Polar Science:
Arctic Environmental Change

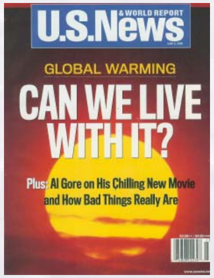
Peter Schlosser

Columbia University, New York

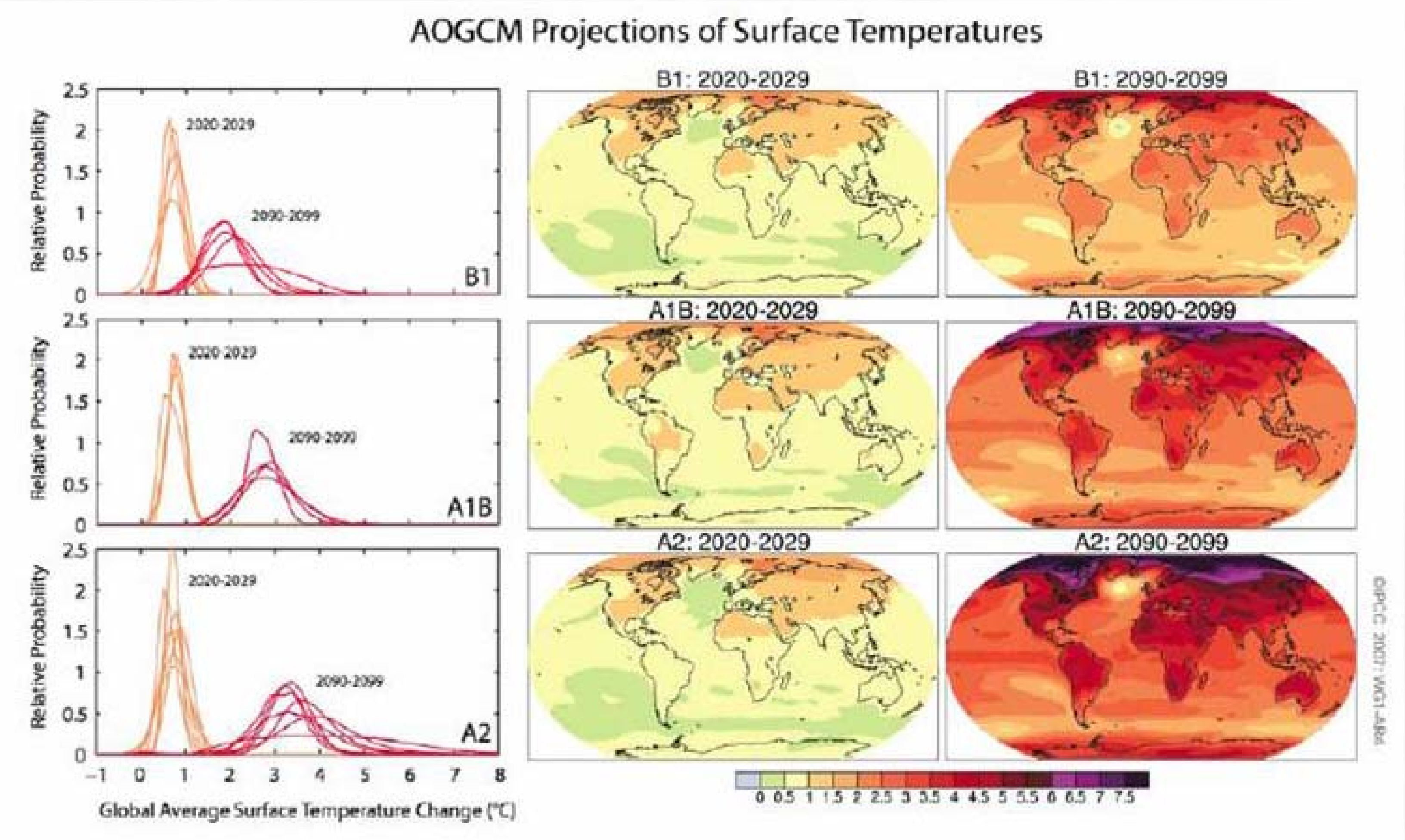
CLIVAR Summit; Denver, July 7, 2010

Outline

- Recent changes in the Arctic
- Global connection: freshwater budget
- SEARCH
- Arctic Observing System
- Perspectives



IPCC 2007

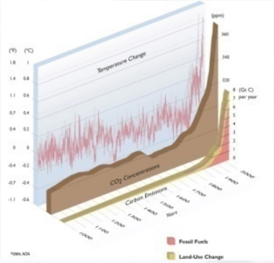


http://www.ipcc.ch/SPM2feb07.pdf

Recent changes in the Arctic

Recently, the Arctic has been characterized by a complex of rapid, interrelated, pan-Arctic changes e.g,

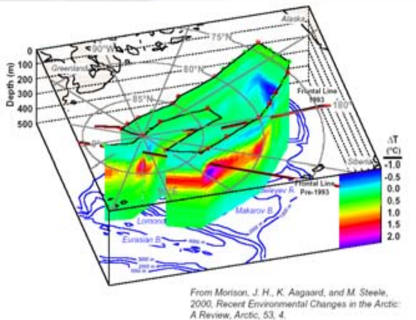
- **Reduced sea ice cover**
- **Warmer Atlantic waters,**
- **Increased air temperature over most of the Arctic,**
- **Warming of permafrost,**
- **Melting of Greenland ice sheet**

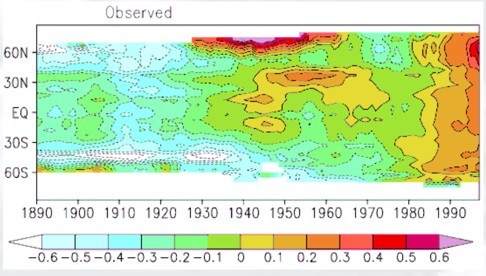


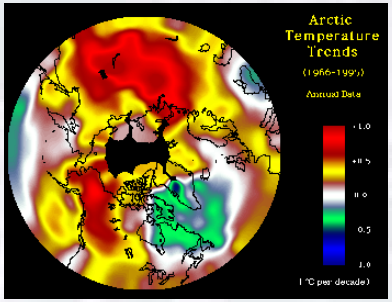
The physical changes have large impacts on the Arctic ecosystems and society.

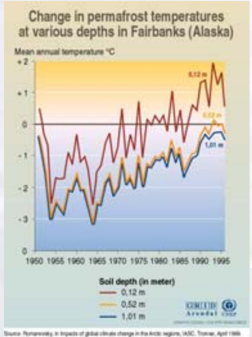
Anthropogenically driven climate change interacts with natural variability (SI and DECCEN time scales).

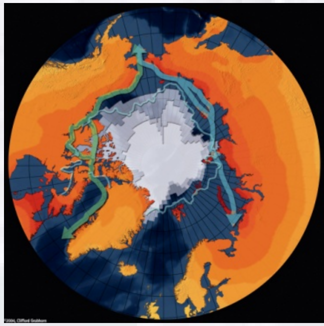
Adaptation and mitigation are needed to respond to the changes







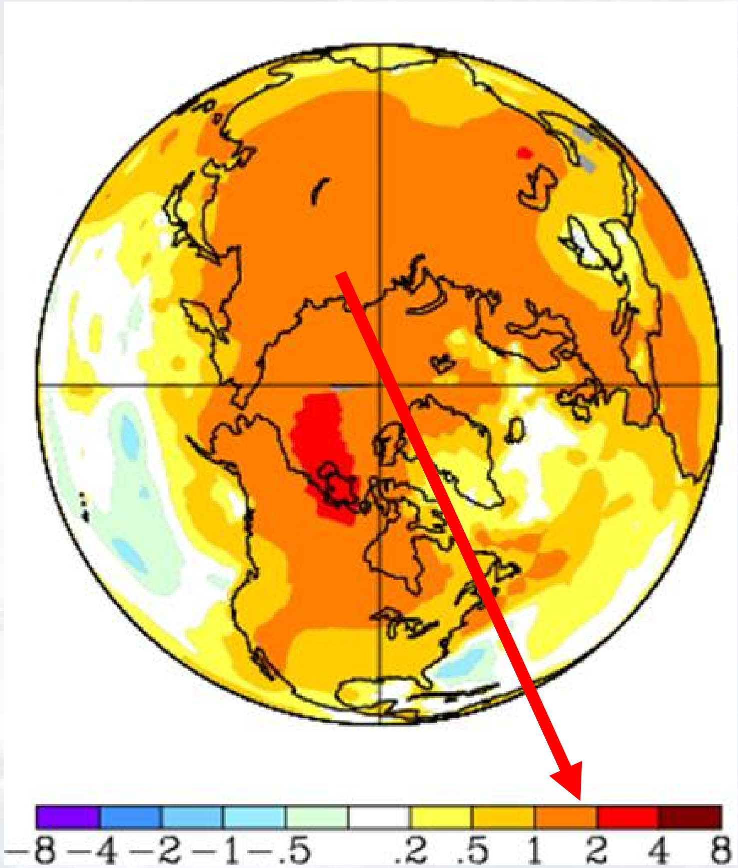




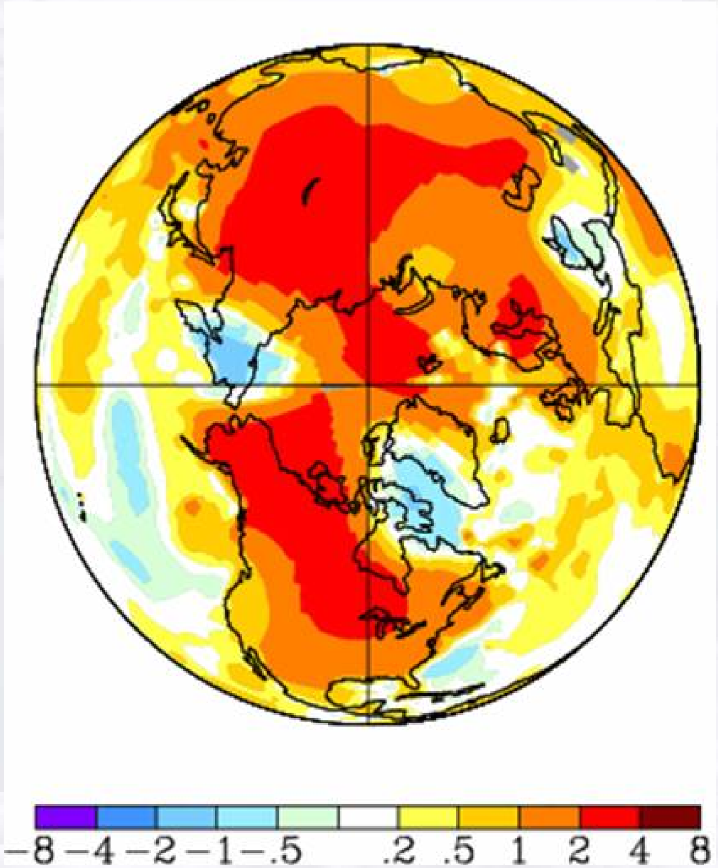
Recent observations: SAT

Change Surface Air Temperature (°C), 1957-2006 ***[from NASA GISS]***

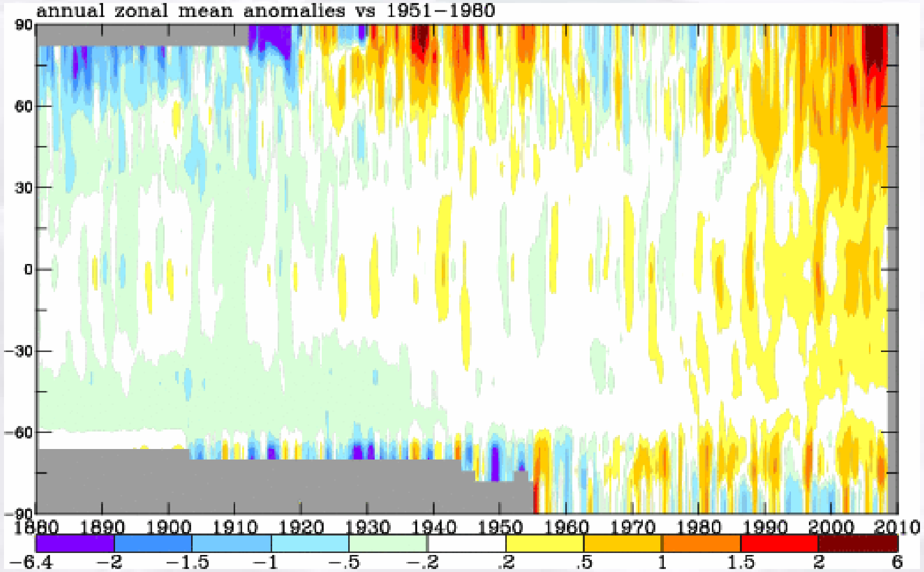
Annual

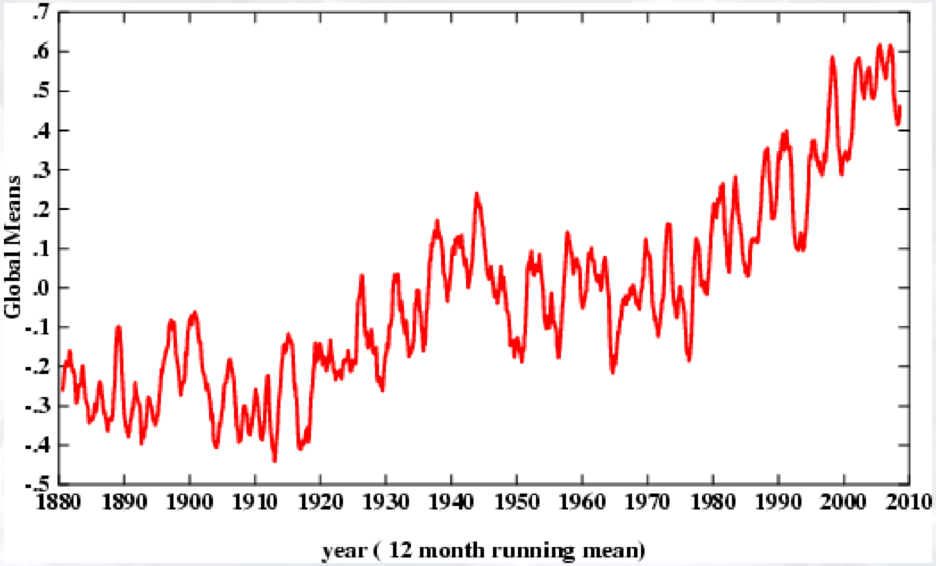


Winter



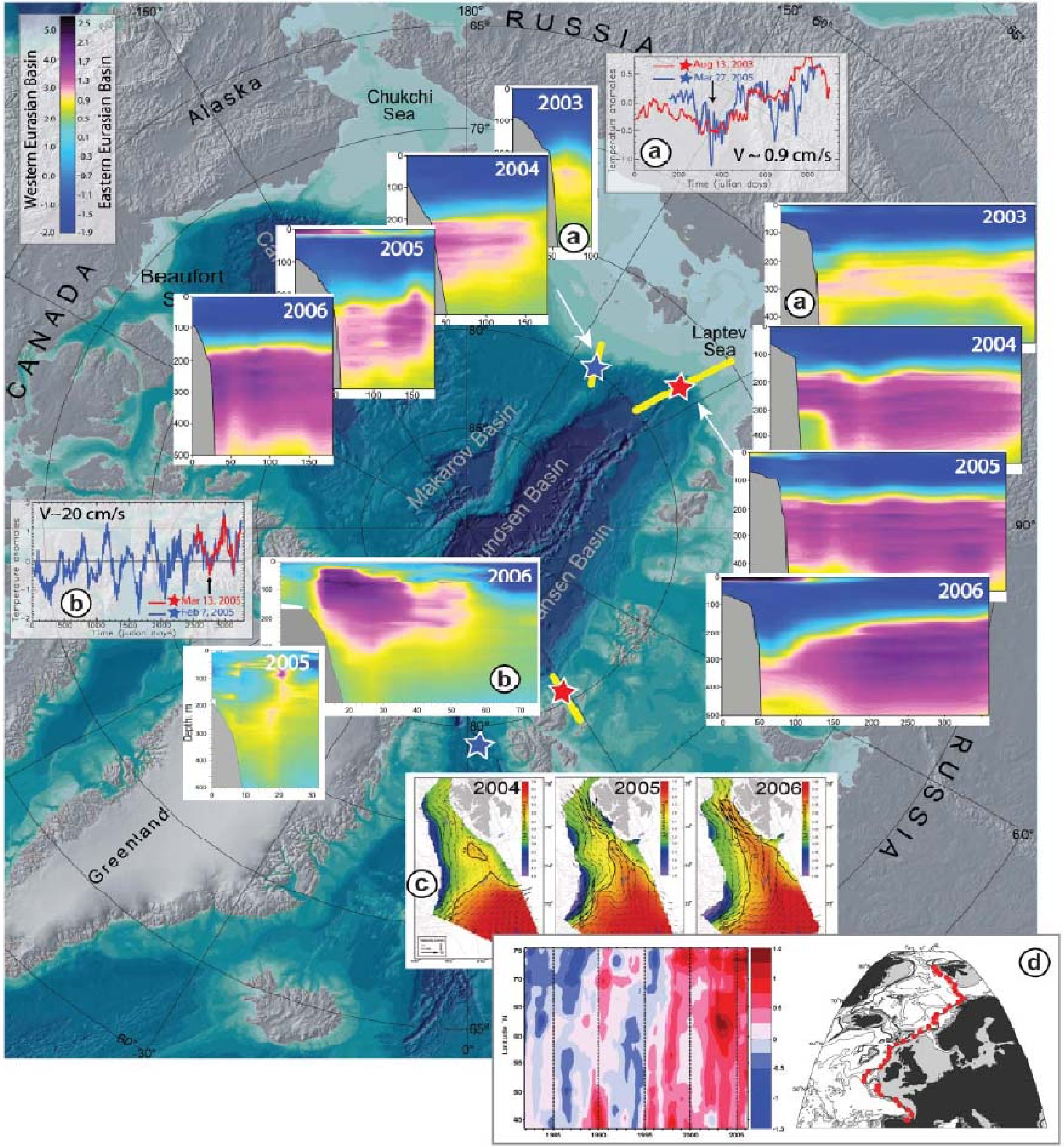
SAT changes





http://data.giss.nasa.gov/cgi-bin/cdrar/do_LTmapE.py

Eos, Vol. 88, No. 40, 2 October 2007



Warming of the Arctic Ocean

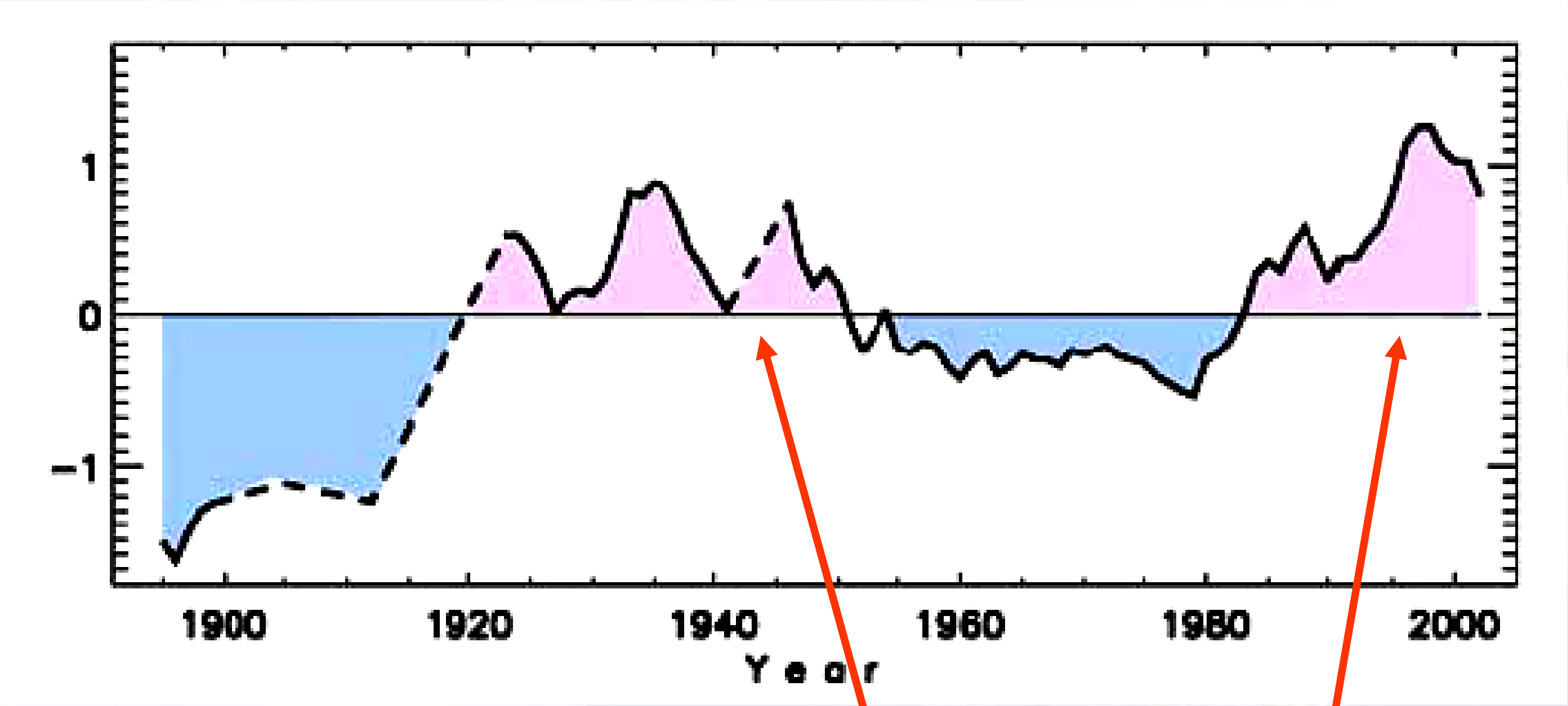
Polyakov et al., 2007

Observational Program Tracks Arctic Ocean Transition to a Warmer State

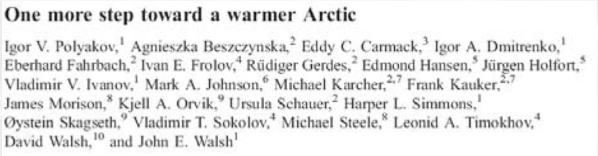
Eos, Vol. 88, No. 40, 2 October 2007

Temperature increase in core of AW of up to ca. 0.75°C; thicker AW layer

Trends? Or natural Variability?



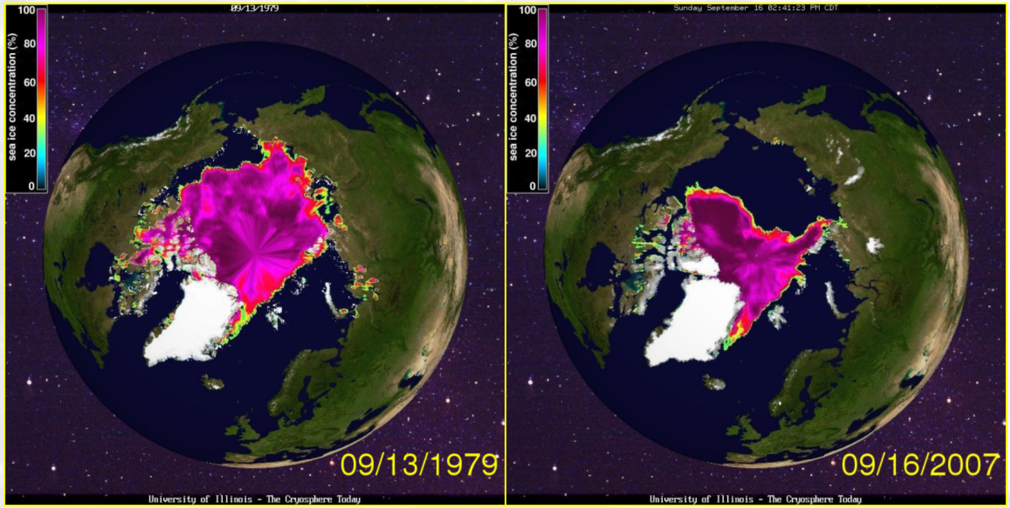
AW temperature: Variability or secular change?


