# GOES-R AWG Product Validation Tool Development

## *Sounding Application Team*

Tim Schmit (STAR)
with contributions from many others, such as Jun Li, Zhenglong Li, Jinlong Li, Xin Jin, Seth Gutman, Eva Borbas, Wayne Feltz, Ralph Petersen, etc.

# OUTLINE

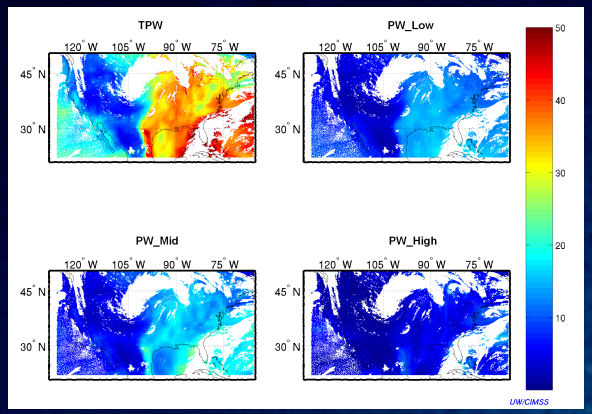
- **Products** (1-2 slides)
- **Validation Strategies** (3-4 slides)
- **Routine Validation Tools** (4-5 slides)
- **"Deep-Dive" Validation Tools** (4-5 slides)
- **Ideas for the Further Enhancement and Utility of Validation Tools** (1-2 slides)
- **Summary**

# Products

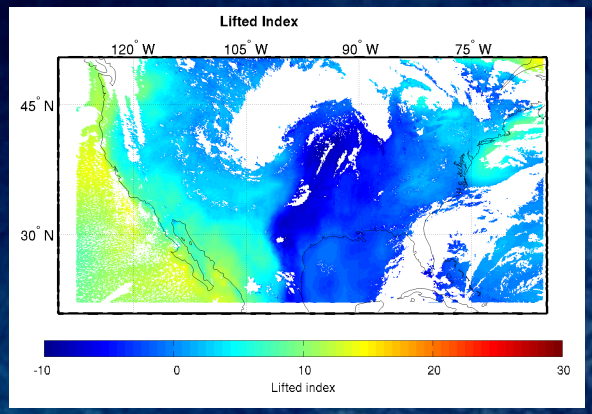
- Legacy atmospheric temperature profile (10 km, hourly, disk)
- Legacy atmospheric moisture profile (10 km, hourly, disk)
- Total precipitable water (10 km, hourly, disk)
  - Layered PW only an intermediate product
- Lifted index (10 km, hourly, disk)
- Convective available potential energy (10 km, hourly, disk)
- Total totals index (10 km, hourly, disk)
- Showalter index (10 km, hourly, disk)
- K-index (10 km, hourly, disk)

# Example LAP Output using Simulated ABI data

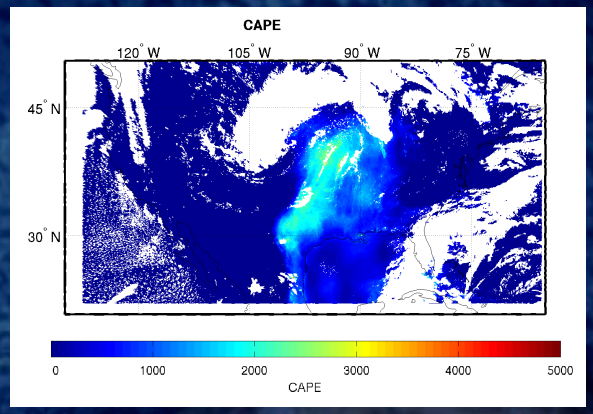
## TPW and layered PW



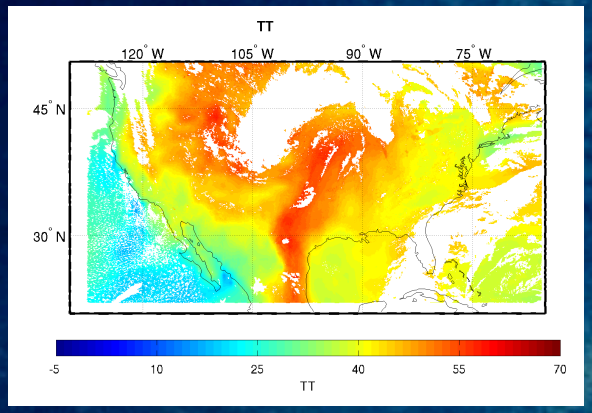

## Lifted Index



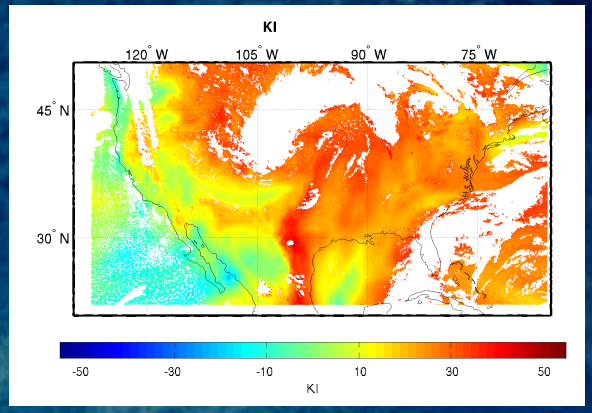

## Convective Available Potential Energy



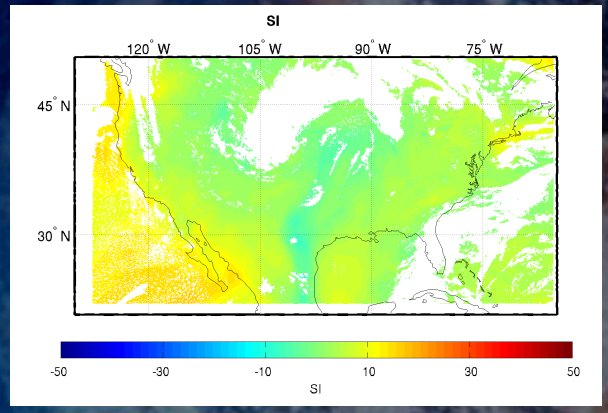

## Total Totals




## K Index




## Showalter Index

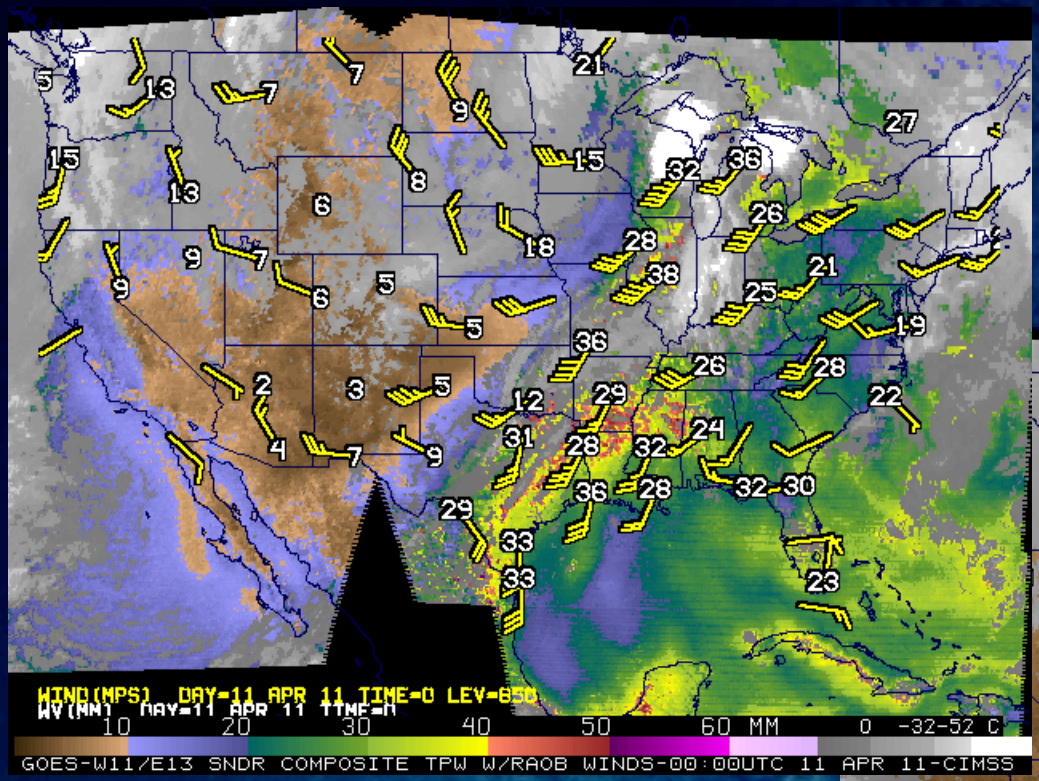


# Validation Strategies

- **SEVIRI** onboard MSG is good proxy for ABI LAP sounding validation
- **MODIS** is proxy for ABI LAP validation over GOES-R domain (pre-launch)
- **GOES Sounder** is proxy for ABI LAP validation over CONUS and adjacent region (pre-launch)
- ECMWF 6-hr **analysis** profile products are good for full disk evaluation
- **AMSR-E** TPW product (**AIRS, IASI, CrIS**) as well
- Operational conventional **radiosonde** dataset collected twice a day at WMO weather stations is the best for validation over land
- **ARM** sites MWR TPW and radiosondes (4 times/day) have good quality for validating GOES-R LAP profiles and derived products
- **GPS-Met** and **WVSS2** allows for monitoring other than 00 and 12 UTC

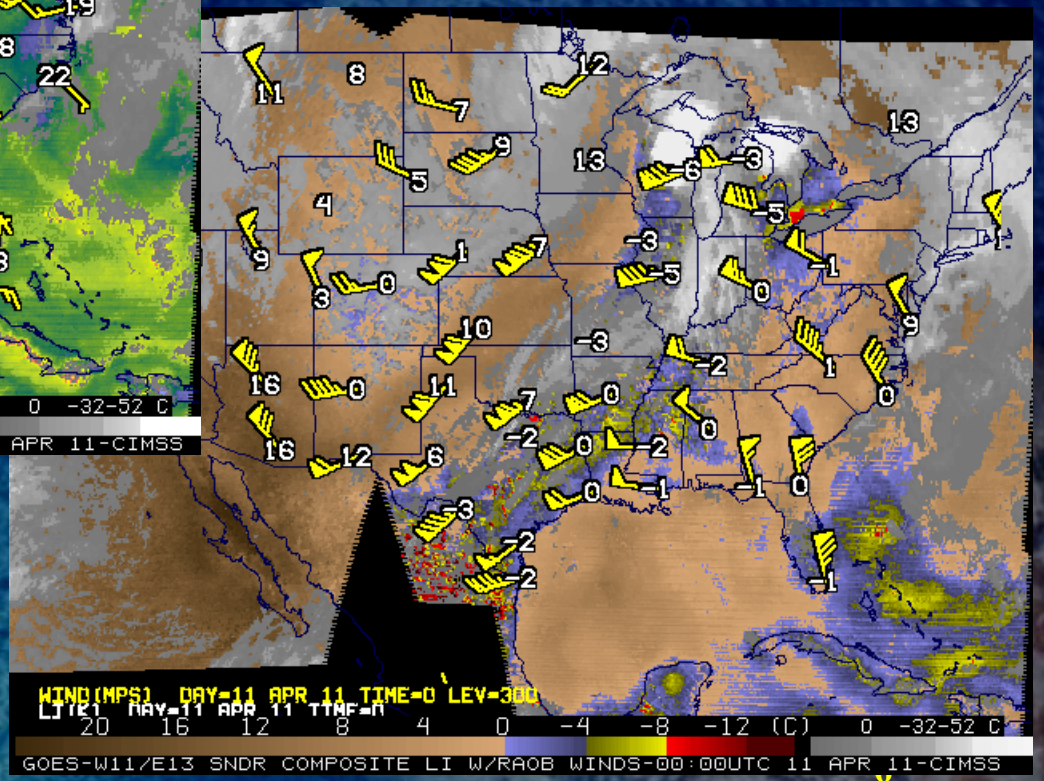
The long-term dataset (radiosondes, ARM TPW and aircraft) makes it possible to validate the algorithm's seasonal, diurnal, and latitudinal performance, or the performance over different surfaces

# Current GOES example




TPW

LI



# Current GOES example

http://www.star.nesdis.noaa.gov/smcd/opdb/goes/soundings/html/stats23L.html

National Oceanic and Atmospheric Administration's Satellite and Information Service

Search the NOAA Satellites and Information Web

Horizontal Sounding Fields | Vertical Sounding Profile Loops | Cross-Sections | DPI Fields | GOES Products

**Statistics**

*GOES Soundings Statistics are updated weekly on Monday morning.*

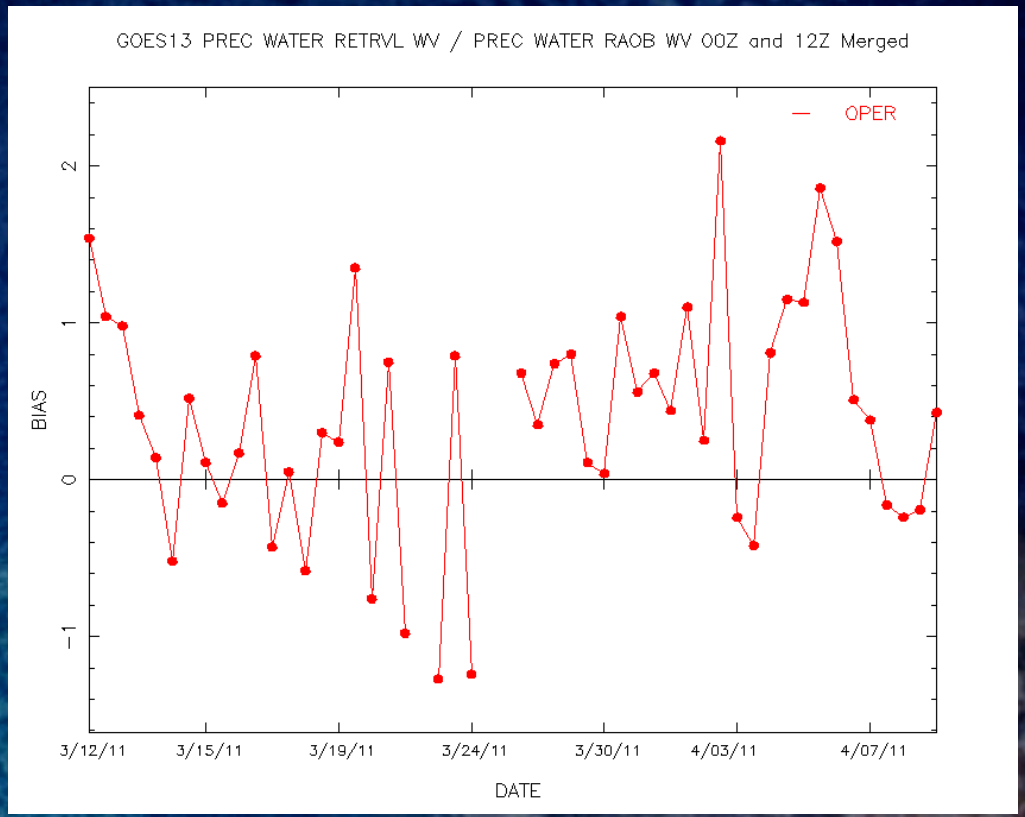
**GOES-East**

Daily Statistics for the last 30 Days

| Ops Sndngs | Ops Guess | FPDT Sndngs | FPDT Guess | UWisc Sndngs* | Uwisc Guess* |
|---|---|---|---|---|---|
| RMSE norm | RMSE norm | RMSE norm | RMSE norm | RMSE norm | RMSE norm |
| Bias | Bias | Bias | Bias | Bias | Bias |
| Correlation | Correlation | Correlation | Correlation | Correlation | Correlation |
| RMSE and Act. TPW | RMSE and Act. TPW | RMSE and Act. TPW | RMSE and Act. TPW | RMSE and Act. TPW | RMSE and Act. TPW |

