Interannual Variability of Global Coastal Upwelling Inferred from a Satellite Wind-Derived Coastal Upwelling Index Database

Steve Morey
Center for Ocean – Atmospheric Prediction Studies
The Florida State University

This project was sponsored by the NASA/JPL Ocean Vector Winds Science Team

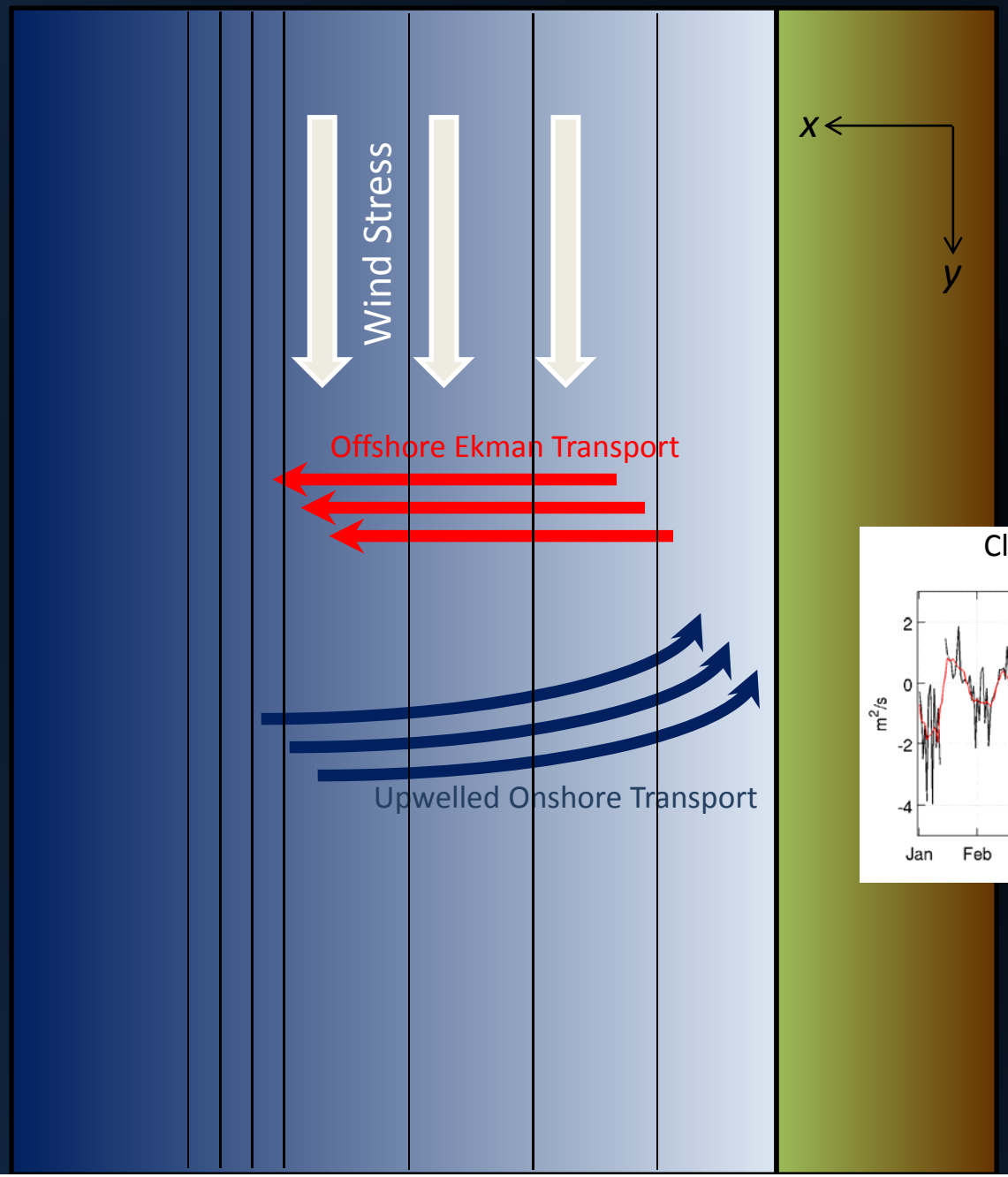
Project Objectives:

- Develop an improved global database of coastal upwelling indices from satellite scatterometer-derived wind products.
- Develop methods for extending application of upwelling indices to coastal regions with complex shelf geometry.
- Use this global product to examine spatio-temporal variability of upwelling/downwelling over Earth's coastal regions at multiple scales.

