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Arctic connections between sea ice, ocean dynamics and biogeochemistry in the UK Earth System Model (UK ESM1) future scenarios

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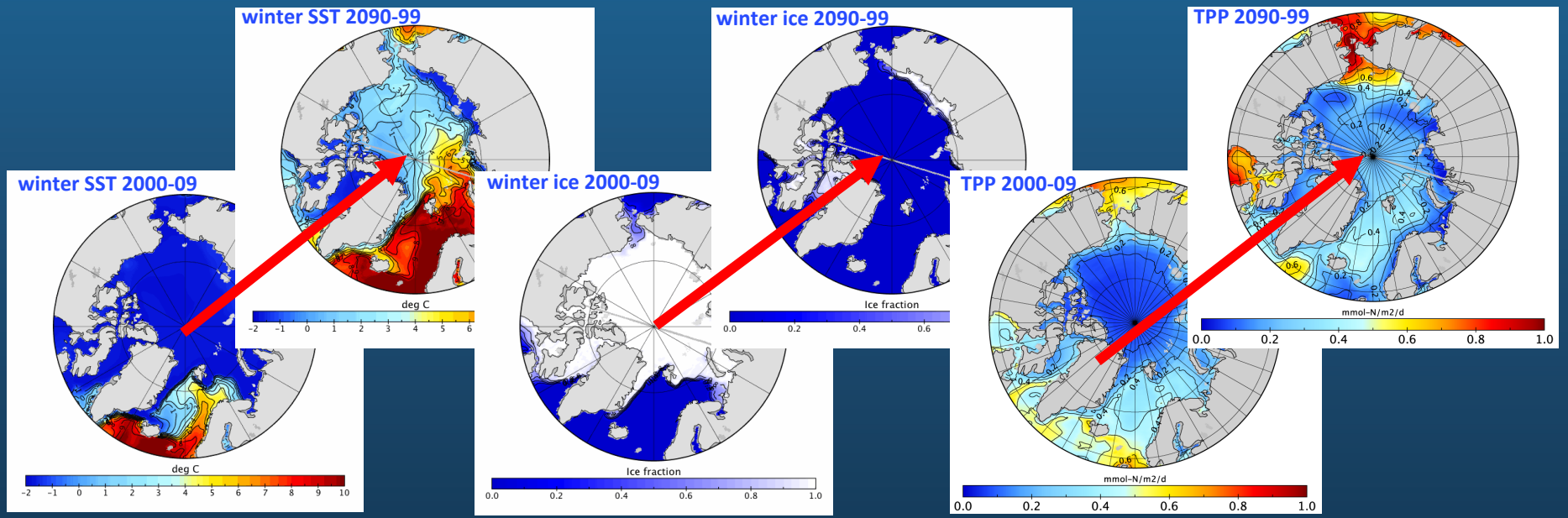
Atlantic Inflow (SST & Nutrients) Increases → **Ice retreat (more light in summer & warmer SST)** → **Total Primary Production in the Arctic increases**



Making Sense of Changing Seas for a Sustainable Future

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Motivation

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- Observed increase in the Atlantic & Pacific inflows *[Polyakov Sci. 2017; Woodgate Progr. Oc. 2018]*
- Intensified shelf-ocean exchanges and role of boundary currents *[Luneva J.Geophys. Res, 2020]*
- Future increase in connectivity between the Atlantic & Arctic; convergence of DIN/PP in the Atlantic & Arctic *[Yool J.Geophys. Res. 2016]*
- Arctic primary production is less light-limited with ice decline
- Longer ice-free season reduces regional differences
- Influences of ocean changes in the Arctic on BGC are unclear *[Yool, 2020]*
- Mitigation of climate changes requires robust coupled projections of sea ice, ocean & ecosystems

Methods

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- Global UKESM1 (NEMO-CICE-MEDUSA) historical & IPCC6 SSP1/SSP5 scenarios 1850-2099
- 9 ensembles to examine changes in ocean, BGC and sea ice
- Current climate state compared with observations
- Projected scenarios for 2015-2099 are compared for changes in Arctic ocean circulation, primary production, DIN and sea ice

