On Θ-peaks and wild updrafts

Ulrich Blahak

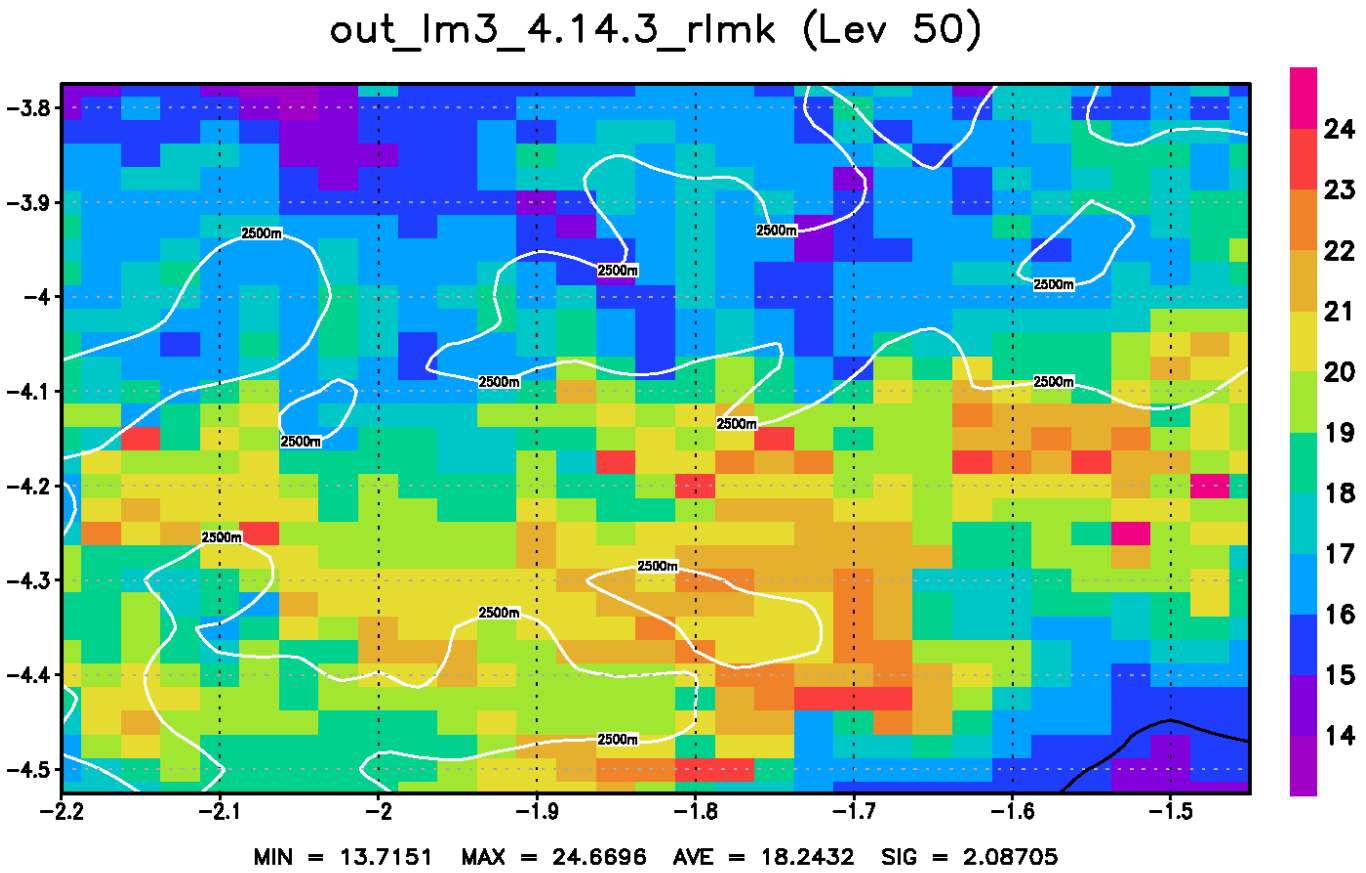
DWD

with warm thanks to Oliver Fuhrer, Matthias Raschendorfer and Bodo Ritter!

Problem

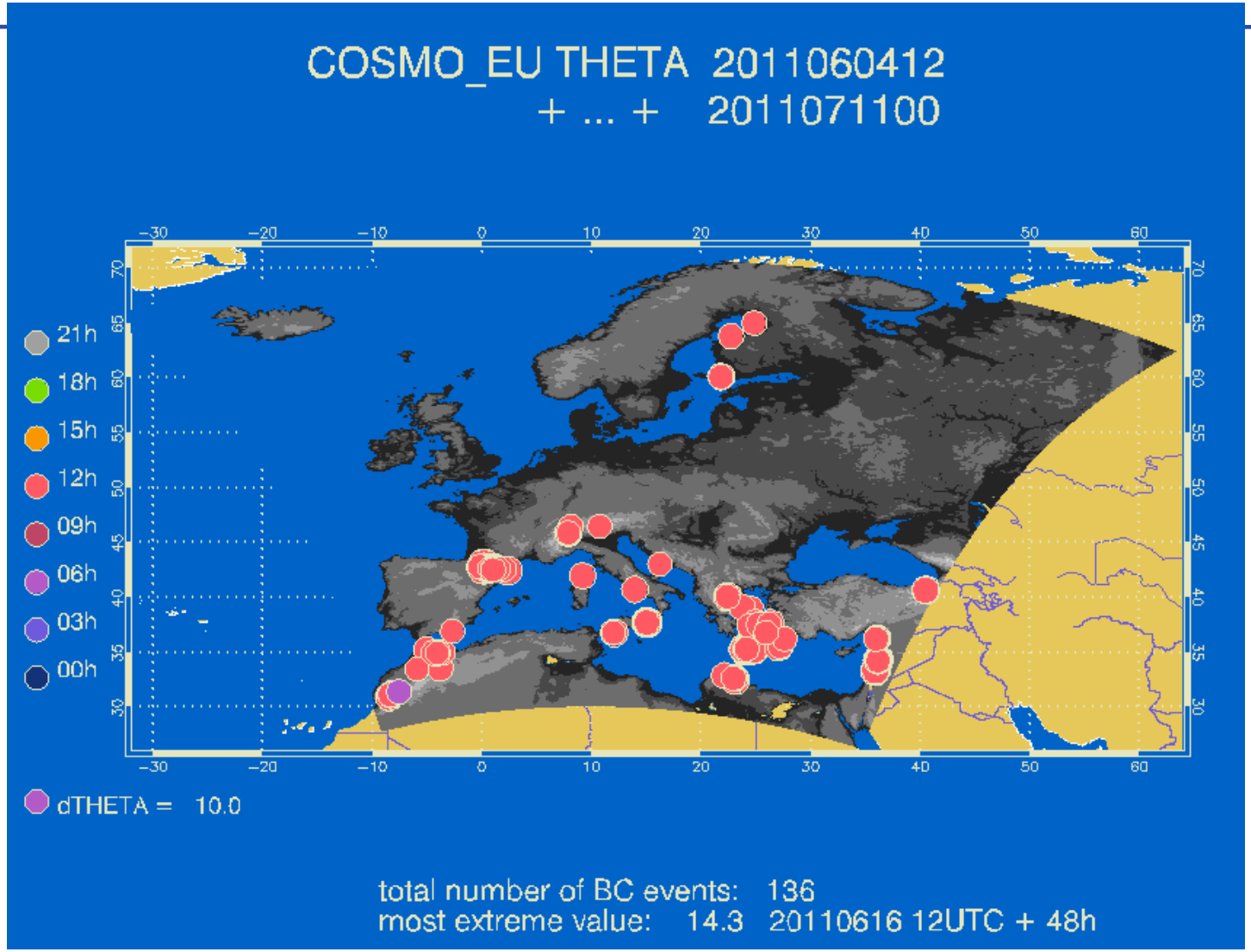
- The COSMO-model generates, in conjunction with small-scale thermally driven circulations, „strange“ effects such as isolated „Θ-peaks“ in alpine valleys, or as „grid point storms“ in mountaineous regions or at coasts (visible as isolated surface pixels with very high precipitation).

Problem



COSMO-DE 13.04.2011, 00 UTC + 11 h © M. Raschendorfer

Problem



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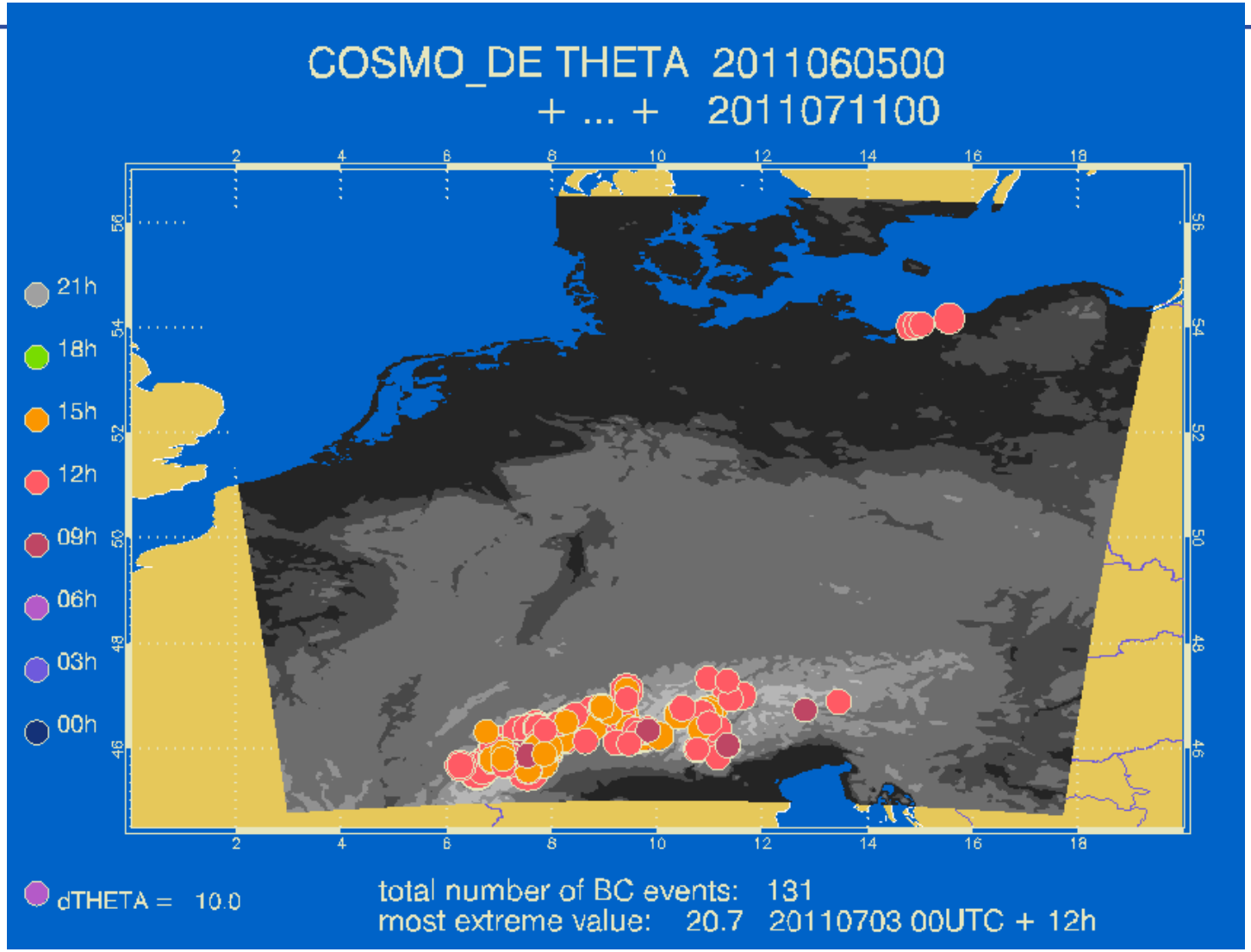

