Reply

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There are three main issues raised by Dr. Houtekamer, which I list hereafter with my answers.

1) There is an incorrect statement in Molteni et al. (1996) about isotropic distributions and the spectrum of the analysis error estimate.

I agree with Dr. Houtekamer on this point; Fig. 4a should have shown a linear dependency of the total energy on the total wavenumber, proportional to $2n + 1$, as it is the case for the spectrum of the singular vectors computed with very small horizontal diffusion in Buizza (1998).

2) Enstrophy seems to be a better approximation than total energy to a metric based on the analysis error covariance matrix (AECM).

I do not agree on this point. I refer Dr. Houtekamer to Palmer et al. (1998), which is entirely devoted to the problem of the choice of the metric for either predictability or more general fluid dynamics instability problems.

In Palmer et al. (1998) the argument brought forward in favor of total energy versus kinetic energy, enstrophy, or squared streamfunction is based on the level of inconsistency between the initial time singular vectors and the analysis error estimates. According to this argument, a trial metric is to be considered an approximation to the AECM if the spectrum of the singular vectors is not inconsistent with the spectrum of the estimated analysis errors in the sense that the singular vector spectrum does not peak in a wavenumber band where the analysis error spectrum is small.

This argument seems to be stronger, and possibly more convincing, than the one of Molteni et al. (1996). Results shown in Palmer et al. (1998) support the conclusion that total energy best approximates the AECM metric. By contrast, the analysis error has very little enstrophy in the part of the spectrum where most of the amplitude of enstrophy singular vectors resides.

3) Different constraints should be used to compute singular vectors for predictability studies.

I agree on this point, and as mentioned in Palmer et al. (1998), work is under progress to implement this in the European Centre for Medium-Range Weather Forecasts Ensemble Prediction System. Preliminary results using a T21L3 model (Barkmeijer et al. 1998) have also been published. In the meantime, horizontal diffusion can be used to shape the singular vector spectrum (Buizza 1998).

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