OS51B-0485

Ocean-Atmosphere Flux Variability in the Gulf of Mexico

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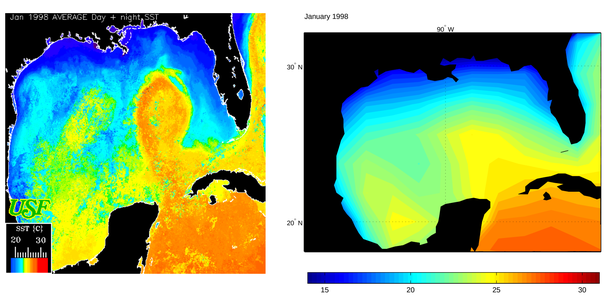
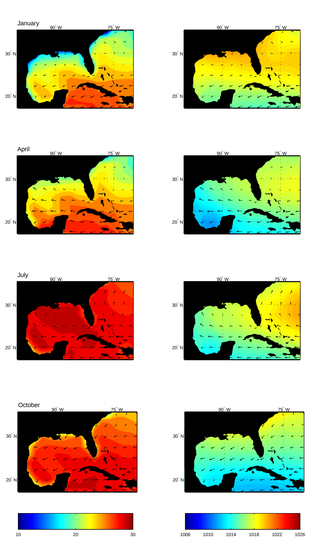
ABSTRACT

Gulf of Mexico (GOM) sea surface temperature (SST) shows considerable spatial and temporal variability. Understanding causes of this variability is important because the region is a major source of moisture flux into the U. S. Heartlands. Some of the variability is due to ocean dynamics associated with coastal upwelling and the Loop Current, but an equally important amount is due to local ocean-atmosphere fluxes. Many commonly available data sets are unable to reproduce observed temporal and spatial variability due to coarse spatial resolution. This is a particular problem along the continental shelves and prevents the study of ocean-atmosphere interactions in these critical regions. In-situ measurements of oceanic and atmospheric parameters on the West Florida Shelf (WFS) allow us to describe the annual cycle of fluxes on the WFS and how they interact with the underlying ocean circulation and mixed layer. Comparisons have also been made with NCEP reananlysis fields. Driving ocean models with the reanalysis fields, without flux corrections, fails to produce observed seasonally varying features on the WFS. Reconciling these differences and their impacts on the climate variability of this region provides challenges to coupled ocean-atmosphere models and their supporting observing systems.

INTRODUCTION

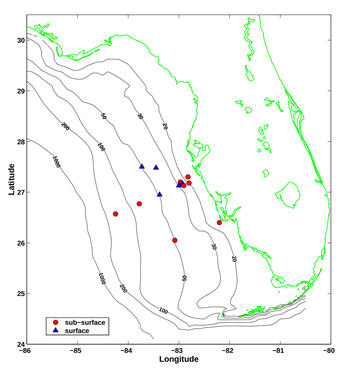


AVHRR SST image (left) in January 1998 shows warm mid-basin waters by Loop Current intrusions, and cooler coastal waters by upwelling. The small-scale temperature variability is not apparent in NCEP reanalysis (right).

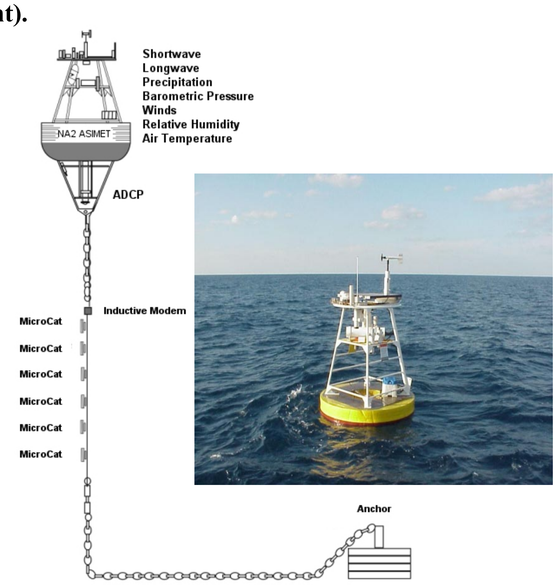


NCEP climatology annual cycle of SST (left) and SLP (right).

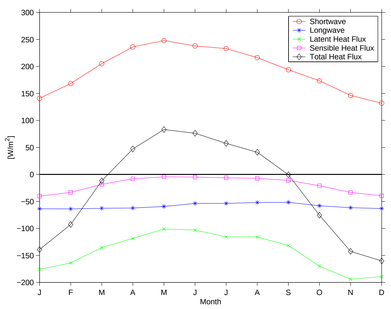
OBSERVATIONS & MODEL



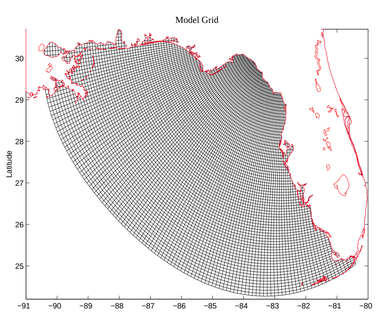
USF moored array from June 1998-August 2001: measured currents, temperature and salinity, and some meteorological variables.



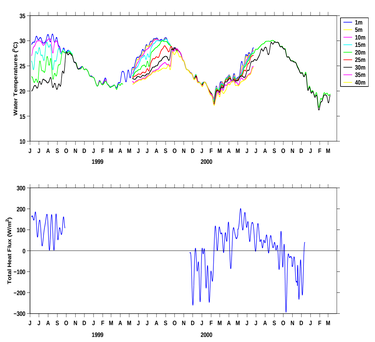
Surface mooring with met packet.



