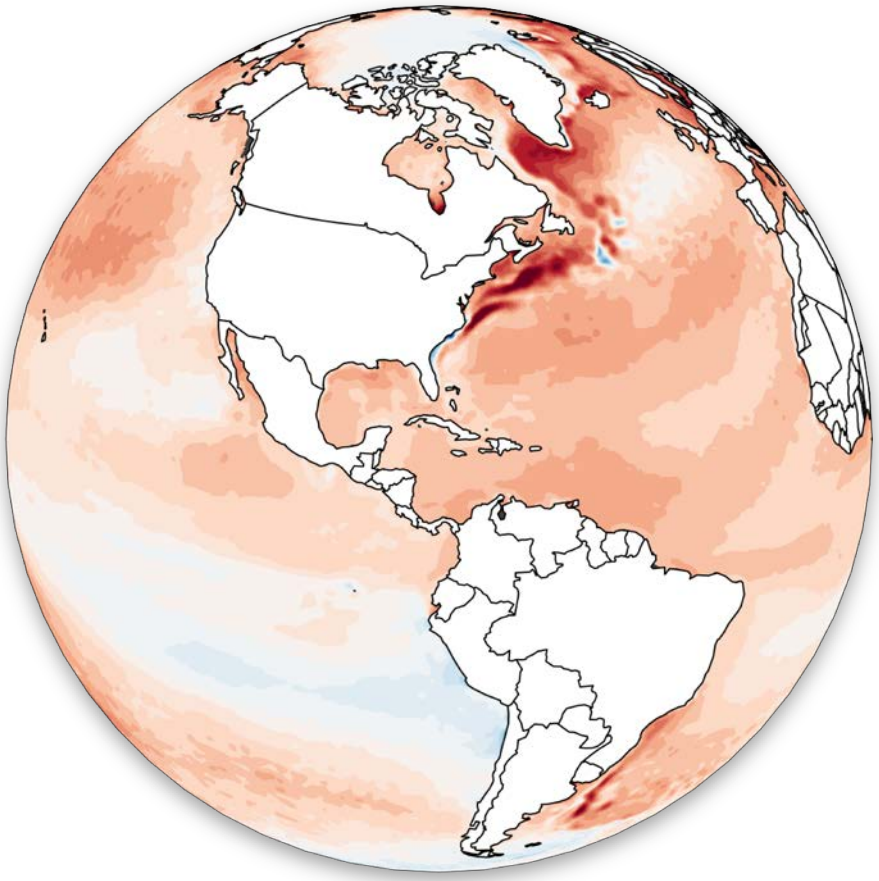

40-year temperature trend

Drivers of **Marine Heatwaves** in the Northwest Atlantic

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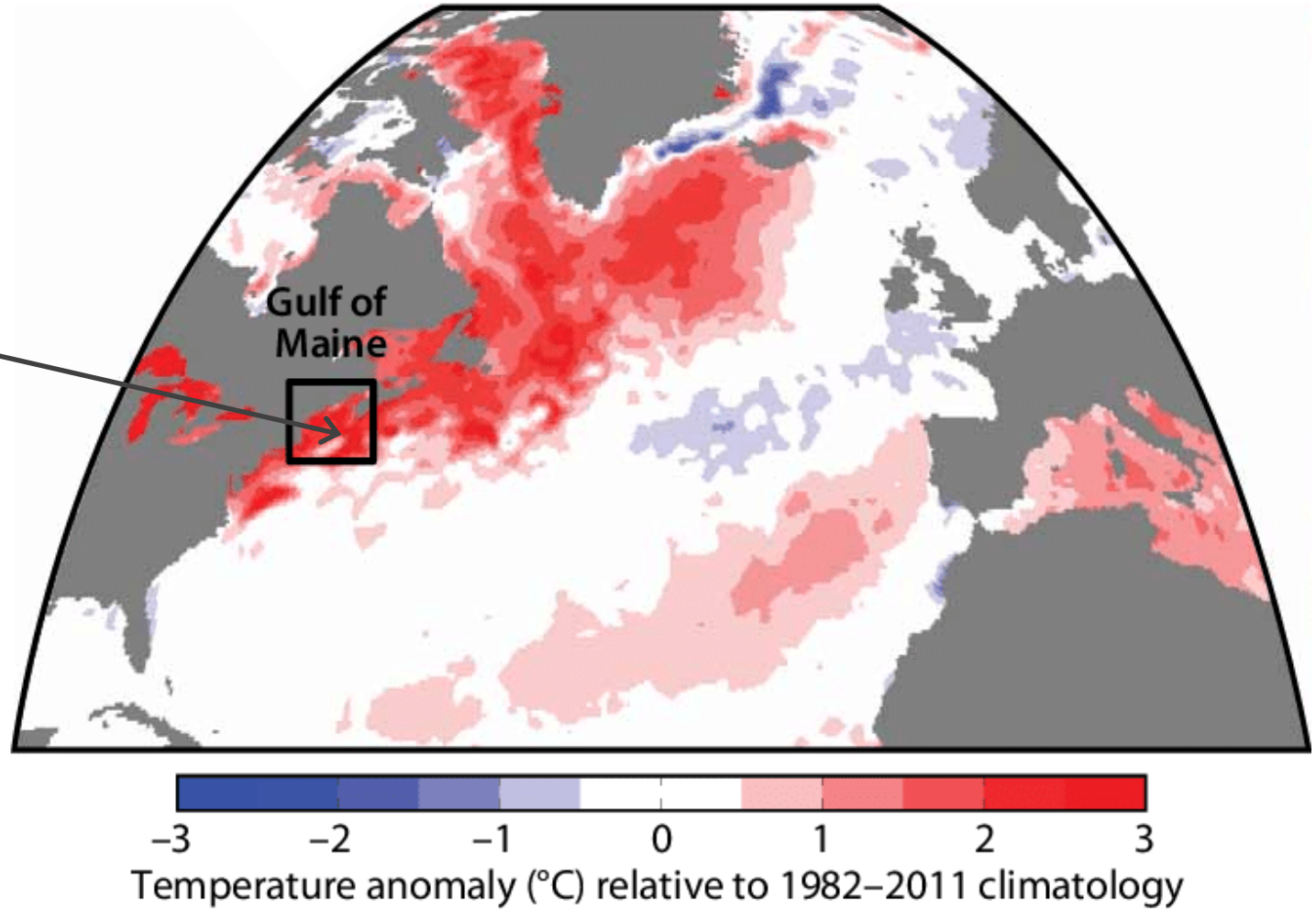
Marine heatwaves are prolonged discrete anomalously warm water events

