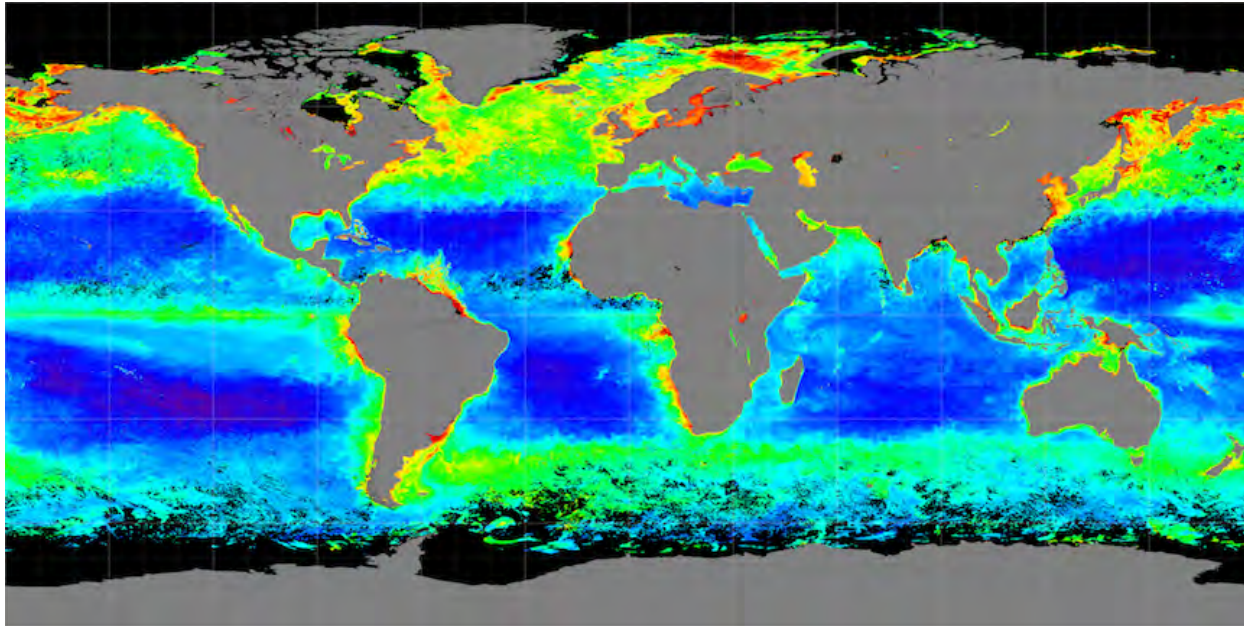


Life in a Patchy World:

Submesoscale dynamics and phytoplankton growth in the oligotrophic North Pacific



Naomi M. Levine

sos.noaa.gov

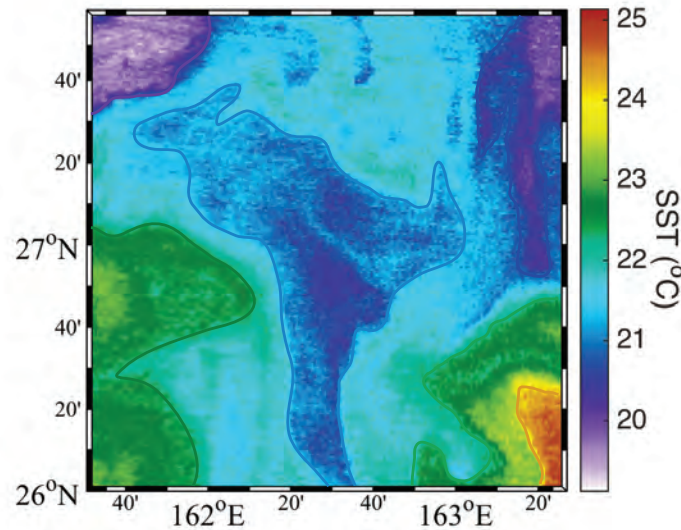
Xiao Liu

Marine and Environmental Biology
University of Southern California

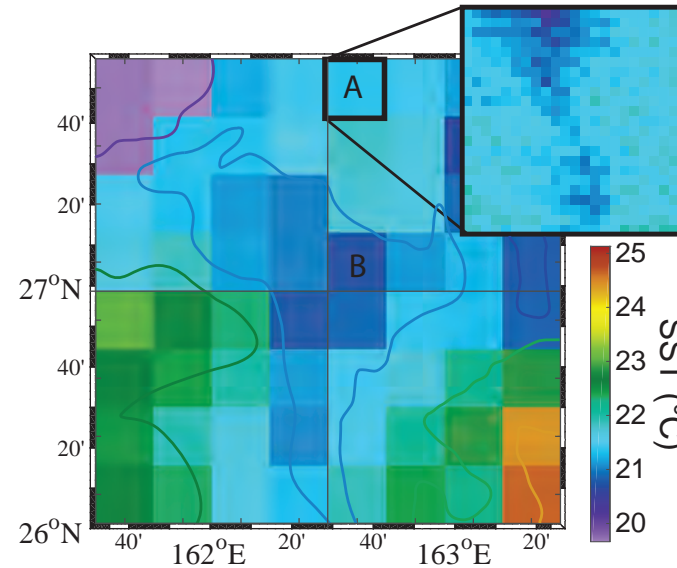


The Impact of Submesoscale Processes on Large-scale Carbon Cycling

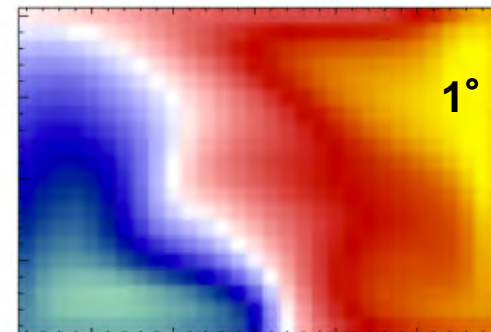
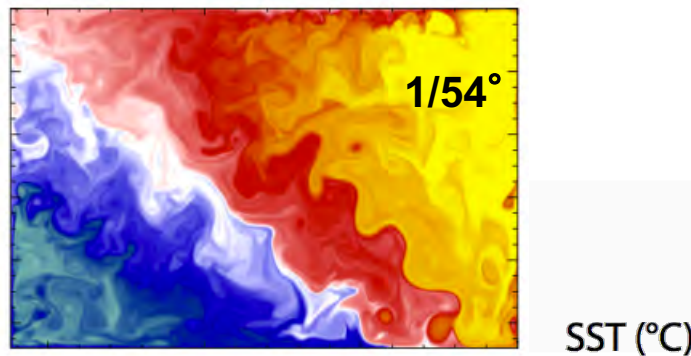
Fine Resolution



Coarse Resolution



Levine, submitted

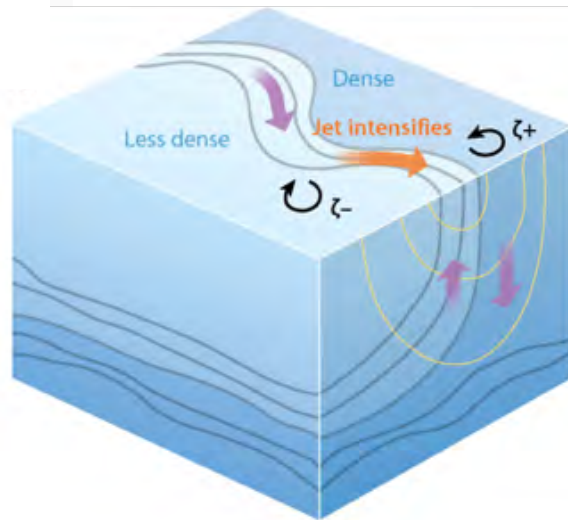


9. 11. 13. 15. 17. 19. 21. 23.

Levy et al. 2012

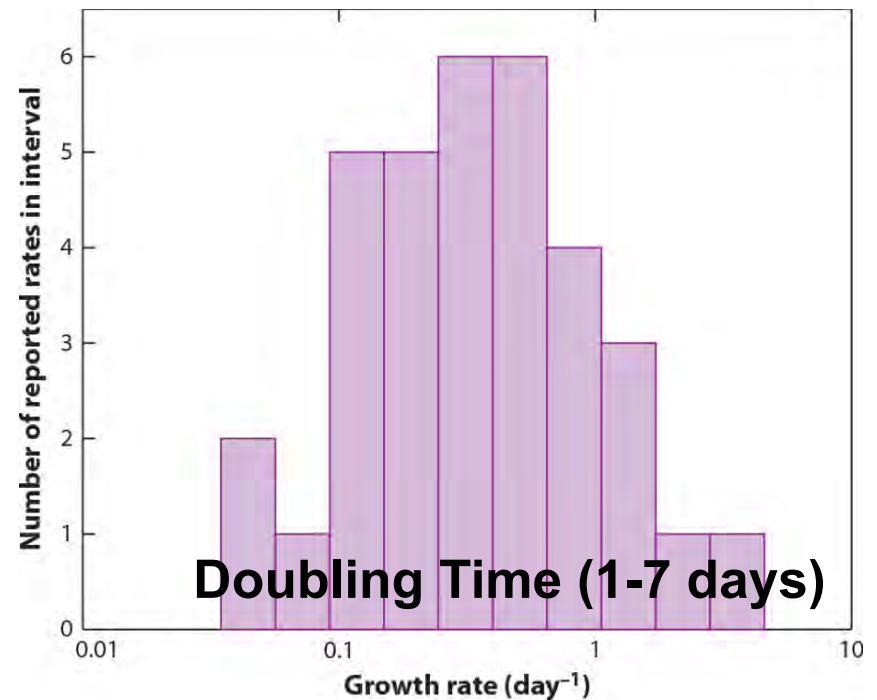
The Impact of Submesoscale Processes on Large-scale Carbon Cycling

