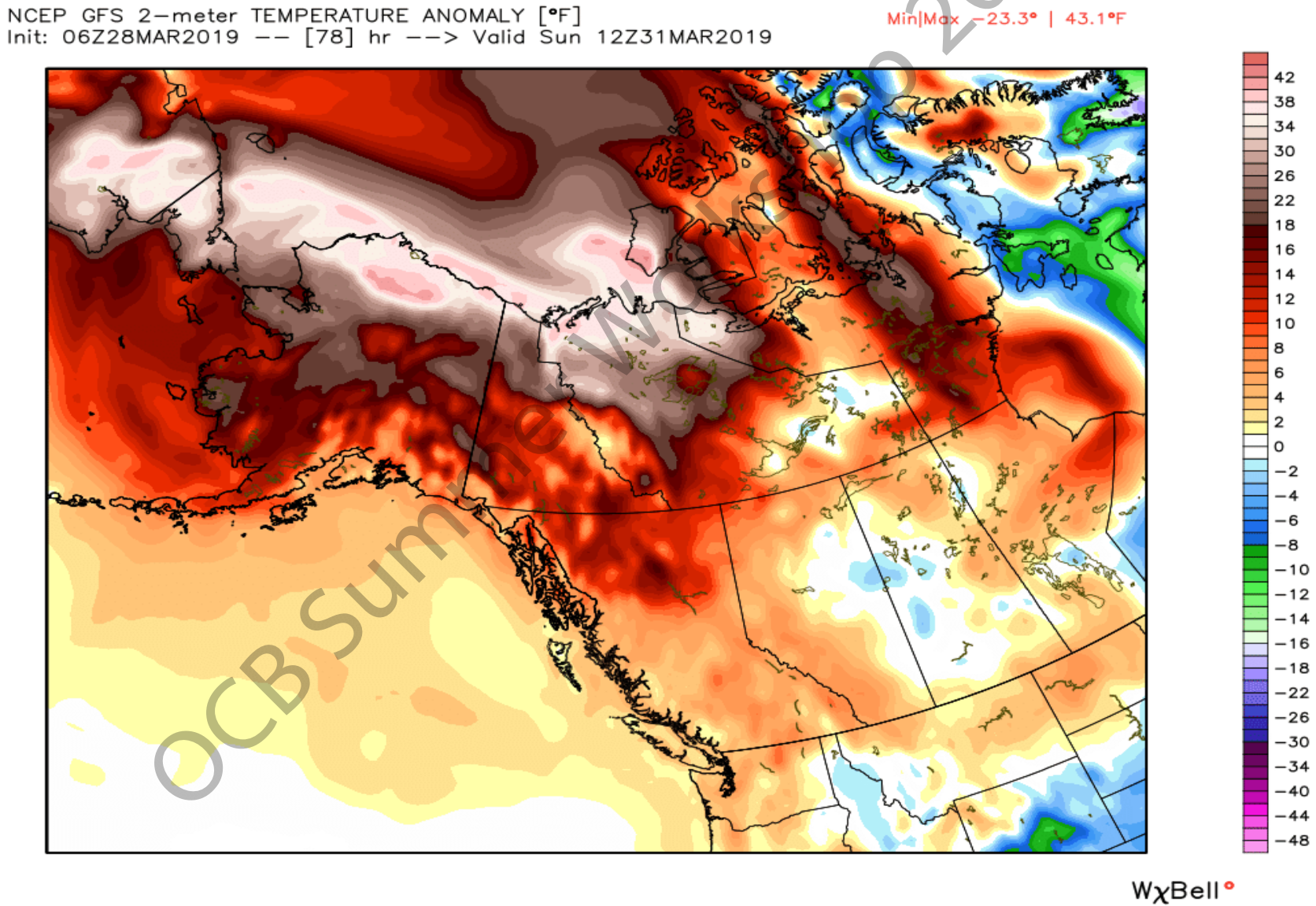
Arctic COLORS

Arctic - Coastal Land Ocean Interactions

Maria Tzortziou, Marjorie Friedrichs, Peter Hernes, Antonio Mannino, Patricia Matrai, Joe Salisbury, Carlos Del Castillo

The Washington Post
Democracy Dies in Darkness

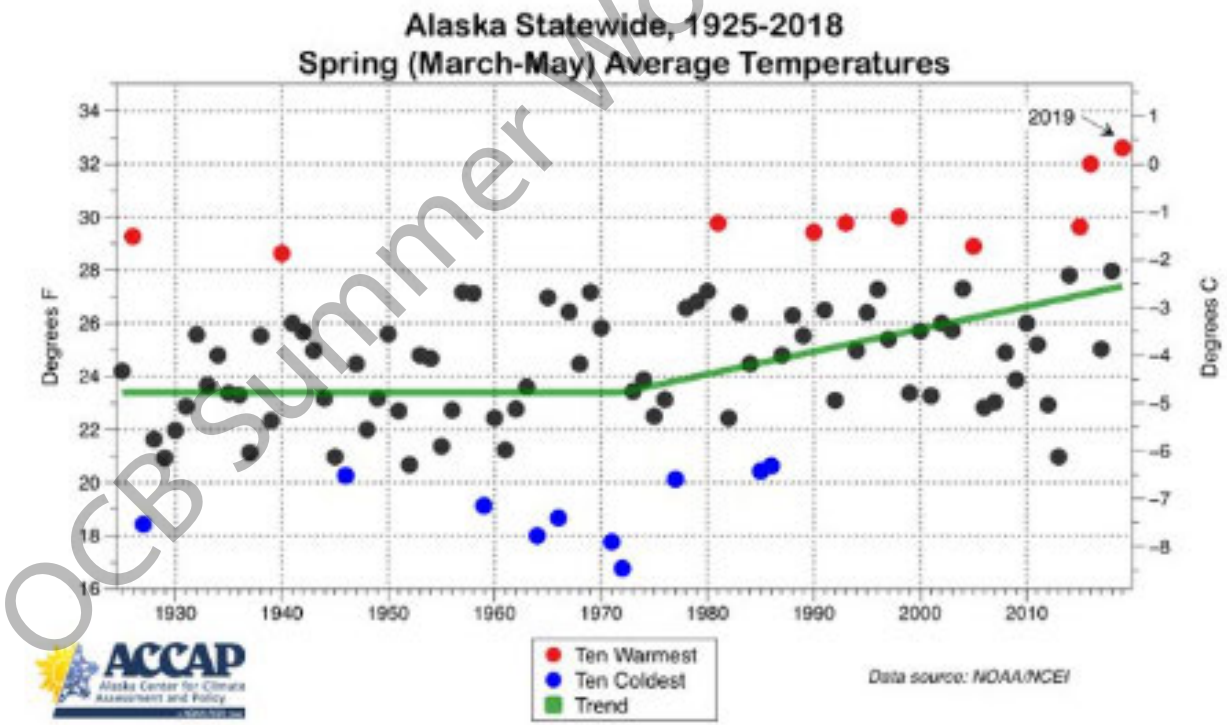
Alaska is baking in an exceptionally toasty March as steep, long-term warming presses on

