Arctic COLORS: Coastal Land Ocean Interactions

M. TZORTZIOU, A. MANNINO, I. OVEREEM (AC-SDT Leads, on behalf of the AC Science Definition Team)

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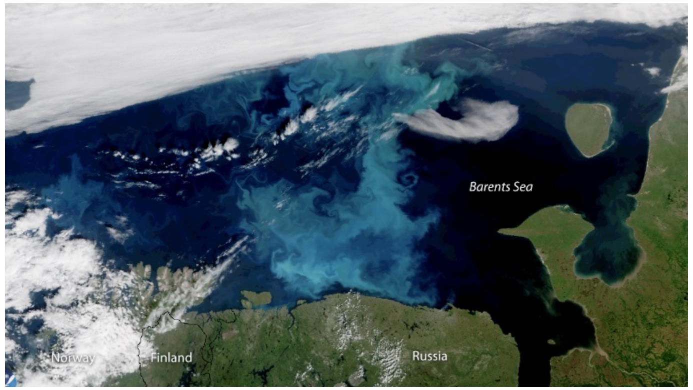
The Arctic coastal zone, a vulnerable and complex contiguous landscape of lakes, streams, wetlands, permafrost, rivers, lagoons, estuaries, and coastal seas—all modified by snow and ice—remains poorly understood.













NASA Arctic COLORS Field Campaign

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**”*

NASA OBB Program Scientist
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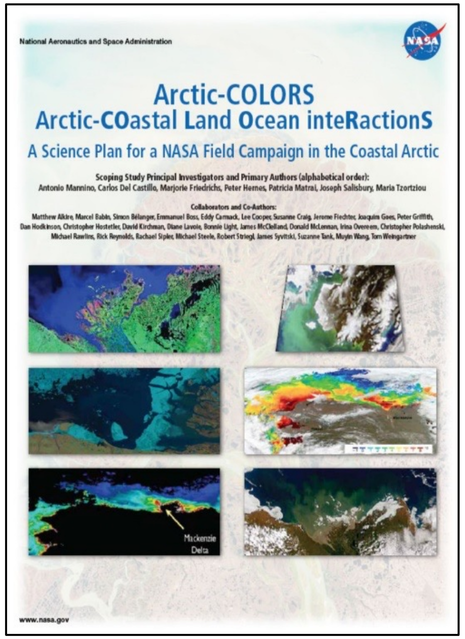
http://arctic-colors.gsfc.nasa.gov

NASA Arctic COLORS Field Campaign

Arctic COLORS has resulted in…

- a **Science Plan** developed by the broader community
- an **International Team of Collaborators**, to (i) identify high priority science and (ii) link to/leverage other field activities in the Arctic region
- a **Project Website** with information on Mission, Science, Team, News, Updates, Contact Information (http://arctic-colors.gsfc.nasa.gov)
- Phase I: Pre-Arctic COLORS field campaigns: currently
- **Implementation Team**: ~2022-2023
- **Phase II: Fieldwork**, starting after 2025

Science Plan



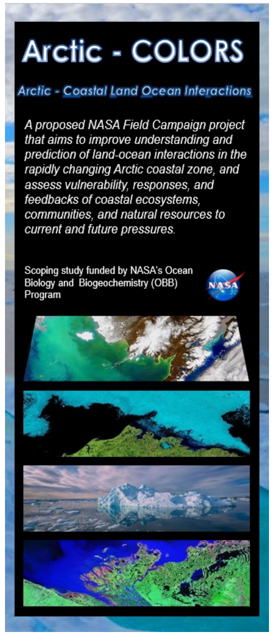
International Team of Collaborators

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	**Laura Lorenzoni**	NASA HQ
David Kirchman	U. Delaware	**Kelsey Bisson**	NASA HQ

Arctic COLORS Project Website

Outreach Materials



NASA Arctic COLORS Field Campaign

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

NASA Arctic COLORS Field Campaign

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**?




NASA Arctic COLORS Field Campaign

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

- 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?

