CORS Contributions to Weather Forecasting

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Topics

- **Introduction:**
  How CORS data provides important new information for weather forecasting.
- **Implementation:**
  How the NOAA Forecast Systems Laboratory is using CORS data to improve weather forecast accuracy.
- **A Look Toward the Future:**
  How NOAA might use the growing CORS infrastructure to improve operational weather forecasting in 2010.

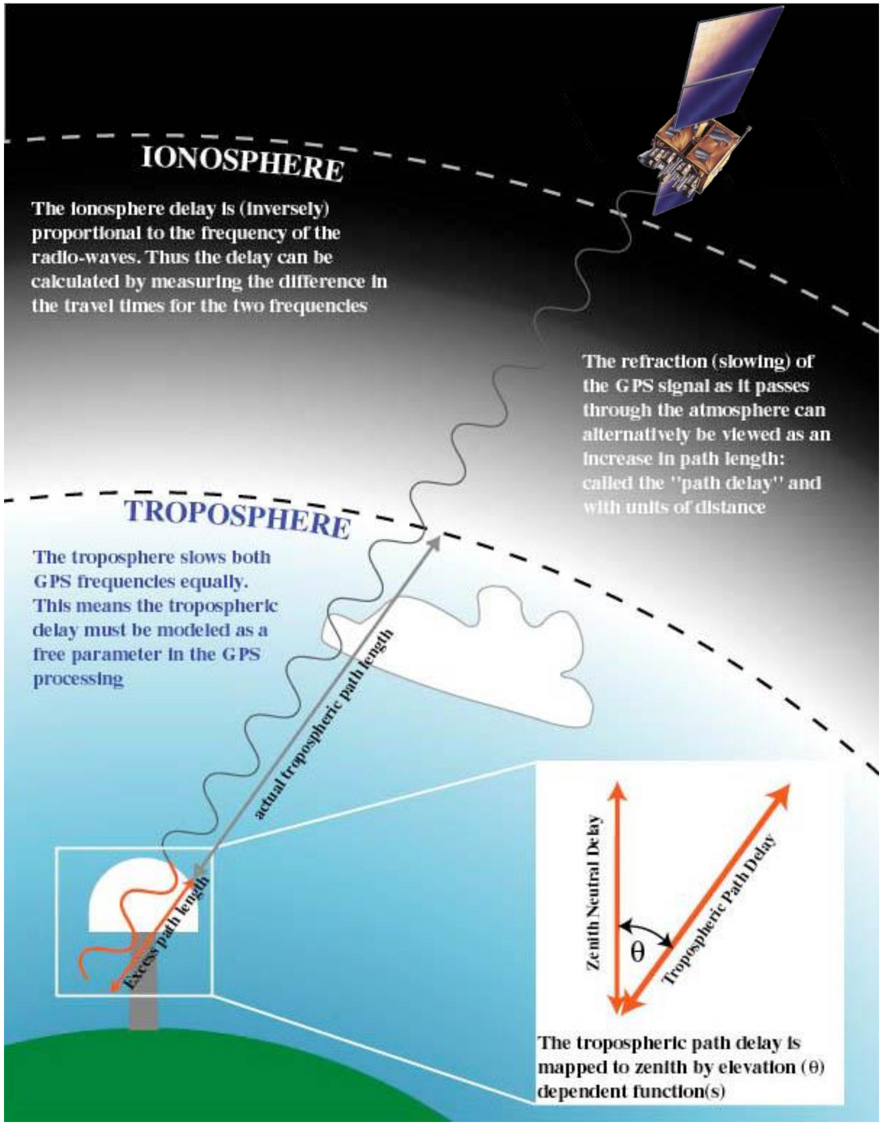
Introduction

- Improved short-term weather forecasts, especially of severe weather and precipitation, is an important goal for NOAA, the National Oceanic and Atmospheric Administration.
- Our ability to do so, however, is currently limited by the lack of timely and accurate observations of water vapor in the atmosphere.
- Water vapor is one of the most important components of the Earth's atmosphere. It is the source of clouds and precipitation, and an ingredient in most major weather events.
- Water vapor varies greatly in time and space, making it difficult to monitor with conventional observing systems, such as weather balloons, surface observations, and satellites.

Introduction

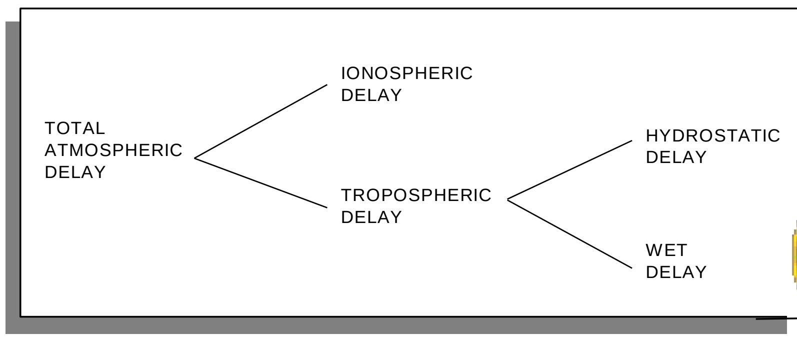
- Water vapor variability is also largely responsible for time-dependant errors in GPS positioning, especially in the measurement of the vertical coordinate.
- To mitigate this problem, methods have been developed to treat the signal delays caused by the neutral atmosphere as a nuisance parameter and remove them to improve survey accuracy.
- Verification of the accuracy of these signal delay estimation techniques has led to the development of a new atmospheric remote sensing tool called GPS Meteorology or GPS-Met for short.
- In GPS-Met, we use data from a network of CORS sites, in conjunction with improved GPS satellite orbits, to estimate the ***total excess signal path length*** caused by refractivity in the troposphere.