Timescale of days



Mahadevan 2016

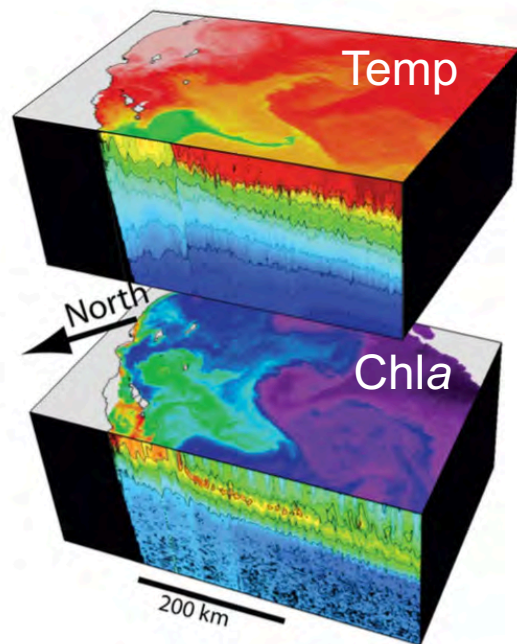
Phytoplankton Growth Rates (day^{-1})



Laws (2013) ARMS; data from Goldman et al. (1979) and Eppley (1981)

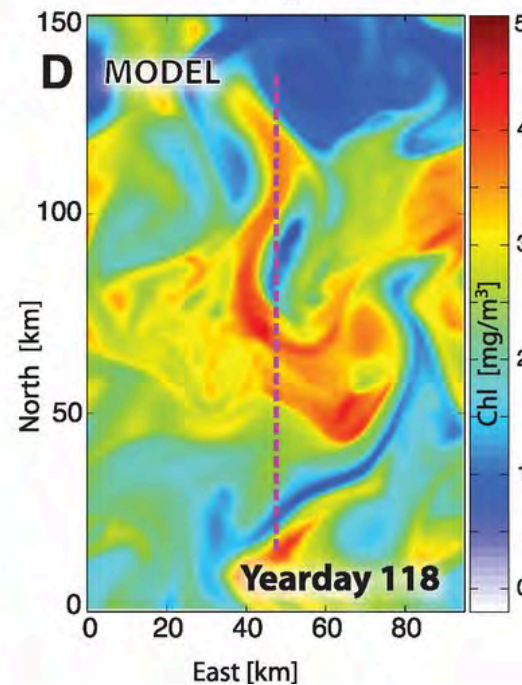
The Impact of Submesoscale Processes on Large-scale Carbon Cycling

in situ



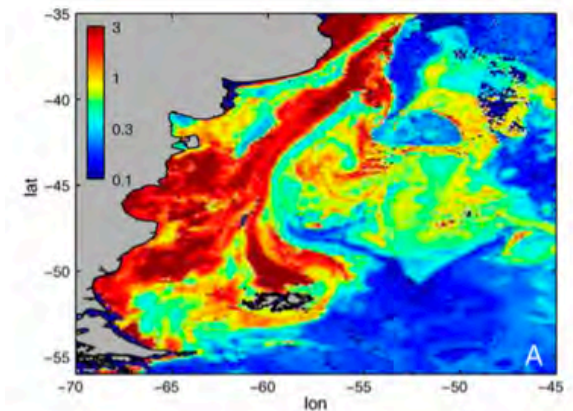
Levy et al. 2012

modeling

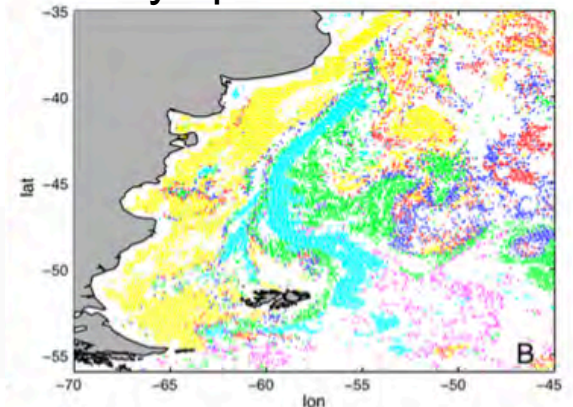


Mahadevan et al. 2012

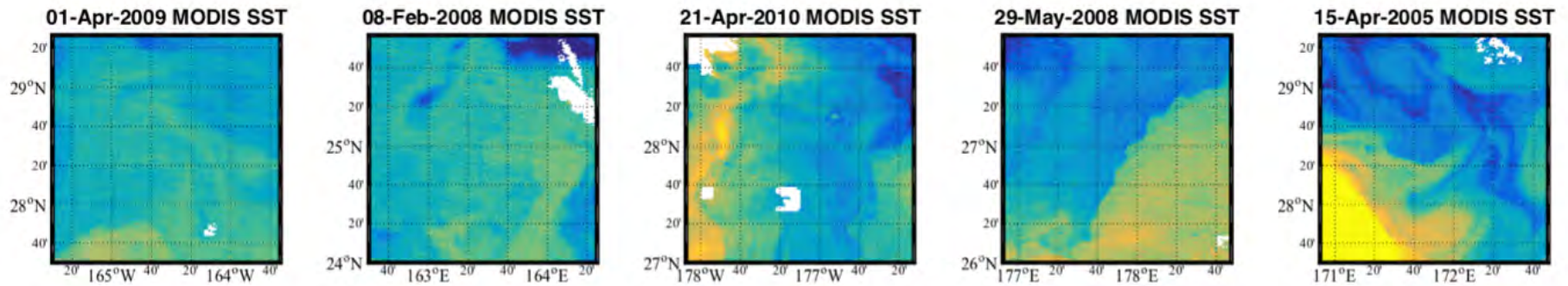
Remote Sensing
Chlorophyll a



Phytoplankton niches



D'Ovidio et al 2010 PNAS



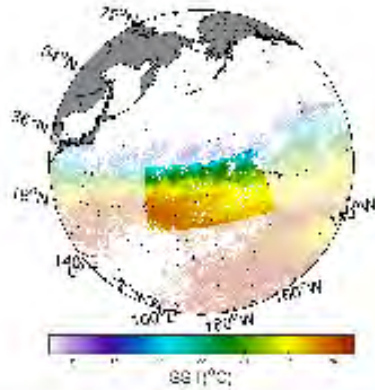
What fraction is occupied by submesoscale features?

How patchy is the ocean?

How do you quantify patchiness?

Relationship between patchiness and productivity?

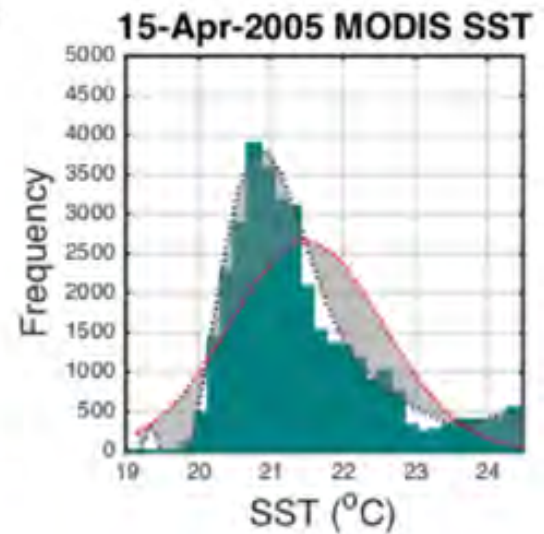
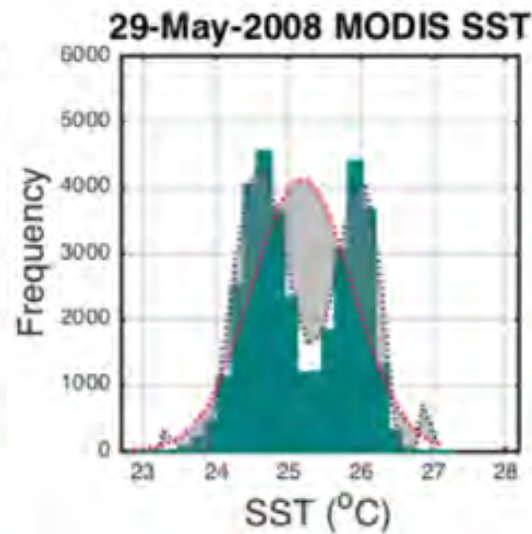
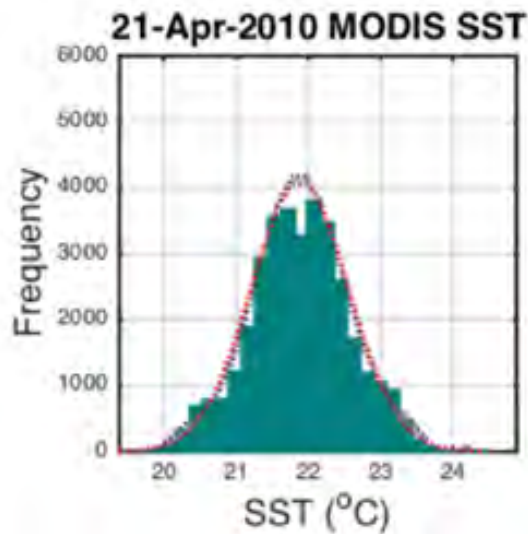
The Heterogeneity Index (HI) [0 1]



