Multi-scale variations of ocean temperature off the coast of Nova Scotia:

Analyses of *in situ* and remote sensing observations and high-resolution ocean models towards applications in ecosystem and fishery

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Acknowledgment
Collaborators (detailed in presentation)
Supports in work & funding from management

Motivation

- Ocean temperatures (T) are observed with satellite remote sensing & *in situ* (ship-based, moorings/buoys, drifters, Argo profiling floats, gliders) platforms. Observed data can be taken as "truth", but usually has gaps and contains noise
- Numerical ocean models provide hindcast, forecast & climate projection of T. Modelled T has high resolutions in space-time, but contains bias.
- With quality-controlled & validated data, multi-scale T variations in space & time can be revealed; some aspects of T variations have been linked to various aspects of ecosystem & fishery variations
- Can ocean T analyses can be enhanced to reveal more links, for understanding past changes & predicting future changes of ecosystem & fishery?

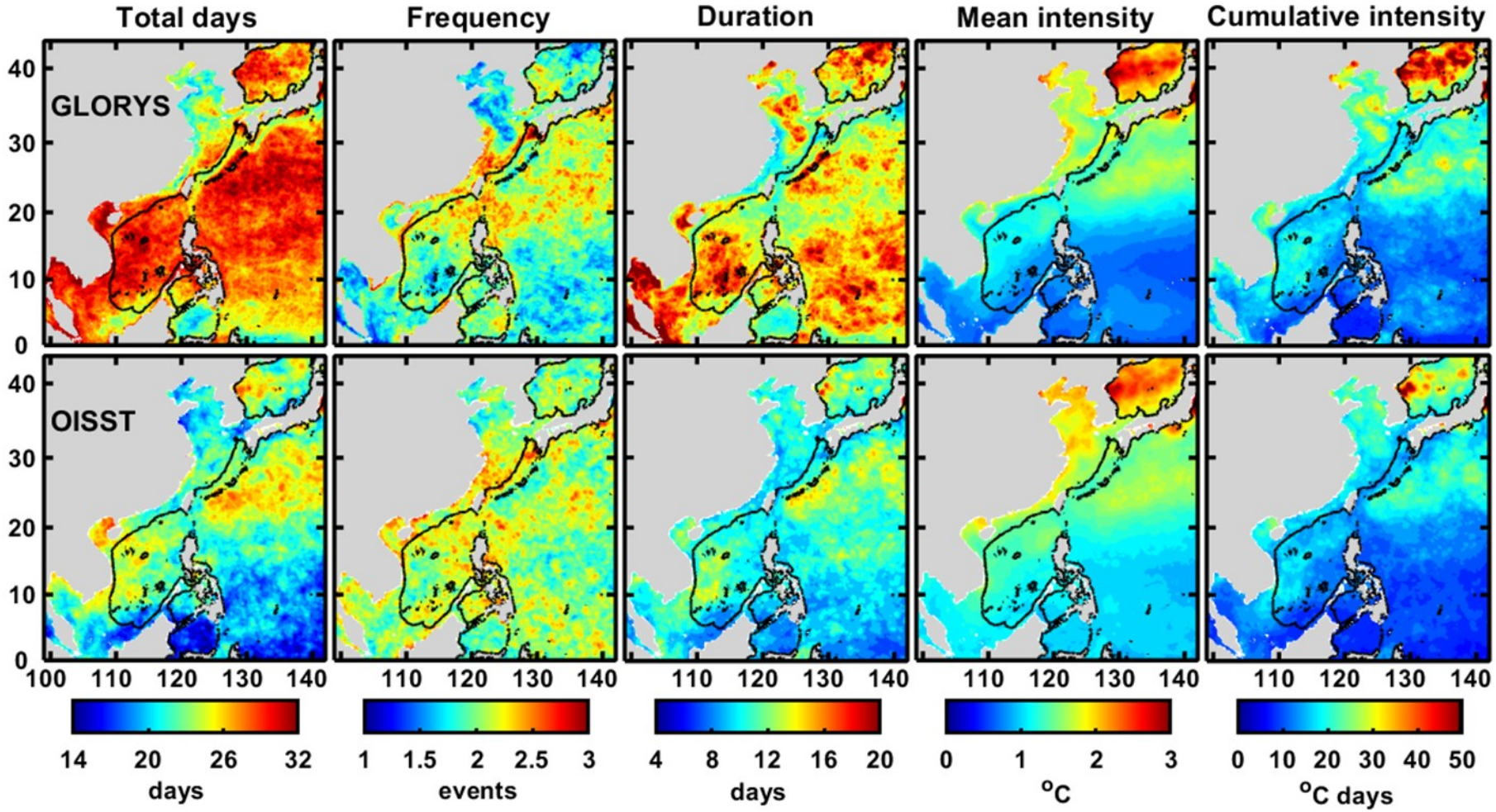
This presentation:

Examples from recent & ongoing analyses of my collaborators mainly in DFO on ocean T variations at multiple space-time scales, and their potential applications

1. **Comparison of surface marine heatwave parameters from remote sensing & modelled T – similarities & differences**
2. **Rapid cooling in nearshore waters during cold air outbreaks – small spatial-scale variations that are hard to resolve by observations & models**
3. **Interannual variations of coastal upwelling – combination of remote sensing & modelled T**
4. **Bottom T variations off Nova Scotia during 2008-2023, and relationship with lobster catching rate**

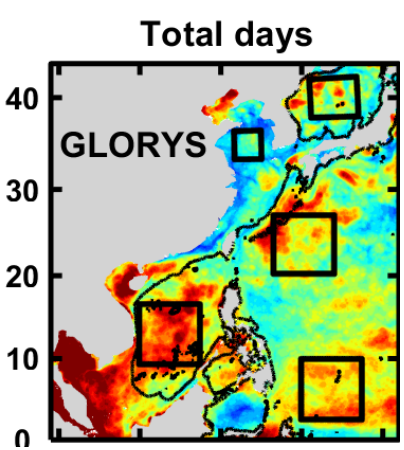
1. Surface marine heat wave parameters from OISST v2.1 & GLORYS 12v1 Haiyan Wang et al. 2024: Frontiers in Marine Science

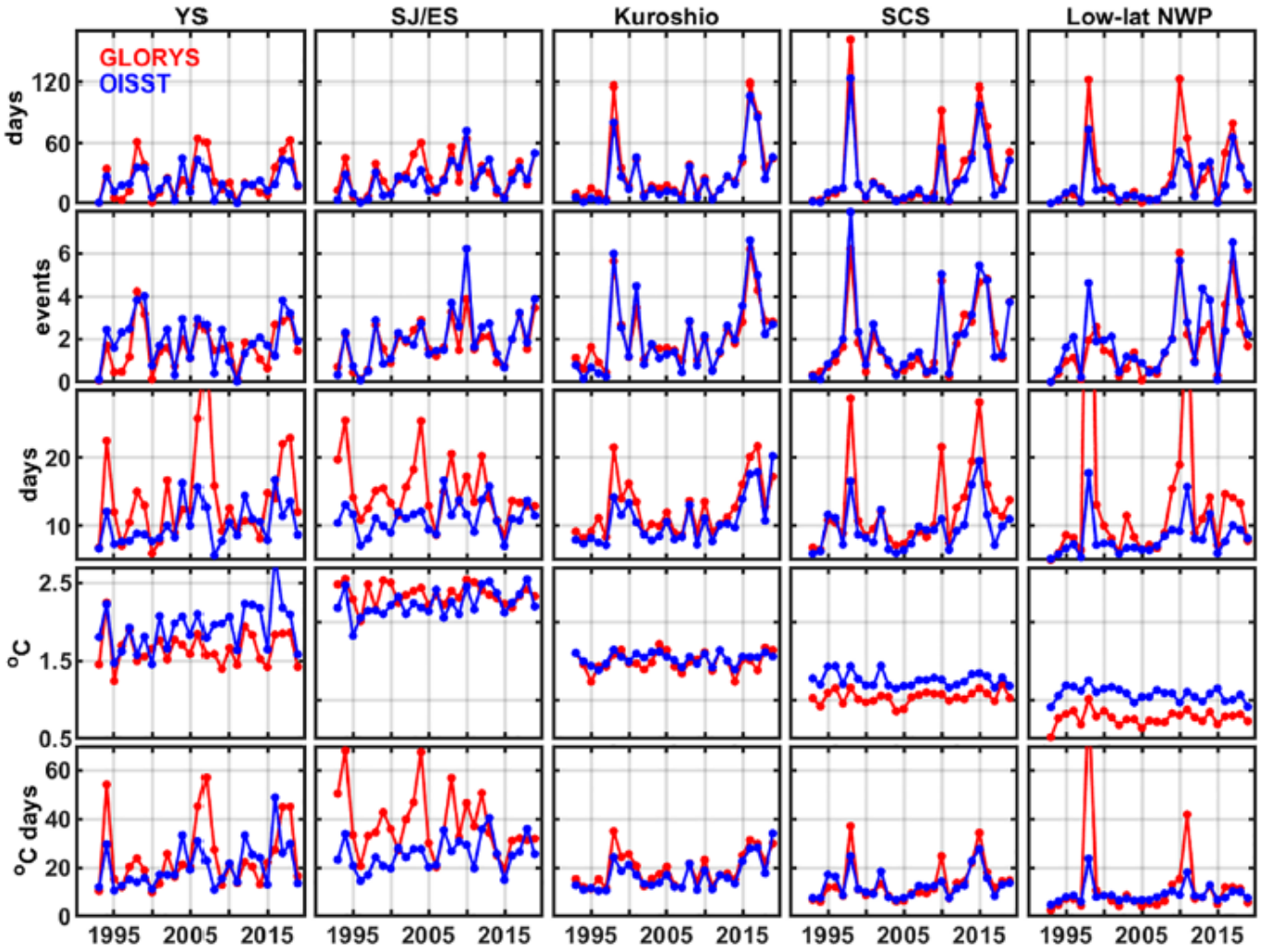
NW Pacific annual statistics during 1993-2019



