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Future Change in ocean productivity

Is the Arctic the new Atlantic?

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NERC SCIENCE OF THE ENVIRONMENT

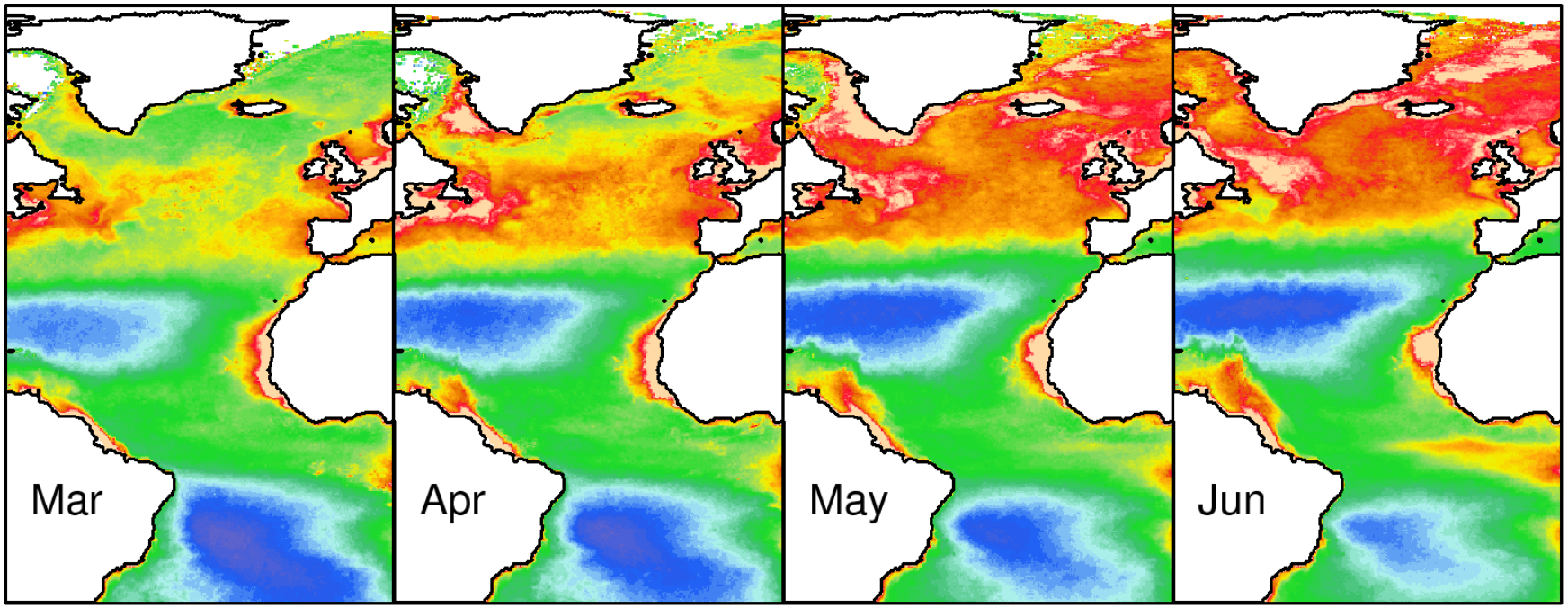
Overview

- Background
- Model overview
- (Cursory) Model validation
- 21st century change
- The “new Atlantic”?
- Conclusions

Background

- Seasonal phytoplankton blooms play a key role in ocean biogeochemical cycles
- Blooms strongest and most coherent in the North Atlantic with seasonal poleward tracking
- Arctic blooms currently restricted by sea-ice
- Seasonally ice-free Arctic widely forecast for 21st century
- Will the future-Arctic become like the present-Atlantic with sea-ice decline?

Observed surface chlorophyll

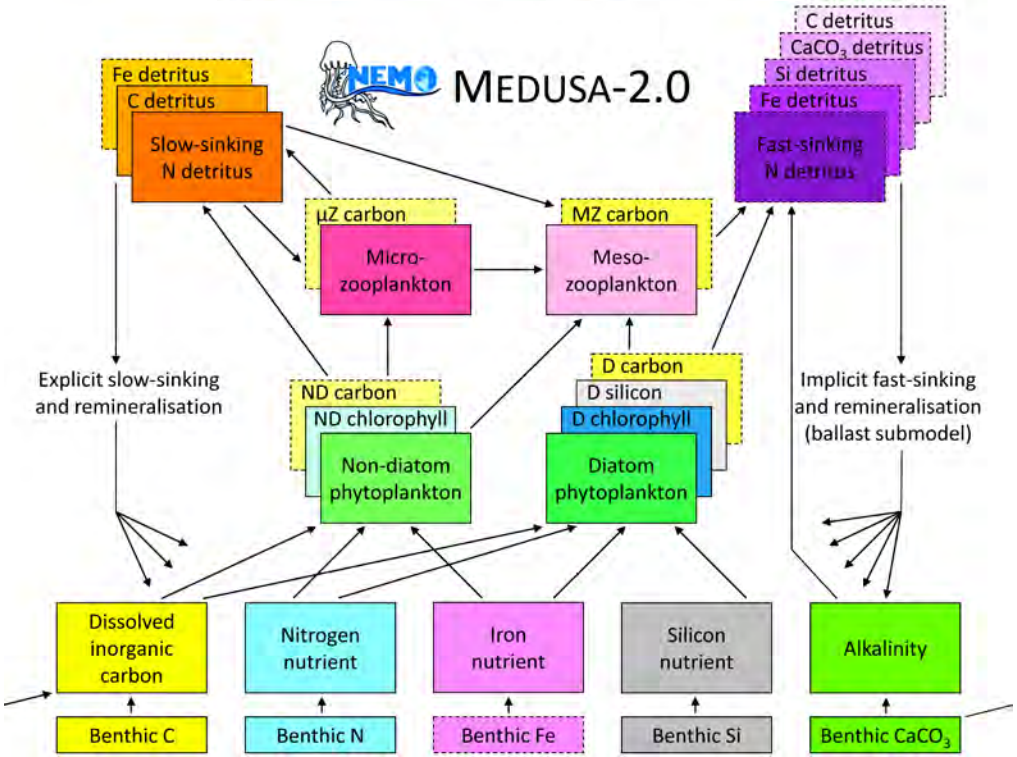


ESA CCI

CMIP5 insights

- CMIP5 models agree on present Arctic productivity, and broadly agree on increased future productivity
- But there is variability, largely driven by the nutrient status of the Arctic and masked at present by light limitation caused by sea-ice
- Sea-ice loss allows these differences to emerge
- But CMIP5 models are typically “low” resolution (~1°), so circulation detail, etc., limited

