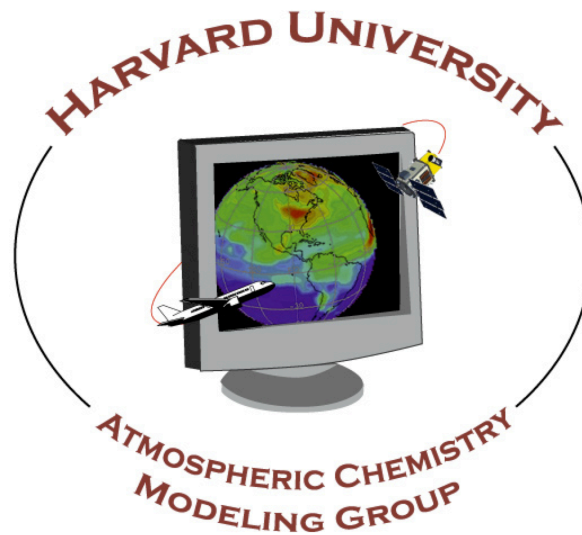


# Regional Climate Response to U.S. Aerosol Sources



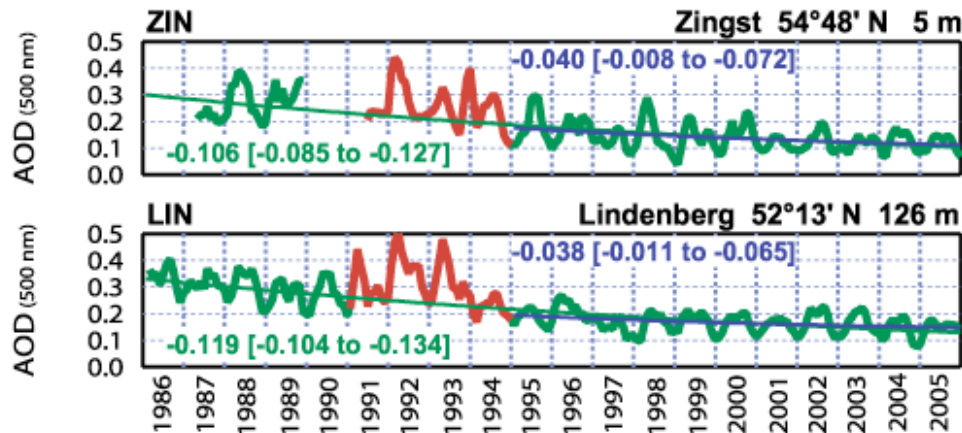
Loretta J. Mickley,  
**Eric M. Leibensperger,**  
Daniel J. Jacob

[eleibens@fas.harvard.edu](mailto:eleibens@fas.harvard.edu)

With Support From:



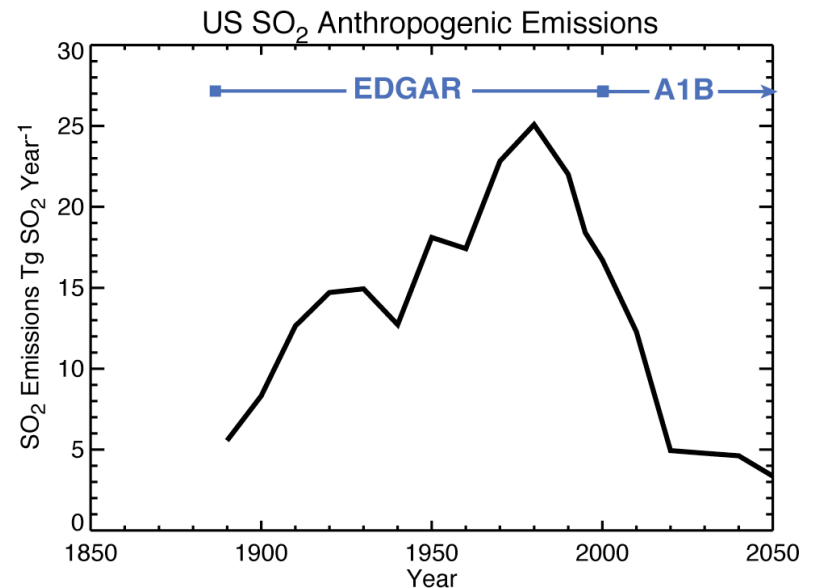
# Decreases in Anthropogenic Aerosols



Decreasing European SO<sub>2</sub> emissions have induced a surface radiative forcing of  $\sim 1 \text{ Wm}^{-2}\text{dec}^{-1}$ .

