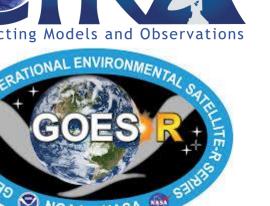# Improving Blended Total Precipitable Water (TPW) Products for Forecasters Via Advection and Inclusion of GOES-R

John M. Forsythe, Stanley Q. Kidder, Sheldon J. Kusselson, Dan Bikos, Andrew S. Jones, Louie Grasso, Ed Szoke
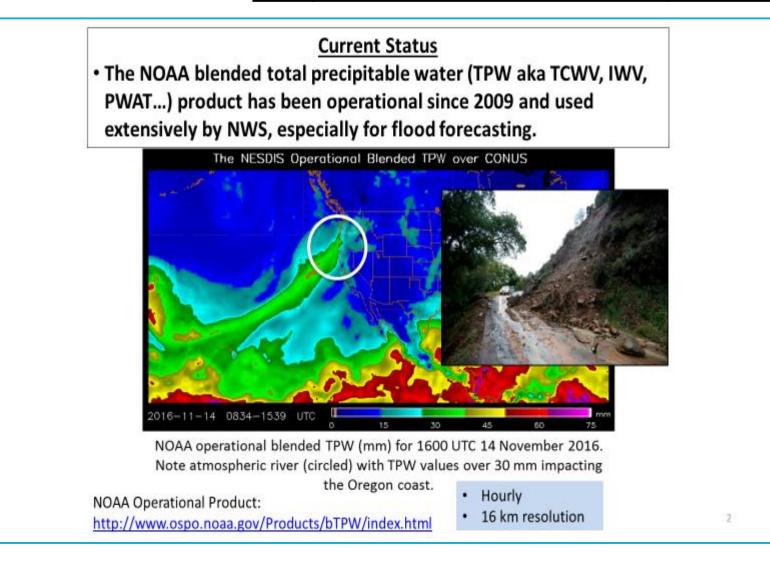
Cooperative Institute for Research in the Atmosphere, Colorado State University
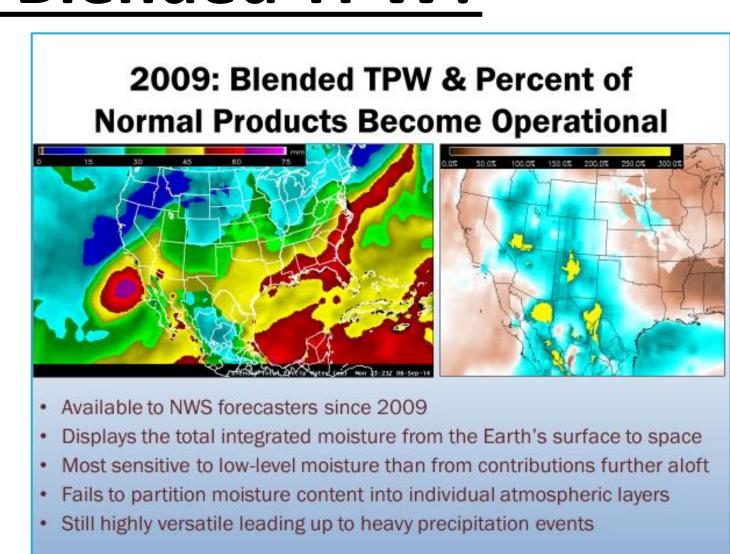
