A Weakened AMOC may prolong greenhouse gas induced Mediterranean drying even with significant and rapid reductions in greenhouse gas emissions after 2040

Thomas L. Delworth, William F. Cooke, Vaishali Naik, David Paynter, and Liping Zhang
Geophysical Fluid Dynamics Laboratory/NOAA
Princeton, NJ USA
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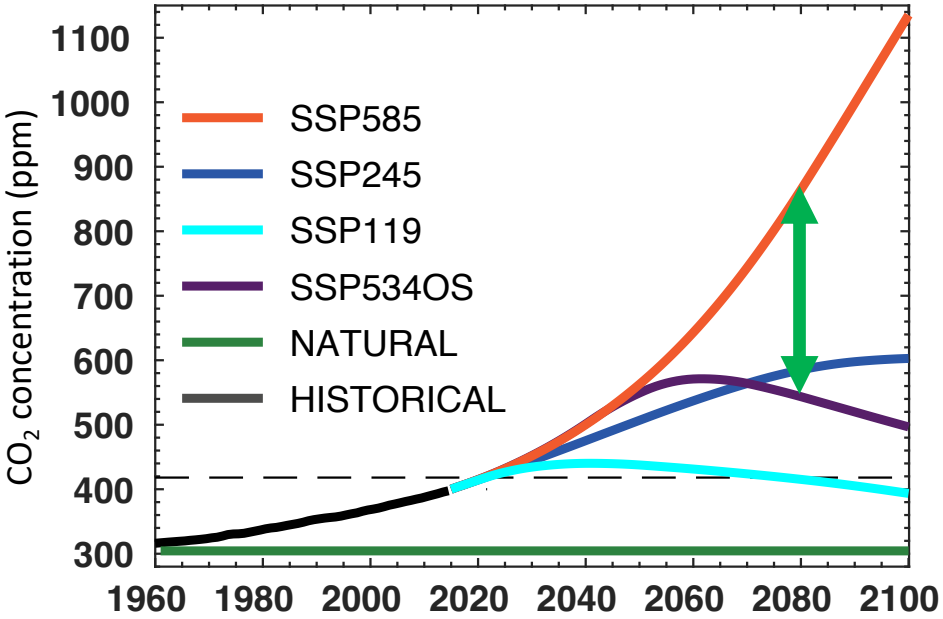
We use large ensembles of a high-resolution climate model driven by various radiative forcing scenarios over the 21st century to explore, and find:

- Mediterranean winter precipitation declines in response to increasing greenhouse gases
- Decline in greenhouse gases after mid 21st century does not induce precipitation recovery
- A persistently weakened AMOC creates atmospheric teleconnection patterns that prolong the Mediterranean drying

Explore climate reversibility using 30-member ensembles

- *For each scenario we run a 30-member ensemble over the period 1921-2100*
- *Use GFDL SPEAR (50 km atmospheric resolution, 1° ocean)*
- *Each scenario has prescribed CO_2, CH_4, and other forcing agents*



