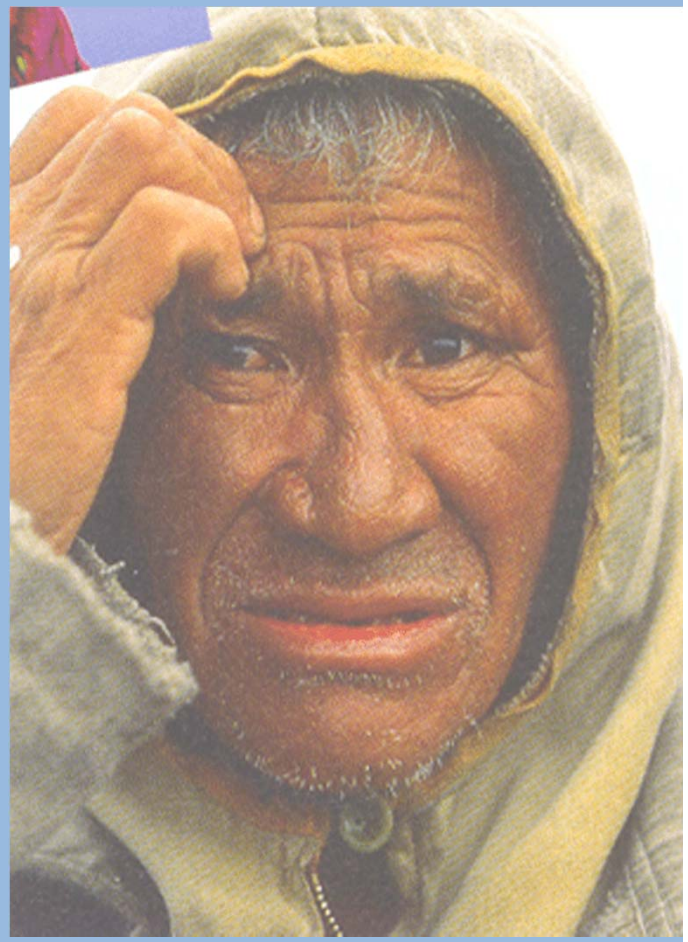
AMAP

Arctic Monitoring and Assessment Programme

An Arctic Perspective

SED 4-2
8-9 February 2015



Lars-Otto Reiersen
AMAP Secretariat, Oslo, Norway.

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Arctic Monitoring and Assessment Programme

AMAP's geographical coverage

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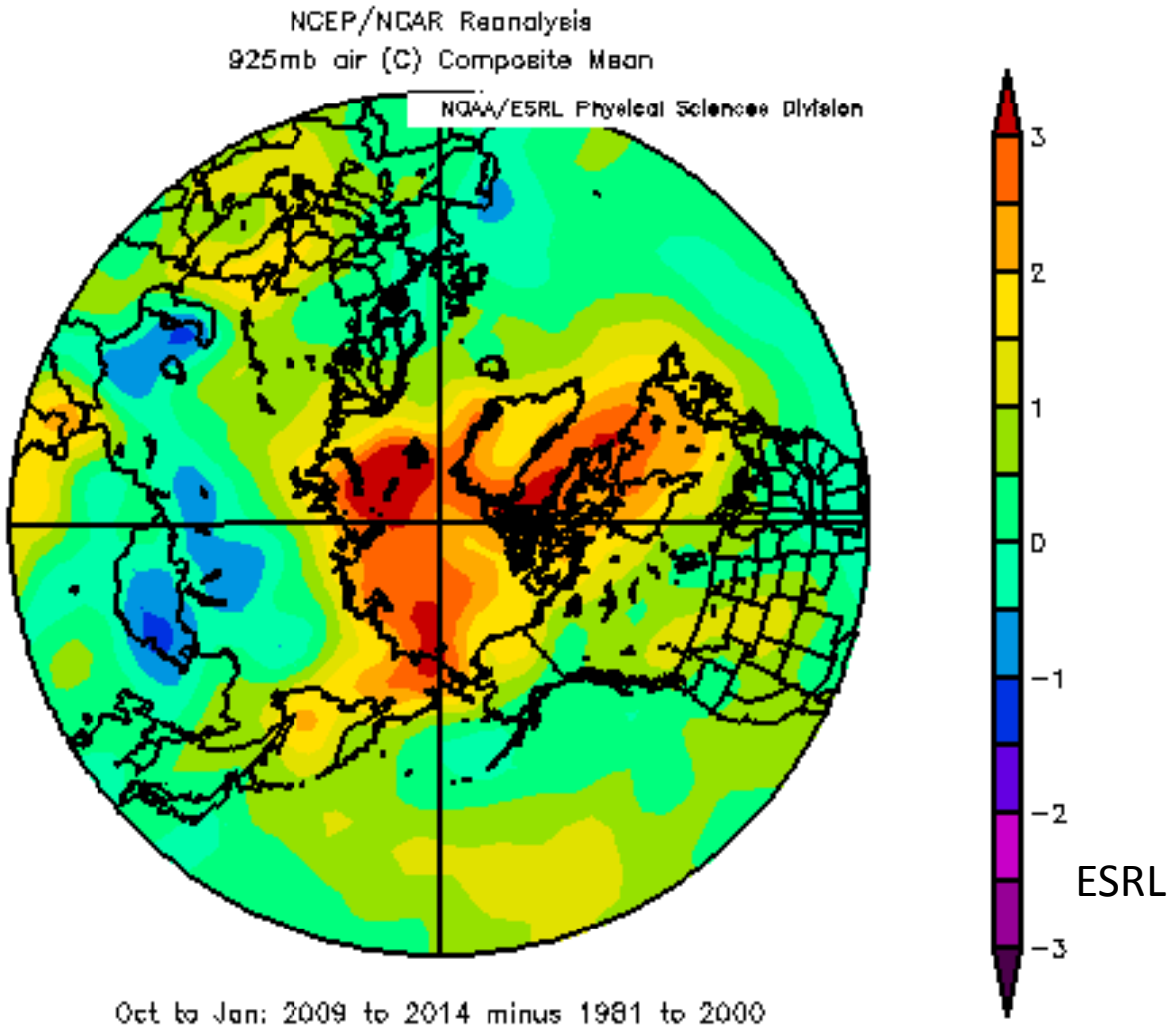
Arctic Monitoring and Assessment Programme

AMAP Climate Assessments - leads

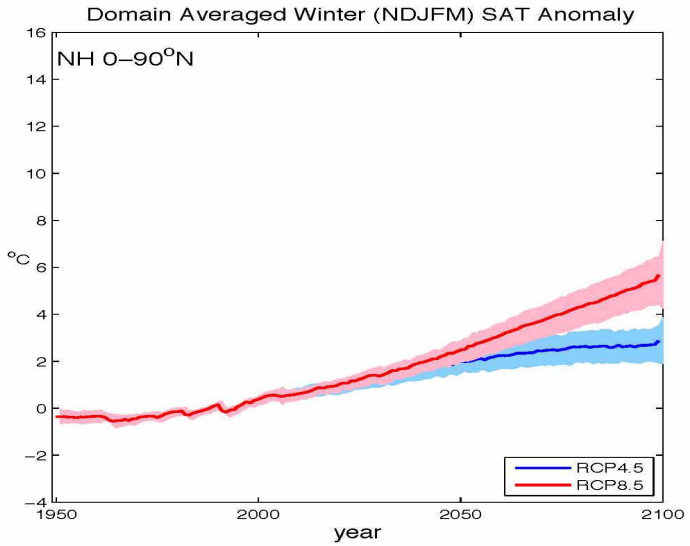
Status, Feedbacks & Forecast:		Russia & USA
Land ice:		Canada, Denmark/Greenland, Russia & USA
Sea ice:		Canada, Norway & USA
Permafrost:		Russia & USA
Snow:		Canada
Arctic Freshwater Synthesis:		Canada
Ocean Acidification:		Norway & USA
SLCF:	- BC & Ozone:	Norway & USA
	- Methane:	Canada & USA

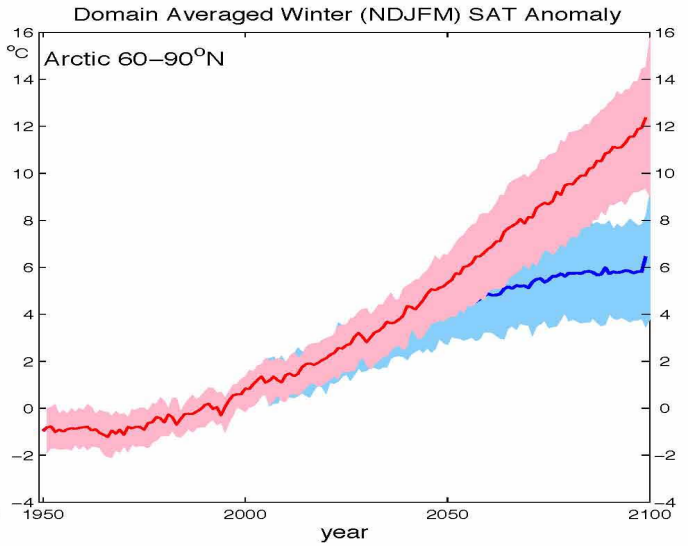
http://www.amap.no, ,Feedbacks

Arctic (temperature) Amplification: 2-3 times changes in Mid-latitudes



Arctic Temperature Redone figures from the Pithan feedback paper and the Arctic temp plot from our Earth's Future paper (Overland et. al. 2014)