NASA Arctic COLORS Field Campaign

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

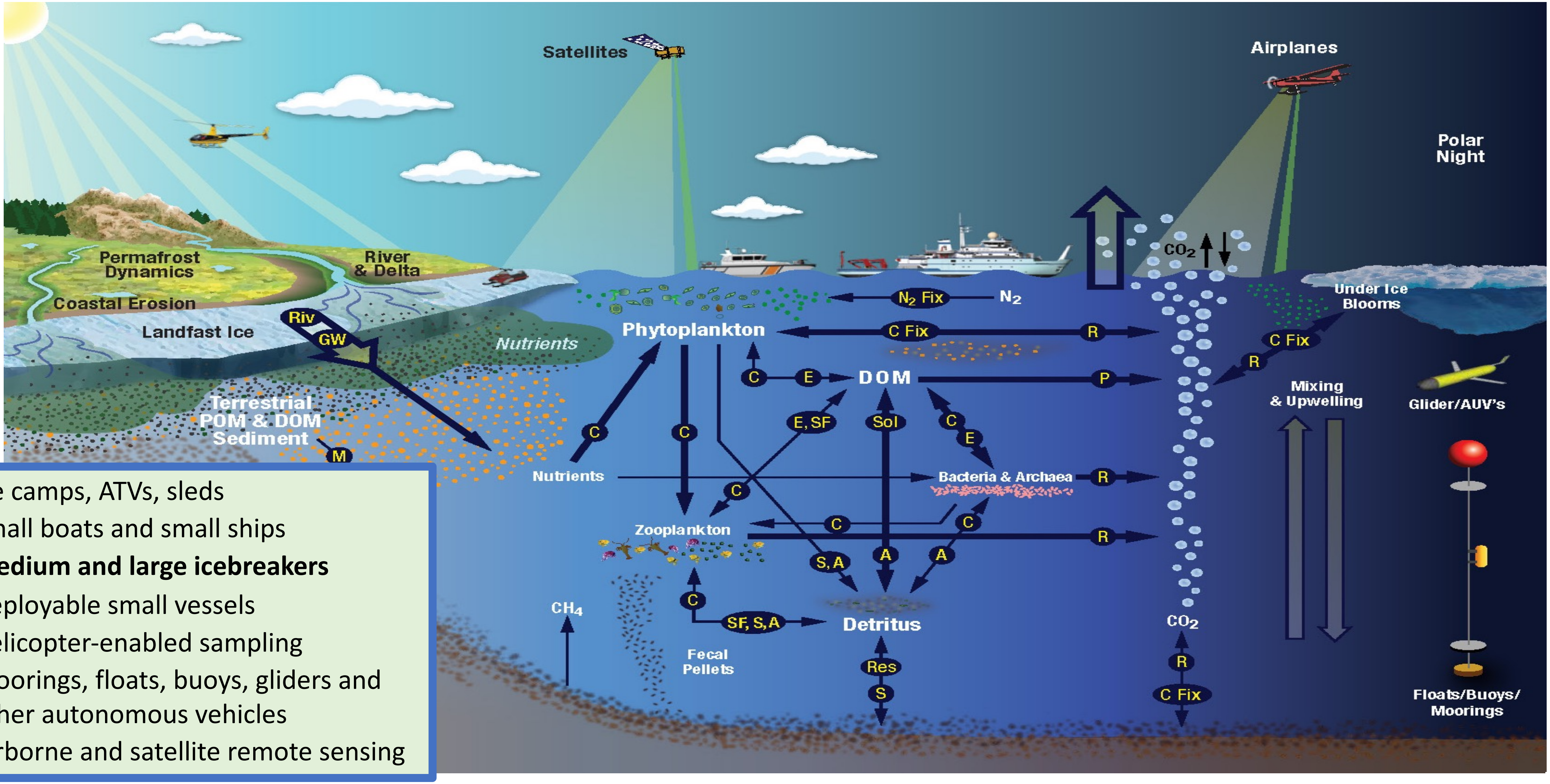
I. Effect of land on nearshore Arctic biogeochemistry

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?

