Cubic, quadratic or linear truncation: compute cost and quality

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Background

In early days, spectral models were using the so-called quadratic grid, i.e. the shortest wave length was 3 Δx. It avoided the aliasing in the case of the Eulerian advection and also the stationary 2 Δx forcing;

Later, the move to the semi-Lagrangian advection removed the aliasing trouble and so the linear grid came along with the 2 Δx shortest wave length except the orography because of the stationary forcing;

Increasing the resolution however made this strategy quite expensive, especially in case of global models. We have witnessed the proposal of the cubic grid, i.e. 4 Δx shortest wave length.

What about the spectral resolution choice in the case of a LAM?

Further comments

What means to go for a lower truncation:

1) Saving compute cost:

- ✔ Spectral transforms (in bi-Fourier of the LAM case it is maybe not by that much);
- ✔ Spectral space computations;
- ✔ Time step length;

2) Saving size of history files;

3) Increasing the numerical stability (less steep slopes);

4) ? What about the model answer to it …

Experiment set-up

A) Resolution: $\Delta x = 1.16$ km, ***linear grid***, $\Delta t = 45$ s;

B) Resolution: $\Delta x = 1.16$ km, ***quadratic grid***, $\Delta t = 72$ s;

C) Resolution: $\Delta x = 1.16$ km, ***cubic grid***, $\Delta t = 72$ s;

Remark: even cubic grid does not allow a longer time-step than 72 s, otherwise there are trajectories going underground;

In all experiments, there is a 6-h assimilation cycle, applying the combination of CANARI surface analysis and upper-air Digital Filter Blending. The cut-off blending truncation is kept the same.

There is NO change in the model setup to adapt more to varying spectral resolution.

