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# 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

# Disclaimer

A few bits of this presentation were generated with Google Translate

# 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)

130050Z VRB01KT 4500 BR BKN006 04/03 Q1020 NOSIG=
130220Z 10002KT 0900 R05/P2000N R23/1300D FG VV004 03/03 Q1020 NOSIG=
130320Z 05002KT 0200 R05/0300N R23/0350N FG VV001 02/02 Q1020 NOSIG=
130350Z VRB01KT 0150 R05/0250N R23/0350N FG VV001 02/02 Q1020 RERASN NOSIG=
130420Z 00000KT 0150 R05/0375N R23/0300N FG VV001 02/02 Q1019 RERASN NOSIG=
130450Z 00000KT 0150 R05/0375N R23/0350N FG VV001 02/02 Q1019 RERASN NOSIG=
130520Z 00000KT 0200 R05/0450N R23/0375N FG VV001 01/01 Q1019 NOSIG=
130550Z VRB01KT 0200 R05/0400N R23/0375N FG VV001 02/02 Q1019 NOSIG=
130620Z VRB02KT 0250 R05/0400N R23/0550N FG VV001 02/02 Q101
130650Z 00000KT 0300 R05/0400N R23/0600N FG VV001 01/01 Q1018
130720Z 03001KT 0300 R05/0400N R23/0650N FG VV001 01/01 Q1018
130750Z VRB02KT 0600 R05/0400N R23/1000N FG VV002 01/01 Q101
OVC002=
130820Z 00000KT 0450 R05/0450N R23/1100D FG VV002 01/01 Q1018 BECMG 1500 BCFG BR OVC002=
130850Z 00000KT 0300 R05/0450N R23/0650D FG VV002 02/02 Q1017 BECMG 1500 BCFG BR OVC002=
130920Z 00000KT 1200 R05/0550N R23/P2000U BCFG BR SCT001 BKN002 02/02 Q1017 BECMG 1500
BCFG BR OVC002=
130950Z 00000KT 0700 R05/0800U R23/0800N FG VV002 02/02 Q1017 BECMG 1500 BCFG BR OVC002=
131020Z 00000KT 1200 R05/0800D R23/P2000N BCFG BR SCT001 OVC002 02/02 Q1017 BECMG 3000
BCFG BR BKN003=
131050Z 00000KT 2000 R05/1000N R23/P2000U BCFG BR SCT001 BKN003 03/03 Q1016 BECMG 3000
RA BCFG BKN003=

**TREND = 2 hour forecast**

# FOG forecast (TAF)

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=

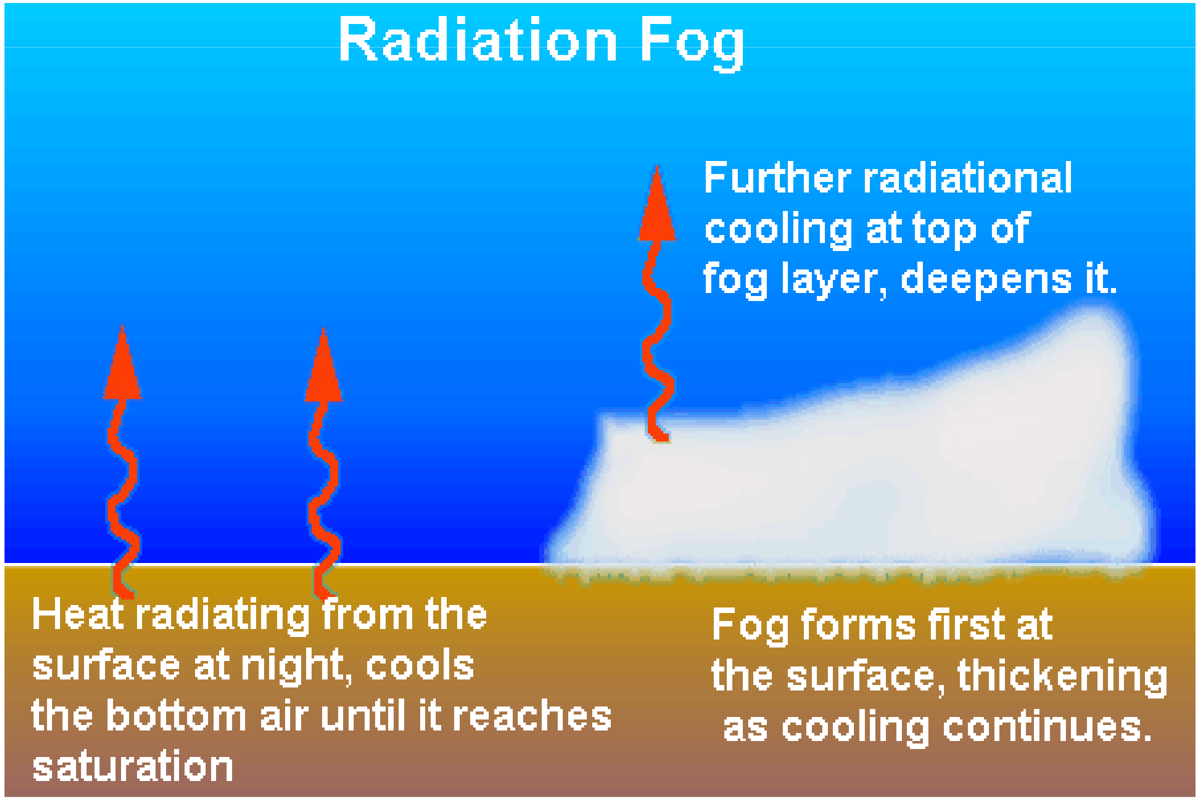
# Fog types

- 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)