New Developments:

- Introduction of seasonality to account for variable stratification
- Computation of seasonally-varying metrics to gauge applicability of the upwelling indices

Idealized Coastal Upwelling

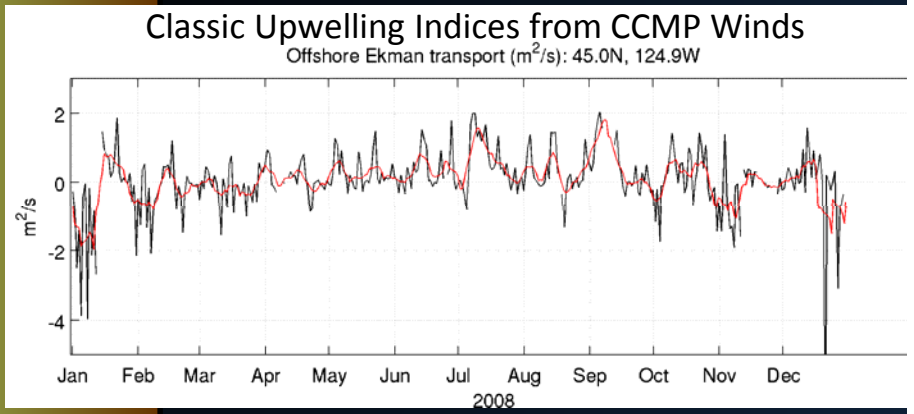


The offshore Ekman transport is

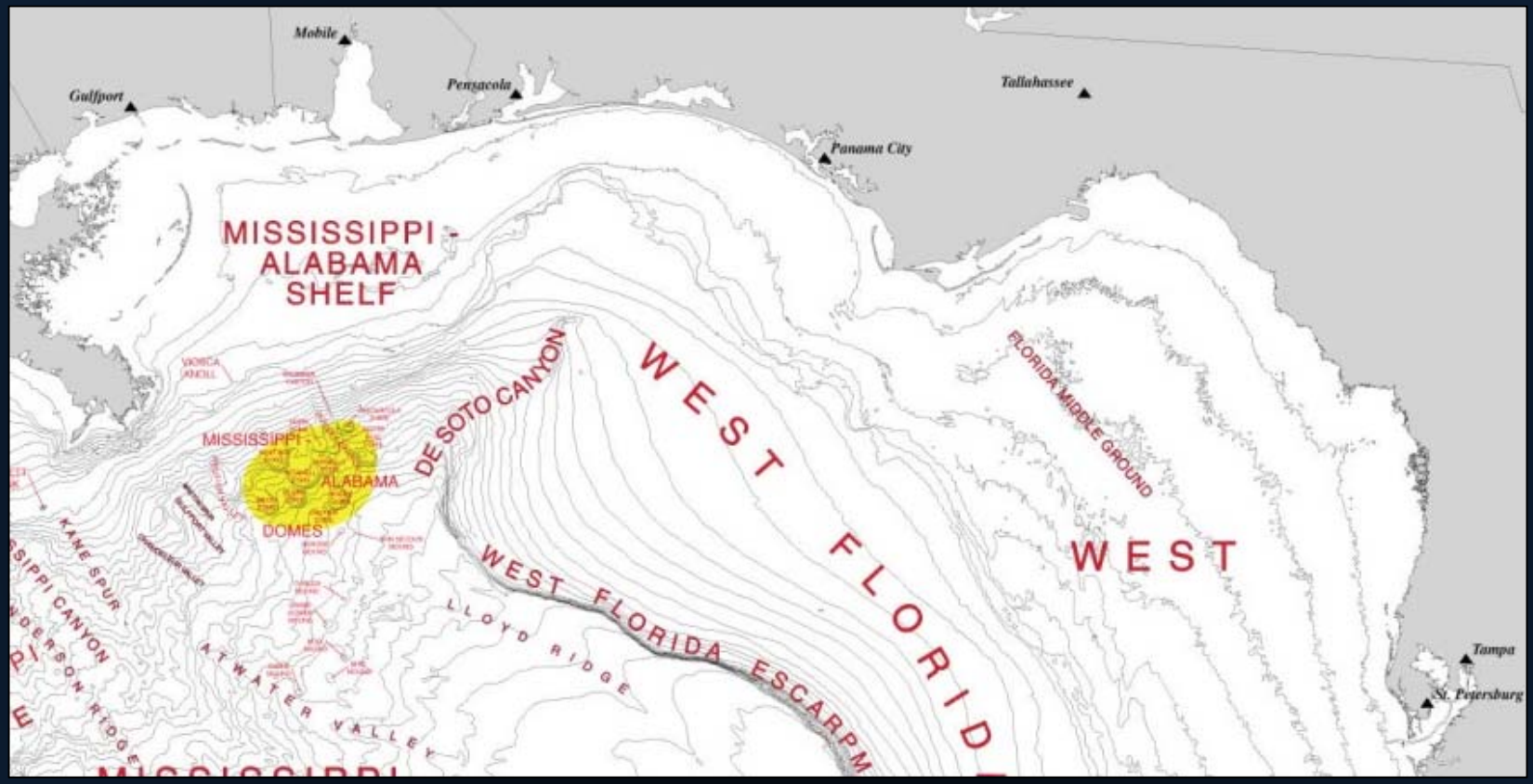