Current and Projected Changes: UK ESM

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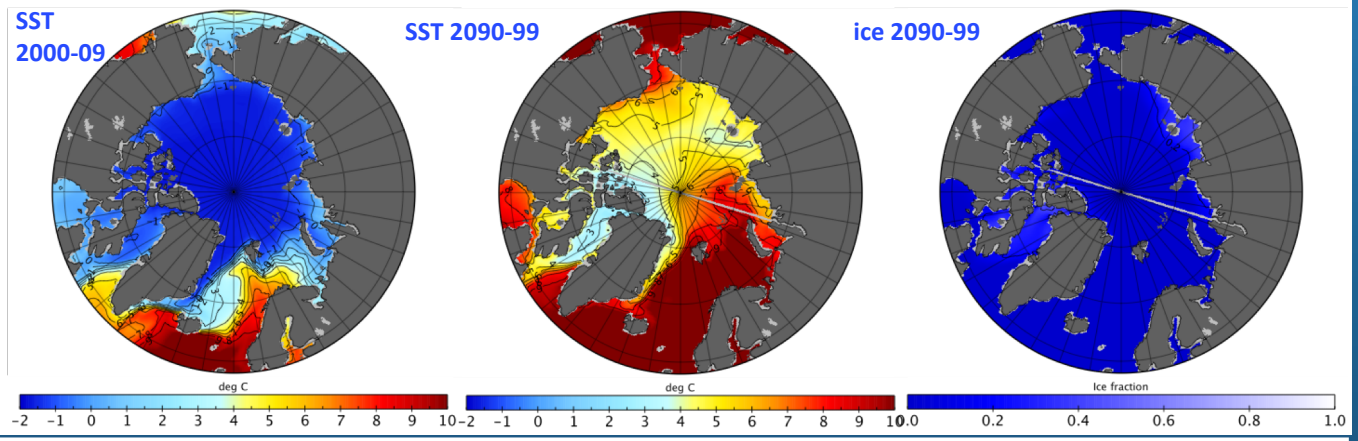
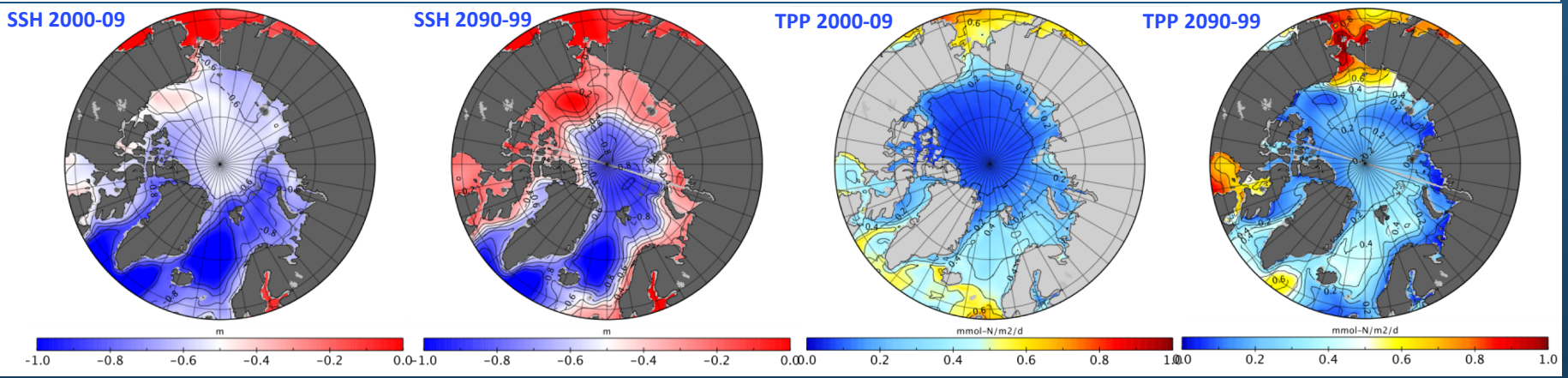
- SSP5 scenario shows ice disappearance by the 2090s
- Pacific-Atlantic front shifts to the Canadian Basin
- Winter Arctic SST is >0°C

Atlantic & Pacific heat inflows increase; more light in ice-free ocean



Changes in ocean currents (SSH as proxy) & connectivity: Primary Production in the Arctic increases