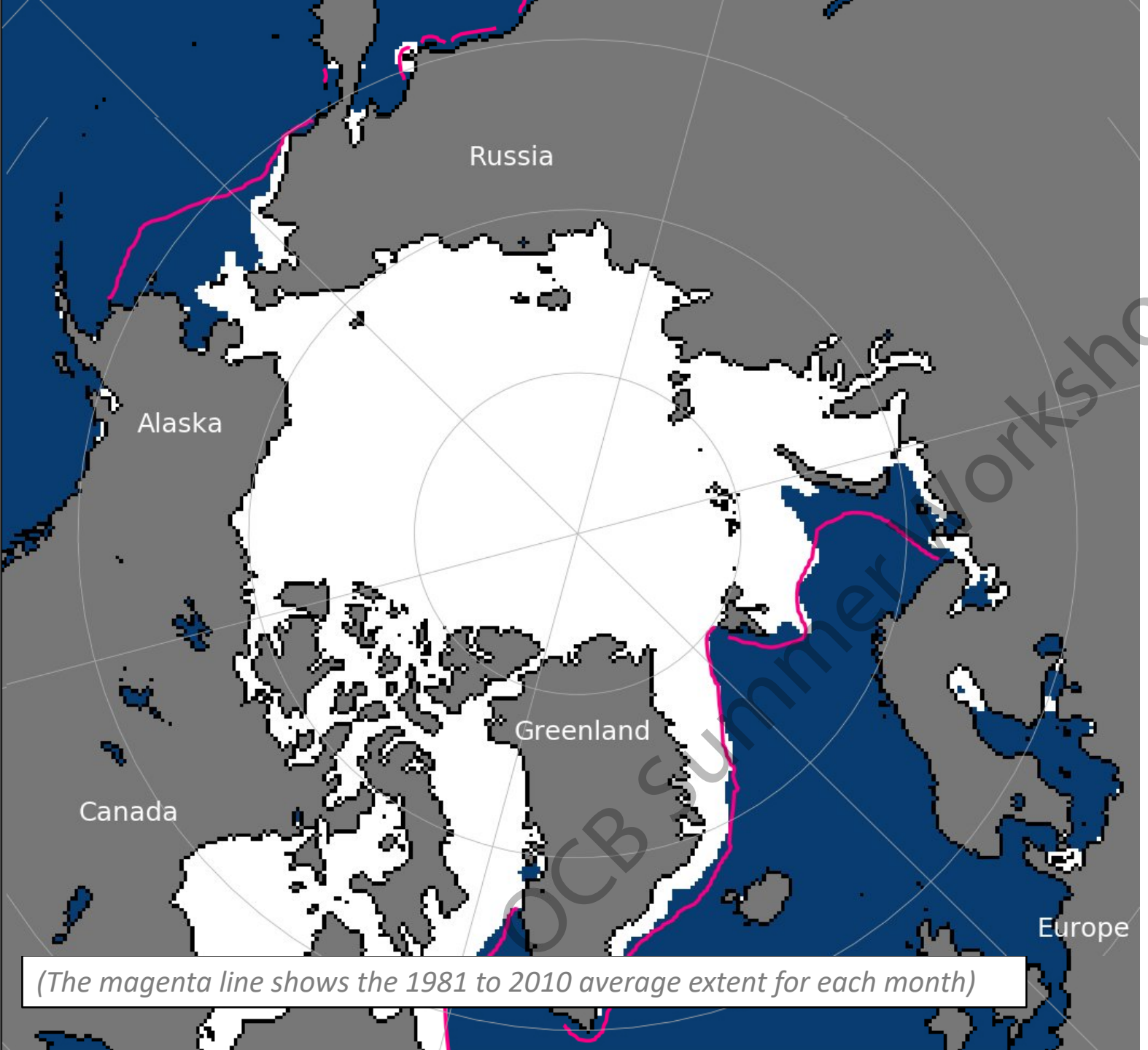


Rick Thoman
@AlaskaWx

Springtime in Alaska isn't what it used to be. This is the 3rd time past 21 years we can say" warmest spring of record". 1998 was the warmest to date, exceeded in 2016 and now 2016 exceeded in 2019. Trend +4.0F (+2.2C) since the 1970s. #akwx #Arctic @Climatologist49 @IARC_Alaska

♡ 31 1:41 PM - Jun 6, 2019





(The magenta line shows the 1981 to 2010 average extent for each month)

Arctic sea ice extent for April 2019 was the **lowest for any April on record** (National Snow and Ice Data Center).

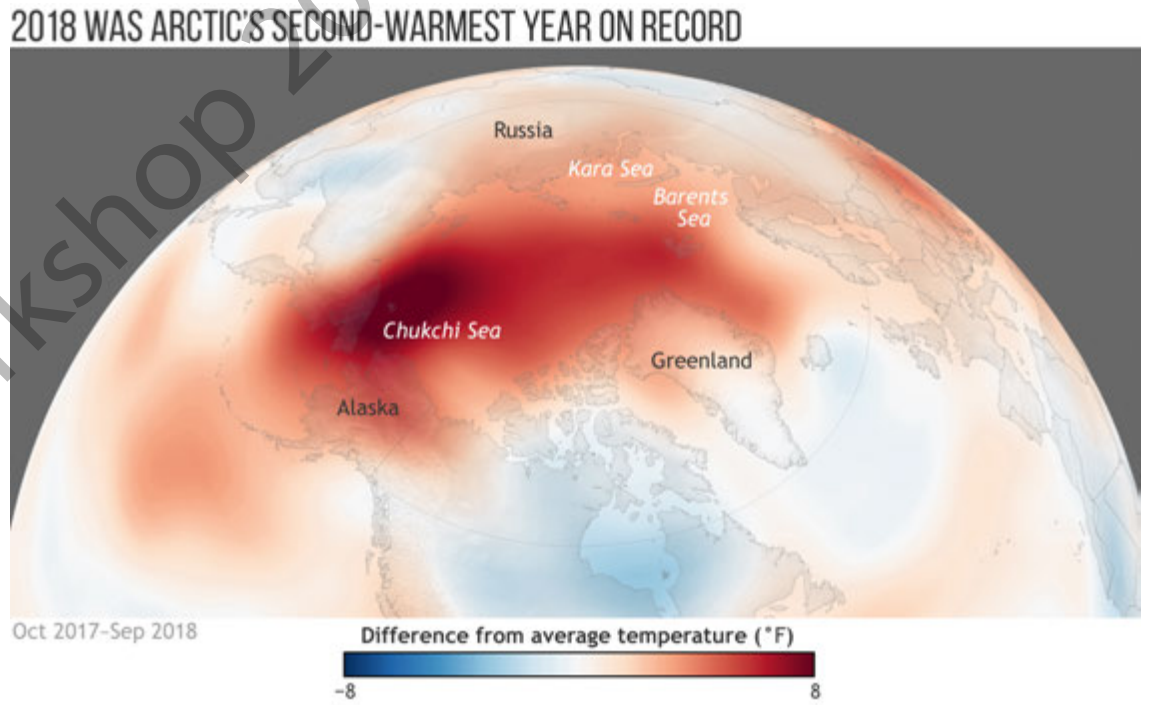
Arctic sea ice extent for May 2019 was the **second-lowest for that month** in the satellite history, and the Pacific side of the Arctic has especially large areas of open water (National Snow and Ice Data Center).

