

Arctic Freshwater in CMIP6: Declining Sea Ice, Increasing Ocean Storage and Export



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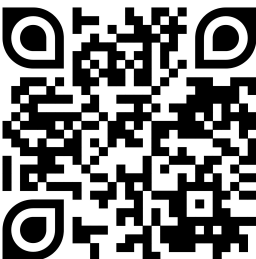


Marika Holland

National Center for Atmospheric Research

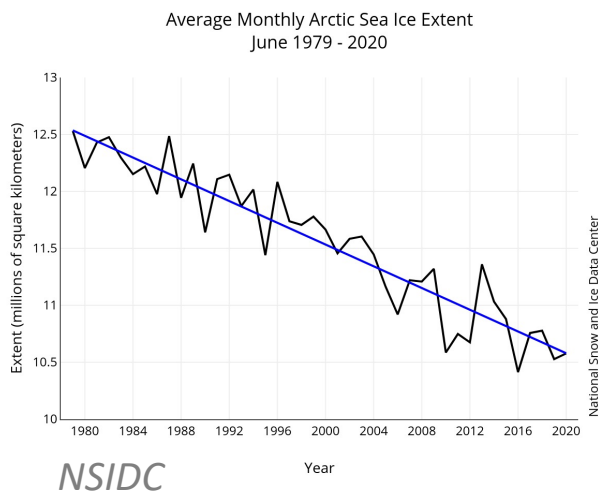


Zanowski et al., 2021, JGR: Oceans

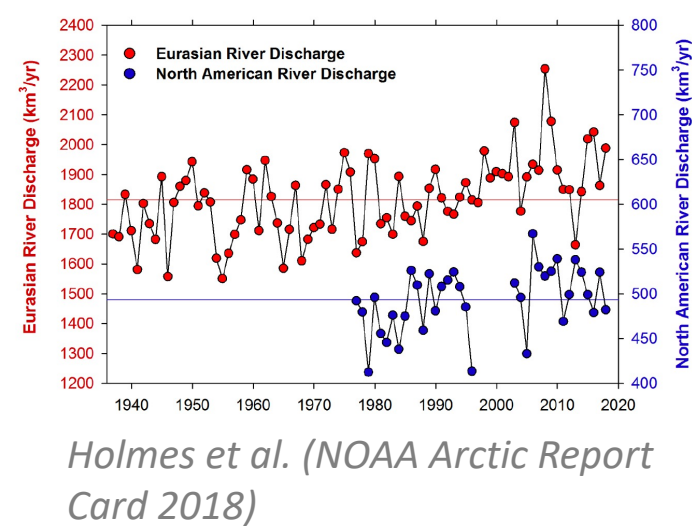


The Arctic is one of the fastest changing regions on the planet

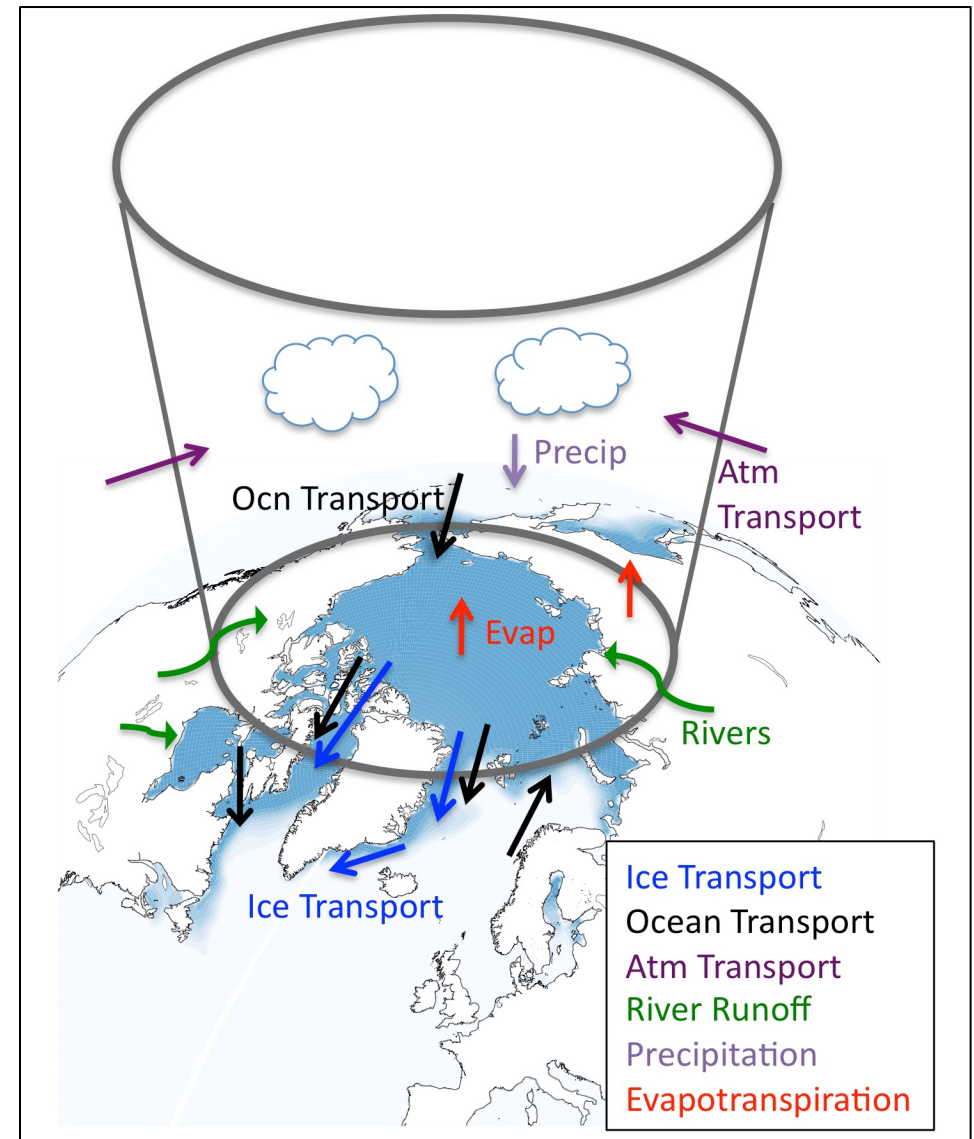
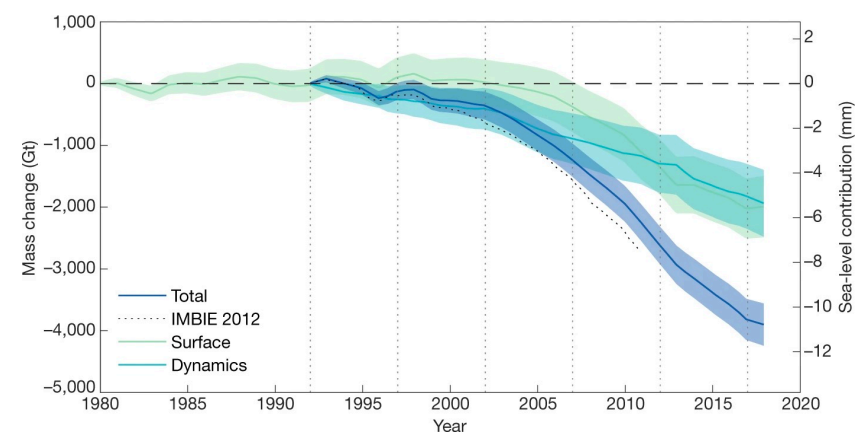
Sea ice is declining...



River Discharge is increasing...



The Greenland ice sheet is melting...



