Taking the Pulse of the Arctic Ocean System, from the Shelves to the Pole – The International Distributed Biological Observatory and the Developing Synoptic Arctic Survey

Jackie M. Grebmeier
Chesapeake Biological Laboratory
University of Maryland Center for Environmental Science, Solomons, MD, USA

U.S. Maritime Domain Awareness in the Arctic Symposium
National Geospatial Intelligence Agency
Springfield, VA
November 21, 2019

IASC

Synoptic Arctic Survey

NSF

Background

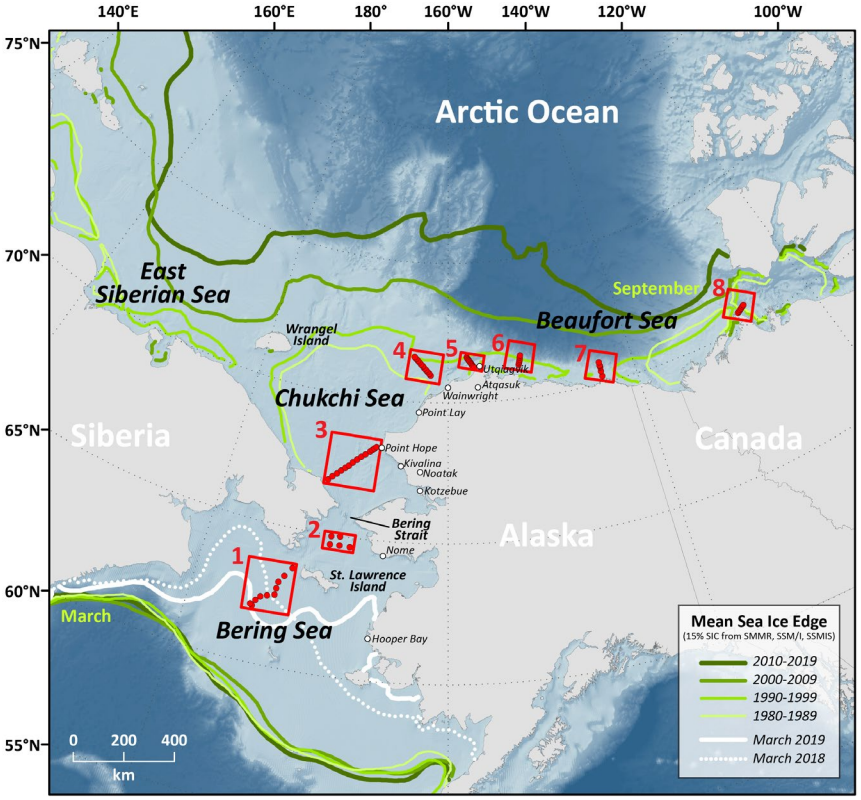
- The rapidly changing sea ice conditions and linkage to atmospheric and oceanographic components, accelerated opening of the Central Arctic Ocean for human use (e.g., transportation, potential fisheries, military use) as well as potential for cascading ecosystem changes in the high Arctic and girdling Arctic seas highlight the need for coordinated data collections and analysis

- The **D**istributed **B**iological **O**bservatory (**DBO**) – is a coordinated, network of international time series observations in the Pacific Arctic being expanding to a pan-Arctic effort; an example for the Synoptic Arctic Survey activities

- The **S**ynoptic **A**rctic **S**urvey (**SAS**) - a bottom-up, researcher driven initiative to define the present state of the Arctic Ocean and understand the major ongoing transformations, with an emphasis on water masses, the marine ecosystem and carbon cycling through research cruises in 2020/2021

- The 2020/2021 SAS effort is a pan-Arctic, multi-ship, multi-disciplinary study in August/September that will collect standard environmental data to determine status and trends of the opening Arctic Ocean

