# Arctic - COLORS

## *Arctic-Coastal Land Ocean Interactions*

***Arctic-COLORS** is A NASA OBB - Field Campaign Scoping Study that aims to improve understanding and prediction of responses of terrestrial fluxes, productivity, biodiversity and foodwebs in the rapidly changing Arctic coastal zone, and assess vulnerability, responses, and feedbacks of coastal ecosystems, communities, and natural resources to current and future pressures.*


Project PIs:

Antonio Mannino (NASA/GSFC)
Carlos Del Castillo, (NASA/GSFC)
Marjorie Friedrichs (VIMS)
Peter Hernes (UC Davis)
Patricia Matrai (Bigelow)
Joseph Salisbury (Univ. of NH)
Maria Tzortziou (CCNY / CUNY)


**http://arctic-colors.gsfc.nasa.gov**

# **Arctic-COLORS:** a **collective effort** by members of the broader science community

| Name | Institution | Expertise |
|---|---|---|
| Carlos Del Castillo, PI | NASA GSFC | Ocean optics; CDOM & DOC river fluxes; DOM biogeochemistry |
| Marjorie Friedrichs, PI | VIMS | Coupled physical-biogeochemical modeling; data assimiliation; remote sensing of primary productivity |
| Peter Hernes, PI | UC-Davis | River and coastal biogeochemistry, organic biomarkers, land-water interactions; CDOM photochemistry |
| Antonio Mannino, lead PI | NASA GSFC | Coastal C cycling; CDOM and DOM biogeochemistry, ocean color remote sensing; estuarine processes |
| Patricia Matrai, PI | Bigelow | Coastal DIC processes; land-ocean interactions; remote sensing |
| Joseph Salisbury, PI | UNH | Estuarine and coastal biogeochemistry, land/ocean/atmosphere interactions, remote sensing, optics |
| Maria Tzorziou, PI | UMD/ GSFC | Ocean optics; CDOM and DOM dynamics; remote sensing of ocean color; MALINA expedition in Beaufort Sea |
| Matthew Alkire | U. Wa | Ocean optics; on-going field activities in the Arctic |
| Marcel Babin | U. Laval | Arctic Ocean OM biogeochemistry; stable and radioisotopes; SBI PI |
| Simon Bélanger | UQAR, Canada | Coupled physical-biogeochemical modeling; Gulf of Alaska |
| Emmanuel Boss | U. Maine | Carbon cycle; ocean microbiology; ABoVE Program Chief Support Scientist |
| Eddy Carmack | Fisheries & Oce Canada | Mixed climate change impacts on PP & C fluxes in Canadian Arctic |
| Lee Cooper | UMCES/ CBL | Radiative transfer in ice & snow, optical & structural properties of Arctic sea ice |
| Susanne Craig | Dalhousie Univ | Arctic land-sea coupling/coastal ecosystem dynamics |
| Jerome Fiechter | UC Santa Cruz | Arctic rivers and sea ice |
| Joaquim Goes | Lamont-She | Arctic meteorology, climate variability; ABoVE SDT member |
| Peter Griffith | Sigma Space/ GSFC | Arctic freshwater export; physical oceanography |
| David Kirchman | U. Delaware | Ocean optics; ICESCAPE |
| Diane Lavoie | Fisheries & Oceans Canada | River carbon chemistry – Yukon; ABoVE SDT member |
| Bonnie Light | U. Washington | Rivers, deltas, estuaries, particle dynamics, sediment transport & stratigraphy |
| James McClelland | U. Texas | Ecology & Biogeochemistry at land-river-ocean interface in Canadian Arctic |
| Donald McLennan | CHARS | Climate and climate change in the Arctic; sea ice projections |
| Irina Overeem | U. Colorado | Coastal Arctic Ocean physical oceanography |
| Chris Polashenski | U.S. A Engine | Biological oceanography; ocean color remote sensing |
| Michael Rawlins | U. Mas | |
| Rick Reynolds | Scripps | |
| Michael Steele | U. Washington | |
| Dariusz Stramski | Scripps/ UCSD | |
| Robert Striegl | USGS | |
| James Syvitski | U. Colorado | |
| Suzanne Tank | U. Alberta | |
| Muyin Wang | U. Washington | |
| Tom Weingartner | U. Washington | |
| Paula Bontempi | NASA HQ | |

International team of Collaborators

Broader community involved in:

- Identify the high priority science questions
- Determine the study domain and research phases for the field campaign
- explore opportunities for linking to/leveraging other field activities in the Arctic region

**12 meetings so far (townhalls, special sessions) and two dedicated 2-day workshops where community & collaborators provided input**

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# Why Coastal Arctic?

