Clustering to characterize extreme marine conditions for the benthic region of the Northeastern Pacific continental margin

A. M. Holdsworth

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Fisheries and Oceans Canada

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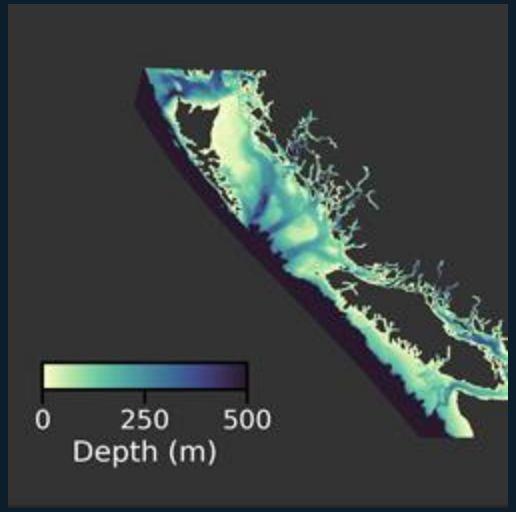
Northeastern Pacific Canadian Ocean Ecosystem Model

Model	NEMO v3.6 (biogeochemistry and tides)
Grid spacing	1/36˚ lat, lon and 75 vertical levels
Atmospheric forcing	ERA5 + CO_2 (MLO trend + mid-latitude annual cycle)
OBC	GLORYS12v1, GLODAP BGC, tides
Time period	1996 to 2019 after spinning up perpetual 1996

NEP36-CanOE

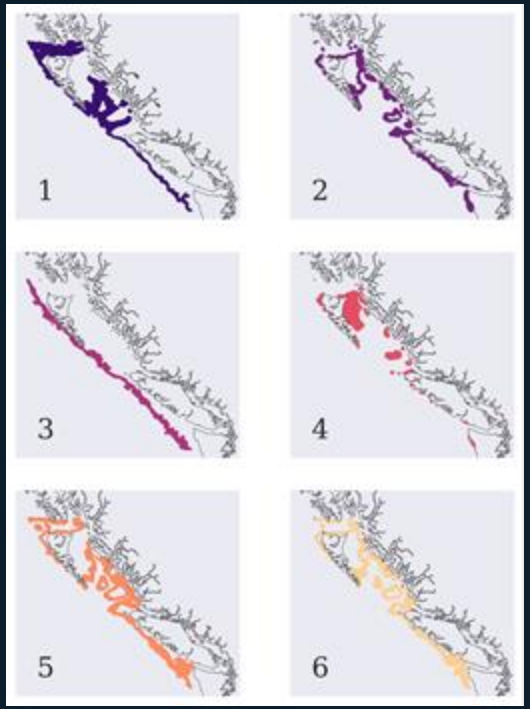


daily subsets for T, S, O_2, NO_3, DIC, TALK

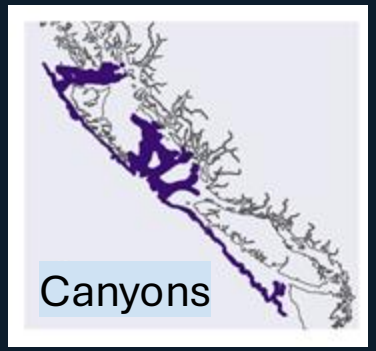
Characterizing extremes using unsupervised clustering and relative thresholds