Model configuration characteristics

The operational CHMI setup of CY46T1 with local enhancements was used

– **Dynamics**: **Non-hydrostatic**

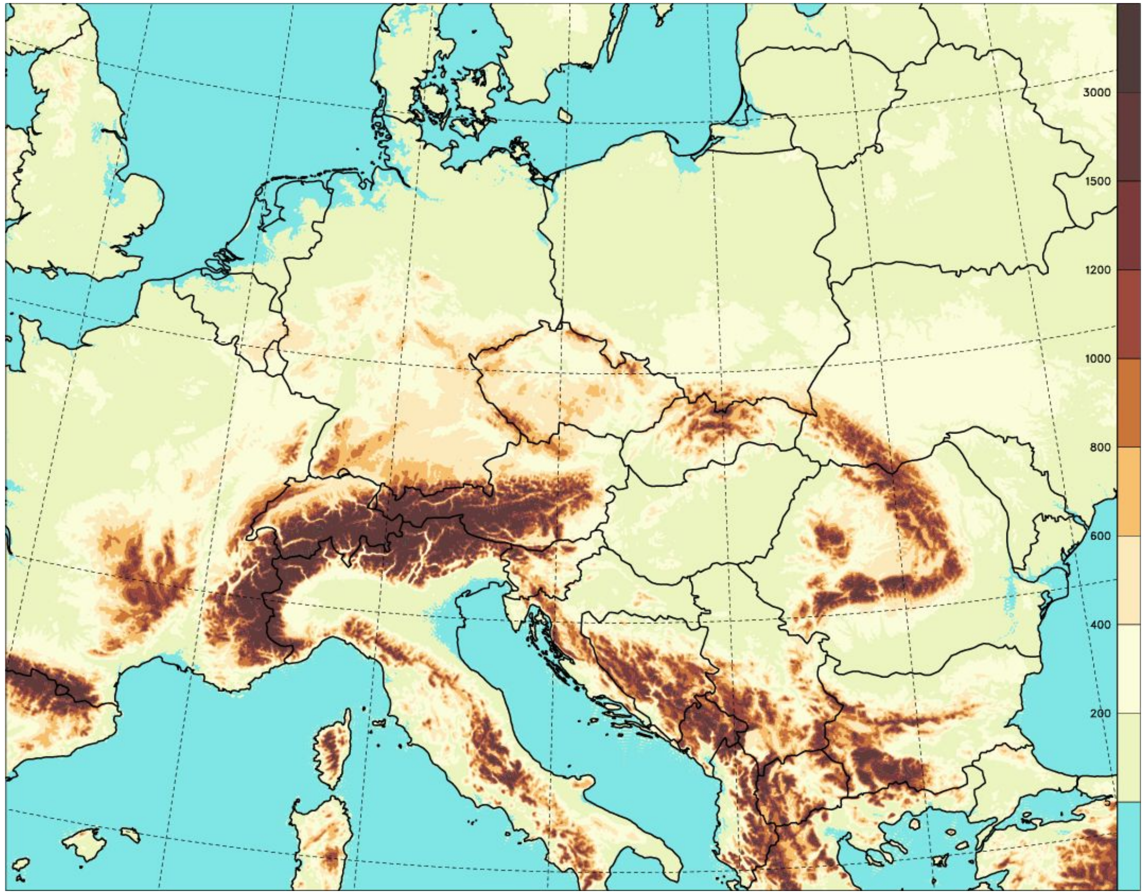
1 iteration PC NESC, SLHD diffusion

– **Physics: ALARO-1vB**

ACRANEB2, TOUCANS with two prognostic energies TKE and TTE, 3MT;

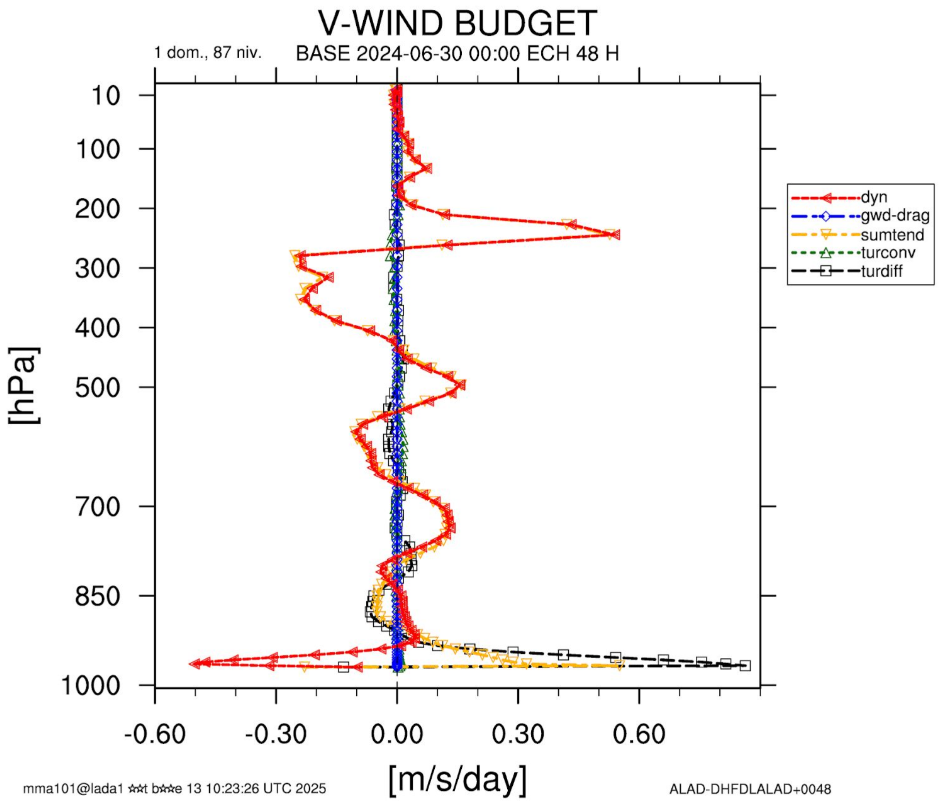
No GWD;

