# Compound marine heatwave and low net primary production extremes in the ocean over the satellite period

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# Motivation

Le Grix, Zscheischler, Rousseaux, Laufkötter, Frölicher (2021, Biogeosciences)

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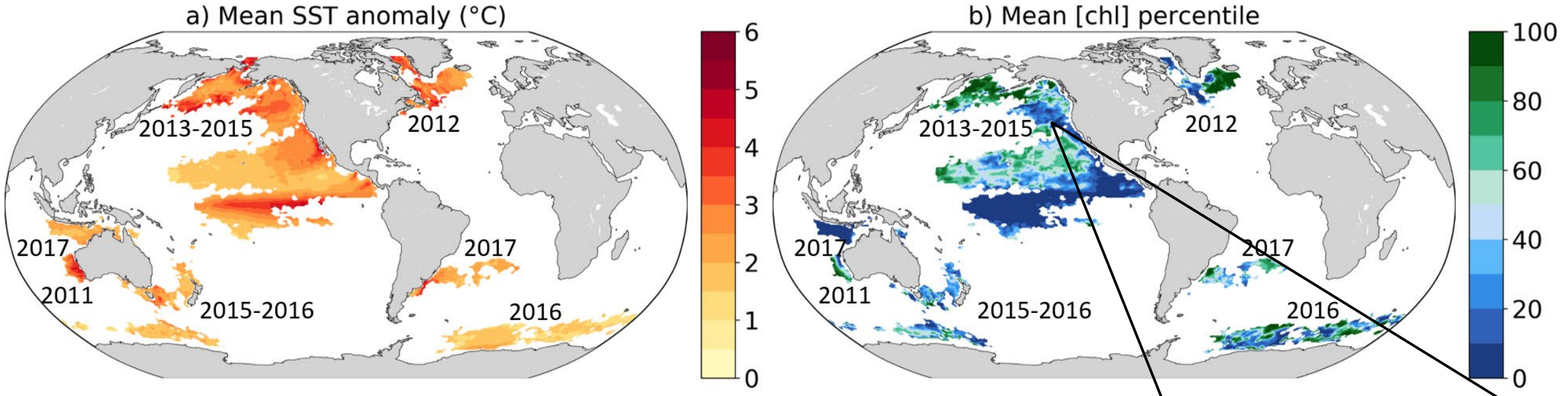
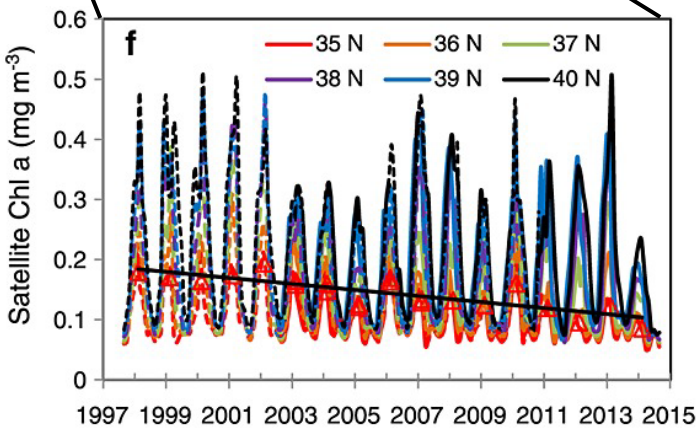



*Legrix et al. 2021*

Compound marine heatwave (MHW) and low net primary productivity (NPPX) events have profound impacts on ecosystems.

*fisheries.noaa.gov* *Nature*




*Whitney et al. 2015*

# Research questions

1. Where are hotspots of compound MHW-NPPX events?

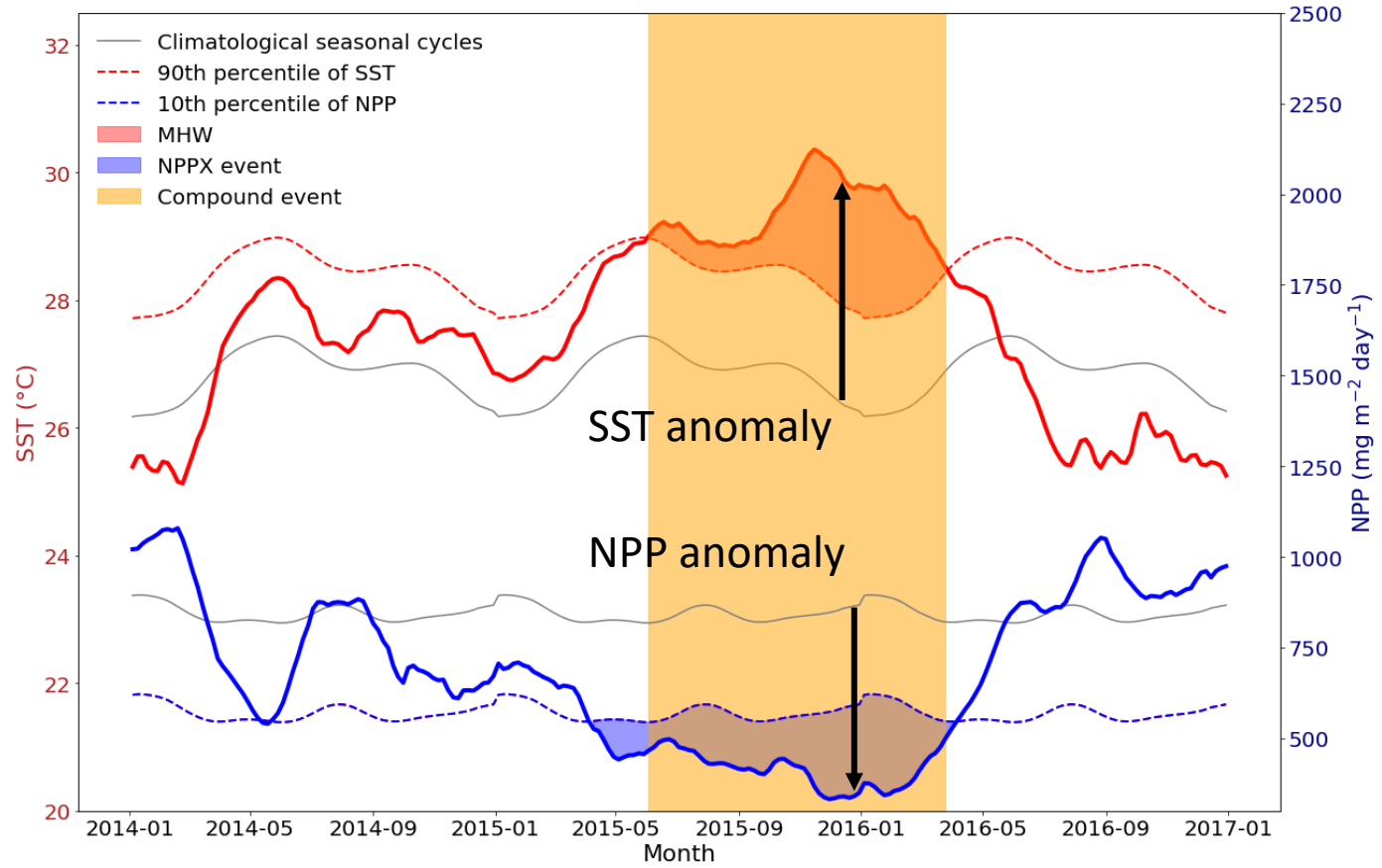
→ Satellite-based SST (OISST) and NPP products (NOBM, Standard-VGPM, Eppley-VGPM, CbPM-VGPM, CAFE-VGPM) over 1998-2018