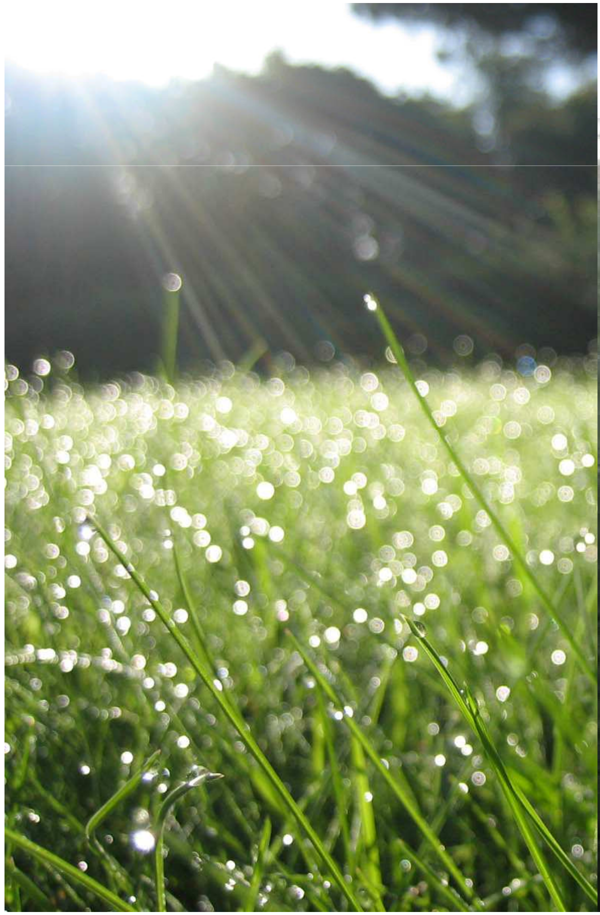
# Radiation fog

## In theory



# 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?

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- What makes the difference
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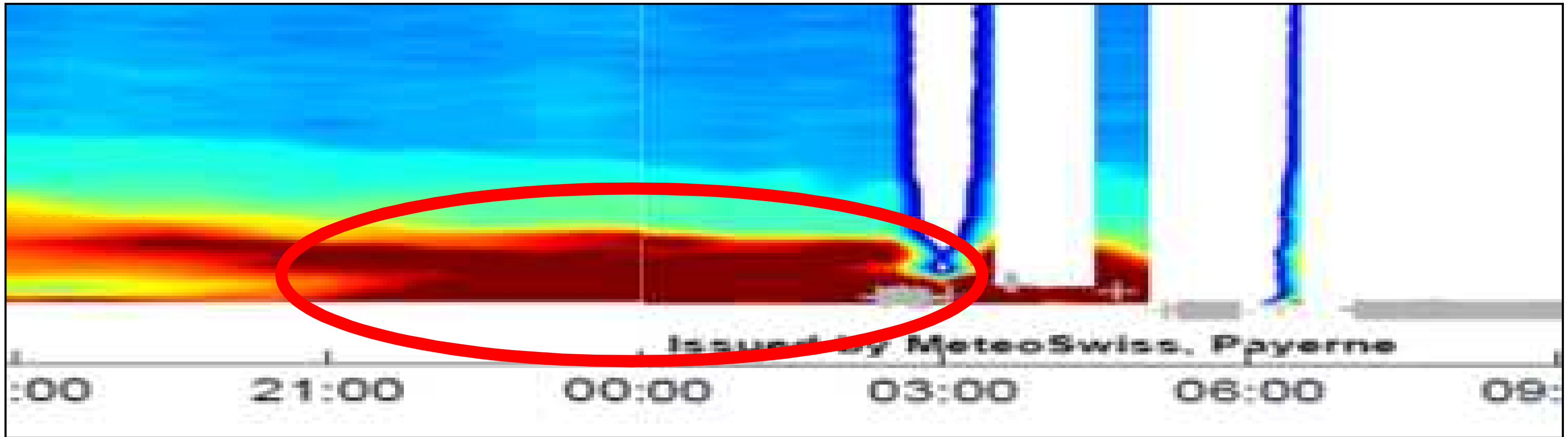
- Mixing (a little bit of wind)?
- Amount and distribution of aerosols?

# Detection of aerosols by Lidar




| | |
|---|---|
| LSMP | ------- |
| LSMP | 240350Z AUTO VRB01KT 0250NDV R05/0250N R23/0500N FG SCT002 M01/M01 Q1018 RMK RED= |
| LSMP | ------- |
| LSMP | 240250Z AUTO 20003KT 0400NDV R05/0400V0550N R23/0350V0550D FG SCT001 M01/M01 Q1018 RMK RED= |
| LSMP | ------- |
| LSMP | 240150Z AUTO 21003KT 0250NDV R05/0300N R23/0350V0500N FZFG FEW001 M01/M01 Q1018 RMK RED= |
| LSMP | ------- |
| LSMP | 240050Z AUTO VRB02KT 0350NDV R05/0800N R23/P2000N BR NCD 00/M00 Q1019 RMK RED= |
| LSMP | ------- |
| LSMP | 232350Z AUTO 00000KT 1500NDV BR FEW120 M00/M00 Q1019 RMK AMB= |
| LSMP | ------- |
| LSMP | 232250Z AUTO VRB01KT 4000NDV BR FEW130 01/00 Q1019 RMK GRN= |
| LSMP | ------- |
| LSMP | 232150Z AUTO 21001KT 1800NDV BCFG FEW130 02/01 Q1020 RMK AMB= |
| LSMP | ------- |
| LSMP | 232050Z AUTO 00000KT 1000NDV R05/P2000N R23/P2000N BR NCD 02/02 Q1020 RMK RED= |
| LSMP | ------- |
| LSMP | 231950Z AUTO VRB02KT 4500NDV NCD 03/03 Q1020 RMK GRN= |
| LSMP | ------- |
| LSMP | 231850Z AUTO 21003KT 9999NDV NCD 03/02 Q1020 RMK BLU= |
| LSMP | ------- |
| LSMP | 231750Z AUTO 00000KT 9999NDV NCD 05/04 Q1020 RMK BLU= |

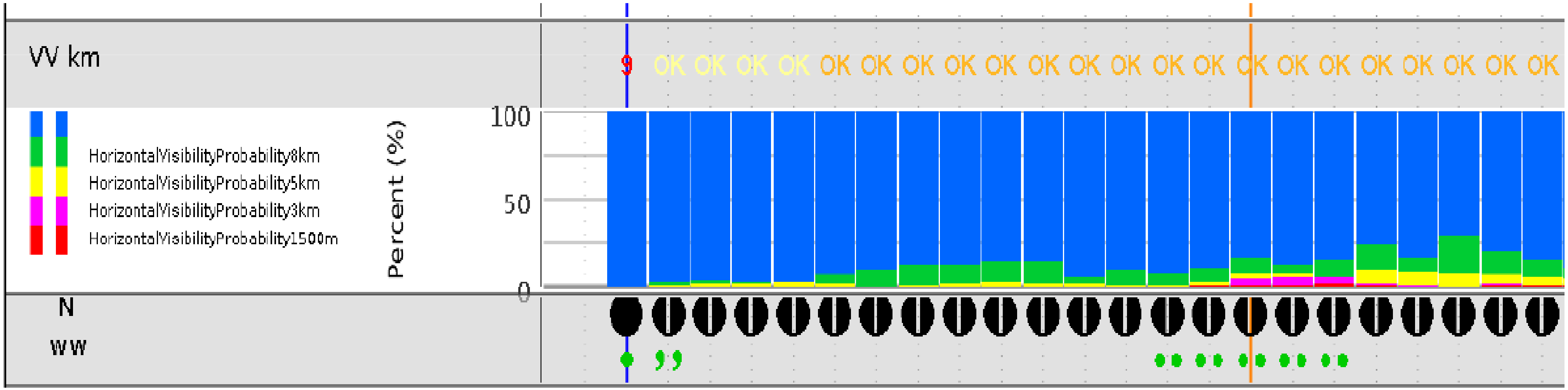
# Aerosols

- 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).