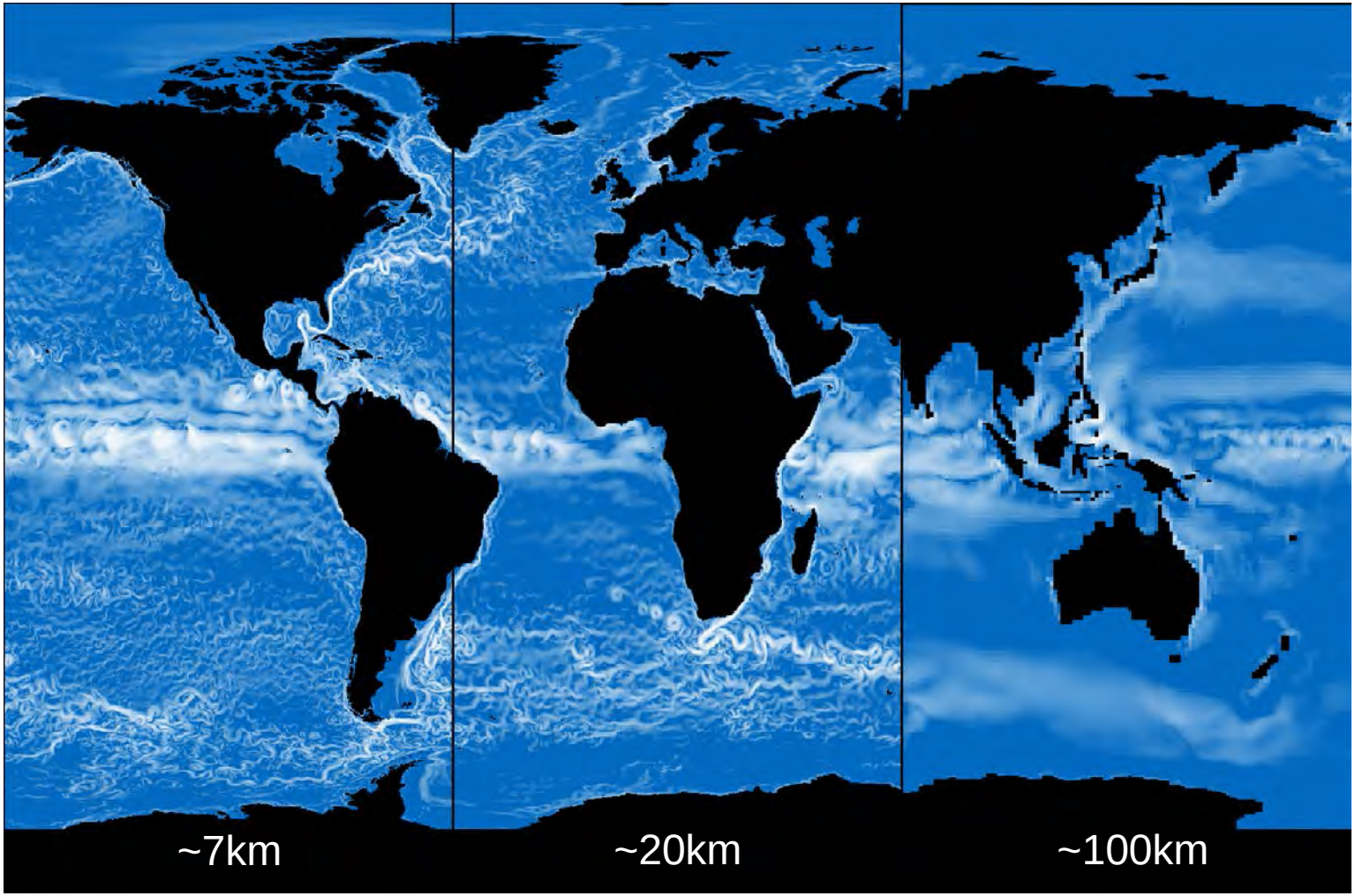
NEMO-MEDUSA



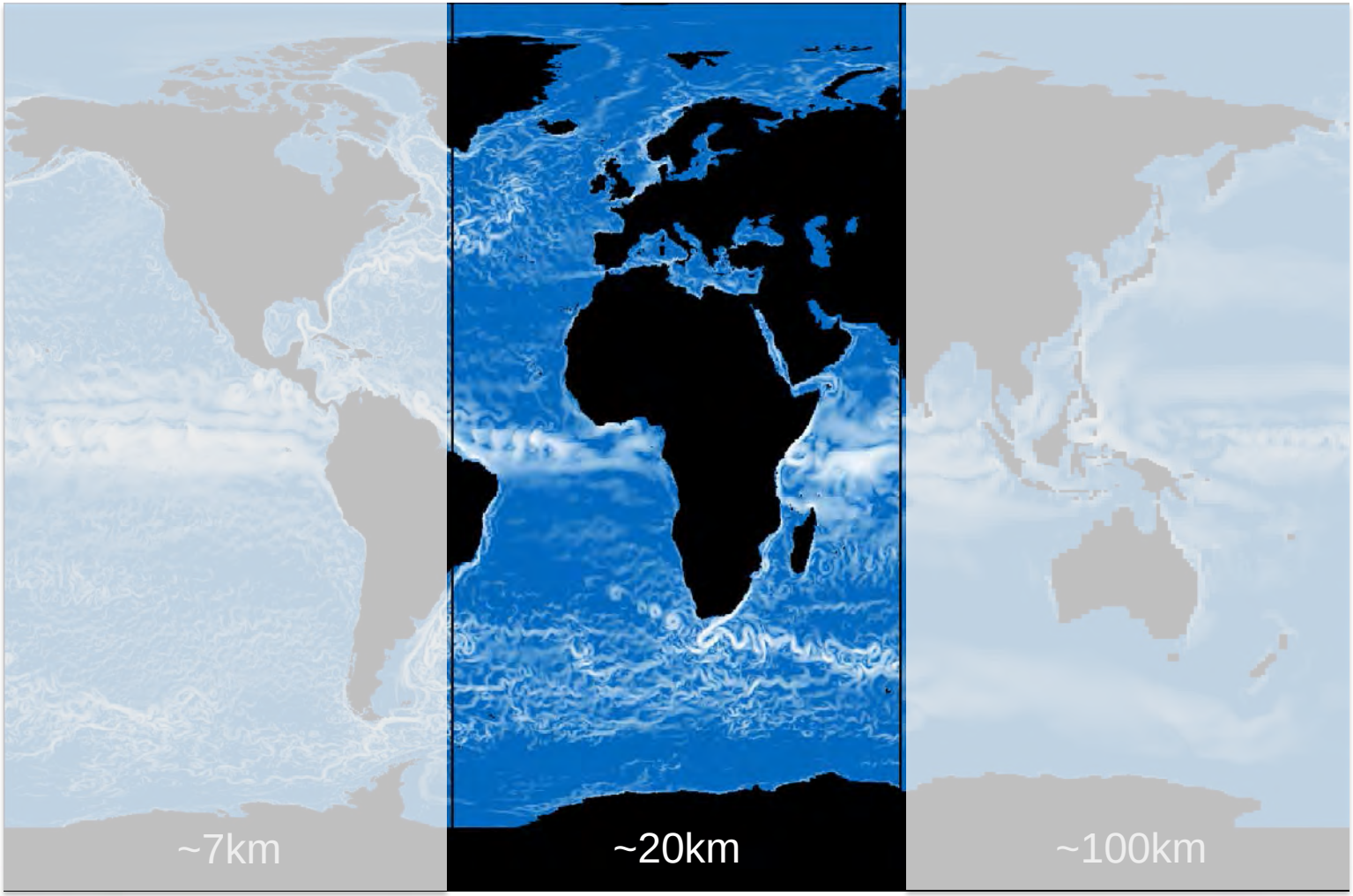
- **NEMO** ocean GCM
- **¼-degree** resolution
- Forced with coupled model output

