8.5 **AN UPDATE ON THE OPERATIONAL IMPLEMENTATION OF BLENDED TOTAL PRECIPITABLE WATER PRODUCTS**


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## 1. INTRODUCTION

During the past several years, university and government researchers and NOAA National Weather Service (NWS) forecasters and Satellite Service (NESDIS) analysts have collaborated in developing separate unified/Blended Total Precipitable Water (TPW) and Anomaly products that are available on the internet at: http://amsu.cira.colostate.edu and http://amsu.cira.colostate.edu/gpstpw . These products are produced with the blending/merger of TPW products produced from various sensors on different remote sensing platforms, including AMSU on board the POES and METOP polar-orbiting satellites, SSM/I on board the DMSP F-13 satellite, GOES sounders and ground-based Global Positioning System (GPS) equipment (Forsythe, et.al., 2009). The products will be operational and available to all NOAA forecasters through the Advanced Weather Interactive Processing System (AWIPS) starting in February 2009. A plan is in place to improve these TPW products with additional satellites and microwave retrievals overland beyond 2009. NESDIS Satellite Services Division (SSD) meteorologists are also involved in educating forecasters in how to use and apply the products so they can improve their ability to recognize and respond faster and more accurately to impending heavy precipitation with longer watch/warning lead times for flooding. This paper presents the operational Total Precipitable Water (TPW) products and future improvements; examples of the products and a few applications of these blended TPW products for high impact heavy precipitation cases during the past few years.


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## 2. CURRENT AND FUTURE TPW PRODUCTS

NOAA/NESDIS has generated global composited single sensor multi-satellite DMSP SSM/I (Figure 1***a***) and NOAA AMSU (Figure 1***c***) TPW products for use by forecasters since 1991 (Kusselson, 1993) and 2000, respectively. During the past several years an effort has been made by CIRA/Colorado State University researchers to blend TPW products over the water from DMSP SSM/I and POES/METOP AMSU polar-orbiting microwave sensor satellites (Kidder and Jones, 2007) with ground-based GPS-MET (Gutman and Benjamin, 2001) water vapor observations produced experimentally by NOAA's Earth System Research Laboratory over the CONUS and other areas of the Western Hemisphere ( http://gpsmet.noaa.gov ). Figures 1 ***a-c*** show the operational remote sensing data that went into producing the blended TPW product (***d***) from DMSP SSM/I, POES/METOP AMSU over water and Western Hemisphere ground-based GPS-MET and GOES sounder data overland.

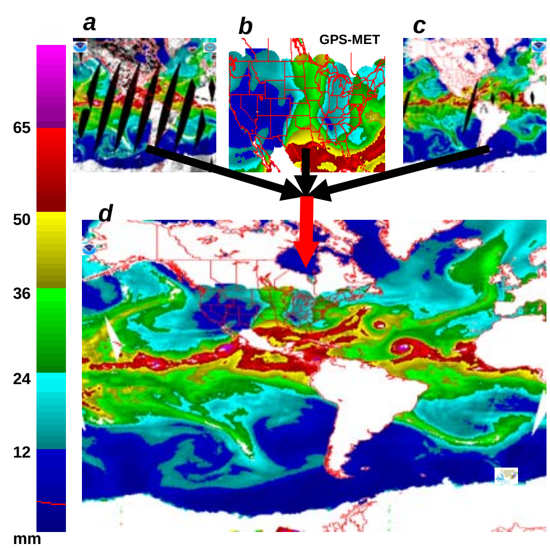



Fig. 1. ***a)*** DMSP SSM/I single sensor one satellite TPW composite; ***b)*** Ground-based GPS-MET and GOES sounder TPW overland; ***c)*** NOAA -15, 16, 17, 18 and METOP-2A AMSU TPW composite = ***d)*** Blended Remote Sensing TPW product.

With more frequent updates, less data gaps, the elimination of biases between the data and superior analysis over land, the greatest benefit of using an operationally supported multi-remote sensing blended TPW product, especially in the NPP/NPOESS era, will be that analysis time will be significantly reduced at forecast and warning sites and likely contribute to further improvements in the warning lead time and forecast accuracy of heavy precipitation/flooding.
A complimentary Blended TPW Anomaly product, Figure 2 below as an example, is also being produced that takes the current Blended TPW product and compares it with a 1988-1999 climatology of SSM/I TPW over the ocean and a mix of radiosonde/TOVS soundings over land (conversation/e-mail with co-author and research meteorologist John Forsythe of CIRA/Colorado State University, 2006).

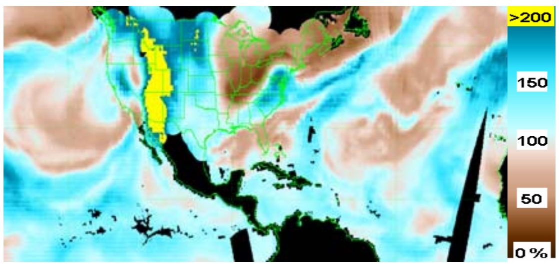



Fig. 2. Blended DMSP SSM/I - GPS/MET - POES/METOP AMSU TPW Anomaly product for 1200 UTC October 6, 2006 with various aqua and yellow color shades representing above normal and brown color shades representing below normal.

