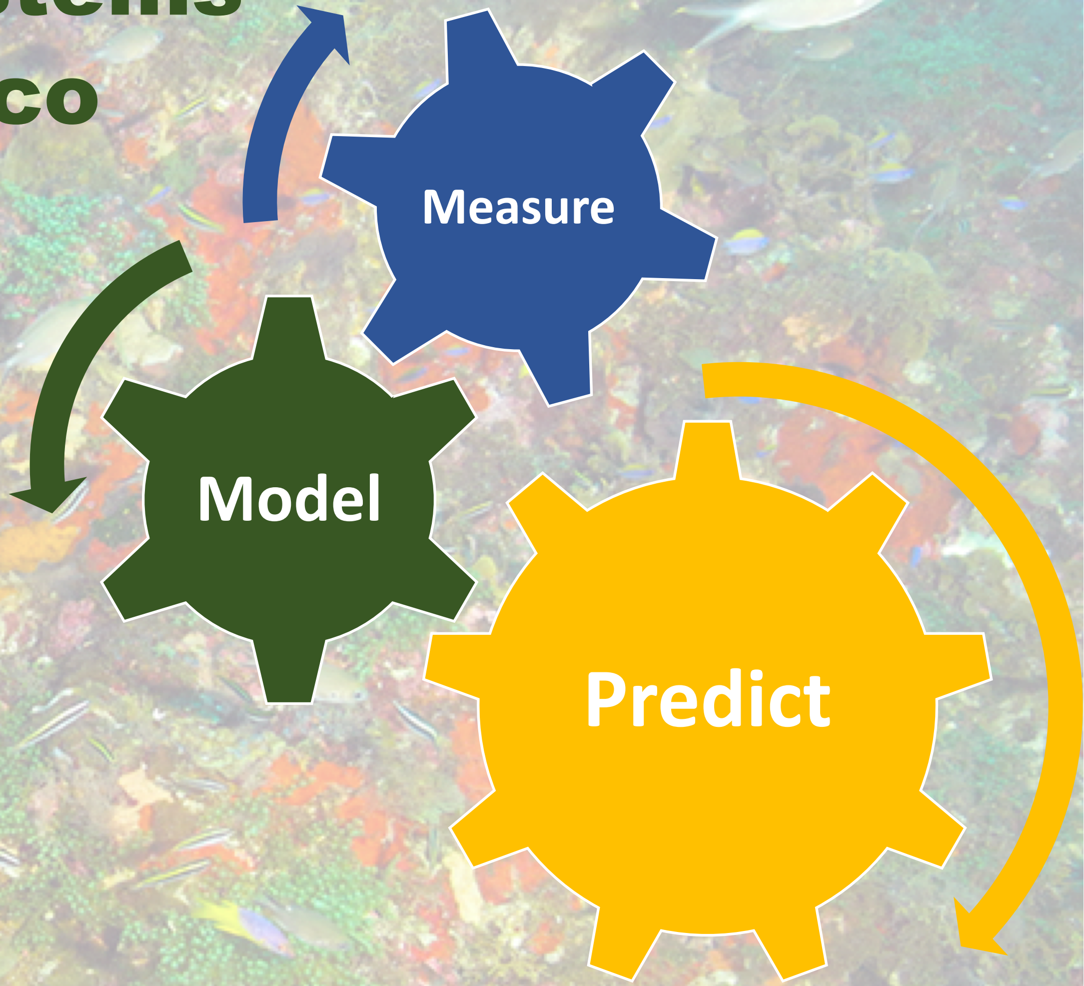
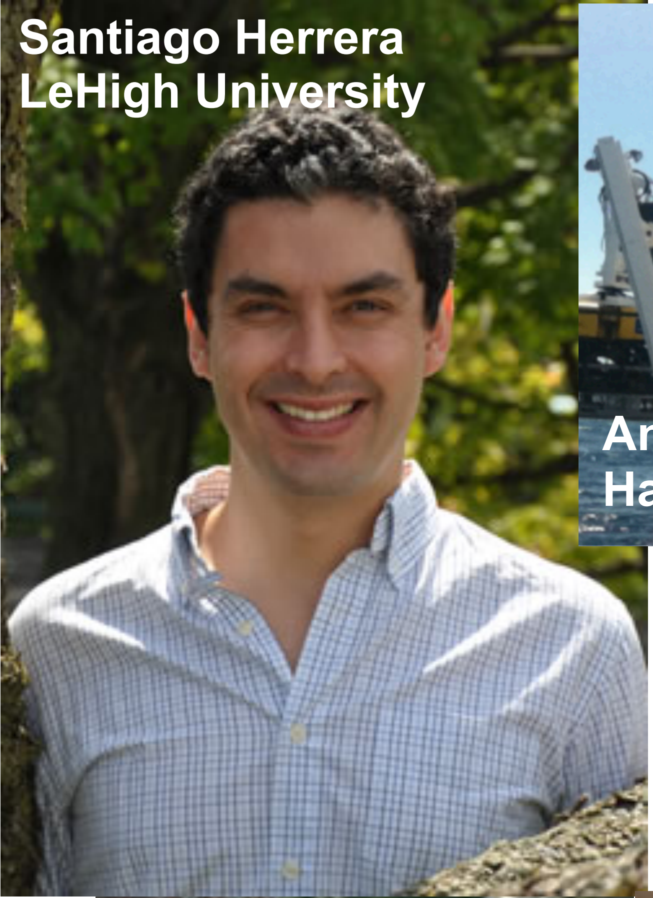
CYCLE

ConnectivitY of CoraL Ecosystems in the northern Gulf of Mexico

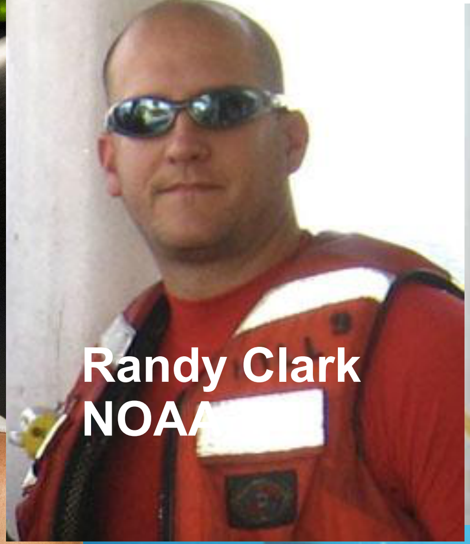
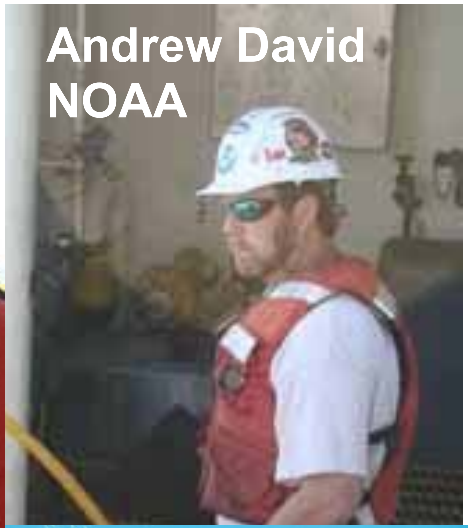