Daily Statistics for the last 6 Months

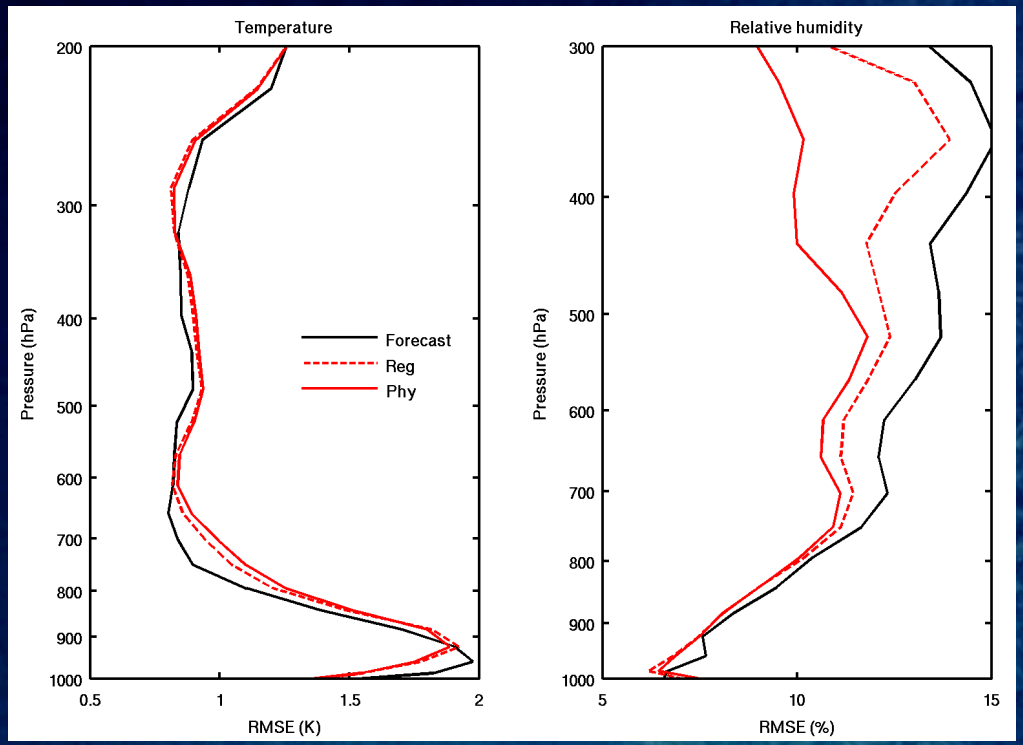
| Ops Sndngs | Ops Guess | FPDT Sndngs | FPDT Guess | UWisc Sndngs* | Uwisc Guess* |
|---|---|---|---|---|---|
| RMSE norm | RMSE norm | RMSE norm | RMSE norm | RMSE norm | RMSE norm |
| Bias | Bias | Bias | Bias | Bias | Bias |
| Correlation | Correlation | Correlation | Correlation | Correlation | Correlation |
| RMSE and Act. TPW | RMSE and Act. TPW | RMSE and Act. TPW | RMSE and Act. TPW | RMSE and Act. TPW | RMSE and Act. TPW |

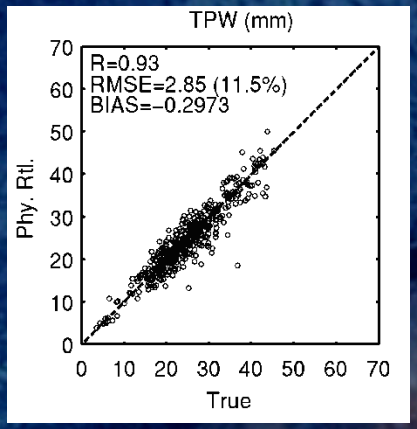



***TPW***

# Temperature/Moisture Profile Validation over Land

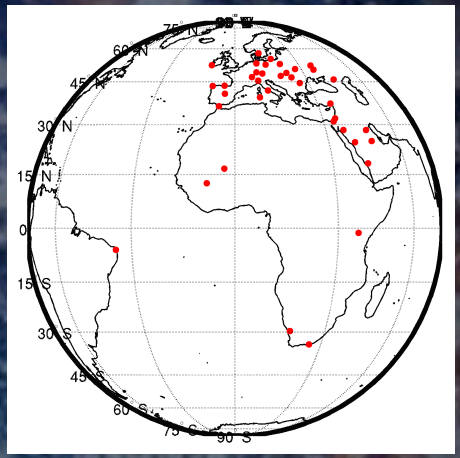
*The following images illustrate the temperature/moisture/TPW retrieval by SEVIRI against 475 radiosonde measurements over land for August 2006*




← *TPW*

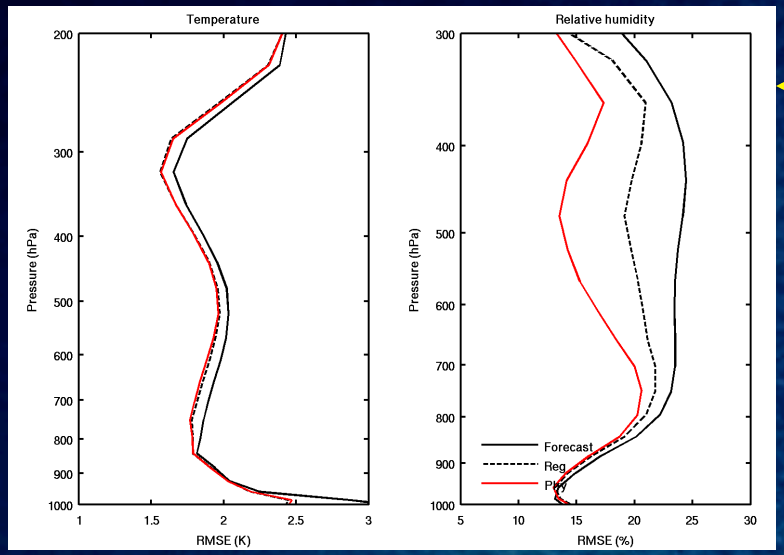
*Sample sites*



*Accuracy = -0.3 mm and Precision = 2.85 for TPW*

# Temperature/Moisture Profile Validation over Land (con'd)

***The following images illustrate the temperature/moisture/TPW retrieval by SEVIRI against 203491 ECMWF analysis profiles over land for January 2008***

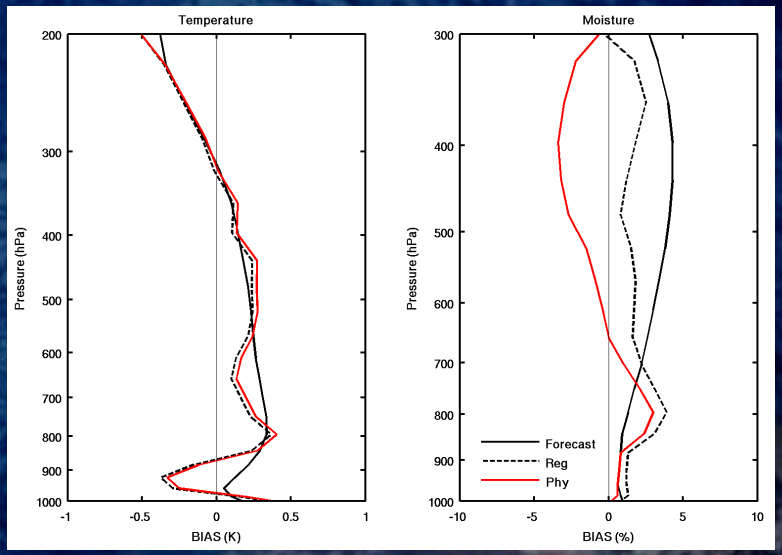


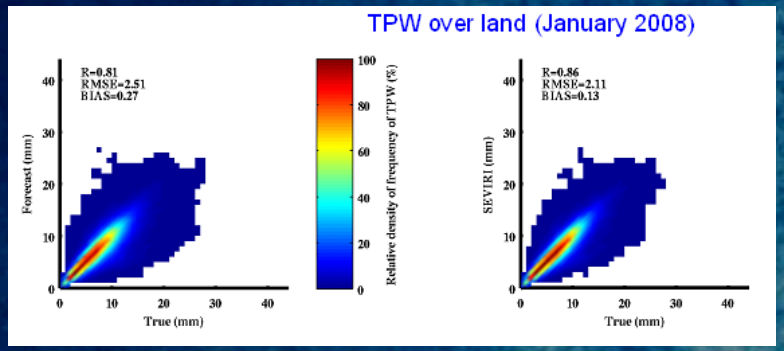

***RMSE***

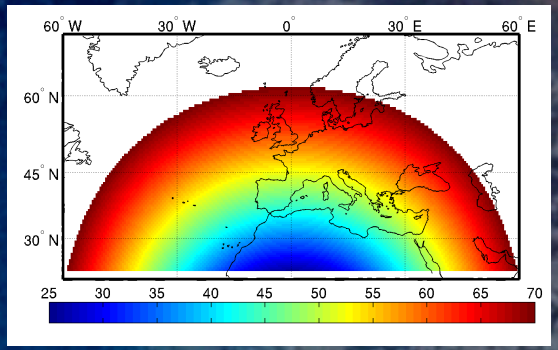
***(Precision)***

***BIAS***

***(Accuracy)***



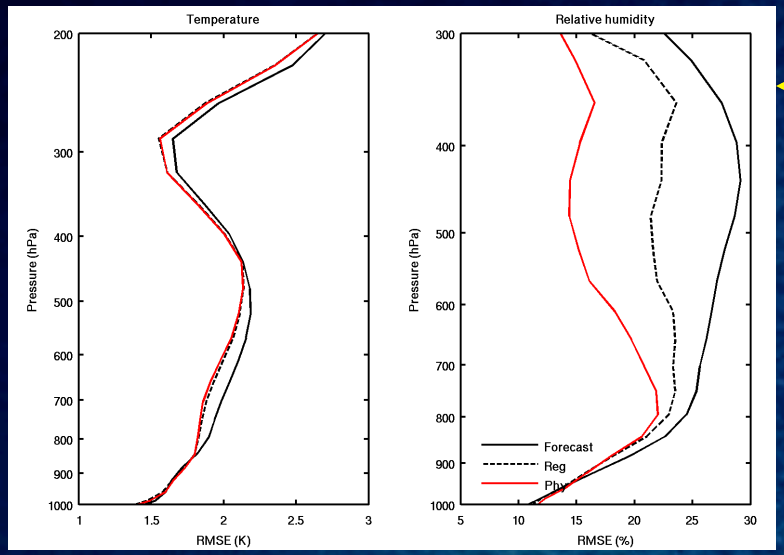




***Sample area***

# Temperature/Moisture Profile Validation over Ocean

***The following images illustrate the temperature/moisture/TPW retrieval by SEVIRI against 149721 ECMWF analysis profiles over ocean for January 2008***

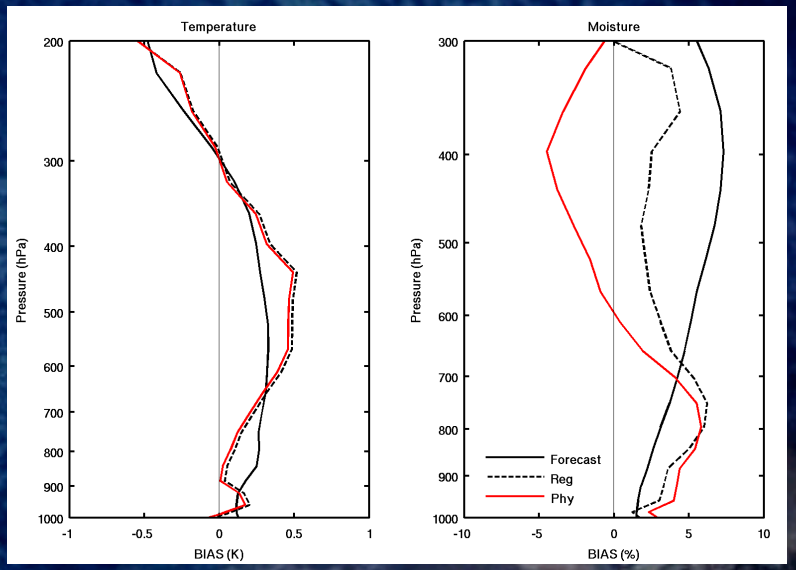


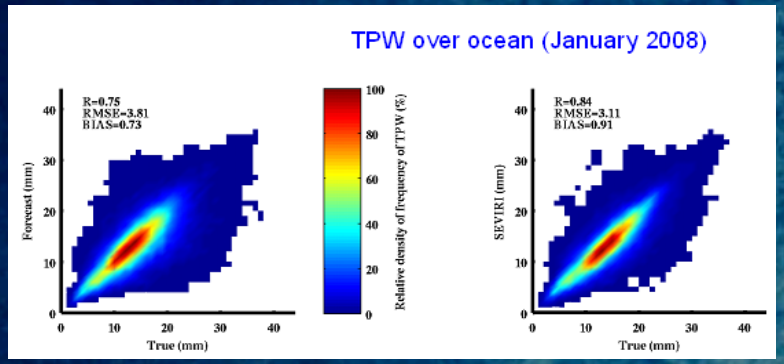

***RMSE***

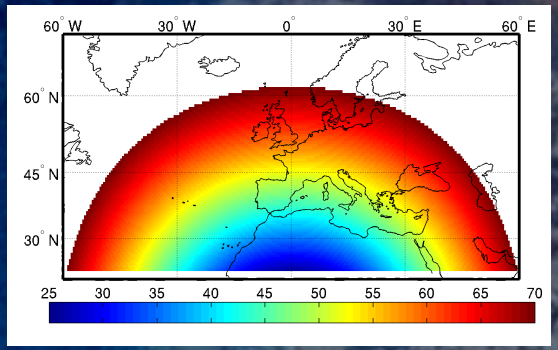
***(Precision)***

***BIAS***

***(Accuracy)***



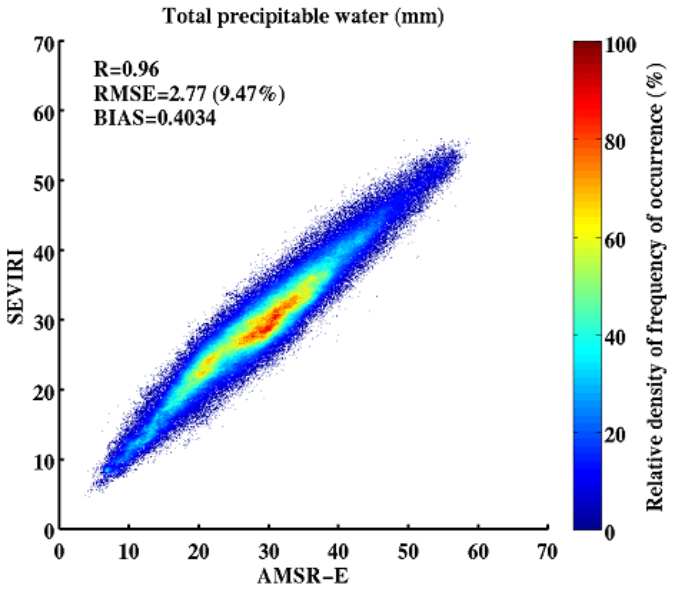
***Sample area***

# TPW Validation over Ocean

- *AMSR-E level-2 provides TPW over ocean.*
- ***Accuracy = 0.4 mm***
- ***Precision = 2.77 mm***