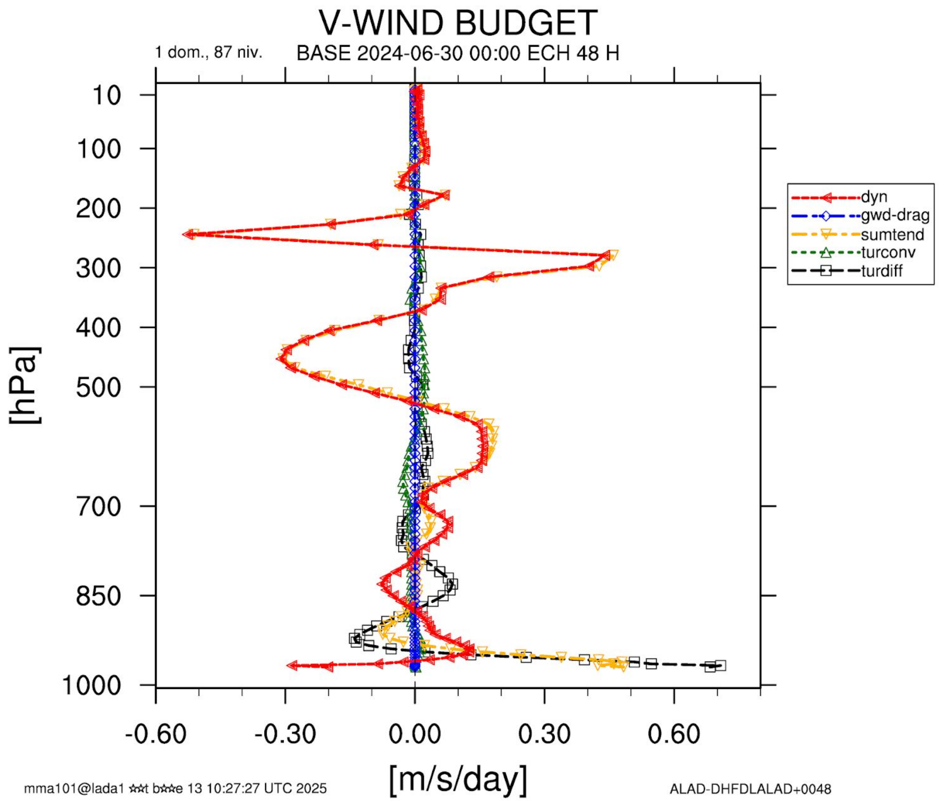
Number of grid points: 2160 x 1728 x 87



Geographical area was preserved at 1 km resolution

Model response in terms of momentum transport

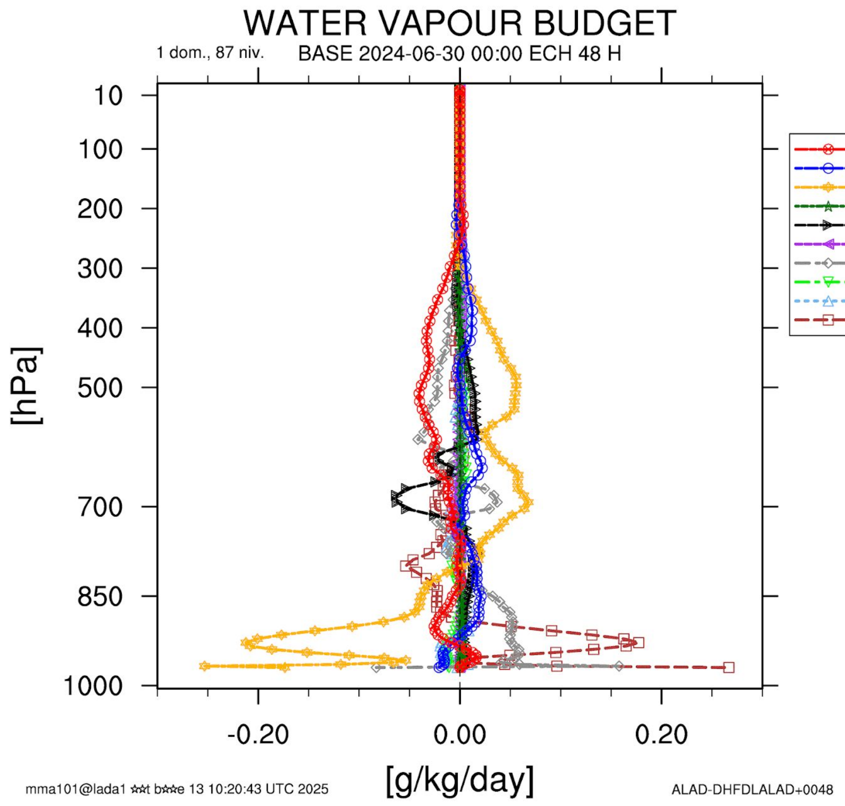




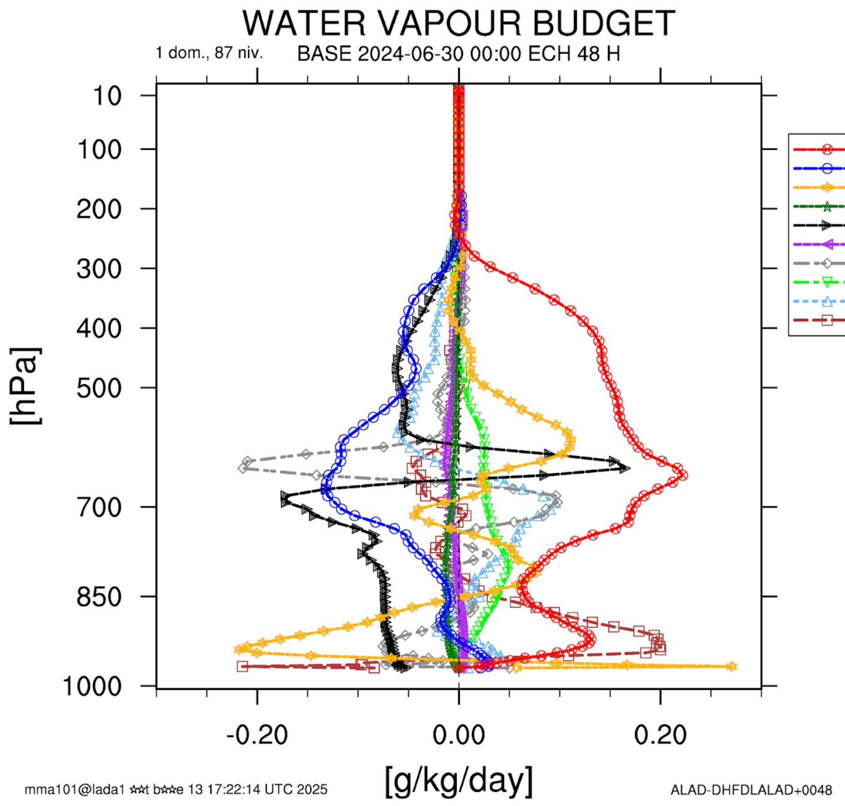
1) Budget difference: cubic => quadratic truncation increases the resolution also of orography: more friction and turbulence.