# TAF guidance




**Based on global (or ~10 km) models**
**Long history is needed**

# Postprocessing
M. Hacker et al. Uni Bonn

COSMO-DE forecasts

**First Step: Fog Stability Index**
Deterministic approach

**From FSI to FOGCAST**
Probabilistic approach

# Postprocessing

## M. Hacker et al. Uni Bonn

**F**og **S**tability **I**ndex (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

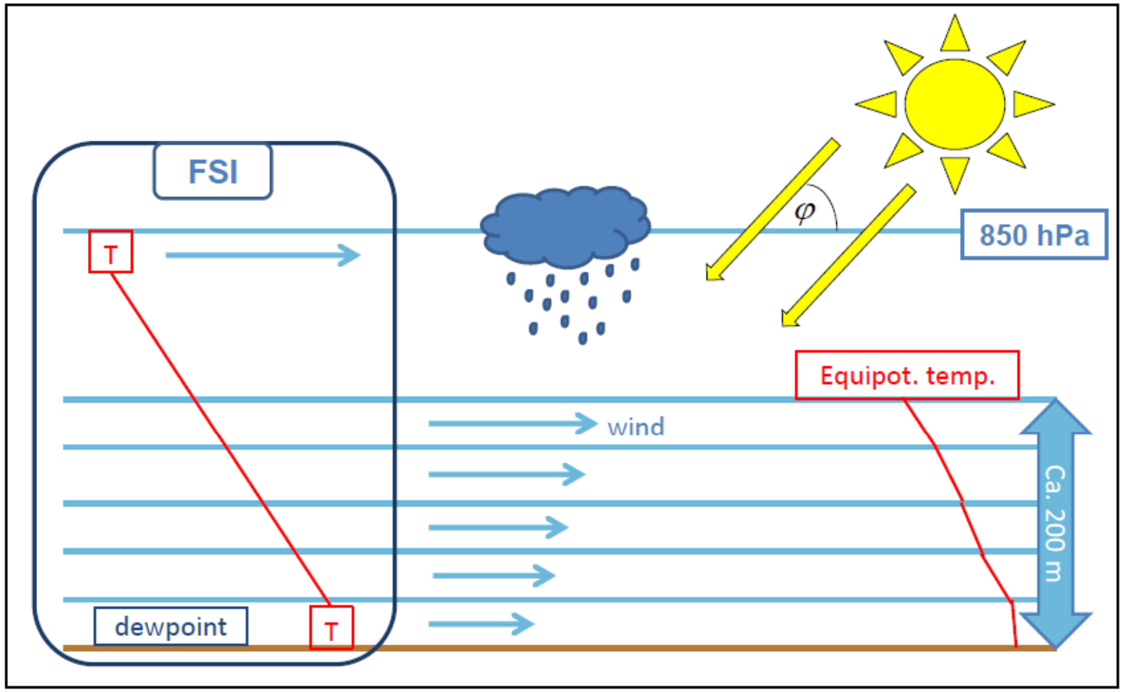
Fog risk

$FSI < 31$ $\quad$ $31 < FSI < 55$ $\quad$ $FSI > 55$

# Postprocessing

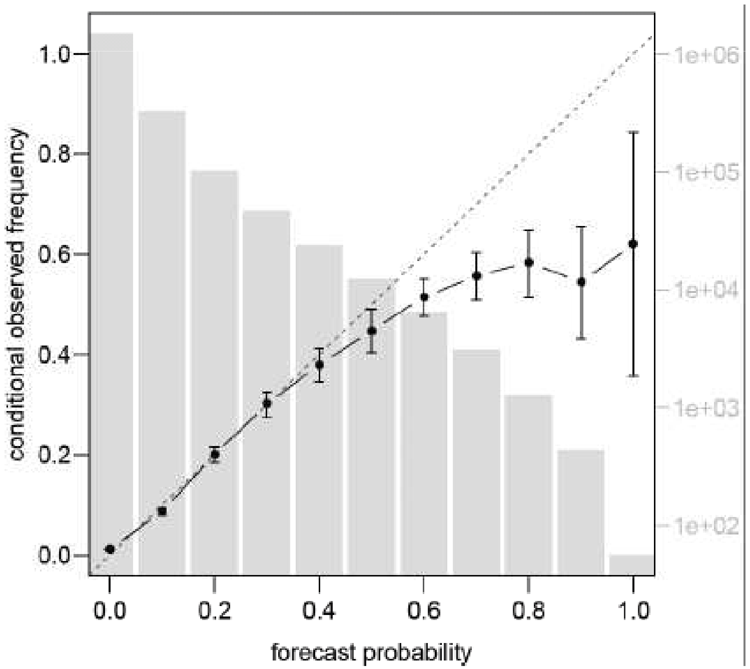
More predictors and selection method (LASSO)
Probabilistic forecast

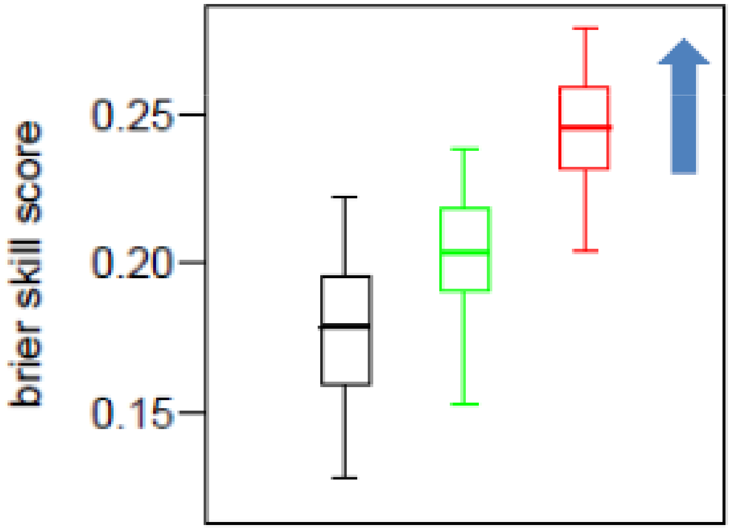
Choice of Predictors



# 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

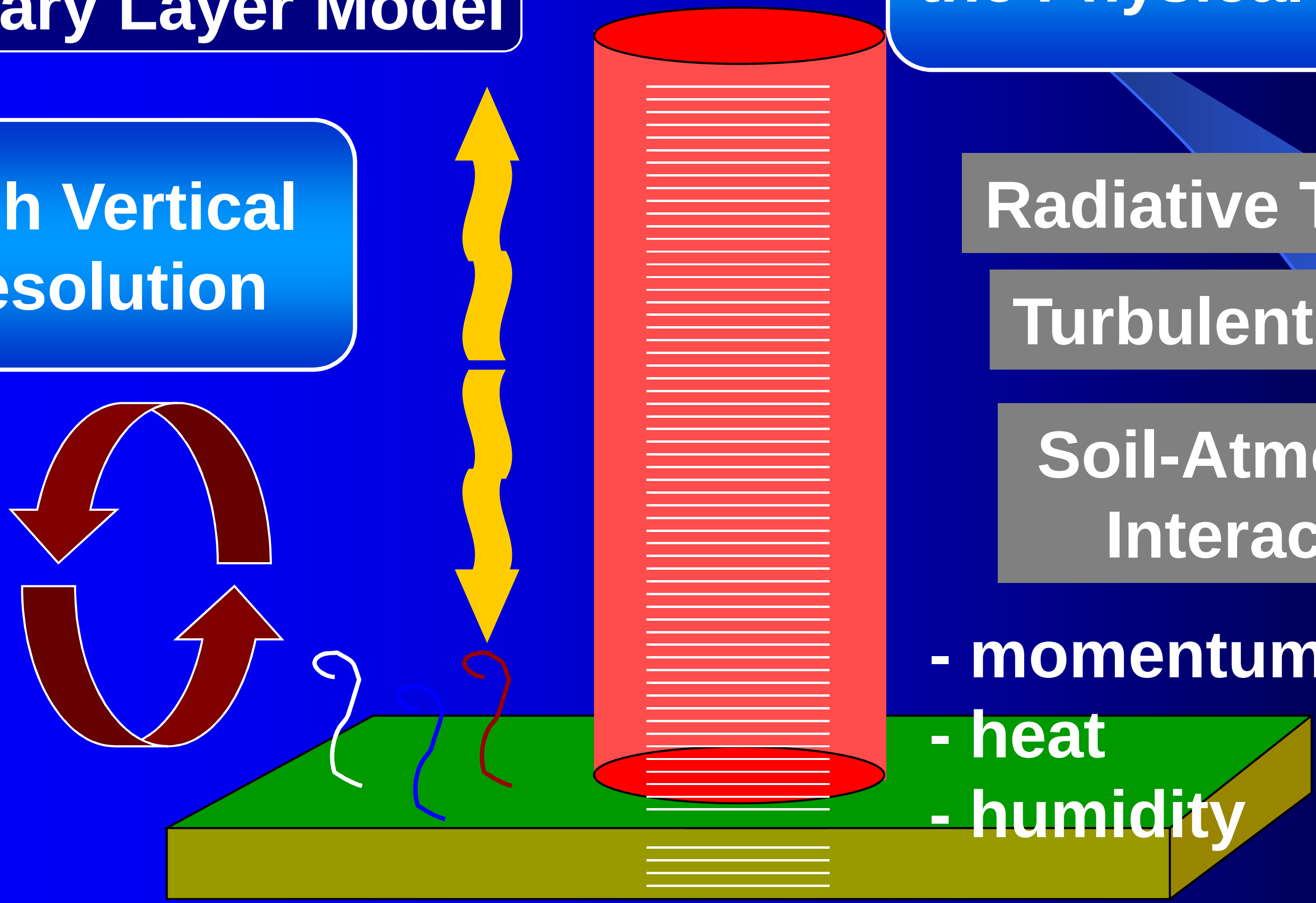
- Soil moisture (2 layers=>0-5cm, 5cm-1m)
- Incoming solar flux at top of radiative grid (5.3km)
- Soil temperatures (3 levels=>0cm, -10cm, -1m)
- Roughness lengths (momentum & heat)
- Coriolis parameter
- Soil specific heat
- Surface emissivity
- Surface albedo
- Soil type
- Surface atmospheric pressure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