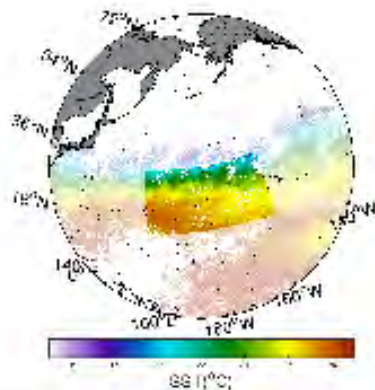
A new metric for ocean surface patchiness using MODIS/Aqua 1-km SST

$$HI = a \left(b|\gamma| + c \frac{\sigma}{\sqrt{n}} + dP \right)$$

skewness
standard deviation
misfit between polynomial and normal fits

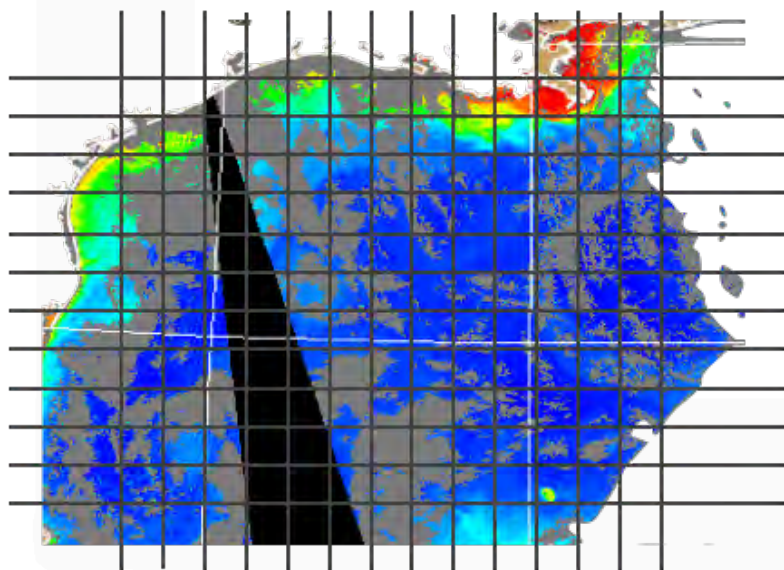


The Heterogeneity Index (HI) [0 1]

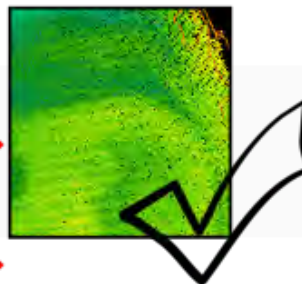
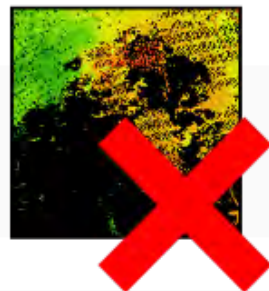


A new metric for ocean surface patchiness using MODIS/Aqua 1-km SST

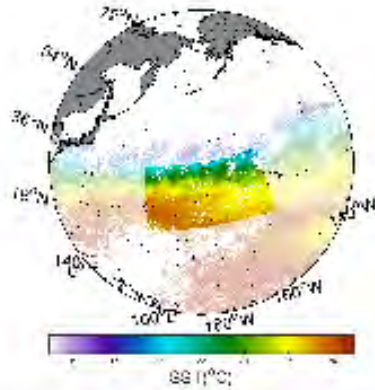
$$HI = a \left(b|\gamma| + c \frac{\sigma}{\sqrt{n}} + dP \right)$$



- MODIS-Aqua 2002-2015
- Spatial resolution: ~ 1 km
- 32,222 100x100 km images
- Average SST coverage 86%
- average Chl coverage 79%

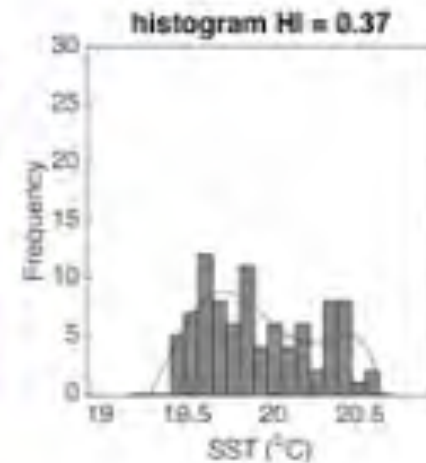
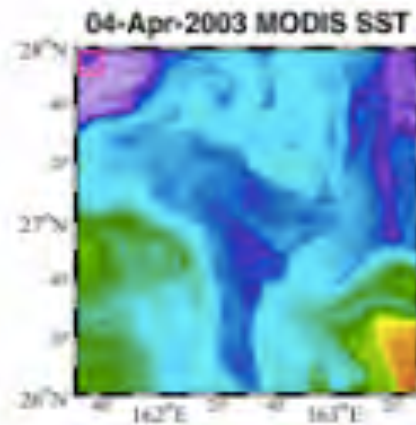


The Heterogeneity Index (HI) [0 1]

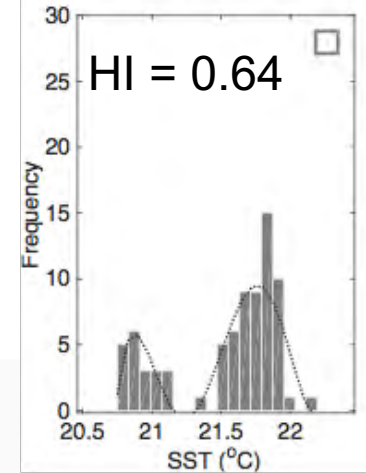
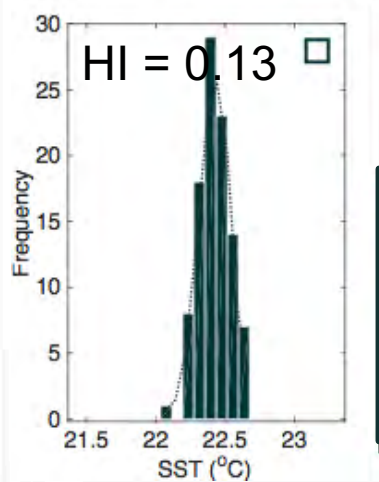
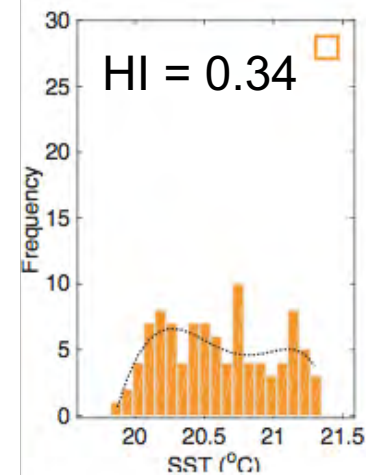
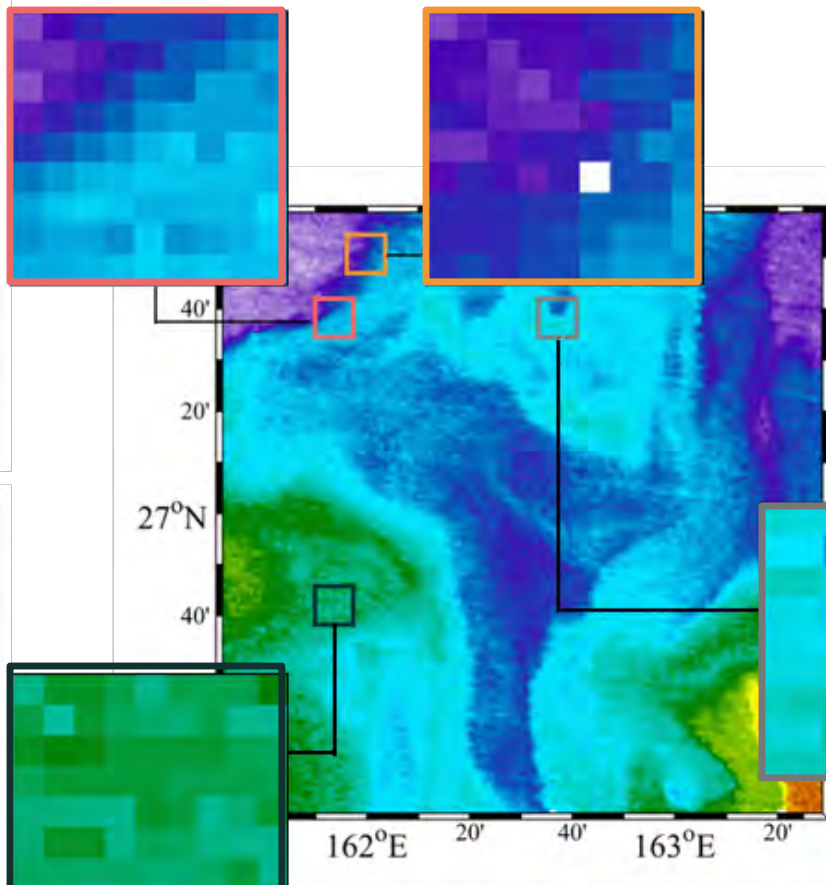
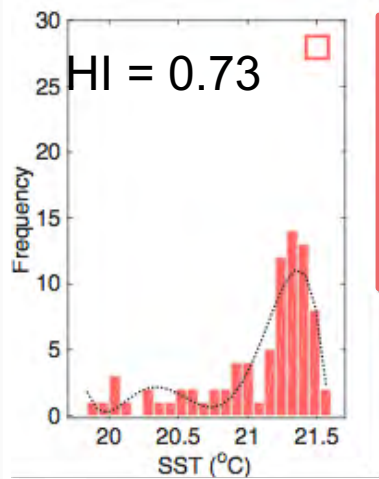


