Woods Hole Oceanographic Institution
Upper Ocean Processes Group
Technical Note

A Comparison of *In Situ*, Model and Climatological Surface Forcing

A clockwise atmospheric circulation around the Bermuda/Azores High makes the Subtropical North Atlantic a preferred region for Ekman layer convergence and subduction, the process by which mixed layer water is injected into the main thermocline. A major aim of the Subduction Experiment was to observe the large-scale horizontal variations in atmospheric forcing which influence the subduction process. If subduction is to be simulated numerically using realistic surface forcing fields, then *in situ* data must be utilized in conjunction with either model or climatological forcing fields. Before these fields can be utilized, however, inherent biases must be identified. To this end, *in situ* heat, momentum, and radiometric fluxes were compared to 6hr forecasts of similar quantities from the European Centre for Medium Range Weather Forecasts (ECMWF) and the National Meteorological Center (NMC), as well as 30yr monthly averages from the Isemer and Hasse (Isemer and Hasse, 1987) and Oberhuber (Oberhuber, 1988) climatological data sets.

The mooring component of the Subduction Experiment consisted of a large-scale five mooring array that was maintained across the eastern flank of the Bermuda/Azores High from June 1991 through June 1993 (Figure 1). A Vector Averaging Wind Recorder (VAWR) measured barometric pressure, wind speed and direction, air temperature, sea temperature, relative humidity, and incoming shortwave and longwave radiation, while an Improved METeorological (IMET) recorder measured all of the variables measured by the VAWR and rainfall as well. Air-sea fluxes were estimated using 15min averages of the basic observables and a state-of-the-art bulk flux algorithm.

Substantial differences are exhibited between the surface forcing components garnered from the Subduction moorings and those offered by the model and climatological products. Many of these discrepancies are of similar sign across the array and differ only quantitatively. Thus, in the interest of brevity, only the differences observed at the northeast (NE) mooring are addressed here (Table 1).

The mooring estimates of annual oceanic sensible heat loss are greater than those of Oberhuber, but smaller than those of Isemer and Hasse. The greater annual wind speeds of Isemer and Hasse are the primary cause of this data set's larger losses with disparities in air/sea thermal gradients playing only a secondary role. The annual sensible heat losses predicted by both models are also greater than those estimated at the mooring. The greatest sensible heat losses predicted by the NMC model are primarily a product of cooler air temperatures.

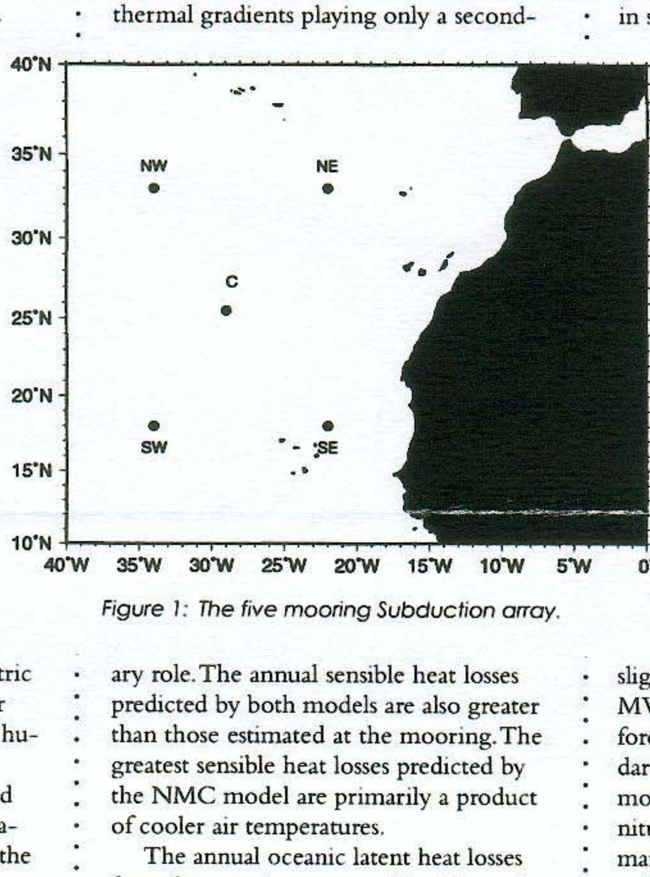

Figure 1: The five mooring Subduction array.

The annual oceanic latent heat losses from the mooring are considerably smaller than those of Isemer and Hasse, but are comparable to those of Oberhuber. Once again, the greater wind speeds of Isemer and Hasse are the primary cause of its greater heat loss. The annual latent heat losses forecast by the models are fairly similar to each other, but are typically greater than those estimated at the mooring.

On shorter time scales, large standard deviations between the mooring heat flux estimates and those of the models are indicative of the models' inability to correctly forecast high frequency variations in the heat fluxes. One potential problem is the utilization of a seven day running mean sea surface temperature analysis within both models. Such an analysis reduces changes in sea surface temperature, which can be both rapid and dramatic. Relatively large mean standard deviations in sensible and latent heat of $9W/m^2$ and $38W/m^2$, respectively, are a reflection of the models' deficiencies in this regard.

