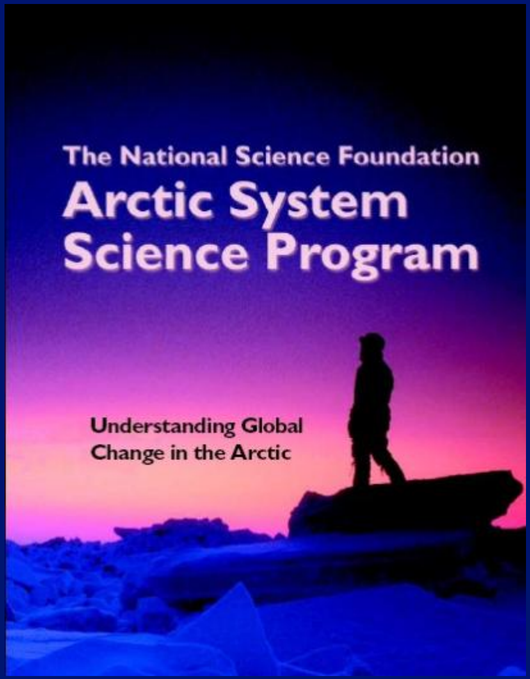
Setting a Course for Antarctic Integrated and Systems Science (AISS):

Lessons from ARCSS

A personal perspective

Joshua Schimel,
University of California Santa Barbara,
ARCSS Committee Chair

On behalf of the ARCSS Committee and ARCSS Science Management Office



My Background:

- B.A. in Chemistry
- Ph.D. in Soil Microbiology

My research focuses on the links between soil microorganisms and ecosystem function.

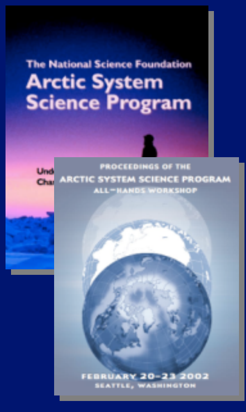
ARCSS

- History
- Accomplishments
- Limitations
- Management

ARCSS Program History

Milestones

- 1989 - Began as one of 22 Global Change Research programs at NSF
- 1996 All-Hands Workshop - “Toward An Arctic System Synthesis: Results and Recommendations”
- 2002 All-Hands Workshop - Transition from “domain” groupings to integrated program
- 2003/2004 - Program reorganized to advance system-science, synthesis approaches



Understanding Global Change in the Arctic: Arctic System Science

The Earth system has always been dynamic and changing, but because of human activities, it now is changing at an ever-increasing pace. Climate models suggest, and recent data indicate, that changes will be amplified in the Arctic and, thus, will be detected there first. The Arctic is an ideal place to study global change because of the relative simplicity and vulnerability of its ecosystems:

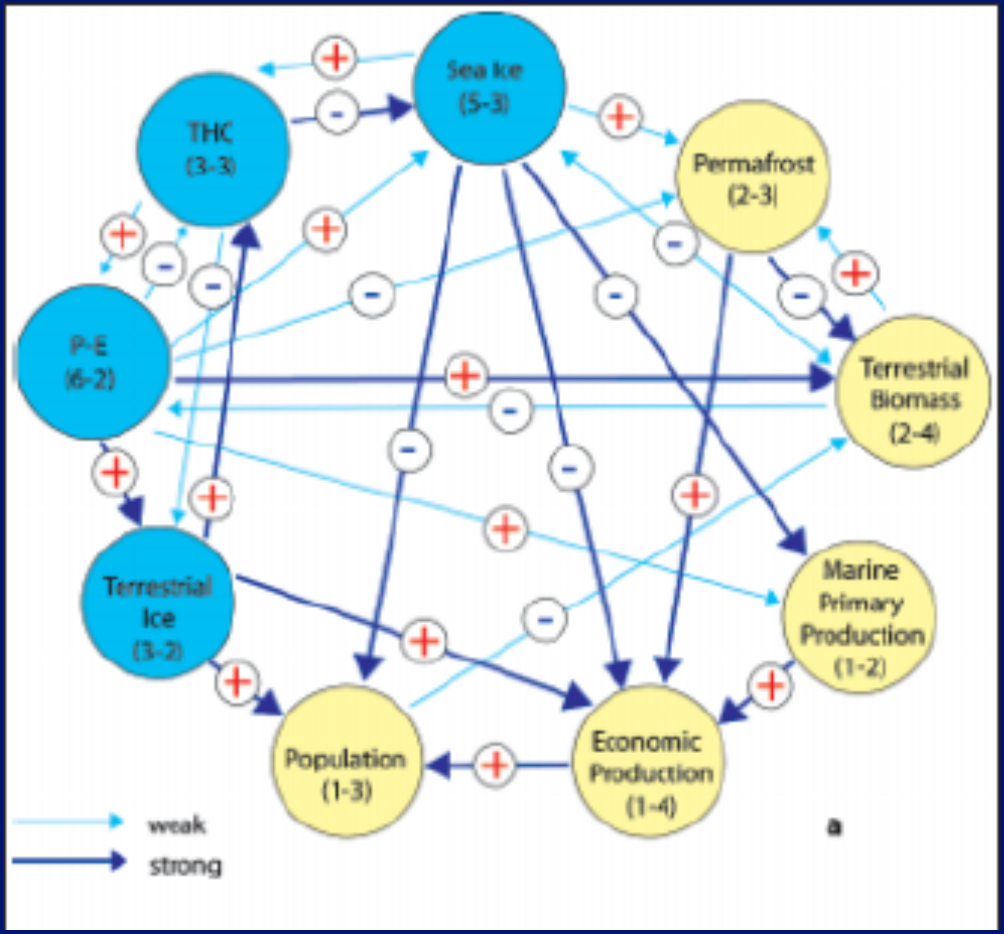
- The arctic environment interacts in complex and significant ways with global climate systems. For example, floating sea ice affects the global weather by acting as a variable lid on the polar oceans, reflecting the sun's energy rather than allowing it to be absorbed by the dark ocean. The ice cover also prevents the release of the ocean's heat energy upward to the atmosphere.
- The permafrost, ice sheets, and lake and ocean sediments contain records of past climates that can describe complex climate systems.
- The Arctic is one of two heat "sinks" in the global heat engine; the Antarctic is the other.
- The region has large reserves of natural resources, some of which have been extensively developed and used. The cumulative effects of development and exploitation on natural systems are major concerns of global change research and can be readily studied in the Arctic.
- Global change is likely to have profound consequences for the region's human communities, particularly the indigenous people who depend on local resources.
- Much of the region is remote, so basic scientific understanding of the arctic environment has been limited.

Since 1989, the Arctic System Science (ARCSS) Program has been a leader within the research community in implementing a systems science approach to the study of a region. U.S. and international investigators have worked throughout the Arctic, collaborating on integrated long-term research. ARCSS researchers are striving to understand the responses of physical, biological, and social systems within the Arctic to global changes, and how changes in the Arctic may affect the rest of the globe. The goals of the ARCSS Program are:

- to understand the processes of the arctic system that interact with the total Earth system and contribute to, or are influenced by, global change, in order
- to advance the scientific basis for predicting environmental change, and for formulating policy options in response to the anticipated impacts of global changes on human beings and societal support systems.

The ARCSS Program contributes a regional perspective to the development of a thorough scientific understanding of the Earth system, providing the foundation for understanding climate fluctuations and long-term climate change, as well as vulnerabilities to changes in other important environmental factors. This research is a critical investment toward informed decision making on environmental issues and the future of this nation.

