

# LBC's and initialization status (and plans)

**Piet Termonia**

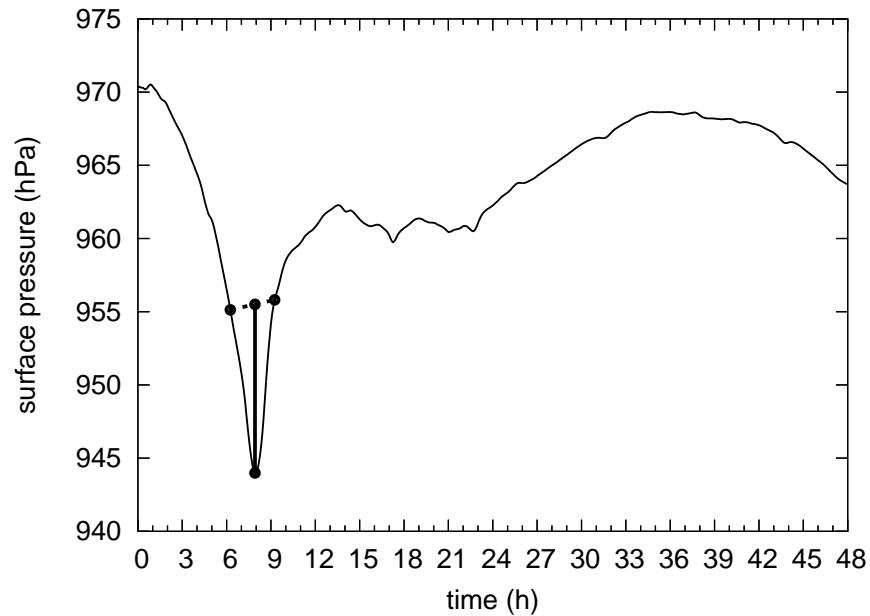
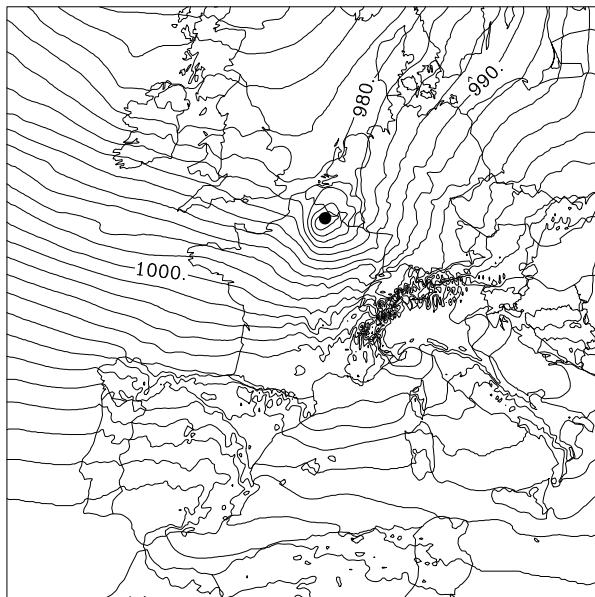
Royal Meteorological Institute of Belgium

# Contents

- The temporal resolution problem: gridpoint nudging
- Filtering too much in DFI?
- “something about Boyd’s solution”
- We should treat LBC’s as model error and thus in an EPS sense?

# The LBC Temporal problem

$p_s$  in the ALADIN-Fr Lothar stom run in the indicated point for a field provide with 3-h temporal resolution:

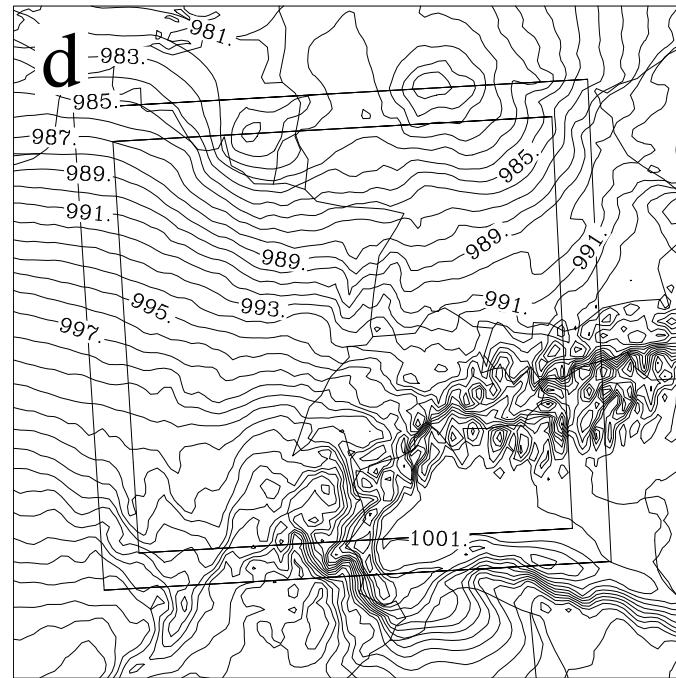
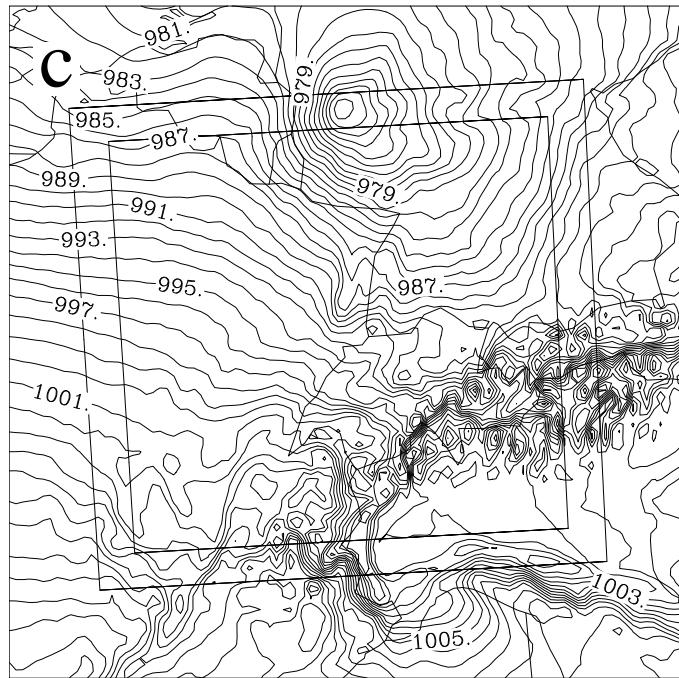


The error between interpolation and real field is 11.5 hPa!!!!

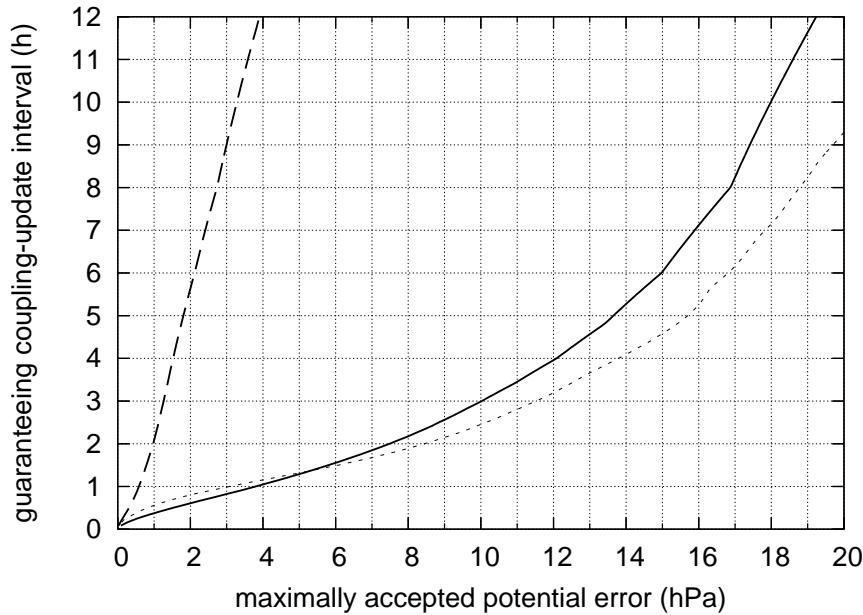
**The interpolated low is always LESS deep!**

# The dipole

Tudor and Termonia, MWR, 2010: A 3-h interpolation creates a dipole (see Fig d),



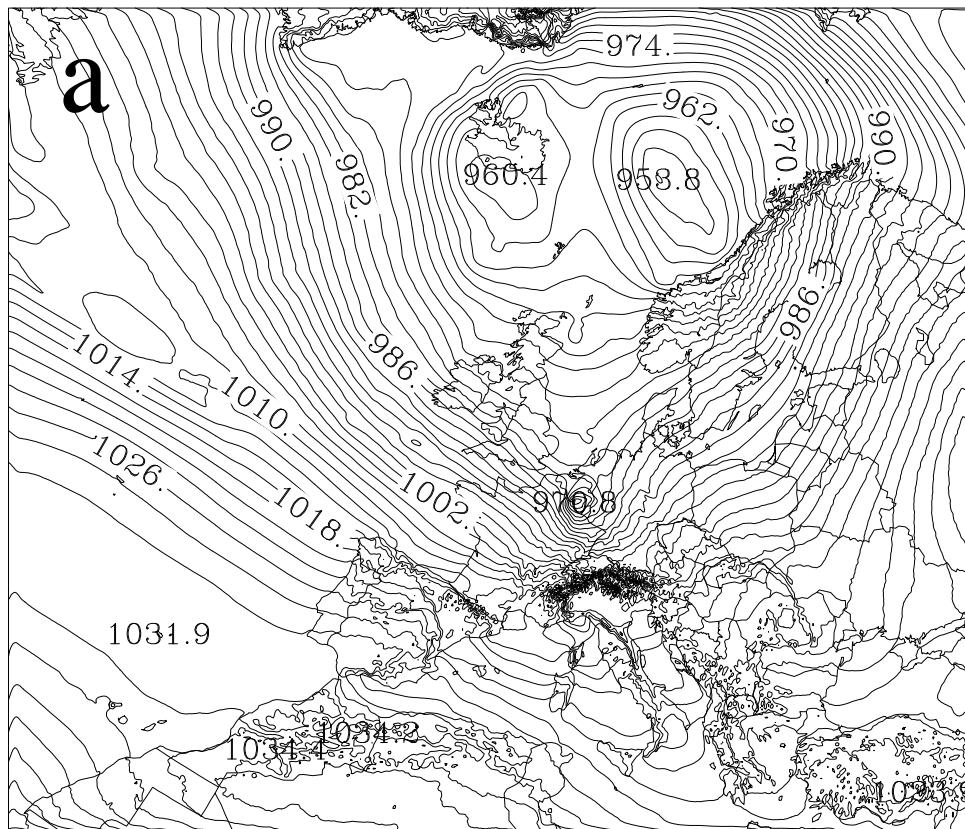
# What coupling interval should we use?