[Ruckstuhl et al., 2008]

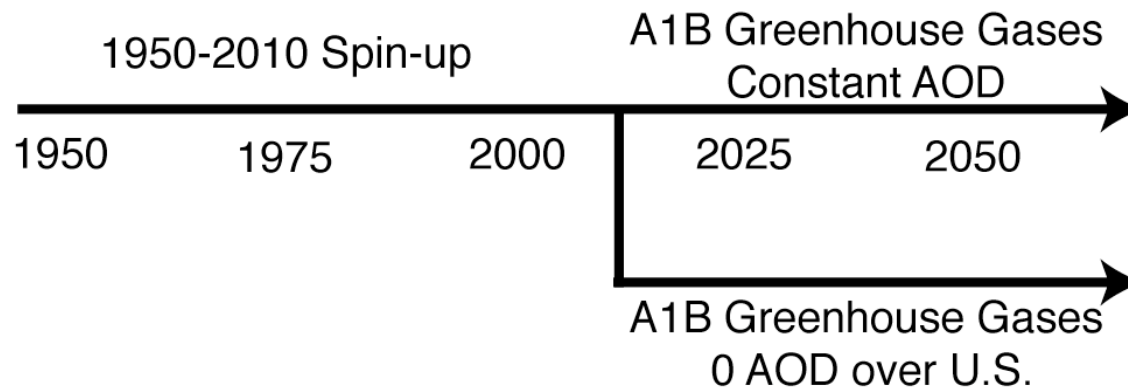
What effects will continued decreases of US emissions of aerosols and aerosol precursors have on climate?



# GCM Simulations

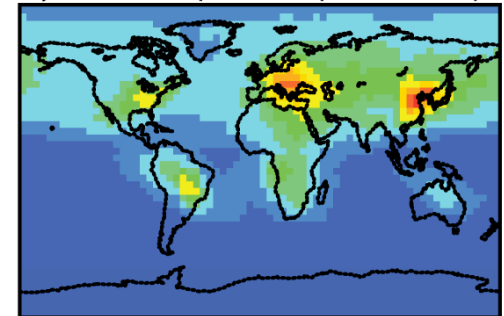
**GISS** general circulation model 3 [Rind et al., 2007]

Climate Sensitivity: 2.8 °C for 2xCO<sub>2</sub>



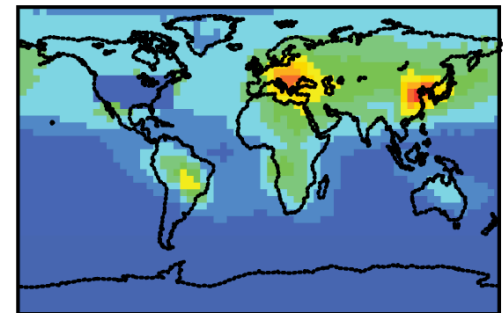
Two realizations each of these scenarios were conducted:  
**Control:** aerosol optical depths fixed at 1990s levels.  
**Sensitivity:** U.S. aerosol optical depths set to zero (providing a radiative forcing of about +2 W m<sup>-2</sup> locally over the US); elsewhere, same as in control simulation.

July Aerosol Optical Depth at 0.55 μm



0.0 0.2 0.4

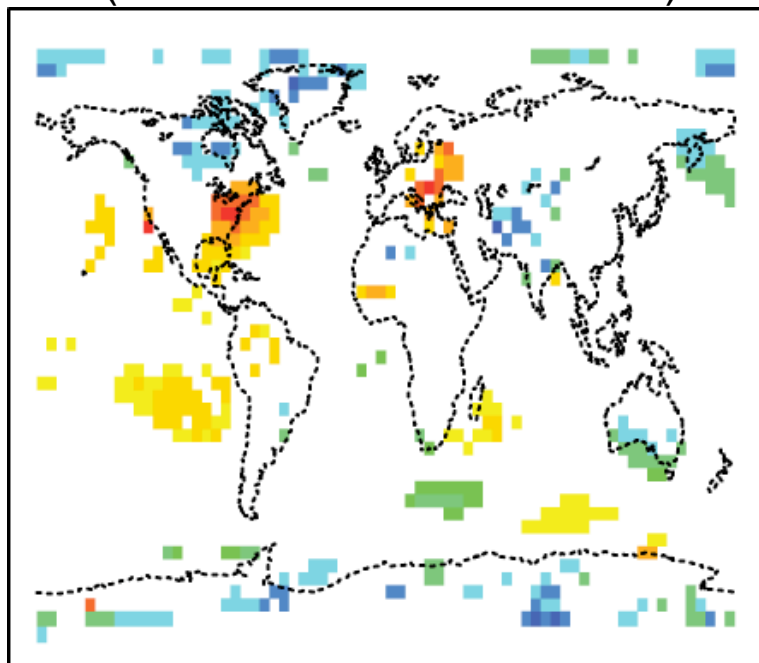
July Aerosol Optical Depth at 0.55 μm  
0 over U.S.



