

*40-year temperature trend*

# Drivers of Marine Heatwaves in the Northwest Atlantic

Hillary Scannell, PhD

[scannell@ldeo.columbia.edu](mailto:scannell@ldeo.columbia.edu)

**Lamont-Doherty Earth Observatory**

COLUMBIA UNIVERSITY | EARTH INSTITUTE

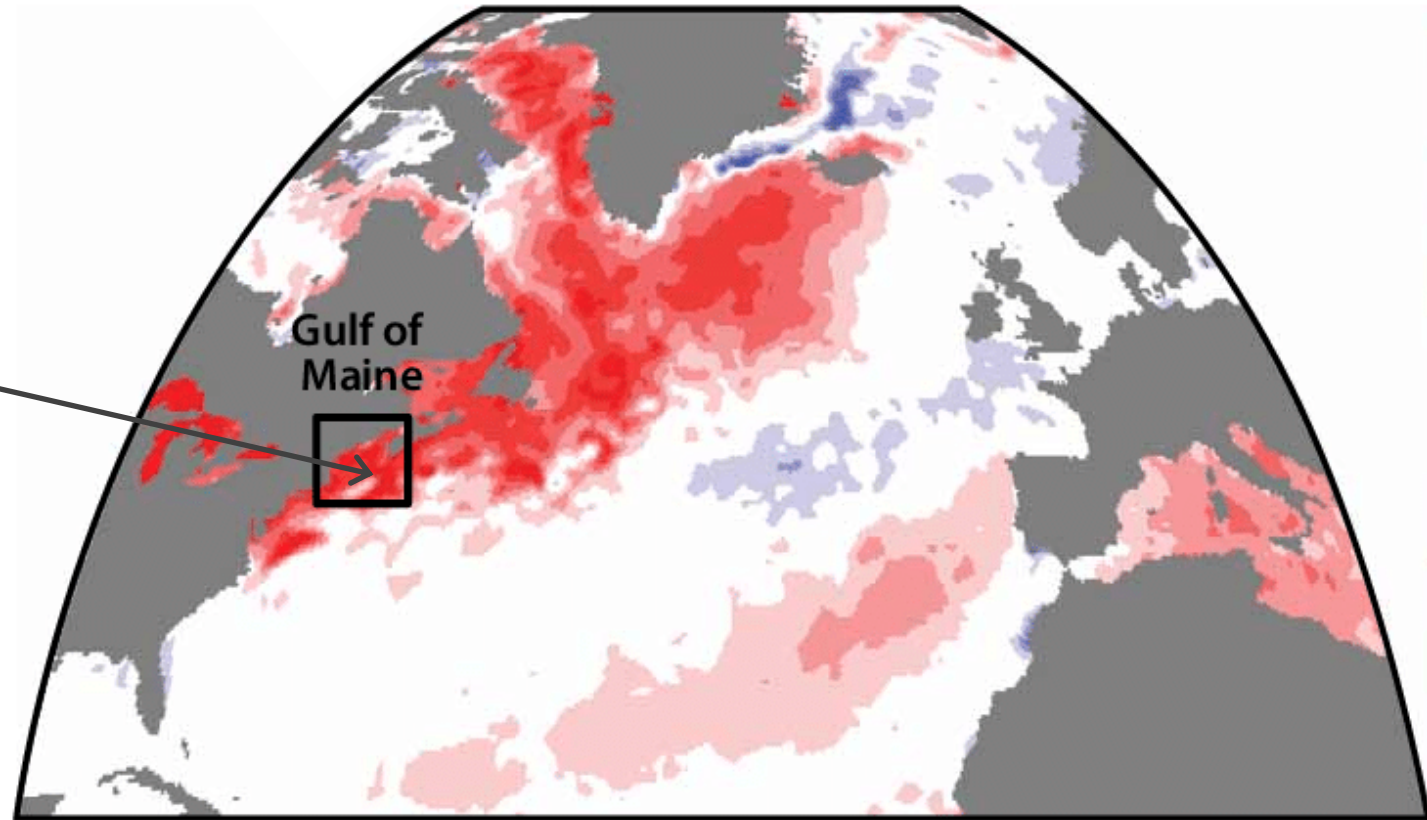
**Marine heatwaves** are prolonged discrete anomalously warm water events