2. Can ESMs simulate compound MHW-NPPX events?

3. What are their biological and physical drivers?

→ Large ensemble simulations from 2 Earth System models: GFDL-ESM2M and CESM2

# Definition of compound MHW-NPPX events



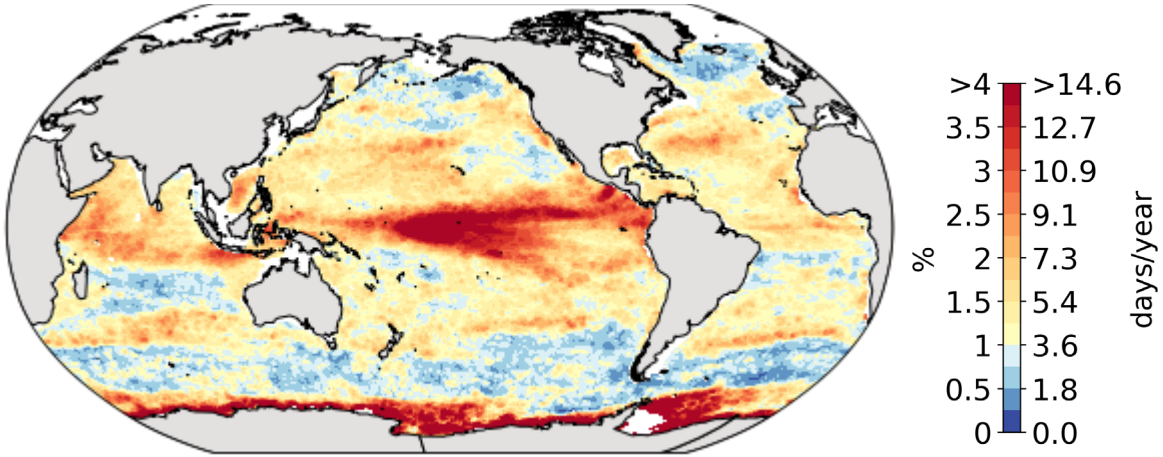

De-seasonalized SST anomaly > 90P → High SST event = MHW
De-seasonalized NPP anomaly < 10P → Low NPP event =NPPX