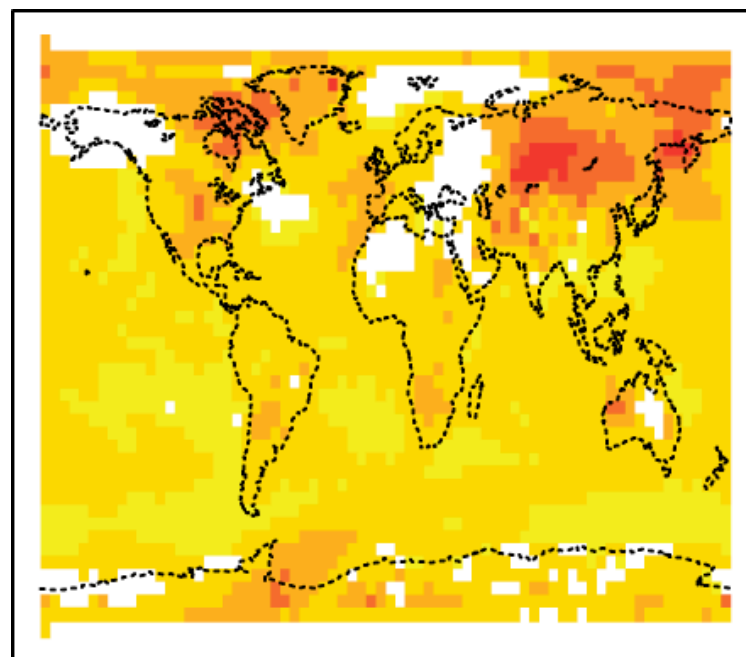
0.0 0.2 0.4

# Change in Annual Mean Temperature

Difference in 2010-2025 Annual Temperature  
(No US Aerosols – Control)



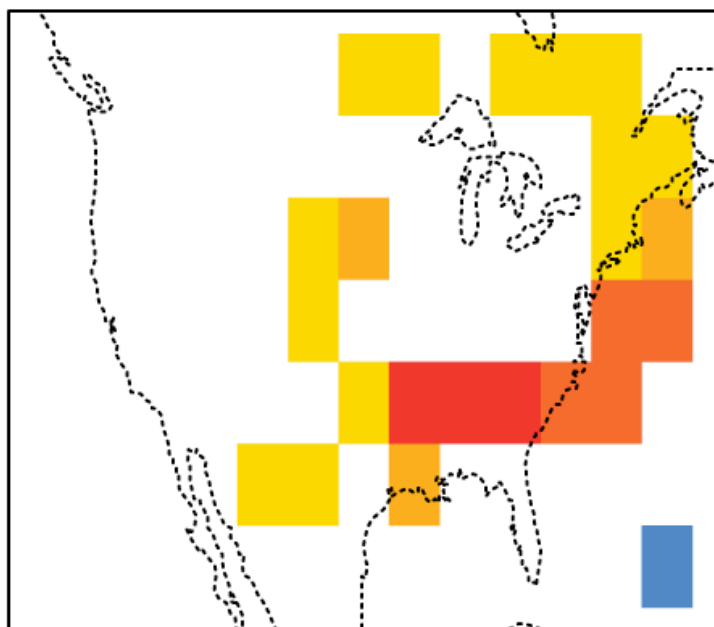
Warming in Control  
(2010-2025 – 2000-2010, A1B)



Removing anthropogenic aerosols warms the eastern U.S. by  $\sim 0.5^{\circ}\text{C}$ . This warming is comparable to the warming over the US due to the A1B scenario by 2030.

