US Update on Synoptic Arctic Survey Planning Activities

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Pacific Arctic Group Meeting
Hangzhou, Zhejiang Province, China
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Background

- The **S**ynoptic **A**rctic **S**urvey (**SAS**) is a bottom-up, researcher driven an initiative that seeks 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

- 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) as well as the potential for cascading ecosystem changes in the high Arctic and girdling Arctic seas highlight the need for data to be collected, analyzed and understood in concert with each other.

- A group of international scientists propose that it is necessary for a pan-Arctic, multi-ship, multi-disciplinary study at the same month and year(s) collect standard environmental data to determine status and trends of the opening Arctic Ocean

- Planning is underway for multi-ship operations (confirmed and planned) from the shelves into the Arctic basin in 2020 and 2021

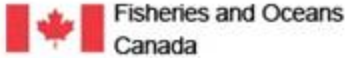
Synoptic Arctic Survey

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

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)



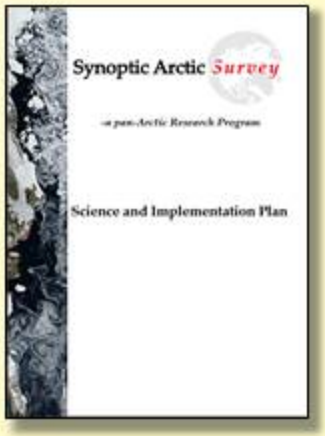
Simplified Timeline

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

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?

Rq4

Rq3

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

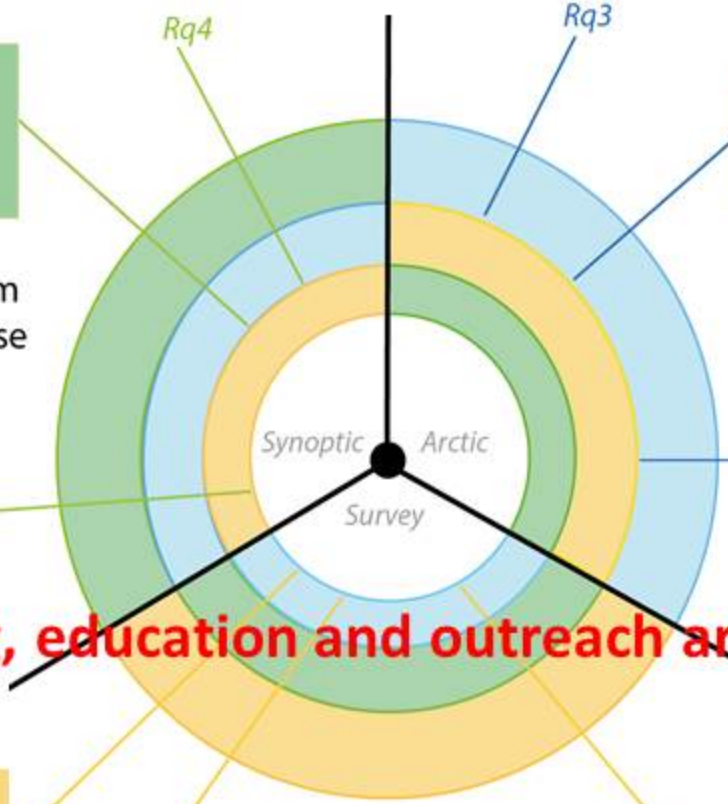
What are the states of, and changes in, heat and freshwater budgets in the Arctic regions?

Ecosystem Response

Physical Response

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?



Rq6

Training, education and outreach are integral

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

Rq8

Carbon Cycle & Acidification

Rq9

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?

Recommended Set of Measurements

Variable	Sampling
Physical and chemical measurements	
Pressure	CTD
Temperature	CTD
Salinity	CTD + Niskin
Dissolved Oxygen	CTD + Niskin
Nutrients (NO_3/NO_2, PO_4, SiO_3)	Niskin
CFCs and SF_6	Niskin
Dissolved Inorganic Carbon	Niskin
Total Alkalinity	Niskin
pH	Niskin
$\delta^{18}O$ of H_2O	Niskin
Methane	Niskin
Dissolved Organic Carbon (DOC)	Niskin
Particulate Organic Carbon (POC)	Niskin
Water column ecosystem measurements	
Chlorophyll	Niskin
Primary production	Incubation
Viruses	Niskin
Bacteria	Niskin
Phytoplankton composition	Niskin
Microzooplankton	Niskin
Meso-and Macro- zooplankton	Bongo nets, Multinet, Optical Instruments, Acoustics
Icthyoplankton	Aluette or Tucker Trawls, Acoustics
Fish	Trawls, Acoustics
Marine mammals	Passive acoustics, Visual observations
Other Carbon transformation rates	Selected process studies (e.g., grazing, reproduction, sinking, respiration)
Benthic measurements	
Meio- and Macro- fauna	Box Core or Multicore or other corers
Epifauna	Benthic camera, Beam trawl
Other Carbon transformation rates	Selected process studies (e.g., grazing, reproduction, sinking, respiration)
Other	
Epontic Communities	Under-ice imaging, ice cores, sub-ice sampling
Seabirds	Visual Observations