Termonia, Deckmyn, Hamdi, 2009, MWR

- *But in normal cases 3h is OK.*
- *To have a guarantee that we never make an interpolation error of more than 1 hPa we would need to couple with about 15-20 min intervals!*
- *With 1-h intervals we could get 4 hPa.*

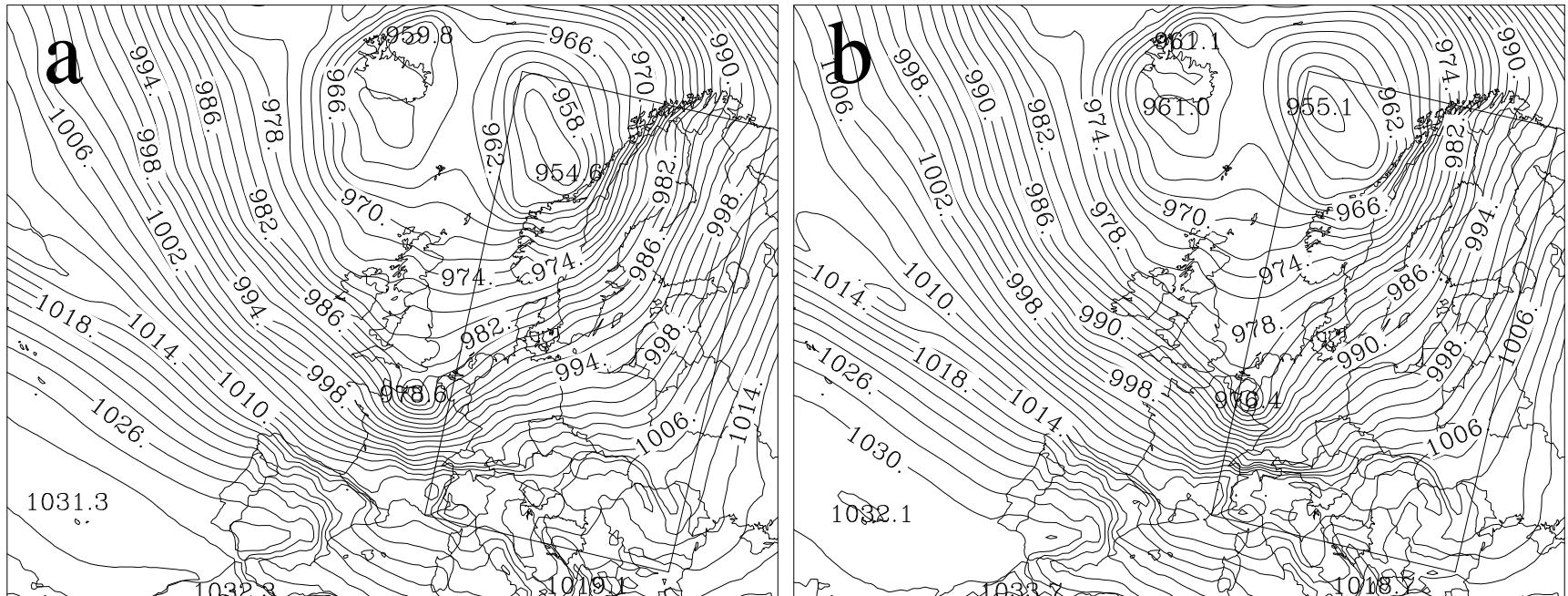
# Perfect model tests



Termonia, Degrauwe, Hamdi

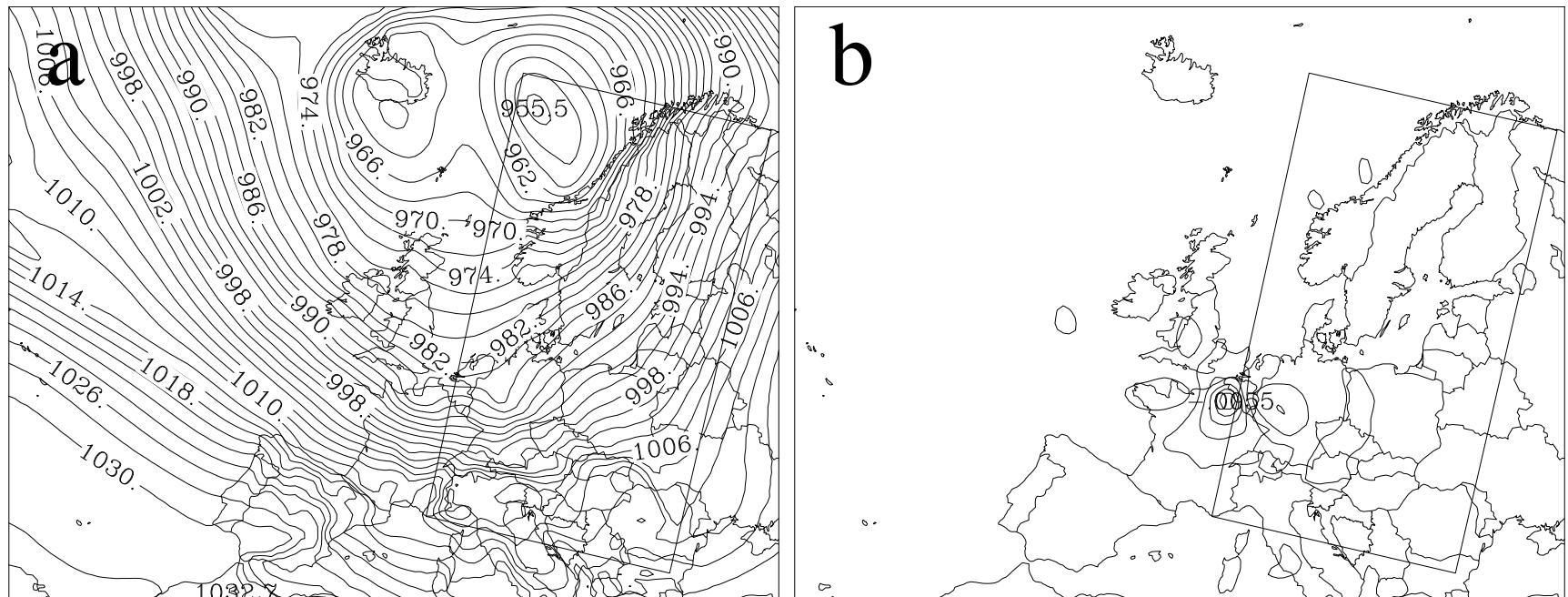
The perfect-model run with a resolution of 10 km at 0900 UTC. The contour interval is 2 hPa. The depth of the eye if the depression is 970.8 hPa.

# Host model at 40-km resolution



**Figure 1:** The host model output of the Lothar storm at 40-km resolution: (a) at 0600 UTC (the depth of the depression is 978.6 hPa), (b) at 0900 UTC (**976.4 hPa**). The rectangles in the four panels show a subdomain that has been used as a guest domain for a limited-area model.

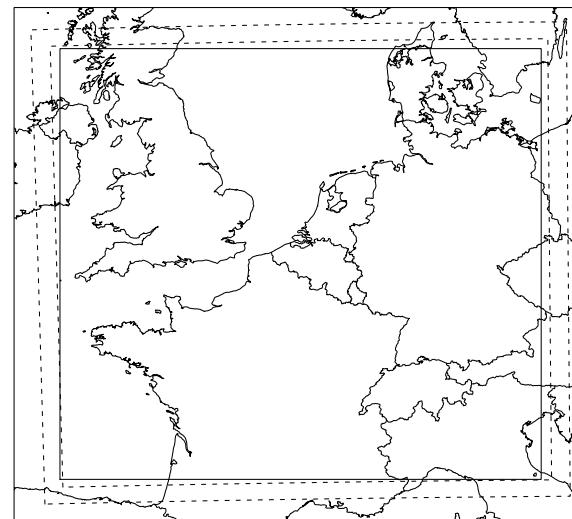
# Interpolation and MCUF



**Figure 2:** An illustration of the temporal resolution problem: (a) The temporal interpolation between the 0600 UTC and the 1200 UTC of the 40-km resolution host-model output, taken in the middle of the time interval, i.e. 0900 UTC and (b) the high-pass filtered logarithmic surface pressure (Termonia, 2004), **MCUF** field at 0900 UTC with a 3-h cutoff.

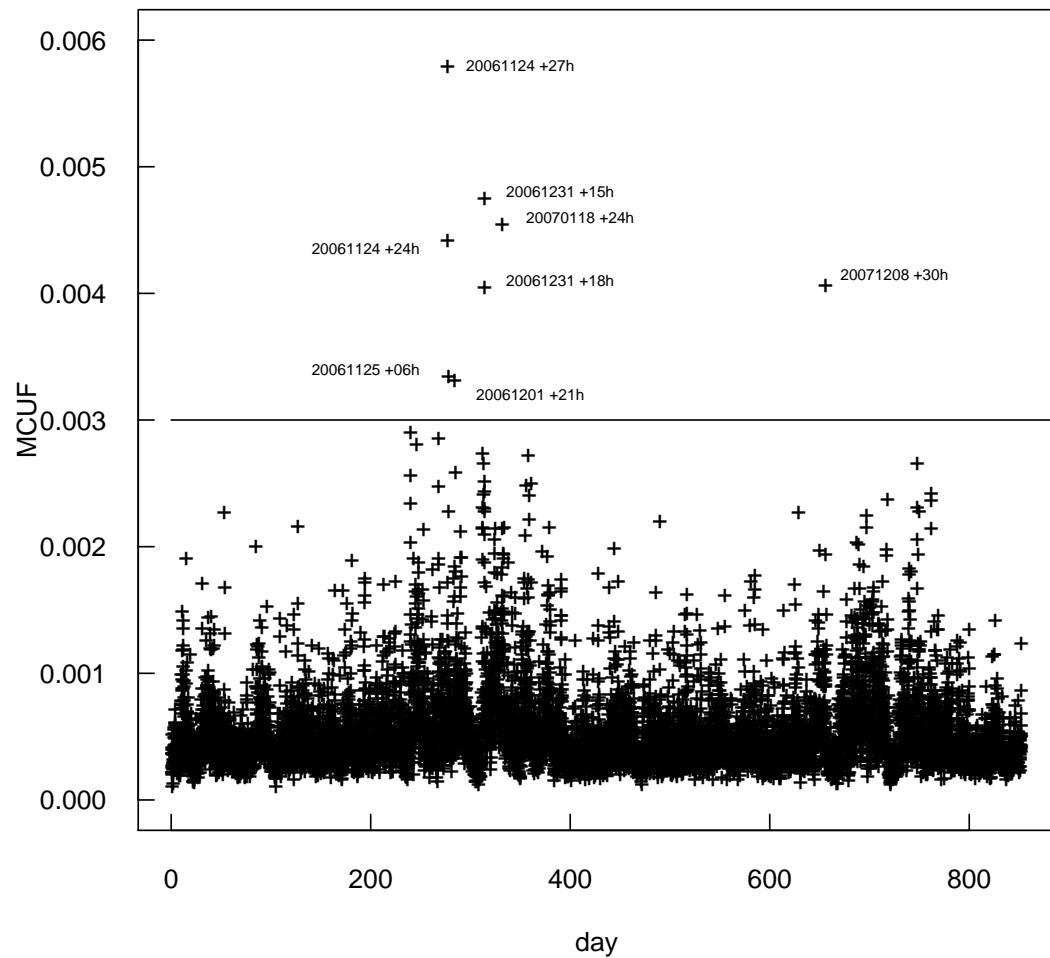
# MCUF

This MCUF field is operationally computed in ARPEGE and written to the coupling files of the ALADIN models. We considered it in the frame (solid line) covering the Davies zone (dashed),



