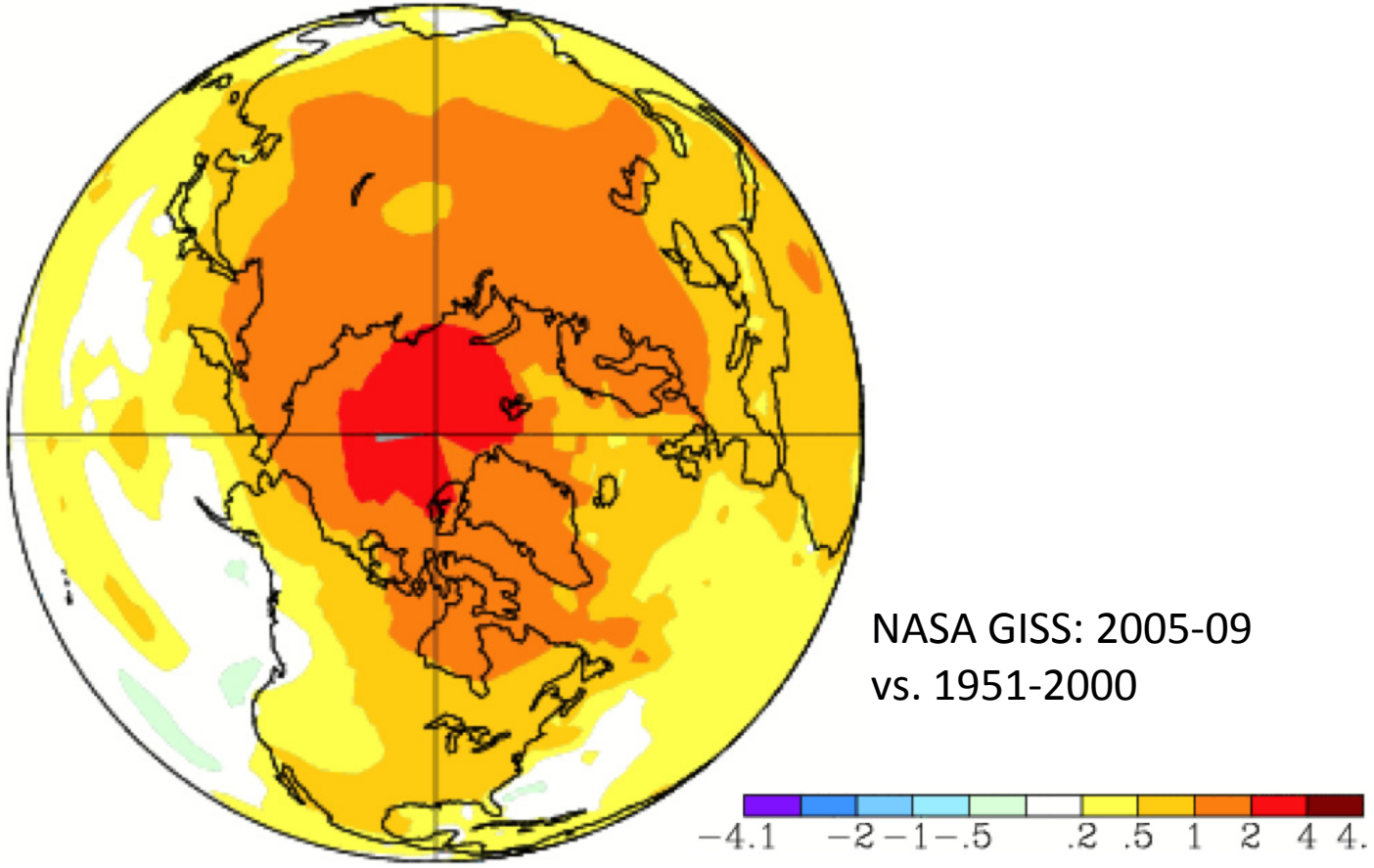
# Arctic amplification

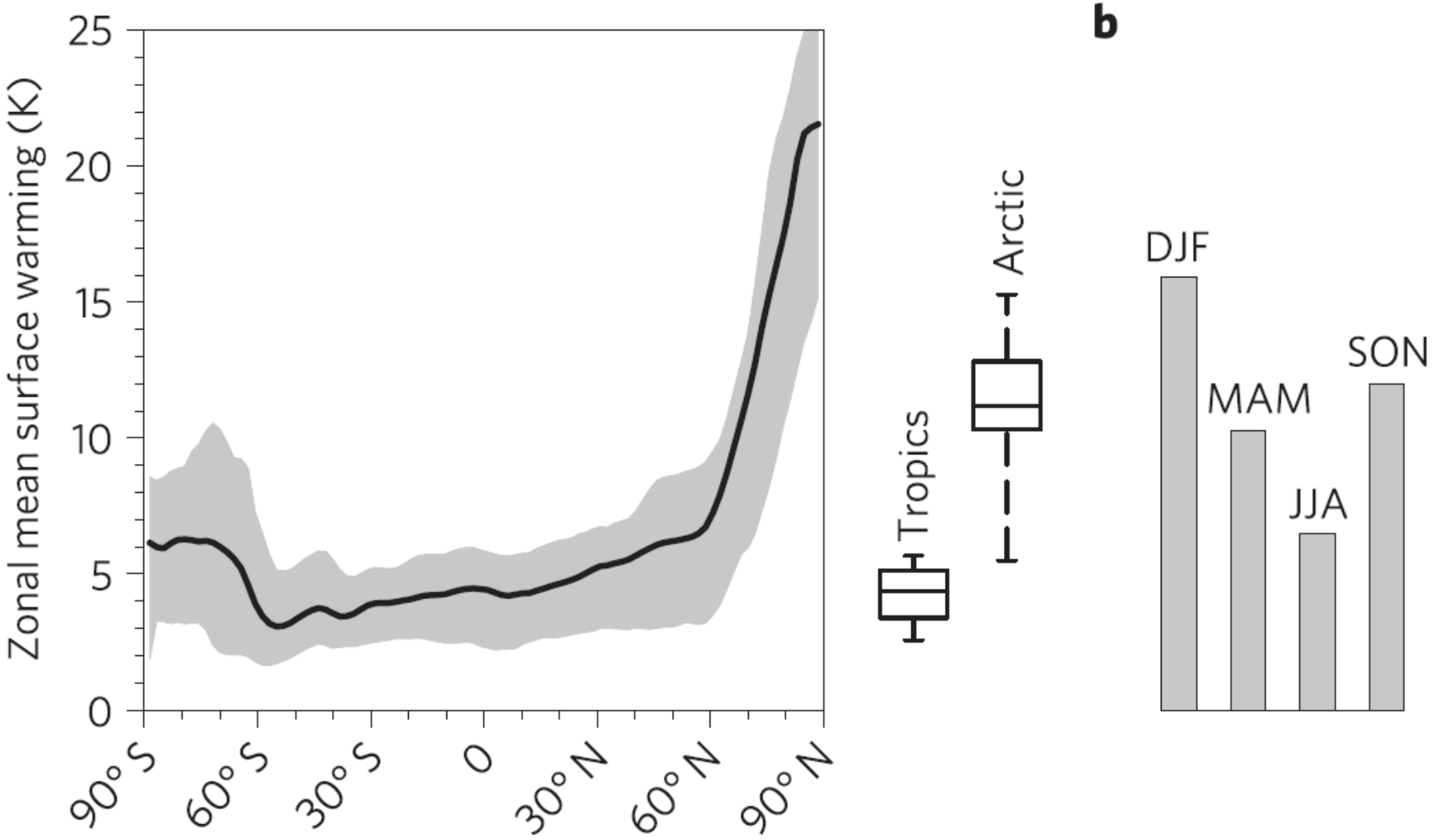



Peter L. Langen

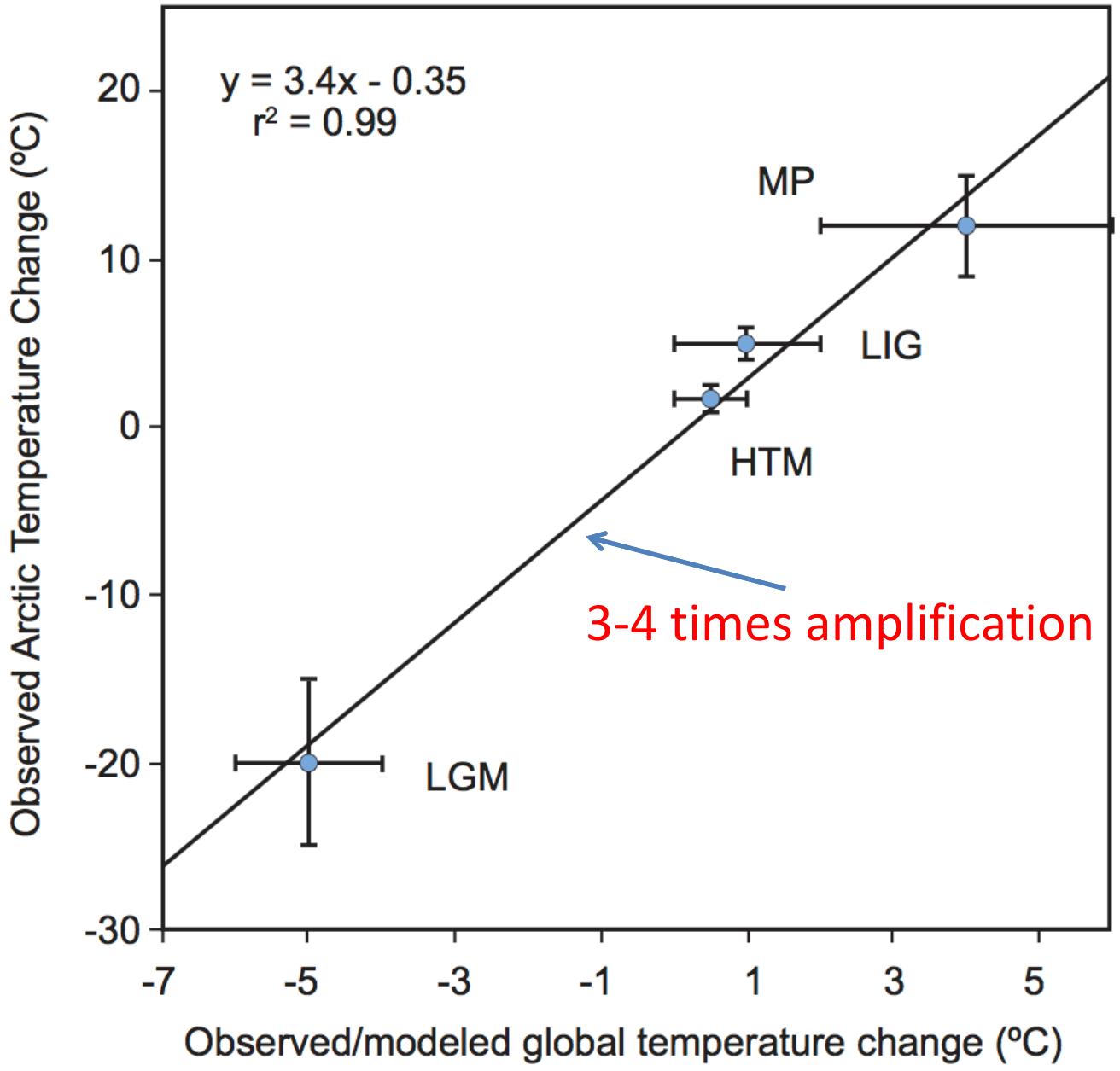
Climate and Arctic Research

DMI

CMIP5 multi-model 4xCO2 warming




*Pithan and Mauritsen (Nature Geosci, 2014)*



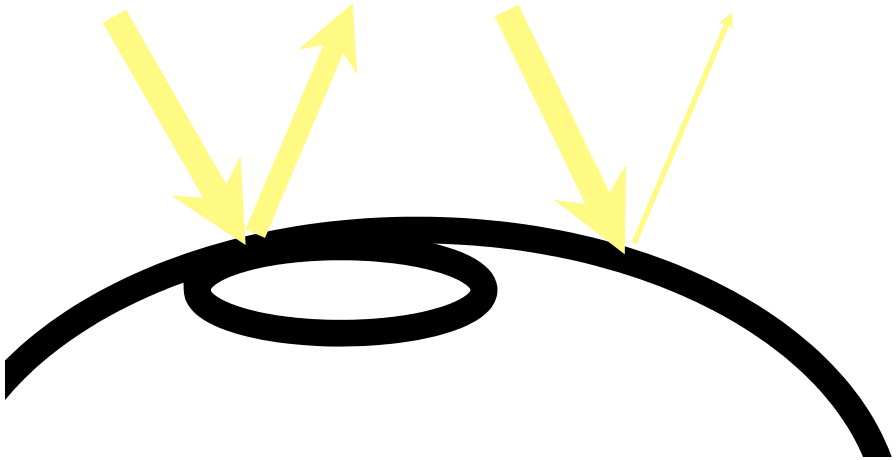

*Miller et al. (QSR, 2010)*

# Overview

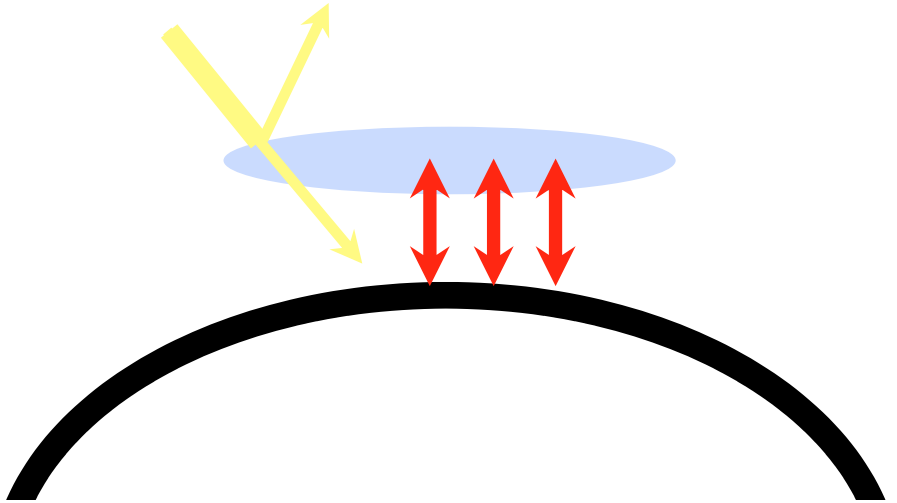
- **Mechanisms and feedbacks**
- Disentangling the relative roles of the feedbacks
- Local or remote controls on Arctic warming

