Transient Response of the MOC and Climate to Potential Melting of the Greenland Ice Sheet in the 21st Century

Aixue Hu[1], Gerald A. Meehl[1], Weiqing Han[2] and Jianjun Yin[3]

[1]NCAR, Boulder [2]University of Colorado, Boulder [3]Florida State University, Tallahassee

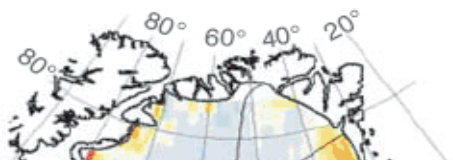
GRL, in press

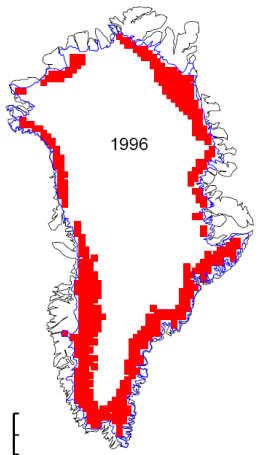
NCAR

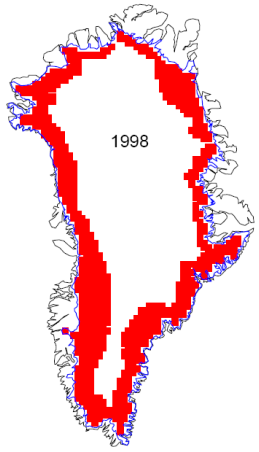
UNIVERSITY OF COLORADO 1876 LET YOUR LIGHT SHINE

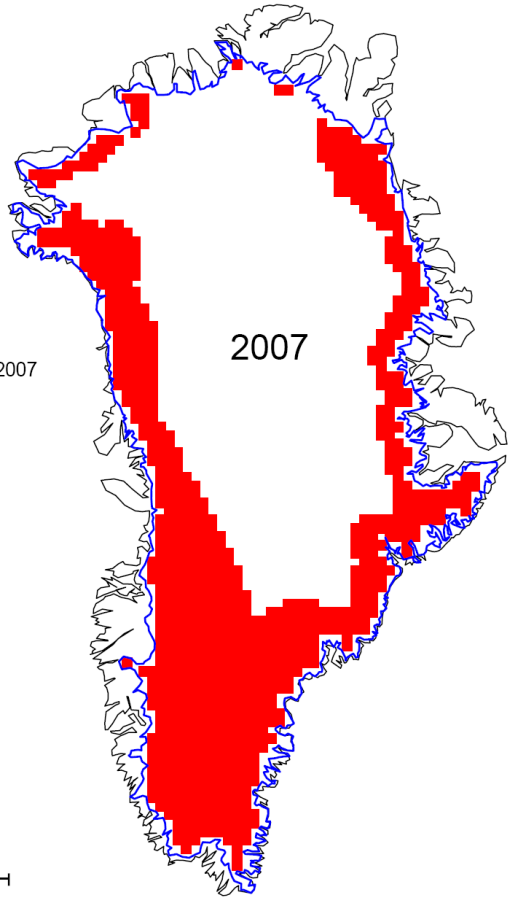
FLORIDA STATE UNIVERSITY 1851 VIRES ARTES MORES

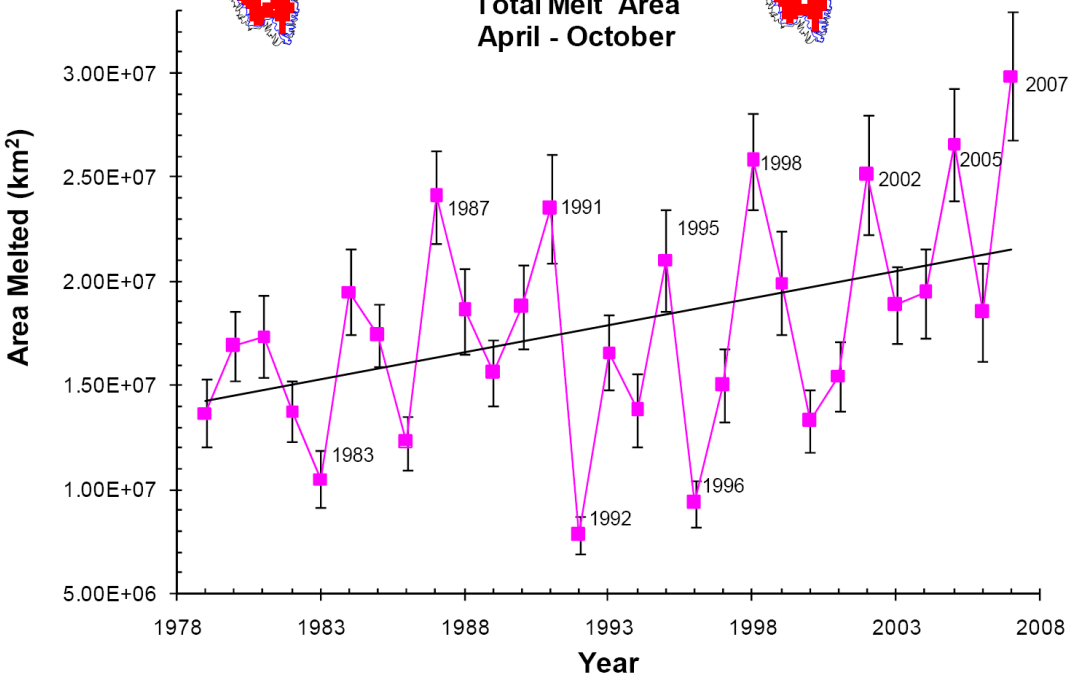
Introduction:

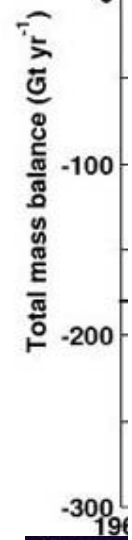












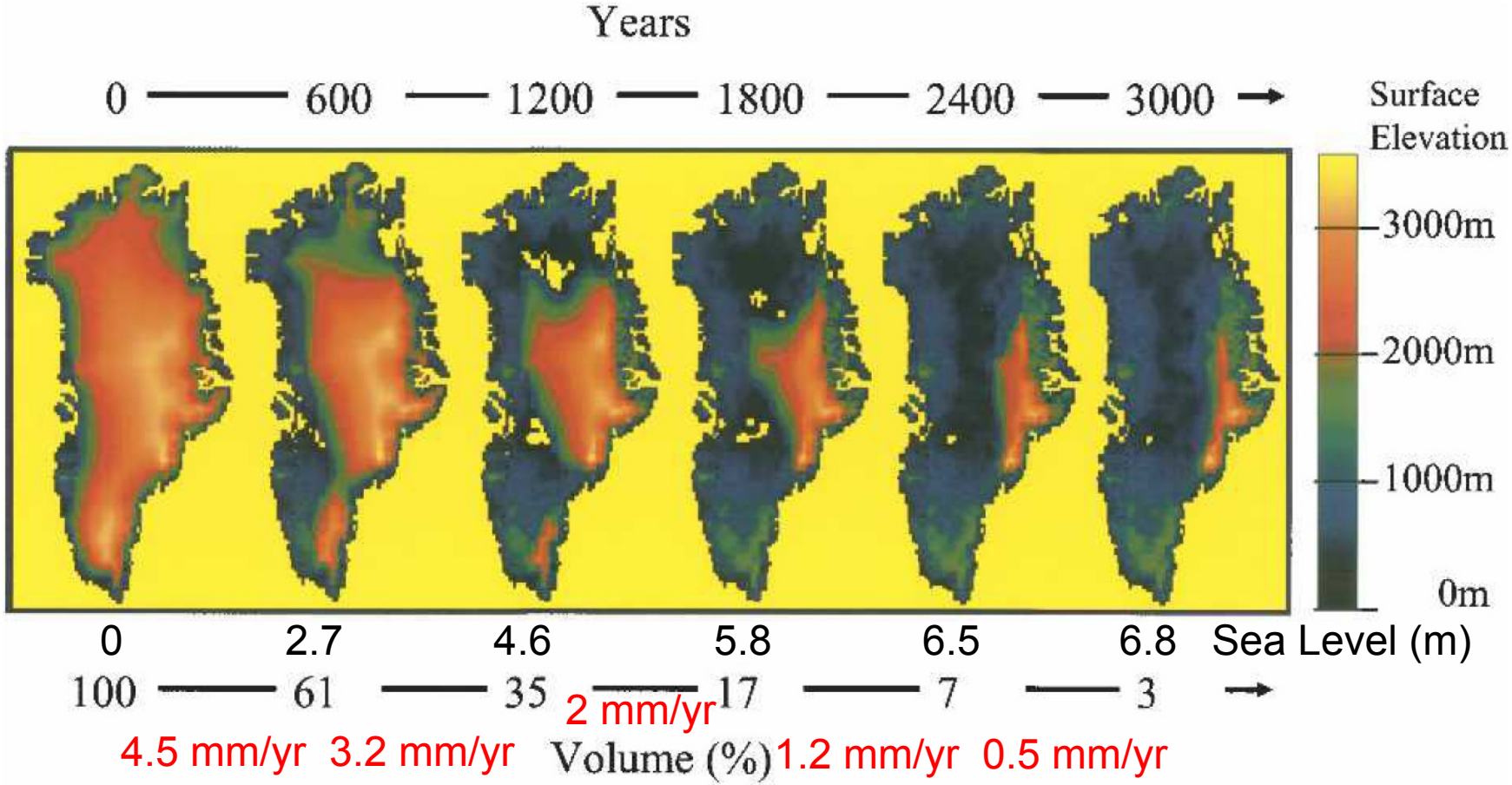
Konrad Steffen and Russell Huff, CIRES, University of Colorado at Boulder

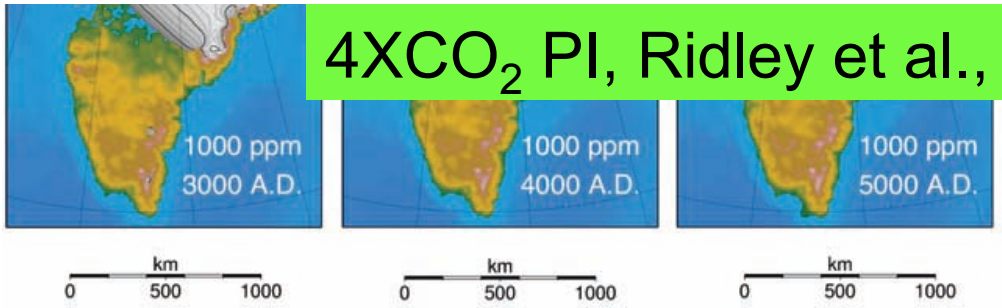
Konra
and F
Huff, 2005

Luthcke et al., 2006

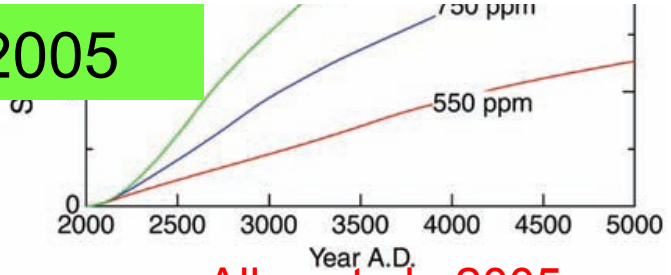
Year

How fast can Greenland Icesheet melt away?