# 1-Dimensional Modeling

**1-D (Column)**
**Boundary Layer Model**

**A Detailed Look at the Physical Processes**

**High Vertical Resolution**



**Radiative Transfer**

**Turbulent Mixing**

**Soil-Atmosphere Interactions**

- momentum
- heat
- humidity

# 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)

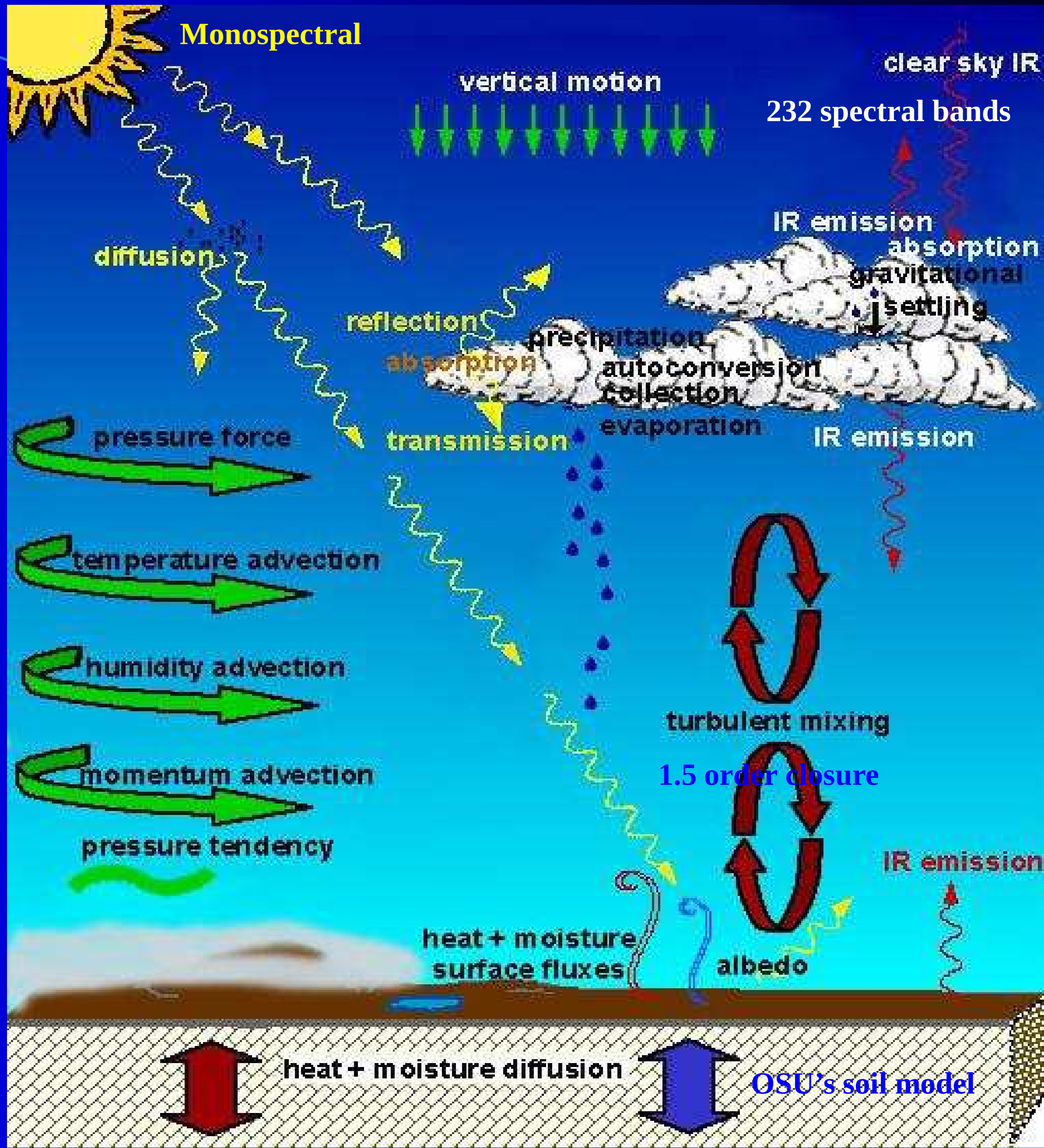
- **Gravitational settling of cloud droplets**
- **TKE production**
  - **(by wind shear, buoyancy, transport, dissipation)**
- **Horizontal pressure force** **(external forcing)**
- **Horizontal advection** **(external forcing)**
  - **(temperature, humidity, momentum)**
- **Vertical advection** **(by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