One more step toward a warmer Arctic

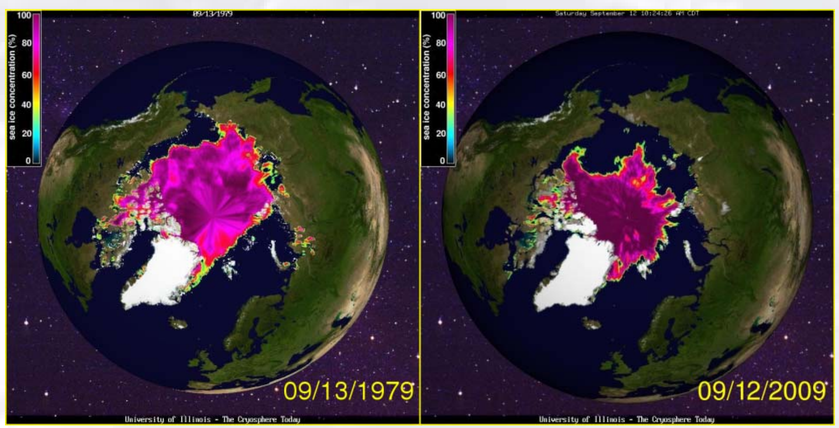
Igor V. Polyakov,[1] Agnieszka Beszczynska,[2] Eddy C. Carmack,[3] Igor A. Dmitrenko,[1] Eberhard Fahrbach,[2] Ivan E. Frolov,[4] Rüdiger Gerdes,[2] Edmond Hansen,[5] Jürgen Holfort,[5] Vladimir V. Ivanov,[1] Mark A. Johnson,[6] Michael Karcher,[2,7] Frank Kauker,[2,7] James Morison,[8] Kjell A. Orvik,[9] Ursula Schauer,[2] Harper L. Simmons,[1] Øystein Skagseth,[9] Vladimir T. Sokolov,[4] Michael Steele,[8] Leonid A. Timokhov,[4] David Walsh,[10] and John E. Walsh[1]

NABOS program, Polyakov et al.; IARC

Sea Ice Trends: Ice Extent



http://igloo.atmos.uiuc.edu/cgi-bin/test/print.sh?fm=09&fd=12&fy=1979&sm=09&sd=16&sy=2007



http://igloo.atmos.uiuc.edu/cgi-bin/test/print.sh?fm=09&fd=12&fy=1979&sm=09&sd=12&sy=2009

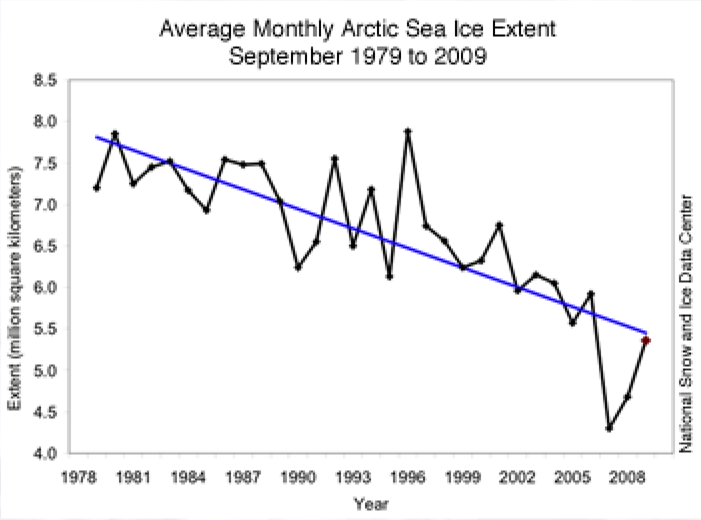
Sea-ice trends: ice extent

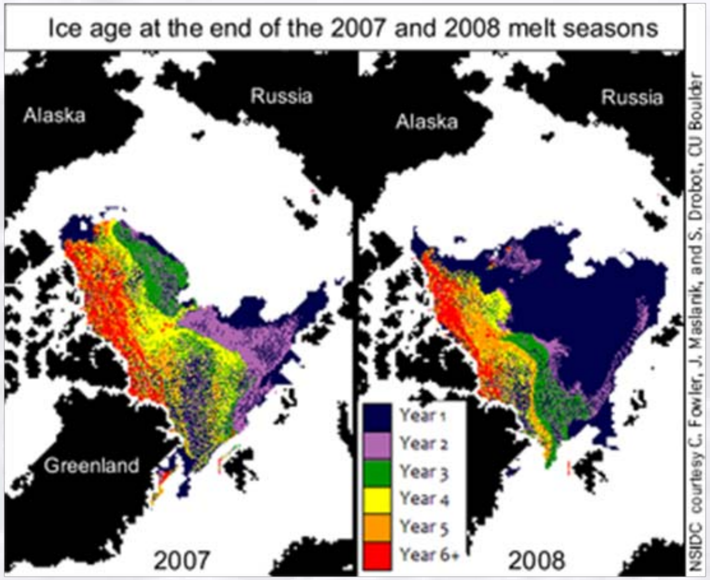
Arctic Sea Ice Down to Second-Lowest Extent

2007: Minimum sea ice extent

2008: Likely Record-Low Volume

Abrupt changes will present surprises



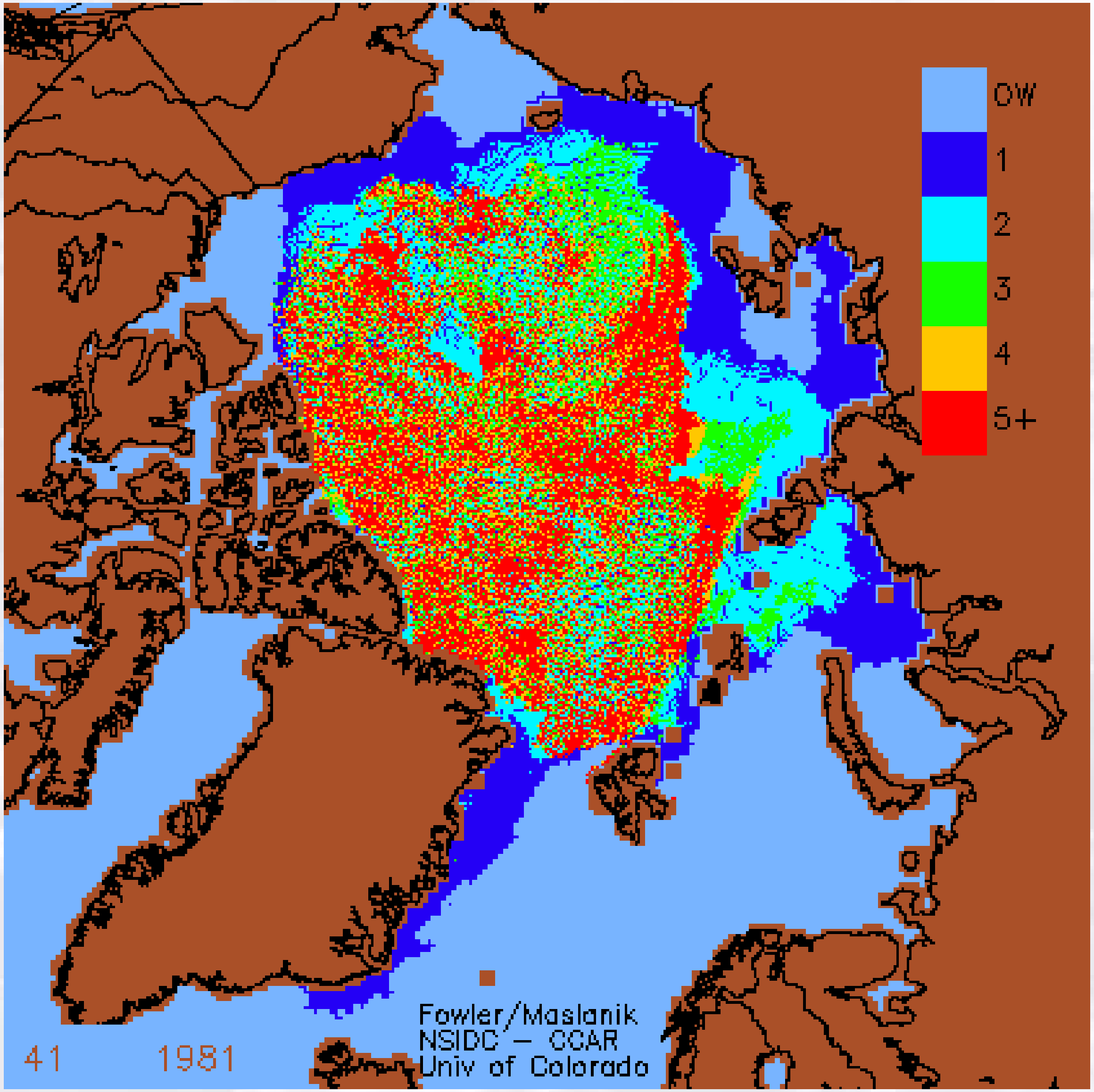


http://nsidc.org/news/images/20081002_Figure3.png

http://nsidc.org/arcticseaicenews/

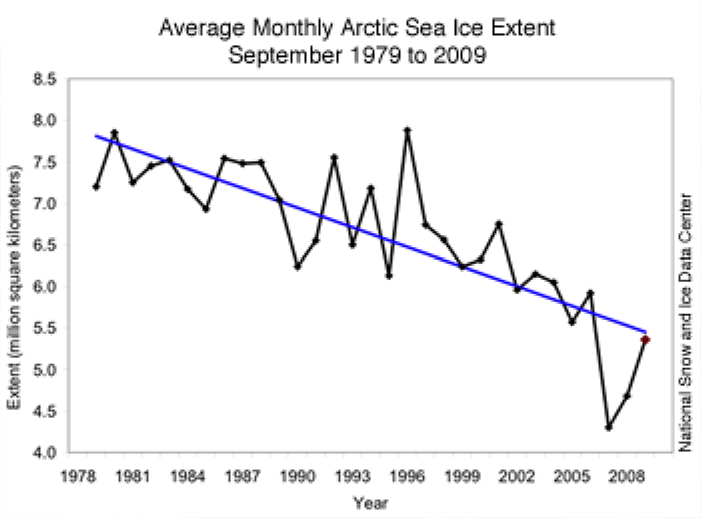
Sea-ice trends

Disappearance of old sea ice between 1982 and 2007



Credit: Animation from NSIDC courtesy of C. Fowler and J. Maslanik; Colorado Center for Astrodynamics Research.

Sea-ice trends: ice extent

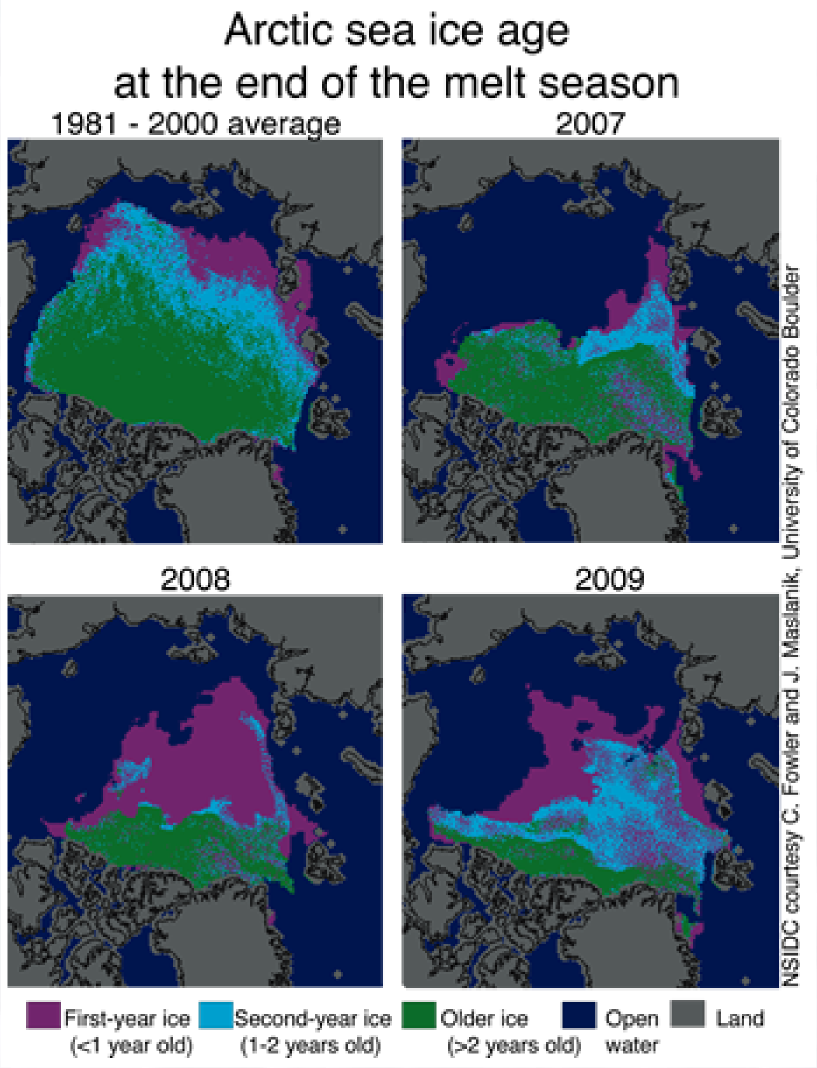


-11.2% per decade

Non-linear systems

Abrupt changes

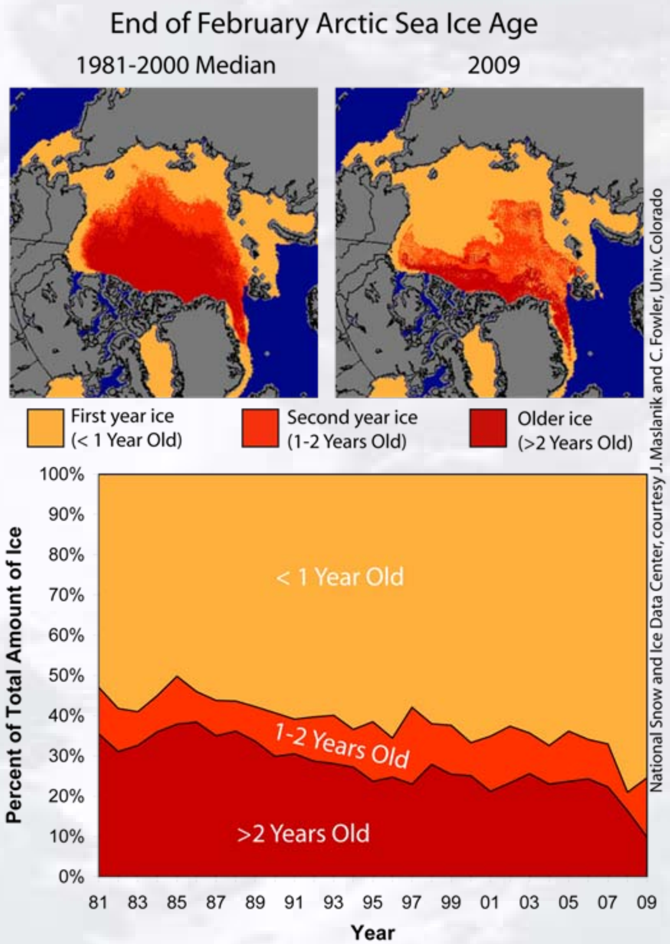
Need to learn how to interpret data from observing systems



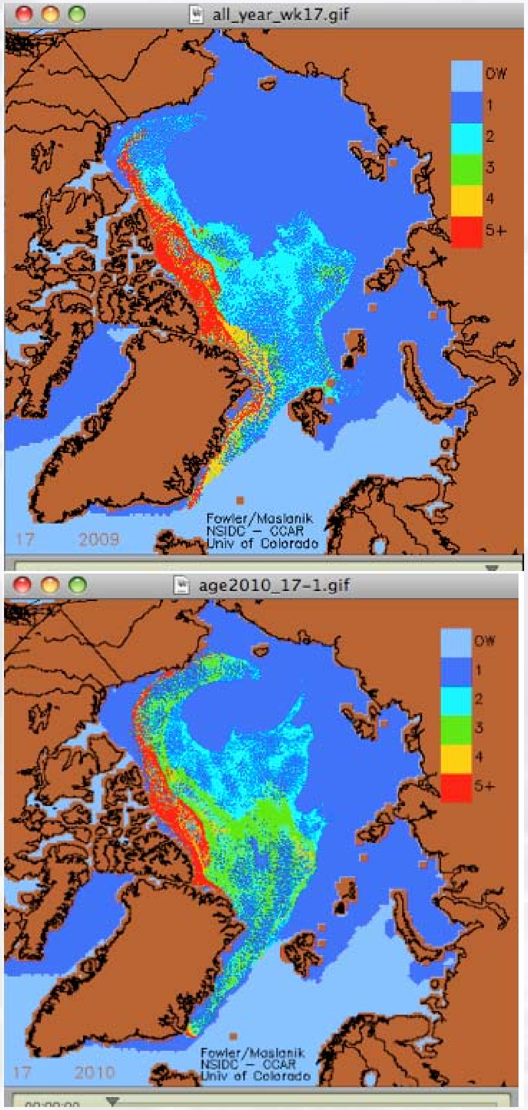
http://nsidc.org/news/press/20091005_minimumpr.html

Sea-ice trends

Disappearance of old sea ice

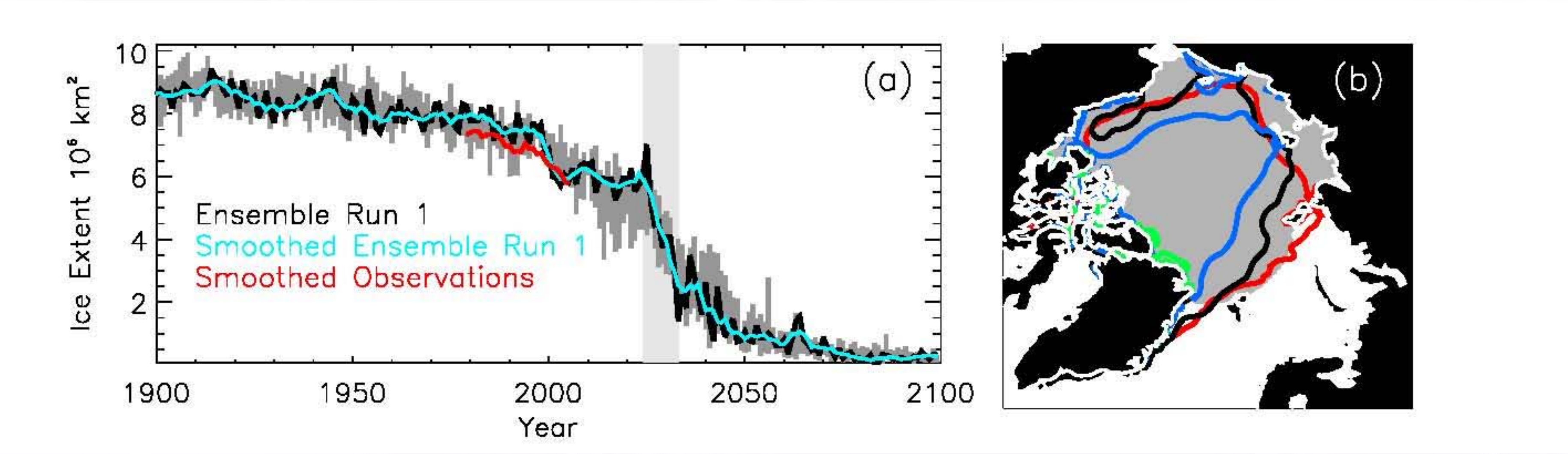


http://nsidc.org/images/arcticseaicenews/20090406_Figure5.png



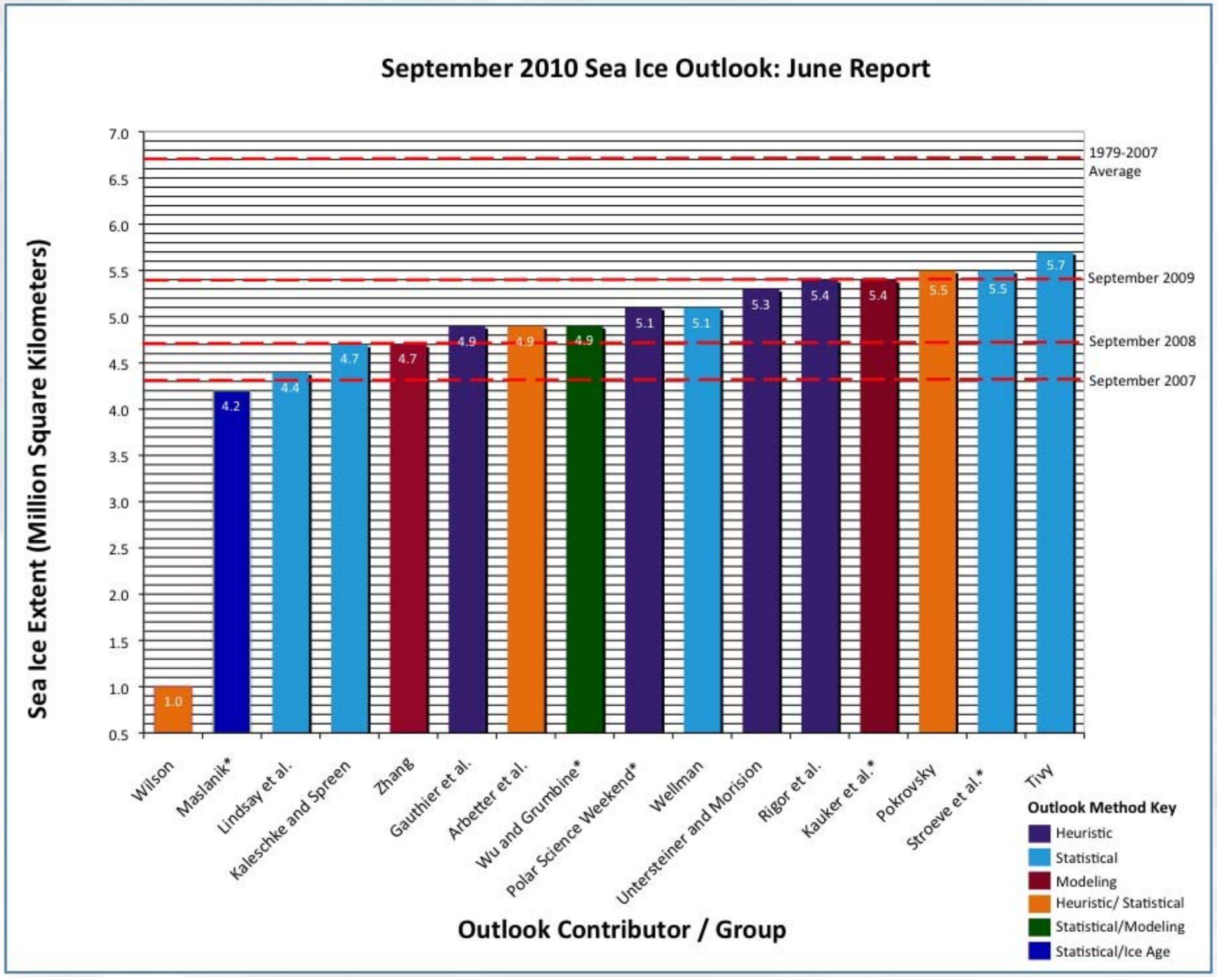
http://www.arcus.org/search/seaiceoutlook/2010/june

