

GOESR3 Periodic Reporting

Reporting Period: January 2019 – June 2019 (2nd half of FY19 funding cycle)

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Collaborators / Participants: Andy Edman (NWS Western Region), Limin Zhao (NOAA/NESDIS/OSPO); Mark Klein (NOAA/NWS/WPC), Andrew Orrison (NOAA/NWS/WPC)

Project Title: Using the New Capabilities of GOES-R to Improve Blended, Multisensor Water Vapor Products for Forecasters

Project Number: 444

Executive Summary

The second half of the second year of this project saw participation and evaluation of the new GOES-16 infused Total Precipitable Water (TPW) product, called Merged TPW (MTPW) in two major testbed evaluations. These were the Hazardous Weather Testbed – Experimental Warning Program (6 weeks; April – June 2019) at NSSL and the Flash Flood and Intense Rainfall (FFaIR) experiment (4 weeks – June-July 2019) at WPC. In total, over 150 responses were gathered evaluating MTPW. Roughly 70% of forecasters responded that the new MTPW product performed better than the current NOAA operational blended TPW product, and a majority said that hourly resolution is sufficient.

Near-realtime animations of the MTPW are online at CIRA, using data processed with the same data processing system as used in NESDIS operations. A variety of near-realtime GOES-16 TPW and related product animations are available at http://cat.cira.colostate.edu/abi_tpw/ (CONUS) and http://cat.cira.colostate.edu/ABI_TPW_FD/ (Full Disk). This includes an advected TPW product, which is likely the future direction of blended TPW products for forecasters. Continued routine inspection of the GOES-16 TPW data overlaid onto the advected TPW derived from polar orbiters indicates that the GOES-16 TPW is of high quality, with no obvious artifacts or diurnal biases. Daily comparisons to surface-based GPS sites also indicate that GOES-16 TPW is a stable, low-noise product, with a RMS error typically of 2-3 mm and minimal bias. This low error encourages inclusion of GOES-R TPW into operational products and is a major finding of this risk reduction research.

Near-realtime animations of simulated cloud free Channel 9 (6.9 μm) imagery from GOES-16 and a “Cirrus Masking Dry” product have been created for GOES-16 and are available at http://cat.cira.colostate.edu/GR3/GOESR_TB09_SIM_Hourly.htm. Simulations of GOES-17 Channel 9 are also running in near realtime and are at http://cat.cira.colostate.edu/GR3/GOES17_TB09_SIM_Hourly.htm. Both of these products are driven by the Advected Layer Precipitable Water (ALPW) product derived from 7 polar orbiters. These products thus represent a fusion of NOAA’s geostationary and polar satellite data. The expected user audience for these products is in tropical cyclone forecasting, although we expect other uses to be discovered.

Progress toward FY19 Milestones

There were two project milestones this reporting period (Quarter 3 and 4):

Quarter 3 Task: Gather comments from forecasters and adjust products accordingly. Finalize advected TPW product and compare to GOES-R TPW. Analyze matchup statistics.

The major effort under this milestone was project participation in the Hazardous Weather Testbed – Experimental Warning Program (6 weeks; April – June 2019) at NSSL and the Flash Flood and Intense Rainfall (FFaIR) experiment (4 weeks – June-July 2019) at WPC. At both of these experiments, near-realtime Merged TPW data was provided in AWIPS-2 format, served via the CIRA LDM. Deb Molnar of the CIRA RAMMB is acknowledged for valuable technical assistance with this delivery. An example of the product being displayed in AWIPS-2 is shown in Figure 1.

A near-realtime advectively blended TPW product has been created, and is available hourly for both CONUS and full-disk domains at http://cat.cira.colostate.edu/abi_tpw/ (CONUS) and http://cat.cira.colostate.edu/ABI_TPW_FD/ (Full disk). The current algorithm to create MTPW is shown in Figure 2. Advected microwave-derived TPW data from polar orbiters is first mapped onto the output grid. Then GOES-16 TPW is overlaid where clear. It is noteworthy that seams or gradients between these two datasets are not usually large, which would cause distracting artifacts and result in poor forecaster reviews.

At HTW and FFaIR, forecasters were posed these three questions:

1. Did the new Merged TPW product perform better than the operational blended TPW?
2. Is hourly temporal resolution sufficient?
3. Would you like a TPW product that is completely independent of model moisture fields?