NASA Arctic COLORS Field Campaign



- Ice camps, ATVs, sleds
- Small boats and small ships
- **Medium and large icebreakers**
- Deployable small vessels
- Helicopter-enabled sampling
- Moorings, floats, buoys, gliders and other autonomous vehicles
- Airborne and satellite remote sensing

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

NASA Arctic COLORS Field Campaign – Study Region

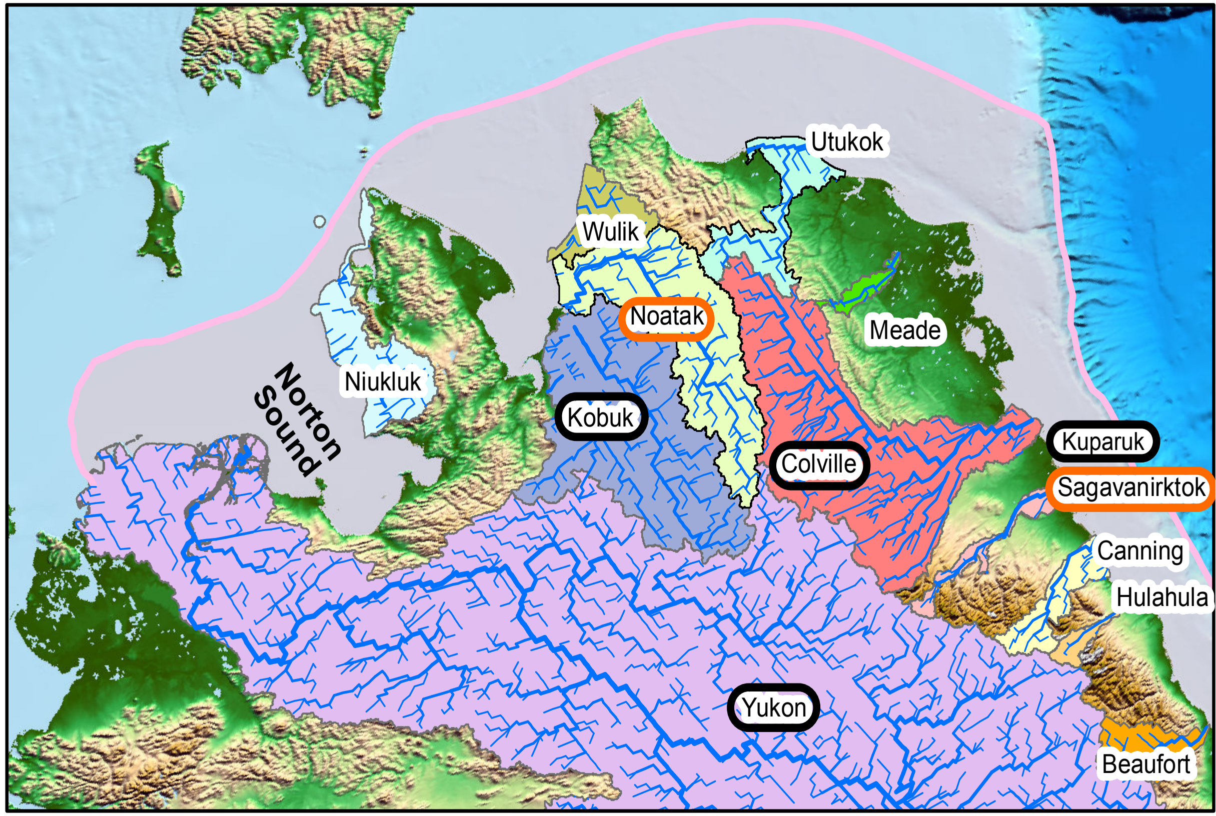
Combination of Intensive Studies and Synoptic Surveys

Intensive Studies

- Detailed **characterization of processes** and rates
- **Complete seasonality:** continuous year-round measurements with floats, buoys, moorings, AUVs, satellites

Synoptic Surveys

- Assess **spatial heterogeneity** across different shelf regions
- Evaluate **model simulations** across temporal and spatial scales
- **Scale up** using remote sensing observations



