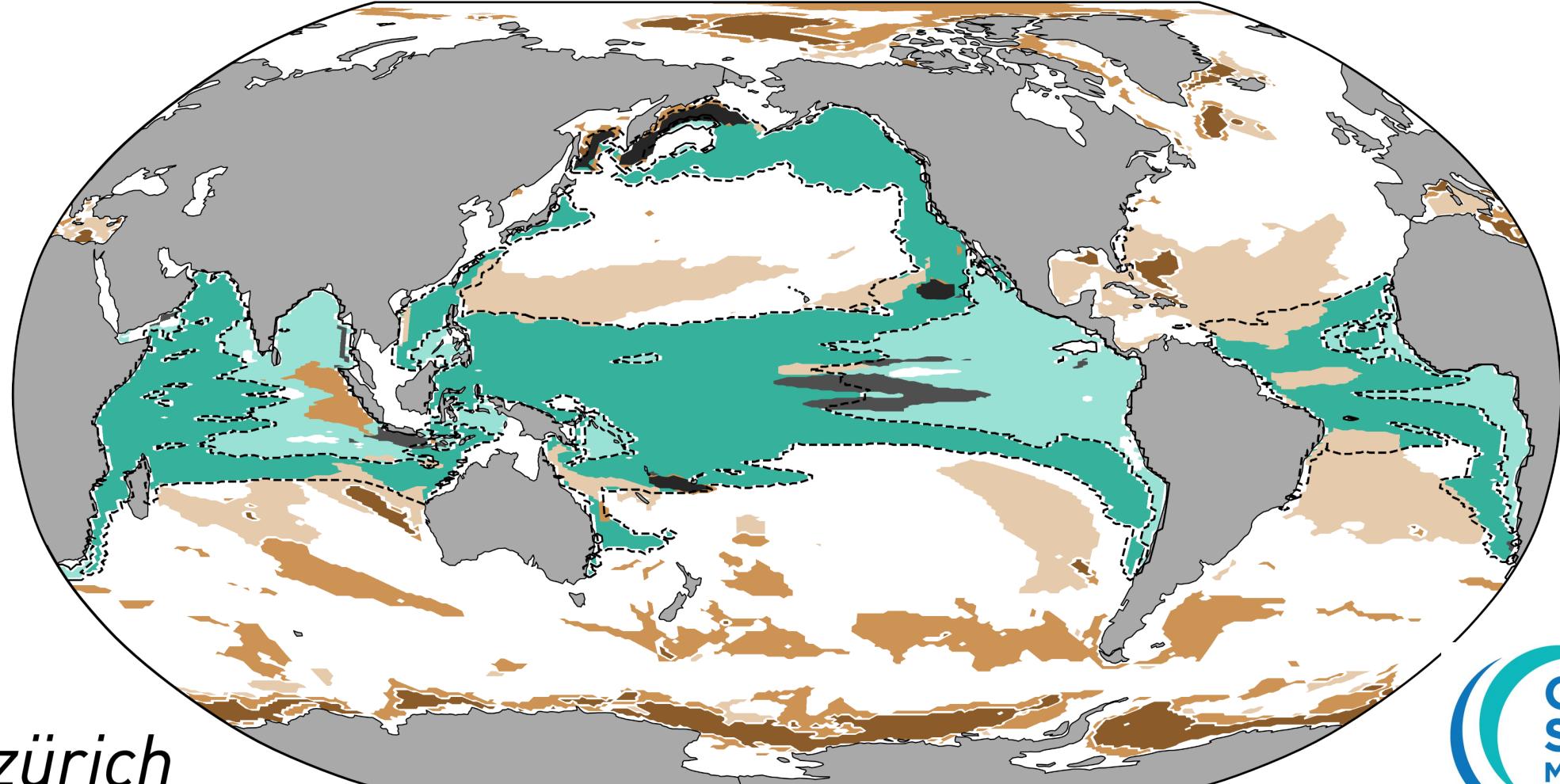


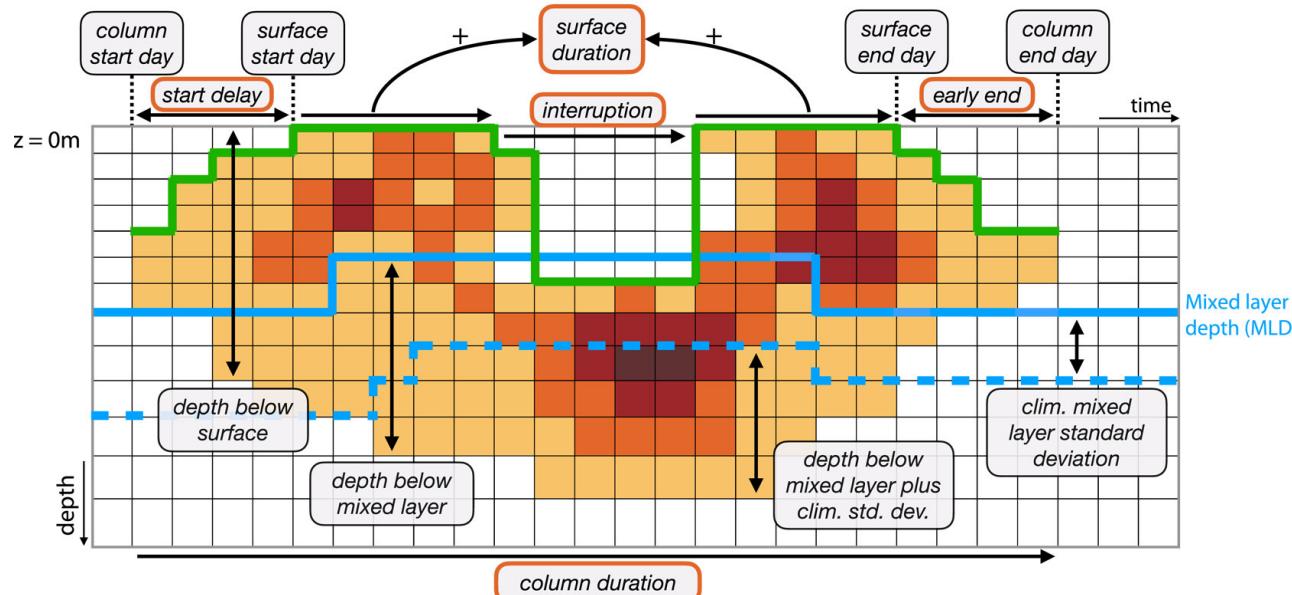
Column-Compound Extremes in the Global Ocean

