A new algorithm for dust detection over water utilizing the AVHRR imager

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1 Introduction

The Advanced Very High Resolution Radiometer (AVHRR) is one of the instruments onboard the NOAA series of Polar Orbiting Satellites. Because of the extensive temporal coverage, high spatial resolution (with a nominal resolution of 4 km) and daily global coverage afforded by these imagers, the opportunity exists to create not only a satellite dust climatology as the NOAA PATMOS data reprocessing commences (Jacobwitz 2003), but also a real-time dust coverage over water product. Furthermore, because current efforts for global cloud cover classification utilizing AVHRR regularly misclassify dust storms that extend over the world's oceans as cloud or clear-sky, also adversely affecting sea surface temperature retrievals, there is a need for an AVHRR global dust detection algorithm to act as a correction to current cloud masking efforts.

Airborne soil-derived aerosols are often variable in their spectral signatures due to differing chemical compositions (depending on the aerosol source regions) (Longtin 1988) and changing atmospheric conditions. Additionally, particle concentration and size distribution change as a dust layer is advected from the source region (Ackerman 1997). Despite these spectral variations dust outbreaks over water are detectable primarily via the brightness temperature differences between the 11 and 12 μm channels created by the warm air masses that advect the aerosols (Dunion et al., 2003). Beyond this there are many nuances between different dust plumes' spectral signatures that must be accounted for if there is to be a separation between dust outbreaks and clouds.

In this abstract the basis for a dust detection algorithm is presented relying on the spectral variability observed in dust plumes utilizing all 5 channels of the AVHRR imager. The goal of this work is to derive an algorithm that will consistently make a "dust-correction" to the current NOAA cloud masking efforts.

2 Algorithm

As a dust plume is advected over the oceans it was observed that a decrease in BT_{11}-BT_{12} accompanied the airborne aerosol. However, while an optically thick dust plume advected over water will initially depress BT_{11}-BT_{12}, as the optical thickness continues to increase it is observed that the BT_{11}-BT_{12} value will actually increase and may even change sign (Ackerman 1997). Further, suspended aerosols vary significantly in concentration (Kopke et al., 1997), which also acts to alter the observed BT_{11}-BT_{12} values. Additionally, as a dust laden air mass is transported away from the source region the plume spreads out spatially as it mixes with the surrounding air, often causing a large variation in the BT_{11}-BT_{12} values for a single dust event.

These variations in BT_{11}-BT_{12} are problematic if that depression is the sole basis for a dust detection algorithm as it is observed that a far greater surface area over the ocean, for most dust events, contains these less optically thick dust regions than the very thick regions with a highly depressed BT_{11}-BT_{12} value. Therefore, for the purpose of decreasing cloud misclassification and increasing SST retrieval accuracy, an algorithm should also be concerned with these dust-laden regions that do not produce as great a BT_{11}-BT_{12} depression.

Consistent with BT_{11}-BT_{12} observations, accurate classification of dust outbreaks was aided by separating plumes into two categories of optical thickness by establishing an $alb_{0.6}$ threshold, above which an increase in observed BT_{11}-BT_{12} values are primarily due to an increase in optical thickness, while below this threshold an increase in observed BT_{11}-BT_{12} values are more likely due to a decrease in particle concentration.

Another issue with the remote sensing of dust plumes is the variability of particle composition (Longtin 1988), shape (Zhoa et al., 2003) and size distribution. These observed qualities contribute to the fact that RT modeling, based on calculating the spectral properties of the aerosols with mie theory, has not consistently been able to predict the observed spectral signatures of various dust outbreaks. Therefore, the approach to algorithm development has largely consisted of using generalized aspects of dust outbreaks such as: $BT_{3.6}$-BT_{12} , $alb_{0.6}/alb_{0.8}$, Normalized Difference Vegetative Difference and $alb_{3.6}/alb_{0.8}$ with the thresholds for these values changing depending on the values of BT_{11}-BT_{12} and $alb_{0.6}$ for the pixel in question.