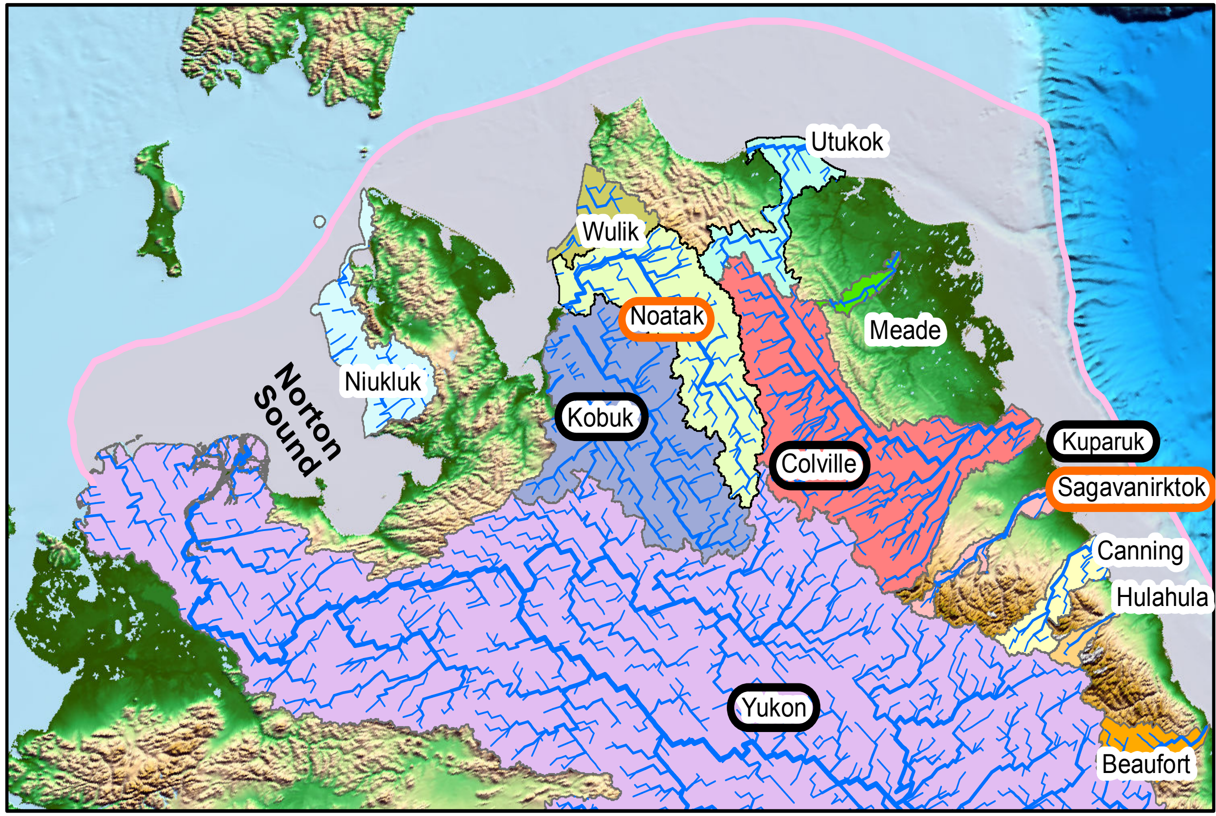
Black outline: Tier 1 sites (high priority); Orange outline: Tier 2 sites (medium priority)

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

NASA Arctic COLORS Field Campaign – Study Region

Need for & Use of Ice-breakers:

- Measurements in **offshore shelf waters**
- Measurements in **cross-shelf & along shelf transects**
- **Duration** of measurements: 30+ days
- **Berthing** for 15-25 scientists
- **Wet & Dry Lab** space
- **Ultrapure water** for lab measurements
- **Underway uncontaminated** seawater system
- Chemical fume hoods and laminar flow hood
- **Deck space** for experiments and deployment of RS sensors
- **Deployment** of CTD-rosette, in-water sensors/optical packages
- **Deployment & retrieval capabilities**: moorings, gliders, profilers, small boats, drones, helicopter
- **Underway measurements** (e.g., Temp, Sal, pH, DIC, pCO2)



