Quantification of divergence in ALADIN/SI

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The atmospheric mesoscale spectra of vorticity and divergence are investigated with the ALADIN model to quantify the average distribution of divergence. The results show that the divergence increases as the scale decreases, up to the effective model resolution of 7Δx (~30 km). A more complex distribution of divergence is found in the vertical direction. There is a maximum of divergence in the PBL close to the surface, a secondary maximum in the mid-troposphere while the absolute divergence maximum is found in the stratosphere.

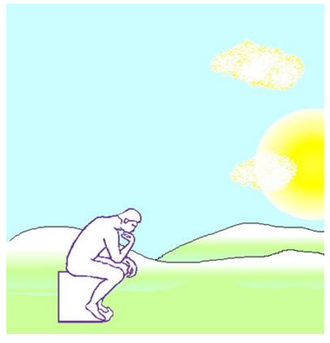
Background

➢ It is well-known that the importance of divergence increases as the scales of atmospheric phenomena decrease. In the mid-latitudes, divergence is an essential ingredient of many mesoscale processes. Their analysis and reliable prediction remains a challenge for mesoscale NWP models.

➢ The role of divergence in the mesoscale data assimilation and model errors is a subject of active research.

➢ On the mesoscale, divergence represents unbalanced or inertio-gravity motions. Its energy contribution is believed to change the slope of the kinetic energy spectrum from −3 on synoptic scales to −5/3 (Nastrom and Gage, 1985). The balanced motion is mainly represented by the vorticity.

➢ The distribution of energy between the balanced (quasi-geostrophic) and unbalanced motions (inertio-gravity) as a function of scale is not well understood. Recent study of the global analyses suggest that about 10% of the global wave motions is on average unbalanced (Žagar et al., 2009).



Motivation

➢The goal of this study is to quantify the divergent energy on the mesoscale. It is expected that the average contribution of divergent energy is larger than 10% found on large scales.

➢ We are interested in the distribution of divergence versus vorticity as a function of the horizontal scale and the vertical model level.

➢In ALADIN/SI (no assimilation cycle), energy spectra builds up during the initial hours of the forecast. We wonder how different (if) is the energy building-of process near the resolution limit in the divergence and vorticity spectra?

➢ Is the same average percentage of divergence with respect to vorticity, which is present in the model forecast, characteristic also for the forecast errors?

Results

In general, a steeper slope belongs to vorticity while divergence follows well the $k^{-5/3}$ law (Fig. 1). Vorticity dominates at scales of several hundred km. At these scales divergence in free troposphere and PBL is one order of magnitude smaller, but becomes comparable to vorticity below 100 km. In stratosphere however, the divergence already becomes dominant at scales of several hundred km. The diffusion strongly damps the energy at scales below 30 km. The total energy spectrum of PBL is shallower than the other two layers over all scales .
The effective resolution of the model is estimated to approximately 30 km or 7Δx.

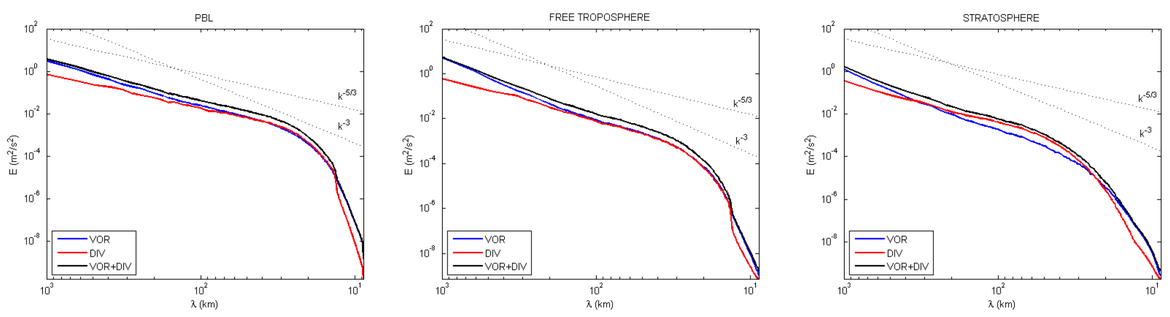


Fig. 1. Monthly and vertically averaged spectra of vorticity (blue), divergence (red) and the sum of two (black) for three following levels: PBL, 850 hPa - ground (left); free troposphere, 250 - 850 hPa (middle); stratosphere, 5 - 250 hPa (right).

