Scenarios & state variables: Arctic system(s), responses to Arctic change & Knowledge to Action

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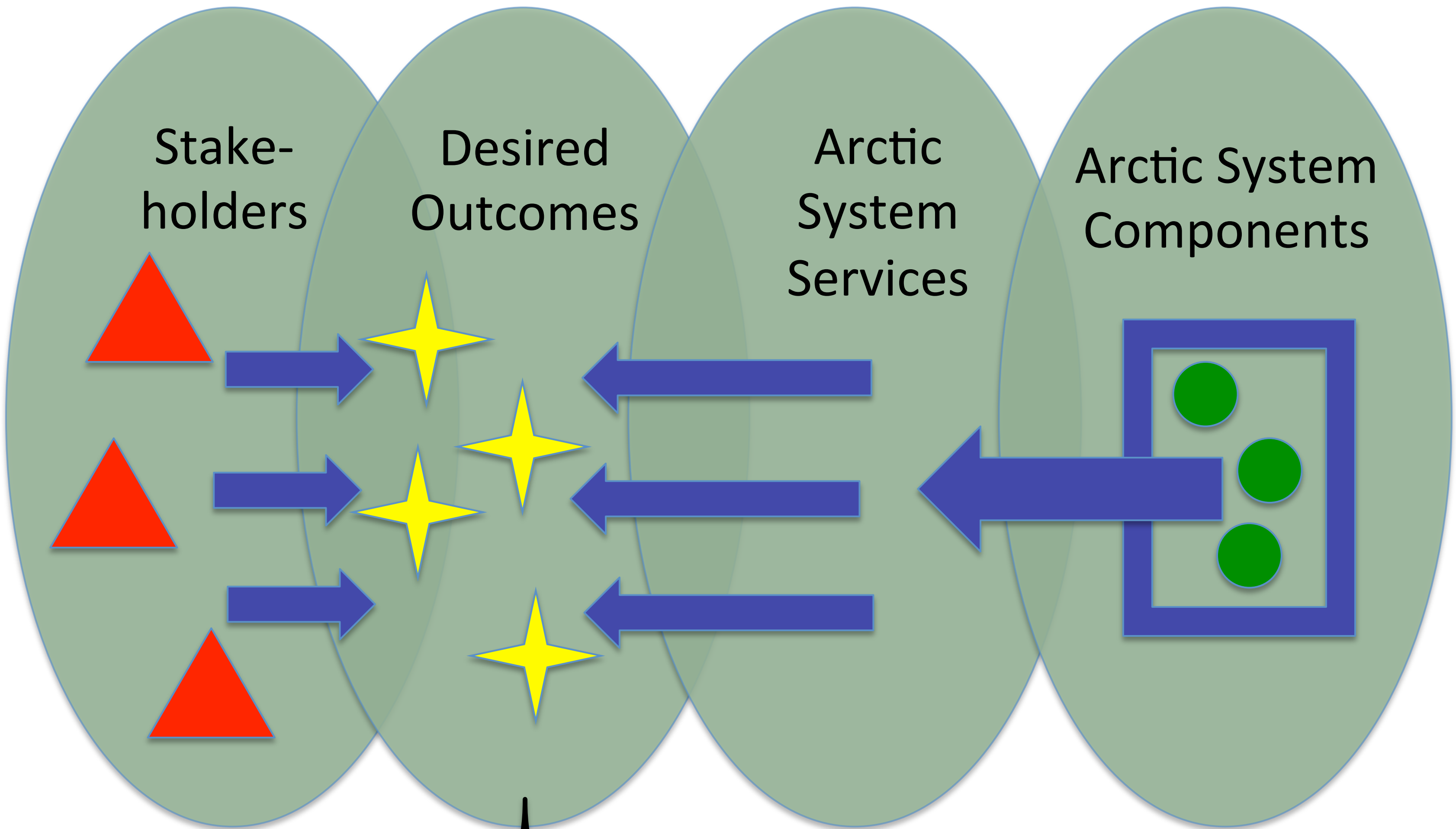
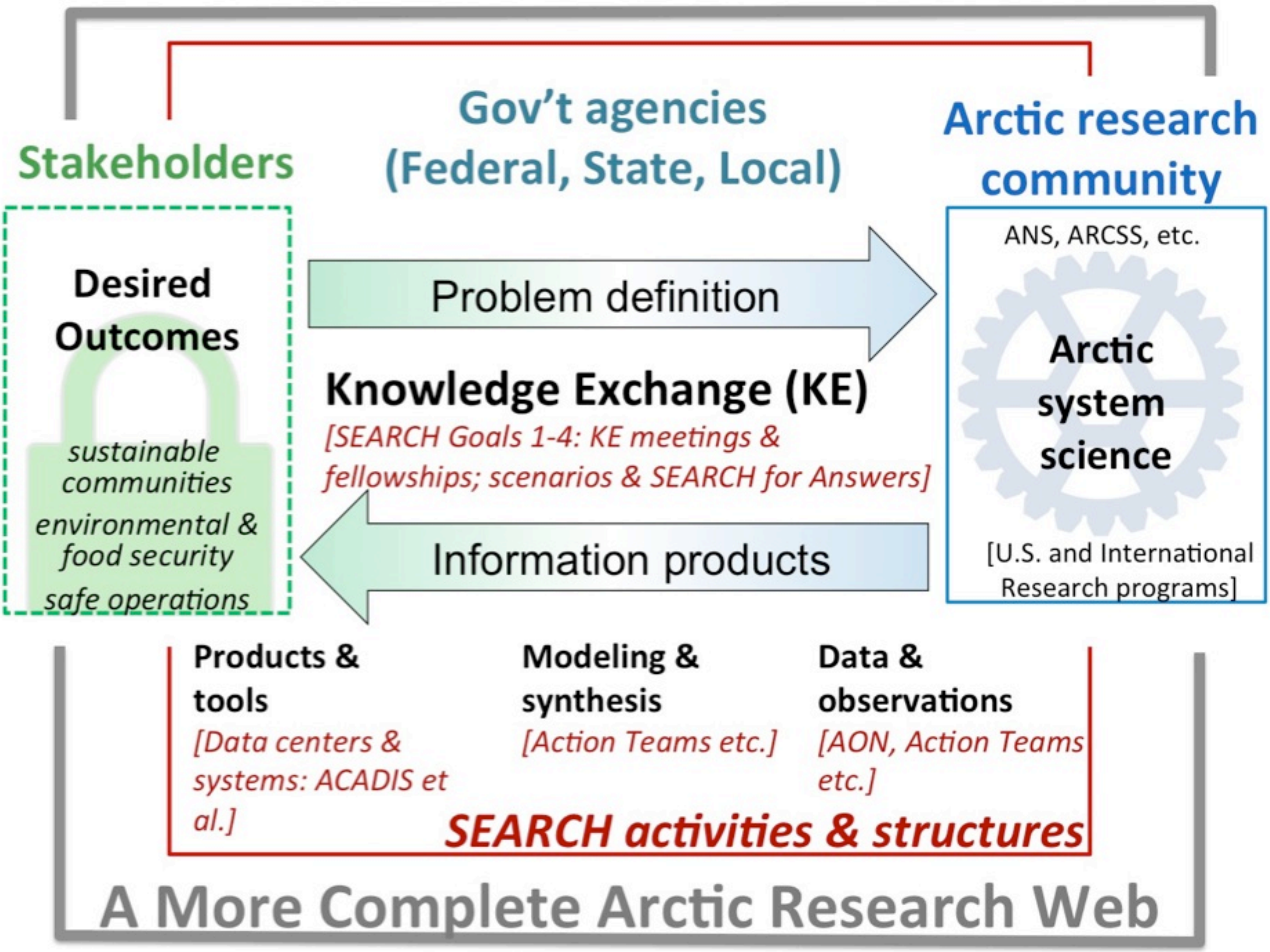
Understanding Arctic Change Workshop Report (2012): Rationale & needs & key questions

(1) Intersection of Arctic system science & studies of Arctic change
(2) Societal needs require advances in climate-system research focused on interactions between physical-biological-human systems
(3) Research questions/programs (also) need to frame problems in terms of management or decision challenges
(4) Development of tools for scaling Arctic-level patterns down to the local-regional level at which most decision-makers operate

(i) How predictable are different aspects of Arctic system; how can improved understanding of predictability facilitate planning, mitigation & adaptation?
(ii) What are Arctic system tipping points?
(iii) How will critical intersections between human and natural systems in the Arctic change over next several decades?
(iv) What are the critical linkages between Arctic & global system(s)?
(v) How will changes in cryosphere drive changes in economic, social & environmental components of the Arctic system?