Introduction

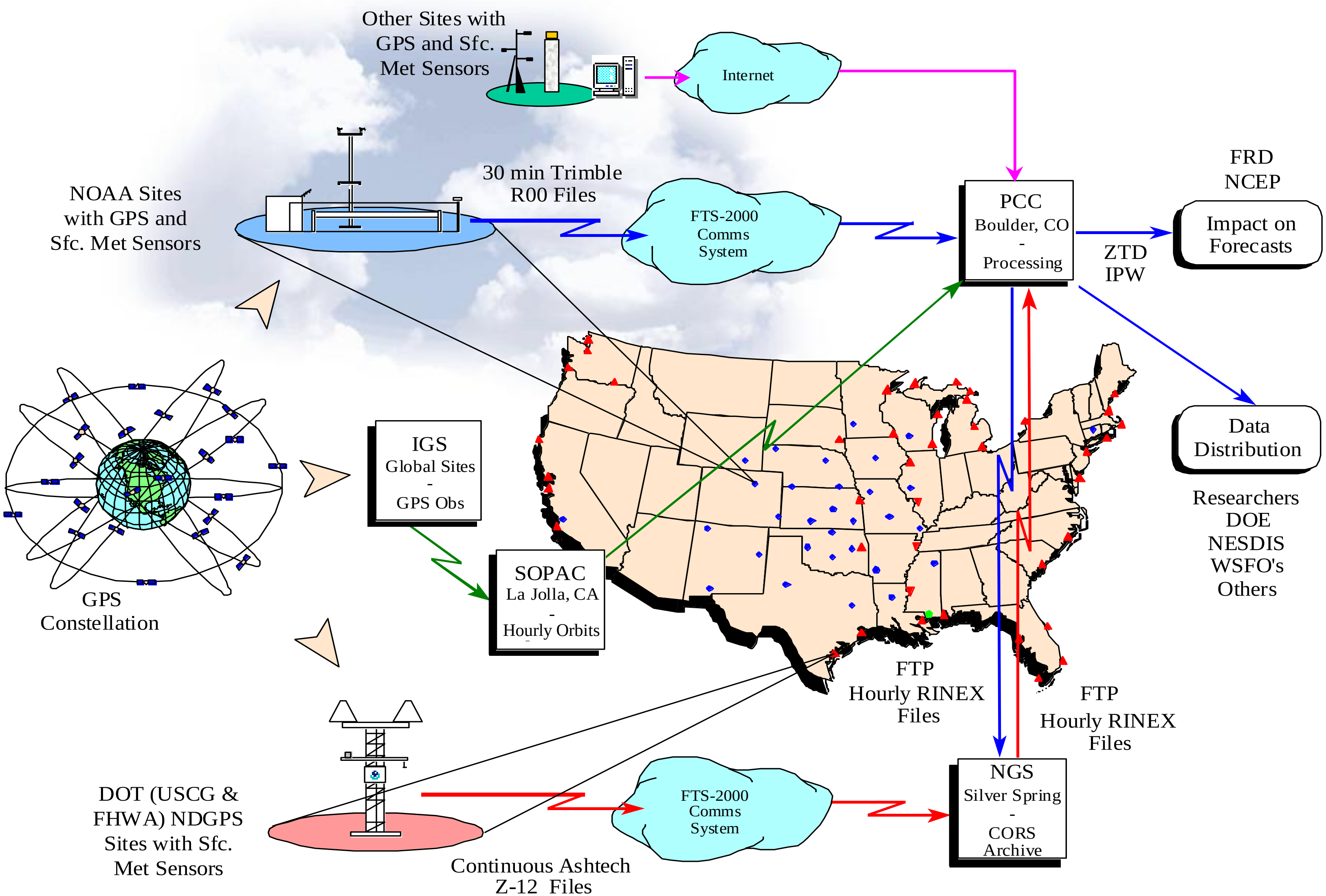


- The total tropospheric signal delay has a wet and dry component.
- The dry delay is caused by the mass of the atmosphere, and can be estimated with high accuracy from a collocated surface pressure measurement.
- The wet delay is simply the difference between the total delay and the dry delay.
- The ratio of the wet delay to the dry delay is the integrated mixing ratio.
- Finally, the wet delay is nearly proportional to the total quantity of precipitable water vapor in the atmosphere directly above a CORS site.

GPS Signal Delay Structure



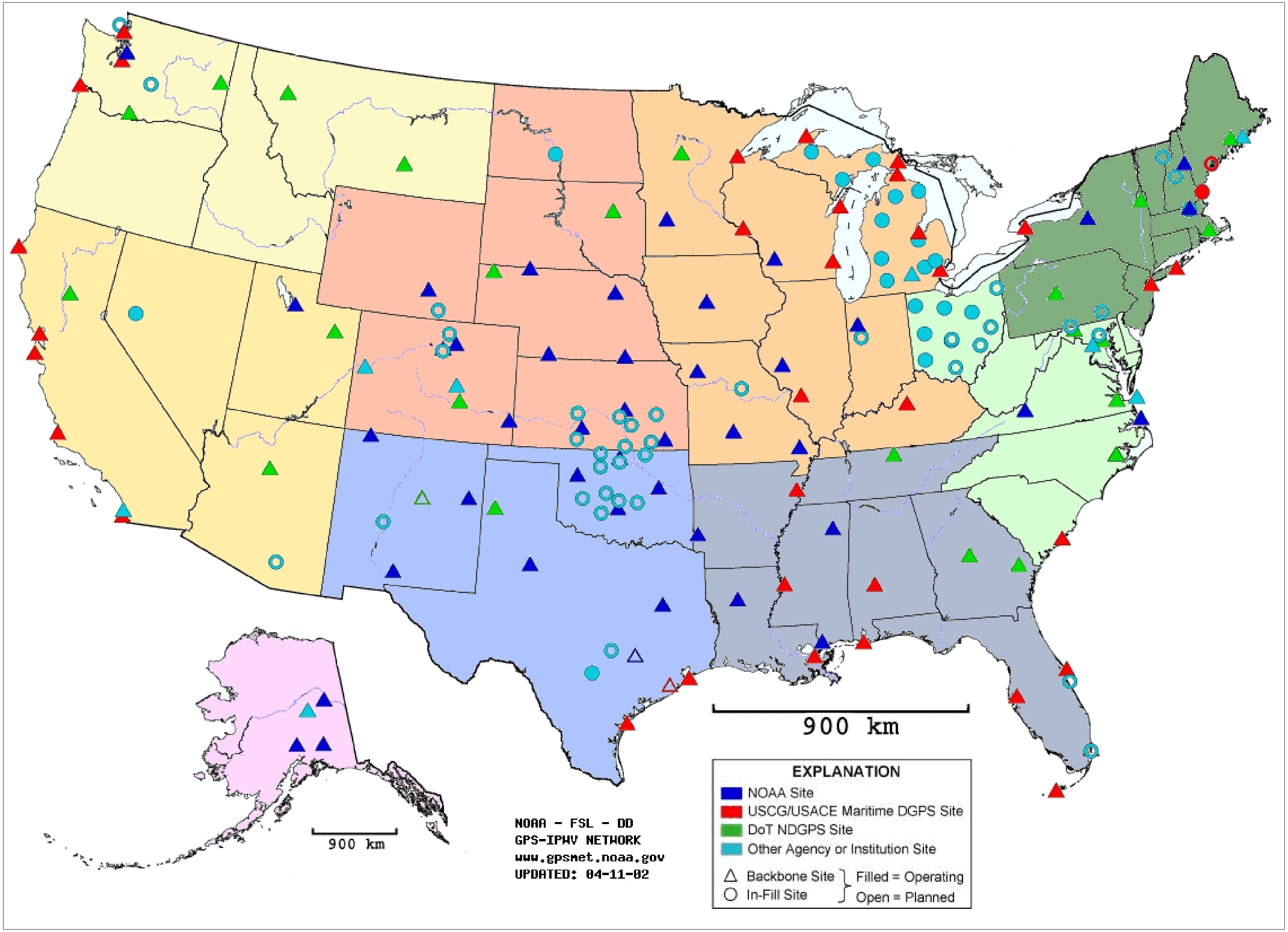
Implementation



Implementation

- The GPS-Met Demonstration Network consists of two types of sites: Backbone and In-fill:
  - ***Backbone sites*** belong to NOAA or other federal, state and local government agencies. They have collocated surface met sensors and are maintained as operational systems and as such are considered to be trusted public resources.
  - ***In-fill sites*** belong to government agencies, universities, or other organizations for educational, research, or proprietary applications. They are not necessarily maintained as operational systems and the owners are not obligated to do so.
- The network will expand by acquiring data from both types of sites. In the near term, most will be backbone sites belonging to agencies like NOAA, FHWA and USCG.