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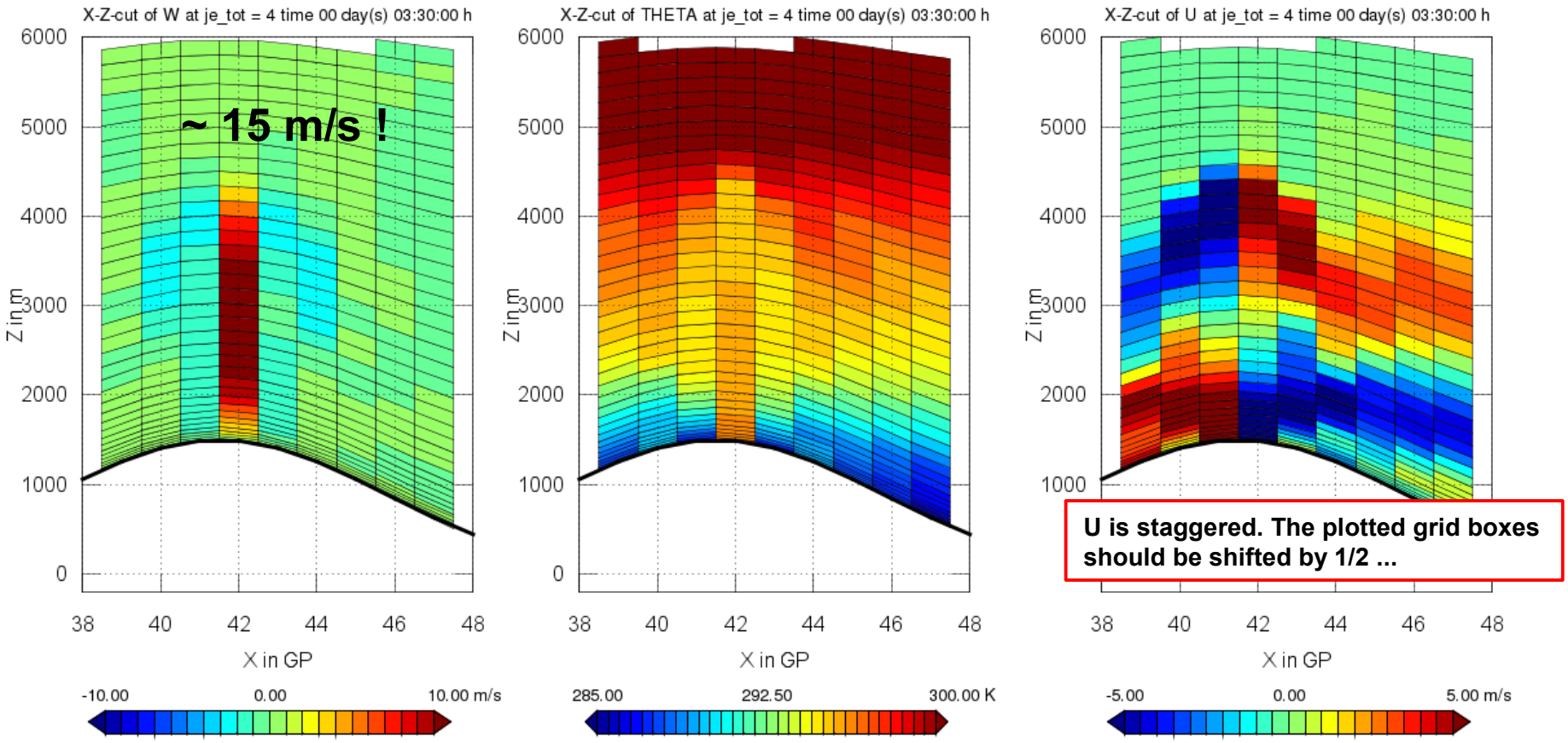
Explanation by means of idealized study

2D-simulation (dry), 2 hills, at start time: V = 0, N = 0.01 s^{-1}, surface overheated



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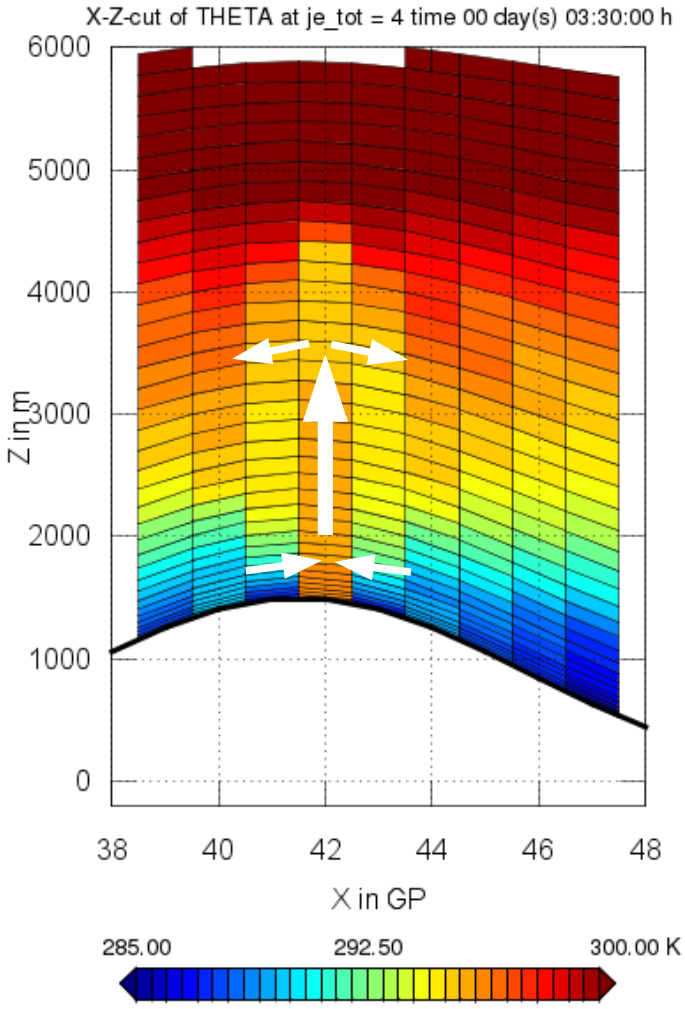
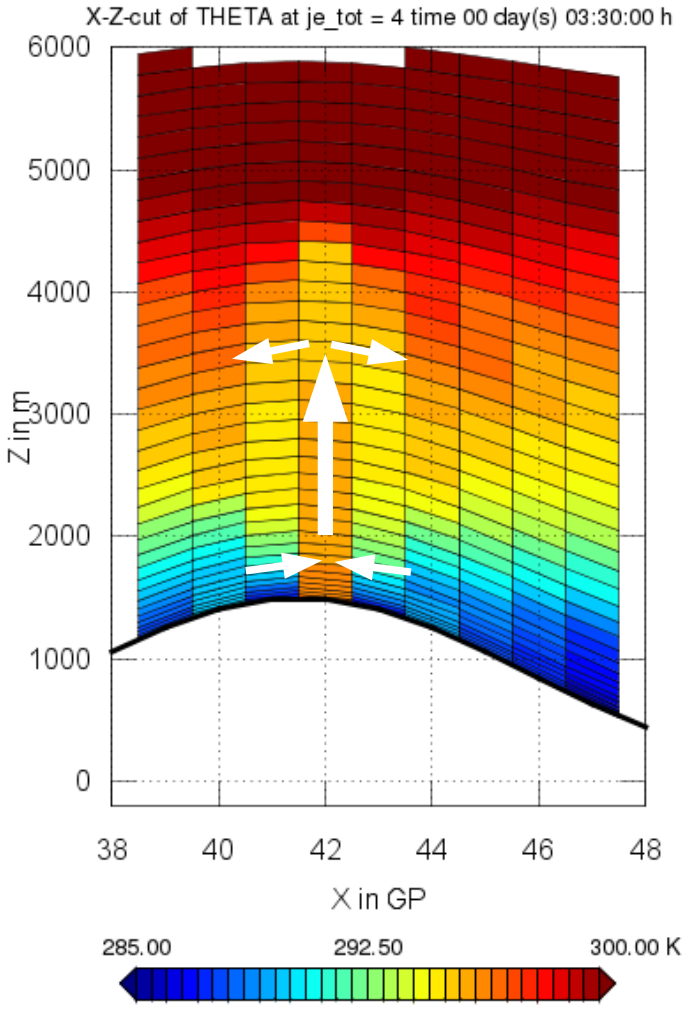


Smallscale circulation with rising warm air within 1 grid column and lateral advection of cooler air ...

