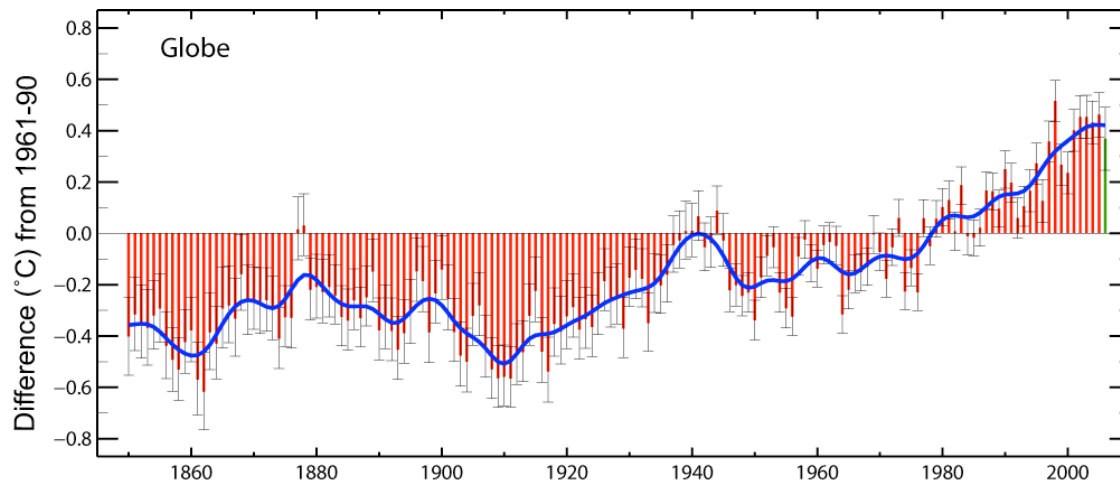


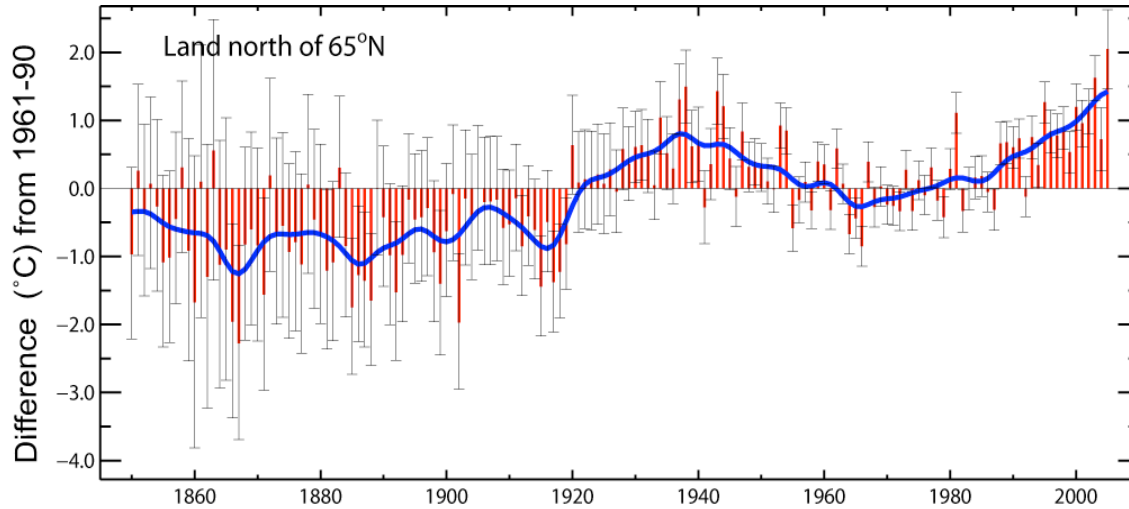
Arctic Feedbacks on Climate Change



Thanks to Melissa Burt, Mark Branson & Abby Ahlert

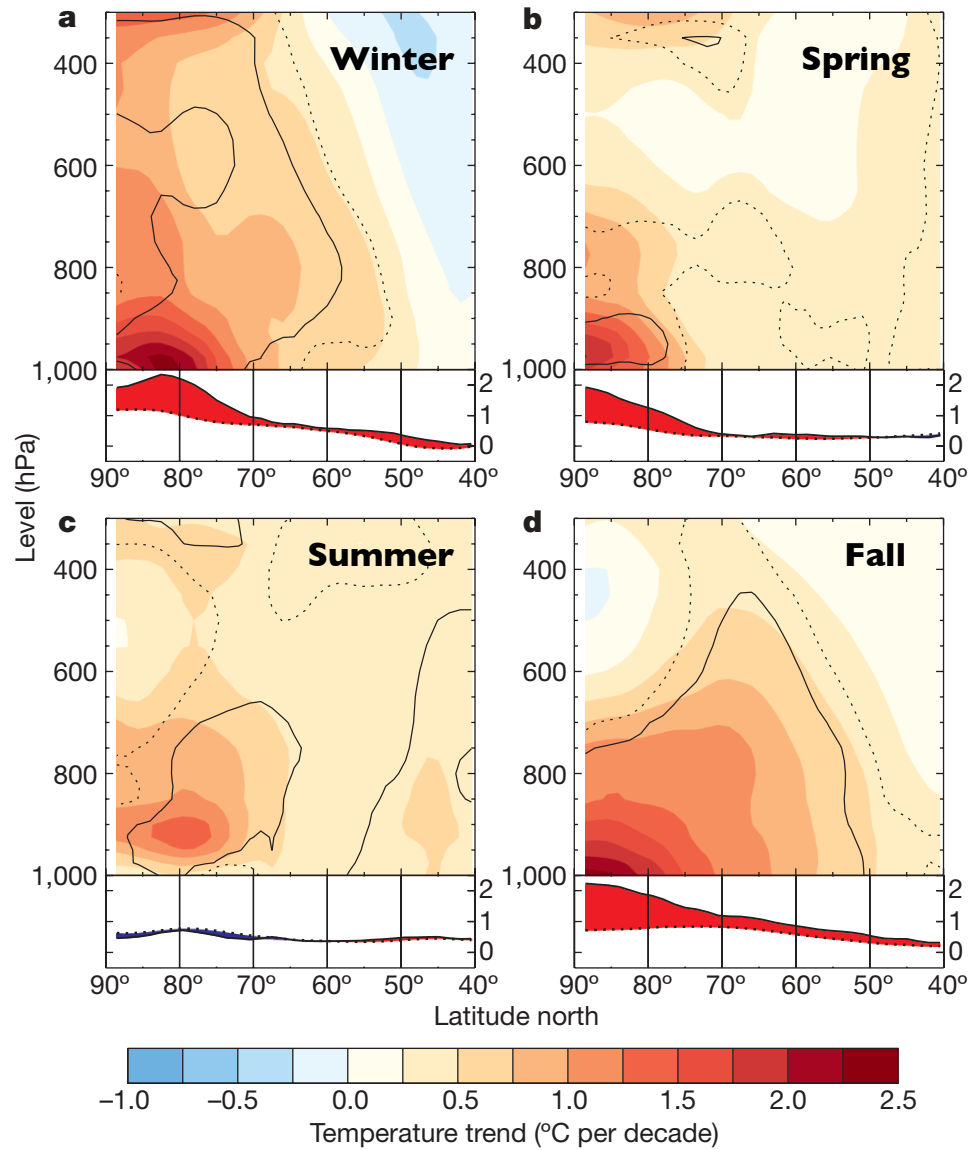


Warming in the Arctic is roughly double that for the whole Earth.

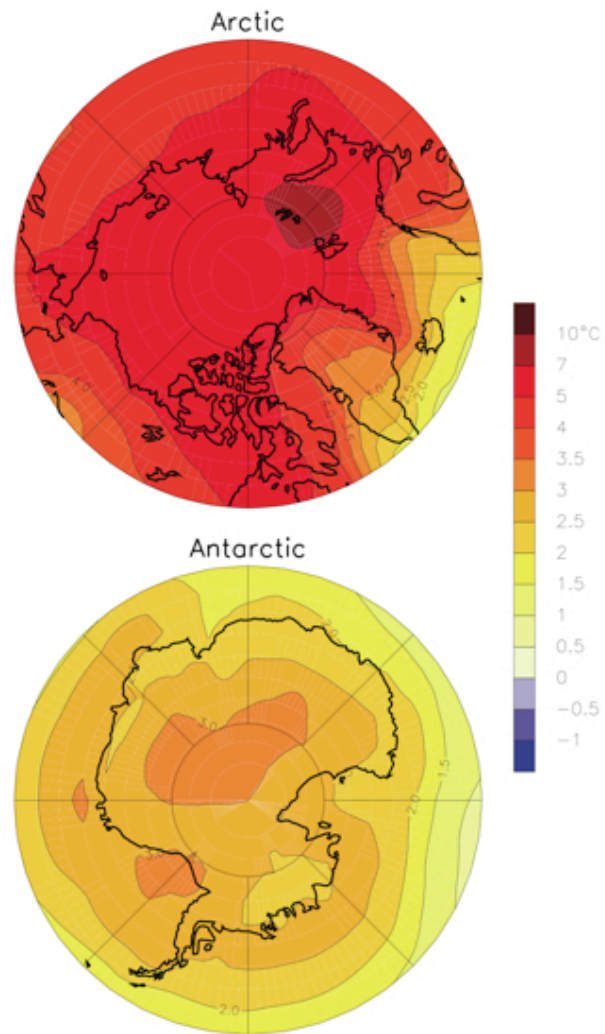


Note different scales.

Observed Arctic Temperature Trends 1989-2008



Predicted warming over the 21st century

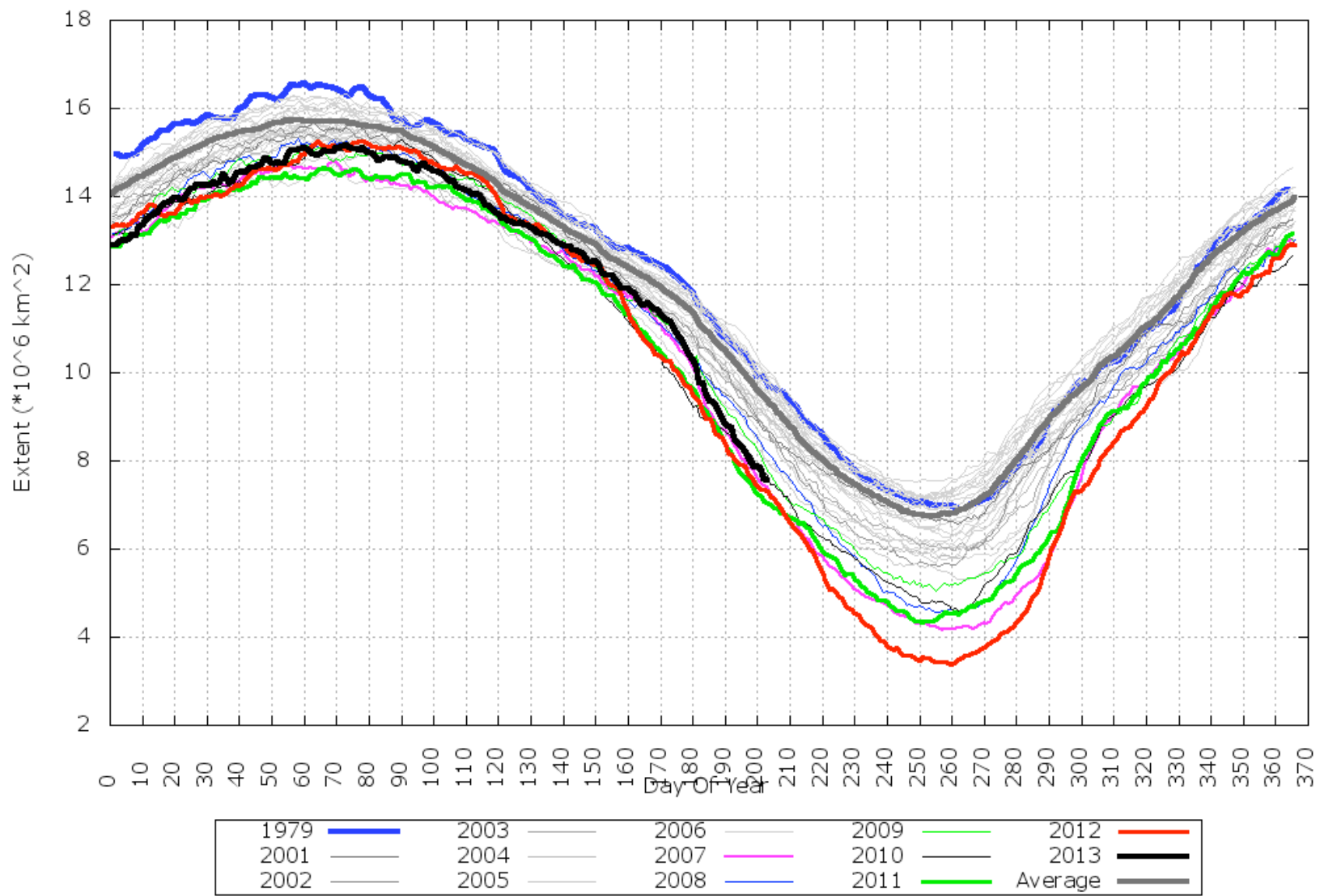




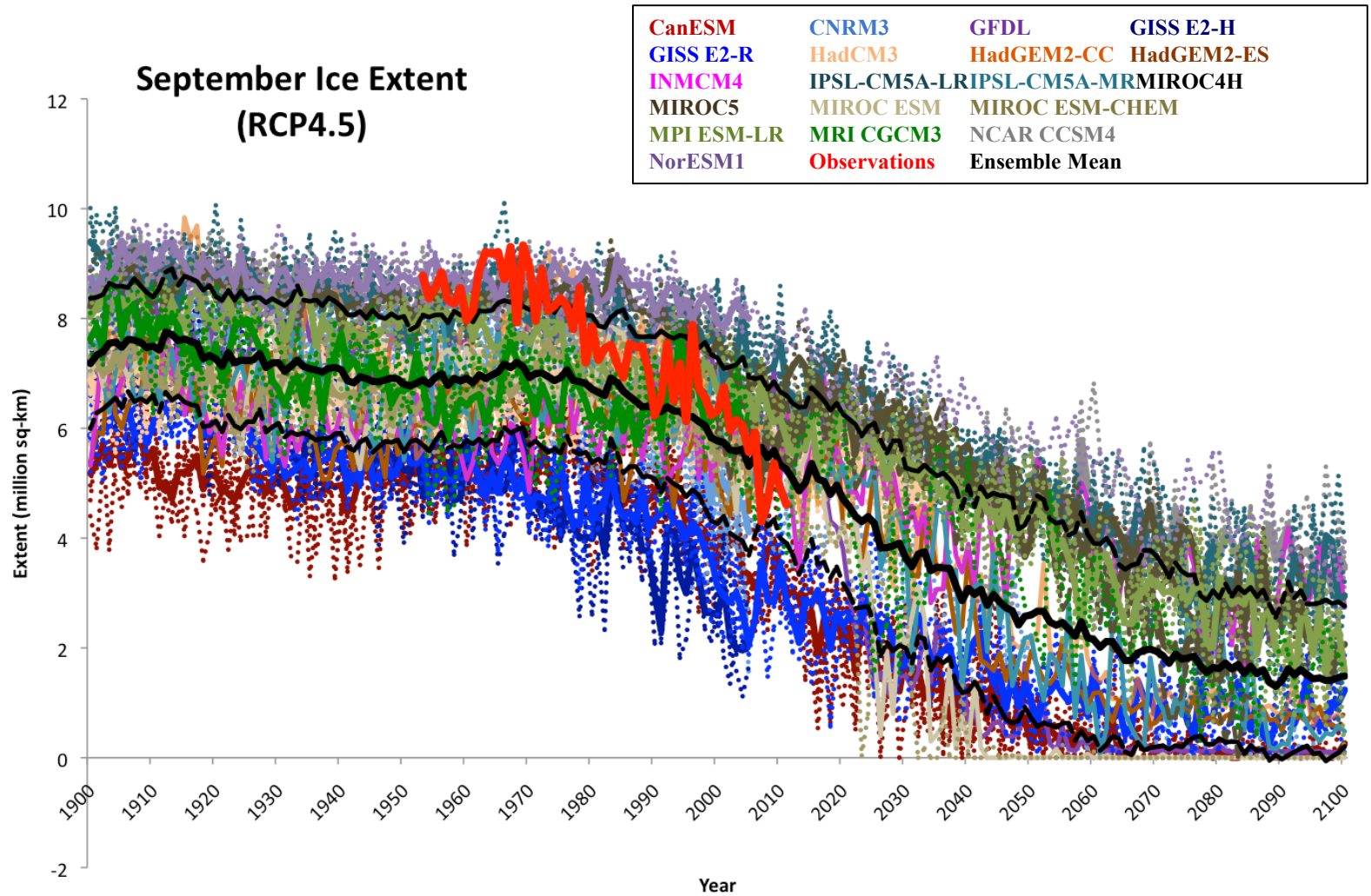
Ellesmere Island
80°N
50 MYA
1200 ppmv CO₂