A summary of the answers to these questions are shown in Figure 3. Each experiment had a different forecast application (severe weather versus flash flooding). Between 68 and 70 % of forecasters rated the MTPW product as better than the current operational NOAA blended TPW product. It should be noted that MTPW currently only uses 4 polar orbiters while operational blended TPW uses 7 spacecraft. And MTPW does not avail itself of highly accurate surface-based GPS data. In the future, the advected MIMIC TPW product from CIMSS will replace the CIRA implementation of MIMIC. The next major upgrade to operational blended TPW will likely include the MIMIC TPW with GOES-16 augmentation. It is encouraging that a version without full utilization of the data outscored the current operational blended TPW product.

Blog entries from HWT are at <https://blog.nssl.noaa.gov/ewp/> and contain additional forecaster comments and case studies, which may be searched by tags such as TPW. Further feedback from FFaIR is expected in Fall 2019.

Quarter 4 Task: Characterize errors of advectively blended TPW using GPS and GOES-16.

Comparisons of GOES-16 TPW to surface GPS TPW data, which is considered a validation standard, continue daily and are available at http://cat.cira.colostate.edu/GPS_TPW_stats/. In Figure 4,

a daily comparison for 25 Sept. 2019 is shown, along with a map of the GPS TPW network. RMS errors of 2.6 mm and minimal bias conform results from previous seasons about the low-noise performance of ABI TPW.

While not a milestone this project period, work progressed on creating simulated GOES-16 and -17 channel 9 radiance simulations. Recall that the hypothesis is that cloud-free simulated radiance imagery can be created from the Advected Layer Precipitable Water (ALPW) product. This would unmask regions where high clouds obscure the water vapor signal for forecasters and yield a “cirrus masking dry” product. An initial target user group is for tropical cyclone forecasting and sensing dry air in the storm environment.

The radiance simulation now contains all of the necessary state variables to create realistic looking imagery. The CRTM configuration for Version 1.0 includes:

- Temperature data from GFS at five fixed pressure levels, + surface. Level, not layer data.
- 300-100 mb mixing ratio estimated at 10% of 500-300 value (poor simulations without this layer).
- Zenith angle effect included
- No aerosols, fixed surface emissivity
- As initial focus is on oceans for NHC, currently no simulations at surface pressure < 850 mb or precipitating regions (black in simulations).

In the next quarter, a water vapor weighted layer temperature will be tried along with the fixed pressure level temperature. It is hypothesized that use of this layer mean temperature, which more closely reflect what the ABI senses, will reduce the scatter in the simulated vs observed data shown in Figure 5 (e). If the scatter is reduced, this bolsters algorithms such as the prototype “cirrus masking dry” product shown in Fig. 5 (d).

Near-realtime imagery is available at:

http://cat.cira.colostate.edu/GR3/GOESR_TB09_SIM_Hourly.htm. (GOES-16) and
http://cat.cira.colostate.edu/GR3/GOES17_TB09_SIM_Hourly.htm. (GOES_17)

An example of the GOES-17 simulation is shown in Figure 6. Only GOES-16 has a panel of products, as we have not yet implemented the GOES-17 channel 9 remapping / graphics at CIRA.

Plans for Next Reporting Period

Milestones in the next reporting period are:

Quarter 1: Deliver cloud-free GOES water vapor imagery to partner offices. Summarize comments from forecasters. Develop VISIT training module on advected BTPW with GOES-R.

Quarter 2: Develop VISIT training module on cloud-free GOES-R water vapor imagery. Submit journal paper, notional title “Cloud-Free GOES-R Water Vapor Imagery for Forecasting”.

The submission timeline of the journal paper on cloud free imagery is likely optimistic, as we will be seeking forecaster feedback on the product, and comparing the “cirrus masking dry” regions to ABI channels for validation.

The Merged TPW product does not currently use GPS surface data. We expect to reap some improvements by judicious use of this network, especially in larges expanse of clouds where GOES

TPW is not available and advection of microwave data is not representative. We will implement a with / without GPS Merged TPW product and examine it initially at CIRA, with the possibility to submit it to HWT / FfaIR in 2020 if the results look encouraging.