Hobday et al., 2016

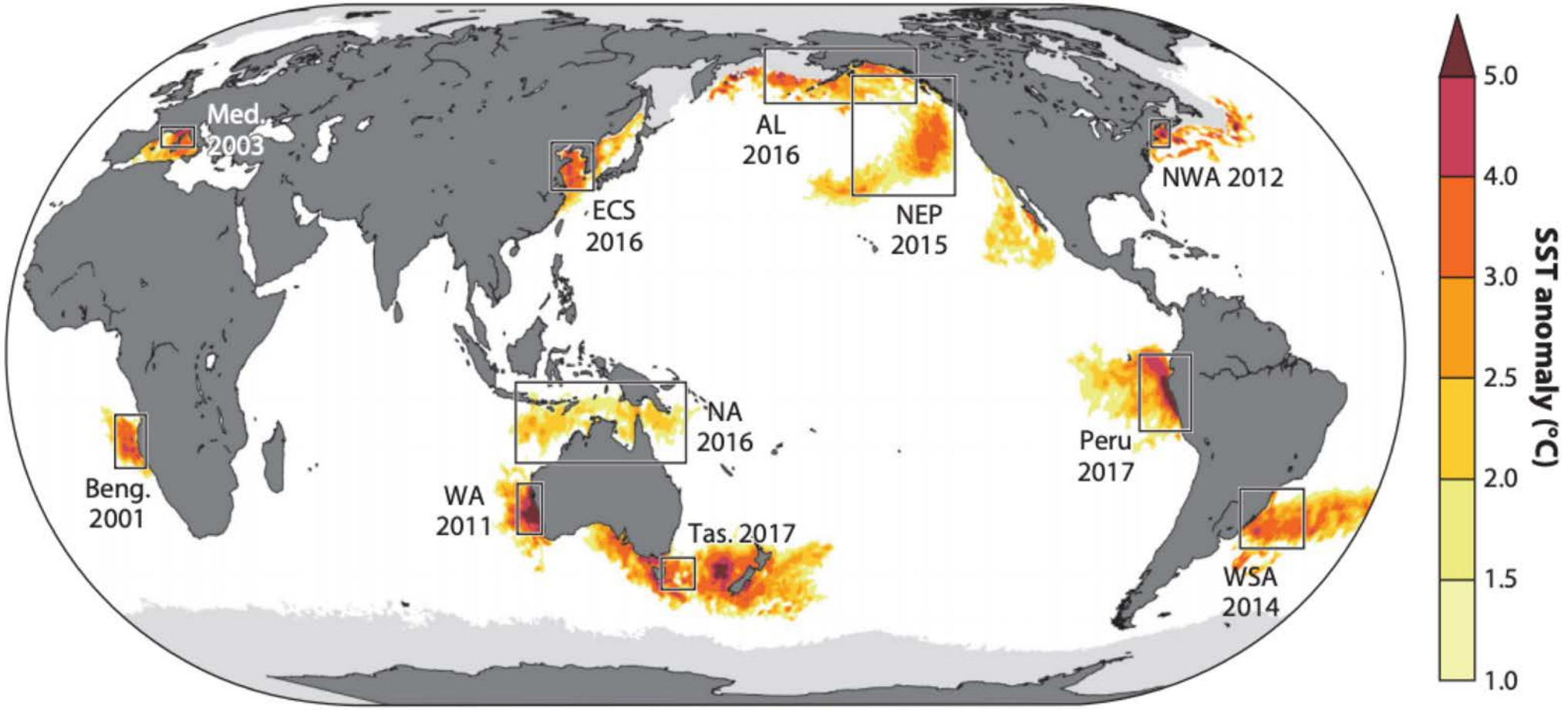
Northwest Atlantic Marine Heatwave
Summer 2012

