Motivation:
Balanced initial condition for the coupled forecast of the ocean and atmosphere requires specification of cross-fluid covariances that can synchronize data assimilation updates in two fluids. If known, for example from an ensemble of coupled forecasts, these covariances can be specified explicitly in a strongly coupled data assimilation (DA) system. Alternatively, these covariances can be generated implicitly by utilizing multiple outer iterations of the four-dimensional DA system. The European Centre for Medium-Range Weather Forecasts has recently developed an implicit coupling approach in the CERA reanalysis system, where otherwise uncoupled atmospheric 4DVAR and ocean 3DVAR are synchronized using 3 outerloop iterations. Since this original work on the outerloop coupling, it has been unclear just how closely does the CERA system with implicit coupled covariances synchronize data assimilation updates in two fluids. If known, for example from an ensemble of coupled forecasts, these covariances can be specified explicitly using the outerloop coupling. For this study, we focused on two special periods of the reanalysis when 20 members of the CERA analysis were available.

Methods:
CERA-20C reanalysis (used in this study) reconstructs the past climate and weather over the 20th century (1901-2010) for the atmosphere, ocean, land, ocean waves and sea ice components of the Earth system. CERA-20C reanalysis assimilate only the surface pressure and marine wind observations in the atmosphere, as well as subsurface temperature and salinity profiles in the ocean. The atmosphere has a 125km horizontal grid resolution and the ocean has a one-degree horizontal grid. For this study, we focused on two special periods of the reanalysis when 20 members of the CERA analysis were available.

Role of the outer loop in coupled DA

Methods:
A series of single-observation experiments in a perfect twin framework has been conducted to evaluate the effectiveness and the efficiency of the outer loop coupling and the amplitude of the implicit cross-correlations. They are compared against a coupled assimilation system that explicitly specifies cross-correlations from an ensemble of coupled forecasts.

(E) Both the implicit outer loop and the explicit ensemble based methods produce equally skillful estimates of the coupled state in the middle of a 24 hour assimilation window.

(F) Atmospheric variables of the coupled system require more outer iterations to converge.

Summary and conclusions:
We find that both the implicit outer loop and the explicit ensemble based methods produce equally skillful estimates of the coupled state in the middle of a 24 hour assimilation window. Our estimates of the speed of the outer loop convergence suggest that atmospheric and ocean states synchronize within the first 6 to 10 hours of the assimilation window. On the other hand, we suggest that explicit coupling is preferable for data assimilation systems with short assimilation windows (e.g. 6 hours or less).