Comparison of MERRA-2 and ECCO-v4 ocean surface heat fluxes: Consequences of different forcing feedbacks on ocean circulation and implications for climate data assimilation

Ehud Strobach\textsuperscript{1,2, †}, Andrea Molod\textsuperscript{1}, Gael Forget\textsuperscript{3}, Jean-Michel Campin\textsuperscript{3}, Chris Hill\textsuperscript{3}, Dimitris Menemenlis\textsuperscript{4} and Patrick Heimbach\textsuperscript{5}

\textsuperscript{1}University of Maryland, \textsuperscript{2}NASA Goddard Space Flight Center, \textsuperscript{3}Massachusetts Institute of Technology, \textsuperscript{4}NASA Jet Propulsion Laboratory, \textsuperscript{5}University of Texas at Austin

1. Introduction
In coupled data-assimilation (DA), feedbacks between the ocean and the atmosphere are active, but, depending on the system “flavor”, they are constrained by the observations. We demonstrate that insights about coupled DA can be gained in an ocean only setup and using different forcing methods which act to limit some of the feedbacks and replace the constraining effect of observations in coupled DA.

2. Experimental Setup
We ran MITgcm ocean model (ECCO-v4 underlying ocean model) forced with fields from MERRA-2 (for which GEOS is the underlying atmospheric model) between 1992 to 2011. Different forcing methods were used to imitate different “flavors” of a coupled GEOS-MITgcm DA system in an ocean-only setup. By doing so we were able to turn off different air-sea feedbacks which, in a coupled DA setup, are partially muted by the constraining observations. The set of experiments, therefore, represents a range of active feedbacks in different “flavors” of coupled data-assimilation systems.

3. Results

\begin{itemize}
  \item MERRA-2-flux
    MITgcm forced with MERRA-2 surface fluxes
  \end{itemize}

MERRA-2-flux can be seen as an amplification of the errors that will propagate from the atmosphere to the ocean in a strongly constrained coupled DA system.

\begin{itemize}
  \item MERRA-2-state
    MITgcm forced with MERRA-2 state variables
  \end{itemize}

MERRA-2-state can be seen as a coupled DA system that is less constrained (more active feedbacks) than the system represented in the MERRA-2-flux experiment.

\begin{itemize}
  \item MERRA-2-turb
    MITgcm forced with MERRA-2 turbulent fluxes
  \end{itemize}

MERRA-2-turb may reflect a “compromise” state between the ocean and the atmosphere in a coupled DA system.

4. Conclusions

- Errors in the atmospheric DA are expected to propagate to different components of the ocean model in a coupled DA. The “flavor” of the DA system will determine where the errors propagate.
- The investigation of air-sea flux errors in the uncoupled components of the model can help anticipate and avoid errors in the coupled version of the system.
- Heat flux components are the same in MERRA-2-flux and MERRA-2 by definition.
- Latent heat flux feedback acted to increase SST.
- Sensible heat and long wave radiation Feedbacks are secondary to Latent heat.
- Long wave radiation acted to increase SST.
- No change to the water cycle compared to MERRA-2.

\textbf{Nomenclature}
- GEOS: Global Earth Observing System Model – MERRA-2 underlying atmospheric model
- ECCO-v4: Estimating the Circulation and Climate of the Ocean Version 4 (ocean state estimate)
- MITgcm: Massachusetts Institute of Technology general circulation model – ECCO-v4 underlying ocean model