June – August 2012



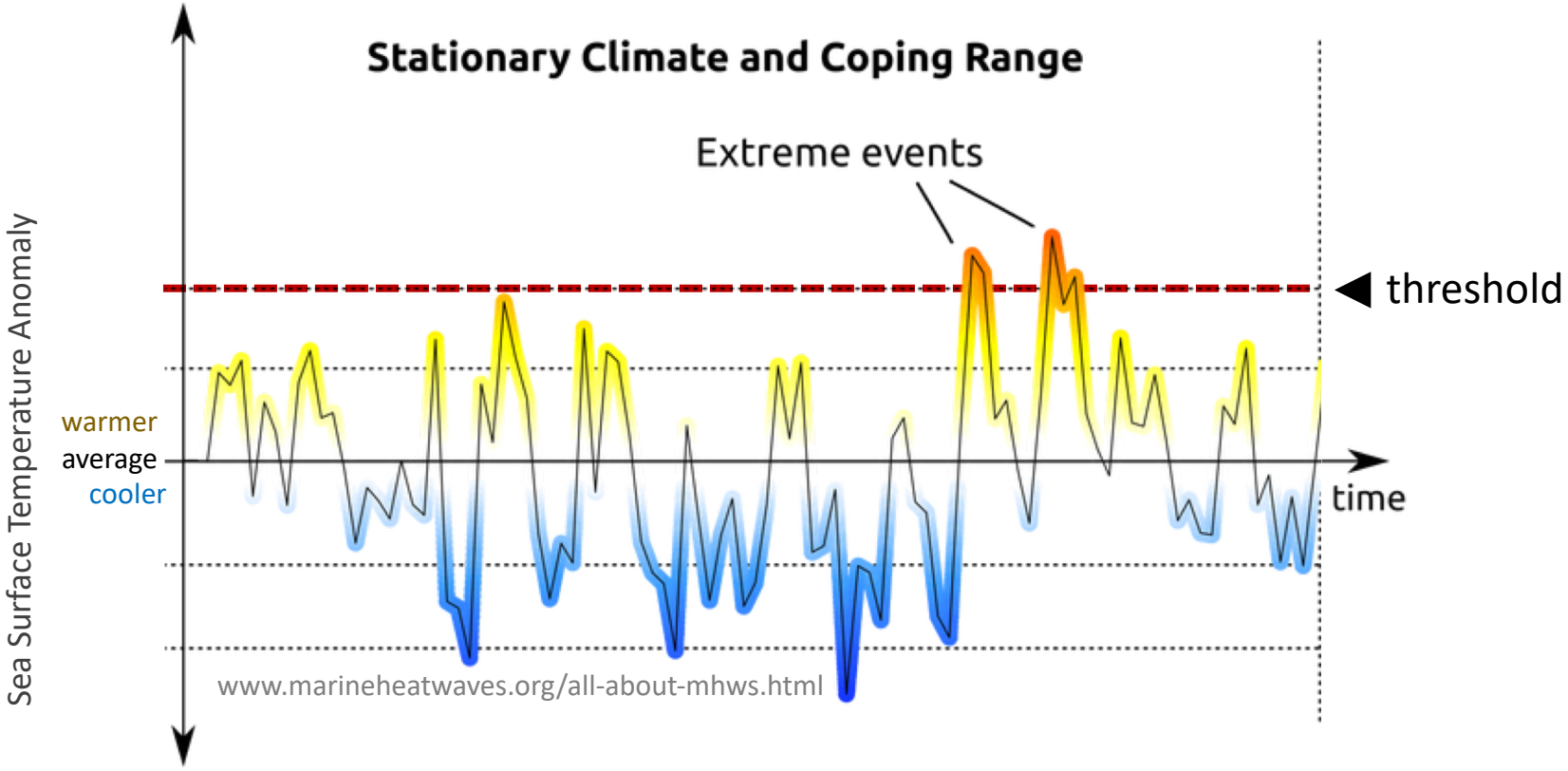
Mills et al., 2013

Prominent 21st Century marine heatwaves

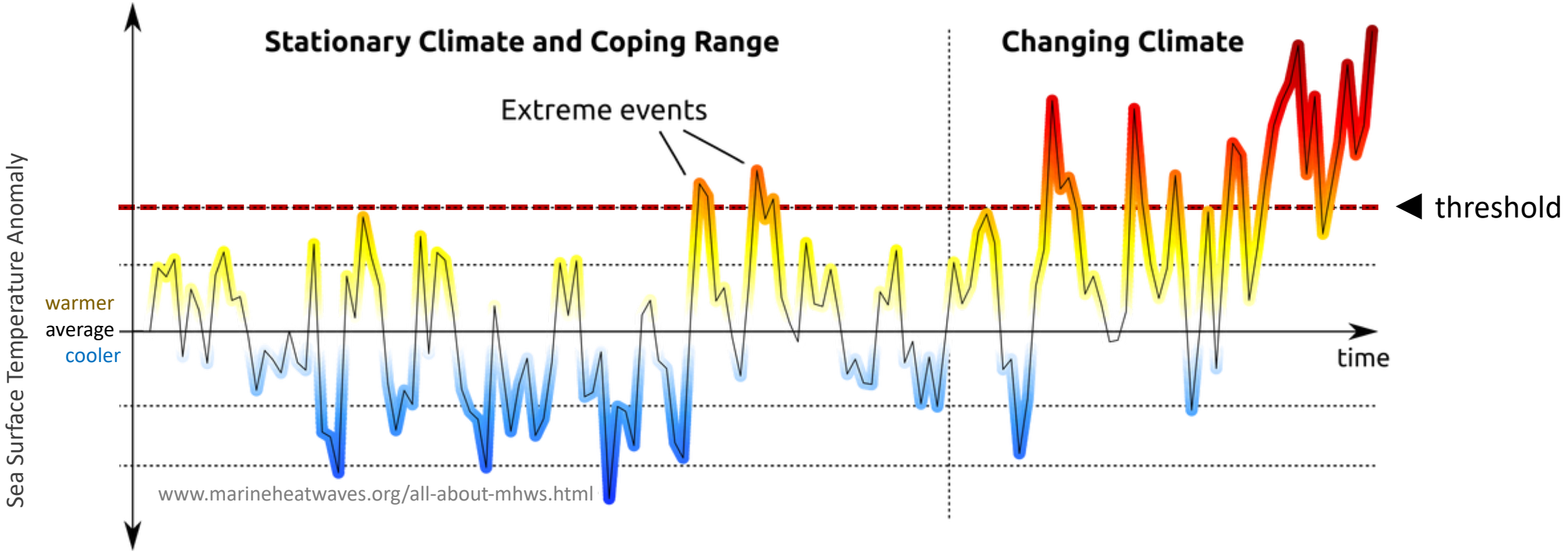


