ANALYSIS OF DIVERGENT ENERGY IN A MESOSCALE MODEL

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AGENCIJA RS ZA OKOLJE

Motivation

The distribution of energy between the balanced and unbalanced motions as a function of scale is not well understood. The energy contribution of inertial-gravity waves on the mesoscale is associated with the change of the slope of the kinetic energy spectrum from −3 on synoptic scales to −5/3.

This research addresses the question of the divergent energy distribution in a mesoscale NWP model. The divergence is considered a proxy for the inertial-gravity waves.

The main question we wish to answer is what is the distribution of divergent versus vortical energy as a function of the horizontal scale and the altitude.

Model

The model used is the spectral limited area model ALADIN. The analysis focused on mesoscale features in short-term forecasts.

The investigation period was one month, July 2007, with 6-hour forecasts, started at 06 and 18 UTC every day.

Model setup

- $\Delta x = \Delta y = 4.4$ km, 43 vertical levels
- IC/BC: ECMWF 4D-Var assimilation system (model cycle 32r3, T255, L91)
- 439 x 421 points in the central and relaxation zone, 11 x 11 points added in the extension zone.

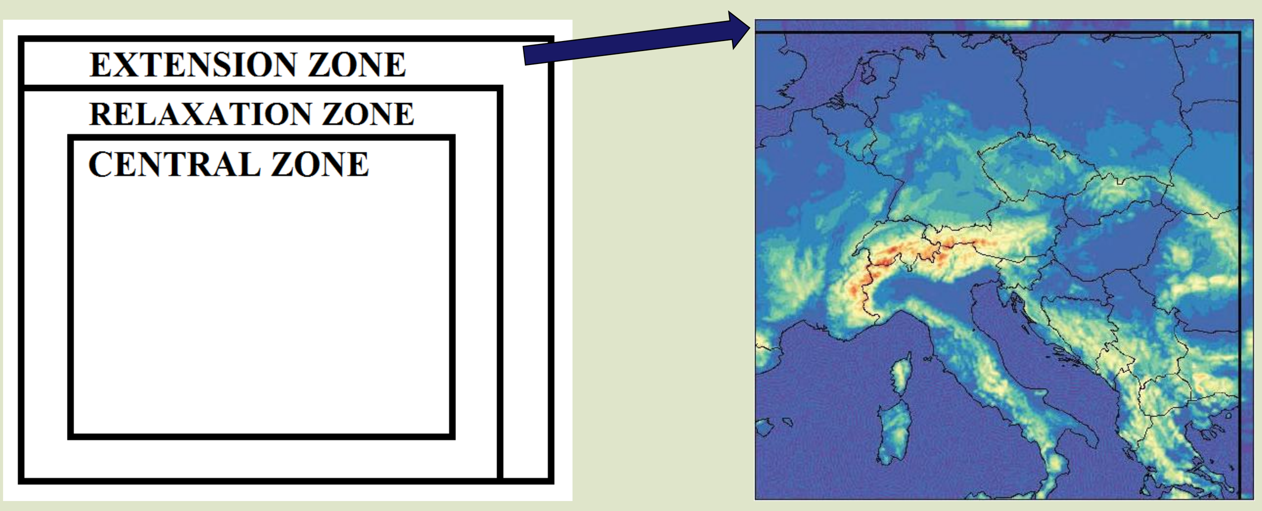


Figure 1: Organization of the ALADIN computational domain. Extension zone ensures periodicity in both horizontal directions.

Calculation of spectra

- Vorticity and divergence fields were calculated in spectral space as derivatives of the wind field.
- The extension zone is included in the spectra calculation.
- The spectra are filtered by the elliptic truncation criterion.
- For each model level, monthly average was applied.

Spin-up process

- The impact of the digital filter initialization (DFI) appears different in the divergent and vortical energy spectra. The difference is the largest in the PBL (Fig. 2). Here, the divergent energy on scales between 300 and 30 km is closer to its average spectra than the vortical energy.
- During the first 4 hours of integration, the spin-up of the PBL vortical energy spectra takes place.
- In the stratosphere, the DFI step decreases energy in both vortical and divergent energy below 50 km, whereas the spin-up process builds up the energy at scales between 300 and 30 km.
- No significant difference is found for the free troposphere.

