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High Resolution Simulations with Different Numerical Schemes for COSMO

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COSMO User Group, Langen, March 5, 2007

Overview

- Model setup at MeteoSwiss
- Some encountered numerical difficulties
- Illustrations of:
  - Configurations used
  - Tools:
    - Namelist or code parameters
    - Inspection of YUPRMEAN
    - Log files from R. Petrik
  - and solutions
- Conclusions
- Outlook

Model setup at MeteoSwiss

- ECMWF IFS or ERA40 Initial and Boundary conditions
- 7km operational domain (385 x 325, L45 NEW)
- 2.2km (520 x 350, L60)
- Both resolutions with Runge-Kutta dynamics (TVD), p*T*-formulation, Δt = 72 / 20 sec (7 / 2.2km)
- Assimilation cycles for both 7 & 2.2km

Case studies and runs

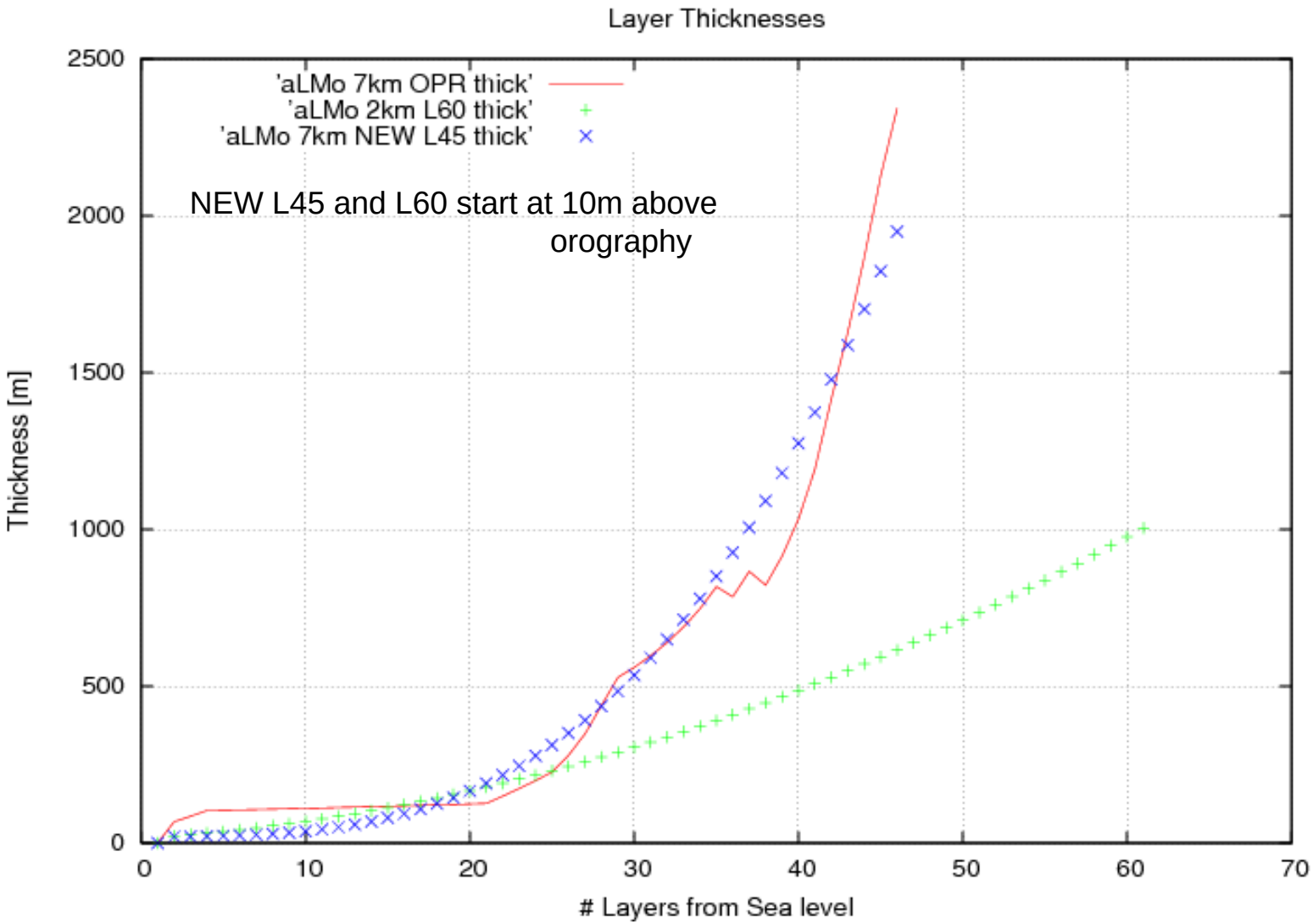
✓ 10 episodes 4 to 6 days in 1999-2004

✓ 72 episodes July-Oct. 1995/97/99 ("WINDBANK"):
with 48h assimilation, 2.2km nested in 7km, followed by 2.2km forecasts of +24h and 3 of +6h

✓ 66 days January 2003 - December 2004 ("WINTER")

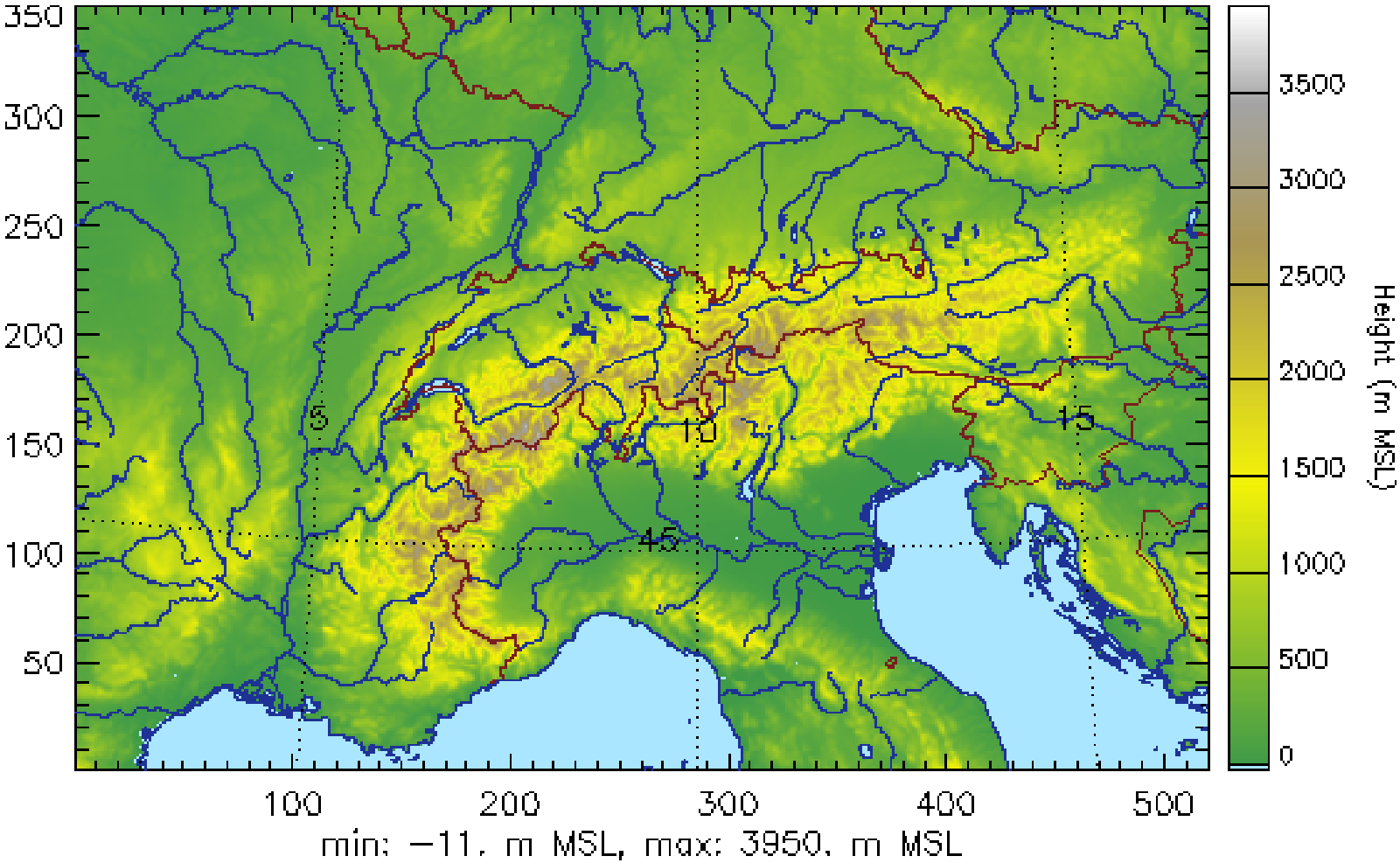
✓ Analysis cycle since August & forecasts since Nov. 2006

Setup ▸ vertical resolutions used



Setup ▸ 2.2km resolution domain

- Orography with ~ 4 grid length filter and maximum 750m height difference



Some encountered numerical difficulties (1)

- "WINDBANK" cases:
  - Difficulties at 7km with TKE diffusion (corrected in LM 3.19)
  - 2.2km cases with start problems at 12UTC (=> start earlier)