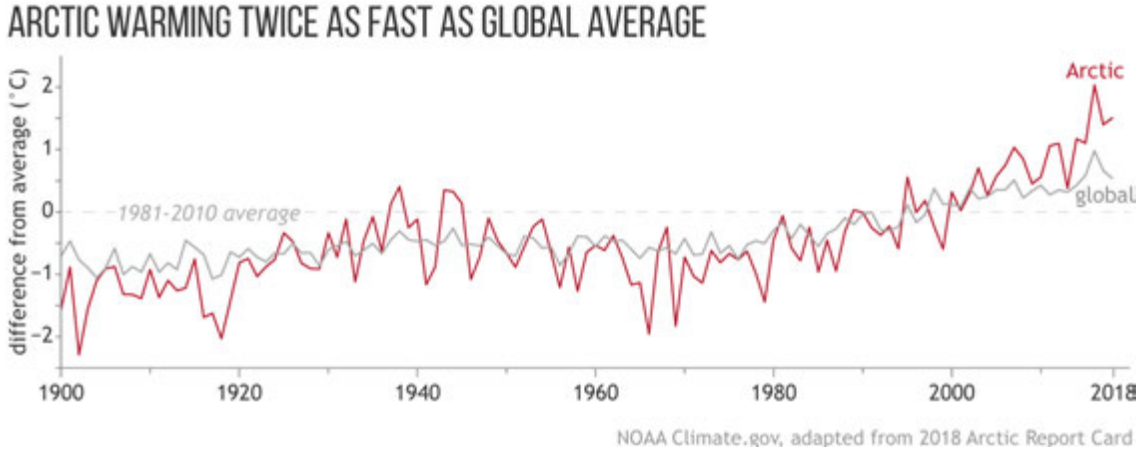
“Barely above the record low for the month reached in 2016”

“The month’s melt was notable in the southern **Chukchi Sea**”

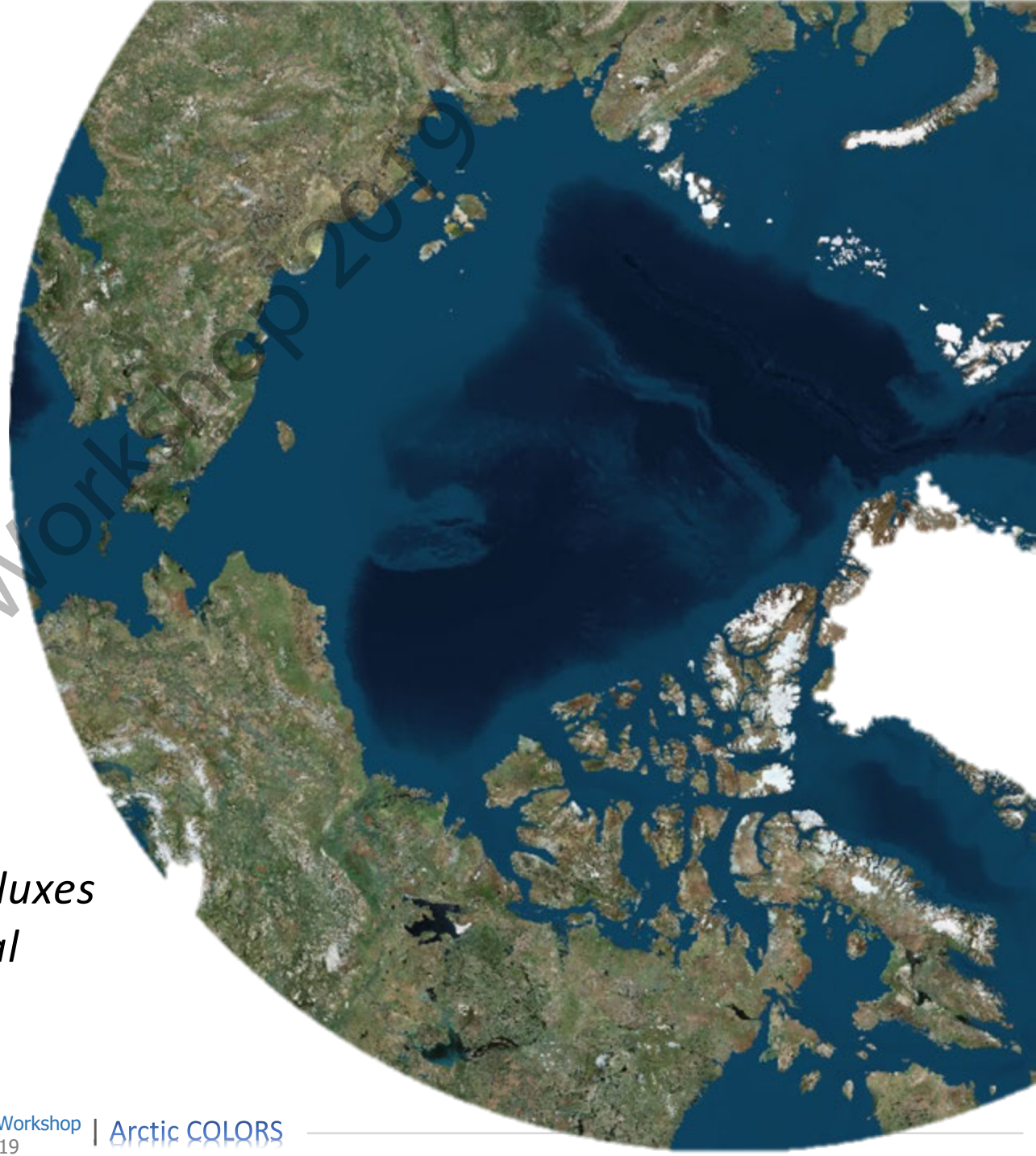
The Arctic of today is a new environment, warming faster than any other region on the planet, changing rapidly, beyond current projections

- Significant increase in **summer SST** over past 50 years
- Substantial **reduction in sea ice coverage** and **ice season length**
- **Increasing light penetration** in the ocean, **increasing primary productivity** and **changing food web dynamics**
- **Permafrost is thawing** /1,672 Petagrams of organic carbon stored in Arctic permafrost globally
- **Changing flows in Arctic rivers**
- **Coastal Erosion** / at rates as high as 25 m yr^{-1}, annual release of up to 46.5 Tg of organic carbon
- Extreme biophysical changes in the Pacific Arctic → *"new normal"* (Jeffries et al., 2013)
- **Ocean acidification** of Arctic seas
- Expansion of **toxic or harmful algal bloom (HABs) species** into and within the Arctic
- Consequences for Arctic wildlife and human populations





Remote Sensing observations from space offer a unique, *integrated Coastal Arctic System* perspective that cannot be achieved by surface measurements alone



Arctic COLORS is driven by this unique perspective

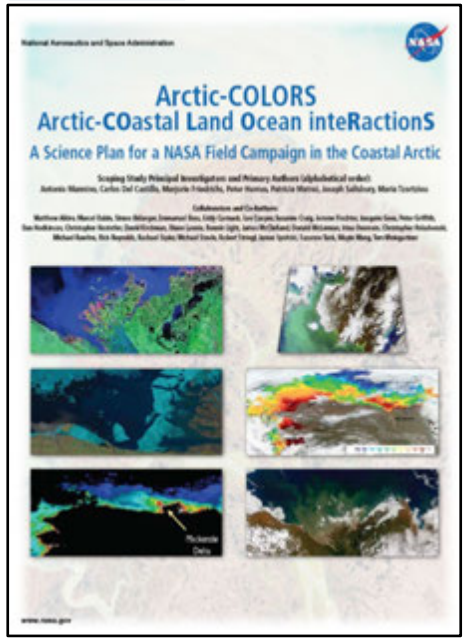
Arctic COLORS aims to *"quantify the coupled biogeochemical/ecological response of the Arctic nearshore system to rapidly changing terrestrial fluxes and ice conditions, in the context of environmental (short-term) and climate (long-term) change"*

