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A One-dimensional Ensemble Forecast and Assimilation System for Fog Prediction

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Abstract—A probabilistic fog forecast system was designed based on two high resolution numerical 1-D models called COBEL and PAFOG. The 1-D models are coupled to several 3-D numerical weather prediction models and thus are able to consider the effects of advection. To deal with the large uncertainty inherent to fog forecasts, a whole ensemble of 1-D runs is computed using the two different numerical models and a set of different initial conditions in combination with distinct boundary conditions. Initial conditions are obtained from variational data assimilation, which optimally combines observations with a first guess taken from operational 3-D models. The design of the ensemble scheme computes members that should fairly well represent the uncertainty of the current meteorological regime. Verification for an entire fog season reveals the importance of advection in complex terrain. The skill of 1-D fog forecasts is significantly improved if advection is considered. Thus the probabilistic forecast system has the potential to support the forecaster and therefore to provide more accurate fog forecasts.

Key words: Fog, one-dimensional, ensemble prediction, assimilation, model coupling, advection, verification.

1. Introduction

Reductions in visibility have an important impact on the capacity of an airport. Different initiatives by the International Civil Aviation Organization (ICAO) and also by Eurocontrol endeavor to address this problem. In Europe the Meteorological support for Air Traffic Management Group (METATMG) has, as one of its tasks, to study the possibilities to improve visibility and runway visual range (RVR) forecasts (METATMG, 2005). A large industry project (SESAR) under the lead of Eurocontrol intends to increase the air traffic capacity in Europe in the coming years by factors on different levels (EUROCONTROL, 2006), meteorology along with visibility forecast is one of the subtasks of the project. Imperfect visibility

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forecast always has an adverse impact on capacity regulated airports. It results in an overload when actual capacity is lower than expected, and in a capacity loss when conditions and the actual capacity are better than expected. In 2003 Swiss International Airlines estimated the accumulated delay due to one hour of erroneous visibility forecast in the morning for Zürich airport to 1400 minutes throughout the day (Werner Suhner, Swiss Int. Airlines, pers. comm., 2003).

Fog and visibility forecasts are provided in the Terminal Area Forecast (TAF) code for the so-called terminal area (airport). It is current practice to provide point forecast for such locations and the two main approaches are based either on statistical methods or on numerical models. Statistical approaches combine long records of site-specific observations with forecast variables generally provided by numerical weather prediction. A human forecast is, to a large extent, based on experience, and thus a subjective system of pattern recognition and climatological knowledge. For this work the focus lies on the second approach, using dedicated models for fog prediction without the need for long statistical training records.

The formation and dispersion of fog is the result of a complex interaction between thermodynamic and dynamical processes. DUYNKERKE (1990) identified the most important factors for fog formation to be:

- cooling of moist air by radiative flux divergence,
- mixing of heat and moisture,
- vegetation,
- horizontal and vertical wind,
- heat and moisture transport in soil,
- advection,
- topographic effects,

where atmospheric conditions, location and season decide upon the relative importance of each factor. The presence of clouds increases the incoming longwave radiation at ground level and thus reduces the longwave radiative cooling at the surface, which has great influence on fog formation. Therefore a good cloud forecast, computed by a 3-D model, is also needed. In complex topography cold air outflow and pooling as well as advection in the heterogeneous landscape become very important. Once the fog has formed there are further influences:

- longwave radiative cooling at fog top,
- fog microphysics,
- shortwave radiation.

Starting with the work of ZDUNKOWSKI and NIELSEN (1969) some of the above listed processes were included in fog models. In this early model there was no parameterization for the sedimentation of liquid water nor turbulence exchange coefficients. The latter were introduced by ZDUNKOWSKI and BARR (1972). An even more sophisticated model was developed by BROWN and ROACH (1976) and further