Spectral nudging in regional climate modelling: Does it induce additional gravity waves?

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The “spectral nudging” method (SN) imposes the known large-scale state on the simulation of regional climate with a RCM (von Storch et al., 2000) additional to the conventional prescription of lateral values in a “sponge zone”. SN operates by adding a nudging term to the largest horizontal waves in the spectral domain. The method is a rational approach to implement the idea of state-space modelling, which combines dynamical knowledge (RCM) and empirical knowledge (the large-scale state). The method has by now been tested with several aspects with favourable results.

This method allows for superior reconstruction of space-time detailed weather than the conventional use of RCMs, with a forcing only along the lateral boundaries and in a narrow “sponge zone”. SN prevents intermittent divergence in phase space (Weisse et al., 2000) and guarantees that the RCM simulates regional features consistent with a given large scale state (in the spirit of downscaling). When the method was introduced, a table was prepared, demonstrating the success of returning the same level of variability of large scales as the driving NCEP analysis, but significantly increased variability of regional scales (von Storch et al., 2000, Table 1, page 3667):

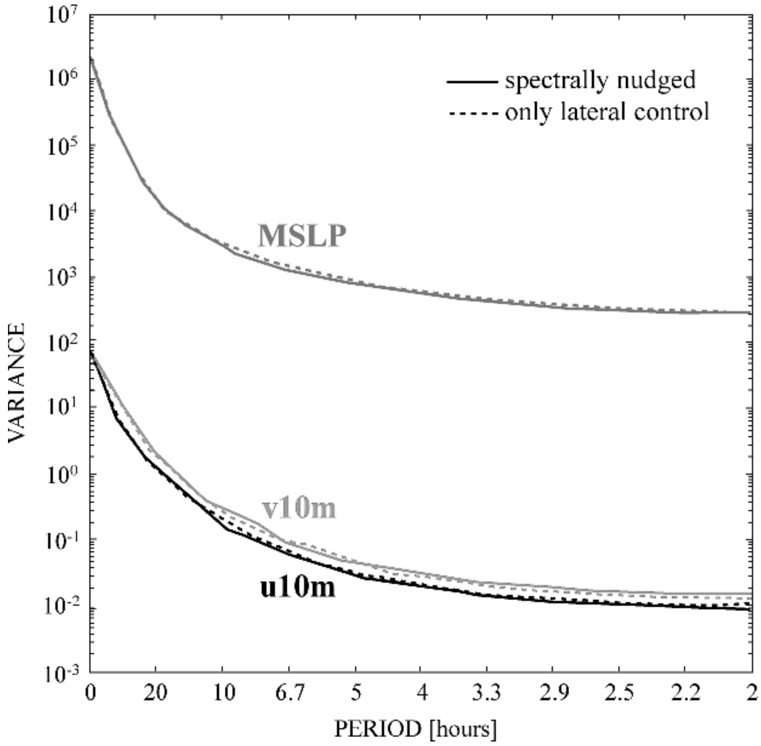
Scale/variable in 850 hPa	Unit m^2s^{-2}	NCEP reanalysis	RCM standard run	RCM with SN formulation
Zonal wind				
Large scale	10^{-2}	1.6	1.2	1.6
Small scale	10^{-6}	3.7	7.7	8.1
Meridional wind				
Large scale	10^{-2}	1.4	1.3	1.5
Small scale	10^{-6}	2.1	6.5	8.5

The table shows the spatially averaged variance of the wind in 850 hPa. This level is the lowest level at which the spectral nudging is activated. It is applied only to the two horizontal wind components.

The large-scale variability in the standard runs is slightly reduced compared to the driving NCEP re-analyses, while the SN-run reproduces or even increases the variability a bit. On the small scales (which are all not considered “large”), the variability is increased in both cases –

and it is increased in SN more than in the standard case. This last detail has caused the hypothesis that the continuously applied (small) correction would excite additionally gravity waves in the domain of the regional atmospheric model.

We have now tested this method by simply determining the time spectrum of zonal and meridional wind at a height of 10 m and of air pressure at sea level, averaged across the integration domain. Spectral densities are shown for periods less or equal 24 hours for both the standard run and the SN run. If the hypothesis would be correct, we would observe that the SN-variability of time scales of a few hours would be increased compared to the standard run. This is obviously not the case. The hypothesis may be rejected.



We conclude that the SN approach is not inducing additional gravity waves in a regional climate model.

von Storch, H., H. Langenberg and F. Feser, 2000: A spectral nudging technique for dynamical downscaling purposes. Mon. Wea. Rev. 128: 3664-3673

Weisse, R., H. Heyen and H. von Storch, 2000: Sensitivity of a regional atmospheric model to a sea state dependent roughness and the need of ensemble calculations. Mon. Wea. Rev. 128: 3631-3642