Intersection of agency, stakeholder &
scientific community interests


Gov't agencies
(Federal, State, Local)
Stakeholders
Arctic research community
Desired Outcomes
sustainable communities
environmental & food security
safe operations
Problem definition
Knowledge Exchange (KE)
[SEARCH Goals 1-4: KE meetings & fellowships; scenarios & SEARCH for Answers]
Information products
ANS, ARCSS, etc.
Arctic system science
[U.S. and International Research programs]
Products & tools
[Data centers & systems: ACADIS et al.]
Modeling & synthesis
[Action Teams etc.]
Data & observations
[AON, Action Teams etc.]
SEARCH activities & structures
A More Complete Arctic Research Web

Observing, understanding & responding to Arctic change

(1) Observing, understanding & responding to Arctic change requires past data and future projections of the state of Arctic system(s)

(2) State variables – e.g., equation of state of seawater

- Description of the physico-chemical state (e.g., a body of water – T, S, P)
- Specification of (non)equilibrium conditions (e.g., supercooling)
- Prediction of future states (e.g., freezing with lowering of T)
- Derivation of other variables and properties (e.g., compressibility or speed of sound from T, S, P)

(3) What is our understanding of Arctic system state variables?

Arctic System Science

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

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

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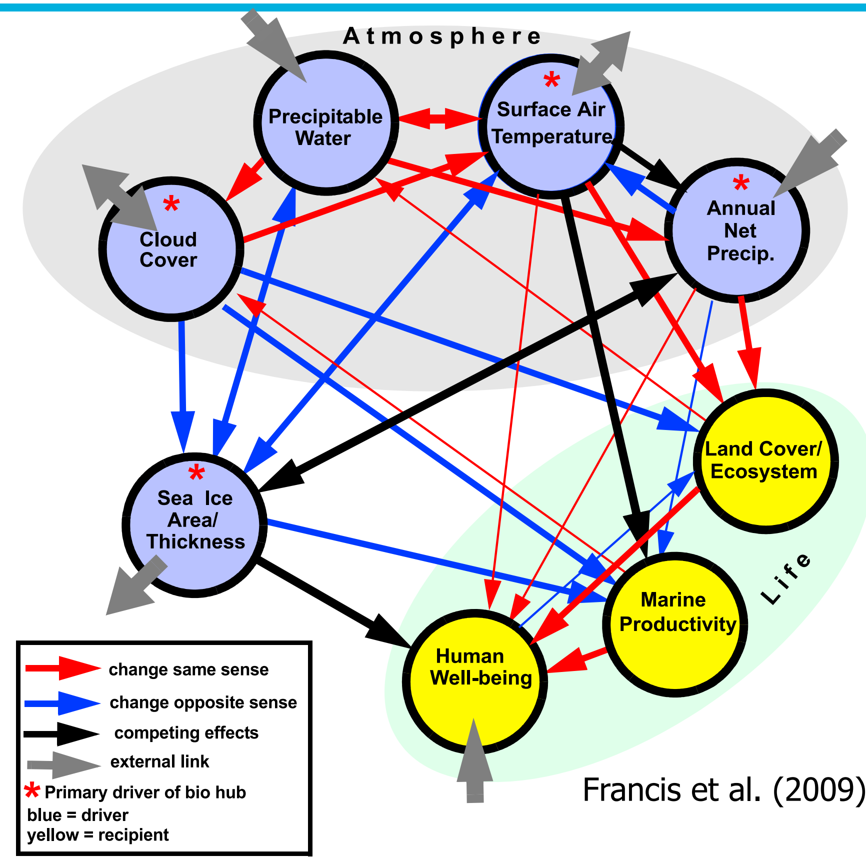
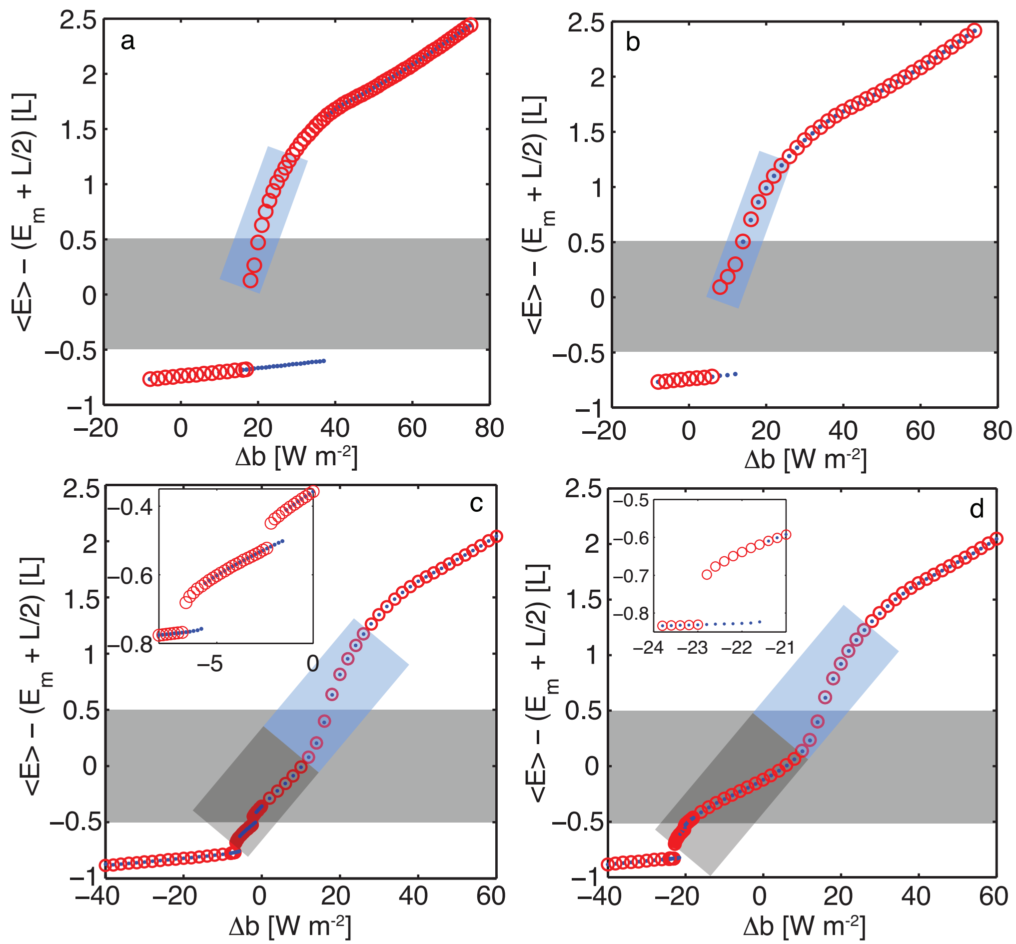


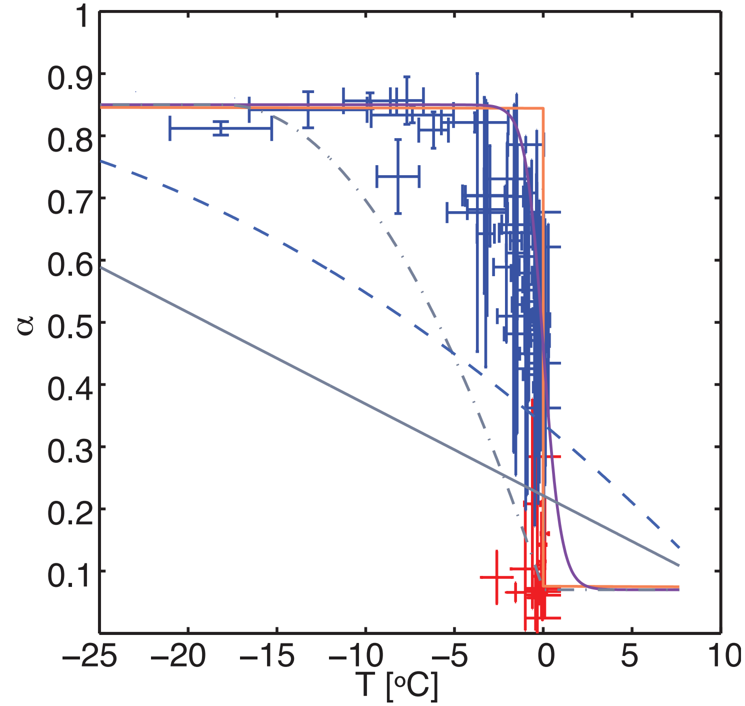
Francis et al. (2009)

- Francis et al. (2009): An arctic hydrologic system in transition: Feedbacks and impacts on terrestrial, marine, and human life; J. Geophys. Res. 114, doi: 10.1029/2008JG000902.

