COSMO-PAFOG

Three-dimensional fog forecasting with the high-resolution COSMO-model

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COSMO / CLM / ICON / ART User Seminar 2017
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Motivation

- Requirements for **fog forecasting**
  - Detailed cloud microphysics
  - High spatial resolution

- **1D models**
  - \+ Advanced microphysical parameterization schemes
  - \+ High vertical resolution
  - – Horizontal homogeneity

- **3D models**
  - \+ Dynamical processes, e.g. advection
  - – Limited spatial resolution → fog subgrid-scale

→ Microphysics parameterization + mesoscale model = **3D fog model**

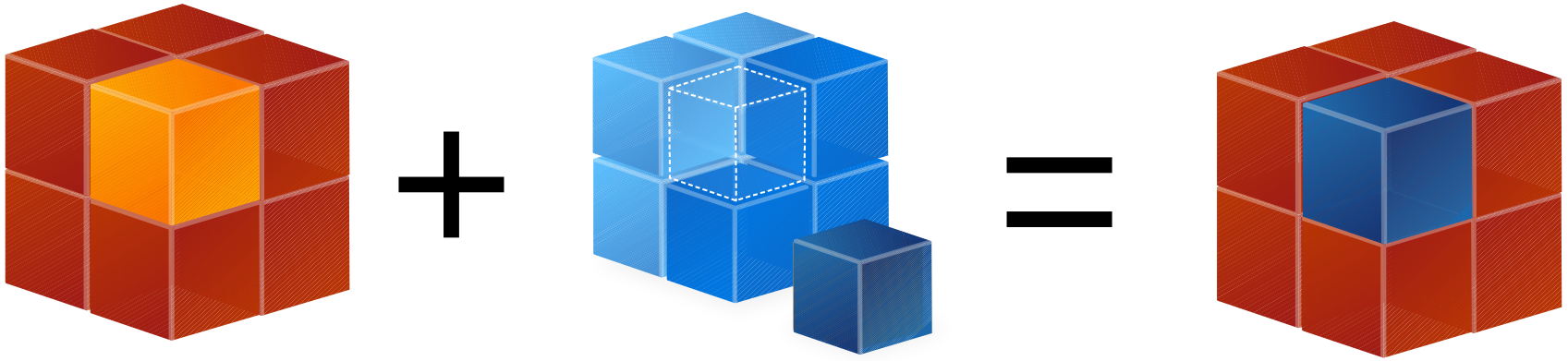
Outline

COSMO + PAFOG

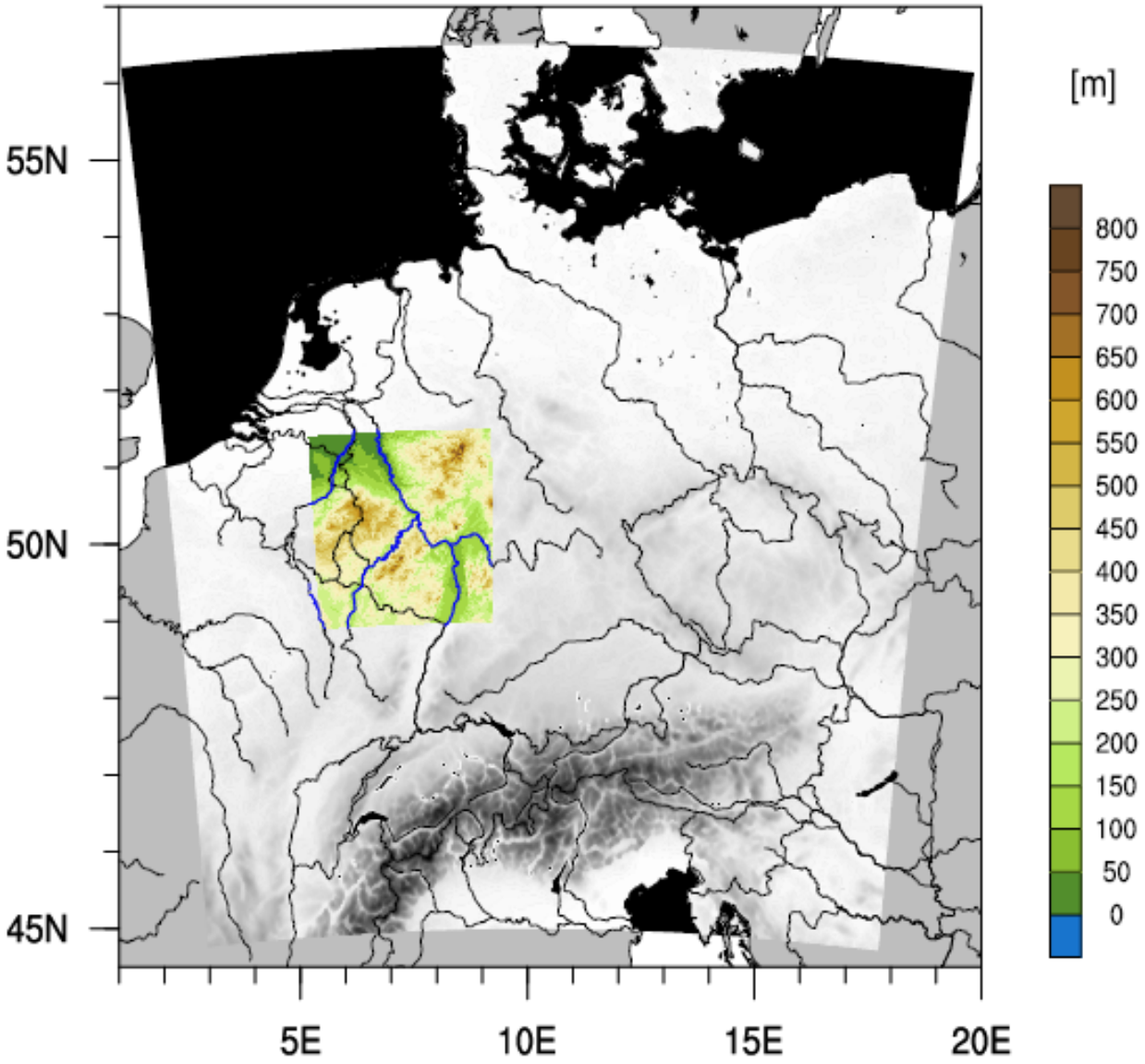
Preliminary Results

Conclusion and Outlook

COSMO + PAFOG
=
COSMO-PAFOG



COSMO-model in COSMO-PAFOG



Model Setup

- Compressible, nonhydrostatic model formulation (Baldauf et al., 2014)