NSIDC Arctic Sea Ice Extent
Data: NSIDC
Last Day: 2013-07-22 (7.53945)

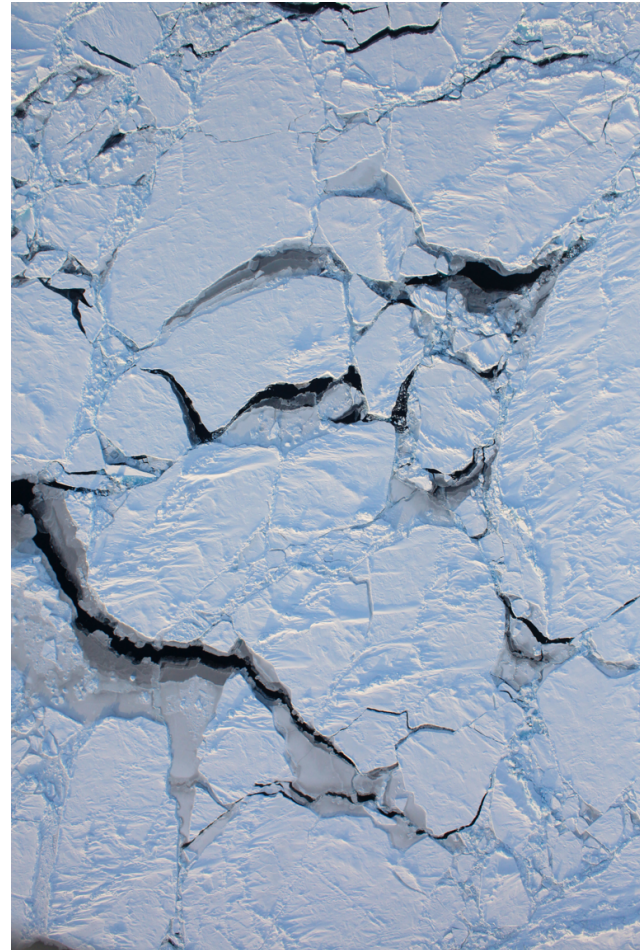


CMIP5 results

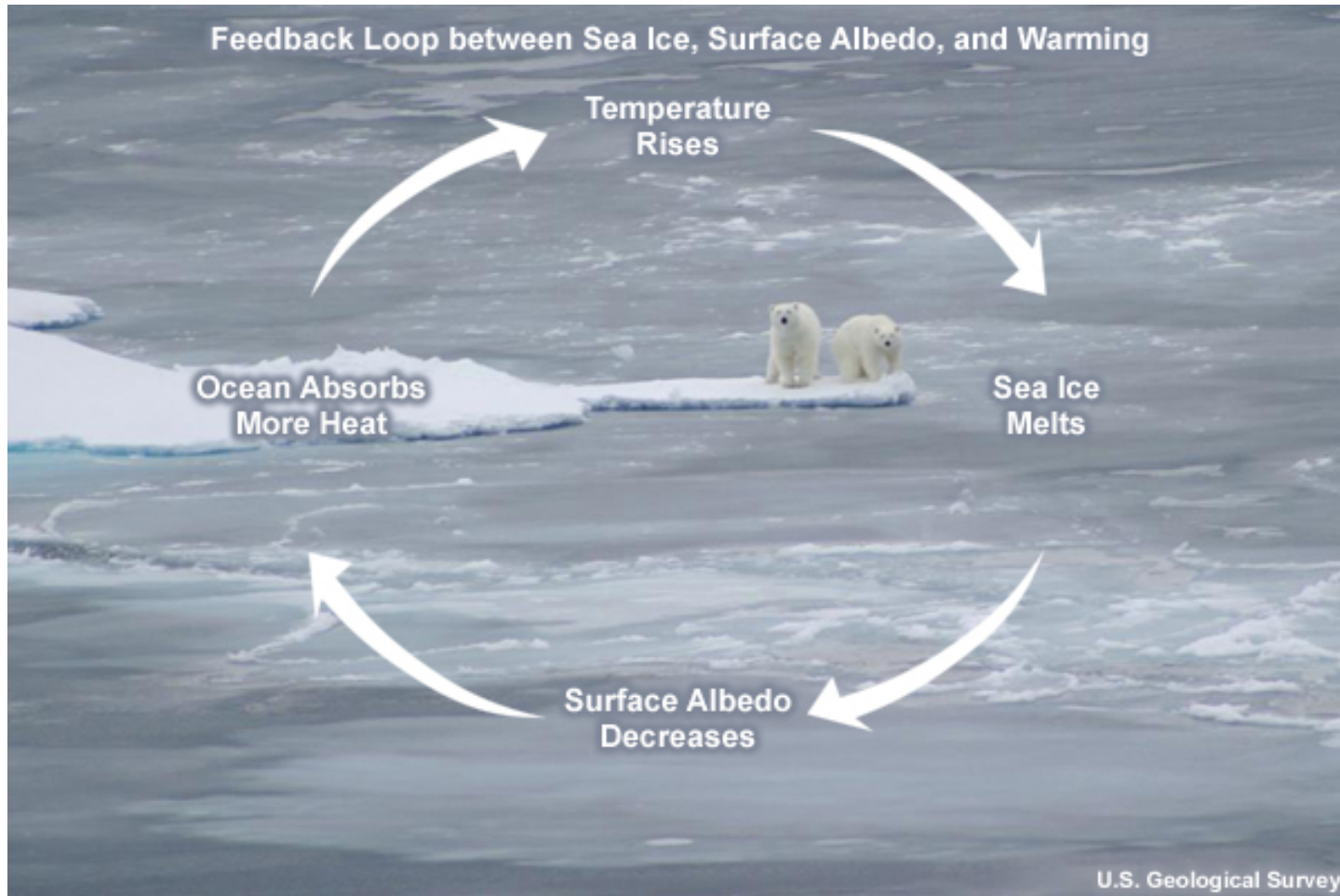


Sea ice

- Reflects sunlight
- Blocks heat exchange between the ocean below and the air above

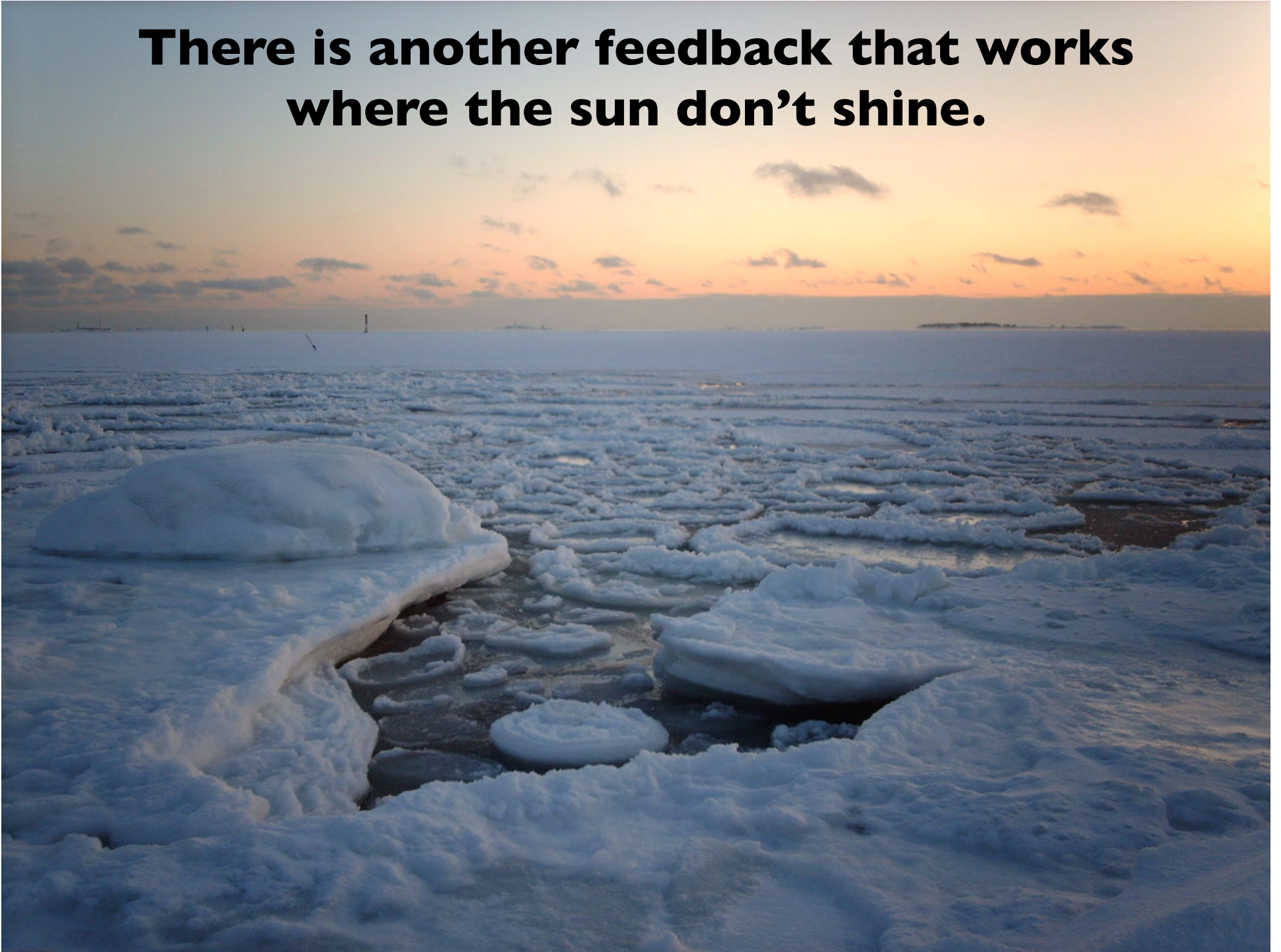


The Ice & Snow Albedo Feedback



This feedback is at work during the summer months, until the summer ice melts.

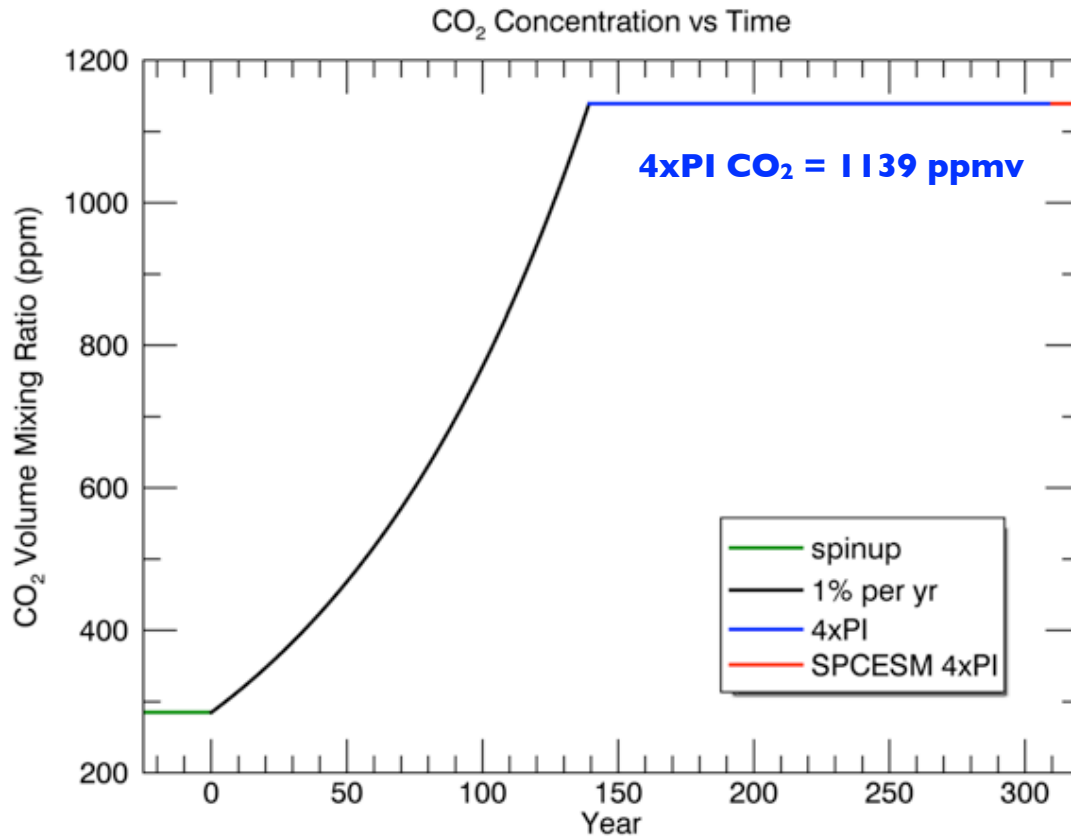
**There is another feedback that works
where the sun don't shine.**



Experimental Design

- Fully-coupled **Community Earth System Model 1.0.2**, CAM4 Physics, Finite Volume dynamical core
- $1.9^\circ \times 2.5^\circ$ grid for atmos and land components , 30 vertical levels
- gxlv6 displaced pole grid for ocean and ice components
- Ocean model has reached equilibrium (500 year spinup from previous simulation)

Experimental Design

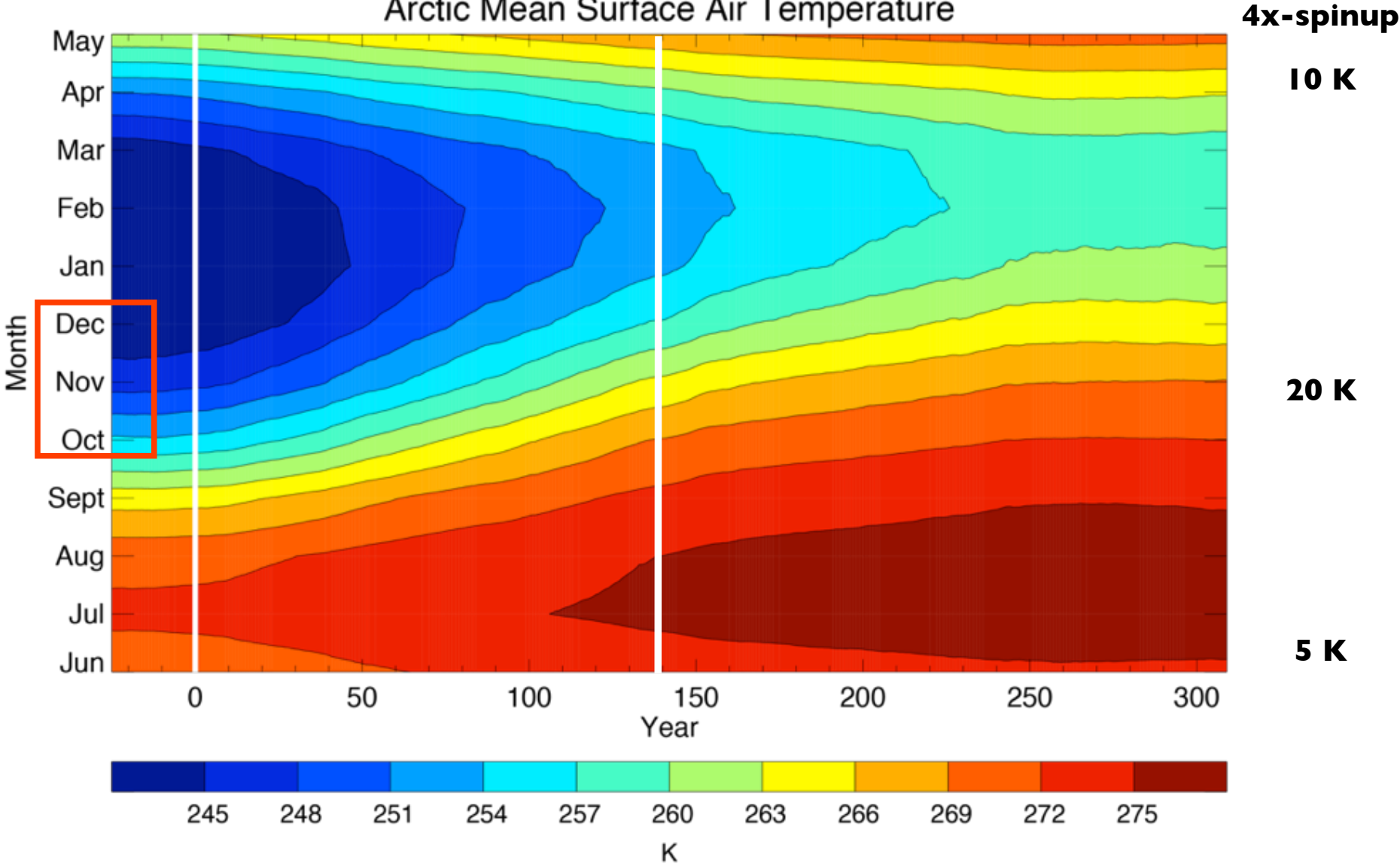


- 25-year spinup simulation holding all trace gases constant at PI
- Followed by 1% per year CO₂ increase
- CO₂ held constant at 1139 ppmv for 200 years
- SP-CESM 10-year sim started from end of CESM 4xPI

Experiment was designed in collaboration with Eli Tziperman (Harvard) and Dorian Abbot (U. Chicago).