Lique et al. 2016

How will Arctic freshwater storage and fluxes change in the future?

Goal: characterize CMIP6 model Arctic freshwater storage and export during the end of the 20th and 21st centuries to understand future change

Compare ensembles from 7 CMIP6 models in 3 CMIP6 experiments:

- Historical (1980-2000)
- Shared Socioeconomic Pathways (SSPs)
 - SSP1-2.6, SSP5-8.5 (2080-2100)

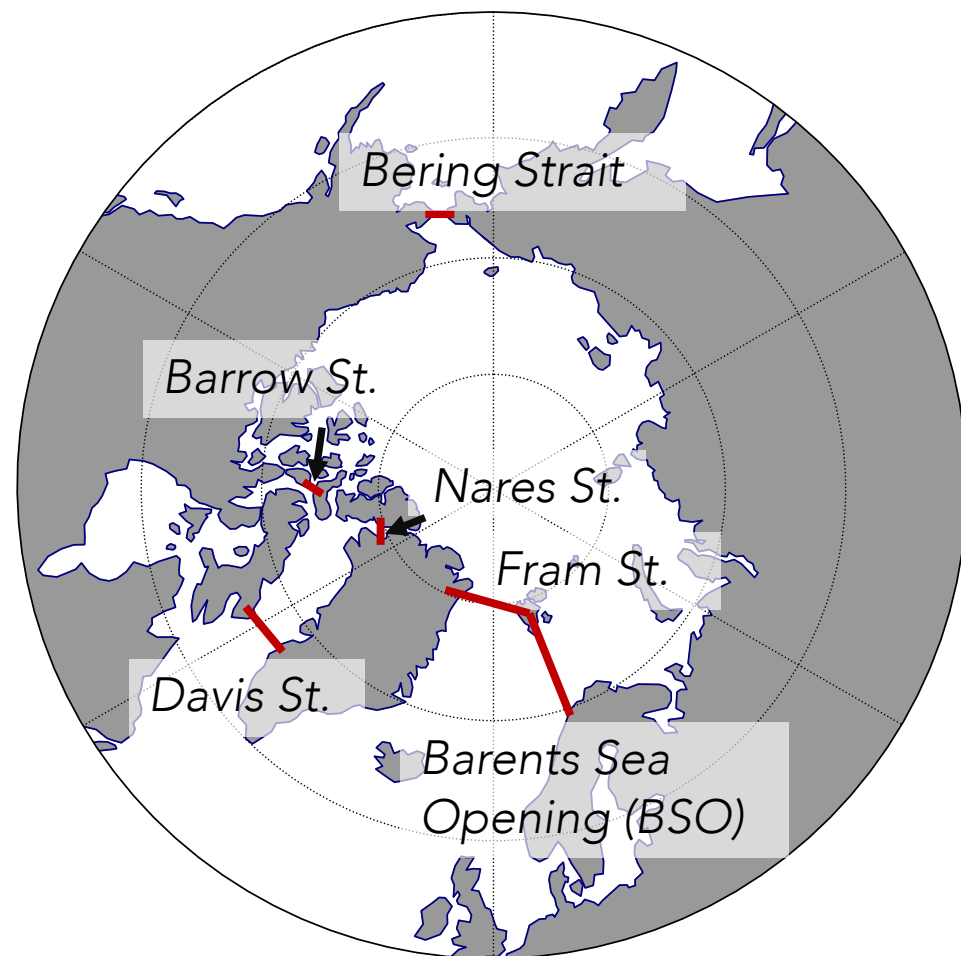
Storage: Volume in the Arctic

$$\int_A \int_z \frac{S_{ref} - S}{S_{ref}} dz dA$$

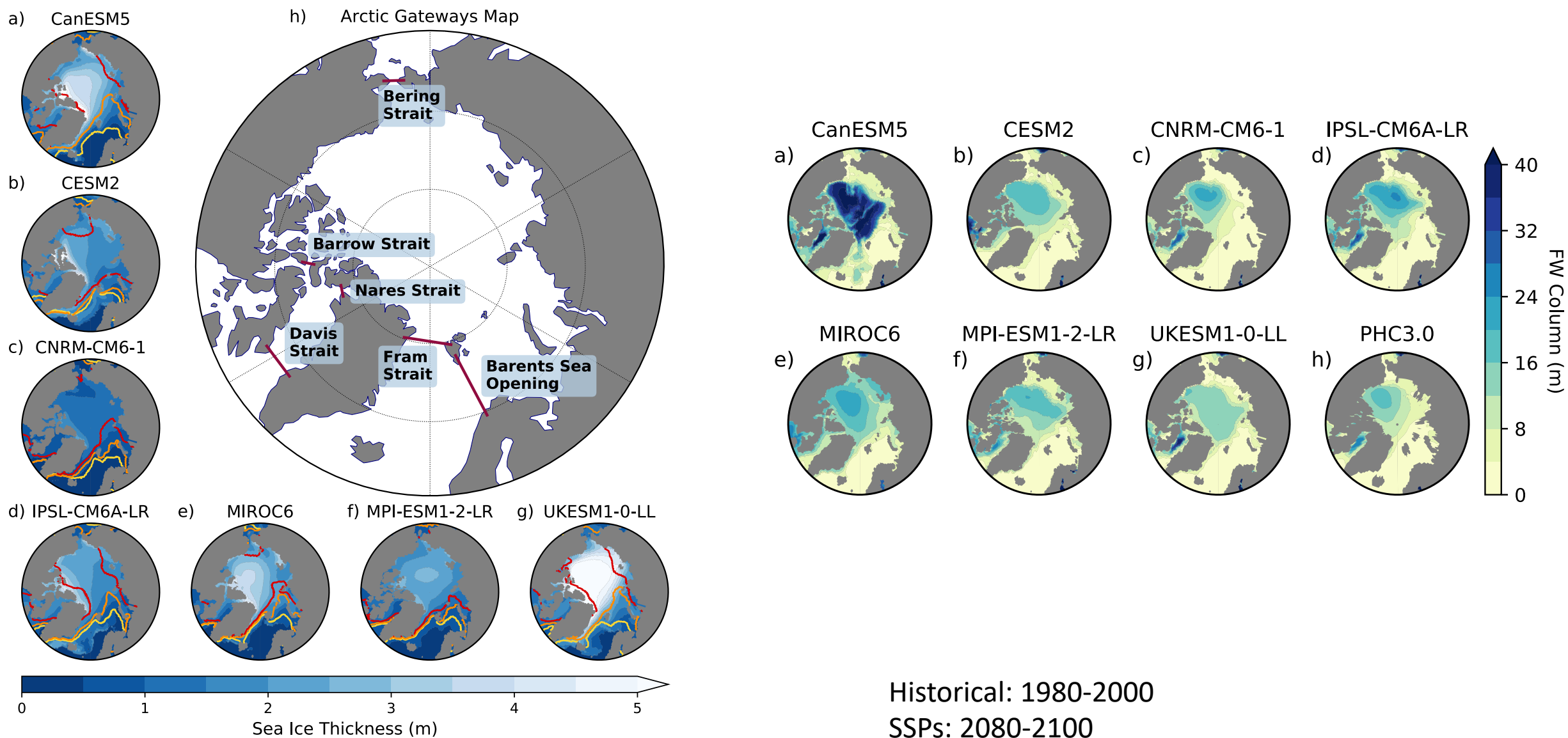
$S_{ref}=34.8$
 z =depth of S_{ref} isohaline