4XCO$_2$ PI, Ridley et al., 2005

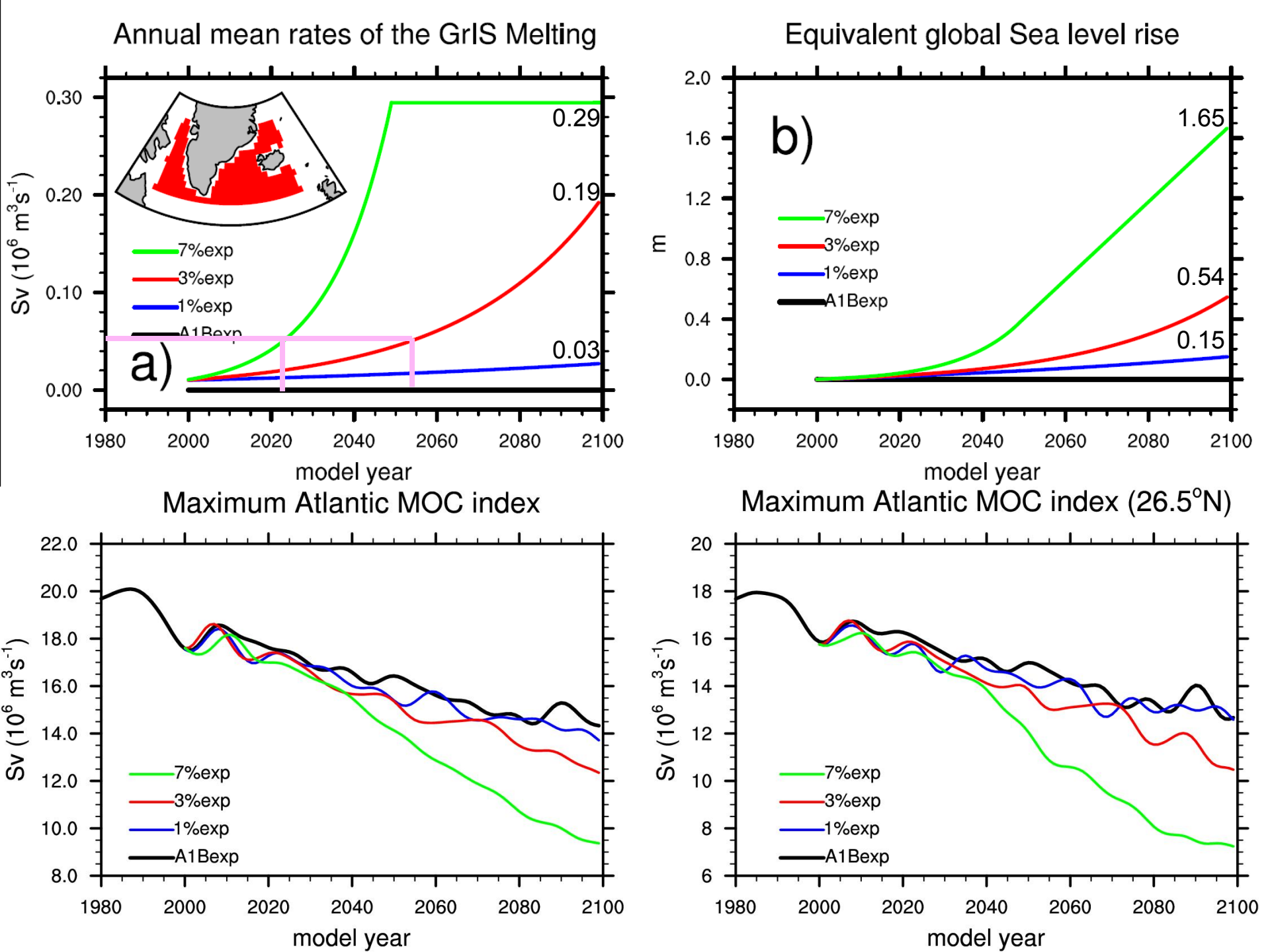


Alley et al., 2005

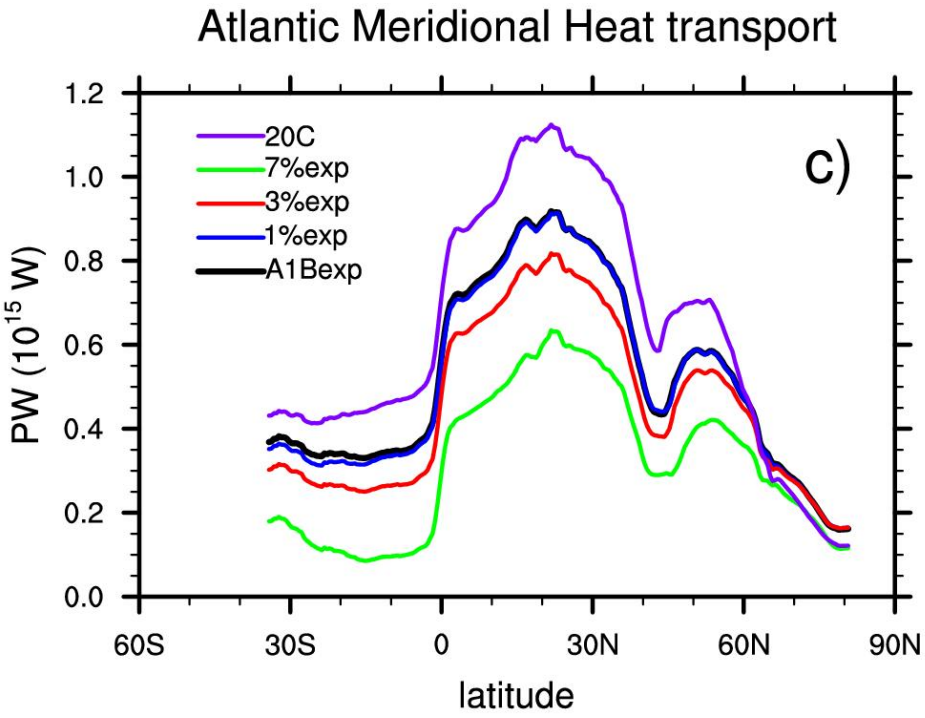
Model and Experiments

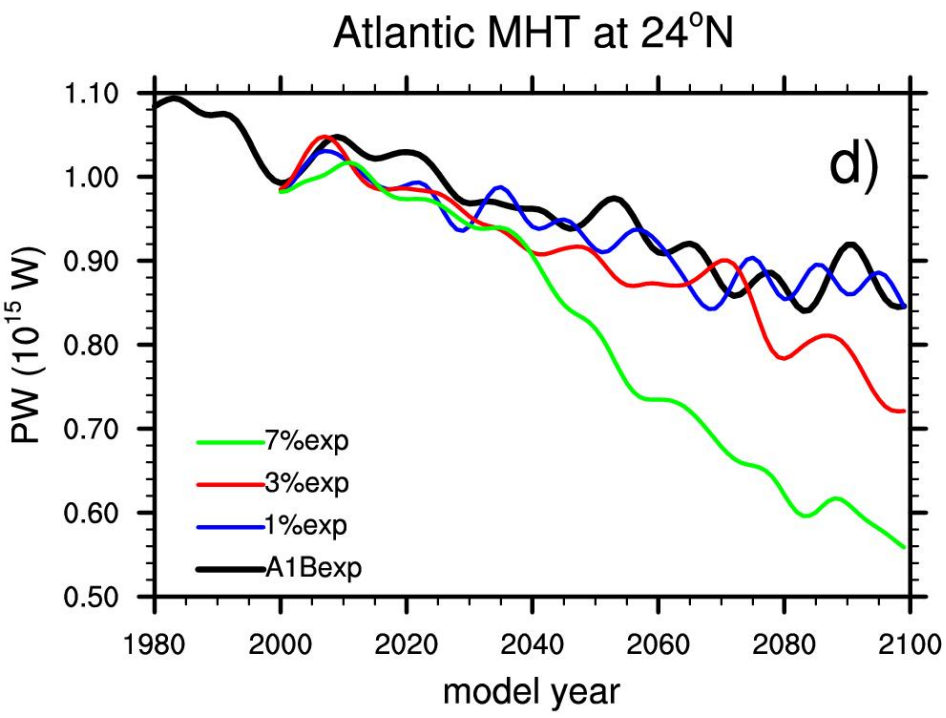
- CAM3 with T42 horizontally and 26 levels vertically
- POP with 1 degree horizontally and 40 levels vertically
- CSIM5
- CLM3
- Climate forcing: A1B

Experiments: Four simulations: 1, standard A1B; 2. A1B with 0.01 Sv Greenland melting flux only added in summer months (May-Oct) which is increasing 1% per year till 2100; 3. same as 2, but 3% per year; 4. same as 2, but 7% per year till 2050, then kept constant afterwards.