Oliver et al. 2020

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



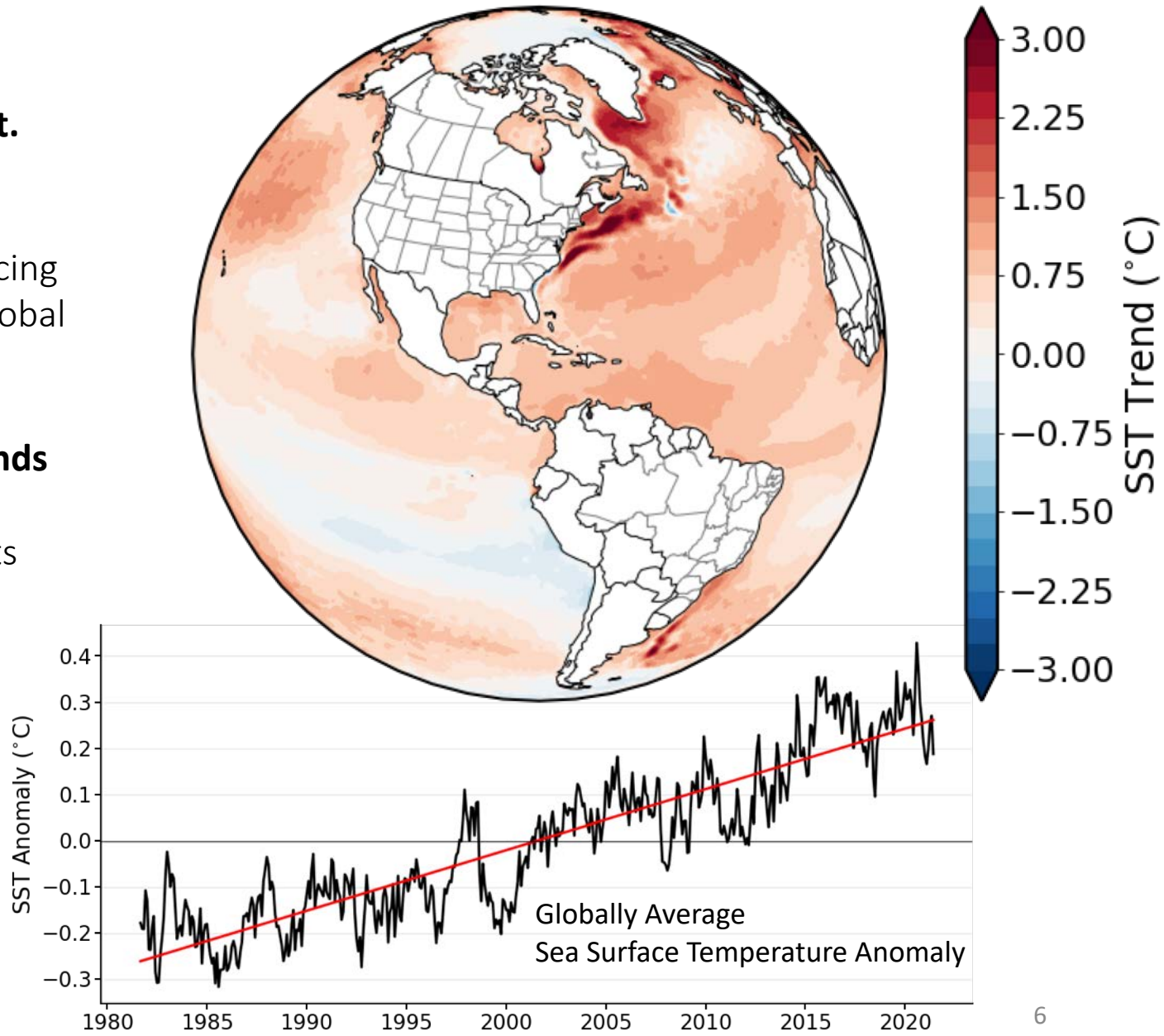
As temperatures rise, heat extremes become more deadly