Arctic-COLORS: a proposed NASA Field Campaign to improve understanding and prediction of the rapidly changing coastal Arctic

Updates on:

- Revised top level **science questions**
- Revised **study domain** for Arctic-COLORS
- Potential **timeline**
- **What's next**

Science Plan



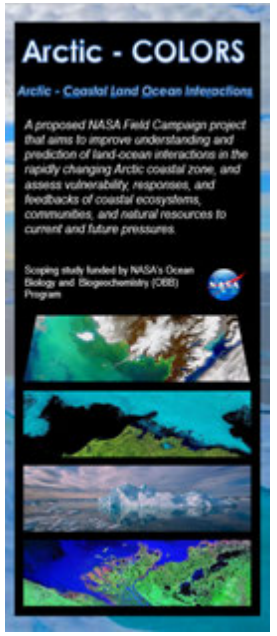
International Team of Collaborators

Science Team

Name	Institution	Name	Institution
Carlos Del Castillo	NASA GSFC	**David Kirchman**	U. Delaware
Marjorie Friedrichs	VIMS	**Diane Lavoie**	Fisheries & Oceans Canada
Peter Hernes	UC-Davis	**Bonnie Light**	U. Washington
Antonio Mannino	NASA GSFC	**James McClelland**	U. Texas / MSI
Patricia Matrai	Bigelow	**Donald McLennan**	CHARS
Joseph Salisbury	UNH	**Irina Overeem**	U. Colorado
Maria Tzorziou	CCNY	**Chris Polashenski**	U.S. Army Corps of Engineers
Matthew Alkire	U. Washington	**Michael Rawlins**	U. Massachussetts
Marcel Babin	U. Laval	**Rick Reynolds**	Scripps/ UCSD
Simon Bélanger	UQAR Canada	**Michael Steele**	U. Washington
Emmanuel Boss	U. Maine	**Dariusz Stramski**	Scripps/ UCSD
Eddy Carmack	Fisheries & Oceans Canada	**Robert Striegl**	USGS
Lee Cooper	UMCES/ CBL	**James Syvitski**	U. Colorado
Susanne Craig	Dalhousie University	**Suzanne Tank**	U. Alberta
Jerome Fiechter	UC Santa Cruz	**Muyin Wang**	U. Washington
Joaquim Goes	Lamont-Doherty	**Tom Weingartner**	U. Washington
Peter Griffith	SSAI/ GSFC	**Paula Bontempi**	NASA HQ
David Kirchman	U. Delaware		

Arctic COLORS Project Website

Outreach Materials



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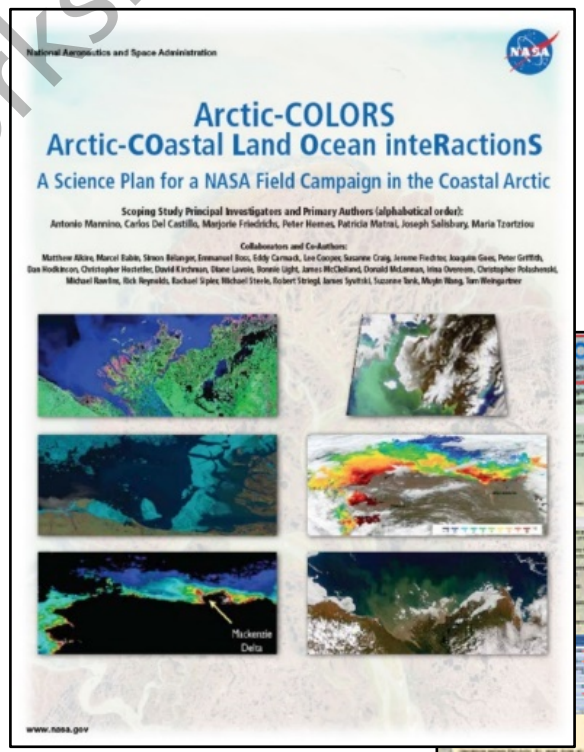

