Fog forecasting: synoptical methods, aerosols and 1D models

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Outline

- Fog: characteristics and influence
- The difficult child: radiation fog
- Role of aerosols
- Heuristic methods and postprocessing
- 1-d models
- COSMO-ART
- Conclusions
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Fog hazards

- Shipping
- Roads
- Sports
- Aviation
Fog in aviation

- Fog usually does not forbid air traffic but slows it down by a factor of ~2.
- Implies loss of a lot of money by the event itself
- A part is due to “incorrect” forecasts (onset, dissipation)

- Time scales:
  - 2-4 hours for European flights.
    - Planning alternates
    - ATC slot control
  - 1-3 days: ATC planning

  typical potential application of small scale (ensemble) models
FOG observation (METAR)

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130220Z 10002KT 0900 R05/P2000N R23/1300D FG VV004 03/03 Q1020 NOSIG=
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130850Z 00000KT 0300 R05/0450N R23/0650D FG VV002 02/02 Q1017
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TREND = 2 hour forecast

BECMG 1500 BCFG BR OVC002=
BECMG 1500 BCFG BR OVC002=

EWGLAM SRNWP | Belgrade, October 2015
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121125Z 1212/1318 VRB03KT 6000 FEW003 BKN007
TX07/1214Z TN00/1306Z TX05/1315Z BECMG
1212/1214 SCT010 BECMG 1220/1222 1500 BCFG
NSC BECMG 1300/1303 0800 FG VV003 PROB30
TEMPO 1302/1306 0300 FG VV001 BECMG 1310/1312
23010KT 6000 -RA FEW003 BKN040=

FOG forecast (TAF)
Fog types

• Definition: horizontal visibility < 1000 m

• Advection fog
• Coastal fog
• Hill (upslope) fog

• Radiation fog
  • Shallow fog (MIFG)
  • Fog patches (BCFG)
  • Partial fog (PRFG)
  • Fog (FG, FZFG)
Radiation fog

In theory

Heat radiating from the surface at night, cools the bottom air until it reaches saturation.

Fog forms first at the surface, thickening as cooling continues.

Further radiational cooling at top of fog layer, deepens it.
Radiation fog

In practice (often)

Dew

Hoarfrost
Deposition or fog?

• What makes the difference?
• Strength of vertical inversion?
• Mixing (a little bit of wind)?
• Amount and distribution of aerosols?
Deposition or fog?

• What makes the difference
• Strength of vertical inversion?
• Mixing (a little bit of wind)?
• Amount and distribution of aerosols?
## Detection of aerosols by Lidar

![Lidar Image]

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</tr>
</tbody>
</table>

Belgrade, October 2015

Pierre.Eckert[@]meteoswiss.ch
Aerosols

- The monitoring of the hygroscopic growth of aerosols by ALC (Automatic LIDAR-ceilometer) enables to predict before 10-45 min the occurrence or not of the radiation fog.
- Research is in progress, but the influence of aerosols is crucial.
Fog forecasting: heuristic methods

• Estimation of the minimal temperature and comparison with the measured dew point remains a must (but the problem fog or deposition remains).
• The month number is a good predictor, mainly for the time of dissipation.
• A weather classification also gives good clues: in Geneva fog forms in SW situations, never in NE situations (always stratus).
• Various MOS methods have been developed (i.e. TAF guidance).
Based on global (or ~10 km) models
Long history is needed
Postprocessing
M. Hacker et al. Uni Bonn

First Step: Fog Stability Index
Deterministic approach

From FSI to FOGCAST
Probabilistic approach
Postprocessing
M. Hacker et al. Uni Bonn

**Fog Stability Index (Air Weather Service (1979))**

\[
FSI = 2 \cdot (T - T_d) + 2 \cdot (T - T_{850}) + V_{h,850}
\]

- **Dewpoint spread**
- **Horizontal wind speed at 850 hPa**
- **Vertical temperature gradient**

**Fog risk**

- **FSI < 31**
- **31 < FSI < 55**
- **FSI > 55**
Postprocessing

More predictors and selection method (LASSO)
Probabilistic forecast
Postprocessing (score)

FOGCAST (COSMO-DE)

FSI
Components of FSI
FOGCAST
1d models

- Radiation fog is a thin phenomenon
- Some processes have to be modelled in more detail than in full 3d models.
  - 1d models with very high vertical resolution
  - Forced by 3d “normal” model.
  - Inclusion local characteristics (soil type, albedo,...)
  - Inclusion of local observations (T, Td, evt. vertical profile,...)
- For example COBEL
A Little History on COBEL...