Implementation



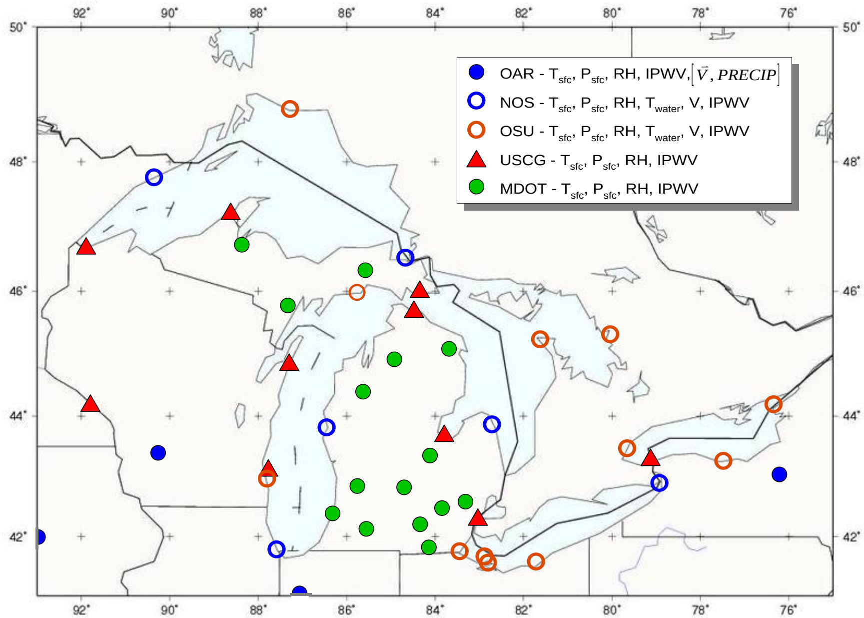
115 CORS GPS-Met Sites + 58 waiting for positions and Sfc. Met.