Hobday et al., 2016

**Northwest Atlantic Marine Heatwave**  
Summer 2012



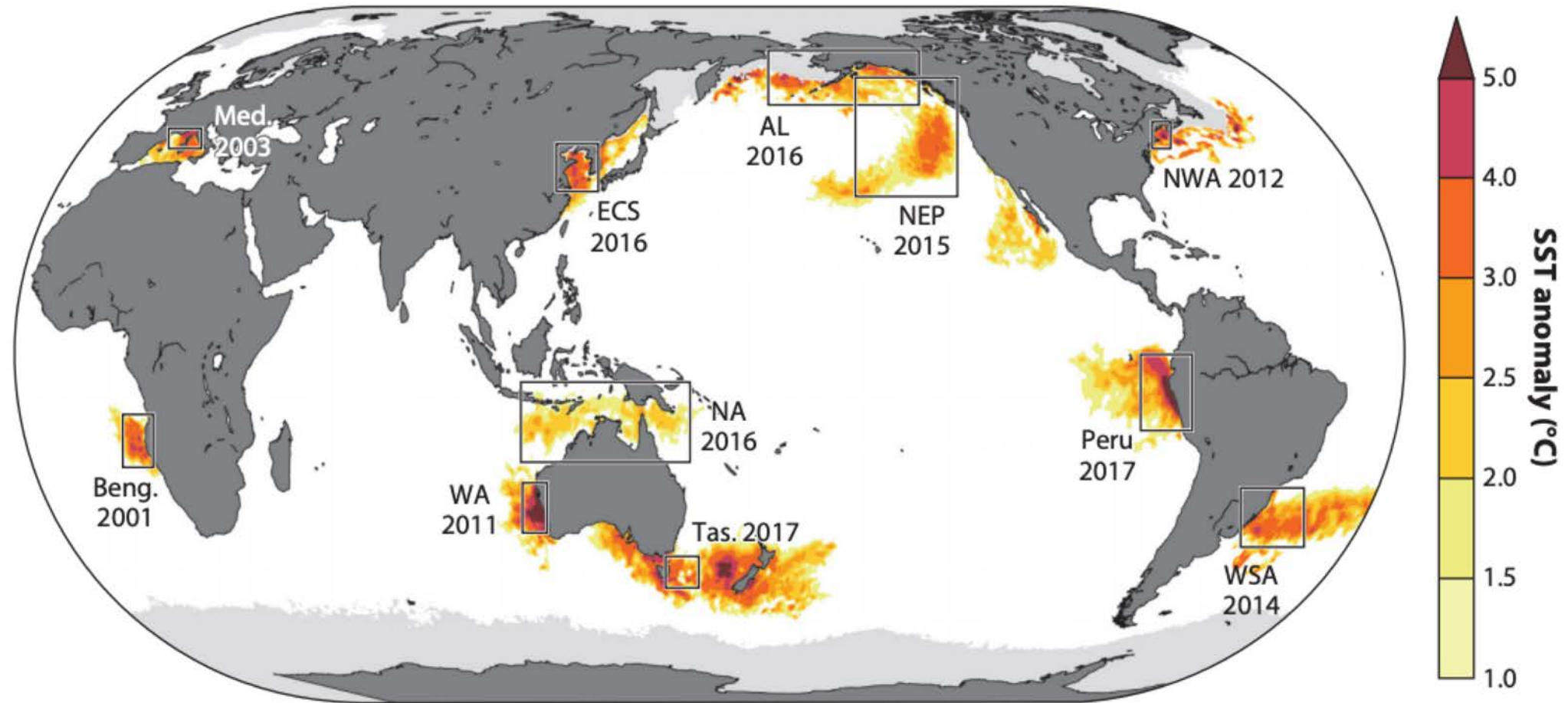
June – August 2012



Temperature anomaly (°C) relative to 1982–2011 climatology

Mills et al., 2013

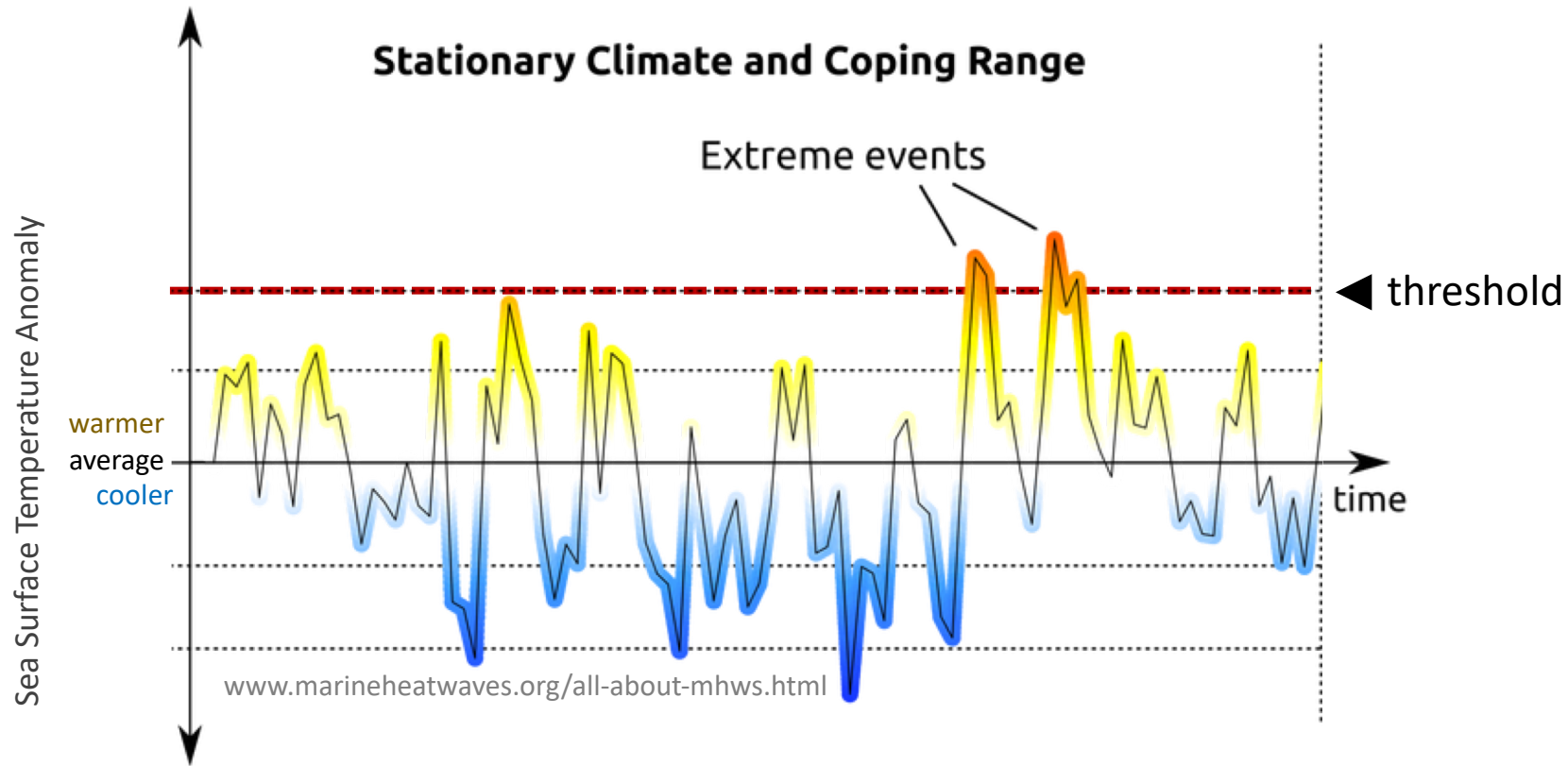
## Prominent 21<sup>st</sup> Century marine heatwaves