- Developed in France for the study of physical processes in nocturnal BL (Univ. Paul Sabatier, 1988)
- Used as a fog forecasting tool (1993)
  ⇒ Paul Sabatier + Météo France (Nord pas de Calais)
- Adapted to day conditions, more external forcings, data assimilation, wake vortex studies
  (UQAM, 1993-1997)
- Stratus dissipation forecasting at SFO
  (UQAM, 1997 - present)
- Radiation fog forecasting for Ohio River Basin
  ⇒ Texas A&M + ILN NWSFO (1999 - present)
Hard coded input variables into COBEL

- Soil moisture (2 layers=>0-5cm, 5cm-1m)
- Incoming solar flux at top of radiative grid (5.3km)
- Soil temperatures (3 levels=>0cm, -10cm, -1m)
- Roughness lengths (momentum & heat)
- Coriolis parameter
- Soil specific heat
- Surface emissivity
- Surface albedo
- Soil type
- Surface atmospheric pressure
- Vegetation parameters
1- Dimensional Modeling

1-D (Column) Boundary Layer Model

A Detailed Look at the Physical Processes

- Radiative Transfer
- Turbulent Mixing
- Soil-Atmosphere Interactions

- momentum
- heat
- humidity

High Vertical Resolution

UQÀM Department of Atmospheric Sciences
Simulated Physical Processes

- **LW radiative transfer** (emission, absorption)
- **SW radiative transfer**
  - (scattering, transmission, reflection, absorption)
- **Turbulent mixing w/ variable stratification**
  - (very stable, stable, neutral, unstable profiles)
- **Surface/atmosphere exchanges**
  - (heat, moisture, momentum)
- **Soil moisture vertical transport**
  - (diffusion, conductivity)
- **Diabatic effects** (condensation, evaporation)
- **Precipitation physics**
  - (autoconversion, collection, evaporation)
Physical Processes (continued)

- Gravitational settling of cloud droplets
- TKE production
  - (by wind shear, buoyancy, transport, dissipation)
- Horizontal pressure force (external forcing)
- Horizontal advection (external forcing)
  - (temperature, humidity, momentum)
- Vertical advection (by mesoscale vertical motion)
- Pressure tendency (external forcing)
COBEL

Physical Processes

- SW $\Rightarrow$ Fouquart & Bonnel (1980)
- IR $\Rightarrow$ Vehil et al. 1989
- Microphysics $\Rightarrow$ Kessler (1969)
- Soil $\Rightarrow$ Mahrt & Pan (1984)
- Turbulent Mixing $\Rightarrow$ TKE w/ 1.5 order closure

Department of Atmospheric Sciences
COBEL Vertical Resolution

- 2 staggered grids
- Log-linear increase in resolution (0-1.4km)
  - Finest: 0.5 meters
  - Coarsest: 30 meters
- Above 1.4km => 5 levels for radiative calc. Only

- Secondary grid => radiative fluxes, turbulent fluxes, TKE (31 levels)
- Primary grid => temp, wind, humidity, cloud water, TKE flux (30 levels)

“Extension of primary grid”
(5 levels => soil temp only)
Boundary Conditions

- **Fluxes**
  - Top: turbulent fluxes of $\theta$, $q$, $q_l = 0$ (above 1.4km),
  - IR flux from clouds above rad. grid
  - Bottom: flux of TKE=0 ($z_0$), sfc albedo & emissivity