Implementation

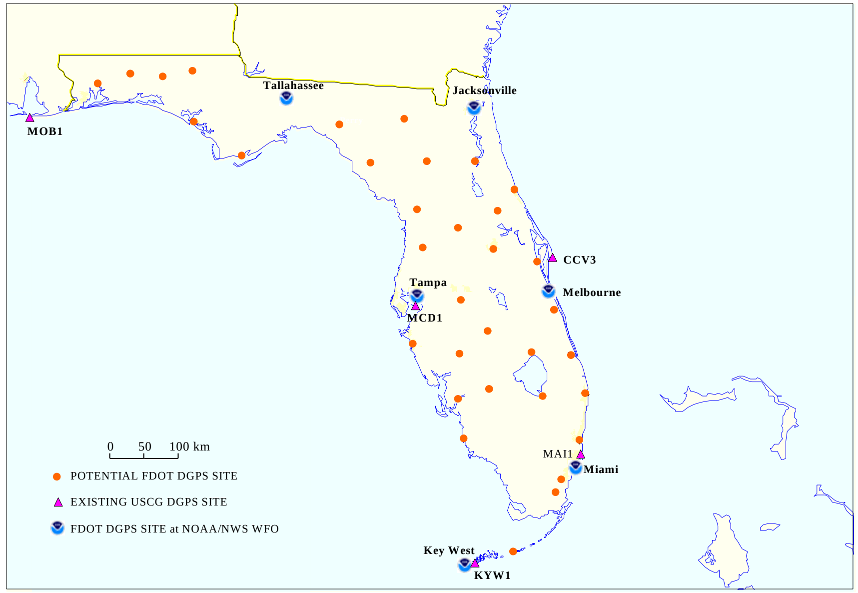
NDGPS Site at Appleton, WA

Implementation

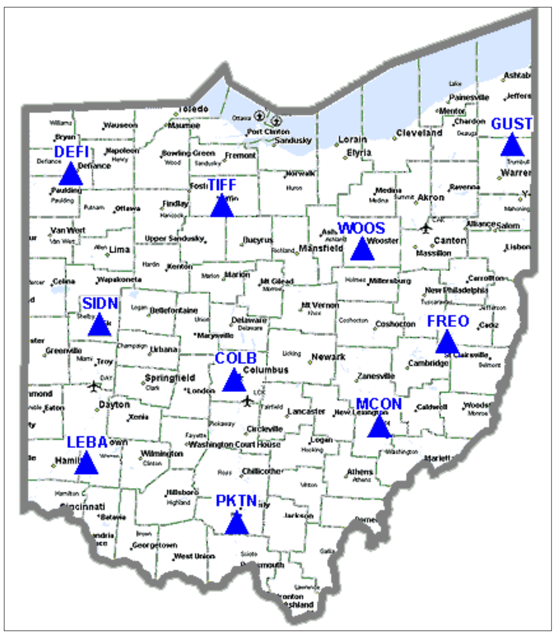
Great Lakes CO-OPS Project & MDOT



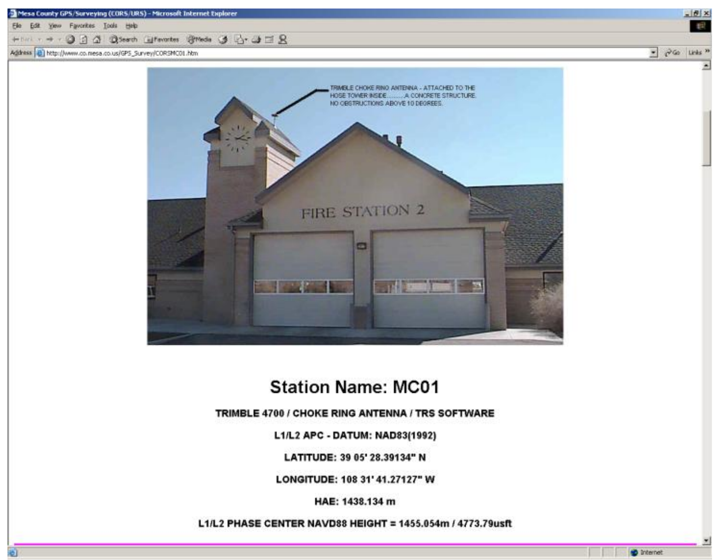
Florida DOT



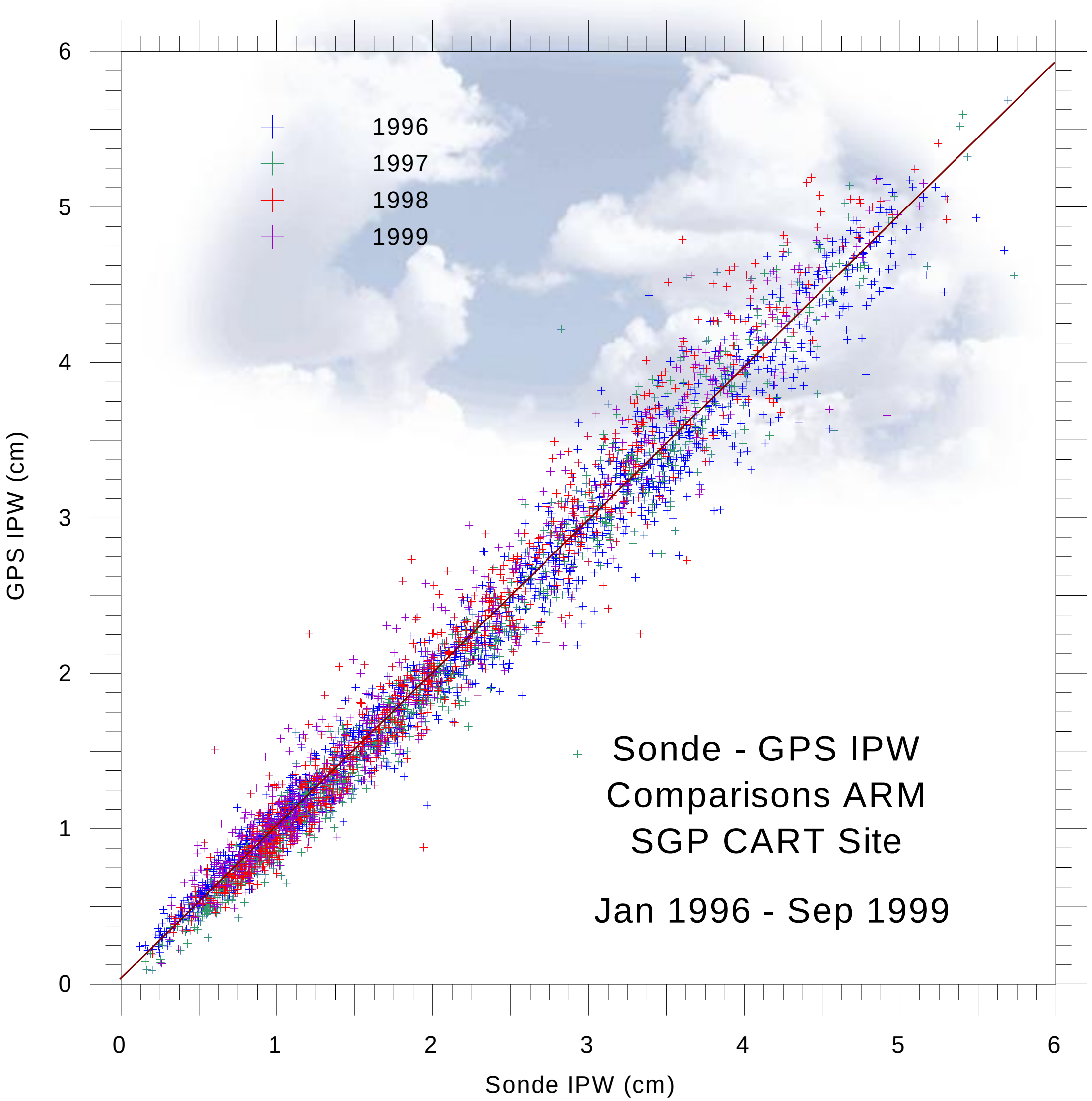
Ohio DOT



Mesa County, CO



Long-Term Comparison of GPS and Rawinsondes



1996

N = 1382
Mean Dif. = 0.0346 cm
Std. Dev. = 0.1977 cm
Corr. = 0.9886

1997

N = 813
Mean Dif. = 0.0501 cm
Std. Dev. = 0.1965 cm
Corr. = 0.9874

1998

N = 771
Mean Dif. = -0.0431 cm
Std. Dev. = 0.2308 cm
Corr. = 0.9817

1999

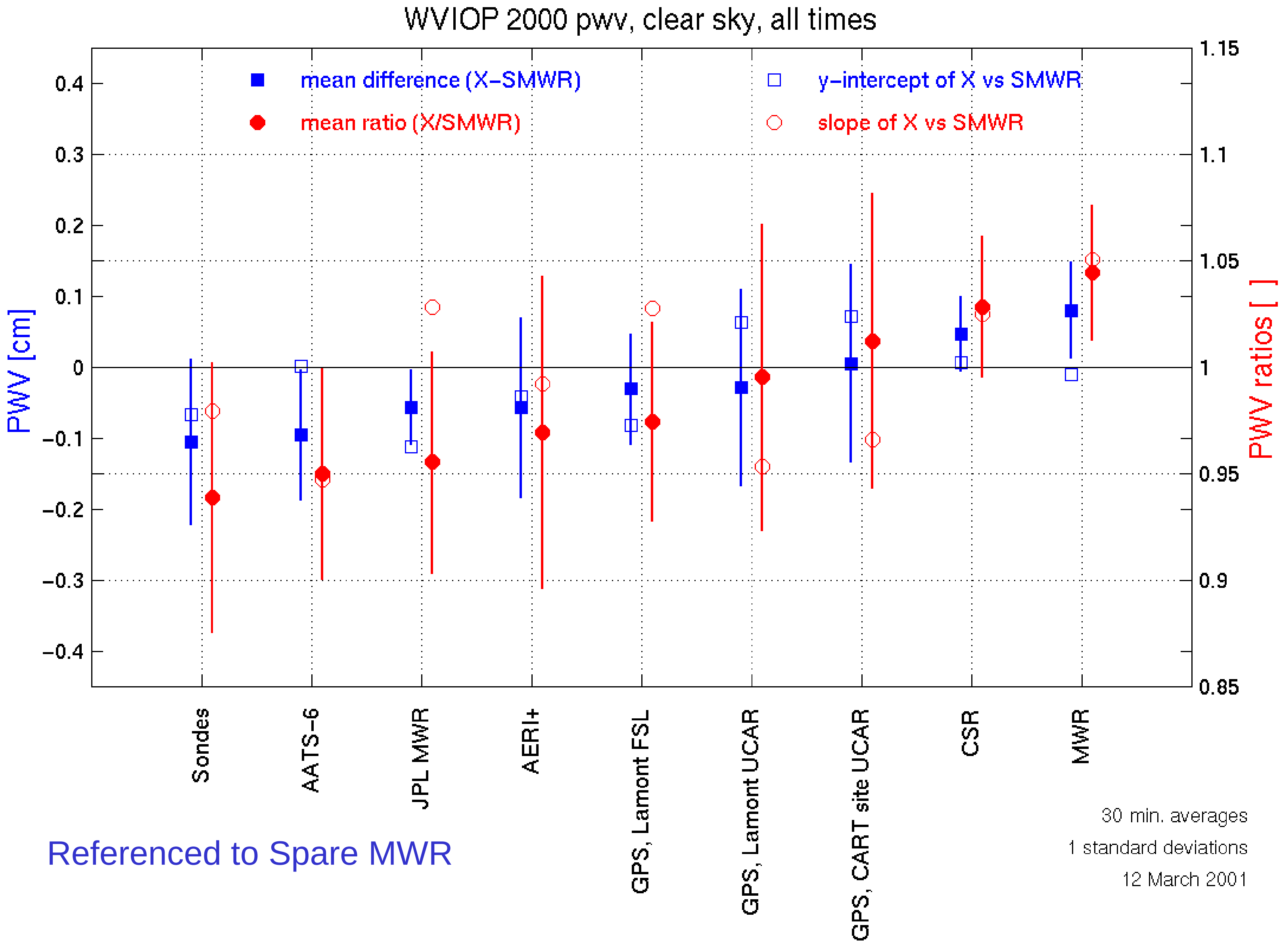
N = 551
Mean Dif. = -0.0460 cm
Std. Dev. = 0.2070 cm
Corr. = 0.9851