- Hinzman et al. (2013): Trajectory of the Arctic as an integrated system; Ecol. Applic. 23, 1837-

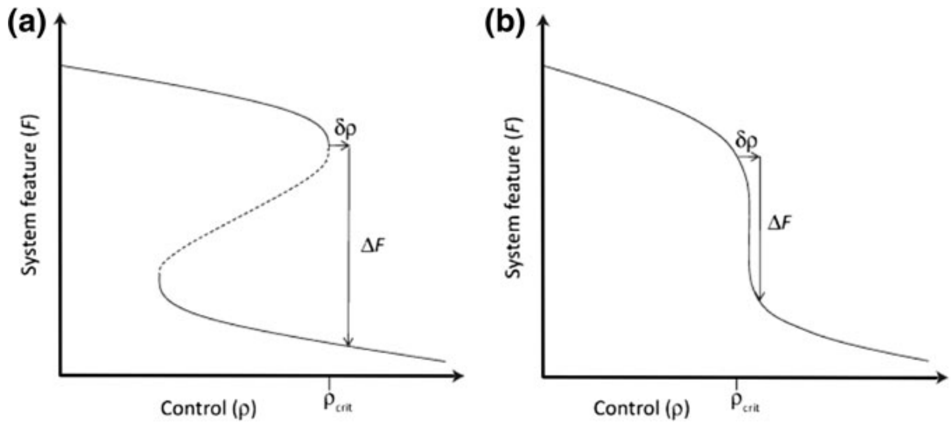
Arctic System Science: State variables (1)

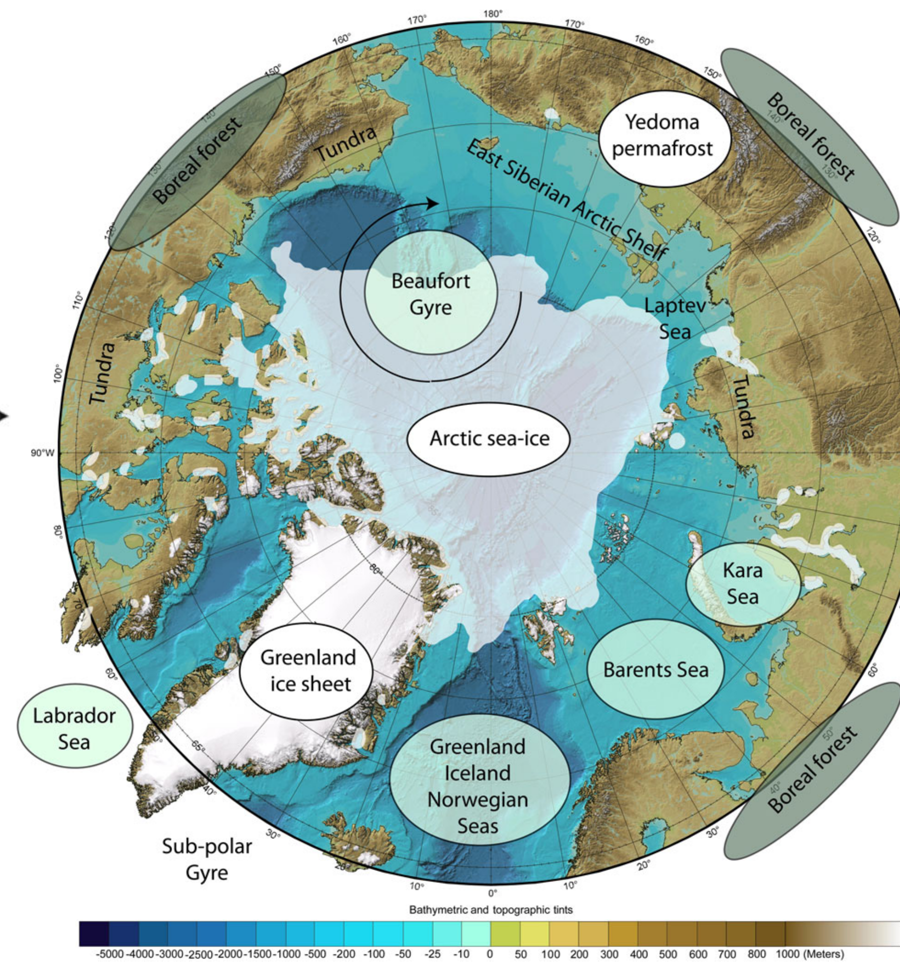




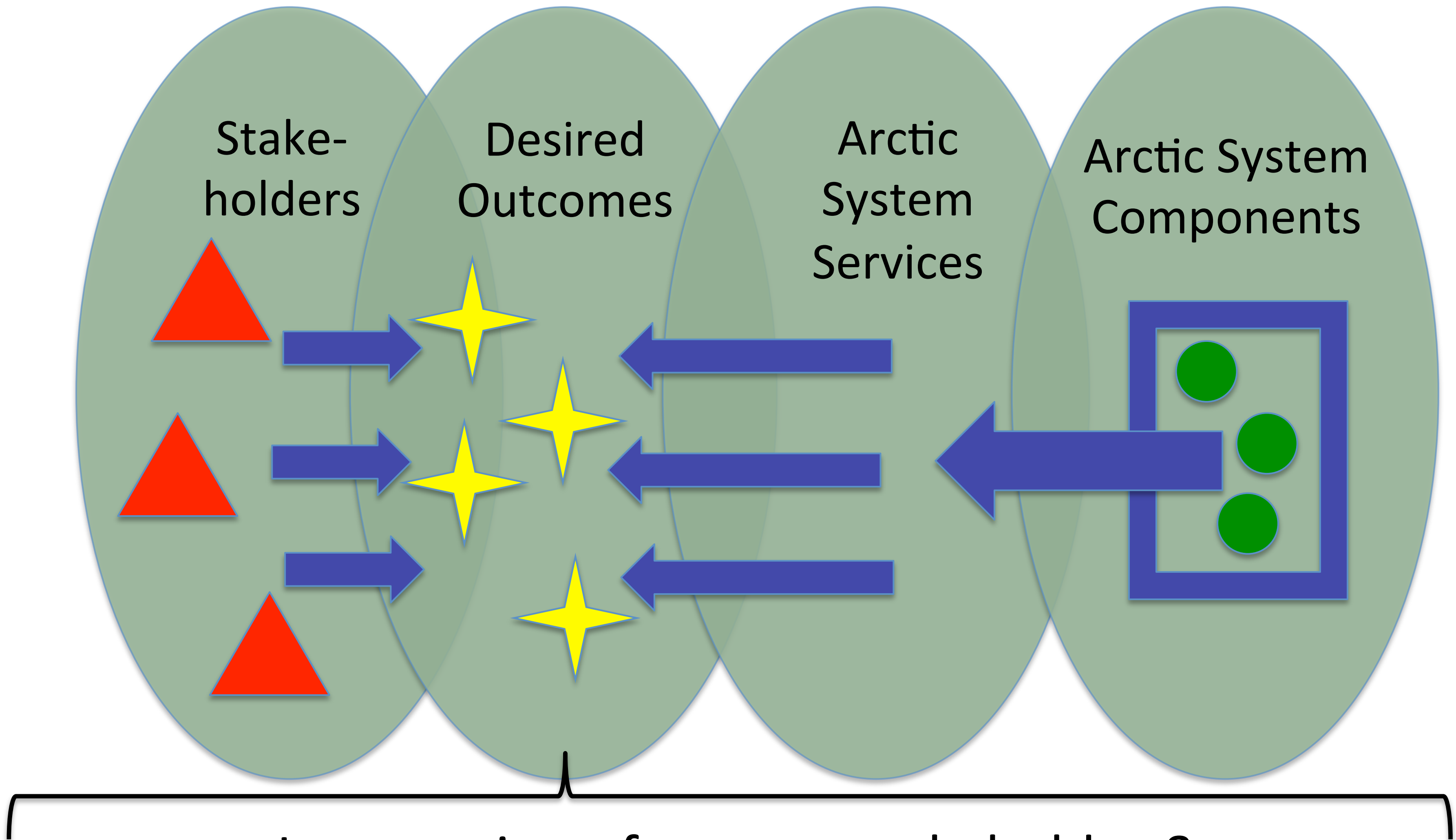
- Müller-Stoffels & Wackerbauer (2012) Albedo parametrization and reversibility of sea ice decay, Nonlin. Processes Geophys., 19, doi:10.5194/npg-19-81-2012

Arctic System Science: State variables (2)