2) Budget difference: quadratic => linear truncation: no change in the resolution of orography: still more turbulence – where from?

Model response in terms of phase changes



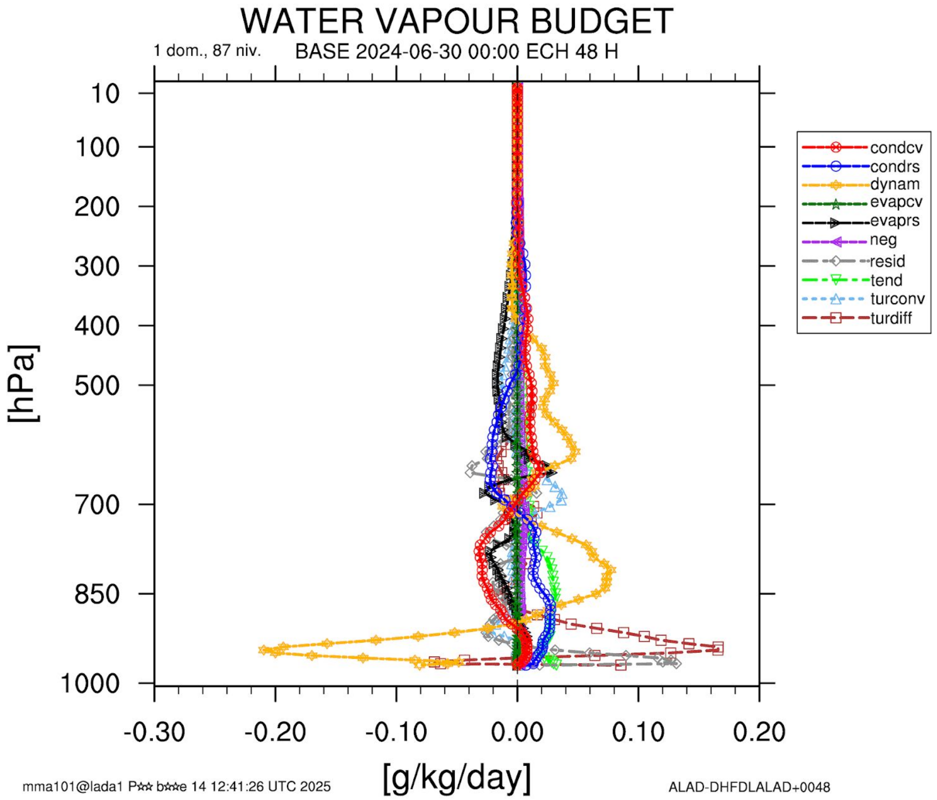
1) Budget difference: cubic => quadratic truncation influences namely transport of water vapor – dynamics and turbulence.



