

Scales of Stress

Site-specific ecological assessments
from *larger-scale* datasets, or...

“Better Living Through Physics”

Sargasso Sea Workshop, Mar 21, 2016

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Introduction

The Coral Health and Monitoring Program (CHAMP) at NOAA AOML in Miami

- A network of reef monitoring stations
- Integrated with satellite and model products
- Daily ecosystem impact alerts

CHAMP Network

www.coral.noaa.gov/champportal/

NOAA/CHAMP Coral Reef Stations

Stations/Sensors

- Atlantic
 - Bermuda
 - Bermuda CRW Site [BE...]
- Australia
- Caribbean
 - Belize
 - Calabash Caye [CCBZ...]
 - Glover's Reef [GRBZ1]...
 - Glover's Reef CRW Sit...
 - Half-Moon Caye [HCBZ...]
 - South Water Caye [SW...]
 - Eastern Caribbean
 - Antigua, North [NAAN...]
 - Barbados, Dottin's Re...
 - Barbados, Folkestone ...
 - Barbados, Heyman's R...
 - Martinique, South Islan...
 - St. Lucia, N Soufriere B...
 - Tobago, Angel's Reef [...]
 - Tobago, Buccoo MP [B...
 - Venezuela, Los Roque...
 - Northern Caribbean
 - Bahamas, N Norman's ...
 - Bahamas, N Norman's ...
 - Dominican Republic, C...
 - Dominican Republic, P...
 - Dominican Republic, D...

Map Satellite

United States

Mexico

Caribbean Sea

Gulf of Mexico

Google

Map data ©2016 Google, INEGI | 500 km | Terms of Use

User Guide Release Notes Plots

Welcome to the CHAMP Portal web site!

The Coral Health and Monitoring Program (CHAMP) Portal is a query tool for accessing oceanographic and meteorological data from the CHAMP database. This database defines many "stations," or latitude-longitude pairs, which may be physical observation platforms of some kind (CREWS pylons, SEAKEYS light towers, CCCC buoys, or other) or "virtual" stations at points of interest for which remotely-sensed parameters are collected and stored.

Quick Start

The key steps for loading data into the CHAMP Portal are (1) selecting one or more "sensors" using the hierarchical list of stations and sensors on the left and then (2) selecting a date range of interest by right-clicking on any one of those selected sensors. For Mac users "right-clicking" may mean control-clicking or possibly two-fingered clicking on a trackpad. Please see below for more detailed descriptions of these steps.

Introducing the Parts of the Site

The site is divided vertically into two sections. The upper section is titled "NOAA/CHAMP Coral Reef Stations" and provides tools for selecting stations/sensors and dates/times of interest (left third), a map to indicate station locations (central third), and an informational area (right third) which contains tabs for Release Notes and this User Guide as well as a tab for drawing Plots of the queried data. The lower section is titled "Data" and contains a spreadsheet-like "grid" of queried data, along with controls for sorting and downloading these data. Both the Plots tab and the Data grid are empty until data have been queried and loaded into the portal.

Symbols Used in the Portal

Symbols	Meaning
	includes data from the last 24hrs
	does not include data from the last 24hrs
	Includes data from <i>in situ</i> sensors
	does not include data from <i>in situ</i> sensors

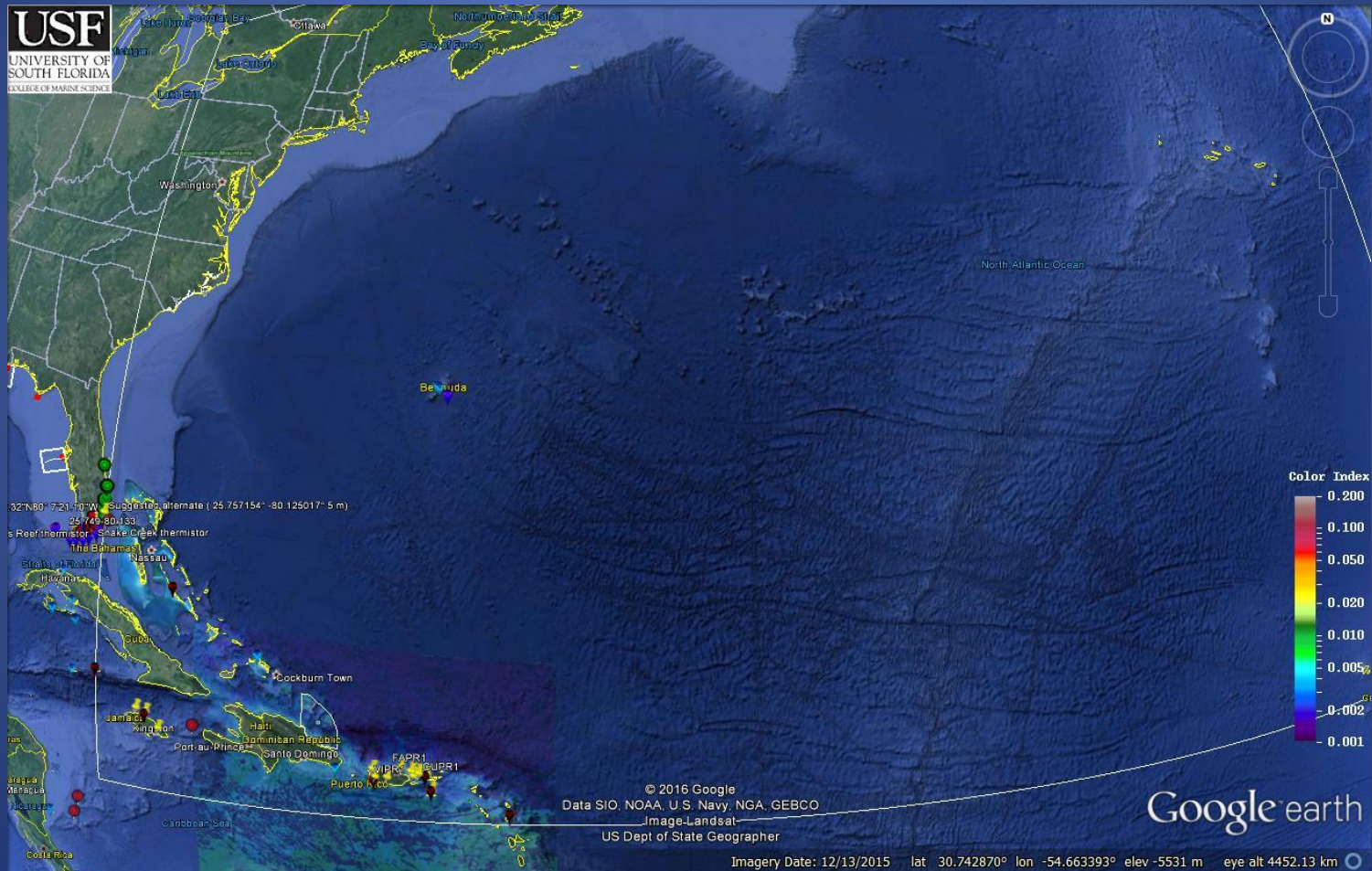
Data Download Data (CSV)

CHAMP Network

The screenshot displays the NOAA/CHAMP Coral Reef Stations web portal. The browser address bar shows www.coral.noaa.gov/champportal/. The page features a map of the Florida Keys with various sensor locations marked by colored pins. A pop-up window for Molasses Reef (MLRF1) provides details: "Molasses Reef [MLRF1] data from 1992-07-27 to 2016-03-21 lat, lon: 25.012, -80.376". The map includes a legend for "Stations/Sensors" with categories like Atlantic, Bermuda, Australia, Caribbean, Florida, and Florida Keys. The Florida Keys section lists sensors such as Air Temperature, AMODIS Color-Derived, AMODIS SeaDAS, Barometer, OISST Microwave, Salinity, Sea Temperature, Sea Temperature N..., TMODIS Color-Derived, TMODIS SeaDAS, Wind Direction, and Wind Gust. On the right, a line graph titled "MLRF1: Sea Temperature NDBC, 1-min" shows the sea temperature in degrees Celsius from 04/01 00:00 to 01/01 00:00. The graph shows a seasonal cycle with a peak around 30°C in the summer and a minimum around 22°C in the winter. Below the graph, a data table shows the first six rows of the dataset:

date/time	MLRF1_SEATEMP_NDBC_01M_DEGC (°C)
1 2015-03-22 00:00:00	25.700
2 2015-03-22 01:00:00	25.700
3 2015-03-22 02:00:00	25.600
4 2015-03-22 03:00:00	26.100
5 2015-03-22 04:00:00	26.100
6 2015-03-22 05:00:00	26.200