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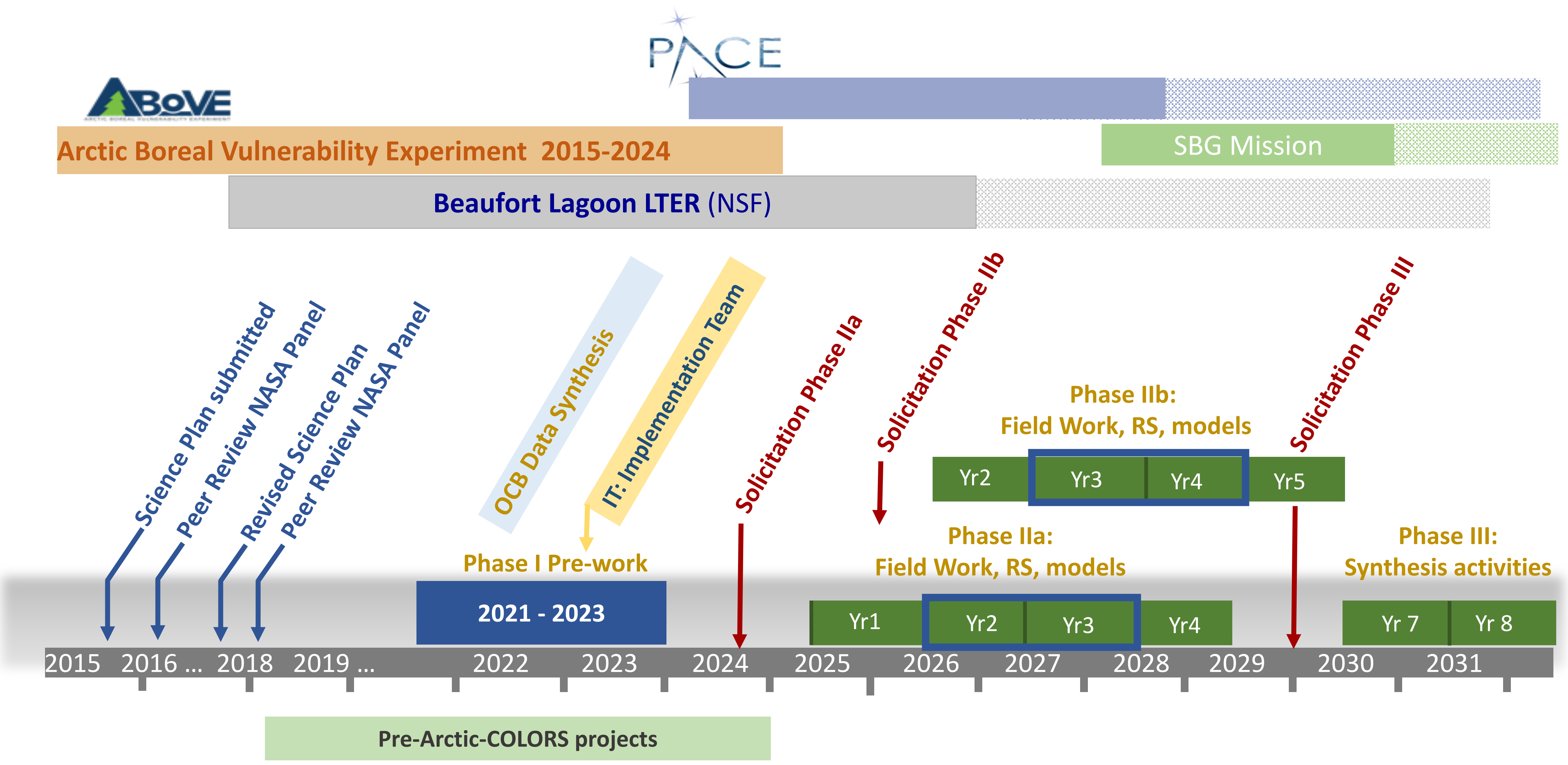
NASA Arctic COLORS Notional Timeline



NASA Arctic COLORS Field Campaign

Arctic COLORS Implementation Team - Selected in January 2023

*Charged with developing **detailed study designs for the Arctic-COLORS field campaign,** discussing and refining **implementation scenarios,** logistical and field sampling approaches.*

