CESM1: The effects of a seasonally ice-free Arctic on the Atlantic Meridional Overturning Circulation

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Background

- Experiments with CCSM3 (prescribed sea ice and SSTs) suggest that most of high-latitude warming response to GHG forcing at end of 20th C is due to Arctic sea ice loss (Deser et al., 2010)
- How would an ice-free summer Arctic effect the ocean, (separate from the effects of warming associated with increasing GHGs)?

Background

- Experiments with CCSM3 (prescribed sea ice and SSTs) suggest that most of high-latitude warming response to GHG forcing at end of 20th C is due to Arctic sea ice loss (Deser et al., 2010)
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Related work:

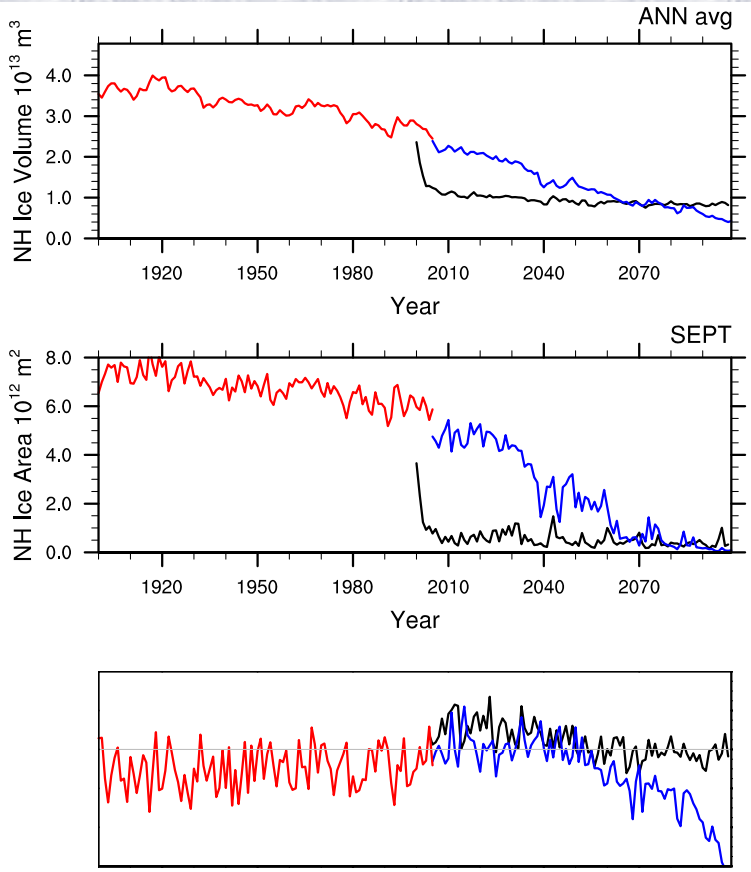
•Arctic sea ice loss in CCSM4-CMP5 simulations (Alex Jahn and Marika Holland – next talk)

•Impacts of a seasonally ice-free Arctic on the atmosphere (Clara Deser and Bob Tomas)

Model set-up

- CESM1 fully coupled
- Change radiative parameters in sea ice model (R_snw, R_ice, Rsnw_melt_in, dT_mlt_in)such that Arctic goes ice free most summers
- Initialized from 20th C CMIP5 ensemble member (b40.20thC.track1.1deg.007) in simulation year 1990
- Run at constant 2000 conditions for 100 yrs.
- Figures compare 3 simulations:
  - 20thC ensemble member used for initialization (007)
  - RCP8.5 initialized from same 20thC run (005)
  - “Summer Ice-Free Arctic” simulation

Arctic Summer Sea Ice loss



Ice-Free run:

- immediate decrease in annual volume and summer ice
- Seasonality (max-minimum ice volume) slightly higher than 20thC simulation

RCP8.5 simulation:

- Seasonality starts decreasing mid-21st C, particularly after reaching summer ice-free conditions

