P5.10 BLENDED SATELLITE PRODUCTS FOR OPERATIONAL FORECASTING

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1. INTRODUCTION

Forecasters need not observations from a single satellite, but meteorologically significant data fields blended from all available satellites. In this paper we detail our process for blending total precipitable water (TPW) data from the Advanced Microwave Sounding Unit (AMSU) instruments on three NOAA satellites (Weng et al. 2003) with data from the Special Sensor Microwave/Imager (SSM/I) instruments on three Defense Meteorological Satellite Program (DMSP) satellites (Ferraro et al. 1996) to form a unified product. The process involves applying corrections to ensure that the data from different satellites are compatible, mapping the data on an orbit-by-orbit basis to a convenient projection, and compositing the mapped data into a combined product in a suitable format for use in operations. In addition, the computer processing environment in which the products are produced is discussed. Nearly global, Mercator TPW composites are constructed hourly and made available in real time to forecasters at the Satellite Services Division of NOAA's National Environmental Satellite and Information Service.

2. CORRECTIONS

When constructing mapped products for forecasters, it is important to prepare the data in such a way that the meteorological fields are emphasized and that artifacts in the retrieval or mapping or compositing of the data are minimized. When one thinks of making corrections to data, one usually thinks of removing biases and, perhaps, adjusting the standard deviations. This works well for data which are normally distributed and for which there is a standard, that is, for which "truth" is known. TPW data from different satellite instruments do not fit this description. First, a "truth" data set is not readily available; and, second, TPW retrievals from the two instruments differ in a non-normal way from each other. To solve this problem, we developed a technique to make the probability distribution function (PDF) of the SSM/I TPW data look like the PDF of the AMSU TPW data. We call this our Pentad PDF correction.

The first step in the process is constructing histograms of TPW values for a five-day period. A histogram is constructed for each satellite instrument at each scan angle. The assumption is that in a five-day period, each scan position of each instrument will observe the global distribution of TPW. While we do not know what the true TPW distribution is, we can choose one set of observations to be "truth" and calculate a correction to be applied to all observations that will make the distribution approximate the "truth" distribution. We choose to use the average TPW PDF of the three AMSU instruments (scan positions 6–25 only) as the "correct" PDF, and we call this PDF "Truth."

The second step in the correction process is constructing the "Truth" PDF. The cumulative "Truth" PDF for the five day period ending at 2245 UTC on 19 July 2004 is shown in Fig. 1 as the blue line.

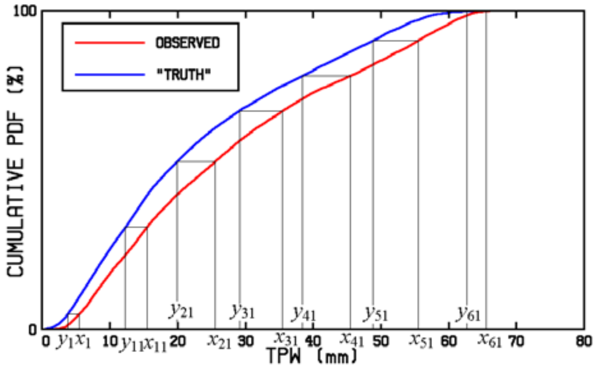

Figure 1. Illustration of the polynomial correction procedure.

The third step in the process is the construction of a correction for each scan position of each instrument (3 SSM/I instruments × 64 scan positions + 3 AMSU instruments × 30 scan positions = 282 corrections). The red line in Fig. 1 shows the cumulative PDF for scan position 32 on the DMSP F13 SSM/I for the time period above. (The "Truth" PDF is the same for each of the 282 corrections.) The TPW histograms are tabulated with 1-mm-width bins centered at 0.5 mm, 1.5 mm, etc. For each bin from 5.5 mm to 68.5 mm (the 64 x_i values) a y_i is interpolated such that the observed cumulative PDF has the same value as the cumulative "Truth" PDF. This step is illustrated in Fig. 1 for a subset of the x_i and y_i values. Note that the SSM/I TPW values are generally higher than the AMSU TPW values, so the SSM/I values need to be adjusted downward to match the AMSU "Truth." Finally, a cubic polynomial is fit to the $(x_i,\ y_i)$ values, and the 282 sets of four polynomial coefficients are stored for use during the correction procedure. Applying the correction is a simple process of selecting the coefficients (as a function of satellite and scan position), using the observed TPW as x, and calculating y. Figure 2 shows the resulting cumulative PDF (dashed line) for the data shown in Fig. 1.

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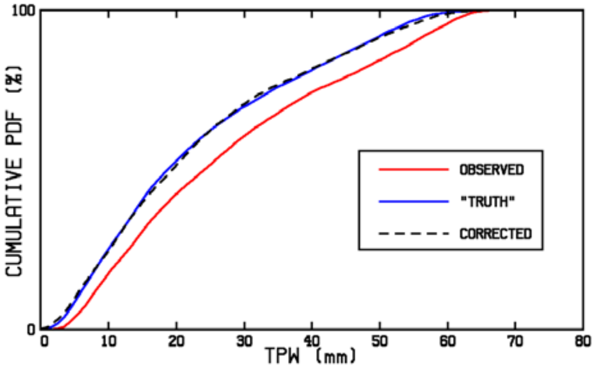

Figure 2. The dashed line shows the results of correcting the observed TPW data with the polynomial correction.