Export: Volume fluxes in/out of the Arctic

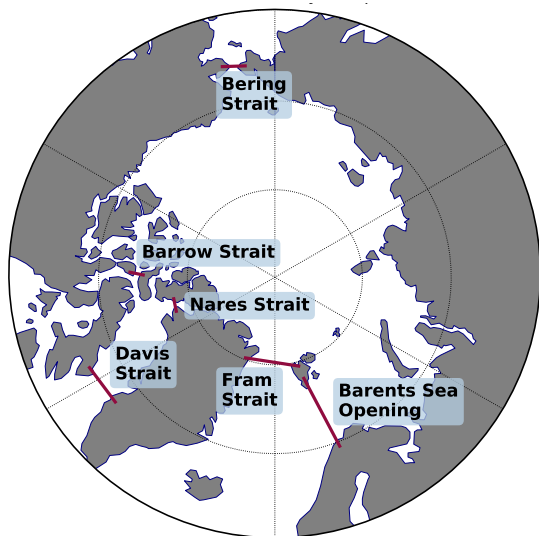
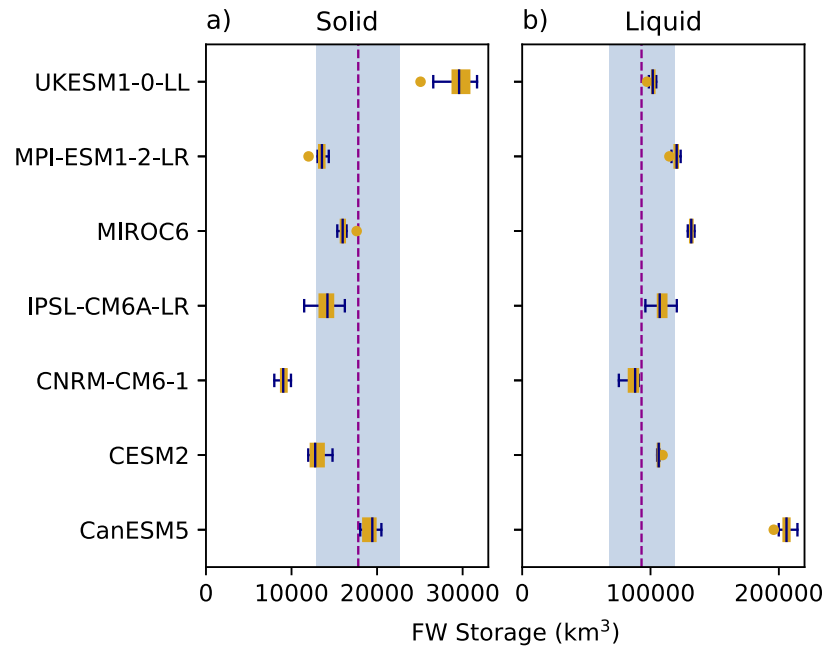
$$\int_A \frac{S_{ref} - S}{S_{ref}} \vec{u} \cdot \hat{n} dA$$



Model ensemble mean sea ice thickness and freshwater column

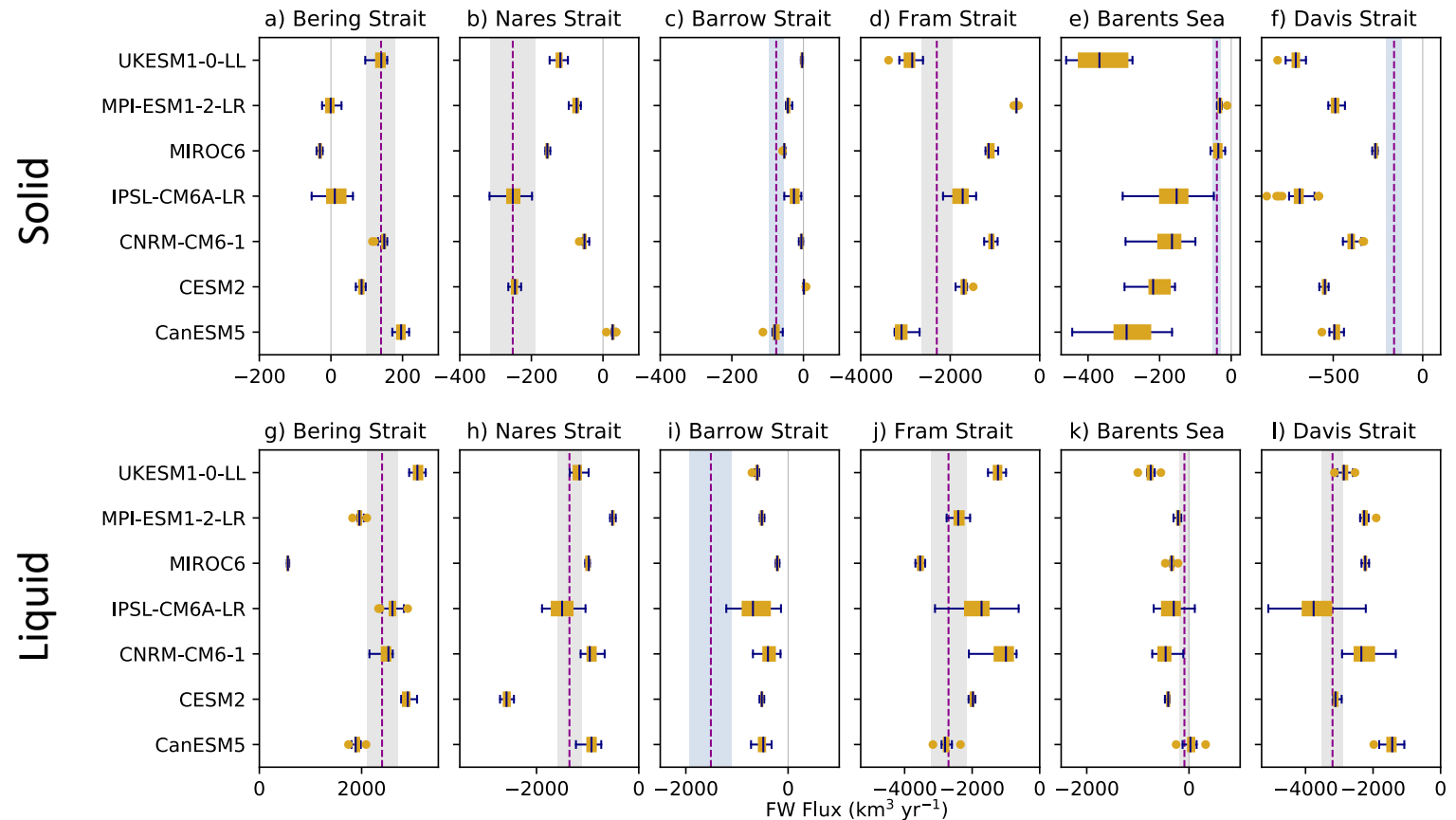


Historical storage and fluxes vary widely across models and disagree with observations