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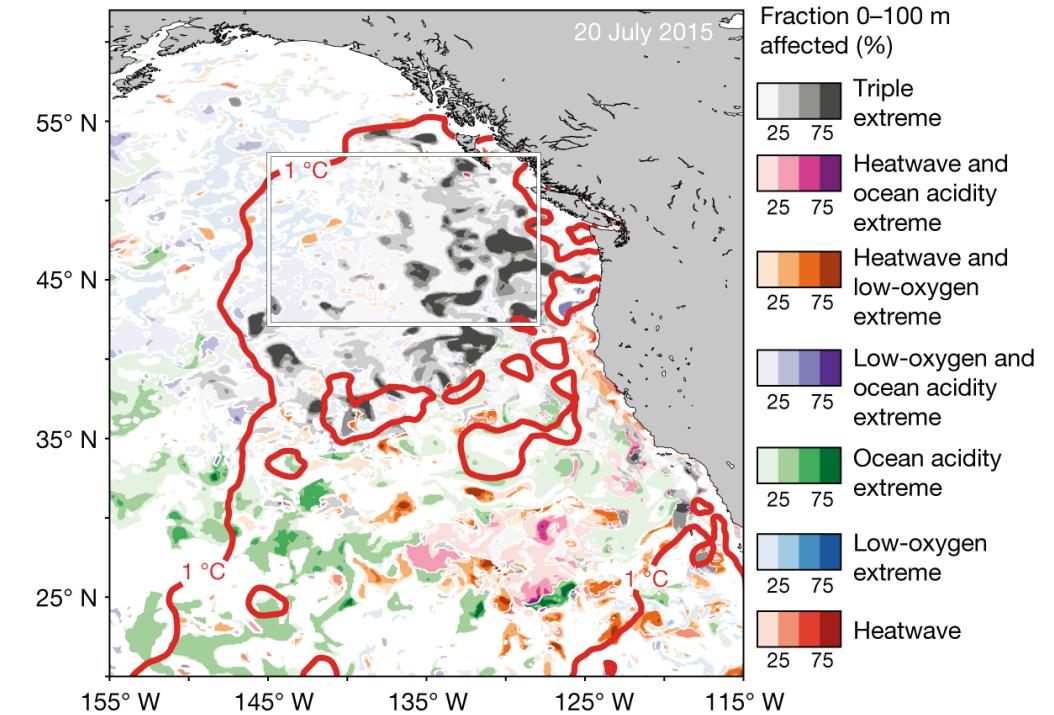


Subsurface and Compound Extremes



On the Vertical Structure and Propagation of Marine Heatwaves in the Eastern Pacific

(Köhn et al. 2023)



Biogeochemical extremes and compound events in the ocean

(Gruber et al. 2021)

Questions



How can we study compound extremes in the vertical water column?



Where and when have column-compound extremes occurred in the oceans?

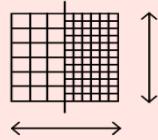


What were the drivers behind them?

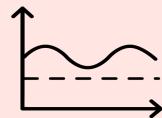
Model and Methods



CESM-BEC, ocean-only daily hindcast (1961-2020)



