Modelling carbonate chemistry and future OA impacts in regional seas

ROAM

Regional Ecosystem & Biogeochemical Impacts of Ocean Acidification – a Modelling Study.

3rd Annual Science Meeting, St. Andrews, 22-24th July 2013

PML PLYMOUTH MARINE LABORATORY

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office Hadley Centre

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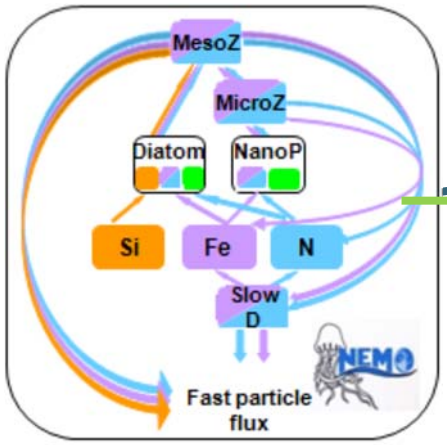
Arctic regional ¼° Global

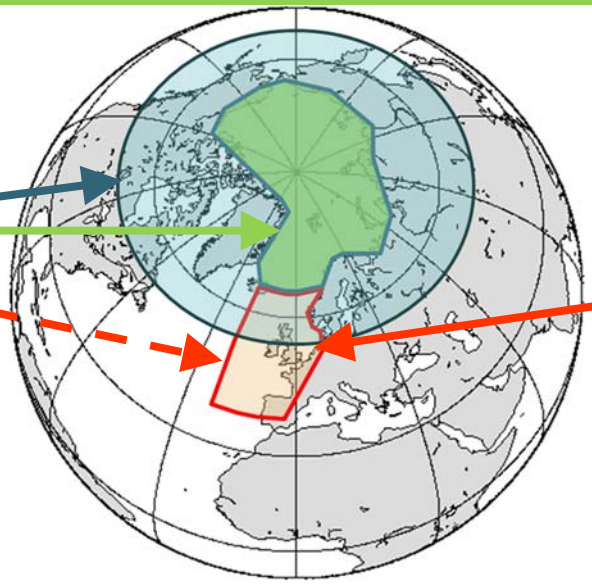
3 Model Systems

NW European Shelf 7km shelf

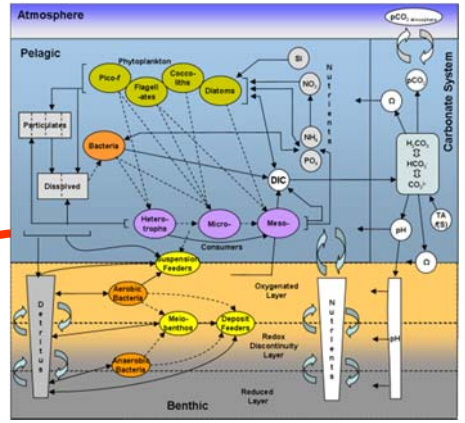
Arctic high res shelf (7-3.5km)

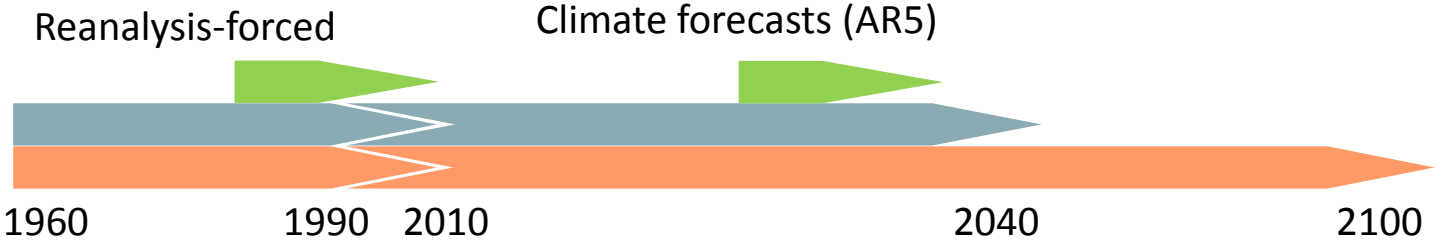
Medusa





ERSEM





Climate forcing from the AR5 simulations. Three emissions scenarios will be considered; relating to changes in radiative forcing of 2.6, 4.5 and 8.5 W/m2 by 2100.

Key science questions:

1. How will forecast CO_2 emission scenarios impact on the spatial and seasonal patterns of carbonate chemistry (pH, etc.) and other key niche defining parameters (T, O_2) via the processes of ocean acidification, climate moderated hydrodynamics, modified fluvial inputs and biological feedbacks.

2. How will the modified physical controls, biological moderators and atmospheric & terrestrial drivers combine to impact carbon pumping and ocean – shelf coupling from a perspective of both regional carbon cycling and impacts on earth system cycles.

3. How will predicted changes in processes that control, for example, carbon-nutrient stoichiometry, calcification and the microbial – classical food web dynamic impact on the functionality and productivity of the target ecosystems.

Ecosystem impacts consensus remains elusive:

Fewer ecosystem impacts in the main production runs

Calcification
Nitrification inhibition
C fixation (ERSEM only)

Address this with focussed sensitivity studies

Air – sea flux parameterisations
C fixation, increased rate or better efficiency?
Export / TEP production,
Bioturbation / bioirrigation rates
Nitrification , impact of inc NH_4^+, less NO_3
Nitrogen fixation enhanced
C:N stoichiometry and grazing
DMS-DMSP production
:

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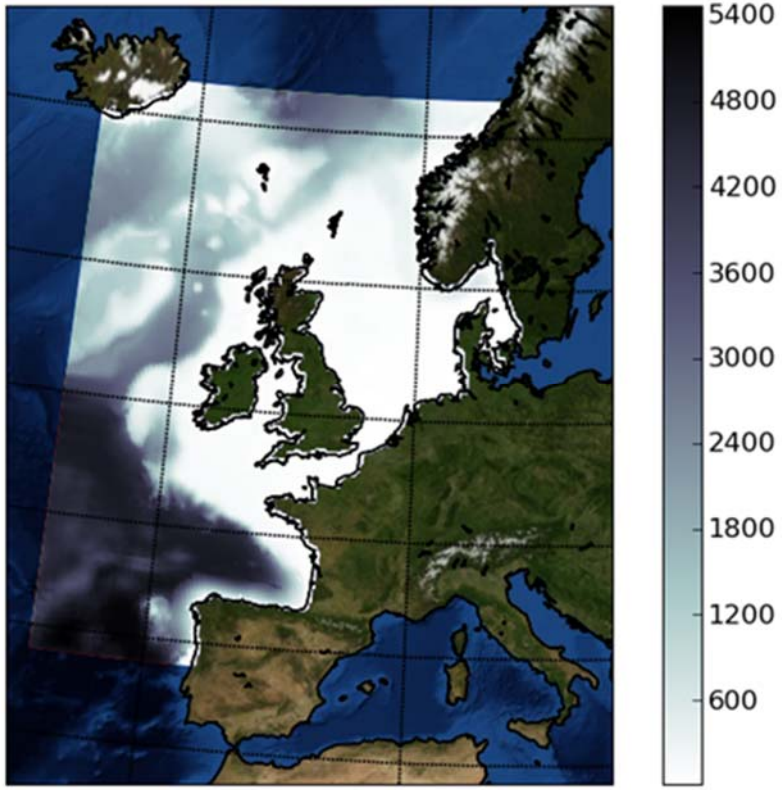
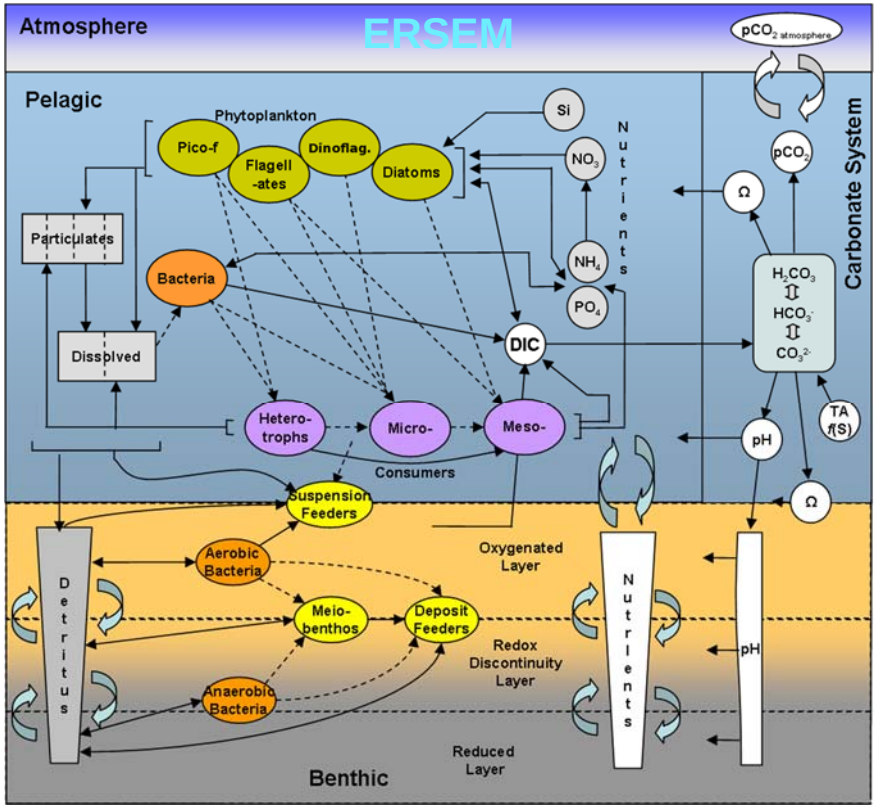
Listen to the ocean

