Underwater Perspective of a Storm and the Potential for Forecast Benefits

MTS Oceans in Action/Port Security Summit

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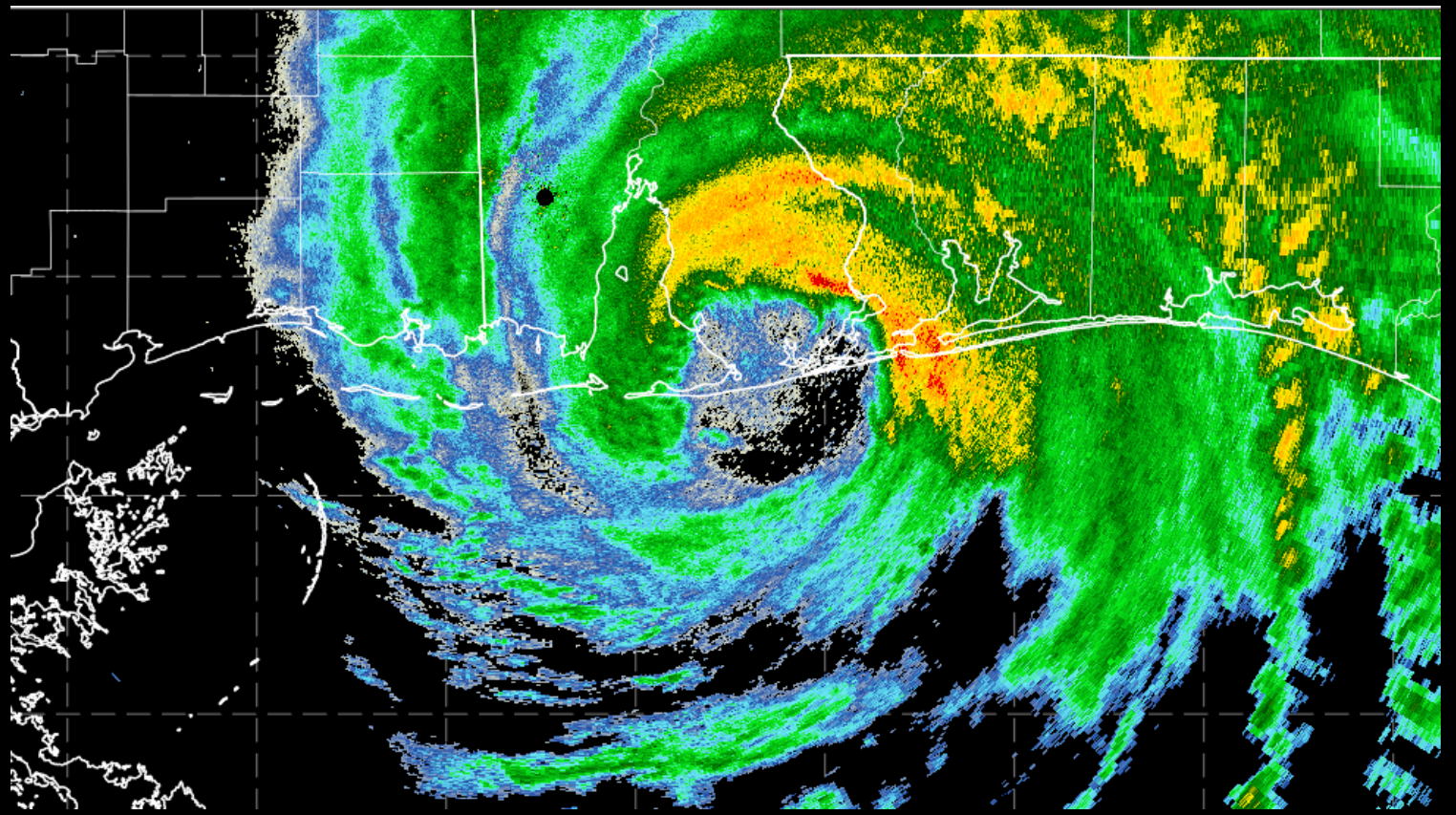


(Image credit: Mark Nissenbaum/Florida State University via https://yaleclimateconnections.org/2020/09/slow-moving-hurricane-sally-gives-coastal-alabama-prolonged-winds-and-storm-surge/)

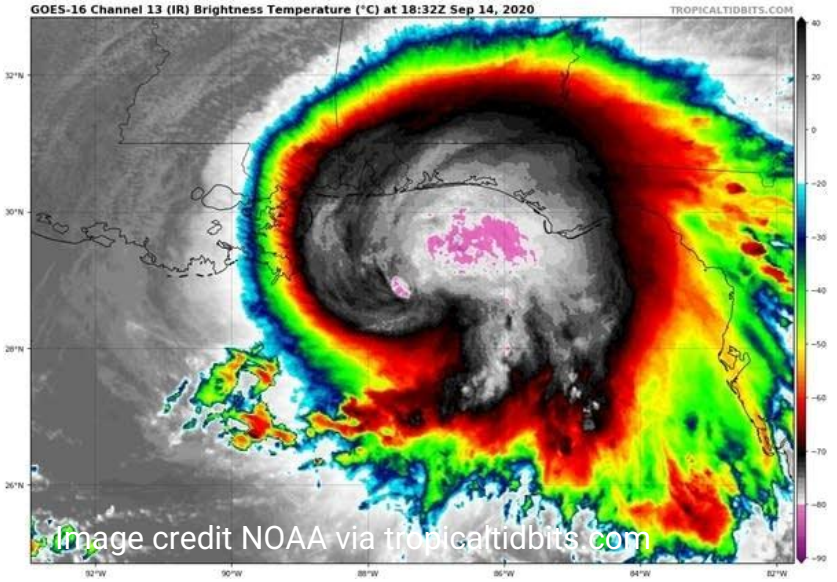
Motivation

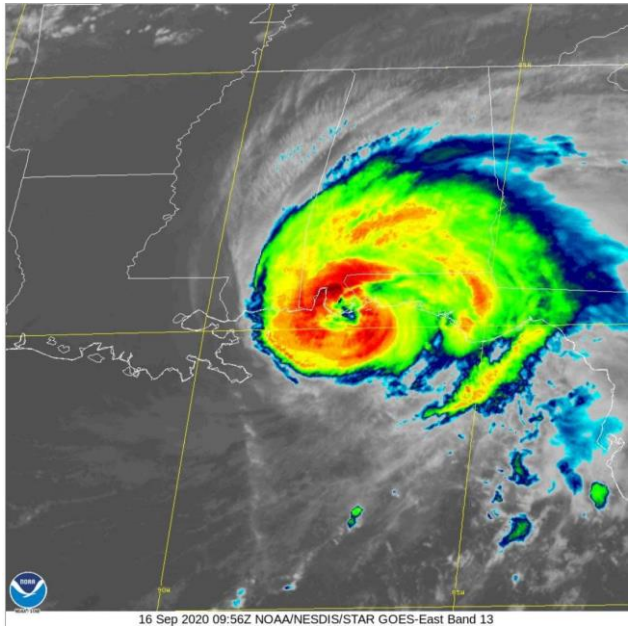
- The accurate prediction of rapid intensification in tropical cyclones is a critical issue in weather forecasting

- Limitations in the understanding of rapid intensification processes constraint society's ability to develop resiliency in the face of a changing climate

- An understanding of shelf conditions and processes that influence rapid intensification in coastal settings are limited

- Ocean is directly connected to storm strength





Objectives: Improve the understanding of compound events that generate ocean conditions favorable for intensification

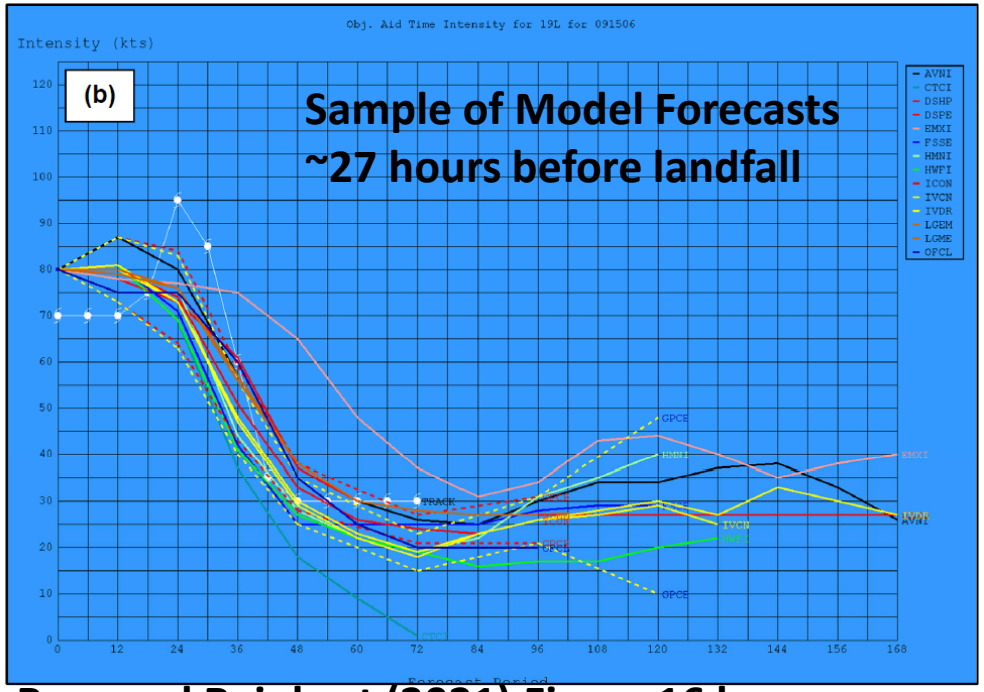
-Focus on warm shelf condition prior to Hurricane Sally (2020)

