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Stability of the Tangent Linearization of a highly Nonlinear Ocean Model

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The 4D-variational data assimilation technique can be used to combine observations with an ocean model to determine an optimal solution that minimizes a cost function (weighted squared errors of data and model dynamics). However, in order to converge to the global minimum of this cost function, the ocean model (and its adjoint) must be linear. Ocean models, especially those that are designed to resolve baroclinic and mesoscale processes, are typically highly nonlinear and must be linearized. Tangent linearization is a linearization method that is performed by expanding the nonlinear dynamics about a background field using the 1st order approximation of Taylor's expansion. The Navy Coastal Ocean Model (NCOM) has been fully tangent linearized. In this presentation, the stability of this tangent linearized model (TLM) will be examined. The accuracy and stability of a TLM is typically a function of the accuracy and consistency of the background and the level of nonlinearity of the ocean model. To test the influence of the background on the TLM, various operational NCOM and HYCOM solutions covering different time periods and regions will be used as background fields. NCOM consists of several dynamic components that are highly nonlinear: horizontal mixing (Smagorinsky), vertical mixing (Mellor Yamada 2.5), advection, density, and bottom stress. The impact that the linearization of each of these individual components has on the overall TLM stability will also be examined. Overall, this presentation goes toward revealing how best to construct a TLM and implement it in an operational assimilation system; i.e., how accurate and dynamically consistent does the background fields need to be and which dynamic components should be linearized under different flow conditions.