- Lenton (2012) Arctic climate tipping points; Ambio, 41, 10-

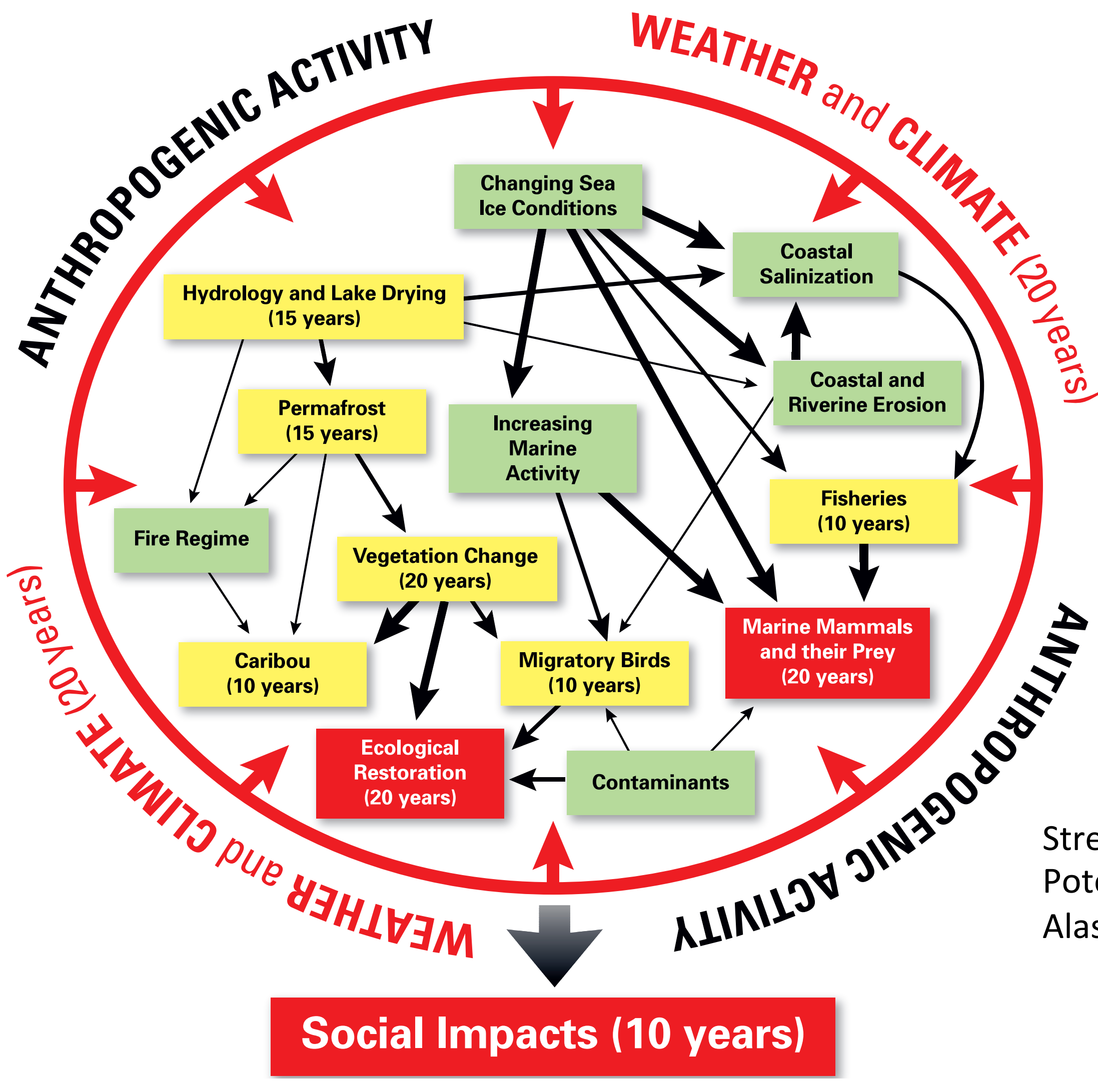


Intersection of agency, stakeholder &
scientific community interests

State variables for the Arctic as a social-environmental system

(1) Nature of state variables in social-environmental systems beyond key concepts poorly understood
(2) Rigorous studies defining and exploring state variables lacking; potential tools include earth-system models, statistical analysis and reduction of large datasets, expert knowledge and heuristic approaches
(3) In the Arctic need for prioritization and coordination of long-term observations of Arctic change and associated decision-making drive identification of "state" variables, e.g.:
  - North Slope Science Initiative emerging issues
  - European Environment Agency indicator variables
(4) State or indicator variables help link Arctic system science to stakeholder-desired outcomes & decision-making (K2A)
(5) Challenges:
  - Lack of clear definition of state variables in social-env. Systems
  - Data for candidate variables are scattered and poorly accessible even to scientific research community
  - State variables or indicators commonly defined post-hoc
(6) Co-production of iconic time series

State variables for the Arctic as a social-environmental system



Streever et al. (2011), Environmental Change and Potential Impacts: Applied Research Priorities for Alaska's North Slope; Arctic 64, 390-

European Environment Agency indicators

(1) European Environment Agency (EEA) has identified indicator variables to help guide EU policy and action at the pan-European and global scale

(2) 177 total indicators, ranging from Agriculture (n=13) to Transport (n=36) to Environment & Health (n=10)

(3) The following indicators are related to Arctic and/or cold regions:
- Greenland ice sheet (cumulative seasonal mass loss & melt)
- European snow cover extent trend
- Arctic & Baltic sea ice extent (min/max, trend)
- Permafrost (borehole temps in Europe, projected changes in total permafrost area)
- Cumulative mass balance of European glaciers
- Duration in ice cover on a lake and a river in Europe

(4) Need for Arctic sustainability indicators identified by European Commission Directorate for Maritime Affairs and Fisheries

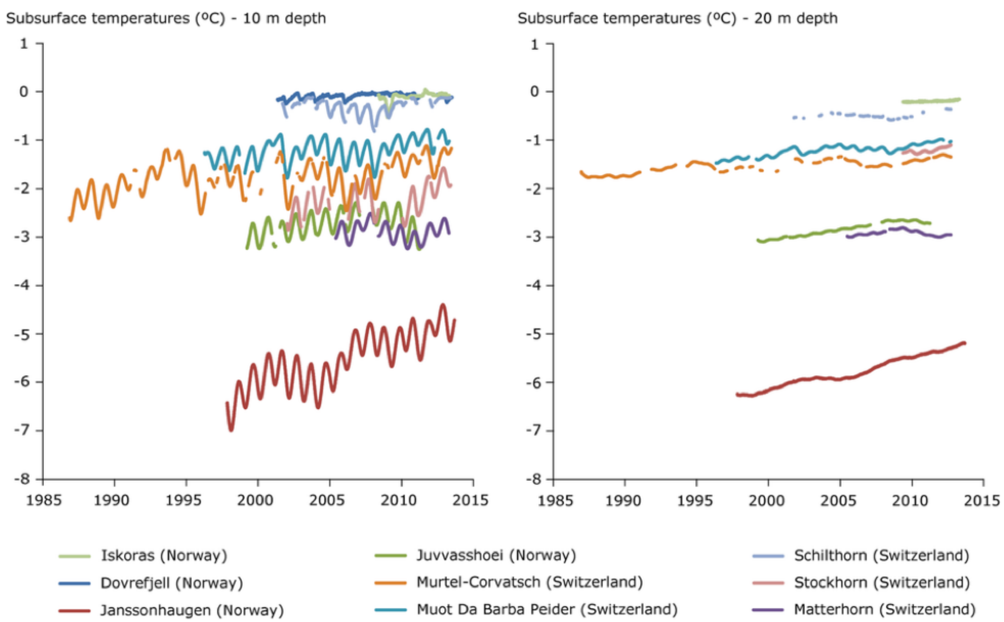
European Environment Agency indicators

Key policy question: What is the trend in the temperature and the thawing depth of permafrost soils across Europe?

Key messages

- In the past 10–20 years European permafrost has shown a general warming trend, with greatest warming in the cold permafrost in Svalbard and Scandinavia. The depth of seasonal thaw has increased at several European permafrost sites. Some sites show great interannual variability, which reflects the complex interaction between the atmospheric conditions and local snow and ground characteristics.
- Recent projections agree on substantial near-surface permafrost degradation resulting in thaw depth deepening (i.e. permafrost degeneration) over much of the permafrost area.
- Warming and thawing of permafrost is expected to increase the risk of rock falls, debris flows and ground subsidence. Thawing of permafrost also affects biodiversity and can contribute to climate change through release of CO_2 and CH_4 from Arctic permafrost areas.

Fig. 1: Observed permafrost temperatures from selected boreholes in European mountains



Note: The figure shows trends in observed permafrost temperatures from 10 m (left) and 20 m (right) depth for selected boreholes in European mountains: the sites include the PACE transect and two additional sites in the Swiss Alps(and two in Norway (Dovrefjell and Iskoras).