Method

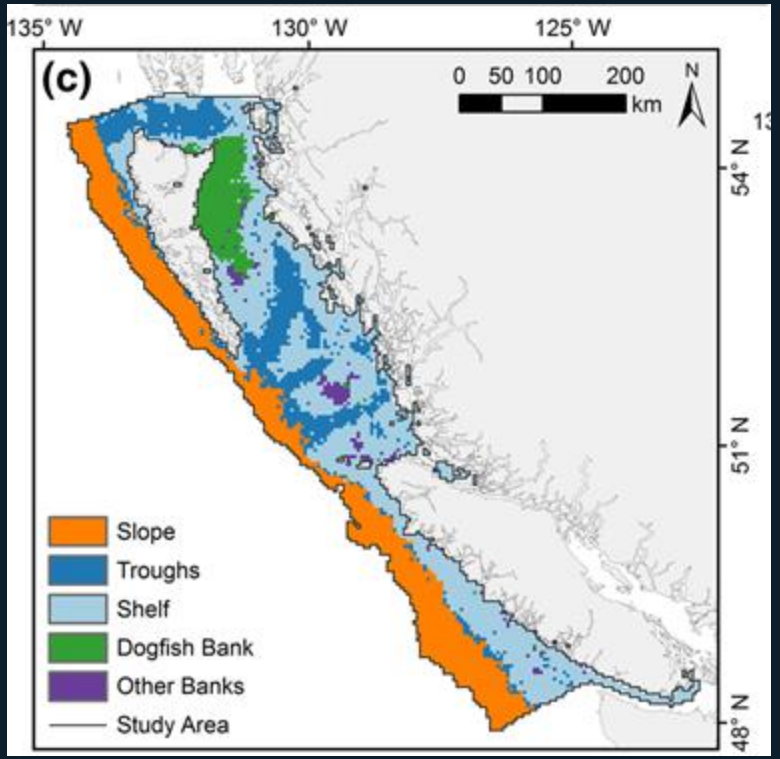
1. Find unique “habitats” using k-means clustering for Apparent oxygen utilization (AOU), T, Ω_A
2. Extremes defined for upwelling/downwelling seasons using the 10th or 90th percentile from a fixed baseline (1996 - 2019).
3. Analyze the historical extremes for each cluster.



Two clusters stand out for their ecological significance







Species associated with the ecoregions	
Slope	7
Troughs	10
Shelf	2
Dogfish Bank	13
Other Banks	4

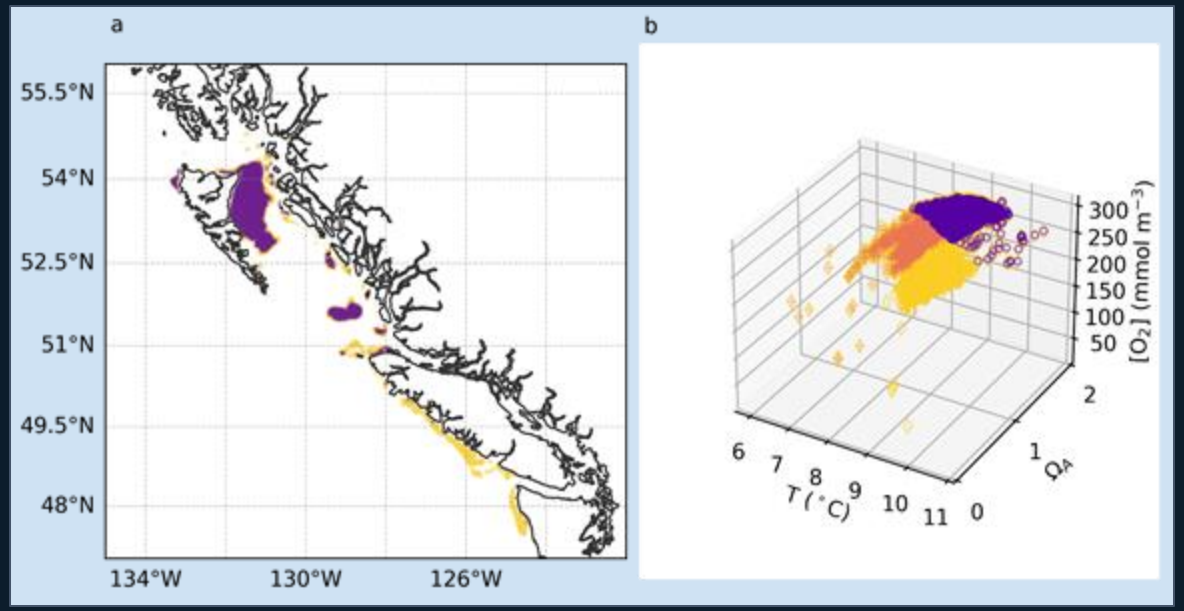
(Rubidge et al. 2016)

Could we use a depth criteria instead of clustering?