- Problem with the 2.2km initial conditions:

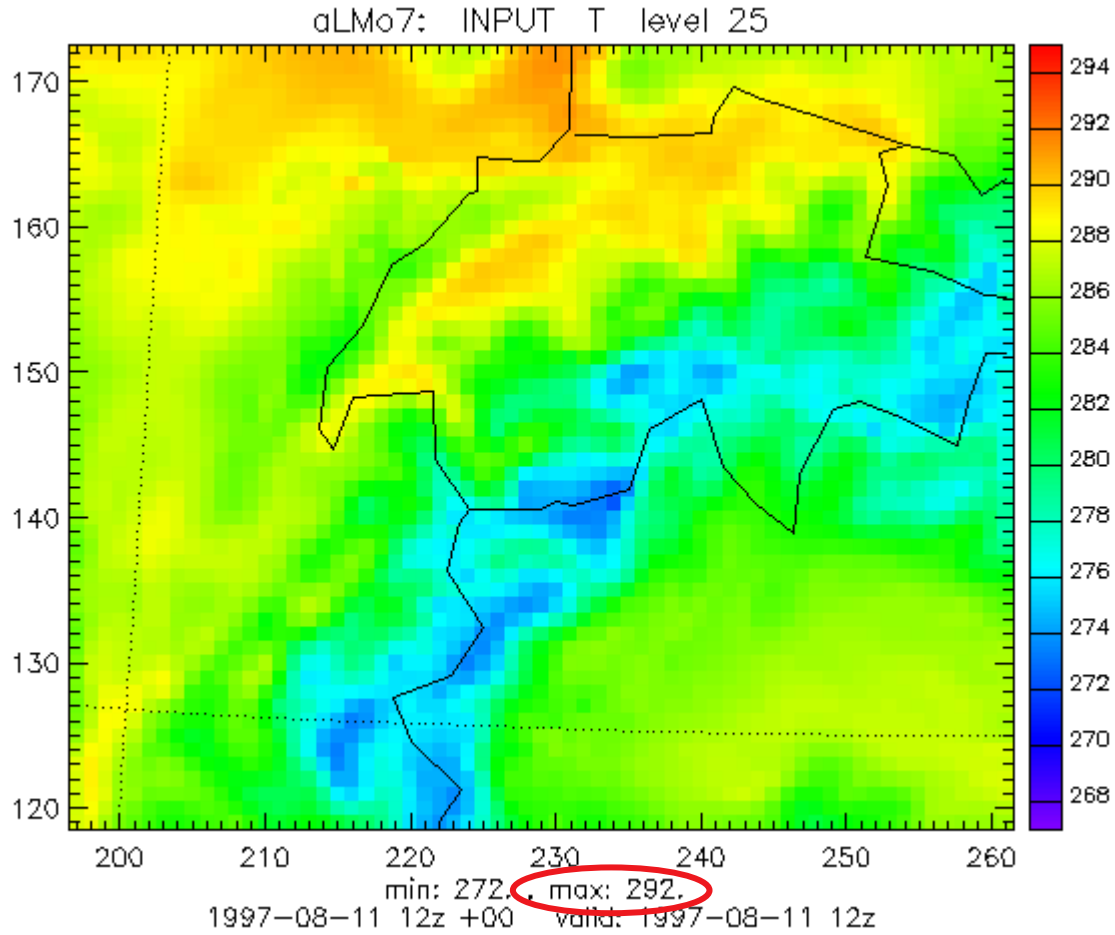
INPUT: 7km analysis => interpolated by LM2LM to the 2.2km grid.

Algorithm used

- Vertical interpolation tries to keep the structure of the 7km boundary layer (BL) winds and temperatures:
  - by lifting or lowering the profiles depending on the 2.2km orography
  - extrapolation procedure is used when lowering the profiles
- BL top is defined as a fixed height for the whole domain as first model level below 850hPa for a profile above sea.

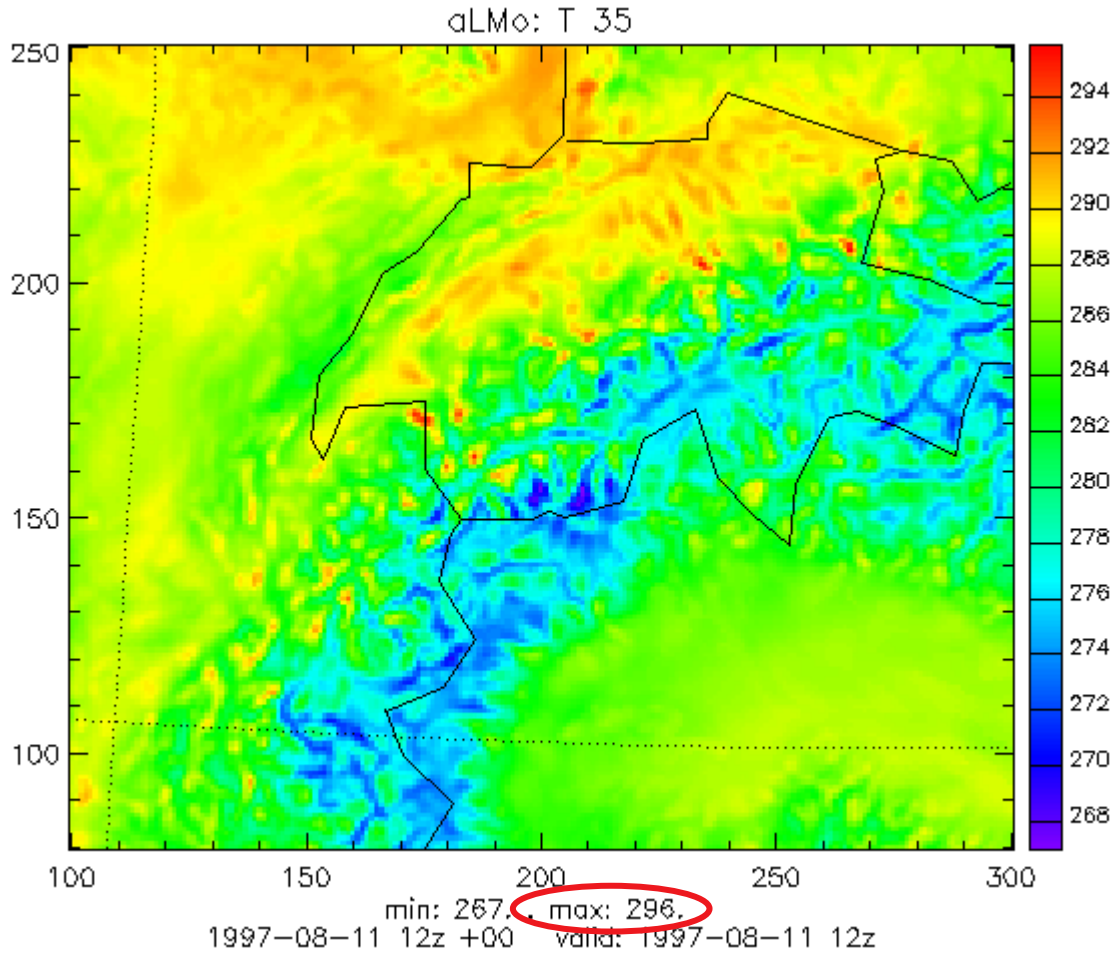
LM2LM for analysis (1)

INPUT 7km temperature at k=25 (1474m) ~ BL top



LM2LM for analysis (2)

