Scales of Stress

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

"Better Living Through Physics"

Sargasso Sea Workshop, Mar 21, 2016

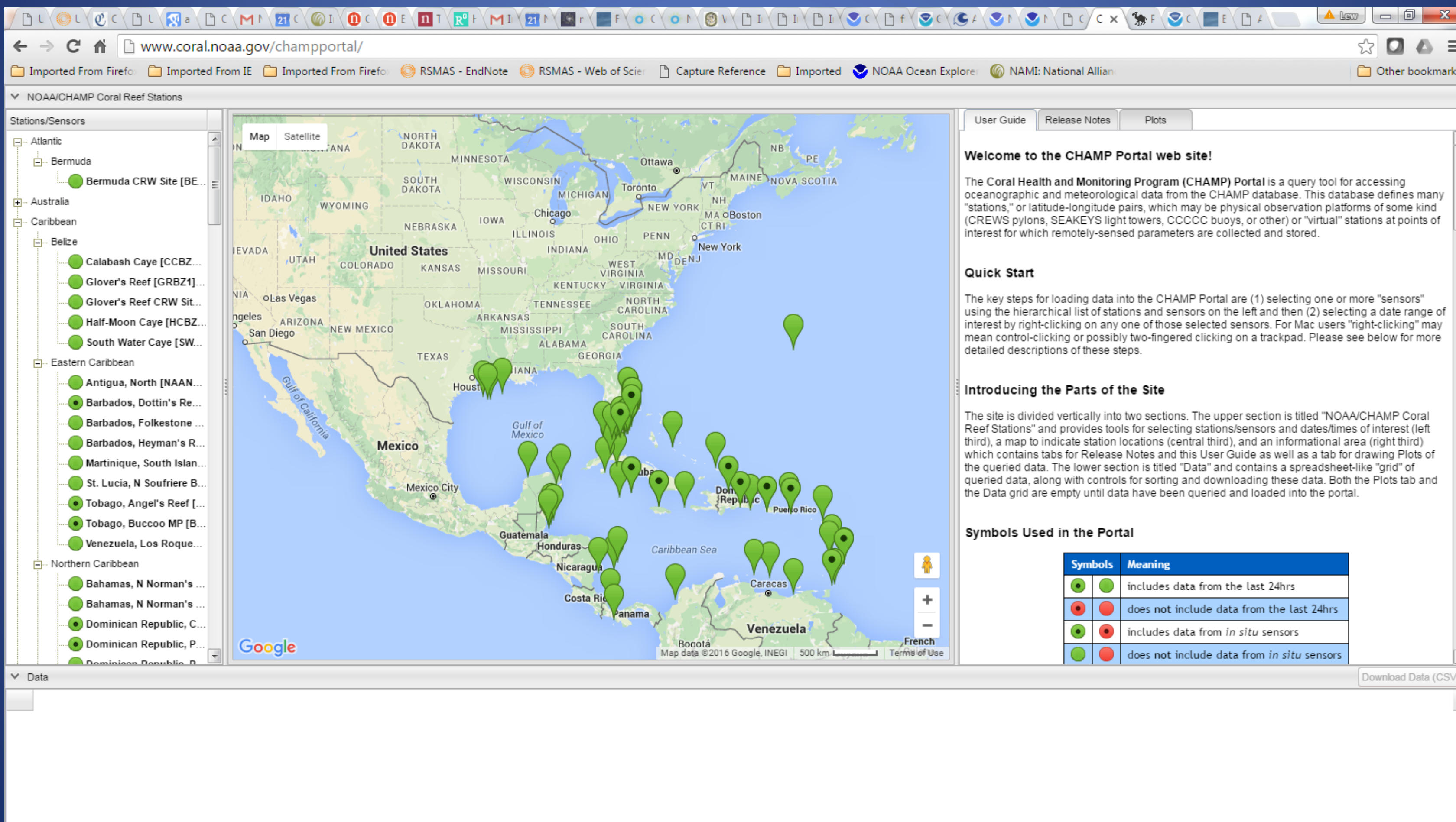
Dr. Lew Gramer, lew.gramer@noaa.gov, CIMAS (UM)
Dr. Jim Hendee, jim.hendee@noaa.gov, NOAA-AOML

Introduction

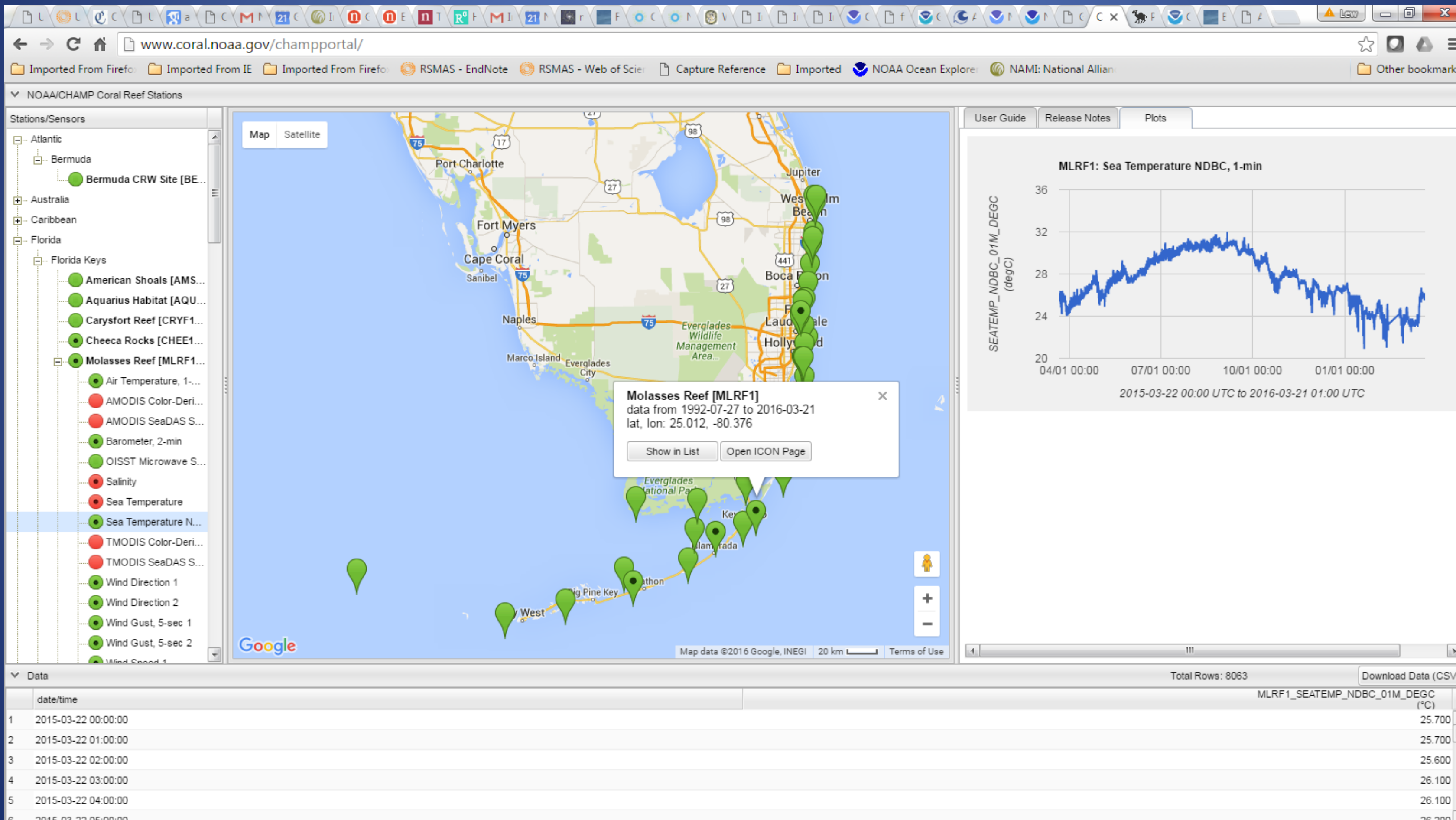
The Coral Health and Monitoring Program (CHAMP) at NOAA AOML in Miami