Products: TPW

Temporal dist < 15 minutes
Spatial dist < 10 km

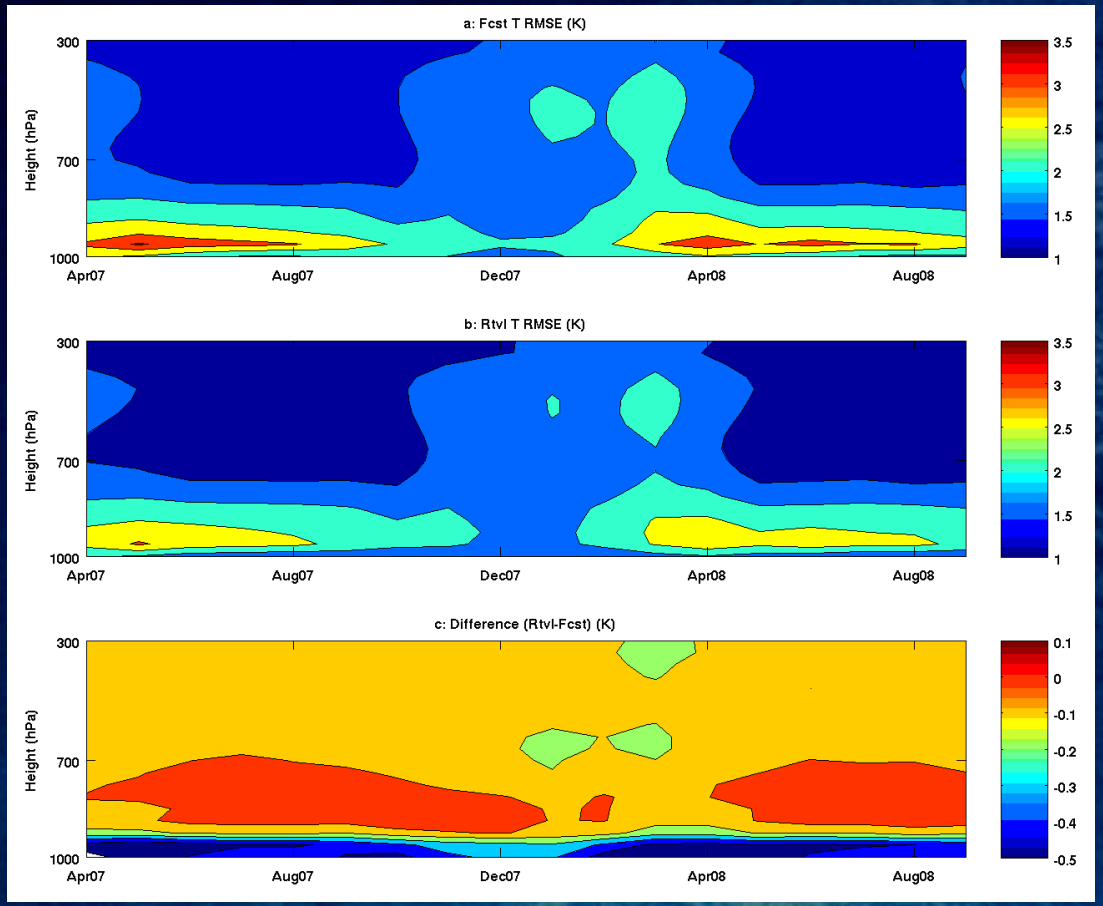



Validation of TPW from physical retrievals compared with TPW from AMSR-E over ocean in August 2006 (2,822,939 samples).

UWCIMSS 48

# Temperature Profile Validation over long term

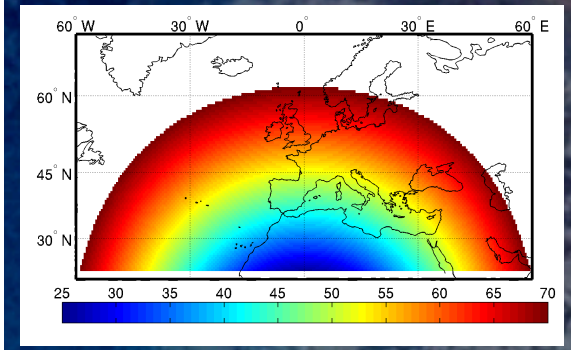
*The following images illustrate the temperature profile retrieval by SEVIRI against ECMWF forecast and analysis profiles over all surfaces between April 2007 and September 2008*




*Improvement is trivial (0 to 0.1 K) at upper levels;*

*Precision improves about 0.5 K at near surface layer;*

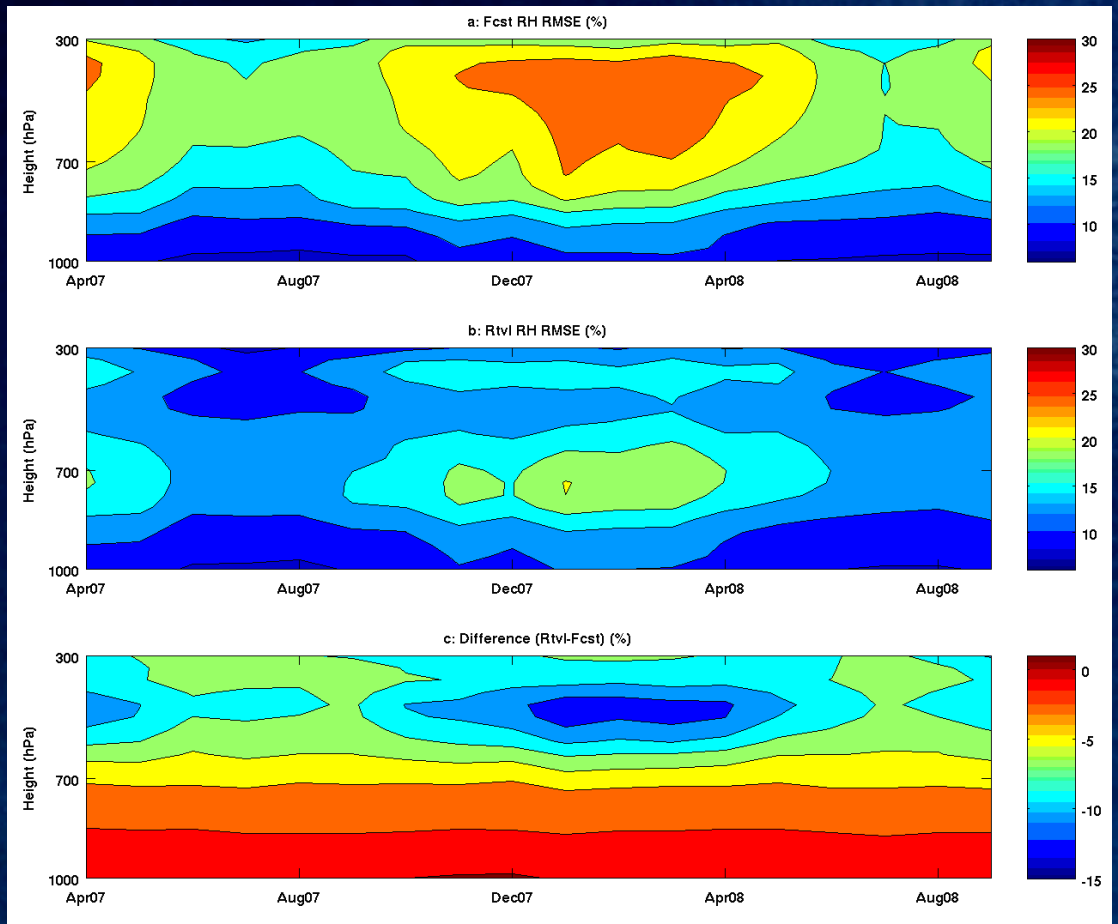
*Algorithm performances better in summer than in winter*




*Sample area*

# Moisture Profile Validation over long term

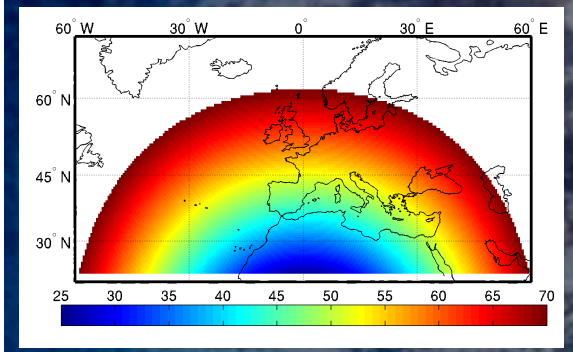
*The following images illustrate the moisture profile retrieval by SEVIRI against ECMWF forecast and analysis profiles over all surfaces between April 2007 and September 2008*




*Improvement is trivial (0 to 3%) at low levels (below 700 hpa);*

*Precision improves more than 5% at high levels (above 700 hPa);*

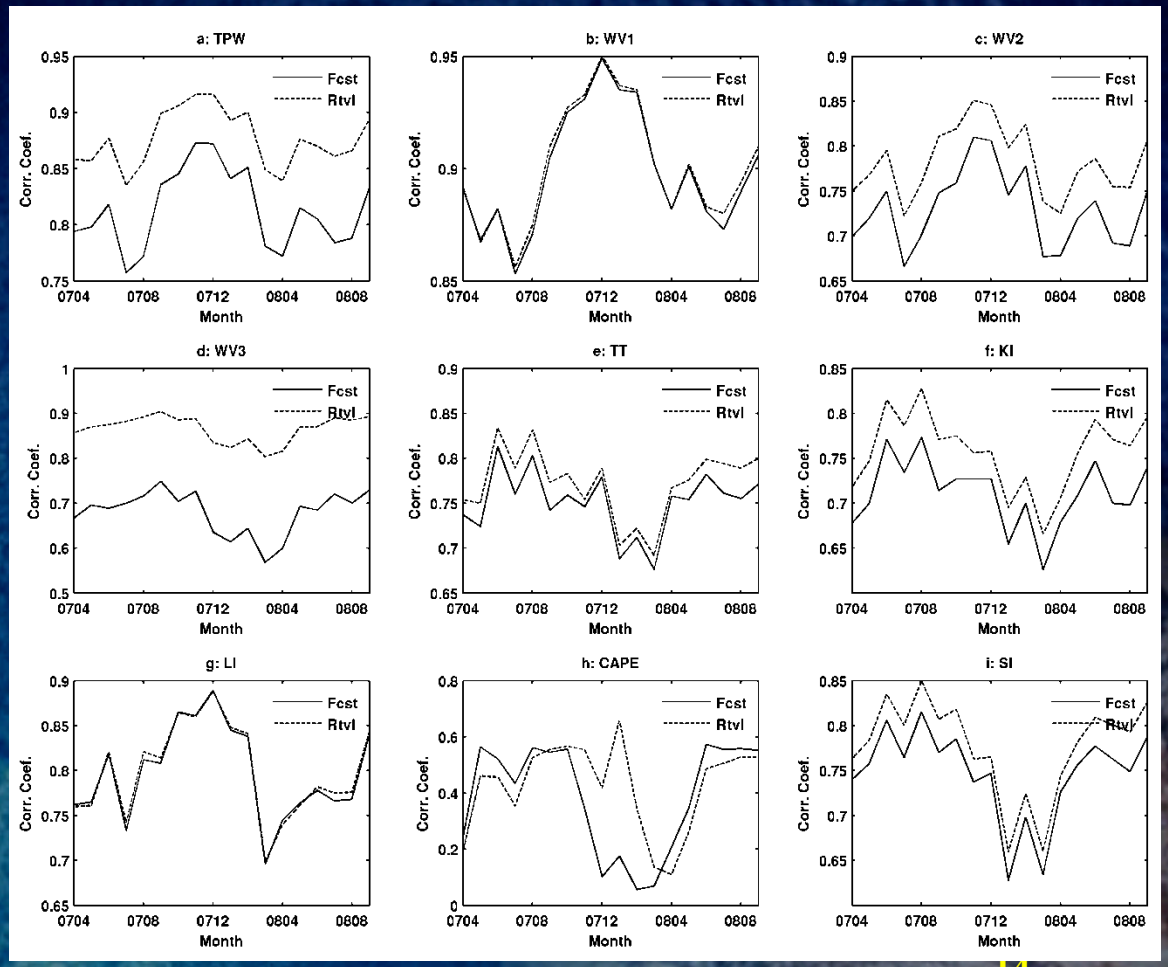
*Algorithm performances better in winter than in summer*



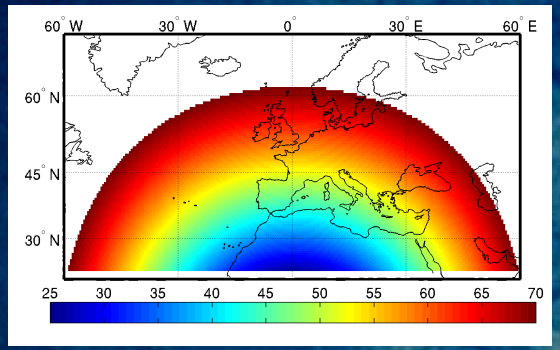

*Sample area*

# Derived Products Validation over long term

- *ECMWF forecast and analysis profiles are used for validation*
- *The correlation coefficients increase after retrieval when compared with the forecast*




*Sample area*



# Routine Validation Tools

Capabilities:

- Monitoring the quality of atmospheric temperature and moisture profiles in near real time
- Monitoring the quality of TPW, LI, TT, CAPE, KI, and SI in near real time