Data source:

- Permafrost in the Swiss Alps provided by **University of Zurich**

Downloads and more info

http://www.eea.europa.eu/data-and-maps/indicators

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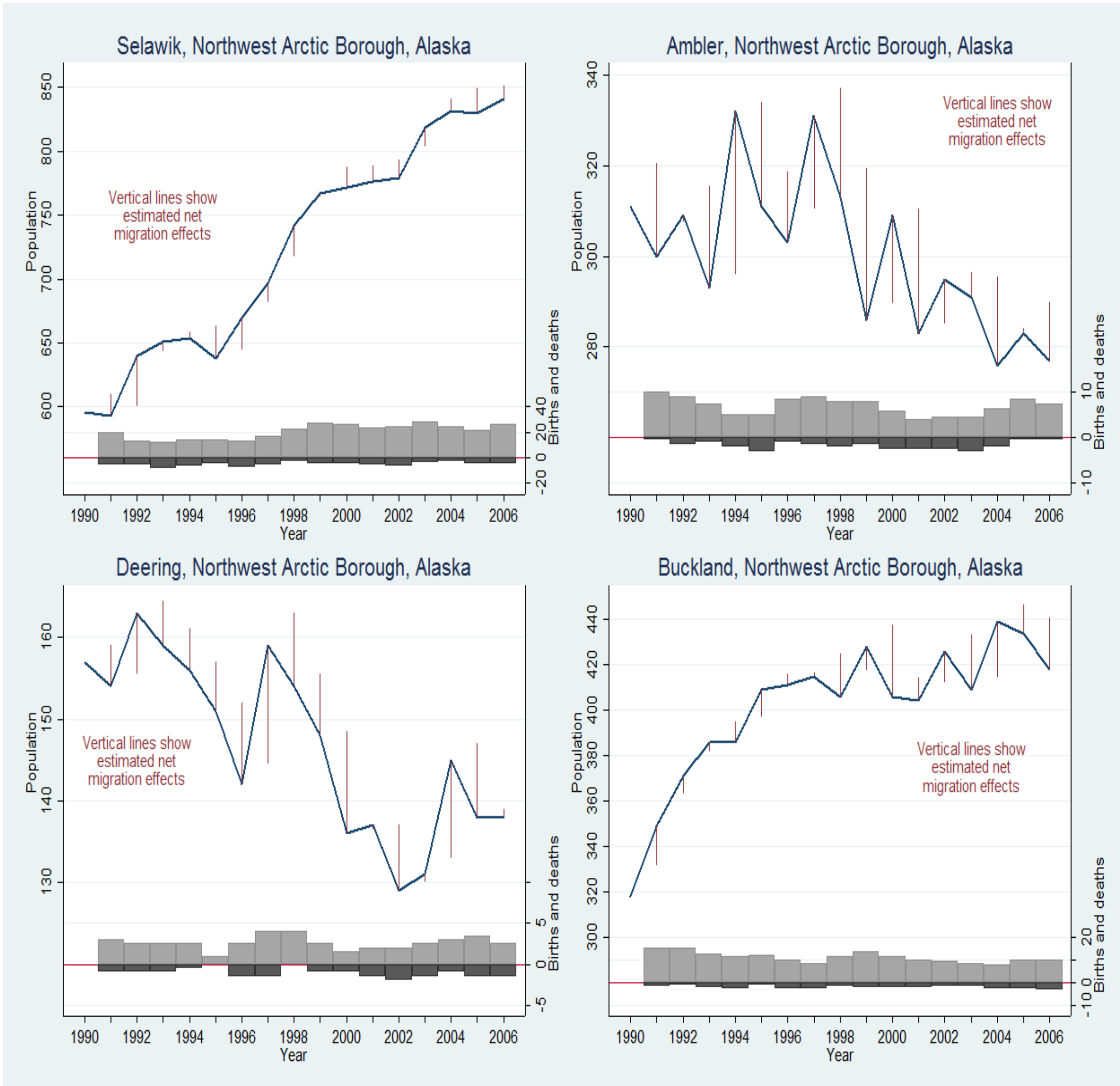
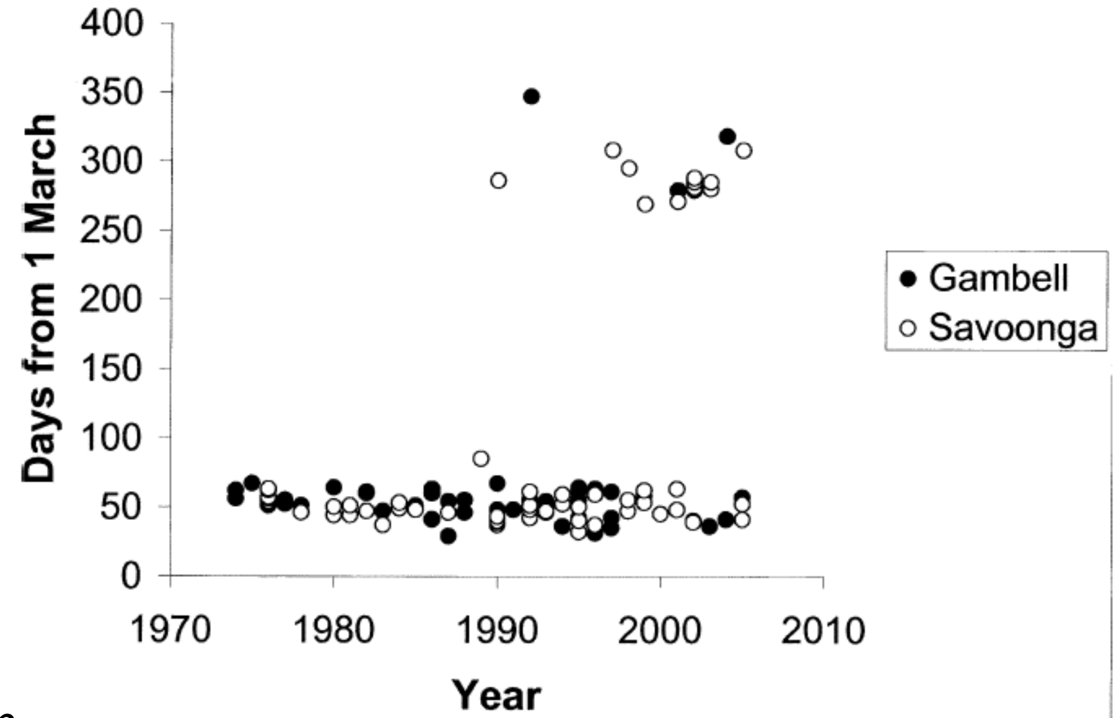
(6) Co-production of iconic time series

State variables
&
iconic Arctic system time series



Population dynamics of four smaller Northwest Arctic Borough villages, 1990–2006. Vertical line segments show estimated net migration effects. Note the different scales used in each graph. From Hamilton & Mitiguy (*Arctic*) 2009



Henry Huntington

Bowhead whale harvests in Gambell and Savoonga (St. Lawrence Island, Alaska) since the early 1970s. Note the innovation starting around 1990, in which the whalers began taking whales in fall as well as spring. This is a reflection of later freeze-up, making it possible to go boating later in the year, as well as an increased whale quota, leaving whale strikes available in the fall for use by these villages. The time series thus reflects the intersection of physical (sea ice) and societal (whale quota) changes, and shows the result of innovation, not just the negative impacts usually attributed to climate change.

Graph taken from:

Noongwook, G., the Native Village of Savoonga, the Native Village of Gambell, H.P. Huntington, and J.C. George. 2007. Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. *Arctic* 60(1):47-54.

Original data from Alaska Eskimo Whaling Commission and North Slope Borough Dept. of Wildlife Management.