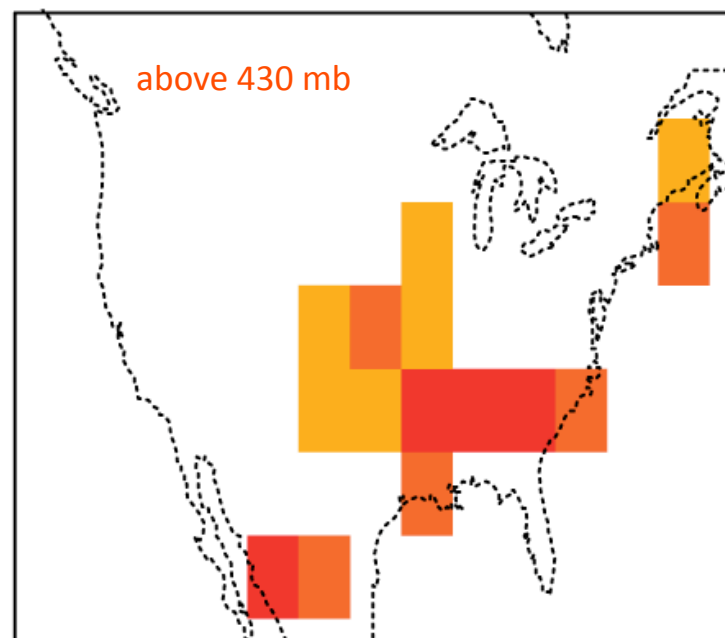
# Change in Annual Cloud Cover and Precipitation

Difference in 2010-2025 Annual Precip.  
(No US Aerosols – Control)



-0.4 -0.2 0 0.2 0.4

Difference in 2010-2025 High Cloud Fraction  
(No US Aerosols – Control)

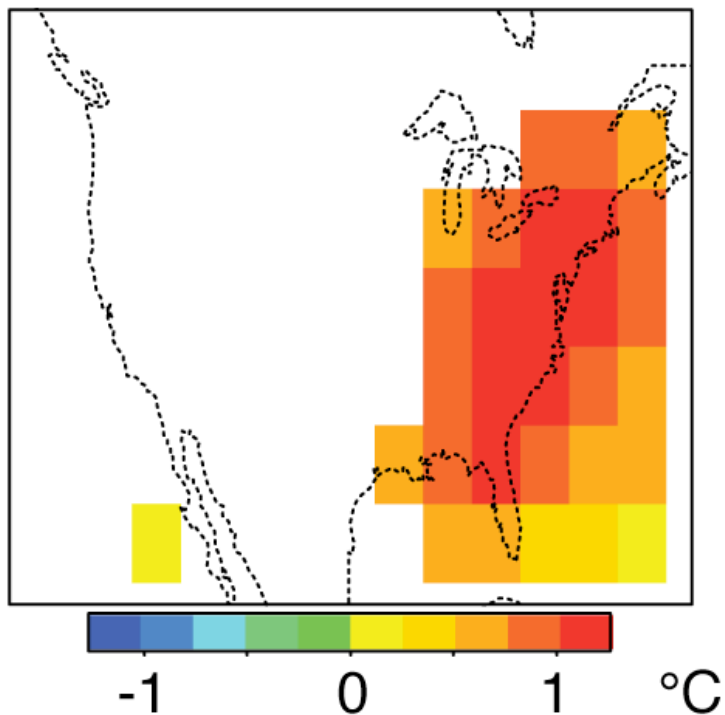


-1 0 1 2 %

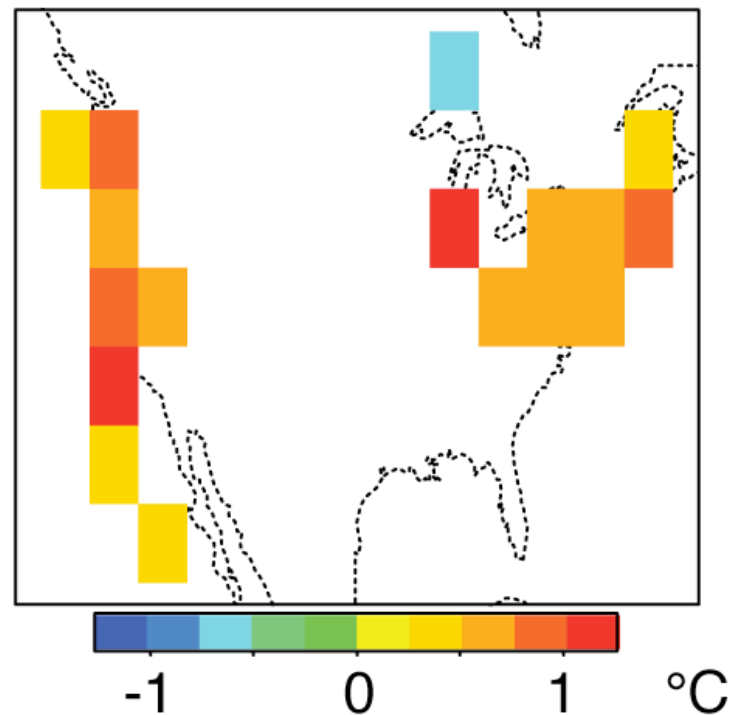
The warmer surface reduces stability and increases cloud cover and precipitation.