Similar spatial distributions; GLORYS obtains larger “Total days” & “Duration”, but lower mean intensity

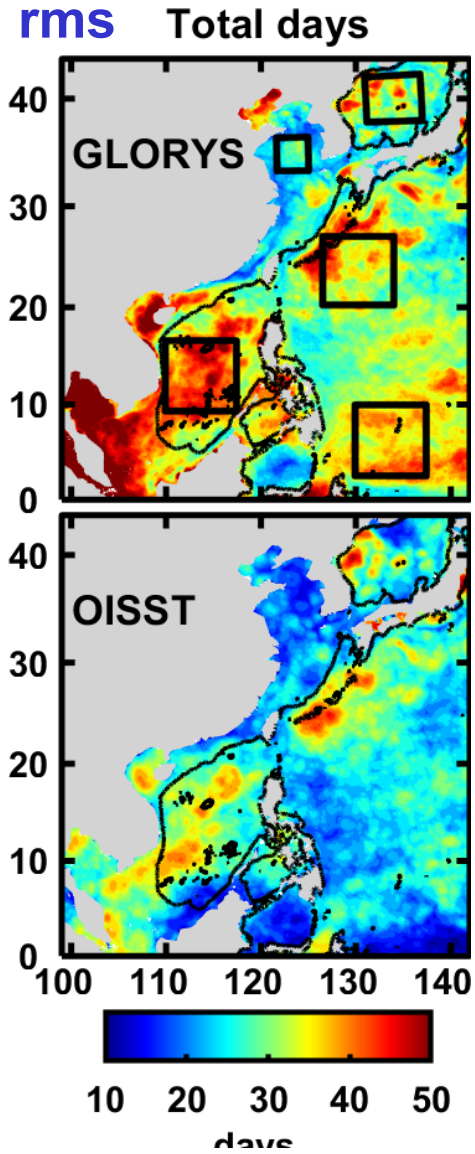
Interannual variations in different regions

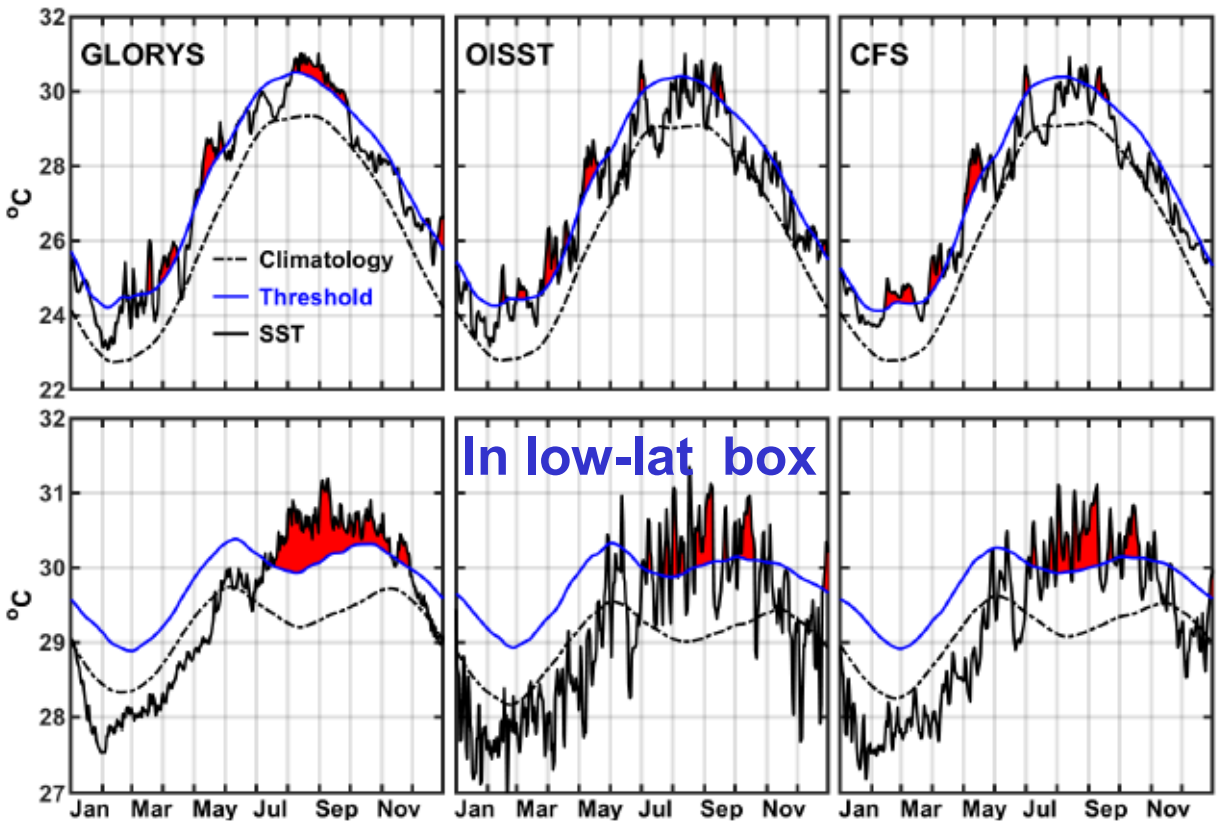




- **Similar** large peaks (**GLORYS higher**) in "Total Days" (1st row), "Duration" (2nd row) & "Cumulative Intensity" (5th row)
- Some large peaks show correspondence with Niño3.4 index