A system view of the Arctic

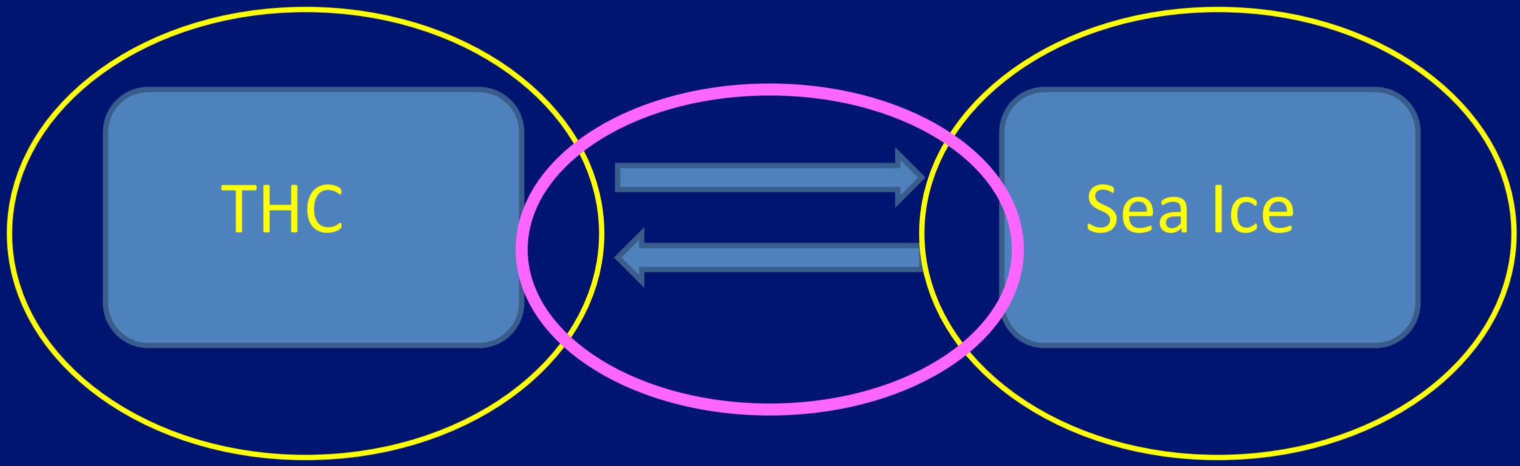


From Overpeck et al. 2005. Arctic System on Trajectory to New, Seasonally, Ice-Free State. EOS. 86: 309, 312-313.

Arctic System Complexity

ARCSS Program

- ARCSS focuses on understanding the connections and feedbacks between components of the Arctic System.



ARCSS Research
Past Components

- **GISP2** - Greenland Ice Sheet Project Two (GISP2)
- **PALE -** Paleoclimates from Arctic Lakes and Estuaries
- **OAII** - Ocean-Atmosphere-Ice Interactions

  NWP, Arctic Ocean Section, SHEBA, SBI
- **LAII** - Land-Atmosphere-Ice Interactions

  Flux, ATLAS, ITEX
- **PARCS** - Paleoenvironmental Arctic Sciences
  (incorporated GISP2 and PALE)
- **RAISE/LSI** - Russian-American Initiative on Shelf-Land Environments in the Arctic

Current ARCSS Research

- ***ARCSS Program currently funds over 160 projects***
- **FWI** - Freshwater Integration Study

  Group 1: year 5; Group 2: year 4
- **SBI** - Western Arctic Shelf-Basin Interactions

  10 years of field data and analysis

  Entering Phase III - Synthesis
- **SNACS** - Study of the Northern Alaska Coastal System

  6 projects, In 3rd year
- **SASS** - Synthesis of Arctic System Science

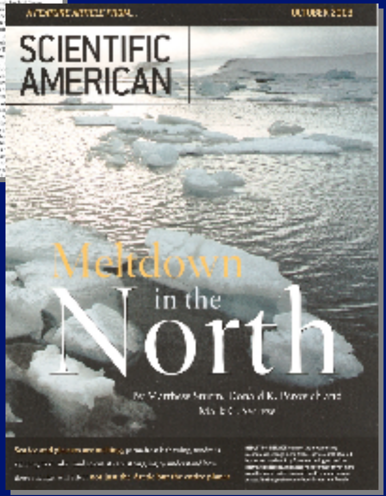
  9 "SASS I" projects (funded 2005)
  8 "SASS II" projects (funded 2006)
- **HARC** - Human Dimensions of the Arctic System

  Since 1997

ARCSS Research

A few Results & Highlights

- GISP2
  - *341 papers*
  - *34 in Science and Nature*
- SHEBA
  - *145 papers*
- LAII *(partial, through 2004)*
  - *115 papers total*
    - *4 in Science and Nature*
    - *5 in BioScience*
  - *25 synthesis papers*
  - *2 TV Documentaries*



First Case Study:

Freshwater Integration study (FWI)

A thematic program

Goals Arctic-CHAMP/ASOF/SEARCH
Freshwater Initiative (FWI) Are Fundamentally Synthetic

Q1: Is the Arctic FW Cycle Intensifying?

- *Quantify Stocks and Fluxes*
- *Document Changes to the Arctic Hydrologic Cycle*

Q2: If So, Why?

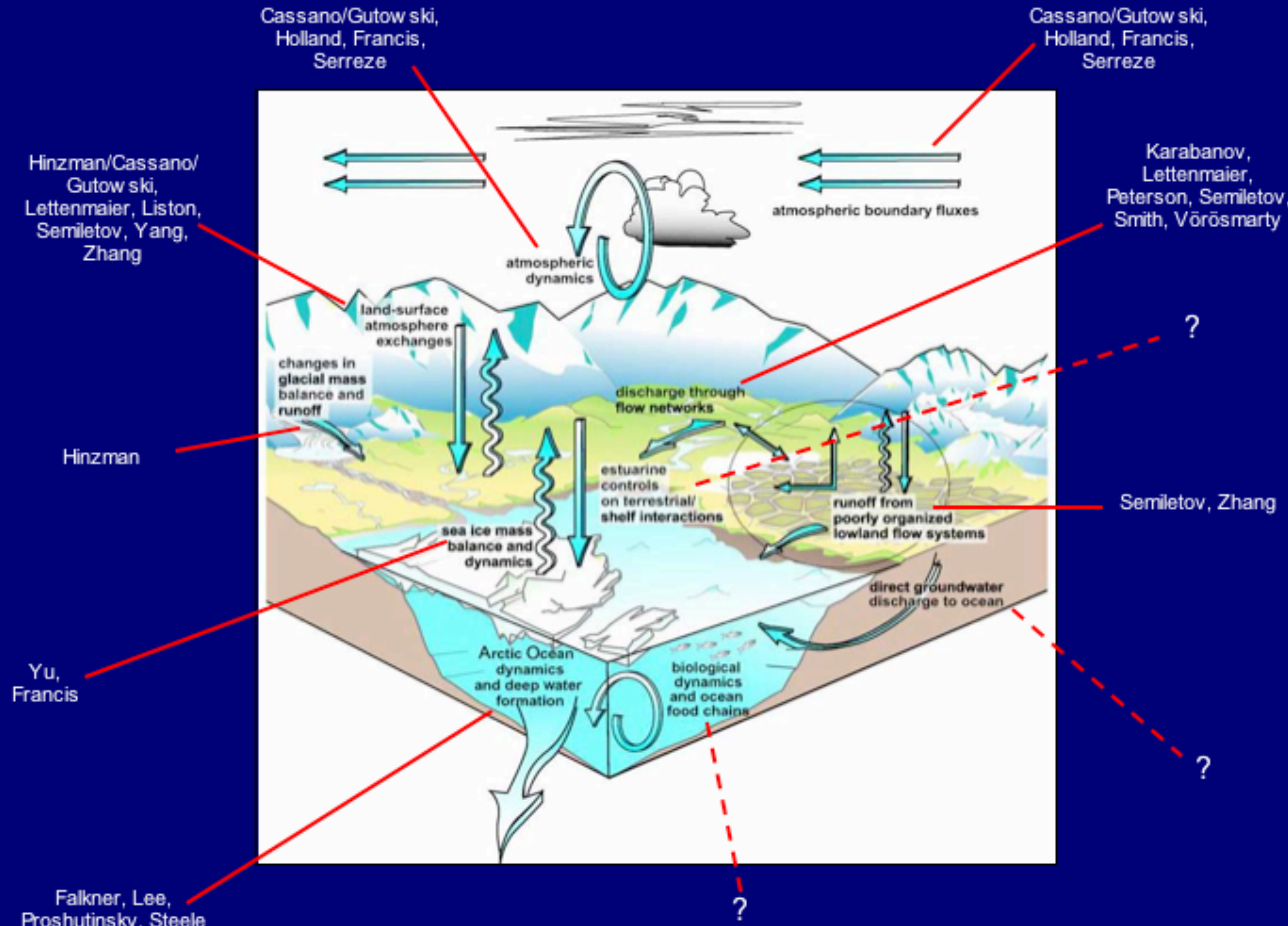
- *Understand the Source of the Change: Attribution*