# Strongest Temperature Response is in Winter

Temperature Change - DJF



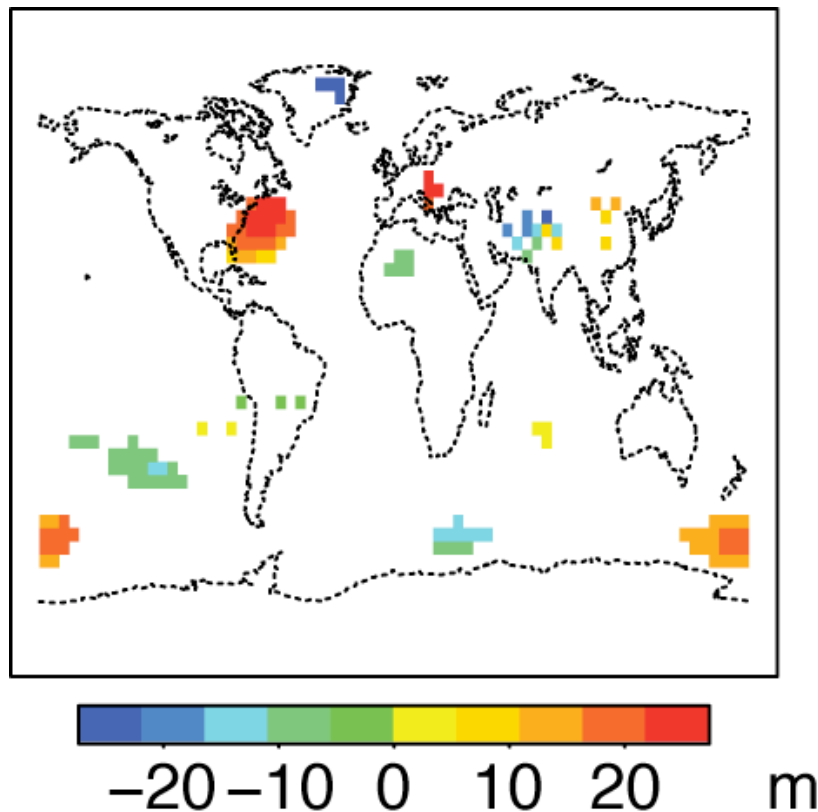
Temperature Change - JJA



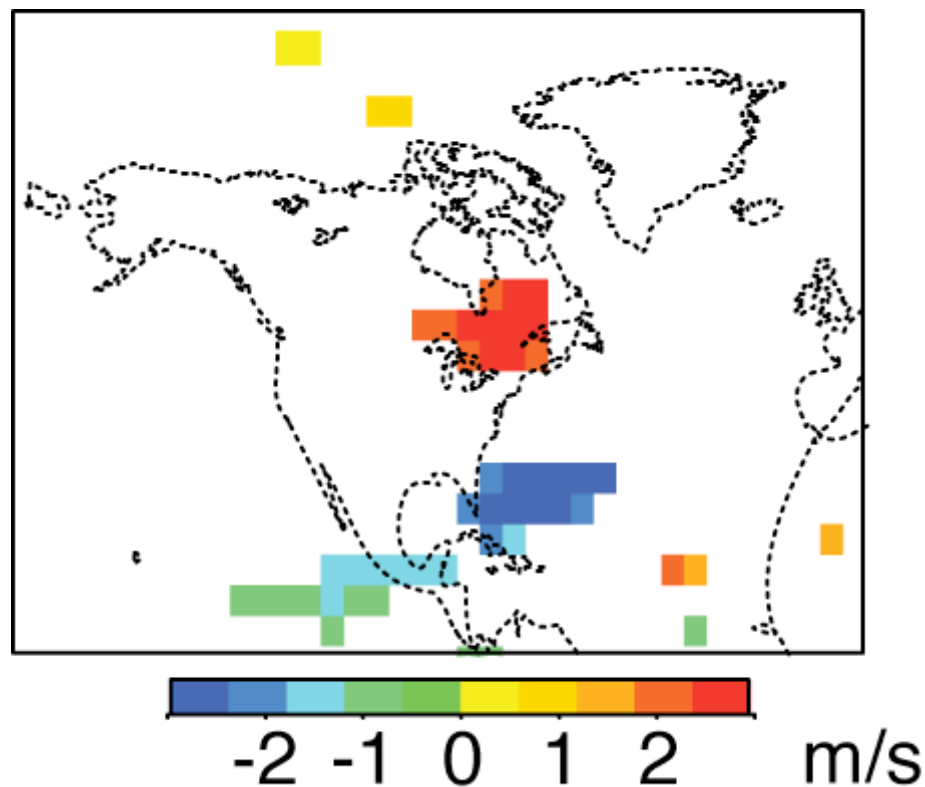
Increased convection and cloud cover reduce the temperature response in the summer. Note the warming pattern in the winter resembles the forcing pattern.