# COBEL

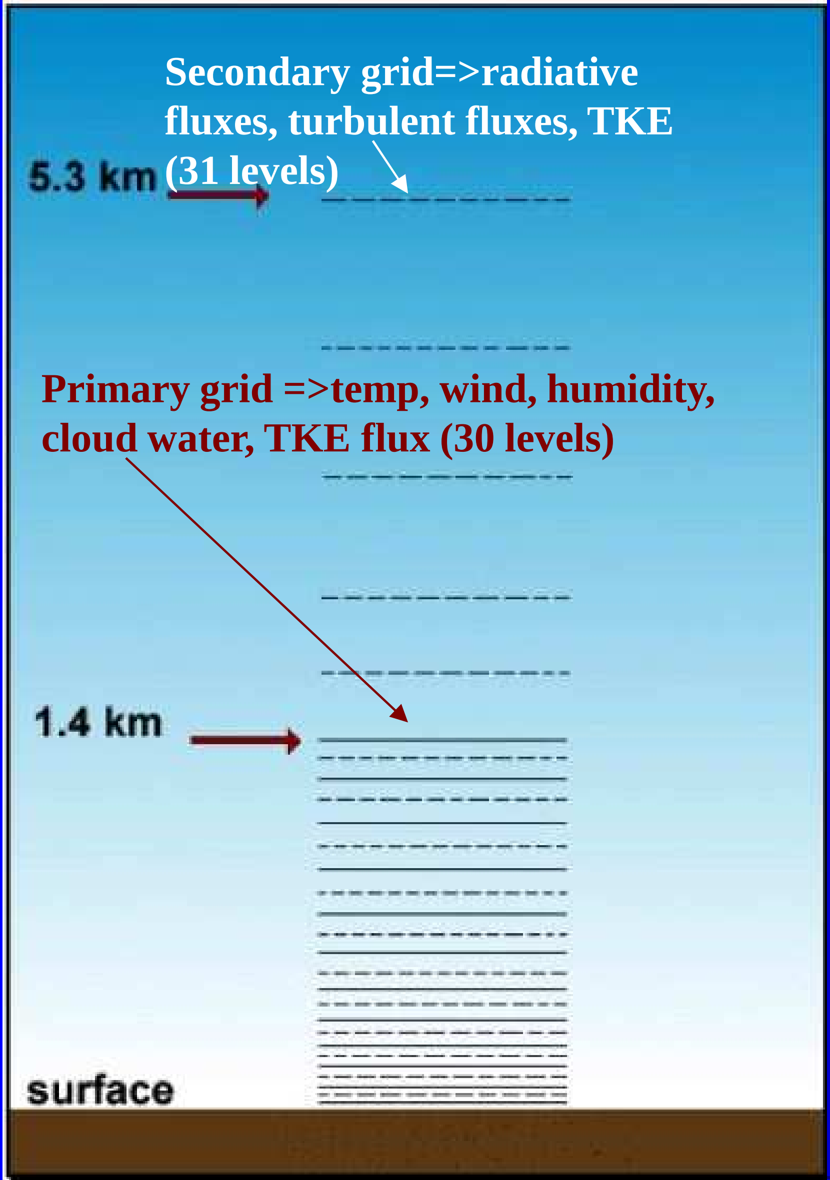
# Physical

# Processes

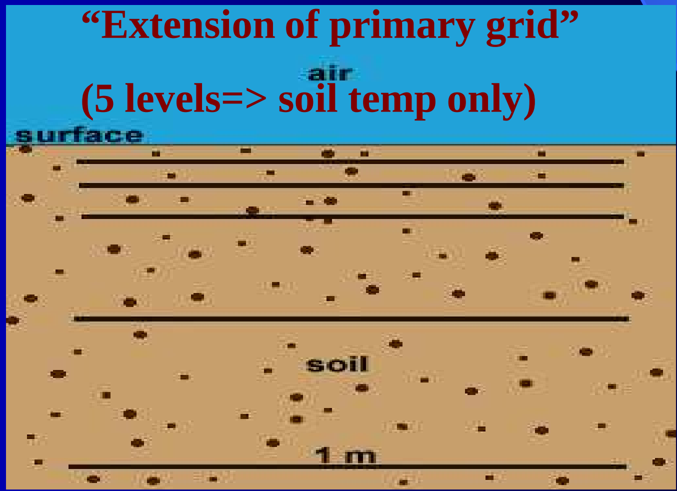
- SW => Fouquart & Bonnel (1980)
- IR => Vehil et al. 1989
- Microphysics =>Kessler (1969)
- Soil => Mahrt & Pan (1984)
- Turbulent Mixing => TKE w/ 1.5 order closure



# 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



# Boundary Conditions

- **Fluxes**
  - Top: turbulent fluxes of θ, q, $q_l$ = 0 (above 1.4km),

    IR flux from clouds above rad. grid
  - Bottom: flux of TKE=0 (z0), 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

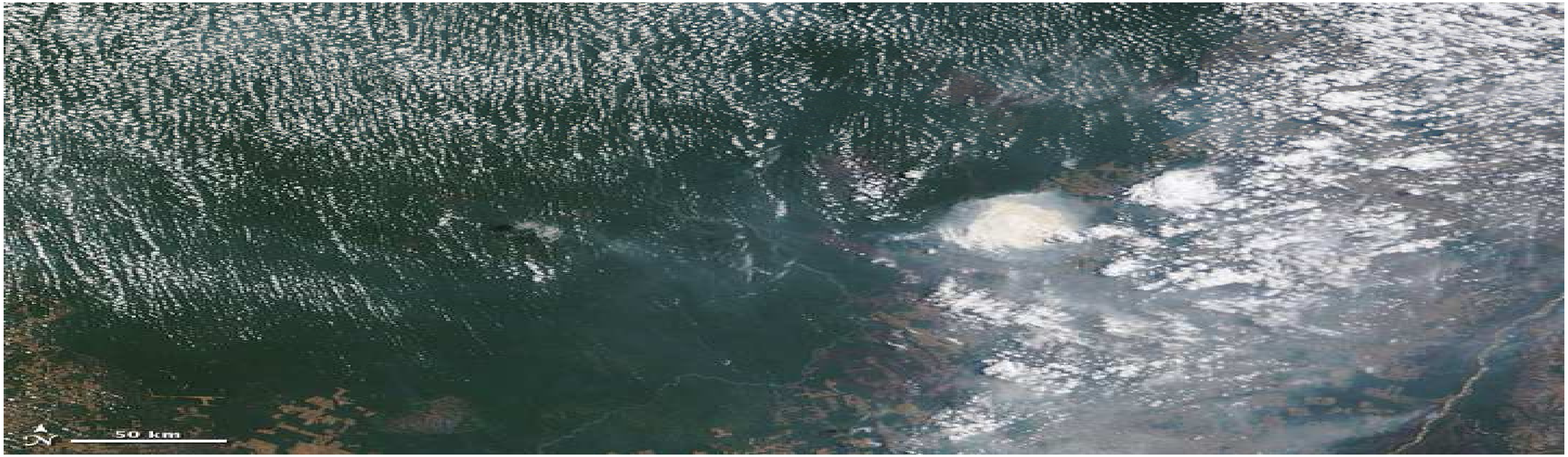
- characterized by a “dynamical period”: fog growth due to the radiative cooling of the top of the fog layer
- triggers convection inside the fog layer.
- high sensitivity to physical parameterizations. The gravitational settling flux cannot be neglected.
- The absence of the gravitational settling term 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.