References

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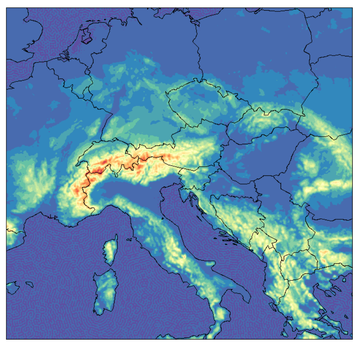
Methodology

Model setup



➢ domain: Δx=Δy=4.4 km, 43 vertical levels

➢ model configuration: AL35T1 using ALARO with 3MT physics

➢ initial and boundary conditions: ECMWF global ensemble of assimilation

➢ investigated data: 6-hour forecasts of 06 and 18 UTC run, July 2007

Calculation of spectra

The vorticity and divergence fields were obtained from the wind fields with FullPos. After detrending in grid-point space, calculation of the spectra was made with Ecto function, implemented in the R library Rfa. A separate analysis was performed to study the spin-up process.

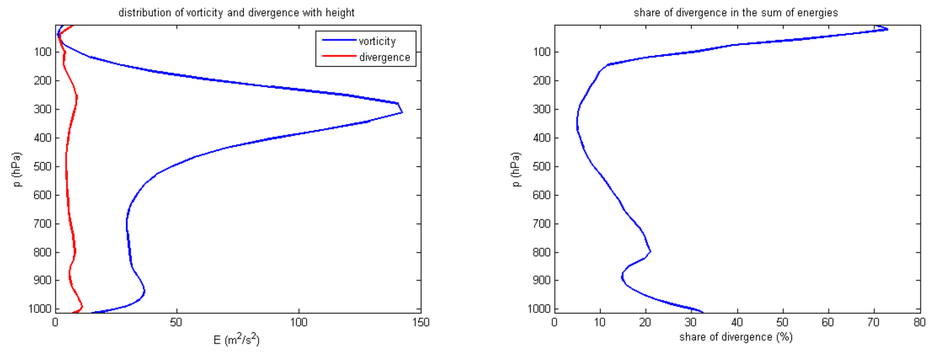


Fig. 2. Left: Distribution of vorticity (blue) and divergence (red) with height. For each level, summation of energy over all wavenumbers was made.
Right: Distribution of average share of divergence in the sum of vorticity and divergence with height. Summation over all wavenumbers.

The contribution of divergence to the total energy increases as the horizontal scale decrease. This applies to all levels, as can be seen in Fig. 3. However, there are significant differences among various layers of the model atmosphere. The divergence on average makes 70% of the energy in PBL with the maximum just above the surface. Throughout the troposphere the divergent part remains below 60% with the maximum located at about 650 hPa and scales about 25 km.
A surprising result is that the absolute maximum is found in the stratosphere at scales between 100 and 40 km where the divergence makes 80% of energy. The reasons are still unclear.

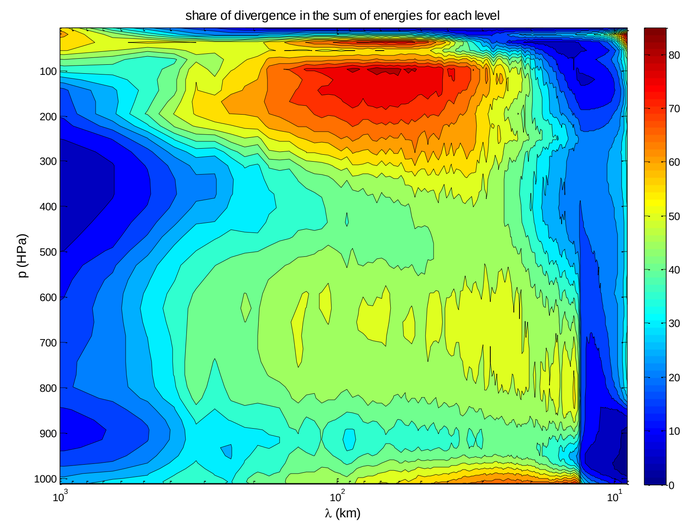


Fig. 3. Vertical distribution of divergent energy expressed in % of the total energy at each model level as a function of the horizontal wavenumber. Contour interval is 5 %.

Conclusions and outlook

➢ The role of divergence increases in mesoscale, particularly at shorter scales and near the surface.
➢ In PBL divergence makes up to 70 % of all kinetic energy. The top of the PBL is characterized by the minimal divergence.
➢ There is a diurnal cycle in the PBL divergence.
➢ The maximum of over 80 % in stratosphere still needs to be explained.
➢ Ongoing research deals with the distribution of divergence during the spin-up process. Further research will study vorticity and divergence in the forecast errors.