Arctic changes and Arctic climate feedbacks

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LGGE/LSCE

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Arctic definition

Permafrost distribution map

Source:International Permafrost Association, 1998.
Circumpolar Active-Layer Permafrost System (CAPS), version 1.0.

Ice sheet

Sea ice

Tundra

Boreal forest

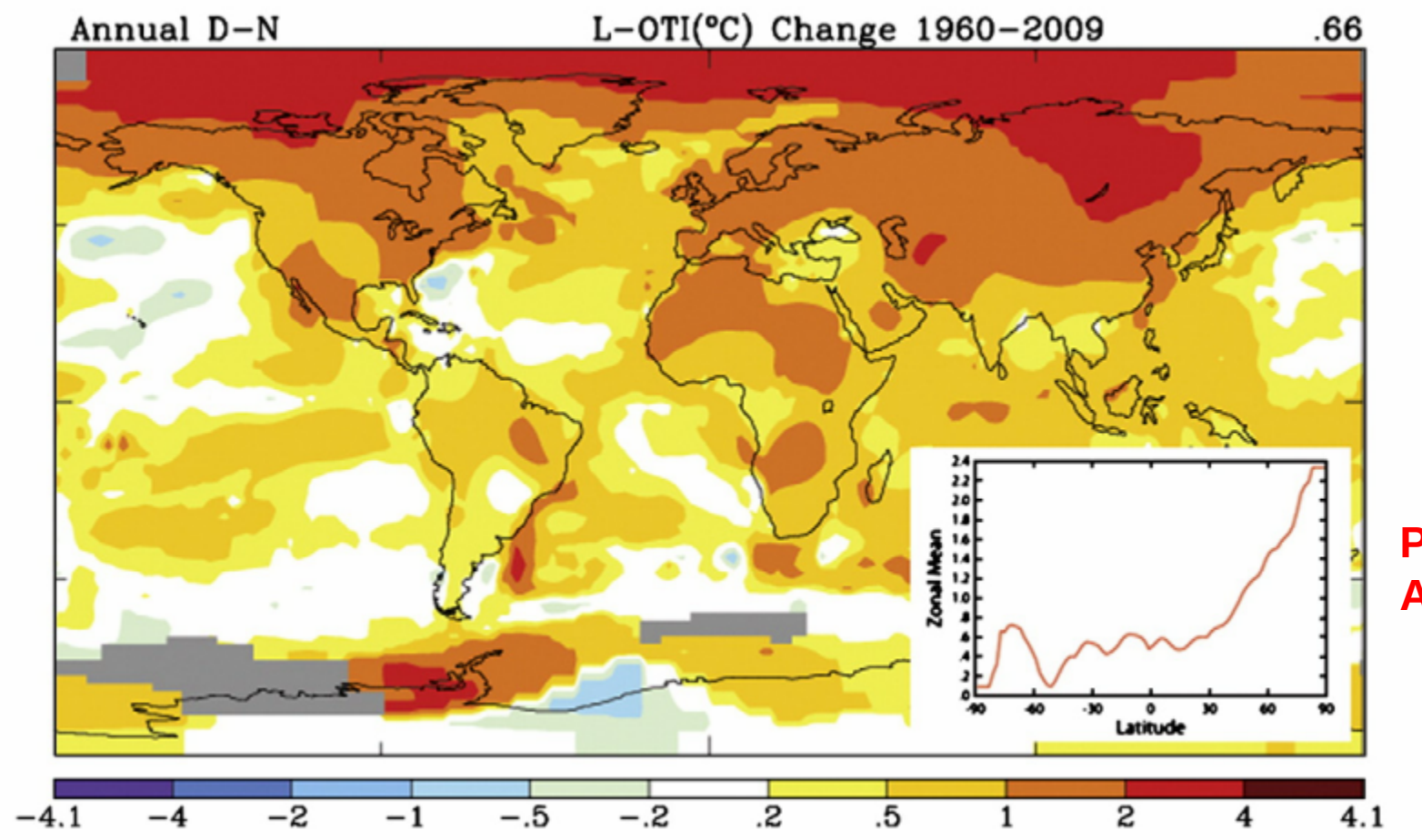
Permafrost

Lakes

…

Arctic climate change

Trend in Arctic temperature

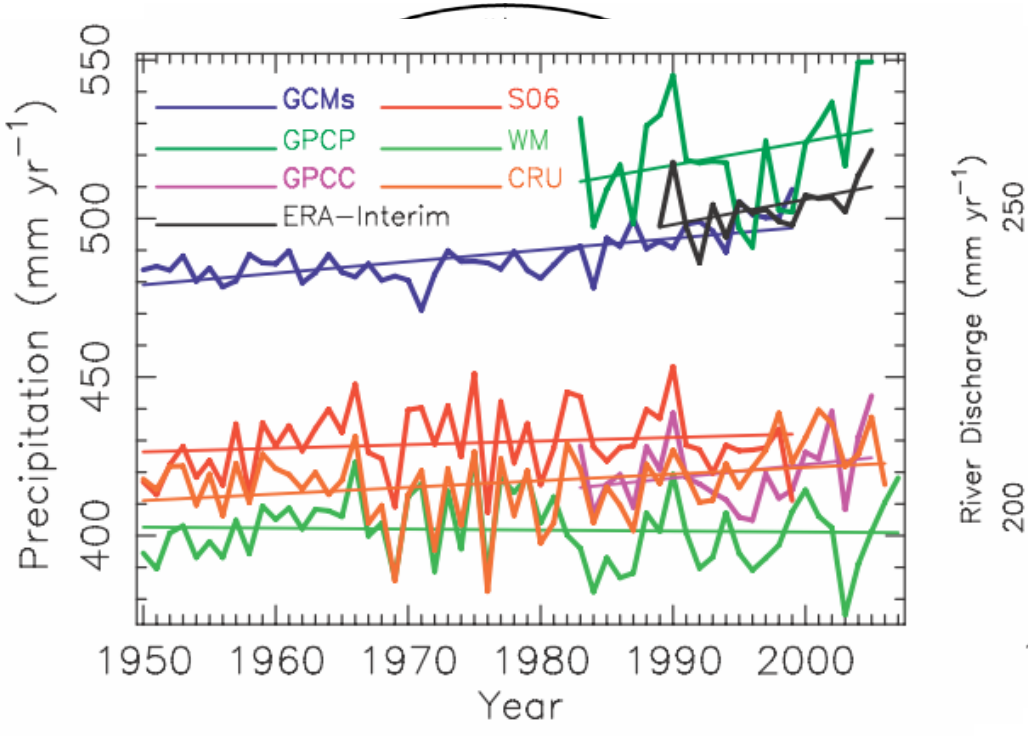


Polar Amplification

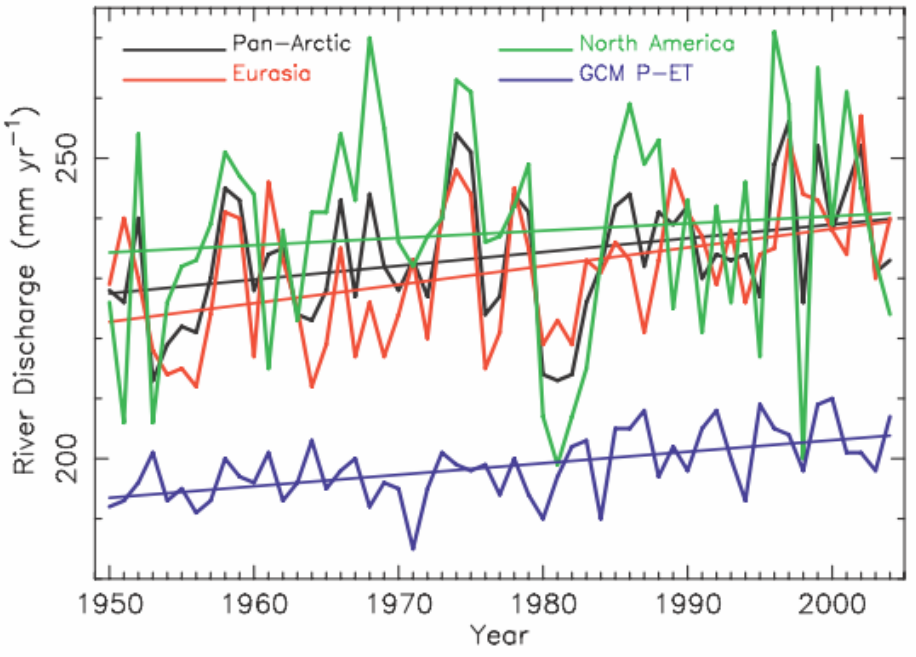
Serreze et al., 2011

Arctic climate change

Increased precipitation



Increased runoff

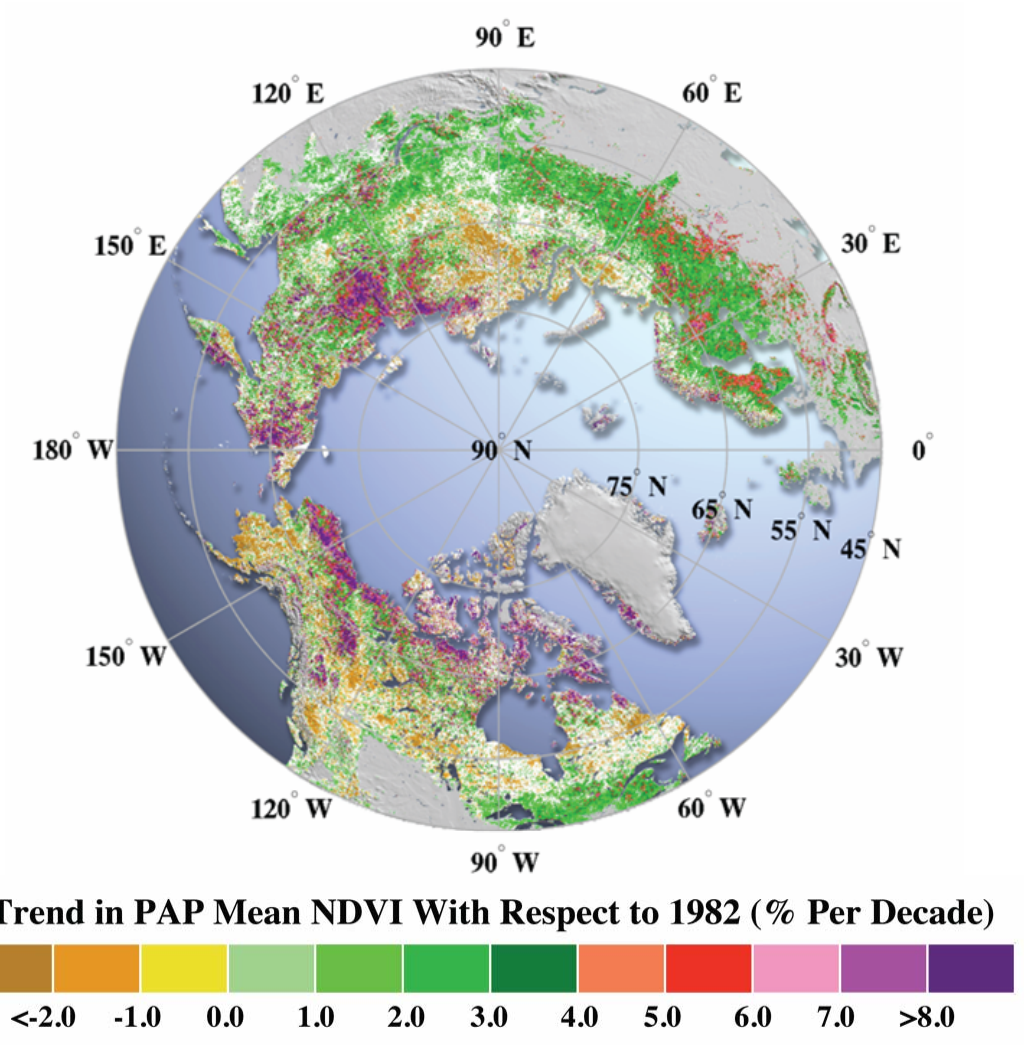


Trend in Arctic precipitation from 1960 to 2009