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

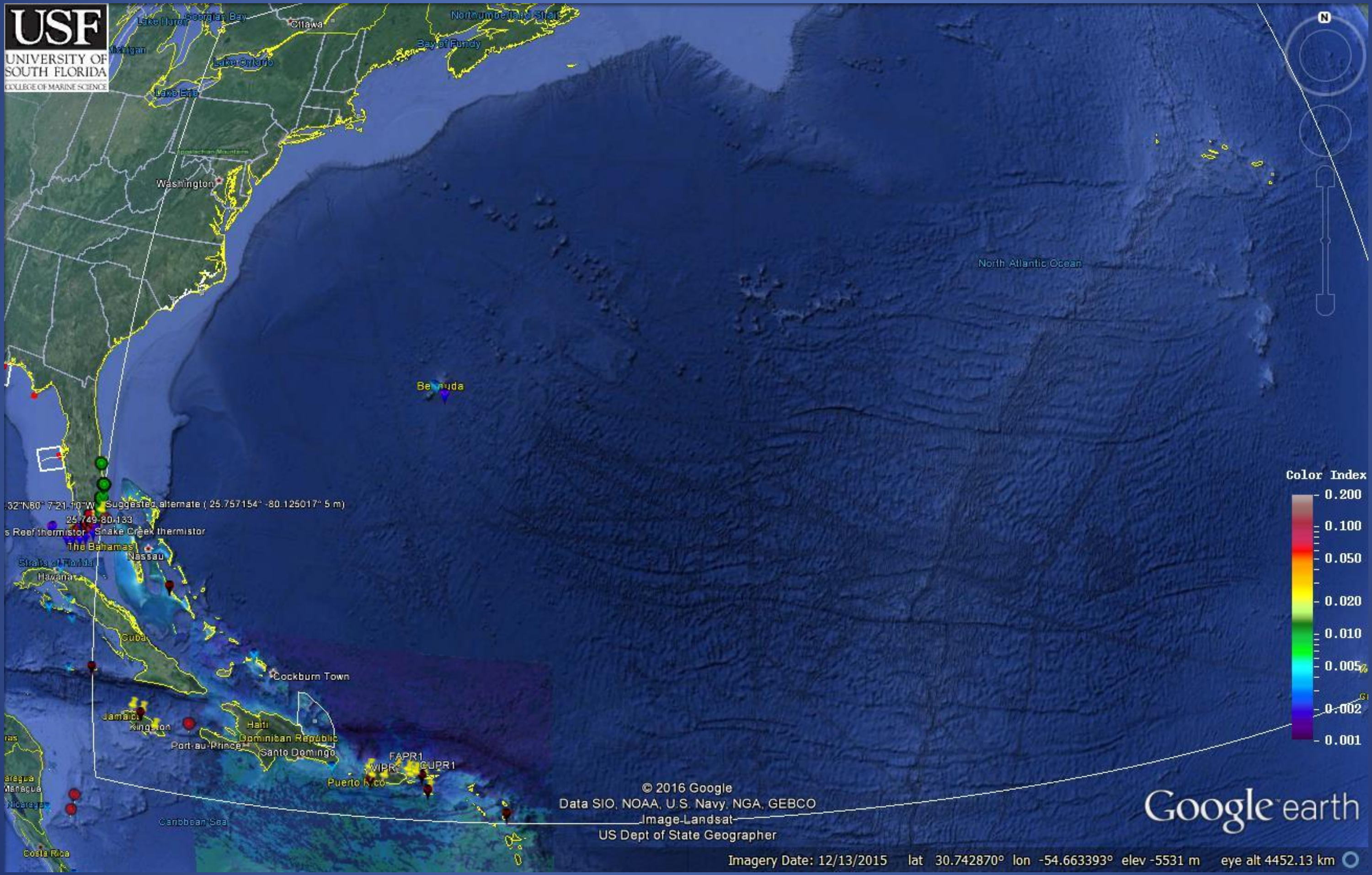
CHAMP Network



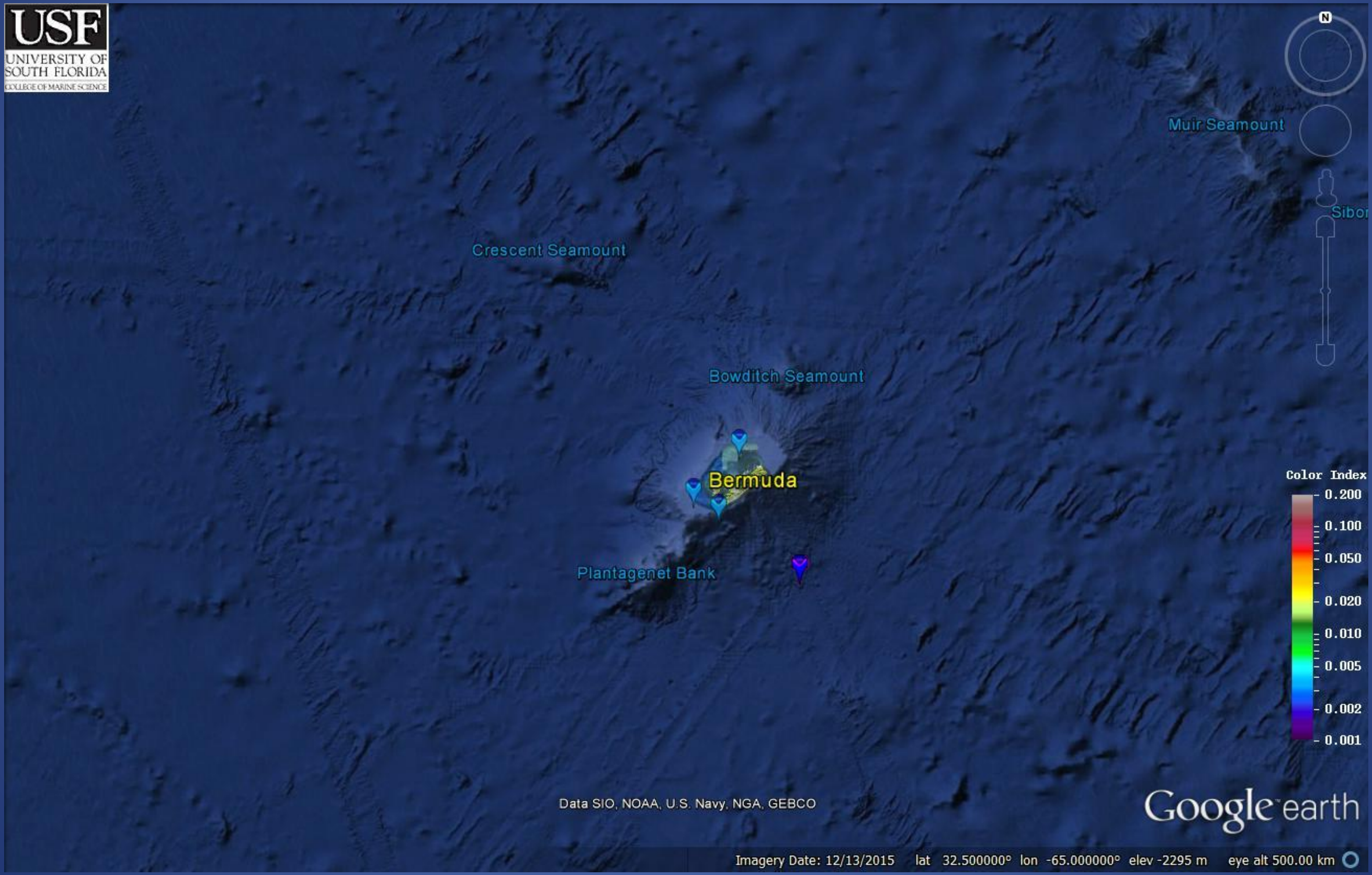
CHAMP Network



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

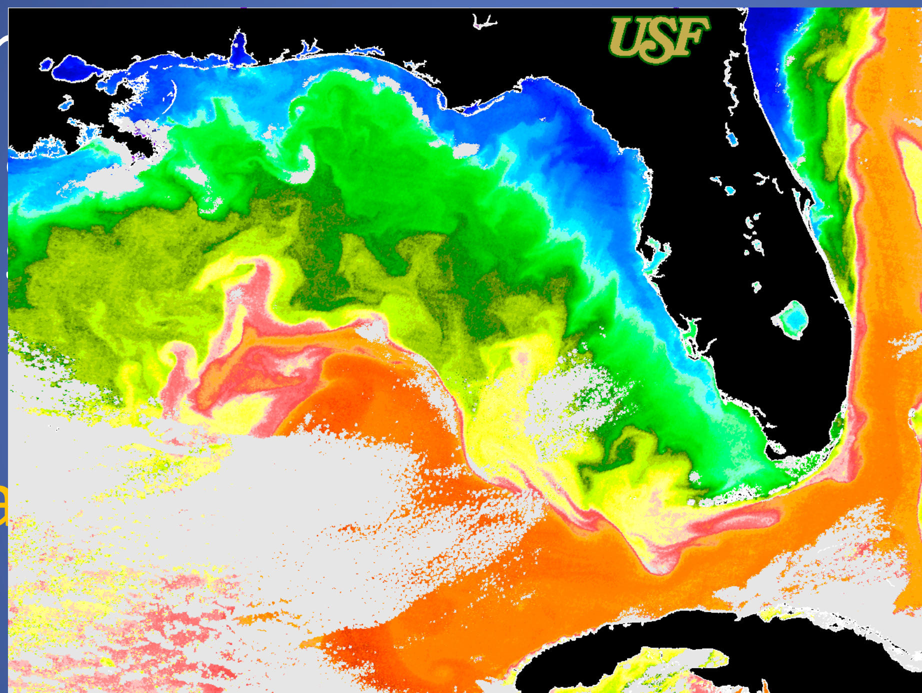
- Reef thermal environments are monitored from satellite data and coupled numerical models at scales of kilometers.

- Circulation and mixing alter thermal balances.

- Physical ocean processes impact the thermal environment of *individual coral communities*.

Reef-scale Sea Temperature

- Reef th monitored from s umerical model

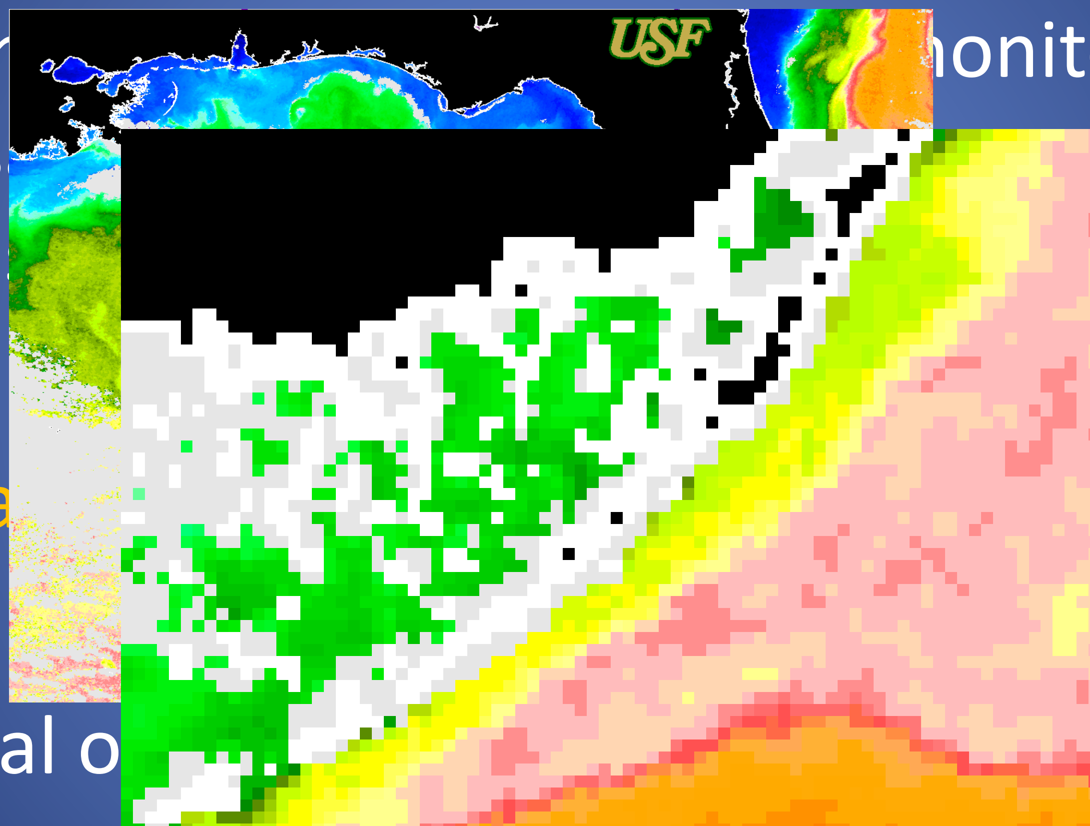


- Circula nal balances.