Sea-ice trends: projections



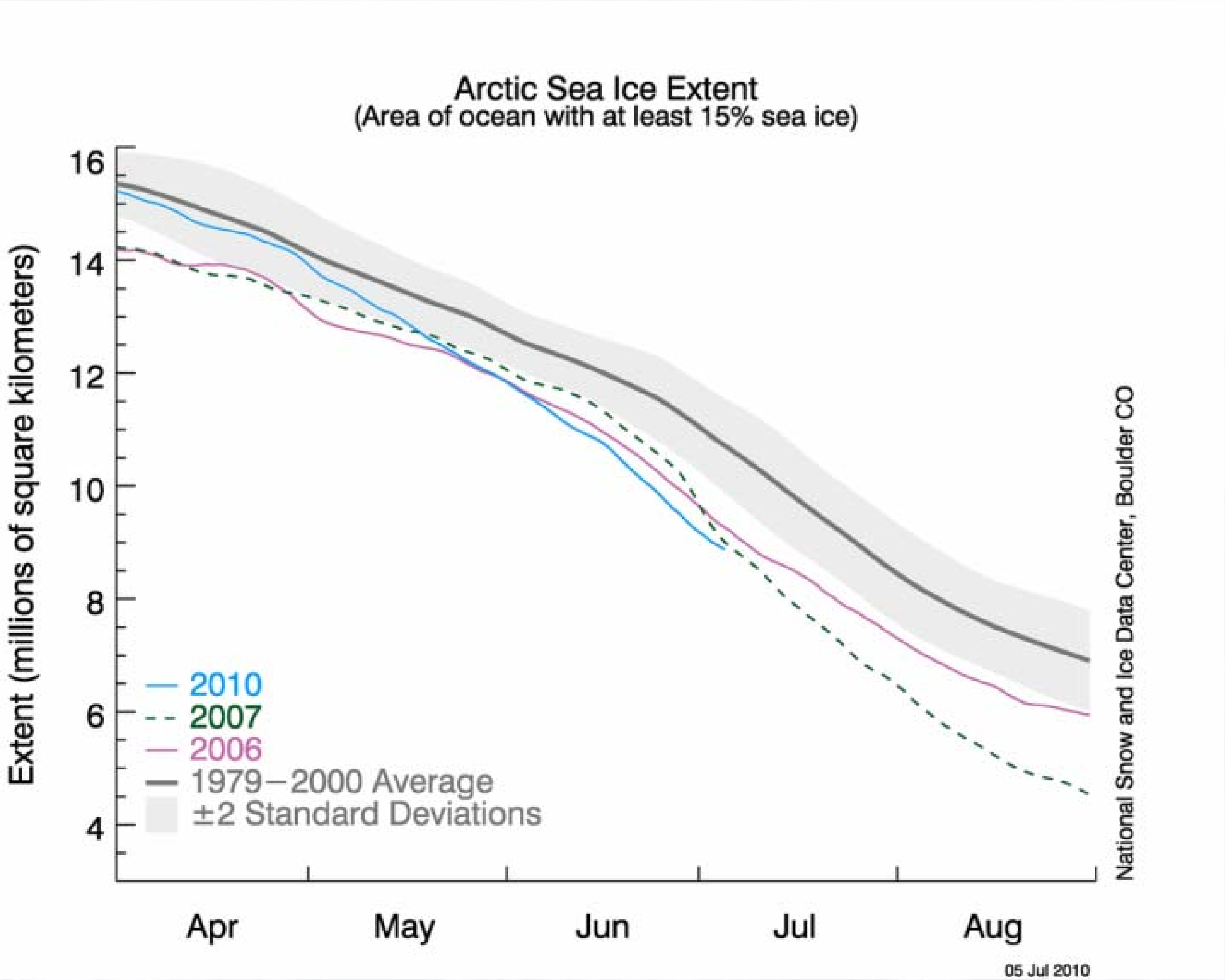
Holland et al., 2006

Sea-ice trends: outlooks



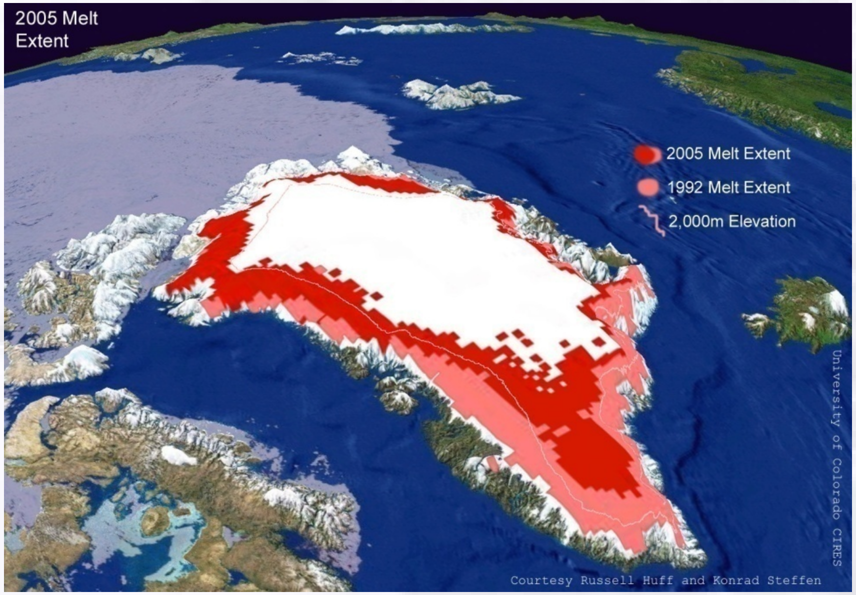
SEARCH Sea Ice Outlook, June 2010;
http://www.arcus.org/files/search/sea-ice-outlook/2010/06/images/summary/sioresultschartfig1rev_0.jpg

Sea-ice trends: ice extent



http://nsidc.org/arcticseaicenews/

Greenland Ice Sheet



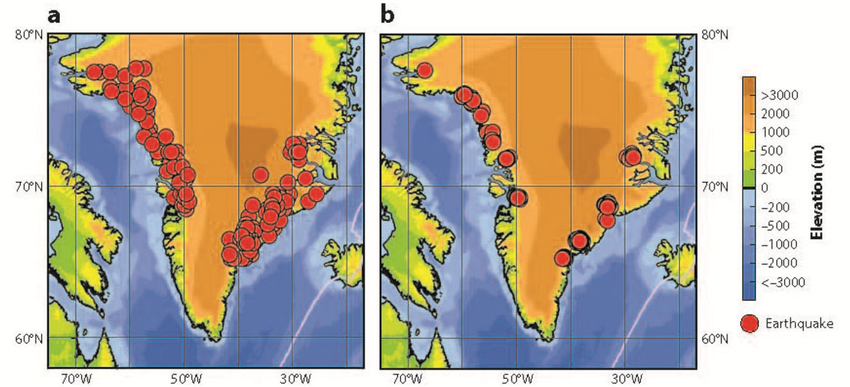


Figure 2

(*a*) Map showing 252 glacial earthquakes in Greenland for the period 1993–2008, detected and located using the surface-wave detection algorithm. (*b*) Map showing the improved locations of 184 glacial earthquakes for the period 1993–2005 analyzed in detail by Tsai & Ekström (2007). Note the tight clustering of the relocated earthquake epicenters near major outlet glaciers.

Glacial Earthquakes in Greenland and Antarctica

Meredith Nettles and Göran Ekström

Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York 10964; email: nettles@ldeo.columbia.edu

Annu. Rev. Earth Planet. Sci. 2010. 38:467–91

First published online as a Review in Advance on February 25, 2010

NSIDC

http://cires.colorado.edu/science/groups/steffen/greenland/melt2005/melt2005and1992.5inch.jpg

$V = 2.8 \cdot 10^6$ km^3

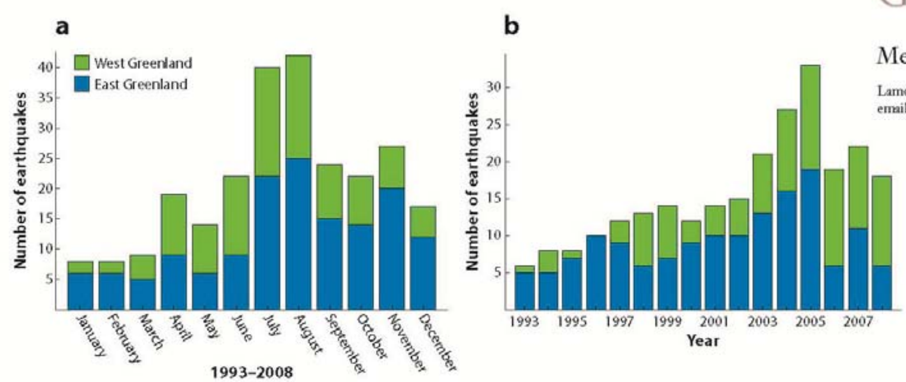
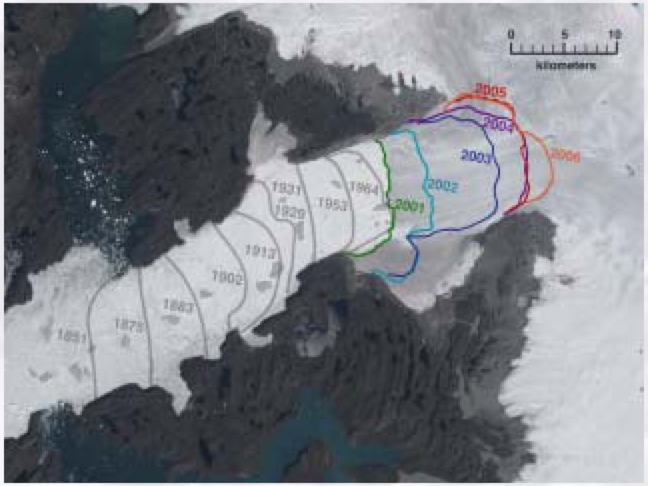


Figure 3

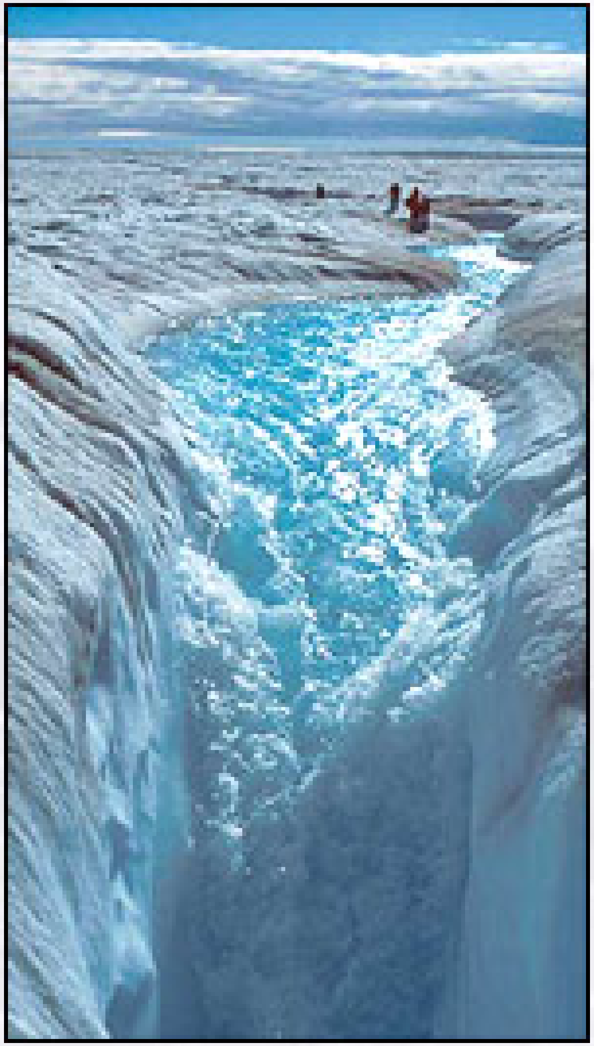
(*a*) Histogram showing seasonality of glacial earthquakes in Greenland based on detections for 1993–2008. Bars show the number of earthquakes per month detected in Greenland. (*b*) Histogram showing the number of glacial earthquakes detected in Greenland each year since 1993.

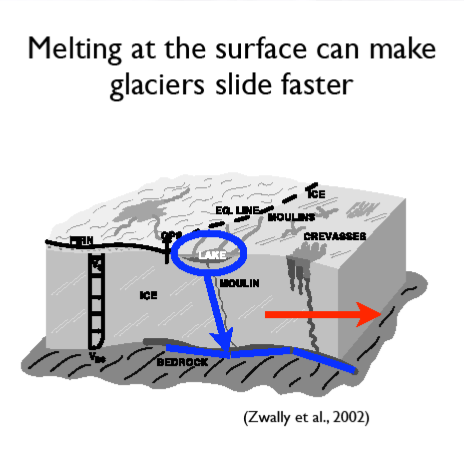
The melt area is increasing … and the slip seems to accelerate

Greenland Ice Sheet



http://svs.gsfc.nasa.gov/vis/a000000/a003300/a003395/JakobshavnOverheadWdates.1024_web.png





Faster flow of outlet glaciers … and faster interaction between surface and grounding line

Thawing permafrost

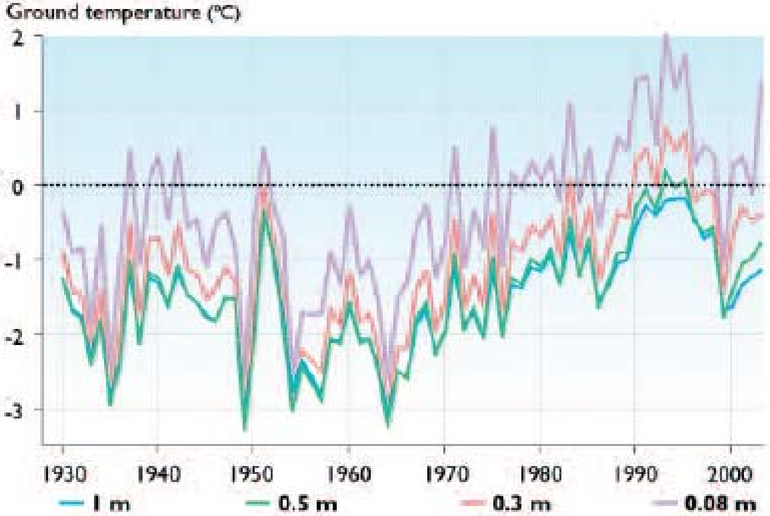
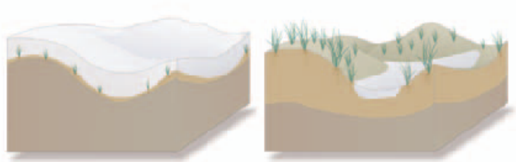


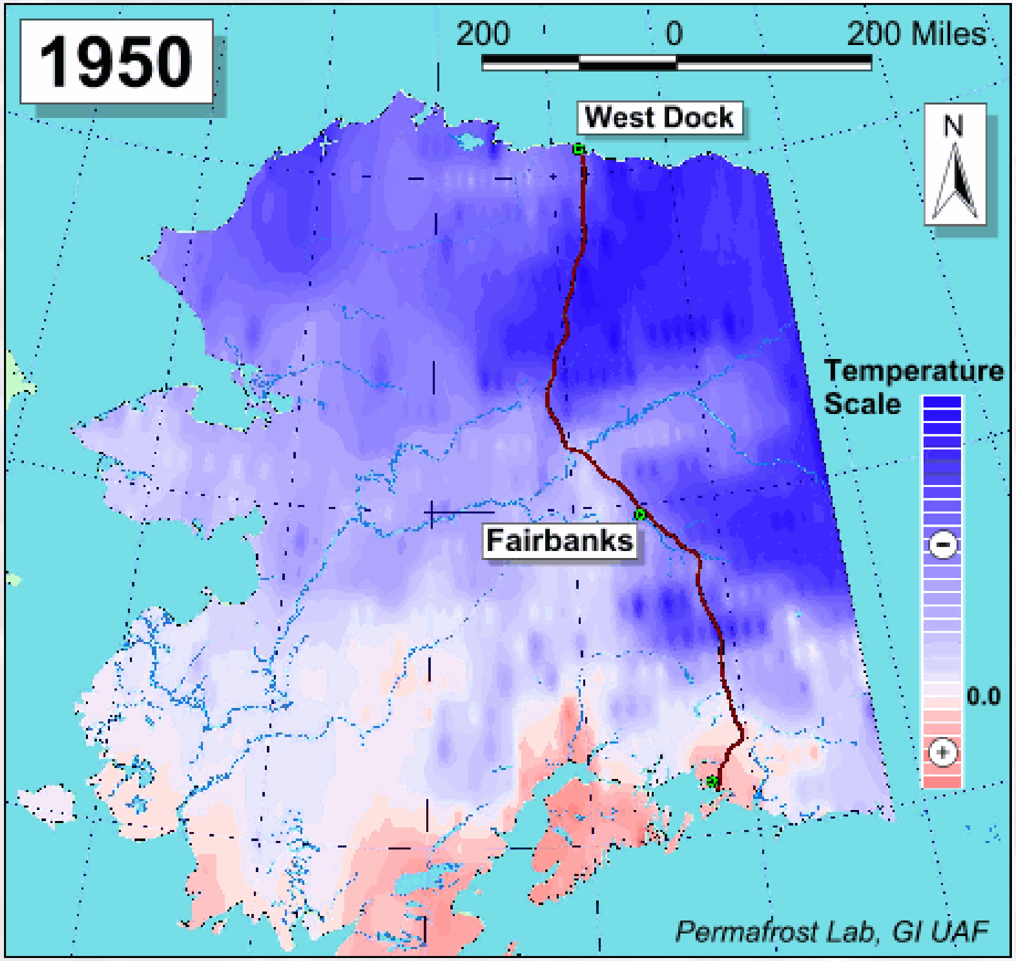
Fig. 6.22. Simulated mean annual ground temperature at Fairbanks (Bonanza Creek), Alaska, from 1930 to 2003 (V. Romanovsky, 2004).

ACIA, 2004

Seasonal Changes in Permafrost

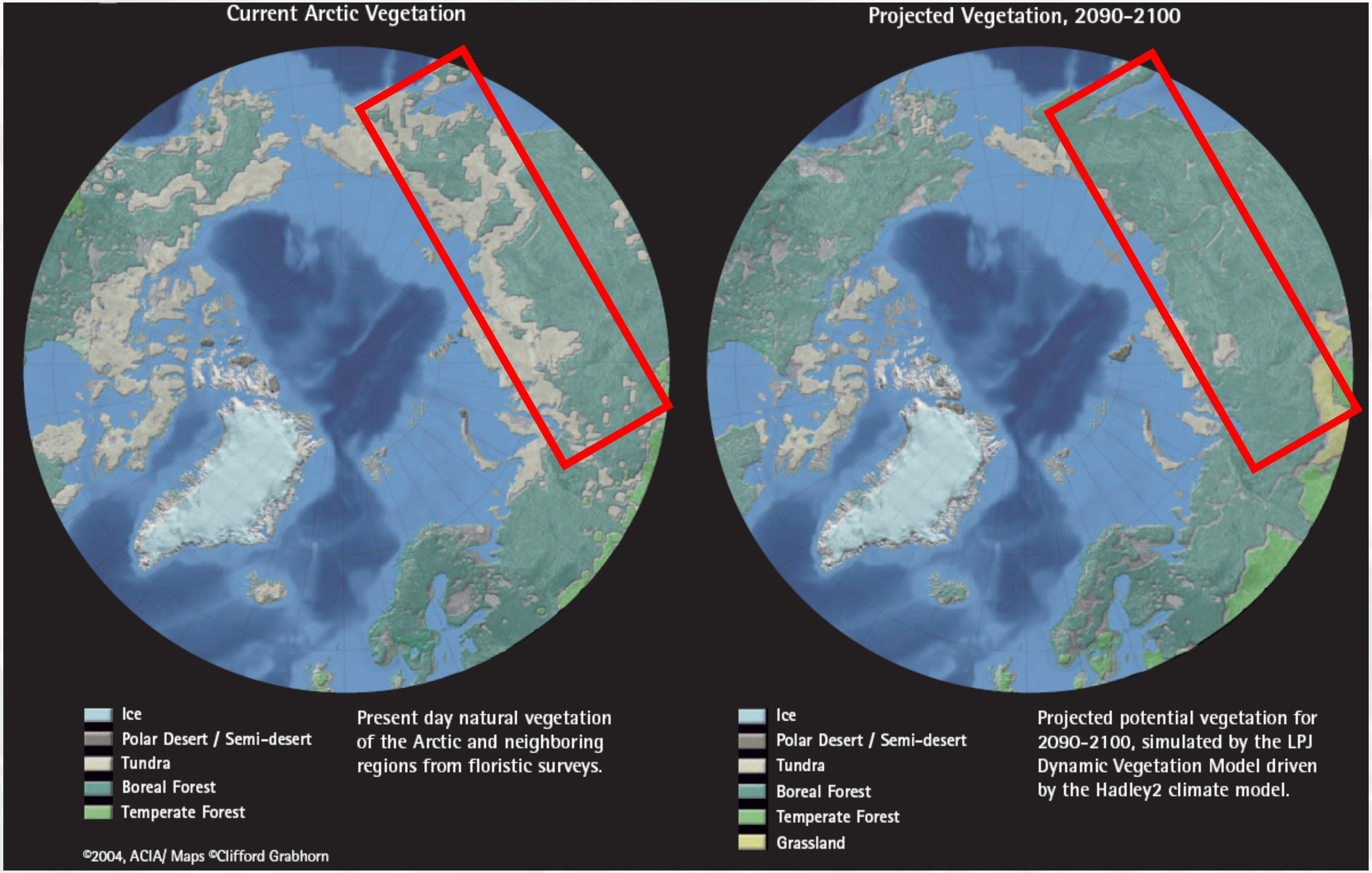


Active layer refers to the top layer of permafrost that thaws each year during the warm season and freezes again in winter.



http://www.gi.alaska.edu/snowice/Permafrost-lab/projects/projects_active/proj_processes_magt1m.html

Shift in vegetation zones



Synthesis

EOS
EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

Arctic System on Trajectory to New, Seasonally Ice-Free State

VOLUME 86 NUMBER 34
23 AUGUST 2005
PAGES 309–316

Big Sky meeting, 2003

20 plus scientists from diverse backgrounds

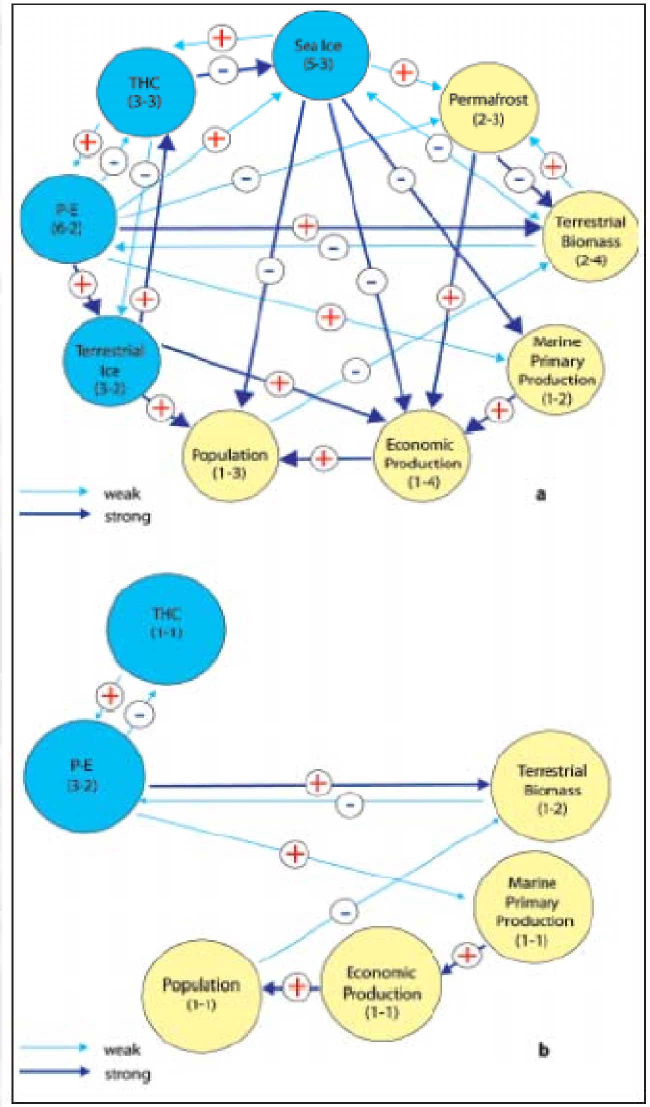
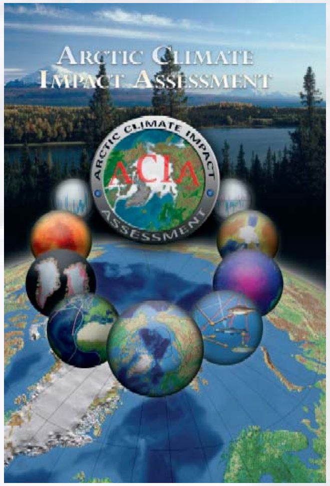
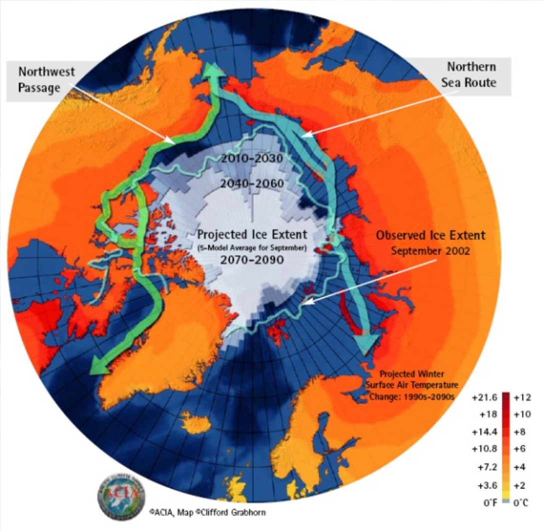
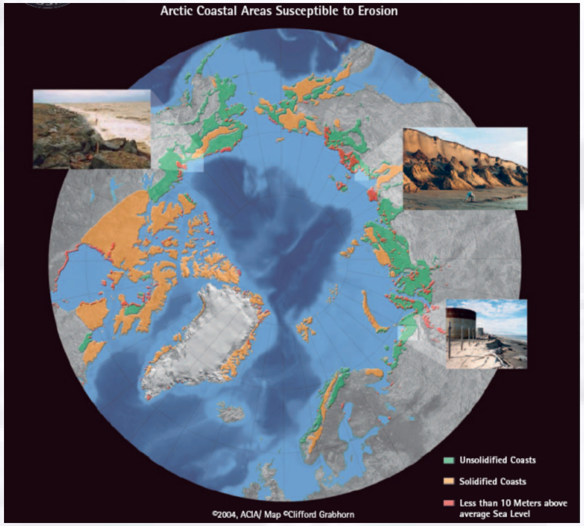


Fig. 2. (a) Schematic of the essential components (or hubs) of the present Arctic system. The main interactions between hubs are denoted by arrows: Single or double arrowheads indicate one- or two-way interactions. Interaction strength is designated by arrow thickness, and the sign (plus or minus) indicates whether a change in one component produces a change in another of the same (plus) or opposite (minus) sign. Numbers in parentheses within each hub indicate the number of interactions going out of, and coming into, that hub. Driver hubs are blue; recipient hubs are yellow. (b) The Arctic system in the future after loss of substantial permanent ice.