# Mechanisms?

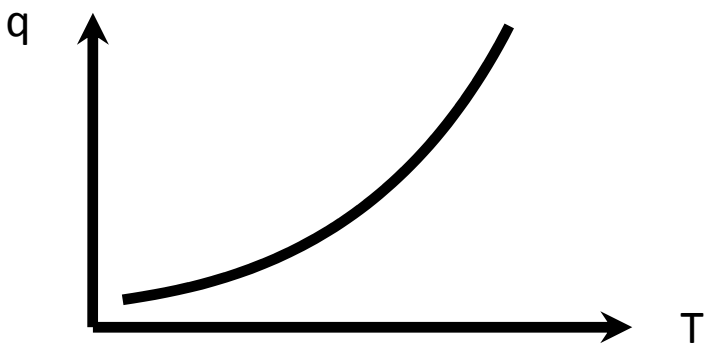
1) Surface albedo feedback



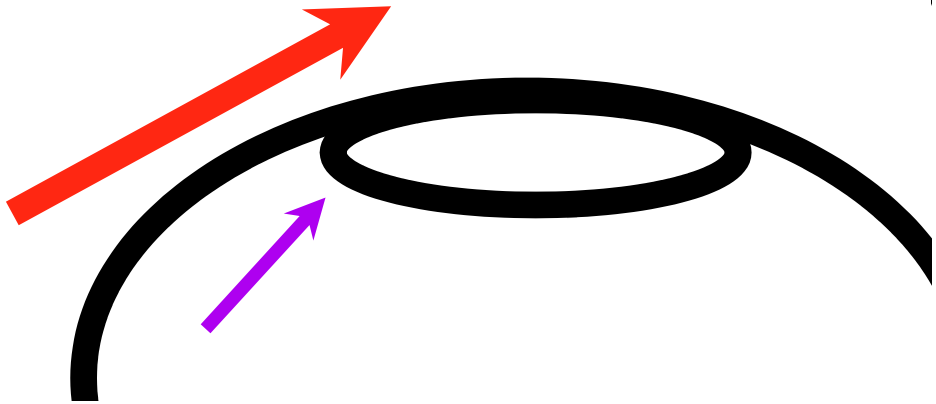
3) Cloud feedbacks



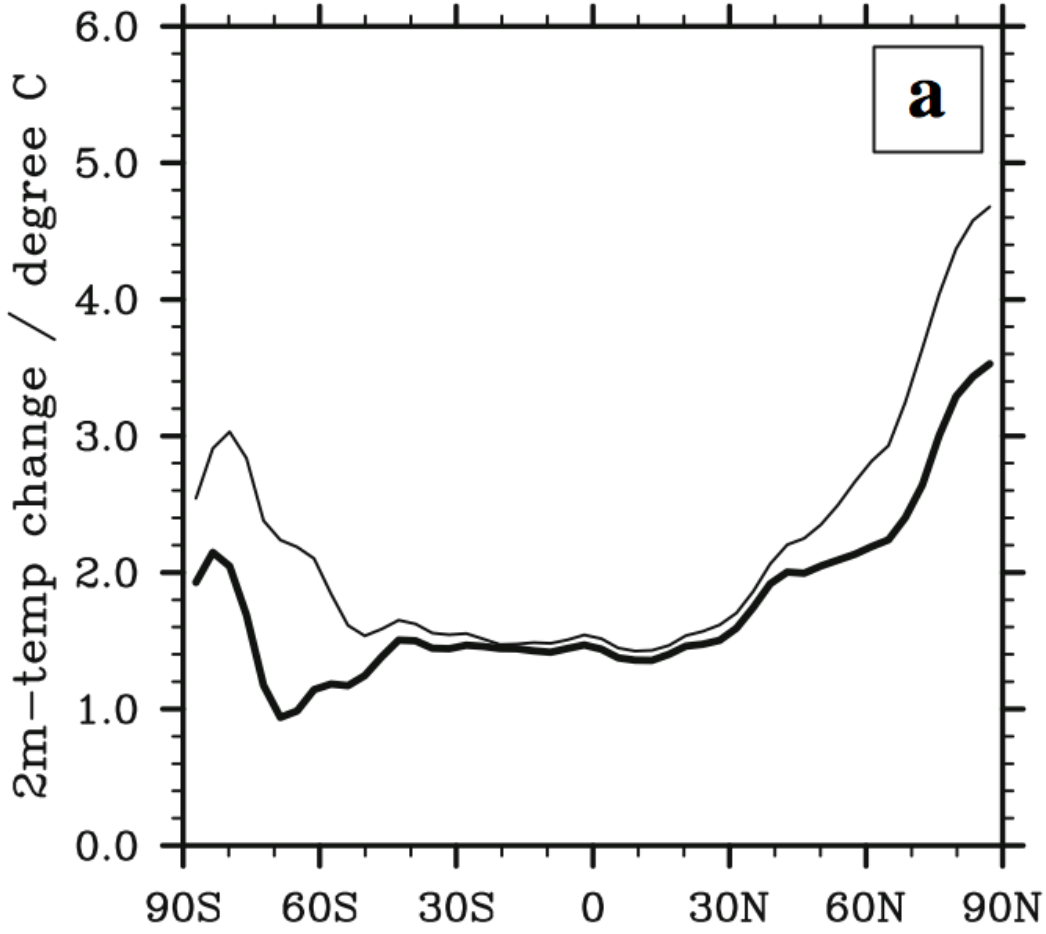
2) Water vapor feedback




4) Circulation and lapse rate

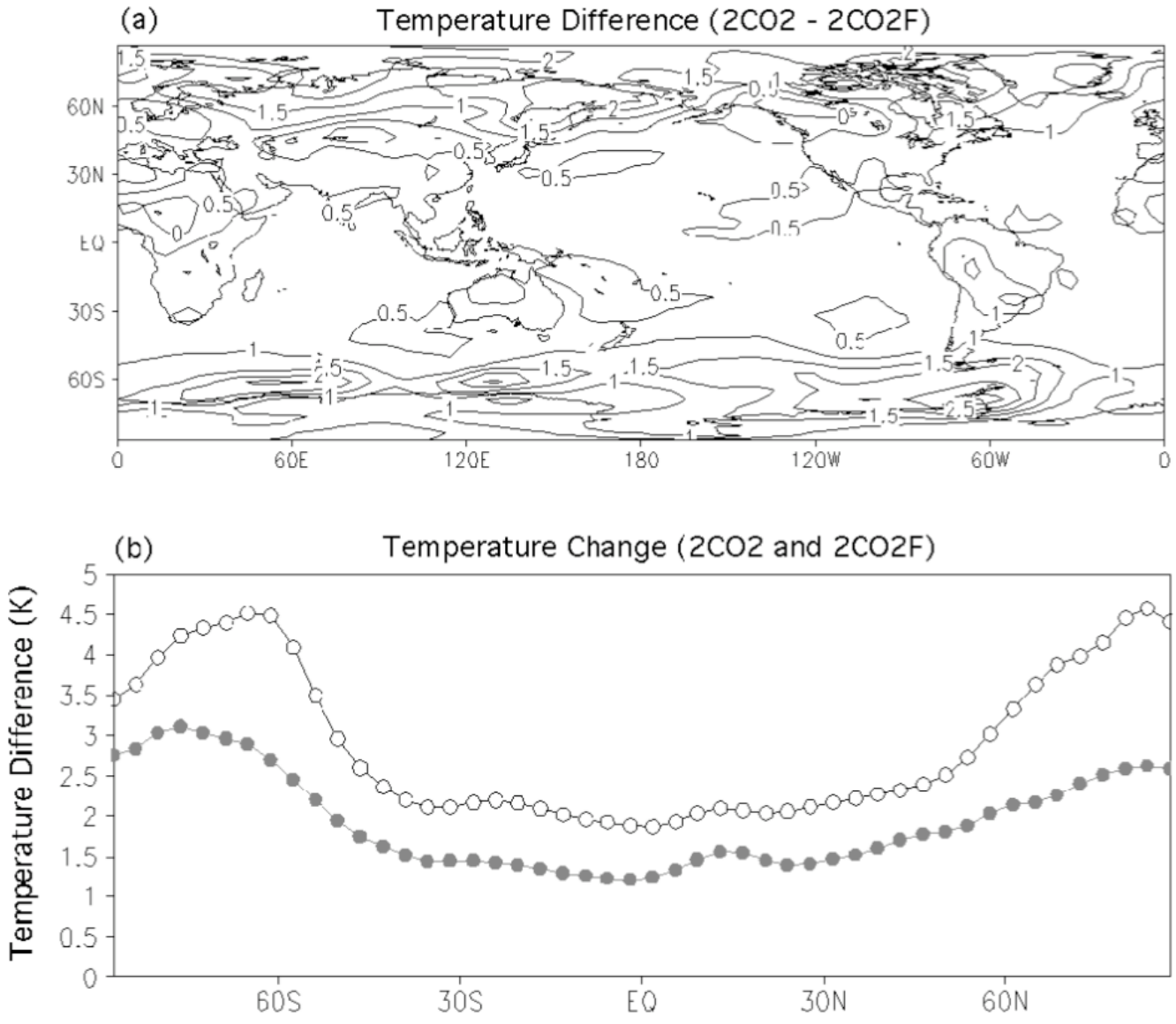


# Surface albedo feedback



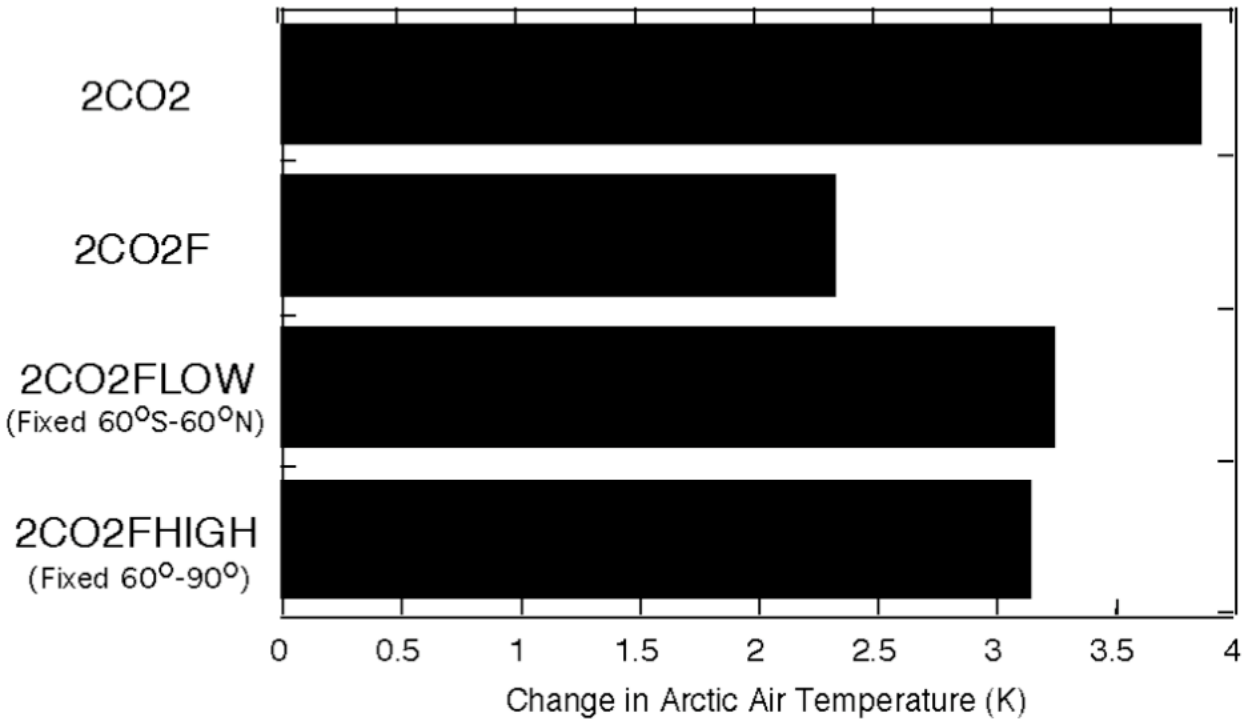

*Graversen and Wang (ClimDyn, 2009)*

# Cloud feedback




*Vavrus (JClim, 2004)*

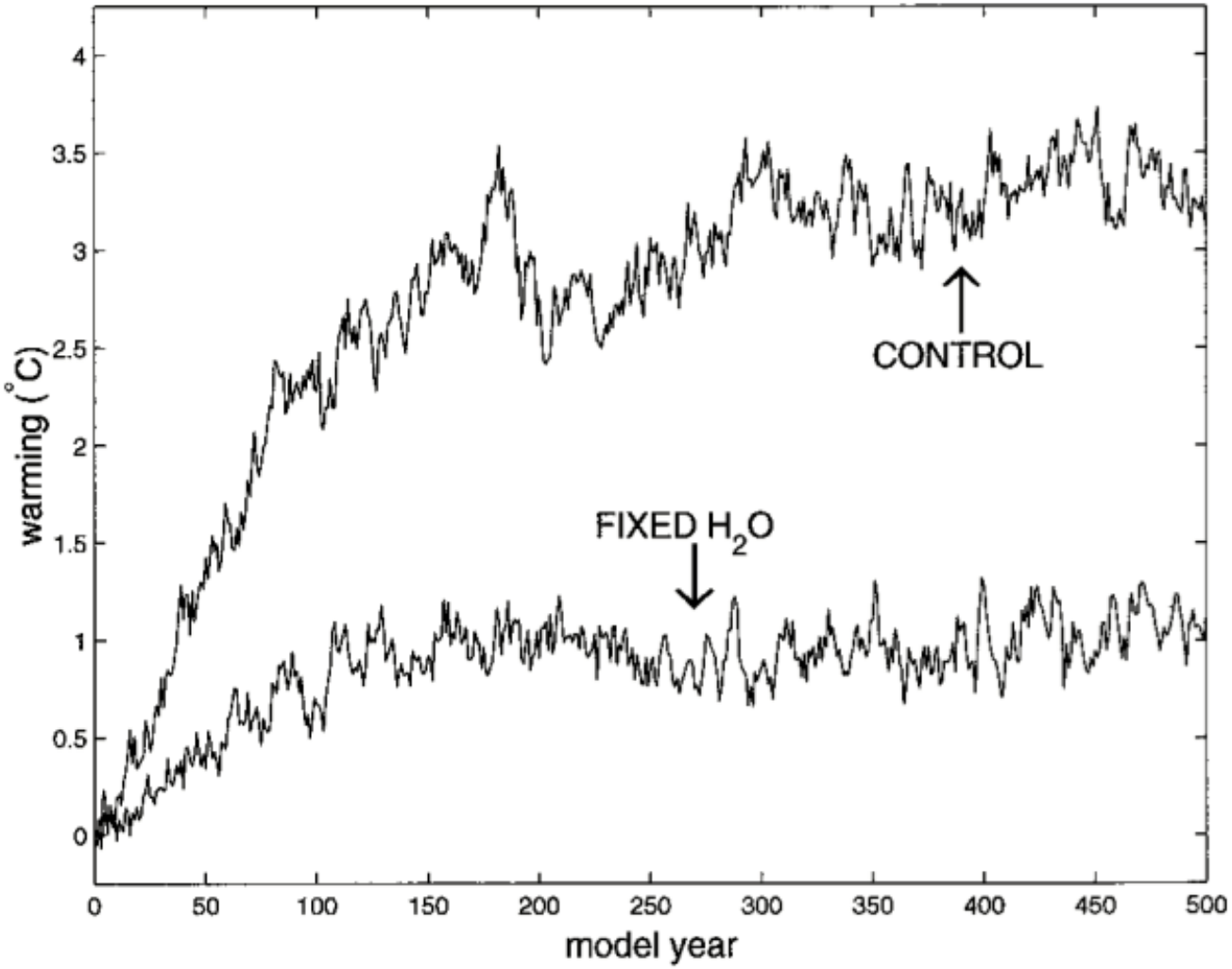
# Cloud feedback




The warming due to low-latitude cloud feedback contributes to high-latitude warming!