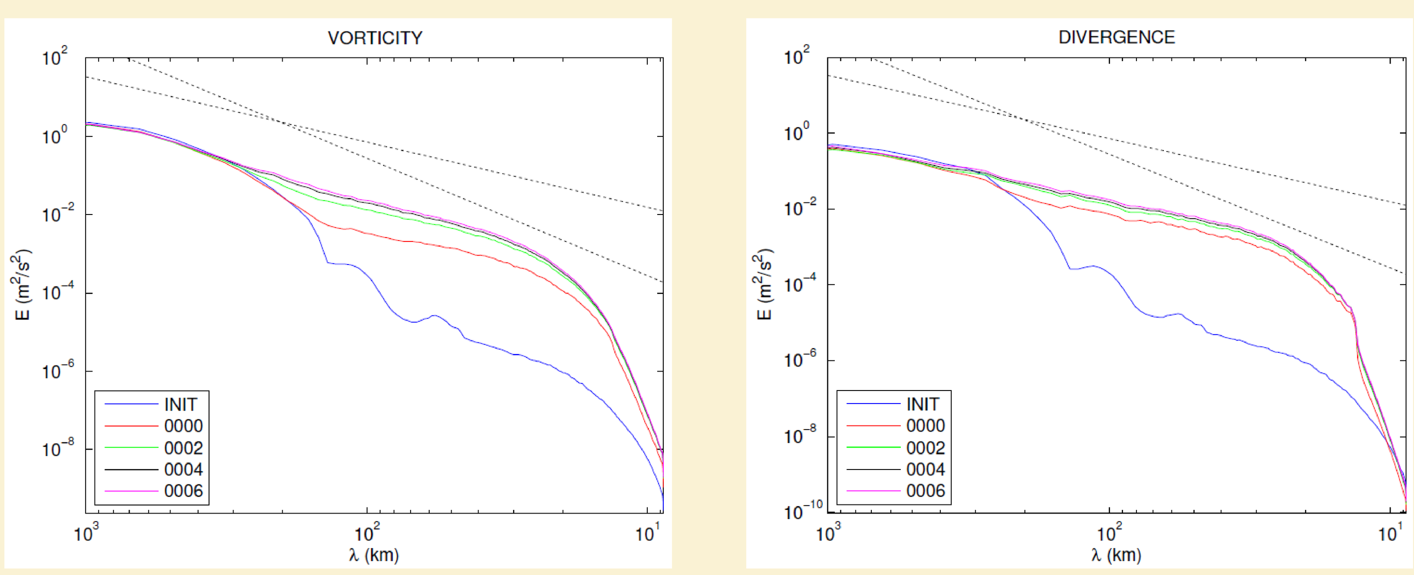


Figure 2: The spin-up process in the PBL in the first six hours of integration for vortical and divergent energy. The reference lines are k^{-3} and $k^{-5/3}$.

Average energy spectra

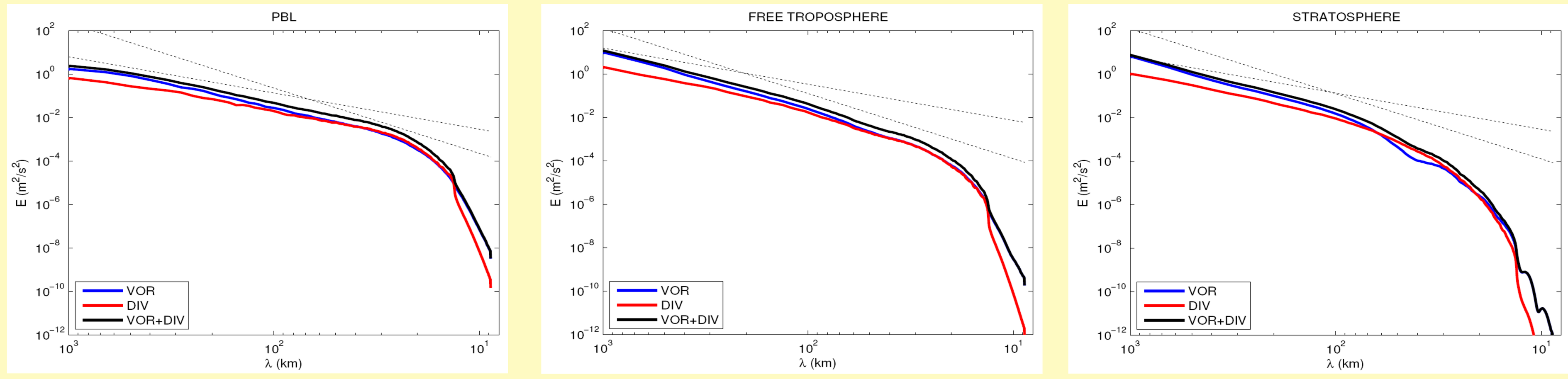


Figure 3: Spectra of the vortical (blue), the divergent (red) and the total kinetic energy (black) for the PBL (left), free troposphere (middle) and stratosphere (right).