The North Western European shelf

Y. Artioli, M. Butenschön, S. Wakelin, J. Holt, J. Blackford

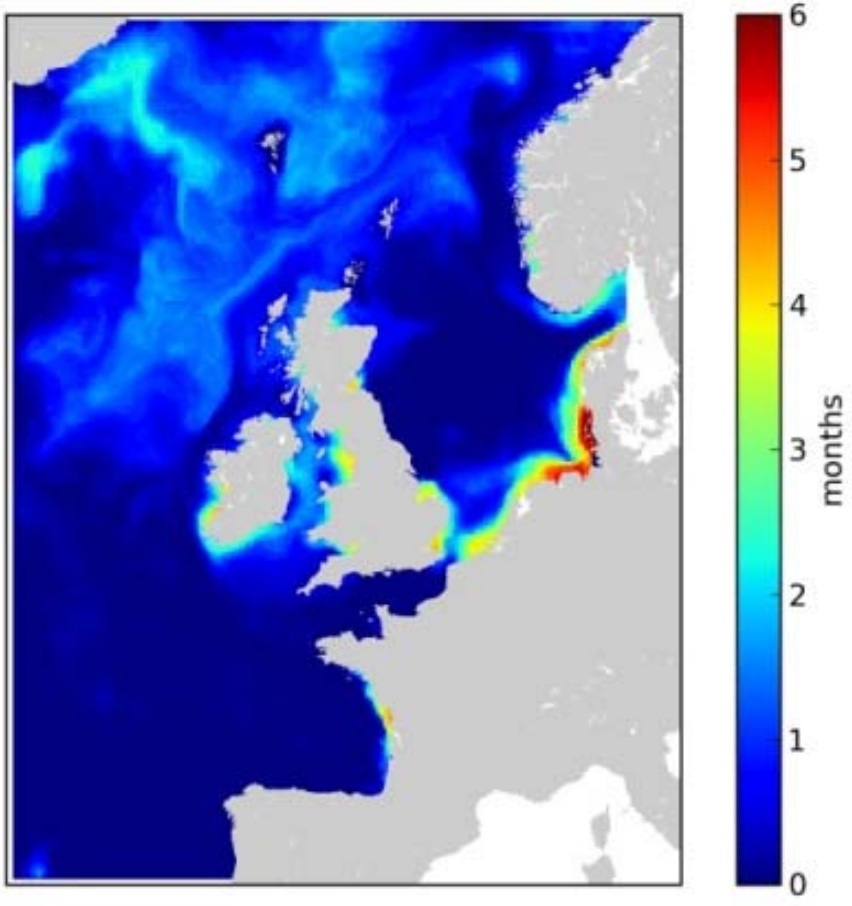
NWES model set-up

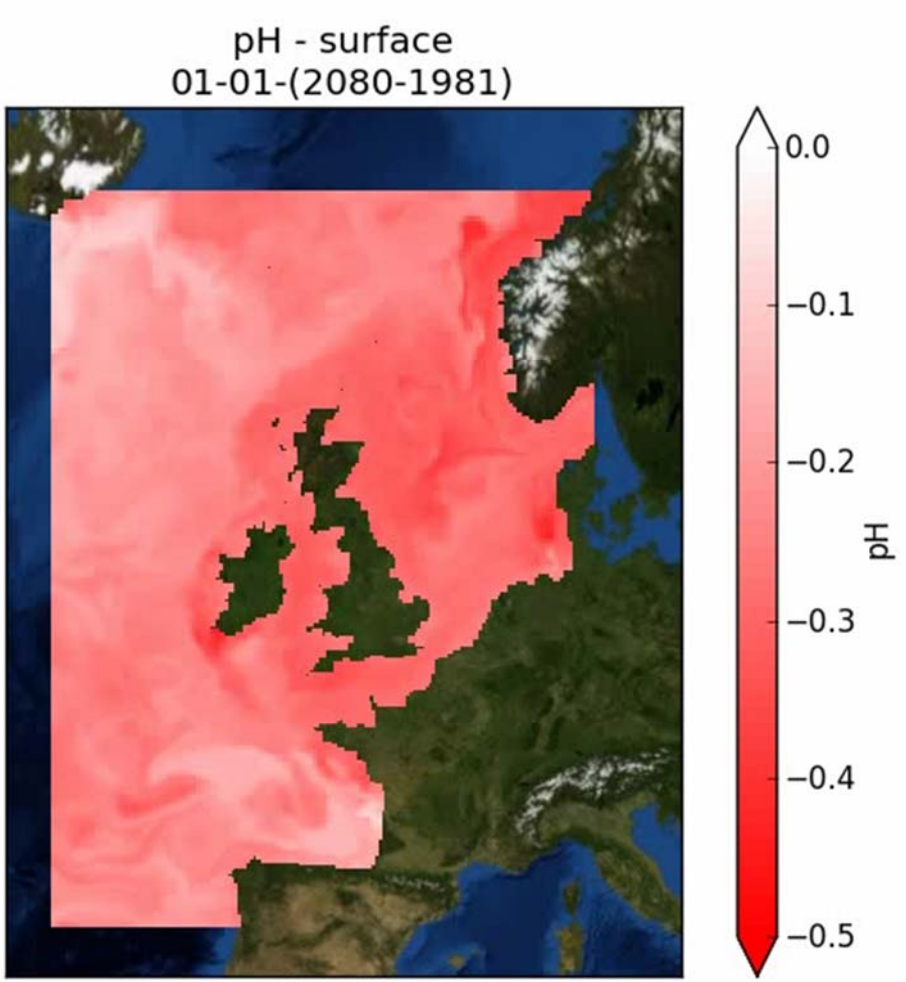




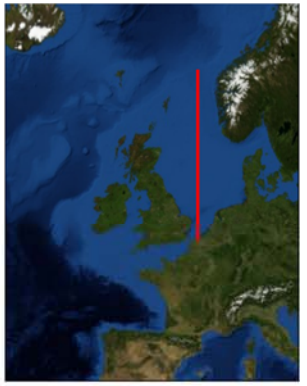
OA impact: Carbonate system

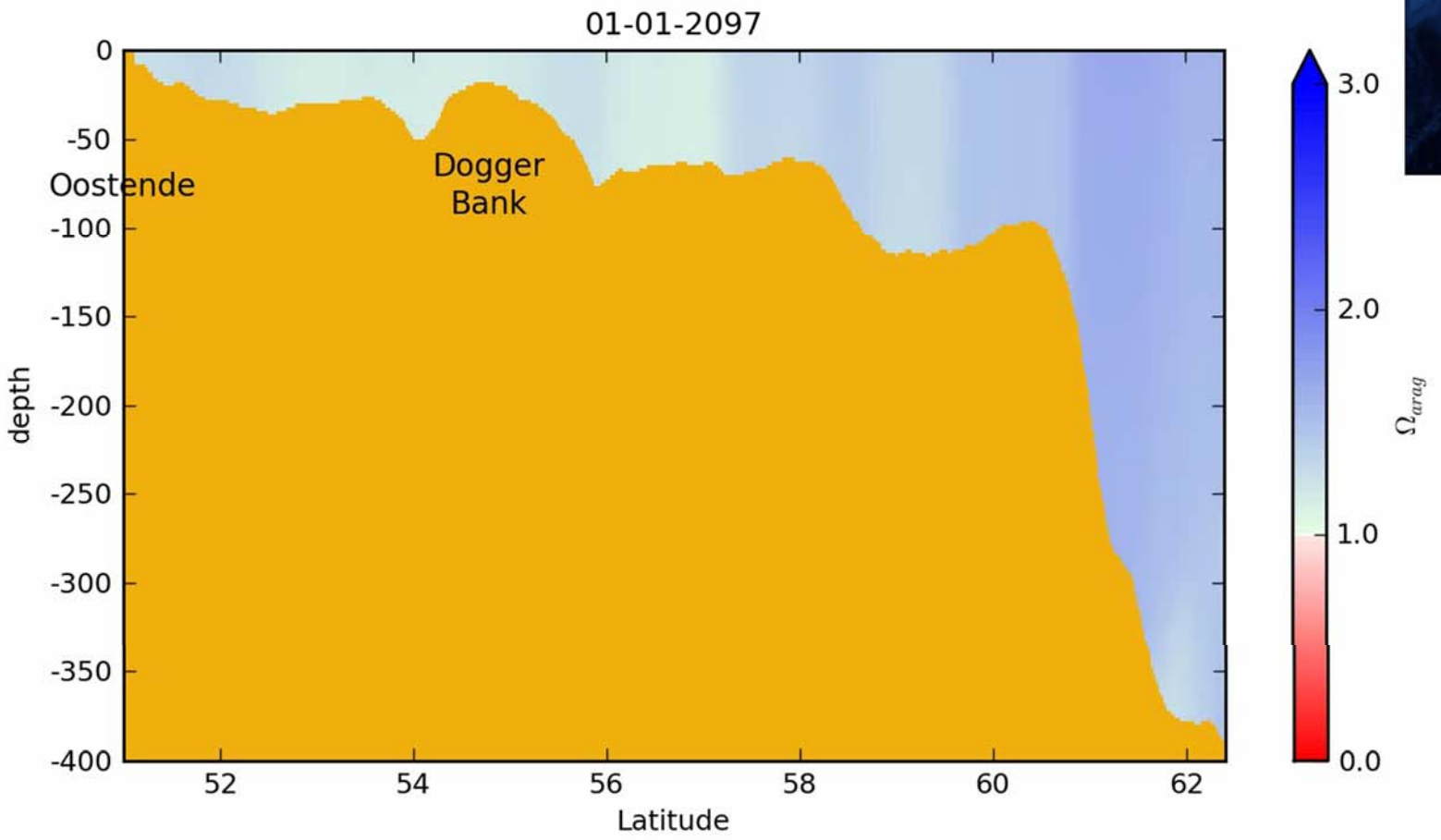
$pH_{surf,overlap}$





OA impact: Carbonate system