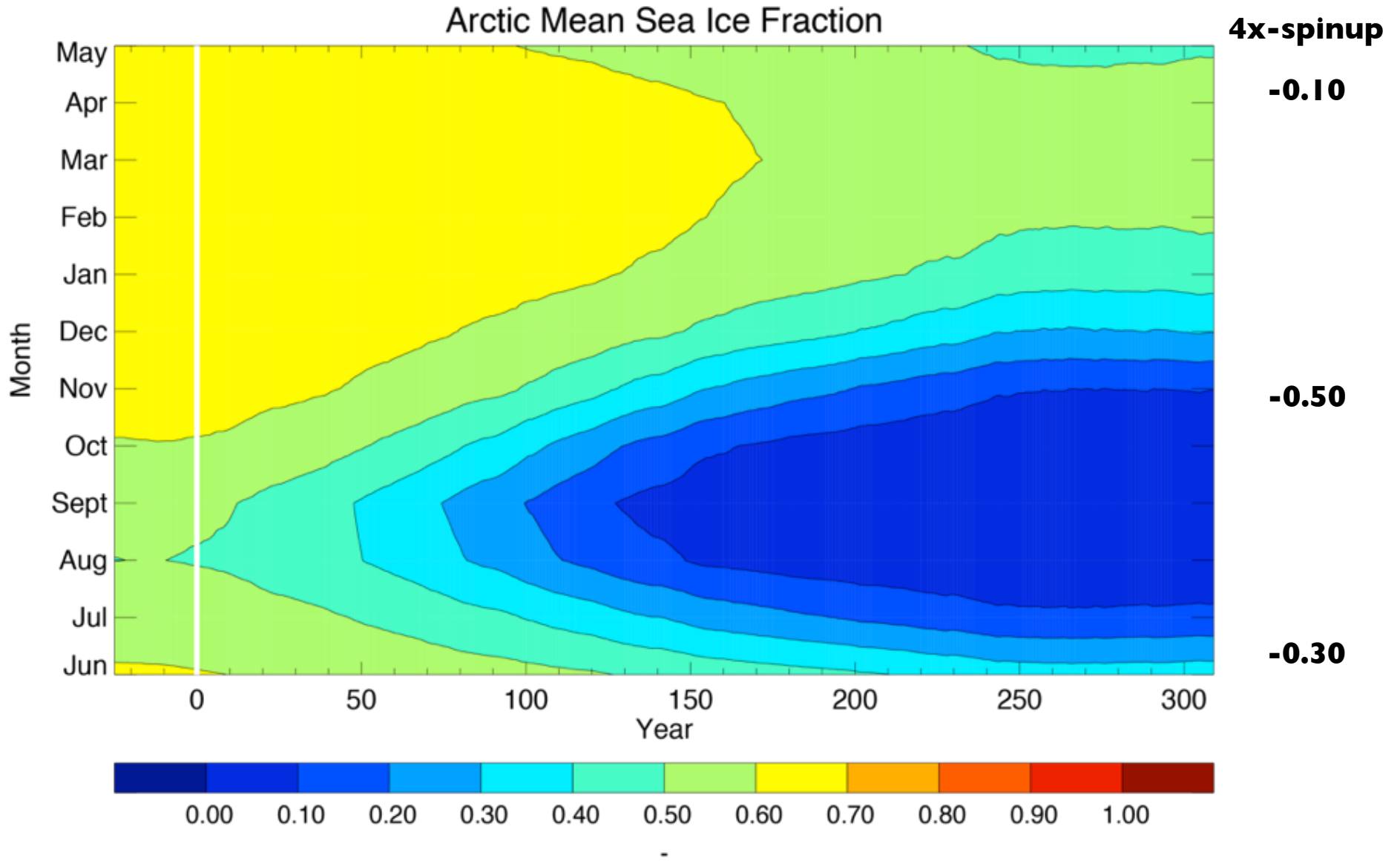
The Arctic warms up.

Arctic Mean Surface Air Temperature



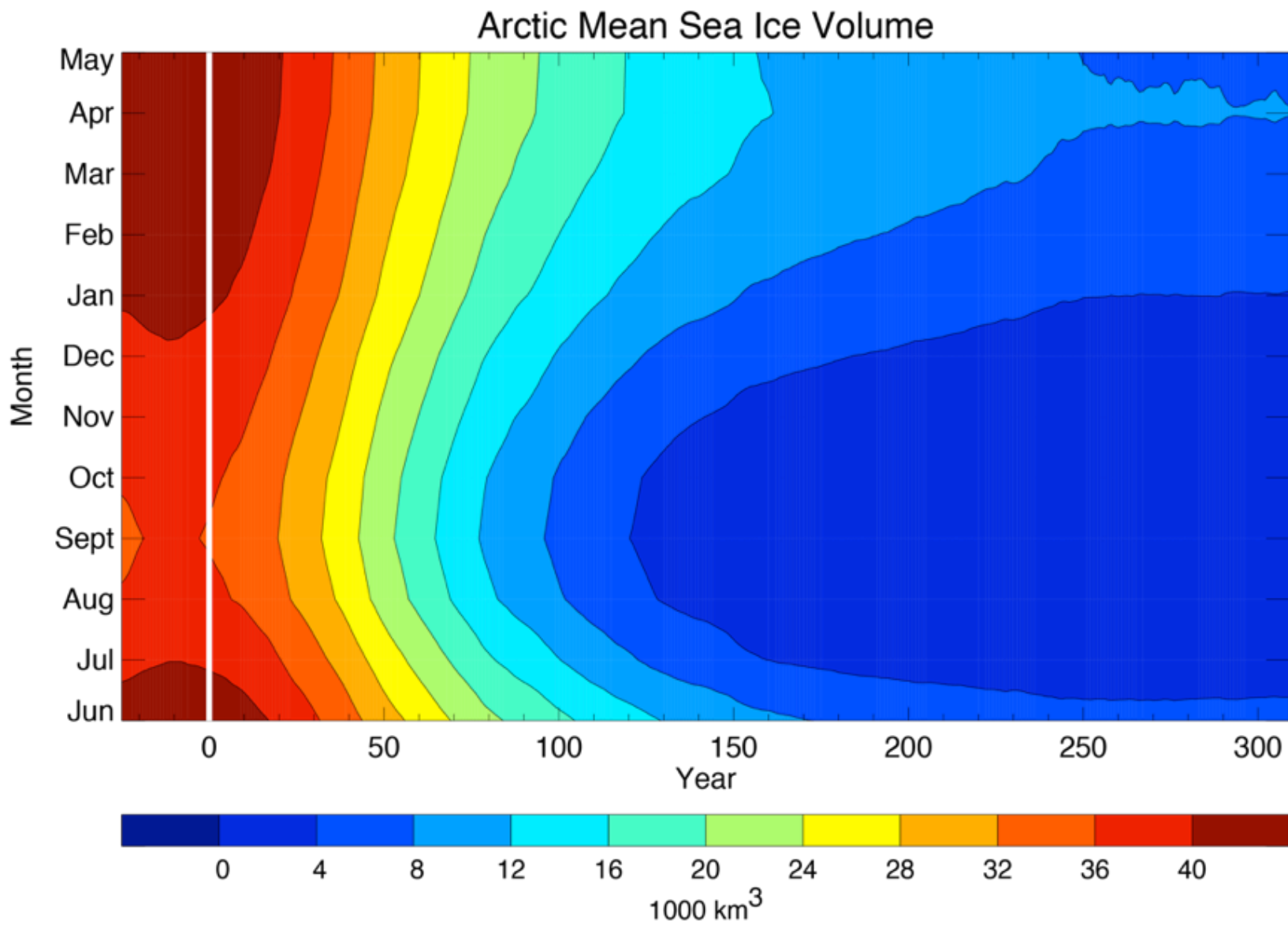
70-90N

Sea ice melts.



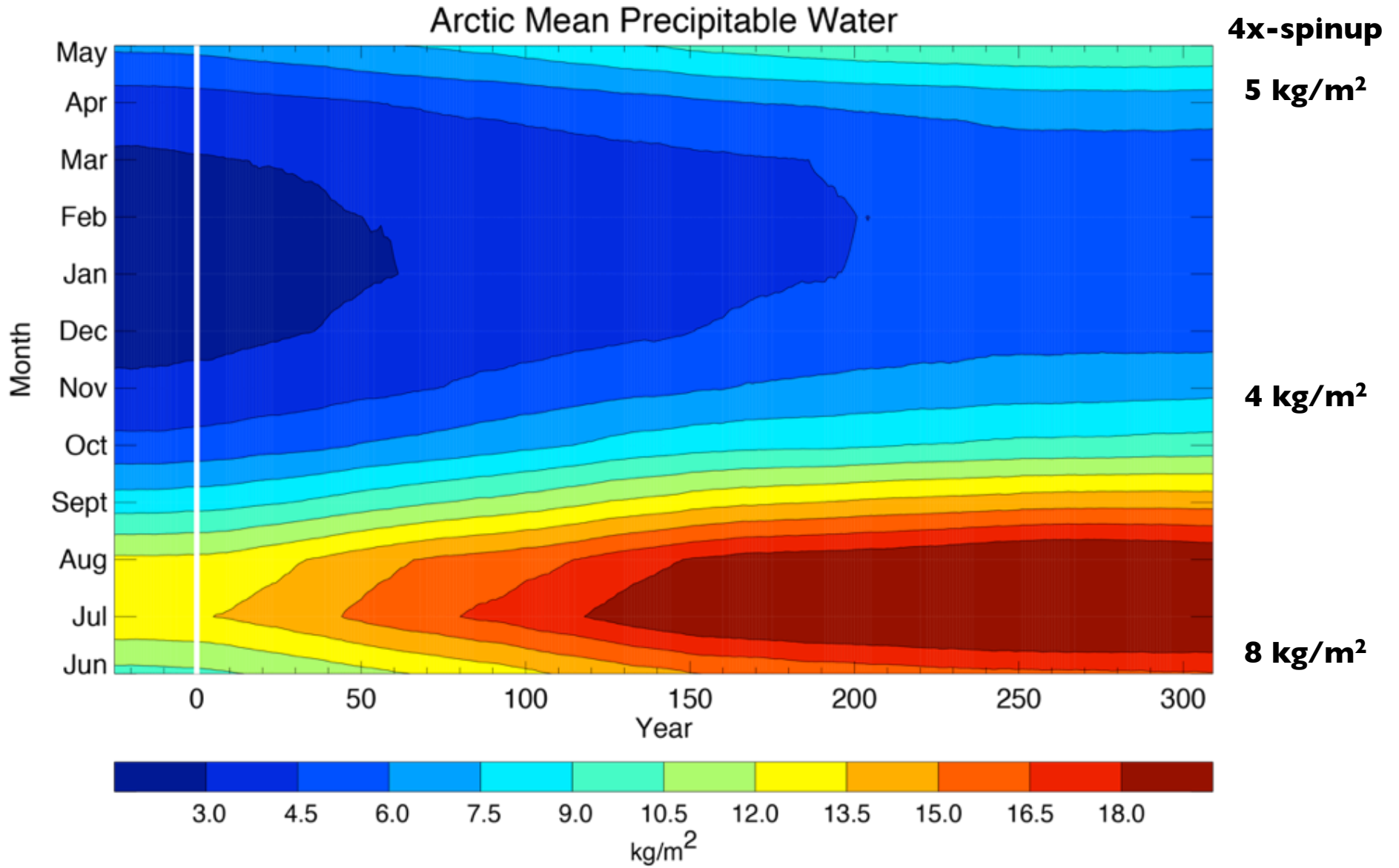
70-90N

Sea ice volume decreases.

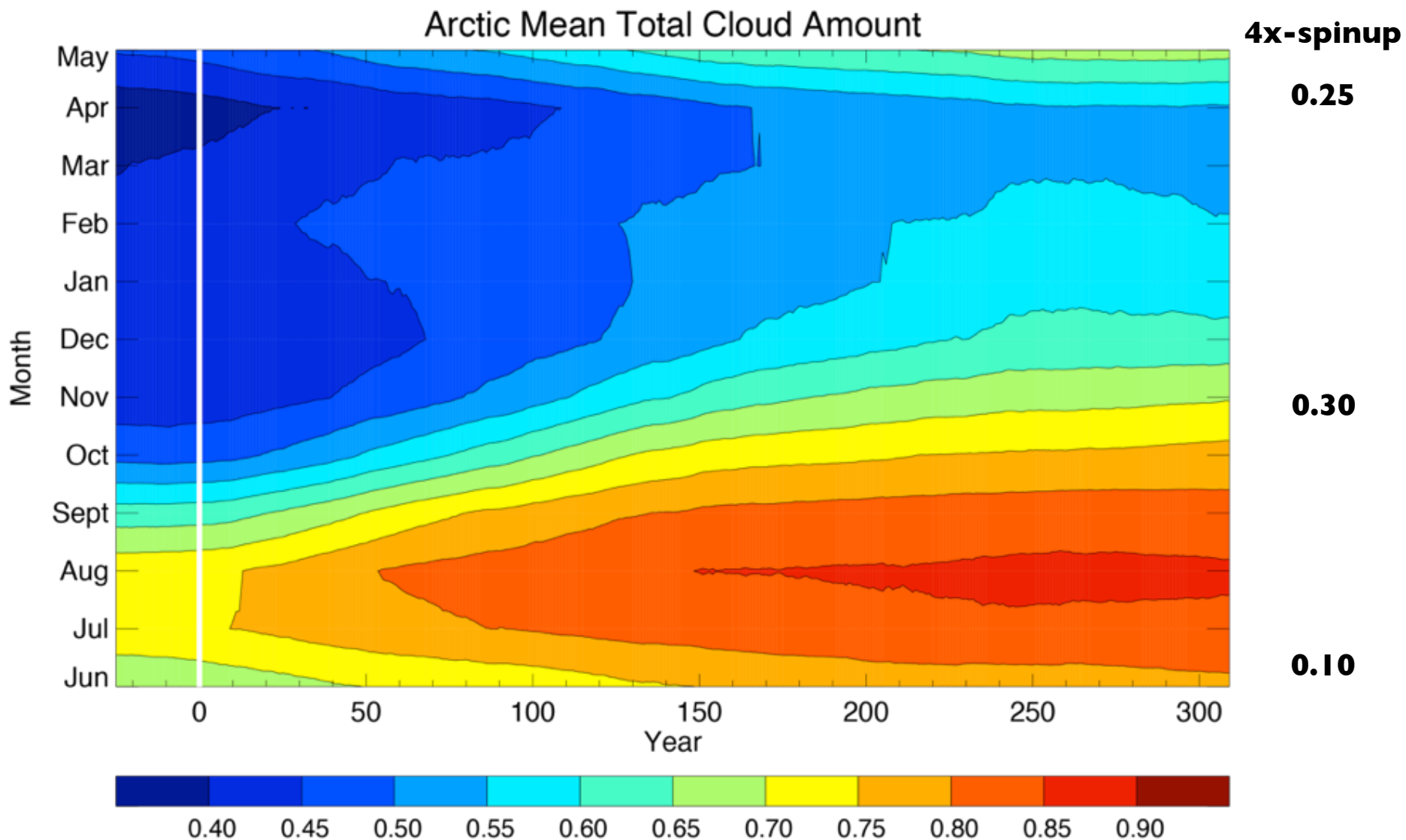


70-90N

Water vapor increases.