NCEP climatological heat fluxes averaged over the GOM show an annual cycle, with heating from March to September and cooling at other times. The annual cycle in latent heat flux is associated with warm Loop Current waters and occurs east of the Mississippi River.



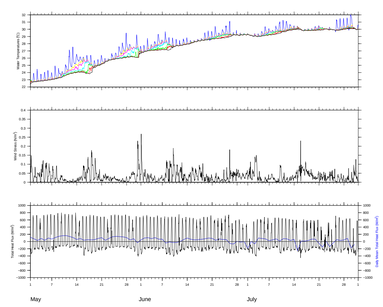
Regional adaptation of the Princeton Ocean Model with 2-6km horizontal resolution and 21 σ-layers.



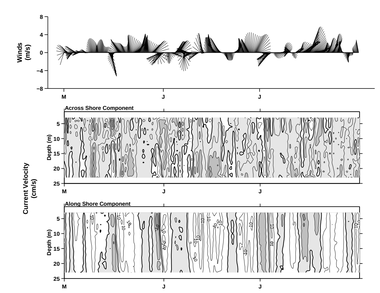
Spring and fall seasonal transitions (top) coincide with changes in sign of the net surface heat flux (bottom). Stratification occurs during spring and early summer, destratification occurs during fall and winter. Inter-annual variability is also observed.

RESULTS

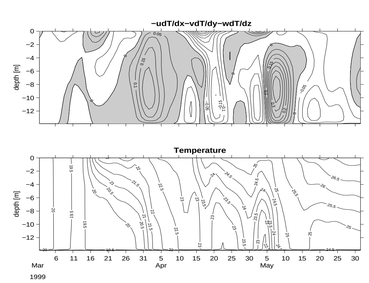
Spring & Summer



Temperatures in spring show synoptic-scale stratification events, due in part to decreased wind stress and increased surface heat flux.

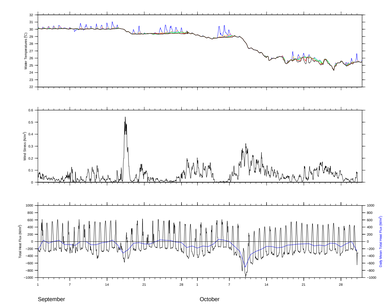


Advection is also responsible for observed SST changes. Upwelling favourable winds lead to on-shore (white) currents at depth, and off-shore (grey) currents at the surface; conversely for downwelling. Stratification occurs during upwelling, and destratification occurs during downwelling.
This is also shown in model results:

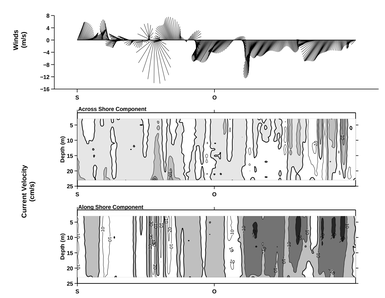


The upper panel shows ocean dynamical cooling (white) and warming (grey), corresponding to stratification and destratification, respectively.

Fall



Fall temperatures show a series of sudden step-like decreases. These are due to tropical storms (e.g. Sept. 17th), extra-tropical systems (e.g. Oct. 10th), and associated ocean circulation responses. The largest momentum flux is associated with hurricanes, but the largest surface heat flux is due to extra-tropical fronts.



Temperature decreases correspond to high speed sub-surface, southward (grey) jets.

REFERENCES

He, R., and R. H. Weisberg, 2001. West Florida Shelf Circulation and Temperature Budget for the 1999 Spring Transition. *Cont. Shelf Res.* (in press).

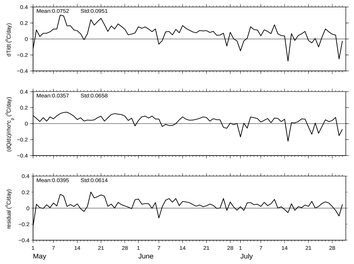
Virmani, J. I., and R. H. Weisberg, 2001. Features of the Observed Annual Ocean-Atmosphere Flux Variability in the West Florida Shelf. Submitted to *J. Climate*.

Temperature Analyses

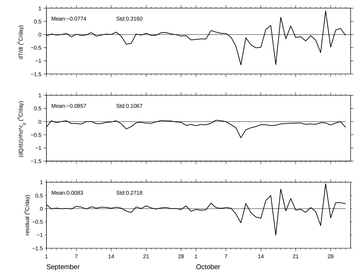
A 1-D temperature analyses follows from:

$$\frac{\partial T}{\partial t} = \frac{1}{\rho c_p}\frac{\partial Q}{\partial z}$$

The residual between the vertically integrated local rate of change and the surface heat flux represents ocean dynamics and errors.



The spring and early summer seasonal change in temperature is due to surface heat flux. Controls on the synoptic scale variability changes with the season: in spring, synoptic variability is due to ocean circulation; in summer, synoptic variability is due to surface heat flux. For the spring transition season, this compares well with model results.



The fall seasonal change in local temperature is due to surface heat flux. Ocean circulation largely controls the synoptic scale variability.

CONCLUSIONS

1. GOM SST gradients, affecting surrounding land mass climate, results from differences between deep and coastal ocean temperatures, and vary seasonally and inter-annually.

2. WFS seasonal transtions coincide with net surface heat flux changes (warming to cooling in fall, and conversely in spring).

3. Inter-annual variability is observed on the WFS.

4. Seasonal and inter-annual SST changes are largely surface heat flux controlled.

5. Synoptic scale variability is due to both ocean circulation and surface heat flux, and the thermodynamics are 3-D.

6. Tropical storms provide the largest momentum flux, but extra-tropical systems may provide larger net heat flux.

7. The necessity for including adequate net surface heat flux in coastal ocean models will challenge evolving coastal ocean observing systems.