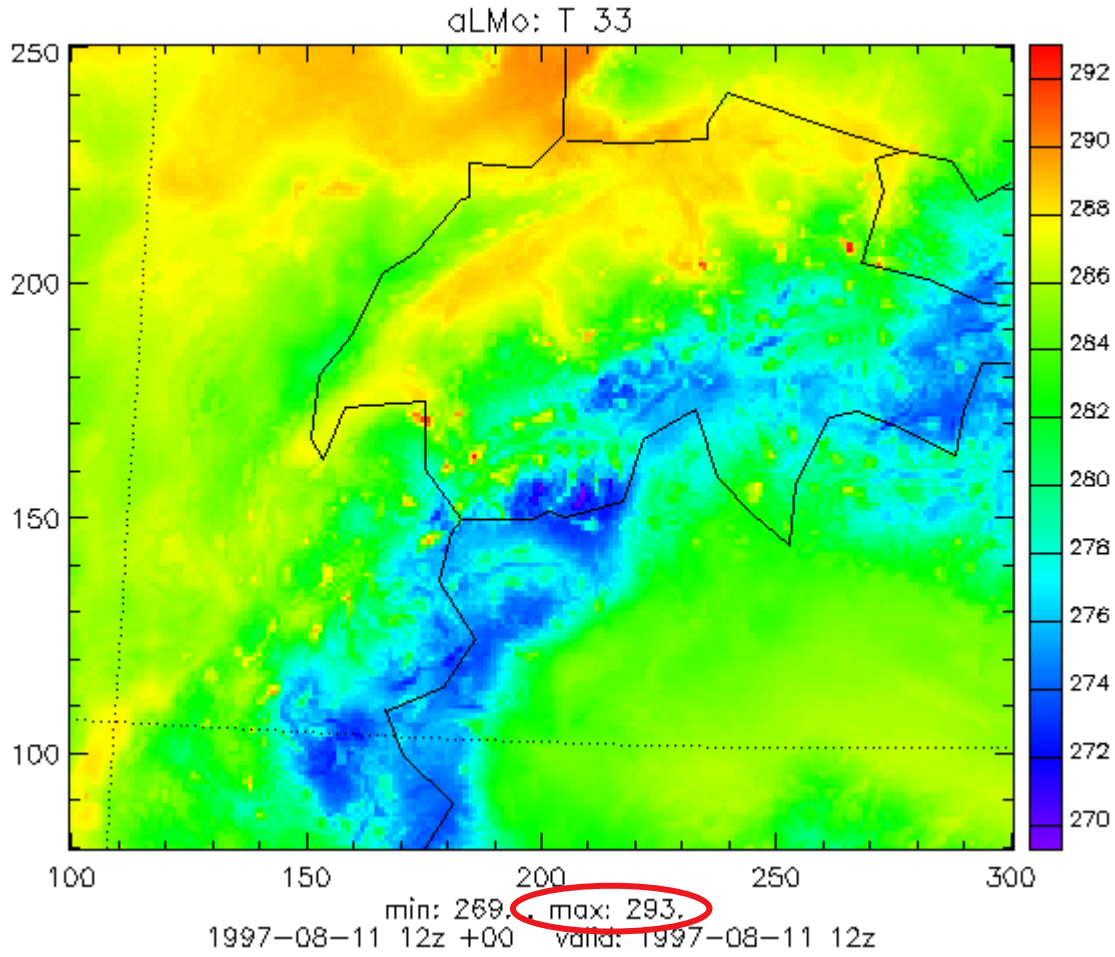
OUTPUT 2.2km temperature at k=35 (1375m)



LM2LM for analysis (3)

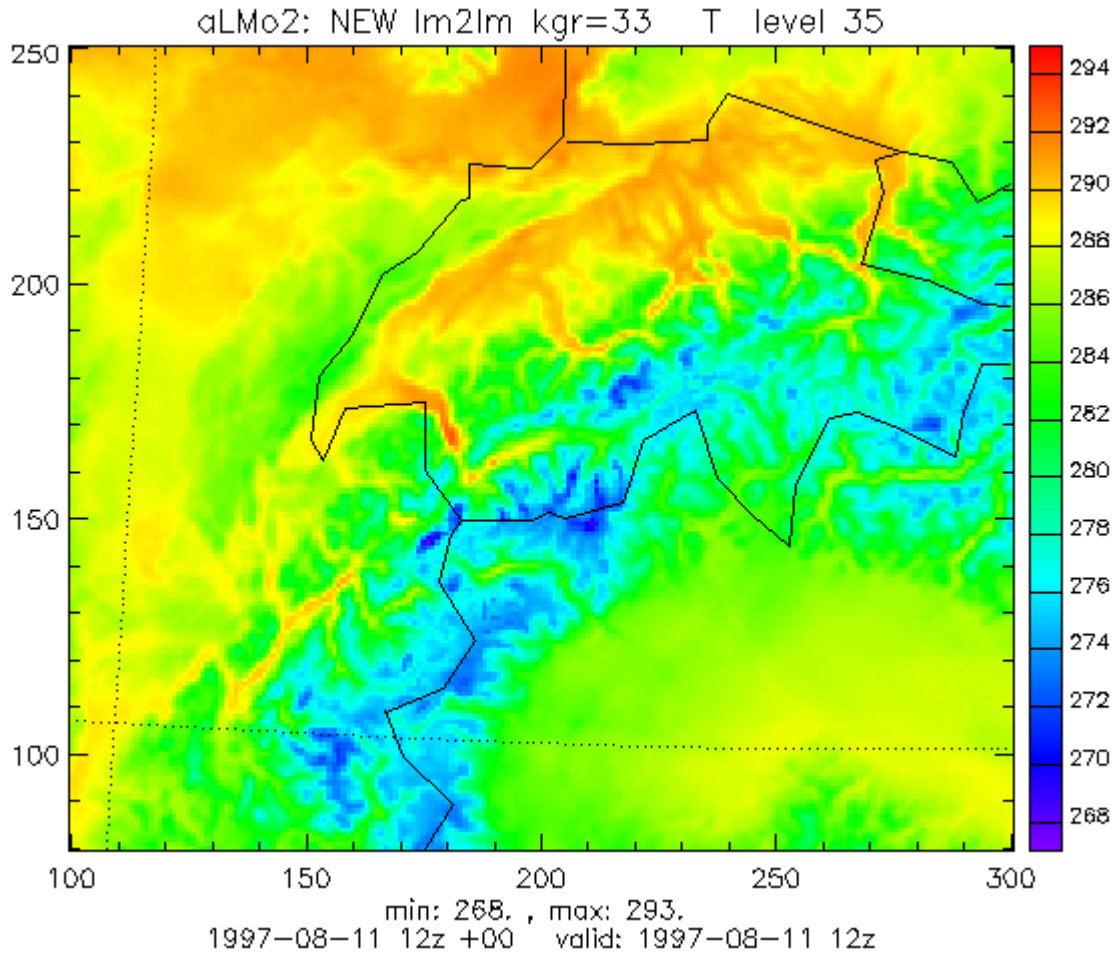
OUTPUT 2.2km temperature at k=33 (1689m)

Warm grid points
=>
Warm air bubbles
=>
Abort in one Δt!



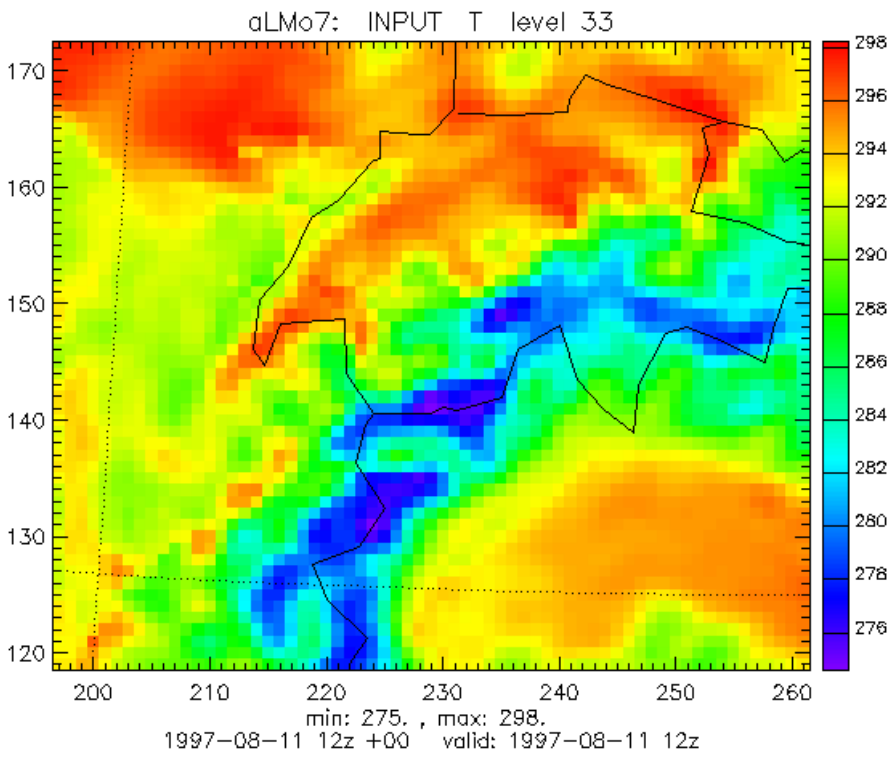
LM2LM new BL top ~ 500m (1)

OUTPUT 2.2km temperature at k=35 (1375m)

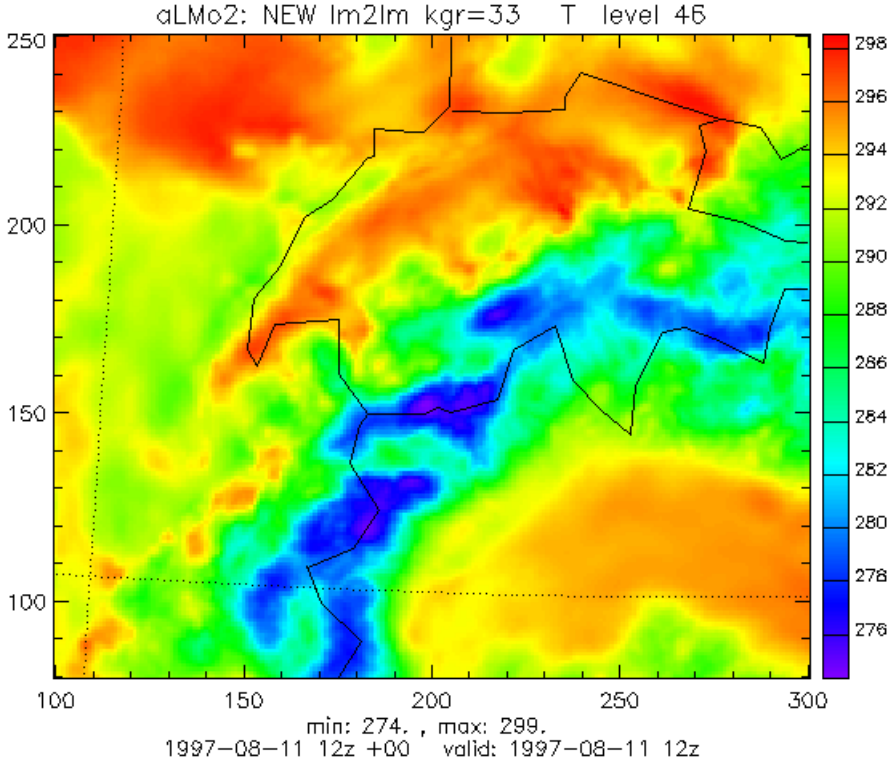


LM2LM new BL top ~ 500m (2)

