DEVELOPING A NEW AUTOMATED TOOL FOR DETECTING AND MONITORING DUST AND SAND STORMS USING MODIS AND METEOSAT SEVIRI-MSG DATA

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ABSTRACT

In the last three decades, significant advances have been made in mapping and monitoring environmental changes from Earth Observation satellites across a range of spatial and temporal scales. For example, with the actual Earth observation satellites, we can observe large areas rather than sparse points and provide unique information about properties of the surface or shallow layers of the earth. Indeed, the extent of many environmental and meteorological events such as vegetation stress, fogs, sandstorms and droughts cannot be captured by ground measurements alone making remote sensing an indispensable tool in environmental monitoring. The harsh nature of sub-African region makes ground-based monitoring and mapping of their local environment difficult and expensive. However, in contrast with their appearing harsh nature, arid desert areas tend to be fragile ecosystems where little climate perturbations may cause tremendous changes in their landscapes. Additionally, due to their low precipitation rates, arid regions are the world’s major source of atmospheric dust that has an impact on local, regional and global climate. This paper will present an overview of current tools used for dust and sandstorm monitoring over bright-reflecting surfaces. An overview of current and potential applications of remote sensing in sub-African countries as well as the challenges that may be faced will also be presented.

Index Terms— Meteosat, MODIS, Sandstorms, NASA-Geovanni tool.

1. INTRODUCTION

Arid and semi arid regions have their specific and unique characteristics and vulnerability that require special attention in adapting existing remote sensing tools to be applied efficiently. Dust and sand storms are create potentially hazardous air quality to humans, and adversely affecting climate on a regional and world-wide scale. Remote sensing has shown to be a valuable tool in detecting, mapping and forecasting such events. In addition to its direct effect on surrounding air quality, excessive presence of airborne dust affects both local and regional environments due to its biogeochemical impact on the ecosystem and its radiative-forcing effect on the climate system [1], [2].

Presently, most of the Earth satellite data is available to users free of charge (or with a minor processing fee) through different governmental space agencies or through their affiliated centers and programs such as NASA, NOAA and European Space Agency (ESA). The acquisition frequency of this data varies from 96 images per day for the European METEOSAT (~ 1km footprint) to 4 images per day for NASA/MODIS (~ 250 m footprint). Acquiring such data can benefit scientists and researchers by incorporating remote-sensing-derived information in their observation systems for environmental monitoring, evaluation and planning.

Application of geostationary and polar orbiting remote sensing in dust and sand storms has been widely investigated in the past two decades [1-5]. In this project, a neural-network-based technique will be developed to detect and mask pixels with moving dust from SEVIRI HRV and the two other visible channels (R01 and R02). This tool will be helped with a second neural network system that detects and extracts predefined features in the dust and sandstorm fields. The obtained dust storm simulations will be then re-sampled and compared to the ones obtained by the NCAR WRF regional prediction model at 16-km resolution [9-10] as well as daily aerosol maps produced by NASA (Geovanni tool). Several well documented dust storm events that occurred between 2006 and 2008 will be used to calibrate and validate the developed tool. The images shown in figure 1 illustrate the temporal evolution of one dust storm event detected by METEOSAT SEVIRI-MSG. With
their high temporal resolution, geostationary satellites are indispensable for detecting and tracking dust and sand storms.

Retrieving dust and sand storm properties over their originating location (i.e., desert, arid and semiarid regions) using conventional visible and near-infrared wavelengths is a difficult task because of the bright underlying surfaces over such regions, limiting their application to over water and dark land surfaces downwind of the source region [3]. This limitation reduces the time response in detecting and monitoring dust and sand storms over the originating area.

To overcome this limitation, several approaches have been developed to retrieve aerosol optical properties over bright land surfaces such as desert. Most of these techniques use the sensor multi spectral properties by selecting highly contrasted areas as reference targets. This approach has shown low efficiency when applied over large and homogenous bright areas like desert with limited land cover variations.

Earth Observing System (EOS) moderate resolution imaging spectroradiometer (MODIS) has been used in several aerosol retrieval applications over land [6-8]. Most of these applications use the dark-target approach which limit their application to land surfaces with reflectance below 0.15 (at 2.1 μm). This approach limits the application of MODIS in large desert and semiarid areas that represent the main source of dust [6].

Thermal channels have also been used in detecting and mapping aerosols over desert. The thermal-based approaches use the comparison between thermal properties of mineral aerosols and the background temperature and water vapor signals. These techniques have shown some limitations due to the difficulties in separating aerosols from terrestrial environment, particularly over desert and semiarid regions [6]. The NASA daily aerosol mapping tool, Geovanni, is also limited to aerosol retrieval over ocean and dark land surfaces.

Other thermal-based techniques used the difference in particle size between airborne dust and surface sand to detect airborne dust over desert. A study performed by Wald and al. has shown strong differences in infrared emissivity between airborne dust particles, with size less than 5 μm, and desert sand particles, with diameter greater than 70 μm. This difference in thermal behavior was detected by MODIS thermal channels and was used to detect the presence and map the extent of airborne dust [11].

2. CASE STUDY

A large dust storm that covered northern to central Sudan between May 10 and May 13 2009 has been selected in this study. The MODIS scene presented in Figure 2 shows the location of the study area and the spatial coverage and the intensity of this event. Six daily Aerosol Optical Depth (AOD) maps were produced over the study area by the Geovanni tool for the period preceding and following the dust storm. AOD is the most used parameter in monitoring the spatial coverage and properties of sand and dust storms. AOD provides a quantitative measurement of the degree to which aerosols prevent the transmission of light. It is usually defined as the integrated fractional depletion of radiance over a vertical column of unit cross section [12].

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Intensive sand and dust storms are commonly observed in the Sahara desert in Africa, as well as across the Arabian Peninsula (throughout Saudi Arabia, the UAE and Oman) and in the most arid regions of Iraq.

The temporal variation of AOD averaged over the study (Figure 4) area shows clearly the effect of dust presence on average AOD. Usually, the AOD is saturated in the presence of dust with values exceeding 0.9 (or 90%).
The daily optical depth maps presented in figure 3 show the temporal evolution of the dust storm over six-day period (May 10-15, 2009). These maps were produced with the Giovanni online data system [12]. As mentioned earlier, Geovanni aerosol products are limited to retrievals over ocean and dark land surfaces. The water pixels are either cloudy or desert pixels. This map sequence shows the high aerosol concentration for dust-covered areas and their temporal and spatial variation over the measurement period. The same pattern can be also observed in the average AOD shown in figure 4.

The aerosol maps presented in figure 5 show a broader picture of the AOD distribution over the African continent. No AOD products are provided over the Sub-Saharan region due to limitation of Geovanni tool to water and dark surfaces.

3. CONCLUSION

This short communication shows how current aerosol monitoring tools can be used to detect and monitor sand and dust storms. An AOD index greater than 0.9 can be used as indicator of heavy dust presence. However, to have an efficient application over the African continent as well as other arid and semi-arid regions, such tools should be complemented by a thermal-based tool to provide aerosol measurement over desert and no vegetated areas.

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REFERENCES