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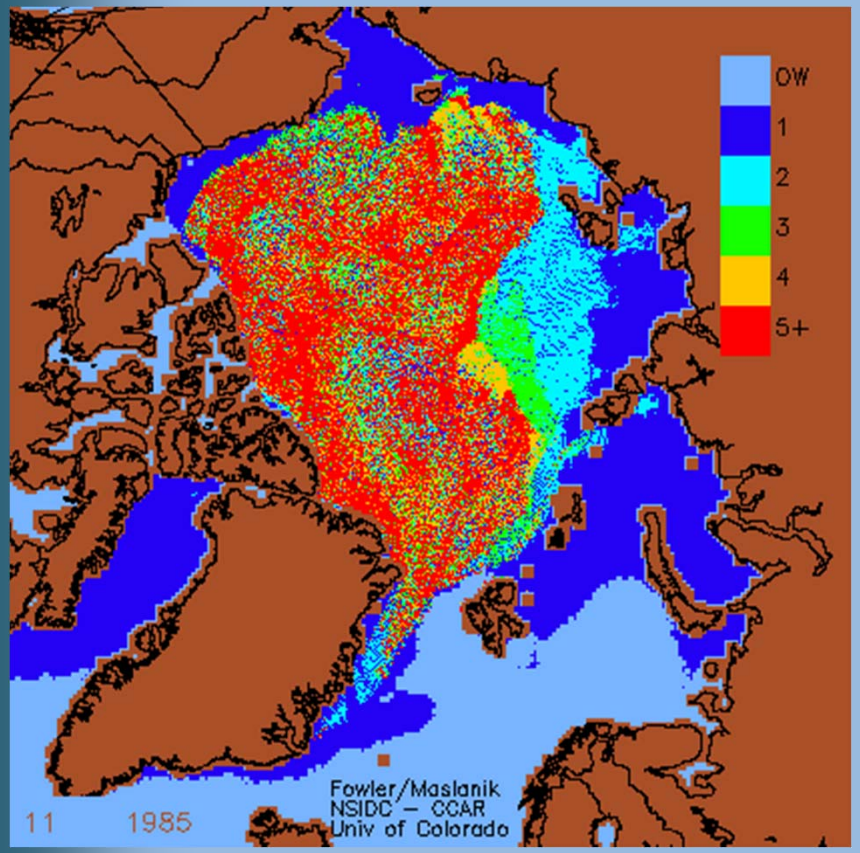
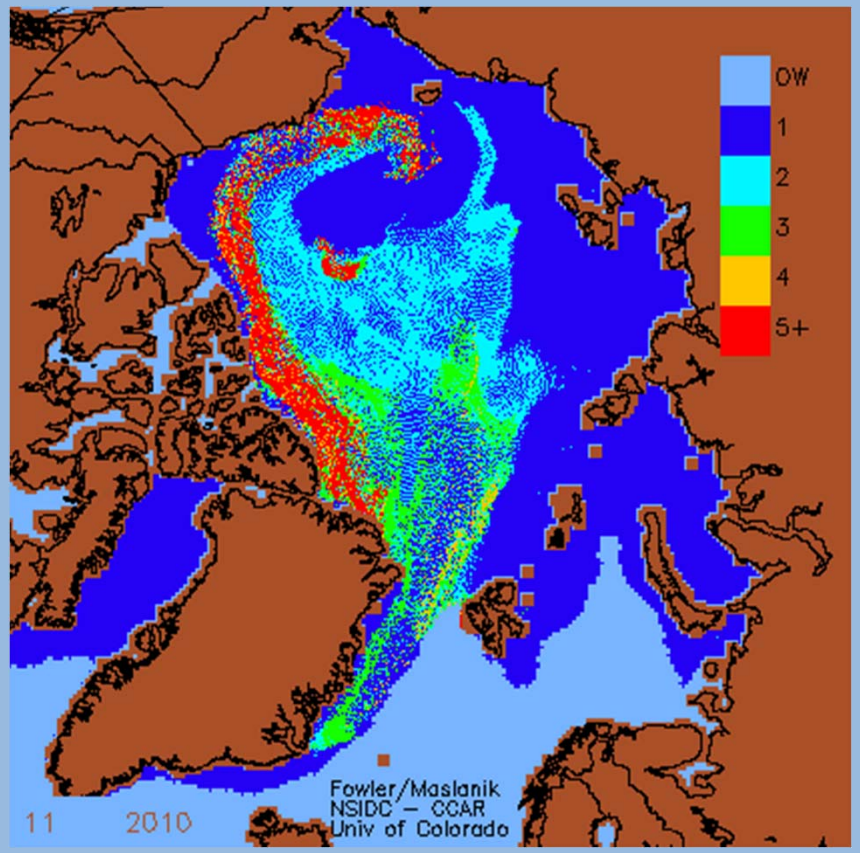
Ice is getting younger and thinner

Much of older, thicker ice north of Alaska now melting away during summer

Mar 1985 – Mar 1986

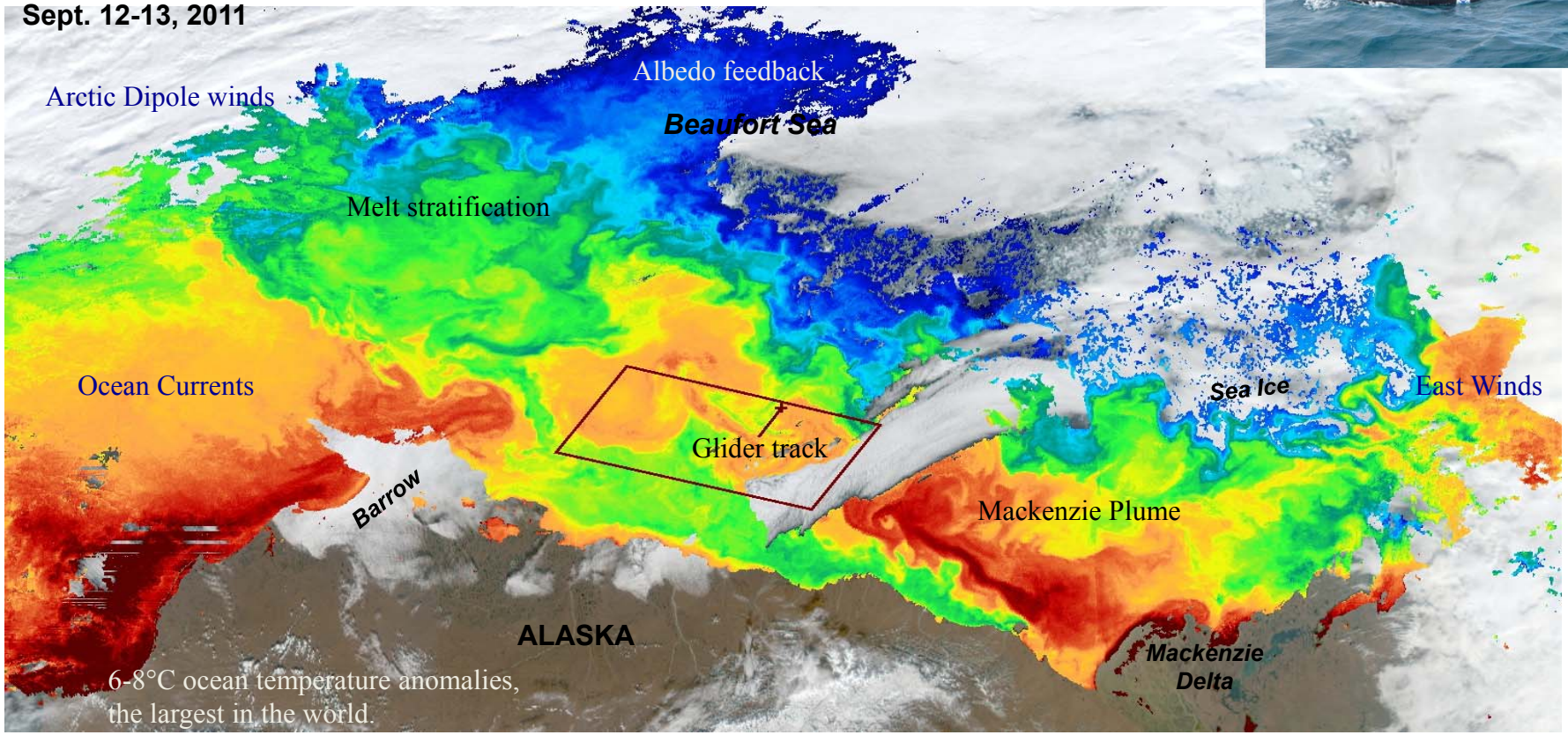


Mar 2010 – Mar 2011



Based on satellite observations; from J. Maslanik, C. Fowler, Univ. Colorado

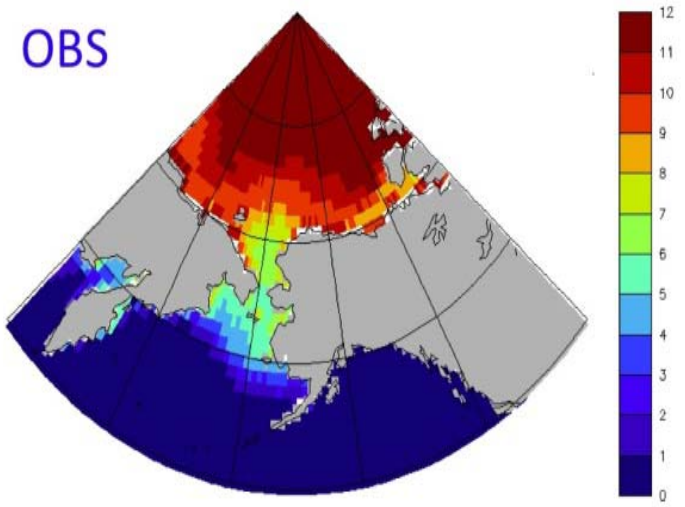
Pacific Arctic Ocean Heat Storage

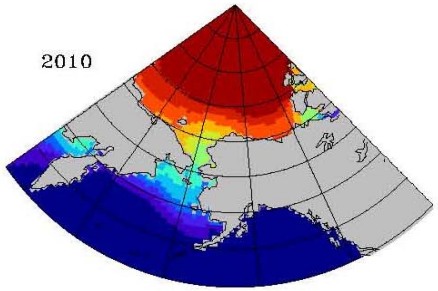


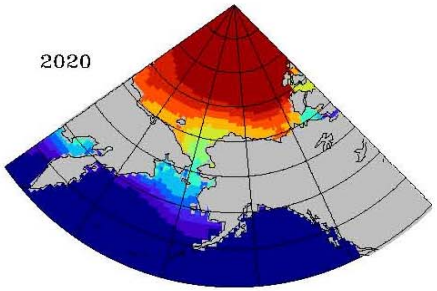
MODIS sea surface temperature (colors) and true-color composite image (land, sea ice, and clouds)