The Distributed Biological Observatory (DBO): Linking Physics to Biology

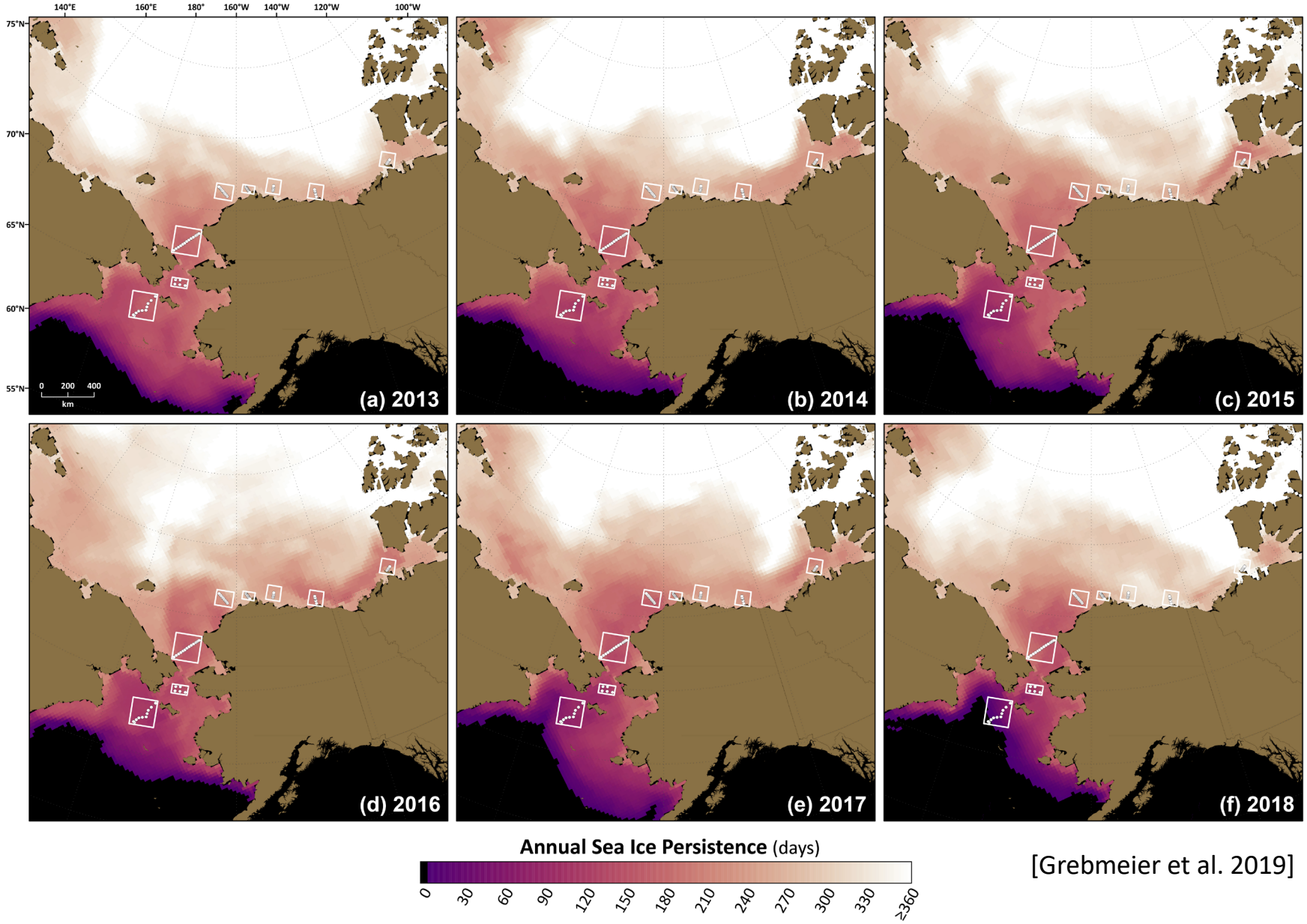


[updated from Grebmeier et al. 2019, DBO DSR Special Issue 162:1-7]

- **Core Ship-based sampling:**
  - CTD and ADCP
  - Chlorophyll, nutrients, carbon products
  - Plankton (size, biomass and composition)
  - Benthos (size, biomass and composition)
  - Seabird and marine mammal surveys
  - Fishery acoustics
  - Bottom trawling (every 3-5 years)
- **Autonomous sensor sampling:**
  - Gliders, moorings, saildrone
  - Satellite observations
- **DBO lines also embedded in process cruises**

