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The individual role of temperature and salinity change for different trophic levels in global climate scenarios downscaled for the Baltic Sea and North Sea

Matthias Gröger[1], Helén Andersson[1] , Christian Dieterich, H.E. Markus Meier[1,2] , Iréne Wåhlström[1], and Brian MacKenzie[3]

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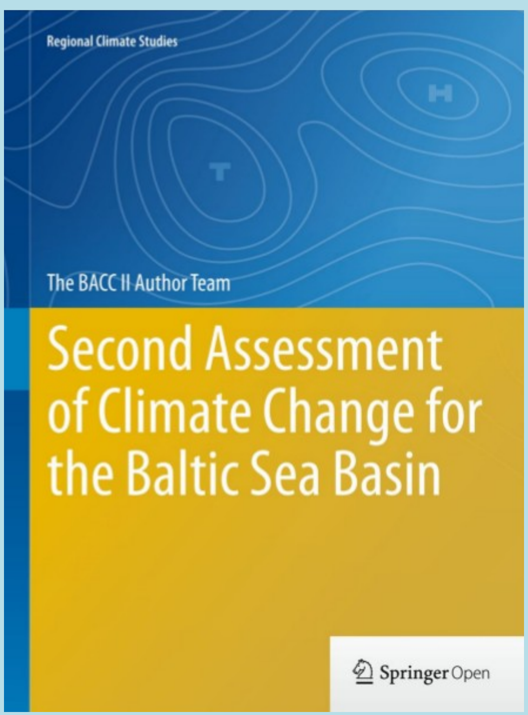

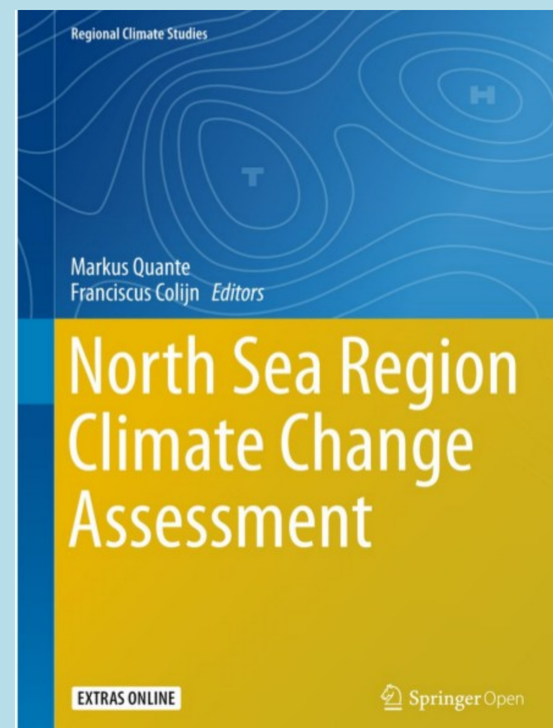

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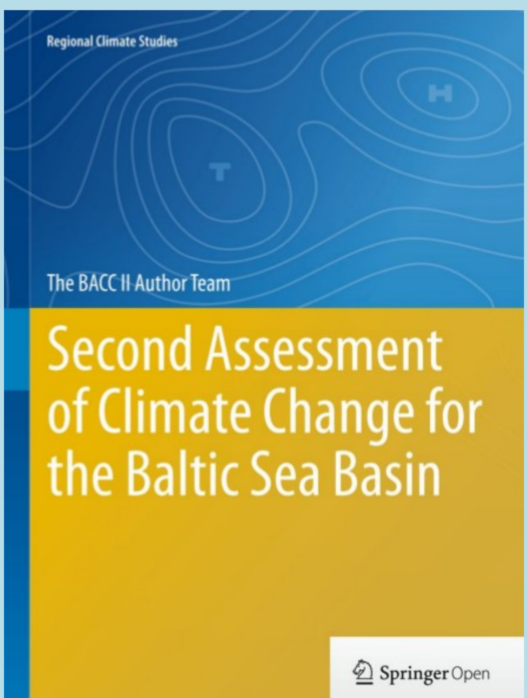
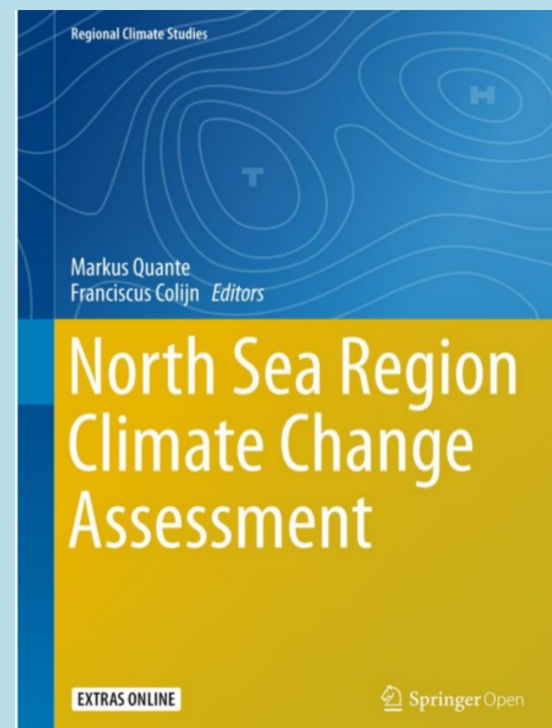


Warmer!
&
Wetter!?



The problem:

Global models disagree much more for precipitation than for temperature

What will be more important for the stratification (→ pycnocline)?

- **projected Changes in water temperature?**
- **projceted changes in water salinity?**

Cascading effects on lower and higher trophic species...

To exactly separate individual effects of T and S change requires

Factor separation technique (Stein and Alpert, 1993)
– requires sensitivity experiments (expensive)
– technically more complicated using coupled ocean – atmosphere models

→ **Impossible to do when using coupled model and large ensembles**

A feasible approach is however:

1. Define a reference period for (1980-1999) and make a monthly climatology for T & S

2. Calculate density time series with
   a) reference temperature and **transient salinity** from climate scenario (RCP8.5)
   b) reference salinity and **transient temperature** from climate scenario (RCP8.5)

3. Calculate pycnocline depth and intensity

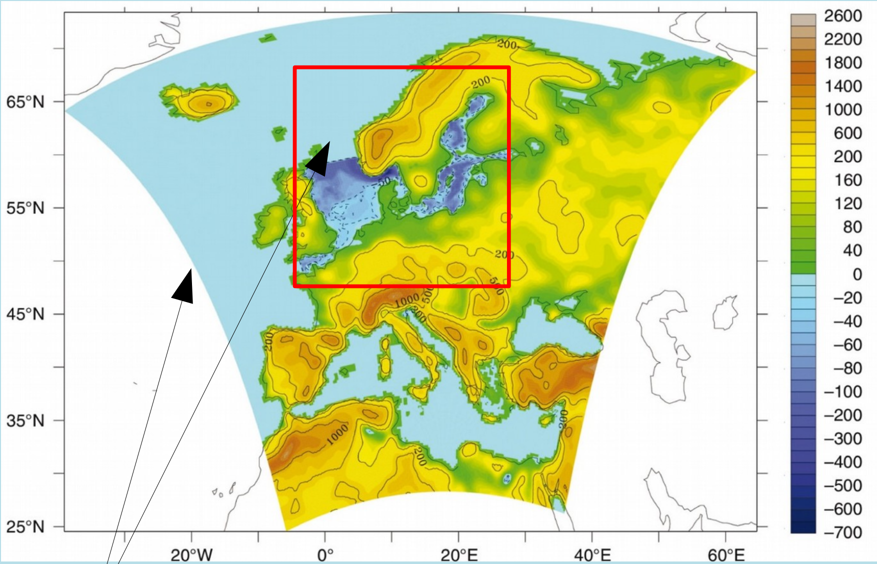
   Pycnocline
   → depth calculated according to the 0.03 kgm^{-3} criterion (de Boyer Montégut et al., 2004)
   → intensity: search max.density gradient in water column ($kgm^{-3}m^{-1}$)

de Boyer Montégut, C., G. Madec, A. S. Fischer, A. Lazar, and D. Iudicone (2004), Mixed layer depth over the global ocean: An examination of profile data and a profile-based climatology, J. Geophys. Res., 109, C12003, doi:10.1029/2004JC002378.