A new metric for ocean surface patchiness using MODIS/Aqua 1-km SST

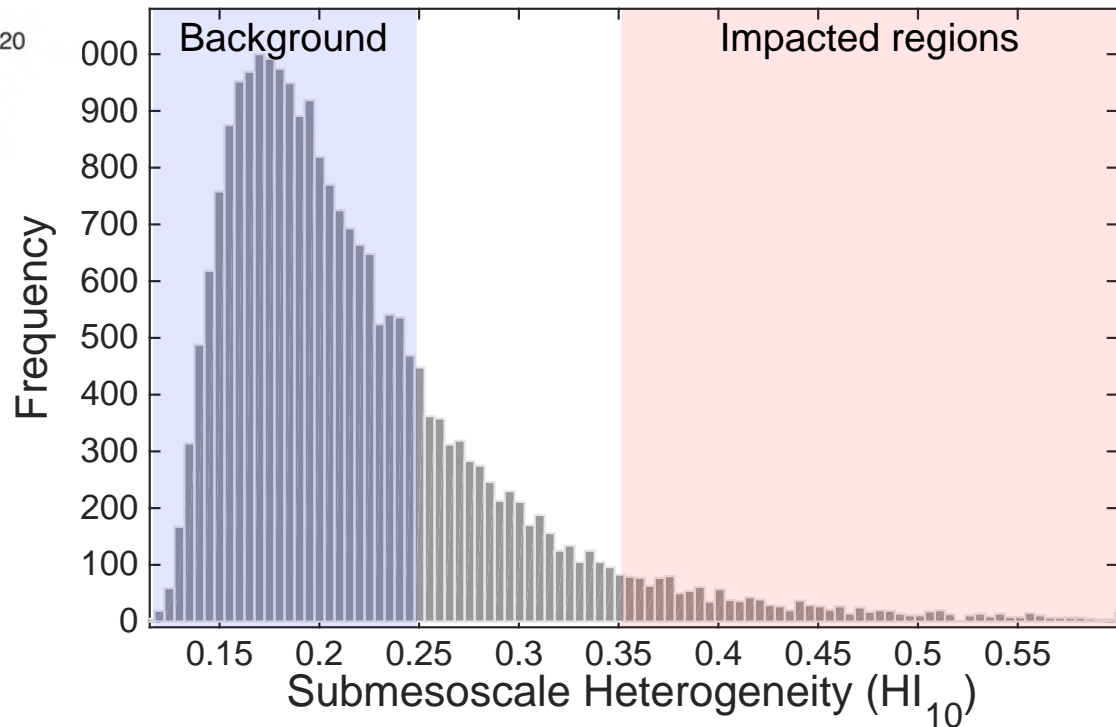
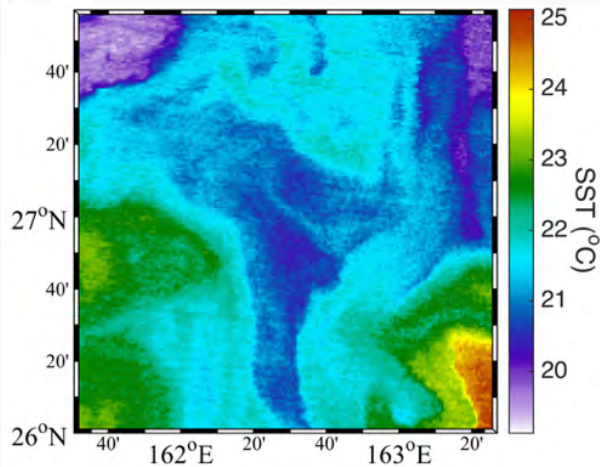
$$HI = a \left(b|\gamma| + c \frac{\sigma}{\sqrt{n}} + dP \right)$$



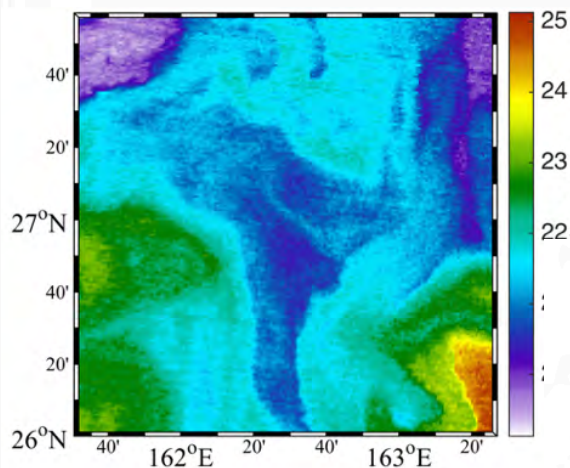
The Heterogeneity Index (HI) [0 1]



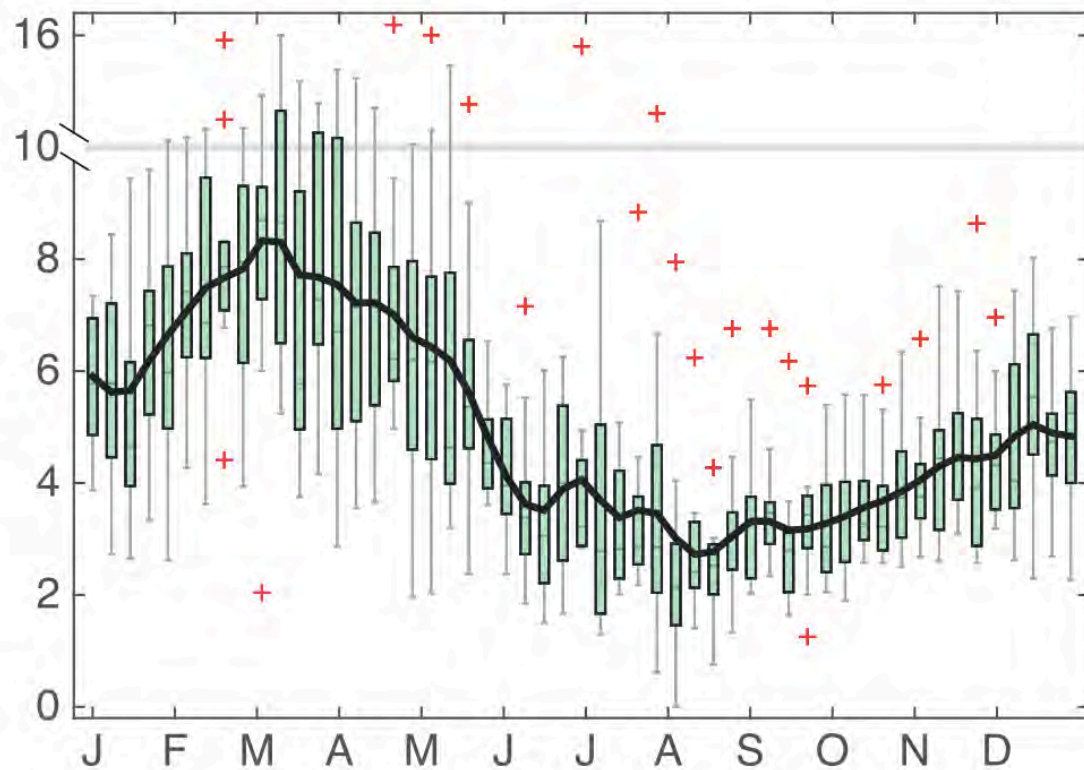
The Heterogeneity Index (HI) [0 1]



