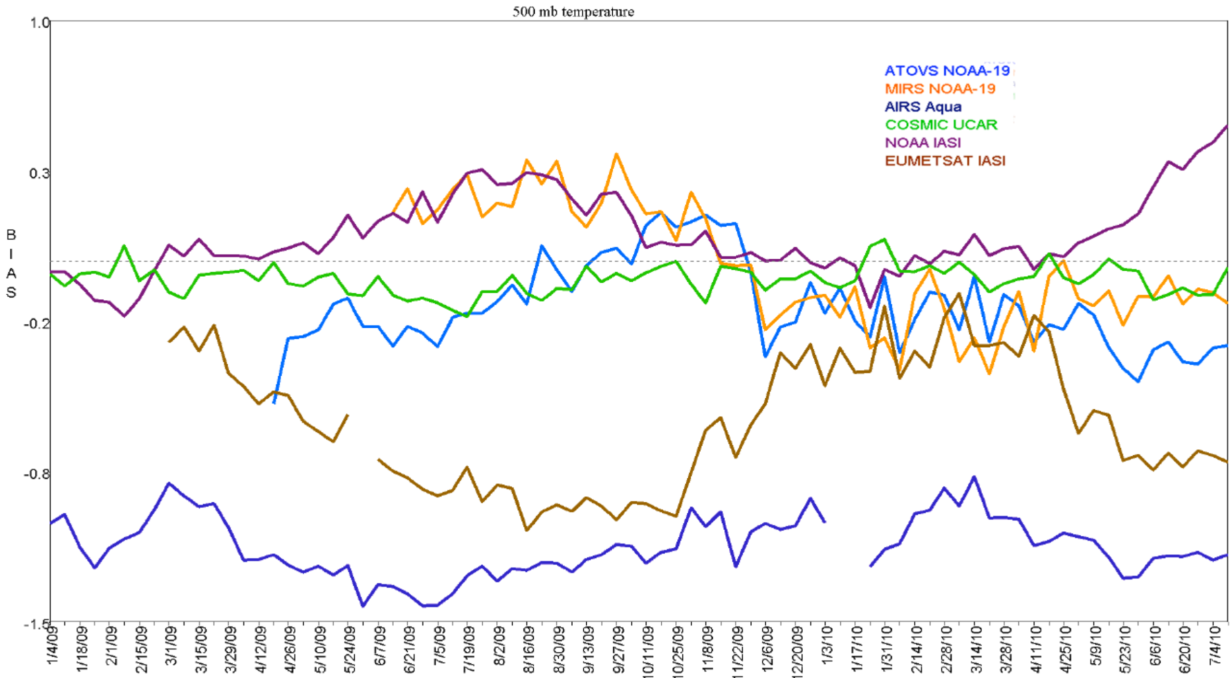

Figure 8: Trend plots of mean Sat-minus-Raob 500mb temperature (K) for denoted satellite systems from January 2009 to July 2010

Unlike the results of Figure 6, the samples used for the curves of Figure 10 are not common denominator but independent and optimized for each system based the subsets of collocation which passed QC. As seen, the relative magnitude and seasonal variation of mean differences varies significantly for each system. AIRS soundings show a distinct cold bias and IASI-EU soundings show the largest seasonal variations. NARCSS provides trend monitoring at several levels for temperature and H20 vapor fraction and included additional breakdowns based on terrain cloudiness and QC.

Visit the web site http://www.star.nesdis.noaa.gov/smcd/opdb/poes/ to review the latest NPROVS capability and download datasets and JAVA utilities to perform data analysis (Figure 2,3 6 and 8) presented in this report.

The sensitivity of collocated observations with respect to spatial and temporal mismatch is another topic of interest that can be addressed with NPROVS collocation datasets. Decision making with respect to network design and operations for the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) (World Meteorological Organization 2008) is underway. This includes the topic of the collocation of observations and the importance of anchoring of satellite data to reference radiosonde observations for monitoring climate. Results from Sun et al. (2010) based on standard deviations of differences between radiosonde and COSMIC soundings are summarized in table 1 and estimate temperature sensitivities in the troposphere to be 0.36K/3hr (0.12K/hr) and 0.4 K/100km, respectively, with comparable results for relative humidity (RH). These values represent global averages for all seasons on “real-time weather scales” which obviously vary with location, season and air mass. Similar studies to assess sensitivities with respect to satellite sensor calibration (in microwave radiance space) and on the climate scale using significantly longer periods than for this study are needed.

(a) time mismatch impact	$SD_{\Delta T}$ (K)	$SD_{\Delta RH}$ (%)
Globe	0.35 (0.042) 0.30 (0.042)	3.30 (0.506)
Mid-high latitude	0.40 (0.049) 0.27 (0.053)	3.52 (0.551)
Low latitude	0.11 (0.121) 0.47 (0.139)	2.32 (0.929)

(b) distance mismatch impact	$SD_{\Delta T}$(K)	$SD_{\Delta RH}$ (%)
Globe	0.42 (0.030) 0.22 (0.025)	3.05 (0.290)
Mid-high latitude	0.46 (0.031) 0.22 (0.025)	3.19 (0.298)
Low latitude	0.20 (0.048) 0.22 (0.052)	2.58 (0.461)

Table 1: Standard deviation errors introduced by (a) time mismatch (per 3 hr) and (b) distance mismatch (per 100 km) for T and RH for troposphere (850 to 200 hPa average) and stratosphere (200 to 10 hPa); Values within the parentheses are the standard errors of the estimates. The low latitude region is defined as 30° N and 30° S, and the mid-high latitude region is 30N to the rest of the world.

4. GCOS Reference Upper Air Network (GRUAN)

Currently, the 15 initial sites shown in (Figure 9) are identified as GRUAN sites (WMO 2010).