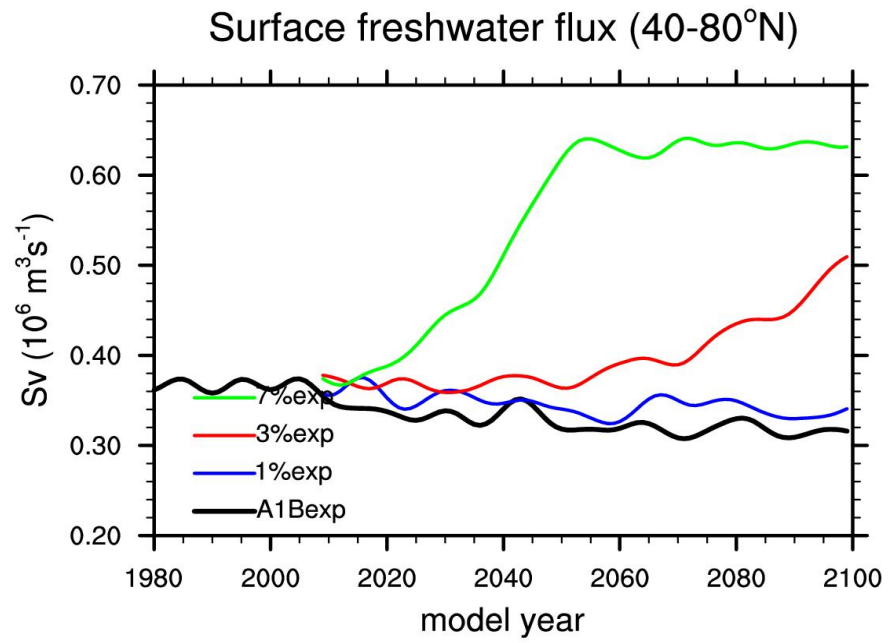

Annual mean rates of the GrIS Melting
Sv (10^6 m^3s^{-1})
0.30
0.20
0.10
0.00
0.29
0.19
0.03
7%exp
3%exp
1%exp
A1Bexp
a)
1980
2000
2020
2040
2060
2080
2100
model year
Equivalent global Sea level rise
m
2.0
1.6
1.2
0.8
0.4
0.0
b)
1.65
0.54
0.15
7%exp
3%exp
1%exp
A1Bexp
1980
2000
2020
2040
2060
2080
2100
model year
Maximum Atlantic MOC index
Sv (10^6 m^3s^{-1})
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
7%exp
3%exp
1%exp
A1Bexp
1980
2000
2020
2040
2060
2080
2100
model year
Maximum Atlantic MOC index (26.5°N)
Sv (10^6 m^3s^{-1})
20
18
16
14
12
10
8
6
7%exp
3%exp
1%exp
A1Bexp
1980
2000
2020
2040
2060
2080
2100
model year

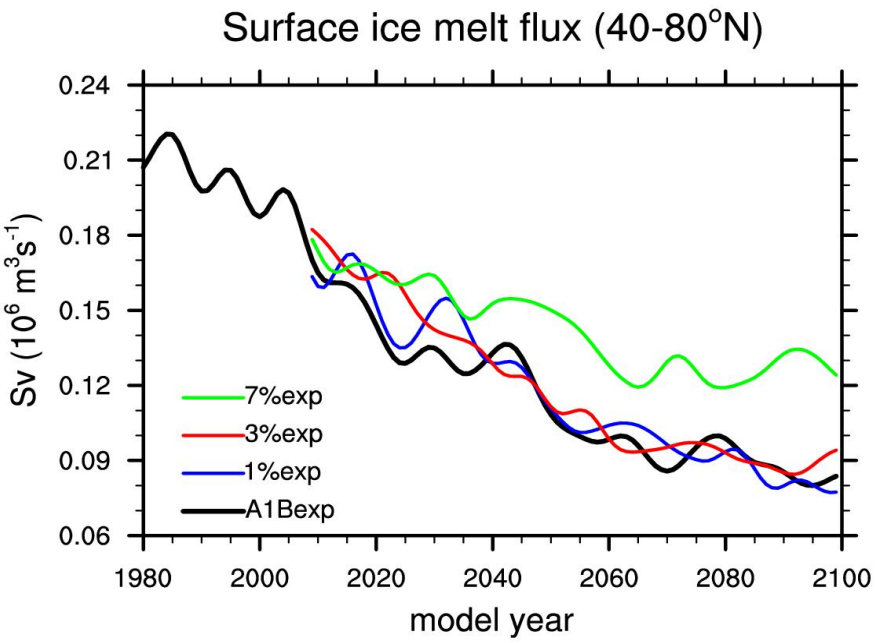
By the end of the 21st century, the mean MOC weakens by 24%, 26%, 33%, and 48% in the A1Bexp, 1% exp, 3%exp, and 7%exp in comparison to the mean of the 20th century.