Compare SST time series in 1998 at two representative sites



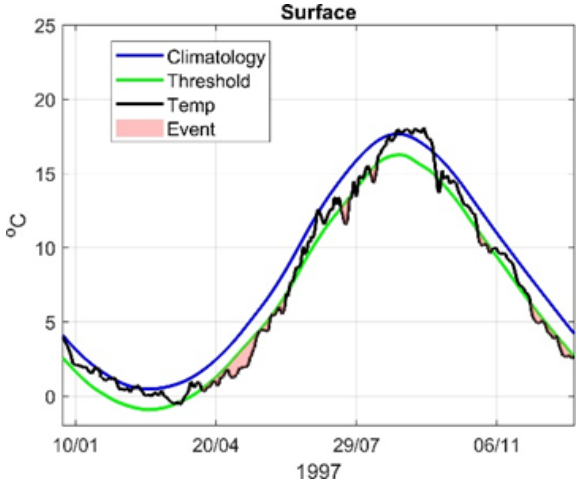


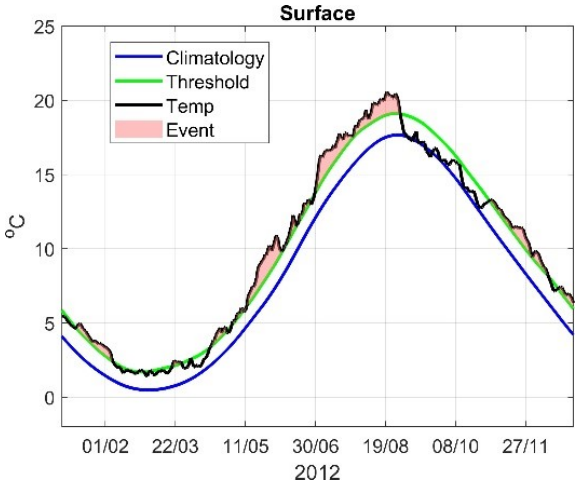
- In low-lat, GLORYS obtains much less high-frequency SST variations than OISST; Climate Forecast System CFS v2 is in between
- Are differences due to issues in OISST or data assimilation? – further work is needed

Recent work: Marine heat waves & cold spells on Scotian Shelf

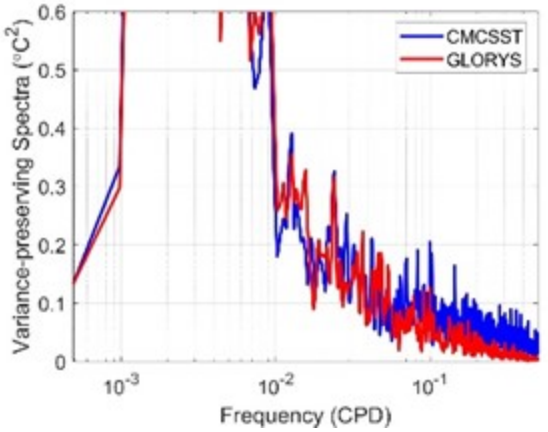
Zhai, Lu, Garric, in progress

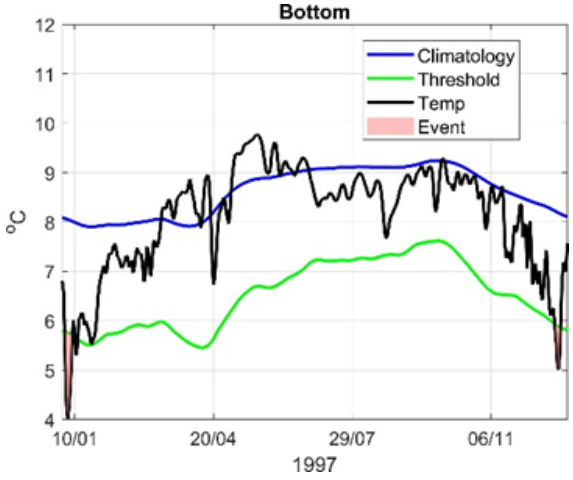
Detection with GLORYS

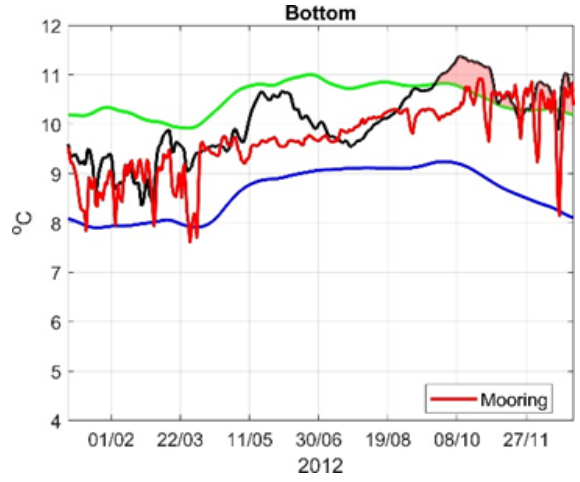




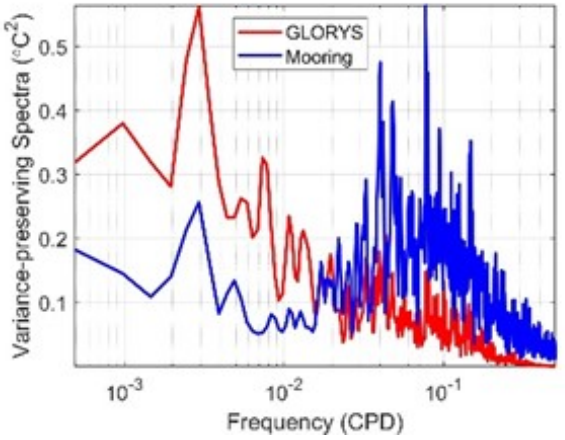
SST: GLORYS & CMCSST has similar spreads





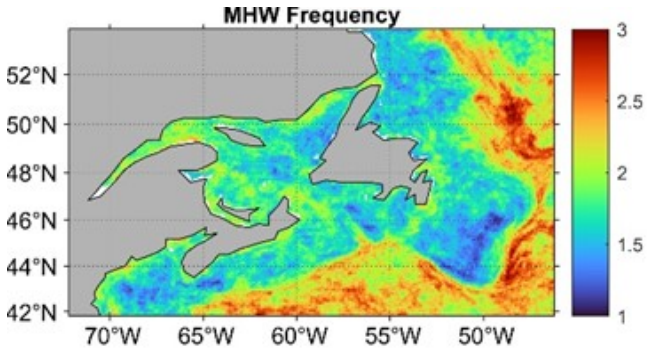


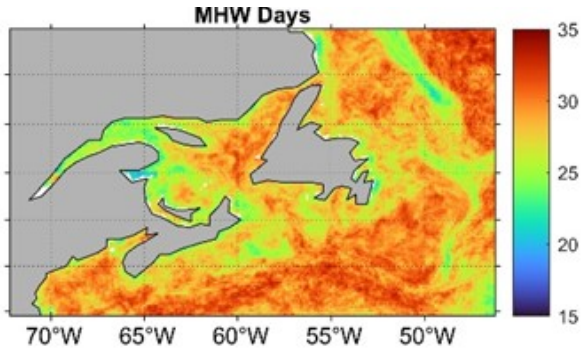
Bottom T: GLORYS & in situ Obs has different spectra

