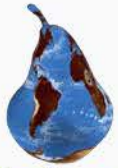
Advective Pathways of nutrients and Ecological Substances in the Arctic (APEAR)



Role of the ocean circulation for marine biogeochemistry and ecosystems

Changing Arctic Ocean Programme

Natural Environment Research Council (NERC, UK) & Bundesminesterium fur Bildung und Forschung (BMBF, Germany)

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Arctic Science Summit Week 2019

22-30 May 2019, Arkhangelsk, Russia

Outline

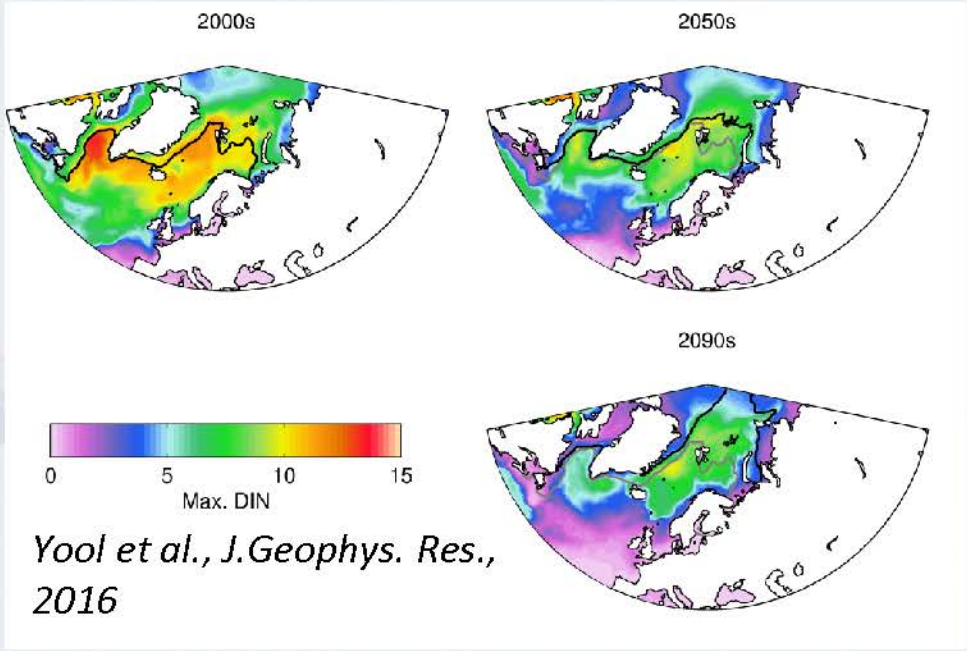
- Motivation
- Hypotheses
- Objectives
- Methods
- Results
- Summary & Outlook

Motivation: Arctic New Atlantic in the 21st century?

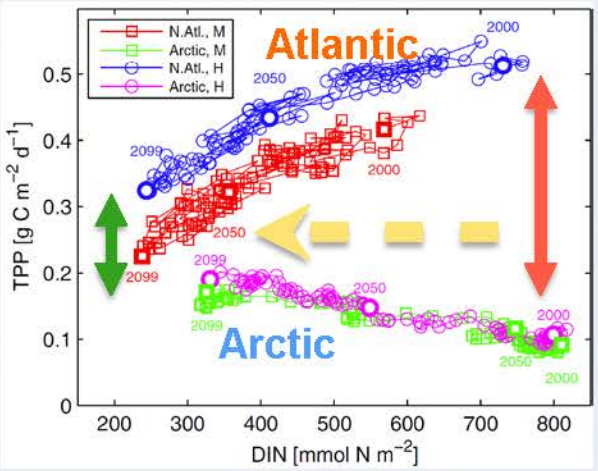
Future changes in Arctic Ocean & marine productivity

Key points

- ☆ Productivity declines in North Atlantic & increases in the Arctic
- ☆ Convergence of nutrients availability
- ☆ Arctic primary production is less light-limited with sea ice decline