0.5 – 1° nominal resolution



Fixed and moving baselines

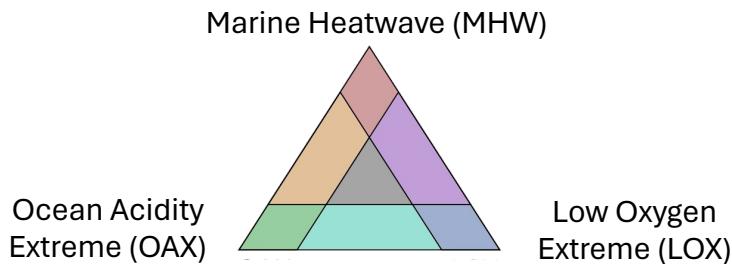
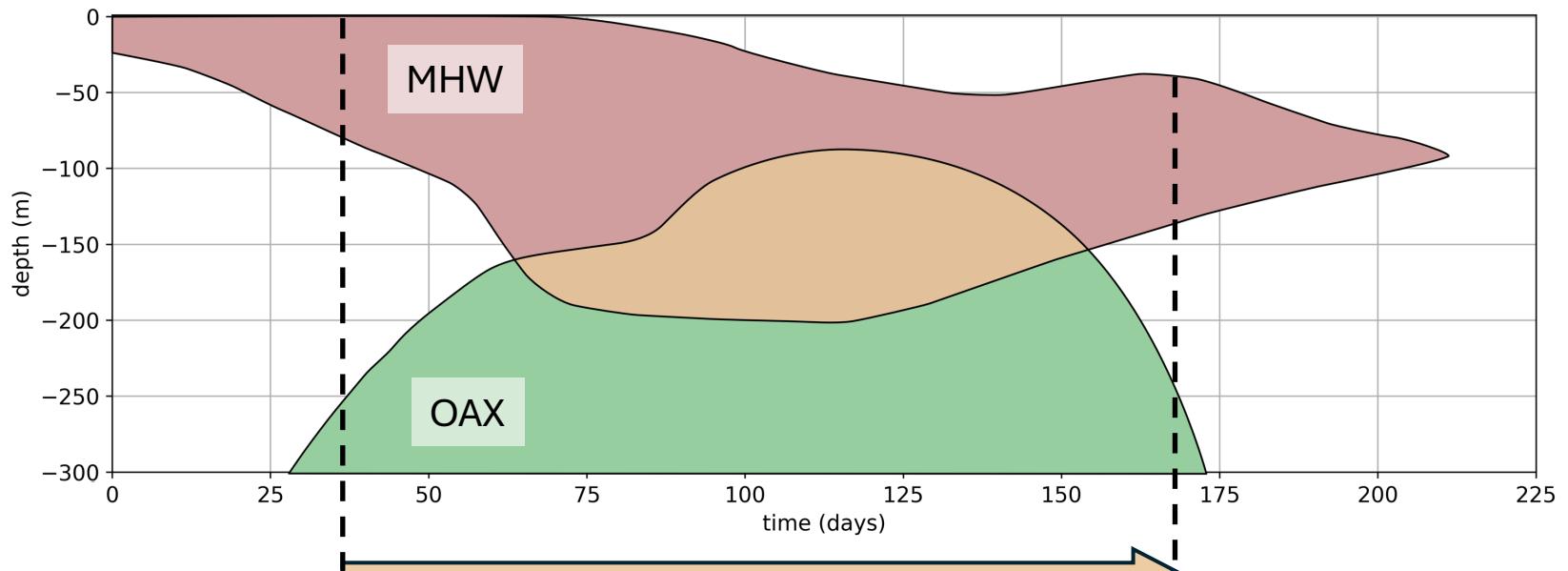
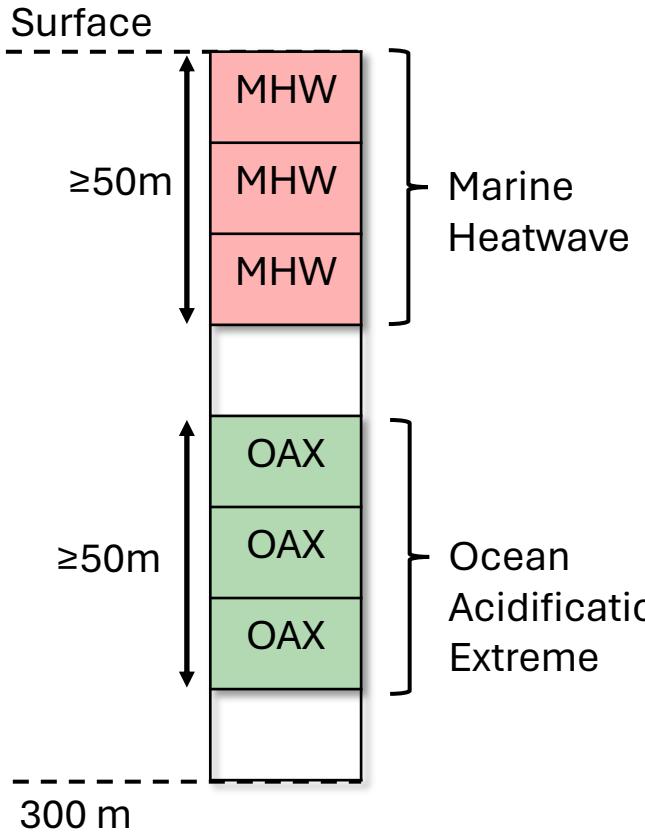


Relative and absolute thresholds

Extreme type	Variable	Percentile threshold	Absolute threshold
Marine Heatwave (MHW)	T	> 95 th	-
Ocean Acidity Extreme (OAX)	$[H^+]$	> 95 th	-
Low Oxygen Extreme (LOX)	$[O_2]$	< 5 th	< 150 μM

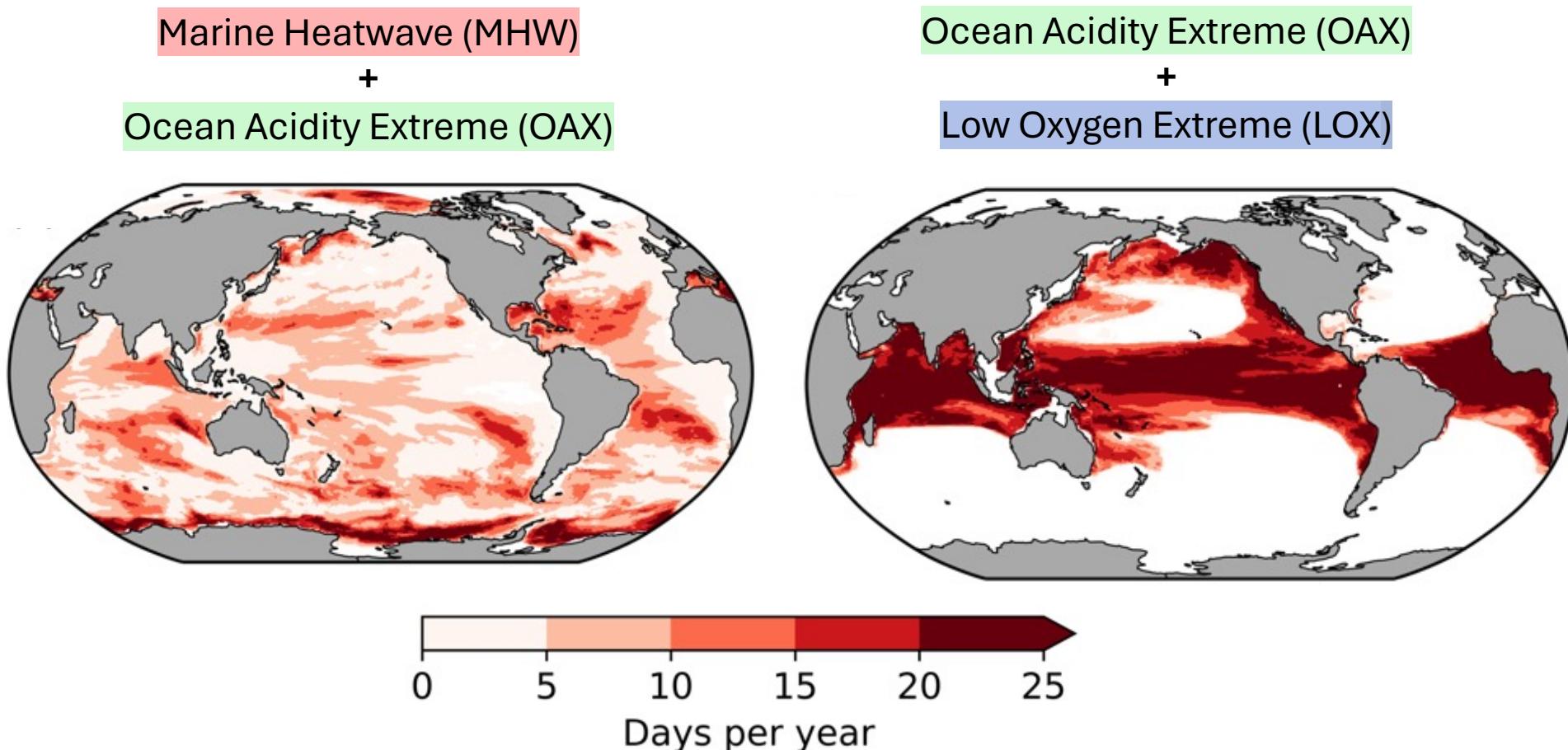
Defining Column-compound Extremes (CCX)