INPUT 7km
temperature at k=33 (422m)



OUTPUT 2.2km
temperature at k=46 (416m)



Some encountered numerical difficulties (2)

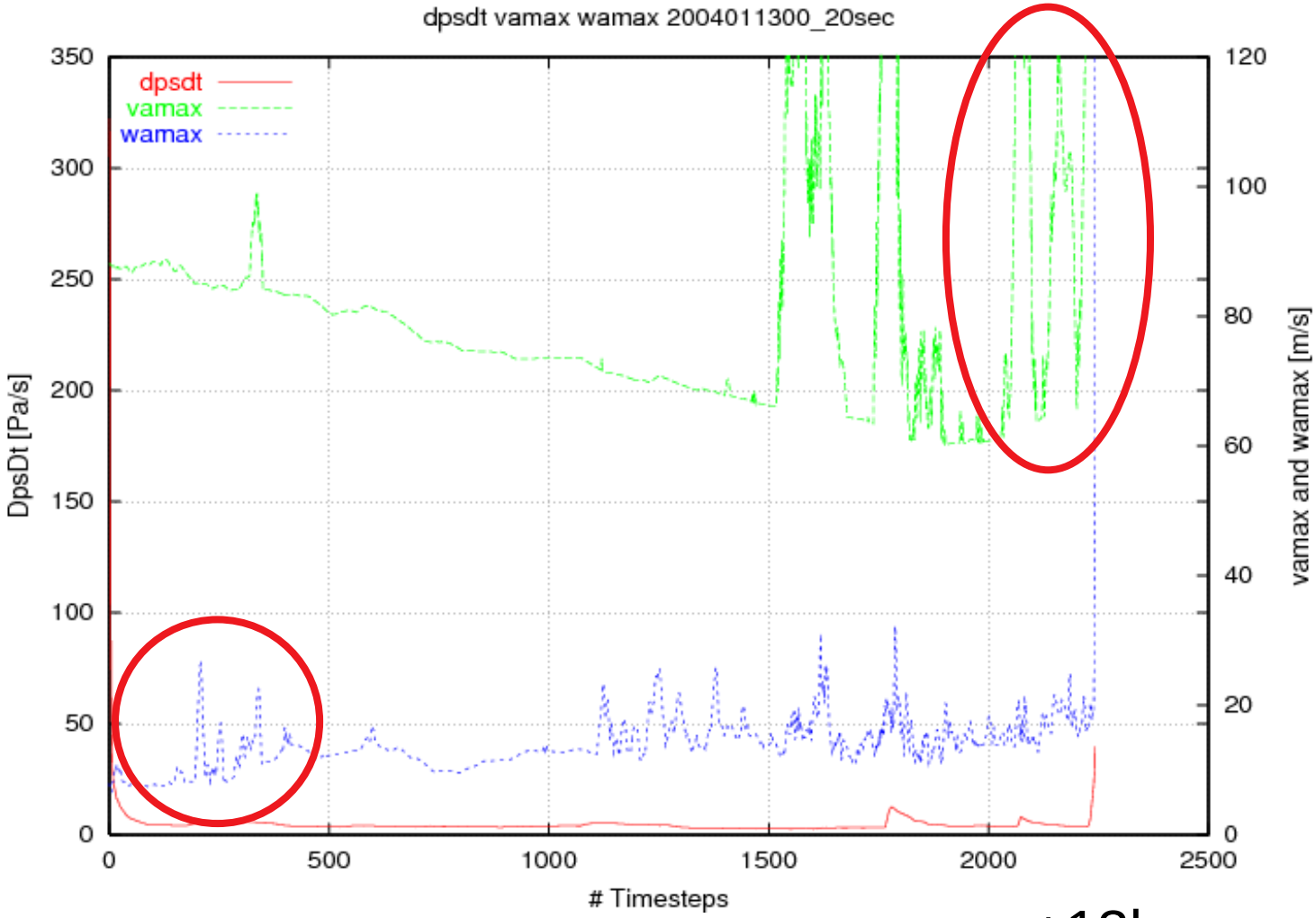
- "WINDBANK" cases:
  - Difficulties at 7km with TKE diffusion (corrected in LM 3.19)
  - 4 cases at 2.2km start problems at 12UTC (=> start earlier)

- "WINTER" cases:
  - Many unstable cases but several OK with: irunge_kutta=1 (no "Total Variation Diminishing" scheme)

- For cases with **strong horizontal winds**:
  in a few time steps, log files showed an unbalance in the fast waves part of the code.

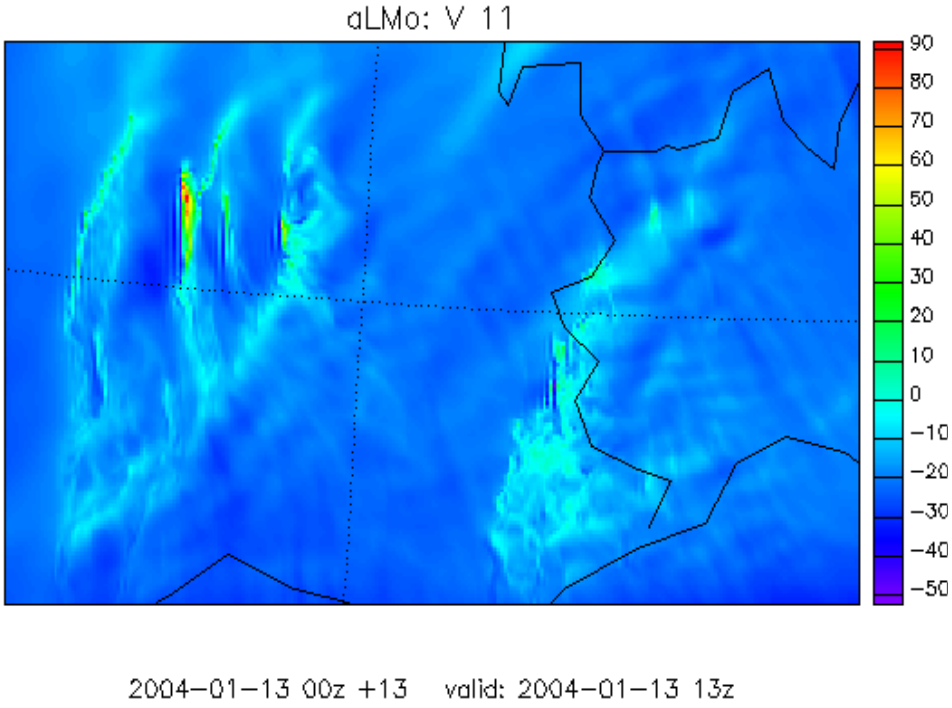
Instability for a „*Winter*“ case (1)