Here: Fatal effect caused by the advection discretization of T (and p) ...

Explanation by means of idealized study



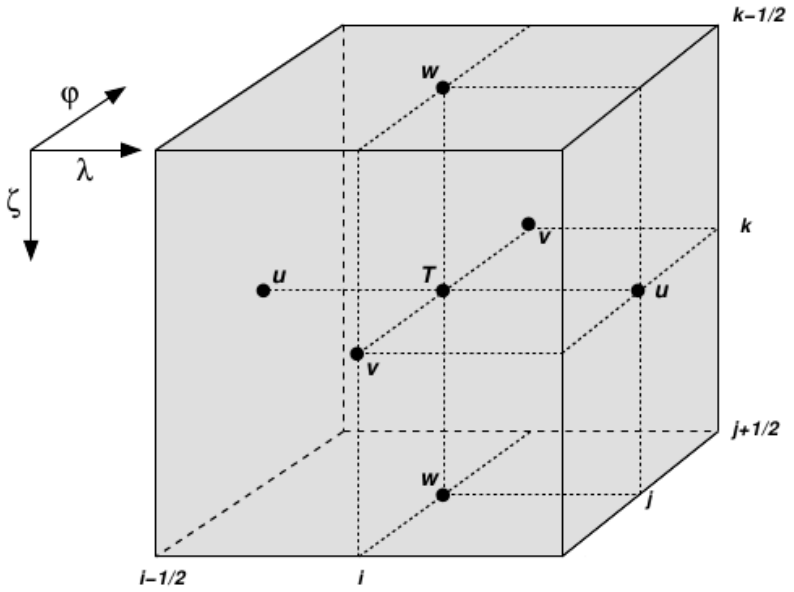
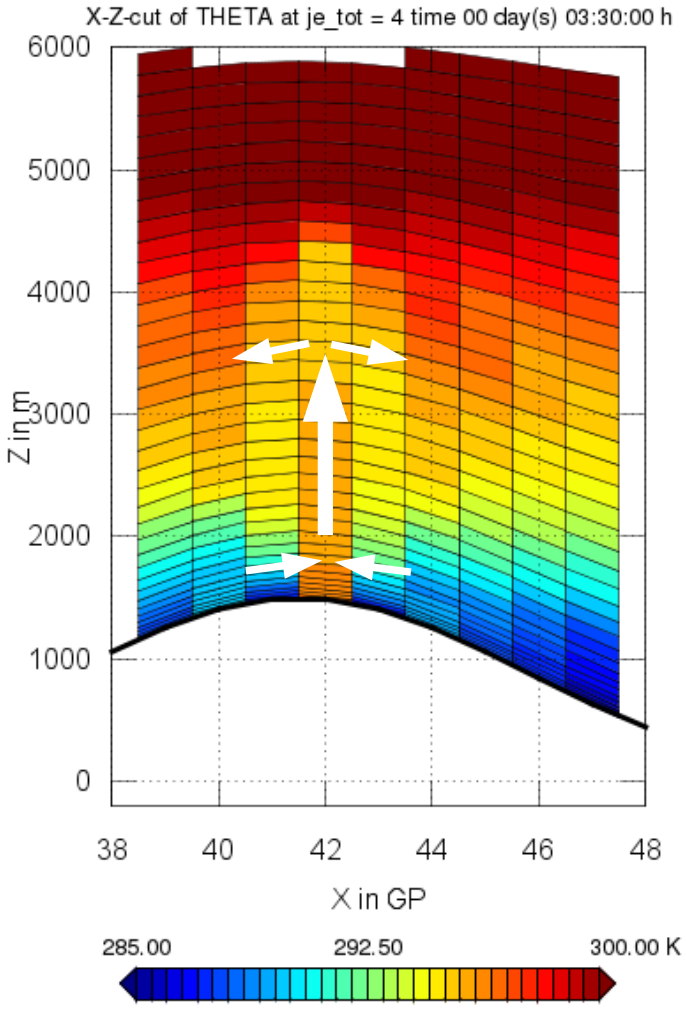
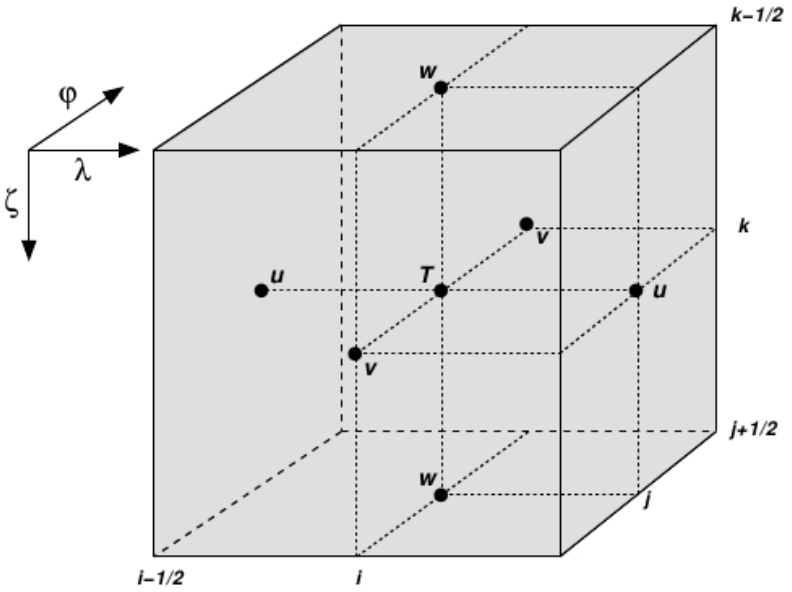


Figure 3.1: A grid box volume $\Delta V = \Delta\zeta\Delta\lambda\Delta\varphi$ showing the Arakawa-C/Lorenz staggering of the dependent model variables.

Explanation by means of idealized study



$$Adv_{X,T} = -U\frac{dT}{dx} \approx -\underbrace{\left(\frac{U_{i-1/2} + U_{i+1/2}}{2}\right)}_{\overline{U}} \Delta_{upwind}\left(T_i, sign\left(\overline{U}\right)\right)$$



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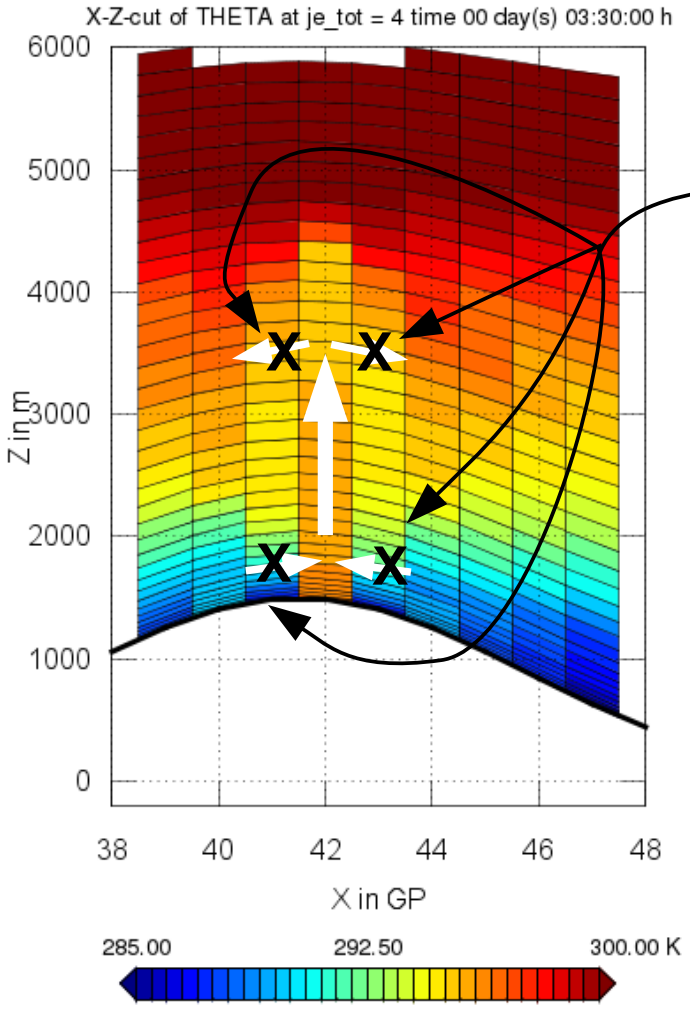

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Correct exactly at the center of the box (extremum), but not representative for the grid box averaged horizontal advektion von T (und p') !
At the same time, vertical adv. and Divergence terms are estimated/discretized more grid-box-average-consistent !

