LM User Seminar 2007

Langen, March 2007

LM-PAFOG: Three-Dimensional Fog Forecasting with the Lokal Modell

M.Masbou[1,2], A. Bott[1], M. D. Müller[3] & Jan Cermak[4]

[1] Meteorological Institute, University of Bonn, Germany, mmasbou@uni-bonn.de

[2] Laboratoire de Météorologie physique, University Blaise Pascal, Clermont-Ferrand, France

[3] Institute of Meteorology, Climatology & Remote Sensing, University of Basel, Switzerland

[4] Laboratory for Climatology & Remote Sensing, University of Marburg, Germany

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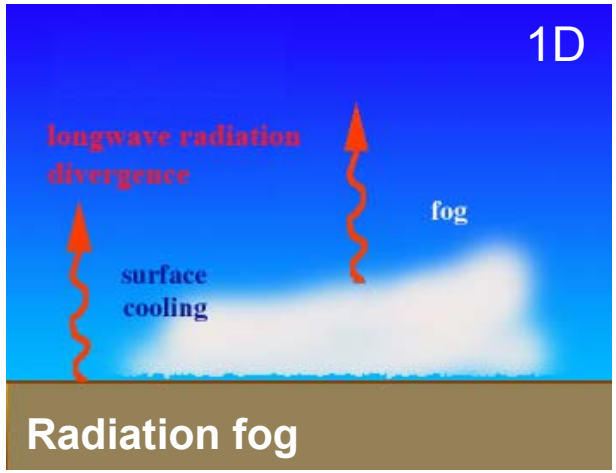
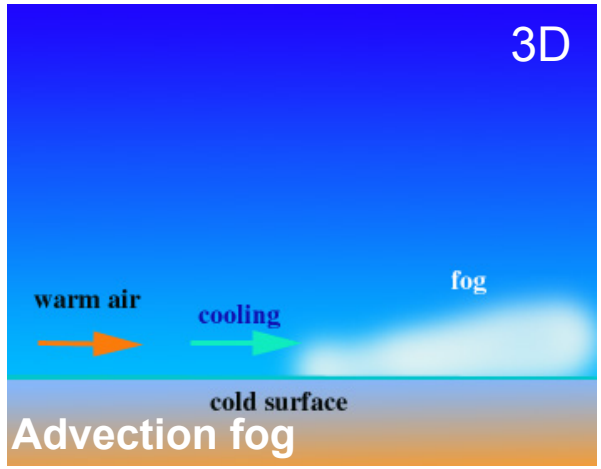
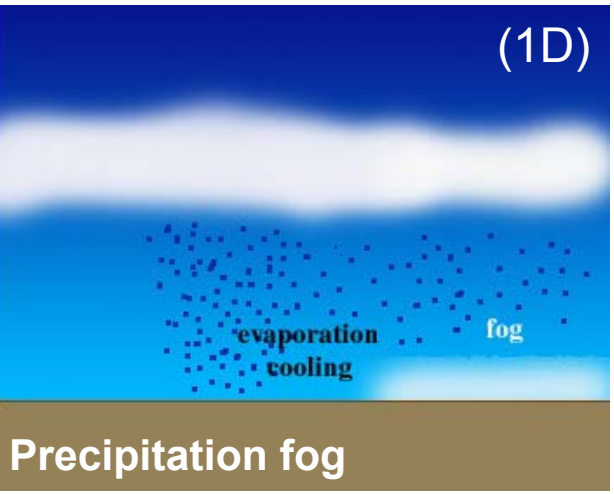
Fog Formation

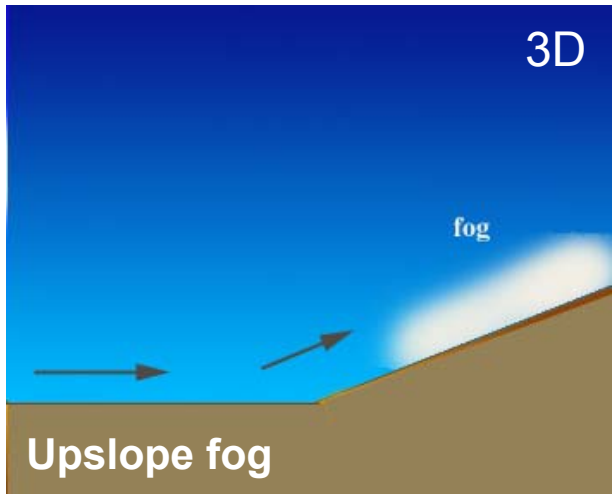
cooling

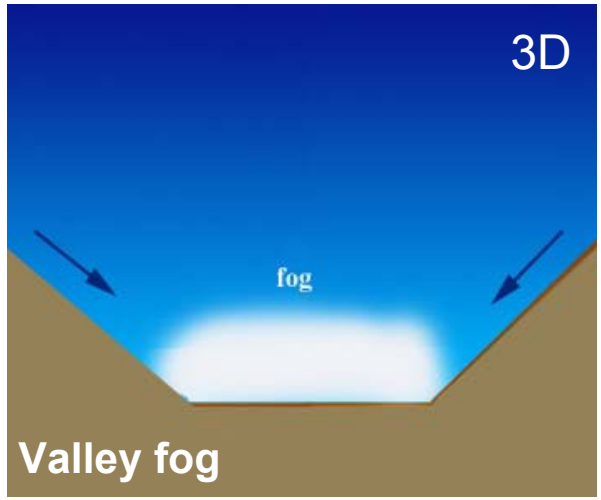
Increase in humidity











3D FOG Model = LM + PAFOG

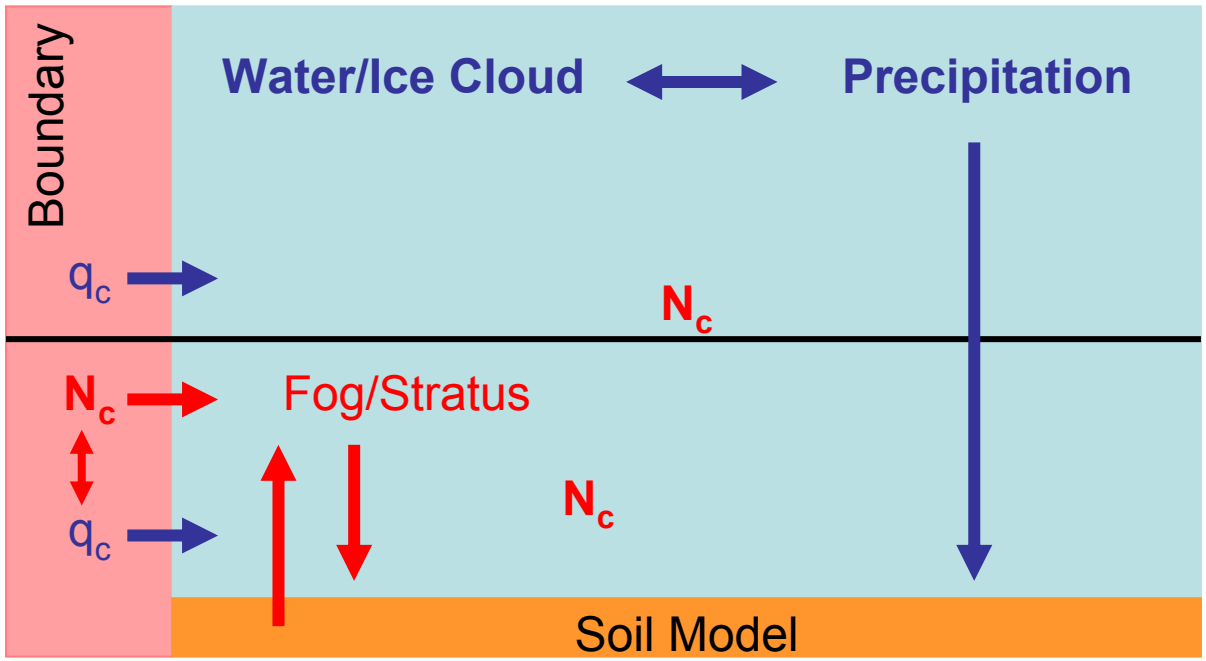
$$\frac{\partial N_c}{\partial t} = ADV(N_c) + DIF(N_c) + \left(\frac{\partial N_c}{\partial t}\right)_{sed} + \sigma(N_c)$$

Droplets number Concentration

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

Liquid Water Content

LM-Dynamics **PAFOG-Microphysics**



20 000 m

2000 m

PAFOG Microphysics

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

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

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

Supersaturation **S**

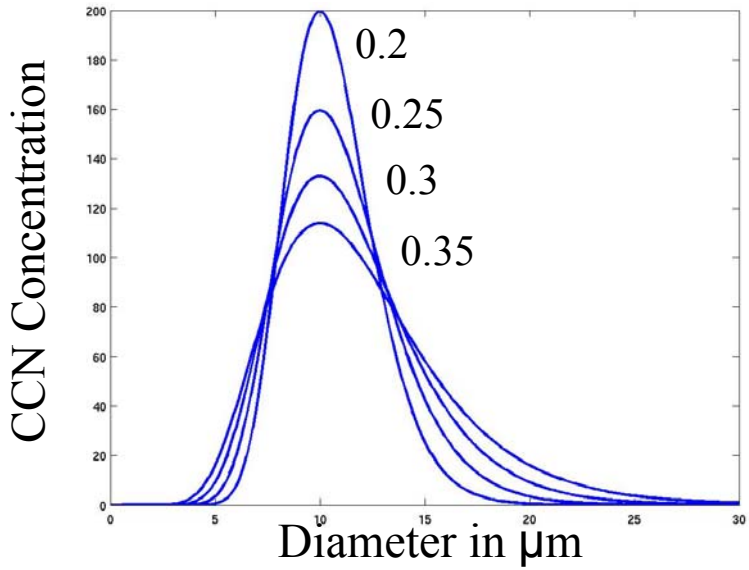
Assumption for droplet spectra : **Log-normal**

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

D droplet Diameter

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

σ_c Standart deviation of size distribution (σ_c=0.2)



PAFOG Microphysics

1- Activation [Twomey (1954)] : $N_{act} = CS^{k}$

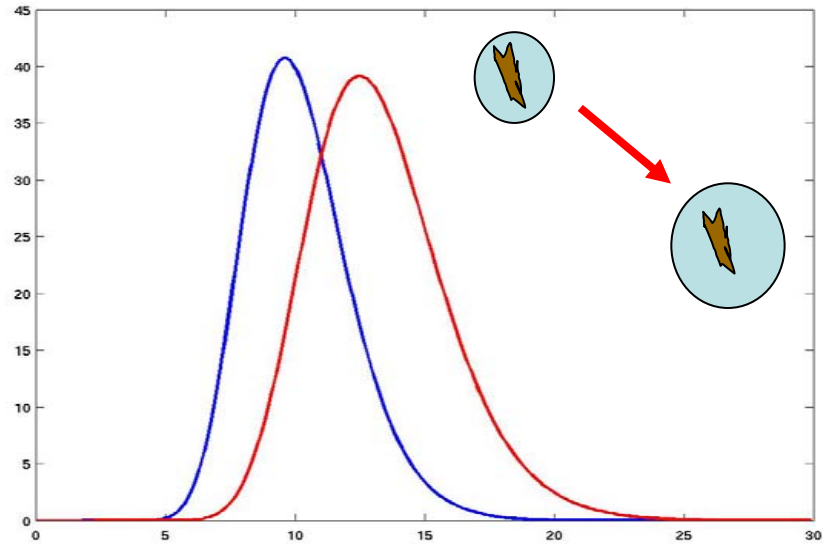
k and C depend on their environment (maritime, rural, urban)

2a-Detailed Condensation/Evaporation : Parameterized Köhler relation

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

2b-Time dependent relation between Supersaturation S and Diameter D

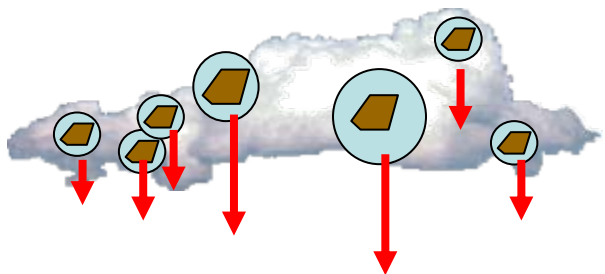
$$\frac{dD}{dt} = A\frac{S}{D}$$



3-Droplet size dependent Sedimentation

Positive Definite Advection Scheme

[Bott (1989)]



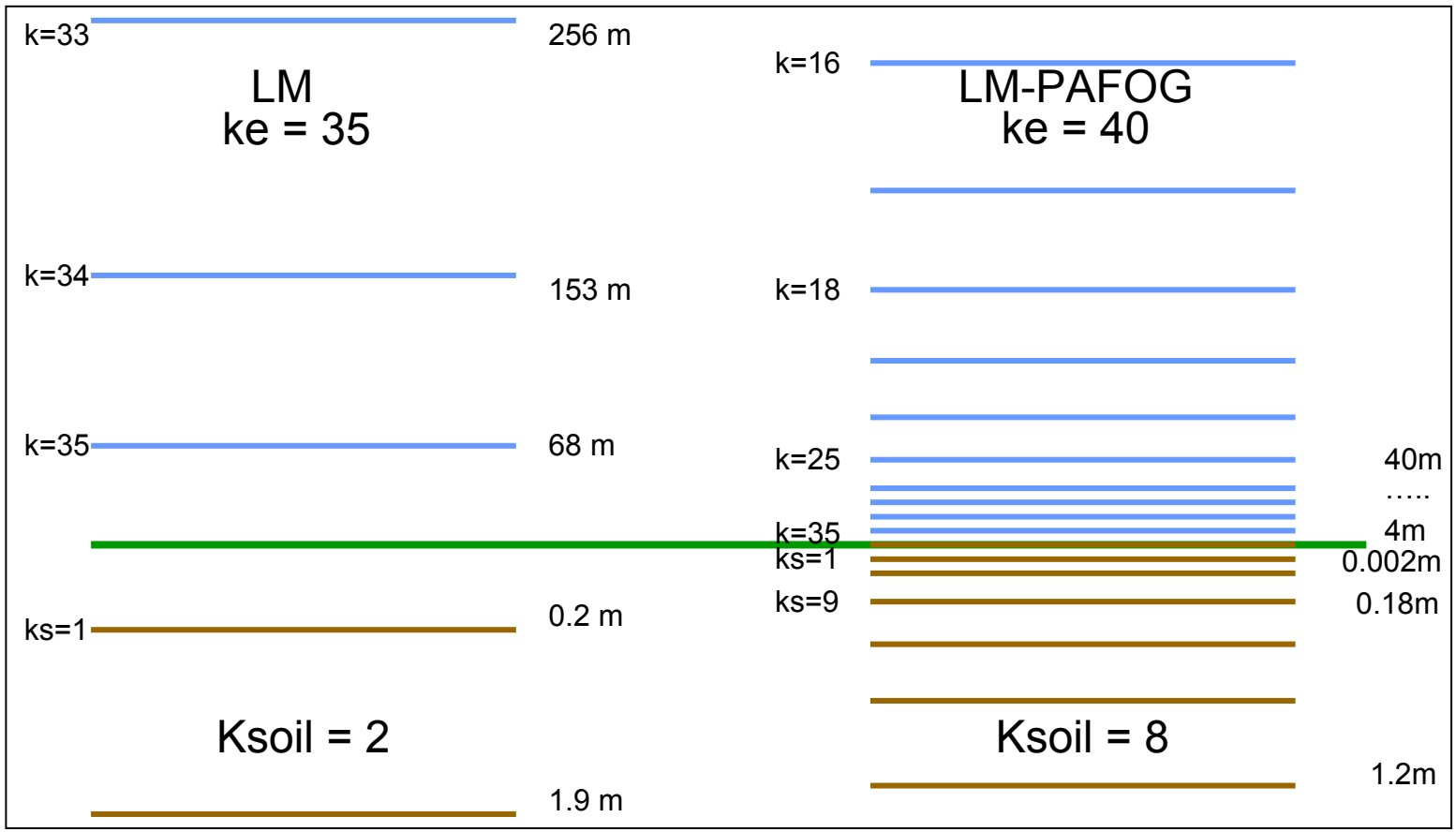
Resolution of LM-PAFOG

Horizontal Resolution : 100 x 100 pixels Δxy = 2.8 km

Vertical Resolution : Atmosphere – 40 levels Δz_{min} = 4m

25 levels in the lowest 2 000 m

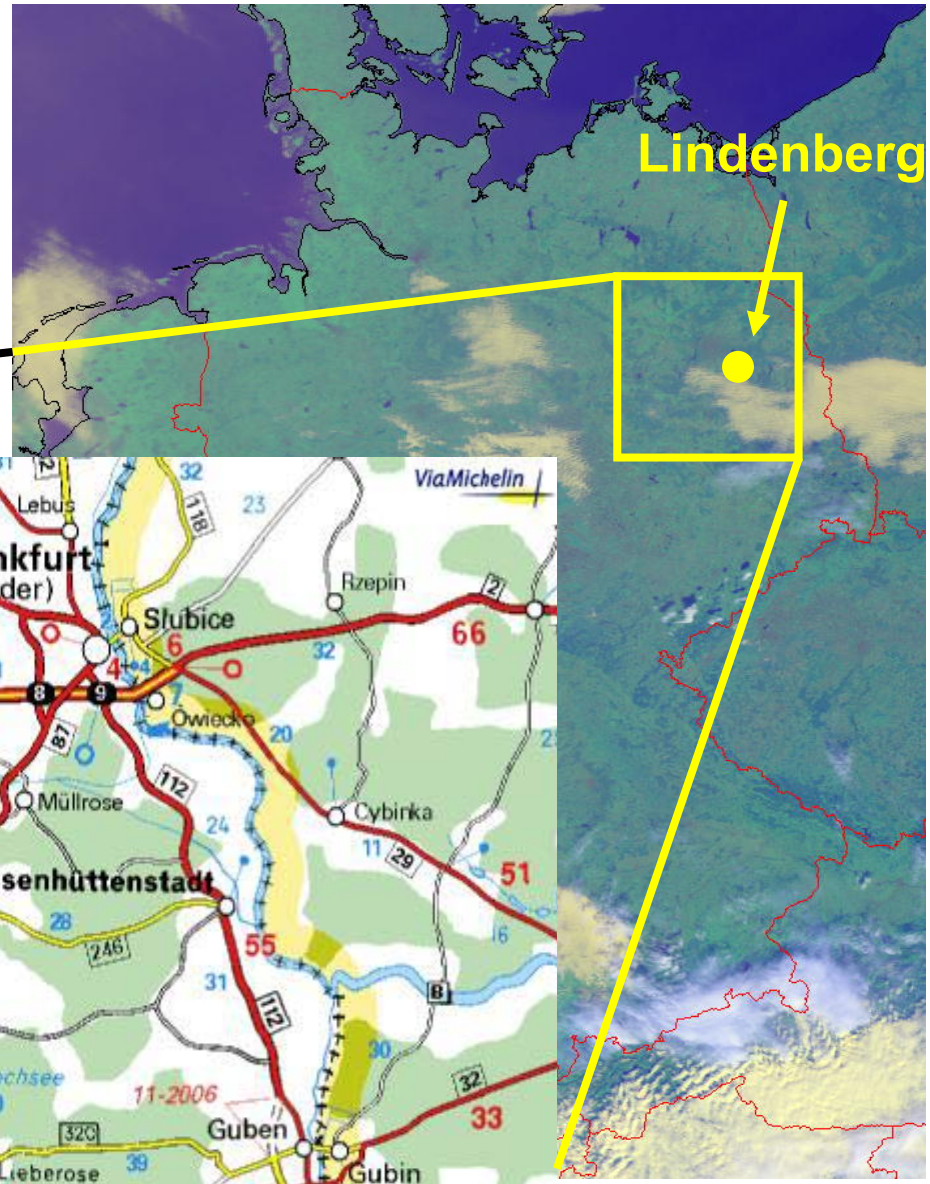
Soil - 8 levels $\Delta z_{s,min}$ = 5 mm



Simulation on Lindenberg Area

Observatory of Lindenberg (MOL)

52°12’31’’ N
14°07’05’’ E



Available Measurements

Each 6 hours:

-Radiosounding: P, T, RH, WD, WS

Each hour:

-Visibility and Cloud Coverage (done by meteorologist)

-Visibility (automatic Station)

Each 10 min.:

-Fluxes : Sensible, Latent, In & Out SW, In & Out LW

-10m Mast: T & RH measurement at 0.5, 1, 2, 4, 10m, WS & WD at 10m

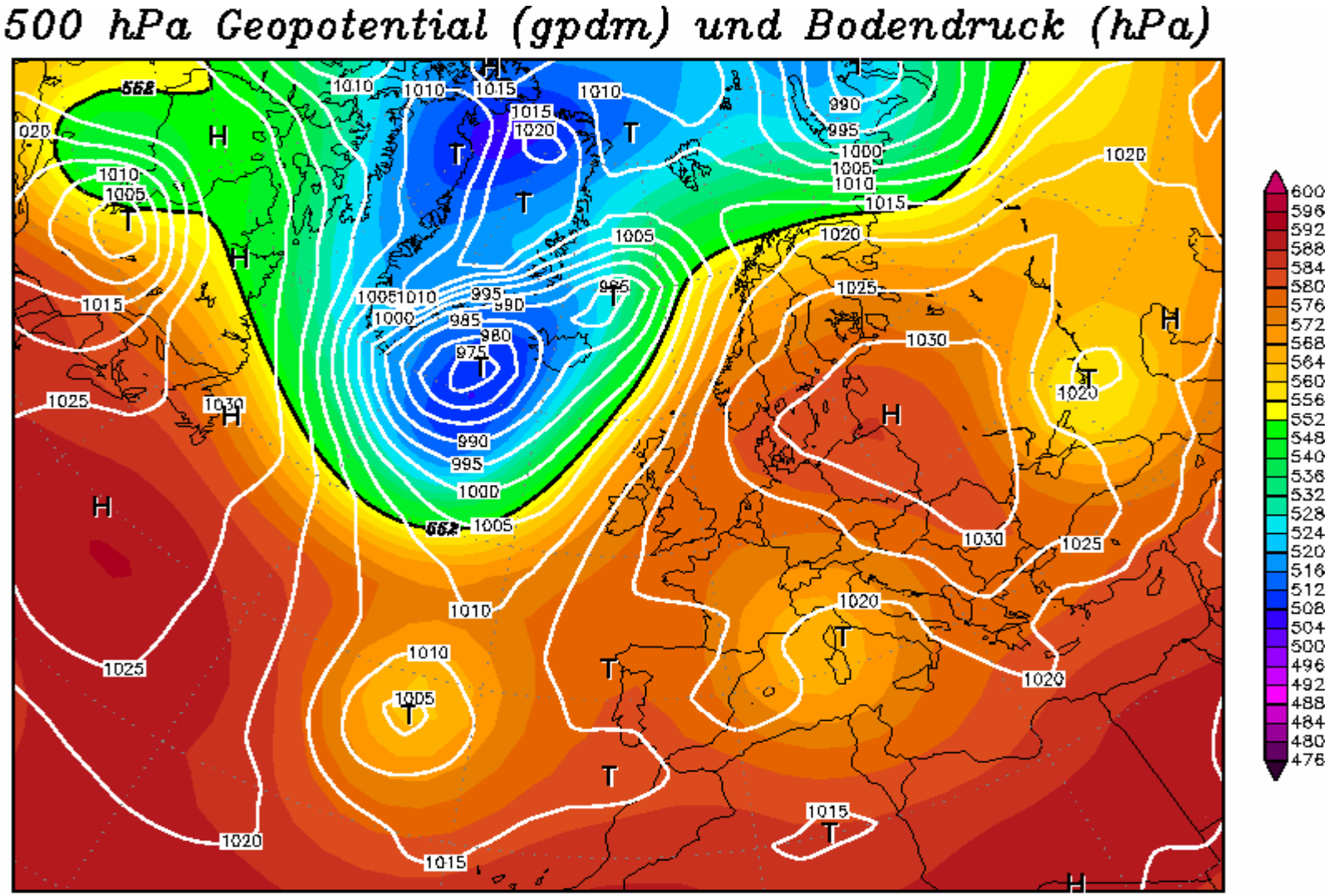
-100m Mast: T & RH measurement 10, 20, 40, 60, 80, 98m, WS & WD at 40, 98m

