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Night time detection of Saharan dust using infrared window channels: Application to NPP/VIIRS

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ABSTRACT

A Saharan Dust Index (SDI) has been produced operationally since 2006 from Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI) data. This SDI, based on brightness temperatures (BTs) at 3.9, 8.7, 10.8 and 12.0 μm, has been used in the Ocean and Sea Ice Satellite Application Facility (OSI-SAF) Sea Surface Temperature (SST) chain to detect Saharan dust and correct for its effect on SST calculations. OSI-SAF has developed a processing chain to derive Sea Surface Temperature (SST) from the Suomi National Polar-orbiting partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) data. In this framework, an SDI algorithm adapted to VIIRS data has been developed. Consistency between various SDI derived from various sensors is essential in the OSI-SAF context. Without absolute definition of this parameter, we have adopted the Meteosat-9 nominal SDI values as reference. In this paper we present a new method to define SDI algorithms, based on the use of simulated BTs contaminated by aerosols at various concentrations and altitudes. This method has been applied to VIIRS data. It shows consistent results with the original 2006 method and a simple regression against Meteosat-9 SDI values when compared to the operational Meteosat-9 SDI. This new method can be used to prepare SDI equations for any sensor with adequate channels once their radiometric characteristics are known. In addition, it ensures consistency with our reference SDI.

1. Introduction

Saharan dust may induce significant errors in Sea Surface Temperature (SST) calculations from satellite infrared radiometer data (Merchant et al., 2006a; Vazquez-Cuervo et al., 2004). Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI) data, covering the Atlantic, the Mediterranean Sea and part of the Indian Ocean are particularly affected by this problem. As a consequence, a night time aerosol detection method using infrared window channels has been developed in the framework of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Ocean and Sea Ice Satellite Application Facility (OSI-SAF) for its MSG SEVIRI SST operational chain. This work (Merchant et al., 2006a) led to the definition of a Saharan Dust Index (SDI) based on using SEVIRI brightness temperatures (BTs) at 3.9, 8.7, 10.8 and 12.0 μm.

Note that there are other approaches using Infrared SEVIRI BTs to detect aerosols (Ackerman, 1997; Brindley & Russell, 2006; Kluser & Schepanski, 2009; Schepanski et al., 2007) and that a SDI has also been defined for the Along Track Scanning radiometers (ATSR SDI), using split window channels only and taking benefit from simultaneous nadir and oblique views (Good et al., 2011).

SEVIRI derived SDI calculations have fully been part of the OSI-SAF operational SST processing at Météo-France Centre de Météorologie Spatiale (CMS) since April 2006. Because of solar contamination of the 3.9 μm channel, a complementary method has been developed (Merchant, 2006b) for daytime applications. This method is based on local regressions of 8.7, 10.8 12.0 and 13.4 μm BTs against the previous night's SDI. It has been implemented within the OSI-SAF operational chain since February 2012. SDI has been used internally in the OSI-SAF chains to detect Saharan dust events, and to correct SST calculations for dust induced errors. SEVIRI derived SDI has also been used in the OSI-SAF chains to calculate SST corrections for other sensors, such as the AVHRR. This approach has obvious limitations due to SEVIRI coverage and resolution.

OSI-SAF has developed an operational chain to derive SST from the Visible Infrared Imaging Radiometer Suite (VIIRS) on board Suomi National Polar-orbiting partnership (NPP). These data have been routinely acquired in direct read out mode at CMS since April 2012. They cover only the Lannion (Brittany) acquisition area: North East Atlantic and Mediterranean Sea. Similarly to what is done for METOP/AVHRR, SEVIRI derived SDI has been used for VIIRS SST corrections. Since VIIRS has channels similar to those of SEVIRI, we wanted to develop an SDI algorithm which would allow retrieval of dust information at full VIIRS spatial resolution. Furthermore, a VIIRS derived SDI has a potential global coverage out of the SEVIRI disk, even though our practical application conditions are limited to the Lannion acquisition area. More generally in the context of OSI-SAF processing, we

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wish to produce homogeneous SDI values for each new sensor data ingested into the SST chains for those sensors with adequate channels. Several methods can be used:

1) The original method using dust free simulated BTs described in Merchant et al. (2006a) can be applied. This method, which will be referred to as “dust free BT method” hereafter, produces algorithms depending on the radiometric properties of the sensor channels. Consistency between SDI derived from different sensors is not guaranteed by this method.
2) Regression against observations (the “regression to observation method”) is the easiest way to obtain an SDI algorithm, and was used for the transition from Meteosat-8 to Meteosat-9. This method ensures some continuity, but it is vulnerable to possible radiometer drifts and requires a sufficient overlap of both sensors (e.g. Meteosat-8 and -9) during the aerosols season (spring and summer). This was not the case, for instance, for the Meteosat-9–10 transition.
3) Dust contaminated BT simulations allow the prediction of variations of BTs in the presence of sand dust for any sensor. By associating a SDI value, independent of the sensor in question, to each simulated case we are able to derive an SDI equation relative to this sensor by regression of the appropriate BTs against this “reference” SDI value. Because we have used SEVIRI derived SDI values with a stable definition for Meteosat-8 and -9 for years, we decided to anchor our SDI definition to values produced during the Meteosat-8 to Meteosat-9 transition in summer 2007 which will be here referred to as the “reference SDI”. This method (“dust contaminated BT method”) guarantees consistency between SDI values derived with various sensors. To achieve this goal, we have built a data set gathering atmospheric profiles with various dust contamination levels associated with the corresponding values of the reference SDI. The Radiative Transfer for TIROS Operational Vertical Sounder (RTTOV, Saunders et al., 2012) has been applied to these profiles to compute dust contaminated BTs. The SDI equation is then defined by regression of those BTs against the reference SDI. This approach is commonly used to derive SST algorithms (see e.g. Francois et al., 2002) yet, to our knowledge, it is the first time it is used for SDI retrieval.