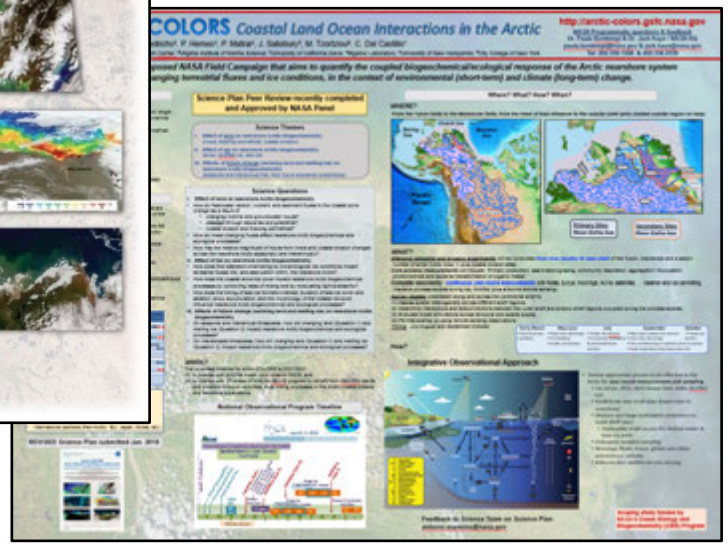

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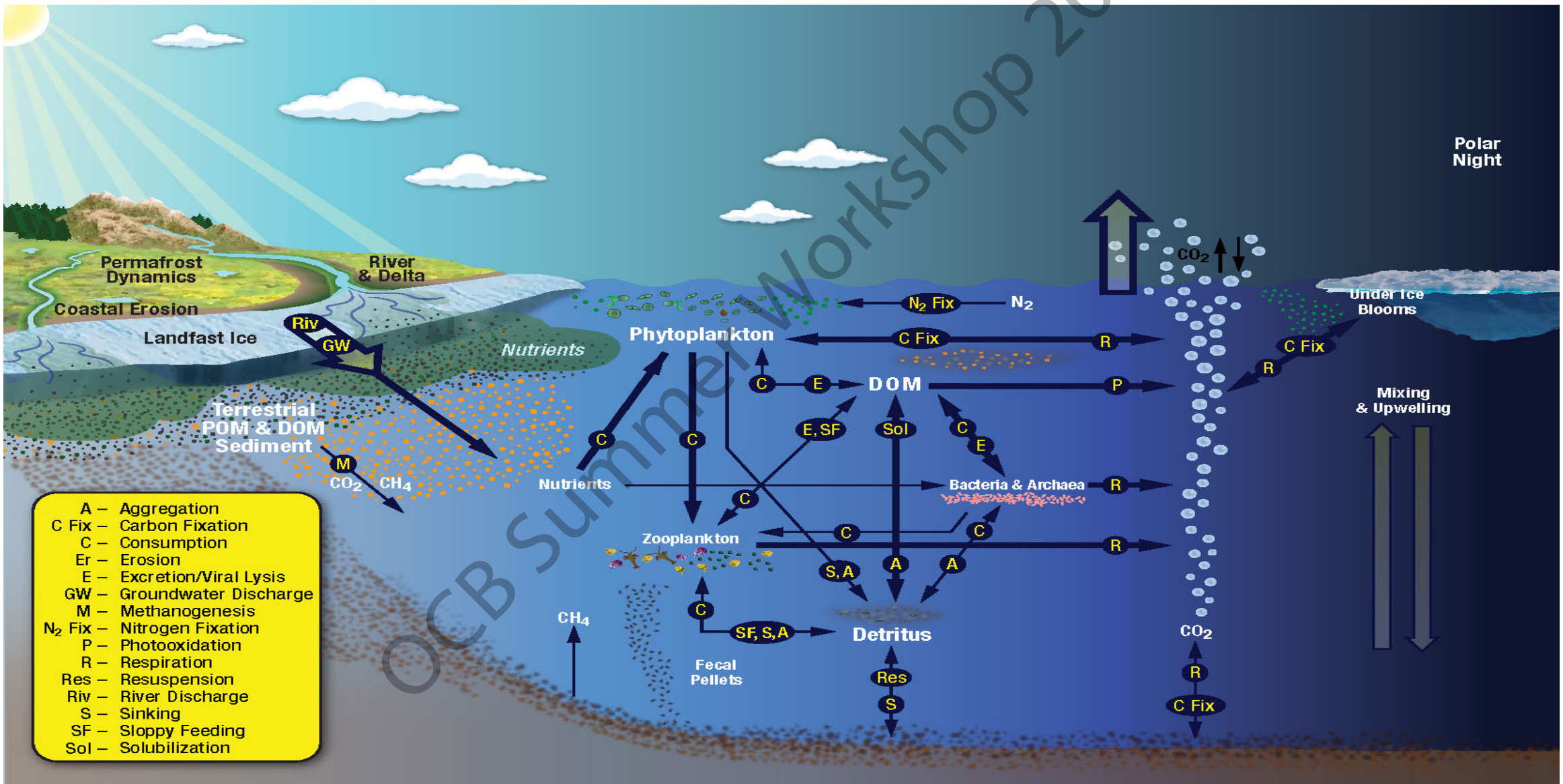

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I. Effect of land on nearshore Arctic biogeochemistry

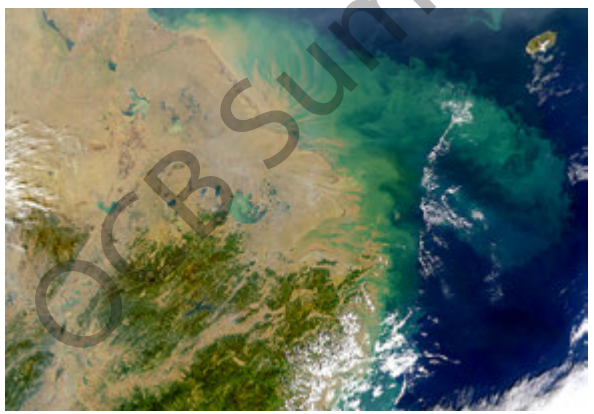
II. Effect of ice on nearshore Arctic biogeochemistry

III. Effects of future change (warming land and melting ice) on nearshore Arctic biogeochemistry

Arctic COLORS aims to **quantify the coupled biogeochemical/ecological response** of the Arctic nearshore system to rapidly changing **terrestrial fluxes and ice conditions**

I. Effect of land on nearshore Arctic biogeochemistry

- How do freshwater, carbon, nutrient, and sediment **fluxes to the coastal zone** change as a result of
  - changing **riverine and groundwater** inputs,
  - passage **through estuaries and gradients**,
  - **coastal erosion** and
  - **thawing permafrost**
- How do these **changing fluxes** affect nearshore Arctic biogeochemical and ecological processes?
- How has the relative magnitude of inputs from rivers and coastal erosion changed across the nearshore Arctic **seasonally and interannually**?

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I. Effect of land on nearshore Arctic biogeochemistry

II. Effect of ice on nearshore Arctic biogeochemistry

- How does **flow alteration/channeling by morphological ice conditions** impact terrestrial fluxes into, and attenuation within, the nearshore Arctic?
- How does the **coastal snow/ice cover** impact nearshore Arctic biogeochemical processes by controlling rates of mixing and by modulating light availability?
- How does the **timing of sea ice formation/retreat**, **duration of sea ice cover** and **ablation, snow accumulation**, and the **morphology of the coastal ice zone** influence nearshore Arctic biogeochemical and ecological processes?




Arctic COLORS aims to **quantify the coupled biogeochemical/ecological response** of the Arctic nearshore system to rapidly changing **terrestrial fluxes and ice conditions**

I. Effect of land on nearshore Arctic biogeochemistry

II. Effect of ice on nearshore Arctic biogeochemistry

III. Effects of future change (warming land and melting ice) on nearshore Arctic biogeochemistry

- On **seasonal and inter-annual timescales**, how will changing land (Question 1) and melting ice (Question 2) impact nearshore Arctic biogeochemical and ecological processes?
- On **inter-decadal timescales**, how will changing land (Question 1) and melting ice (Question 2) impact nearshore Arctic biogeochemical and ecological processes?




Large globally important rivers, regionally important rivers including smaller tundra rivers, coastal lagoons, erosional bluffs

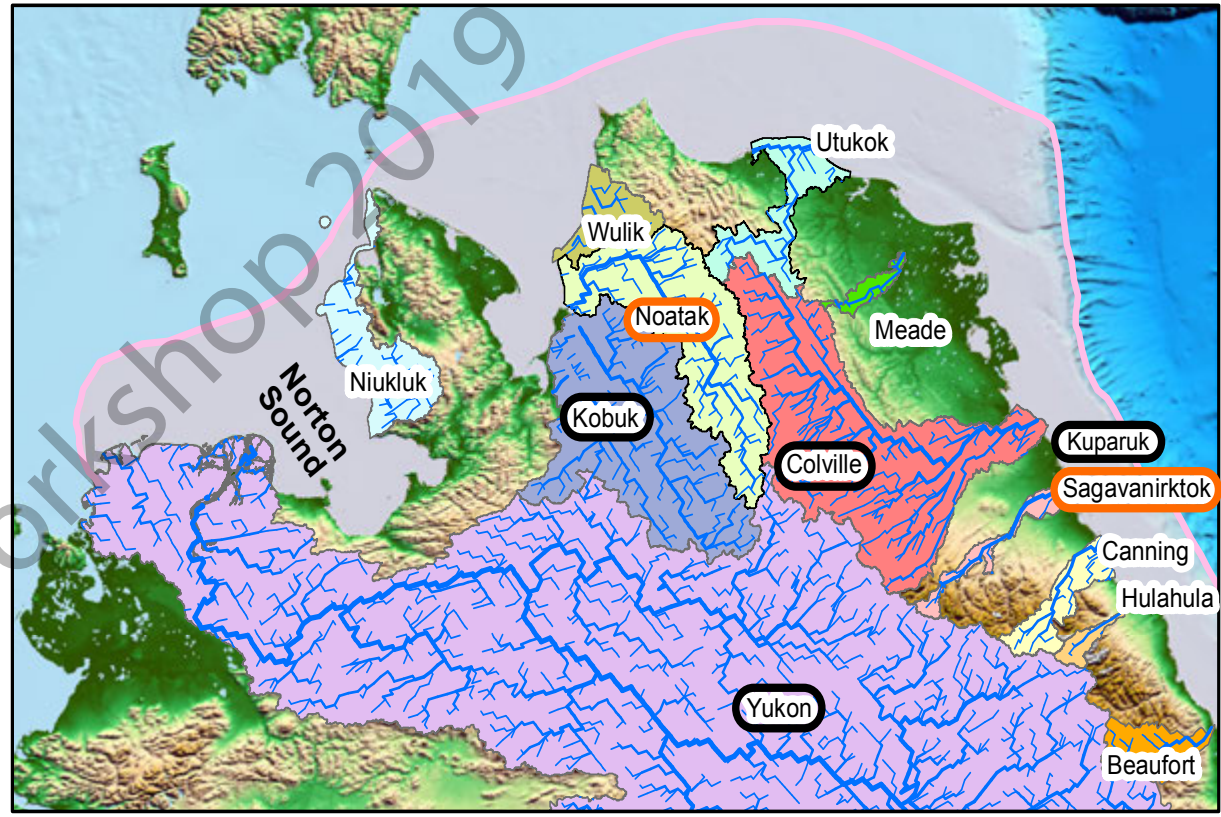
Intensive sampling & process experiments

