Introducing New Approaches for Dust Storms Detection Using Remote Sensing Technology

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Abstract—**Dust storms present environmental risks and affect the climate. They have worsened in the Mediterranean and East Asia regions over the last decade due to massive deforestation and increased droughts. Storms can travel over large parts of the Earth, in Asia, Africa, even affecting North America and Europe. Moreover dust storms are related to precipitation, soil moisture, land use/land cover practices, and other human activities. This work is a continuation of previous research in which we analyzed several remote sensing instruments capabilities in monitoring dust storms. Here we introduce the usage of the Multi-angle Imaging SpectroRadiometer (MISR) and TRMM Microwave Imager (TMI) as an optical and microwave combination in enhancing dust storm detection.**

Keywords-Dust Storms; MISR; TOMS; MODIS; TMI

I. Introduction

Air pollution from dust storms is a significant health hazard for people with respiratory discards and can adversely impact urban areas. Timely warnings of dust storms must be initiated in populated regions for health concerns and traffic control. Storms can travel over large parts of the Earth, in Asia, Africa, affecting even North America and Europe. Dust storm detection and tracking could be difficult as they share some similar characteristics to clouds. Dust storms can vary in their shape, particle size, distribution and normally show a variable behavior [1].

This work analyzes the capabilities of several remote sensing instruments with respect to monitoring dust storms and considers the Nile Delta as a case study. Earlier works [2] have produced results based on arrays of optical sensors but did not focus much on the microwave region of the spectrum. We have carried out a study of the dust behavior over the microwave region of the spectrum [3]. The differing behavior of the dust and haze in different regions of the electromagnetic spectrum needs to be studied in order to detect and track them. In the optical part of the spectrum, dust storms have a very high albedo and hence appear quite bright. Therefore, we look for high reflectance and anomalous water vapor to serve as indicators of dust storms [3]. In the longer wavelength microwave region, dust storms respond strongly to scattering and this leads to reduced brightness temperature.

Past capabilities have relied on GOES, Landsat, SeaWiFS, TOMS, and AVHRR. Terra/Aqua provides increased capabilities that may enhance dust storm detection and hence need to be explored. Geosynchronous satellites such as GOES are the most suitable satellites to track the time evolution of active and short lived dust storms because of their high temporal resolution (15 minutes) [4]. Suspended dust is detected via brightness changes. However, due to their poor spatial (1 km) and spectral (one visible) resolutions, they can only detect and monitor very large dust storms [4]. On the other hand, Landsat TM has very good spatial resolution. Therefore, it can map the dust source location accurately if the image is cloud-free. However, it has poor temporal resolution (2 weeks) and like GOES, has inherent difficulty in penetrating clouds. The spectral resolution of SeaWiFS images is one of the better ones available for detecting large dust plumes that last for a long time and have a dark (low-radiance) background (i.e., the ocean). With such properties SeaWiFS images have been used in previous work to detect the very large dust plumes generated by winds in Africa and Asia [5], [6]. However, dust detection of small dust events over desert areas having a bright (high-radiance) background using SeaWiFS can be difficult [4] as shown in Fig. 1.

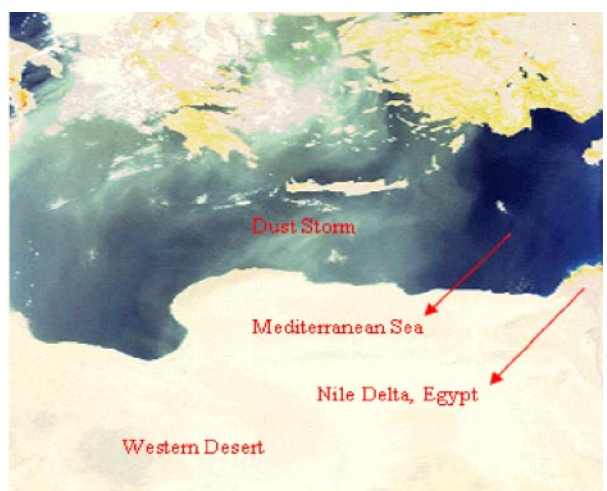

Figure 1. True Color Composite of bands 6, 5 and 1 of September 1st 2000, showing the dust storm from the Sahara approaching the Mediterranean Sea.