Additional Information

4. Interaction with operational partners –

GOES-R plots and updates on the work as needed are provided to Limin Zhao, who is the Precipitation Products Area Lead at NESDIS OSPO. These occur through biweekly telecons related to operational blended product support. Initial discussions with Limin on transitioning the Merged TPW to operations indicate that the advected polar and GOES TPW should be added together, not as two separate efforts. The timeline for this will be determined by OSPO priorities.

Merged TPW products are flowing into the AWIPS-2 system at the WPC, as a result of the FfaIR experiment. Andrew Orrison, Satellite Focal Point at WPC, and PI Forsythe have discussed the product.

2. Conference/workshop participation –

Sheldon Kusselson presented the talk “Improving Blended Total Precipitable Water (TPW) Products for Forecasters via Advection and Inclusion of GOES-R Satellite Data” at the National Weather Association Annual Meeting in September 2019.

John Forsythe will present a talk with the same title “Improving Blended Total Precipitable Water (TPW) Products for Forecasters via Advection and Inclusion of GOES-R Satellite Data” at the AMS Satellite Meteorology and Oceanography Conference in October 2019. The contents of each talk will be different to focus on the different audiences at each meeting (forecast applications vs. algorithm and validation).

3. Outside project publicity –

N/A

4. Journal articles –

N/A

Key Graphics

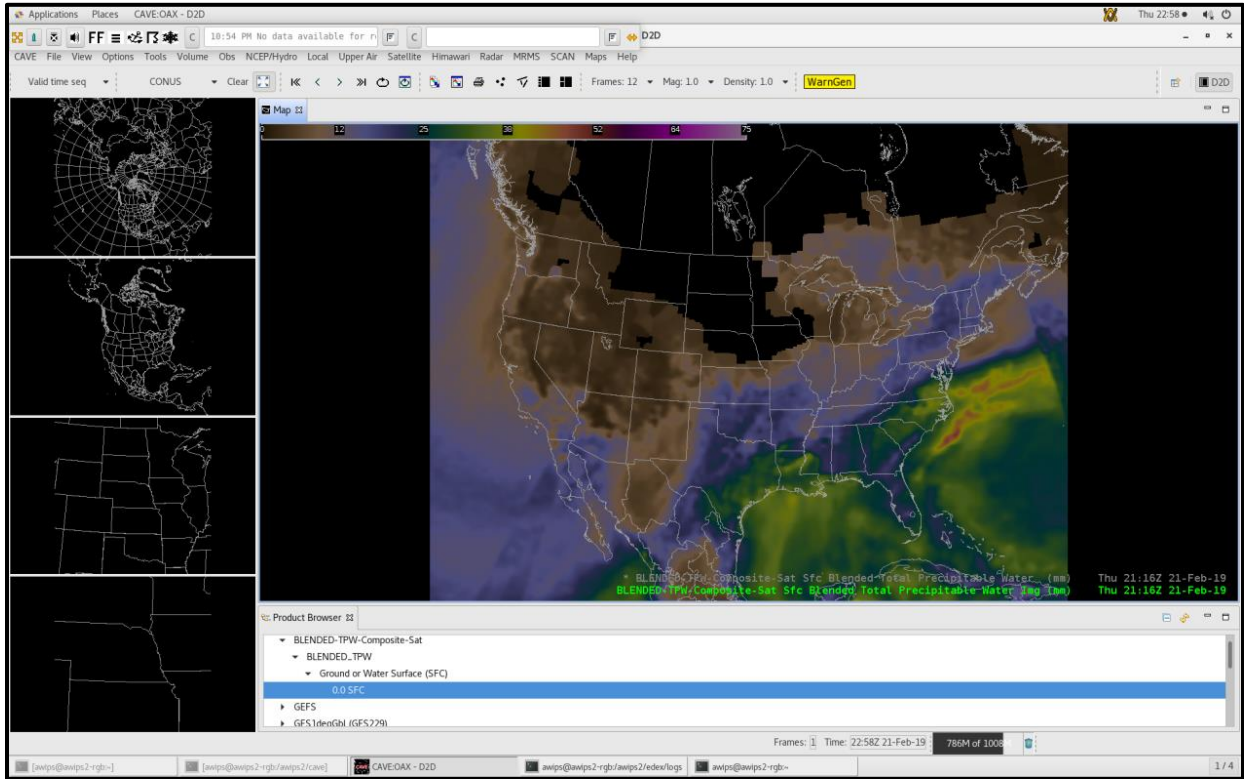


Figure 1: Example of the Merged TPW product in the AWIPS-2 display from 21 UTC 21 February 1919. This was an early test to exercise the data format and display were correct.

