Air-Sea Fluxes: Ocean-model Needs from Reanalyses

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1. Abstract

The presentation highlights the differences in ocean surface forcing products. Surface momentum, heat, and freshwater forcing from different sources and their impact during ocean assimilation are compared. Requirements for improved surface forcing from reanalyses, identified during the 2003 U.S. Workshop on the Ongoing Analysis of the Climate Record, are summarized.

2. Background

Fluxes through the interface between the atmosphere and the ocean, and land surface, including sea-ice, represent the exchanges between the fast component and those components that represent the memory in the climate system. Although critical for understanding climate variability and change, global surface flux products have large errors and are a major source of error and uncertainty for ocean and land surface products. The WCRP/SCOR Working Group on Air-Sea Fluxes provided a report (Taylor, 2000) on an intercomparison of flux fields, including those from reanalysis (ERA-15, not ERA-40). They also identified the requirements for high quality flux products: 3-hourly, 50km resolution, errors of a few Wm^{-2}, with a need for consistency and continuity of products.

Biases in products and analyses derived from numerical weather prediction efforts often have a deleterious effect on ocean and land simulations, leading a number of groups to generate their own products, correcting the fields input to flux computations. Reanalysis fields are often replaced with corrected fields or other observational analyses (such as satellite-based surface radiation or precipitation). In addition, there is a preference to calculate the fluxes according to the underlying ocean model state, requiring accurate analyses of surface fields rather than accurate fluxes.

As examples, Large and Yeager (2004) have developed a corrected/adjusted set of surface forcing fields and a bulk forcing methodology for stand-alone (uncoupled) simulations of ocean and sea-ice models, both correcting and merging different data sets according to their known error characteristics or according to physical intuition. Corrections were made so that the long-term mean heat and freshwater fluxes are in balance. QuikSCAT data were used to correct the surface winds. The global data sets were developed for the Common Ocean-ice Reference Experiments (CORE) for CLIVAR Working Group on Ocean Model Development and are available at http://data1.gfdl.noaa.gov/nomads/forms/mom4/CORE.html. A different set of surface heat flux estimates are provided by the Objectively Analyzed air-sea FLUXes (OAFLUX) project at WHOI (see Yu et al., 2004a, b and http://oaflux.whoi.edu/data.html). OAFLUX is a synthesis of satellite observations with surface fields from both NCEP-2 reanalyses and ECMWF operational analyses.

Comparisons between these flux products and those from NCEP1 and NCEP2 reanalysis show significant differences, particularly in the western boundary current regions and in the tropical oceans. Seasonal climatology differences in latent heat flux can exceed 100 Wm^{-2}. Differences in variability can be smaller, but standard deviations are over 20 Wm^{-2} in areas of the tropical oceans. As an example, the variations in turbulent surface fluxes during 1997/98 are shown in Figure 1. Although the overall large scale signals are similar in each of the products, significant differences are noticeable, including the sign of the flux in the western Pacific.