- Physics, carbon chemistry, nutrients, and oxygen following GO-SHIP practices
- Include ecosystem measurements
- Tailored to Arctic science

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

- Fifty-nine participants from both the US (40) and abroad (19)
- Special effort to engage early career scientists (ECS)
  - Travel support offered to early career scientists through an application process.
  - Seventeen early career scientists participated. Of these, nine were postdocs and eight were graduate students
  - Six of the ECS were supported by the NSF workshop grant to Ashjian (US ECS); six were supported by funds granted to Grebmeier by the IASC Marine, Atmosphere, and Cryosphere Working Groups (international ECS). The remainder did not require funding.
- Kaare Erickson, UIC Science, participated in the workshop as an indigenous community member and early career scientists (Erickson is presently a graduate student in addition to working)
- Six of the seven US SSC members participated. Seven of the international SSC members participated; those who could not join either sent a substitute or provided an update

Synoptic Arctic Survey (SAS) Open Planning Workshop

- Two day workshop, open to the national and international scientific workshop
- Plenary and breakout group sessions
- Each breakout group was led by an established scientist (often from the US SSC) and an early career scientist. The two worked together to present the discussions in the breakout and to provide a summary for the workshop report (in draft)
- 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

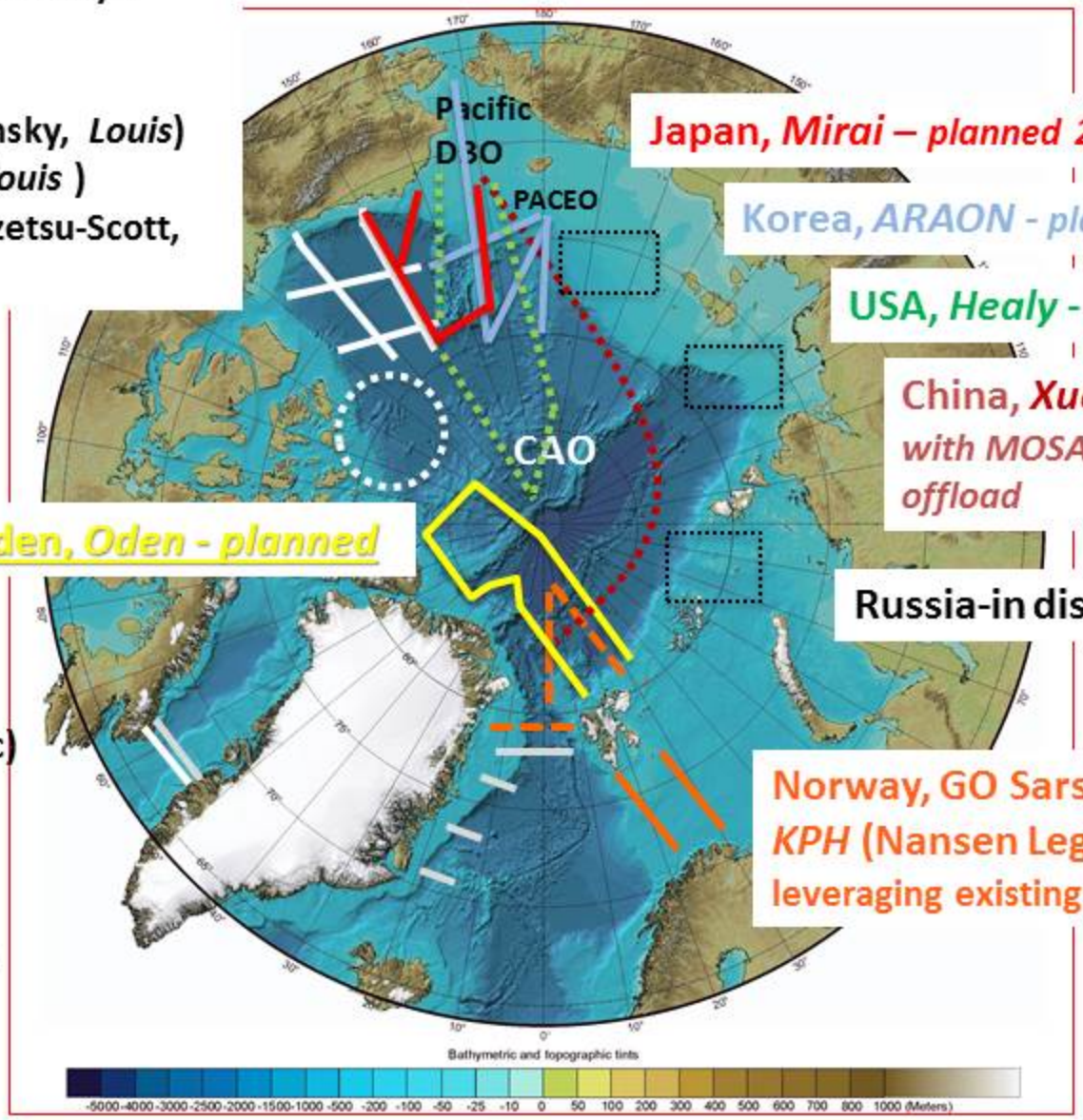
Synoptic Arctic Survey (SAS) Open Planning Workshop