Study Region

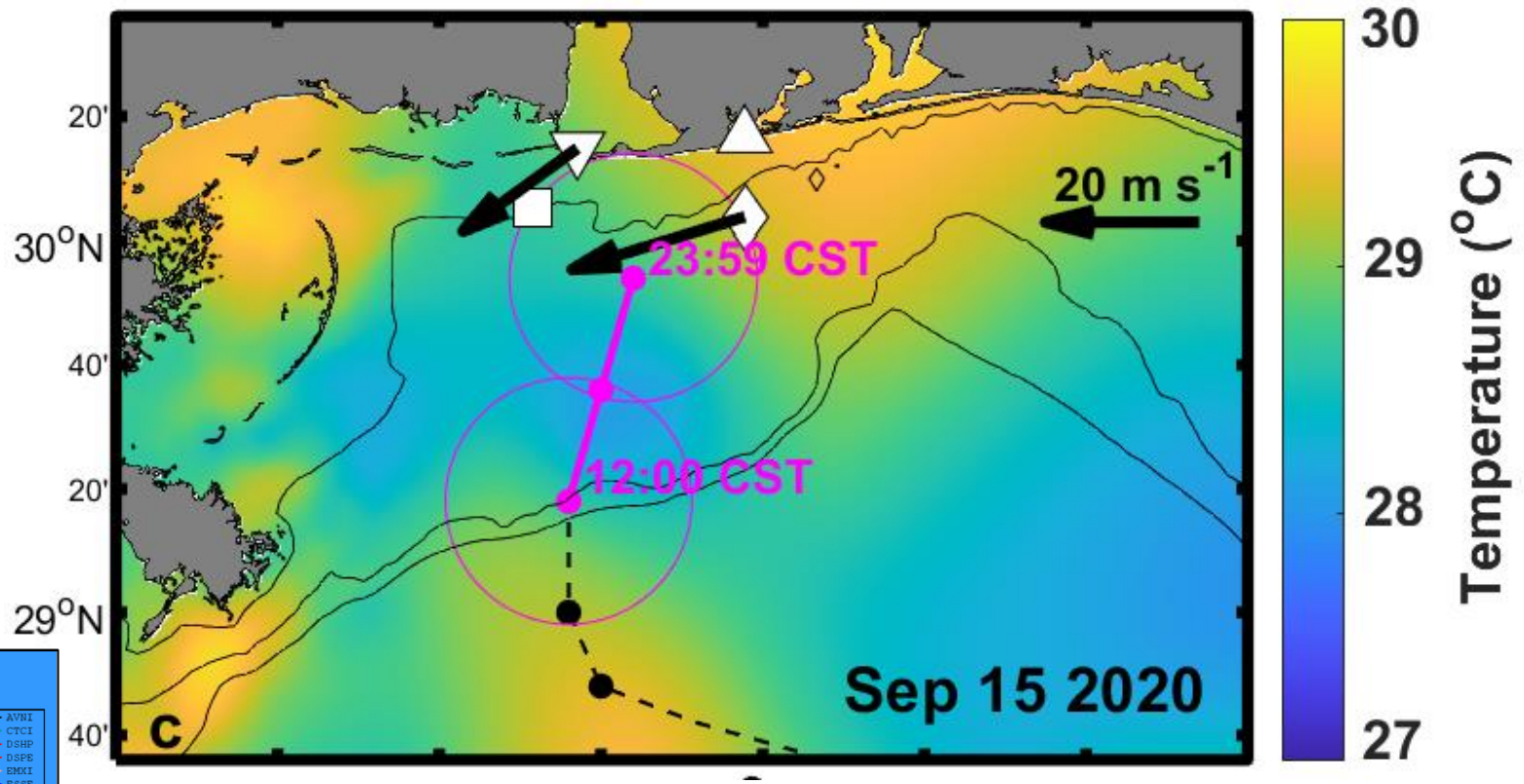
Mississippi Bight
Aug - Sep 2020

Hurricane Sally

Some forecast difficulties
Nearly Cat 3.



Berg and Reinhart (2021) Figure 16 b



Study Region

Mississippi Bight
Aug - Sep 2020

Hydrographic Data

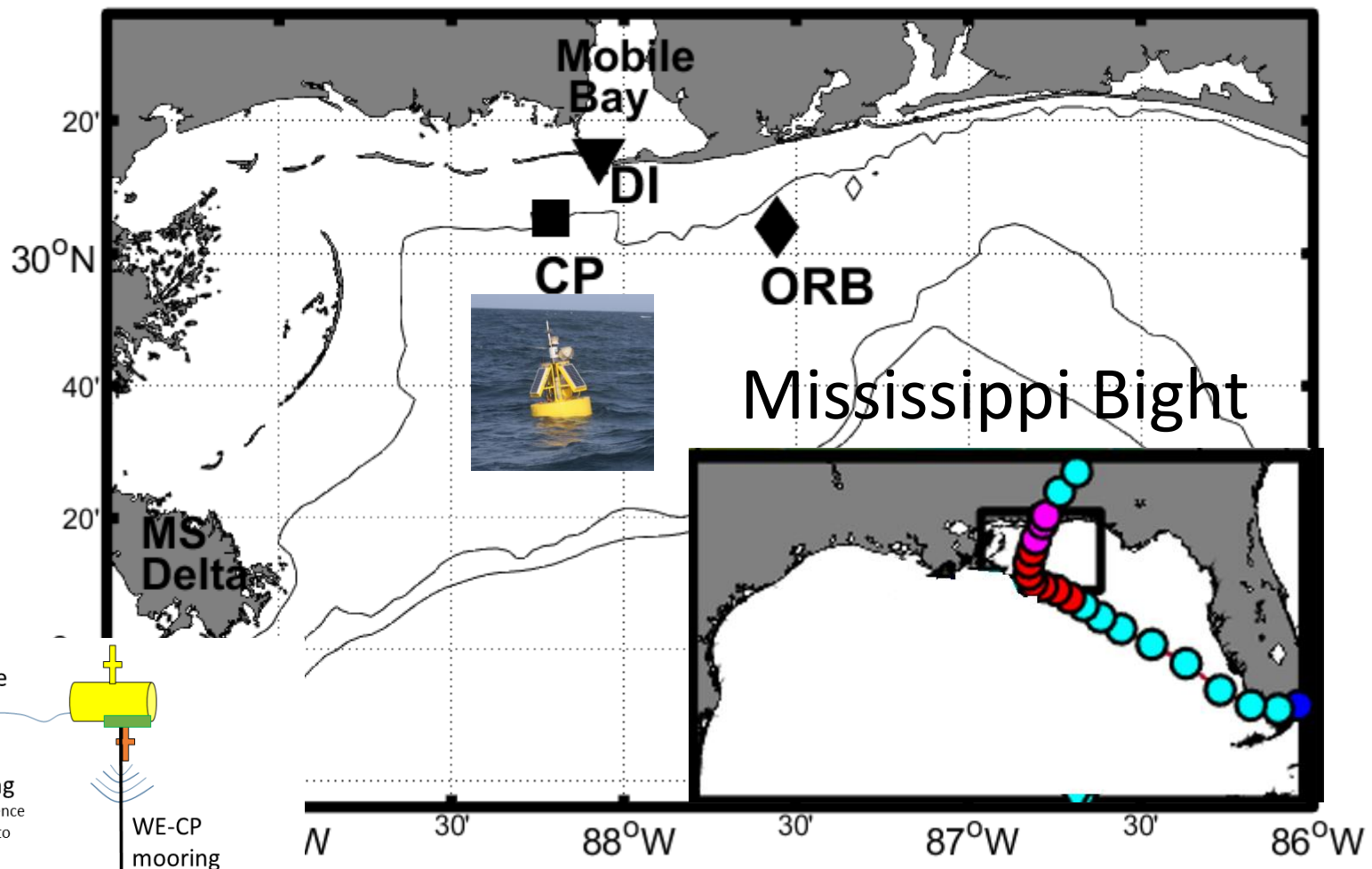
- FOCAL/CP ~ 20 m depth
- Dauphin Island (DI) ~3.0 m depth
- Orange Beach (ORB) ~21.5 m depth

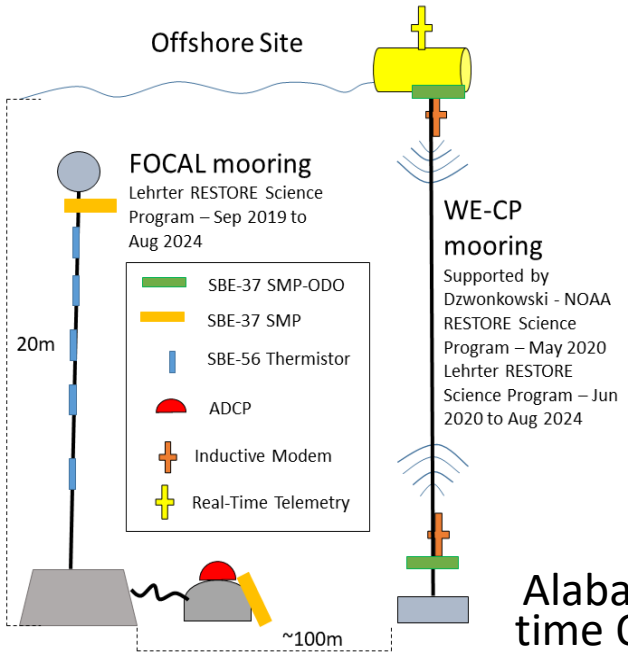
Atmospheric Data

- Dauphin Island (DI)
- Orange Beach (ORB)