Scales of Stress



Scales of Stress



Scales of Stress



Reef and Fisheries Stressors

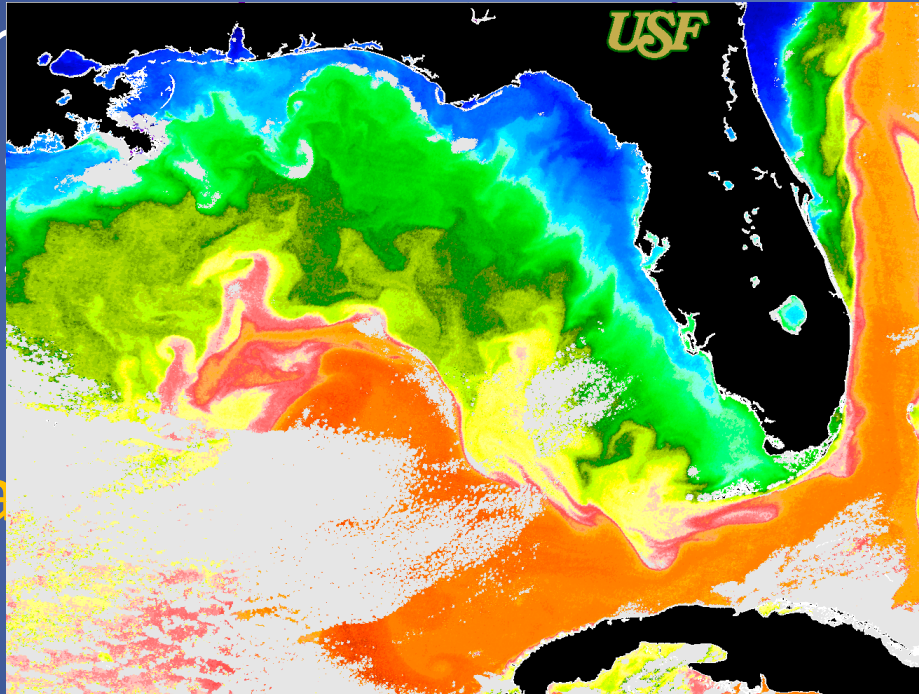
- CHAMP assesses stress on individual reefs and key coastal fisheries sites...
- We improve accuracy with ocean physics
- We automate alerts with rule-based inference
- We alert managers of potential stress daily

Reef-scale Sea Temperature

- Reef thermal environments are monitored from satellite data and coupled numerical models at scales of **kilometers**.
- **Circulation** and **mixing** alter thermal balances.
- Physical ocean processes impact the thermal environment of *individual coral communities*.

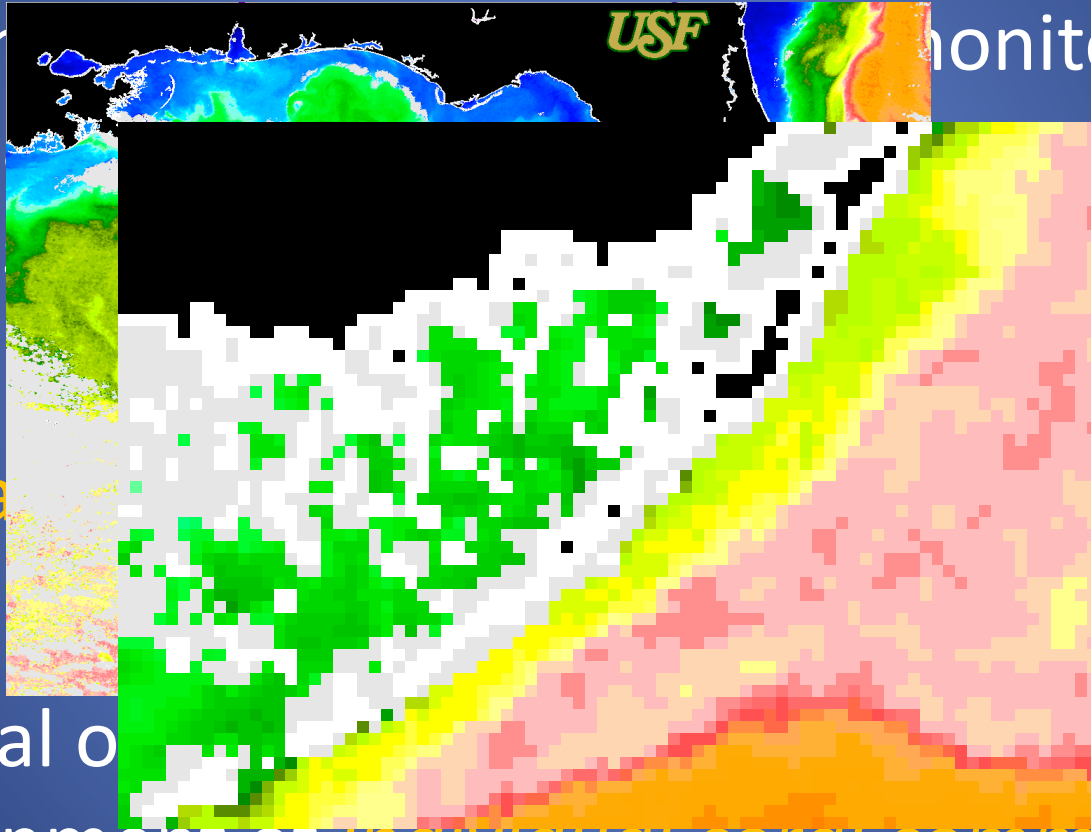
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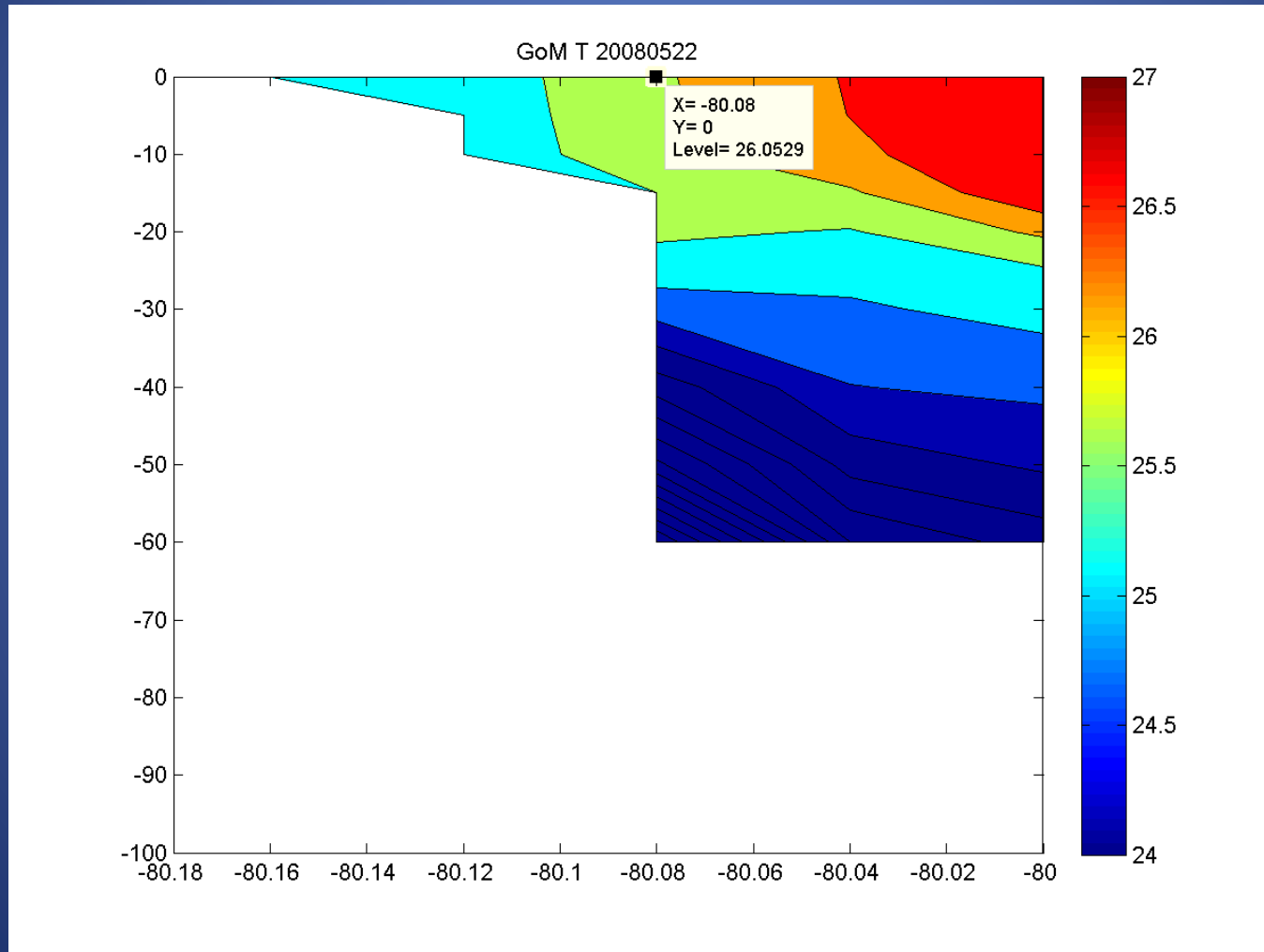