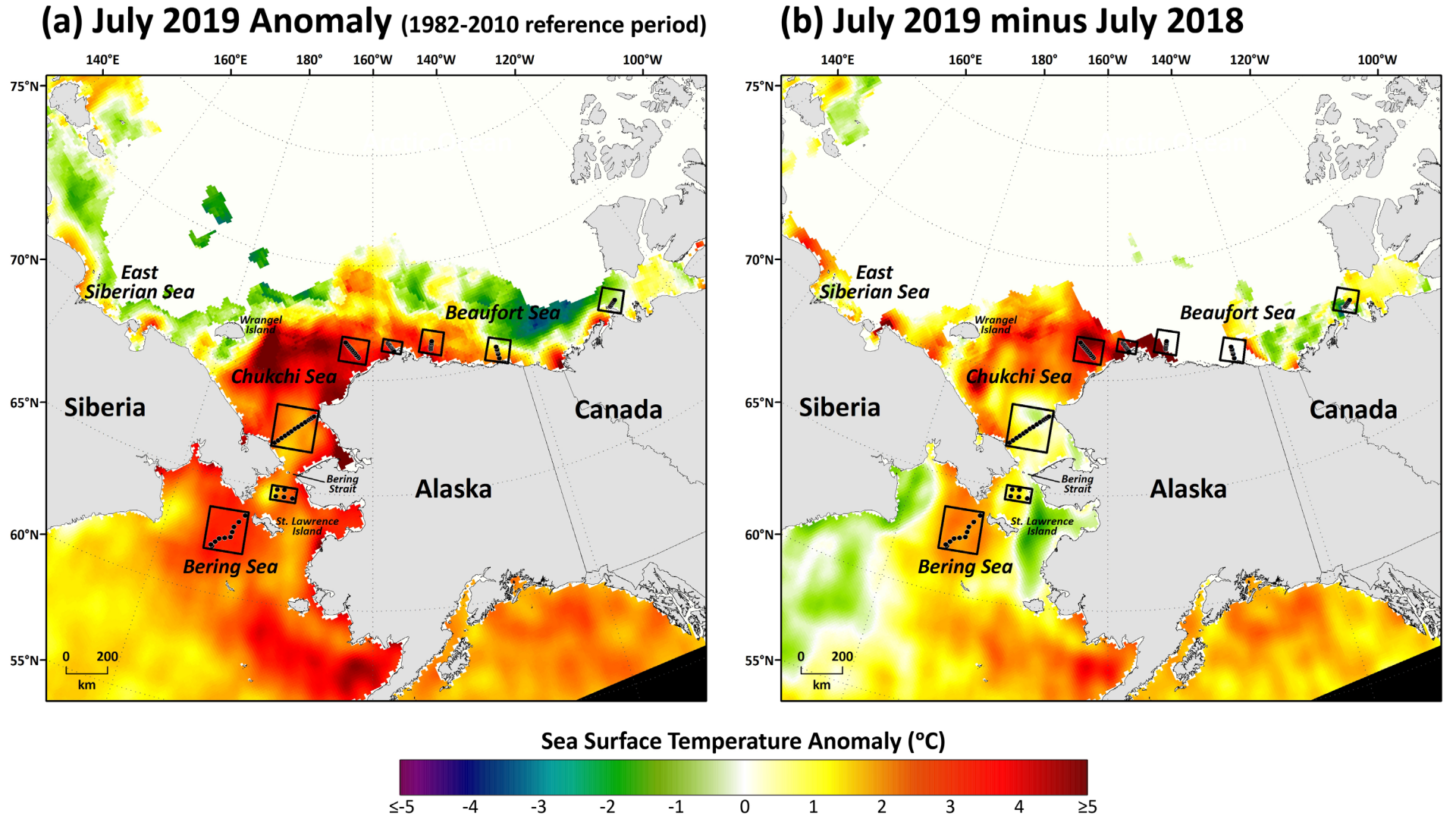
- DBO sites (red boxes) are **regional "hotspot"** transect lines and stations, based on high productivity, biodiversity, and/or overall **rates of change**
- DBO serves as a **change detection array** for consistent monitoring of biophysical responses
- Sites occupied by **national and international entities** with shared data plan