Surface Temperature Response

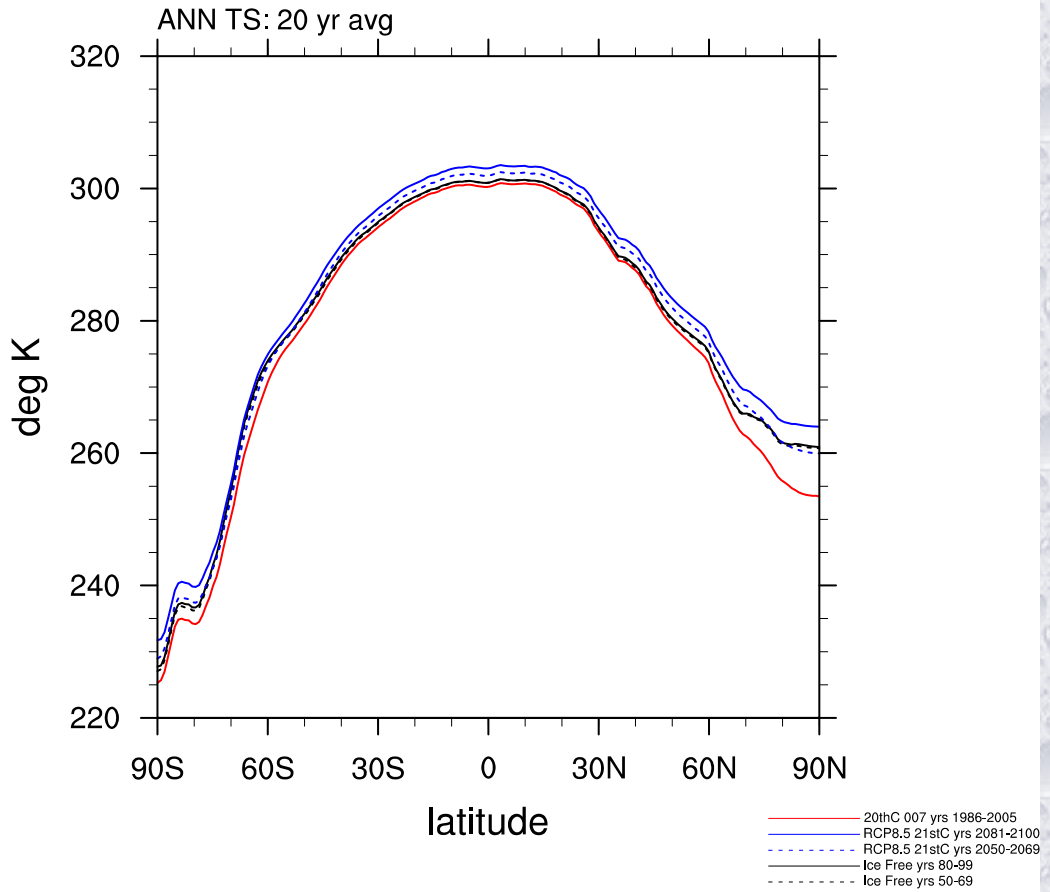
Compared with 20th C simulation:

Ice Free run

- increased high latitude temperatures, very little tropical temperature response

