Stratosphere-troposphere interaction and its role in climate dynamics and prediction

Conveners:

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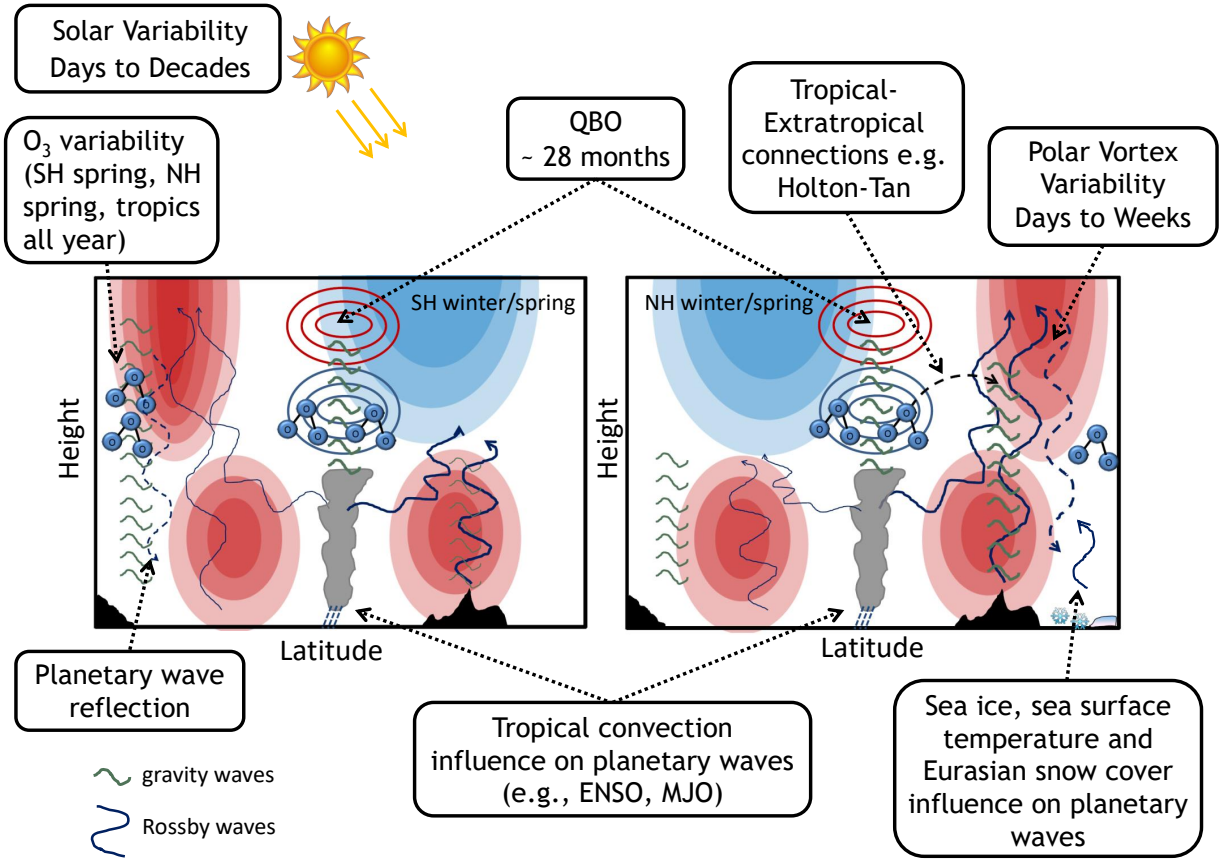
Amy Butler (PSMI)

Qinghua Ding (PPAI)

Time: March 15, 3:30-5:30 ET

Stratosphere-troposphere coupling plays a role in many components of climate variability



- Stratosphere-troposphere coupling = "two-way" coupling between the tropospheric and stratospheric circulations
- The stratosphere provides an additional pathway for tropical-extratropical or surface boundary-atmosphere teleconnections
- The stratosphere is an important element in climate because its processes are intrinsically slower-evolving than tropospheric processes, which imparts memory to the system