Some results regarding reversibility …

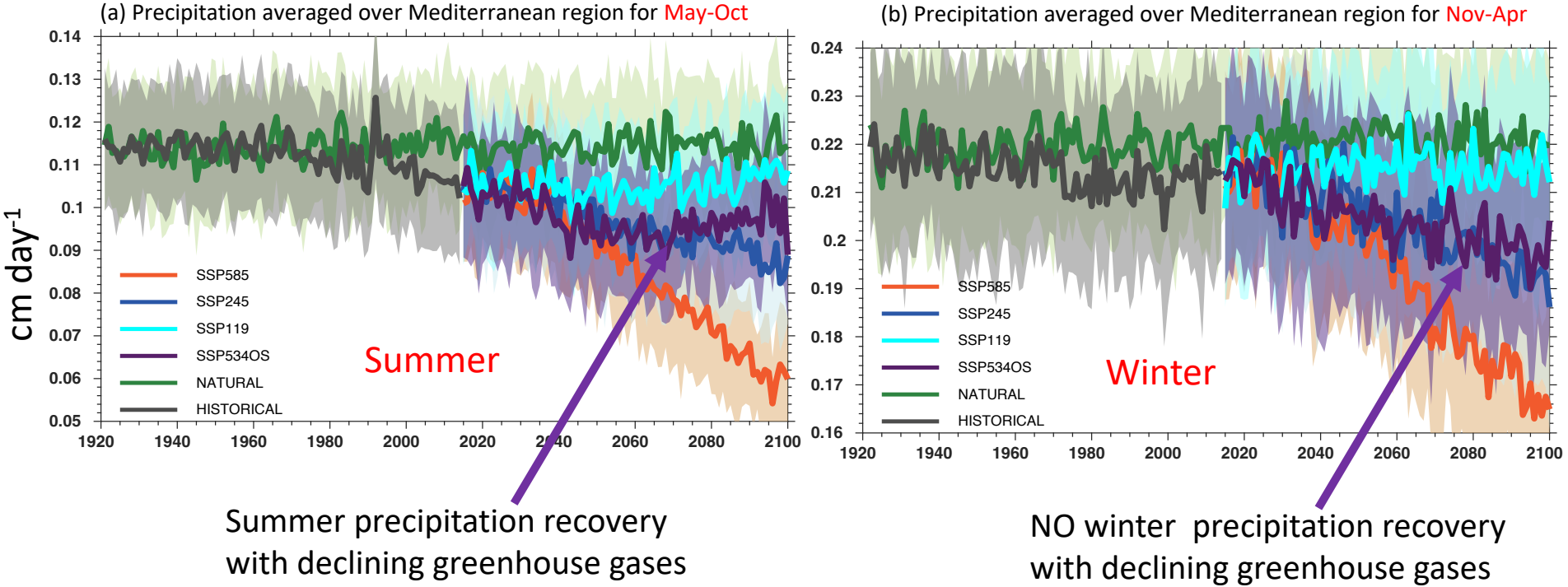
Temperature – follows greenhouse gases with lag
Arctic Sea Ice – follows greenhouse gases with lag

AMOC – little to no recovery in 21st century

Mediterranean precipitation – surprising behavior!

- *For SSP534OS CO_2 and CH_4 decline after mid century.*

A curious surprise for Mediterranean winter precipitation … it declines when greenhouse gases are increasing … and when they are decreasing.