Yool et al., J.Geophys. Res., 2016



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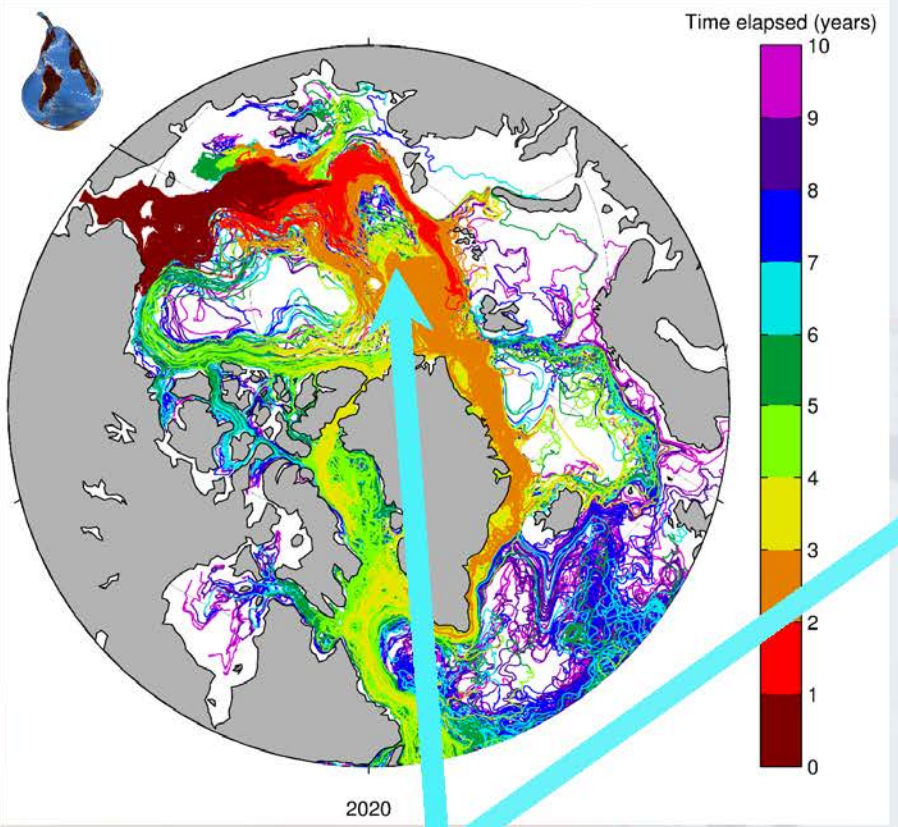
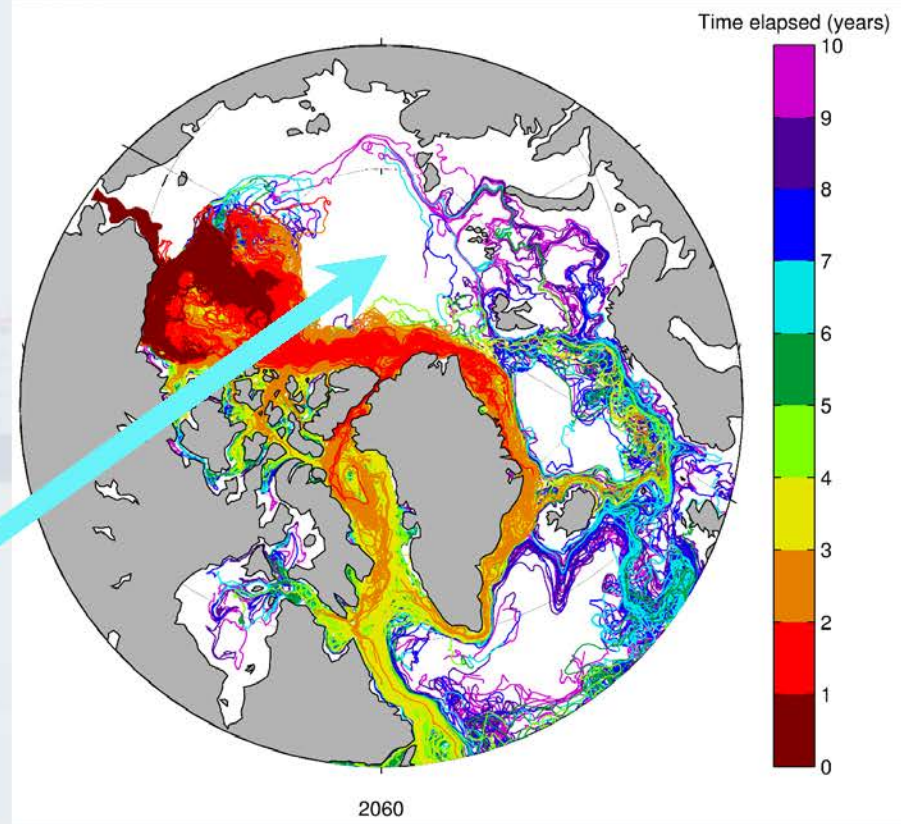
Motivation: Less Pacific Influence affects nutrients





Pacific water inflow shows reduction by ~30% and less spread in the Eurasian Arctic by 2060s (IPCC AR5)

JOURNAL OF GEOPHYSICAL RESEARCH: OCEANS, VOL. 118, 1571–1586, doi:10.1002/jgrc.20126, 2013

Role of advection in Arctic Ocean lower trophic dynamics: A modeling perspective

E. E. Popova,[1] A. Yool,[1] Y. Aksenov,[1] and A. C. Coward[1]

Received 3 August 2012; revised 7 February 2013; accepted 12 February 2013; published 28 March 2013.