Collaborators: Tony Wimmers (CIMSS), Limin Zhao (NOAA OSPO), Ralph Ferraro (NOAA STAR), Chris Grassotti (CISESS-Univ of MD), Andrew Orrison (NOAA WPC), Chris Gitro, Mike Jurewicz, Dan Leins (NOAA/NWS)
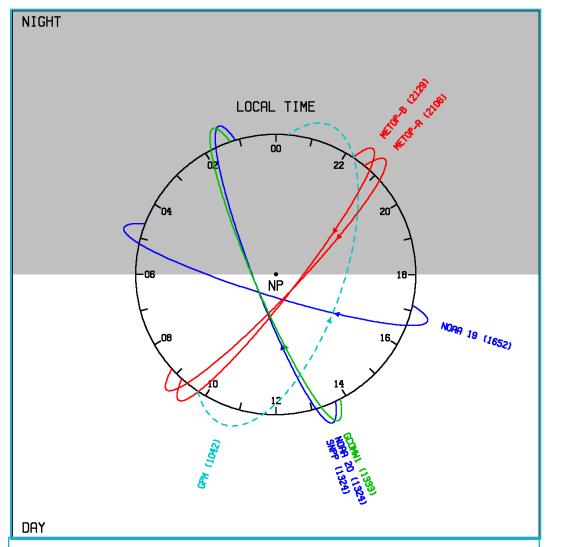
View near-realtime animations at: http://cat.cira.colostate.edu/ABI_TPW_FD/Merged_TPW.htm http://cat.cira.colostate.edu/GR3/GOESR_TB09_SIM_Hourly.htm htm http://cat.cira.colostate.edu/ GR3/GOES17_TB09_SIM_Hourly.htm
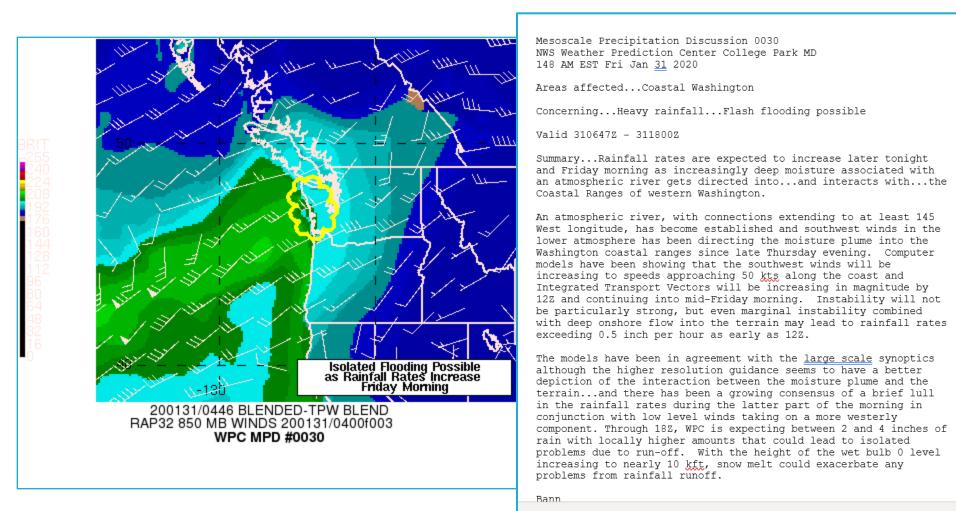
John.Forsythe@colostate.edu