Impacts








The New York Times

Alaska Thaws, Complicating the Hunt for Oil

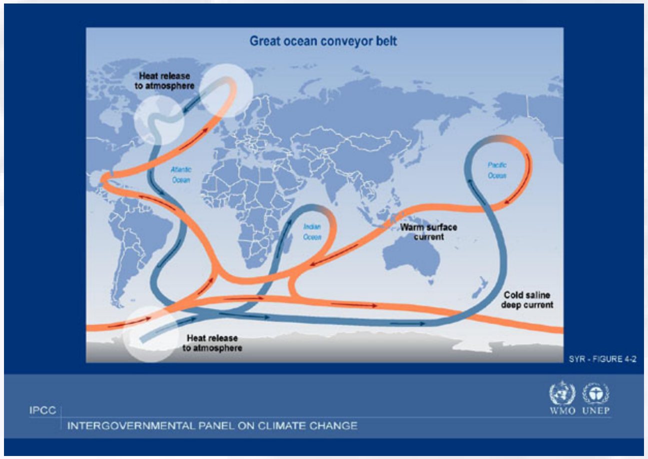
To gain a greater understanding of the tundra's ability to withstand oil exploration, heavy vehicles are sent to perform Figure 8's every two weeks throughout the winter. In the summer, Alaskan officials assess the damage.

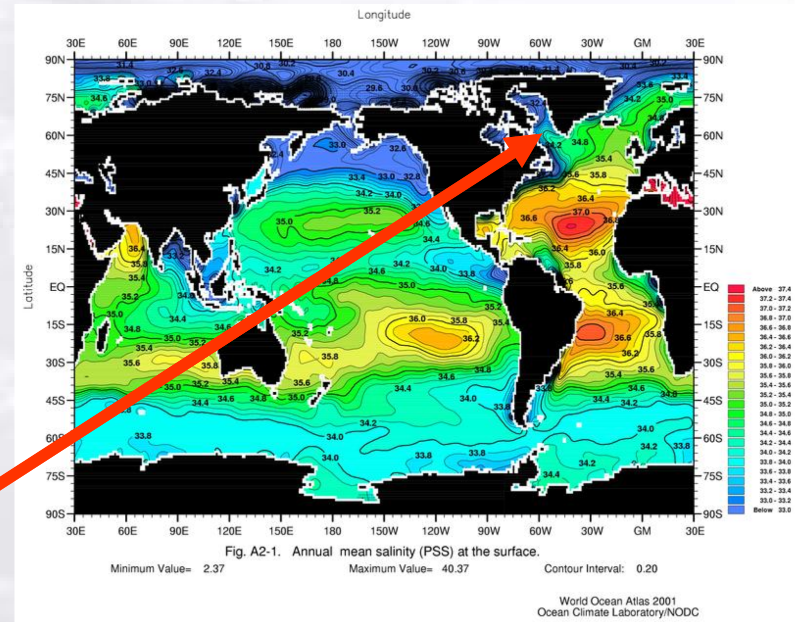
Impacts

Climate Change as part of Environmental Change

- *Climate Change can not be seen in isolation*
- *In principle, the same human-induced pressures that are forcing the climate system towards a new state have significant effects on other environmental systems such as water resources, ecosystems, food supply, etc.*
- *The physical changes have large impacts on the Arctic ecosystems and society.*
- *Adaptation and mitigation are needed to respond to the changes*

Arctic feedback on global climate: Freshwater connection

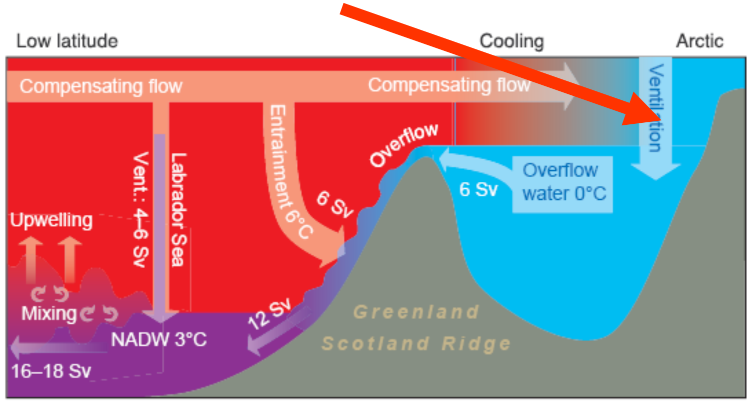




'Great Ocean Conveyor Belt' principle; Broecker, 1991

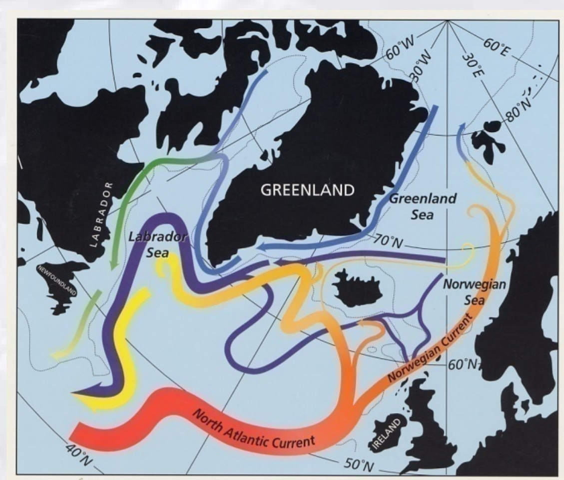
Freshwater export from Arctic to North Atl.

Heat transfer from ocean to atmosphere



Already the Day After Tomorrow?

Bogi Hansen, Svein Østerhus, Detlef Quadfasel, William Turrell



Arctic and global climate: Future conveyor shutdown?

Key Questions:

- Can changes in freshwater fluxes from the Arctic to the North Atlantic shut down the conveyor (MOC, THC)?
- What would be the consequences of a conveyor shutdown in a greenhouse world?

The Arctic freshwater reservoir

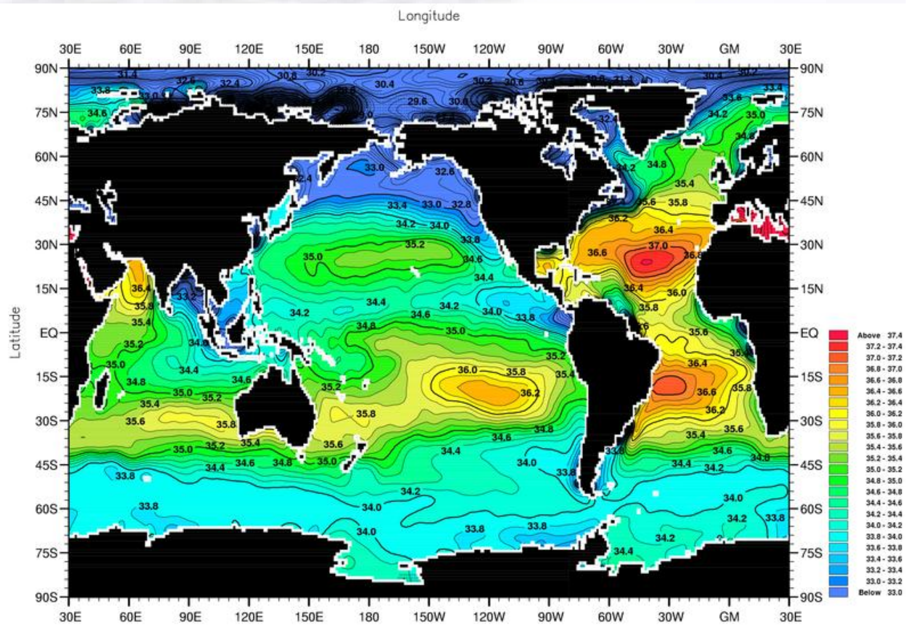


Fig. A2-1. Annual mean salinity (PSS) at the surface.

Minimum Value= 2.37 Maximum Value= 40.37 Contour Interval: 0.20

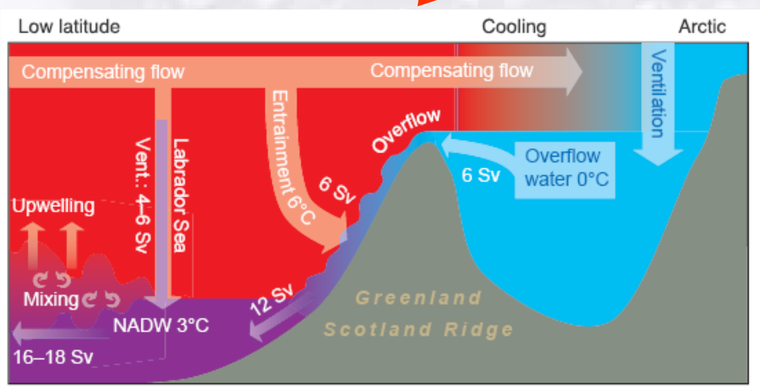
World Ocean Atlas 2001
Ocean Climate Laboratory/NODC

Arctic and global climate: Freshwater connection

'Great Ocean Conveyor Belt' principle; Broecker, 1991

Freshwater export from Arctic to North Atl.

Heat transfer from ocean to atmosphere



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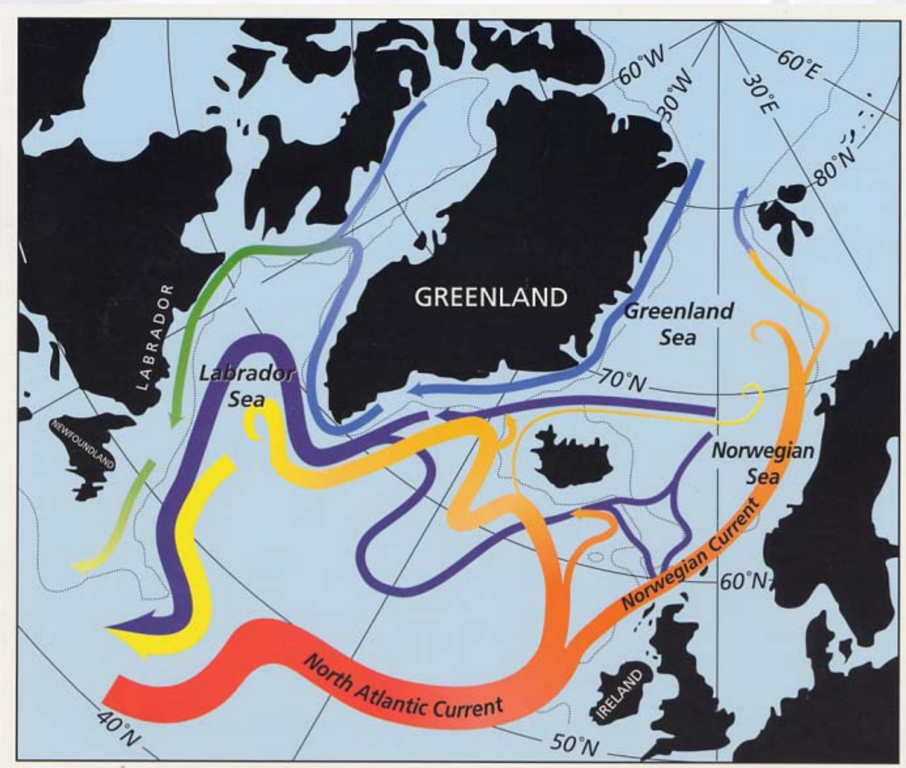
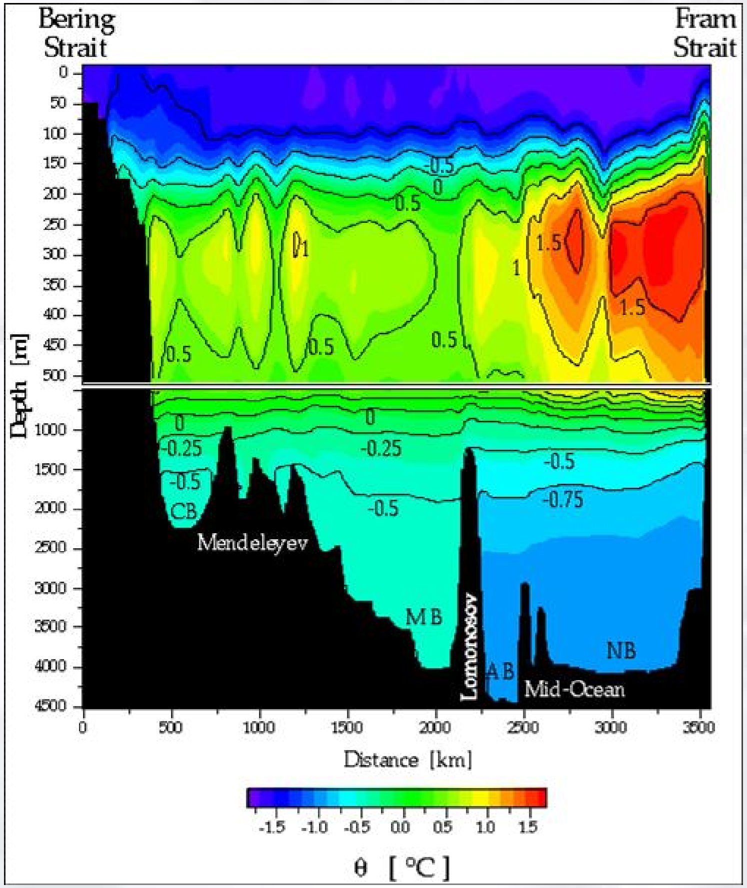
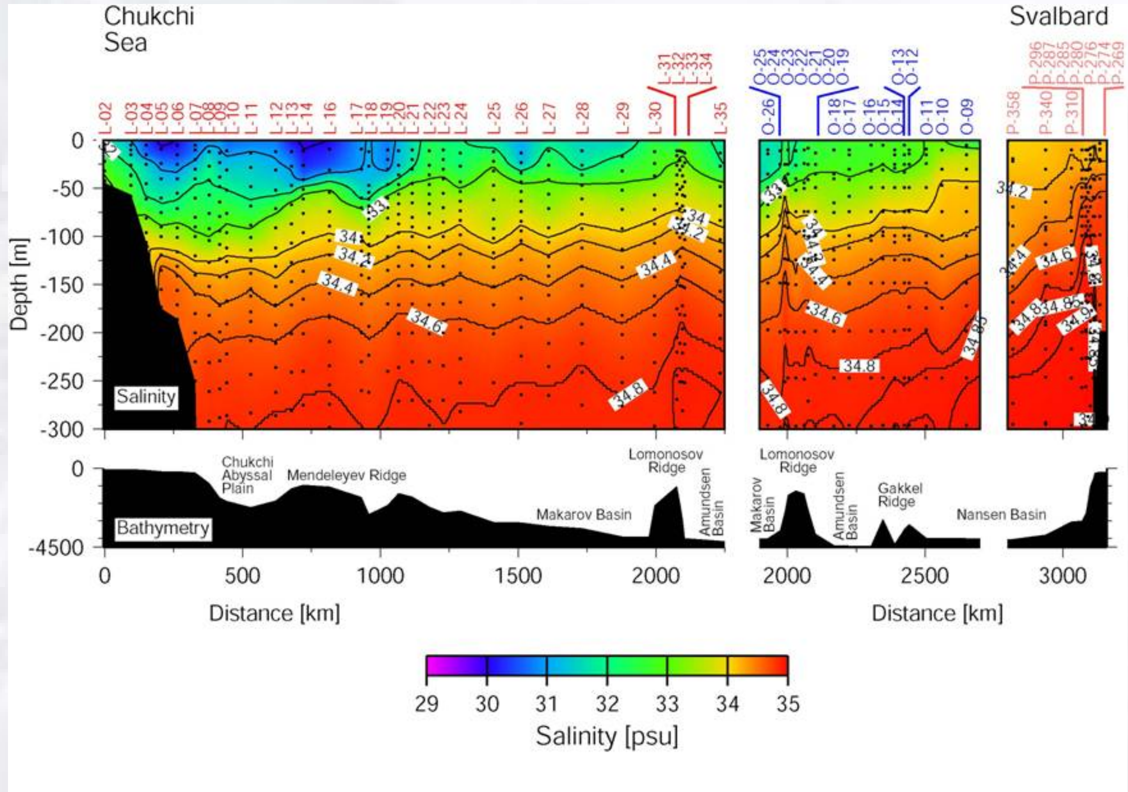
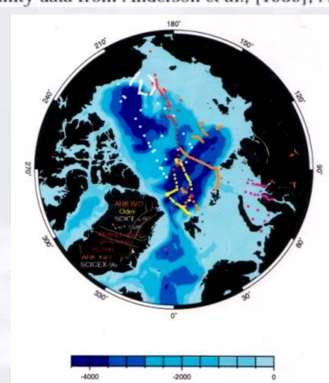


80’s and 90’s: Emerging details





Salinity data from Anderson et al., [1989], Anderson et al., [1994], and Swift et al,. [1997].



First signs of change: Rossiya 1990

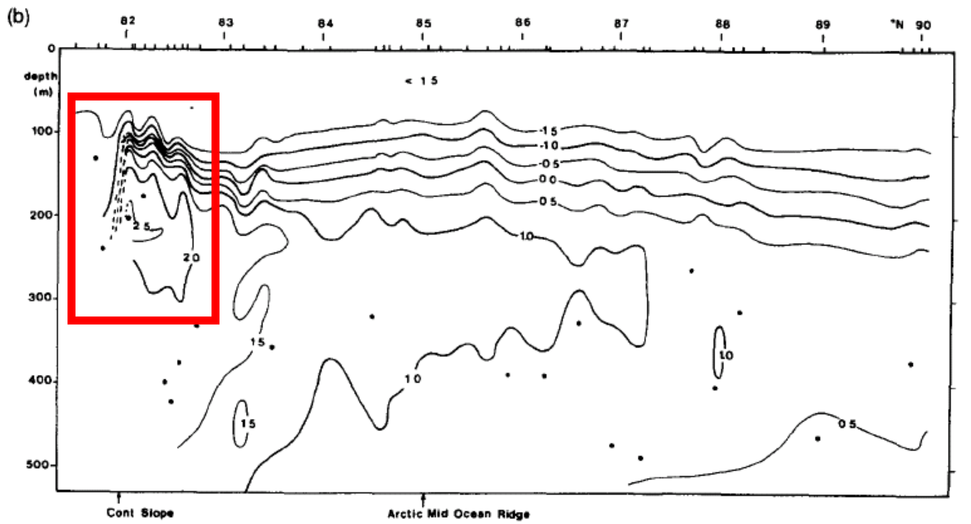
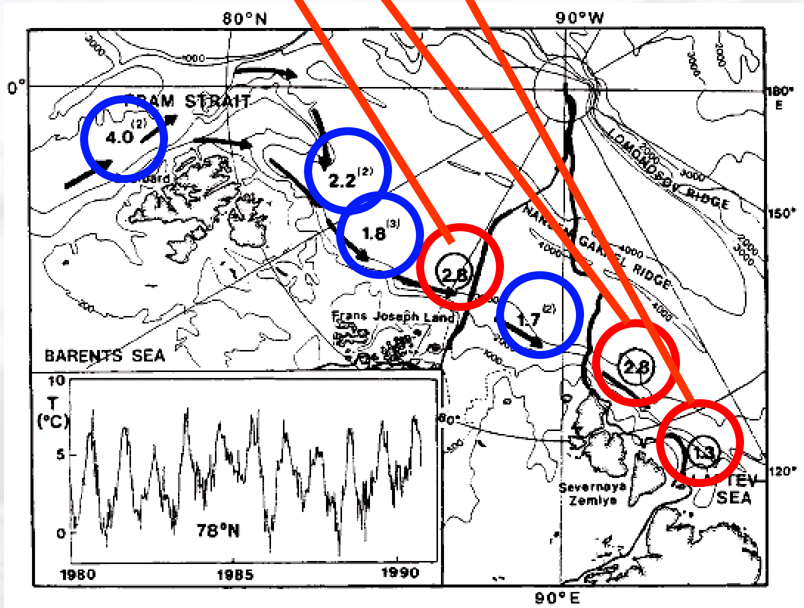


Fig 3 Vertical distribution of temperature along the two sections across the Eurasian Basin, plotted vs latitude. For location see Fig 1 The small dots denote the maximum observation depth at the respective station. When no dots are shown, good data return was achieved to depths below 500 m.

Temperature increase: ca. 1°C



Maximum temperature in the Atlantic layer over the Eurasian Basin of the Arctic Ocean. Circled numbers, *Rossiya* observations along the tracks shown as bold lines. Other numbers are taken from the references given in brackets. The inset shows the maximum sea surface temperature in Fram Strait at 78° N during 1980 — 90.

Quadfasel et al., Nature, 1991; Deep-Sea Res., 1993

More changes

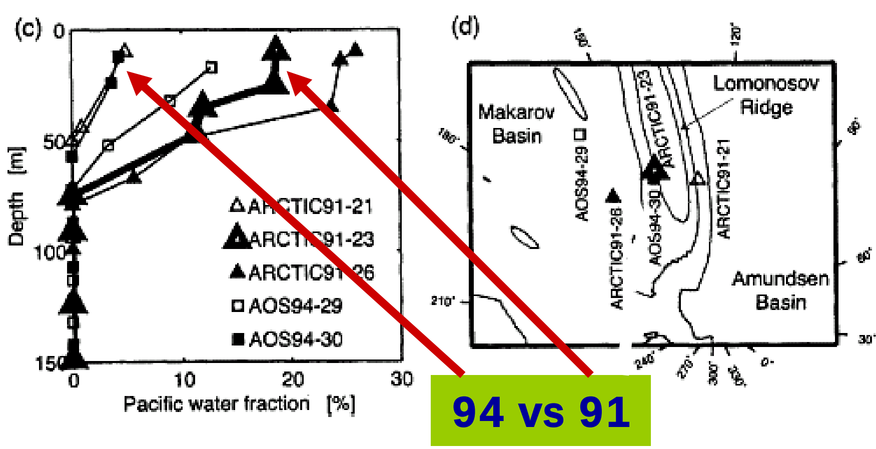
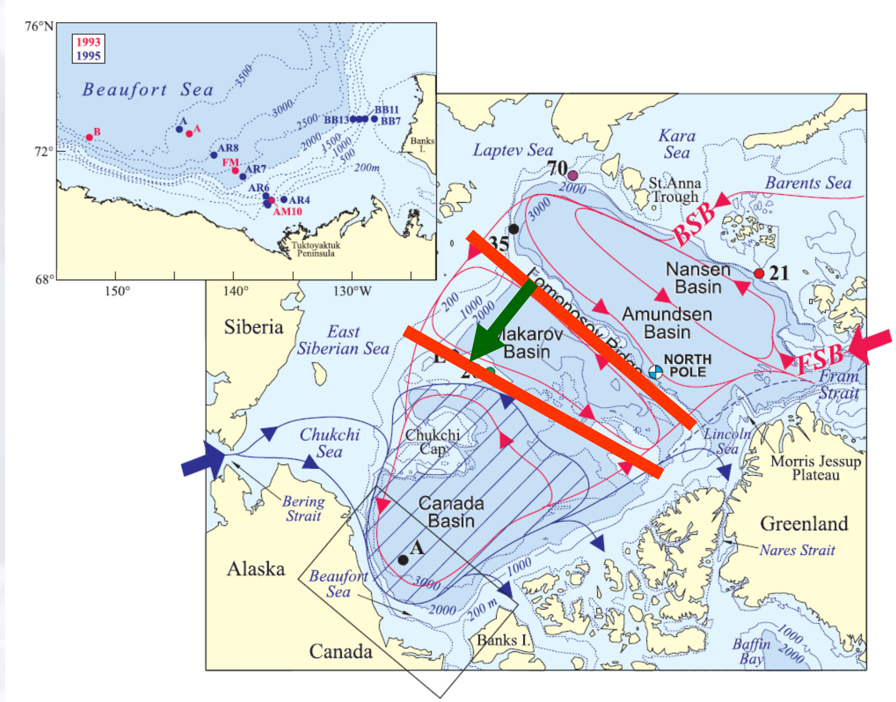


Figure 8. Comparison of 1991 and 1994 stations near the Lomonosov Ridge for (a) river runoff fraction, (b) sea ice meltwater fraction (positive = meltwater; negative = ice formation), (c) Pacific water fraction, and (d) location for these stations.

River runoff, sea ice meltwater, and Pacific water distribution and mean residence times in the Arctic Ocean

Brenda Ekwurzel,[1] Peter Schlosser,[2,3] Richard A. Mortlock, and Richard G. Fairbanks[2]
Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York

19 - 2 MCLAUGHLIN ET AL.: CANADA BASIN 1989–1995 AND FAR-FIELD EFFECTS



Changes in the Greenland Sea: Related?

