Primary drivers of marine heatwaves in the Northwest Atlantic

Primary drivers

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Marine heatwaves (MHWs)

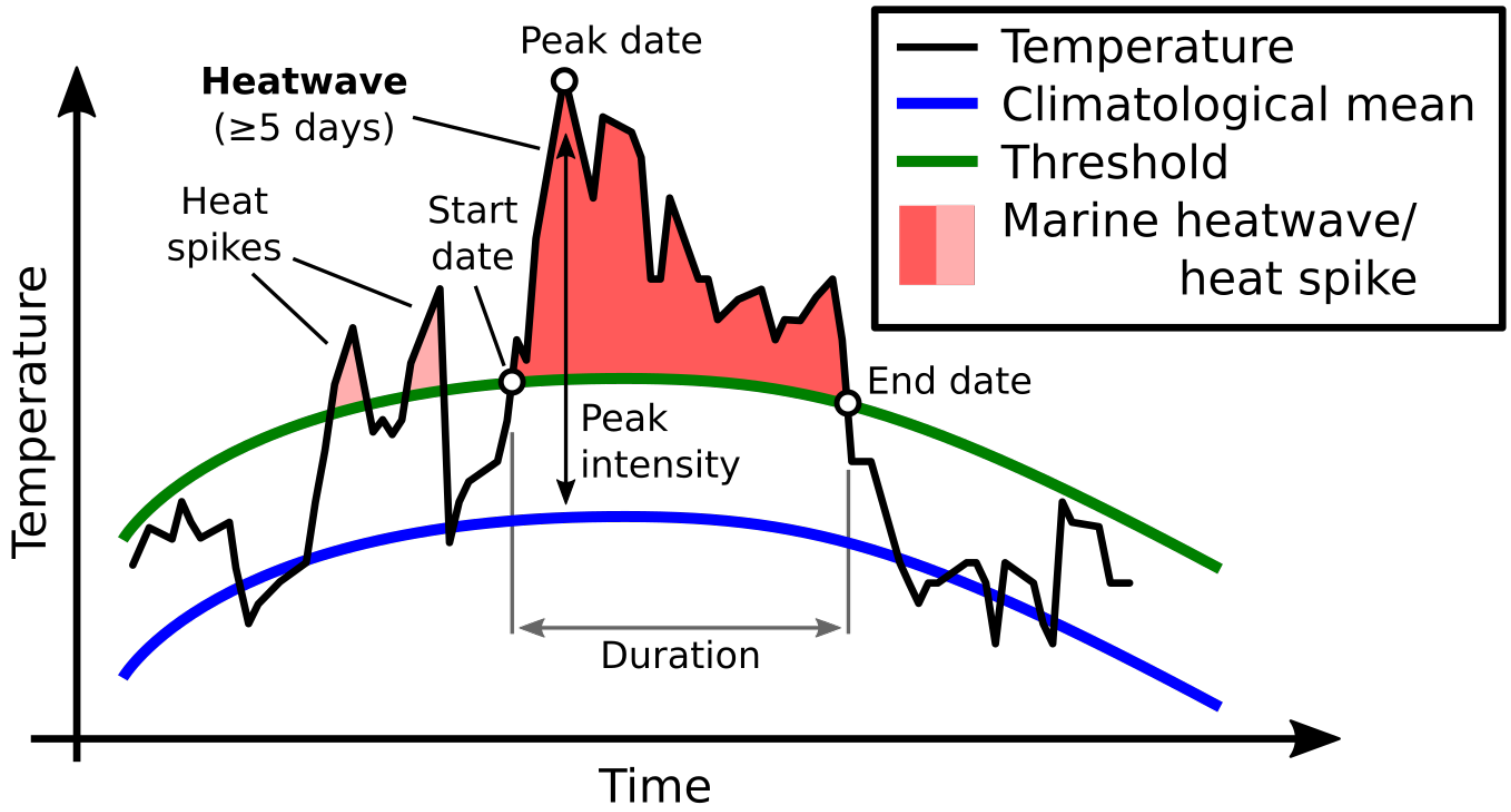
Definition

"A prolonged discrete anomalously warm water event that can be described by its duration, intensity, rate of evolution, and spatial extent."

(Hobday et al., 2016)

- The temperature at a location exceeds the 90% percentile of that calendar day
- This occurs at least 5 days in a row with no more than a 2 day gap thereafter

Schematic



(*Eric Oliver, www.marineheatwaves.org*)

How does heat enter/exit the ocean?