Downscaled Climate Scenarios with RCA4-NEMO coupled ocean atmosphere GCM

Experiment	Historical	RCP 8.5	RCP 4.5	RCP 2.6
ERA40	1961 – 2010			
MPI-ESM-LR	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099
EC-EARTH	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099
GFDL-ESM2M	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099
HadGEM2-ES	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099
IPSL-CM5A_MR	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099

Table 2: Existing downscaled scenarios using interactive ocean – atmosphere coupling

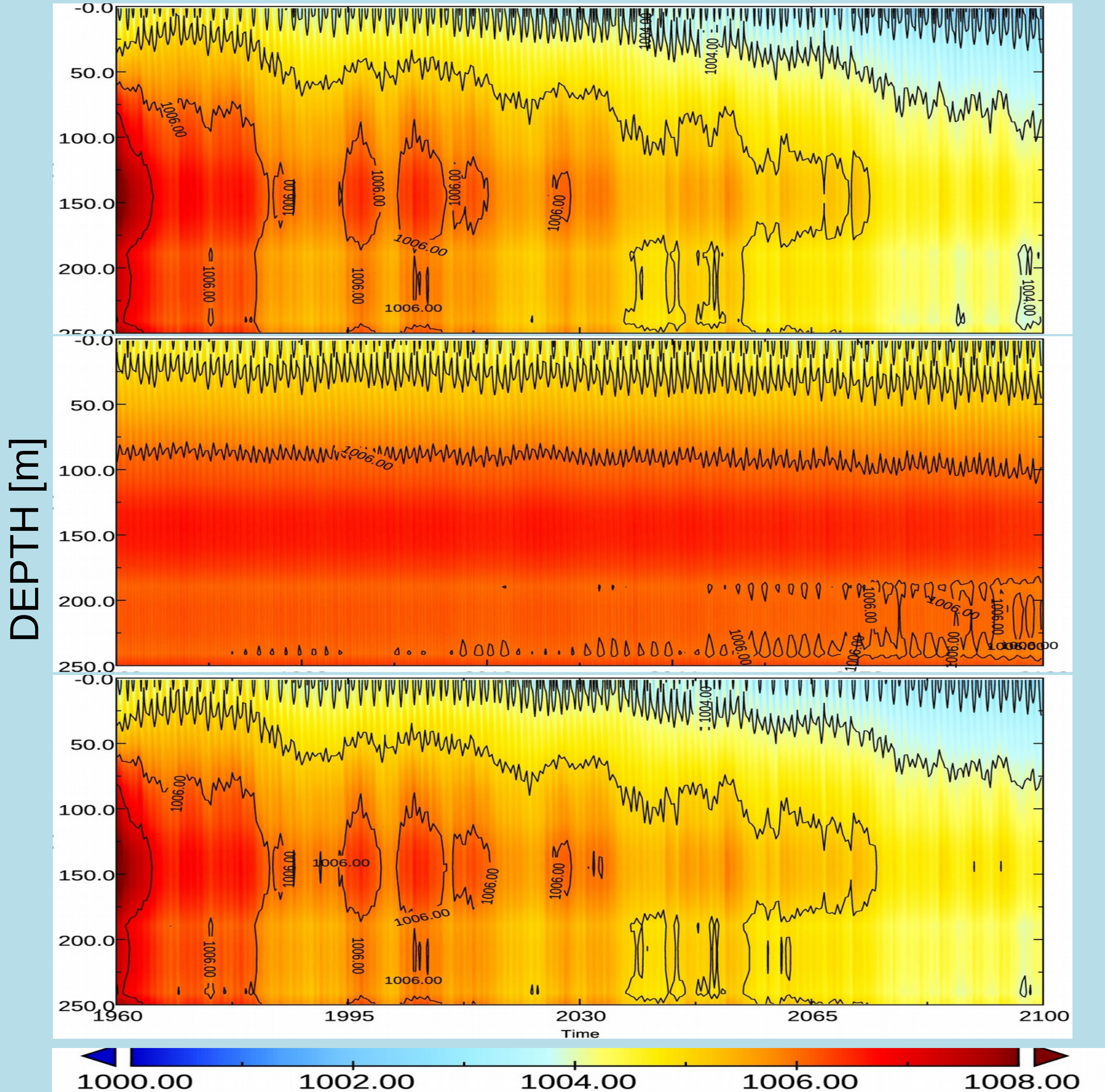


lateral borders: ESM driven

Atmosphere GCM
Rossby Center Atmosphere model 4
24 km

Ocean GCM
NEMO3.3.1 ocean component
(North Sea + Baltic Sea)
2 NM, 56 vertical levels

Example: Downscaled MPI-ESM-LR RCP8.5 scenario Changes in vertical density averaged over the Baltic Sea