- 50 vertical layers, Δz_{min}=20m
- 250x250 grid points, Δx=1km

Turbulence

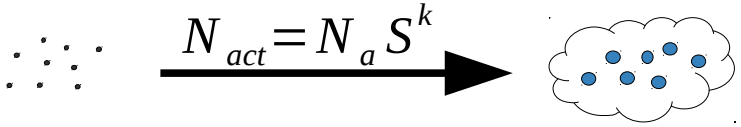
- 1D TKE-based closure on level 2.5 (Mellor and Yamada, 1982)

Cloud microphysics

- bulk scheme (Reinhardt and Seifert, 2006)
- Condensation / evaporation with **saturation adjustment**

PAFOG microphysics

Activation (Twomey, 1959)



S: supersaturation, N_a: number concentration of dry aerosols, *k*: empirical constant, depend on environment

Condensation / Evaporation

Time-dependent relation between diameter D and supersaturation S

$$\frac{dD}{dt} = C\frac{S}{D}$$

Critical droplet diameter determines change of droplet number concentration

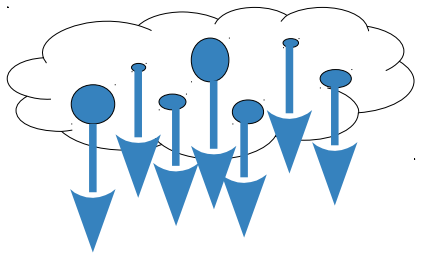
Sedimentation

Dependent on mean droplet diameter $\overline{D_0}$ (Berry and Pranger, 1974)

$$v(\overline{D_0}) = \frac{\eta Re}{\overline{D_0}\rho}$$

v: sedimentation velocity, η: viscosity, Re: Reynolds number, ρ: density

Positive-definite advection scheme (Bott, 1989)