purple - shallows
(deepest depth = 69m)

yellow - all depths <69m

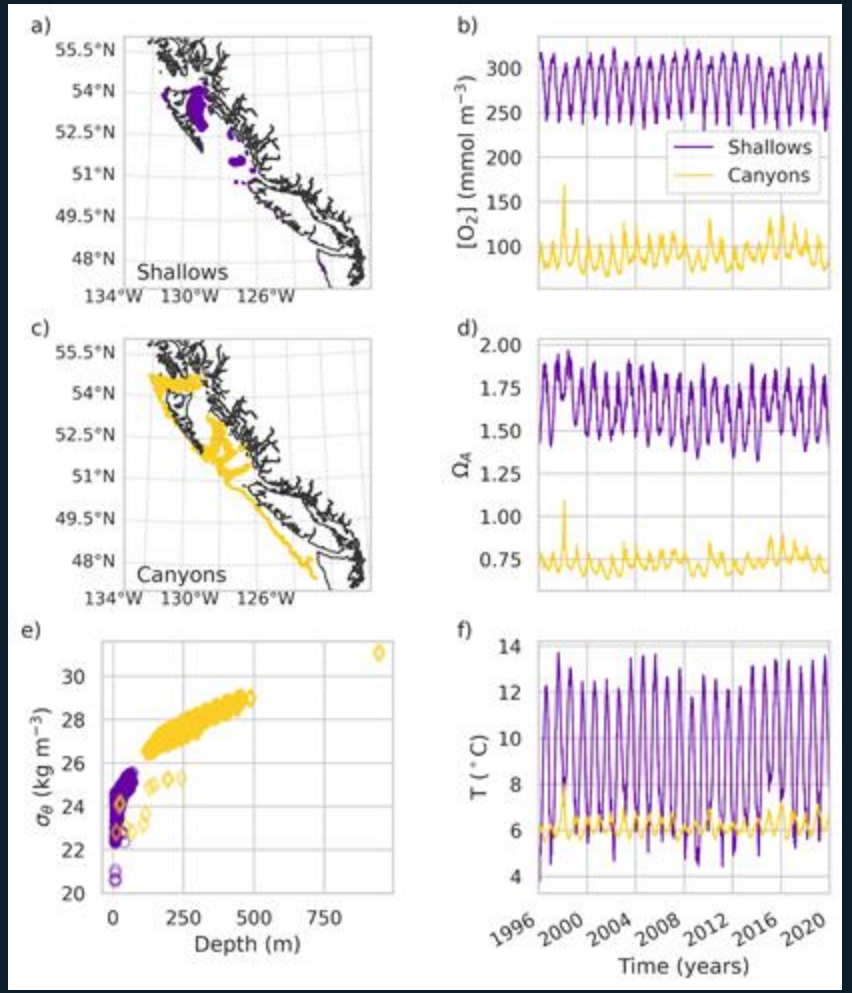
orange - all depths <69m
and north of 51°



spatial subsetting ignores the fact that these variables can vary significantly at the same depth

Average conditions within two of the benthic clusters

Cluster	$[O_2]$ (mmol m^{-3})	Ω_A	T (°C)	Depth (m)