$$S_x = \frac{\tau_y}{\rho_0 f}$$

S_x is used as an upwelling Index

Classic Upwelling Indices from CCMP Winds



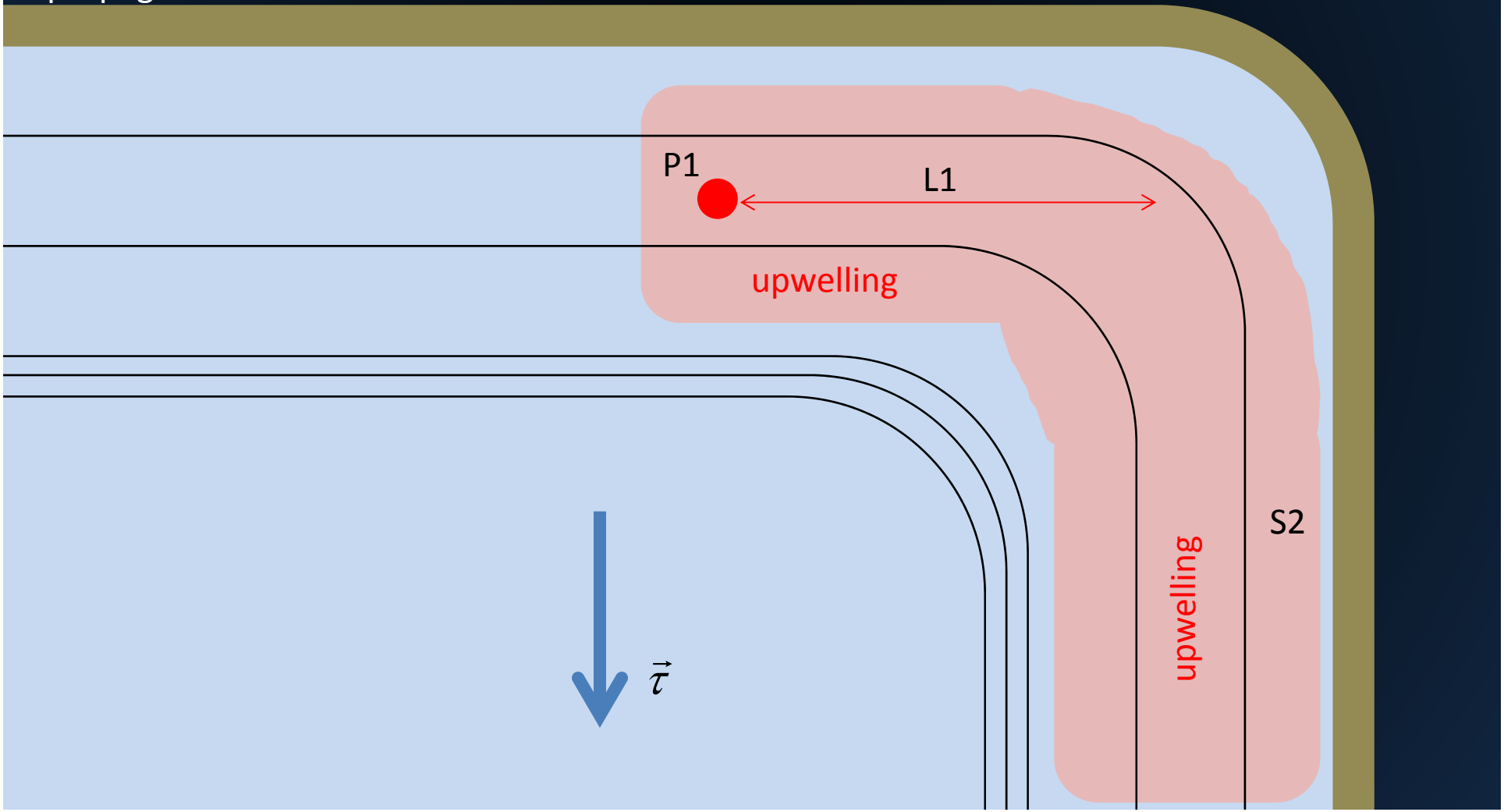
Wind-Induced Upwelling on a Shelf with Complex Geometry



This is not a long straight coastline.
Does upwelling/downwelling necessarily respond to local along-isobath winds?

