LM_PAFOG: three-dimensional fog forecasting with the Lokal Modell

Matthieu MASBOU & Andreas BOTT

LM User seminar – Langen, 6 March 2006
\( f(a, r, x, y, \ldots) \)

PAFOG Parameterized microphysics

LM \( \rightarrow \) LM-PAFOG

Simulations & outlooks
Parameterized FOG

\[
\frac{\partial N_c}{\partial t} = \left( \frac{\partial N_c}{\partial t} \right)_{act} + \Delta(S) \left( \frac{\partial N_c}{\partial t} \right)_{eva} + \left( \frac{\partial N_c}{\partial t} \right)_{sed}
\]

\[
\frac{\partial q_c}{\partial t} = \left( \frac{\partial q_c}{\partial t} \right)_{con/eva} + \left( \frac{\partial q_c}{\partial t} \right)_{sed}
\]

where \( S \) is the Supersaturation

Assumption on the droplet size distribution : Log-normal function

\[
dN_c = \frac{N_c}{\sqrt{2\pi s_c}} \left( \frac{D}{D_{c,0}} \right) \exp \left( -\frac{1}{2 s_c} \ln^2 \left( \frac{D}{D_{c,0}} \right) \right) dD
\]

\( D \) droplet Diameter

\( D_{c,0} \) mean value of \( D \)

\( s_c \) Standart deviation of the given droplet size distribution (\( s_c = 0.2 \))
Activation

\[ N_{act} = CS^k \]

\( f(a, r, x, y, \ldots) \)

k and C describe the aerosol model:

- Maritime: \( k=0.7, \ C=100 \ \text{cm}^{-3} \)
- Continental: \( k=0.9, \ C=3500 \ \text{cm}^{-3} \)
- Rural: \( k=0.9, \ C=10000 \ \text{cm}^{-3} \)
Condensation/Evaporation

Time dependent relation between Supersaturation $S$ and Diameter $D$

Chaumerliac et al. (1987) and Sakakibara (1979)

\[
\frac{dD}{dt} = A \frac{S}{D}
\]

\[
\frac{dS}{dt} = S(r,t)
\]
Time dependent relation between Supersaturation $S$ and Diameter $D$

Chaumerliac et al. (1987) and Sakakibara (1979)

\[
\frac{dD}{dt} = A \frac{S}{D}
\]

\[
\frac{dS}{dt} = S(r,t)
\]
Using the formulation of Berry & Pranger (1974):

\[ v(D) = \frac{\eta \, \text{Re}}{D \rho} \]

with

- \( \eta = \eta(D) \) Viscosity
- \( \text{Re} = \text{Re}(D) \) Reynolds number

**Numerical solution**: positive definite advection scheme

(Bott 1989)
Forecast Area

- Fog formation = complex and highly non linear fashion (Turbulences, soil/atmosphere,…)

3D Fog forecasting Model = fine horizontal resolution

But, not feasible for operational mesoscale models

One way interactive Nesting LM2LM

LM : 325x325 ?xy=7x7 km

LM-PAFOG
100x100
?xy=2.8x2.8 km
Forecast Area (2)

Interactions Soil/Atmosphere = a predominant role in the fog formation (latent fluxes, turbulences, …)

Fine resolution at Soil/Atmosphere Interface

- $k = 33$
- $k = 34$
- $k = 35$
- $k_s = 1$
- $k_s = 9$
- $k_s = 1$
- $k_s = 35$

- $K_{soil} = 2$
- $K_{soil} = 14$

- $LM$ $ke = 35$
- $LM$ $ke = 35$
- $LM$ $ke = 35$
- $LM-PAFOG$ $ke = 35$
- $LM-PAFOG$ $ke = 35$
- $LM-PAFOG$ $ke = 35$

- $256$ m
- $153$ m
- $68$ m
- $0.2$ m
- $1.9$ m
- $40$ m
- $4$ m
- $0.002$ m
- $0.18$ m
- $1.2$ m

$k = 25$
$k = 18$
$k = 16$
$k = 40$
Parameterized Microphysics

Comes from PAFOG (Bott & Trautmann 2002):

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

\[
\frac{\partial q_c}{\partial t} = \text{ADV}(q_c) + \text{DIF}(q_c) + \left( \frac{\partial q_c}{\partial t} \right)_{\text{sed}} + \sigma(q_c)
\]

ADV (Advection) and DIF (Turbulent Diffusion) are computed by the dynamical framework of LM.

\[
\begin{pmatrix}
\frac{\partial q_c}{\partial t} \\
\frac{\partial N_c}{\partial t}
\end{pmatrix}_{\text{sed}}
\begin{pmatrix}
\frac{\partial q_c}{\partial t} \\
\frac{\partial N_c}{\partial t}
\end{pmatrix}_{\text{sed}}
\]

Sedimentation of cloud droplets

\[
\sigma(q_c) \quad \sigma(N_c)
\]

Source-sink terms between gaseous and liquid phase
Parameterized Microphysics (2)

Fog Microphysics determines clouds development, if:

\[ Z < 2000 \text{ m} \]
Parameterized Microphysics (3)

Rain

Cloud Water

Water Vapour

CCN

Snow

Smelt, Sfrz

Sau

Sac

Sshed

Sc

Snucl

Srim

Evap

Supersaturation

Sed

Sev

Sdep

Ps

Pr

Fv

Precipitation and evapotranspiration at ground level
Simulation Conditions

Lindenberg (Germany)
Lon 52 10´01˝ Lat 14 07´27˝

6 October 2005 00 UTC – 8 October 2005 00UTC

100x100 pixels with dx = 2.8 km

Timestep : 10 sec.

No cloud cover excepting FOG formation
07.10.2005 01UTC

Horiz. Cross Section 2 m

Vert. Cross Section

LWC in g/kg
07.10.2005 05UTC

LWC in g/kg

Horiz. Cross Section 2 m

Vert. Cross Section
Visibility 2m

![Graph showing visibility over time]
Relative Humidity 2m

Time in hour

RH in %

FOG

FOG
Clouds & Radiative Scheme

Modified Cloud Scheme

Original LM Cloud Scheme

T2m in time

T2m in time
CONCLUSIONS

- **PAFOG** = parameterized microphysics of CCN
  
  Activation Condensation/Evaporation Sedimentation

  Based on Log-normal distribution

- **PAFOG + LM** → **LM_PAFOG**

  Smaller Area 100 x 100 km

  Fine Horizontal resolution \(?x = 2.8\) km

  Fine Vertical resolution \(?z_{\text{min}} = 4\) m

- Simulations produce fog during the observed fog periods

- Boundaries Condition plays an important in fog formation

  **Cloud Cover parameterization have a decisive role in fog formation**
OUTLOOKS

Satellite Data, Jan Cermak & Jorg Bendix, University of Marburg, WG1

Test Spatial distribution of fog

Original Satellite Data

Stratus Mask
References