Surface heat flux (W/m^2):

- Q_s: The short wave energy radiated from the sun (shortwave radiation)
- Q_l: The net long-wave energy radiated back from the ocean (longwave radiation)
- Q_e: The heat loss by evaporation (latent heat flux)
- Q_h: The sensible heat loss by conduction (sensible heat flux)
- $Q_{net} = Q_s + Q_l + Q_e + Q_h$ (net positive downward heat flux)

Surface movement

- $\mathbf{u_{mix}} = (u_{mix}, v_{mix})$: Horizontal velocity averaged within the mixed layer
- $\nabla_h = (\partial / \partial x, \partial / \partial y)$: Horizontal gradient operator
- $\mathbf{u_{mix}} \cdot \nabla_h T_{mix}$ = Temperature change due to horizontal advection

Mixed layer depth

- H: MLD (mixed-layer depth)
- T_{mix}: MLD temperature
- ρ_0: Density of sea water
- c_p: Specific heat of sea water

Surface temperature

$$\delta T_{mix} \,/\, \delta t = (\,(Q_{net} - (Q_s(-H)))\,/\,\rho_0 c_p H\,) - \mathbf{u_{mix}} \cdot \nabla_h T_{mix} + (res)$$

(Benthuysen et al., 2014; Chen et al., 2015; Oliver et al., 2017)

Known drivers of past MHWs

- Advection and heat flux are the primary drivers of SST
- For much of the coastal oceans the primary driver is abnormal movement (advection) of warm currents into the nearshore
- For large seas (i.e. the Mediterranean) warm air (heat flux) plays a more important role
- The primary drivers of MHWs are generally determined by analysing the contribution of heat budget terms to the occurrence of one large event at a time

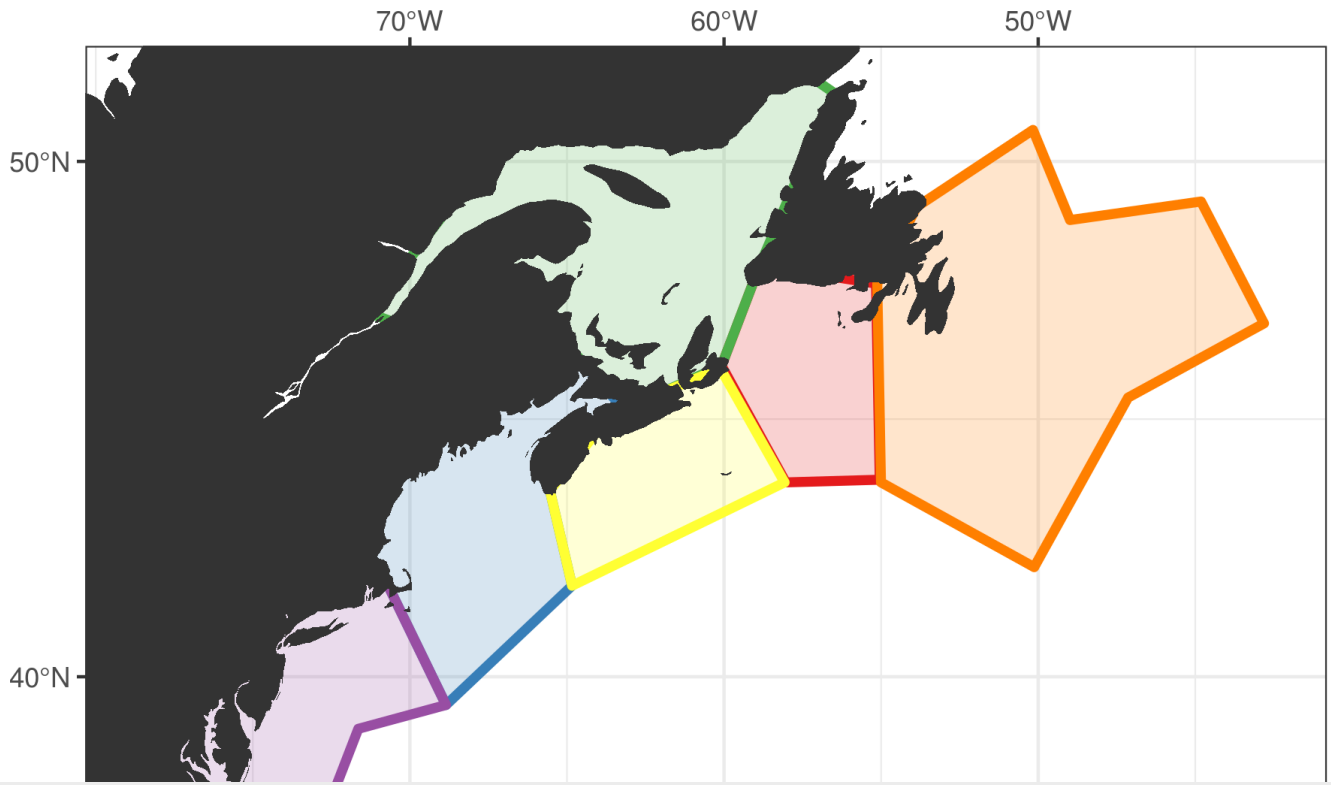
Methods

What is problematic with the current methodology?