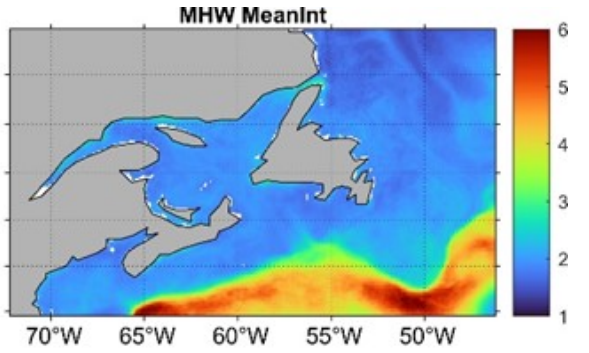


GLORYS MHW parameters averaged over 1993-2023

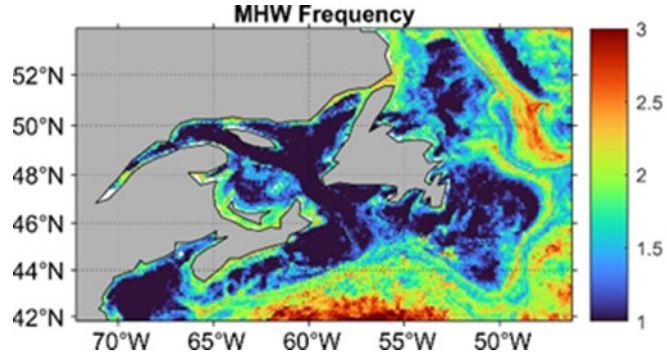
Surface

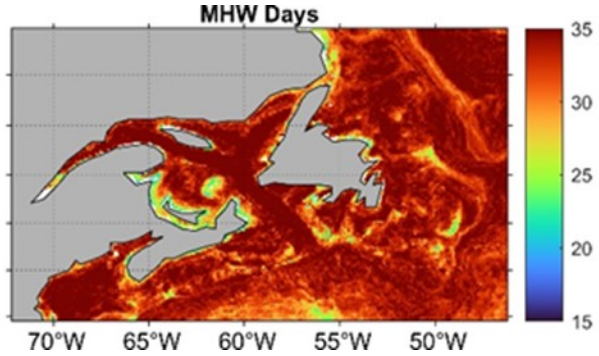


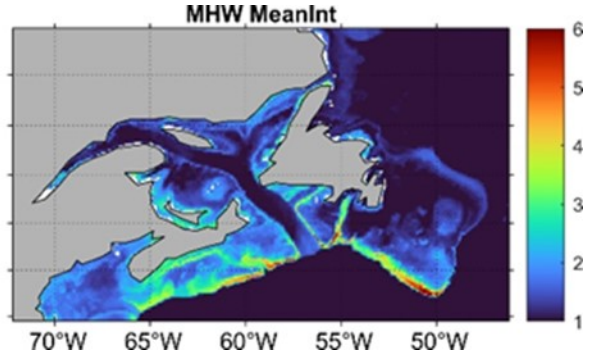




Bottom

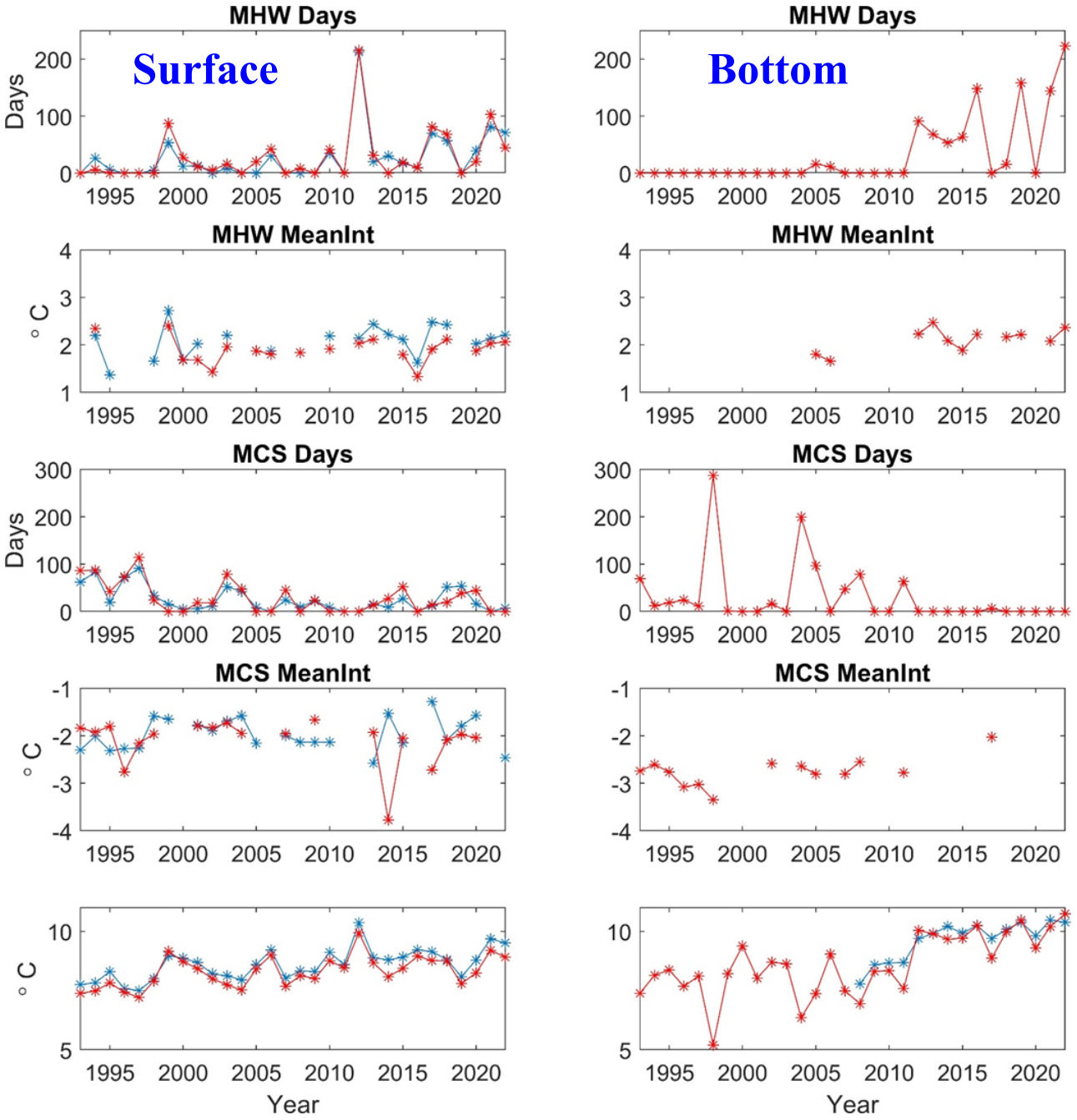






Spatial variations can be attributed to circulation, eddies, etc.

Interannual variations of heatwave & cold spell parameters



Further work

- Forcing mechanism of space-time variations
- Applications: Do heatwaves & cols spells impact fish physiology?

2. Rapid drops of ocean temperatures in nearshore shallow bays during cold air outbreaks

Casey, Lu, Petrie, MacDermid, Paquin, *Proc NS Institute of Science*, in revision

Event on Feb 3-5, 2023

Kalin Mitchell
CTV News Atlantic Chief Meteorologist
Follow | Contact

Updated Feb. 6, 2023 5:18 p.m. AST
Published Feb. 6, 2023 4:31 p.m. AST

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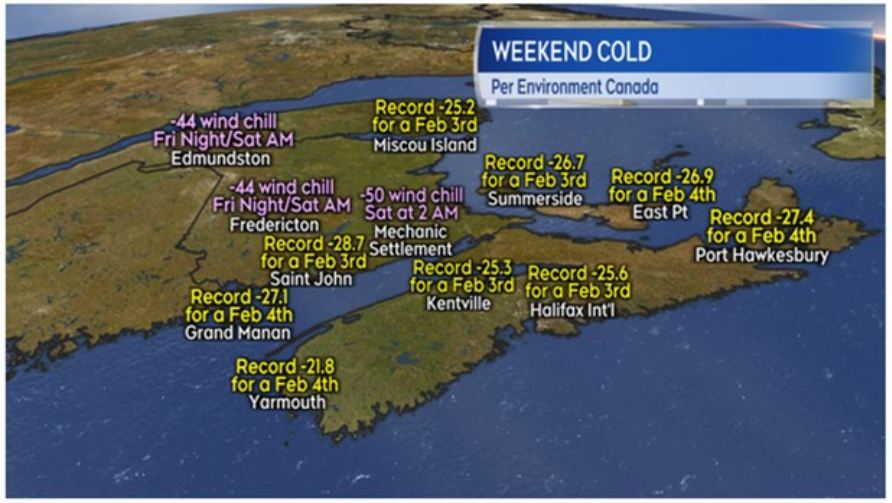
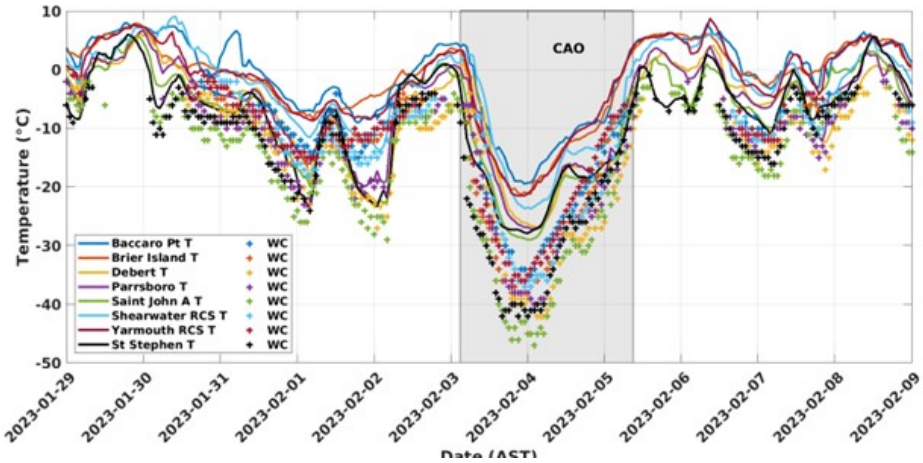
While relatively short-lived, the blast of Arctic air in the Maritimes was enough to break some long-standing low temperature records for all three Maritime provinces Friday and Saturday.