Future Pacific water pathways

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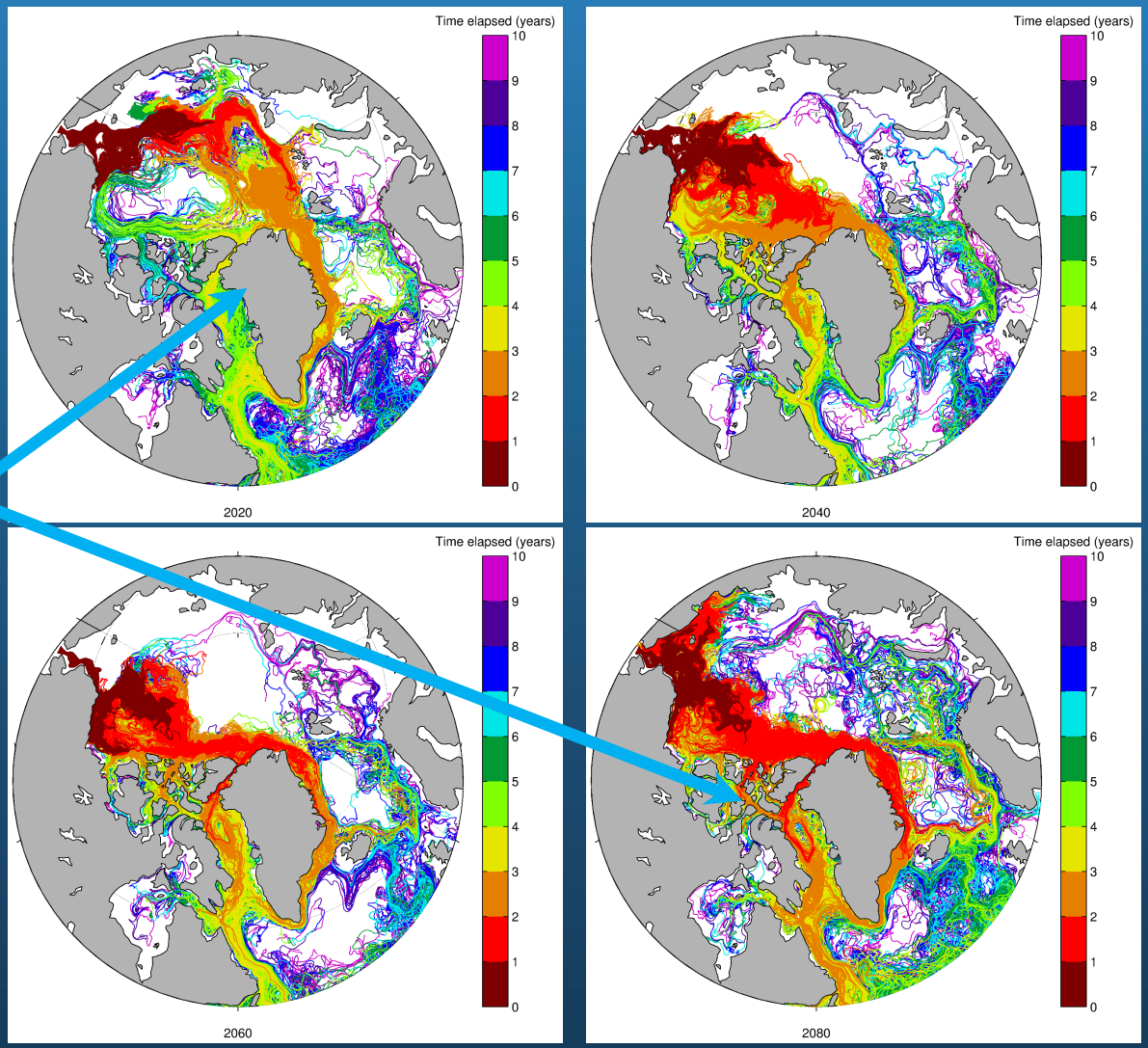
- Pacific-to-Atlantic
- travel time
- reduction
- by ~30% in the 2080s
- Incerased flow through Canadian Archipelago



