universitätbonn

Meteorologisches Institut Universität Bonn

LM_PAFOG : three-dimensional fog forecasting with the Lokal Modell

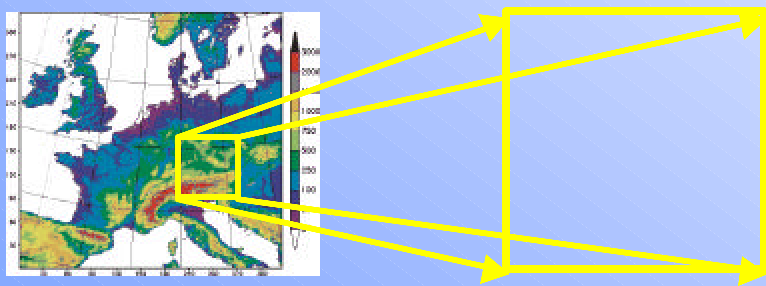
Matthieu MASBOU & Andreas BOTT

LM User seminar– Langen, 6 March 2006

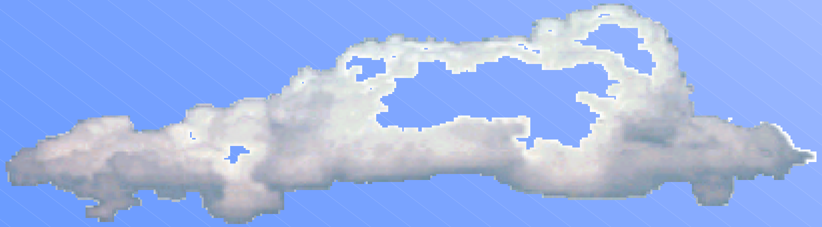

FOG CONDITIONS POSSIBLE
WHEN FLASHING
64
RIGHT LANE
CHARLESTON, WV
Covered With Fog
THE WEATHER CHANNEL
82°
FRIDAY'S FORECAST
Charleston
HI: 83°
weather.com

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

PAFOG
Parameterized microphysics



LM → LM-PAFOG



Simulations
&
outlooks

PArameterized FOG

$$f(a, r, x, y, \dots)$$

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

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

$$\Delta(\overline{S}) = \begin{cases} 1, if\,(\overline{S}) < 0 \\ 0, if\,(\overline{S}) \geq 0 \end{cases}$$

where S is the Supersaturation

Assumption on the droplet size distribution : Log-normal function

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

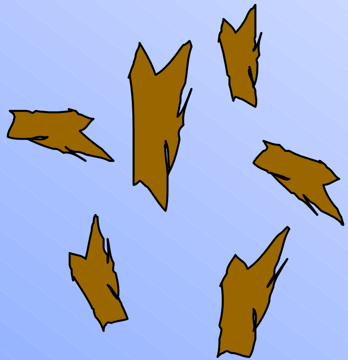
D droplet Diameter

$D_{c,0}$ mean value of D

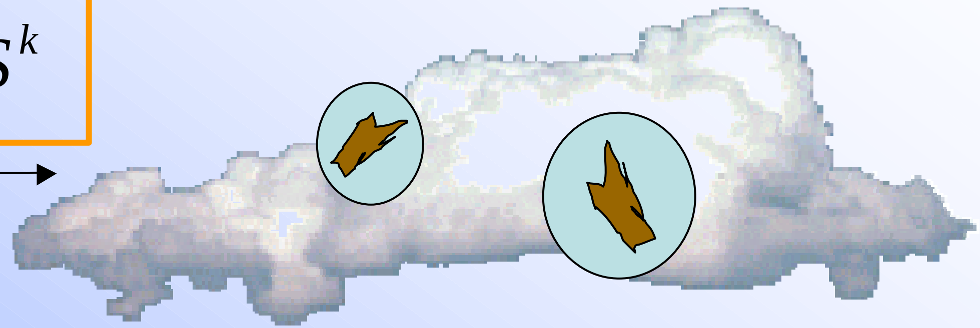
s_c Standart deviation of the given droplet size distribution (s_c=0.2)

Activation

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



$$N_{act} = CS^{k}$$



k and C describe the aerosol model :

Maritime : k=0.7, $C=100\ cm^{-3}$

Continental : k=0.9, $C=3500\ cm^{-3}$

Rural : k=0.9, $C=10000 cm^{-3}$

Condensation/Evaporation

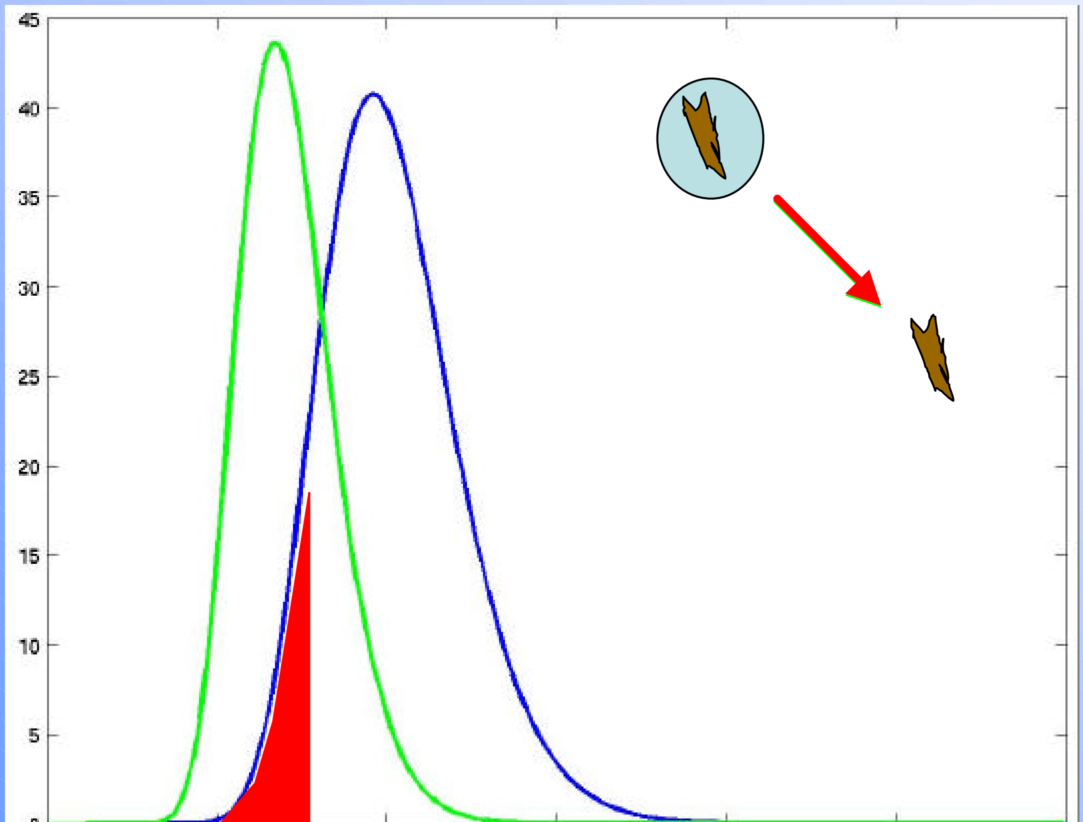
$$f(a,r,x,y,\ldots)$$

Time dependent relation between Supersaturation S and Diameter D

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

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

$$\frac{d\overline{S}}{dt} = S(r,t)$$



Condensation/Evaporation

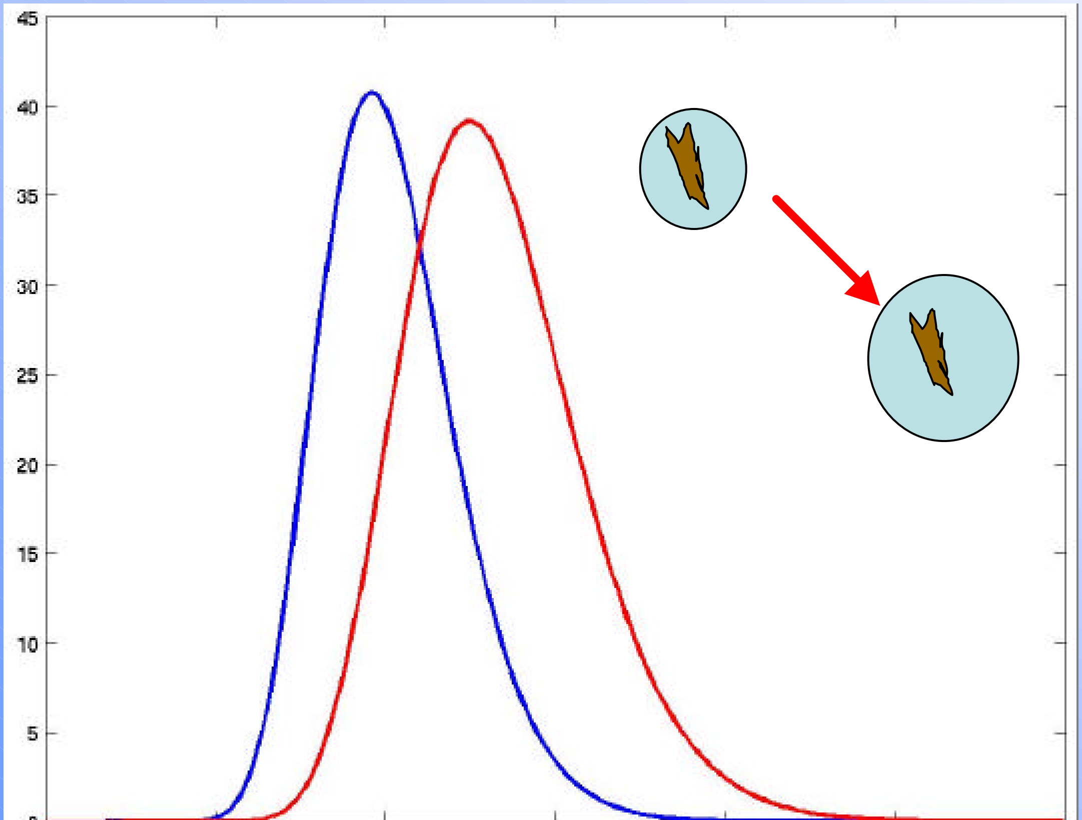
$$f(a,r,x,y,\ldots)$$

Time dependent relation between Supersaturation S and Diameter D

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

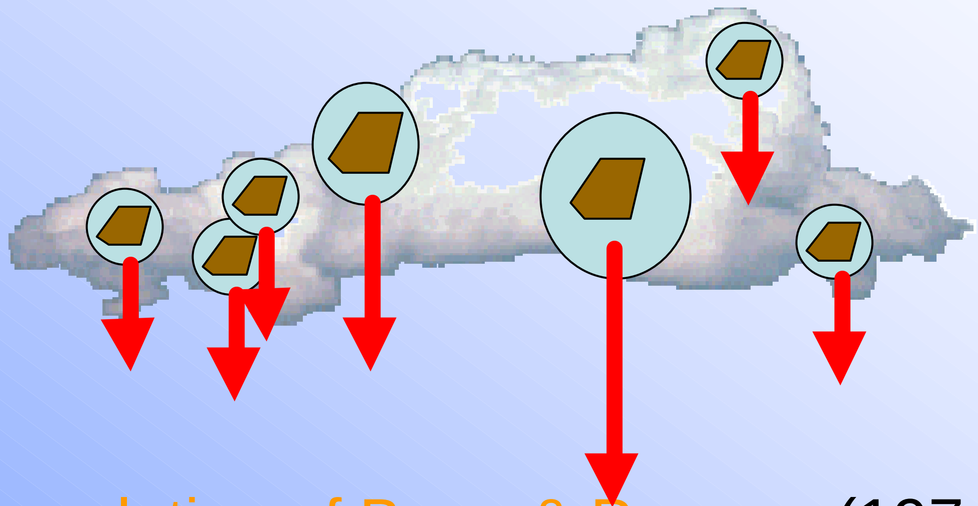
Chaumerliac et al. (1987) and Sakakibara (1979)

$$\frac{d\overline{S}}{dt} = S(r,t)$$



Sedimentation

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



Using the formulation of Berry & Pranger (1974) :

$$v(D) = \frac{h \,\mathrm{Re}}{D r}$$

with

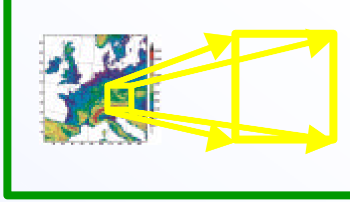
$h = h(D)$ Viscosity

$\mathrm{Re} = \mathrm{Re}(D)$ Reynolds number

Numerical solution : positive definite advection scheme

(Bott 1989)