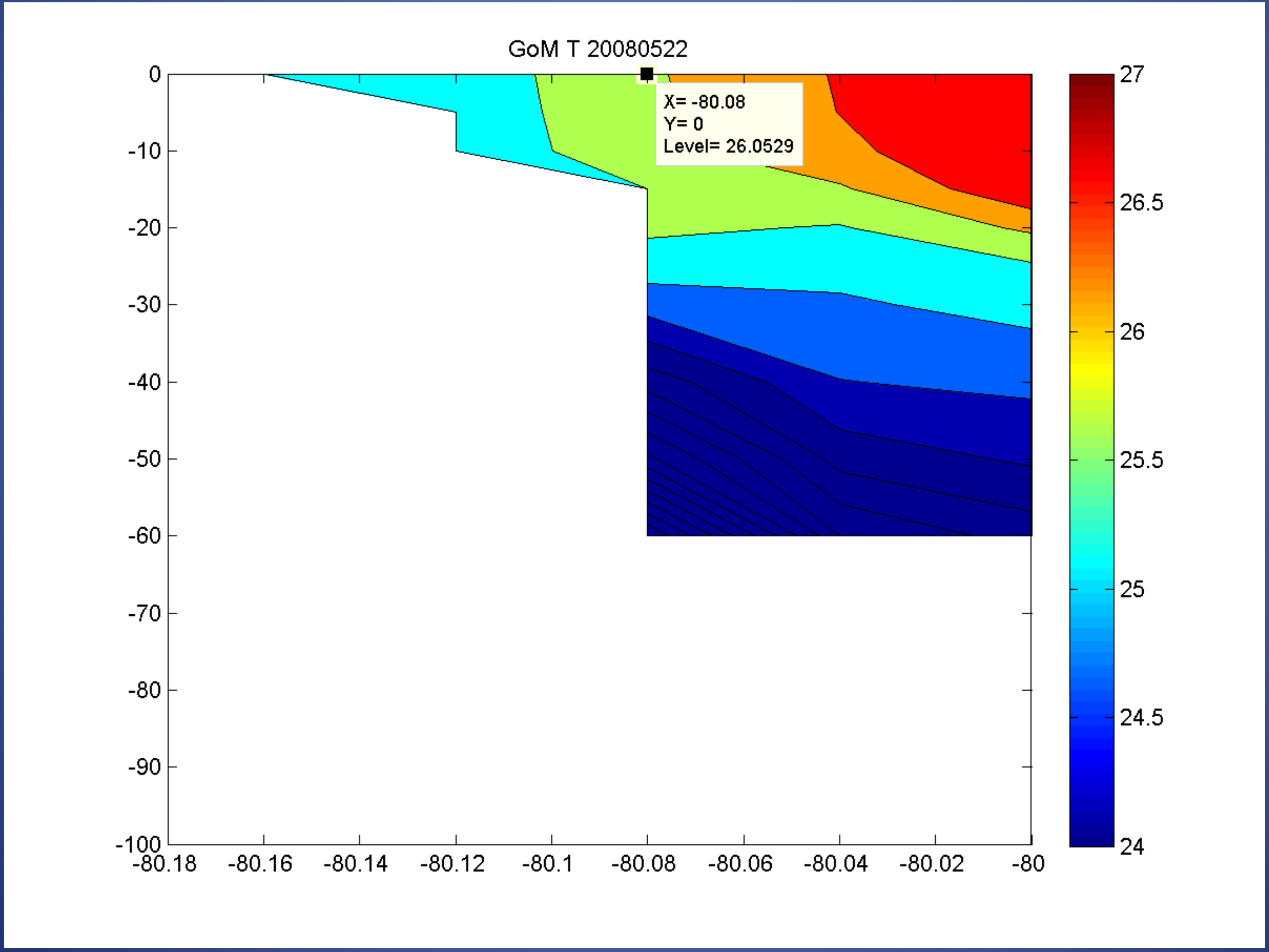
- Physical ocean processes impact the thermal environment of *individual coral communities*.

Reef-scale Sea Temperature

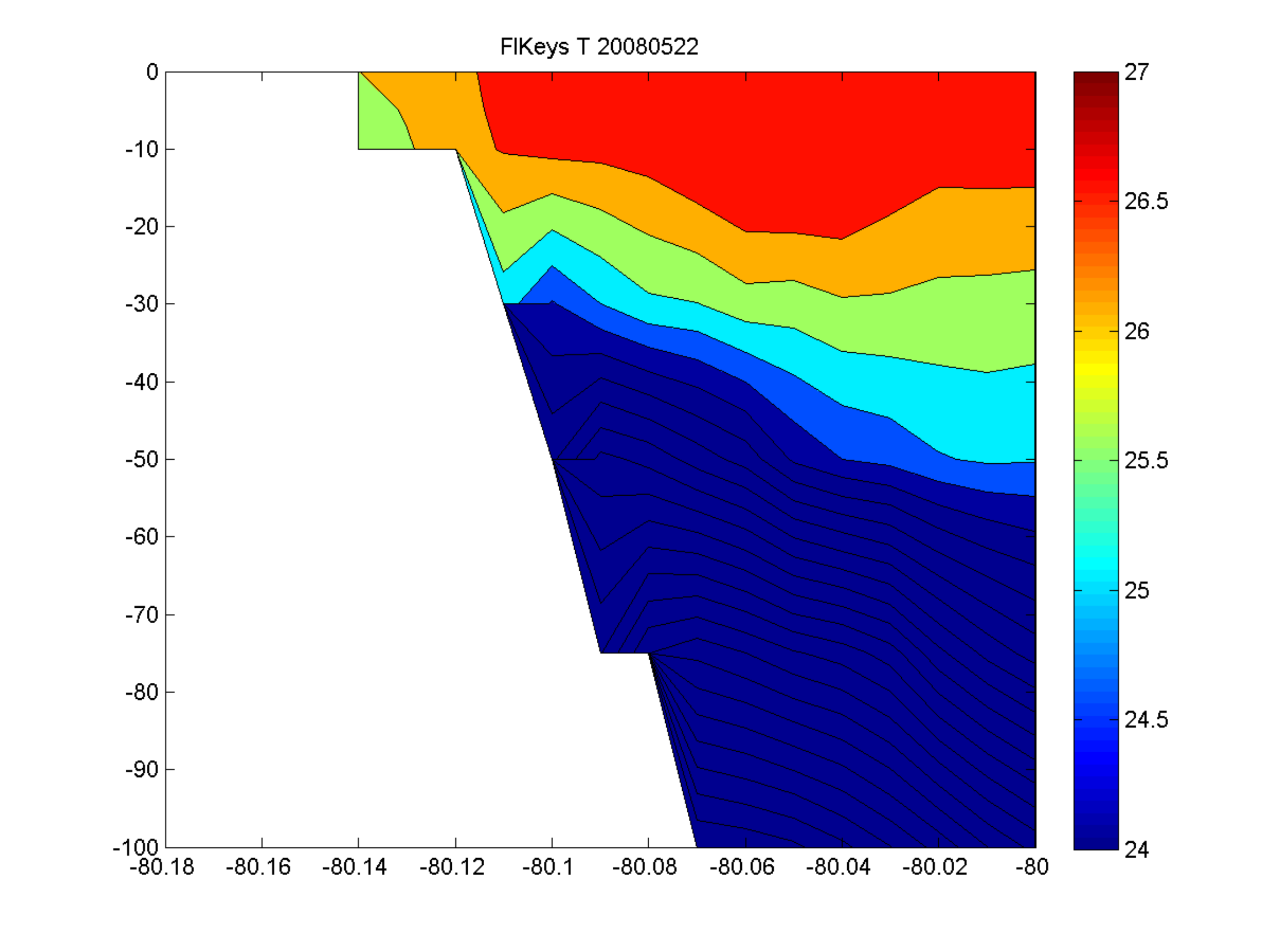
- Reef th… monitored from s… rical model…
- Circula… alances.
- Physical o… hermal environment of *individual coral communities*.