Annalisa Bracco

Georgia Tech


Santiago Herrera
LeHigh University

Andrea Quattrini
Harvey Mudd College

Annalisa Bracco
Georgia Tech

Randy Clark
NOAA

Andrew David
NOAA

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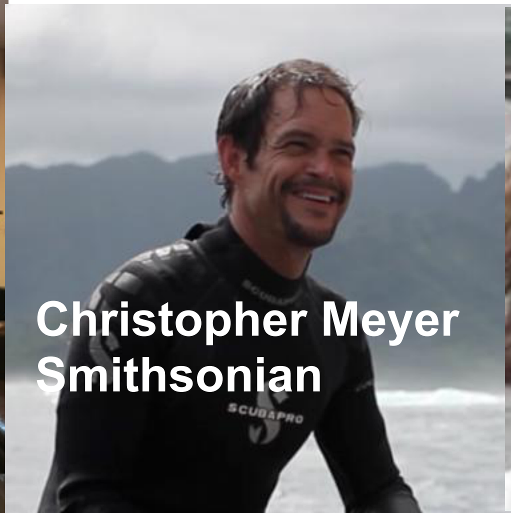
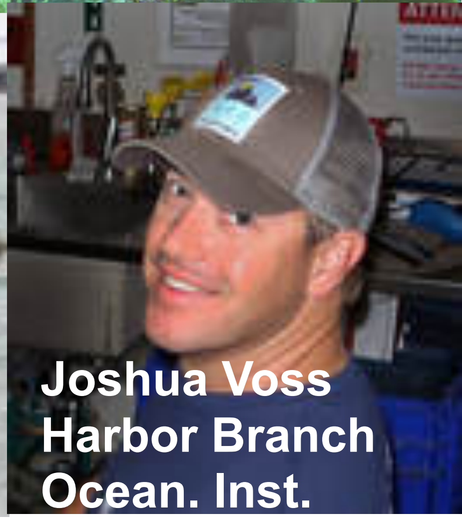
Peter Etnoyer
NOAA

Amanda Demopoulos
USGS

Stacey Harter
NOAA

Christopher Meyer
Smithsonian

Nancy Prouty
USGS

Joshua Voss
Harbor Branch
Ocean. Inst.

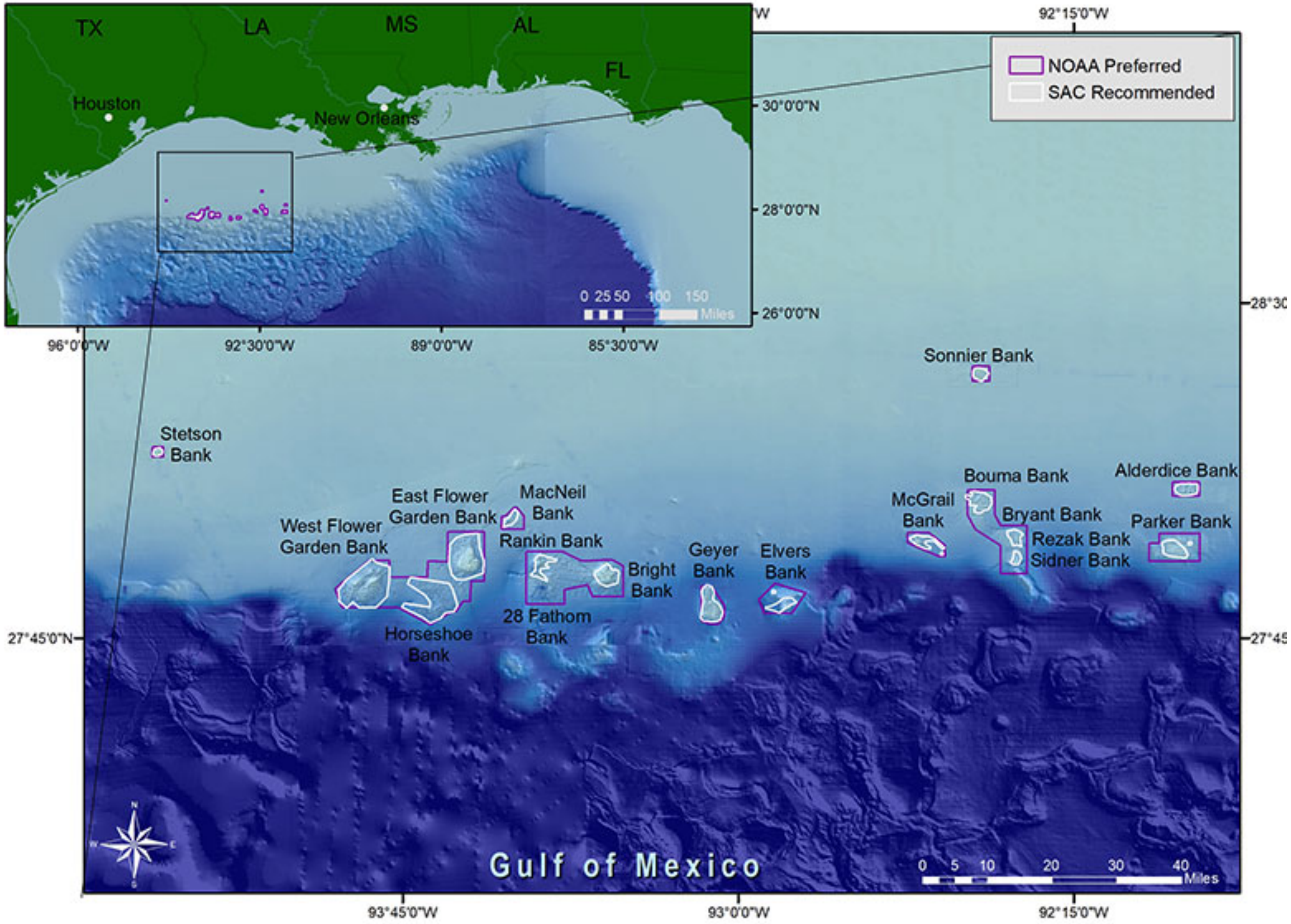
PROBLEM

- Continued anthropogenic threats in the marine environment → urgent need to to effective **manage and conserve vulnerable coral ecosystems** in the Gulf of Mexico (GoM).

- **Marine protected areas (MPAs)** are essential to protect and conserve coral ecosystems → **key restoration strategy for benthic communities** impacted by the *Deepwater Horizon* oil spill.

- The **Flower Garden Banks National Marine Sanctuary** (FGBNMS) has proposed to **expand current boundaries** to encompass additional coral sites.


Flower Garden Banks National Marine Sanctuary Expansion: Sanctuary Advisory Council Recommendation May 2018



CYCLE

A **collaborative effort** to enhance understanding of GoM ecosystems and link research with regional conservation initiatives to 1) **inform the restoration of degraded deepwater coral communities**, and 2) **preserve long-term viability of coastal ecosystems**.