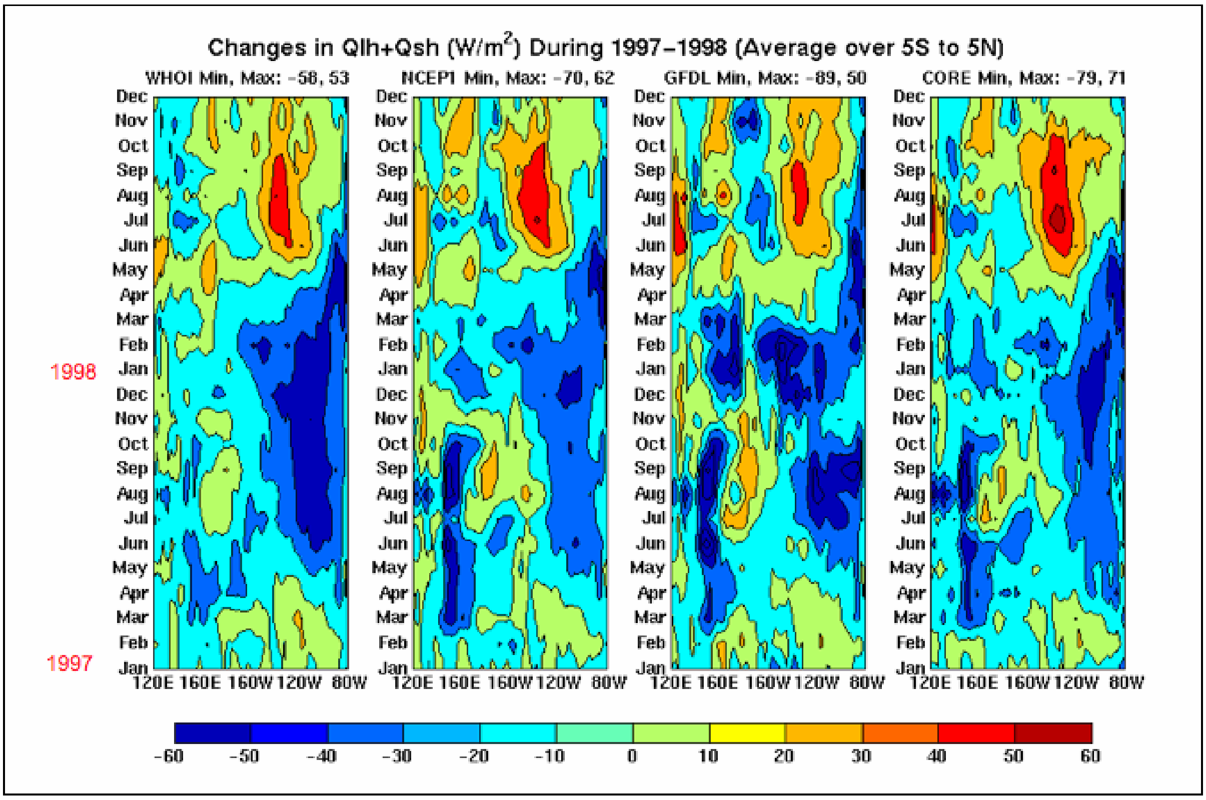

Figure 1 Comparison of time varying turbulent flux along the equatorial Pacific from OAFLUX (WHOI), NCEP1, NCEP2 (GFDL) and CORE during the 1997/98 El Niño and La Niña.

3. Surface forcing impacts during ocean data assimilation

One of the primary roles of assimilation in the ocean is to compensate for errors in surface forcing. However, surface forcing has an impact on ocean state estimates even in assimilation mode. This is particularly true prior to the altimetry era – with the paucity of ocean interior observations, much of the time-varying upper ocean state estimate is directly forced by air-sea fluxes. In the tropical Pacific, well-sampled for seasonal time-scales since 1994 by the TAO/TRITRON mooring array, assimilation does reduce the differences that would be forced by different surface wind products (e.g., Alves et al., 2004). However, even with assimilation, smaller differences remain, with some impact on coupled forecasts. A comparison of GMAO ocean analyses with different surface forcing products and with different treatment of salinity during assimilation shows larger differences arising from the different surface forcing, particularly in the eastern equatorial Pacific where the thermocline is shallow. Standard deviations of the differences in thermocline temperatures reach over 1.2ºC in that region compared to about 0.8ºC due to the treatment of salinity and 1.0ºC using a different model and assimilation system (that from GFDL) but the same forcing and input data stream (Sun et al., 2006).

4. Recommendations from U.S. Workshop

The issue of surface fluxes from reanalyses was addressed by the surface flux panel at the 2003 U.S. Workshop for an Ongoing Analysis of the Climate System (Arkin et al., 2003; see http://www.joss.ucar.edu/joss_psg/meetings/climatesystem/).

The panel noted the inadequacy of current reanalysis surface flux products and the need for accurate surface fields even more than accurate fluxes. Recommendations included:

- Atmosphere, Ocean, Land Surface, Sea-ice analyses and the fluxes for each should be “synchronized”, i.e., they should be coordinated programmatically;
- Atmospheric analyses for climate purposes (such as CDAS) should be kept current;
- Analysis should be the best estimate of the state since that is what is measured;
- Surface analyses should encompass realistic variability in the modern era down to 1 degree resolution globally, resolving the diurnal cycle;
- R&D priorities should be to:
    - Improve cloud and planetary boundary layer (atmosphere and ocean) representations so that analyses can produce realistic fluxes;
    - Develop assimilation for coupled systems;
    - Improve assimilation methods so as to use surface observations more effectively.

In addition to better products, there was a request for information on error statistics as input to ocean and land surface data assimilation.

5. Summary

Satellite products – surface wind, precipitation and moisture – have helped improve some surface field estimates needed for air-sea fluxes. Upcoming measurements, such as from Aquarius, have the potential to help constrain the surface freshwater flux. It is important that we learn to use these measurements effectively, in the separate analysis components and in a coupled system. In addition to better flux products from reanalyses, the ocean modeling community also needs improvements in the representation of upper ocean physics to make better use of surface forcing information.

6. References

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