ALGORITHM MAINTENANCE AND VALIDATION OF MODIS CLOUD MASK, CLOUD TOP-PRESSURE, CLOUD PHASE AND ATMOSPHERIC SOUNDING ALGORITHMS

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Introduction

The goal of this work is to maintain, validate and refine four Terra and Aqua MODIS algorithms: cloud mask (MOD35/MYD35) and associated clear sky composite maps, atmospheric profiles (MOD07/MYD07), cloud top properties (CTP) including cloud-top pressure, temperature, and phase (part of MOD06/MYD06). Maintenance requires (a) monitoring changes in calibration and associated adjustment of cloud detection thresholds, (b) considering replacement channels when primary channels exhibit calibration problems, and (c) continuing validation through comparisons with products from other satellite based algorithms, ground-based observations and focused field experiments.

The team has focused on monitoring results and processes associated with of Collection 6 code. This is accomplished through comparison with other satellite derived products as well as surface based platforms and through monitoring trends. The team also interacts with the MODIS processing team as they make modifications to the processing stream or ancillary data. This report summarizes results for the 1st year of this work.

Activities

Working with Drs. Foster and Heidinger and Mr. Maddux, we compared cloud cover trends from MODIS with other satellite missions. This was published in BAMS (Foster et al, 2015) and some of the activity is summarized here. Global mean annual cloudiness anomalies from seven satellite records and three reanalysis products are shown in Figure 1. The PATMOS-x (Pathfinder Atmospheres Extended) and MODIS C6 (Moderate Resolution Imaging Spectroradiometer Collection 6) records showed global cloudiness to remain stable relative to 2013 (less than 0.1% difference) while the MODIS C5 (Collection 5) record shows an increase of 0.6%. Differences between MODIS C5 and MODIS C6 can be attributed to updates in calibration and cloud masking in Collection 6. ISCCP (International Satellite Cloud Climatology Project), HIRS (High Resolution Infrared Sounder), CLARA-A1 (Cloud, ALbedo and RAdiation dataset), and MISR (Multiangle Imaging Spectroradiometer) are also shown though they currently do not extend through 2014 (MISR has an annual cloudiness anomaly for 2014 but at the time of this writing was only processed through August). Reanalysis estimates from ERA-Interim, JRA-55 and NCEP-CFSR are also provided.

Historically, 2014 was 1.8% less cloudy than the 34-year PATMOS-x record mean, the primary data set used here. It replaced 2013 as the sixth least cloudy year. The satellite and reanalysis records are in good agreement during the common reference period of 2000-2008, but there is more variability in the earlier part of the record. Much of this difference may be due to the availability of advanced satellites with more stable calibration in recent years, though it is possible that increased variability in earlier years may be in part attributable to specific events.

For example, 1982 and 1991 saw the eruptions of El Chichón and Pinatubo respectively. ENSO variability also affects global cloudiness (see Foster et al 2015). Hence, the strong El Niños in 1982-1983 and 1997-1998 may also have contributed. In addition, variability in the CLARA-A1 and HIRS records may in part be due to satellite drift. A correction term has been applied to the PATMOS-x record in an attempt to account for this issue (Foster and Heidinger, 2013).

