On the performance of the COSMO model regarding the PBL structure and PBL clouds

COSMO Workshop

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Deutscher Wetterdienst, FE 14

Outline

1) The problem with simulating PBL clouds (an example)

2) Results from an experiment using reduced minimal diffusivity (K_H^{min} and K_m^{min})
   - Experiment setup
   - Positive and negative effects
   - What do we learn

3) Single Column Model (SCM), Lindenberg (2009010512-2009010712)
   - SCM: sensitivity to reduced minimal diffusivity
   - SCM: near surface behaviour

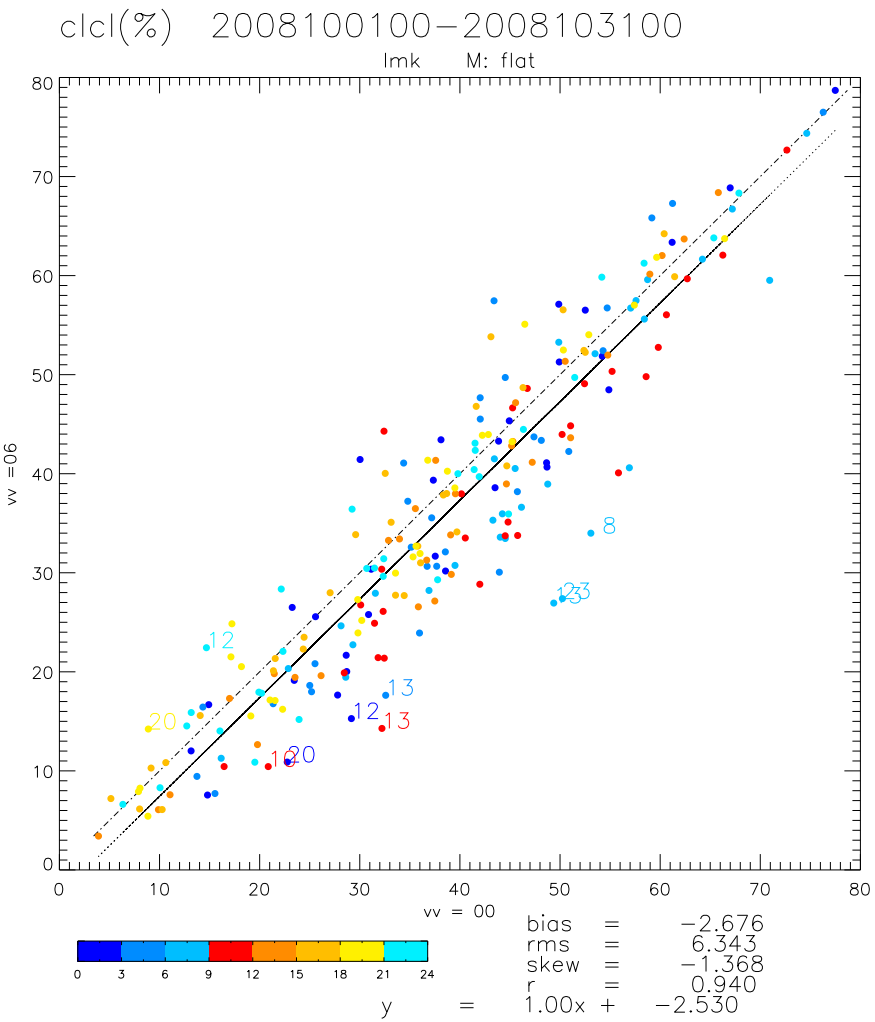
4) Near surface behaviour at Lindenberg (Falkenberg)
   - Overview
   - Near surface behaviour Cosmo-DE vs. Lindenberg (20081001-20090531)

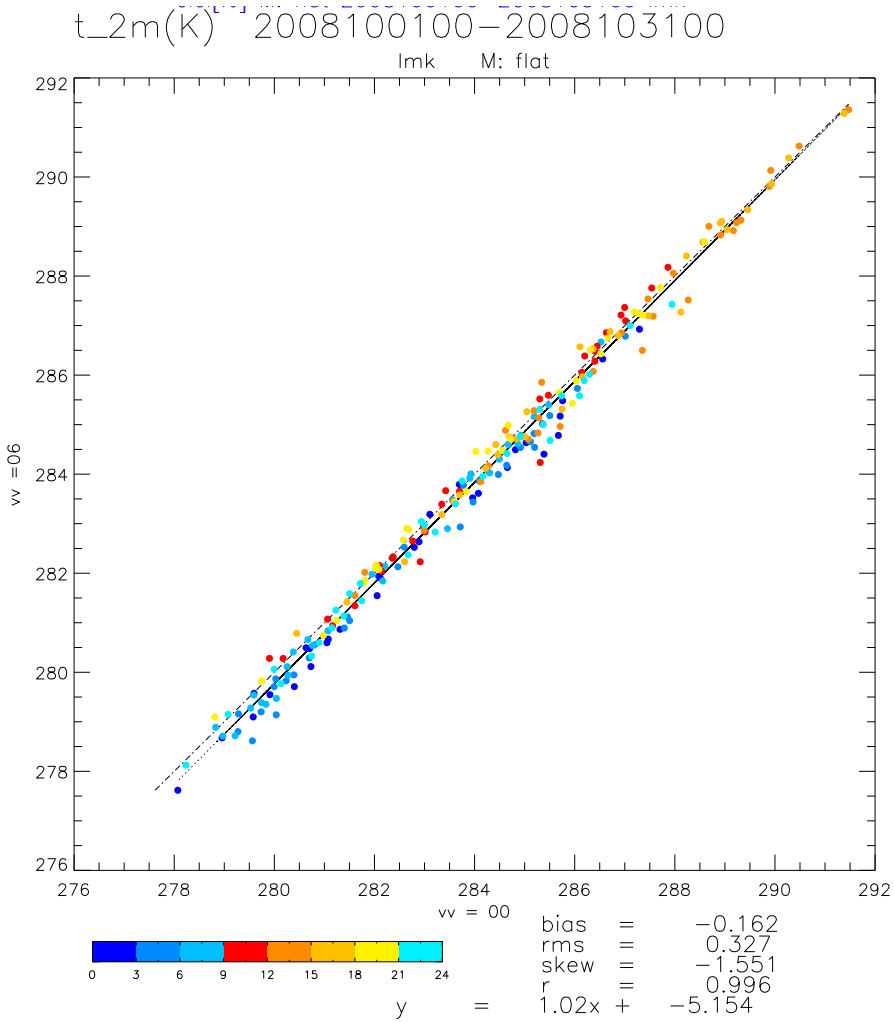
5) Conclusions and ongoing work

Problem with simulating PBL clouds

Underestimation of boundary layer clouds?
20081001-20081031, CLCL and T2m
06h-Forecast vs. 00h forecast COSMO-DE

Every dot represents a domain average of a forecast at a given target date (00, 03, 06, 09, 12, 15, 18 und 21 UTC) vs. the reference (00h forecast) at the same instance





Problem with simulating PBL clouds

Underestimation of boundary layer clouds
20081009-20081013, CLCL (Lon: 7.3, 13.3, Lat: 48.3, 50.3)
06h-Forecast vs. 00h forecast COSMO-DE

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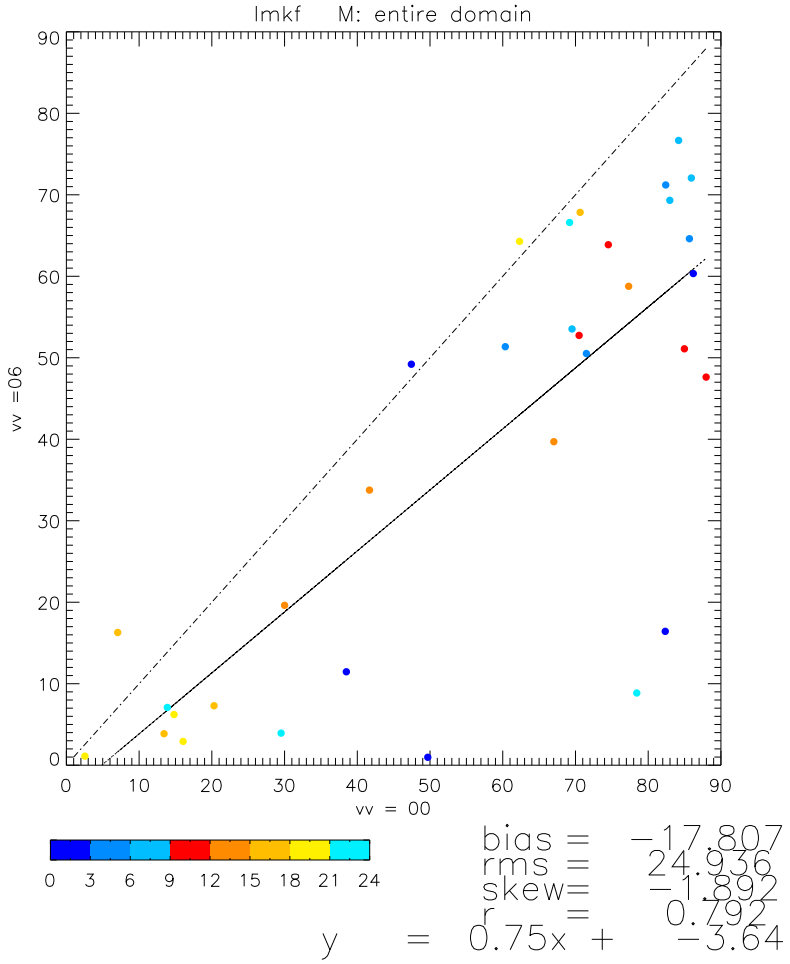

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Experiment using reduced minimal diffusivity

Reduction of the minimal diffusion coefficient.

In the operational model we use for the minimal diffusion coefficients (heat and momentum) the value of 1 m^2/s, which in a stable stratified Layer, causes artificial mixing. This might lead to a break up of the boundary layer clouds.

Experiment Information:

Period:	20090103-20090114	
Model:	COSMO-EU	
Initialisation:	00h und 12h	
Forecast:	78h	
Changed:	K_m^{min}	$\rightarrow$ 0.01 m^2/s
	K_H^{min}	$\rightarrow$ 0.01 m^2/s

For this entire period the DWD **Lindenberg meteorological observatory provided** a **complete measurement data set**!

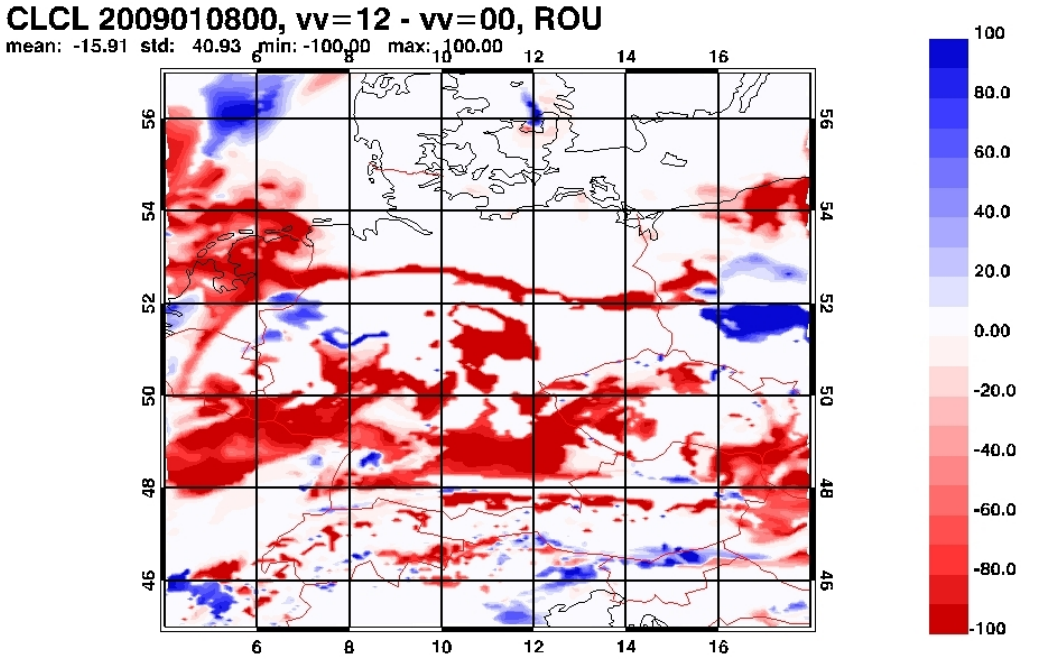
CLCL 2009010800 (COSMO-DE Domain)

