Primary drivers of marine heatwaves in the Northwest Atlantic

Robert W. Schlegel [1,*]
@wiederweiter
robert.schlegel@dal.ca

Eric C. J. Oliver [1]

[1] *Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada*

What are known drivers of past MHWs?

Advection, heat flux, and intrinsic ocean modes are the primary drivers of sea surface temperature (SST) **(Deser et al. 2010)**.
Different regions of the world show different primary drivers for anomalously warm SST.
MHWs in the coastal oceans are primarily driven by abnormal movement of warm currents onto the coast **(Schlegel et al. 2017; Oliver et al. 2018)**.
For large seas like the Mediterranean, heat flux is dominant **(Garrabou et al. 2009)**.
Events in the open oceans tend to be driven by a combination of factors **(Bond et al. 2015)**.

Why use a new method to determine drivers?

The current standard is to analyse the drivers of one large MHW at a time.
MHWs are occurring too rapidly to spend a year understanding the drivers of an individual event.
Smaller events that would normally escape our notice may also be important.
Machine learning may be a better choice moving forwards.

Self-organising maps

Are there recurrent environmental patterns during MHWs?
If so, can these be detected/quantified by a computer?
Environmental data during MHWs are fed to the SOM to produce 12 most common states (nodes).

Calculating MHWs and creating synoptic states

All of the SST pixels within each sub-region (Figure 1) were averaged together into one time series.
MHWs were calculated from these averaged time series.
The start and end dates of each MHW were used to create a packet of synoptic information (Figure 2).

What do the results look like?

Figure 3 shows the results from node 5 of the SOM.
In this node we see a strong warm nearshore Gulf Stream current.
The centre of the heat anomaly has a deeper mixed layer and negative downward heat flux.
The MHWs occurred predominantly in the Mid-Atlantic Bight (mab) region.
No overall seasonality, but more recent events occurring in spring and increasing in intensity.

Conclusions

The SOM technique functions as expected in the Northwest Atlantic.
Each node tells a different complex story.
Many of the nodes show drivers that occurred over a few years or less.
Most of the nodes show drivers that occur during specific seasons.
Drivers usually affected multiple regions concurrently.
To see all of the results please follow the QR code.

Future work

Extend the methodology seen here into the third and fourth dimensions of the data.
Run this same analysis 1, 2, 3, etc. months prior to the MHWs to see how well it detects patterns.
Test these drivers (node synoptic states) as predictors for events in different data products.
Rank the drivers by their predictive accuracy.
Create operational prediction data layer for public use/consumption.

- **Marine heatwaves** usually occur along the **Northwest Atlantic** coast when the **Gulf Stream** anomaly is **warm** (cold) and the **Labrador Sea** anomaly is **cold** (warm)

- The **Gulf Stream** drives the **most intense marine heatwaves**

- Follow the **QR code** for a **complete** breakdown of the **predominant drivers**

OCEAN FRONTIER INSTITUTE

DALHOUSIE UNIVERSITY

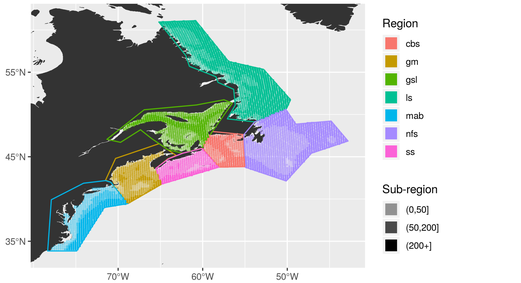

*Figure 1: The regions of the coast were divided up by their temperature and salinity regimes based on work by **Richaud et al. (2016)**. The region abbreviations are: gm = Gulf of Maine, gls = Gulf of St. Lawrence, ls = Labrador Shelf, mab = Mid-Atlantic Bight, nfs = Newfoundland Shelf, ss = Scotian Shelf. The regions were furthered divided into sub-regions based on their depth.*