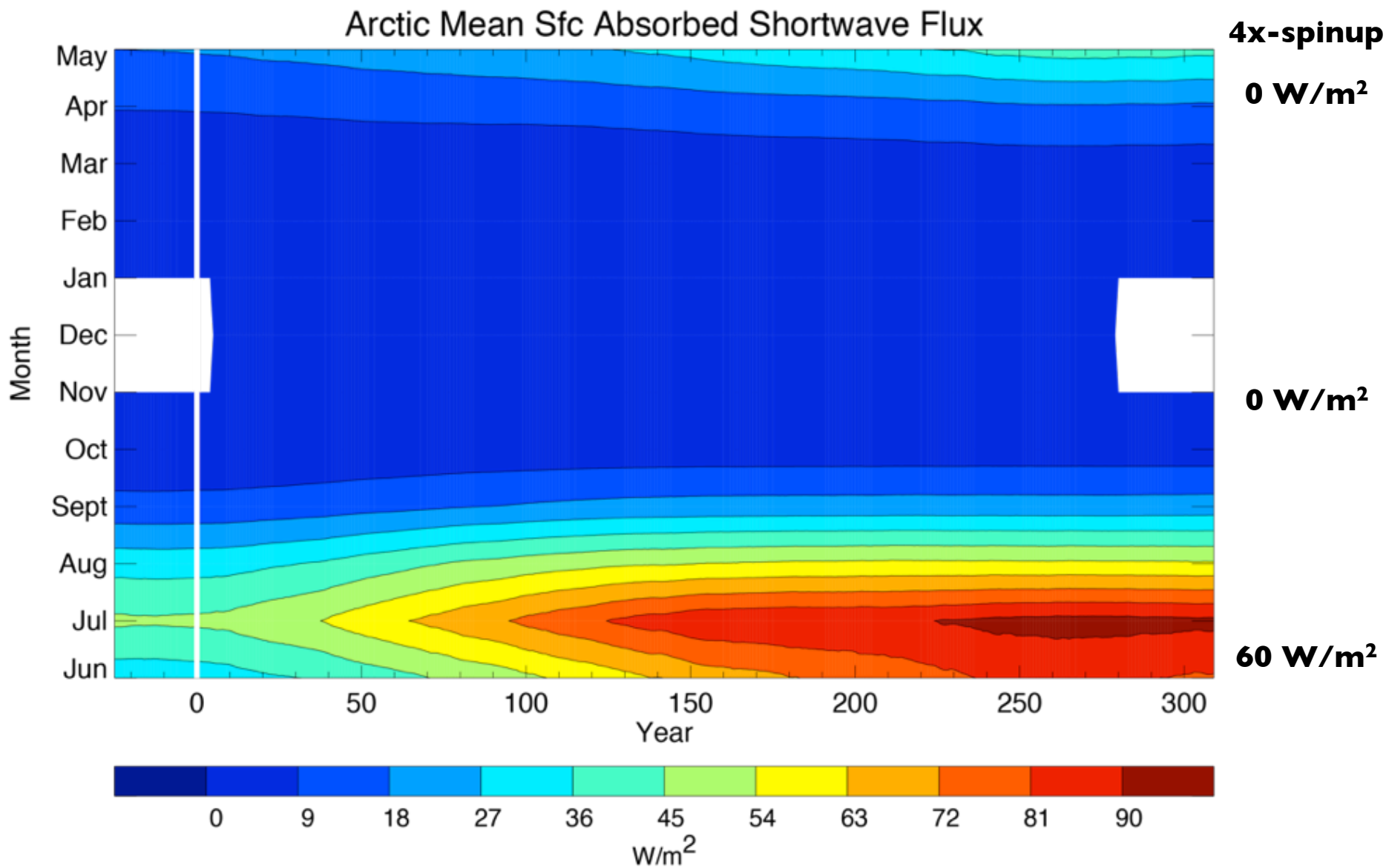


The Arctic gets cloudier.



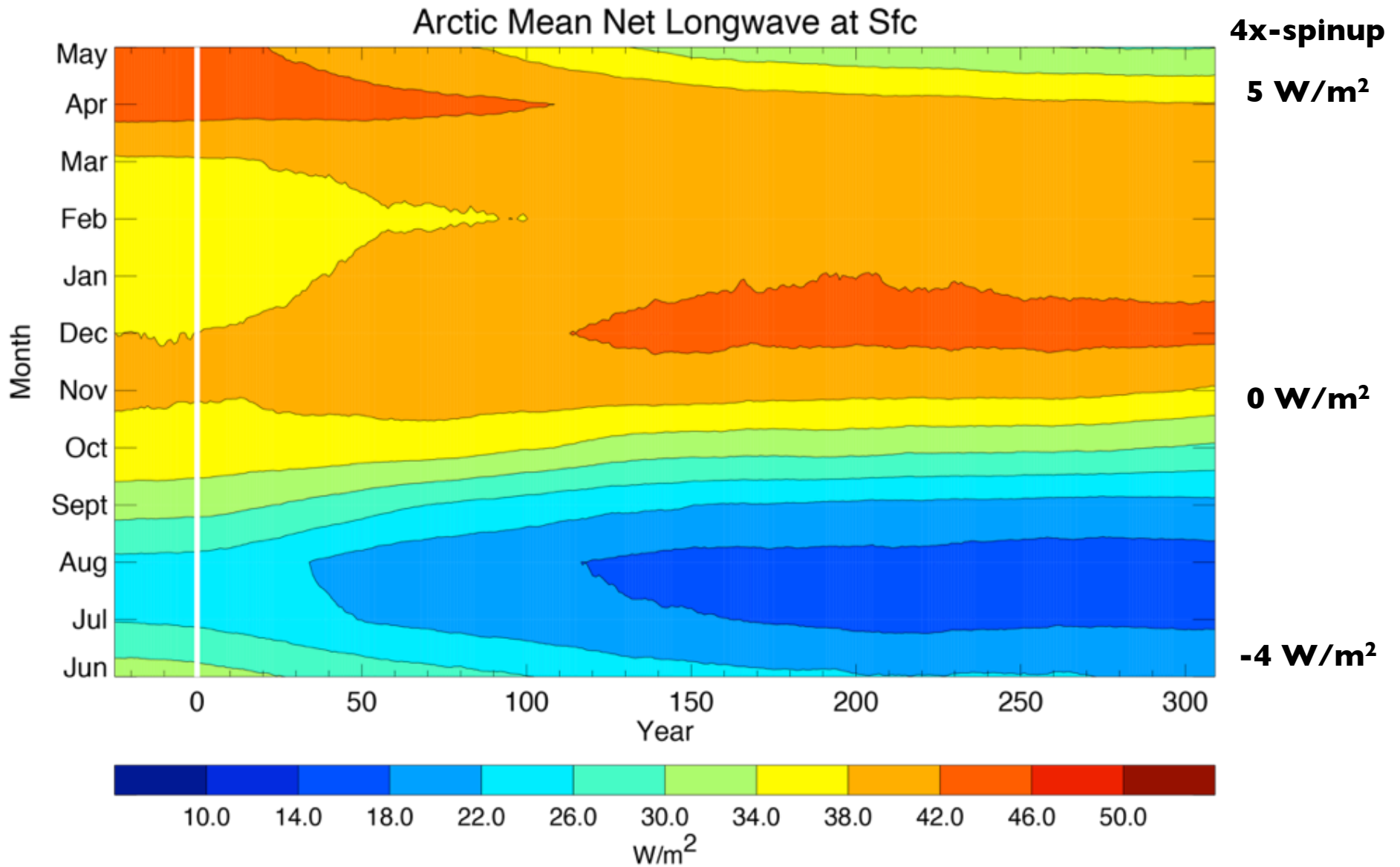
70-90N

Absorbed SW increases in summer.



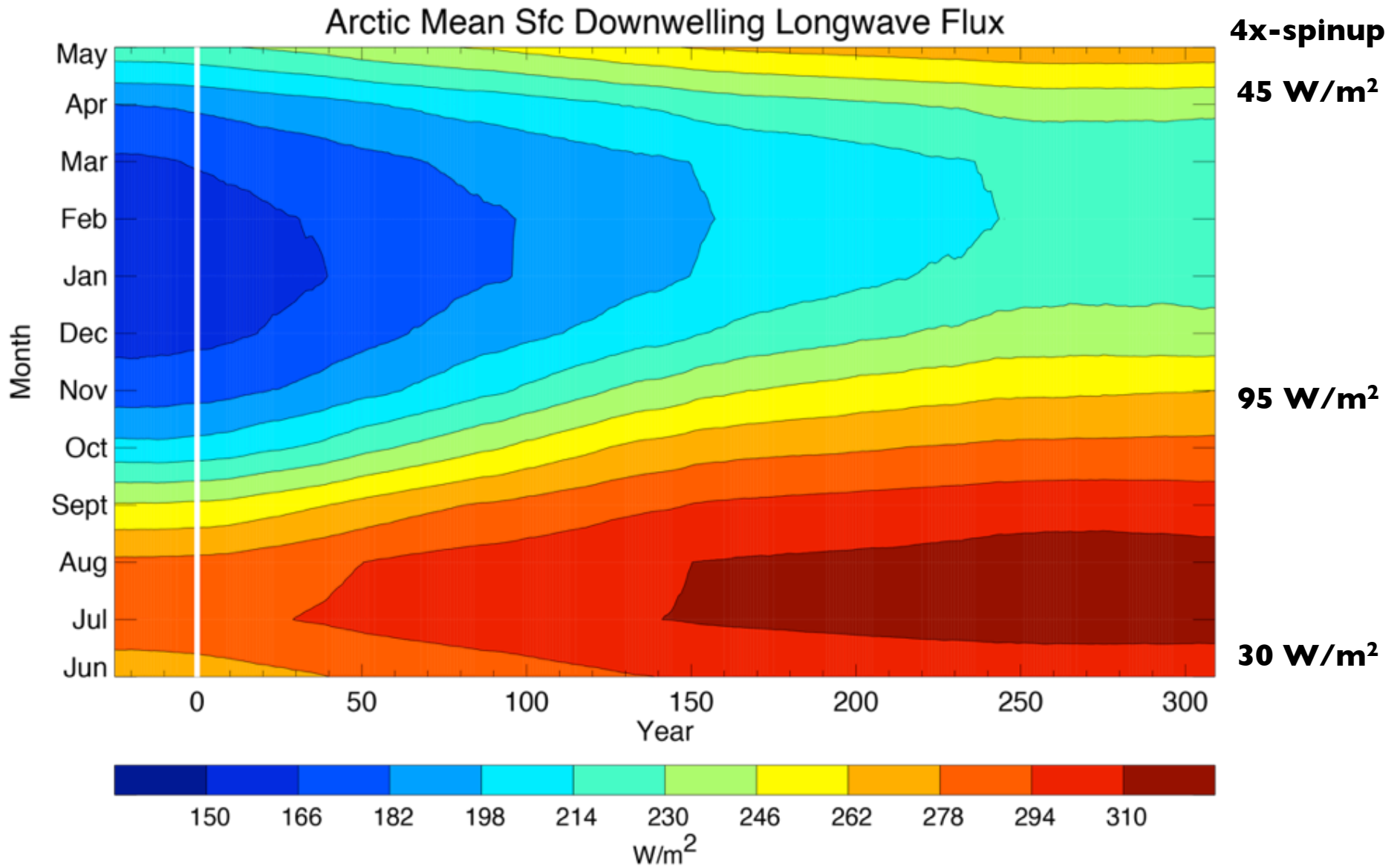
70-90N

Net LW at surface does not change much.



70-90N

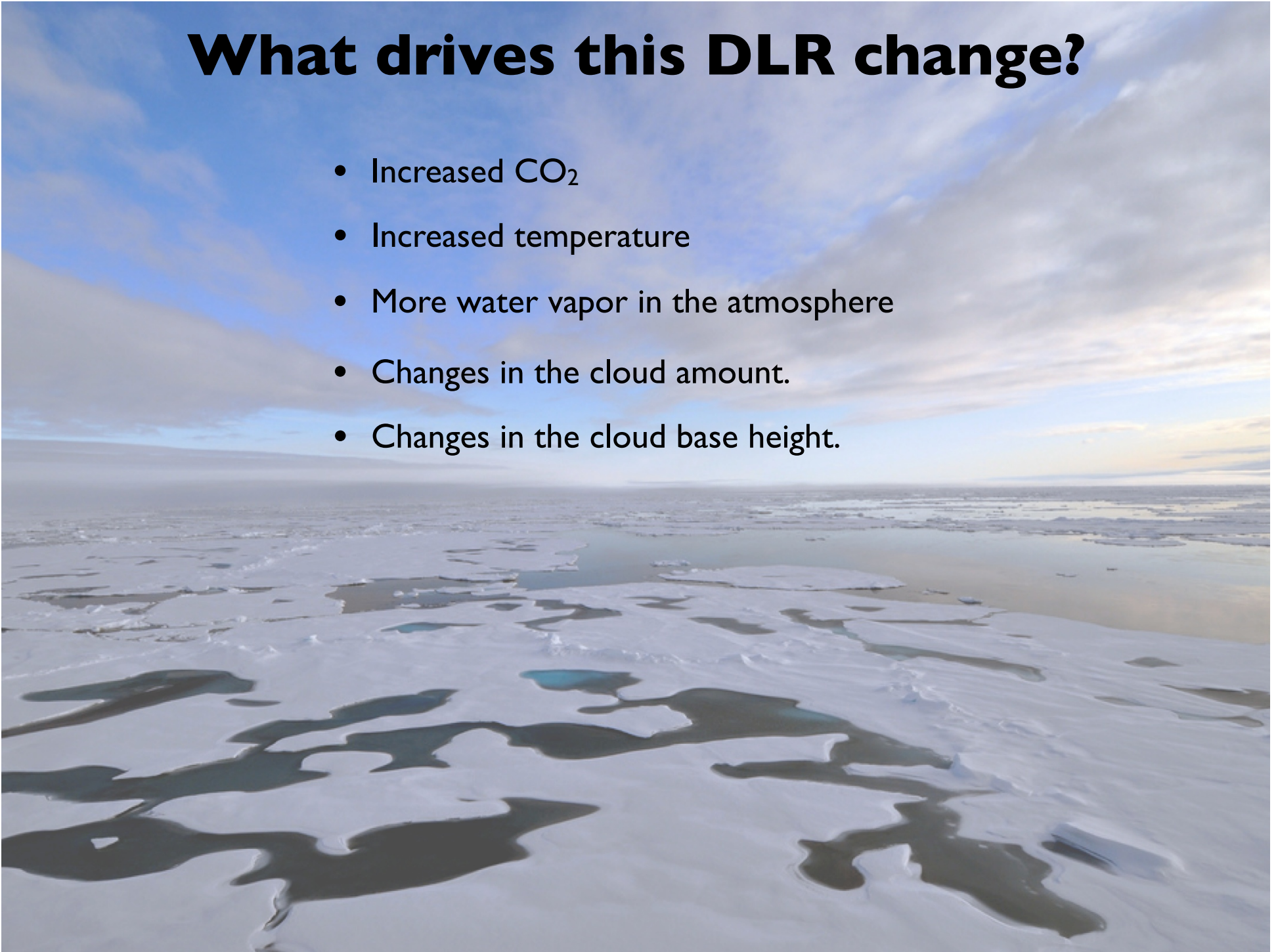
Downwelling LW at surface gets stronger.



