WAGENINGEN UNIVERSITY
METEOROLOGY AND AIR QUALITY

KNMI

Kennis voor Klimaat

Modeling and Forecasting the Onset and Duration of a Fog Event during Frost Conditions

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Introduction

Fog and low clouds seriously affect airport operations (Fig 1). Lack of knowledge of the relevant atmospheric, hydrological and chemical fog processes inhibit successful fog forecasting. This exploratory study evaluates the 3D models WRF and HIRLAM for a case of radiation fog in the Netherlands. We identify the role of model formulation, parameterization selection and resolution in forecasting the fog's onset and duration. The study is supported by 1D model tests of HIRLAM and Duynkerke (1991, D91).

Case study: 25 November 2004 at Amsterdam Airport

Widespread radiation fog developed under high pressure conditions, with clear skies, light winds and subsidence. Observations indicate a 150 m deep fog layer in the west in the early morning of 25 Nov, and which persisted the full day (Fig. 2). This is the first evaluation of WRF for fog. Also, the environmental conditions are particularly challenging, i.e. fog occurs for T<0ºC, fog onset relatively late at night and fog persists during daytime, and the fog was overlain by a very dry layer ($T-T_d$>20ºC), while T <0ºC close to the ground.

WRF-ARW 3.0.1:

Resolution: 3 nests: 33x33, 56x56, 61x61 grids with 30, 6, 1.2 km resolution

First level @ 6 m, 9 layers below 240 m

NCEP-FNL or ECMWF boundary conditions

Tested permutations:

Microphysics: Eta-Ferrier (2 moment), WSM3 (bulk), and WSM6 (bulk).

PBL: YSU (1st order), MYJ (TKE-l scheme).

Land: NOAH and 5 soil layer scheme

One day spin up.

HIRLAM 7.2

Resolution: 11 km, 296x306 grids

First level @ 30 m

Run in an 6 h assimilation cycle with ECMWF boundary conditions

Microphysics: bulk microphysics with 4 hydrometeors

PBL: TKE-l scheme

Land: ISBA

Fig 1: Fog is a serious problem for aviation

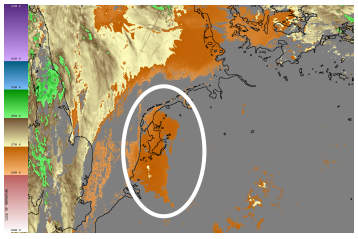

Fig 2: Observed cloud top temperature 25 Nov 2004 10.05 UTC (http://wdc.dlr.de/apollo). Brown indicates the fog layer.

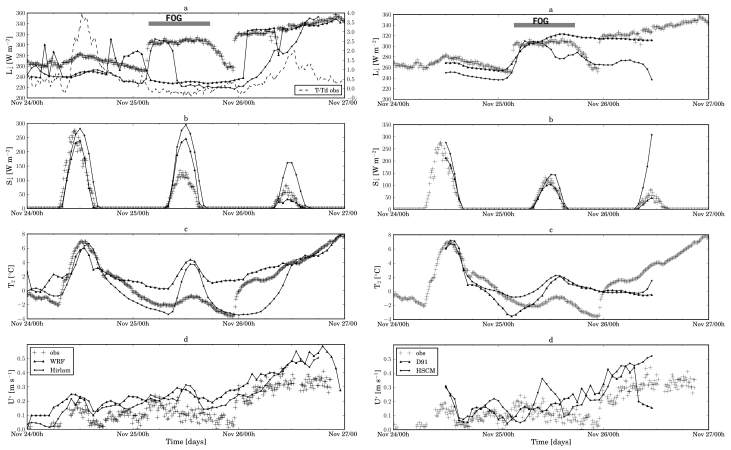

Fig 3: Modelled and observed longwave (a) and shortwave (b) downwelling radiation, 2m temperature (c), and friction velocity (d). Left: 3D models, right: 1D models