We expect 1% of compound MHW-NPPX days

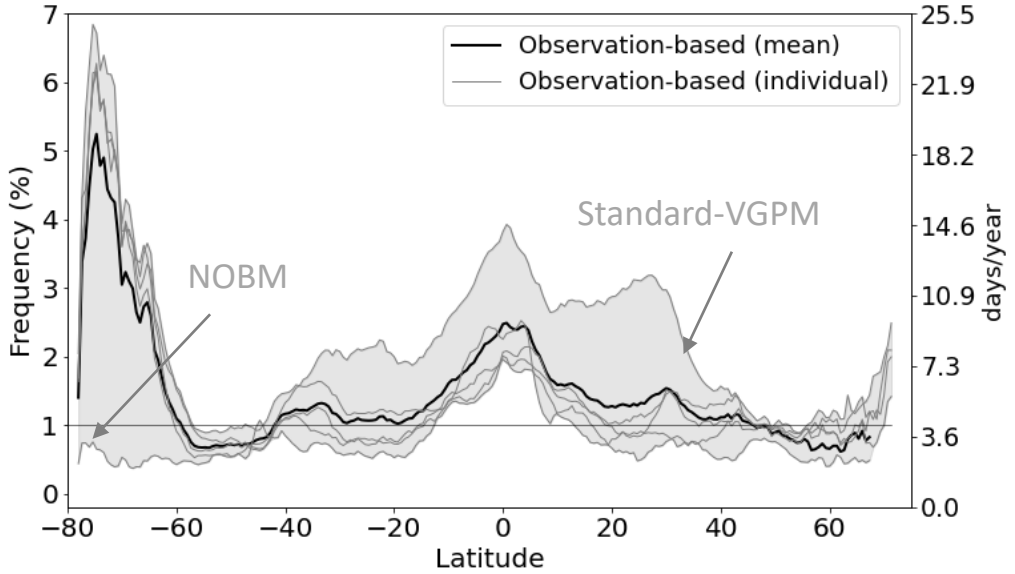
# Frequency of compound MHW-NPPX events

1

Mean of 5 observation-based estimates



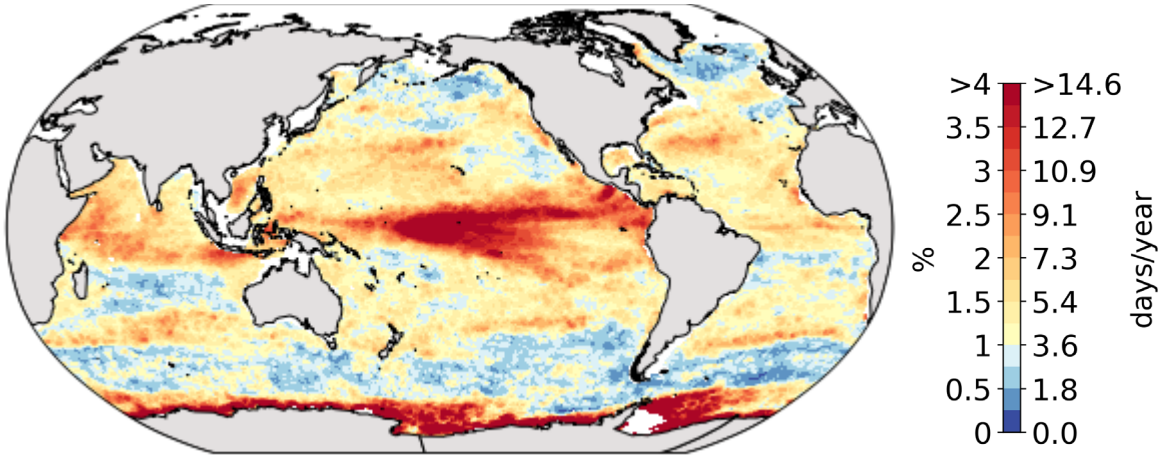

Zonal mean



# Frequency of compound MHW-NPPX events



Mean of 5 observation-based estimates

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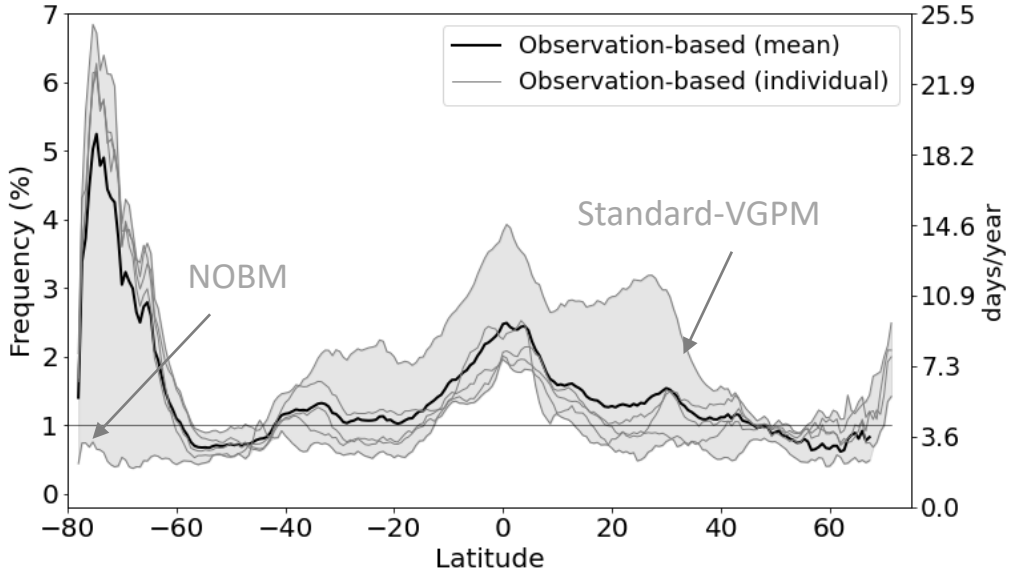
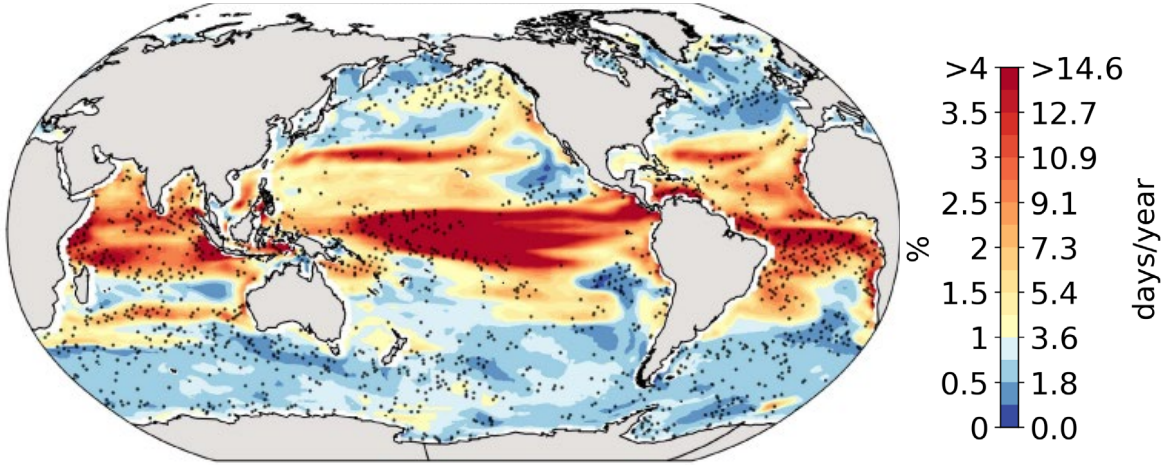
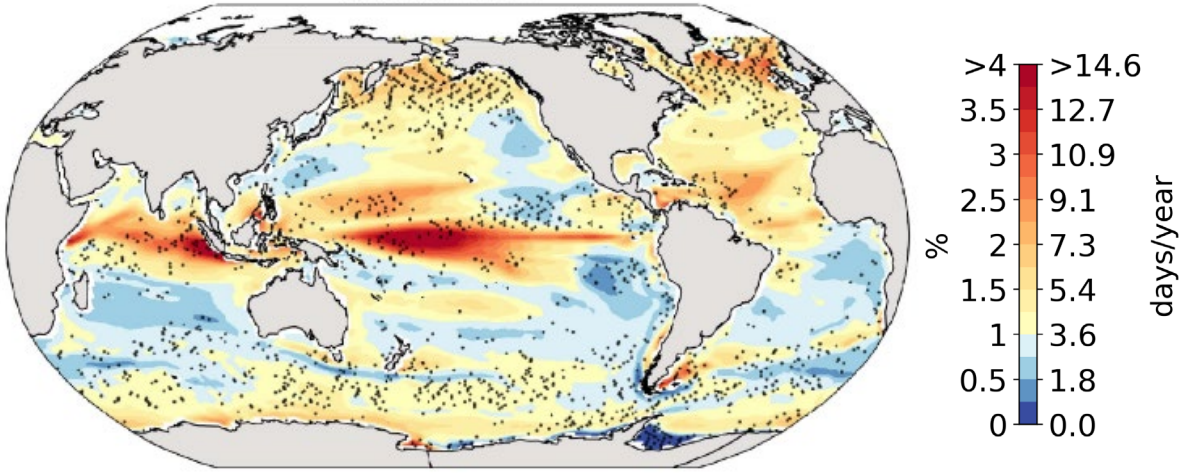