At least 50 m of each extreme type compounded in the 300 m vertical column

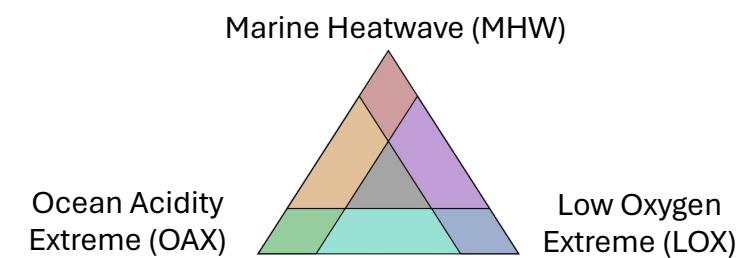
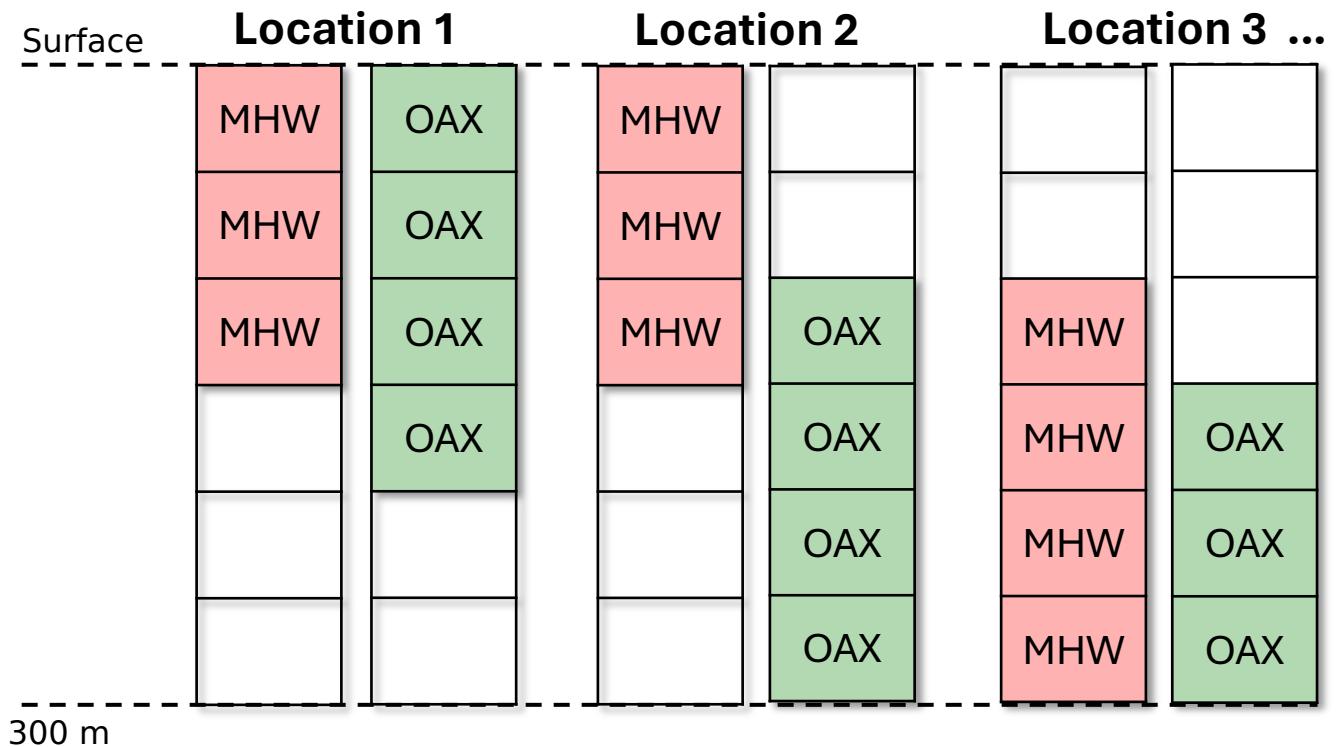
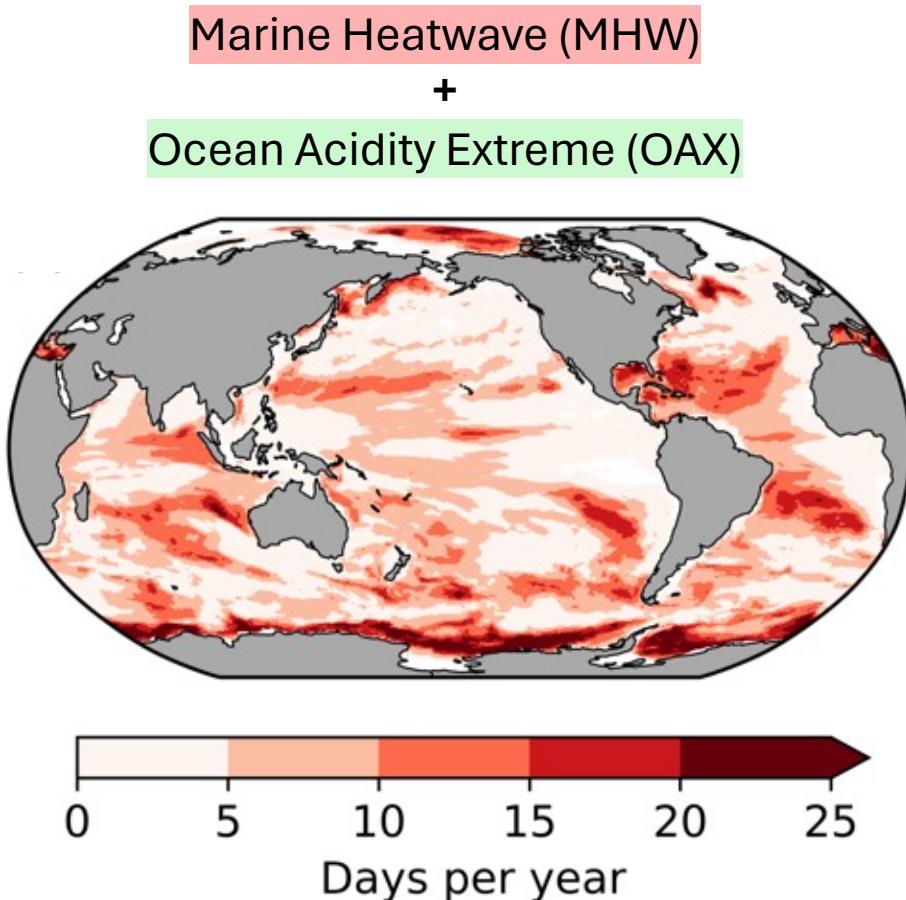