Annual sea ice persistence (# of days/year of sea ice presence) across the DBO1–8 regions in the Pacific Arctic from 2013–2018



[Grebmeier et al. 2019]

Sea Surface Temperature Anomalies July 2018-2019



[courtesy Karen Frey, Clark University]

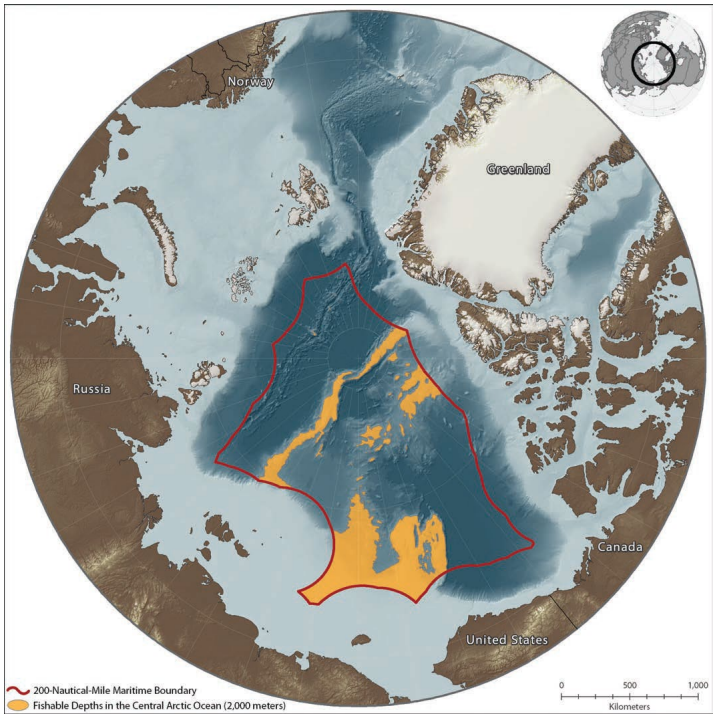
Addressing Arctic Challenges Requires a Synoptic Ocean Survey

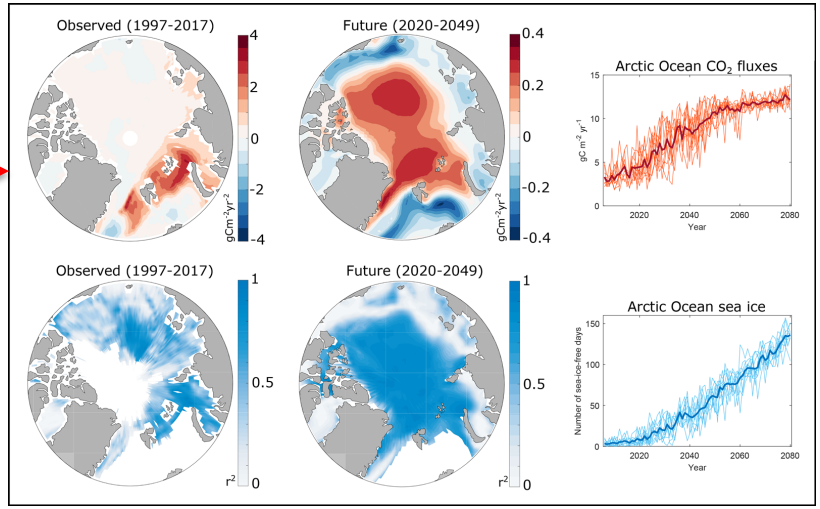
A coordinated effort involving trailblazing science—and icebreaking ships—from many nations is needed to fill gaps in our understanding of the Arctic Ocean and how it's changing.

In this 2007 photo, the Swedish icebreaker *Oden* (left) runs a seismic cable in the wake of the Russian nuclear-powered icebreaker *50 Let Pobedy*, which is plowing through heavy ice north of Greenland. The Synoptic Arctic Survey team plans to launch a coordinated multinational campaign using icebreaker ships to gather data in the Arctic Ocean beginning in 2020. Credit: Leif Anderson

[Paasche et al. 2019 Eos, Nov; hard copy January 2020]

Fishable depths were derived from IBCAO v3 bathymetry (www.ngdc.noaa.gov/mgg/bathymetry/arctic/).