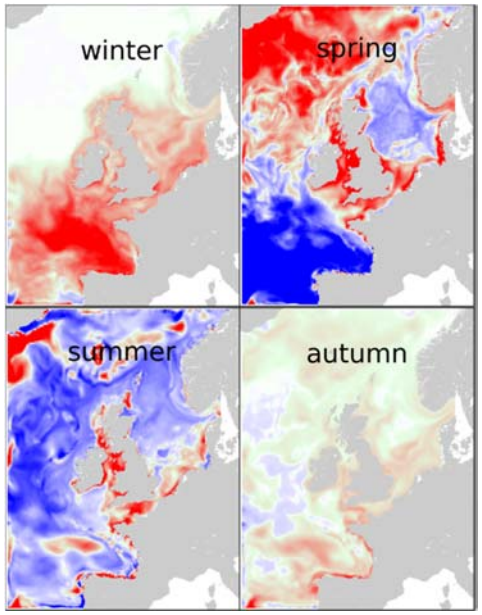




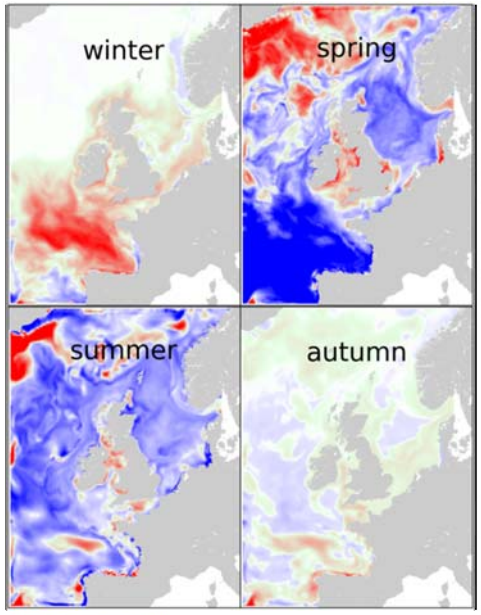
OA impact: netPP difference with present day

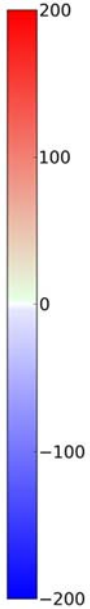
$$\text{OA impact on PP} \begin{cases} C_{enh} = 0.0005 \cdot \left(pCO_{2,a} - pCO_{2,a}\big|_{2005} \right) \\ gPP_{enh} = gPP \cdot \left(1 + C_{enh}\right) \\ act.resp._{enh} = asct.resp. \cdot \left(1 + C_{enh}\right) \end{cases}$$

