SESSION: (B2) Modelling issues in S2D prediction

(B2-13)

Application of normal mode functions for the improved balance in the CAFE data assimilation system and characterisation of modes of variability

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In the context of multi-year simulations of the atmosphere and ocean, the goal of data assimilation (DA) is to both shift the simulations toward the physical observations and attempt to achieve a balanced state. In general, the DA process of incrementing the simulated flow fields such that the resulting analysis fields approach the observations, can introduce further imbalance into the system. With application to the CSIRO Climate Analysis Forecast Ensemble (CAFE) decadal prediction system, we demonstrate the use of normal mode functions (NMFs) to filter out the imbalanced component of the atmosphere. In the CAFE system an ensemble transform Kalman filter of 96 ensemble members is used to assimilate observations of the atmosphere and ocean in a fully coupled manner. That is all observations, regardless of their realm, impact both the ocean and atmosphere via a dynamically evolving cross-variance matrix. The NMF filtering is applied online to the atmospheric fields of the individual ensemble members immediately following each DA cycle.

The advantage of using NMFs is that they act as a physically based filter. They result from the eigensolutions of a primitive equation model on a sphere. For a specified static stability profile the NMFs simultaneously represent the fluctuations in the mass and velocity fields in the atmosphere. Note, in comparison, spherical harmonics are the eigenvectors of the global barotropic vorticity equation and hence represent a simplified physical view of the atmosphere. Each NMF is characterised by a zonal wavenumber, meridional wavenumber, and vertical mode number. From the properties of the eigenvectors, the NMFs are additionally classified as being either balanced modes (Rossby wave like), imbalanced westerly propagating inertial gravity waves or imbalanced easterly propagating inertial gravity waves. The balanced modes are slower evolving and potentially predictable. The inertial gravity modes have much shorter time scales (for a given spatial scale) and dominate the predictability error growth. We perform the NMF calculations using the MODES code developed at the National Center for Atmospheric Research as described in Žagar et. al. (2015).

In addition, we use the NMFs as an offline diagnostic tool to both determine the extent of balance in the final dataset, and also to characterise various modes of variability. In fact, we have devised an index representing the Madden-Julian Oscillation (MJO) using the NMFs, which agrees with the widely adopted index of Wheeler & Hendon (2004). However, as our NMF based index is derived from the equations of motion it additionally has the ability to interact with other modes of variability and potentially capture the onset of MJO events.

References:

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N. Žagar, A. Kasahara, K. Terasaki, J. Tribbia & H. Tanaka, 2015, Normal-mode function representation of global 3-D data sets: open-access software for the atmospheric research community, Geosci. Model Dev., Vol. 8, p1169-1195.