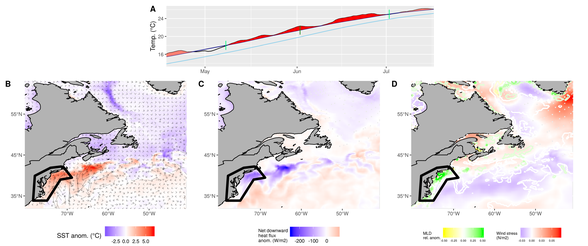

Figure 2: An overview of the information contained in one MHW data packet. The region of the focus event is shown in black. A) The focus MHW is shown in red and other MHWs occurring within the same year are shown in salmon; the start and end dates of the focus event are marked in light green while the peak date is marked with dark green. B) The SST and surface current anomalies during the MHW. C) The anomalous net downward heat flux. D) The wind stress and relative mixed layer depth anomalies.

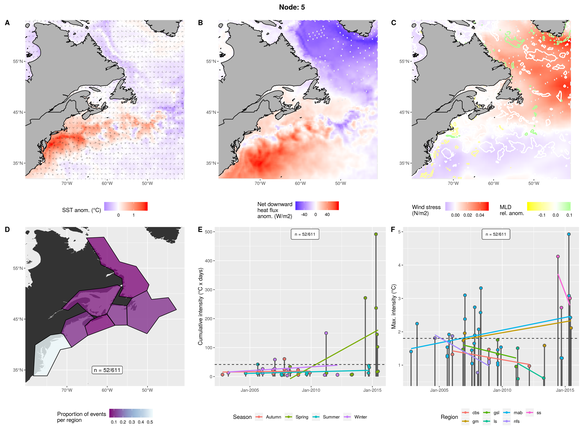

Figure 3: Summary visuals for the results from node 5. A) The SST and surface current anomalies. B) The net downward heat flux anomaly. C) The wind stress and mixed layer depth anomalies. D) The proportion of events that occurred in each region. E) The cumulative intensity and season of occurrence for each MHW. F) The max intensity and region of occurrence for each MHW.

References

Bond, Nicholas A., Meghan F. Cronin, Howard Freeland, and Nathan Mantua. 2015. "Causes and Impacts of the 2014 warm anomaly in the NE Pacific." *Geophysical Research Letters* 42 (9): 3414–20. https://doi.org/10.1002/2015GL064308.

Deser, C, M A Alexander, S P Xie, and A S Phillips. 2010. "Sea surface temperature variability: patterns and mechanisms." *Annual Review of Marine Science* 2: 115–43. https://doi.org/10.1146/annurev-marine-120408-151453.

Garrabou, J, R Coma, N Bensoussan, M Bally, P Chevaldonné, M Cigliano, D Diaz, et al. 2009. "Mass mortality in Northwestern Mediterranean rocky benthic communities: effects of the 2003 heat wave." *Global Change Biology* 15 (5): 1090–1103. https://doi.org/10.1111/j.1365-2486.2008.01823.x.

Oliver, Eric CJ, Véronique Lago, Alistair J Hobday, Neil J Holbrook, Scott D Ling, and Craig N Mundy. 2018. "Marine Heatwaves Off Eastern Tasmania: Trends, Interannual Variability, and Predictability." *Progress in Oceanography* 161. Elsevier: 116–30.

Richaud, Benjamin, Young-Oh Kwon, Terrence M Joyce, Paula S Fratantoni, and Steven J Lentz. 2016. "Surface and Bottom Temperature and Salinity Climatology Along the Continental Shelf Off the Canadian and Us East Coasts." *Continental Shelf Research* 124. Elsevier: 165–81.

Schlegel, Robert W, Eric CJ Oliver, Sarah Perkins-Kirkpatrick, Andries Kruger, and Albertus J Smit. 2017. "Predominant Atmospheric and Oceanic Patterns During Coastal Marine Heatwaves." *Frontiers in Marine Science* 4. Frontiers: 323.