# The maximum MCUF in the frame

in the period 21 February 2006 – 30 June 2008

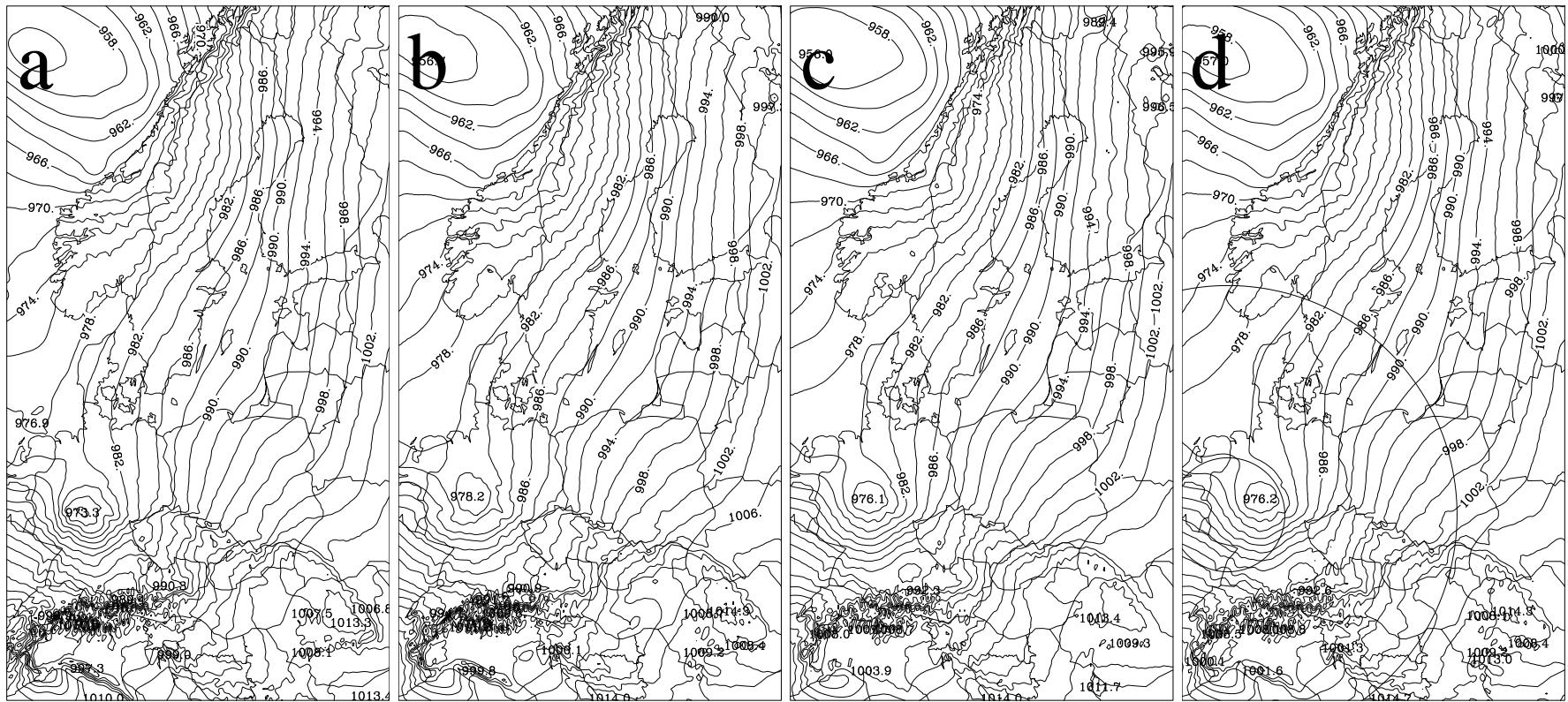


Let us consider  
a threshold  
value of 0.003.  
Then we had 8  
alerts.

# Claim

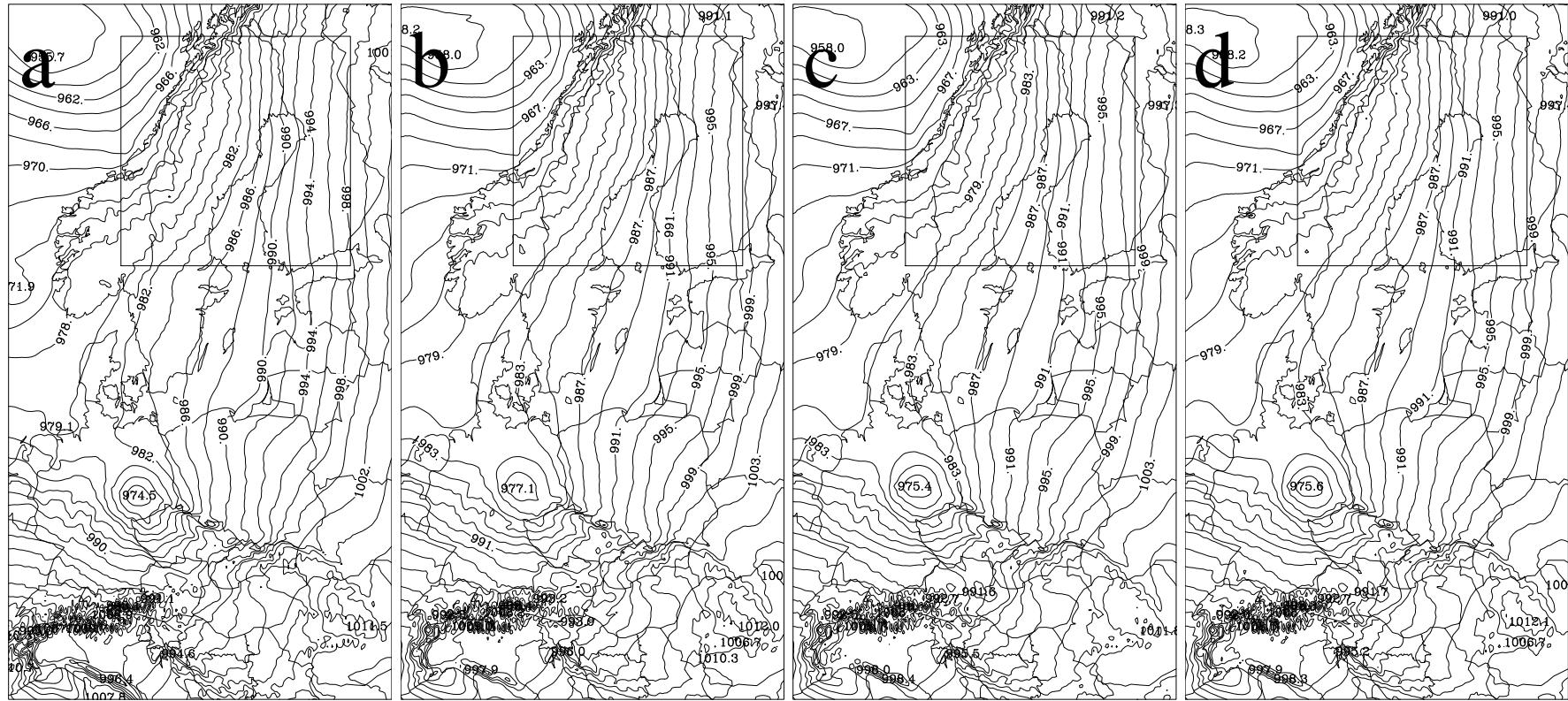
- As said 3-h is OK normally
- In the previous figure we saw that in 99,9 percent this is OK.
- Then should we transfer all these data in an optimal nesting strategy within the consortia?

# The guest model at 10-km resolution



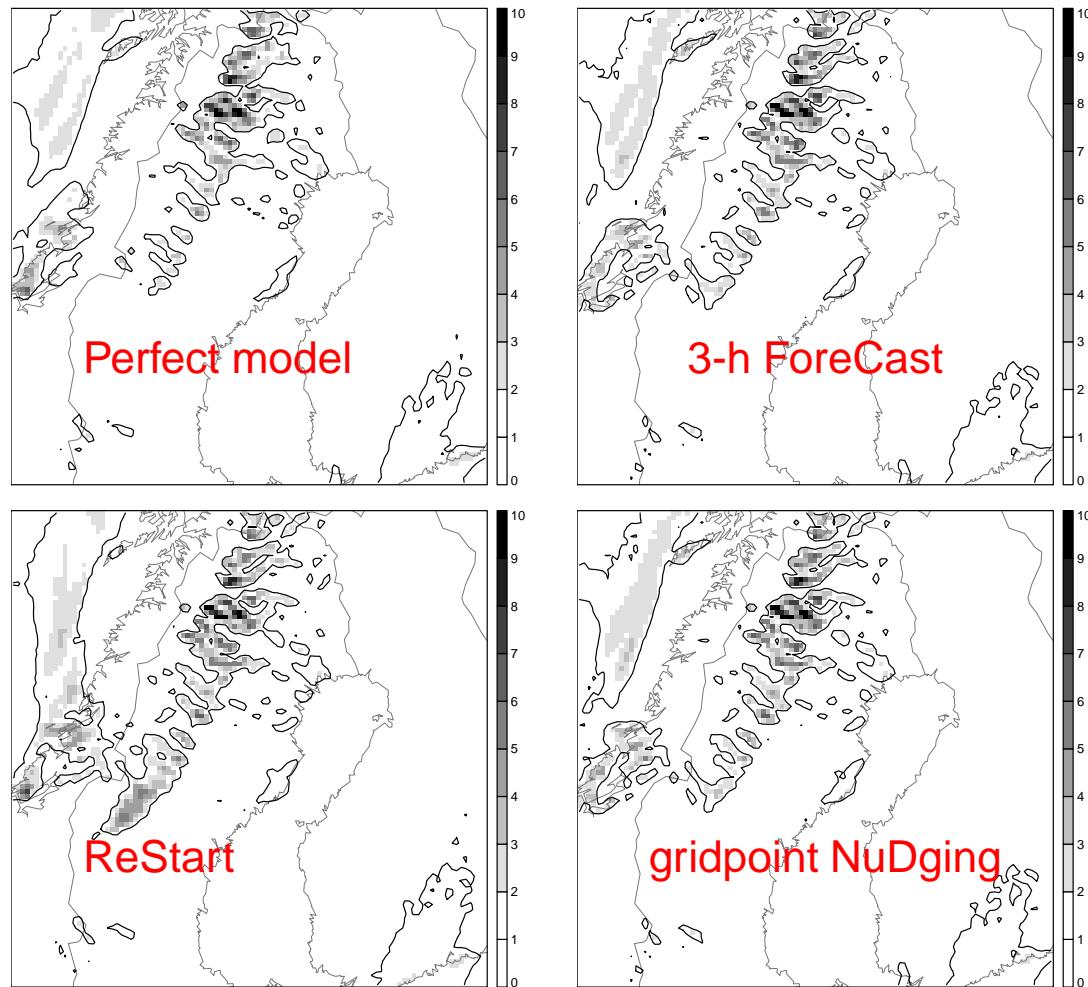
**Figure 3:** The Lothar storm at 1200 UTC of (a) the perfect model run (**973.3 hPa**), (b) the run on the small domain with boundary data coming from the 40-km run (**978.2 hPa**), (c) a restart with boundary data coming from the 40-km runs (**976.1 hPa**), and (d) the gridpoint nudging with boundary data coming from the 40-km run (**976.2 hPa**)

# The guest model at 10-km resolution



**Figure 4:** The Lothar storm at 1500 UTC of (a) the perfect model run, (b) the run on the small domain with boundary data coming from the 40-km run, (c) a restart with boundary data coming from the 40-km runs, and (d) the gridpoint nudging with boundary data coming from the 40-km run

# Precipitation outside nudged area



Accumulated precipitation [mm] between 15 h and 18 h for the Lothar storm case on 26 December 1999: SAL computed for FC, RS, ND, with respect to the perfect model.