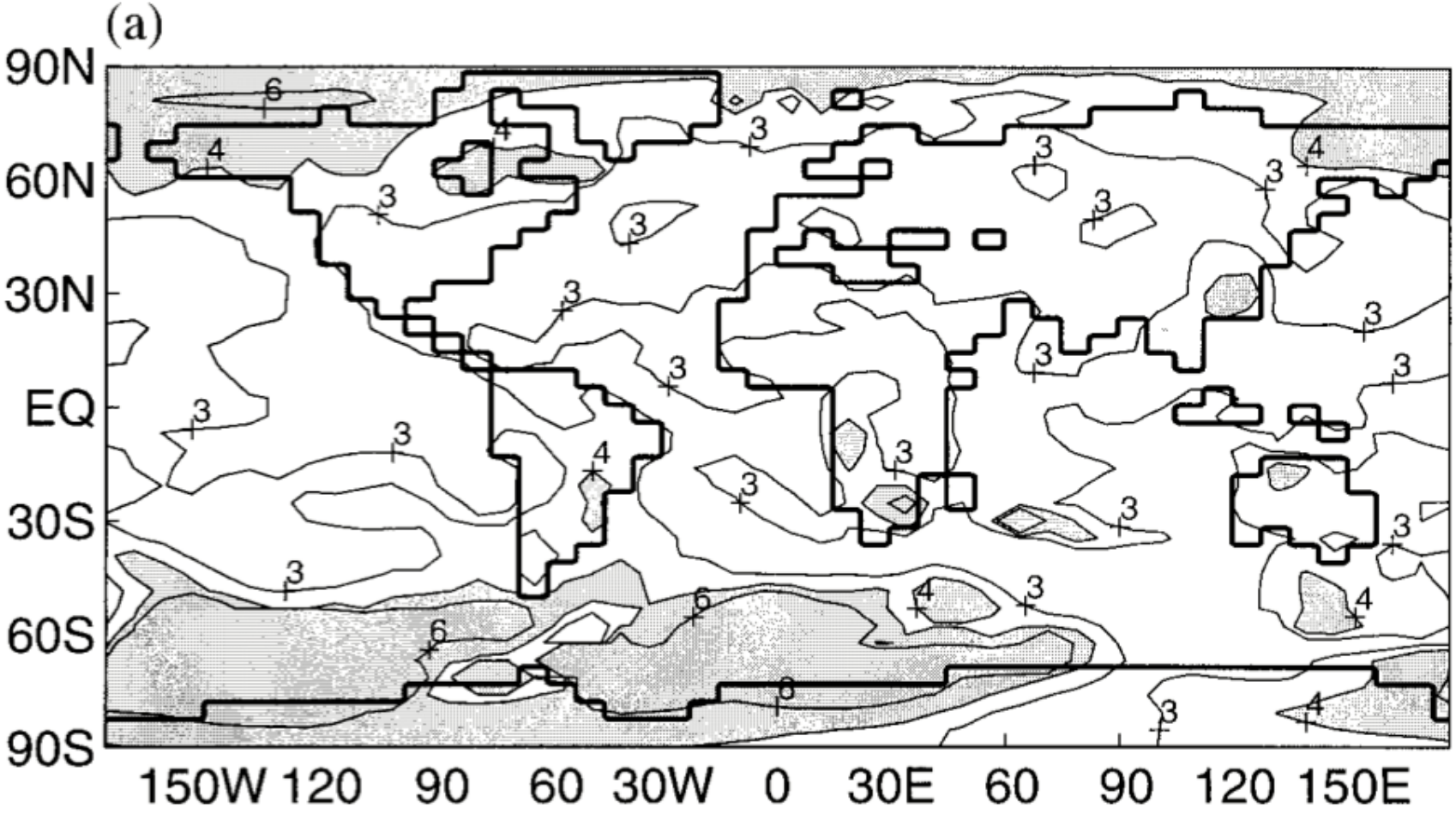
*Vavrus (JClim, 2004)*

# Water vapor feedback




*Hall and Manabe (JClim, 1999)*

# Water vapor feedback

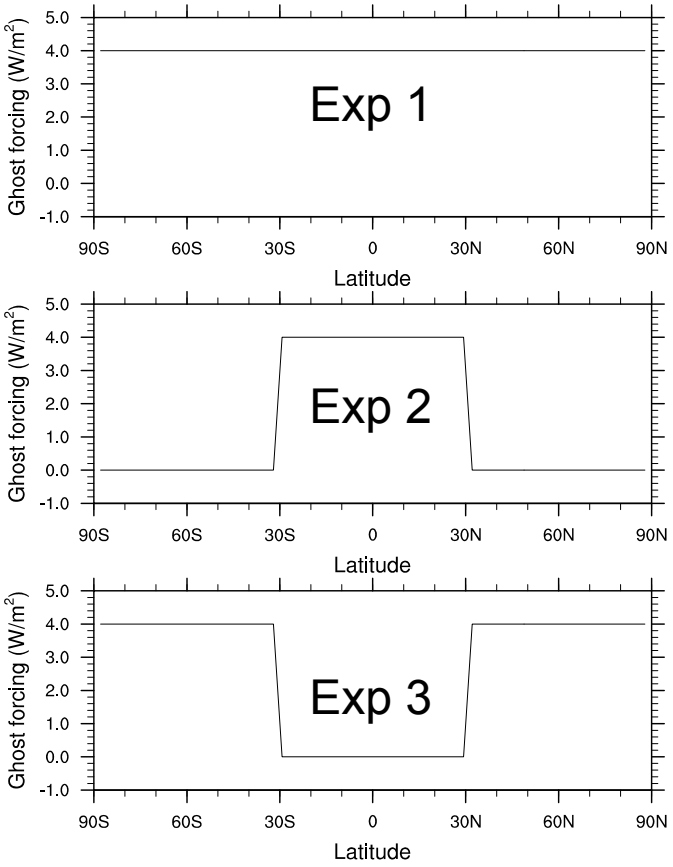



*Hall and Manabe (JClim, 1999)*

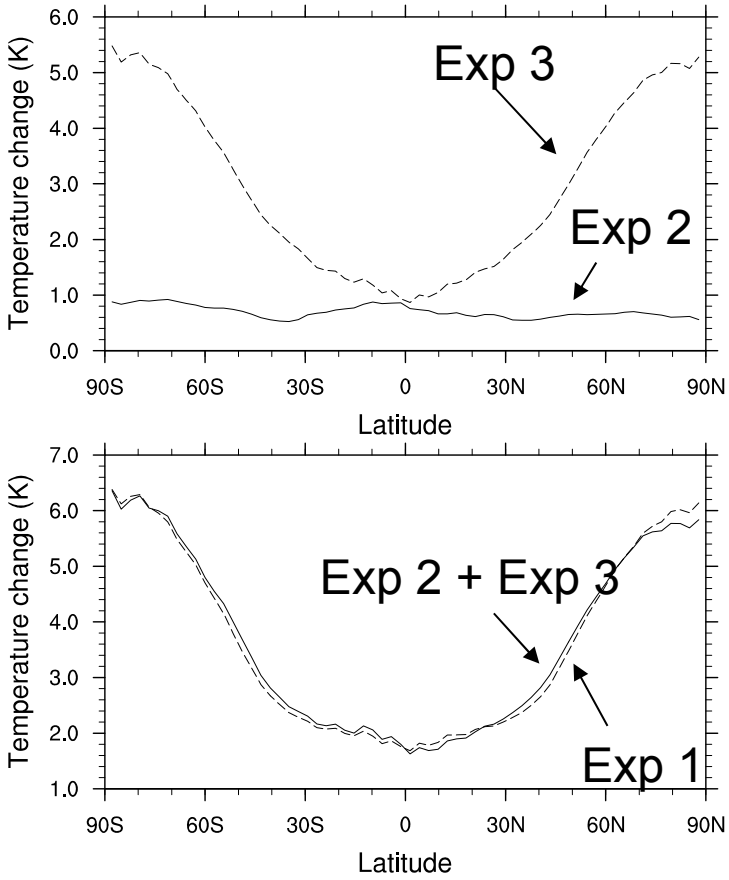

In the future, maps of the world will be fairly easy to make

# Atmospheric heat transport

Forcing

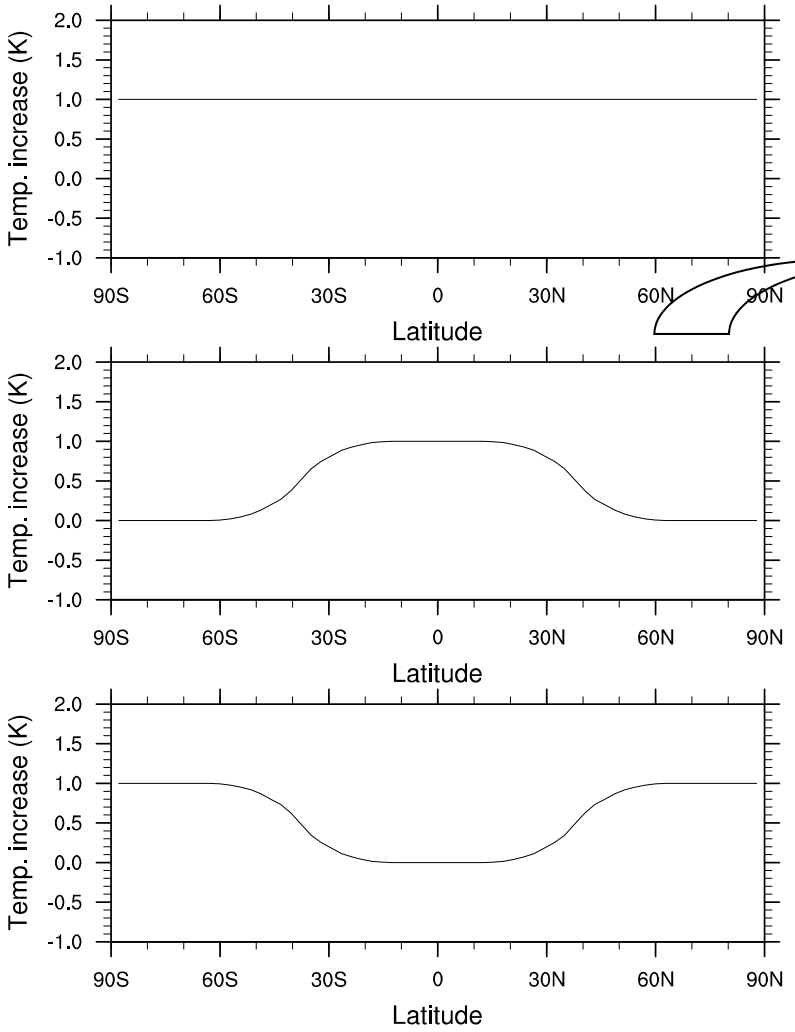



Response

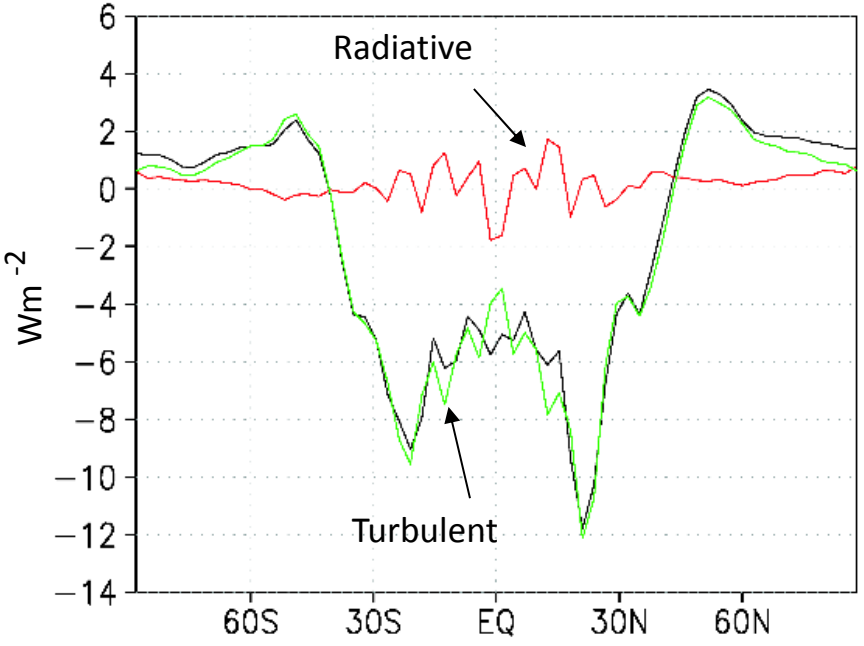



*Alexeev, Langen and Bates (ClimDyn, 2005)*

# Low-to-high latitude communication



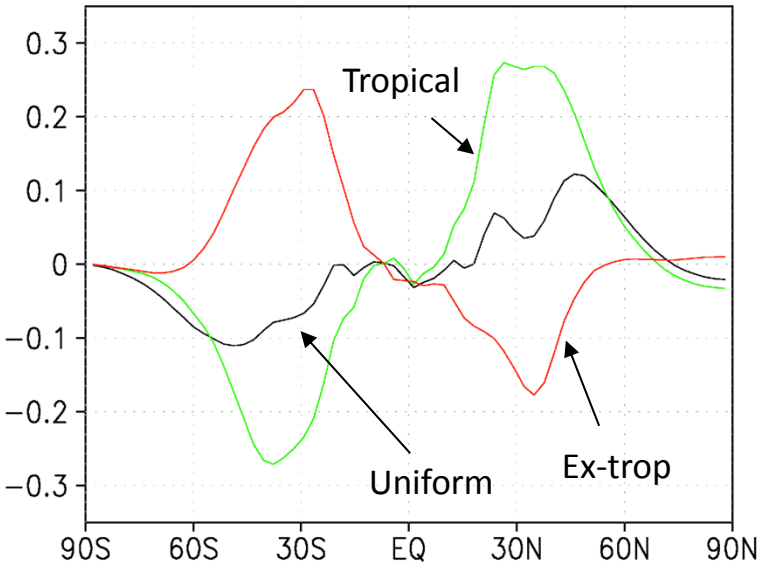