What Do Forecasters Currently Use Operationally for Blended TPW?

Current Status
- The NOAA blended total precipitable water (TPW aka TCWV, IWV, PWAT…) product has been operational since 2009 and used extensively by NWS, especially for flood forecasting.

The NESDIS Operational Blended TPW over CONUS

NOAA operational blended TPW (mm) for 1600 UTC 14 November 2016. Note atmospheric river (circled) with TPW values over 30 mm impacting the Oregon coast.

NOAA Operational Product:
http://www.ospo.noaa.gov/Products/bTPW/index.html

2009: Blended TPW & Percent of Normal Products Become Operational
- Available to NWS forecasters since 2009
- Displays the total integrated moisture from the Earth's surface to space
- Most sensitive to low-level moisture than from contributions further aloft
- Fails to partition moisture content into individual atmospheric layers
- Still highly versatile leading up to heavy precipitation events
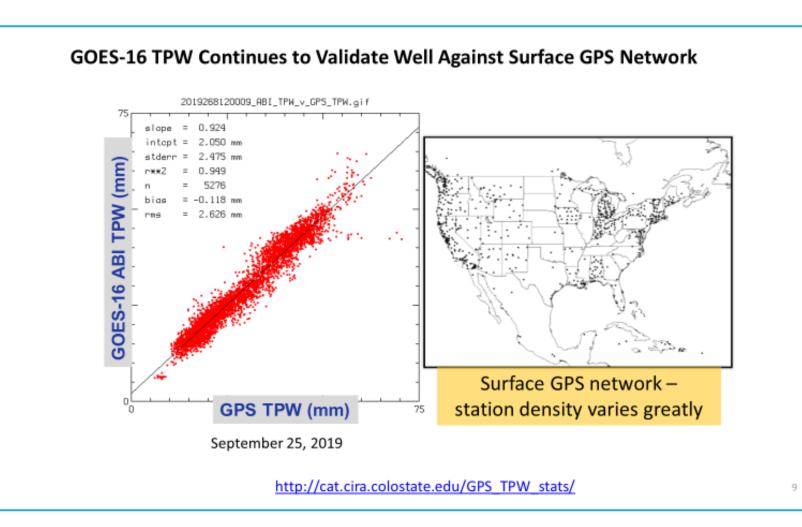- Hourly
- 16 km resolution

Current satellite suite used at OSPO for blended TPW. Times of ascending / descending nodes show for synsynchronous satellites. GPM precesses through all times.
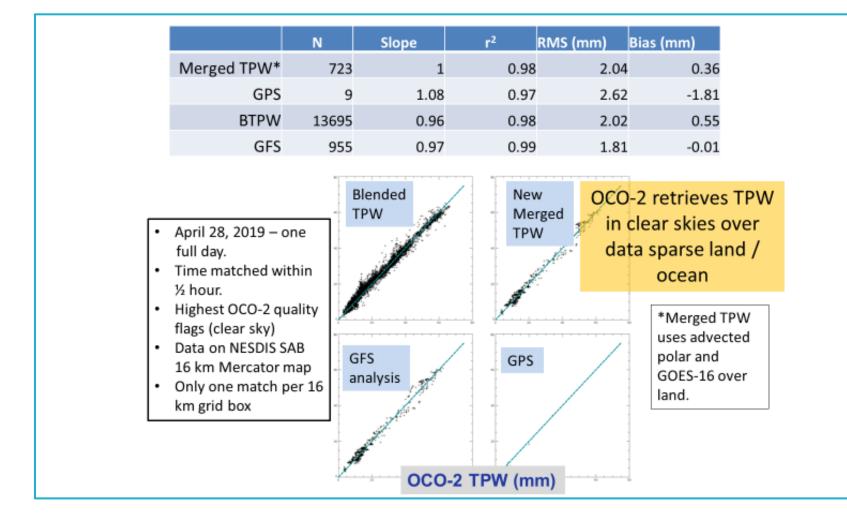
Mesoscale Precipitation Discussion 0020
NWS Weather Prediction Center College Park MD
149 AM EST Fri Jan 31 2020

But current product does not include GOES-R data…

GOES-16 TPW Continues to Validate Well

GOES-16 TPW Continues to Validate Well Against Surface GPS Network

Surface GPS network – station density varies greatly

September 25, 2019

http://cat.cira.colostate.edu/GPS_TPW_stats/

Daily validation against surface GPS stations

	N	Slope	r²	RMS (mm)	Bias (mm)
Merged TPW*	723	1	0.98	2.04	0.36
GPS	9	1.08	0.97	2.62	-1.81
BTPW	13695	0.96	0.98	2.02	0.55
GFS	955	0.97	0.99	1.81	-0.01

- April 28, 2019 – one full day.
- Time matched within ½ hour.
- Highest OCO-2 quality flags (clear sky)
- Data on NESDIS SAB 16 km Mercator map
- Only one match per 16 km grid box

OCO-2 retrieves TPW in clear skies over data sparse land / ocean

*Merged TPW uses advected polar and GOES-16 over land.