Conducted from river mouths to near-shelf of:
At least one large river (Yukon River, Mackenzie), and a select number of small rivers plus coastal erosion sites.

Core process measurements will include:
Primary production, assimilation/grazing, community respiration, aggregation/ flocculation, photochemical and bacterial transformation of organic matter.

Complete seasonality: continuous year-round measurements with floats, buoys, moorings, AUVs, satellites, … weather and ice permitting.

Intensive process studies during key months (plus airborne RS)



Black outline: Tier 1 sites (high priority); Orange outline: Tier 2 sites (medium priority)

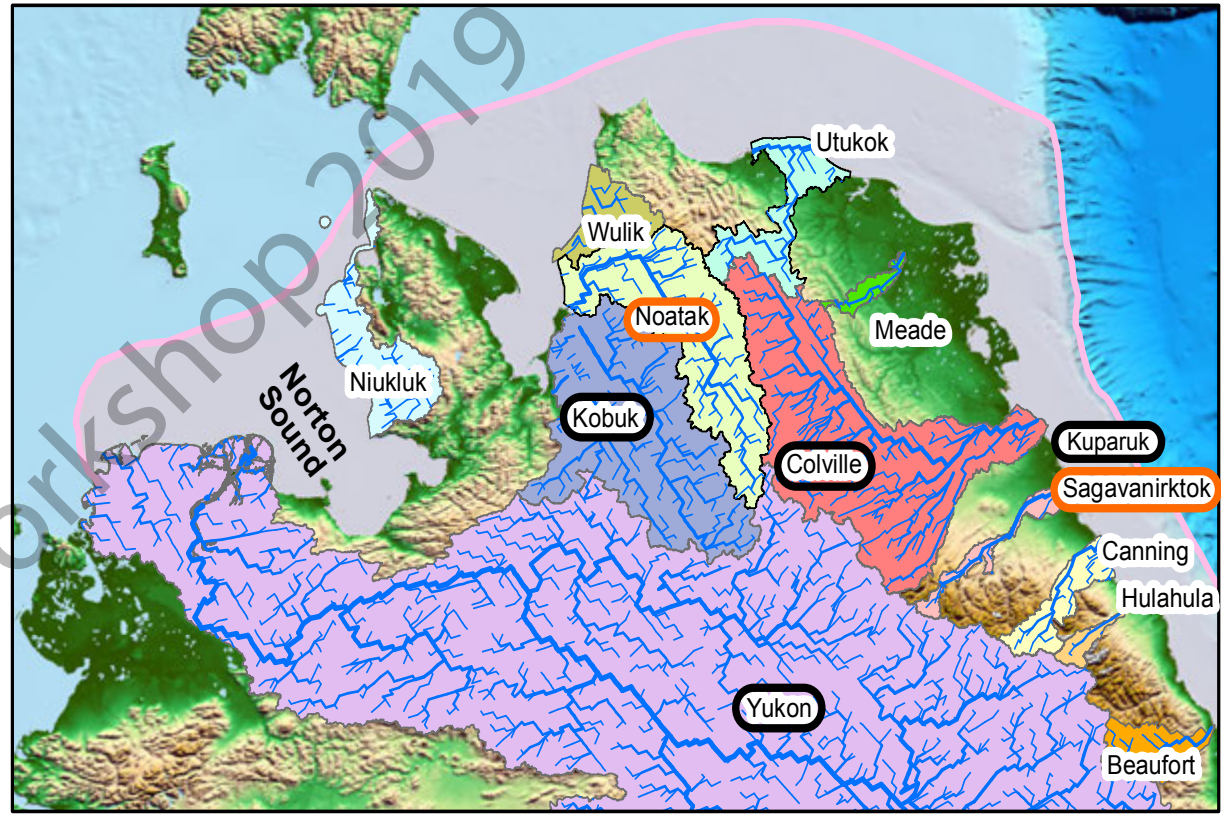
Early March	May-June	July	September	October
• End of winter	• Peak river discharge • Ice breakup • Under ice blooms	• Under ice blooms • Increasing biological & photochemical activity	• Max open water/min sea ice • Low river discharge • Preconditioning prior to winter • Peak respiration late Sept-Oct	• Freeze-up period

Survey studies

Undertaken along and across the continental shelf to

- Assess spatial heterogeneity across different shelf regions,
- Determine interactions and teleconnections between the outer shelf and shallow shelf regions occupied during the process studies,
- Evaluate model simulations across temporal and spatial scales,
- Permits scaling up using remote sensing observations