with OA feedback

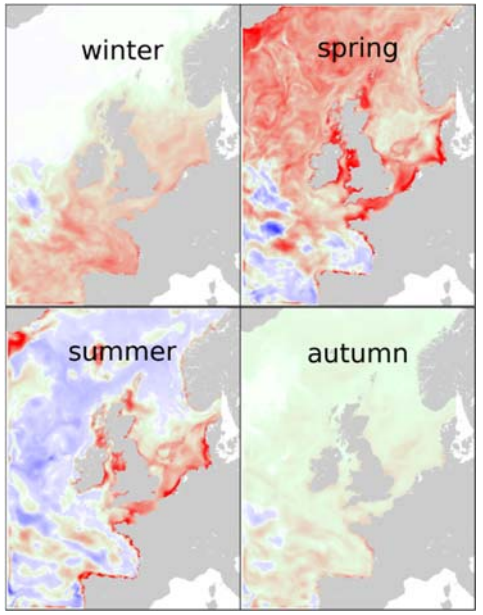


without feedbacks





only OA feedback



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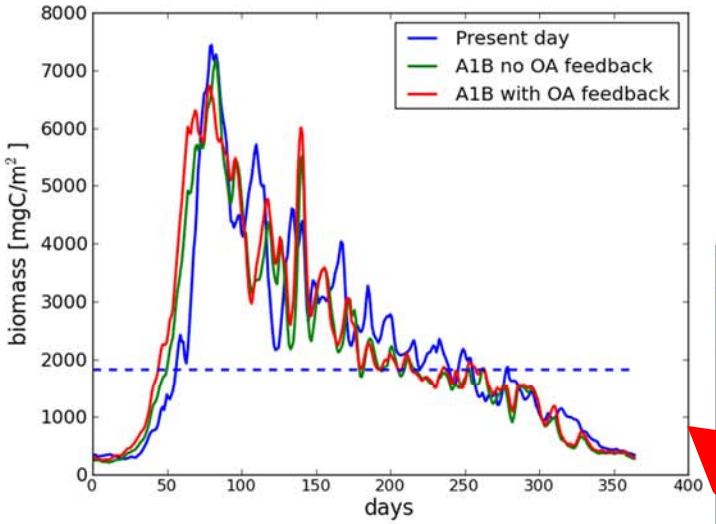
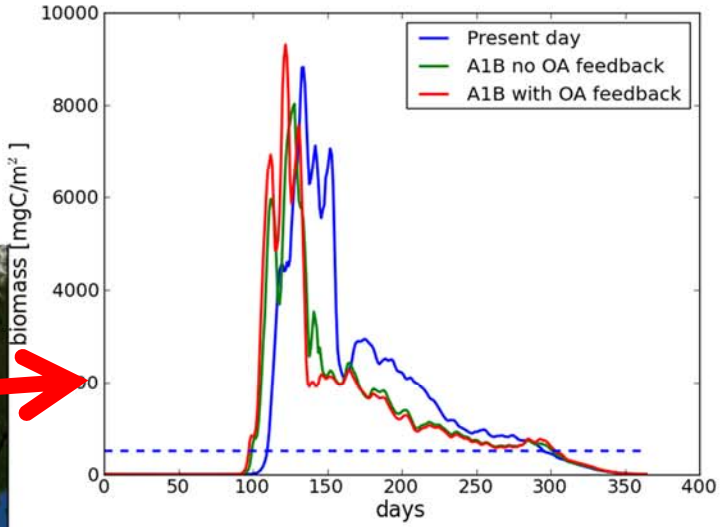
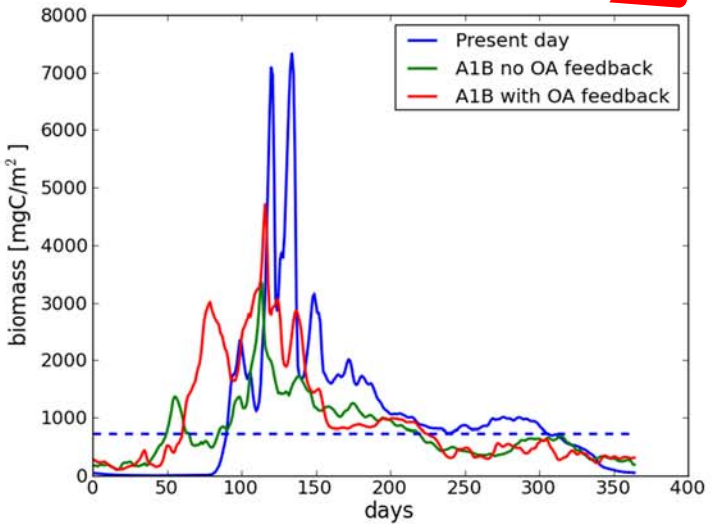
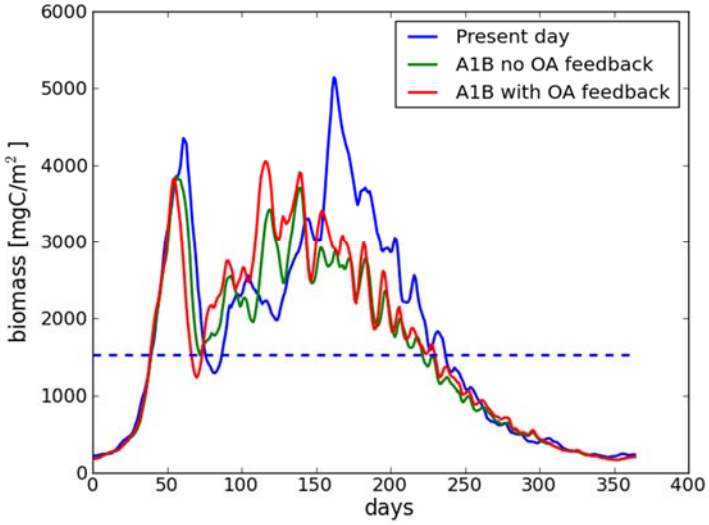
Phytoplankton phenology