	FC	RS	ND
S	-0.054	-0.151	-0.058
A	0.013	0.117	0.025
L	0.021	0.063	0.026

# Conclusion on coupling updates

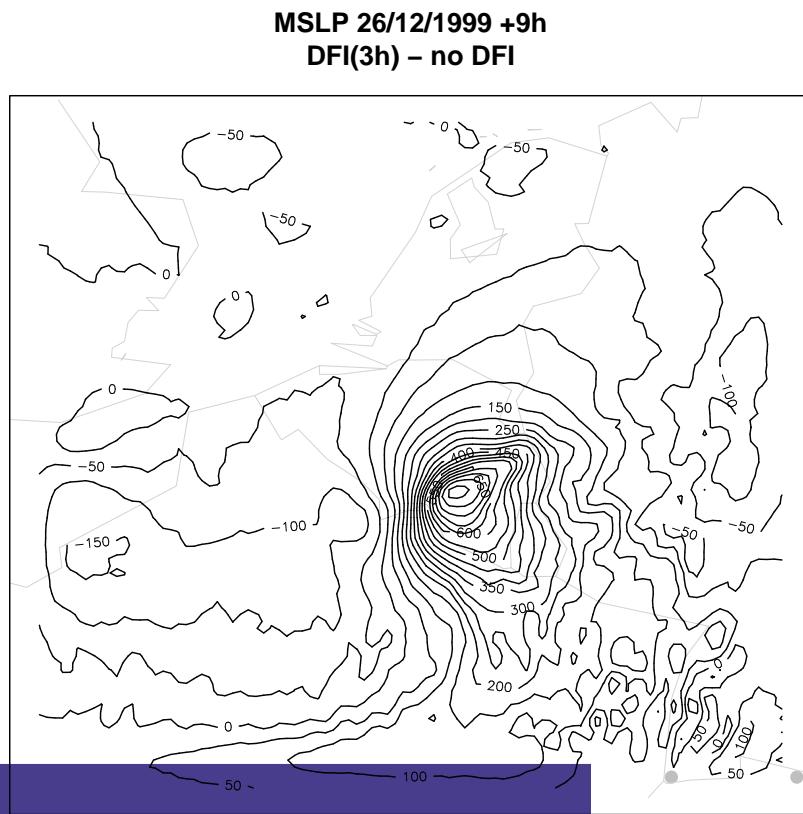
With gridpoint nudging we can get the best of both worlds (build up in the interior and deeper storm).

An optimal nesting strategy might include a monitoring strategy by means of the MCUF field, and a restart in the very rare cases when we detect a sampling error at the boundaries.

We should filter more diagnostically

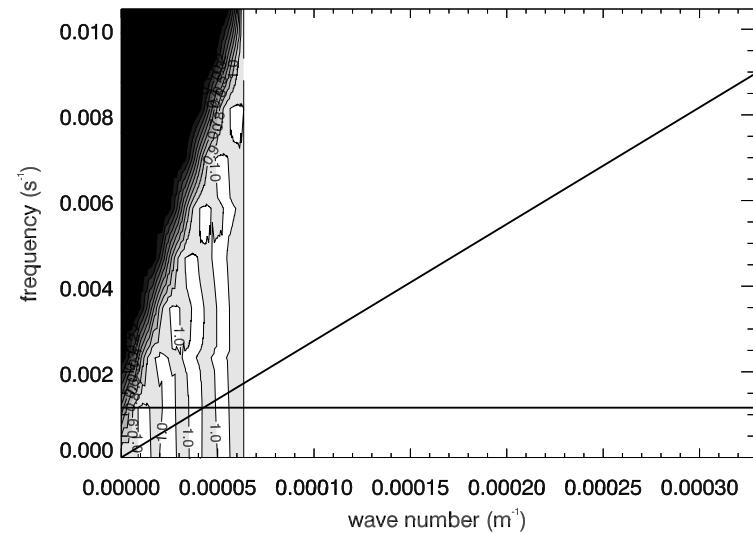
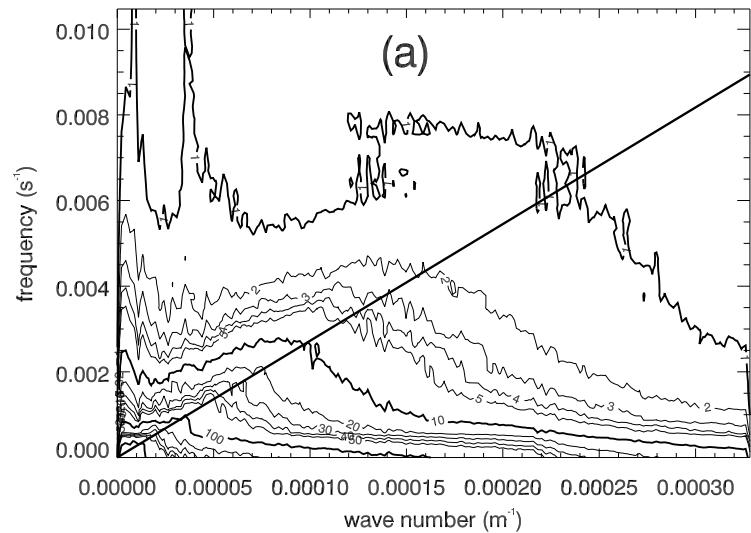
# DFI

However these restarts should be initialized by a DFI!!!



max difference of  
about 8.5 hPa!

# Scale-selective low-pass windows



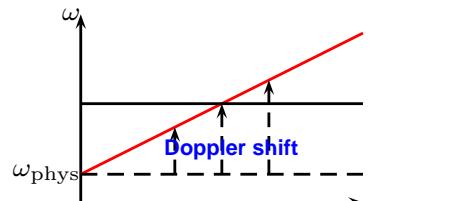
The **scale-selective** cut-off frequency of a low-pass Lanczos filter:

$$\omega_c(\kappa) = \begin{cases} \omega_c^0 + \frac{\kappa}{\kappa_c} \left( \frac{\pi}{\Delta t} - \omega_c^0 \right) & \text{if } \kappa \leq \kappa_c \\ \frac{\pi}{\Delta t} & \text{if } \kappa > \kappa_c \end{cases}$$

The cut-off period is  $T_c^0 = 2\pi/\omega_c^0$  while the *slope* of the cut-off frequencies is  $c = \pi/(\kappa_c \Delta t)$ .

# going to higher resolution

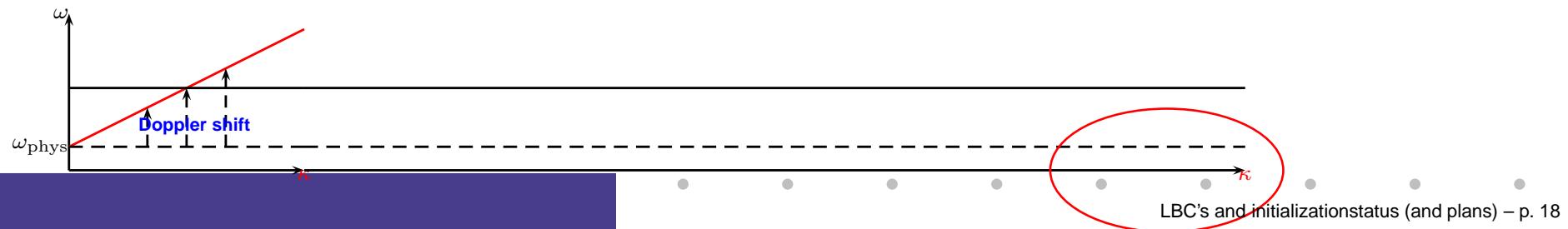
ALADIN<sub>10km</sub> → AROME/HARMONIE<sub>2km</sub>: problems will start already with smaller ( $5\times$ ) propagation speeds:



# going to higher resolution

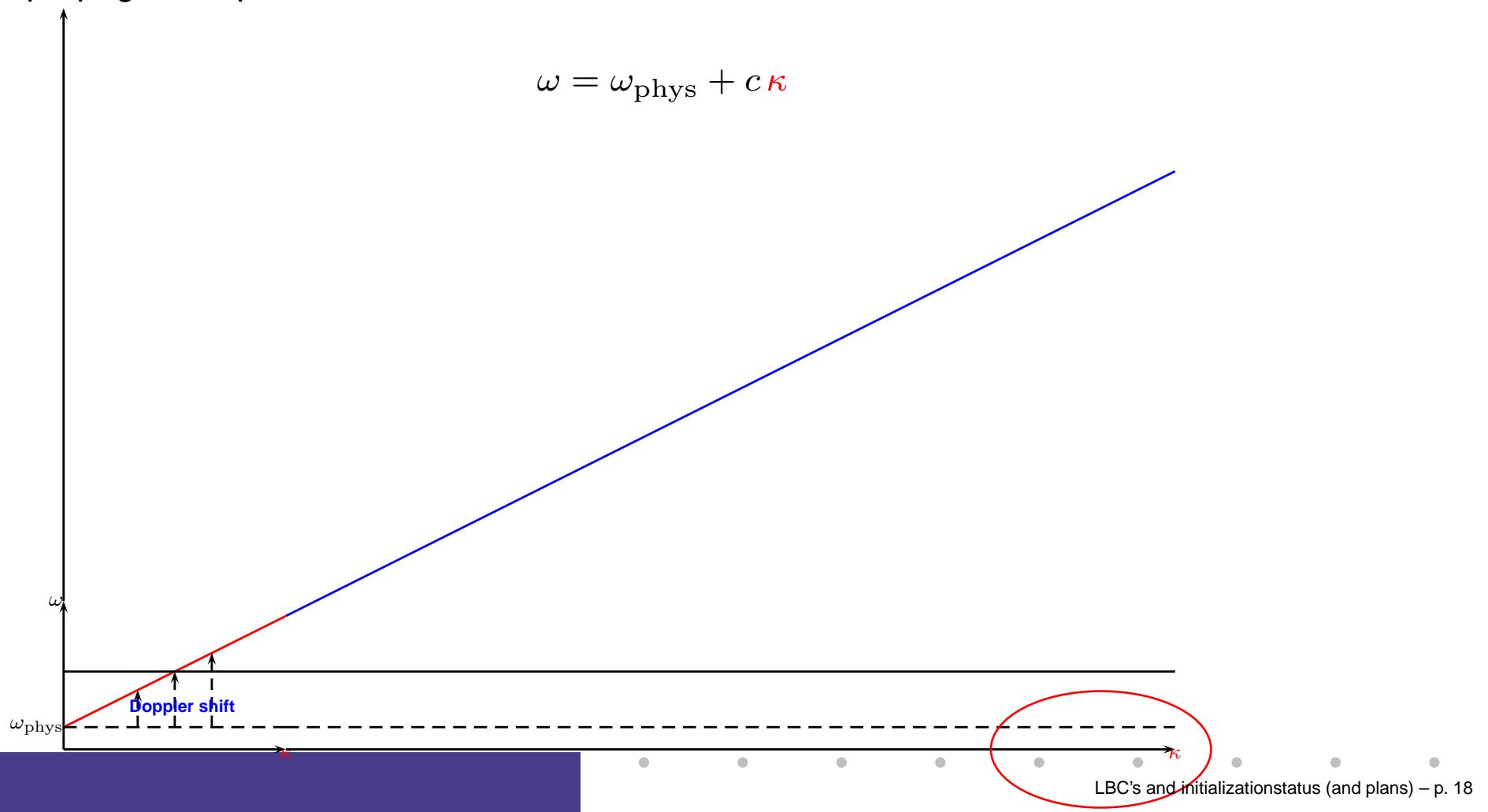
ALADIN<sub>10km</sub> → AROME/HARMONIE<sub>2km</sub>: problems will start already with smaller ( $5\times$ ) propagation speeds:

$$\omega = \omega_{\text{phys}} + c \kappa$$



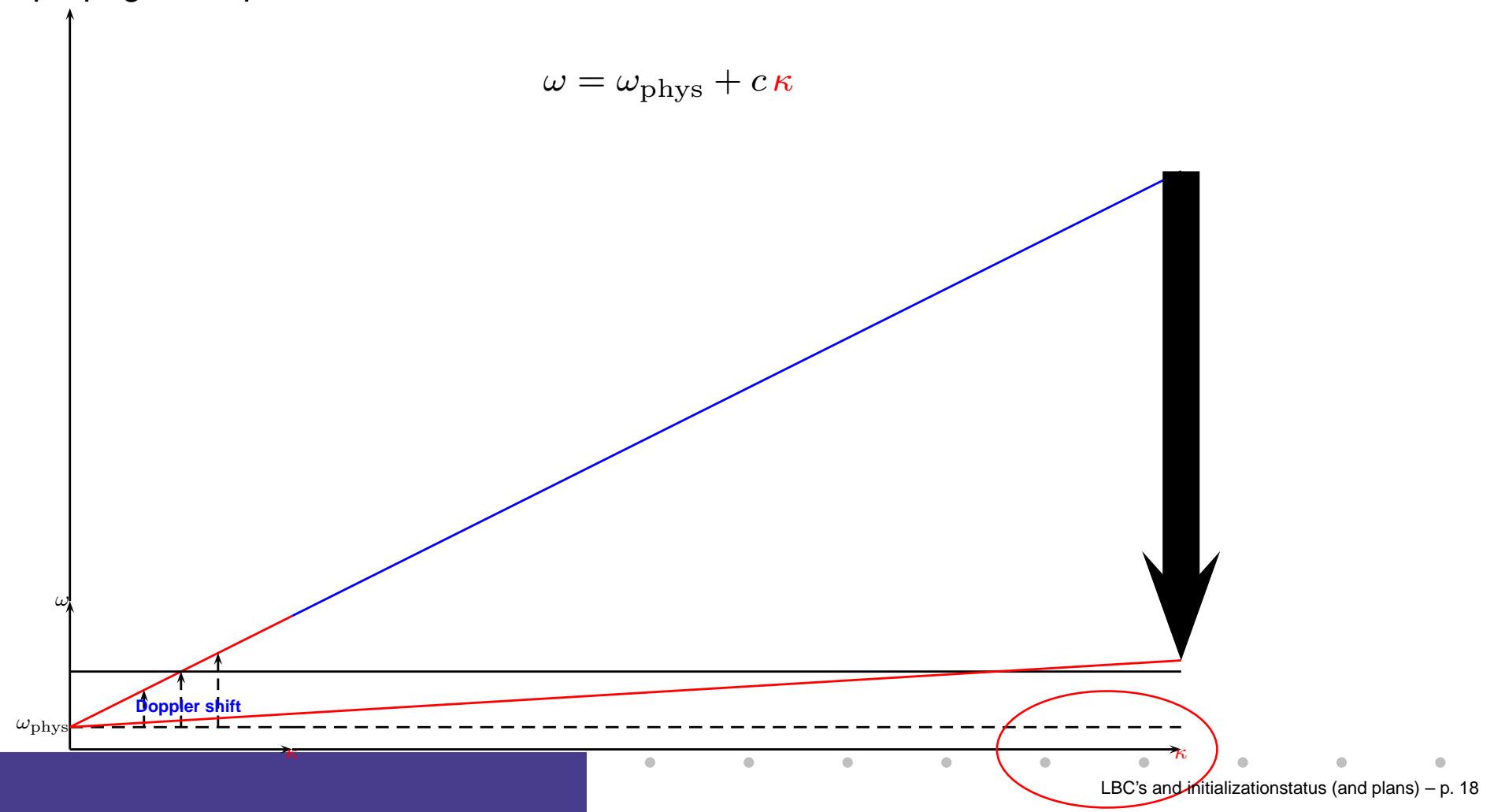
# going to higher resolution

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# going to higher resolution

ALADIN<sub>10km</sub> → AROME/HARMONIE<sub>2km</sub>: problems will start already with smaller ( $5\times$ ) propagation speeds:

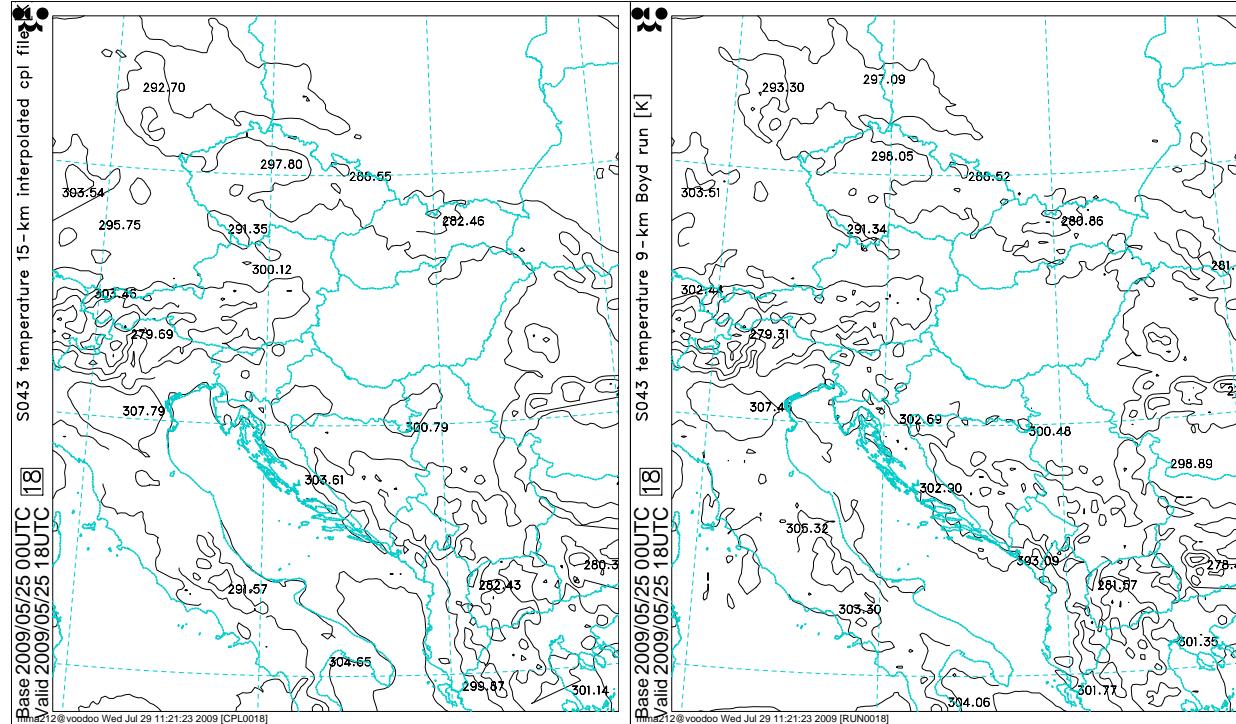


# Claim

When we go to higher resolution there will be a time when DFI will start to filter out the features we assimilate at those scales.

we may start to filter too much at high resolutions!

# Boyd's periodization: a first run



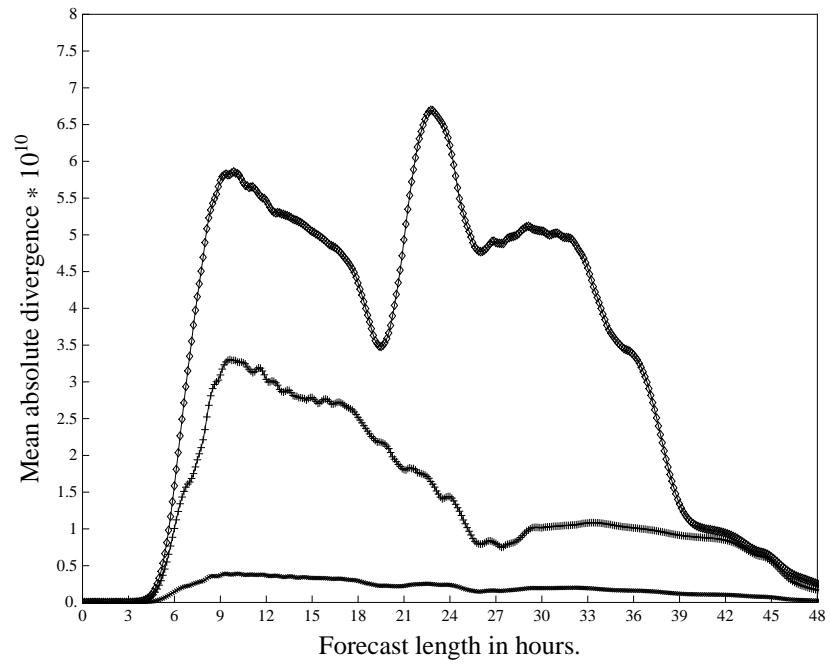
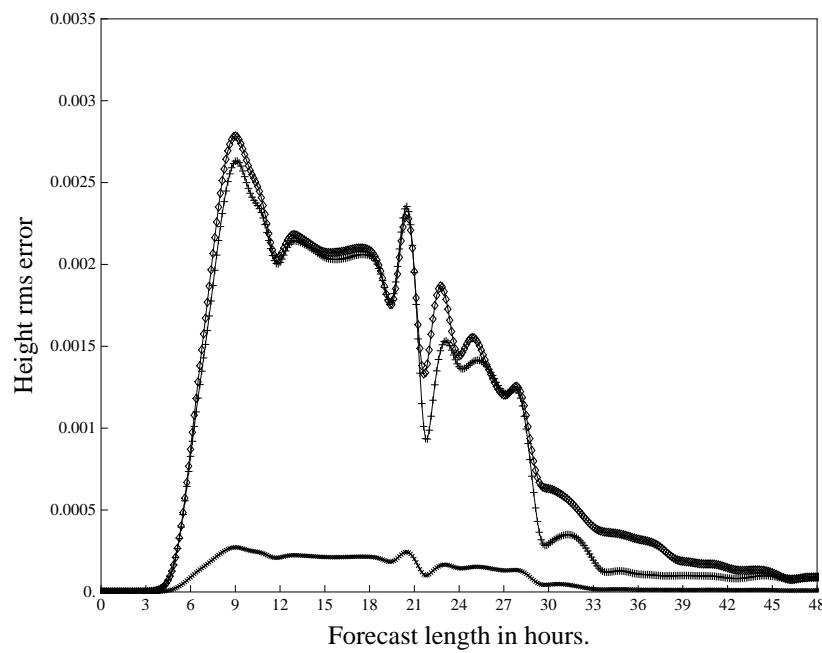
**Figure 5:** A preliminary run: the content of the original domain (resolution 15 km) after being interpolated to 9 km (left), and the run (resolution 9 km), at 18-h forecast range (right).

