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Arctic stratosphere dynamical response to global warming

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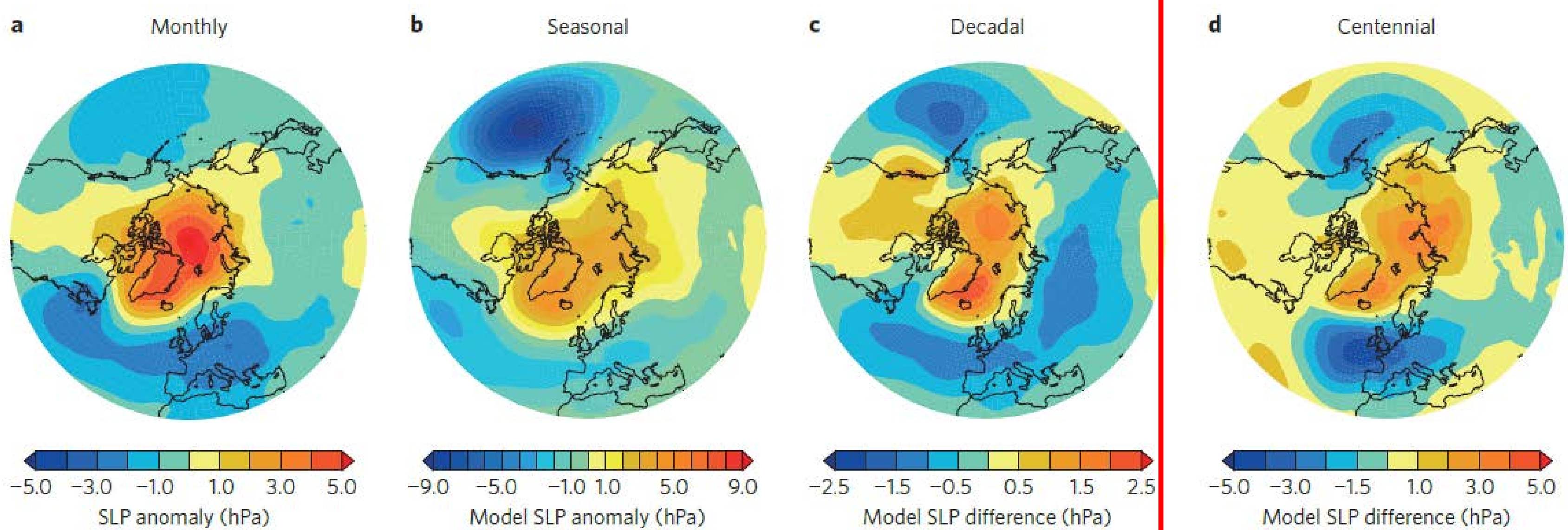
FMI

