COSMO-FOG: numerical short range fog forecast with 3D fog forecast model

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Fog Formation

- Cooling
- Moistening
- Turbulent Mixing

Reach saturation

Source figures: R. Tardiff’s Website
### 3D FOG Model = COSMO + PAFOG

#### LM-Dynamics

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

#### PAFOG-Microphysics

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

**Droplet number concentration**

**Liquid Water Content**

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**LM-Dynamics**

- **Water/Ice Cloud**
  
  - $q_c$

- **Precipitation**

**PAFOG-Microphysics**

- **Fog/Stratus**
  
  - $N_c$

- **Soil Model**

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20 000 m

2000 m
Assumption for droplet spectra : \textbf{Log-normal}

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

\( D \) droplet diameter
\( D_{c,0} \) mean value of \( D \)
\( \sigma_c \) standard deviation of size distribution (\( \sigma_c = 0.2 \))
PAFOG Microphysics

1- Activation [Twomey (1954)]:

\[ N_{act} = N_a S^k \]

k and \( N_a \) depend on their environment (maritime, rural, urban)

2a-Detailed Condensation/Evaporation: parametrised Köhler relation

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

2b-Time dependent relation between supersaturation \( S \) and diameter \( D \)

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

3-Droplet size dependent sedimentation

[Berry and Pranger 1974]

Positive Definite Advection Scheme

[Bott (1989)]
STANDARD-PAFOG Microphysics

LWC-PAFOG microphysics

LWC-Standard microphysics

CCN-PAFOG microphysics

Lindenberg Observatory
2005 September 27th 03 UTC
27 hours forecast
Vertical resolution

14 layers below 2000 m
- 94 m
- 51 m
- 20 m

COSMO operational

25 layers below 2000 m

COSMO-FOG

10 layers
Δz=4m

40 m

Atmosphere

Soil

Tatm

Tsoil

8 levels: 0.005; 0.02; 0.08; 0.24; 0.78 cm…
Turbulent mixing terms are given by a flux gradient relation

\[
M_T = \frac{1}{\rho \sqrt{G}} \frac{\partial}{\partial \zeta} \left( \frac{\rho \pi K_H}{\sqrt{G}} \frac{\partial \theta}{\partial \zeta} \right)
\]

\[
M_{q^x} = \frac{1}{\rho \sqrt{G}} \frac{\partial}{\partial \zeta} \left( \frac{\rho K_H}{\sqrt{G}} \frac{\partial q^x}{\partial \zeta} \right)
\]

\[
M_u = \frac{1}{\rho \sqrt{G}} \frac{\partial}{\partial \zeta} \left( \frac{\rho K_M}{\sqrt{G}} \frac{\partial u}{\partial \zeta} \right)
\]

\[
M_v = \frac{1}{\rho \sqrt{G}} \frac{\partial}{\partial \zeta} \left( \frac{\rho K_M}{\sqrt{G}} \frac{\partial v}{\partial \zeta} \right)
\]

Parametrized following Mellor and Yamada (1982)

2.5th-Order

(Raschendorfer, 2001)
Modification of Turbulence Scheme

Collaboration with Olivier Fuhrer, Meteoswiss

Step 1: replace semi-implicit calculation of the TKE diffusion term by a implicit calculation

Step 2: Based on the work of M. Buzzy, 2008

Instability due to wind Shear term:

\[
G_M = \frac{\kappa^2}{q^2} \left[ \left( \frac{\partial}{\partial z} u \right)^2 + \left( \frac{\partial}{\partial z} v \right)^2 \right]
\]

Filtering the wind gradient before evaluating the stability function

\[
f_k^{new} = 0.5 f_k + 0.2(f_{k-1} + f_{k+1}) + 0.05(f_{k-2} + f_{k+2})
\]

More details about problem of the instability in stable turbulence regime.

See Buchard and Deleersnijder 2001, Mellor 2003, Buzzi 2008
Modification of Turbulence Scheme

Min Kh=1.0

Min Kh=0.001

$K_h$

- 1 UTC
- 2 UTC
- 3 UTC
- 4 UTC
- 5 UTC
Modification of Turbulence Scheme

Min $K_h = 1.0$

Min $K_h = 0.001$

$K_h$

- 7 UTC
- 8 UTC
- 9 UTC
- 10 UTC
- 11 UTC
3 Sites:
- **Cabauw** (the Netherlands), flat terrain.
- Lindenberg (Germany), bumpy terrain, alt: 0-500 m. (results not shown)
- **Zürich** (Switzerland), mountaineous terrain, alt: 200-3000 m.

Weather Situation:
- 1st-15th October 2005
- **High Pressure** System over Europe (Omega weather situation)
- No cloud cover

only Radiative fog & valley fog

Comparison with MSG satellite product for fog and low stratus
MSG-product for fog and low stratus

Specific water content in kg/kg (COSMO-FOG)

TKVH min = 0.001

TKVH min = 0.7
MSG-product for fog and low stratus

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TKVH min = 0.001
Cabauw- 05 October 12UTC-24hours

TKVH min = 0.7
Zürich - 11 October 12UTC-24hours

12th October 2005-06:30UTC

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12th October 2005-06:30UTC

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TKVH min = 0.7
CONCLUSION

- COSMO-FOG = 3D COSMO + PAFOG
- Implementation of new turbulent diffusion scheme
- Turbulent Scheme very sensitive of TKVH min value
- Forecasted fog at 3 different terrains with same setup

Outlook

- Sensitivity study of TKVH and TKVM min values
- Sensitivity study of microphysic parameters
- longer verification period