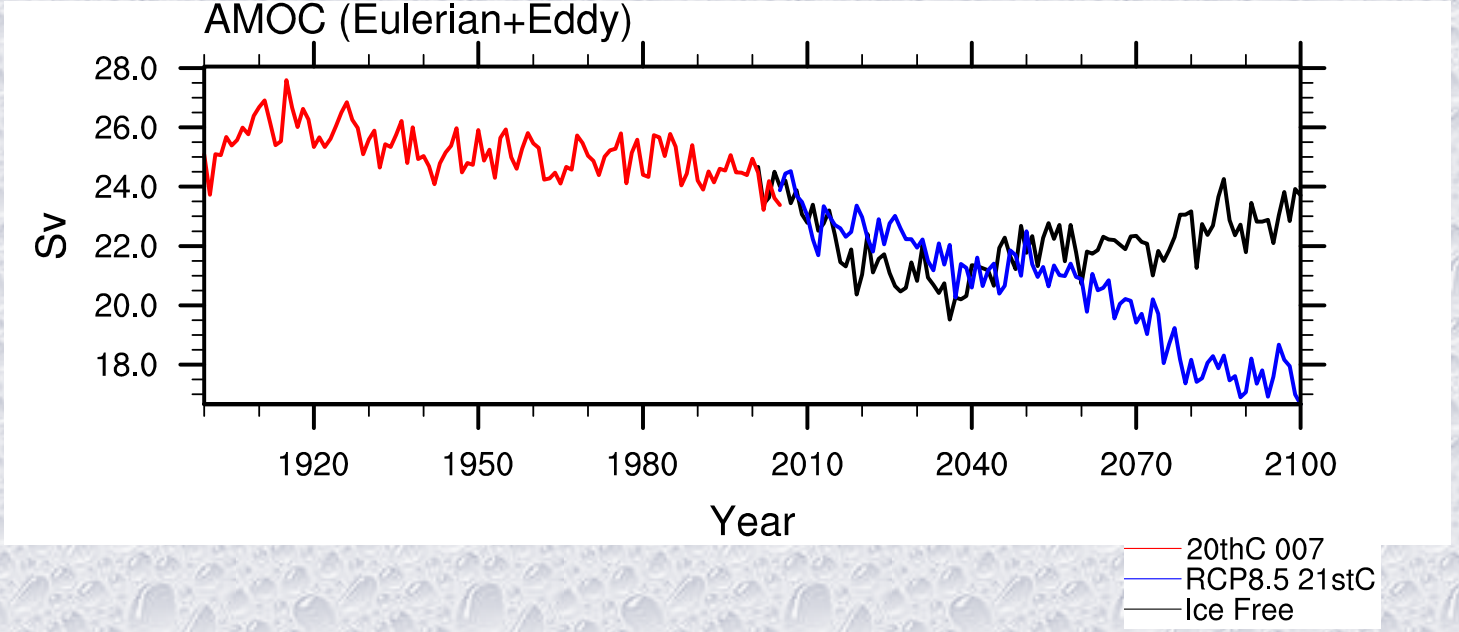
RCP8.5

- global TS response
- high latitudes mid-21st C comparable to Ice-Free simulation

