Verification of Global Upper-Air Observations

Consolidated Comments to the Climate Monitoring Breakout Group

by

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Introduction

- After more than 60 years, radiosondes are still our most important upper-air observing system.
- They make *in situ* observations of the primary mass and momentum state variables: wind, temperature, pressure, and relative humidity.
- As such, they provide the standard data set for:
  - numerical weather prediction;
  - regional weather forecasting;
  - climatology;
  - and research.
- And they serve as “ground-truth” for satellite-derived estimates of temperature, moisture and other parameters.

Introduction

- Raobs can be difficult to verify because (1) they are launched infrequently from widely spaced locations and (2) other observations are rarely available for comparison.
- Numerical models assimilating radiosondes usually weight them heavily, so using a model to verify a raob is always interesting.
- Verification of satellite retrievals of temperature, moisture and other parameters is also difficult because of the lack of redundant observations, especially in remote locations (e.g. the oceans and polar regions).

Introduction

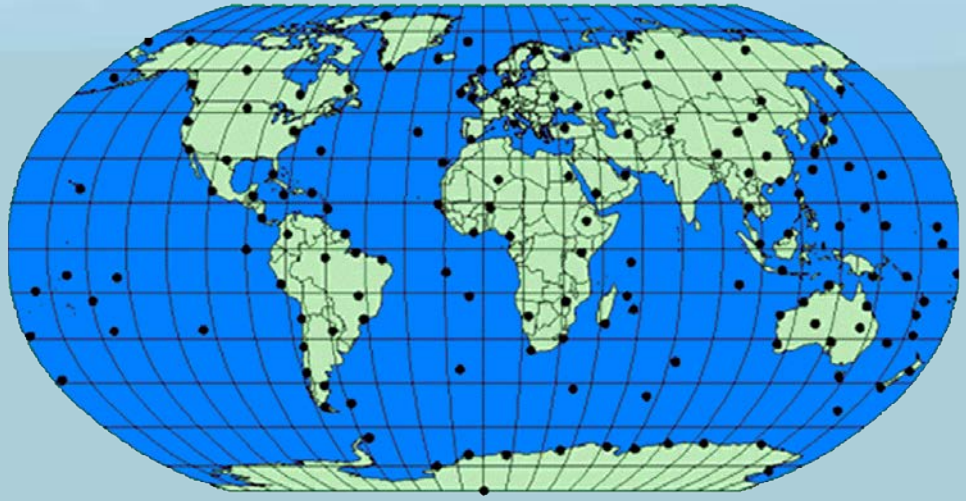
- As a consequence, the accuracy of regional weather/water warnings & forecasts and global climate predictions depend on the accuracy of relatively few upper-air observations.
- It's hard to imagine that significant improvements in weather & climate models, and the forecasts derived from them, can occur without improvements in the accuracy and reliability of these (radiosonde and satellite) observing systems.
- Furthermore, it's unreasonable to assume that the scientific goals of IEOS/GEOSS can be achieved without improvements in these and related areas.