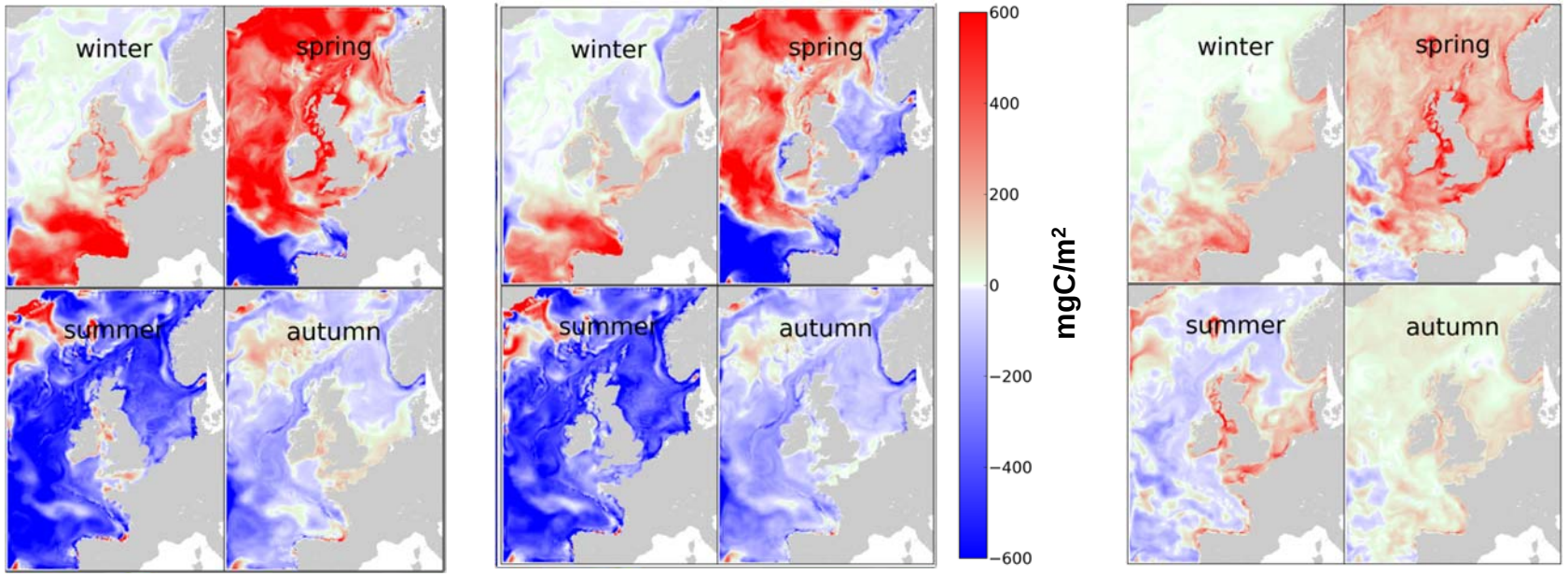


OA impact: Zooplankton biomass

with OA feedback

without feedbacks

only OA feedback



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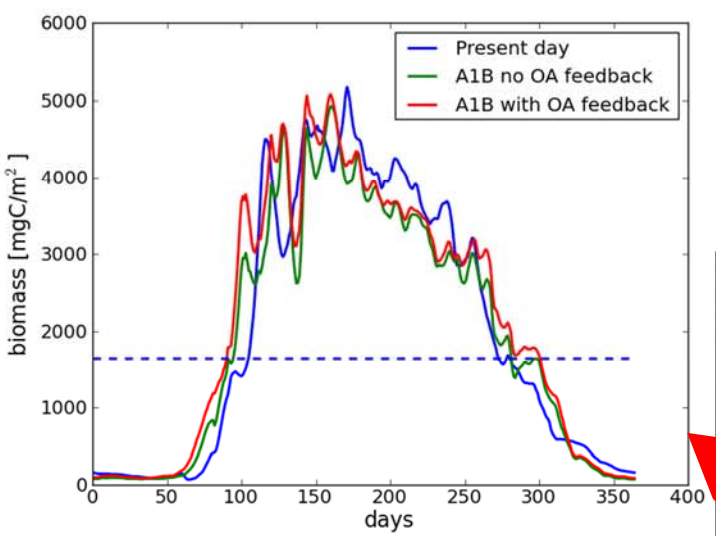
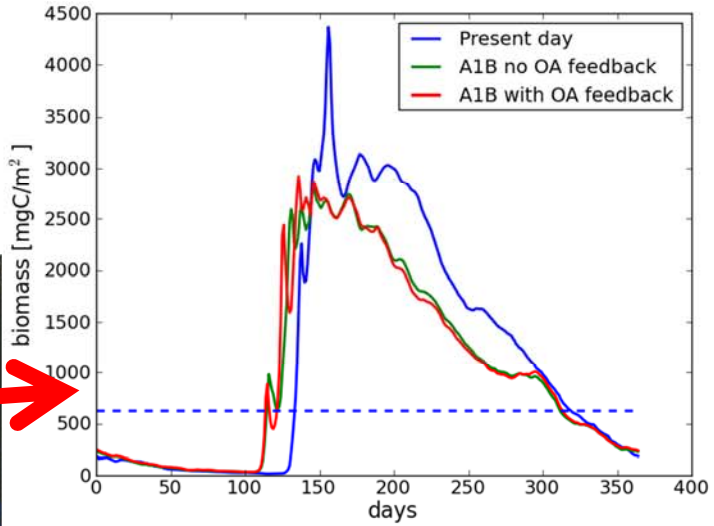
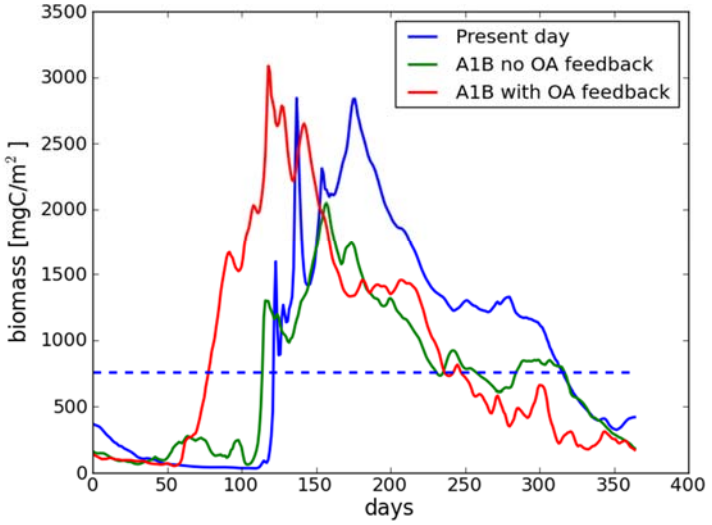
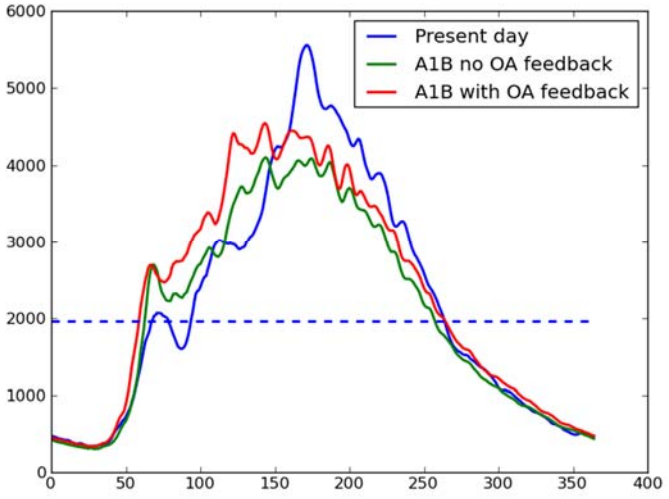
Zooplankton phenology