Karlsruhe Institute of Technology

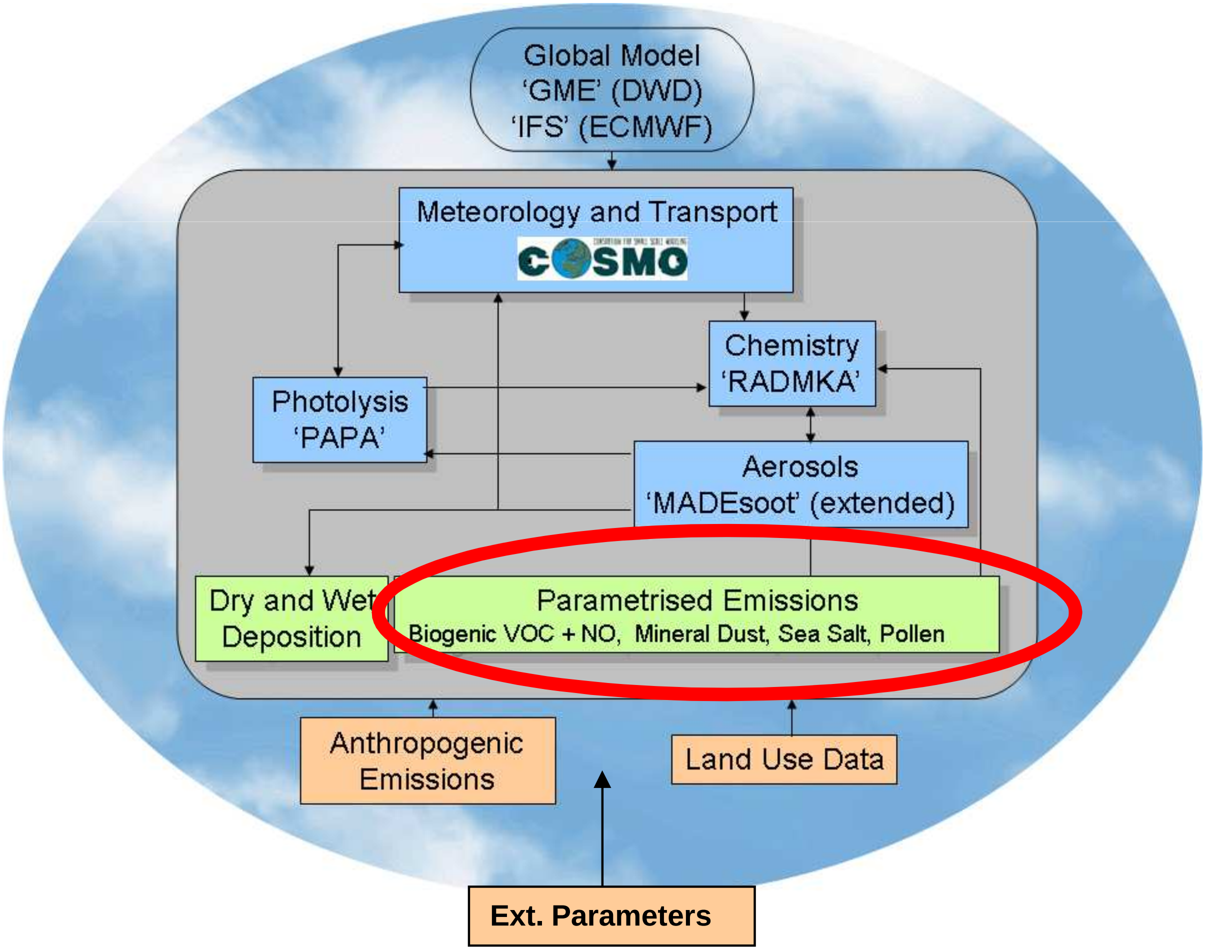
# Visibility forecast with COSMO-ART

**B. Vogel**

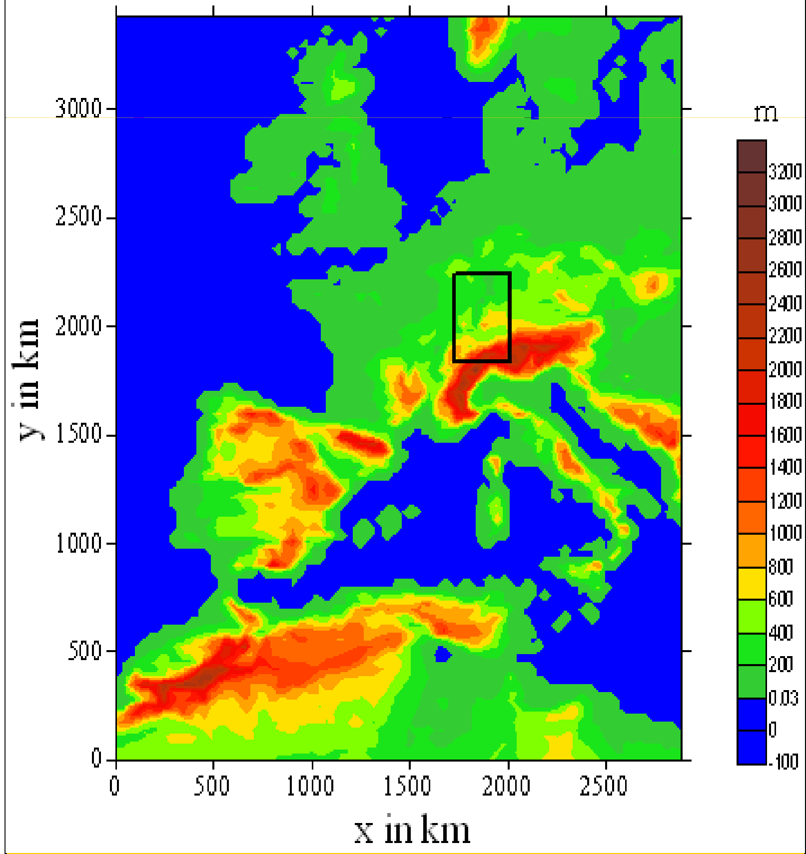
Aerosols and Climate Processes, Institute for Meteorology and Climate Research - Troposphere



# COSMO–ART (ART = Aerosols and Reactive Trace Gases)




## Concept:




Vogel et al., 2009, ACP

COSMO = operational weather forecast model (DWD)

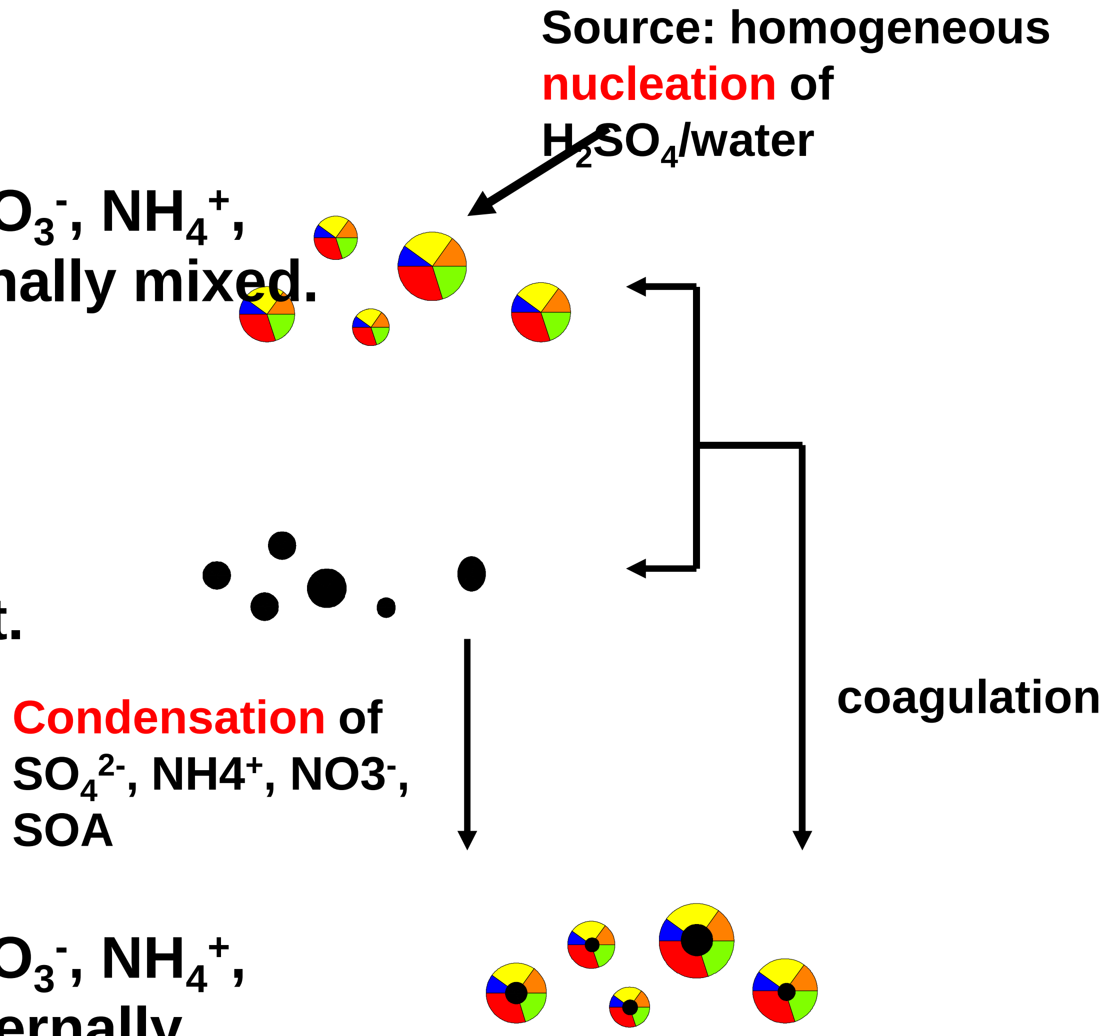
# Treatment of Aerosol Particles

## Interaction of five modes:

- **Two modes** for $SO_4^{2-}$, $NO_3^-$, $NH_4^+$, $H_2O$, SOA, internally mixed.

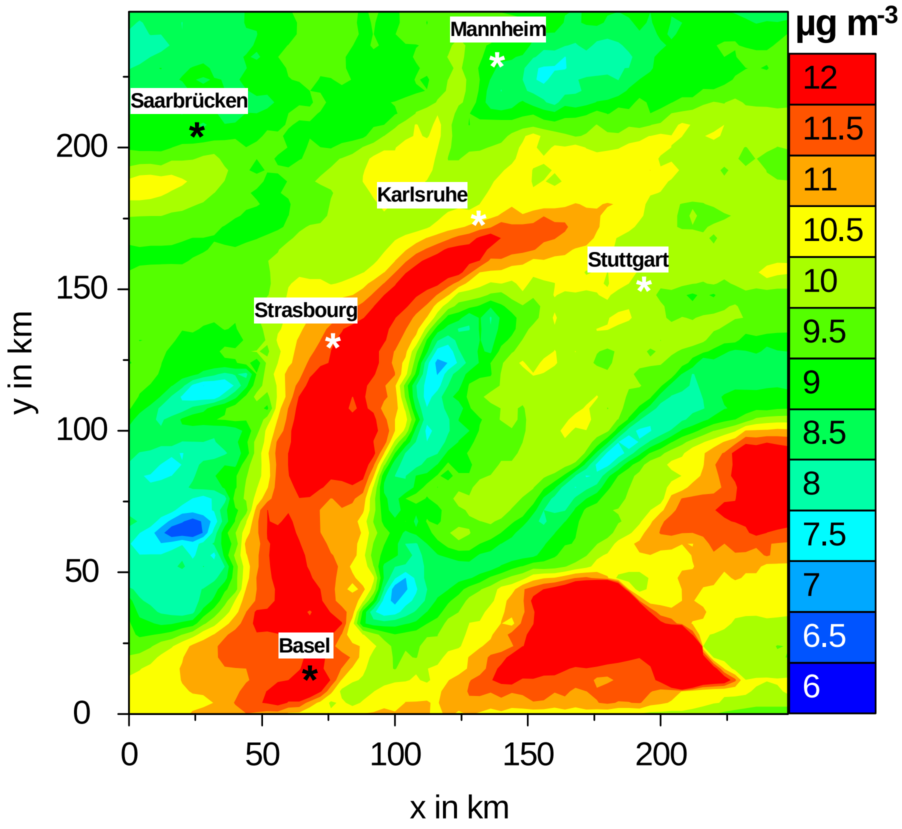
- **One mode** for pure soot.