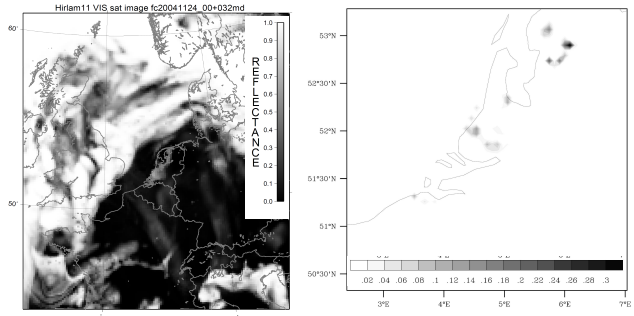

Fig 4: Modelled spatial distribution of reflectivity (HIRLAM, left) and near surface liquid water content (WRF, right, unit: g/kg)

Results I: 3D models

Both WRF and HIRLAM have difficulties with the fog evolution (Fig 3). WRF only forecasts fog for a few permutations of the parameterizations, but the fog onset is offset in time and location, and the fog is spatially scattered (Fig 4). HIRLAM correctly forecasts the fog onset, but the fog layer remains at the lowest model layer (Fig 5). Both models overestimate friction velocity. Hence, in both models fog does not persist, but is quickly dispersed.

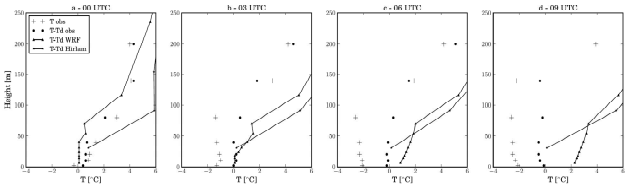

Fig 5: Modelled and observed (Cabauw) vertical profile of dew point depression (T-Td) for WRF and 3D HIRLAM for 25 Nov 2004

Results II: 1D models

Two column models performed well for the fog onset and its mature stage, although their results were sensitive to the initial and conditions and prescribed external forcings (Fig. 3). High vertical resolution close to the surface is essential for fog modeling. Resolution at higher levels is important when the fog lifts to a stratus layer (Fig. 6).

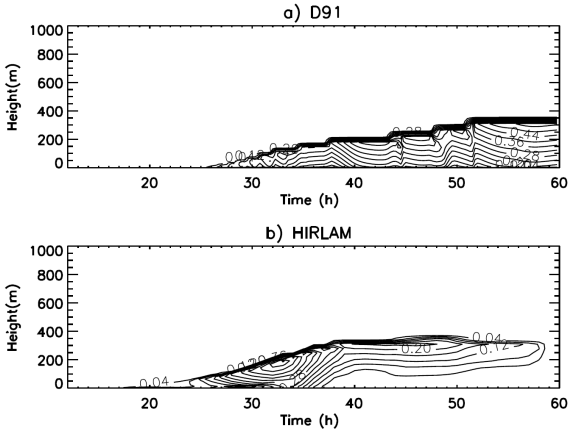

Fig 6: Modelled liquid water content by the Duynkerke (1991, panel a) and HIRLAM (panel b) column models.

Conclusions

- Fog is a subtle result of a mixture of processes working together.
- Current high resolution weather forecast models (WRF + HIRLAM) encounter extreme difficulties in forecasting fog.
- WRF and HIRLAM models can't maintain fog during daylight hours.
- Duynkerke 1-D model performs better than 1D HIRLAM; although fog thickness is overestimated.
- More fundamental research on fog dispersal needed.

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References:

Duynkerke, P.G., 1991: Radiation fog: a comparison of model simulation with detailed observations. Mon. Wea. Rev., 119, 324-341.
Velde, I.R. van der, G.J. Steeneveld, B.G.J. Wichers Schreur, A.A.M. Holtslag, 2010: Modeling and forecasting the onset and duration of severe radiation fog under frost conditions, Mon. Wea. Rev., 10.1175/2010MWR3427.1

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