2) Budget difference: quadratic => linear truncation: important change in condensation processes. Much less convective condensation. Reason?

Another experiment – time step length

D) Resolution: Δx = 1.16 km, ***quadratic grid, Δt = 45 s***;



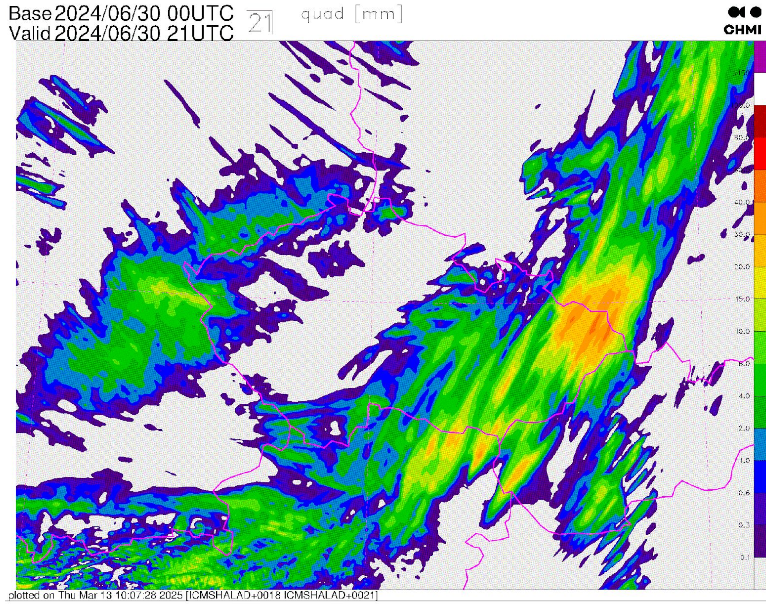
Budget difference: quadratic Δt = 45 s => linear truncation:

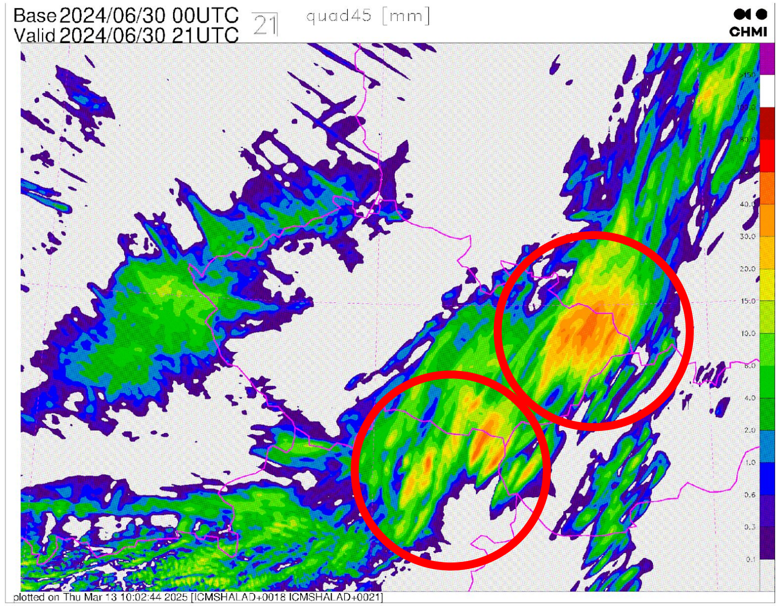
A strong impact on condensation process is gone.

