A numerical study of the Yucatan upwelling processes

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1. Introduction

Hydrographic observations of upwelling in the Yucatan Peninsula have been reported more than 40 years ago by *Cochrane* [1], *Ruiz* [3], and more recently by *Merino* [2]; however, there is no general agreement on the physical processes that cause it. *Merino* [2] reported upwelled water with temperature between 16°C and 20°C and a seasonal variation (events are more frequent and intense during the summer). The region studied here is located on the Campeche Bank (CB), north of the Yucatan Peninsula (Figure 1). According to the observations by *Merino* [2], upwelling in the Yucatan Shelf (YS) cannot be explained by the classical wind-driven mechanism. The region is strongly influenced by the Yucatan Current, which flows along the Yucatan Channel (YCh), and feeds the Loop Current.

The aim of this study is to analyze the dynamical mechanisms of the Yucatan upwelling, using realistic bathymetric and climatological conditions of the area.

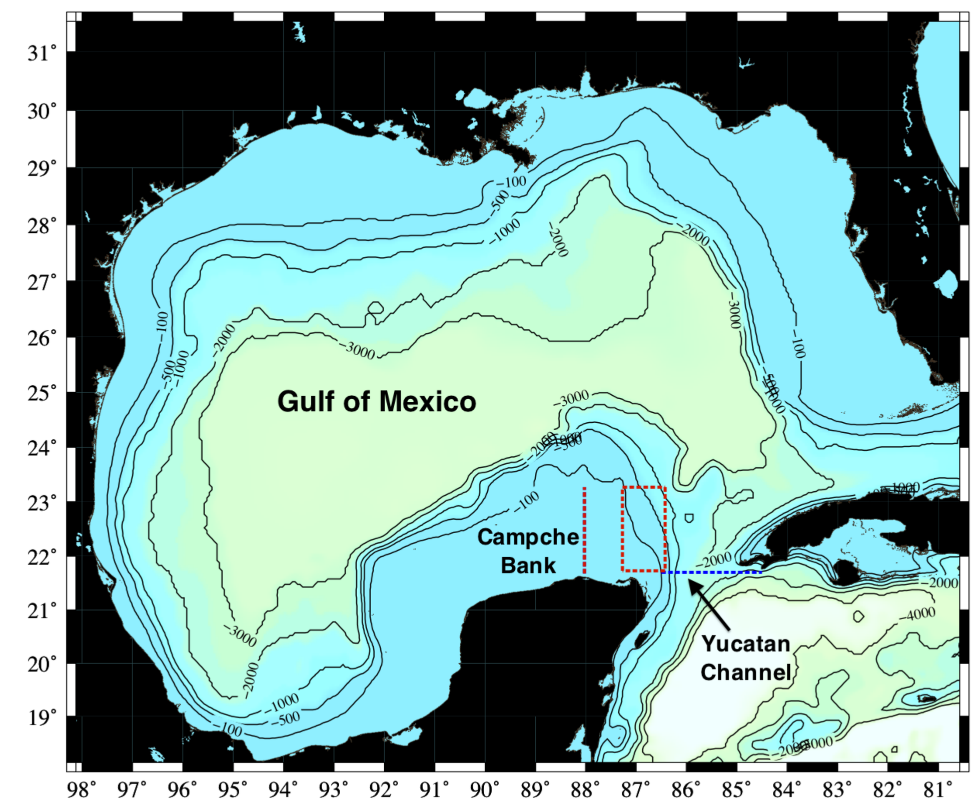

Figure 1

2. Numerical Set-up

- Horizontal domain: The Gulf of Mexico (98.10°W to 80.15°W, 18.10°N to 31.15°N) on an Arakawa C regular grid with a horizontal resolution of 1/20°.Bathymetic data taken from the General Bathymetric Chart of the Oceans (GEBCO) 1 min resolution.
- Vertical grid: 48 z-levels with a resolution of 5 m for the 20 levels. The deepest level is located at 4500 m.
- Time domain: 5 years (2007-2011) with daily outputs of temperature, velocity components, SSH, salinity and pressure.
- Initial and open boundary conditions (u,v,T,S,SSH) were taken from the Hybrid Coordinate Ocean Model (HYCOM) 1/25° Gulf of Mexico experiment. Open boundary conditions were set on the east and south boundaries of the domain with a 15 days periodicity.
- Forcing fields: On the surface, every 6 hours, with incident long and short wave radiation, air temperature, relative humidity and precipitation extracted from the NCEP/NCAR reanalysis; winds were taken from NARR.