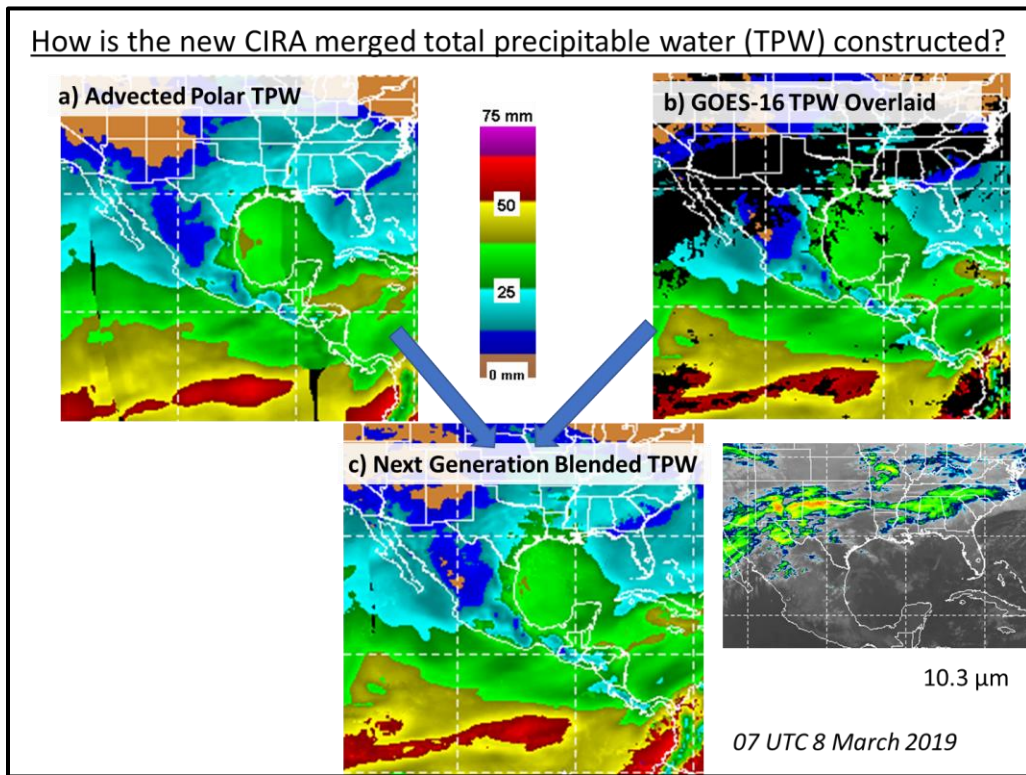


Figure 2: Outline of the process to create Merged TPW, or Next Generation as labeled here. GOES-16 TPW is overlaid in preference onto advected TPW derived from passive microwave sensors. The microwave data fills in cloudy areas as seen throughout the southeast and south central U.S. in this example.

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 <u>hourly</u> 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 <u>independent</u> 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%

Figure 3: Summary of forecaster rankings from the HWT and FFaIR experiments in spring and summer, 2019.