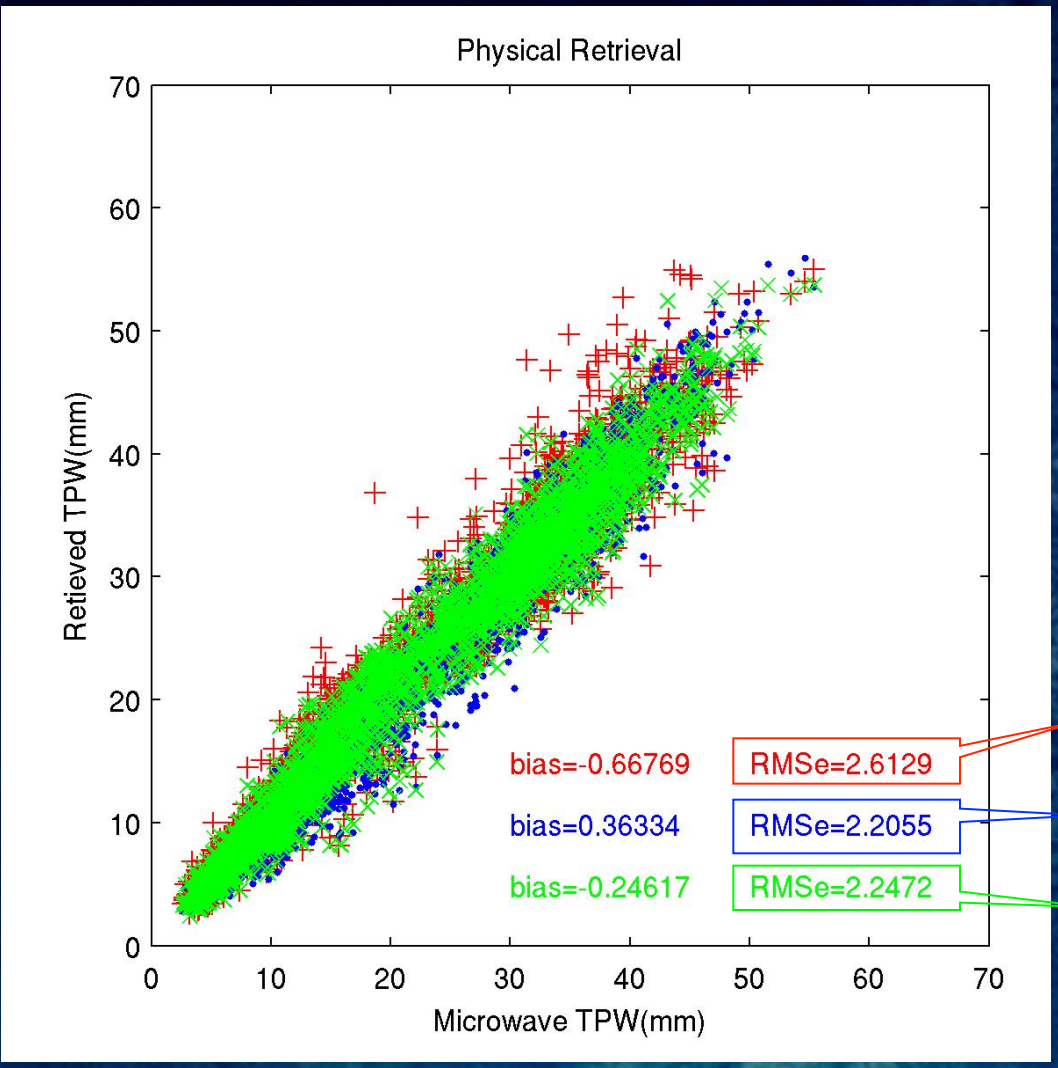
Datasets used:

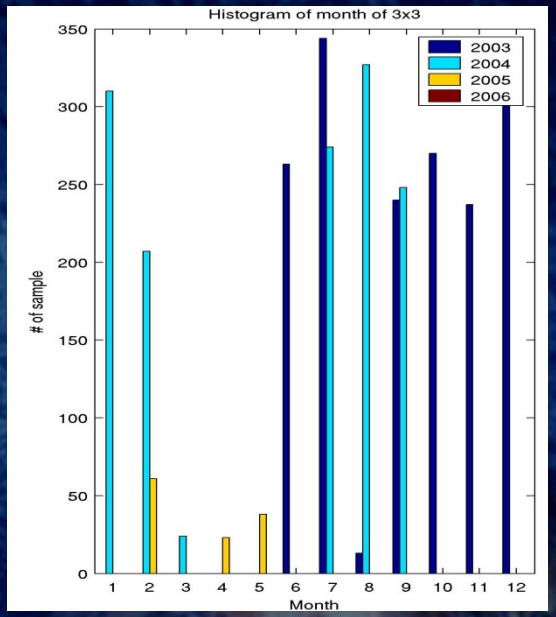
Radiosondes (conventional, ARM site); ARM site microwave radiometer TPW; NWP forecast used in the LAP retrieval; ABI IR brightness temperatures

Visualization and software tools (scripts + McIDAS + Matlab)

- Time series of BT difference (obs – cals (FCST)) images for ABI IR channels
- Time series of difference (RTVL - FCST) images (TWP, LI, CAPE, TT, KI, SI)
- Time series of LI, CAPE, TT, KI, SI from GOES-R RTVLs, FCSTs and radiosondes at ARM site
- Time series of GOES-R TPW, FCST TPW, and MWR TPW at ARM site
- Statistics of retrievals against conventional radiosondes over land
- Statistics of retrievals against ECMWF analysis over ocean
- Animations
- Generate zoomed difference images
- Monitor product quality
- Compare to other products (e.g., CrIS)

# GOES-12 Sounder TPW versus MWR at ARM site



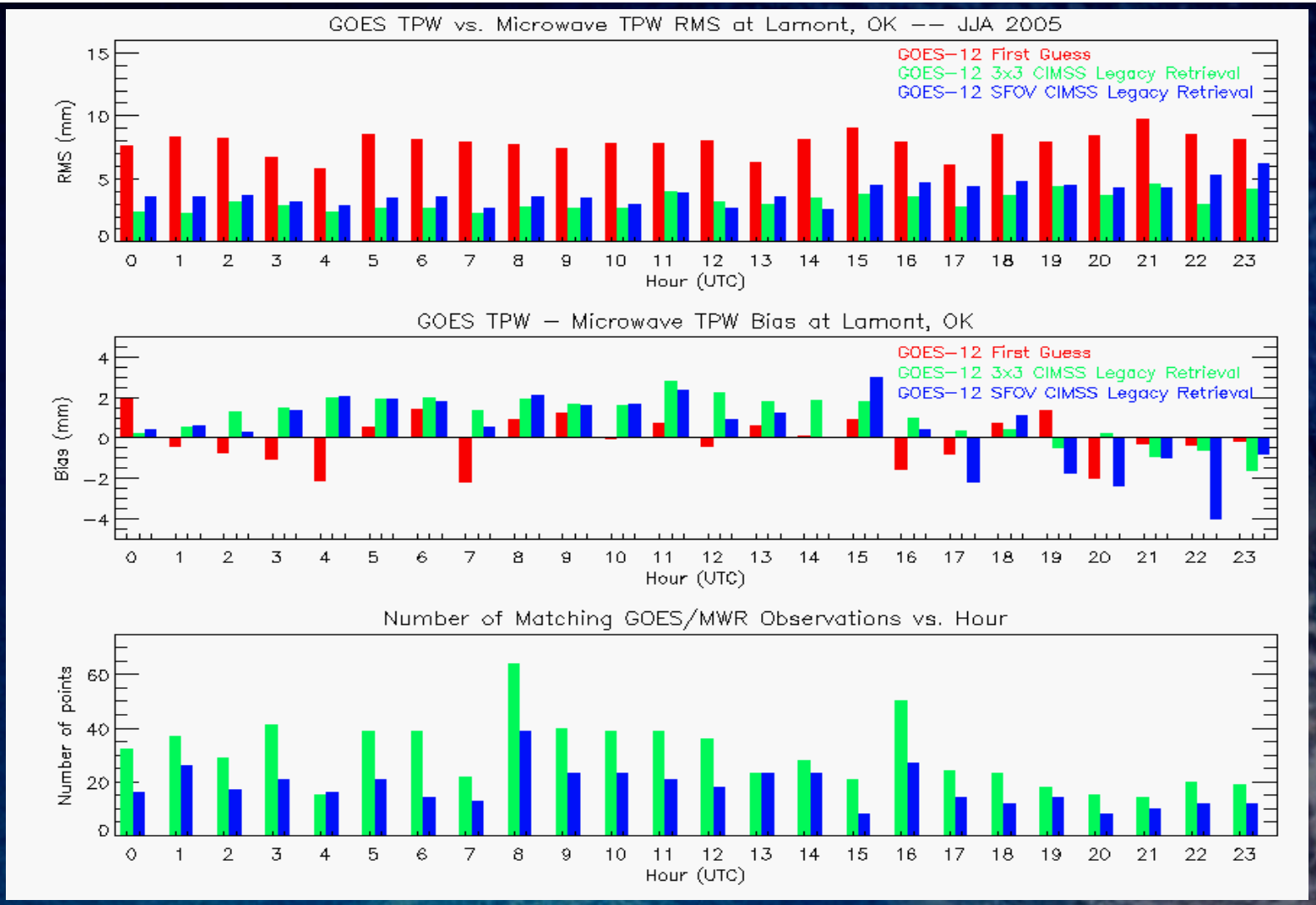

***Legacy***

***Phy1:Regression***

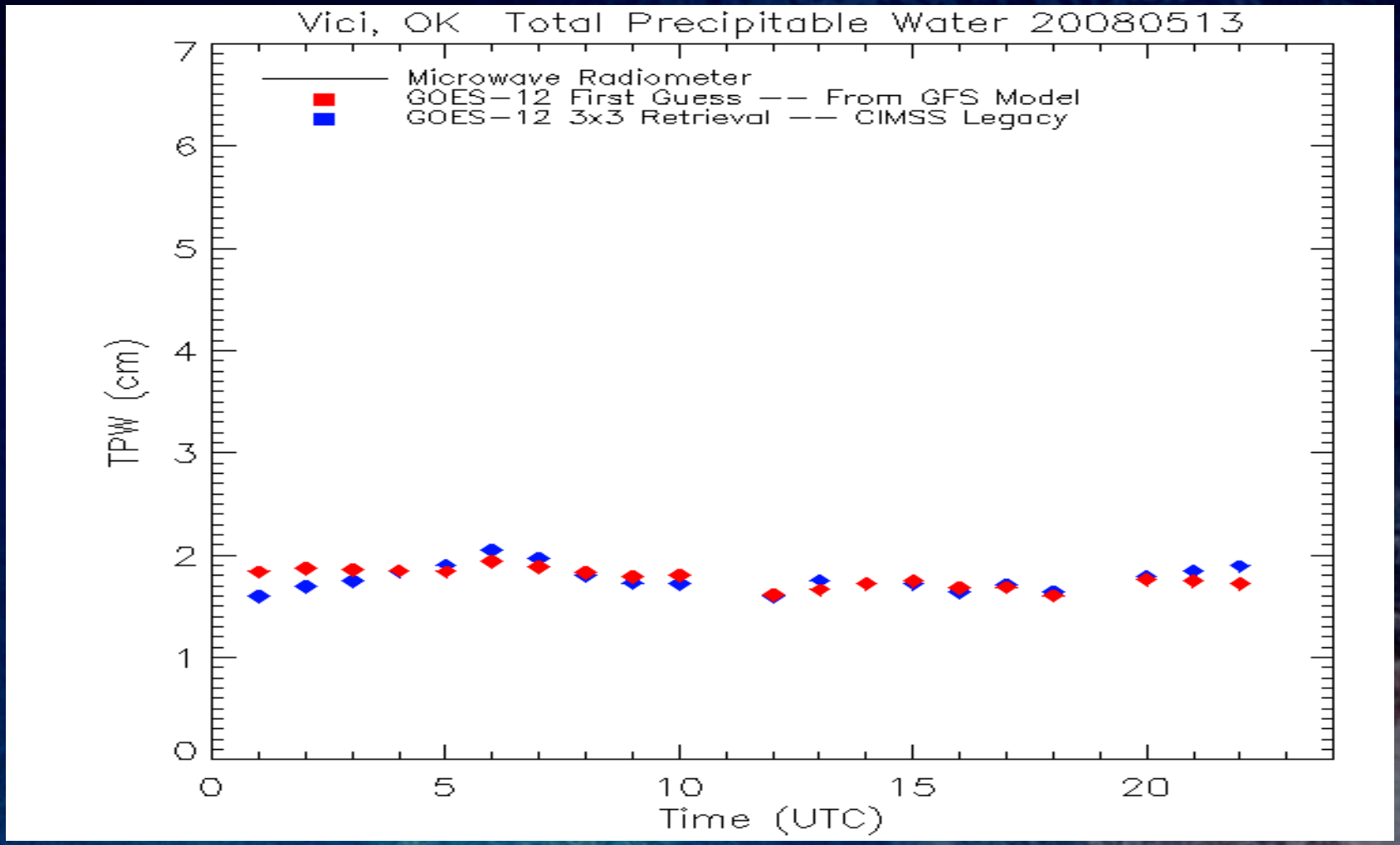
***Phy2:Forecast***

***Compared with microwave measured TPW at SGP ARM site from June 2003 to May 2005***

# GOES-12 Sounder TPW at ARM CART site - statistics



# Time series GOES-12 Sounder TPW (forecast versus retrievals)



# Time series of GOES-12 TPW (MWR VS forecast/retrieval)

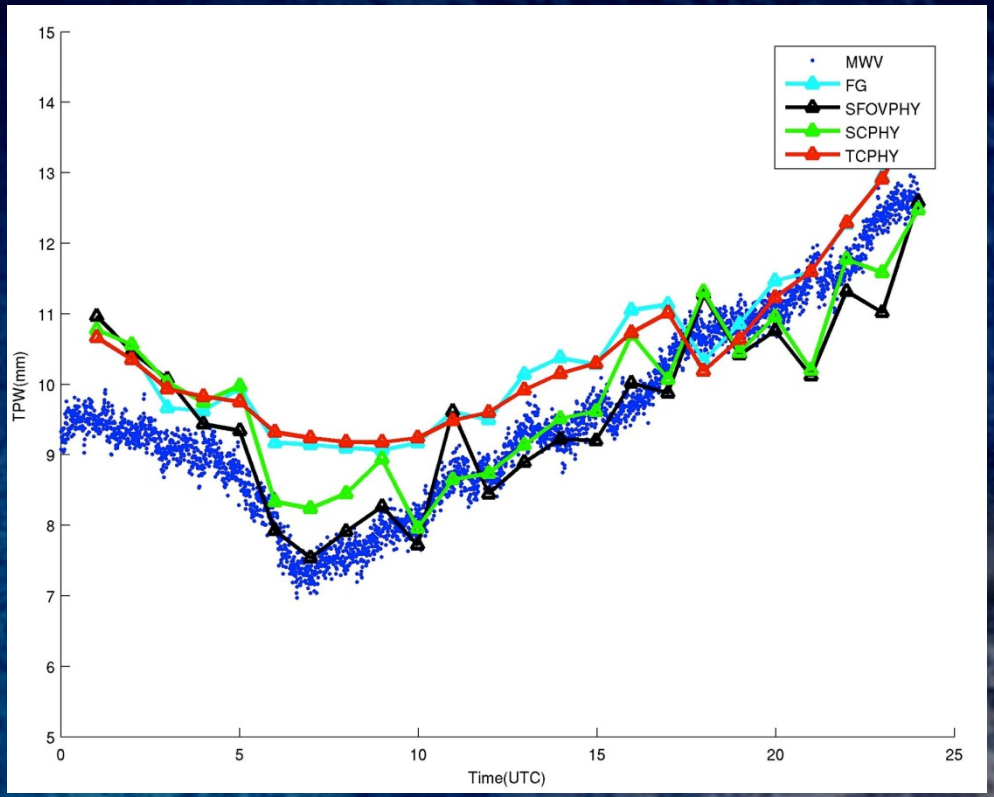
***MWR***

***FCST***

***GOES Sounder SFOV***

***GOES Sounder Spatial continuity***

***GOES Sounder time continuity***




***Physically retrieved TPWs from single FOV, spatial continuity and time continuity. The blue dots are microwave measured TPWs at Cart Site (36.61º, -97.49º). The cyan line is the first guess for physical retrievals. The green line is the physical retrieval with spatial continuity. And the red line is the physical retrieval with time continuity. Case study of 00 UTC on Dec 25 2005.***