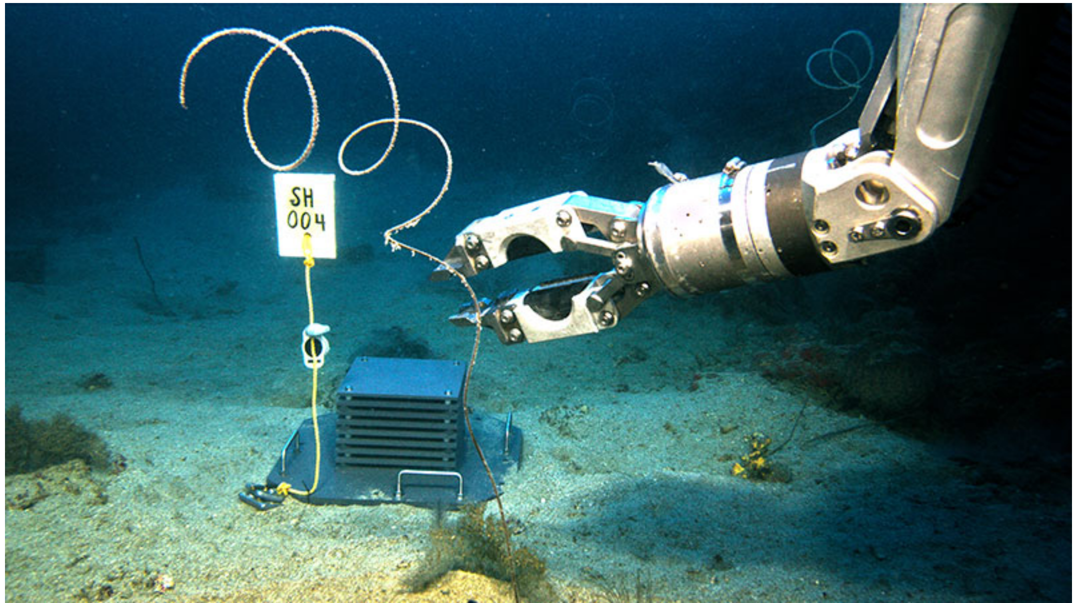
CYCLE will

- provide ecosystem connectivity information and tools to managers to effectively manage the FGBNMS MPAs, the boundary expansion alternatives, and areas further afield.
- improve understanding of **the processes that shape 3D connectivity networks in shallow (15-40m), upper mesophotic (40-85m), lower mesophotic (85-150m) and deepwater (> 150m) coral ecosystems in the GoM**.

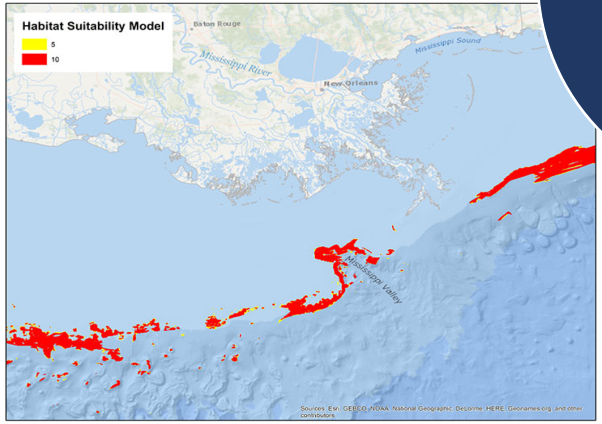
- Focus on twelve species: two hard corals (*Montastraea cavernosa* and *Orbicella faveolata*), two soft corals (*Swiftia exserta* and *Hypnogorgia pendula*), one black coral (*Stichopathes lutkeni*), one sponge (*Xestospongia muta*), two fishes (red snapper *Lutjanas campechanus* and tomtate *Haemulon aurolineatum*) and four octocoral species (*Hypnogorgia pendula* and *Swiftia exserta* from mesophotic areas; *Callogorgia delta* from the upper continental slope and *Paramuricea biscaya)*.

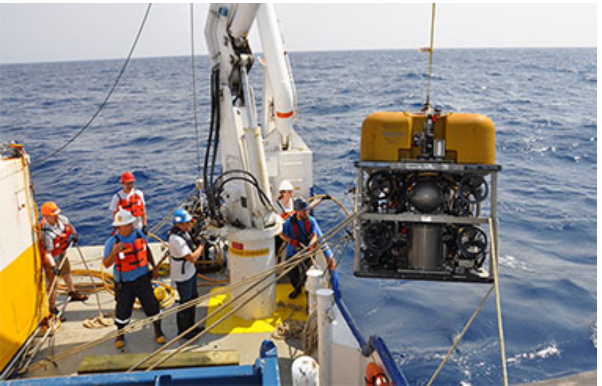
- Integration of field sampling and genetic, chemical, and ecological analyses with habitat suitability, oceanographic, and larval dispersal modeling.

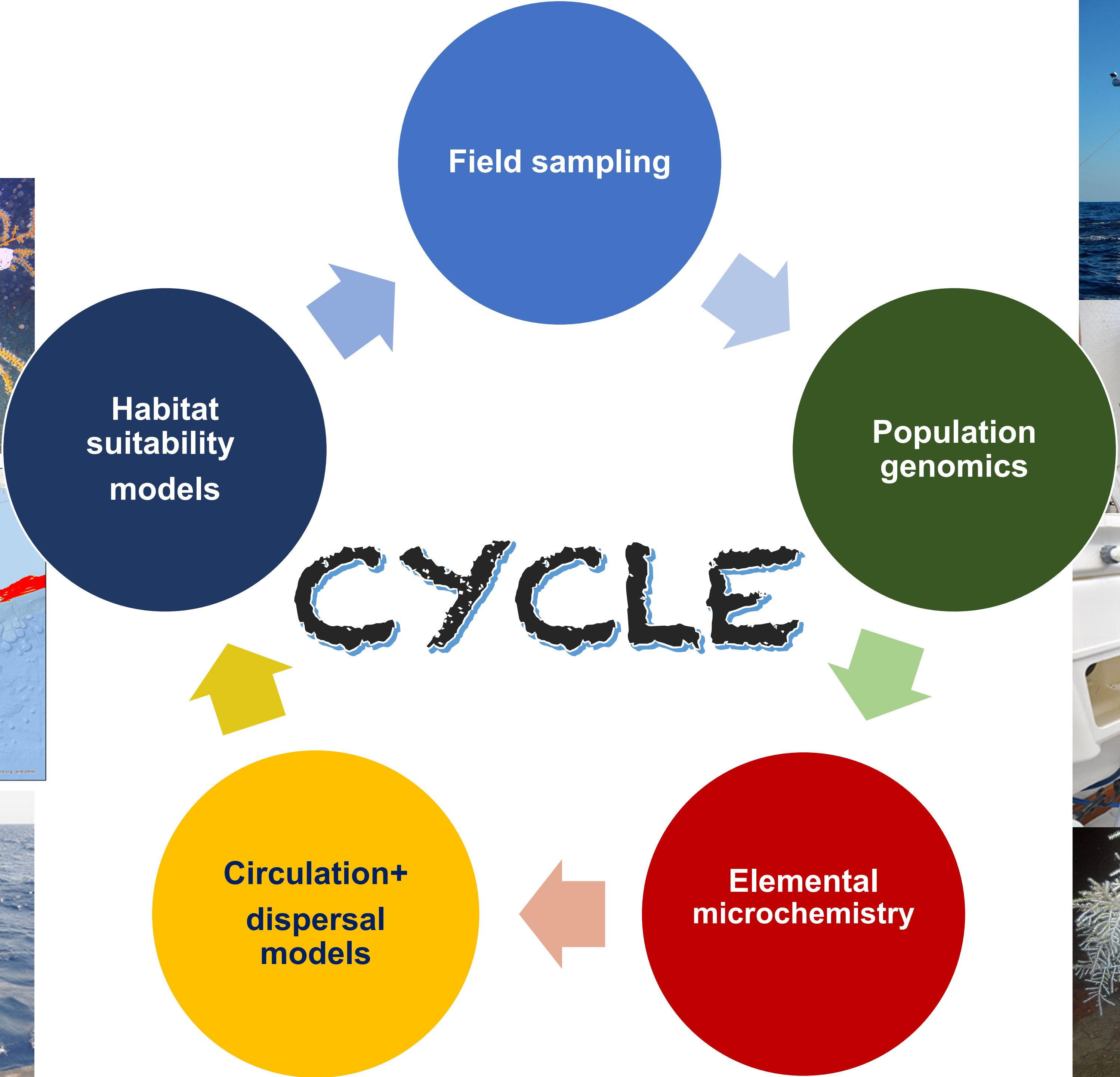
- Additionally, analysis of coral recruitment and species biodiversity through the use of Autonomous Reef Monitoring Structures or ARMS.