3. MAPPING

The base map which we use was chosen to be compatible with the mapped data at the NOAA/NESDIS/OSDPD Satellite Services Division (SSD). It is a Mercator projection with 16 km resolution at the equator. The map is centered at the equator and 160° west. It has 1437 lines and 2500 elements, which covers the earth from about 71° north to 71° south.

The TPW data that we receive from NESDIS are in files which represent approximately one orbit. The SSM/I is a conical scanner, and the AMSU is a cross-track scanner. Before mapping, the TPW value for each scan spot is corrected with the cubic polynomial correction described in Section 2. Then each scan spot is mapped by filling a quadrilateral that represents the scan spot. The SSM/I quadrilaterals are 25 × 25 km, and the AMSU quadrilaterals are 48 × 48 km at nadir and approximately 79 × 143 km at the edges of the scan. The quadrilaterals are contiguous both along the scan lines and from scan line to scan line. Thus, the resulting map has no holes within the scanned area. (However, because the microwave swaths do not overlap near the equator, there are gaps between adjacent swaths.). Figure 3 shows TPW values from a single orbit of DMSP F13.

In addition to mapping the TPW value, we map the time that the scan spot was observed and the satellite which observed it. When the single orbits are composited (see next section) these additional mapped values help interpret the data.

4. COMPOSITING

Satellite data may be composited or blended in a variety of ways depending on the use to which the blended product is to be put. Perhaps the most common way to blend data is to average them over a specified time period. Figure 4 shows the TPW from three AMSU instruments and 3 SSM/I instruments averaged for a 12-h period ending at 2030 UTC on 21 July 2004. Because data from six satellites are used in the composite, there are few places which are unobserved, which is the goal of compositing—one wants to know the water vapor field for the entire globe, not simply the field as observed by a single satellite in one orbit, as in Fig. 3.

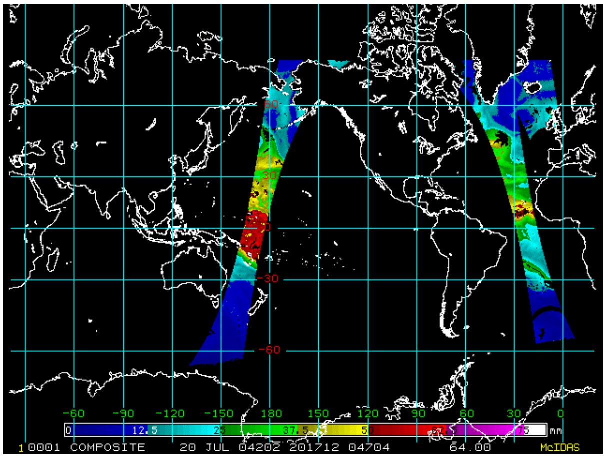

Figure 3. Corrected and mapped TPW values during one orbit of the DMSP F13 satellite.

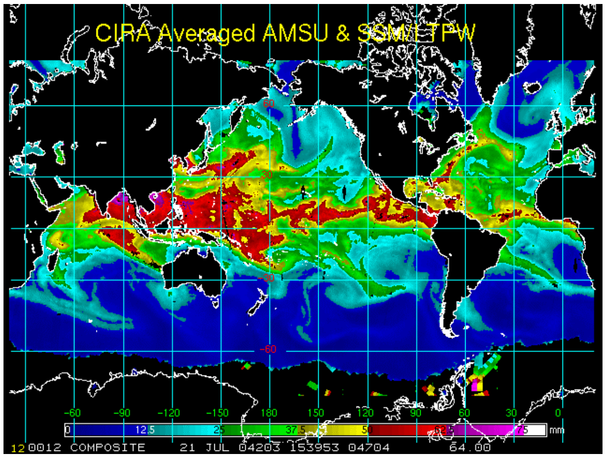

Figure 4. Average TPW for the 12-h period ending at 2030 UTC 21 July 2004. Approximately 30 orbits went into this composite

Another way to composite data is to overlay newer data on top of older data; only the latest data are displayed. This method of compositing is favored by forecasters because it is the most up-to-date image possible. Figure 5 shows an overlaid composite for the same time period as the averaged composite in Fig. 4. A disadvantage of the averaged composite, from the forecaster's point of view, is that averaging "retards" weather systems; that is, a moving weather system, if observed more than once in a 12-h period, will appear to be "behind" it's position in the overlaid composite. An advantage of the averaged composite is that it is smoother than the overlaid composite. The Data Processing and Error Analysis (DPEAS) software (see Section 5) which we used to construct these composites is also capable of doing a weighted average of the observations, with older observations being weight less than newer observations. This method is "between" the averaged product, which has uniform weights for every data point, and the overlaid product, which weights the newest observation one and all older observations zero.

