INTRODUCTION
Coupled ocean-atmosphere data assimilation can be used for advancing and improving coupled model forecasts numerical weather prediction, and seasonal and interannual predictions. Challenges of coupled ocean-atmosphere data assimilation include differing time and spatial scales of the atmospheric and oceanic system vast range of growing instabilities of the system. We seek to investigate the performance of sequential and variational data assimilation methods using a simple coupled ocean-atmosphere model of different time scales and amplitude.

To study this problem, we consider a very simple triple coupled Lorenz (1963) model that includes a slow "ocean" component strongly coupled with a fast "tropical atmosphere component" in turn weakly coupled with a fast "extratropical atmosphere".


Extra-tropical Atmosphere

\[ x = (0V_y - x - c_z)(S_z + k_z) \]
\[ y = (\alpha - y - x - c_y)(S_y + k_y) \]
\[ z = (x - b_z - b_x) \]

Tropical Atmosphere

\[ x = (0V_y - x - c_z)(S_z + k_z) \]
\[ y = (\alpha - y - c_y)(S_y + k_y) \]
\[ z = (x - b_z - b_x) \]

Ocean

\[ X = 10V(\alpha - x - c_y - b_y) \]
\[ Y = 1VX + Y(1 + k_y) \]
\[ Z = (1 - S_Z - b_y) \]

DATA ASSIMILATION METHODS

<table>
<thead>
<tr>
<th>Method</th>
<th>Observations</th>
<th>Control Variables</th>
<th>Forecast Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETKF</td>
<td>Fast and slow variables together</td>
<td>At analysis time</td>
<td>Fully Coupled 4D-Var initial state, Simple coupled ocean-atmosphere model</td>
</tr>
<tr>
<td>4D-ETKF</td>
<td>Fast and slow variables together</td>
<td>Throughout an assimilation window</td>
<td>Ocean 4D-Var initial ocean model state, initial atmosphere fluxes</td>
</tr>
<tr>
<td>LETKF</td>
<td>3-dimensional</td>
<td>All assimilation windows</td>
<td>Ocean 4D-Var initial ocean model state, initial atmosphere fluxes</td>
</tr>
<tr>
<td>LETKF</td>
<td>3-dimensional</td>
<td>All assimilation windows</td>
<td>Ocean 4D-Var initial ocean model state, initial atmosphere fluxes</td>
</tr>
<tr>
<td>ETKF-2D</td>
<td>Fast and slow variables together</td>
<td>At analysis time</td>
<td>ECCO 4D-Var initial ocean model state, initial atmosphere fluxes</td>
</tr>
<tr>
<td>4D-LETKF</td>
<td>Fast and slow variables separately</td>
<td>Ocean analysis</td>
<td>Initial ocean model state, initial atmosphere fluxes</td>
</tr>
<tr>
<td>ECCO-4D Var</td>
<td>Fast and slow variables separately</td>
<td>Ocean analysis</td>
<td>Initial ocean model state, initial atmosphere fluxes</td>
</tr>
</tbody>
</table>

RESULTS

- ETKF-based algorithms without a quasi outer loop or model localization experience filter divergence for long assimilation windows. As expected, their accuracy depends on the covariance inflation and number of ensemble members (we used a full-rank ensemble of 9 members).
- The fully coupled 4D-Var analyses provided a good estimate of the model states, but required the implementation of the Quasi-stochastic Variational Analysis (QVA) as well as the tuning of the amplitude of growing instabilities of the system. We seek to investigate the performance of sequential and variational data assimilation methods using a simple coupled ocean-atmosphere model of different time scales and amplitude.

DISCUSSION

- The data assimilation experiments offer insight on developing and advancing sequential and variational data assimilation systems for coupled models.

Conclusions

Future work includes

- Performing data assimilation experiments with model errors
- Applying a QOL to 4D-ETKF and 4D-LETKF
- Applying adaptive inflation to EnKF-based methods (Li et al., 2009; Miyoshi, 2011)
- Extend ECCO-like 4D-Var to much longer assimilation windows

REFERENCES