-Soil heat Fluxes at 0.5 and 1m deep

-Soil Moisture at 8, 15, 30, 45, 60, 90 cm

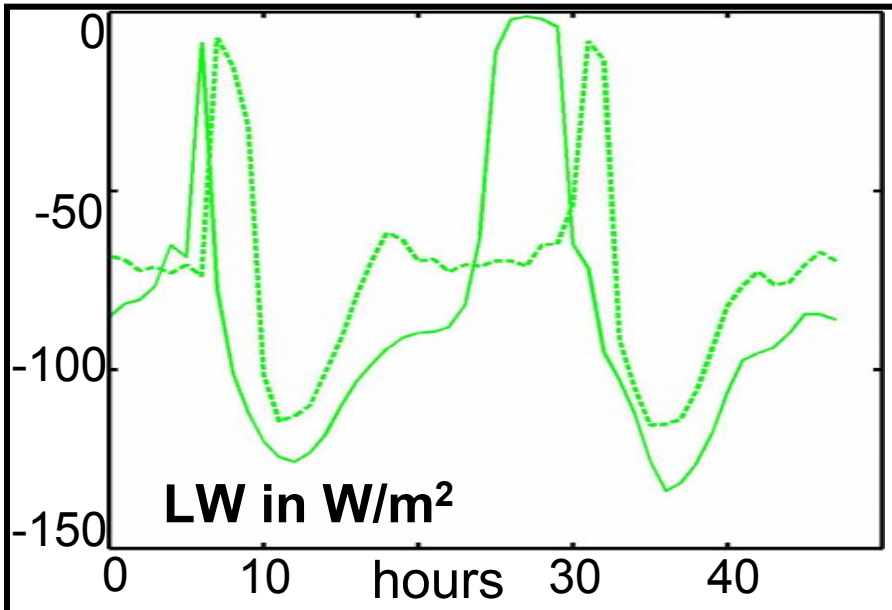
-Soil Temperature at 5, 10, 15, 20, 30, 45, 50, 60, 90 cm

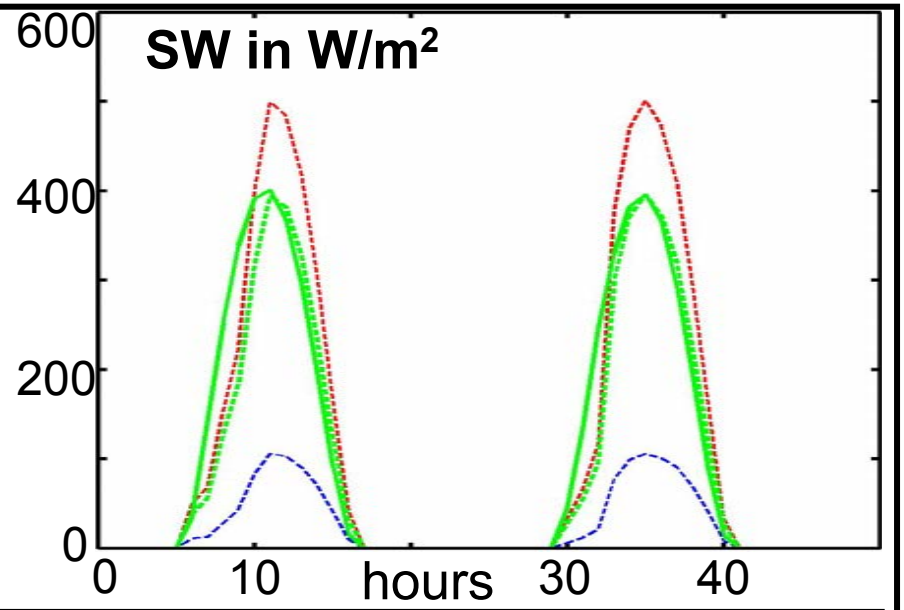
Case Study October 2005, 7th

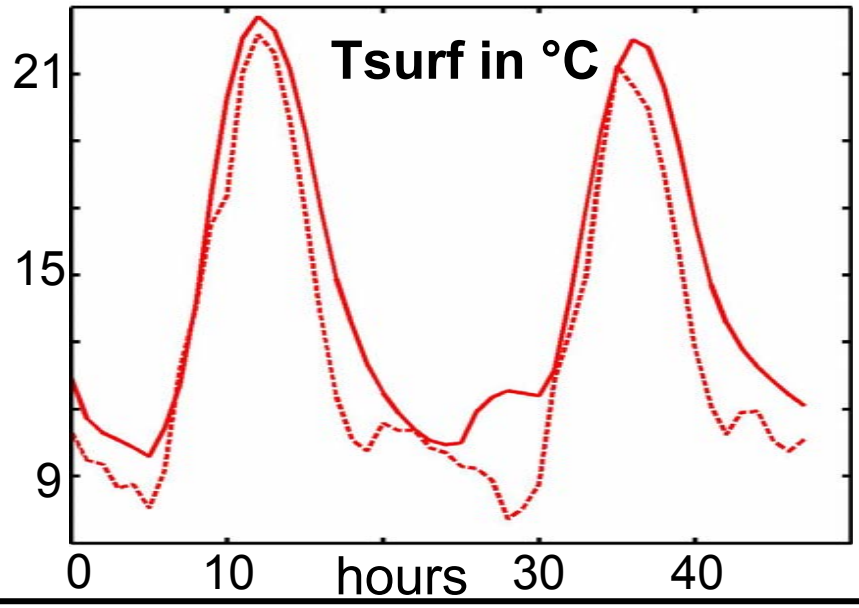


Source: www.wetterzentrale.de

Surface Fluxes





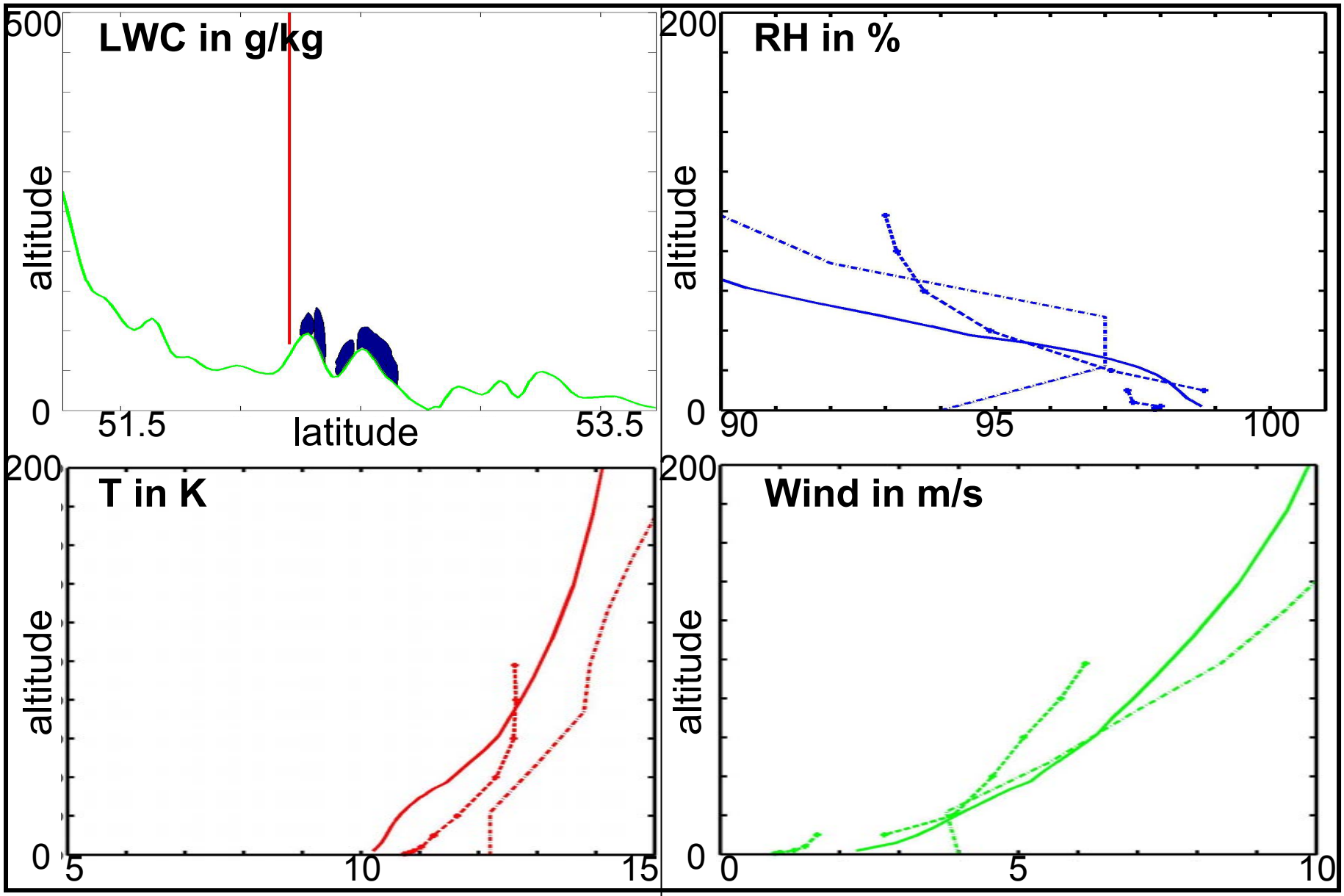


Initialization: 2005 October 6th 00UTC

48 hours forecast

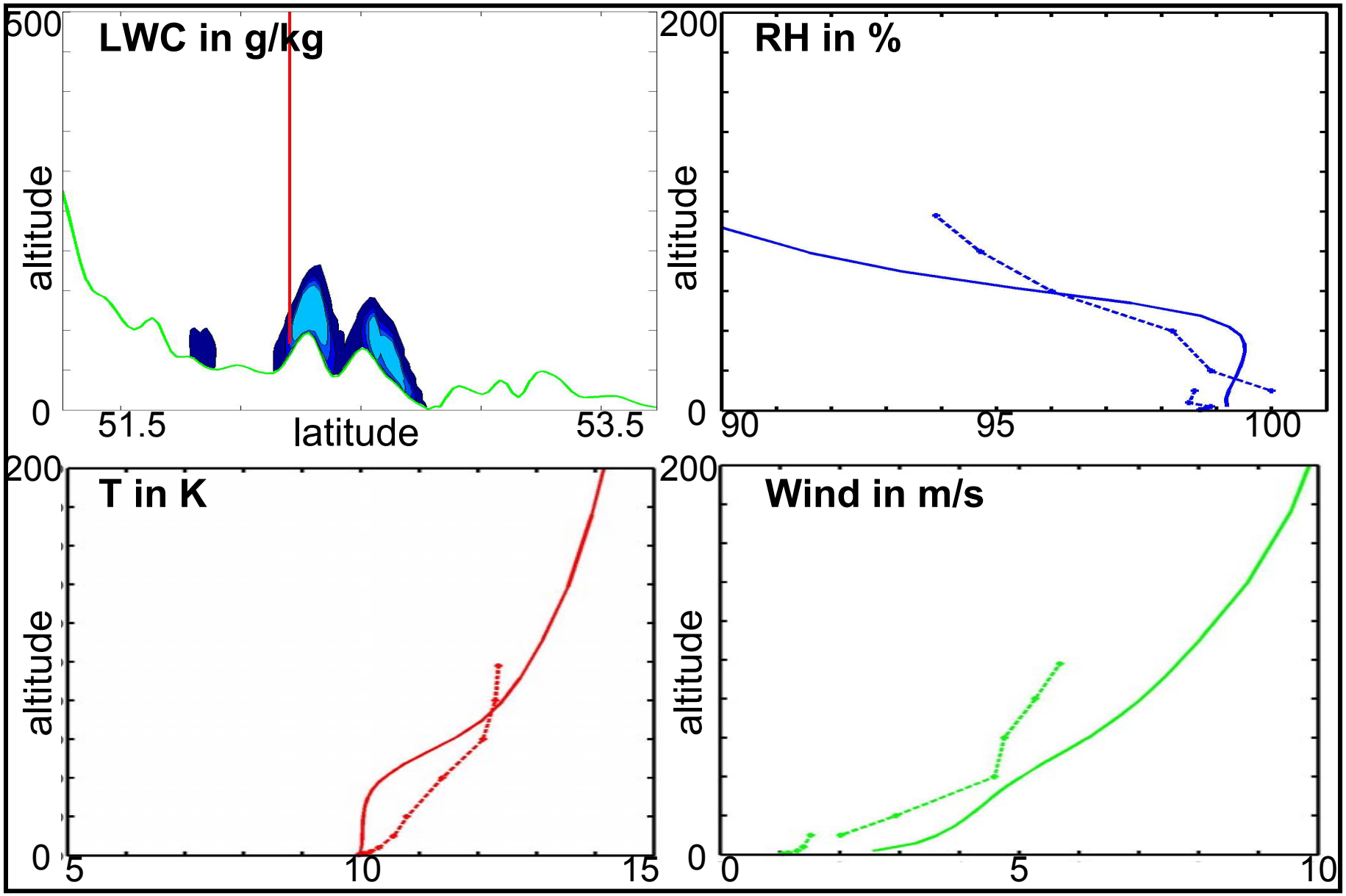
Time Step: 10 sec.

October 2005, 7th 00 UTC



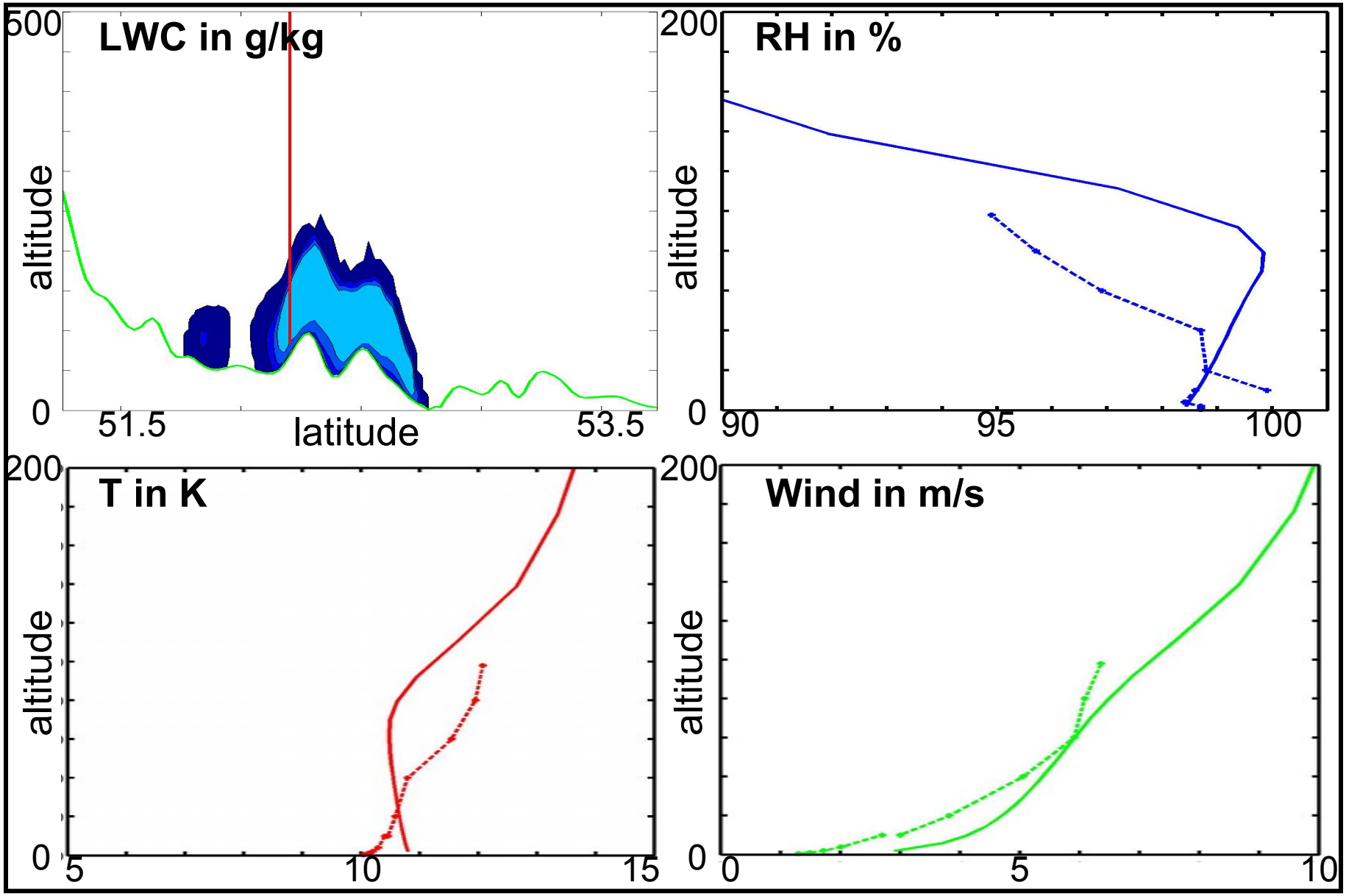
FOG

October 2005, 7th 01 UTC



FOG

October 2005, 7th 02 UTC



FOG

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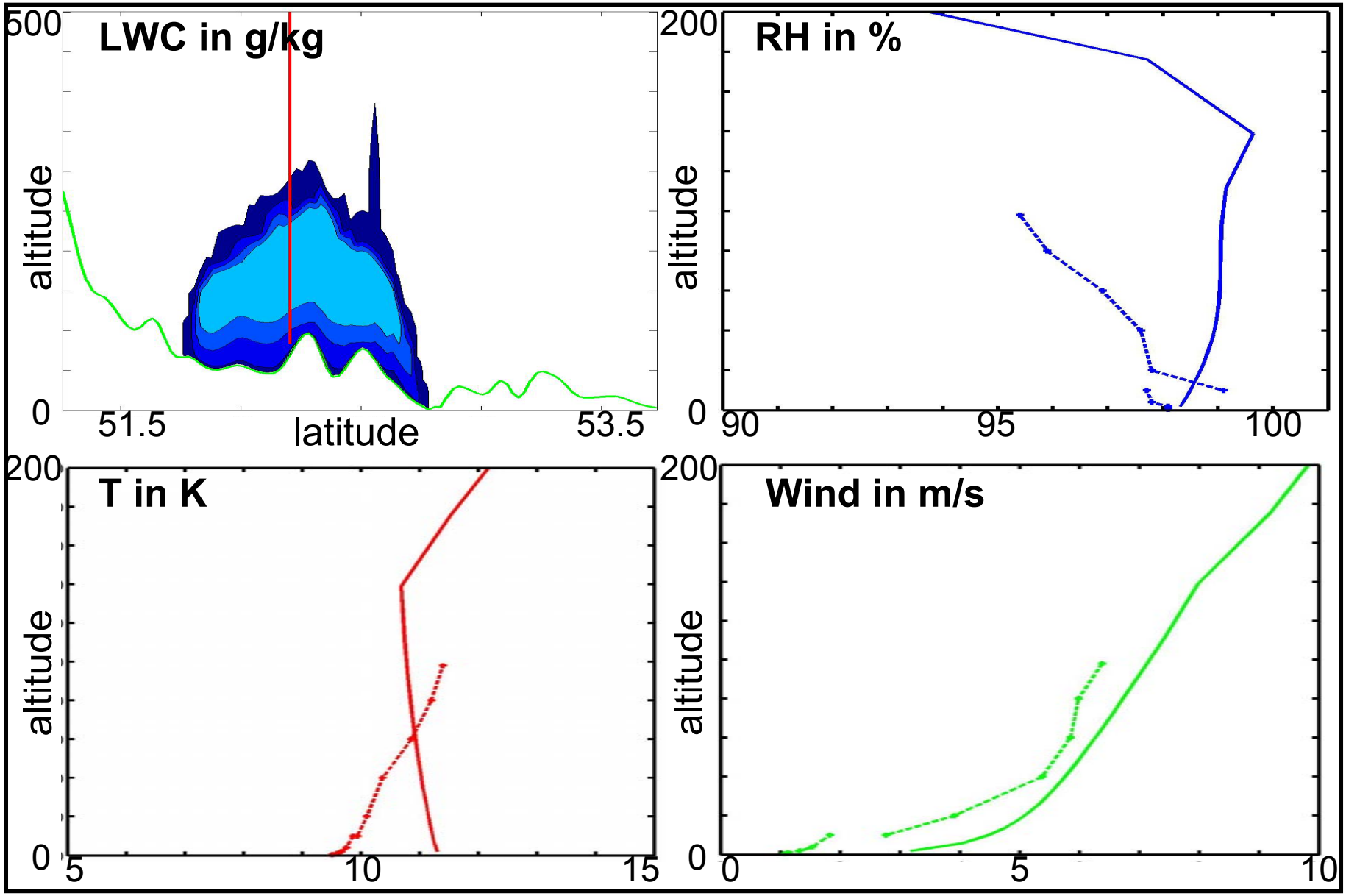

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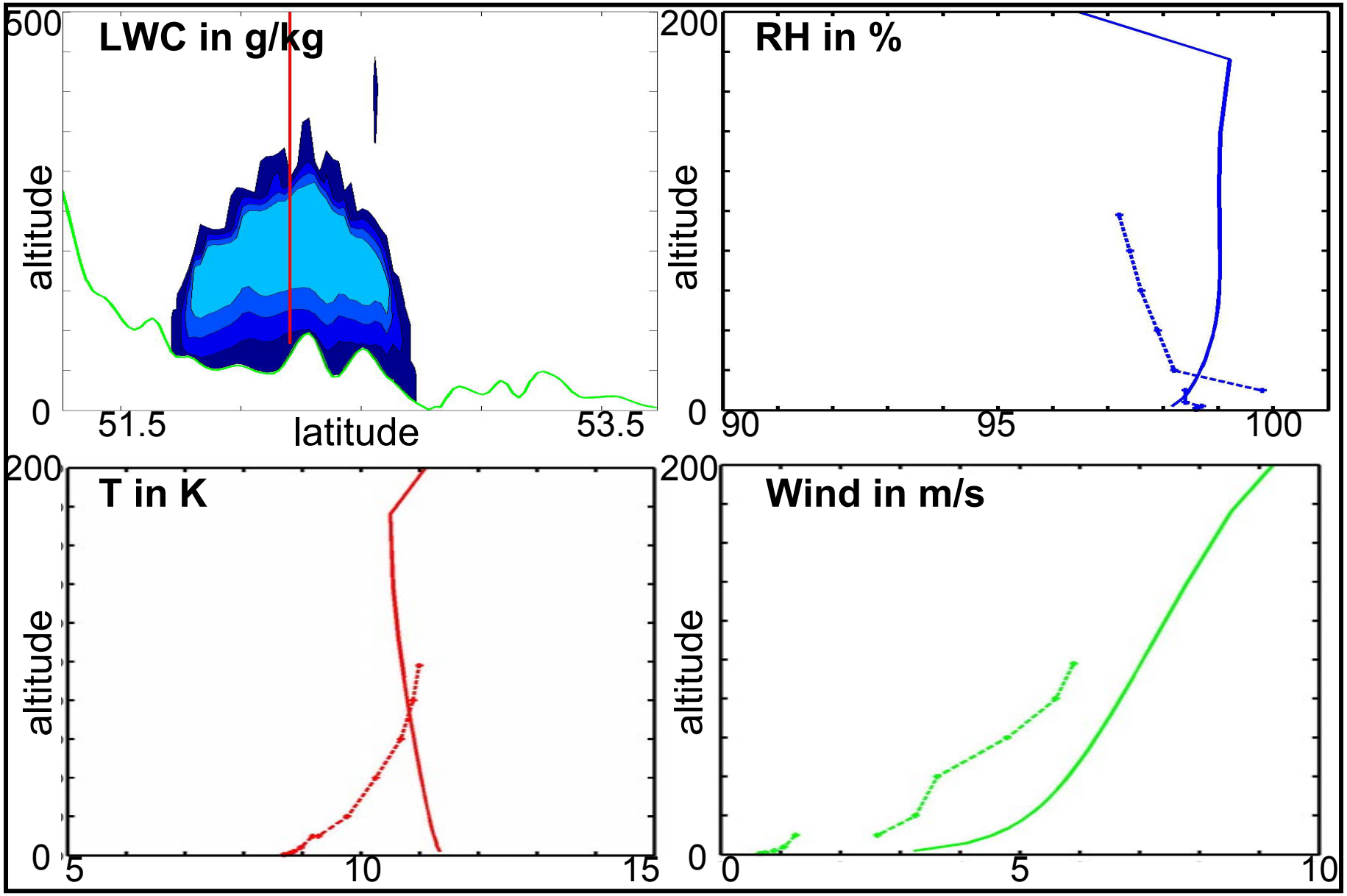