Canyons	91	0.7	6.2	262
Shallows	282	1.6	9.1	29



Defining Extreme Conditions

Extremes are defined for upwelling/downwelling seasons using the 10th or 90th percentile from a fixed baseline (1996 - 2019).

Thresholds

SHALLOWS

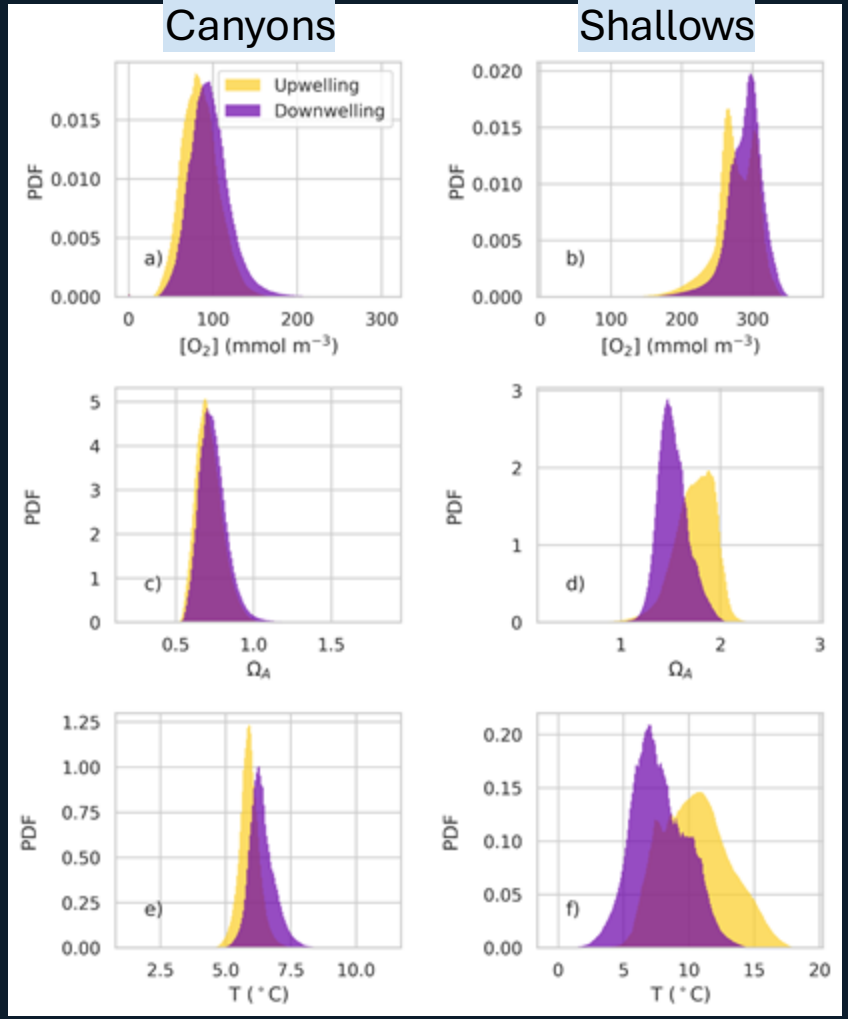
Upwelling
T =14.1 °C
O_2 = 241
Ω_a = 1.5