Forecast Area

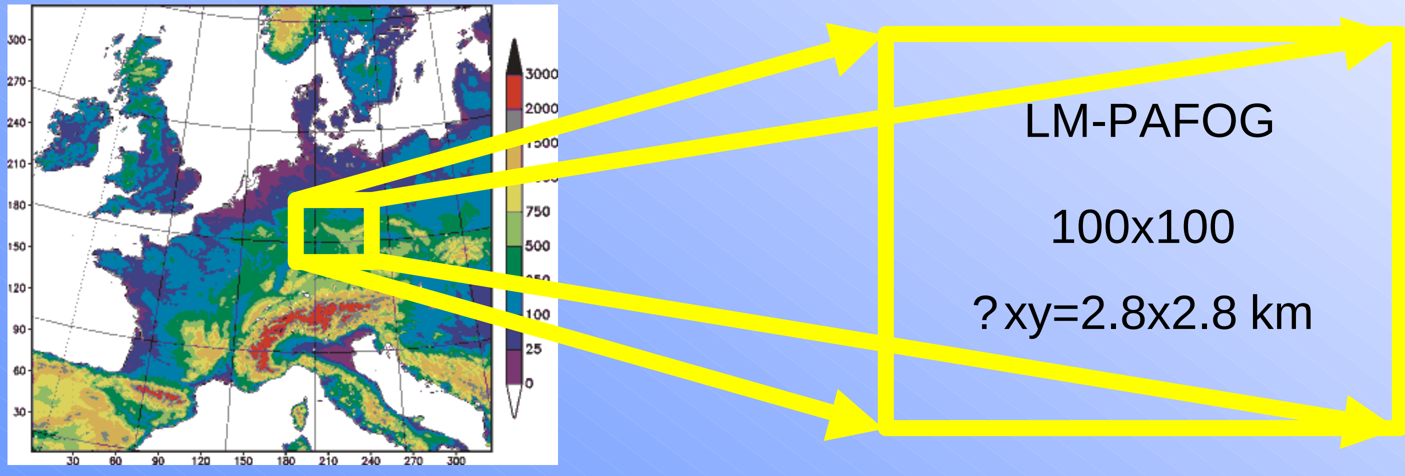


- Fog formation = complex and highly non linear fashion
(Turbulences, soil/atmosphere,…)

→ 3D Fog forecasting Model = fine horizontal resolution

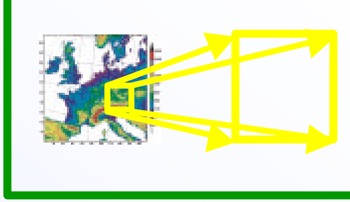
But, not feasible for operational mesoscale models

→ **One way interactive Nesting LM2LM**



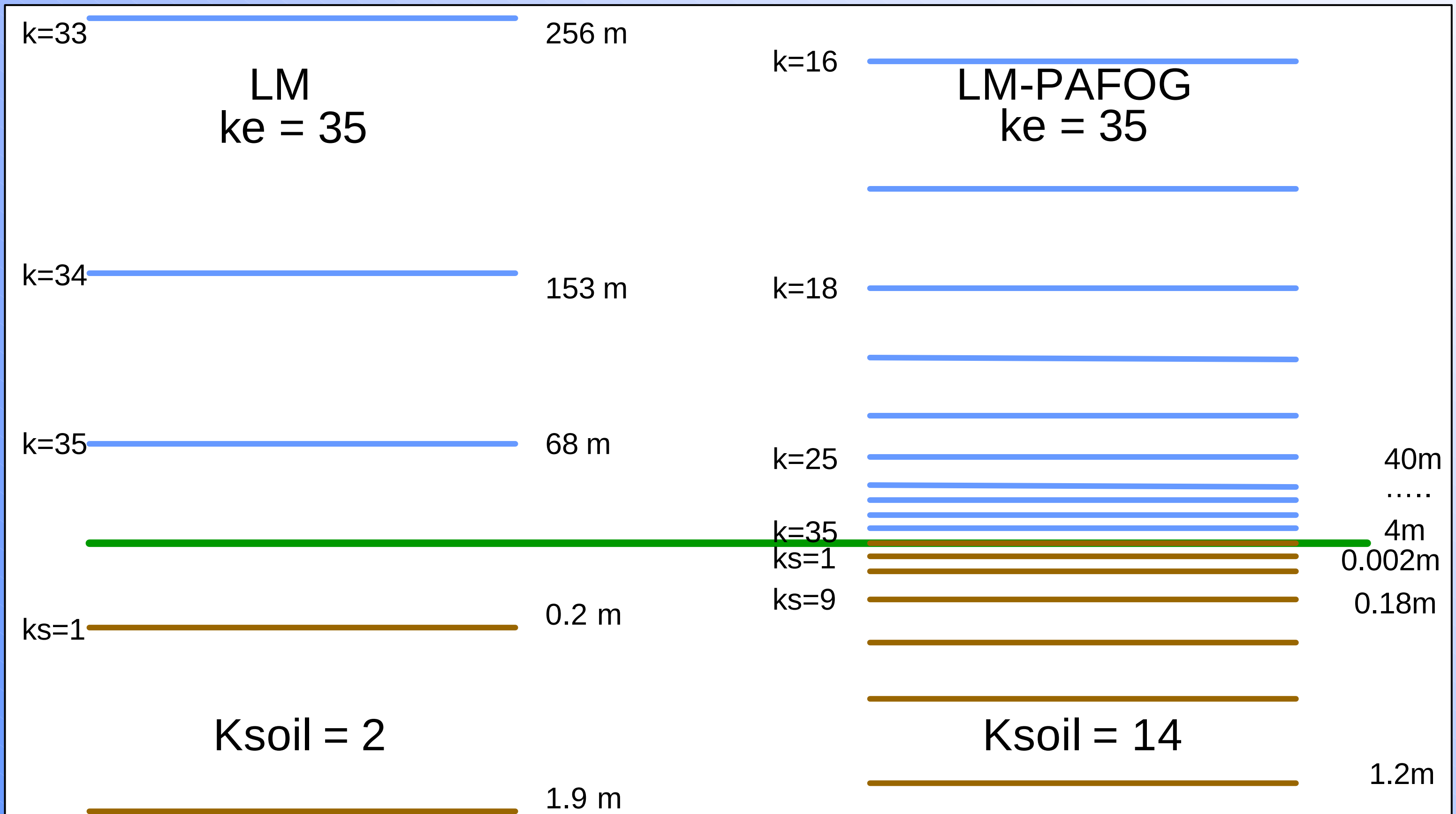
LM : 325x325 ?xy=7x7 km

Forecast Area(2)



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

➔ Fine resolution at Soil/Atmosphere Interface



Parameterized Microphysics

Comes from PAFOG (Bott & Trautmann 2002) :

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

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

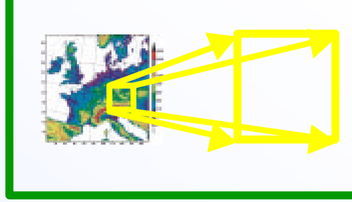
ADV (Advection) and DIF (Turbulent Diffusion)

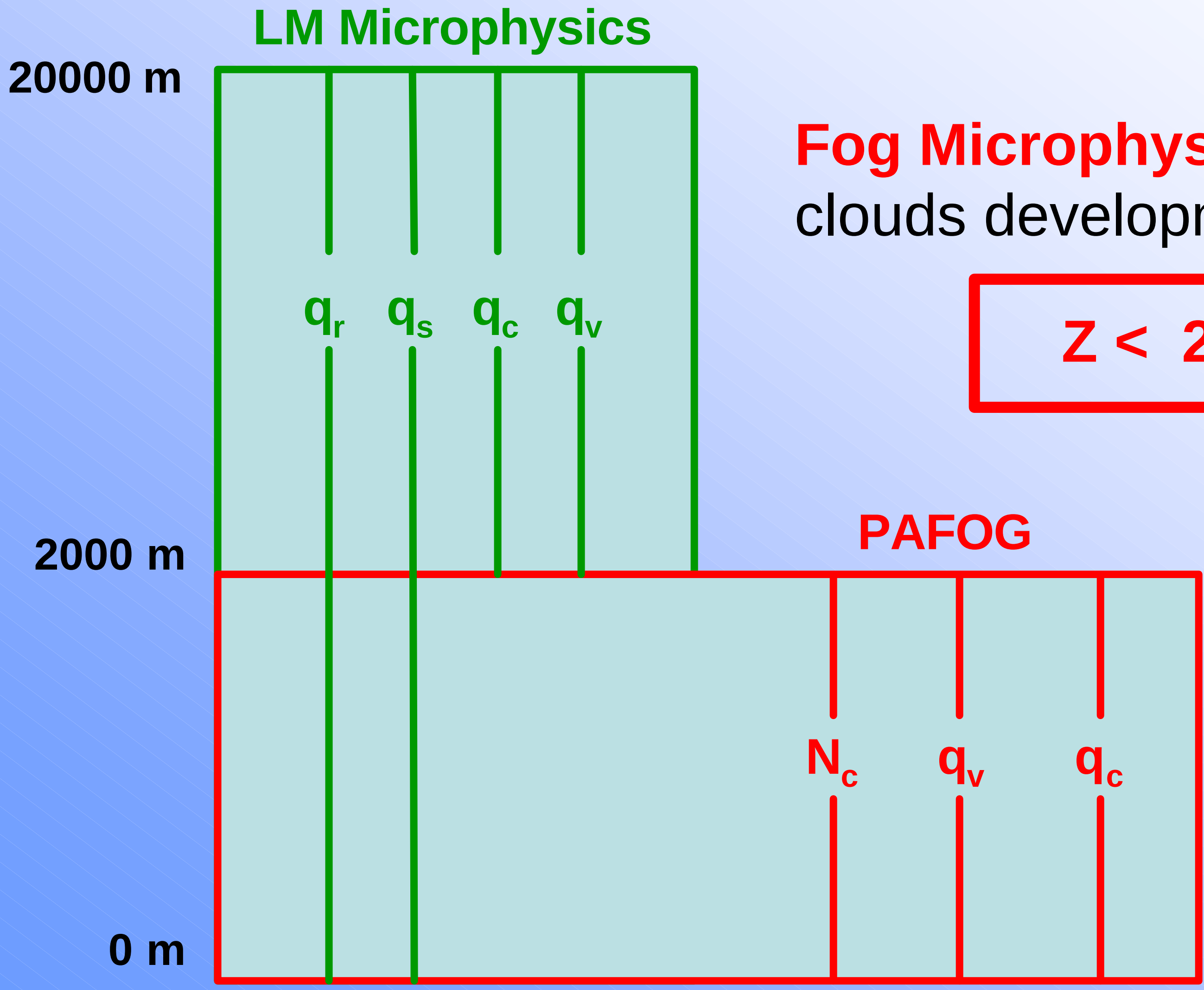
are **computed by the dynamical framework of LM**