Hypotheses

★As Arctic sea ice retreats, flows of Atlantic and Pacific waters across the Lomonosov Ridge change

★Ocean circulation in Eurasian Arctic and Canada Basin may become less coupled, leading to divergence of either ecosystem

★Longer ice-free season can reduce regional differences through stronger oceanic mixing

Objectives

- Through the synthesis of the existing and new data from drifting observatory *MOSAiC* 2019/20 and data from (~km) coupled biogeochemical models we
- Investigate fluxes of nutrients & Dissolved Organic Carbon (DOC)
- Analyse current large-scale/long-term changes in the Arctic biogeochemistry and
- Analyse future changes in Arctic ecosystems in the 21st century

Study across scales

APEAR: Role of ocean circulation for marine ecosystems

- **Multidisciplinary Observatory for the Study of Arctic Climate (*MOSAiC*): *RV Polarstern* trans-Arctic drift in 2019/20 https://www.mosaic-expedition.org/**
- **Cross-scale (spatial and temporal) multidisciplinary observations from multiple platforms (ships, ice camp, autonomous buoys, aircrafts and satellites)**
- **Comprehensive air-sea ice-ocean-ecosystems observations and process studies**
- **Unique winter data from the central Arctic Ocean**
- **Full depth CFC/SF6 sampling, water mass pathways and age (leg 3 & 4), combined with model CFC/DSF6 tracers**
- **Near real time model/observations validation & studies**