# Gains from SL trajectories

- Tests with 1D spectral shallow water Eq. with a 2TL SI SL scheme.
- a bell-shaped geostrophic wave propagates through the domain and should get out.
- 3 solutions:
  - classic splines as known
  - Boyd's solution but with SL truncation
  - Boyd's solution but SL trajectories extending into the E zone

# Gains from SL trajectories

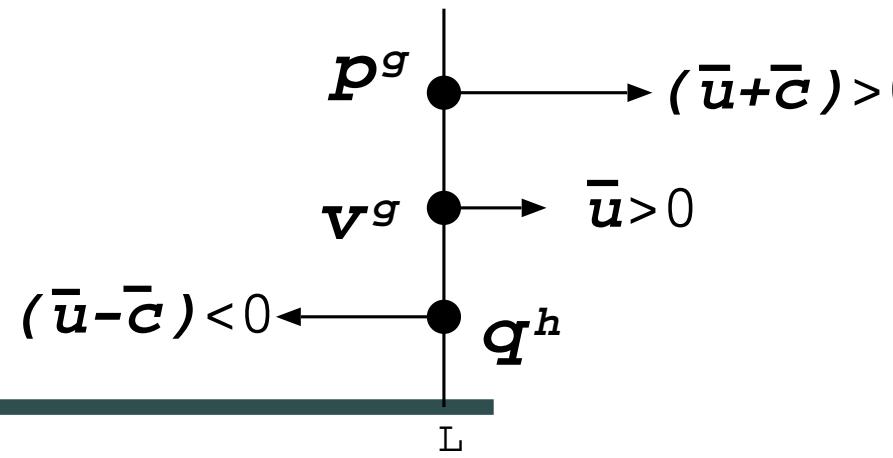
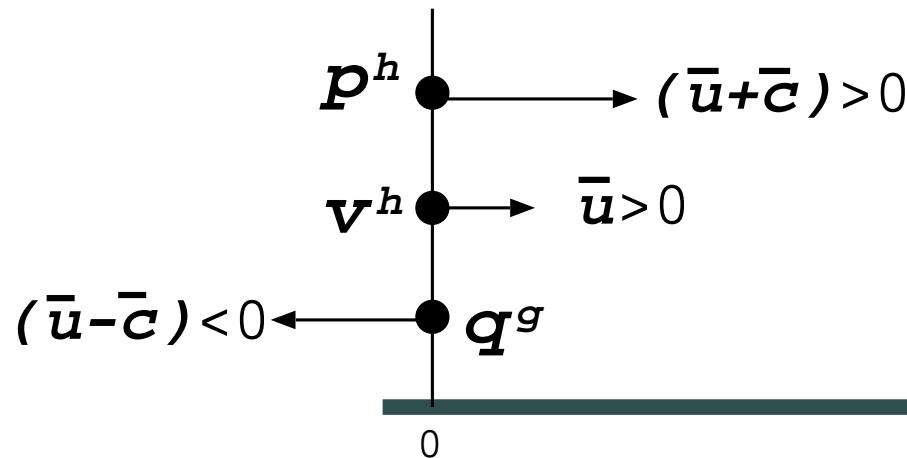
1D shallow water model with 2TL SL, and propagating geostrophic wave  
 $\bar{c} = 300m/s, u = 100m/s, L = 5000km, \Delta x = 10km, \Delta t = 475.s.$



diamond: spline cubic test, '+' Boyd's extension method, 'x' Boyd's extension but using SL trajectories in the vicinity of the inner borders of the E zone where the departure points are outside the domain.

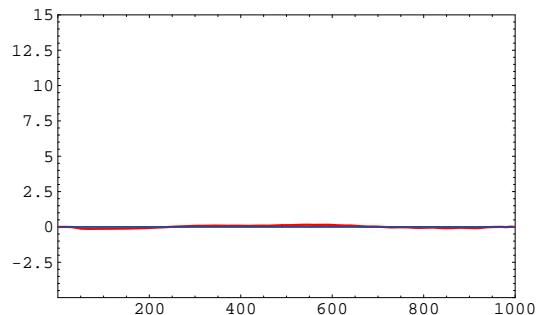
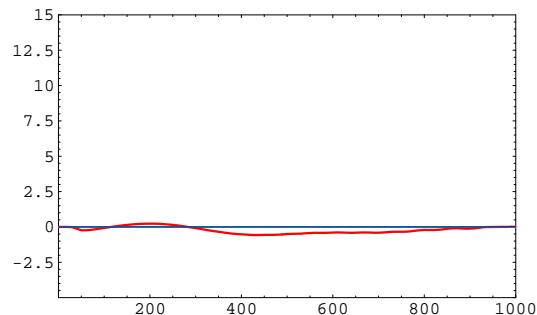
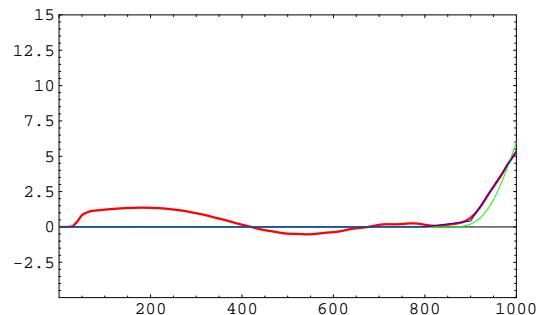
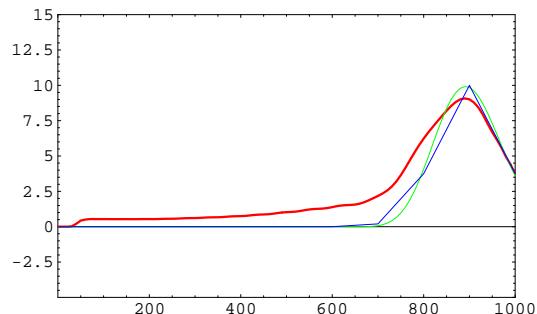
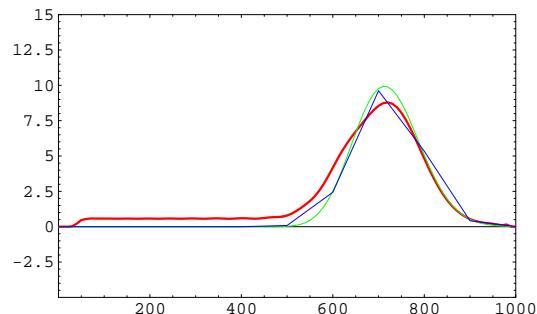
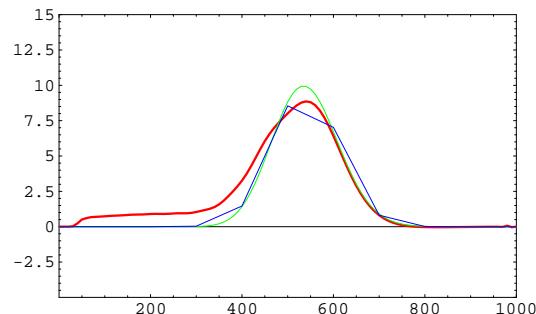
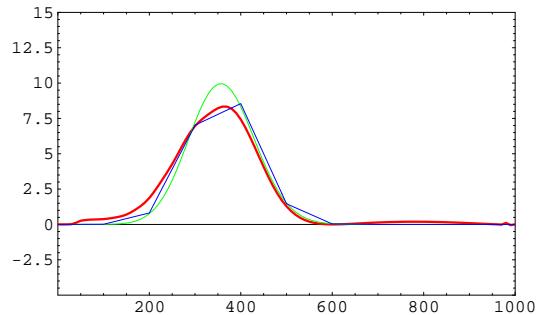
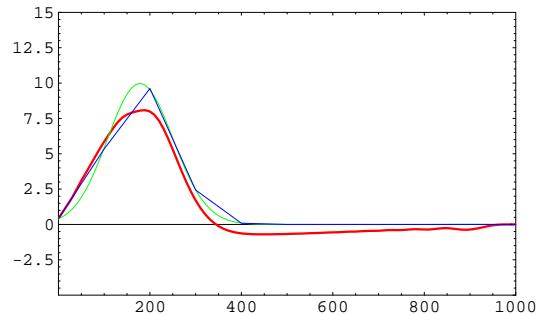
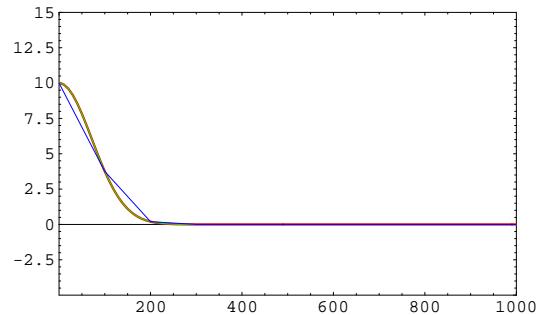
# Open boundaries

Linearize the system and identify the characteristics.