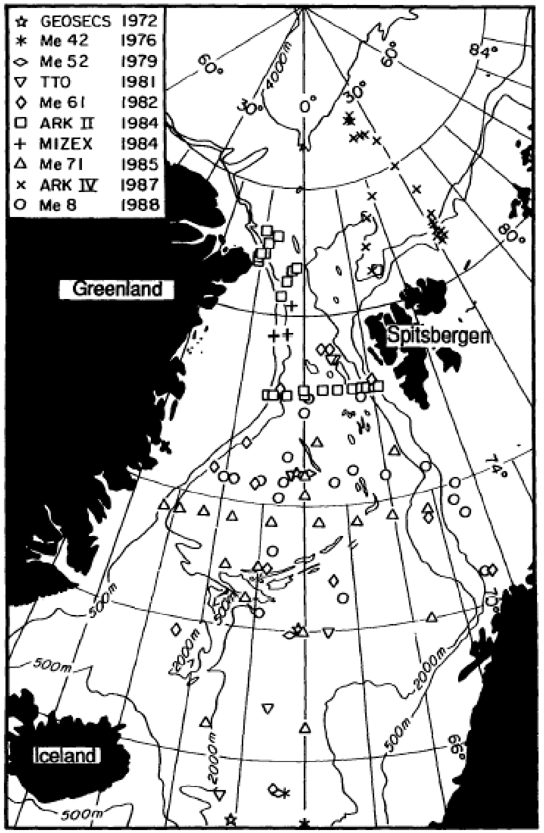
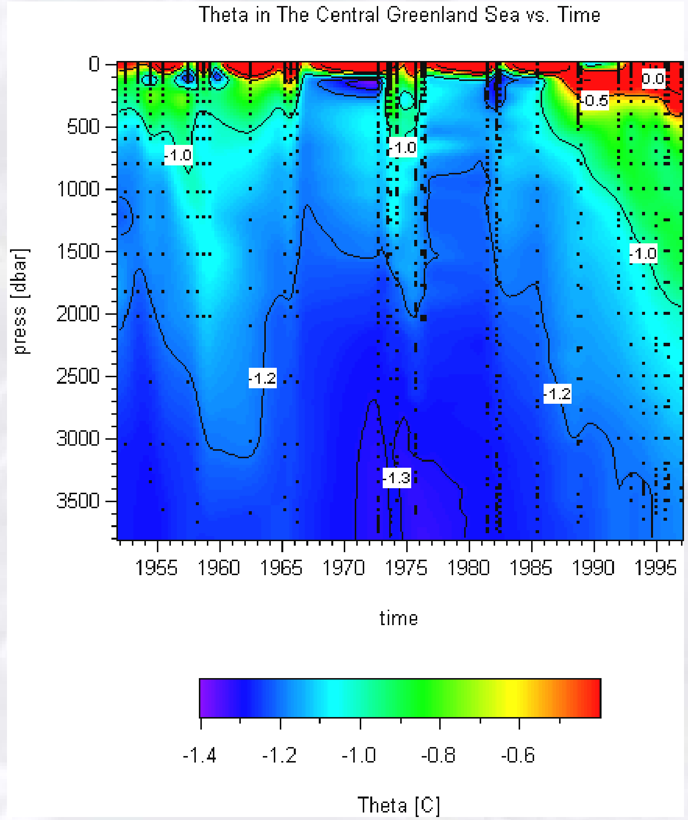
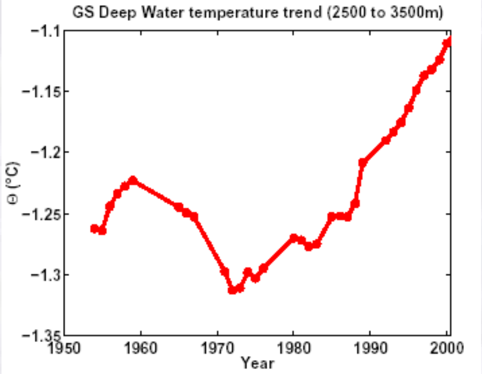


Fig. 1. Locations of tritium and ^{3}He stations occupied on several cruises (*6*) between 1972 and 1988. The Greenland Sea data used in this study are from cruises GEOSECS, Me42, Me52, TTO, Me62, Me71, and Me8. Only some of the available samples have been measured from Me71 and Me8. Station maps for the CFC stations are in (*5*, *11*, *12*).



Long–term trends of temperature, salinity, density, and transient tracers in the central Greenland Sea

Gerhard Bönisch,[1] Johan Blindheim,[2] John L. Bullister,[3] Peter Schlosser,[1,4] and Douglas W. R. Wallace [5]

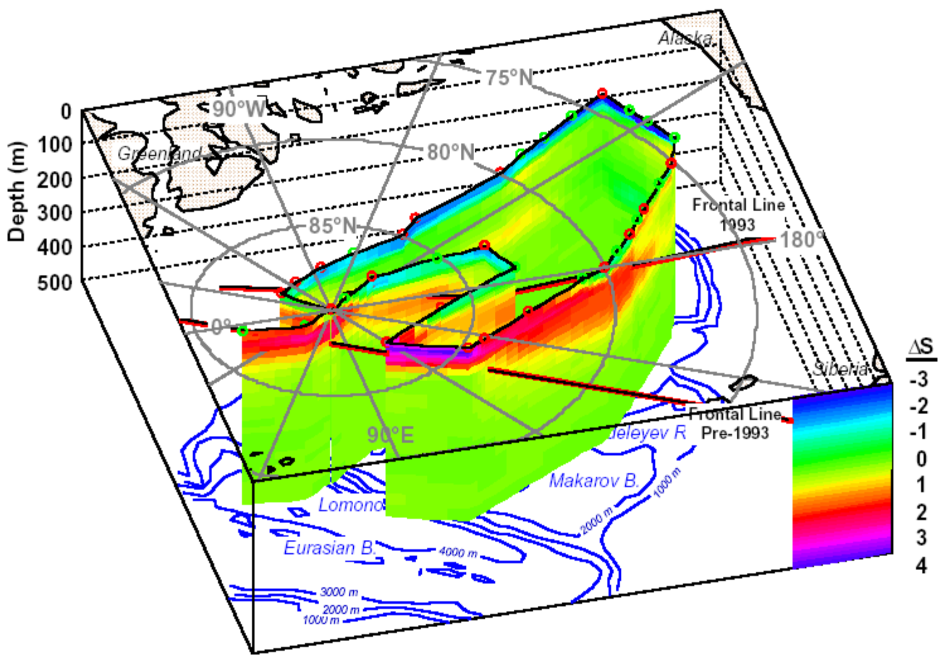


Reduction of Deepwater Formation in the Greenland Sea During the 1980s: Evidence from Tracer Data

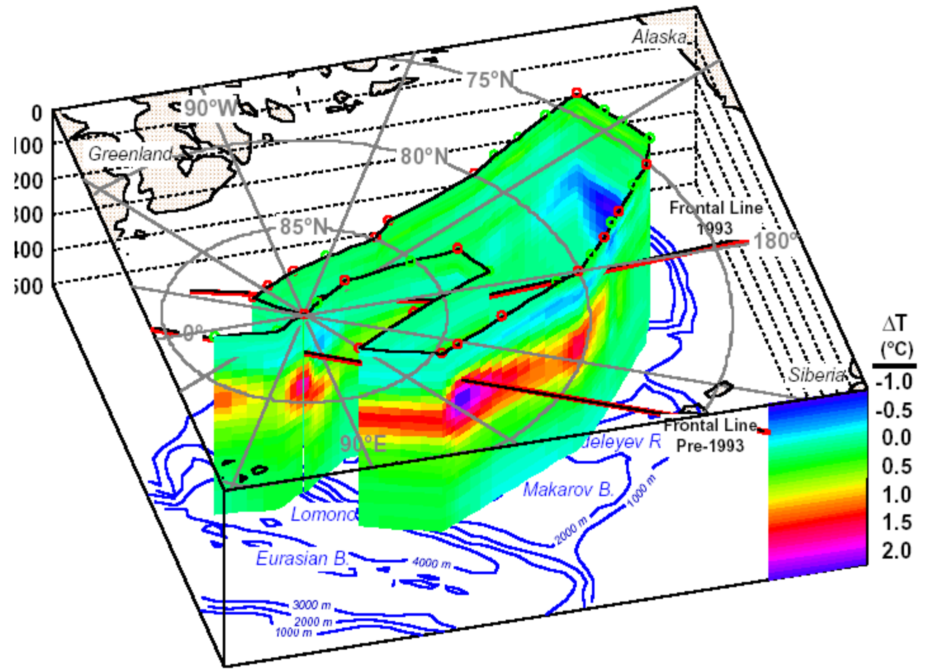
Peter Schlosser; Gerhard Bonisch; Monika Rhein; Reinhold Bayer

Science, New Series, Vol. 251, No. 4997 (Mar. 1, 1991), 1054-1056.

1990's: Basin - scale changes



From Morison, J. H., K. Aagaard, and M. Steele, 2000, Recent Environmental Changes in the Arctic: A Review, Arctic, 53, 4.

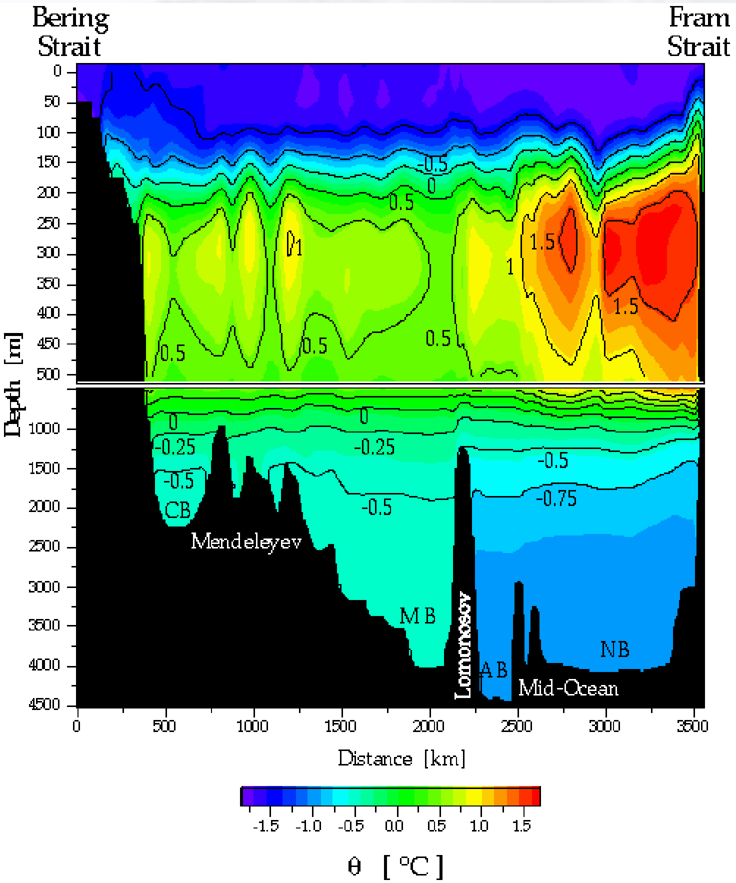


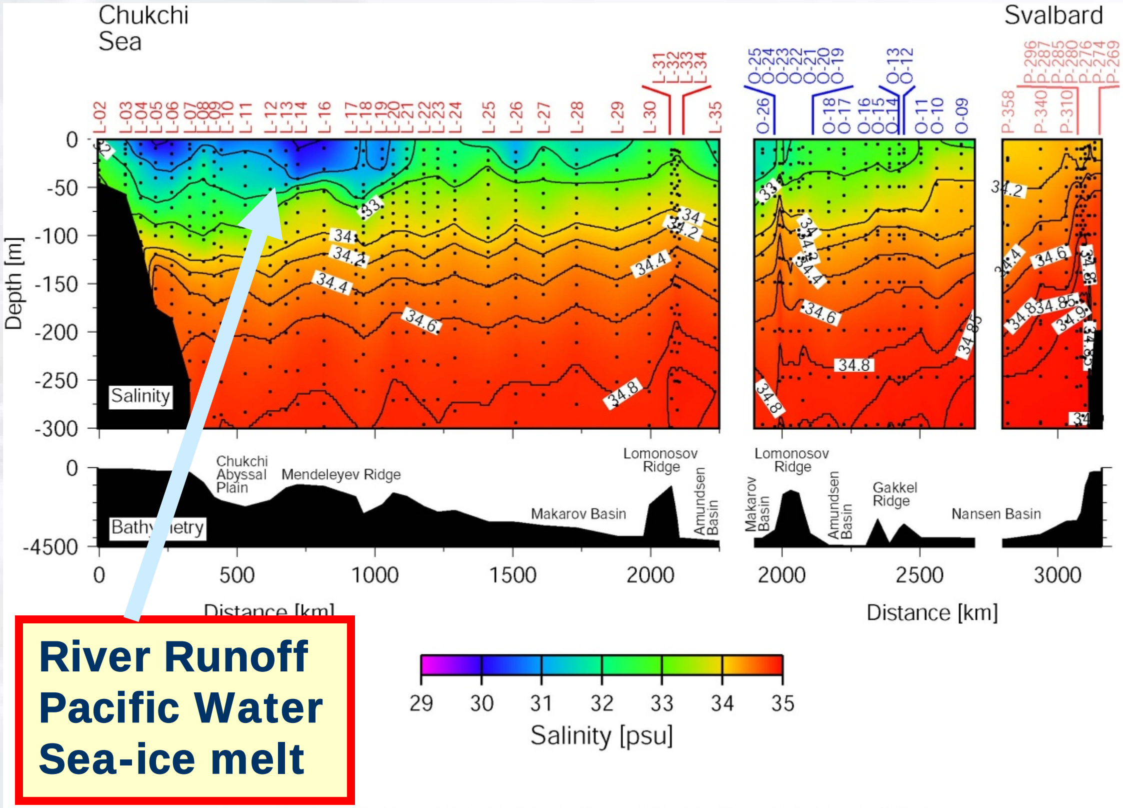
From Morison, J. H., K. Aagaard, and M. Steele, 2000, Recent Environmental Changes in the Arctic: A Review, Arctic, 53, 4.

Shift in front between Atlantic and Pacific Water

Temperature increase in core of Atlantic water (up to ca. 2^{o}C)

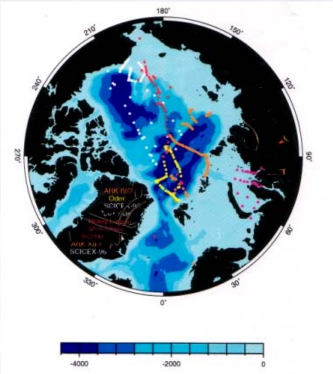
Arctic freshwater distribution





River Runoff
Pacific Water
Sea-ice melt

Salinity data from Anderson et al., [1989], Anderson et al., [1994], and Swift et al,. [1997].



Arctic freshwater components

Balances of mass, salt, ^{18}O, and nutrients allow us to quantify the individual freshwater components

P. Schlosser et al. / The Science of the Total Environment 237/238 (1999) 15–30 25

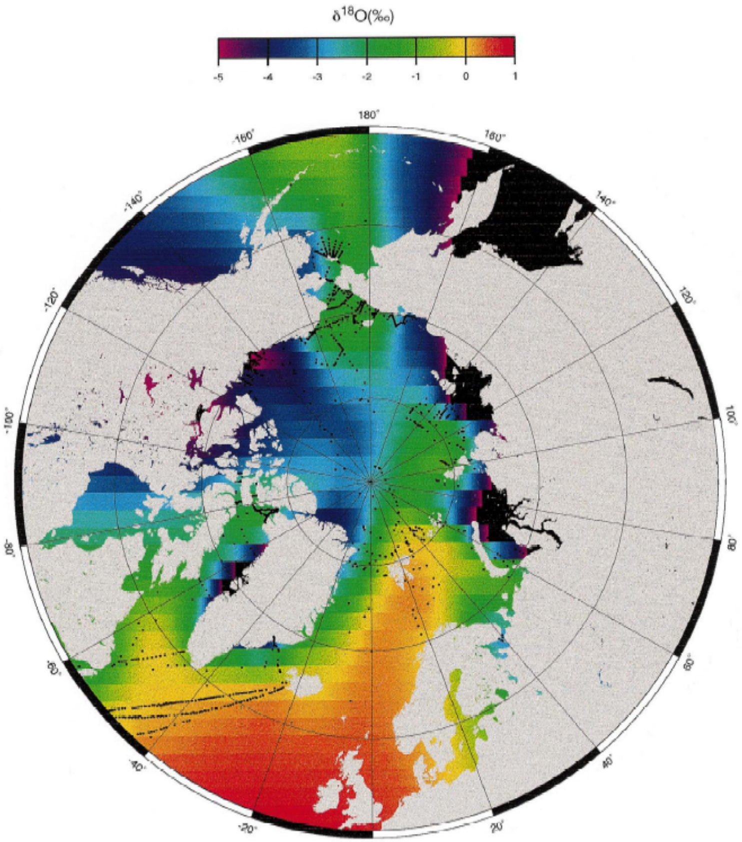


Fig. 7. Distribution of $\delta^{18}O$ in the surface waters (depth < 15 m) of the Arctic Ocean and the adjacent seas.

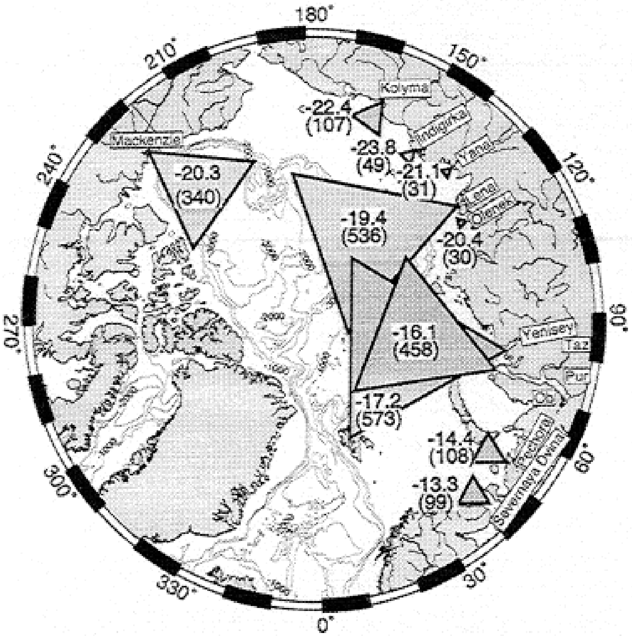


Figure 3. Mean annual discharge and $\delta^{18}O$ data available in the literature for Arctic Rivers. River discharge ($km^3\ yr^{-1}$) is proportional to triangle size and is listed in parenthesis within or near the triangle symbol for the river [*Becker*, 1995; *Pavlov et al.*, 1996]. The negative numbers within or near the triangle symbol for each river are the $\delta^{18}O$ (‰) values [*Macdonald et al.*, 1989; *Létolle et al.*, 1993; *Ekwurzel*, 1998].

$$f_a + f_p + f_r + f_i = 1,$$

$$f_a S_a + f_p S_p + f_r S_r + f_i S_i = S_m,$$

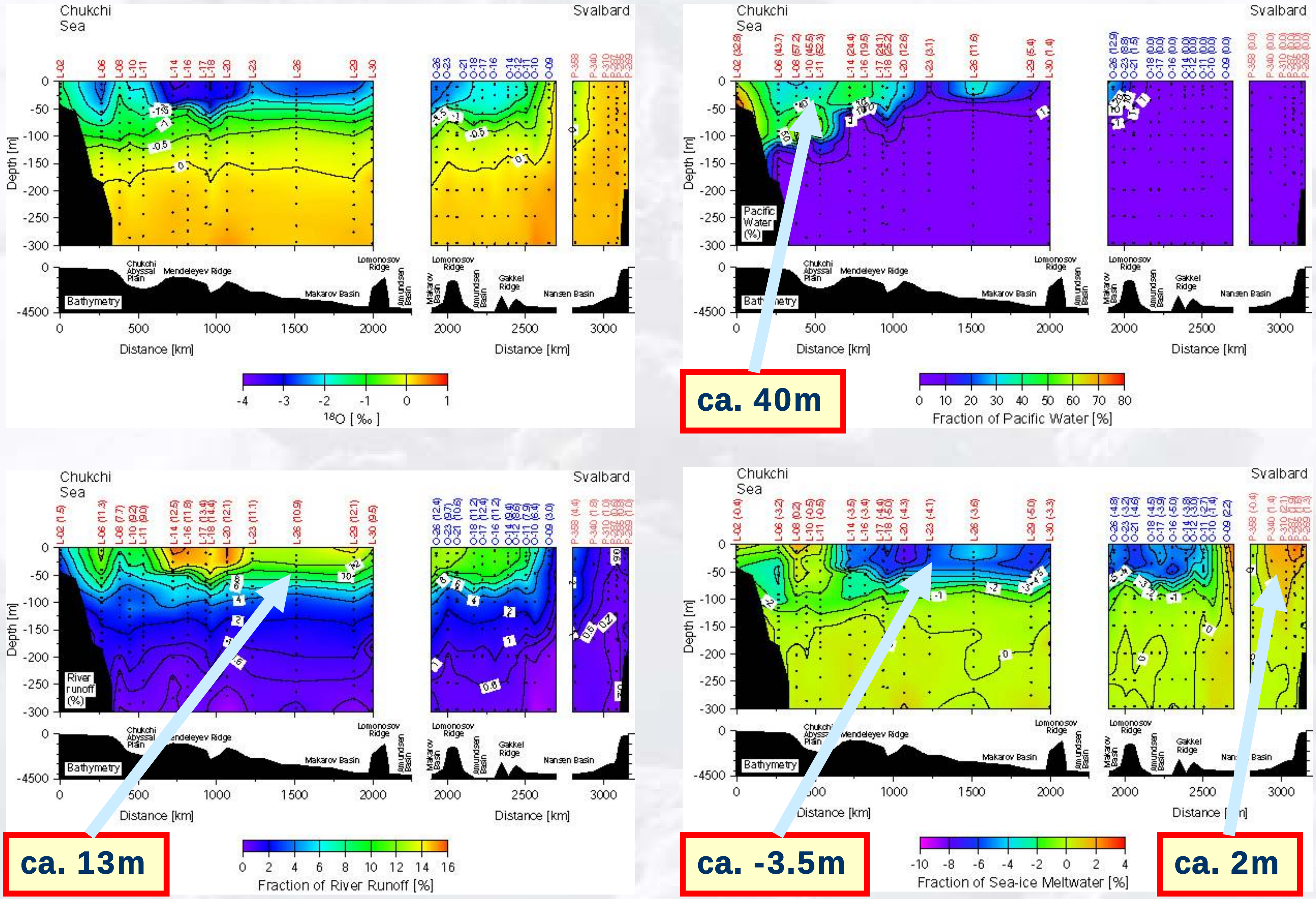
$$f_a \delta^{18}O_a + f_p \delta^{18}O_p + f_r \delta^{18}O_r + f_i \delta^{18}O_i = \delta^{18}O_m,$$

$$f_a PO_4{}^*{}_a + f_p PO_4{}^*{}_p + f_r PO_4{}^*{}_r + f_i PO_4{}^*{}_i = PO_4{}^*{}_m,$$

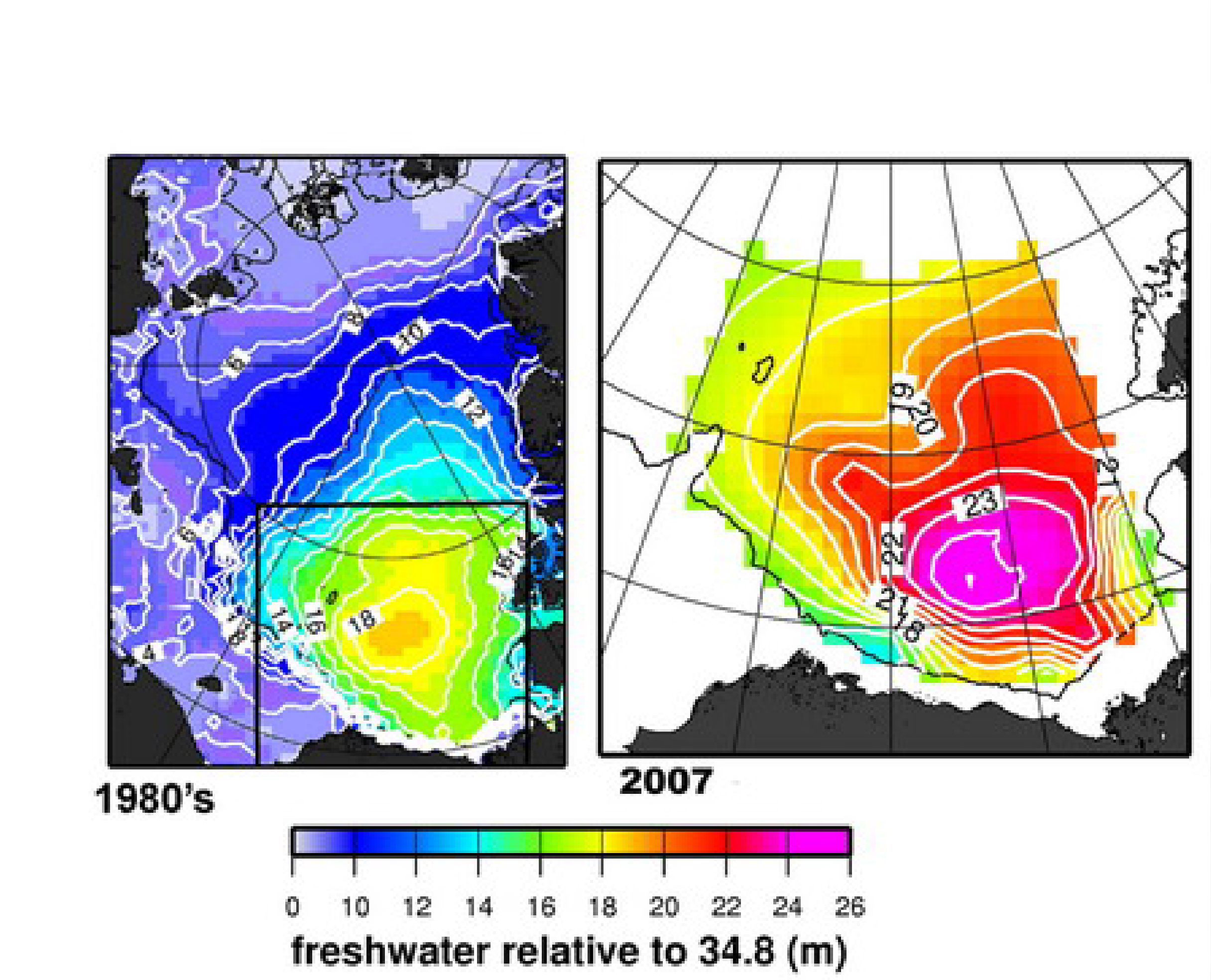
River runoff, sea ice meltwater, and Pacific water distribution and mean residence times in the Arctic Ocean