O *Arctic regional* & global models

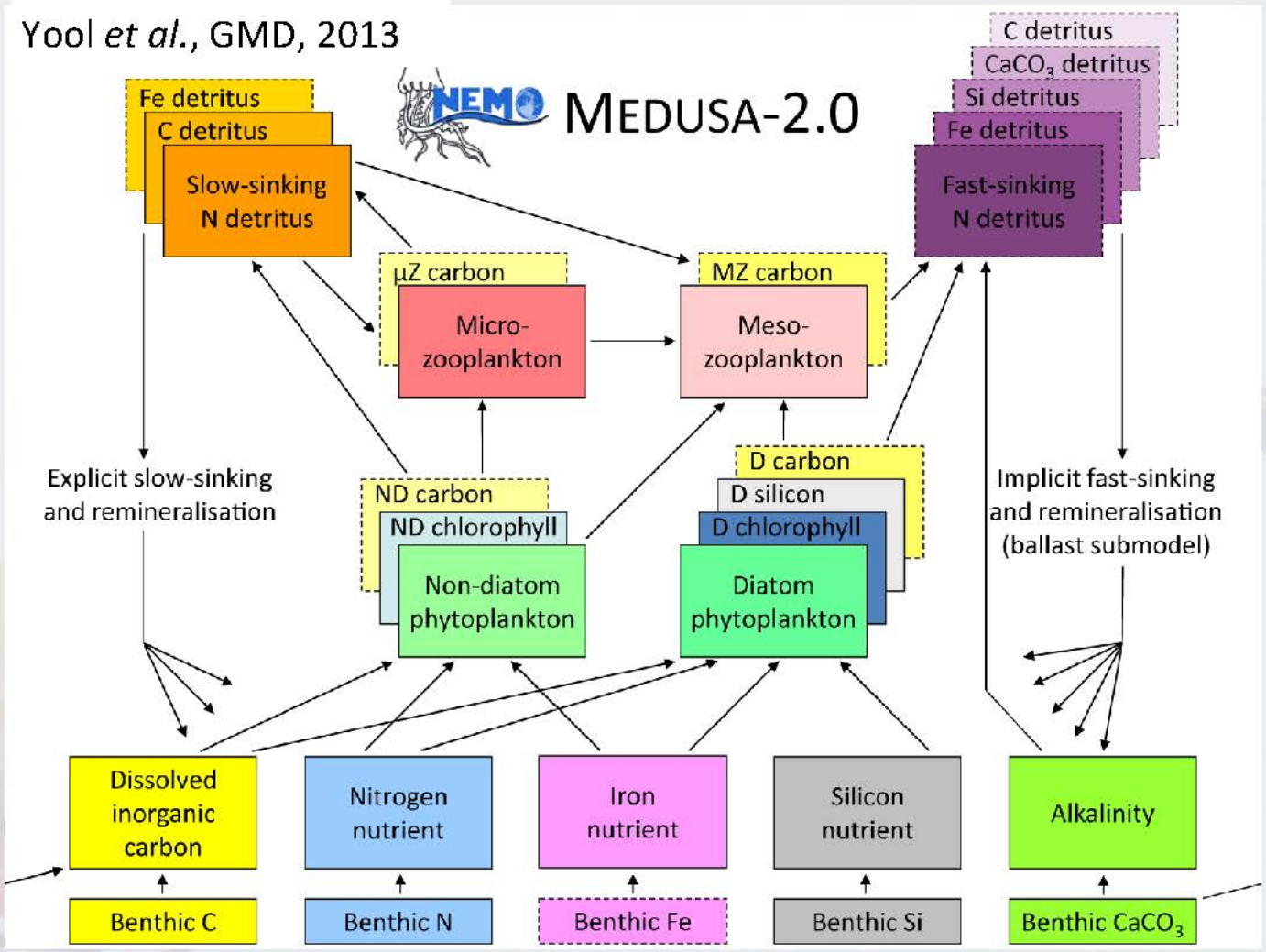
Multi-resolution models

APEAR: Role of ocean circulation for marine ecosystems

- **Models:** global *3-9 km* resolution (eddies & boundary currents) NEMO (Nucleus for European Modeling of the Ocean) & MEDUSA (Model for Ecosystem Dynamics, carbon Utilisation, Sequestration and Acidification)
- NEMO-MEDUSA-2 Arctic regional (3 km) with tides and wave mixing, forced present-21st century
- UK Earth System Model (UKESM) global 1º & 1/4º (10 km) ~100 yrs x 4 scenarios (IPCC AR6) x 5 ensembles
- Coupled UK MetOffice UM Atmosphere and Ocean Global Circulation Model (AOGCM): 1/12º (3 km & 25 km) 100 yrs
- **Advection of nutrients & off-line tracking** of the CFC/F6 (ARIANE)

MEDUSA-2

APEAR: Role of ocean circulation for marine ecosystems



NEMO MEDUSA

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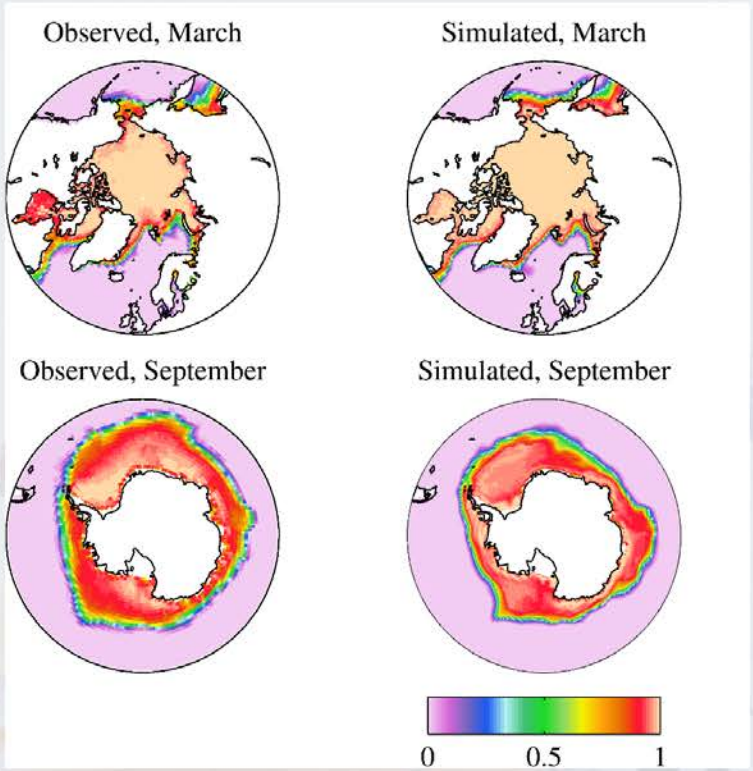
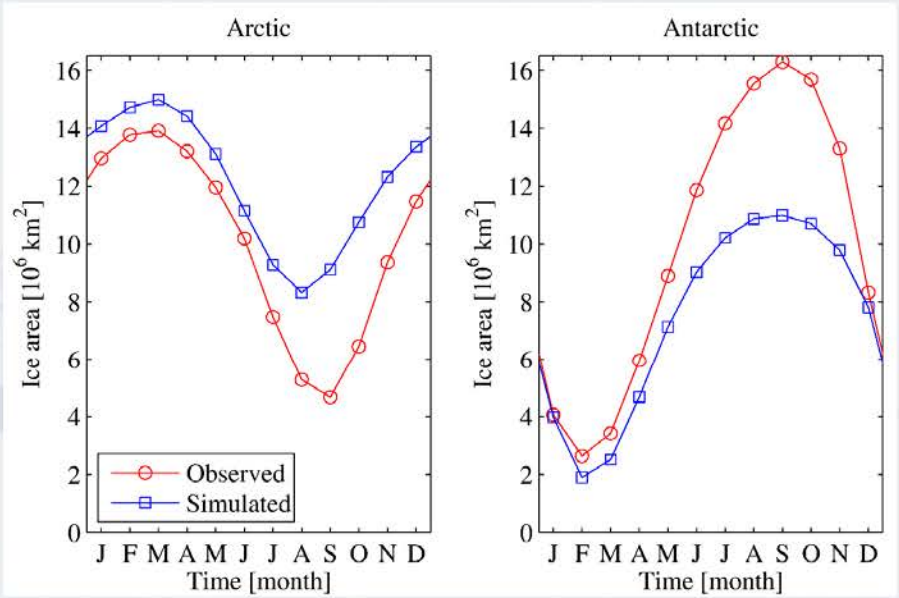
Sea Ice 2000-09