$\left(\frac{\partial q_c}{\partial t}\right)_{sed}$ $\left(\frac{\partial N_c}{\partial t}\right)_{sed}$ Sedimentation of cloud droplets

$s\,(q_c)$ $s\,(N_c)$ Source-sink terms between gaseous and liquid phase

Parameterized Microphysics(2)

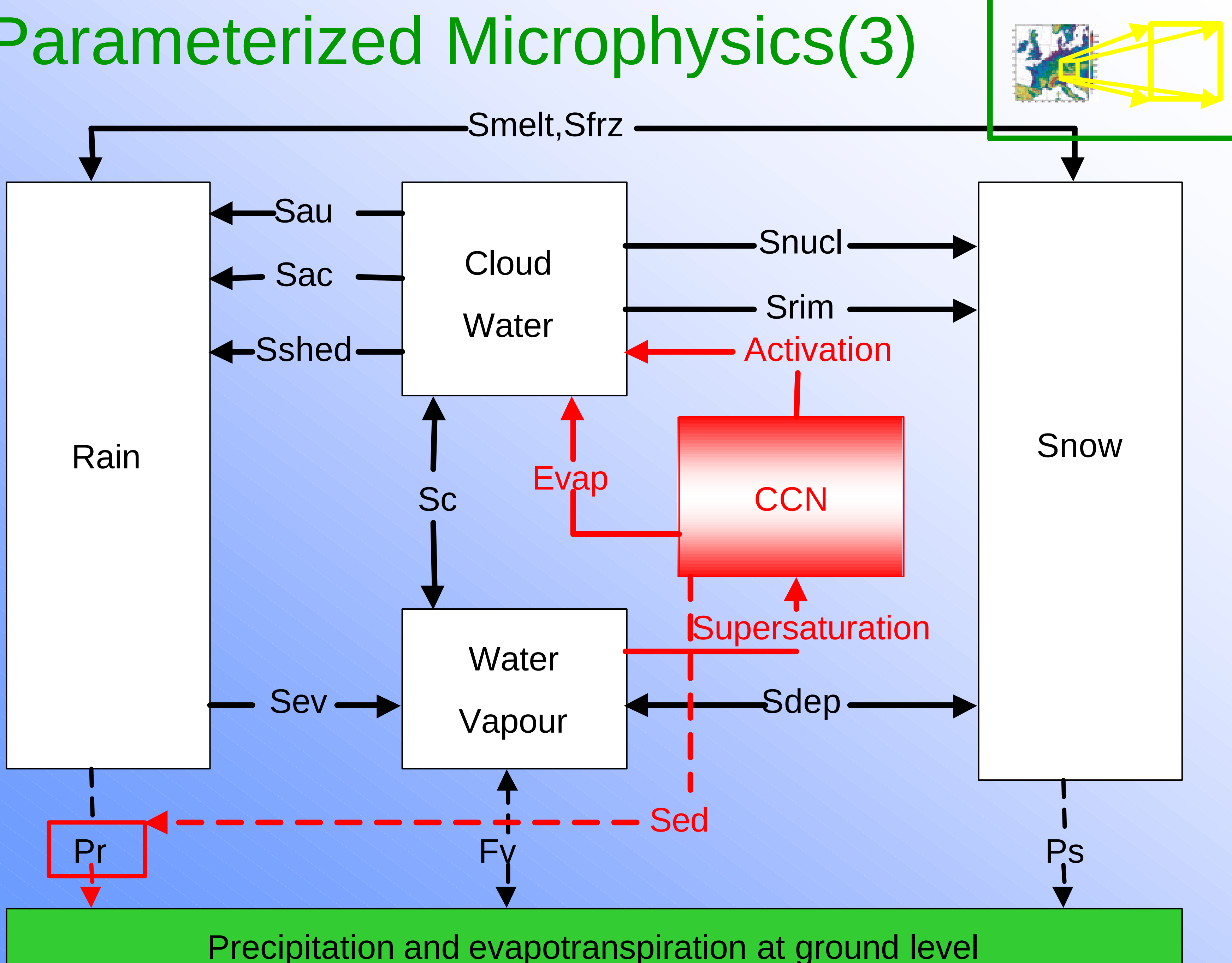




Fog Microphysics determines clouds development, if :

Z < 2000 m

Parameterized Microphysics(3)



Simulation Conditions

Lindenberg (Germany)

Lon 52 10´01´´ Lat 14 07´27´´

6 October 2005 00 UTC – 8 October 2005 00UTC

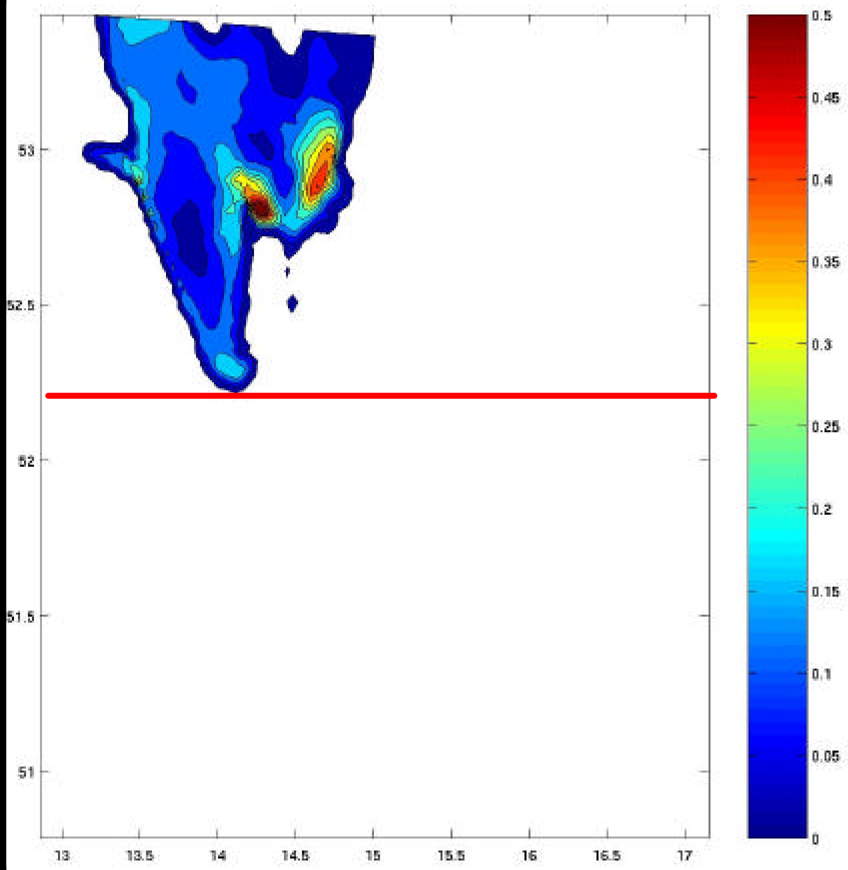
100x100 pixels with dx = 2.8 km

Timestep : 10 sec.

