Impact of compounding atmospheric events on shelf heat content: Potential implications for Hurricane Michael and beyond.

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Introduction

- Resiliency of nature and human systems are tested by extreme events
- Advancing the understanding of extreme events is fundamental to risk and vulnerability assessments
- Tropical cyclones are major concerns for coastal systems in many regions

Objectives:

Improve the understanding of the compounding processes that set up environmental conditions conducive to extreme storms in coastal systems

Focus on:

Shelf heat content - a critical driver of storm intensity

Demonstrate a novel sequence of compounding atmospheric events that can set up extreme temperature conditions on the shelf (i.e. a marine heatwave)

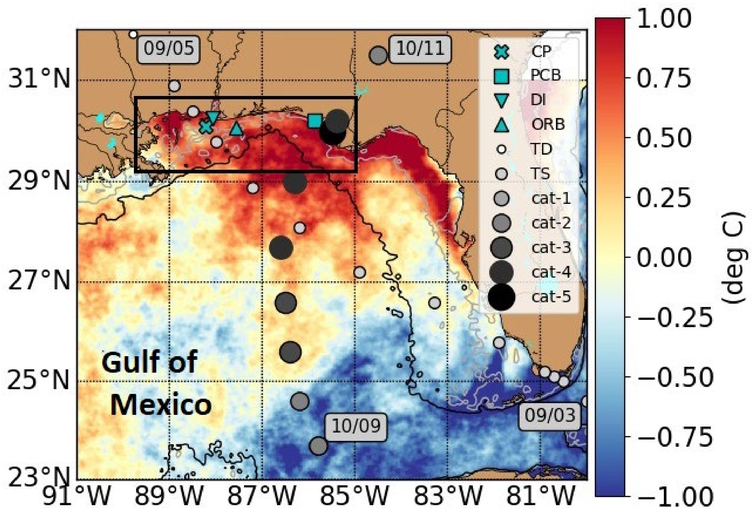

Fig. 1 Map of the northeast Gulf of Mexico with 10-day averaged high resolution (1 km) SST anomalies relative to a climatological mean (2003-2014) plus two standard deviations from September 29-Oct 7th, the period of time identified as a marine heatwave. Included are storm tracks for Tropical Storm Gordon (lighter greys) and Hurricane Michael (darker greys) with reference dates as well as location of insitu observations: site CP (CP, **X**), DPIA (DI, ▲), Orange Beach Buoy (ORB, ▼), and Panama City Beach Fishing Pier (PCB, ■). ***:NOTE: Results are consistent with OISST data and marine heatwave detection methods of Hobday et al. 2016.***

Data and Methods

- Time series data of regional oceanographic and meteorological conditions
- Satellite-derived Sea Surface Temperature and Salinity
- Reanalysis data (NARRS)
- Basic times series analysis techniques including ensemble averaging
- Use of standard heat flux algorithms (TOGA-COARE and Simpson and Bower 1984)
- One-dimensional vertical model
  - Post storm conditions
  - 'Twin' experiments (stratified vs mixed)

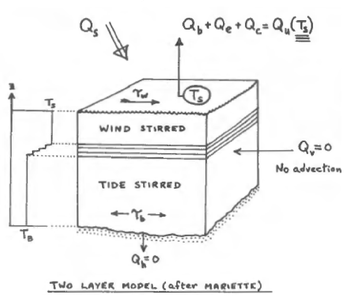

Fig 1. from Simpson and Bowers 1984

Hurricane Michael

- Occurred in early October of 2018 – late in the hurricane season
- Intensified through landfall reaching Category 5 strength
- Intensification was not consistently predicted
- Latest and strongest storm on record to hit the Florida Panhandle
- Caused 16 fatalities and ~$25 billion in damage

Extreme events

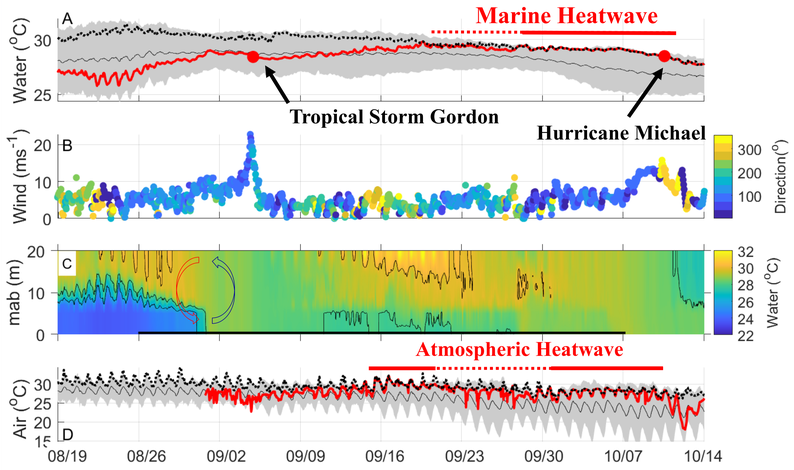

*Fig. 2: Time series from Fall of 2018 for (A) depth-averaged temperature, a proxy for heat content, with the 13-year mean and standard deviation at site CP (B) wind magnitude and direction (coloration) from the NOAA NBDC ORB station, (C) vertical temperature structure at site CP (D) air temperature from DI station with the 32 year mean and standard deviation. In (A)and (D), thin black line = long-term mean, dotted line = maximum observed value, and grey shading = 2*STDs.*

- Prior to landfall of Hurricane Michael shelf heat content was in an extreme state
- Depth average temperature experience two heating event that lead to extreme temperature conditions in late September in 2018
- Tropical Strom Gordon mixes heat downward, removing colder bottom waters
- Atmospheric heat wave from mid-September and very warm condition through early Oct allow for full water column marine heatwave to develop across the region