Ocean Color Data

- MODIS

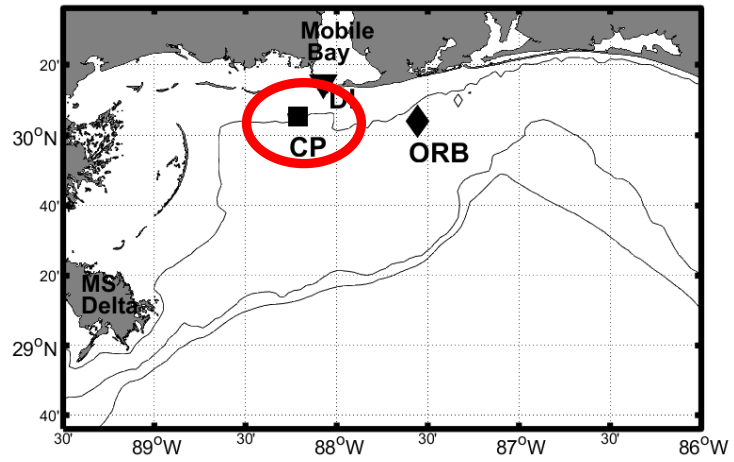


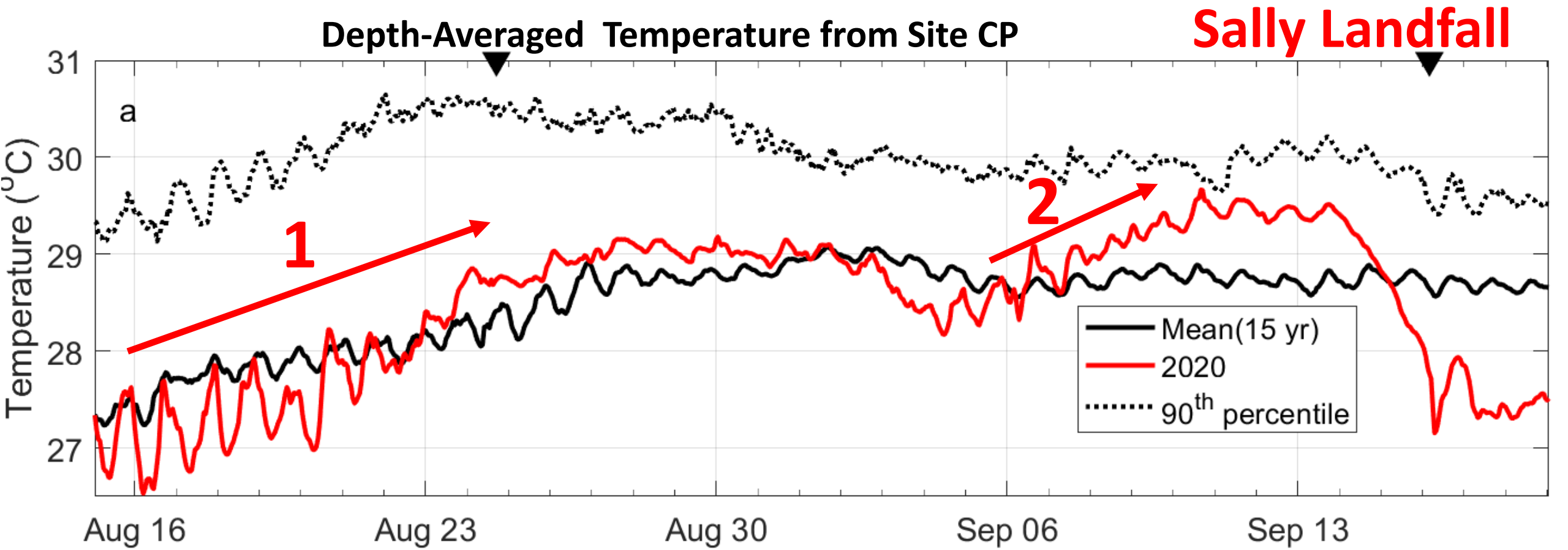


Alabama Coastal Real-time Observing System

Shelf Setup

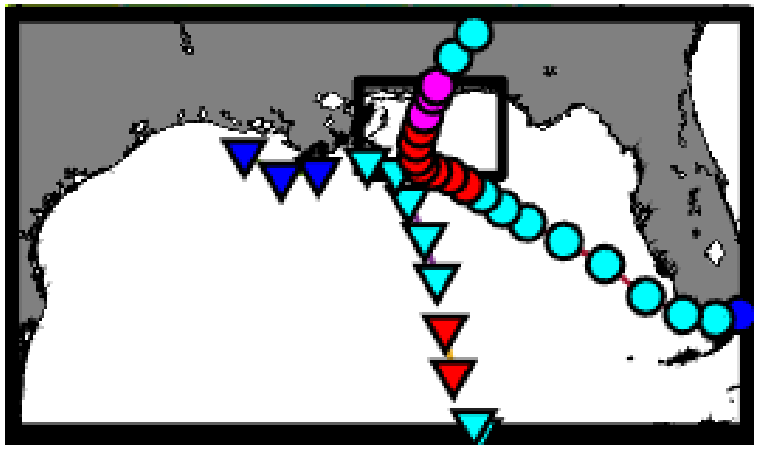
- Shelf heat content at annual peak prior to Hurricane Sally
- Two critical warming periods

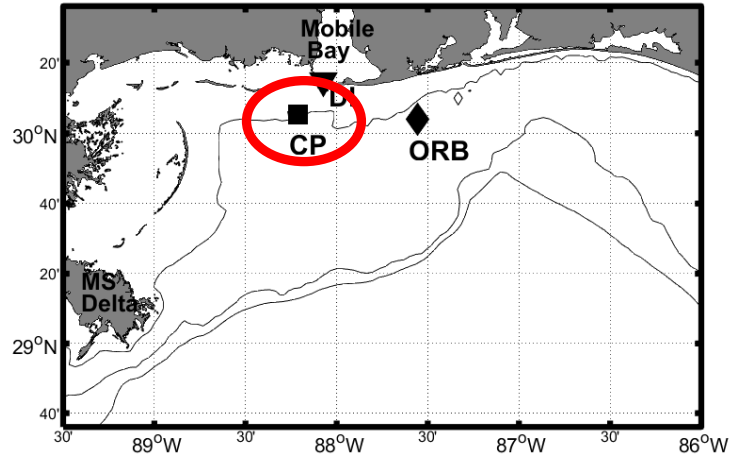




Shelf Setup

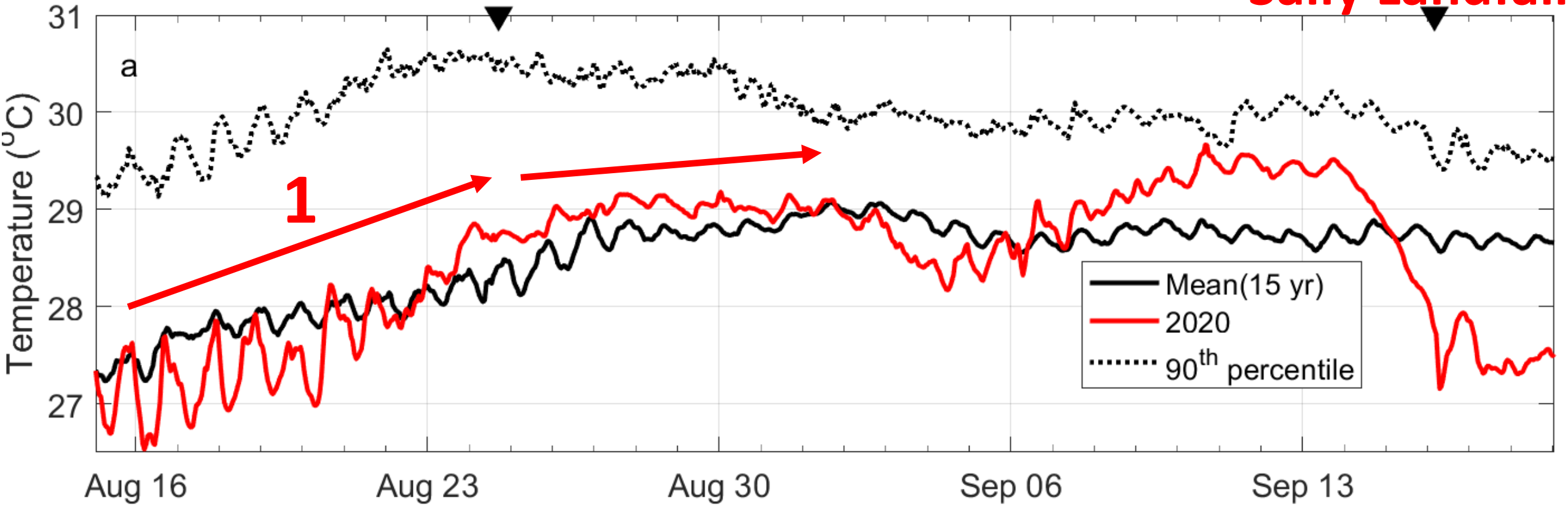
- Warming 1 – occurred prior to Hurricane Marco impacting the area