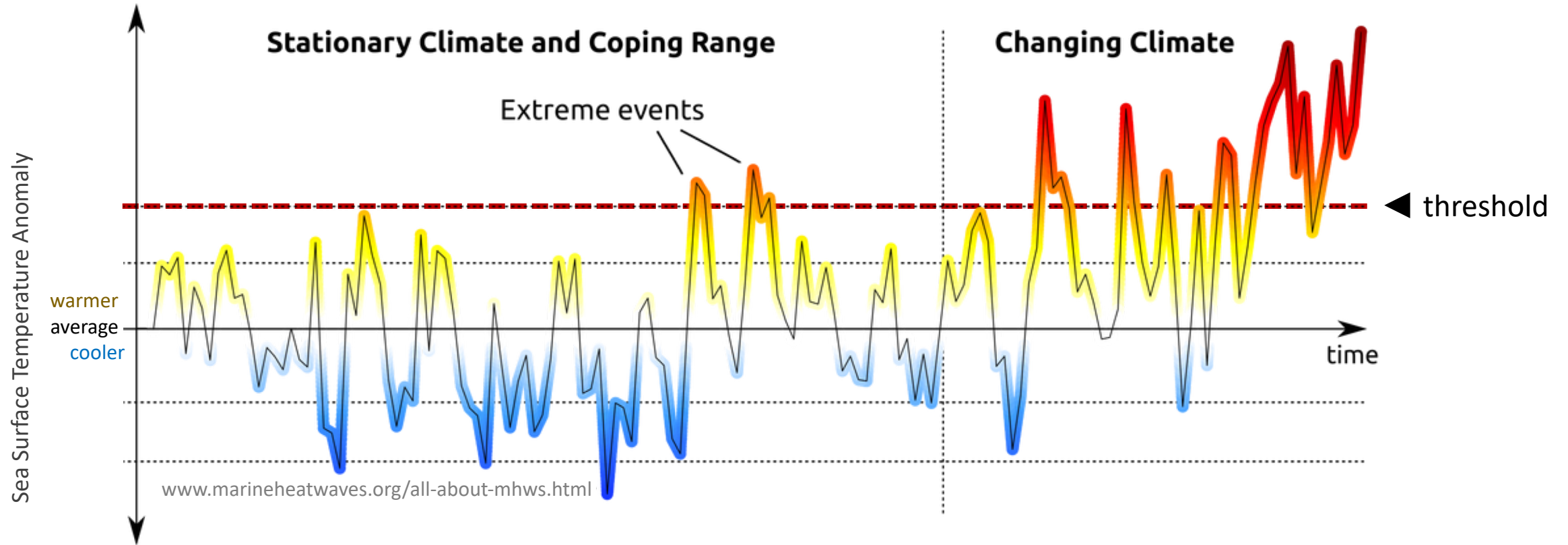
Oliver et al. 2020



Natural temperature fluctuations can cause extremes that most species can cope with

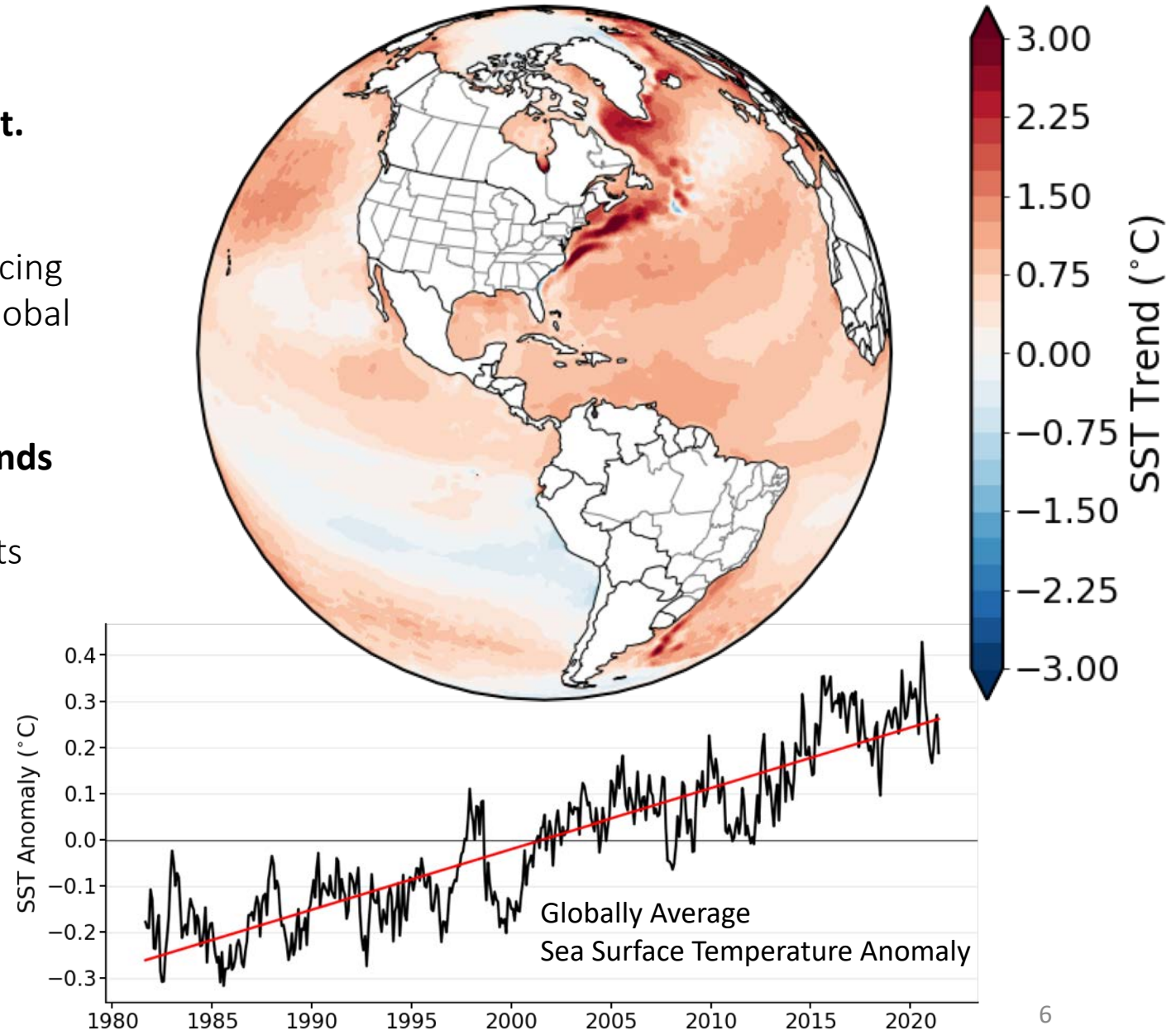


As temperatures rise, heat extremes become more deadly



## 1981–2020 Trend in Sea Surface Temperature

- Warming temperatures make marine heatwaves **longer lasting, more intense, and more frequent**.  
Oliver et al., 2018
- Northwest Atlantic shelf-slope region is experiencing a faster rate of warming than compared to the global average. Pershing et al., 2015
- While **warming contributes to the observed trends in marine heatwave properties**, it doesn't completely explain the drivers of individual events



