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Dynamical Nighttime Fog/Low Stratus Detection Based on Meteosat SEVIRI Data: A Feasibility Study

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Abstract—Automated detection of fog and low stratus in nighttime satellite data has been implemented on the basis of numerous satellite systems in past decades. Commonly, differences in small-droplet emissivities at 11μm and 3.9μm are utilized. With Meteosat SEVIRI, however, this method cannot be applied with a fixed threshold due to instrument design: The 3.9μm band is exceptionally wide and overlaps with the 4μm CO_2 absorption band. Therefore, the emissivity difference varies with the length of the slant atmospheric column between sensor and object. To account for this effect, the new technique presented in this paper is based on the dynamical extraction of emissivity difference thresholds for different satellite viewing zenith angles. In this way, varying concentrations of CO_2 and column depths are accounted for. The new scheme is exemplified in a plausibility study and shown to provide reliable results.

Key words: Fog, low stratus, satellite retrieval, meteosat SEVIRI, CO_2 absorption, limb effect.

1. Introduction

1.1. Background

Fog and low stratus (FLS) are of great importance from several perspectives: As a modifier in the climate system (e.g., HOUGHTON *et al.*, 2001), as an obstruction to traffic at land, sea and in the air (e.g., PAGOWSKI *et al.*, 2004; LEIGH, 1995), and as a factor with an impact on air quality (e.g., KRAUS and EBEL, 1989; BENDIX, 2002). Climatically, low clouds are expected to have a slight cooling effect (cf., the review by STEPHENS, 2005).

Reliable near-real time information on the spatio-temporal distribution of FLS can only be obtained from satellite data; station measurements lack the spatial component and the interpolation of point visibility data is impractical, due to the complex nature of spatial visibility distribution. Some approaches combine model

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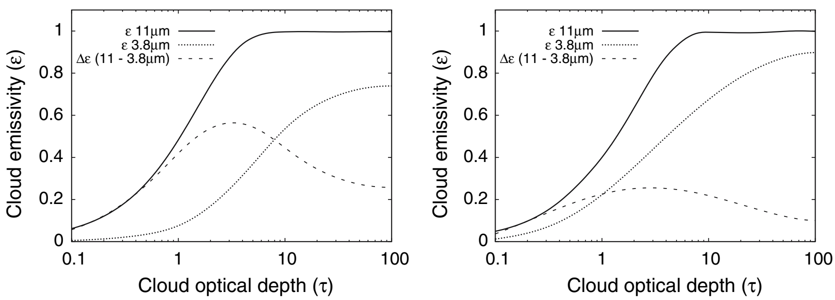

Figure 1
Emissivities as a function of droplet size and wavelength vs. cloud optical depth, after HUNT (1973). ϵ is the emissivity at wavelength λ, $\Delta\epsilon$ the difference in emissivities. The panel on the left-hand side shows the emissive behaviour for an effective droplet radius of 4 μm, the right-hand side for 10 μm.

output and satellite observations (e.g., GULTEPE *et al.*, 2007). However, model data are not always reliable and available, consequently this paper focusses on satellite data only.

Satellite-based detection of FLS has been performed on a wide range of platforms for a long time. Some of these can be applied in operational processing, i.e., they offer an objective decision on the presence of FLS, others require a pre-selection of scenes. Operational algorithms for daytime FLS detection have recently been proposed by BENDIX *et al.* (2006) (Terra MODIS) and ČERMAK and BENDIX (2006) (Meteosat SEVIRI). At night, an operationally applicable technique for the delineation of FLS has been in widespread use since it was first presented by EYRE *et al.* (1984). These authors take the difference in radiances at 10.8 and 3.7 μm as an indication of fog presence. In essence, the technique based on this principle identifies low clouds with predominantly small droplets; a combination of properties found in FLS (e.g., WMO, 1992, 1996; ROACH, 1994). The physical basis is the emissivity difference between infrared and middle infrared wavelengths as a function of cloud droplet size as presented by HUNT (1973). This relationship is shown in Figure 1 for clouds of various optical depths. It can be seen that emissivity differences between both wavelengths are considerably larger for small droplets (effective radius = 4 μm in Fig. 1) than for larger droplets (effective radius = 10 μm). This principle is used to identify small-droplet clouds in satellite imagery. Since its first application, the method has been widely used by numerous authors with NOAA AVHRR, Terra/Aqua MODIS and GOES Imager data (TURNER *et al.*, 1986; ALLAM 1987; D'ENTREMONT and THOMASON, 1987; BENDIX and BACHMANN, 1991; DERRIEN *et al.*, 1993; BENDIX, 1995; ELLROD, 1995; LEE *et al.*, 1997; REUDENBACH and BENDIX, 1998; PUTSAY *et al.*, 2001; BENDIX, 2002; UNDERWOOD *et al.*, 2004). It has been shown that this method provides accurate detection of small-droplet clouds in the studies cited, with clear separations of FLS from cloud-free regions, snow and other clouds by applying a static blackbody temperature difference threshold.