Arctic Cloud Feedbacks in a 4xCO_2 Simulation with the Superparameterized CESM

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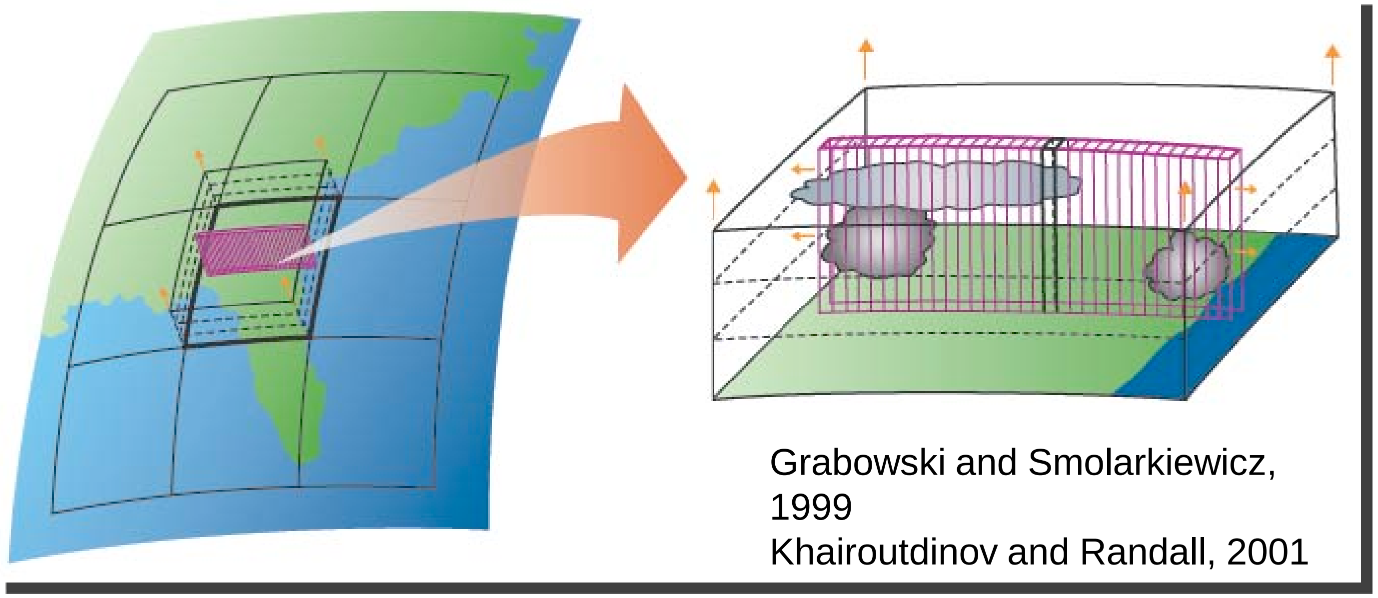
What is Superparameterization?



Grabowski and Smolarkiewicz, 1999
Khairoutdinov and Randall, 2001

Traditional convective parameterizations are replaced by embedding a two dimensional cloud resolving model in each grid cell of a GCM.

Like a public opinion poll, the superparameterization represents a sample of the cloud-scale processes in each grid cell.

Previous work using Superparameterization:

The Madden Julian Oscillation
(Benedict and Randall, 2009; Thayer-Calder and Randall, 2009)

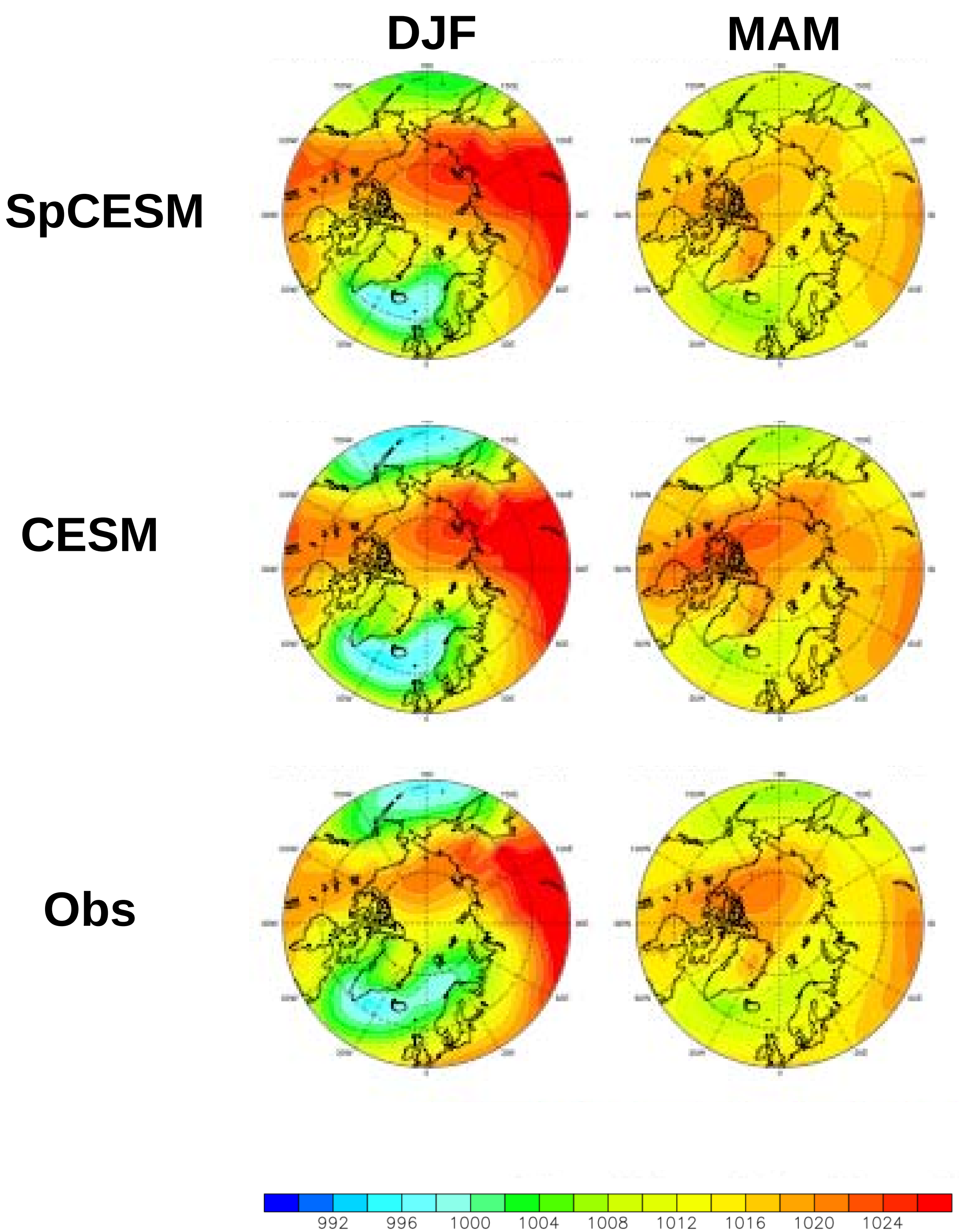
Diurnal Cycle of Precipitation
(Pritchard and Somerville, 2009)

El Nino Southern Oscillation
(Stan et al., 2010)