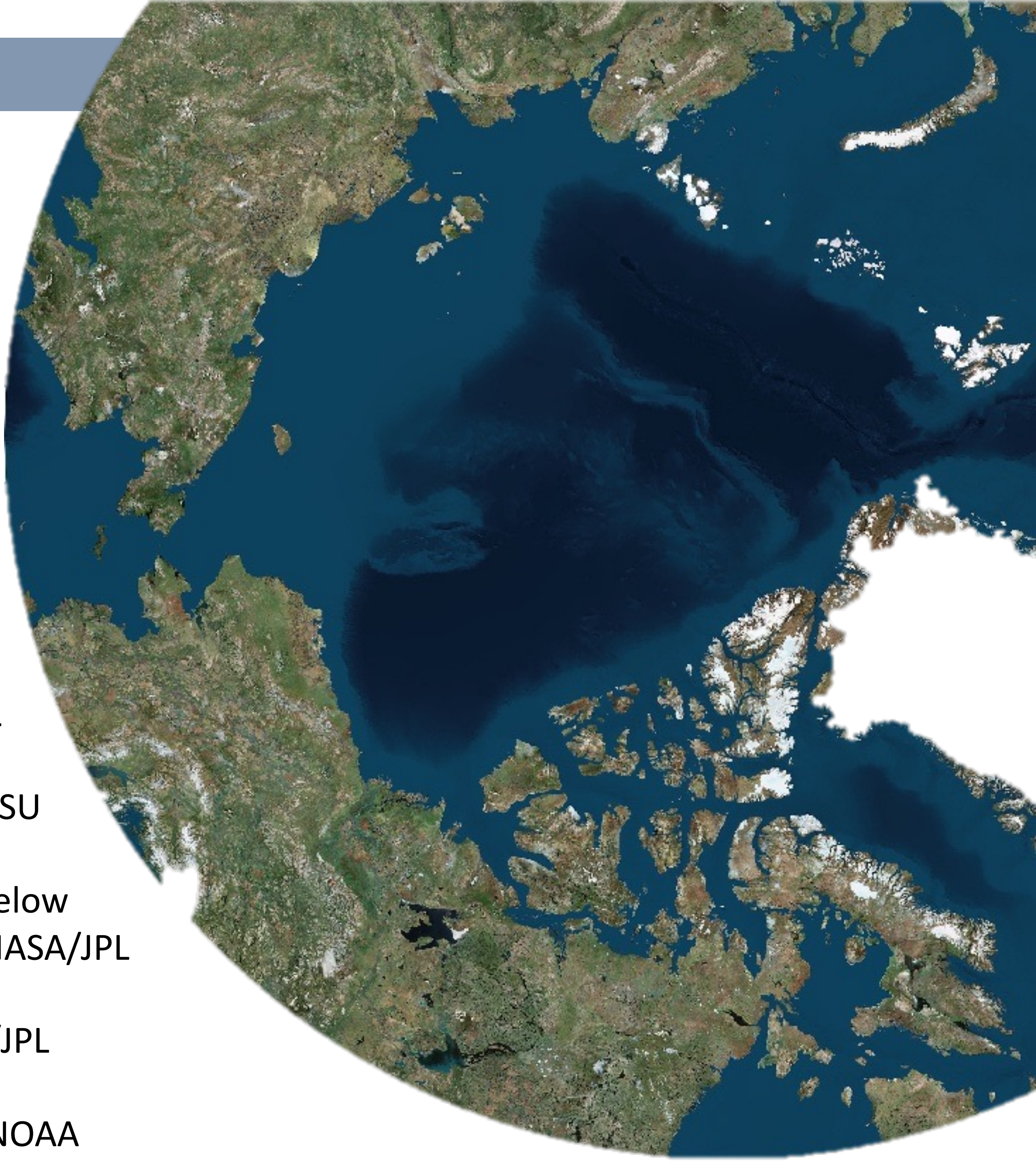
NASA HQs:

Laura Lorenzoni (OBB), Kelsey M. Bisson (OBB)

AC-SDT Members:

Maria Tzortziou, CCNY (Co-Lead)
Antonio Mannino, NASA/GSFC (Co-Lead)
Irina Overeem, UCB (Co-Lead)
David E. Butman, UW
Angela Bliss, NASA/GSFC
Atsushi Matsuoka, UNH
Wes Moses, NRL
Aimee Renee Neeley, NASA/GSFC
Craig M. Lee, UW

Trina Merrick, NRL
Juhls Bennet, AWI
Anne Kellerman, FSU
Karen Frey, ClarkU
Alex Michaud, Bigelow
Melissa Schwab, NASA/JPL
Rainer Amon, NSF
Chip Miller, NASA/JPL
Donald McLennan
Albert Hermann, NOAA



Additional Information

Arctic COLORS

Science Traceability Matrix

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)

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)

	Measurements and modeling	Map to Science	Map to approach
FIELD OBSERVATIONS	**Geomorphology and land-ocean fluxes characterization:** freshwater discharge/volume transport (river, groundwater, surface runoff, coastal erosion fluxes, bathymetry	Q1, Q3	B, C, D, E, F
	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	
	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