Long-standing low temperature records were broken in the Maritimes on both Friday and Saturday.

- Short lived – approximately 2.5 days
- Relatively warm season up to that point

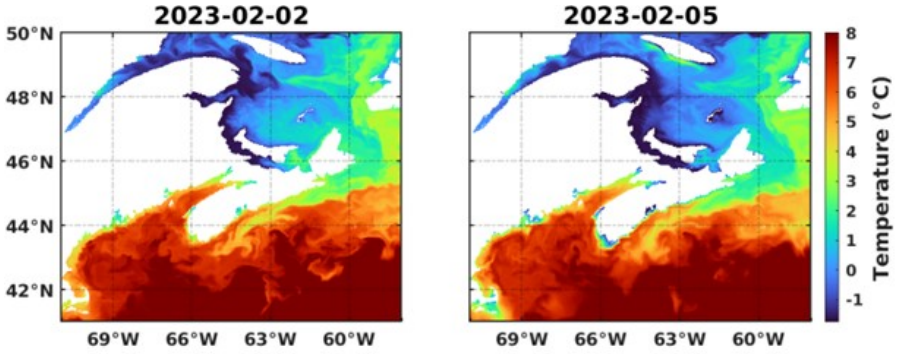
Air T at Shearwater Airport



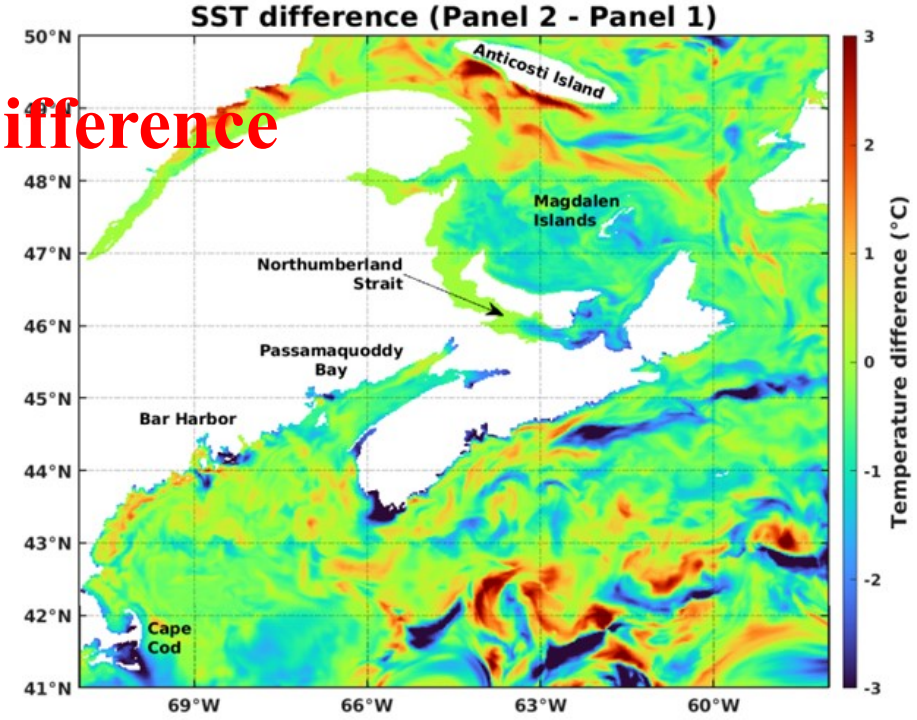
How & where does ocean temperature change?

Analyze CIOPS-E model results

Daily SST before & after CAO



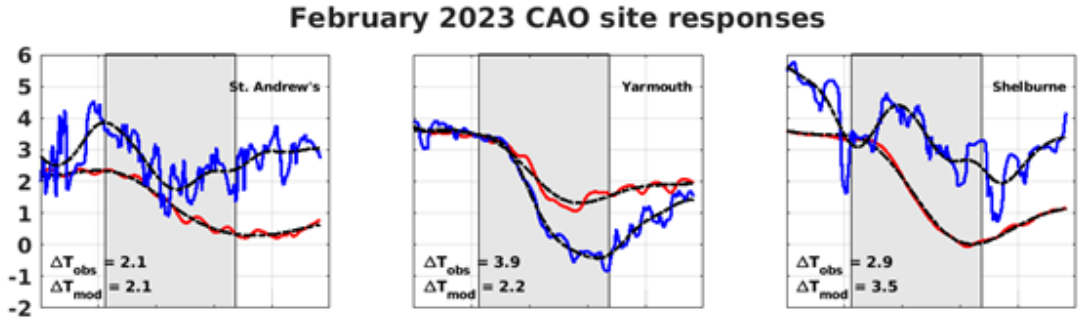
Difference

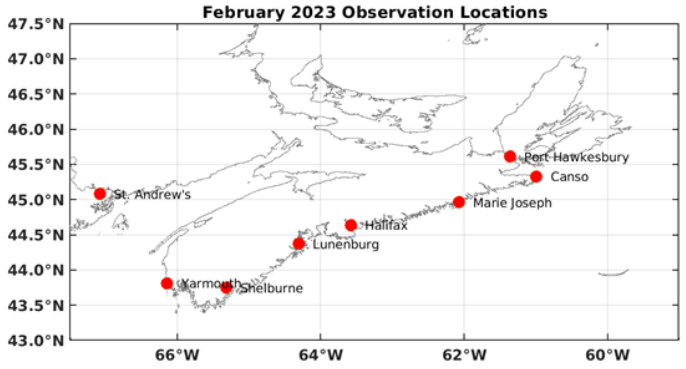


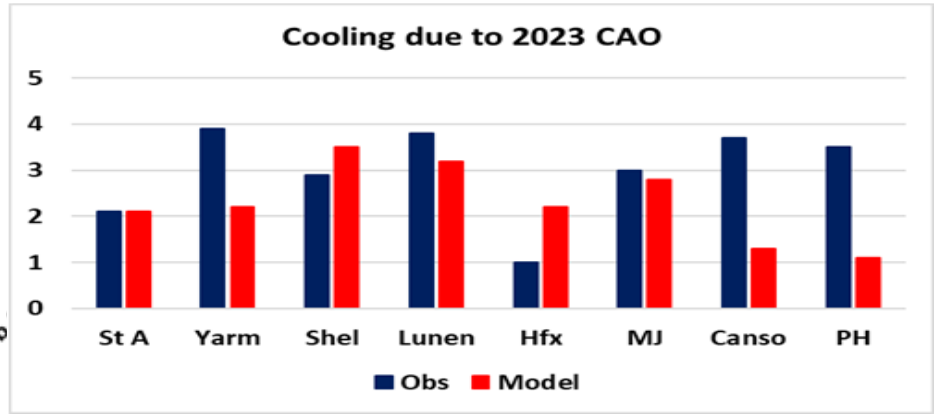
Model shows 1.5 - 5 ℃ drops of water temperature (surface to bottom) in relatively isolated shallow bays & straits: St. Margaret's, Mahone, St. Mary's, Cobequid &Chignecto Bays; Pubnico/Cape Sable shallow areas; Northumberland Strait

Comparison of model T with *in situ* observations

Blue: Obs **Red: model**







- **Model bias may be attributed to 2.5 km spatial resolution**
- **It may be challenging for satellite data to resolve T changes in nearshore water**

Can rapid ocean cooling impact fish?