- 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



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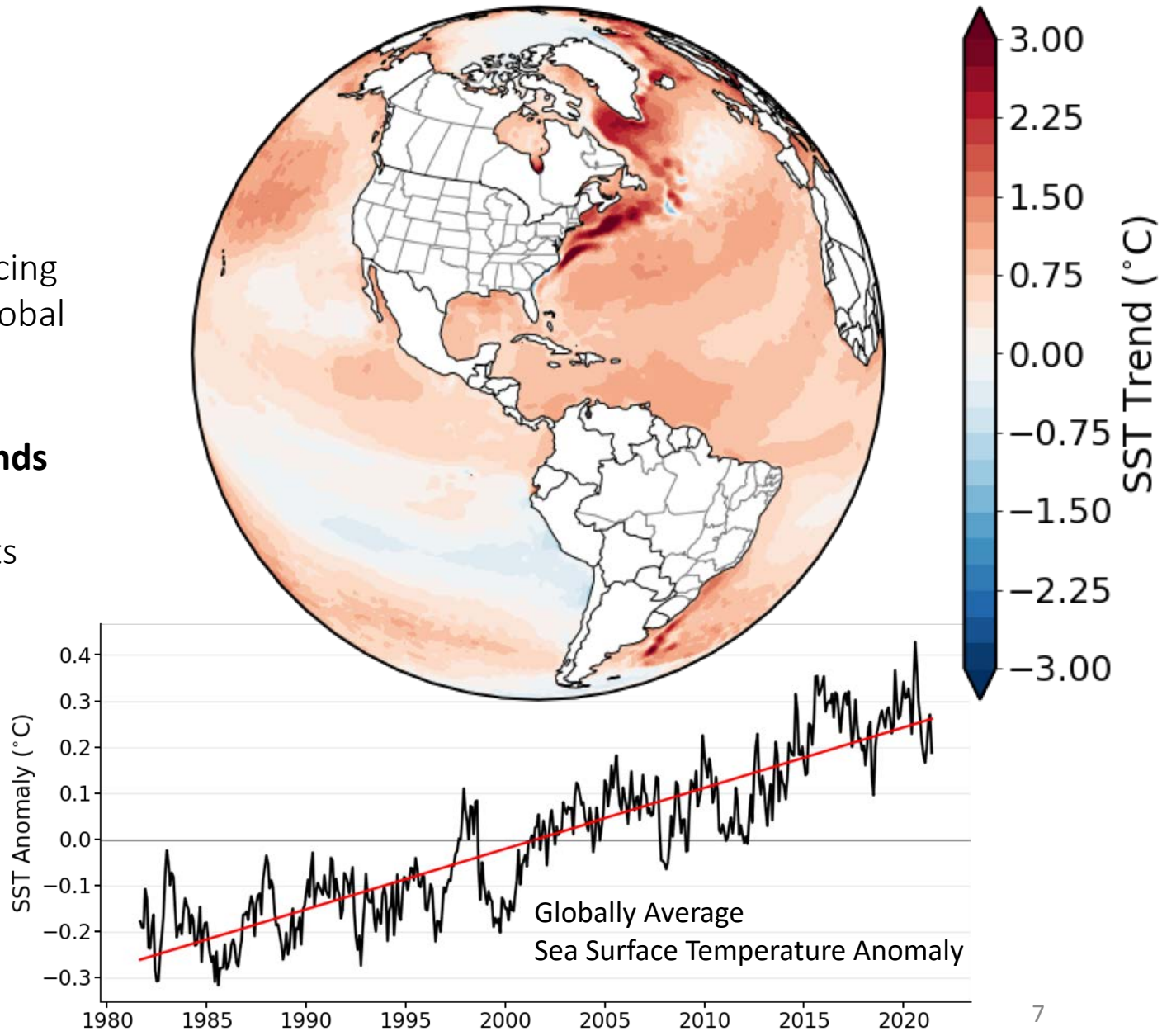
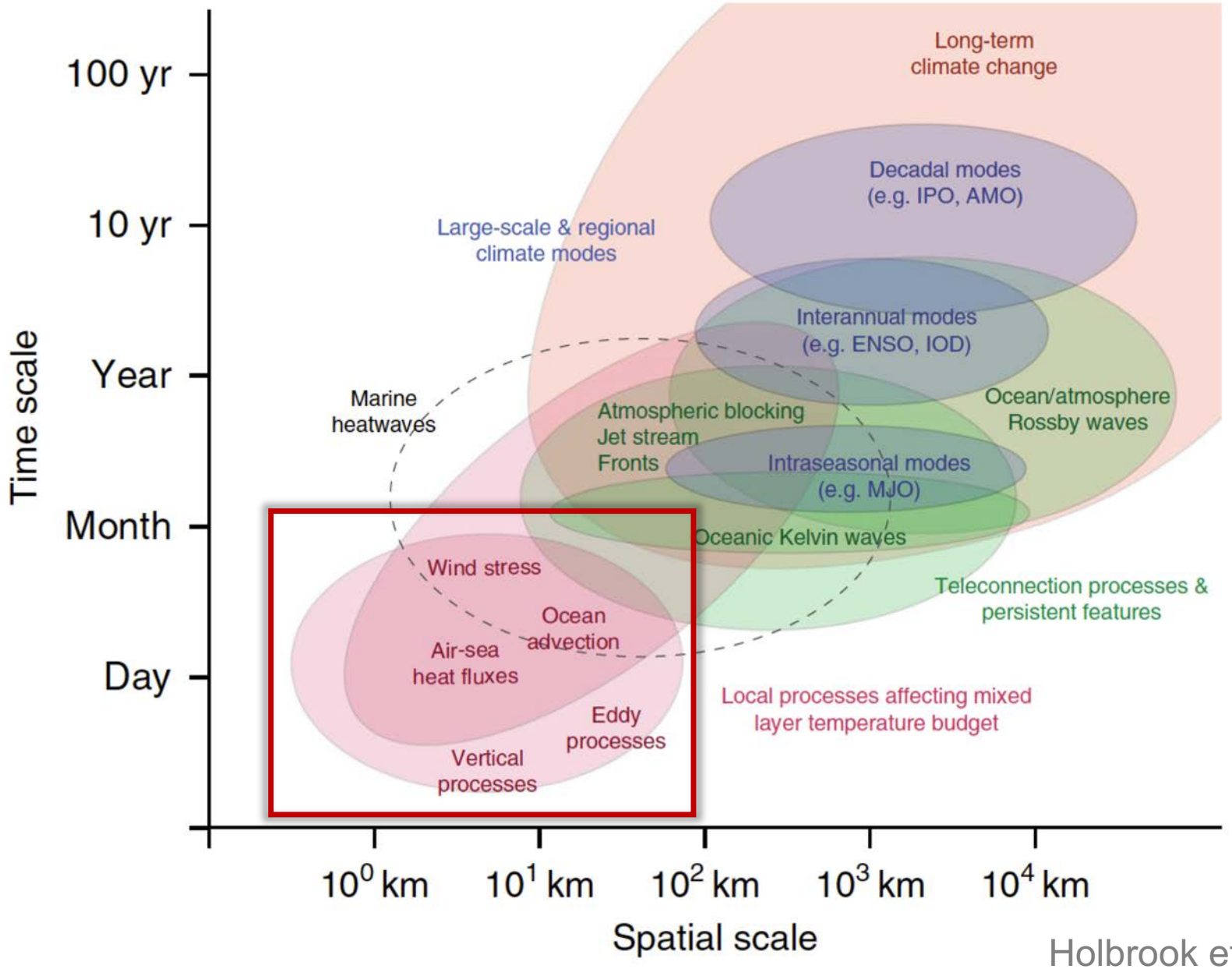
Two primary drivers of Marine Heatwaves