Brenda Ekwurzel,[1] Peter Schlosser,[2,3] Richard A. Mortlock, and Richard G. Fairbanks[2]
Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York

Freshwater components



Changing freshwater inventories



From: Arctic report card
http://www.arctic.noaa.gov/reportcard/images/essays/ocean/o3-lrg.jpg

Transfer of freshwater signals

1922 *R. R. Dickson, R. Curry and I. Yashayaev*

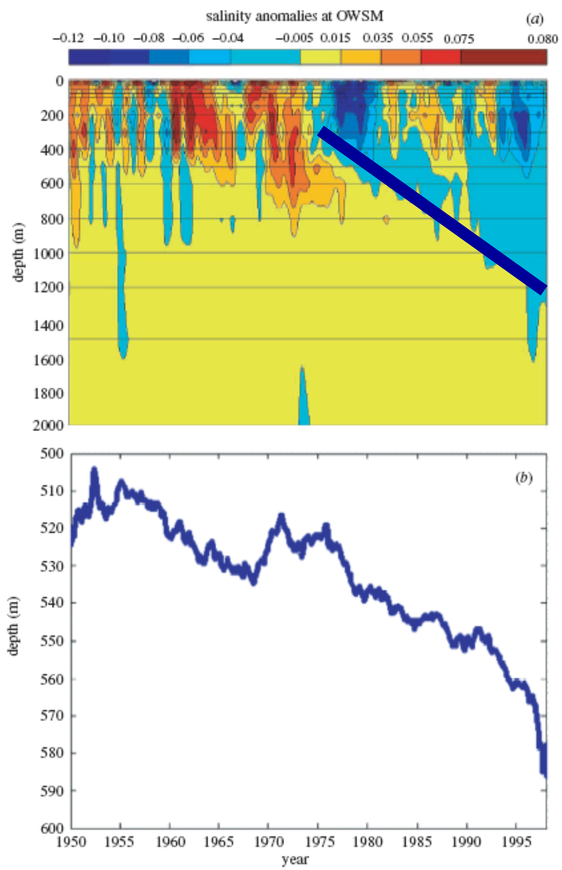
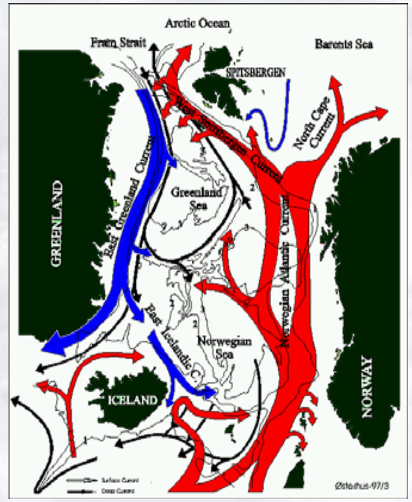


Figure 2. (*a*) Change in salinity with time and depth at OWS Mike in the Norwegian Sea since 1950, showing the progressive freshening in the upper 1 km over the past five decades (unpublished data, reproduced with kind permission of Dr Svein Østerhus, University of Bergen). (*b*) The associated slow deepening of the $\sigma t = 28.0$ isopycnal at OWS Mike since 1950 (see Hansen *et al.* 2001).

Phil. Trans. R. Soc. Lond. A (2003)



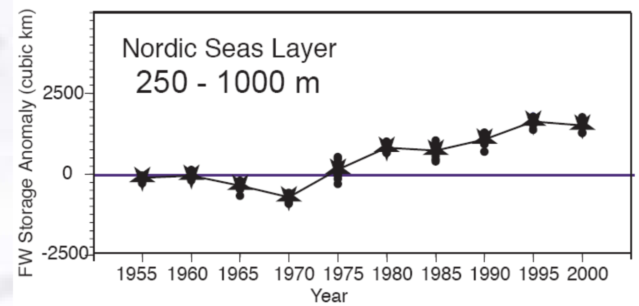
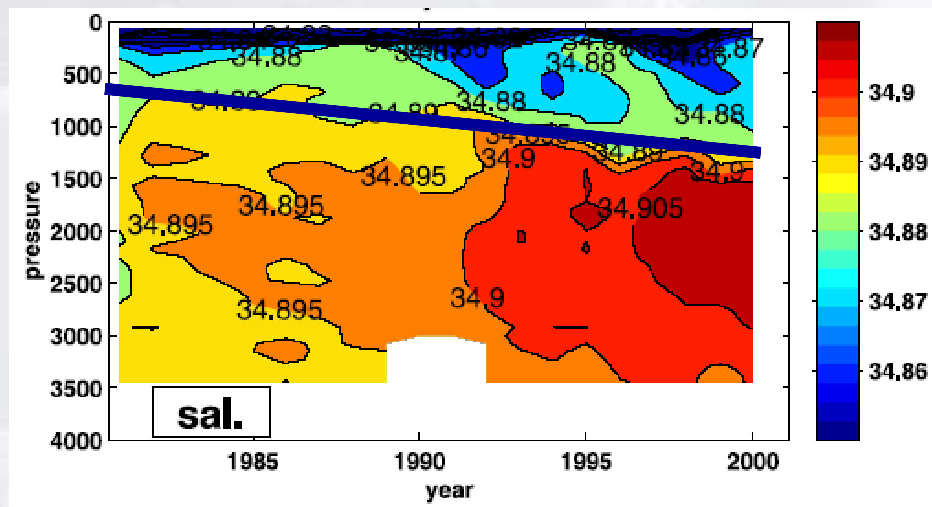


Figure 2. Timeseries of FW storage (cubic km) in Nordic Seas layer 250-1000 m.

How much Freshwater was added to the Northern North Atlantic in Recent Decades?

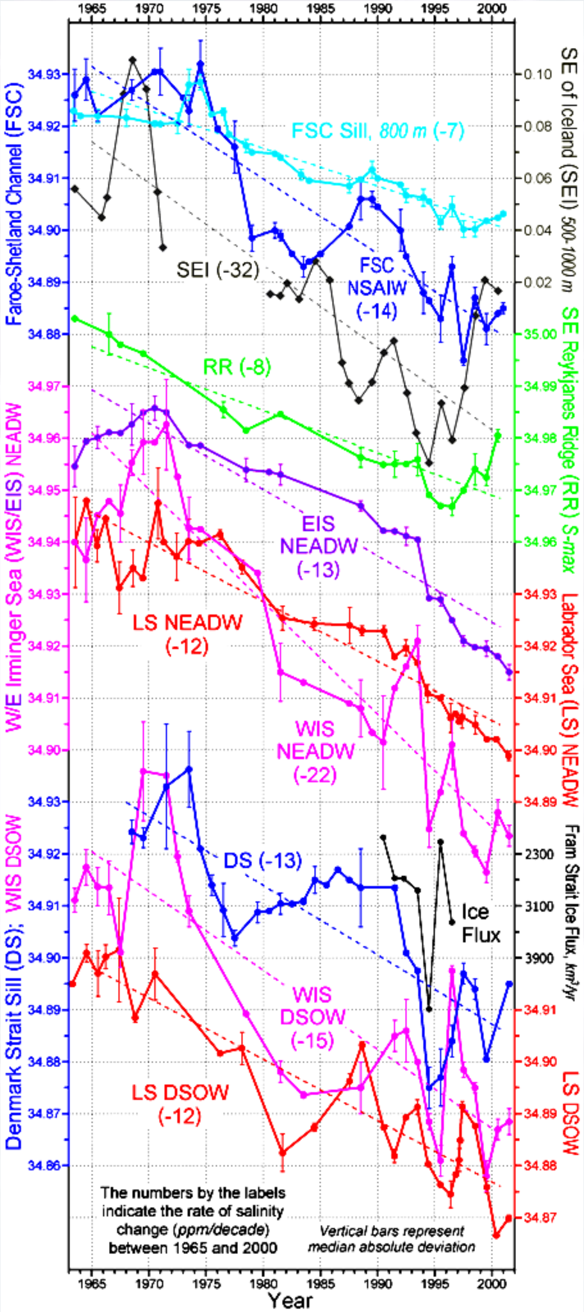
by R. Curry
Woods Hole Oceanographic Institution, Woods Hole, USA



Water mass transformation in the Greenland Sea during the 1990s

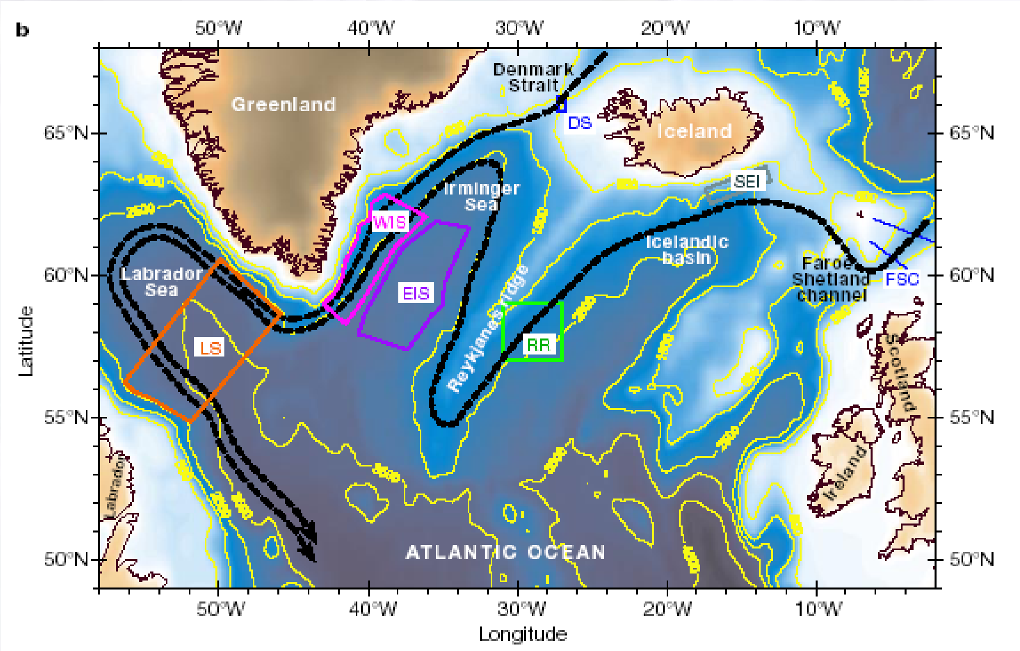
J. Karstensen,[1,2] P. Schlosser,[3,4] D. W. R. Wallace,[1] J. L. Bullister,[5] and J. Blindheim[6]

North Atlantic signals

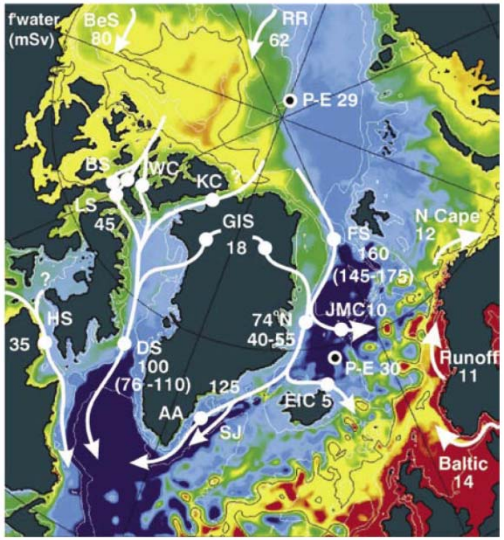


‘A change in the ocean-climate of sub-arctic seas has thus been transferred to the deep and abyssal ocean at the headwaters of the “Great Conveyor”’

Dickson et al 2002

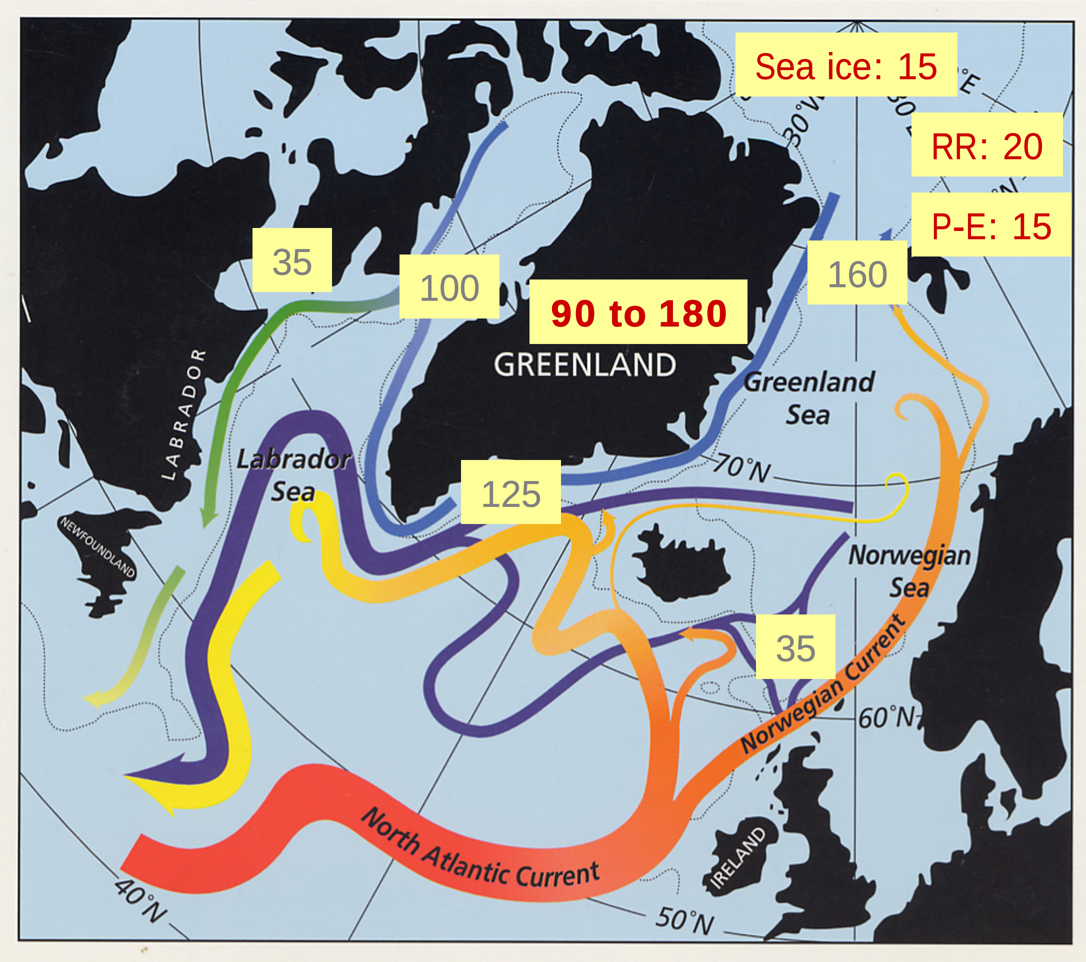


Additional freshwater fluxes



Total:	283

P-E:	15
RR:	20
Sea ice:	15
(50 years)	
Greenland:	90 - 180
(500 – 1000 ys)	
Total:	140 - 230



NADW formation rate and global SST

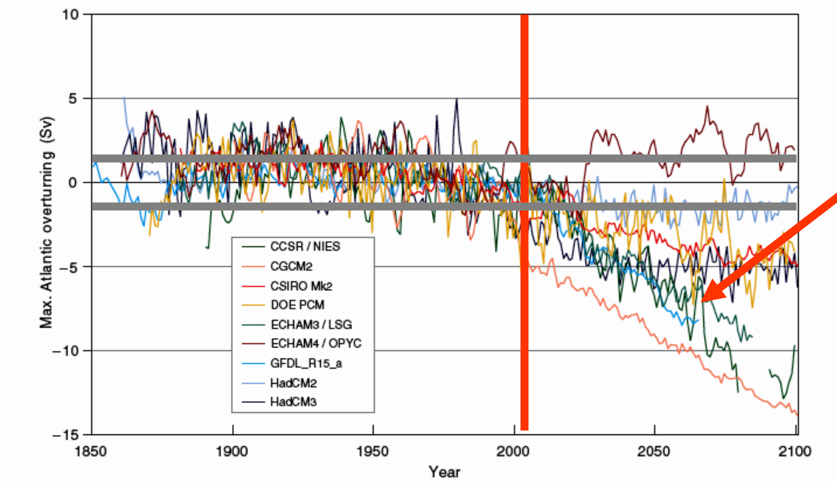


Figure 9.21: Simulated water-volume transport change of the Atlantic "conveyor belt" (Atlantic overturning) in a range of global warming scenarios computed by different climate research centres. Shown is the annual mean relative to the mean of the years (1961 to 1990) (Unit: SV, $10^6\ m^3s^{-1}$). The past forcings are only due to greenhouse gases and aerosols. The future-forcing scenario is the IS92a scenario. See Table 9.1 for more information on the individual models used here.

In many coupled climate model simulations global warming leads to reduction of DWF in the North Atlantic IPCC, 2001

Global warming and thermohaline circulation stability

By Richard A. Wood, Michael Vellinga and Robert Thorpe

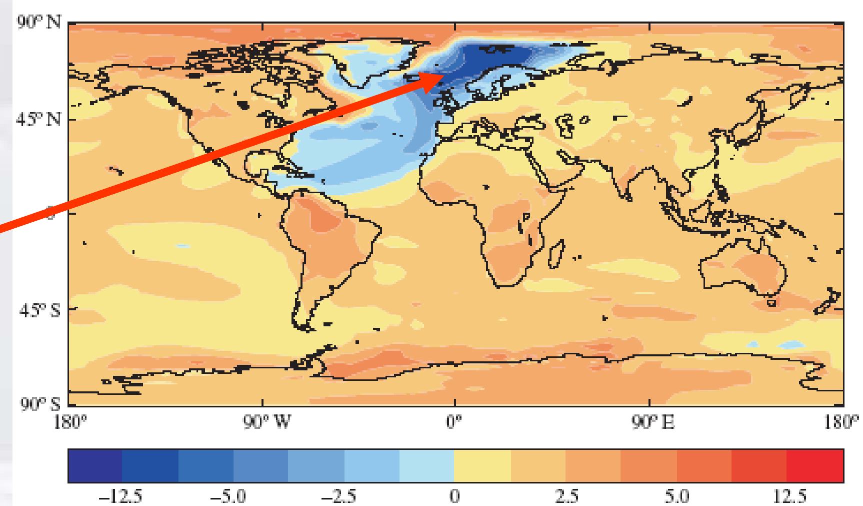


Figure 5. Surface temperature change (°C) due to a hypothetical THC shutdown in 2049. The HadCM3 model has been run to 2049 under the IPCC IS92a greenhouse-gas-forcing scenario. At this point, fresh water was added to the North Atlantic to induce a THC shutdown. Anomalies shown are the mean for the first decade after fresh-water addition, relative to the pre-industrial climate. See text for interpretation.

Reduction of deep water formation in the NA leads to cooling, mostly over the North Atlantic.

Feedback loops:

Future: hot house or big chill?

Consequences of Conveyor Shutdown

The total freshwater input into the North Atlantic in a greenhouse world could be significantly above 100 mSv

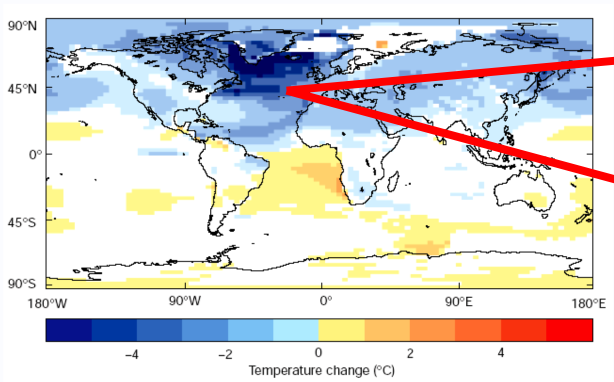
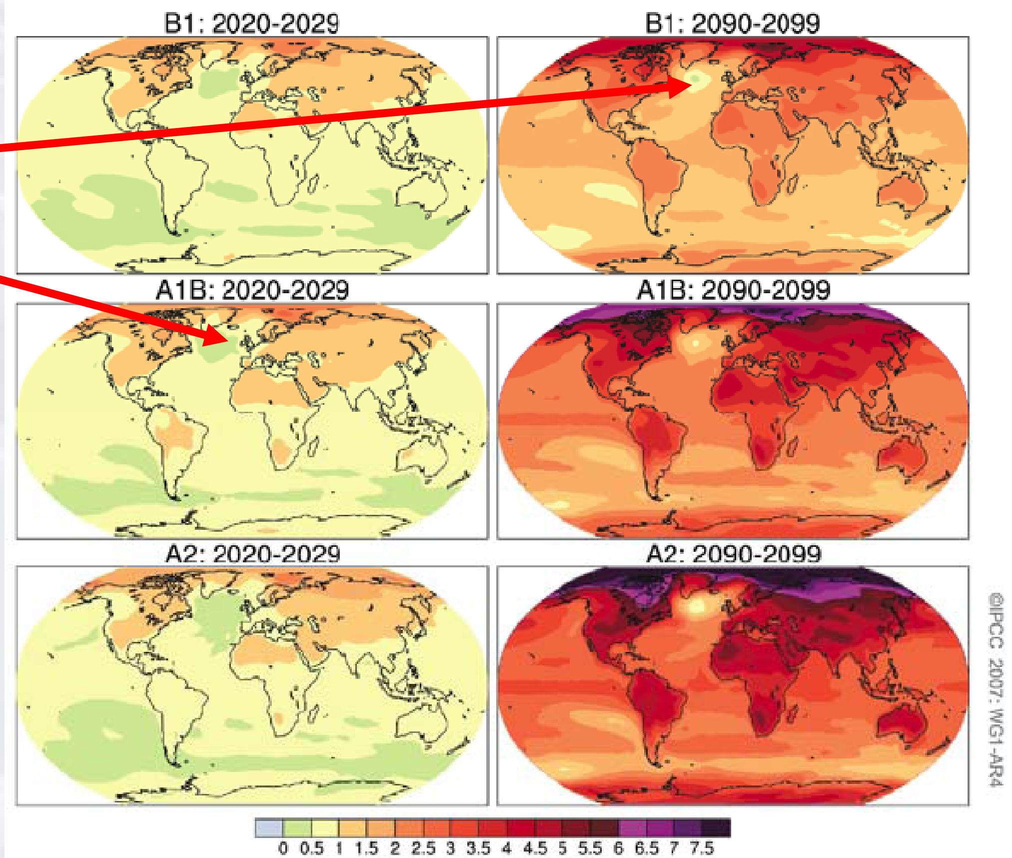


Figure 1 Changes in surface air temperature caused by a shutdown of North Atlantic Deep Water (NADW) formation in a current ocean–atmosphere circulation model. Note the hemispheric see-saw (Northern Hemisphere cools while the Southern Hemisphere warms) and the maximum cooling over the northern Atlantic. In this particular model (HadCM3)[7], the surface cooling resulting from switching off NADW formation is up to 6 °C. It is further to the west compared with most models, which tend to put the maximum cooling near Scandinavia. This probably depends on the exact location of deep-water formation (an aspect not well represented in current coarse-resolution models) and on the sea-ice distribution in the models, as ice-margin shifts act to amplify the cooling. The largest air temperature cooling is thus greater than the largest sea surface temperature (SST) cooling. The latter is typically around 5 °C and roughly corresponds to the observed SST difference between the northern Atlantic and Pacific at a given latitude. In most models, maximum air temperature cooling ranges from 6 °C to 11 °C in annual mean; the effect is generally stronger in winter.

Ocean circulation and climate during the past 120,000 years

Stefan Rahmstorf

Potsdam Institute for Climate Impact Research, PO Box 601203, 14412 Potsdam, Germany

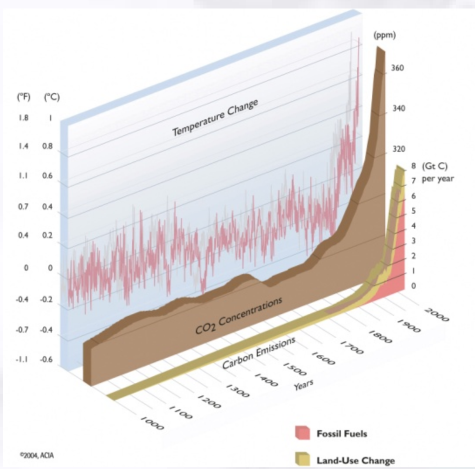


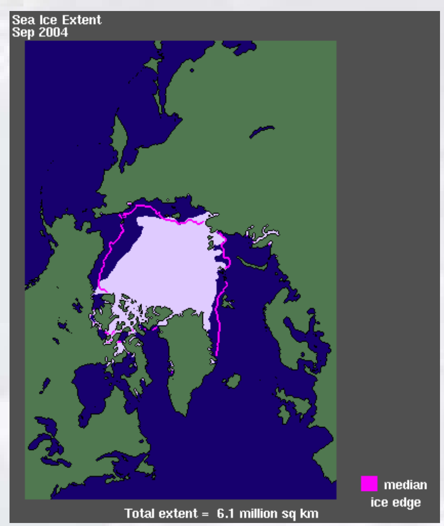
IPCC, 2007

SEARCH: Study of Environmental Arctic Change

The overall objective of SEARCH is to

Understand the nature, extent and future development of the system-scale change presently seen in the Arctic.