Of particular interest in dust storm detection and monitoring are the AVHRR and MODIS sensors because of their relatively higher temporal resolutions (once per day) compared with Landsat. The nighttime thermal imaging capability of AVHRR and the higher spectral resolution of MODIS should also assist with detecting dust emission and mapping the vulnerability of the landscape to wind erosion. MODIS proved to be superior in detecting Middle East Dust storms owing to its spectral and spatial resolutions [7]. Utilizing Terra and Aqua MODIS provides an improved temporal resolution over AVHRR as their combined coverage is now twice per day.

Quantifying information in the vertical for models using RS data is extremely important. Terra/Aqua quantitative data are necessary for the identification of spatiotemporal distribution of dust plumes as well as for vertical profiling at pre-selected locations in order to inter-compare models with RS in the vertical distribution.

II. ANALYSIS AND DISCUSSION

A. *Monitoring Dust Storms in the Ultraviolet range*

We have used Total Ozone Mapping Spectrometer (TOMS) data for detection of dust storms in the ultraviolet region. The TOMS instrument detects aerosol particles by measuring the amount of backscattered ultraviolet radiation. Here we show the TOMS derived aerosol index over the Nile delta and adjacent areas in Fig. 2.

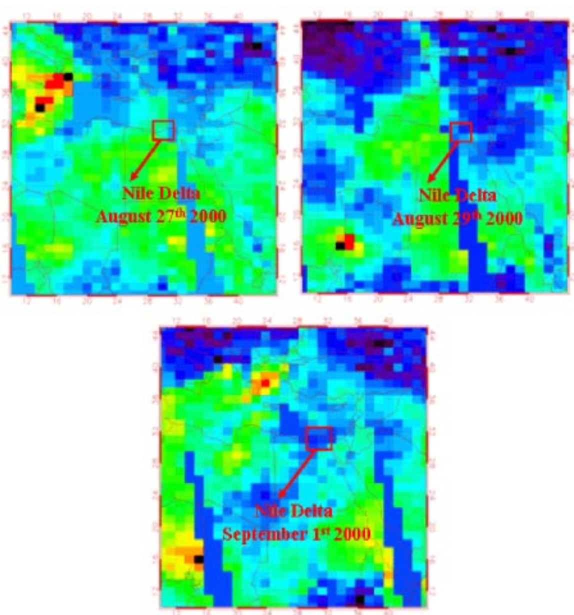

Figure 2. TOMS derived aerosol index over the Nile delta and adjoining areas.

As it is apparent from Fig. 2, the poor spatial resolution of TOMS is very unsuitable for detecting dust storms over a small area, specifically the Nile Delta. Furthermore, the TOMS sensor responds to backscattered radiation caused by Rayleigh scattering which is most prominent at relatively long wavelengths compared to particle size. Dust particles on the other hand are predominantly coarser and respond to Mie scattering that is appropriate for a cloudy atmosphere.

B. *Monitoring Dust Storms in the Visible range*

MISR is the world first satellite sensor with multi-angle viewing capability aboard Terra. The dust event under study was also observed using MISR as shown in Fig. 3.

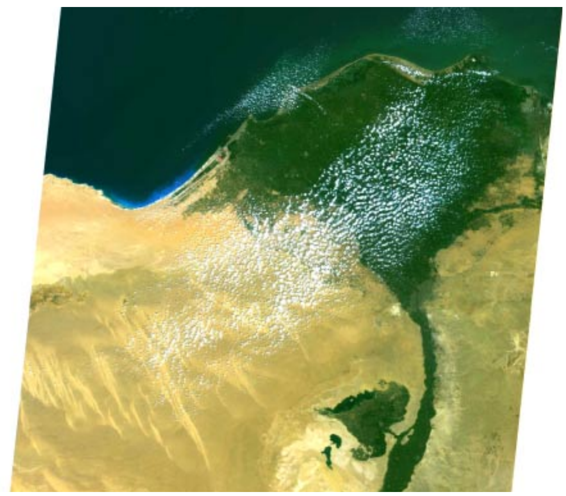

Figure. 3 MISR Nadir image showing Nile Delta dust storm for August 31st of 2000.