# Changes in Atmospheric Dynamics

Difference in 2010-2025 DJF 500 hPa Height  
(No US Aerosols – Control)



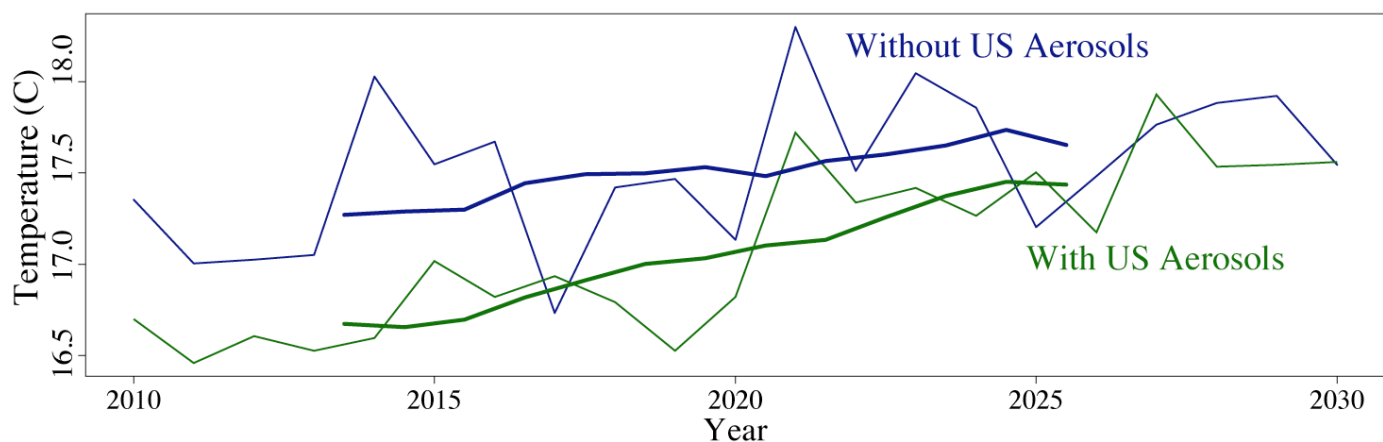
Difference in 2010-2025 DJF Jet Stream  
(No US Aerosols – Control)



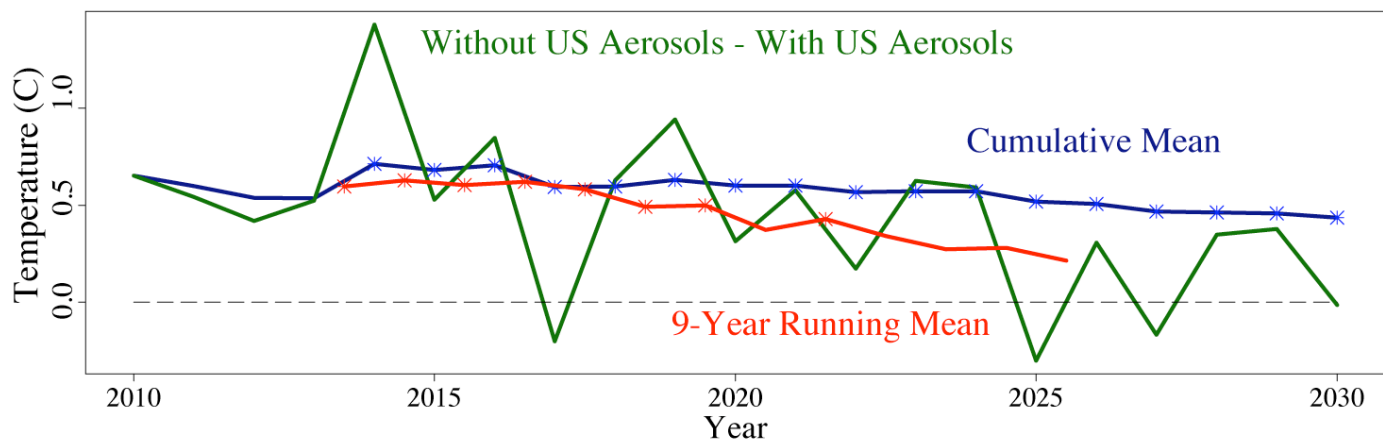
The warming over the United States reduces the meridional temperature gradient over the US, but enhances it over Canada, resulting in a northward shift of the storm tracks.