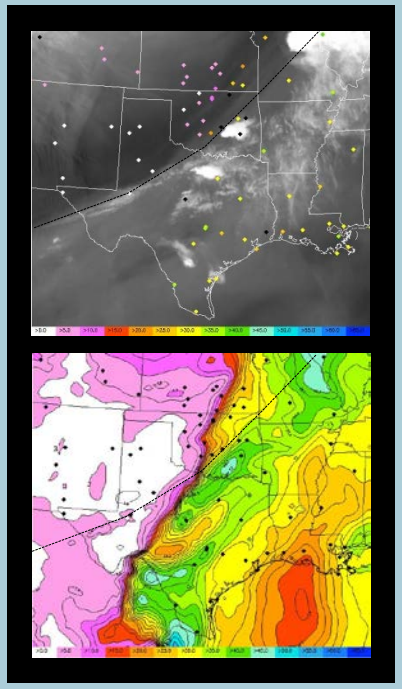
Suggested Approach

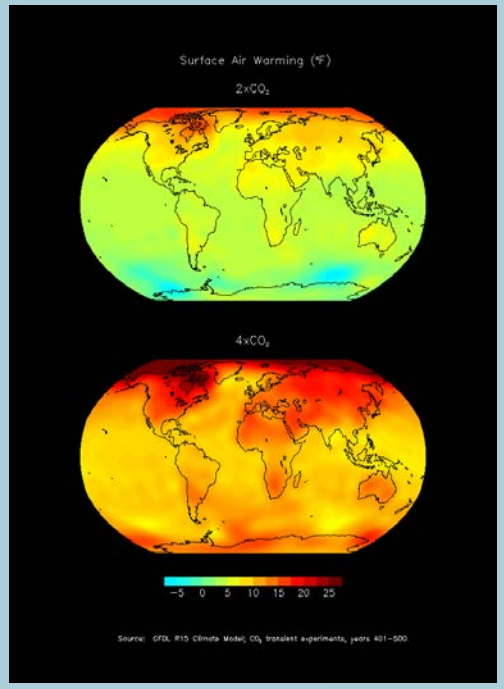
- As technology advances, and new ways of making measurements are developed or made more economical, it becomes feasible to make comparative measurements of the same parameters using totally independent techniques.
- One such technique is Ground-Based GPS Meteorology (GPS-Met).
- The remainder of these comments address a way to quickly and inexpensively expand the number of global upper-air moisture observations for radiosonde and satellite verification.
- This approach will also benefit other disciplines by providing continuous and reliable GPS observations for space weather forecasting, transportation, and solid Earth geophysics.

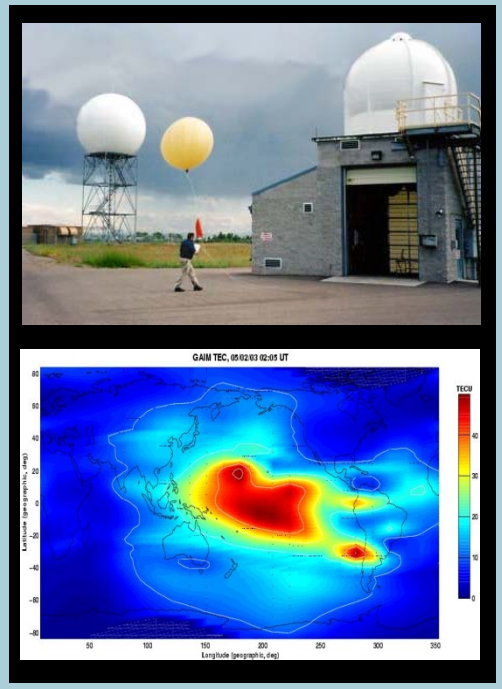
Suggested Approach

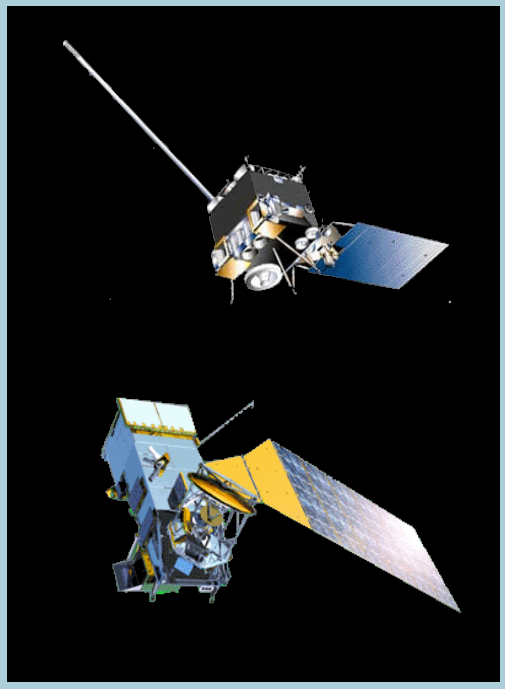
- Proposal: install GPS (and later Galileo) GNSS receivers at all 150 GCOS/GUAN sites, and upgrade power and communications at these sites to insure real-time data availability.