1996 - 1999

N = 3600
Mean Dif. = 0.0080 cm
Std. Dev. = 0.2102 cm
Corr. = 0.9854

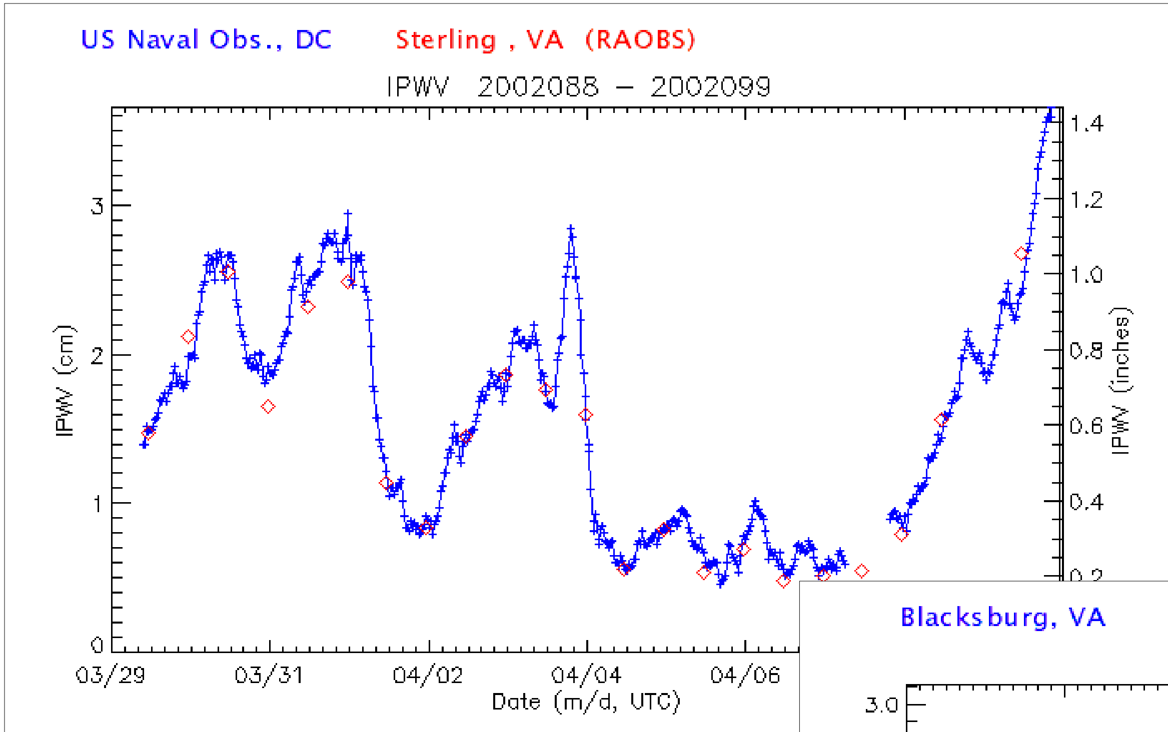
Equation of best fit line
$Y = 0.9876125443 * X + 0.01837114798$

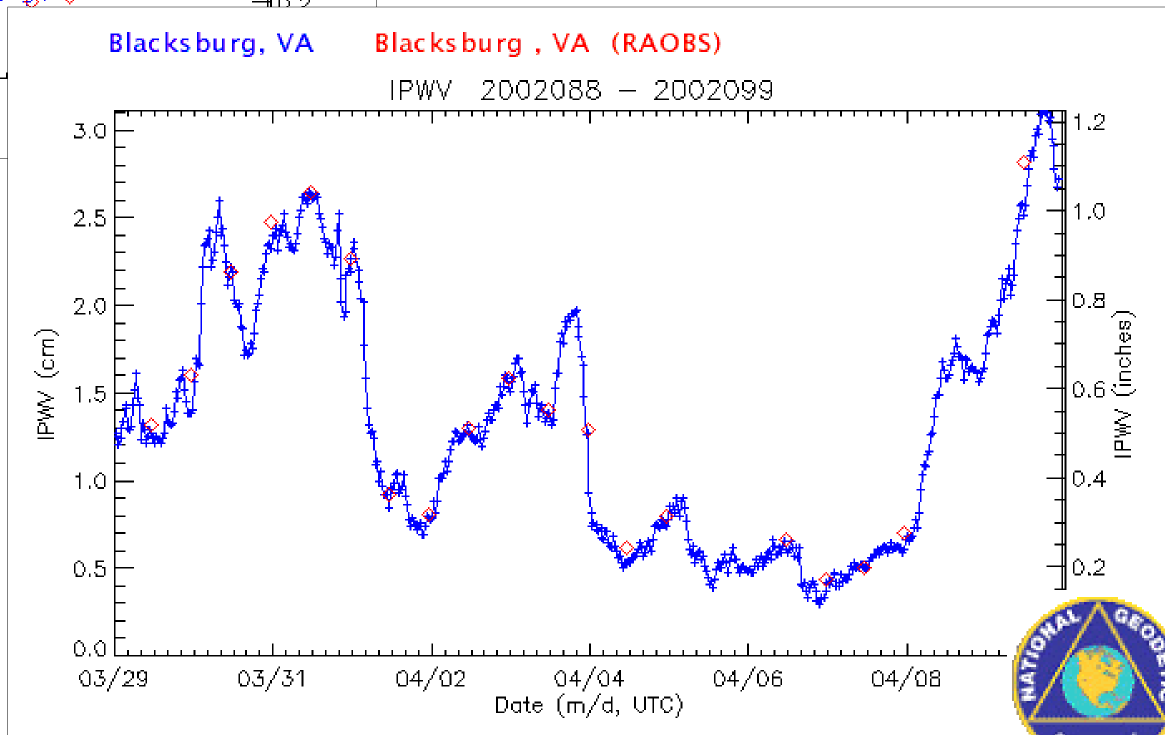
WVIOP 2000 PWV (Clear Sky) Data Comparisons



