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An anomaly transform method based on total energy and ocean heat content norms for generating ocean dynamics disturbances for decadal climate forecasts

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Strategies for ensemble generation necessary for climate prediction systems have to emphasize on extracting instabilities which match the uncertainties produced from physical processes responsible for climatic variability. Several methods are used to construct a-priori the perturbations around a given initial state derived from observations. Singular Vectors (SV) of a linear forward model e.g. assume linear dynamics of non-linear processes, whereas Bred Vectors (BV) breed over the time iteratively the nonlinear fastest growing errors. The Ensemble Transform (ET) method is similar to the breeding technique but applies orthogonality of the perturbation fields at every recursive cycle and as such improves the spread in the phase space.

In our study we use the Anomaly Transform, a special case of ET, in which orthogonality of the applied initial disturbances is required and the perturbation patterns are designed such that they pick up typical balanced anomaly structures in space and time and between variables. The problem is formulated as an eigen problem. The metric used to set up the eigen problem is taken to be on one hand the weighted total energy with its zonal, meridional kinetic and available potential energy terms having equal contributions, and on the other hand the weighted ocean heat content in which a disturbance is applied only to the initial temperature fields. The choice of a reference state and the selected sequence of anomalies, once on a seasonal timescales and second on an interannual timescales, project a-priori only the slow modes of the ocean physical processes, such that the disturbances grow mainly in the Western Boundary Currents as well as in the ACC and ENSO region. An additional set of initial conditions was designed to fit in a least square sense the STORM high resolution ocean data simulation.

Using the AT produced initial conditions and MPIOM-ESM coupled model, five hind-cast ensemble experiments were performed in the frames of AODA-PENG, MiKlip project. The weighted total energy norm is used to monitor the amplitudes and rates of the fastest growing error modes. The results showed minor dependence of the instabilities growth on the selected metric but considerable change due to the rescaling coefficients magnitude on the perturbation amplitude. In contrary to similar atmospheric applications, we find an energy conversion from kinetic to available potential energy, which suggests different dynamics in the ocean compared to weather prediction in the atmosphere, where the baroclinic instabilities prevail on a short and medium timescales setting the stage for the growth of uncertainty.