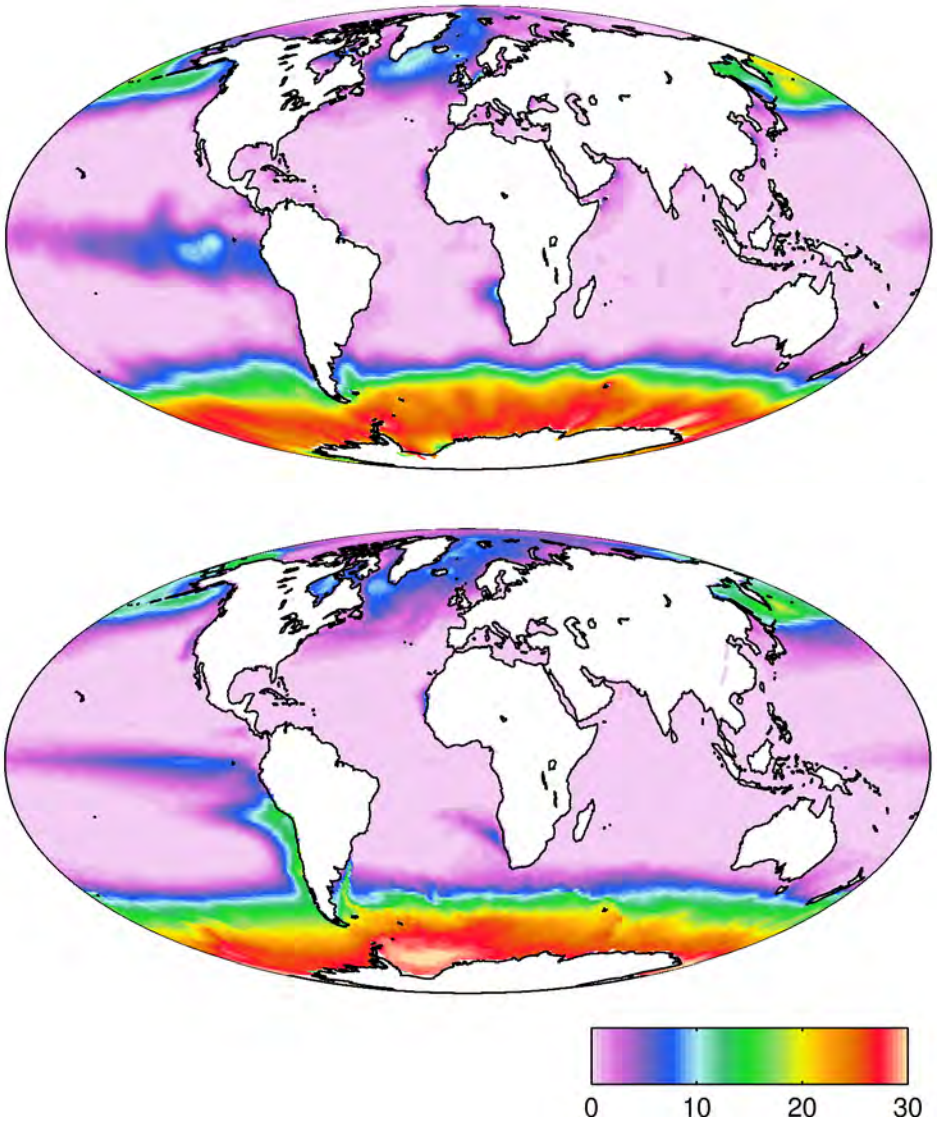
- **MEDUSA** ocean biogeochemistry
- N, Si, Fe, C, O_2
- Intermediate complexity