Validation against NASA Orbiting Carbon Observatory-2

Supports results in:

Schmit, T. J., Li, J., Lee, S. J., Li, Z., Dworak, R., Lee, Y.-K., et al. (2019). Legacy atmospheric profiles and derived products from GOES-16: Validation and applications. Earth and Space Science, 6, 1730–1748. https:// doi.org/10.1029/2019EA000729

Forecaster Surveys from Hazardous Weather Testbed (HWT) and Flash Flood and Intense Rainfall Experiment (FFaIR)
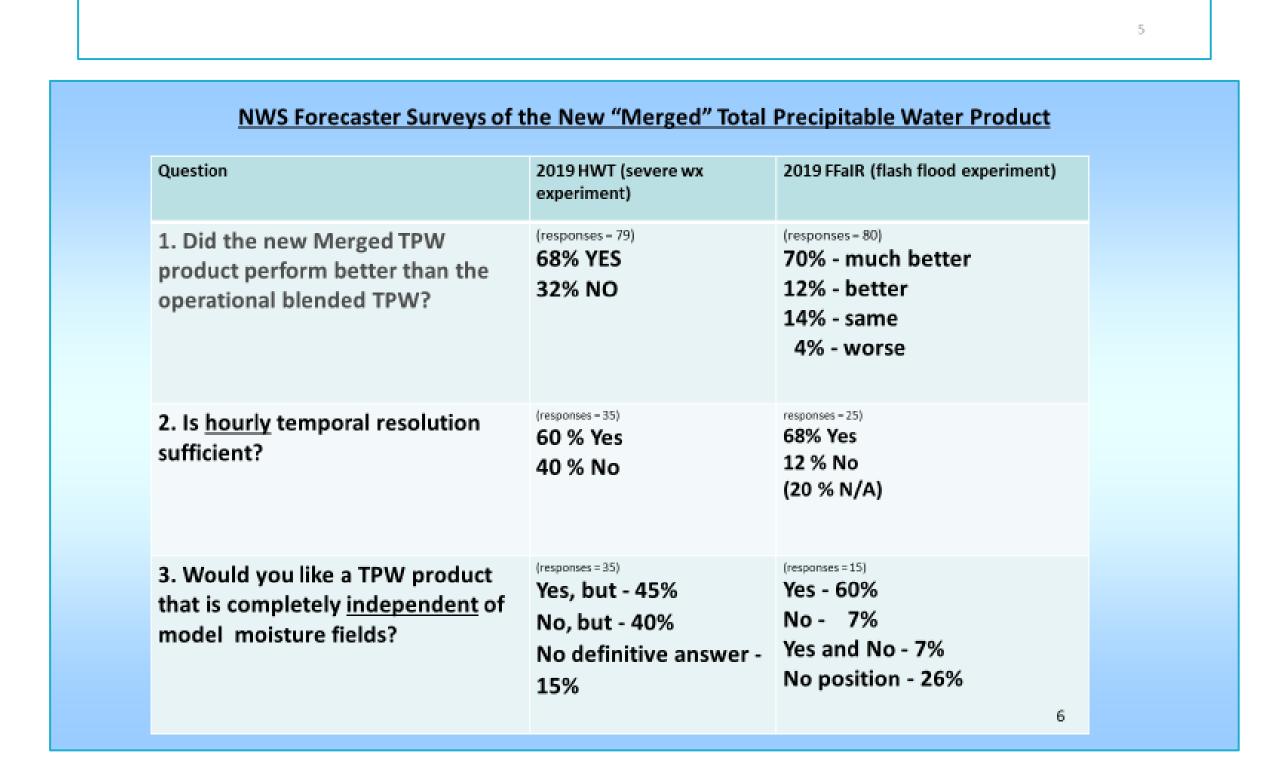
Questions posed to Forecasters in 2019 at Hazardous Weather Testbed (HWT - NSSL) and Flash Flood and Intense Rainfall Experiment (FFaIR - WPC)
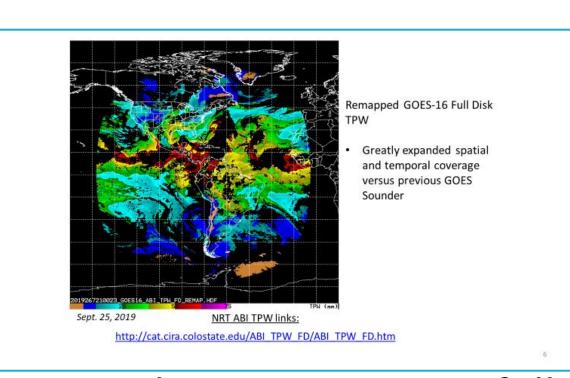
1. Is the Merged TPW product preferable to the operational blended TPW?