Tropical-only SST change gives positive high-latitude tendency:

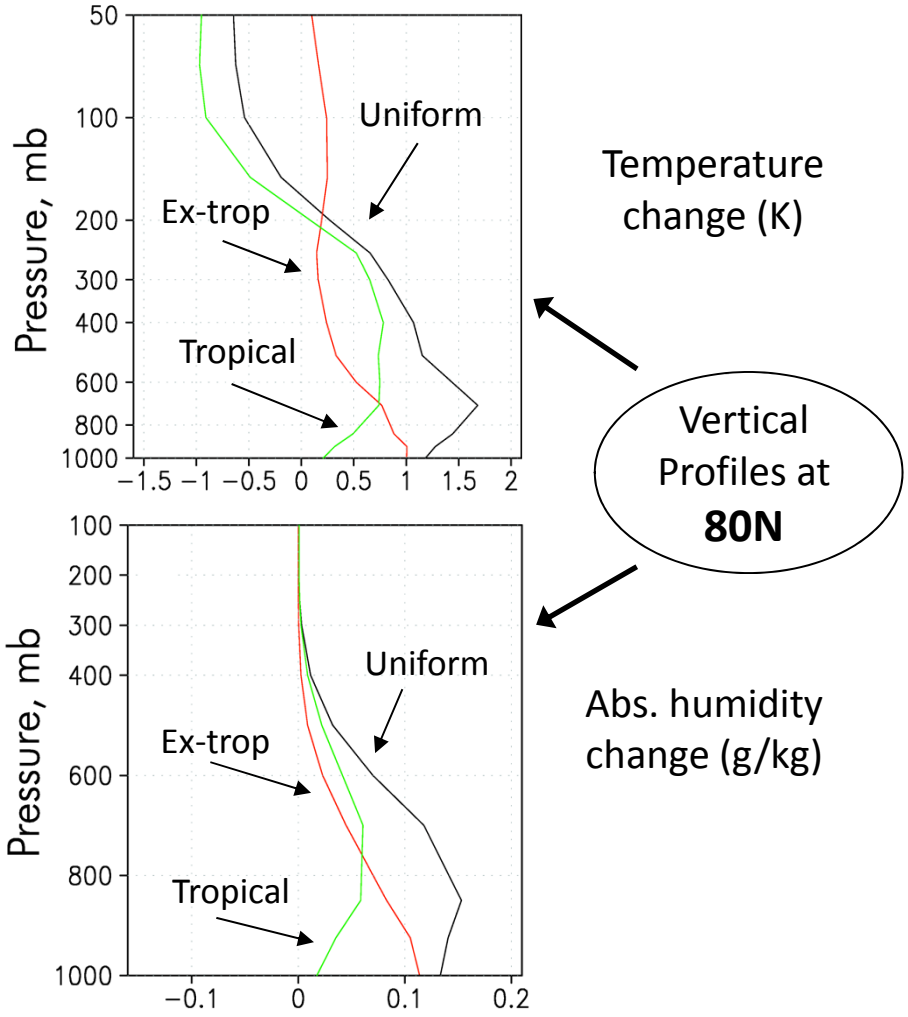



*Alexeev, Langen and Bates (ClimDyn, 2005)*

# High latitude profiles of T and Q

Increased heat transport warms and moistens high-latitude troposphere



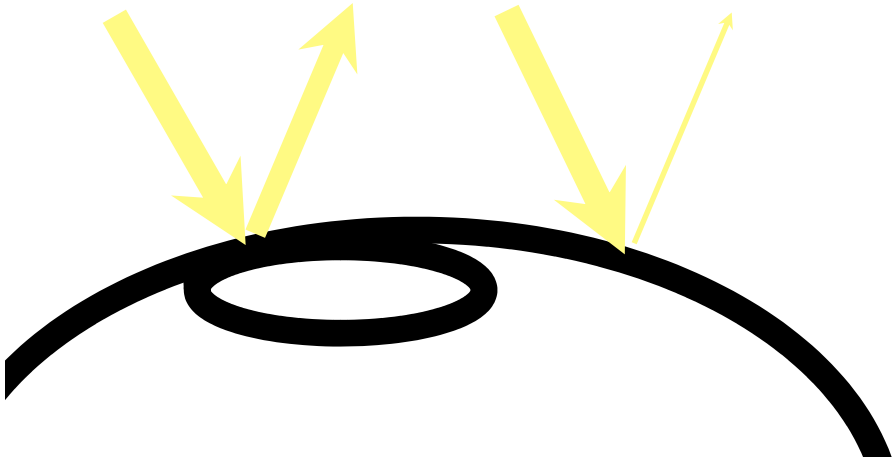

*Alexeev, Langen and Bates (ClimDyn, 2005)*

# Overview

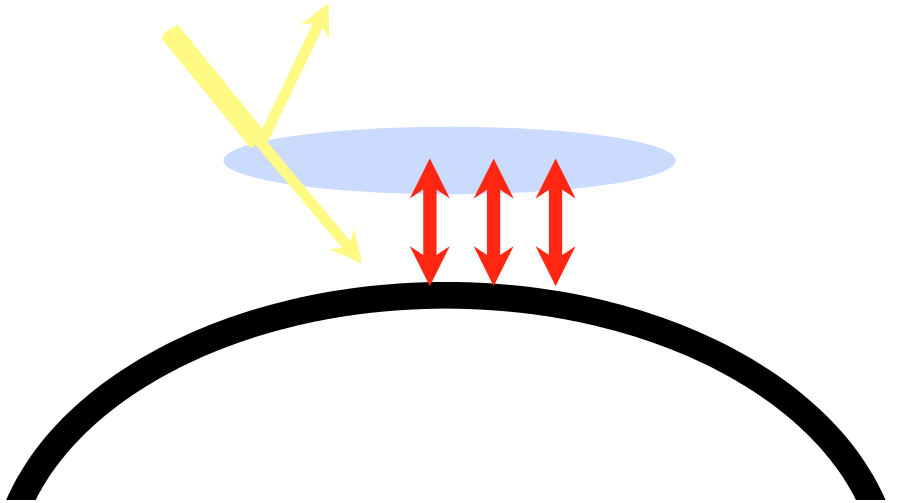
- Mechanisms and feedbacks
- **Disentangling the relative roles of the feedbacks**
- Local or remote controls on Arctic warming