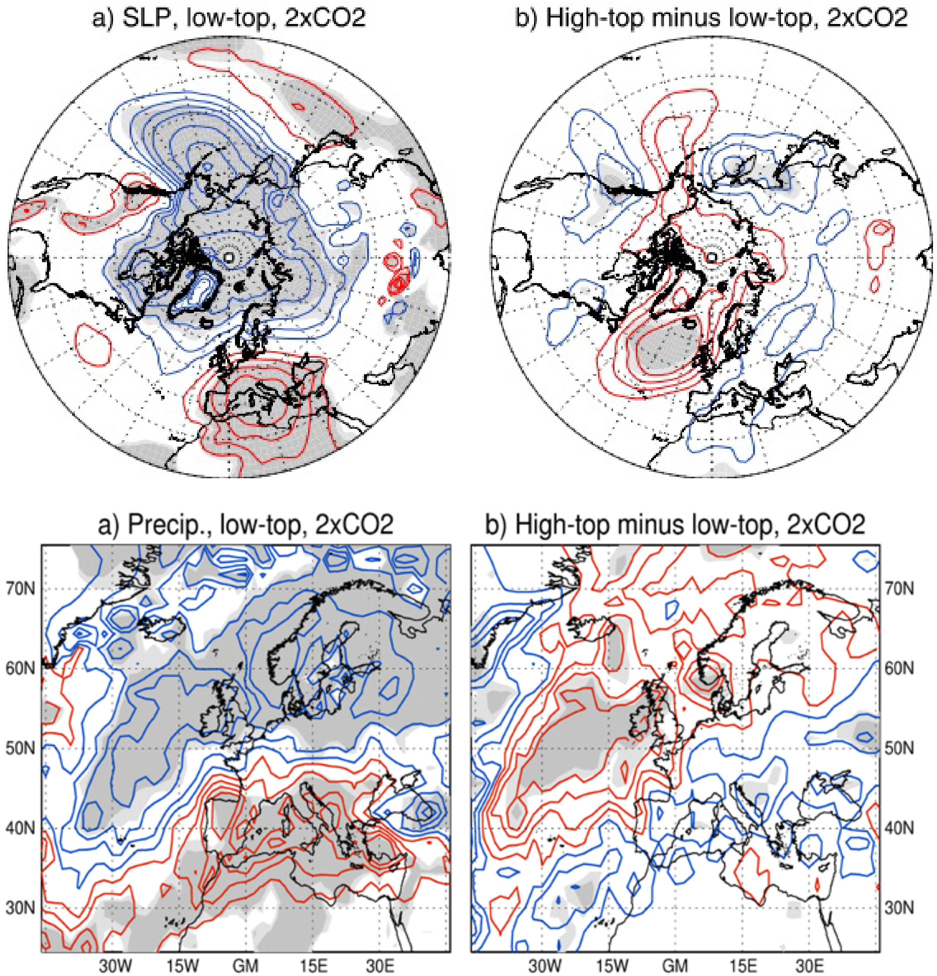
Motivation

- Stratospheric circulation is known to influence the troposphere during winter
- Future changes in stratospheric circulation will affect the troposphere
- **How will the Arctic stratosphere change?**



Kidston et al. 2015

Motivation (2)

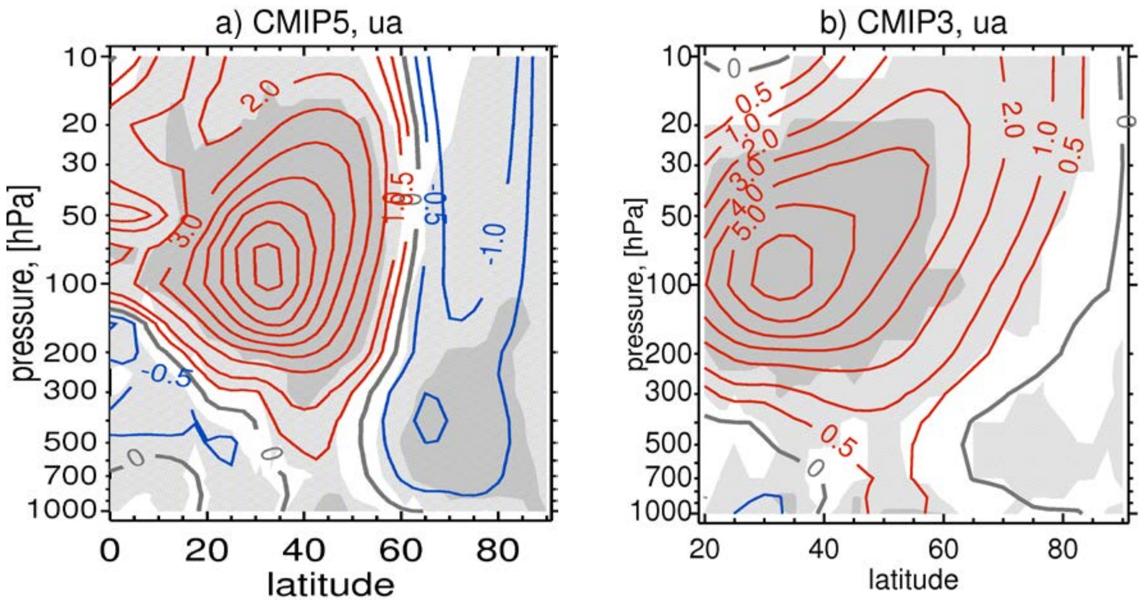


- The Arctic SLP decreases in response to climate change
- Dynamical warming of the Arctic stratosphere offsets the SLP response to climate change
- SLP response influences climatic responses
- In particular, Northern Europe (Mediterranean) gets more (less) precipitation in climate changes scenarios
- The precipitation response is reduced due to the changes in the stratospheric circulation

Karpechko and Manzini 2012

Arctic polar vortex changes -> ?

