Horizontal and Vertical Resolution Dependence of the Representation of a Rapidly Developing Extratropical Cyclone in a Mesoscale Model.

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Modelling experiments have been carried out on the FASTEX IOP16 case of a rapidly moving, rapidly developing secondary cyclone. The model used is the new non-hydrostatic version of the Met Office Unified model (Cullen et al 1997**)**. The model has been run for 12 hours in which time the system develops rapidly from two troughs in the original 12km analysis. The development takes place entirely over the ocean which means that all structures smaller than 12km are self generated by the model. The main points of interest in this case are the line convection on the two fronts in the system, multiple cross frontal slantwise circulations and the corresponding multiple cloud head structures. In general the model representation of the system is good. The depth and position of the system are well represented and similar frontal and cloud head features are seen to those in the FASTEX observations (Roberts et. al. 2001).

The model has been run with horizontal gridlengths of approximately 60,24,12,4 and 2km with a level spacing of about 300m in the mid troposphere. This set of runs have been analysed in terms of the isotropic power spectra of their 800hPa vertical velocity fields taken 9 hours into the runs (figure 1). The spectra all tend to the same value at small wavenumbers implying that the large scale structures are similarly represented in all the models (the cut off at small wavenumbers is simply due to the size of the domain used for calculating the spectra). The turn up at the largest values of wavenumber (close to the $2\Delta x$ cut off) in the 24,12 and 4km models is due to the line convection at the fronts since it disappears if the spectra are calculated over an area not including them. The implication is that there is aliasing to the gridscale in all but the 2km model (the 60km model is too low resolution to resolve the line convection).

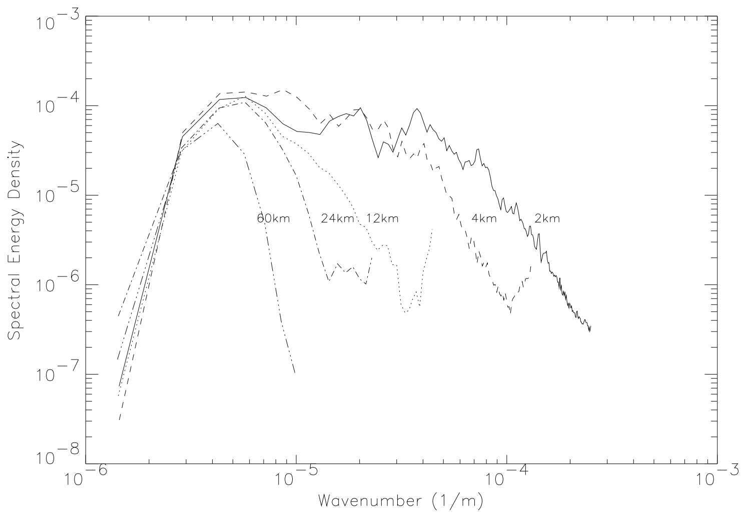

Figure 1. 800hpa Vertical Velocity Power Spectra for various gridlength models

Close examination of the model fields shows that the fronts do, indeed, appear to collapse down to 1 gridlength width in the 24,12 and 4km models but are somewhat broader in the 2km model. The reason for this requires further work. The final interesting aspect of these spectra is the way that the curves decay as the wavenumber increases. In order to understand this more clearly the same spectra are shown in figure 2 as a fraction of the 2km curve with the wavenumber axis renormalised according to gridlength. These curves represent the way that the response falls off as the wavenumber increases towards the cut off (i.e. as the wavelength reduces towards the $2\Delta x$ limit). The four curves lie roughly on top of each other showing that there is a universal fall off in response as the gridlength is approached. It may be seen that the curves start to drop of at roughly 0.1 on the x axis which corresponds to a wavelength of $10\Delta x$. The implication is, therefore, that features seen in the model smaller than around 5 gridlengths are attenuated by the model.

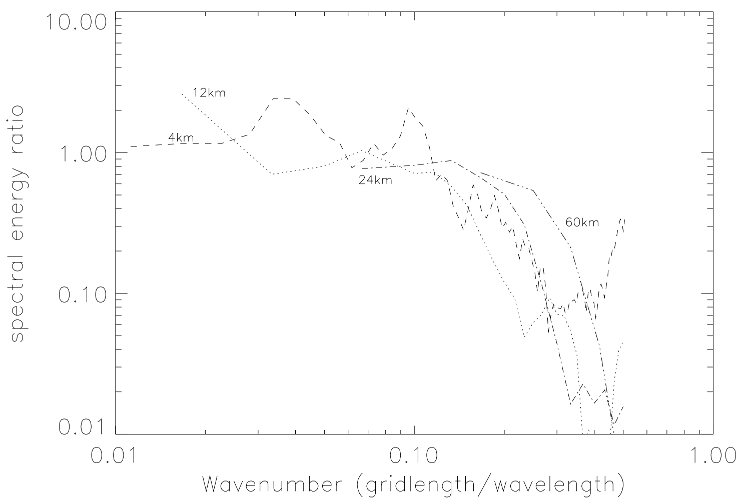

Figure 2. Power Spectra relative to 2km model as described in text

The 4km and 2km models have also been run with the vertical level spacing reduced to 150m and 100m. The representation of the large scale structure of the system with enhanced vertical resolution is unchanged. However the 2km runs with smaller level spacing show additional layering in the cross frontal slantwise circulations which is qualitatively very similar to that observed in the FASTEX dropsonde data. The increased layering looks very similar in the runs with 150 and 100m level spacing in the mid troposphere which implies a degree of convergence with decreasing spacing. The 4km runs, however, show no additional slantwise circulations with increased vertical resolution. The implication is that, at least as far as representation of these types of features is concerned, there is no point in increasing the vertical resolution of the model without also reducing the horizontal gridlength. This fits with the expectation that the aspect ratio of the model grid should be consistent with the slope of the features being represented.

References

Cullen, M.J.P., Davies, T., Mawson, M.H., James, J.A., Coulter, S.C. and Malcolm A., 1997 "An overview of Numerical Methods for the Next Generation UK NWP and Climate Model" Numerical Methods in Atmospheric and Ocean Modelling. The Andre J.Robert memorial volume. Edited by Charles A Lin, Rene Laprise and Harold Ritchie 425-444

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