Tropospheric Moisture Retrievals from HIRS, MODIS, and VIIRS plus CrIS

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Abstract

Tropospheric moisture data records derived from HIRS and MODIS are compared from 2003 to 2013 and from VIIRS plus CrIS fusion and MODIS for one year 2017. Tropospheric Precipitable Water (TPW) and Upper Tropospheric Precipitable Water (UTPW or UTH) are derived using infrared spectral bands in CO2 and H2O absorption bands (fusion with CrIS has recently added these bands to VIIRS plus IR window bands. Retrieval of TPW and UTH uses a statistical regression algorithm performed using clear sky radiances (and brightness temperatures) measured over land and ocean for both day and night. TPW and UTH seasonal cycles of all three observing systems are found to be in synchronization with zonal mean values in good agreement.

Processing Moisture Products

All three moisture records include total column precipitable water vapor (TPW) as well as integrated high (UTH), mid, and low layer tropospheric precipitable water vapor. The statistical regression is developed from an atmospheric profile database that consists of geographically and seasonally distributed radiosonde, ozonesonde, and ECMWF reanalysis data. TPW and UTH are determined for clear sky radiance (and brightness temperatures, BTs) over land and ocean for both day and night at 1-day spatial resolution with monthly average values for one of four possible time periods daily (night before and after midnight and day before and after noon), compiled for the operational months of each satellite. The regression coefficients are generated using calculated synthetic radiance and the matching atmospheric profile. The regression seeks a "best-fit" atmospheric profile that is computed using least squares methods applied to actual measurements. Integration over the total column yields TPW and integration from 440 to 1500 nm gives the UTH. The Aqua MODIS and S-NPP VIIRS equator crossing time has been maintained at 13:30 Local Time (LT) for NOAA-16, -18, and -19 from 14:00 to 15:00 LT during their operational lifetimes. VIIRS plus CrIS fusion products are compared to MODIS for one year in 2017 (below) and HIRS and MODIS are compared from 2003 to 2013 (right).

VIIRS plus CrIS Fusion Creating MODIS-like Radiances

Retrieval of atmospheric WV properties from VIIRS measurements from S-NPP is accomplished using IR absorption bands constructed through fusion with the CrIS data. Weiss et al. (2017) demonstrated a fusion method to construct IR water vapor and carbon dioxide absorption bands for VIIRS at 750 nm spatial resolution. Mean clear-sky VIIRS-CRS fusion minus MODIS BT differences are found to be less than 0.5 K (1.0 K) for MODIS CO2 (H2O) for IR B7s ranging from 202 to 285 K.

VIIRS Fusion and MODIS TPW (left) and UTPW (right) Comparison (1 day)

Global one day mean of TPW derived from the VIIRS+CrIS is found to be 0.3 mm too low with a scatter of 3.3 mm when compared to the MYD08 TPW; VIIRS+CrIS is a bit higher in the tropics and lower in the mid-latitudes. UTPW derived from the VIIRS+CrIS is found to be 0.2 mm higher than 0.14 mm when compared to the MODIS UTPW. Local differences of 1.1 mm are found in the tropics.

VIIRS Fusion and MODIS TPW (4 seasonal months)

VIIRS-CRS TPW differences with respect to MYD08 TPW are shown for January, April, July, and October 2017. Mean agreement ranges from 0.1 mm in April and 0.4 mm in October; the standard deviation is largest in July at 1.8 mm. Local VIIRS-CRS correspondences occur over Australian desert in January and during the Indian monsoon in July; underestimation is found in the Brazilian rainforest and the ICTZ in January and the Saharan desert in July. Overall VIIRS-CRS+MODIS agrees very well with MODIS TPW for all four months representing the four seasons.

References:


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HIRS and MODIS TPW (left) and UTPW (right) Comparison (11 yrs)

Month to month changes in TPW detection for each instrument for three latitude bands (mid latitude north 30 to 60 N, tropics 30 N to 30 S, and mid latitude south 30 to 60 S). Tropical TPW shows relatively constant in time (for MODIS ~36 mm and HIRS ~34 mm). In both, northern mid-latitude TPW remains constant in year, with southern mid-latitude TPW having the northern mid-latitudes have a water maximum as well as a drier minimum each year (seasonal change of 17 mm) compared to the south mid-latitudes (seasonal change of 7 mm). Month to month changes in UTPW detected by MODIS and HIRS show similar features. Tropical TPW shows no discernable seasonal range, northern mid-latitude UTPW seasonally varies (seasonal change of 0.45 mm) out of synchronization with the southern mid-latitude UTPW (0.22 mm). Dotted lines show HIRS transition years.

The largest TPW values are found in the tropics, with a seasonal maximum in the northern hemisphere in the mid-year (June–July–August, JJA) that shifts to the southern hemisphere in the second half of the year (December–January–February, DIF). Both MODIS and HIRS show a strong seasonal fluctuation, with the mid-year northern hemisphere maximum somewhat smaller than the southern hemisphere maximum six months later. Differences between HIRS and MODIS TPW amount to as large as 5 mm (roughly 5%) in N, 3 mm (roughly 3%) in S; MODIS and HIRS show some notice (less than 2 mm, 10%) in JJA and DIF. The maximum mean UTPW decrease of 1.4 mm has been pointed out in the literature, the clear sky condition imposed on infrared TPW and UTPW determinations is necessarily introducing a dry bias by avoiding the cloudy regions associated with higher humidity.

Conclusions

• TPW & UTPW retrieved from hyperspectral sounder CrIS measurements and provided at VIIRS high spatial resolution (753m) from Suomi-NPP compare favorably with colocated operational Aqua MODIS moisture products.

• For January 2017, global mean of VIIRS+CrIS fusion TPW is 0.2 mm too high with a scatter of 1.4 mm when compared to the MYD08 TPW. TPW results are similar for a month in each season of 2017 (Jan, Apr, Jul, & Oct).

• VIIRS-CRS UTPW, now possible with the addition of the fusion radiances, is within 10% of the MYD08 UTPW in mean and scatter for the same four months.

• While limited in scope, these one year findings demonstrate fusion IR absorption spectral bands enable generation of moisture products that offer record continuation from MODIS and previous generations of polar orbiting satellite sensors.

• HIRS and MODIS Hovmoller plots for 2003 to 2013 suggest overall good qualitative agreement in the seasonal changes with max disagreements of 5 mm in TPW and 20% in UTPW amounts

• MODIS and HIRS tropospheric moisture records compare very well implying that HIRS TPW and UTPW determinations from the MODIS years can be a bridge to the years of HIRS data that go back to 1980.

• TPW and UTPW seasonal cycles of all three observing systems are in synchronization with zonal mean values for 1 deg latitude bands for the same four months.

The usefulness of combining HIRS, MODIS, and VIIRS+CrIS offers a moisture record that will eventually span more than sixty years.