- **Two modes** for $SO_4^{2-}$, $NO_3^-$, $NH_4^+$, $H_2O$, SOA, and soot internally mixed.

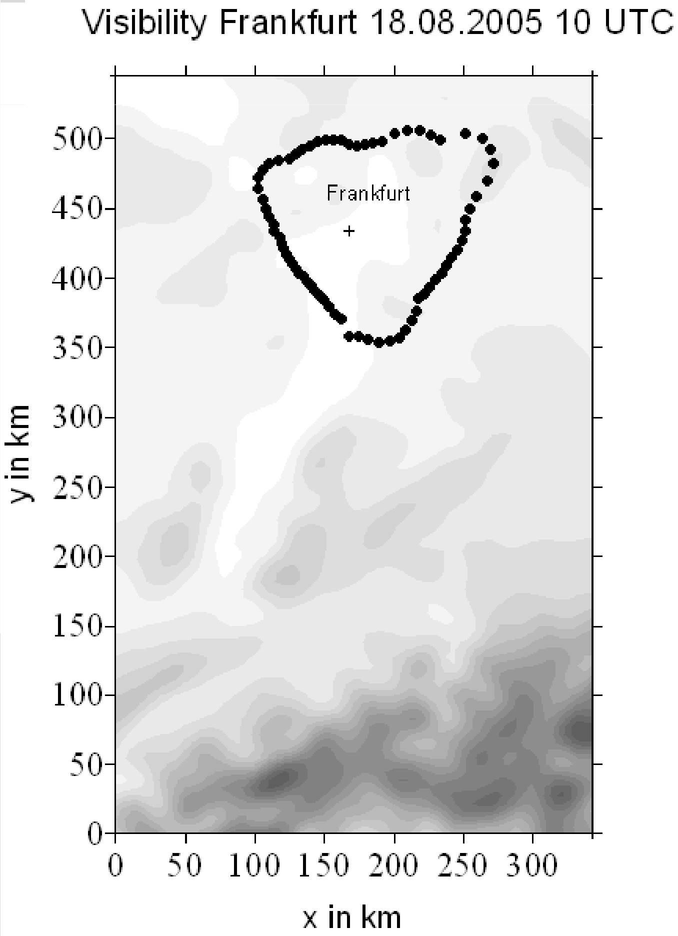


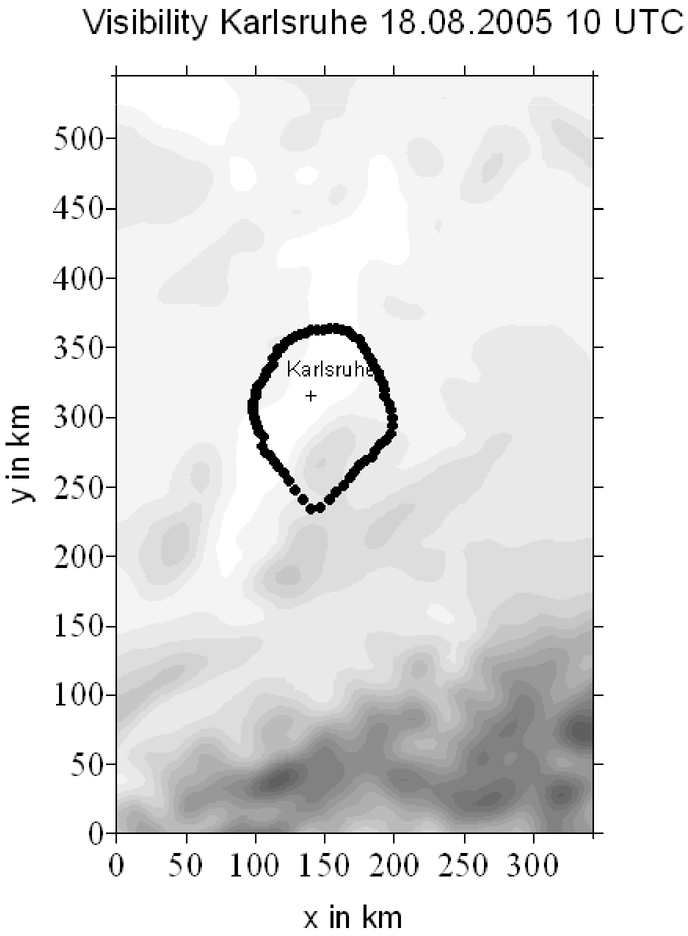

**Three modes for mineral dust particles + Three modes for sea salt particles + Pollen**

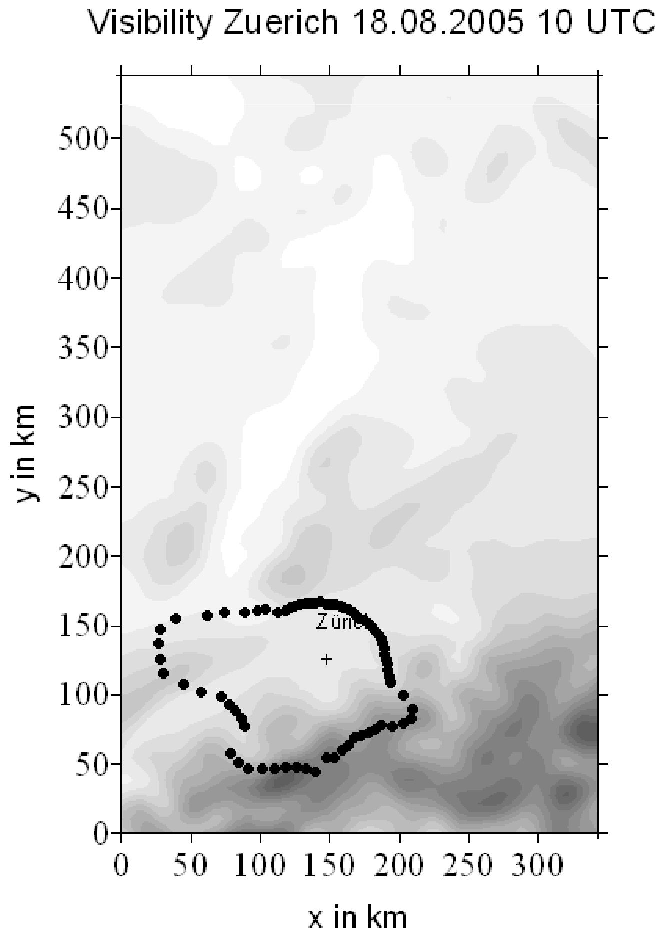