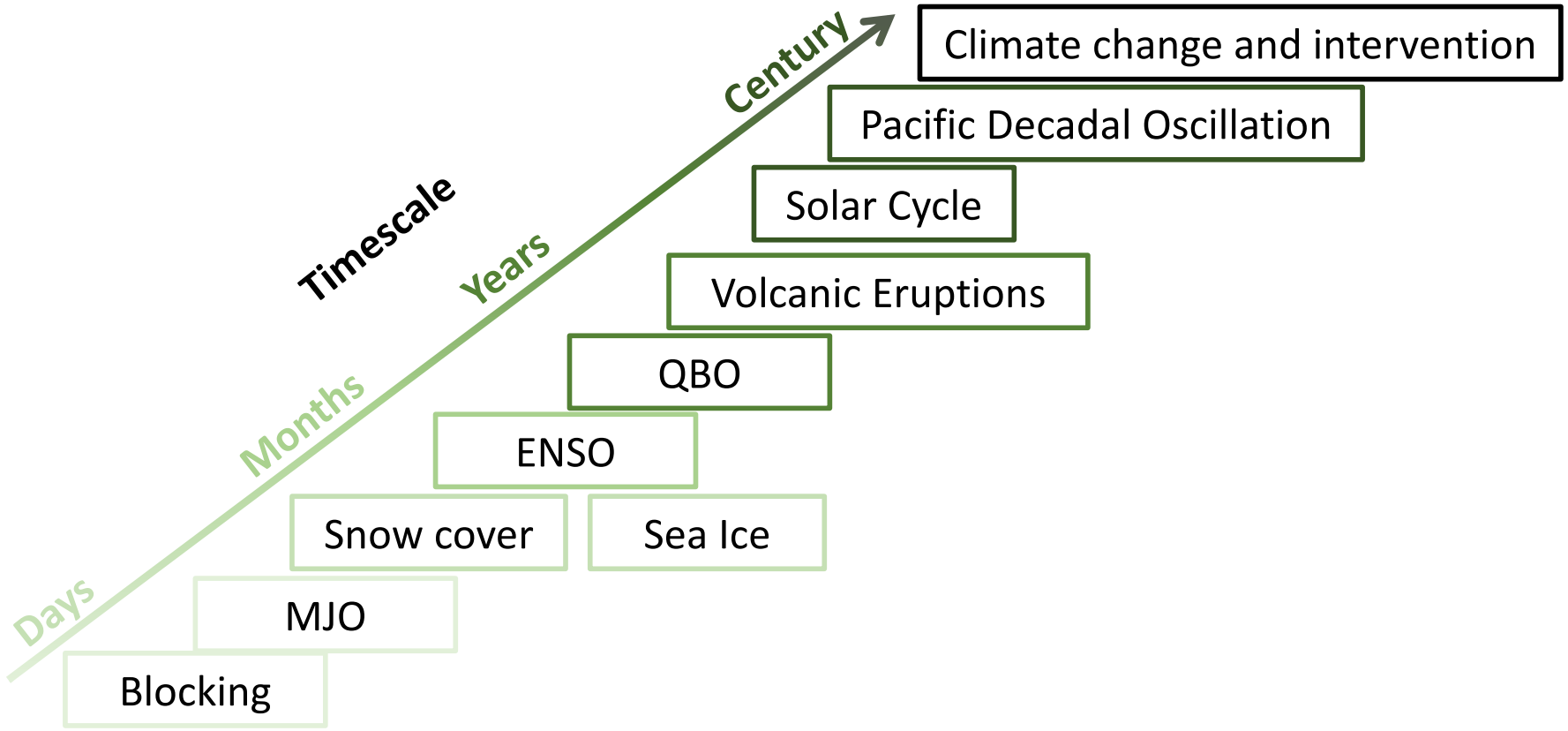
Butler et al. 2019, S2S book chapter

Stratosphere-troposphere coupling is linked to a broad range of global extremes

	stratospheric precursor	tropospheric extreme event	impact	affected region
Northern Hemisphere	sudden stratospheric warming	(marine) cold air outbreak	infrastructure damage, health impacts	Arctic, northern Europe, North Atlantic
		increased storminess	flooding, wind damage	southern Europe
		regional sea ice changes	shipping impacts, resource extraction	Arctic
	strong vortex event	storm series	flooding, wind damage	northern Europe, North Atlantic
		drought	agricultural damage	southern Europe
	wave reflection	cold air outbreak	health impacts	North America