Downwelling
T = 10.7 °C
O_2 = 260
Ω_a = 1.3

CANYONS

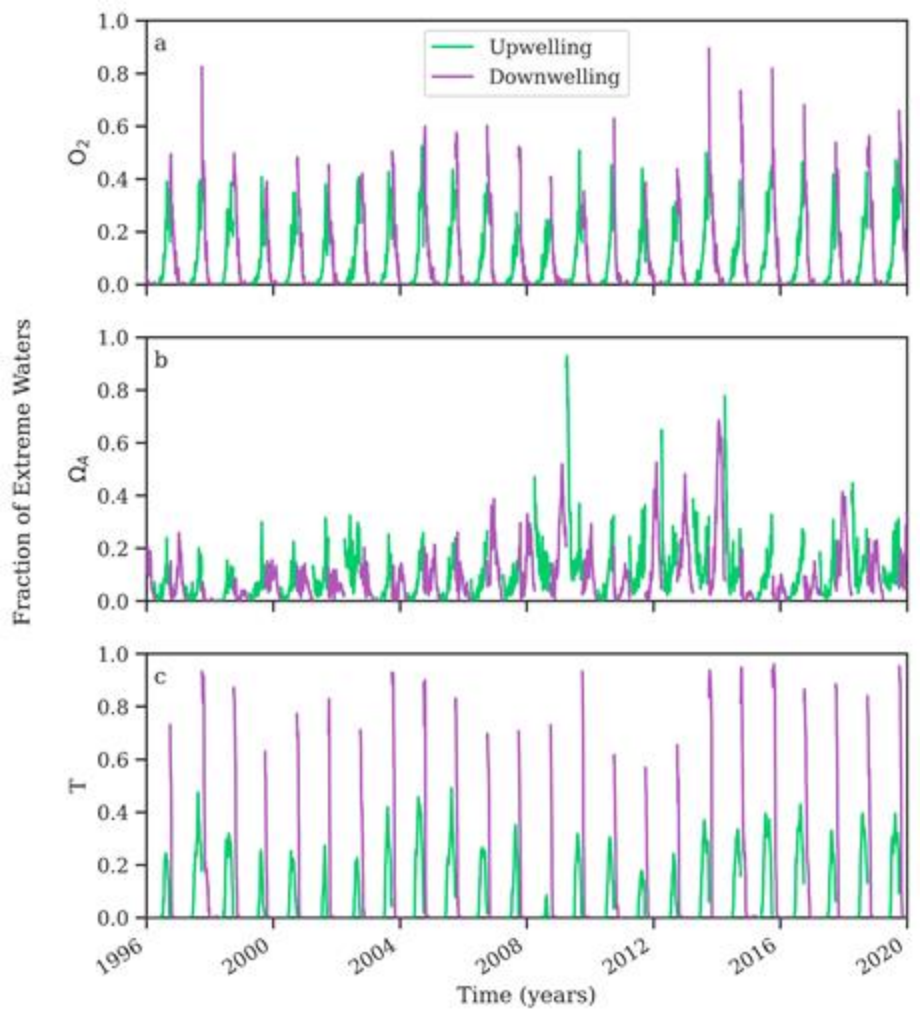
Upwelling
T = 6.4 °C
O_2 = 59
Ω_a = 0.6

Downwelling
T = 7.1 °C
O_2 = 69
Ω_a = 0.6



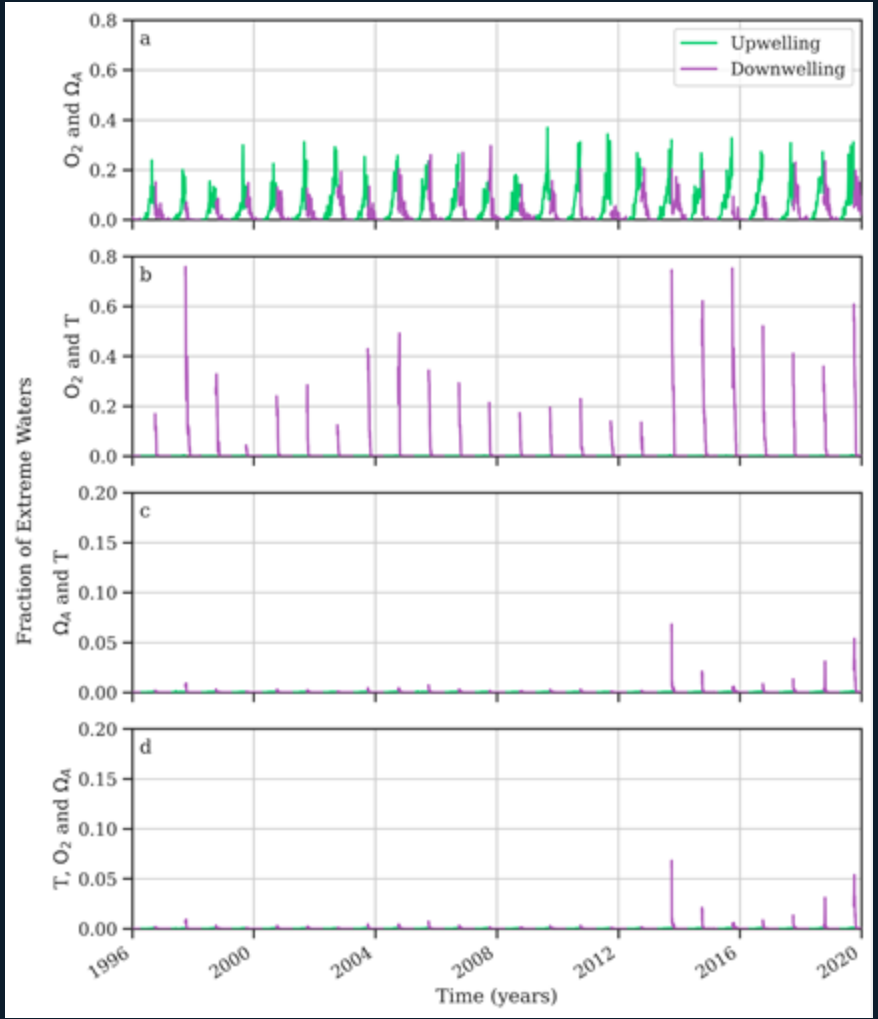
Fraction of extreme waters in the Shallows



