Climate Variability in Ocean Surface Turbulent Fluxes

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Project Summary

FSU produces fields of surface turbulent air-sea fluxes and the flux related variables (winds, SST, near surface air temperature, near surface humidity, and surface pressure) for use in global climate studies. Surface fluxes are by definition rates of exchange, per unit surface area, between the ocean and the atmosphere. Stress is the flux of horizontal momentum (imparted by the wind on the ocean). The evaporative moisture flux would be the rate, per unit area, at which moisture is transferred from the ocean to the air. The latent heat flux (LHF) is related to the moisture flux: it is the rate (per unit area) at which energy associated with the phase change of water is transferred from the ocean to the atmosphere. Similarly, the sensible heat flux (SHF) is the rate at which thermal energy (associated with heating, but without a phase change) is transferred from the ocean to the atmosphere. In the tropics, the latent heat flux is typically an order of magnitude greater than the sensible heat flux; however, in the polar regions the SHF can dominate.

We examine these fluxes on the basis of in situ data (funded solely by NOAA) and satellite data (leveraged from several NASA projects and from the PI being the NASA Ocean Vector Winds Science Team Leader). The in situ product is well suited for long time scale studies, and comparisons to reanalyses[1]. We find that the variability between flux products is far greater than the accuracy need to resolve climate variability[2], indicating that a great deal more work is needed to make products that are well suited to ocean process studies where the processes are sensitive to the fluxes (as is often the case). We have also found that it is very important to consider high frequency variability[3] (e.g., finer scale synoptic variability) in the calculation of longer-term average fluxes (particularly the ocean uptake of CO_2), and in the case of the Gulf of Mexico's West Florida Shelf, for correctly modeling the regional ocean climate[4]. This is very important for the local ecosystem including some important finfish and shellfish. We maintained our website on variability in northern hemisphere tropical cyclone activity through most of the year; however, it is now moved to the website of the former student that did the work and maintained the site. These studies add to the evidence demonstrating the importance of consider the ocean and the atmosphere as coupled for climate applications.

The FSU activity is motivated by a need to better understand interactions between the ocean and atmosphere on weekly to interdecadal time scales. Air-sea exchanges (fluxes) are sensitive

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[1] **Smith, S.**, P. Hughes, and **M. Bourassa**, 2011: A comparison of nine monthly air-sea flux products. *Int. J. Climatology*, **31**, 1002-1027, doi: 10.1002/joc.2225.
[2] **Bourassa, M. A.**, S. Gille, D. L. Jackson, B. J. Roberts, and G. A. Wick: Ocean Winds and Turbulent Air-Sea Fluxes Inferred From Remote Sensing. *Oceanography*, **23**, 36-51.
[3] Hughes, P., and **M. A. Bourassa**, J. Rolph, and **S. R. Smith**, 2011: An examination of FSU3 turbulent heat flux methodology. *J. Clim.*, (submitted).
[4] Morey, S. L., D. S. Dukhovskoy, and **M. A. Bourassa**, 2009: Connectivity between variability of the Apalachicola River flow and the biophysical oceanic properties of the northern West Florida Shelf. *Continental Shelf Research*, doi:10.1016/j.csr.2009.02.003.

indicators of changes in the climate, with links to floods and droughts[5] and East Coast storm intensity and storm tracks[6]. On smaller spatial and temporal scales they can be related to the storm surge[7], and tropical storm intensity. On longer temporal scales, several well-known climate variations (e.g., El Niño/Southern Oscillation (ENSO); North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO)) have been identified as having direct impact on the U.S. economy and its citizens. Improved predictions of ENSO phase and associated impact on regional weather patterns could be extremely useful to the agricultural community. Agricultural decisions in the southeast U.S. sector based on ENSO predictions could benefit the U.S. economy by over $100 million annually[8]. A similar, more recent estimate for the entire U.S. agricultural production suggests economic value of non-perfect ENSO predictions to be over $240 million annually[9]. These impacts could easily be extended to other economic sectors, adding further economic value. Moreover, similar economic value could be foreseen in other world economies, making the present study valuable to the global meteorological community.

ENSO, PDO, and NAO (AO) each have atmospheric and oceanic components that are linked through the surface of the ocean. Changes in the upper ocean circulation result in modifications to the SST and near surface wind patterns. Variations in SSTs can be related to ENSO and other climate patterns; however, it is the fluxes of heat and radiation near the ocean surface that transfer energy across the air-sea interface. It is an improved understanding of these turbulent fluxes and their variability that motivates our research (radiative fluxes are difficult to accurately estimate from in situ data; however, satellite-based estimates are available). By constructing high quality fields of surface fluxes we provide the research community the improved capabilities to investigate the energy exchange at the ocean surface.

