Fog Forecast: A Review of Current Approaches

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PP-AWARE Meeting
4 June 2020

Fog / Visibility:

- study history *[Gultepe, 2007]*
- classification of fogs, physical characteristics, conditions and formation processes *[Roach, 1994, 1995; Matveev, 2000; Pruppacher, Klett, 2010; Haeffelin, 2010; ...]*
- meteorological visibility theory

Fog / Visibility Forecast Methods at the Hydrometeorological Center of Russia:

- synoptic-statistical approaches *[Shakina, 2016]*

COSMO / ICON at the Hydrometeorological Center of Russia: opportunities

- review of important parameterizations for the forecast of fog - microphysics, turbulence, cloud macrophysics, underlying surface, radiation, aerosols

Fog / visibility forecasting methods at leading meteorological centers in the world:

- **NCEP** — diagnostic scheme based on an asymptotic analytical study of radiation fog *[Zhou, 2011, 2012]*
- **Met Office** — London Model, high-resolution numerical model *[Boutle et al., 2016]* + microphysical parameterization of the fog *[Wilkinson et al., 2013]*
- **Meteorological Institute University of Bonn** — COSMO-PAFOG, a combination of a 3D numerical weather forecast model and a 1D model of fog *[Hacker, 2016]*

Forecast of Low Visibility and Fog from NCEP

1. Visibility diagnosis method
2. Multi-rule fog diagnosis
3. Probabilistic fog forecast derived from the NCEP SREF system
4. Combination of two previous approaches

} Fog occurence

5. Diagnostic scheme, based on an asymptotic analytical study of radiation fog

Fog LWC / intensity

Balance among cooling, turbulence and droplet settling onto the ground

→

Critical turbulent exchange coefficient

$$K_c \sim \frac{cooling\ rate}{fog\ depth}$$

upper bound of turbulence intensity which a persisting fog can withstand

→

$$K < K_c$$

fog can form and continue to exist

[Zhou B. (2011). Introduction to a new fog diagnostic scheme.
Zhou B. et al. (2012). Forecast of low visibility and fog from NCEP: Current status and efforts. Pure Appl. Geophys.]

Forecasting fog at 333 m resolution in Met Office

Configuration **London Model** (hor. grid spac. 333 m) ← Operational model **UKV** (1.5 km)

Model set up

Time step:
50 s → 10 s

1D boundary-layer scheme for vertical mixing +
2D Smagorinsky scheme for horizontal mixing
↓
3D Smagorinsky sub-grid turbulence scheme
↓ *?*
Grey-zone turbulence parametrization

- RH_{crit} for cloud parametrization is increased
- Model orography and land usage characteristics with more detail

Updated aerosol emissions database

[Wilkinson J.M. (2013). Improved microphysical parametrization of drizzle and fog for operational forecasting using the Met Office Unified Model. Q. J. R. Meteorol. Soc.
Boutle I.A. et al. (2016). The London Model : forecasting fog at 333 m resolution. Q. J. R. Meteorol. Soc.]

Three-dimensional fog forecast with COSMO-PAFOG

Coupling of two-moment microphysics parameterization of the 1D fog model PAFOG with the nonhydrostatic 3D mesoscale model COSMO → 3D fog model

Concept of COSMO-PAFOG: dynamical processes (advection ADV, diffusion DIF) calculated by COSMO dynamics, microphysical processes (phase transitions σ, sedimentation) solved by PAFOG microphysics:

$$\frac{\partial N_c}{\partial t} = ADV(N_c) + DIF(N_c) + \left(\frac{\partial N_c}{\partial t}\right)_{sed} + \sigma(N_c)$$

Cloud droplet concentration

$$\frac{\partial q_c}{\partial t} = ADV(q_c) + DIF(q_c) + \left(\frac{\partial q_c}{\partial t}\right)_{sed} + \sigma(q_c).$$

Cloud water content

COSMO Dynamics | **PAFOG Microphysics**

[Hacker M. (2016). COSMO-PAFOG: Three-dimensional fog forecasting with the high-resolution COSMO-model]


Thank you for the attention!