Rawlins et al., 2010

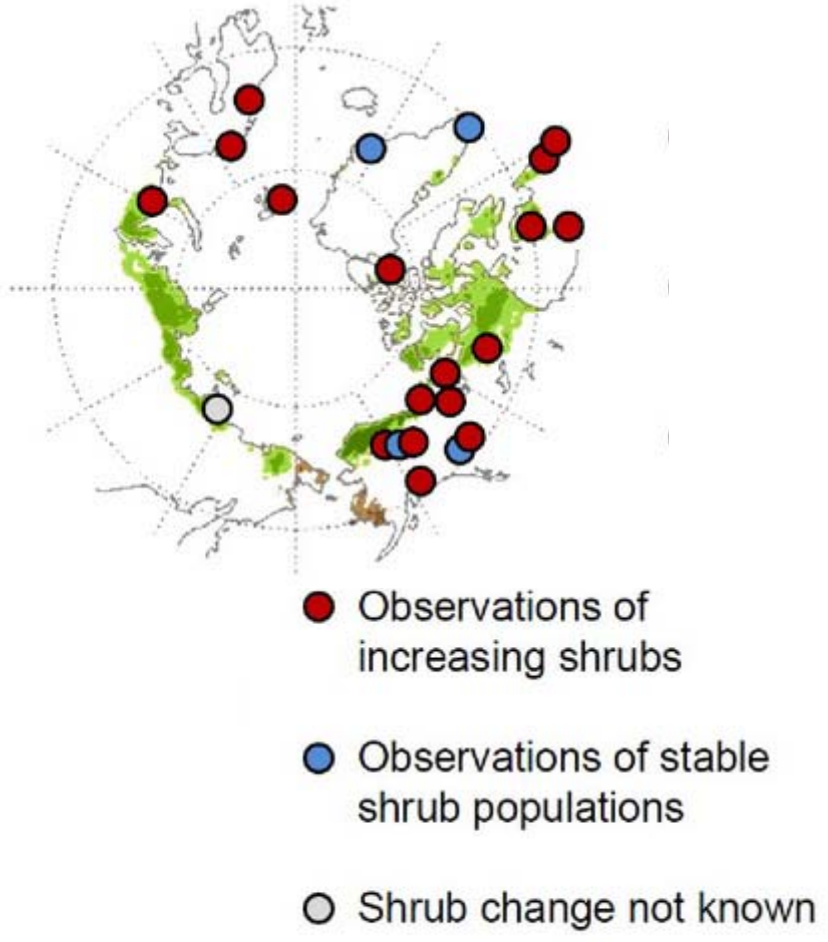
Arctic vegetation changes

Increased growing season NDVI



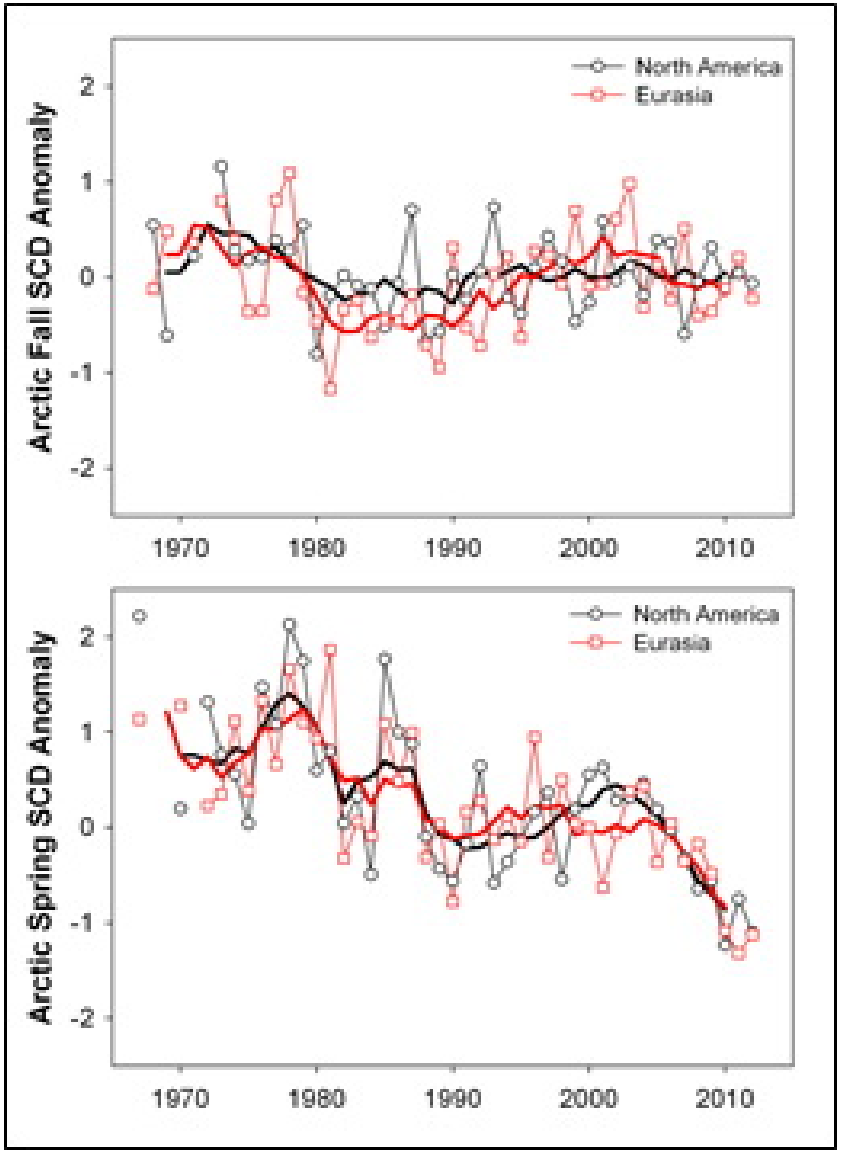
Xu et al., 2013

Shrub expansion



http://www.arctic.noaa.gov/

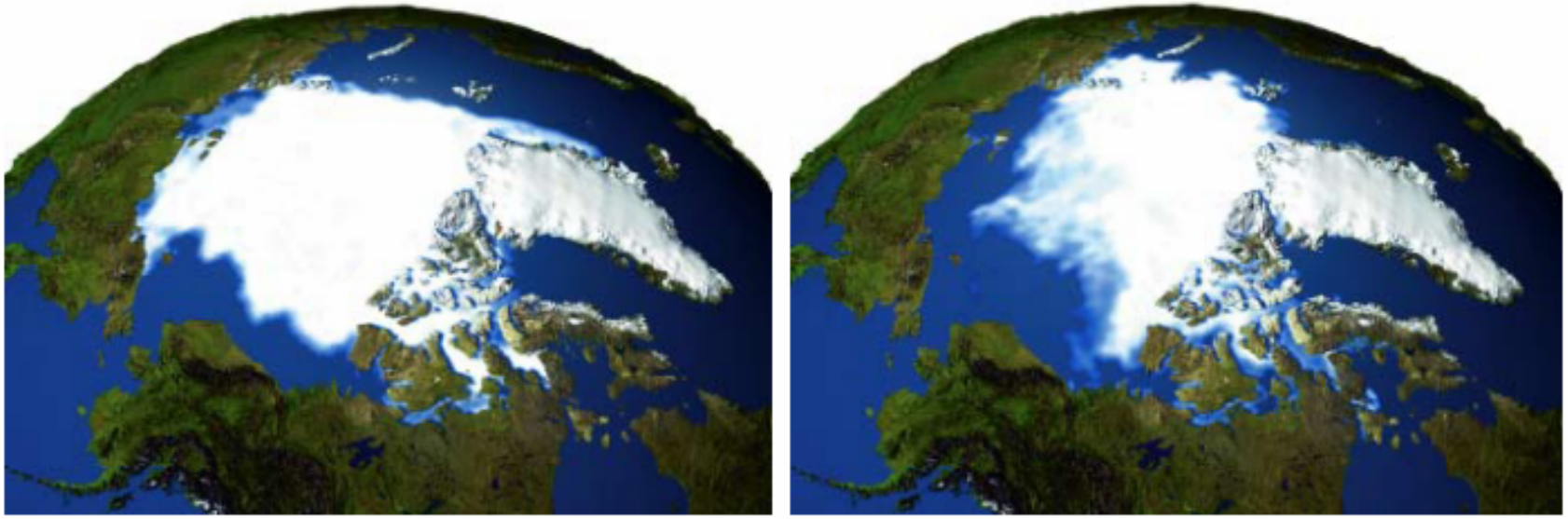
Arctic snow cover extent changes



http://www.arctic.noaa.gov/

Arctic sea ice changes

Decreased sea ice



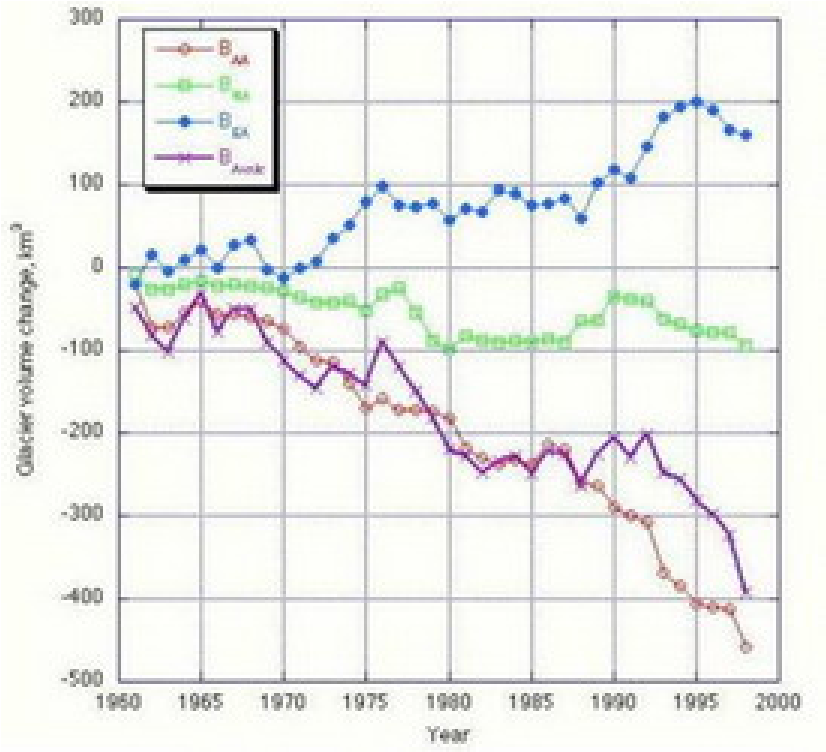
These two images, constructed from satellite data, compare arctic sea ice concentrations in September of 1979 and 2003. September is the month in which sea ice is at its yearly minimum and 1979 marks the first year that data of this kind became available in meaningful form. The lowest concentration of sea ice on record was in September 2002.