APEAR: Role of ocean circulation for marine ecosystems

Sea-ice annual maximum



Sea-ice annual cycle



- Annual maximum is realistic
- Arctic magnitude is good
- Seasonal minimum is too high
- Antarctic seasonal minimum is good
- Antarctic maximum is ~40% lower
- Implications for future climate change

NEMO MEDUSA

UKESM

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Mixed Layer 2000-09

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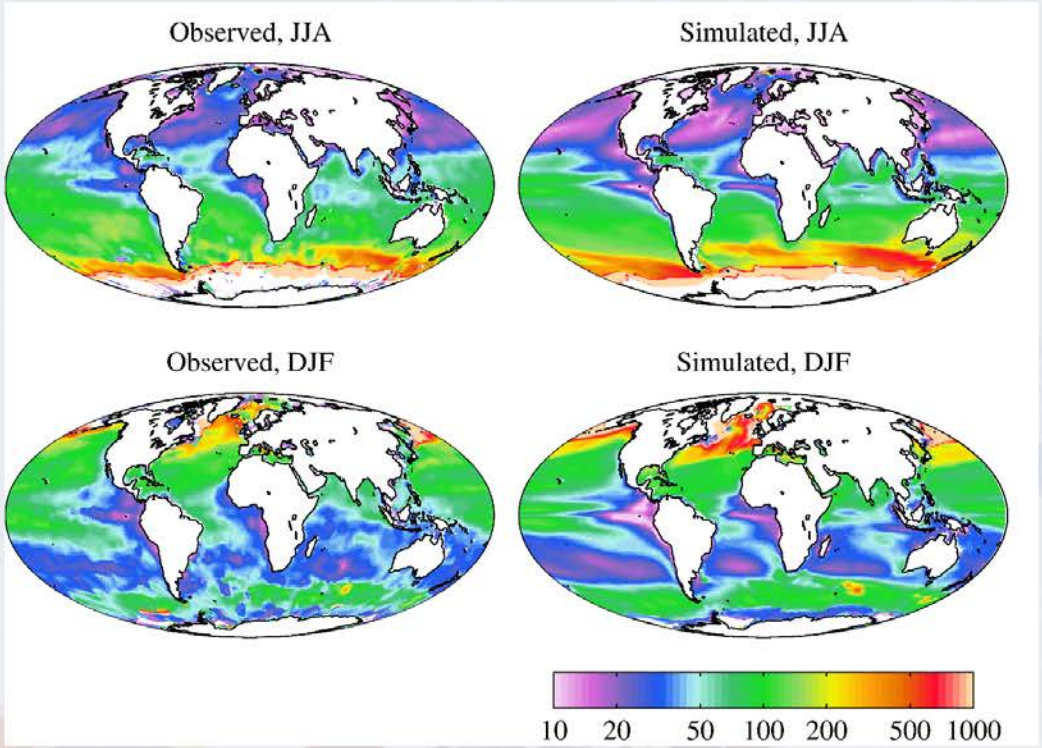

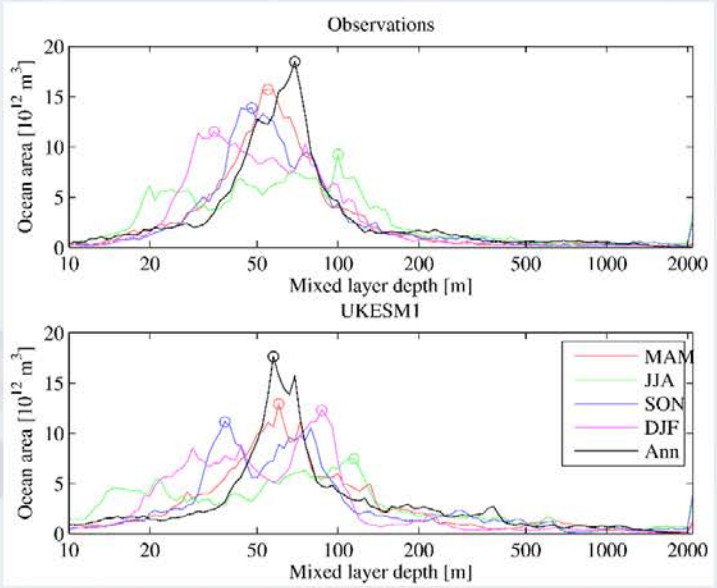

- Patterns generally are well-represented
- Magnitudes are exaggerated with deeper winter and shallower summer mixing
- Excessive mixing in the northern Atlantic and Pacific