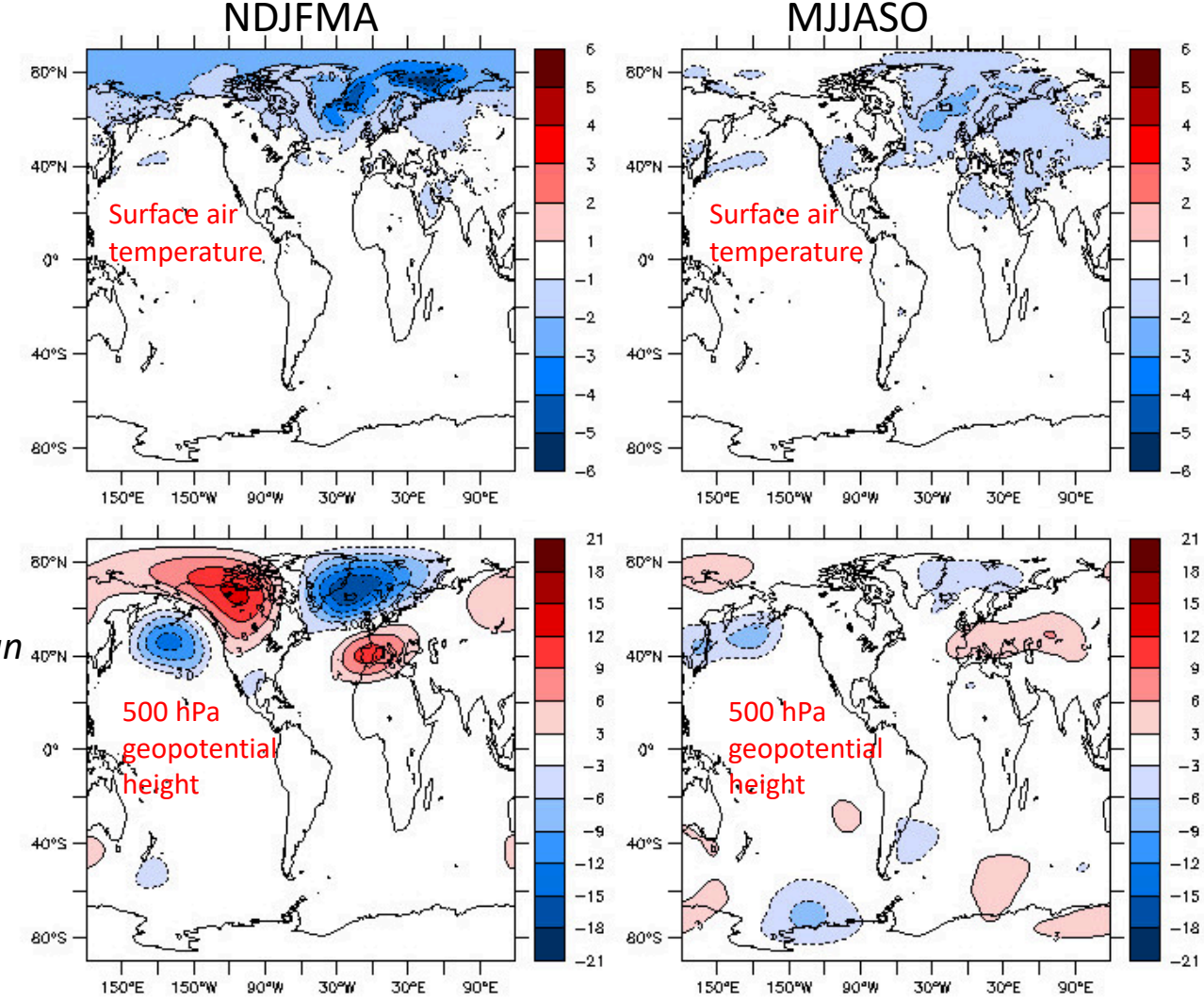


➔ *For this model, continued decline of winter Mediterranean precipitation is related to AMOC weakening and sea ice growth.*

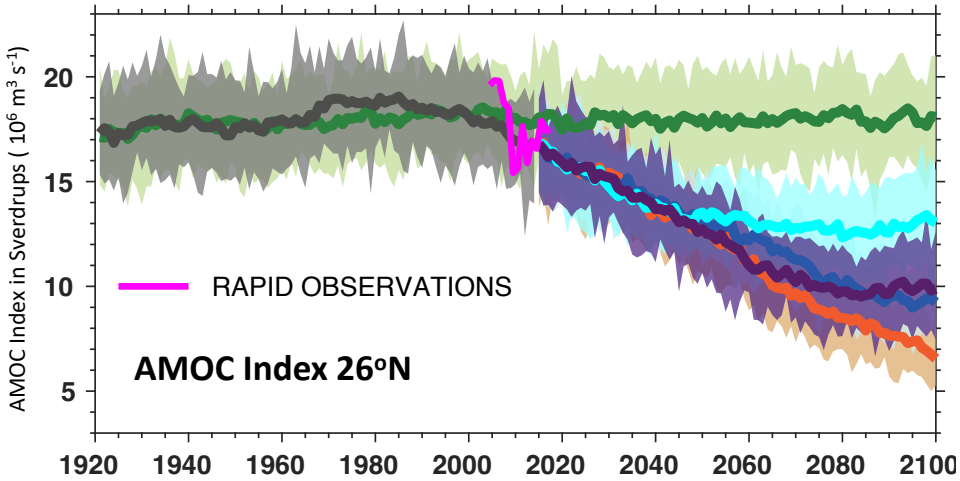
SSP534OS:

Yrs 2081-2100
Minus
Yrs 2041-2060

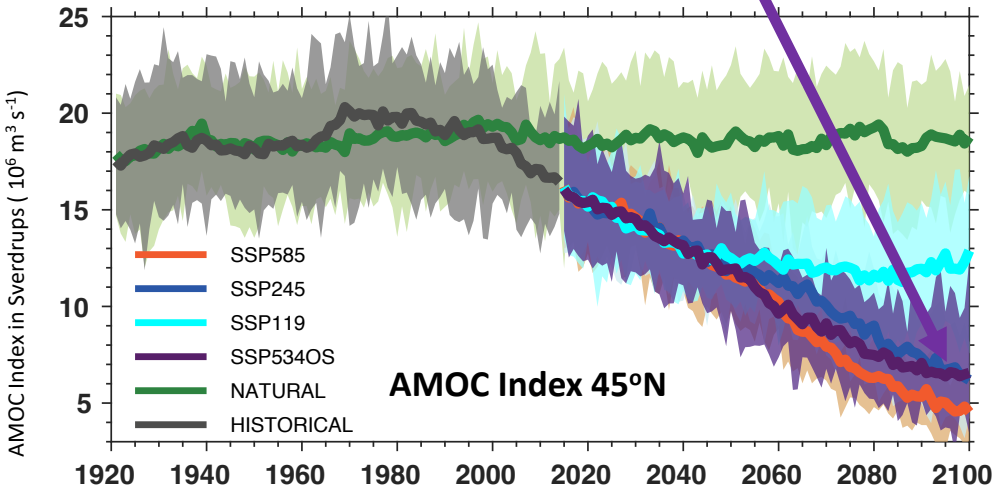
Cooling in Norwegian and Greenland Seas appears to drive atmospheric teleconnection that impacts Mediterranean precipitation



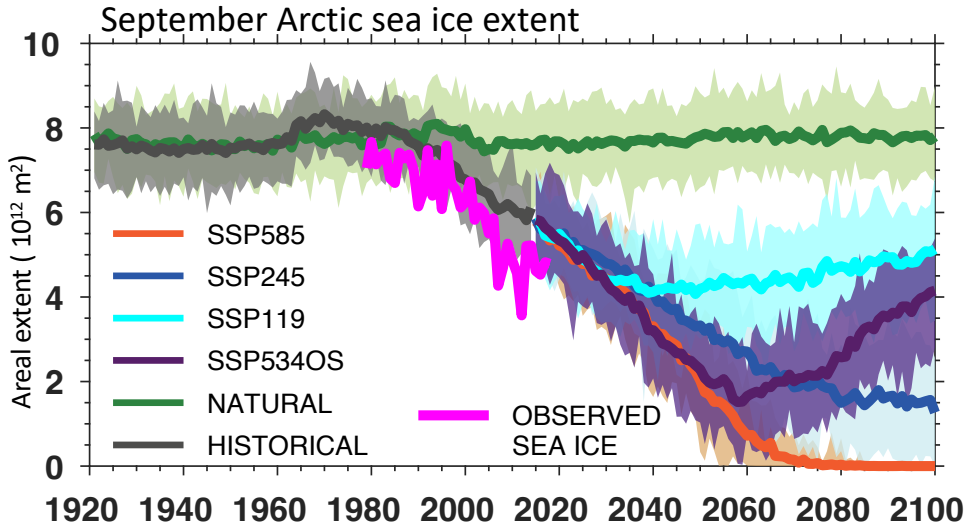
Little to no recovery of Atlantic Meridional Overturning Circulation (AMOC) by 2100