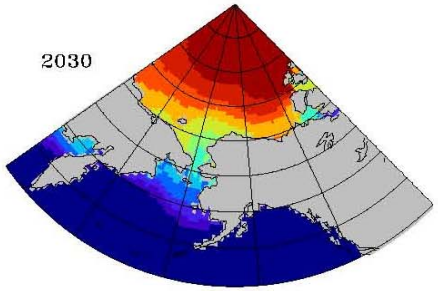
−1 0 1 2 3 4 5 6 7 8 °C

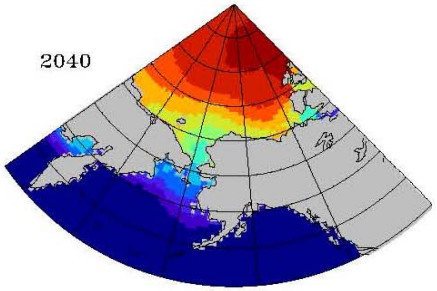
Temperature Color Scale

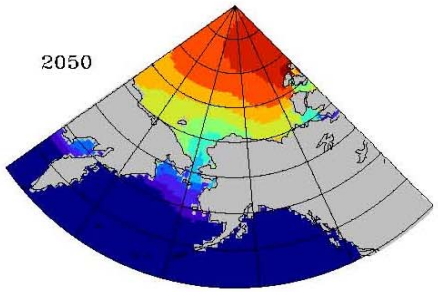


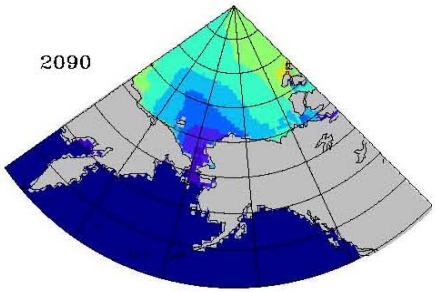










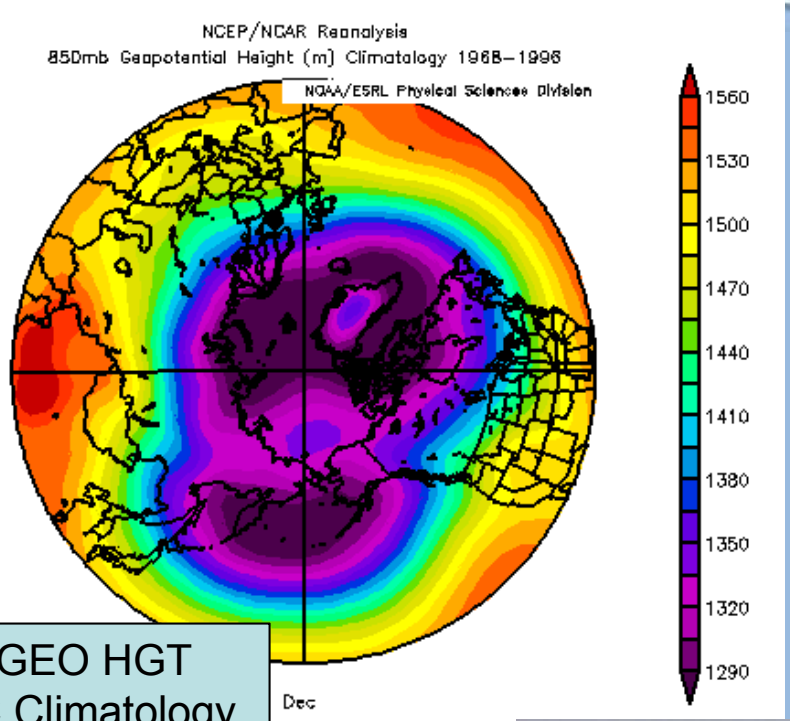


Chukchi Sea
Number of months of ice cover from IPCC Models (more than 15% ice concentration)

Ice Free:
Shift from 2-3 Months to 4-5 months by 2030
Winter still wins!

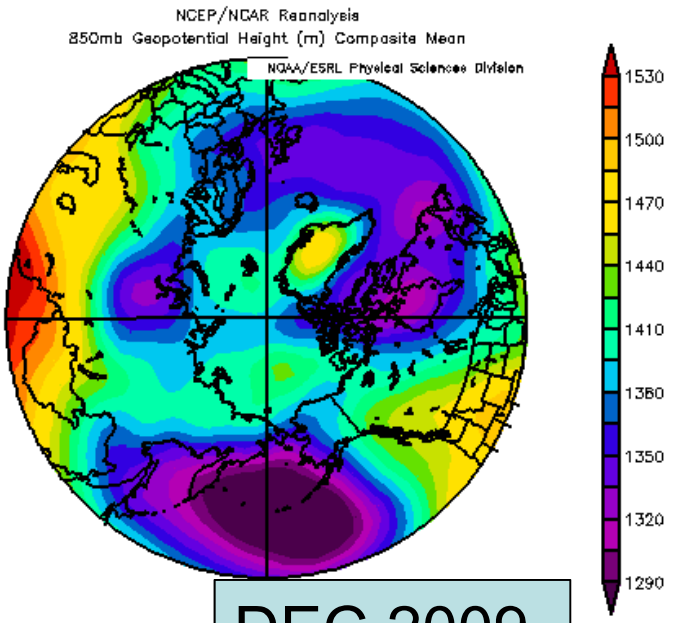
Wang and Overland in press

Normal “POLAR VORTEX” of west to east flowing winds traps cold air in the Arctic:



850 GEO HGT
DEC Climatology

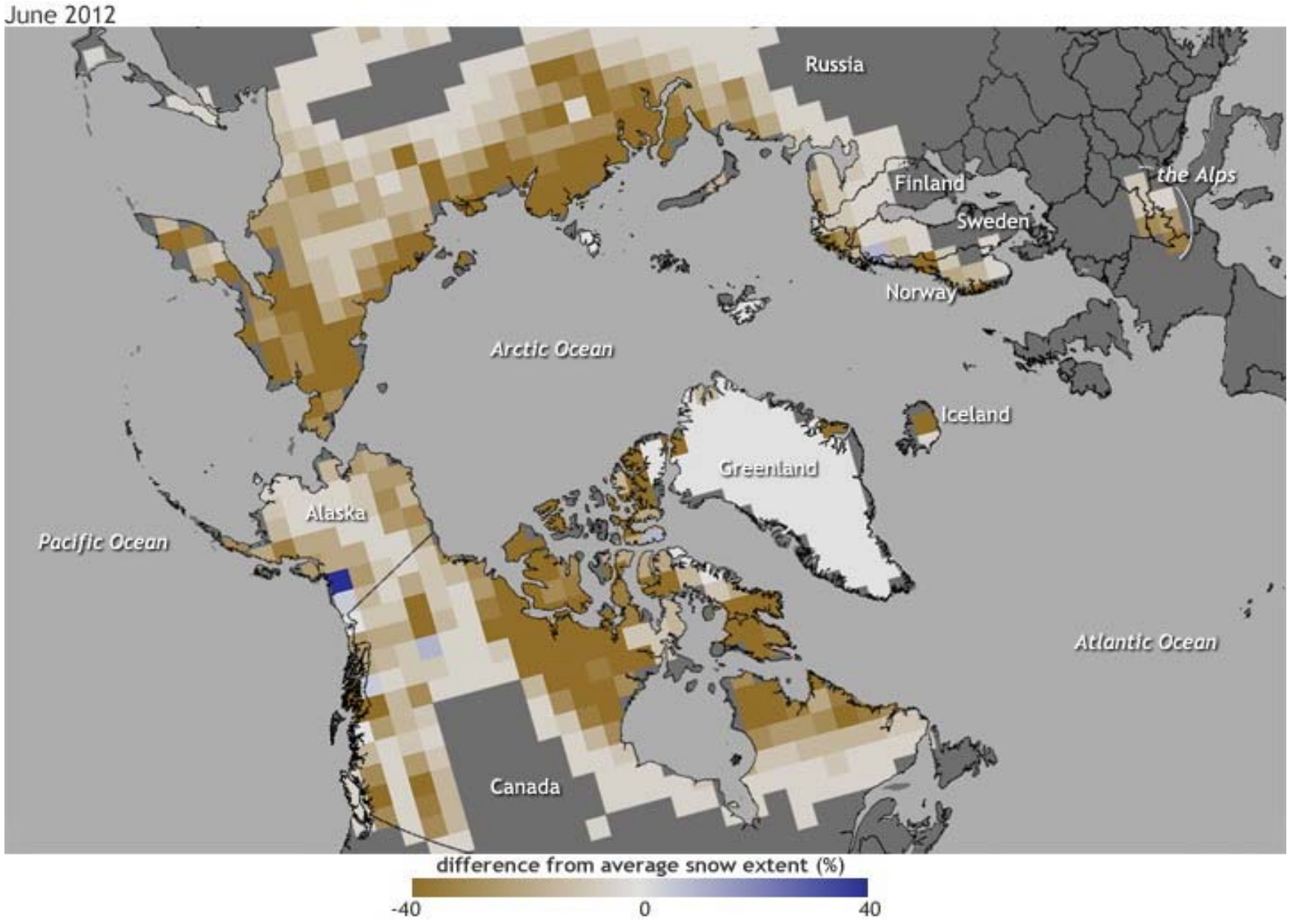
But this pattern broke down in December 2009 allowing cold air to spill southwards