No cloud cover excepting FOG formation

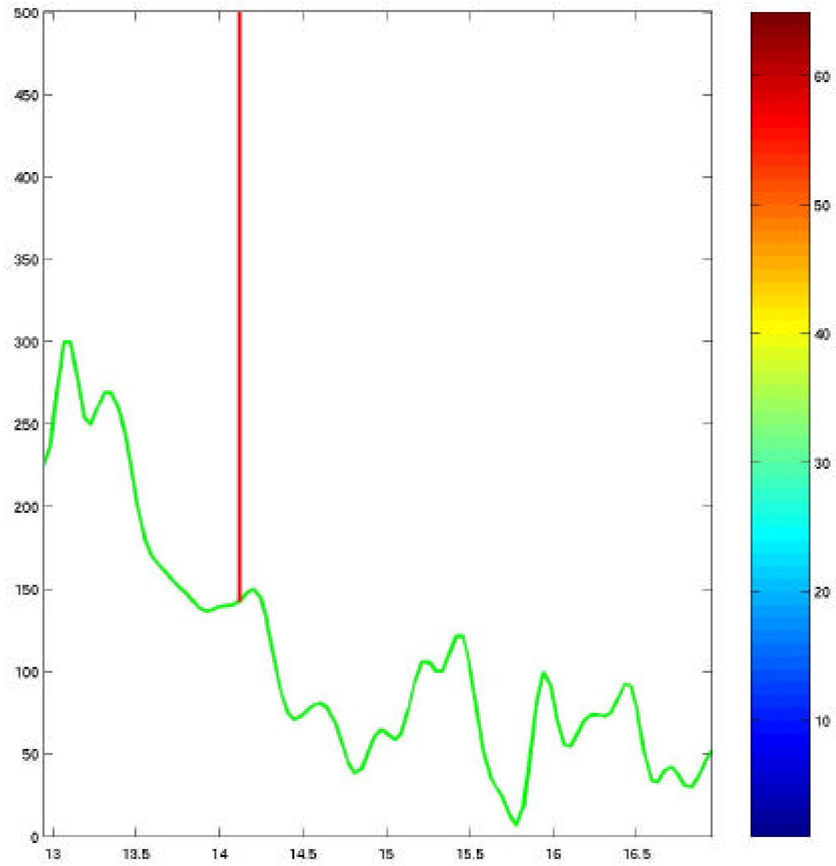
07.10.2005 **01UTC**

LWC in g/kg



Horiz. Cross Section 2 m

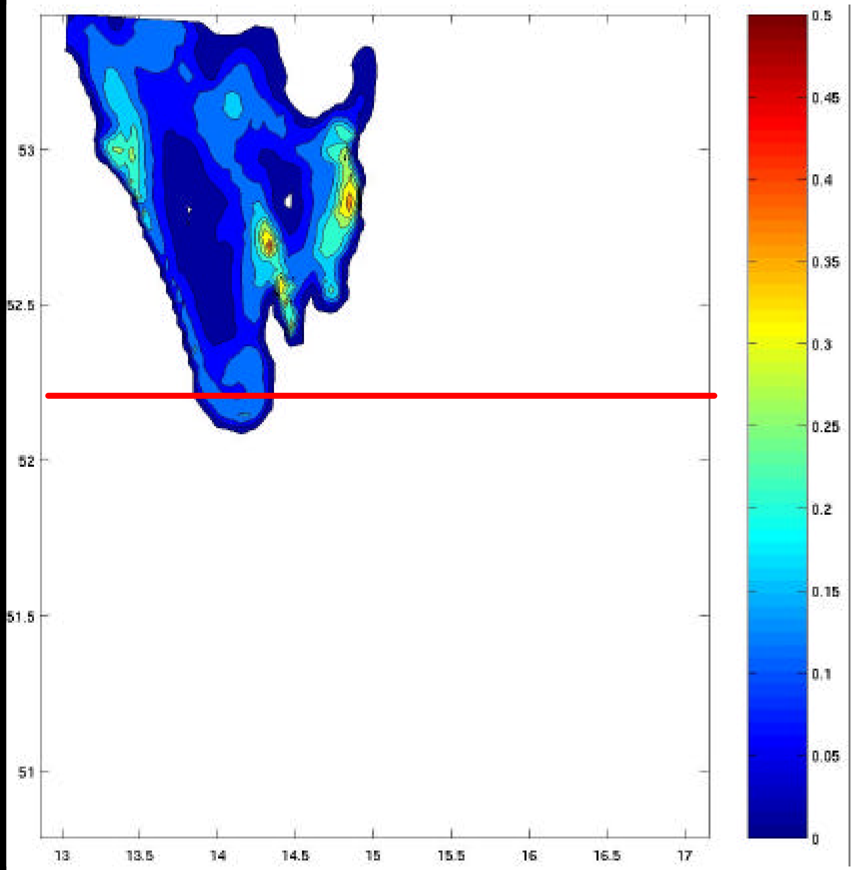
LWC in g/kg



Vert. Cross Section

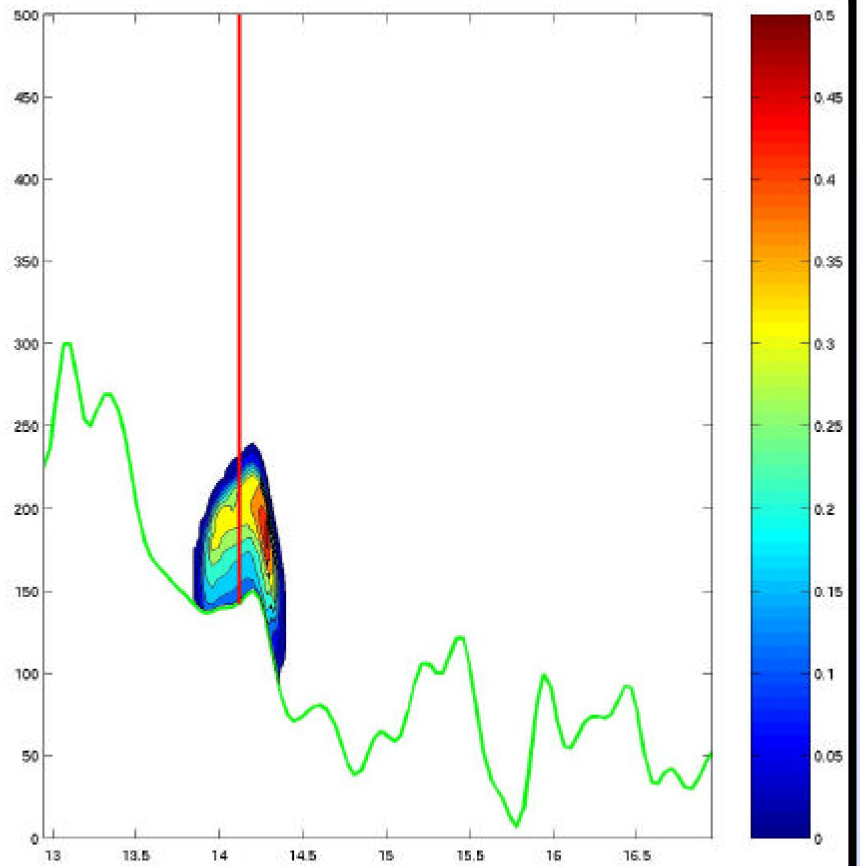
07.10.2005 **02UTC**

LWC in g/kg



Horiz. Cross Section 2 m

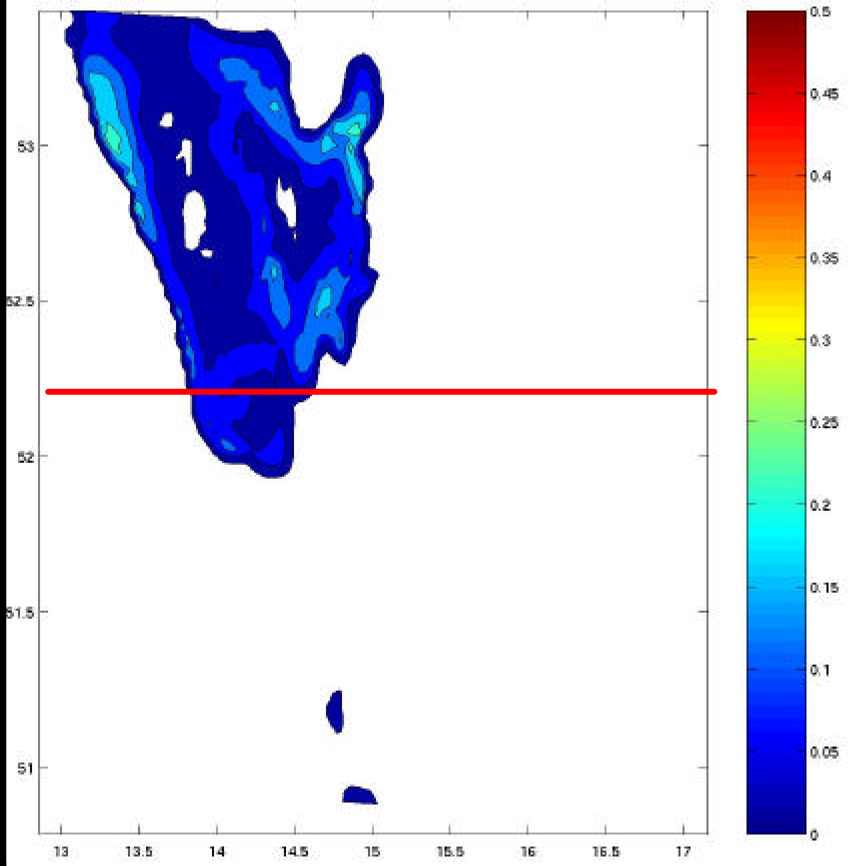
LWC in g/kg



Vert. Cross Section

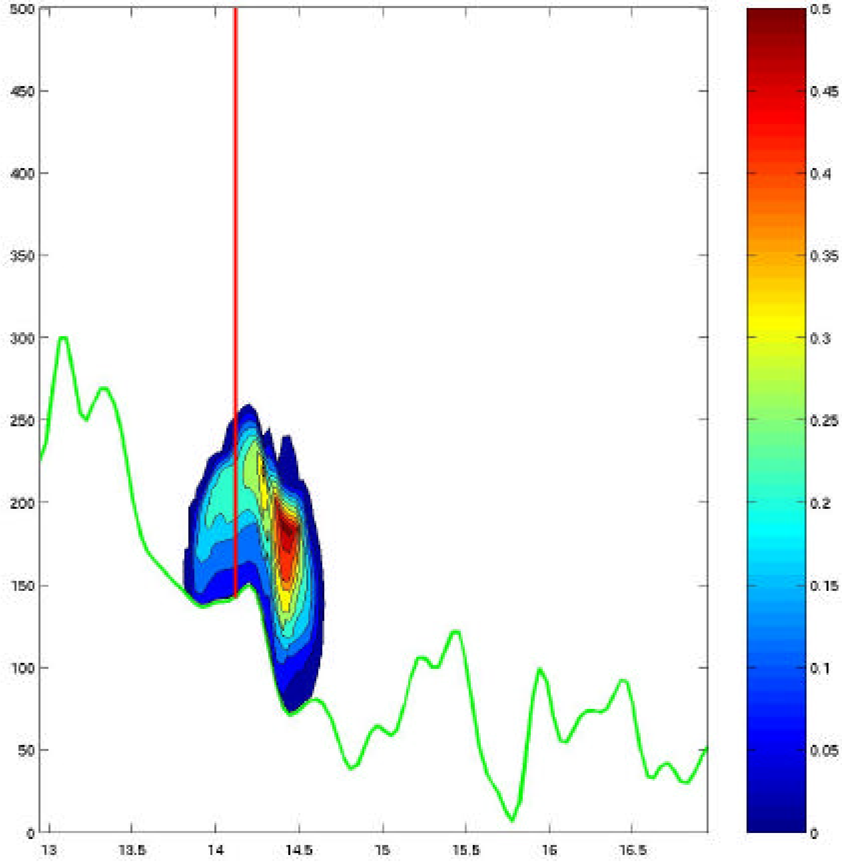
07.10.2005 **03UTC**

LWC in g/kg



Horiz. Cross Section 2 m

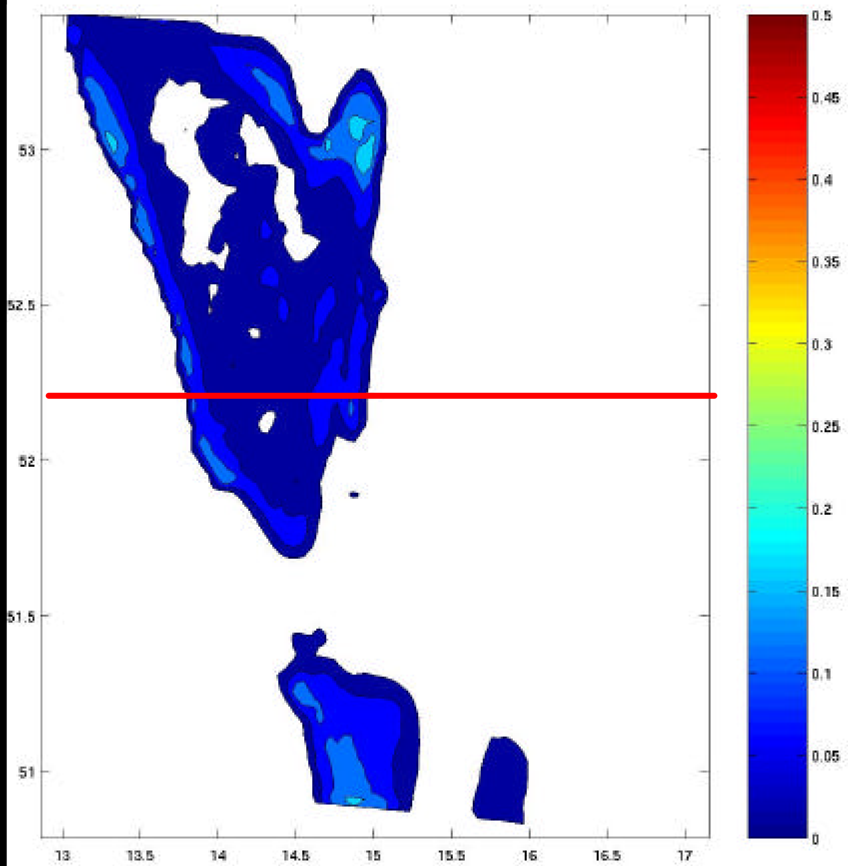
LWC in g/kg



Vert. Cross Section

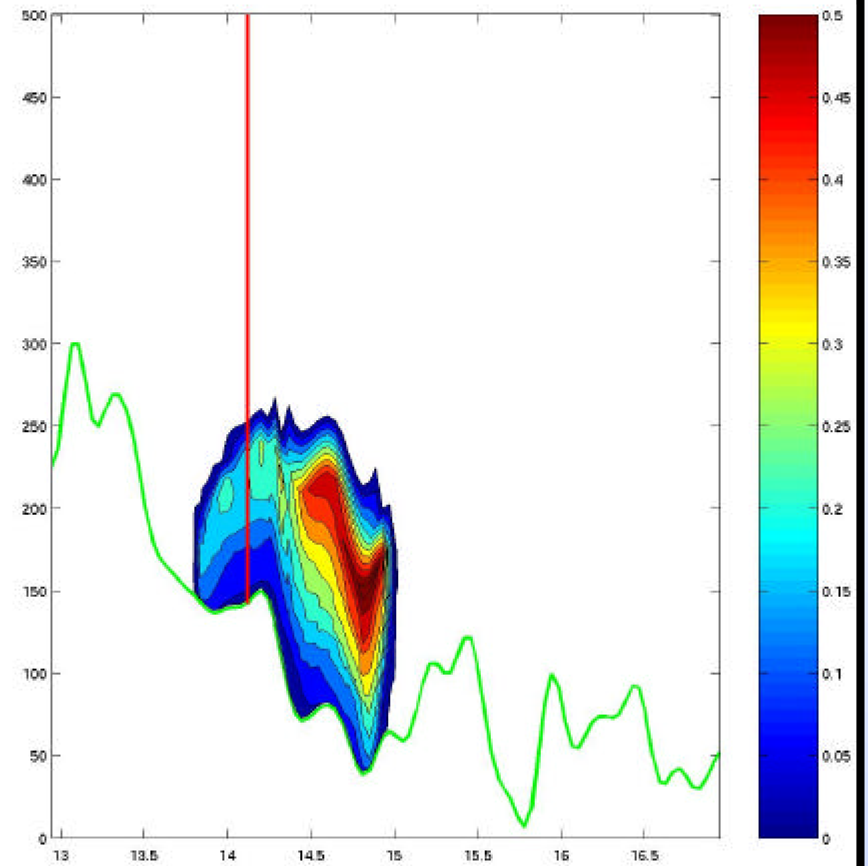
07.10.2005 **04UTC**