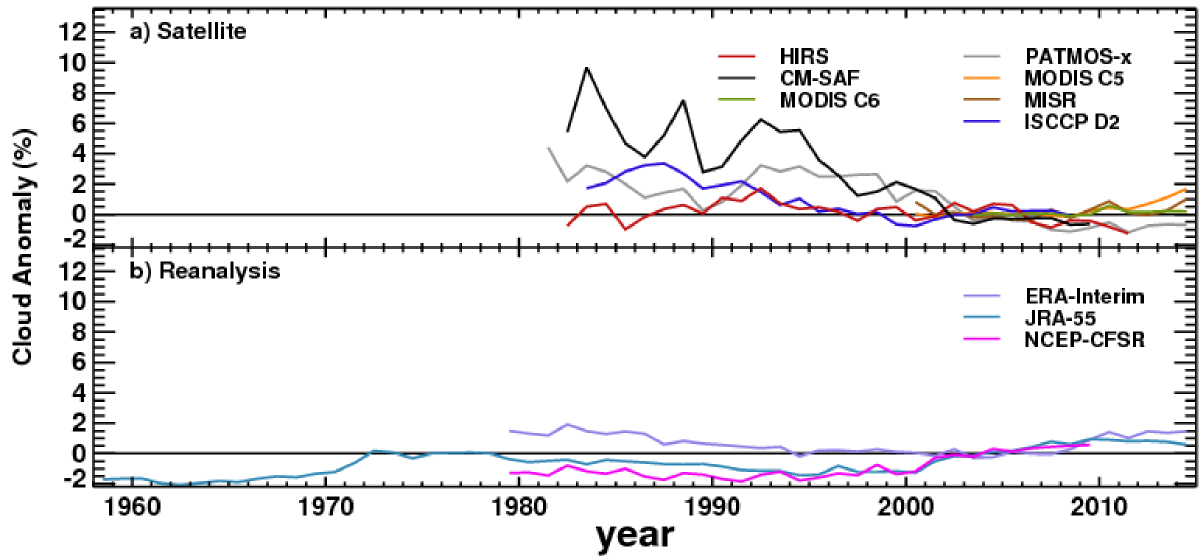
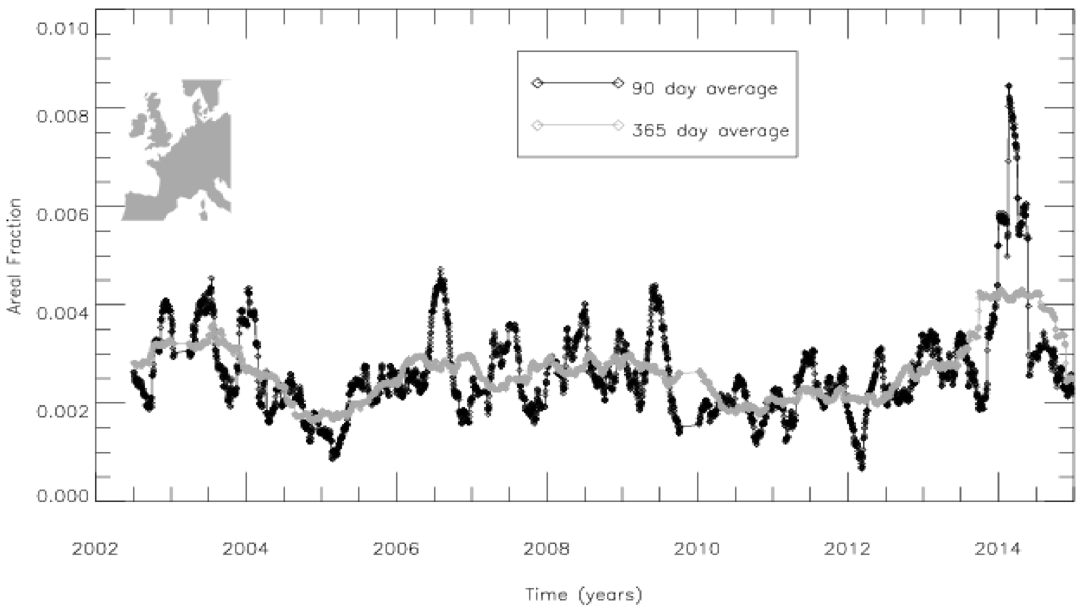


Figure 1. Annual global cloudiness anomalies for 1981-2014. The anomaly is defined as the annual value minus the mean, derived between 2000 and 2008, a period common to all of the satellite records included here except MODIS C6 where 2003-2008 is used. a) The datasets include: MODIS C5, MODIS C6 (Ackerman et al., 2008), and MISR instruments (Di Girolamo et al., (2010). MISR is located on NASA's Terra satellite and spans 2000 to present while MODIS instruments are located on both Terra and NASA's Aqua satellite, which spans 2003 to present. MODIS C5 includes both Aqua and Terra data, while the version of MODIS C6 shown here includes only Aqua data. Also included are ISCCP data (derived from the imaging radiometers on the operational weather satellites of several nations); HIRS (Wylie et al., 2005); CLARA-A1 (Karlsson et al., (2013) from AVHRR data covering 1982 through 2009); and PATMOS-x (Heidinger et al., (2013) also derived from the AVHRR imager record but covers 1981 through present). b) Reanalyses data from ERA-Interim (Dee et al. 2011b), JRA-55 (Kobayashi et al., 2015) and NCEP-CFSR. See Foster et al 2015 for details.