- Large MHWs are happening too rapidly to spend a year working on them one at a time
- Smaller events may also be important
- The use of self-organising maps (SOM) to identify MHW drivers has already been tested
- This technique allows a machine to clarify for us which drivers are most prominent during hundreds of MHWs simultaneously
- We are effectively asking these two questions:
  1. Are there recurrent environmental patterns during marine heatwaves?
  2. If so, can these be detected/quantified by the computer?

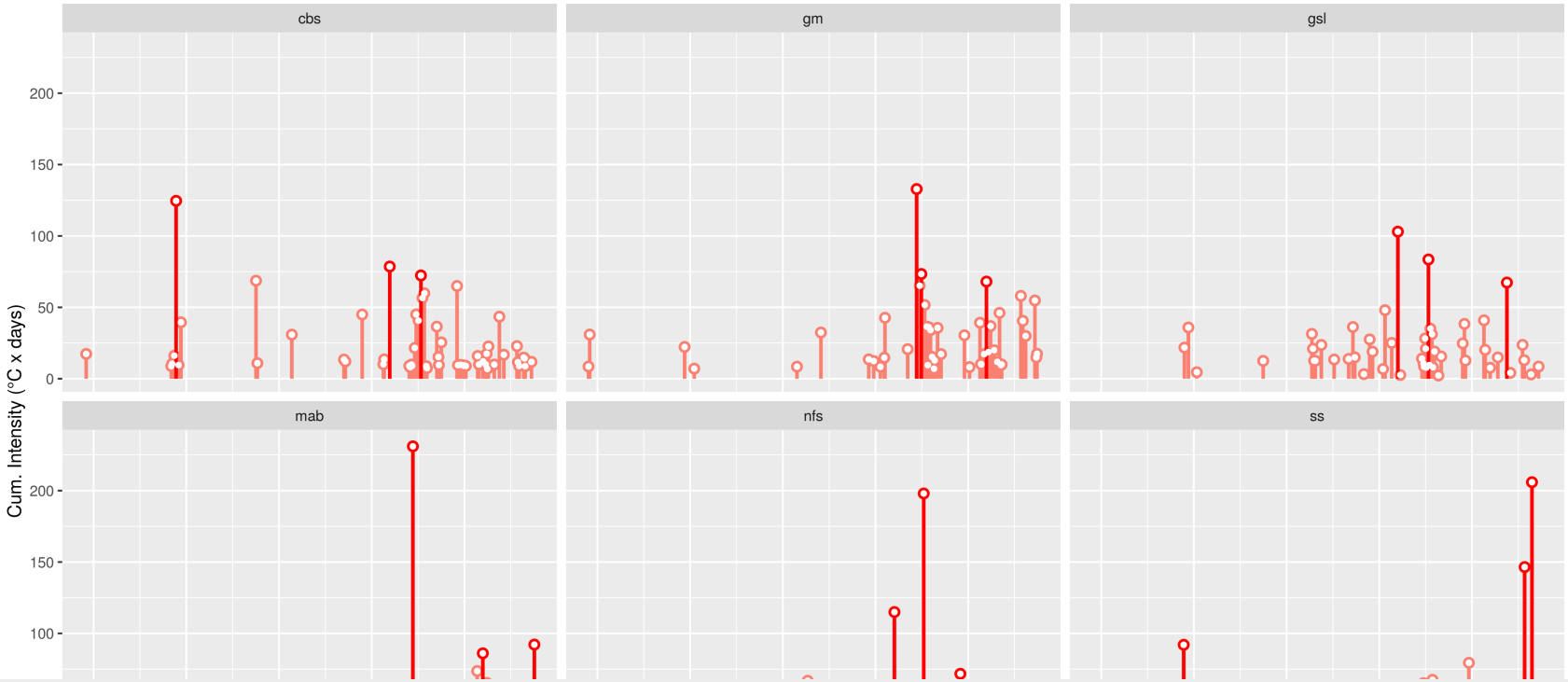
Study area

- The coastline of the Northwest Atlantic, divided into six regions based on their SST and SSS climatologies (Richaud et al., 2016)



MHW detection

- All of the SST pixels within each region were averaged together into one time series
- MHWs were calculated from these six averaged time series
- A total of 289 MHWs were detected