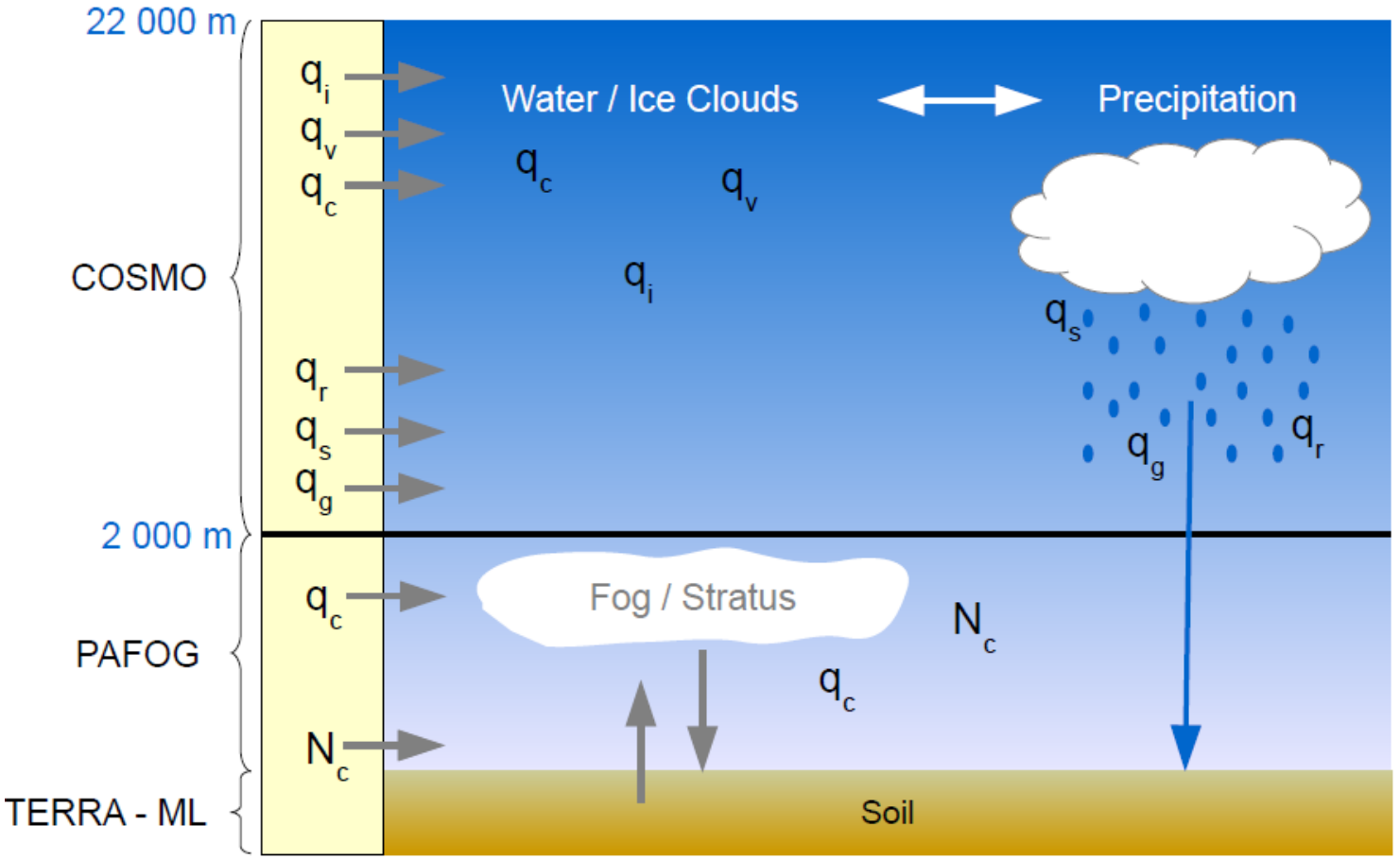
Visibility

Parameterization of Gultepe (2006)

$$VIS = \frac{1.002}{(LWC \cdot N_c)^{0.6473}}$$

Nc: droplet number concentration

Reimplementation of PAFOG



Based on Masbou (2008)

