Optical Remote Sensing Technologies for Dust Storms Monitoring and Detection

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Abstract

Air pollution caused by dust storms is considered to be a significant health hazard for people with respiratory discards and can adversely impact urban areas. Dust storm detection and tracking could be difficult as they share some similar characteristics to clouds. They vary in their shape, particle size distribution and normally show an oscillatory behavior. Earlier works have produced results based on arrays of optical sensors, which proves to be useful for dust detection. 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. Multiangle Imaging Spectro Radiometer (MISR) with its capability of viewing at 9 different angles adds more weight for dust storms detection. Using the Moderate Resolution Imaging Spectroradiometer (MODIS) technology for dust detection,

matches the presence of dust events detected from the Aerosol optical depth product during the same time frame.

1. Introduction

Under normal climatic conditions different types of dust particles and aerosols float around. However, under the force of strong winds particles of dust or sand are lifted into the air from arid regions that are mainly deserts, dry lakebeds, semi-arid desert fringes, and other sources as temperate, tropical, sub-tropical and drier regions where vegetation has been reduced or soil surfaces have been disturbed (Williams, 2001). Dust storms are one of the most serious environmental hazards and are characterized by their dynamic behavior as in no time particle size, distribution, and direction vary significantly (MacKinnon and Chavez, 1993).

Airborne particles from dust storms can alter the local climatic conditions by intercepting sunlight. They participate in modifying the energy budget through their behavior by cooling due to reflection of solar radiation and heating the atmosphere due to the absorption of IR radiation (Liepert, 2002). The presence of an absorbing dust layer results in a substantial decrease in the incoming short wave solar radiation, resulting in a major change to the surface energy balance. Moreover, the atmospheric stabilization occurs when dust differentially warms a layer of the atmosphere at the expense of near-surface cooling. They affect rainfall in cloud condensation nuclei (CCN) particles that can decrease precipitation and shorten the lifetime of the clouds. Dust deposition affects the marine ecosystems (e.g. algae blooms) and results in microbes' transportation and the amplification of the desertification effects. Dust storms are detected by a series of sensors over the different regions of the electromagnetic spectrum (Chavez et al., 2002; El-Askary et al., 2002, 2003a, 2003b, 2004, 2005). Occasionally, Saharan dust storms travel all the way to Asia with the seasonal summer monsoons (Dey et al., 2004, El-Askary et al., 2004). In this paper, we will shed light on different case studies of dust detection the showing

usefulness of optical remote sensing data for monitoring dust storms. MODIS and MISR on board Terra/Aqua platforms are used for the optical sensing of dust storms.

2. Data Used for Dust Storms Monitoring

In this research we are addressing the use of MODIS and MISR sensors for dust monitoring and detection. The used data are applied to case studies over Saudi Arabia and Gulf area, where dust events represent major hazards. MODIS aerosol optical depth and MISR terrain data are used in this study.

3. Analysis and Discussion

3.1 Dust Storms Detection using MODIS

MODIS senses the entire Earth surface in 36 spectral bands, spanning from the visible (0.415 μm) to infrared (14.235 μm) spectrum, with spatial resolutions of 1000, 500 and 250 m, at nadir, and both land and atmospheric products can be derived with the same spatial and temporal coverage twice a day. MODIS has been used for monitoring dust storms successfully (El-Askary et al., 2000). Moreover, MODIS aerosol products provide good global spatial and temporal coverage with regional dust properties. A dust storm over Arabia region is detected from MODIS measurements on August 5, 2003 where a wide dust plume is clearly observed. Figure 1 shows the occurrence of a strong desert dust outbreak detected by MODIS. The large extension of the dust plume is clearly observed; whose coverage reaches Qatar and United Arab Emirates due to the dynamic circulation patterns of the dust plume. The MODIS aerosol optical depth (AOD) product measures how much light is obstructed from flowing through the

atmospheric column by airborne particles. This is due to the fact that aerosols tend to absorb or reflect incoming sunlight, thus reducing visibility and increasing optical depth. Aerosols are scientifically important because they represent an area of great uncertainty in efforts to understand and predict global climate change. Moreover, they can influence rainfall patterns as well as cause respiratory problems in humans and animals. Figure 2 shows the variability of the AOD values over the year 2003. A maximum is observed over the month of July and the early few days of August 2003 matching the observed output from the MODIS sensor.