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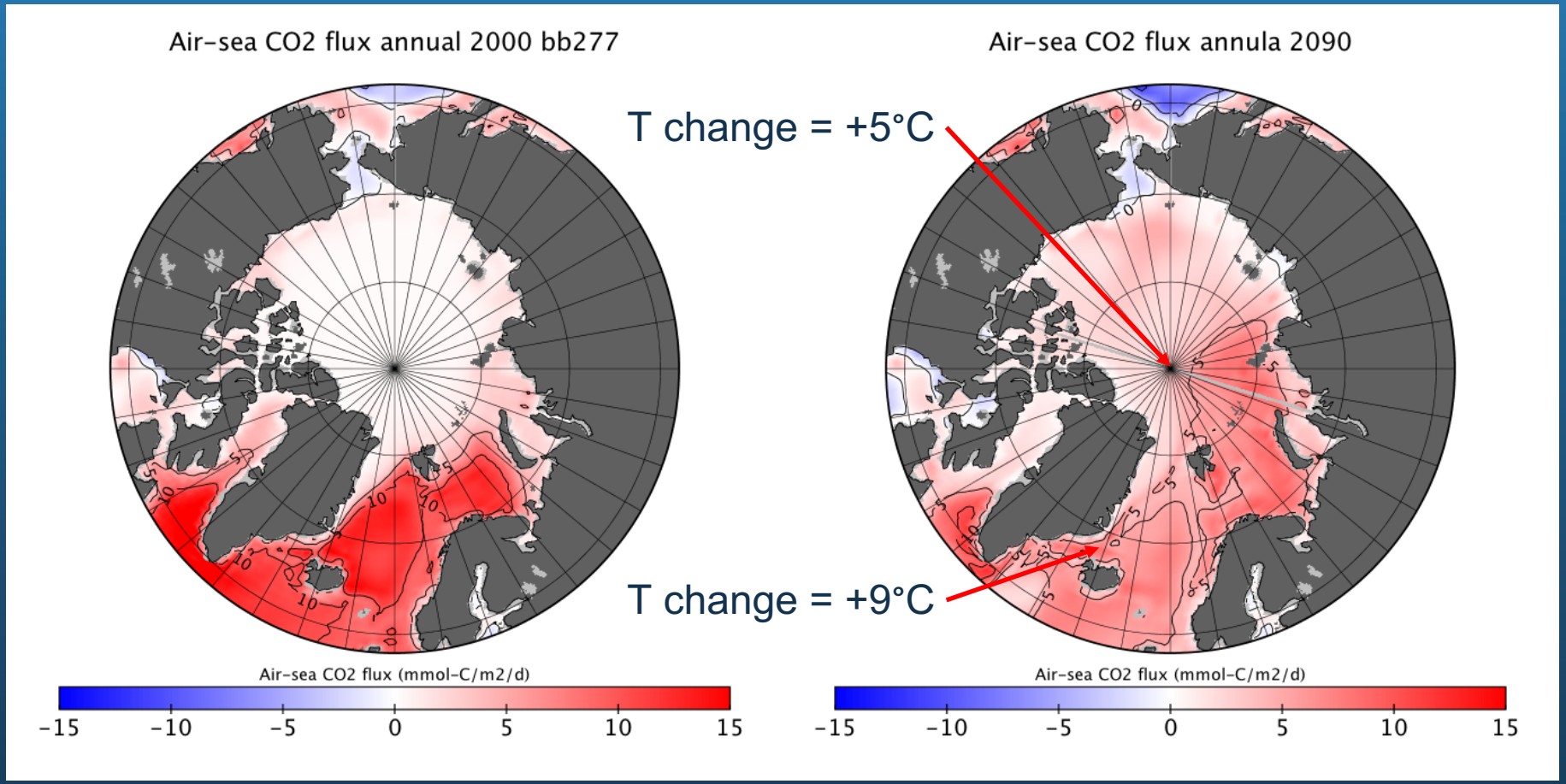
Long-term air-sea CO2 flux



Despite higher atmosphere CO2, future fluxes lower

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Key Results

- Simulated present ocean and ice are are in agreement with data
- Warmer inflows from the Atlantic & Pacific Oceans have a key effect on water masses, sea ice, nutrients & primary production in the central Arctic
- Total primary production in the Arctic Ocean increases by ca. 100%
- by the 2090s in SSP1/SSP5 scenarios cf. the present climate
- Initial high nutrients availability in the inflows is the primary cause
- Higher Atlantic and Pacific inflows prolong ice-free season
- Delayed ice formation & strong autumn mixing reduces regional differences in productivity in the Arctic, making it similar to the N. Atlantic
- Faster connections through the Arctic Ocean and higher SST allow species to survive through the winter

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Summary: Current & Projected Changes

- Key findings: future changes in upper ocean currents, sea ice & BGC
- Key effects:
  - sea ice loss & increased Atlantic inflow lead to higher ocean temperatures
  - easier connectivity with global oceans: travel time reduction across Arctic
  - thus, invaders & increase in Arctic productivity
- Key mechanisms:
  - increased oceanic connectivity between Arctic provinces
  - higher nutrients and light availability

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