The importance of resolution



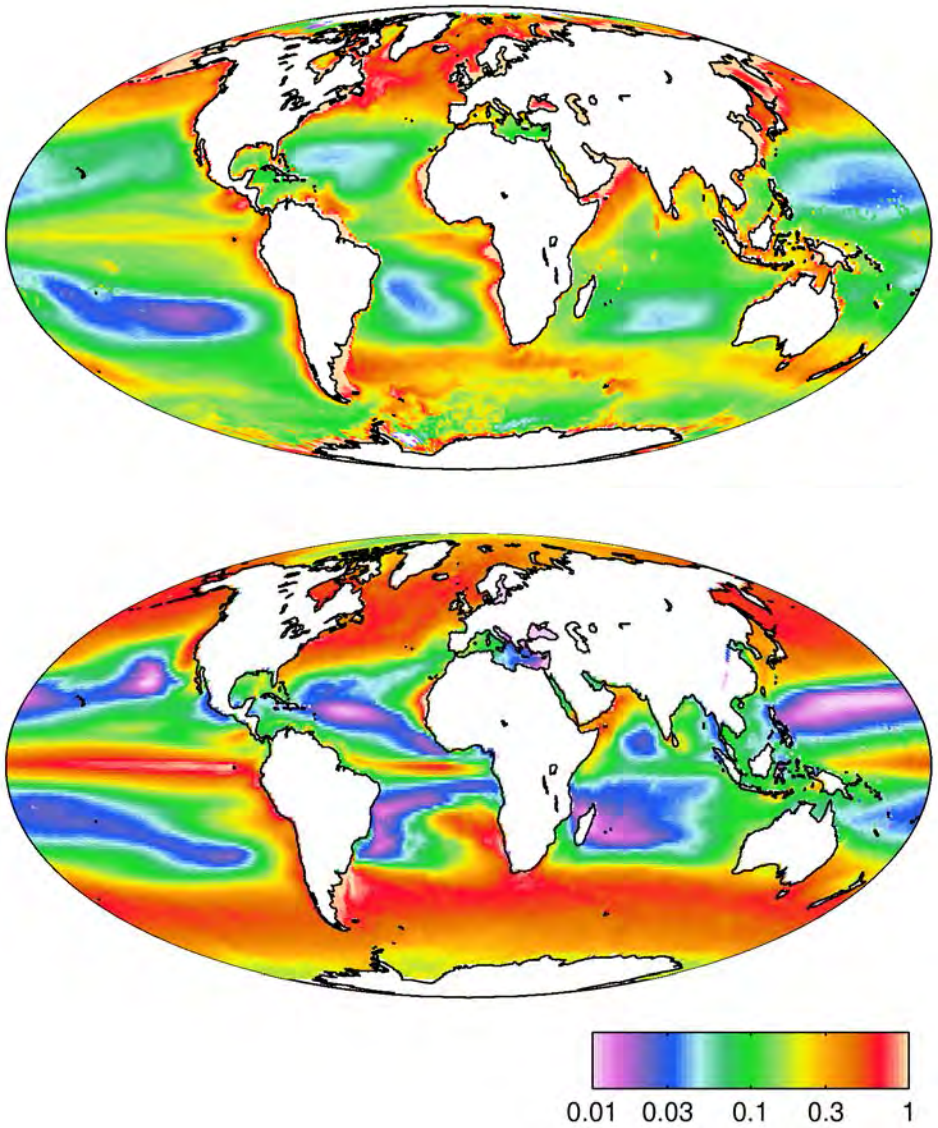
The importance of resolution





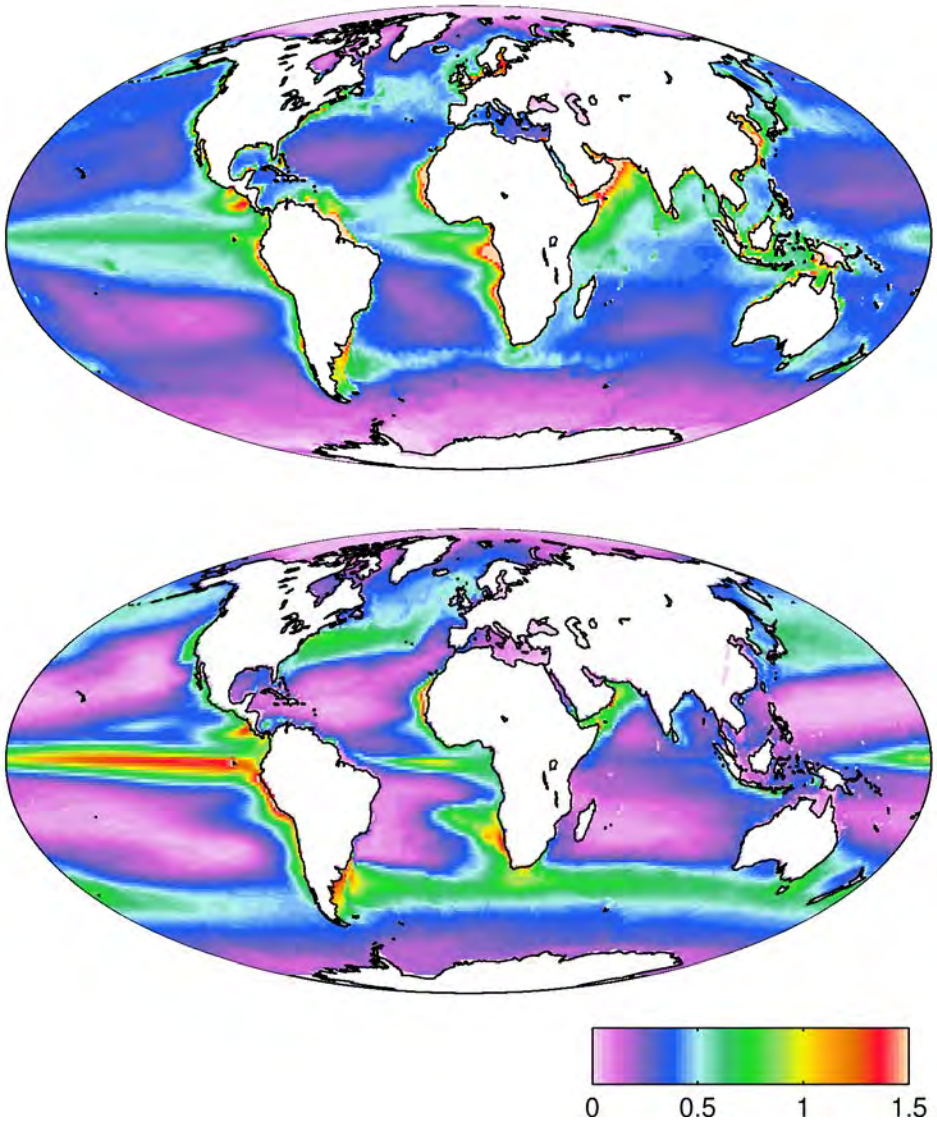
DIN

- Concentrations are broadly in line with climatology
- Excessive in the Peruvian upwelling
- Slightly too low in the northern Atlantic and Pacific basins



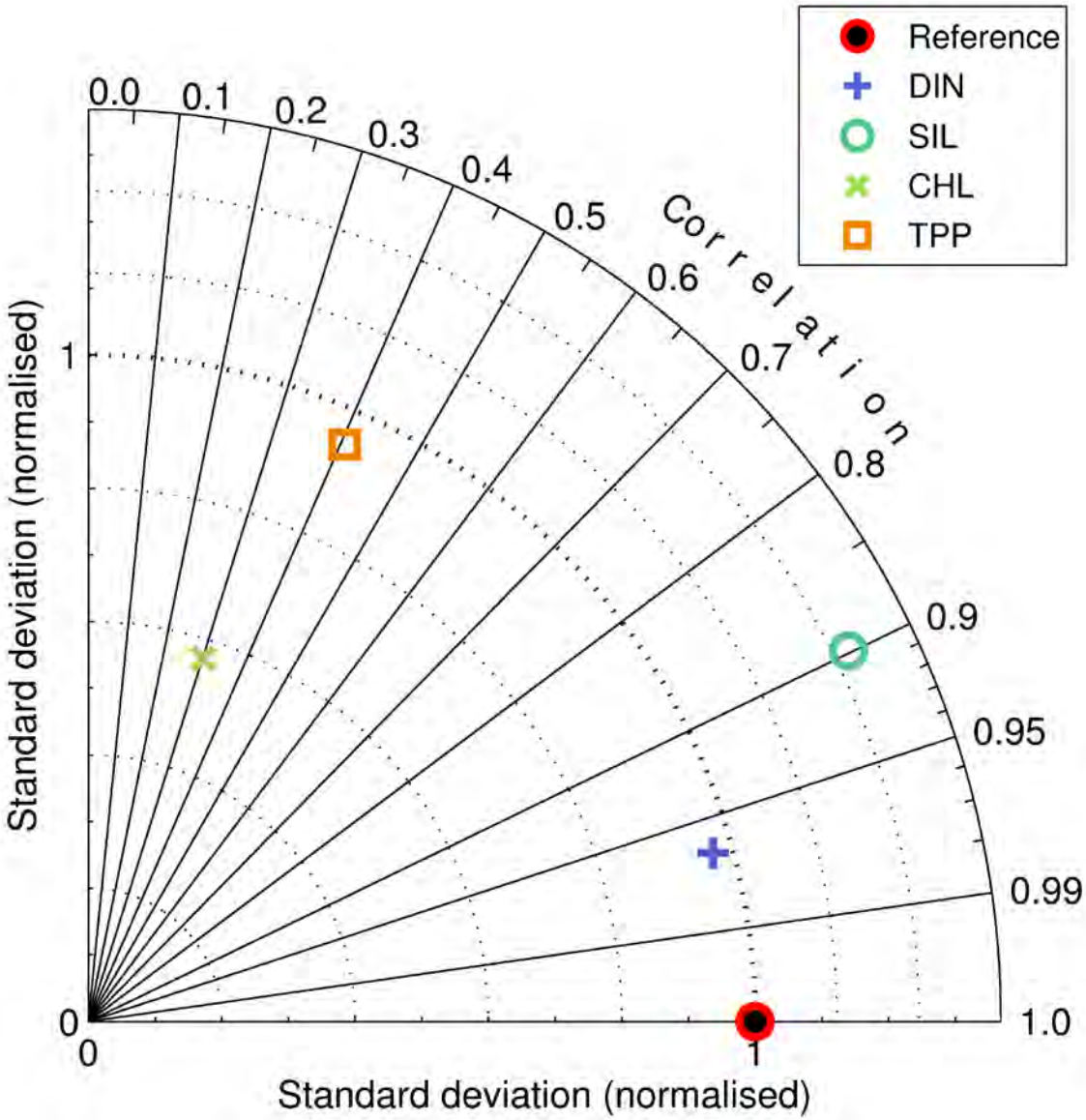
Chlorophyll

- Model typically underestimates low gyre values
- Markedly over-estimated in the Southern Ocean (but data aren't good here either)
- Looks worse than it is!