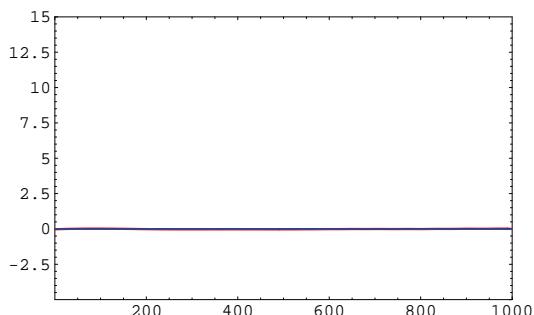
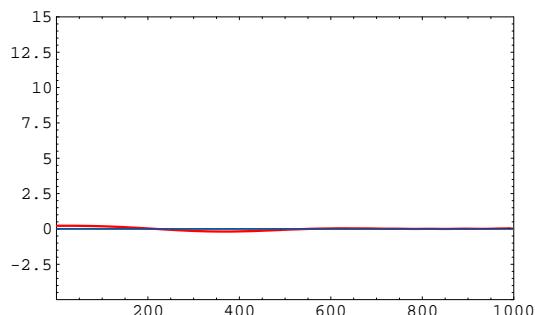
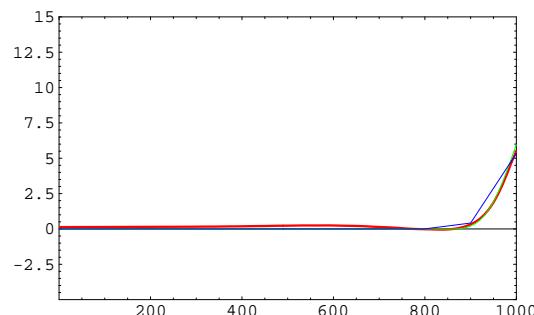
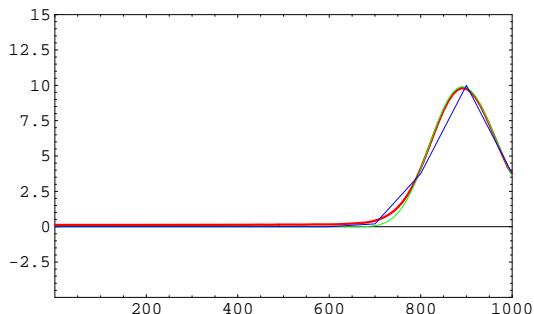
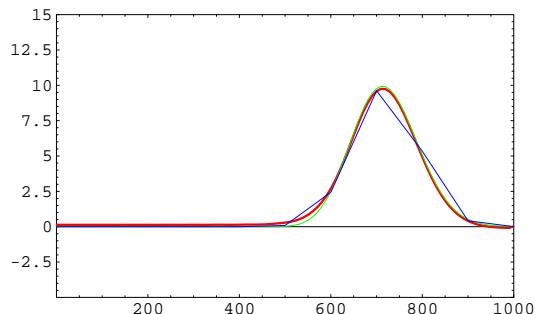
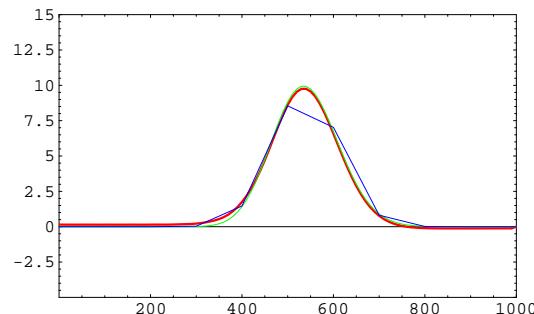
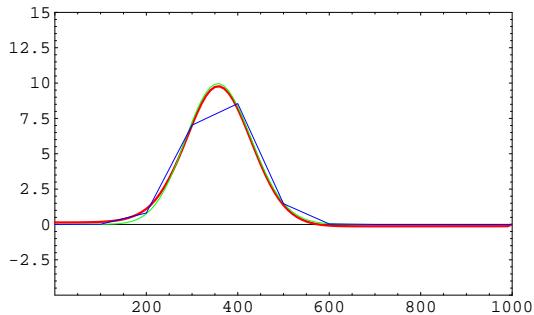
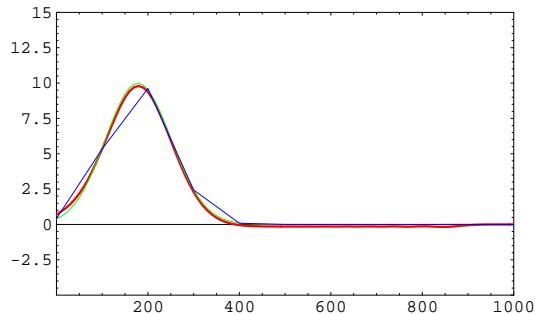
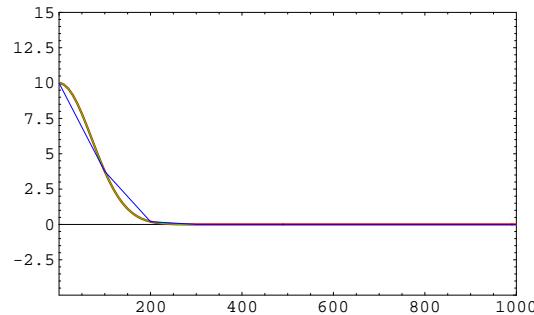


*we impose the incoming characteristics, but extrapolate the outgoing ones*

# Davies, no orography

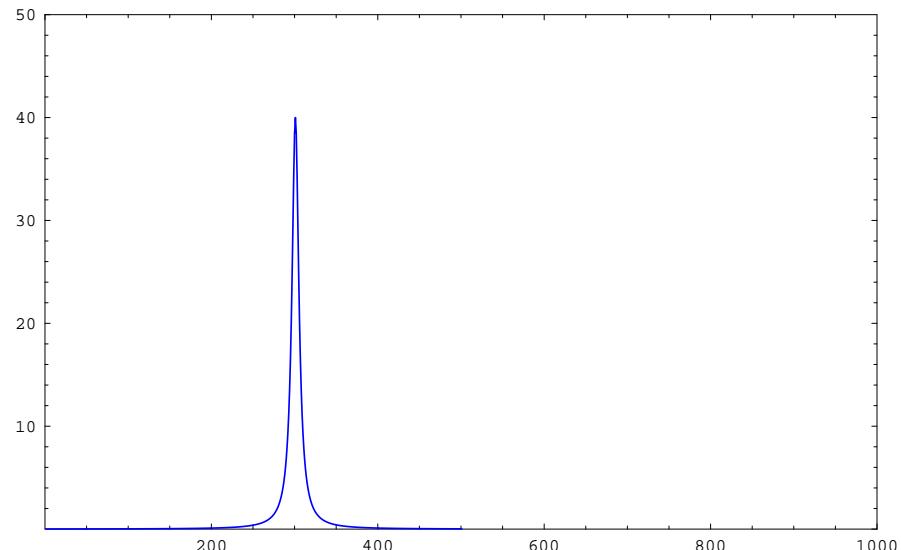


# Open boundaries, no orography

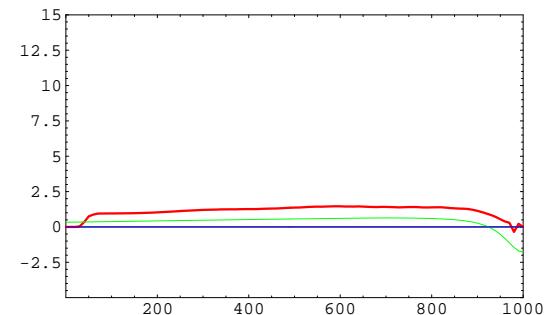
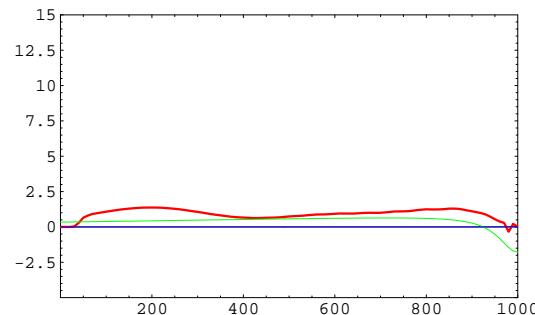
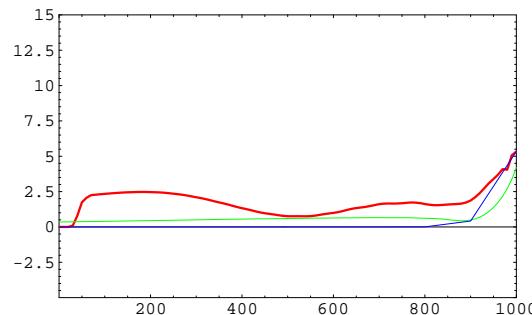
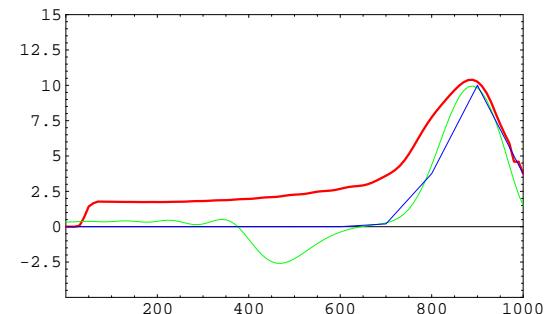
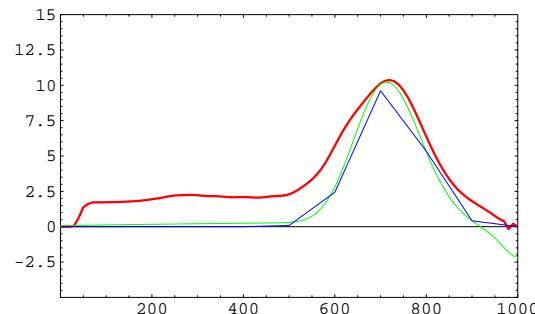
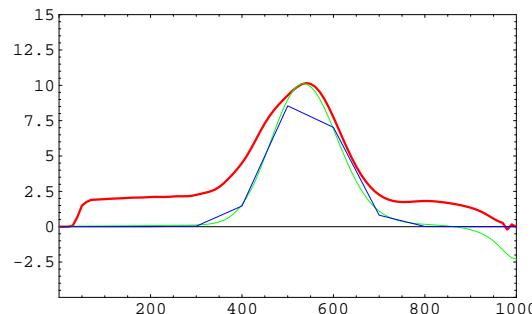
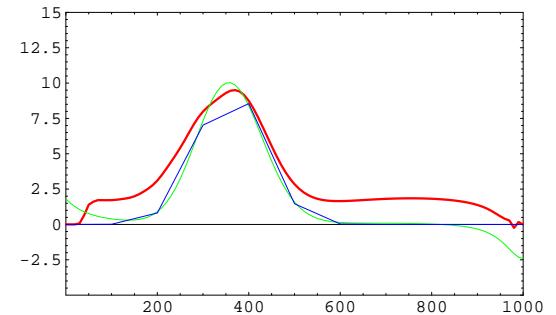
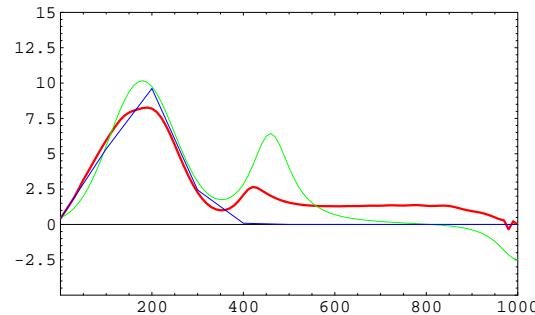
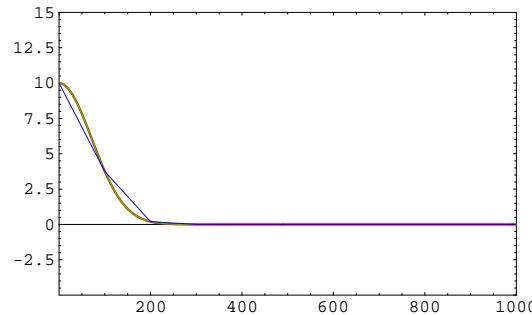