This incompatibility leeds to too low lateral inflow of cooler air into the grid column

→ **artificial heat source !!!**

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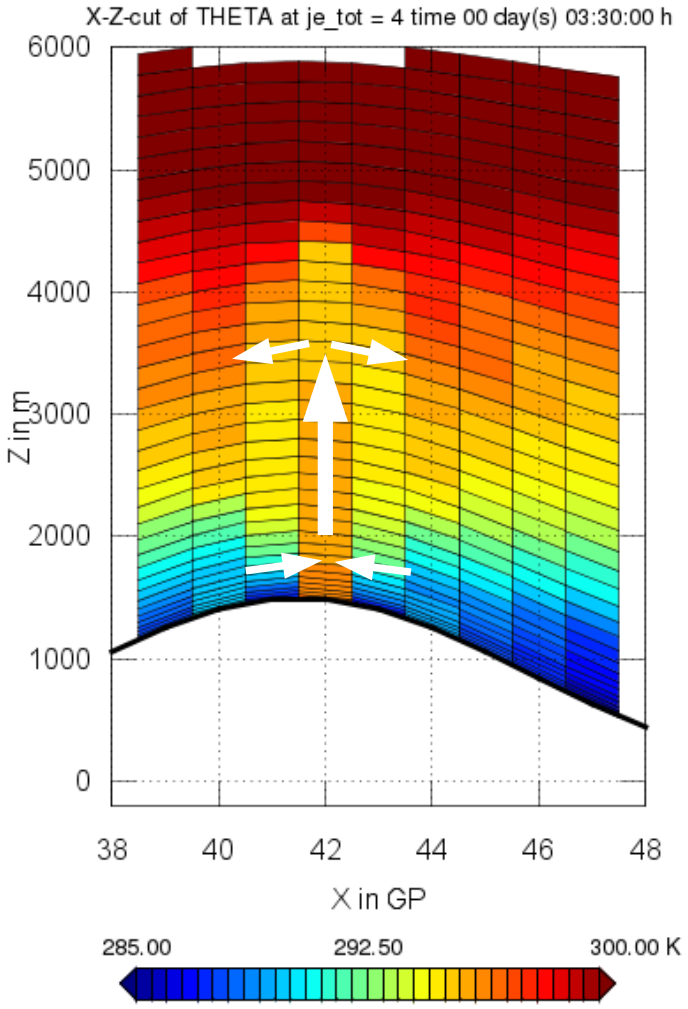

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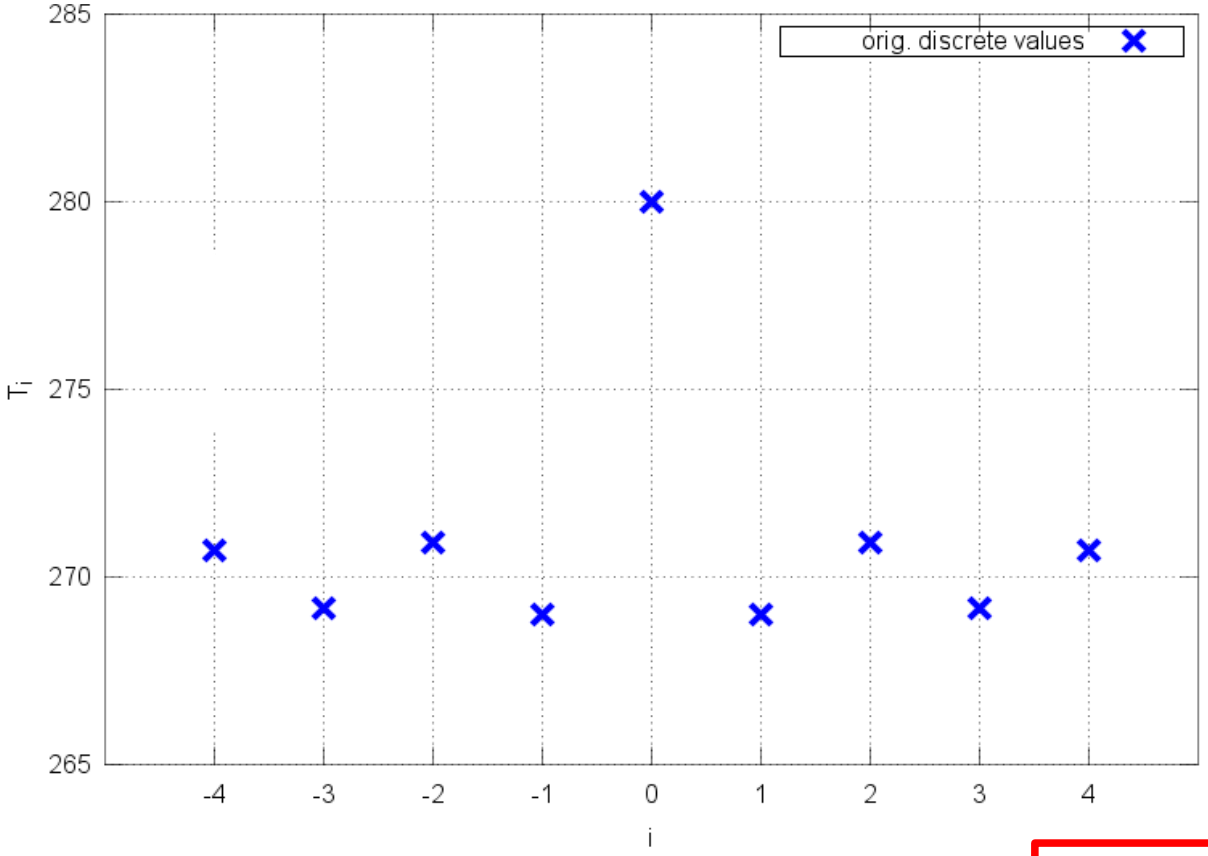
Ad-hoc correction:

$$Adv_{X,T} \approx -\frac{1}{2}\left\{ U_{i-1/2}\ \Delta_{upwind}\left(T_i, sign\left(U_{i-1/2}\right)\right) + U_{i+1/2}\ \Delta_{upwind}\left(T_i, sign\left(U_{i+1/2}\right)\right) \right\}$$

Schematic explanation of ad-hoc correction

$$\Delta^{(5)}_{upwind}\left(T_{0,} sign\left(U_{xxx}\right)\right)$$



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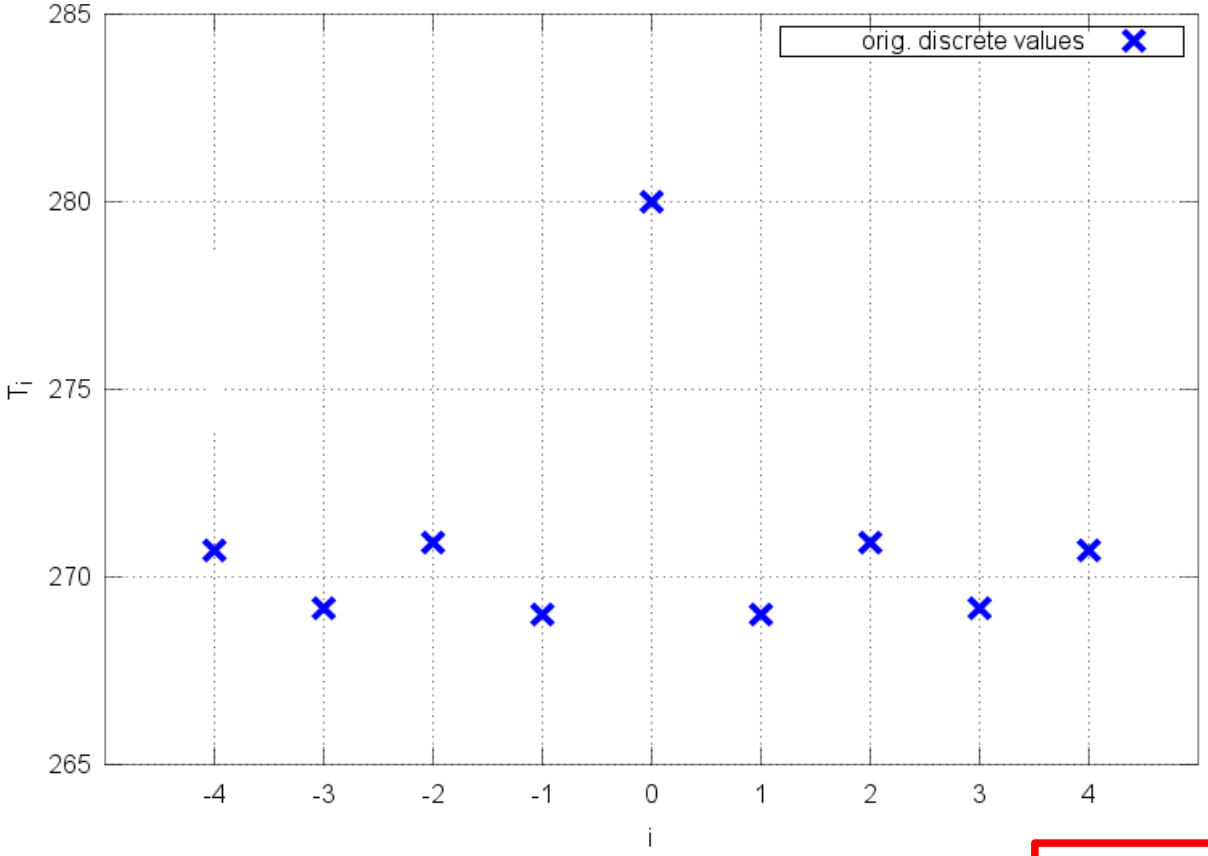

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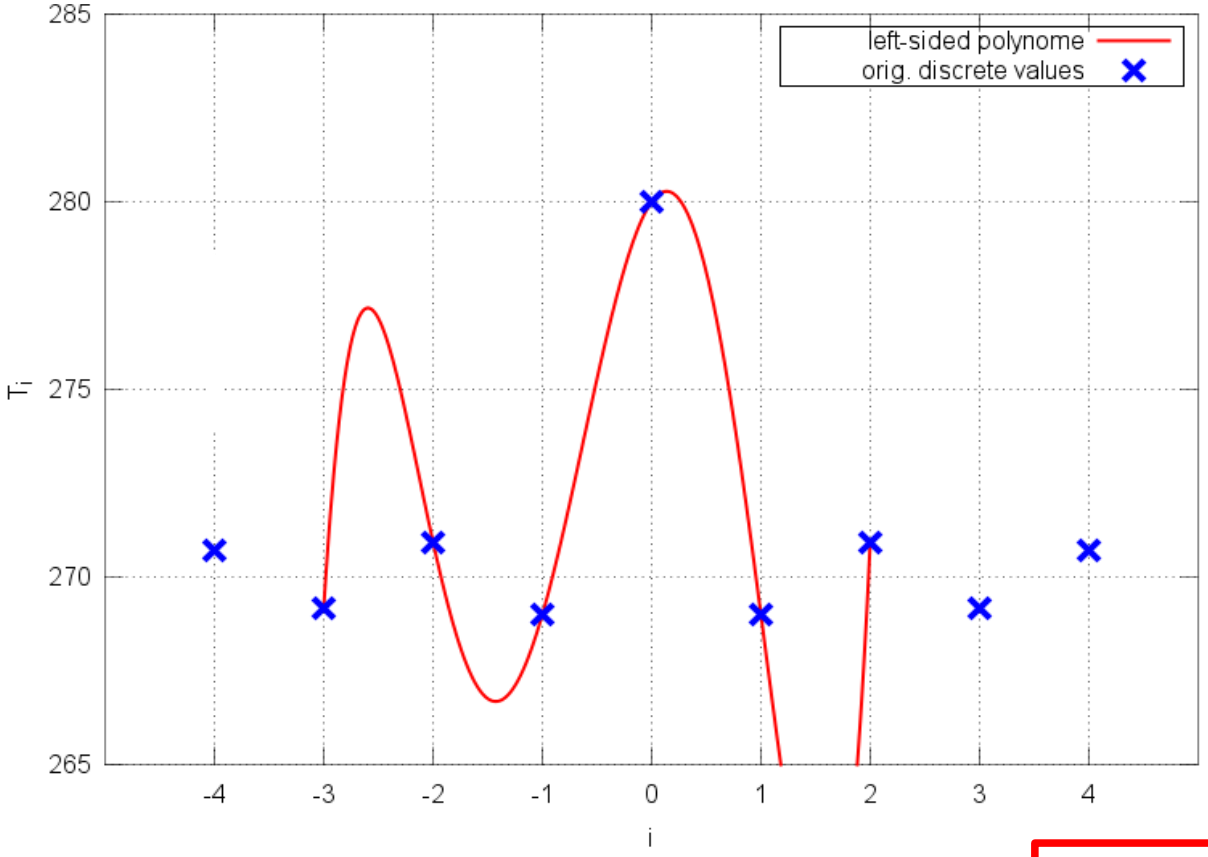