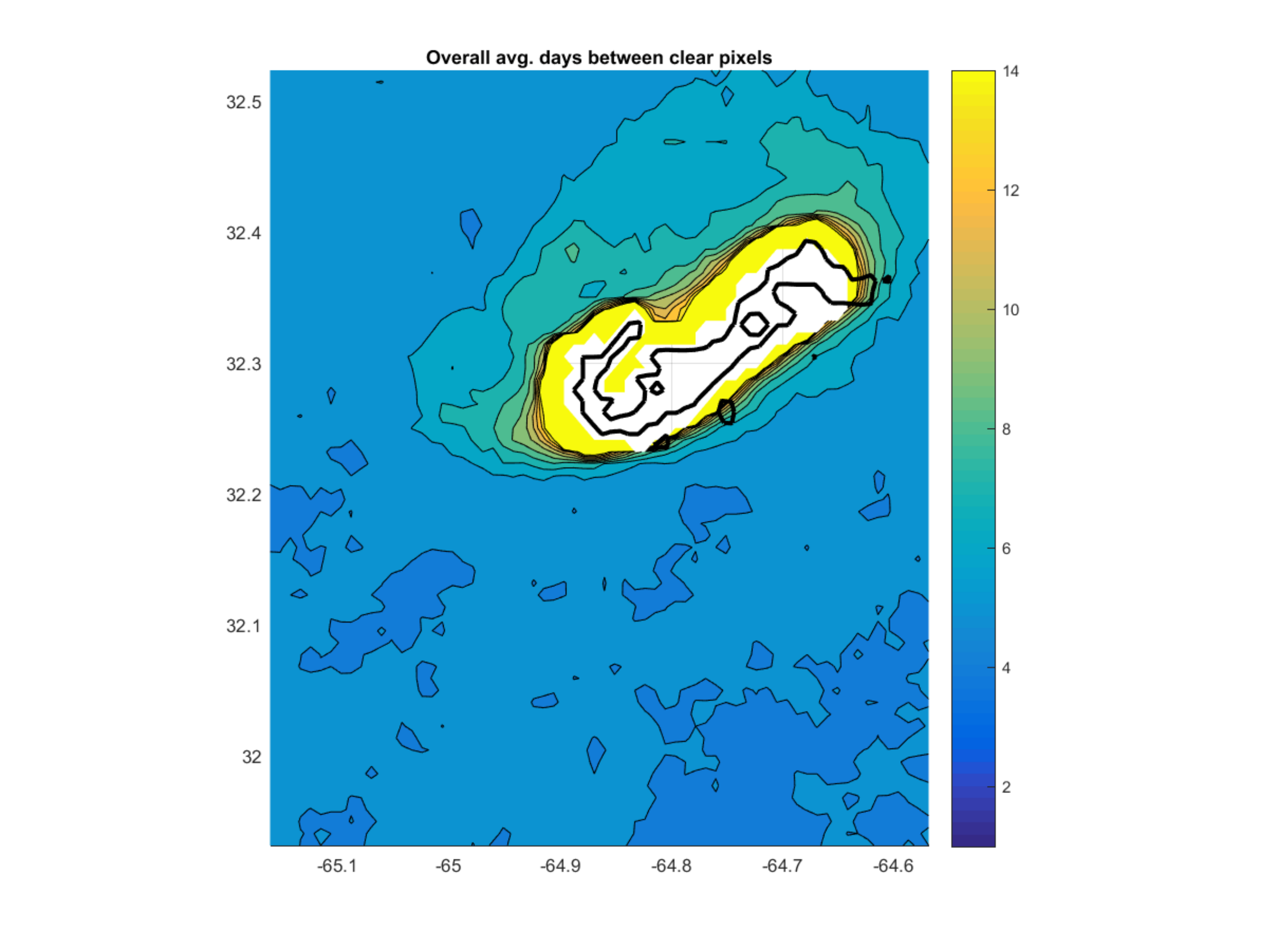
Cross-shore temperature profile – Gulf of Mexico HYCOM (May 2008)



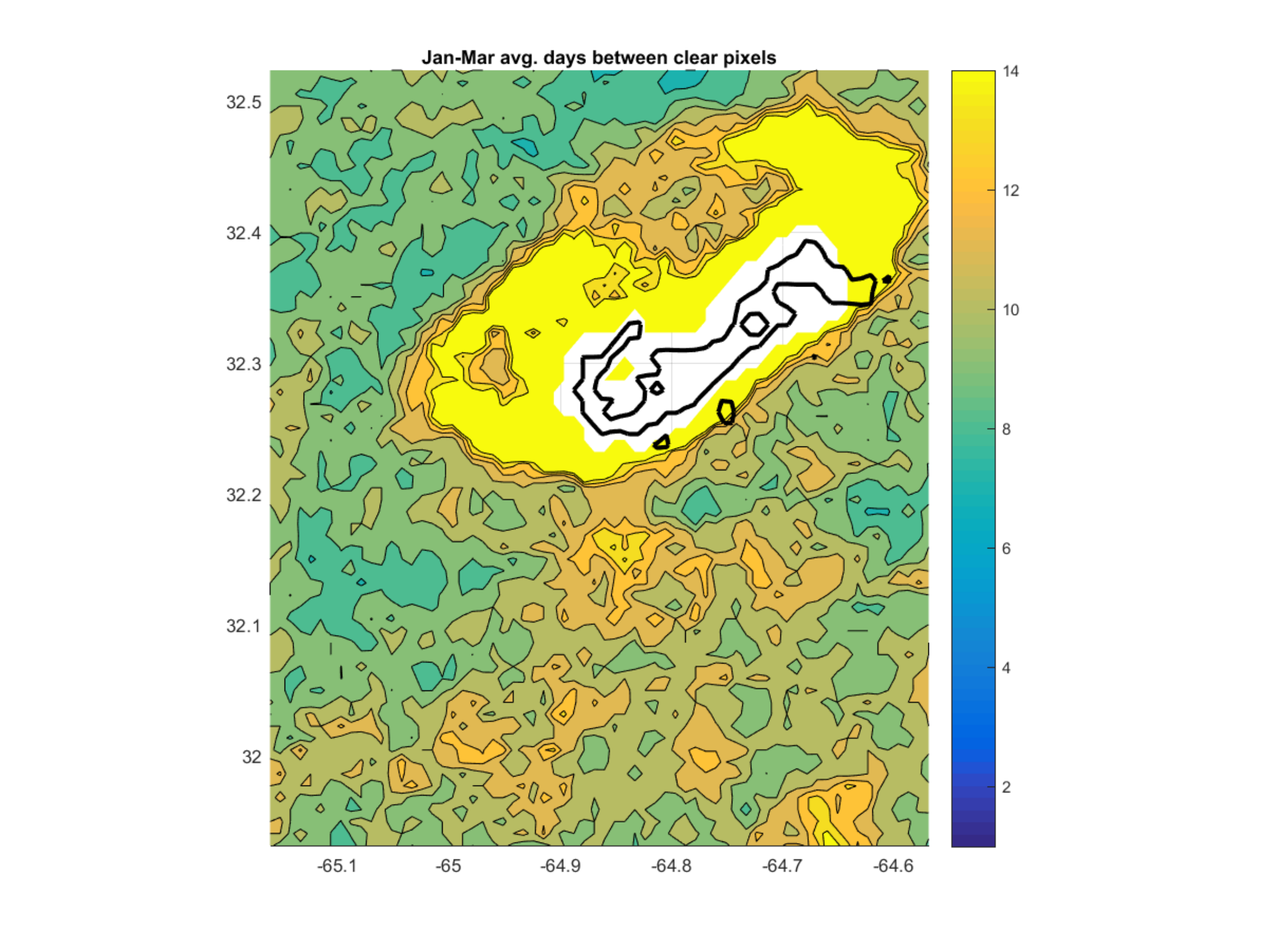
Cross-shore temperature profile – Florida Keys HYCOM (May 2008)