as simulated

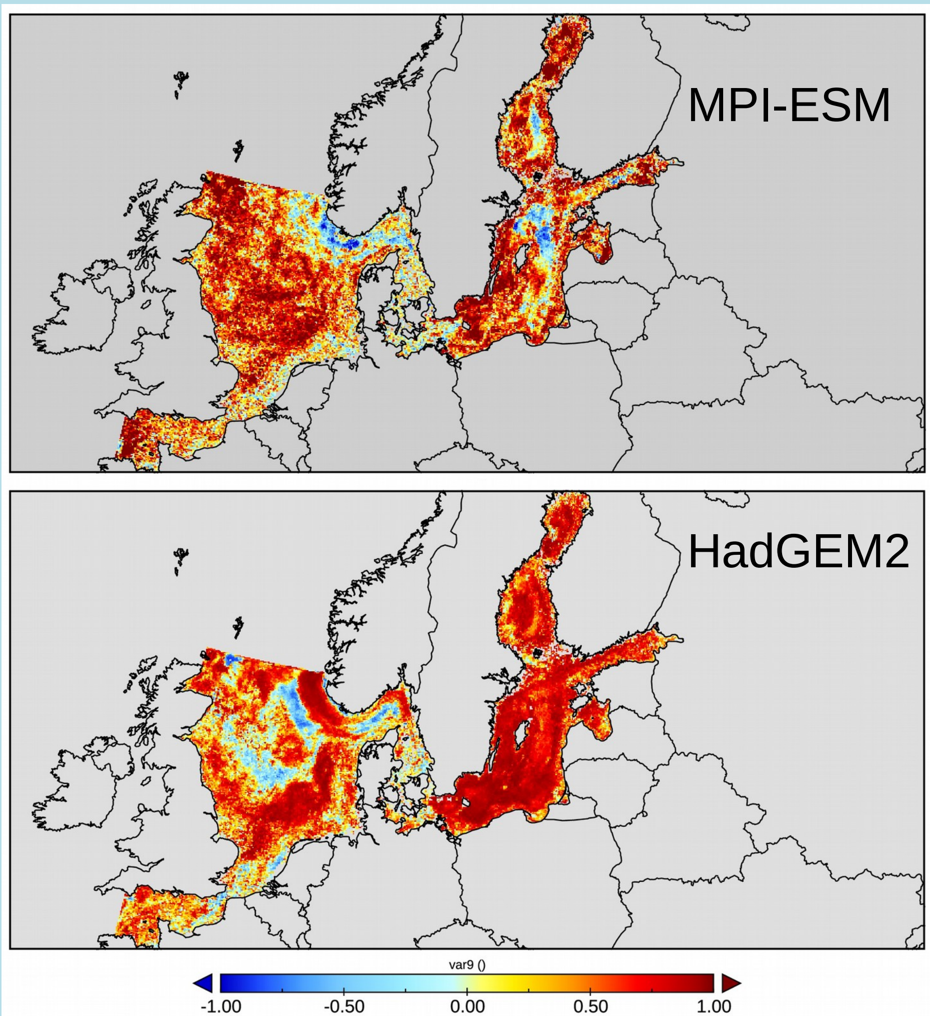
temperature effect

effect of salinity

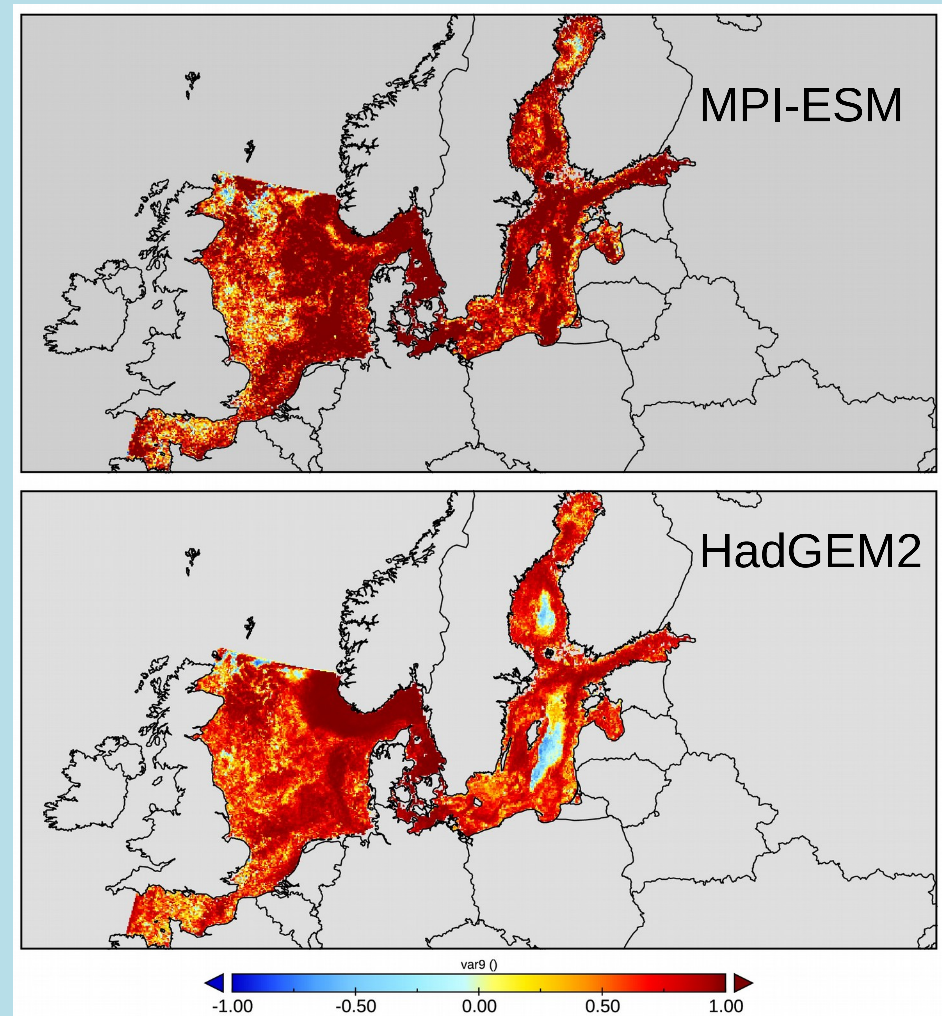
[kgm^{-3}]

What governs the interannual variability of pycnocline depth in a 100 year year climate scenario RCP8.5?

Effect of temperature change
on pycnocline depth variability



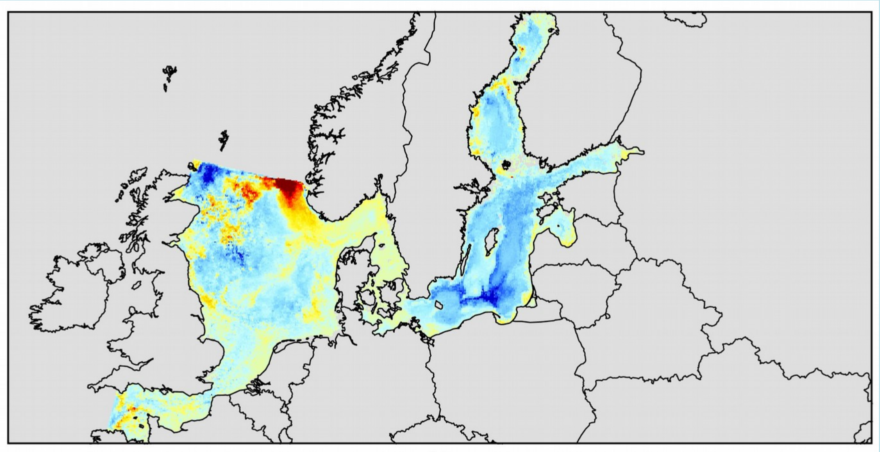
Effect of salinity change
on pycnocline depth variabilty



Correlation of pycnocline depth as simulated with pycnocline depth caused by temperature (left) and salinity change (right)

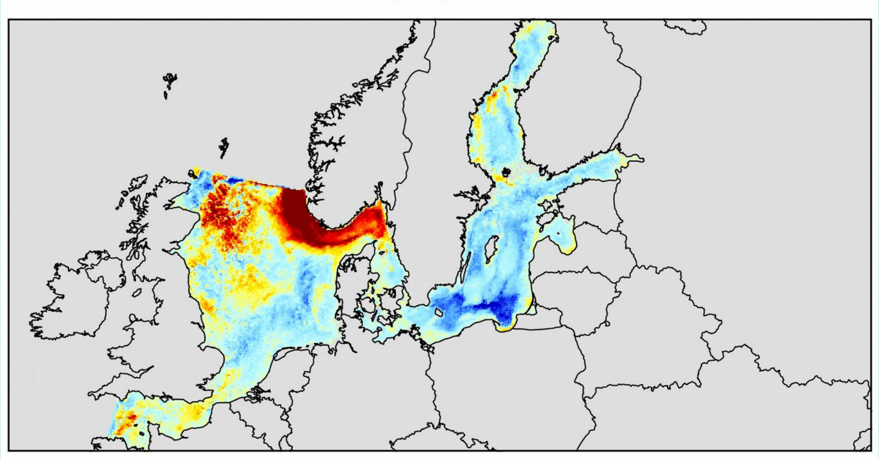
What determines the change (2080-2099 minus 1980-1999) in pycnocline depth in a climate scenario RCP8.5?