Spatial distribution of CCX

- Subtropics and high latitudes (MHW-OAX)
- Tropics and North Pacific (OAX-LOX)

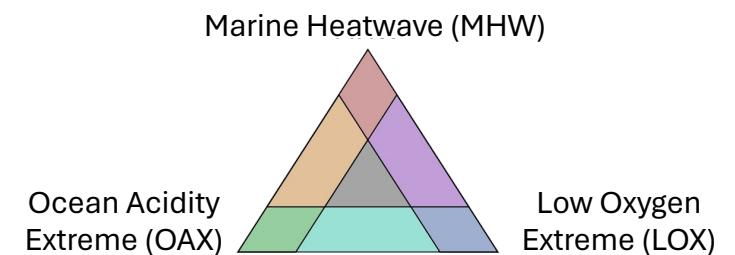
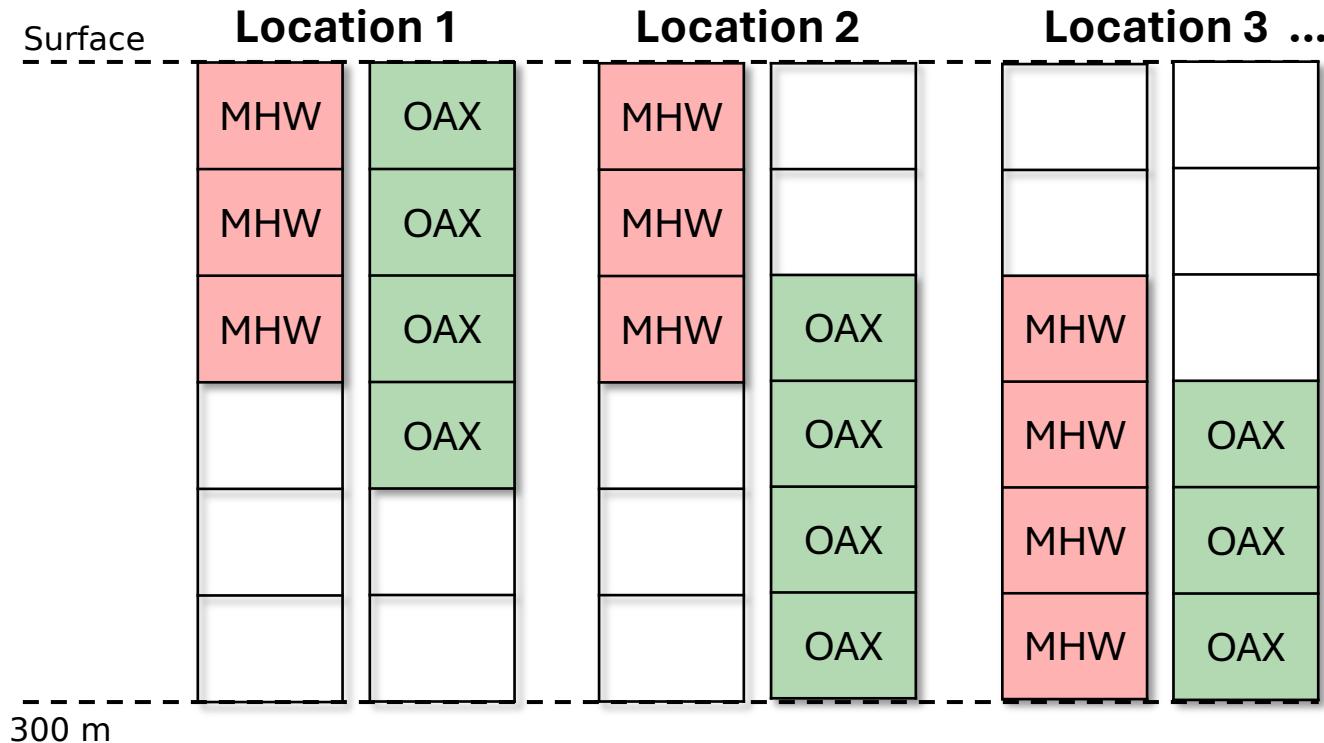