ACIA, 2004

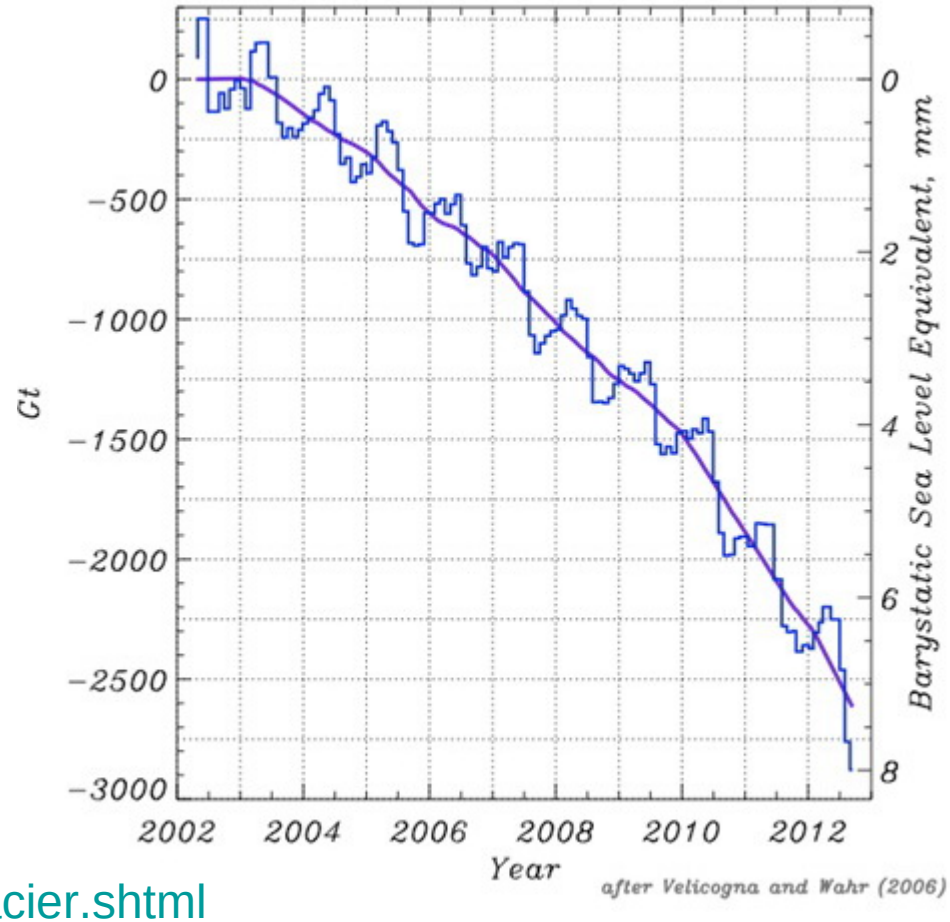
http://www.arctic.noaa.gov/

Arctic glacial / ice-cap changes

Glacial changes

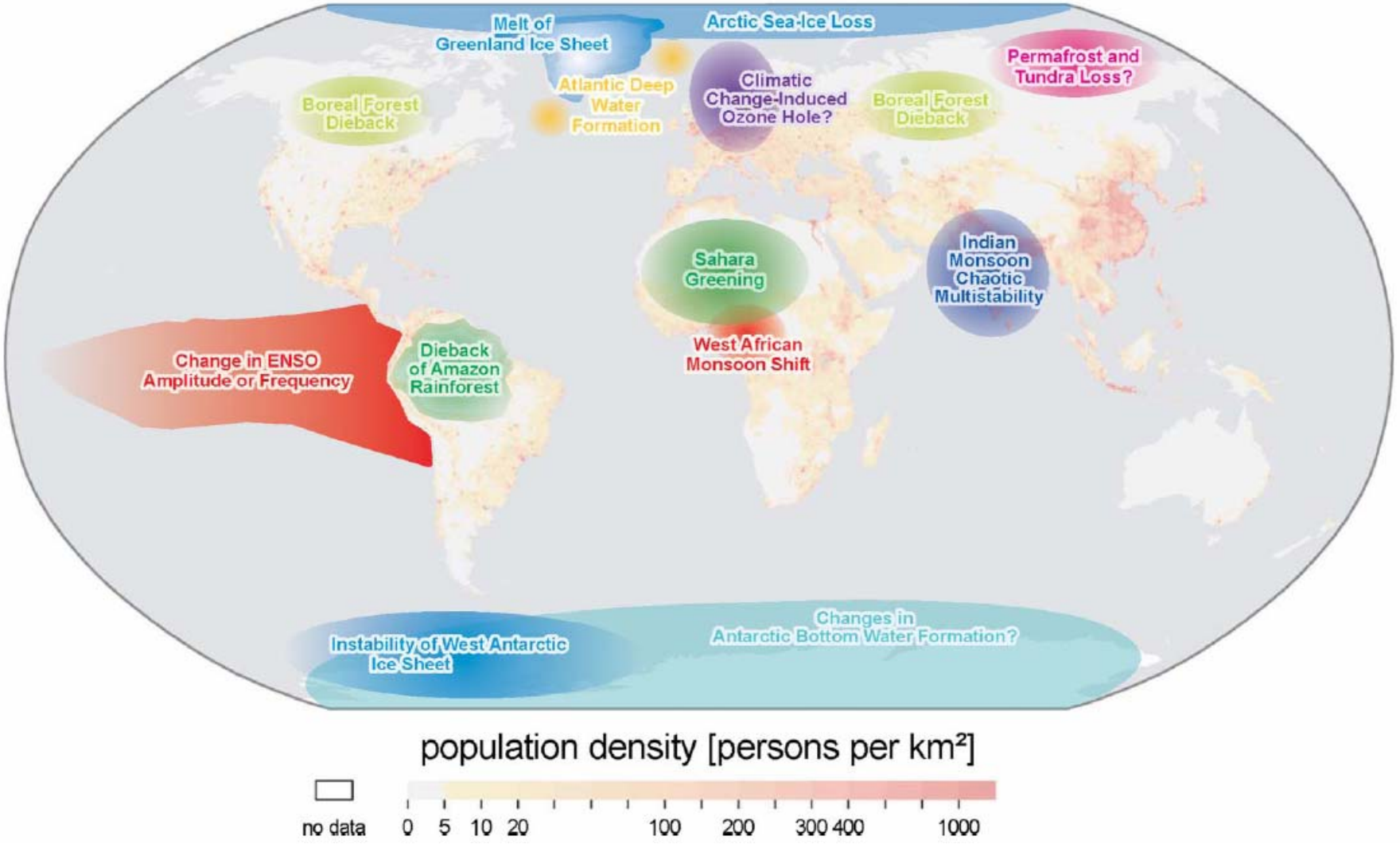


Greenland mass loss



http://www.arctic.noaa.gov/detect/ice-glacier.shtml

Arctic importance to Earth system



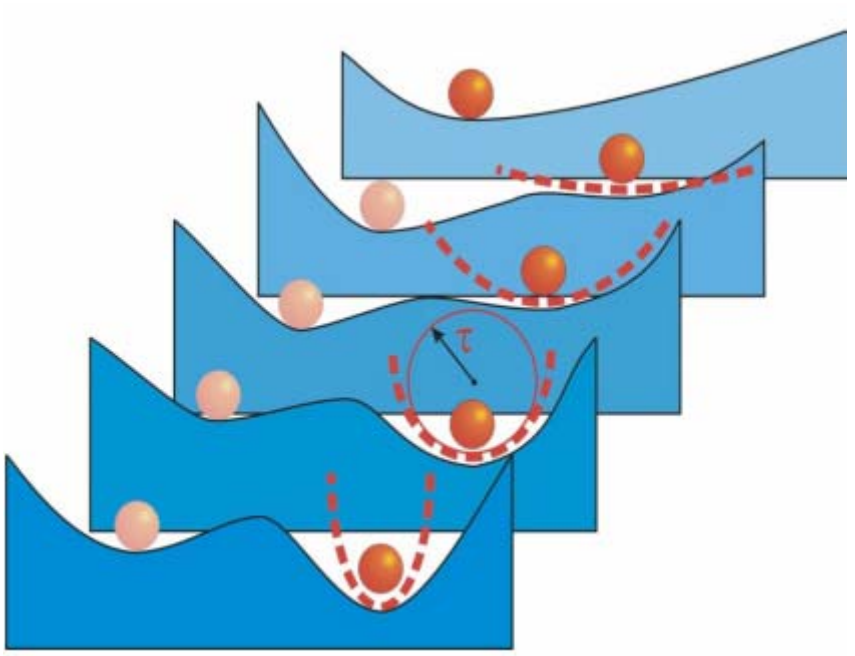
Lenton, et al., 2008, PNAS

Arctic importance to Earth system

1. Have Arctic changes during the past decades triggered positive/negative feedbacks to Earth's climate system?

2. If positive feedbacks domain in Arctic, does tipping point happen in the past or future?

3. If tipping point could happen, when and how could tipping point of Arctic happen?



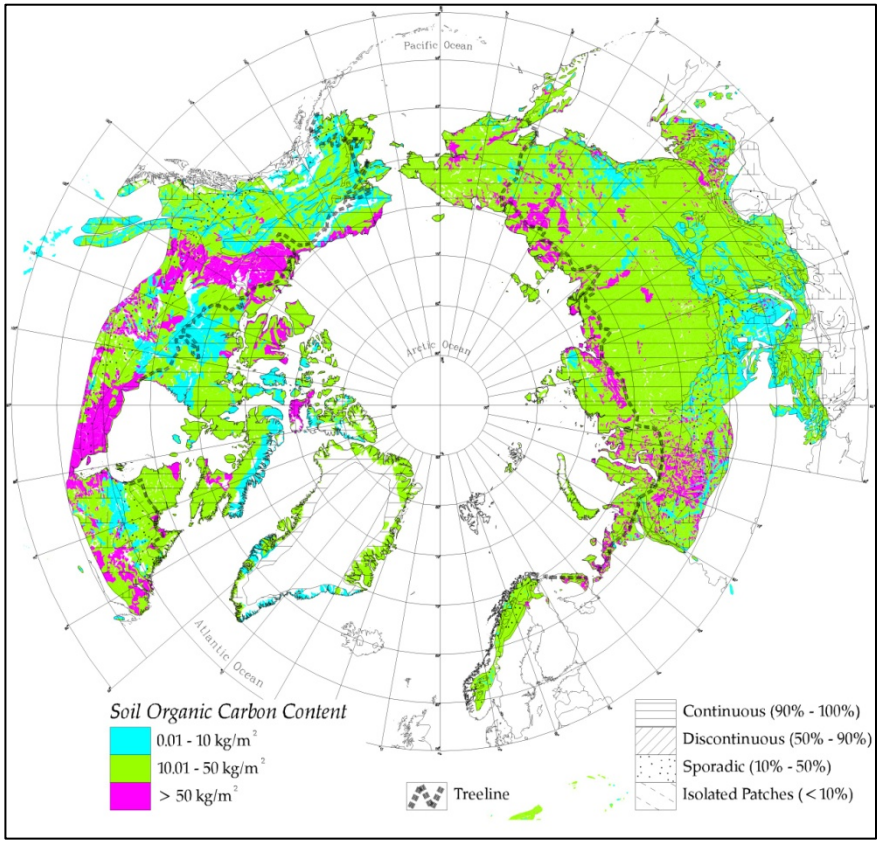
Lenton, et al., 2008, PNAS

Arctic climate feedbacks

Permafrost

Tunnel man, episode 1

Permafrost: a large global carbon pool

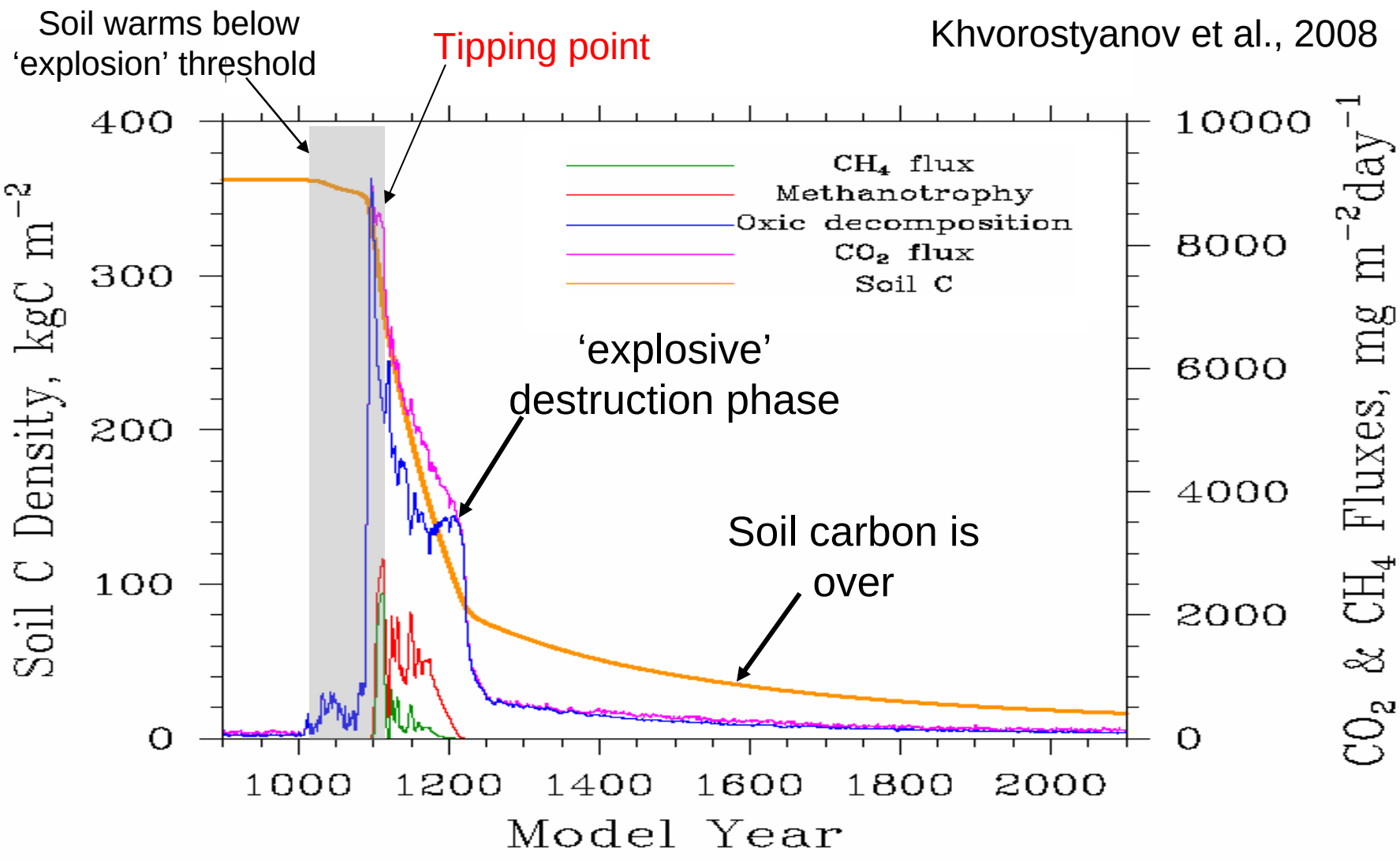