In addition to the total cloud amount, satellites detect deep convective clouds (DCC). DCC are defined here as convective clouds which reach the tropopause and often enter the stratosphere. They often indicate severe weather and intense precipitation. The method used to detect DCC is that given by Schmetz et al. (1997) and this method was applied to the MODIS C6 record. Figure 2 shows two DCC time-series over Western Europe and Brazil. Both of these regions experienced a 2014 that was warmer and less cloudy than average. Climatologically, DCC occurrence in Western Europe is clearly rare relative to Brazil. However, for Western Europe, the first-half of 2014 showed a DCC fraction that was much larger than seen in the previous twelve years. These intense convective events caused significant weather-related damage. In Western Europe, the warm and less cloudy conditions may have favored the abovenormal DCC occurrence in 2014. In Brazil, the DCC annual cycle is much stronger than in Western Europe. The DCC time-series shows that Brazil in 2014 had the smallest DCC fraction since 2010. Brazil suffered major drought conditions in 2010 and again in 2014. It appears that the increased surface heating in 2014 over Brazil did not increase the occurrence of DCC.



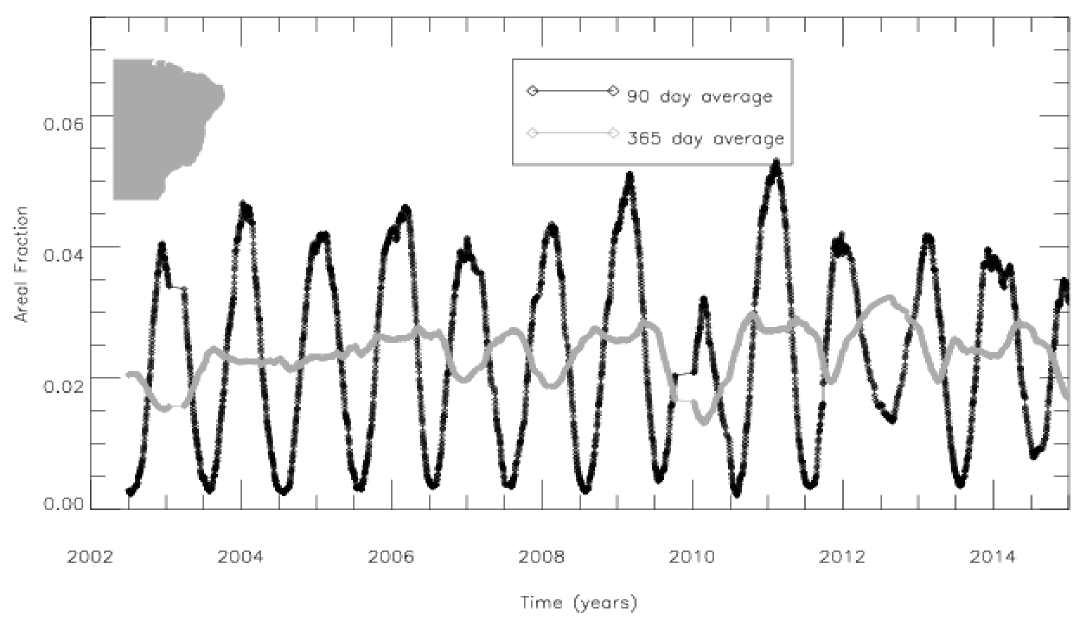


Figure 2. Time-series of areal fraction of deep convective cloud determined from MODIS/AQUA data over Western Europe (top) and Brazil (bottom). Deep convective cloud is defined as convective clouds that reach the tropopause. The black curve is a seasonal average and the grey curve is an annual average.