Diagnozed effect from temperature change

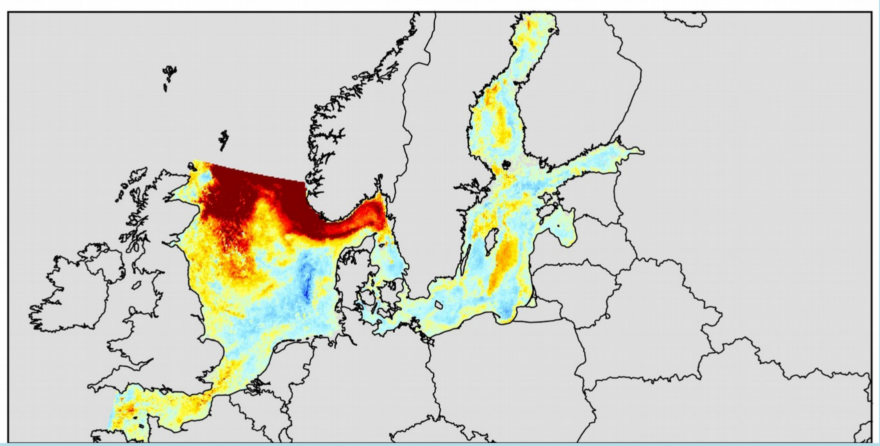


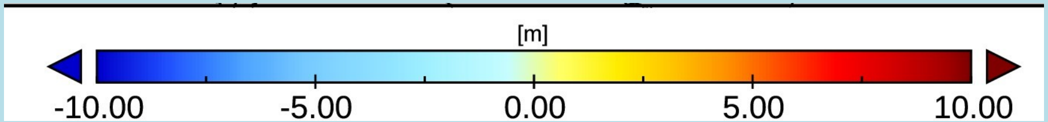
Model: HadGEM2

Pycnocline depth change as simulated



Diagnozed effect from salinity change

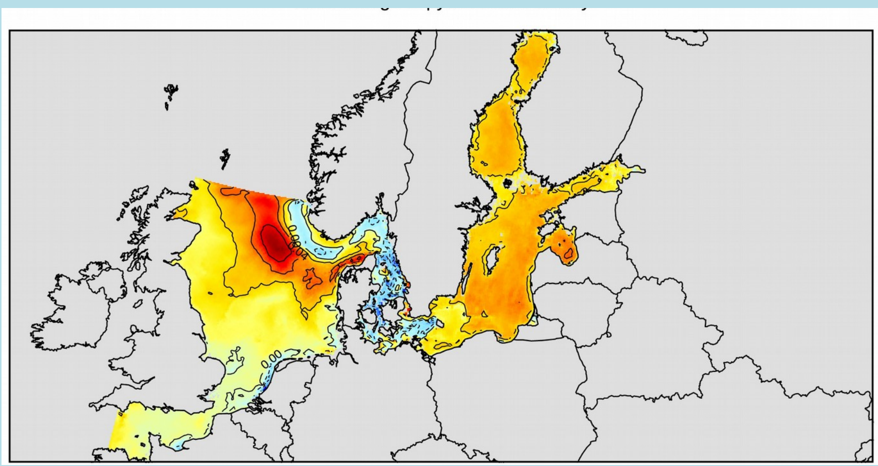


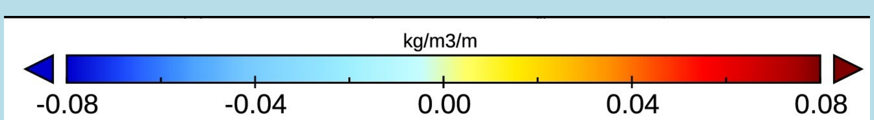


What determines the change (2080-2099 minus 1980-1999) in pycnocline intensity in a 100 year climate scenario RCP8.5?