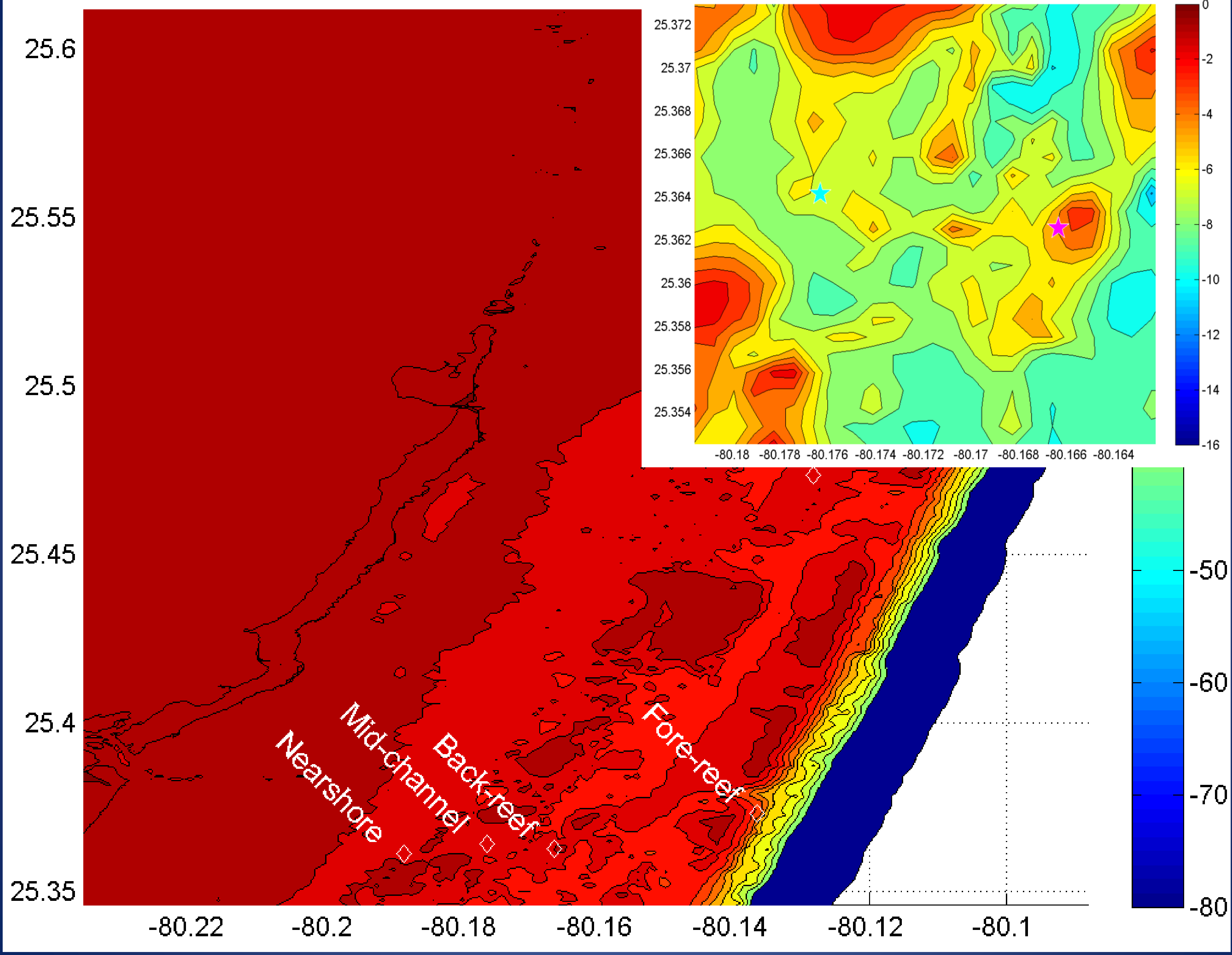


High resolution can still fail…

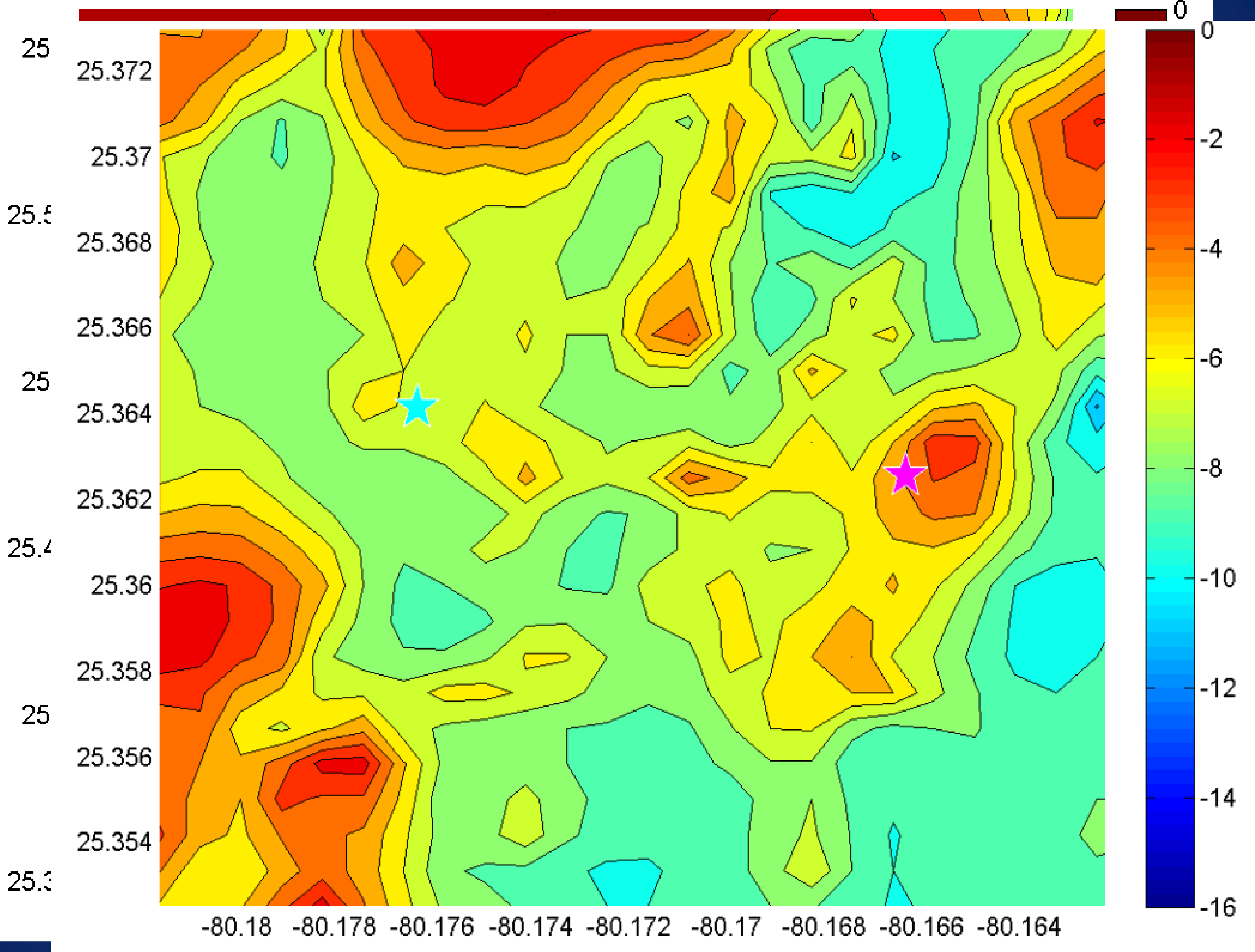


High resolution can still fail…

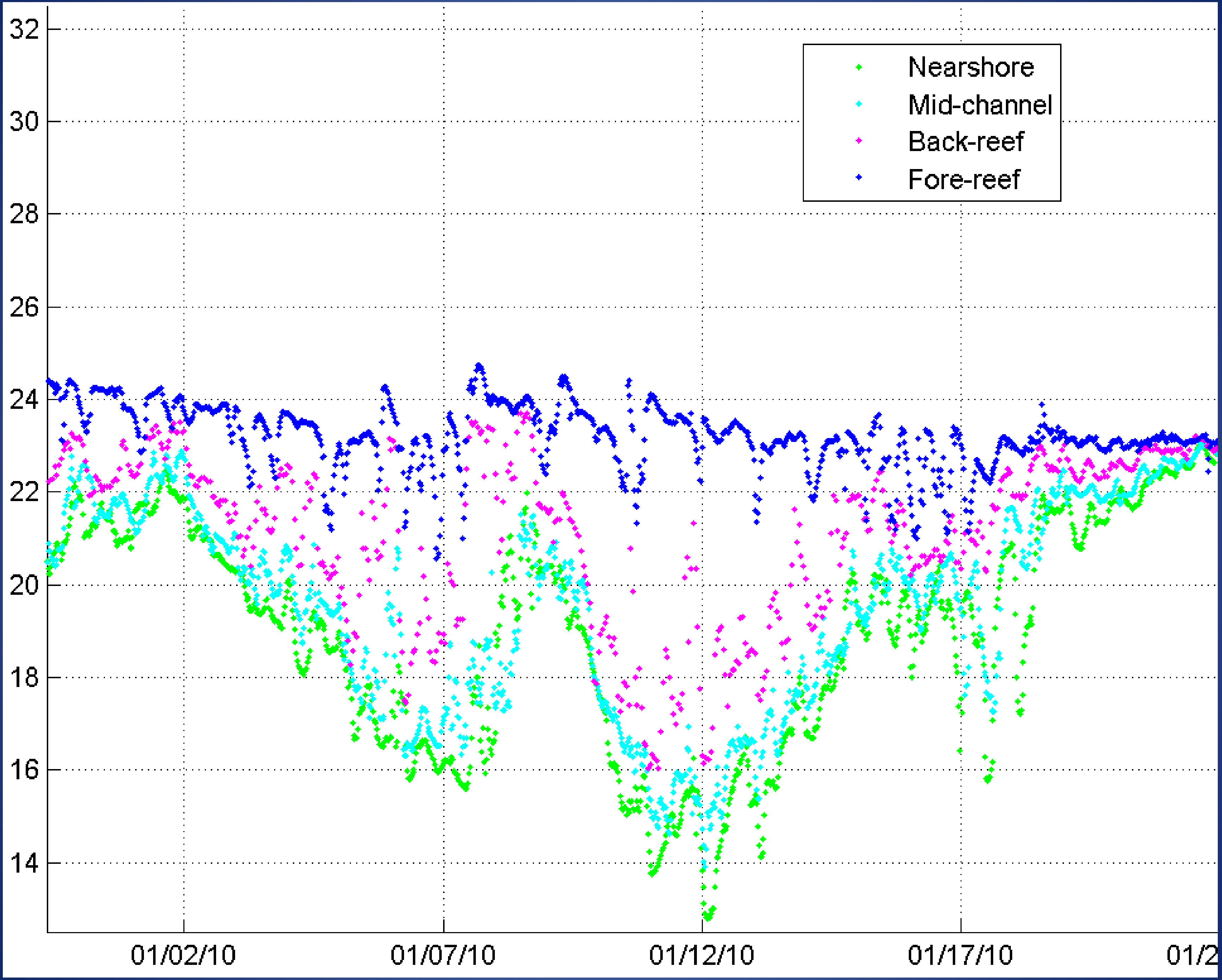




25.6
25.55
25.5
25.45
25.4
25.35
-80.22
-80.2
-80.18
-80.16
-80.14
-80.12
-80.1
Nearshore
Mid-channel
Back-reef
Fore-reef
-50
-60
-70
-80
25.372
25.37
25.368
25.366
25.364
25.362
25.36
25.358
25.356
25.354
-80.18
-80.178
-80.176
-80.174
-80.172
-80.17
-80.168
-80.166
-80.164
0
-2
-4
-6
-8
-10
-12
-14
-16



25.372
25.37
25.368
25.366
25.364
25.362
25.36
25.358
25.356
25.354
-80.18
-80.178
-80.176
-80.174
-80.172
-80.17
-80.168
-80.166
-80.164
0
-2
-4
-6
-8
-10
-12
-14
-16



32
30
28
26
24
22
20
18
16
14
Nearshore
Mid-channel
Back-reef
Fore-reef
01/02/10
01/07/10
01/12/10
01/17/10

The Gory Details

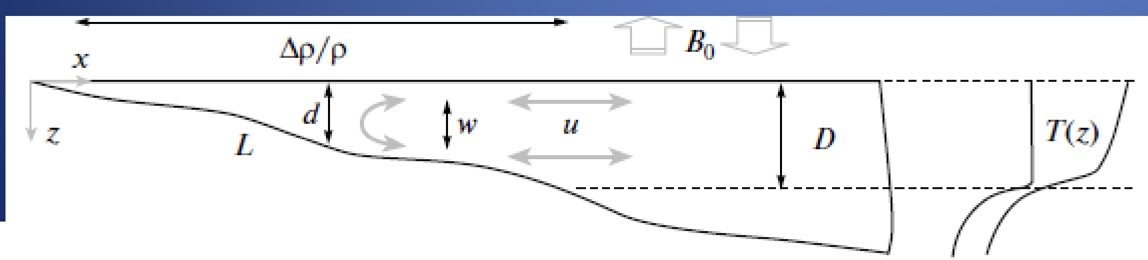
$$\partial_t T = -[\vec{u}_{km} \bullet \nabla_h + K_{H\theta}^{km} \nabla_h{}^2 + \vec{u}_{qe} \bullet \nabla_h + K_{H\theta}^{SGS} \nabla_h{}^2]T_{km} - \vec{u}_{hc} \bullet \nabla_h T_{hc}(Q_0, h, \beta) + \frac{Q_0}{\rho C_p h}$$

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

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

Absorption factor $\gamma = 1 - A_b \cdot \tau_{PAR} \cdot (1 - \tau_{PAR})$ 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 $Q_{shortwave}$.