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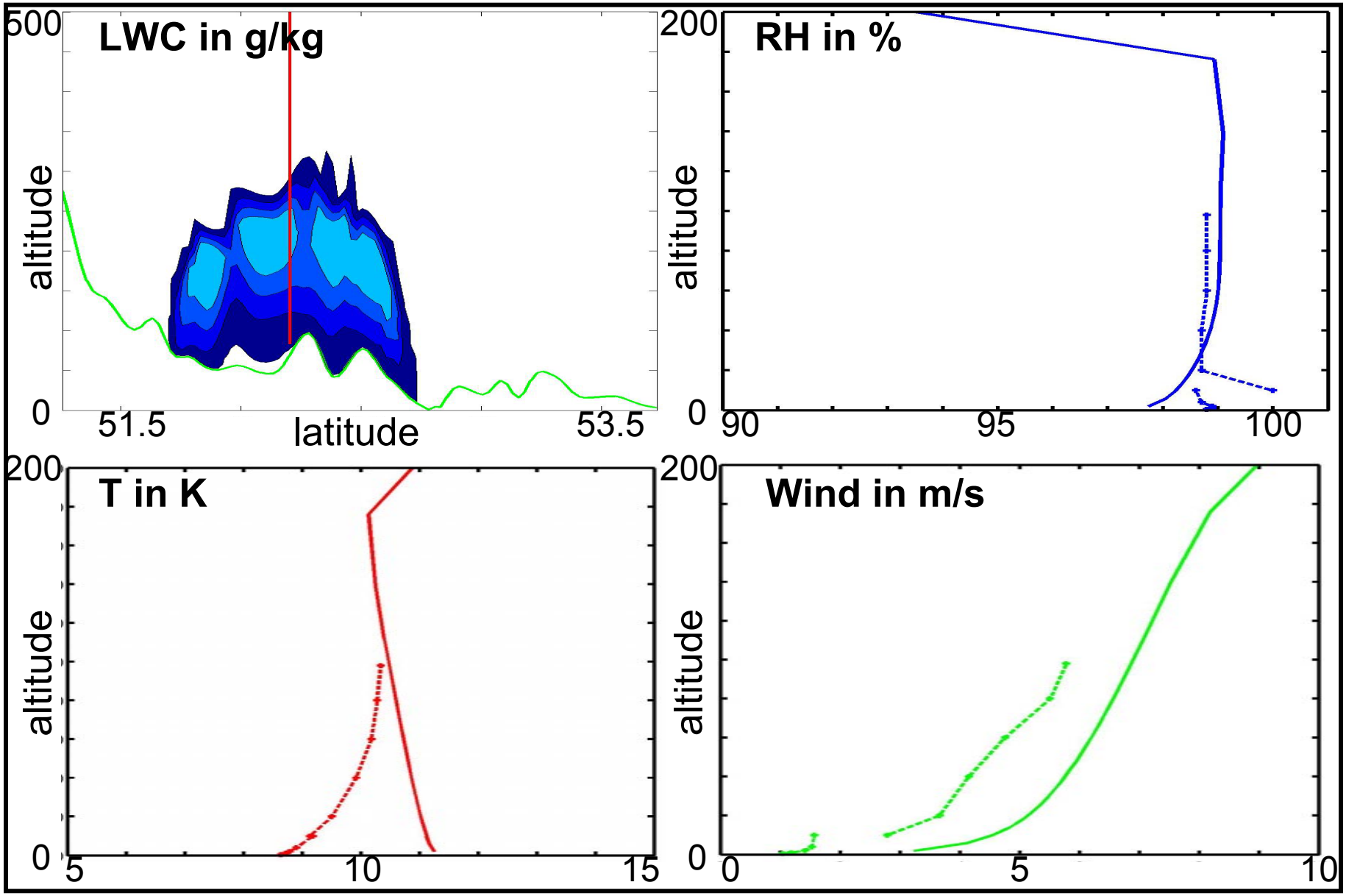
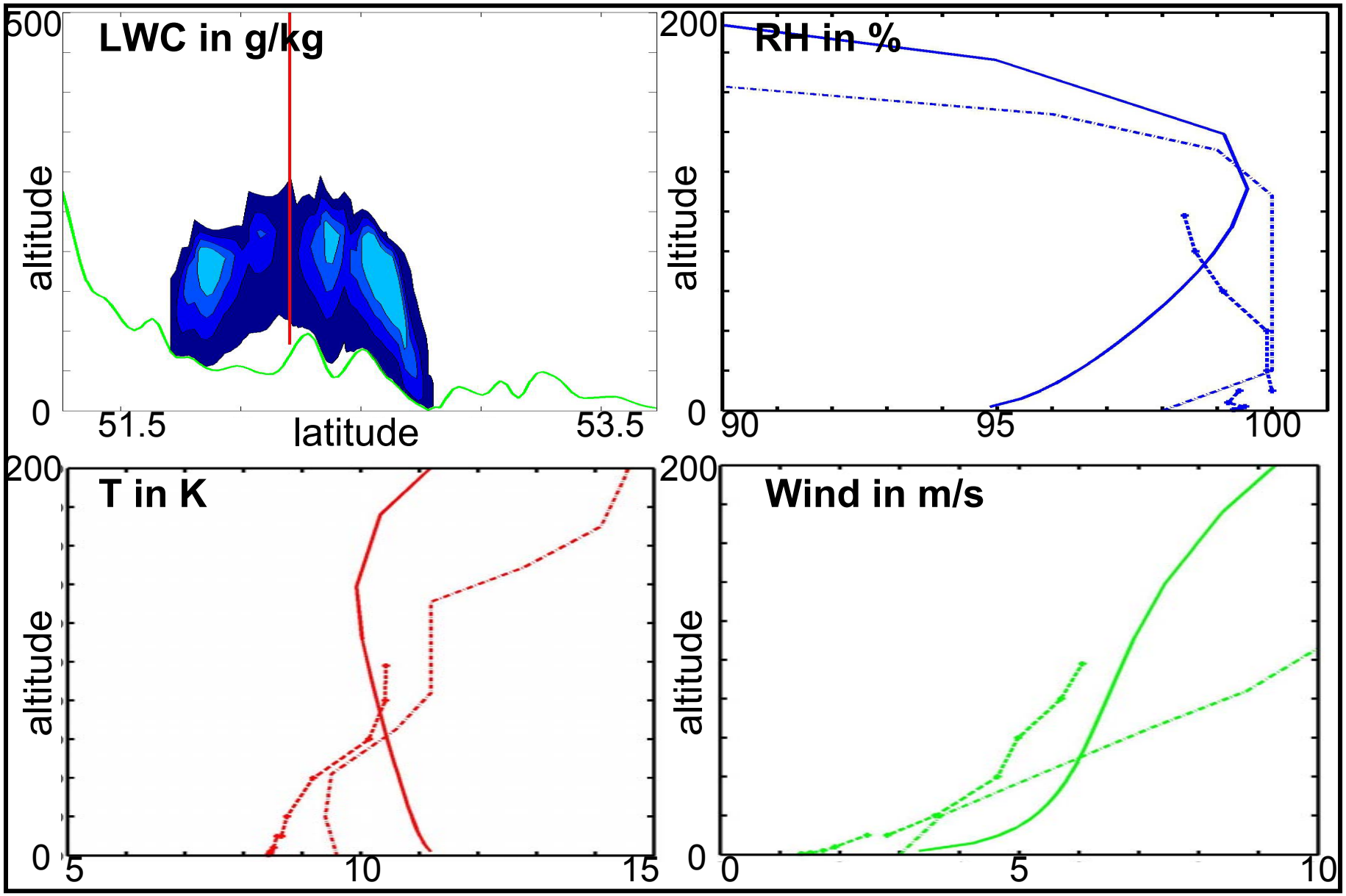


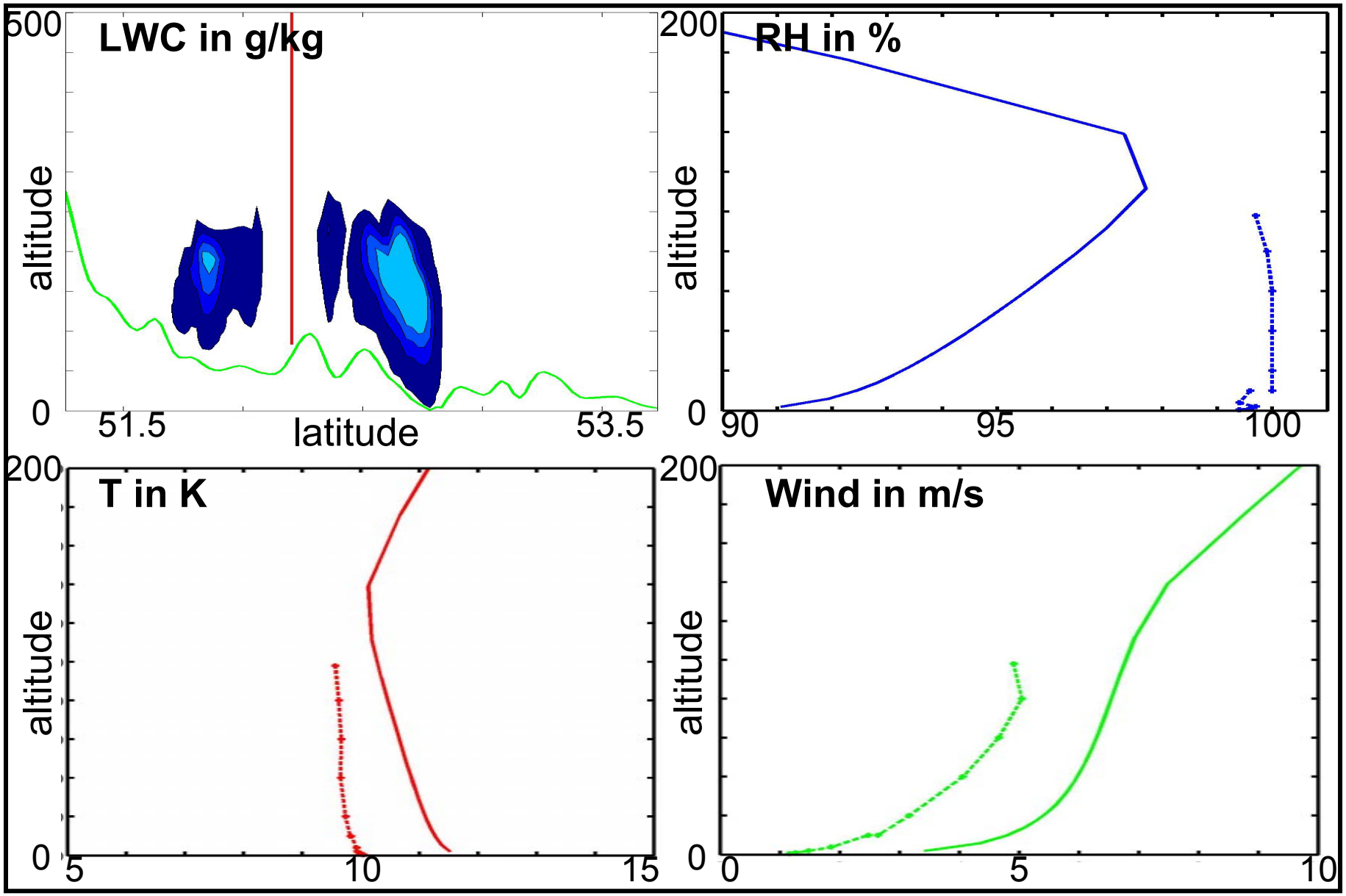
October 2005, 7th 06 UTC

FOG



October 2005, 7th 07 UTC

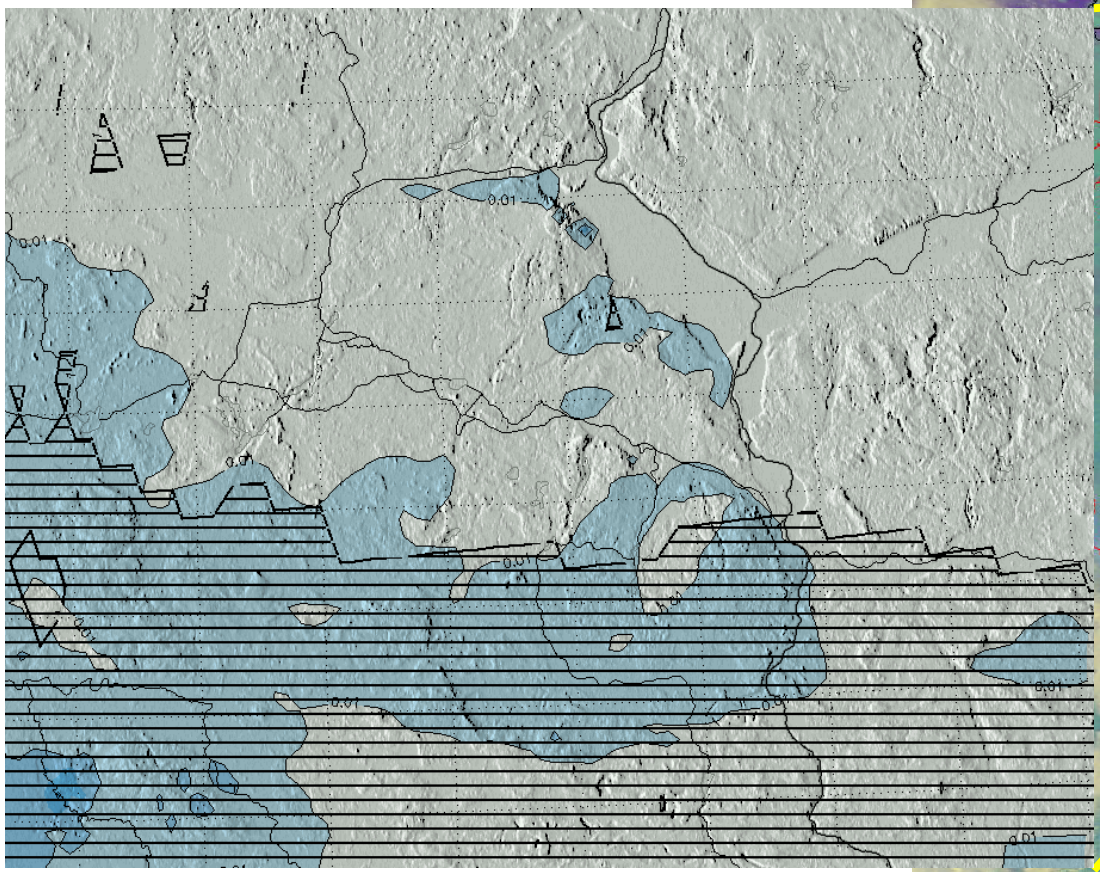
FOG

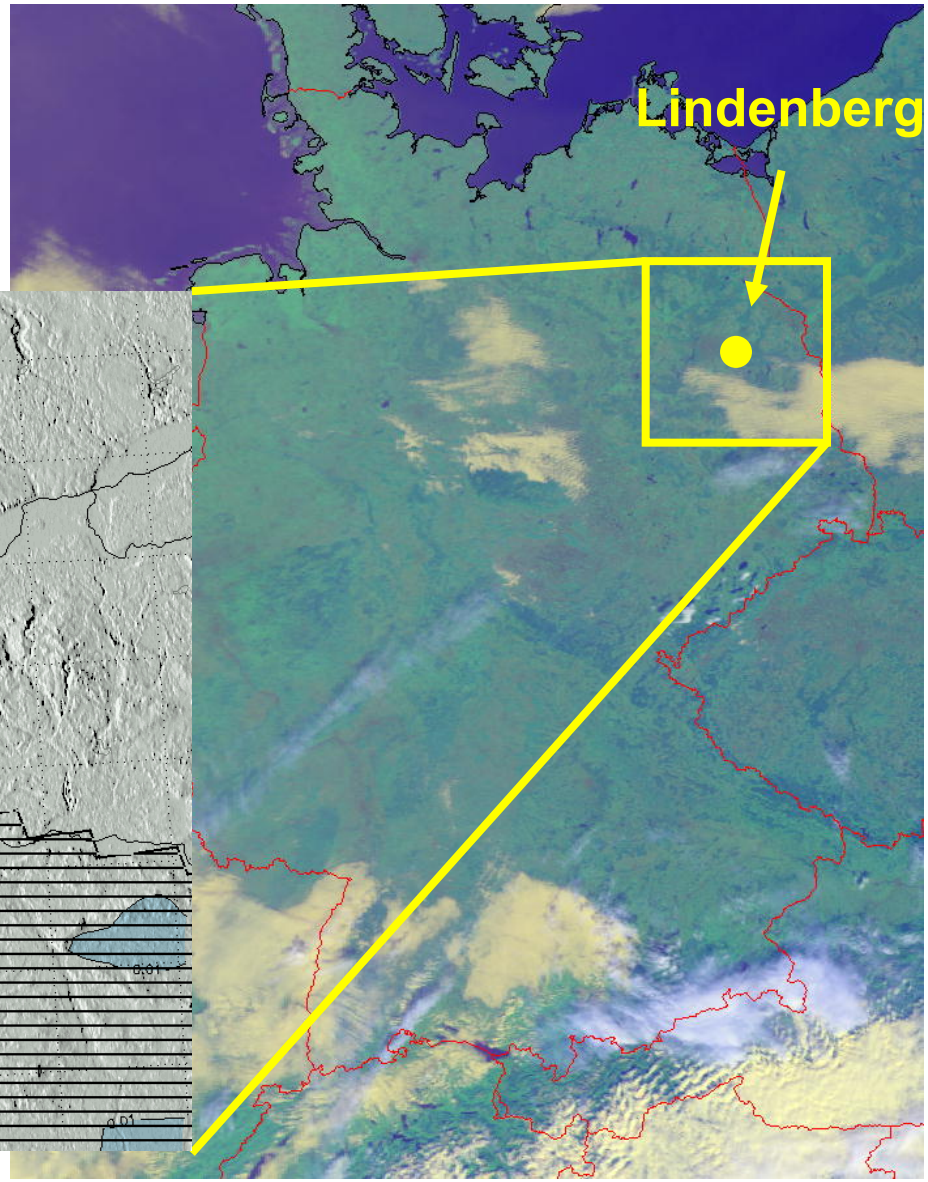


Satellite Verification

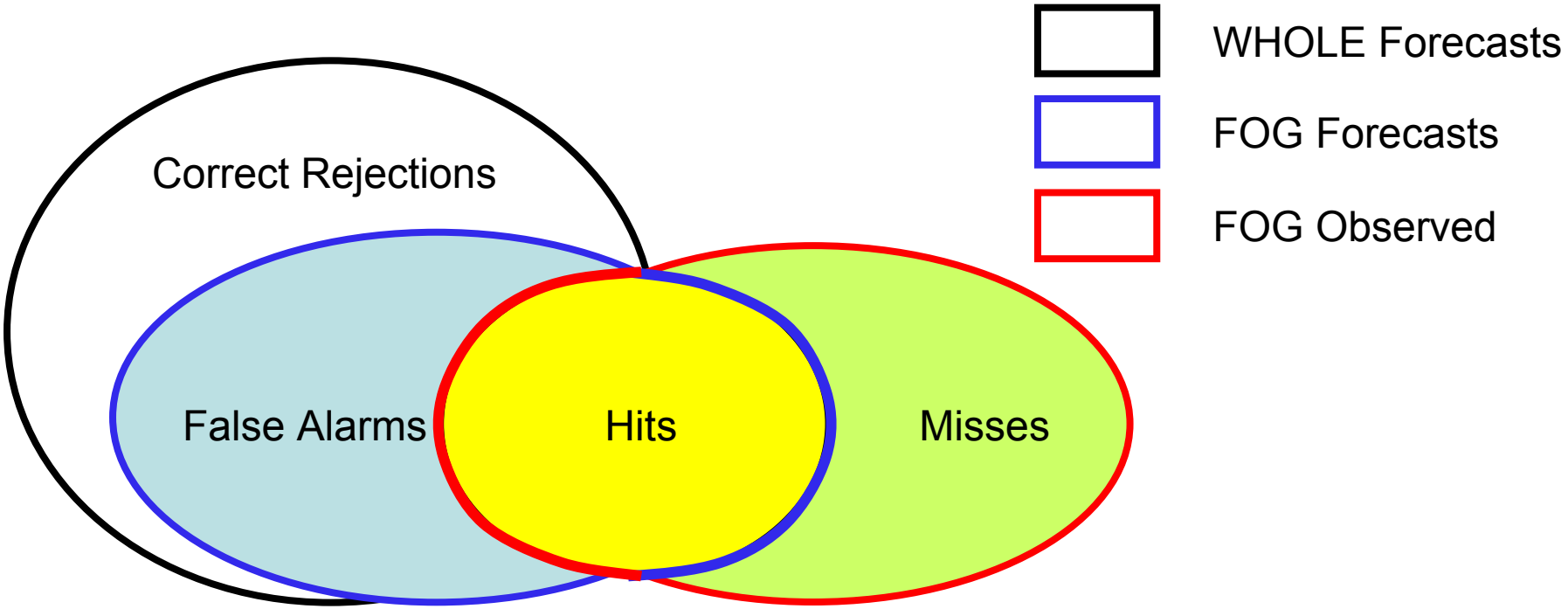
October 2005, 6th

Lindenberg





Observations – LM-PAFOG : How to proceed ?