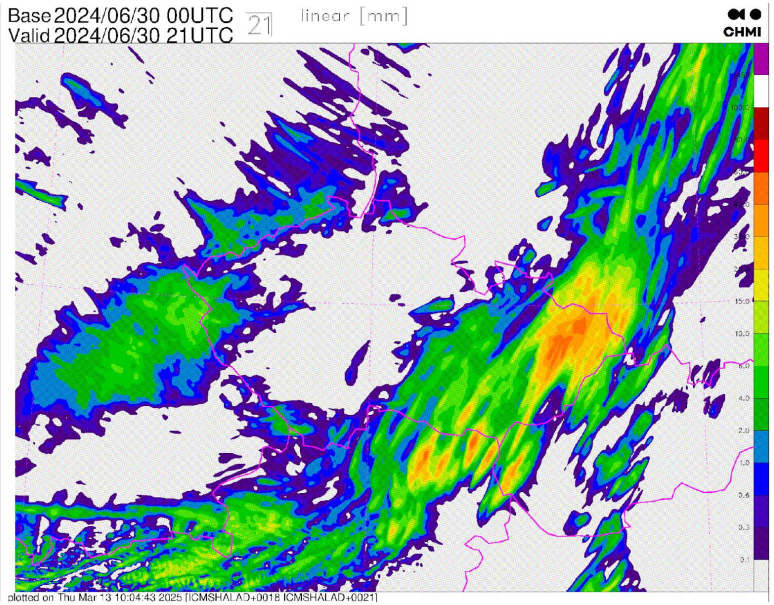
There are schemes having quite some sensitivity to the time-step length, namely

- convection;
- turbulence

Precipitation field – confirmation on Δt influence

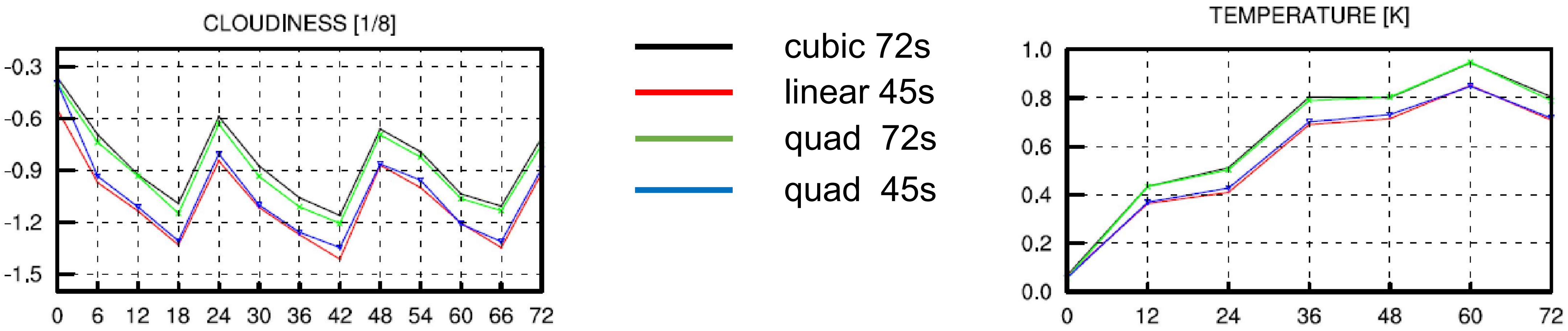






3h – precipitation sum: structures and intensities are more similar when the time-step is the same.