OA impact: Community composition

		Net primary production				Zooplankton Biomass		
		Diatoms mgC/m2/d	Flagellates mgC/m2/d	Picophytopl. mgC/m2/d	Dinoflagellates mgC/m2/d	Mesozoopl. mgC/m2	Microzoopl. mgC/m2	Heterotr. Nanofl. mgC/m2
Climate change only	winter	10.68	4.03	9.49	0.83	69.45	5.81	-7.71
	spring	-11.6	-1.5	-33.97	-21.4	150.97	-107	-29.36
	summer	0.83	-4.73	-18.47	-19.68	-53.16	-244.2	-43.49
	autumn	2.78	0.85	1.46	-0.07	-8.45	-68.97	-35.25
	annual mean	**0.67**	**-0.33**	**-10.37**	**-10.08**	**39.7025**	**-103.59**	**-28.9525**
With OA feedback	winter	16.44	7.99	22.50	1.96	97.52	30.29	3.62
	spring	-4.85	5.92	-2.81	-11.11	209.01	-28.20	-12.85
	summer	3.44	-5.11	-11.67	-17.27	-47.92	-239.96	-45.41
	autumn	4.26	2.55	7.82	1.86	10.89	-55.56	-30.64
	annual mean	**4.82**	**2.84**	**3.96**	**-6.14**	**67.38**	**-73.36**	**-21.32**
Only OA (OA-CC)	winter	5.77	3.95	13.01	1.12	28.06	24.48	11.33
	spring	6.75	7.42	31.16	10.29	58.04	78.8	16.51
	summer	2.62	-0.39	6.8	2.41	5.25	4.24	-1.92
	autumn	1.48	1.69	6.36	1.93	25.34	13.41	4.61
	annual mean	**4.15**	**3.16**	**14.33**	**3.93**	**29.1725**	**30.2325**	**7.6325**

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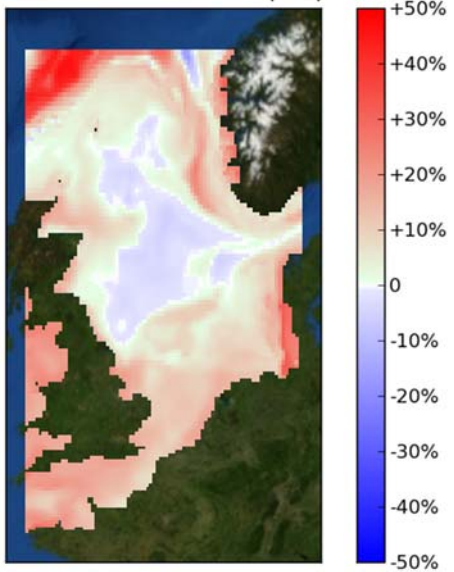
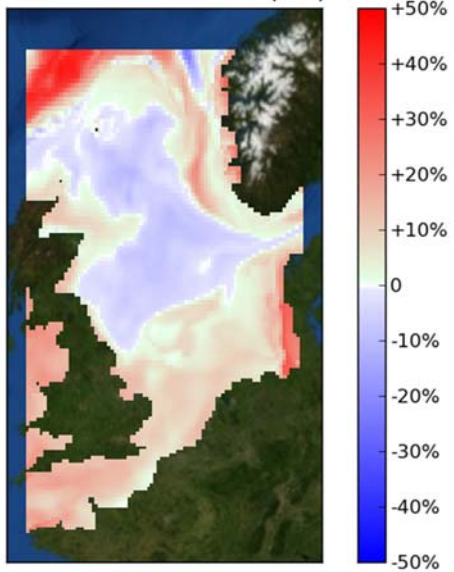
Impact on benthic system

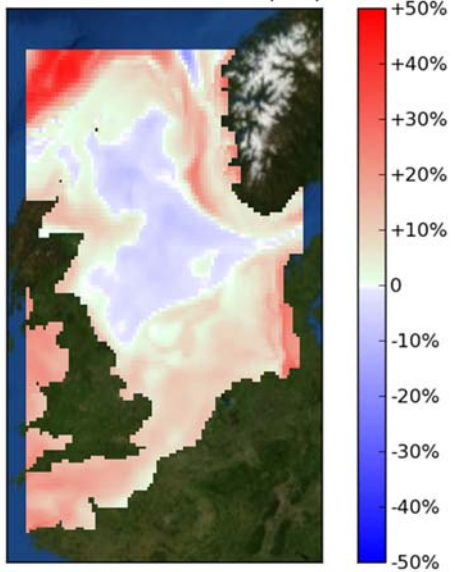
A1Benh-PD
C flux to benthos mmolC/m^2 /d



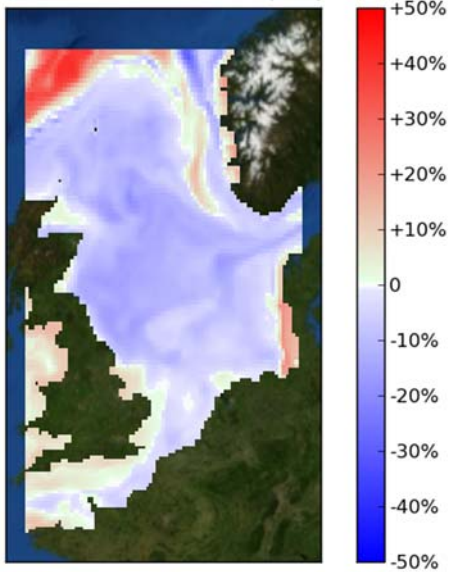
A1Benh-PD
N flux to benthos mmolN/m^2 /d



