First Passage Time (FPT) for Determining Large Ocean Model Predictability

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First passage time (FPT) is used to evaluate large ocean (or atmosphere) model predictability. FPT is defined as the time period when the prediction error first exceeds a pre-determined criterion (i.e., the tolerance level). It depends not only on the instantaneous error growth, but also on the noise level, the initial error, and tolerance level. The model predictability skill is then represented by a single scalar, FPT. The longer the FPT, the higher the model predictability skill is. A theoretical framework on the base of the backward Fokker-Planck equation is developed to determine FPT.

In this paper, we investigate error propagation near an unstable equilibrium state (classified as an unstable focus) for spatially uncorrelated and correlated finite-amplitude initial perturbations using short- (up to several weeks) and intermediate (up to two months) range forecast ensembles produced by a barotropic regional ocean model. An ensemble of initial perturbations is generated by the Latin Hypercube design strategy, and its optimal size is estimated through the Kullback - Liebler distance (the relative entropy). Although the ocean model is simple, the prediction error (PE) demonstrates non-trivial behavior similar to that existing in 3D ocean circulation models. In particular, in the limit of zero horizontal viscosity, the PE at first decays with time for all scales due to dissipation caused by nonlinear bottom friction, and then grows faster than [quasi]-exponentially. Statistics of a prediction time scale (i.e., FPT) quickly depart from Gaussian (the linear predictability regime) and becomes Weibullian (the non-linear predictability regime) as amplitude of initial perturbations grows. A transition from linear to non-linear predictability is clearly detected by the specific behavior of FPT variance. A new analytical formula for the model predictability horizon is introduced and applied to estimate the limit of predictability for the ocean model.

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