# Sample ARM Site Timeseries



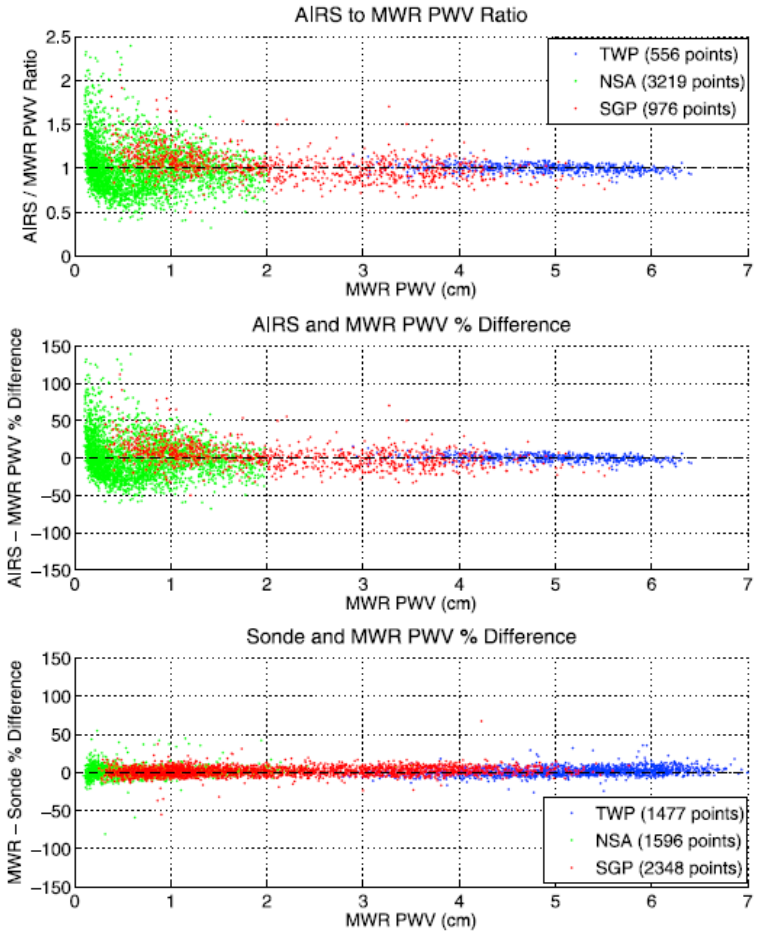
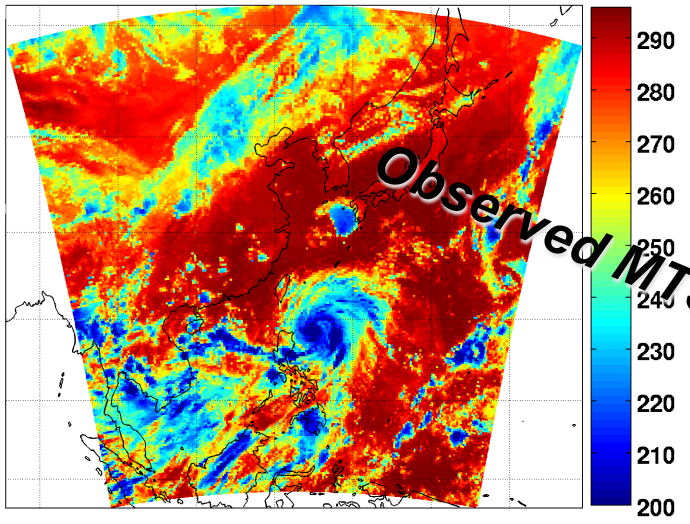



**Figure 12.** All plots show all PWV data from both day and night, colored according to site (red, SGP; blue, TWP; green, NSA). (top) Ratio of spatially and temporally colocated AIRS to MWR observations of PWV. (middle) Percentage difference between spatially and temporally colocated AIRS and MWR observations of PWV. (bottom) Percentage difference between spatially and temporally colocated MWR and rawinsode observations of PWV.

# "Deep-Dive" Validation Tools

- Capabilities:
  - Monitor any anomalies of any GOES-R LAP product and identify the cause
  - Quantify the error/uncertainty of GOES-R LAP products for better applications
- Tools include, but is not limited to:
  - Full and/or zoomed difference (TPW, LI, CAPE, KI, TT, SI) between RTVLs and FCSTs images
  - Generate residual images (obs – cals from FCSTs) for each IR channel
  - Generate quality flag images
  - Times series of GOES-R TPW, FCST TPW and microwave radiometer TPW over ARM CART site
    - Longer times series
  - Daily statistics of temperature and moisture profiles against radiosondes (FCSTs, RTVLs) over CONUS
    - Longer times series
  - Individual IR brightness temperature images with calibration events
  - Cloud mask image
  - Aerosol/dust product images
- McIDAS + Matlab + scripts

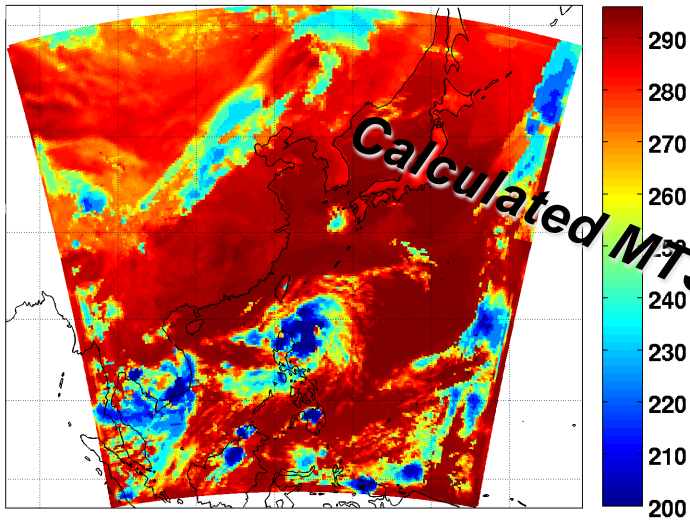
Observed MTSAT-1R ch 2 Tb( K, 10.8 μm)




Observed MTSAT IR Images

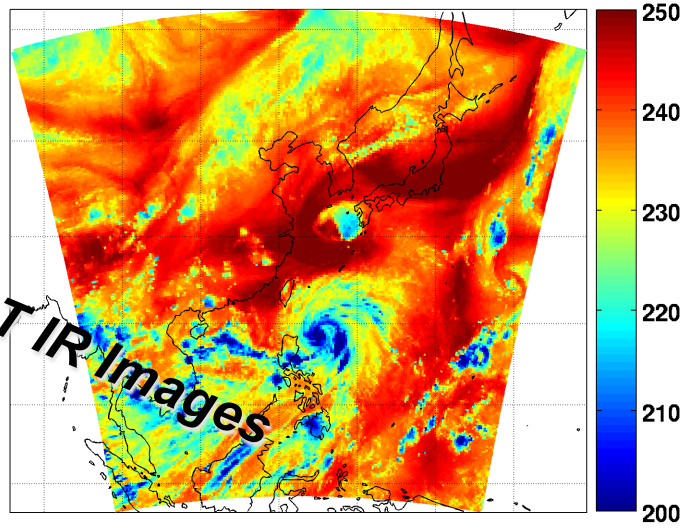
*10.8 μm*

Simulated MTSAT-1R ch 2 Tb( K, 10.8 μm)



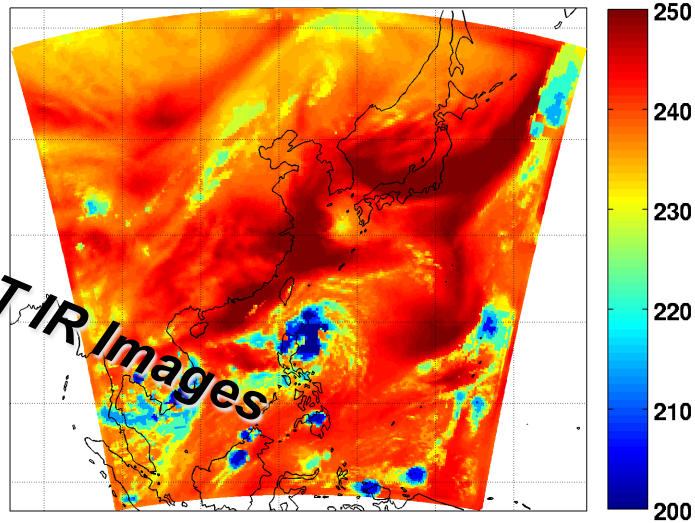

Calculated MTSAT IR Images

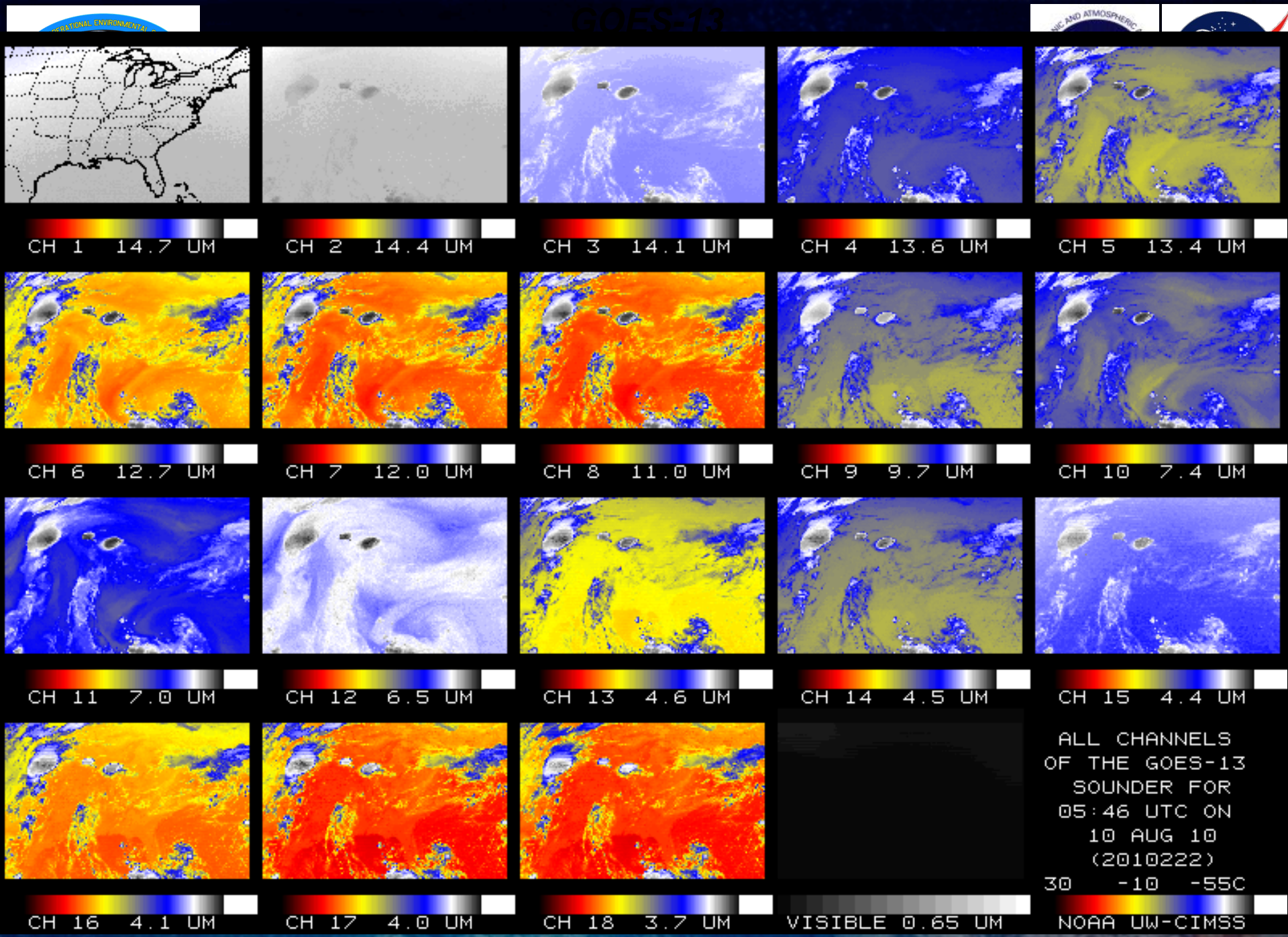
Observed MTSAT-1R ch 4 Tb( K, 6.75 μm)