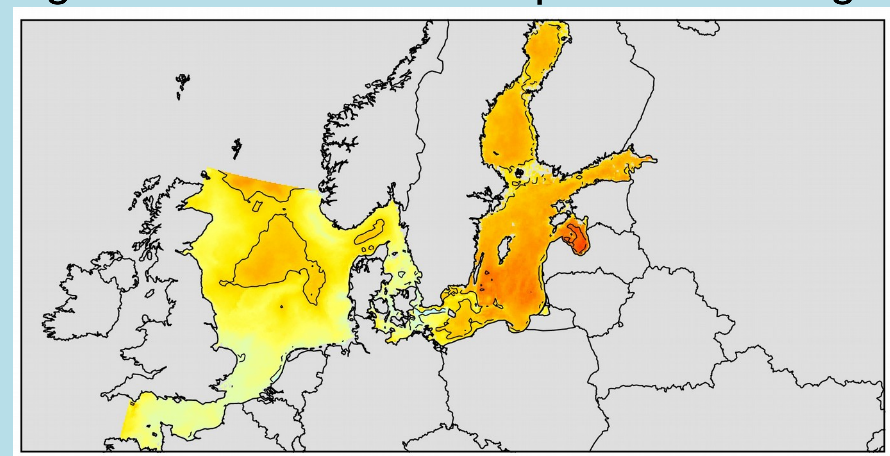
Model: HadGEM2

Pycnocline intensity change as simulated

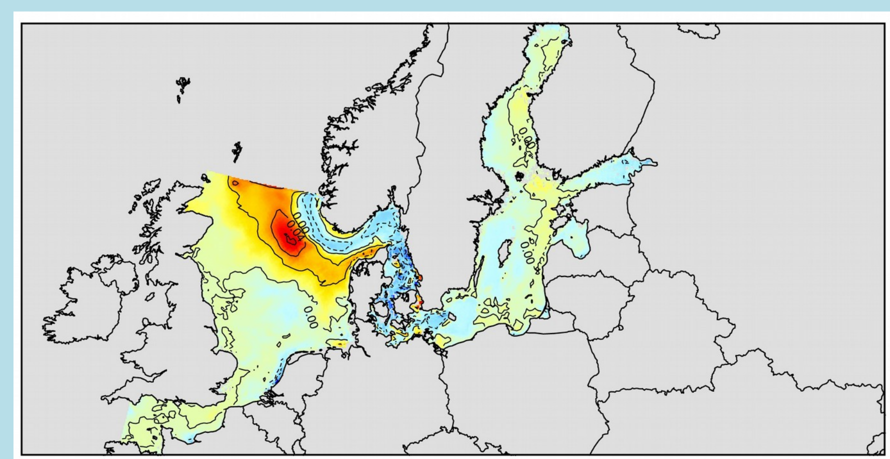




Diagnozed effect from temperature change



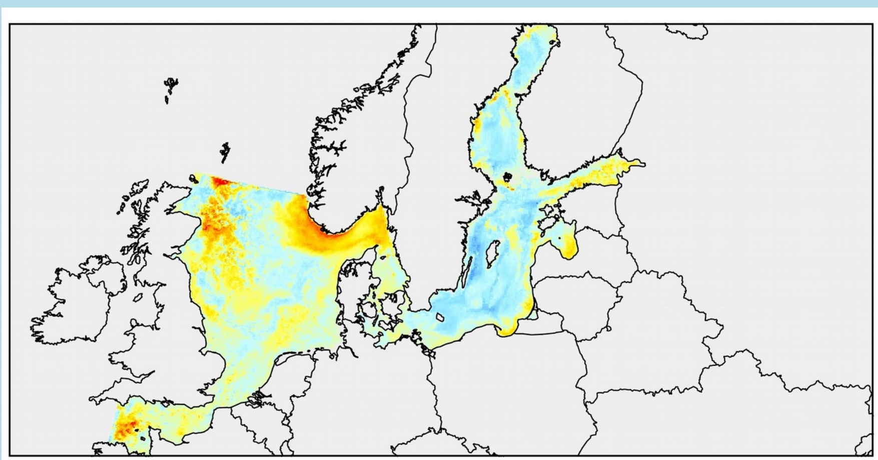
Diagnozed effect from salinity change

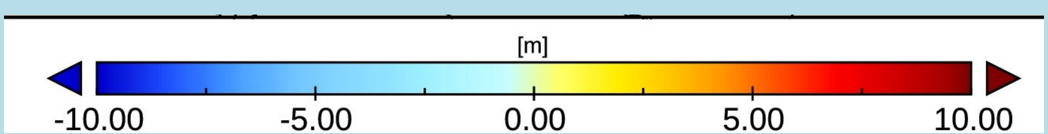


What determines the change (2080-2099 minus 1980-1999) in pycnocline depth in a climate scenario RCP8.5?

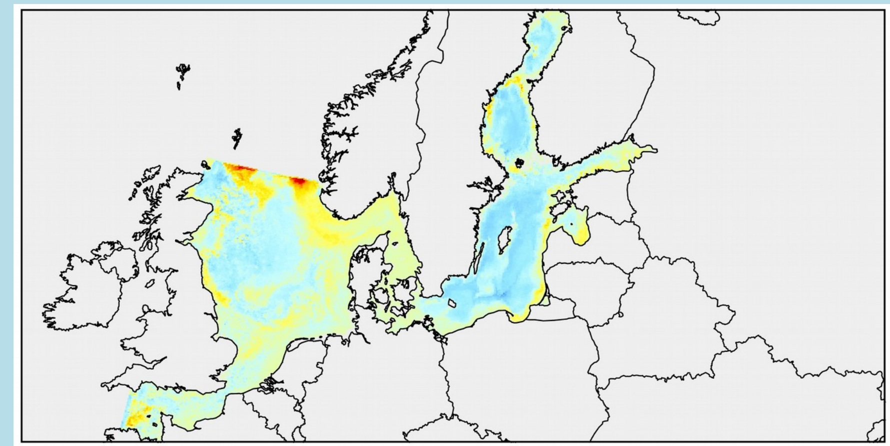
Model: Ens_mean

Pycnocline depth change as simulated

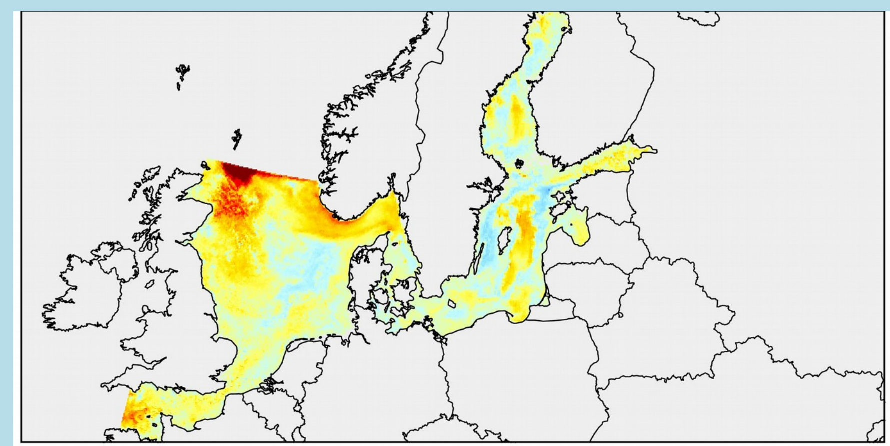




Diagnozed effect from temperature change



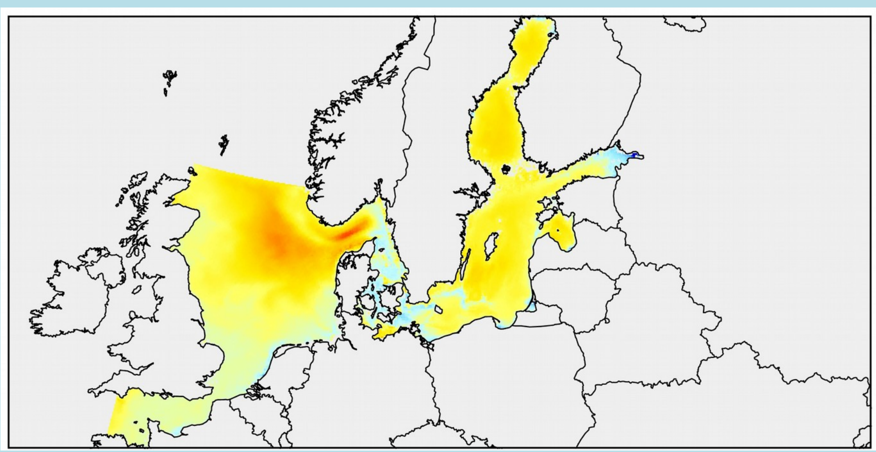
Diagnozed effect from salinity change



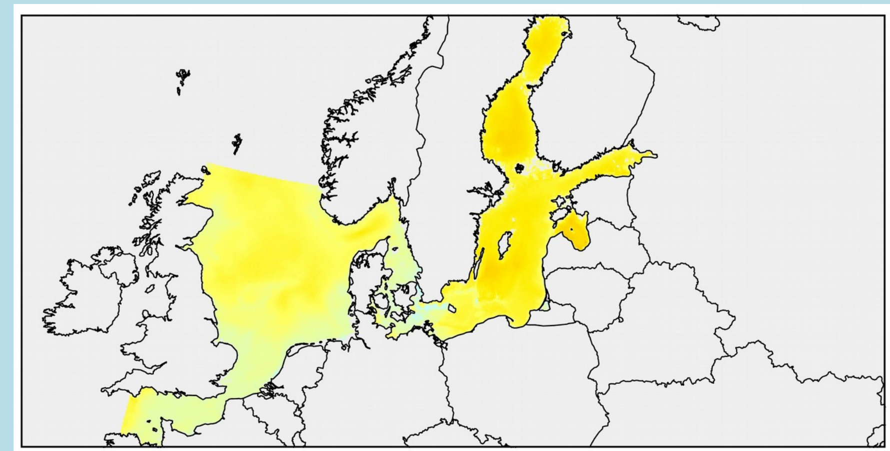
What determines the change (2080-2099 minus 1980-1999) in pycnocline intensity in a 100 year climate scenario RCP8.5?