Reef-scale Sea Temperature

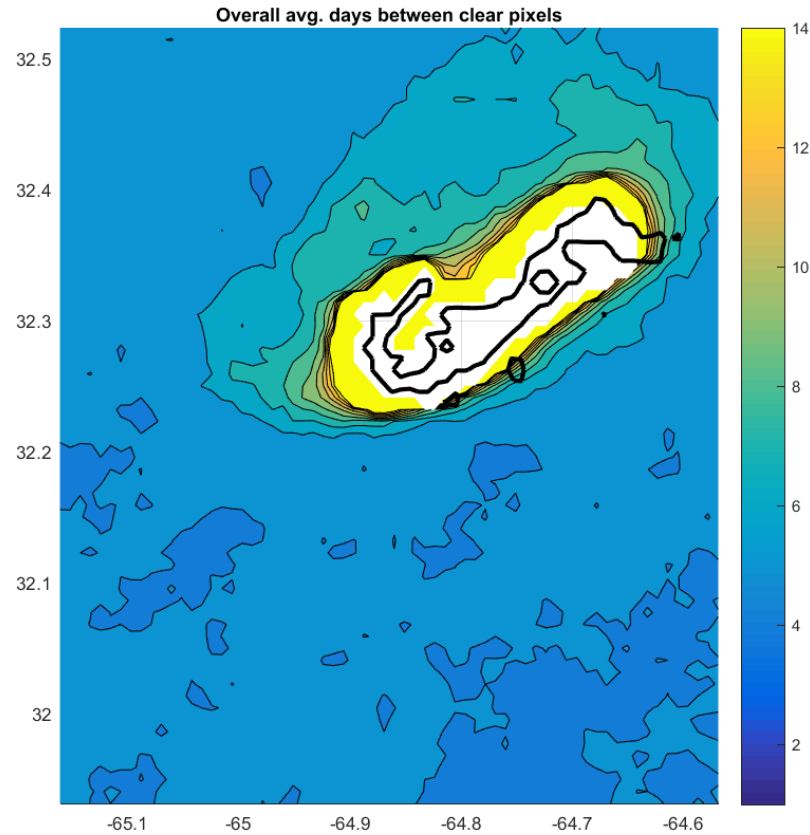
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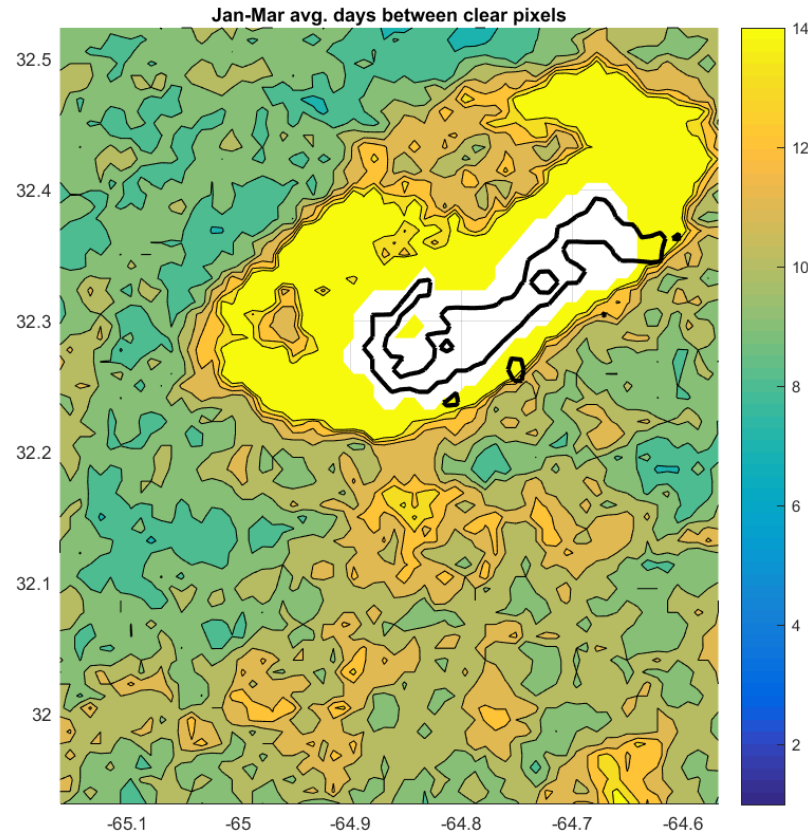
Cross-shore temperature profile – Gulf of Mexico HYCOM (May 2008)