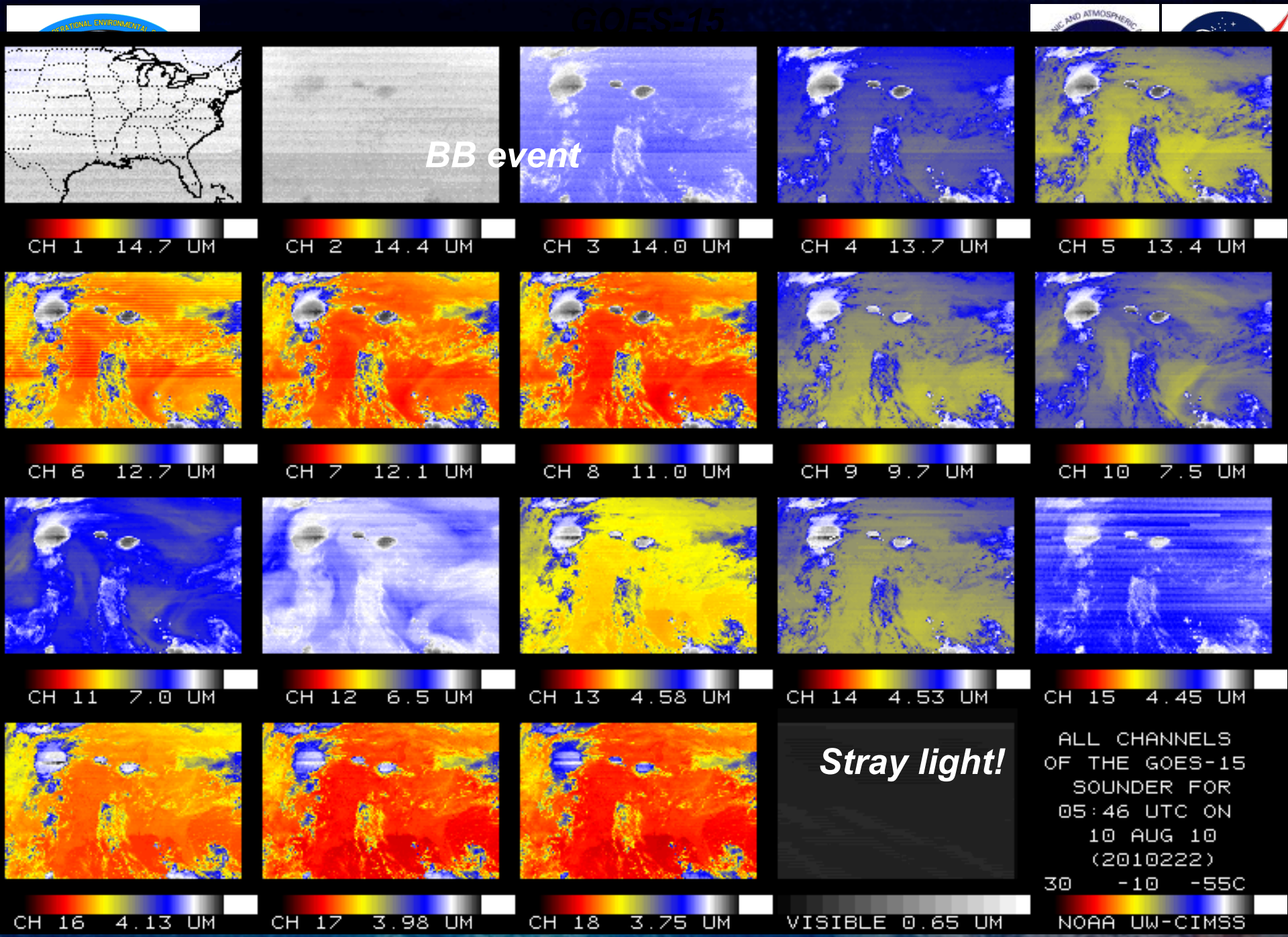



*6.75 μm*

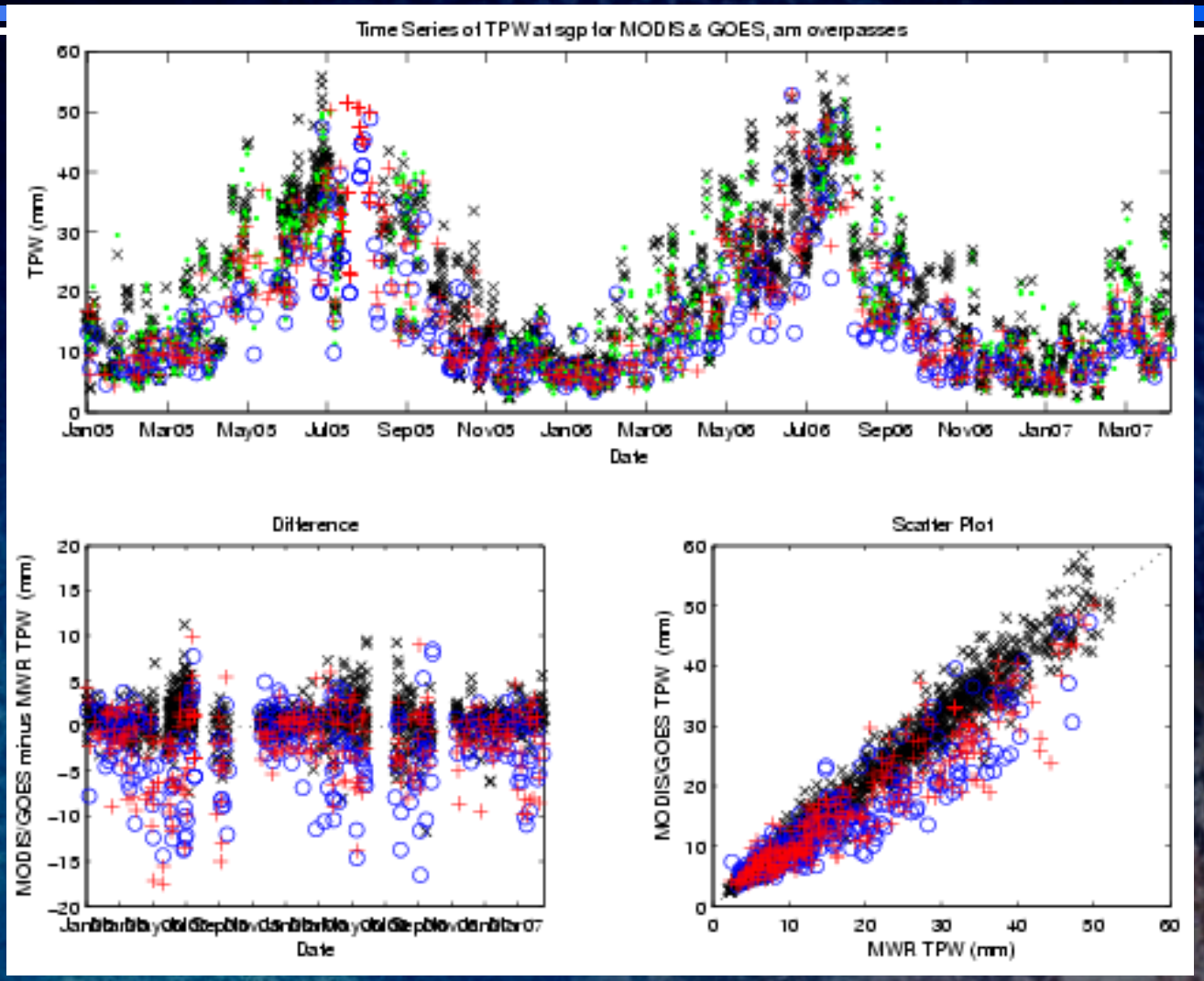
Simulated MTSAT-1R ch 4 Tb( K, 6.75 μm)




GOES-13
CH 1 14.7 UM
CH 2 14.4 UM
CH 3 14.1 UM
CH 4 13.6 UM
CH 5 13.4 UM
CH 6 12.7 UM
CH 7 12.0 UM
CH 8 11.0 UM
CH 9 9.7 UM
CH 10 7.4 UM
CH 11 7.0 UM
CH 12 6.5 UM
CH 13 4.6 UM
CH 14 4.5 UM
CH 15 4.4 UM
CH 16 4.1 UM
CH 17 4.0 UM
CH 18 3.7 UM
VISIBLE 0.65 UM
ALL CHANNELS
OF THE GOES-13
SOUNDER FOR
05:46 UTC ON
10 AUG 10
(2010222)
30 -10 -55C
NOAA UW-CIMSS

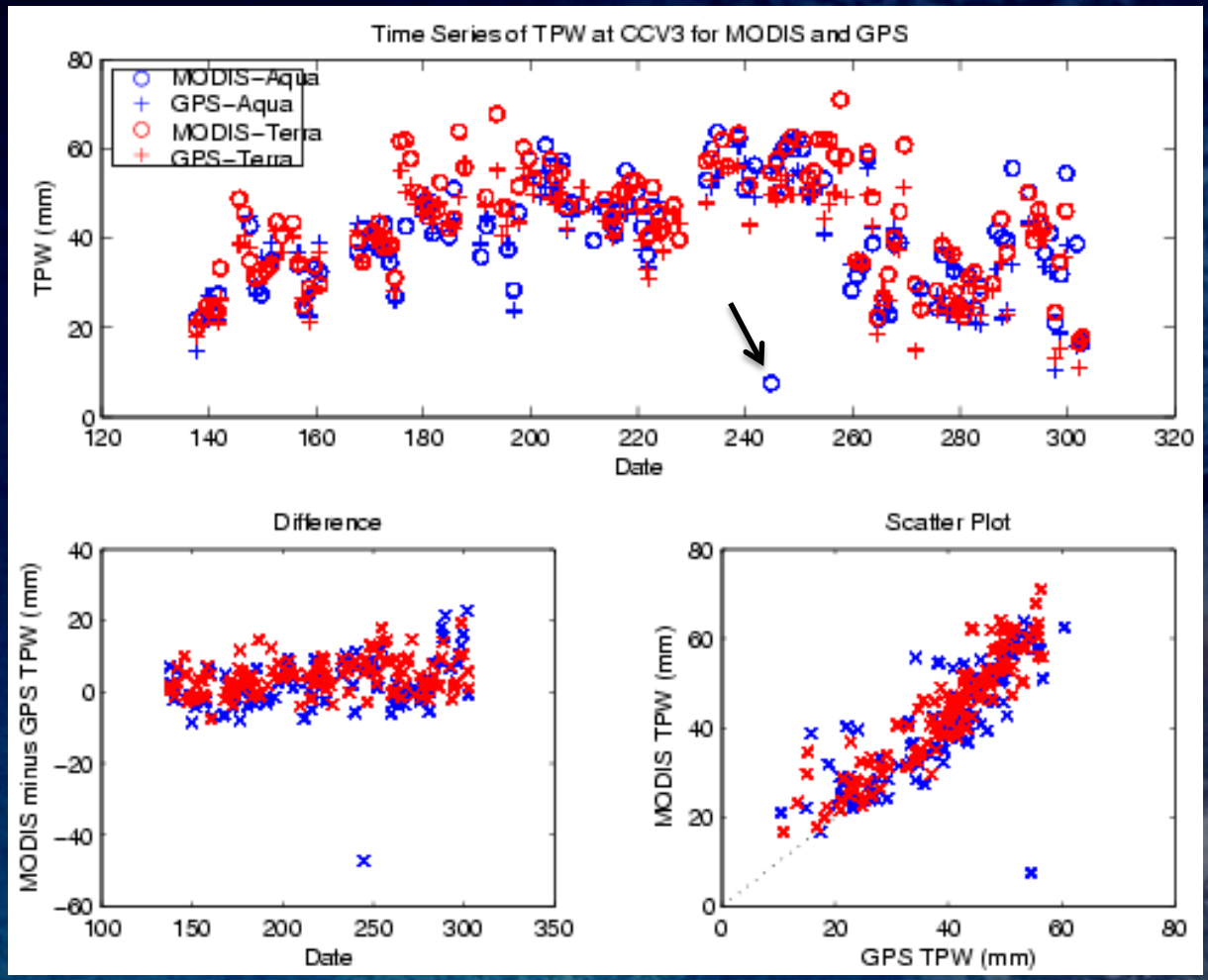

BB event
CH 1 14.7 UM
CH 2 14.4 UM
CH 3 14.0 UM
CH 4 13.7 UM
CH 5 13.4 UM
CH 6 12.7 UM
CH 7 12.1 UM
CH 8 11.0 UM
CH 9 9.7 UM
CH 10 7.5 UM
CH 11 7.0 UM
CH 12 6.5 UM
CH 13 4.58 UM
CH 14 4.53 UM
CH 15 4.45 UM
Stray light!
ALL CHANNELS
OF THE GOES-15
SOUNDER FOR
05:46 UTC ON
10 AUG 10
(2010222)
30 -10 -55C
CH 16 4.13 UM
CH 17 3.98 UM
CH 18 3.75 UM
VISIBLE 0.65 UM
NOAA UW-CIMSS

# Time series of TPW (MODIS, GOES Sounder, MWR)



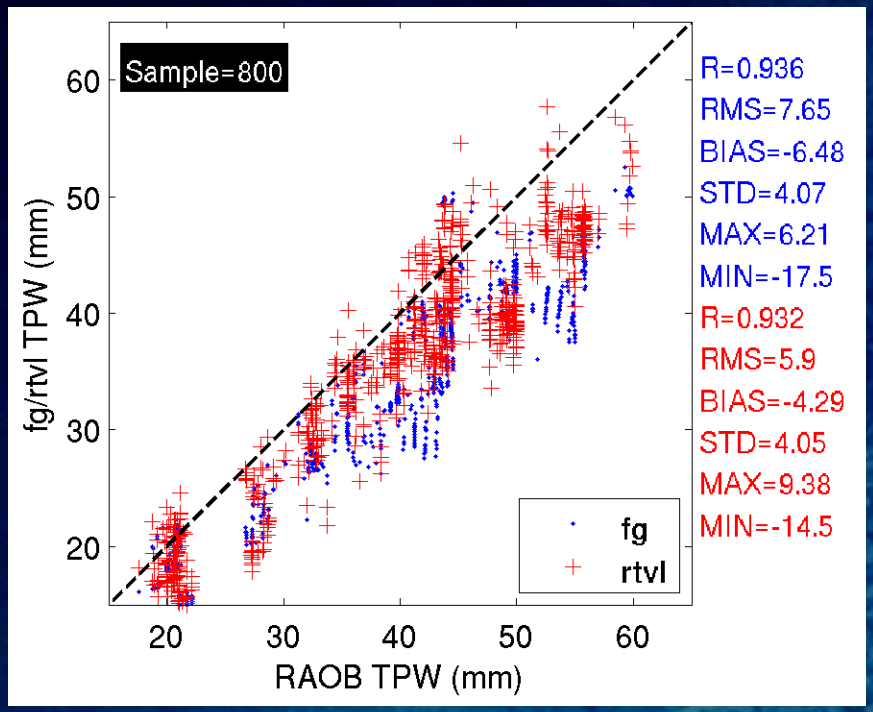

*Aqua MODIS (o)*
*Terra MODIS (+)*
*GOES Sounder (x)*
*SGP MWR (·)*

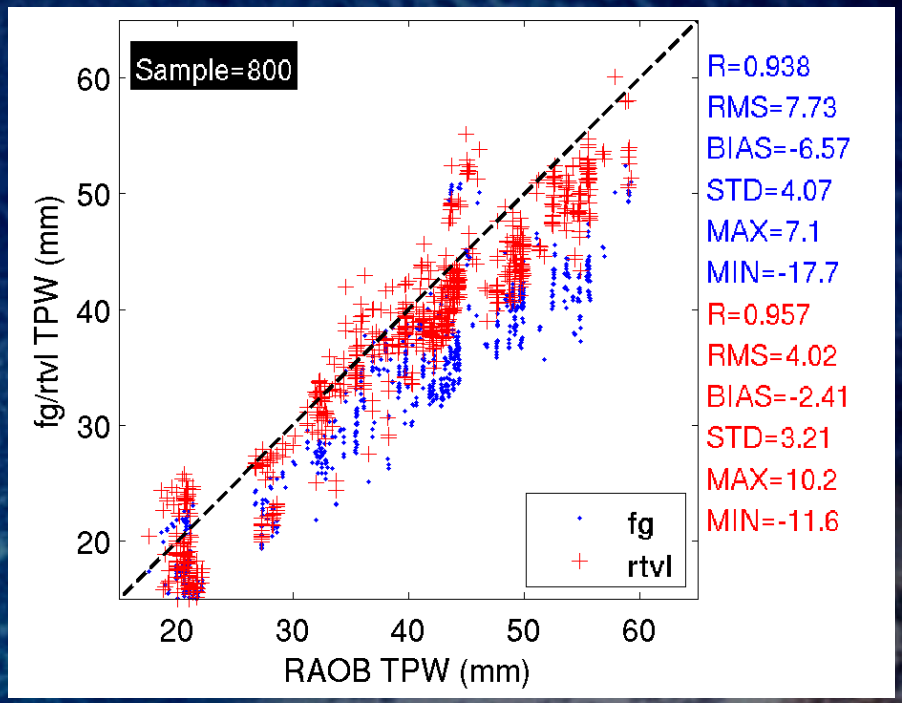
# Time series of TPW (MODIS, GPS)