Referenced to Spare MWR

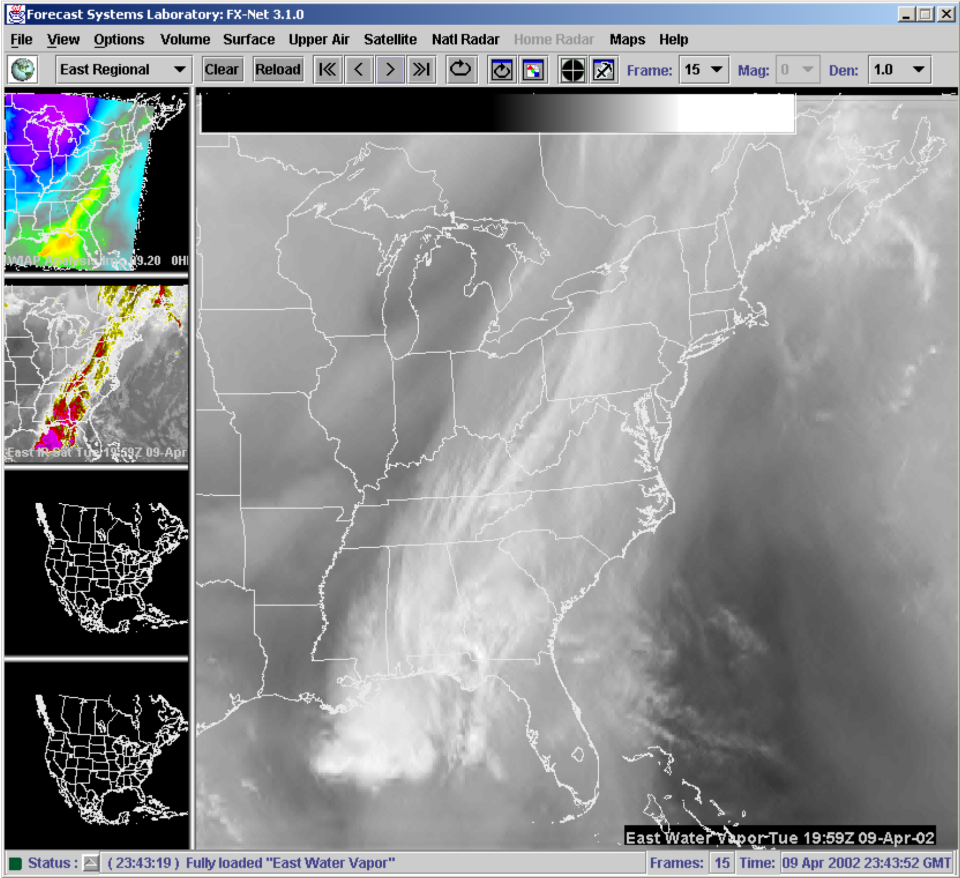
Recent Comparisons



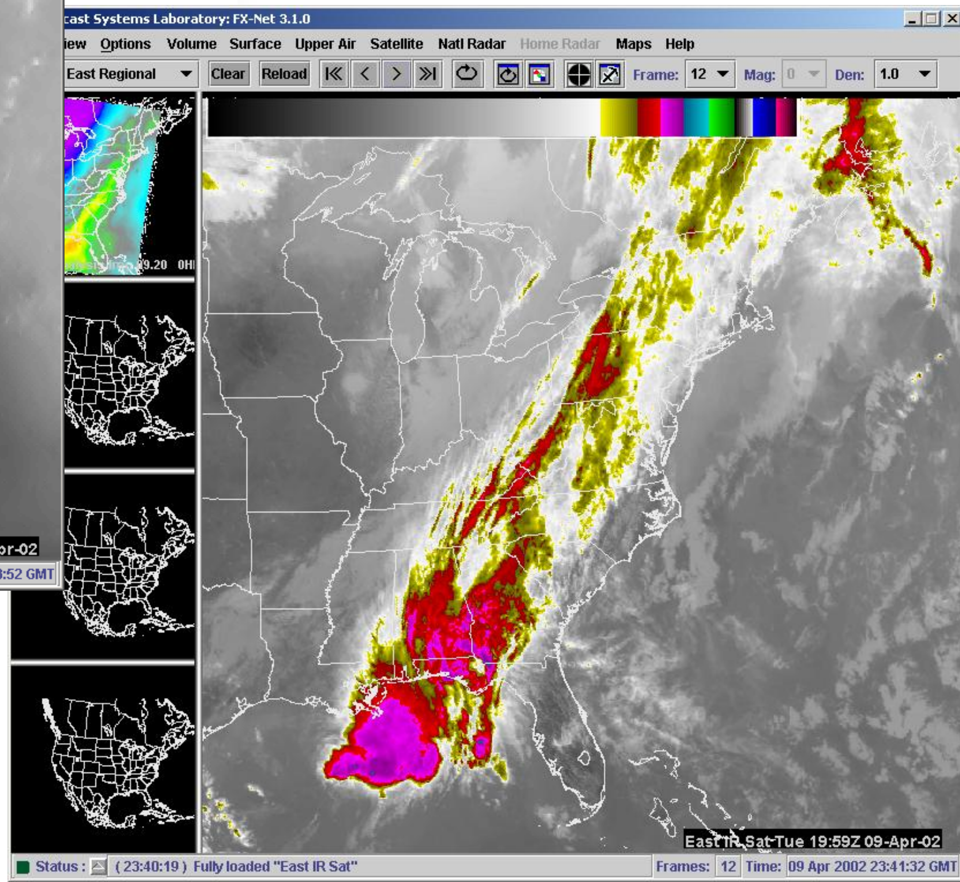


Observations

GOES-8 WV

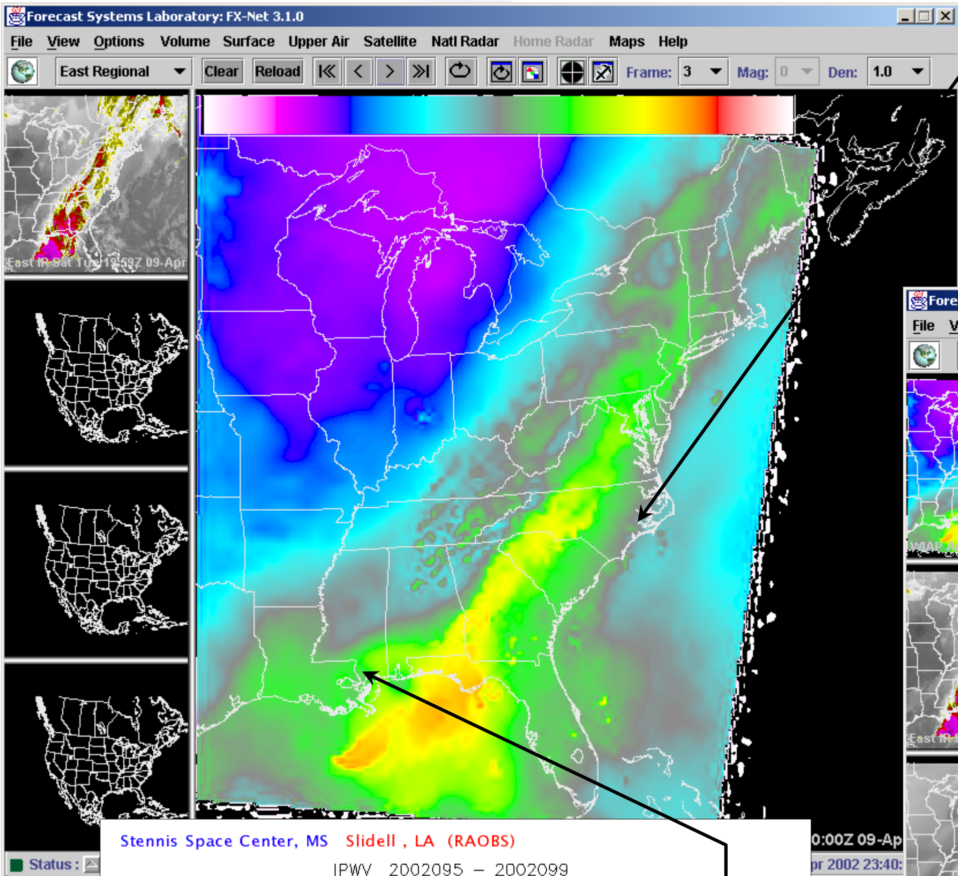


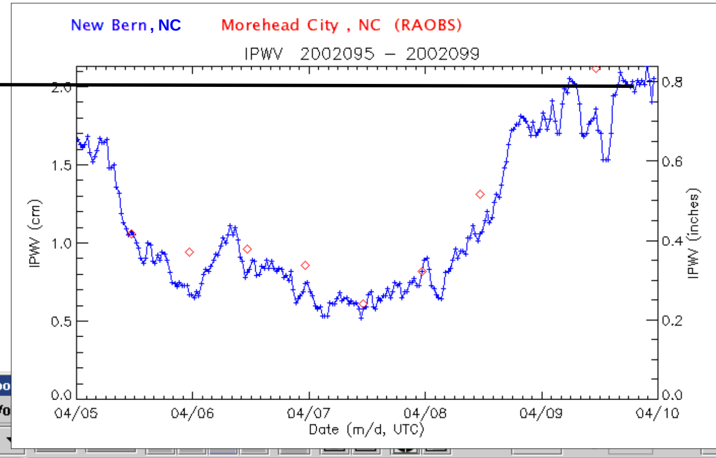
GOES-8 IR

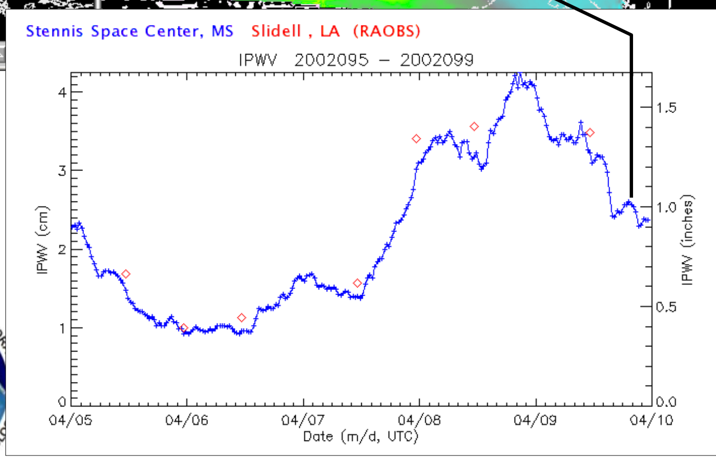


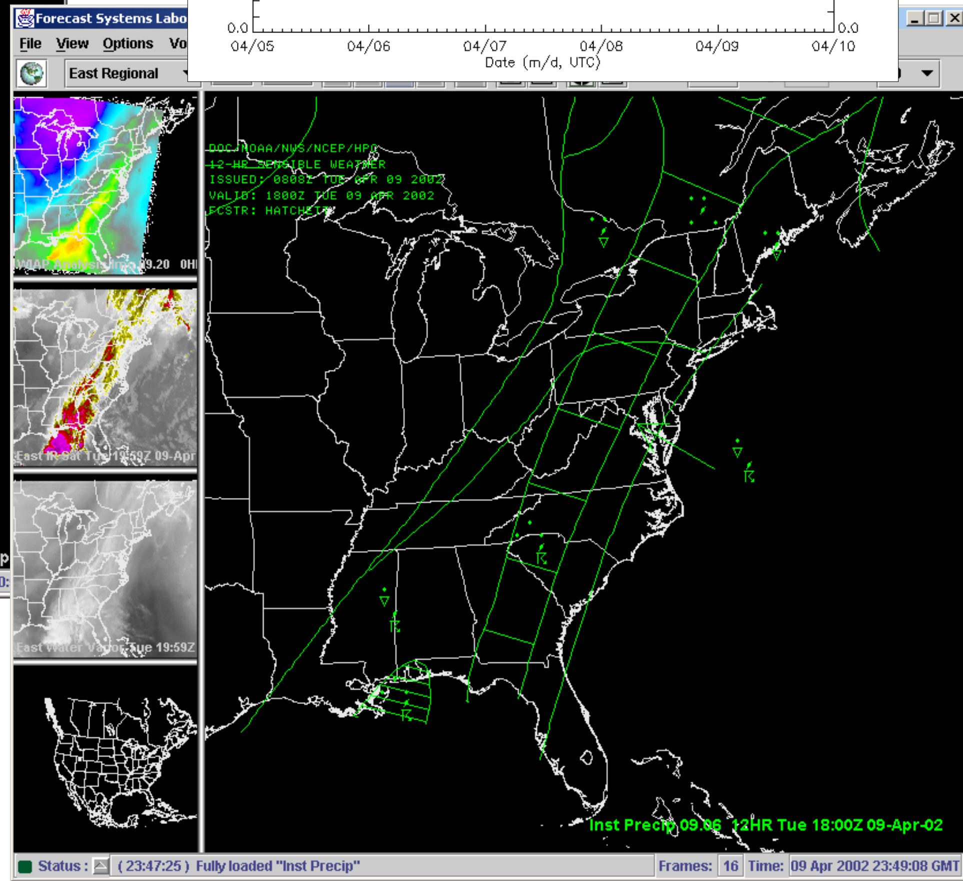
Analysis & Forecast

WIAP 13km PWV Analysis w/GPS-Met







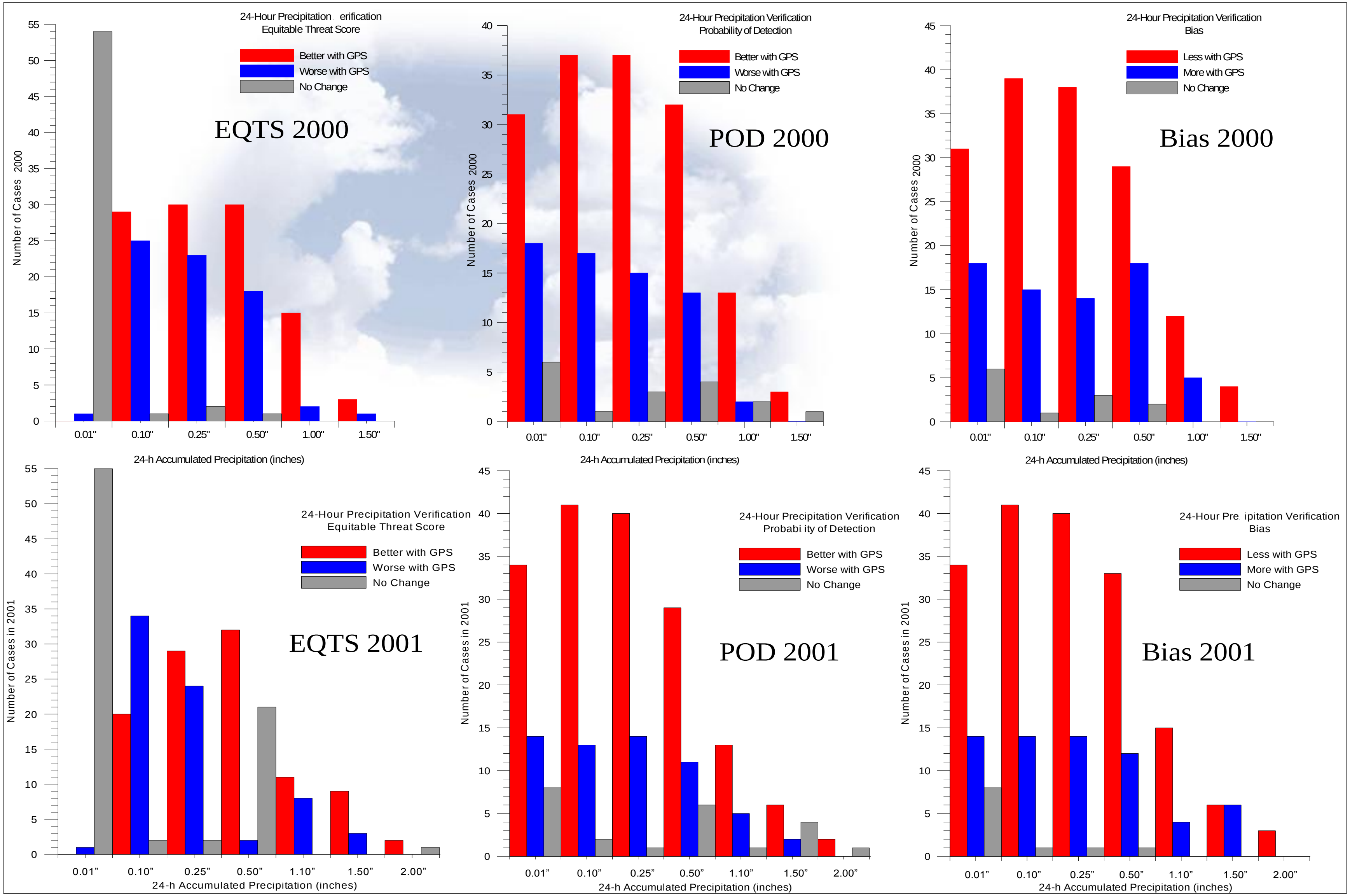


NCEP Instantaneous Precip Product

Implementation

- Assessments of the impact of ground-based GPS-Met on weather forecast accuracy have been carried out at FSL since 1997.
- They utilize a research version of the RUC-20 NWP model with a 1-hour data assimilation cycle over a region in the central U.S. approximately 700 km x 900 km.
- Each cycle uses all available observations including rawinsonde, surface, aircraft, wind profiler, and GOES satellite TPW.
- The only difference is that a second (parallel) run includes ground-based GPS-Met observations.