tropics	Quasi-Biennial Oscillation	changes in the Madden-Julian Oscillation	precipitation extremes	tropics, subtropics
		atmospheric rivers	flooding	western North America
		changes in the monsoon	drought / flooding, agricultural impacts	India, Southeast Asia
Southern Hemisphere	early vortex weakening	heat, drought	wildfires, agricultural losses	Australia, Antarctica
		cold spell	health impacts	southeastern Africa, South America
	ozone anomalies	poleward shift of storm track	sea ice changes	Southern Ocean
		increased UV radiation	health impacts	Australia
		hot spells	health impacts	southern Africa, Australia, South America

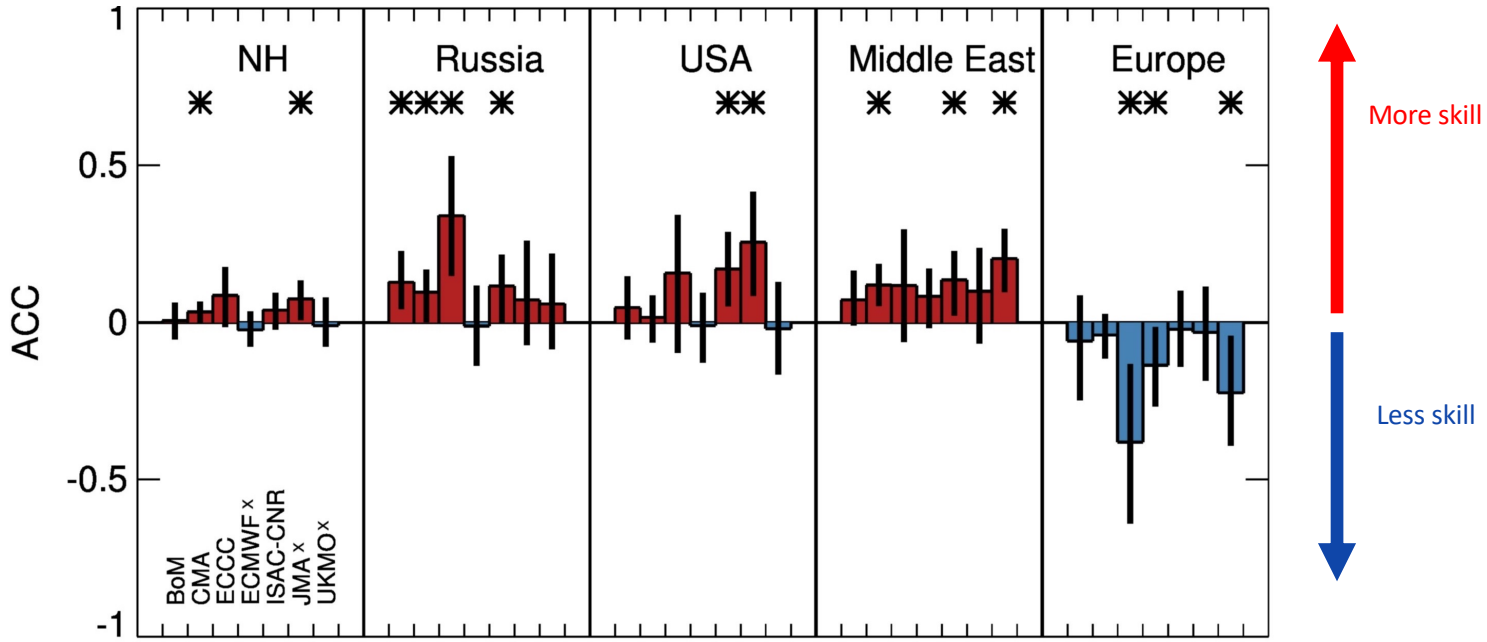
Domeisen and Butler, "Stratospheric drivers of extreme events at the Earth's surface" Communications Earth & Environment, 2020

