SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(C1-03)

Coupled data assimilation and ensemble initialization with application to multi-year ENSO prediction

O'Kane, Terence (1), Sandery, Paul (1), Monselesan, Didier (1), Chamberlain, Matt (1), Sakov, Pavel (2), Matear, Richard (1)

CSIRO Oceans and Atmosphere (1), Australian Bureau of Meteorology (2)

We develop and compare variants of coupled data assimilation (DA) systems based on ensemble optimal interpolation (EnOI) and ensemble transform Kalman filter (ETKF) methods. The assimilation system is first tested on a simple multiscale paradigm model of the coupled tropical-extratropical climate system, then implemented for a coupled general circulation model (GCM). Strongly coupled DA was employed to perform an observing system simulation experiment (OSSE) and to assess the impact of assimilating ocean observations on the atmospheric state analysis update via the cross-domain error covariances from the coupled-model background ensemble. We examine the relationship between ensemble spread, analysis increments and forecast skill in multi-year ENSO prediction experiments with a particular focus on the atmospheric response to tropical ocean perturbations. Various approaches to generating flow dependent initial forecast perturbations, either in terms of ETKF and bred vectors (BV) whose norms are based on 3-D inband variance structures (within isosurfaces).

Our focus is on seasonal and longer timescales, and in particular ENSO. Therefore, our premise underpinning the OSSEs is that predictability primarily resides in the oceans and the fast atmosphere acts as a stochastic driver on the longer timescale ocean variability. While the ETKF analysis was generally less biased and with lower errors, both systems performed comparably in the tropics. Outside the tropics the ETKF system produced dramatically lower forecast bias and forecast mean absolute deviation error than the EnOI system. The reason for the low analysis error in the EnOI system in the tropics was found to be a result of larger ensemble spread in the EnOI background covariances, relative to the ETKF, systematically weighting observations more.

BVs representative of growing coupled tropical instabilities were found to modify tropical convection, in particularly in the region of the maritime continent, which in turn generate a coherent modulation of the Hadley circulation. A direct renormalization of thermocline disturbances was found to be most effective in communicating information from the tropical ocean to the midlatitude atmosphere on timescales of a couple of weeks to a month. Comparison of ensemble forecasts based on bred perturbations centred about the EnOI analysed state reveal a substantial reduction in uncertainties, where disturbances not directly associated with thermocline variability are masked. In particular, excluding SST disturbances led to a significant reduction in forecast errors in multi-year ENSO predictions. Ensemble forecasts initialised with ETKF perturbations were very much less skilful, even after bias correction was applied.

The OSSEs and methods discussed form a systematic basis for coupled DA relevant to multi-year near term climate forecasts. The masked isosurface BV approach allows for the specific targeting of regions of large scale variability pertinent to dynamical processes that determine predictability on seasonal to interannual spatio-temporal scales. Beyond a season, strongly coupled data assimilation, where the slow ocean modes are explicitly constrained including projection onto the background atmospheric states (i.e. jets, cells etc) while leaving the fast atmospheric dynamics free, including targeted forecast perturbations, offers a systematic approach to determining the mechanisms and predictability of the key climate modes.