TPP

- Productivity patterns agree much better than chlorophyll
- Still too low in gyres and too high in Southern Ocean
- Production pattern in Indian Ocean also wide of the mark



Nutrients: **good**

Productivity: **meh**

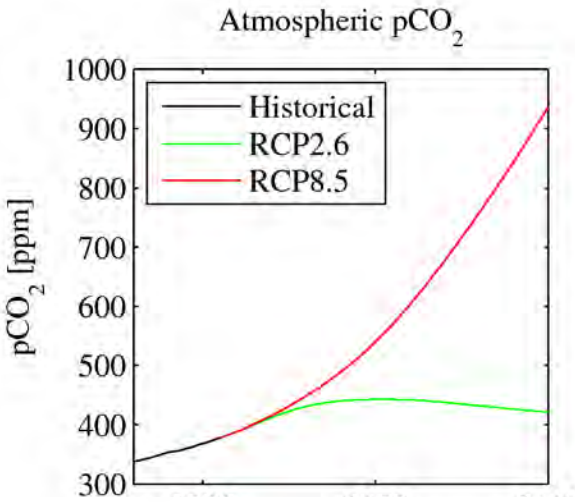
Chlorophyll: **weak**

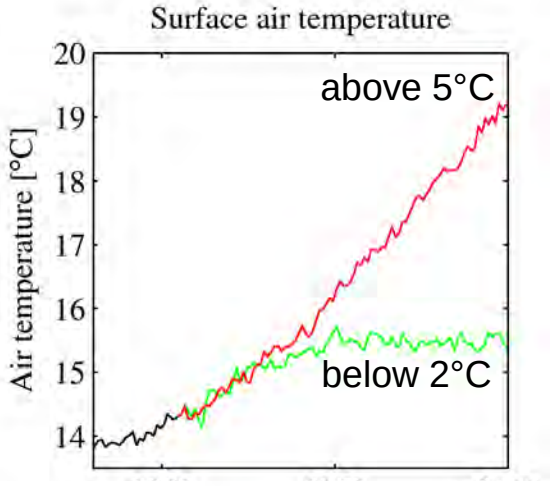
Consistent with other models, and better than low resolution versions of the same model

21st century change

- Ocean-only model forced at the surface with HadGEM2-ES output from CMIP5 / IPCC AR5
- RCP 2.6 (emissions decline) and RCP 8.5 (business-as-usual) scenarios investigated
- Results presented here focus on RCP 8.5 scenario
- This experiences complete seasonal sea-ice loss by the 2050s