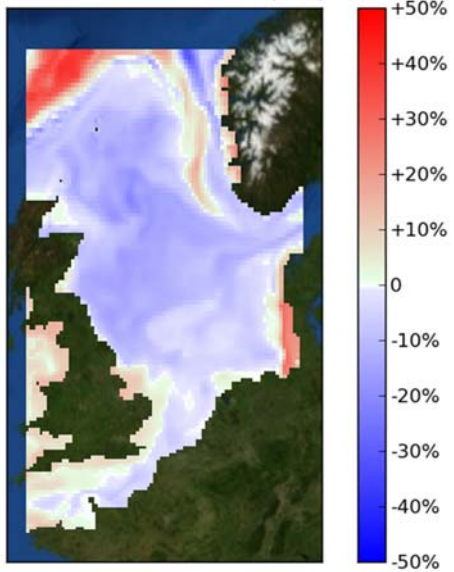
A1Benh-PD
P flux to benthos mmolP/m^2 /d



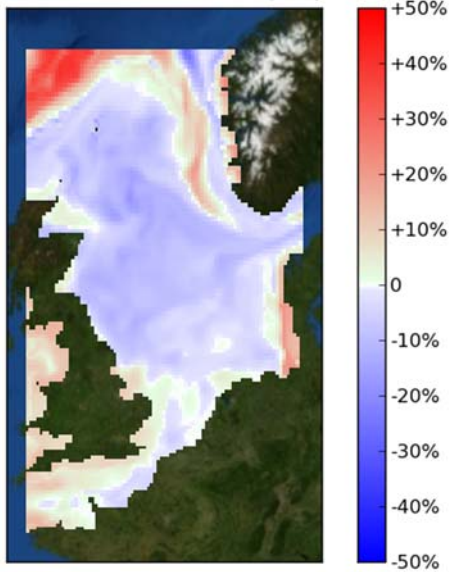
A1B-PD
C flux to benthos mmolC/m^2 /d



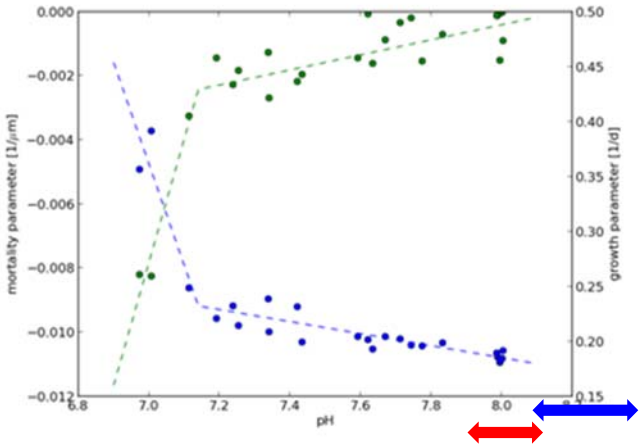
A1B-PD
N flux to benthos mmolN/m^2 /d

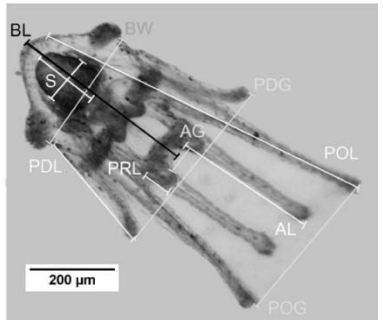


A1B-PD
P flux to benthos mmolP/m^2 /d



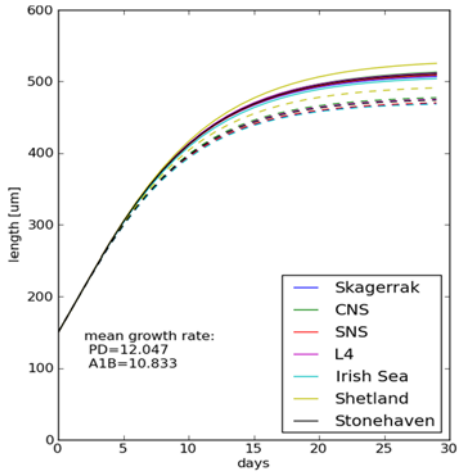
OA impact: sea-urchin larvae



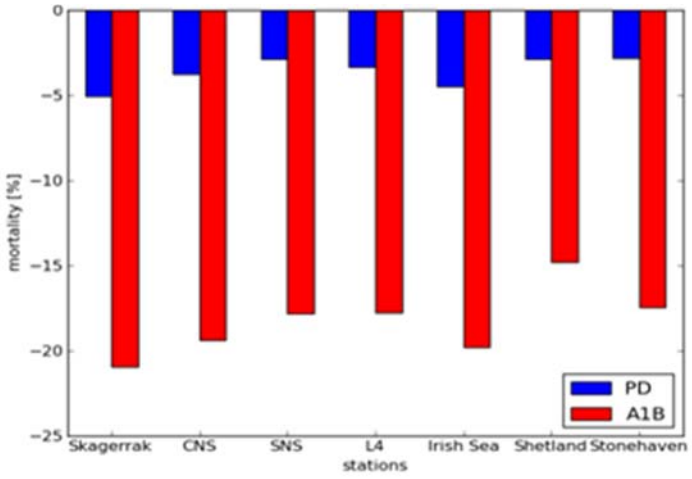


N. Dorey et al., GCB, 2013

growth



Mortality before pluteus stage



In collaboration with S. Dupont and N. Dorey

Take-home messages

- High temporal and spatial variability of the impact ➔
  ➔ windows of opportunity and hotspot ➔
  biodiversity (MSFD d.1)
- OA can hinder/exacerbate climate change signal on netPP
  ➔ CLIMATE REGULATION SERVICE
- OA impacts on PP are transferred to higher trophic level ➔
  ➔ commercial species (MSFD d. 2) and trophic web (MSFD d. 4)
- OA potentially alters phenology & community structures ➔
  ➔ trophic web (MSFD d4)