Permafrost zones	0-30 cm	0-100 cm
Continuous	110.38	298.75
Discontinuous	25.5	67.44
Sporadic	26.36	63.13
Isolated Patches	29.05	67.10
Total	**191.29**	**496.42**

Soil or deposit type	**C stocks**
Soils 0–300 cm	**1024**
Yedoma sediments	407
Deltaic deposits	241
Total	**1672**

Tarnocai et al. 2009

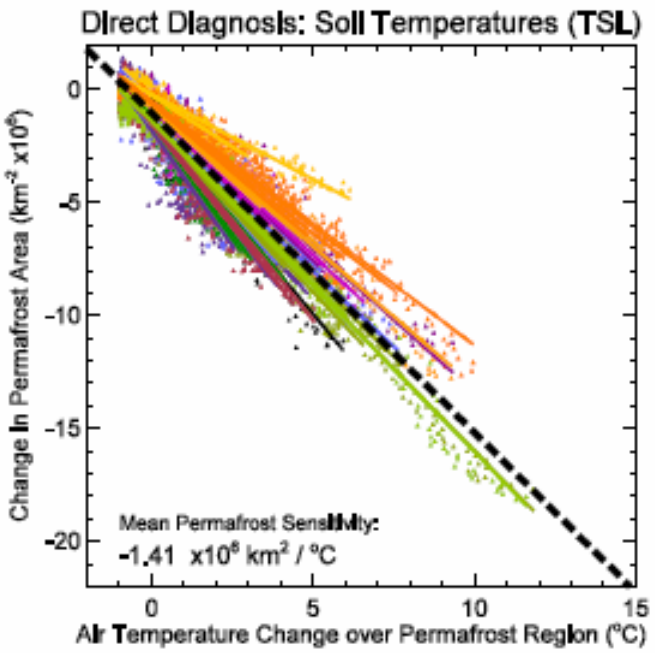
Permafrost: 1 dimension model for Yedoma point

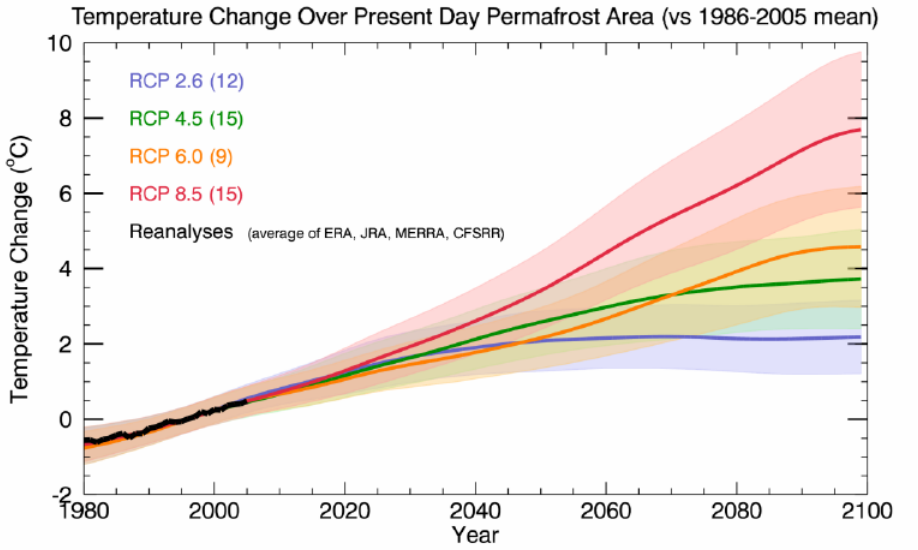


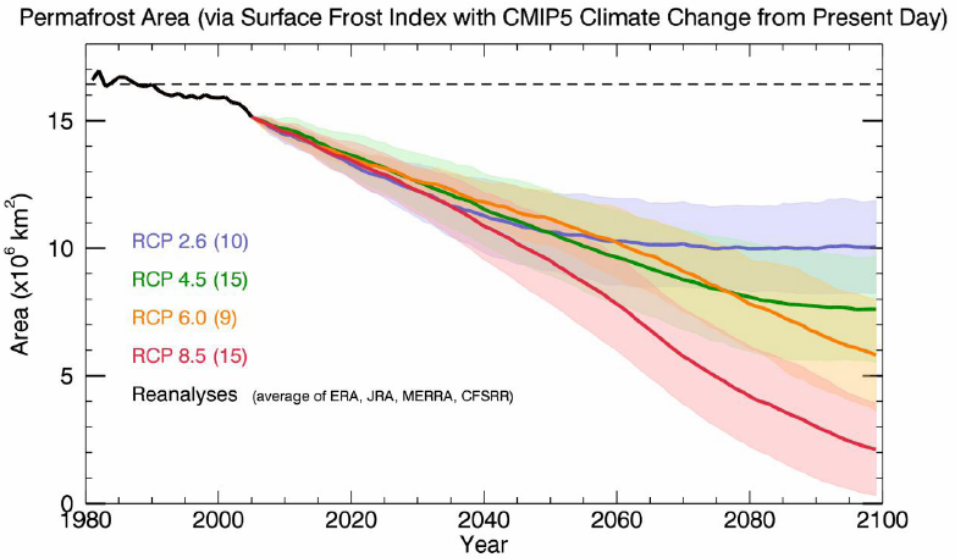
Response to a 100 yrs-long step warming of +3°C

Sensitivity of Permafrost area to temperature

CMIP5 climate models outputs

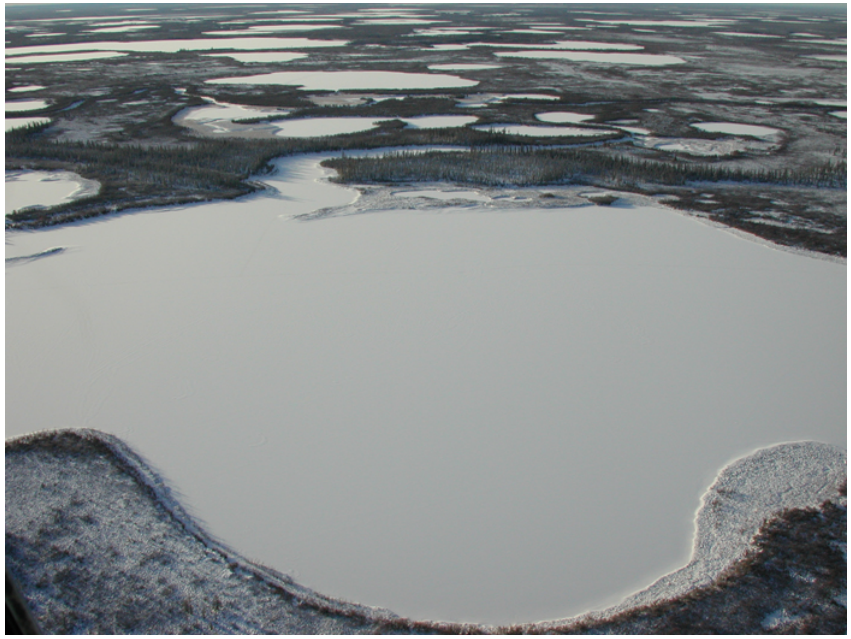






Slater & Lawrence, 2013, JC

Thermokarst



Source from Chen et al., 2013; WERC, UAF

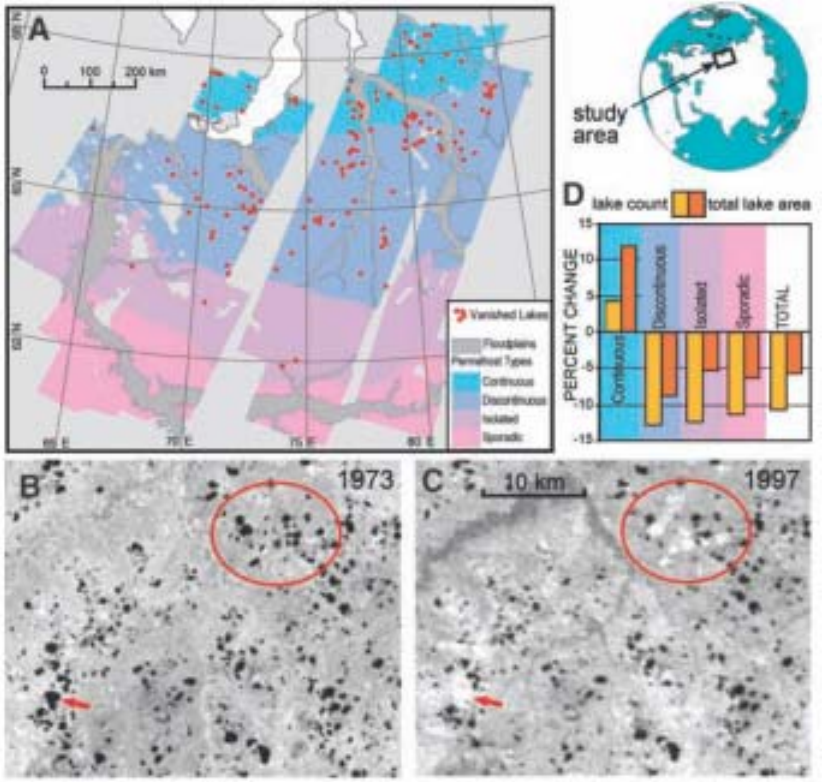
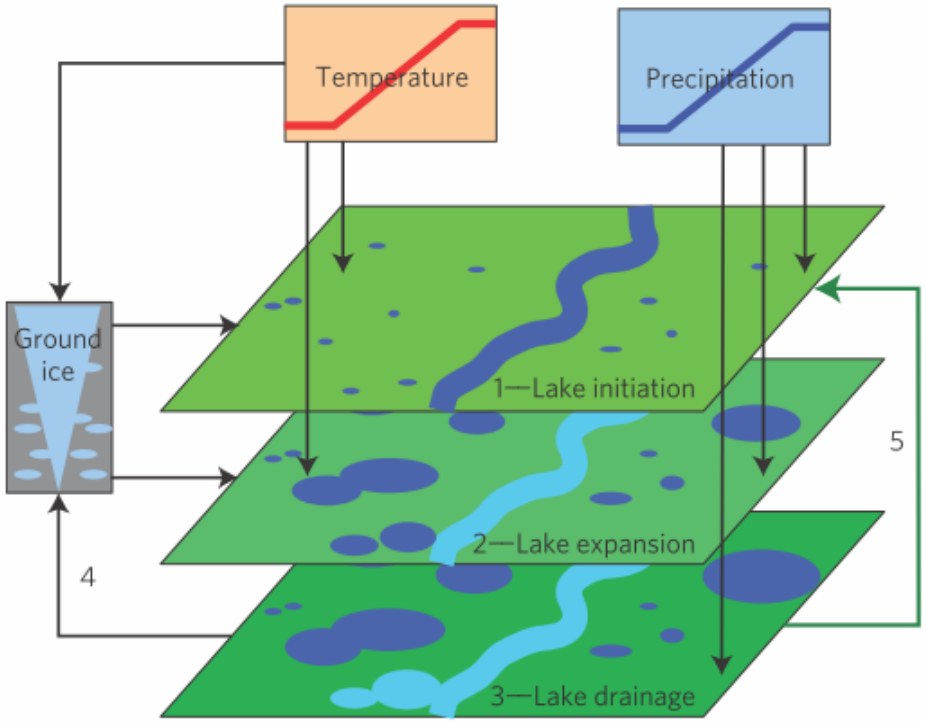
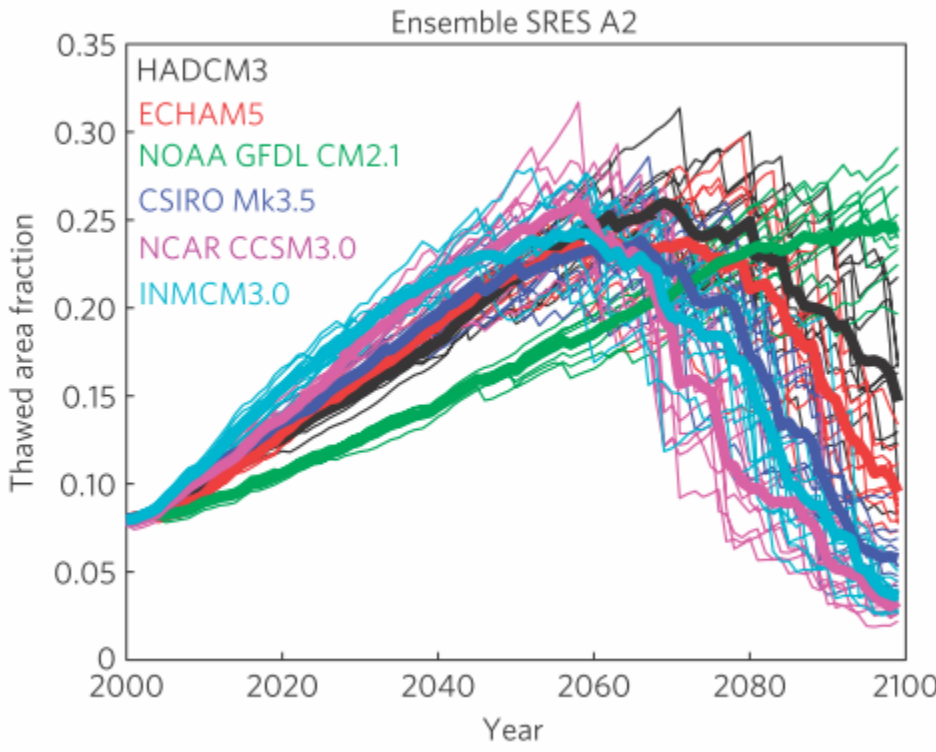


