CLIMATOLOGICAL EVALUATION OF FOG/LOW STRATUS DISTRIBUTION BASED ON METEOSAT 8 AND 9 SEVIRI DATA

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Abstract

This paper describes a technique for the automated delineation of fog and low stratus area from geostationary satellite imagery. The application of this technique for the derivation of climatologically relevant information is shown.

THE PROBLEM

Low stratiform clouds play an important role in the global climate system. Fog more specifically also has a direct impact on human safety and quality of life. The spatially accurate mapping of low stratus and fog distribution has posed problems in the past, not to speak of climatological aggregation. The availability of fog climatologies would be of use in the regional assessment of fog/low stratus risk and in estimating the radiative effect.

A fog/low stratus climatology should ideally provide
- A high resolution in time and space
- Constant spatial coverage
- Continuous availability of compatible data, i.e. be robust with respect to satellite system transitions
- Operational applicability; in order to compile climatologically relevant information, automated application needs to be provided for.

To date, two approaches exist to the evaluation of fog/low stratus occurrence in time and space: Systematic evaluation of ground-based measurements and the interpretation of polar-orbiter data. The former approach mostly suffers from the lack of spatial coherence. Interpolation of visibility data proves difficult to accomplish so that spatial detail is lost inevitably. Based on National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data, Bendix (2002) assessed nighttime low stratus frequency using a total of 354 selected scenes. While some spatial patterns can be observed in this type of pre-climatology, two main draw-backs remain: a) Since manual scene selection is required, automation is not possible b) The technique applied covers nighttime only.

This paper presents a new technique to operationally detect fog and low stratus and shows some applications in the form of preliminary climatologies of fog and low stratus for Europe.
FOG/LOW STRATUS DETECTION APPROACH

Newest generation geostationary satellite data for the first time provide the potential for automated high-resolution fog and low stratus detection and thus climatological evaluation.

This is exploited here for the generation of climatologies. The retrieval methodology used is based on SEVIRI (Spinning-Enhanced Visible and Infra-Red Imager) data from Meteosat 8 and 9. A combination of spectral and spatial tests serves to identify low stratus clouds; a microphysics-based analysis of cloud vertical extent further allows for the delineation of (ground) fog areas.

The automated detection of fog and low stratus from satellite imagery during daytime from satellite imagery is hard to accomplish using only individual channels or simple channel-combination tests. Therefore, a complex procedure involving a sequence of tests and techniques has been developed to delineate areas with fog and low stratus during daytime and at night.

The approach consecutively tests for a number of properties assumed to be fulfilled in fog and low stratus. These clouds are addressed as:
- a cloud
- in the water phase (ice fog is deliberately ignored as it is less frequent)
- low above the ground
- with a stratiform surface
- impairing visibility at the ground (ground fog)

These attributes are tested for in spectral threshold tests and spatial tests. The former compare a number computed from one or more spectral channels to a threshold derived e.g. by histogram analysis and thus determine class membership. In spatial testing, not only individual pixels are considered, but also the surrounding areas and the change of properties with space.

Fog detection is a two-step process: First, low stratus clouds need to be distinguished from other surfaces in a 2D perspective. This involves discarding other cloud types and clear areas, covered by snow or not (see Figure 1). Secondly, to determine ground fog presence, some vertical information needs to be present. A computed cloud base is compared to the surface elevation in a given location. Where the cloud is at the ground, ground fog presence can be assumed.

Figure 1: The delineation of low stratus cloud areas as a series of consecutive tests.
A great portion of these tests are performed on the basis of spatial entities. These are spatially discrete and coherent regions of pixels belonging to the same category by preliminary classification. Surface homogeneity/stratiformity is one parameter tested for in this way.

The delineation of ground fog requires some knowledge of the geometry of the cloud. In order to compute a cloud base height for comparison with surface elevation (from a digital elevation model, DEM), cloud top height and geometrical thickness need to be known. The former is computed using terrain and geometrical temperature lapse rates (see Cermak 2006). For the latter, a relationship between geometrical thickness and liquid water path is used. Liquid water path can be derived from satellite data (Kawamoto et al. 2001). It is related to geometrical thickness via the distribution of liquid water within the cloud. This is approximated using a microphysical model of cloud properties, approximating a sub-adiabatic distribution (Cermak 2006).

The algorithms have been extensively validated using METAR data as a reference (Cermak & Bendix 2007, 2008).

Changes in channel calibration, e.g. due to system transitions, need to be addressed by a robust operational scheme. MSG2 became operational in 2007; in May 2008 there was a change in the way MSG radiances are computed. In the present scheme, dynamic thresholding plays an important role. Thresholds are computed anew with each run, so that changes in calibration can be more or less neglected.

**AGGREGATION SAMPLES**

This section presents some initial satellite-based "climatologies" of low stratus and fog for Europe, based on SEVIRI data, which has been available since 2004. The climatologies have a nominal spatial resolution of 3km; the high temporal resolution of the data (15min) allows for the computation of

![Image](image.png)

*Figure 2: Hours with ground fog, December 2004, daytime. n = 1665 scenes (31 days)*
parameters such as average fog/low stratus hours per day and average fog dissipation time. In this way, the temporal aggregation of the SEVIRI-based fog/low stratus products can contribute to the understanding of inter- and intra-annual variability of fog and low stratus distribution at various spatial scales, and set a sound basis for long-term climate change monitoring.

Figure 2 shows the number of hours with ground fog observed in December 2004 during daytime. In Figure 3, the number of days is shown with fog or low stratus, around the clock, for October 2005.

CONCLUSIONS AND OUTLOOK

Fog and low stratus detection based on geostationary satellite data seems to show promise, also regarding its use as a basis for climatological information. It is very important that system continuity is provided for so that long-term analysis becomes possible.

In the near future, the system described here will be improved by including an operational quality assessment based on comparisons with ground-based observations. Also, ground contact information will be included at nighttime in the future.

REFERENCES

Bendix, J. (2002), A satellite-based climatology of fog and low-level stratus in Germany and adjacent areas, Atmospheric Research, 64: 3-18.