3. Results

Several upwelling events were identified throughout the simulation.The events are similar but some are more intense and may vary from a few days up to two months. In general, it was found that water with a temperature of approximately 18°C ascends from depths under 120 m and irrupts in the 37.5 m level on the eastern side of the continental shelf. On the vertical dimension, a cold water dome evolves during the upwelling event and spreads into the YS. Figure 3 shows the development of a representative upwelling event that occurred during the 4th year of the simulation.

Upwelling events were divided into two processes: the ascension of water over the slope and the intrusion of this upwelled water onto the YS. The first one was characterized by the transport of ascending water across the area delimited in Figure 1 (red, dotted square) at a depth of 37.5 m; the second one, by the westward transport of water with a temperature lower than 18°C across the meridional cross-section in Figure 1 (red, dotted line), hereafter E-W transport.

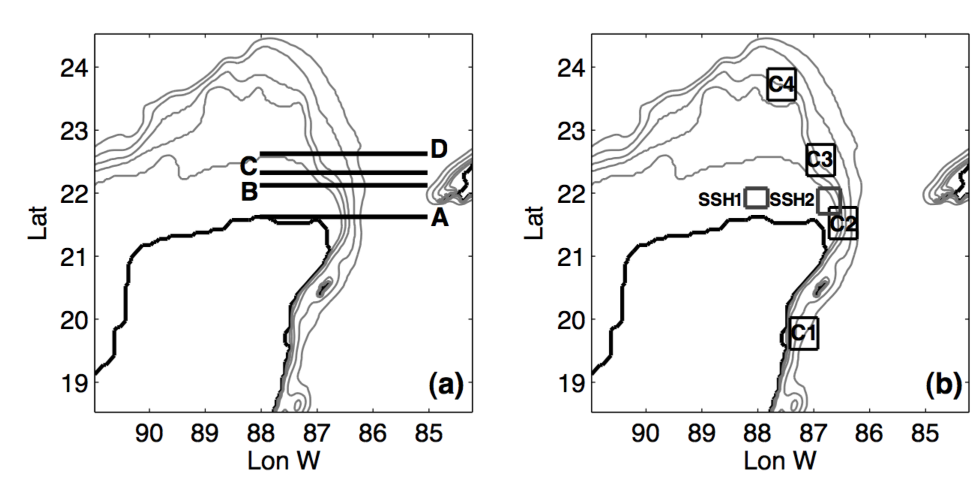

Figure 2: **(a)** Zonal cross-sections in 3A. **(b)** Areas averaged to calculate the spectra.

7. References

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[3] Ruiz, F. G. (1979), Upwelling north of the Yucatan Peninsula., MSc. Thesis, Department of Oceanography. Texas A & M.

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8. Aknowledgements

This study was funded by UNAM through the Programa de Apoyo a Proyectos de Investigación e InnovacióTecnológica (PAPIIT) projects IN116111and RR11611.