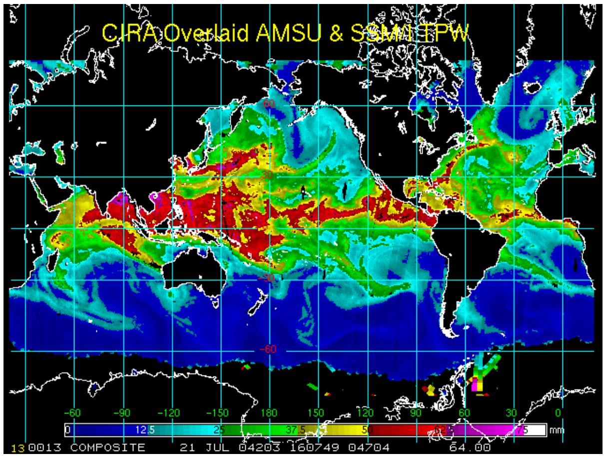

Figure 5. Overlaid TPW for the 12-h period ending at 2030 UTC 21 July 2004 (only the most recent datum at a point is shown). Approximately 30 orbits went into this composite. Note that the correction described in Section 2 has removed the “seams” in the data caused by different instruments observing adjacent locations. In other words, one cannot pick out the individual orbits in the composite.

When the overlaid composite is constructed, we can optionally map the time of the most recent observation and the satellite which made it. These data are useful for analyzing the resultant TPW field. Figure 6 shows the mapped times. The individual orbits are clearly shown, as are the older data. Figure 7 shows the satellite which made the observation.

5. PROCESSING ENVIRONMENT

The TPW composites are produced in real-time using DPEAS (Jones and Vonder Haar 2002). The system runs on a cluster of Windows NT computers. Each hour, new AMSU and SSM/I data are acquired from NESDIS, the corrections are constructed, the data are mapped, and the composites are formed. The system handles about 200 GB of data per day. The DPEAS reliability exceeds 99.97% due to its fault-resilient, grid-computing capabilities. Internet reliability and other non-DPEAS issues reduce the total aggregate system reliability to approximately 98%.

6. SUMMARY AND CONCLUSIONS

Satellites offer the only way to observe the global distribution of some meteorologically important parameters. Forecasters need these parameters to make informed forecasts. When constructing these products, it is important to remember that forecasters need products that are accurate, reliably produced, readily available, and are free of distracting artifacts This paper has show how we blend TPW observations from six satellites in real time to produce nearly global, hourly TPW analyses for use by forecasters at SSD and elsewhere.

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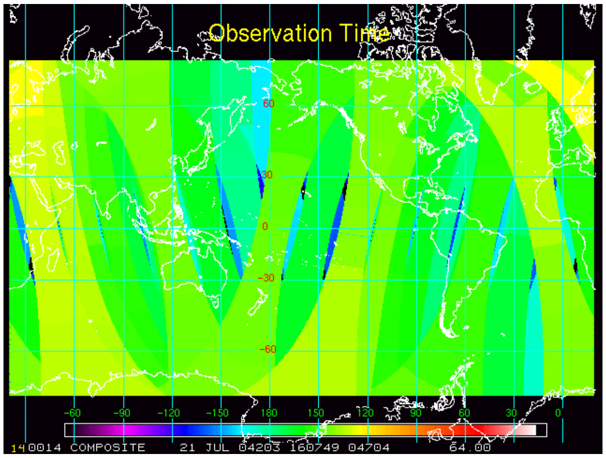

Figure 6. Time of latest observation for the composite shown in Fig. 5. The times are UTC to the nearest 10 minutes. Using the color bar (left is 0000 UTC, right is 2350 UTC), one can get an approximate idea of the time of observation. We use McIDAS to display the data, and with the IMGPROBE command, one can get the precise time (within 10 min) of each point.

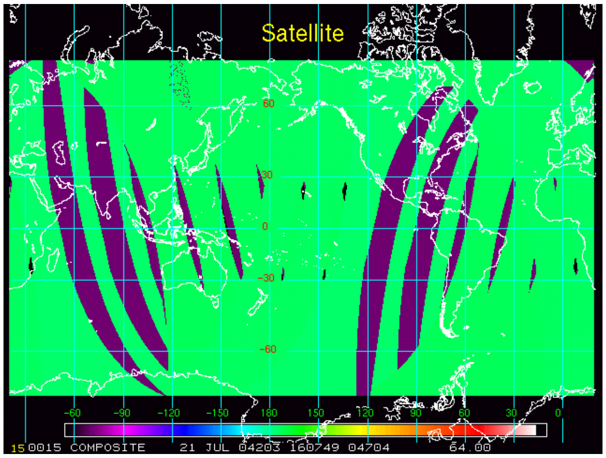

Figure 7. The satellite which made the observations plotted in Fig. 5. Green points were observed with AMSU, purple points were observed with SSM/I. Using the IMGPROBE command in McIDAS, one can discover which NOAA satellite (NOAA 15, 16, or 17) made the AMSU observations and which DMSP satellite (F13, F14, F15) made the SSM/I observations.

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