# Mechanisms?

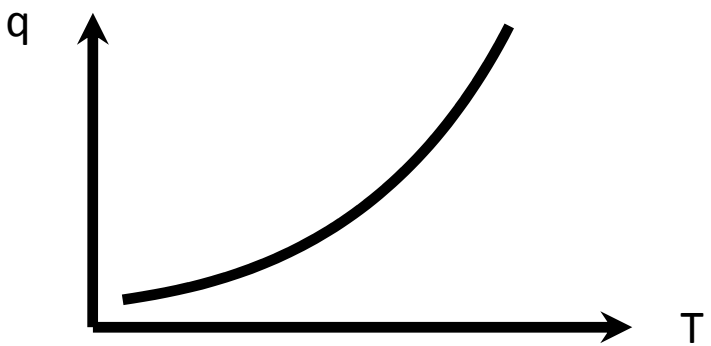
1) Surface albedo feedback



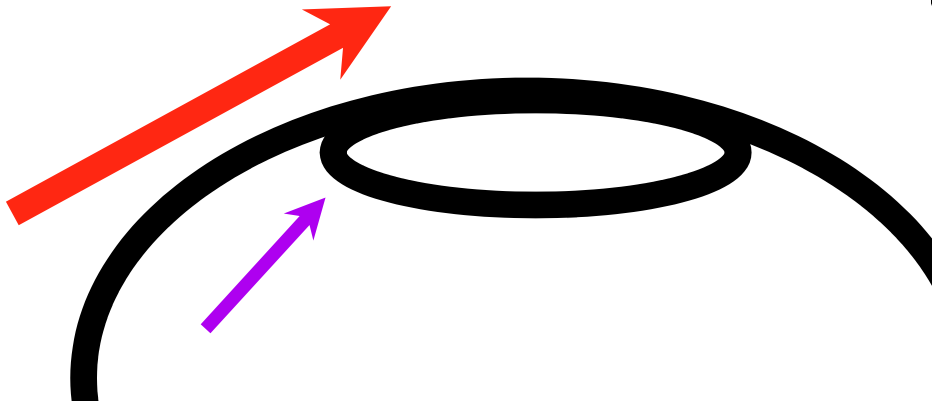
3) Cloud feedbacks



2) Water vapor feedback

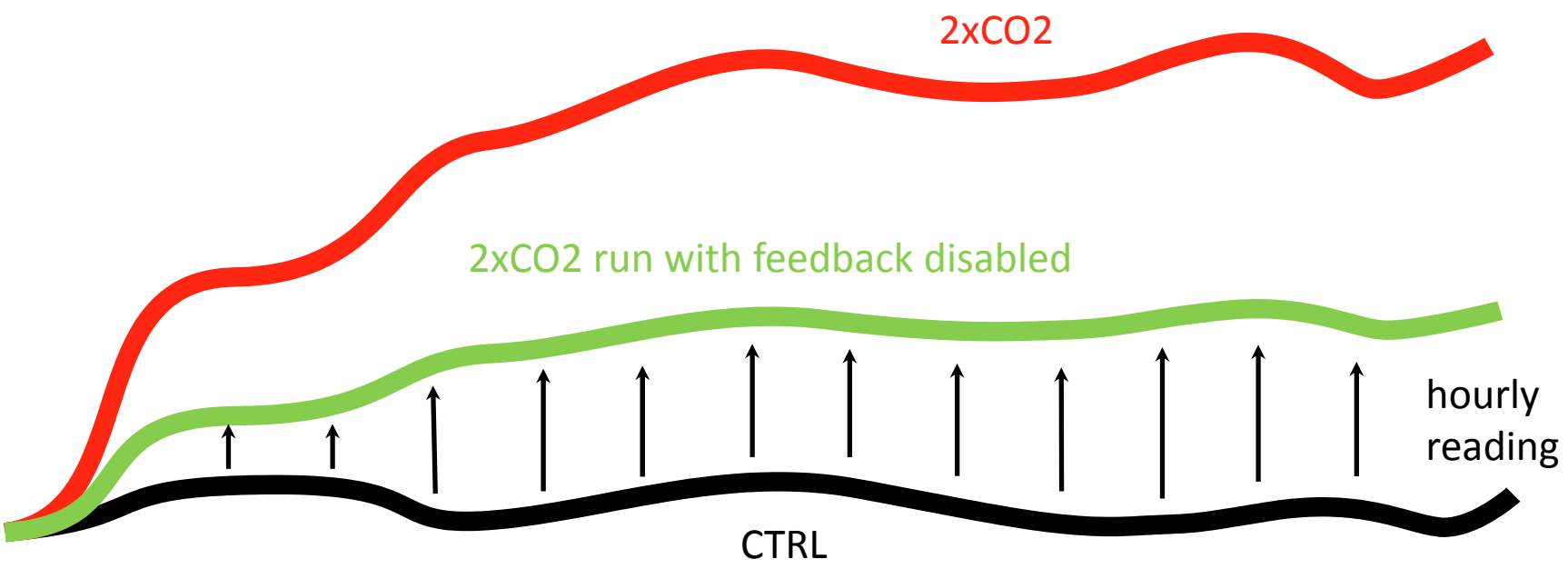



4) Circulation and lapse rate



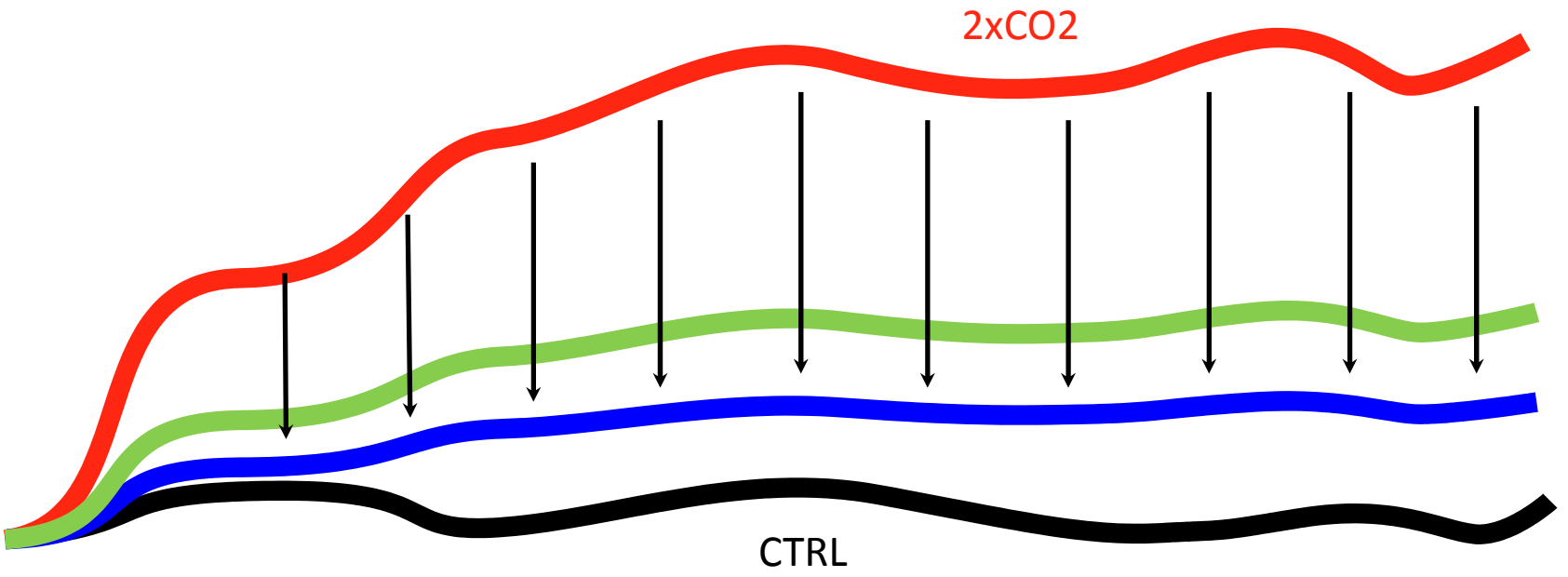
# On-line locking of feedbacks

Feedbacks are disabled by reading in values from CTRL to the radiation code throughout the experiment