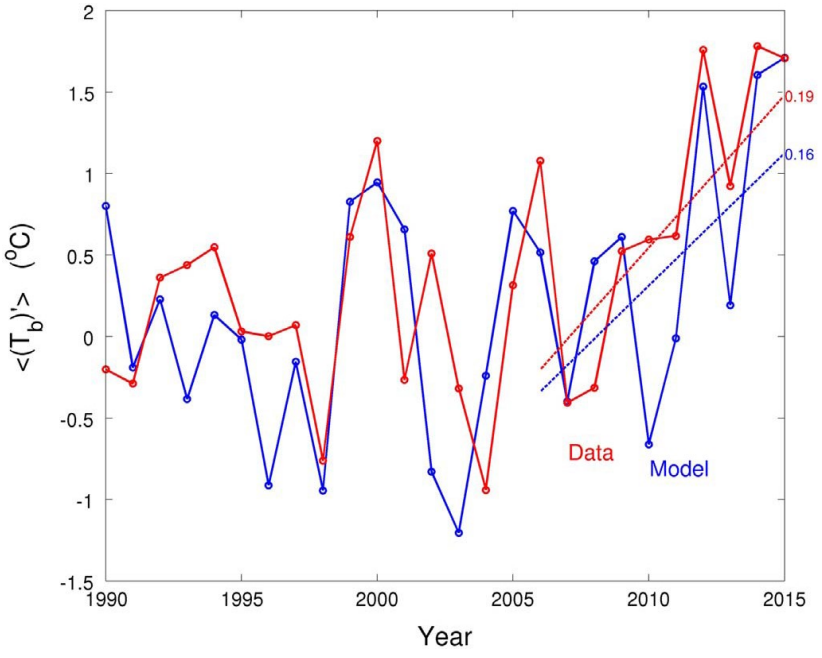
December 2016 CAO is coincidental with fish kill in St. Mary's Bay, Nova Scotia

4. Bottom T variations off Nova Scotia during 2008-2023, and relationship with lobster catching rate

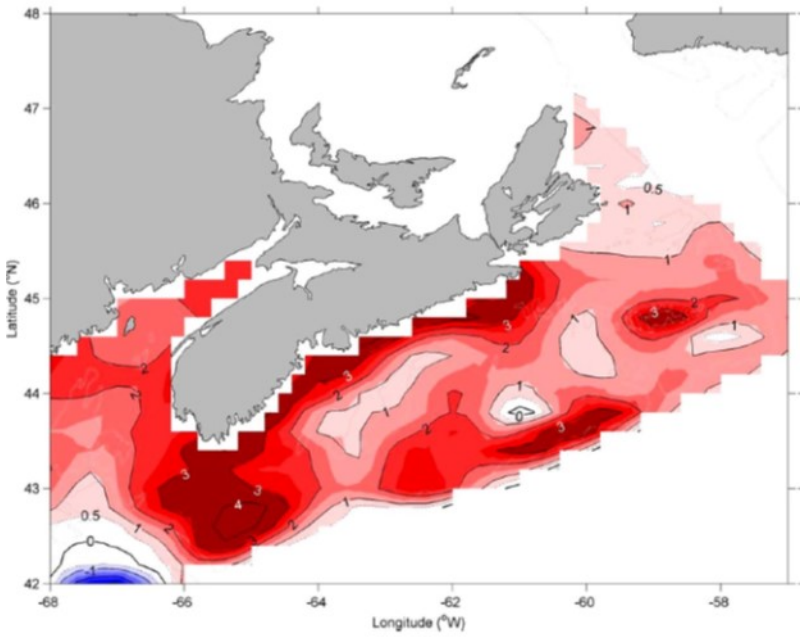
Lu, Hu & Cool et al, in progress

Previous study: 2012, 2014 & 2015 warm events on Scotian Shelf –using GLORYS12v1 & AZMP data **Brickman et al 2018**

July bottom T anomalies



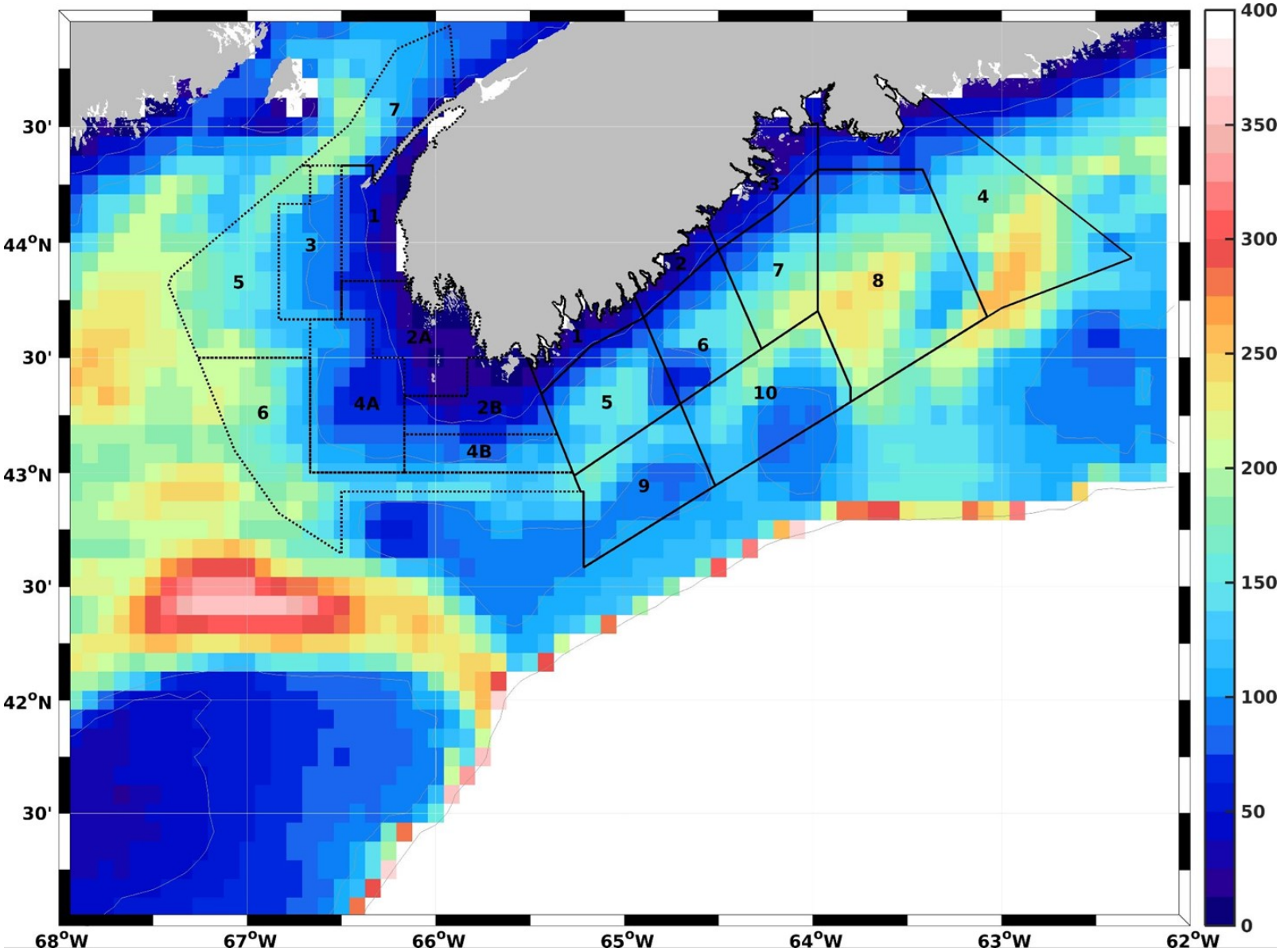
AZMP July 2012 bottom T anomaly relative to 1981-2010