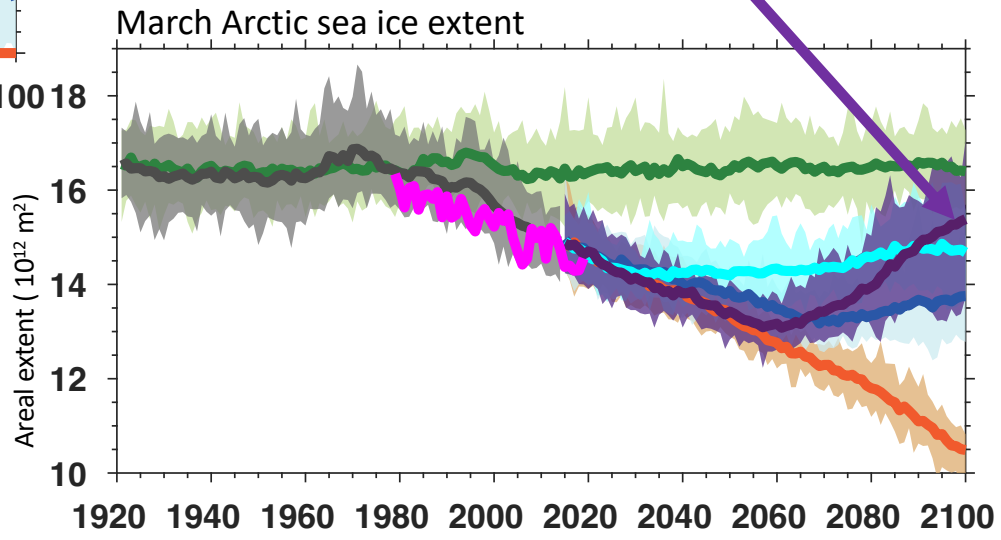
AMOC still declining in subpolar gyre for SSP534OS in year 2100



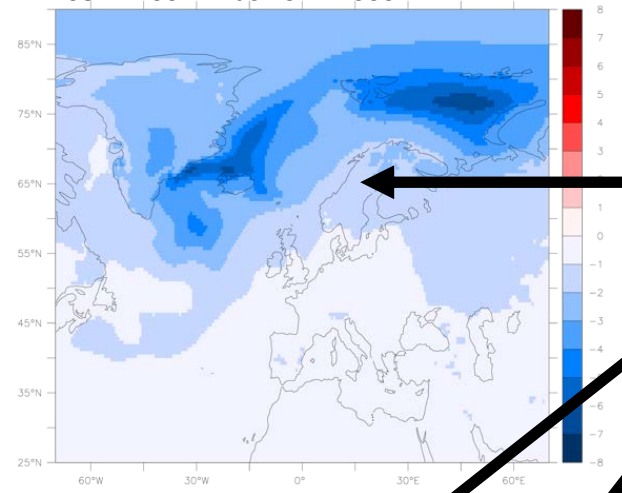
Recovery of Arctic Sea Ice Extent after emissions reduction



"Rapid recovery": *March Arctic sea ice extent for SSP534OS is approaching 1920 levels by the year 2100.*



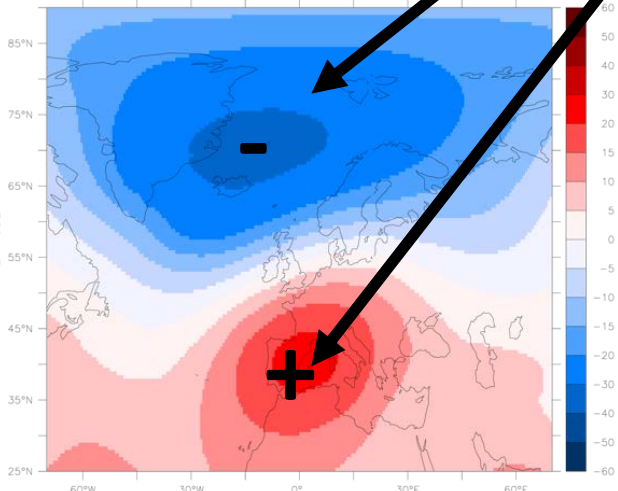
Response of DJF surface air temperature
2081-2100 minus 2041-2060