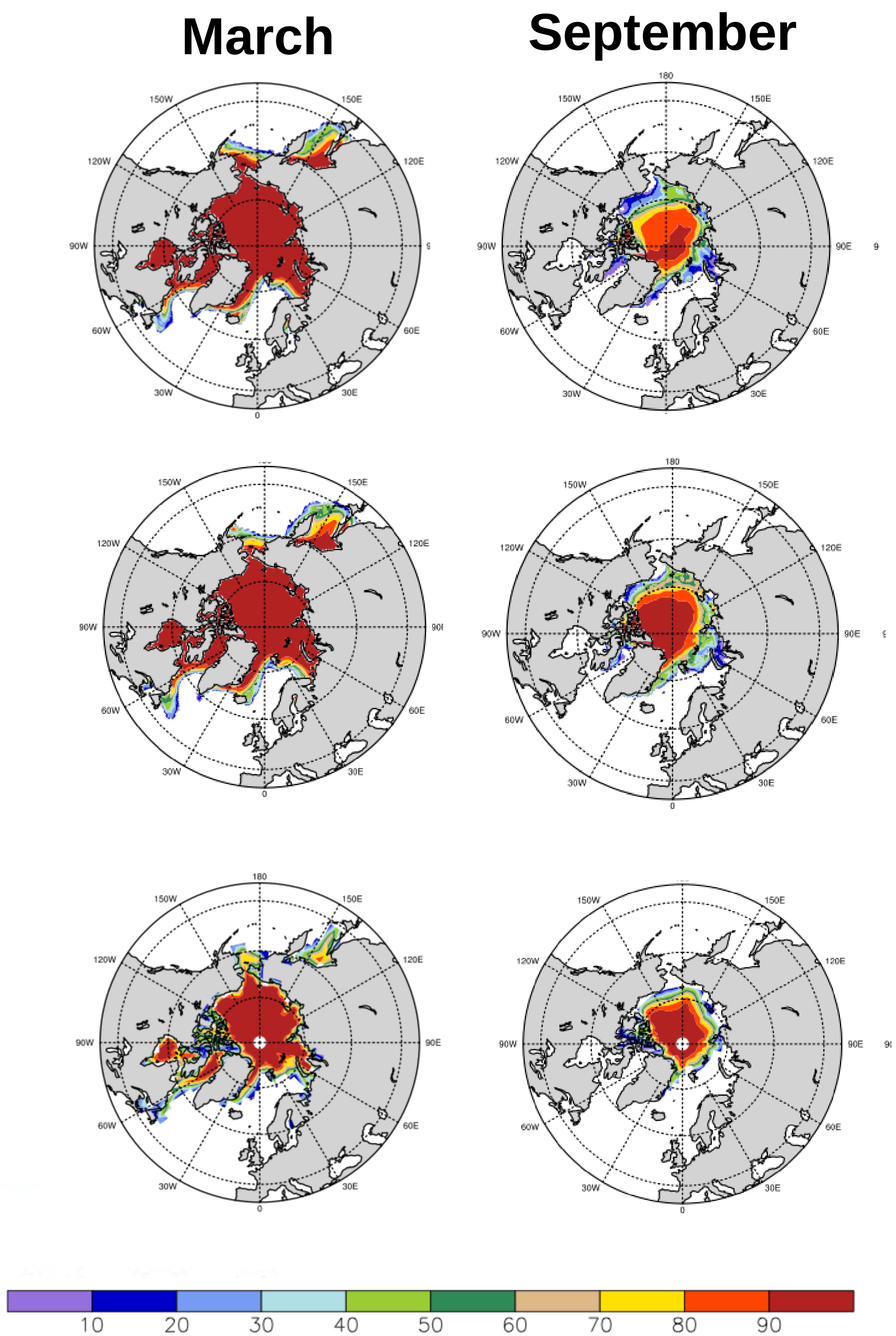
The Asian Monsoon
(DeMott et al., 2011 and 2012)

West African Monsoon
(McCrary 2012)

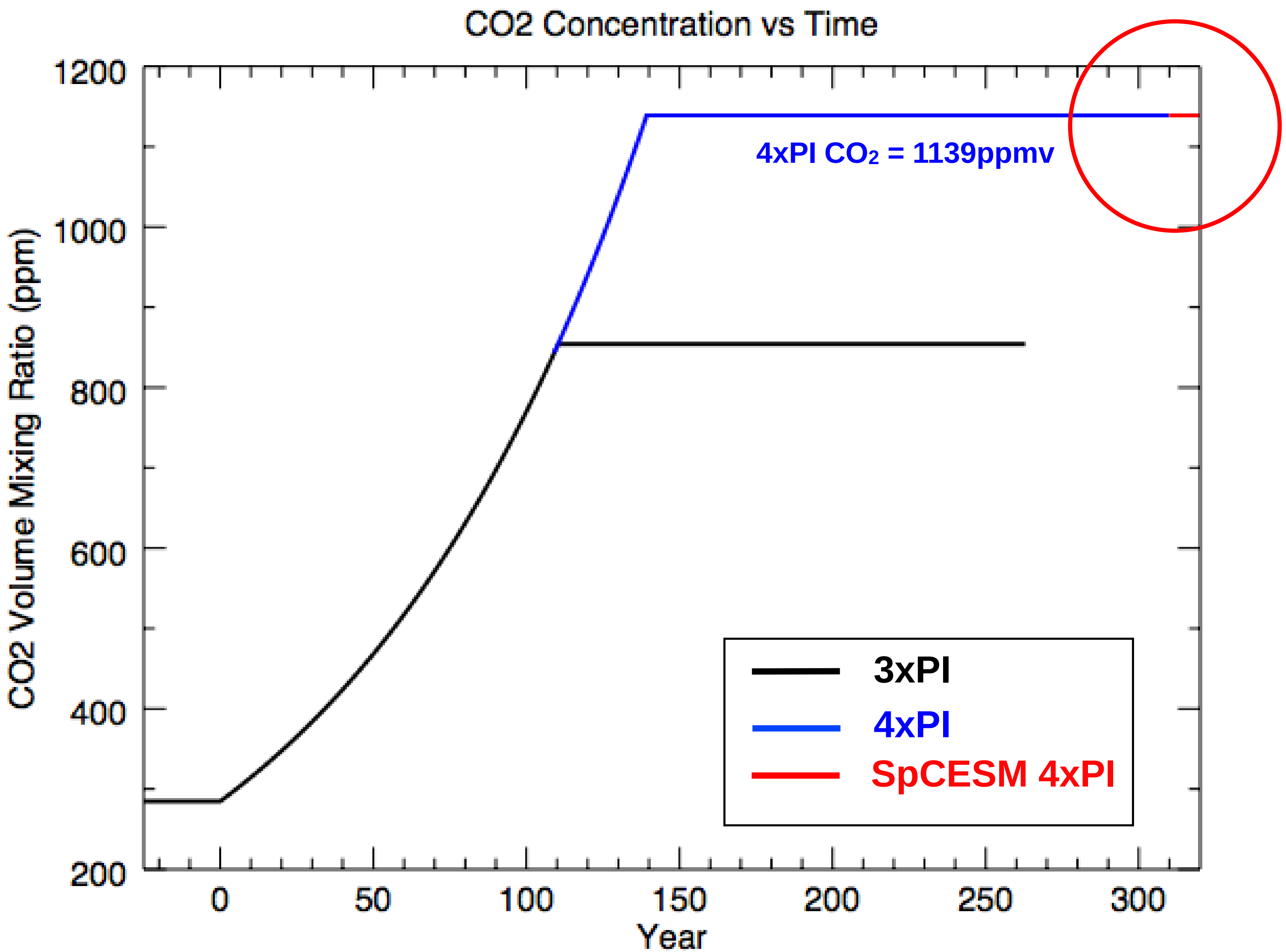
Mean SLP (mb)



Sea Ice Area (%)



Experimental Design



- Fully-coupled **CESM1.0.2**, CAM4 Physics, Finite Volume dynamical core
- 1.9°x2.5° grid for atmos and land components with the gx1v6 displaced pole grid for ocean and ice
- 25-year spinup simulation holding all trace gases constant (initialized from year 501of the b40.1850.track1.2deg.003 simulation)
- Followed by 1% per year CO_2 increase
- SpCESM 10-year sim started from end of CESM 4xPI
- SAM single-moment microphysics, 4km CRM grid spacing