4. Results

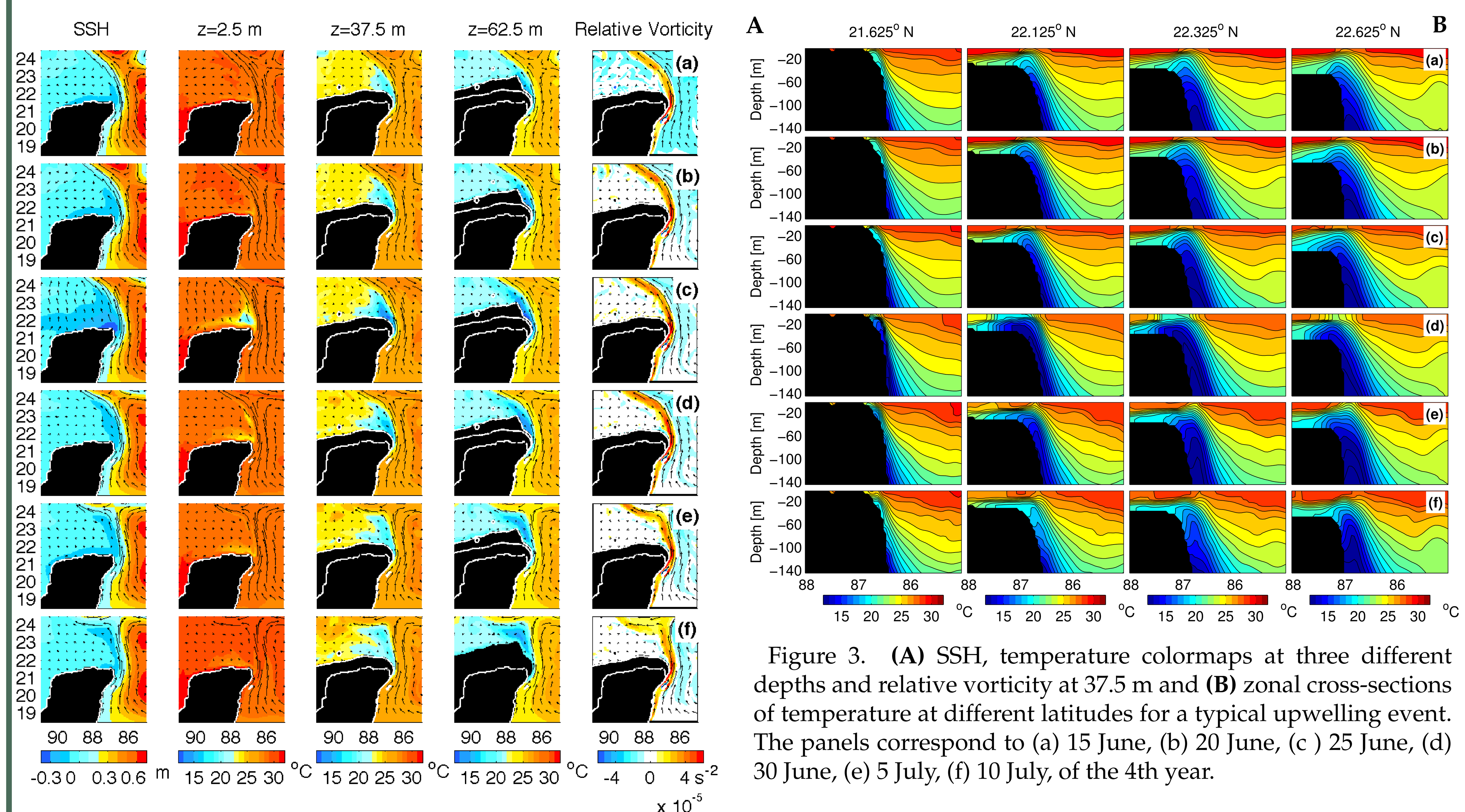

Figure 3. **(A)** SSH, temperature colormaps at three different depths and relative vorticity at 37.5 m and **(B)** zonal cross-sections of temperature at different latitudes for a typical upwelling event. The panels correspond to (a) 15 June, (b) 20 June, (c) 25 June, (d) 30 June, (e) 5 July, (f) 10 July, of the 4th year.