Horizontal Convection:



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

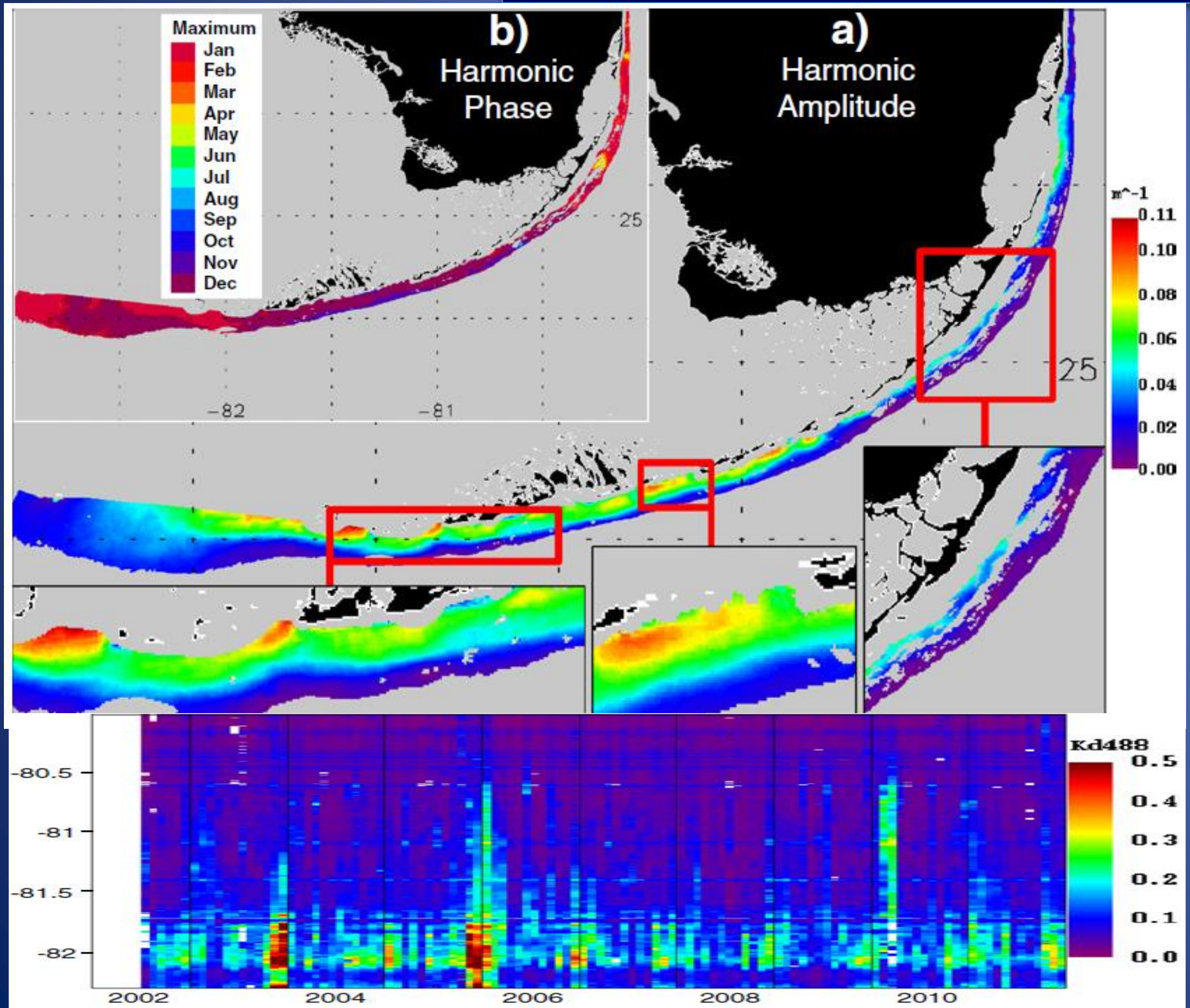
Beyond **weather & km-scale oceanography,** *thermally-driven mixing* also plays a major role:

· enhanced ***lateral heat diffusion*** (Hearn 2011)

· ***horizontal convection*** *(Monismith et al. 2006)*

Absorbed sunlight

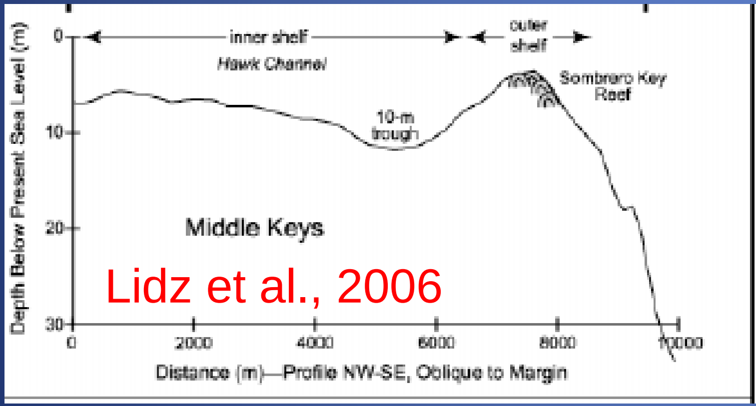
Barnes *et al.* (2013), their Figures 8b and 9

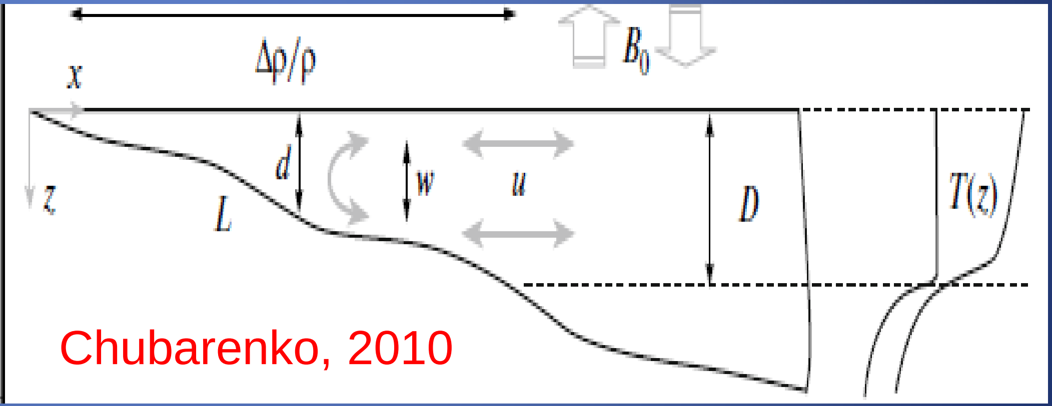


Shallow sites: insolation is absorbed at different rates during a year. Amplitude and phase of annual cycle vary along the length of the FRT, and across multiple years.

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?