False Alarm Rate: $$FAR = \frac{false\_alarm}{false\_alarm + correct\_rejection}$$

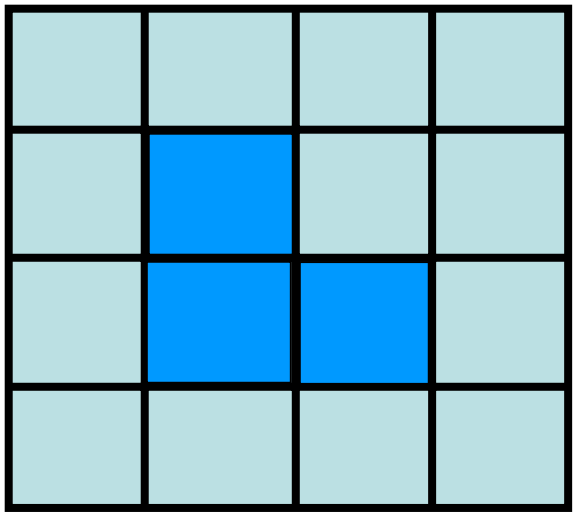
Hit Rate: $$H = \frac{hits}{hits + misses}$$

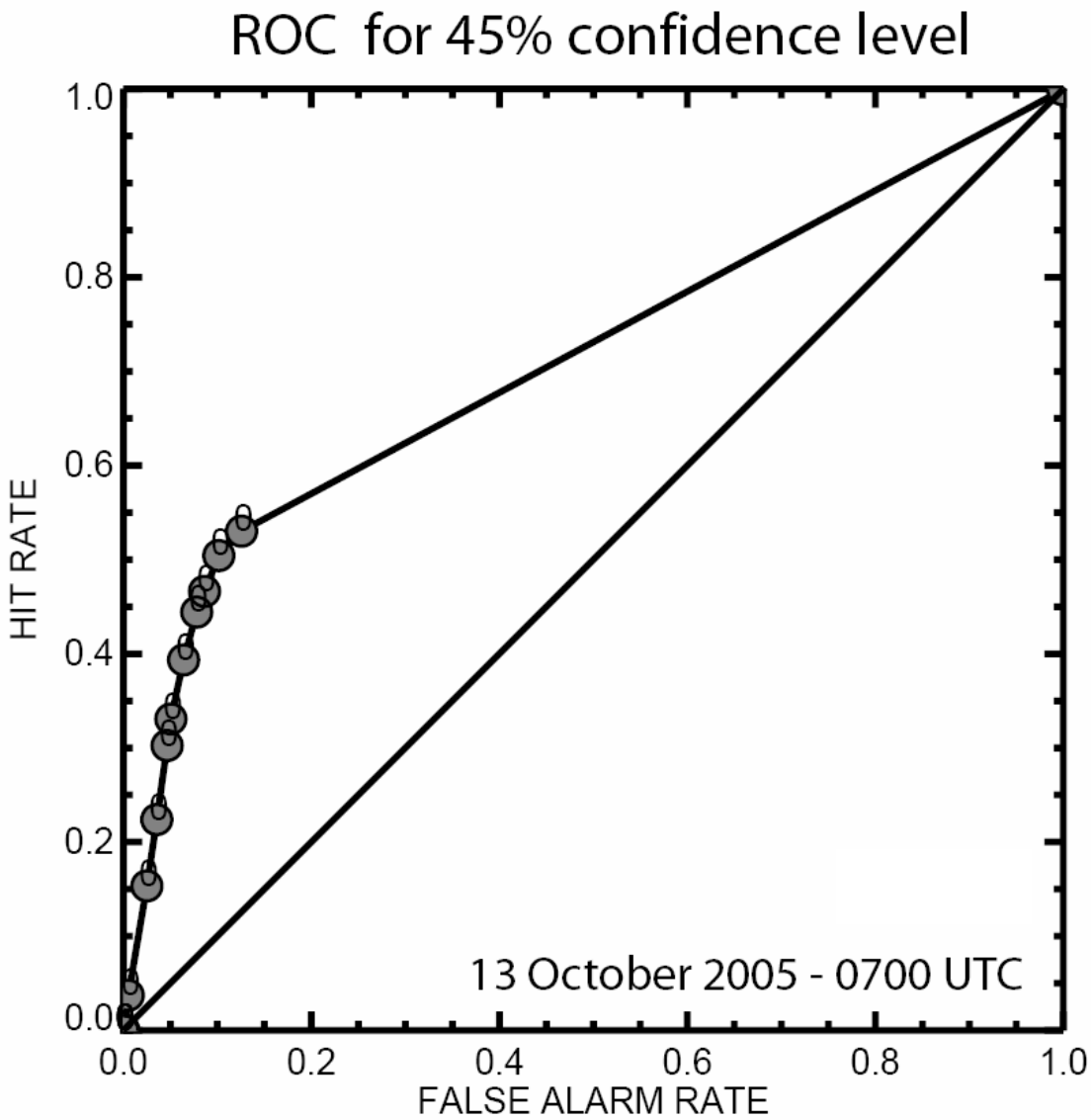
Comparison 3D Models – Satellite Products : How to proceed ?

Interpolation of satellite data to high resolution model grid

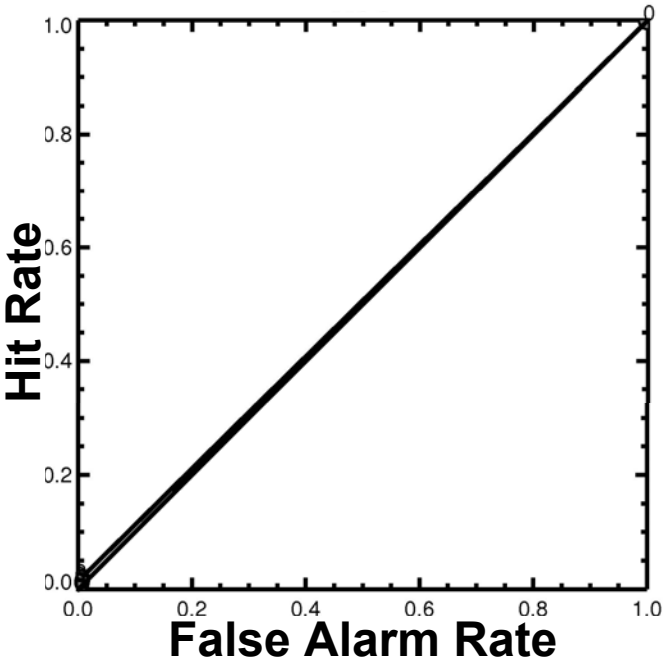
Compute contingency table based on pixel values.

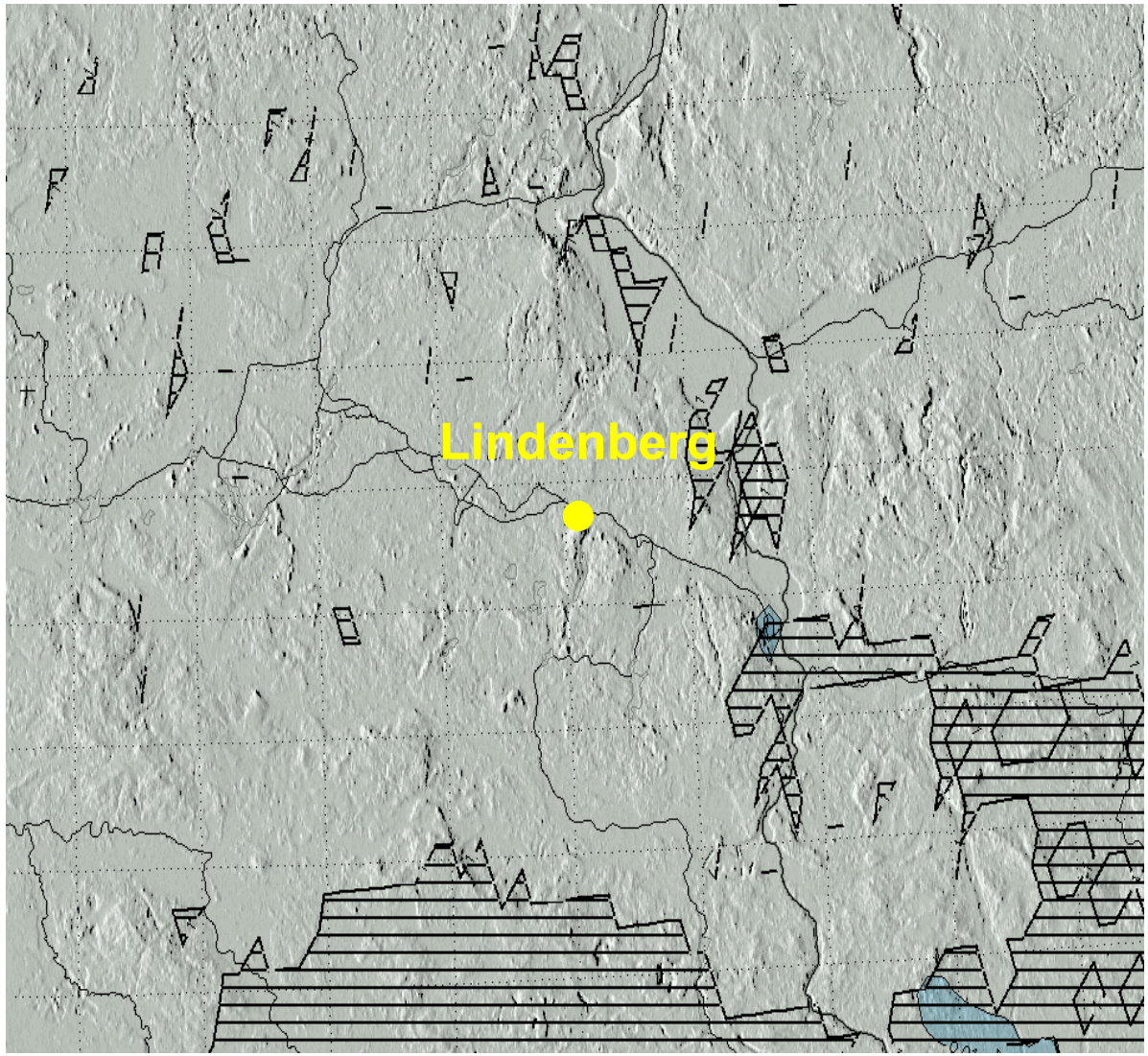
Confidence value threshold of 45 % for fog discrimination





October 2005, 6th 22 UTC





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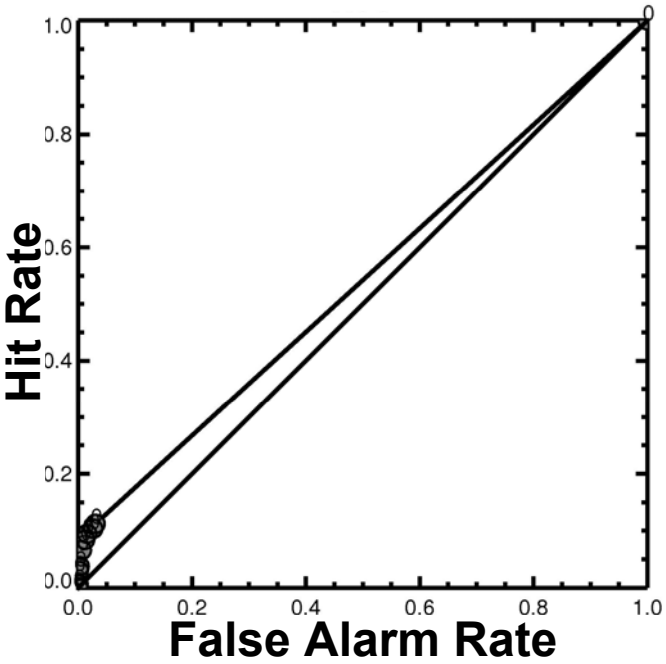

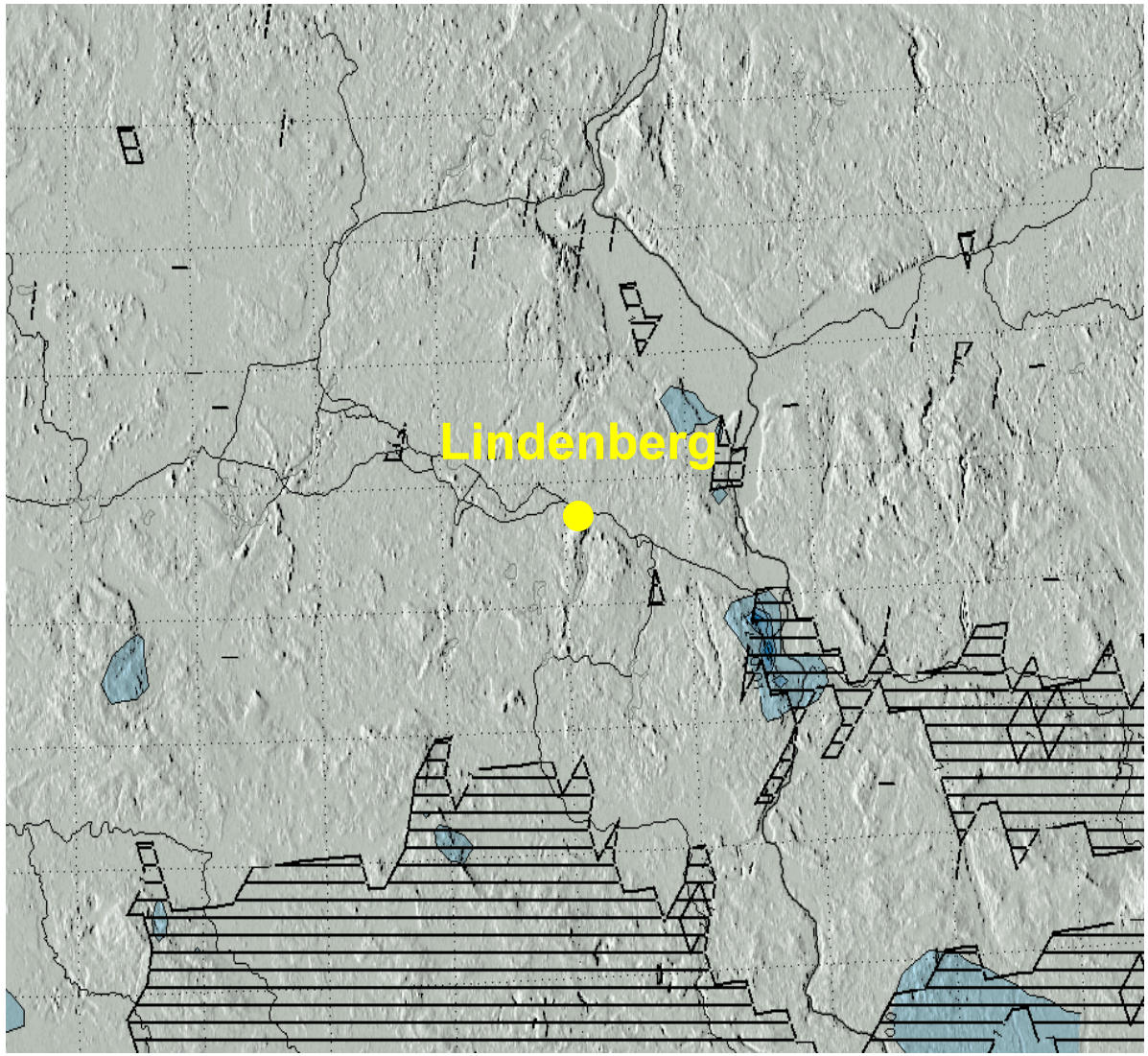

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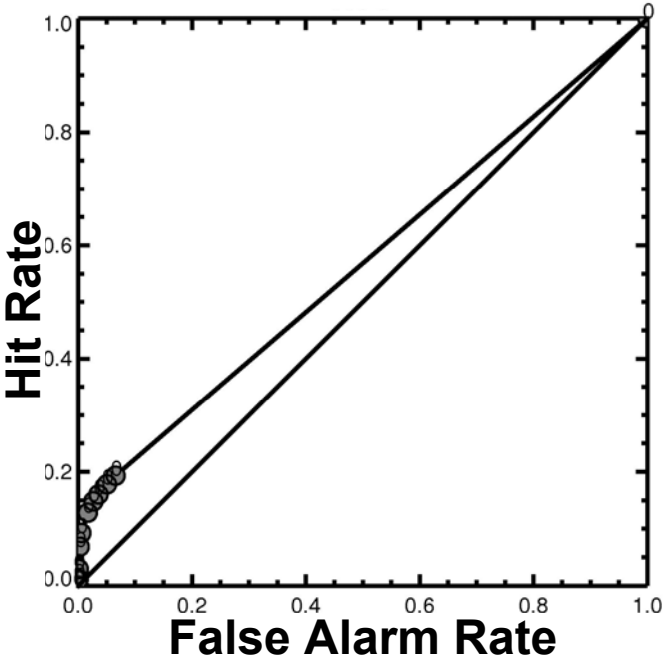

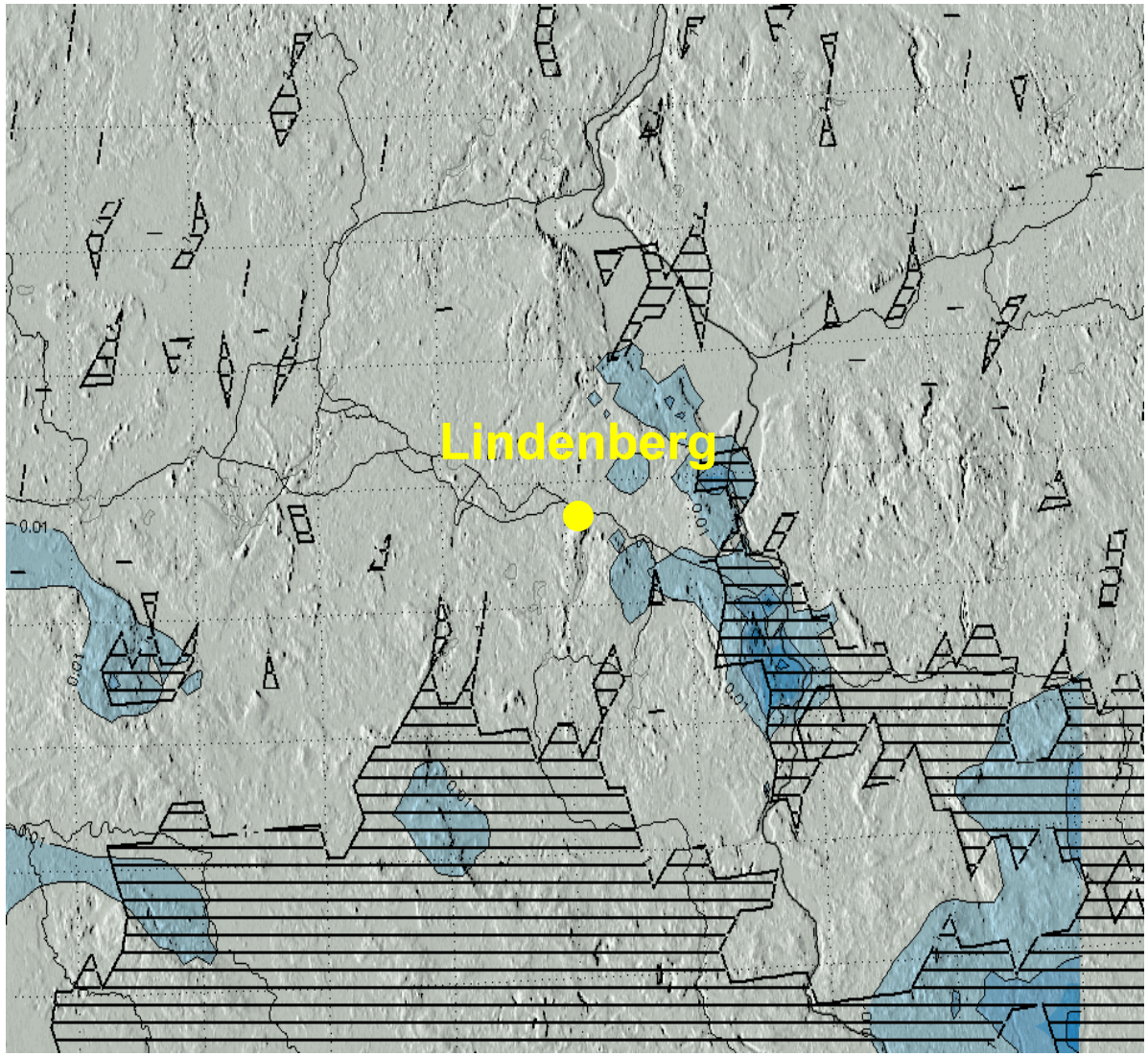

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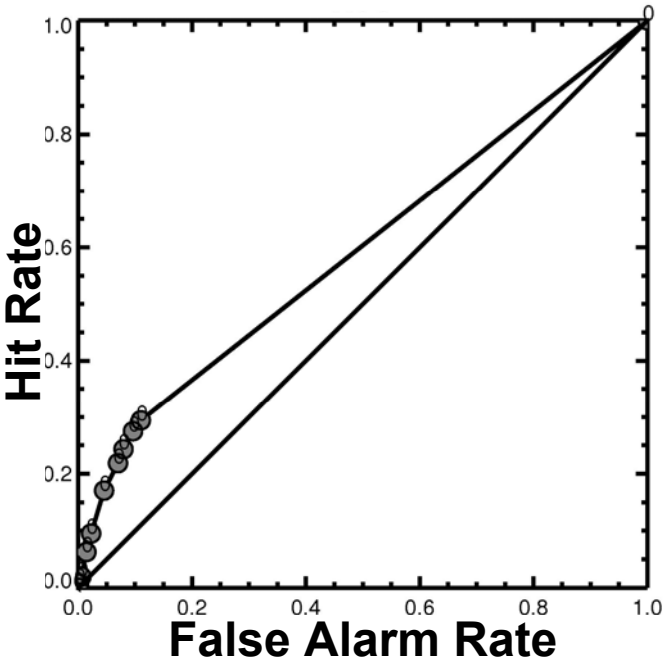

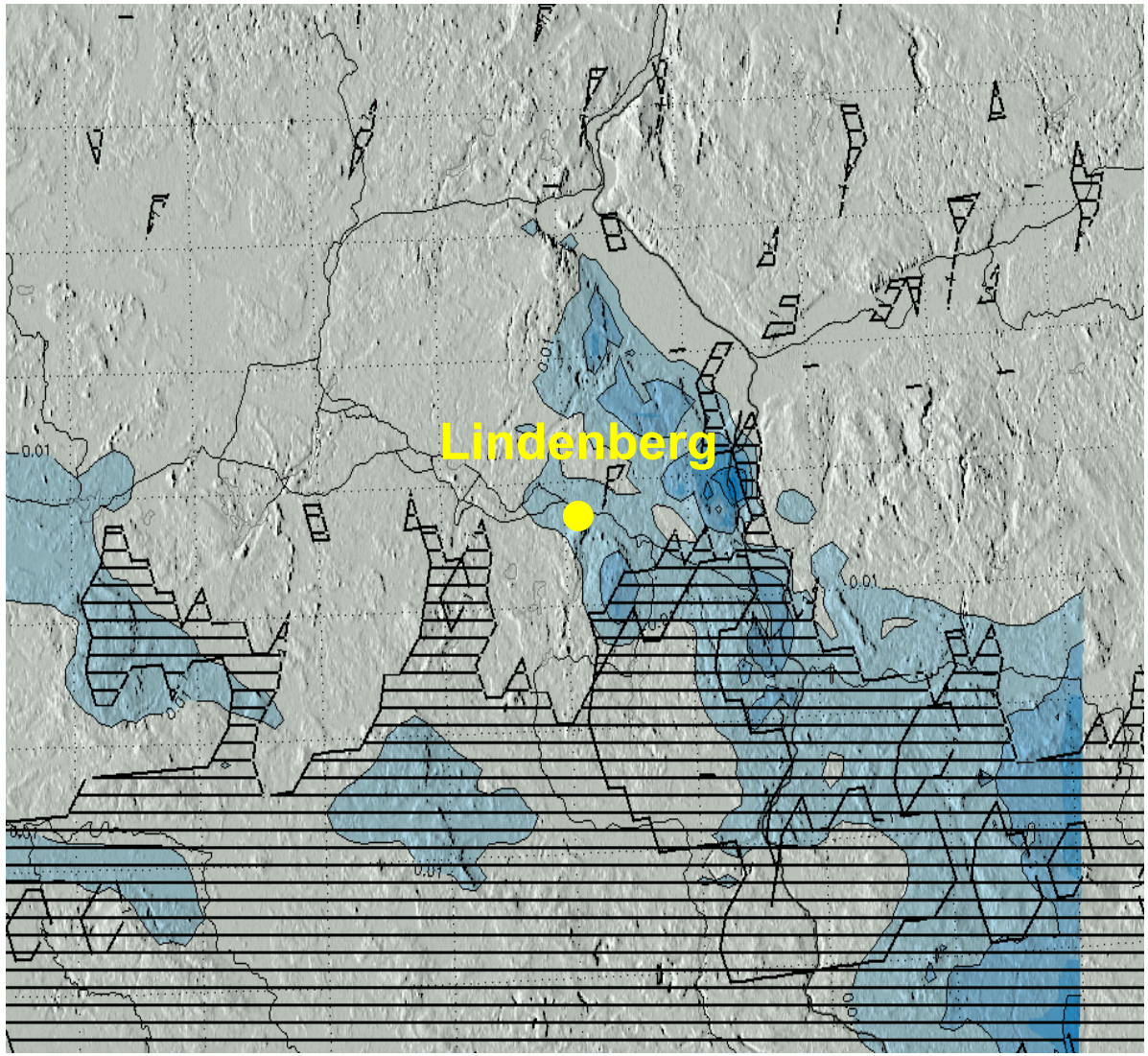

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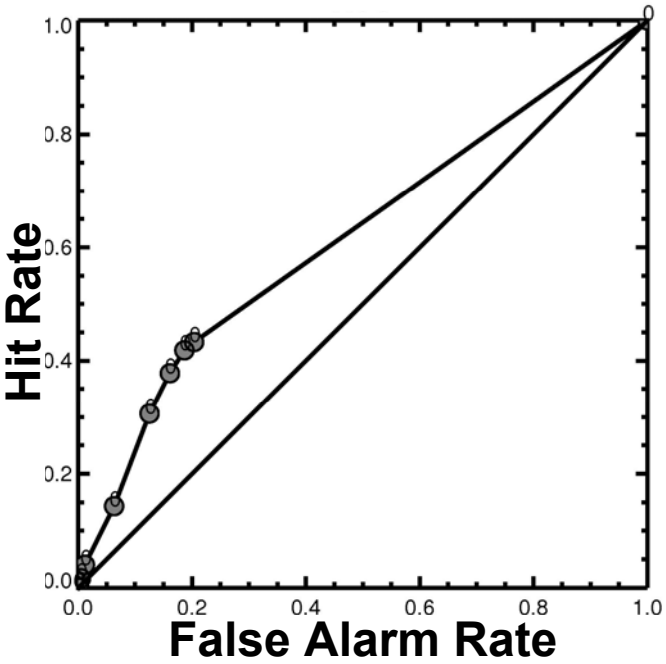