In the Northern Hemisphere future changes in the Arctic polar vortex remain poorly understood



Manzini et al. 2014

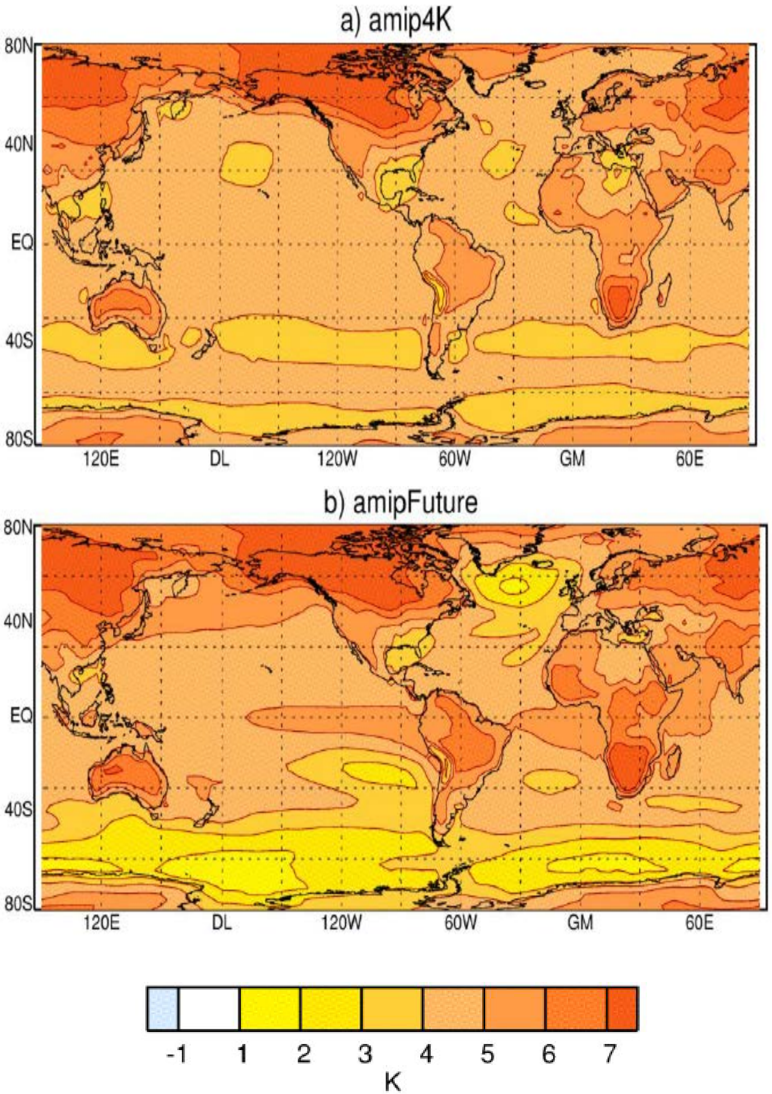
- Equatorward shift of the polar night jet
- Most common response to GHG increases in stratosphere-resolving models (~70% of CMIP5 models)

but

- …not robust across models
- unknown mechanisms

→ **Large uncertainty**

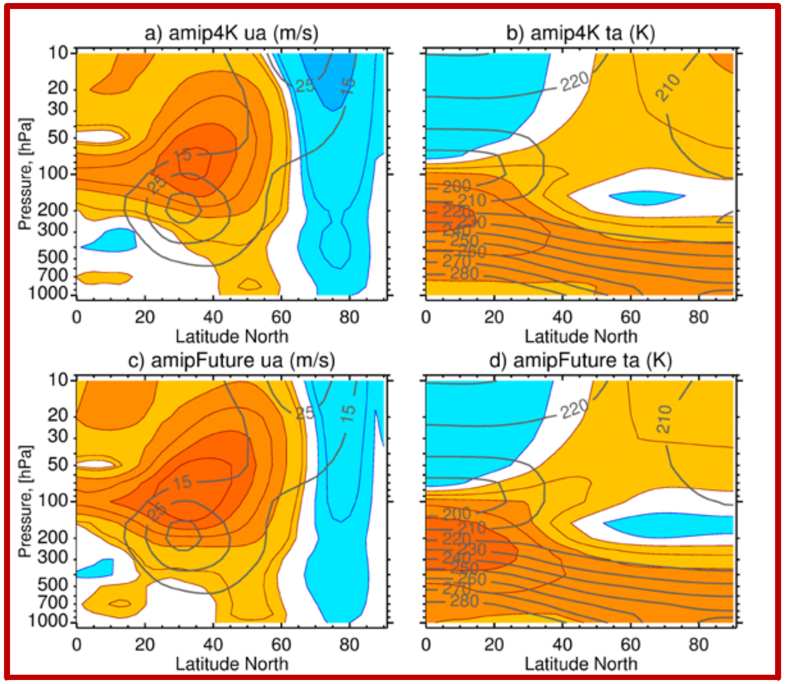
CMIP5 Amip experiments



The experiment:

- 12 models in amip4K and amipFuture experiments
- Constrained atmospheric warming, ~ similar across all models

CMIP5 Amip experiments



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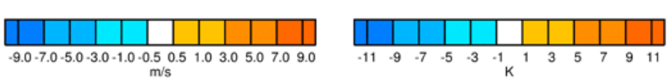


The experiment:

- 12 models in amip4K and amipFuture experiments
- Constrained atmospheric warming, ~ similar across all models

The response:

- Strengthening of the subtropical jet
- Weakening of the extratropical winds in the stratosphere and troposphere
- Temperature change in the stratosphere dominated by equator cooling /polar warming pattern
  - The pattern suggests a dynamical origin of the temperature changes

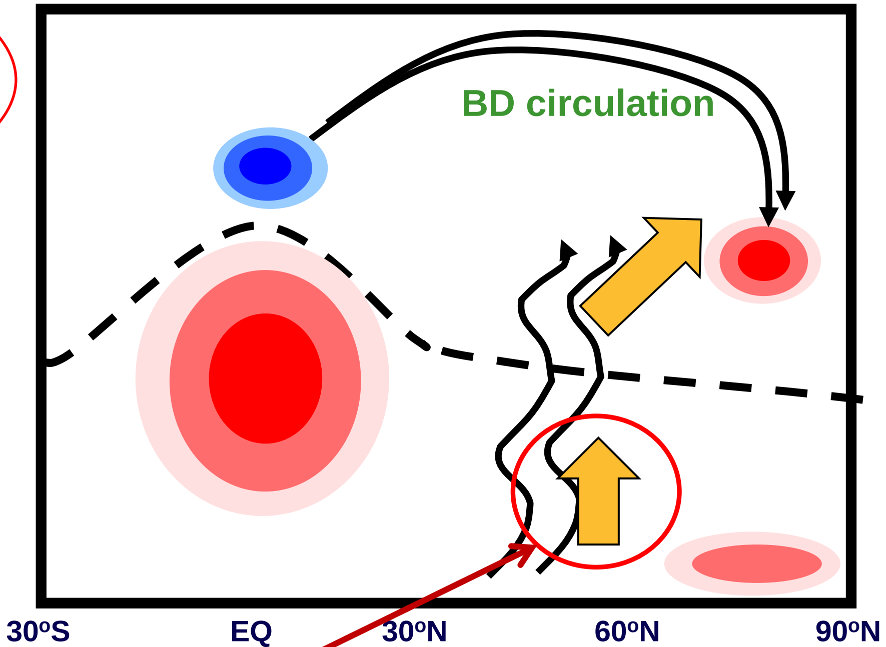
Karpechko and Manzini 2017

Causes for dynamical heating of the stratosphere

Changes in wave generation: more wave activity is generated in the troposphere