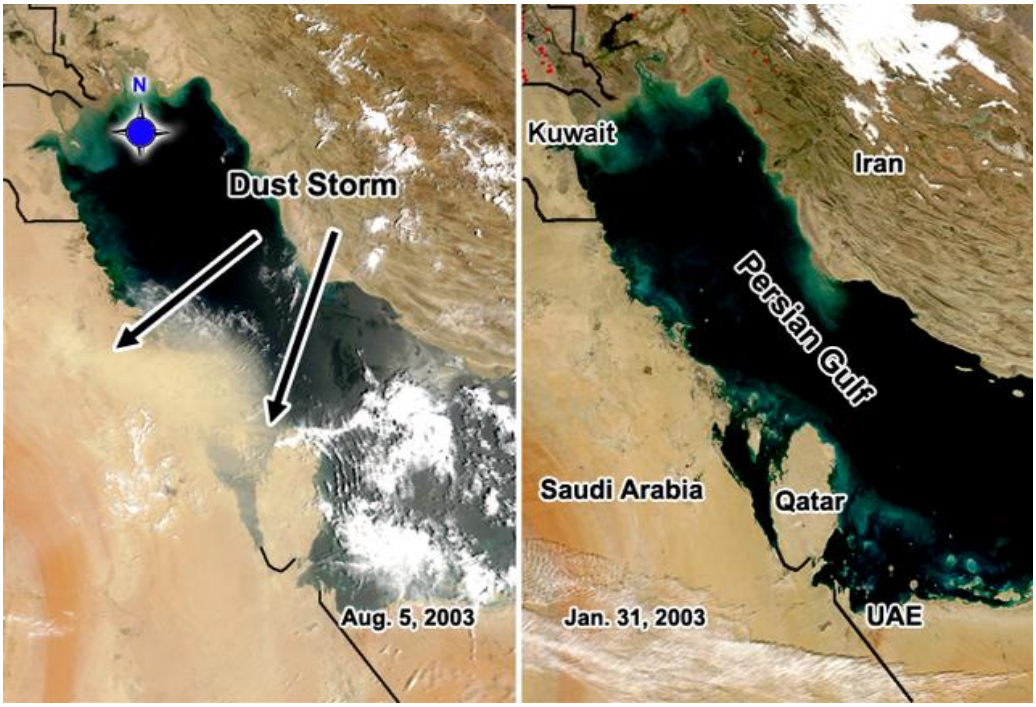
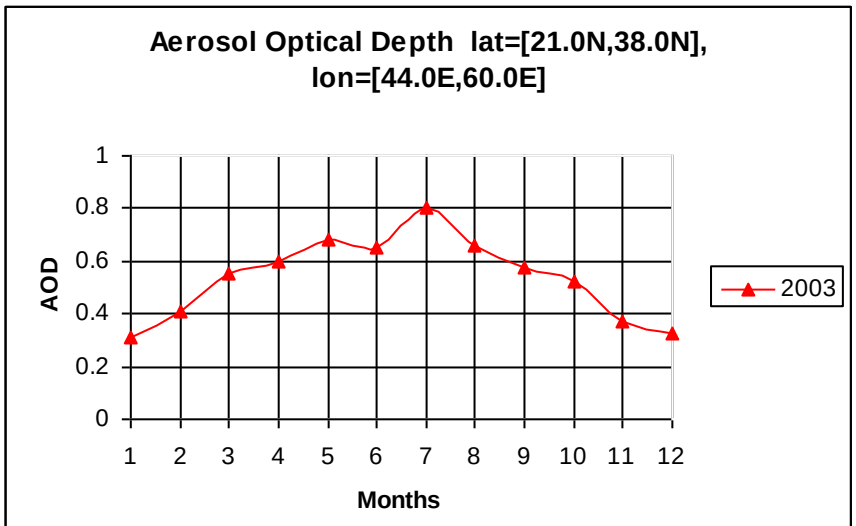


