DEVELOPING A SATELLITE-BASED TOOL TO MONITOR DUST AND SAND STORMS IN THE UAE

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1. INTRODUCTION

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. Dust and sand storms create potentially hazardous air quality to humans, and adversely affecting climate on a regional and world-wide scale. 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.

The objective of this research is to develop a thermal-based technique to detect and monitor dust and sand storm events in the UAE from space. The developed tool will use the difference in particle size between airborne dust and surface sand to detect airborne dust over desert. Previous similar studies have observed 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 has been used in this study to detect the presence and map the extent of airborne dust over the study area. Several well-documented dust storm events that occurred between 2008 and 2009 have been used to calibrate and validate the new tool. Due to their high temporal resolution, geostationary data from METEOSAT SEVIRI-MSG were selected. Preliminary data assessment tests have shown a great potential of this approach in detecting airborne dust and sand over the bright underlying surfaces.

2. BACKGROUND

Dust and sand storms are creating potentially hazardous air quality to humans, and adversely affecting climate on a regional and worldwide 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 through different governmental space agencies or through their affiliated centers and programs. The acquisition frequency of this data varies from 96 images per day for the European METEOSAT (~ 1km 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 new 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 [6-7] as well as daily aerosol maps produced by NASA (Geovanni tool). The images shown in Figure 1 illustrate the temporal evolution of one dust storm event detected by METEOSAT SEVIRI-MSG.

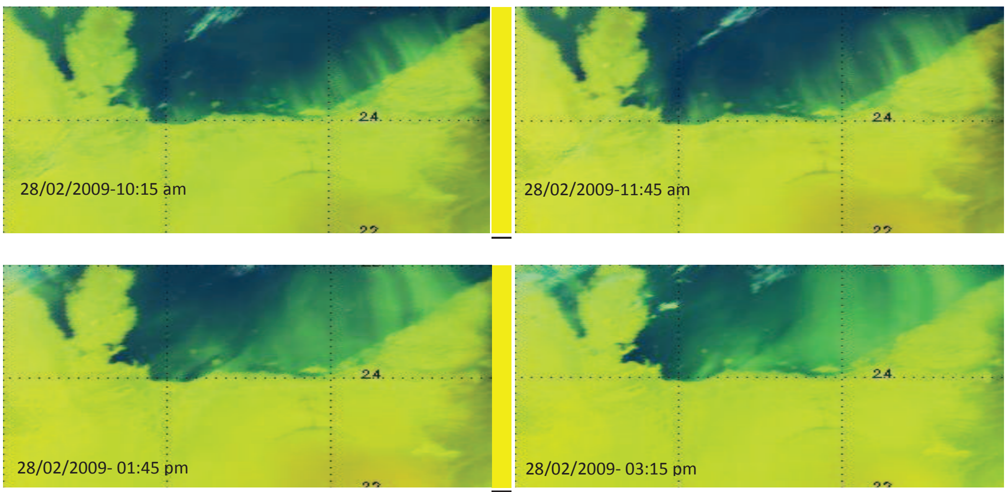

Figure 1: Dust storm event over the UAE captured by METEOSAT-SEVIRI on February 28th, 2009

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 [8]. The NASA daily aerosol-mapping tool, Geovanni, is also limited to aerosol retrieval over ocean and dark land surfaces.

3. METHODOLOGY

The graph presented in figure 2 shows the temporal variation of AOD averaged over water pixels in the UAE coastal area. The two images shown in this figure were acquired by Meteosat satellite in one clear day (November 2008) and one dusty day (February 2009). The selected coastal pixels are located in the rectangle shown on the top image. This figure shows clearly the effect of dust presence on satellite derived AOD. Usually, the AOD is saturated in the presence of dust with values exceeding 0.9 (or 90%). The developed tool will use the difference in particle size between airborne dust and surface sand to detect airborne dust over desert.