DEC 2009

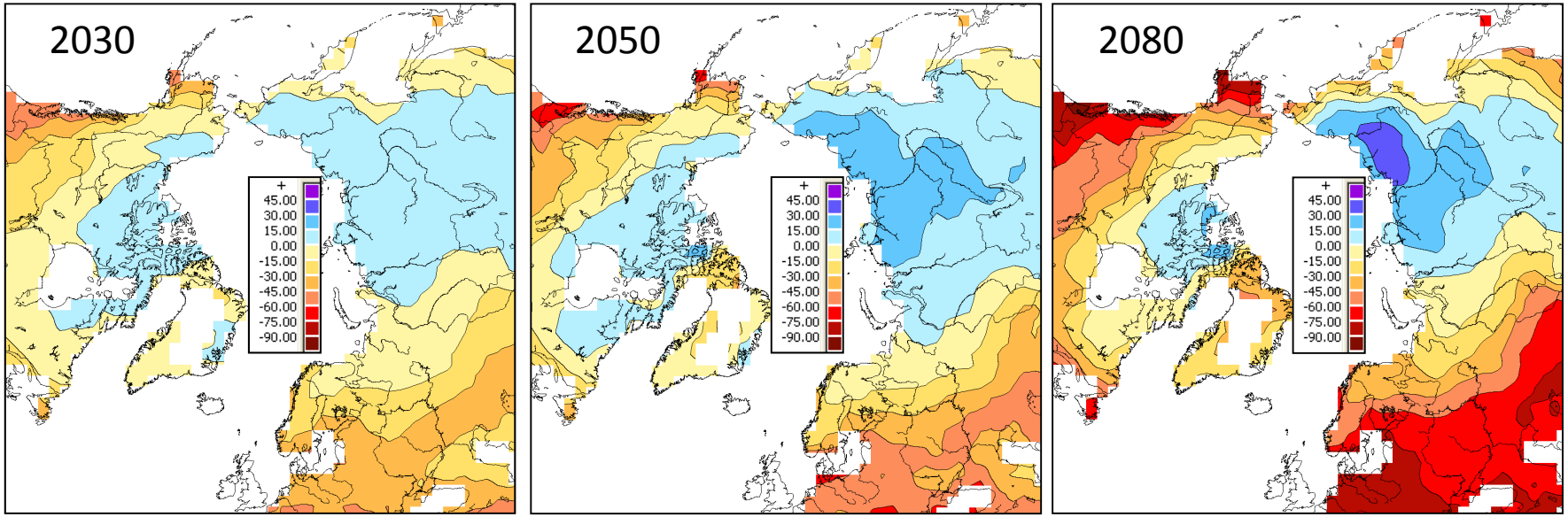
Present Climate “Surprise”

June Snow Cover 2012 relative to 1971-2000

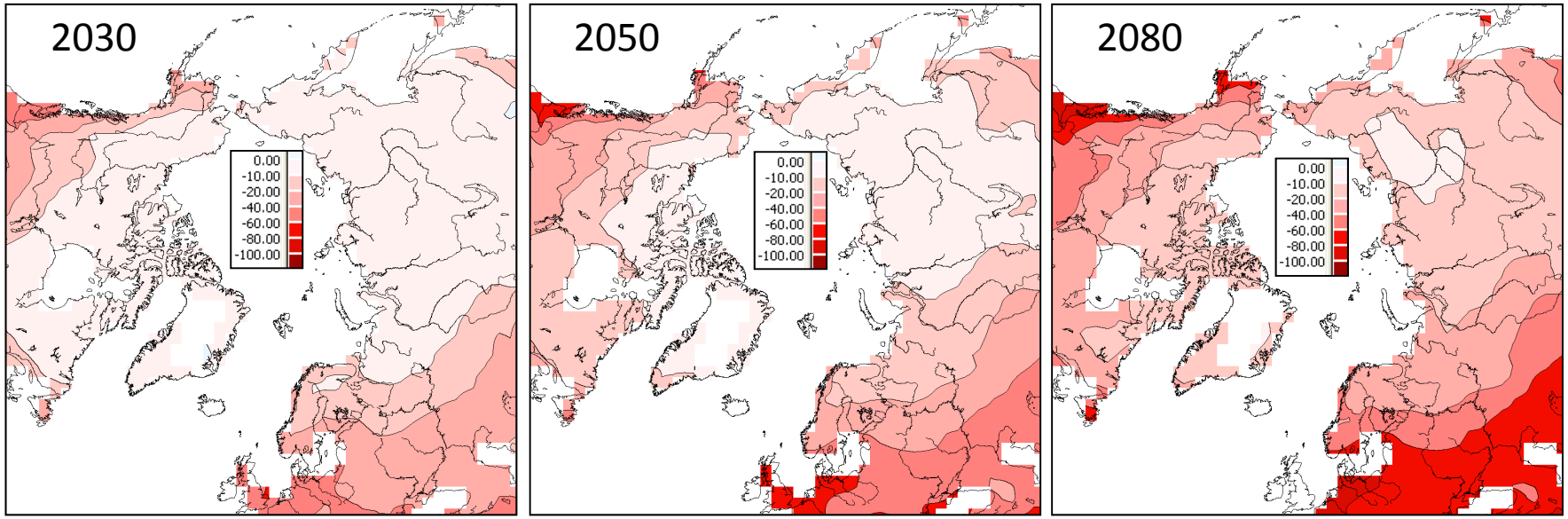


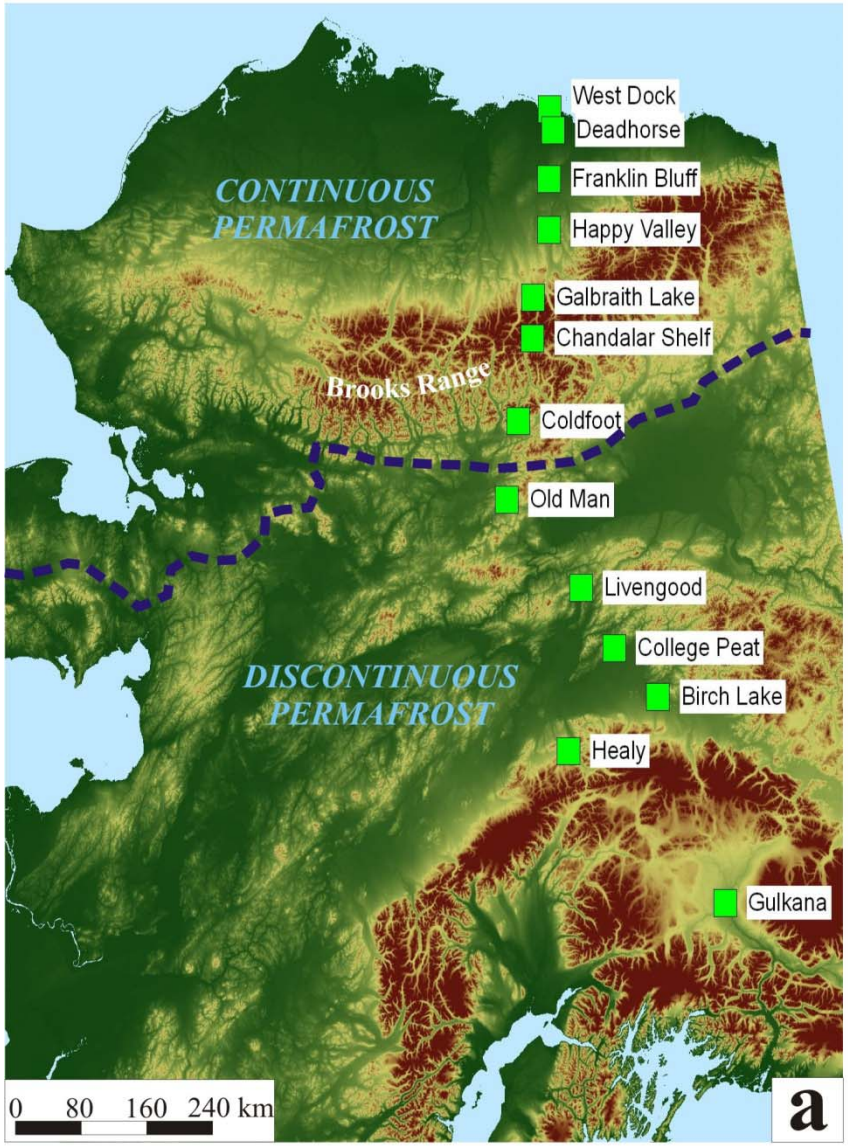
Projected mean change (%) in snow cover from 16 CMIP5 models for rcp85