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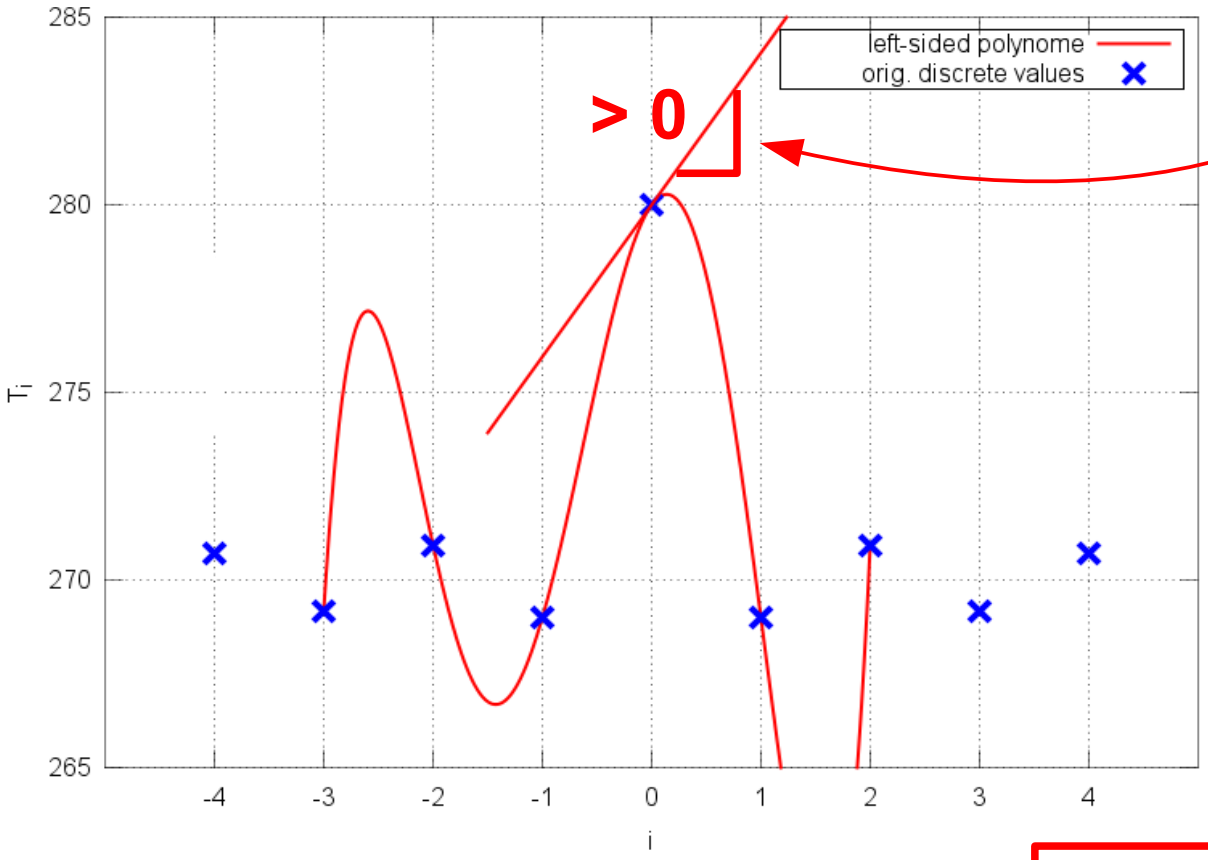

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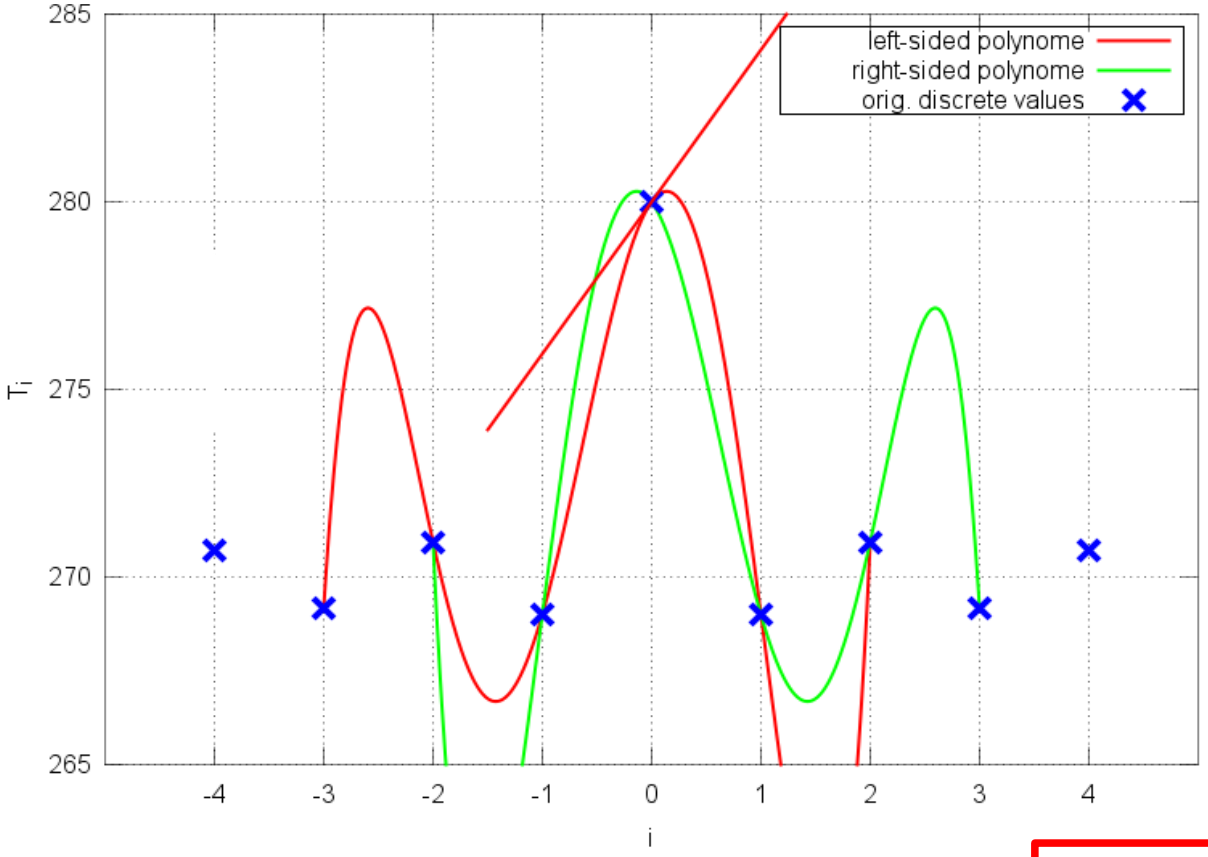

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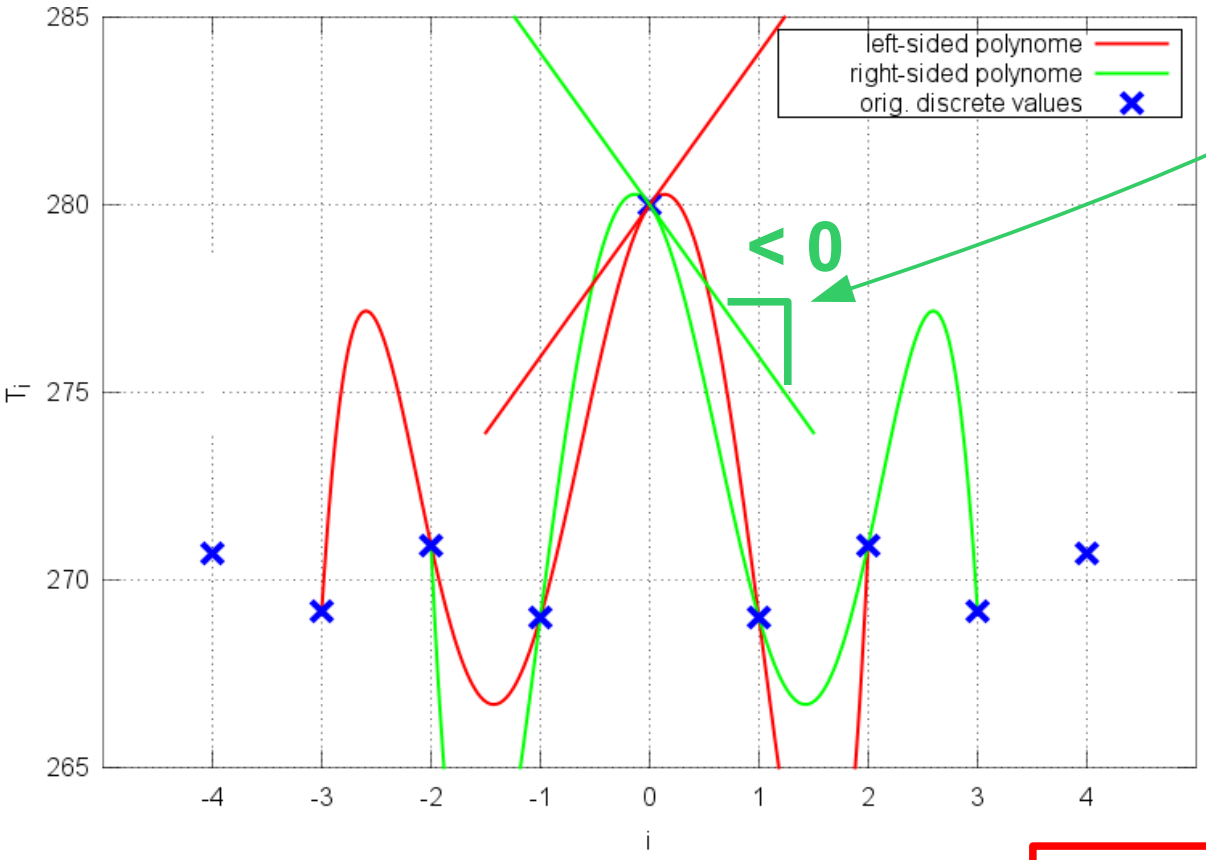