An international, researcher driven, initiative

Leif Anderson, Are Olsen, Øyvind Paasche, Takashi Kikuchi, Carin Ashjian, Peter Schlosser, Jim Swift, Heidimarie Kassens, Sebastian Gerland, Jeremy Wilkinson, Jackie Grebmeier,, Eddy Carmack, Melissa Chierici, Kumiko Azetsu-Scott, Jeremy Mathis, Jackie Grebmeier, Vidar Lien, Lise Lotte Sørensen, Jens Hölemann, Andrey Novikhin, Kyoung-Ho Cho, Karen Edelvang, Motoyoh Itoh, Oleg Titov, Michio Yamamoto-Kawai, Vladimir Ivanov, Colin Stedmon, Bill Williams (and even more people who helped write or reviewed the science plan)

UNIVERSITAS BERGENSIS

JAMSTEC

AWI

LAMONT-DOHERTY EARTH OBSERVATORY
THE EARTH INSTITUTE AT COLUMBIA UNIVERSITY

NORSK·POLARINSTITUTT

GEOMAR
Helmholtz-Zentrum für Ozeanforschung Kiel

Fisheries and Oceans Canada

NOAA

NSF

SCRIPPS INSTITUTION OF OCEANOGRAPHY UCSD

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

HAVFORSKNINGSINSTITUTTET

KOPRI
Korea Polar Research Institute

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

UNIVERSITAS GOTHOBURGENSIS 1891

BEDFORD INSTITUTE OF OCEANOGRAPHY
BIO
INSTITUT OCÉANOGRAPHIQUE DE BEDFORD

ARCTIC RESEARCH CENTRE

PAG
PACIFIC ARCTIC GROUP

UArctic

IASC

Synoptic Arctic Survey

What are the present state and major ongoing transformations of the Arctic marine system? (specifically the ecosystem and carbon system)

- Describe the present state of the Arctic Ocean to provide the foundation against which future states can by compared to quantify change.
- Three key foci:
    1) Physical drivers of importance to the ecosystem and carbon cycle,
    2) Ecosystem response, and
    3) Carbon cycle and ocean acidification
- Envisioned to repeat each decade

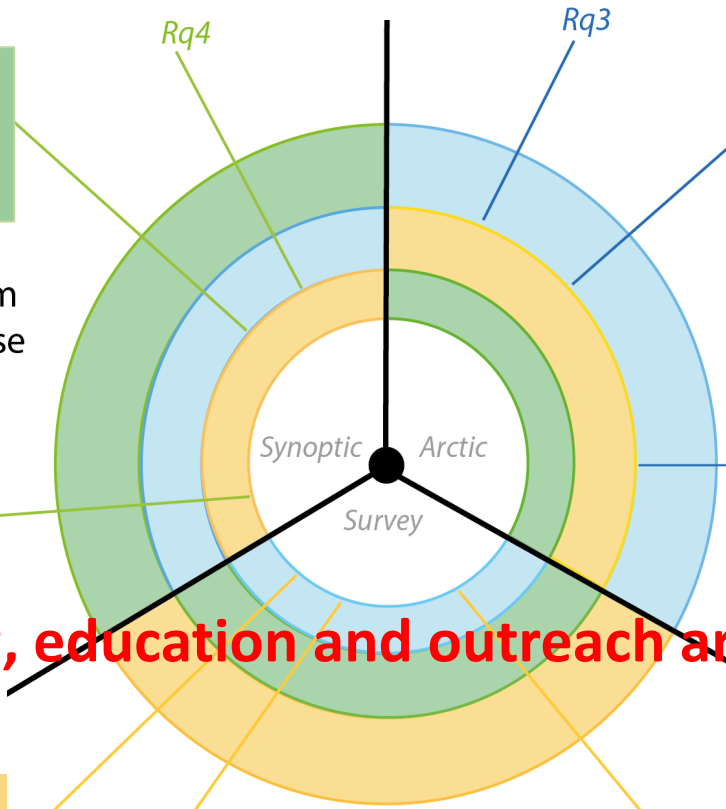
What are the present state and major ongoing transformations of the Arctic marine system?