How

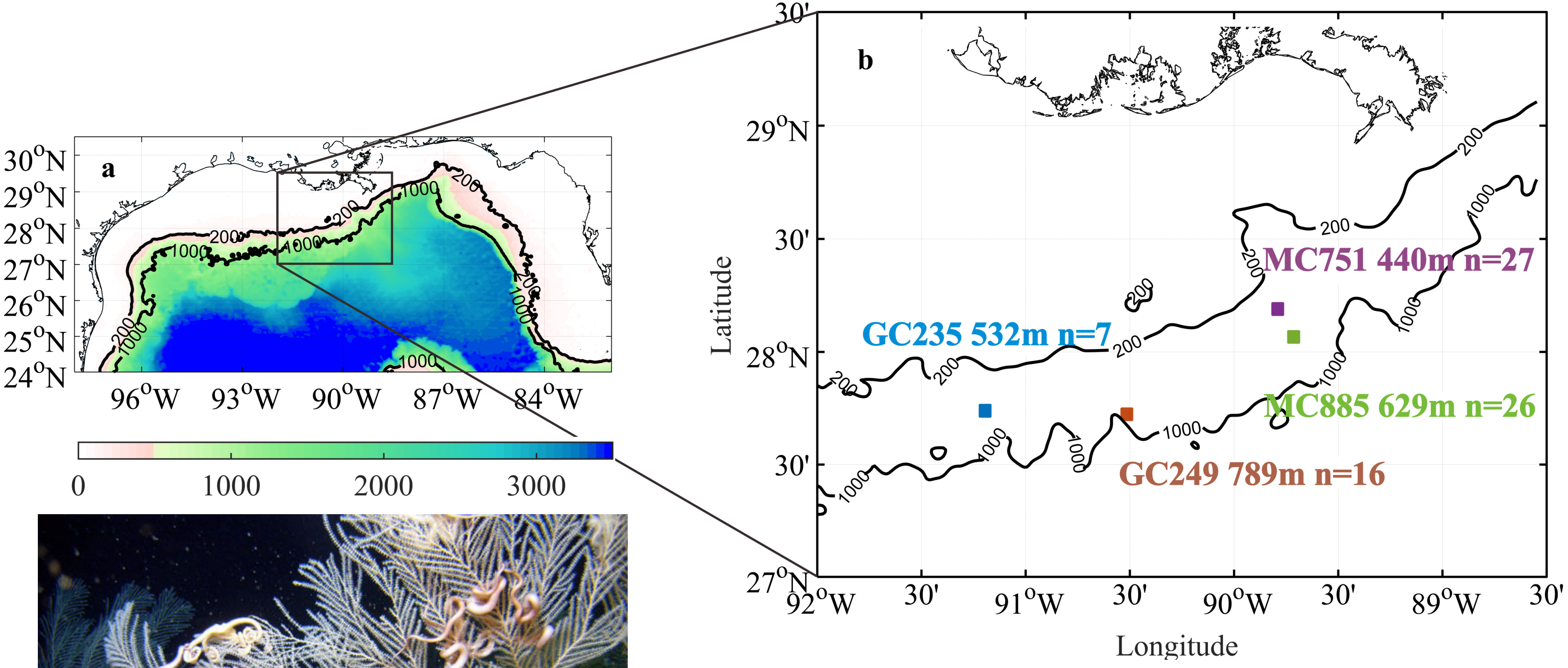

Habitat Suitability Model
5
10
Baton Rouge
Mississippi Sound
Mississippi River
New Orleans
Mississippi Valley

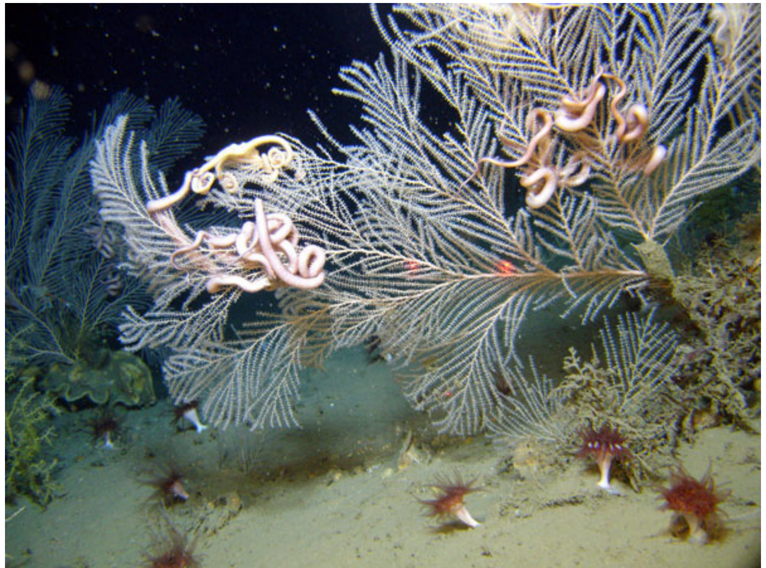



Field sampling
Population genomics
Elemental microchemistry
Circulation+ dispersal models
Habitat suitability models
CYCLE


PELICAN

Potential connectivity of *Callogorgia delta* in the Northern Gulf of Mexico





Bracco et al., JMS, in review

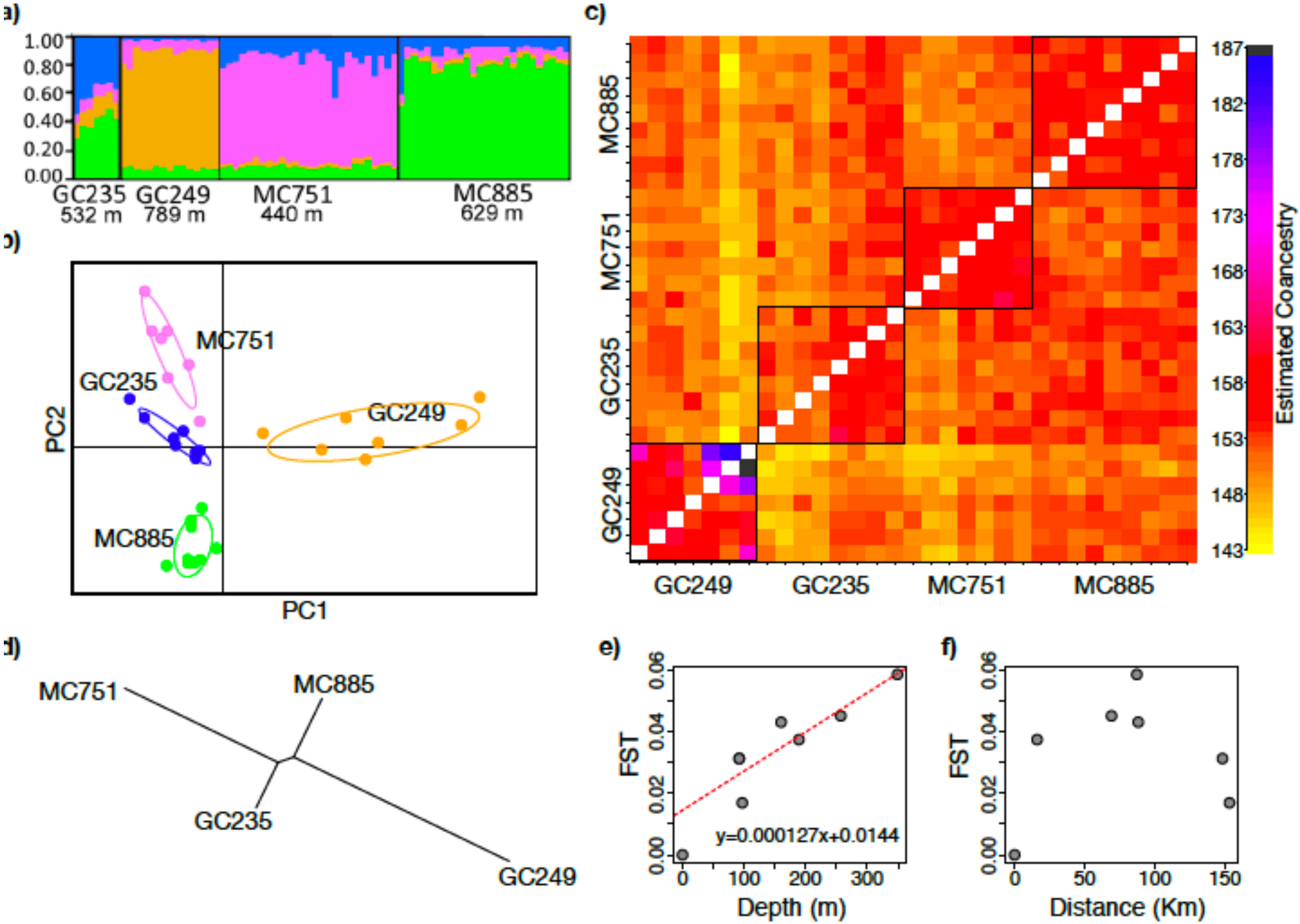
Testing processes involved in the depth differentiation hypothesis