NASA Arctic COLORS Core Datasets

Table 8.2. Planned Arctic-COLORS Field Campaign Core and Non-Core Measurements

	Core Measurements	Non-Core Measurements
Aquatic Biogeochemical	Water column profiles of phytoplankton pigments, chlorophyll-a, POC/PN, DOC/DON, DIC, pCO_2, TA, nutrients (NO_3, NO_2, NH_4, PO_4, $SiOH_4$), DO, SPM,	Profiles of size fractionated chlorophyll-a and POC/PN, POP and DOP, calcium, phytoplankton C and N Biomarkers and isotopic tracers: Lignin phenols, black carbon, petroleum hydrocarbons, other lipid biomarkers, amino acids, stable CNS isotopes, radiocarbon isotopes, water oxygen isotopes
Aquatic optics	Hyperspectral above-water (UV-Vis-NIR-SWIR) and in-water (UV-Vis-NIR) AOPs (Kd, radiometry) Profiles and surface underway IOPs: hyperspectral absorption attenuation; multi-spectral VSF, backscatter, and beam attenuation; chlorophyll and CDOM fluorometry; particle size spectra. Discrete particle and CDOM absorption	Profiles and surface particle size spectra Discrete CDOM excitation-emission matrices; particle size spectra and abundances
Aquatic Biological/ Biogeochemical/ Physical rates and processes	Profiles of gross and net primary productivity and respiration, Air-sea CO_2 fluxes	Micro- and meso-zooplankton grazing Particle sinking rates Photooxidation of DOM and particles Profiles of net community production, microbial productivity Air-sea CH_4 fluxes POC/PN and DOC/DON remineralization rates Flocculation of DOM Nitrification, denitrification, nitrogen fixation, ammonification, ammonox
Biodiversity	Phytoplankton taxonomic abundances and functional type (size or taxonomic classification) Coastal and sea ice phytoplankton taxonomy	Microbial community composition Zooplankton to higher trophic levels Benthic microbial community, meiofauna, macrofauna, and megafauna
Physical oceanographic	SST, SSS, profiles of temperature, salinity, and density, wave height, horizontal current velocities, vertical current velocities	Wave height, horizontal current velocities, vertical current velocities
Landfast and Sea Ice	Biogeochemical constituents and physical properties of ice, brine water, and melt-water: salnity, chlorophyll-a, POC/PN, DOC/DON, DIC, pCO_2, TA, nutrients, SPM Ice thickness, temperature, areal extent, freeboard, other characteristics Under ice gross and net primary productivity Melt pond characteristics; above and in-water hyperspectral radiometry	Biogeochemical constituents and physical properties of ice, brine water, and melt-water: salinity, phytoplankton pigments, salinity, POP and DOP, black carbon, stable CNS isotopes, radiocarbon isotopes, oxygen isotopes Snow cover
Meteorological/ Atmospheric	Surface wind direction and velocity, temperature, humidity, pCO_2	Cloud cover, pressure, precipitation, albedo, surface heat flux, water vapor content, solar radiation Aerosol optical depth and vertical layer height and thickness Boundary layer CH_4 Total column ozone and NO_2 concentration
Sediment properties		SOC/SN, porewater DOC/DON, DIC, TA, pH, nutrients, DO, SPM, black carbon, lignin phenols, stable isotopes, seabed erodibility, acoustic scans of seabed to characterize sub-sea floor permafrost, etc.
Benthic rates and processes		Sedimentation and burial rates of SPM, POC/PN Oxygen respiration, denitrification, sulfate reduction, methanogenesis Sediment resuspension Benthic-pelagic fluxes
Hydrological		Freshwater discharge/ volume transport (river, groundwater, surface runoff)
Geomorphology		Coastal erosion fluxes of sediment load, POC/PN, IC, nutrients Bathymetry of channels at river head of tides
Airborne Remote Sensing	Hyperspectral radiometry (UV-Vis-NIR-SWIR) HSRL for in-water particle profiles, CDOM and chlorophyll absorption SST and SSS	HSRL melt pond depth, freeboard at ice edge, aerosol optical depth, aerosol type and microphysical properties Ranging lidar: coastal erosion, snow levels and permafrost.