# On-line locking of feedbacks

… and enabled by reading in values from 2xCO2

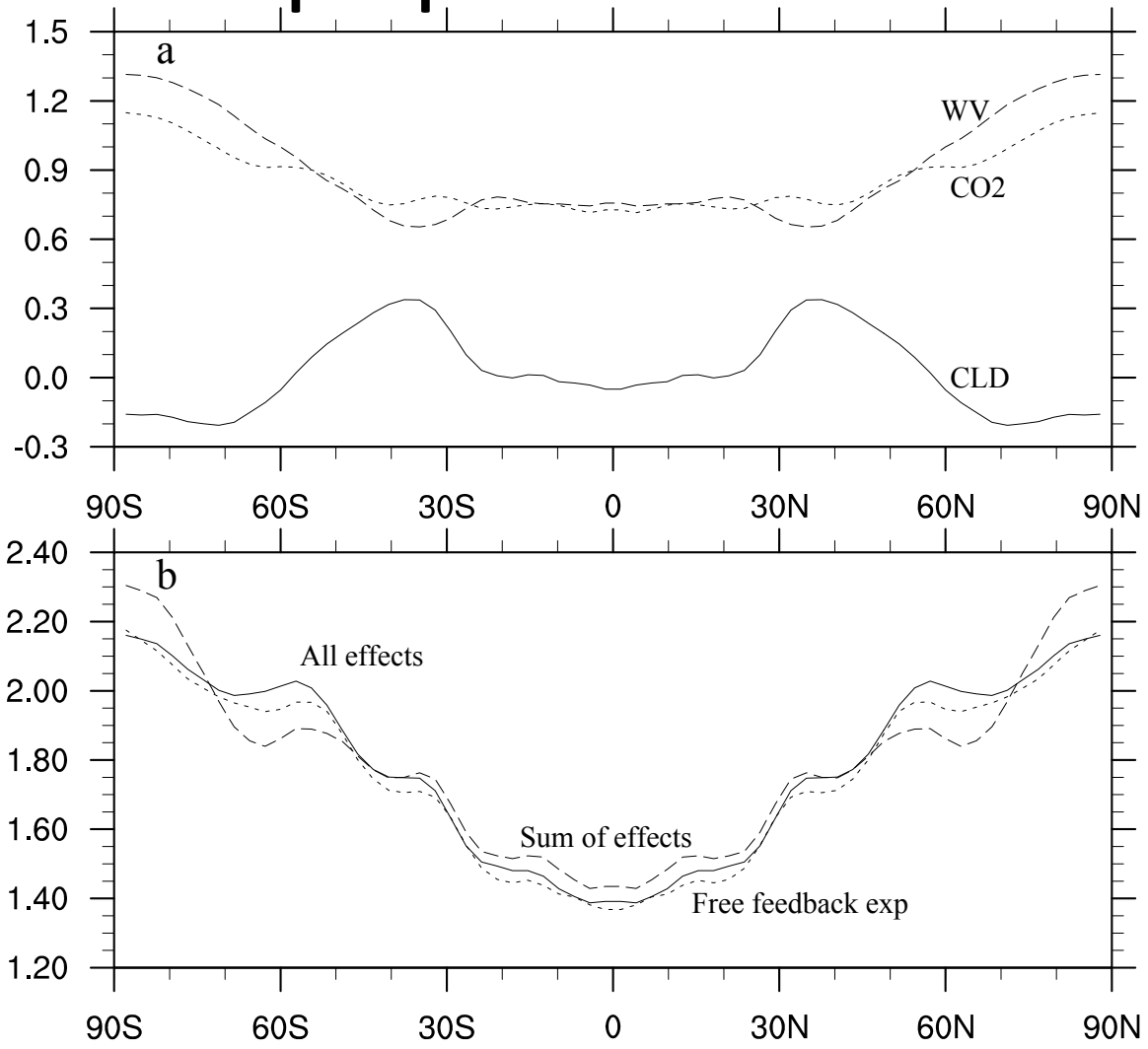



1xCO2 run with effect of feedback included

# Zonal average warming in CAM3 aquaplanet

*Atmosphere:*
**NCAR CAM3**

*Ocean:*
Slab ocean
Aquaplanet
No sea ice



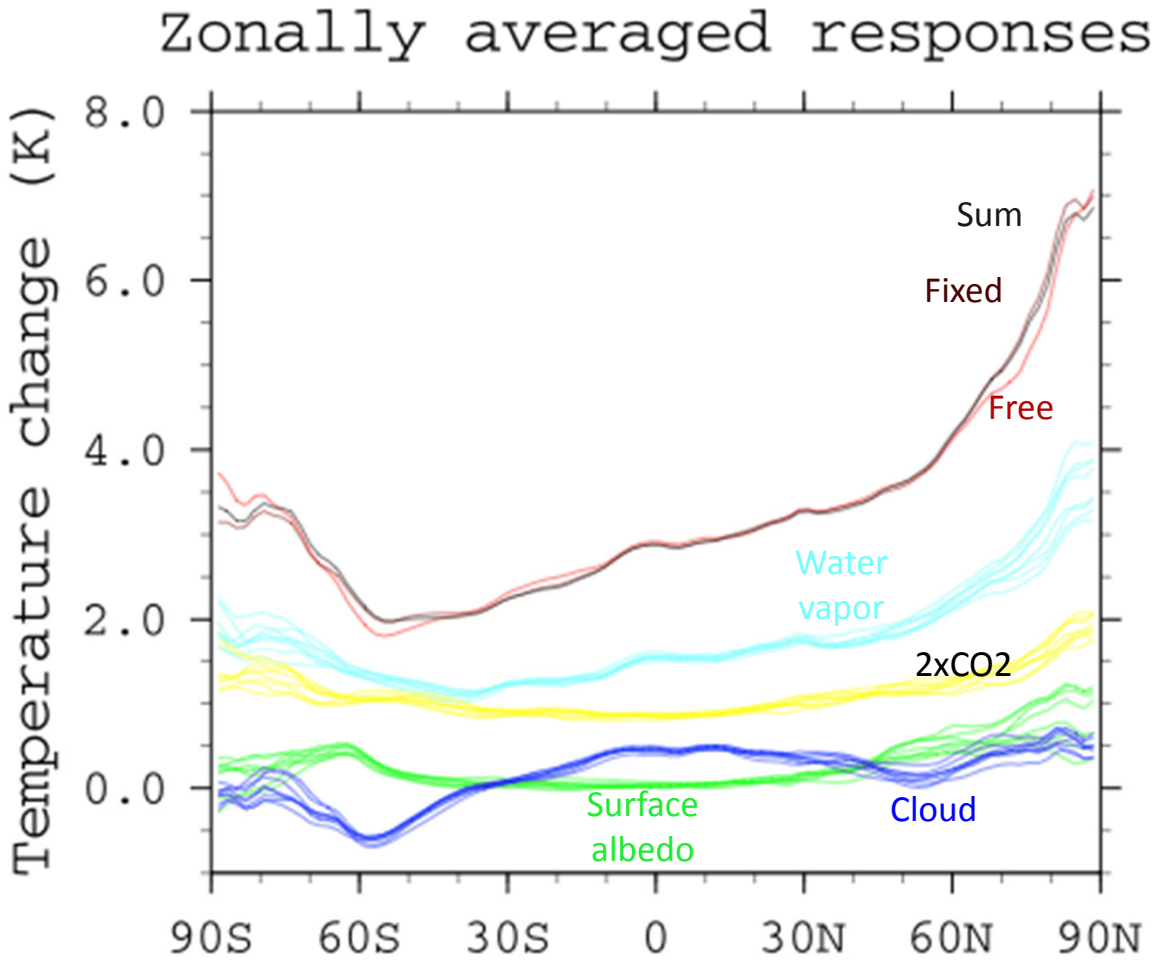

*Langen et al. (JClim, 2012)*

# In ECHAM6

*Atmosphere:*
**ECHAM 6.0**

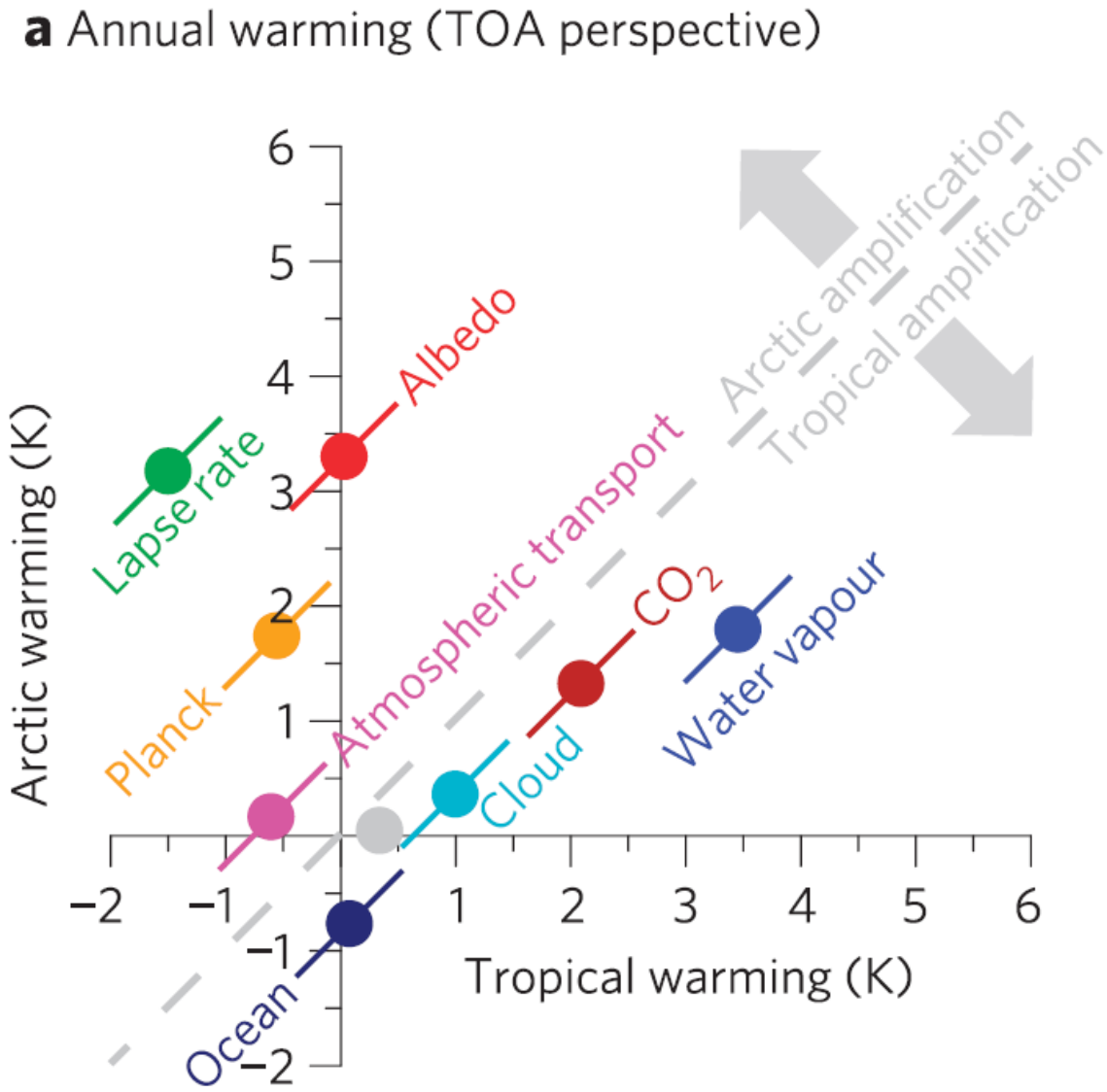
*Ocean:*
Slab ocean

Resolution: T63L47




*Mauritsen et al. (unpublished)*

# Using radiative kernel-approach on the CMIP5 ensemble




*Pithan and Mauritsen (Nature Geosci, 2014)*

# Overview

- Mechanisms and feedbacks
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- **Local or remote controls on Arctic warming**

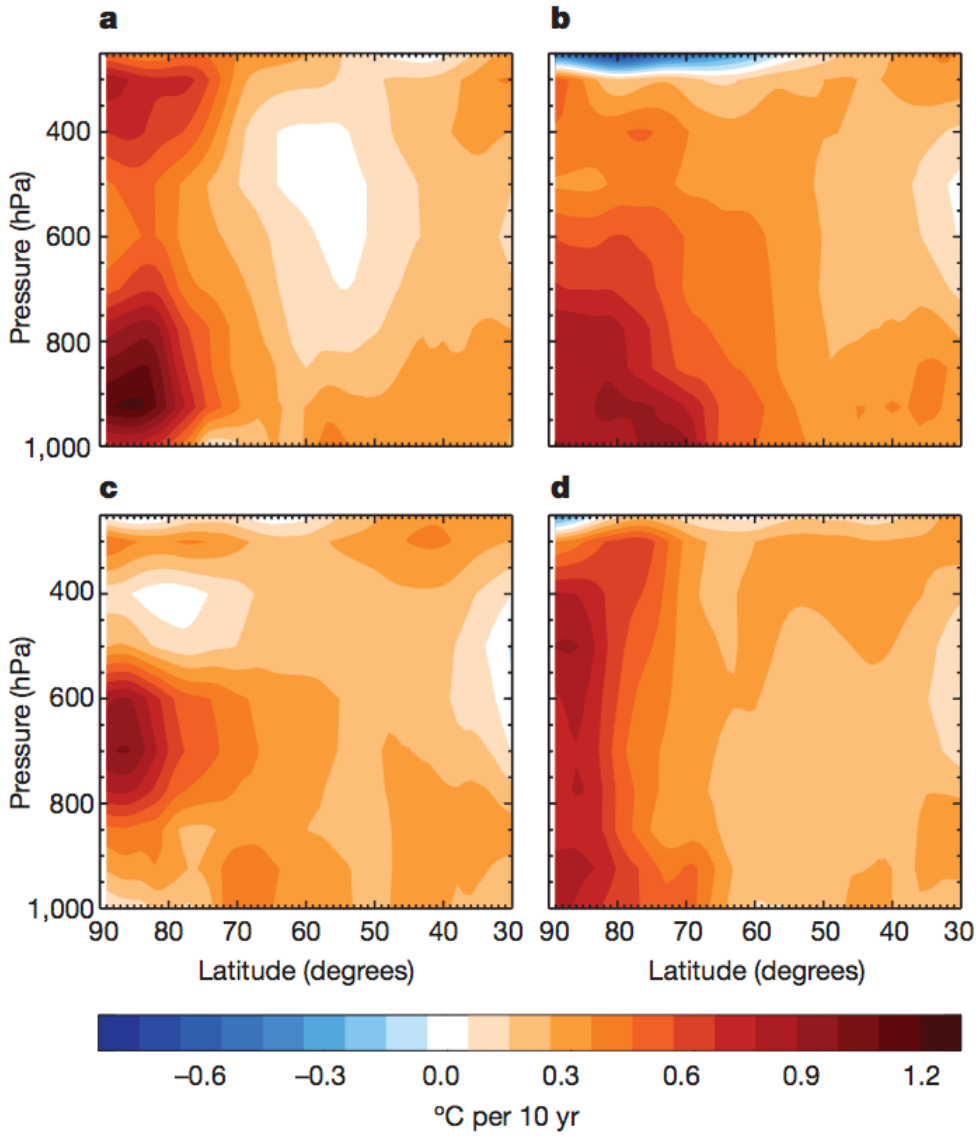
# Vertical structure of recent Arctic warming