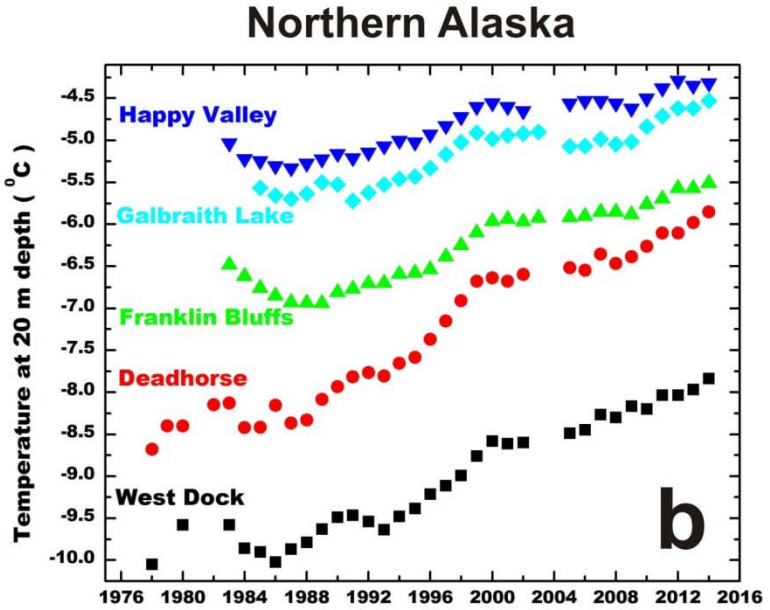
Annual maximum monthly SWE

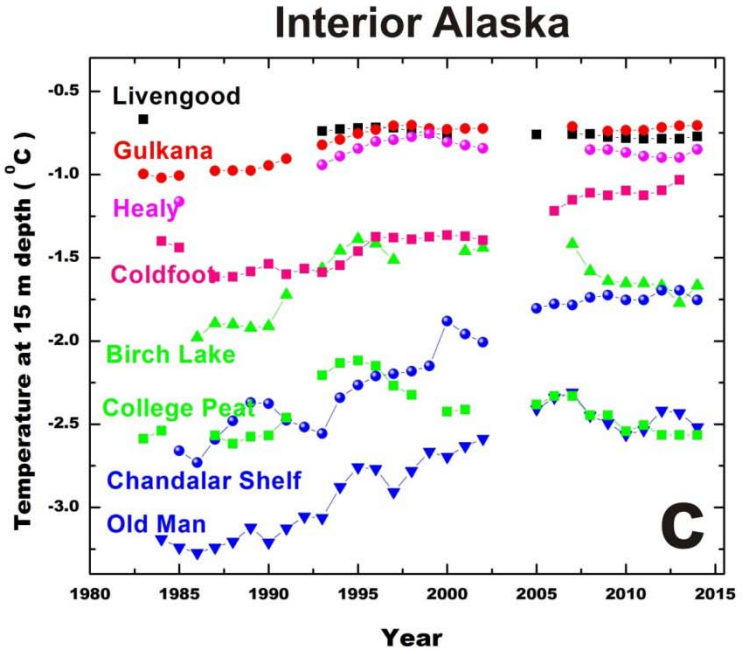


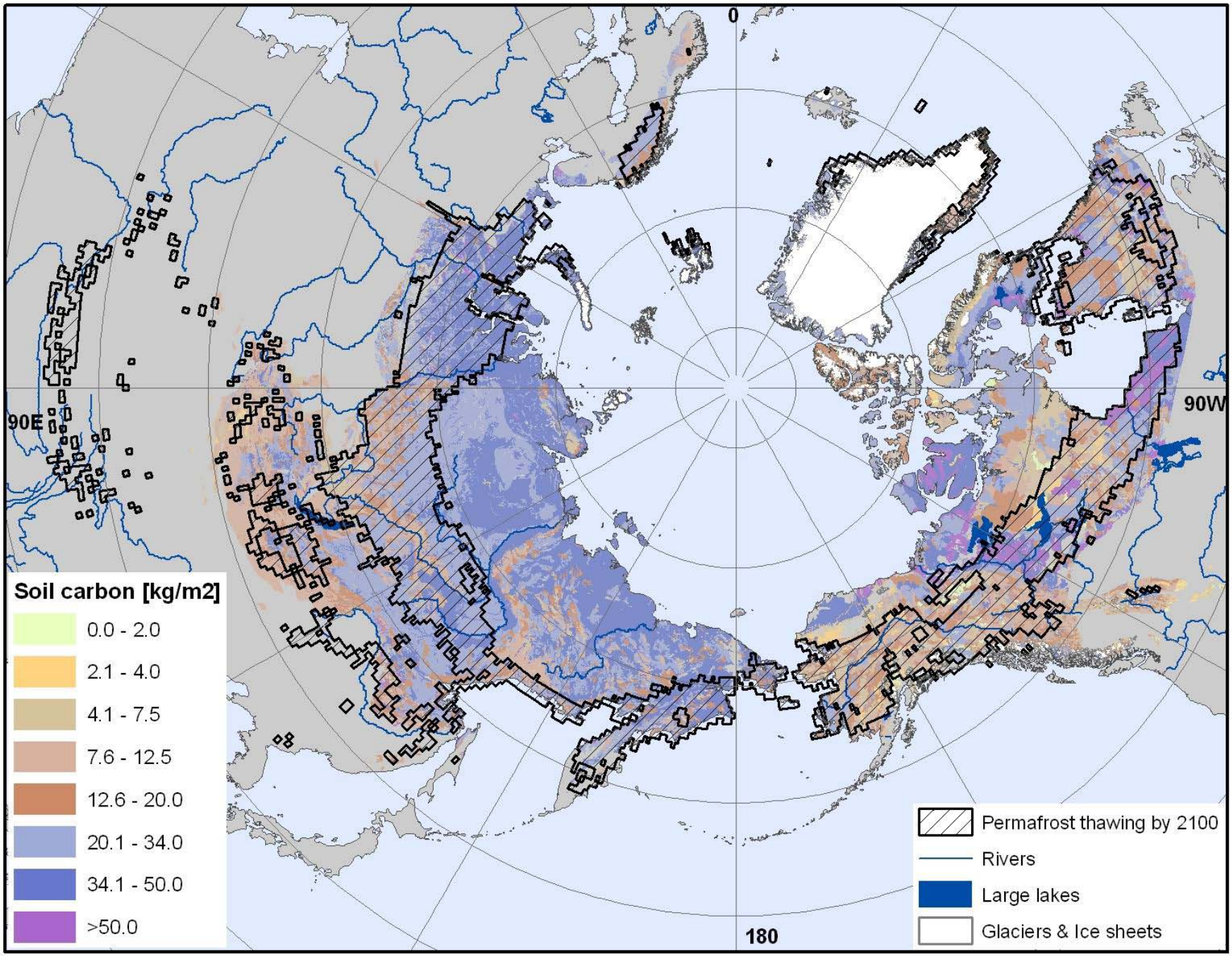
Annual snow cover duration




West Dock
Deadhorse
Franklin Bluff
Happy Valley
Galbraith Lake
Chandalar Shelf
Brooks Range
Coldfoot
Old Man
Livengood
College Peat
Birch Lake
Healy
Gulkana
CONTINUOUS PERMAFROST
DISCONTINUOUS PERMAFROST
0 80 160 240 km
a


Northern Alaska
Happy Valley
Galbraith Lake
Franklin Bluffs
Deadhorse
West Dock
Temperature at 20 m depth (°C)
-4.5
-5.0
-5.5
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
-9.0
-9.5
-10.0
1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016
b


Interior Alaska
Livengood
Gulkana
Healy
Coldfoot
Birch Lake
College Peat
Chandalar Shelf
Old Man
Temperature at 15 m depth (°C)
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
1980 1985 1990 1995 2000 2005 2010 2015
Year
c


0
90E
90W
180
Soil carbon [kg/m2]
0.0 - 2.0
2.1 - 4.0
4.1 - 7.5
7.6 - 12.5
12.6 - 20.0
20.1 - 34.0
34.1 - 50.0
>50.0
Permafrost thawing by 2100
Rivers
Large lakes
Glaciers & Ice sheets

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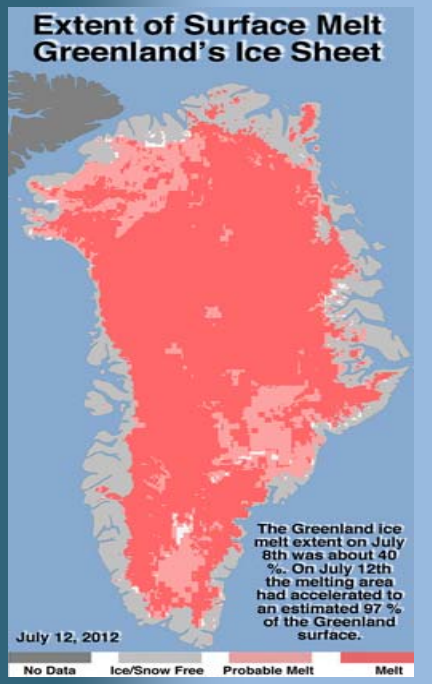
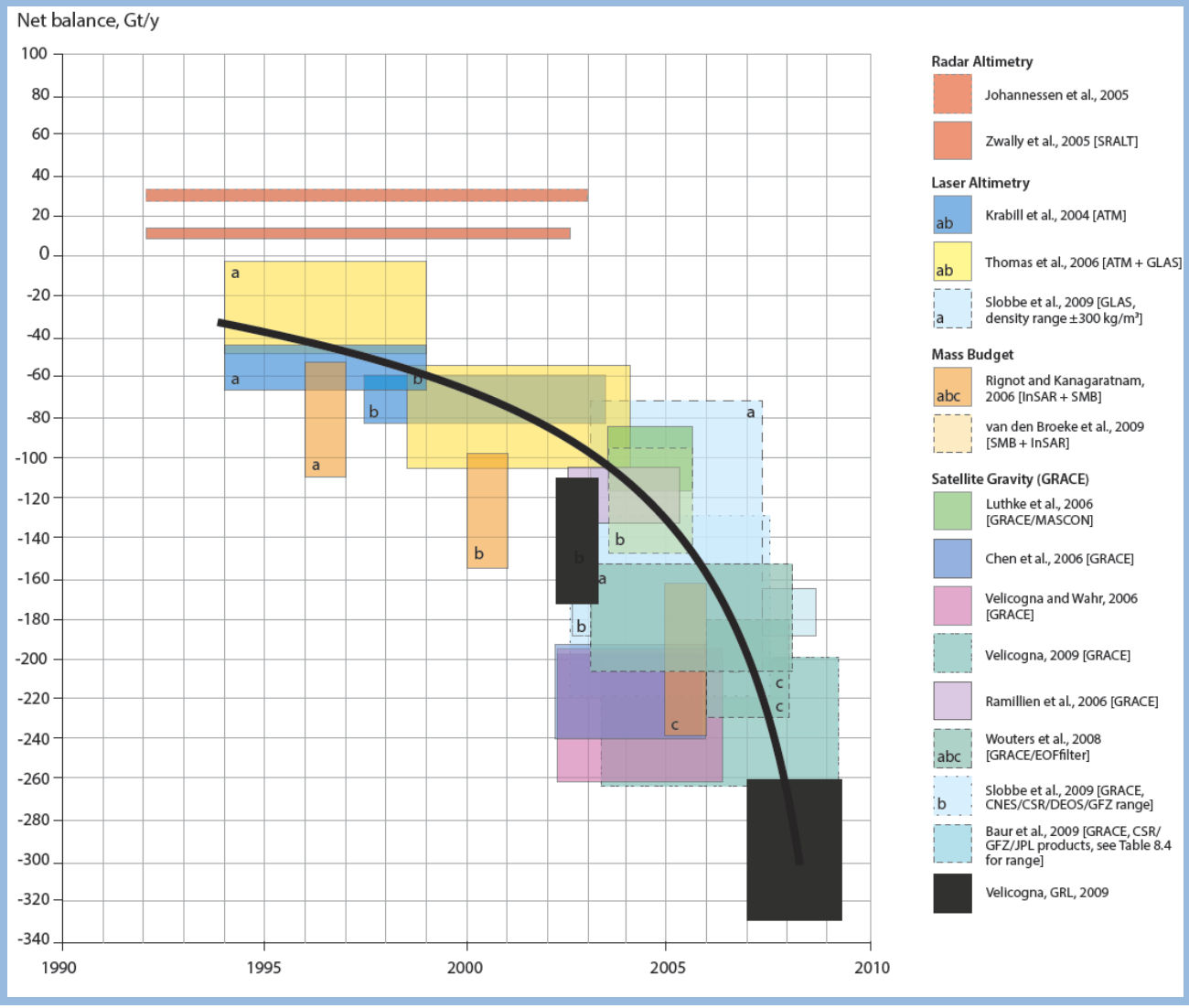
Greenland Mass Balance