Δt = 20sec

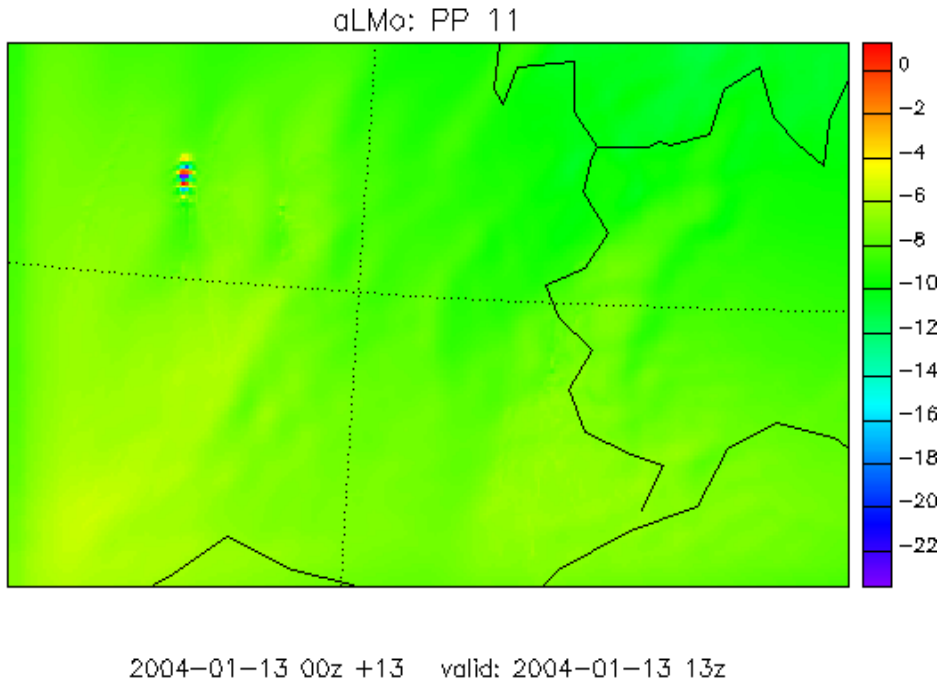


+13h

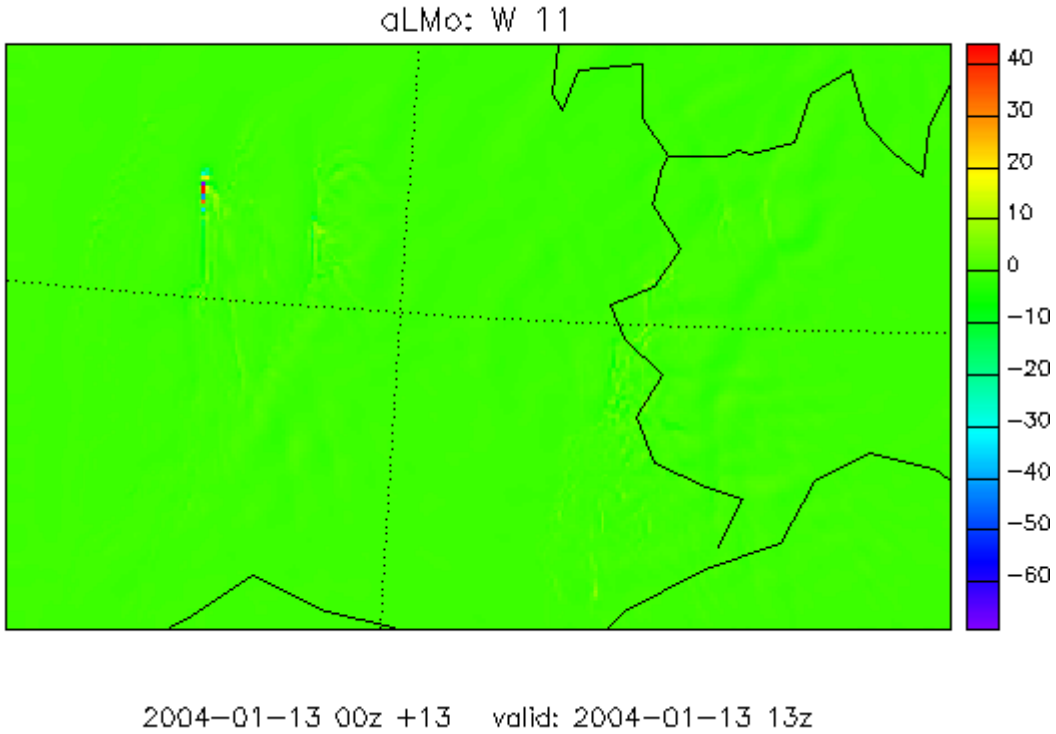
Instability for a „*Winter*“ case (2)



13.01.2004, 00UTC – run
Near the tropopause at +13h

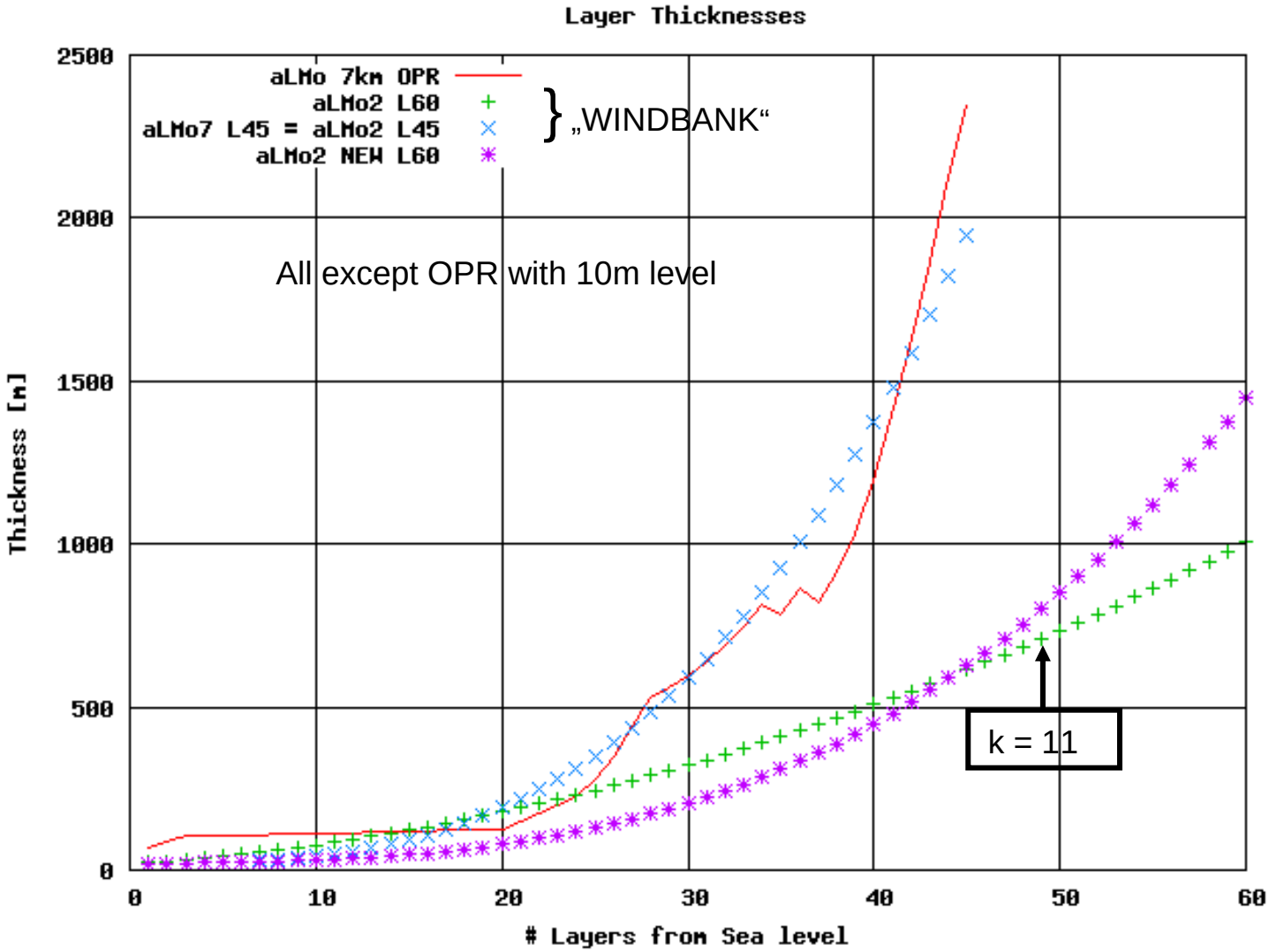


Instability for a „*Winter*“ case (3)



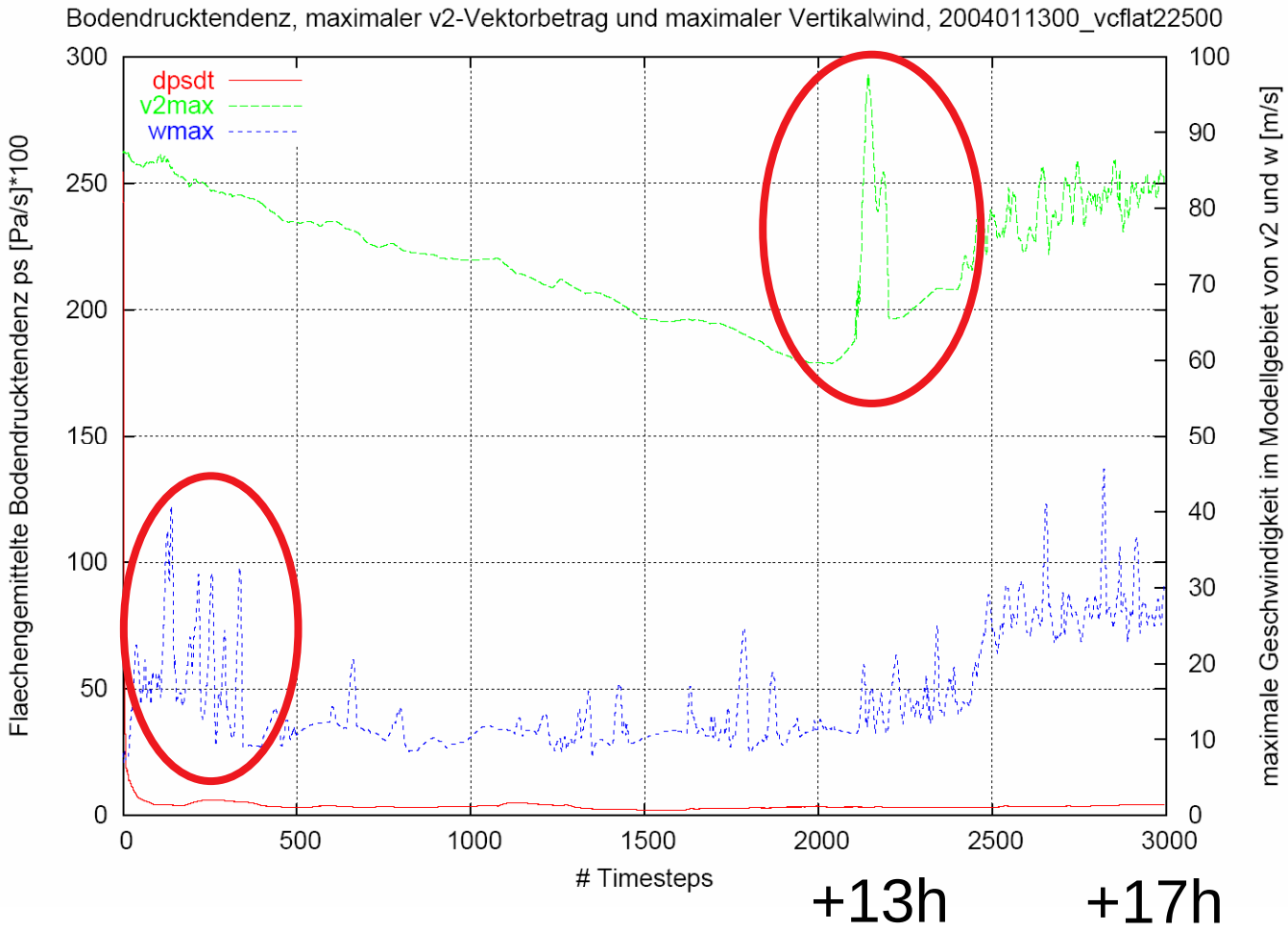
13.01.2004, 00UTC – run
Near the tropopause at +13h