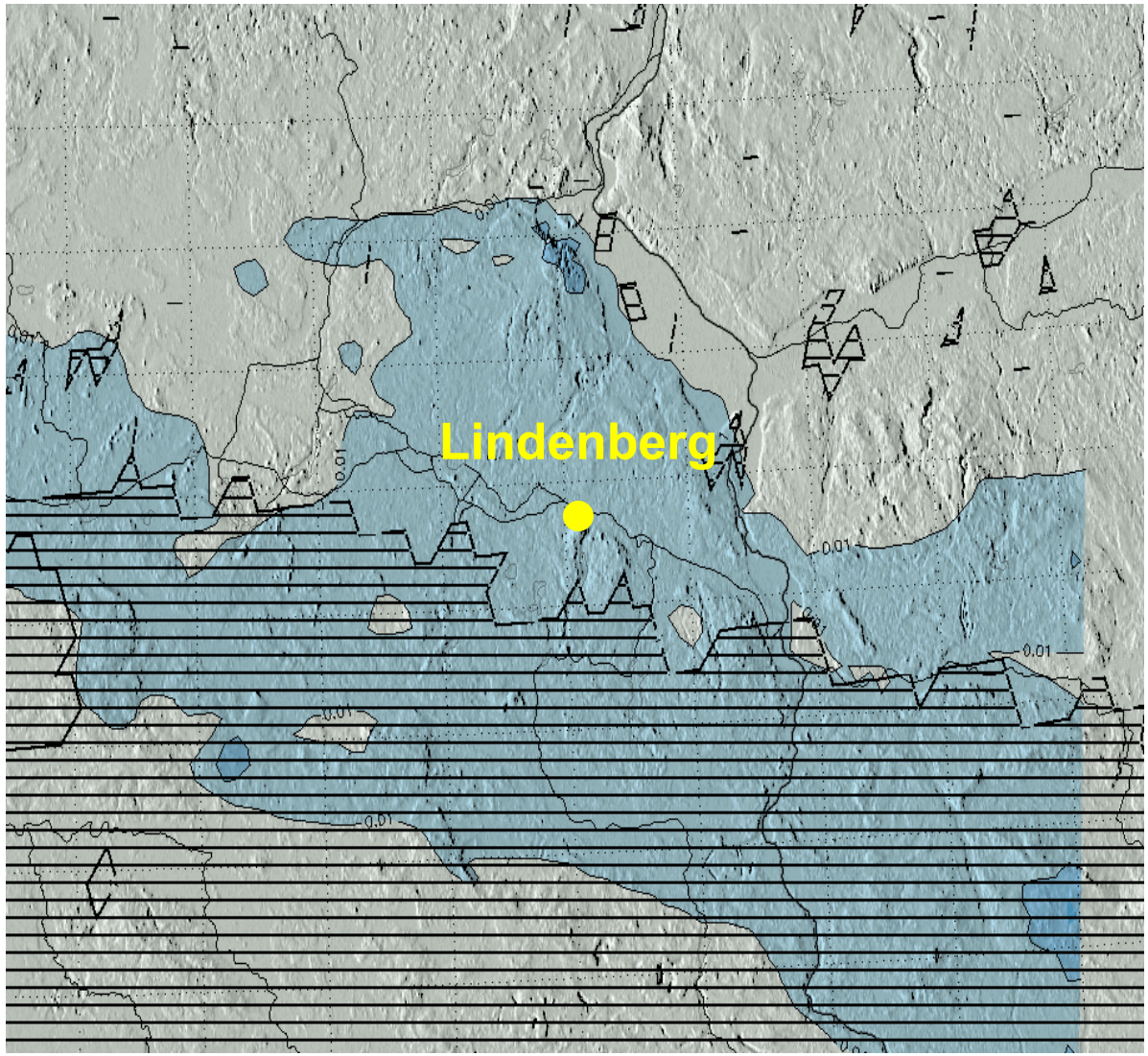

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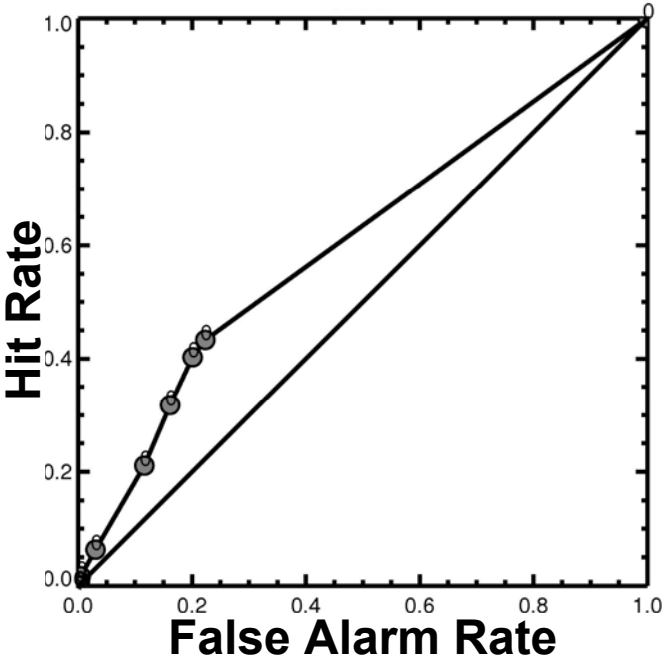

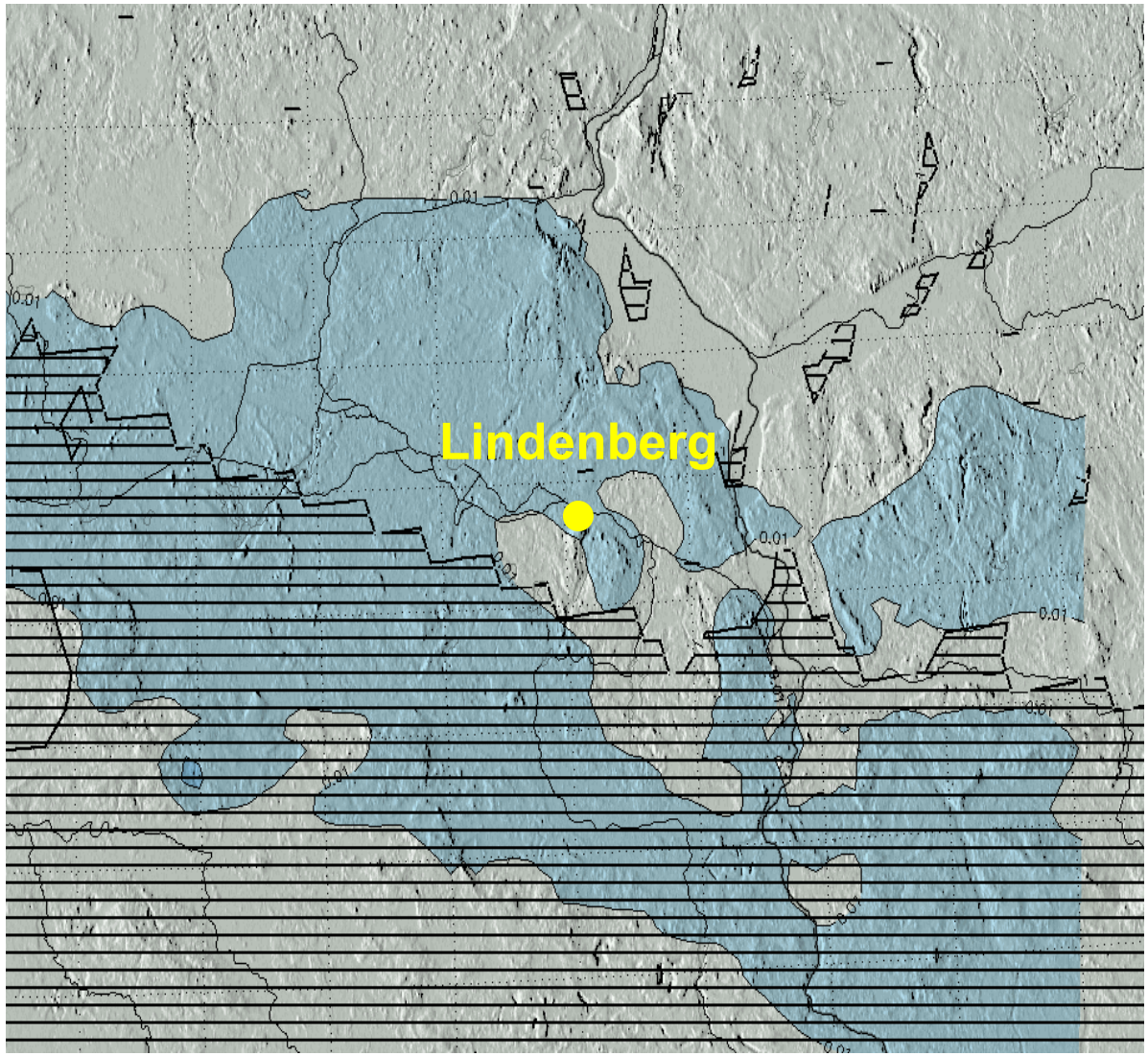

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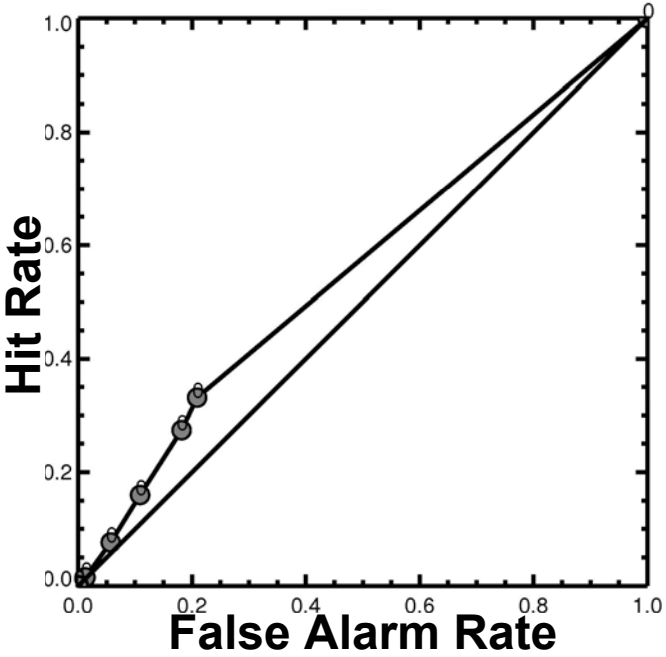

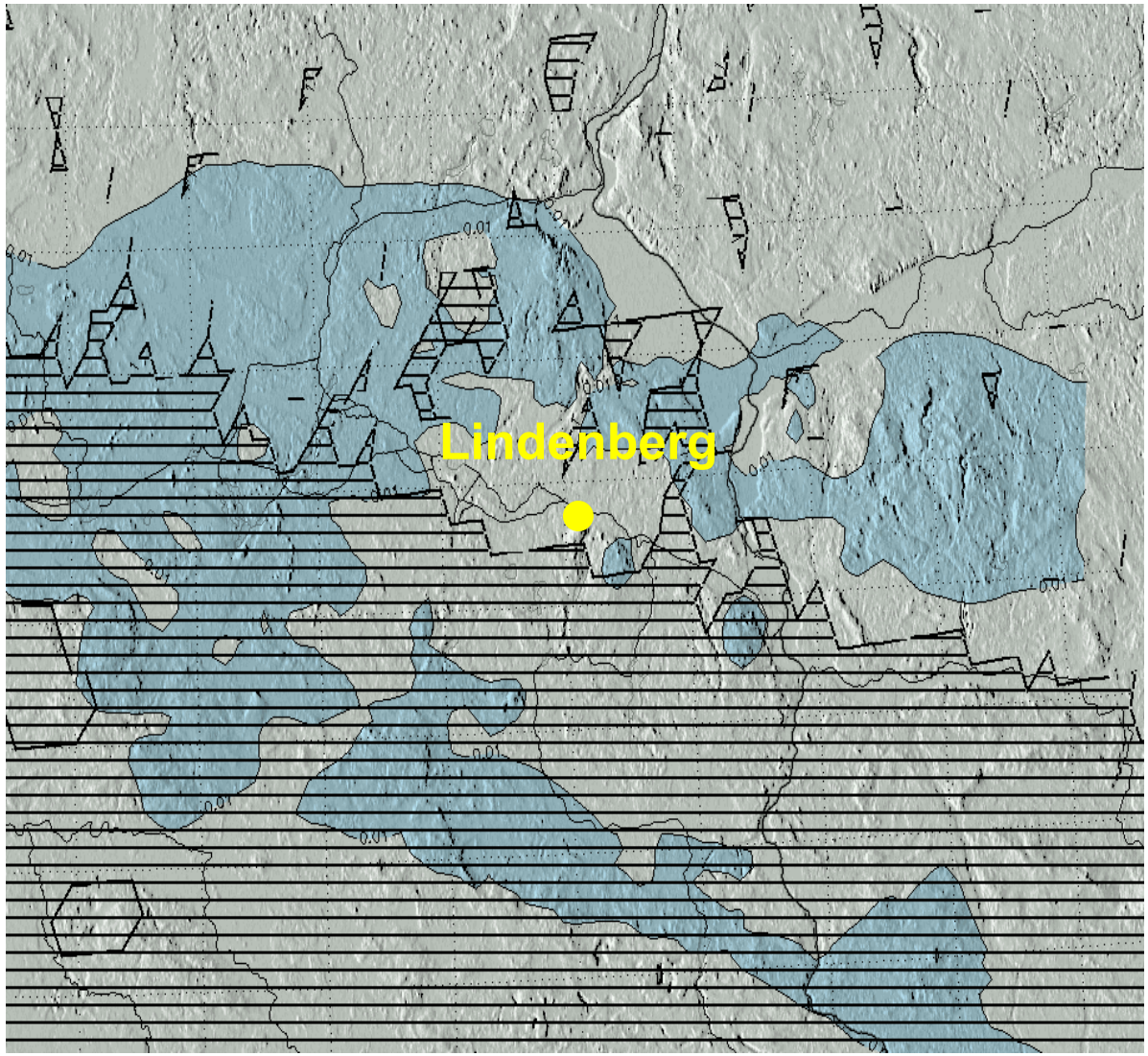

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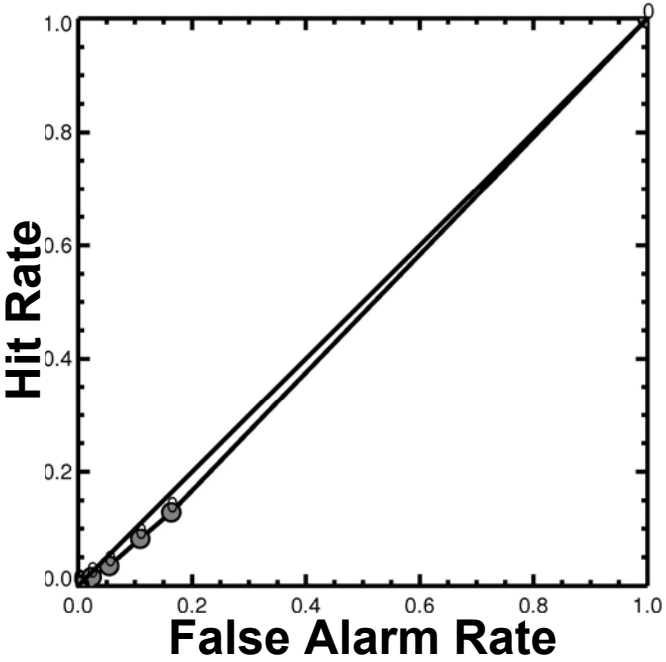
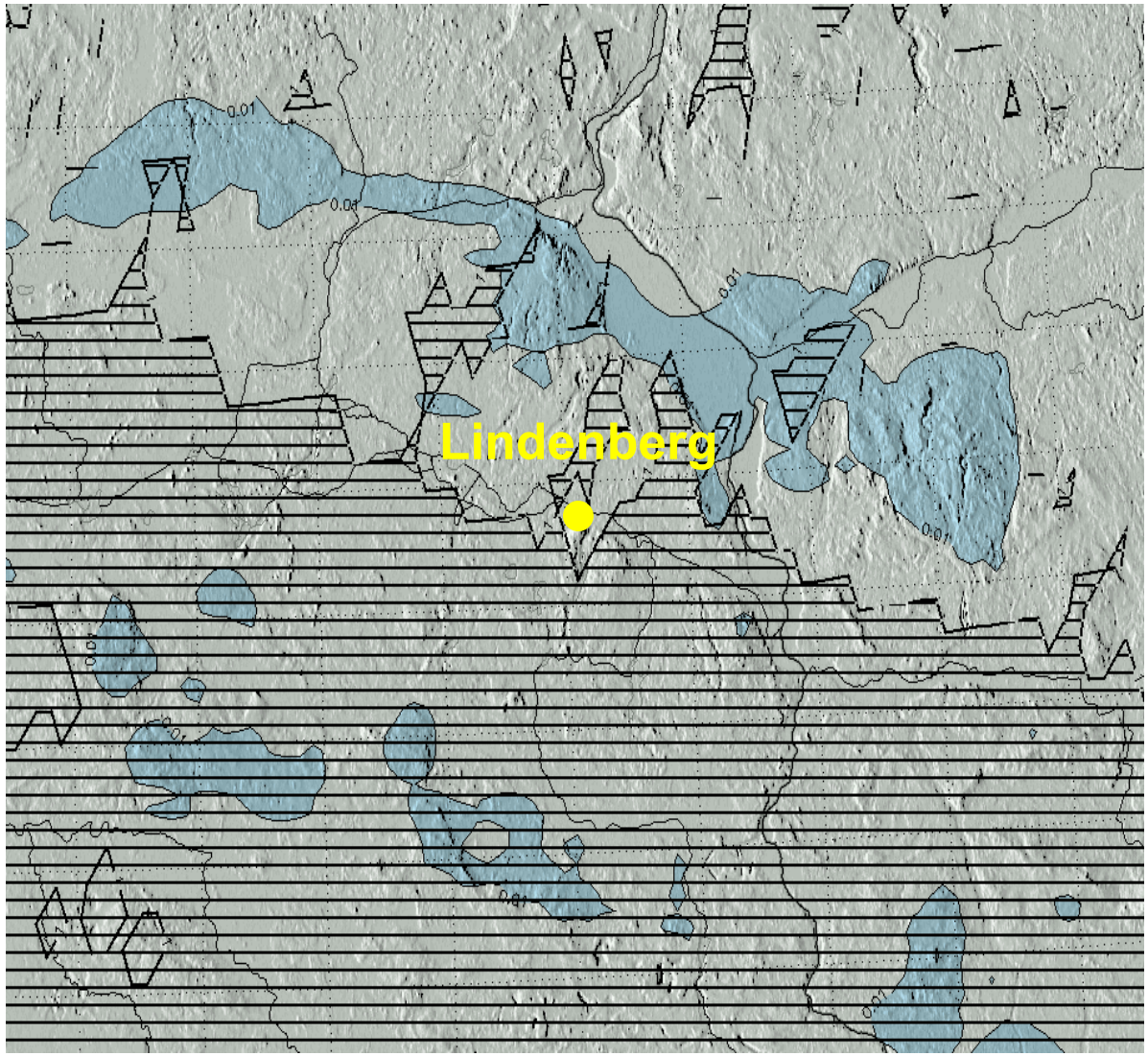
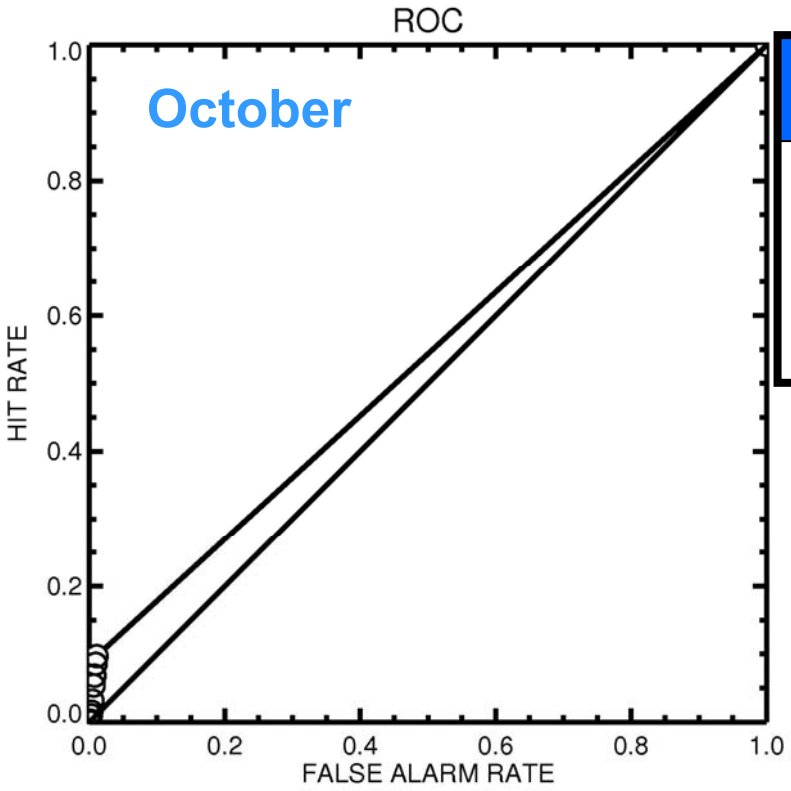