# orography

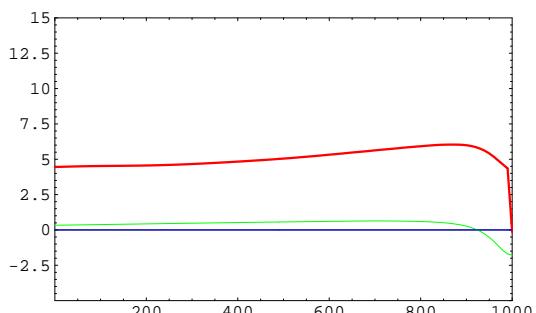
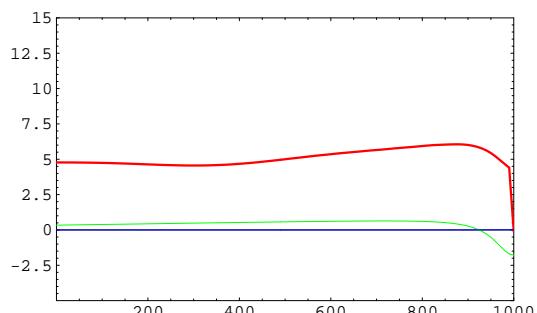
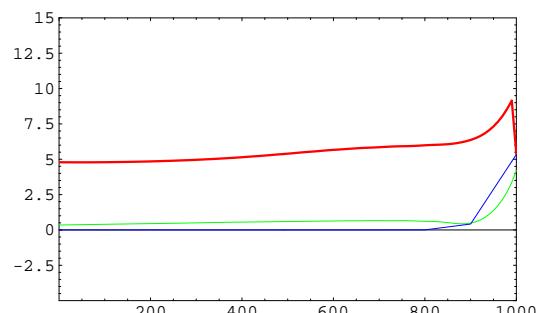
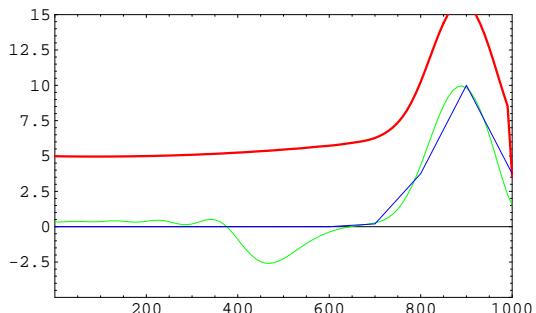
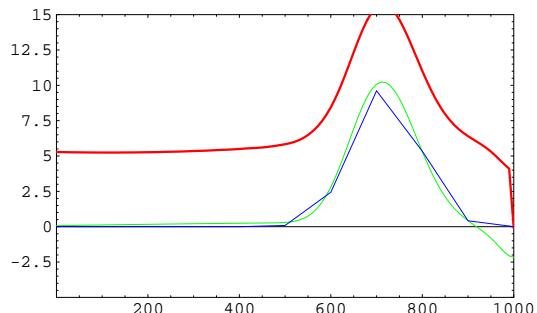
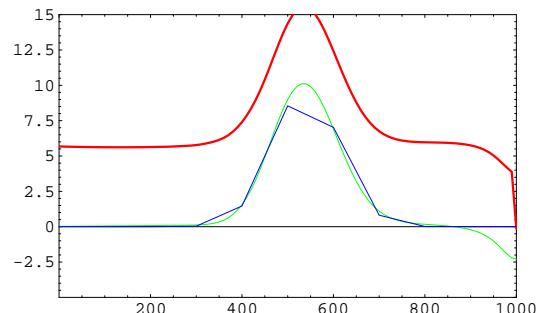
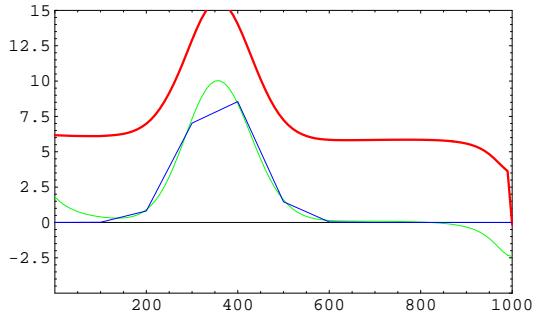
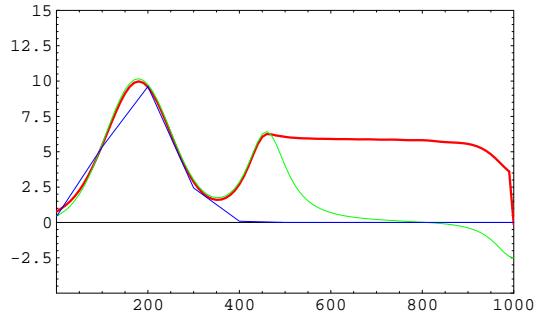
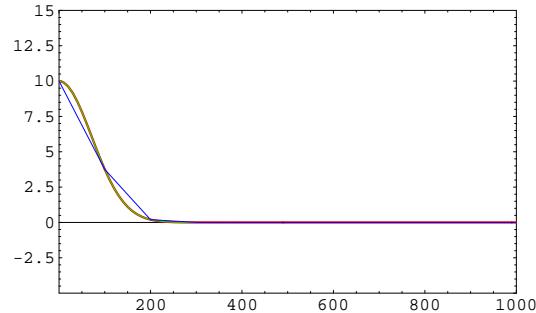
- There is of course a difference between the low resolution large-scale coupling model and high-resolution coupled model.
- The essence of this in dynamical adaptation is the orography
- So let's put a mountain in the domain, that is NOT resolved by the large-scale model but is resolved by the coupled model.



# Davies, with orography



# Open, with orography

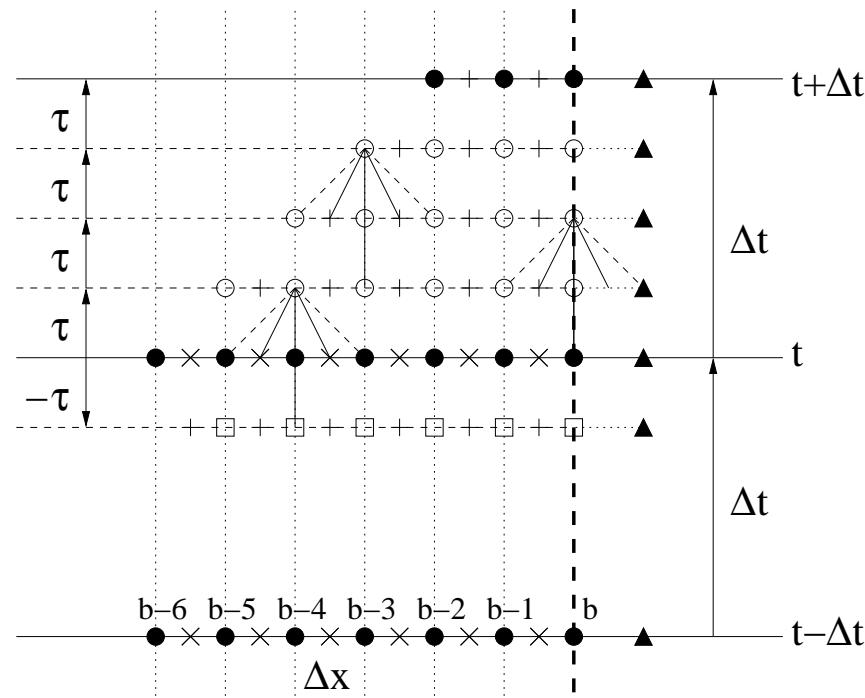


# So...

- Well-posed LBC's works better if nothing “unforeseen” happens in the interior domain.
- If there are features created by the higher resolution in the interior domain, than we don't know what to impose and they work less well.
- This gives a mixed conclusion.

# Extrinsic LBCs

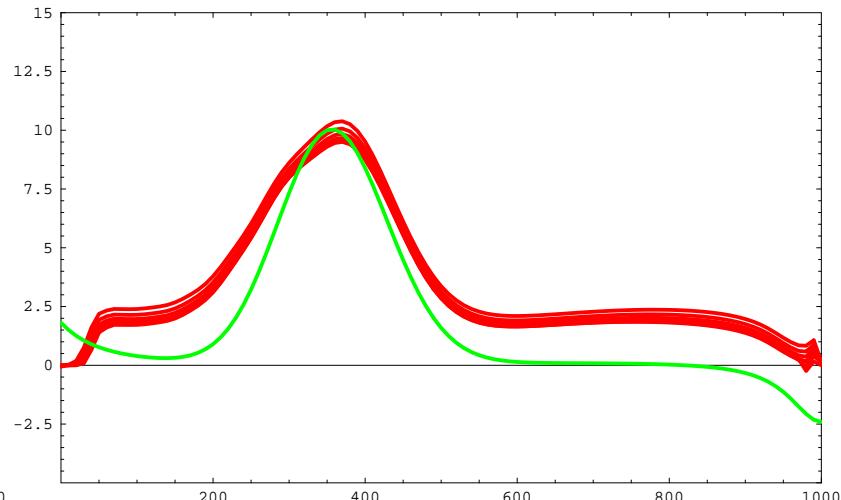
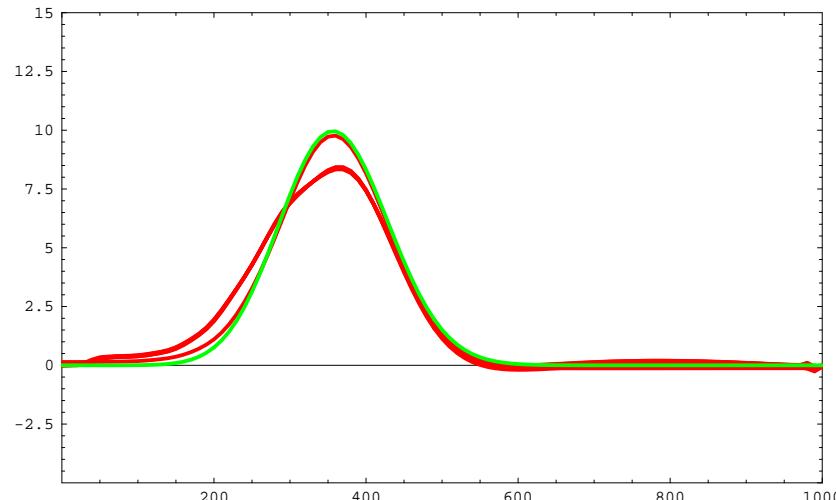
Termonia and Voitus, 2007, *Tellus A*: it is possible to compute the incoming and outgoing characteristics *outside* the dynamical core of the model: extrinsic LBCs.



# An ensemble, orography

$$X_{perturbed} = X_{global} + \sigma (X_{open} - X_{global}) = X_{global} + \sigma \delta X$$

$$X_{coupled} = (1 - \alpha)X_{timestep} + \alpha X_{perturbed} \quad (1)$$



# Claim

We should give up the ambition to have open LBC's, but instead,

- accept LBC's, and the temporal resolution problem as “model errors”, and
- use all our science we gathered up to now (cfr. work of A. McDonald) to “perturb” the boundaries in an intelligent way.

By the way one could also include MCUF in this to perturb the boundaries, but then the model error is the interpolation.

# Conclusions

- In order to have a guarantee that we never make an interpolation error of more than 1 hPa we would need to couple with about 15-20 min intervals!
- But in normal cases 3h is OK.
- The need for 20-min intervals is extremely rare.
- *Should we couple (most of the time too much) with 1-h interval, if we only need at most a few times per year, even then in a specific 3-h interval?*
- *We should filter more for diagnostic monitoring.*
- When we go to higher resolution there will be a time when DFI will start to filter out the features we assimilate at those scales.
- Improving the LBCs other than the Davies scheme is a frustrating business. I argued that the best way is to "give up" to improve them in a deterministic sense, but to see theoretical improvements as *intelligent perturbations of the LBC's in an ensemble system*. We consider the LBC limitations as model errors, and treat them similarly as stochastic physics.
- Even MCUF could be used to perturb the boundaries, to take into account "model-error" due to "dipoles".

# Discussion

- We would write gridpoint fields only to  $C + I$ . Is that a problem for anyone?
- Project on nesting strategy: is something missing?
- LBCEPS, some reaction of EPS specialists?