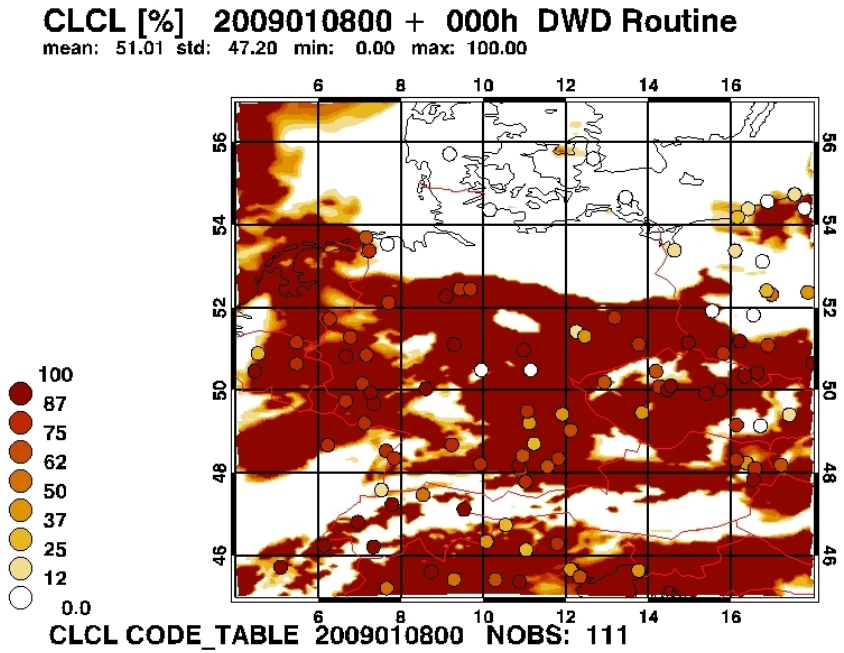
Rou
Exp

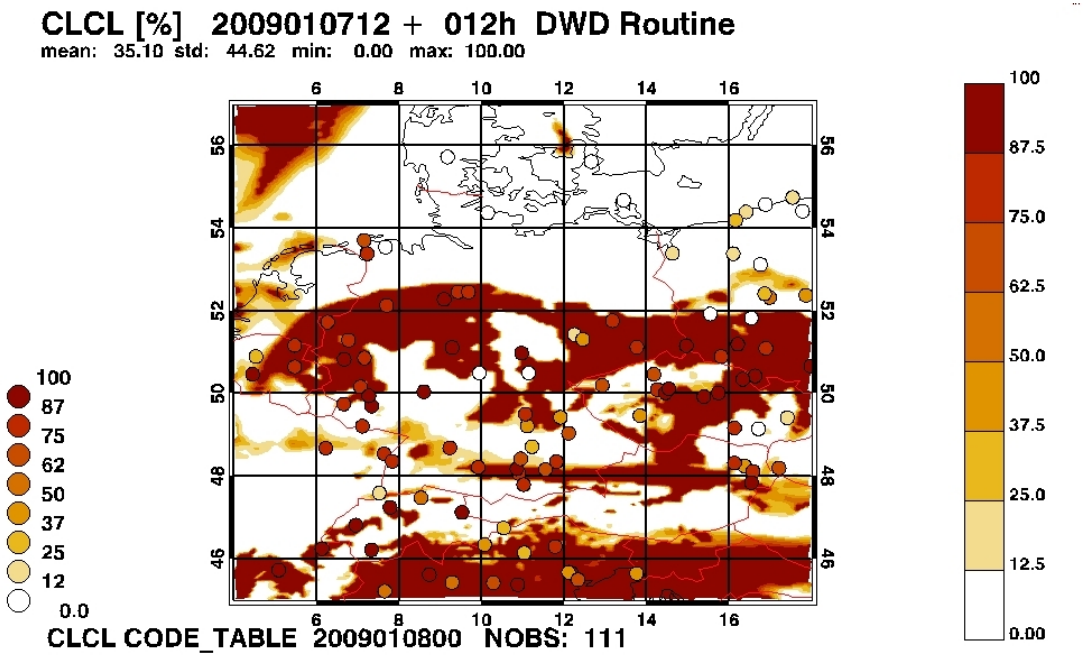
CLCL 2009010800 (COSMO-DE Domain)

Rou

Exp

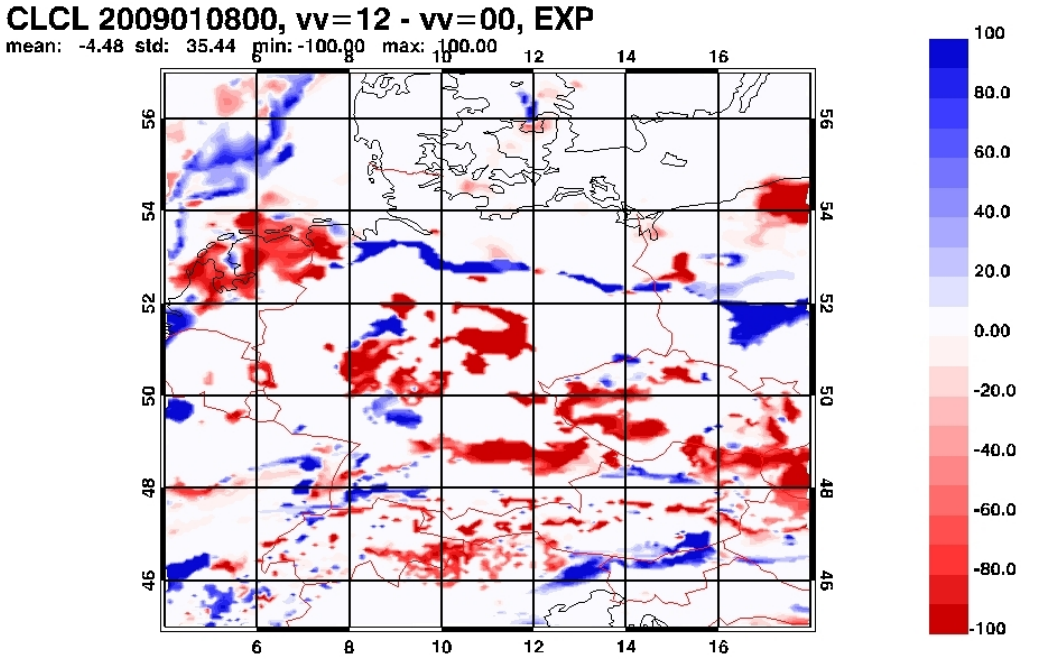


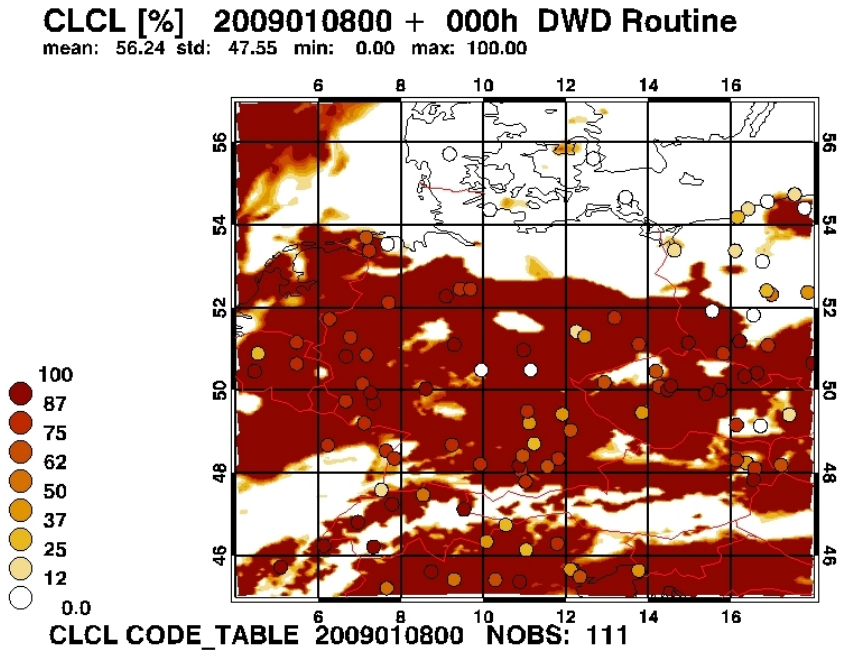


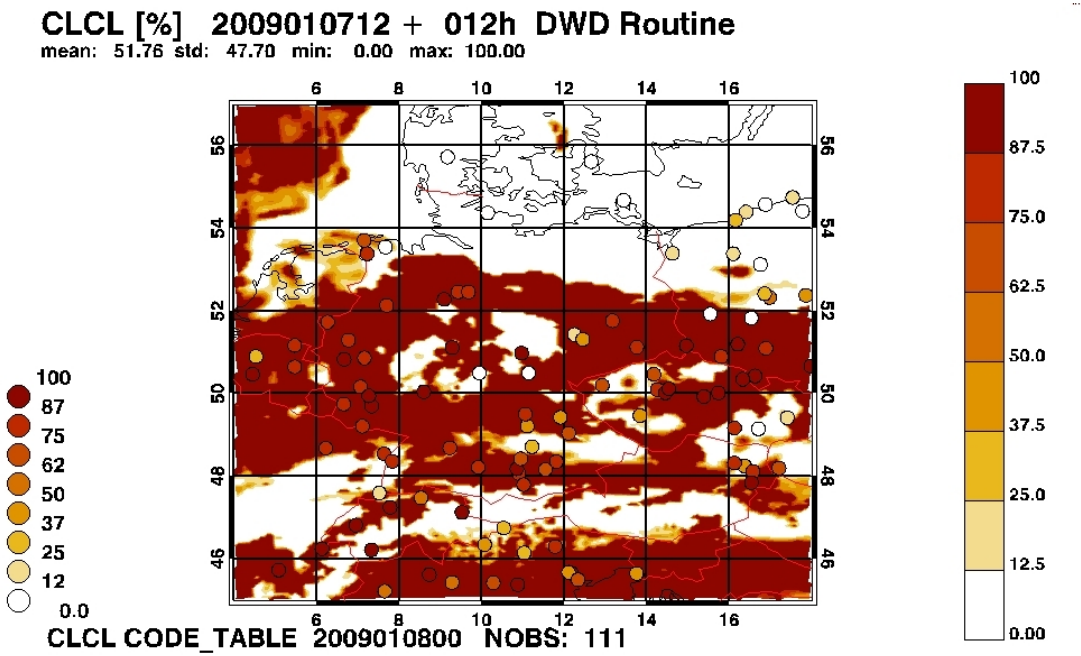


CLCL 2009010800 (COSMO-DE Domain)

Rou
Exp



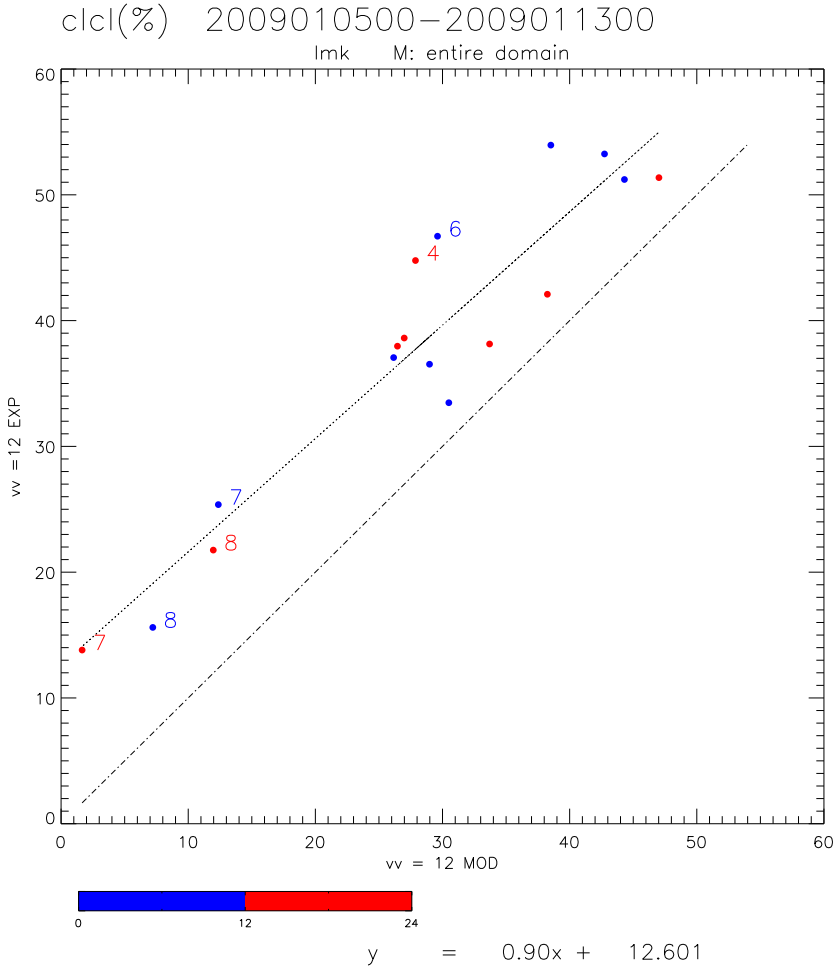




Monitoring 2009010500-2009011300 (COSMO-DE Domain)

Scatter plot (EXP vs. Operational forecast) indicates that we had at every instance at the 12h forecast a higher cloud cover.

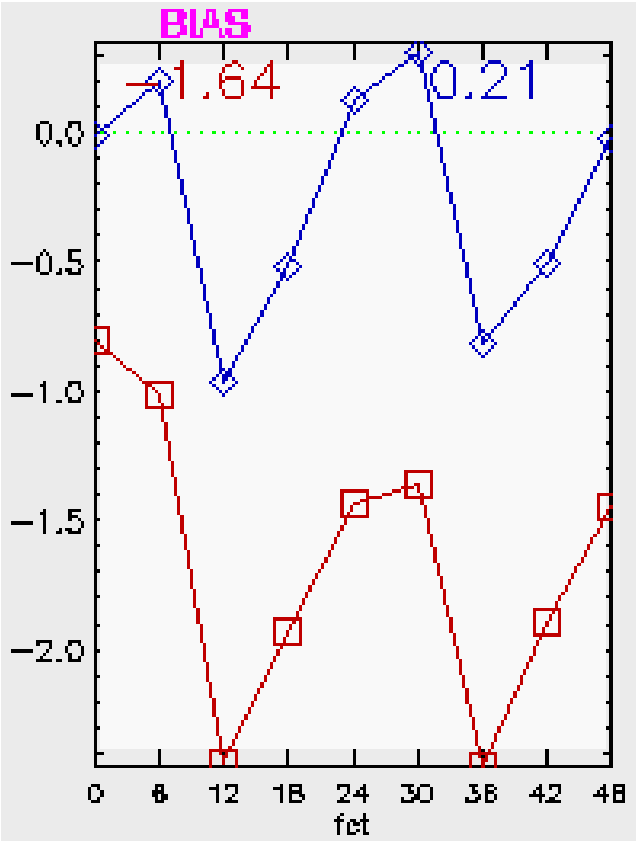
vv=12 EXP vs. vv=12 Operational forecast

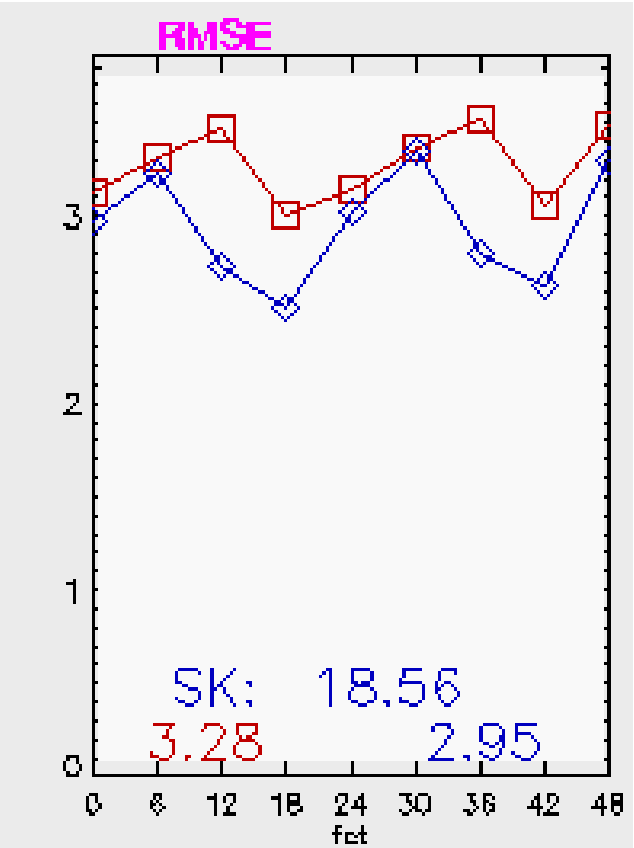


→ At every time step we had a higher cloud cover in the experiment compared to the operational model!