Q3: What Are the Implications

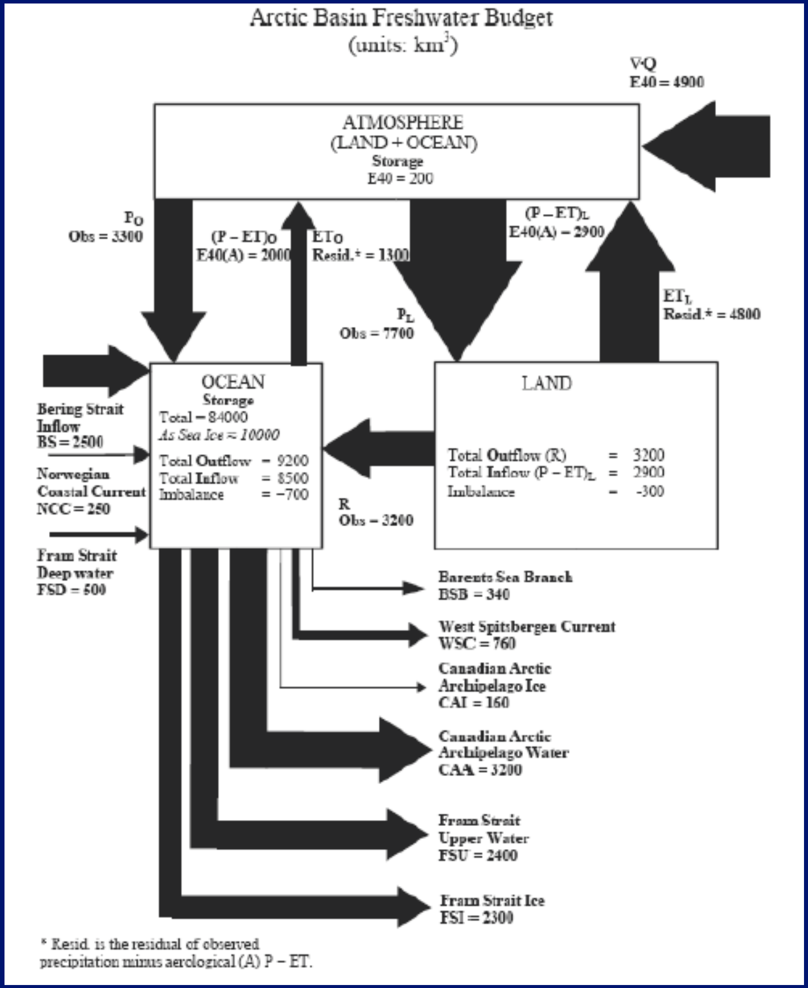
- *Develop Predictive Simulations of Feedbacks to the Earth and Human Systems*

Arctic-CHAMP= Community-wide Hydrologic Analysis and Monitoring Program

ASOF = Int’l Arctic-Sub-Arctic Ocean Flux study


Cassano/Gutow ski,
Holland, Francis,
Serreze
Cassano/Gutow ski,
Holland, Francis,
Serreze
Hinzman/Cassano/
Gutow ski,
Lettenmaier, Liston,
Semiletov, Yang,
Zhang
Karabanov,
Lettenmaier,
Peterson, Semiletov,
Smith, Vörösmarty
atmospheric boundary fluxes
atmospheric dynamics
land-surface atmosphere exchanges
changes in glacial mass balance and runoff
discharge through flow networks
?
Hinzman
estuarine controls on terrestrial/ shelf interactions
runoff from poorly organized lowland flow systems
Semiletov, Zhang
sea ice mass balance and dynamics
direct groundwater discharge to ocean
Arctic Ocean dynamics and deep water formation
biological dynamics and ocean food chains
Yu,
Francis
?
Falkner, Lee,
Proshutinsky, Steele
?

Example of FWI Synthesis: Budgeteers Group

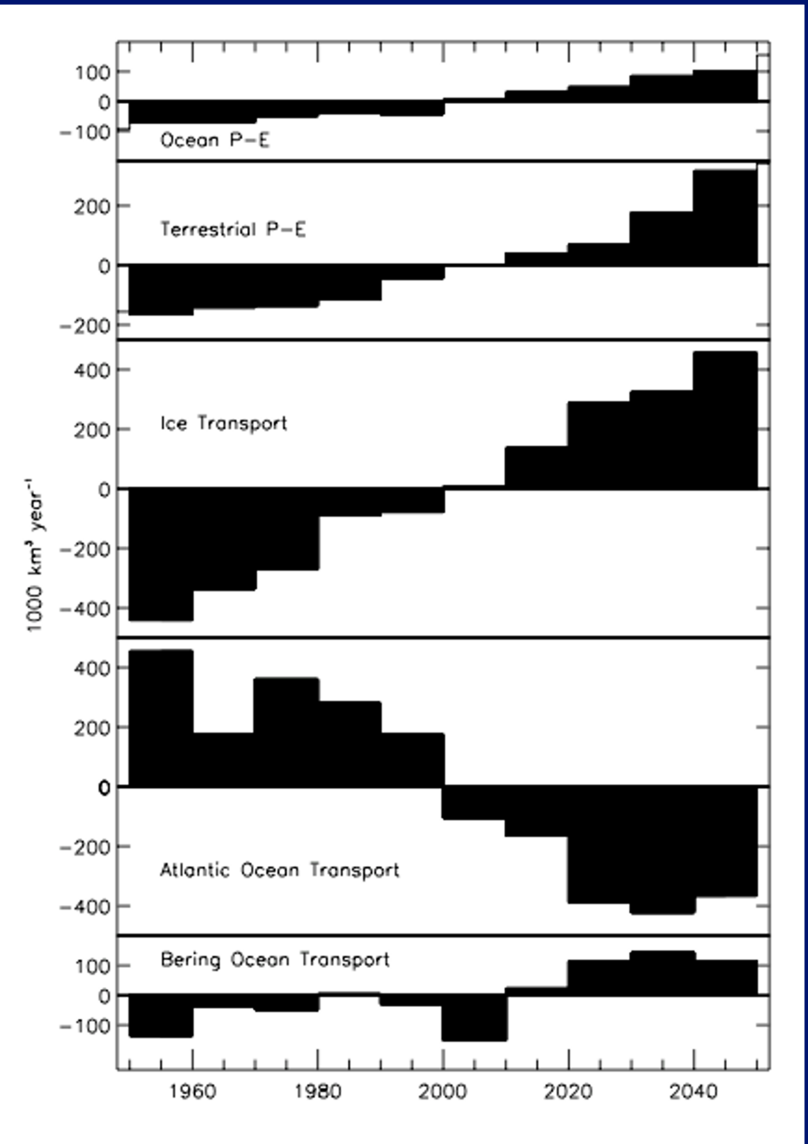


The Arctic Freshwater Budget

- Well-focused target
- System-wide view
- Many perspectives
- Directions for future work