LWC in g/kg



Horiz. Cross Section 2 m

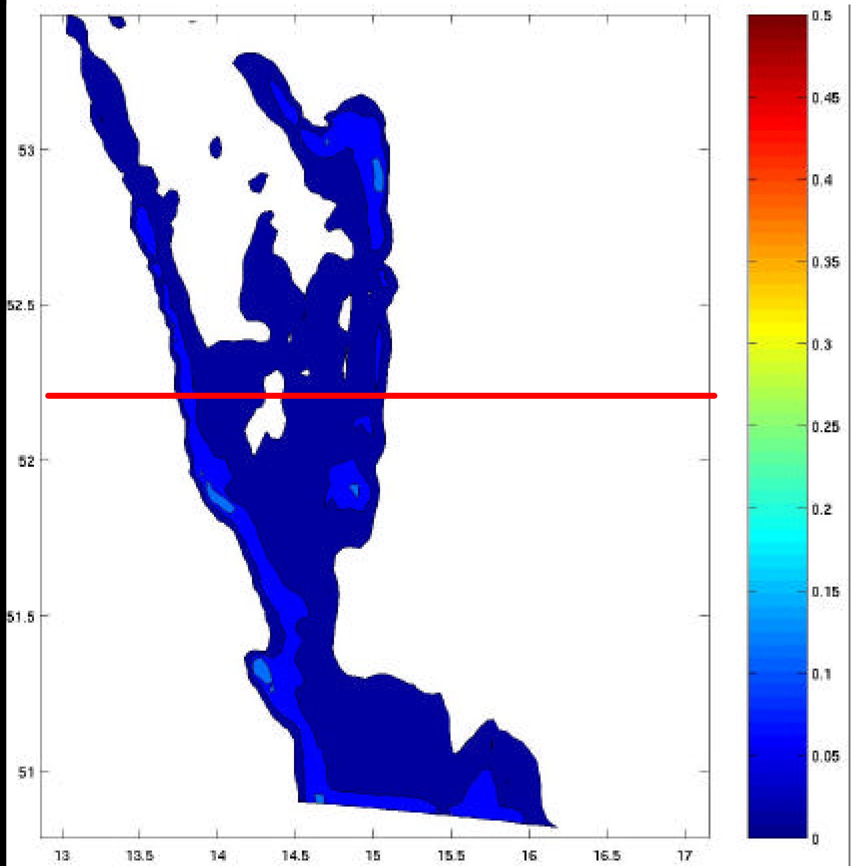
LWC in g/kg



Vert. Cross Section

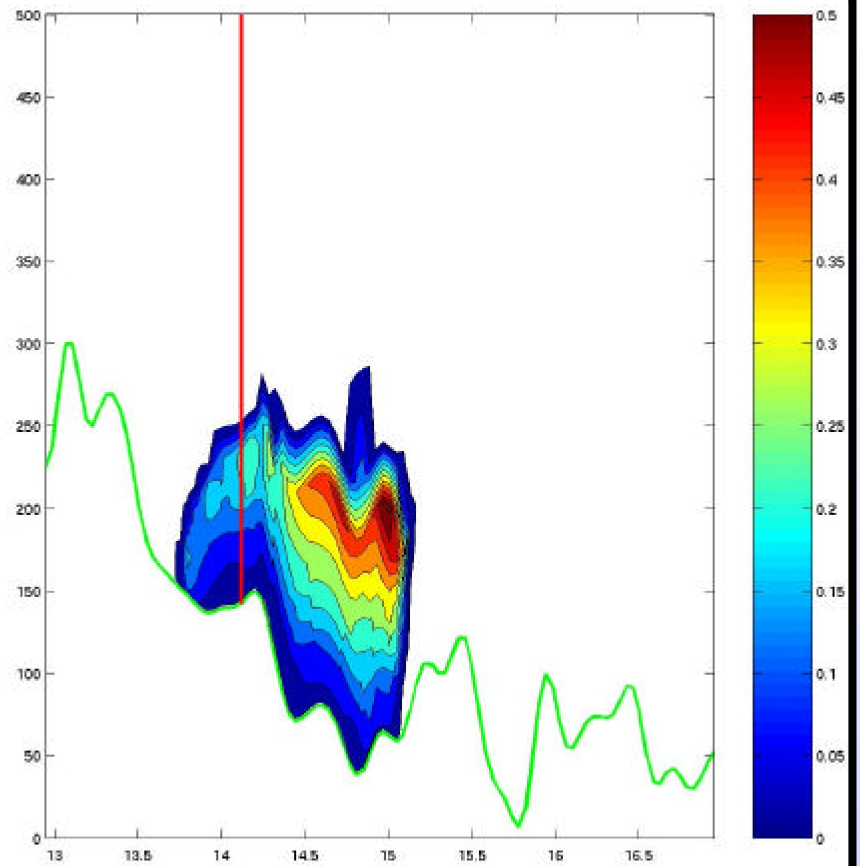
07.10.2005 **05UTC**

LWC in g/kg



Horiz. Cross Section 2 m

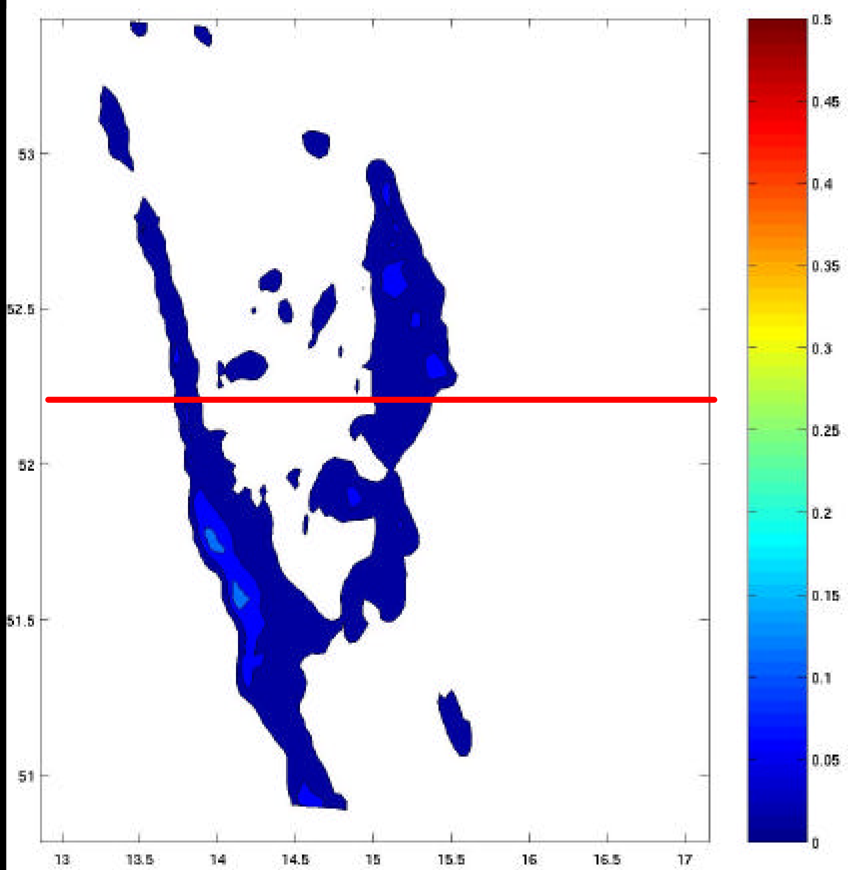
LWC in g/kg



Vert. Cross Section

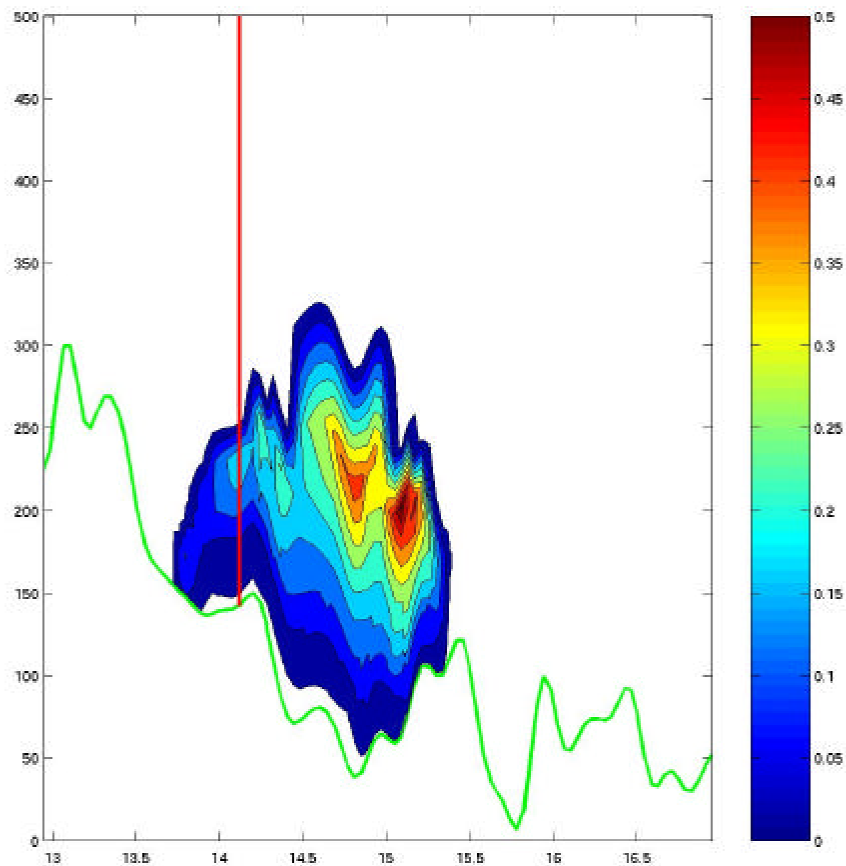
07.10.2005 **06UTC**

LWC in g/kg



Horiz. Cross Section 2 m

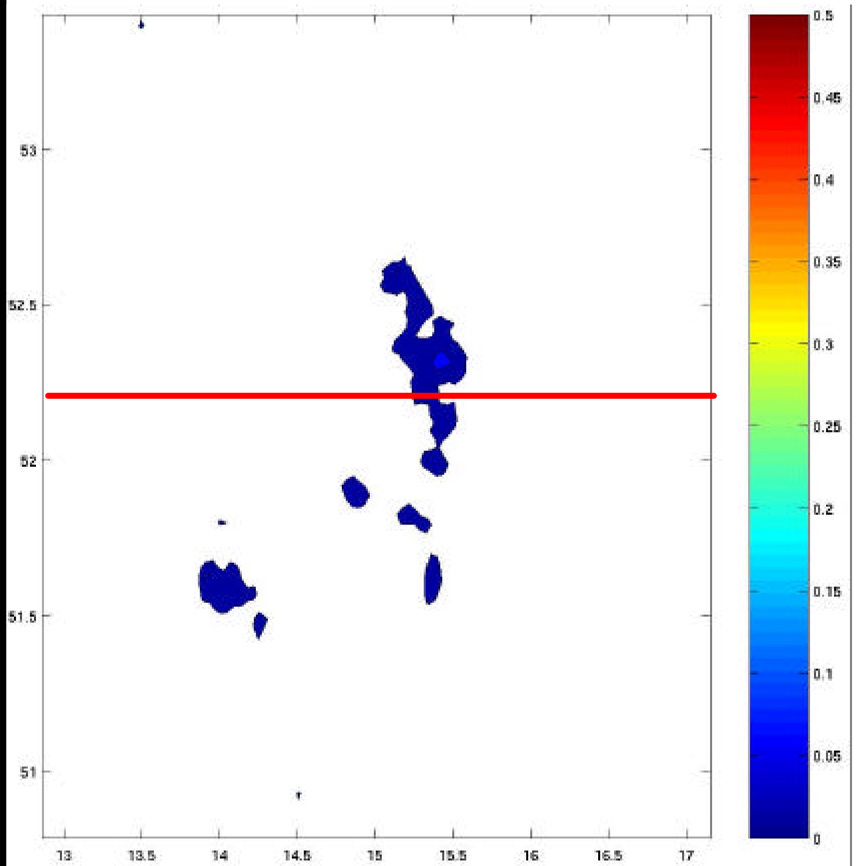
LWC in g/kg



Vert. Cross Section

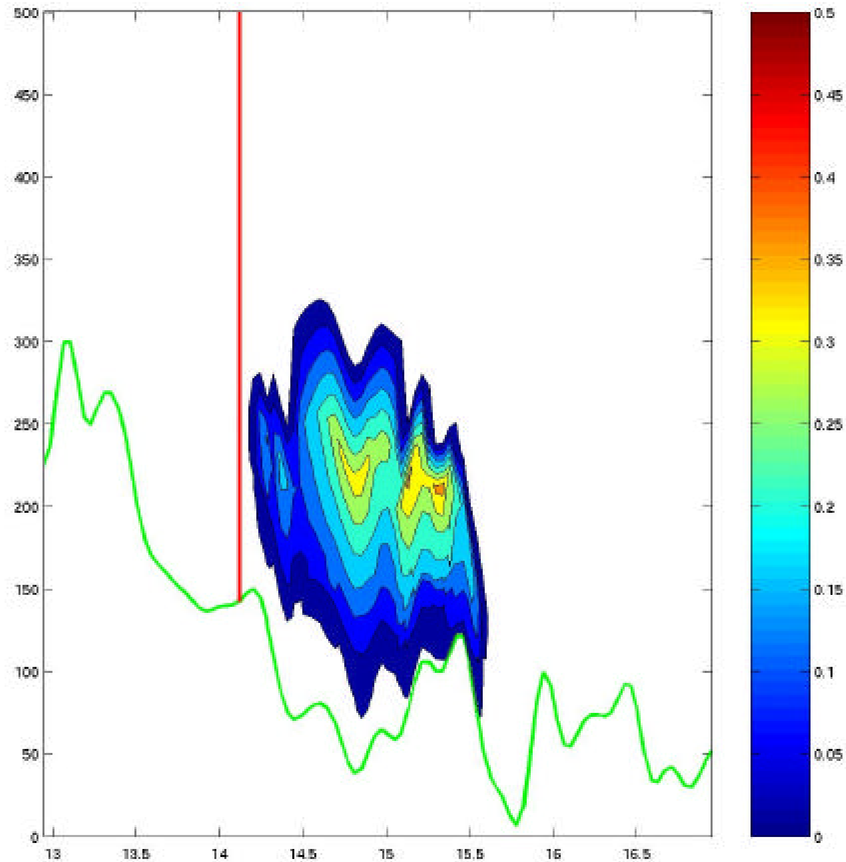
07.10.2005 **07UTC**

LWC in g/kg



Horiz. Cross Section 2 m

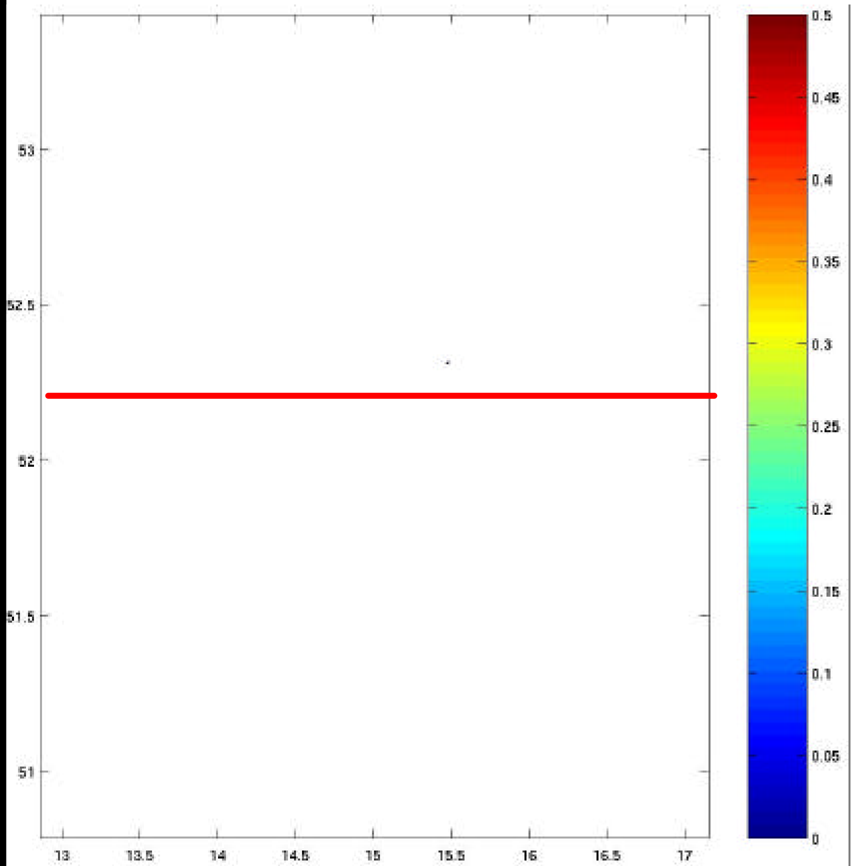
LWC in g/kg