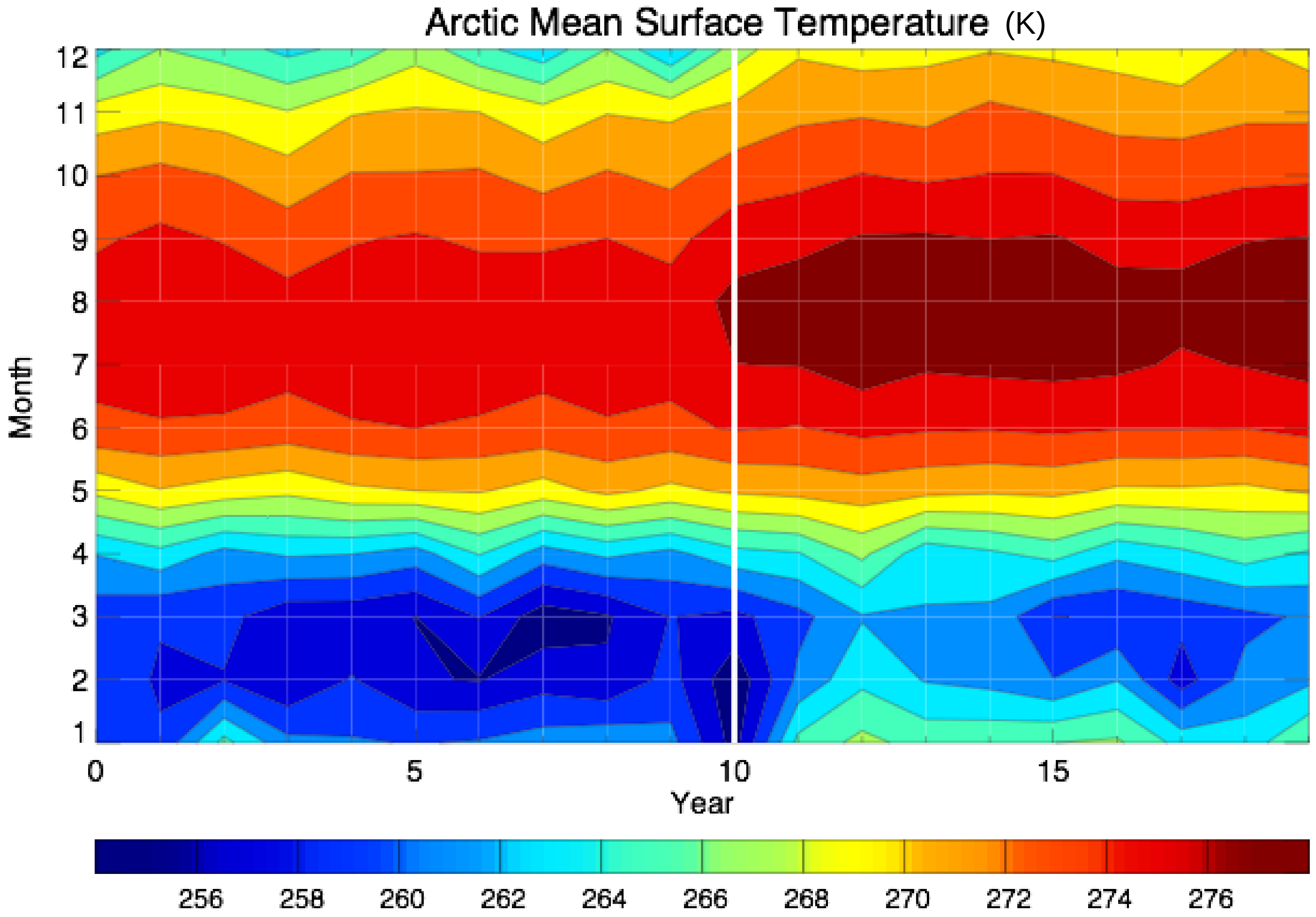
Mean Global and Arctic response to increased CO_2

	Global CTL (4x)	Arctic CTL (4x)
Surface Temp, K	287 (292)	258 (270)
Total Precip, mm/day	2.8 (3.13)	0.86 (1.33)
Precip. Water, mm	23 (31)	6.5 (10.8)
Low Cloud, %	35 (36)	38 (68)
Total Cloud, %	53 (53)	67 (76)
SWCE, W/m^2	-54 (-50)	-18 (-32)
LWCE, W/m^2	32 (28)	12 (17)

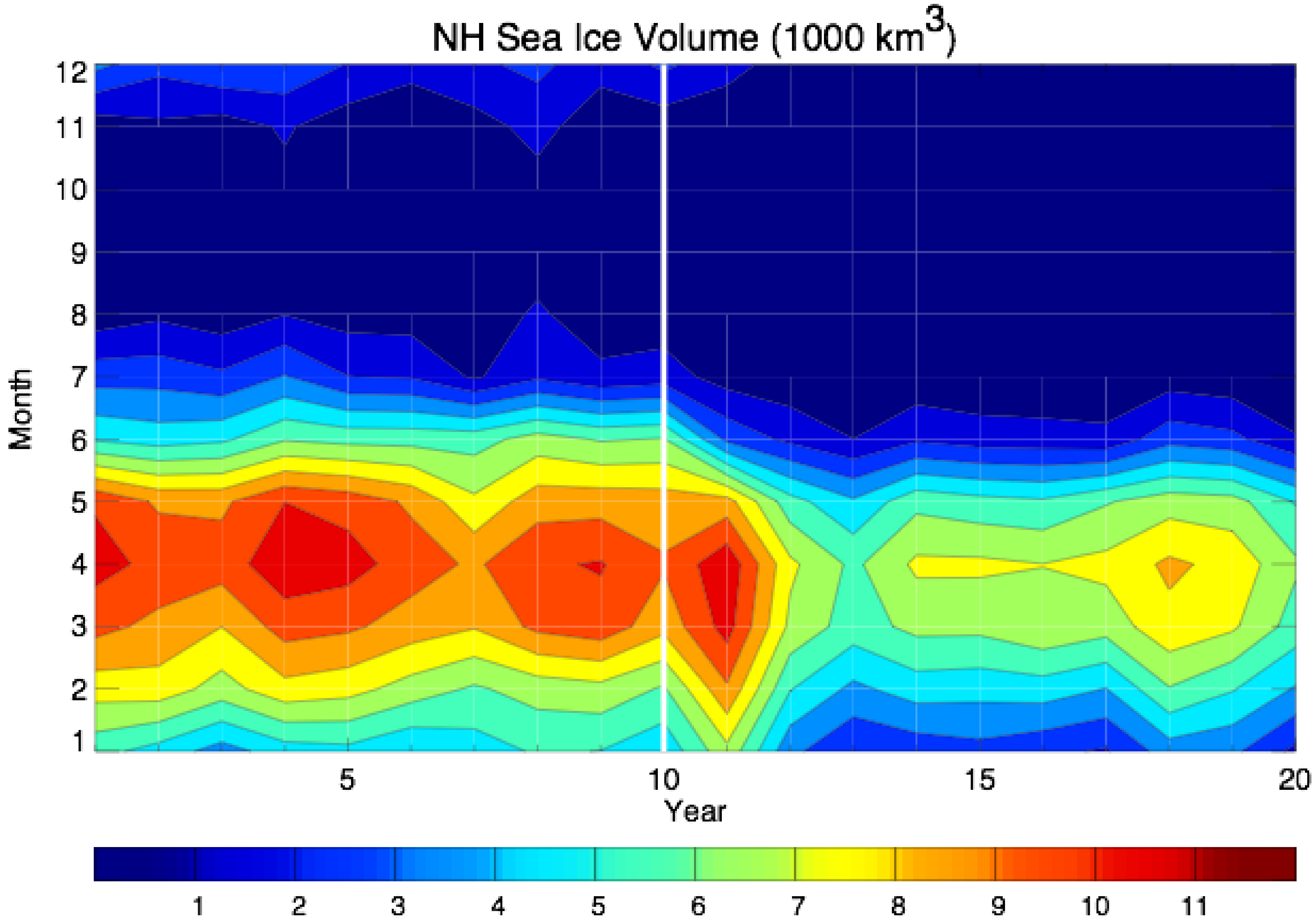
Weaker in 4x
Stronger in 4x

Annual mean statistics for the Arctic (70-90N) for SpCESM 4xPI relative to its control.