70-90N

What drives this DLR change?

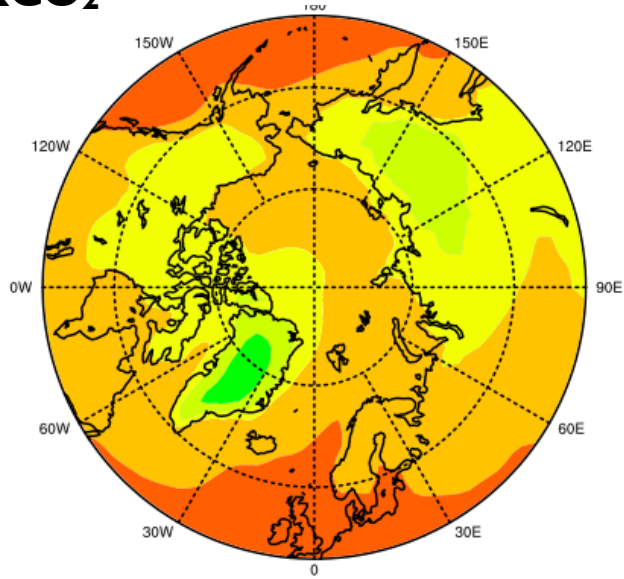
- Increased CO₂
- Increased temperature
- More water vapor in the atmosphere
- Changes in the cloud amount.
- Changes in the cloud base height.



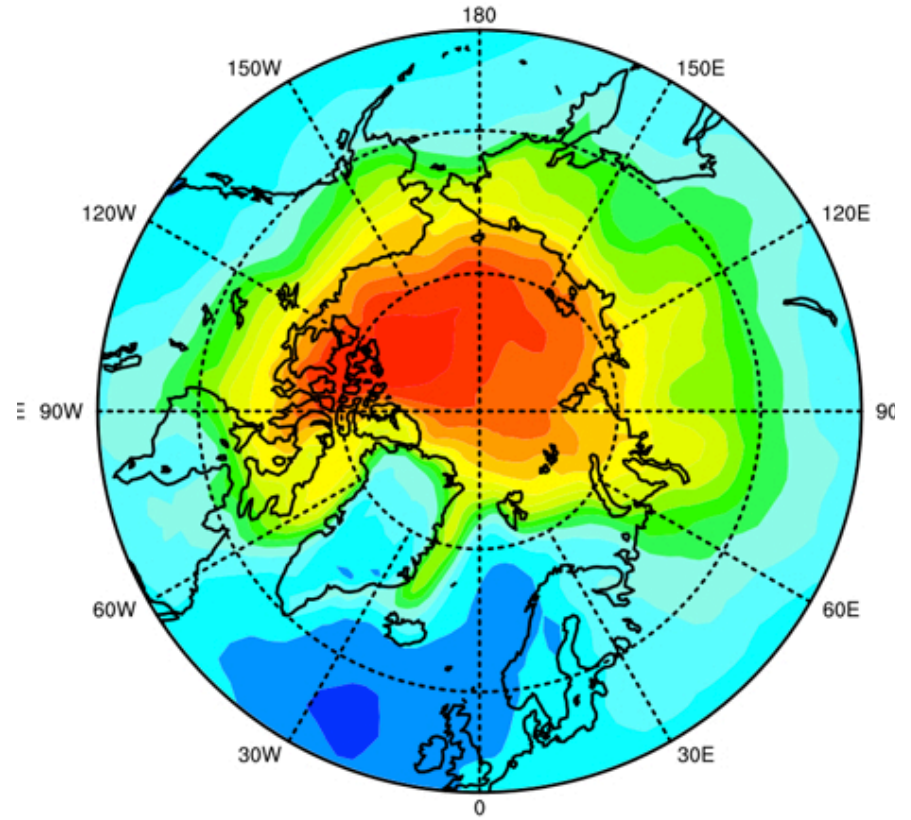
2m Temperature (K)

November

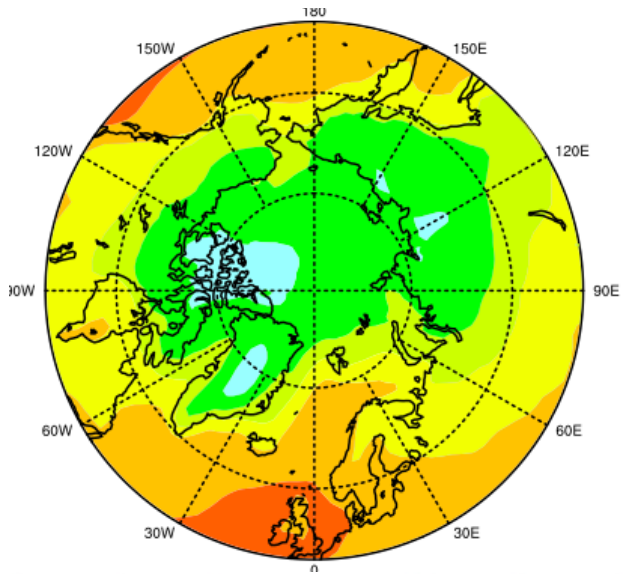
4xCO₂



4xCO₂ - CTL



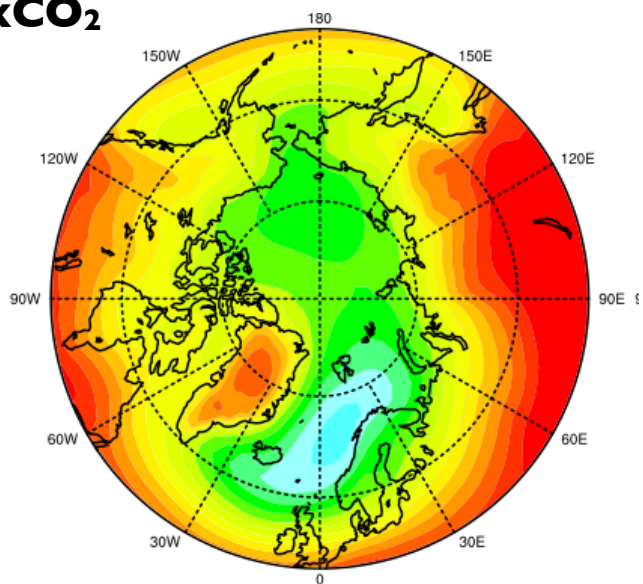
CTL



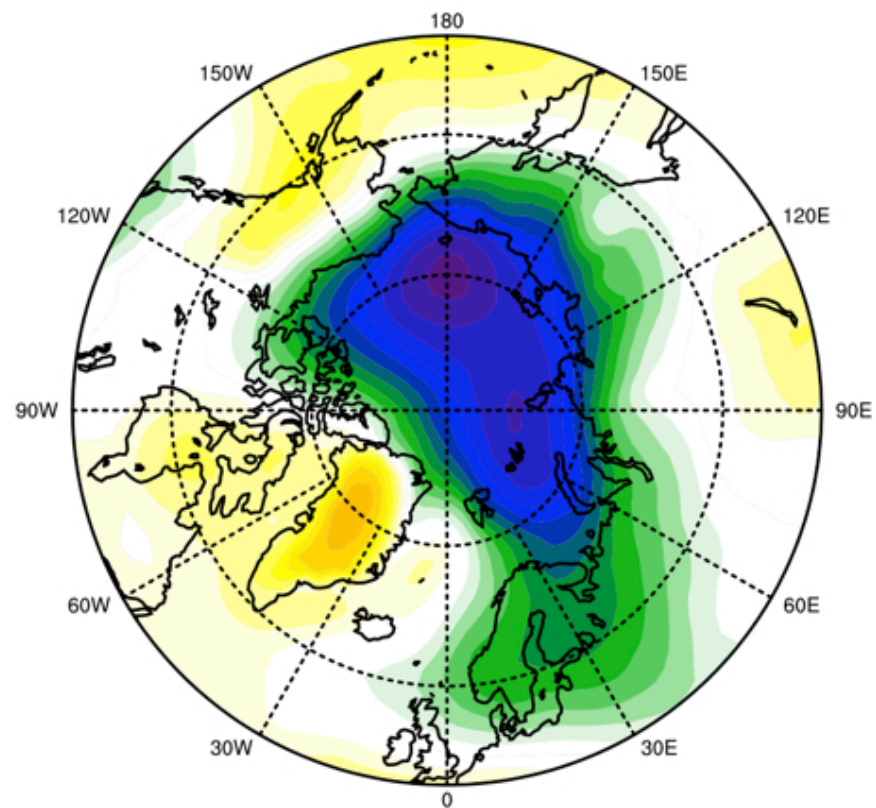
Sea Level Pressure (hPa)

November

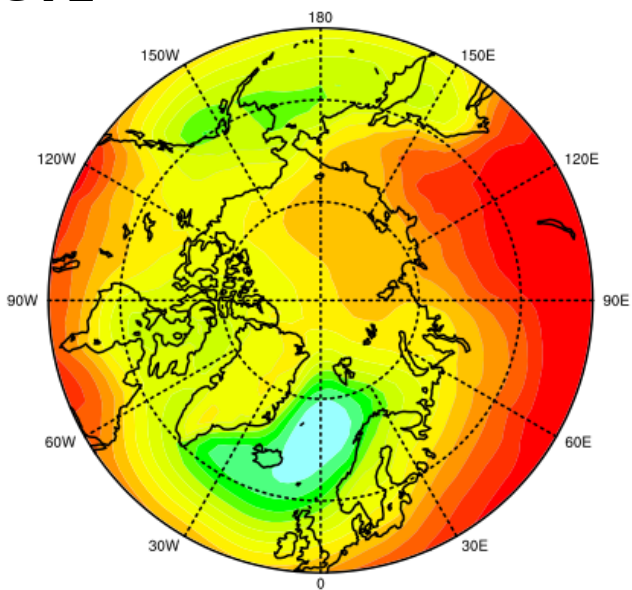
4xCO₂



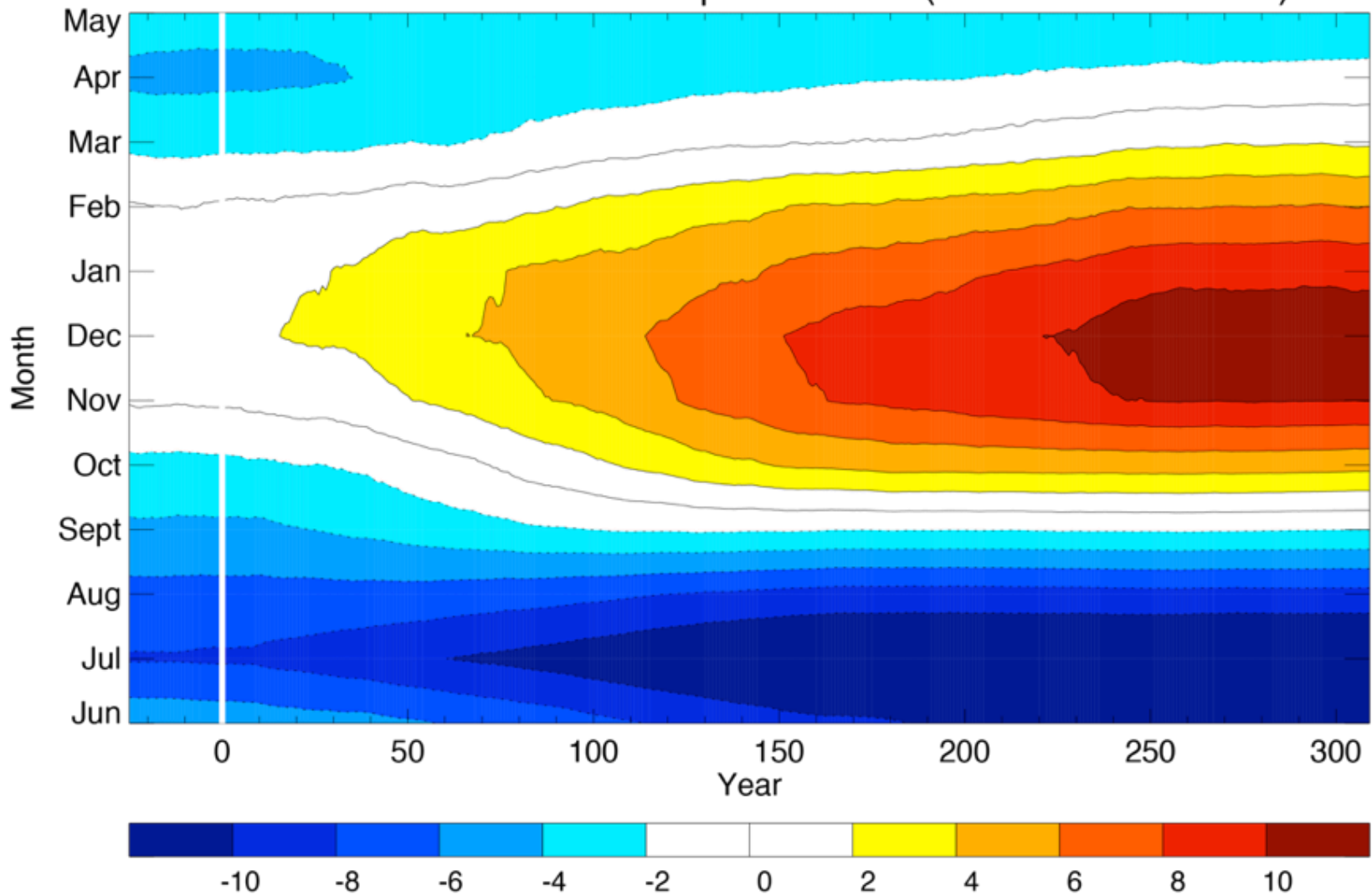
4xCO₂ - CTL



CTL



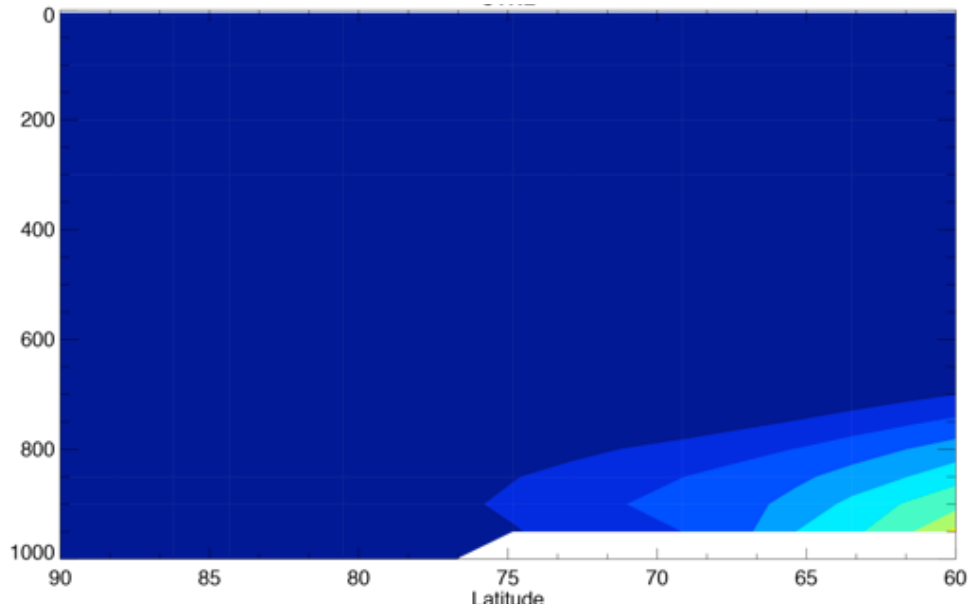
Arctic Mean Surface Air Temperature Diff (Ocn/Ice minus Land)