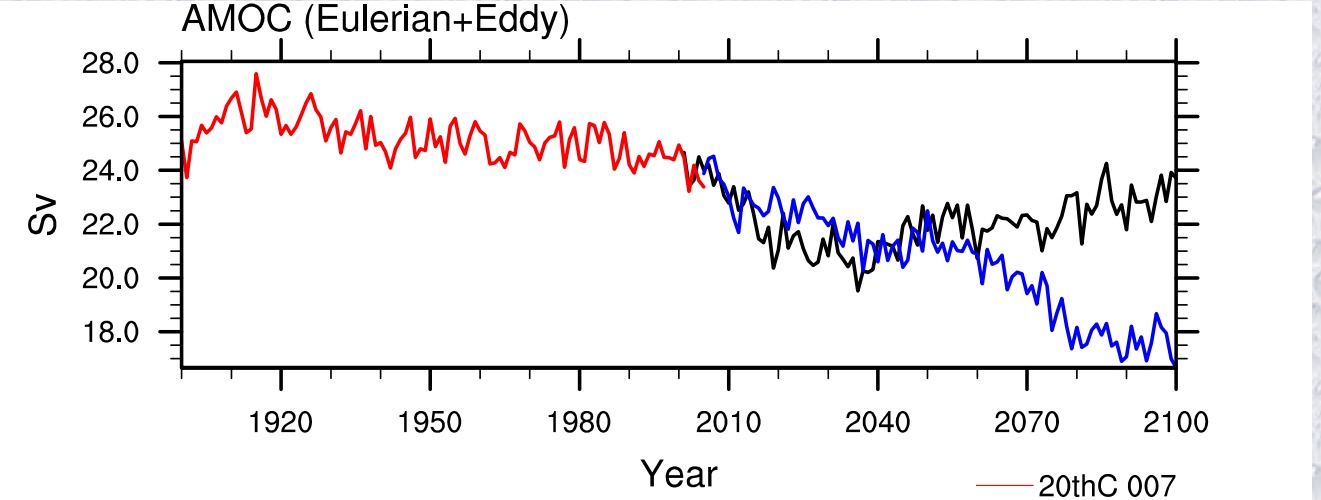


NESL

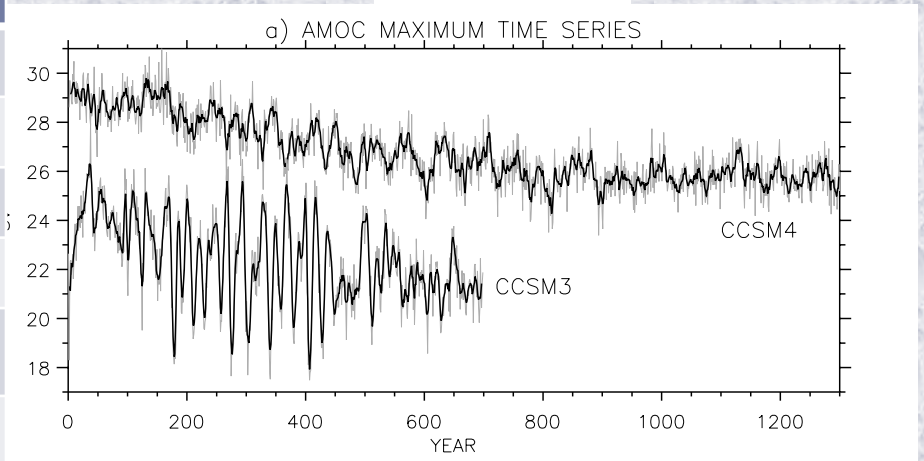
Ocean Response: Atl MOC



Ocean Response: Atl MOC



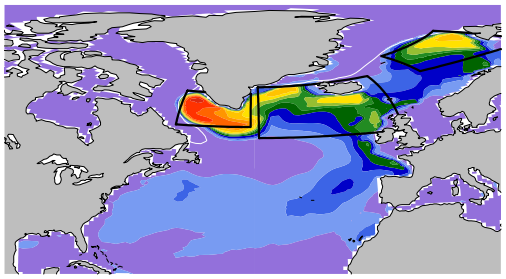
Model run (yrs)	AMOC in Sv
Ice Free summer Arctic (41-60)	21.4
Ice Free summer Arctic (81-100)	22.9
CCSM4 20th C 007 (1986-2005)	24.4
CCSM4 20th C 007 (1850-2005)	25.5
CCSM4 RCP8.5 005 (2081-2100)	17.6
CCSM4 RCP8.5 005 (2041-2060)	21.2
CCSM4 1850 control run (700-1299)	25.8



From Fig.1 in Danabasoglu et al., 2012, *JClim.*, **25**.

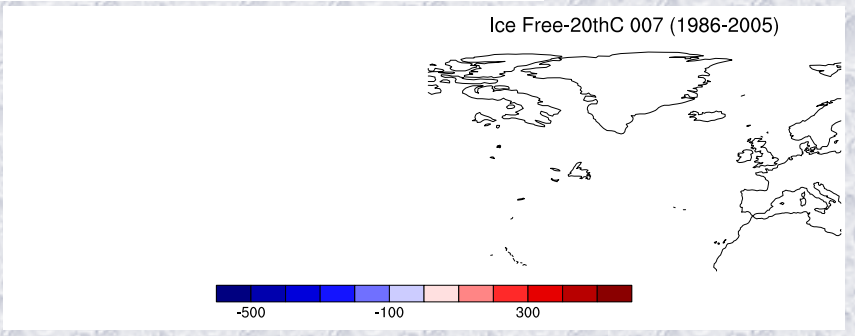
NESL

Ocean response to seasonal sea ice loss: maximum mixed layer depths

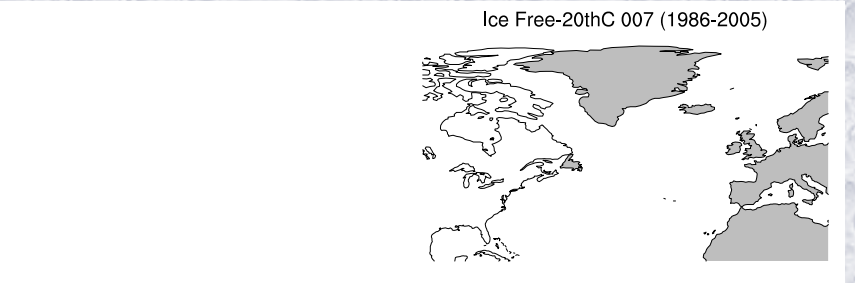


Largest max. mixed layer depths and largest changes w.r.t. 20thC and RCP8.5 in 3 regions:

- Labrador Sea
- South of Iceland
- Nordic Seas



Ice Free yrs. 41-60



Ice Free yrs. 81-100

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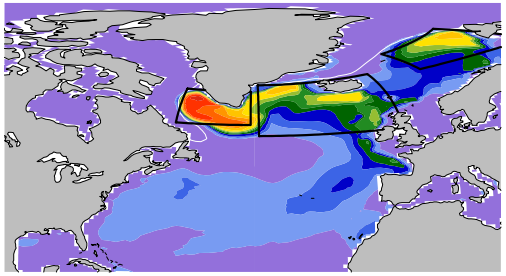