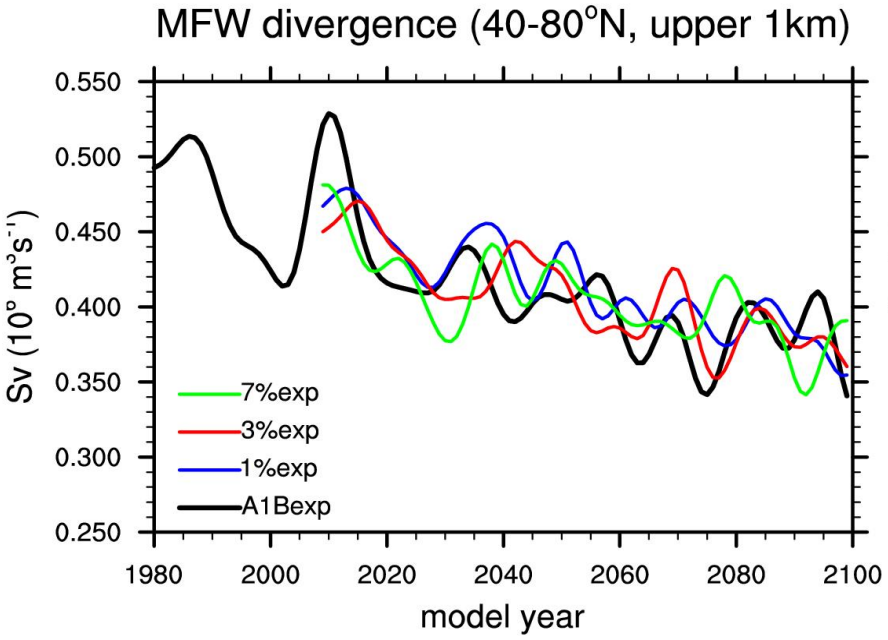


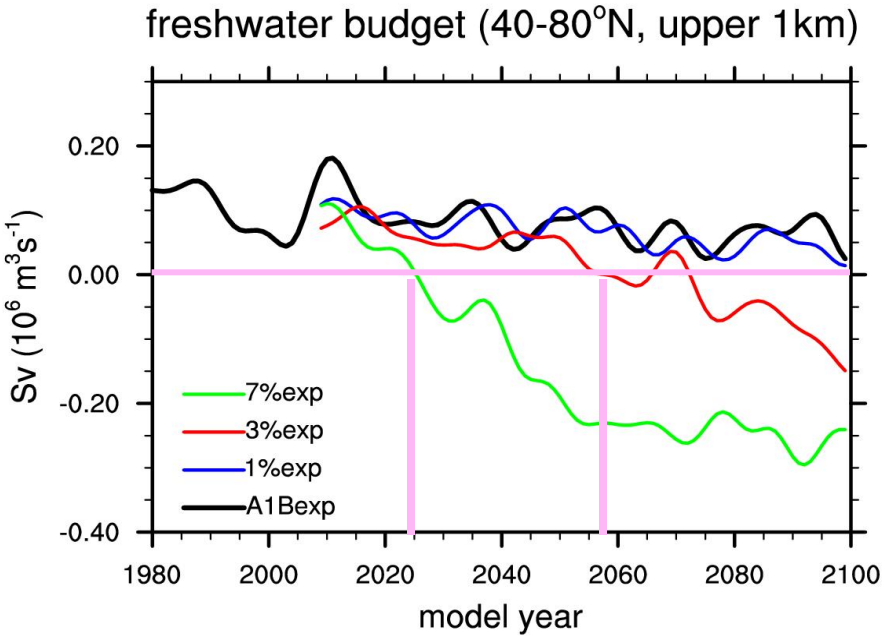


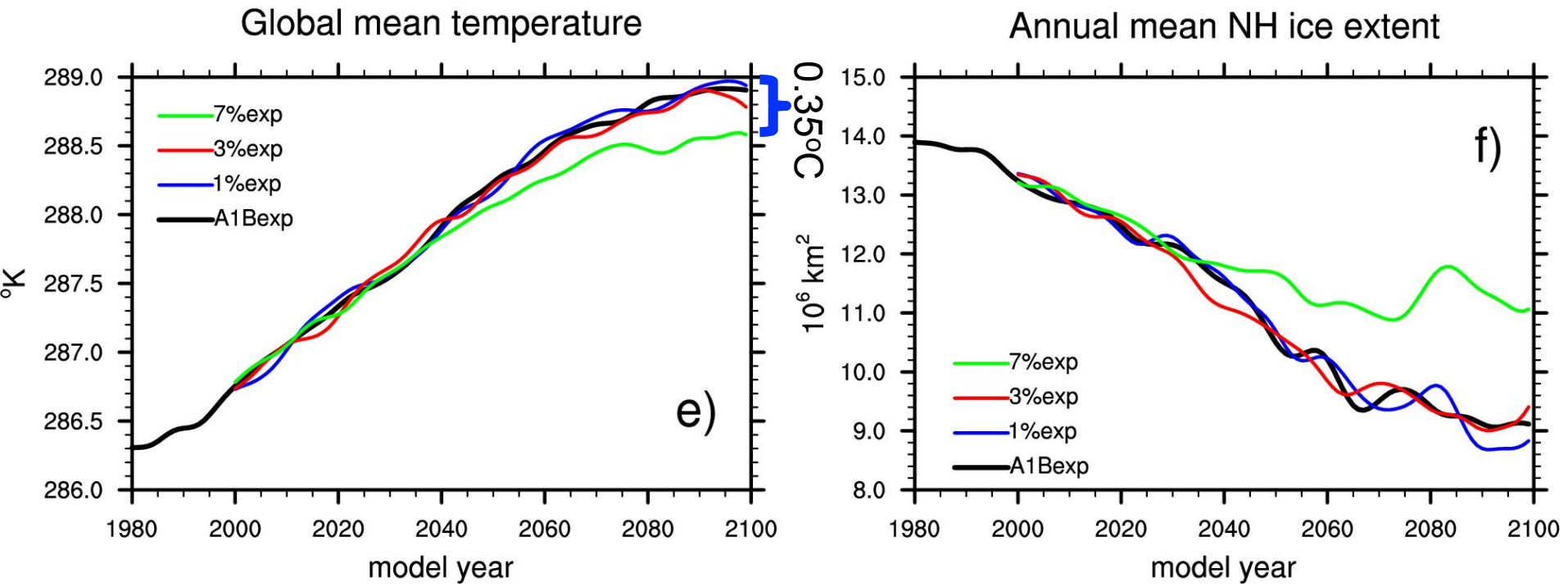
Freshwater flux analysis







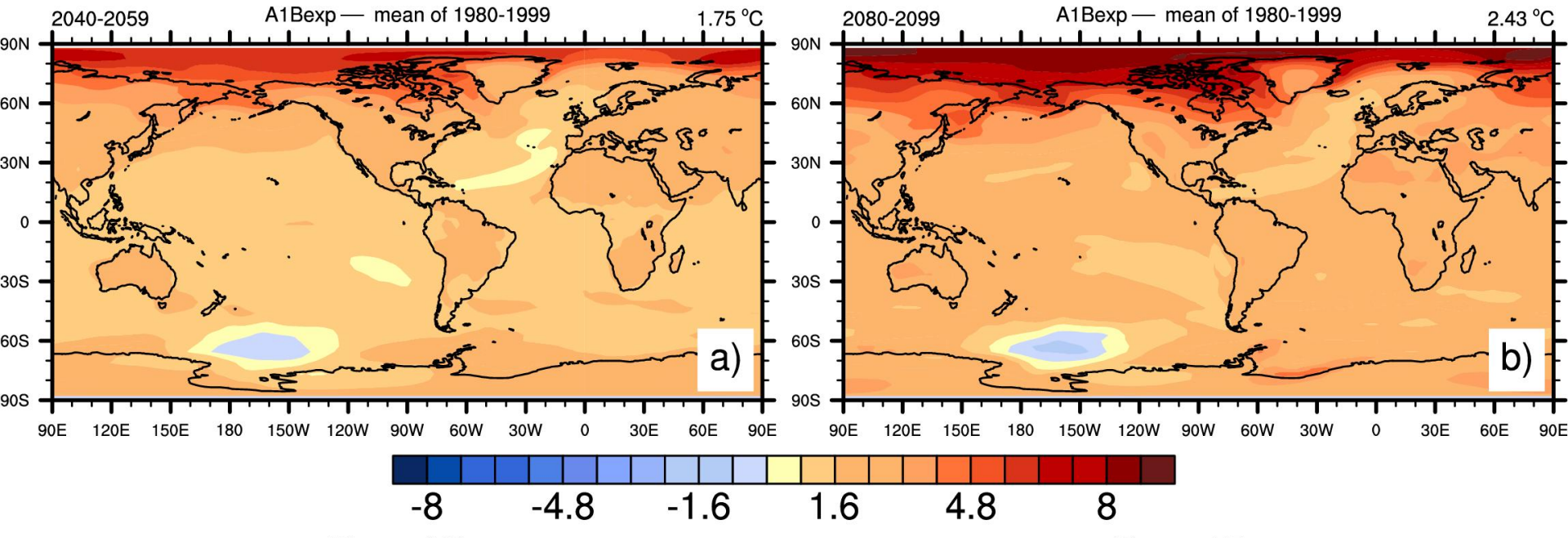




1. Global mean surface temperature changes are very small in the 1%exp and 3%exp, and only cools by a few 10th degree in 7%exp by the end of the 21st century.