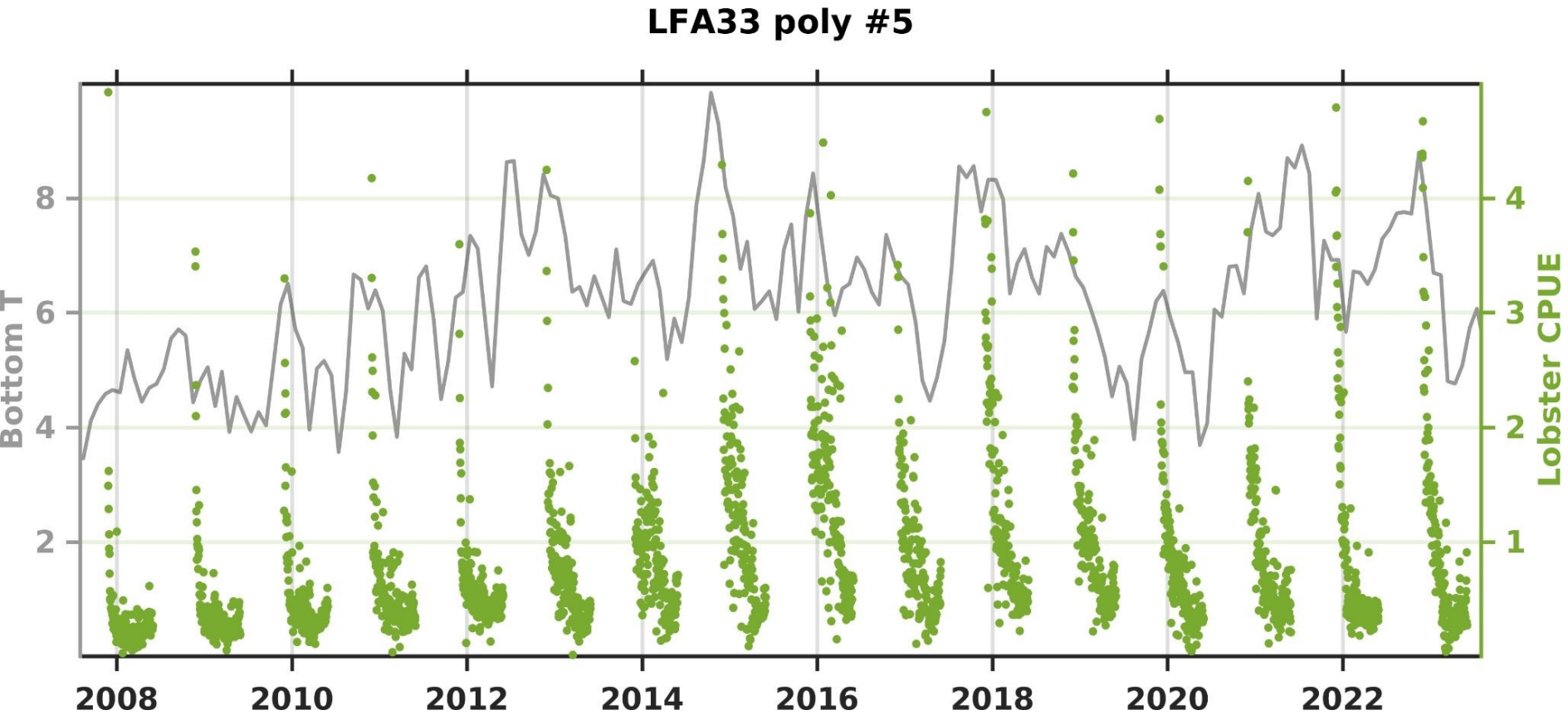
Warm anomaly in 2011/2012 appears to have negative impacts on some life stages of snow crab

Zisserson & Cook 2017

Focus on LFA33, Polygons #1-7



Bottom temperature from GLORYS12v1 & Lobster CUPE (catch per unit effort)



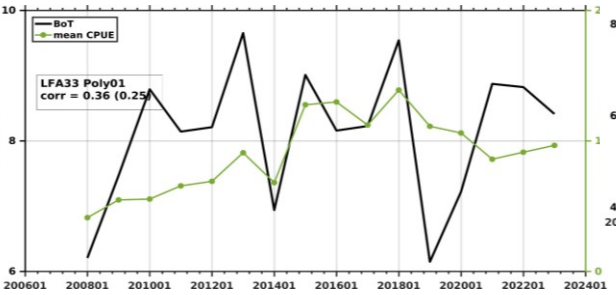
There are different ways to examine their relations

– needs for collaborative analysis

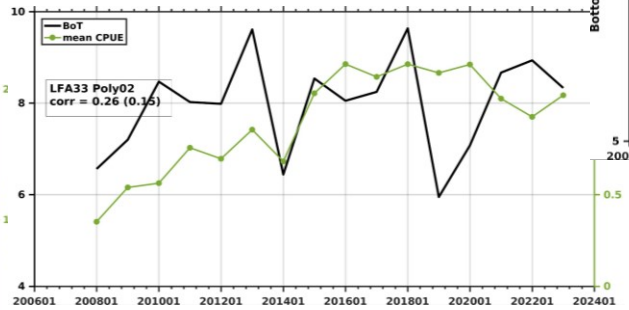
Original time series: Nov-Dec averaged bottom T vs Fishing season (Nov-Apr) averaged Lobster CPUE

Pearson correlation (Kendall tau)

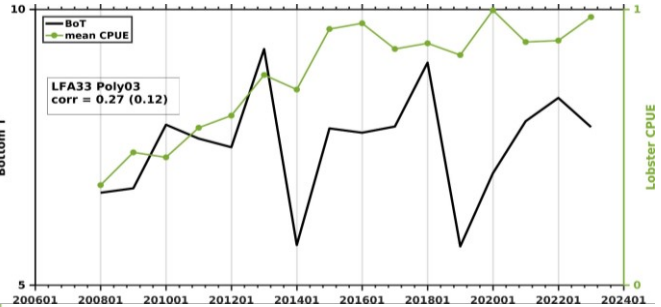
#1, R=0.36 (0.25)



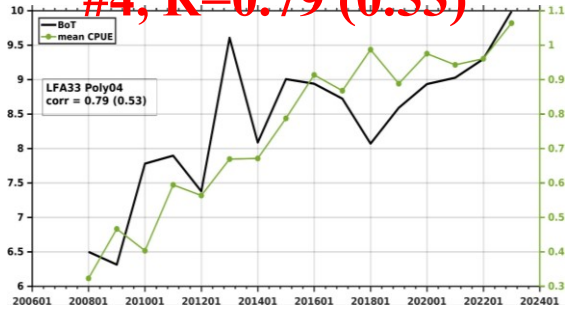
#2, R=0.26 (0.15)



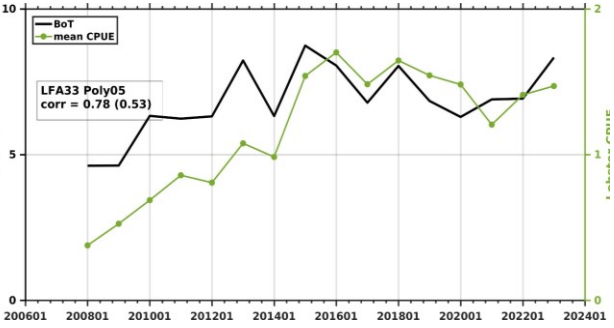
#3, R=0.27 (0.12)



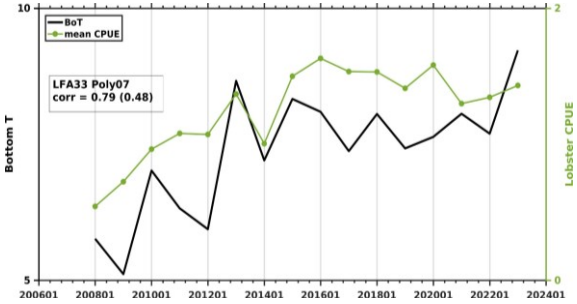
#4, R=0.79 (0.53)