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

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



Japan, *Mirai* – *planned 2020 (also 2021 mod)*

Korea, *ARAON* - *planned*

USA, *Healy* - *planning ongoing*

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

Sweden, *Oden* - *planned*

Russia-in discussion

United Kingdom - proposing ongoing (NERC highlight topic)

Norway, GO Sars (IMR)
***KPH* (Nansen Legacy) 2021;**
leveraging existing programs

Note: we are developing maps to identify international shelf programs, too

[modified B. Williams and J. Grebmeier, May 2019]

Open SAS Meeting, Arctic Science Summit Week, May 26, 2019; Arkhangelsk, Russia

- The **S**ynoptic **A**rctic **S**urvey (**SAS**) is an initiative that seeks 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

- 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) as well as the potential for cascading ecosystem changes in the high Arctic and girdling Arctic seas highlight

- We propose that a pan-Arctic, multi-ship, multi-disciplinary study to collect standard environmental data to determine status and trends of the opening Arctic Ocean

- Planning is underway for multi-ship operations (confirmed and planned) from the shelves into the Arctic basin in 2020/2021

- All interested participants welcome to this open discussion period

Open SAS Meeting, Arctic Science Summit Week
May 26, 2019, Arkhangelsk, Russia
Meetings at Shirshov Institute, Moscow, Russia

- Thirty people attended the ASSW SAS meeting led by Jackie Grebmeier, although there was limited involvement of Russian scientists. Discussion focused on adding basic atmospheric measurements and on shared data network.

- Jackie Grebmeier and Lee Cooper visited the Shirshov Institute and had productive discussions with the Deputy Director and scientists. The Russians have onoing projects on the Russian shelves that could synergize with SAS. They are also interested in including a couple of scientists on the International SSC.

SAS International Science Steering Committee

Canada	Kumiko Azetsu-Scott (DFO), Bill Williams (DFO)
China	Jianfeng He (Polar Research Institute of China, Shanghai)
Denmark	Karen Edelvang (DTU-AQUA), Lise Lotte Sørensen (Aarhus Univ.)
Germany	Heidimarie Kassens (GEOMAR), Sinhué Torre-Valdes (AWI)
Japan	Takashi Kikuchi (JAMSTEC)
Norway	Are Olsen and Øyvind Paasche (boh UiB/Bjerknes Centre)
Russia	TBD
South 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)

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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)

Next Steps

- Discuss with the NSF a path forward for promoting a US SAS program (how to do this?)
- Further engage other interested funding agencies (e.g., BOEM, NOAA)

US SAS Plans

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
- * are EOVs in proposal by proposal PIs
- ~ 50%ship open for other participants to submit proposals to NSF, NOAA, other US agencies and international collaborators