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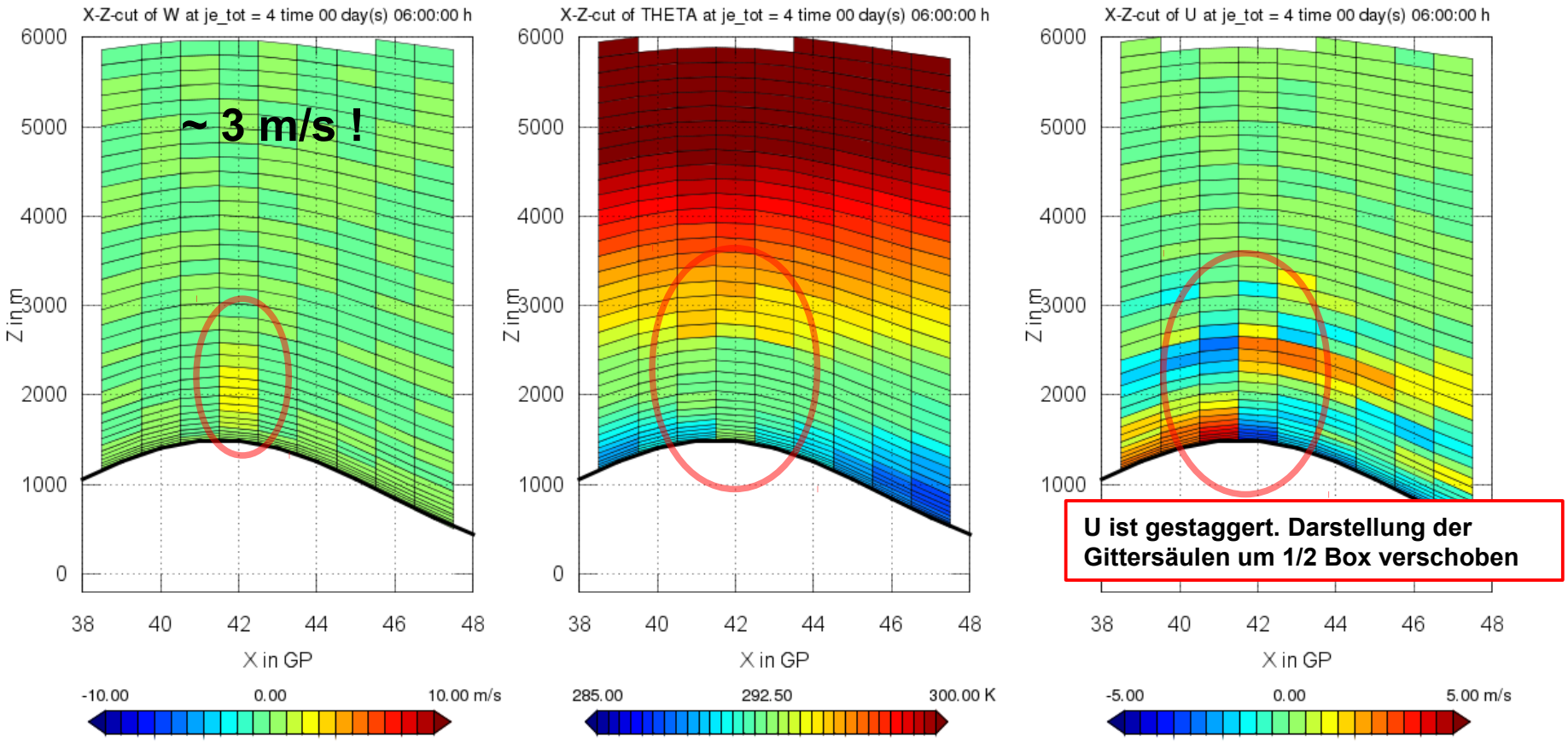
Effect on the idealized study

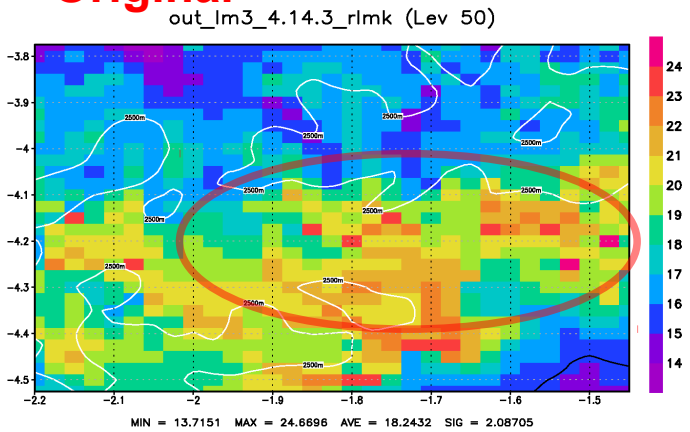
2D-simulation (dry), 2 hills, at start time: V = 0, N = 0.01 s^{-1}, surface overheated

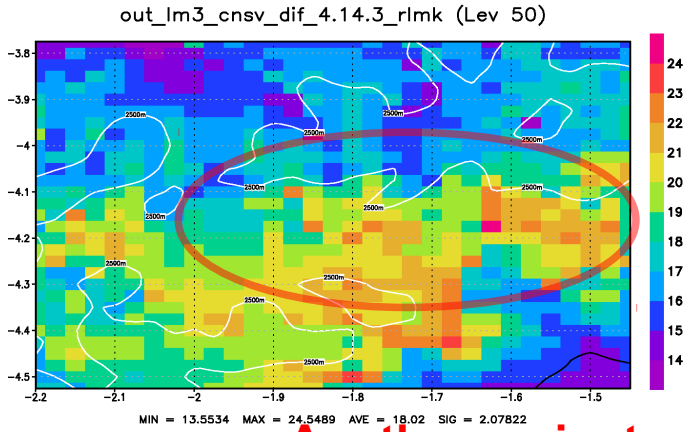


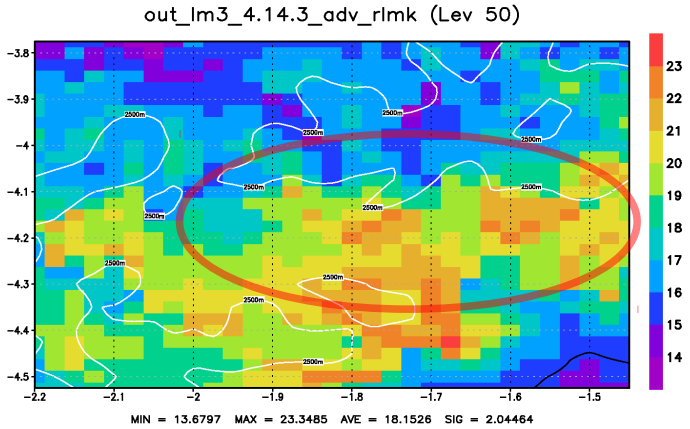
COSMO-DE 13.4.2011 00 UTC + 11 h

Potential temperature [C]

Original







Adv-patch

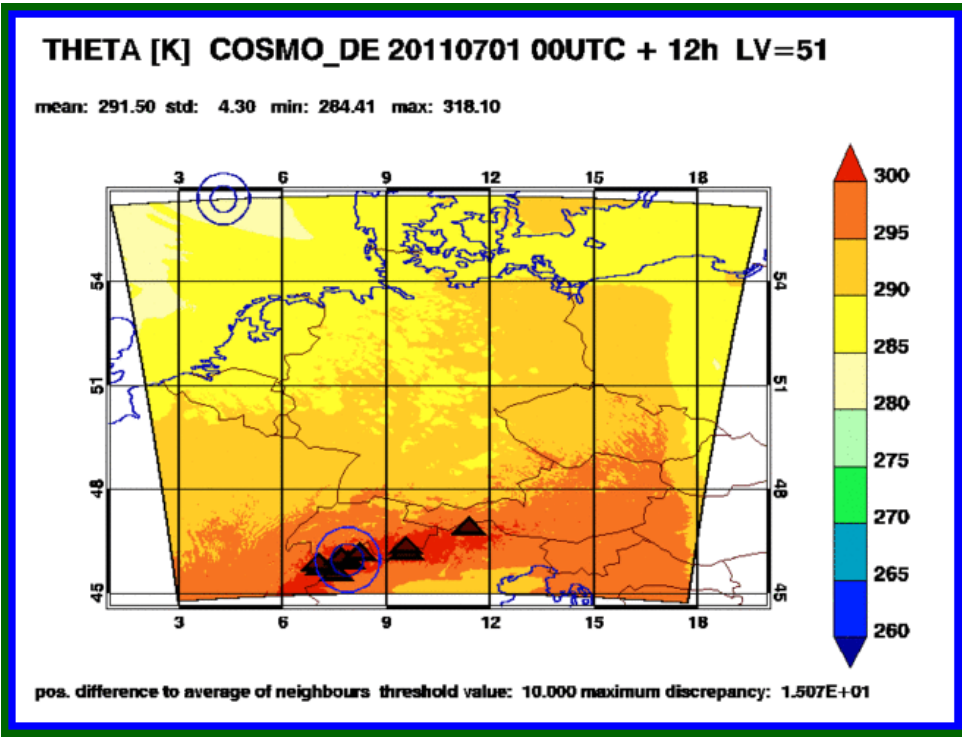
Another variant with diffusion of conserved quantities (M. Raschendorfer)