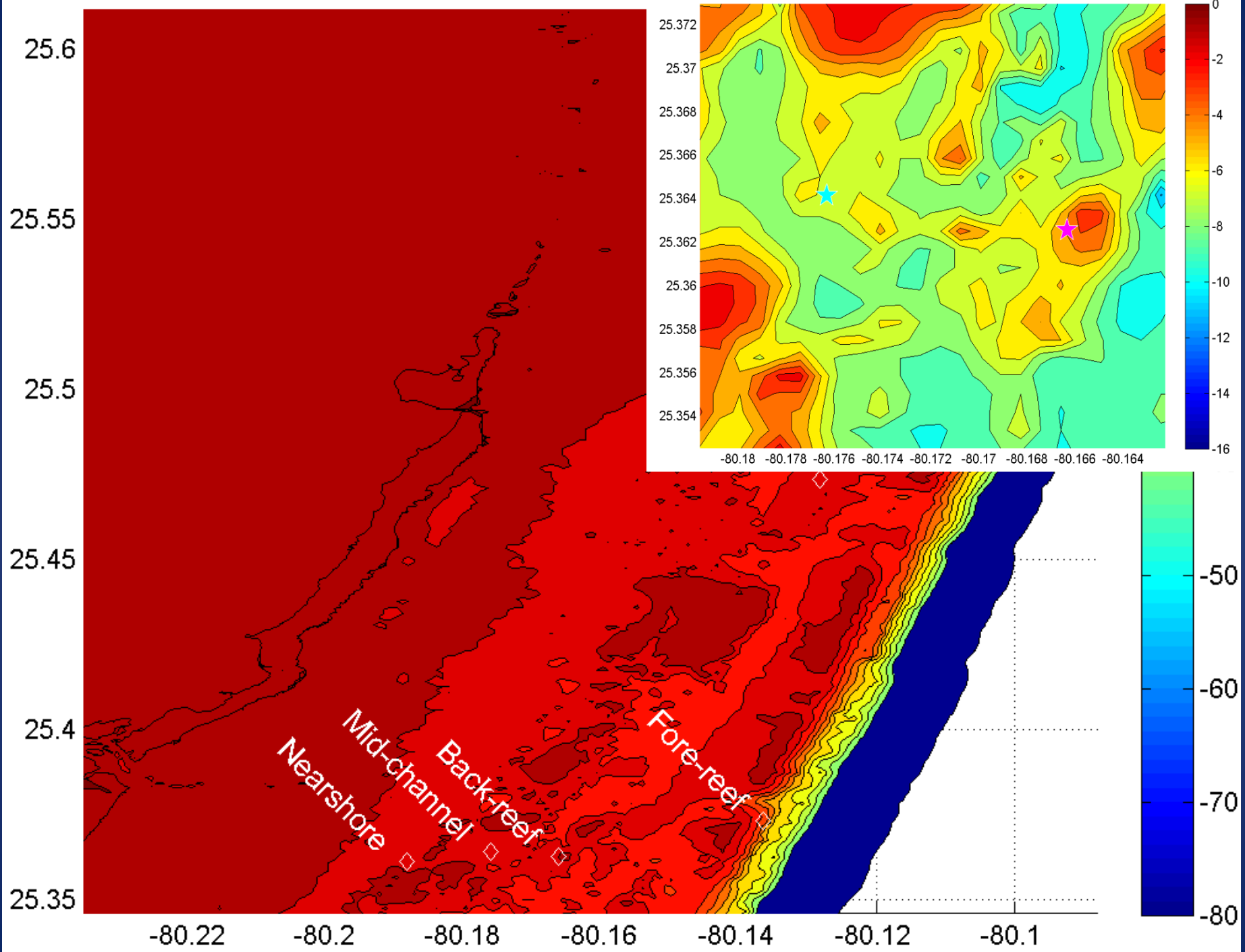


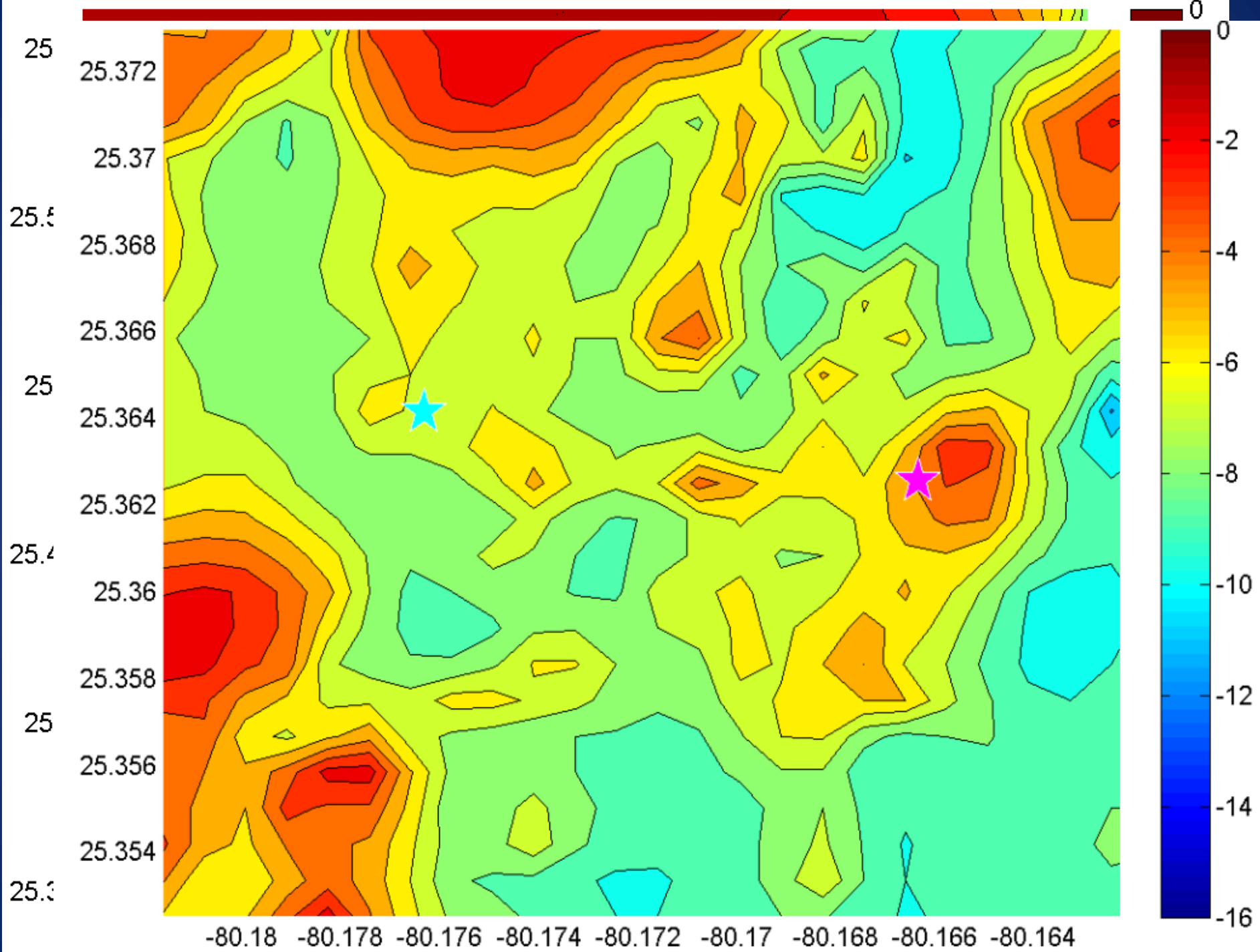
High resolution can still fail...

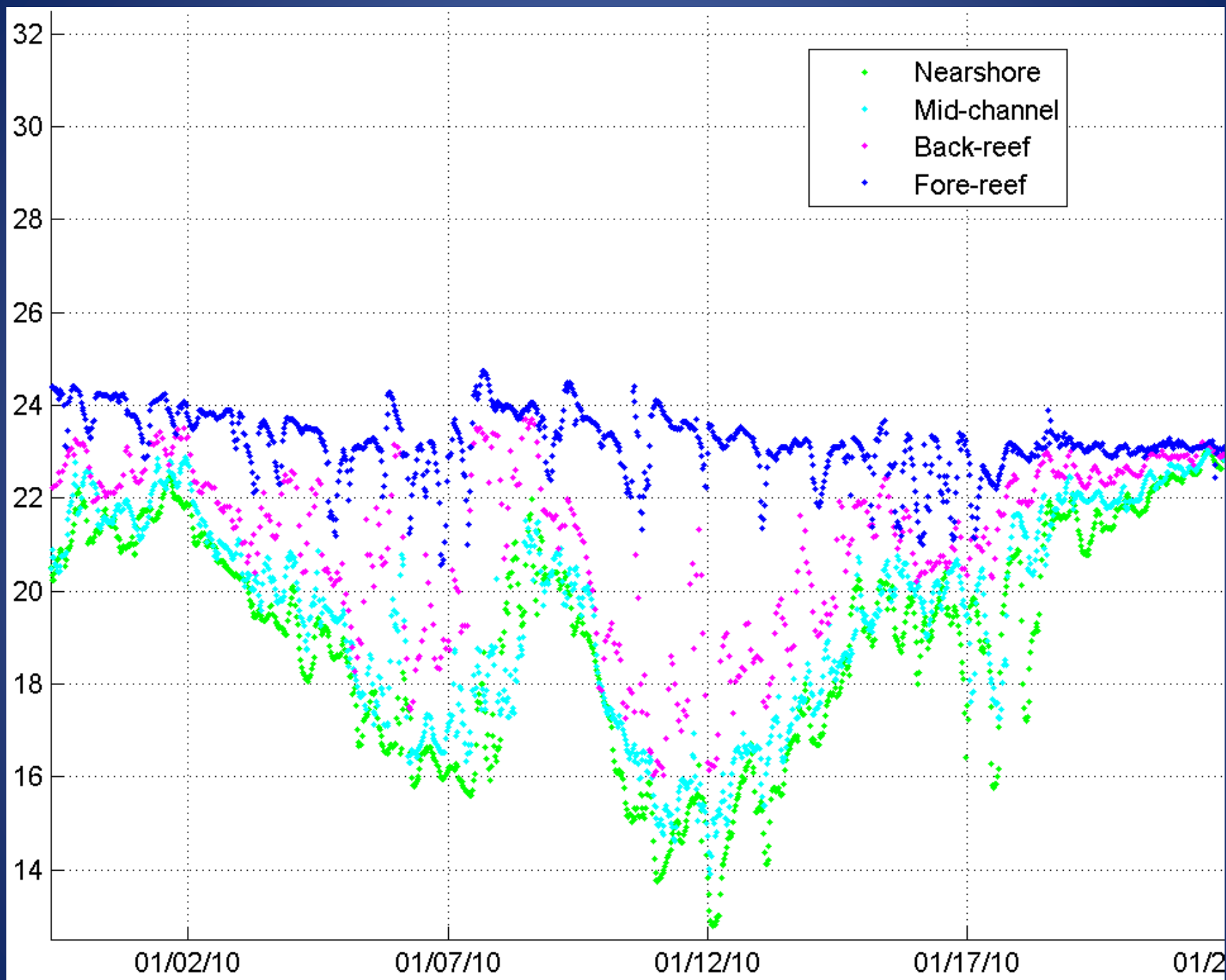


High resolution can still fail...