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

Cloud droplet concentration

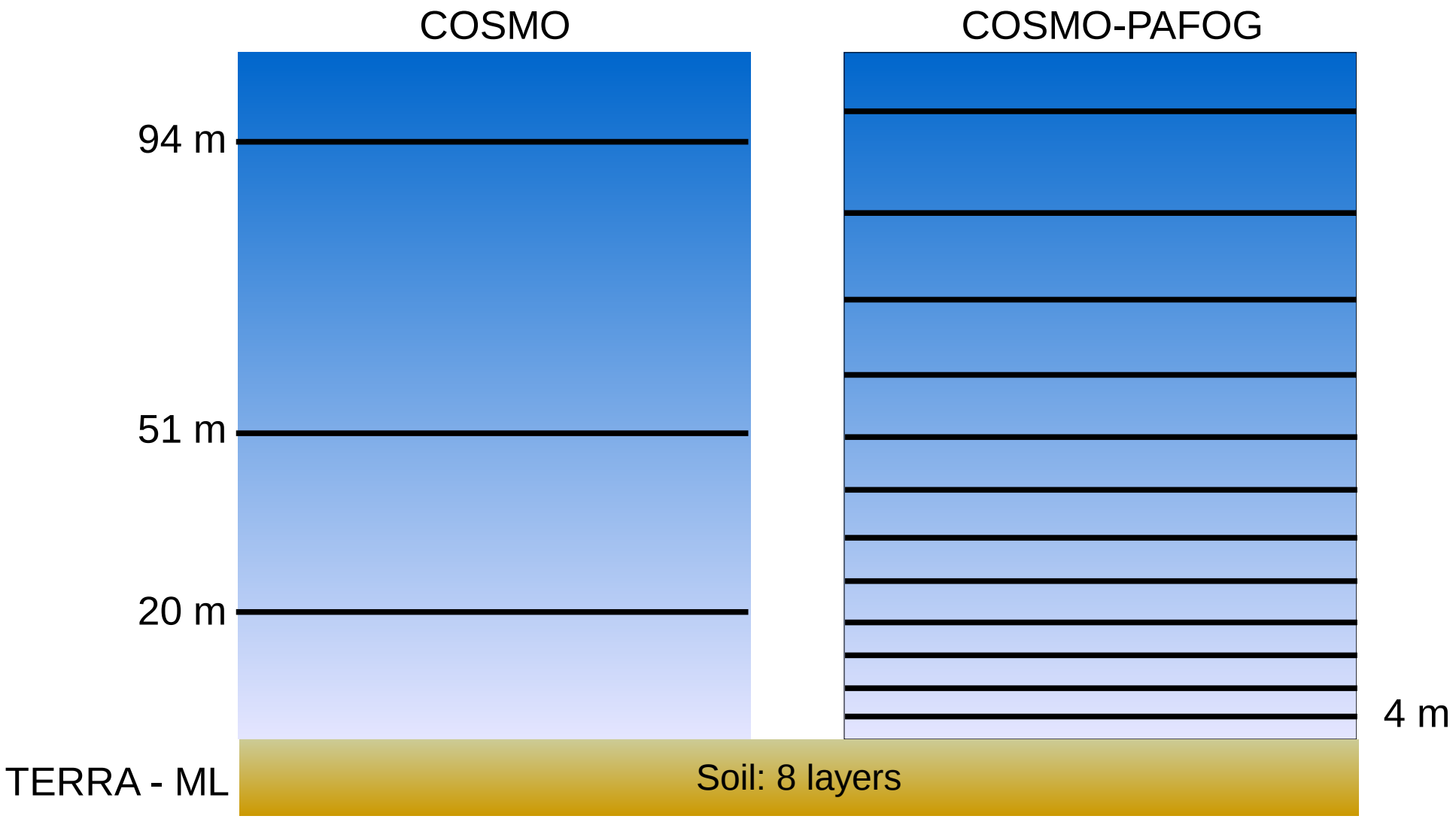
$$\frac{\partial q_c}{\partial t} = ADV(q_c) + DIF(q_c) + \left(\frac{\partial q_c}{\partial t}\right)_{sed} + \sigma(q_c)$$