Passage of Hurricane Marco

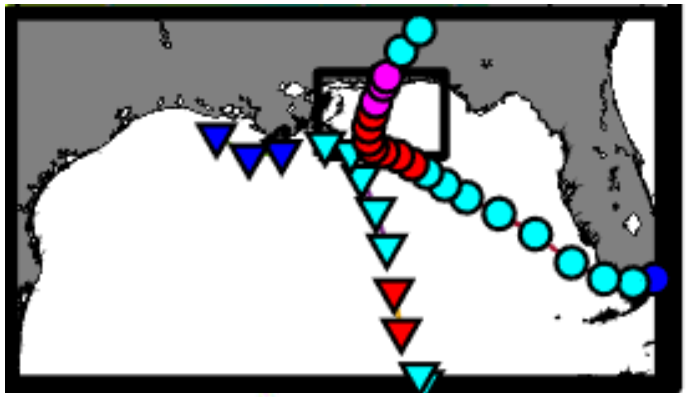
Sally Landfall

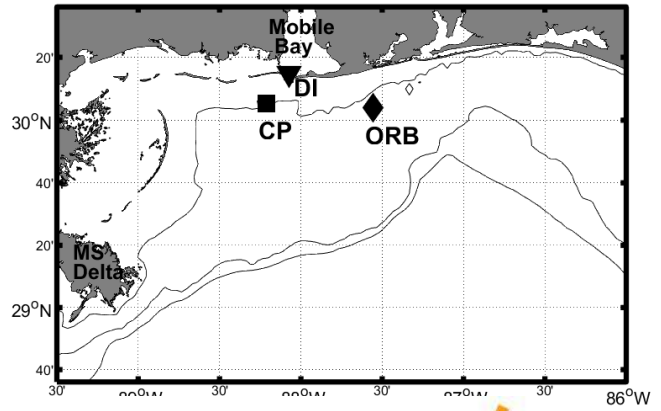


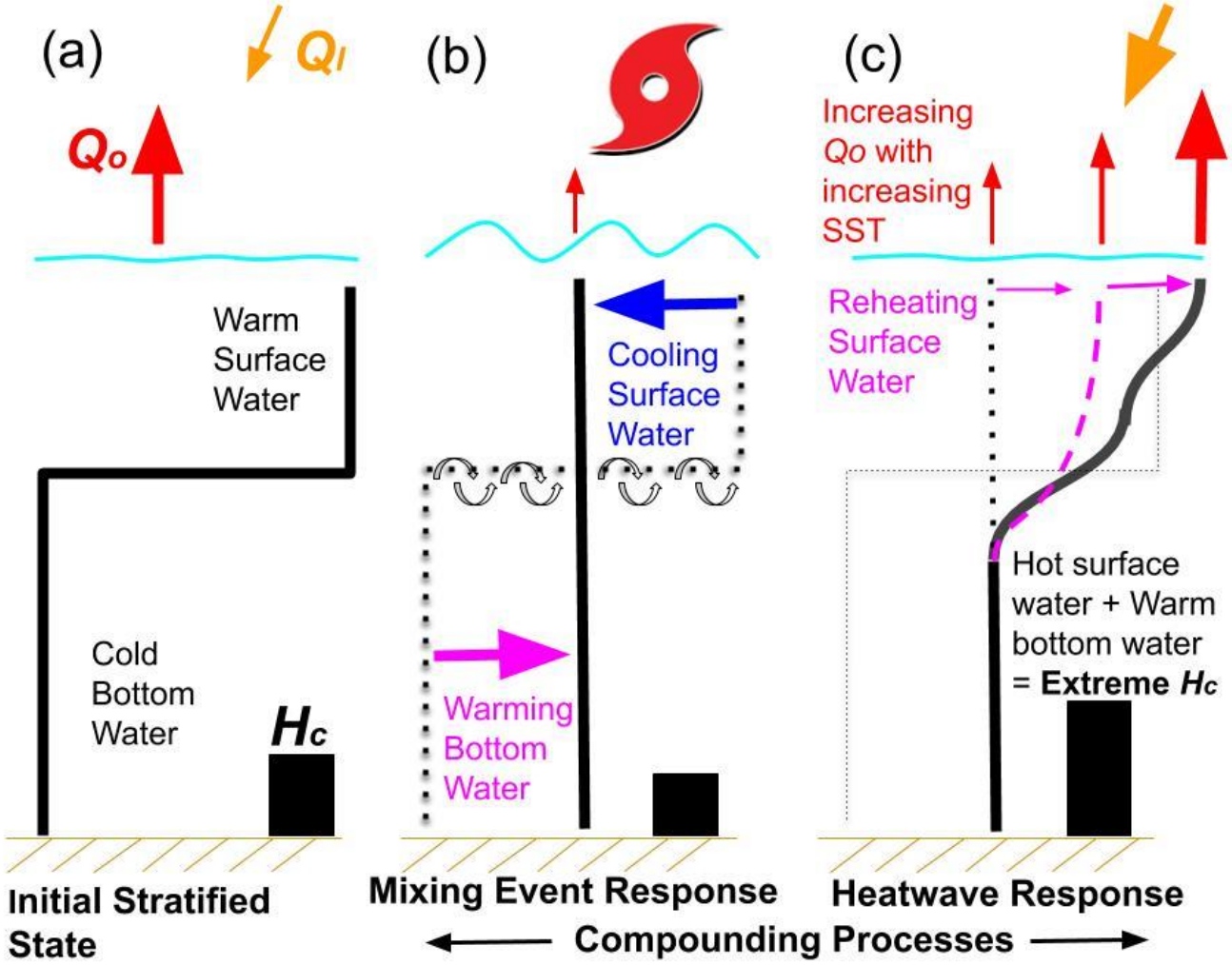
Shelf Setup

- Warming 1 – occurred prior to Hurricane Marco impacting the area

- Provides a chance to explore the finding of **Dzwonkowski et al. (2020)** which put forth a compounding process that amplified coastal heat content prior Hurricane Michael (2018)
  - Storm mixing water column warming bottom
  - Warm weather subsequently reheats the upper ocean
  - Leading **Extreme Heat Content** over the shelf.

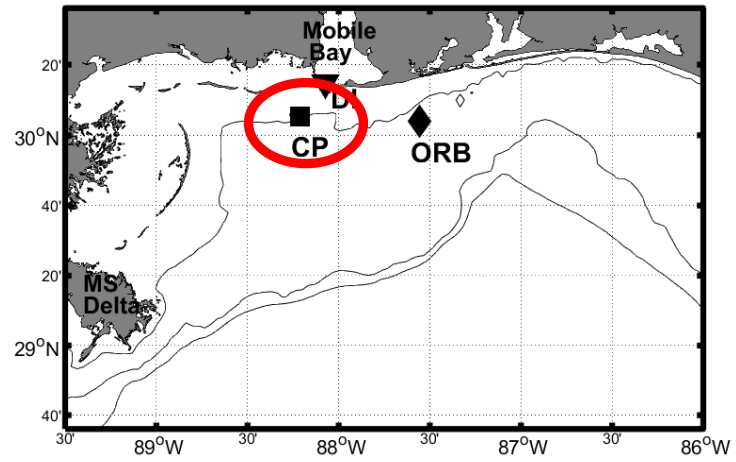


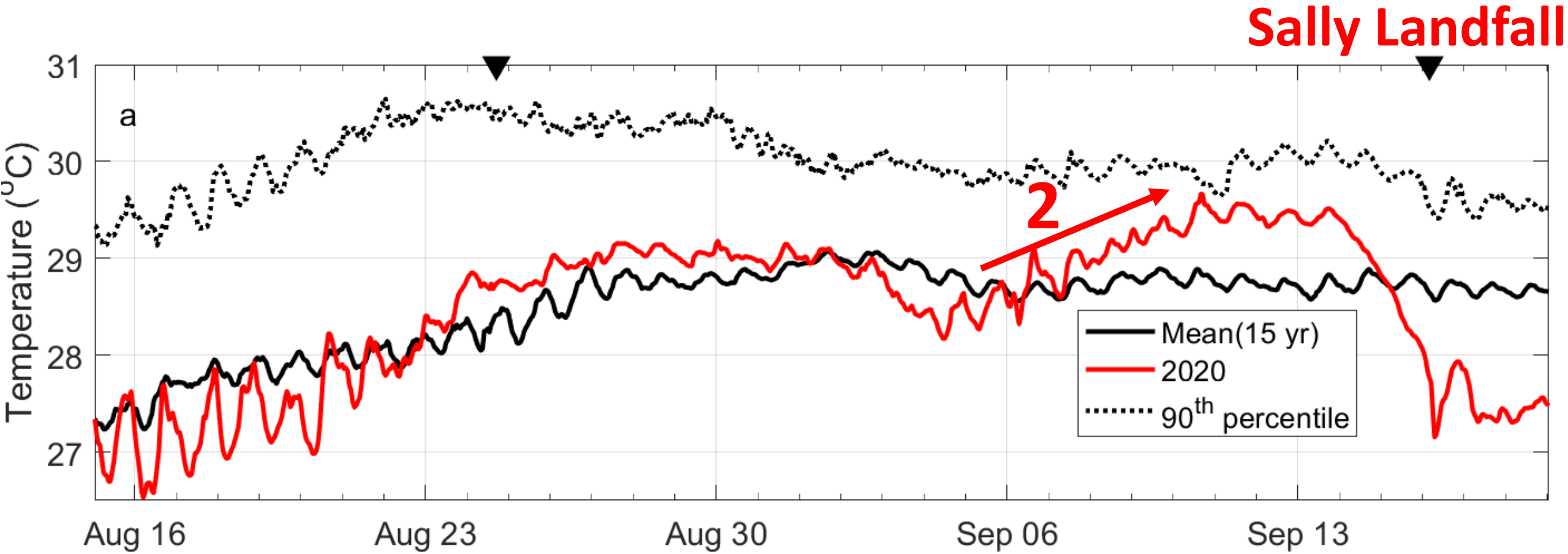




Shelf Setup

- Warming 2 – began 2 weeks prior to arrival of Hurricane Sally and held steady till the direct impact of Sally