Fig. 1. (A) Locations of Siberian lake inventories, permafrost distribution, and vanished lakes. Total lake abundance and inundation area have declined since 1973 (B), including (C) permanent drainage and revegetation of former lakebeds (the arrow and oval show representative areas). (D) Net increases in lake abundance and area have occurred in continuous permafrost, suggesting an initial but transitory increase in surface ponding.

Smith et al., 2005, Science

Thermokarst in the future: CH4 release





Van Huissteden et al., 2012, NCC

Vegetation feedbacks

Shrub expansion

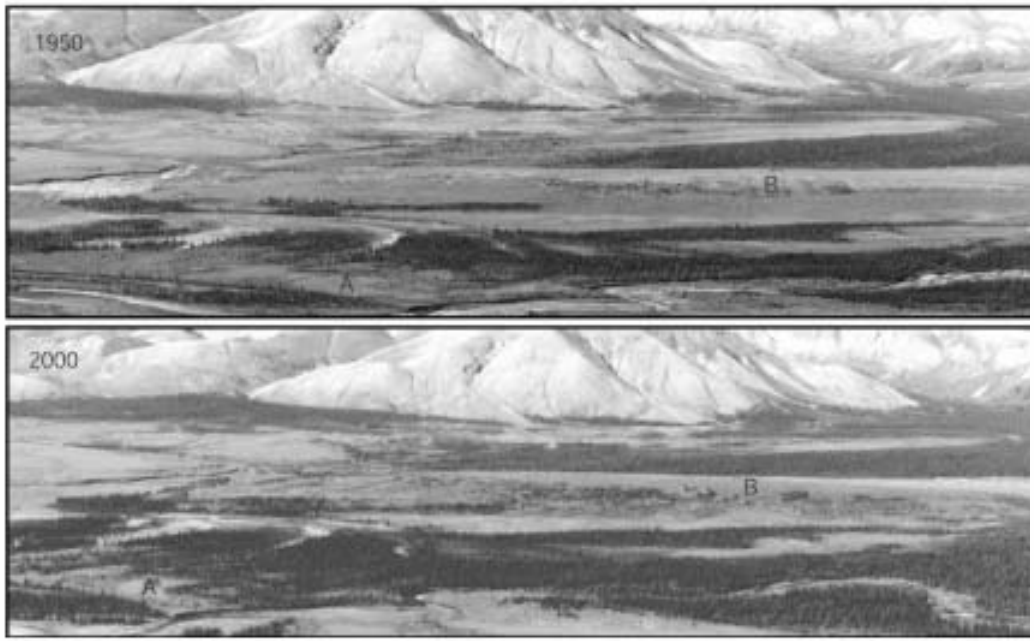


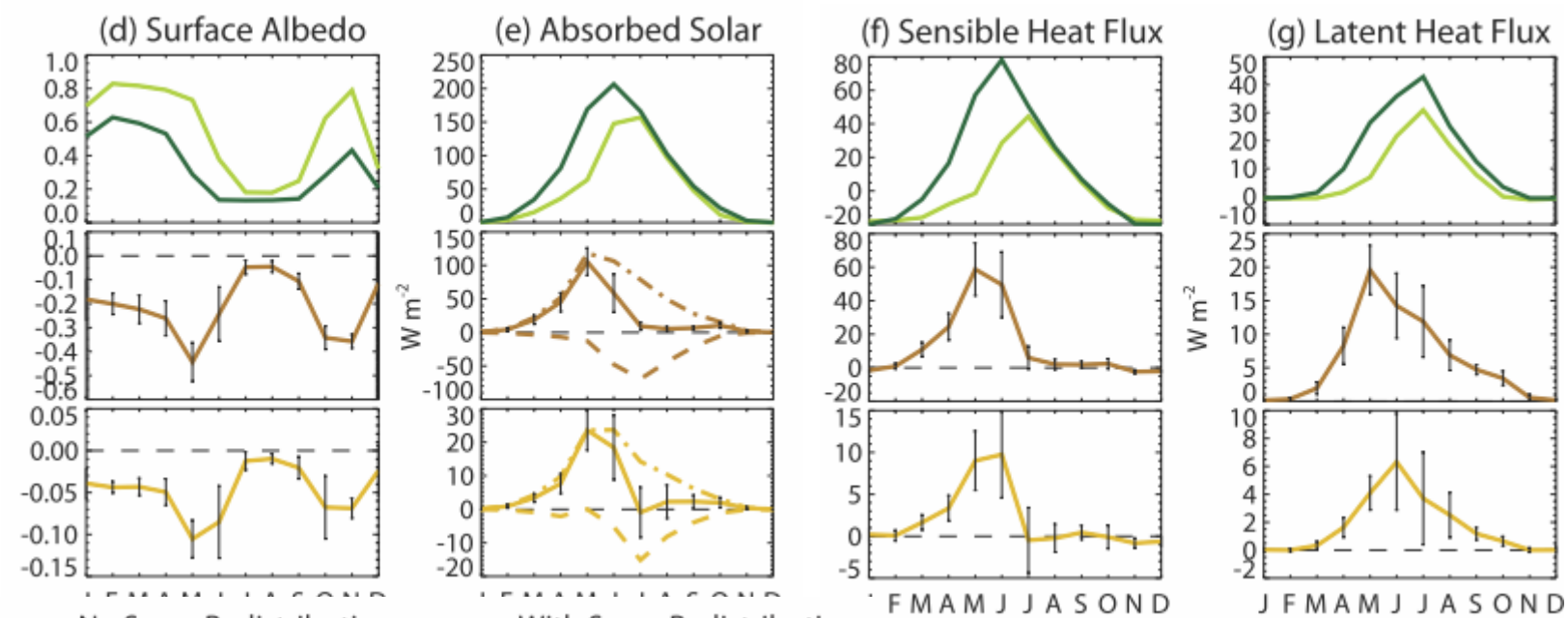
Figure 2 The Kugururok River (N68° 06', W161° 31'), showing in-filling of spruce stands (A) and increased abundance of shrubs i middle ground (B); A and B denote the same locations in the old and new photographs.