Key Findings: Ocean Chemistry

Key finding 1
Arctic marine waters are experiencing widespread and **rapid ocean acidification**

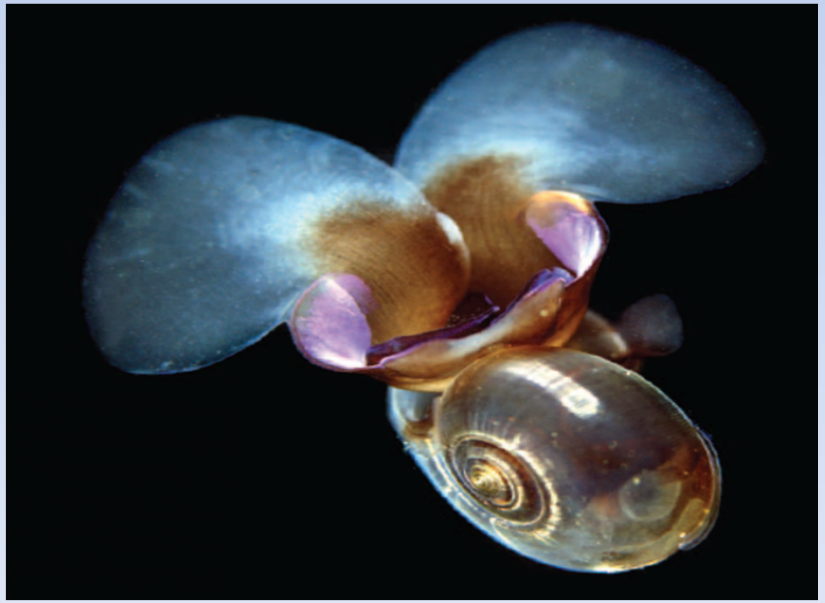
Key finding 2
The **primary driver** of ocean acidification is uptake of carbon dioxide emitted to the atmosphere by **human activities**

Key finding 3
The Arctic Ocean is especially **vulnerable** to ocean acidification

Key finding 4
Acidification is **not uniform** across the Arctic Ocean

pH	H+ (moles per liter)	change in acidity
7.2	6.3×10^{-8}	+900%
7.3	5.0×10^{-8}	+694%
7.4	4.0×10^{-8}	+531%
7.5	3.2×10^{-8}	+401%
7.6	2.5×10^{-8}	+298%
7.7	2.0×10^{-8}	+216%
7.8	1.6×10^{-8}	+151%
7.9	1.3×10^{-8}	+100%
8.0	1.0×10^{-8}	+58%
8.1	7.9×10^{-9}	+26%
8.2	6.3×10^{-9}	

Average global surface ocean pH has fallen from a pre-industrial value of 8.21 to 8.10, corresponding to an increase in acidity of 28.8%. Values of 7.8–7.9 are expected by 2100, representing a 100–150% increase in acidity (NOAA/PMEL)



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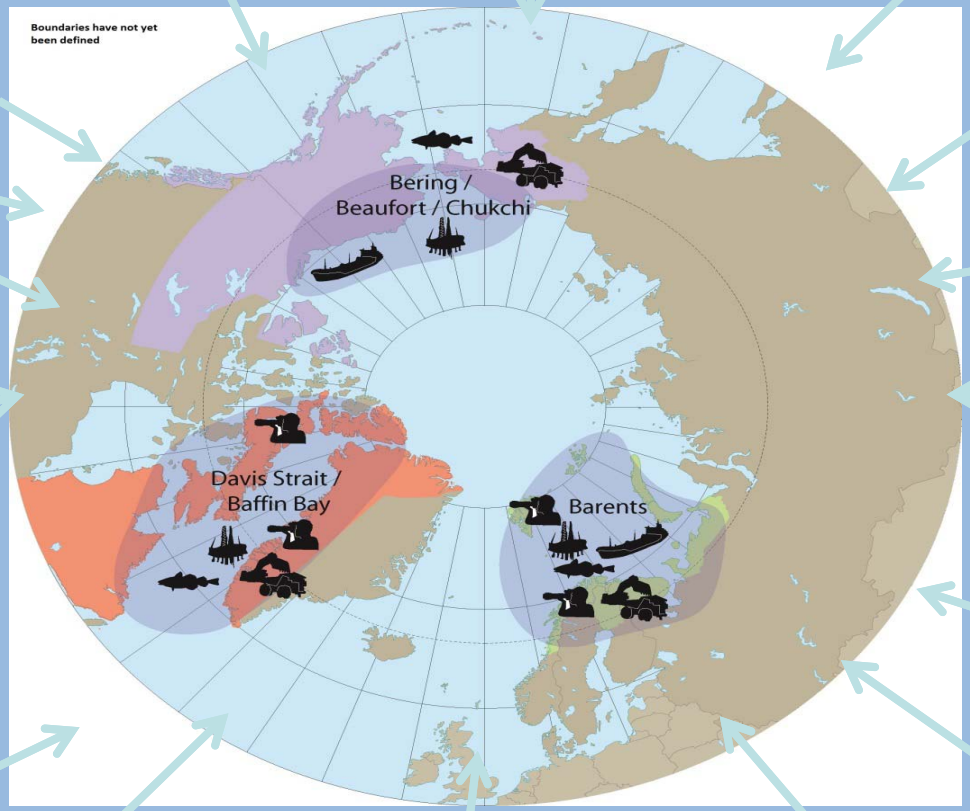
Some drivers of Arctic change



Ecosystem change

Erosion

Recreation and tourism

Mining

Population

Climate change

Oil and gas

Ocean acidification

Local development

Global economic development

Transport and shipping

Technology development

Migration

Fisheries

Infrastructure

Global pollution

Loss of sea ice

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The charismatic losers: Walrus: Calves get separated from their mothers; Haul-outs are on land

Carin Ashjian, 2004

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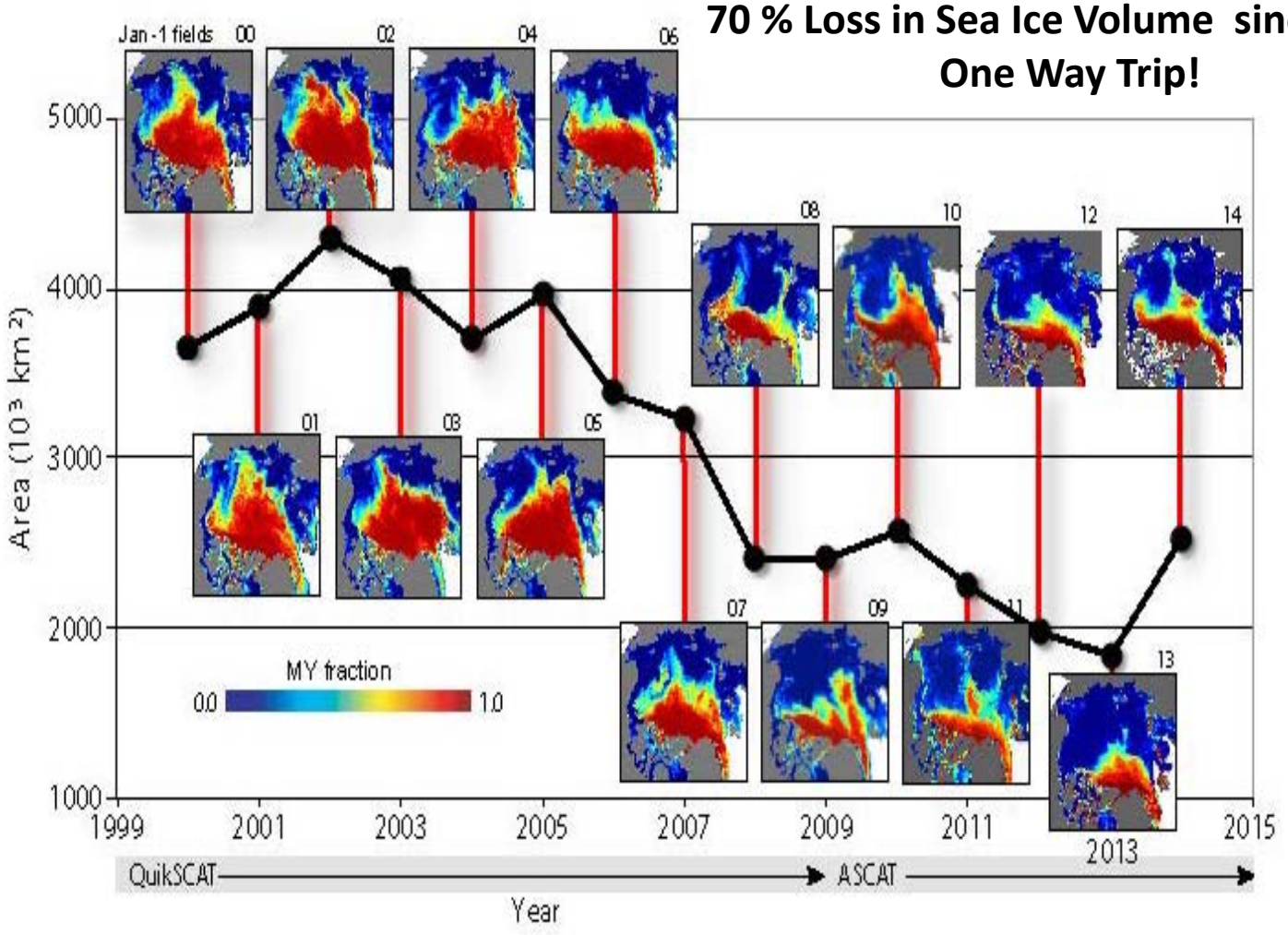
Arctic – the Barometer of the Globe

