Influence of a New Stochastic Physics Scheme on Weather Regimes in the North Pacific Region

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Improvements of atmospheric circulation models in recent years have led to a substantial reduction of systematic model error in the short-range and medium-range; in the extended-range and beyond, however, systematic errors still constitute a significant source of forecast uncertainty (Jung, 2005). Moreover, the spatial structure of systematic model error has hardly changed during the last two decades (in the ECMWF model). As pointed out by Palmer (2001), one way to explain the above characteristics is that the very methodology used to approximate the equations of motion (i.e., neglecting the variability of unresolved scales) is itself a source of large-scale systematic error. From the above reasoning Palmer (2001) proposes the use of stochastic-dynamical parameterization schemes.

Such a scheme, which is based on a combination of a cellular automaton model (CA) with a stochastic backscatter scheme (SB), has recently been developed at ECMWF (Shutts 2004, Palmer et al. 2005). In this new stochastic physics scheme (CASB hereafter), the pattern of the stream function perturbation matches that of the CA and its (local) magntiude is proportional to the square root of the dissipation rate associated with the conventional parametrizations.

In this study we describe first results from climate runs with the ECMWF model without (CNTL hereafter) and with (CASB hereafter) the new stochastic physics scheme. The focus is on systematic error of the atmospheric circulation in the North Pacific region interpreted in terms of the frequency of occurrence of weather regimes. The model cycle used (26r3) has been operational at ECMWF from 7 October 2003 to 8 March 2004. The resolution used is T_L95 with 60 levels in the vertical. For each winter of the years 1962–2001 one 6-month long integration has been carried out (started at 1 October). The focus of this study is on the North Pacific region and the winter months from December through March. ERA-40 data are used for verification. The main parameter being considered is geopotential height at the 500hPa level (Z500).

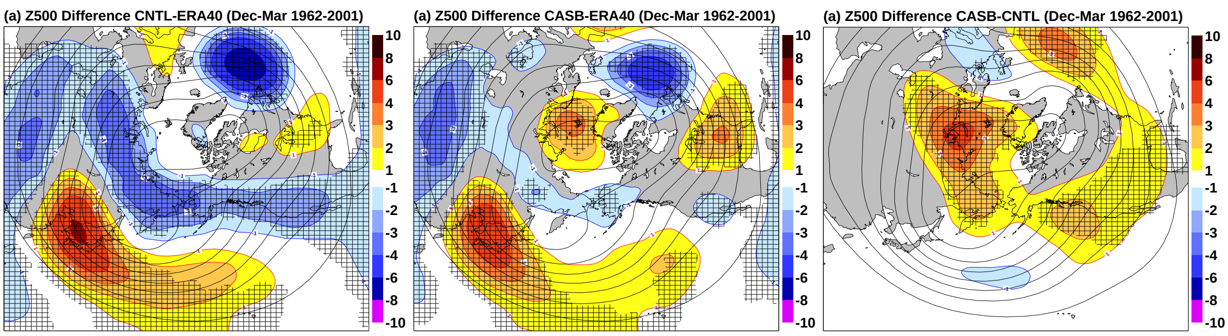

Figure 1: Difference of wintertime (Dec–Mar) mean Z500 (*dam*) between (a) the control integration and ERA-40 data, (b) the integration with the new stochastic physics scheme and ERA-40 data, and (c) the integration with the new stochastic physics scheme and the control integration. Results are based on 40 seasonal integrations (1962–2001) with the ECMWF model. Statistically significant differences (at the 95% confidence level) are hatched.

Systematic Z500 errors for the control integration are shown in Fig. 1a. In the North Pacific the model clearly overestimates the strength of the mid-latitude westerly winds. This overestimation is considerably reduced in the experiment with the CASB scheme (Fig. 1b). The Z500 difference between CASB and CNTL is shown in Fig. 1c and confirms that the CASB scheme has a significant impact on the model climate in the extratropics. It is worth mentioning, that the reduction of the westerly wind bias by the CASB scheme is consistent with a significant improvement of the frequency of occurrence of North Pacific blocking events described by Palmer et al. (1995).