2. How important is it that blended TPW be independent of forecast model TPW?
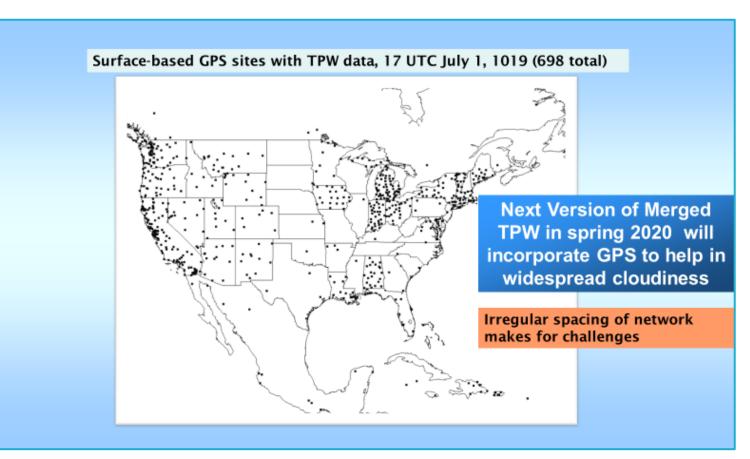
3. Is hourly temporal resolution sufficient?

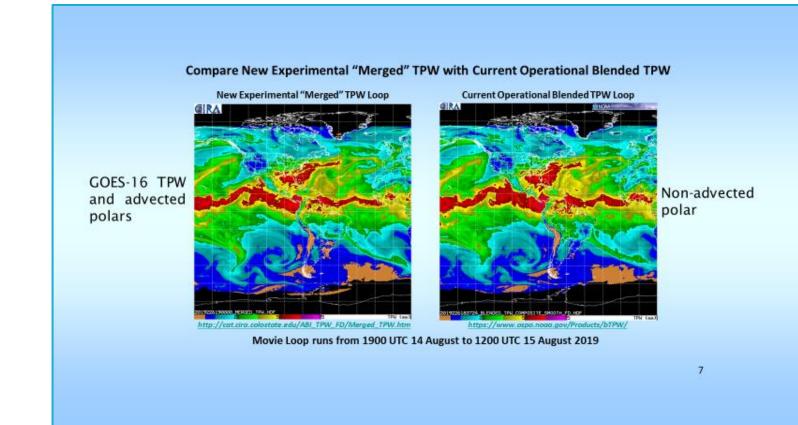**NWS Forecaster Surveys of the New "Merged" Total Precipitable Water Product**

Question	2019 HWT (severe wx experiment)	2019 FFaIR (flash flood experiment)
1. Did the new Merged TPW product perform better than the operational blended TPW?	(responses = 79) 68% YES 32% NO	(responses = 80) 70% - much better 12% - better 14% - same 4% - worse
2. Is hourly temporal resolution sufficient?	(responses = 35) 60 % Yes 40 % No	(responses = 25) 68% Yes 12 % No (20 % N/A)
3. Would you like a TPW product that is completely independent of model moisture fields?	(responses = 35) Yes, but – 45% No, but – 40% No definitive answer – 15%	(responses = 15) Yes - 60% No - 7% Yes and No - 7% No position - 26%

How is the Merged TPW with GOES-16 Created?