The spectrum becomes shallower towards the surface. The effective model resolution is estimated to about 30 km or $7\Delta x$.

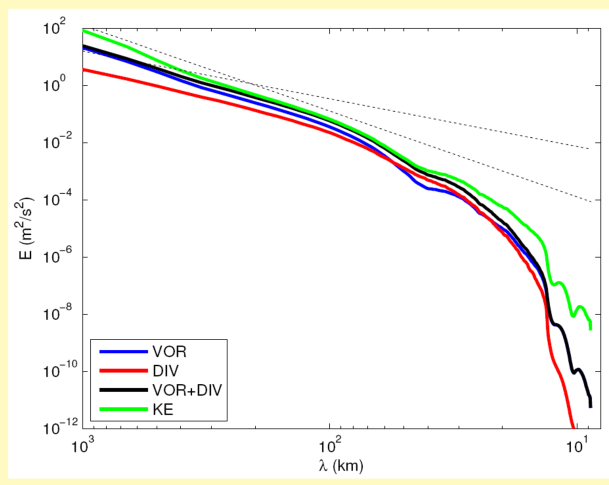


Figure 4: The comparison between the standard kinetic energy spectrum ($1/2(u^2+v^2)$, green) and the energy spectra in terms of the divergent and vortical parts in the Nastrom-Gage altitude range .The differences arise from the lack of zonally averaged component (large scales) and post-processing methods (small scales).

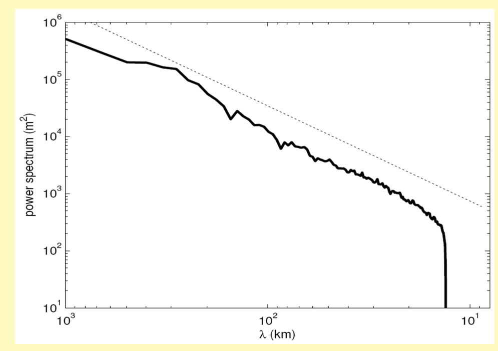
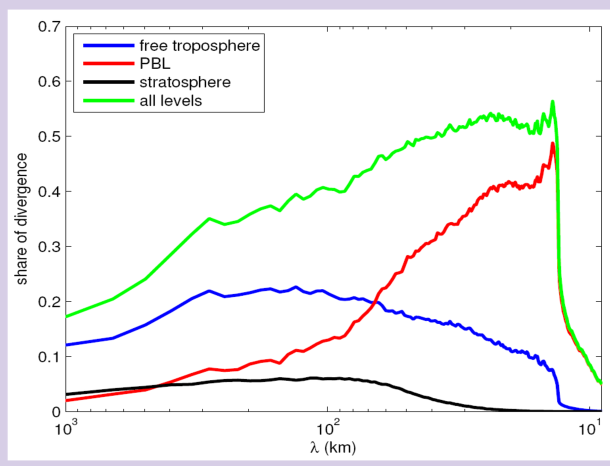
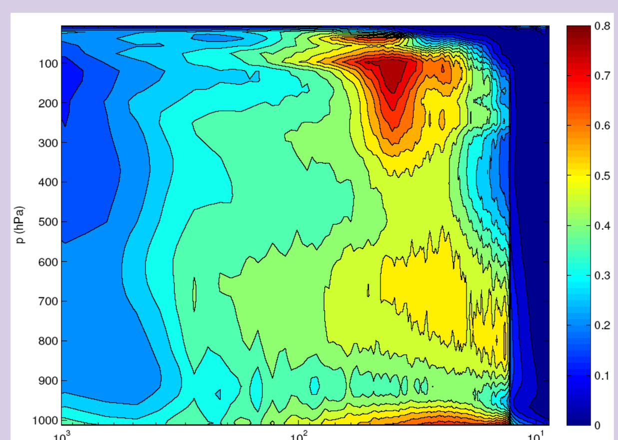


Figure 5: Model orography spectrum. The reference line is $k^{-5/3}$.