Official Verification T2m 2009010300-2009011400 Germany

Operational
Experiment





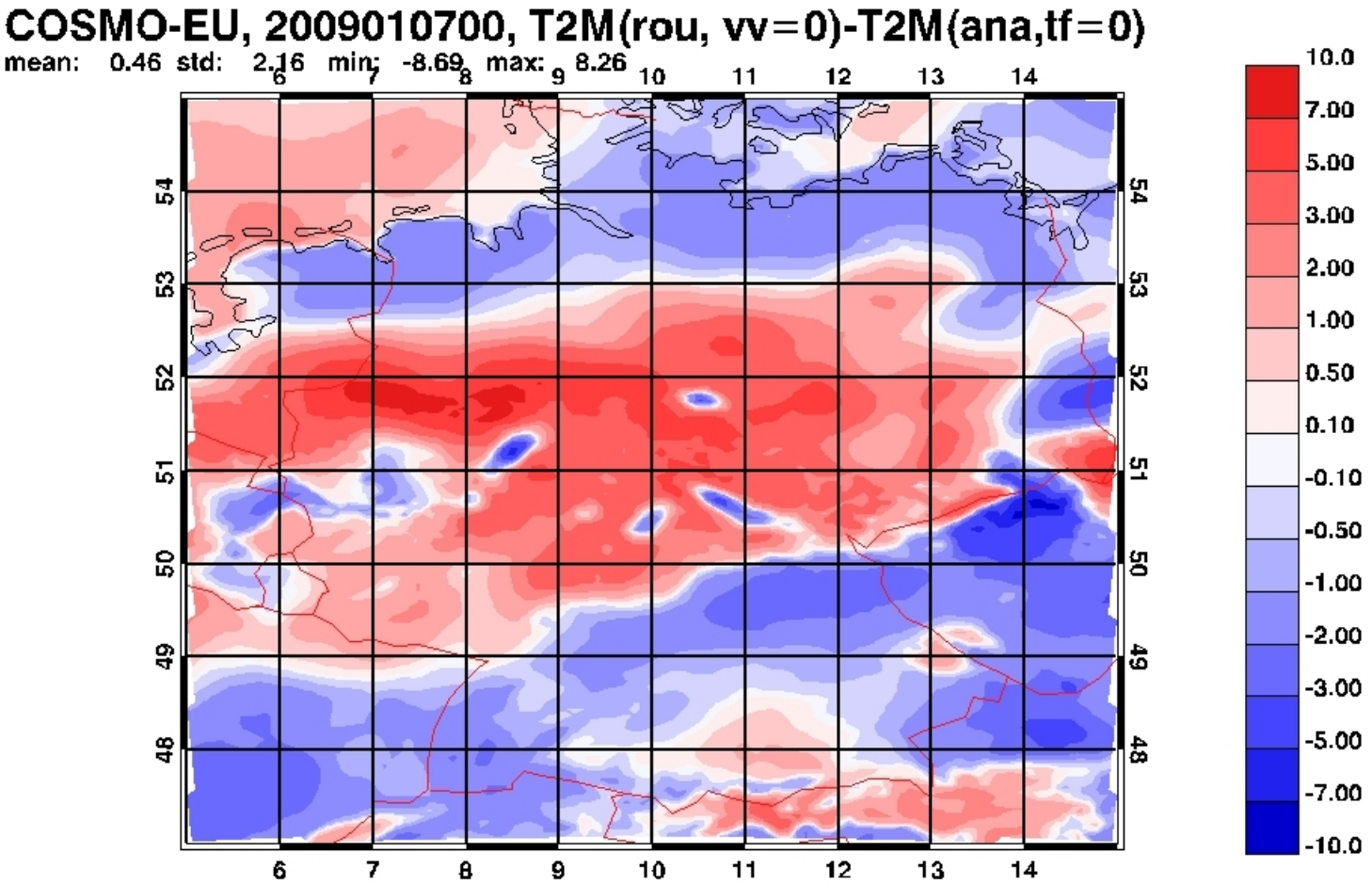
FBI in model and exp too high (2-δ distribution)
POD better in exp, FAR equal

- Operational forecast has almost no bias at 00-UTC!
- Experiment generally colder than operational forecast

Notice: Verification takes only synoptical stations into account

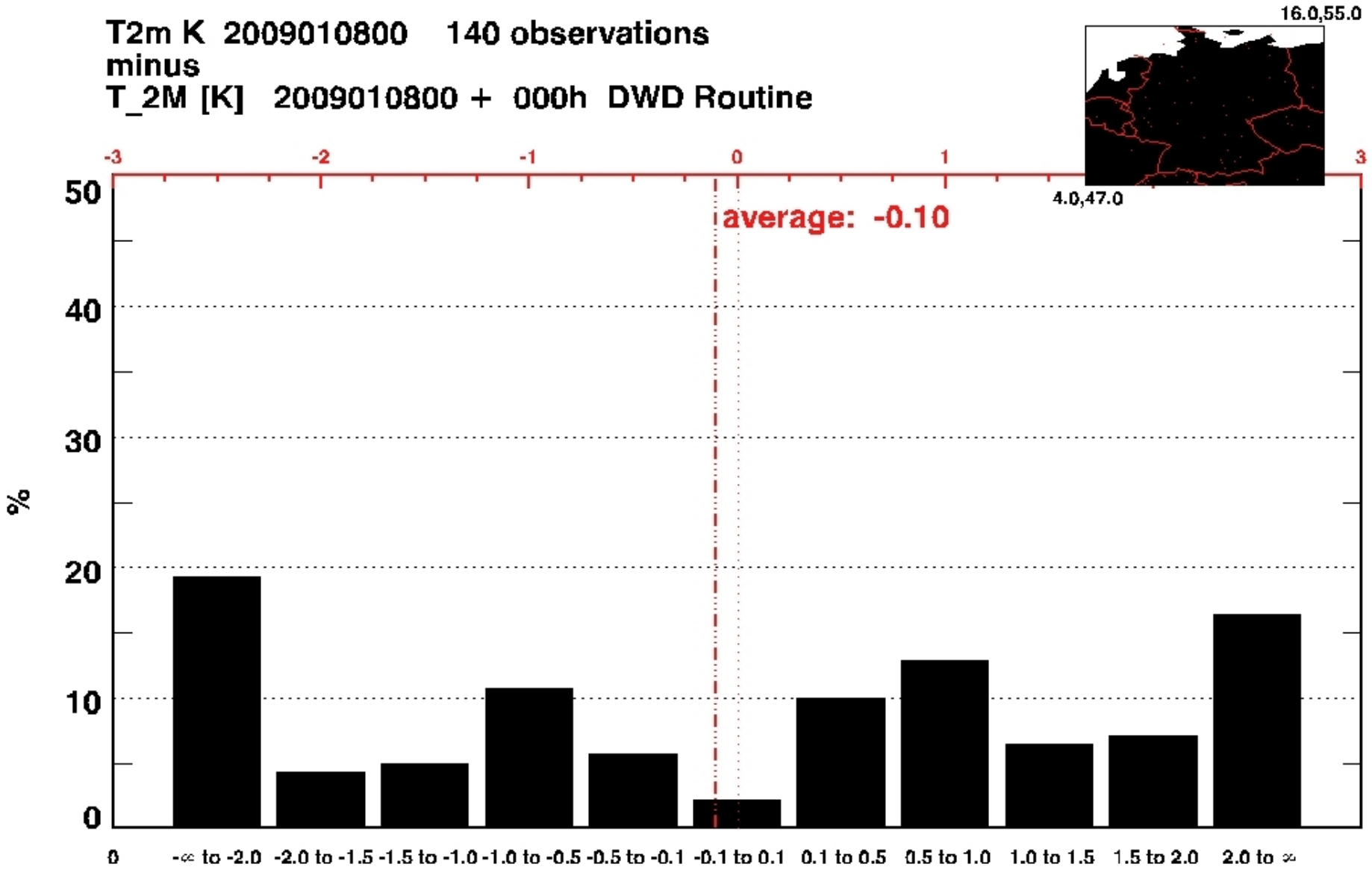
T2m 2009010700 Difference plot

Operational forecast (vv=0) – Analyse(tflag=0)



Notice: Good verification results only due to error compensation!

T2m 2009010800 HISTOGRAMM



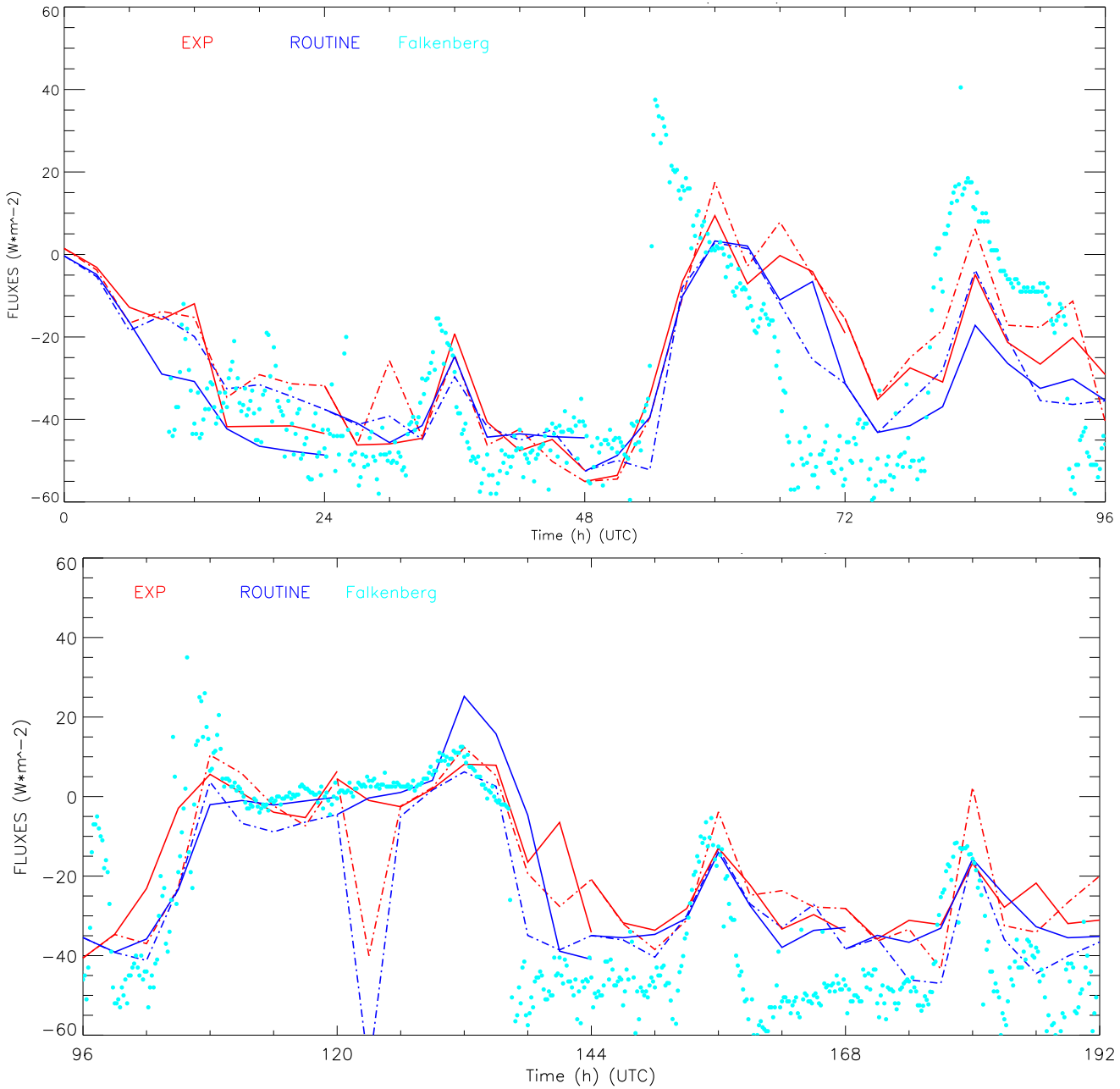
Histogram from difference in T2m between synoptical Observations and operational forecast. Almost **no events at the mean**, most of the **events fall in the extrema!**

Lindenberg results (reduced diffusivity coefficients)

Experiment:

- **Surface temperate** fits better the observations (upto 7K)
- **Long wave radiation budget** fits better the observations
- **Sensible heat flux** fits better the observations (average gain of $8.5W/m^2$)
- **Temperature Profile** fits better the observations

Lindenberg: Flux budget (2009010500-2009011300)



Interesting: Budgets are similar, only because of the **compensating errors** of long wave radiation and sensible heat flux in the **Model!**

Results of EXP (reduced diffusion coefficients)

POSITIVE:

In entire COSMO-DE domain:

- The tendency of the PBL clouds to disappear decreases

Lindenberg:

- **Surface temperate** fits **better** the observations
- **Long wave radiation budget** fits **better** the observations
- **Sensible heat flux** fits **better** the observations
- **Temperature Profile** fits **better** the observations

NEGATIVE:

In entire COSMO-DE domain:

- **Negative Bias in T2m**
- RMSE in T2m slightly increased

→ At this moment we can not introduce the reduced minimal diffusion coeficients!