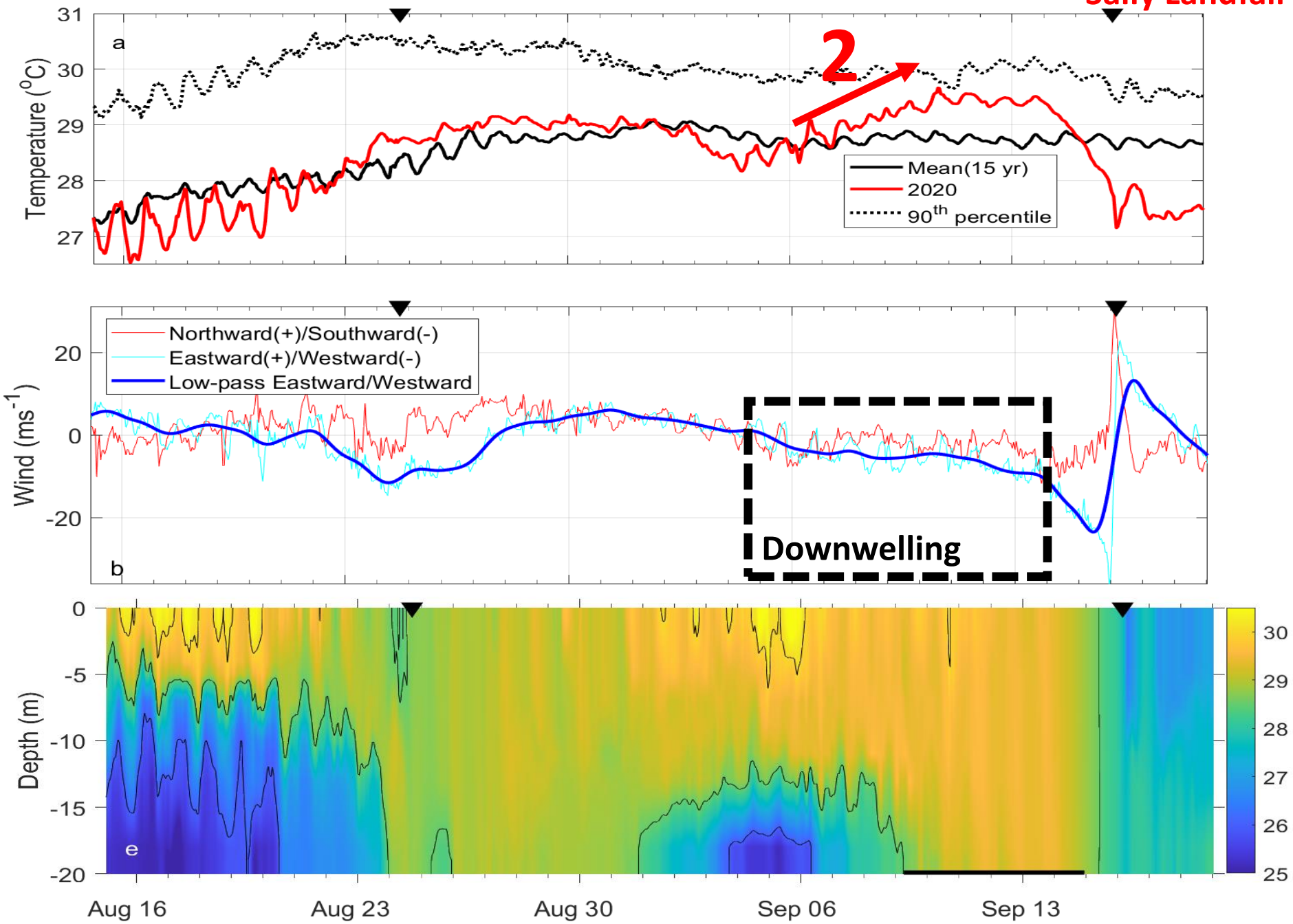




Shelf Setup

- Downwelling induced warming of the inner shelf

Sally Landfall



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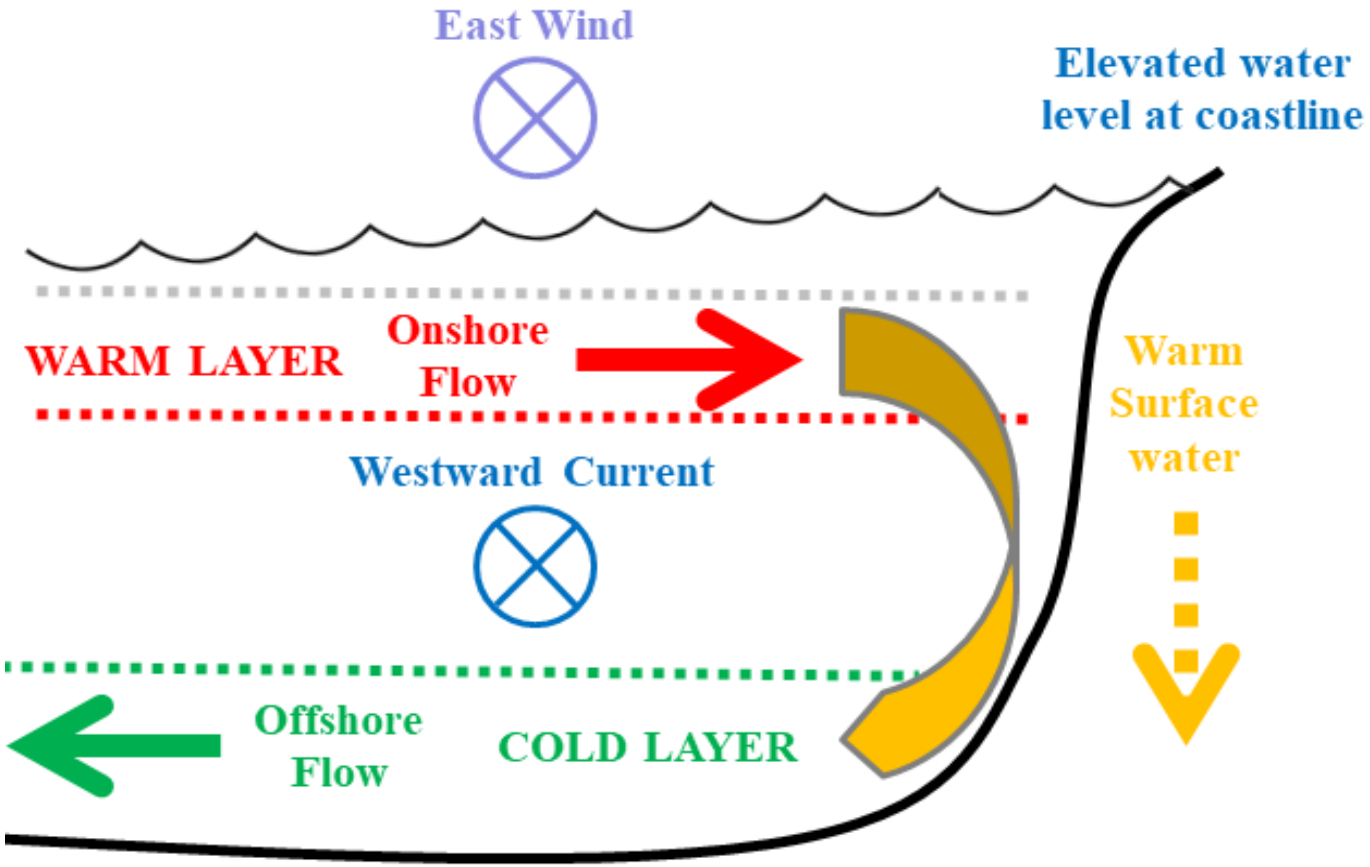