- Atmospheric Forcing
- Oceanic processes

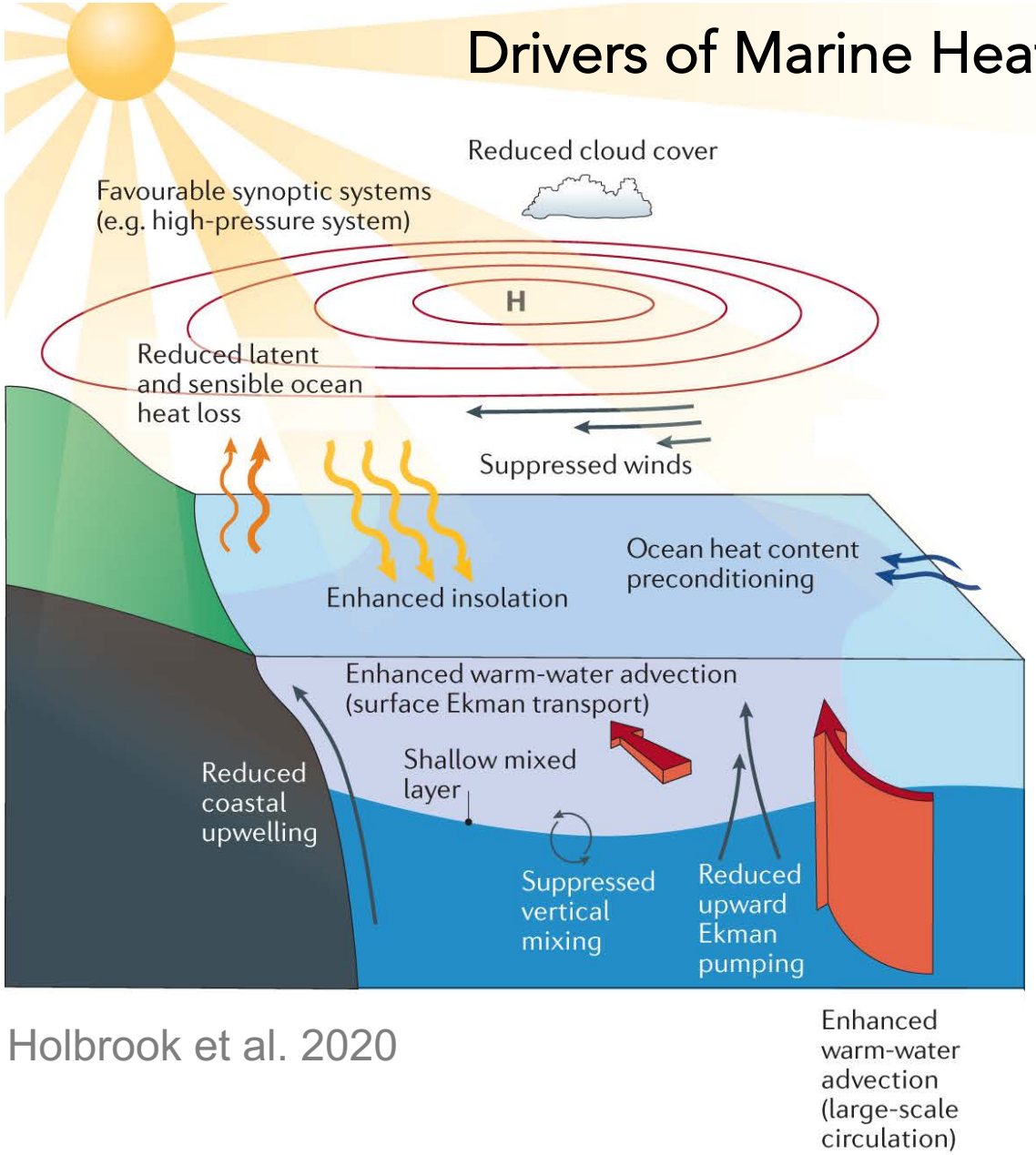


Spatial and temporal scales of marine heatwave drivers



Holbrook et al. 2019

Drivers of Marine Heatwaves

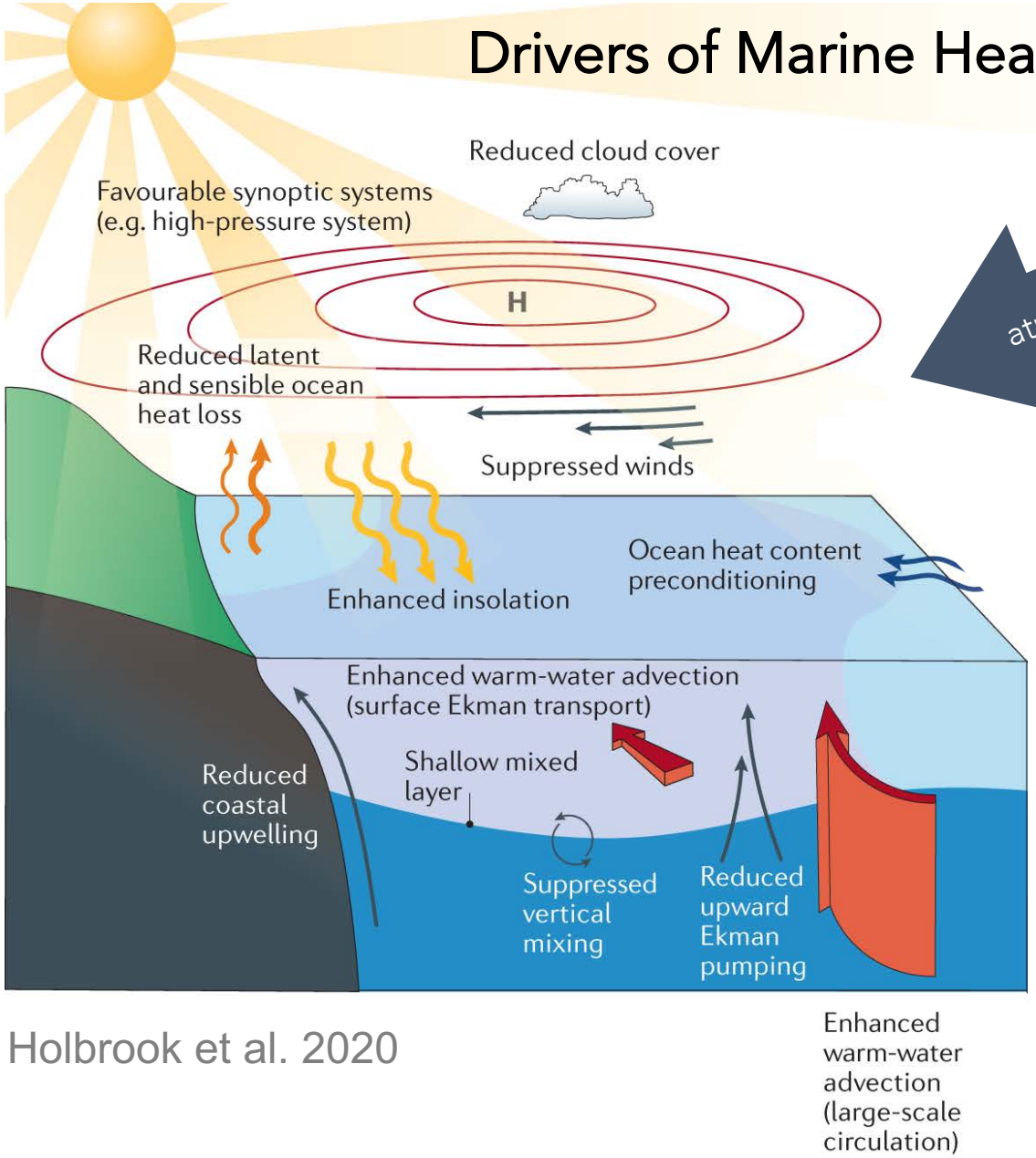


Holbrook et al. 2020

Marine heatwave drivers are diagnosed using a mixed layer temperature budget

Temperature change =
ocean + atmospheric processes

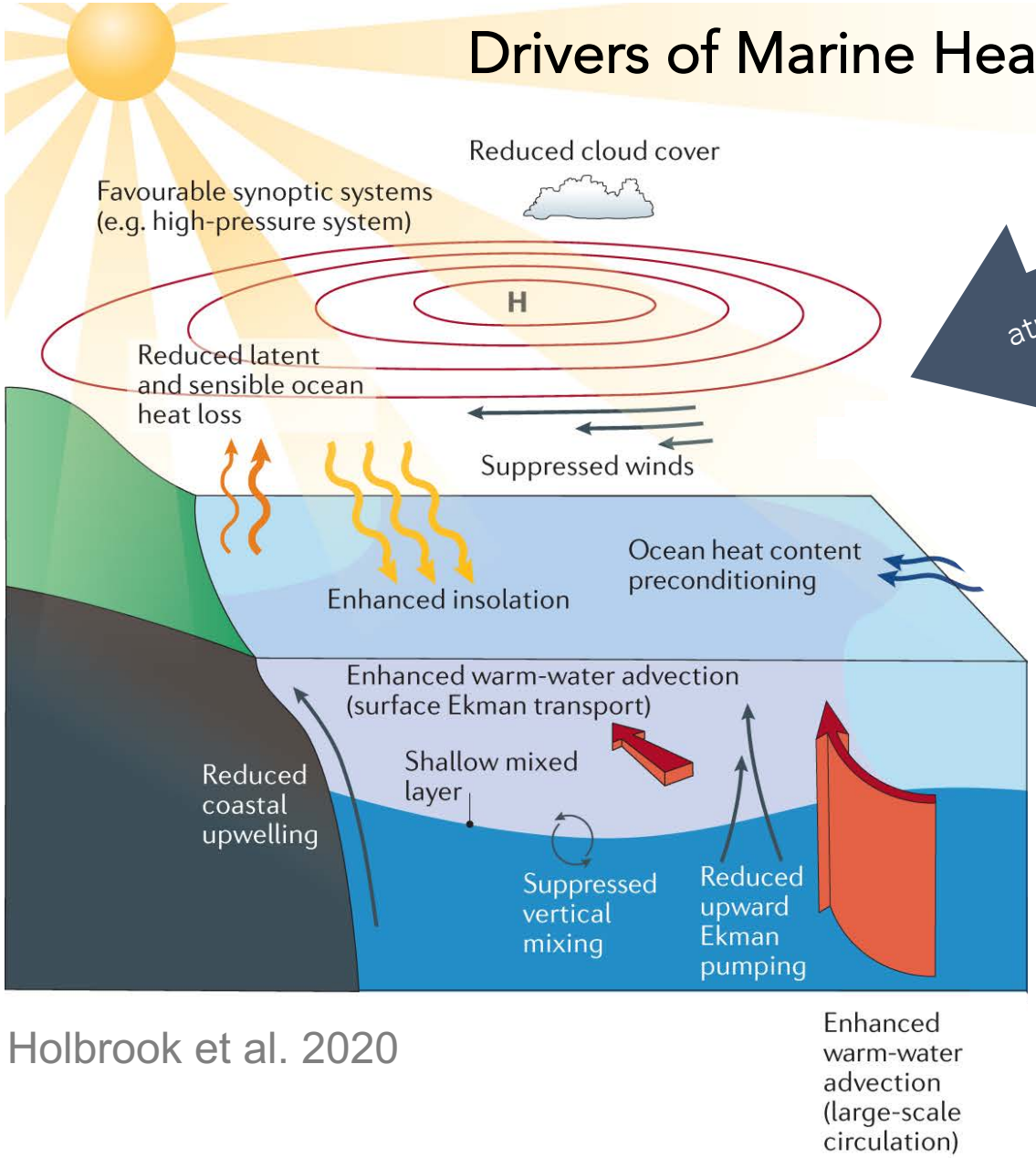