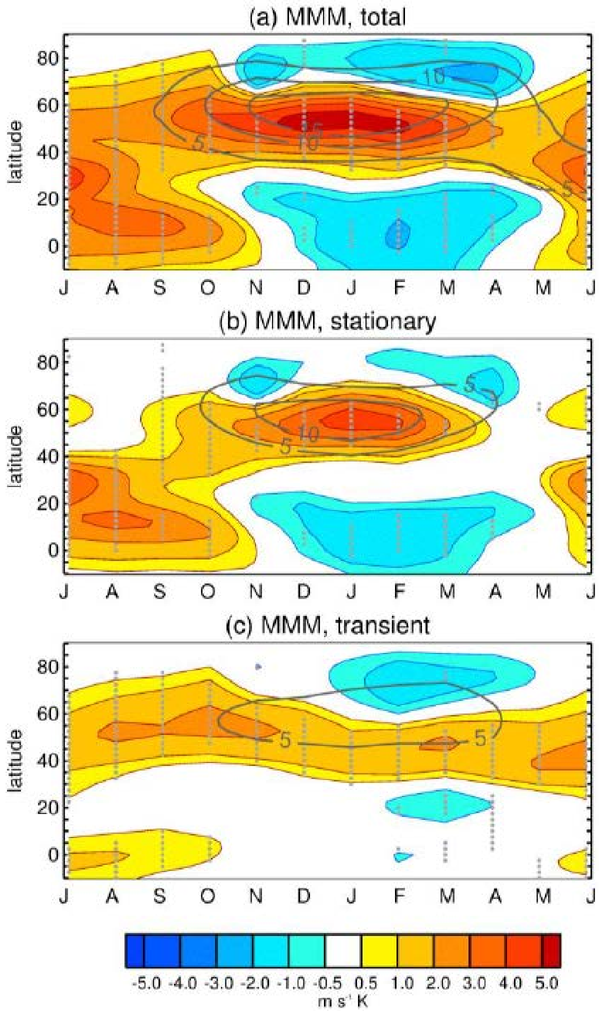
or / and

Changes in transmitting properties of the atmosphere: wave activity more effectively influences polar vortex (e.g. Sigmond and Scinocca 2010)



Diagnosed by increased eddy heat flux at 100 hPa

Dynamical driving of stratospheric changes



Karpechko and Manzini 2017

- Eddy heat flux at 100 hPa
- Separated into stationary (monthly scale) and transient (sub-monthly scale) components
- Eddy heat flux increases in extratropics during winter
- The increase is mostly due to stationary wave component (and mostly wave 1 component)
- The increase is remarkably robust across models and similar in both amip4K and amipFuture scenarios

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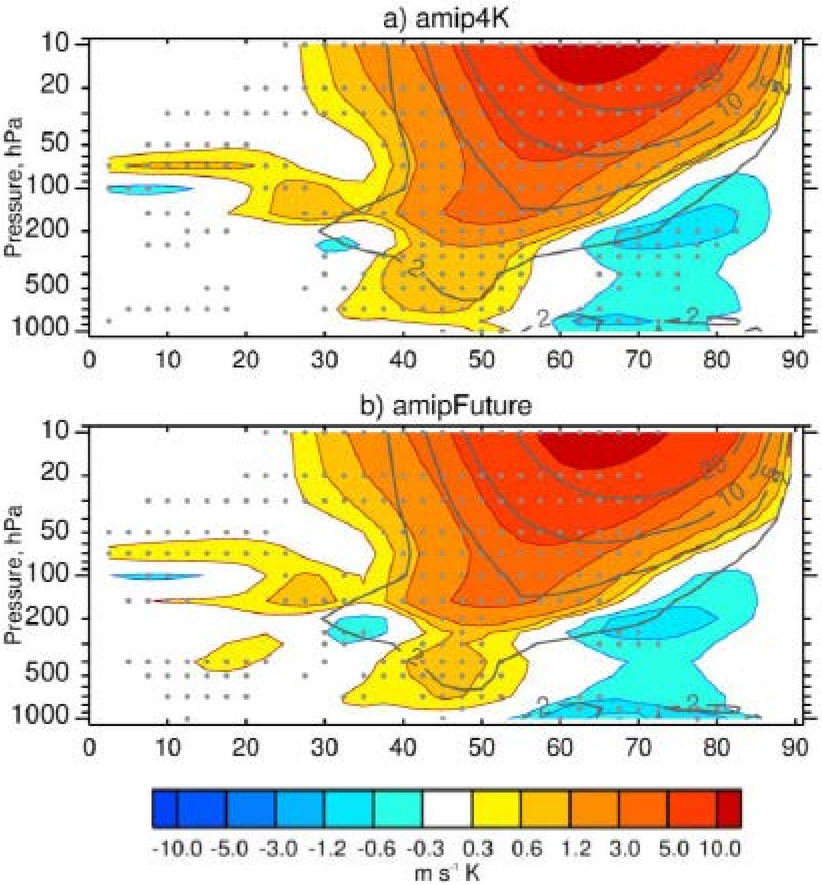
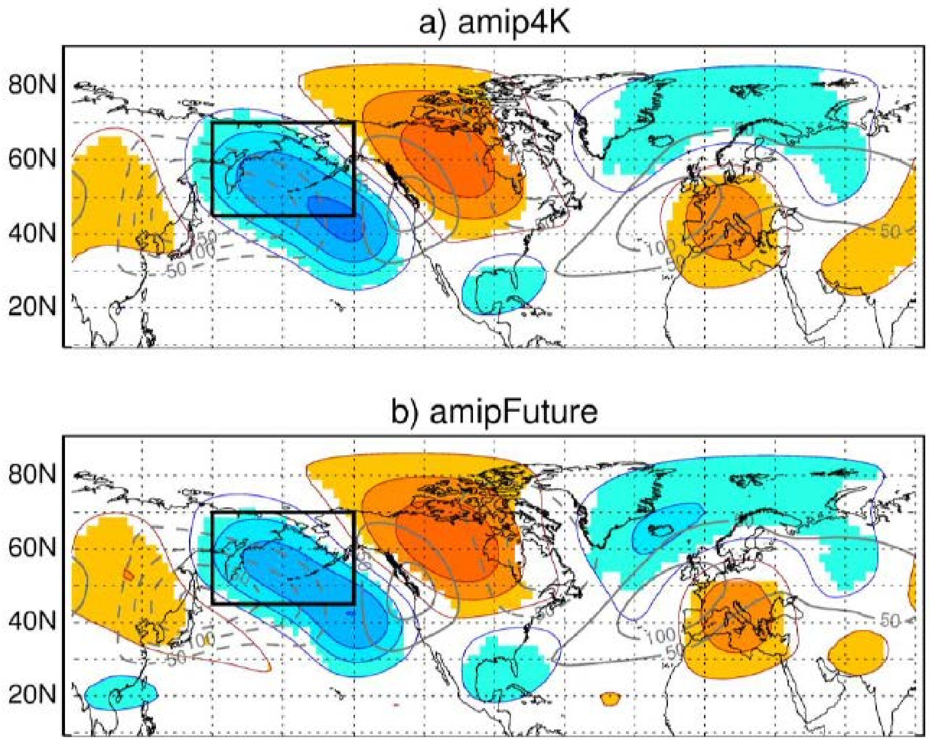
Dynamical driving of stratospheric changes