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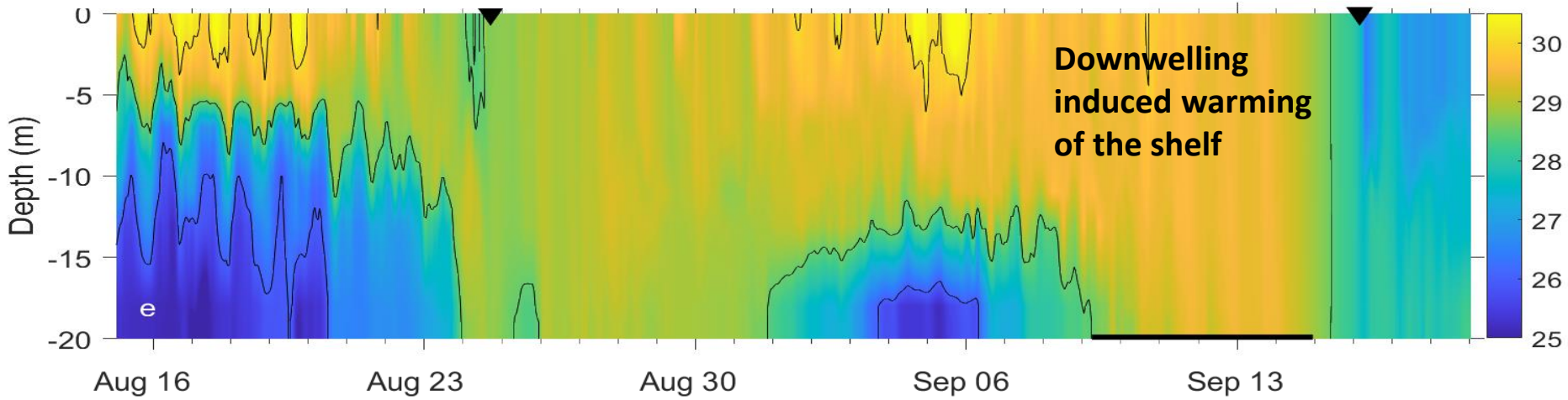
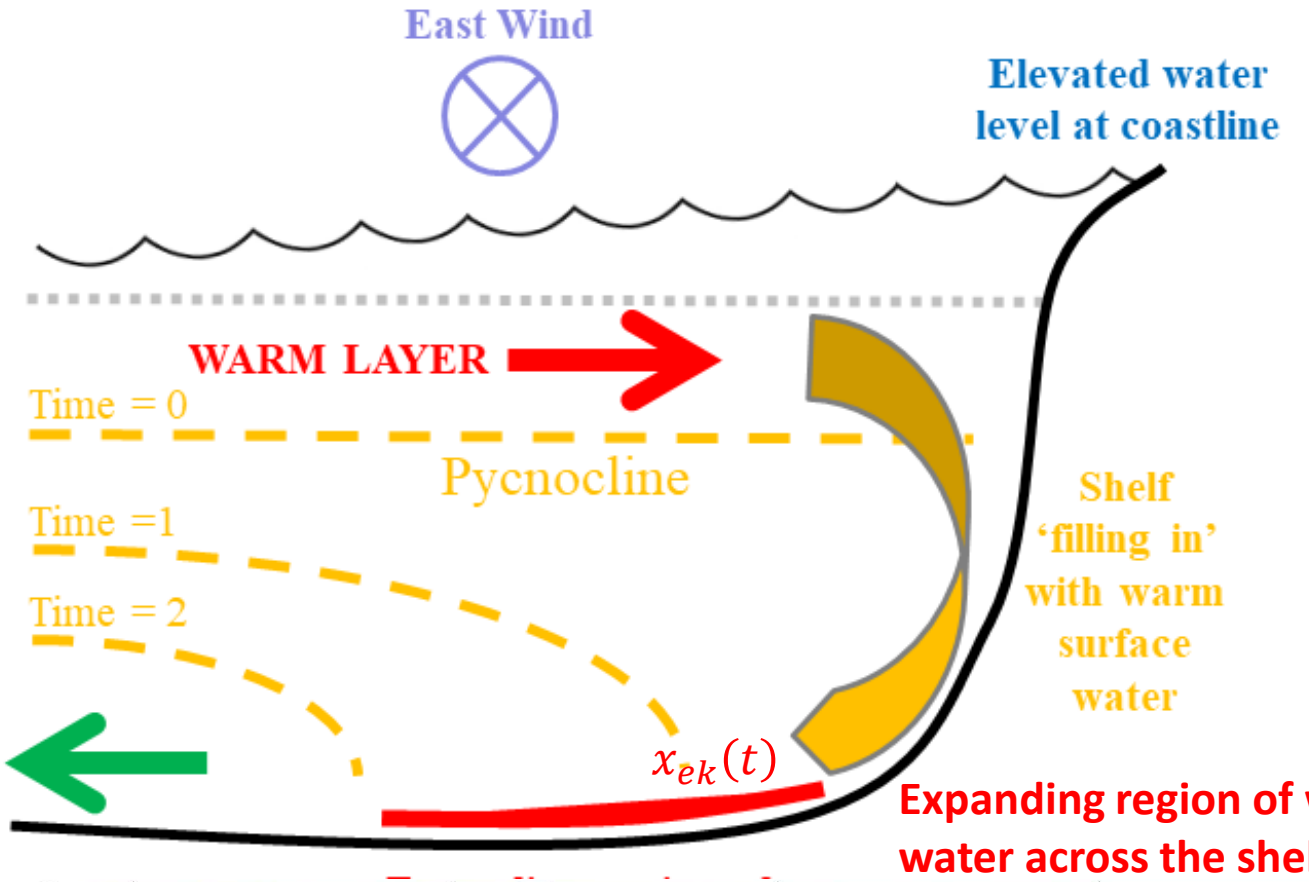


Shelf Setup

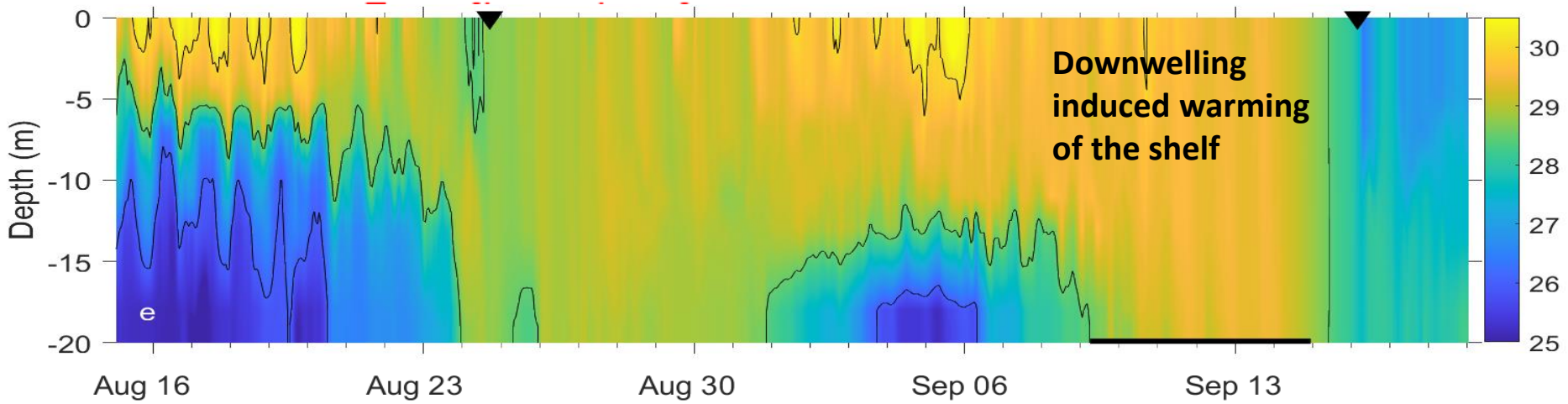
- Downwelling induced warming of the inner shelf
- How much of the shelf was impacted prior to the storm?

$$x_{ek}(t) = X_o + \sqrt{\int_0^t \frac{2 * U_s}{\alpha} dt}$$

Where $X_{ek}(t)$ is the location of the downwelling front (Austin and Lentz, 2001)



Expanding region of warm water across the shelf



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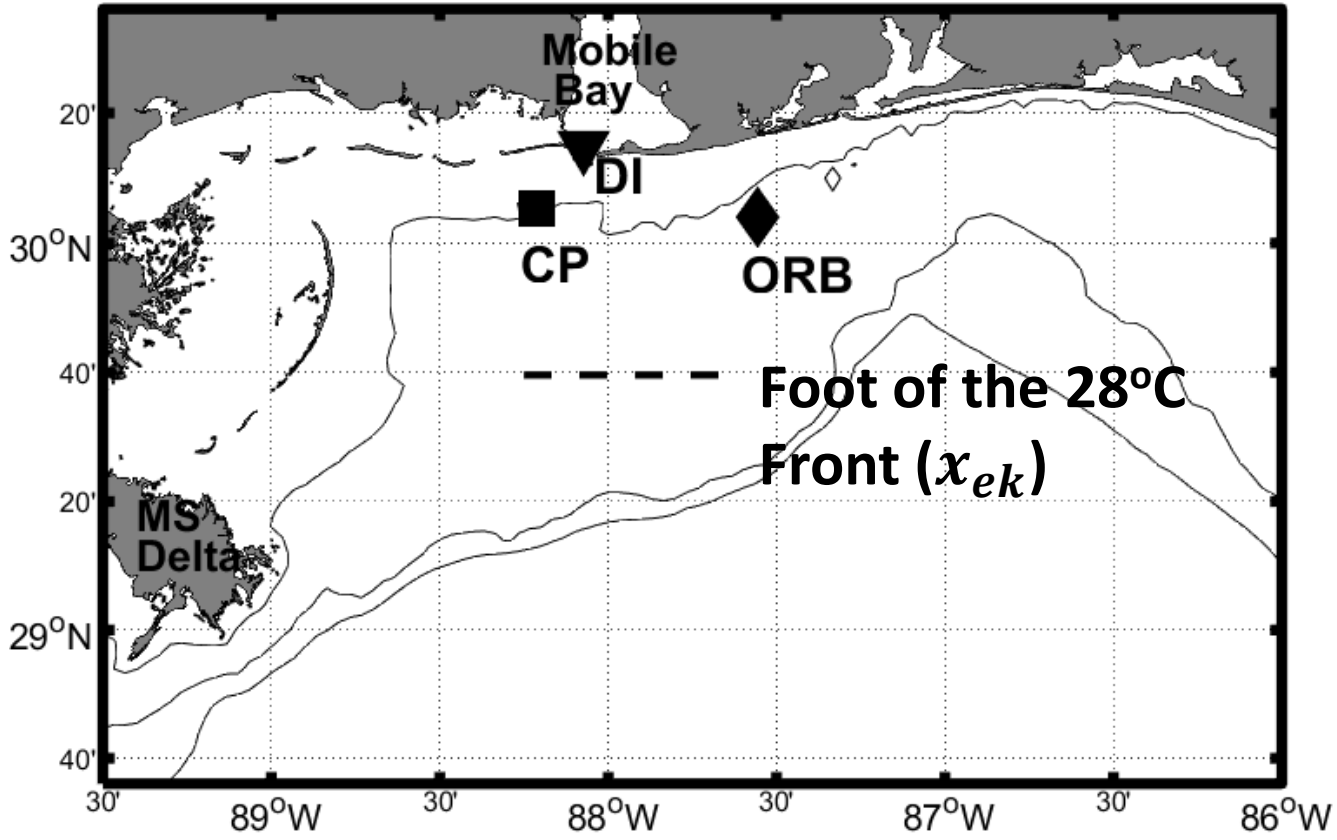
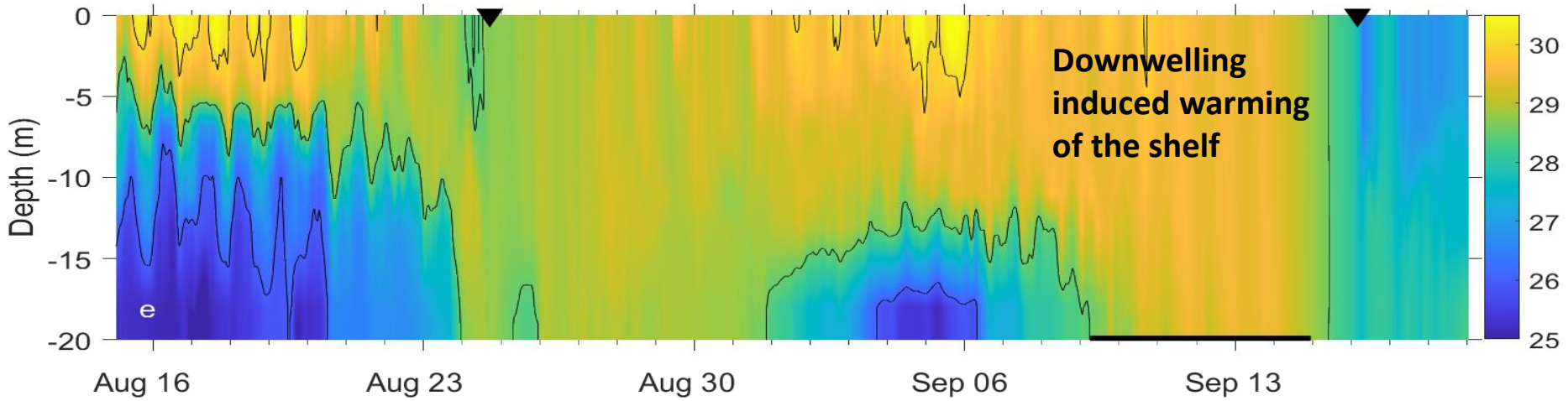
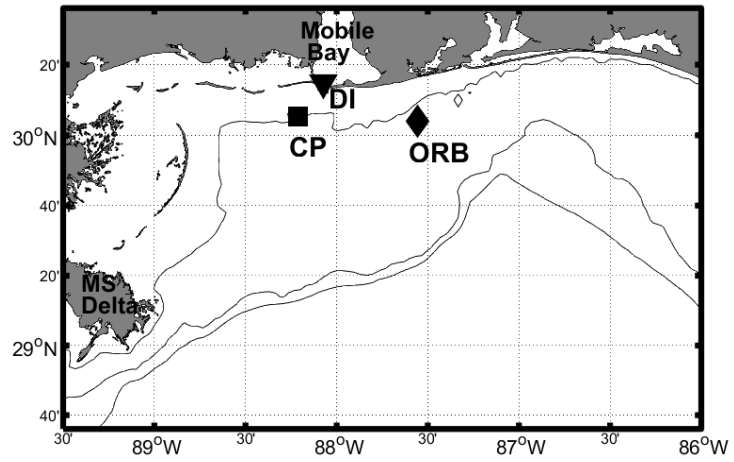