# The Effect of Removing Aerosols Diminishes

Trend in Annual Mean Temperature over the Eastern United States



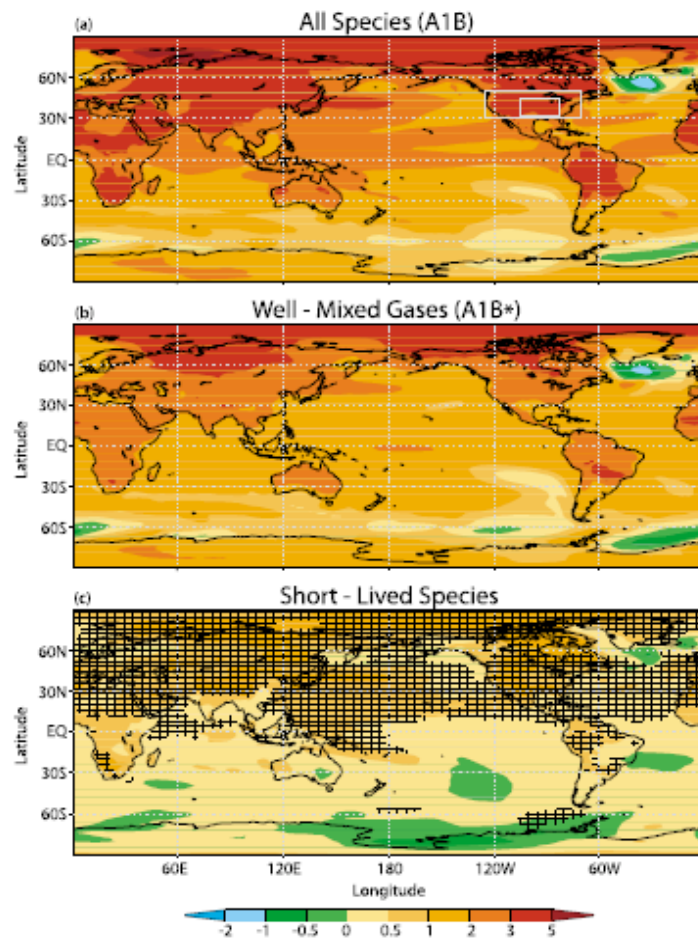
Differences in Annual Mean Temperature Trends



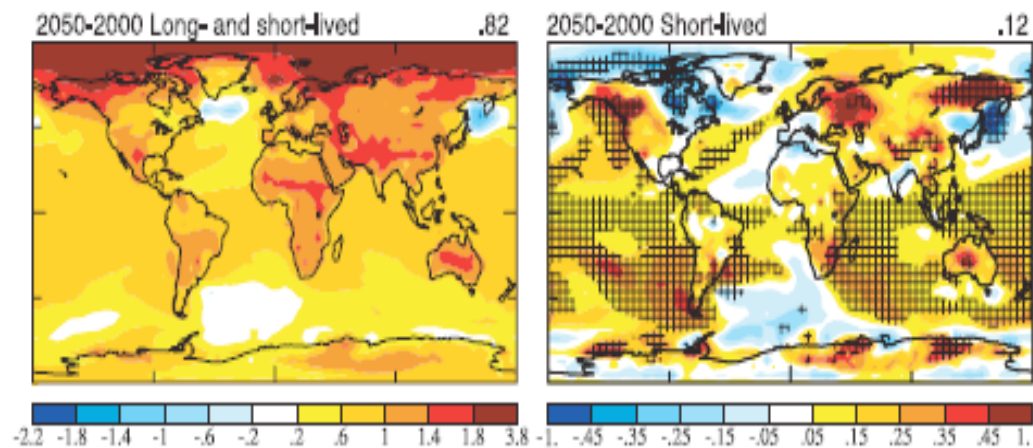
The two cases (each consisting of two realizations so far) converge as the forcing and feedbacks due to the well-mixed greenhouse gases begins to dominate.