60-90N

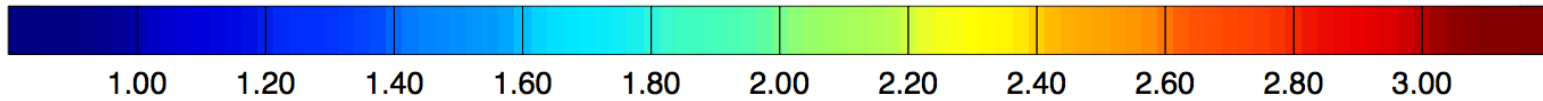
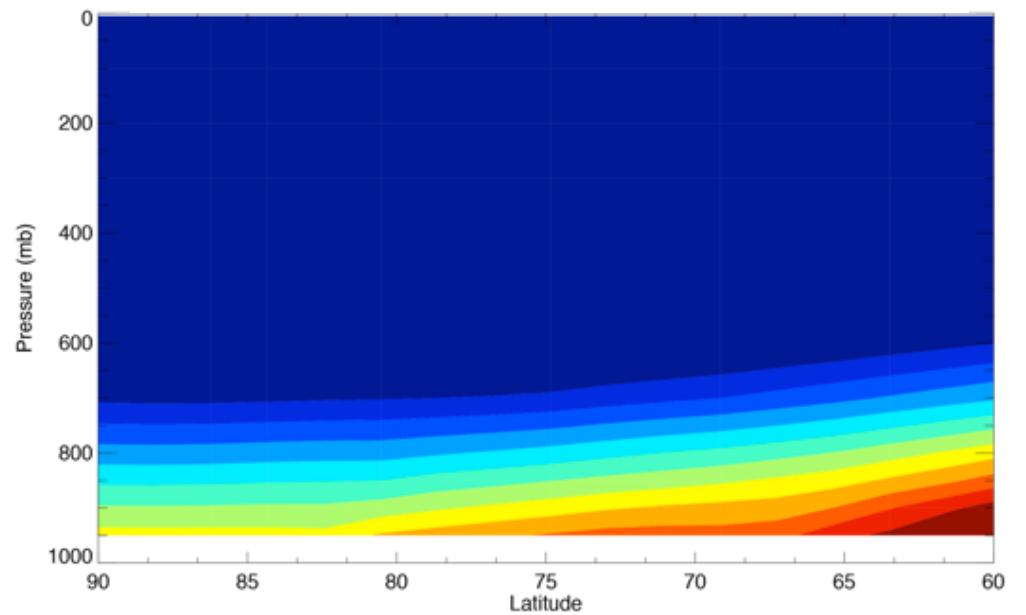
November

CTL



Specific Humidity (g/kg)

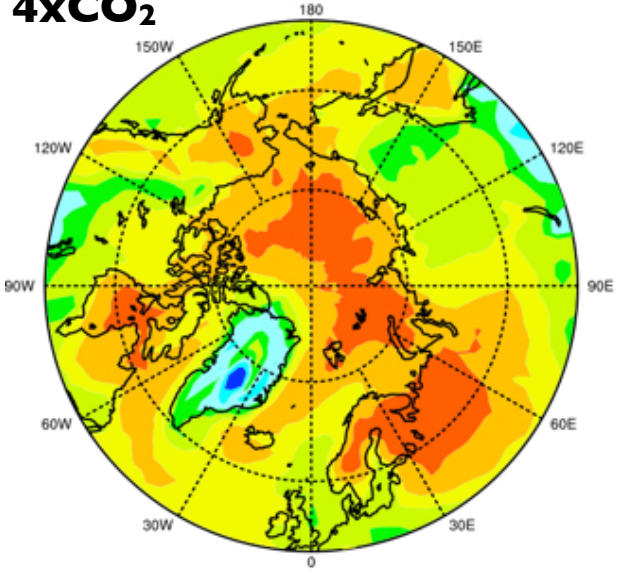
4xCO₂



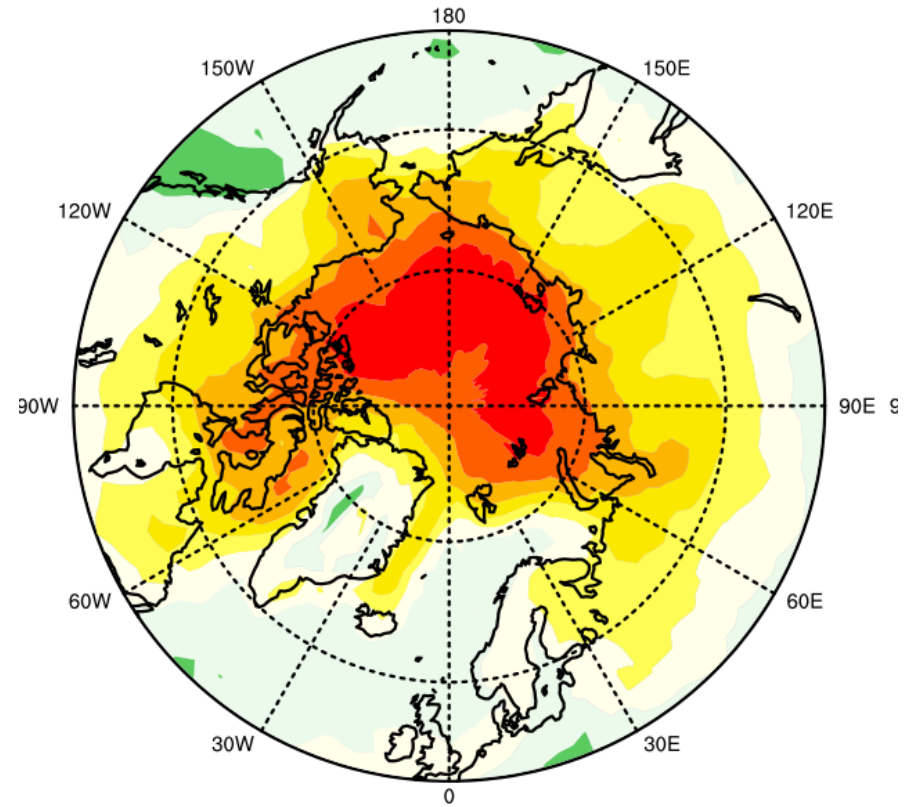
Low Cloud Fraction

November

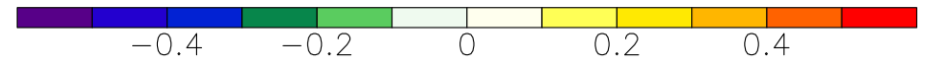
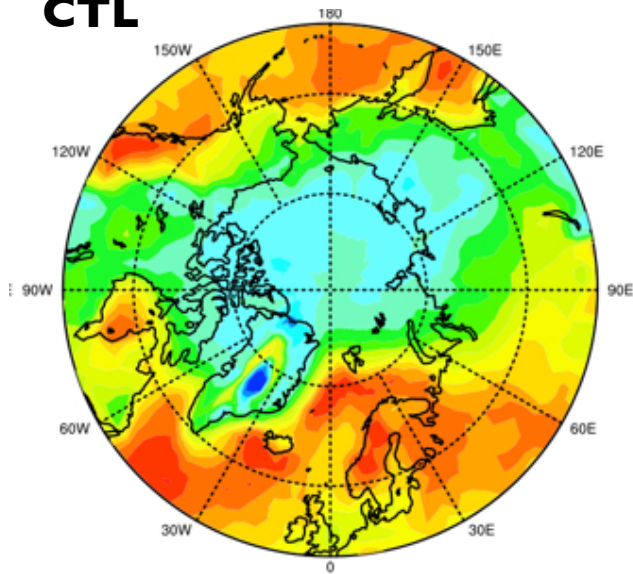
4xCO₂



4xCO₂ - CTL

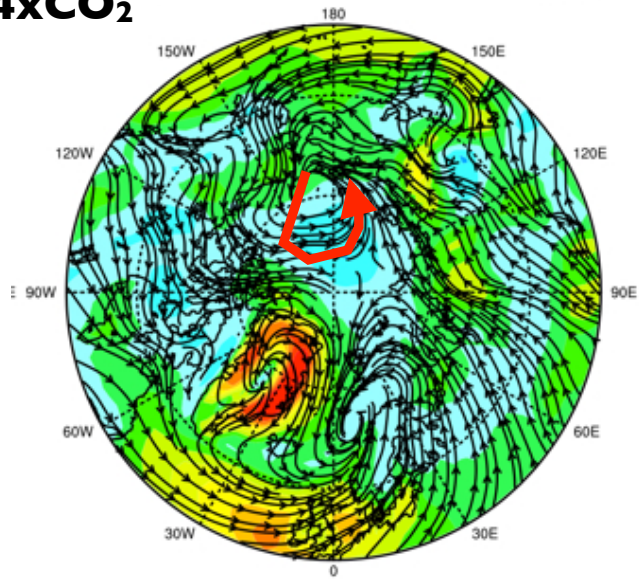


CTL

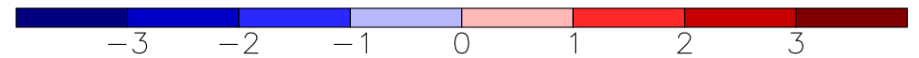
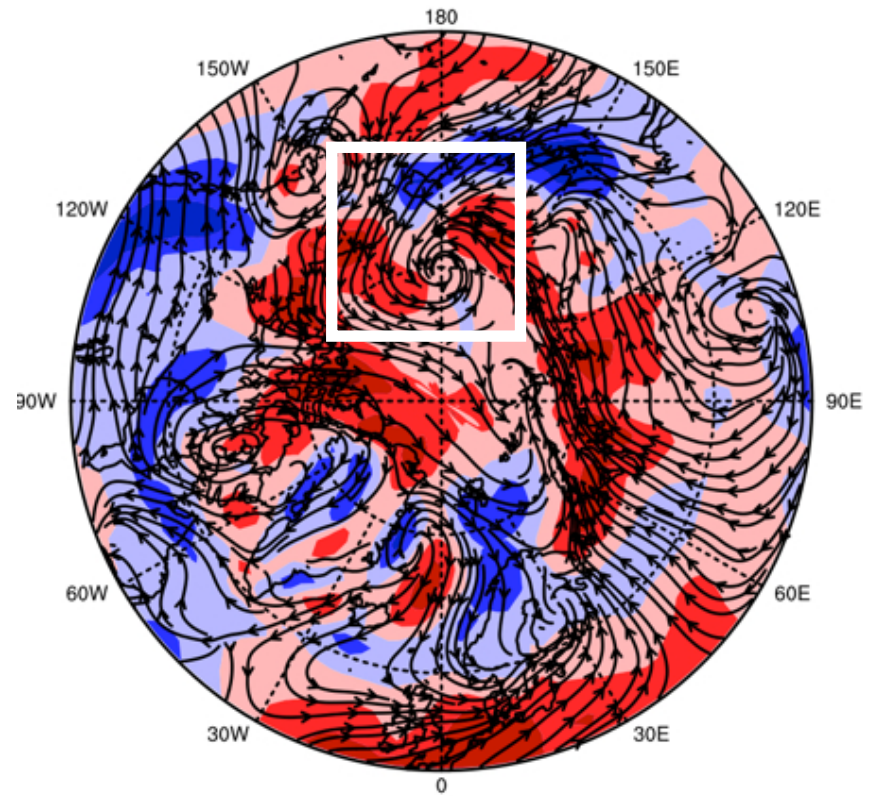


Near Surface Wind (m/s)