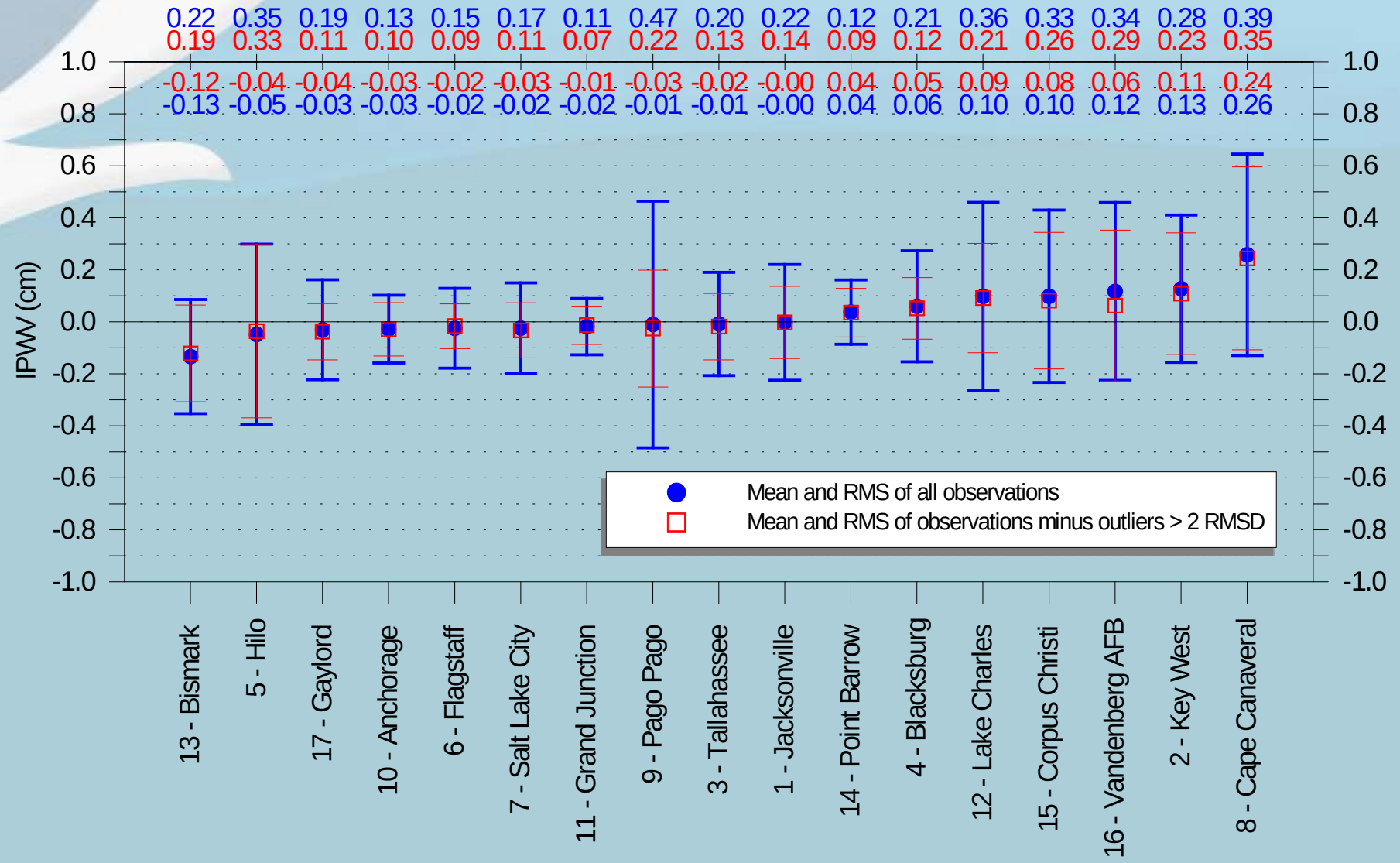






Radiosonde – GPS Comparisons

- When outliers (PW differences between sondes and GPS > 2 RMS) are eliminated, GPS and raobs have negligible bias and small 1.5 mm differences.
- Outliers occur about 4% of the time with NWS sondes.
- The occurrence of outliers is non-systematic, and usually manifested by high RH above the tropopause.
- Undetected outliers assimilated into NWP models can significantly impact RH forecast accuracy over extremely large regions for up to 12 hours.
- Additionally, outliers add uncertainty (noise) in long-term climate studies negatively impact satellite cal/cal.