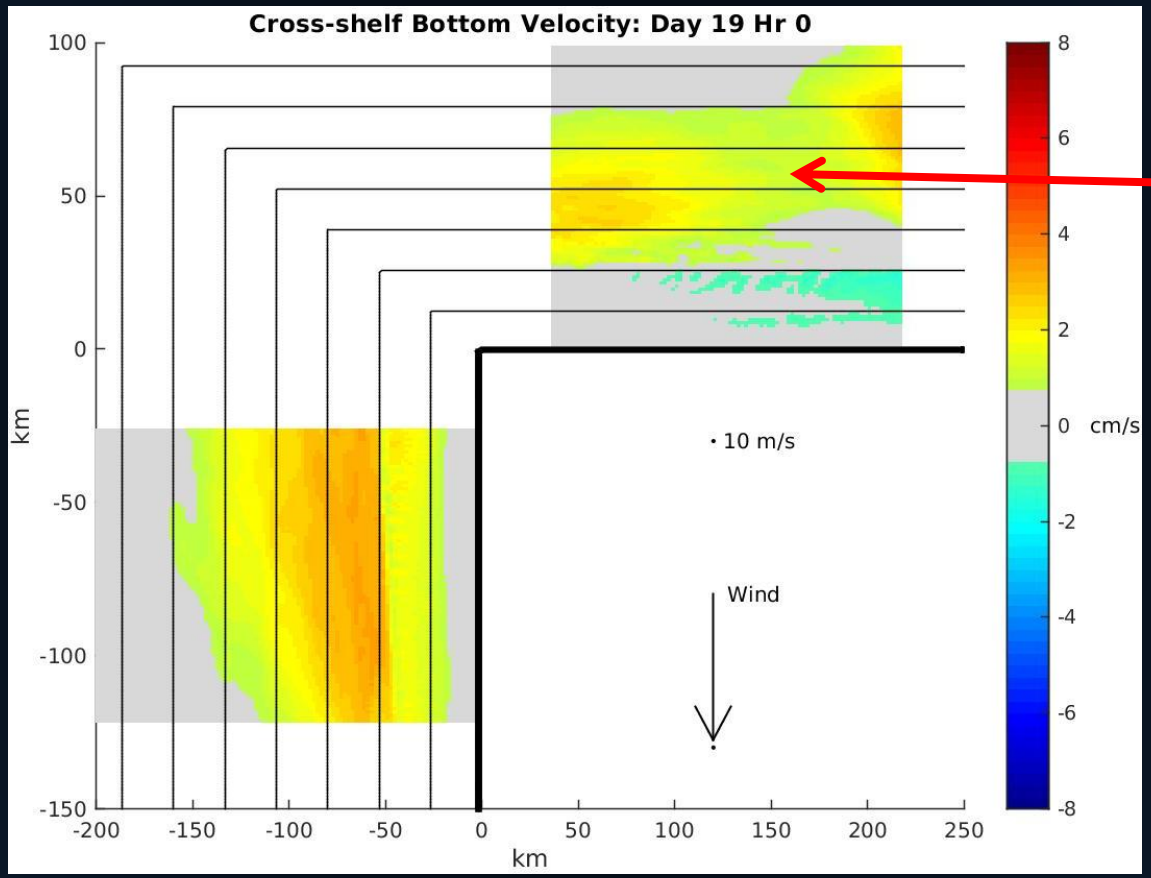
Wind-driven coastal pressure anomalies propagate in the downcoast direction as coastal trapped waves. Their structure is modified by local wind along their propagation characteristics (Clarke, JPO 1977).

Upwelling downcoast may be approximately related to local winds not of along-coast orientation given large wind spatial scales and slow time scales compared to wave propagation