Model: Ens_mean

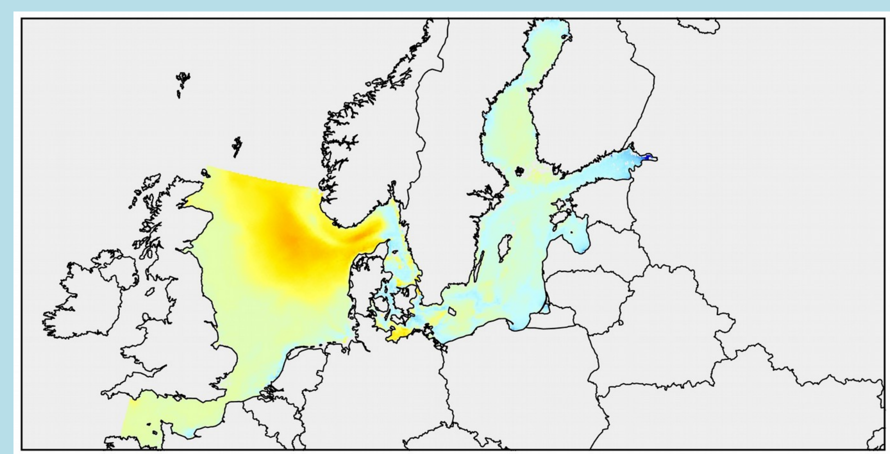
Pycnocline intensity change as simulated

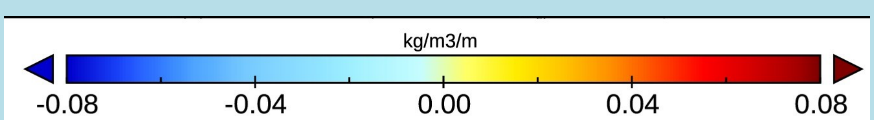


Diagnozed effect from temperature change



Diagnozed effect from salinity change





Summary

Spatial correlation between simulated pycnocline depth and that

forced by salinity (S) change
forced by temperature (T) change

	MPI-ESM		HadGEM2		EC-Earth		GFDL		IPSL		Ens Mean	
	S	T	S	T	S	T	S	T	S	T	S	T
North Sea	0.61	0.57	0.72	0.48	0.83	0.68	0.82	0.05	0.86	0.31	0.59	0.41
Baltic Sea	0.70	0.28	0.65	0.72	0.62	0.75	0.78	0.51	0.71	0.51	0.60	0.74

T dominated
S dominated

Preliminary Conclusions

Baltic Sea:

Pycnocline becomes shallower, this is more attributable temperature changes

Intensity: Both temperature and salinity related changes lead to a stronger pycnocline

North Sea:

No homgenous pattern seen in pycnocline depth, the pattern of change
follows rather the changes in salinty

Intensity: Both temperature and salinity related changes lead to a stronger pycnocline

General:

Pycnocline intensity increases almost everywhere, T & S work into the same direction

The spatial pattern of pycnocline depth is more variable:
in the NS it is cleary dominated by salinity changes, in the BS both T or S can can dominate depending on the model GCM

Habitat modelling for higher trophic species

Problem: How can changing watermasses influence reproduction of higher trophic species?

Approach:

Using available literature to get salinity, temperature, and oxygen tolerances for the reproduction of key species

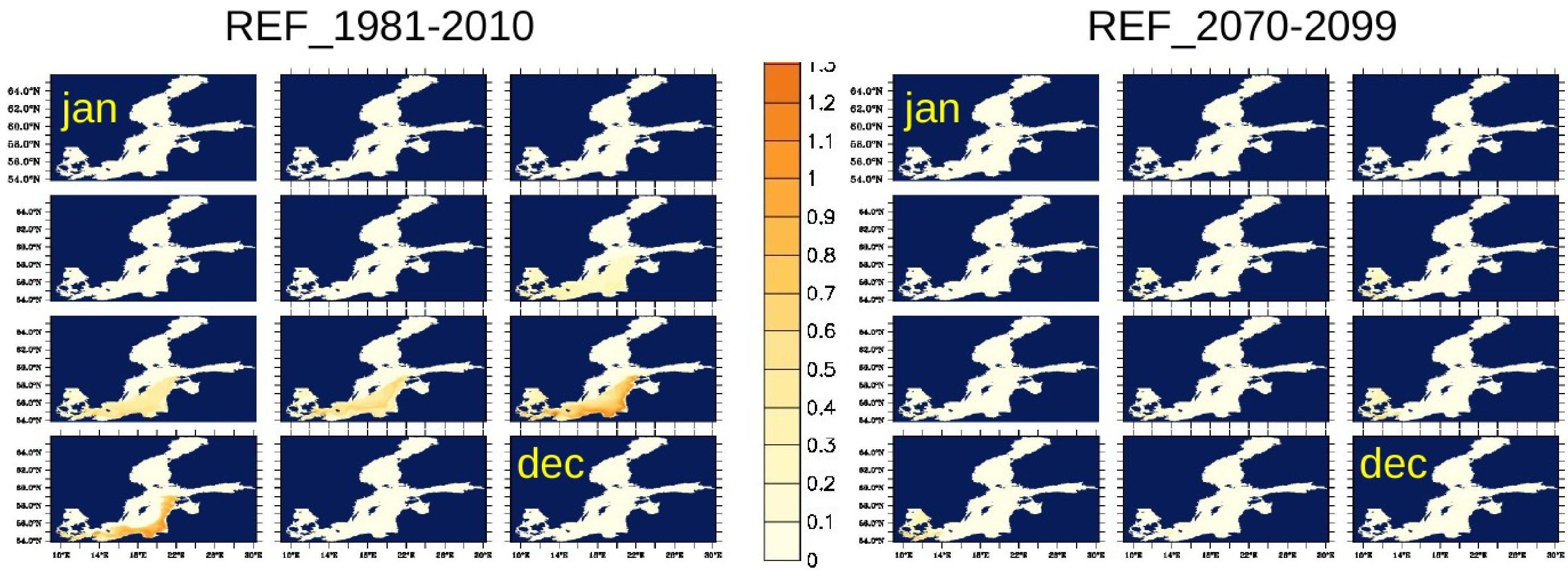
Using another hydrodynamic-biogeochemistry model developed for the Baltic Sea RCO-SCOBI