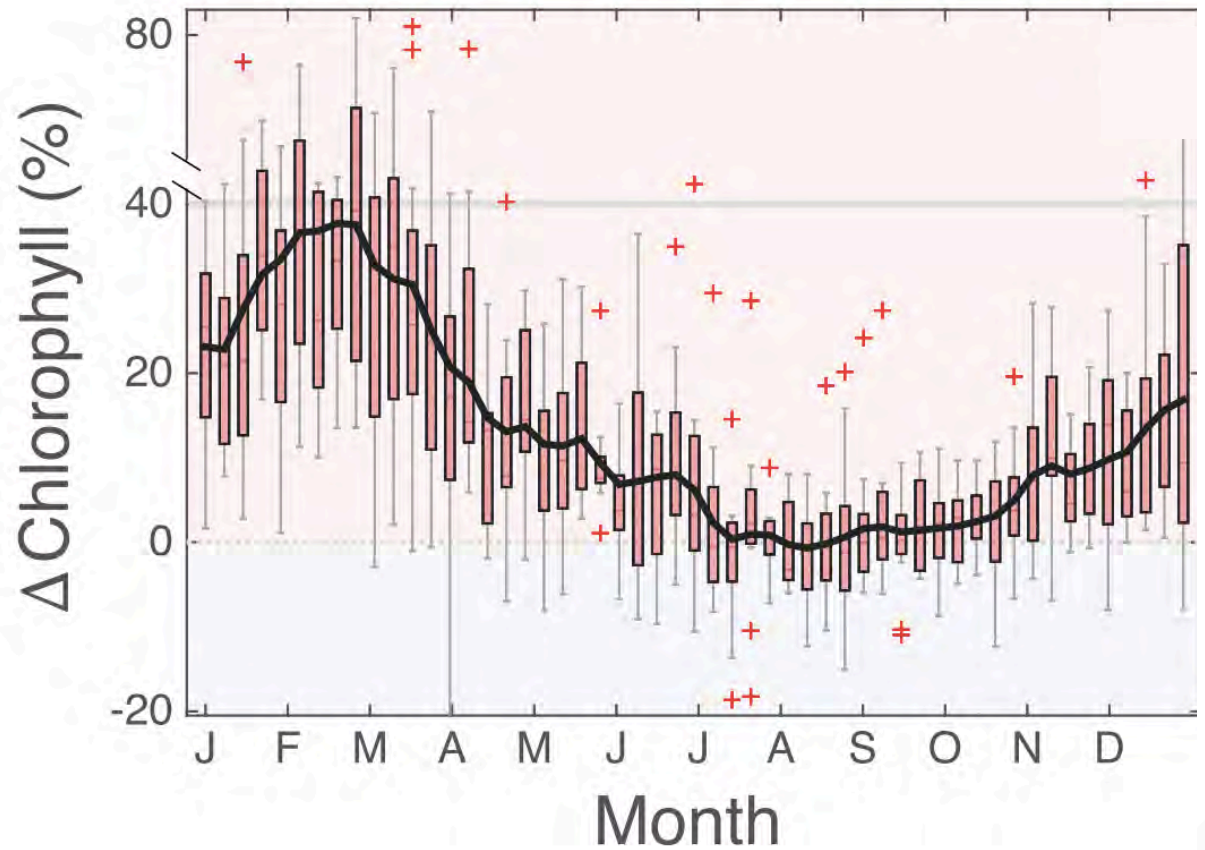
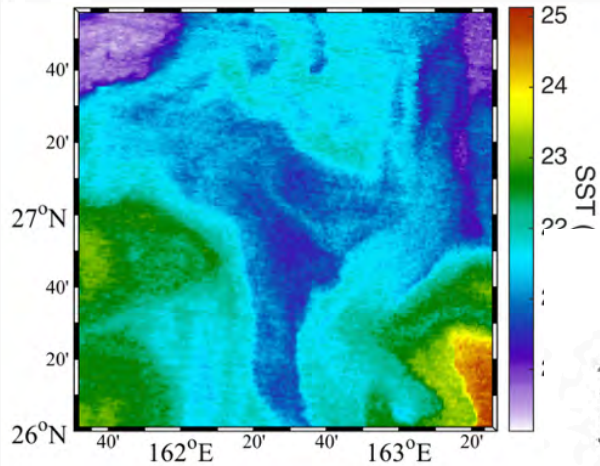
The Heterogeneity Index (HI) [0 1]



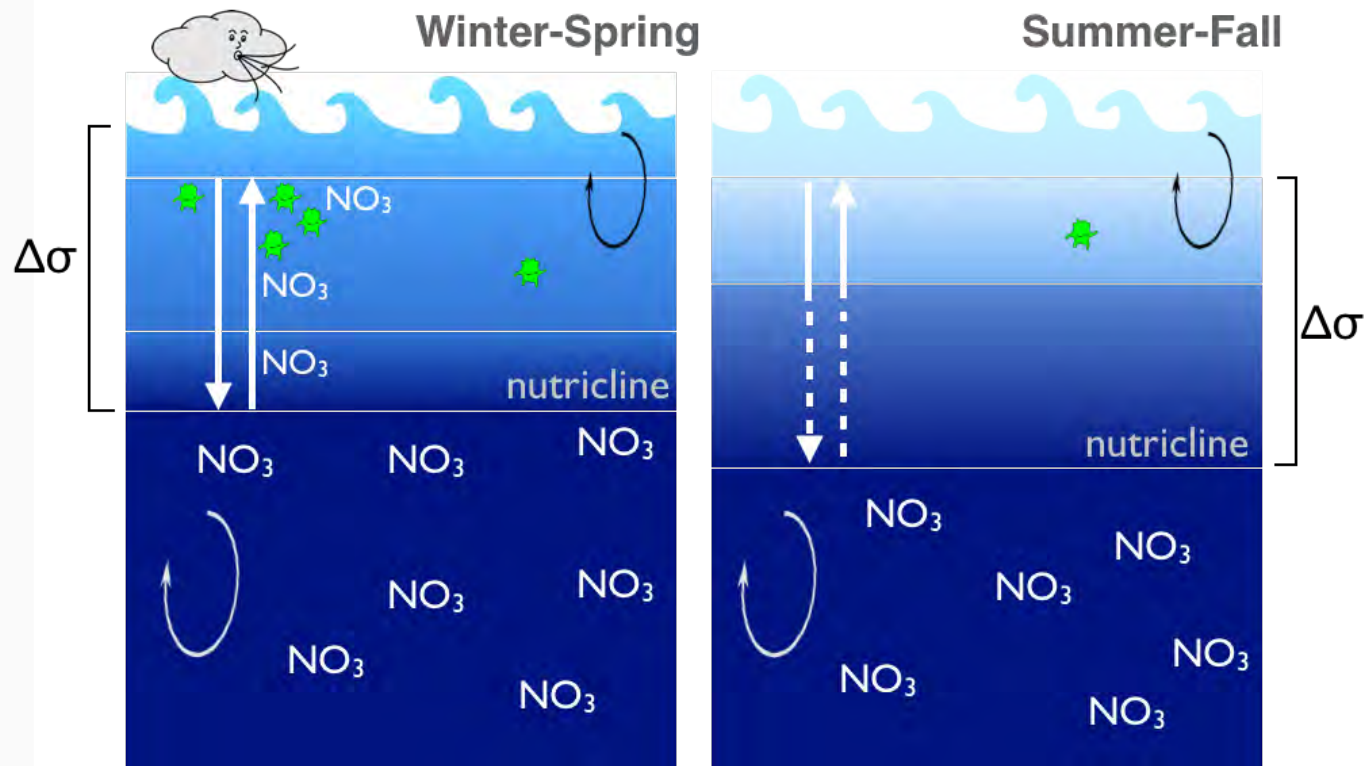
Fraction of Impacted Area (%)



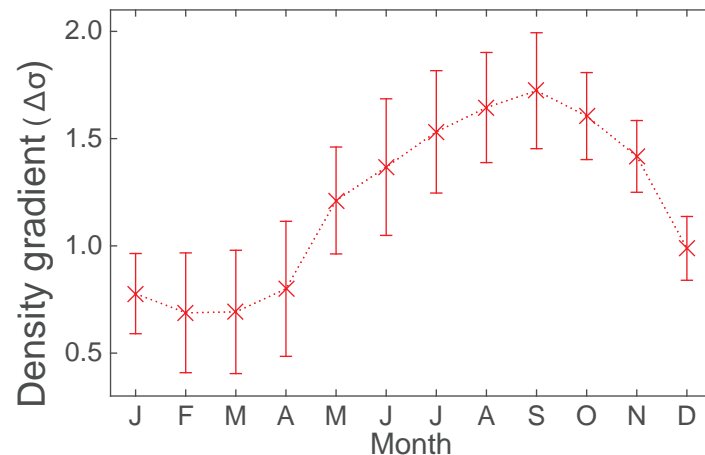
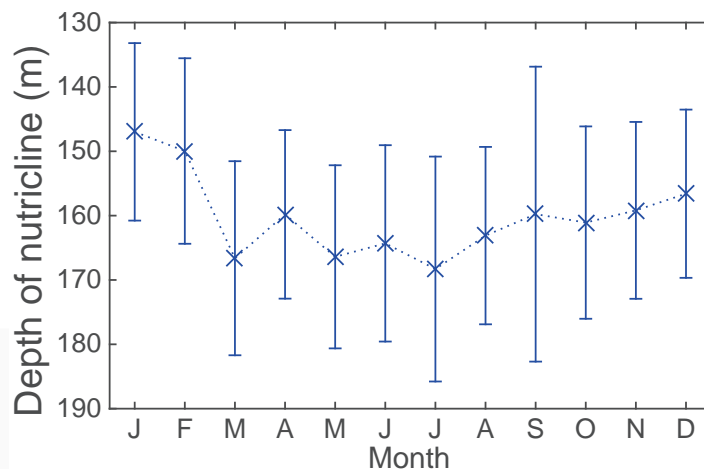
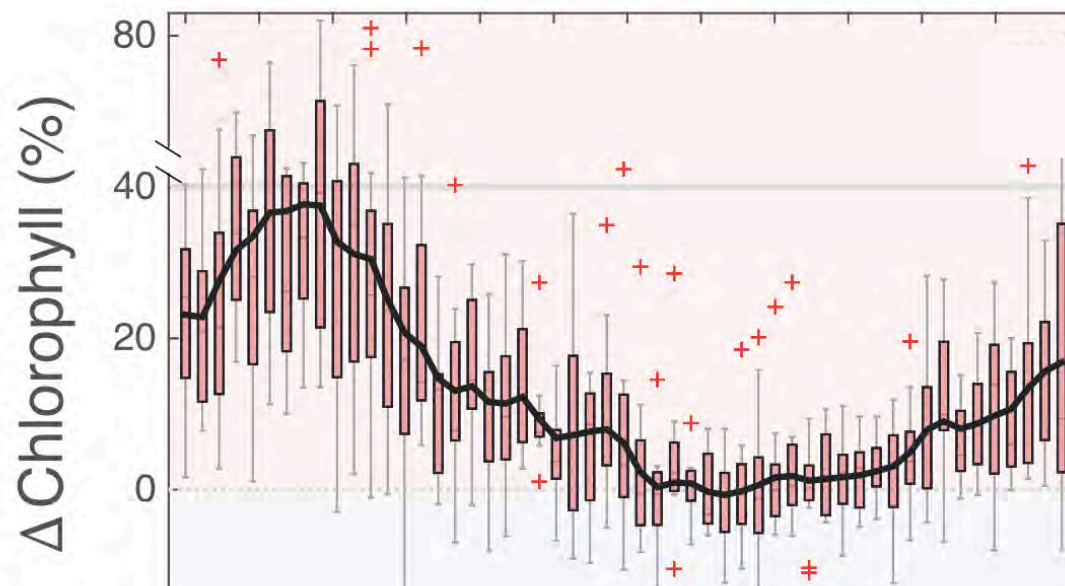
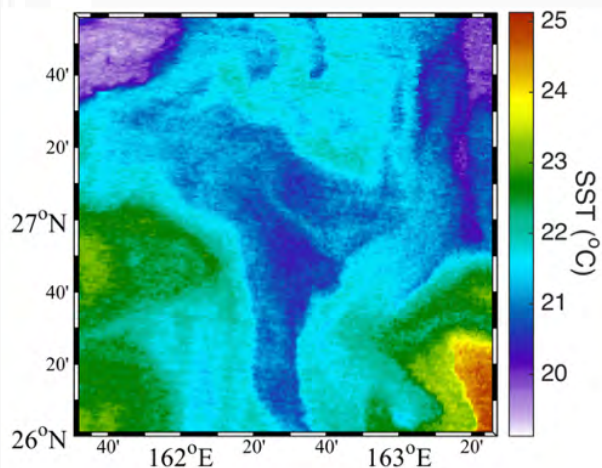
The Heterogeneity Index (HI) [0 1]