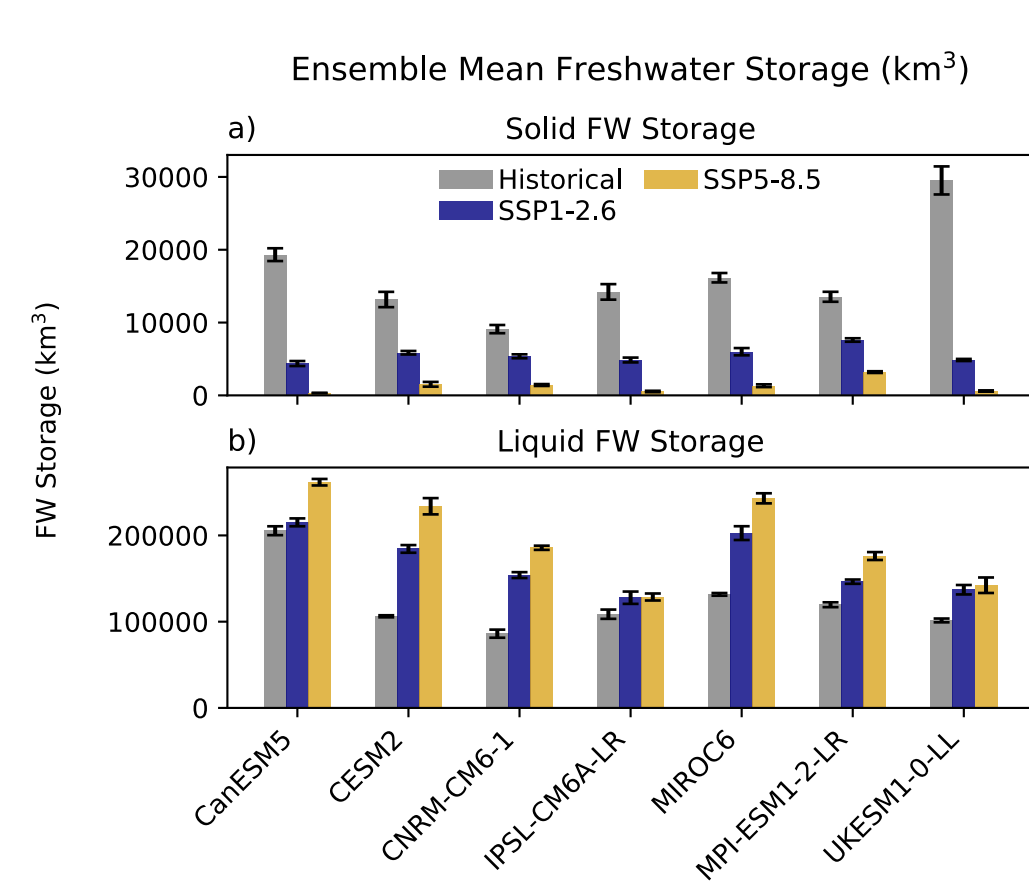


Historical: 1980-2000
SSPs: 2080-2100

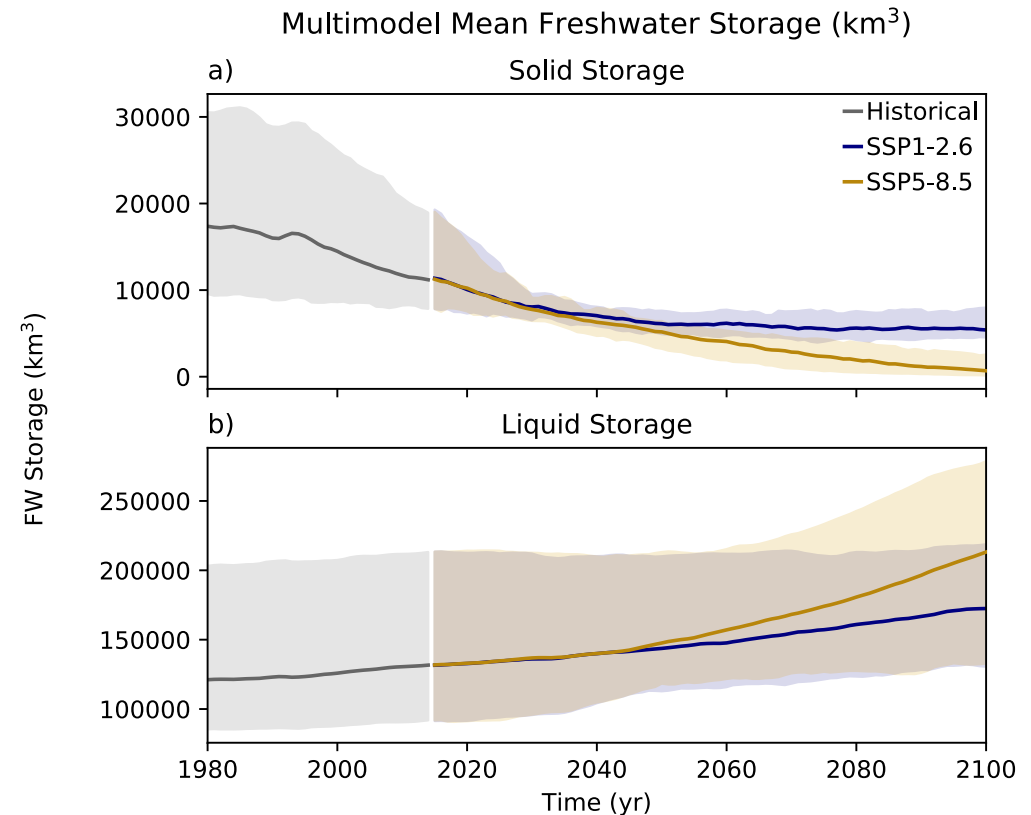
Sign Convention:
+ Into the Arctic
– Out of the Arctic



Future solid freshwater storage declines while liquid freshwater storage increases