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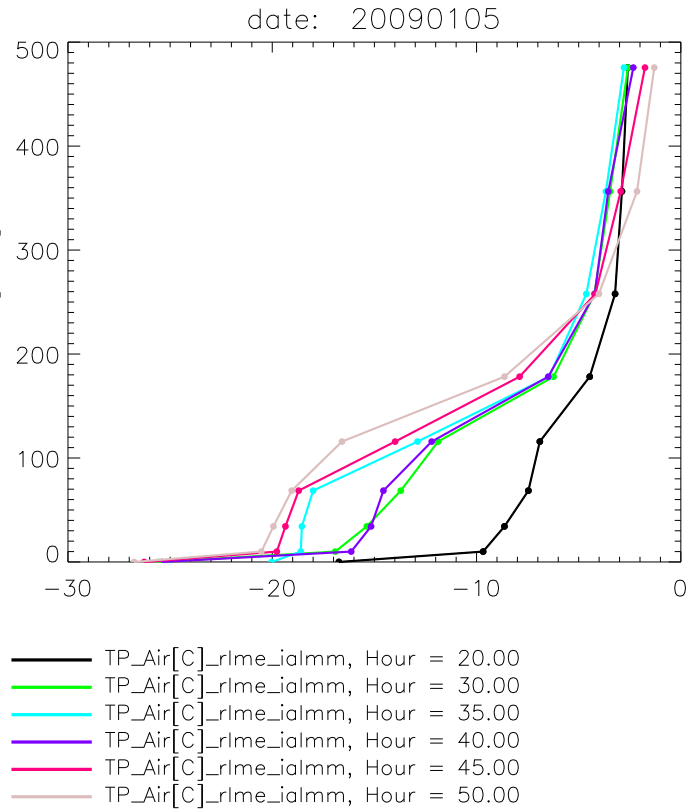
SCM: sensitivity to reduced minimal diffusivity (2009010512-2009010712)

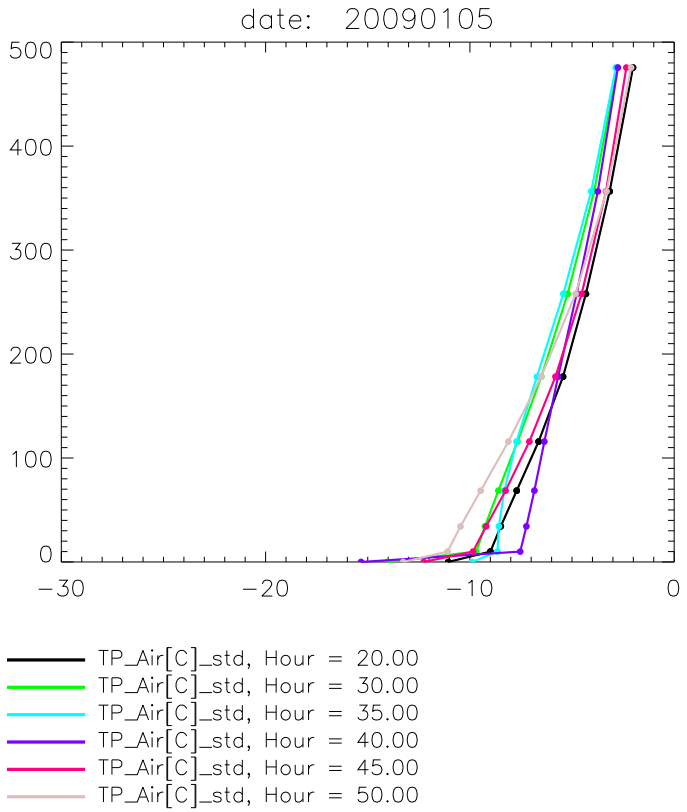
The measure field of the observatory was completely snow covered (8cm)

First the θ-**Profile** of the operational forecast where compared to observations

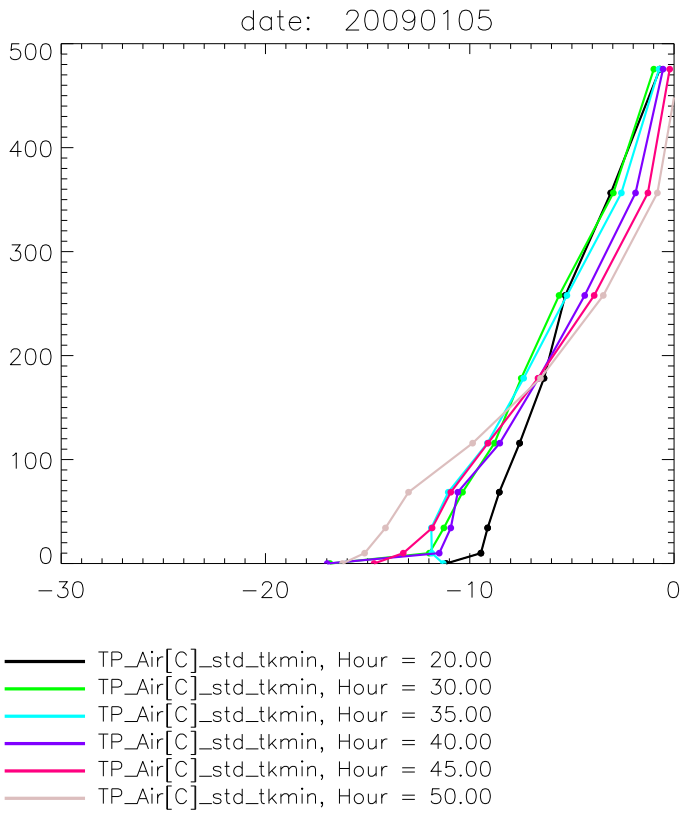
Observations



Operational forecast



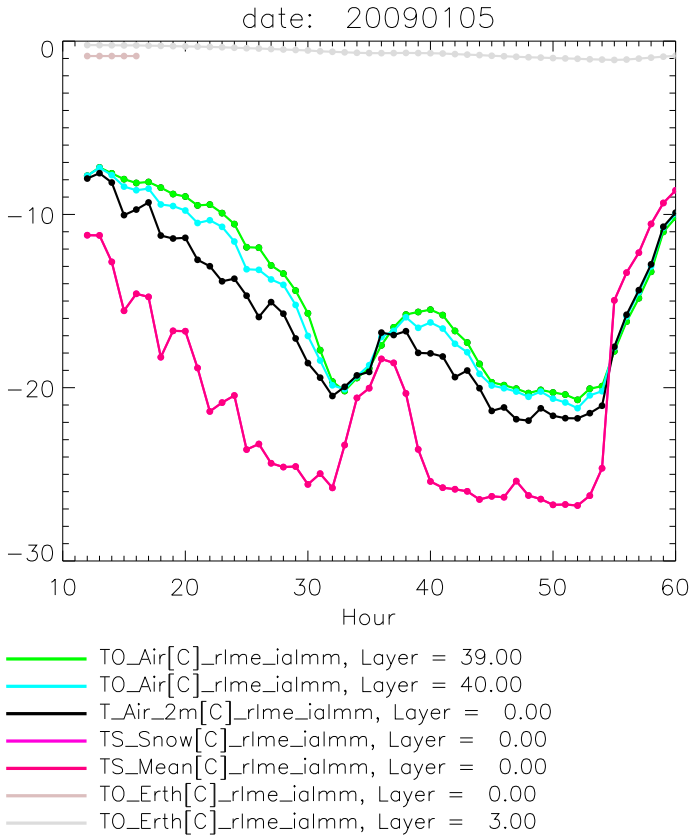
reduced min. diffusivity



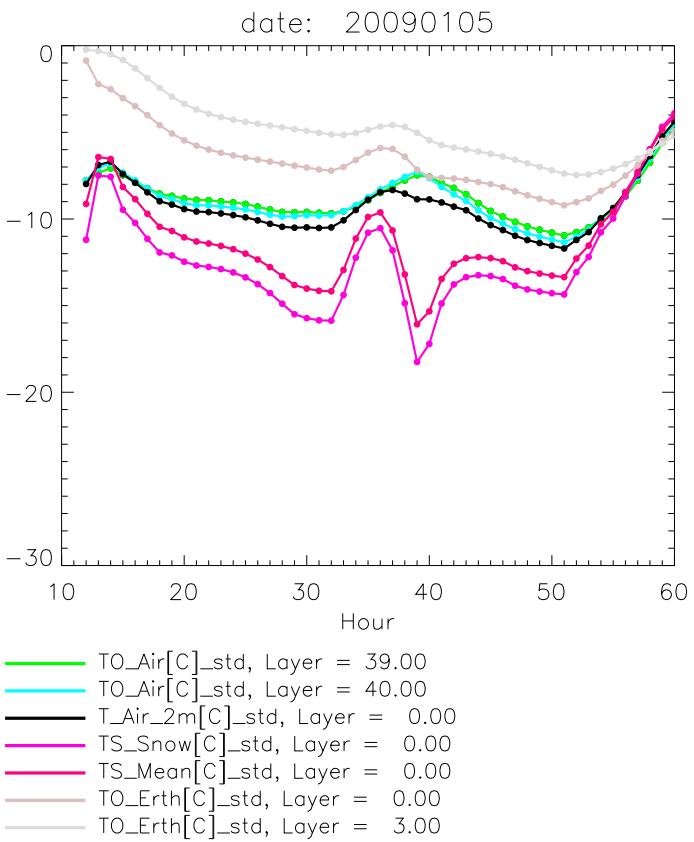
Reduced minimal diffusivity give a more realistic θ profile

SCM: near surface behaviour (2009010512-2009010712)

Observations (T)



Operational forecast (T)



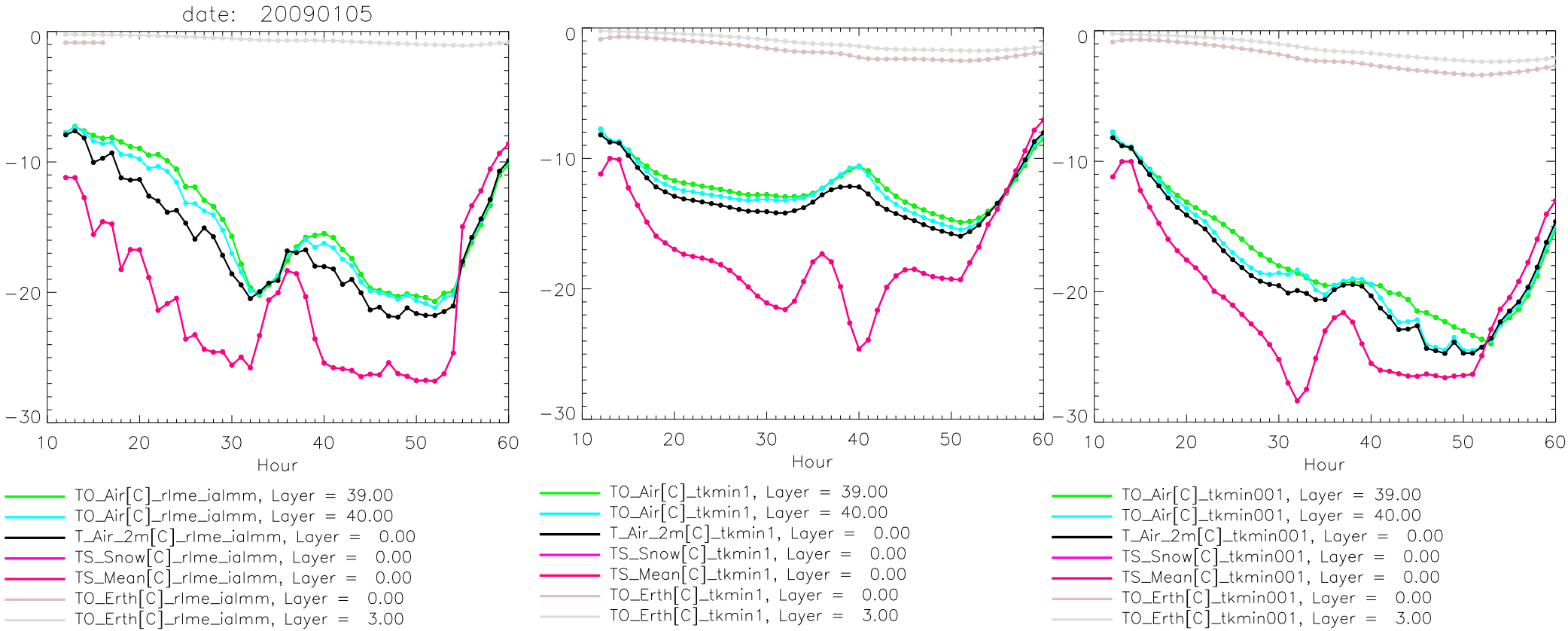
→ snow cover **partial** (Tsnow $\neq$ Ts), snow conduction to high, Tsnow don't react intense enough to short wave radiation (2nd day)

Changed

Partial snow cover:	Increase threshold coefficient (cf_snow) regarding snow cover
Snow conductivity:	Snow layer + 50cm
Radiation sensitivity:	Linear extrapolation → Polynomial extrapolation

SCM: near surface behaviour (2009010512-2009010712)

Observations Modifications operational Modifications & red. min. diff.

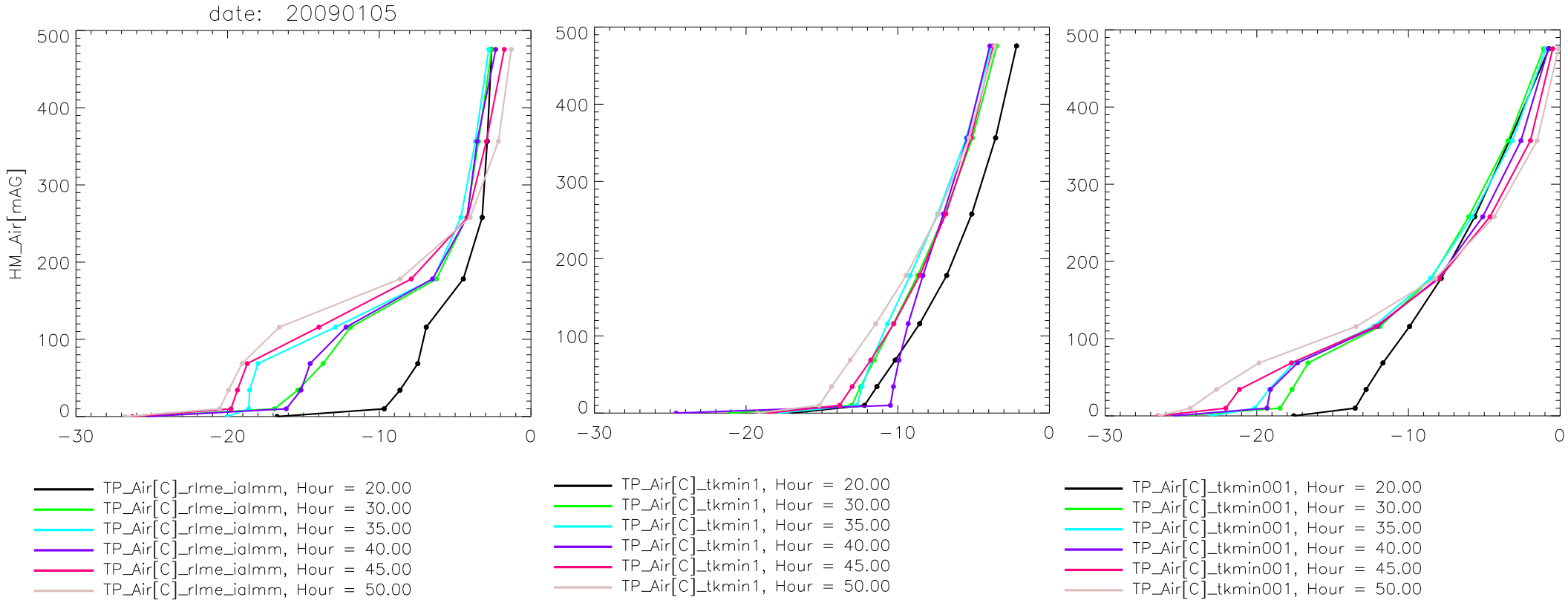


With reduced min. diffusivity the surface temperature fits better with observations. Coupling between surface and low atmosphere is to strong in the second part of the simulation due to too high fluxes

SCM: reduced minimal diffusivity (2009010512-2009010712)

First the θ-**Profile** of the operational forecast

Observations Modifications operational Modifications & red. min. diff.