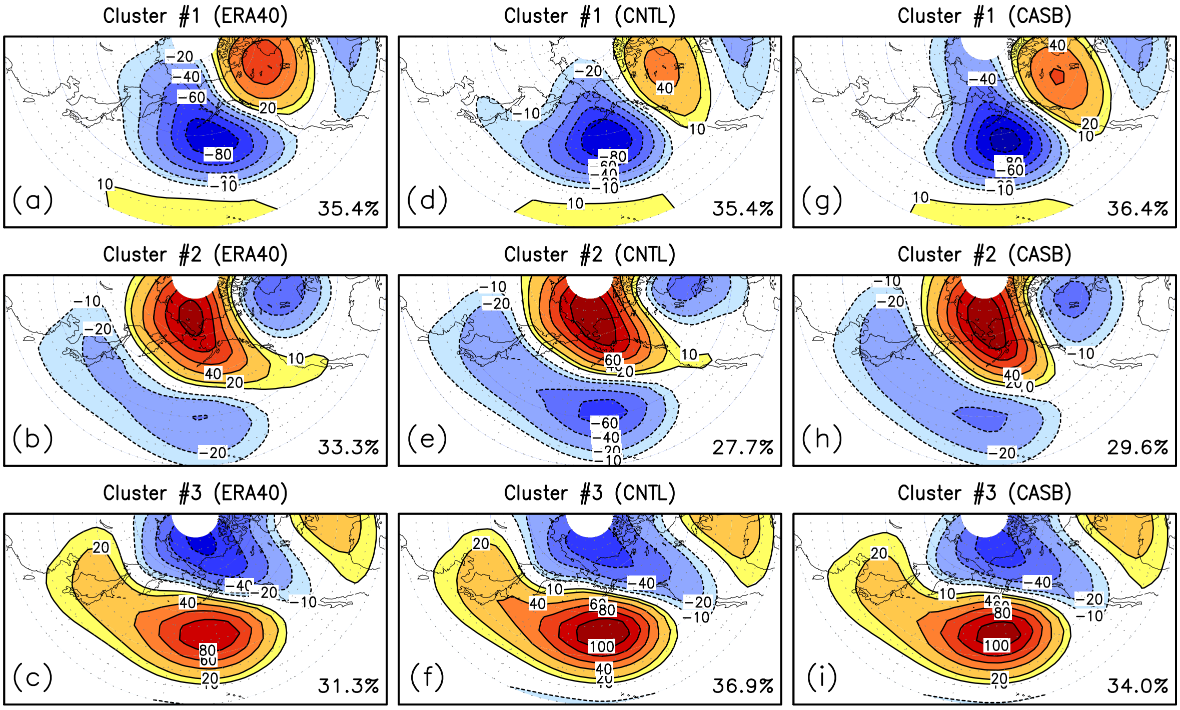

Figure 2: The first three clusters of wintertime Z500 anomalies (m): (a)–(c) ERA-40 reanalysis data, (d)–(f) control integration, and (g)–(i) integration with the new stochastic physics scheme (CASB). The results are based on 40 seasonal integrations (1962–2001) of the ECMWF model (cycle 26r3). The percentage of days spent in each of the clusters is also given.

In order to study simulated weather regimes in the North Pacific, K-means cluster analysis has been carried out. The analysis has been applied to the ten leading PCs of lowpass-filtered Z500 anomalies (annual cycle has been removed). The resulting three Z500 clusters are shown in Fig. 2 for ERA-40 data (left panel), the control integration (middle panel), and the experiment with the CASB scheme (right panel). The first thing to notice is that the ECMWF model, both, with and without stochastic physics, performs extremely well in simulating the spatial structure of the three observed cluster centroids. (Note, that separate analyses have been carried out for each of the datasets.) Furthermore, the frequency of occurrence of the first cluster is also very well simulated by the ECMWF model. The frequency of occurrence of the second and third cluster, however, is underestimated and overestimated, respectively, by the model compared to the observations. This frequency bias is consistent with a mean westerly wind bias shown in Fig. 1. Interestingly, the underestimation (overestimation) of the frequency of occurrence of the second (third) cluster is reduced in the experiment with the CASB scheme. Summarizing, the model error in simulating the frequency of occurrence of weather regimes has been almost halved by the introduction of the CASB scheme. For a more detailed discussion of how the CASB scheme might have changed the large-scale circulation the reader is referred to the papers by Palmer (2001) and Palmer et al. (2005).

References

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