Which role of the Δt length in the scores



Bias at surface

Bias at 250 hPa

In case of bias we see clearly ***the signature of the time step length*** – experiments with the same Δt have very similar ***bias***.
It is not like that for standard deviation.

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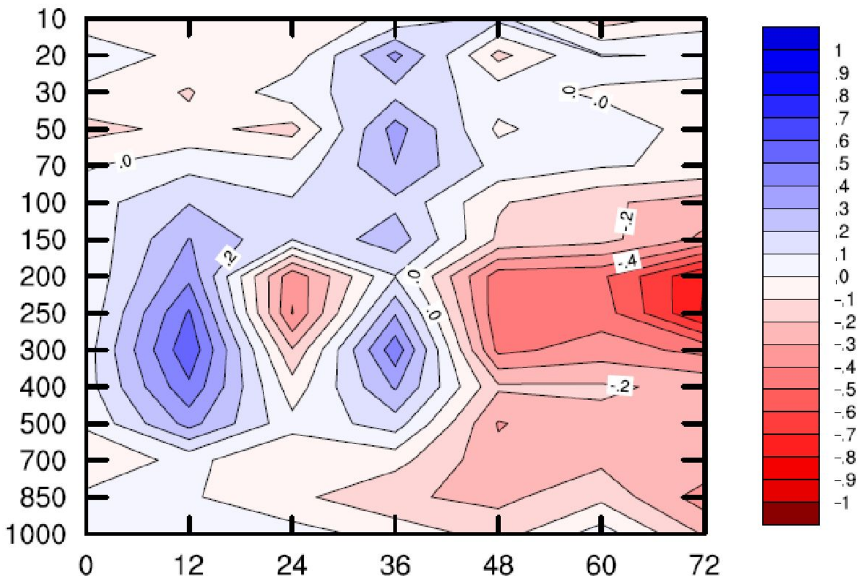
Cost issues

Cost of the 24 h forecast was measured on the 12 nodes of the SX-Aurora with Vector Engines of the second generation.

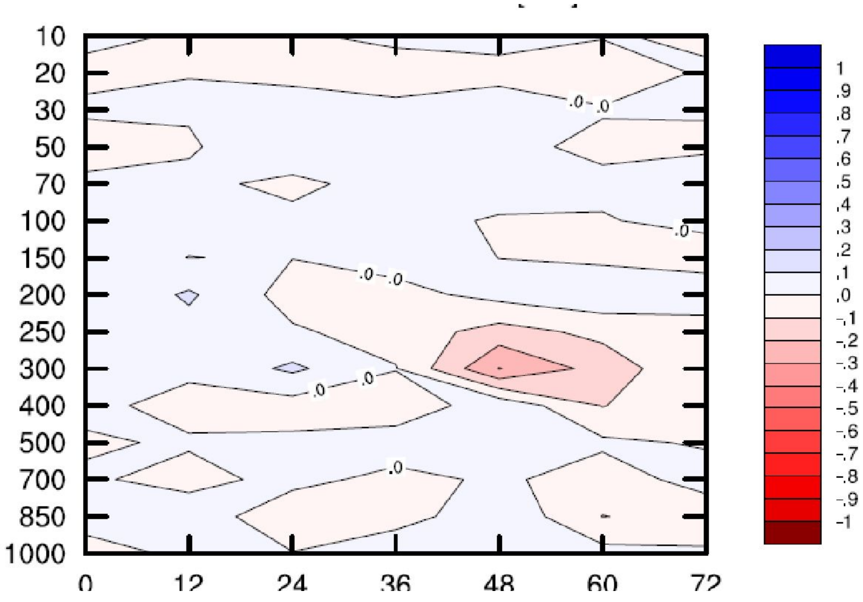
Truncation	Time – step	Wall clock time of 24 h forecast	Size of a ICMSH file
linear	45 s	2140 s	5.27 GB
quadratic	45 s	1779 s	3.33 GB
cubic	45 s	1591 s	2.65 GB
quadratic	72 s	1176 s	
cubic	72 s	1044 s	

There is more gain when going from the linear truncation to the quadratic one. The time-step length gain is also important.
From the cost point of view, should we consider either quadratic or cubic truncations?