Cloud water content

COSMO Dynamics

PAFOG Microphysics

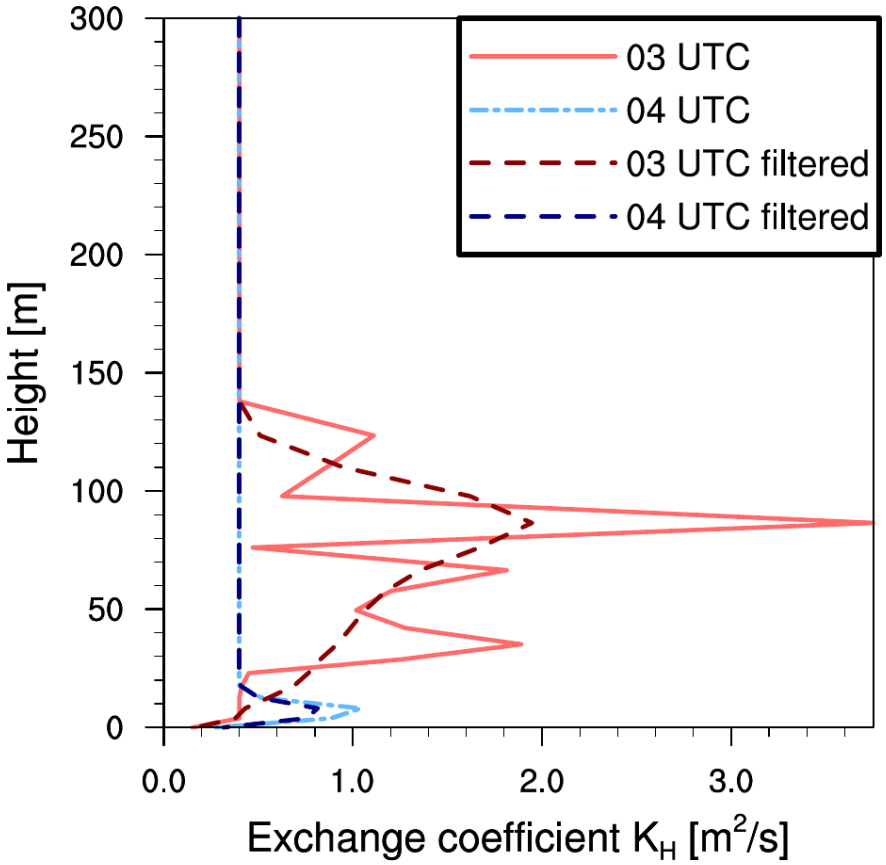
Vertical resolution of COSMO-PAFOG

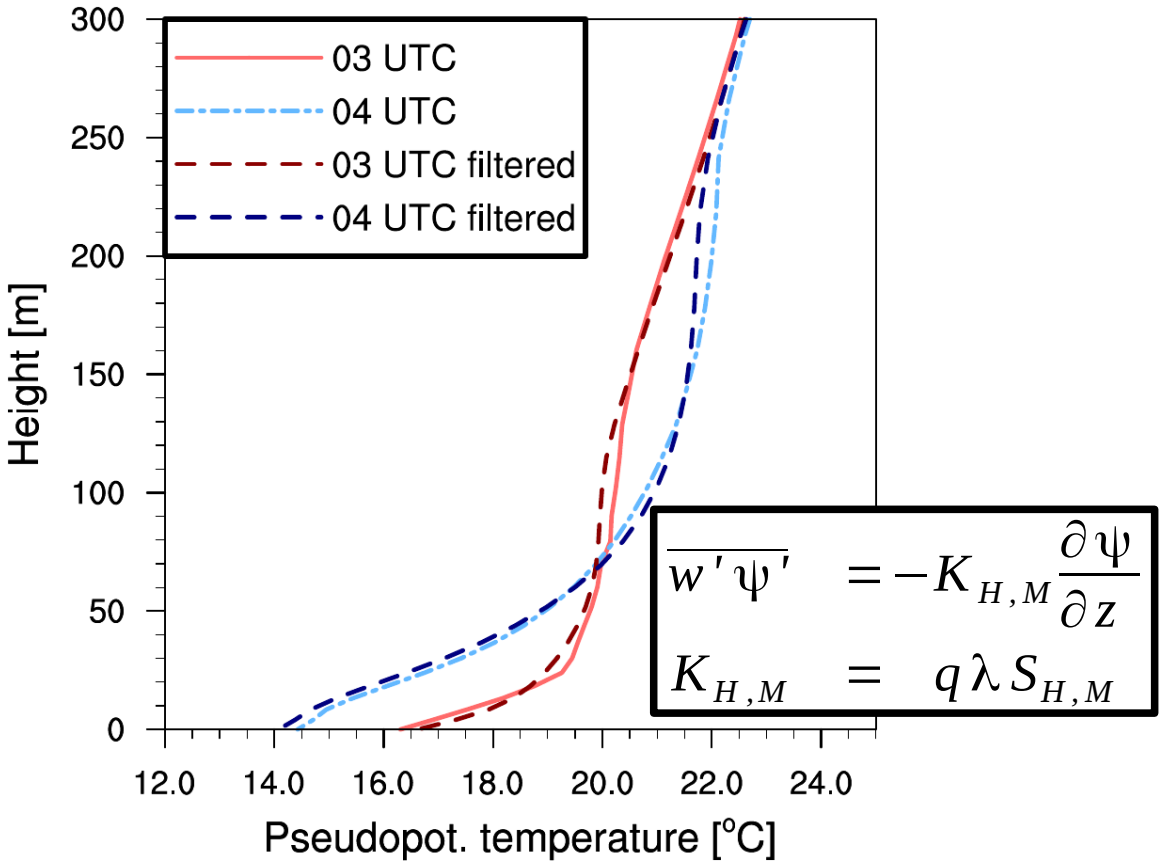


- 50 layers
- 16 layers below 2000 m

- 80 layers
- 45 layers below 2000 m

Adaption of the turbulence scheme





Filtering (based on Mellor, 2003)

K(k) = bK*(k) + (1-b)/2 [K*(k+1)+K*(k-1)] b = 0.8

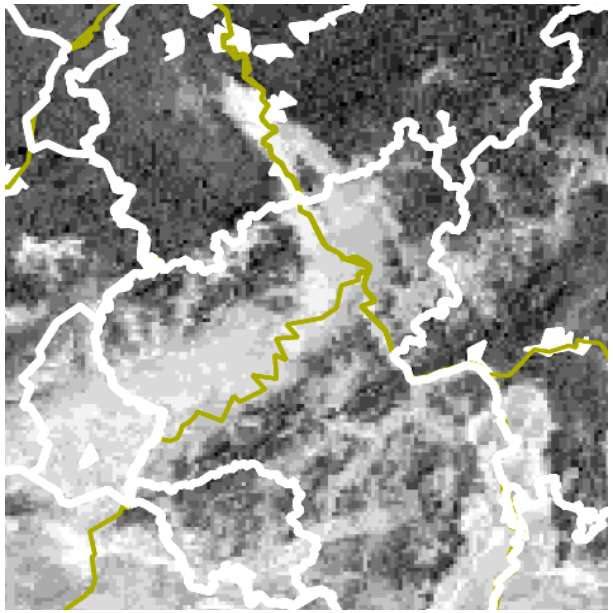
Preliminary Results

Horizontal extension of fog

Fog defined by vertically integrated liquid water content (white areas)