How does primary production and associated availability of nutrients vary between Arctic regions?

What are the changes in water mass sources, sinks and transformations?

Does northward range expansion of subarctic species vary regionally and are any of these species likely to establish permanent populations in Arctic regions?

What are the states of, and changes in, heat and freshwater budgets in the Arctic regions?



How does biomass flow vary across regional ecosystems of the Arctic?

How are Arctic Ocean water masses and circulation responding to changes in sea ice properties, and atmospheric, advective and freshwater forcing?

Training, education and outreach are integral

What is the contribution of the Arctic Ocean to maintaining the global ocean carbon dioxide reservoir and uptake?

What are the magnitude, drivers, and impacts of Ocean Acidification in the different regions of the Arctic Ocean?

What are the input and fate of terrestrial and subsea carbon to the Arctic Ocean?

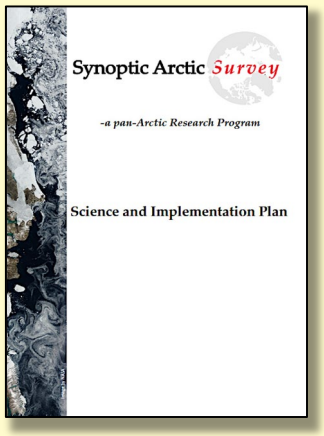
Simplified Timeline

2014
Idea conceived, Japan-Norway Marine Science week

2015
First international SAS workshop, Washington DC

2016
St. Petersburg Meeting
Town Hall, Ocean Sciences Meeting
Gothenburg, start develop SAS Science and Implementation plan

2017
First draft of Science Plan Completed
International reviews of science plan solicited
First national group formed, Sweden
Presentation and steering meeting, Prague
Presentation, OCB Meeting, Woods Hole



2018
National meeting Japan (ISAR)
National meeting Norway
Reviews of science plan received and plan revised
Updated plan available:
http://www.synopticarcticsurvey.info/splan.html
International Scientific Steering Committee Formed
US Scientific Steering Committee Formed (Ashjian and Grebmeier, leads)
International Scientific Steering Committee Meeting, Oct., Woods Hole
Informational Meeting, AGU, Washington DC, December 13

2019
SAS Implementation Workshop, Woods Hole MA (May 15-17)
Open SAS side meeting, ASSW 2019, Arkhangelsk, Russia (May 26)
US SAS SAC submitted SAS proposal to US NSF, interest by other US agencies

2020 and/or 2021
Planned year of the Synoptic Arctic Survey

Synoptic Arctic Survey (SAS) Open Planning Workshop

May 15-16, 2019

Woods Hole Oceanographic Institution

Sponsors: US National Science Foundation, the International Arctic Science Committee Working Groups, and the Woods Hole Oceanographic Institution

- 59 participants from US (40) and abroad (19)
- Special effort to engage early career scientists (ECS): 17 participated, of which 9 were postdocs and 8 were graduate students; funding from NSF-USA and IASC the IASC Marine, Atmosphere, and Cryosphere Working Groups
- 6 of 7 US SSC + 7 international SSC members
- Kaare Erickson, UIC Science, indigenous community member and early career scientists

Twelve workshop goals:

- Review discipline specific research questions, methods, and measurements
- Data management
- Nurturing ECS
- Elements missing from present SAS science plan
- Additional measurements beyond core
- Planned transects
- Non-ship assets
- Cross-calibration between ships
- Indigenous community engagement and participation
- Education
- Outreach
- Coordination with other ongoing efforts

US SAS Plans and Relevancy to Arctic Domain Awareness

Box 2. Essential Ocean Variables (EOVs) of the SAS
('*' indicates variable here proposed to be measured)