Idealized Shelf Model

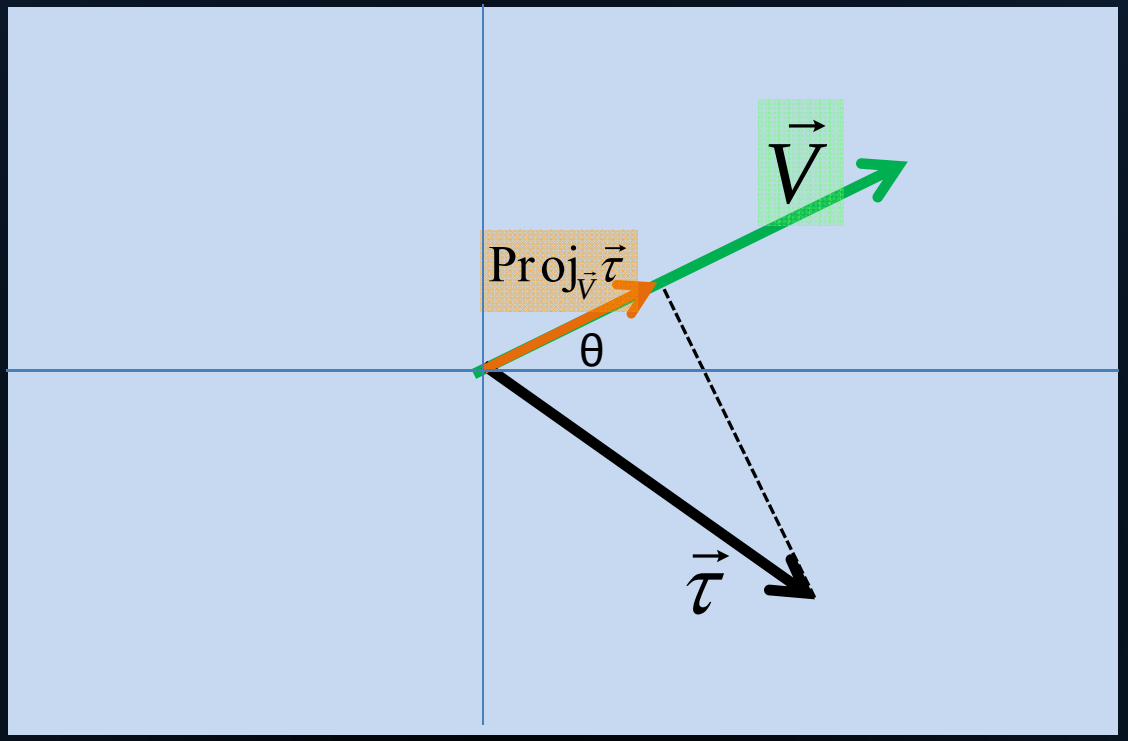
- Stratified water column
- Spatially uniform oscillating winds (5-day period)



Onshore winds (not alongshore) appear to be associated with an upwelling signal.

The downwelling and upwelling motions generated via Ekman transport on the western shelf propagate as a CTW to the northern shelf.

A Modified Upwelling Index



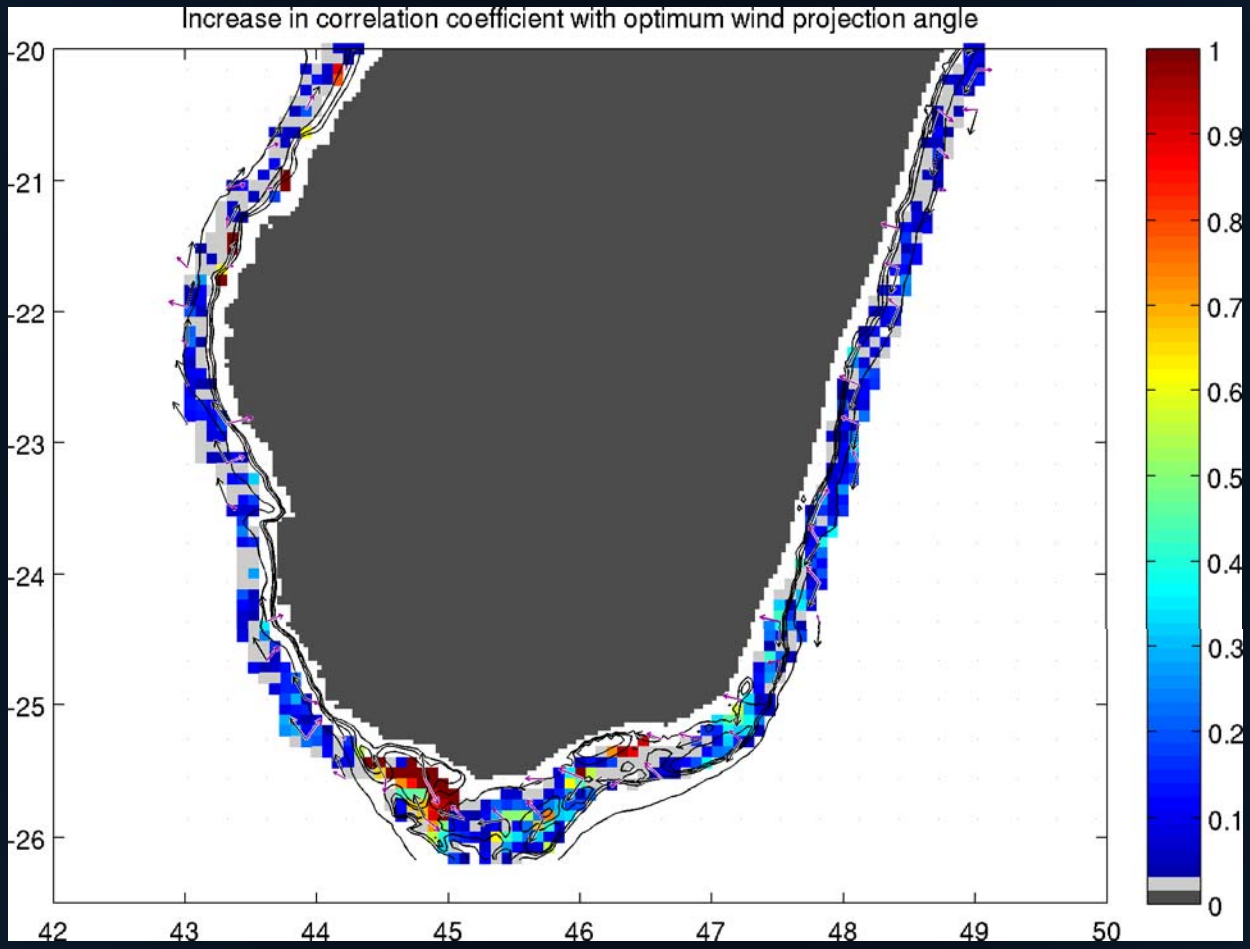
1. Project τ onto the vector V rotating through all angles. Here, τ is backward averaged over a 24-hour period