Vert. Cross Section

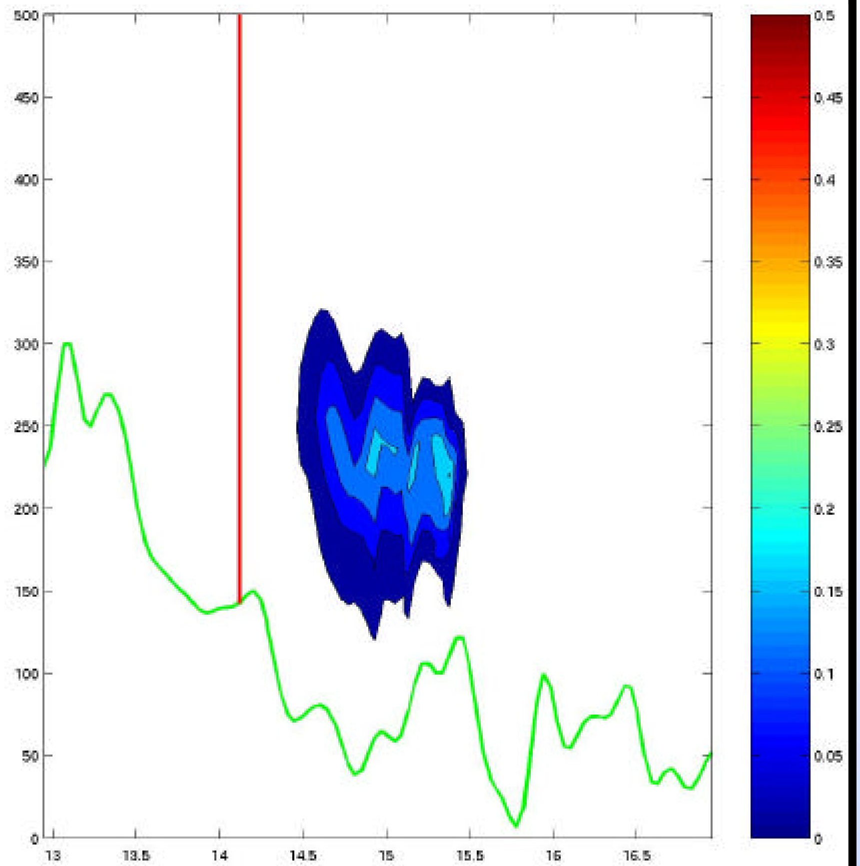
07.10.2005 **08UTC**

LWC in g/kg



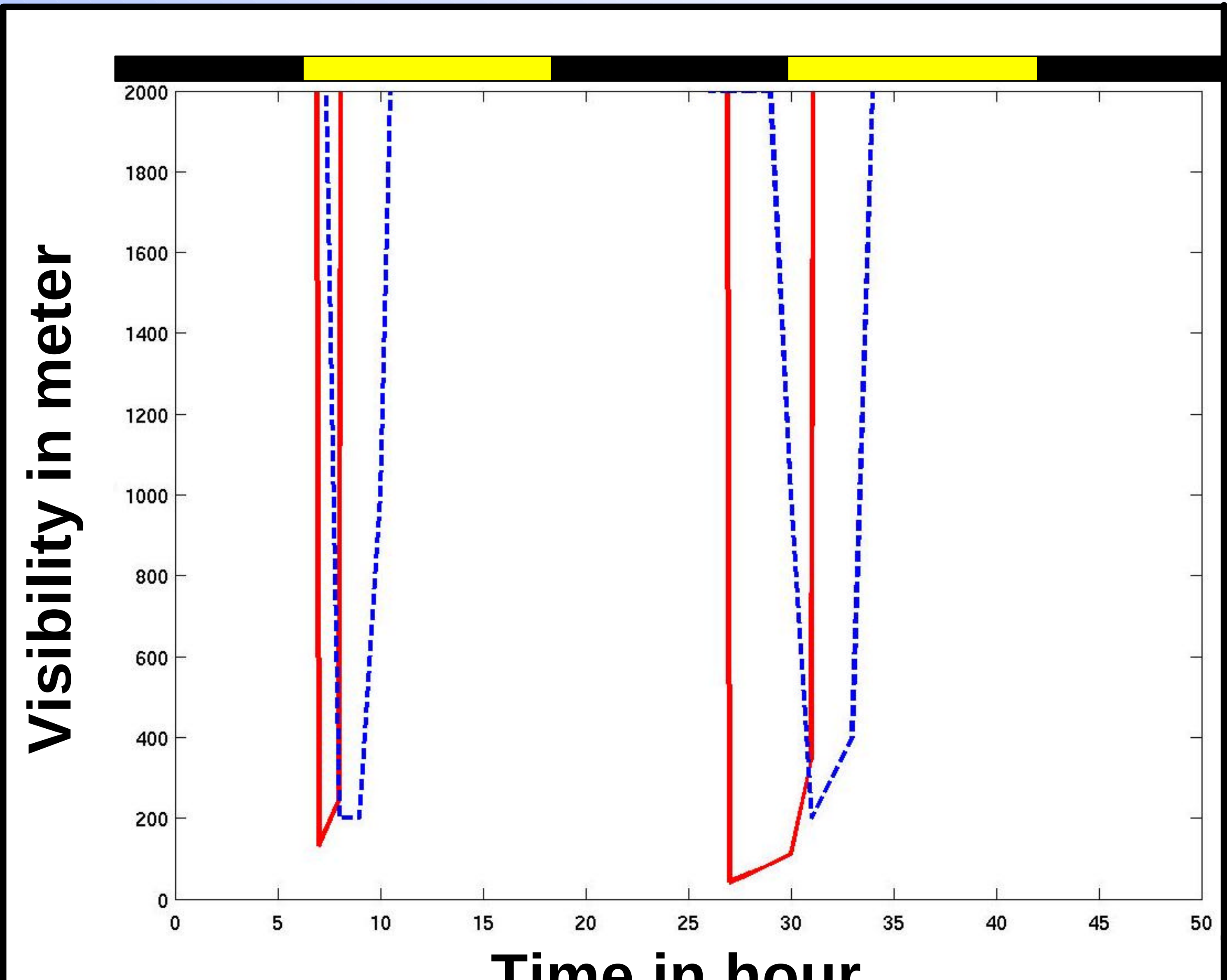
Horiz. Cross Section 2 m

LWC in g/kg

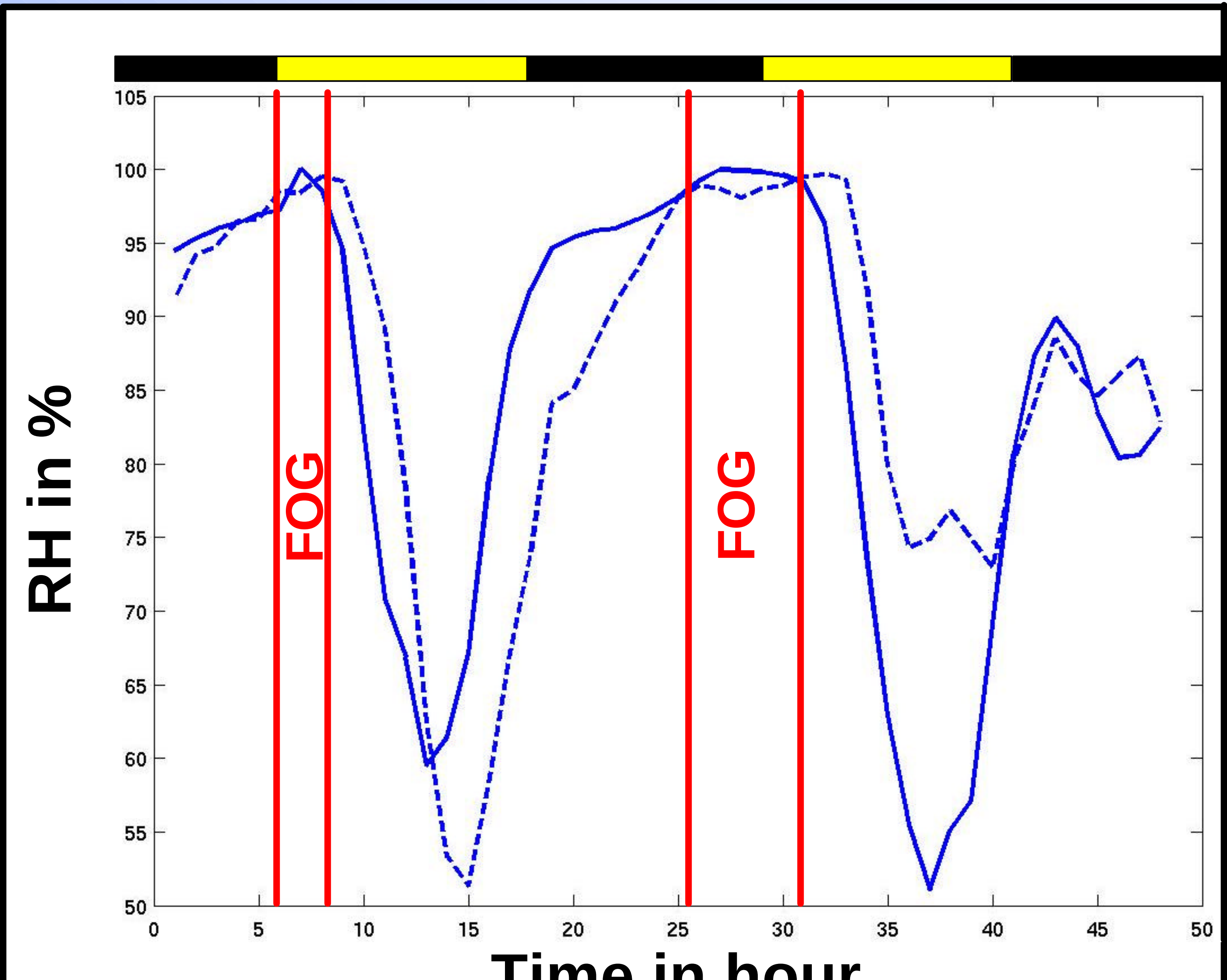


Vert. Cross Section

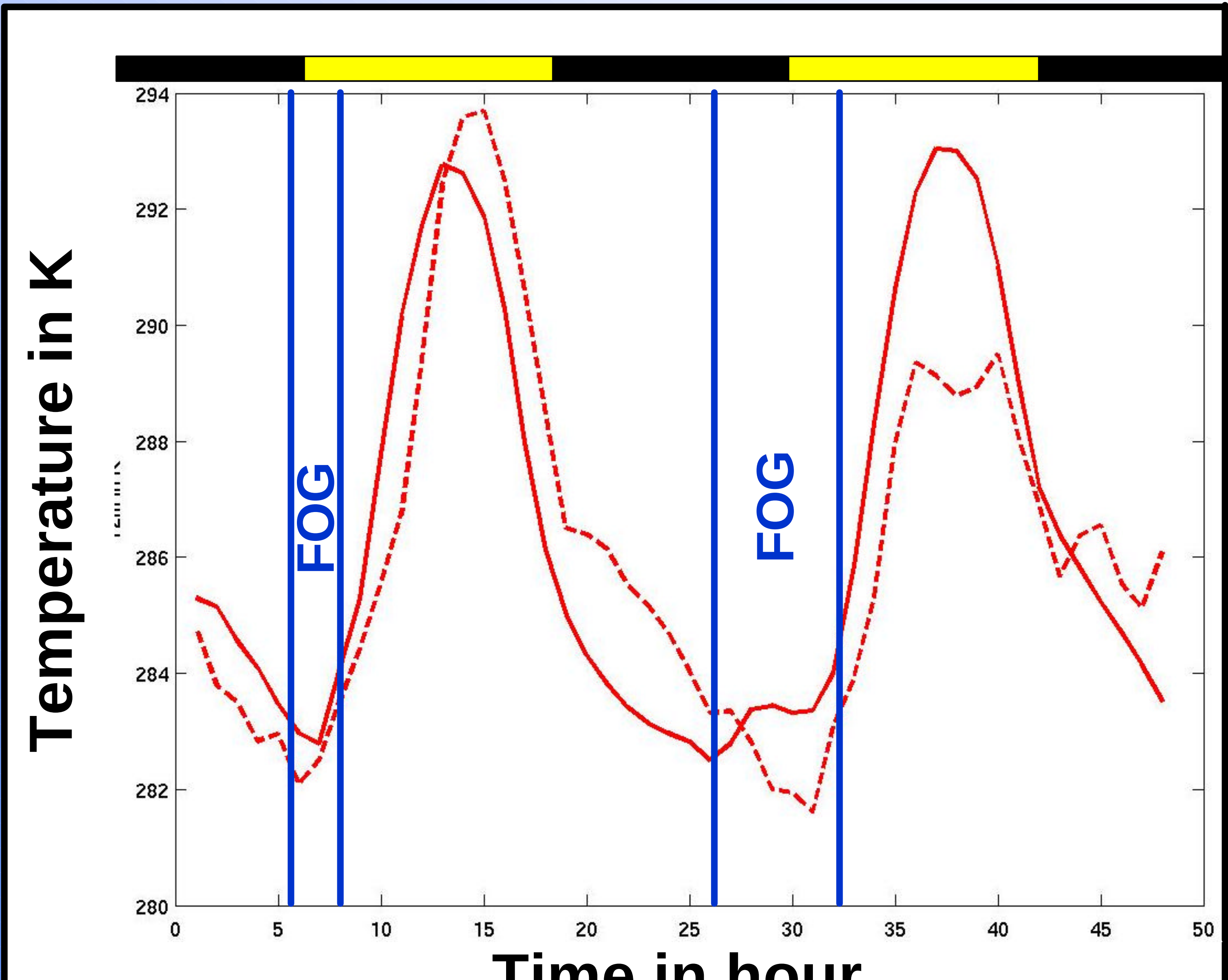
Visibility 2m



Relative Humidity 2m

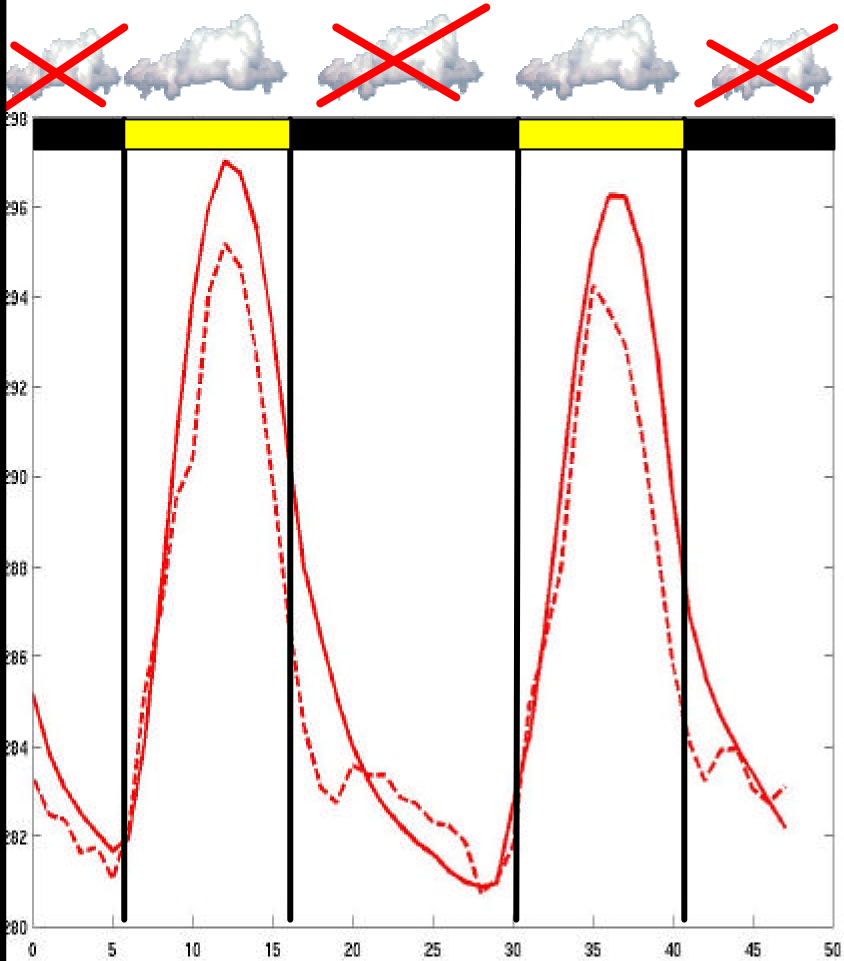


Temperature 2m



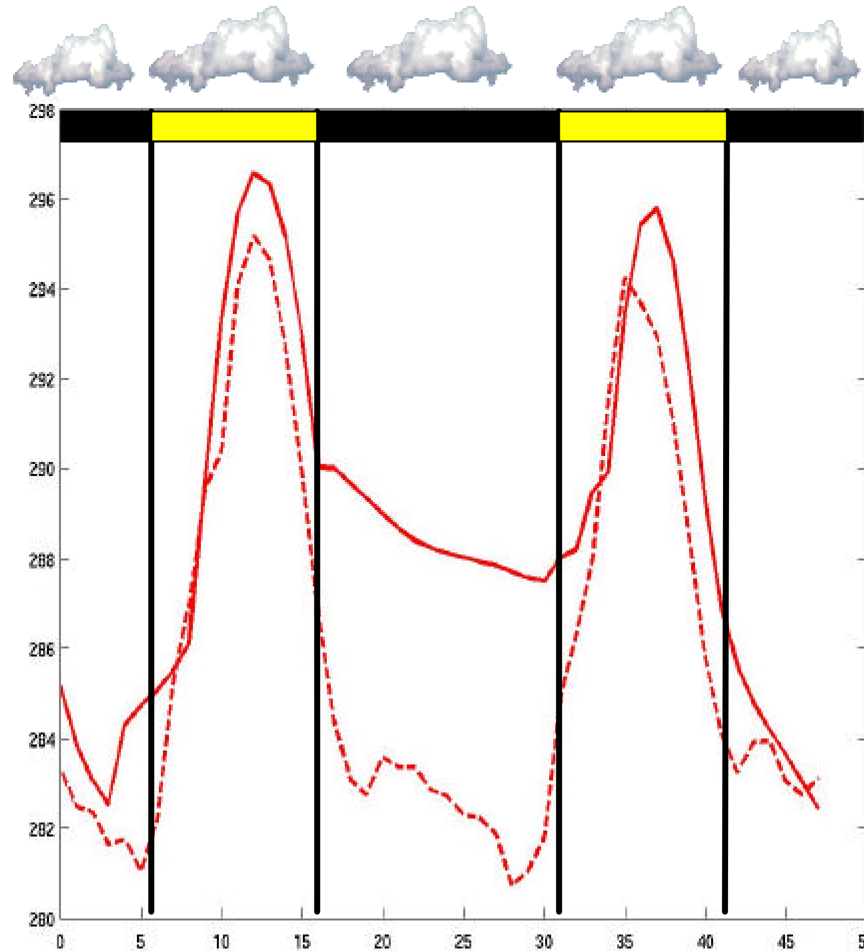
Clouds & Radiative Scheme

Modified Cloud Scheme



T2m in time

Original LM Cloud Scheme



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

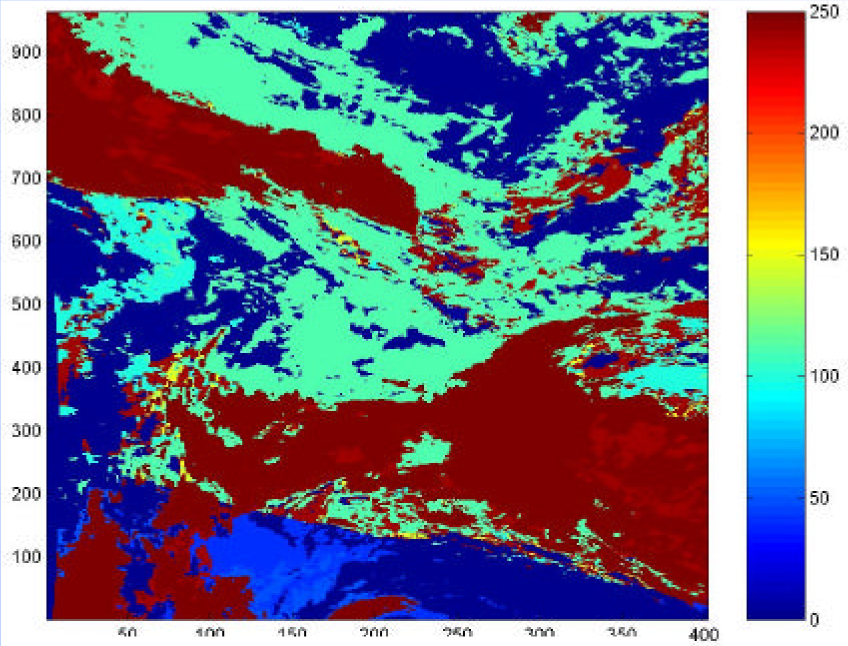
Fine Vertical resolution ?z_{min} = 4 m