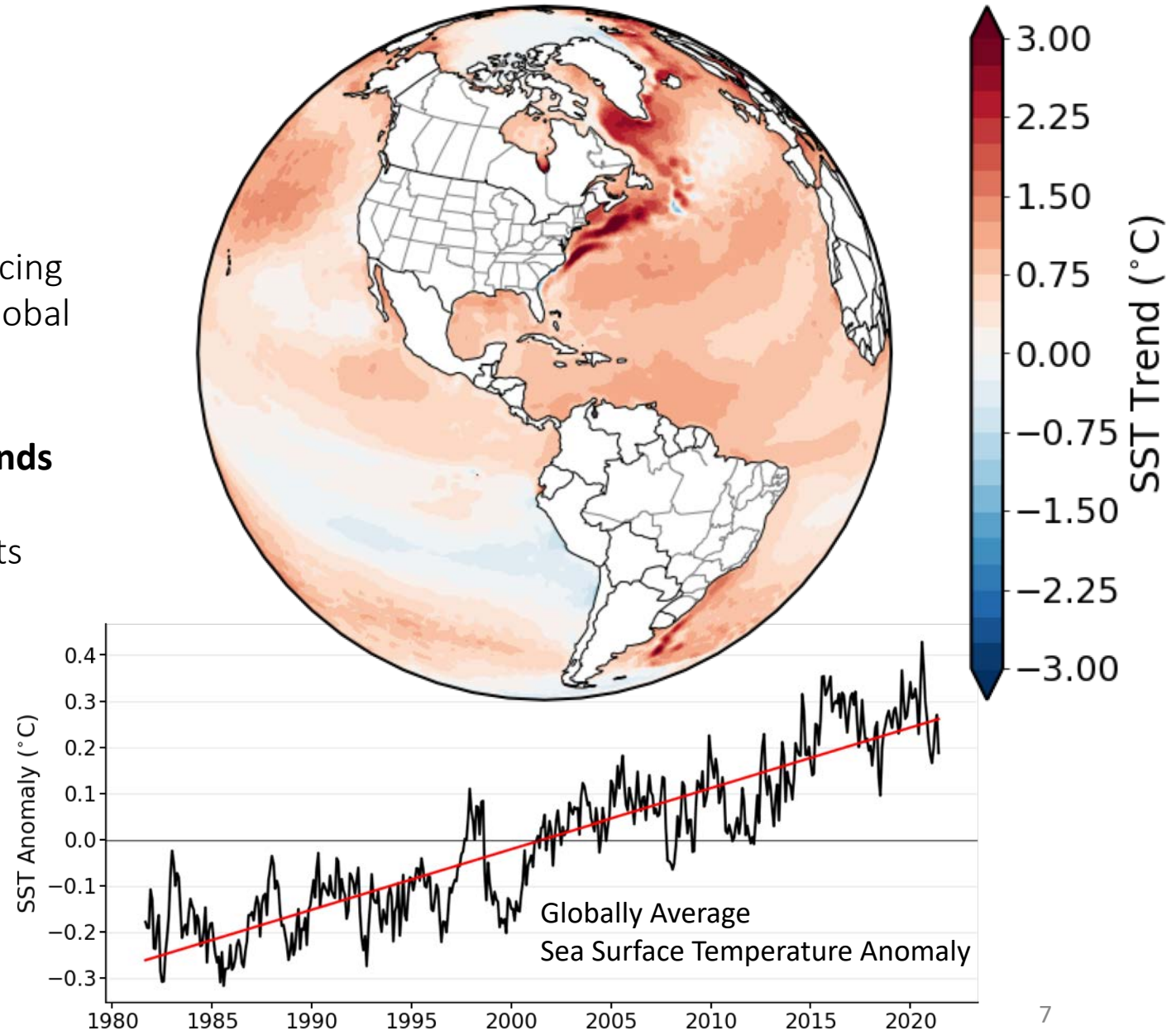


## 1981–2020 Trend in Sea Surface Temperature

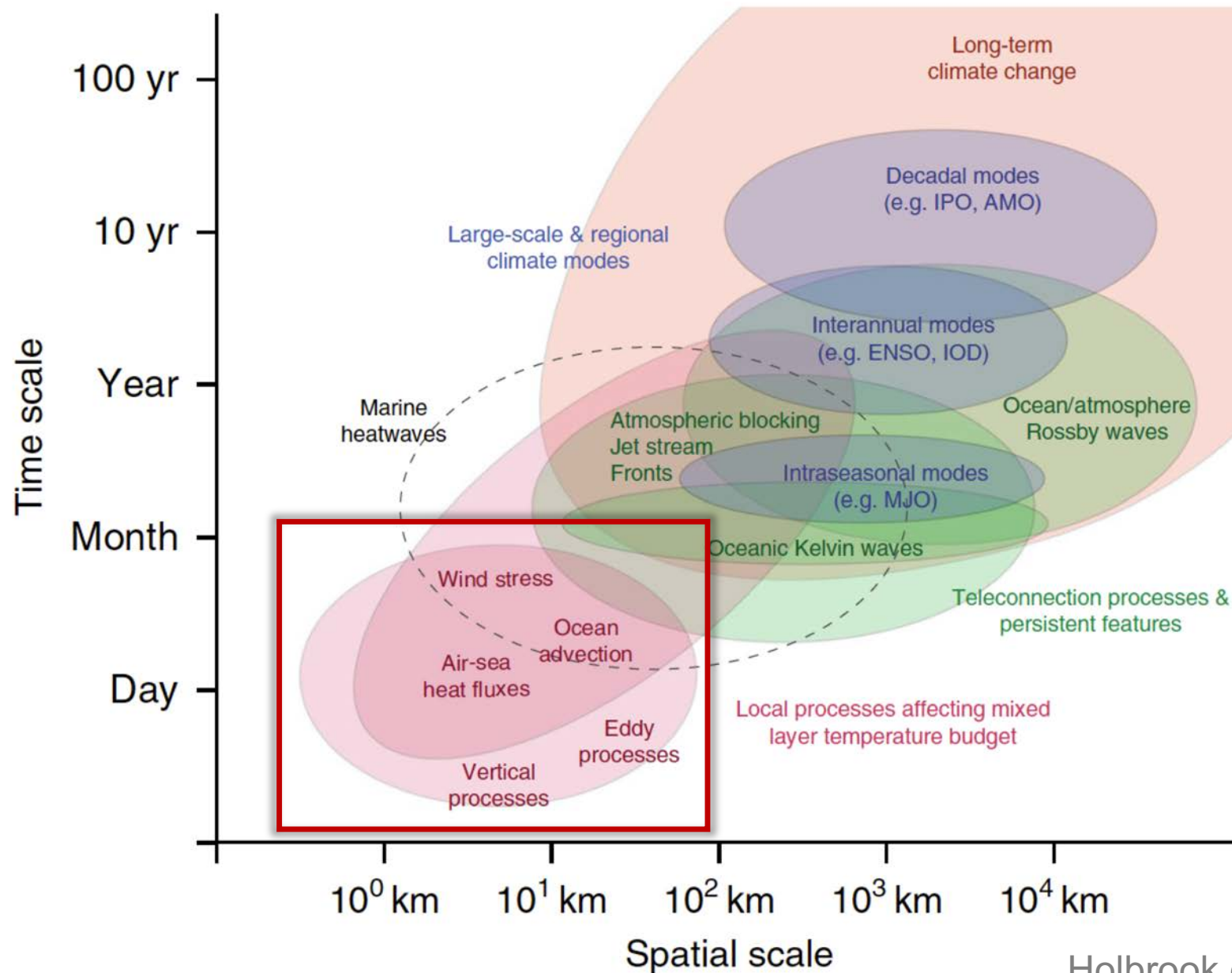
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### Two primary drivers of Marine Heatwaves

