Investigating the effects of dry air layer intrusions on the accuracy of the MODIS SST retrieval algorithm using LBLRTM

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Objective

To quantify the effects that dry layers, such as the Saharan Air Layer (SAL), and the level at which they are located in the atmosphere, have on the retrieved MODIS SSTs.

Introduction

The algorithm used in obtaining SST from MODIS radiance measurements is based on statistical relationships between MODIS channels brightness temperatures and SST measured by ground instruments. The MODIS SST retrieval formula has the following form:

\[
\text{SST} = \alpha_0 + \alpha_1 T_\text{a} + \alpha_2 T_\text{c} - T_\text{a} + \alpha_3 T_\text{a} - T_\text{c} \sec \, \zeta \eta + \delta
\]

where \( T_\text{a}, T_\text{c} \) are brightness temperatures in MODIS channels 31 and 32. \( T_\text{a} \) is a reference or “first guess” temperature, which is often taken as the Reynolds SST (ref), \( \zeta \) is the satellite viewing angle, and \( \eta, \delta \) are coefficients. The coefficients are obtained from match-ups with buoy measurements and are particular to each satellite instrument.

In the currently used version of the SST retrieval algorithm (V5) the ‘a’ coefficients are derived separately for each month of the year. The new Version 6 (V6) of the algorithm that has been recently developed has coefficients depending on the month of the year and also the latitude band of the measurement in order to better capture the regional variability of atmospheric conditions between the sea level and the satellite.

The global accuracy of the V5 retrievals is about 0.5 to 0.4K. However, as with any statistical approach a question arises how good are these ‘a’ algorithm based retrievals if they are applied to conditions that depart from the ‘average’ that is represented in the statistical coefficients. Intrusions of Saharan air layer (SAL), for example, over eastern Atlantic are a seasonal phenomenon and represent such departure from average atmospheric conditions.

Approach

To assess the dry layer effect we conducted numerical simulations of MODIS retrieved SST for atmospheres with dry layers at various levels. We define the accuracy of the MODIS retrieval \( \text{ASSST} \) as the difference of MODIS SST retrieved \( (\text{SST}_\text{MODIS}) \) and the in situ SST \( (\text{SST}_\text{in situ}) \):

\[
\text{ASSST} = \text{SST}_\text{MODIS} - \text{SST}_\text{in situ}
\]

The dry layer effect is the difference between the MODIS retrieval accuracy for atmosphere with and without a dry layer. The procedure we employed is as follows:

1) We used the Line by Line Radiative Transfer Model (LBLRTM) of Clough, et al. at 1995 to compute the top of the atmosphere (TOA) radiance spectra in the infrared range. LBLRTM input data were:
   a) atmospheric profiles measured by radiosondes during research cruises conducted by the University of Miami Remote Sensing Group in Northern Atlantic (SAL region) in 2004 and 2006, and in the Tropical Western Pacific, north of Darwin, Australia (TWP) in 2006.
   b) sea surface temperatures were SSTs measured radiometrically from a ship by the Marine Atmosphere (EMI) Radiance Interferometer (M-AERI) by Minnett et al. 2001.
   c) atmospheric profiles of six other atmospheric species (CO2, O3, NO2, CO, CH4 and O2) were taken from the Standard Tropical Atmospheric.
   d) sea surface emissivity was found from http://dataواسطاء.is.esa.int/dipseed as a function of the emission angle, wind speed, and the SST.
   e) detector spectral relative spectral response functions (rsrs) were obtained from NASA MODIS webpage. The AQUA instrument values were used.

2) Channel 31 and 32 rsrs were applied to the LBLRTM simulated TOA radiance spectra to calculate the MODIS channel 31 and 32 radiances. These radiances were then converted to brightness temperatures \( T_\text{a} \) and \( T_\text{c} \) using Planck function look up tables for the central wavelength of each channel.

3) Two values of the MODIS SSTs were calculated for each set of brightness temperature \( T_\text{a} \) and \( T_\text{c} \) according to Eq. (1). SSTf and SSTs, corresponding to the version 5 and 6 of the ‘a’ coefficients. For this paper the LBLRTM simulations and the SST retrievals were performed for zenith measurements, i.e. a view angle of 0°.

4) V6 and V6 MODIS SST simulated accuracies, ASSSTf and ASSSTs were calculated according to Eq.2 where the in situ SSTs were the MAERI measured instruments used in the LBLRTM simulation.

Results

The average accuracies of retrievals version 5 and 6 were calculated for each class of profiles in all datasets according to the procedure outlined in section 2. The results are shown in Table 3 for SAL06 and TWP06 and in Table 4 for SAL04. The difference between the average measured total column water vapor (TWV) calculated by integrating the water vapor profile measured by each radiosonde, of a class of profiles and the STA total water vapor (TWVSTA = 4.08 cm) is also shown in Tables 3 and 4. This difference (ΔTWV) can be view as a measure of the departure of the actual measured atmospheric profiles from the standard conditions.

Summary and Conclusions

MODIS retrieved SSTs 6 is sensitive to dry layers in the atmosphere.

1) Retrieval coefficients chosen for best global fit are not necessarily the best for specific area, season, and conditions.

2) ASSSTs,6 depends on the amount of water vapor in the atmosphere TWV.

3) simulated MODIS SSTs,6 changes if intervening atmosphere is modified to dry layers.

4) dry layers in lower atmosphere increase ASSST,6

5) dry layers in upper atmosphere decrease ASSST,6

6) coefficients good for standard conditions not necessarily good for atmospheres with extensive or strong dry layers.

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