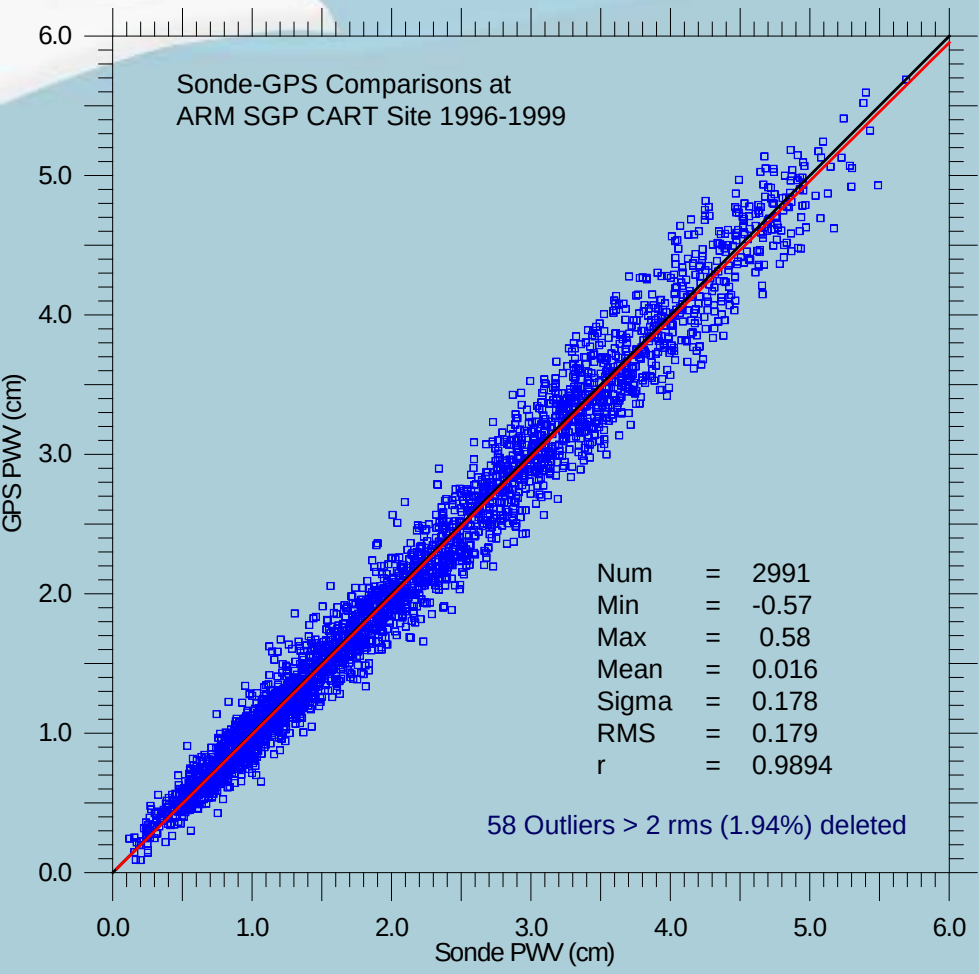


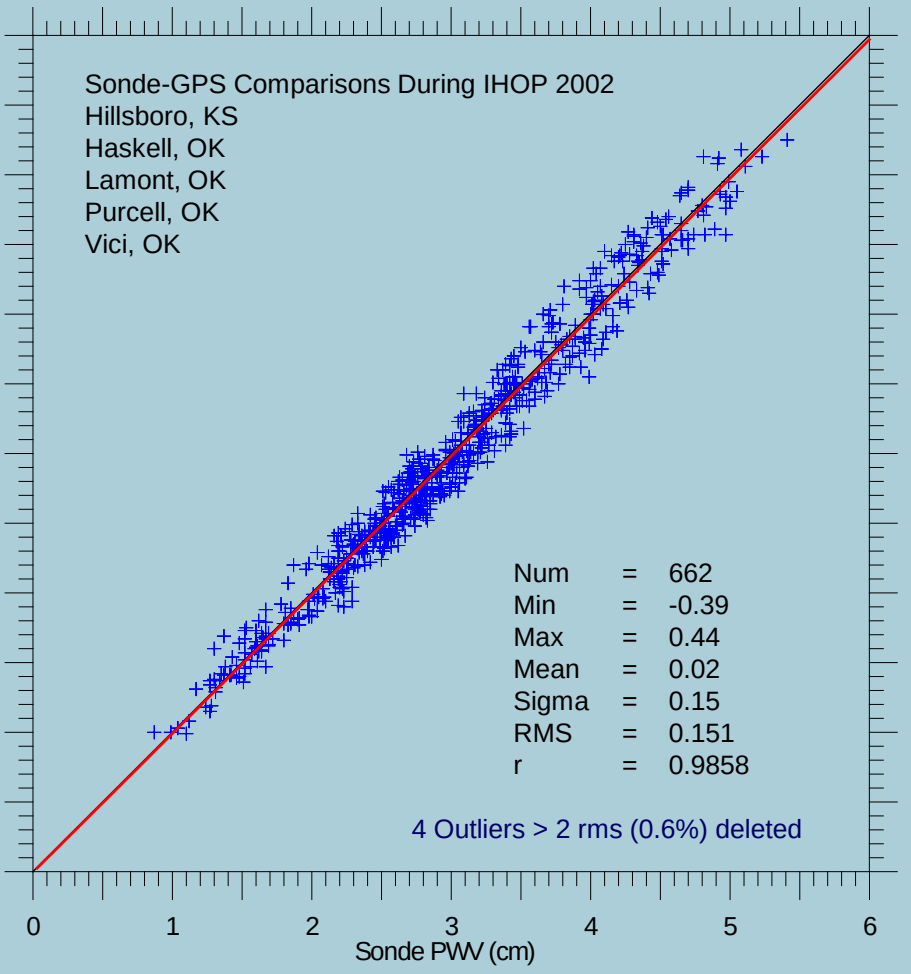
One Year, 17 UA Sites

	Total Num	Avg Num	Min	Max	Mean	Sigma	RMS	Corr
All Comparisons	10361	609	-1.64	1.60	0.03	0.24	0.25	0.96