- ➢ Eddy heat flux due to stationary wave 1 in NDJF
- ➢ The heat flux increases through most of the stratosphere
- ➢ The heat flux increases in mid-latitude troposphere, suggesting increased wave generation followed by increased upward and poleward propagation of wave activity
- ➢ The increase is remarkably robust across models and similar in both amip4K and amipFuture scenarios

Karpechko and Manzini 2017

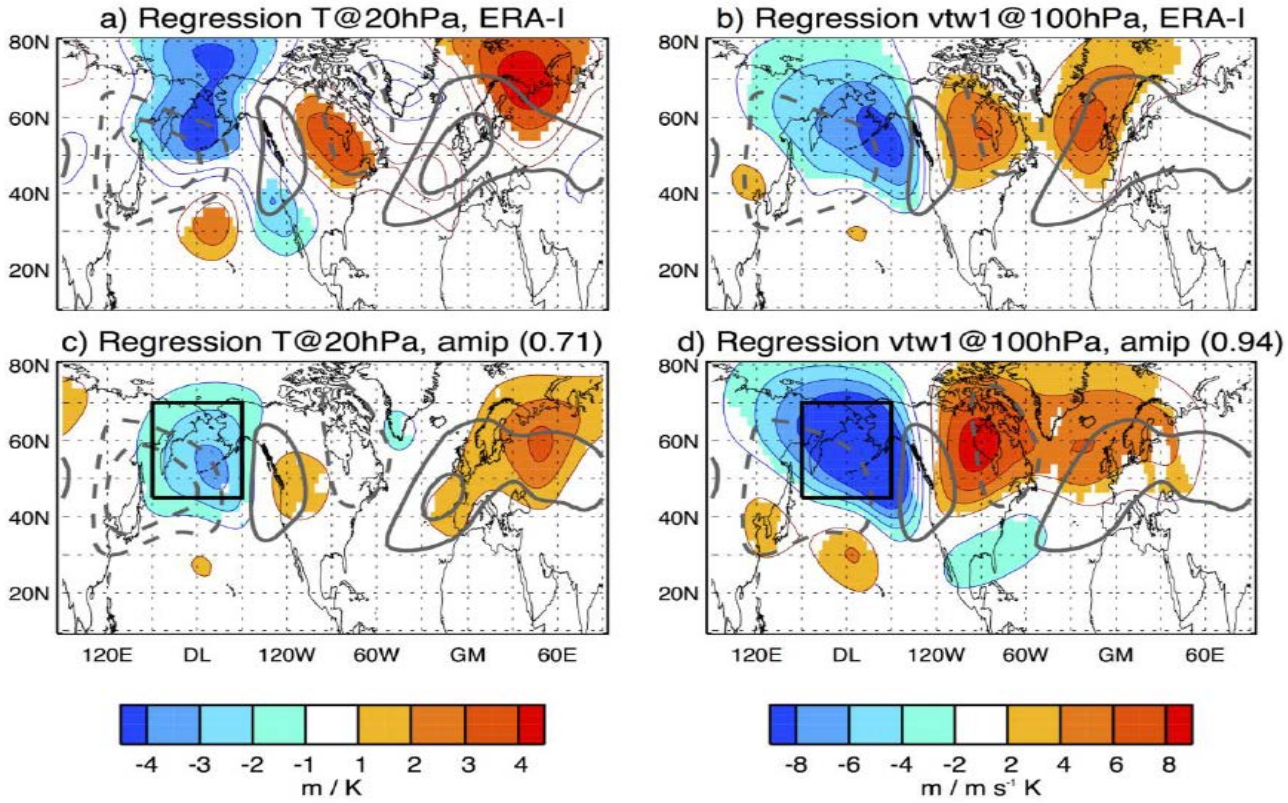