Stratosphere-troposphere coupling exists across timescales



Stratosphere-troposphere coupling is increasingly recognized as a major source of S2S predictability

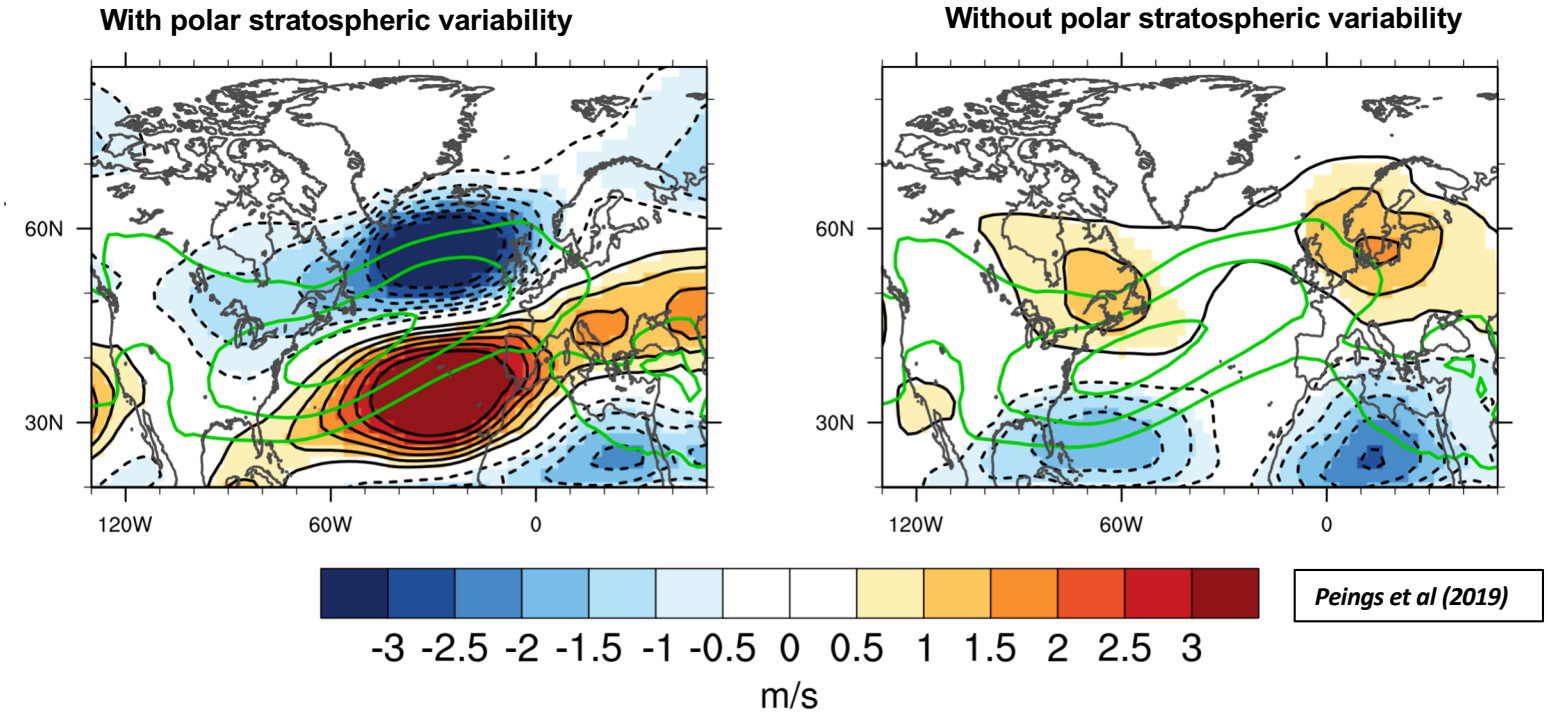
Change in forecasting skill of near-surface temperature for Week 3-4 following polar vortex weakening