2. For each angle, compute correlation between the projected (filtered or lagged) wind stress time series and the near-bottom cross-isobath ocean velocity component.

3. Determine the rotation angle of maximum correlation

4. Project wind time series (e.g., QuikSCAT L2b, CCMP, etc.) onto this optimum vector.

Southern Madagascar Example

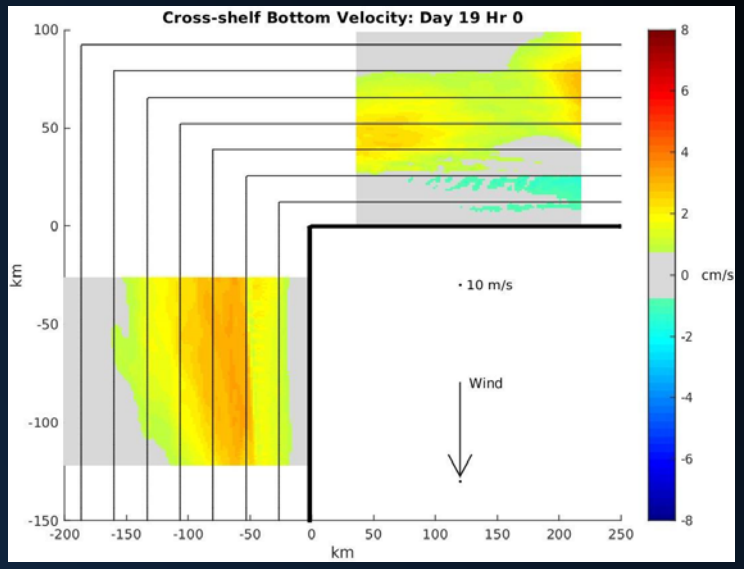


Wait a minute! Upwelling is a **baroclinic** process dependent on stratification. What happens if a shelf becomes **unstratified**?

The long wave solution for a stratified ocean over a sloping bottom is the **coastal trapped wave (CTW)** , a hybrid of the limiting cases of:

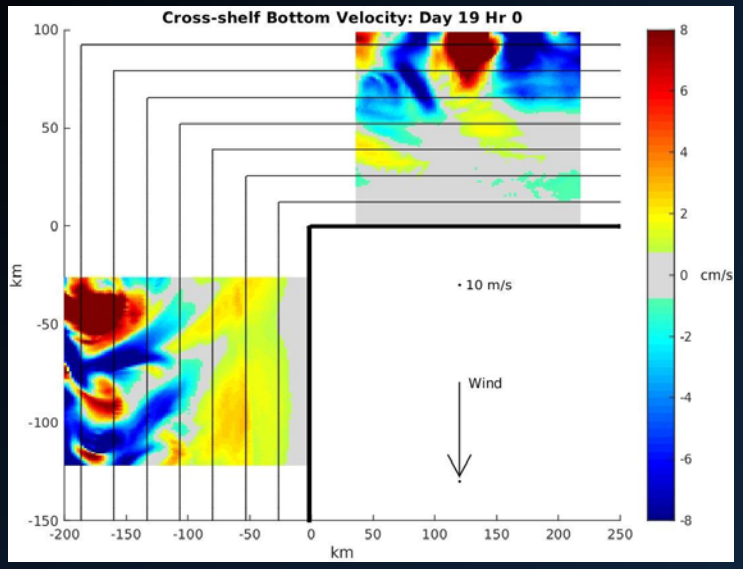
- The **Topographic Rossby Wave (TRW)** (barotropic shelf wave)– the wave solution for an unstratified ocean over a sloping shelf, and
- The **Baroclinic Kelvin Wave** – the wave solution for the limiting case of a flat bottom and a wall in a stratified ocean**.**

Reduction in stratification alters the along-slope propagation of long waves, and under no stratification, cross-shelf motion is limited.