ESM2M-LE

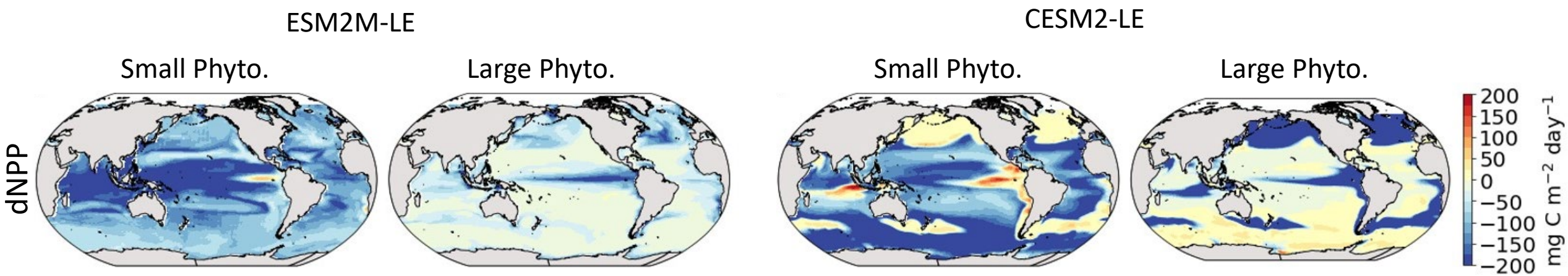



CESM2-LE



# Drivers of an extremely negative NPP anomaly during MHWs





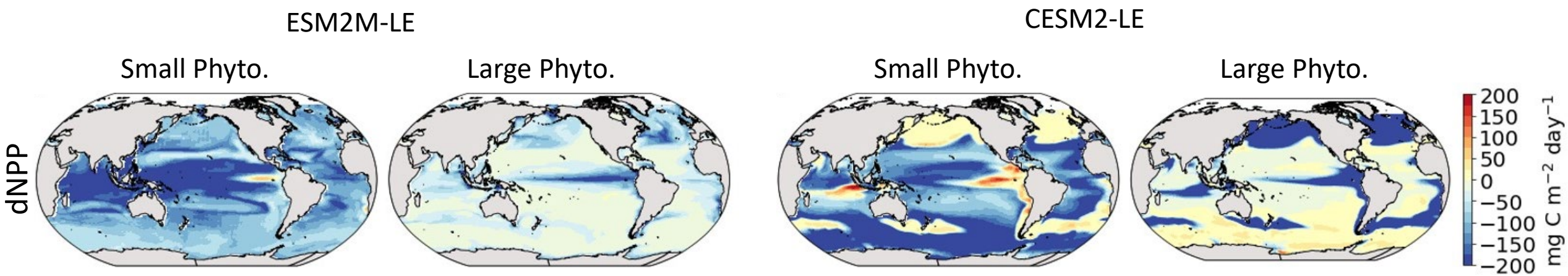

NPP anomaly explained by:

- Reduced small phytoplankton NPP in most regions
- Reduced large phytoplankton NPP in the eastern equatorial Pacific and in the northern high latitudes

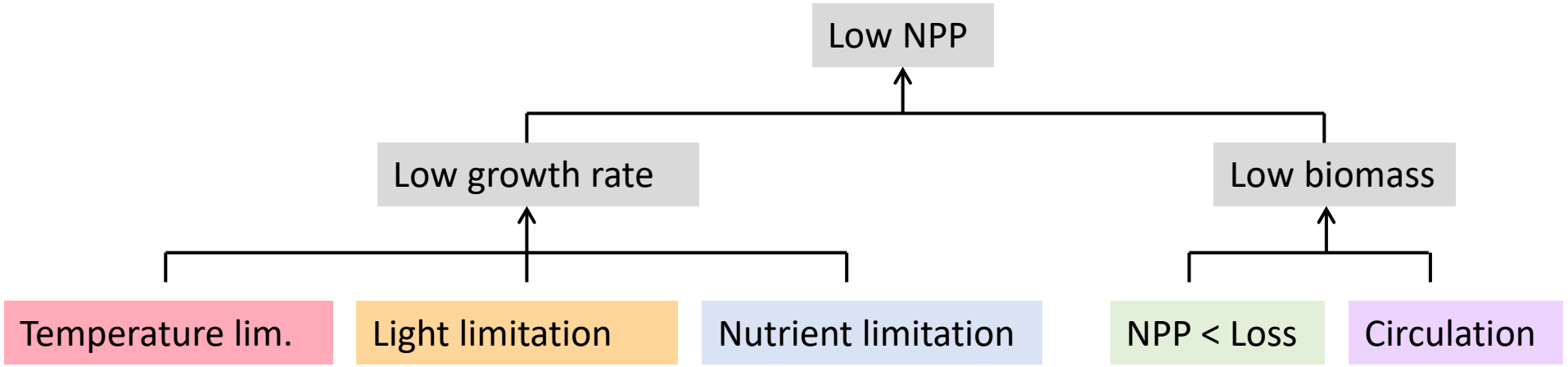
→ community shifts with potential impacts on marine ecosystems