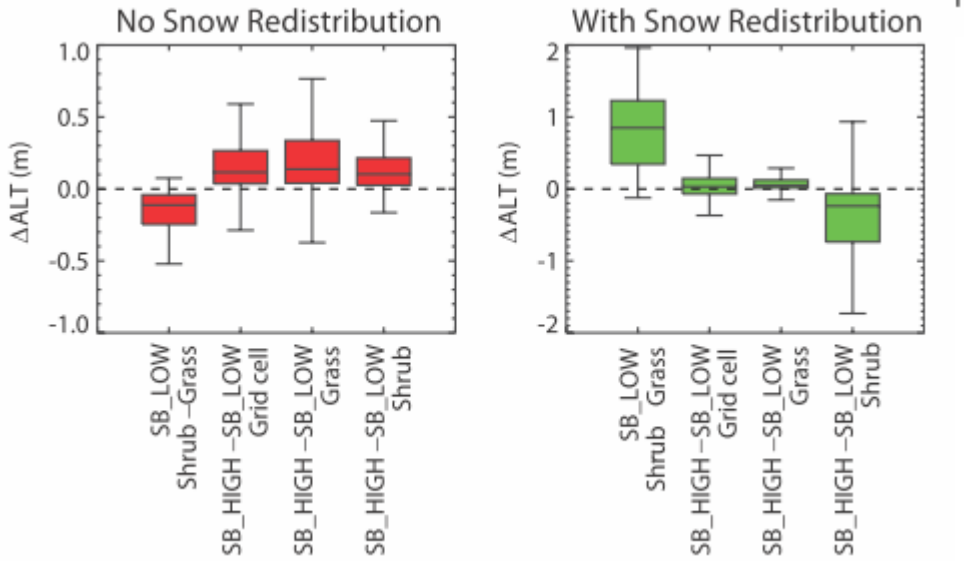
Sturm et al., 2001, Nature

Northward shifting treeline

ACIA, 2004

Vegetation feedbacks

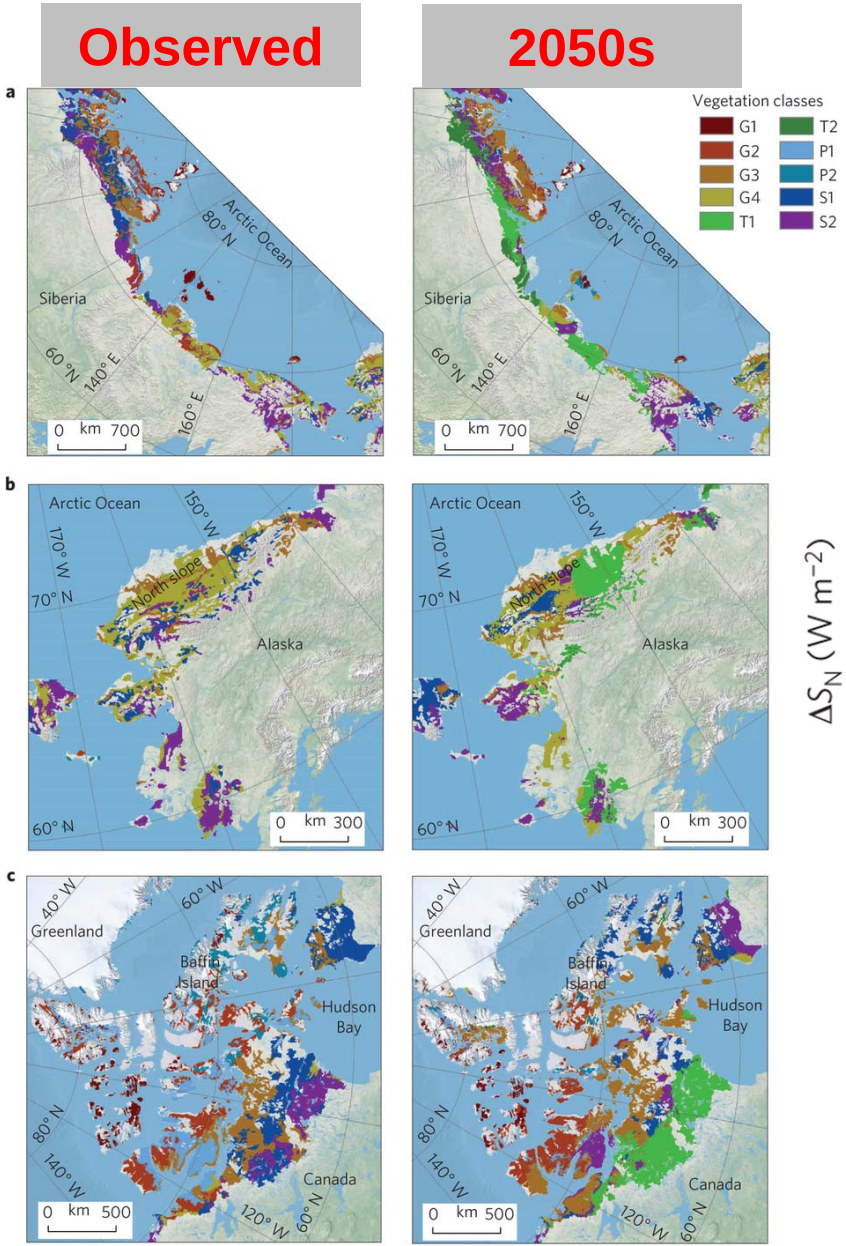




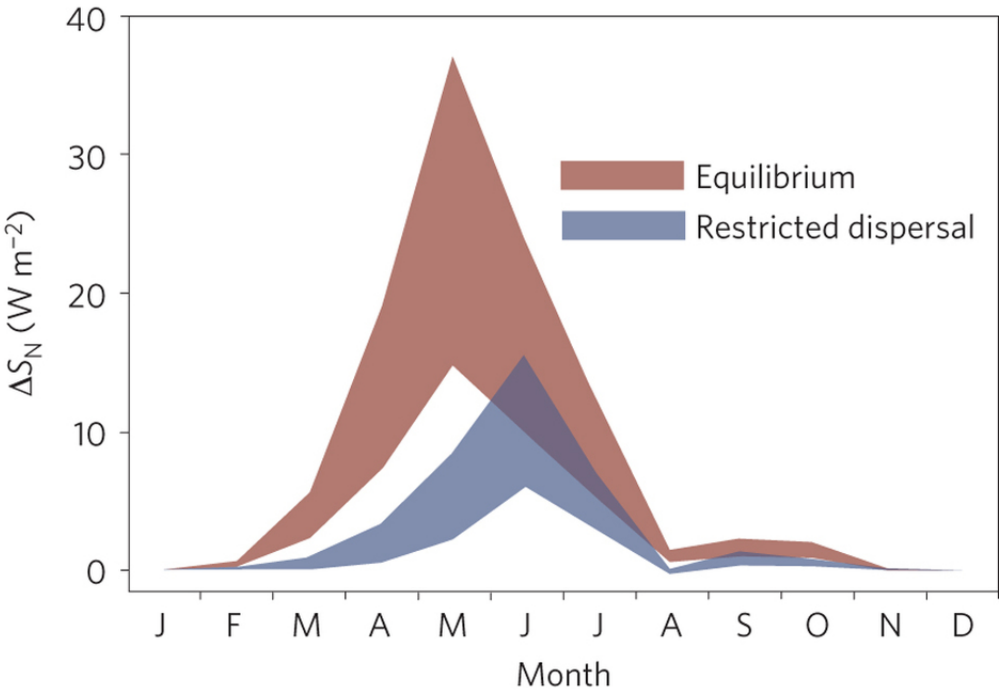
Shrub increase permafrost active layer depth

Lawrence & Swenson, 2013, ERL

Vegetation feedbacks



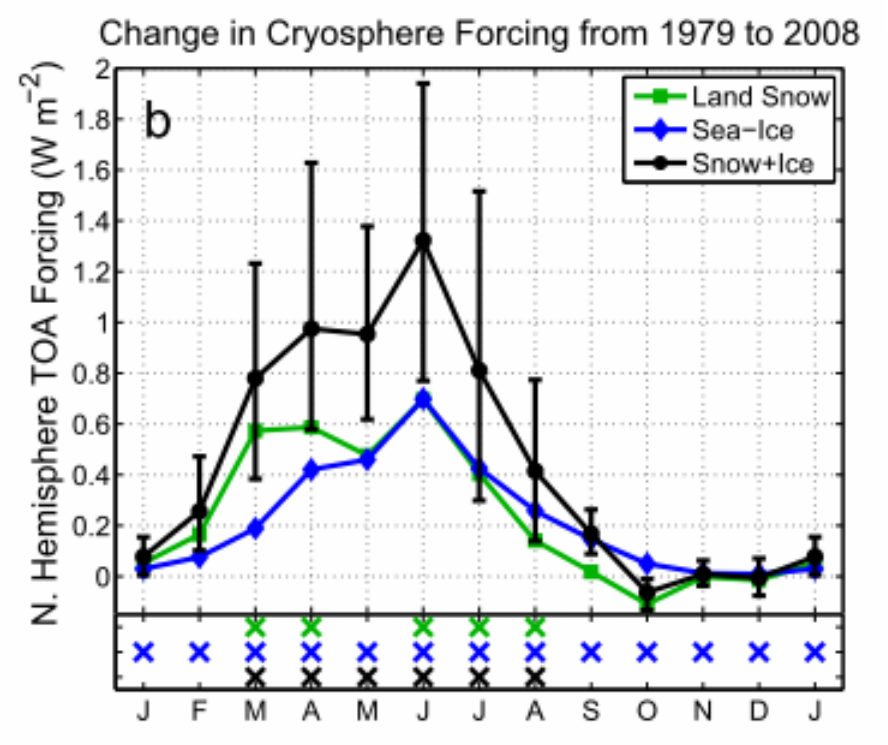
Predicted monthly changes in surface net short-wave radiation for the 2050s

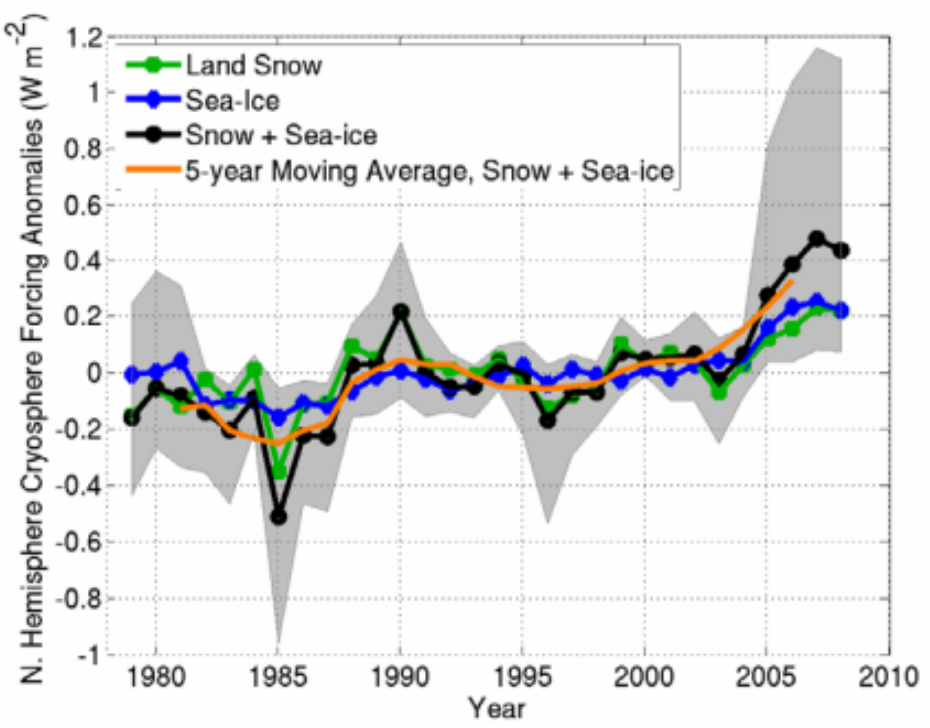


Pearson et al., 2013, NCC

Snow and Sea ice feedbacks

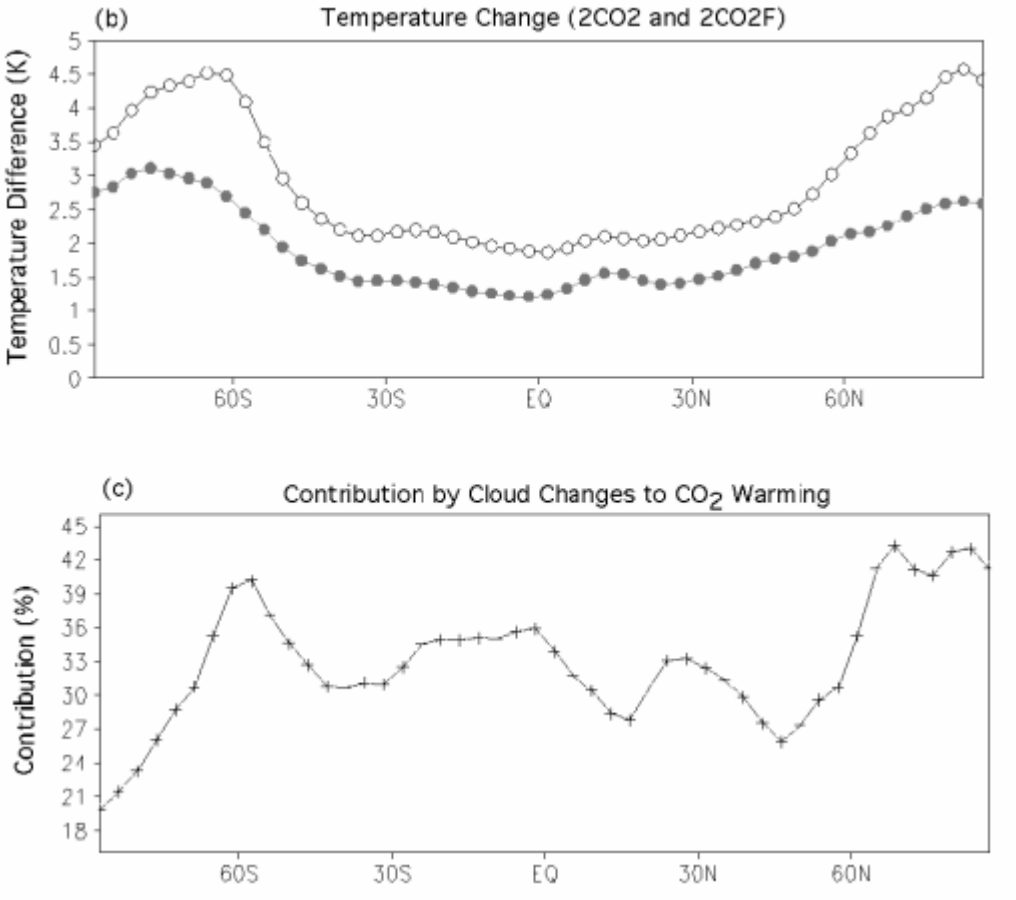
Radiative forcing and albedo feedback from the Northern Hemisphere snow and sea ice between 1979 and 2008