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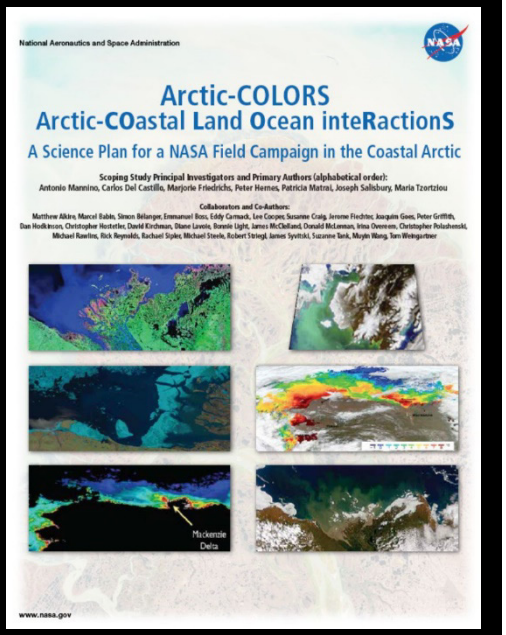
- Significant increase in summer SST over the past 50 years
  - Substantial reduction in sea ice coverage and ice season length.
- Increasing Primary Productivity and changing food web dynamics
- Permafrost is thawing
  - 1672 Pg of organic carbon stored in Arctic permafrost globally
- Coastal Erosion
  - 17-20 m/yr in most exposed Beaufort sites; 0.3 m/yr in Chukchi
- Ocean acidification of Arctic seas
- Consequences for Arctic wildlife and human populations

# *Scoping Study Timeline*




**2014**

Kick-off in January 2014

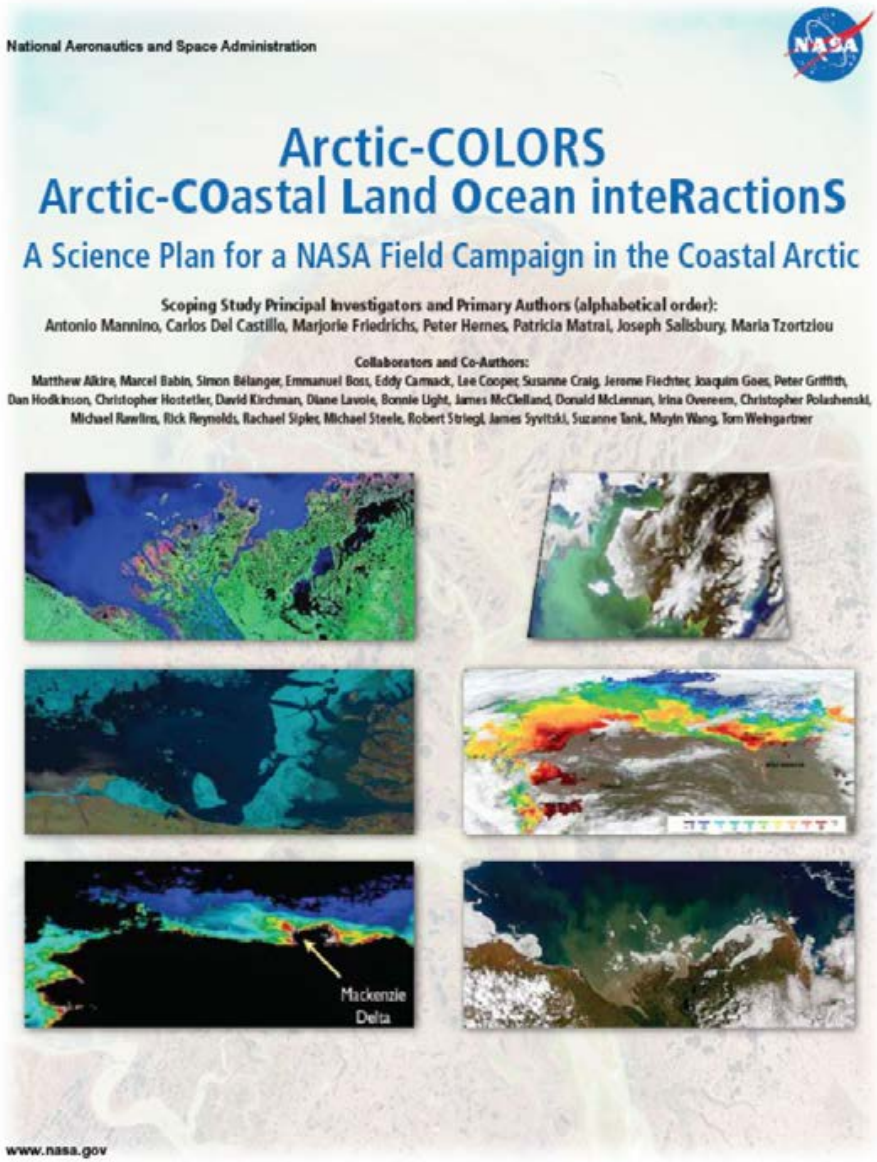
- 1st Team Workshop in June
- 2nd Team Workshop in November

**2015**

- Posted draft Science Plan in August for community comment
- Submitted the Science Plan to NASA on Sept. 30, 2015
- NASA posted the Science Plan for 30-day comment