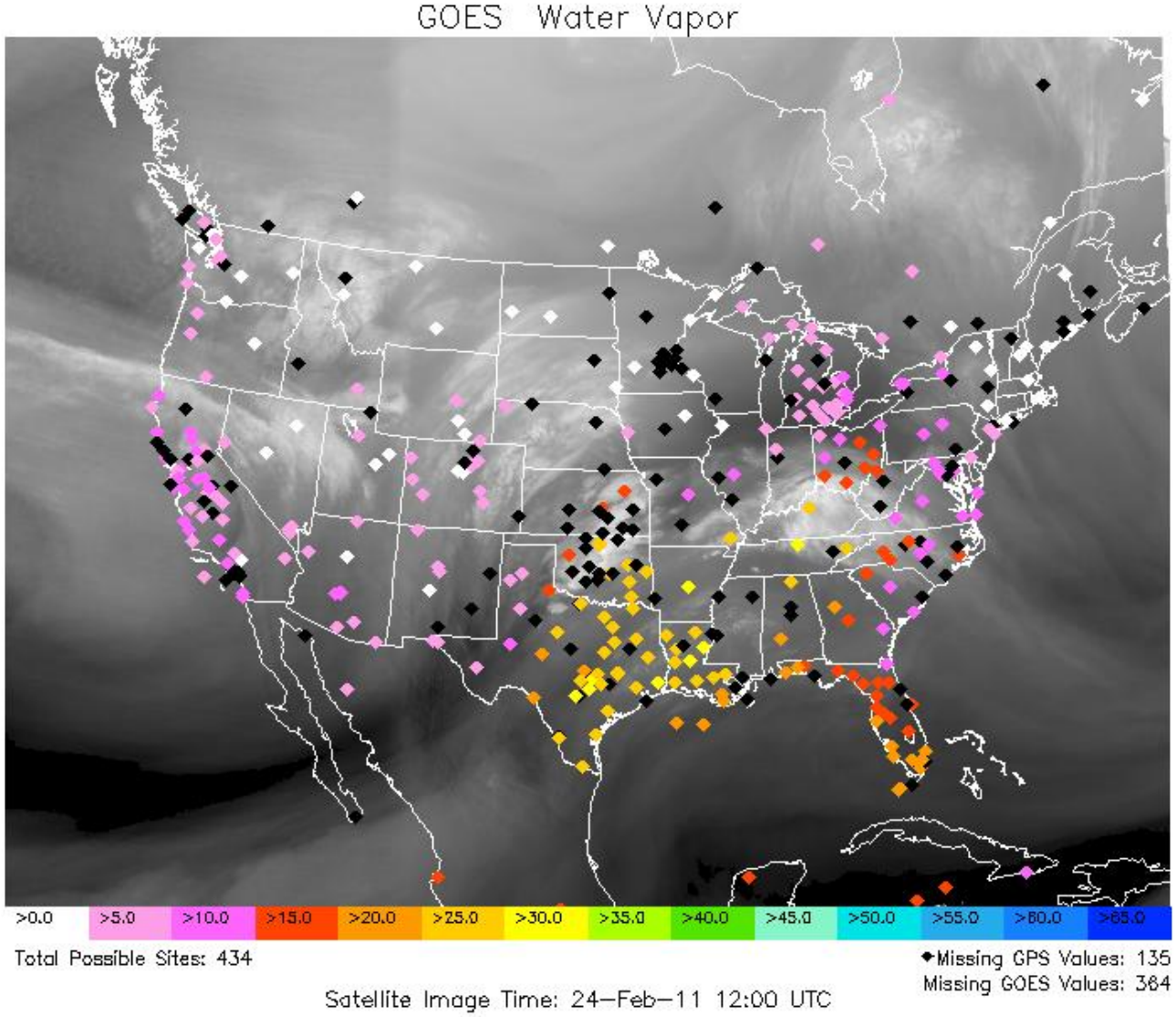
# Validation of GOES-13 TPW using conventional RAOB

*Ma* *Li*



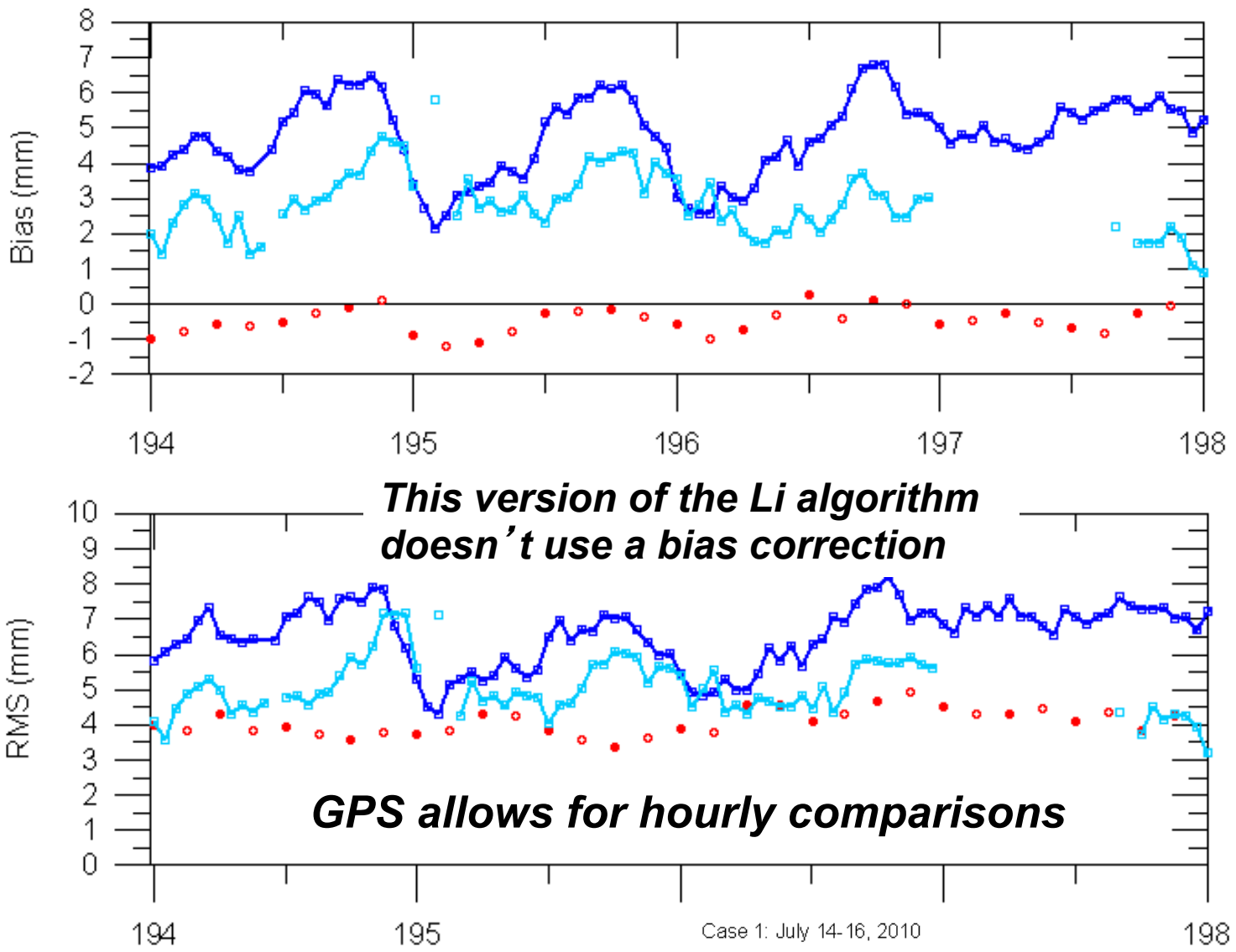



# GOES-GPS TPW Comparisons - CONUS Domain




***GPS allows for hourly comparisons***

# CONUS Avg TPW Differences for Case 1




***This version of the Li algorithm doesn't use a bias correction***

***GPS allows for hourly comparisons***

| | GFS0h-GPS |
|---|---|
| Num | 16 |
| # Sites | 273 |
| Min | -1.099 |
| Max | 0.260 |
| Mean | -0.458 |
| RMS | 4.059 |

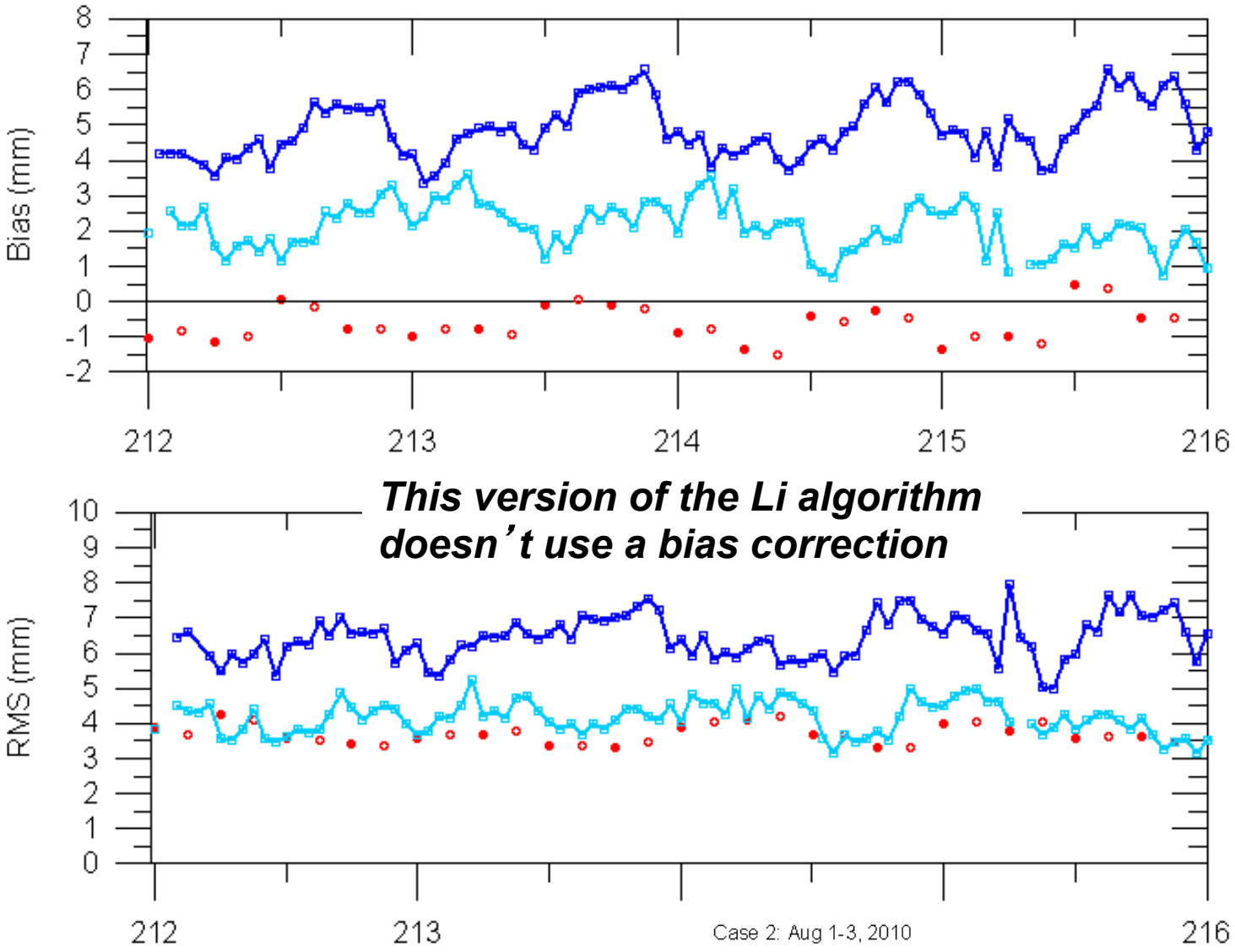
| | GFS3h-GPS |
|---|---|
| Num | 16 |
| # Sites | 274 |
| Min | -1.195 |
| Max | 0.089 |
| Mean | -0.475 |
| RMS | 4.084 |

| | Li-GPS |
|---|---|
| Num | 96 |
| # Sites | 137 |
| Min | 2.160 |
| Max | 6.810 |
| Mean | 4.785 |
| RMS | 6.575 |

| | Ma-GPS |
|---|---|
| Num | 77 |
| # Sites | 102 |
| Min | 0.920 |
| Max | 5.810 |
| Mean | 2.858 |
| RMS | 5.045 |

noaaresearch

# CONUS Avg TPW Differences for Case 2




***This version of the Li algorithm doesn't use a bias correction***

| | GFS0h-GPS |
|---|---|
| Num | 16 |
| # Sites | 273 |
| Min | -1.099 |
| Max | 0.260 |
| Mean | -0.458 |
| RMS | 3.691 |

| | GFS3h-GPS |
|---|---|
| Num | 16 |
| # Sites | 272 |
| Min | -1.507 |
| Max | 0.356 |
| Mean | -0.632 |
| RMS | 3.707 |

| | Li-GPS |
|---|---|
| Num | 95 |
| # Sites | 132 |
| Min | 3.37 |
| Max | 6.6 |
| Mean | 4.9 |
| RMS | 6.436 |

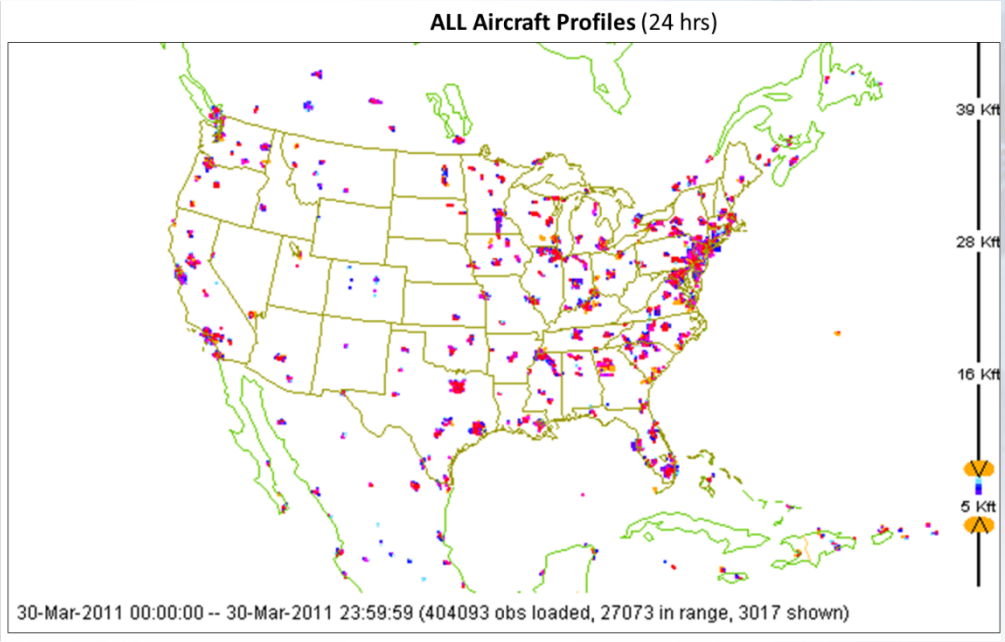
| | Ma-GPS |
|---|---|
| Num | 77 |
| # Sites | 102 |
| Min | 0.920 |
| Max | 5.810 |
| Mean | 2.858 |
| RMS | 4.155 |

# Ideas for the Further Enhancement and Utility of Validation Tools

- The matchup data can be used for verifying an improved algorithm via re-processing just for the validation sites
- The validation tools can be used to identify any radiance anomalies
- The validation tools can be used to quantify the product uncertainties
- JPSS soundings can be included for GEO/LEO comparisons
- Comparisons to aircraft measurements of temperature and moisture, e.g., the Water Vapor Sensor System (WVSS II).