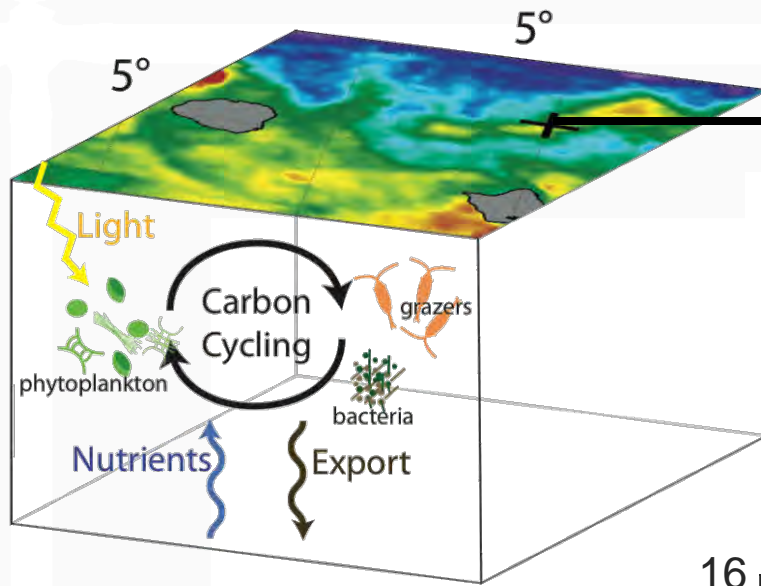


The Heterogeneity Index (HI) [0 1]

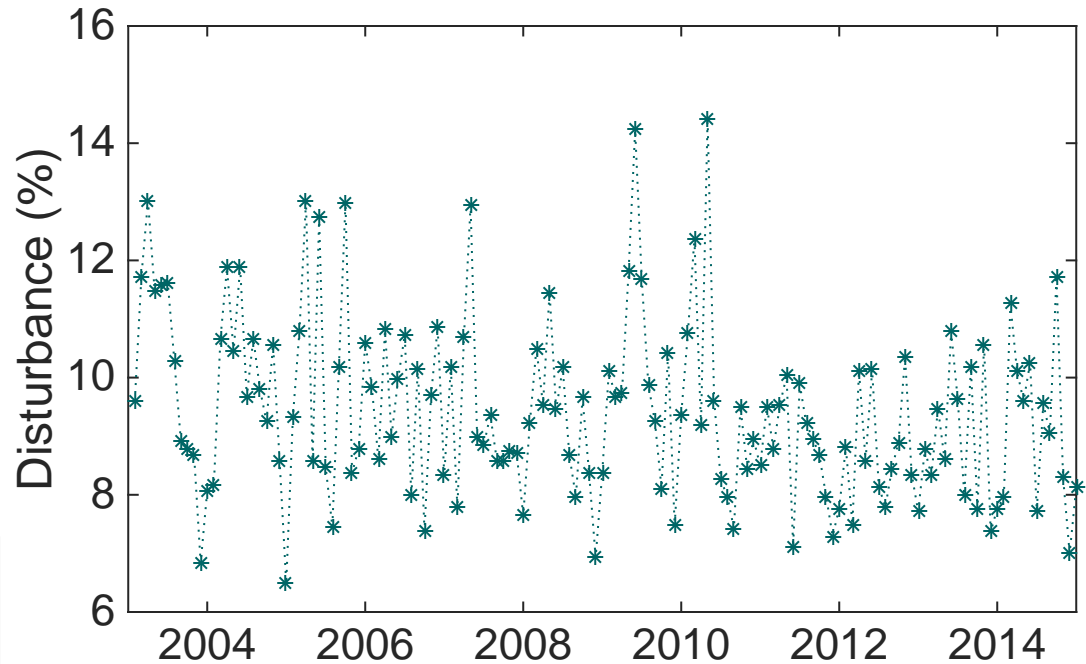


The Heterogeneity Index (HI) [0 1]



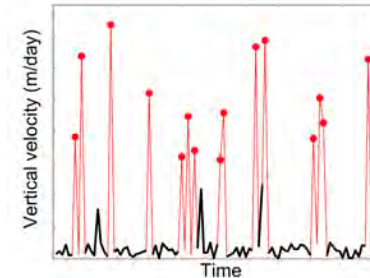
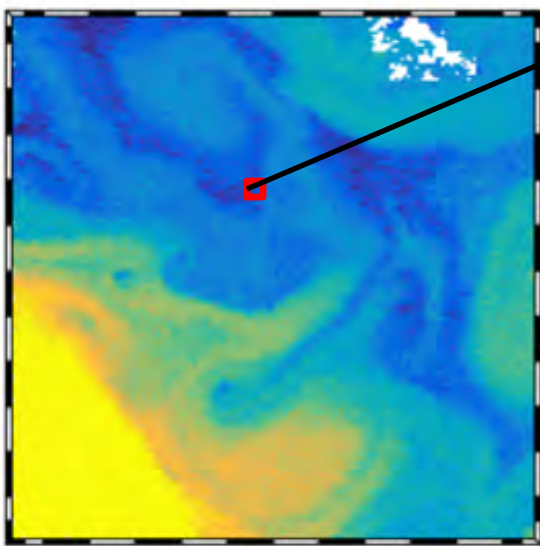


Water column responses?
 Ecosystem and carbon dynamics?
 Climate impact and feedbacks?

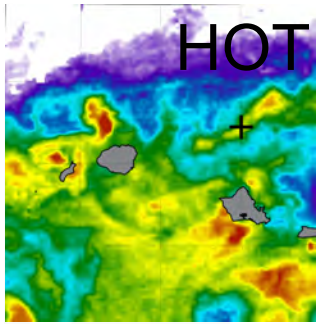


Spatially Heterogeneous Dynamic Plankton Model (SHiP)