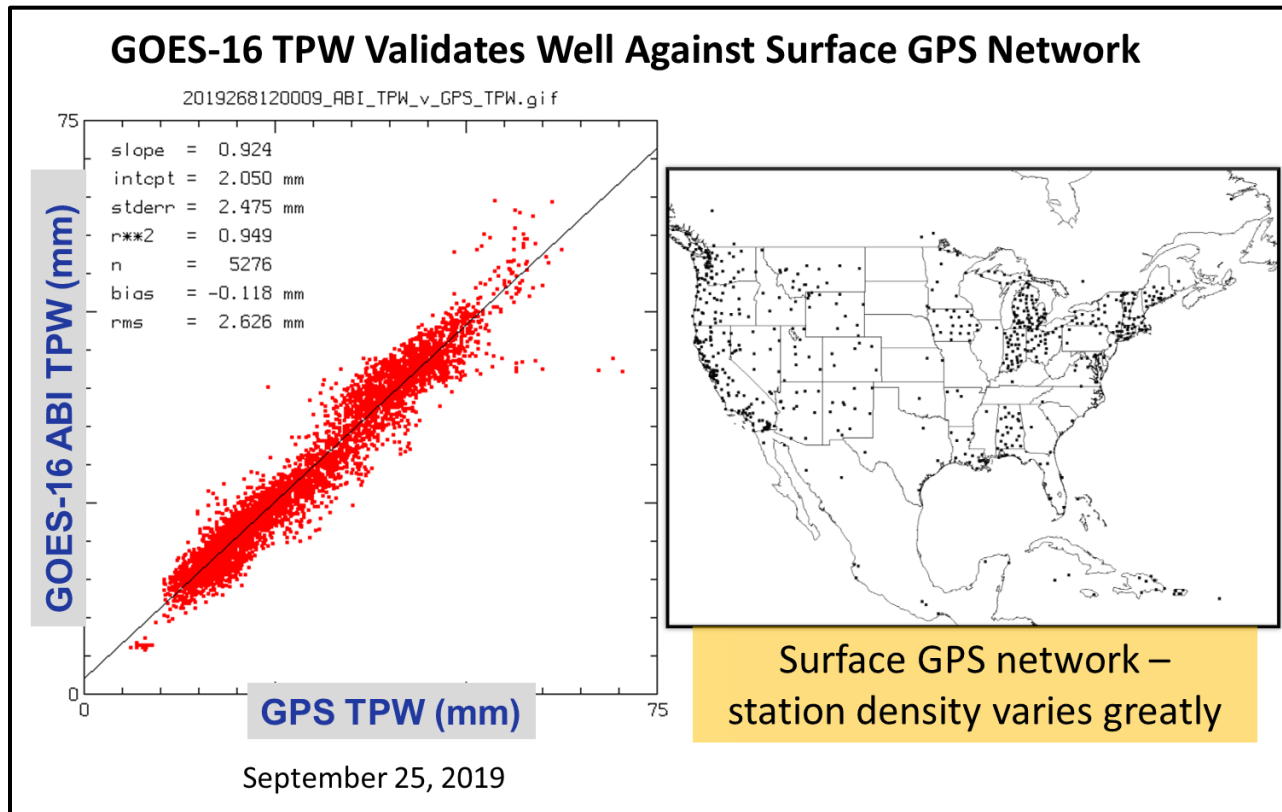


Figure 4: Validation of GOES-16 TPW against the surface GPS network over CONUS and adjacent regions for 25 Sept. 2019. RMS error is 2.6 mm, with a bias of -0.1 mm. Near-realtime daily comparisons are available at http://cat.cira.colostate.edu/GPS_TPW_stats/.