Changes in tropospheric waves



- Eddy geopotential height response at 500 hPa averaged during Nov-Feb
- The response features a wave train across North Pacific and North America
- The strongest response is a low in North Pacific (also a high in North America)
- The response is remarkably robust across models and similar in both amip4K and amipFuture scenarios

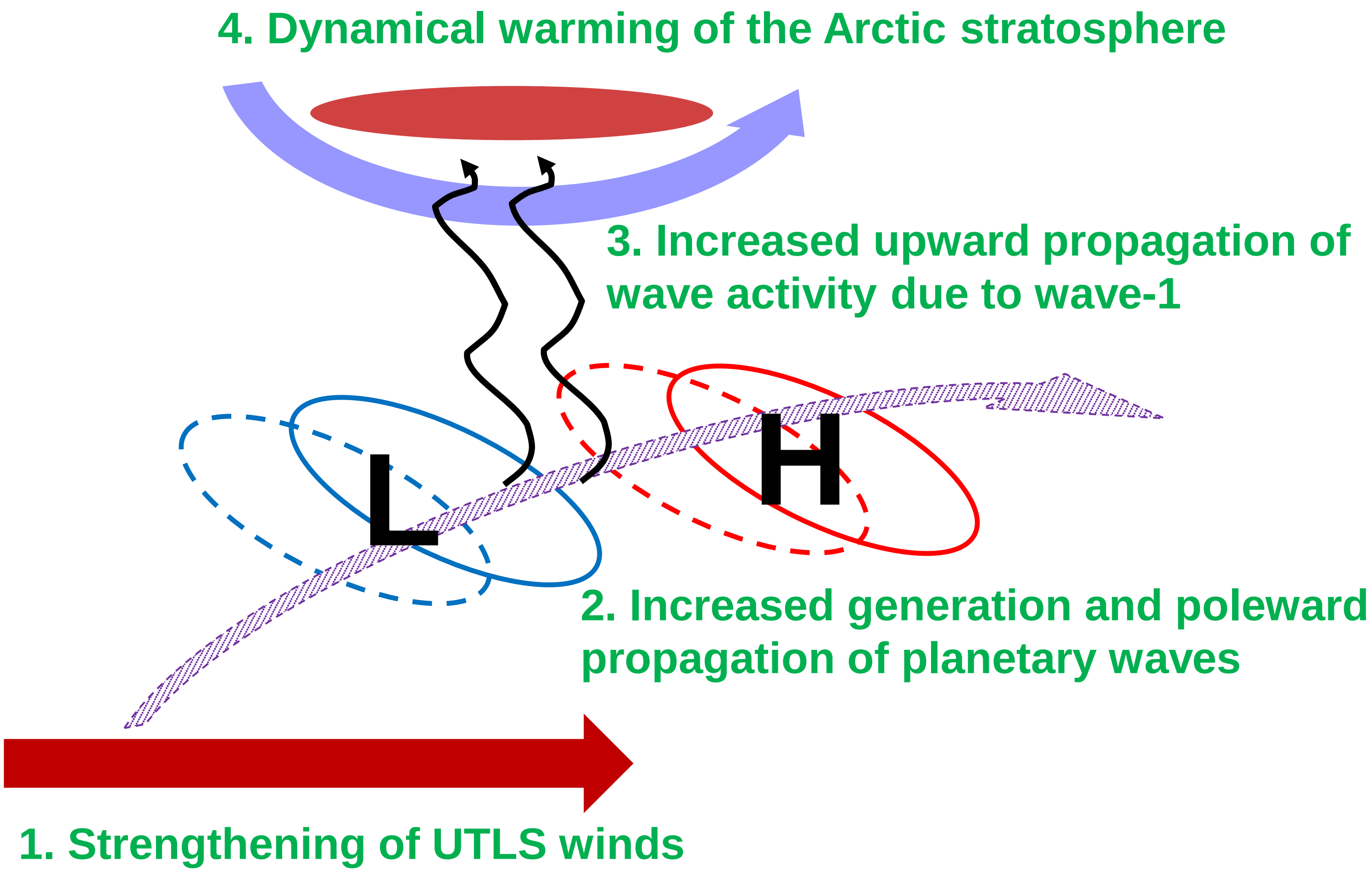
Karpechko and Manzini 2017

Changes in tropospheric waves (cont.)