Decline in Arctic Multiyear Sea Ice Coverage 40 % Since 1980 (Red)

Arctic is Now Mostly First Year Sea Ice(Blue)

70 % Loss in Sea Ice Volume since 1980

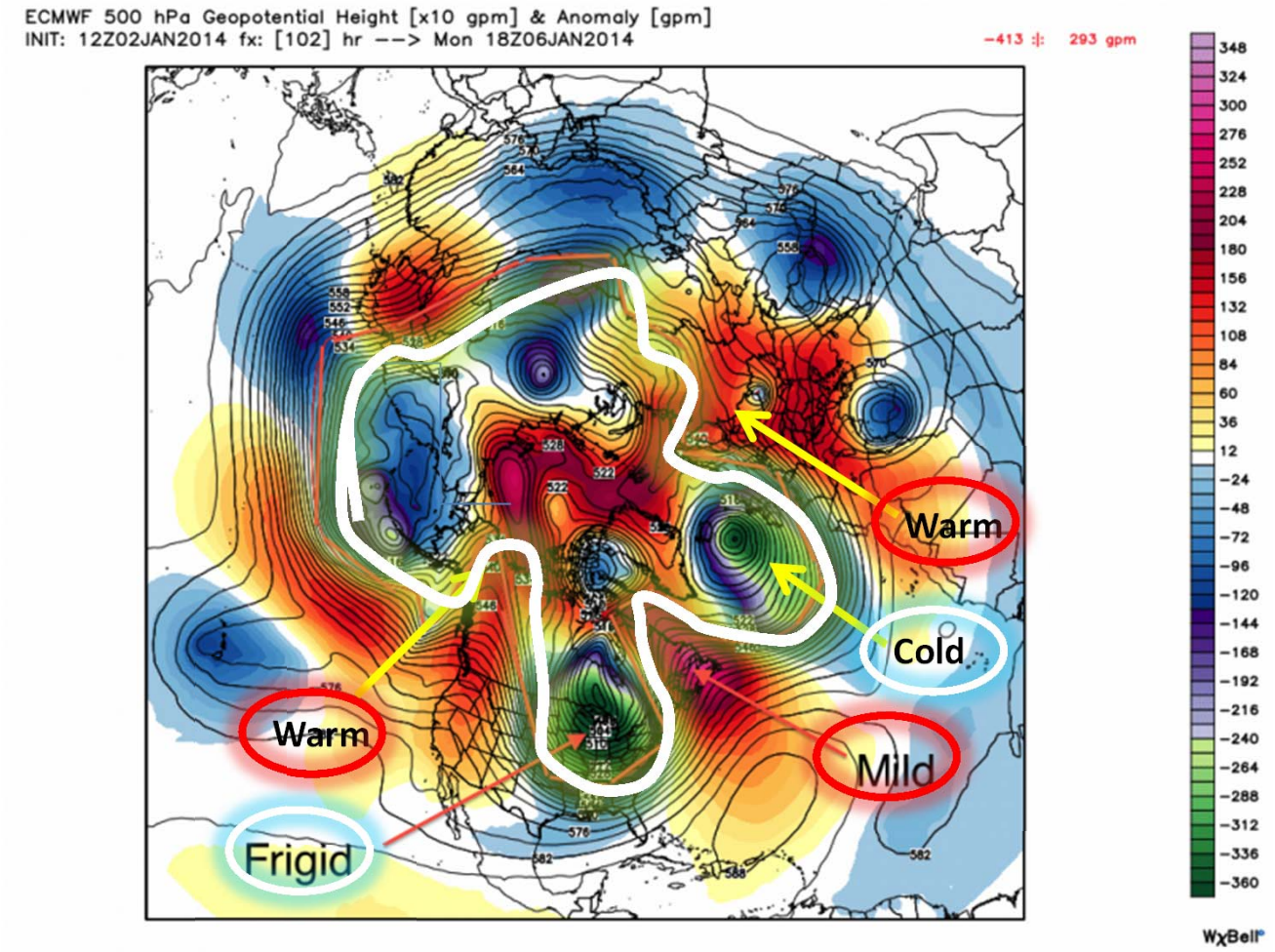
One Way Trip!



R. Kwok

Climate changes appears to increase the north-south range of the Jet Stream and slowing, even locking sometimes, it position over the northern hemisphere

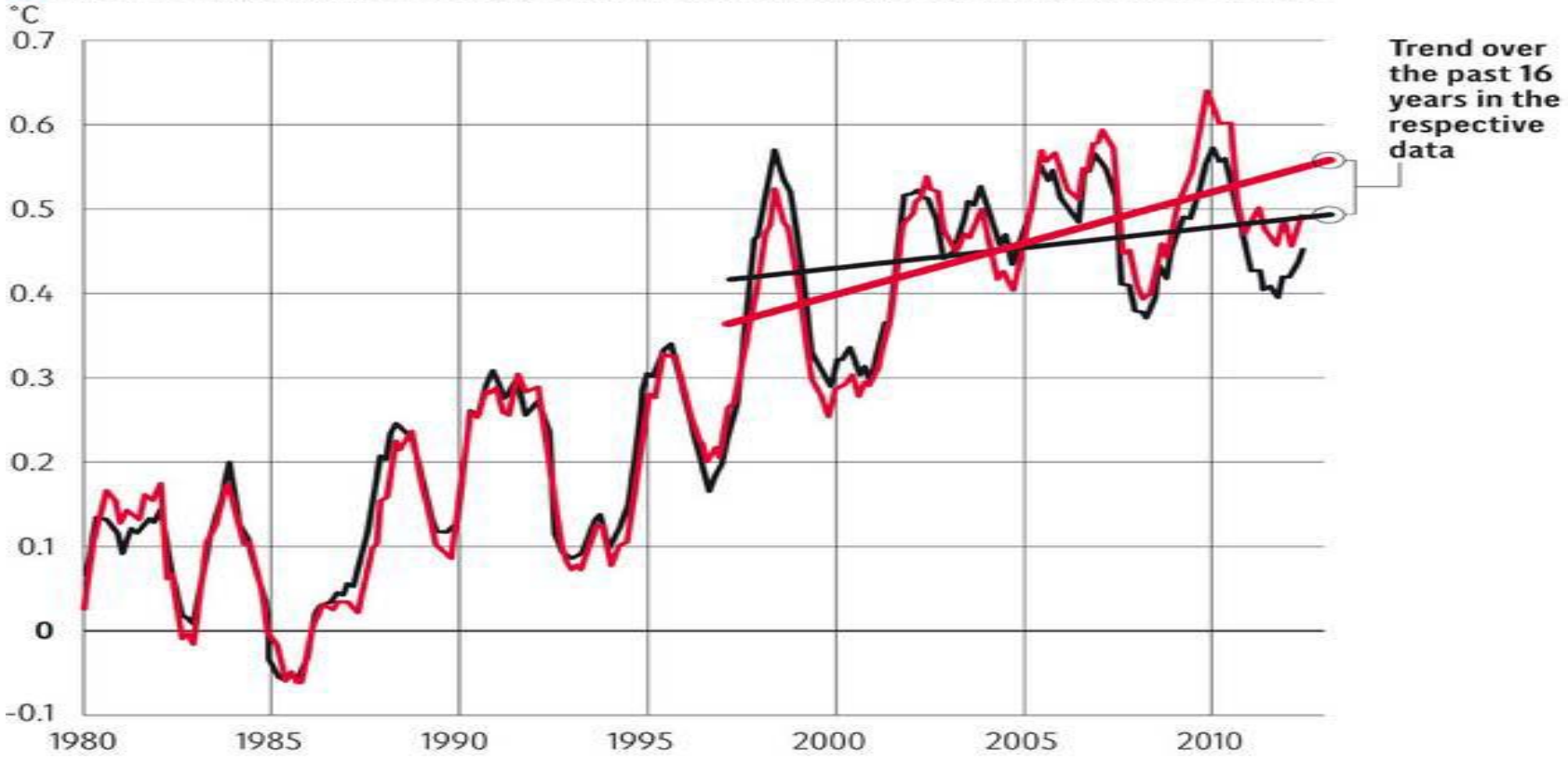
Attack of the Polar Vortex – Early January 2014



GLOBAL WARMING THE NEW PICTURE

TEMPERATURE CHANGE SINCE 1980

● MET OFFICE GLOBAL AVERAGE TEMPERATURES ESTIMATE
● NEW FIGURES TAKING INTO ACCOUNT FRESH ESTIMATES FOR THE ARCTIC SURFACE