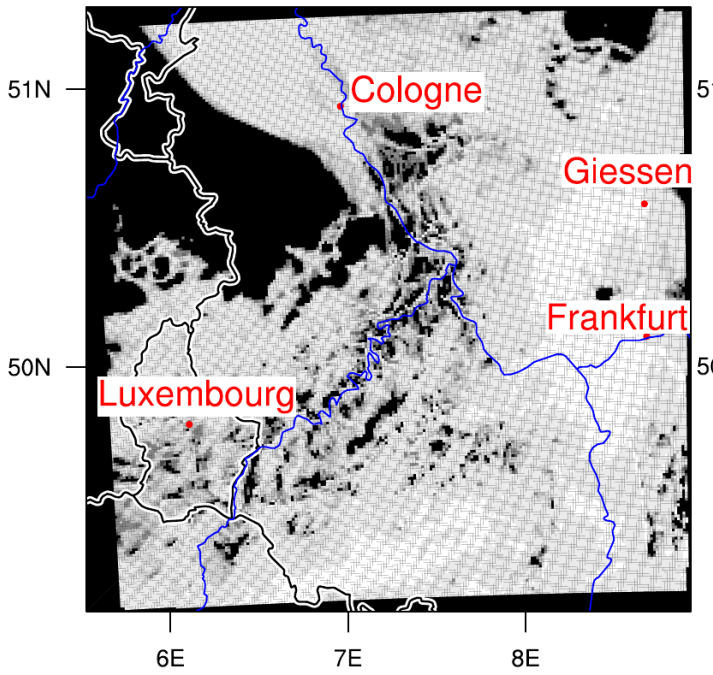
Satellite Image

IR 3.7 – IR 10.8



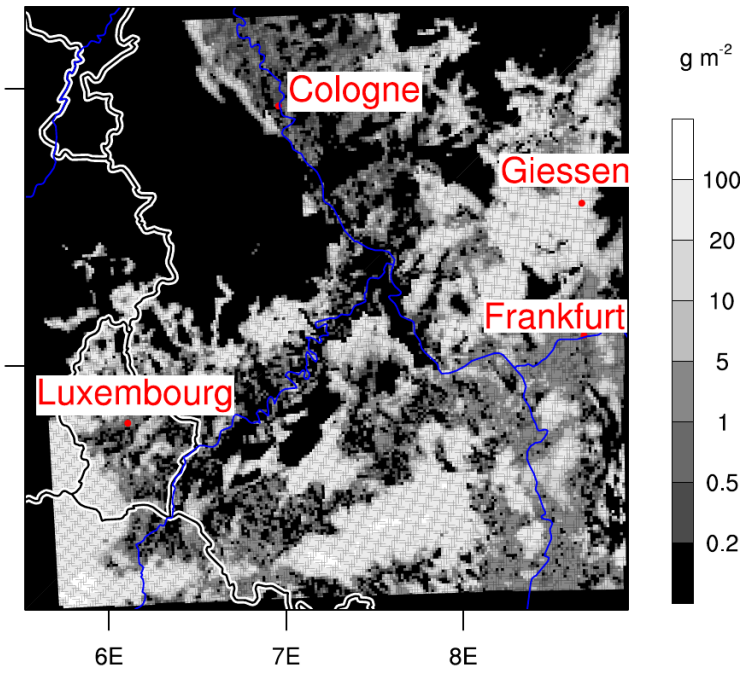
COSMO

LWP 01.11.2015 06 UTC



COSMO-PAFOG

LWP 01.11.2015 06 UTC