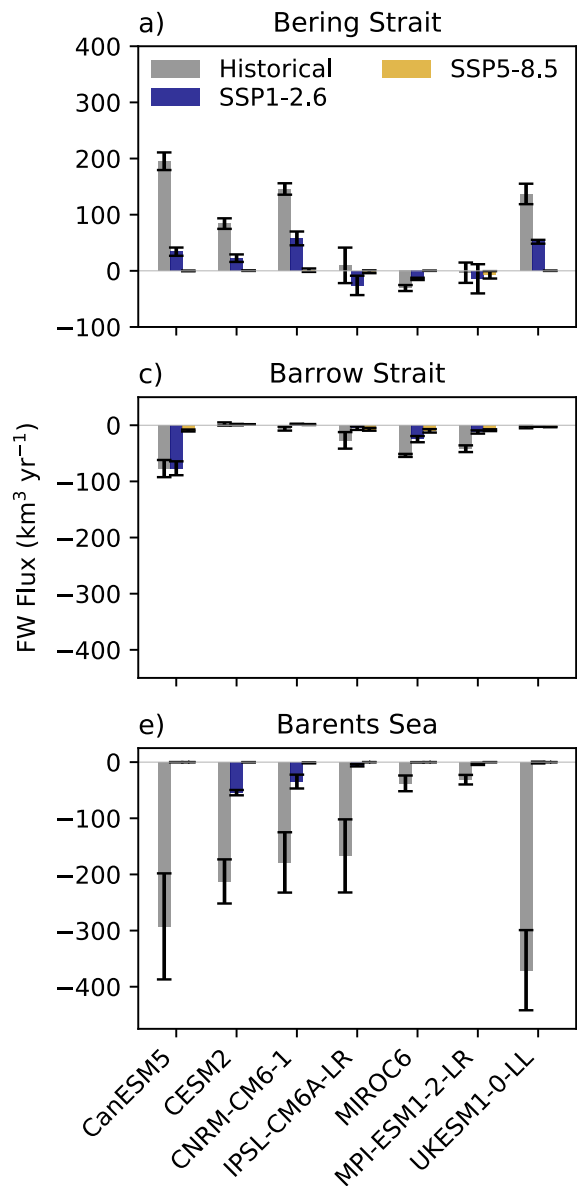


Historical: 1980-2000
SSPs: 2080-2100



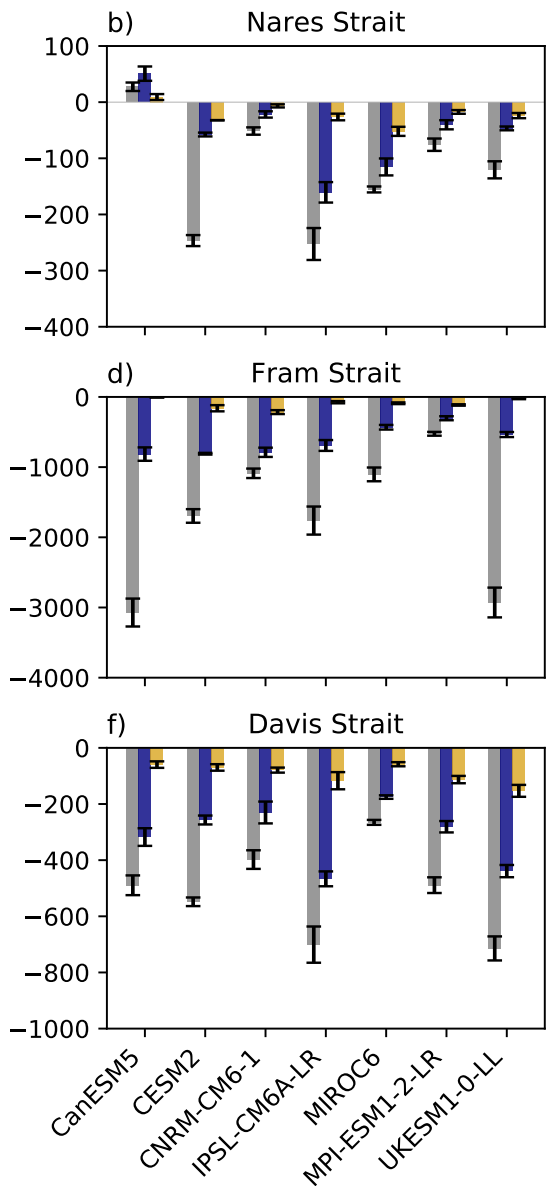
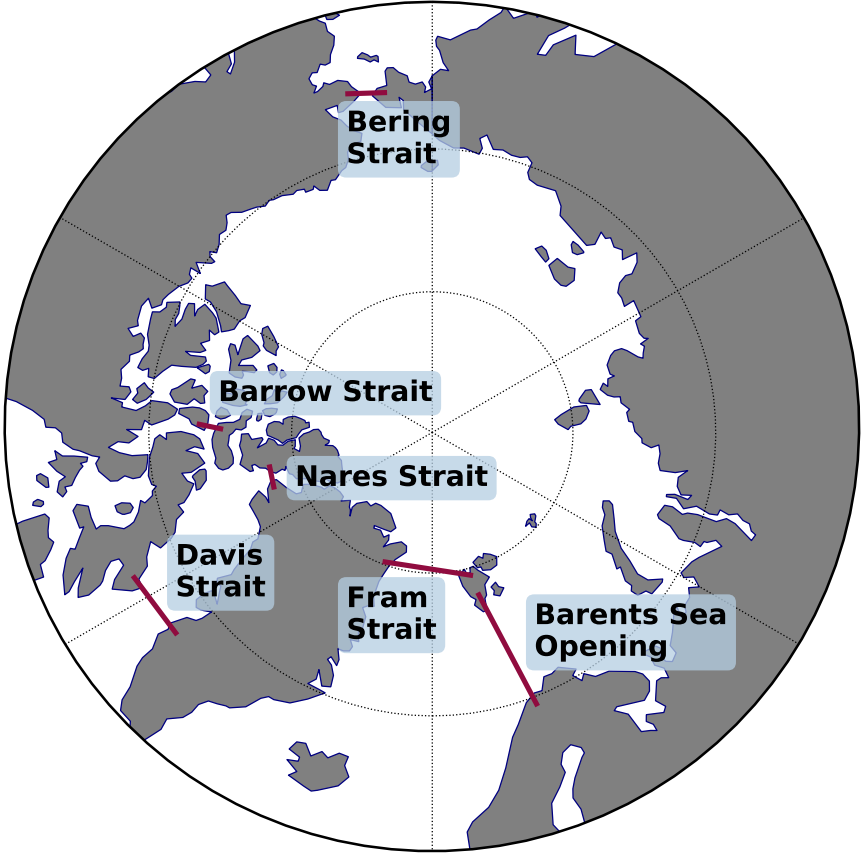
- Multimodel mean = mean of ensemble means of each of the 7 models
- Envelopes show the max/min of the 7 ensemble means