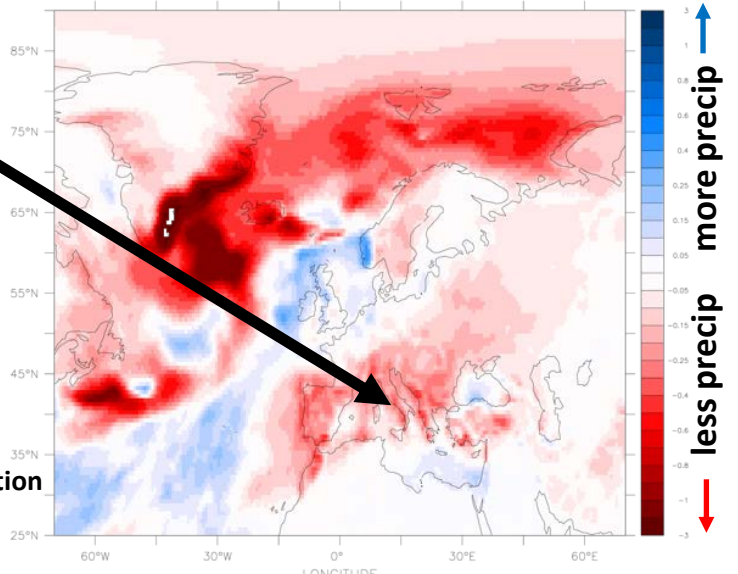
Hypothesized mechanism for persistent Mediterranean precipitation reduction (despite ghg reduction)

GHG reductions in SSP534OS (& weak AMOC) lead to:

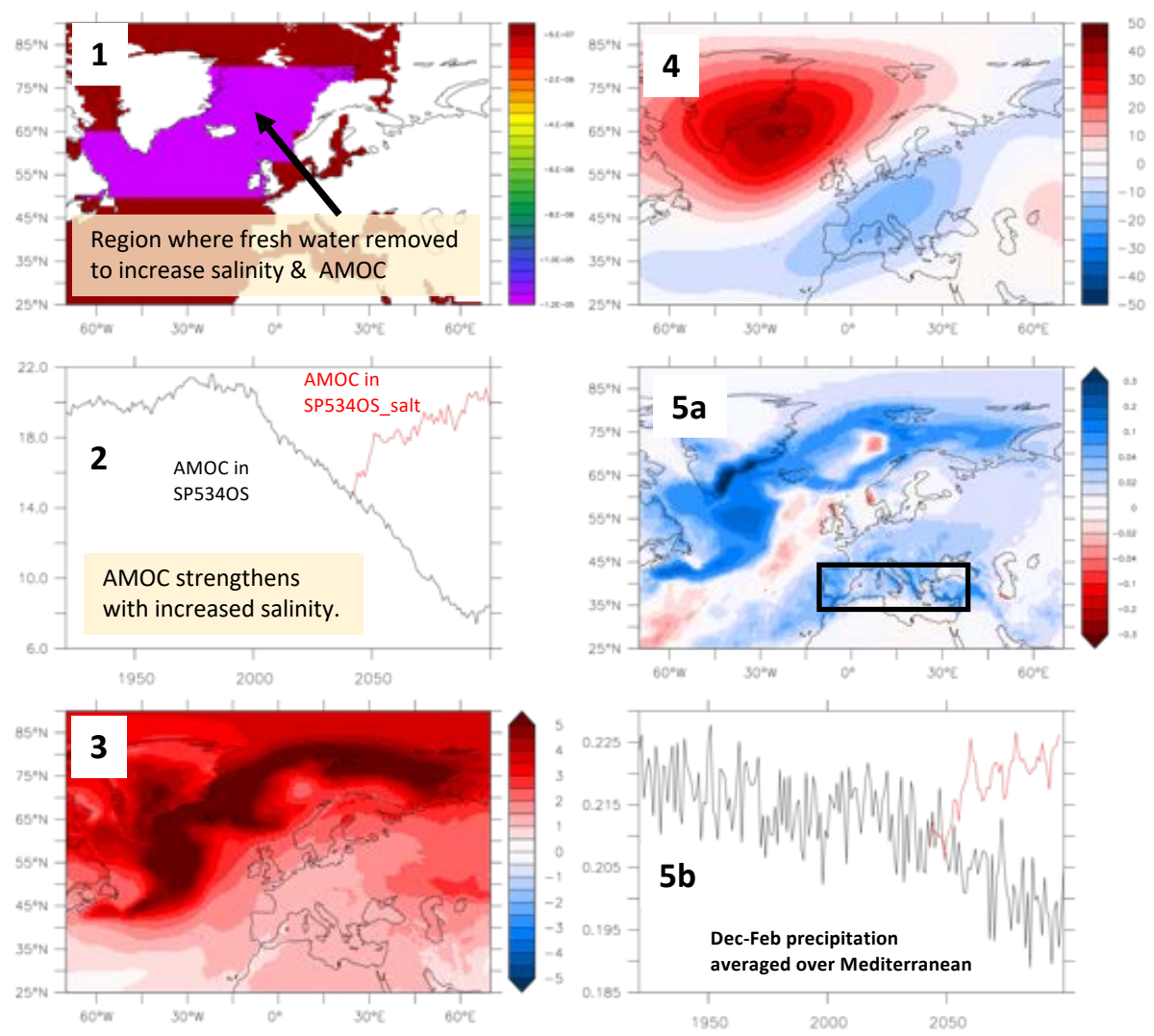
- Enhanced sea ice &cooling in subpolar North Atlantic
- Deep anomalous cyclonic atmospheric circulation
- Anticyclonic circulation over Mediterranean as a teleconnection
- Reduced precipitation over the Mediterranean