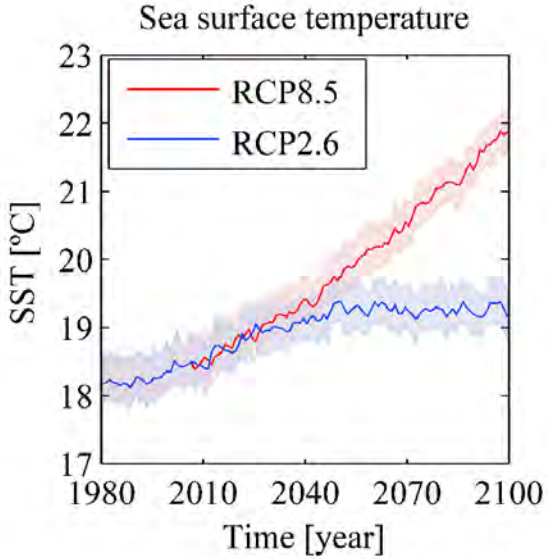
Atmos. pCO_2

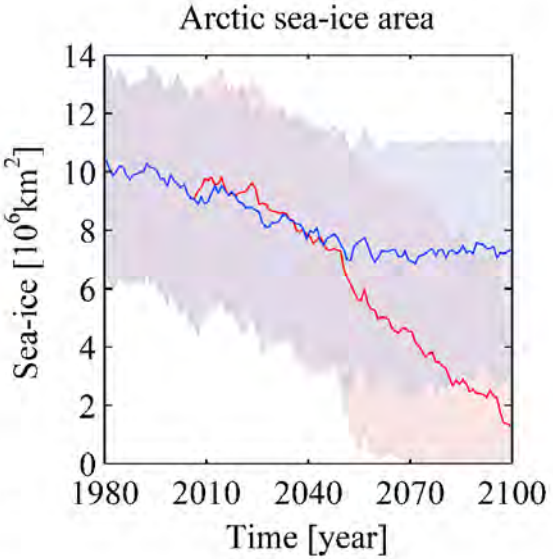




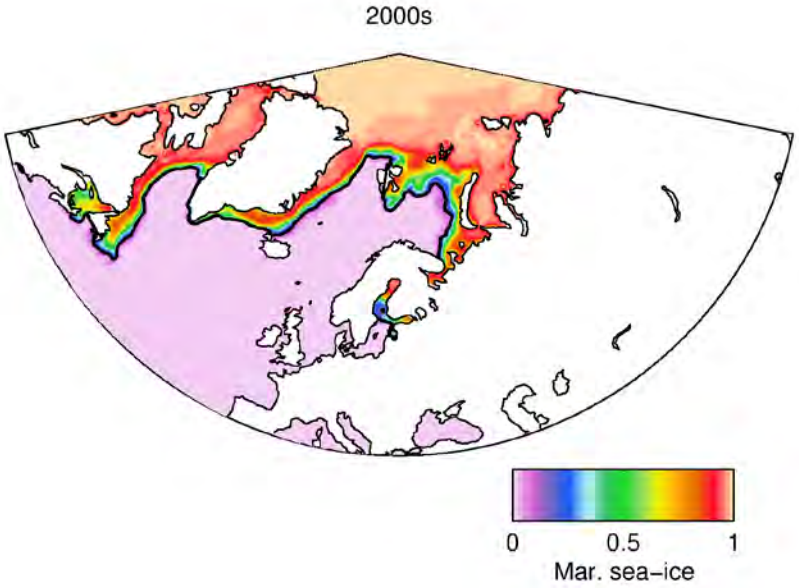
Atmos. temperature

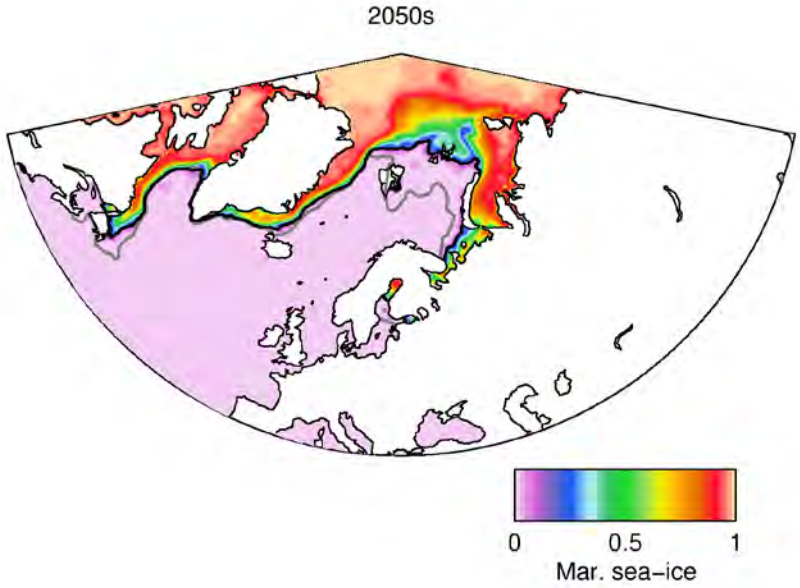
Ocean temperature

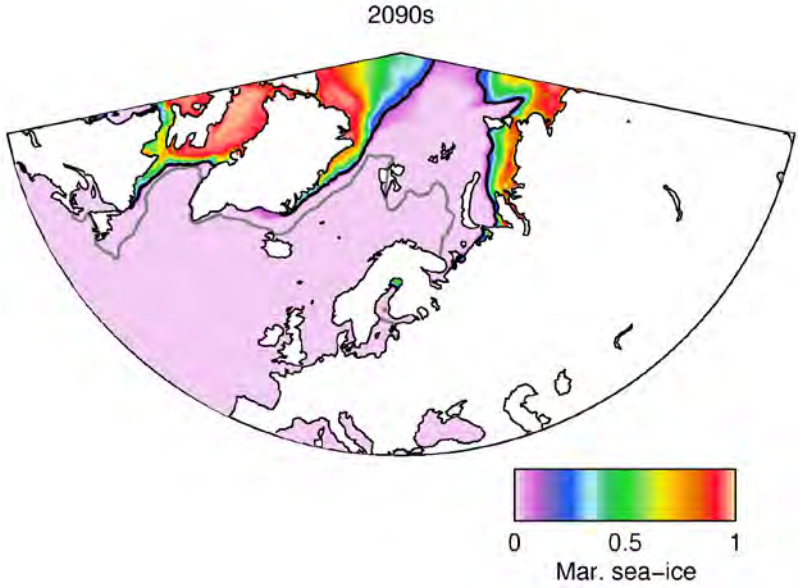




Arctic sea-ice

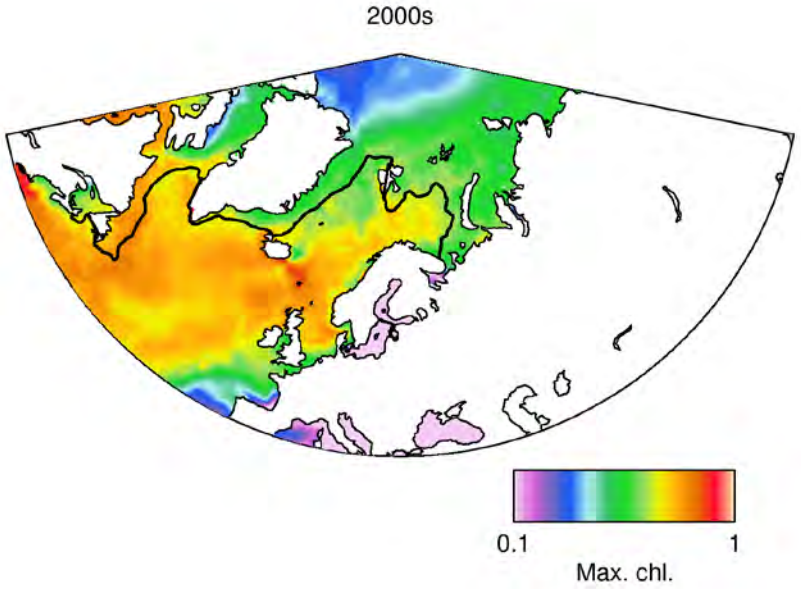


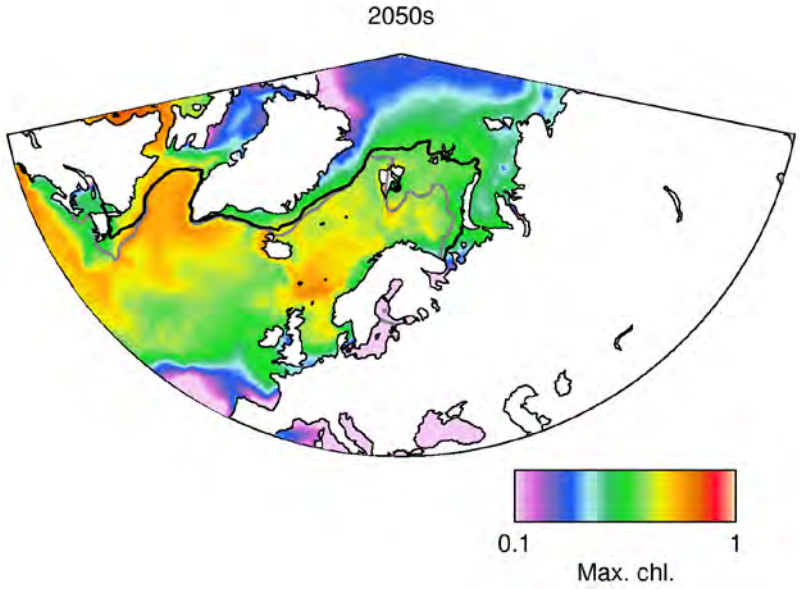


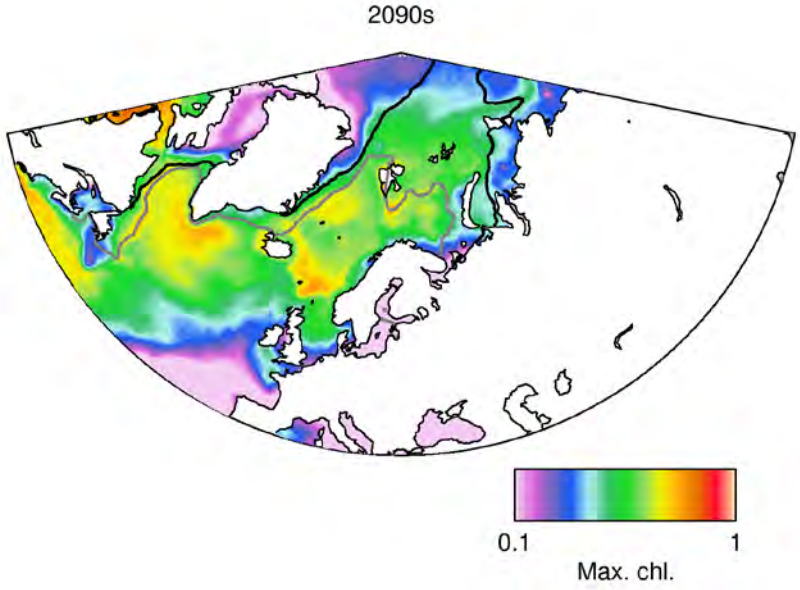


Decade-average March sea-ice cover = seasonal maximum

Though seasonally ice-free from the 2050s, the Arctic continues to be thinly ice-covered during the winter