„*Winter*“ setup of 2.2km vertical levels



Instability for a „*Winter*“ case (4)

13.01.2004, 00UTC Δt = 20sec vcflat=22.5km

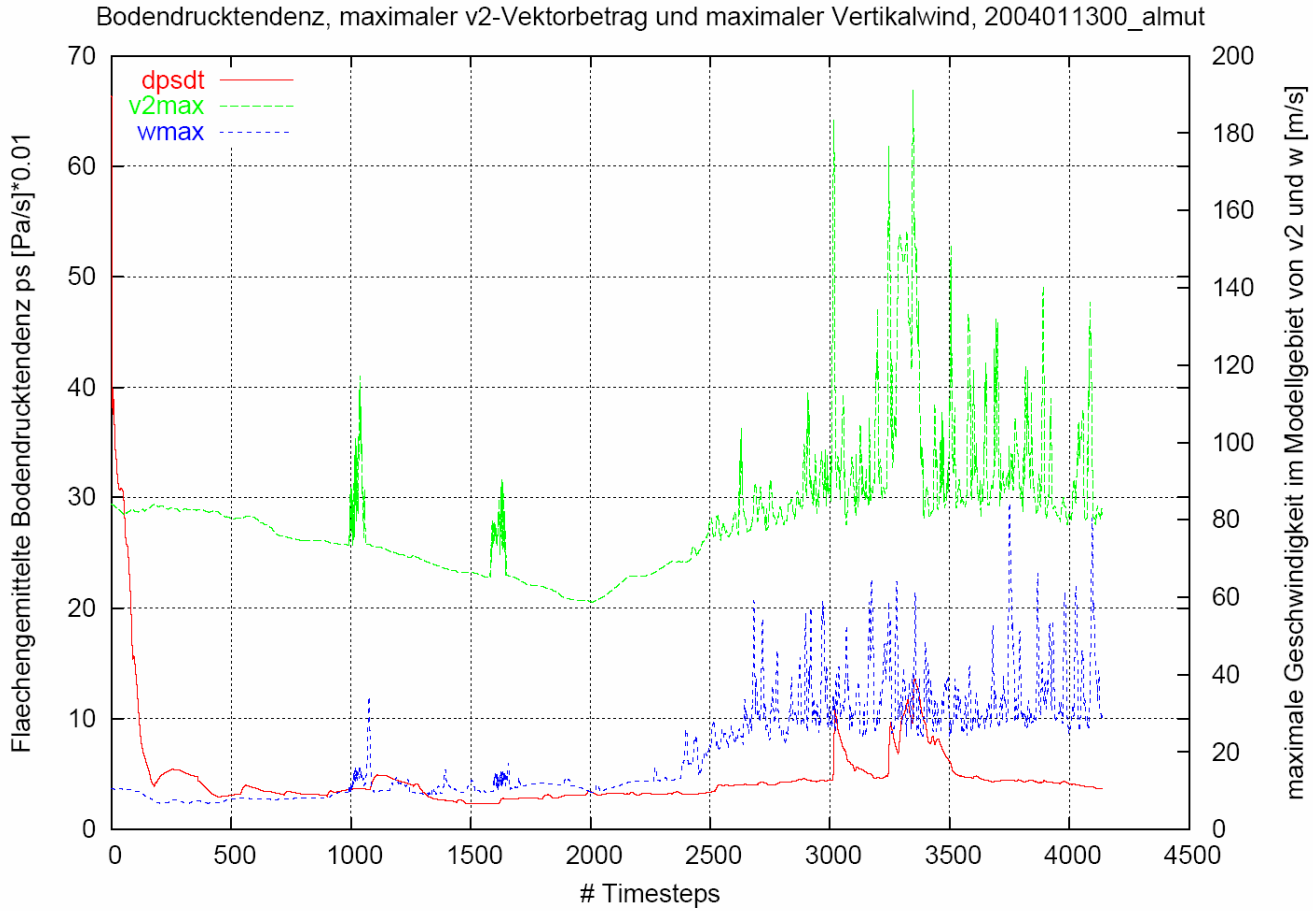


List of tried tests

- *"Easy"*: reduce time step! OK, but not a solution!
- Rayleigh damping zone (terrain following, vcflat=top)
- Rayleigh damping parameters (nrdtau)
- Lateral boundary conditions (llbc_smooth) in INT2LM:
  over 10 grid points smooth transition
  from outer to inner orography
- Horizontal diffusion (itype_hdiff, ldiff_mask)
- No prognostic TKE
- Almut Gassmann's 2 TL scheme:
  ALM in LM 3.15,
  old turbulence scheme i.e. without prognostic TKE
- *"LMK"* configuration (2.8km, DWD domain, L50, Δt = 30 sec)
- Semi-Lagrange advection of humidity variables

Instability for a „*Winter*“ case (5)