Compound event

- Simple 1-D model represent key features in the observations
- Model runs show that mixing event is key to extreme conditions
  - Transports heat downward
  - Enhances surface re-heating efficient (lowers SST and SST warming)
- Response depend on hydrographic condition and depth

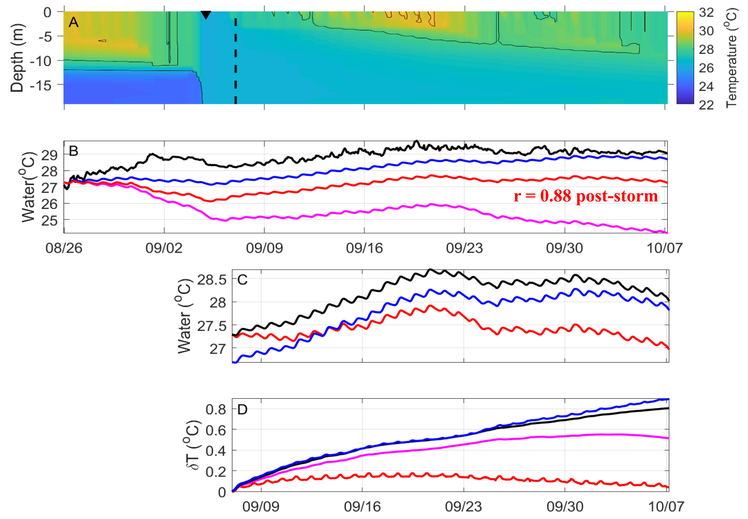

Fig. 7 Time series of model outputs including (a) model temperature structure using Simpson and Bowers 1984 heat flux parameterization, (b) observed and modeled depth-averaged temperature from the three modelled heat flux parameterizations, (c) depth-averaged temperature twin experiments using the observed initial temperature structure on August 26 and the S&B (1984) heat flux parameterizations, and (d) Depth-averaged temperature difference between the mixed and stratified model runs using an idealize temperature structure and different water column depths.:

Evidence of Regional Impacts

- Satellite SST and SSS data indicate mixing occurred over entire MS Bight Region
- PCB SST data consistent with changes in SST at site CP
- Factors suggest extreme heat condition impacted region (i.e., Hurricane Michael track)

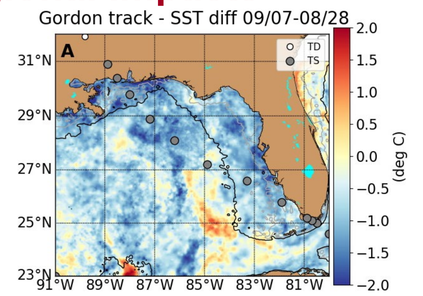

Fig. 4. SST difference before and after Tropical Storm Gordon

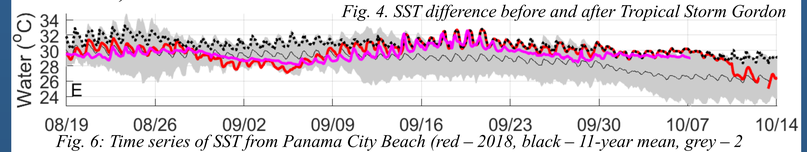

Fig. 6: Time series of SST from Panama City Beach (red – 2018, black – 11-year mean, grey – 2 STD, and dotted is maximum observed) and site CP (magenta – 2018).

Conclusions

1. Novel perspective of an extreme marine event (using long-term water column data), a challenging environment to obtain such measurements.

2. New mechanisms (via compounding events) for generating extreme conditions are identified that can impact significant portions of the global coastal ocean

3. Extreme heat content events have significant implications for a range of scientific and management interests (e.g. coral bleaching, hypoxia)

4. Impact and frequency of this type compounding event should increase under expected climate change conditions

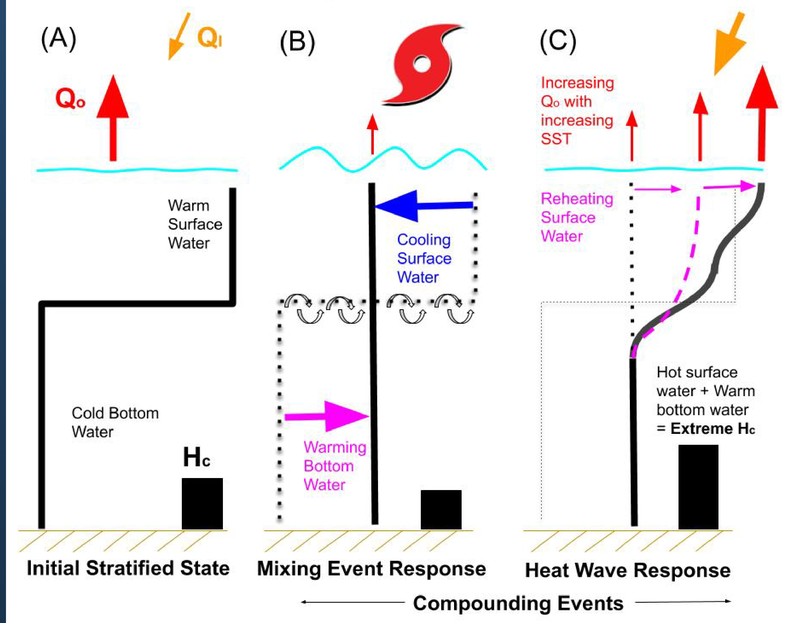

Fig. 6: Conceptual diagram demonstrating the compounding events that can drive in extreme shelf heat content

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