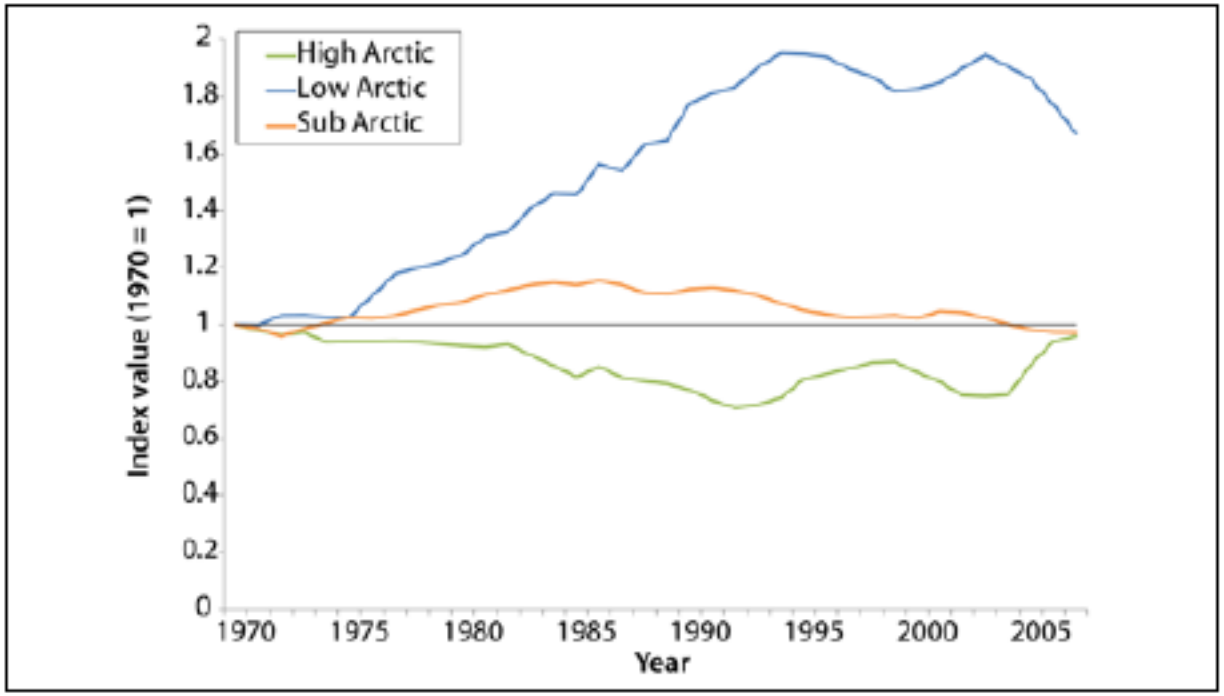


Figure 2. ASTI 2011 for species grouped by high, low, and sub Arctic from 1970 to 2007.

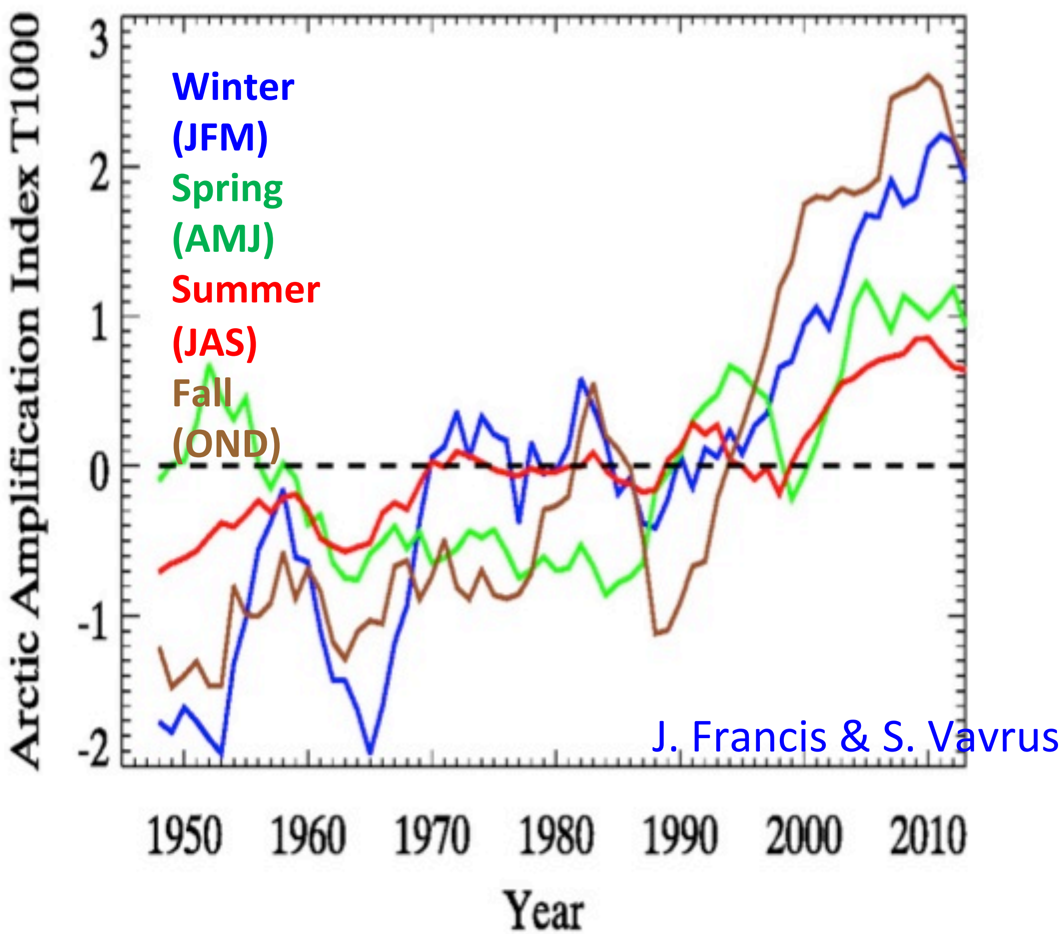
1.2 When species abundance is grouped by broad ecozones, a different picture emerges, with low Arctic species abundance increasing in the first two decades much more than high Arctic and sub Arctic species abundance. The low Arctic index has stabilized since the mid-1990s while the high Arctic index appears to be recovering in recent years and the sub Arctic index has been declining since a peak in the mid-1980s.

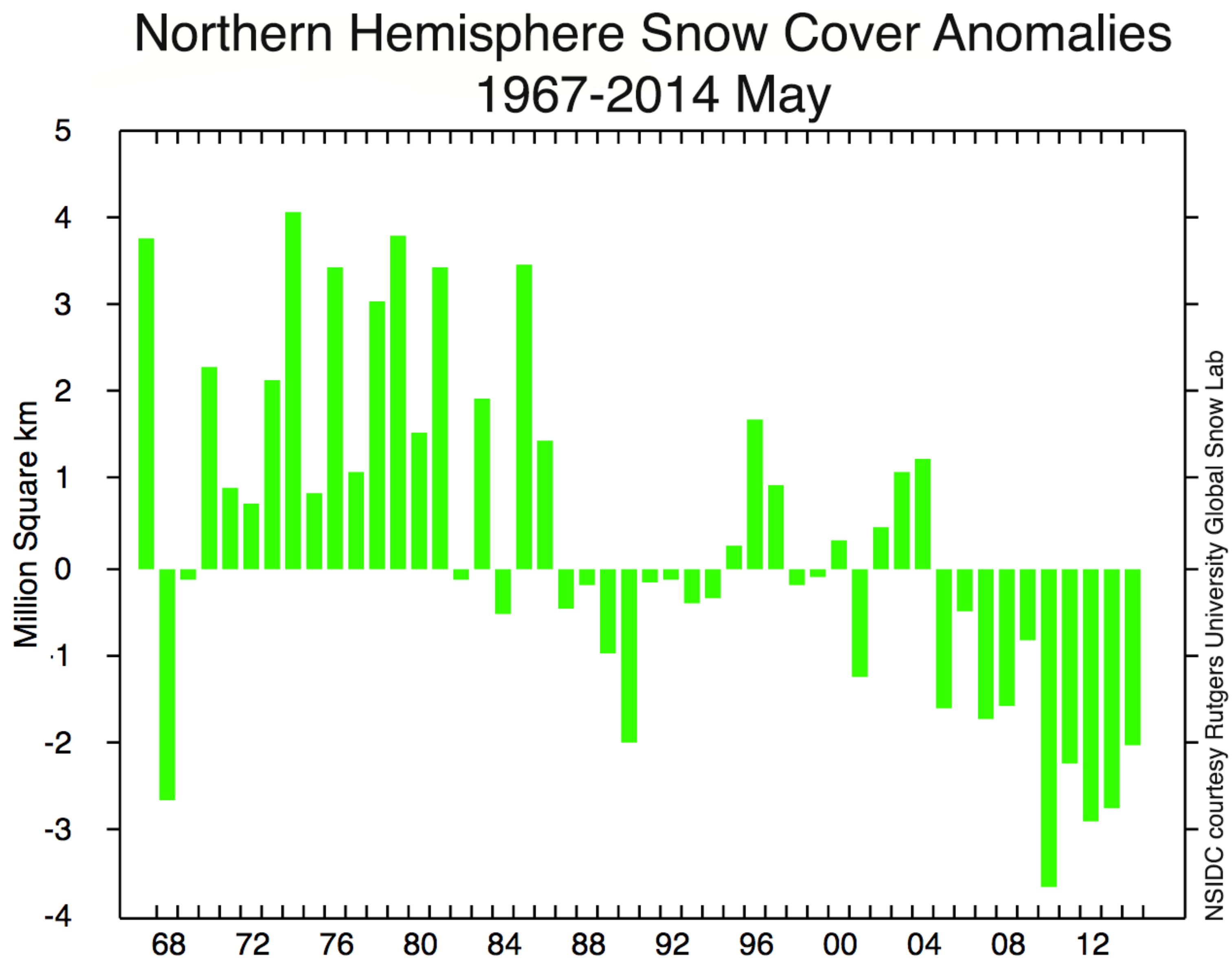
Olivia Lee:
This figure shows an index describing trends in species abundance for 323 species from 1970 to 2007. Even though the figure shows general trends, there are some sampling biases that require special consideration in interpretation.