13.01.2004, 00UTC Δt = 20sec LM 3.15 + ALM

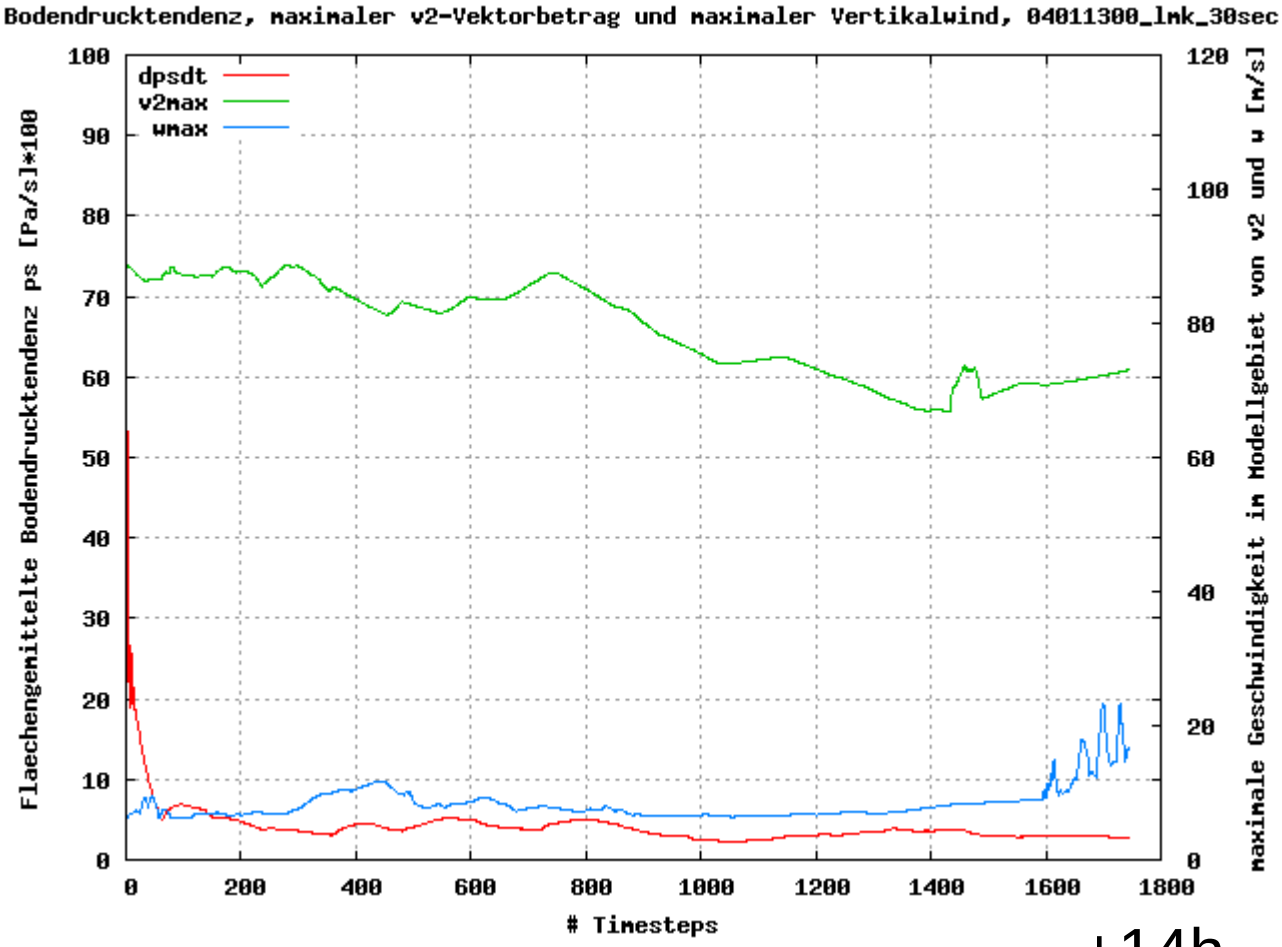


+24h

Test with „*LMK*“ configuration (1)

Δt = 30sec
⇒ not OK!

With Nudging
⇒ +16h

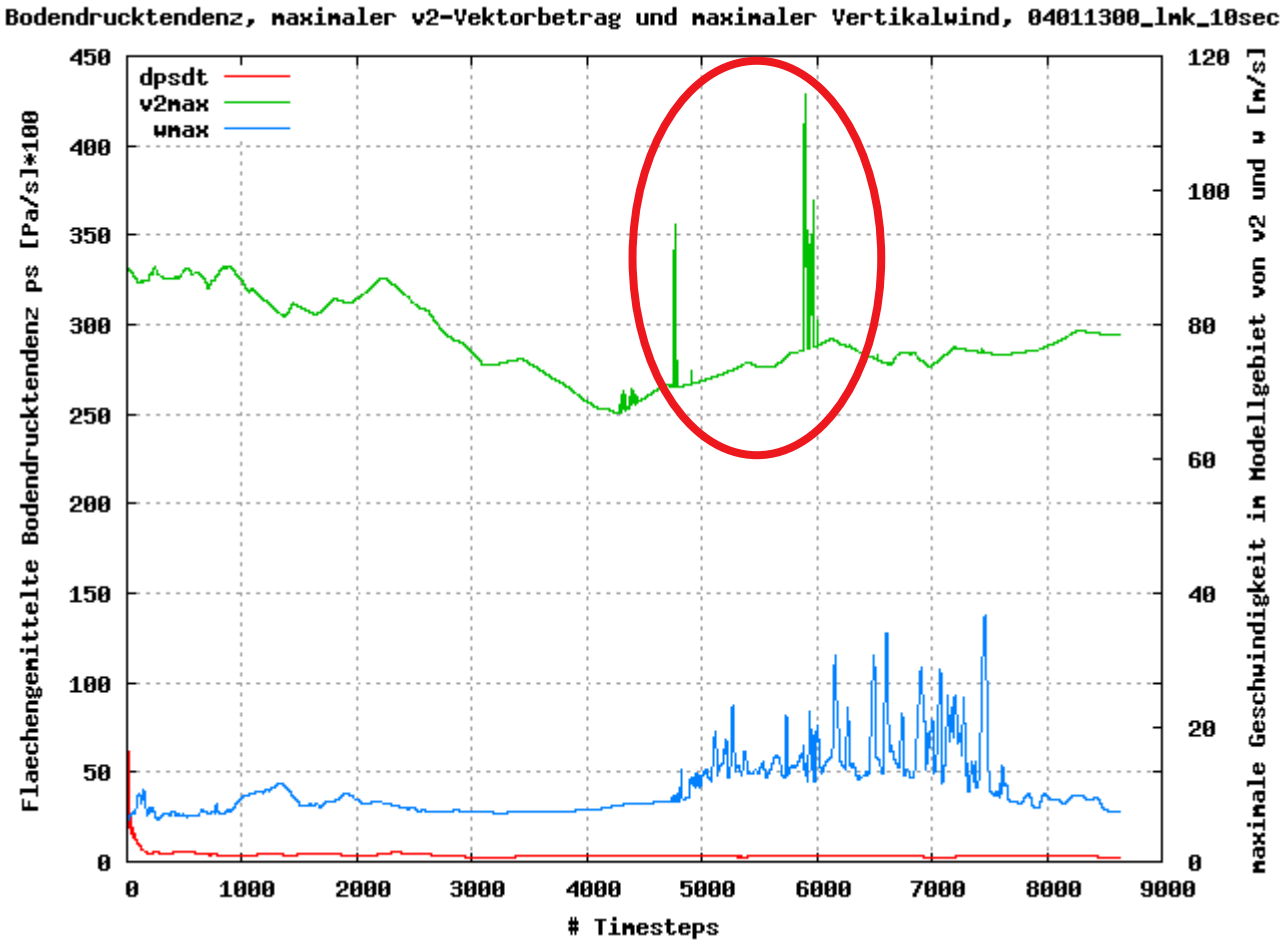


+14h

Test with „*LMK*“ configuration (2)

Δt = 10sec

=> „OK“



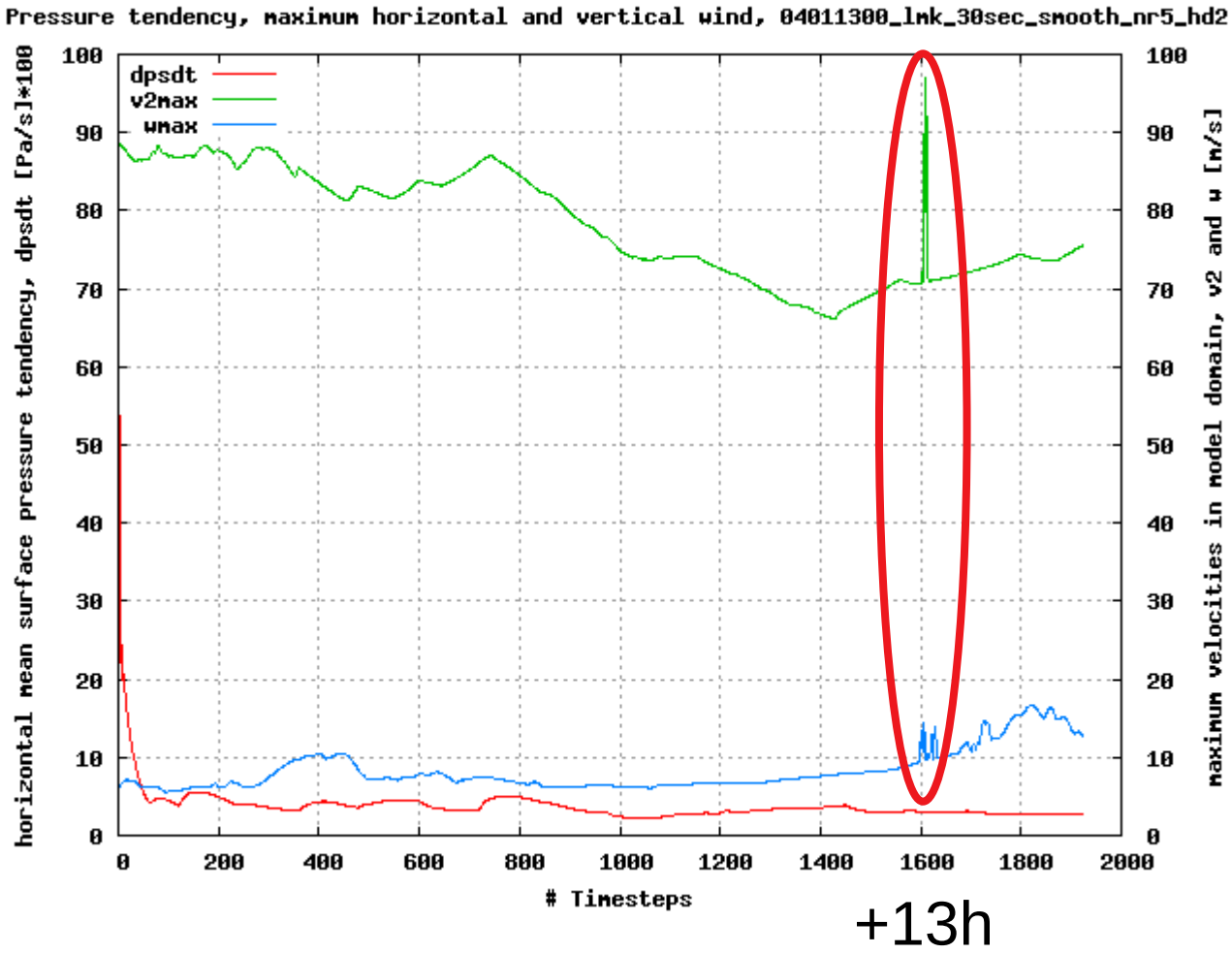
+13h +17h +24h

Test with „*LMK*“ configuration (3)

Δt = 30sec

llbc_smooth=.T.
nrdtau=5
itype_hdiff=2

=>
not OK at +16h!