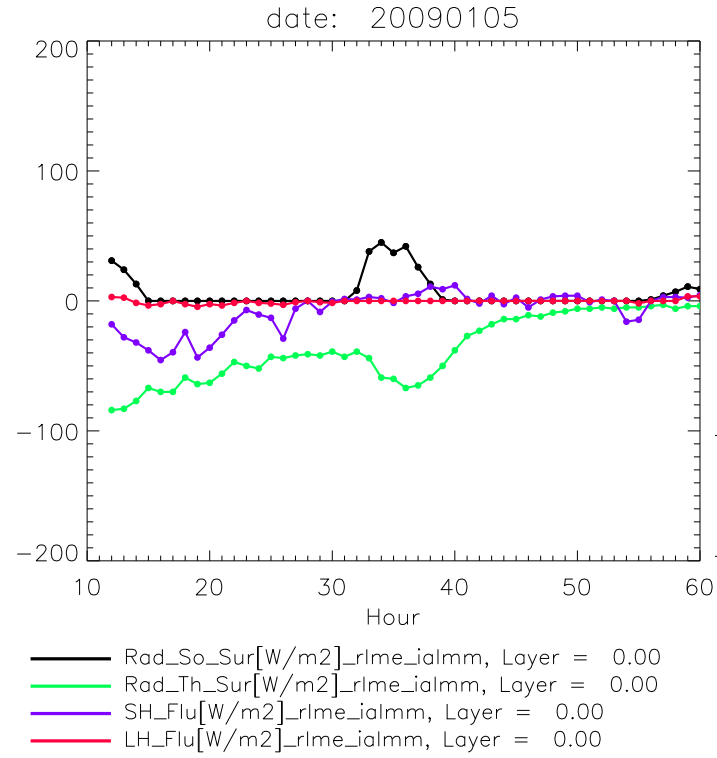


With **reduced minimal diffusivity the structure fits better** the observations

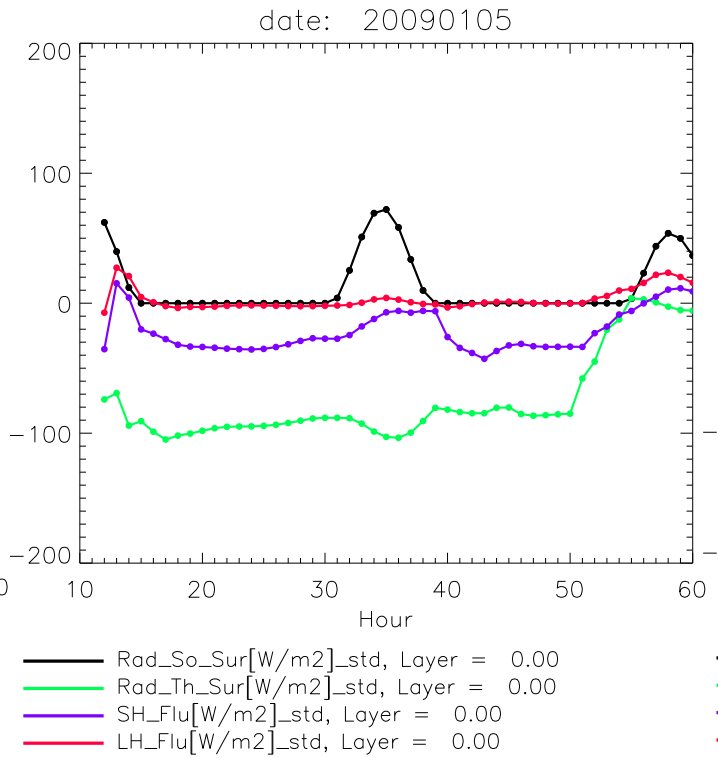
SCM at Lindenberg: Period 2009010512-2009010712

Surface fluxes:

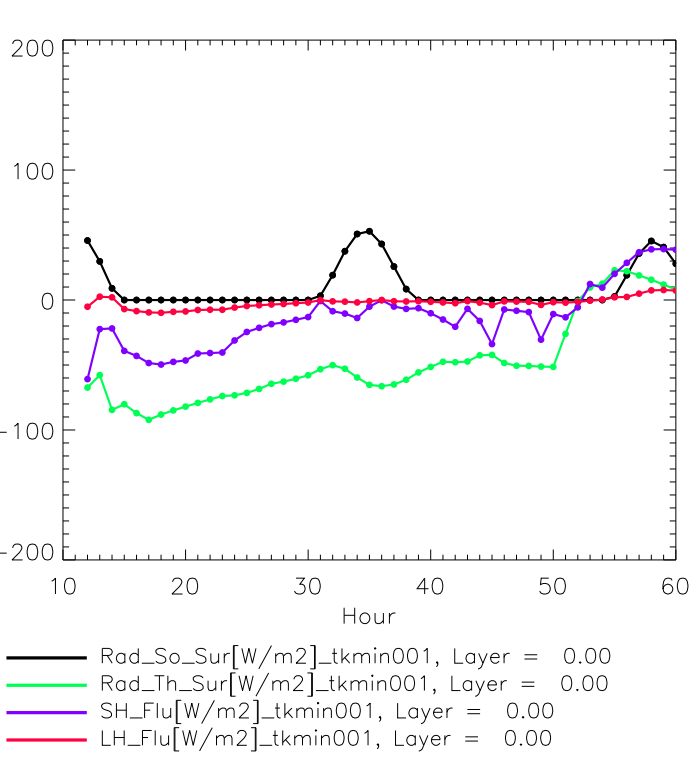
Observations



Modifications Operational



Modifications & red. min. diff.



Sensible heat flux operational too high with reduced minimal diffusivity better

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Near surface behaviour at Lindenberg, overview

A T2m error can be caused by:

- T10m a/o T surface error
- Interpolation error

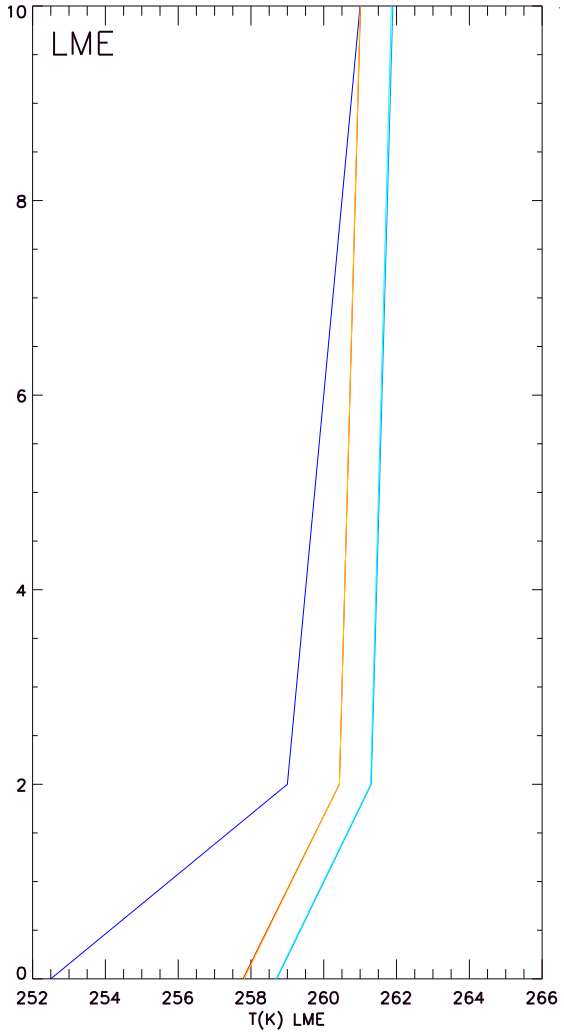
We noticed a large positive bias in the surface temperature Tg between observations and the operational forecast in January 2009

We assume in stable stratified layers at 10m the smallest errors and at the surface the largest

→ We suspect that the problem in a great part is caused by the soil

Possible solutions are:

- Component testing with SCM
- Initial Soil correction at 00-UTC with T2m error



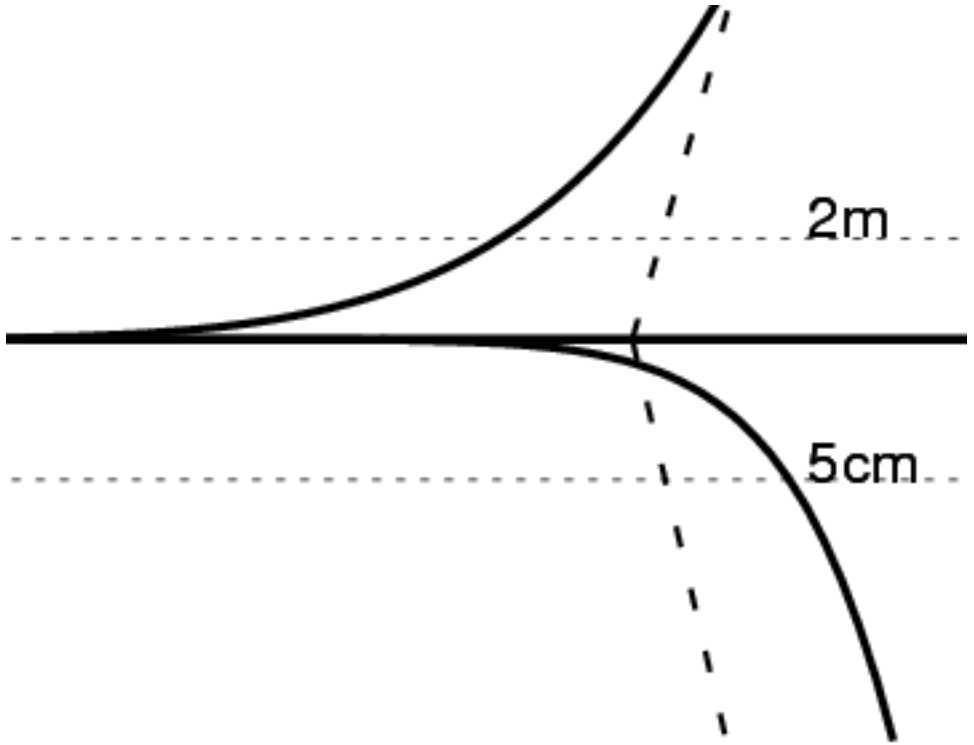
2009010600
vv=06
vv=12
Lindenberg

Cosmo vs. Lindenberg data (20081001-20090531)

A long term analysis shows a too diffusive atmosphere and a too conductive soil (at least at Lindenberg).

E.g. in a stable stratified PBL we can expect a schematic temperature profile near the surface:

Model:	Dashed
Observations:	Solid line



If we use the two meter temperature difference to correct the soil temperature we risk to make the soil temperature bias even bigger. We have to be careful to the correction parameters.

