SAHARAN DUST MOTION EXTRACTION FROM MSG-SEVIRI

Iliana Genkova, Chris Velden, Mel Shapiro, Hsiao-Ming Hsu, Jason Dunion, Dave Stettner

University of Wisconsin – Madison
Space Science and Engineering Center
Cooperative Institute for Meteorological Satellite Studies
1225 W. Dayton St., Madison, WI 53706

Abstract

In recent years, the Saharan Air Layer has been recognized for its role in African climate and Atlantic Tropical Cyclone activity. Severe dust events can impact the: i) radiation fluxes on various time and spatial scales; ii) process of tropical cyclone genesis; iii) meningitis and respiratory diseases in the region; iv) nitrate and ferousoxide fertilization of the biota of the Atlantic Ocean and associated carbon dioxide uptake. The determination of Saharan dust motion vectors is a novel input to investigate the intricate relationships between the dust transport and propagation patterns, and the mechanisms/occurrence of meteorological events in the domain.

A split-window based dust detection algorithm has been applied to MSG SEVIRI satellite imagery to mask out the areas with moving dust, and some basic image processing is used to augment existing features in the dust fields before an automated feature tracking extraction algorithm is employed. At this time, the presented technique has been tested over land only. The derived dust motion vectors data sets are quality assessed through comparisons with RAOBs and dropwindsondes from measurement campaigns. The vectors are also compared to dust propagation simulations with the NCAR WRF regional prediction model at 16-km resolution.

INTRODUCTION

Saharan dust has long been studied because of its effect on radiation fluxes and land-atmospheric interactions (Slingo et. al., 2006), Atlantic's ocean biota (Caquineau, et.al., 2002), socio-economical impact and relation between dust composition, propagation and health issues. Research at CIMSS has recognized the Saharan dust as one of the factors governing the genesis of Tropical cyclones (Evan, et.al., 2006a). Recently an algorithm for dust detection has been developed (Evan, et.al.,2006b). This paper presents some of the preliminary results from adopting the winds detection algorithm and applying it for tracking Sahara dust applications.

METHODOLOGY

Infrared brightness temperature differences are often used to detect aerosols. Over land, the variation of surface emissivity is adding to the complexity of the problem. Nevertheless, the presence of soil-derived aerosols can be detected with infrared observations and negative split-window brightness differences are observed to occur for dust storms over Africa and the southwest United States (Ackerman, 1997). Following the split-window aerosol detection approach, we have empirically derived and applied the following dust masking thresholds to apply to MSG-SEVIRI images:

$$-0.5°K \geq (BT\_10.8 - BT\_12.1) \geq -3.5°K$$
$$BT\_10.8 \geq 280°K$$

The second threshold condition is needed to eliminate thin cirrus clouds contaminated pixels which often have similar spectral signature as the propagating dust. After a successful determination of the dust covered areas, the images then undergo a histogram equalization step which improves their contrast and augment features appropriate for subsequent tracking. Tracking employs the current CIMSS automated winds tracking algorithm. Dust features are usually smaller than cloud features, thus the tracking is using smaller target and search box sizes – 5x5 pixels (15x15km) and 11x19 pixels (55x95km) boxes. After the dust motion vectors are derived, their quality is assessed by calculating their quality indicators (QI) (Holmlund, 1998).

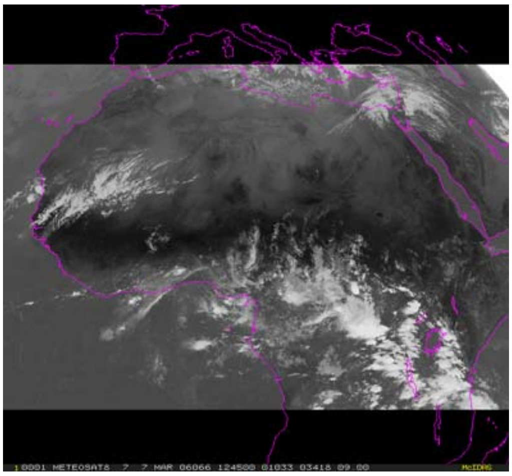
PRELIMINARY RESULTS

During winter time, cold air outbreaks from Europe toward Africa often lead to large-scale dust storms over the Sahara. Such a major dust outbreak was observed on 5-9 March 2006. It starts from Morocco and Algeria when the cold front of a cyclone reached Northern Africa. During the following days, the cyclone moved from the Western to the Eastern Mediterranean Sea and the cold front crossed Northern Africa from west to east, with the dust storm following it (Jochen Kerkmann, 2007).