The bathyal region (~200 – 2000 m) is a source of genetic diversity + a high rate of species formation → genetic differentiation should occur over relatively small vertical distances

Is it true in the northern Gulf of Mexico?

What is the controlling factor?

Genetic structuring with distance

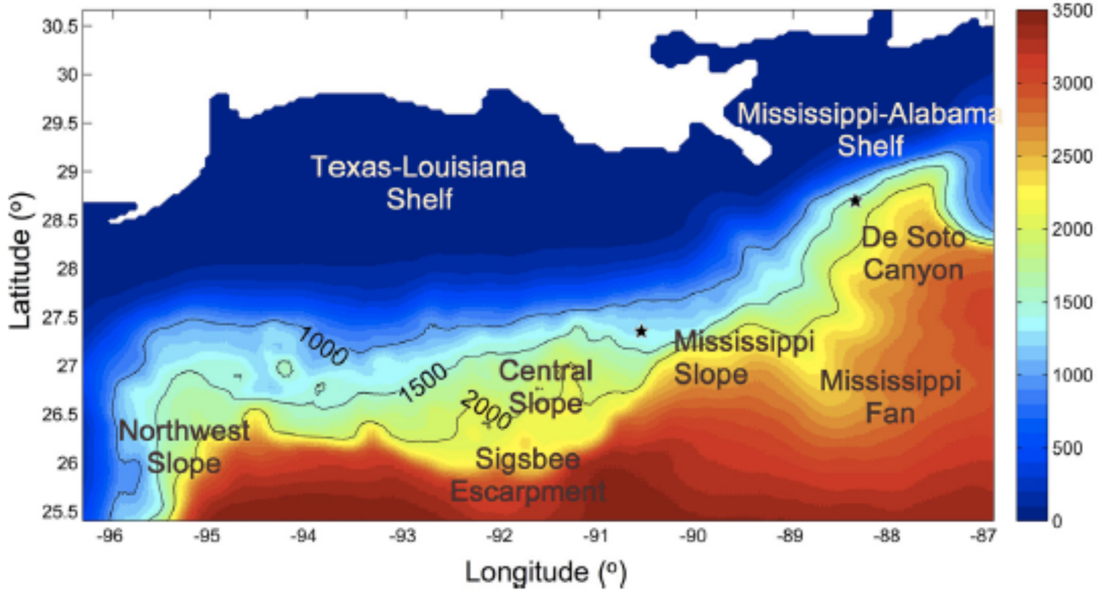


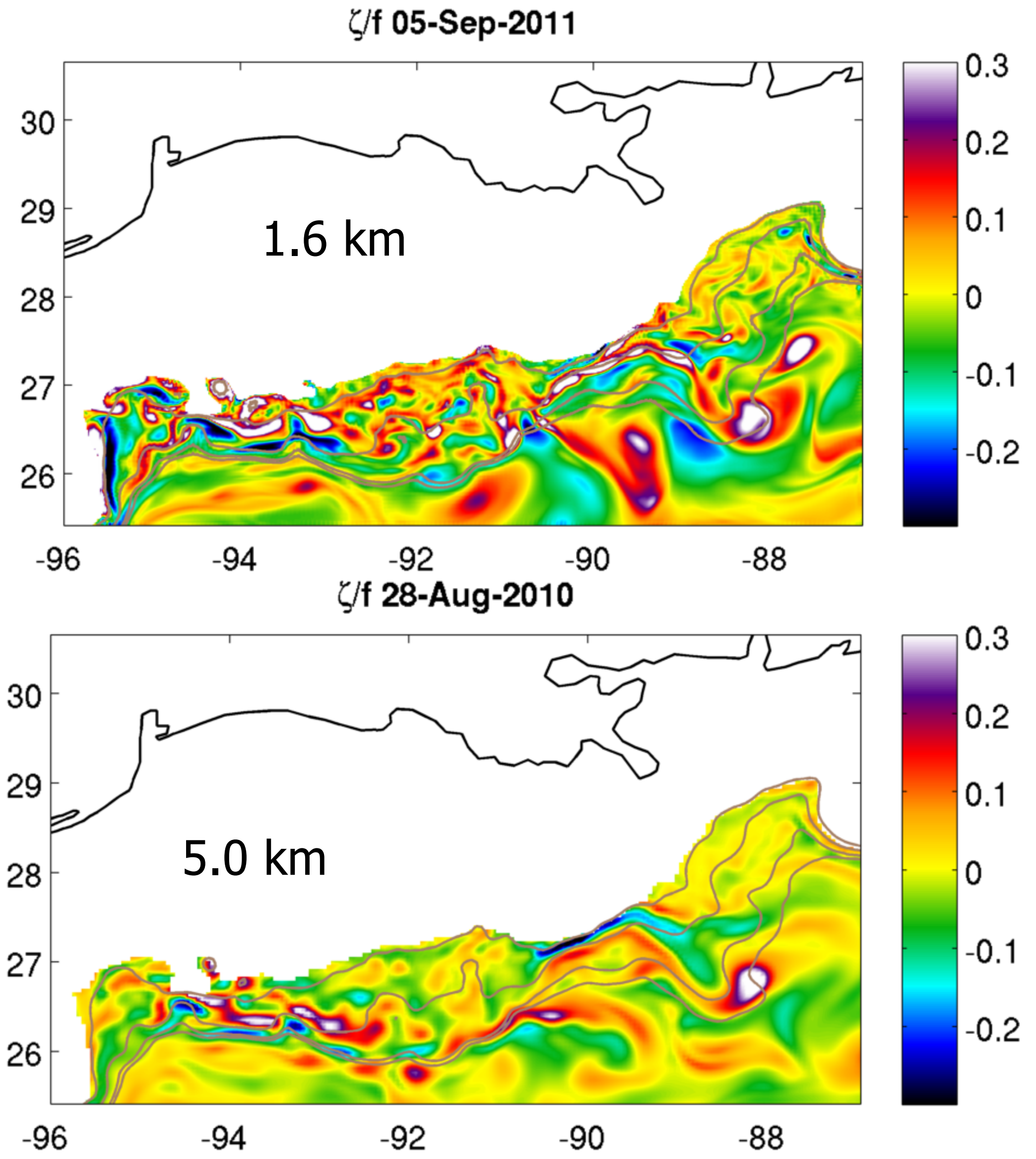
Callogorgia delta

61,179 loci

Fst 0.0115-0.0691

PATTERN FORMATION AND SUBMESOSCALES
Transport along the continental slope





Bracco, Choi et al. Ocean Modelling, 2016

GENERATION OF SUBMESOSCALE EDDIES ALONG CONTINENTAL SLOPES

- **Vertical velocities have to go to zero at the bottom -> horizontal shear layer near the bottom**