Timing: **July-August** and **September-October**



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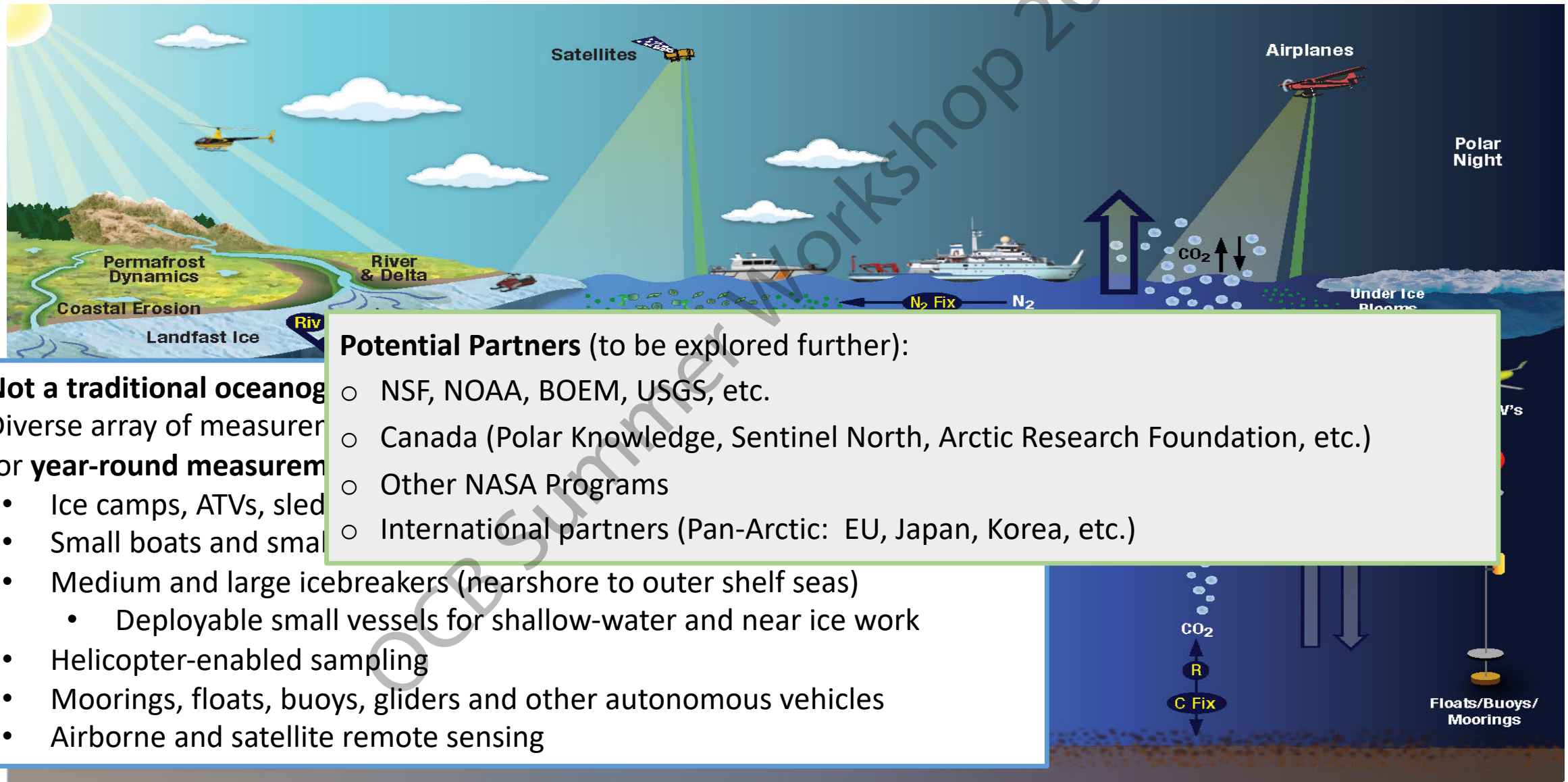


- **Not a traditional oceanog**
- Diverse array of measurer
  for **year-round measurem**
  - Ice camps, ATVs, sled
  - Small boats and smal
  - Medium and large icebreakers (nearshore to outer shelf seas)
    - Deployable small vessels for shallow-water and near ice work
  - Helicopter-enabled sampling
  - Moorings, floats, buoys, gliders and other autonomous vehicles
  - Airborne and satellite remote sensing

Potential Partners (to be explored further):

- NSF, NOAA, BOEM, USGS, etc.
- Canada (Polar Knowledge, Sentinel North, Arctic Research Foundation, etc.)
- Other NASA Programs
- International partners (Pan-Arctic: EU, Japan, Korea, etc.)

Arctic COLORS Science Traceability Matrix (STM)

Science Questions

Q1 What are the effects of land on nearshore Arctic biogeochemistry?

- How do freshwater carbon, nutrient, and sediment fluxes to the coastal zone change as a results of:
  - changing riverine and groundwater inputs,
  - passage through estuaries and gradients,
  - and coastal erosion and thawing permafrost?
- How do these changing fluxes affect nearshore Arctic biogeochemical and ecological processes?
- How has the relative magnitude of inputs from rivers and coastal erosion changed across the nearshore Arctic seasonally and interannually?

Q2 What are the effects of ice on nearshore Arctic biogeochemistry?

- How does flow alteration/channeling by morphological ice conditions impact terrestrial fluxes into and attenuation within, the nearshore Arctic?
- How does the coastal snow/ice cover impact nearshore Arctic biogeochemical processes by controlling rates of mixing and by modulating light availability?
- How does the timing of sea ice formation/retreat, duration of sea ice cover and ablation, snow accumulation, and the morphology of the coastal ice zone influence nearshore Arctic biogeochemical and ecological processes?

Q3 What will be the effects of future change (warming land and melting ice) on nearshore Arctic biogeochemistry?

- On seasonal to interannual time scales, how will changing land (Question 1) and melting ice (Question 2) impact nearshore Arctic biogeochemical and ecological processes?
- On interdecadal time scales, how will changing land (Question 1) and melting ice (Question 2) impact nearshore Arctic biogeochemical and ecological processes?

Approach

Map to Science

A Use a rich synthesized dataset of existing field and satellite datasets (Phase I) (i) for initial RS algorithm and model development and (ii) to optimize the design of field studies and deployments — Q1 Q2 Q3

B Conduct new field observations and process studies/quantitative experiments across intensive study sites (Tier 1 and 2) and synoptic surveys (Tier 3 sites) (Phase II), to: (i) assess current conditions in the coastal Arctic, (ii) develop improved coupled hydrodynamic-bio-geochemical model parameterizations, and (iii) develop new RS algorithms and ocean color products — Q1 Q2 Q3

C Extend ship and boat based measurements over different seasons and multiple years using buoys, moorings and autonomous platforms, to assess seasonality and capture year-to-year variability in Arctic processes — Q1 Q2

D Link in-situ observations to remotely sensed quantities, for quantitative assessments of land-ice-ocean interactions from RS (space and suborbital) assets, and use RS in hindcast mode to distinguish between climate change trends and shorter term variability — Q1 Q2

E Use in-situ and RS datasets to develop new coupled hydrodynamic-ecological models for assessing impacts of future change on nearshore Arctic biogeochemistry. — Q3

F Integrate measurements and model results during a 2-year Synthesis Phase (Phase III) — Q1 Q2 Q3

Measurements and modeling

Map to Science & approach

FIELD OBSERVATIONS

Geomorphology and land-ocean fluxes characterization: freshwater discharge/volume transport (river, groundwater, surface runoff, coastal erosion fluxes, bathymetry — Q1 Q3

Ice/snow characterization: land fast and ice properties (thickness, temperature, area extent) — Q2 Q3

Water column characterization: water column physicochemical properties, sediment properties, circulation, hyperspectral UV-VIS-NIR optics, lidar-based profiling of optical properties. — Q1 Q2 Q3 — B C D E F

Biogeochemical/ecological processes: biogeochemical stocks and fluxes, transformation rates, primary production, assimilation/grazing, community respiration, aggregation/flocculation, photochemical and bacterial transformation of organic matter, plankton community structure, algal bloom development, development of hypoxia, acidification. — Q1 Q2 Q3

Meteorological/atmospheric measurements: clouds, precipitation, humidity, winds, temperature, aerosols, trace gases. — Q1 Q2 Q3