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Conclusions and ongoing work

Conclusion

- **Minimun diffusion coefficients should be reduced to maintain the PBL clouds and to improve the PBL temperature structure**
- **Apart from PBL clouds, reduced minimum diffusion coefficients improve the forecast of the PBL temperature structure, of the surface temperature, and of the components of the surface energy budget**
- The deep soil layers in the COSMO model are coupled too tightly with the atmospheric surface layer (the soil heat conductivity seems to be too high)

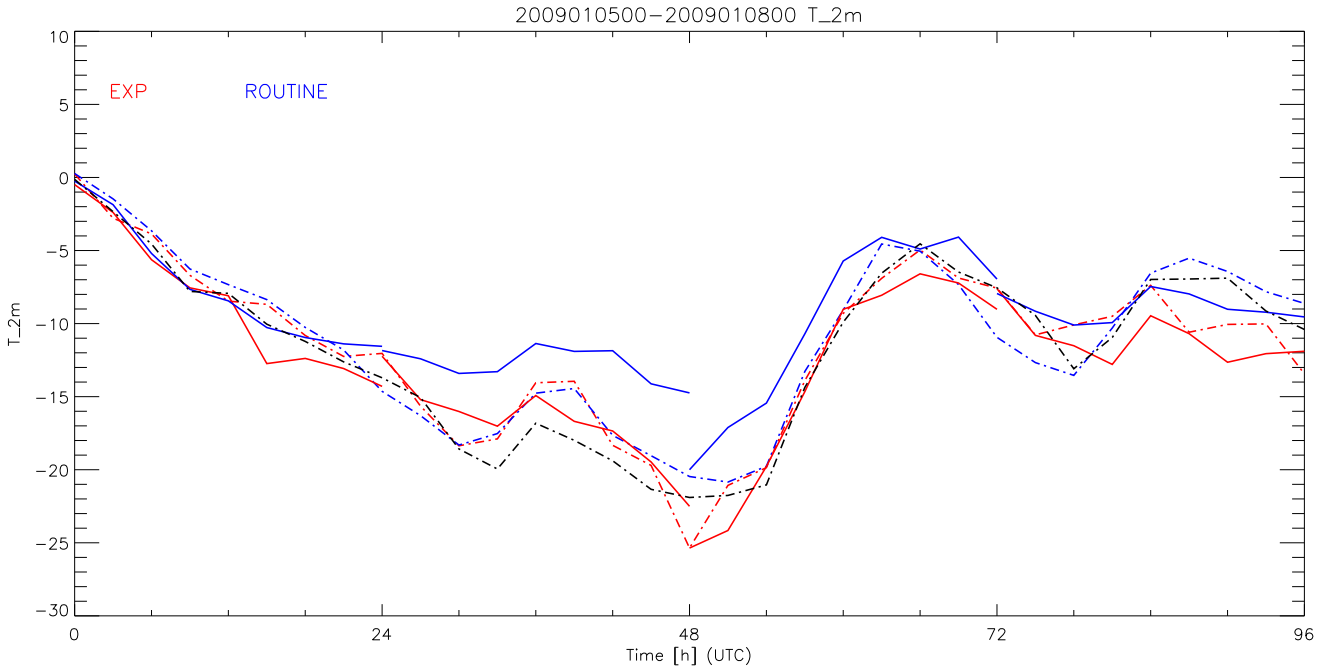
Ongoing work

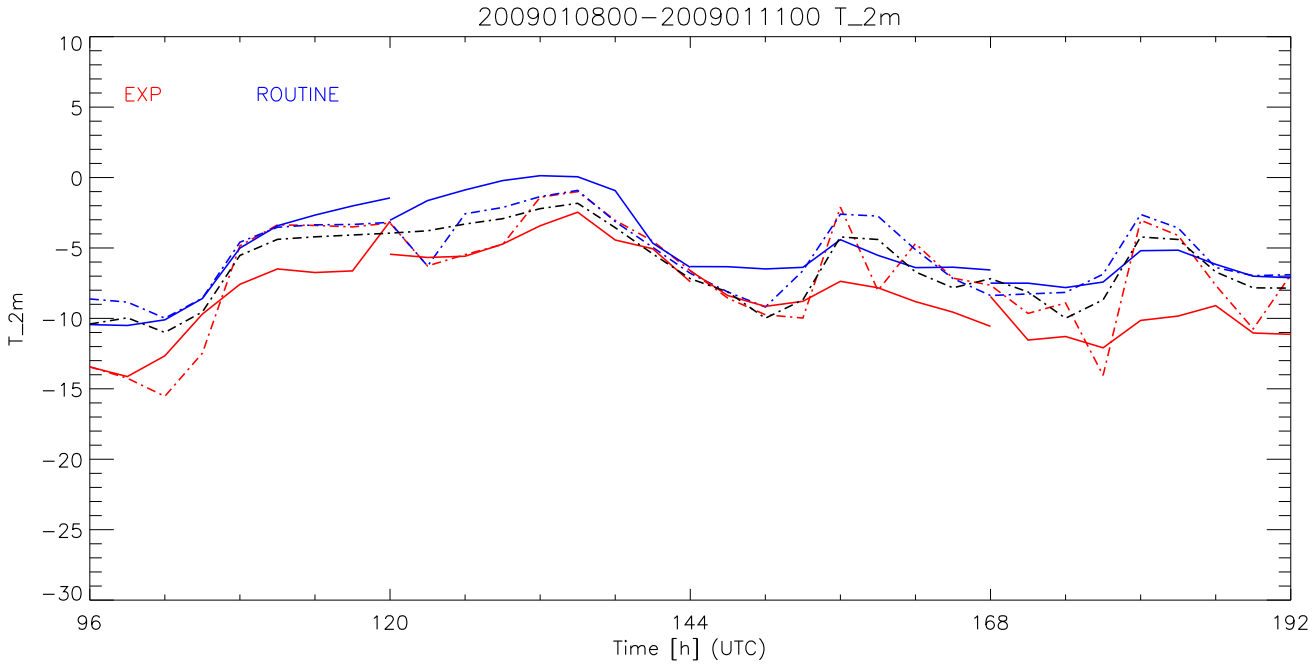
1) Sensitivity experiments with modified soil heat conductivity (the perpetual-year solutions hold promise)
2) Component testing againts available observational data
3) Correction to the soil temperature profile as dependent of the T2m forecast/analysis error

Lindenberg: T2m (2009010500-2009011300)

EU_00UTC
Experiment
Falkenberg

Ana: Dotted
VV: Solid



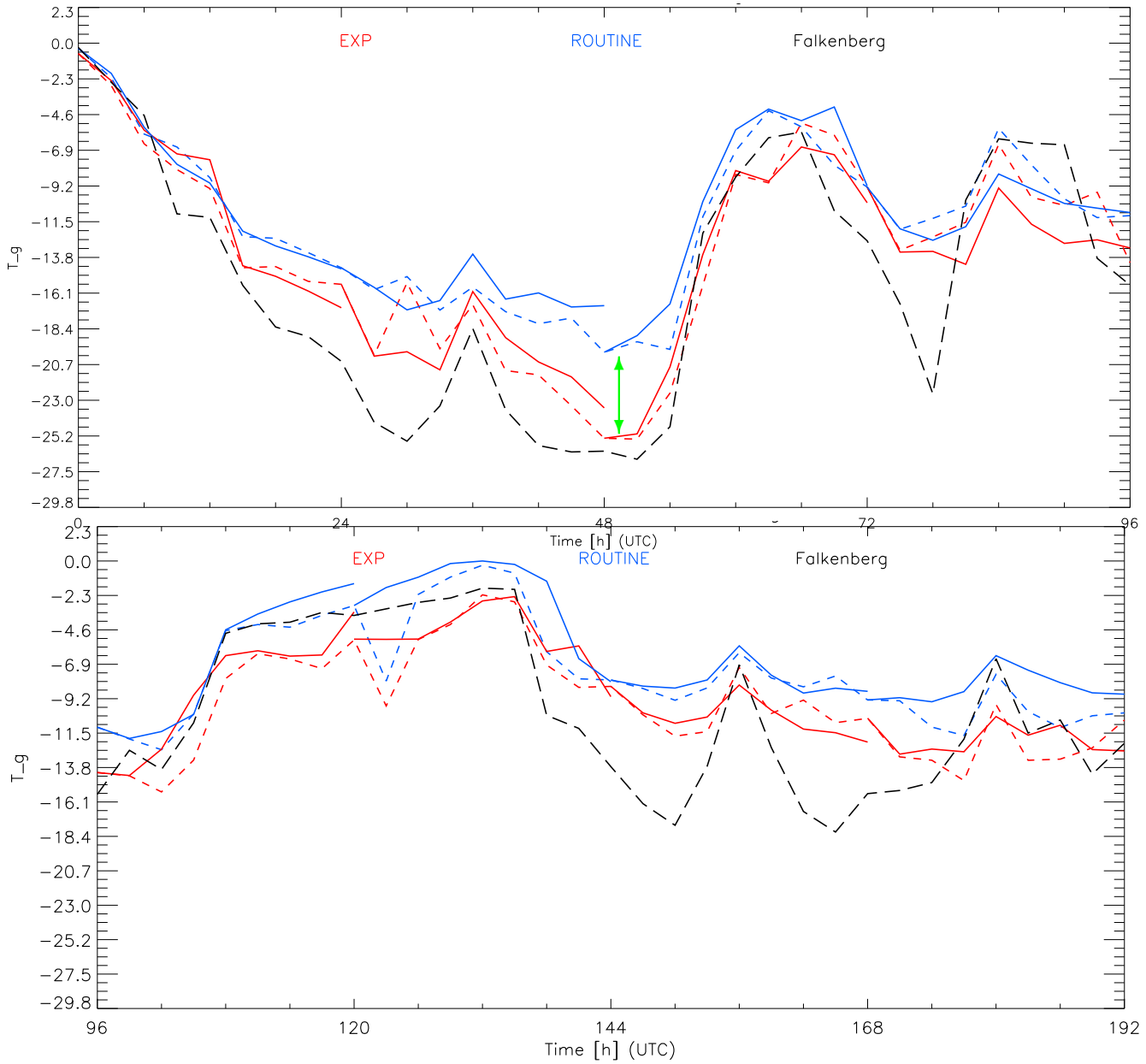


At Lindenberg the T2m of the experiment fits better in the first part and gets too low in the second part of the observed period

Lindenberg: Surface Temperature (Tg) (2009010500-2009011300)

EU_00UTC
Experiment
Falkenberg

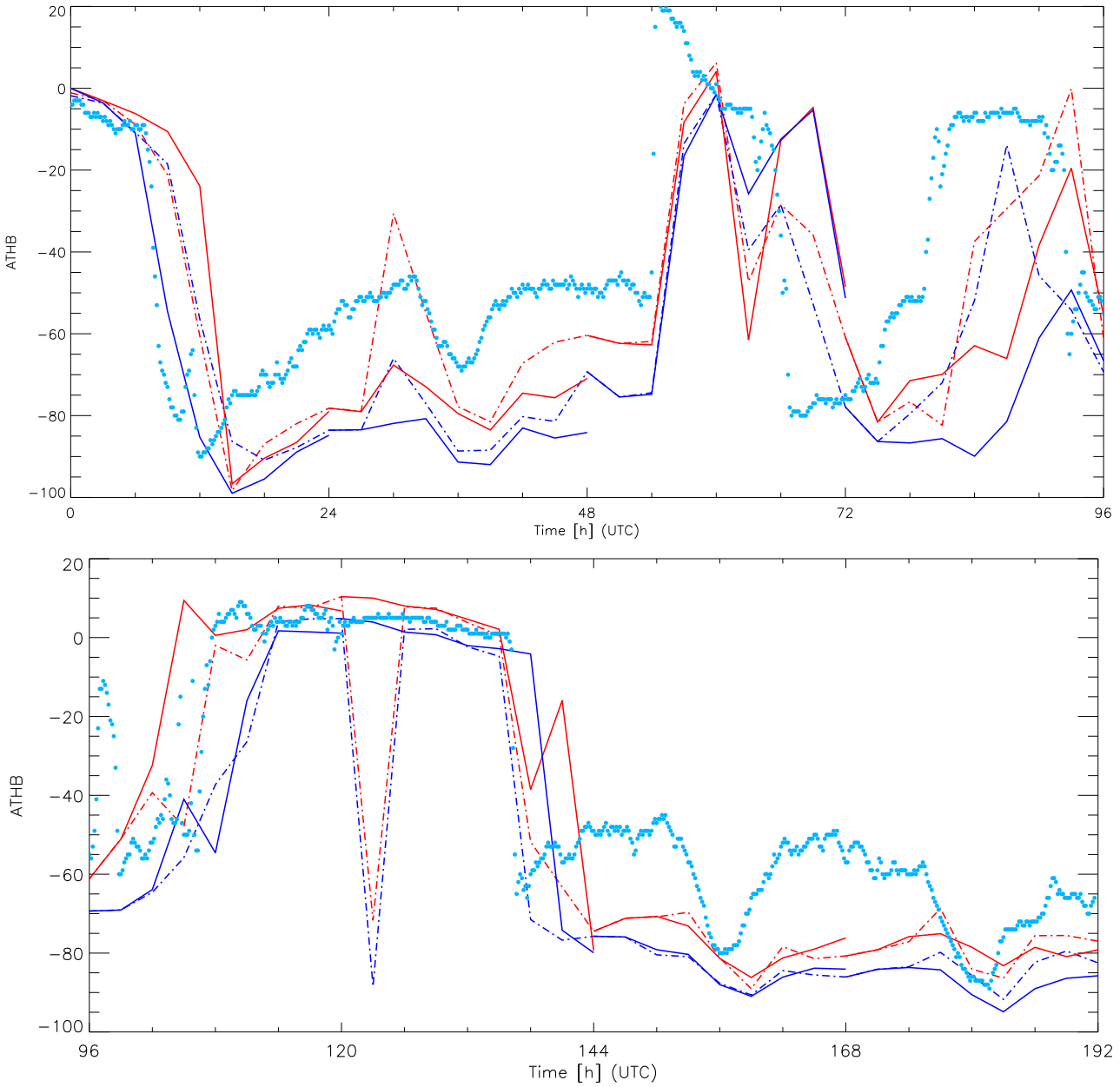
Ana: Dotted
VV: Solid



The difference in Tg between Exp and Operational run is up to **7K**.
The experiment is closer to observations! → Long wave outgoing radiation is better!

Lindenberg: Long wave rad. Budget (2009010500-2009011300)

EU 00-UTC
Experiment
Lindenberg



A net income longwave radiation budget is defined positive.
We notice the consequence of the lower surface temperature.