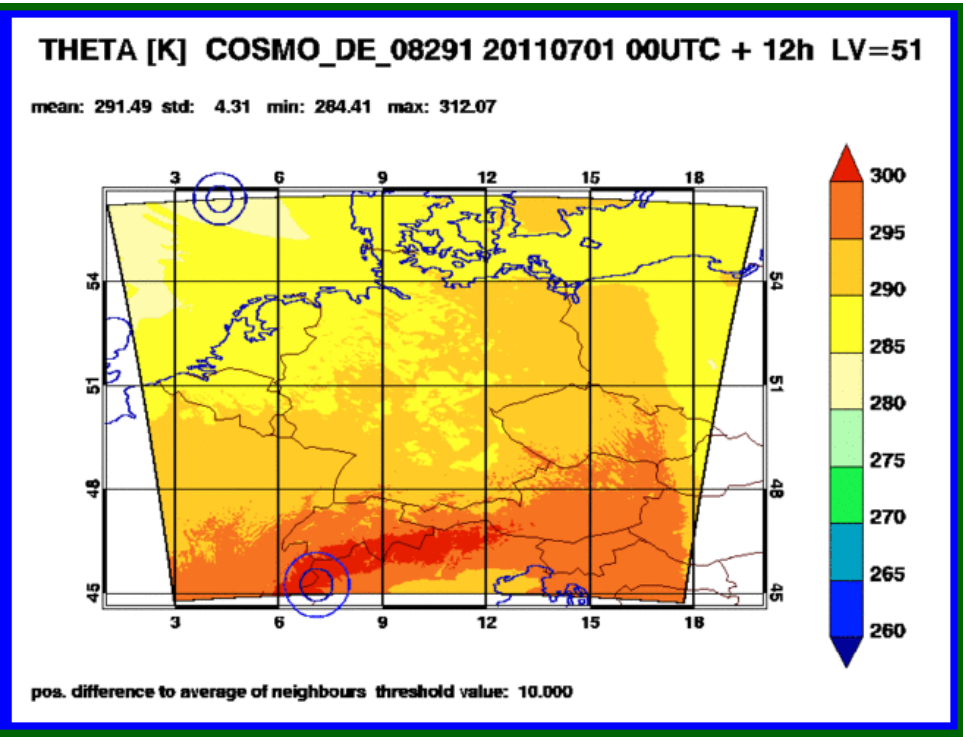
© M. Raschendorfer

pr_time=11Z13APR2011 pr_hour=11hr

Experiment: 1.6. - ~20.7.2011

Reduction of „Theta-peaks“ in July 2011 (COSMO-DE)





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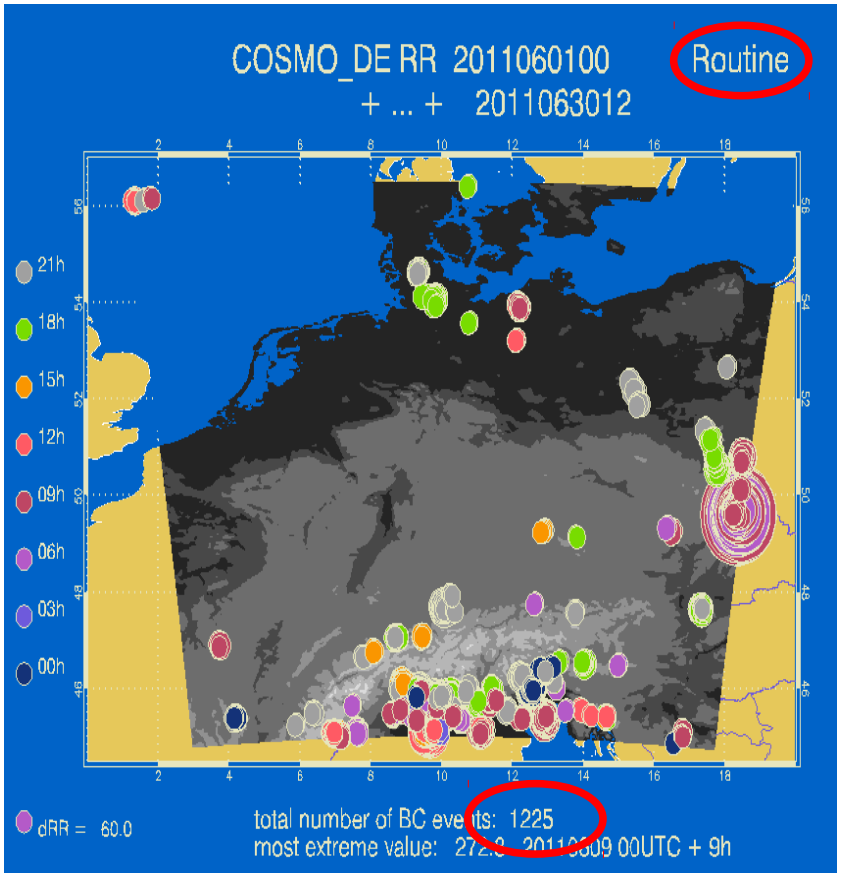
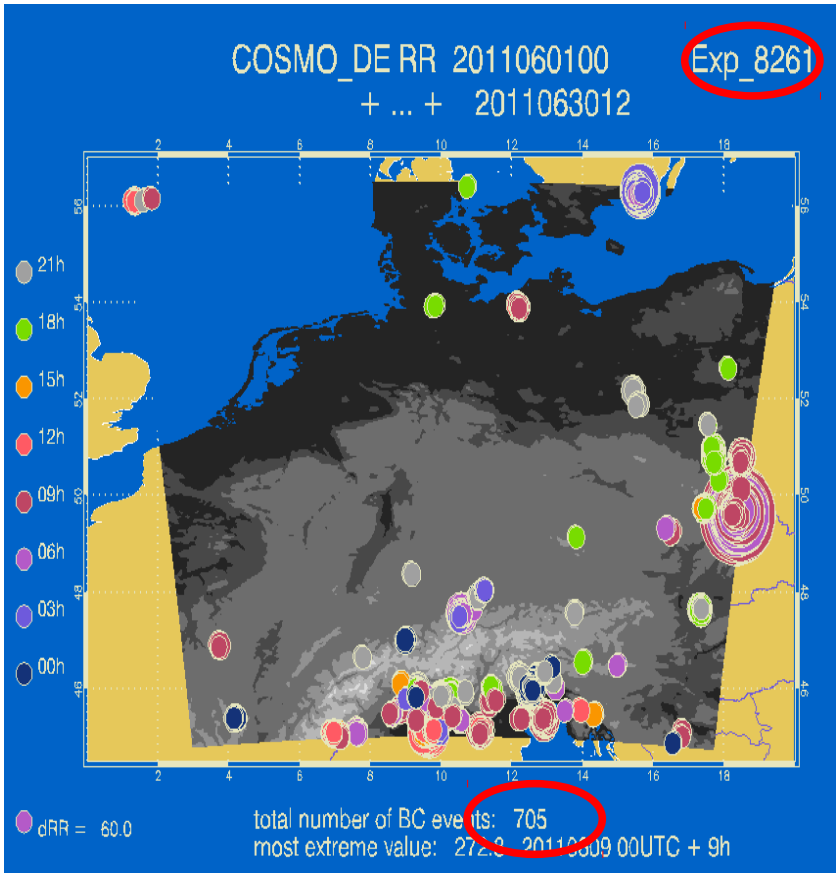
Experiment: 1.6. - ??.7.2011

Reduction of „grid point storms“ in June 2011





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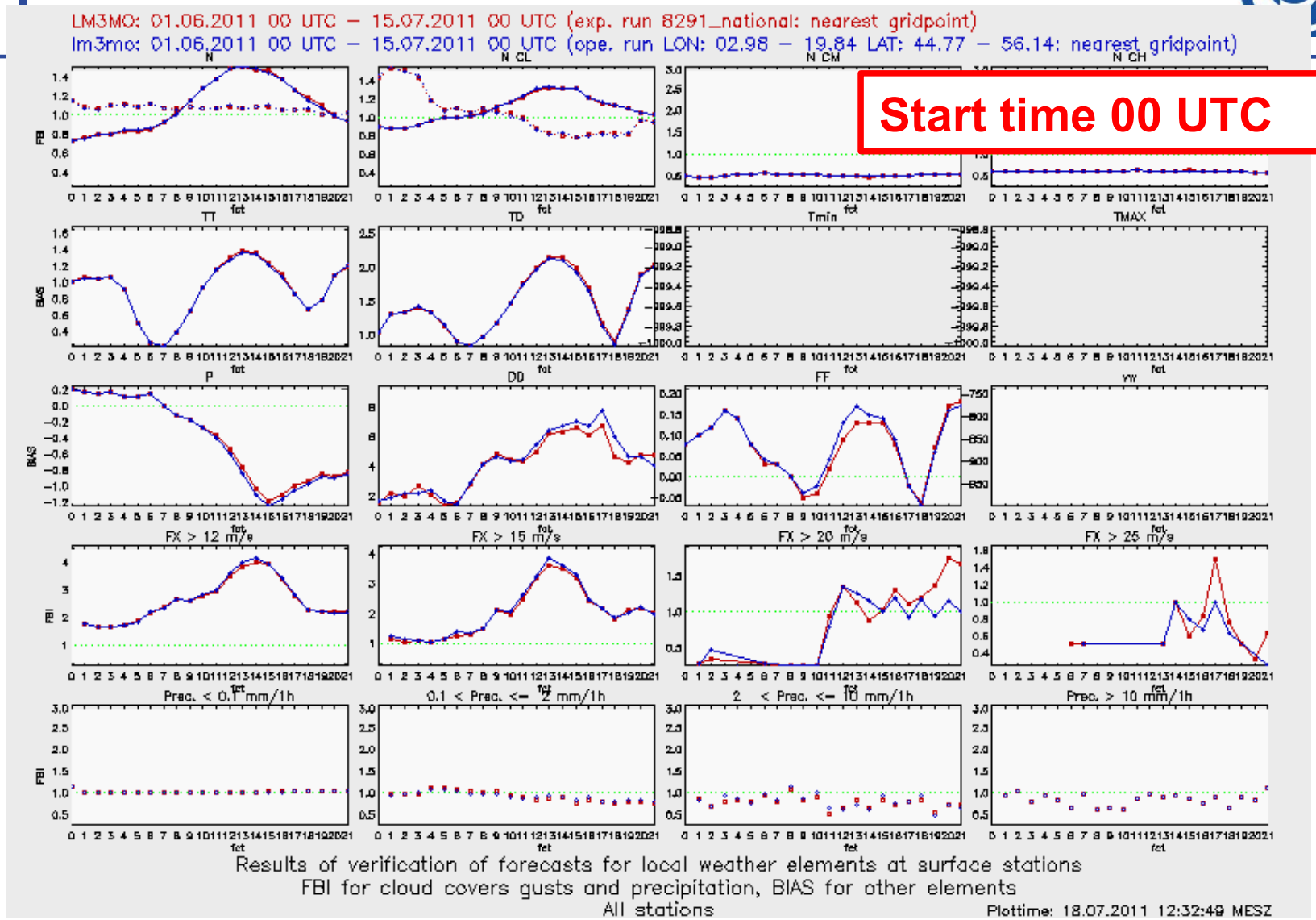
Summary