Response of DJF 500 hPa
geopotential height
2081-2100 minus 2041-2060



Response of winter precipitation
2081-2100 minus 2041-2060



A test of the proposed mechanism …

Repeat SSP534OS from 2041-2100, but remove fresh water from North Atlantic to strengthen the AMOC.

SSP534OS

SSP534OS_salt

➔ (removed fresh water from N Atl)

Mechanism:

(1) Removed fresh water increases salinity
(2) stronger AMOC
(3) warmer subpolar N Atl ➔
(4) anticyclone over subpolar N Atl & cyclon
circulation over Med
(5a,b) more precip over Med

Summary and Discussion

We explore aspects of 21st century climate change in response to a variety of radiative forcing scenarios using large ensembles with a high-resolution climate model.

We find for this model:

- Some aspects of climate, especially those related to the large-scale energy balance, respond directly and "rapidly" to declining concentrations of greenhouse gases (global temp, Arctic sea ice)
- Simulated AMOC show little to no recovery in the 21st century.
- We find a surprise in simulated winter precipitation over the Mediterranean, with precipitation continuing to decline even after greenhouse gases decline. This appears to be related to AMOC and sea ice influences.
- Is this robust? Similar behavior in at least one other model (CESM-WACCM).

Summary and Discussion

Key ingredients for "surprising" Mediterranean winter precipitation behavior:

- Weakened AMOC state persists through 21st century despite greenhouse gas reversal
- Strong late 21st century cooling & sea ice recovery in subpolar North Atlantic ocean create strong regional cooling and atmospheric teleconnection response with positive height anomalies over Mediterranean

Key issues:

- What controls amplitude and timescale of AMOC weakening and recovery?
- How robust is the pattern of ocean temperature change with greenhouse gas weakening?
- How robust is the atmos. response to the pattern of model ocean temperature change?
- Other climate surprises induced by persistent ocean changes?