Cloud Mask (MOD35/MYD35)

As part of our routine assessment, we have Google Alerts send e-mails with the links of any web site that mentions "MODIS" and "clouds" in the same document title. An 8-day composite of Terra MODIS cloud top temperature came across and an imaged should that the entire Gulf of Oman and the northern Arabian Sea were almost completely cloudy for 8 straight days with surface-like cloud temperatures. We've identified the likely cause of the problem in the Terra cloud mask. The day and night ocean 8.6-11 micron BTD test is over-detecting clouds. The calibration team has observed a very slow warming trend in the measured 8.6 micron radiances relative to those from 11 microns for some time. Apparently, this warming has finally caused the 8.6-11 test to fail (report false clouds) in many scenes. The problem is masked to a certain extent by clear-sky restoral tests where clear pixels are reported as "probably clear" instead of "confident clear". This effect is seen in many ocean granules at least since the beginning of 2015. As a temporary fix, we have modified the threshold files to account for this drift in the thermal channel.

Calibration

Figure 3 is a composite of the trending plots for Terra MODIS and for Aqua MODIS (from Moeller et al. 2014). These comparisons are SNOs (with MetOp-A IASI) and thus do not cover a global domain. While these comparisons do show a clear trend in band 29, the impact on the cloud mask raise a question if the near-Polar SNOs are truly representative of the trends in equatorial zone (warmer temperatures, much additional moisture). Its speculated that the trend could be a result of electronic crosstalk influence in the PVLWIR bands (27-30) so the electronic crosstalk influence could be different in very moist atmospheres of the tropics than it is in the near polar drier atmospheres. This continues to be explored and will be discussed at an upcoming MODIS calibration and science team meetings.

Thermodynamic Profiles (MOD07/MYD07)

The following problems have been identified and scientific tests have been evaluated related to the MOD07 products.

1. Improper night time GDAS file selection for MOD07 has been identified
2. Unstable Atmospheric Profile Retrievals over Antarctica (low impact meter) have been found
3. Cross-talk to Terra MODIS band 27 has been identified via inter-calibration with IASI (gradual drift of calibration causing TPW issues)
4. Science test of new TOAST input data has been evaluated
5. E-mail support of the MOD07 user community (~20 requests/questions per year)

1. Forward stream processing has been corrupted for both Terra and Aqua MOD07 after March 13, 2014 and reprocessing all Aqua MOD07 data. Improper GDAS file has been selected as input for nighttime granules. The problem has been fixed by MODAPS .

2. Unstable Atmospheric Profile Retrievals over Antarctica have been identified in the MOD07 L3 products. In Collection 006, the cloud mask is failing to detect high thick clouds over the Weddell Sea area when it is ice-covered. This represents a small area in very dry conditions, but it is causing high and noisy retrievals (high standard deviation) in the integrated water vapor values (440-10 hPa) and unrealistic values in the retrieved temperature profiles and total ozone. Users with additional checks can filter out these problem pixels until this is fixed in the future PGE03 delivery.

3. Over a 14 year time series, three layers (high, low and mid) of integrated water vapor contents show a strong water vapor decrease globally in the middle layer, a smaller decrease in the low and the slight increase in the top layer mean water vapor. These large changes in the water vapor amount have been found to be due to the annual change of the crosstalk error in Terra MODIS band 27 (personal communication with Chris Moeller, MODIS Calibration Team). The MCST is working on the crosstalk correction of Band 27 and is going to facilitate some test L1B data (8 global days for 2005 and same for 2012) for further corrective study.

4. Science test of change of TOAST input data on three Terra and three Aqua MODIS global days has been evaluated. As expected there is no impact from this change on the PGE03 MOD07 products.

Work Plan

Continue monitoring performance of all relevant algorithms, including instrument performance, making adjustments as appropriate. We will be attending the upcoming MODIS/VIIRS team meetings in May 2015.