# Drivers of an extremely negative NPP anomaly during MHWs



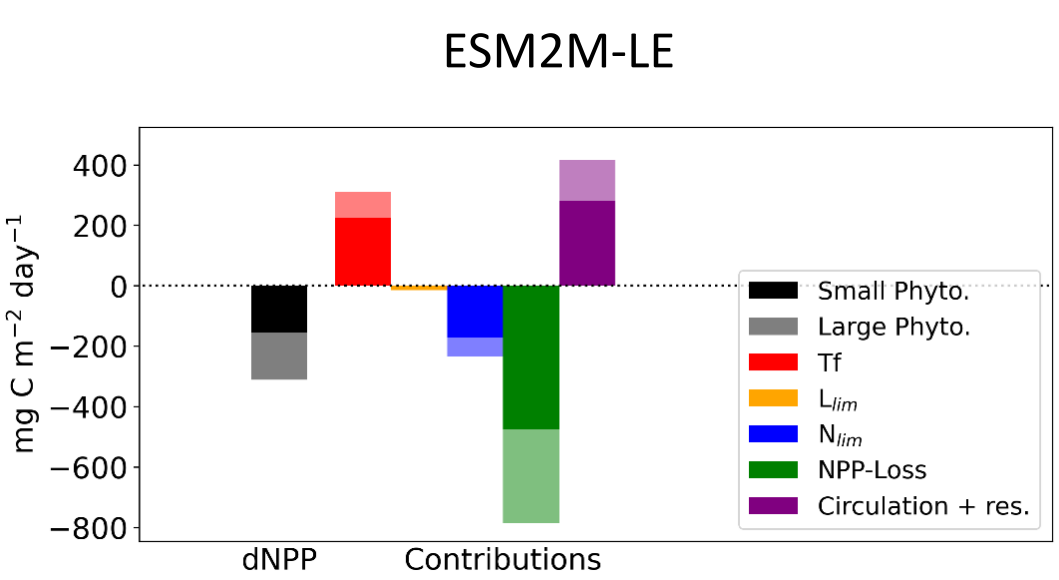


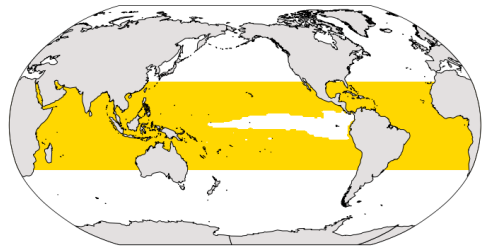

For small and large phytoplankton, we investigate the drivers of reduced NPP.



# The models have different drivers of low NPP events





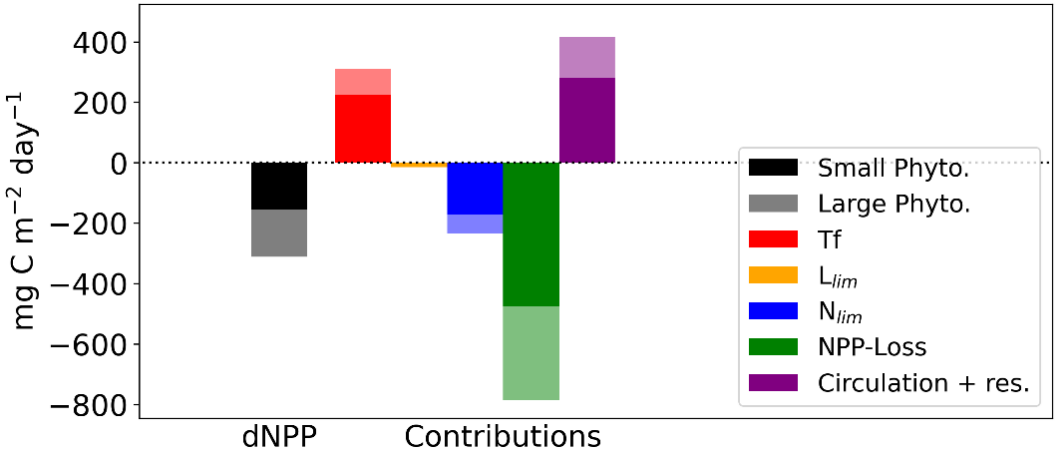
**In the low latitudes:**

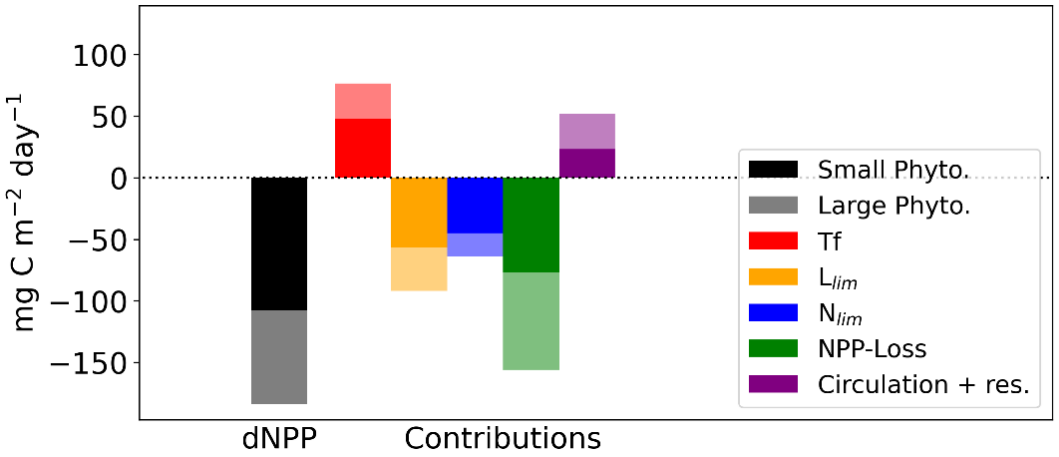
- Lower growth because of nutrient limitation
- Lower phytoplankton biomass because phytoplankton loss (i.e. grazing) exceeds its production

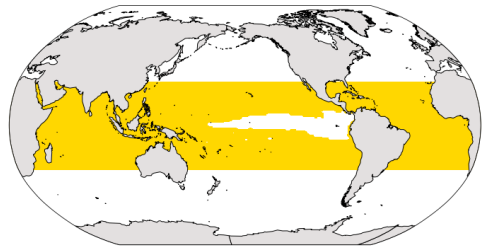
# The models have different drivers of low NPP events



ESM2M-LE



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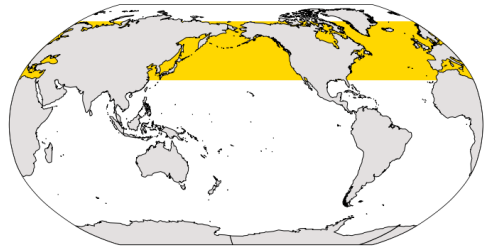