Serreze et al., 2006, JGR-Oceans

Evidence for an accelerating FW cycle



Multi-model mean changes in Arctic Ocean FW Budgets 1950-2050

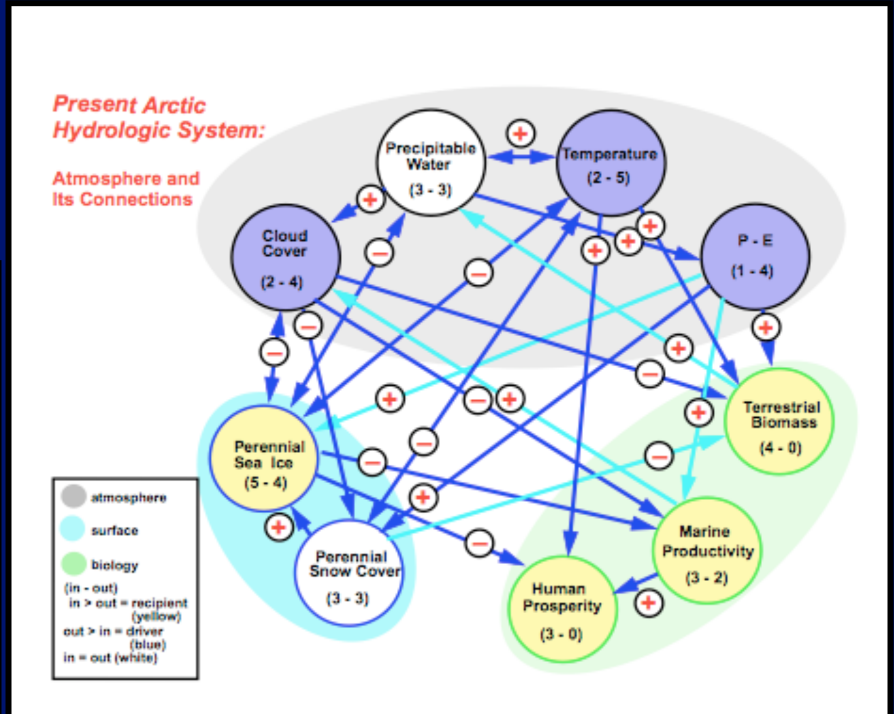
- Increasing net precipitation over land and ocean
- Increasing ice melt, resulting in reduced ice transport
- Increasing liquid FW transport to the Atlantic ocean
- Small increase in Bering Strait FW inflow

Positive means net flux into Arctic

Holland et al., 2007

CHANGES AND ATTRIBUTION Working Group

Feedbacks & implications on major subsystems



Francis et al., (in prep.)

White et al. JGR, Biogeosciences (submitted)

Changes in Key Stocks and Fluxes
Over "Period of Record"

VARIABLE	TREND	CONFIDENCE
Atmospheric Moisture Transport	Increasing	Very Good
Atmospheric Storage	Increasing	Very Good
Precipitation	Increasing	Very Good
River Discharge – Eurasian River Discharge – N. American	Increasing No Trend	Very Good Good
Lakes / Wetland	?	?
Reservoirs	Increasing	Excellent
Groundwater	?	?
Permafrost – Active Layer Thickness – Eurasia Active Layer Thickness – N. America Permafrost – Storage	Increasing No Trend ?	Good Good ?
Sea Ice – Area Sea Ice – Volume Sea Ice – First Year	Decreasing Decreasing Decreasing	Excellent Good Excellent
North Atlantic / Nordic Sea	Increasing	Excellent
Fram Strait Outflow – Liquid Fram Strait Outflow – Ice	? Increasing	? Very Good?
Pacific Inflow	Increasing	Very Good
Arctic Ocean	?	?

Document basic character of Δ

FWI PROGRESS THROUGH 2007

- >100 peer-reviewed publications
- >100 presentations at National and Int'l forums:
  ACIA, ARCSS Synthesis Retreats, AGU, EGU, ASLO, etc.
- >24 Graduate and Undergraduate students
- Outreach efforts:
  AGU Press Conference, CNN, NY Times documentary,
  Discovery Channel, Canadian Broadcasting Co.,
  NPR's 'All Things Considered'

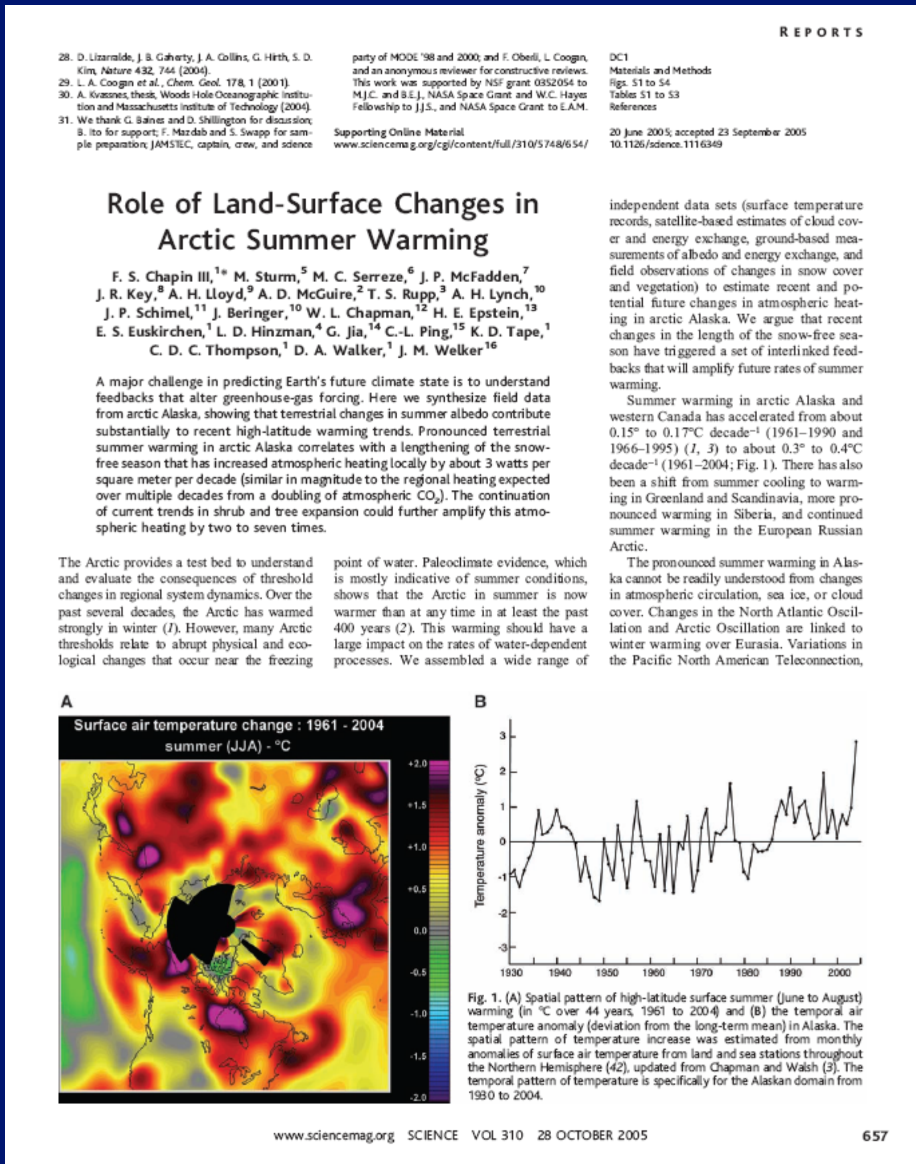
Second Case Study:

Role of land-surface changes in Arctic summer warming

Chapin et al. 2005

Science 310:657-659

An “accidental” success?



28. D. Lizarralde, J. B. Gaherty, J. A. Collins, G. Hirth, S. D. Kim, *Nature* 432, 744 (2004).
29. L. A. Coogan *et al.*, *Chem. Geol.* 178, 1 (2001).
30. A. Kvassnes, thesis, Woods Hole Oceanographic Institution and Massachusetts Institute of Technology (2004).
31. We thank G. Baines and D. Shillington for discussion; B. Ito for support; F. Mazdab and S. Swapp for sample preparation; JAMSTEC, captain, crew, and science party of MODE '98 and 2000; and F. Oberli, L. Coogan, and an anonymous reviewer for constructive reviews. This work was supported by NSF grant 0352054 to M.J.C. and B.E.J., NASA Space Grant and W.C. Hayes Fellowship to J.J.S., and NASA Space Grant to E.A.M.