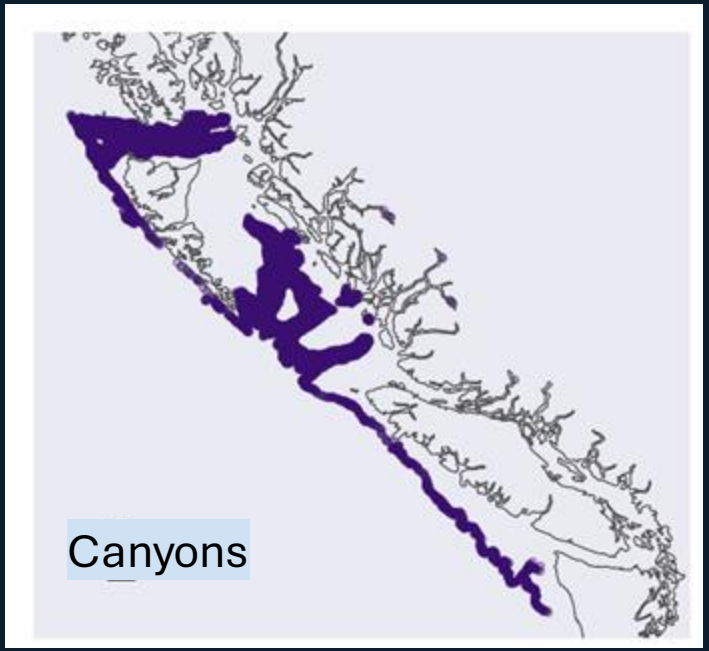


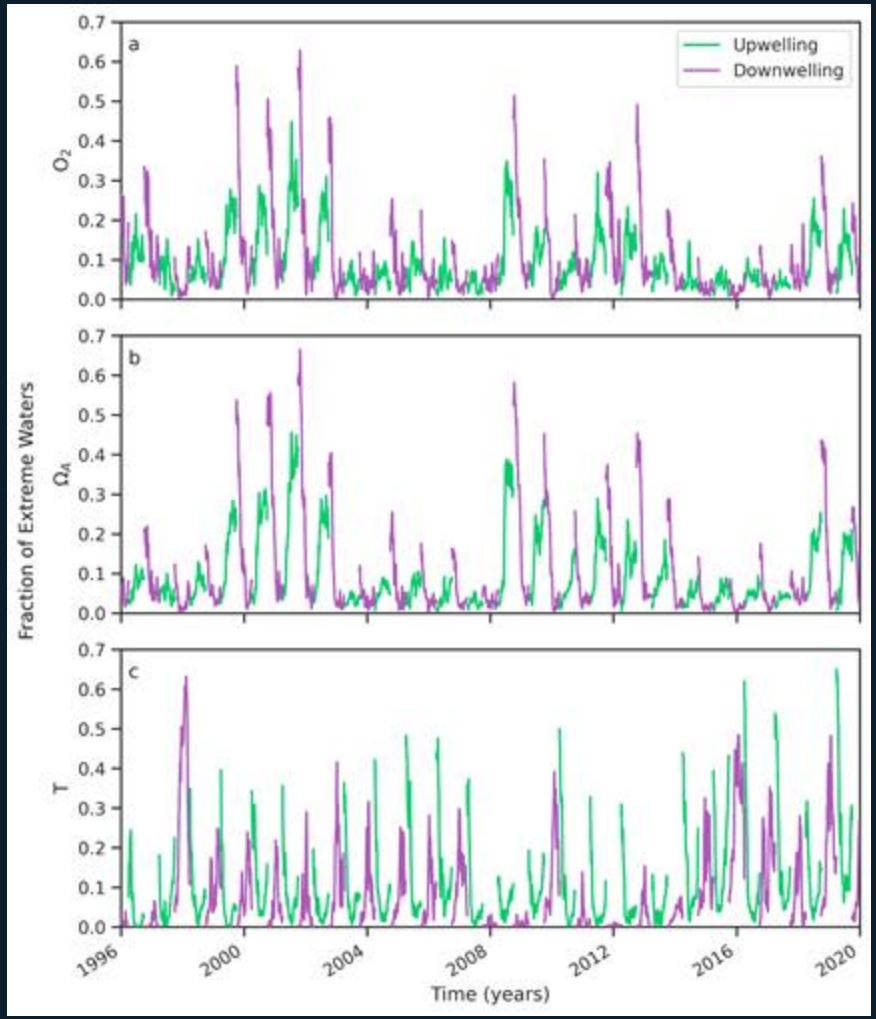
Compound extremes in the Shallows





Fraction of extreme waters in the Canyons





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