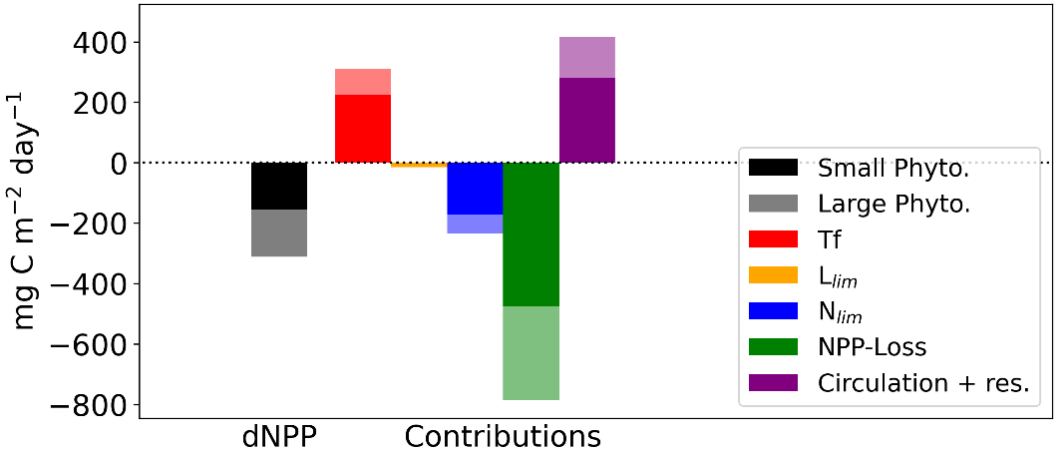
**In the northern high latitudes:**

- Lower growth because of nutrient limitation and light limitation
- Lower phytoplankton biomass because phytoplankton loss exceeds its production

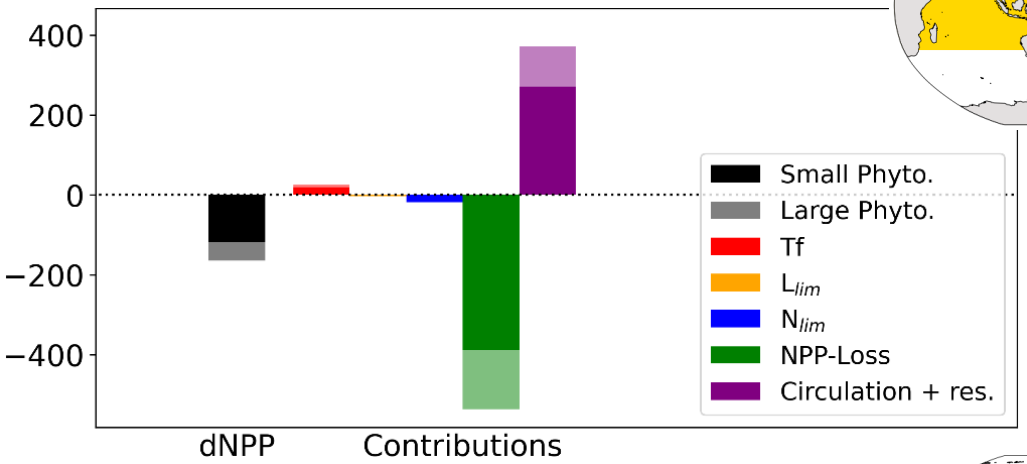
# The models have different drivers of low NPP events

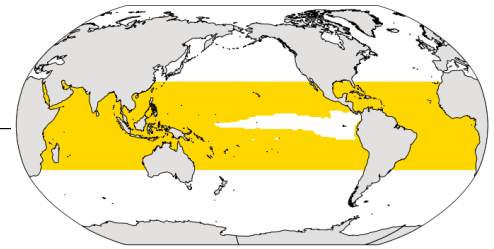


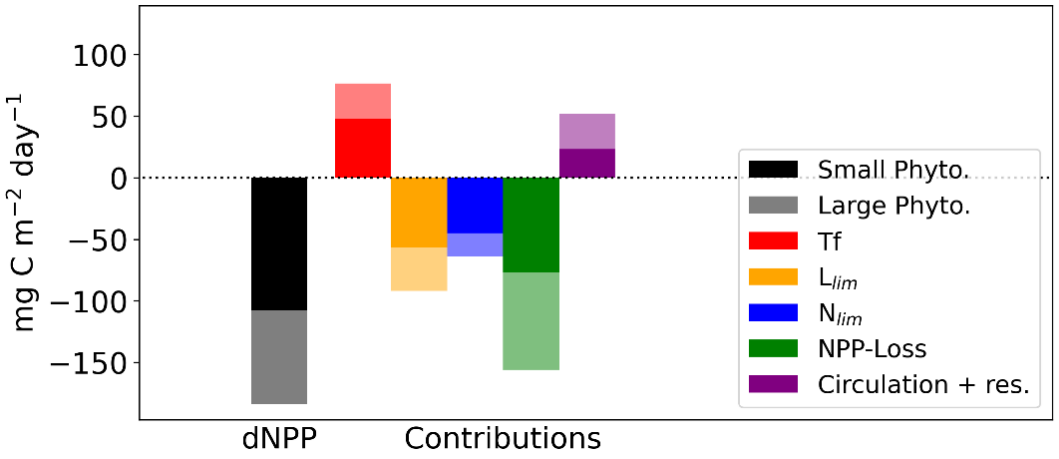
ESM2M-LE

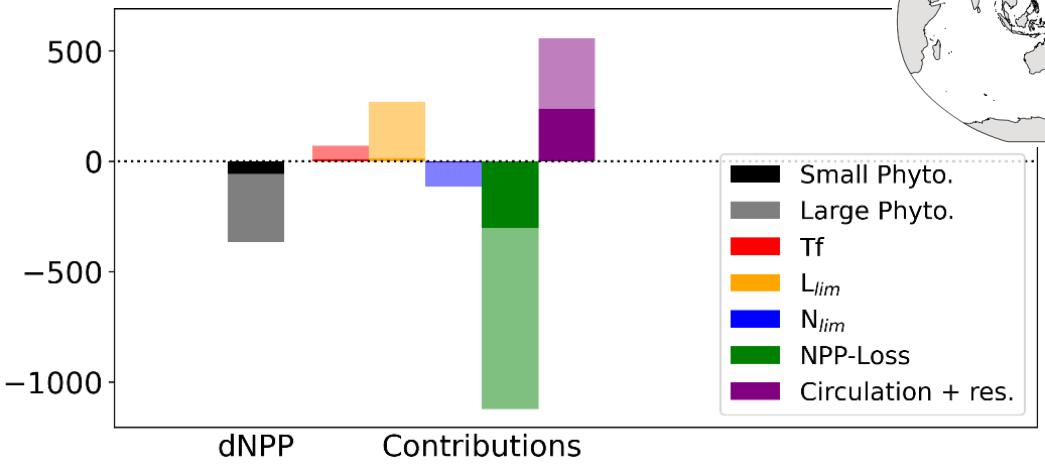


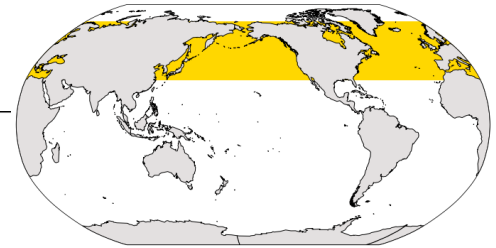

CESM2-LE





# Summary

Le Grix, Zscheischler, Rousseaux, Laufkötter, Frölicher (2021, Biogeosciences)
Le Grix, Zscheischler, Rodgers, Yamaguchi, Frölicher (in prep.)