The annual net shortwave radiation observed at the mooring exceeds that depicted by both climatological data sets. These departures from climatology are not entirely surprising, given that climatological shortwave is computed from estimates of clear sky radiation and cloud cover. The superior agreement between the in situ shortwave measurements and the shortwave estimates of Isemer and Hasse primarily stems from the latter's use of larger clear sky radiation estimates and, to a lesser extent, a more realistic albedo than its climatological counterpart. The annual net shortwave measured at the mooring is slightly less than that forecast by the ECMWF model, but generally exceeds that forecast by the NMC model. Mean standard deviations between the *in situ* and model data are $75W/m^2$. The large magnitude of these standard deviations is primarily a consequence of large temporal and spatial variability in cloudiness coupled with the cost saving measure of only considering the effect of clouds on the models' radiometric fluxes once every three hours and then over a coarser grid.

The annual net longwave loss measured at the mooring exceeds that offered by either climatology. Differences between the two climatologies primarily stem from the utilization of disparate longwave parameterization schemes. Both models, however, forecast greater annual net longwave losses. Mean standard deviations between the mooring longwave estimates and the model data are $22W/m^2$ and are again a reflection of the cost efficient use of the full radiative transfer equation coupled with the inherent large variability in cloud cover.

Despite the fact that the Isemer and Hasse wind speeds are substantially larger than those measured at the mooring, the annual wind stress from the mooring exceeds that of Isemer and Hasse. This behavior is largely a consequence of the large directional variability of the winds coupled with the fact that the climatological wind stress was computed from its monthly mean vector components rather than on an individual observation basis. Although the annual stress predicted by the models is quite similar, the stress estimated at the mooring is substantially larger than that of either model. Mean standard deviations between the mooring and model data are $0.04N/m^2$ and are again a reflection of the high frequency variability of the wind.

The net air/sea heat flux is calculated by subtracting the sensible, latent, and longwave heat losses from the shortwave gain. All of the model and climatological products predict greater annual net heat losses than those of the mooring. In general, the mooring data reflect a greater summer heat gain and a smaller winter

Variable	Avg. Period	Wind Stress (N/m^2)	Sensible Heat Flux (W/m^2)	Latent Heat Flux (W/m^2)	Net SW Flux (Wm^2)	Net LW Flux (W/m^2)	Net Heat Flux (W/m^2)
NE Mooring	Year 1	0.089	-8.4	-94	191	-63	25
NE Mooring	Year 2	0.094	-10.3	-102	196	-69	14
ECMWF	Year 1	0.075	-11.1	-103	203	-74	15
ECMWF	Year 2	0.074	-14.3	-116	199	-75	-7
NMC	Year 1	0.065	-14.8	-97	196	-73	11
NMC	Year 2	0.070	-16.8	-102	191	-73	0
Isemer-Hasse	Year	0.066	-14.4	-131	174	-44	-15
Oberhuber	Year	NA	-5.7	-97	154	-57	-5

Table 1: Annual averages of in situ, model, and climatological surface forcing at the NE mooring location.

heat loss relative to their model and climatological counterparts.

Although scientists rely on global model and climatological surface forcing products to provide appropriate boundary conditions with which to drive their models, *in situ* estimates of the exchange of heat, moisture, and momentum with which to gauge the local representativeness of these surface forcing fields are scarce over oceanic regions. Consequently, reliable long-term *in situ* estimates of surface forcing, such as those garnered from the Subduction moorings, are quite useful, for they not only facilitate future improvements in the parameterization schemes used to produce these model and climatological products, but also inform current users of existing biases within the products as well.

ACKNOWLEDGMENTS

The author would like to recognize the Data Support Section of the National Center for Atmospheric Research (NCAR) for providing the model data utilized in this technical note. This work is supported by the Office of Naval Research under Contract No. N00014-90-J-1490.

REFERENCES

Isemer, H.-J., and L. Hasse, 1987: The *Bunker Climate Atlas of the North Atlantic Ocean. Vol. 2: Air-Sea Interactions*. Springer-Verlag, New York, 252pp.

Oberhuber, J.M., 1988: An atlas based on the COADS data set: The budgets of heat, buoyancy, and turbulent kinetic energy at the surface of the global ocean. *Max Planck Institut für Meteorologie, Rep. No. 15.*

This technical note was written by Dr. Kerry A. Moyer, who is a postdoctoral investigator in the Physical Oceanography Department and a member of the Upper Oceans Processes Group at the Woods Hole Oceanographic Institution.

Note: Previous issues of the UOP Technote can be found on our homepage at http:/uop.whoi.edu

Published by the Upper Ocean Processes Group, Woods Hole Oceanographic Institution, Woods Hole MA 02543-1542.
Contact: Rick Trask, ext. 2395. Design by Jeannine Pires, WHOI Graphics

Upper Ocean Processes Group
Woods Hole Oceanographic Institution
Woods Hole, MA 02543-1542