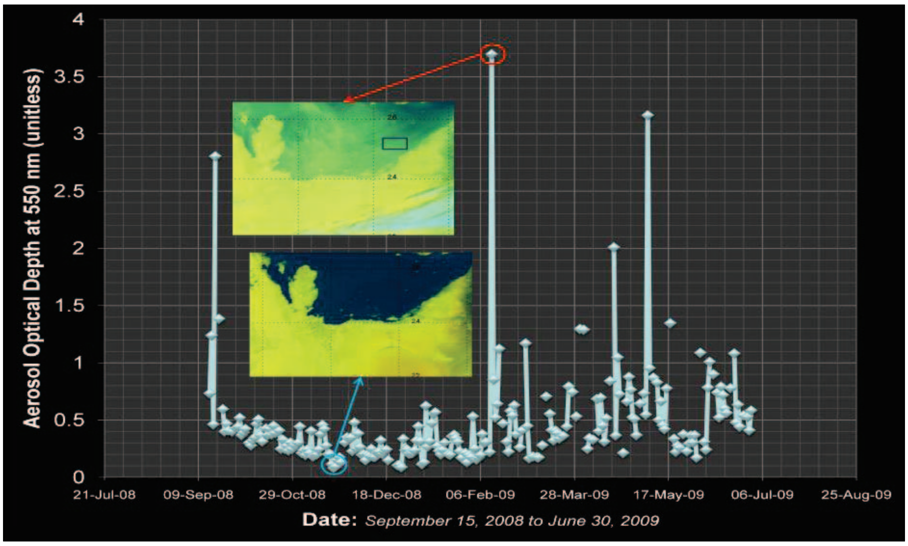

Figure 2: Temporal variation of Aerosol Optical Depth (AOD) in UAE coastal area.

Other thermal-based techniques used the difference in particle size between airborne dust and surface sand to detect airborne dust over desert as shown in Figure 3. 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 [9].

4. CONCLUSION

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.

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.

To overcome this limitation, thermal channels have been tested 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. The NASA daily aerosol mapping tool, Geovanni, is also limited to aerosol retrieval over ocean and dark land surfaces.

5. REFERENCES

[1] J. Haywood and O. Bougher, “Estimates of the direct and indirect radiative forcing due to tropospheric aerosols: A review,” *Rev. Geophys.*, vol. 38, no. 4, pp. 513–543, 2000.

[2] N. C. Hsu, J. R. Herman, and C.Weaver, “Determination of radiative forcing of Saharan dust using combined TOMS and ERBE data,” *J. Geophys. Res.*, vol. 105, no. D16, pp. 20 649–20 661, 2000.

[3] M. D. King, Y. J. Kaufman, D. Tanré, and T. Nakajima, “Remote sensing of tropospheric aerosols from space: Past, present and future,” *Bull. Amer. Meteorol. Soc.*, vol. 80, no. 11, pp. 2229–2259, Nov. 1999.

[4] D. Tanré and M. Legrand, “On the satellite retrieval of Saharan dust optical thickness over land: Two different approaches,” *J. Geophys. Res.*,vol. 96, no. D3, pp. 5221–5227, Mar. 1991.

[5] D. Tanré, E. F. Vermote, B. N. Holben, and Y. J. Kaufman, “Satellite aerosol retrieval over land surfaces using the structure functions,” in *Proc .IGARSS*, 1992, vol. 2, pp. 1474–1477.

[6] S. Caquineau, A. Gaudichet, L. Gomes, and M. Legrand (2002), Mineralogy of Saharan dust transported over northwestern tropical Atlantic Ocean in relation to source regions, J. Geophys. Res., 107(D15), 4251, doi:10.1029/2000JD000247.

[7] A. T. Evan, A. K. Heidinger, and M. J. Pavolonis (2006), Development of a new over–water advanced very high resolution radiometer dust detection algorithm, International Journal of Remote Sensing, 27(18), pp. 3903-3924.

[8] Hsu, N.C. Si-Chee Tsay King, M.D. Herman, J.R. (2004). Aerosol Properties over Bright-Reflecting Source Regions IEEE Transactions on Geoscience and Remote Sensing, vol. 42, no. 3, march 2004

[9] Wald, A. E., Y. J. Kaufman, D. Tanré, and B.-C. Gao (1998), Daytime and nighttime detection of mineral dust over desert using infrared spectral contrast, J. Geophys. Res., 103(D24), 32,307–32,313.