Domeisen et al. (2020), Part II

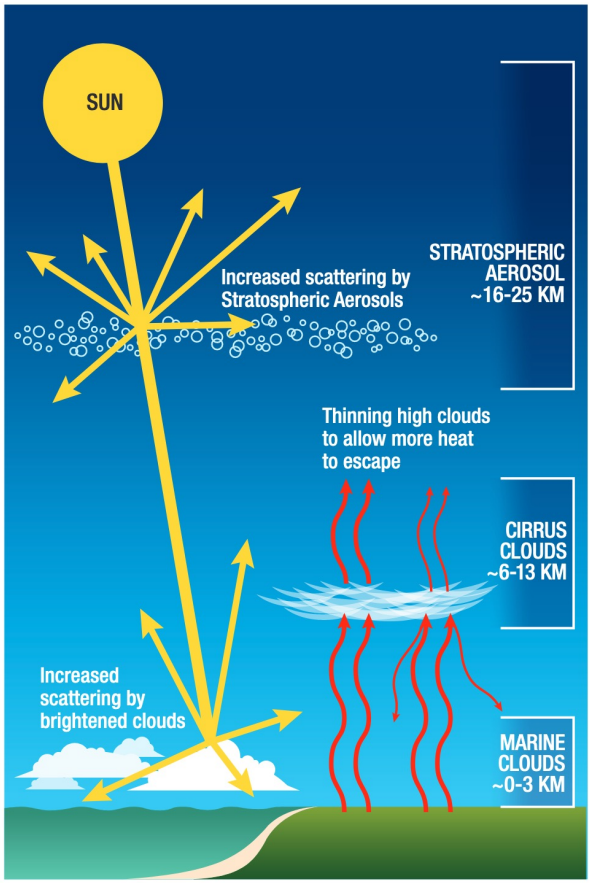
Uncertainty in future projections of stratospheric circulation contributes to uncertainty in surface climate projections

The polar stratosphere modulates the “tug-of-war” between Arctic amplification and upper tropical warming in future climate change projections.



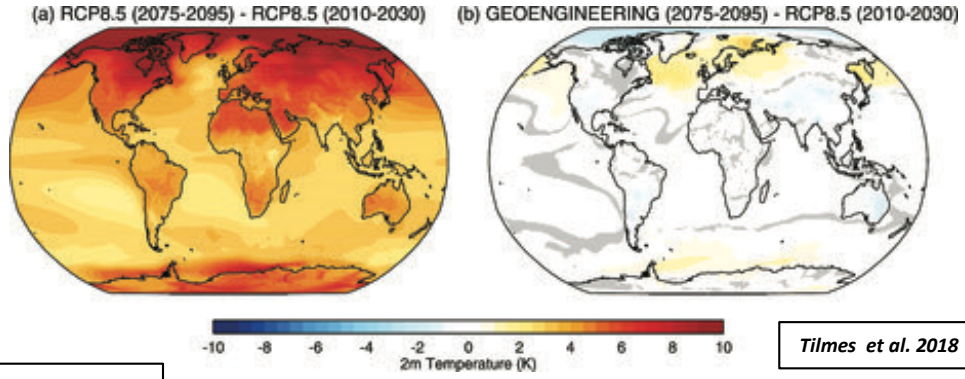
DJFM response of U700 to tropical warming, with and without variability of the polar stratosphere