Supporting Online Material
www.sciencemag.org/cgi/content/full/310/5748/654/DC1
Materials and Methods
Figs. S1 to S4
Tables S1 to S3
References

20 June 2005; accepted 23 September 2005
10.1126/science.1116349

Role of Land-Surface Changes in Arctic Summer Warming

F. S. Chapin III,[1*] M. Sturm,[5] M. C. Serreze,[6] J. P. McFadden,[7] J. R. Key,[8] A. H. Lloyd,[9] A. D. McGuire,[2] T. S. Rupp,[3] A. H. Lynch,[10] J. P. Schimel,[11] J. Beringer,[10] W. L. Chapman,[12] H. E. Epstein,[13] E. S. Euskirchen,[1] L. D. Hinzman,[4] G. Jia,[14] C.-L. Ping,[15] K. D. Tape,[1] C. D. C. Thompson,[1] D. A. Walker,[1] J. M. Welker[16]

A major challenge in predicting Earth's future climate state is to understand feedbacks that alter greenhouse-gas forcing. Here we synthesize field data from arctic Alaska, showing that terrestrial changes in summer albedo contribute substantially to recent high-latitude warming trends. Pronounced terrestrial summer warming in arctic Alaska correlates with a lengthening of the snow-free season that has increased atmospheric heating locally by about 3 watts per square meter per decade (similar in magnitude to the regional heating expected over multiple decades from a doubling of atmospheric CO_2). The continuation of current trends in shrub and tree expansion could further amplify this atmospheric heating by two to seven times.

The Arctic provides a test bed to understand and evaluate the consequences of threshold changes in regional system dynamics. Over the past several decades, the Arctic has warmed strongly in winter (*1*). However, many Arctic thresholds relate to abrupt physical and ecological changes that occur near the freezing point of water. Paleoclimate evidence, which is mostly indicative of summer conditions, shows that the Arctic in summer is now warmer than at any time in at least the past 400 years (*2*). This warming should have a large impact on the rates of water-dependent processes. We assembled a wide range of independent data sets (surface temperature records, satellite-based estimates of cloud cover and energy exchange, ground-based measurements of albedo and energy exchange, and field observations of changes in snow cover and vegetation) to estimate recent and potential future changes in atmospheric heating in arctic Alaska. We argue that recent changes in the length of the snow-free season have triggered a set of interlinked feedbacks that will amplify future rates of summer warming.

Summer warming in arctic Alaska and western Canada has accelerated from about 0.15° to 0.17°C decade^{-1} (1961–1990 and 1966–1995) (*1*, *3*) to about 0.3° to 0.4°C decade^{-1} (1961–2004; Fig. 1). There has also been a shift from summer cooling to warming in Greenland and Scandinavia, more pronounced warming in Siberia, and continued summer warming in the European Russian Arctic.

The pronounced summer warming in Alaska cannot be readily understood from changes in atmospheric circulation, sea ice, or cloud cover. Changes in the North Atlantic Oscillation and Arctic Oscillation are linked to winter warming over Eurasia. Variations in the Pacific North American Teleconnection,

Fig. 1. (A) Spatial pattern of high-latitude surface summer (June to August) warming (in °C over 44 years, 1961 to 2004) and (B) the temporal air temperature anomaly (deviation from the long-term mean) in Alaska. The spatial pattern of temperature increase was estimated from monthly anomalies of surface air temperature from land and sea stations throughout the Northern Hemisphere (*42*), updated from Chapman and Walsh (*3*). The temporal pattern of temperature is specifically for the Alaskan domain from 1930 to 2004.

Key findings:

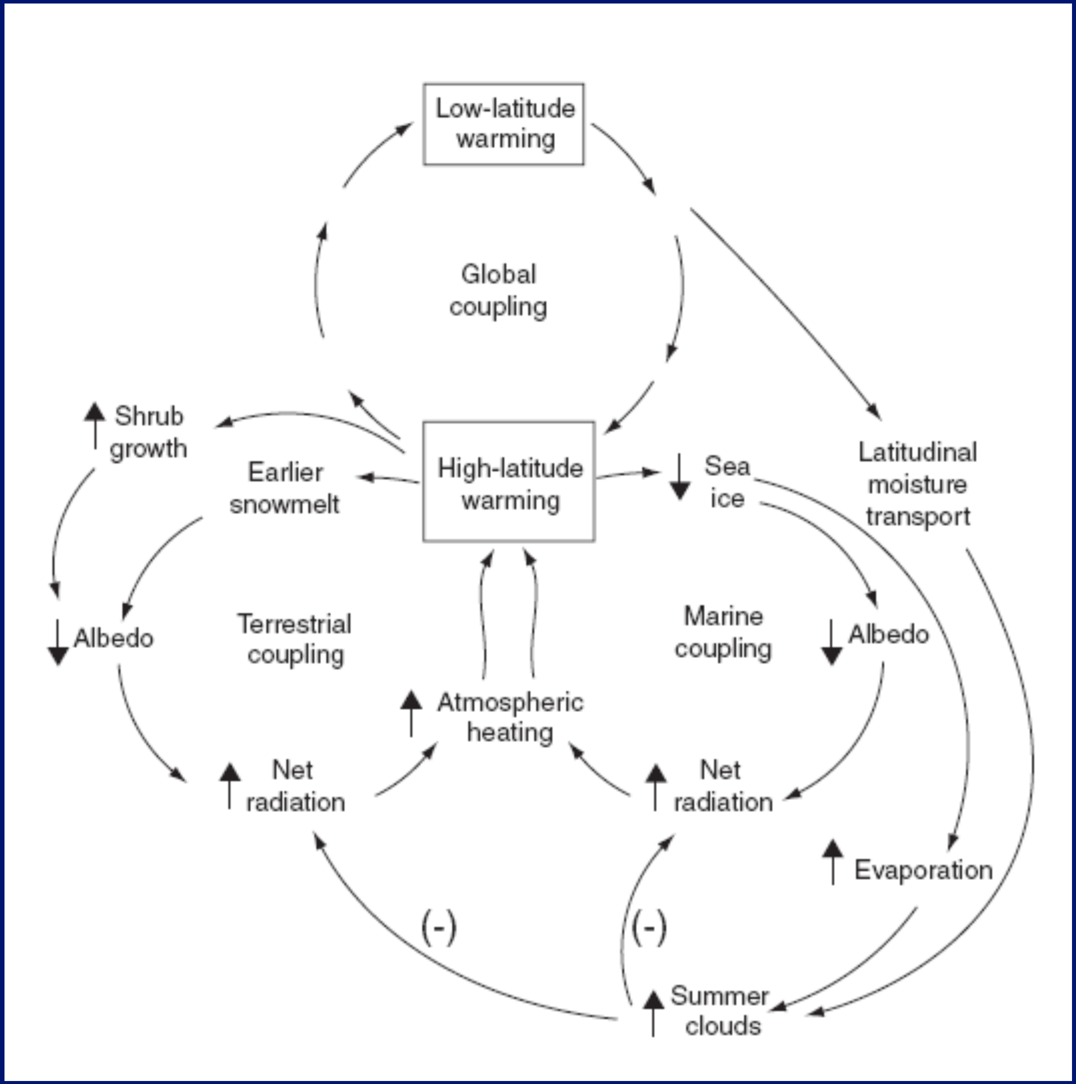
Summer warming so far is associated with longer season