Shelf Setup

- Sequence of events coupled to elevate shelf heat content
- Downwelling winds were critical in both warming periods



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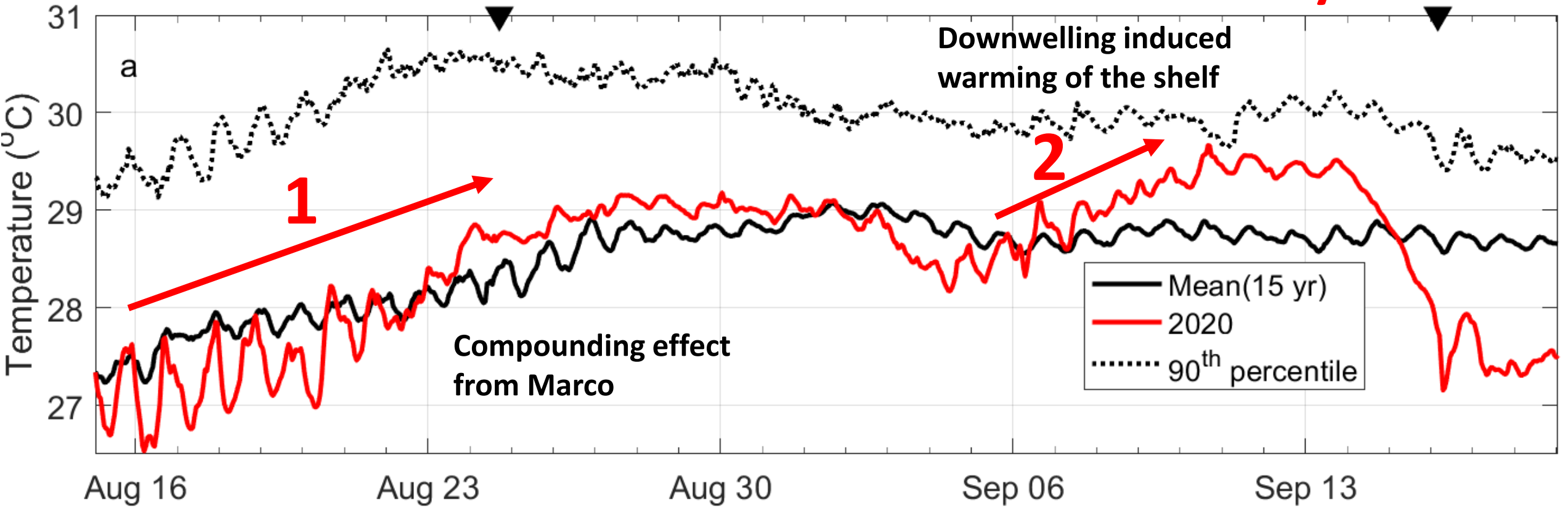
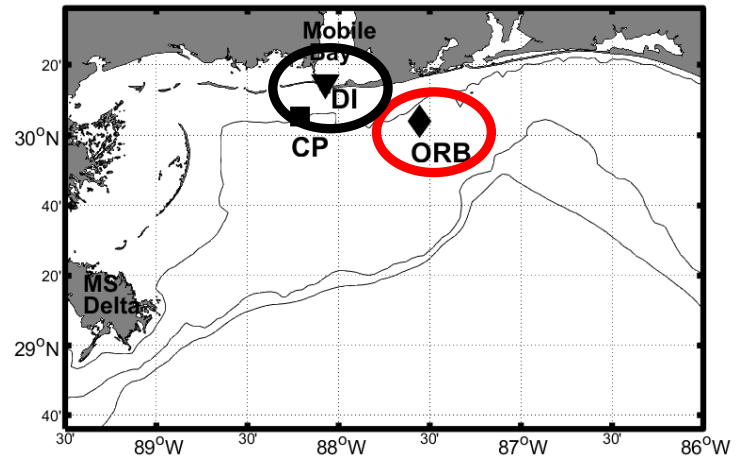
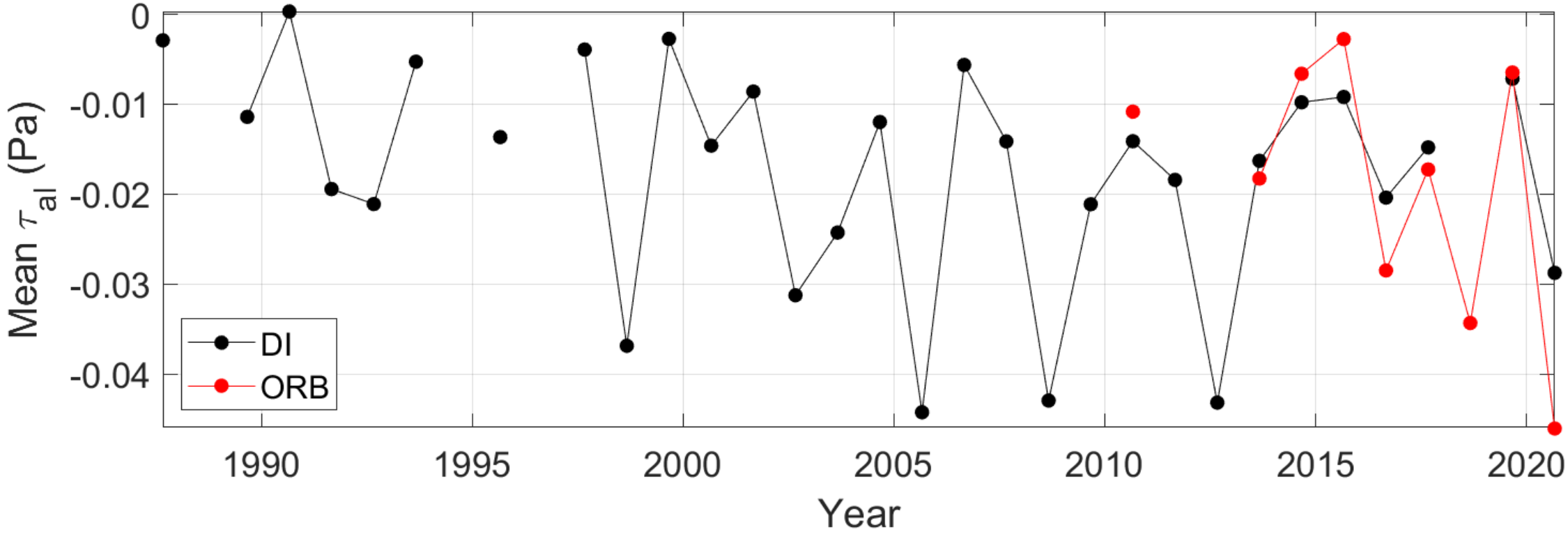