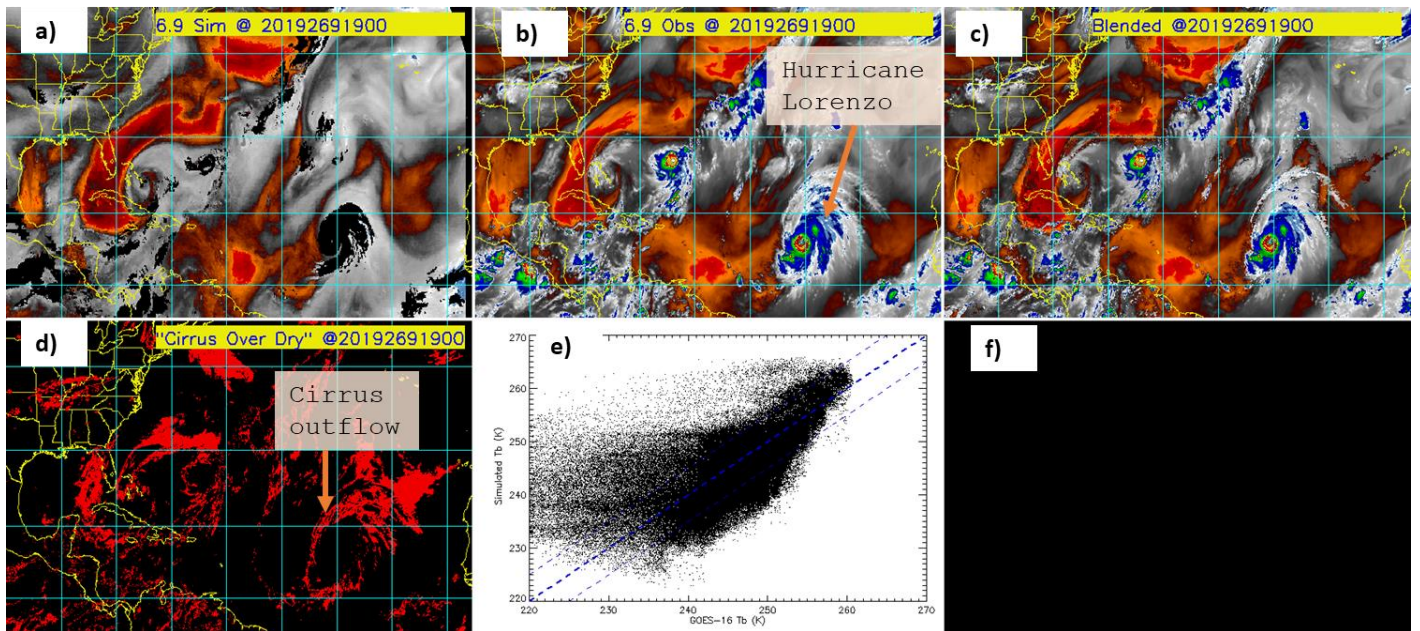


Figure 5: 6-panel plot of simulated and observed GOES-16 Channel 9 data from 1900 UTC 26 Sept. 2019. a) Simulated cloud-free brightness temperature. b) Observed brightness temperature. c) Prototype merged product, using observed but adding simulated according to the “cirrus over dry” mask in d). Note cirrus outflow ring around Hurricane Lorenzo. e) Scatter plot of observed (x-axis) and simulated (y-axis) brightness temperatures. Tails leading to the left are cloud-impacted radiances. f) Reserved for future use.

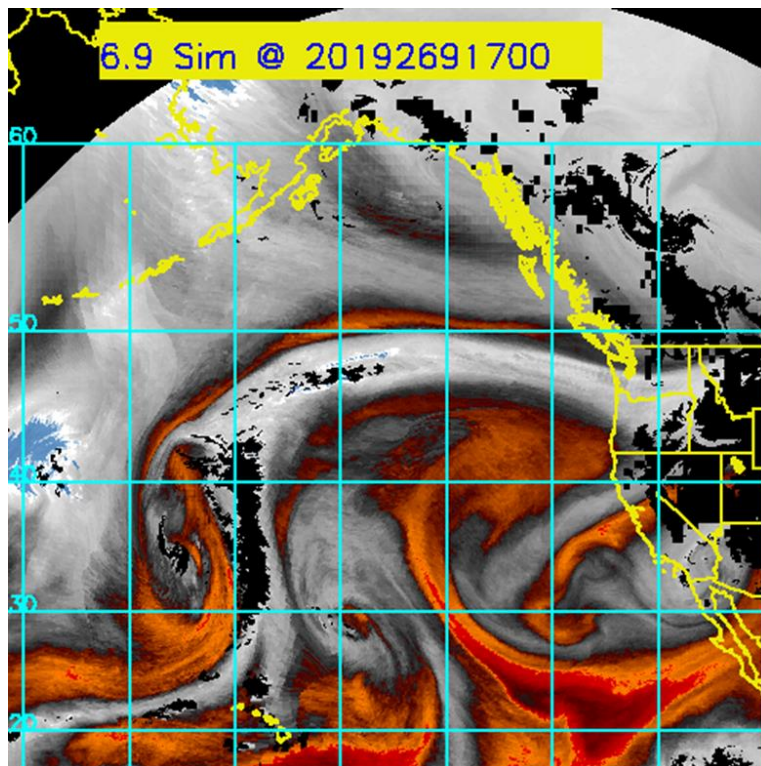


Figure 6: GOES-17 simulated channel 9 imagery, 1700 UTC 26 Sept. 2019.