- Evaluation is based on Equitable Threat Score (EQT), Probability of Detection (POD), and Bias.

Wx Forecast Improvement



A Look Toward the Future

It's April 19, 2010.

- The GPS Block IIF satellites are being replaced by the new Block III spacecraft.
- The EC Galileo constellation has been fully operational for about one year.
- There are 15-20 Global Navigation Satellites in view at all times over North America.
- The NOAA GPS-Met Demonstration Network transitioned from research to operations within the National Weather Service back in 2008.
- The Operational GPS-Met Network consists of about 400 backbone sites and 600 in-fill sites throughout North America.

GPS-Met in 2010

- The GPS-Met Network continues to grow as new CORS sites are brought on line for real-time operations.
- The network delivers absolute tropospheric delays, delay gradients and IPWV every 15 minutes. Relative delays and IPWV are calculated every epoch in areas of very dense coverage under special conditions (e.g. severe weather).
- Data from the IGS Global Tracking Network are used routinely for environmental satellite calibration and validation, seamlessly tying together the observations from hundreds of platforms and sensors in space and time.

GPS-Met in 2010

- Differential correctors are provided by NGS for real-time high accuracy (~ 20 cm) GPS positioning and navigation.
- The correctors are calculated from data provided by NOAA high resolution space and tropospheric weather models that continuously assimilate data from all available environmental observing systems, including CORS and space-based GPS receivers.
- This leads to private/commercial hands-off or robotic land, sea, and air transportation systems.
- For National Defense, re-locatable windows can be quickly established anywhere on the planet that produce *very high accuracy* correctors for unmanned or tele-operated military operations.