- Atmospheric Forcing
- Oceanic processes

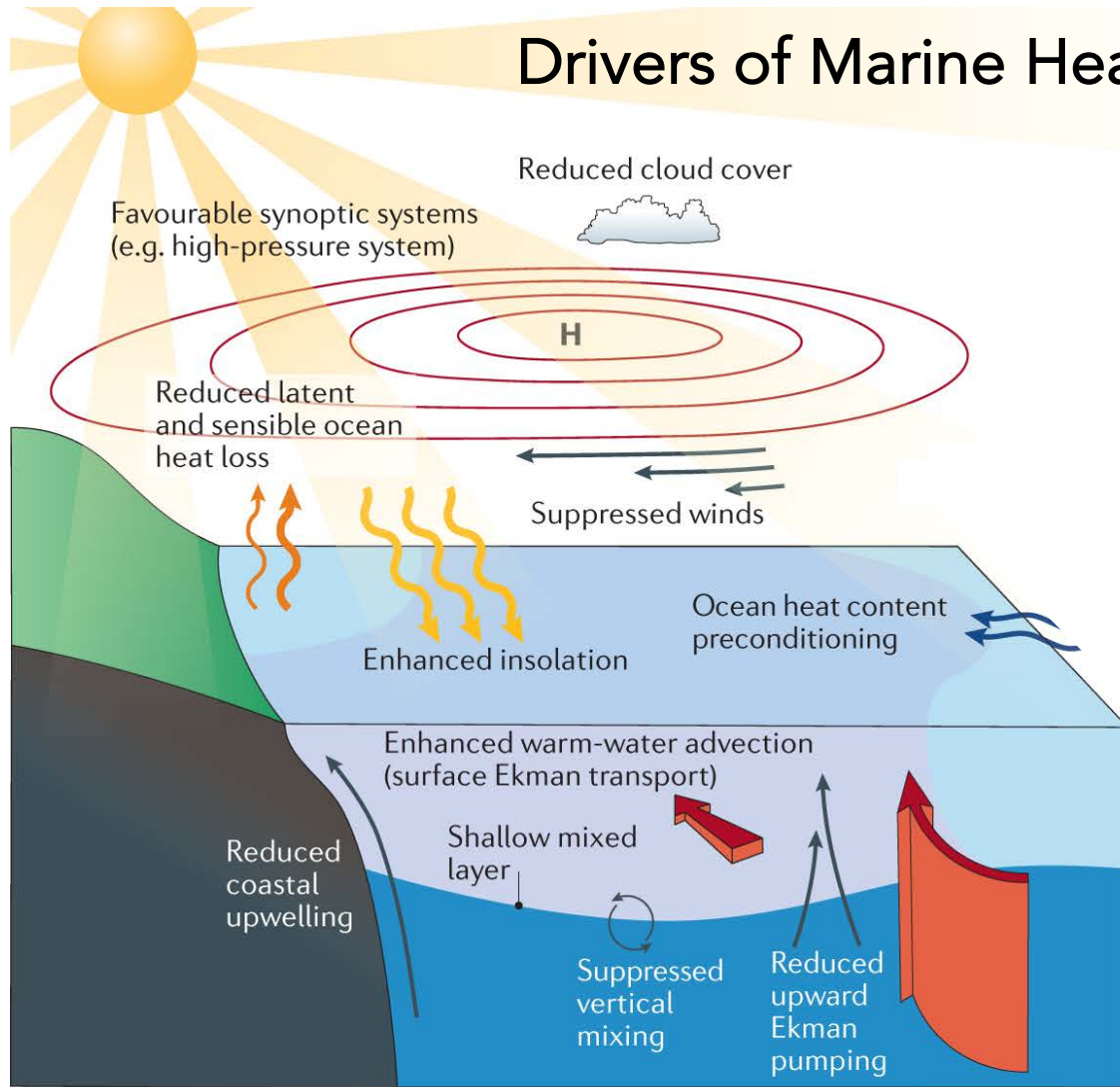


# Spatial and temporal scales of marine heatwave drivers





# Drivers of Marine Heatwaves

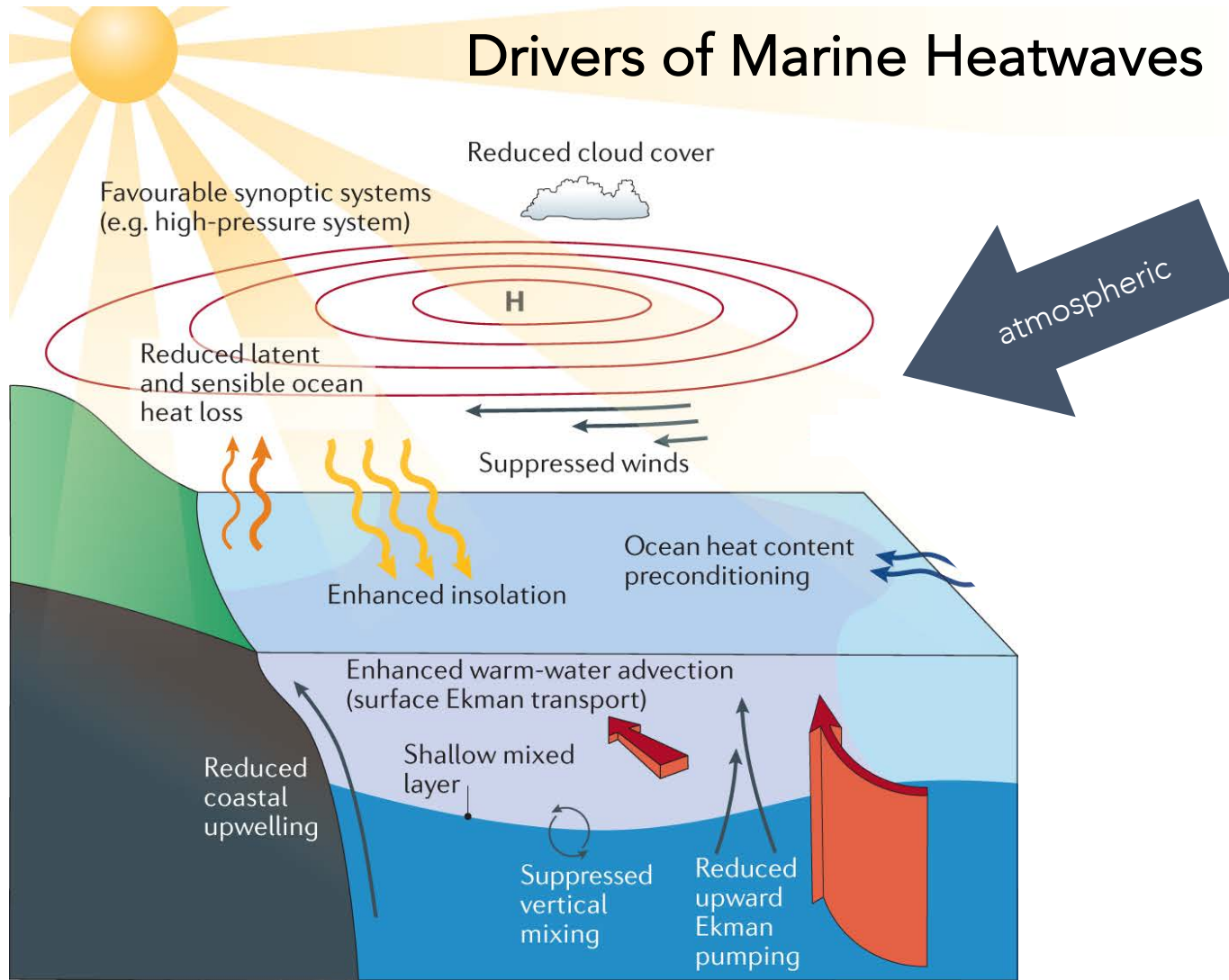


Holbrook et al. 2020

Marine heatwave drivers are diagnosed using a mixed layer temperature budget

**Temperature change** =  
ocean + atmospheric processes

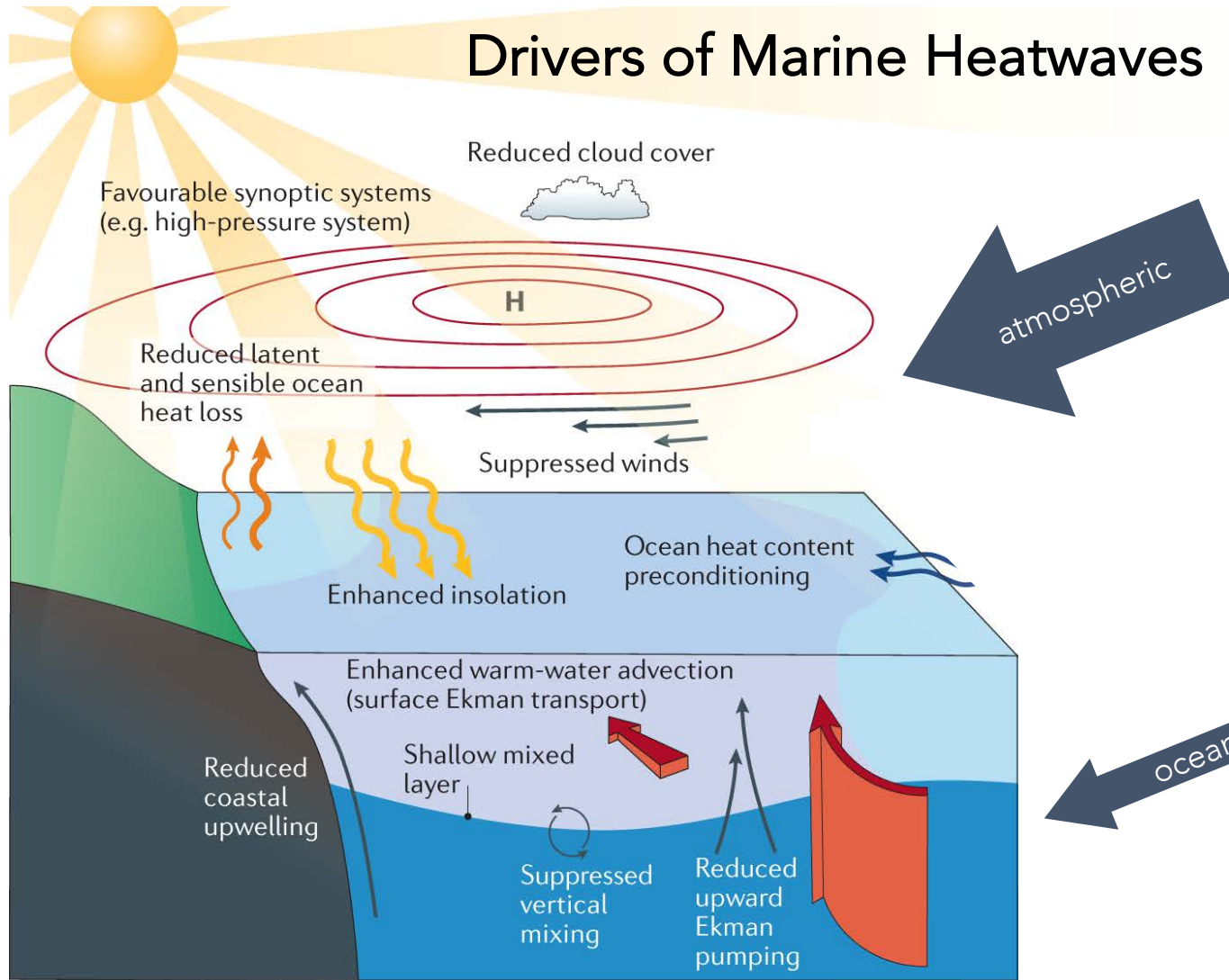
# Drivers of Marine Heatwaves



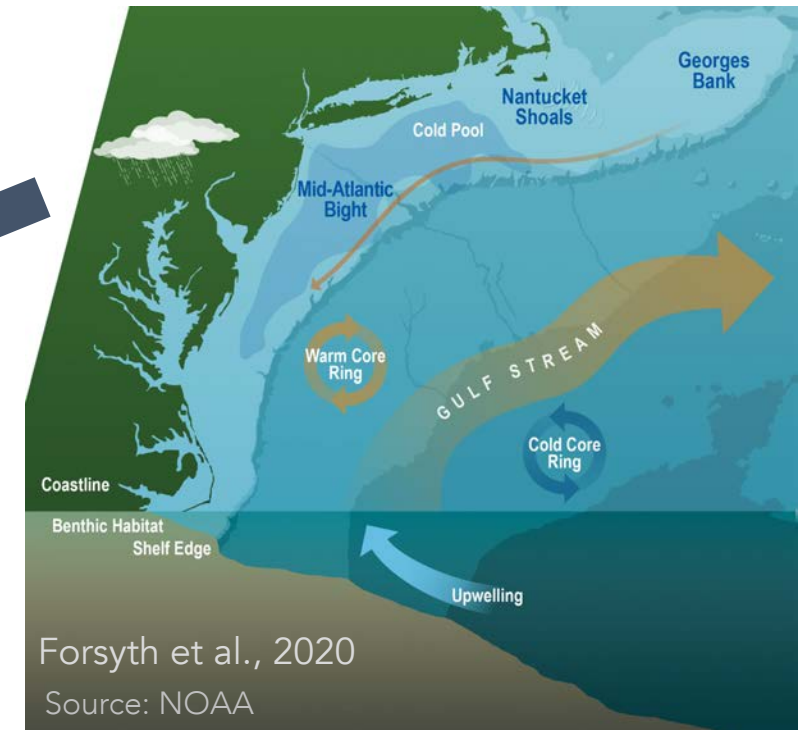