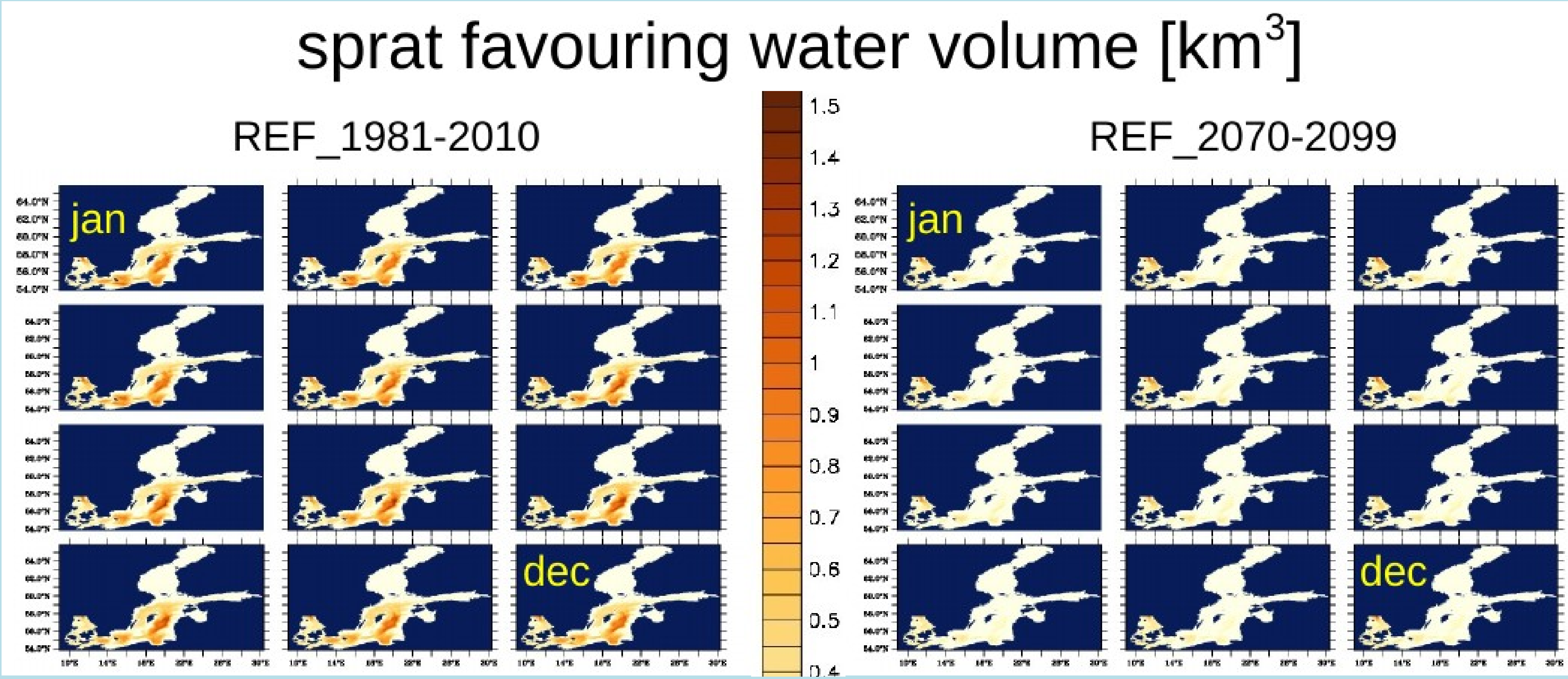
Using downscaled mean climate from 3x A1B (moderate scenario) 1xA2
2 global models HadCM3 and ECHAM

HadCM3_A1B
ECHAM5_A1B3
ECHAM5_A1B1
ECHAM5_A2

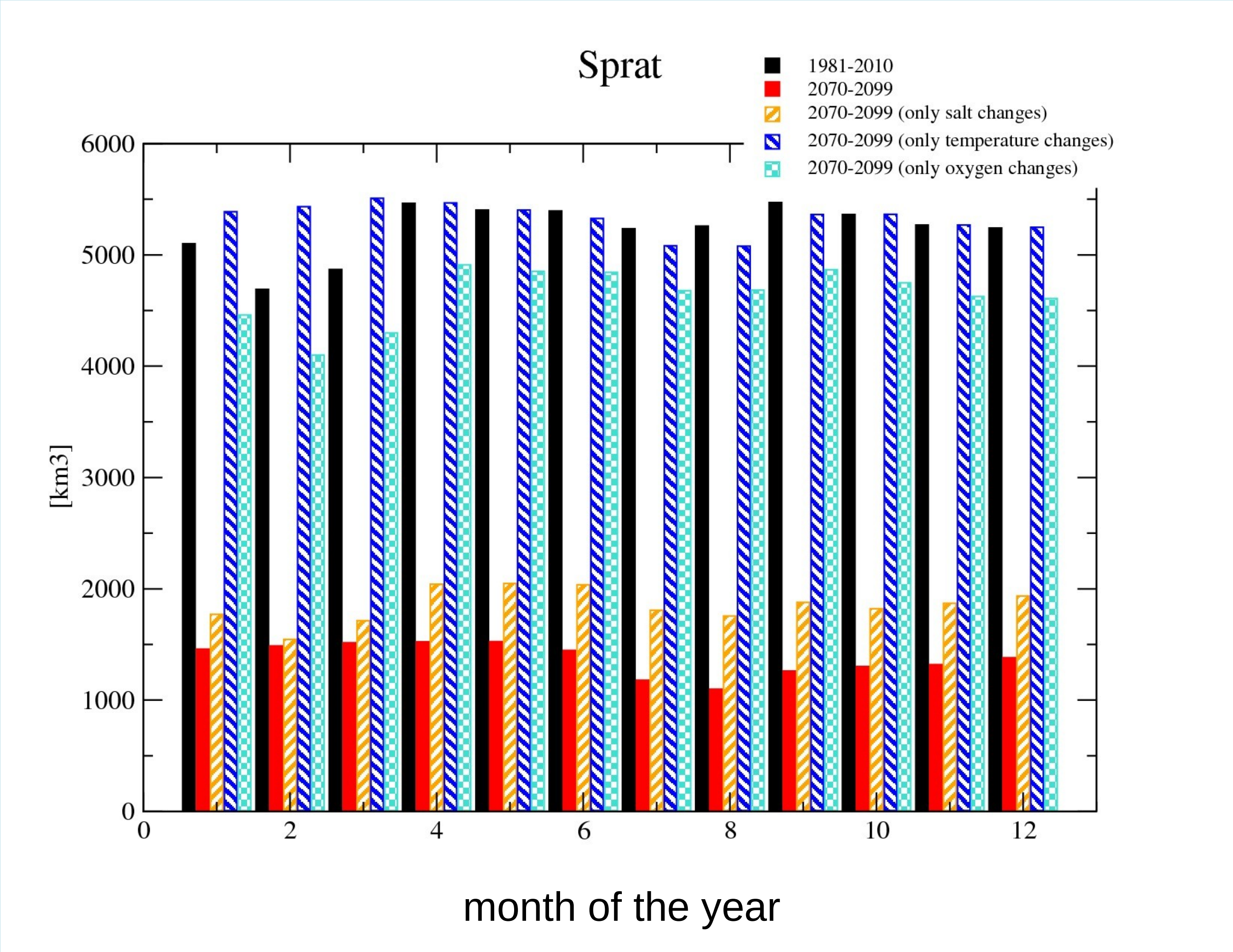
Calculate water volumes favorable for 18 species in total including different trophic levels as well as benthic and pelagic species

turbot favouring water volume [km^3]