All models show future declines in solid freshwater fluxes

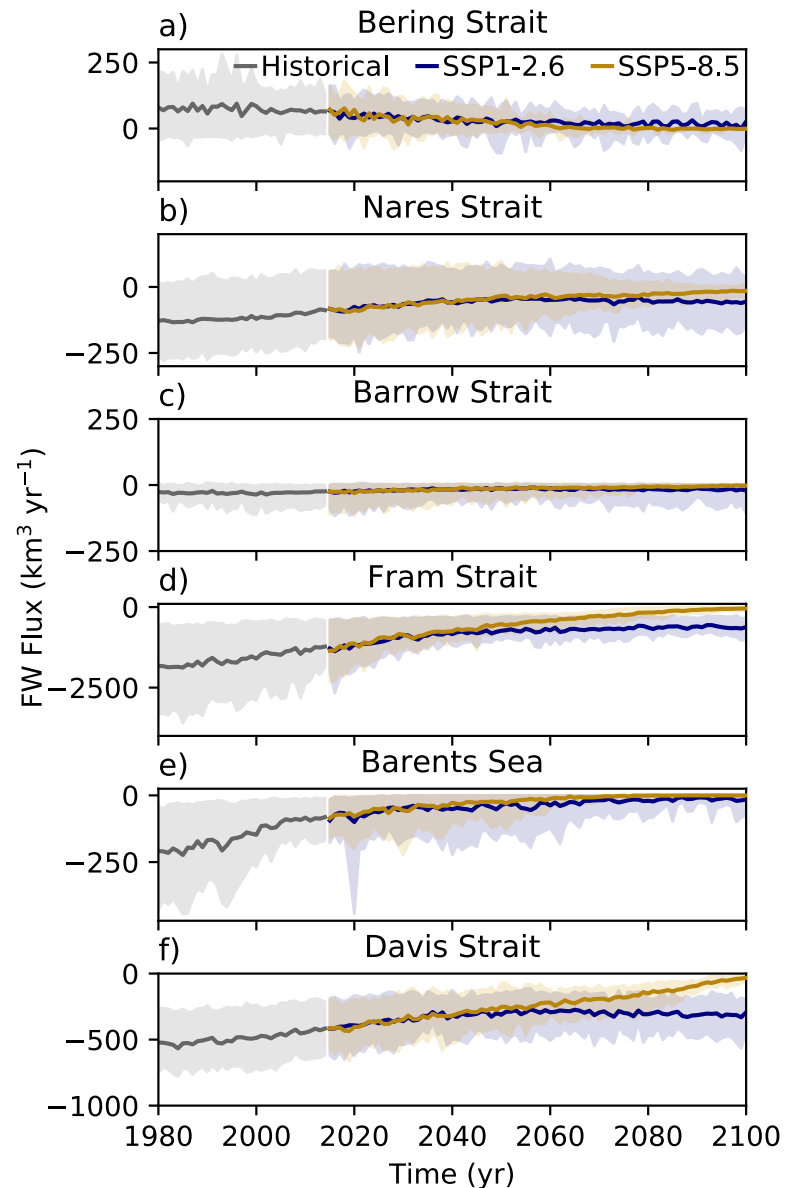


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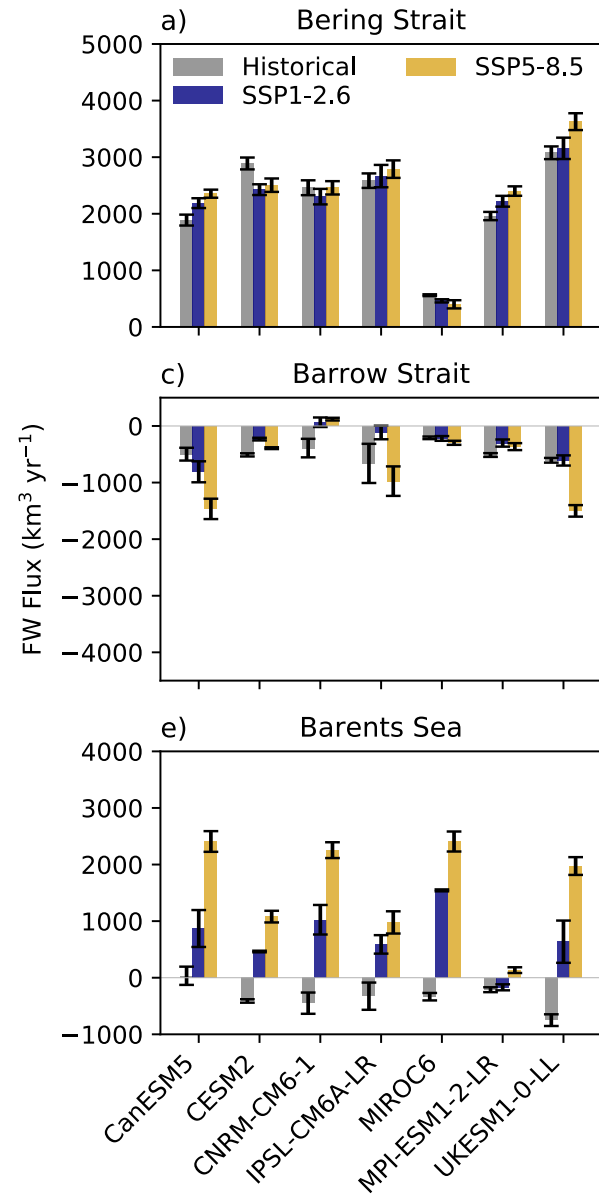
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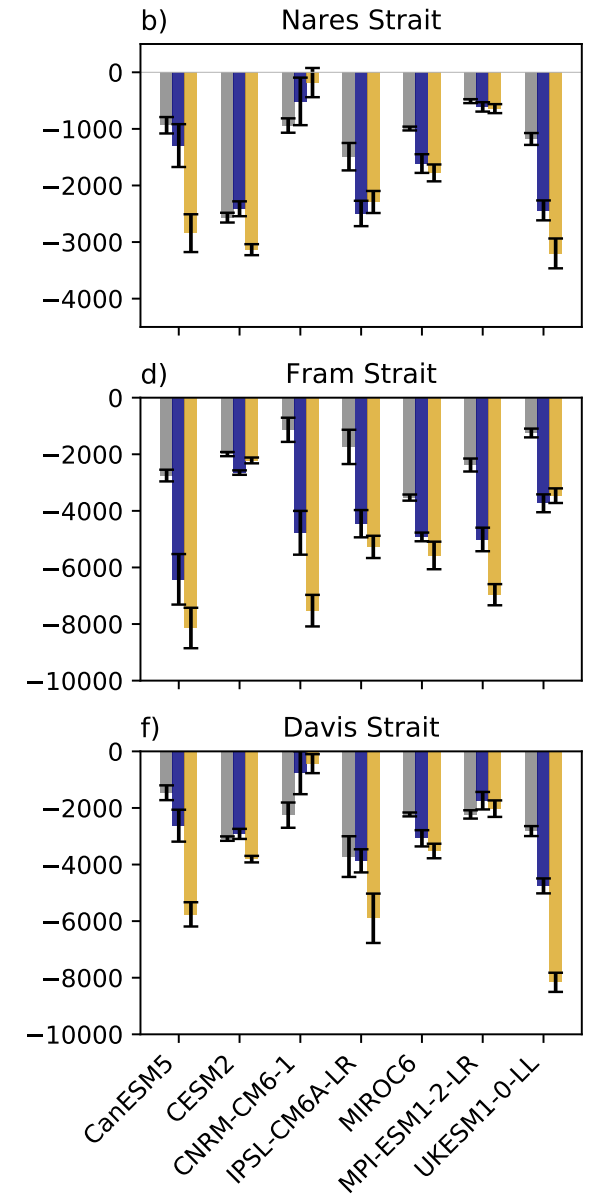
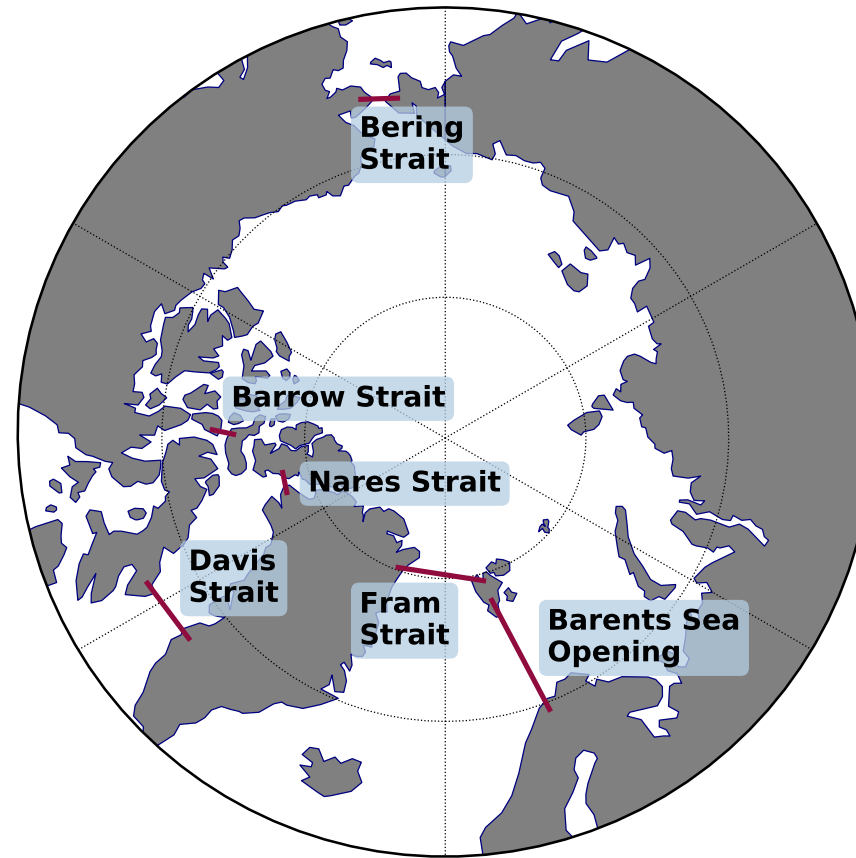
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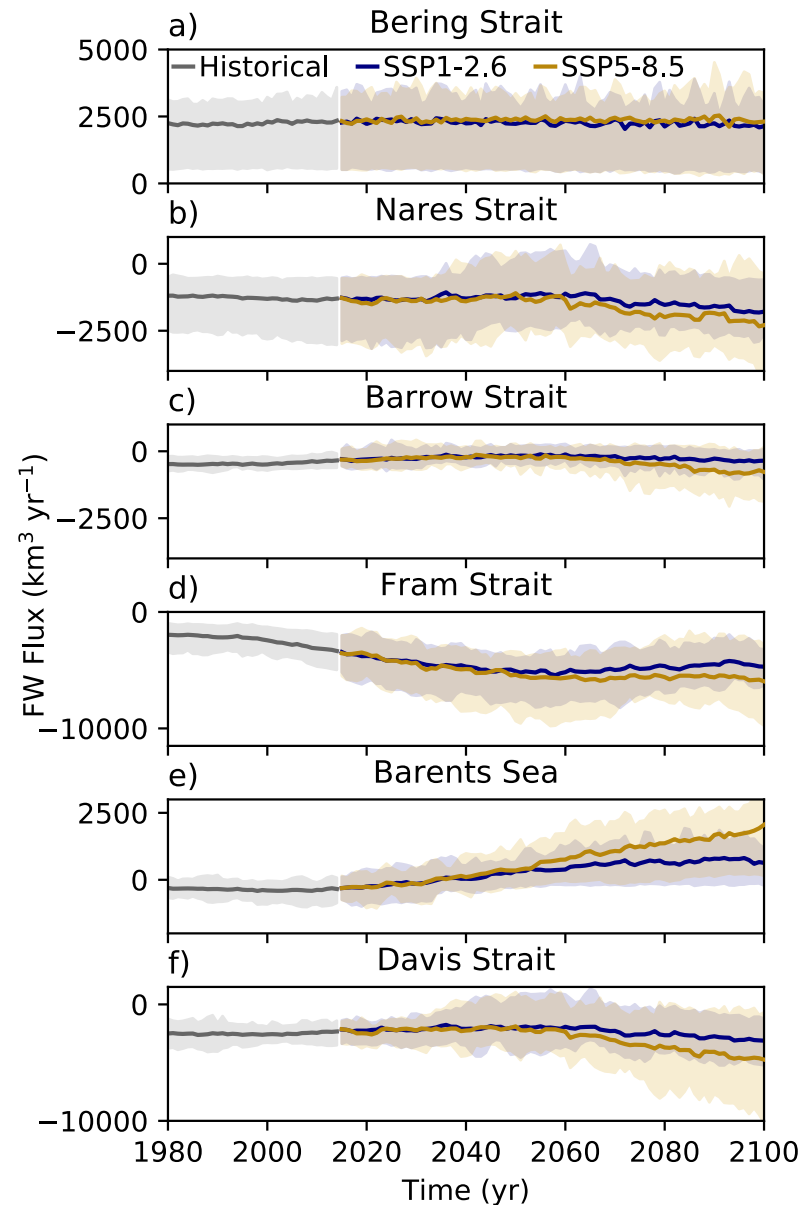
Future liquid fluxes show increased freshwater export except for Bering Strait and the Barents Sea Opening