Drivers of Marine Heatwaves



atmospheric

Holbrook et al. 2020

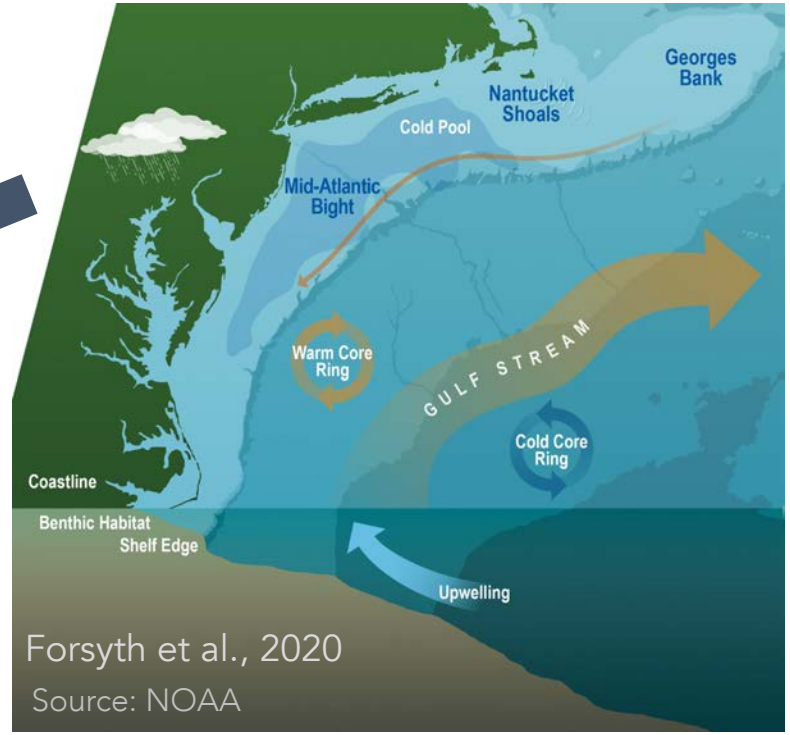
Drivers of Marine Heatwaves



Holbrook et al. 2020

atmospheric

oceanic

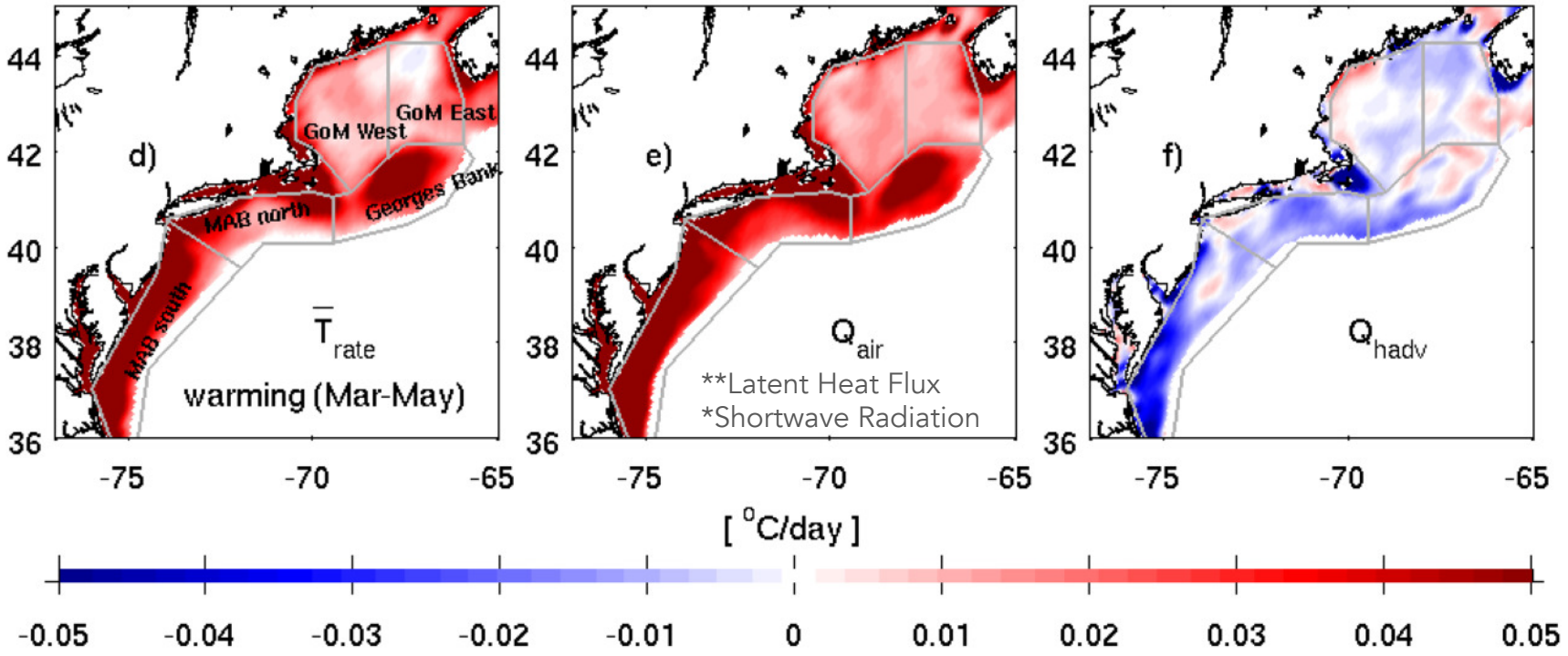


Forsyth et al., 2020

Source: NOAA

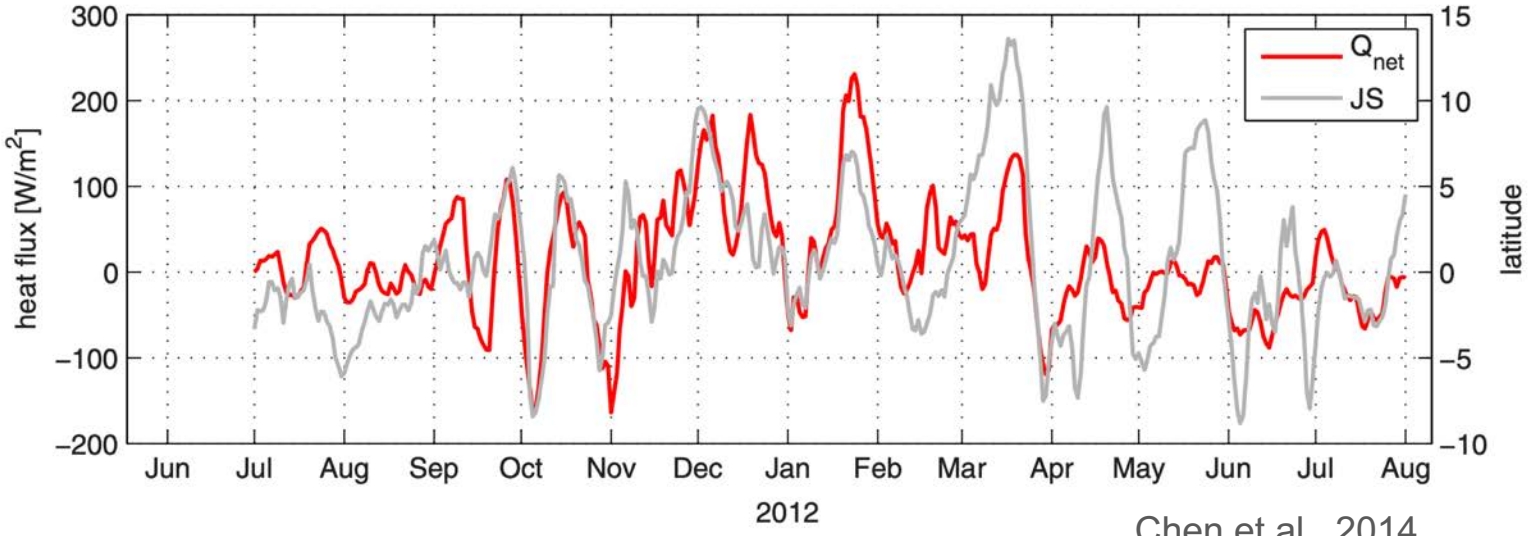
Drivers of warming during the 2012 marine heatwave

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