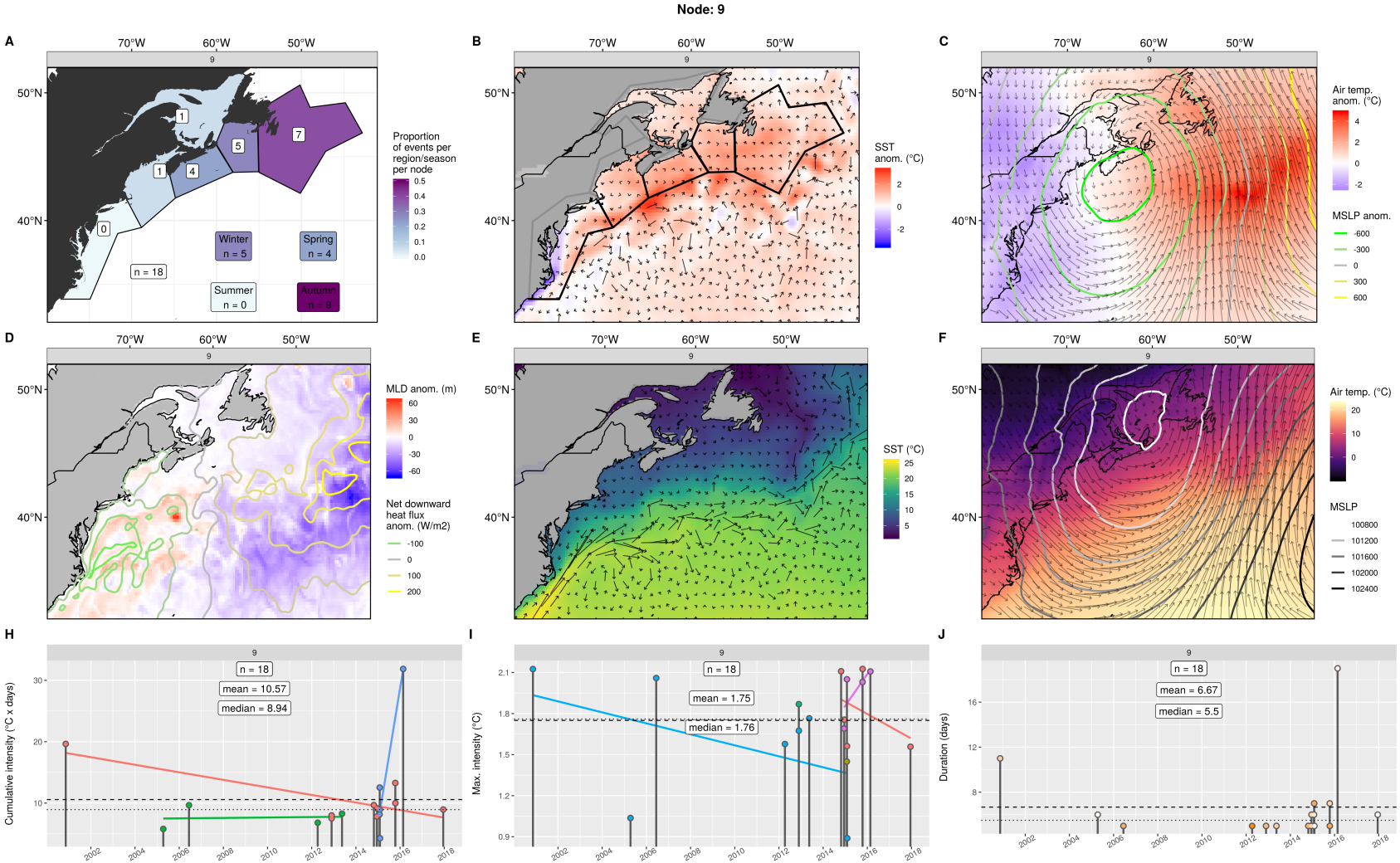


Data packets

- One data packet was created for each detected MHW
- These packets consisted of the mean anomalous air/sea state during that MHW
- The physical variables in these packets were: SST, U, V, t2m, U10, V10, MLD, Q_{net}
- All 289 data packets were then fed to the SOM to produce the 12 most common synoptic air/sea patterns

Results

Results



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Conclusions

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- The nodes tell three main stories:
  - Warm GS + air pushing up from south along coast
  - Warm air sitting over entire coast
  - Warm air being pushed over the AO from the South/Southeast onto the coast
- A few nodes tell smaller stories:
  - Short lived storms that barely manage to perturb T_{mix} for long enough to qualify as a MHW
  - These are distinctly different from the patterns associated with intense MHWs
- Overall the most intense MHWs occur during Autumn/Winter when they match patterns that are normally seen in Summer
- It is likely that this SOM technique will not work on scales larger than one meso-scale feature at a time

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