Seasonal Time Series of Arctic Amplification

Based on 1000 hPa Temperature Anomalies

Arctic (70ºN to 90ºN) – Mid-Latitudes (30ºN to 60ºN)




Northern Hemisphere Snow Cover Anomalies
1967-2014 May
Million Square km
5
4
3
2
1
0
-1
-2
-3
-4
68
72
76
80
84
88
92
96
00
04
08
12
NSIDC courtesy Rutgers University Global Snow Lab

Ted Scambos

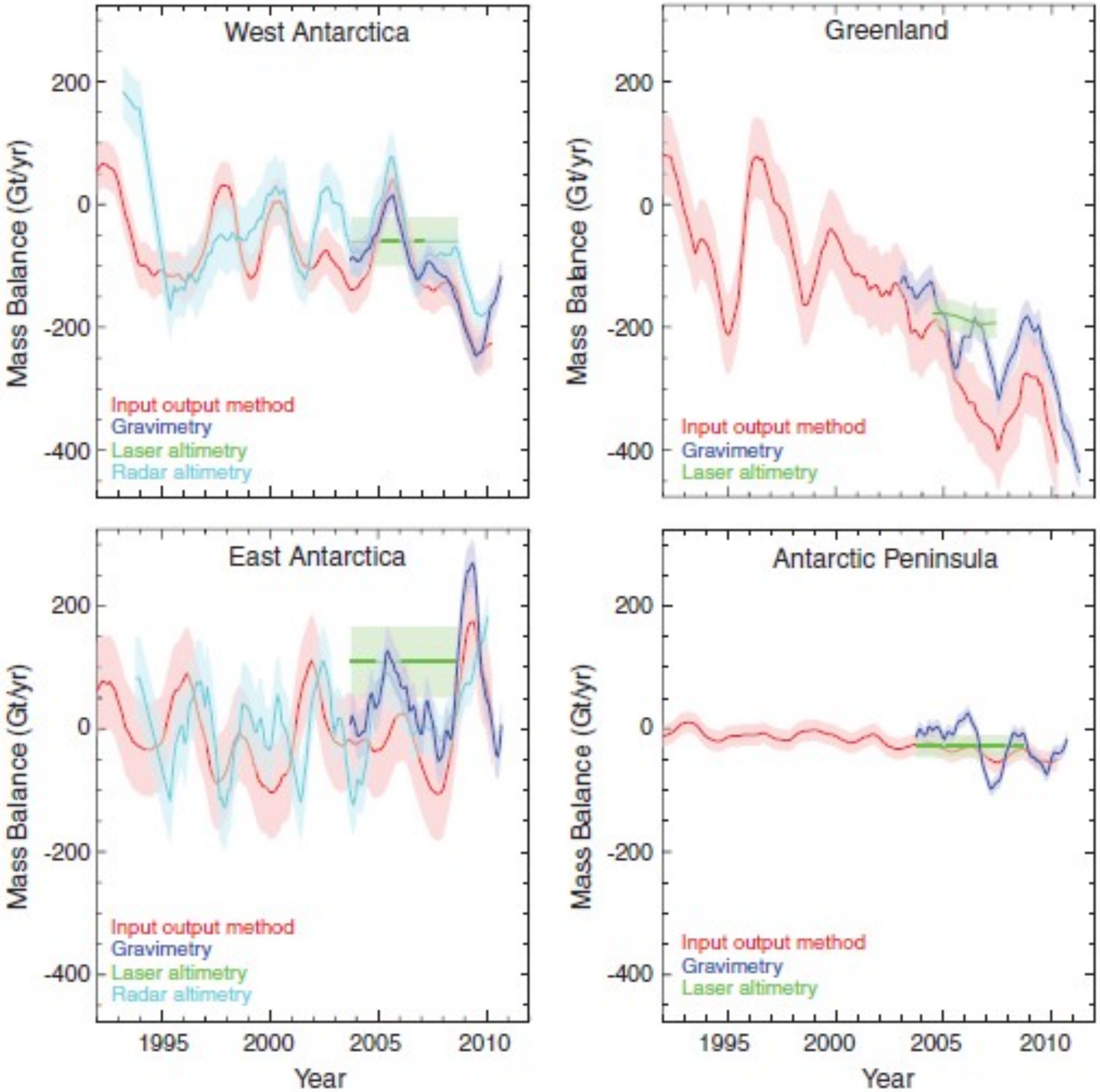
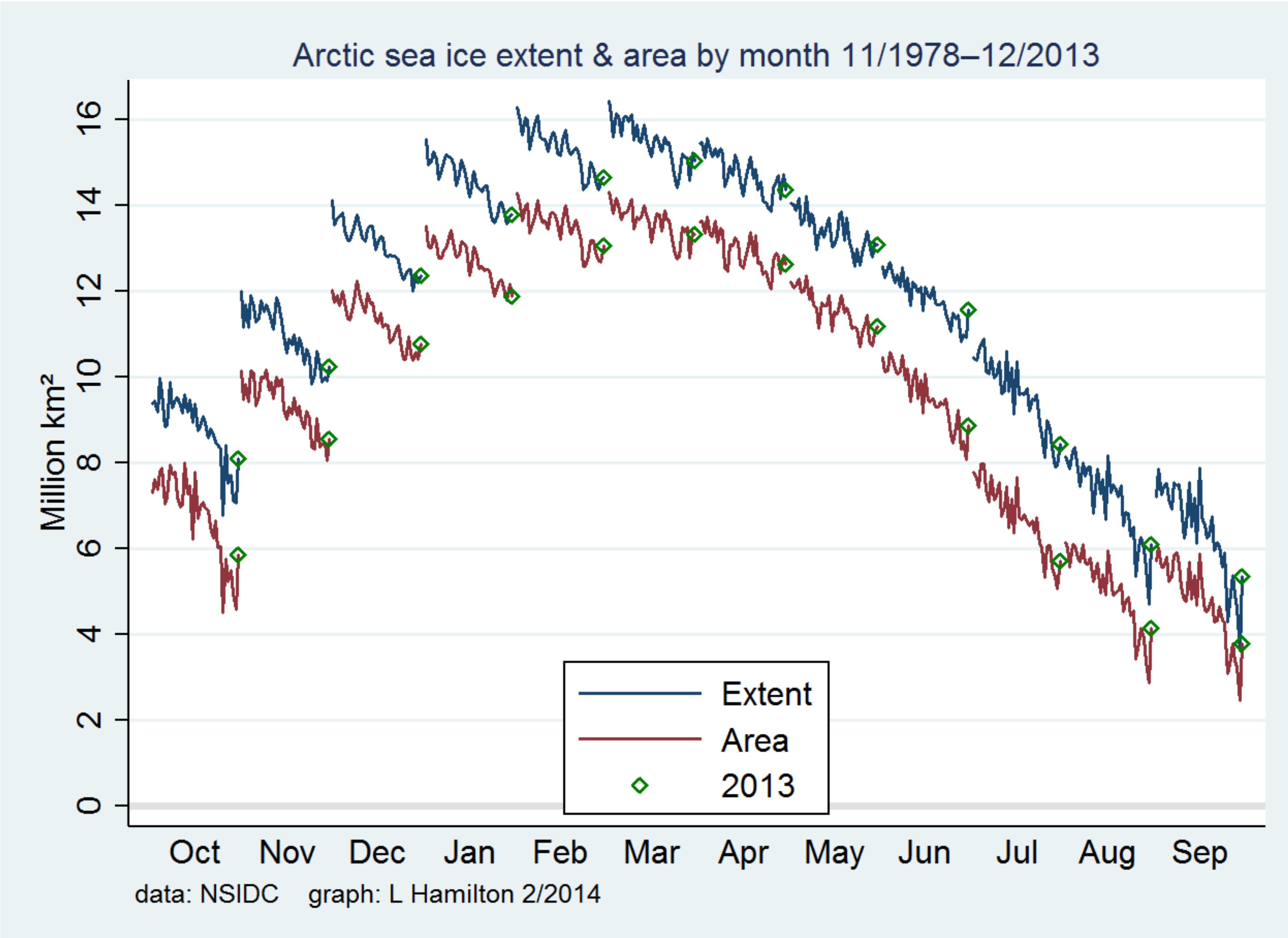
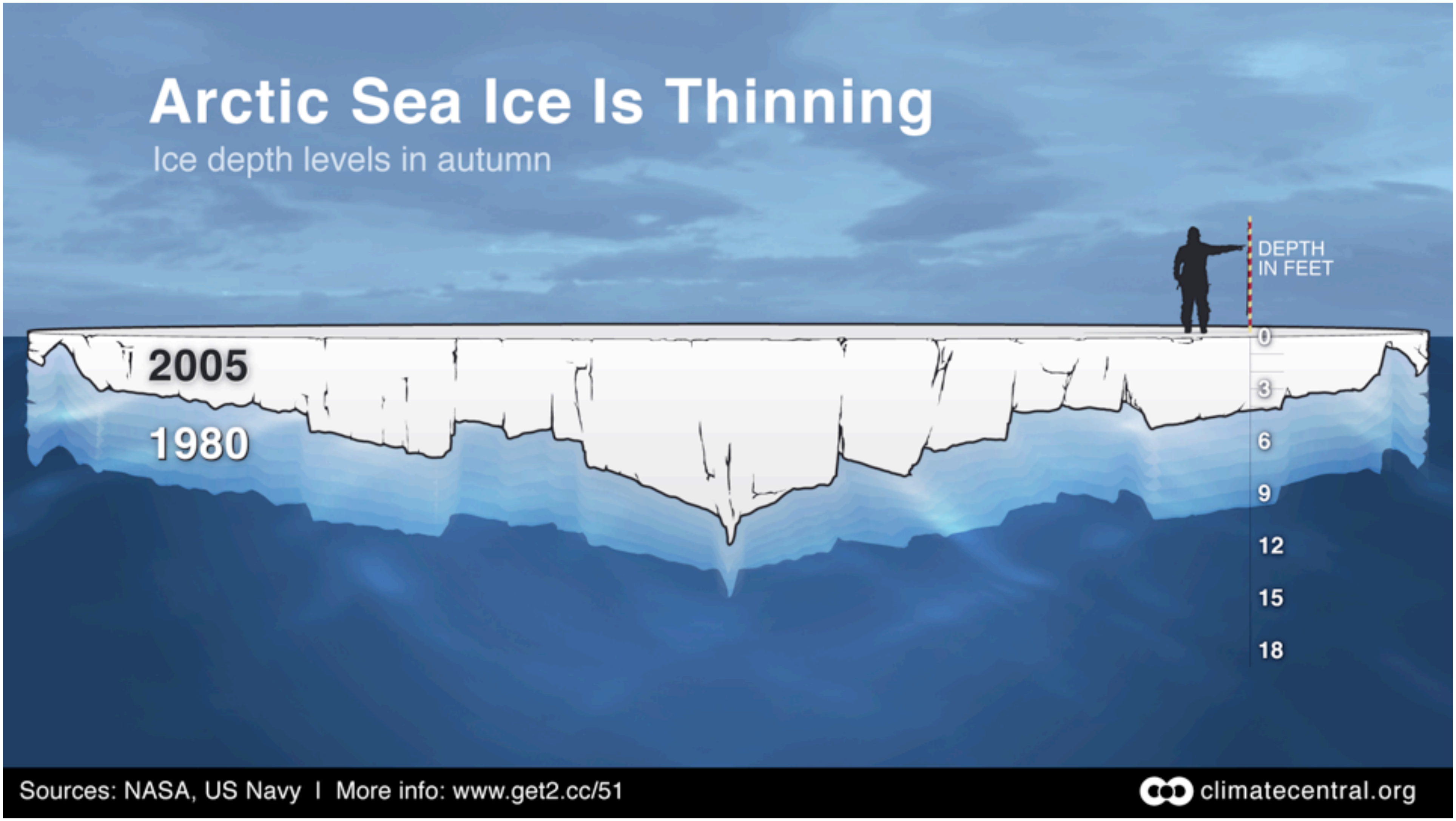