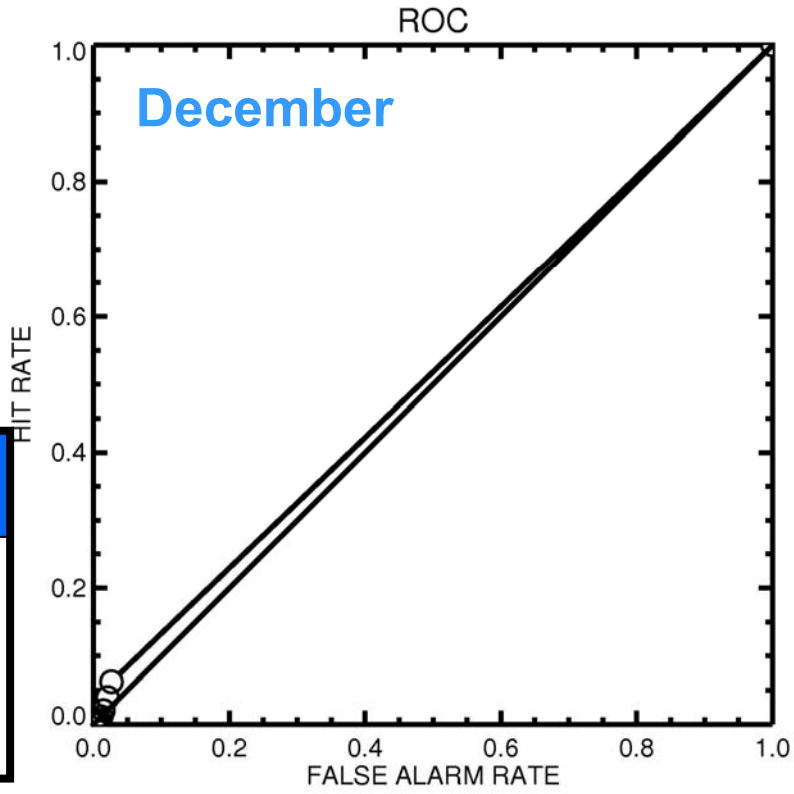
Larger Statistic: October 2005 and December 2005



October 2005

Large Period without Cloud Cover

on Lindenberg Area

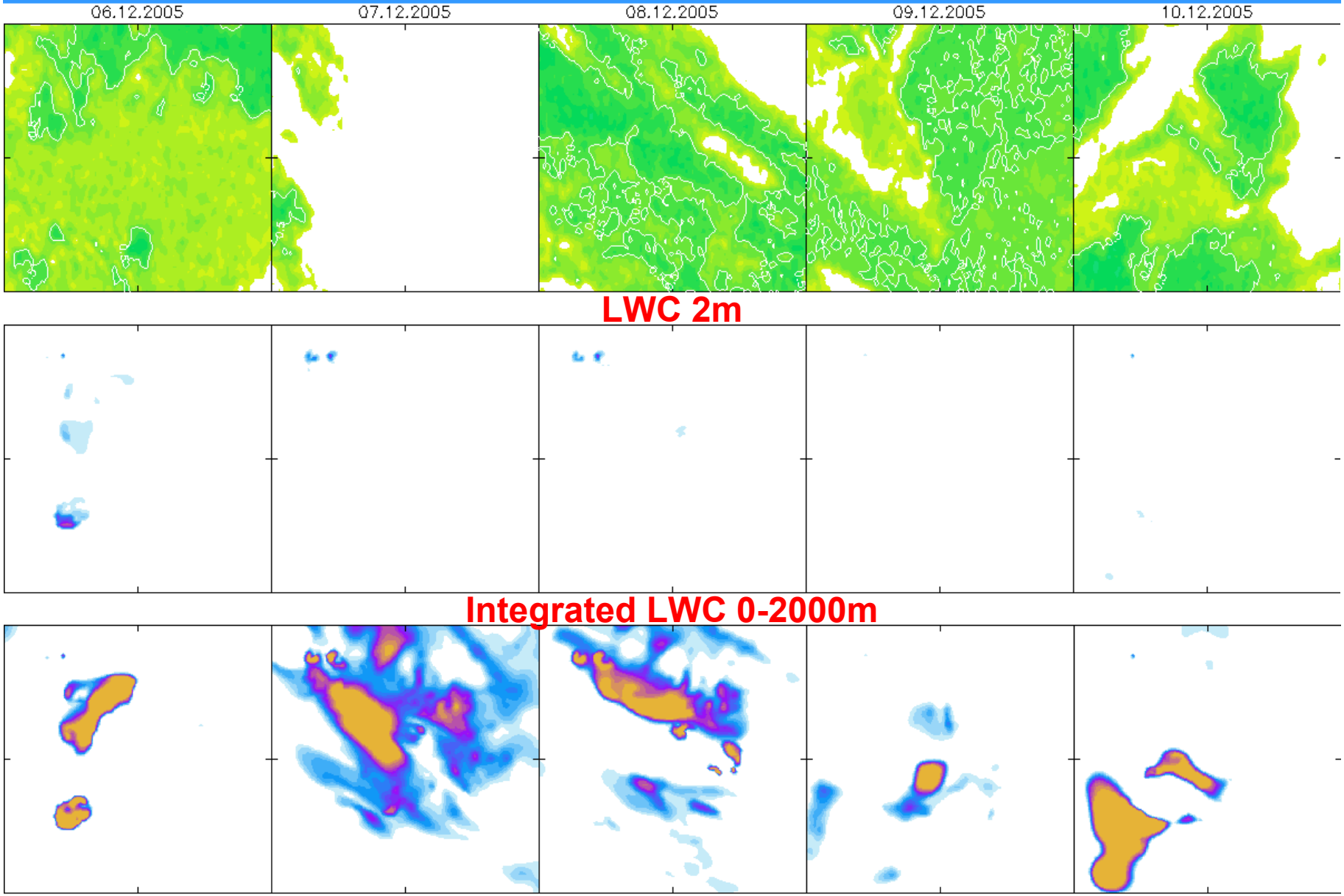


December 2005

Large Period with low Stratus

on Lindenberg Area

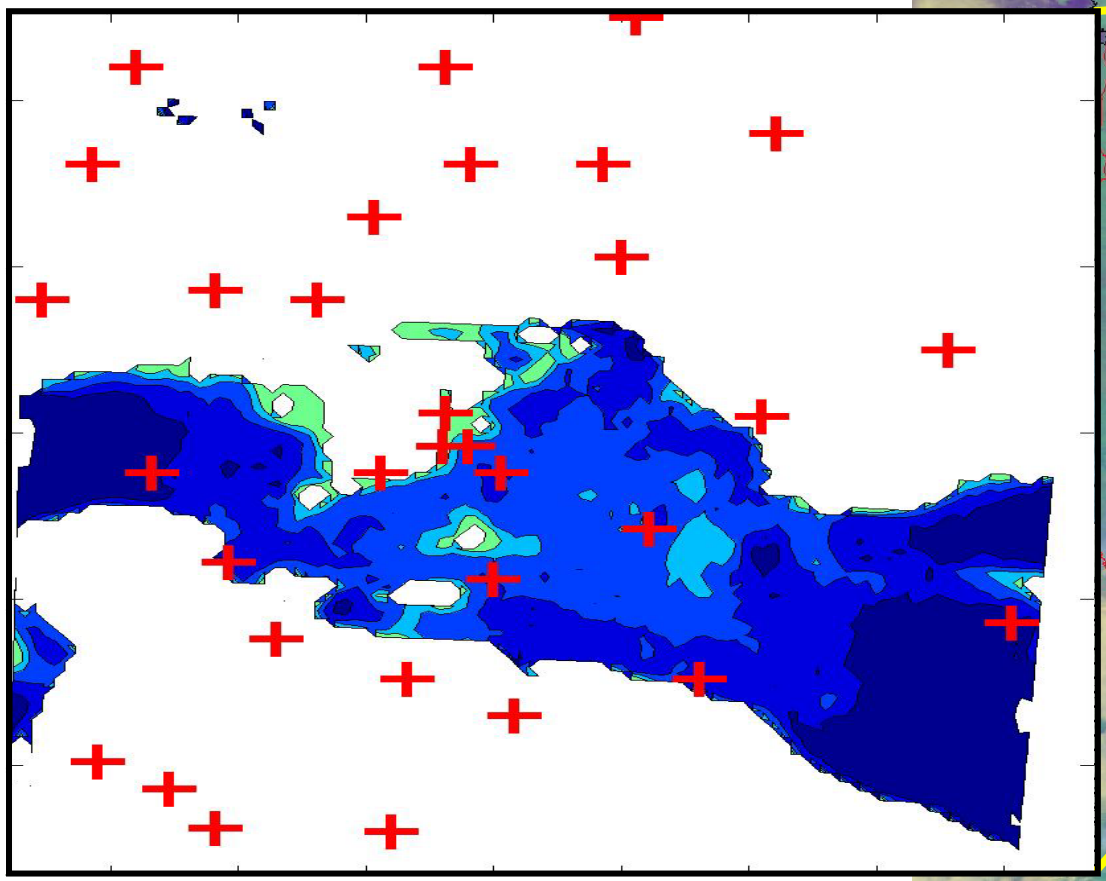
LM-PAFOG: Forecast hour 10 UTC – DECEMBER 2005