NEMO MEDUSA

UKESM

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Primary Production (PP)

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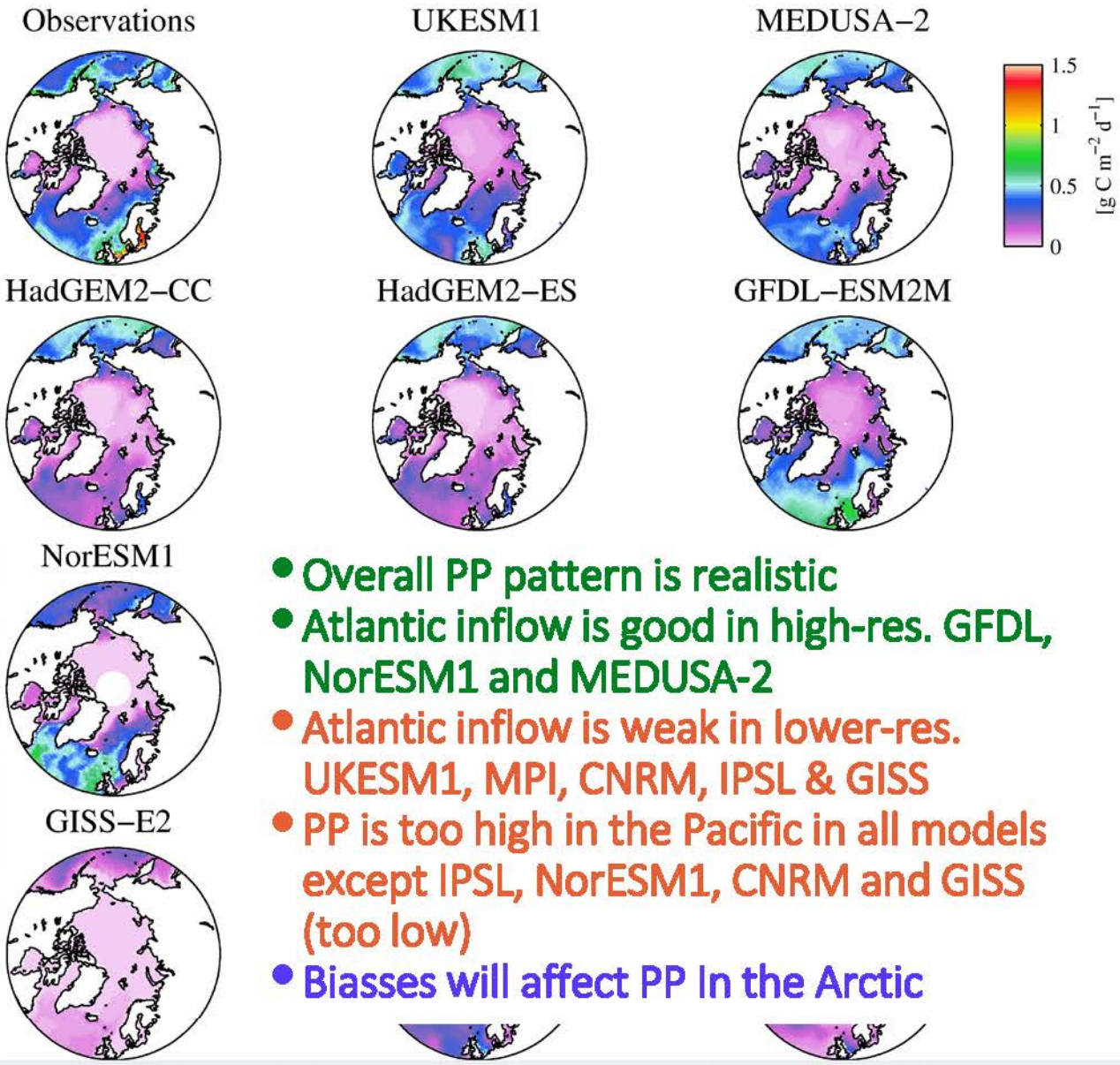

- Overall PP pattern is realistic
- Atlantic inflow is good in high-res. GFDL, NorESM1 and MEDUSA-2
- Atlantic inflow is weak in lower-res. UKESM1, MPI, CNRM, IPSL & GISS
- PP is too high in the Pacific in all models except IPSL, NorESM1, CNRM and GISS (too low)
- Biasses will affect PP In the Arctic