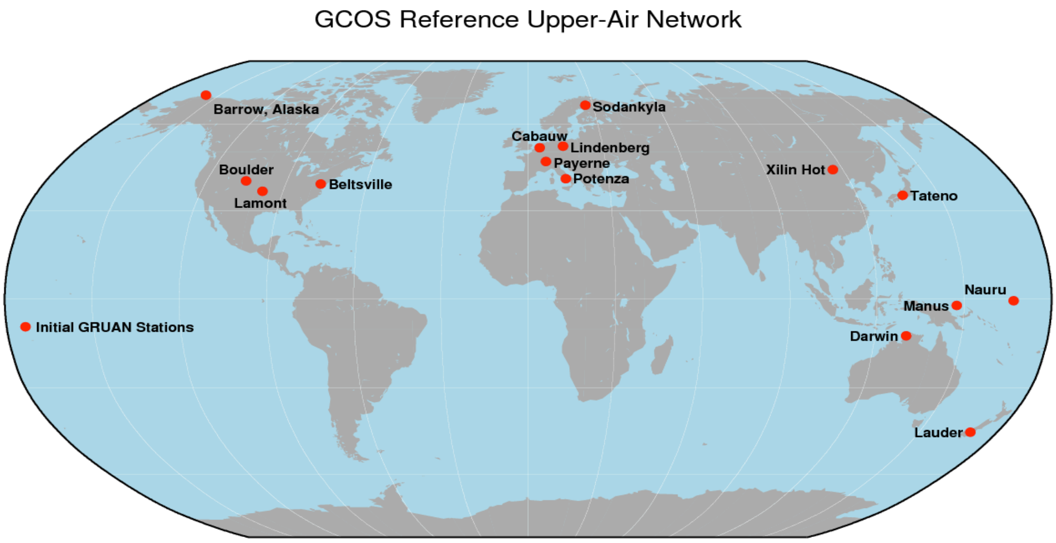

Figure 9: GRUAN Sites

NOAA recognizes the potential value of GRUAN to support current and future environmental satellite programs and in particular:

- GSICS international activities to ensure the accuracy and comparability of measurements from earth observing satellites,
- the validation of atmospheric radiative transfer physical models underlying derived product processing, and
- the validation of derived atmospheric products

A goal for NPROVS is the routine access and integration of specially processed reference radiosondes observations from GRUAN sites. The data management concept for GRUAN (WMO 2010) is for reference radiosondes from GRUAN sites to be processed at the Lead Centre (Lindenberg, DWD), with supplemental processing of RS92 data at ARM sites, and ultimately disseminated (with uncertainty estimates) by the Lead Centre to NCDC for global accessibility via the NCDC Global Observing System Information Center. The start of operational data collection, processing and dissemination via the Lead Centre was originally scheduled for August 2010 but has been delayed (until later 2010).

The GRUAN Implementation and Coordination meeting (ICM-2) held in Payerne, Switzerland in early March also resulted in the establishment of the following Task Teams (TT1 to TT5):

- ***Team 1: Radiosondes***
  *t*o evaluate the data products (uncertainty budget etc.) and bring in missing knowledge
- ***Team 2: GPS-PW***
  *t*o draw conclusions on the suitability of the deployed equipment and to standardize processing across the network.
- ***Team 3: Measurement schedules and associated site requirements***
  *t*o develop defensible, quantifiable, scientifically-sound guidance
- ***Team 4: Site assessment, expansion and certification*** |
  *t*o define assessment criteria for sites and provide regular assessments
- ***Team 5: Ancillary measurements***
  to interface with satellite experts and NDACC with initial focus on MWR, Lidars and FTIR

Among the Topics of Reference (ToR) established for Teams 3 and 5 was the inter-comparison of satellite observations against reference measurements at GRUAN sites.

Among the goals of TT-5 is the routine access and display of “ancillary” measurements comprised of selected ground measurements (with initial focus on FTIR, MW and Lidars) and derived satellite products within NPROVS for use in the routine cross validation and uncertainty budget calculations. This would require the development of a special NPROVS/GRUAN interface to focus on individual site monitoring and ground system performance not available within the existing NPROVS protocol.

Among the goals of TT-3, the broader goal of satellite validation is addressed with a focus of establishing consistency between individual satellite records and the support of post launch validation intensives. Reconciling aspects of the regular measurement schedule and requirements of particular satellite validation exercises is an objective of this team.

Reports and recommendations from these groups are scheduled for presentation at ICM-3 scheduled for 28 February to 4 March, 2004 in Queenstown, New Zealand.

Recommendation:

- STAR NPROVS to pursue the access of available reference radiosonde observations from GRUAN sites for use in the routine validation of satellite product systems with the goal of achieving an initial capability by early 2011.

- STAR NPROVS to pursue the access of available selected “ancillary” ground measurements (including available reference radiosonde observations) from GRUAN sites to support routine cross validation and energy budget calculations.

- GRUAN to focus on providing long-term support for the satellite community, particularly in the area of data satellite record ‘gap-filling’, post-launch data intensives (in support of GSICS, NPP/JPSS) and as feasible provide scheduling adjustments (for reference radiosondes) to meet these requirements

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 COSMIC environmental satellites. This is achieved through the compilation and analysis of collocated radiosonde, dropsonde, 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 including satellite and Raob QC, space and time windows, terrain designation, individual and common denominator sampling, radiosonde instrument type selection, regional (ie GOE Conus) designation for short term (weekly) and longer term (monthly, annual) analysis (http://www.star.nesdis.noaa.gov/smcd/opdb/poes/). Staged efforts to create a dedicated NPROVS interface to integrate 1)reference radiosonde observations and 2)selected ground observations from GRUAN sites are planned once the data are routinely available.

6. REFERENCES

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