DJF

MAM

JJA

SON




ERA 40 1979-2001

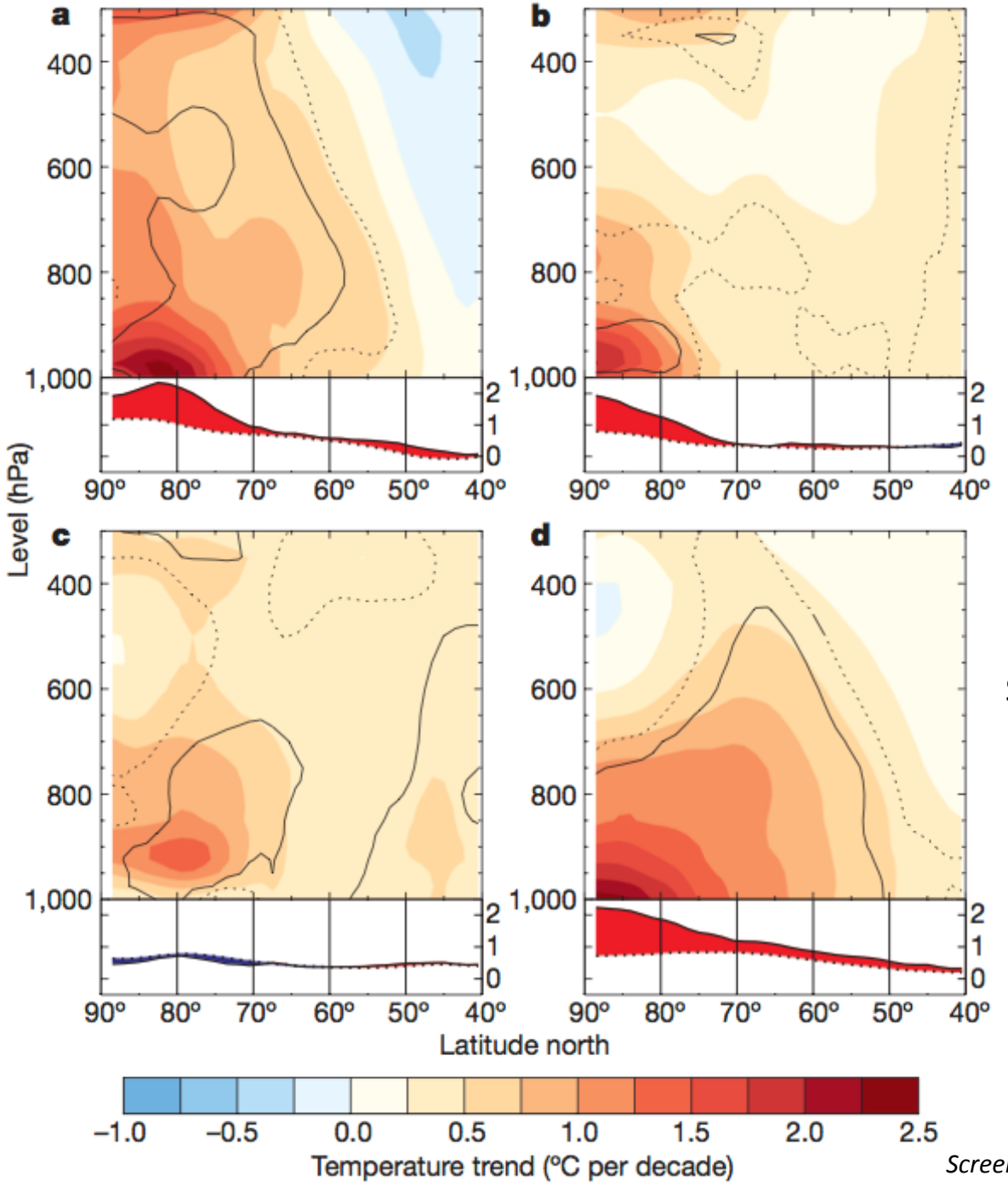
*Graversen et al. (Nature, 2008)*

DJF

MAM

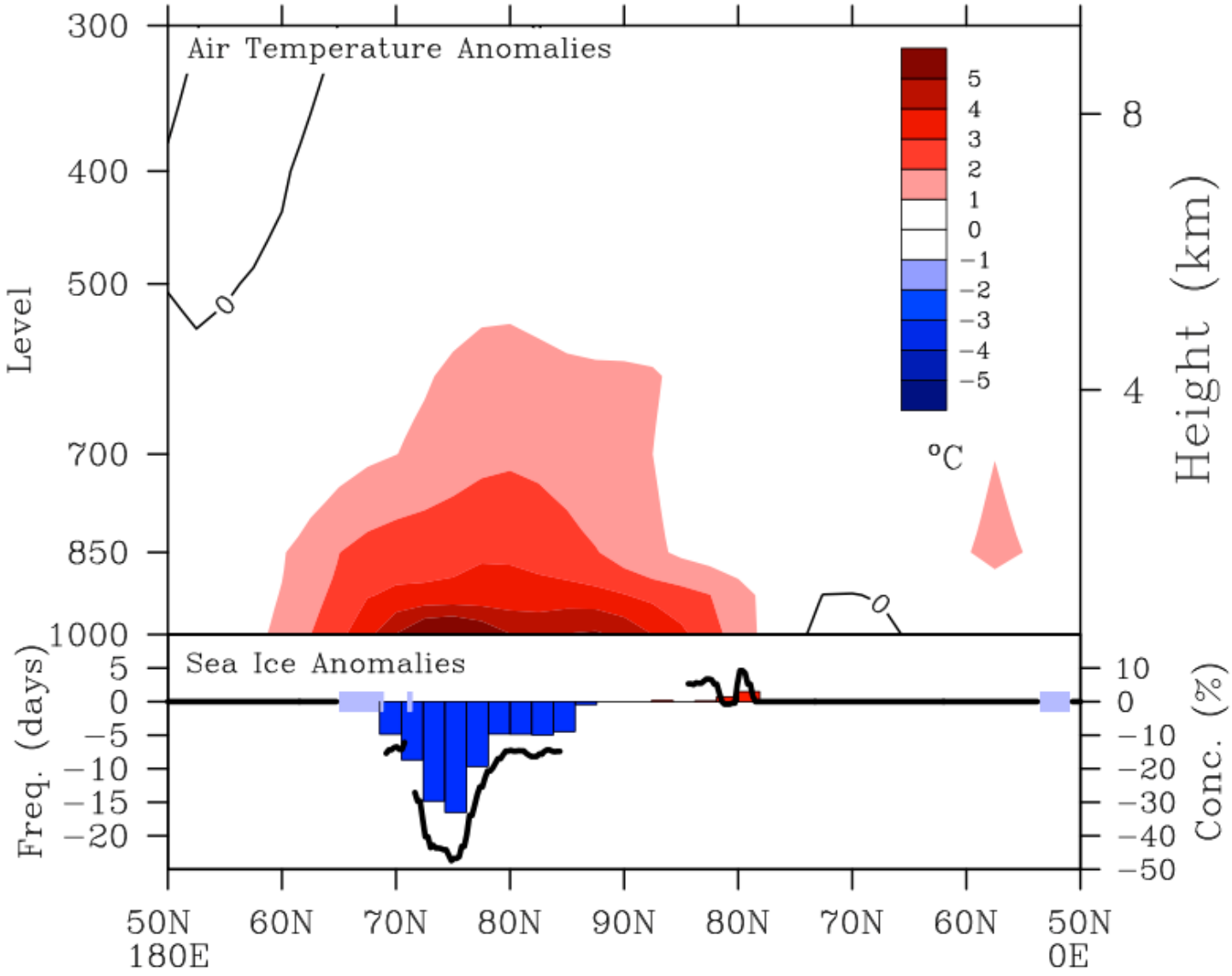
JJA

SON



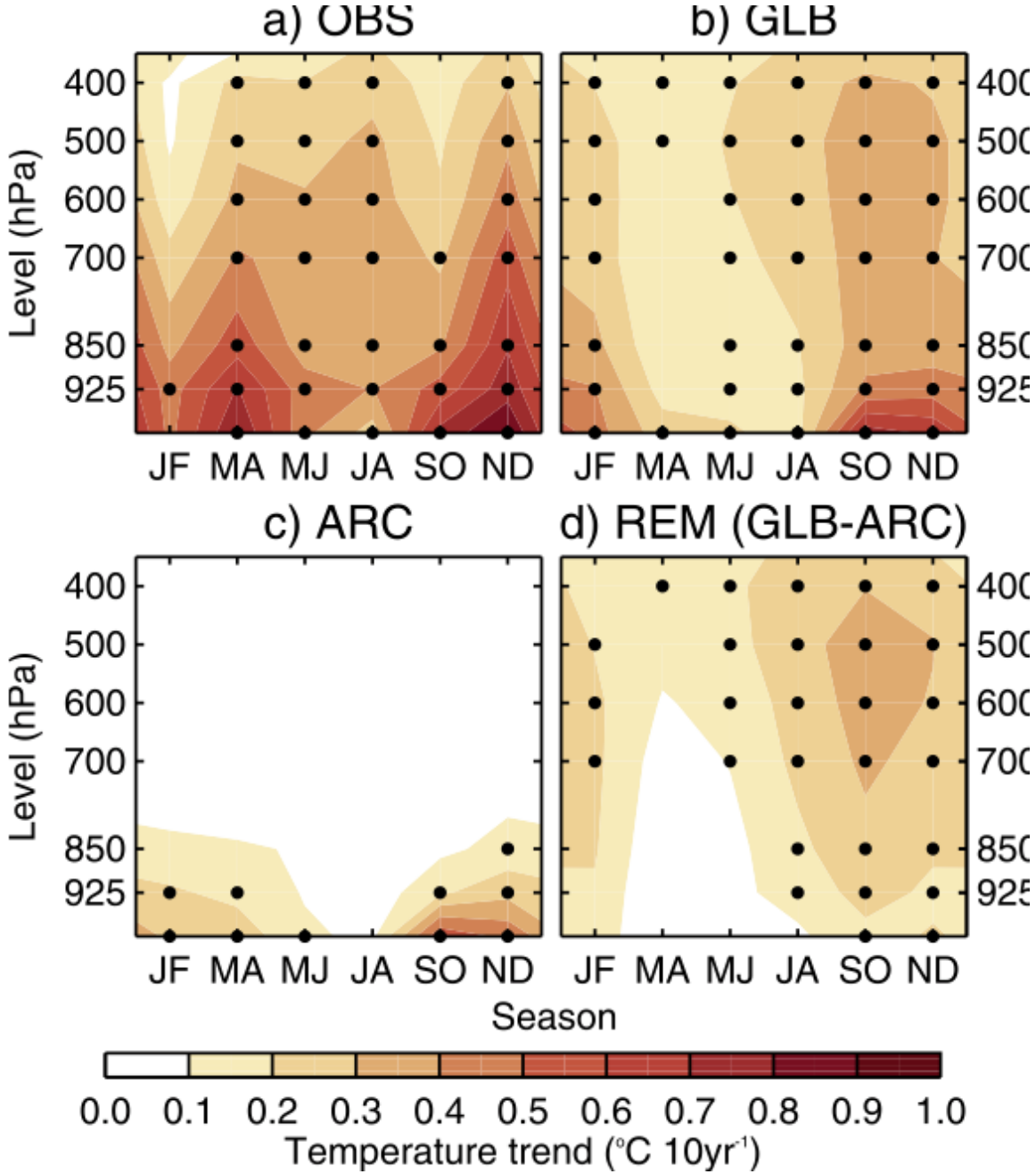

ERA-Interim
1989-2008

*Screen and Simmonds (Nature, 2010)*




NCEP Sep-Nov 2003–2007, relative to 1979–2007 means

*Serreze et al. (Crysoph., 2009)*




*Screen et al. (GRL, 2012)*

# Local and remote forcing of Arctic climate change under $CO_2$ doubling

## Local

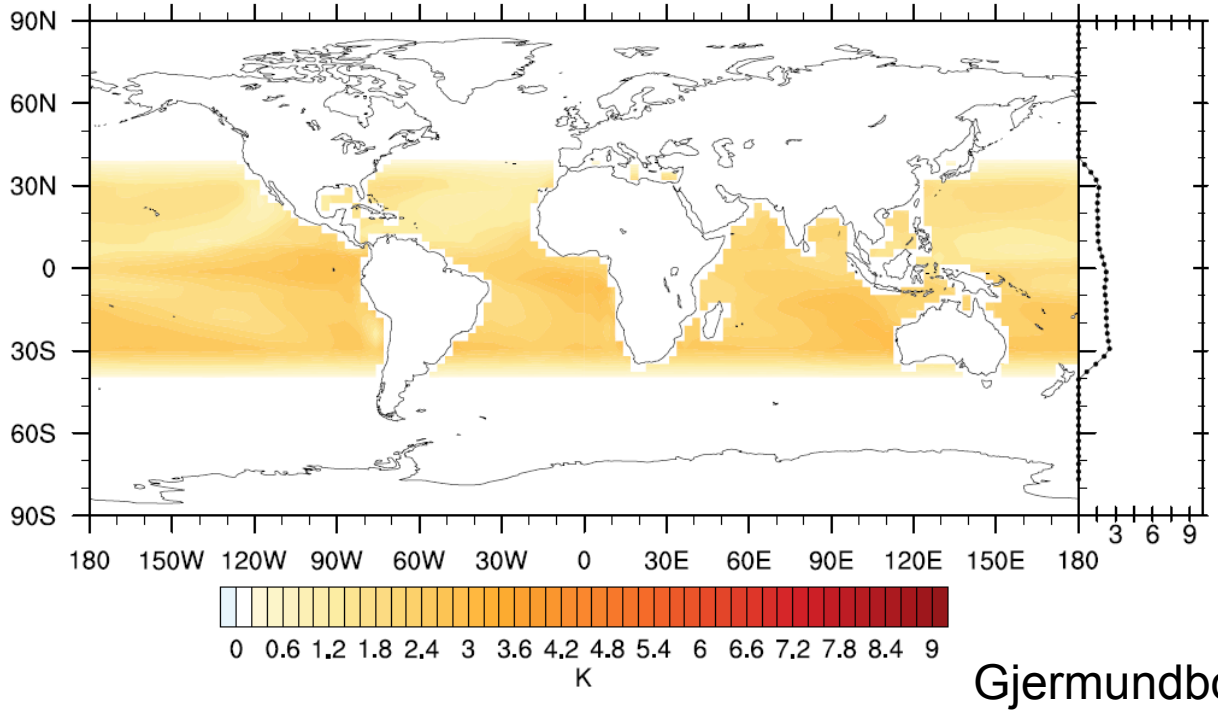
- No sea surface temperature change at low latitudes.
- 2x$CO_2$ in atmosphere

  **Response in Arctic is due to change in $CO_2$**

## Remote

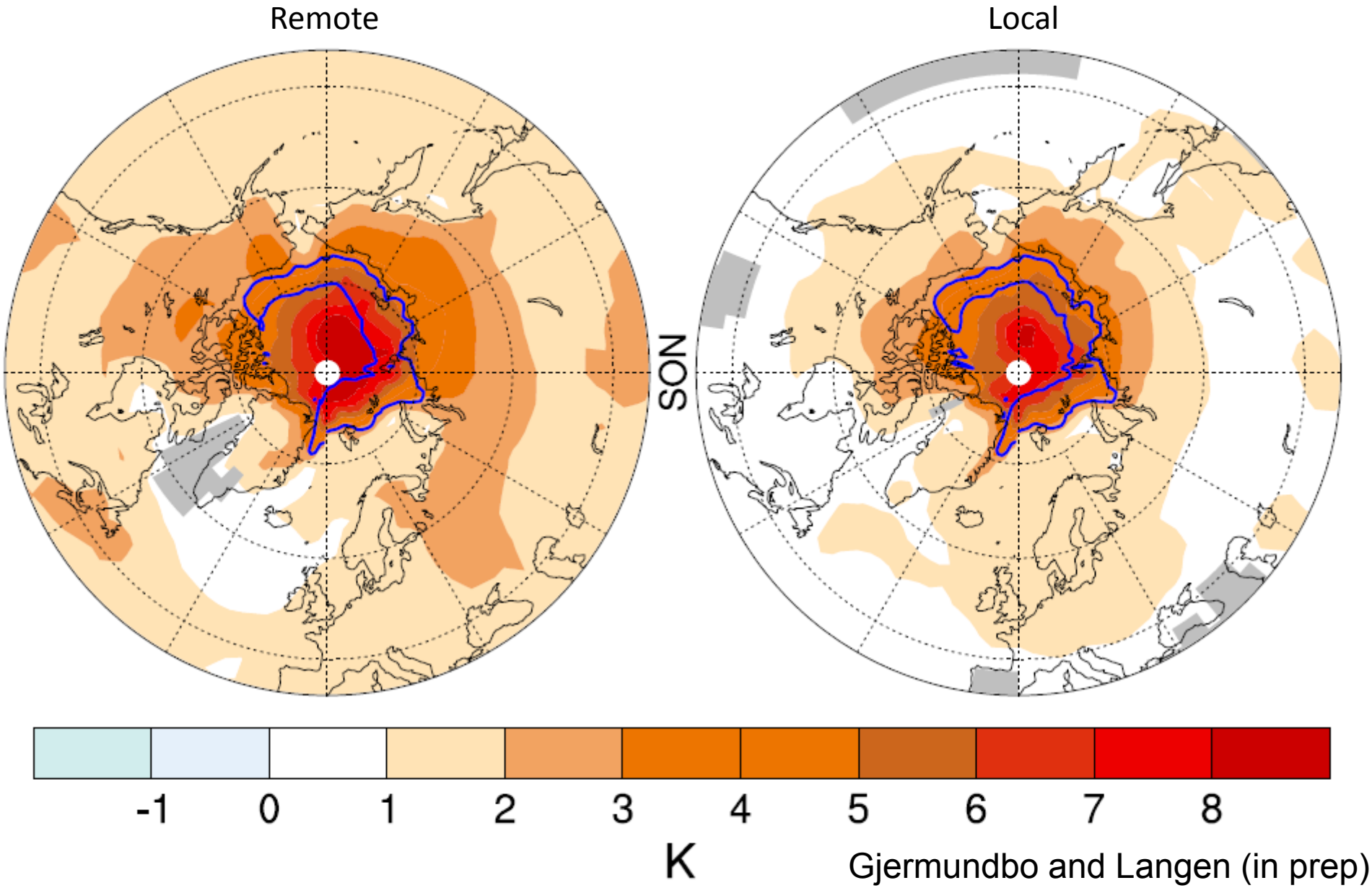
- 2x$CO_2$ climate sea surface temperature change at low latitudes.
- 1x$CO_2$ in atmosphere