As warm water clouds at low latitudes present the largest source of misclassifying cloud as dust, another approach used relies on the spatial variability between aerosols and clouds where dust plumes are observed to have a higher uniformity in the visible channels (Remer et al., 2004). Due to the data processing technique in PATMOS the radiant and thermal uniformity of a 2 by 2 pixel array is calculated by taking the maximum value for any pixel cluster, subtracting the minimum value and then dividing this by the mean of the cluster.

Thresholds were determined based on observations made of a training set containing many different dust outbreaks in various parts of the world (GAO et al., 2003). The resultant algorithm has been tested on several days of full orbits during different times of the year to determine what types of atmospheric conditions would trip the dust mask when dust was not present. This information was then implemented into the dust algorithm in order to minimize false classification of dust while maintaining the maximum amount of positive dust classification and subsequent cloud misclassification in PATMOS. Issues still did persist regarding very warm and uniform water clouds, but these types of misclassifications are further suppressed by only labeling a pixel as dust if every pixel in a 2 by 3 array containing that pixel were also labeled as dust.

Validation of the algorithm is underway via RT modeling using a generalized dust refractive index and size distribution (Kopke et al., 1997), co-locating MODIS data that has been processed using a new MODIS dust algorithm (Remer et al., 2004) and co-locating with AERONET information gathered during large dust outbreaks.

3 Results

To illustrate the competency of the algorithm a scene containing a dust outbreak over the Arabian Sea (figure 1) is processed using the current PATMOS cloud mask as well as the new dust detection algorithm (figure 2). As the image indicates most of the dust plume is considered to be cloud, which the subsequent dust correction accounts for. Additionally, there are a large number of pixels that have been misclassified as clear-sky which the dust mask corrects, avoiding improper sea surface temperature retrievals. The performance of the algorithm in this image has been duplicated for many other areas of the world during different times of the year.

Figure 1: AVHRR false color image (R: Ch 1, G: Ch 1, B: Ch3) from NOAA-16 (2003, day 347) for a dust plume extending over the Arabian Sea

4 Conclusions

A global retrieval has been developed to remotely sense airborne soil derived aerosols over water utilizing the AVHRR imagers. The preliminary results show that a substantial amount of dust from an outbreak can be detected while rarely misclassifying clouds as dust. While small variations in the algorithm are still being made and validation is ongoing, the algorithm will be implemented in the NOAA PATMOS AVHRR data reprocessing efforts. After the algorithm is finalized and validated the opportunity exists to create a satellite dust climatology, which has many applications to not only atmospheric research but also to other disciplines interested in environmental changes that may cause a trend in dust outbreak frequency and tendency.

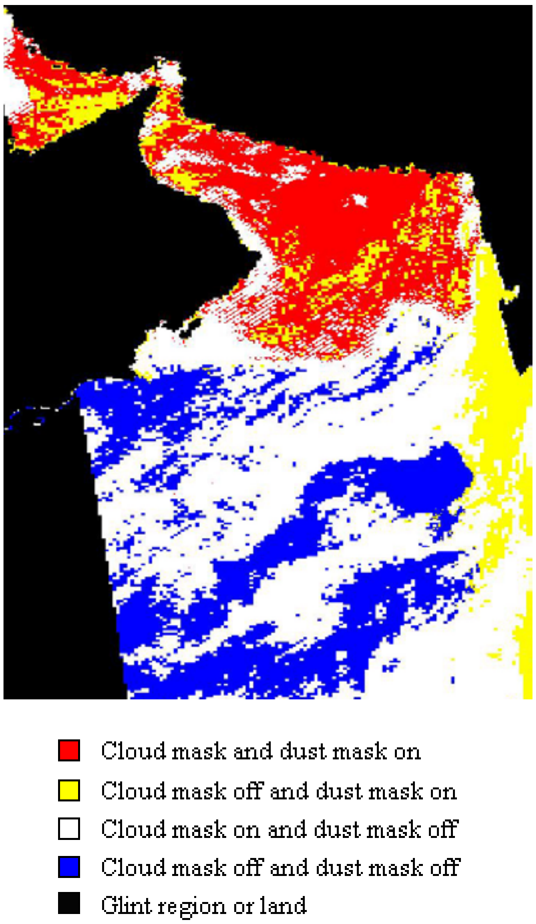

Figure 2: Results of how dust mask changes the classification of the image in Fig. 1

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