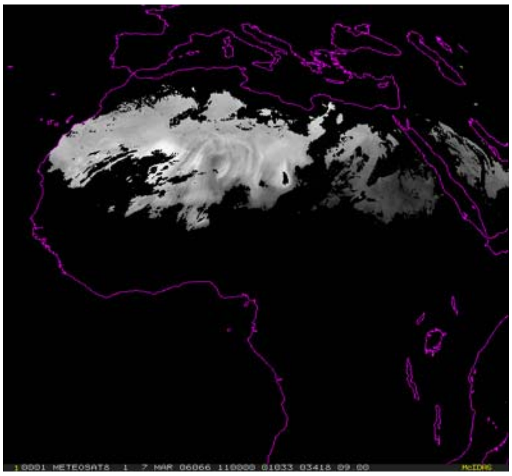
We use the 7-8 March 2006, 15 minutes MSG-SEVIRI imagery data over North Africa, to test the described above dust masking algorithm and tracking dust features. Figure 1 illustrates the dust motion vector extraction routine steps. The original band 9 (10.8 micron) radiances for 7 March 2006, 12 UTC, are shown on Figure 1(a). Although it is easy for the human eye to recognize between the dust plums and the brighter and colder cirrus clouds over West and Central Africa, the feature tracking algorithm is not capable of finding many good tracers in this raw image. Instead, we apply the dust masking threshold technique followed by a median filtration step to eliminate single cirrus pixels within the dust areas. Subsequently, histogram equalization is applied, and the enhanced pre-processed images like the one on Figure 1(b) serve as input to the tracking algorithm.

The extracted dust motion vectors are shown on Figure 1(c). They all have passed a quality assessment and only winds with quality indicator 80 or greater are shown. The dust flow over Western Sahara and Mauritania is quite well depicted. Same is true for the dust winds over Algeria, East Mali and Niger. Most of the motion vectors over Egypt are also coherent despite the fact that the dust layer is thinner and traced features are less augmented. Only over Libya, Sudan and the few vectors over Saudi Arabia show lack of consistency in direction and speed. The high number of dust motion vectors is encouraging first results, proving that the dust mask is applied with success and that the tracking algorithm tuning is efficient. On Figure 1(d) the dust motion vectors (in yellow) are plotted along with the operationally derived AMV data set (in magenta) employing larger target and search box sizes and using 30 minutes imagery. It is evident that it is beneficial to use smaller size targets and enhanced imagery, leading to more vectors (showing spatial consistency) and better spatial coverage.

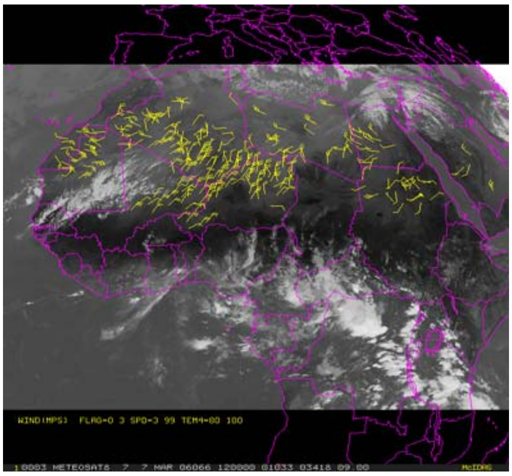
Due to limited number of RAOBs launched over North Aftrica, we can not provide such statistical comparison. Future work may include collecting sondes data from various experimental campaigns carried out during dust storms times. At this time we performed visual comparison to model output – dust propagation simulations with the NCAR WRF regional prediction model at 16-km resolution are shown on Figure 2. Model is initiated at 00:00 UTC on 5 March 2006, and the winds fields are from 11 LST on March 7, 2006. Very good consistency in the dust flow depiction – both in terms of direction and speed, is observed near the South borders of Algeria and Libya, and the North border of Niger and Chad.



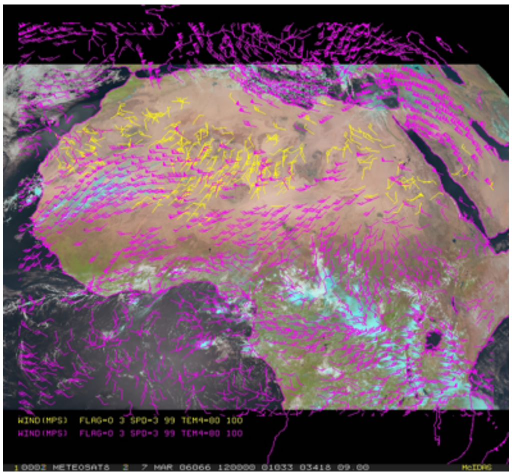
(a)



(b)



(c)



(d)

Figure 1. (a) MSG-SEVIRI band 9 (10.8 micron) radiances, 7 March 2006, 12:00 UTC; (b) same as (a), but after dust mask and histogram equalization; (c) dust motion vectors ; (d) dust motion vectors (yellow) and cloud features tracked AMVs (magenta)

ANALISYS AND FUTURE WORK

The presented here study finds useful to apply dust masking and image augmentations techniques before attempting to extract dust motion vectors from satellite imagery. We propose a set of thresholds tuned for MSG-SEVIRI imagery, and show that it derives a dust motion vector data sets of encouraging quality. Preliminary comparisons with WRF model data demonstrate capability to well depict the dust flow. One of the major issues leading to low quality dust winds is tracking cirrus contaminated pixels in areas where high thin cloud and dust overlap, thus leading to erroneous direction and/or speed retrieval. Also, as the dust plums rise above the ground, turbulence is observed and tracking becomes unreliable, especially if the dust plum is not too thick.

To overcome these and possibly other dust motion retrieval issues, we plan on future work involving: 1) improving the dust mask and determining different threshold sets for day and night time, and also over land and ocean; 2) validate the height assignment, which is now using model guess profile to assign a vector altitude based on the 10.8 micron brightness temperature of the tracer; 3) validate the dust winds against sondes from campaigns and finer spatial resolution model output (WRF 4 km out put will be available).

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