- **Temperature**
  - Soil temp assumed constant at –1meters

- **Wind**
  - Top: no boundary condition used
  - Bottom: $u=v=0$, TKE flux=0
1d-Models : some conclusions
Bergot et al. 2005

Single-column numerical models were able to reproduce some of the major features of the life cycle of a fog layer
• characterized by a “dynamical period”: fog growth due to the radiative cooling of the top of the fog layer
• triggers convection inside the fog layer.
• high sensitivity to physical parameterizations. The gravitational settling flux cannot be neglected.
• The absence of the gravitational settling term in the microphysical parameterization leads to unrealistically high cloud water contents inside the fog layer and consequently to significant errors during the fog dissipation phase.
Visibility forecast with COSMO-ART

B. Vogel

Aerosols and Climate Processes, Institute for Meteorology and Climate Research - Troposphere
COSMO–ART (ART = Aerosols and Reactive Trace Gases)

Concept:

Global Model ‘GME’ (DWD)
‘IFS’ (ECMWF)

Meteorology and Transport

Photolysis ‘PAPA’

Chemistry ‘RADMKA’

Aerosols ‘MADEsoot’ (extended)

Dry and Wet Deposition

Parametrised Emissions
Biogenic VOC + NO, Mineral Dust, Sea Salt, Pollen

Anthropogenic Emissions

Land Use Data

Ext. Parameters

Vogel et al., 2009, ACP

EWGLAM SRNWP; Belgrade, October 2015
Pierre.Eckert[at]meteoswiss.ch

= operational weather forecast model (DWD)
Interaction of five modes:

- **Two modes** for $\text{SO}_4^{2-}$, $\text{NO}_3^-$, $\text{NH}_4^+$, $\text{H}_2\text{O}$, SOA, internally mixed.

- **One mode** for pure soot.

- **Two modes** for $\text{SO}_4^{2-}$, $\text{NO}_3^-$, $\text{NH}_4^+$, $\text{H}_2\text{O}$, SOA, and soot internally mixed.

Source: homogeneous nucleation of $\text{H}_2\text{SO}_4$/water

Condensation of $\text{SO}_4^{2-}$, $\text{NH}_4^+$, $\text{NO}_3^-$, SOA

coagulation

Three modes for **mineral dust** particles + Three modes for **sea salt** particles + Pollen
Total amount of aerosols

The diagram shows the distribution of aerosols in different locations. The x-axis represents distance in km, ranging from 0 to 200, and the y-axis represents distance in km, ranging from 0 to 200. The color scale indicates the concentration of aerosols in μg m⁻³, with values ranging from 6 to 12 μg m⁻³. The following cities are marked on the diagram:

- Saarbrücken
- Karlsruhe
- Stuttgart
- Strasbourg
- Basel

The concentration levels are as follows:

- Saarbrücken: 12 μg m⁻³
- Karlsruhe: 11.5 μg m⁻³
- Stuttgart: 11 μg m⁻³
- Strasbourg: 10.5 μg m⁻³
- Basel: 10 μg m⁻³
- Others: 9.5 μg m⁻³, 9 μg m⁻³, 8.5 μg m⁻³, 8 μg m⁻³, 7.5 μg m⁻³, 7 μg m⁻³, 6.5 μg m⁻³, 6 μg m⁻³
PM10 and Visibility, Karlsruhe

PM 10

Visibility

date 2005
date 2005

measurements
simulation

visibility roses (minimum)
local visibility (Koschmieder)
measurements
Conclusions

- Radiation fog forecasting is difficult
- Local recipes still have skill
- Postprocessing provides estimates on a probabilistic basis
- 1d models show a good potential but have to be tuned and provided with additional local information
- The two latter would benefit from better predictors issued by small scale models.
- Including aerosols as a prognostic variable in the full models certainly has a good potential w.r. to fog forecasting.
- I am looking forward in ideas in assimilation, dynamics, physics, ensembles,...
Хвала вам пуно на пажњи пацијента

Thank you very much for your patient attention