The Met Office has temperature observations for only **84%** of the planet

SOURCE: KEVIN COWTAN AND ROBERT WAY

ARCTIC FRESHWATER SYNTHESIS

Components & Key Issues

Scientific Steering Group

Sponsors

Diagram by: Terry Prowse

INFORMATION FROM HISTORICAL TRENDS AND LITERATURE

ATMOSPHERE	OCEAN	TERRESTRIAL HYDROLOGY	TERRESTRIAL ECOLOGY	RESOURCES
• S-N "atmospheric rivers" • Poleward increases in precipitation	• FW effects on, and contributions from, sea ice growth/ablation	• Hydroclimatology of contributing catchments • Changes in storage • Soil moisture regimes/ effects of permafrost thaw	• Effects of water budget changes on vegetation regimes (greening)	• Sustainability of water supply for industrial development and communities
• Arctic effects on mid-latitude hydroclimates and extremes (e.g. floods/droughts)	• Controls of FW storage and release within the Arctic Ocean • FW pathways and constrictors (e.g., GIS)	• Contributions from shrinking cryosphere (e.g., glaciers/small ice caps/GIS)	• Related climatic effects: e.g., vegetation changes on radiation regimes/ source sink relationships for trace gases	• Threats from extremes: e.g. floods/droughts on infrastructure and people
• Resultant freshwater feedbacks to the Arctic	• Effects on thermohaline circulation & radiation regimes • Role in marine productivity	• River flow • Floods (open-water & ice regime) • Droughts	• Effects of FW/ cryosphere changes on lentic and lotic ecology/ productivity	• Engineering/design challenges with changing FW/ cryosphere regimes

INFORMATION FROM CLIMATE MODELS (Historical & Future)

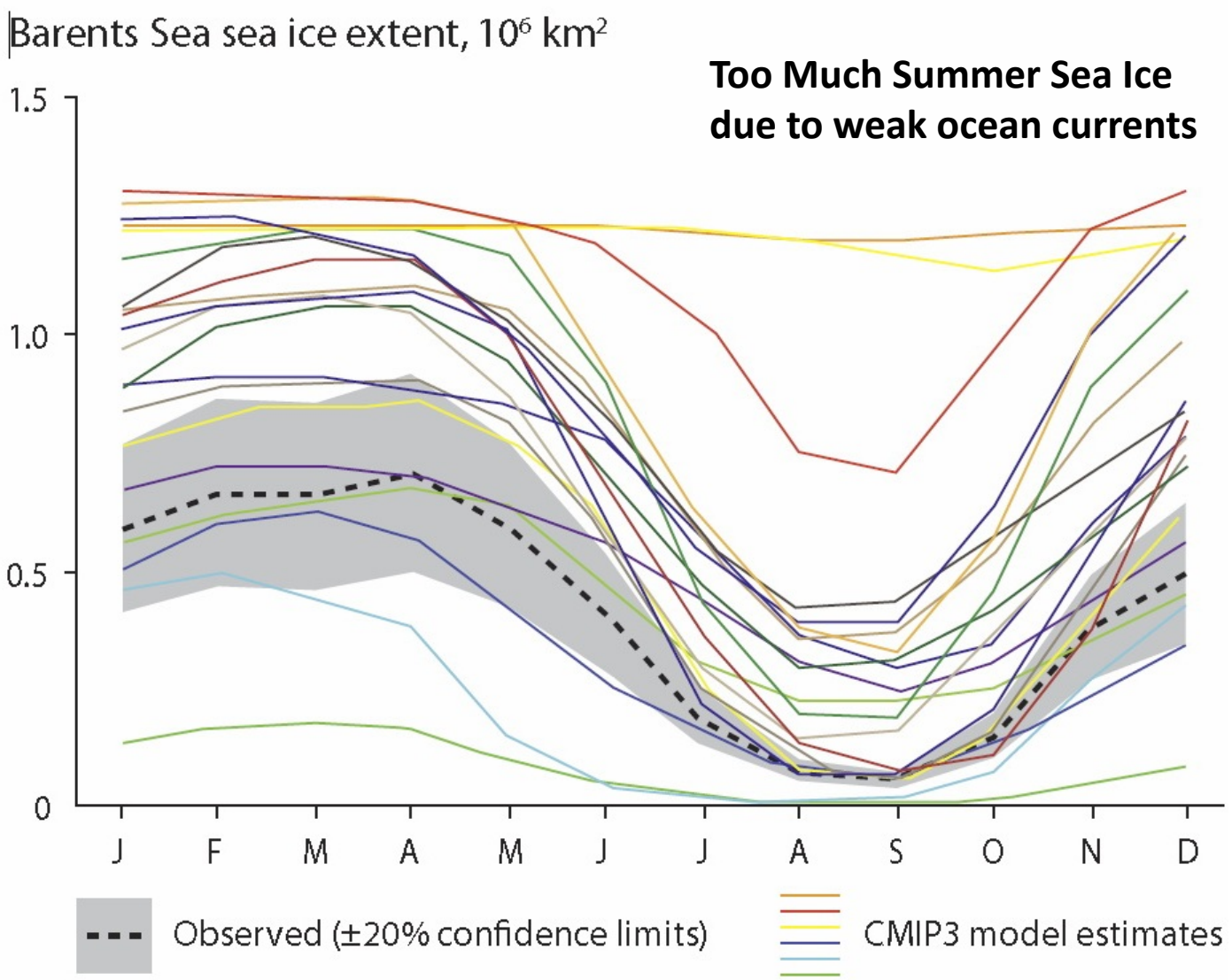
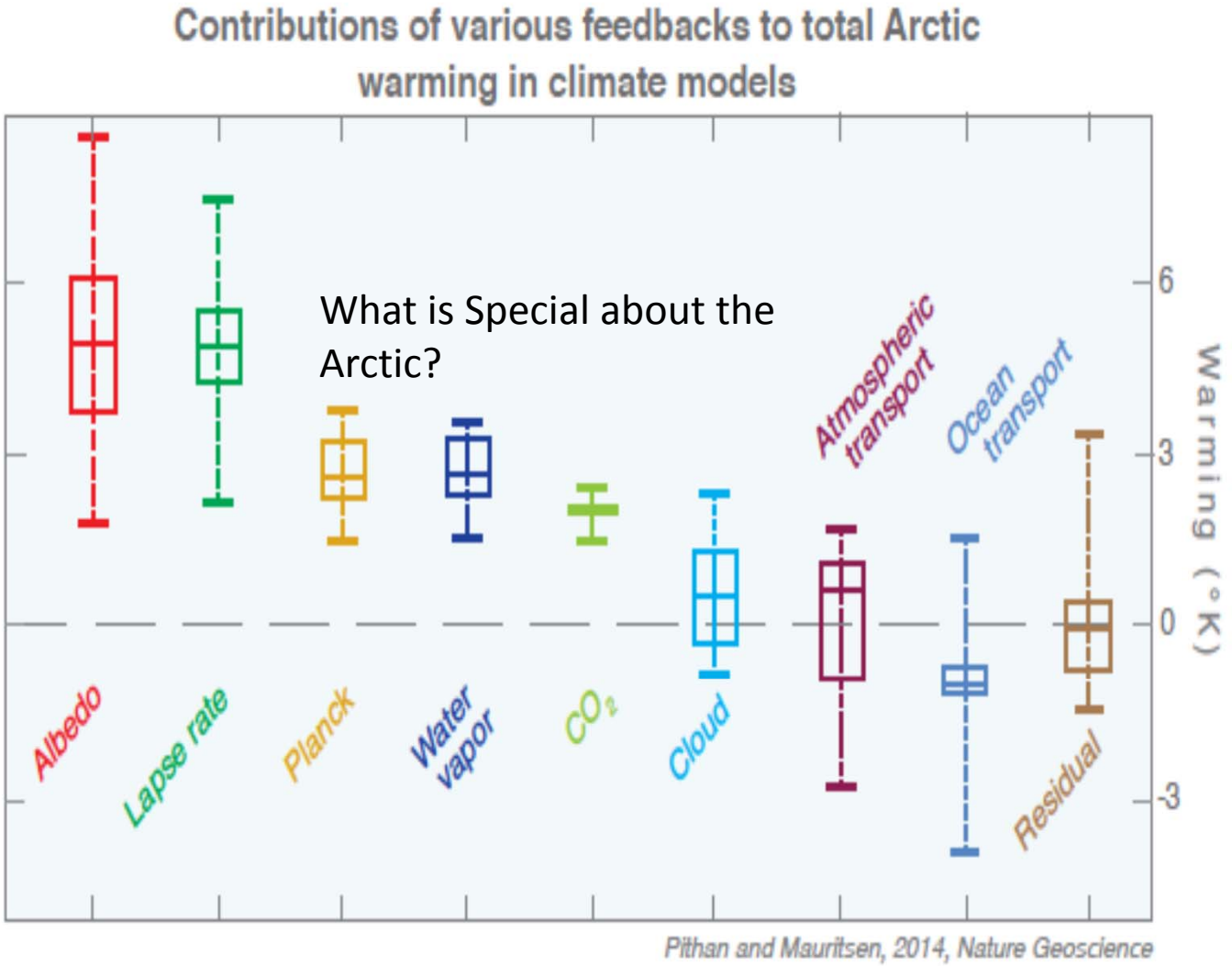


Figure 3.7. Seasonal cycle of sea ice in the Barents Sea according to various CMIP3 models. Note that most models show too much sea ice coverage. Source: modified version of figure 3 from Overland and Wang (2007).


Contributions of various feedbacks to total Arctic warming in climate models
What is Special about the Arctic?
Albedo
Lapse rate
Planck
Water vapor
CO_2
Cloud
Atmospheric transport
Ocean transport
Residual
6
3
0
-3
Warming (°K)
Pithan and Mauritsen, 2014, Nature Geoscience