Using the new feature of MISR with different viewing angles, identification of dust storms can be improved. For example, dust storm events which are difficult to be detected by Nadir viewing may be easily detected by off-nadir angle views, because off-nadir sensors view thicker depth of atmosphere. MISR has the potential to enhance the detection of small dust storms, thus it might be helpful in early detection of dust storms. In addition, combining the information from different angle views could be useful in discriminating between dust clouds and regular clouds. Also, it could be beneficial in decreasing the background effects for desert regions by selecting suitable viewing angles. We are currently developing useful indices by combining the spectral measurements at different viewing angles. If several storm cases are available, we will relate these indices to the different intensities of dust storms. Therefore, we may be able to indicate at which levels of dust storm development, a storm can be successfully detected using MISR data. Also, we are using different levels of MISR products (generally level 1B2 and level 2 products) to extract physical parameters of dust storms such as optical thickness, dust particle size and its distribution, concentration, and land surface cover underneath to feed the simulation models. This information also can be provided to the public and government agencies for decision making purpose. When the above indices are used dynamically, they could be used to study the development, movement and transport of dust storms for both model simulation validation and for public and government agencies.

C. *Monitoring Dust Storms in the Microwave range*

We are studying dust storms by looking at their effect on water vapor as has been presented here. The dust particles act as small cloud condensation nuclei around which water vapor droplets can accrete and give rise to smog and fog. This can be verified through Fig. 4. We note from Fig. 4 the way the water vapor shifts with the drift in dust storm for of September 1st and 3rd 2000 and hence the location of water vapor or smog matches quite well with the position of the haze and dust storm as inferred from Fig. 5 [2].

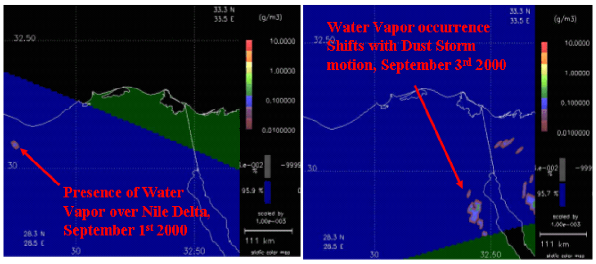

Figure 4. Anomalous water vapor concentration over and adjacent to the Nile Delta.

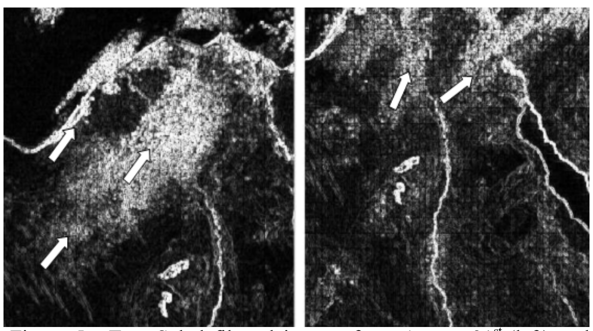

Figure 5. Two Sobel filtered images from August 31st (left) and September 1st (right) of 2000, showing the general direction of the dust storm over Nile Delta.

III. CONCLUSIONS

New approaches for detecting, studying and monitoring dust storms have been presented. These utilize new global observing sensors on-board of Terra/Aqua. When coupled with other sensors at different parts of the spectrum, they can provide powerful means to not only study specific storms but to understand better the physics involved. All the Earth's surface features, clouds and even tiny particles floating in the air, respond differently and hence, reflect the sunlight differently when viewing from different angles. Therefore, multi-angle measurements can provide more information than traditional single angle RS measurements, thus enhancing the fine discrimination between materials.

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