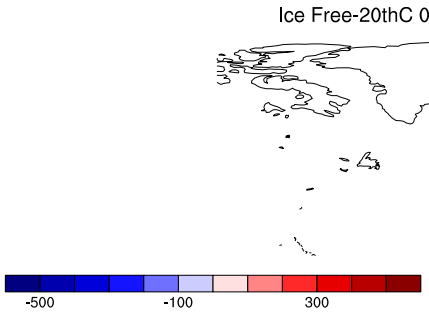

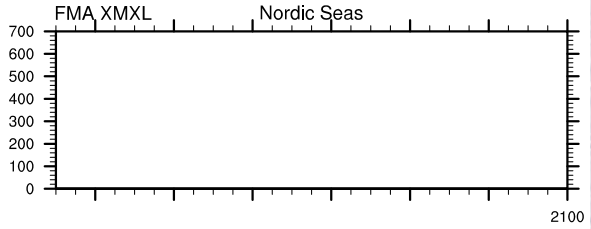

20thC 007
RCP8.5 21stC
Ice Free

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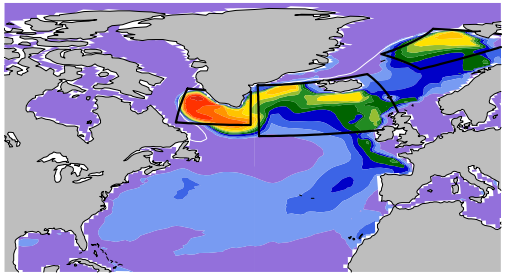
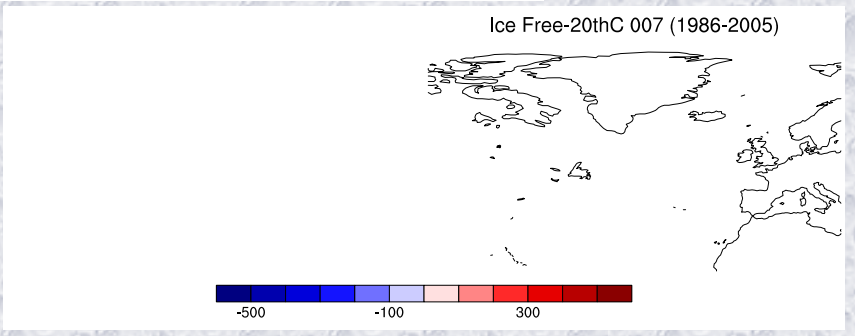
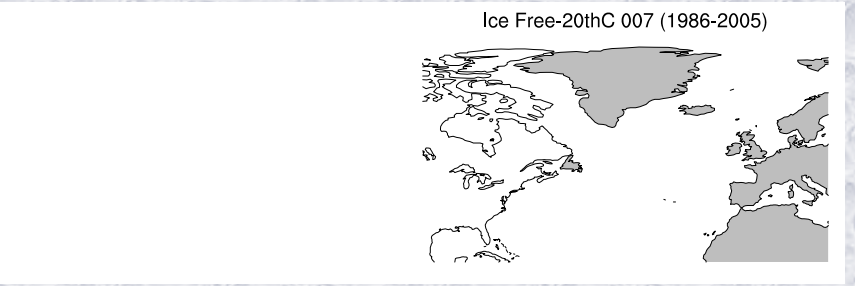
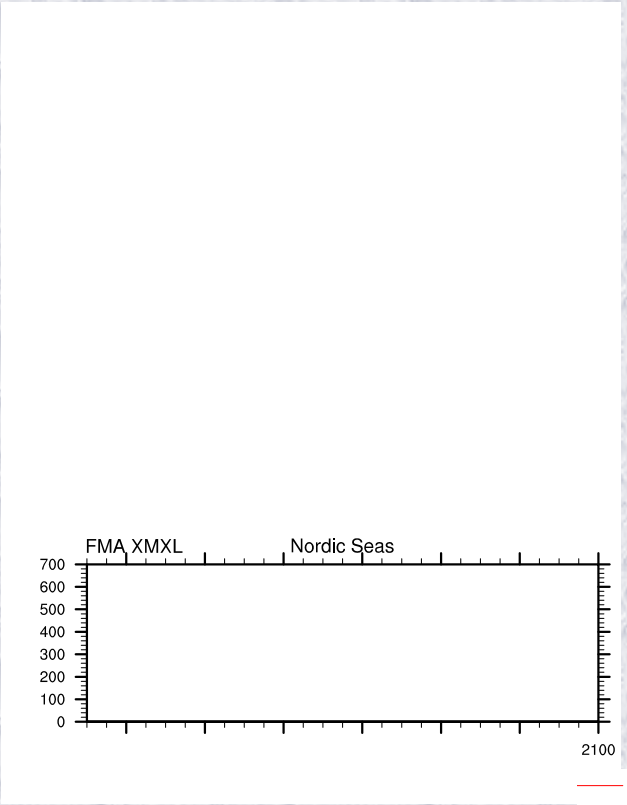
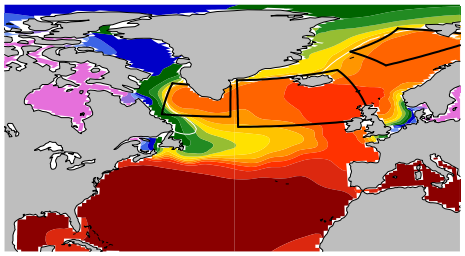