Increasing woody vegetation exacerbates warming

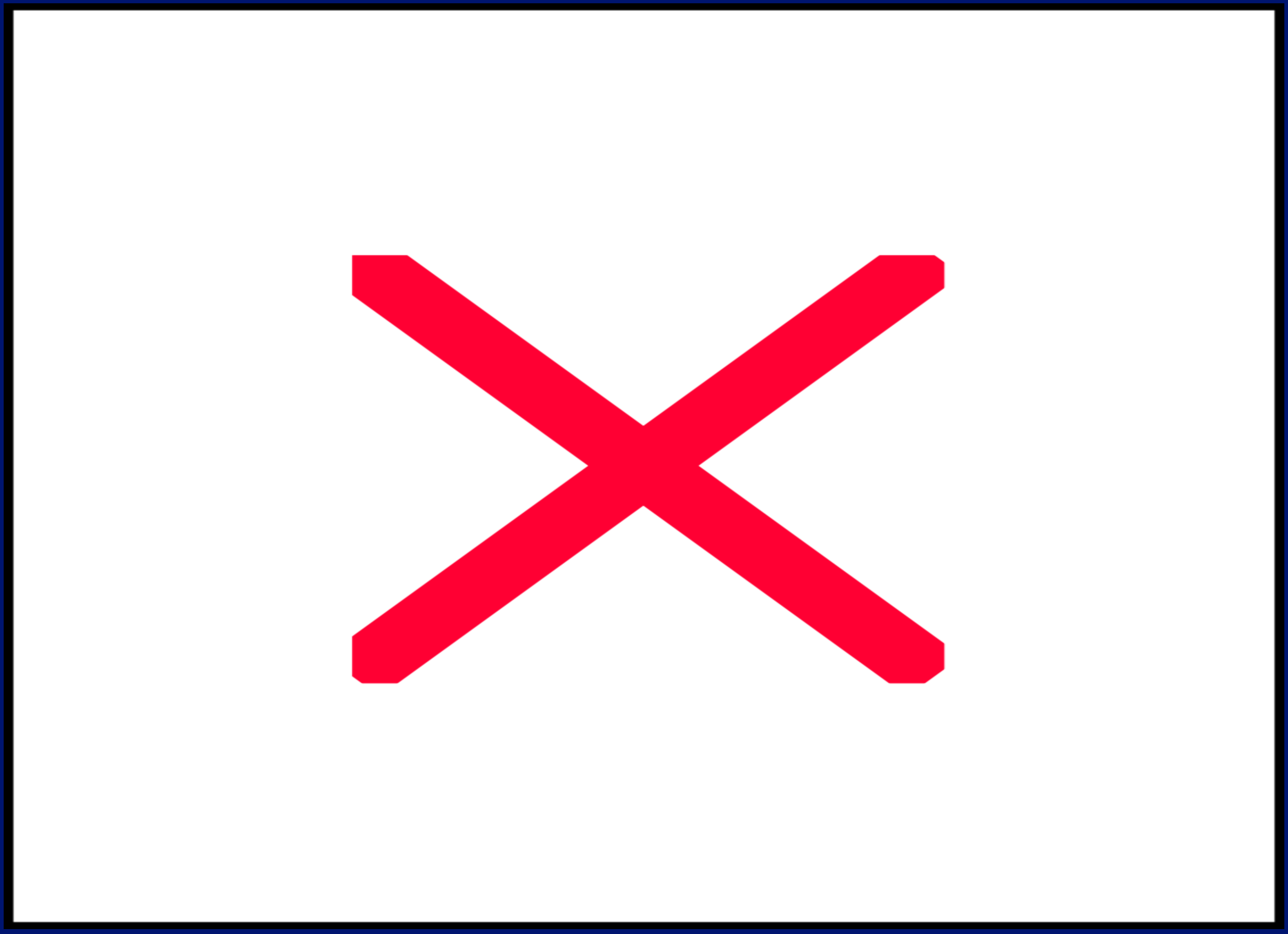
Shrub expansion is driven by internal positive feedbacks, involving nutrient cycling

A "climate surprise" identified before it has happened.

Integrated conceptual model of linkages and feedbacks driving warming



Synthesis grew from network of ATLAS collaborations



So: this synthesis was *NOT* "accidental" at all.

ATLAS targeted land surface - climate interactions.

Created a framework to pull in "peripheral" projects.

Developed a research community interested in collaborating on the larger synthesis.

ATLAS created opportunity for new synthesis

Successes:

Tons of important papers
Integrated understanding
Societally relevant science

Science that would not have grown from disciplinary programs

New scholars: *undergrad, grad, postdoc*
Outreach

Challenges and Limitations of System Science

1. Community building and support

    Requires active support & development

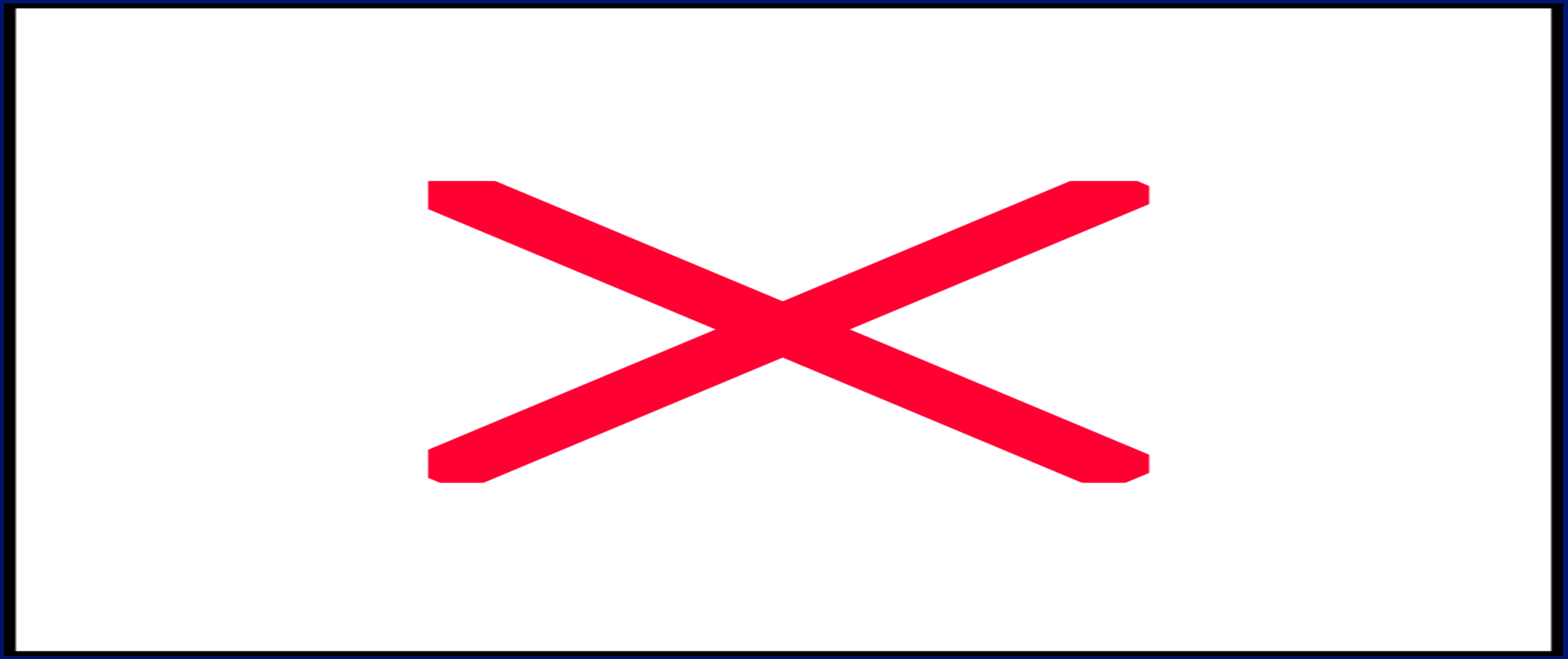
2. Interaction with disciplinary research