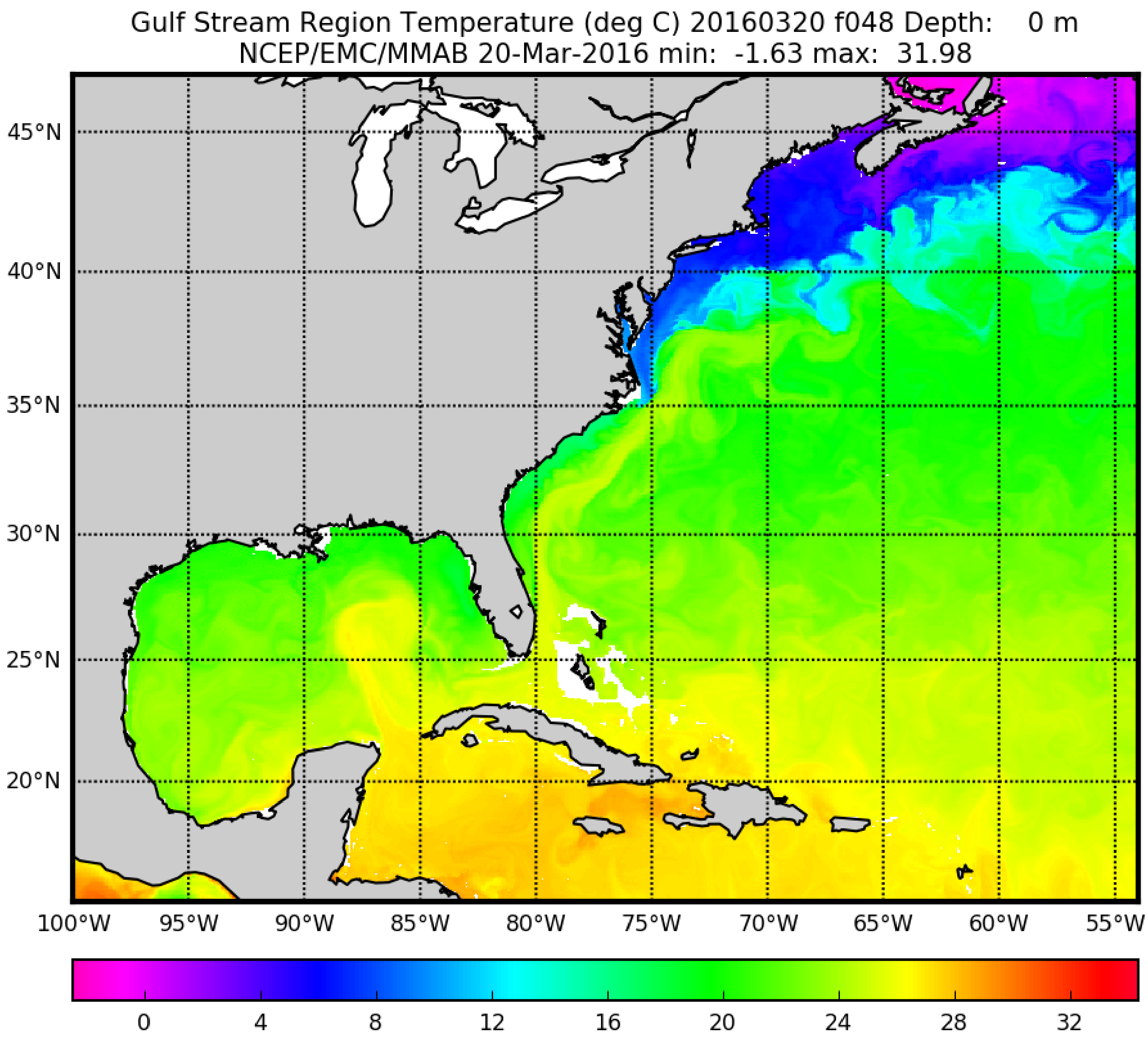


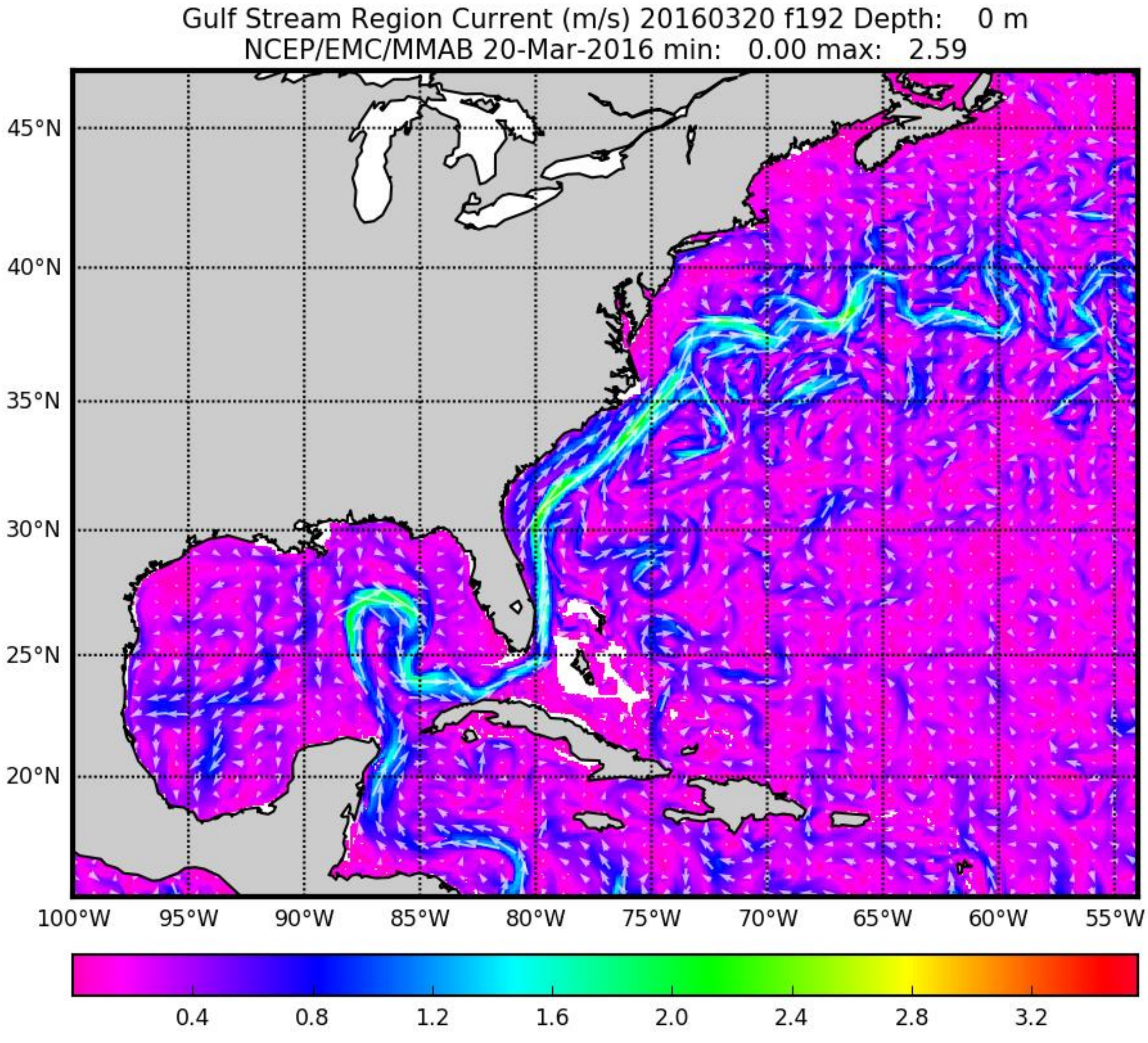


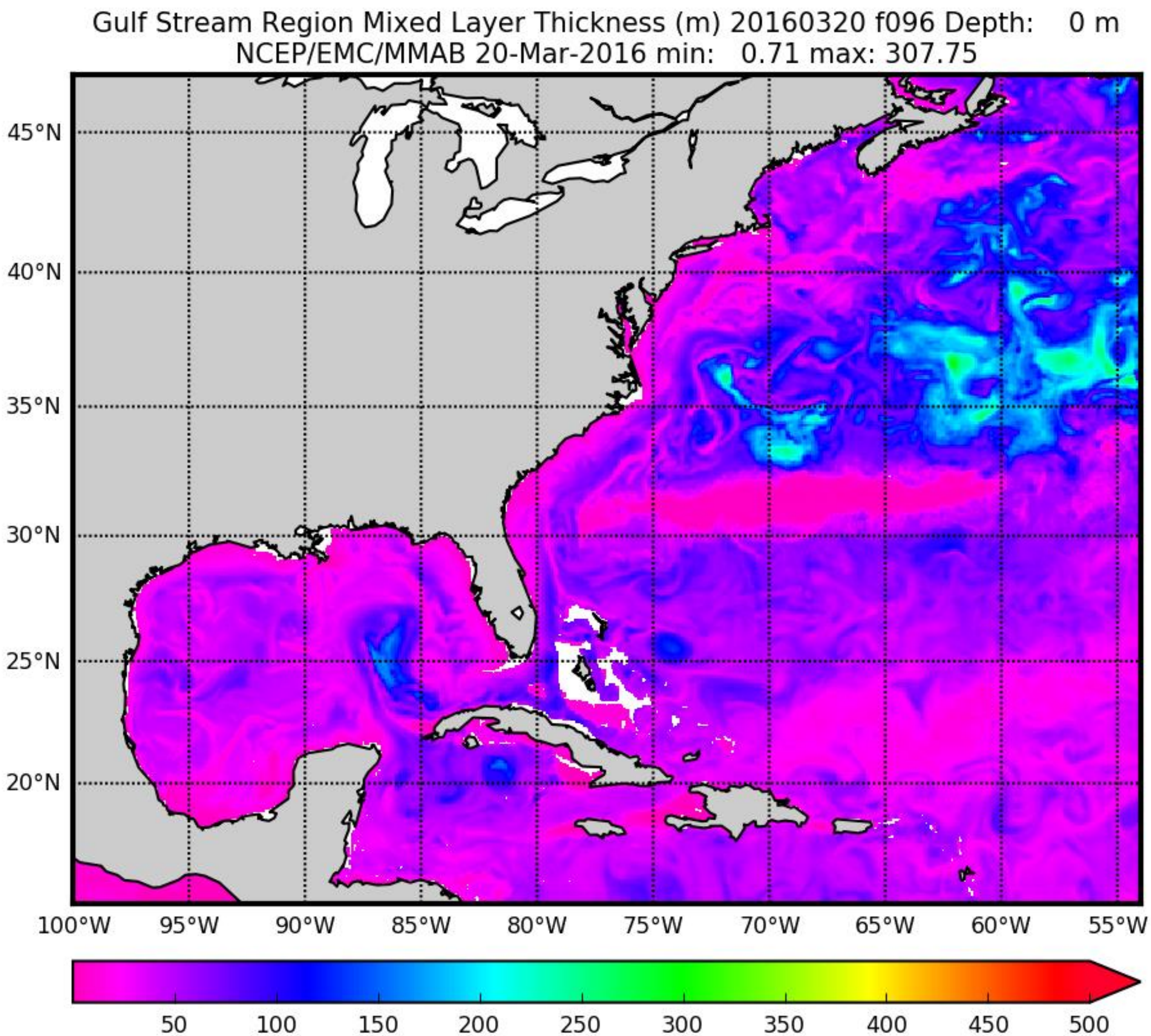
Monismith et al., 2006

TABLE 1. Possible scalings for ΔV.

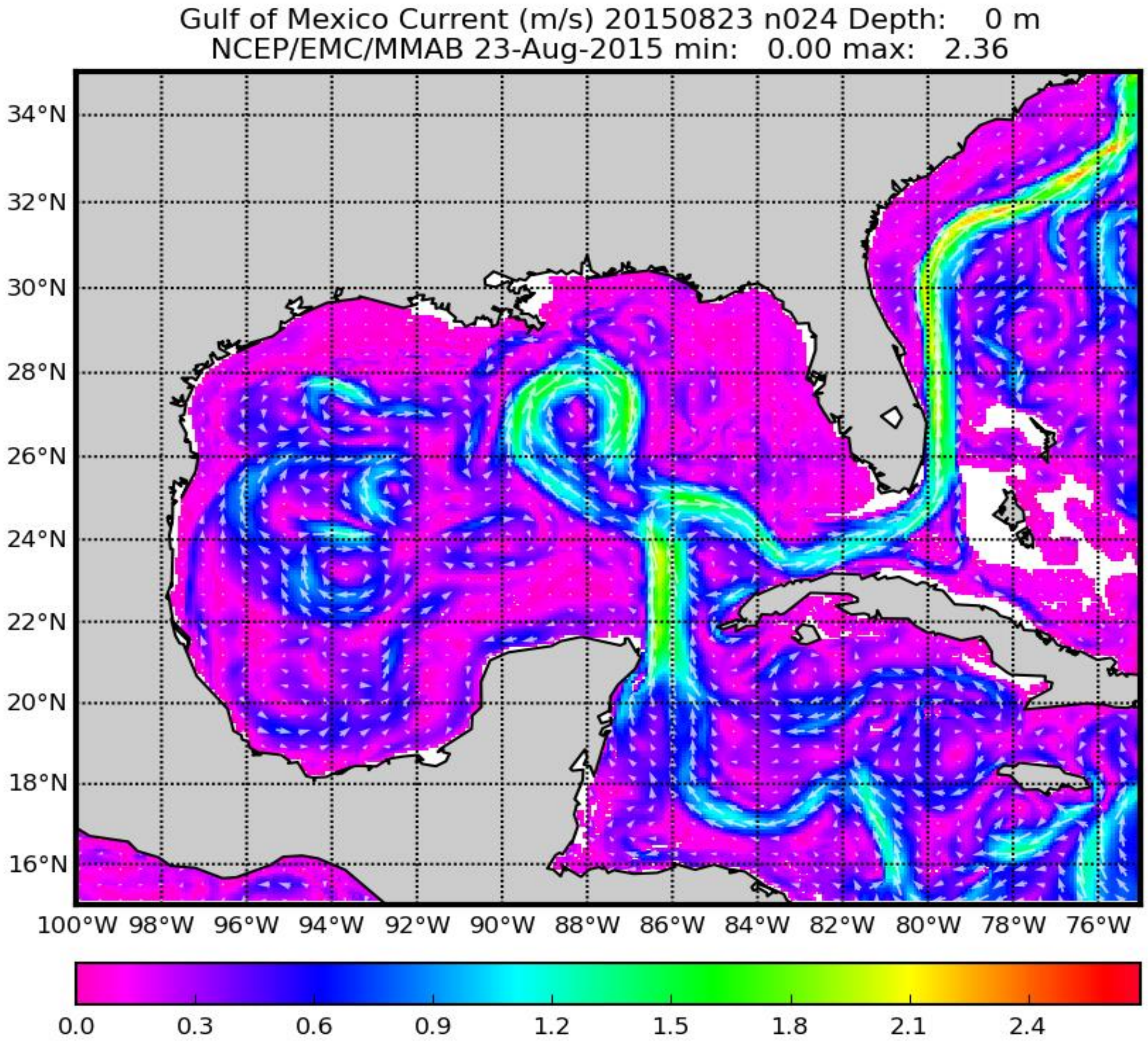
Balance	Unsteady inertia	Stress divergence	Advective inertia
Steady temperature	$V_{US} \sim (u_f^3 T/D)^{1/2}$	$V_{VS} \sim (u_f^{3/2}/q^{1/2})$	$V_{NS} \sim \beta^{-1/3} u_f$
Unsteady temperature	**$V_{UU} \sim (\beta u_f^3 T^2/D_0^2)$**	$V_{VU} \sim (\beta u_f^3 T/qD)$	$V_{NU} \sim (u_f^3 T/D)^{1/2}$