Figure 1. Comparing MODIS images of a Dust outbreak in Arabia on August 5, 2003, with clear sky on January 31, 2003. Credit: Storm Center



3.2 Dust Storms Detection using MISR

MISR observes the daylit Earth continuously and every 9 days views the entire globe between 82 degrees north and 82 degrees south latitude. MISR is the world satellite sensor with multi-angle viewing capability and is viewing the earth in four bands. Another potential of visible sensing of dust outbreaks utilizes MISR, which can be used to detect large dust storms like the one over Saudi Arabia (Figure 3) (El-Askary et al., 2004).

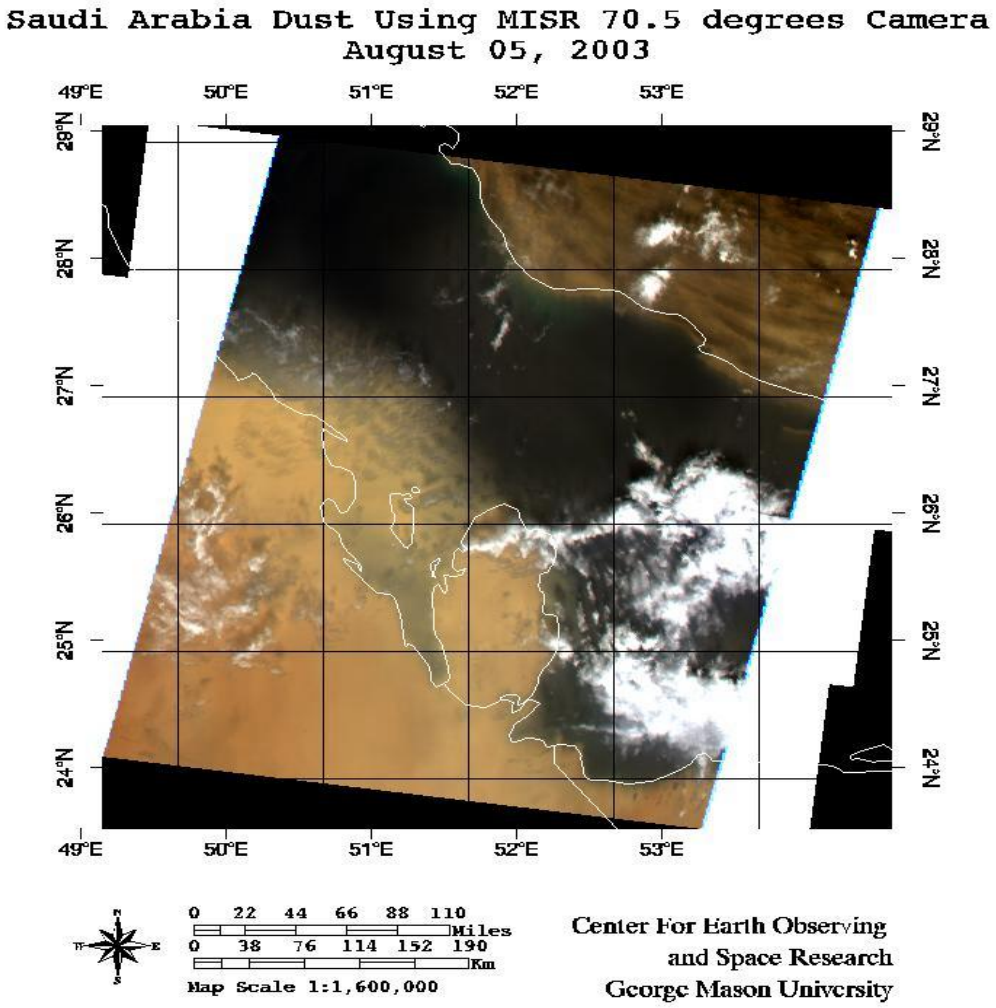


Figure 3. Dust outburst detected by MISR sensor at 70.0 degrees forward

MISR is characterized by its ability of different viewing angles, and hence identification of dust storms can be greatly improved (El-Askary et al., 2003b). Hence, dust storm events hard to be detected by Nadir viewing may be easily detected by off-nadir angle views, because off-nadir sensors view thicker depth of atmosphere. The different viewing angles of MISR provide information about dust particles through their discrimination from other suspended particles. The dust outbreak over Saudi Arabia observed using the MODIS sensor is well observed as well using the MISR viewing capability using the 70.0 degrees camera (Figure 3).