Minus Outliers	9957	586	-0.48	0.49	0.02	0.15	0.18	0.98

Outliers > 2 sigma = ~ 3.8%

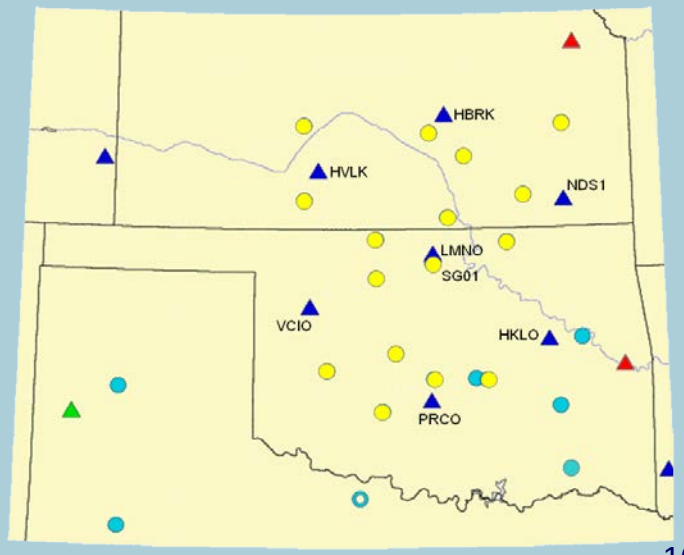
GPS as a Proxy for RAOBs in PW Comparisons