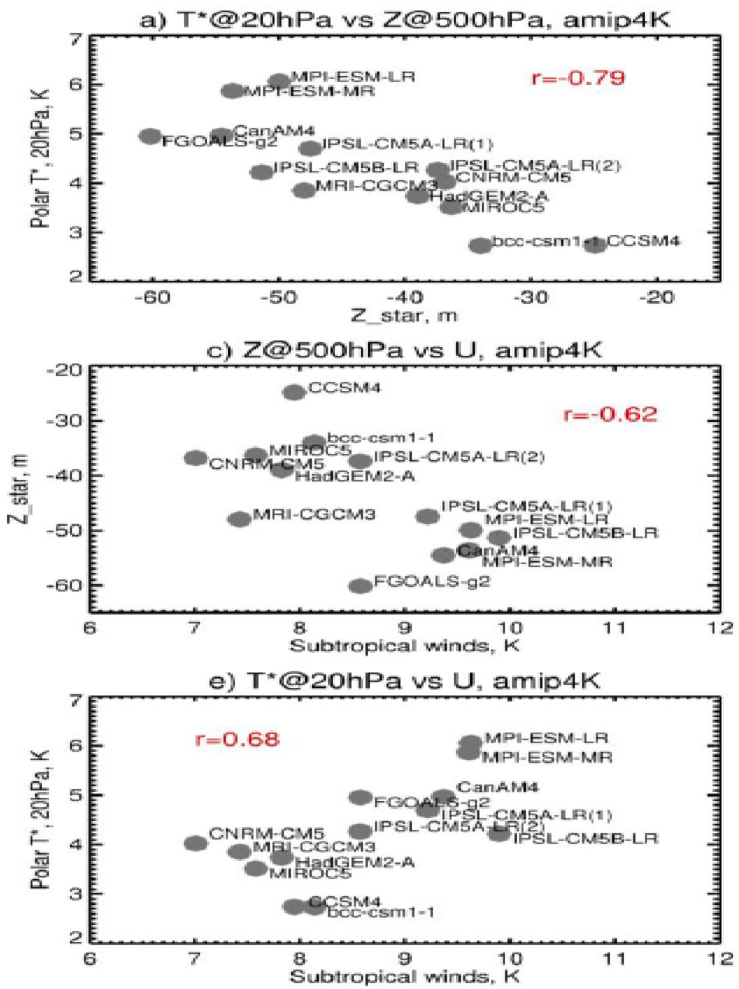


- A low in North Pacific is consistent with warming of the Arctic stratosphere both in models and in ERA-I
- A low in North Pacific is consistent with increased wave 1 eddy heat flux to the Arctic stratosphere both in models and in ERA-I

Proposed mechanism



Intermodel spread



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- Arctic stratosphere warming correlates with changes in tropospheric waves in North Pacific across models
- Changes in tropospheric waves in North Pacific correlates with changes in subtropical winds across models
- Changes in subtropical winds correlates with Arctic stratosphere warming across models
- The above statistics provide support for the mechanism and suggests that a dynamical warming of the Arctic stratosphere is the most likely response

Summary

- **The Arctic stratosphere warms, and the sub-polar stratospheric westerly winds weaken in the CMIP5 amip experiments with prescribed SST warming**
- **The stratospheric changes are driven by increased wave activity flux into the stratosphere**
- **The increased stratospheric wave activity is mostly due to increased generation of stationary wave 1 in the troposphere**
- **The above changes are remarkably robust across all models participating in the experiments**
- **We propose that the increased wave activity and Arctic stratosphere warming are ultimately related to increased wind speed of the subtropical jet stream, a robust response to the global warming**

Mechanism

Stronger subtropical winds

↓

Increased generation of planetary wave activity

↓

Larger amplitude of stationary wave 1 in the troposphere

↓

Larger wave activity flux into the stratosphere

↓

Stronger stratospheric meridional circulation

↓

Warmer polar stratosphere/weaker polar vortex