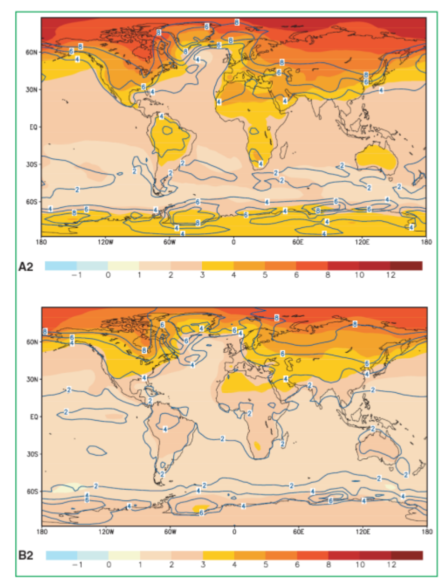


Figure 20: The annual mean change of the temperature (colour shading) and its range (isolines) (Unit: °C) for the SRES scenario A2 (upper panel) and the SRES scenario B2 (lower panel). Both SRES scenarios show the period 2071 to 2100 relative to the period 1961 to 1990 and were performed by OAGCMs. [Based on Figures 9.10d and 9.10e]

SEARCH: Science questions

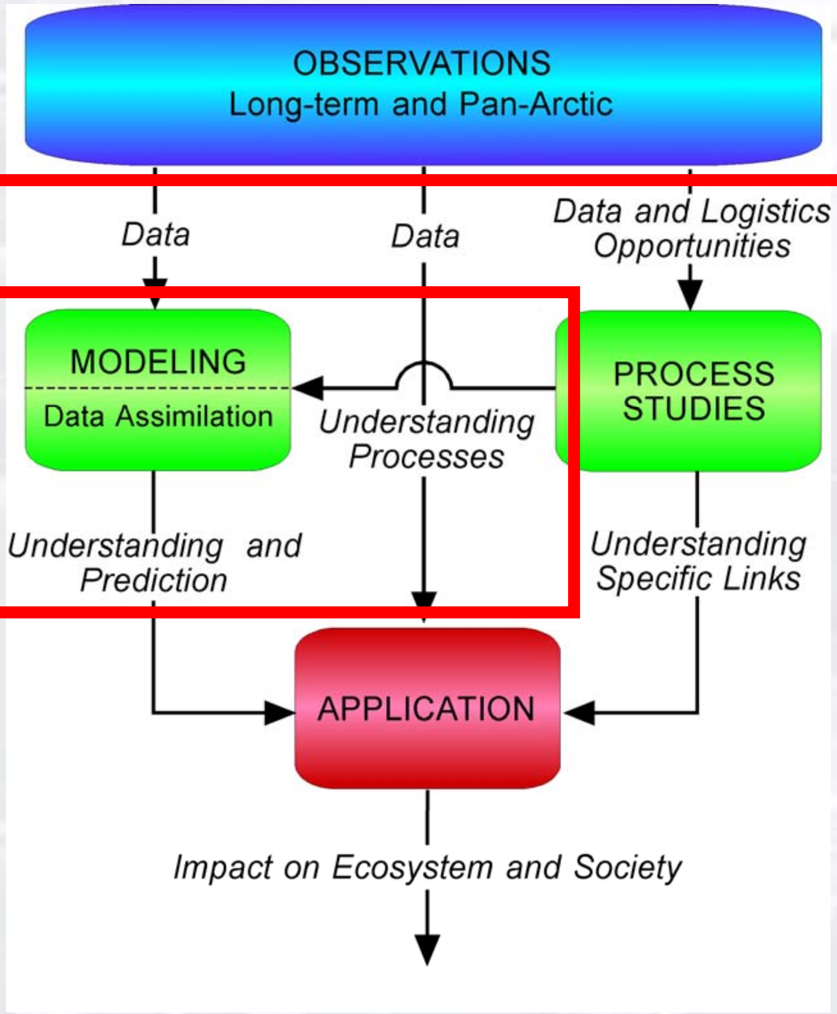
1. Is the arctic system moving to a new state?
2. To what extent is the arctic system predictable (i.e., what are the potential accuracies and/or uncertainties in predictions of relevant arctic variables over different timescales)?
3. To what extent can recent and ongoing climate changes in the Arctic be attributed to anthropogenic forcing, rather than to natural modes of variability?
4. What is the direction and relative importance of system feedbacks?
5. How are terrestrial and marine ecosystems and ecosystem services (i.e., processes by which the environment produces resources that support human life) affected by environmental change and its interaction with human activities?
6. How do cultural and socioeconomic systems interact with arctic environmental change?
7. What are the most consequential links between the arctic and the earth systems?

SEARCH Strategy

Science Plan & Implementation Strategy at:
http://arcus.org/SEARCH/index.php

AON:Focus of IPY AO

SEARCH UCP, ARCSS, Sea ice minimum workshop, 2009 implementation workshop



SEARCH: Observing System

- SEARCH needs to **observe the transition of the Arctic system** from its present state into a warmer world. This will require a **new type of observing system**
- The system has to be part of an **international, pan-Arctic network**, and observe **across domains** (physical, biogeochemical, and socioeconomic)
- The data flow from the observing system will **provide insight into the nature and rate of change**
- The observing system is a tool **that will inform the Understanding Change and Responding to Change activities**


EOS
EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

Arctic System on Trajectory to New, Seasonally Ice-Free State

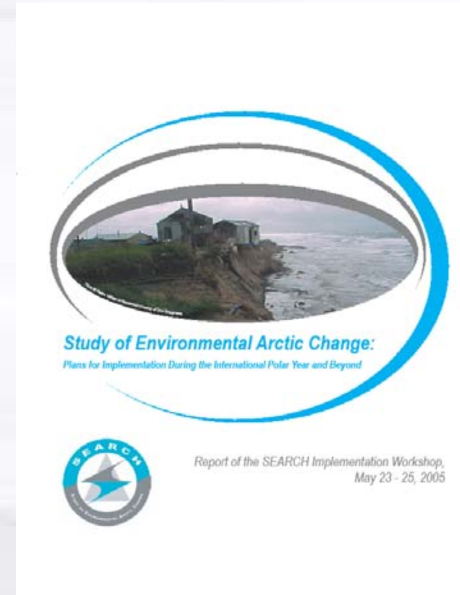
NSF AON Projects

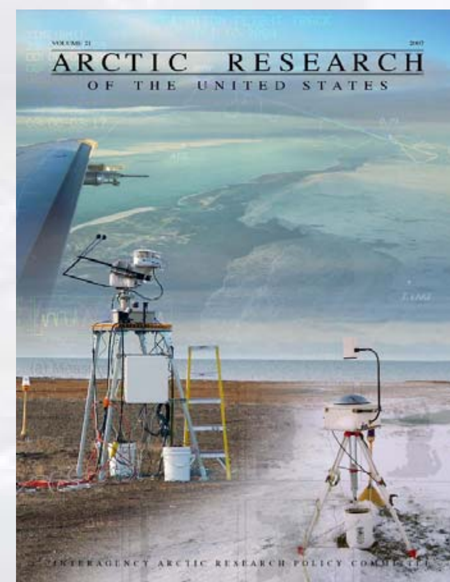
IPY AON Awards

(AON was one of three research focus areas organized according to the number of projects in each SEARCH Implementation Plan category)

Atmosphere 4
Oceans & Sea Ice 9
Hydrology & Cryosphere 2
Terrestrial Ecosystems 2
Human Dimensions 2
Data 2
$\Sigma = 21$

21 IPY projects
~$37M during FY06 – FY09





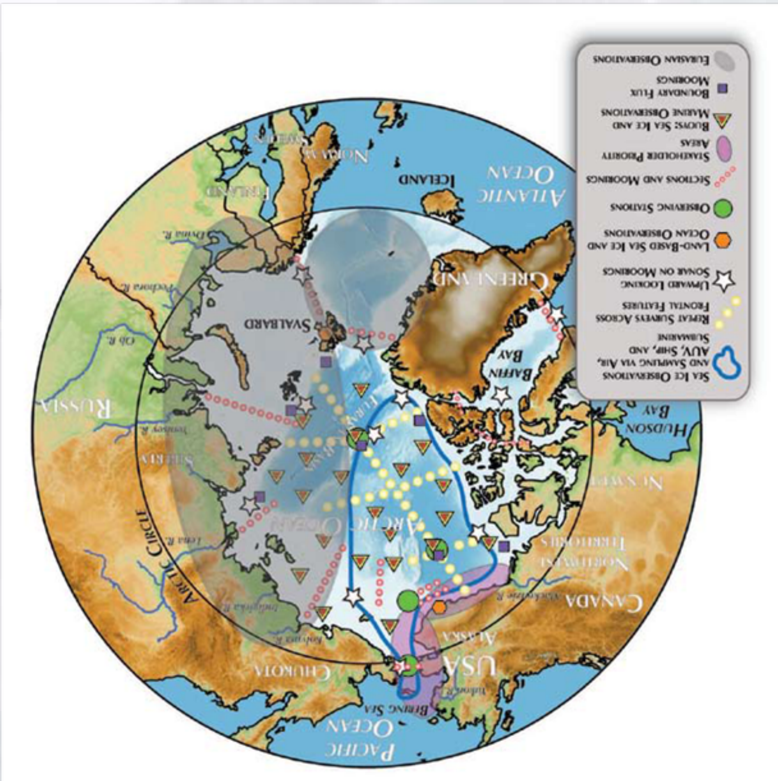
NSF AON Projects

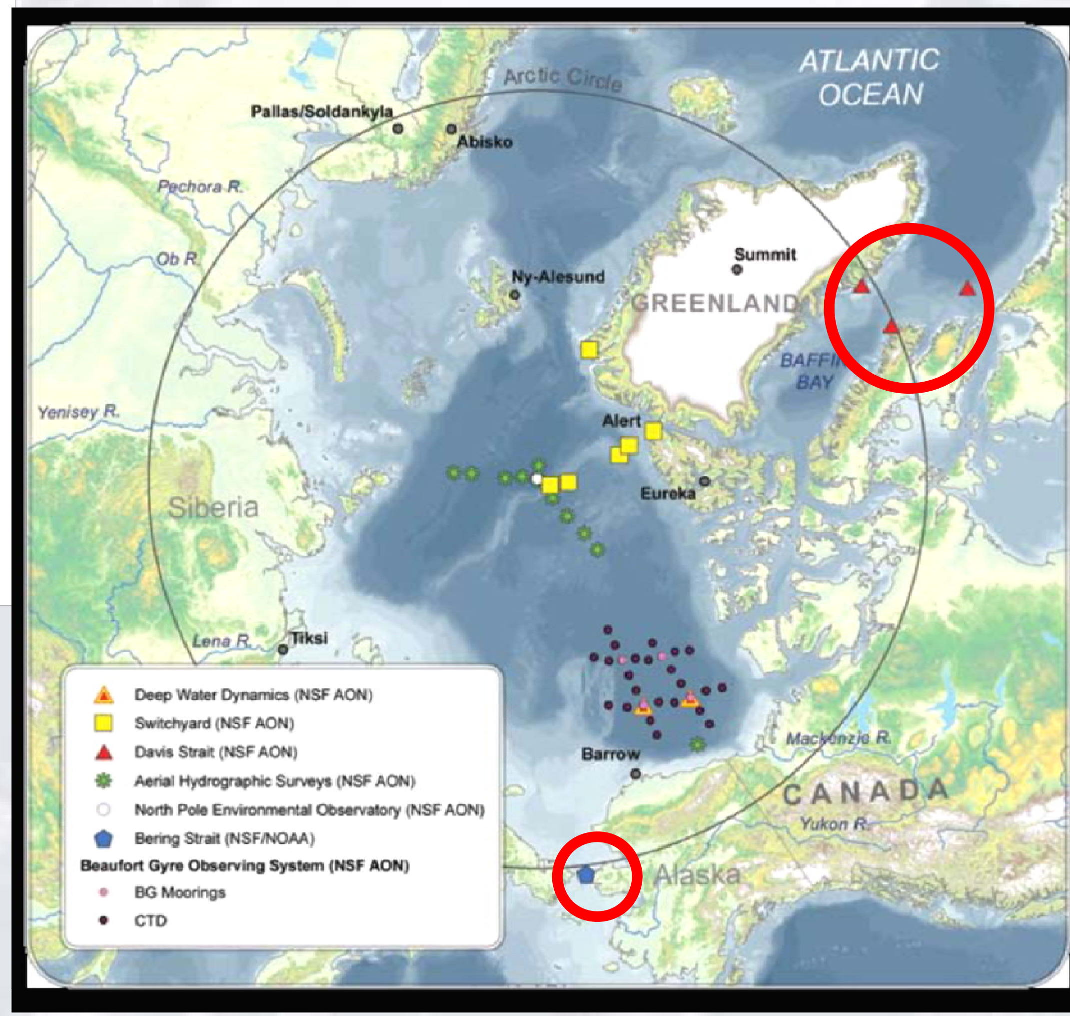
SEARCH Category IPY

Projects distributed among the SEARCH categories as follows:

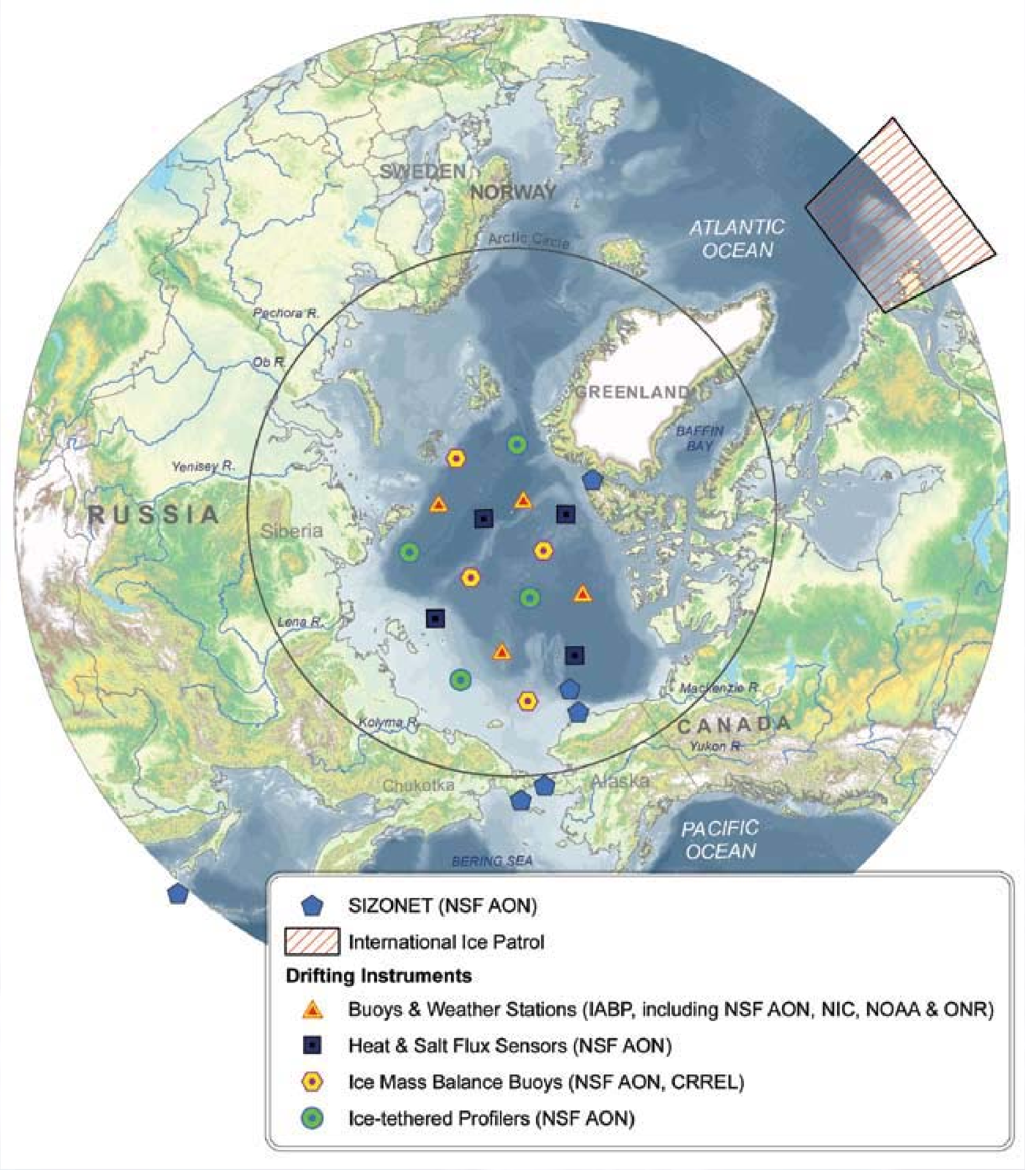
	IPY	LTO	AON
Atmosphere	4	3	7
Oceans & Sea Ice	9	7	16
Hydrology & Cryosphere	2	2	4
Terrestrial Ecosystems	2	1	3
Human Dimensions	2	0	2
Data	2	0	2
Σ = ...	21	13	34

AON Ocean Observations

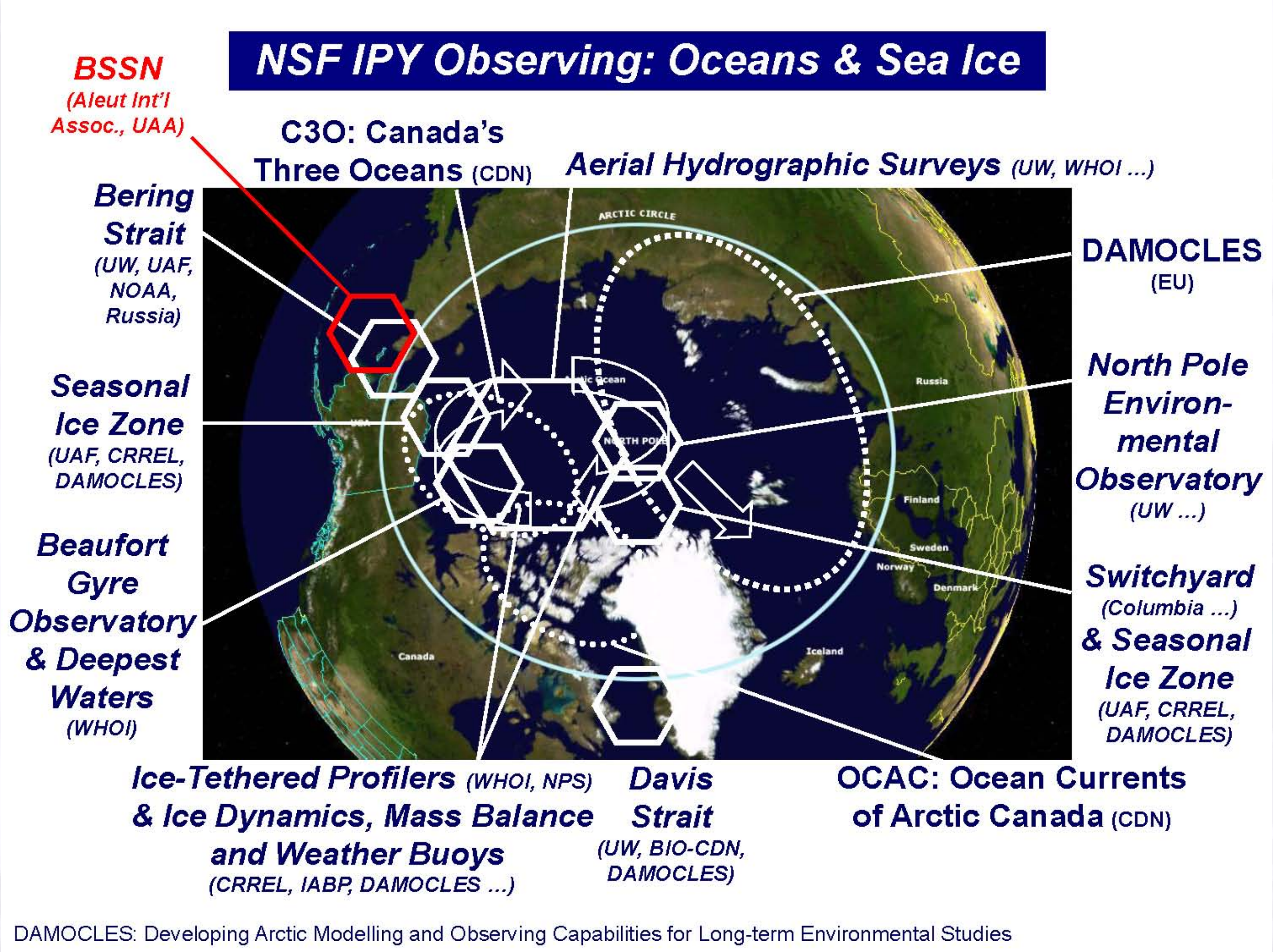




AON Sea Ice Observations



AON Ocean Observations



AON Atmosphere Observations

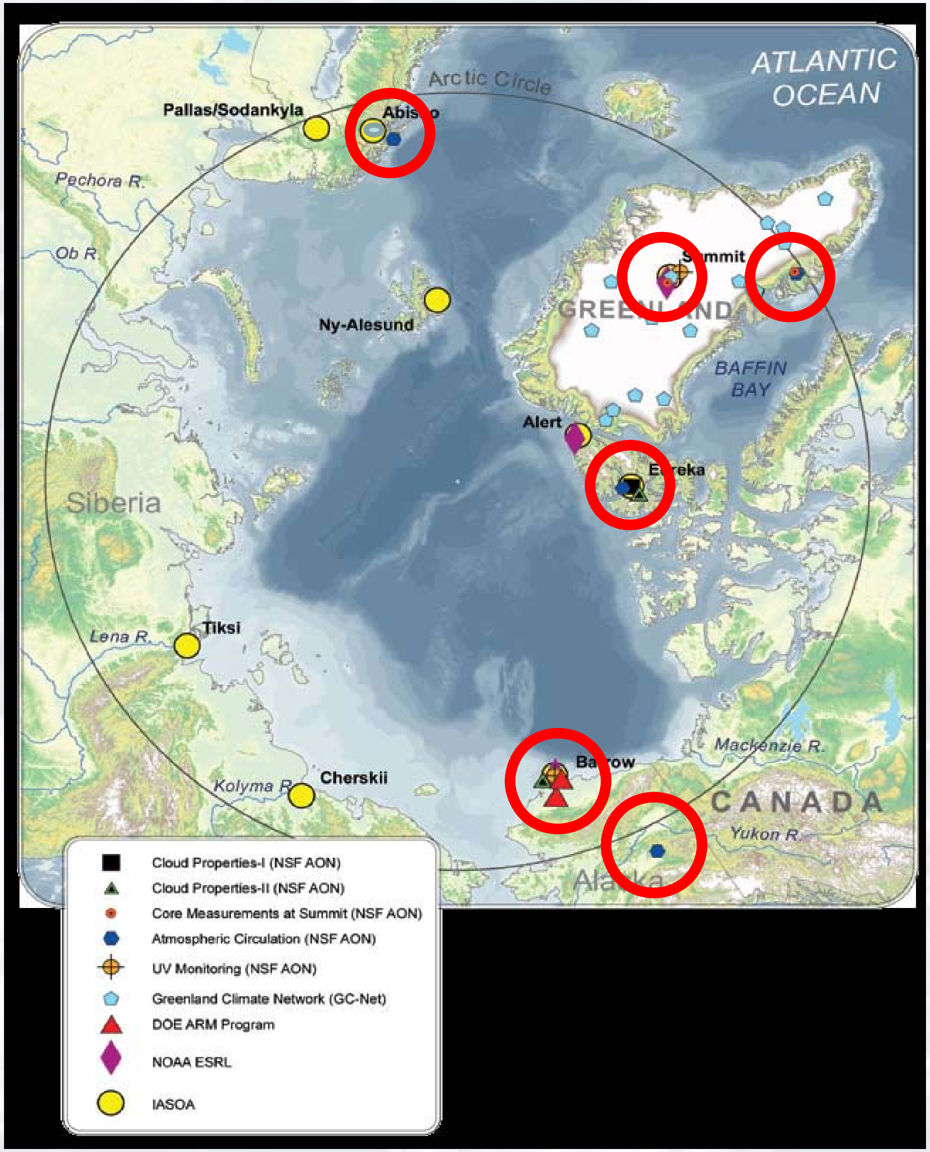
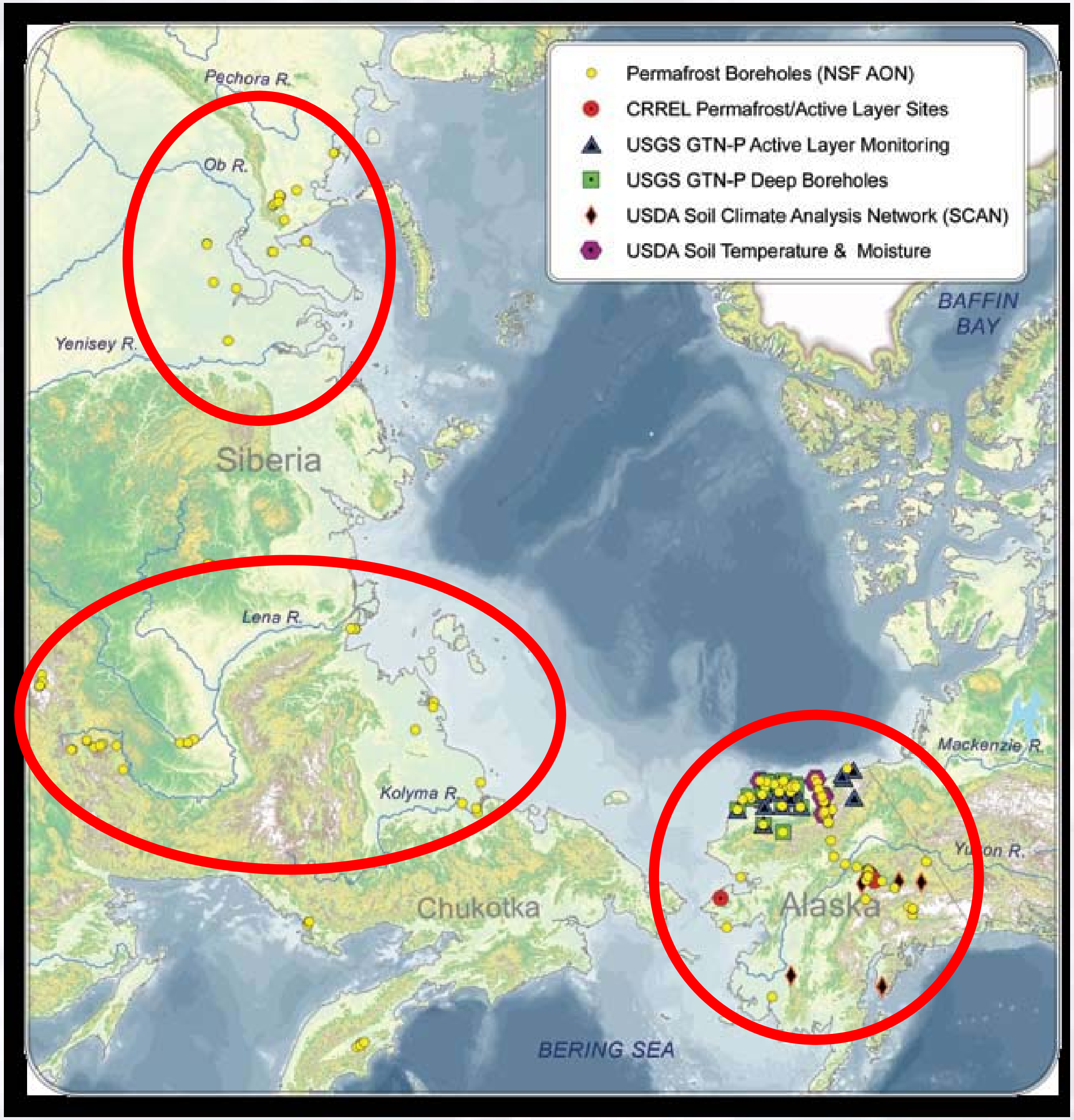