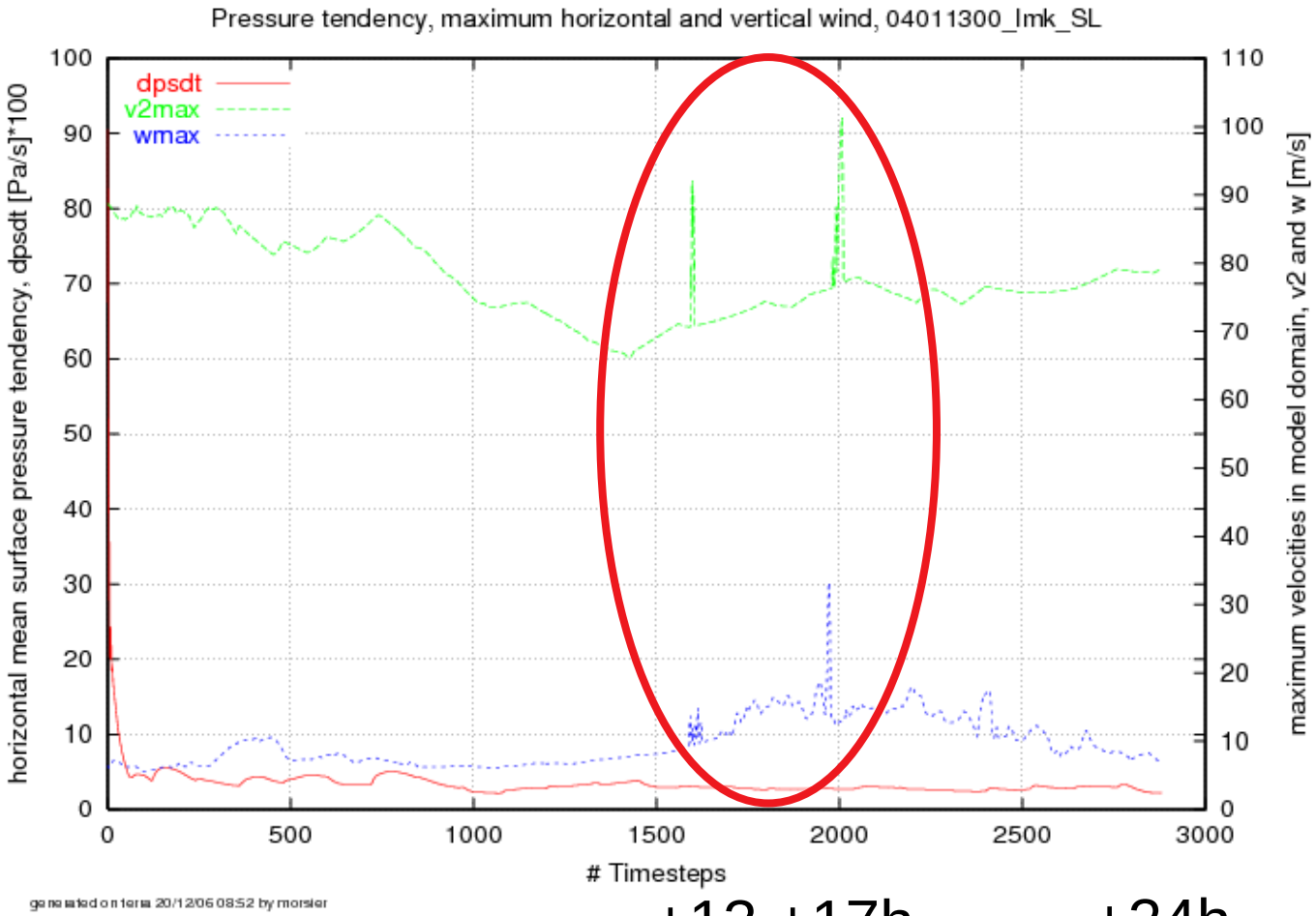


Test with „*LMK*“ configuration (4)

Δt = 30sec

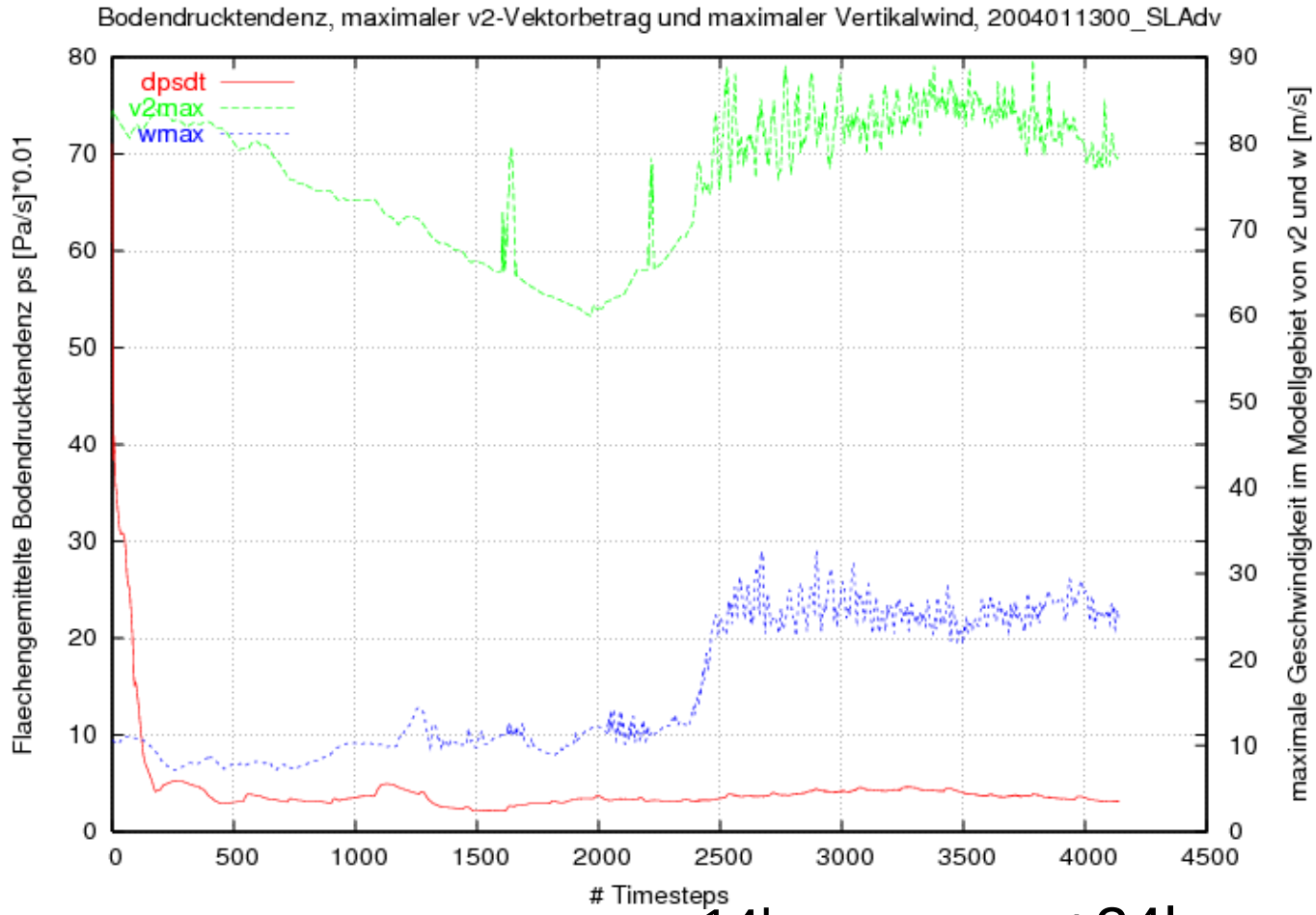
lsl_adv_qx = .T. (Semi-Lagrange advection of humidity variables)

=> „OK“



Instability for a „*Winter*“ case (6)

13.01.2004, 00UTC Δt = 20sec lsl_adv_qx = .T.



Conclusions

- A bad feature of INT2LM was located and a remedy could be fund such that the initial conditions are stable.

- The strong wind instabilities could be explained by:
  - trespassing the CFL-criteria in fast_waves
  - deficient physical-dynamical coupling
  - imprecise advection of humidity variables leading to a positive feed-back mechanism

- The impact of a smooth transition from the 7km to the 2.2km orography in the inside of the domain with the interpolation program INT2LM is small for the studied cases.

Outlook

- Enable a more flexible definition of the height of the BL in INT2LM (through namelist input and/or try diagnostic of BL top)

- Study more precisely the interactions between the momentum variables and the humidity/temperature variables in fast_waves.f90.

- Implement A. Gassmann's ideas in the LM code:
  - What must be improved?
    (=> modification of fast_waves.f90)
  - radiative upper boundary condition (RUBC)

- Impact of SLEVE vertical coordinates for 7 and 2.2km (D. Leuenberger)