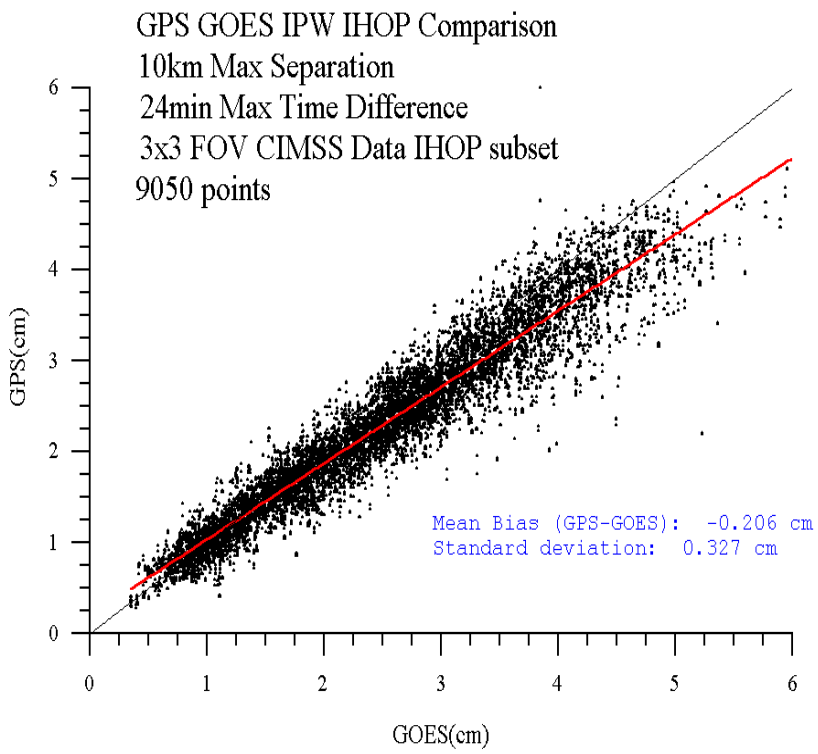


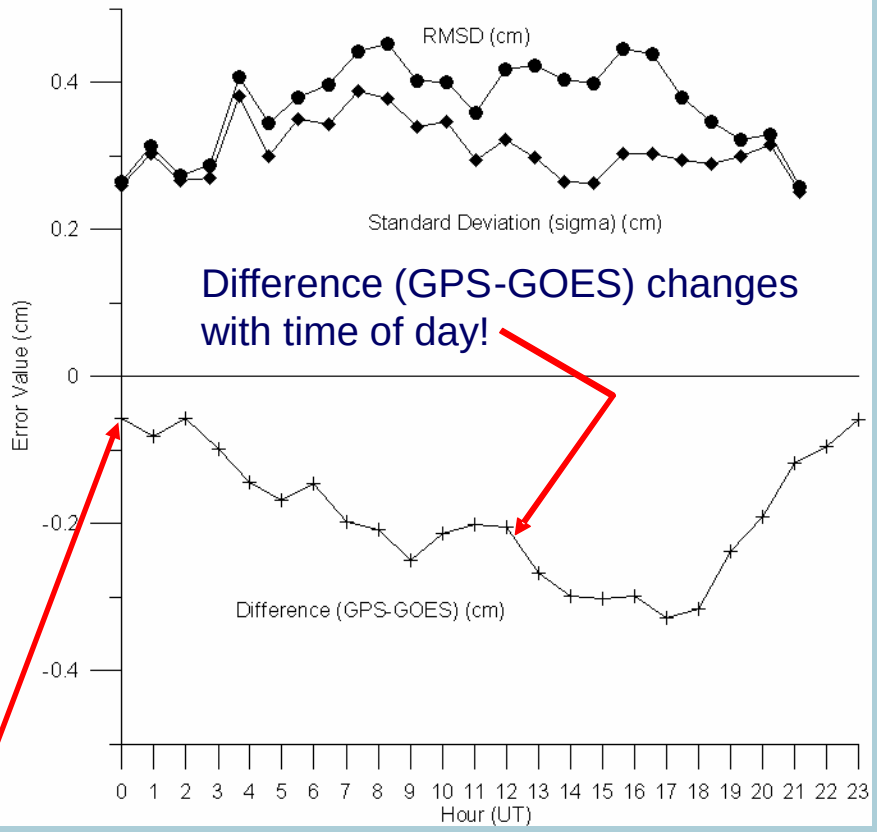
Evaluation of GOES Sounder PW Data

- During the IHOP 2002 campaign, we compared PW from the GOES-8 sounder with ARM radiosondes and GPS for 21 days between 26 May and 15 June, 2002.
- ARM sondes were launched at 3-h intervals from 5 sites, and GPS PW were available continuously at all sites.
- This gave us an opportunity to perform continuous 3-way comparisons between GOES, radiosondes, and GPS.
- The results were surprising.



Evaluation of GOES Sounder PW During IHOP 2002





Instruments Compared	Difference (cm)	Std Dev (cm)	RMSD (cm)	Number Points
GPS – GOES (IHOP)	-0.206	0.327	0.39	9,050
GOES – Sonde	-0.069	0.346	0.35	6568
GPS – Sonde (IHOP)	-0.02	0.15	0.151	662

After Schmit, T. J., W. F. Feltz, W. P. Menzel, J. Jung, A. P. Noel, J. N. Heil, J. P. Nelson, G. S. Wade, 2002: Validation and use of GOES sounder moisture information Wea. Forecasting. 17, 139.

Application to Atmospheric Infrared Sounder (AIRS) Data

- As part of the Aqua/AIRS science team, we also investigated the accuracy of AIRS PW estimates with respect to GPS and radiosondes.
- This experiment lasted four months, and used data from UA sites all over the U.S.
- In general, the agreement between AIRS, GPS, and radiosonde PW was found to be pretty good once radiosonde outliers were identified and removed from the analysis.