The Gory Details

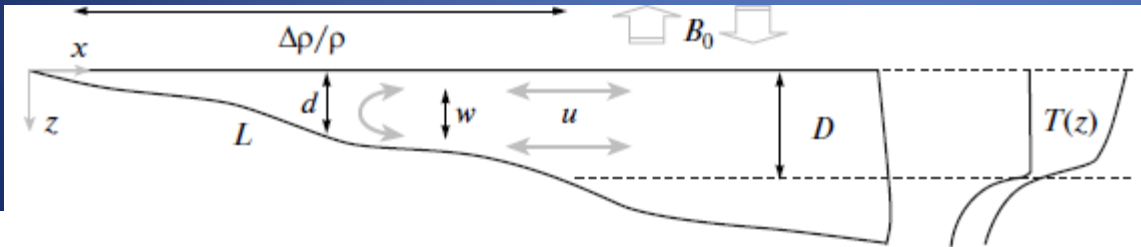
$$\partial_t T = -[\vec{u}_{km} \cdot \nabla_h + K_{H\theta}^{km} \nabla_h^2 + \vec{u}_{qe} \cdot \nabla_h + K_{H\theta}^{SGS} \nabla_h^2] T_{km} - \vec{u}_{hc} \cdot \nabla_h T_{hc}(Q_0, h, \beta) + \frac{Q_0}{\rho C_p h}$$

Advection-Diffusion of Heat: $u \cdot \nabla T + K \nabla^2 T$

Source term: $Q_0 = \gamma Q_{\text{shortwave}} + Q_{\text{longwave}} + Q_{\text{sensible}} + Q_{\text{latent}} + Q_{\text{rain}} + Q_{\text{benthic}}$

Absorption factor $\gamma = 1 - A_b \cdot \tau_{\text{PAR}} \cdot (1 - \tau_{\text{PAR}})$ depends on bottom reflectivity A_b , and attenuation rate for visible and NUV light with depth, τ_{PAR} .
Benthic flux depends on τ_{PAR} , substrate composition, and $Q_{\text{shortwave}}$.

Horizontal Convection:



Balance	Unsteady inertia	Stress divergence	Advective inertia
Steady temperature	$V_{US} \sim (u_f^3 T / D)^{1/2}$	$V_{VS} \sim (u_f^{3/2} / q D^2)$	$V_{NS} \sim \beta^{-1/3} u_f$
Unsteady temperature	$V_{UU} \sim (\beta u_f^3 T^2 / D_0^2)$	$V_{VU} \sim (\beta u_f^3 T / q D)$	$V_{NU} \sim (u_f^3 T / D)^{1/2}$

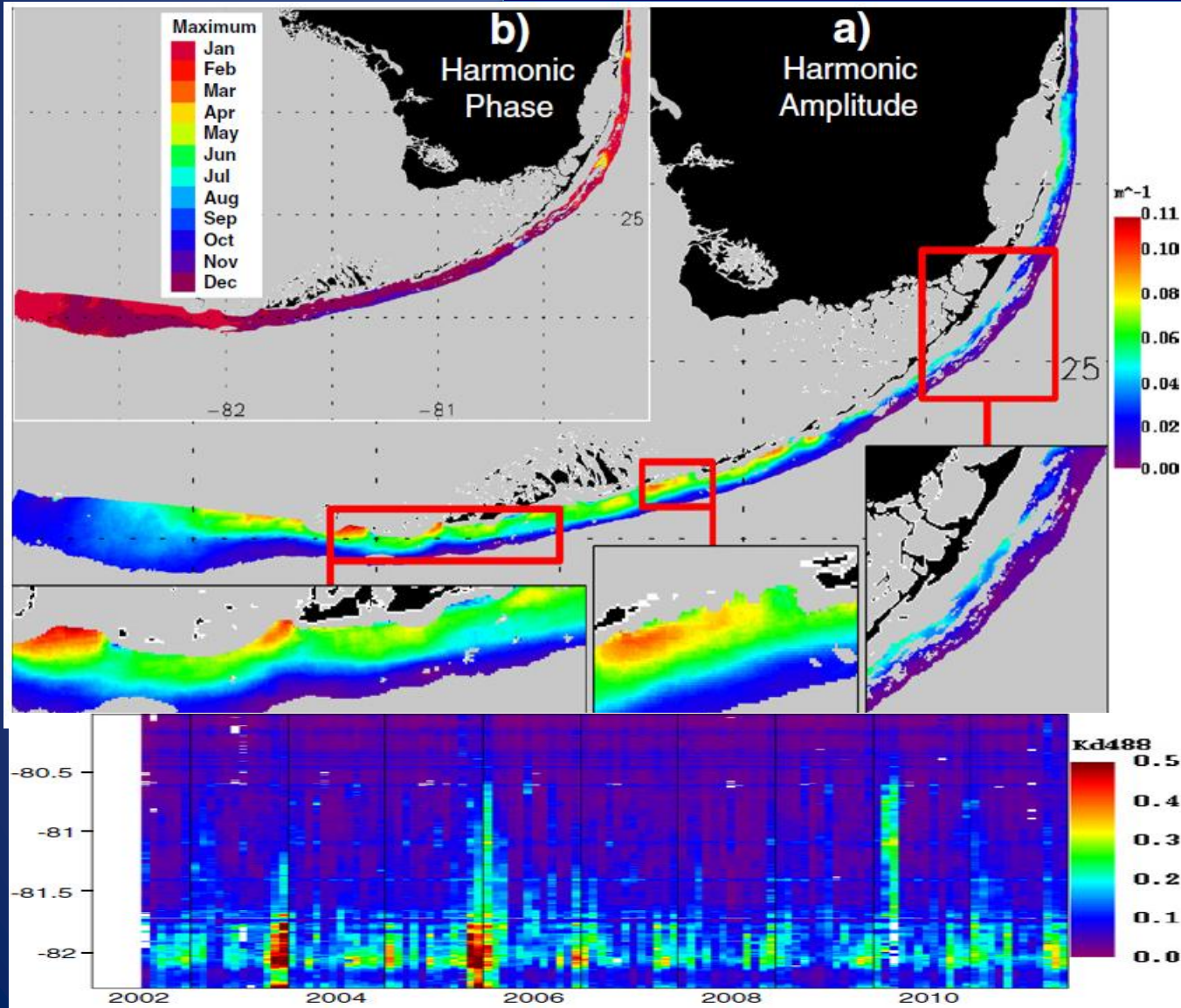
Beyond weather & km-scale oceanography, *thermally-driven mixing* also plays a major role:

- enhanced *lateral heat diffusion* (Hearn 2011)

- horizontal convection* (Monismith et al. 2006)

Absorbed sunlight

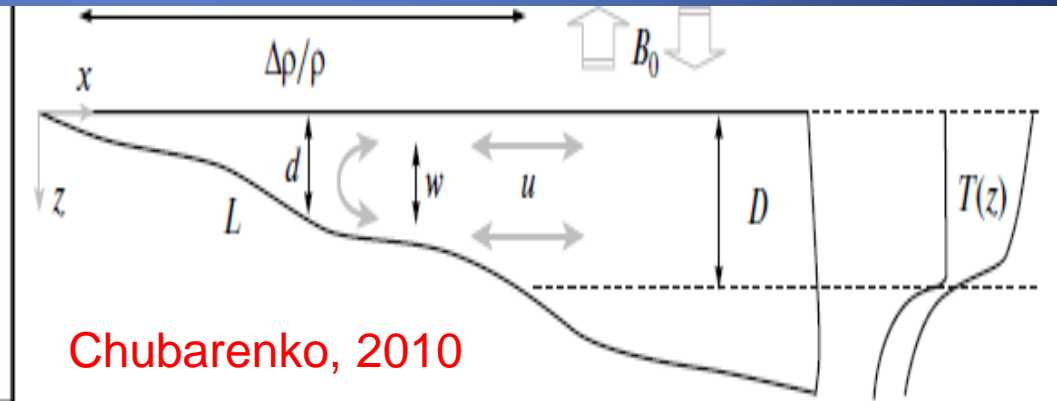
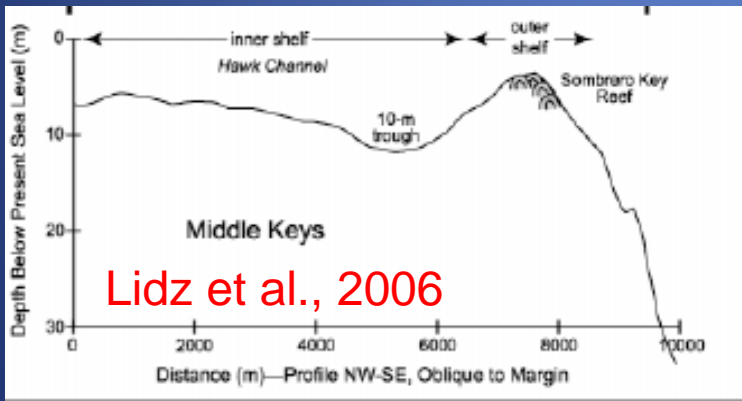
Barnes *et al.* (2013),
their Figures 8b and 9



Shallow sites:
insolation is
absorbed at
different rates
during a year.
Amplitude and
phase of
annual cycle
vary along the
length of the
FRT, and across
multiple years.