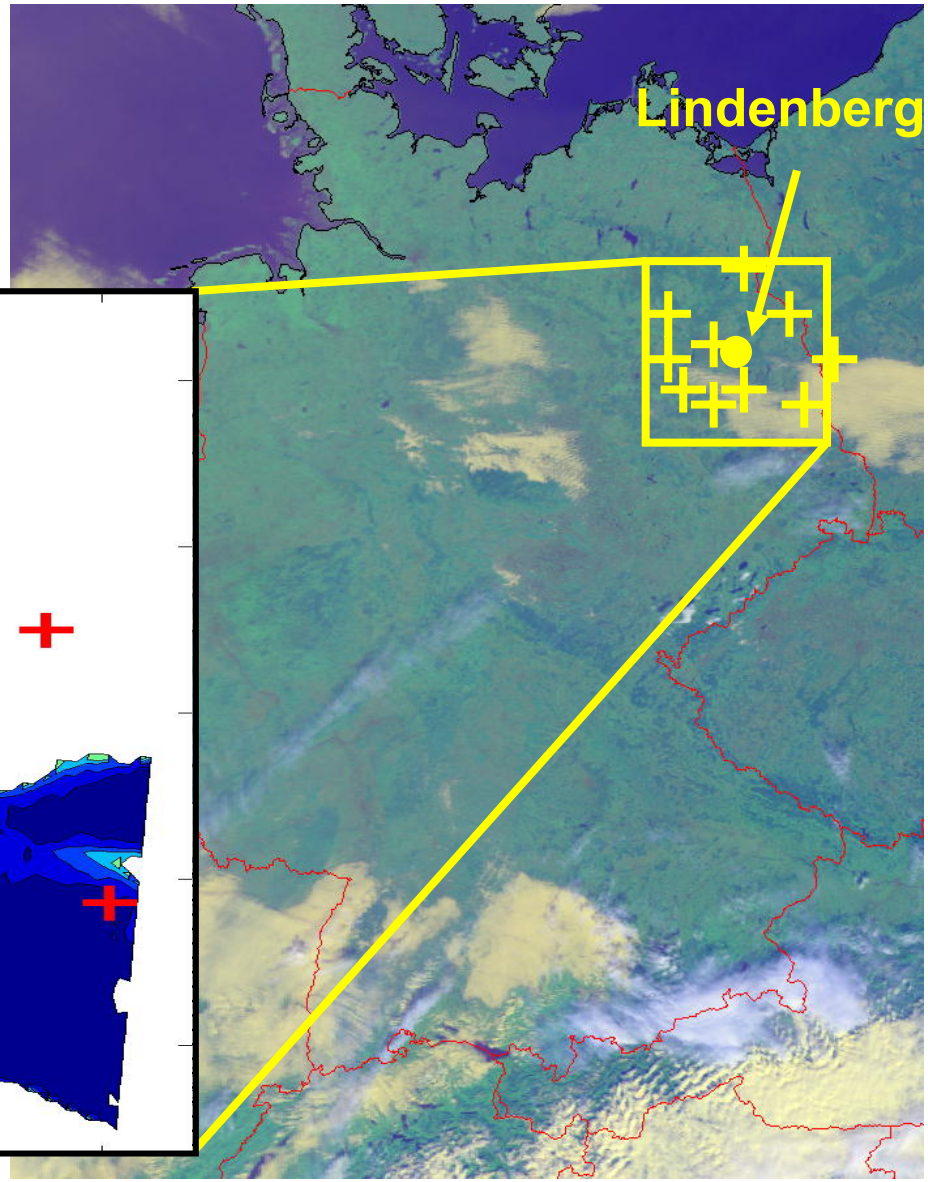


SYNOP Station Verification

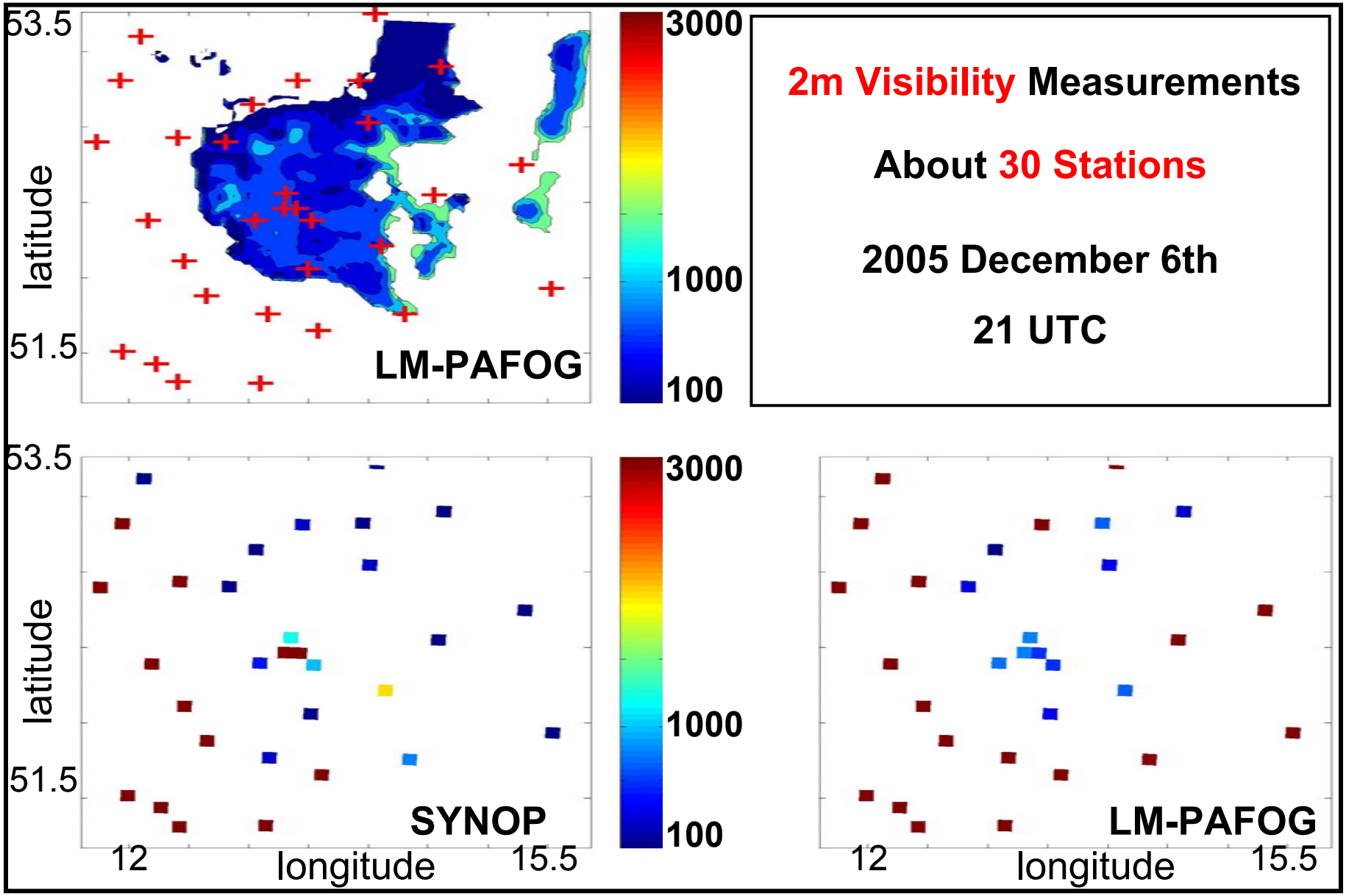
October 2005, 7th

Lindenberg

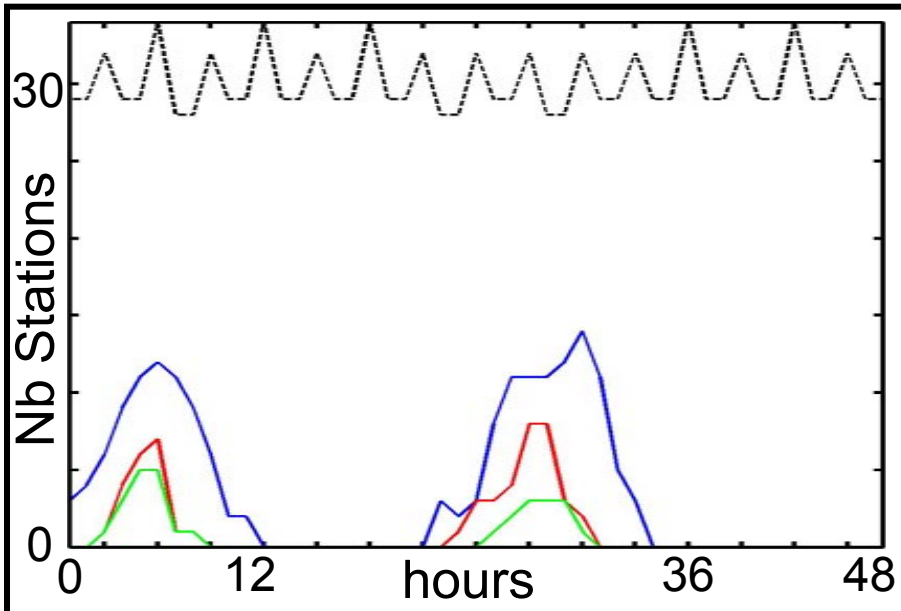


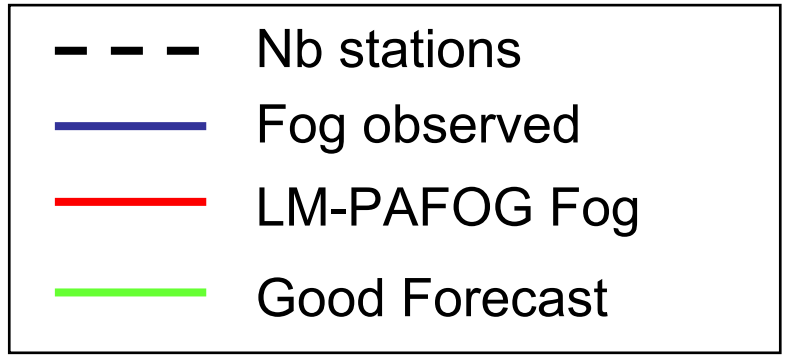


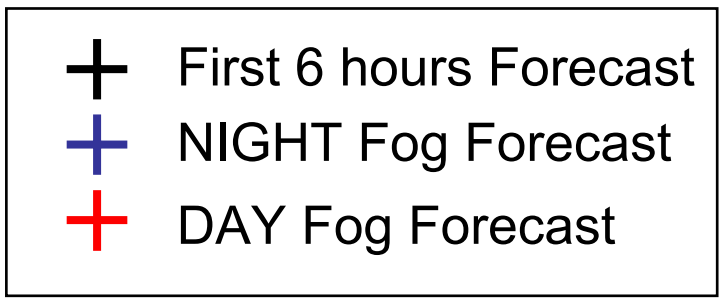
Comparison SYNOP Procedure

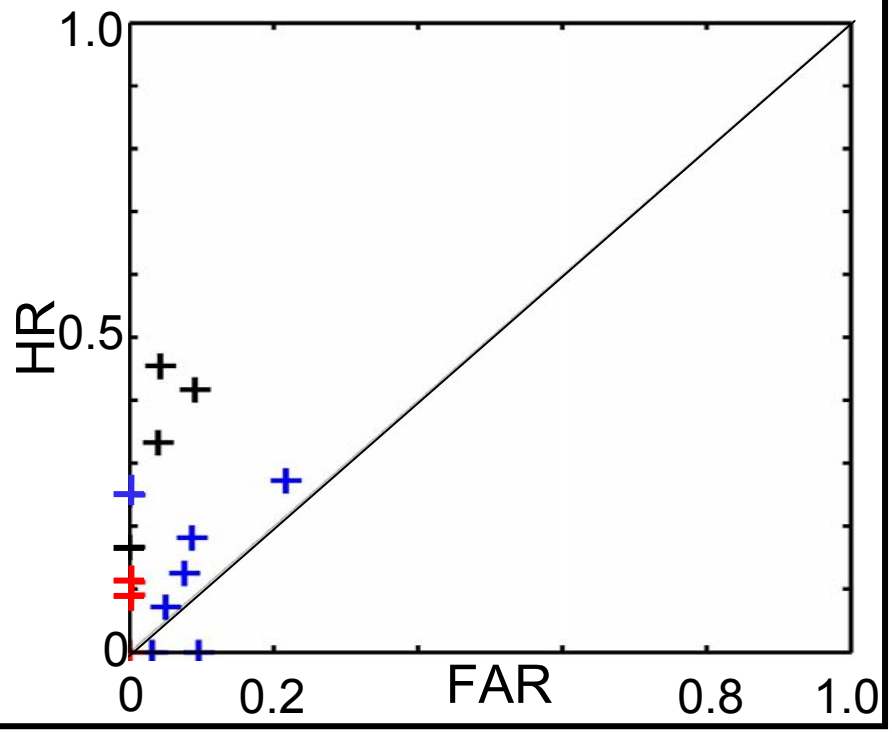


2005 October 6th-Visibility 1000 m

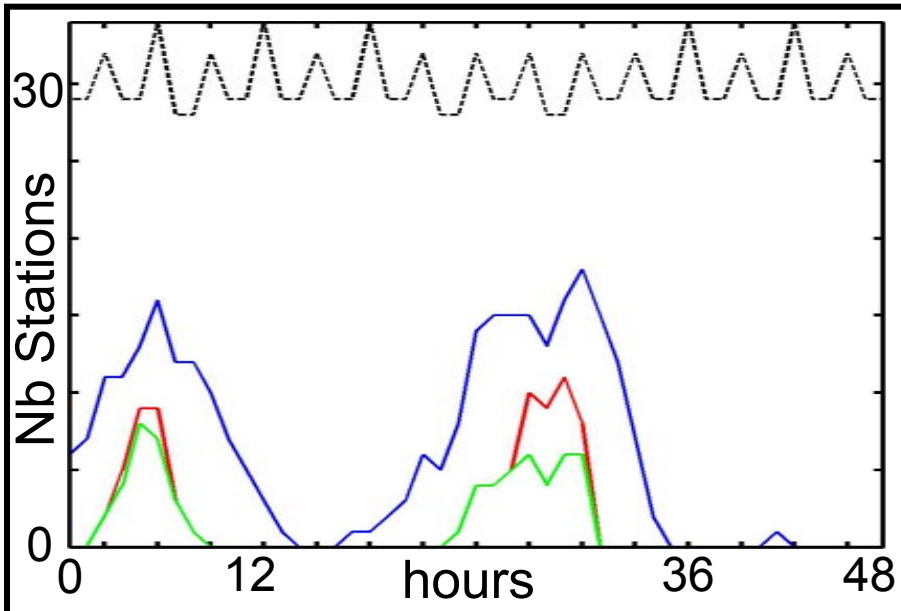


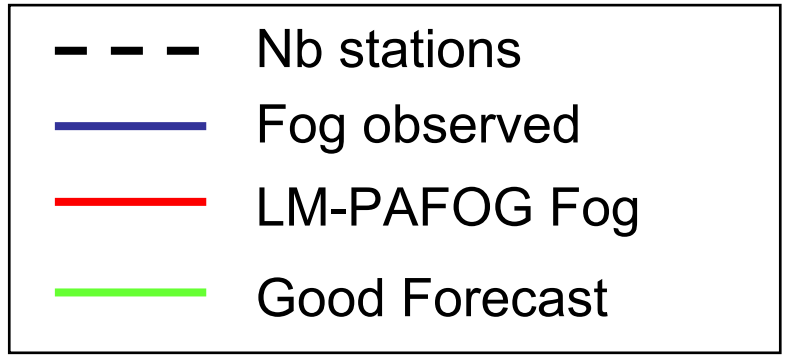


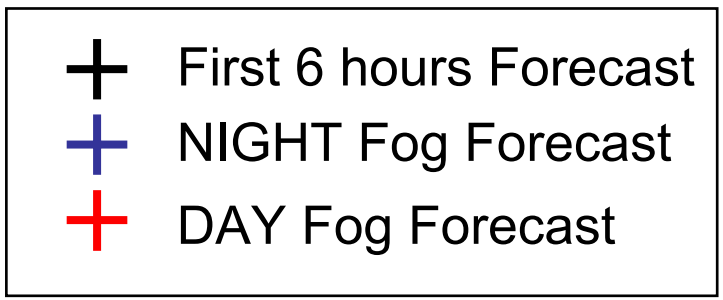


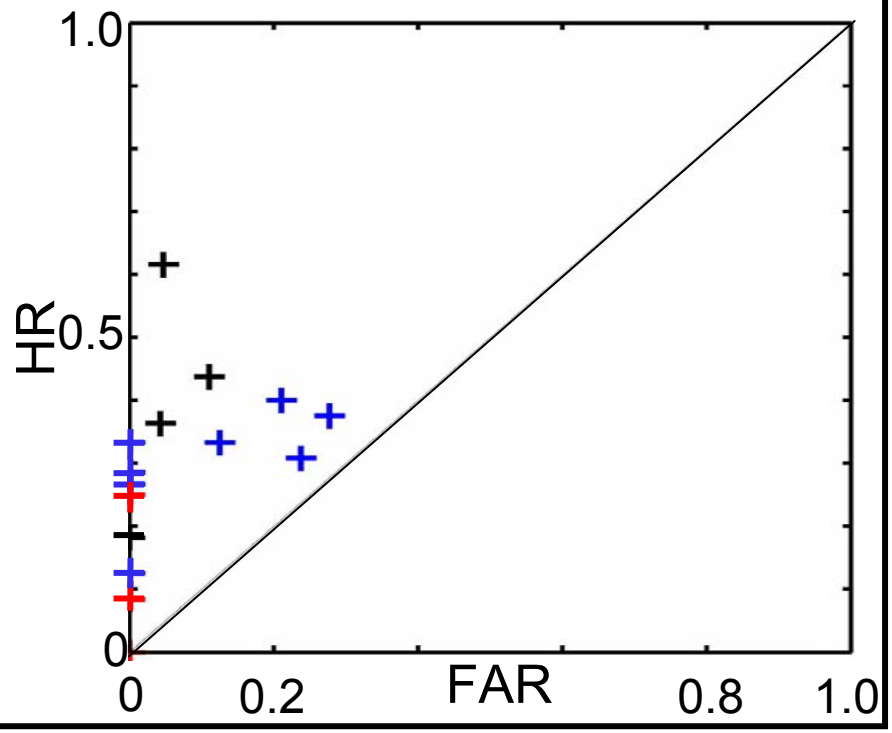


2005 October 6th-Visibility 3000 m





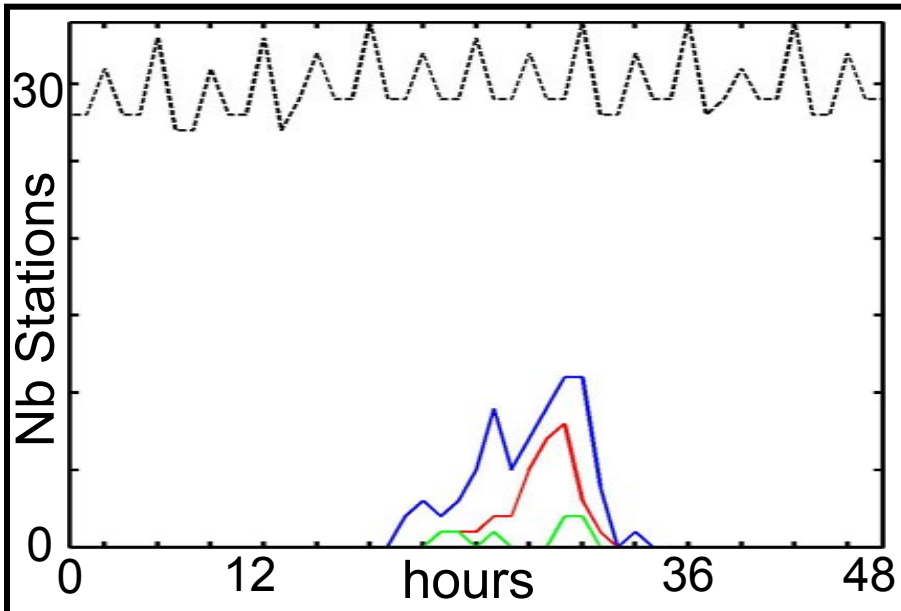


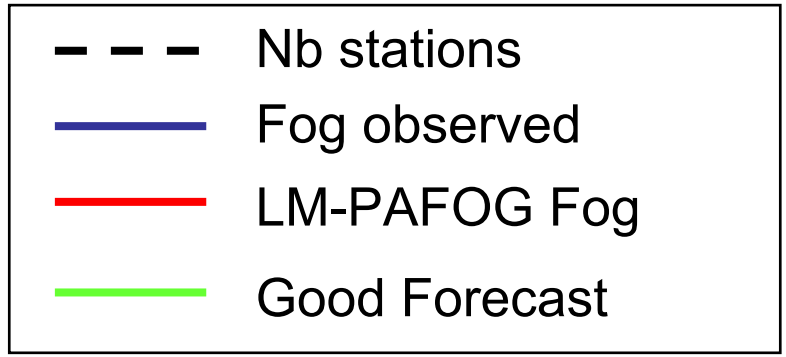


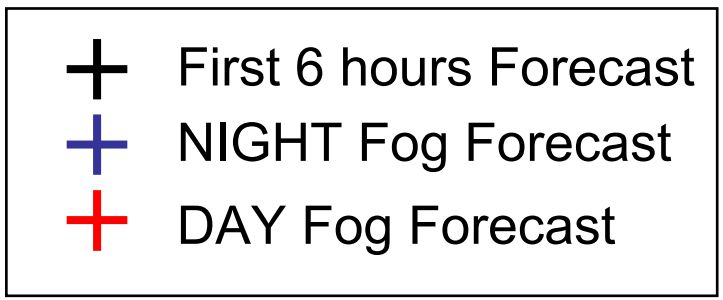
Case Study September 2005, 27th

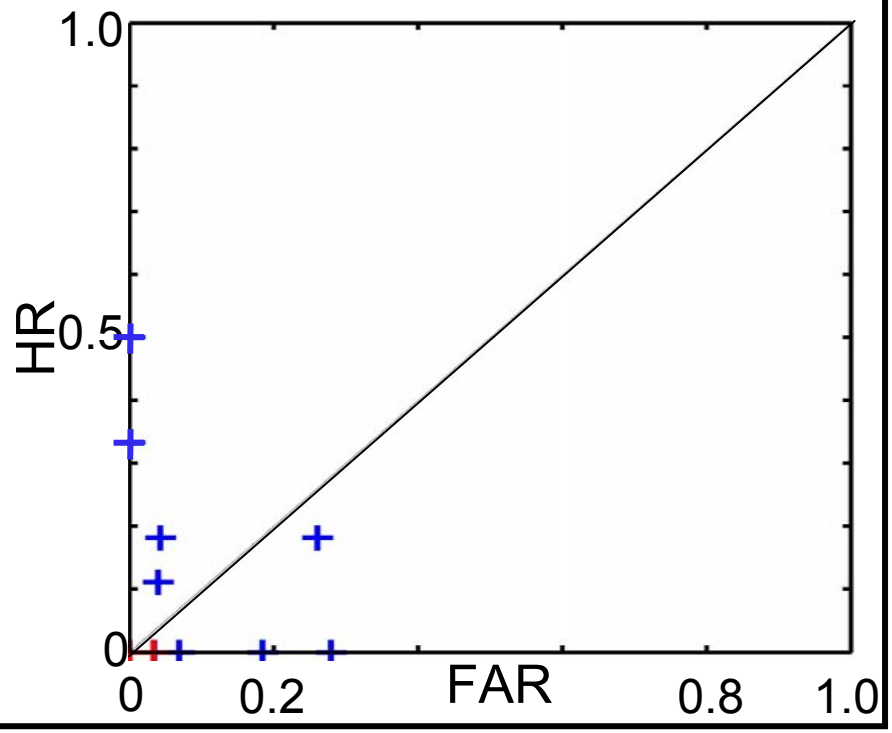
Source: www.wetterzentrale.de

2005 September 26th-Visibility 1000 m

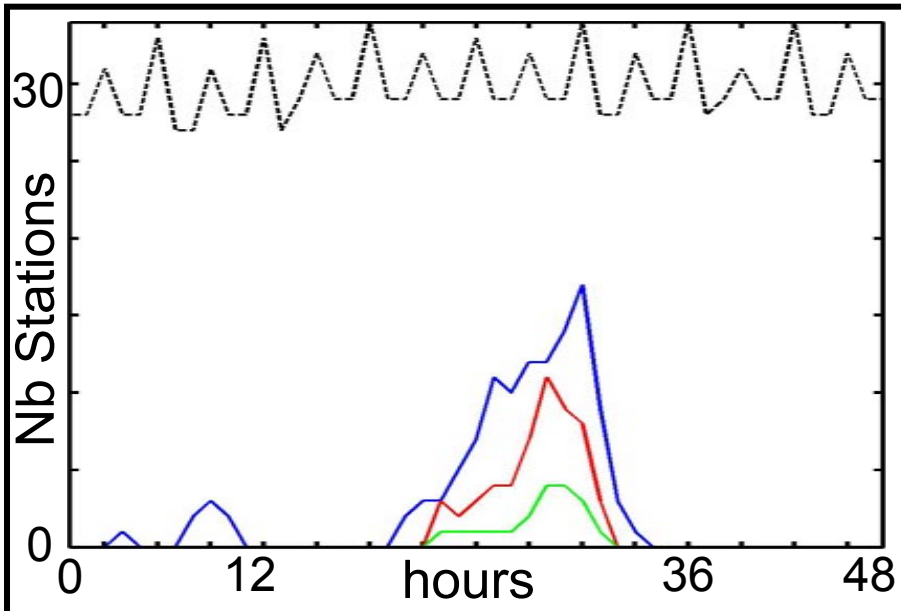


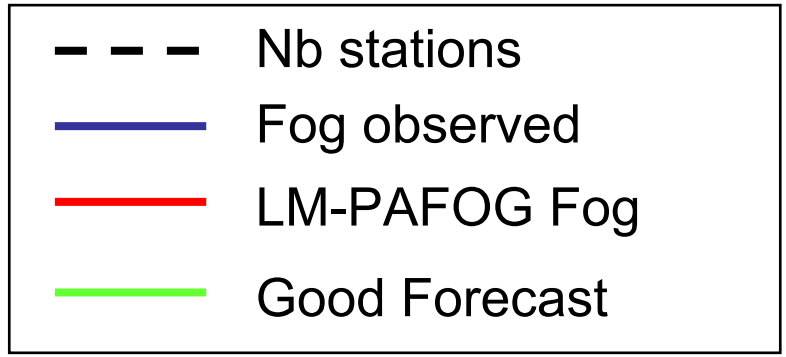


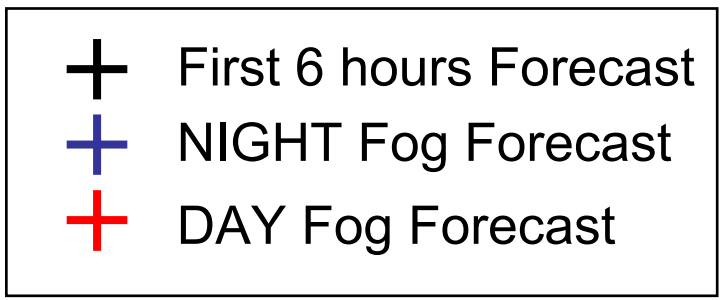


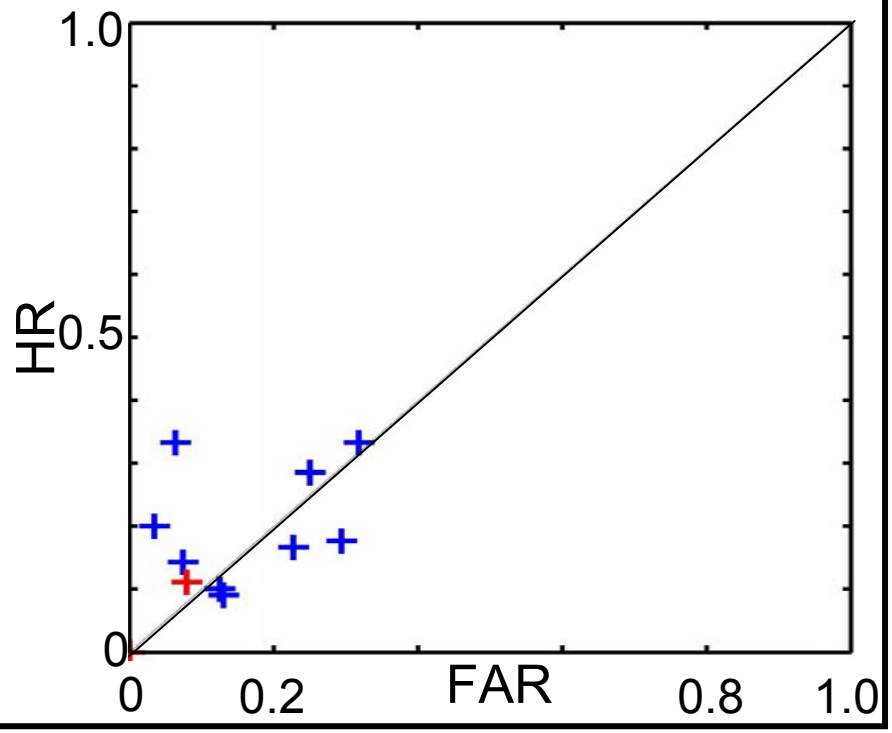


2005 September 26th-Visibility 3000 m

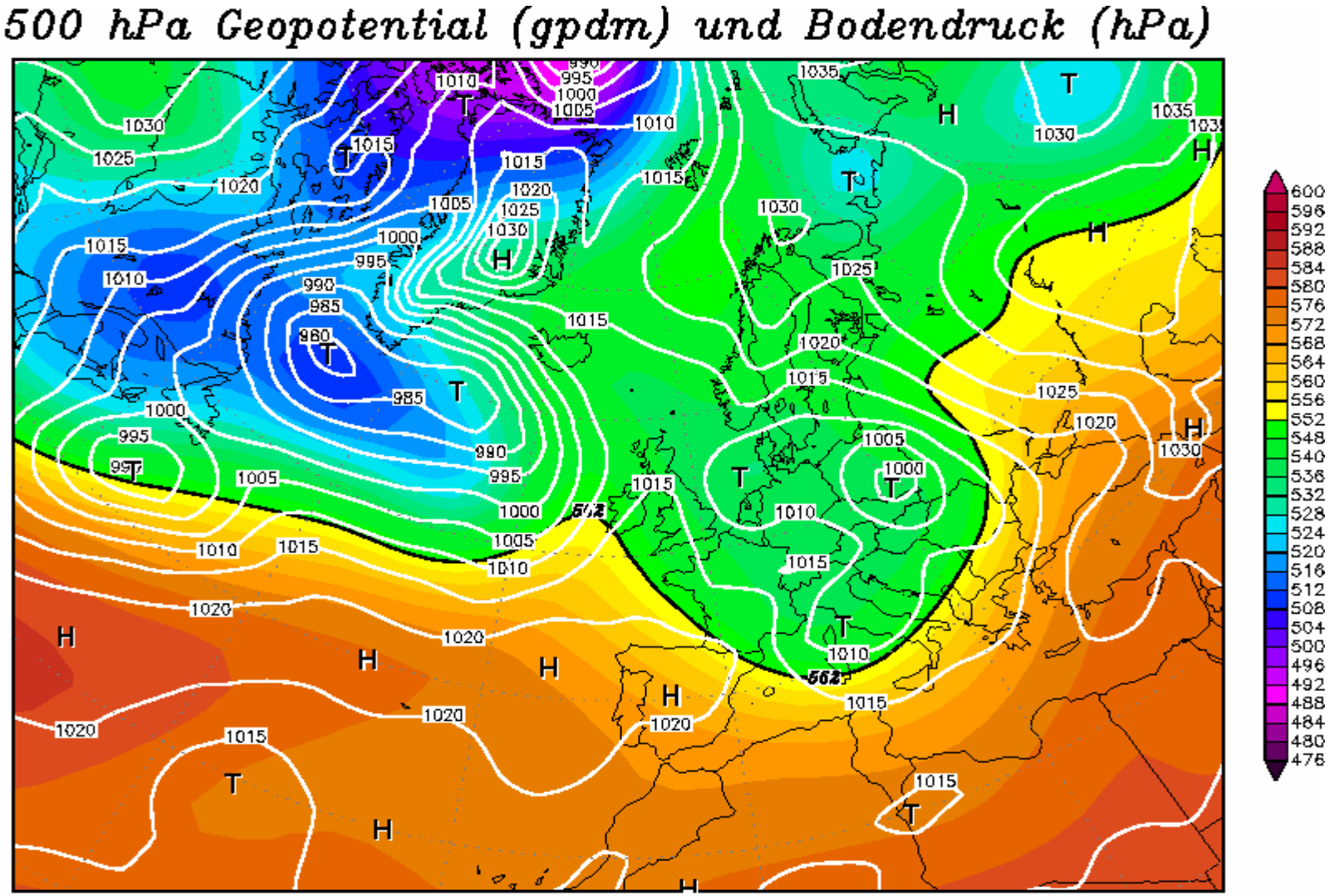






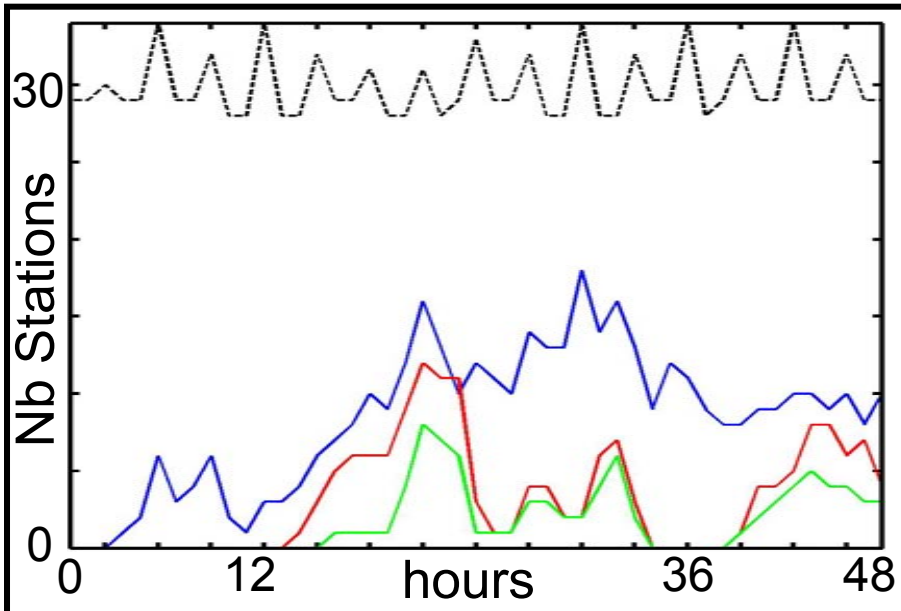


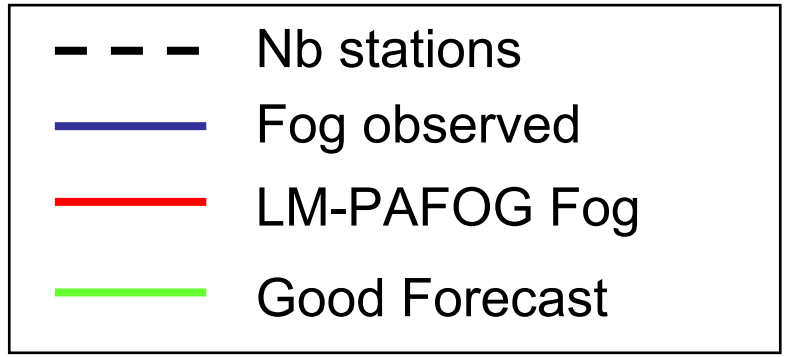
Case Study December 2005, 7th

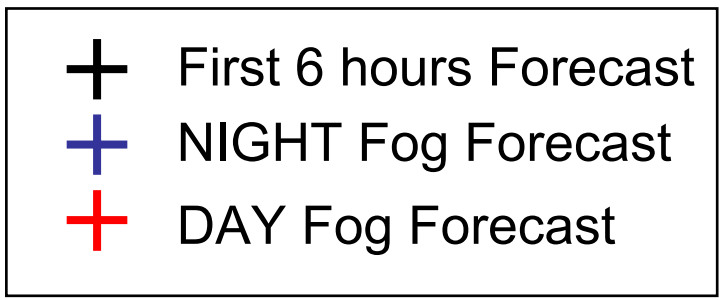


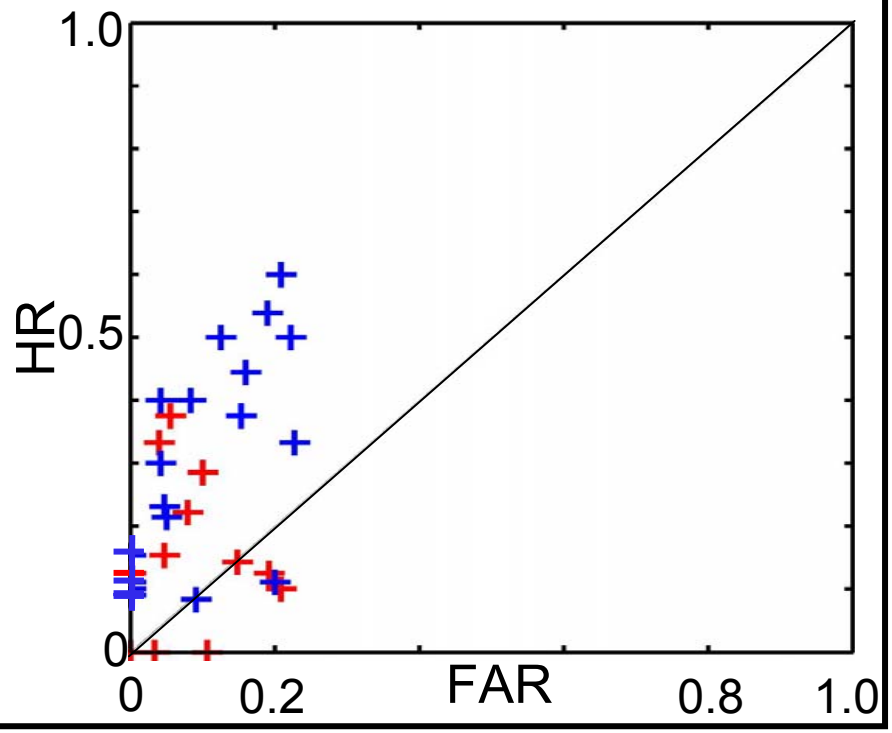
Source: www.wetterzentrale.de

2005 December 6th-Visibility 1000 m

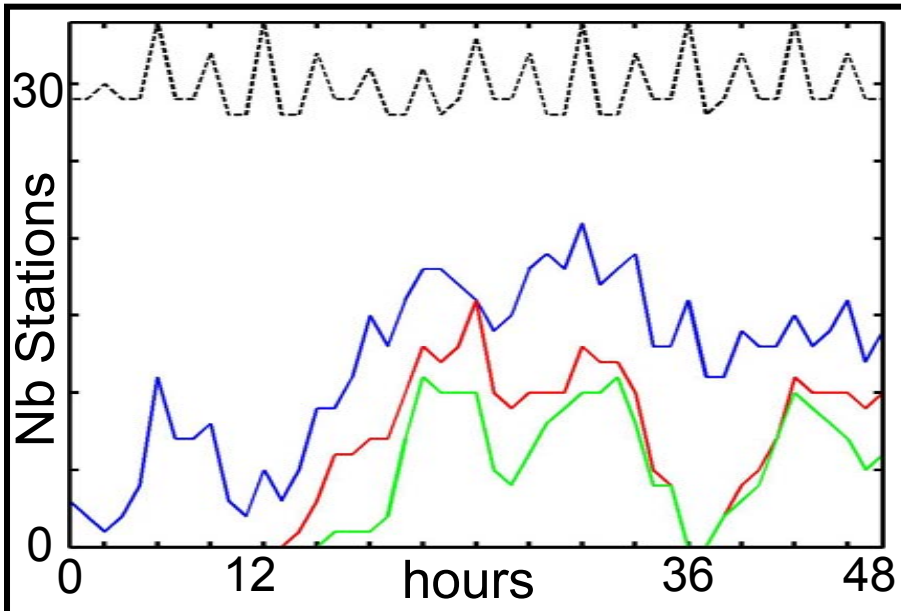


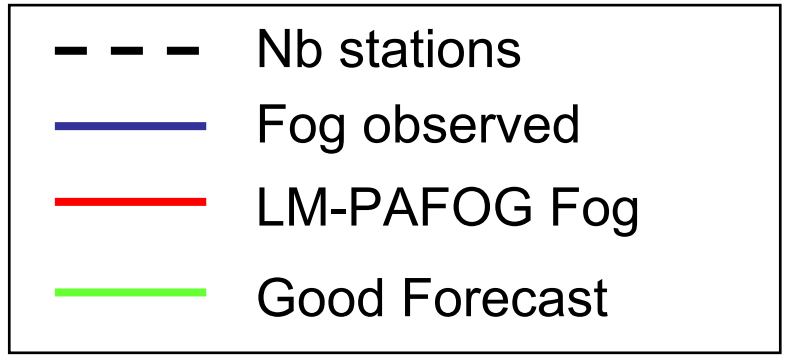


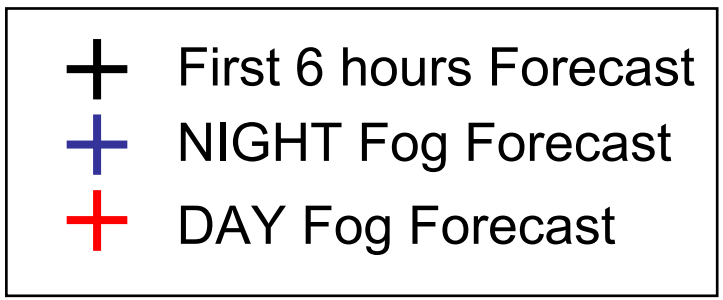


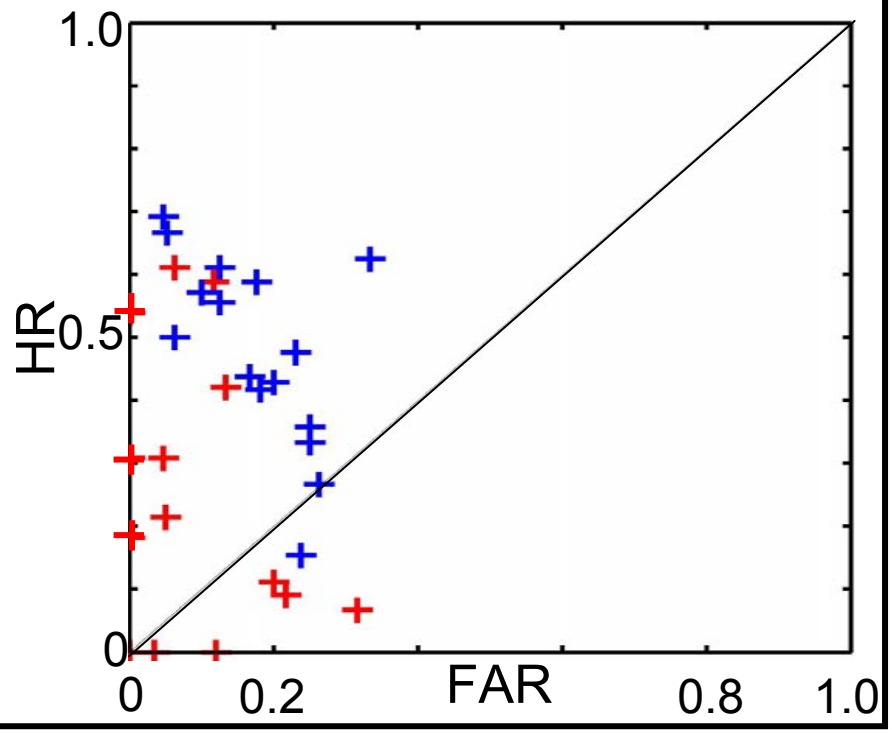


2005 December 6th-Visibility 3000 m









CONCLUSION

- 3D Fog models with complex microphysics and high resolution

Forecast Verification:

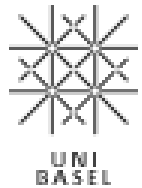
- Lindenberg study: good accuracy in T, RH and Wind
- Satellite Comparison:
  - very good results in case of low cloudiness