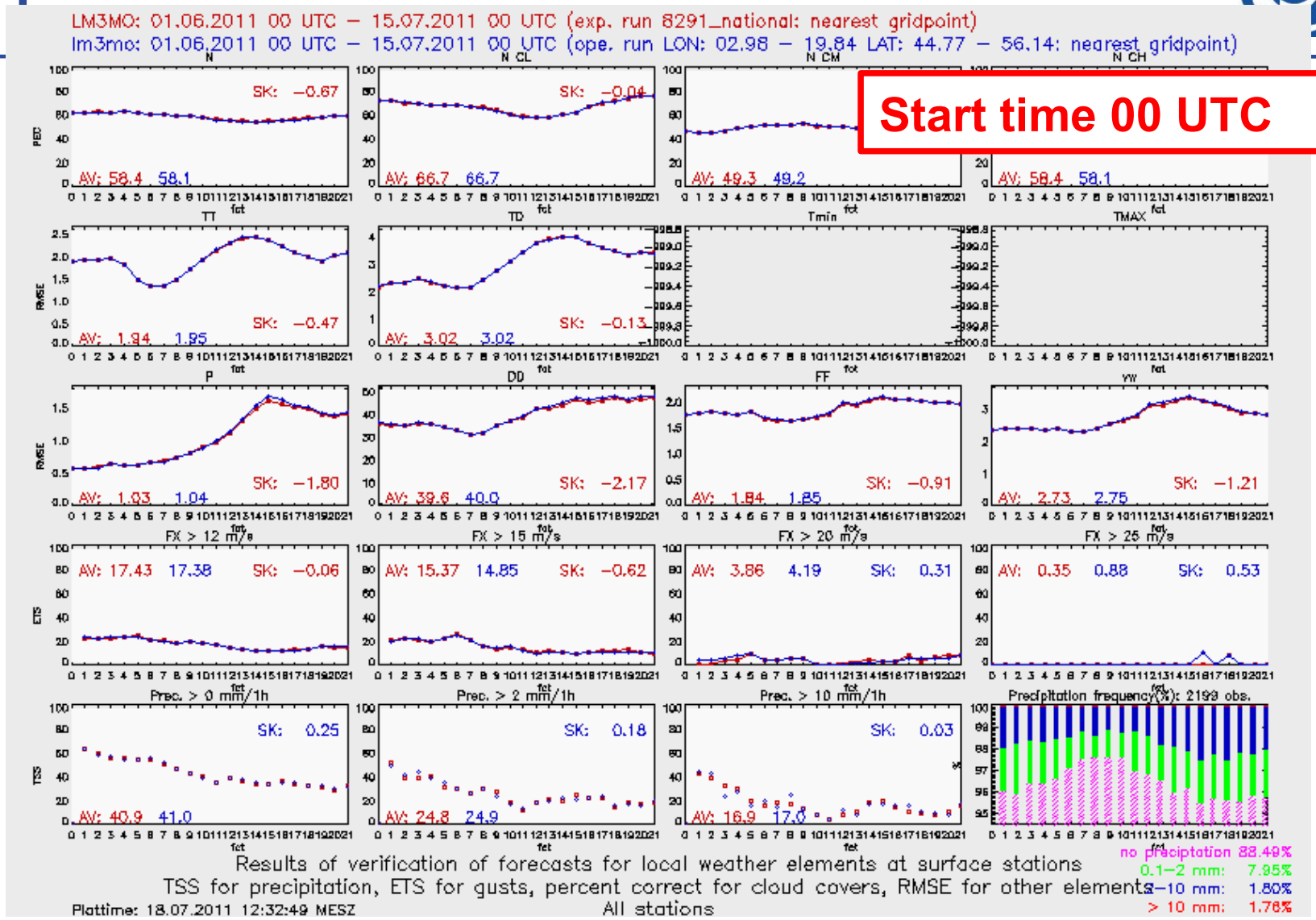
- The COSMO-model generates, in conjunction with small-scale thermally driven circulations, „strange“ effects such as isolated „Θ-peaks“ in alpine valleys, or as „grid point storms“ in mountaineous regions or at coasts (visible as isolated surface pixels with very high precipitation).
- Result: The reason is the special discretization of the T- and p'-advection terms on the staggered grid in situations with locally strong horizontal con- and difluent flow structures (thermally driven updrafts covering only 1 grid column)
- Ad-hoc correction developed
- Case studies (Förstner, Raschendorfer) relating to „Θ-peaks“
- June/July 2011 – Experiment
- Verification results: Neutral to slightly positive regarding p
- Not shown: COSMO 7 km reduction of w_{max}

Experiment Verifikation: 1.6. - 15.7.2011



Start time 00 UTC

Experiment Verifikation: 1.6. - 15.7.2011



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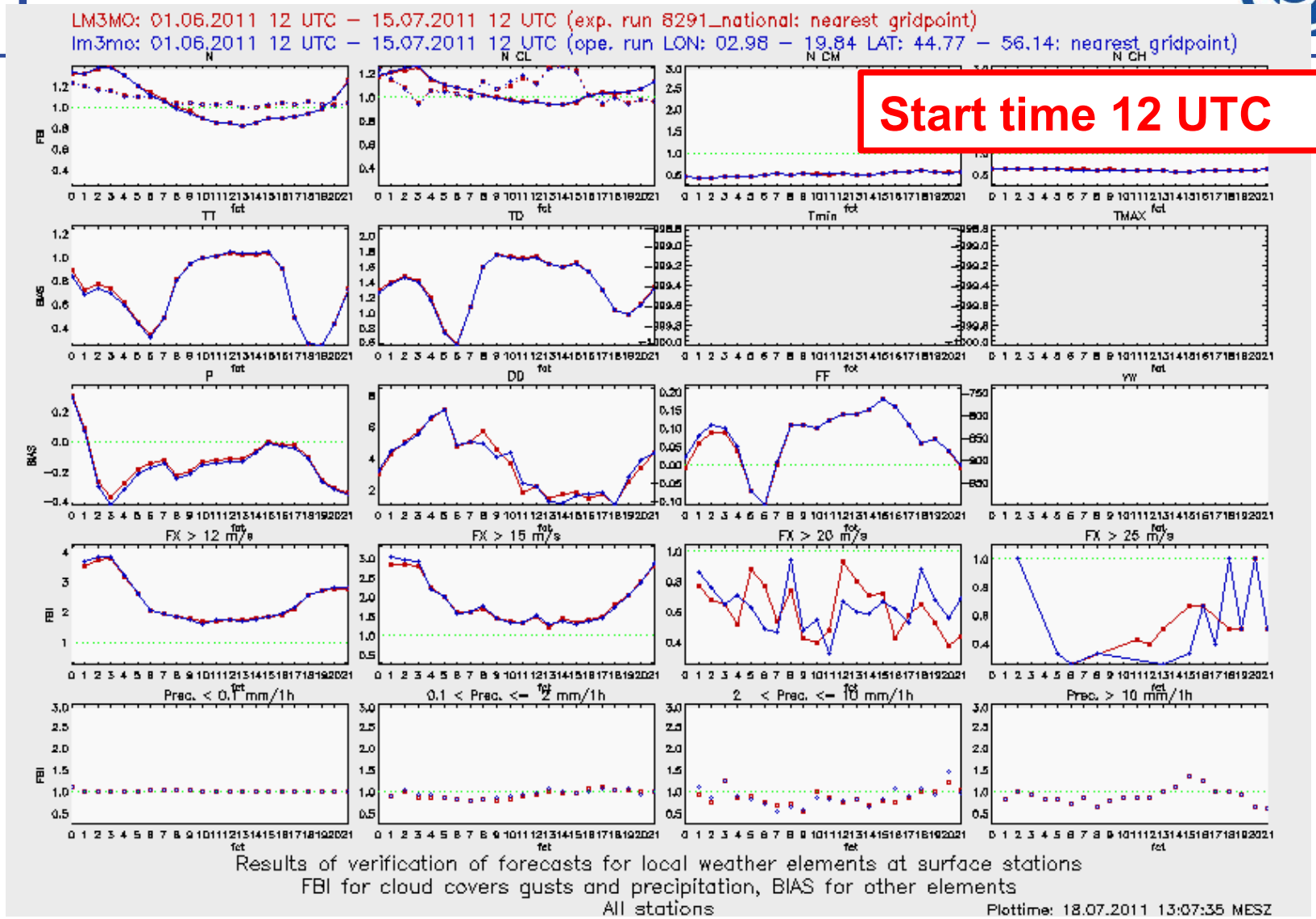

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Experiment Verifikation: 1.6. - 15.7.2011