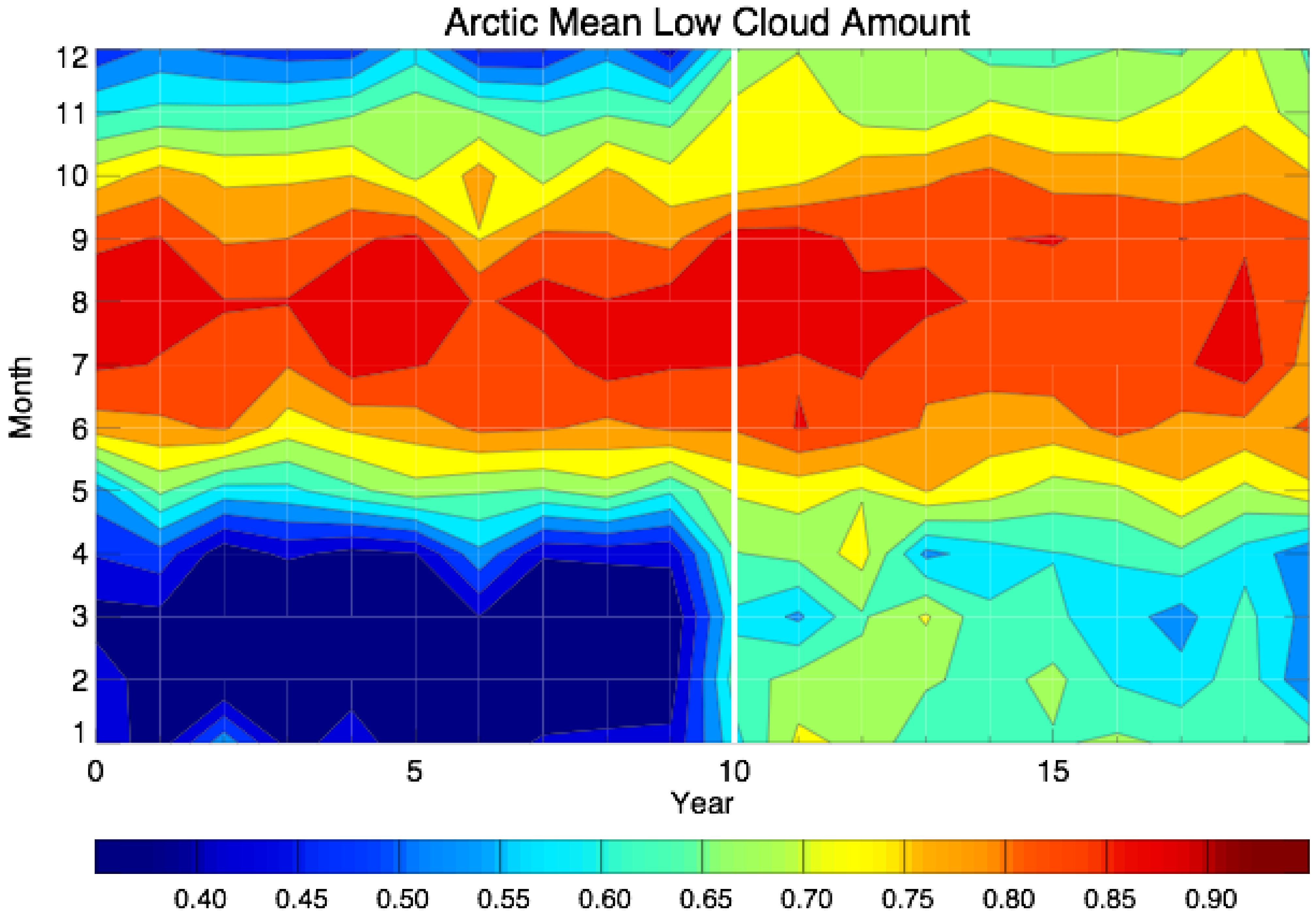
The Arctic warms up.



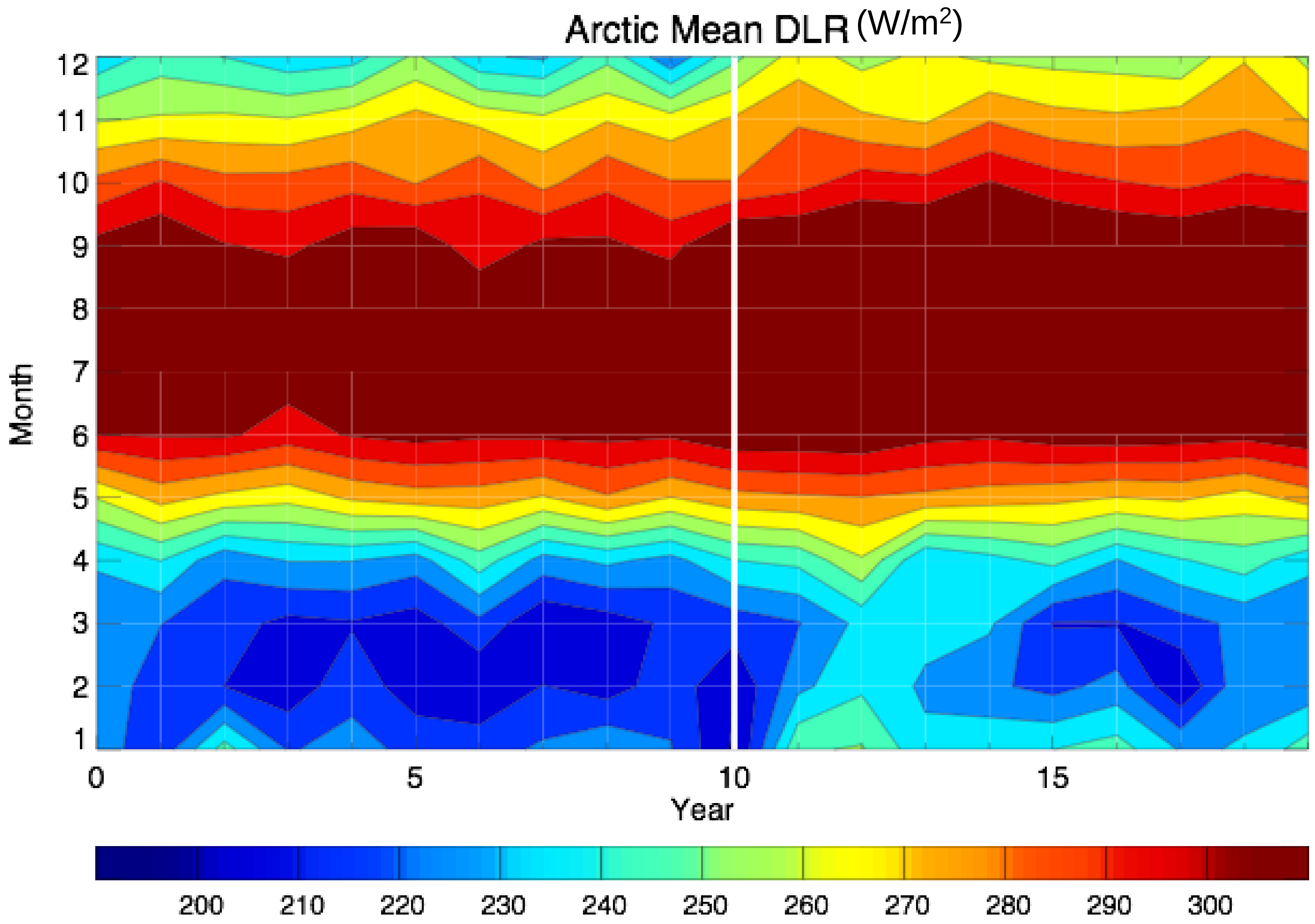
More sea ice melts.



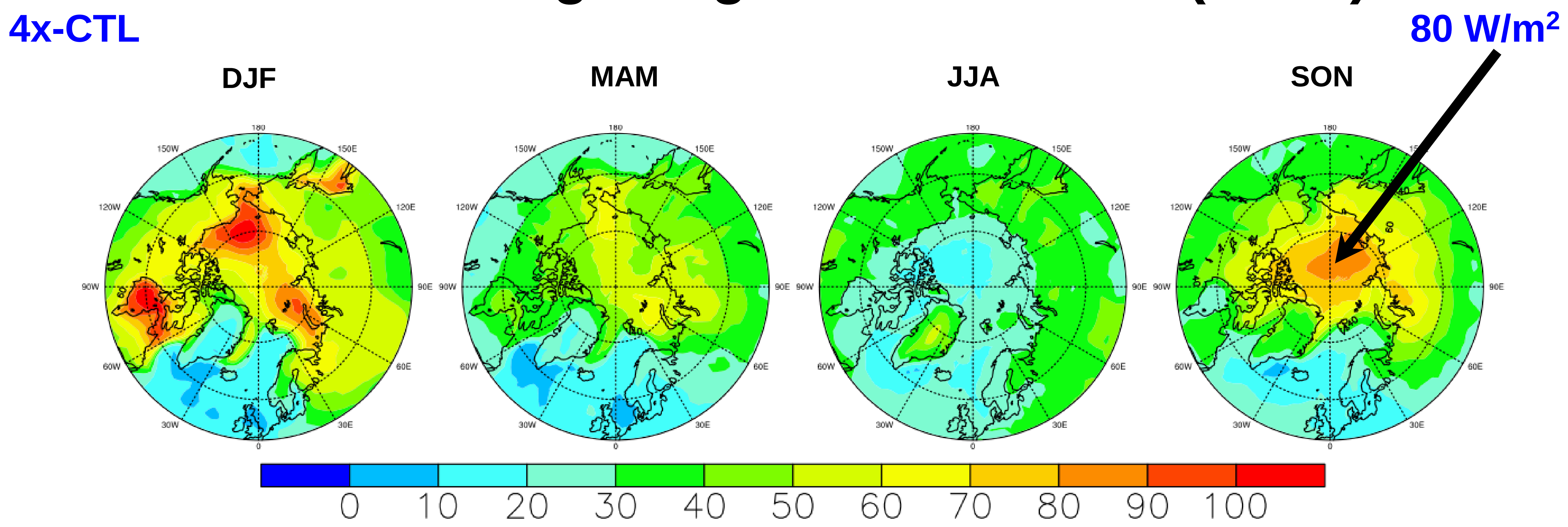
The Arctic gets cloudier.