FSU produces both monthly in-situ based (the FSU3) and hybrid satellite/numerical weather prediction (NWP) fields of fluxes and the flux-related variables. Our long-term monthly fields are well suited for seasonal to decadal studies, and our hybrid satellite/NWP fields will be ideal for daily to inter- annual variability and quality assessment of the monthly products. The flux-related variables are useful for ocean forcing in models, testing coupled ocean/atmospheric models, ENSO forecasts, and for understanding climate related variability (e.g., the monthly Atlantic surface pressure is a good indicator of extreme monthly air temperatures over Florida).

The flux project at FSU targets the data assimilation milestones within the Program Plan. Our assimilation efforts combine ocean surface data from multiple Ocean Observing System networks (e.g., VOS, moored and drifting buoys, and satellites). One set of performance measures targeted in the Program Plan is the **Air-Sea Exchange of Heat, Momentum, and Fresh Water**. These fluxes can be related to **Sea Surface Temperature** and **Ocean Heat Content**. Additional targets are **Ocean Transport** and **Thermohaline Circulation.** Surface

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[5] Enfield, D. B., A. M. Metas-Nuñez, and P. J. Trimble, 2001: The Atlantic multidecadal oscillation and its relation to rainfall and river flows in the continental U.S. *Geophy. Res. Let*., **28**, 2077-2080.
[6] Hurrell, J.W., and R.R. Dickson, 2004: Climate variability over the North Atlantic. Marine Ecosystems and Climate Variation - the North Atlantic. N.C. Stenseth, G. Ottersen, J.W. Hurrell, and A. Belgrano, Eds. Oxford University Press, 2004.
[7] Morey, S. L., S. Baig, **M. A. Bourassa**, D. S. Dukhovskoy, and J. J. O'Brien, 2006: Remote forcing contribution to storm-induced sea level rise during Hurricane Dennis. *Geophys. Res. Letts.*, 33, L19603–19607, doi:10.1029/2006GL027021.
[8] Adams, R. M., K. J. Bryant, B. A. McCarl, D. M. Legler, J. O'Brien, A. Solow, and R. Weiler, 1995: Value of improved long-range weather information. *Contemporary Economic Policy*, **13**, 10-19.
[9] Solow, A. R., R. F. Adams, K. J. Bryant, D. M. Legler, J. J. O'Brien, B. A. McCarl, W. Nayda, and R. Weiler, 1998: The value of improved ENSO prediction to U. S. agriculture. *Climate Change*, **39**, 47-60.

winds (stress) contribute to upper ocean and deep ocean transport. The heat and moisture fluxes also contribution to the thermohaline circulation. **Ocean Carbon Uptake** is highly dependent on wind speed. We have recently worked with other members NOAA climate observing team to estimate the importance of using six hourly winds vs. monthly averaged winds on estimates of **Ocean Carbon Uptake**. The FSU flux project also focuses on the task of evaluating operational assimilation systems[10,11] (e.g., NCEP and ECMWF reanalyses) and continues to provide timely data products that are used for a wide range of ENSO forecast systems. The FSU fluxes support a broad user community. Our web data portal currently shows 169 registered users from 16 countries. Fifty-seven users are from academic institutions, 35 at governmental agencies, four from public/non-profit entities, and one from the military. Although we do not track the users applications, we know that many are using the FSU winds and fluxes to support tropical SST forecast models (e.g., LDEO model; http://rainbow.ldeo.columbia.edu/~dchen/forecast.html).

[10] **Smith, S.**, P. Hughes, and **M. Bourassa**, 2010: A comparison of nine monthly air-sea flux products. *Internat. J. Climatol.*, **30**, 26pp., DOI: 10.1002/joc.2225.

[11] **Bourassa, M**., S. Gille, C. Bitz, D. Carlson, I. Cerovecki, M. Cronin, W. Drennan, C. Fairall, R. Hoffman, G. Magnusdottir, R. Pinker, I. Renfrew, M. Serreze, K. Speer, L. Talley, G. Wick, 2009: High-Latitude Ocean and Sea Ice Surface Fluxes: Requirements and Challenges for Climate Research. *Bull. Amer. Meteor. Soc*. (submitted).