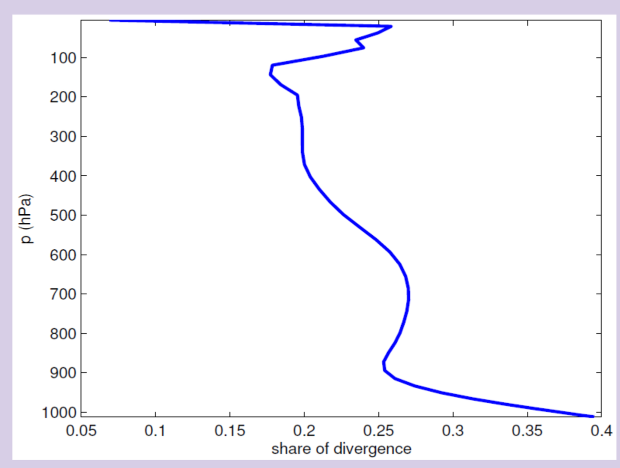
Distribution of the divergent energy



Average percentage of the divergent energy in one layer in the total energy over all layers.



Distribution of average percentage of divergent energy in the total energy with respect to height. Relative - for each level separately. The reason for the stratospheric maximum is not fully understood.

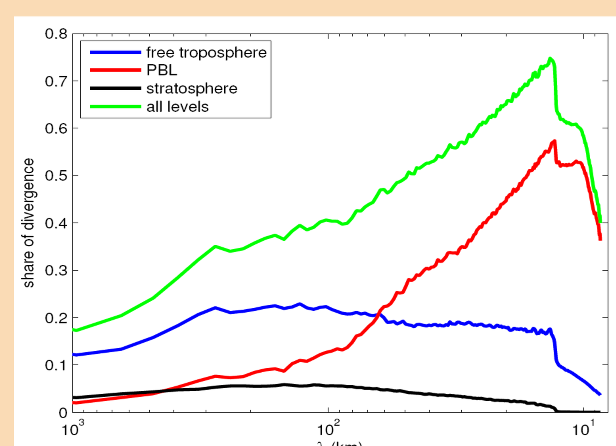


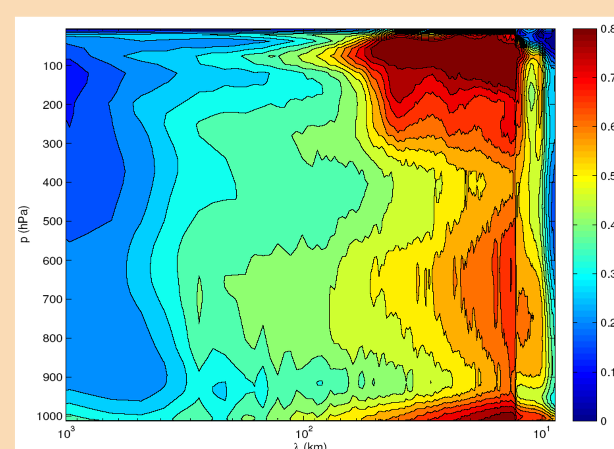
Vertical distribution of the average percentage of divergent in the total energy. For each level, a summation of both energies over all wave numbers was made.

A sensitivity study with respect to diffusion

In this experiment (following the changes in the operational model), the general spectral diffusion was reduced and the semi-Lagrangian horizontal diffusion was enhanced.

The new operational settings allow additional freedom and more divergent energy at the shorter scales, particularly below 30 km.





Similarly to the figures in the above box, here the distribution of the divergent energy is presented with the modified diffusion.

Summary and future work

- The role of the divergent energy increases in the mesoscale, particularly at shortest scales and near the surface. The vertical dependency is more complex.
- The slope of both variables becomes shallower towards the surface.
- At scales above 100 km most of the divergent energy comes from the free troposphere.
- Below the scales of 100 km the divergent energy presents more than half of the total kinetic energy and most of it comes from the PBL.
- The minimum of the divergent energy is located at the top of the PBL.
- The distribution of the divergent energy is very sensitive to the diffusion.
- Future work will extend the analysis to the forecast error fields.

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