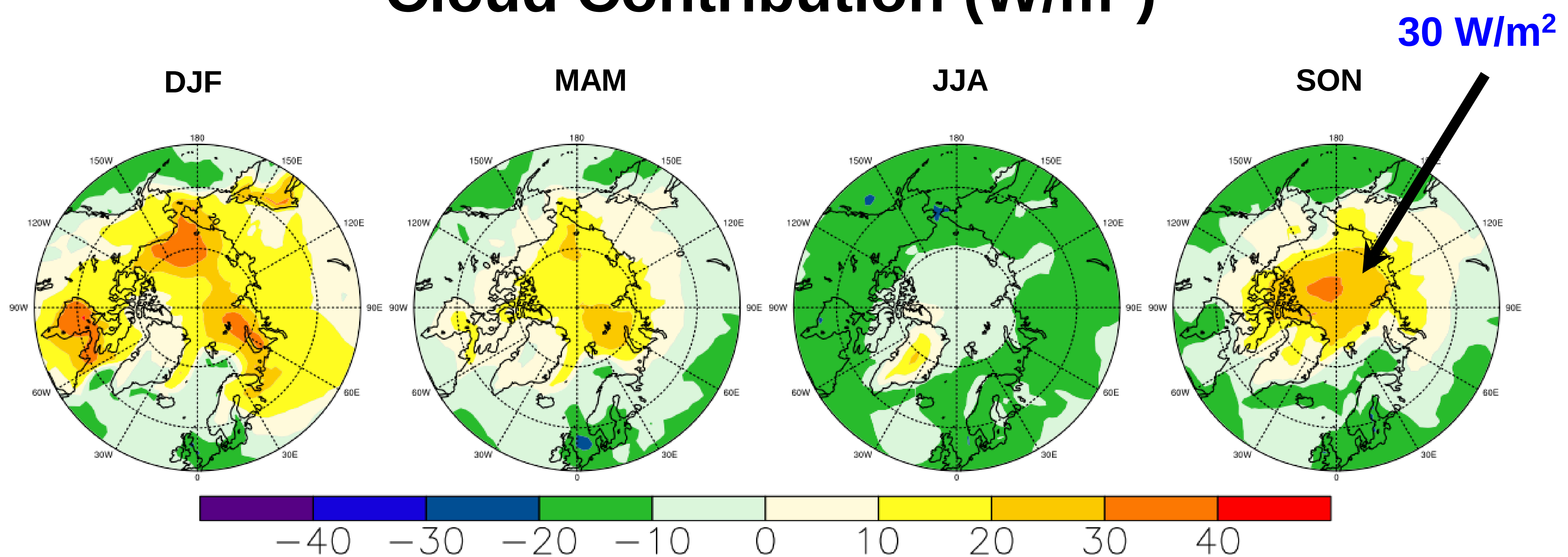
Downwelling LW at surface gets stronger.



Downwelling Longwave Radiation (W/m^2)

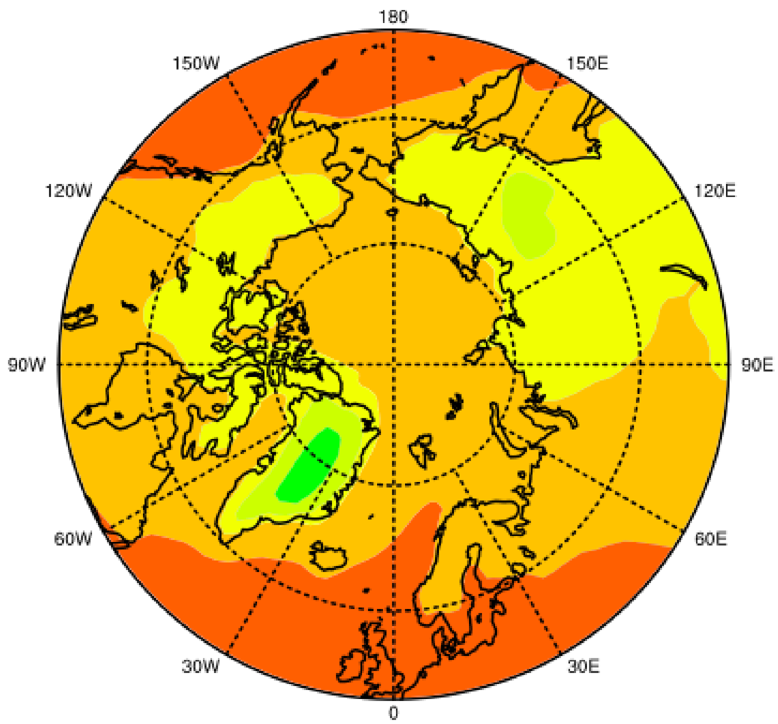


Cloud Contribution (W/m^2)