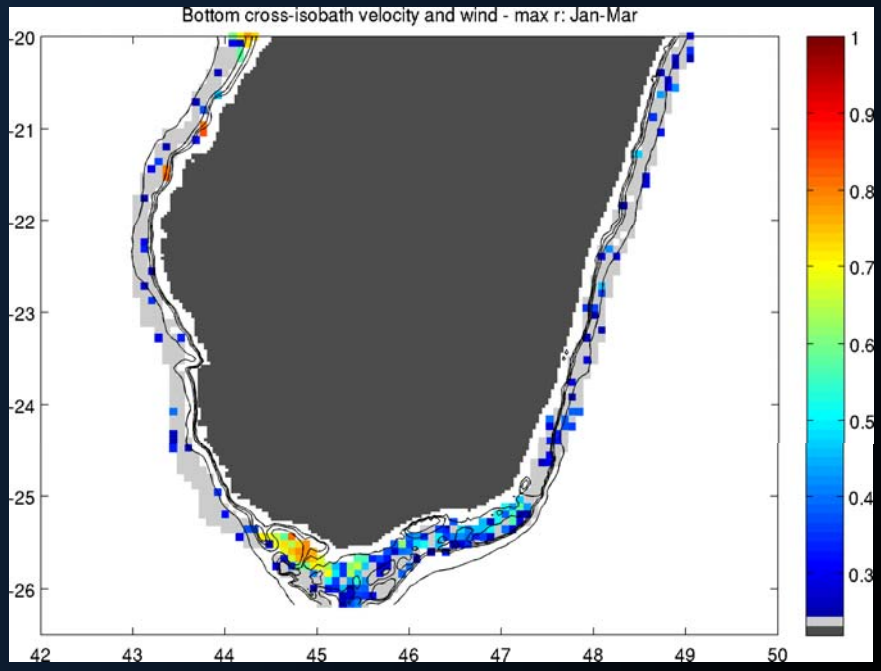


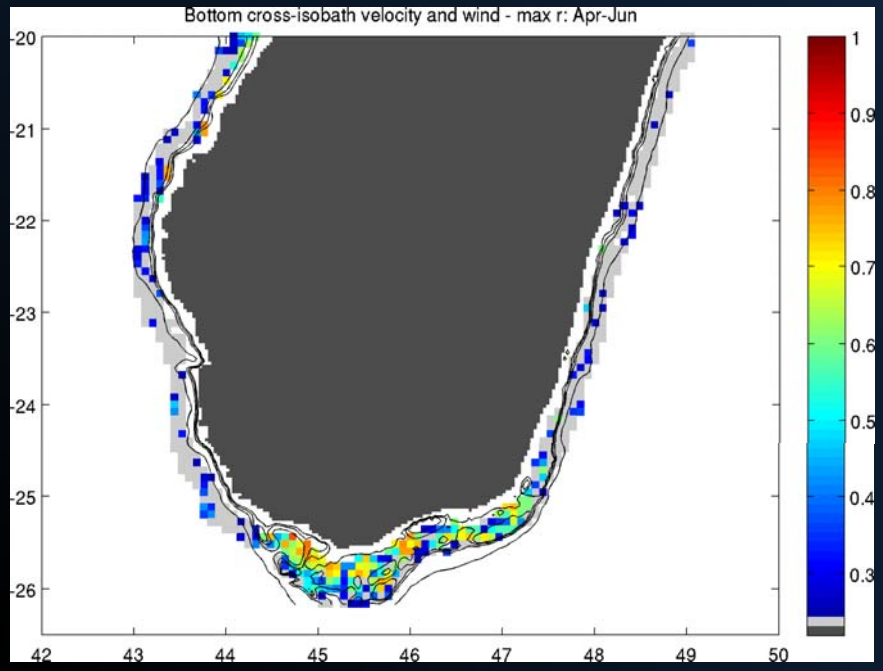
Stratified

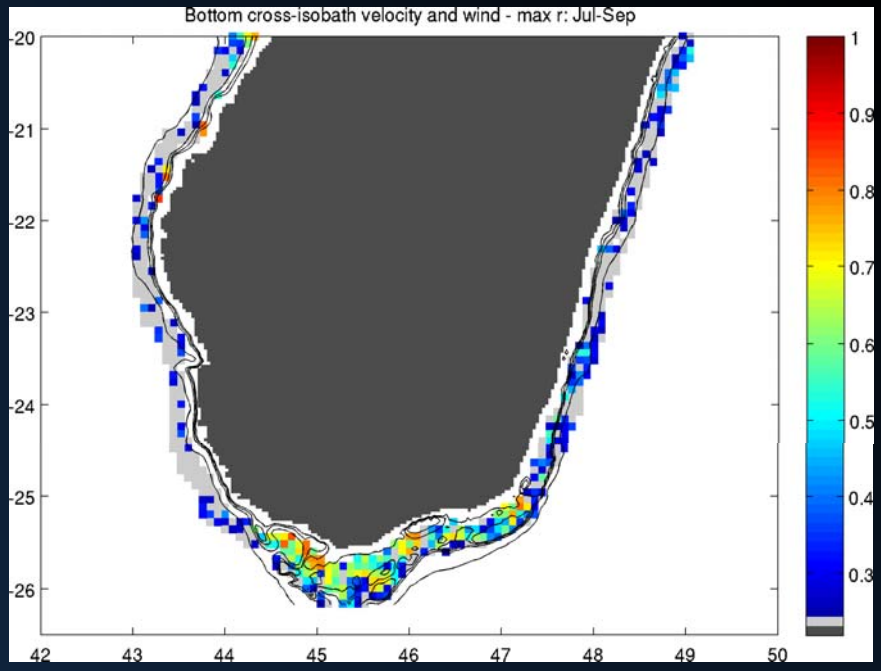
Weakly Stratified

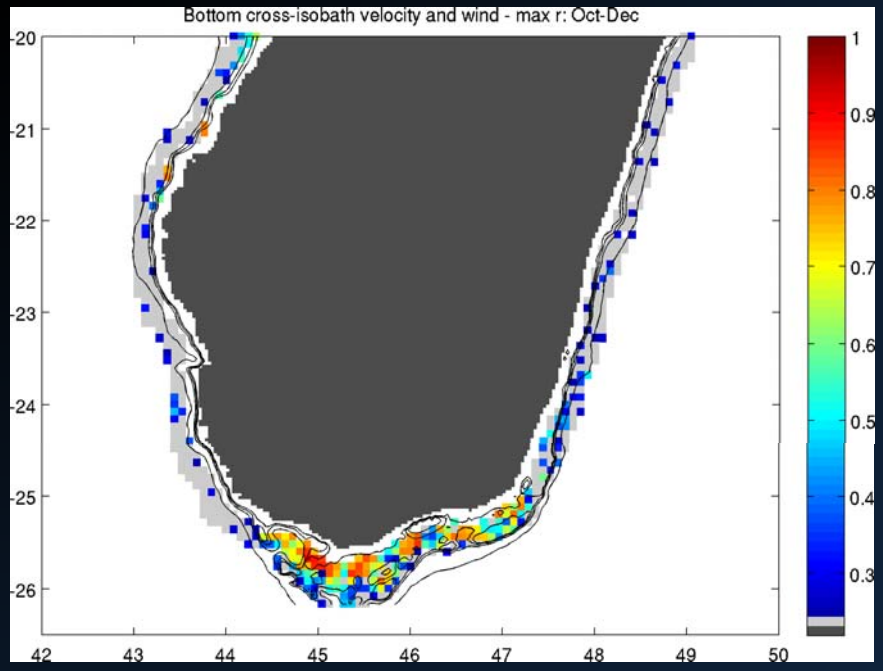


Correlation between new upwelling index and cross-shelf bottom velocity by season









Next Steps

- Compute the new upwelling index database using an extended multi-platform historical wind data product for all regions and compute seasonal metrics.
- Develop new measure of appropriateness of upwelling indices.
- Provide the global databases of upwelling indices and appropriateness metrics via web-based interface with analysis tools and/or data center.
- Use the database for studies of spatio-temporal variability of coastal upwelling globally and regionally with assessment of impacts of climate variability.