UKESM

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Effect of resolution

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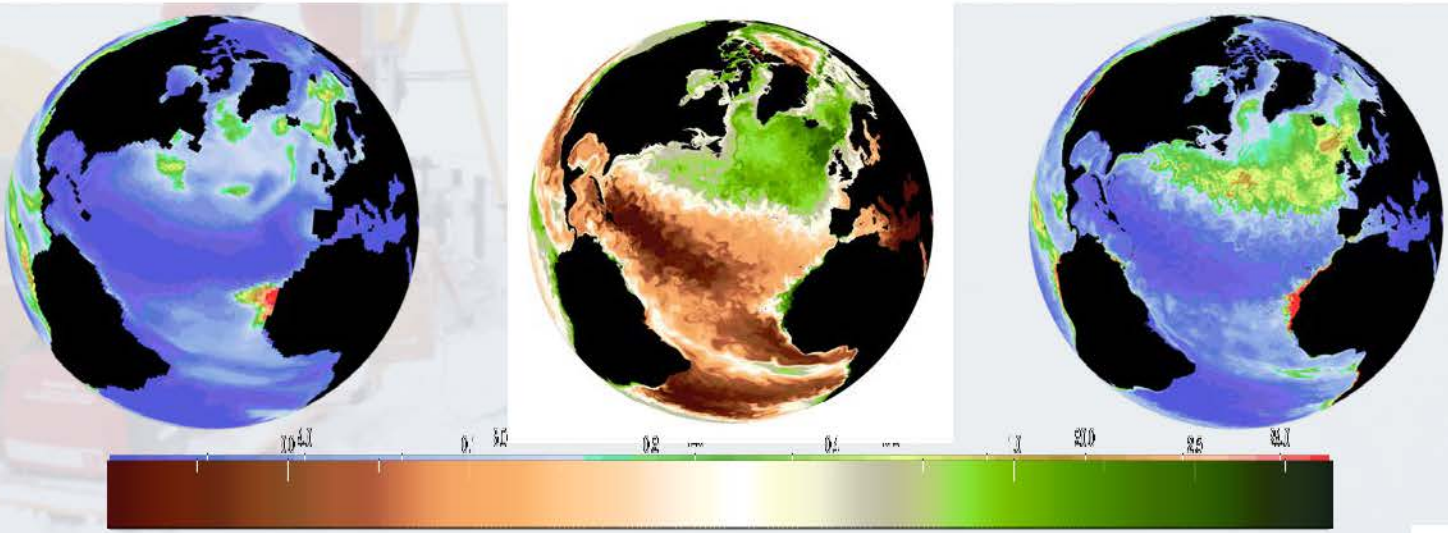
NEMO 1º **NEMO 1/4º** **NEMO 1/12º (~3 km)**

Currents (speed) June 2008

- Higher primary production in North Atlantic Drift and Norwegian & Greenland Seas in the higher-resolution models: higher nutrients supply by the stronger currents
- Highest primary production in Barents Sea in 1/4º: strongest Norwegian Atlantic Current
- Production rates are linked to the nutrient transport by Atlantic water inflow in the Arctic (non-local controls)



NEMO MEDUSA

Non diaton Non diatom Chl-a (mgCh/m^3) /day)

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Mixed Layer temperature & salinity (UDASH)