A 3D view of the same dust event is observed using the MISR capability and the Terrain data embedded (Figure 4). A full discussion of the 3D development is discussed in a separate research article.

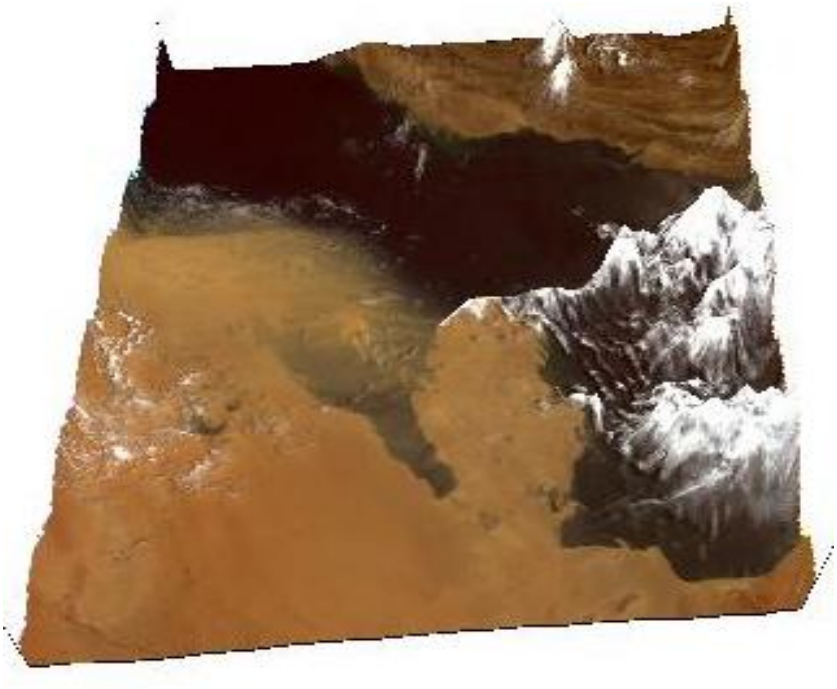


Figure 4. 3D view of the dust outburst over Saudi Arabia on August 5, 2003.

Conclusions

Dust storms can vary in coverage extent, particle size and distribution as well as can change direction. In this research we utilized the optical region of the spectrum using MODIS and MISR for dust storms monitoring and detection. A case study is introduced over Saudi Arabia where a dust outbreak is observed on August 5, 2003. Dust particles are a major component of the aerosol concentration in the dust outbreak over Saudi Arabia. The detection of their presence has been carried out using remote sensing data using MODIS and MISR sensors. Due to the dust event high values of the AOD are observed over August 5, where the true color composites from MODIS and MISR are observed. The anomalous increase is associated with dust events in suspended particulate matter is harmful causing respiratory problems.

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