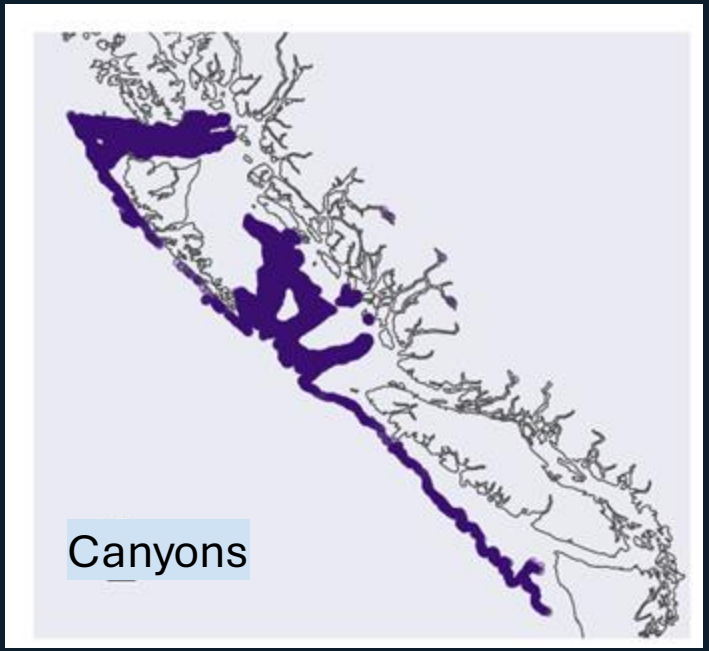

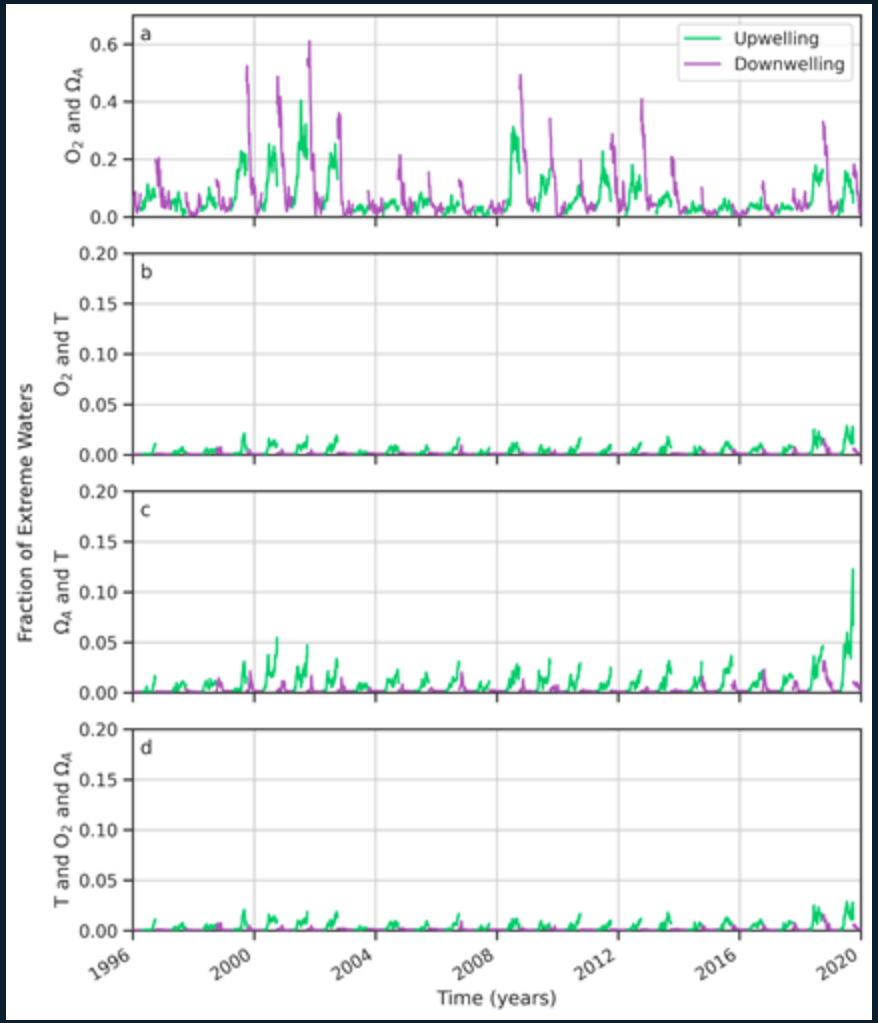

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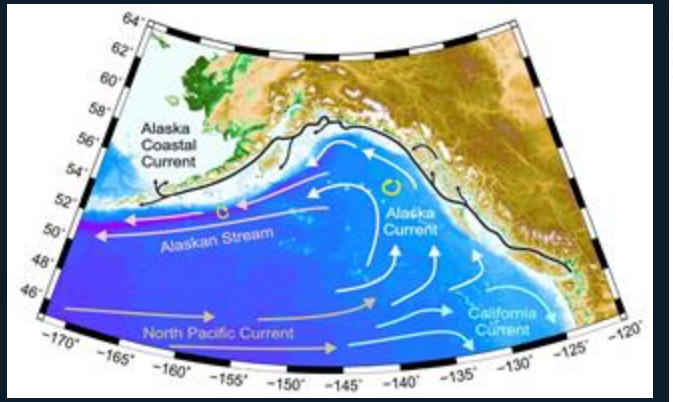