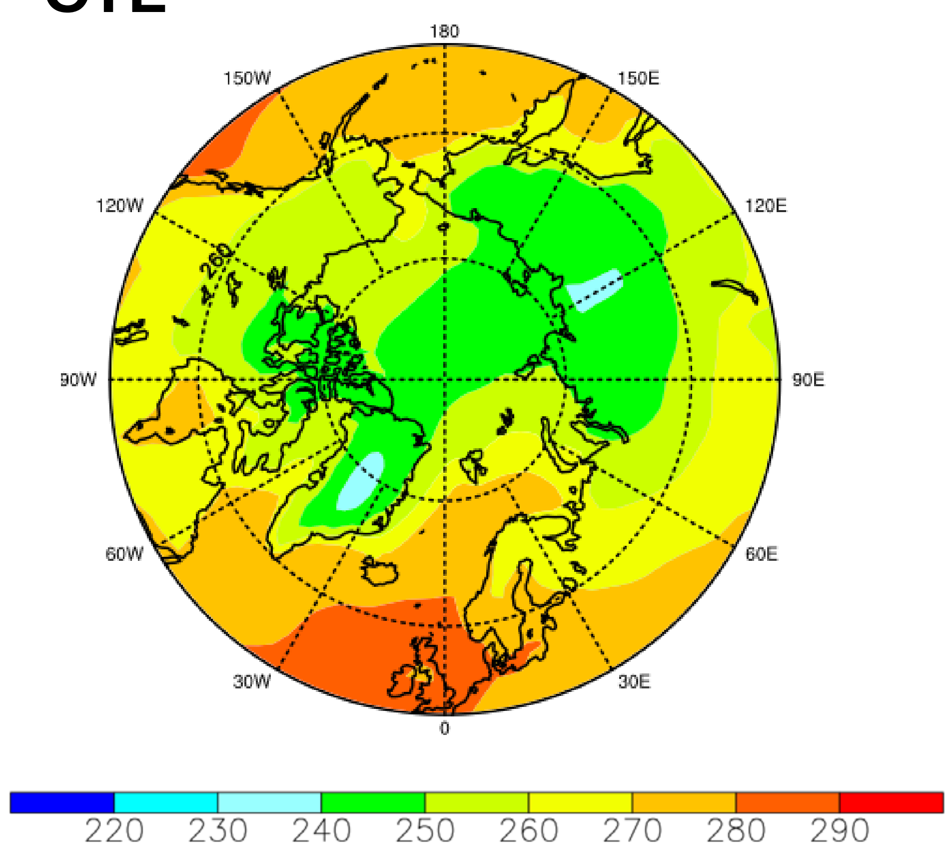


2m Temperature (K)
November

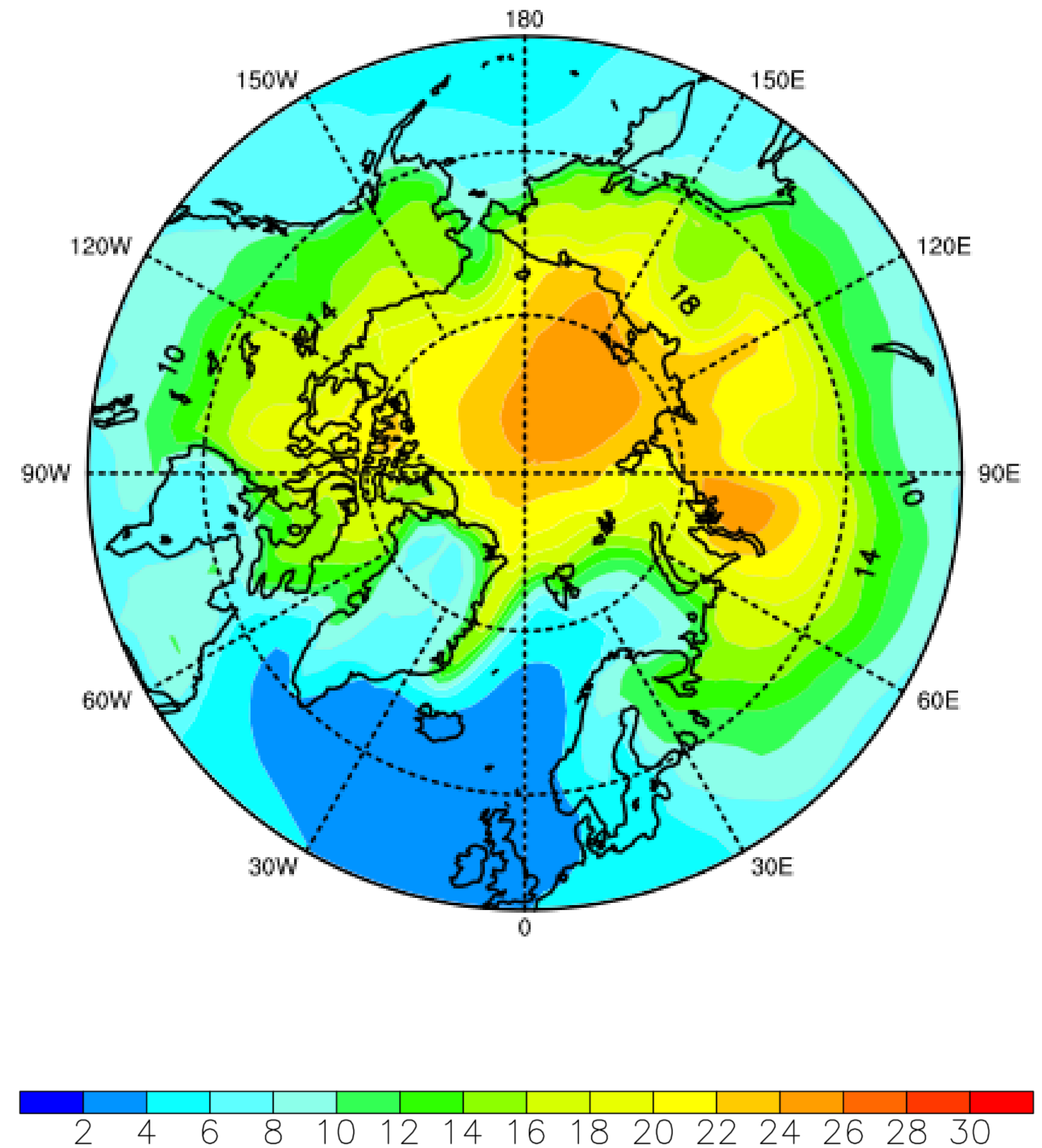
4xCO2



CTL

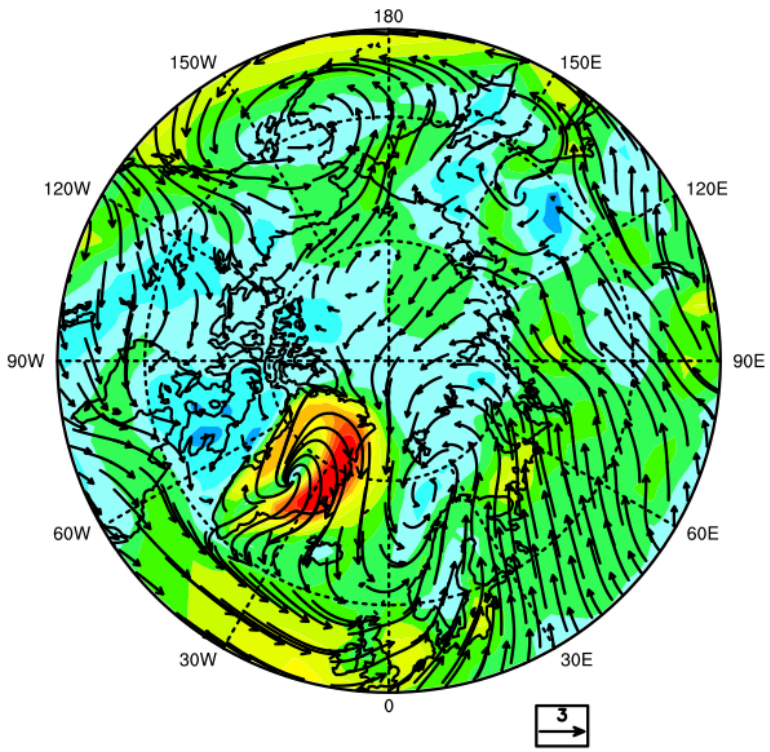


4xCO2 - CTL

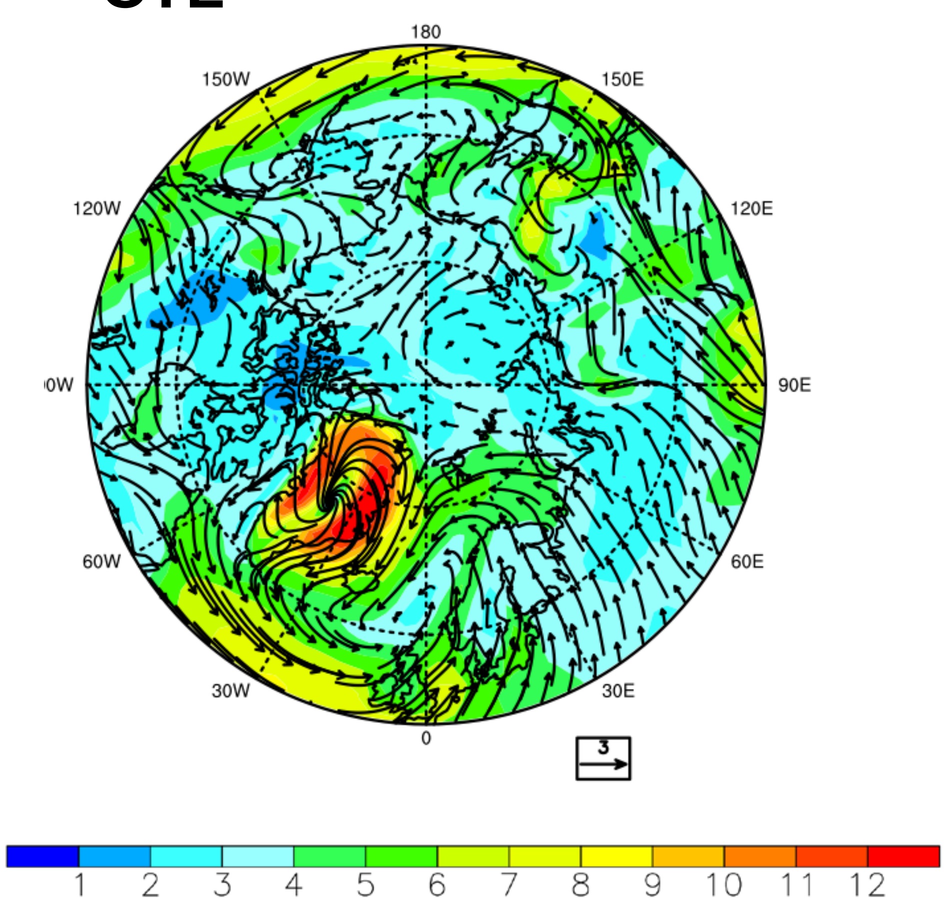


Near Surface Wind (m/s)
November

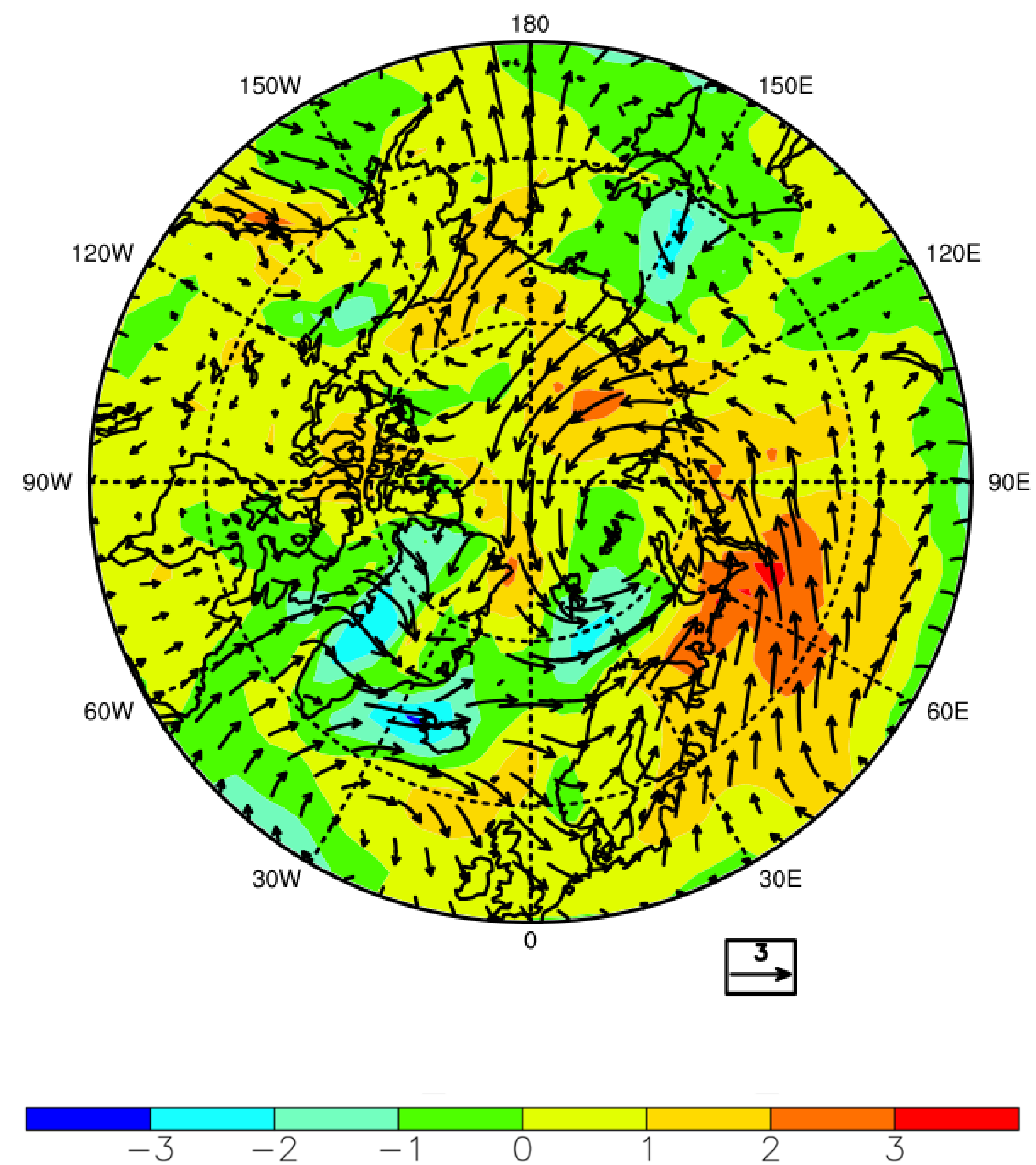
4xCO2



CTL

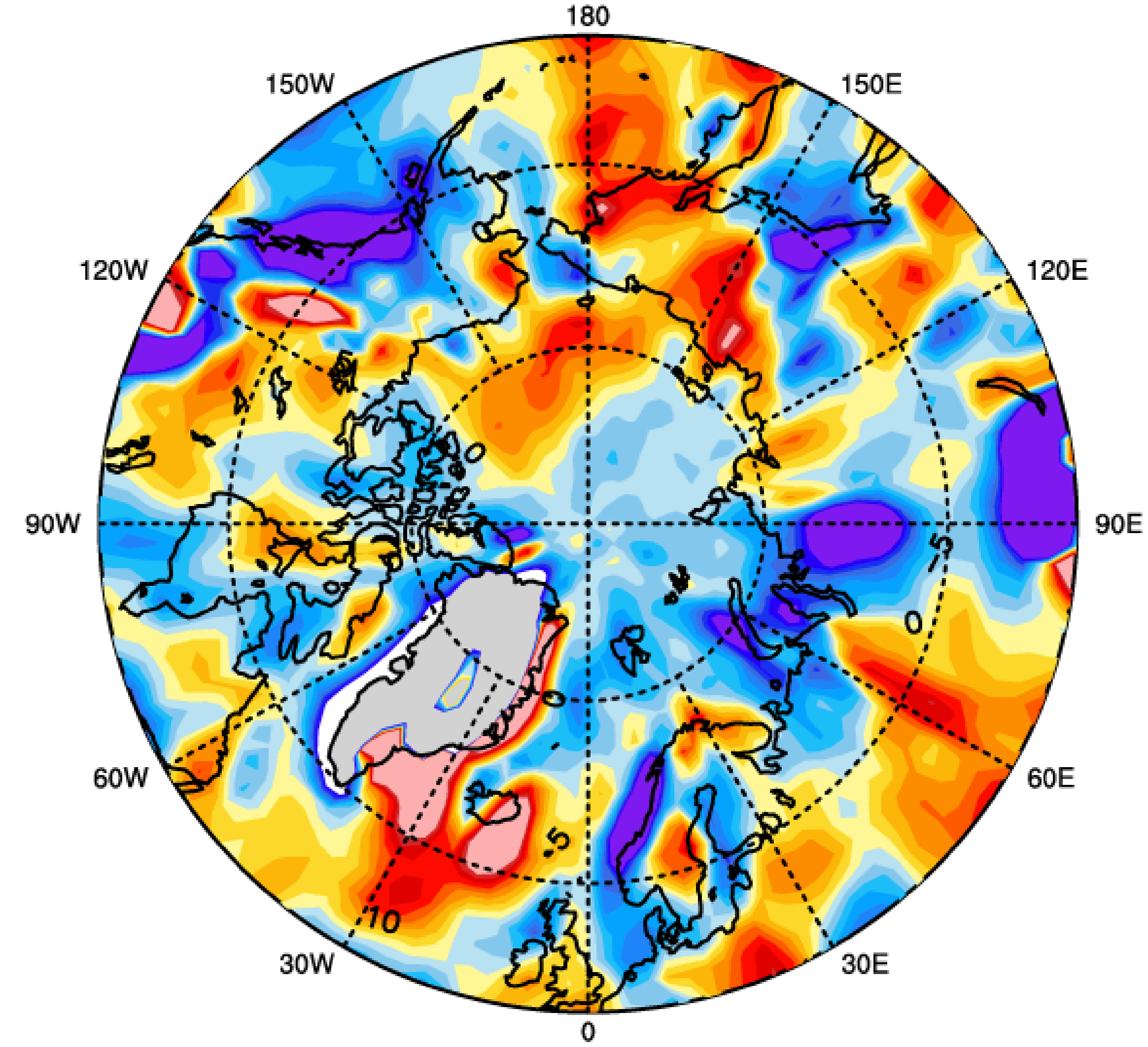


4xCO2 - CTL



Omega (mb/day)
850 mb
November