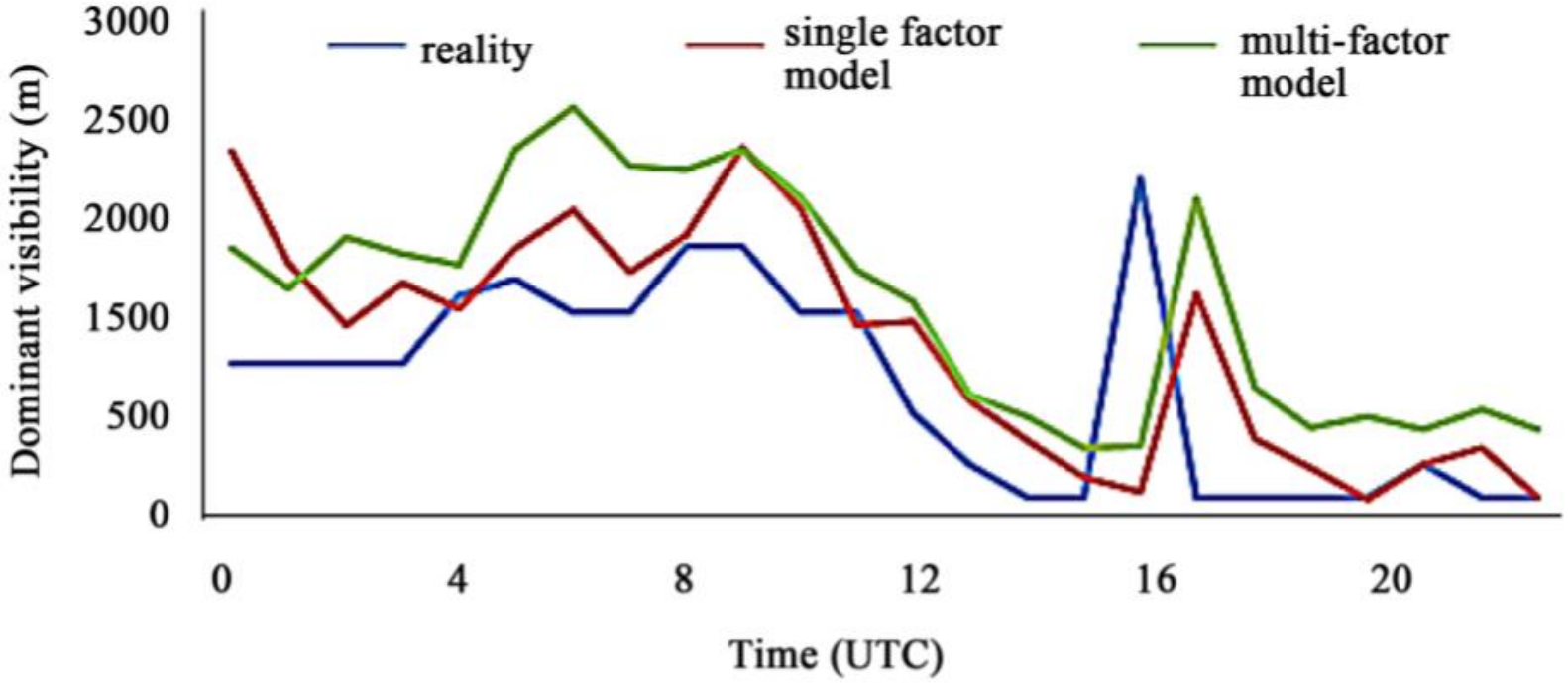

Figure 4. The effect of different models on the forecast of dominant visibility on December 31, 2016.

[Zhu L. et al. (2017). The Application of Deep Learning in Airport Visibility Forecast. Atmospheric and Climate Sciences.]