    Depends on healthy disciplinary research and generates new questions

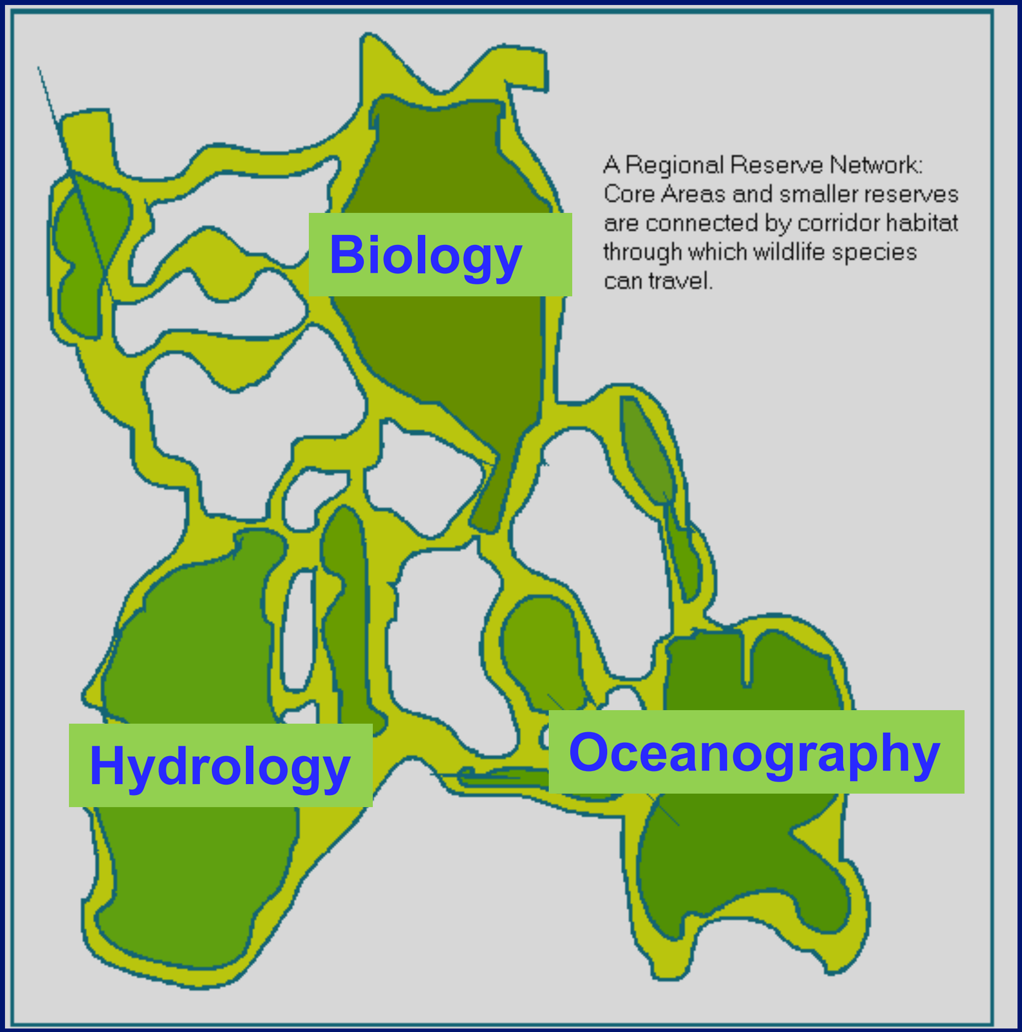
3. Planning is hard

    Time & energy from busy PIs and Program officers

1. Challenge 1: Community



Challenge 1: Community



Need to support the links ***between*** communities

Create a single, larger community

Community Planning Structure

- **Arctic Researchers**
- **National Science Foundation** - NSF ARCSS
- **ARCSS Committee (AC)** - takes lead on behalf of the research community in developing the ARCSS Program
- **Science Management Office** (SMO, currently at ARCUS) - work with NSF, AC, and community on priorities and strategies
- **Project Offices** (Arctic-CHAMP/FWI, SNACS synthesis coordinator, HARC Core Office)

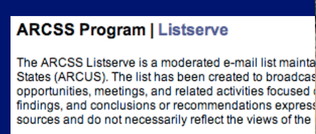
ARCSS Program | Message from the ARCSS Committee

Previous Messages:

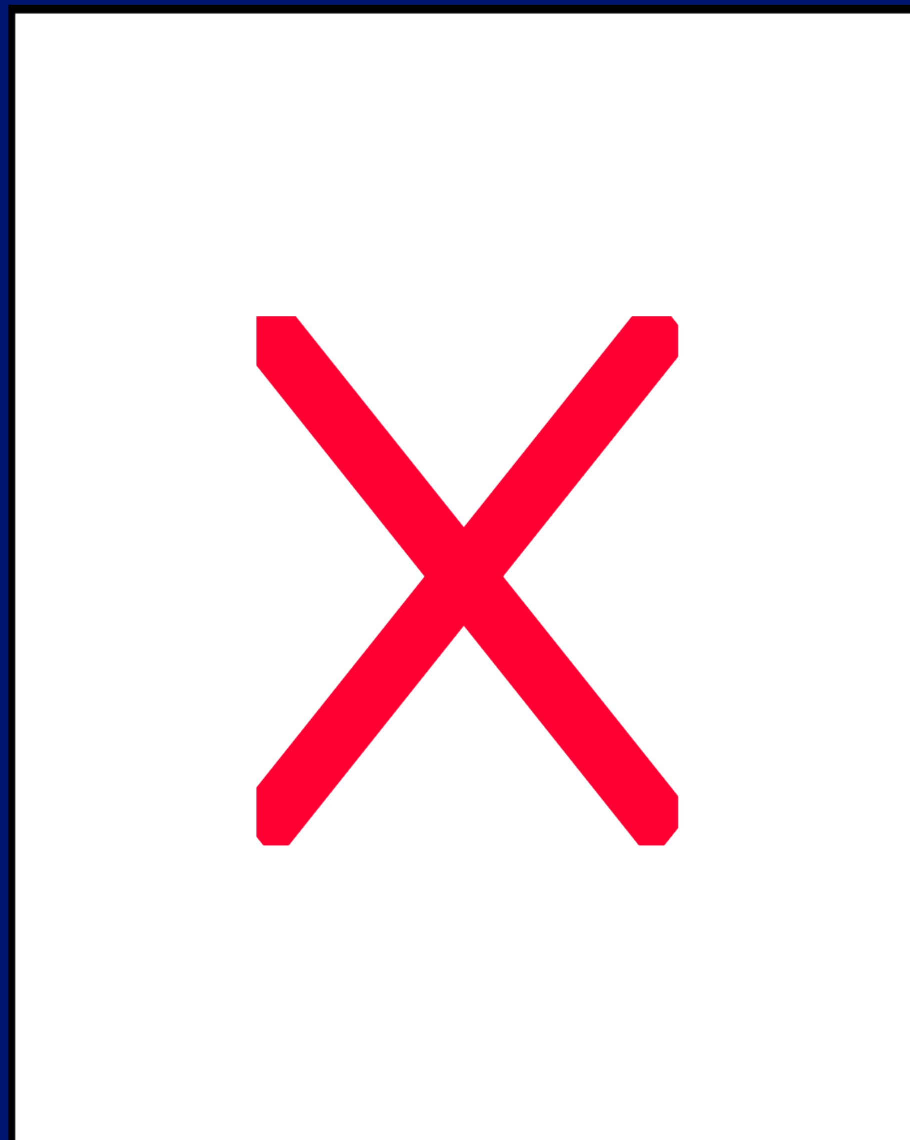
ARCSS Note #1 (2 August 2004): Community Input on Synthesis
ARCSS Note #2 (31 January 2005): Development of a New ARCSS Community Structure
ARCSS Note #3 (4 April 2005): ARCSS eTown Meeting Announcement
ARCSS Note #4 (15 April 2005): Update on ARCSS Program Activities
ARCSS Note #5 (1 August 2005): Call for Communities of Practice