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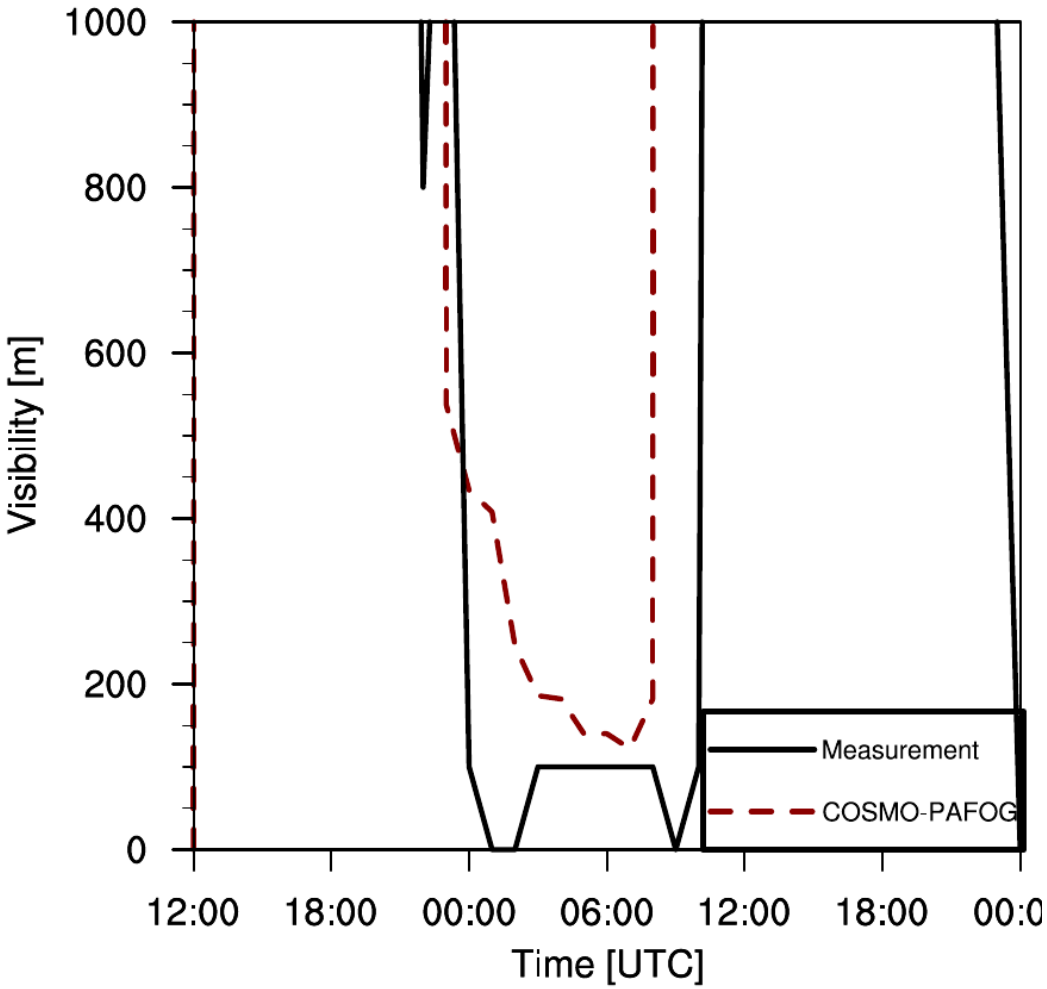
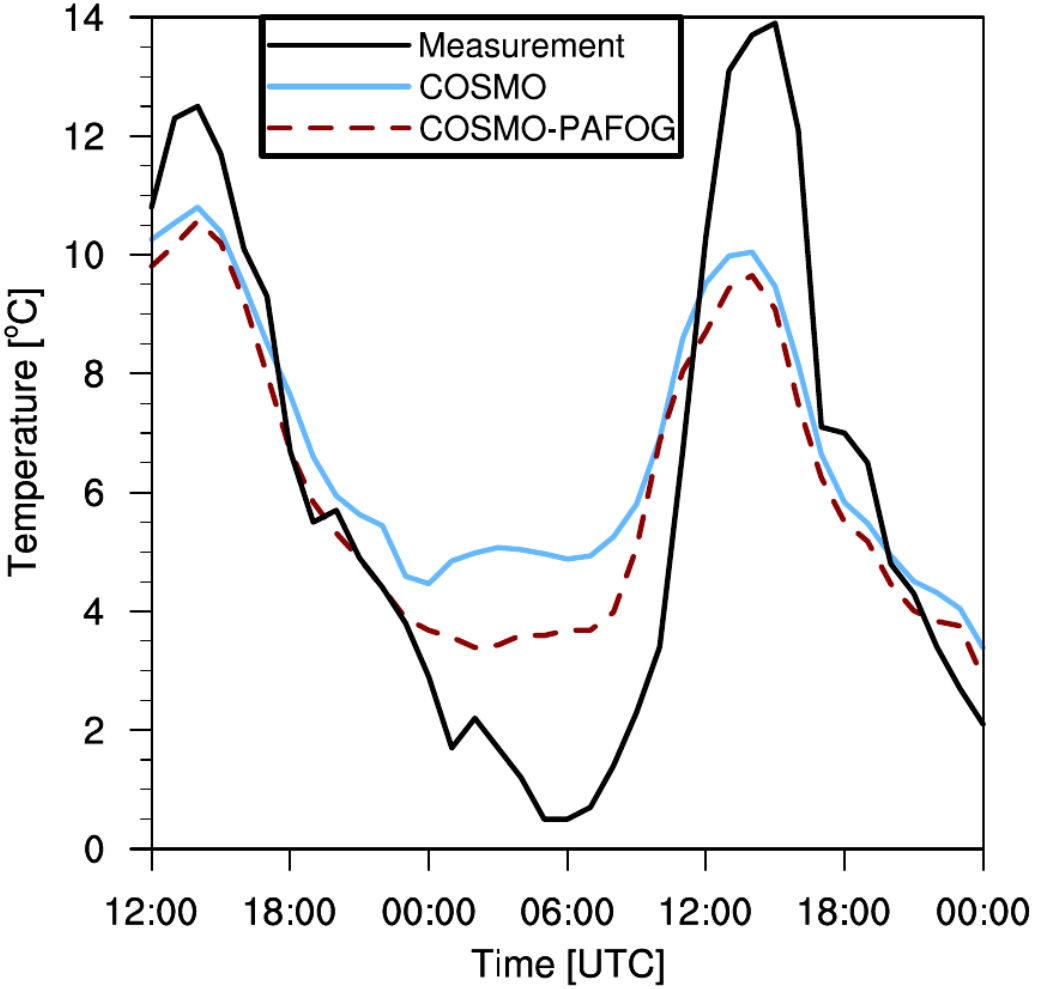
Comparison to SYNOP-Stations