Horizontal Convection – *thermal siphon*

- Air-sea flux and km-scale heat advection alone do not model variability well: is there also a smaller-scale oceanographic process at work?

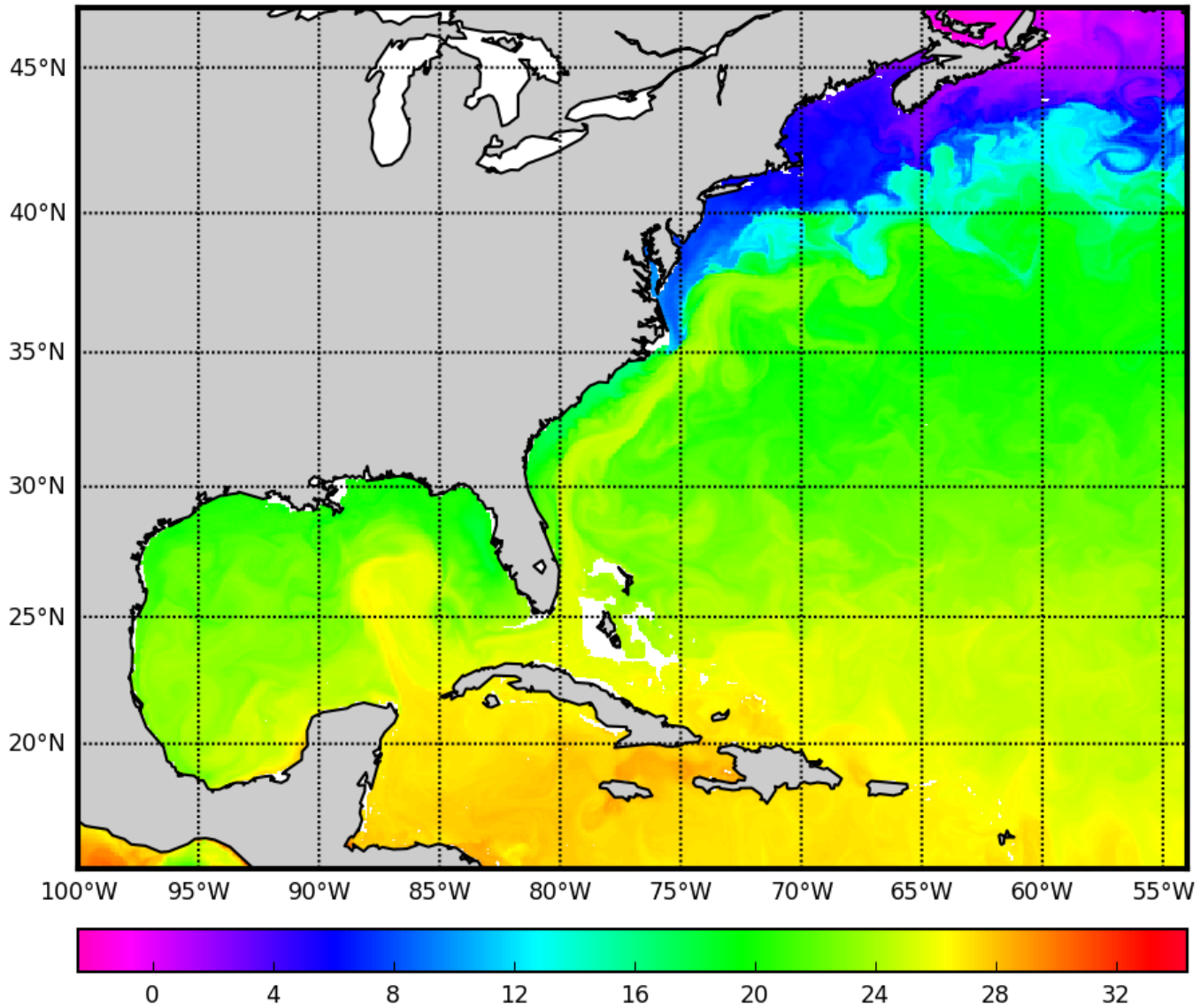


Monismith et al., 2006

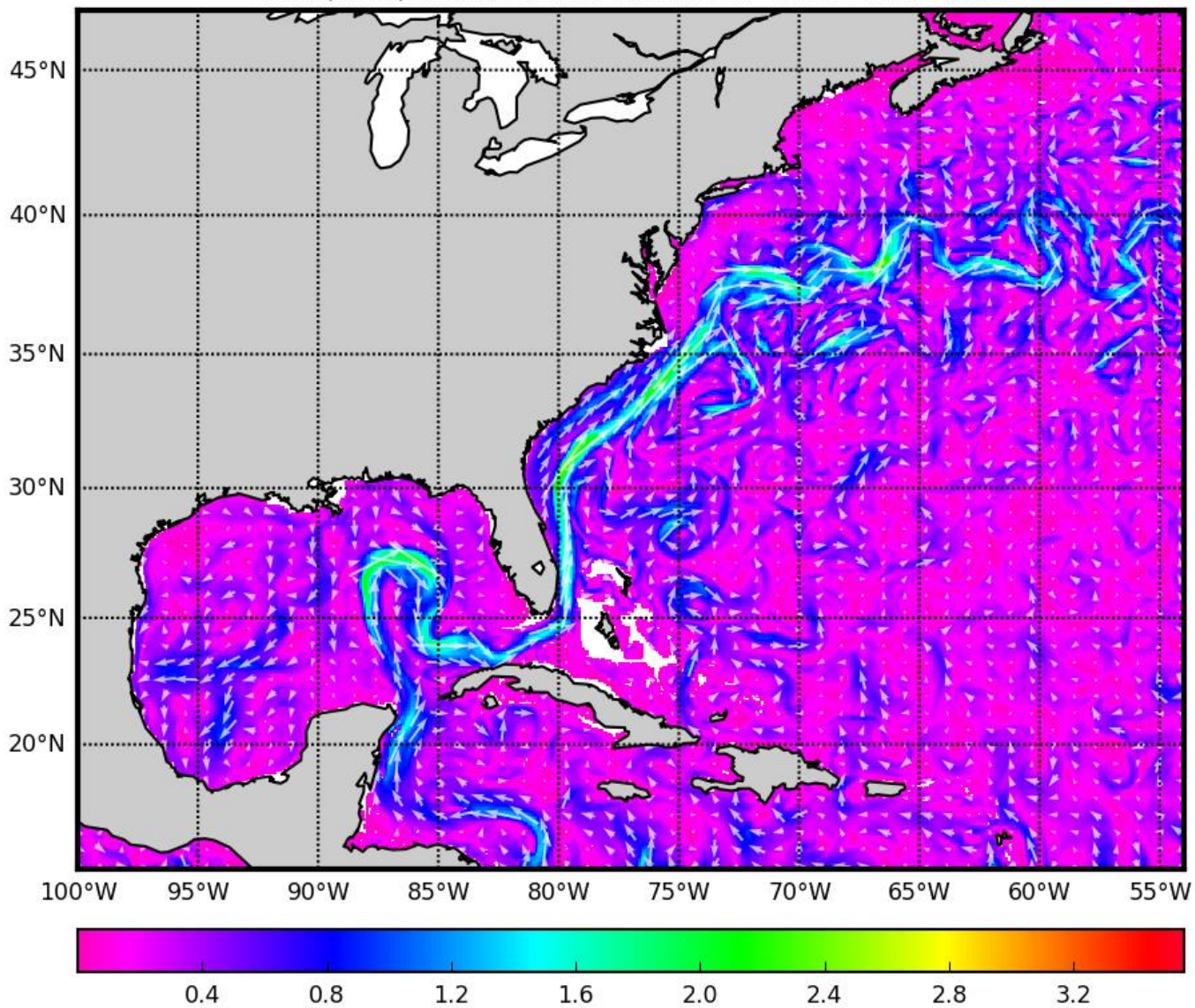
TABLE 1. Possible scalings for ΔV .