Remapped GOES-16 Full Disk TPW
- Greatly expanded spatial and temporal coverage versus previous GOES Sounder

Sept. 25, 2019

GOES-R brings 15 minute full disk coverage in clear areas – big improvement over previous sounders

The Making of a New "Merged" version 1.0 Total Precipitable Water (TPW)

GOES ABI TPW
- Hourly data over CONUS
- Only in mostly clear areas

Polar-Orbiting (PO) Microwave TPW
- Used over ocean and land
- Advected using MIMIC algorithm

0400 UTC 15 August 2019

NWP model dependencies:
- Microwave (MiRS) TPW is independent of dynamic NWP
- GFS model winds used to advect microwave TPW
- GOES-R TPW solution uses GFS as background

- GOES TPW overlaid on advected microwave
- GPS will be added Spring 2020

http://cat.cira.colostate.edu/ABI_TPW_FD/Merged_TPW.htm

Surface-based GPS sites with TPW data, 17 UTC July 1, 1019 (698 total)

Next Version of Merged TPW in spring 2020 will incorporate GPS to help in widespread cloudiness

Irregular spacing of network makes for challenges

Compare New Experimental "Merged" TPW with Current Operational Blended TPW

New Experimental "Merged" TPW Loop | Current Operational Blended TPW Loop

GOES-16 TPW and advected polars | Non-advected polar

Movie Loop runs from 1900 UTC 14 August to 1200 UTC 15 August 2019

Cloud-Free Water Vapor Imagery Derived from Passive Microwave Data

Hypothesis: ABI Water vapor channels (6.2, 6.9 and 7.3 μm) simulated from microwave water vapor soundings will detect dry air masked by cirrus clouds in ABI imagery.

Configuration – Version 1 Cloud-Free Water Vapor Imagery
- Uses Advected Layer Precipitable Water (ALPW - polar satellite microwave product derived from NOAA MiRS soundings)
- GFS temperature profile
- CRTM v2.2.3
- Fixed surface and aerosol properties
- 16 km Mercator projection (same as TPW / ALPW family)
- Produced hourly for GOES-16/-17.

Near-realtime animations available at: http://cat.cira.colostate.edu/GR3/GOESR_TB09_SIM_Hourly.htm

19 UTC 10 Dec. 2019

Simulated | Observed

GOES-16 tropical Atlantic panel

6.9 μm GOES-16 imagery

Version 1.0 GOES-17 6.9 μm (channel 9) imagery simulated from CIRA passive microwave Advected Layer Precipitable Water (ALPW) product (7 polar orbiters).

- Simulates channel 09 without high clouds which block the view of water vapor.
- Temperature refinements in progress ("levels vs layers").
- Louie Grasso modeled aerosol impacts > v. small

Kingston Jamaica Sounding – dry aloft

12 JULY 28 2019

6.9 μm GOES-17 imagery

Cirrus over Dry Atmosphere

Summary and Future Work

Summary

- A new blended TPW product which uses advection and GOES-16 in clear skies has been developed.

- Comparisons of the GOES-16 TPW versus surface GPS and OCO-2 show low error (**RMS ~2 mm**) with good temporal stability.

- Forecasters rated the new product higher than the current operational product.

- Open Question: How much model input is too much?

Future Work
- Transition the new merged TPW into operations, including CIMSS MIMIC product.
- Survey users for applications of cloud-free water vapor imagery.