- Adapting a technique described by Turner et al., 2003 to adjust radiosonde moisture profiles with PW data from microwave WVR's, we found that:

Application to Atmospheric Infrared Sounder (AIRS) Data

- Adjusting the radiosonde RH profile by the ratio of the sonde-to-GPS PW totals resulted in improved comparisons with AIRS PW measurements.
- There is no *a priori* reason that the agreement with AIRS should get better unless applying this correction to the radiosondes is making a real improvement in sonde RH profiles.
- This suggests that it may be possible to use GPS to QC radiosonde moisture soundings, and also reduce the errors between vertical moisture profiles derived from satellites, and other moisture sensing systems such as WVSS and TAMDAR.

Conclusions and Recommendations

- GPS provides a temporally invariant (i.e. stable) and reliable way of measuring total column precipitable water vapor in the atmosphere with reasonably high accuracy (< 1 mm) under all weather conditions.
- GPS water vapor observing systems are inexpensive, reliable, easy to install and maintain.
- Installation of GPS at GCOS/GUAN sites around the globe, and making these data freely available in near real-time, will benefit weather forecasting, climate monitoring and satellite cal/val under IEOS/GEOSS.
- It will also benefit space weather forecasting, solid Earth geophysics, tracking satellites in Earth orbit, and air/sea/land transportation safety.