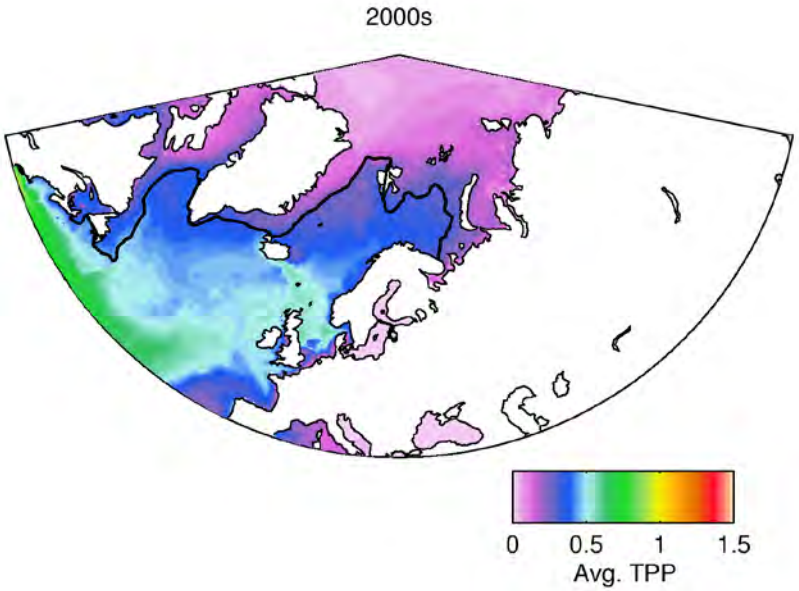


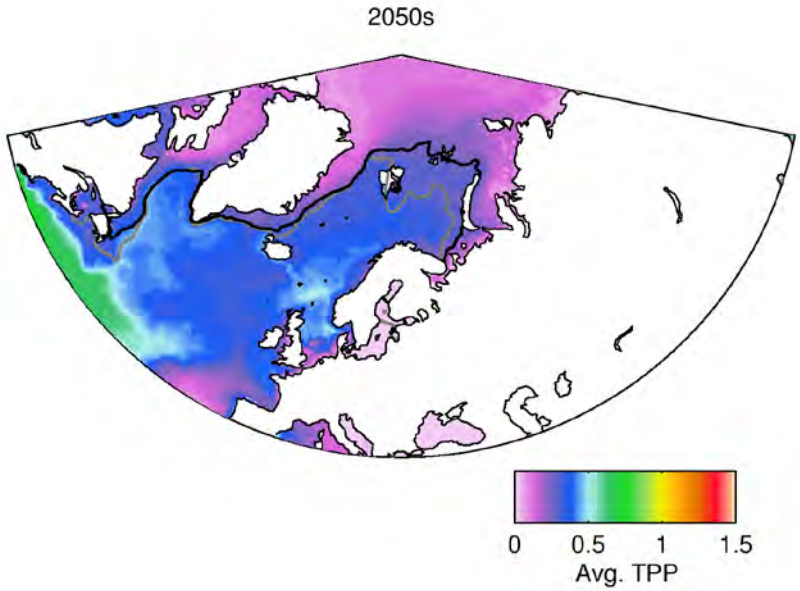


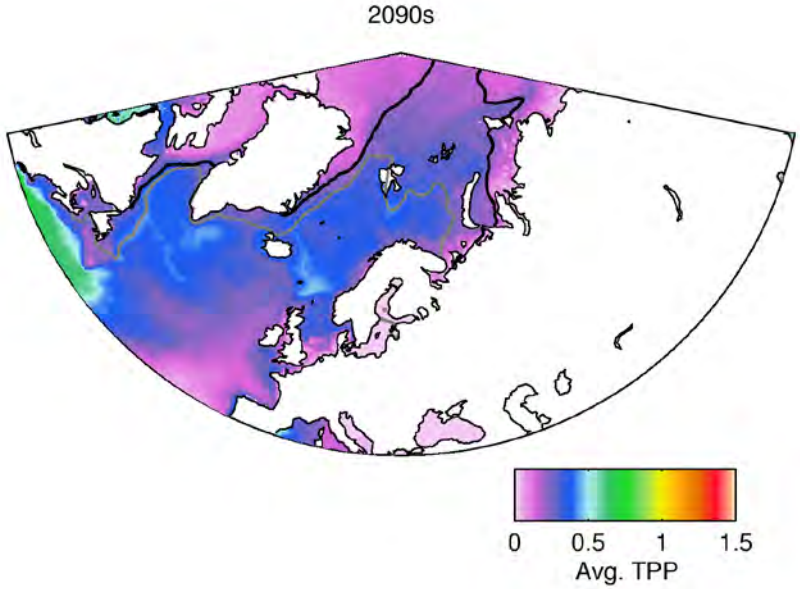
Decade-average seasonal maximum surface chlorophyll

Despite increases in the ice-free area of the Arctic, maximum chlorophyll declines into the future