Physical	Pressure*
	Temperature*
	Salinity*
	Velocity*
	Transmissivity*
	Meteorological Measurements*
	Ice Characteristics
	Microstructure
	Seafloor Depth*
	Sediment Characteristics*
	Gravimetry*, Magnetometry
Biogeochemistry	Dissolved Oxygen*
	Nutrients (NO_3/NO_2, PO_4, SiO_3)*
	CDOM Fluorescence
	Chlorophyll* (pelagic, benthic)
	CFCs and SF_6
	DIC*, DOC*, POC*
	Total Alkalinity*
	pH*
	Methane
Ecosystem	Abundance/Biomass of Viruses, Bacteria, Phytoplankton, Micro- Meso-* and Macro-zooplankton, Benthic Meio-, Macro-*, and Epi-fauna, Epontic Organisms, Ichthyoplankton, Fish, Seabirds, Marine Mammals
	Net Community Production from O_2-Ar* & Nutrients
	Primary Production (^{13}C incubations, O_2 Isotopes*)
	Respiration of Different Trophic Levels*
	Elemental Composition* (C, N, stable isotopes)
	eDNA
	Molecular Voucher Specimens*

- NSF proposal by US SAS Science Advisory Committee-submitted Sept 2019
- Essential Ocean Variables (EOVs) as part of SAS activities
- ~ 50% ship open for other participants to submit proposals to NSF, NOAA, other US agencies and international funding sources
- In particular, EOVs and additional physical measurements relevant to Arctic Domain Awareness needs
- Have suggested that SAS could be a "flagship" activity of IARPC (US Interagency Arctic Research Policy Committee)