- A set of core measurements (Table 8.2) will be conducted across all sites), while non-core measurements will be conducted only at selected (Tier 1 and 2) sites

REMOTE SENSING

- Active and passive (moderate-high resolution UV-VIS-NIR) RS retrievals of ocean optical (e.g., Rrs, a, bb) biogeochemical (e.g., Chla, DOC) and physical (SST, wind, current vectors) properties; active and passive RS of atmospheric composition (for improved OC atmospheric correction) — Q1 Q2 — A B D E F
- RS of land characteristics (e.g., permafrost cover, vegetation cover, fire frequency in river basins) in collaboration with ABoVE — Q1
- RS determination of coastal ice and snow cover — Q2

MODELING

- Linked coupled hydrodynamic-photochemical biogeochemical ocean models to land processes (e.g., permafrost dynamics, watershed processes) — Q1 — A B C E F
- Link coupled coastal ocean biogeochemical models to sea ice models — Q2
- Link land-sea-ice models to ecosystem-based models — Q1 Q2
- Climate modeling — Q3

Requirements

Deployments

- Minimum requirements: 2-year measurements program (shipboard, ground-based and airborne platforms) at Tier 1 sites (2 complete annual cycles) and synoptic survey (one annual cycle), to assess seasonal and inter-annual variability.
- Optimum deployment: 2-year field observations at Tier 1 and Tier 2 sites, and synoptic survey (Tier 3 sites), extending the temporal domain of the campaign to 4 years

Platforms

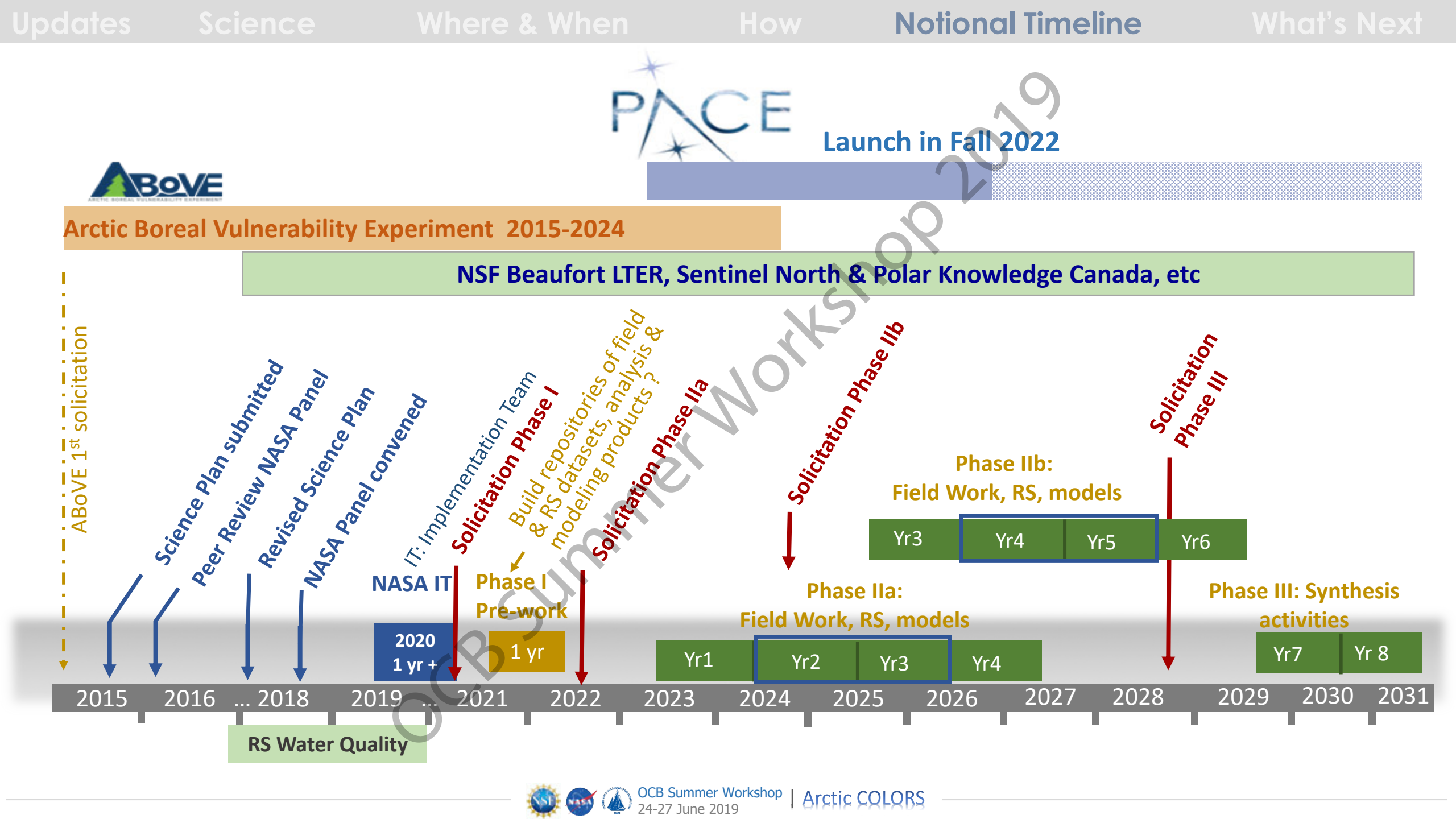
- 6-35 m length landing crafts and small RVs for in-shore and river work.
- 35-80m length coastal research vessels (RVs) with standard hydrographic equipment for coastal work (includes R/V Sikuliaq for light ice-breaking capability)
- Medium-to-large (75-130m length) ice reinforced RVs primarily for deeper shelf waters and during thick ice conditions.
- Buoys, moorings, and gliders
- Land towers for optical and atmospheric instrumentation.
- Small planes/UAV, helicopters, with seasonal deployments over study region
- Over-the-snow/all-terrain vehicles

Integration

- Integration of existing datasets and modeling tools into the project (Phase I)
- Integration across all disciplines, observational approaches and modeling efforts (Phase III)
- Integration with current and future campaigns in the Arctic (Phase I-III)
- Use modeling and remote sensing to scale up fluxes and processes in both temporal and spatial domains

Coordination/partnerships

- Collaboration with other federal and state agencies and regional and private programs
- Engagement of local communities throughout the life cycle of the project
- Leverage existing infrastructure (e.g., ABoVE)
- Partnerships with ongoing U.S. and international efforts in the Arctic (e.g., Polar Knowledge Canada, ArcticNET, and Sentinel North).
- Coordination with other programs addressing climate change and the human dimension in the Arctic.
- Open meetings to engage the community and encourage partnerships



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2019

2020

2021

Moving forward with refining the Arctic COLORS Implementation Plan/defining an Implementation Team
Details forthcoming.

- Critically read the Arctic COLORS science plan (online) and its finalized version (posted in ~Fall 19)
- Send comments to Arctic COLORS PIs (maria.a.tzortziou@nasa.gov)
- Talk about Arctic COLORS
- Generate great, NASA-fundable ideas focusing on the coastal Arctic
- Send letters of interest and/or support to program managers (after the Science plan is finalized)

NASA Programmatic questions & feedback

Dr. Paula Bontempi, Dr. Laura Lorenzoni, Dr. Jack Kaye / NASA HQ

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