Spatial distribution of CCX

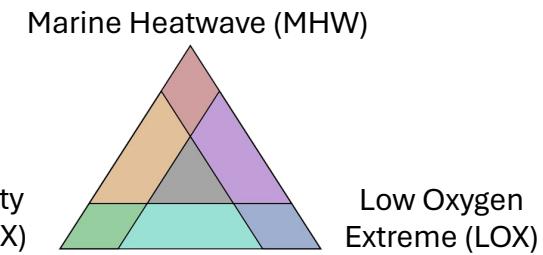
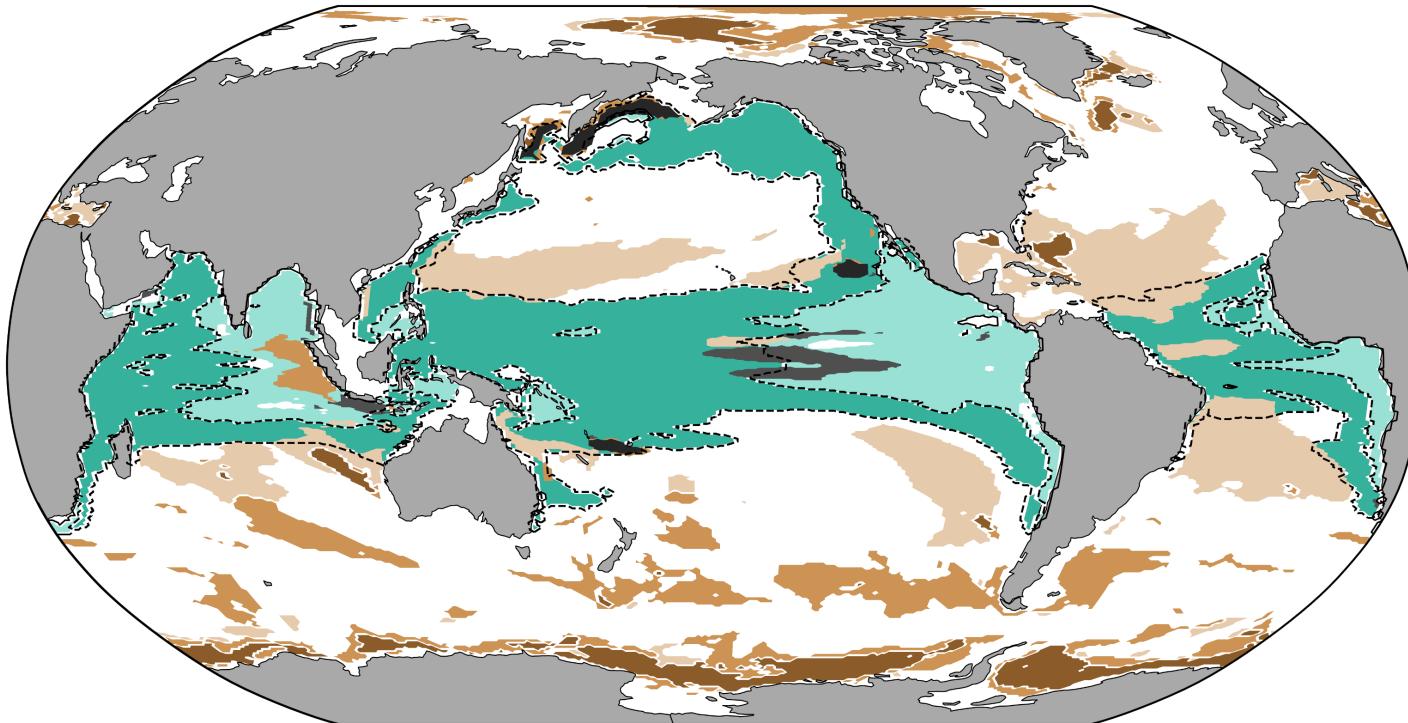