  - Interference of Stratus in case of fog event with large low Cloud Cover
- SYNOP Comparison:
  - Good capacity of LM-PAFOG to forecast fog in different synoptic situations
  - Influence of visibility parameterization
  - Better Forecast by night than by day

FUTURE PLANS

- Complete comparison SYNOP/LM-PAFOG on a larger period

- Implement a better turbulence scheme for soil/atmosphere exchange by day

Thanks



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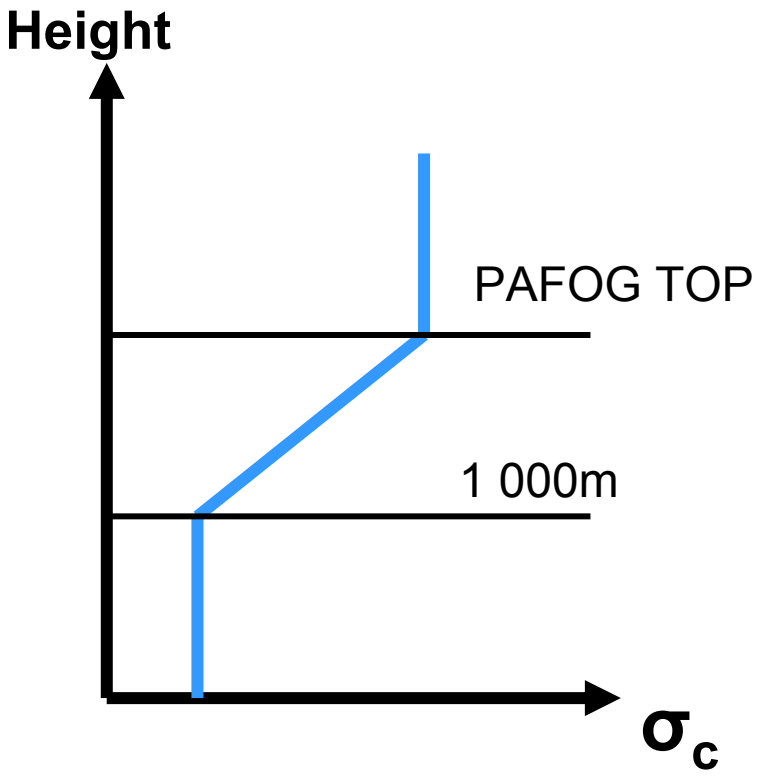
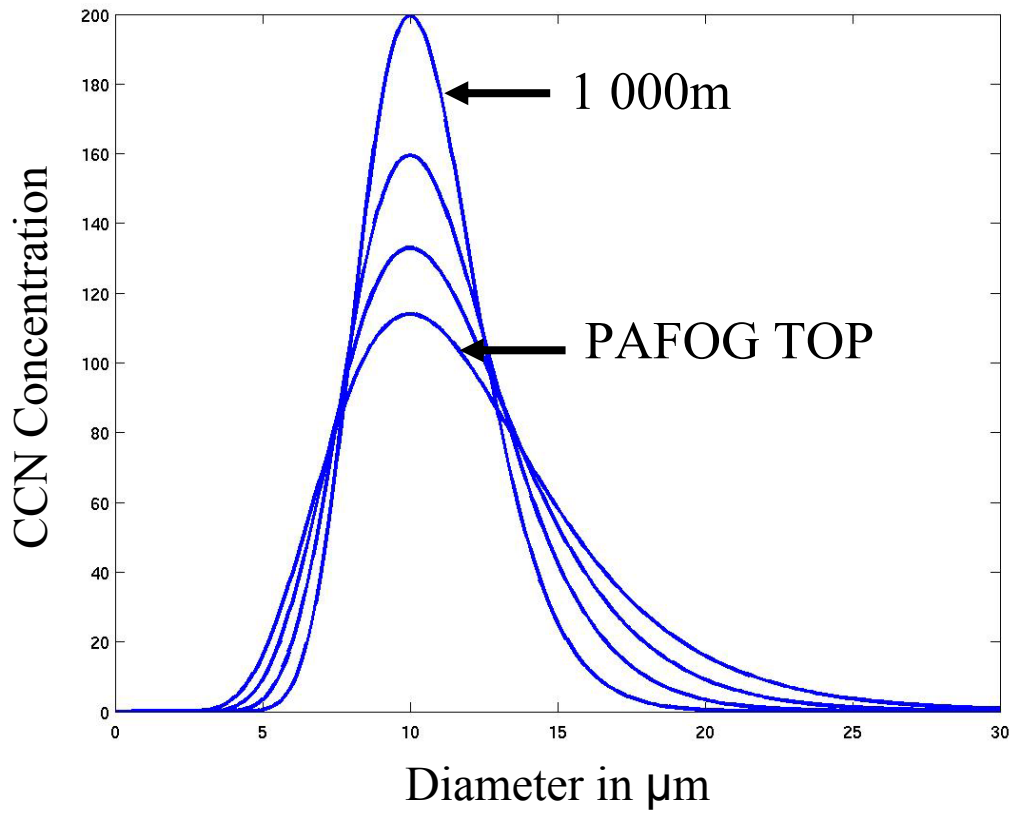
Boundary Condition for Nc





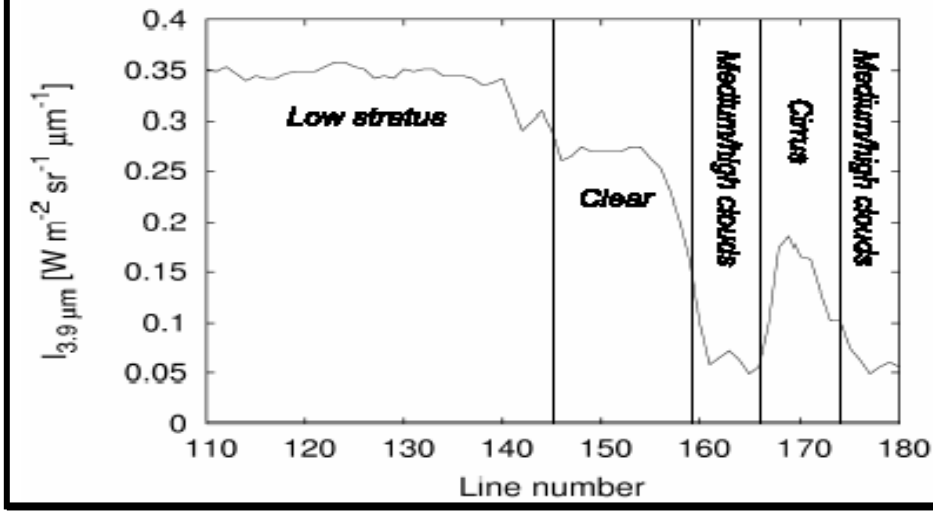
MSG SEVIRI Satellite Products

1- Fog is a cloud

$$I_{IR}(cloud) < I_{MIR}(cloud) \qquad \Delta T(a) = T_{IR}(a) - T_{MIR}(a)$$
$$I_{IR}(clear) \approx I_{MIR}(clear) \qquad \Delta T(a) \leq v_t(C) \rightarrow a \in C$$

2- in water phase

3- composed of small droplets

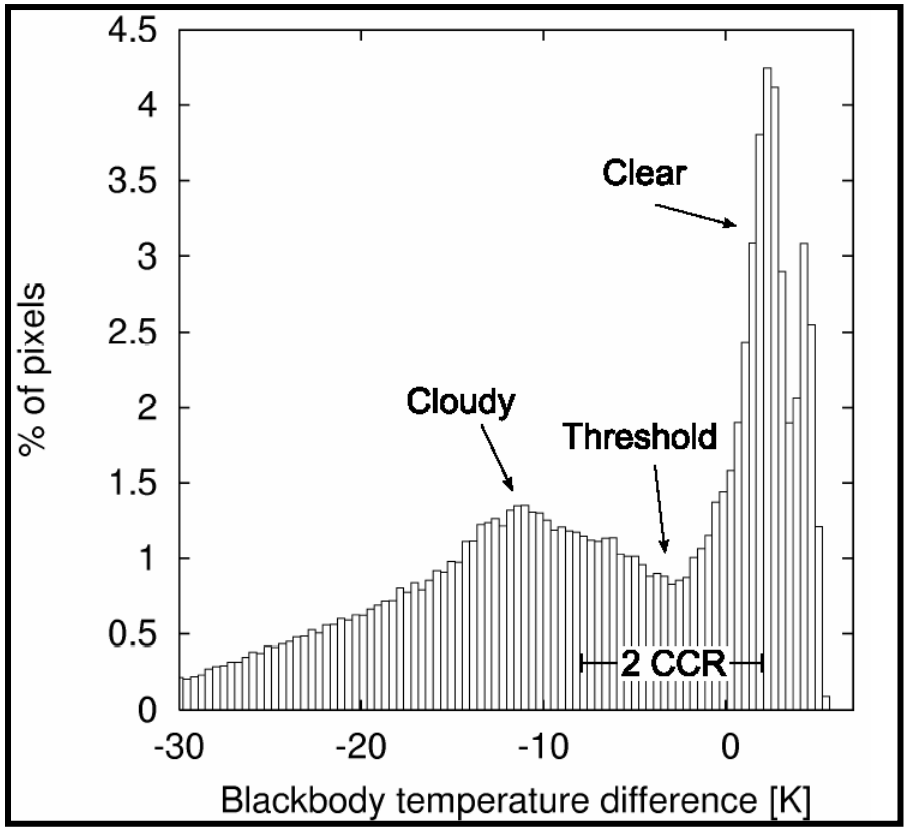


4- low above the ground and 5- stratiform

$$z_t = \frac{T_{cf}(10.8) - T_{cc}(10.8)}{\Gamma} - (z_{cf} - z_{cc})$$

→ **Satellite Products**

P_c- Cloud Confidence Level



Blackbody temperature difference

$$\Delta T(a) = T_{IR}(a) - T_{MIR}(a)$$

$$\Delta T(a) \leq v_t(C) \rightarrow a \in C$$

$v_t(C)$ **Threshold**

CCR **Cloud Confidence Range**

CCR is set to 5 K

$P_c(a)$ **Confidence Level**

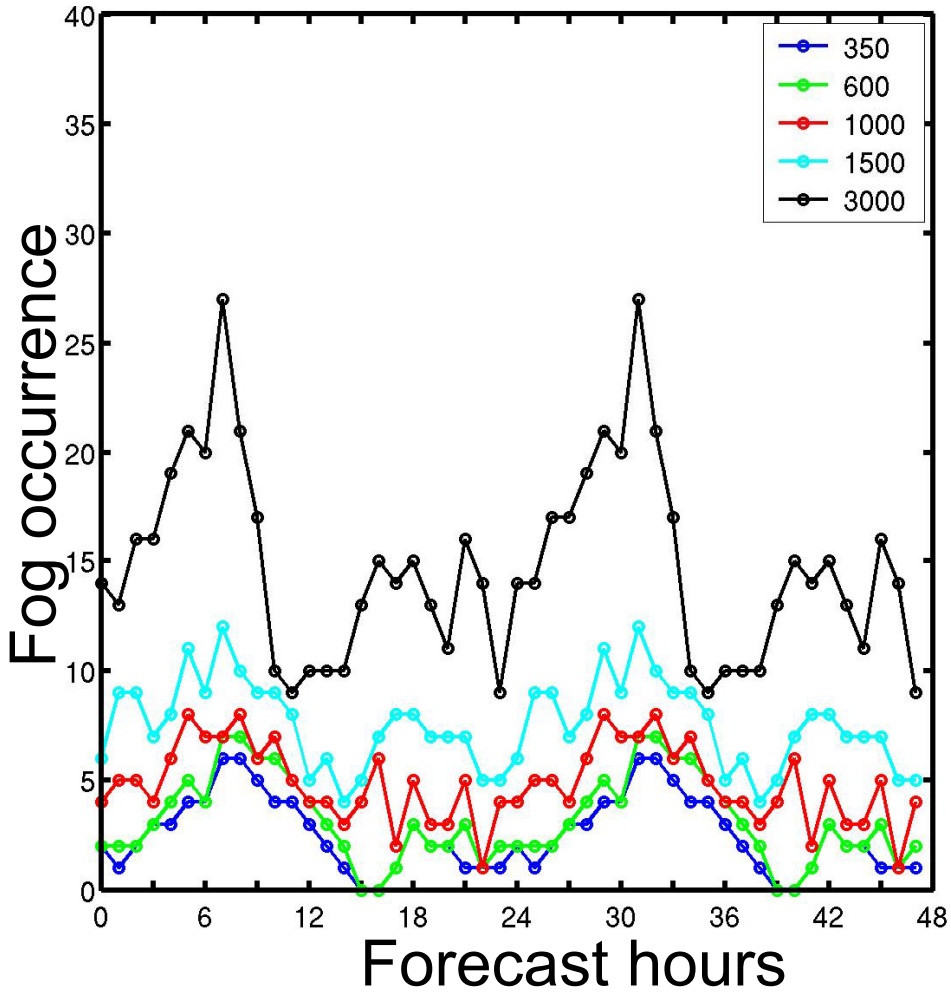
$$P_c(a) = \frac{\Delta T(a) - v_t(C) - CCR}{-2CCR}$$

Cloudy $P_c(a) = 1.0$

If $\Delta T(a) = v_t(C)$ $P_c(a) = 0.5$

Clear $P_c(a) = 0.0$

Fog Frequency



- 4 months forecast (Sept-Dec 2005)

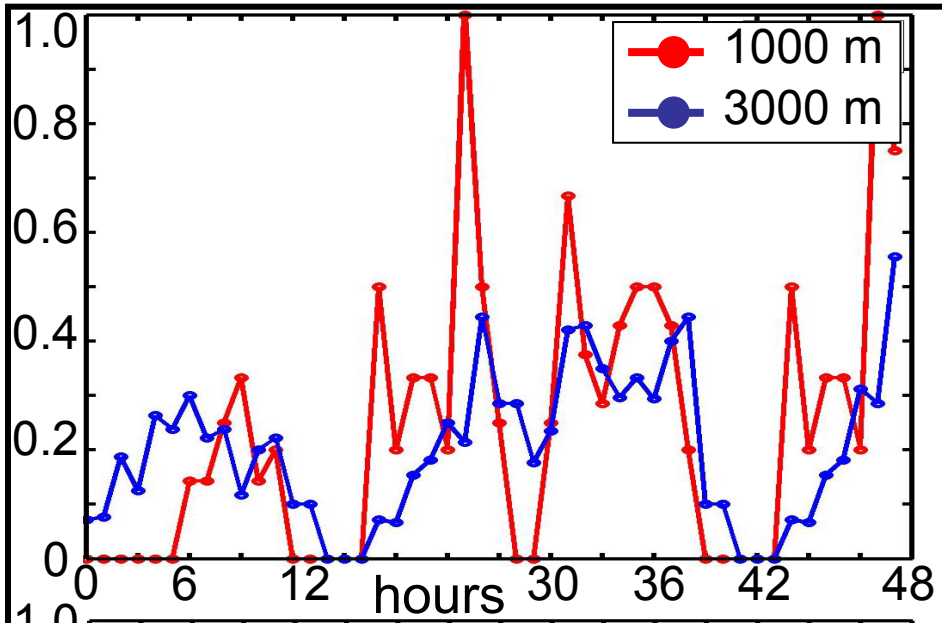
  About 6000 forecast hours

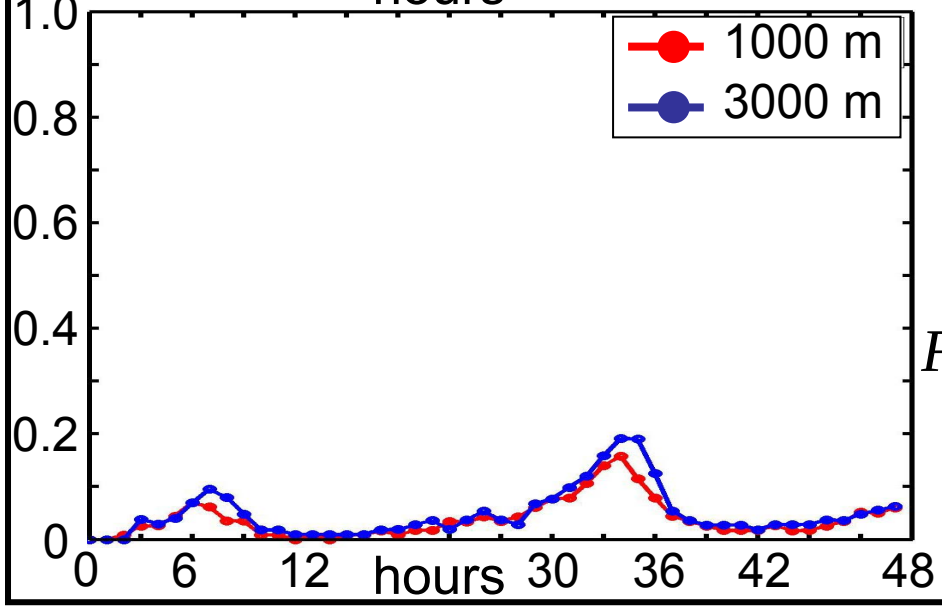
- Fog events: 35

Fog episode very rare

4 % time of studied period

Statistical Study at Lindenberg pixel





Hit Rate

$$H = \frac{hits}{hits + miss}$$

False Alarm Rate

$$FAR = \frac{false\_alarm}{false\_alarm + correct\_neg}$$