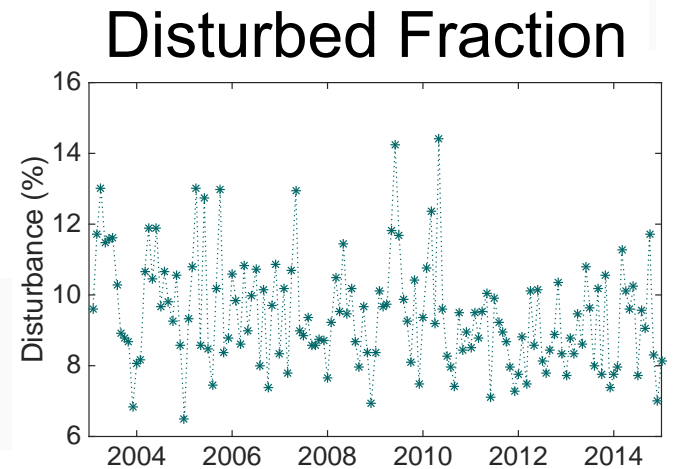
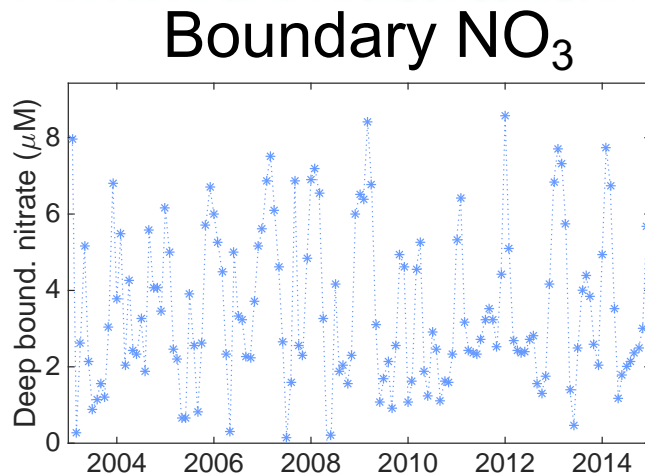
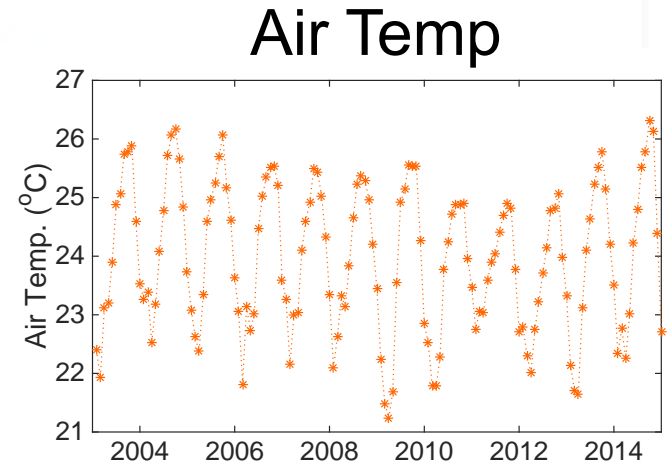
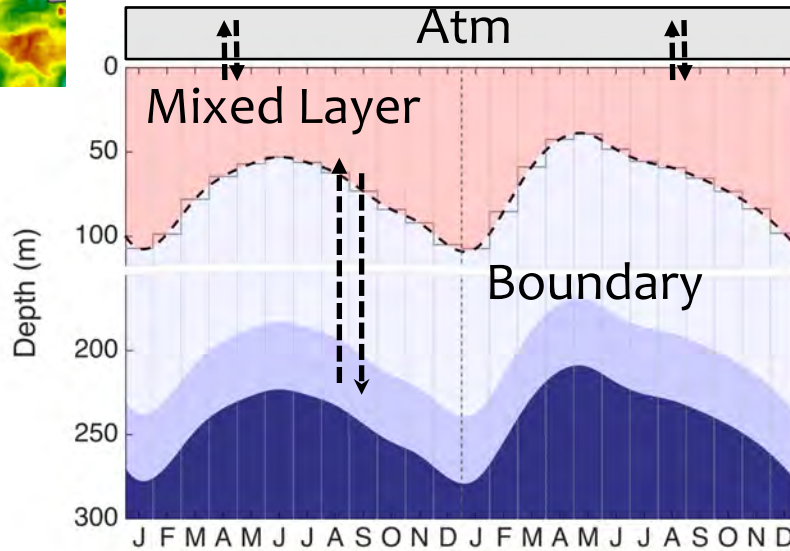
What is the probability of a submesoscale front forming?

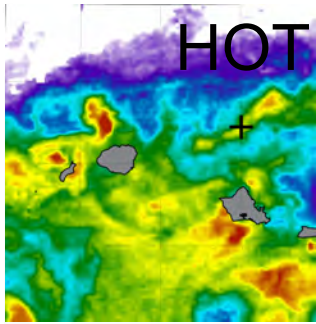


- Episodic nutrient delivery based on probability of disturbance (χ)
- Track fractional areas of environments
 - Common disturbance history
 - Variable fractional area
- Dynamic biogeochemistry and ecosystem

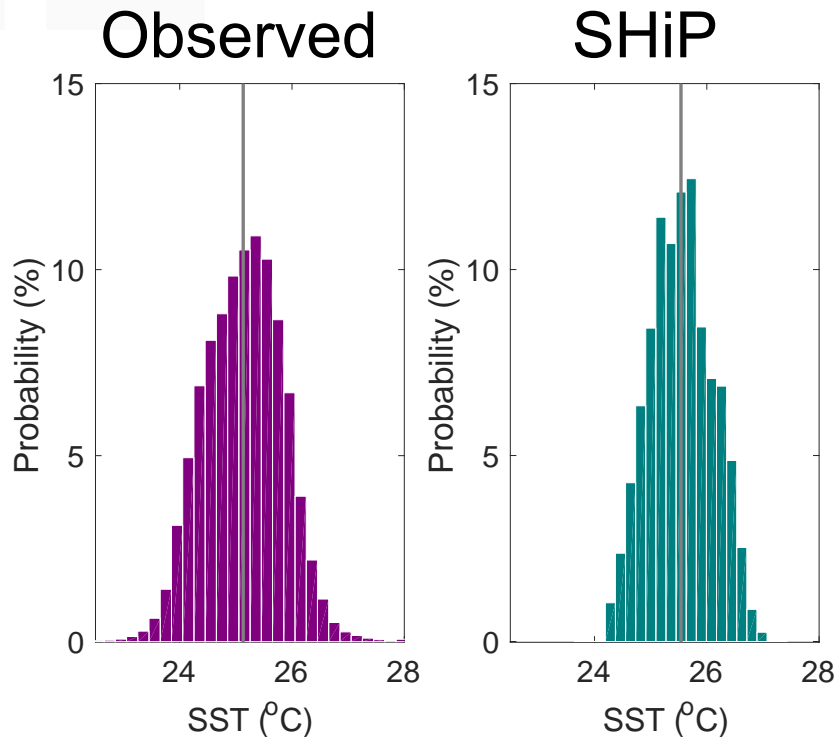


SHiP Mixed Layer Model @ HOT





SHiP Mixed Layer Model @ HOT

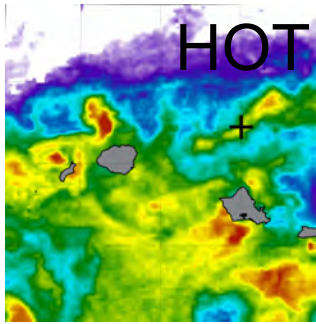


Observed:

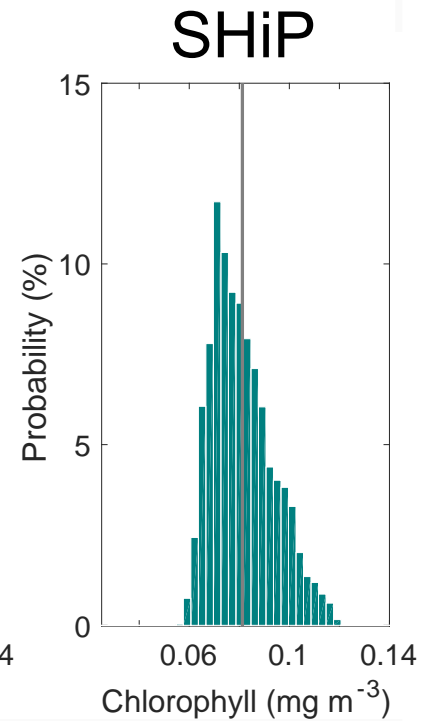
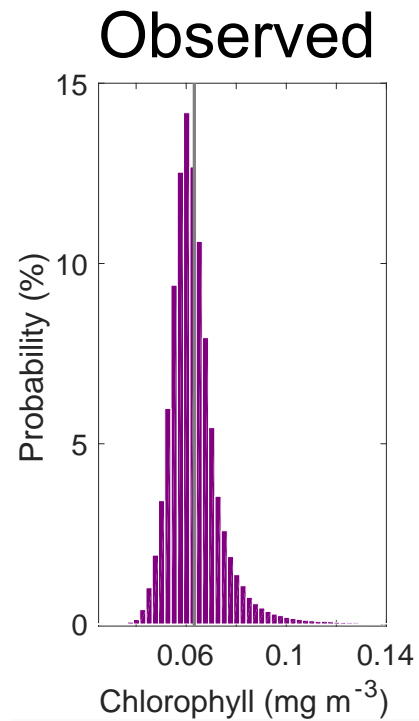
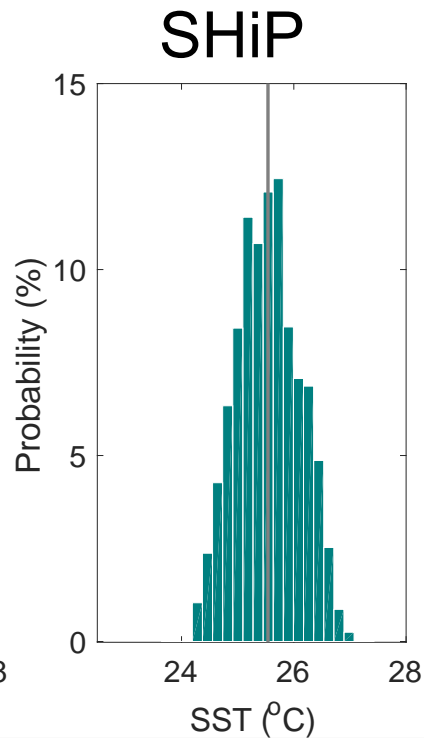
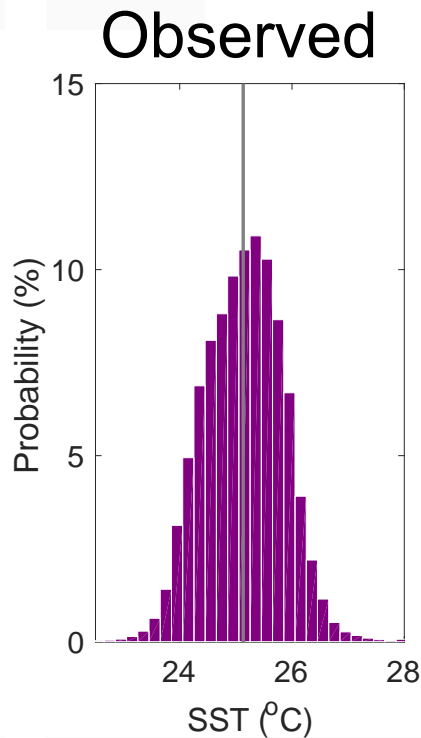
- MODIS 5° x 5°
- up to 15,625 pixels/day
- 30 days