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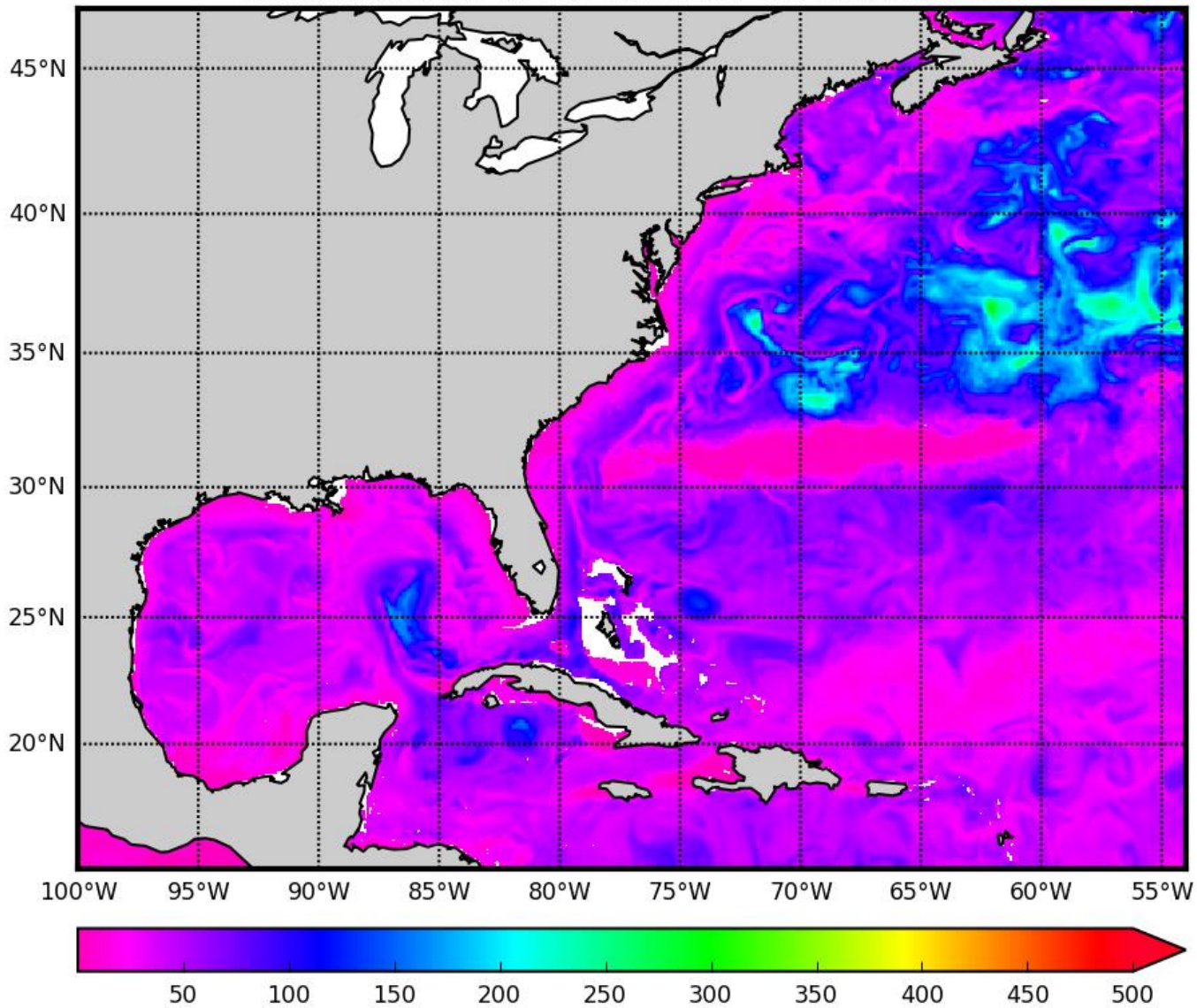
Gulf Stream Region Temperature (deg C) 20160320 f048 Depth: 0 m
NCEP/EMC/MMAB 20-Mar-2016 min: -1.63 max: 31.98



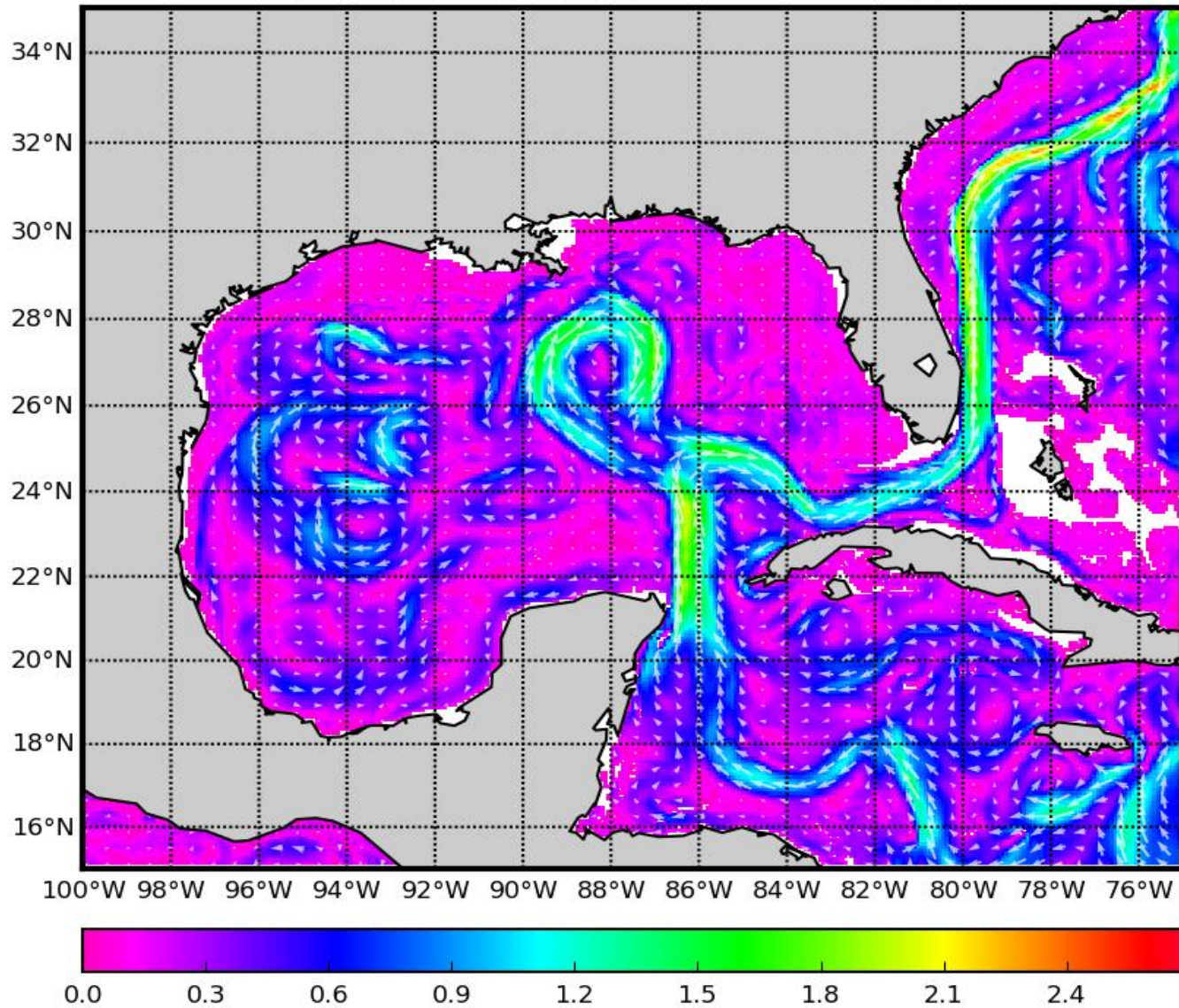
Gulf Stream Region Current (m/s) 20160320 f192 Depth: 0 m
NCEP/EMC/MMAB 20-Mar-2016 min: 0.00 max: 2.59