2. Sea ice cover in the southern hemisphere is similar in all experiments. In the Northern Hemisphere, sea ice cover increases only in the 7%exp

20-year mean surface temperature anomalies



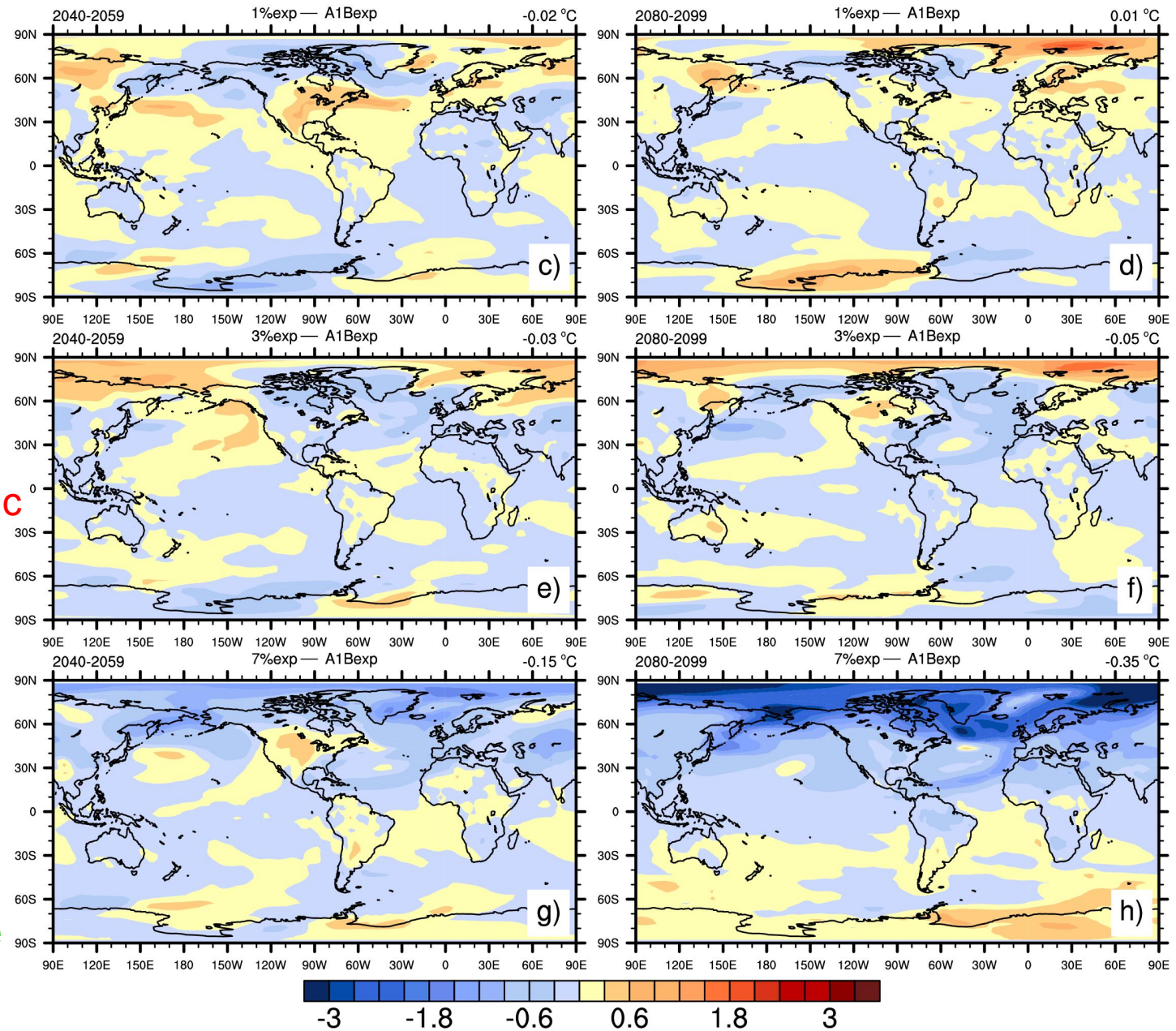
The global mean surface temperature warms by 2.43^{o}C by the end of the 21st century relative to late 20th century. The warming in Arctic region is more than 8^{o}C.

Surface temperature anomaly between GIS runs and A1B

In the 1%exp, there is no significant global mean surface temperature change relative to A1Bexp.

In the 3%exp, more significant cooling shows up in the northern North Atlantic region by up to 1°C relative to A1Bexp.

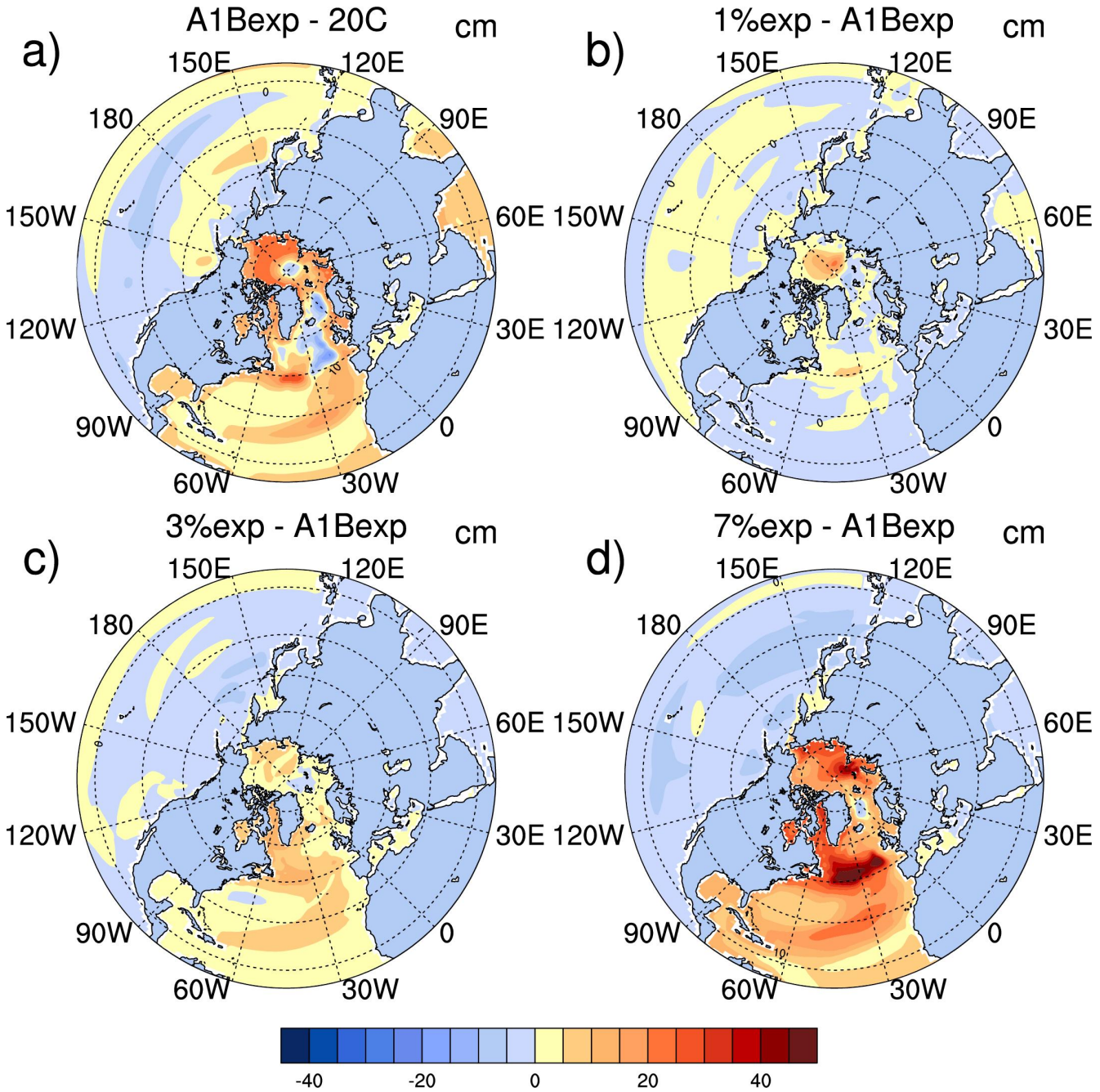
In the 7%exp, the surface cooling is more than 3°C in some areas of the Arctic and subpolar North Atlantic relative to A1Bexp.