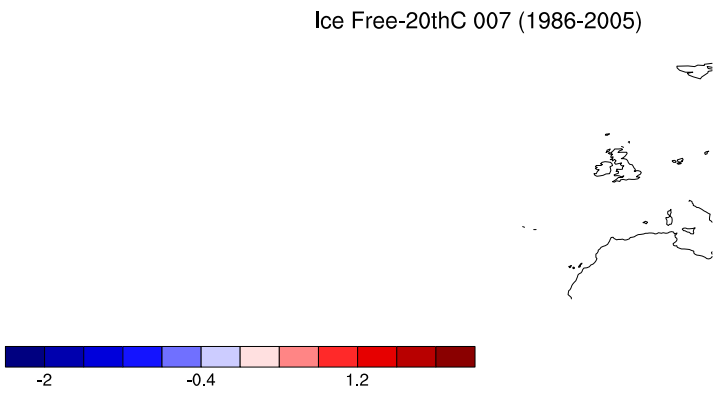


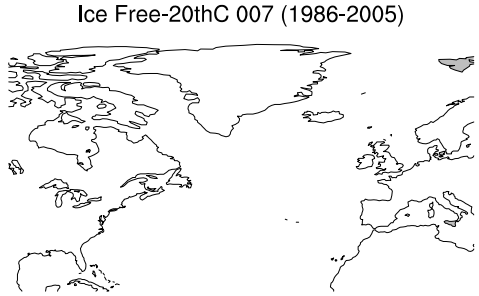




Ocean response to seasonal sea ice loss: salinity







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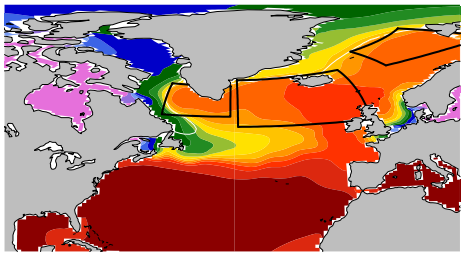