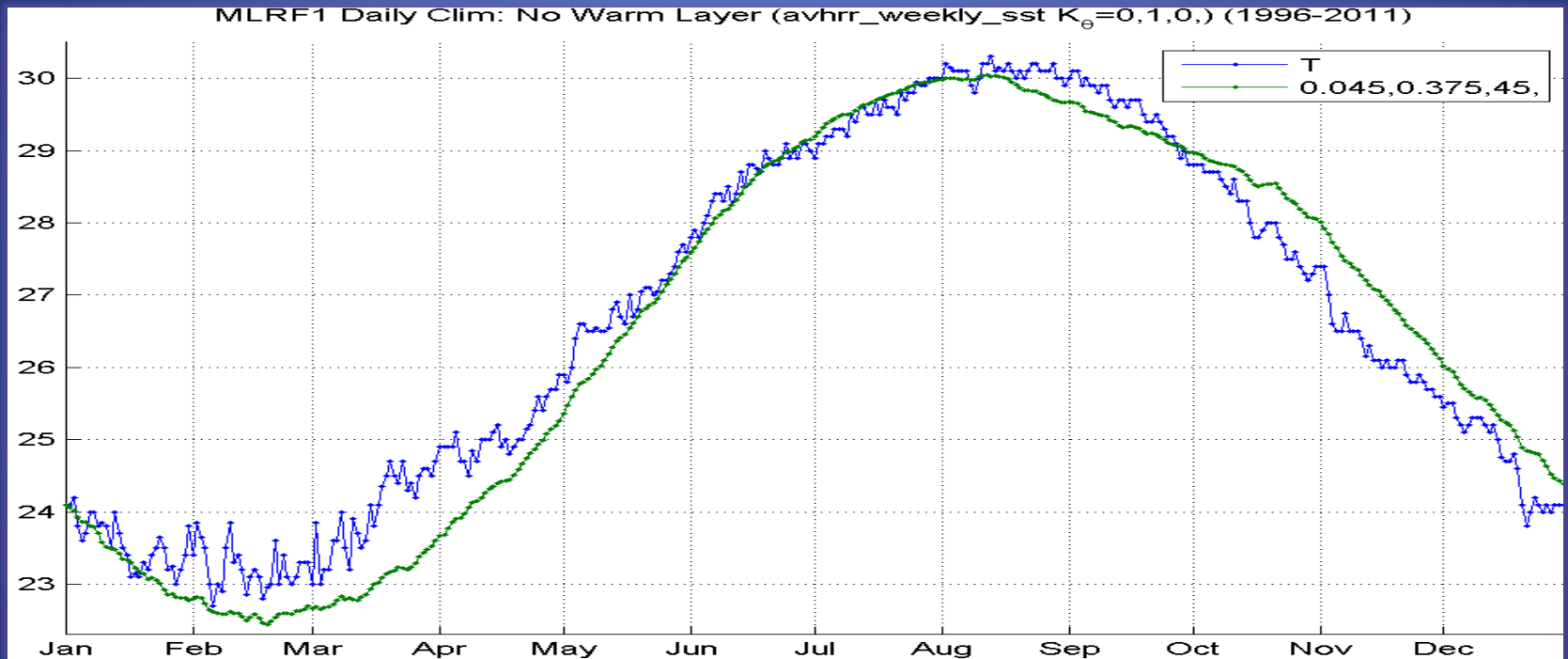
Gulf Stream Region Mixed Layer Thickness (m) 20160320 f096 Depth: 0 m
NCEP/EMC/MMAB 20-Mar-2016 min: 0.71 max: 307.75



Gulf of Mexico Current (m/s) 20150823 n024 Depth: 0 m
NCEP/EMC/MMAB 23-Aug-2015 min: 0.00 max: 2.36



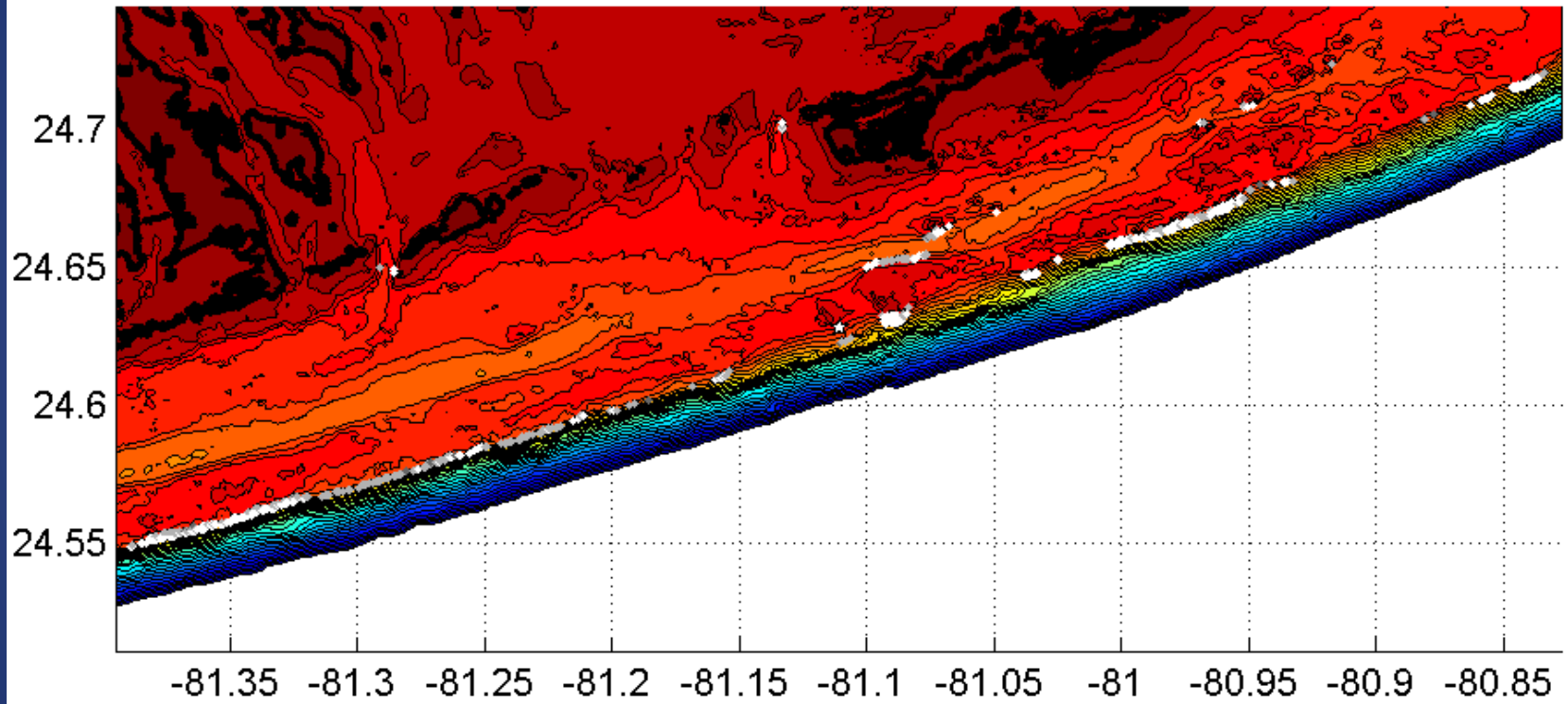
Horizontal convection reproduces seasonal cycles on the reef crest



We train our heat budget (**green**) at reef sites with long records of *in situ* sea temperature (**blue**): Global reanalysis (ECMWF ERA-Interim, Dee et al. 2011) provides all meteorology and ocean wave data.

Sloping seafloor is widespread

Sites with (very, somewhat, slight) reduced exposure to thermal stress (278 m)



Summary

- To model the physical coastal environment, we must account for local *seafloor topography*.
- By parameterizing *reef-scale processes*, we can assess thermal and light variability more realistically from lower-resolution, surface-based data.
- COVERAGE can be a valuable source of larger-scale data for CHAMP in monitoring the Sargasso Sea...
- And CHAMP may be a useful tool for COVERAGE!

An underwater photograph showing two large, rounded, yellowish-brown coral colonies with a bumpy, textured surface. They are situated on a sandy seabed with other smaller coral and rocks in the background. The water is clear and blue.

THANK YOU!

Photo © J. E. N. Veron, Corals of the World, 2000
Large *Porites astreoides* ("mustard hill coral")

<http://www.coral.noaa.gov>