- **Juxtaposition of along-slope frontal currents that are highly variable in speed and direction (very common in the Gulf of Mexico) -> lateral shear layers**

- The width of the layer depends on bathymetric slope; mostly unresolved at >= 5km horizontal resolution and partially resolved at ~ 1 km

- Whenever high values of vorticity are achieved ($\zeta/f > 0.4$) small scales eddies and filaments are generated through partially unbalanced instabilities

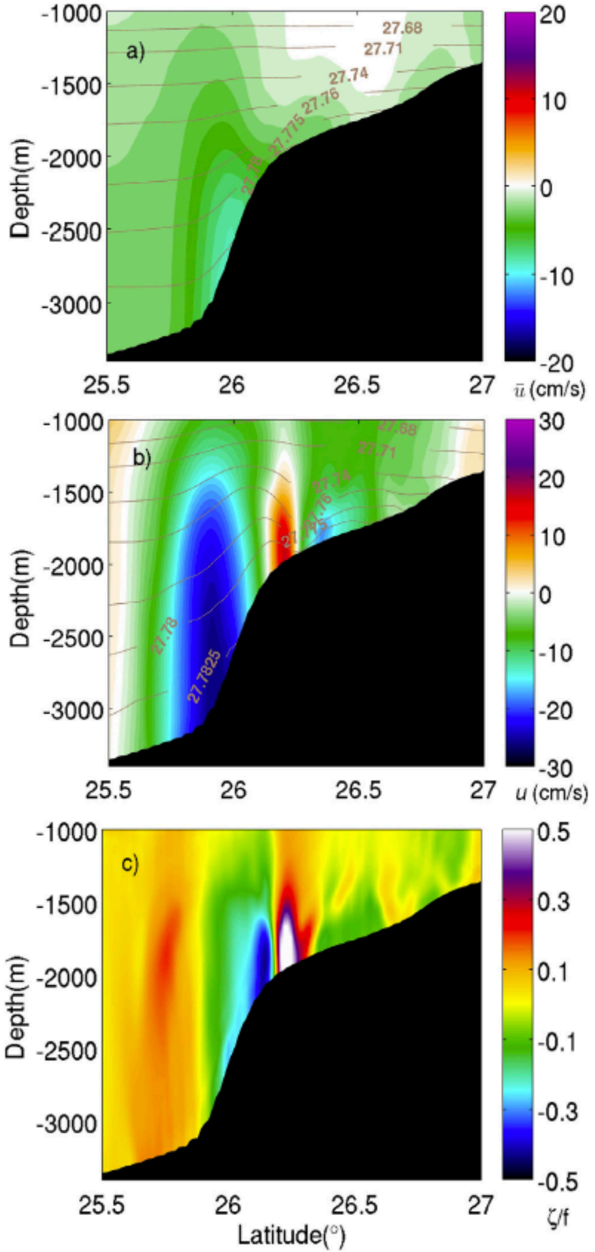
Bracco et al. Ocean Modelling 2016, 2018

Juxtaposition of along-slope frontal currents that are highly variable in speed and direction -> lateral shear layers

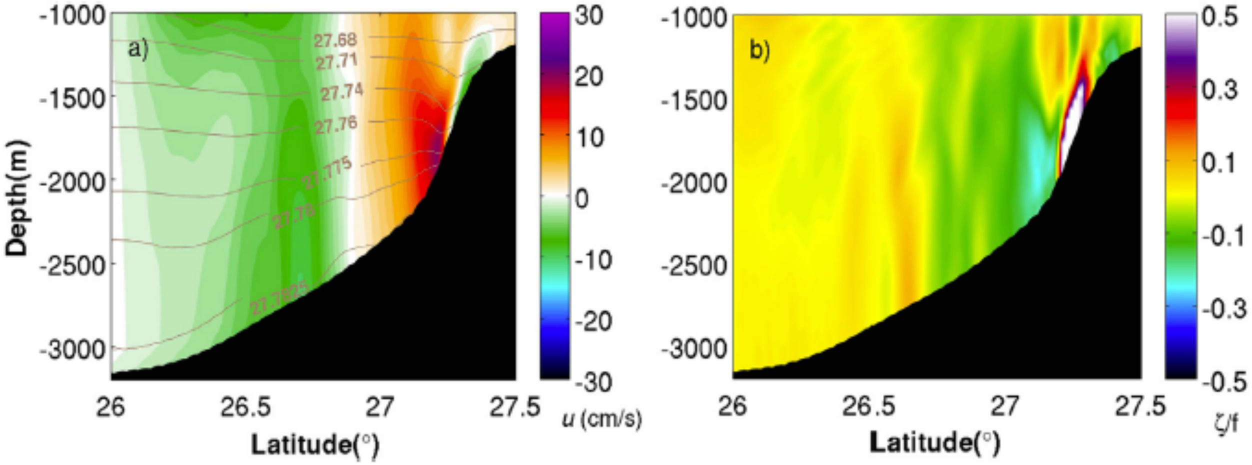
mean u (cm/s)

instantaneous u (cm/s)