Holbrook et al. 2020



# Drivers of Marine Heatwaves



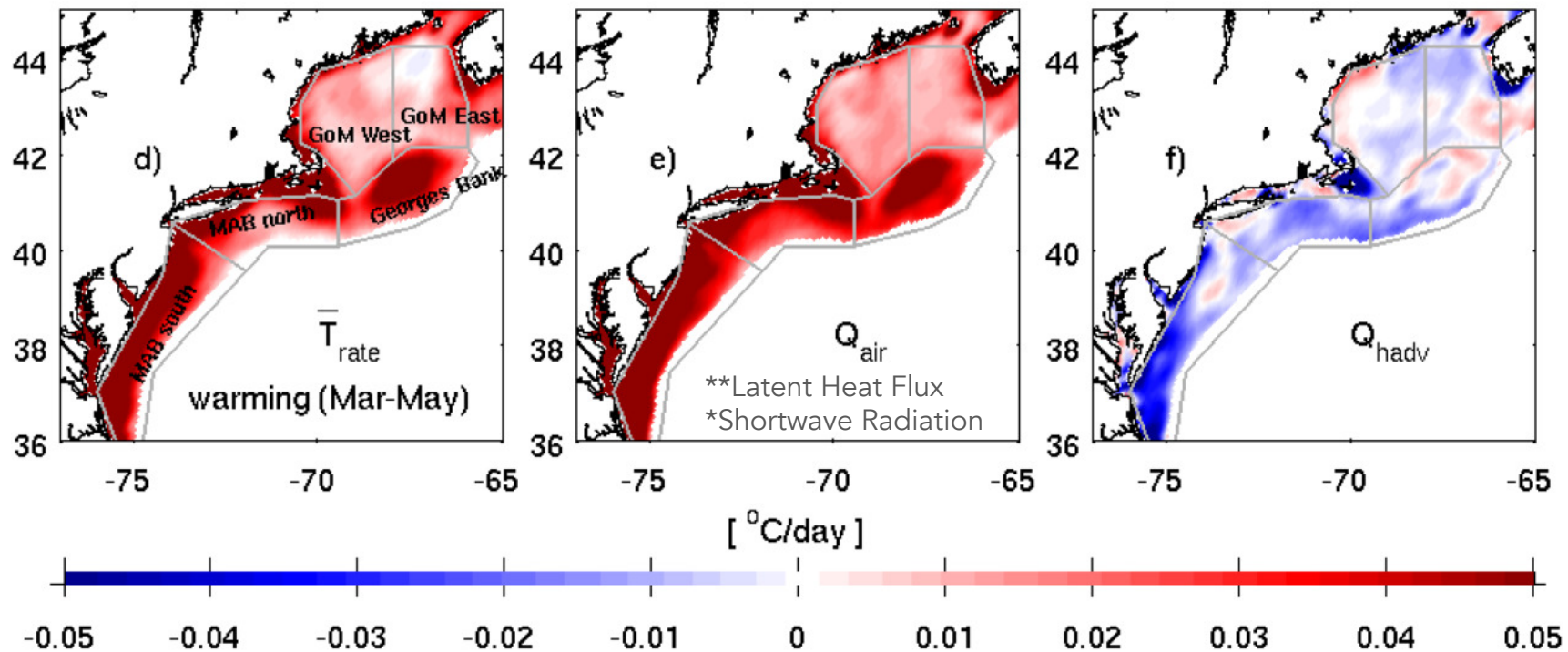
Holbrook et al. 2020





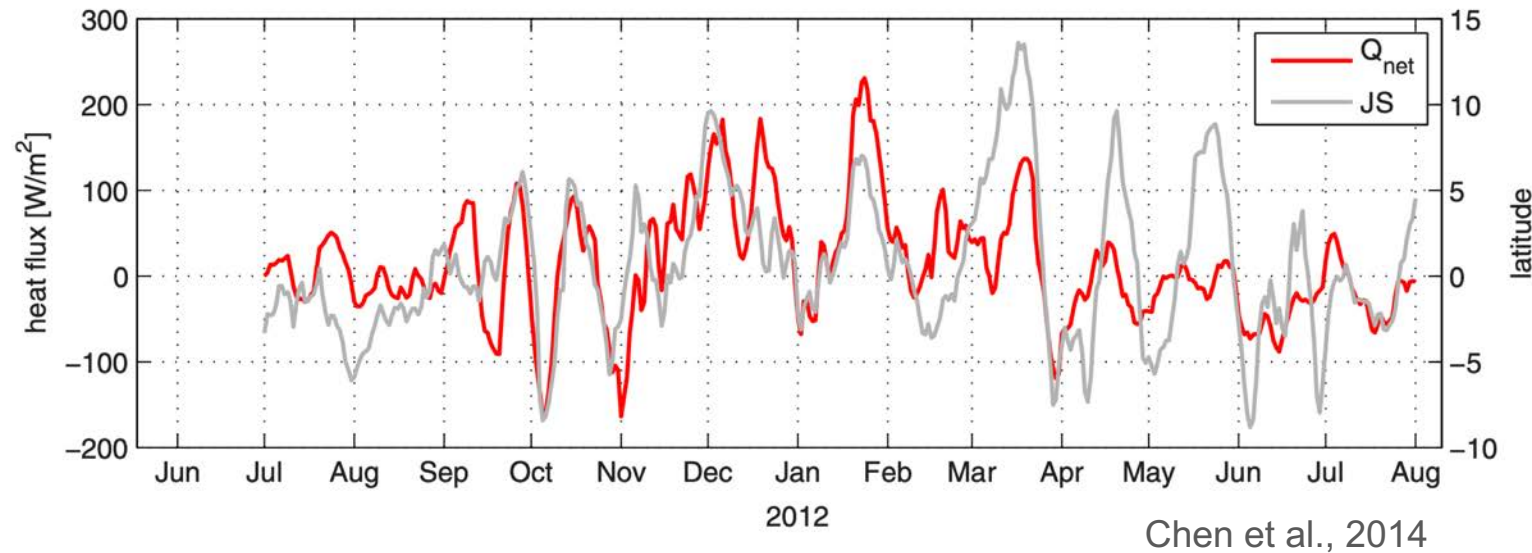
## Drivers of warming during the 2012 marine heatwave

Rate of warming was primarily driven by positive heat flux anomalies into the ocean.  
Ocean advection tended to offset the warming..



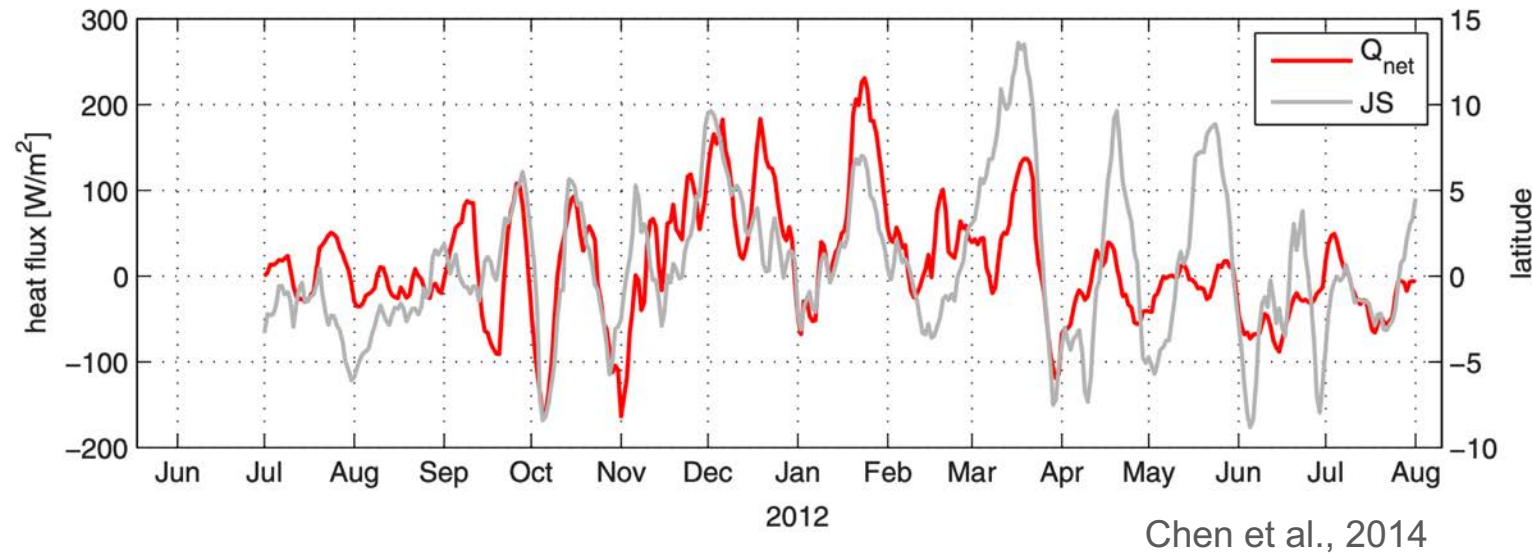
Chen et al., 2015

# Direct link between the midlatitude jet stream and temperature anomalies over the NE continental shelf



- Anomalous northward displacement of the Jet Stream during the winter of 2012
- Led to increased air temperature and humidity
- Relatively weak wind stress inhibited typical wintertime cooling

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**Acted together to drive positive heat flux into the ocean**



# Summary

- **Air-sea heat fluxes** are more responsible for the formation of marine heatwaves during the **cold season**

Anomalous **latent heat flux** (weak wind speeds) and **shortwave radiation** (reduced cloud cover) are the largest contributors

- **Advection** may be more responsible for marine heatwaves during the **warm season**

However, ocean processes (advection and mixing) typically help to dissipate the accumulated heat

- Persistent atmospheric forcing is necessary to maintain long-lived marine heatwaves
- Mixed layer depth shoaling is critical for the onset of most events
- Jet stream activity plays an important role in the formation of anomalously warm water events