The Role of the Land Surface in Fog Modelling - Simulations with COSMO-FOG

Isabel Alberts, Matthieu Masbou and Andreas Bott

Meteorological Institute – University of Bonn,
ialberts@uni-bonn.de
What is FOG?

**World Meteorological Organisation (WMO) definition**

“Suspension of very small, usually microscopic water droplets in the air, generally reducing the horizontal visibility at the earth’s surface to less than 1km”

Webcam: http://www.loewenburger-hof.de/
Ingredients for Fog Formation

- Cooling
- Increase in humidity
- Calm or light winds
Ingredients for Fog Formation

Precipitation fog
Advection fog
Valley fog

- Cooling
- Increase in humidity
- Calm or light winds

Radiation fog
Advection fog
Valley fog
Fog Formation and the Land Surface

**What is the role of the surface?**

**Local Surface Influences**
- Soil type
- Vegetation
- Surface characteristics
- Soil moisture

**Terrain Influences**
- Topography
  - Mountain valley breeze
- Accumulation of cool air

**What processes does the surface affect?**

- Radiative cooling
- Advection
- Vertical mixing of heat and moisture
- Heat and moisture transport in the soil

*e.g. different soil type/vegetation...*
Coupling of **COSMO Model** and **PAFOG** (PArametrized FOG) (Bott & Trautmann (2002))

- $ke=20 \text{ m}$
- $ke=8 \text{ m}$
- $ke=4 \text{ m}$

**Terra - MultiLayer**

**COSMO-Model** (DWD)

**COSMO-FOG**

- $ke=12 \text{ m}$
- $ke=8 \text{ m}$
- $ke=4 \text{ m}$

- 2.8/7 km
- 1.0 km
Coupling of **COSMO Model** and **PAFOG** (PArametrized FOG) (Bott & Trautmann (2002))

Current NWP models run at resolutions that are too coarse for simulation of fog

Microphysics of PAFOG limited to the lower part of the atmosphere (2000m)

Introduction of a new prognostic variable: Concentration of Cloud Condensation Nuclei (CNN)

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**COSMO-Model (DWD)**

ke=20 m

ke=8 m

ke=4 m

**COSMO-FOG**

ke=12 m

ke=8 m

ke=4 m

**Terra - MultiLayer**
Research Area
Needed DATA for description of the surface

Soil type
Vegetation
Topography

Surface roughness
Root depth
Plant cover
Leaf area index
Needed DATA for description of the surface:

- Soil type
- Vegetation
- Topography

Surface roughness
- Root depth
- Plant cover
- Leaf area index

To take the high heterogeneity into account:
set of modified external parameters implemented into COSMO-FOG; resolution 1 km

Source: FAO/UNESCO Soil map of the world (Food and Agricultural Organization of UNO, 10 km resolution)

Source: Soil map 1:50 000 (BK50, Geologisches Landesamt NRW and Rheinland Pfalz, 50 m resolution)
Explicit modelling of vegetation layer as one „big leaf“ which is situated between atmosphere and surface: e.g. vegetation temperature, humidity, wind,... Deardorff (1978); Schädle (1989); Siebert et al. (1992); von Glasow and Bott (1999)

Modifications of:

...radiation ->
ground surface
albedo

\[ \alpha_{\text{veg}} \]

Land use dependant
values Ament, 06

\[ \alpha_{\text{baresoil}} \]

Water content and soil / veg
parameters Schädler, 89

...water fluxes:

Evapotranspiration
controlled by ->
atmospheric resistance

\[ r_a \]

stomata resistance

\[ r_s \]

http://meted.ucar.edu

=> Expect a more detailed simulation of e. g. temperature and humidity over vegetation
**Model Setup**

**Sensitivity Study:** Two model runs with different data set of external parameters and parameterizations concerning boundary layer: 

- **CTL** and **COSMO-VEG**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Initialization:</td>
<td>05.10.2005 12 UTC</td>
</tr>
<tr>
<td>Forecast hours:</td>
<td>48 hours</td>
</tr>
<tr>
<td>Time step:</td>
<td>10s</td>
</tr>
<tr>
<td>Boundary conditions:</td>
<td>COSMO-DE</td>
</tr>
<tr>
<td>Horizontal resolution:</td>
<td>120 x 80 Pixel resolution: 1.0 km</td>
</tr>
<tr>
<td>Vertical resolution:</td>
<td>ATMOSPHERE – 40 layers</td>
</tr>
<tr>
<td></td>
<td>Δzmin= 4m</td>
</tr>
<tr>
<td></td>
<td>25 layers in the lower 2000 m of the atmosphere</td>
</tr>
<tr>
<td></td>
<td>Soil: 8 Layers TERRA-ML</td>
</tr>
</tbody>
</table>
2m Liquid Water Content g/kg  2 UTC

CTL | COSMO-VEG

all pixels with LWC > 0.01g/kg

0.5  0.4  0.3  0.2  0.1  0.05 g/kg
2m Liquid Water Content g/kg 2 UTC

CTL

COSMO-VEG

Forecast hours

ctl

COSMO-VEG
2m-VISIBILITY in m 2 UTC

CTL

COSMO-VEG

all pixels
with
visibility
< 1000

Forecast hours

No. Pixels in %

200  400  600  800  1000

200  400  600  800  1000

COSMO-VEG

CTL
2m-VISIBILITY in m Measurements

VISIBILITY in m COLOGNE AIRPORT

VISIBILITY in m NOERVENICH

VISIBILITY in m BONN

VISIBILITY in m Bad Marienberg

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<table>
<thead>
<tr>
<th>Blue</th>
<th>Red</th>
<th>Black</th>
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<tbody>
<tr>
<td>CTL</td>
<td>COSMO-VEG</td>
<td>Measurement</td>
</tr>
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</table>

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time in hour
Conclusion and Outlook

- COSMO-FOG is sensitive to surface characteristics
- The new implemented surface parameters plus Vegetation module have an impact on the surface fluxes, the surface temperature, and accordingly on the fog formation.
- Characteristic spatial patterns are similar, but results of the simulation with the modified parameters are more heterogenous
- Differences of 2m-temperature are between +2°C and -3,5°C
- Differences of latent heat flux are in the range of +30 and -40 W/m² and of sensible heat flux in the range of +20 and -50 W/m²
- TERRA 2-m temperature as well as surface temp. is higher than COSMO-VEG temp.
- Modifications of TERRA-ML concerning vegetation (canopy temperature, canopy humidity, ...)

Thank you for your attention!