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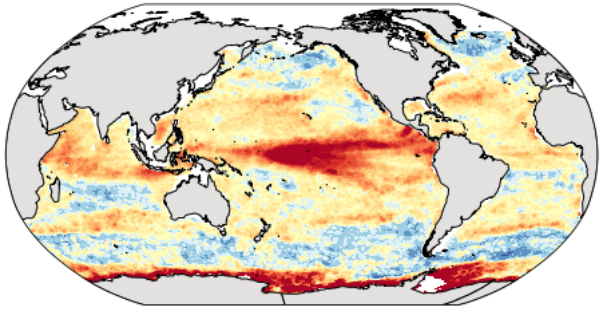
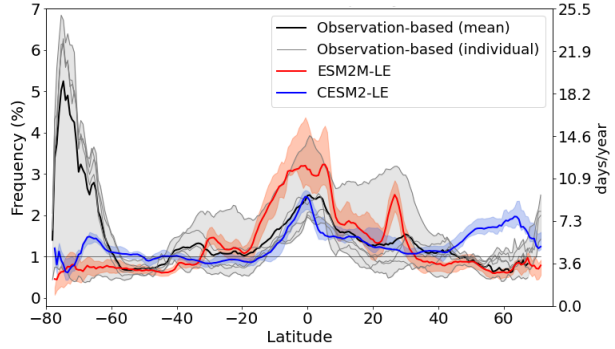
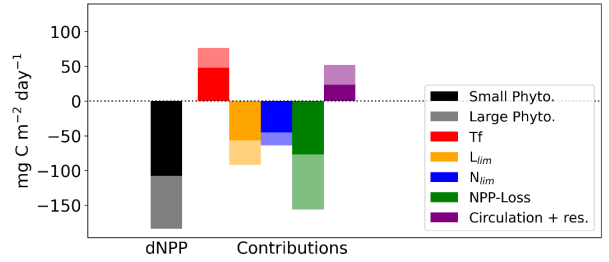
1. Frequent MHW-NPPX events in the low latitudes, in particular in the center of the equatorial Pacific.



2. ESM2M-LE and CESM2-LE correctly simulate the frequency of compound events in the low to mid latitudes but they disagree with observations in the high latitudes.




3. NPP is low during MHWs because of nutrient limitation in the low latitudes, of light limitation in the high latitudes in ESM2M-LE only, and because of a relative increase in phytoplankton grazing.



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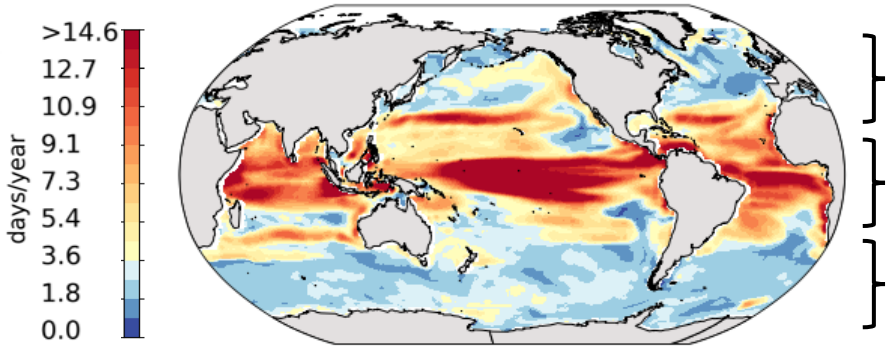
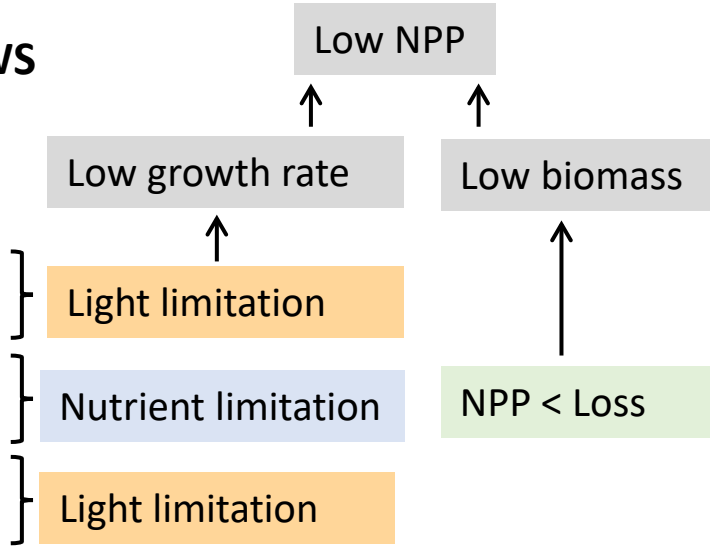
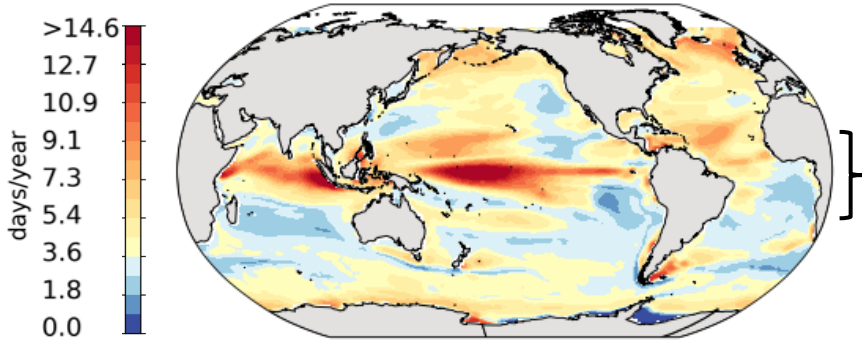
## Main drivers of low NPP during MHWS