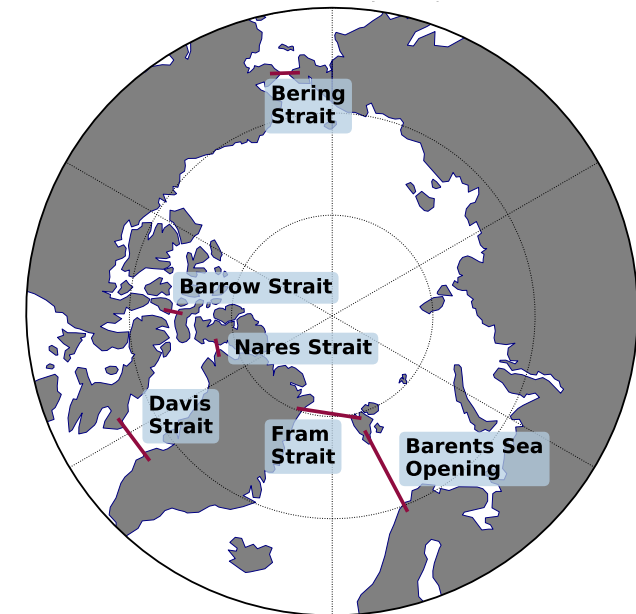
Historical: 1980-2000
SSPs: 2080-2100



Future liquid fluxes show increased freshwater export except for Bering Strait and the Barents Sea Opening



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Why does the BSO liquid flux change sign in the future?

Transport: Volume fluxes in/out of the Arctic

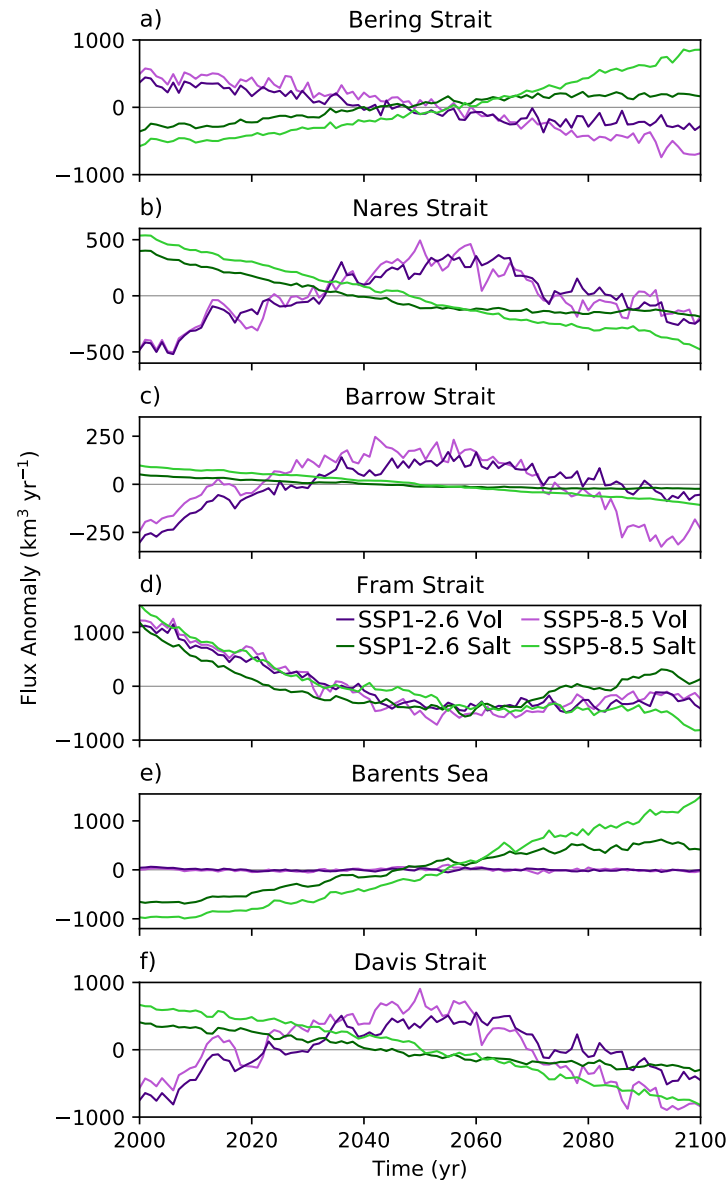
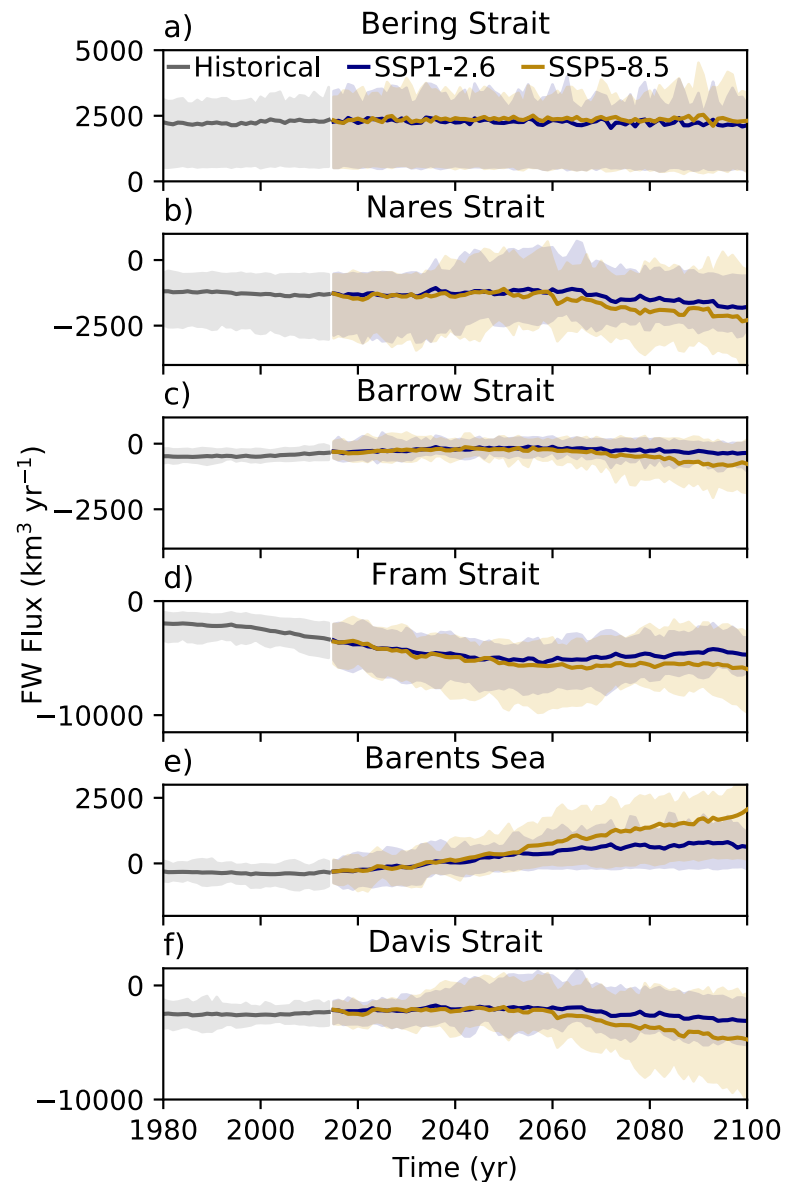
$$\int_A \frac{S_{ref} - S}{S_{ref}} \vec{\mathbf{u}} \cdot \hat{n} dA$$