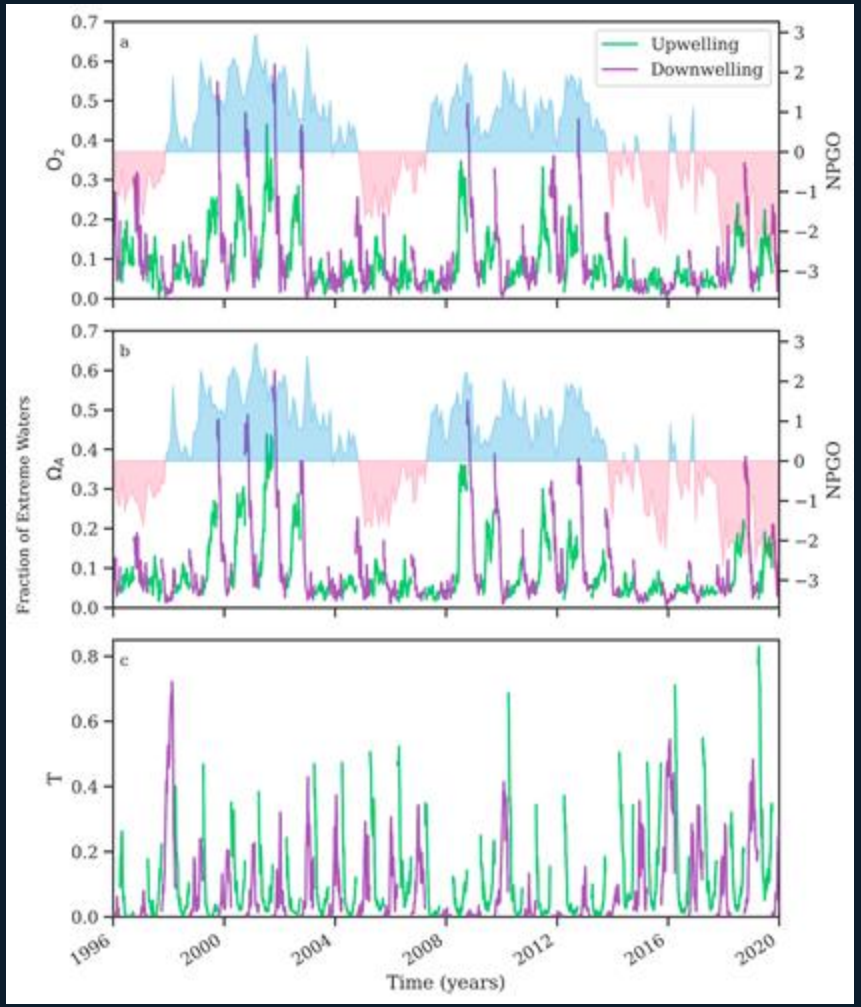

The North Pacific Gyre Oscillation (NPGO)

Statistical characterization of extremes for benthic clusters in the Northeastern Pacific continental margin



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Key Points:

- A generalizable method for characterizing ocean extremes was developed and applied to an Eastern Boundary Current environment
- Climate indices are predictive of extreme conditions for the

Clustering to Characterize Extreme Marine Conditions for the Benthic Region of the Northeastern Pacific Continental Margin

Amber M. Holdsworth[1], Andrew Shao[2], and James R. Christian[1,3]

[1]Fisheries and Oceans Canada, Victoria, BC, Canada, [2]Hewlett Packard Enterprise, Victoria, BC, Canada, [3]Canadian Centre for Climate Modelling and Analysis, Victoria, BC, Canada

1. The direct forcing by the atmosphere (shallows) and upwelling/downwelling (e.g., CTW, NPGO) (canyons) strongly influence extremes.
2. Large scale indices (e.g., NPGO) are predictive of extreme conditions.
3. For the shallows, the apparent increase in Ω_A extremes over time is likely due to increasing anthropogenic CO_2 in the atmosphere.
4. Compound extremes involving all three stressors are rare, but increasing.