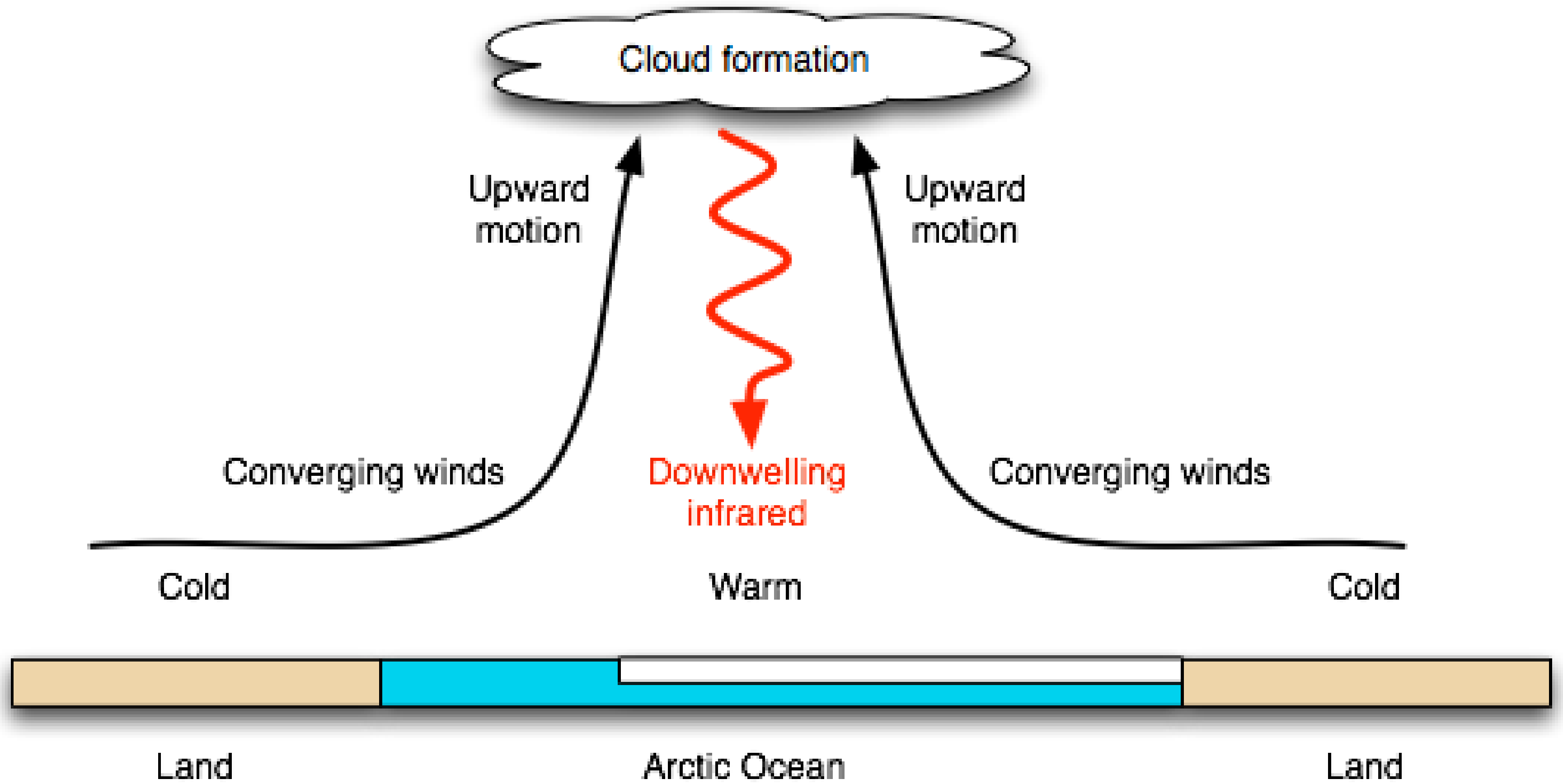
4xCO2 - CTL



−20	−15	−10	−5	0	5	10	15	20

rising motion   descending motion

Cloud Feedback in the Arctic Winter



- Sea ice decreases.
- Arctic Ocean becomes warmer than surrounding continents during fall/winter.
- This leads to low-level convergence and rising motion.
- Water vapor and cloudiness increase.
- Stronger DLR promotes further thinning of the sea ice.