Lindenberg: Sensible heatflux (2009010500-2009011300)

Bias:

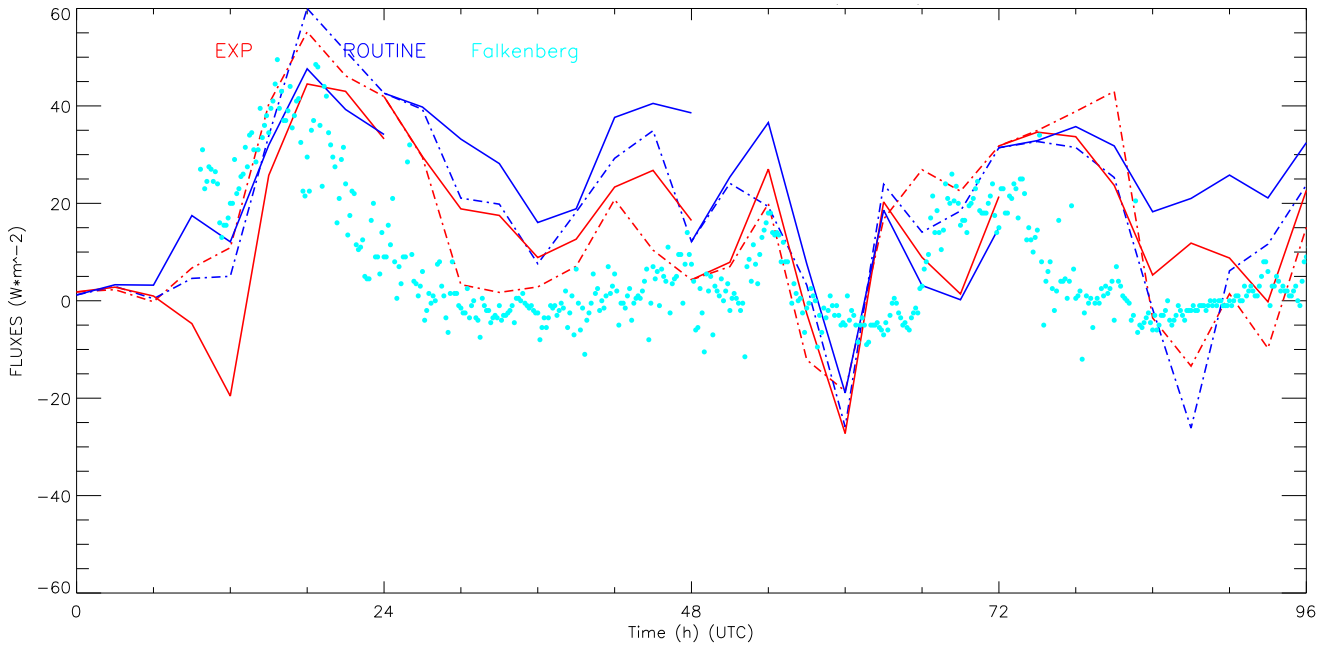
Exp−Rou	-8.50
Rou−Falk	29.57
Exp−Falk	21.07

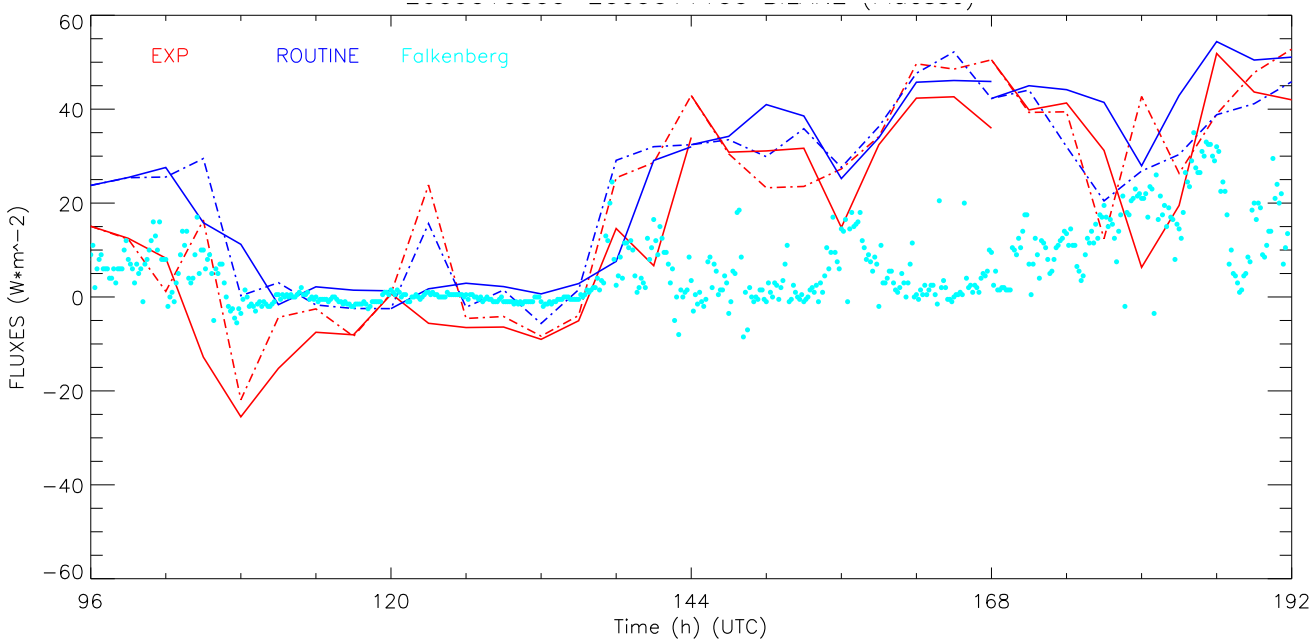
RMS:

Exp−Rou	12.31
Rou−Falk	36.89
Exp−Falk	31.32

Skewness:

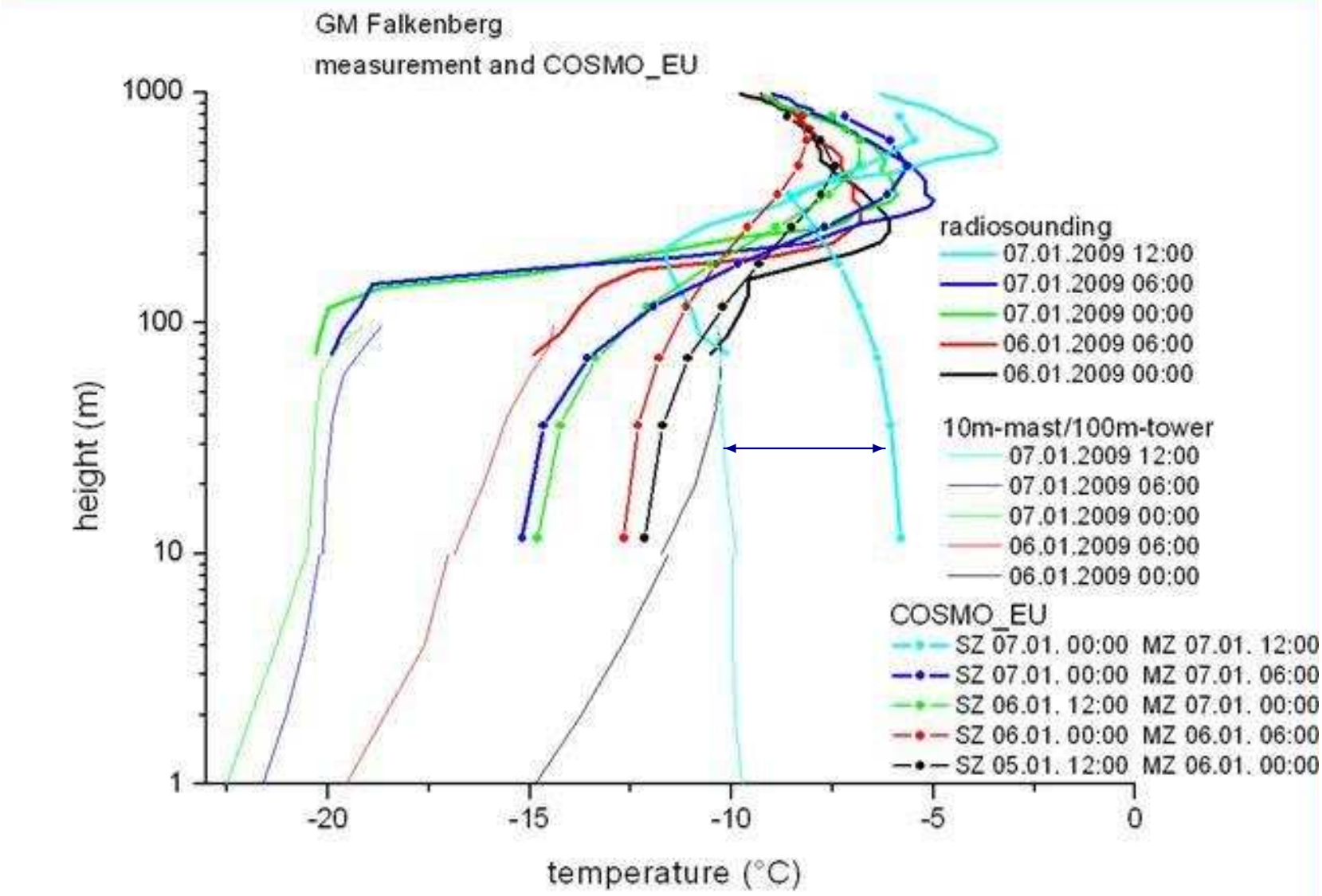
Exp−Rou	-1.72
Rou−Falk	1.41
Exp−Falk	1.48





Total bias (Exp-Rou) is $-8.5\mathrm{W/m^2}$! **Sensible heat flux fits better the obs!**

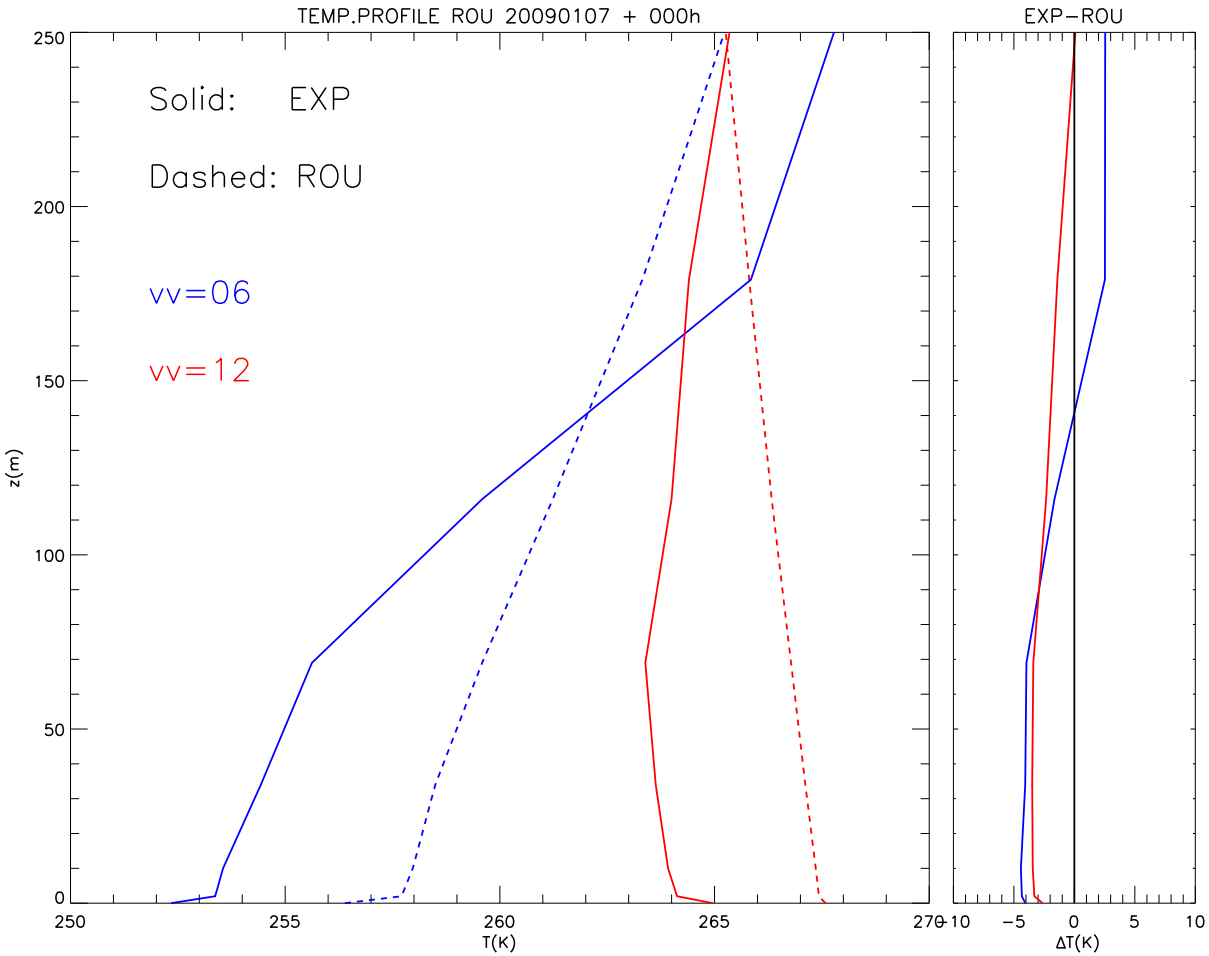
Lindenberg: Temperature Profile (2009010712)



In the 12h forecast from 2009010700 we have a difference of **5K** between observations and COSMO-EU!

Lindenberg: Temperature Profile, Routine and Experiment

Left: 2009010700+06h and 2009010700+12h
Right: Experiment - Operational forecast

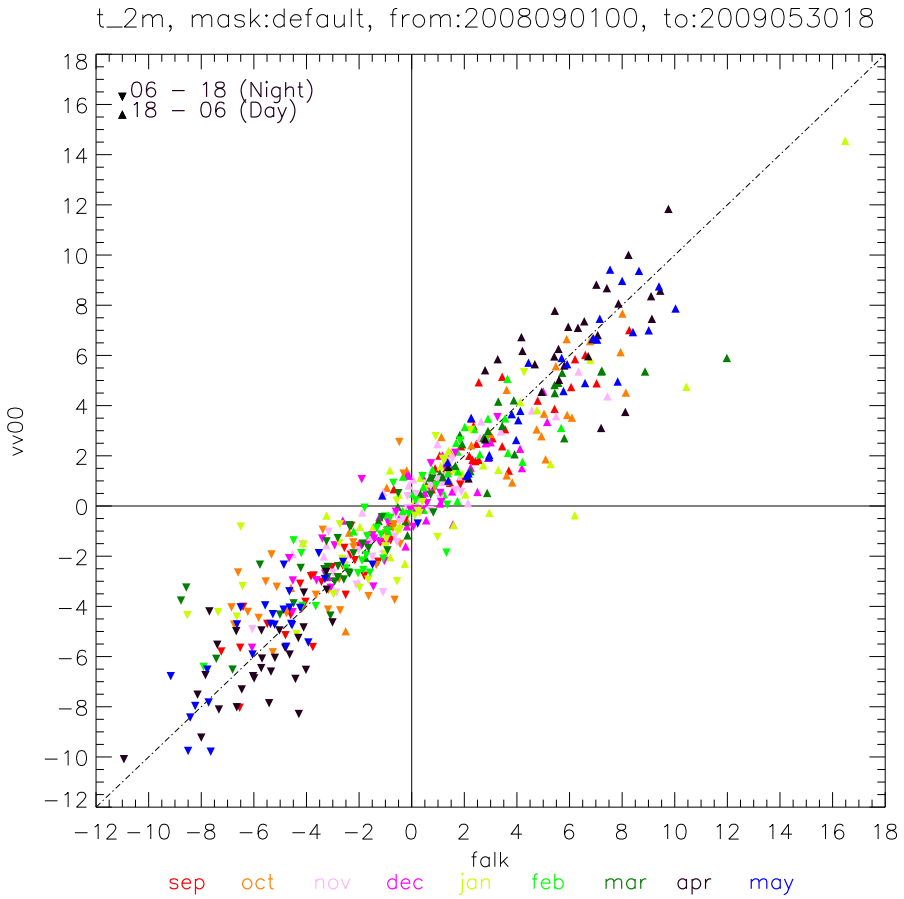


Difference between Experiment and operational model up to **4K**!