The change is starker for the Atlantic



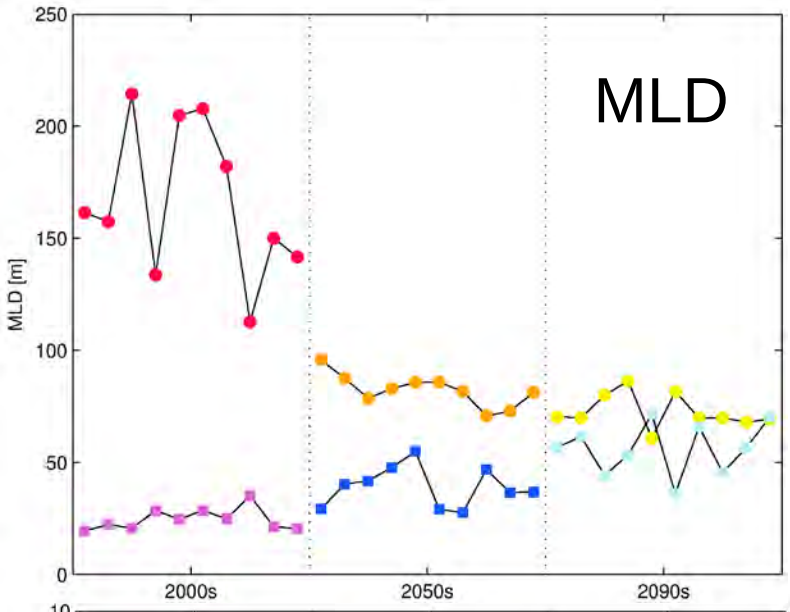


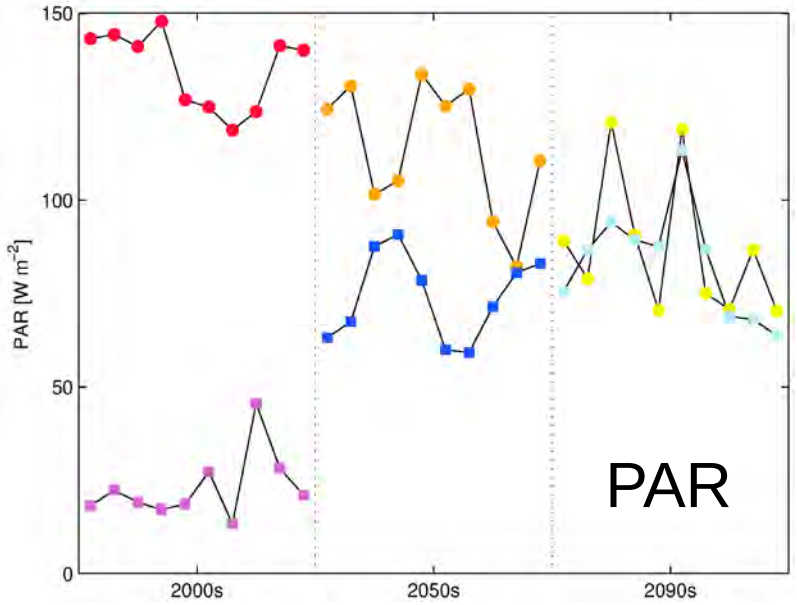


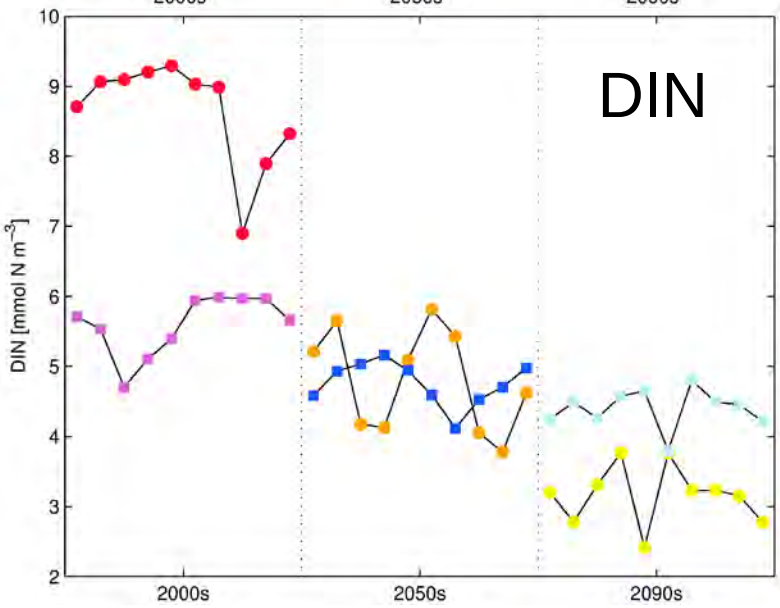
Decade-average ocean production

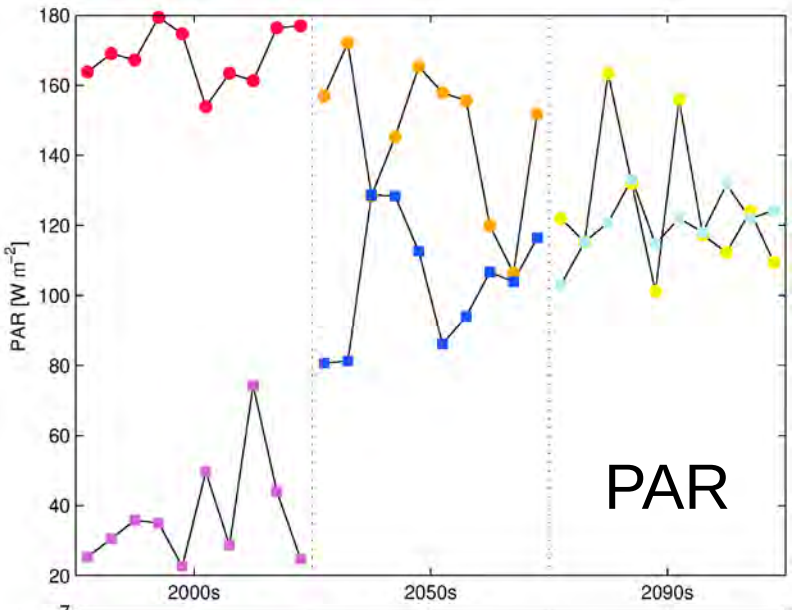
Though surface chlorophyll in the Arctic declines during the 21st century, the area in which (vertically-integrated) productivity rises tracks the retreat of the sea-ice

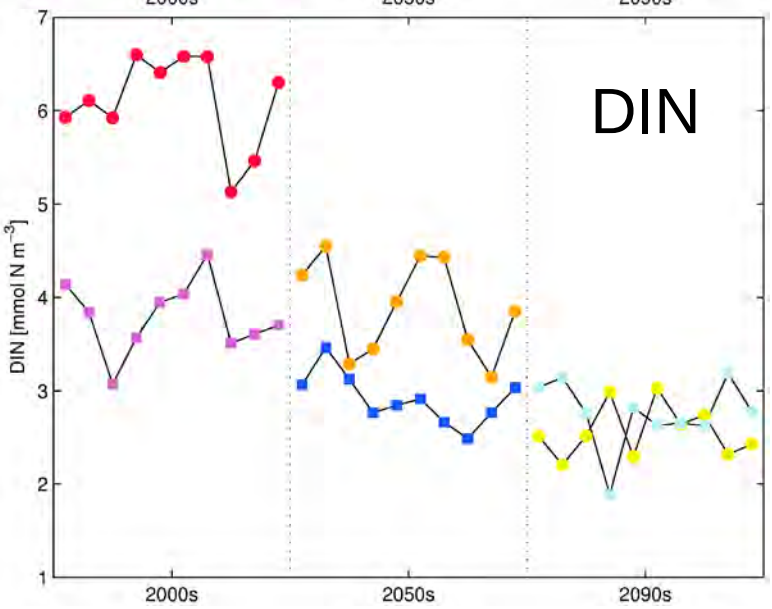
Pre-conditioning of bloom drivers (surface light, mixed layer depth, nutrients) is converging between the North Atlantic (red) and Atlantic-Arctic (blue) across the 21st century …



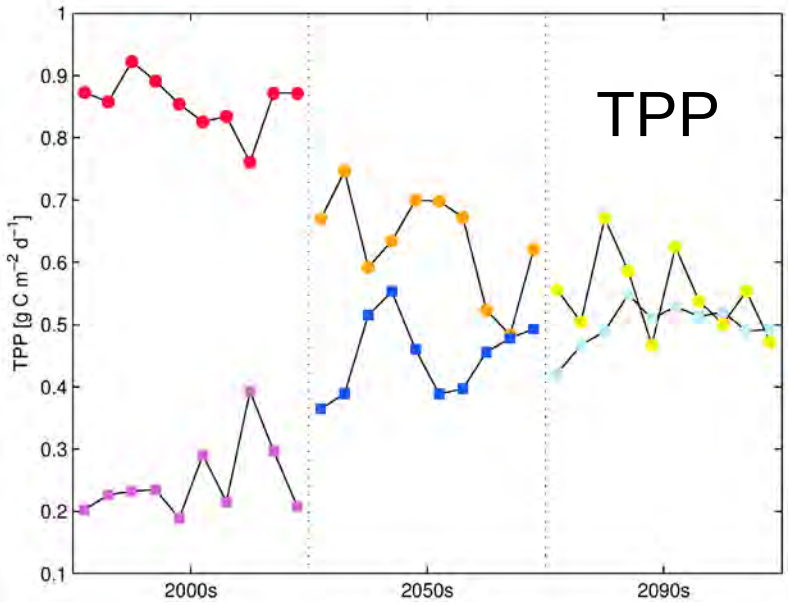








This convergence is even more complete at the time of bloom maxima, and this is further reflected in the corresponding primary production at this time of the year



The “new Atlantic”?

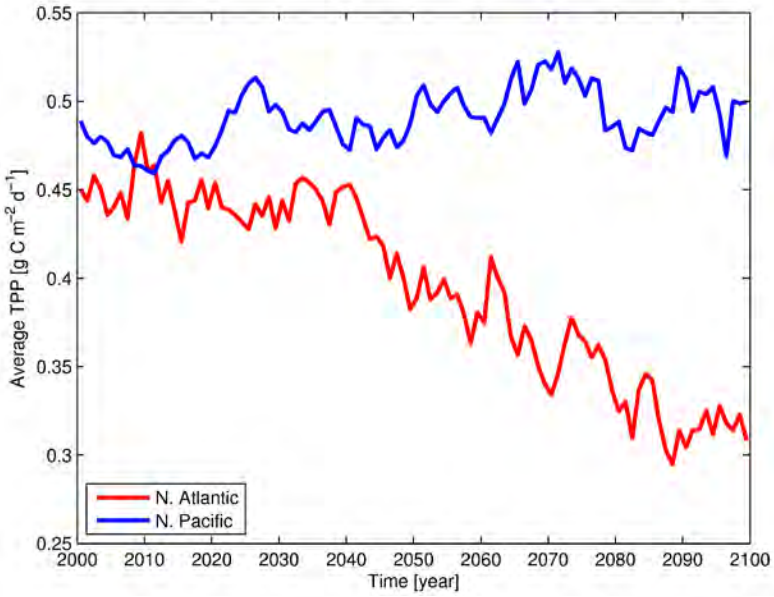
- During the 21st century, Atlantic productivity declines (-30%; from a high base) while Arctic productivity increases (+70%; from a low base)
- But this increase is not as large as would be expected from sea-ice loss in this region
- Examination of growth drivers prior to and during the spring bloom find convergence of Atlantic and Arctic conditions
- The *future*-Arctic is more like the *future*-Atlantic than the *current*-Atlantic (in terms of blooms)

Caveats

- A single run of a single model under a single future forecast
- Though high resolution, the model omits some shelf processes in the relatively shallow Arctic
- While responding to climate change, marine biogeochemistry is still relatively inflexible
- The impact of ocean acidification on export of nutrients is strong in this model, especially so in the vulnerable (though heterogeneous) Arctic

Meanwhile, in the Pacific …

- While North Atlantic productivity collapses, North Pacific productivity remains broadly similar (+5%)
- As such, it is not the Arctic but the Pacific that is perhaps the "new Atlantic"
- … at least in this model



Acknowledgements

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UK Ocean Acidification Research Programme

EURO-BASIN
BASIN SCALE ANALYSIS, SYNTHESIS AND INTEGRATION

GULLS