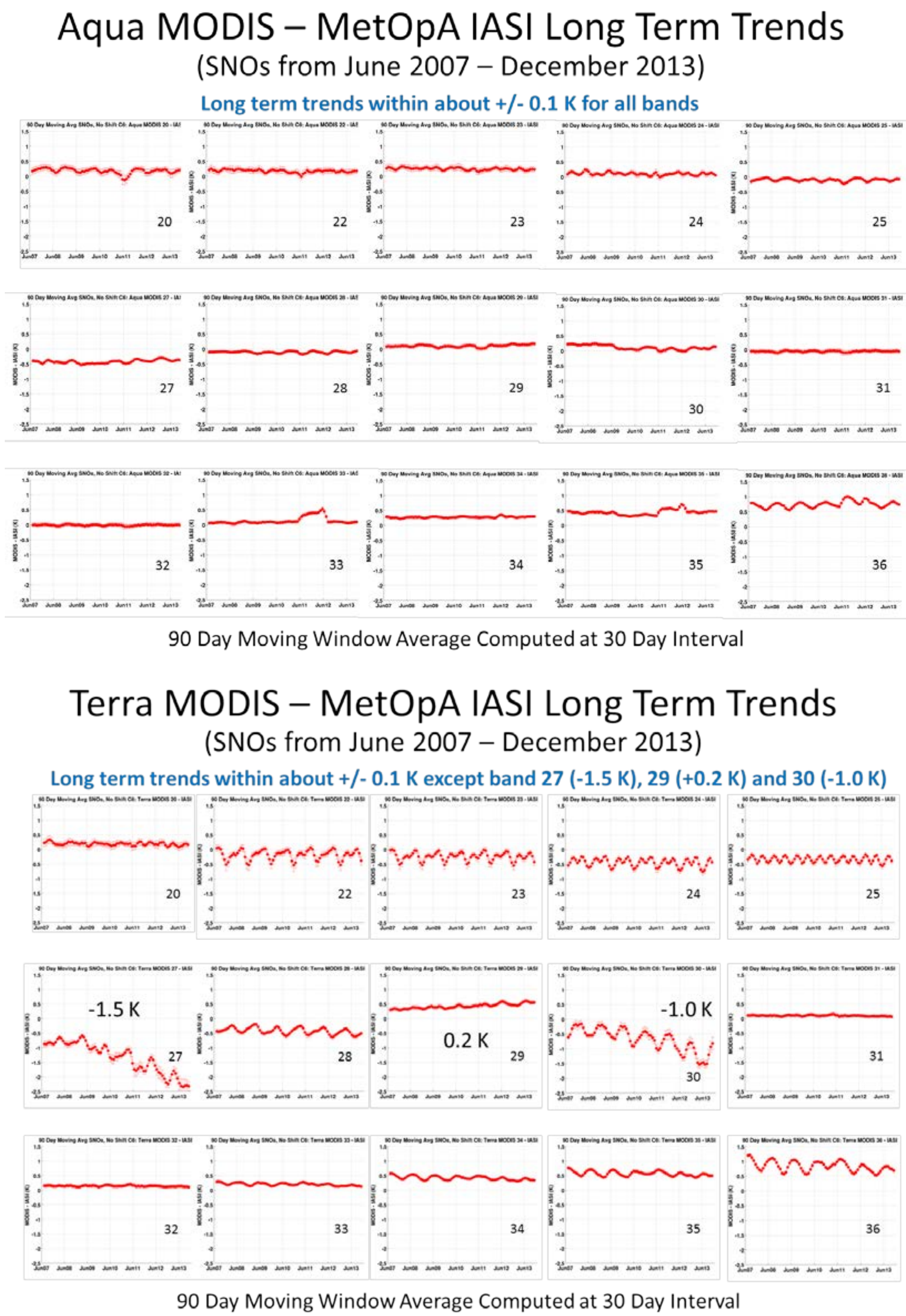


Figure 3. Aqua MODIS-IASI (top) and Terra MODIS-IASI (bottom) brightness temperature biases as a function of time for all SNOs from June 2007 - Dec 2013.

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