US SAS 2021 Plans

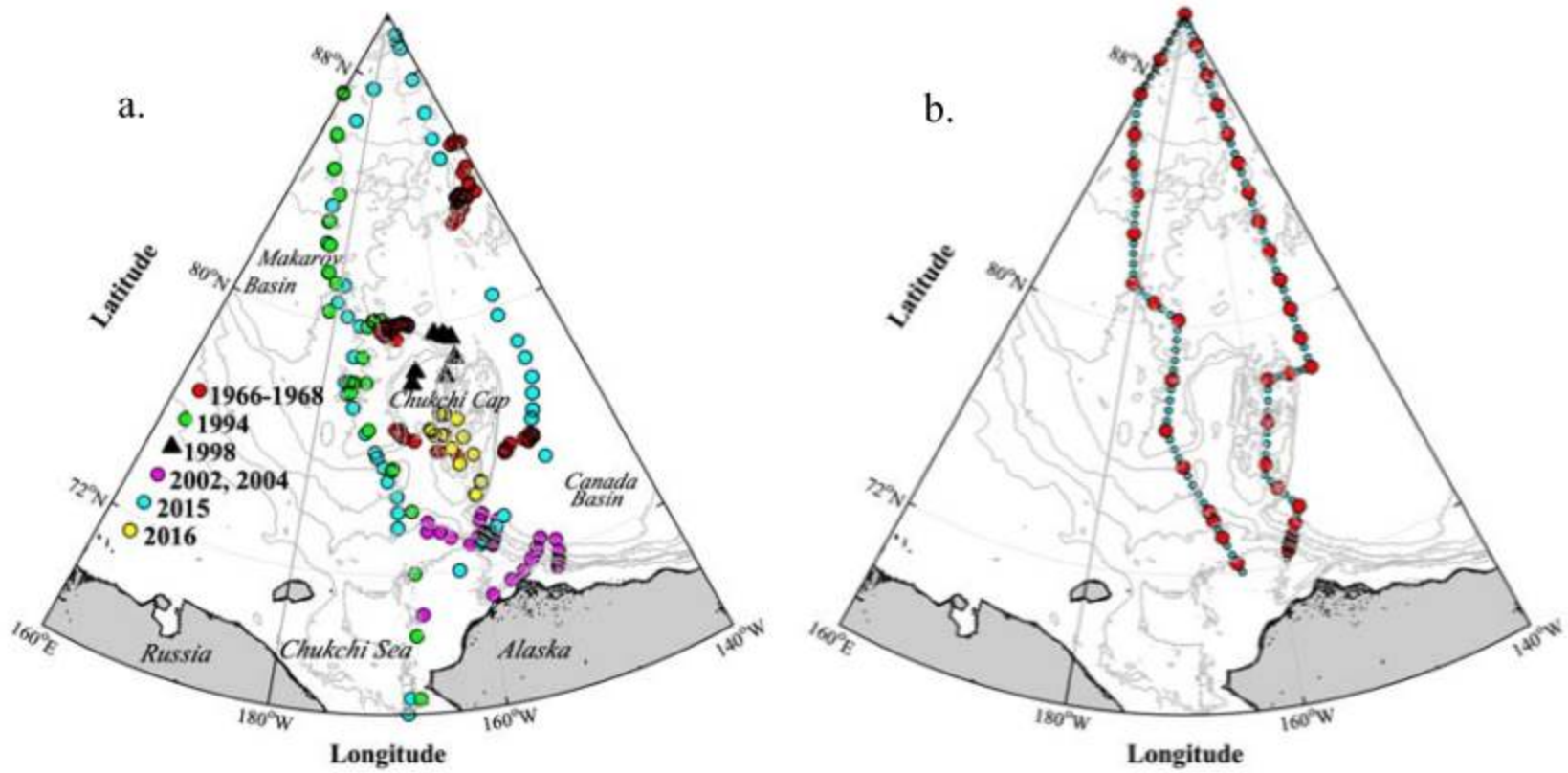

Figure 2. (a) Historic summer stations in the Canadian Basin, including T-3 (1966-1968), AOS (1994), SHEBA (1998), SBI (2002-2004), Arctic GEOTRACES (2015), and Hidden Ocean (2016). (b) DRAFT cruise track for this proposal. Locations subject to change based on ice conditions, cruise scheduling, and water mass distributions. Red=Long Stations; Cyan=Short Stations.

*Proposed for USCGC Healy, with possible shelf work on RV Sikuliaq

US SAS 2021 Plans

Table 1. Timing of key events and meetings.

Activity	**Time**
Pre-Cruise Workshop, Woods Hole MA	Fall 2020
PAG Meeting, Canada or US	Fall 2020
USCGC Healy Visit, Seattle	Fall/Winter 2020
ASSW, Lisbon	Spring 2021
Cruise on *USCGC Healy*	Summer 2021
PAG Meeting, Canada or US	Fall 2021
Post Cruise Workshop , Solomons MD	Spring 2022
Ocean Sciences Meeting, Honolulu	Feb. 2022
ASSW, Tromso	Spring 2022
International Synthesis Workshop, TBD	Fall 2022

Synoptic Arctic Survey

Thank you for your kind attention

Questions?

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

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