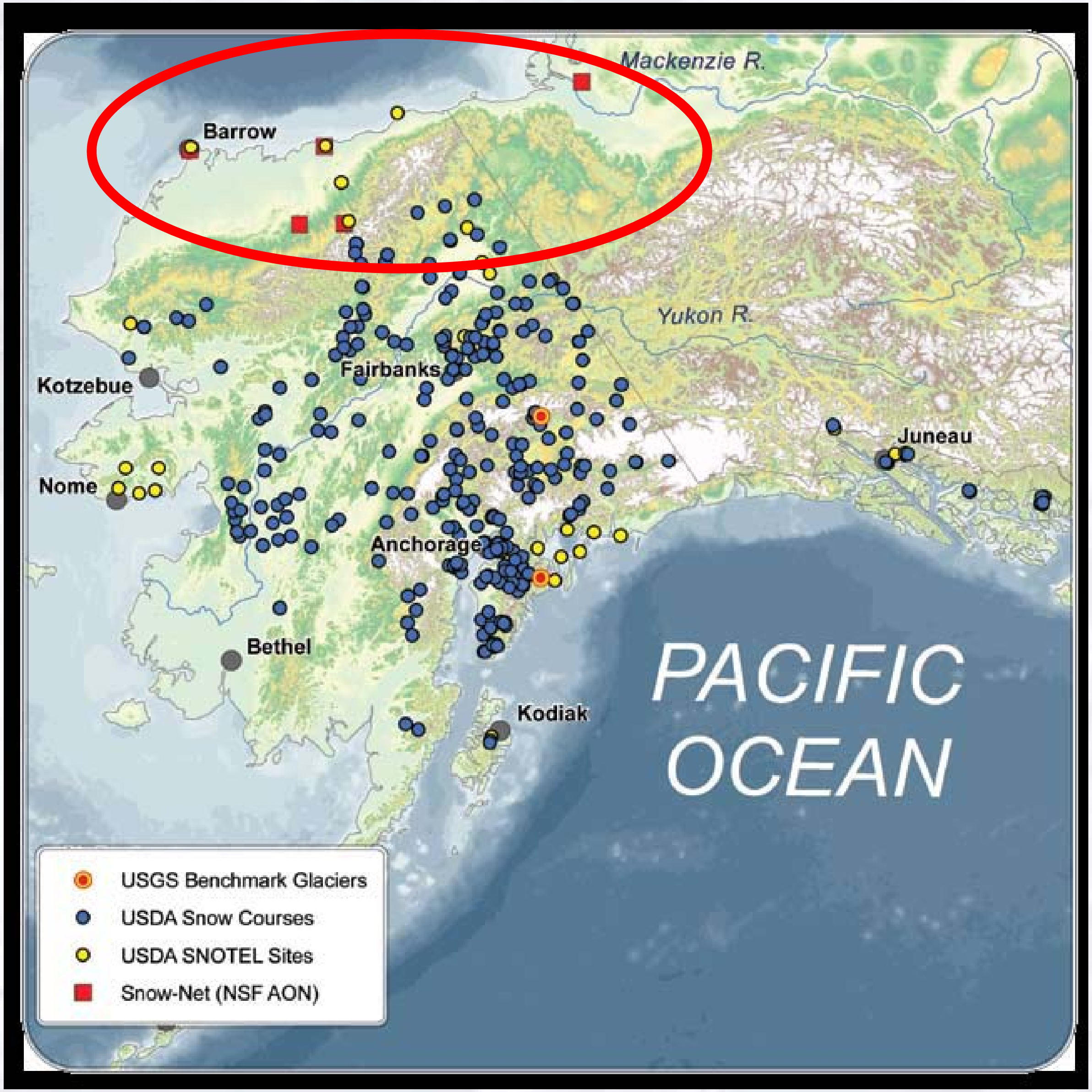
Figure 16. Location of circum-Arctic atmosphere observing sites.

AON Permafrost Observations



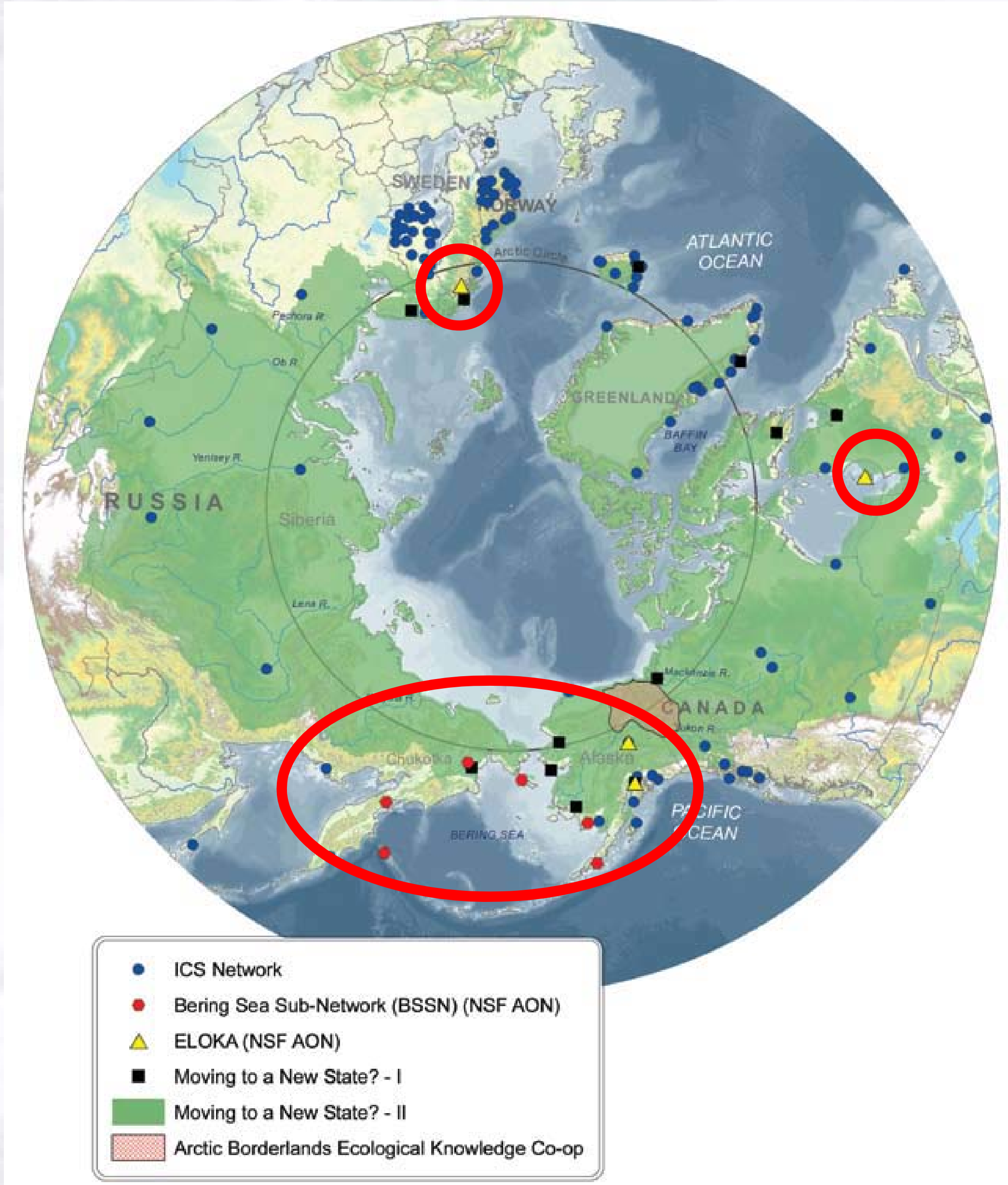
AON Hydrological Observations

AON Snow and Glacier Obs.

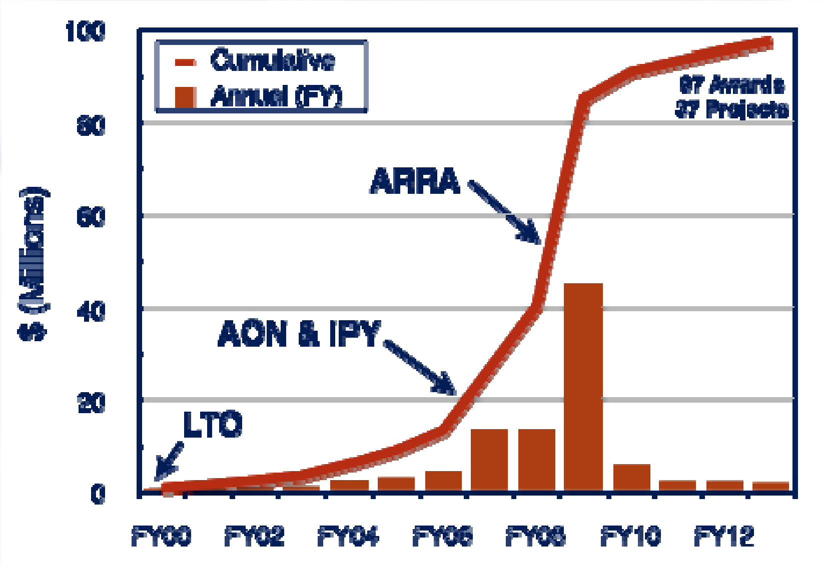


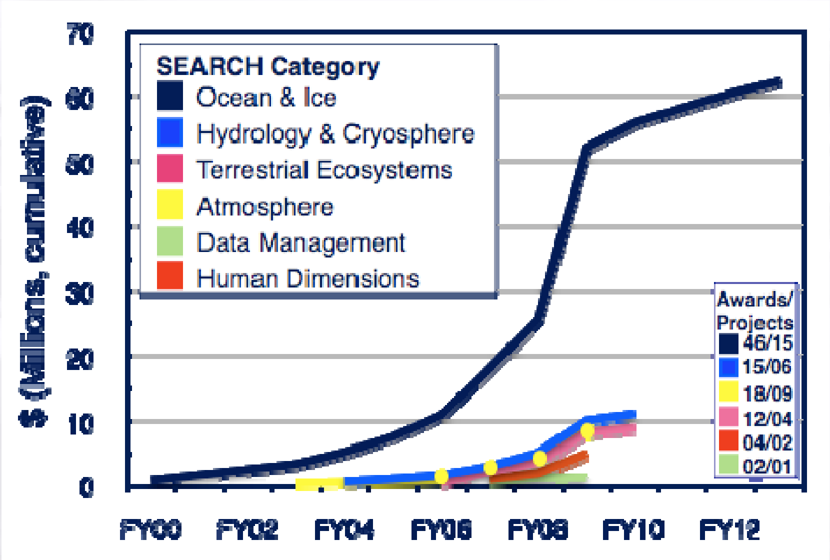
AON Terrestrial Ecosystem Obs.

AON Community Based Obs.



NSF Investments into AON

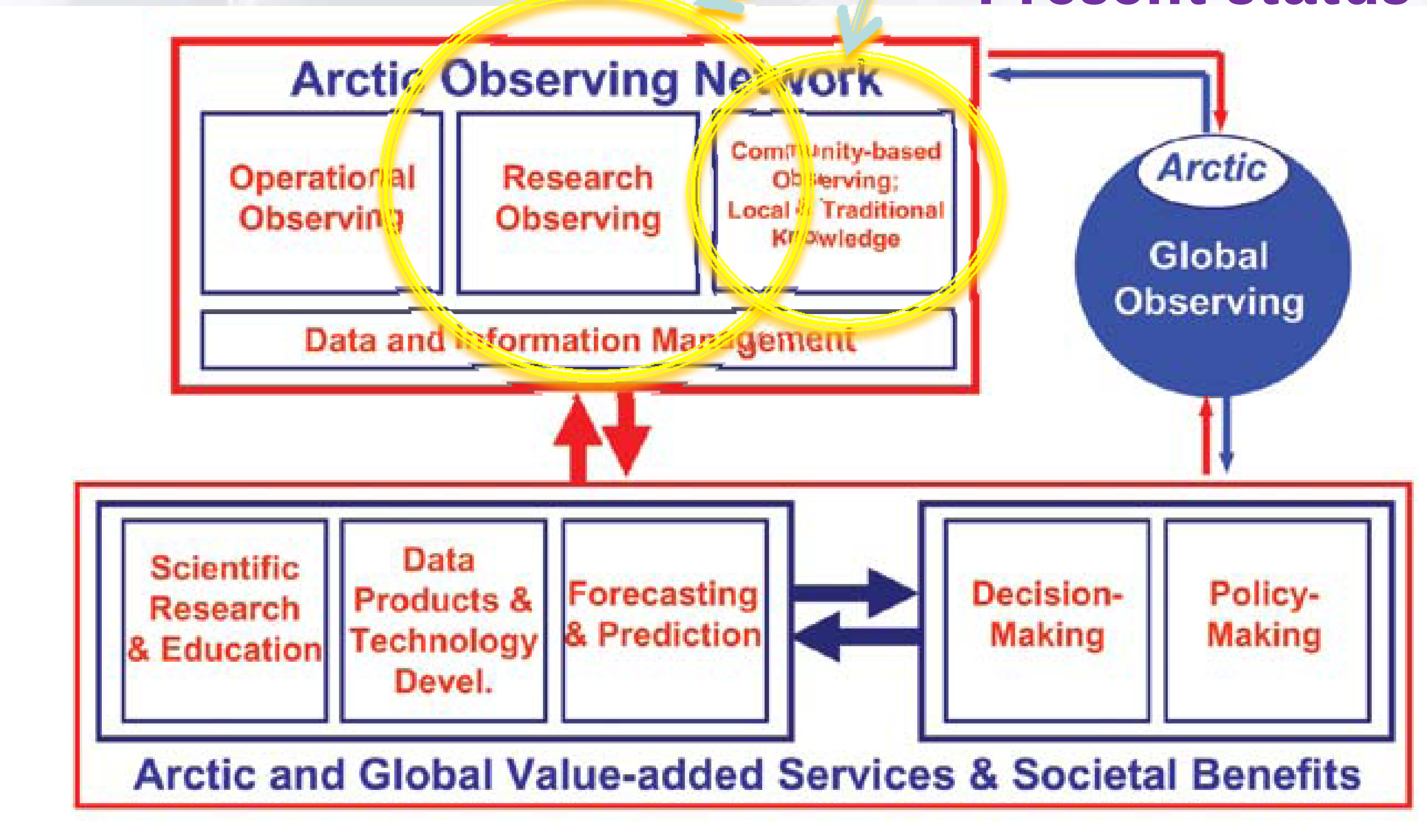




Information from Martin Jeffries, NSF AON program director

AON in Context

SEARCH
Present status



International partners: DAMOCLES

Developing Arctic Modelling and Observing Capabilities for Long-term Environment Studies

- ***reduce the uncertainties in our understanding of climate change in the Arctic and in the impacts thereof***

  - Synoptic observational coverage of the Arctic Ocean sea-ice cover
  - Synoptic observation and investigation of atmospheric key processes
  - Synoptic observation of the Arctic Ocean circulation and key processes
  - Integration and assimilation of observations with large-scale models
  - Assessment of impact on environment and humans
  - User-friendly return of information to the community

ArcticNet
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Arctic Change 2008

DECEMBER 9-12, 2008 Quebec City Convention Centre

Home | Programme | Registration | Call for Abstracts | Sponsors & Exhibitors | Hotels & Venue

Topical Sessions • Conference Programme • Student Day

Conference Programme

Building on the success of previous ArcticNet Annual Scientific Meetings, Arctic Change 2008 is designed with the intent to inform participants of innovative Arctic research, essential to the understanding and management of the natural and built environments of the Arctic impacted by climate change and globalization. In the spirit of trans-sectoral research, the programme will be composed of a mix of concurrent topical sessions and multidisciplinary plenary sessions.

Arctic Change 2008 will begin on the morning of Tuesday, 9 December with the International Student Day, organized by the ArcticNet Student Association. The official Arctic Change 2008 registration reception will follow on Tuesday evening, providing the opportunity to register and meet fellow participants. Topical and plenary sessions will be presented from 08:30 am to 05:00 pm from Wednesday, 10 December to Friday, 12 December. A dedicated poster session/reception will be held on the evening of Wednesday, 10 December. Posters will also be available for viewing during the entire week. A conference banquet dinner will be hosted in the Hilton Hotel Ballroom on Thursday evening.

Preliminary agenda:

	TUESDAY, 9 DECEMBER	WEDNESDAY, 10 DECEMBER	THURSDAY, 11 DECEMBER	FRIDAY, 12 DECEMBER
08:30 - 10:00	Student Day	Plenary Session	Plenary Session	Topical Sessions
10:00 - 10:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break
10:30 - 12:00	Student Day	Topical Sessions	Topical Sessions	Topical Sessions
12:00 - 13:30	Lunch	Lunch	Lunch	Lunch
13:30 - 15:00	Student Day	Topical Sessions	Topical Sessions	Plenary Sessions
15:00 - 15:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break
15:30 - 17:00	Student Day	Plenary Session	Plenary Session	Meeting Adjourns
17:00 - 19:00	Registration/Reception	Poster Session		
19:00 - 23:00	Dinner on your own	Dinner on your own	Banquet	

The Final Programme (agenda, abstracts, list of participants, sponsors and exhibitors) will be available for download on this page in November 2008. Hard copies of the programme will be included in the registration packages.

Sponsors

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Poster Awards

For sponsorship opportunities, click here.

Partners

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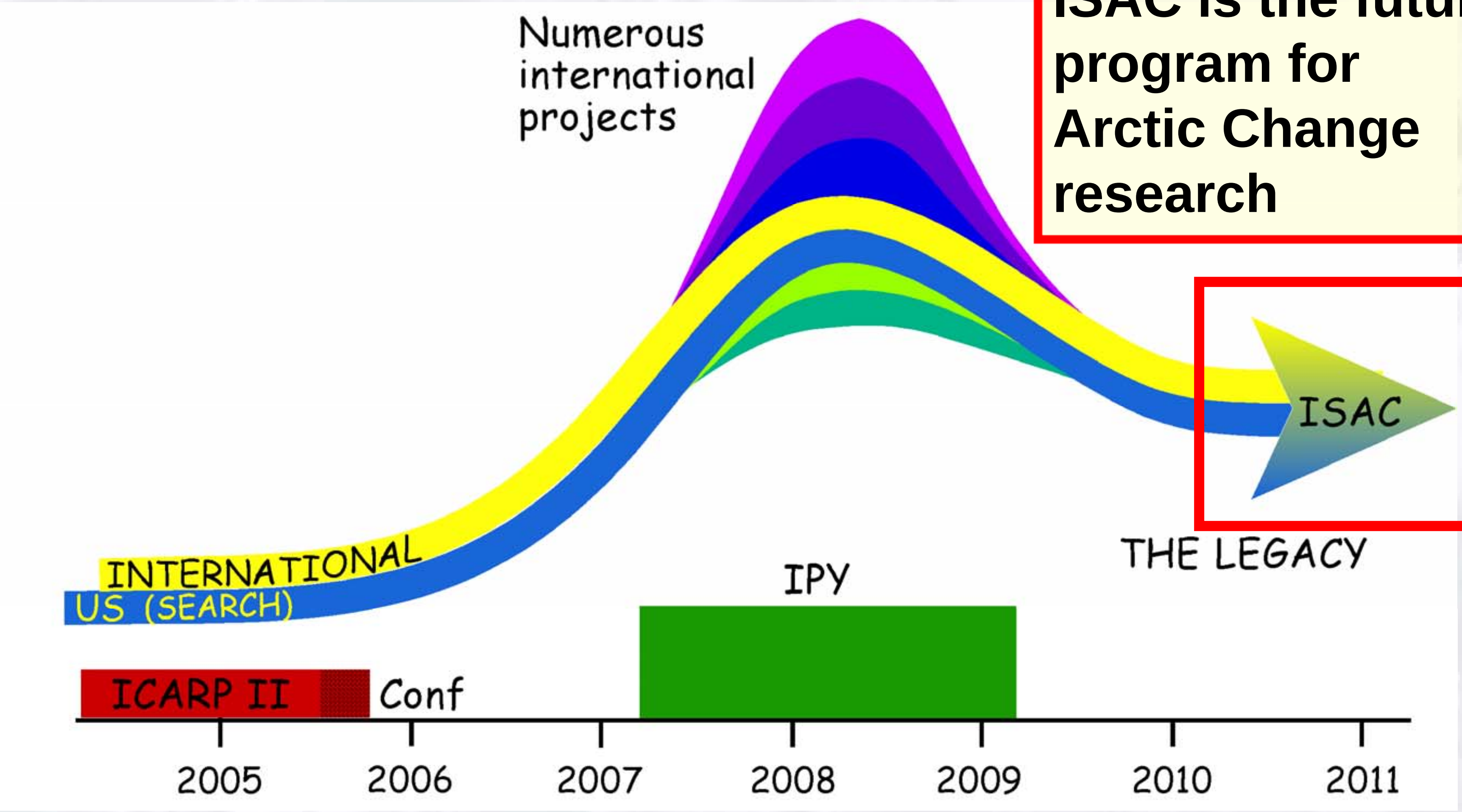
DAMOCLES 2005 - 2009

ISAC: long-term position



ISAC is the future program for Arctic Change research

Anderson; see also Dickson: AOSB Newsletter

Perspectives

- **The Arctic is changing at a rapid pace.**
- **Understanding the changes requires observations, as well as modeling and synthesis activities.**
- **The observations have to be obtained through a pan-Arctic integrated, long-term observing system.**
- **The IPY has provided the impetus to establish the Arctic observing system.**
- **Future international efforts and collaborations needed to effectively finish implementation of Arctic system observing needs in the context of a global Earth observing system (e.g., GEOSS).**
- **Modeling and synthesis efforts have to be strengthened**