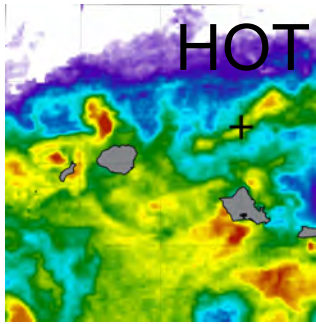
SHiP:

- 25 – 30 environments/day
- 30 days

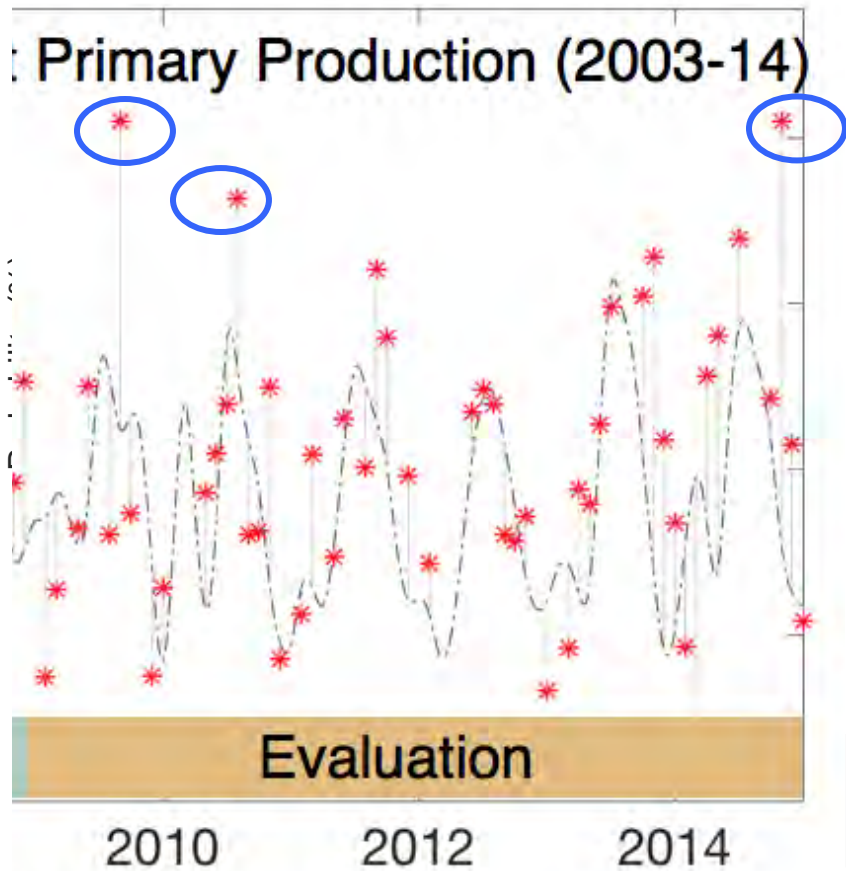


SHiP Mixed Layer Model @ HOT

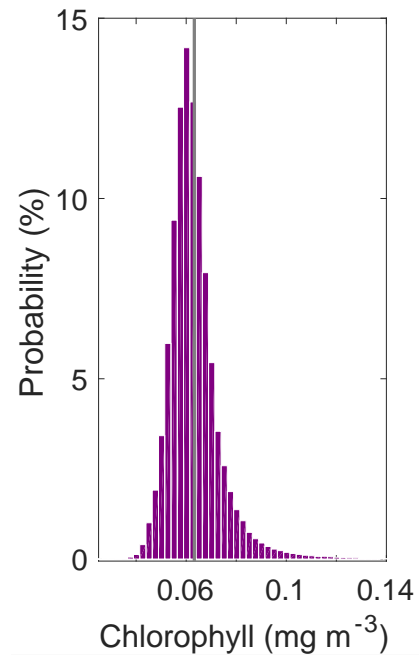




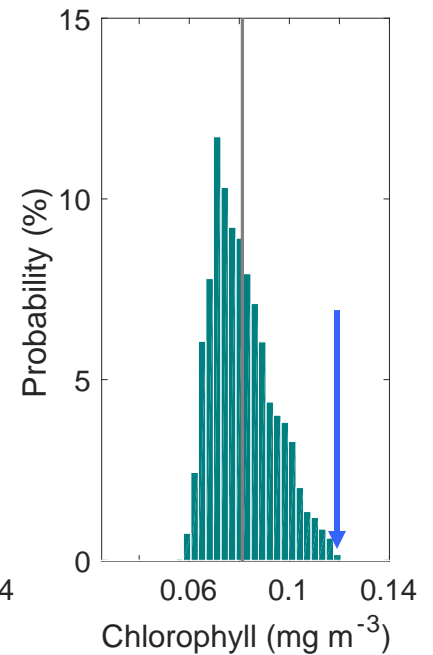
SHiP Mixed Layer Model @ HOT



Observed

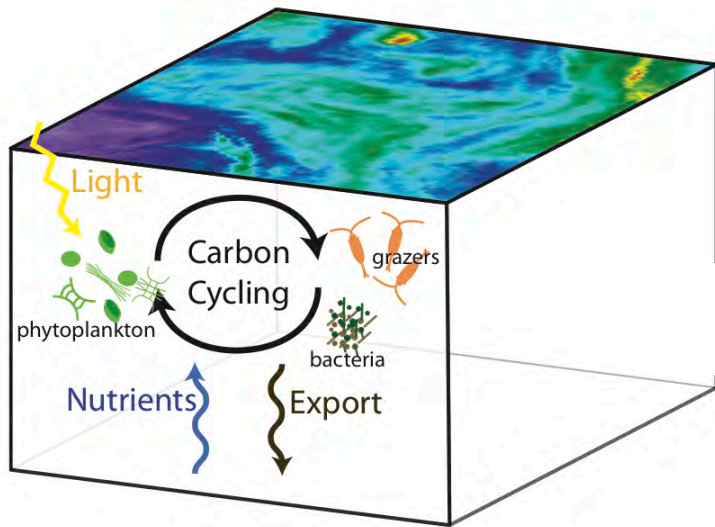


SHiP



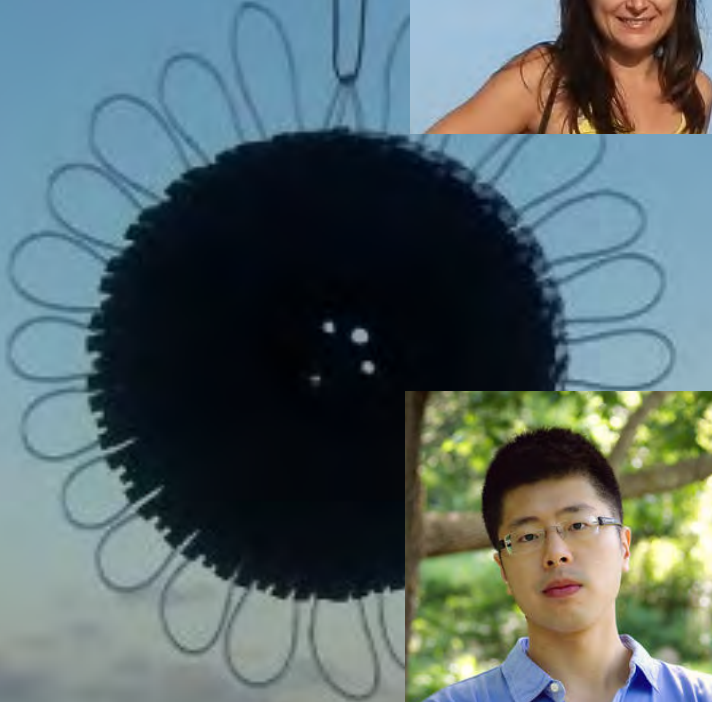
The impact of fine-scale processes on large-scale carbon cycling

Take home messages:



- Submesoscale features ubiquitous
- Increased fine-scale patchiness results in higher chlorophyll (consistent with idealized model results)
- Changes in submesoscale dynamics could offset (augment) warming
- New modeling approach that SHiP captures observed fine-scale variability

Acknowledgements



Levine Lab

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NOAA C&GC
USC (Dornsife, WiSE)

Moorcroft Lab (Harvard)
Matt Long (NCAR)
Scott Doney (WHOI)