Illustration created by D. Randall

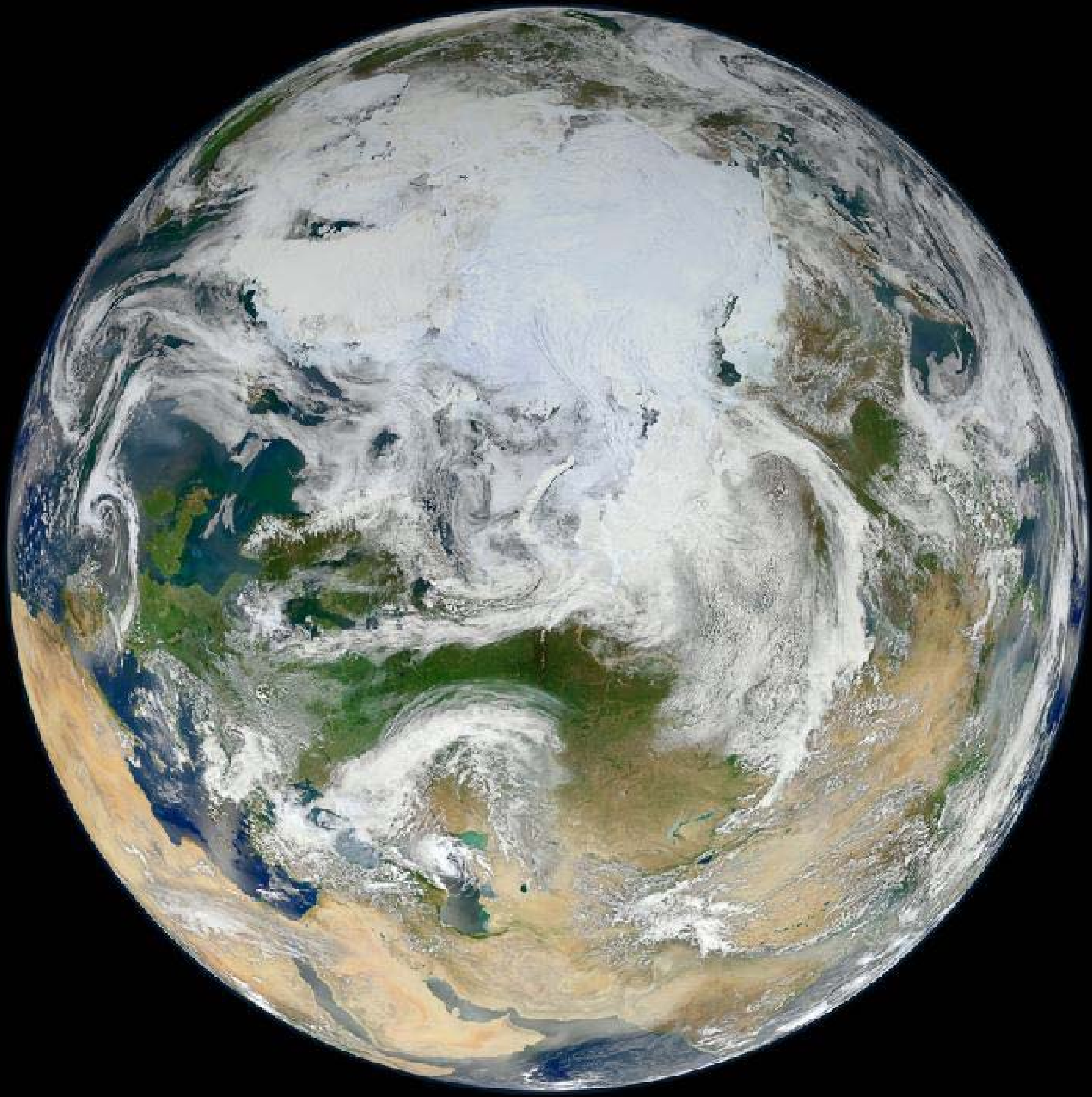
Conclusion

Model supports strong positive feedback that operates in fall/winter.

Next Steps

- Further examine feedback in this warmer Arctic environment.
- Breakdown processes that contribute to increased DLR (Ts, PW, Increased CO_2).
- Look for changes in observations.

Thank you.



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