- 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

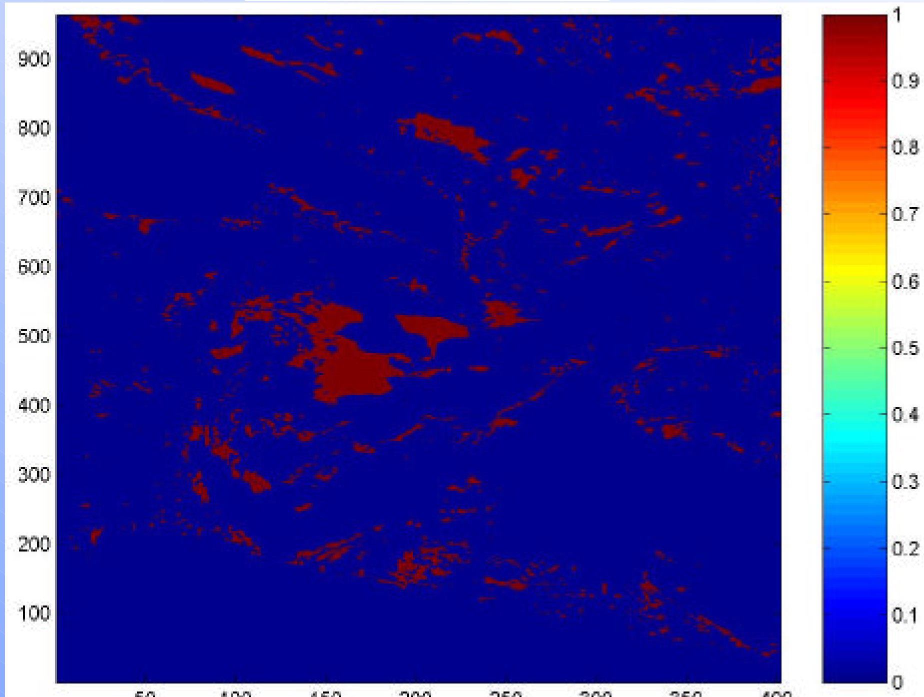


Original Satellite Data

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

→ **Test Spatial distribution of fog**

Stratus Mask



References

Berry, E.X & Pranger, M. P. (1974), Equation for calculating the terminal velocities of water drops, *J. Appl. Meteor.* **13**, 108-113.

Bott, A. (1989), A positive definite advection schemme obtained by nonlinear renormalization of the advective fluxes, *Monthly Weather Review* **117**, 1006-1015.

Bott, A. & Trautmann, T. (2002), PAFOG – a new efficient forecast model of radiation fog and low-level stratiform clouds, *Atmospheric Research* **64**, 191-203.

Chaumerliac, N., Richard, E. & Pinty, J.-P. (1987), Sulfur scavenging in a mesoscale model with quasi-spectral microphysic : Two dimensional results for continental and maritime clouds, *J. Geophys. Res.* **92**, 3114-3126.

Sakakibara, H. (1979), A scheme for stable numerical computation of the condensation process with large time step, *J. Meteorol. Soc. Japan* **57**, 349-353.

Twomey, S. (1959), The nuclei of natural cloud formation. Part ii : The supersaturation in natural clouds and the variation of cloud droplet concentration, *Geophys. Pura Appl.* **43**, 243-249.