Synoptic Arctic Survey (SAS) Open Planning Workshop

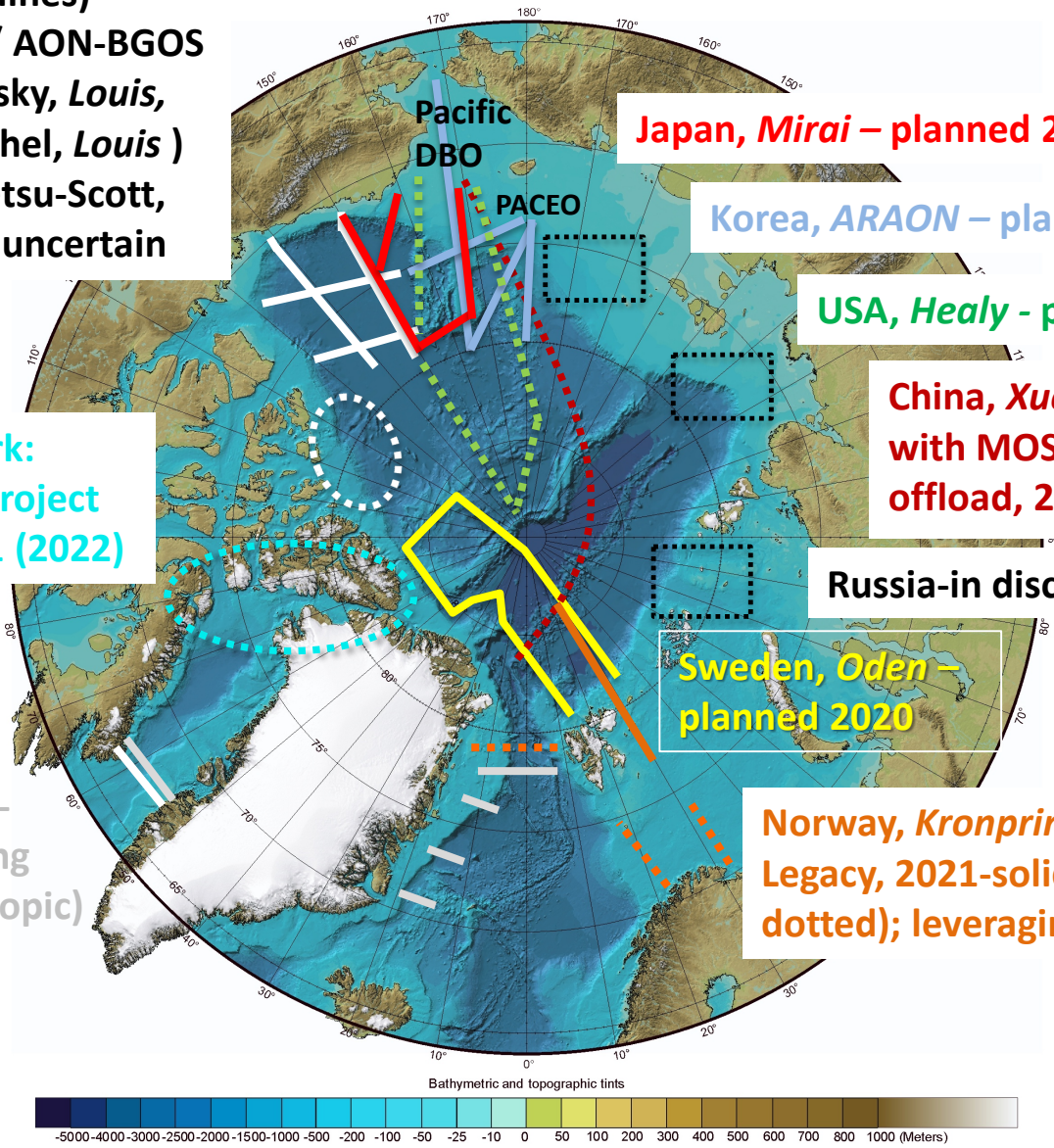
Some Recommendations/Findings

- Core parameters for the three focus areas refined
- Spatial and temporal scales of sampling refined
- The importance of non-core, non-focus area measurements that can be easily collected during the cruises emphasized (e.g., meteorological, topography, gravity)
- Data management plan discussed – networked data storage with open access within program
- Modeling can provide greater spatial and temporal context; the SAS measurements can improve biogeochemical modeling
- Pre-fieldwork and post-fieldwork synthesis activities need to be defined and emphasized
- Ideas advanced for engagement of local, indigenous communities including participation on cruises and pan-Arctic science fairs

SAS WHOI Workshop report: https://web.whoi.edu/sas2019/

SAS 2020/2021 Field Program – Confirmed (solid lines) and Proposed (dashed lines)

Canada, USA (white lines) - collaborations: JOIS/ AON-BGOS (Williams/Proshutinsky, *Louis, 2020*); LIA-MPA (Michel, *Louis*) Davis Strait (Lee/Azetsu-Scott, *Armstrong*); dotted: uncertain



Japan, *Mirai* – planned 2020 (2021 modified)

Korea, *ARAON* – planned 2020

USA, *Healy* - planning ongoing 2021

China, *Xuelong*-conjunction with MOSAiC effort, post offload, 2020

Canada/Denmark: Pikialasorsuaq Project and BBOS - 2021 (2022)

Russia-in discussion

Sweden, *Oden* – planned 2020

United Kingdom - proposing ongoing (NERC highlight topic)

Norway, *Kronprins Haakon* (Nansen Legacy, 2021-solid), *G.O. Sars* (IMR-dotted); leveraging existing programs

[update of B. Williams and J. Grebmeier, May 2019]

SAS International Science Steering Committee

Canada	Kumiko Azetsu-Scott (DFO), Bill Williams (DFO)
China	Jianfeng He (Polar Research Institute of China)
Denmark	Karen Edelvang (DTU-AQUA), Lise Lotte Sørensen
Germany	Heidimarie Kassens (GEOMAR), Sinhué Torre-Valdes
Japan	Takashi Kikuchi (JAMSTEC)
Norway	Are Olsen and Øyvind Paasche (UiB/Bjerknes Centre)
Russia	TBD
S. Korea	Sung-Ho Kang (KOPRI)
Sweden	Sten-Åke Wängberg (University of Gothenburg)
UK	Toby Tyrell (University of Southampton)
USA	Carin Ashjian (WHOI), Jackie Grebmeier (CBL/UMCES)

US Science Steering Committee

BIO	Carin Ashjian (WHOI), Jackie Grebmeier (UMCES)
PO	Seth Danielson (UAF), Mary Louise Timmermans (Yale)
CO	Nick Bates (BIOS), Laurie Juranek (OSU), Cindy Pilskaln (UMass)

Synoptic Arctic Survey

Thank you for your kind attention

Questions?

http://www.synopticarcticsurvey.info/splan.html

https://web.whoi.edu/sas2019/