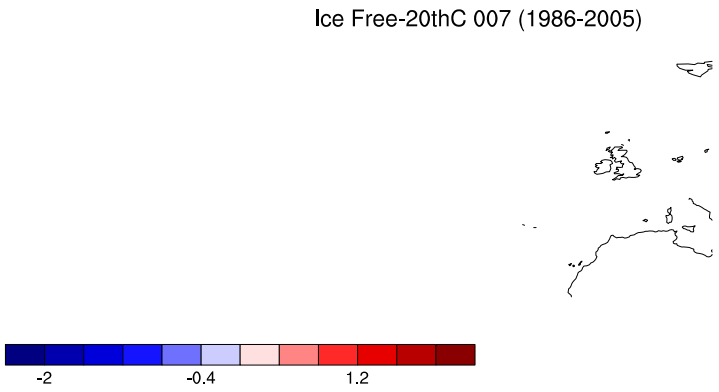

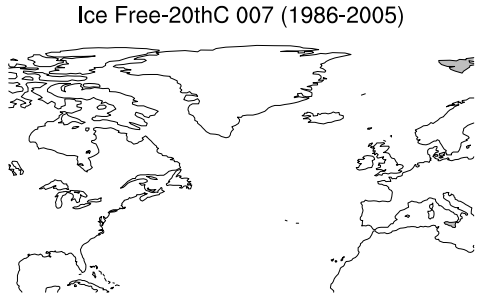

20thC 007
RCP8.5 21stC
Ice Free

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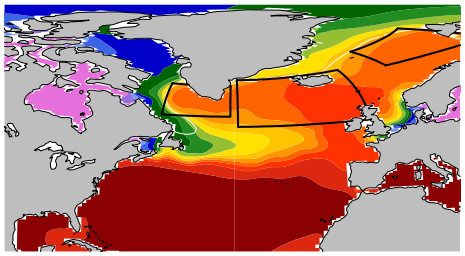
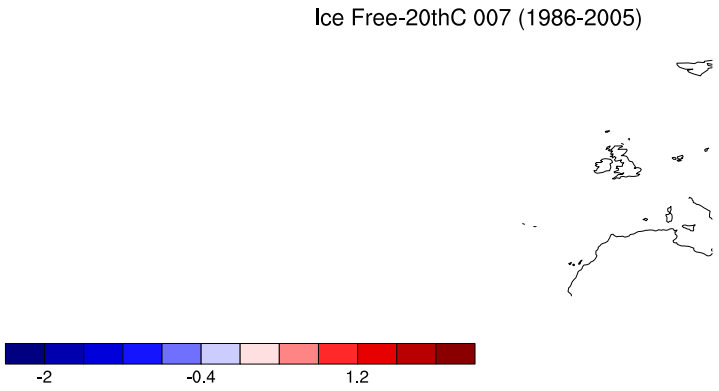
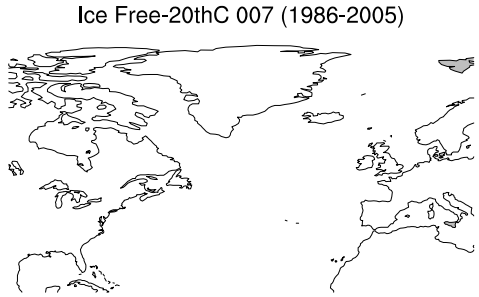
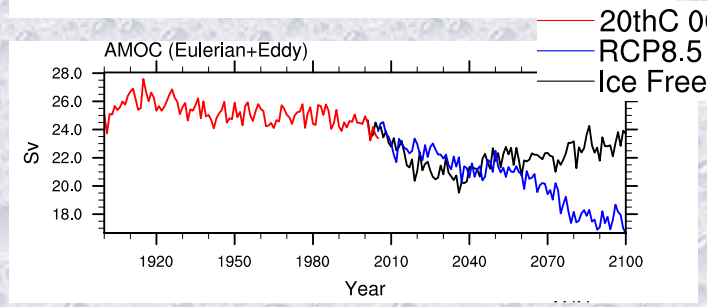
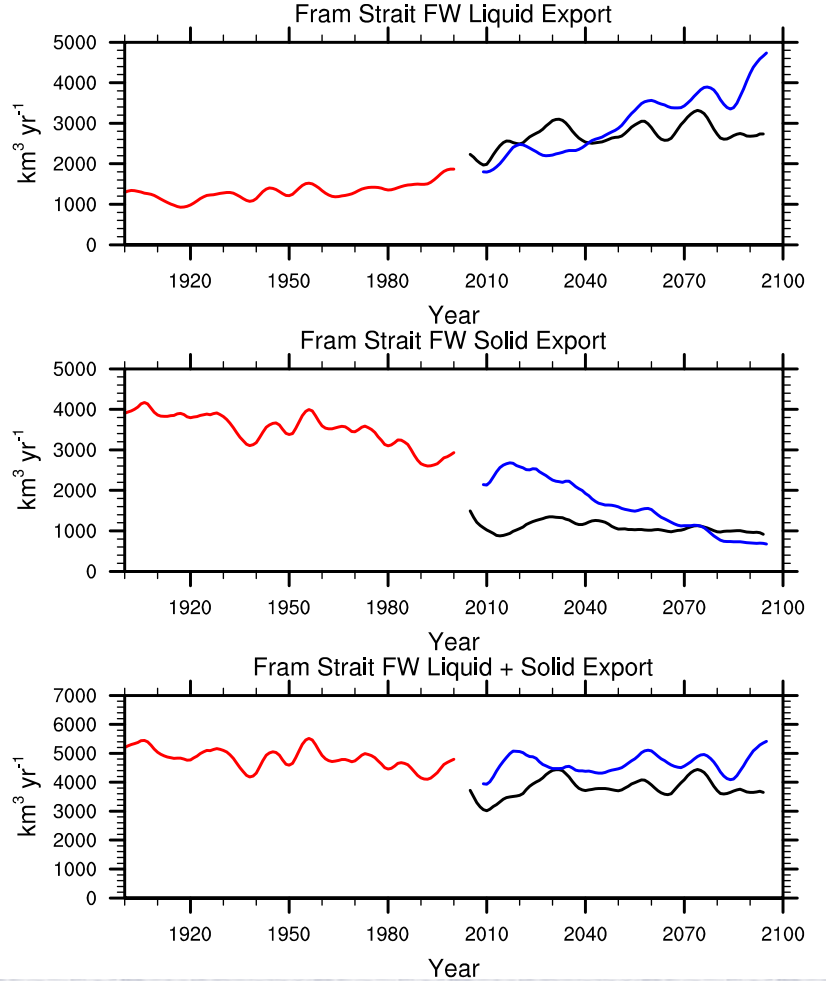