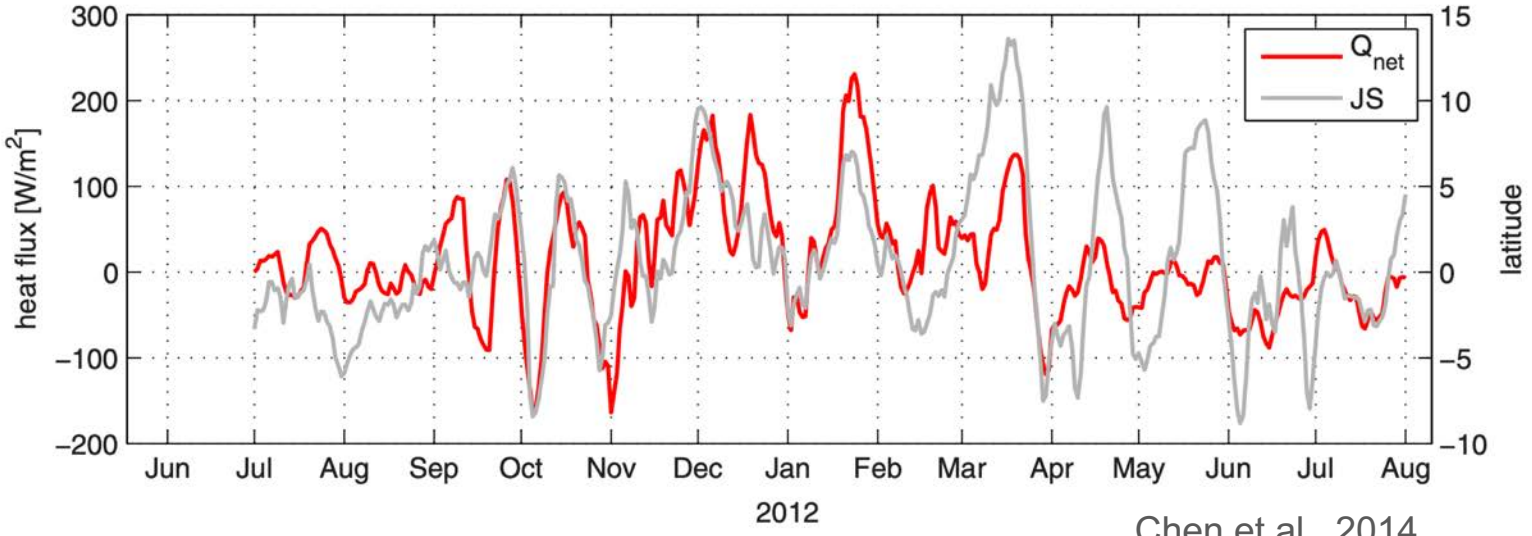
Direct link between the midlatitude jet stream and temperature anomalies over the NE continental shelf



Chen et al., 2014

- 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

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



Chen et al., 2014

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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

Schlegel et al., 2021; Chen et al., 2014