This has already been very helpful to forecasters in giving a climatological (above or below normal) perspective to the current blended TPW values. The current Blended TPW and Anomaly products cover most of the Western Hemisphere and GOES sounder imagery is being used over the CONUS in places where GPS-MET coverage is not adequate. These products are being produced by CIRA/ Colorado State University and distributed on the internet at: http://amsu.cira.colostate.edu/gpstpw .
A separately produced global Blended TPW product only over the oceans using SSM/I and AMSU data can be found at:http://amsu.cira.colostate.edu/TPW .
A Blended TPW and Anomaly product as shown in figures 1***d*** and 2, respectively, are expected to become operational in February 2009. It is hoped that additional TPW data sets, like the one shown in figure 3, from research and operational satellites, will be included in the operational blended products beyond 2009.

**Future SSMI/S, AMSU or ATMS Satellite Sensors' TPW Imagery (land/ocean)**

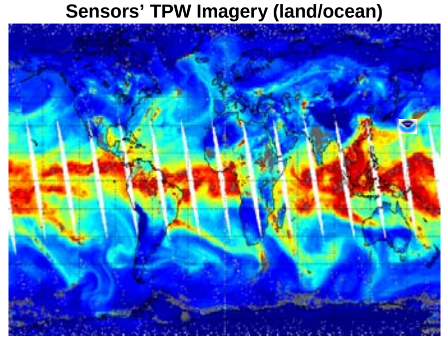


Fig. 3. Microwave sensor TPW data/imagery (land and ocean) in the future that could be included in the operational global blended products.

**3. OPERATIONAL EXAMPLE OF THE USE OF BLENDED TPW PRODUCTS FOR HEAVY PRECIPITATION/FLOOD FORECASTING**

During the later half of June 2006, the Blended TPW and Anomaly products were used operationally by NESDIS analysts to help identify and convey to forecasters on the East Coast of the United States conditions that could result in heavy precipitation and subsequent flooding. Since most of the precipitable water in the atmosphere exists from the surface to 3km (Kusselson, 1993), TPW has been useful for locating concentrations of high low-level moisture (sometimes referred to as the "TPW plume" or "Atmospheric River"). This TPW plume (Ralph, et.al, 2004) is one of the most recognizable satellite signatures of potential heavy rainfall that can lead to flash flooding.

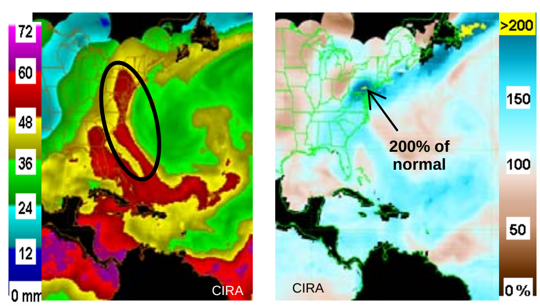
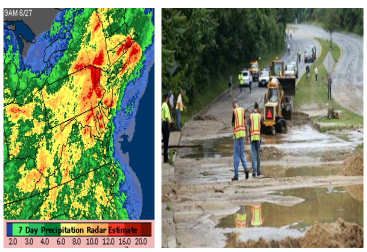



Fig. 4. Blended TPW on left and complimentary TPW Anomaly product on the right from the morning of June 25, 2006.

The left panel of figure 4 shows the Blended TPW product and the black oval highlights the low level moisture plume that extended from the western Atlantic Ocean to the Mid-Atlantic region of the eastern United States. At the same time on the right panel of figure 4, the Blended TPW Anomaly product showed an anomalous TPW area of around 200 percent of normal that was centered over the Mid-Atlantic region. This helped NOAA/NESDIS Satellite Analysis Branch (SAB) analysts focus on this area for potential heavy rain generation and flash flooding and alert NOAA/NWS forecasters of their concerns. During the following 24 to 48 hours, heavy rain developed and increased and subsequent flooding occurred. The results below in figure 5 were an area of 200 - 400 mm of rain that fell through June 27 (left panel); middle panel showing flooding of a major highway in the Maryland suburbs of the Washington, D.C. metropolitan area that resulted in at least one drowning and major problems for rush hour commuters; lead author's observed rainfall (to the right of middle panel picture) at his home in Montgomery County, Maryland. This case serves as a strong proxy to continuing further research in producing reliable polar-orbiting microwave TPW data overland to supplement the ground-based GPS-MET and GOES sounder imagery.




**Rainfall from Silver Spring, Montgomery County, MD**

**217 mm** - 24h totals thru AM Jun 26

**296 mm** - 48h totals thru AM Jun 27

**323 mm** - 84h totals thru AM Jun 28

Fig. 5. Storm rainfall through 13 UTC Jun 27, 2006 on left; highway flooding in Maryland suburbs of Washington, D.C., in the middle panel; the author's rainfall amounts from Silver Spring, Montgomery County, Maryland (far right).