Gulf Stream Region Temperature (deg C) 20160320 f048 Depth: 0 m
NCEP/EMC/MMAB 20-Mar-2016 min: -1.63 max: 31.98
45°N
40°N
35°N
30°N
25°N
20°N
100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
60°W
55°W
0
4
8
12
16
20
24
28
32

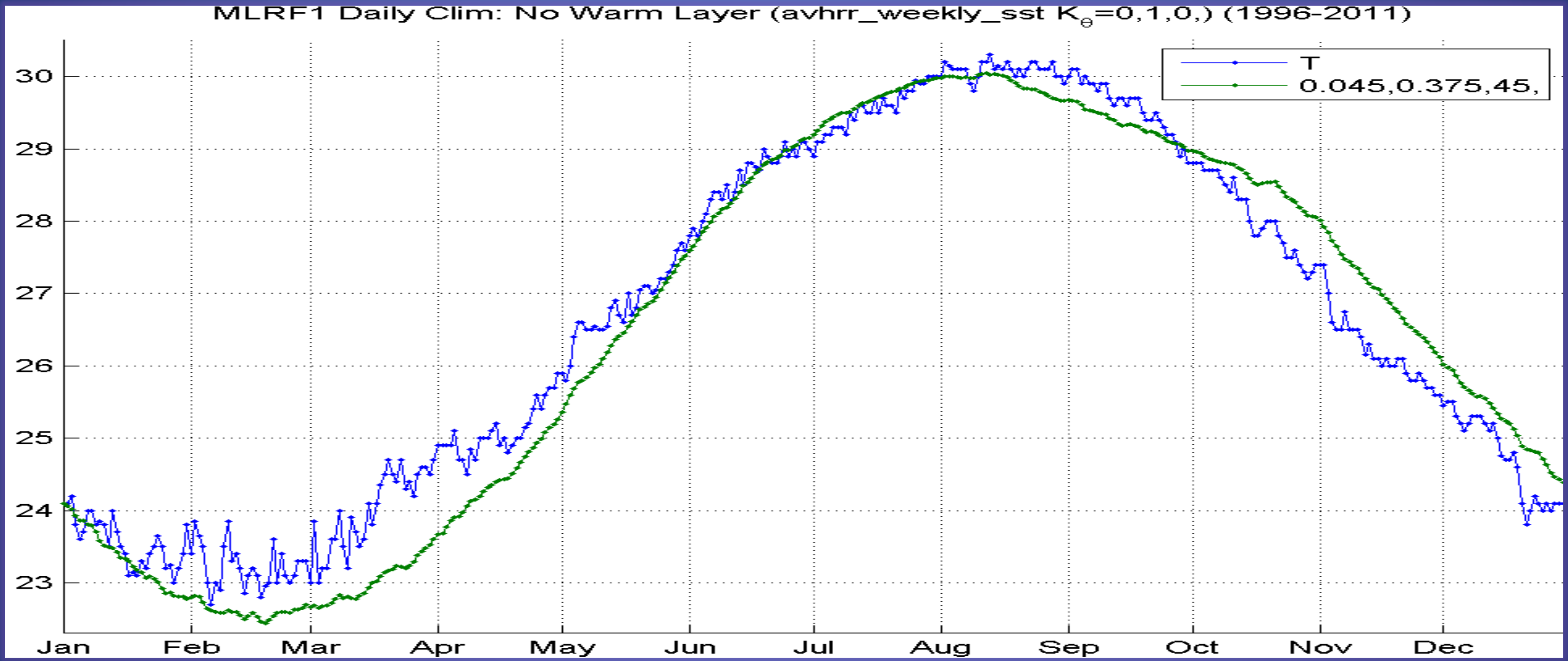

Gulf Stream Region Current (m/s) 20160320 f192 Depth: 0 m
NCEP/EMC/MMAB 20-Mar-2016 min: 0.00 max: 2.59
45°N
40°N
35°N
30°N
25°N
20°N
100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
60°W
55°W
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2



Gulf Stream Region Mixed Layer Thickness (m) 20160320 f096 Depth: 0 m
NCEP/EMC/MMAB 20-Mar-2016 min: 0.71 max: 307.75
45°N
40°N
35°N
30°N
25°N
20°N
100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
60°W
55°W
50
100
150
200
250
300
350
400
450
500

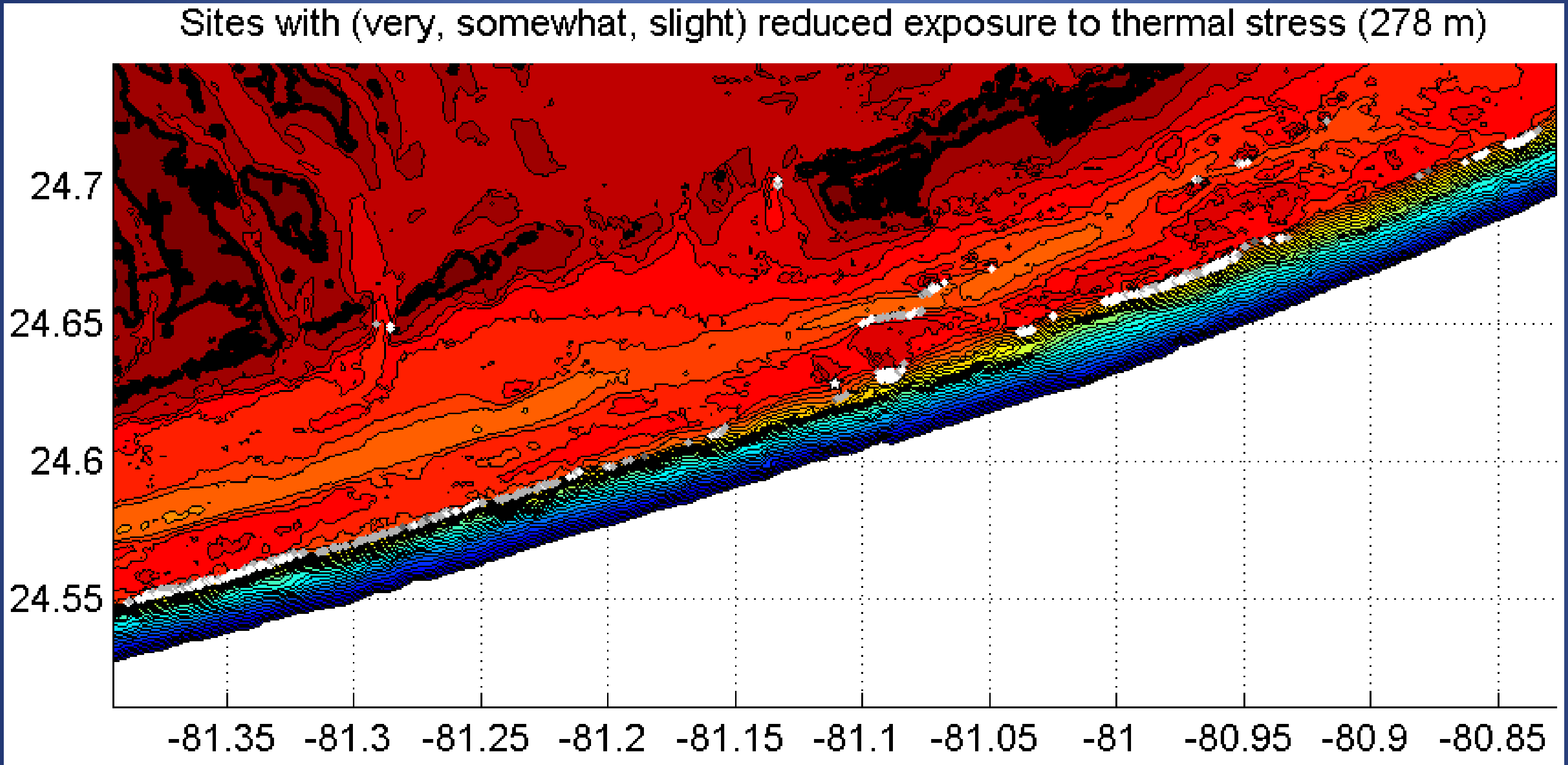

Gulf of Mexico Current (m/s) 20150823 n024 Depth: 0 m
NCEP/EMC/MMAB 23-Aug-2015 min: 0.00 max: 2.36
34°N
32°N
30°N
28°N
26°N
24°N
22°N
20°N
18°N
16°N
100°W 98°W 96°W 94°W 92°W 90°W 88°W 86°W 84°W 82°W 80°W 78°W 76°W
0.0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4

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



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!

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