Comparing and Analyzing Total Precipitable Water from Ground-Based GPS and SSM/I Satellite Remote Sensing

Brittany Fields[1], Janice Bytheway[2], John Forsythe[2], Thomas Vonder Haar[2]

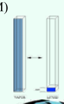
Department of Atmospheric Science, Colorado State University, Fort Collins, CO

Modeling Total Precipitable Water

NASA Water Vapor Project (NVAP)

- Create daily global water vapor dataset spanning 1988 – 2001
- Being reanalyzed and extended under the **NASA- MEaSUREs** program (NVAP-M)

- **NVAP-M**
  - Span 1987 - 2010
  - Collected from satellite and earth-based devices
    - **Global Positioning System (GPS)**
    - **Special Sensor Microwave/Imager (SSM/I)**
    - TIROS Operational Vertical Sounder (TOVS



Total precipitable water (TPW)

- Total atmospheric water vapor within in an imaginary vertical column of unit cross section from the surface of the earth to the top of the atmosphere
- Measured as height of the vertical column if all of the water vapor in the column was condensed

Objective

Use of more accurate GPS to interpret more globally available SSM/I satellites

Data from January 2003
- GPS
- 3 SSM/I Satellites

GPS → F13, F14, F15

Why Important?

Water vapor feedback effect
- Water vapor a dominating greenhouse gas
- Global warming

Better models
- Weather
- Hydrologic
- Climate

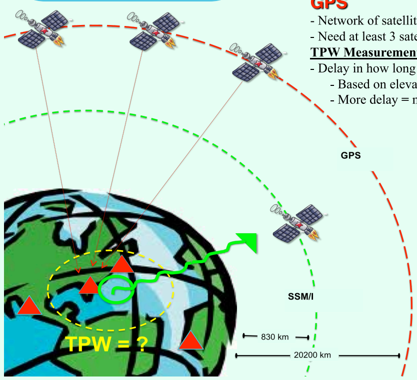
Testing of SSM/I
- Oceanic TPW major source of Earth's water vapor
- GPS accurate validation tool

Problem

SSM/I most accurately used over **OCEAN**
- Land & sea ice contamination

Must use <u>landmask</u>
- Removes coastal regions
- Leaves the 'island' GPS stations

Island stations
- Small area relative to the SSM/I footprint size (50 km)
- Water-dominated fields of view



GPS

- Network of satellites that send information to land receivers
- Need at least 3 satellites to triangulate x, y, z position

<u>TPW Measurement</u>
- Delay in how long satellite signals reach land receivers found
  - Based on elevation and how much water in atmosphere
  - More delay = more water vapor in air

SSM/I

- Flown aboard Defense Meteorological Satellite Program (DMSP)
- 7-Channel, 4-Frequency, linearly-polarized

Advantages:
- Very globally-available

Disadvantages:
- TPW error over:
  - Land
  - Sea Ice
  - Precipitating clouds

<u>TPW Measurement</u>
- Measures microwave emission from the surface and atmosphere
- TPW retrieved from brightness temperature using Elsaesser and Kummerow (2008)

Analysis

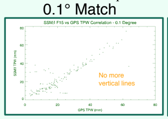
- GPS data matched to SSM/I F13, F14 & F15 data based on time and position
- Each TPW value associated with time of day, latitude and longitude
  - Matched within ½ hour time frame, 0.5° latitude/longitude
    - Each matched TPW point plotted on scatter diagram
- 'Island' points were separated with landmask & plotted as well

<u>2 sets of matched data</u>: TPW from stations & TPW from island stations (*seen below*)

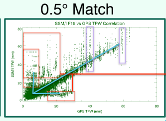
Further Analysis on F15

- SSM/I F15 had more scatter than the other two satellites
  - 'Arrow' – shape
  - More vertical lines
- TPW rematched to be within 0.1° degrees latitude/longitude
  - Decrease footprint size → Decrease # of matches
    - Vertical lines go away
- Latitude/Longitude of TPW points in 'arrow' plotted on world map to the right
  - Most found in Japan

0.1° Match



0.5° Match



TPW Plot Statistics

GPS with SSM/I #	F13	F14	F15
# Points Compared	19455	22298	21275
	7150	16301	14870
Correlation Coefficient	0.962	0.961	0.850
	0.966	0.964	0.857
Slope of Best Fit Line	1.054	1.029	0.960
	1.045	1.030	0.967
RMS	3.388	3.648	6.825
	3.278	3.719	7.161
Bias	1.301	1.821	2.199
	1.231	1.837	2.301

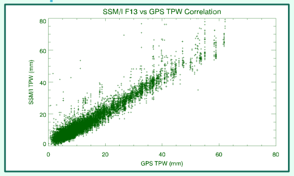
All Stations
Islands

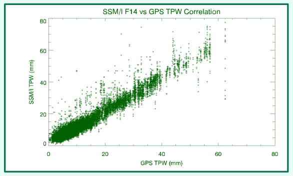
Huh!
Japan has an abundance of GPS sensors to help with earthquake prediction!

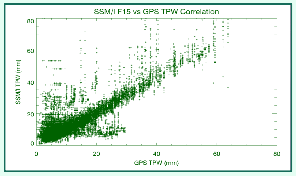
Problem stations from SSM/I F15

Results

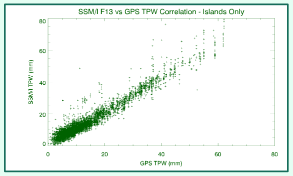
TPW plots with all GPS stations

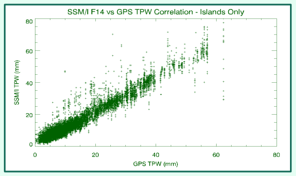


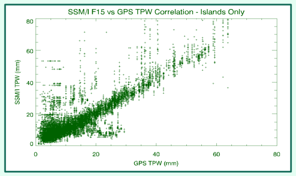




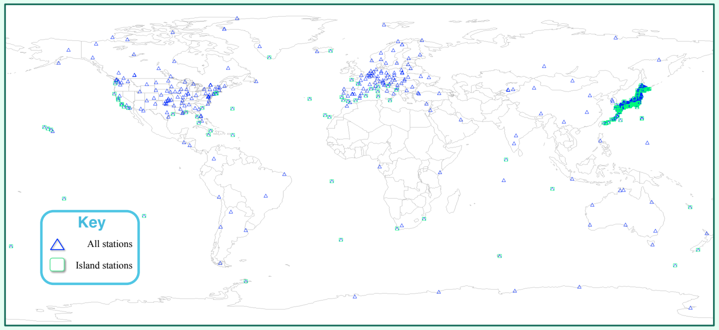
TPW plots with 'island' GPS stations







Global Map of GPS Stations Used



Conclusions

- High correlation between SSM/I and GPS TPW values
- Greatest error from SSM/I F15
- Vertical lines in TPW scatterplots appear from multiple SSM/I matches to one GPS station
  - Many more SSM/I data points than GPS
- Most problem stations from SSM/I F15 located in Japan

Future work

- Better understanding of why SSM/I F15 has more scatter than other SSM/I satellites
- Look into why Japanese stations are creating erroneous data

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Acknowledgments

This work has been supported by the National Science Foundation Science and Technology Center for Multi-Scale Modeling of Atmospheric Processes, managed by Colorado State University under cooperative agreement No. ATM-0425247.

For further information

Please contact Brittany Fields at *brittlou@rams.colostate.edu*.
More information on this and related projects can be obtained at *nvap.stcnet.com*.