ζ/f



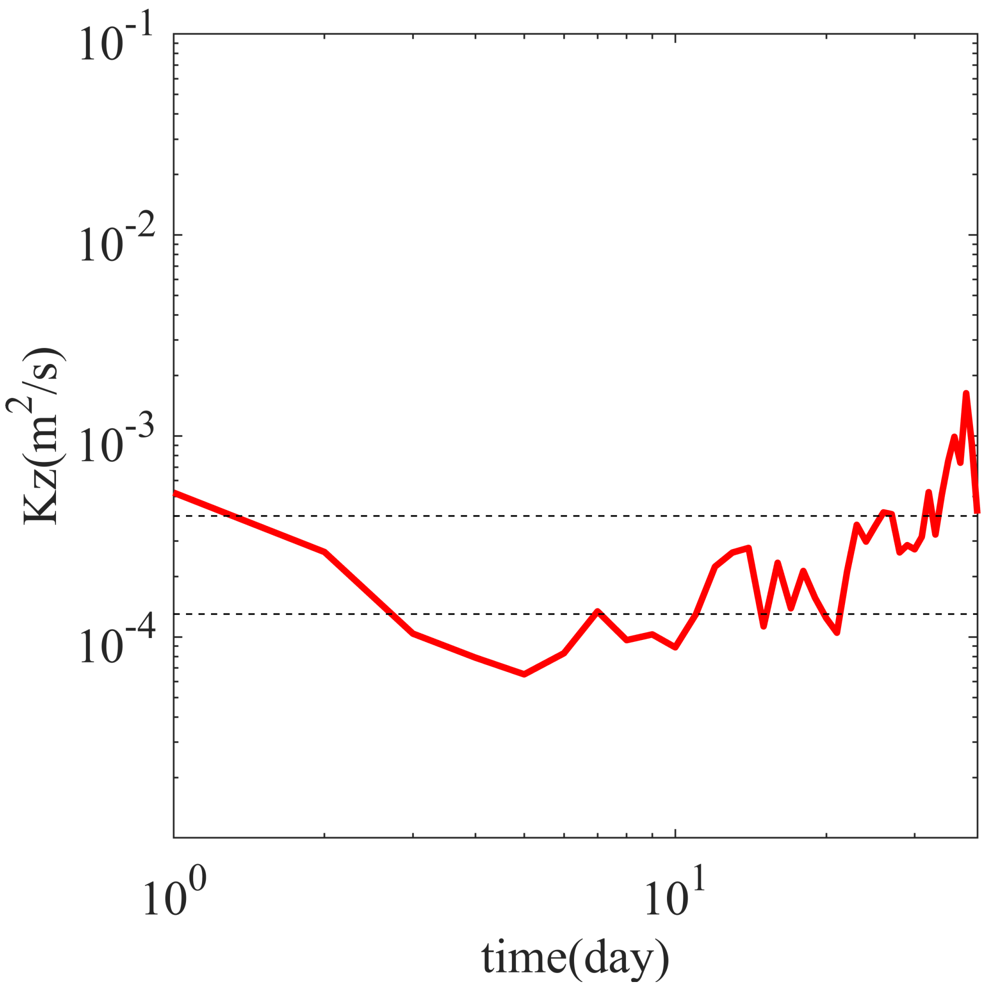
Vertical velocities have to be zero at the bottom -> horizontal shear layer near the bottom



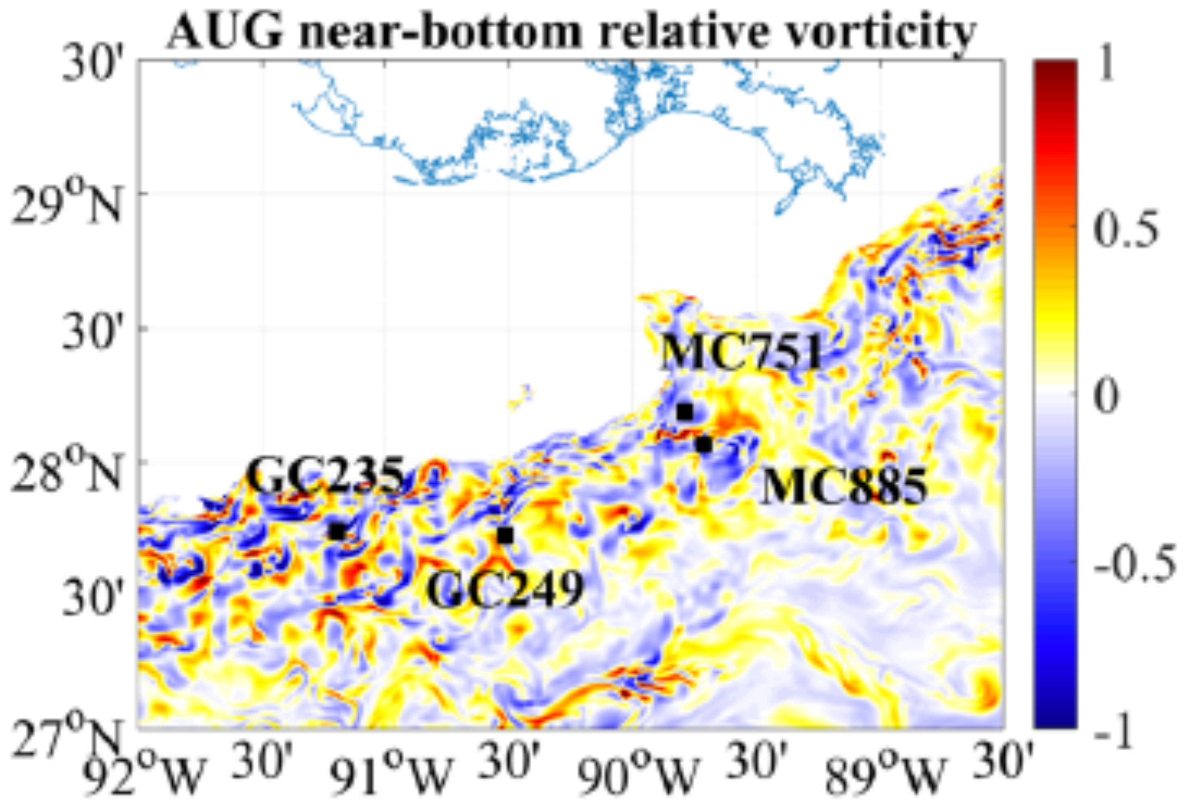
instantaneous u (cm/s)

ζ/f

Bracco et al. Ocean Modelling 2016

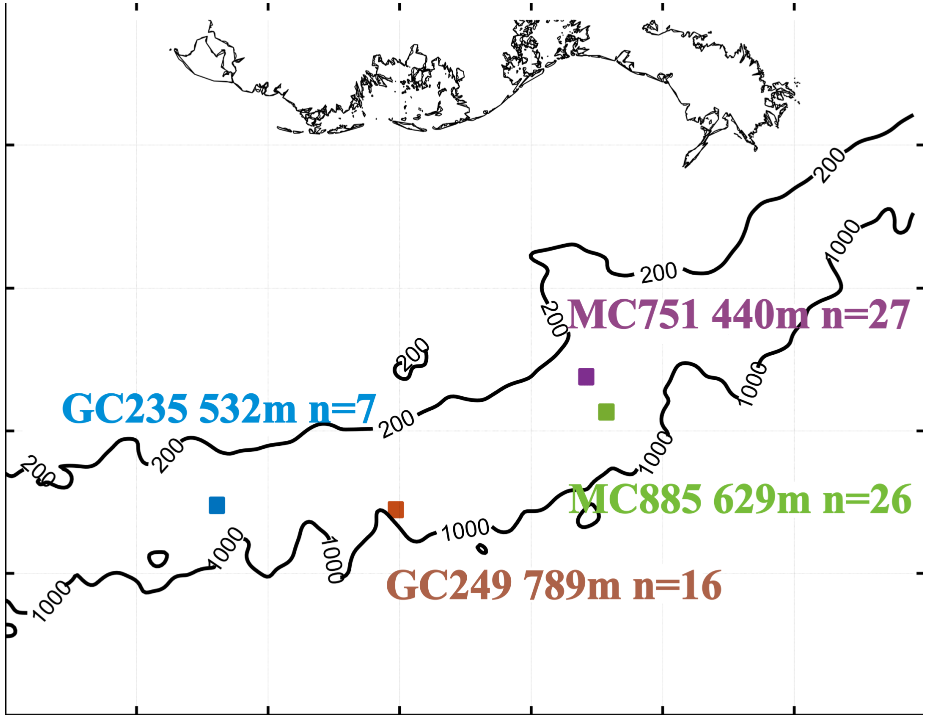


Observed (dashed lines; Jim Ledwell deep release experiment; Ledwell et al., 2017) and **modeled (red)** diapycnal diffusivity in the northern GoM