Fig. 4. Rate of mass change of the four main ice-sheet regions, as derived from the four techniques of satellite RA (cyan), IOM (red), LA (green), and gravimetry (blue), with uncertainty ranges (light shading). Rates of mass balance derived from ICESat LA data were computed as constant and time-varying trends in Antarctica and Greenland, respectively. The gravimetry and RA mass trends were computed after applying a 13-month moving average to the relative mass time series. Where temporal variations are resolved, there is often consistency in the interannual variability as determined by the independent data sets.

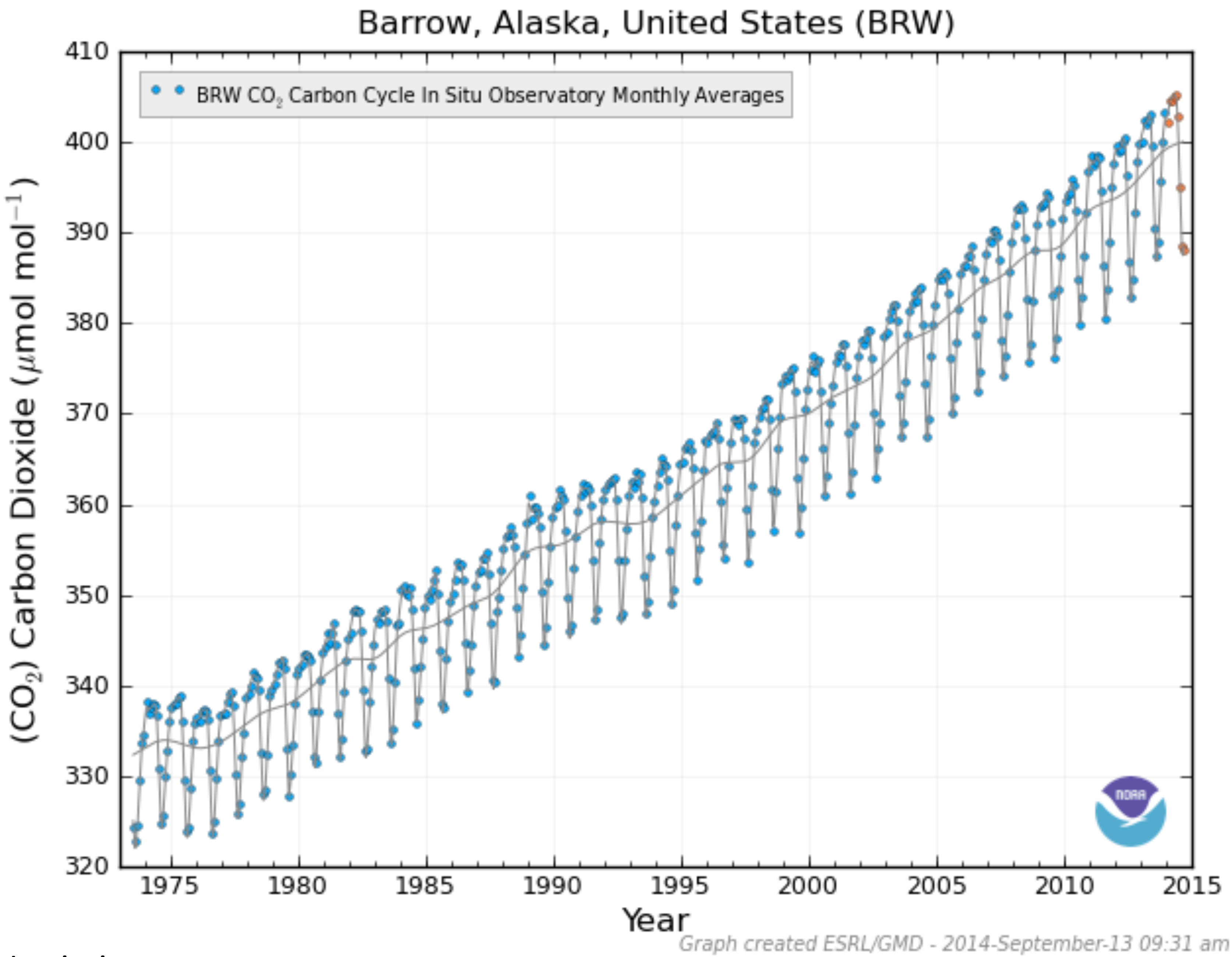
Bob Bindschadler



Arctic sea ice extent & area by month 11/1978–12/2013
Million km²
0
2
4
6
8
10
12
14
16
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Extent
Area
2013
data: NSIDC graph: L Hamilton 2/2014



Caspar Ammann



Janet Intrieri