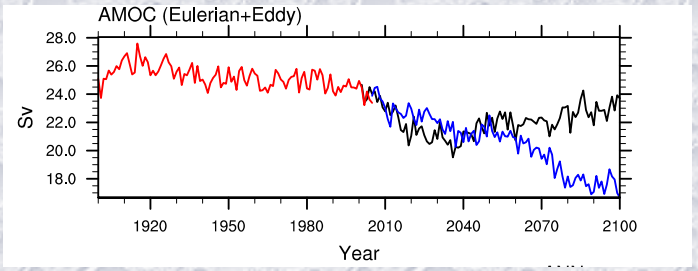






Fram Strait Freshwater transport





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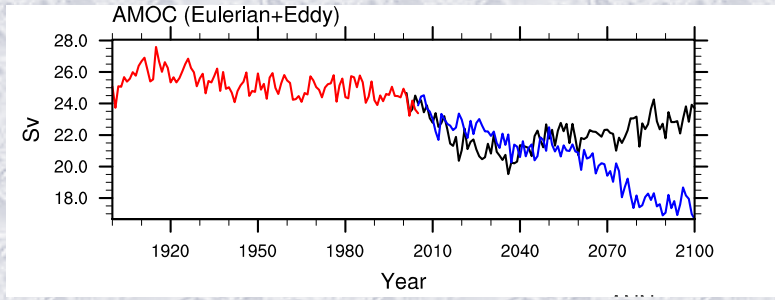
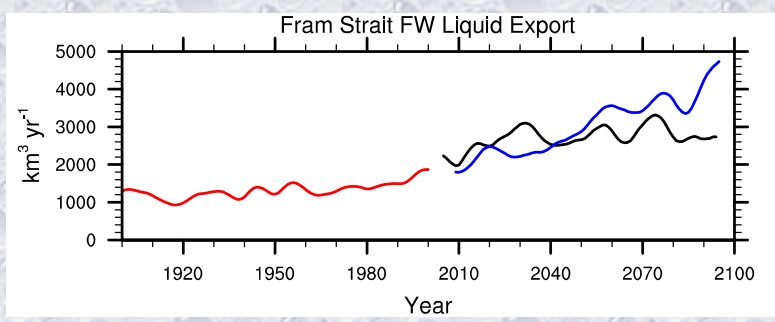
AMOC:

- Fram Strait Liquid FW transport
- Labrador Sea SSS
- Labrador Sea wintertime convection





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Summary

- CESM studies aimed at understanding effects of Arctic Sea Ice loss on ocean
- Seasonally ice-free Arctic impacts NA deep convection and the AMOC
- AMOC changes result from changes in FW export through the Fram Strait and corresponding changes in SSS and wintertime max. mixed layer depths

- What happens on longer time scales in a warming world (GHG)? Stayed tuned…..

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