Snapshot of relative vorticity in the bottom layer 10th, 2015

Virtual connectivity using a regional circulation model



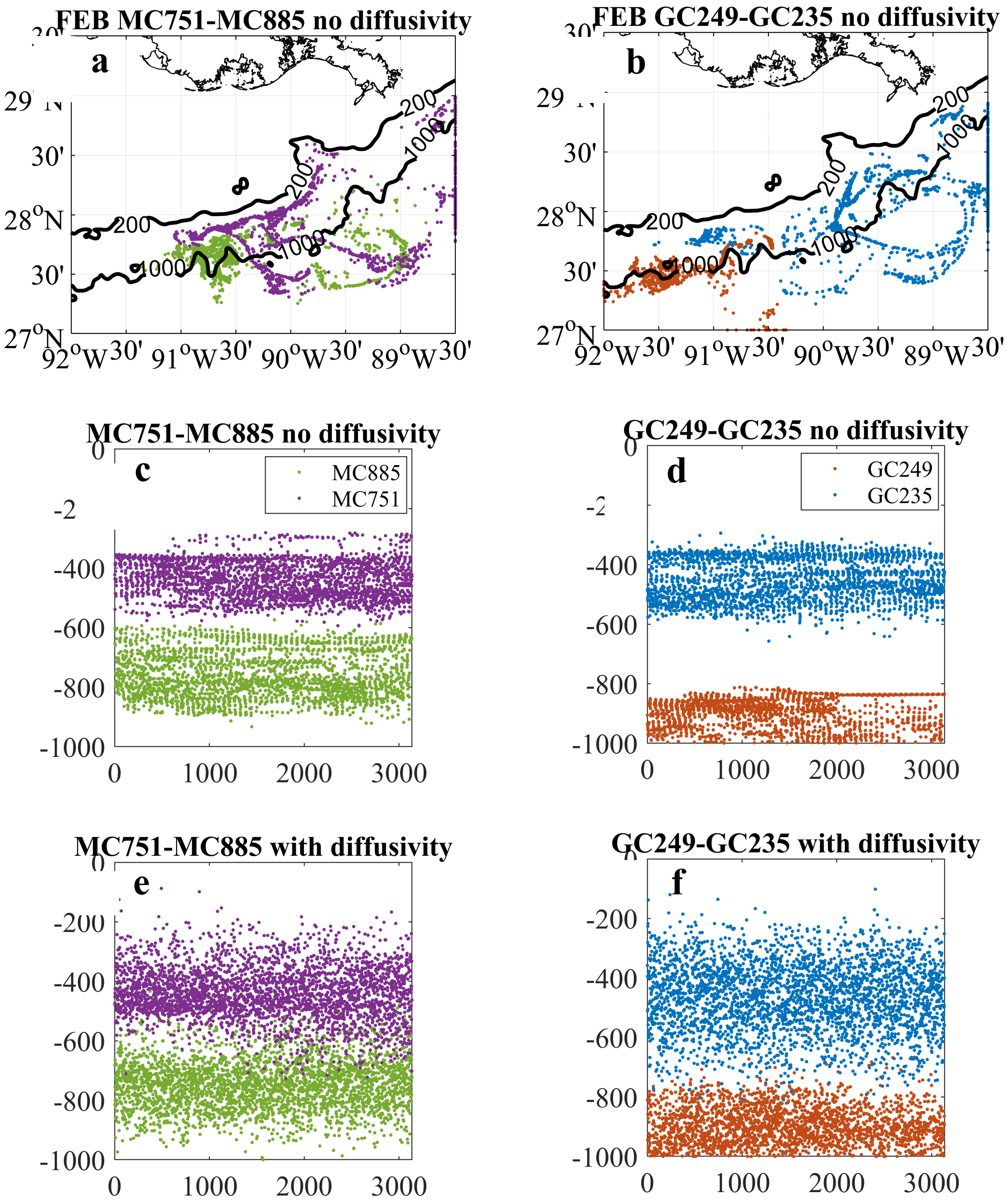
Callogorgia delta

PLD = 40 Days

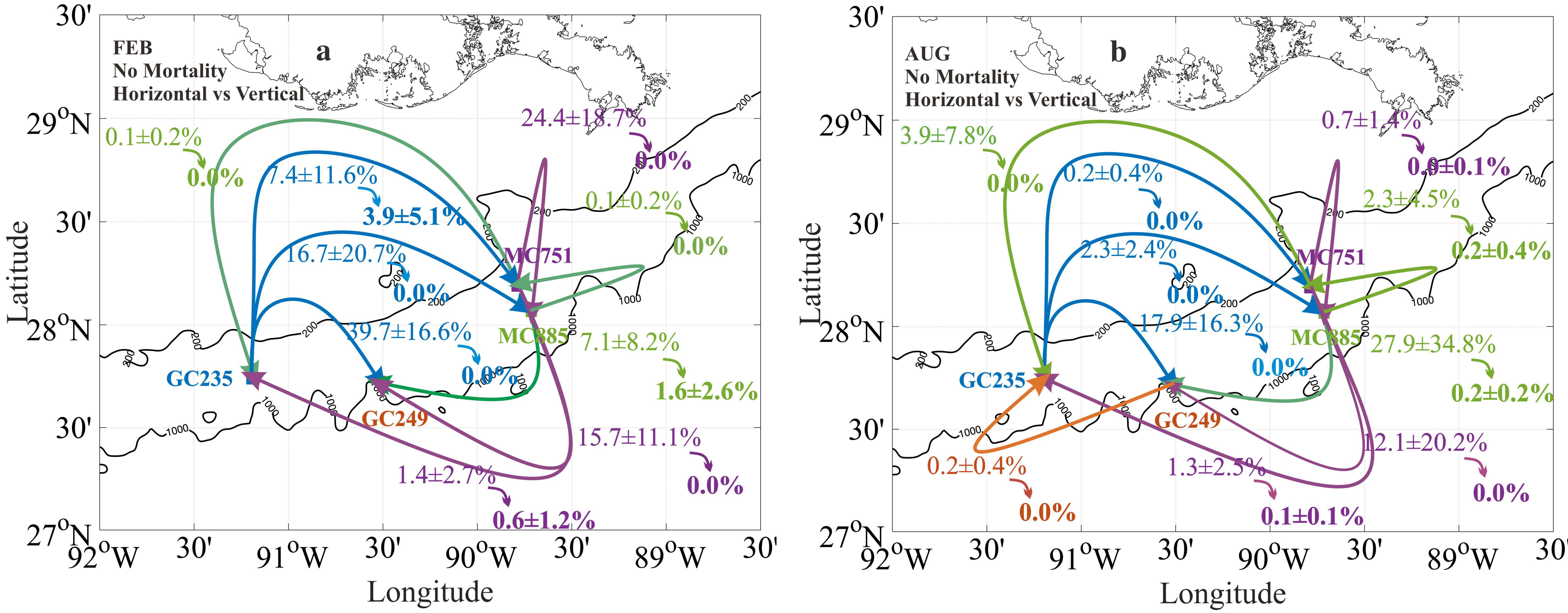
ROMS

1 km horizontal resolution

4 larvae/particle releases in each season in 2015 and 2016



Modeled connectivity



the limited connectivity is controlled by diapycnal mixing

Conclusions

- The new analysis confirms the presence of a pattern of genetic differentiation in *C. delta* across a gradient of depth

- Abiotic gradients associated influence the evolution of deep-sea populations and species

- Future design of protected areas and the Flower Garden Banks expansion should incorporate a variety of depth ranges to capture the diversity within and among vulnerable marine ecosystems