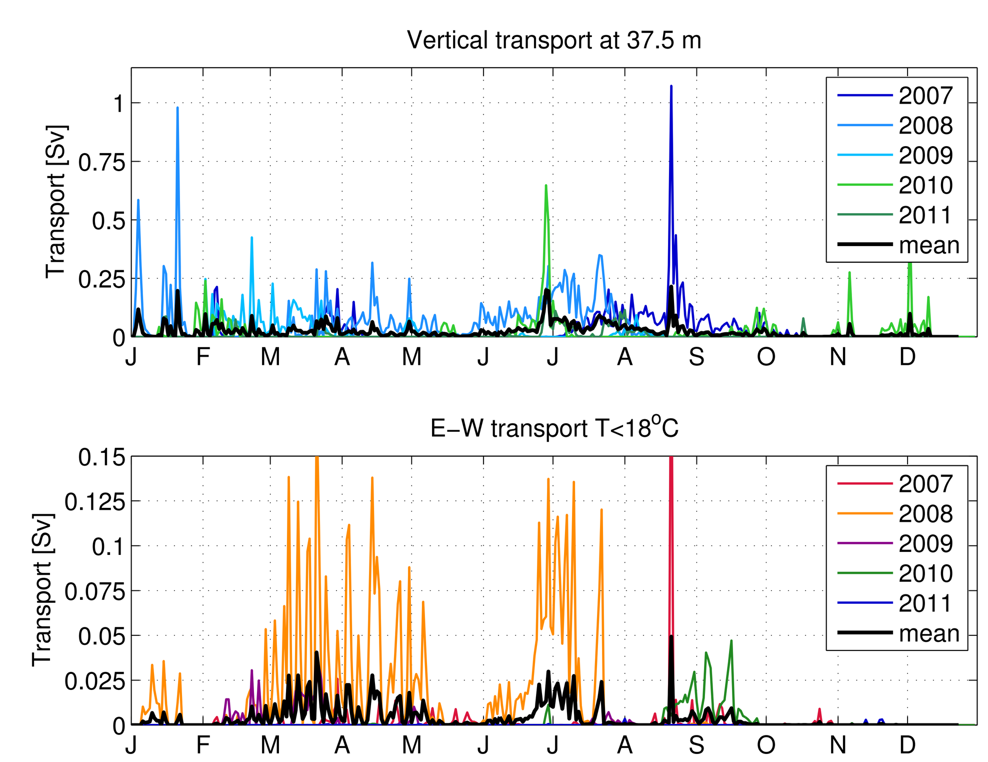

Figure 5

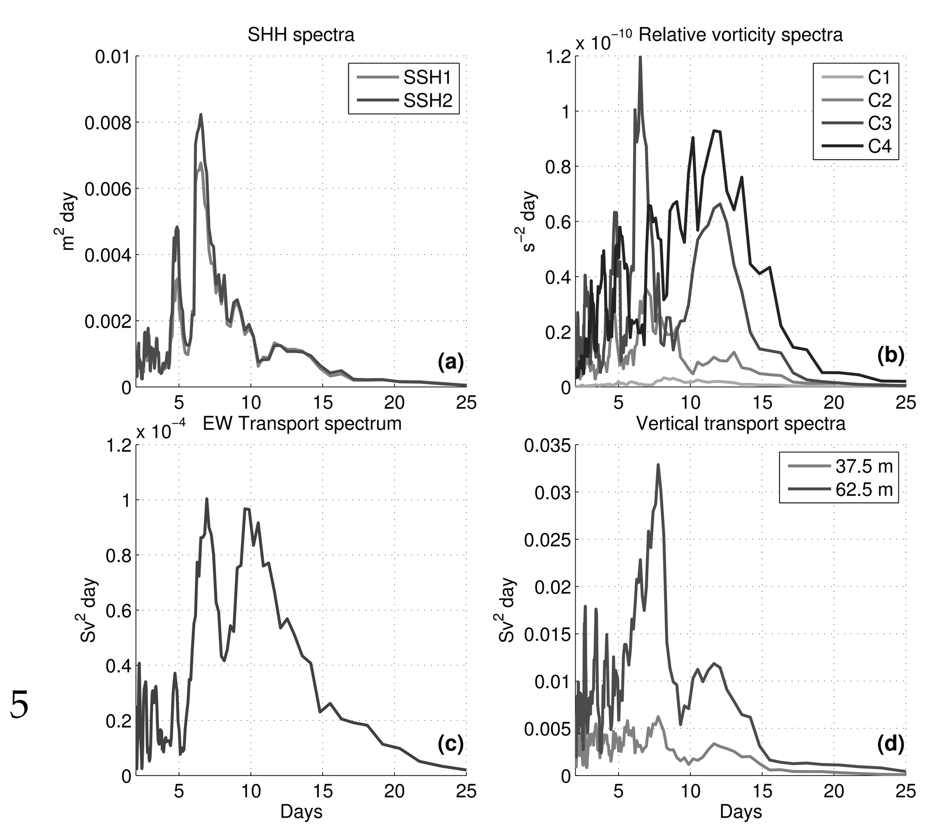

Figure 6

On average, the vertical transport and E-W transport are higher during the summer and almost continuous, but during the first months of the year E-W transport is more active. Throughout the year there are events with shorter duration. This is consistent with the behavior of SSH subsidences, that appear continuously during the summer and have short periods during the rest of the year.

Periods larger than 60 days were filtered out and spectra were computed using the multitaper method [4] with a halfbandwidth of 3.5 and the first 6 slepian sequences. Note a peak between 5 and 10 days for almost all of the analyzed variables. The most remarkable similarity is between the SSH and vertical transports spectra.

6. Conclusions

- Upwelling occurs in episodes of 5 to 10 days when there is vertical motion on the eastern side of the CB associated to cyclonic vortices (LCFE) that develop and evolve along the west rim of the YCh. Considering its period, the development of LCFE seems to be favored by the meanders and the position of the Yucatan Current/Loop Current.
- The SSH over the CB reaches its lowest value when the cold water dome reaches its maximum height, or within of it.
- The vertical transport and the E-W transport of water with temperature below 18°C are the mechanisms that drive the Yucatan upwelling. The first one is episodic and related to pulses of higher vorticity along the eastern edge of the Yucatan Current and its position. The second one is mainly associated with the wind driven current on the CB which varies seasonally and also on meteorological frequencies (3-10 days).
- Future work will consider simulations with different forcing fields, e.g. with and without wind, to determine the role each one has in the upwelling mechanism.