4xCO₂

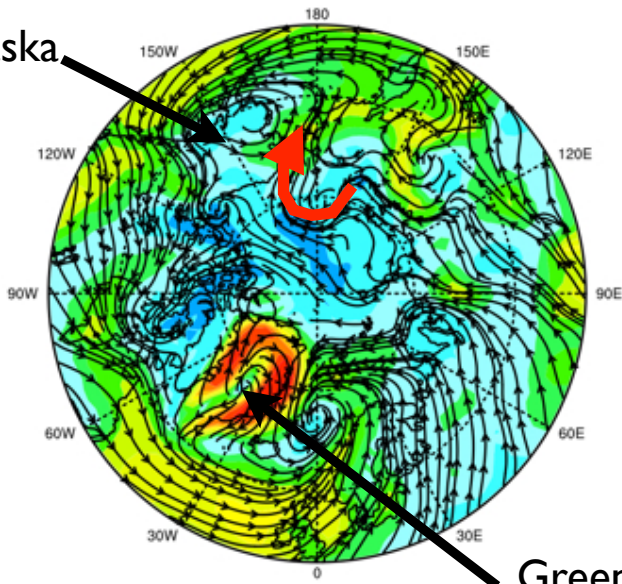


4xCO₂ - CTL



CTL

Alaska

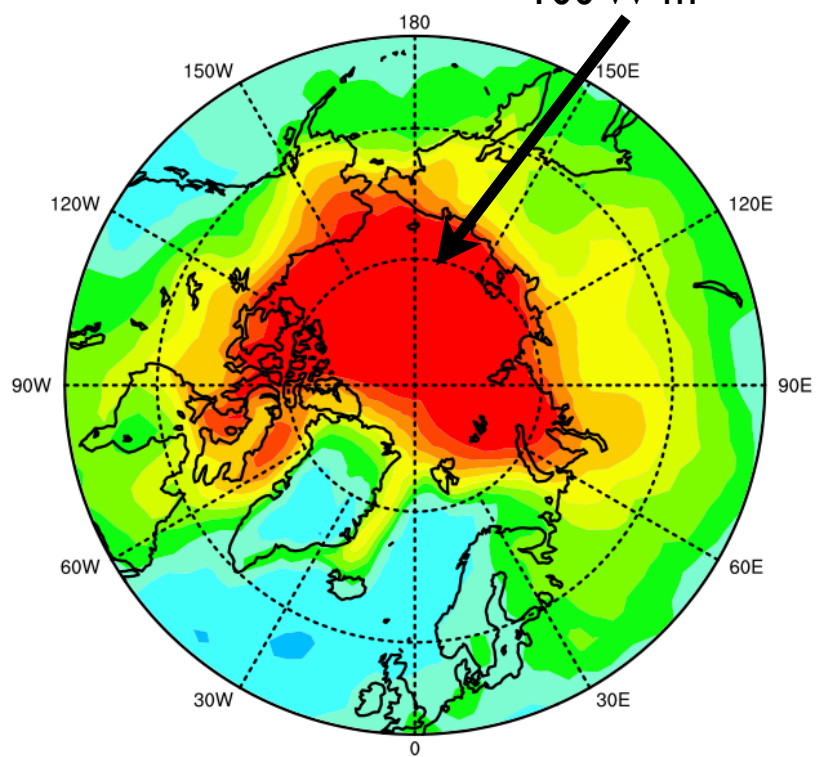


Greenland



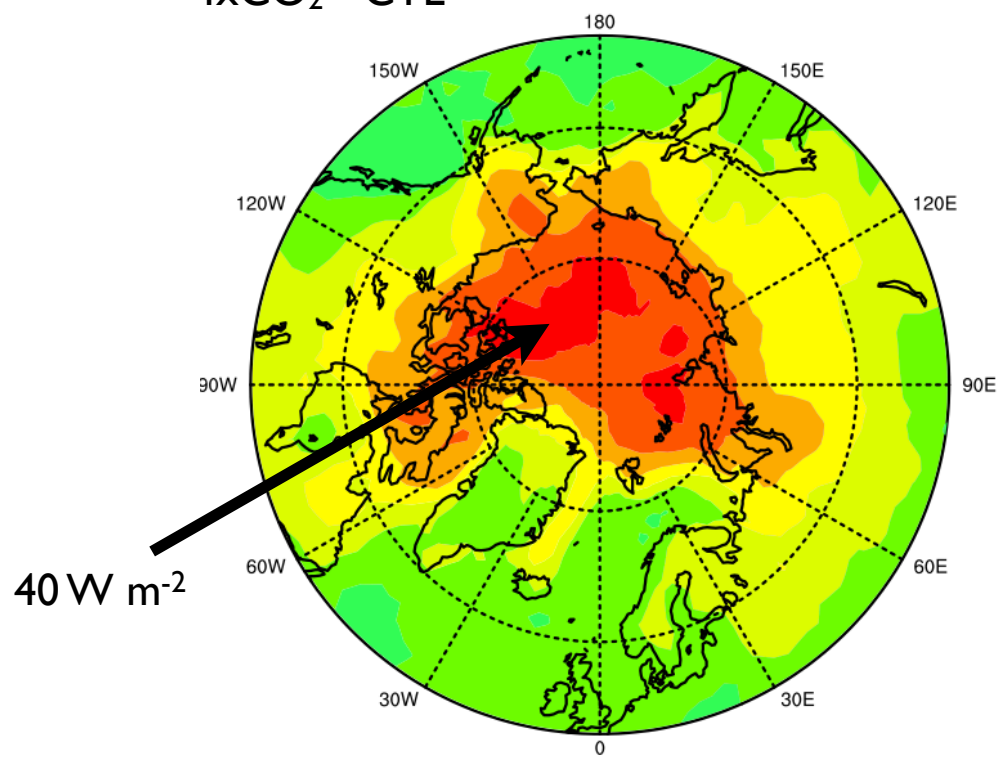
DLR

4xCO₂ - CTL

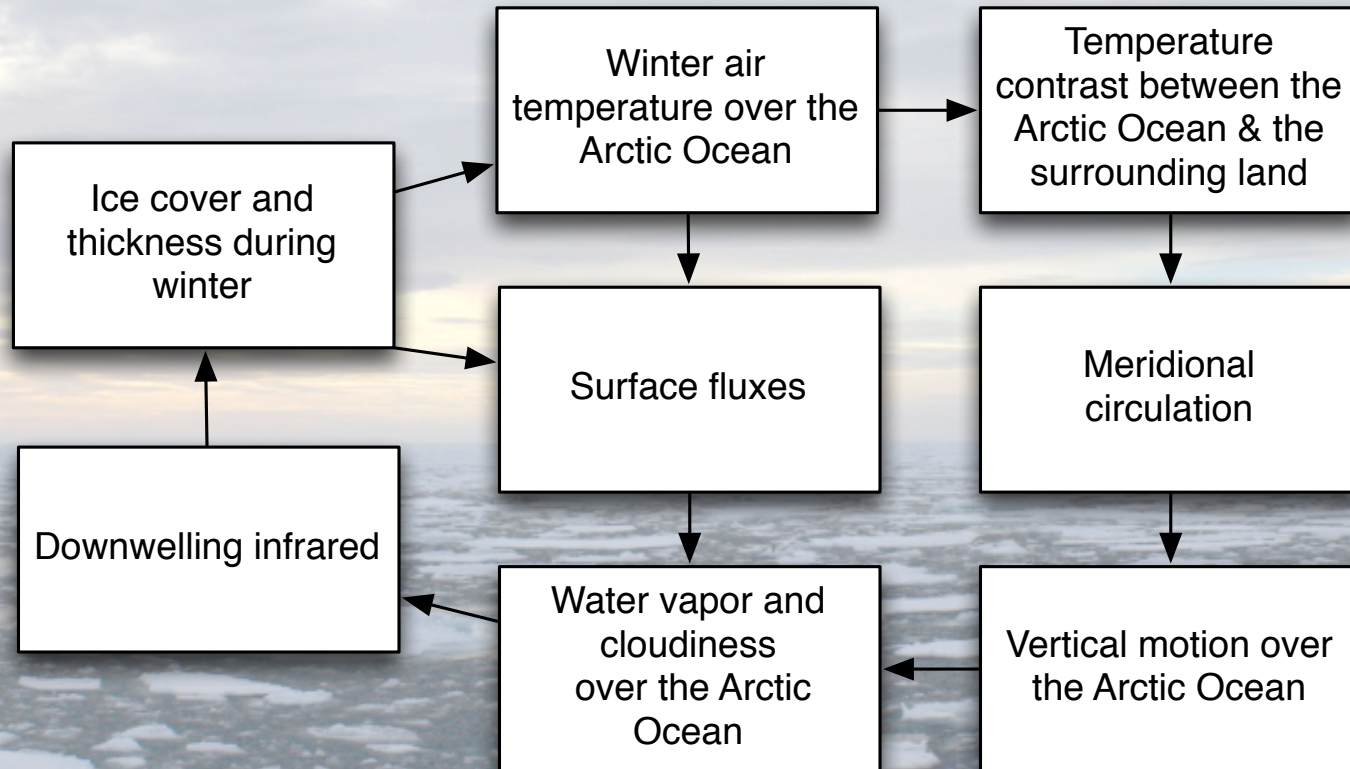


Cloud contribution to DLR

4xCO₂ - CTL

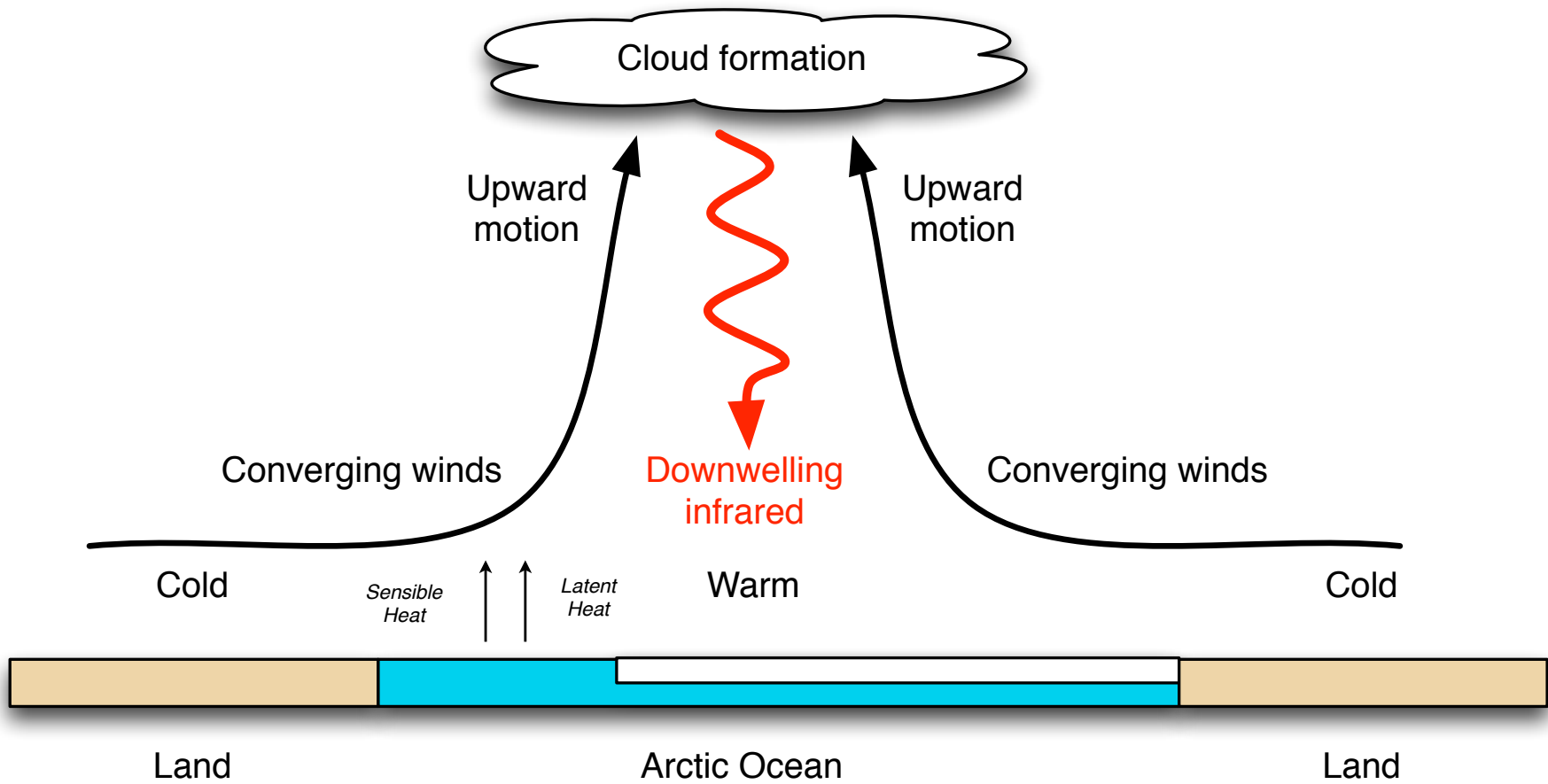


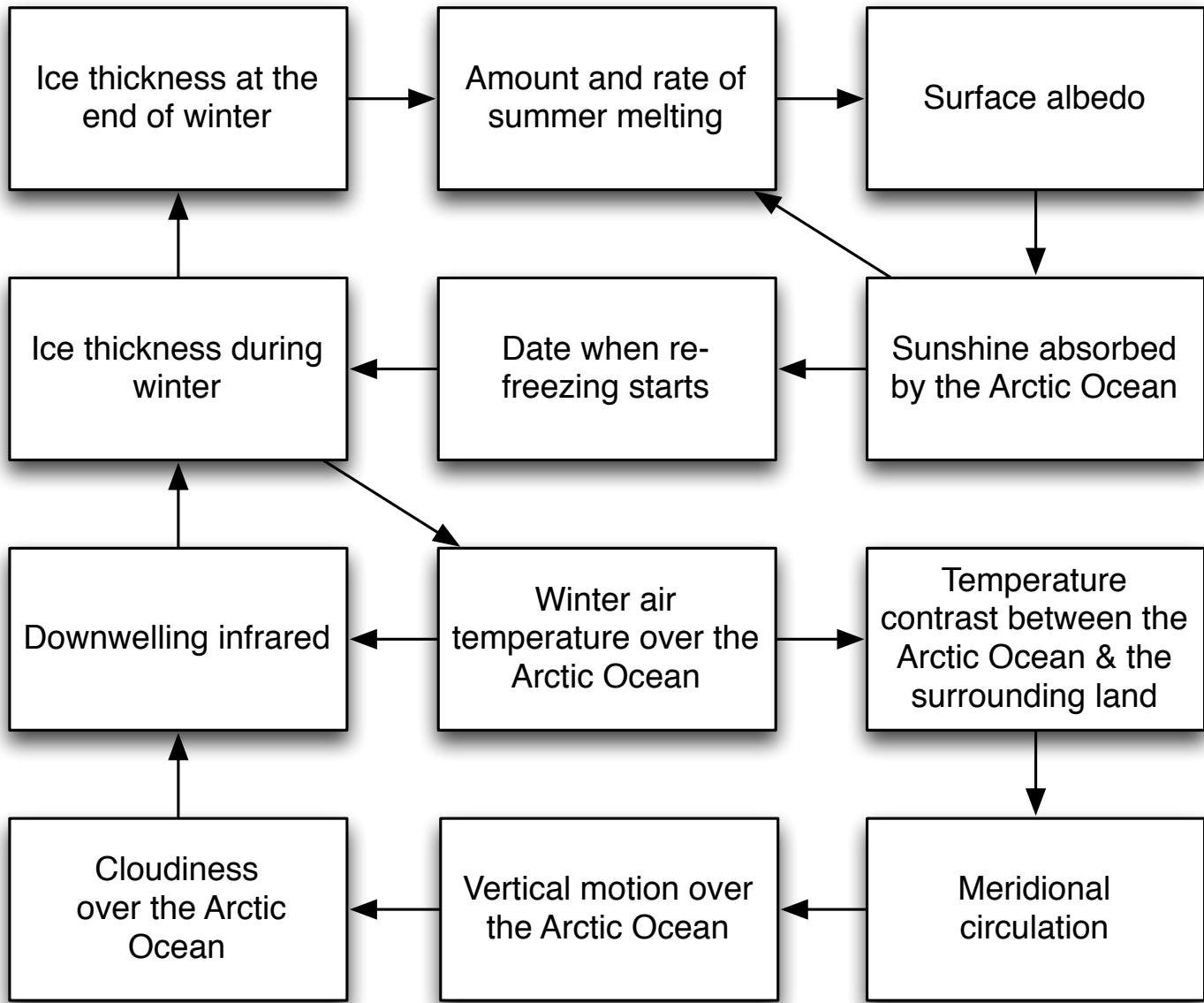
Wintertime longwave feedback



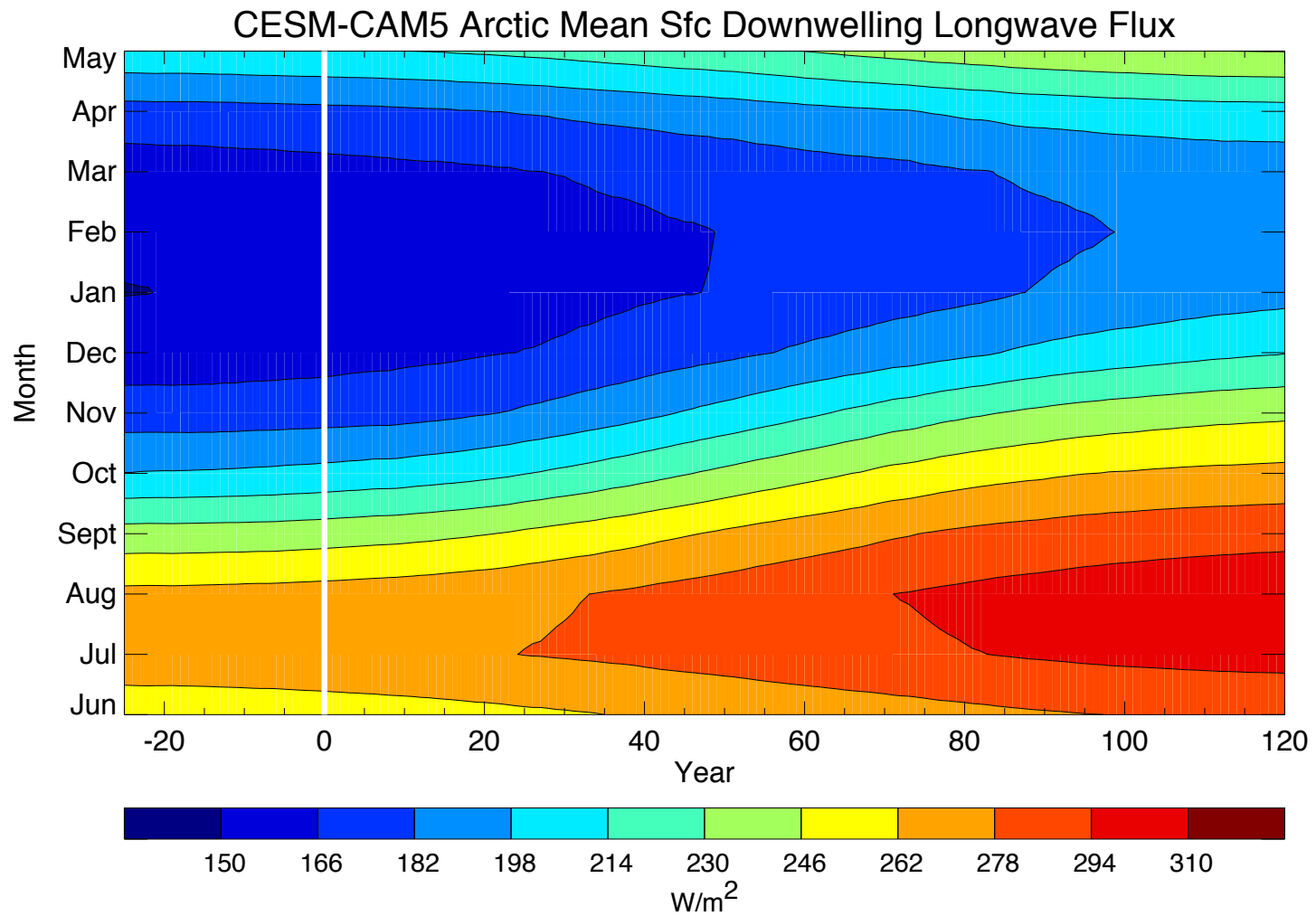
Large scale dynamical and surface processes play a role in this feedback.