Visibility and 2m temperature (Giessen)





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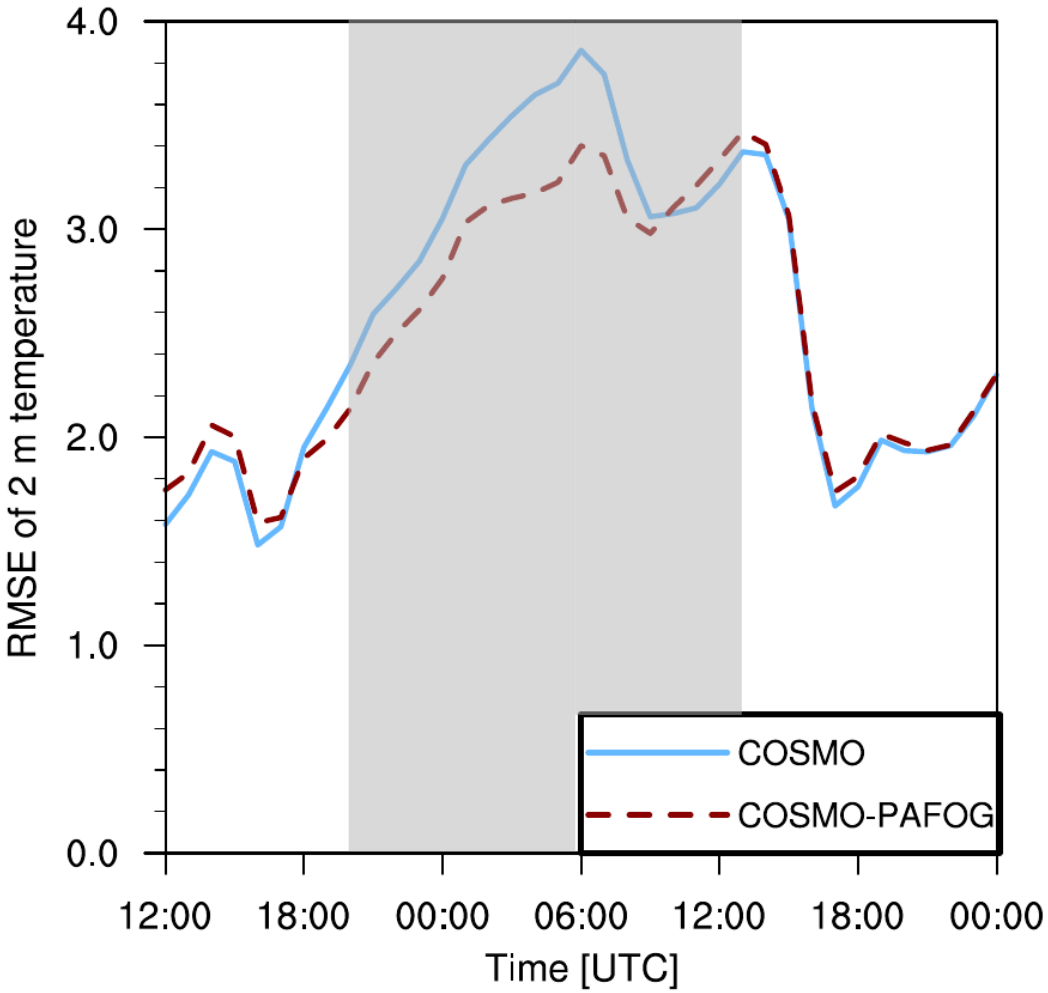
Comparison to SYNOP-Stations

Root-mean-square error of 2m temperature for all SYNOP-Stations



Conclusion and Outlook

Conclusion

Setup of COSMO-PAFOG

- ✔ Reimplementation of PAFOG-microphysics in COSMO 5.0 (based on Masbou (2008))
- ✔ Increase of vertical resolution in the planetary boundary layer
- ✔ First adaption of the turbulence scheme

Comparison of model simulations with observations

- ✔ COSMO-PAFOG better reproduces horizontal extension of fog
- ✔ In COSMO-PAFOG lower liquid water content

  → enhanced radiative cooling
- ✔ Simulated visibility corresponds to observations
- ✗ Delayed fog formation and dissipation too early

Outlook

NaFoLiCA – Namib Fog Life Cycle Analysis

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- **Objectives** of NaFoLiCA
  - Spatio-temporal **patterns**
  - Typical **life stages** of fog events
  - Dynamical and microphysical **properties**
  - **Triggers** of fog formation

  ➔ Application of COSMO-PAFOG in **Namibia**

- **Sensitivity studies** regarding turbulence scheme
- **Statistical verification** during IOP (Sept. 2017)

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