Decompose freshwater fluxes to get separate time-varying salinity and volume contributions

$$\int_A \frac{S_{ref} - (\bar{S} + S')}{S_{ref}} (\bar{\mathbf{u}} + \mathbf{u}') \cdot \hat{n} dA$$

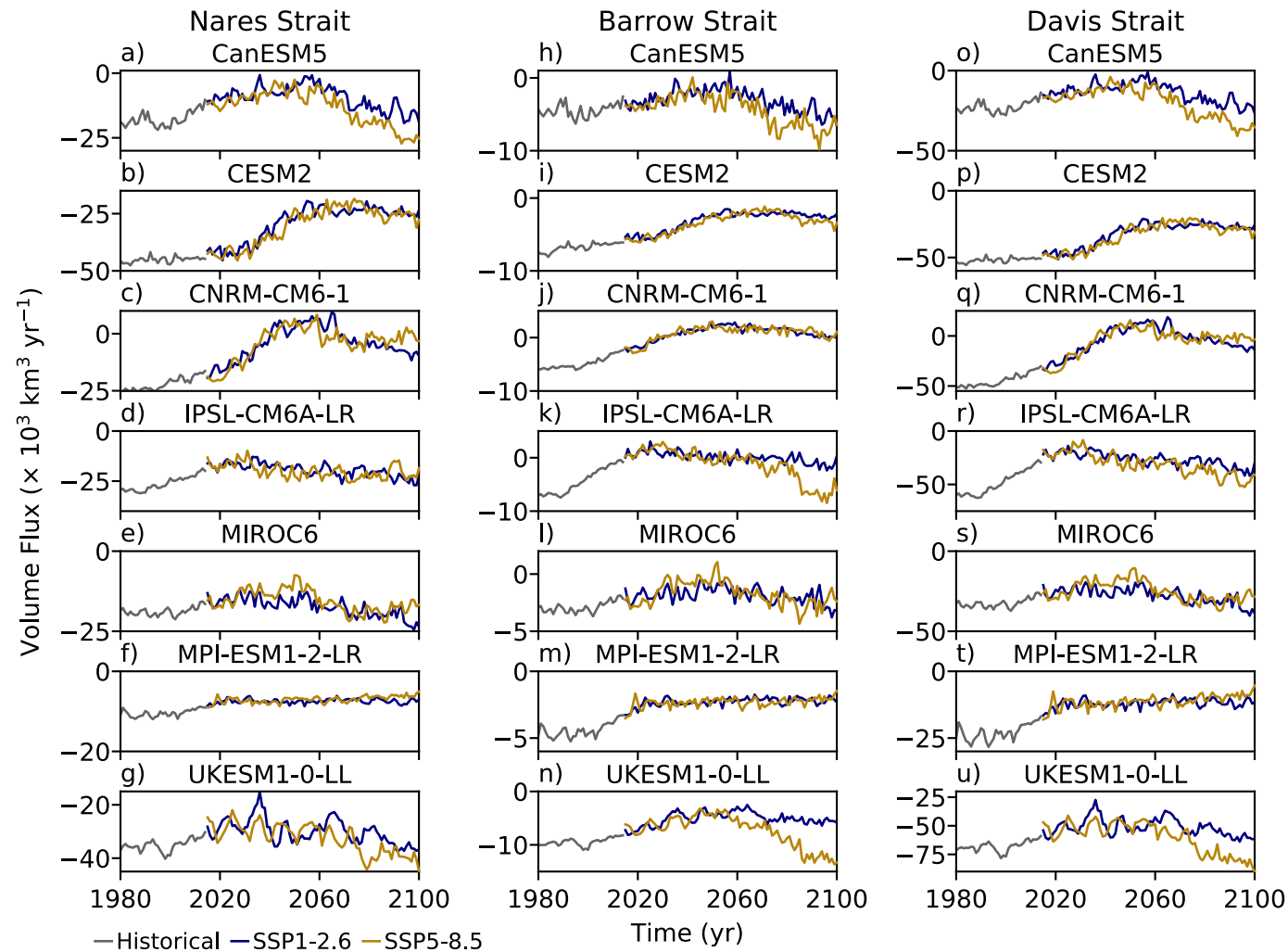
Anomalies relative to 2000-2100 mean

The relative importance of volume/salinity changes depends on the strait



Positive trends =
Arctic freshening

The multimodel mean hides major model differences in the straits west of Greenland



Conclusions

- Freshwater storage and fluxes over 1980-2000 vary widely across models and few are consistently close to observations
- In the future scenarios all models exhibit strong declines in solid storage and fluxes as Arctic sea ice coverage declines
- Liquid freshwater storage and export generally increase in the future in all models
 - Exceptions include the Barents Sea Opening freshwater flux which reverses sign due to freshening and the Bering Strait freshwater flux, which is fairly stable
- The magnitude of all changes are highly model dependent

All models suggest an acceleration of the Arctic freshwater cycle and a dynamically different Arctic by the end of the 21st century