# Validating GOES Water vapor using existing data sources

## Objective: Use newly-available WVSS-II observations from commercial aircraft to validate GOES moisture products




*Current daily WVSS-II sounding locations*
*Funded by NWS and FAA – Endorsed by WMO*

**By end of 2011, 750+ soundings will be available daily from UPS and SouthWest Airlines aircraft**

- *Choice of airlines provides good areal (SWA) and day/night (UPS) coverage*

**Other data sources will also be explored, including RADAM Lidar observations from the ARM/CART site.**

**Data from climate monitoring sites may provide additional validation of both GOES and WVSS-II**

# Routine Aircraft measurements

AMDAR Data Display from ESRL/GSD

NCEP GFS Model Forecasts | Problem loading page | gfs_pcp_072l.gif (GIF Imag... | Schwerdtfeger Library Pub... | Option 2 (excluding Ozon... | AMDAR Data Display from...

http://amdar.noaa.gov/java/

fsl acars

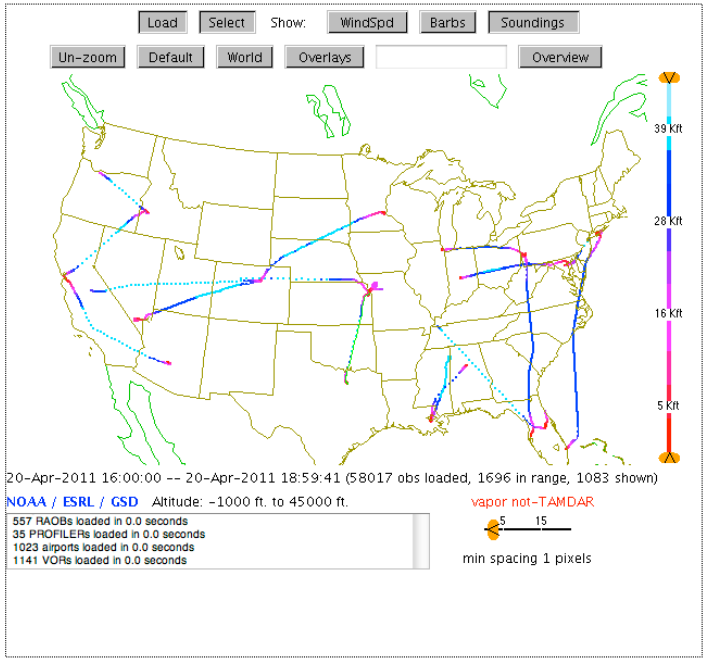
Home | Most Visited | Schwerdtfeger L... | SSEC FTP | UW-Madison Ne... | Storm Prediction... | Sports | NEWS | Weather | Rooftop Weath... | Wisconsin Fishin... | Bookmarks

## AMDAR Data Display from ESRL/GSD

new Latest version: 7-April-2010. **Delta EDR data are now available.** See change details (new window) for more information.
Please notify aircraft_request.gsd@noaa.gov of any problems.

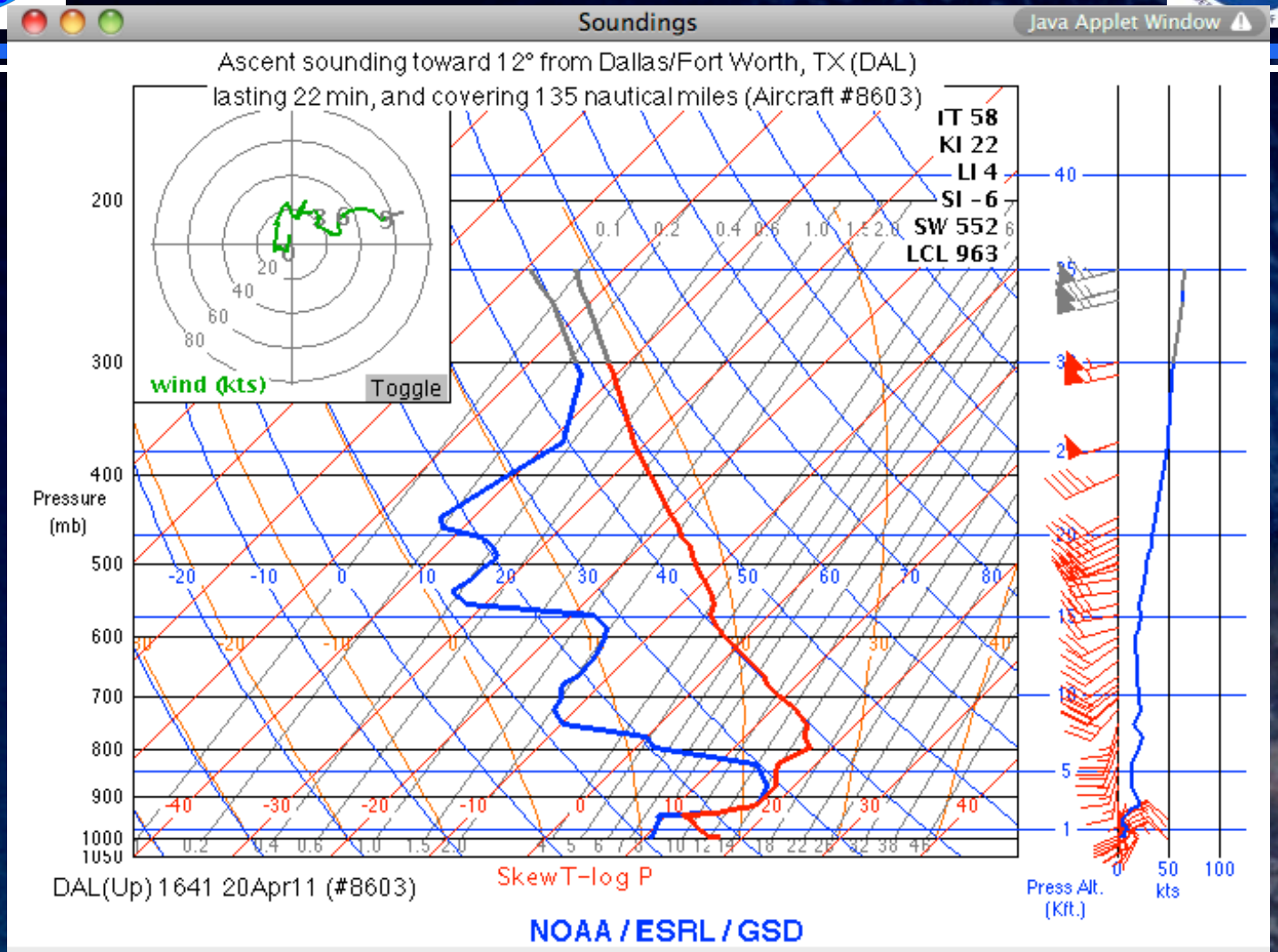
**Per our agreements with participating airlines, this data may not be redstributed to third parties. (Use of images in research publications is allowed and encouraged, however.)**

ESRL/GSD AMDAR Home | FAQ and General Information | Forecast Discussions
Help | **Forum** | Change Details | Set initial defaults | Privacy Statement




National Oceanic and Atmospheric Administration (NOAA)
Earth System Research Laboratory (ESRL)
Global Systems Division (GSD)
*Please notify aircraft_request.gsd@noaa.gov of any problems on this page.*
Last modified: Tue May 4 18:56:21 GMT 2010

# Routine Aircraft measurements



# WVSS-II 2009-10 Rawinsonde Inter-comparisons

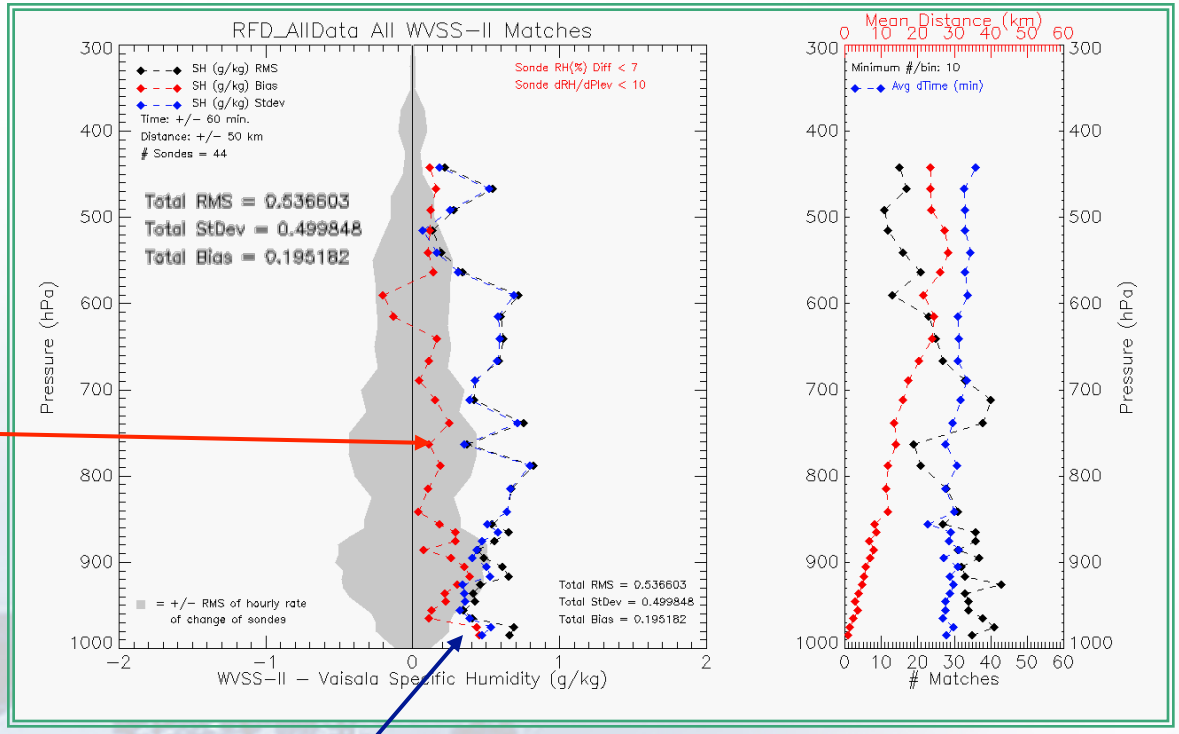
## Specific Humidity

***(Excludes cases with large time and vertical rawinsonde differences)***

***Systematic Differences:***

**WVSS-II Biases at low levels of 0.1 to +0.4 g/kg from surface to 850 hPa.**

**±0.2 g/kg above**




***Random Differences (Including Dry/Moist Environments):***

**Differences between aircraft data and bounding rawinsonde reports generally showed variability of 0.3 to 0.7 g/kg from the surface to 600 hPa – decreases aloft.**

**StdDev slightly larger than 1-hour variability between bounding rawinsonde reports (gray shading).**

***WVSS-II Data meet WMO quality standards.***

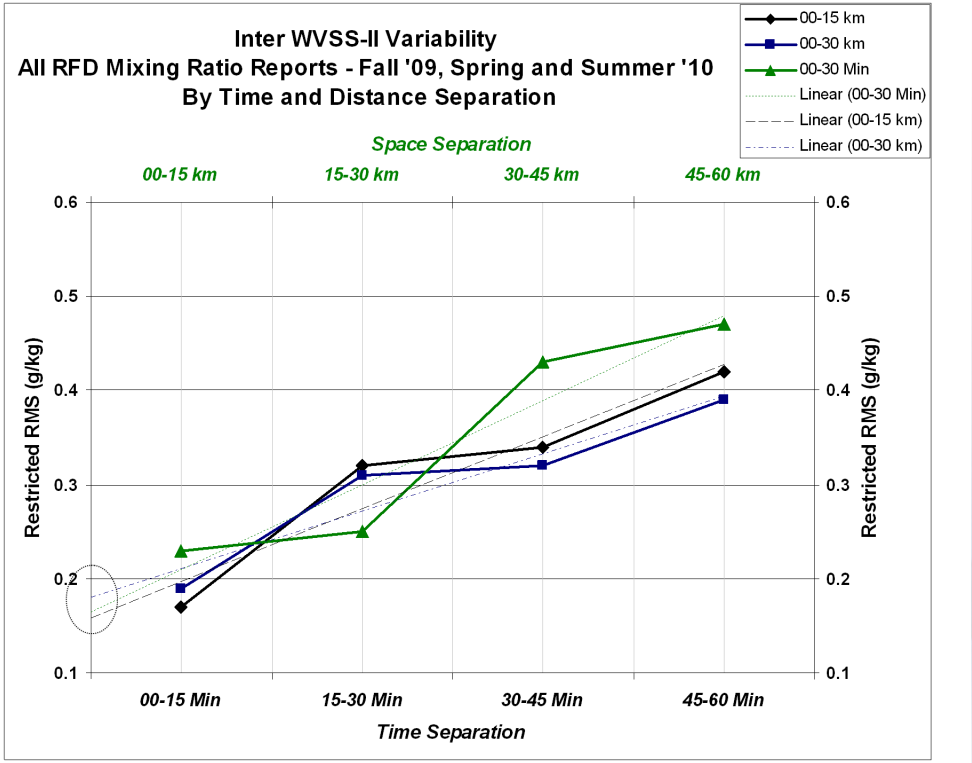
# 2009-2010 Aircraft-to-Aircraft Inter-comparisons

## Approximating WVSS-II Observational Error

***Restricted RMS calculated for:***

***Time ranges of 0-15, 15-30, 30-45 and 45-60 minutes***

***Distance ranges of 0-15, 15-30, 3-45 and 45-60 km***




***Restricted RMSs show** (ALL reports, **Including Dry/Moist Environments):***

**Atmospheric Variability more than doubles from 0-15 to 30-45 minute intervals**
**Spatial Variability increase consistent, but not as regular as temporal**

**Total Variability made up of 1) Instrument Error and 2) Atmospheric Variability**

**Projecting for exact co-locations (*ΔT~0 & Total Variability < 0.2 g/kg*),**
***Expect Operational WVSS-II Instrument Errors should be ~0.1 g/kg***

# Validating GOES Water vapor using existing data sources

## Objective: Use newly-available WVSS-II observations from commercial aircraft to validate GOES moisture products

**Proposed procedure:**

**1 – Establish infrastructure to validate GOES-R over the US**

**2 – Test current GOES products with WVSS-II to establish a baseline**

**3 – Compare GOES with data at other sites (ARM/CART and climate sites)**

**4 – Validate SEVIRI products against WVSS-II systems being mounted in Europe through the E-AMDAR program as an early surrogate for GOES-R**

# Summary

- GOES-R LAP needs sufficient validation tools. Need a flexible system, which allows looping, customized time-series ranges, etc.

- The tools should at least include:
  - Thumbnail of derived product images
  - Full size and/or zoomed derived images
  - Animations of the derived images
  - Times series of products at ARM site
  - BT difference images (obs – cals (FCST))
  - Product difference images (RTVLS – FCSTs)
  - Statistics of RTVLs against radiosondes, other satellites, aircraft, NWP analysis, etc.

- CIMSS MODIS validation experiment website:
  http://cimss.ssec.wisc.edu/modis/mod07/

- Current GOES Sounder experiment websites:
  http://cimss.ssec.wisc.edu/goes/rt/sounder-dpi.php
  http://www.star.nesdis.noaa.gov/smcd/opdb/goes/soundings/html/stats23L.html