**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.

![Extention Zone, Relaxation Zone, Central Zone](image)

**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.

![Spin-up process in the PBL](image)

**Average energy spectra**

- The spectrum becomes shallower towards the surface. The effective model resolution is estimated to about 30 km or 7\(\Delta x\).
- The change of the slope of the kinetic energy spectrum from \(-5/3\) to \(-5\) is significant.
- Gravity waves on the mesoscale spectrum are represented as a line with a slightly negative slope.

![Spectra of the vortical (blue), the divergent (red) and the total kinetic energy (black) for the PBL (left), free troposphere (middle) and stratosphere (right).](image)

**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.

![Comparison between the standard kinetic energy spectrum \((1/2(u^2+v^2))\), the energy spectra in terms of the divergent and vortical parts in the Nastrom-DaFgius altitude range. The differences arise from the lack of zonally averaged component (large scales) and post-processing methods (small scales).](image)

**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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