Climatology Coupling

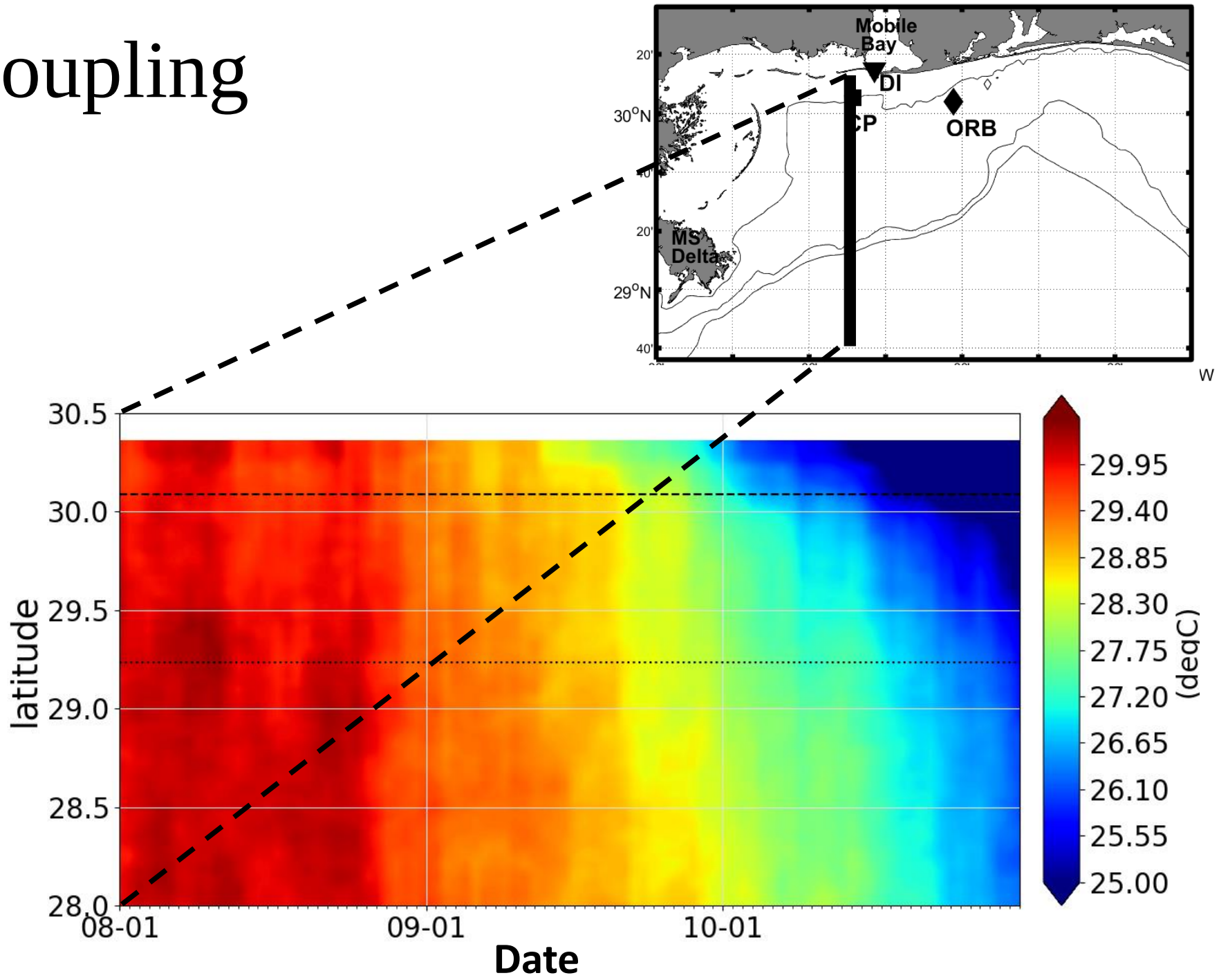
- Local wind data indicates downwelling wind is very common during in Aug 15th –Sep 14th (i.e., downwelling was significant by not extreme)





Climatology Coupling

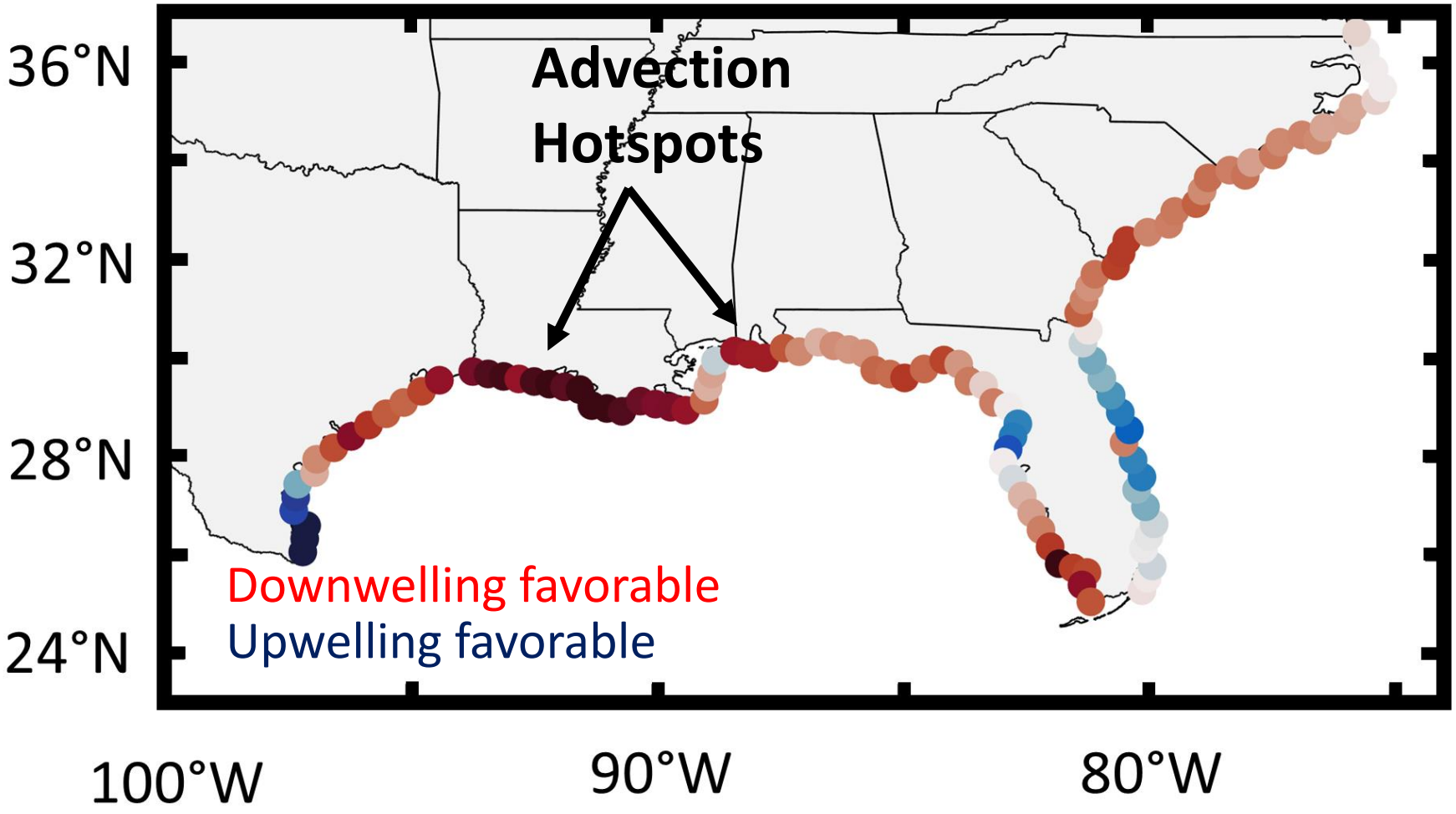
- Fall transition is clear visible
- Offshore temperature stay warmer longer
- Coupled with downwelling winds likely



Broader implications

- Lots of downwelling favorable wind on gently sloping shelves (i.e., wide ‘runways’ for intensification prior to landfall)

- Suggest some coastal regions may have enhance risk from downwelling conditions



Findings

- Annual peak in depth-average temperature occurred prior to shelf transit of Hurricane Sally providing favorable intensification conditions

- Depth-average temperature was set up by a distinct cascade of weather events including persistent downwelling conditions
  - Hurricane Marco – Mixing of upper ocean water minimized any shelf cool pool
  - Persistent downwelling event advected any remaining water far from the coast

- Gulf of Mexico has several ‘hot spot’ for advective shelf warming during the peak of hurricane season

Significance

- Coupling of climatological downwelling winds and warm ocean temperatures suggests an elevated risk of storm intensification over the shelf in some coastal regions.

Questions?

- Brian Dzwonkowski (briandz@disl.org)

Acknowledgements

- Funding Sources

  NOAA RESTORE Program

  NASA Physical Oceanography Program

- Related Manuscripts

Dauphin Island, AL (Sep 16 2020) Courtesy of Caitlin Wessel

Dzwonkowski, B. S. Fourier, G. Lockridge, Z. Liu, J. Coogan, and K. Park (**2021**) Cascading weather events amplify the coastal ocean thermal conditions prior to the shelf transit of Hurricane Sally (2020), *Journal of Geophysical Research - Oceans*. -*126*(12), p.e2021JC017957 - https://doi.org/10.1029/2021JC017957

Dzwonkowski, B. S. Fourier, G. Lockridge, Z. Liu, J. Coogan, and K. Park (**Submitted 2022**) Hurricane Sally (2020) shifts the ocean thermal structure across the inner core during rapid intensification over the shelf, *Journal of Physical Oceanography*. https://www.essoar.org/doi/abs/10.1002/essoar.10509540.1