Flanner et al., 2011, Nature Geoscience

Cloud cover and water vapor feedbacks



Vavcus et al., 2004, JC

1) shortwave cloud feedback

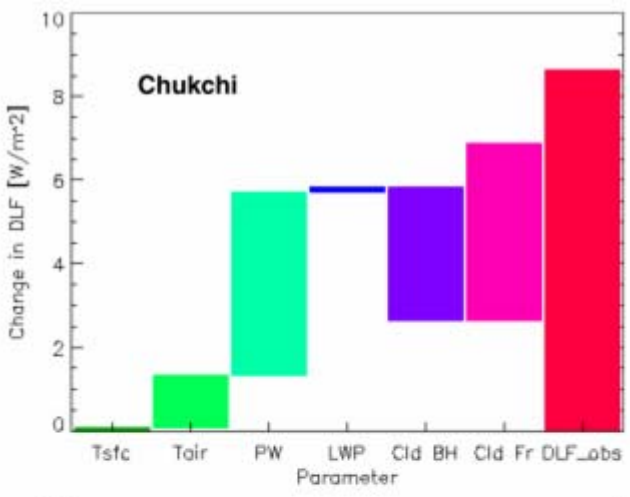
2) longwave cloud feedback

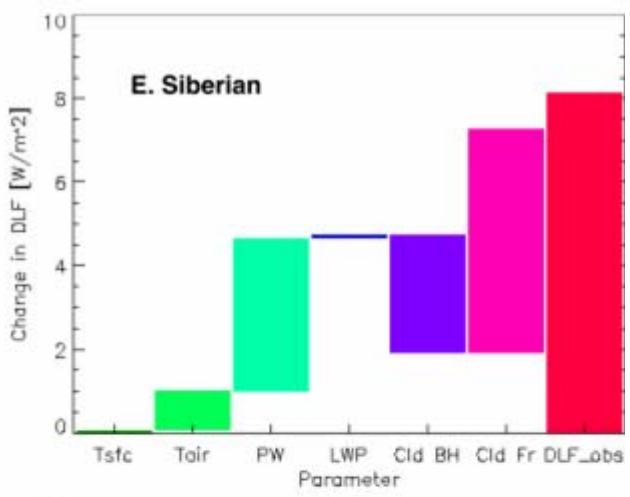
1% decrease in sea ice concentration

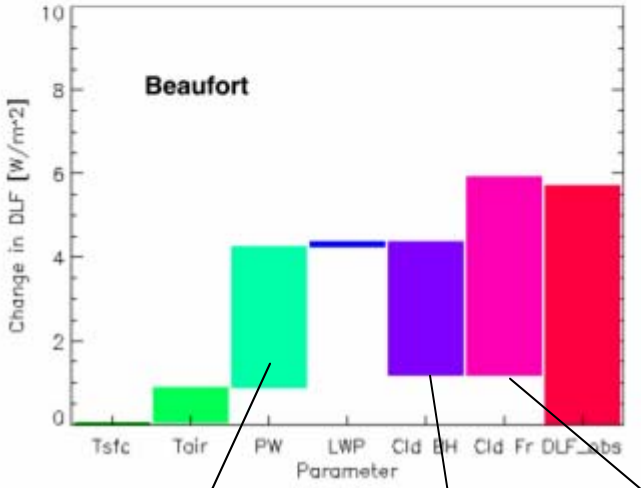
0.36 – 0.47% increase in cloud cover

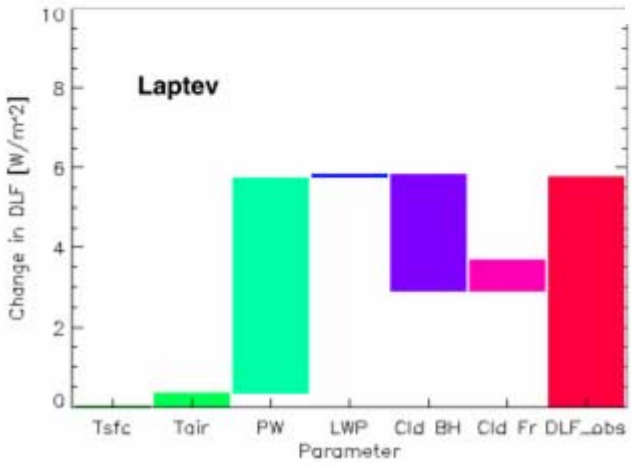
Liu, et al., 2012, GRL

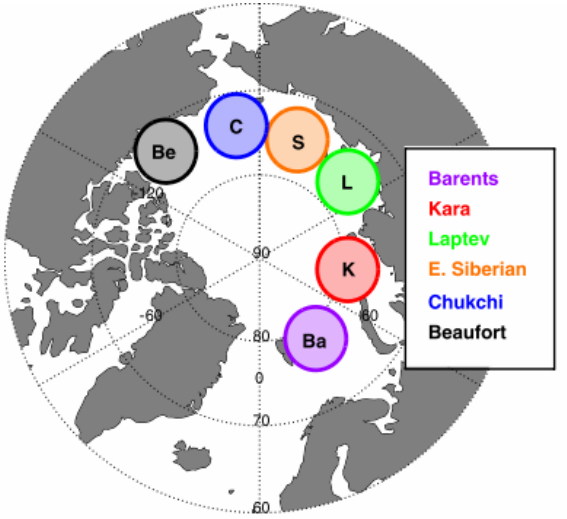
Cloud cover and water vapor feedbacks











Water vapor **Cloud height** **Cloud fraction**

Francis & Hunter, 2007, ERL

Arctic thermohaline circulation feedback

Arctic thermohaline circulation

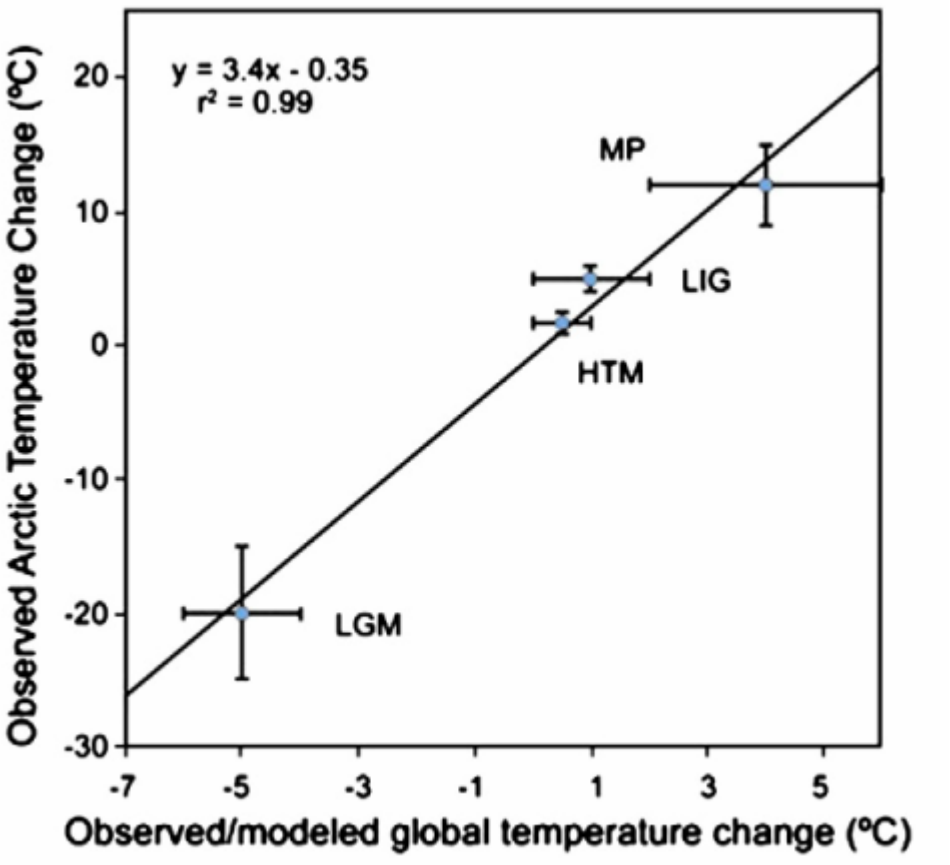
Arctic thermohaline circulation feedback

More freshwater (river discharge, ice cap…)

Arctic thermohaline circulation shut down

Negative feedback !!!

Arctic amplification



LGM: Last Glacial Maximum (20 ka ago)

HTM: Holocene Thermal Maximum (8 ka ago)

LIG: Last Interglaciation (130–125 ka ago)

MP: Middle Pliocene (3.5 Ma ago)

Miller et al., 2010, Quat. Sci. Rev.

Which processes/feedbacks could explain Arctic amplification during the past 3 decades ?

nature

Vol 541|3 January 2008|doi:10.1038/nature06502

Vertical structure of recent Arctic warming

Rune G. Graversen[1], Thorsten Mauritsen[1], Michael Tjernström[1], Erland Källén[1] & Gunilla Svensson[1]

→ **Polarward energy transport**

nature

Vol 464|29 April 2010|doi:10.1038/nature09051

The central role of diminishing sea ice in recent Arctic temperature amplification

James A. Screen[1] & Ian Simmonds[1]

→ **Sea ice decrease**

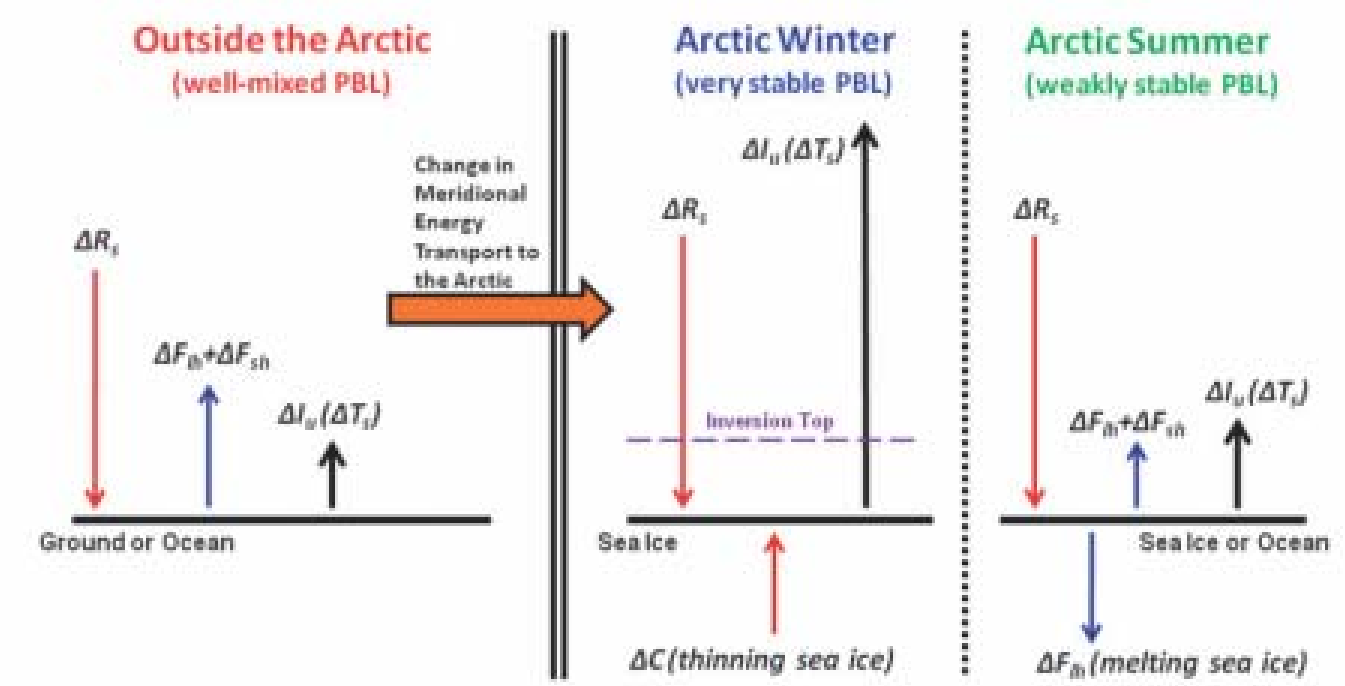
Which processes/feedbacks could explain Arctic amplification during the past 3 decades ?