## 4. FUTURE BLENDED TPW FOR MONITORING A PREDECESSOR RAINFALL EVENT (PRE)

A Predecessor Rain Event or "PRE" is a heavy rain event that can form unexpectedly well in advance of a landfalling and/or near-coastal tracking tropical cyclone (Cote, et.al, 2007). To the right there is a series of Blended TPW images between 18 UTC August 17 and 06 UTC August 19 showing the low level moisture or area of high TPW associated with Tropical Storm Erin. This deep tropical moisture from the remains of Erin, when combined with mid-latitude forcing well away from center, probably helped produced the "PRE" and record rainfall results in the upper Midwest as shown in Figure 7 on the next page.

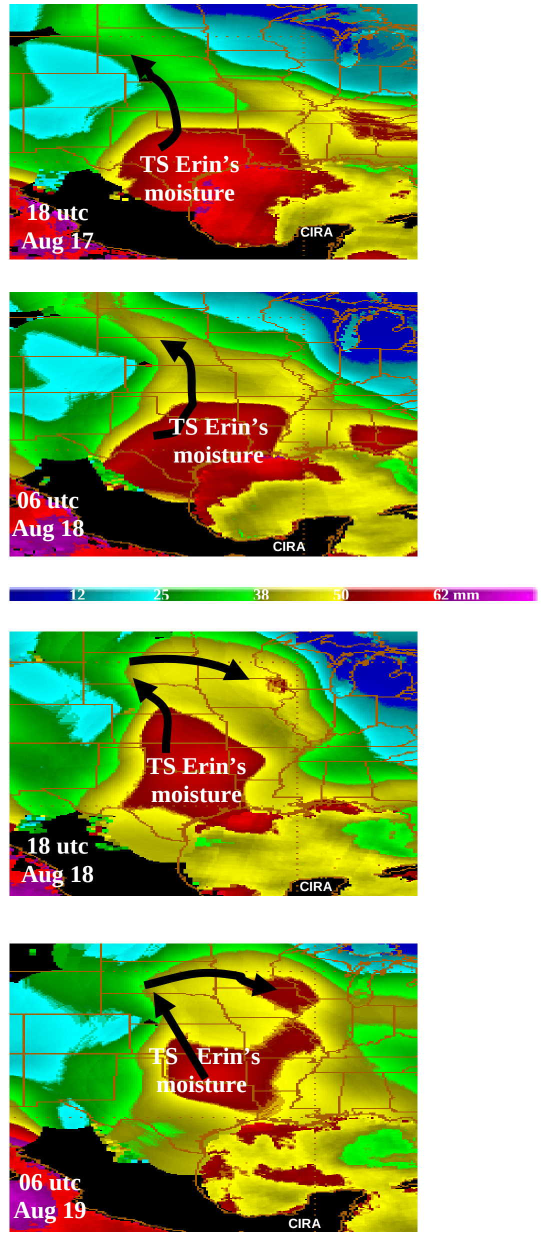
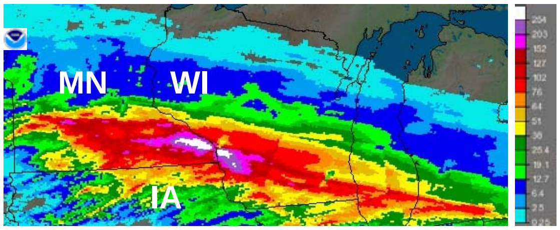



Figure 6. Sequence of Blended TPW images showing progression of moisture from TS Erin in Texas/southern Plains to northern latitudes.




Rainfall 12 UTC Aug 18 to 12 UTC Aug 19, 2007

**Record Rainfall Results:**

**24hr rainfall record for Minnesota: 384mm (15.11")** ending 12 UTC August 19, 2007 near Hokah in Houston County, Minnesota

Figure 7. Record rainfall results from "PRE" interacting with other meteorological factors.

## 5. SUMMARY AND FUTURE

Global blended remote sensing derived TPW products are tools that are already helping NOAA scientists better analyze and forecast precipitation and issue critical flood/flash flood watch/warnings in a timely manner. These products continue to evolve and develop with the help of a unique collaboration between the research and operational forecasting/ satellite analysis communities. Shown in this paper was the evolving of a Blended TPW and companion TPW Anomaly product with heavy precipitation case study examples that led to flood/flash flooding. Future improvements to the products include: blending microwave retrievals overland with the current Western Hemisphere ground-based GPS-MET/GOES sounder data and expanding retrievals overland to the Eastern Hemisphere; the addition of more European Meteorological Satellite Organization (EUMETSAT) METOP AMSU satellites in 2011 and beyond; new satellites, including the NPP and NPOESS Advanced Technology Microwave Sounder (ATMS) in 2011 and 2013, respectively, that could provide more frequent updates and improved latency to the products. The Blended TPW products will be operational very soon and it is anticipated that familiarity and applications of these products will continue to progress so that forecasters will be able to use the improved imagery more efficiently with other meteorological data sets. This will hopefully result in improved forecast locations and lead times for precipitation, especially heavy precipitation that could result in flooding, thus further enhancing NOAA's mission of protecting lives and property.

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