Linear-45s vs quadratic-72s in terms of STDEV



Geopotential difference

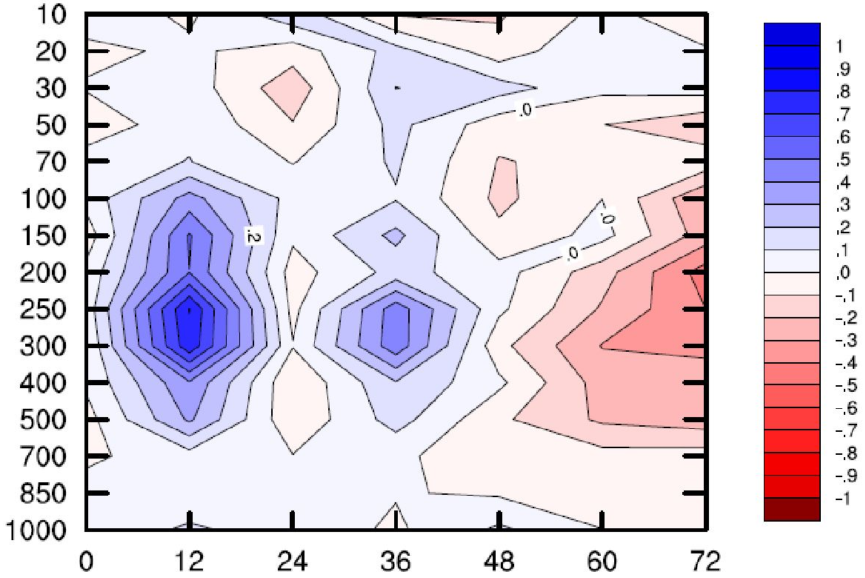


Wind speed difference

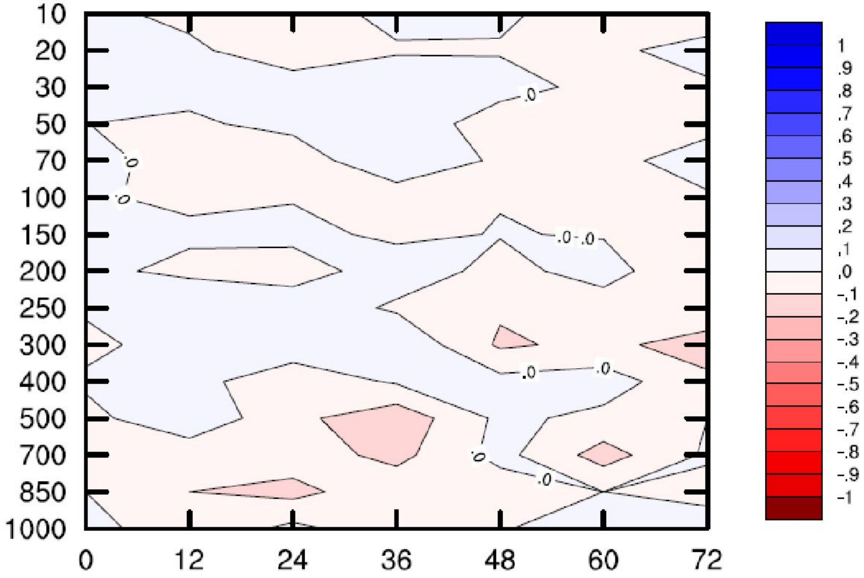
RED color: quadratic truncation is better

At these scales the linear truncation does not seem to bring any added value

Quadratic vs cubic in terms of STDEV



Geopotential difference



Wind speed difference

RED color: quadratic truncation is better

In the mass, there is a clear tendency with the forecast length. Wind speed is better in lower troposphere (resolution of the orography).

Summary

– At the scales of ***1 km resolution of the collocation grid***, the linear truncation does not seem to improve forecast skills compared to the quadratic truncation;

– The linear truncation means double overhead in compute cost, first due to the finer resolution in the spectral space, second in the length of the time-step;

– A question is whether to push in the cost saving further by going to the cubic truncation:

  - This step represents smaller saving;
  - There is a lost in the resolution of orography.

Thank you for your attention

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