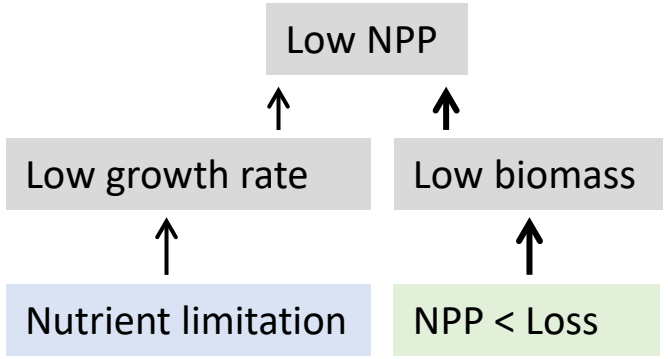
### ESM2M-LE




### CESM2-LE

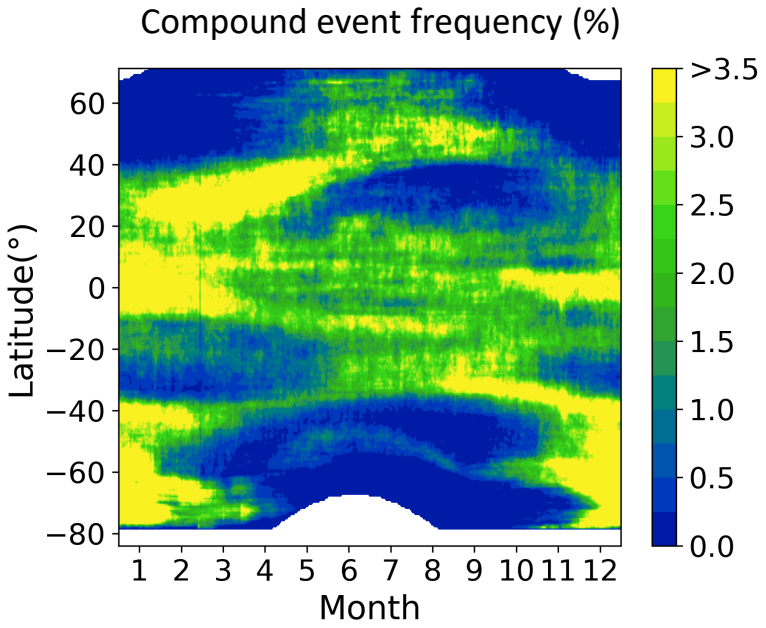


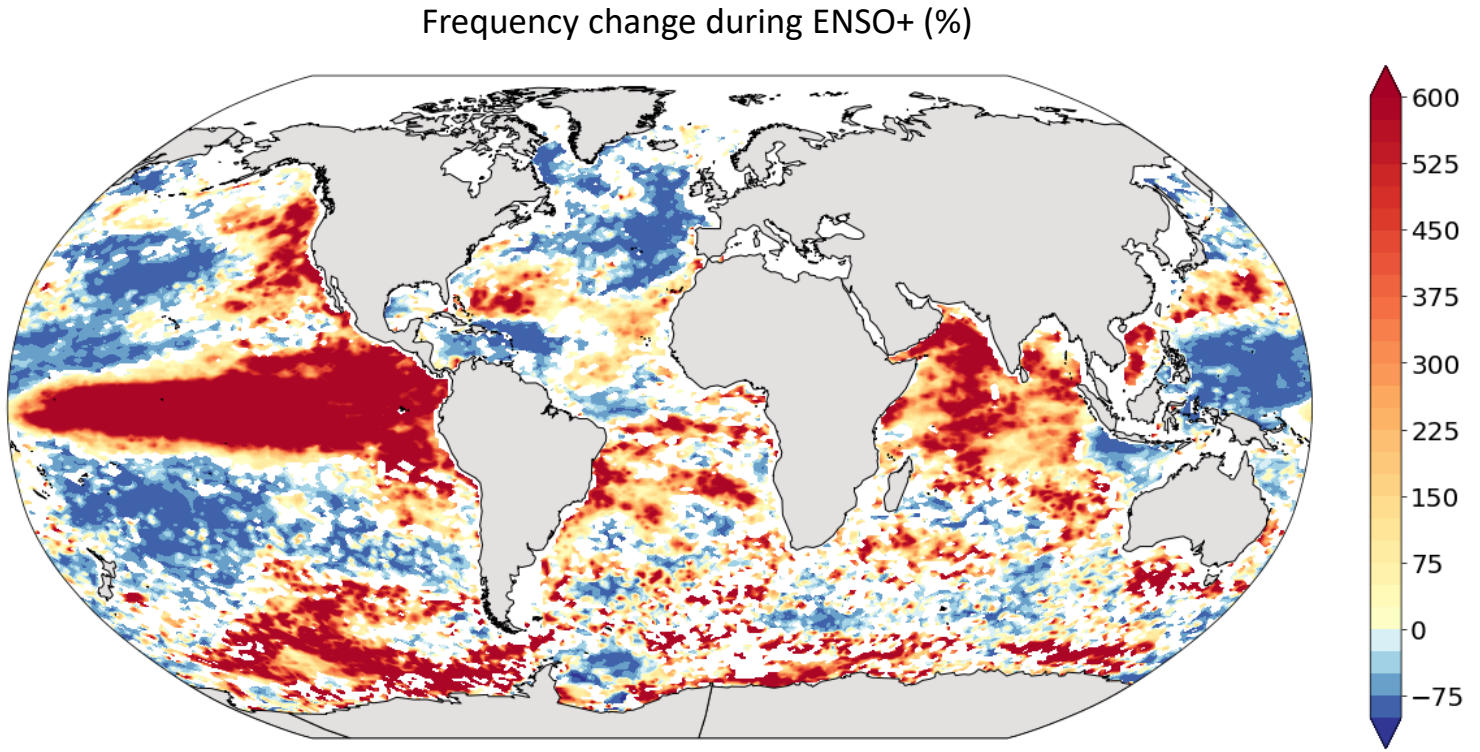

The models agree in the low latitudes but disagree in the high latitudes, where they have different likelihood and drivers of compound events. These drivers depend on how each model represents the factors limiting phytoplankton production.

→ *Need for improved process understanding in the models used for predicting and projecting compound MHW-NPPX events.*

# Appendix: Timing of compound MHW-NPPX events




Most events occur in spring in the mid latitudes and in summer in the high latitudes.




Their frequency is modulated by large-scale climate modes, e.g. ENSO.

Le Grix, Zscheischler, Rousseaux, Laufkötter, Frölicher (2021, Biogeosciences)

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