JOURNAL OF CLIMATE

Surface Energy Balance Framework for Arctic Amplification of Climate Change

GLEN LESINS, THOMAS J. DUCK, AND JAMES R. DRUMMOND

Department of Physics and Atmospheric Science, Dalhousie University, Halifax, Nova Scotia, Canada



Winter inversion in boundary layer

Which processes/feedbacks could explain Arctic amplification during the past 3 decades ?

LETTER

doi:10.1038/nature12002

July 2012 Greenland melt extent enhanced by low-level liquid clouds

R. Bennartz[1], M. D. Shupe[2], D. D. Turner[3], V. P. Walden[4], K. Steffen[2,5], C. J. Cox[4], M. S. Kulie[6], N. B. Miller[6] & C. Pettersen[6]

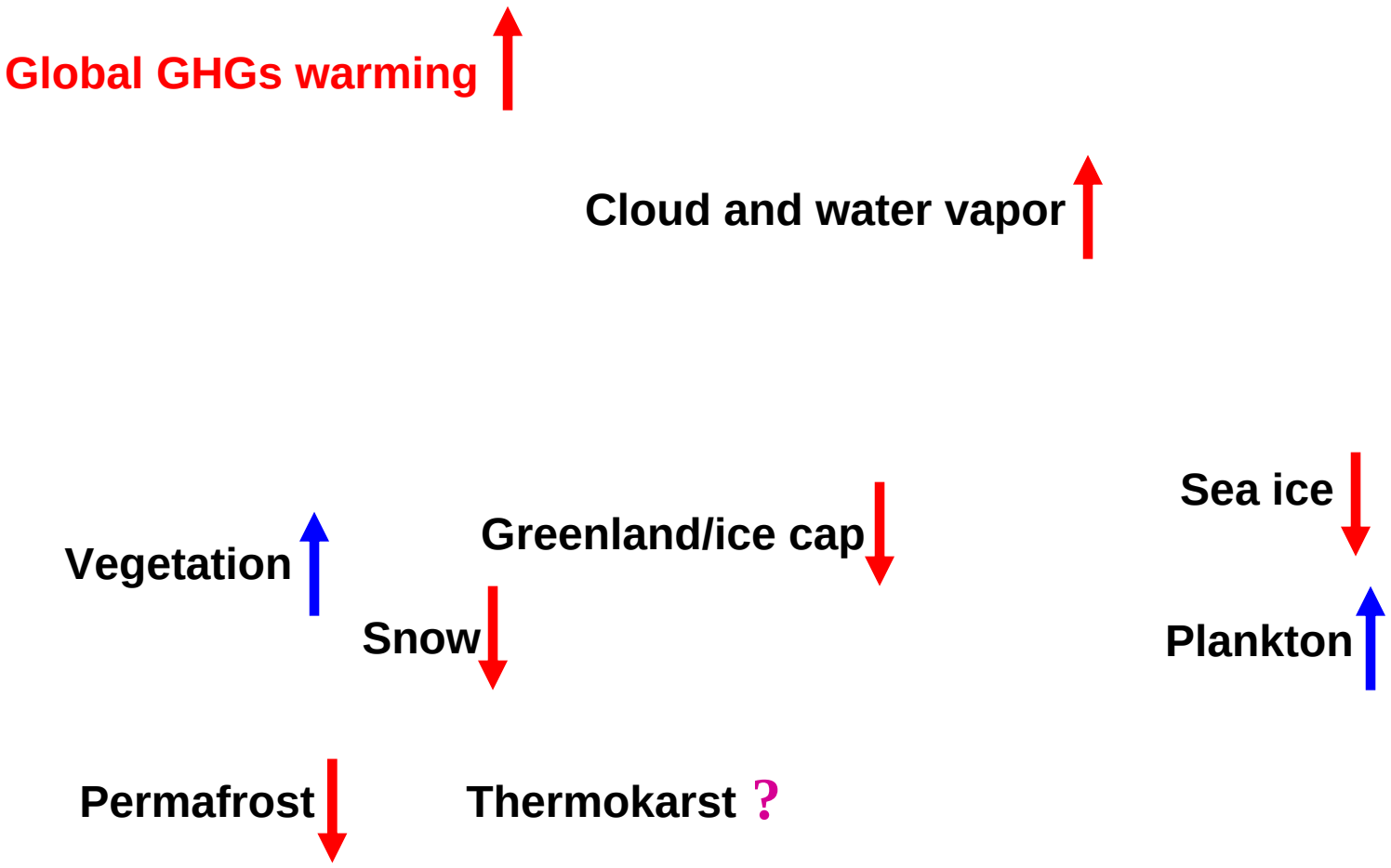
Polarward energy transport

Cloud & water vapor

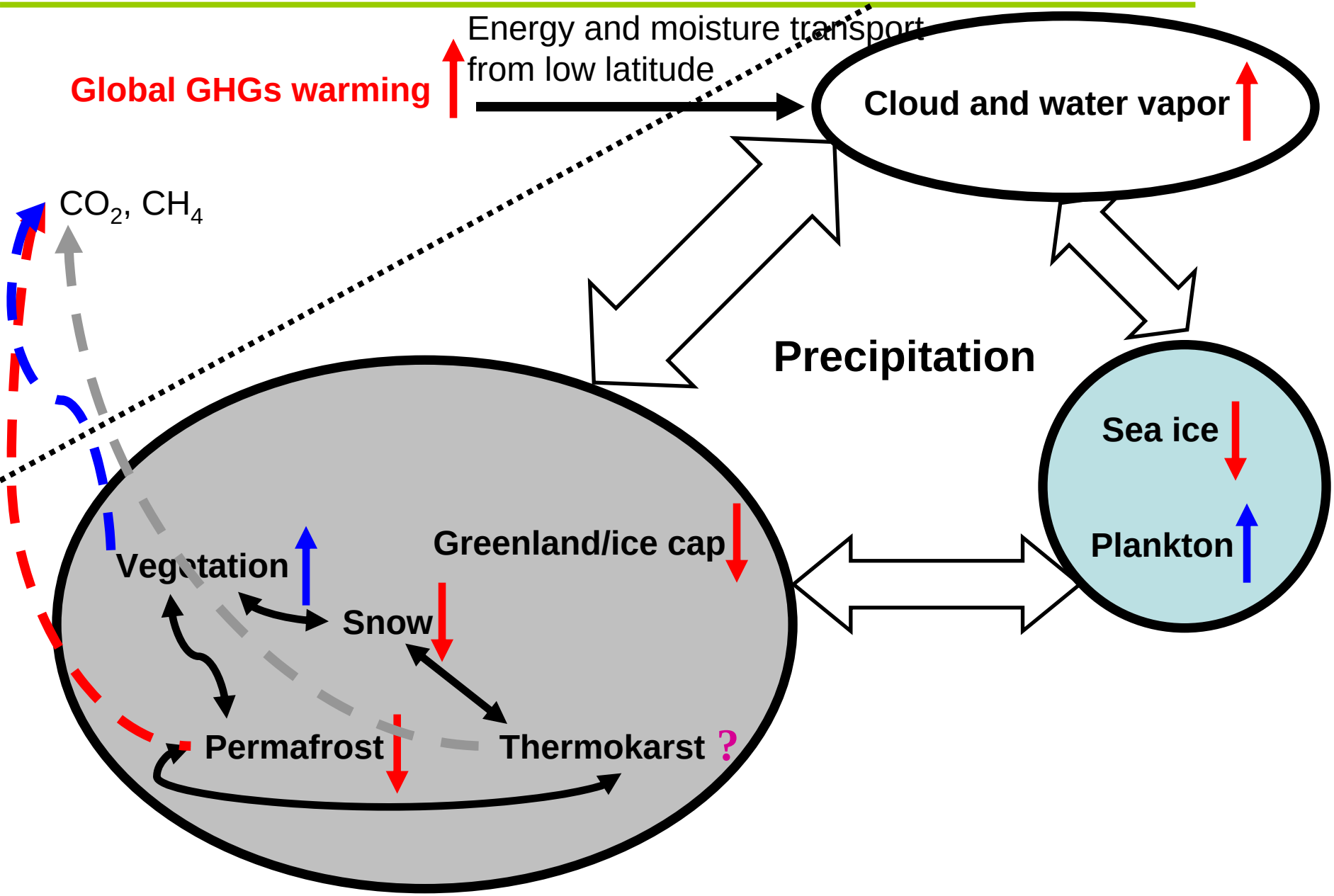
Sea ice/snow decrease

Debate continue…

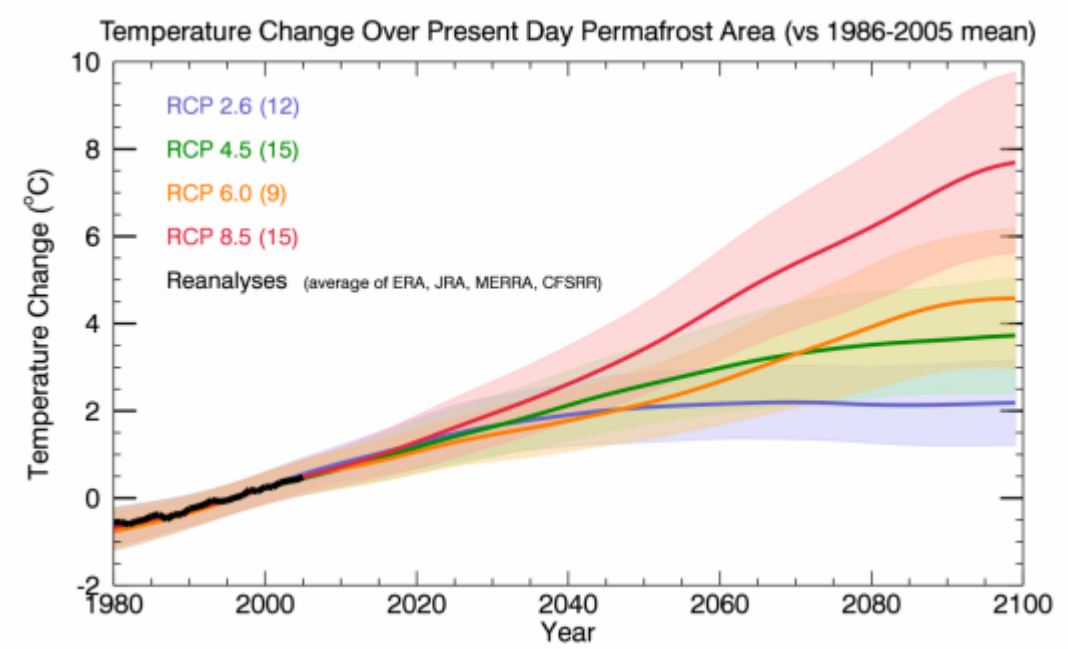
Picture of Arctic

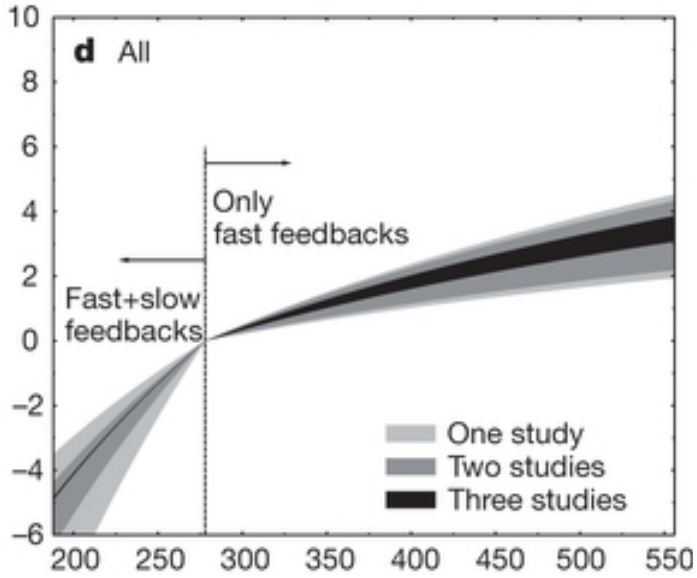


Picture of Arctic



Future???





PALAEOSENS Project Members, 2012, Nautre

Underestimate/overestimate sensitivity of temperature to GHGs concentration? If models did not contain the important fast/slow feedbacks in Arctic.