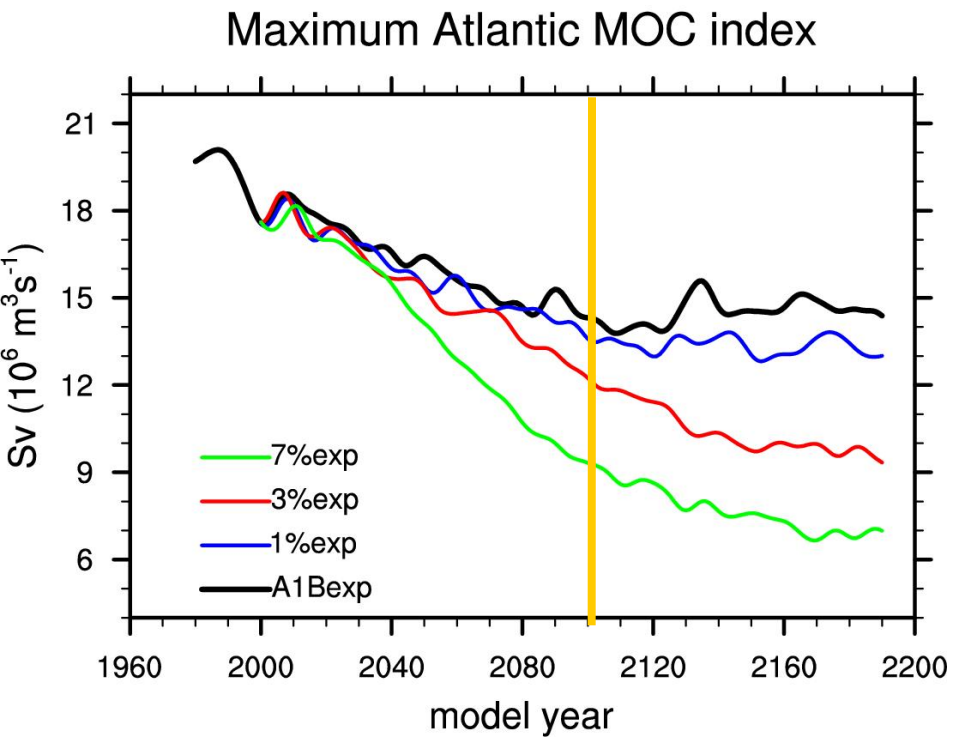
Changes of the dynamic sea level

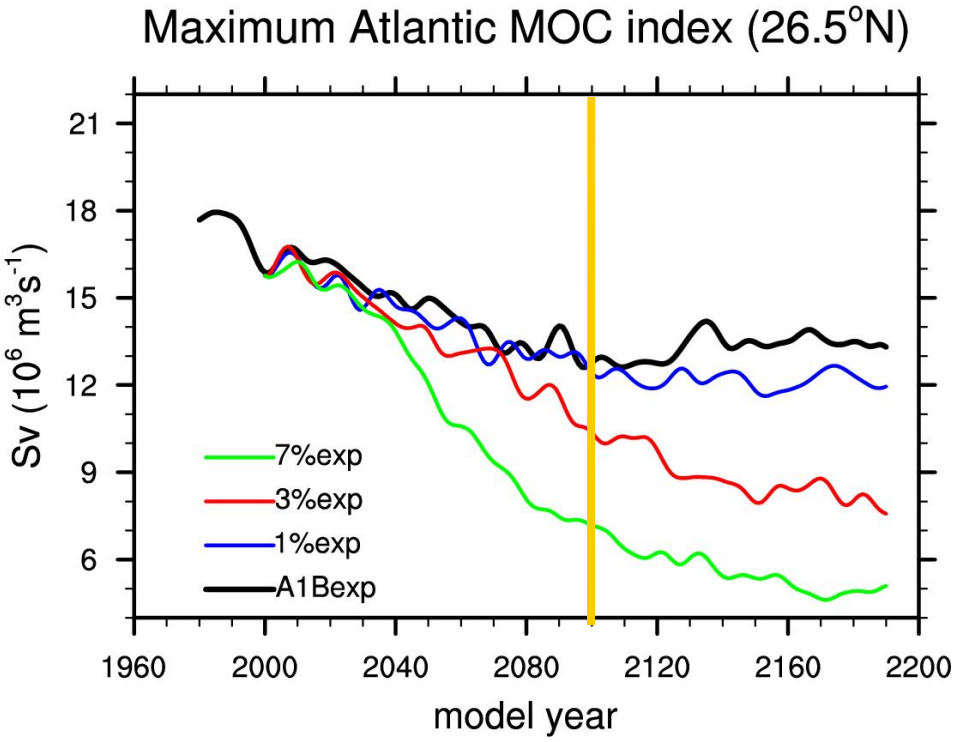
The dynamic sea level rises at the edges of the Atlantic and deepens in the central subpolar North Atlantic, indicating a spinup of the subpolar gyre.

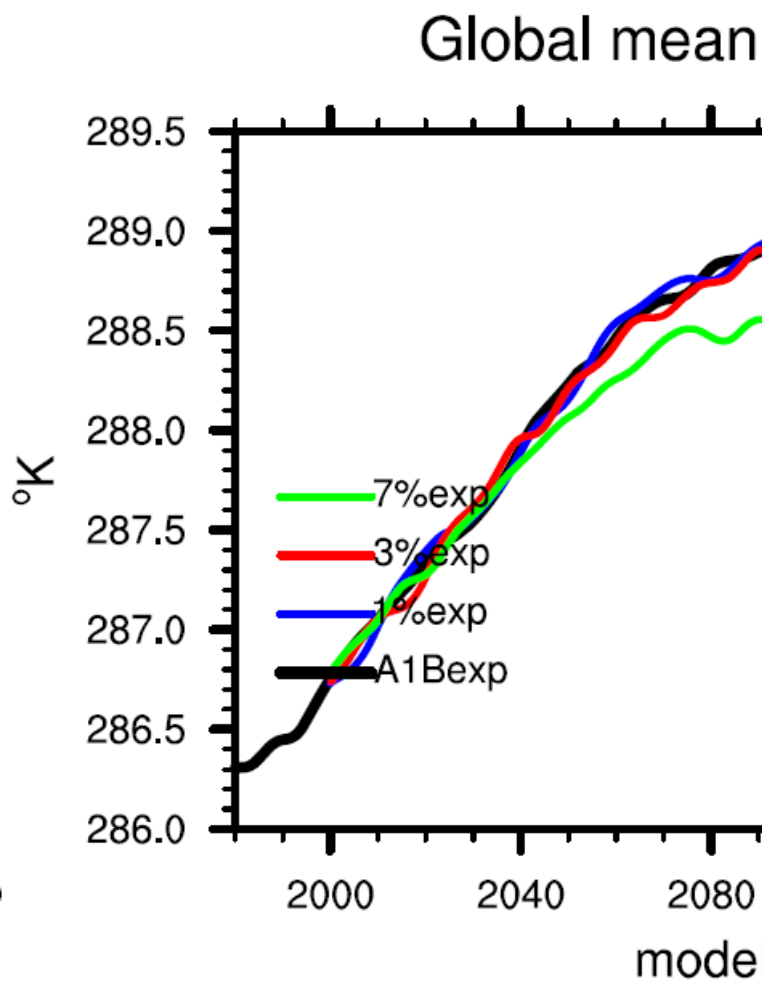
The further slowdown of the MOC could additionally raise the sea level in the North America coast region by up to 30cm by the end of the 21st century relative to the A1Bexp.