The stratosphere is a key region for possible climate change intervention methods



2015 National Research Council report on Climate

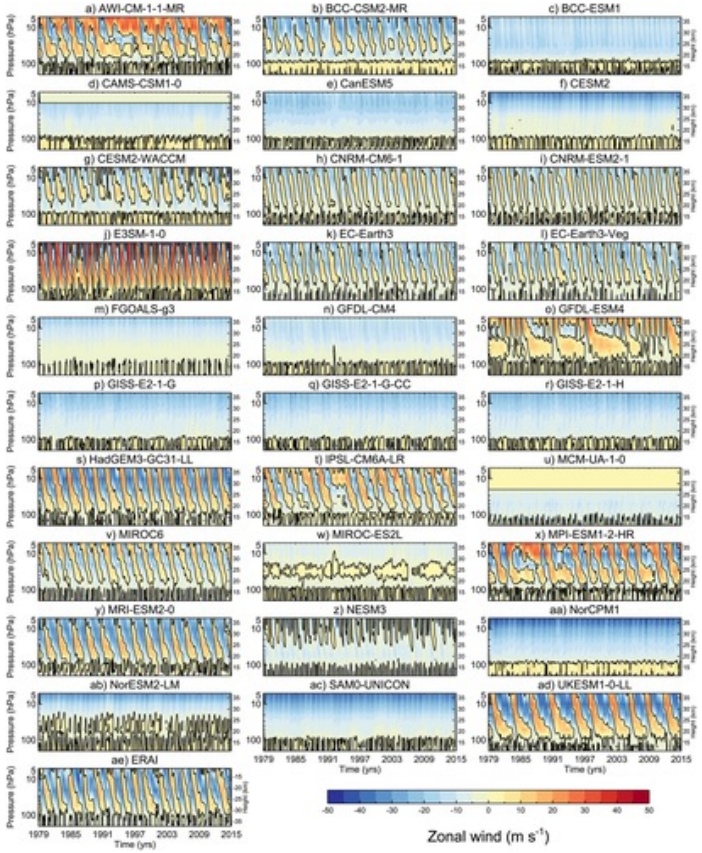
Should it ever become important for society to cool Earth rapidly, albedo modification approaches (in particular stratospheric aerosol injection and possibly marine cloud brightening) are the only ways that have been suggested by which humans could potentially cool Earth within years after deployment.



Tilmes et al. 2018

National Academies of Sciences, Engineering, and Medicine 2021. Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance.

Models are still missing or poorly simulating stratospheric processes like the QBO



Despite the importance of stratosphere-troposphere coupling processes across timescales, many models still lack key dynamical and chemical processes.

Take the **Quasi-Biennial Oscillation**, which most models simulate poorly or not at all.
More measurements of small-scale gravity waves (unresolved in GCMs) may be needed to constrain parameterizations for different regions of the atmosphere.

Richter et al. 2020

Uncertainties and open questions discussed today

1) What stratosphere-troposphere coupling processes contribute to improved predictive skill on S2S timescales, and how do we best take advantage of those “windows of opportunity”?

2) How good are our observations of stratospheric processes, and how might better measurements improve processes in climate/forecast models?

3) What do current climate models suggest would be the impacts on stratospheric aerosol injection on the earth system? What are the uncertainties and which ones are potentially reducible through better process representation?

Invited Speakers

Dr. Jason Furtado
University of Oklahoma
"Overview of current understanding of the role of stratosphere-troposphere interactions in S2S prediction"

Dr. Martina Bramberger
Northwest Research Associates
"The Strateole 2 campaign and the implications of its measurements"

Dr. Simone Tilmes
NCAR
"Current research and challenges of stratospheric climate intervention"