  **Response in Arctic is due to change in low-latitude temperatures**

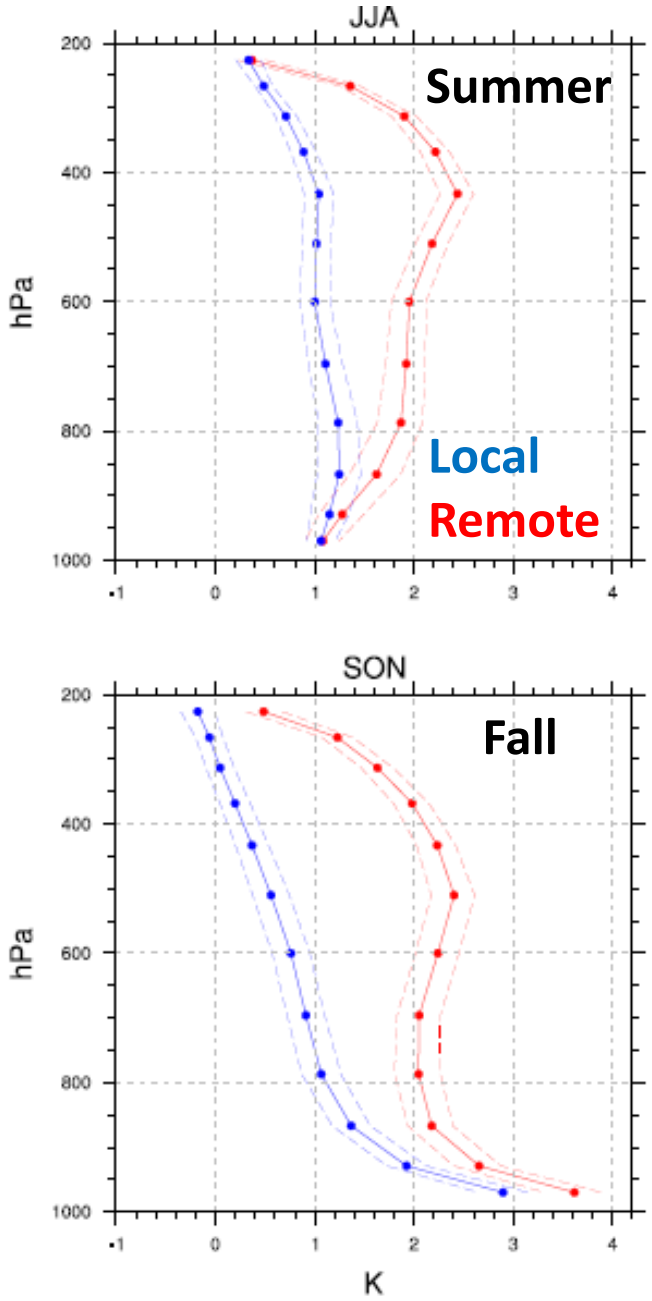



Gjermundbo and Langen (in prep)

# Fall warming

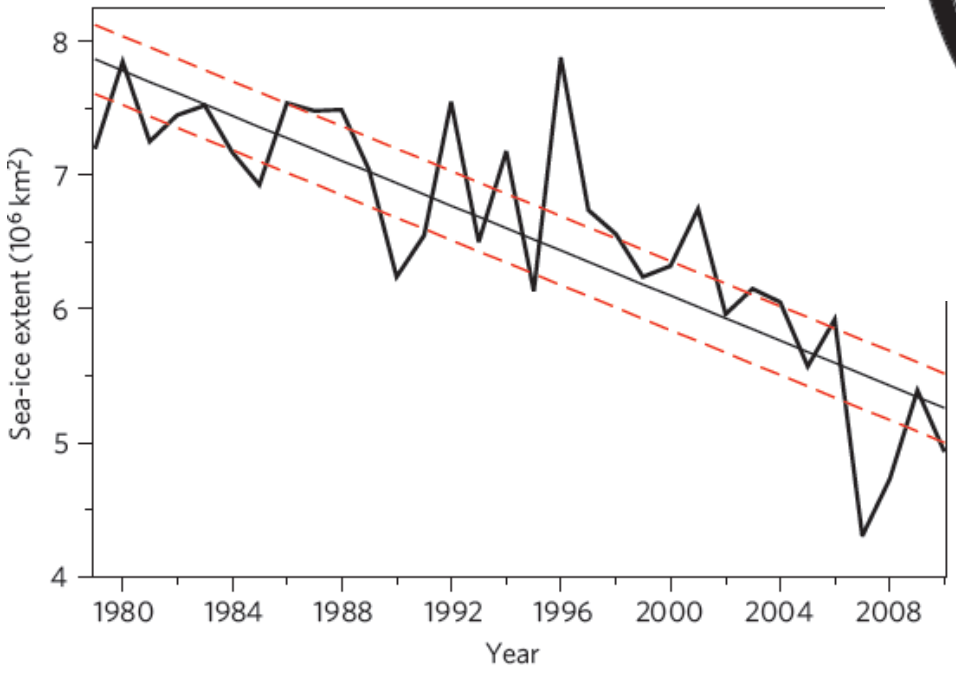


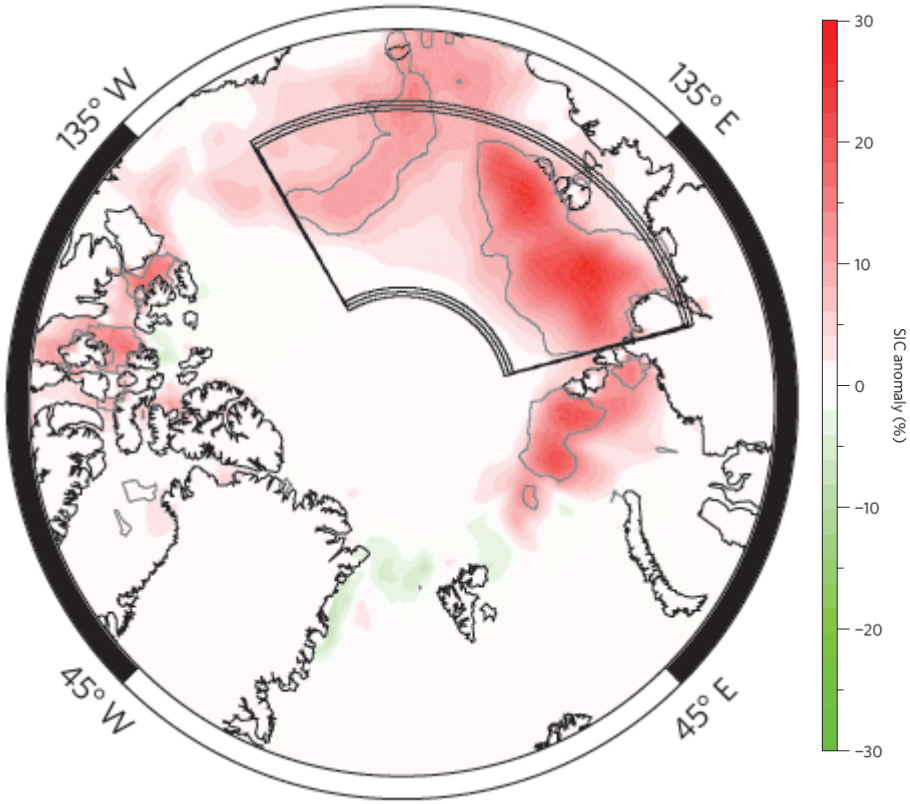
# Warming in the Arctic atmosphere




Gjermundbo and Langen (in prep)

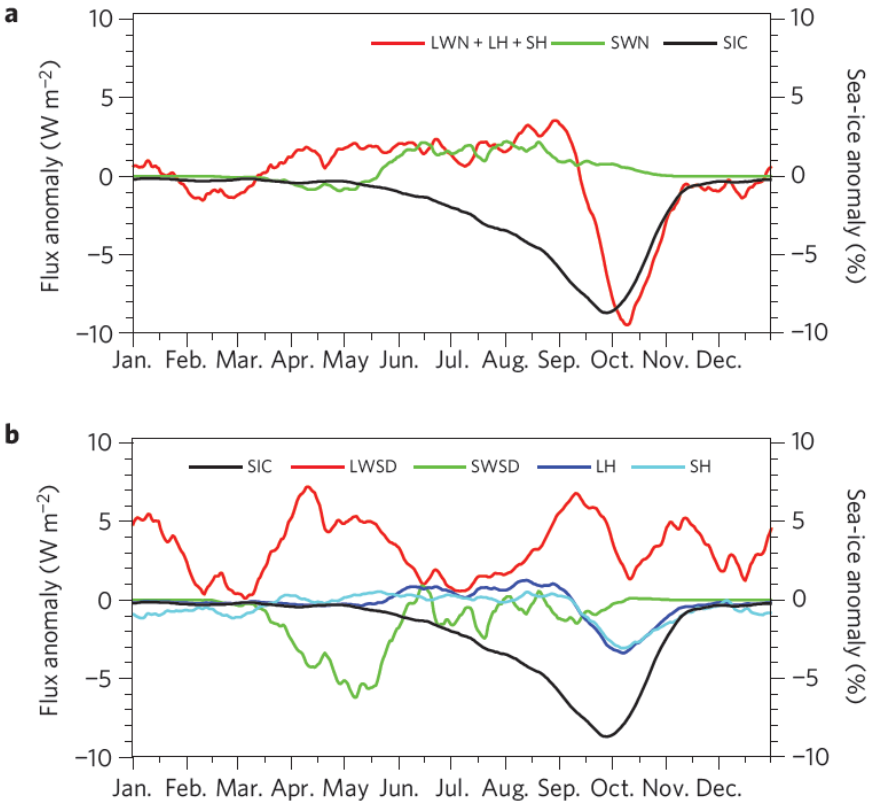
# Non-local influence on sea ice evolution in low-ice years

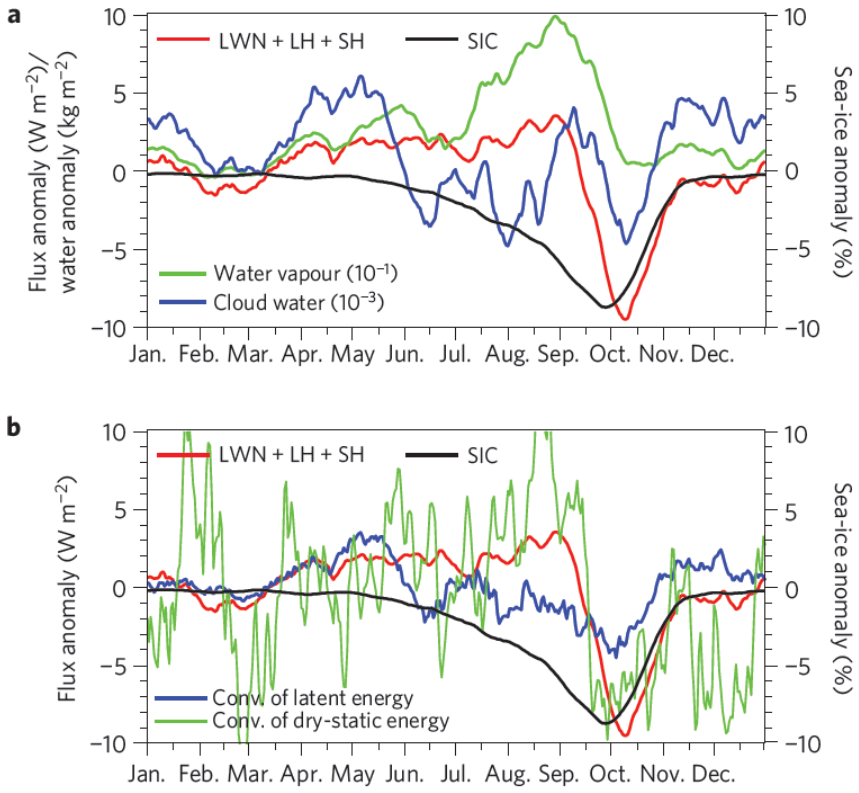



*Kapsch et al. (Nature CC, 2013)*
*ERA-Interim 1979-2007*

# Non-local influence on sea ice evolution in low-ice years




*Kapsch et al. (Nature CC, 2013)*