K-means clustering of CCX

Vertical distribution of single extremes likely reflect drivers



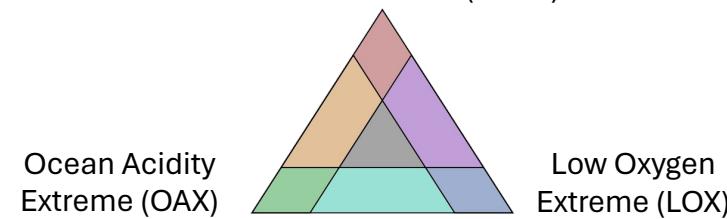
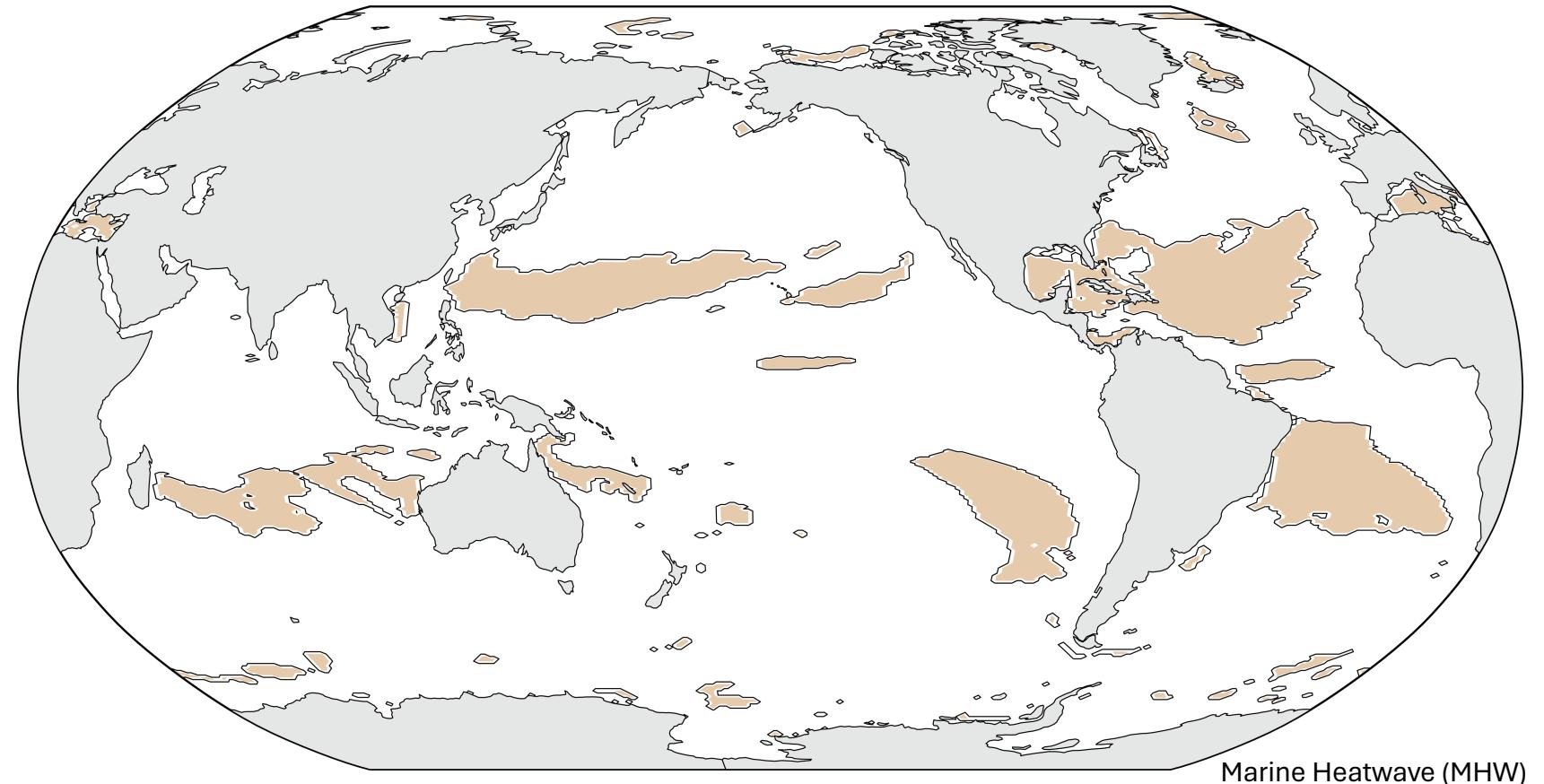
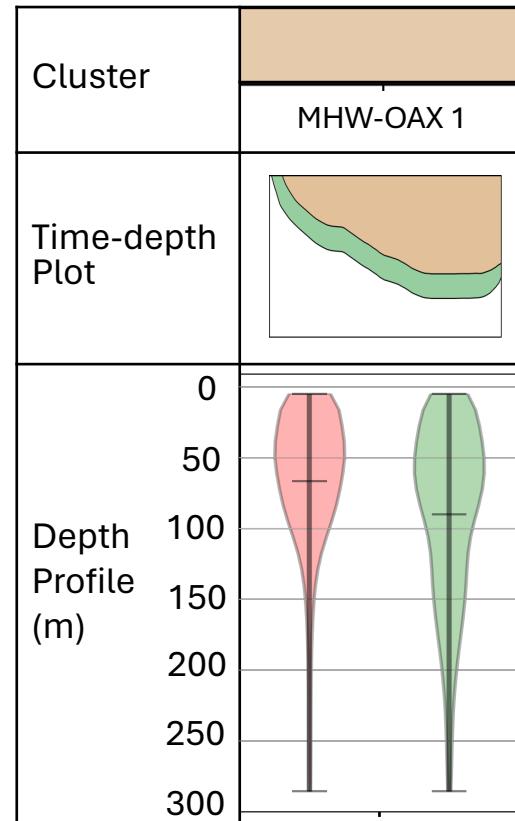
Selected K-means Clusters of CCX



Cluster	MHW-OAX 1	MHW-OAX 2	MHW-OAX 3	OAX-LOX 1	OAX-LOX 2	MHW-OAX-LOX 1	MHW-OAX-LOX 2
Time-depth Plot							