# Spatial Pattern of Warming

Annual mean temperature change,  
2090s – 2000s for A1B scenario.



Previous work has suggested that the spatial pattern of the temperature response to short-lived species does not match the forcing pattern [Shindell et al., 2007; Levy et al., 2008].

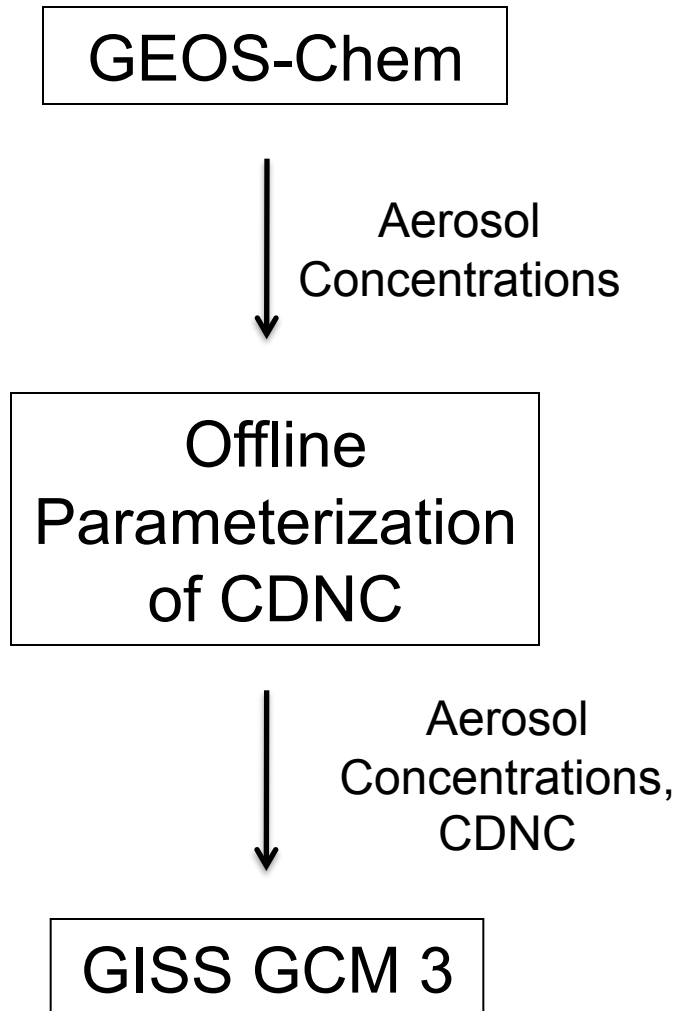


Comparisons over long-time horizons may not capture significant transient effects of short-lived species.

# Conclusions

- Removing US aerosols warms up the eastern U.S. by  $\sim 0.5^{\circ}\text{C}$  over the next 15 years.
- The warming is isolated within the eastern United States and western Atlantic Ocean.
- The difference is significant for only  $\sim 15$  years, after which, the forcing imparted by the well-mixed A1B greenhouse gases begin to dominate.
- This result has important implications for policymakers considering steep reductions in emissions of  $\text{SO}_2$  and  $\text{NO}_x$  – reductions in aerosols cause significant warming in the short term, but the effect diminishes within 20 years.
- It is important to consider the transient effects of short-lived species. Analyzing their influence over long time periods may cause an underestimate due to the strong increases in greenhouse forcing.
- Removing US aerosols also increase precipitation and cloud cover in the southeastern US and potentially alters the Atlantic storm track. These effects mute the temperature response in the summer.

# Future Work – Quantitative Assessment and Including the Indirect Effect



Use historical/projected emissions of  $\text{SO}_2$ ,  $\text{NO}_x$ , BC, and OC to quantify the climatic role of US aerosols in the past and future.

Simulations include:

- 1950-2050 Control simulation (EDGAR/Tami Bond historical emissions and A1B)
- 1950-2050 No US Scattering Aerosols
- 1950-2050 No US Scattering or Absorbing Aerosols
- 2010-2050 Constant US emissions
- 2010-2050 No US aerosols