# Total amount of aerosols



# Visibility Roses

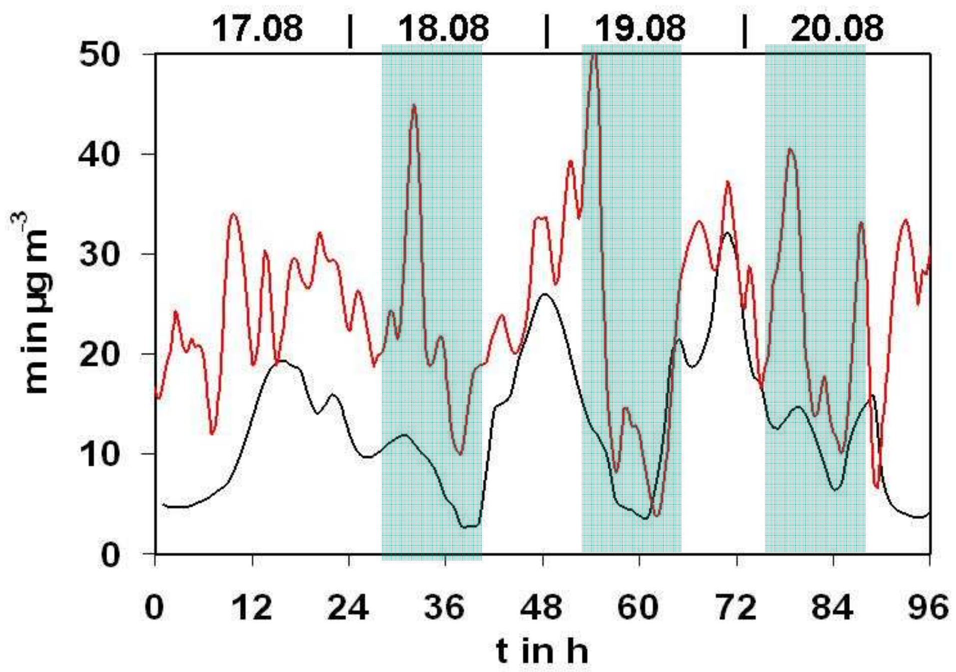


# PM10 an Visibility, Karlsruhe

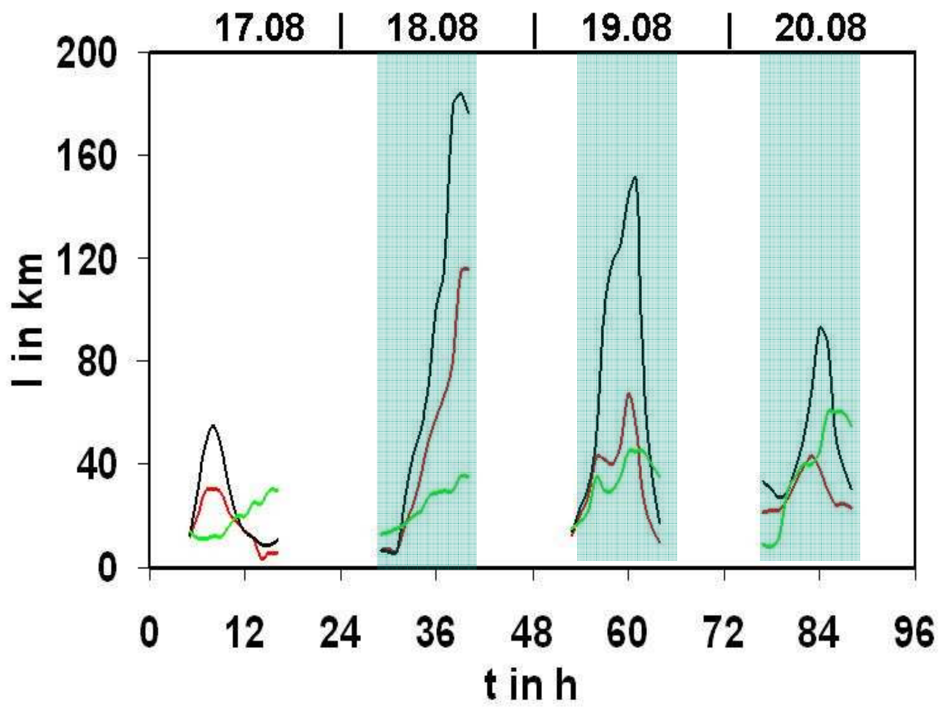
PM 10




measurements

simulation

Visibility



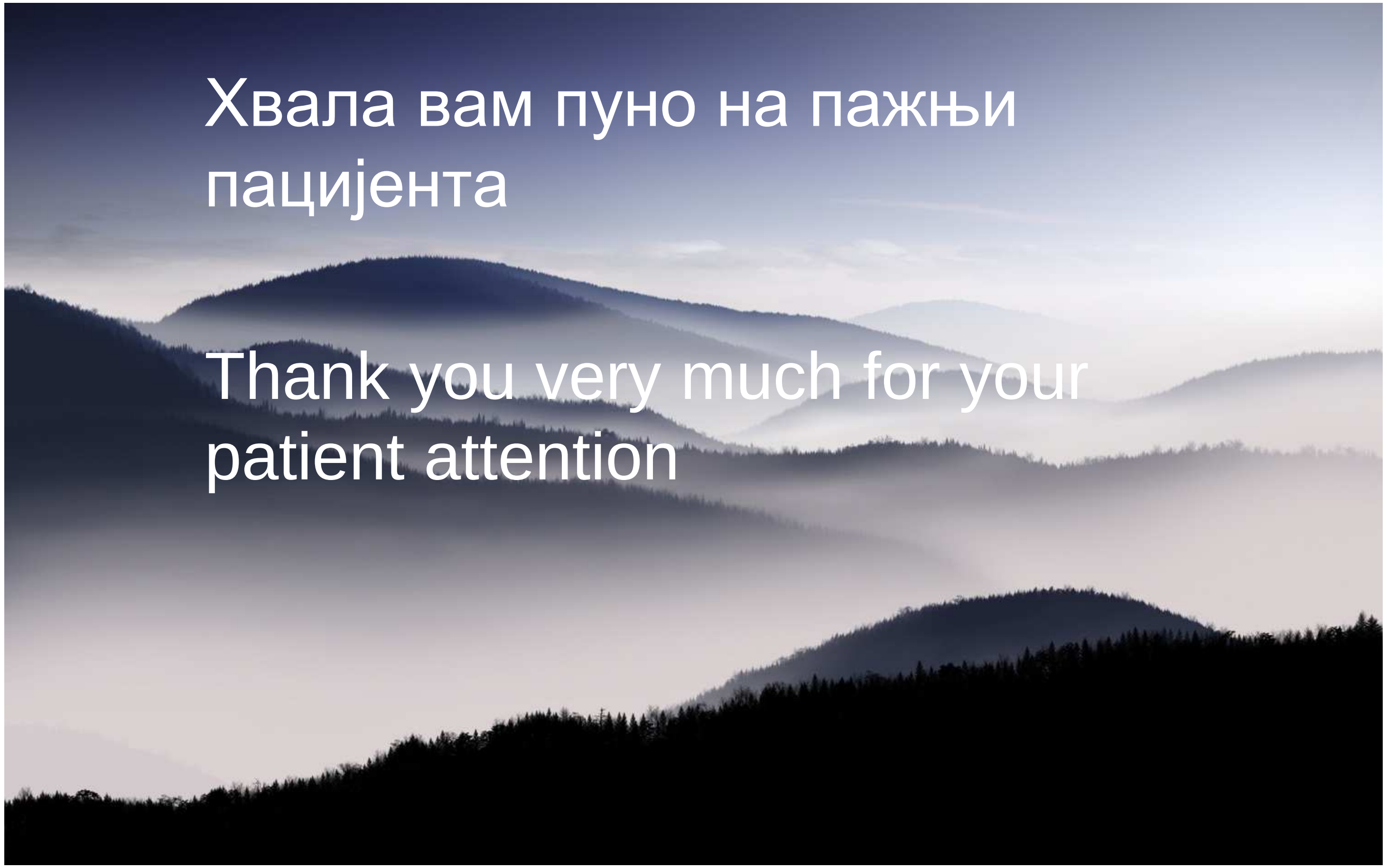

visibility roses (minimum)

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