Arctic Winter Monsoon

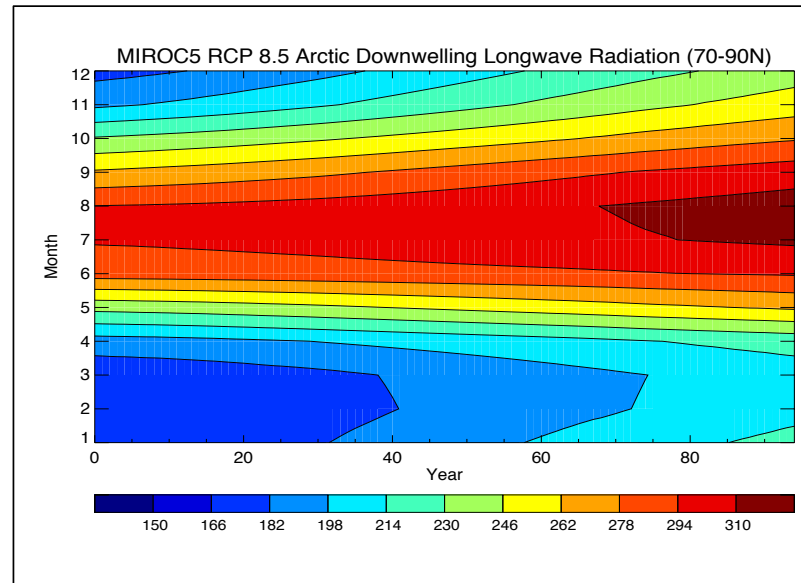
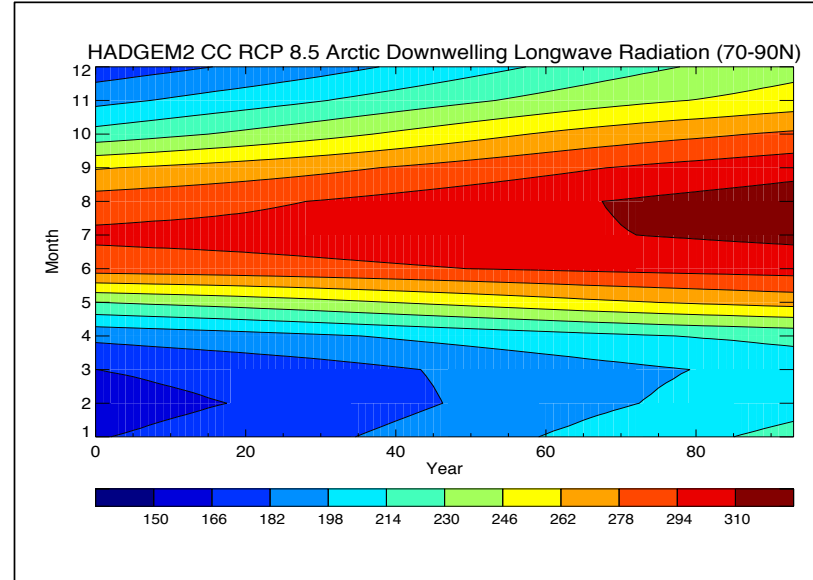
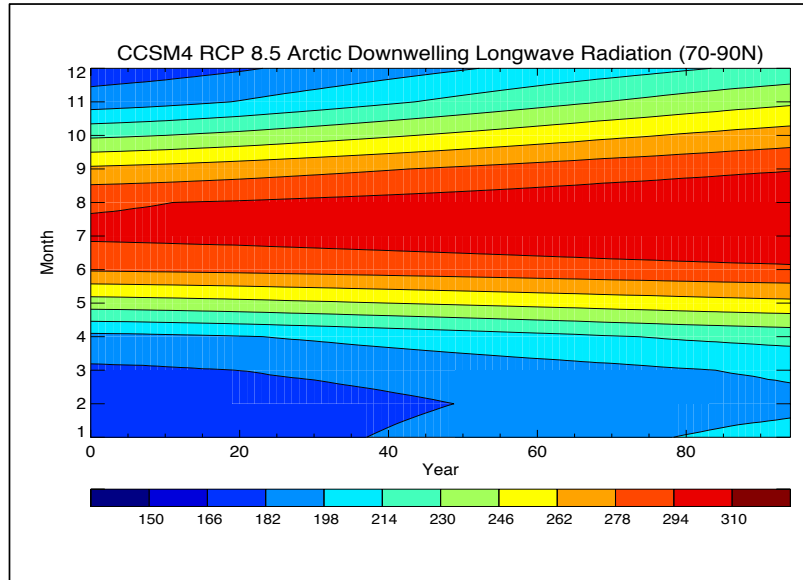




Happens with CESM5.

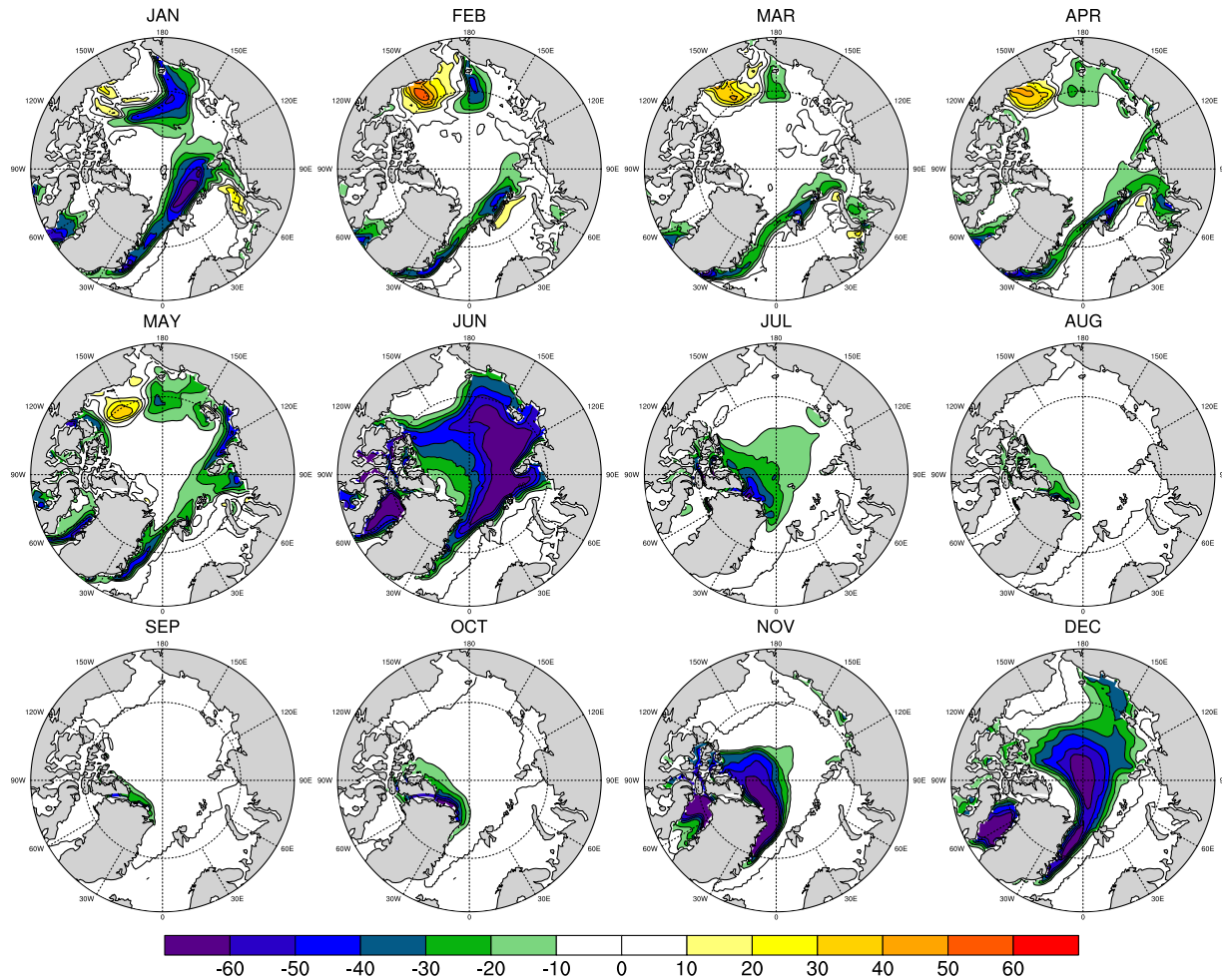


Happens in lots of models.

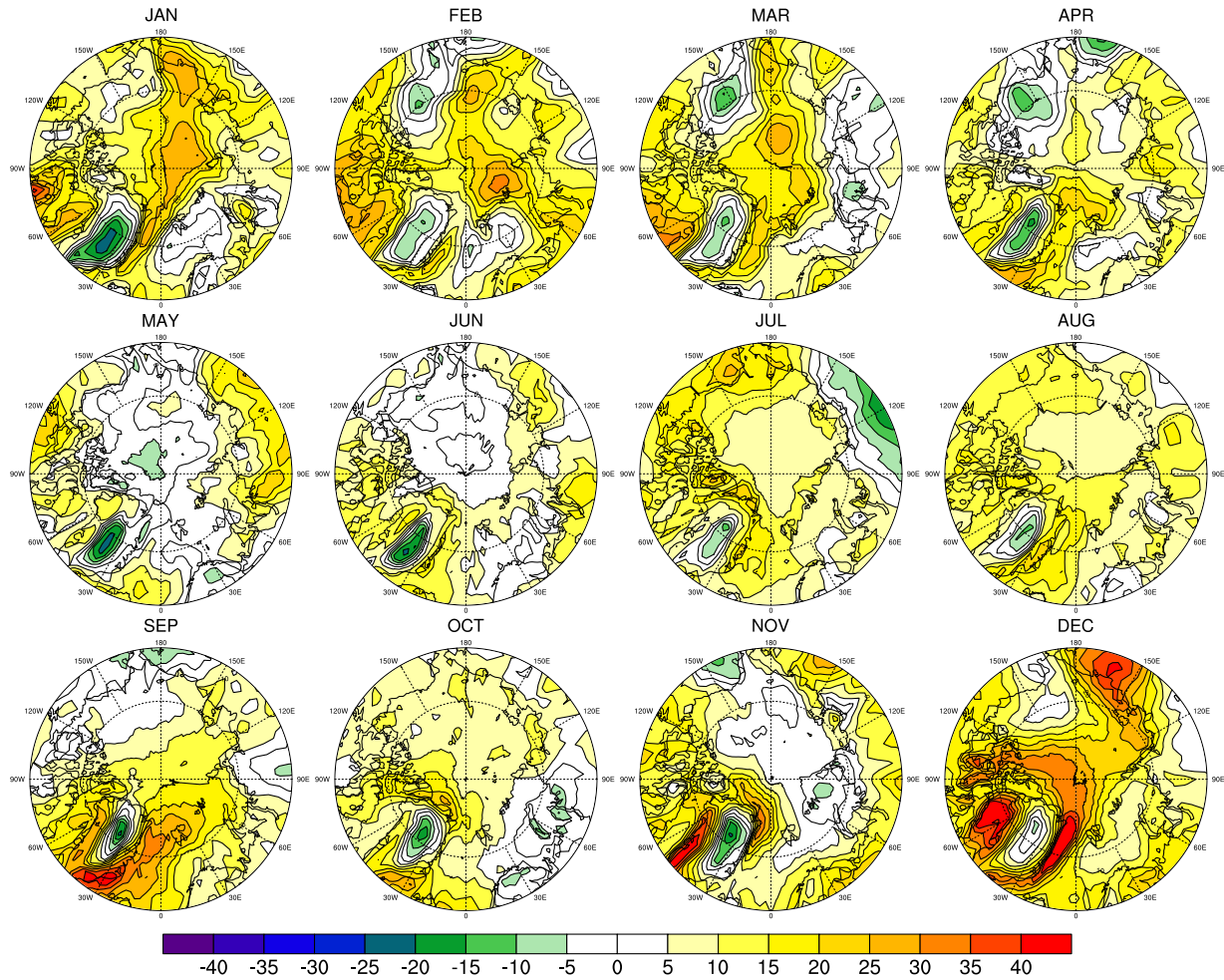


A bit stronger with SP-CESM.

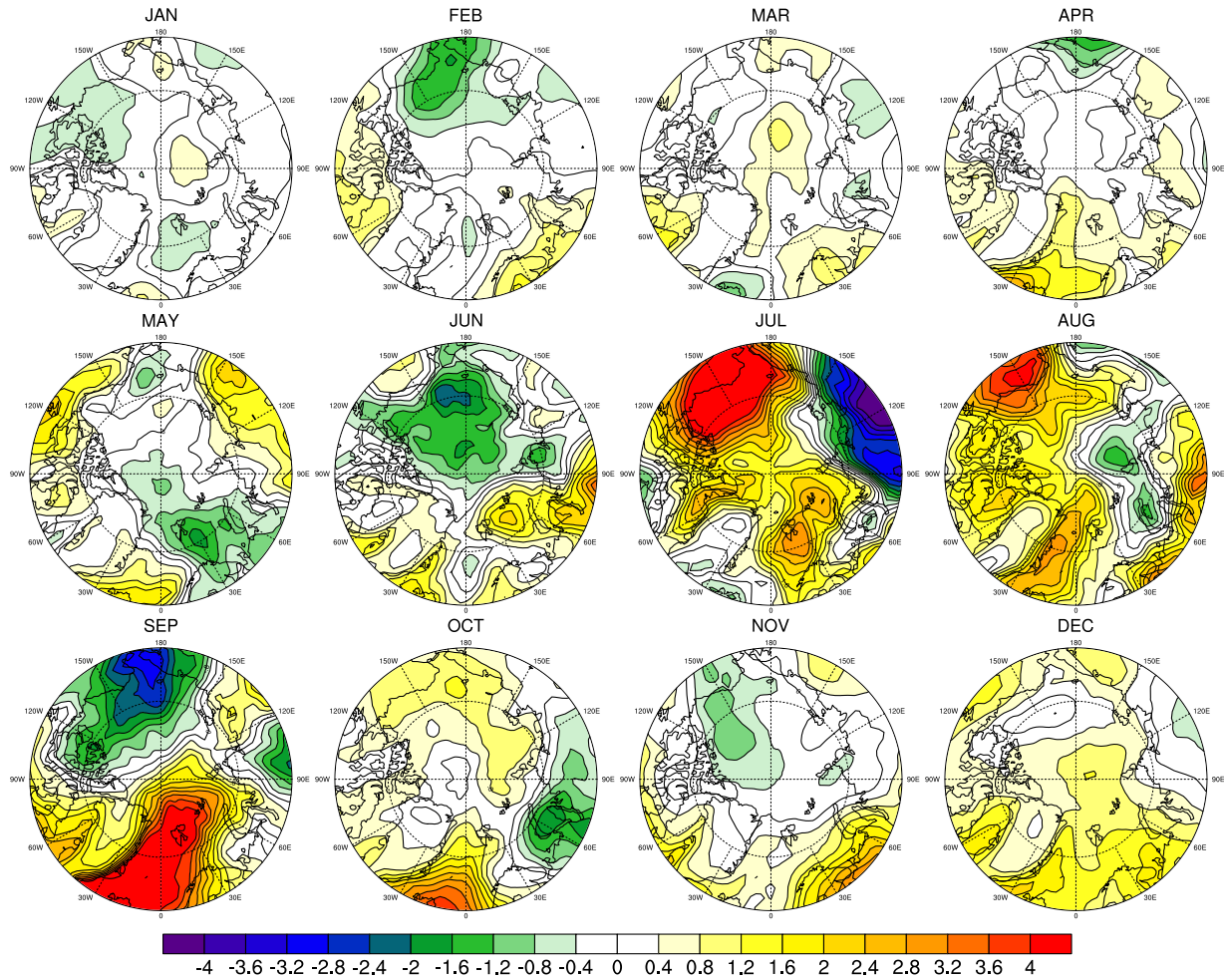
SPCESM-CESM 4xPI: Sea Ice Area (%)



SPCESM-CESM 4xPI: Sfc Downward LW Flux Difference (W/m^2)



SPCESM-CESM 4xPI: Precipitable Water Difference (kg/m²)



Conclusions

- The surface albedo feedback is only part of reason for polar amplification.
- An important longwave feedback works all year round.
- Fall and winter are key to Arctic climate change.