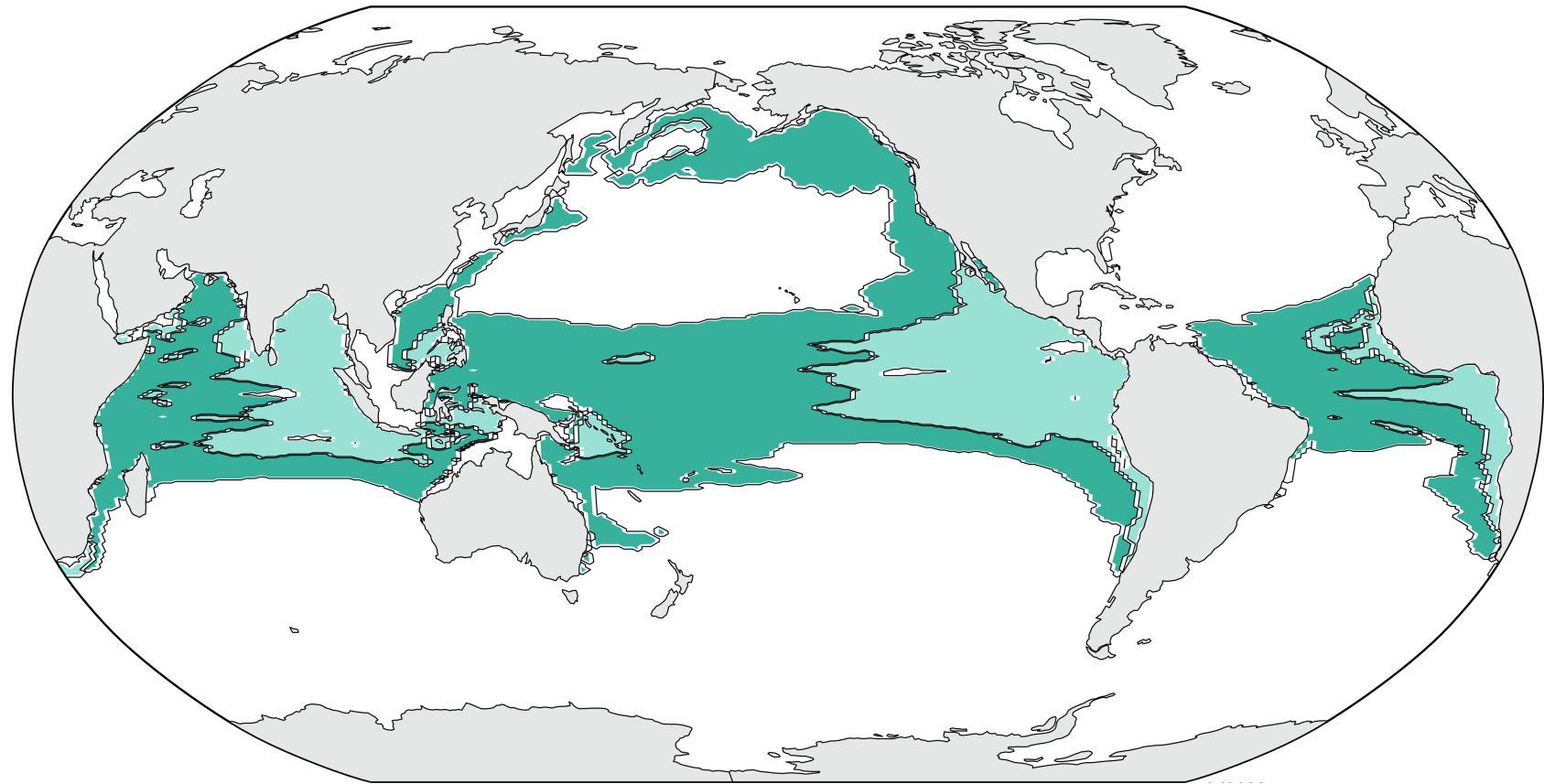
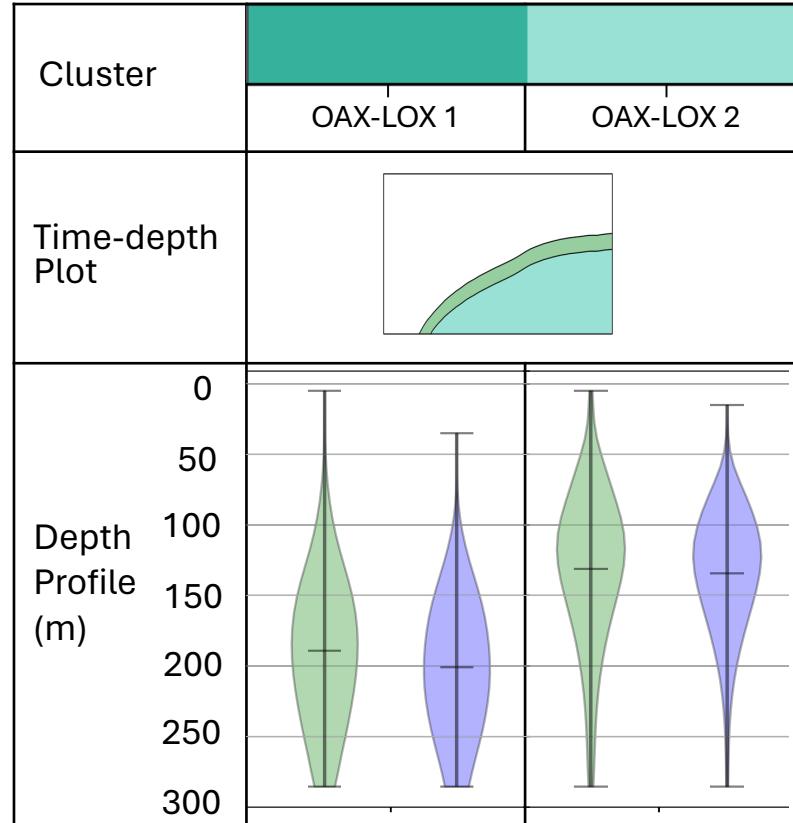
Upper-column OAX driven by temperature

→ 138% of increase in $[H^+]$ can be attributed to increase in temperature



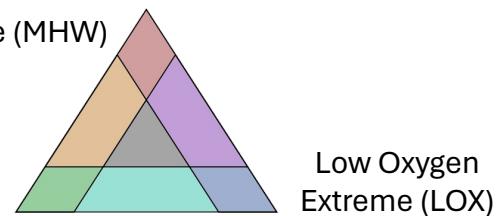
Subsurface OAX and LOX driven by shoaling thermocline

→ Every 10 m shoal of the thermocline roughly doubles OAX-LOX occurrence



Marine Heatwave (MHW)

Ocean Acidity
Extreme (OAX)



Summary

- Developed a framework to study Column-Compound Extremes (CCX)
- Identified and characterized CCX in the global ocean from 1961-2020
- Future work with high resolution model in the Southern Ocean

[ESS OPEN ARCHIVE](#)

Column-Compound Extremes in the Global Ocean

 Joel Wong  [id](#), Matthias Münnich  [id](#), Nicolas Gruber  [id](#)

In review at *AGU Advances*