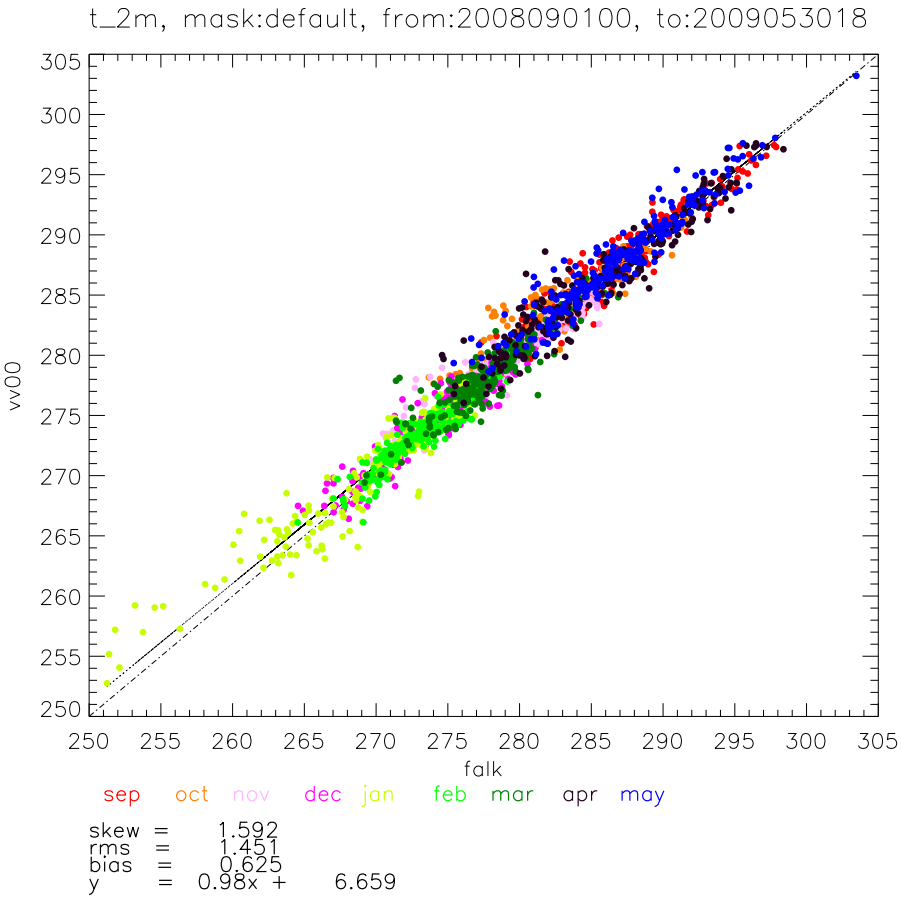
→ Temperature profile of experiment fits better to observations

T2M Cosmo vs. Lindenberg (20081001-20090531)

Left: Diurnal cycle plot



Right: scatter plot



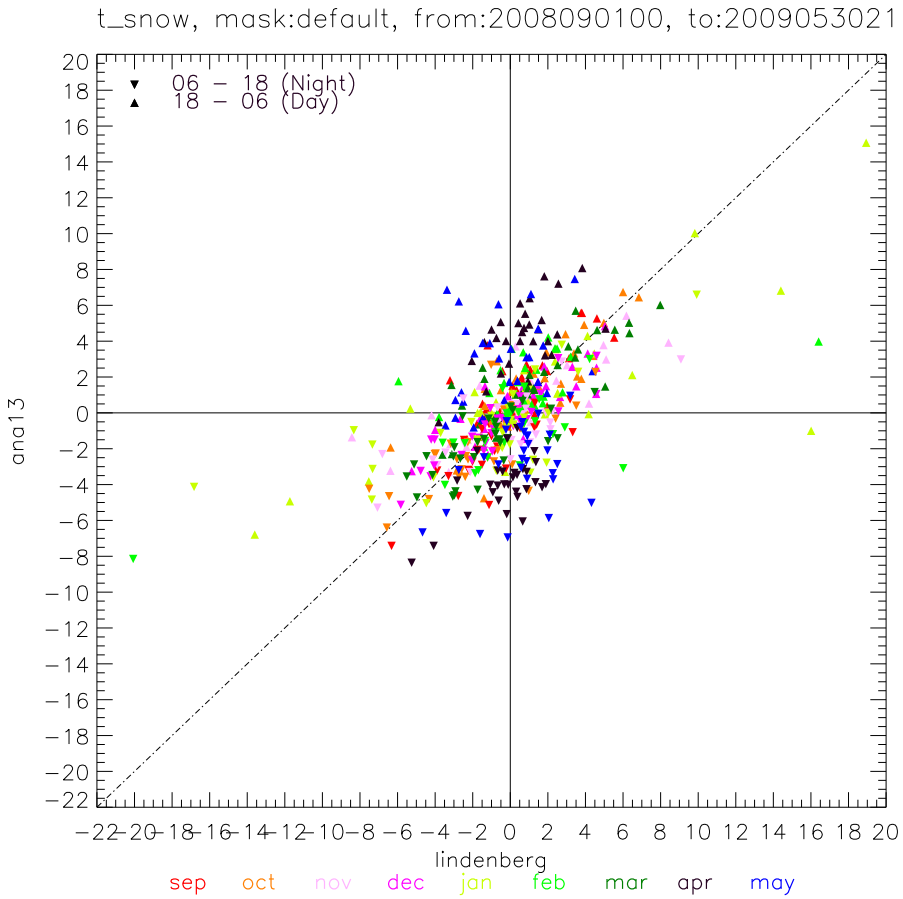
→ Diurnal cycle of T2m of model to small compared to observations and the model tends to overestimate T2m in a stable stratified PBL and vice versa

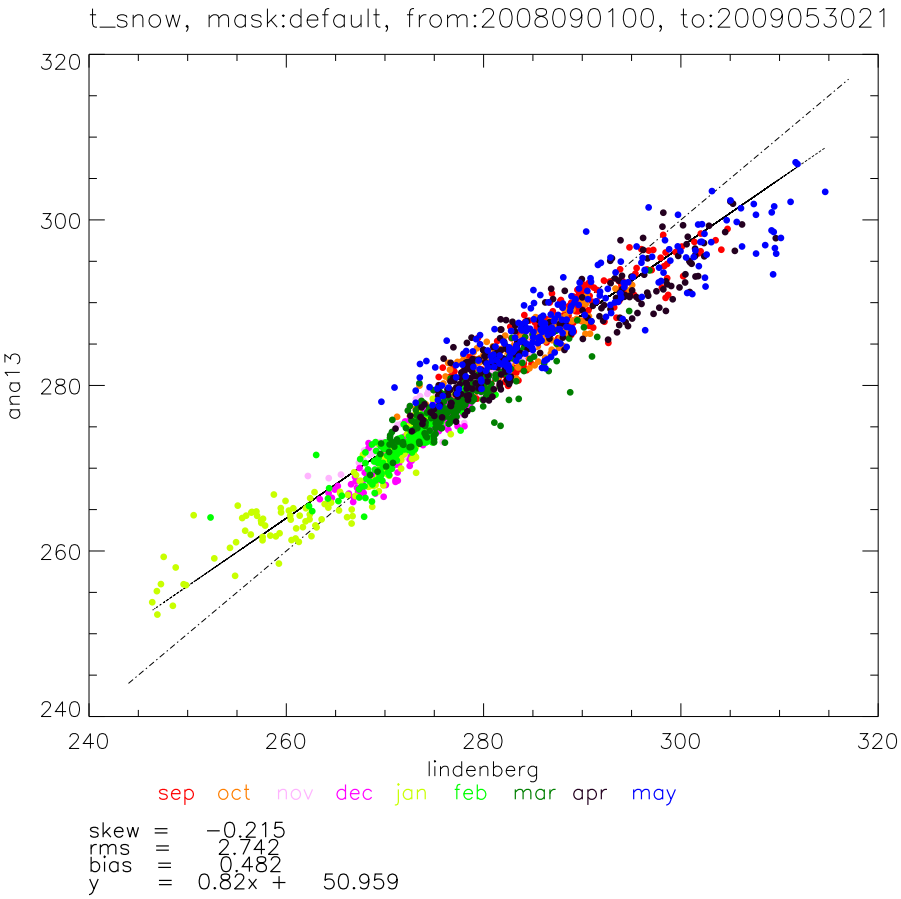
Tsnow Cosmo vs. Lindenberg (20081001-20090531)

Left: Diurnal cycle plot

Right: scatter plot

Tsnow is the surface Temperate (Tg) if no snow is present, else temperature on top of snow cover





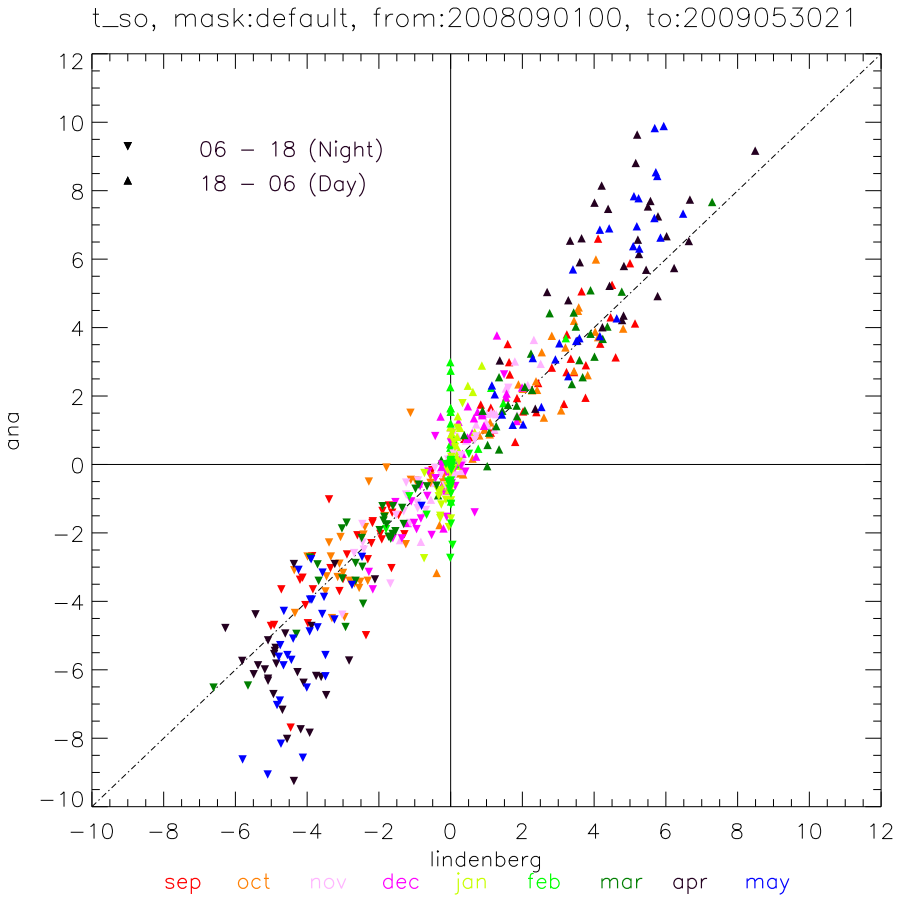
→ The tendency of the T2m behaviour is amplified, the surface temperature is too high in stable conditions

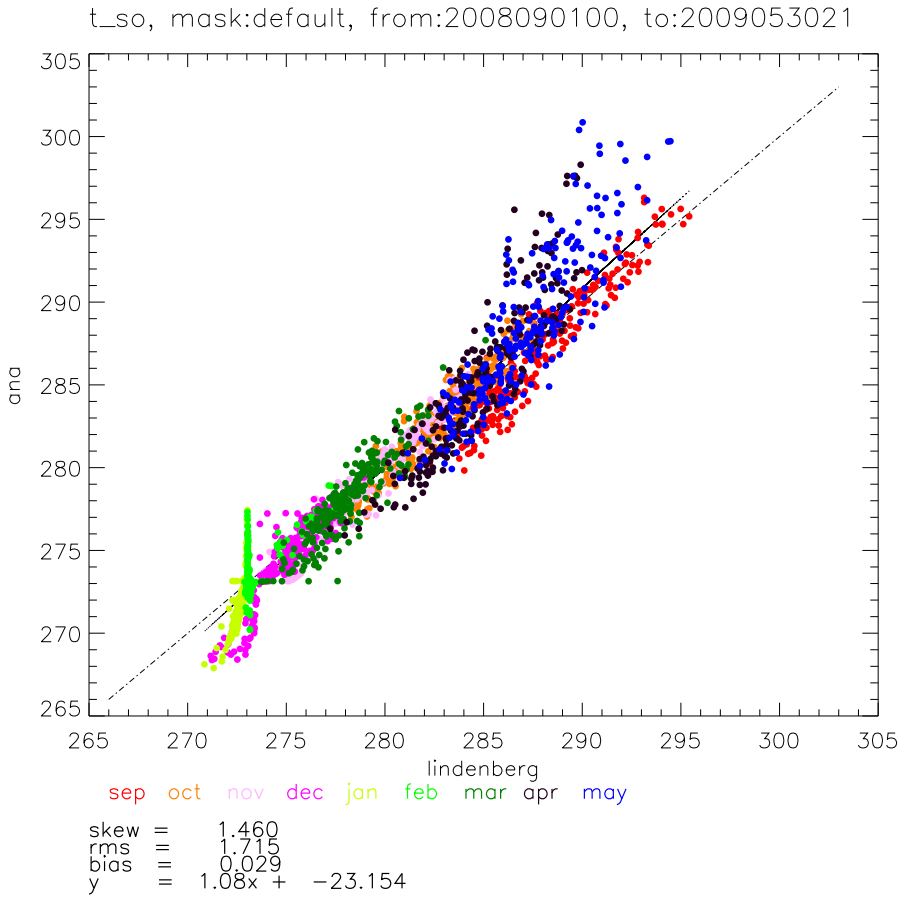
Tso(6cm) Cosmo vs. Lindenberg (20081001-20090531)

Left: Diurnal cycle plot

Right: scatter plot

Tso(6cm) is the soil temperature at 6cm, measurement where taken on 5cm





→ In the soil we have the opposite situation! The diurnal cycle is too high and in a stable stratified PBL the model temperature is below the observed one