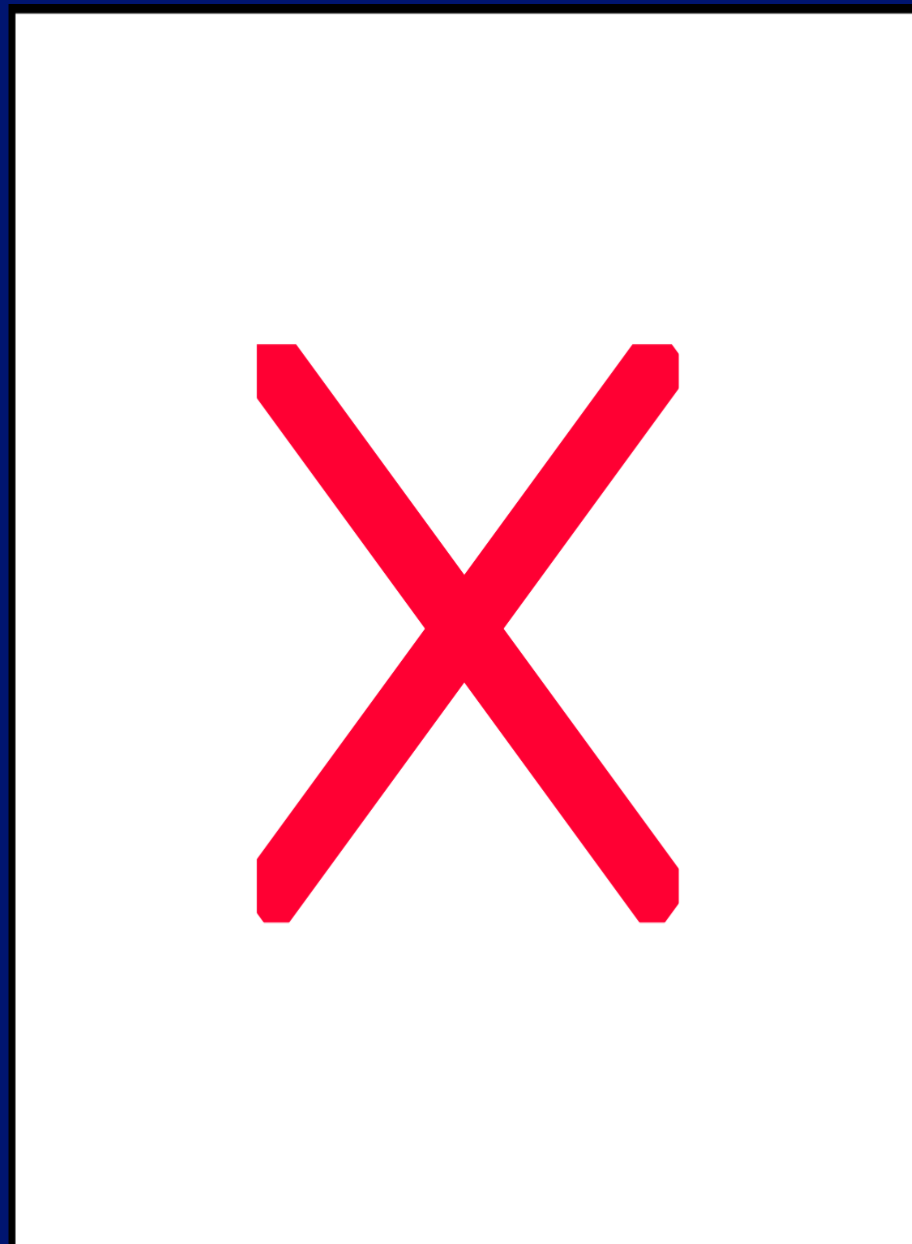
Community Planning Activities

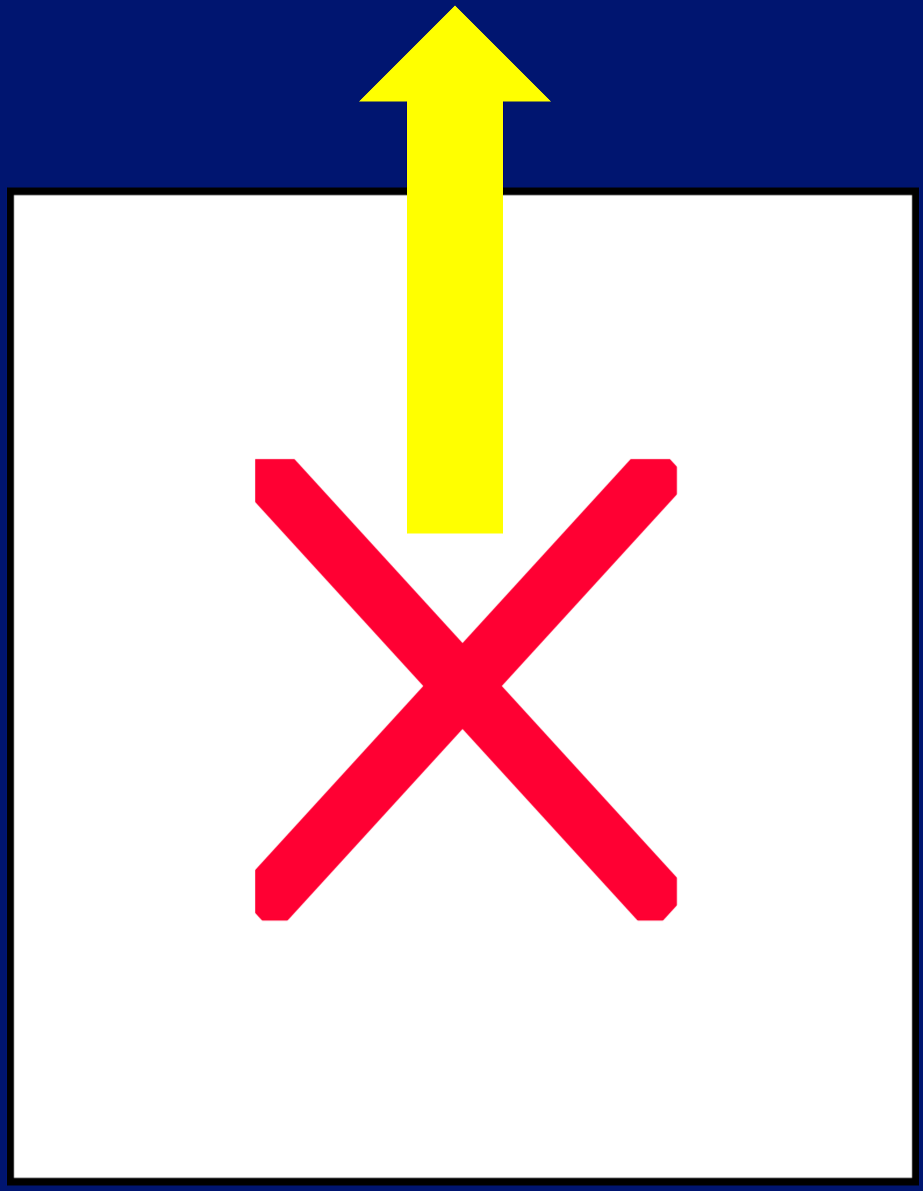
- Engage community to define priorities, initiatives, and implementation strategies
- Face-to-Face Workshops and Meetings
- Web Conferences and eTown Meetings
- Communities of Practice (Co-oPs)
- Communication Tools (email listserve, website, online surveys, etc.)



Challenge 2: Interdisciplinarity




X



Arctic System Complexity

Challenge 2: Interdisciplinarity

Program mutualism vs. competition

Real at a programmatic level, less so at an investigator level

Investigator issues: some don't like interdisciplinary work:

May feel program is a threat

May feel it is an opportunity, but submit weak proposals

May review good interdisciplinary proposals critically

Challenge: Changing definition of "success":

ARCSS started with "domain" programs: GISP2 and PALE, then developed into LAII and OAII

These programs were concrete and built the ability to integrate further:

From the new perspective, some have criticized the earlier programs for not being more integrative.

The more conceptual and synthetic the questions, the harder they can be to sell to the "outside"

Challenge 3: Planning

Good initiatives hit the “sweet spot”:

Broad enough to draw a diverse community

Narrow enough to have focus and coherence

How do you decide who is NOT invited to the party?

This is a real challenge:

Planning, community building, and community maintenance requires a lot of work and energy

Leadership needs to be altruistic:

- Working for the program as a whole
- NOT representing a "constituency"

A limited pool of talent that must be grown

Final Synopsis

ARCSS has been enormously successful

Key Elements in a successful Initiative:

Core: Set of questions that pulls researchers together
Scale: Hit the sweet spot
Structure: Build and maintain community

Final product: science that is important, exciting, and fun