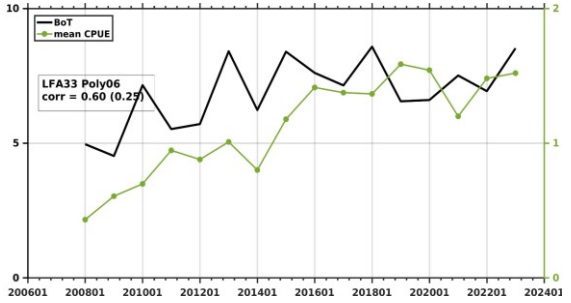
#5, R=0.78 (0.53)



#6, R=0.60 (0.25)



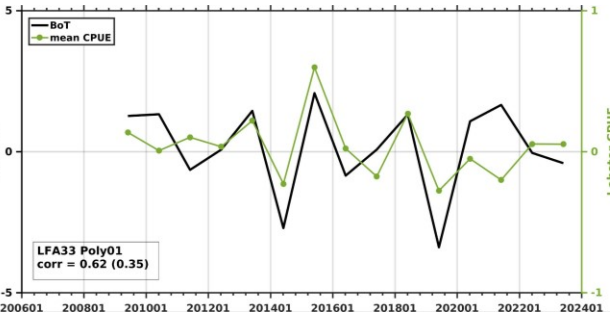
#7, R=0.79 (0.48)



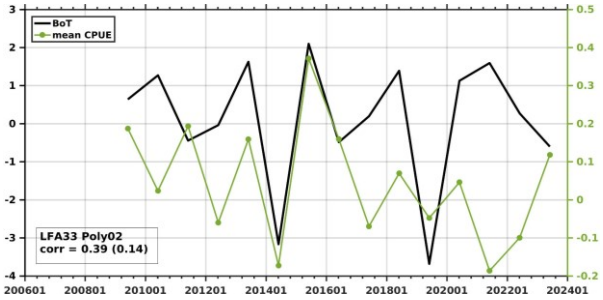
Detrended time series: Nov-Dec averaged bottom T vs Fishing season (Nov-Apr) averaged Lobster CPUE

Pearson correlation (Kendall tau)

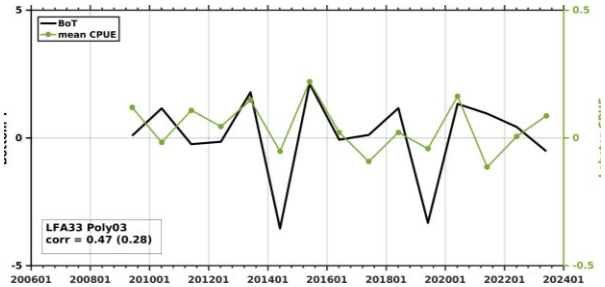
#1, R=0.62 (0.35)



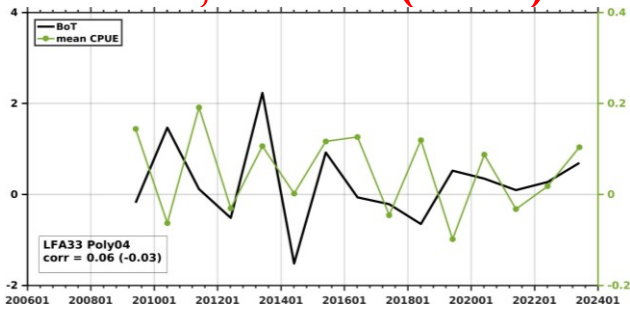
#2, R=0.39 (0.14)



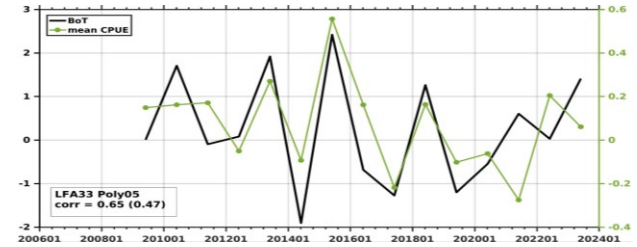
#3, R=0.47 (0.29)



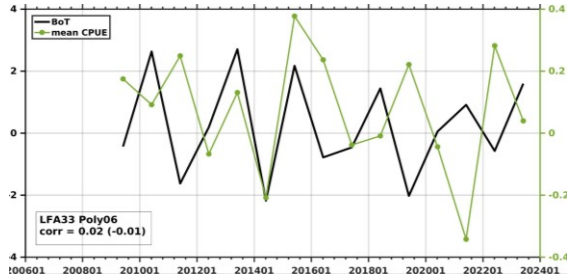
#4, R=0.06 (-0.03)



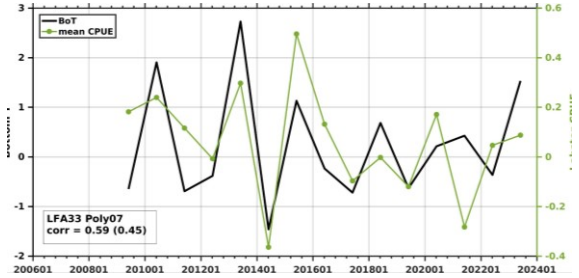
#5, R=0.65 (0.47)



#6, R=0.02 (-0.01)



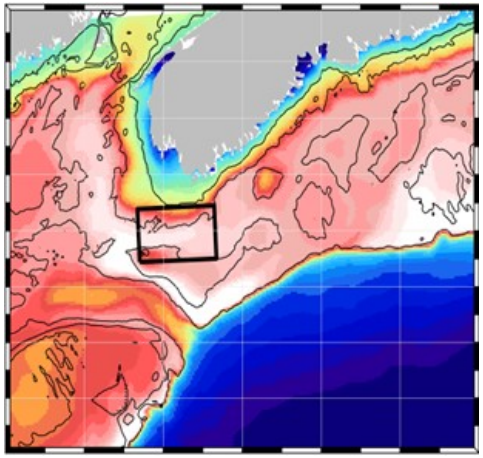
#7, R=0.59 (0.45)

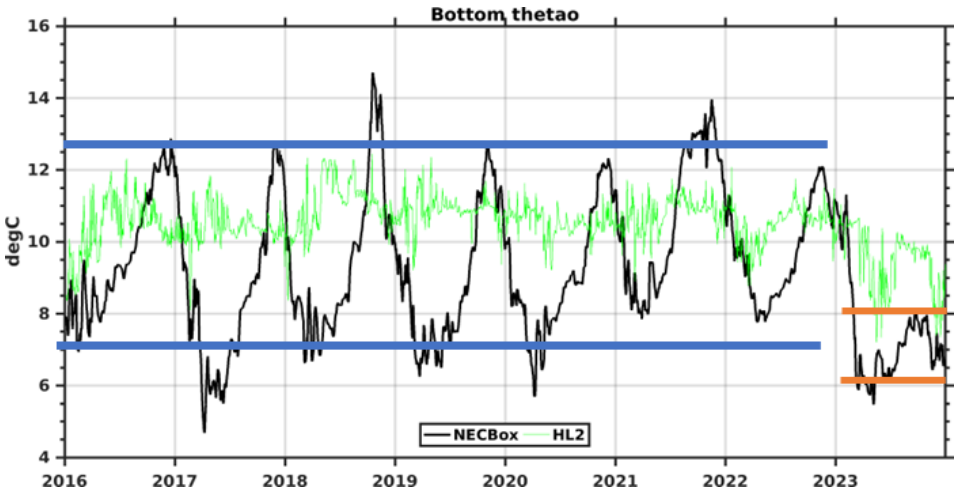


Related work using CIOPS-E: Bottom cold anomaly on Scotian Shelf during 2023

Motivation: Investigate fishermen's finding of abnormally low bottom temperature & low lobster catching rate in LFA34

CIOPS-E model results





Summary

- Remote sensing SST may have different high-frequency statistics with data-assimilative ocean reanalysis – causes?
- Model & observations (*in situ* & remote sensing) have challenges to resolve small spatial-scale ocean T variations
- Quality-control & validation tell accuracy/bias of obs/models, important for deciding where, when & at what scales applications can be developed
- Ocean T variations have multiple space-time scales, which may affect different aspects of marine ecosystem & fishery
- Applications will benefit from continuing development & evaluation of high-resolution ocean T, from remote sensing & in situ obs, & models