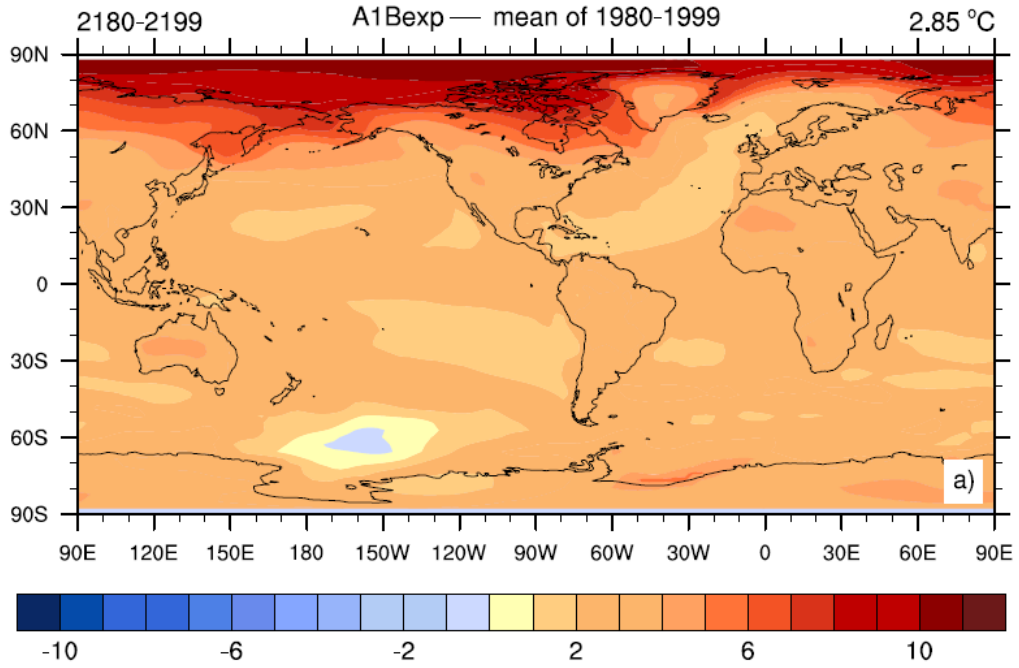


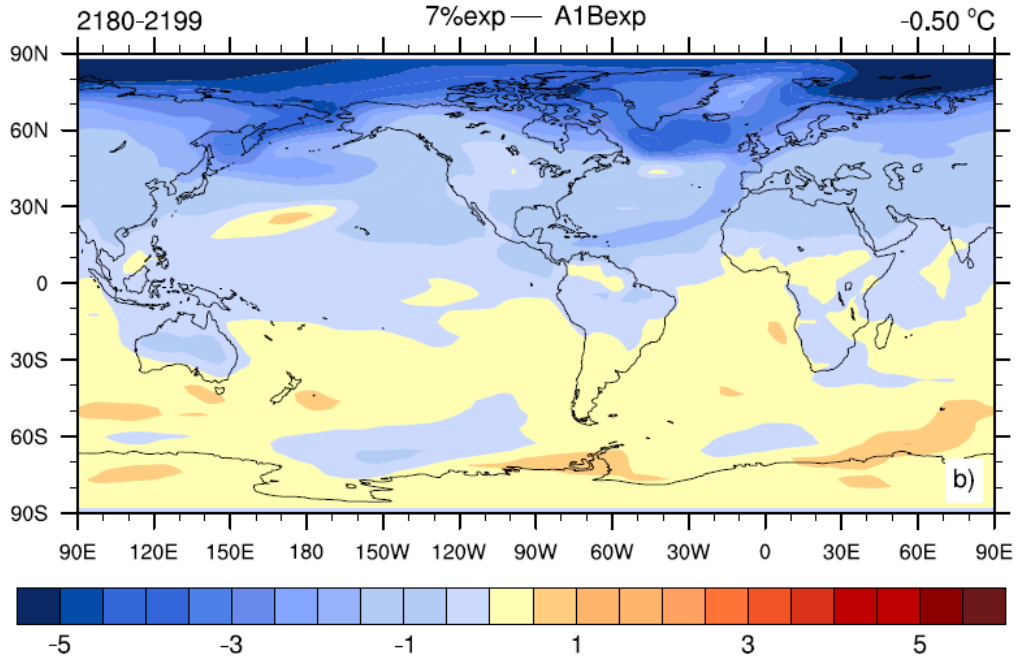
If the freshwater forcing is kept constant after year 2100, the MOC would further slow down in the 3%exp and 7%exp simulations, and the MOC becomes a bit weaker in the 1%exp in comparison to the A1Bexp.






Global mean
289.5
289.0
288.5
288.0
287.5
287.0
286.5
286.0
°K
7%exp
3%exp
1%exp
A1Bexp
2000
2040
2080
mode


2180-2199
A1Bexp — mean of 1980-1999
2.85 °C
90N
60N
30N
0
30S
60S
90S
90E
120E
150E
180
150W
120W
90W
60W
30W
0
30E
60E
90E
a)
-10
-6
-2
2
6
10


2180-2199
7%exp — A1Bexp
-0.50 °C
90N
60N
30N
0
30S
60S
90S
90E
120E
150E
180
150W
120W
90W
60W
30W
0
30E
60E
90E
b)
-5
-3
-1
1
3
5

Summary

- Result shows that an ice sheet melting with a rate up to 0.03 Sv would not alter MOC much in comparison to the simulation without prescribed Greenland Ice Sheet melting. A melting rate exceeding 0.05 Sv would further weaken the MOC by 9-24% by the end of the 21st century.

- This weakened MOC doesn't make the late 21st century global climate cooler than the late 20th century, but does cause the climate up to a few degrees less warm in the northern high latitudes

- the rise of the DSL related to the further slowdown of the MOC added to the sea level rise caused by greenhouse gas induced warming could pose potential impacts on the northeast coast of the America.