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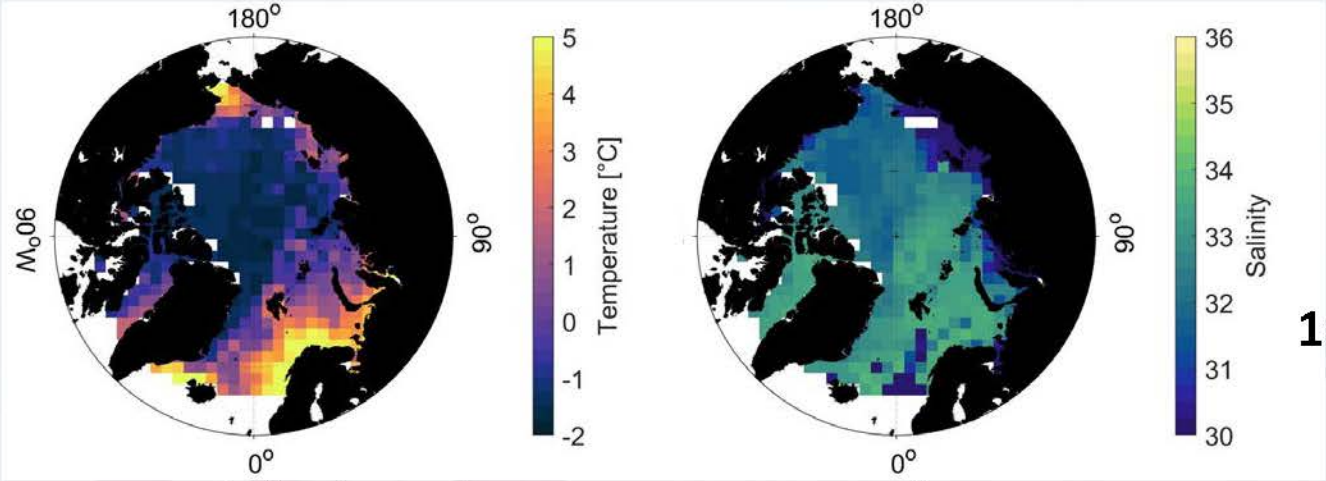
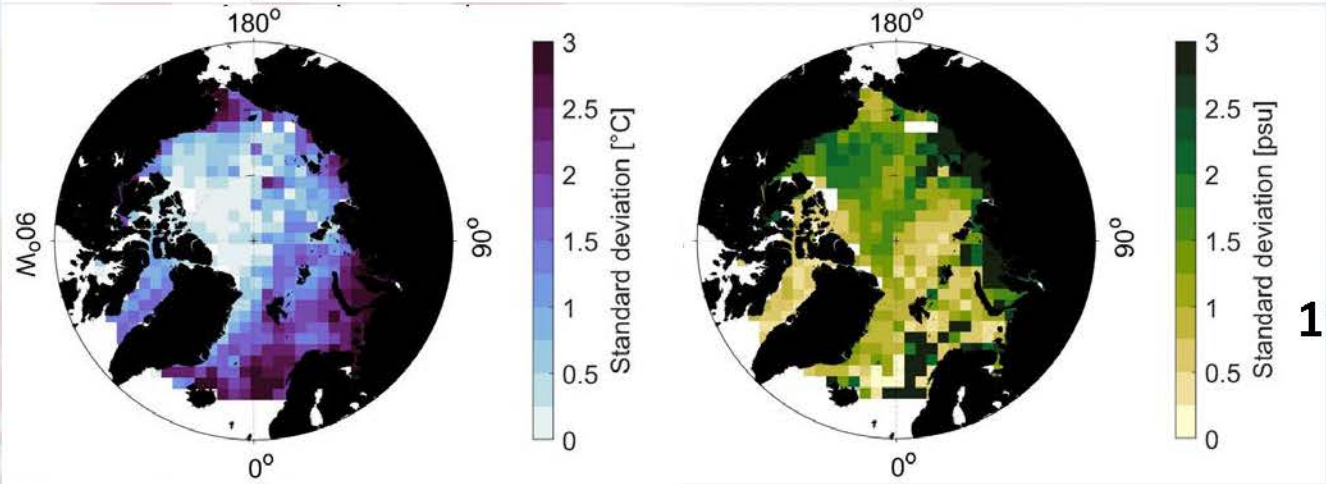
Mean temperature 1980-2015



Mean salinity 1980-2015

Std of temperature 1980-2015



Std of salinity 1980-2015

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Summary & Outlook

APEAR: Role of ocean circulation for marine ecosystems

- We presented an overview of the project "The Advective Pathways of nutrients and key Ecological substances in the ARctic (APEAR)"
- **Motivation:** shift in advective pathways of nutrients caused by changes in sea ice and ocean circulation
- The project analyses current and future changes in the Arctic ecosystems using data (incl. MOSAiC campaign) and high-resolution models synthesis
- **First model results** (sea ice, ocean & BGC) in agreement with data
- Pacific and Atlantic provinces boundary (Pacific/Atlantic front) will shift with the ocean circulation in mid-21 century
- **Outlook:** (i) water masses pathways across the Eurasian and Makarov basins, 1980-present; (ii) new observations on seasonality from MOSAiC; (iii) processes controlling nutrient fluxes and biogeochemical evolution in the Arctic

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Funding

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The study is supported from the project "The Advective Pathways of nutrients and key Ecological substances in the Arctic (APEAR)" (grant NE/R012865/1) funded by the Joint UK NERC/German Federal Ministry of Education and Research Changing Arctic Ocean Programme

We acknowledge funding from the project "Towards a marginal Arctic sea ice cover" (NE/R000654/1) and from the Atlantic Climate System Integrated Study Programme (ACSIS) (NE/N018044/1) for the travel support.

https://www.changing-arctic-ocean.ac.uk/

http://acsis.ac.uk/

NERC SCIENCE OF THE ENVIRONMENT

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Changing Arctic Ocean

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Changing Arctic Ocean Programme

Understand & quantify changes to predict consequences for ocean productivity, species distributions, food webs and ecosystems

Over-arching Research Challenges:

- **What controls spatial and temporal structure and functioning of Arctic ecosystems and biogeochemical cycles?**
- **What are the impacts of multiple stressors on Arctic species, biogeochemical cycles and ecosystem structure?**

https://www.changing-arctic-ocean.ac.uk/

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Thank you!

Are you looking for
A PEAR, Dear?