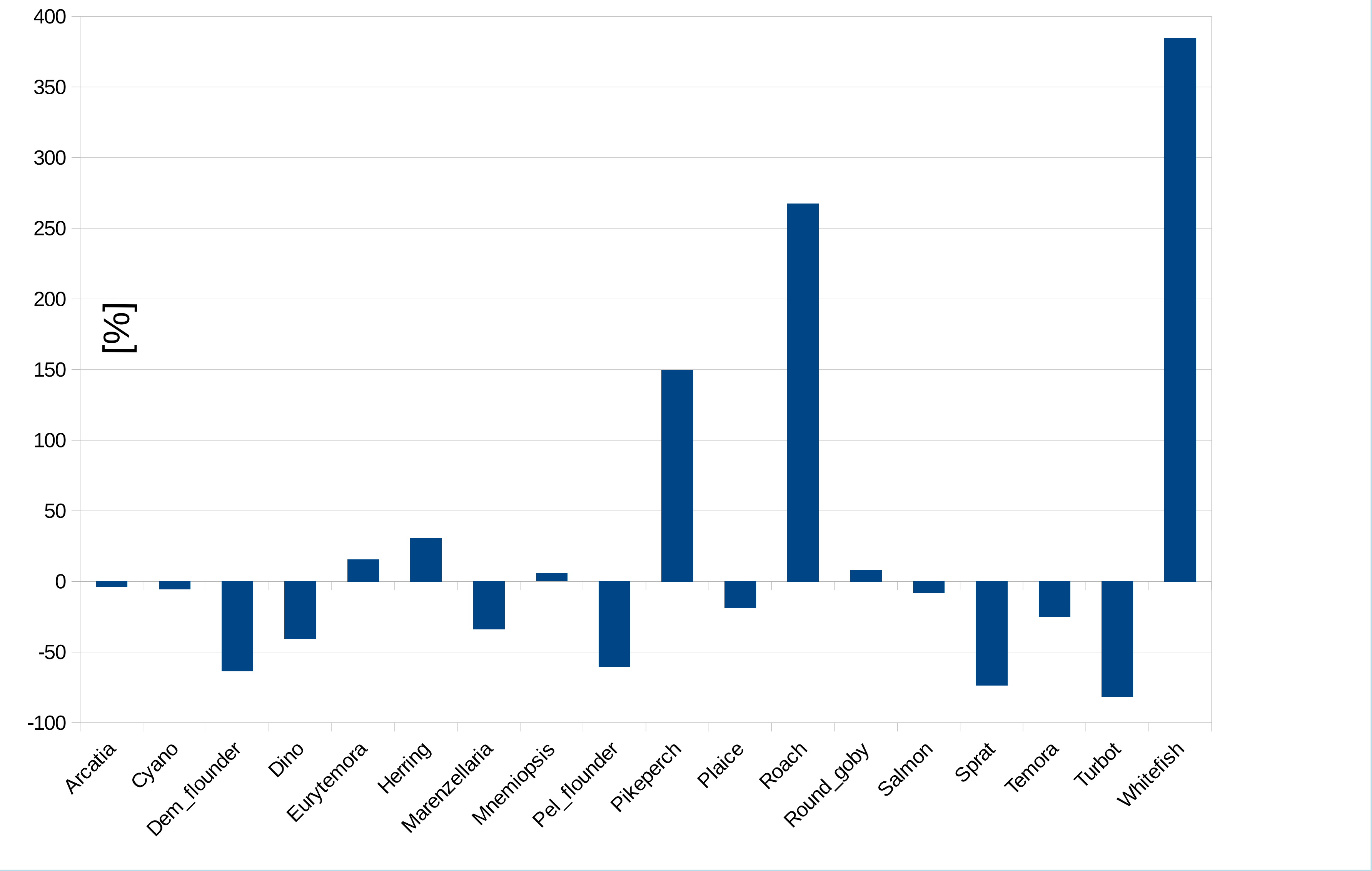



sprat favouring water volume [km3]
REF_1981-2010
REF_2070-2099
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
jan
dec
jan
dec

Changes in integrated habitat size favorable for Sprat



Change in yearly integrated favorable habitat volume for different species)



Preliminary Conclusions

- 5 out of 18 analyze species will likely benefit from climate change

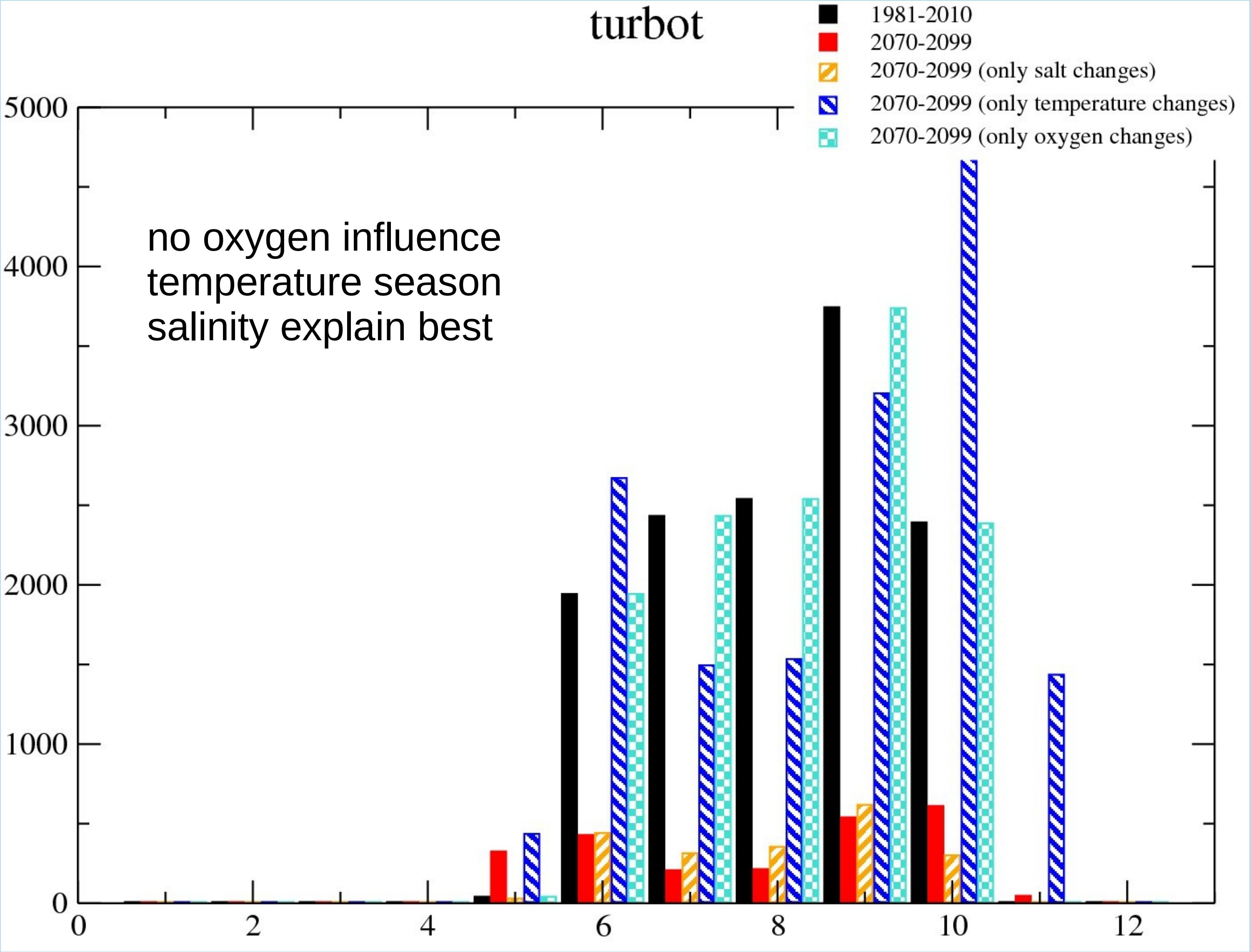
- 8 out of 18 analyze species will likely find worse conditions for reproduction

- 5 species will experience problaby only minor changes

The European Sprat suffer primarily from changes in salinity. Moderate changes from descrising oxygen concentrations are notable during the cold season. The changes in temperature have only ninor effects.

Turbot is nearly uneffected by oxgen changes (BAU???). Changes in salinity explain the most of the chnge in habitat size. Changes in temperature are charactized by positve effects due to a prolongation of the favorable (warm) season.

Changes in integrated habitat size favorable for Turbot



Some speculations about biodiversity in the Baltic Sea

Modified version of the Remane curve (Remane, 1934) showing species richness relative to the salinity ranges defined by the Venice system (Venice System, 1958). Diagonal hatching: freshwater species; vertical hatching: brackish water species; white: marine species.