The objective of this study is to demonstrate that this last method is able to produce, from VIIRS data, SDI values which are consistent with our present operational SEVIRI derived SDI.

This paper describes briefly the data we used in the next section. In Section 3, we define SDI equations for NPP/VIIRS using the three methods introduced above, with an emphasis on the dust contaminated BT method, which constitutes the novel aspect of our work. Section 4 presents evaluation results using VIIRS data acquired at CMS since April 2012. Finally, in Section 5 we conclude and briefly present perspectives for future work.

2. Data

2.1. SEVIRI derived SDI

SDI production has been implemented primarily to detect Saharan dust in SEVIRI imagery and its operational use to correct for dust induced SST errors has been extended to METOP/AVHRR SST, by remapping the SEVIRI SDI onto the various product grids (Fig. 1). SDI values range typically from −0.5 to 1 and Saharan dust effect on SST calculations becomes significant for Metosat-9 SDI values above 0.1. There has been a drift of Meteosat-9 operational SDI from 2009 till 2012, due to a channel 3.9 μm drift of about 0.6 K which has been observed during the same period (see http://www.eumetsat.int/Home/Main/DataProducts/Calibration). SDI is a linear combination of brightness temperatures (BTs) at 3.9, 8.7, 10.8 and 12.0 μm. Given the weight of T3.9 in this combination (0.55, see Section 3.2), this drift led to a decrease of SDI of about 0.3. In what follows we have corrected the operational Meteosat-9 SDI values from this drift. It should be mentioned that this drift did not affect the OSI-SAF operational Meteosat-9 derived SST, since the OSI-SAF algorithms do not use the 3.9 μm channel BTs (see EUMETSAT, 2011).

2.2. VIIRS data

NPP VIIRS data have been acquired at CMS in Lannion (Brittany) in direct readout mode since April 2012. The night time NPP orbit time over Europe is around 02:00 UTC. Simultaneous NOAA-19 AVHRR, Meteosat-9 SEVIRI and VIIRS data were collected over the OSI-SAF North Atlantic Regional (NAR) area, which covers the CMS direct readout acquisition area (Fig. 1). Fig. 2 illustrates the different viewing conditions of Meteosat-9/SEVIRI and NPP/VIIRS over the NAR area. A comparison data set was built using night time NAR NPP

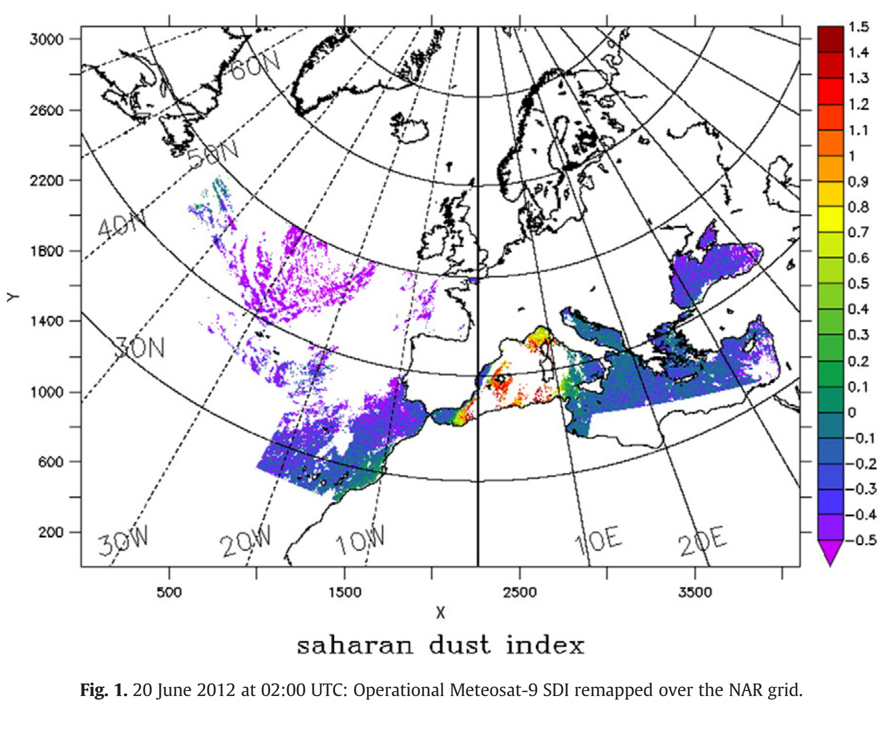

Fig. 1. 20 June 2012 at 02:00 UTC: Operational Meteosat-9 SDI remapped over the NAR grid.