**2016**

# Arctic-COLORS Science Plan




## Table of Contents: Arctic-COLORS Scoping Study Report

# Overarching Science Goal

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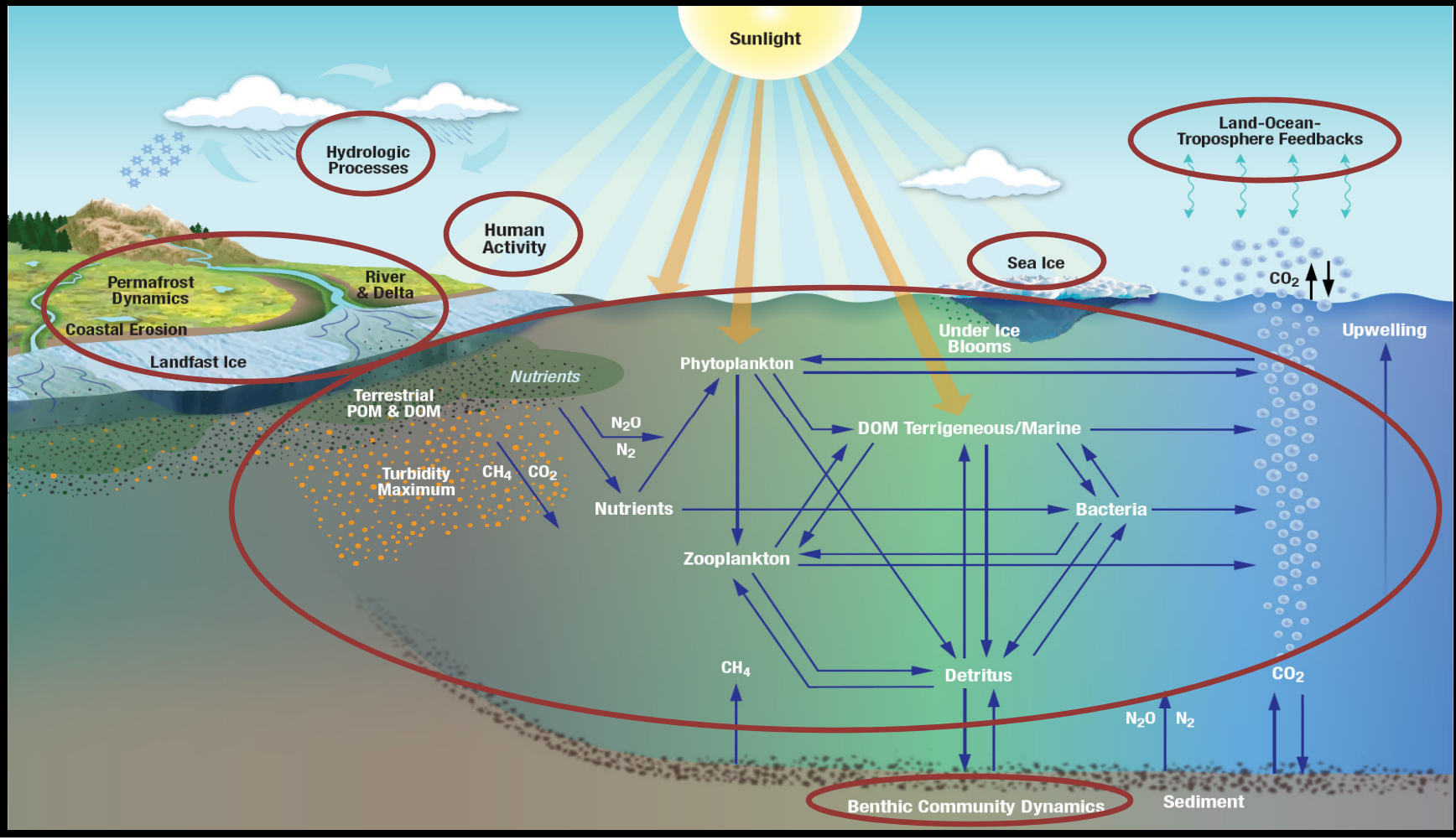
to determine present and future impacts of terrigenous, atmospheric and oceanic fluxes on ecology, biogeochemistry and ecosystem services of the Arctic coastal zone in the context of environmental (short-term) and climate (long-term) changes in the Arctic.



## *Proposed Top-Level Science Questions*

1. How and where are materials from the land, atmosphere, and ocean transformed within the land-ocean continuum of the Arctic coastal zone?
2. How does thawing of Arctic permafrost—either directly through coastal erosion or indirectly through changing freshwater loads from upstream thaw—translate to changes in coastal ecology and biogeochemistry?
3. How do changes in snow/ice conditions and coastal circulation influence Arctic coastal ecology and biogeochemistry?
4. How do changes in fluxes of materials, heat, and buoyancy from the land, atmosphere, and ocean influence Arctic coastal ecology and biogeochemistry?
5. How do changing environmental (short-term) and climate (long-term) conditions alter the Arctic coastal zone's availability and use of ecosystem services?

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# Core Study Domain

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From the head of tidal influence to the coastal shelf


**Extended Domain**

*Victoria and Banks Islands in the Canadian Archipelago -*
*POLAR Knowledge*
(CHARS: Canadian High Arctic Research Station)

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# Core Study Domain

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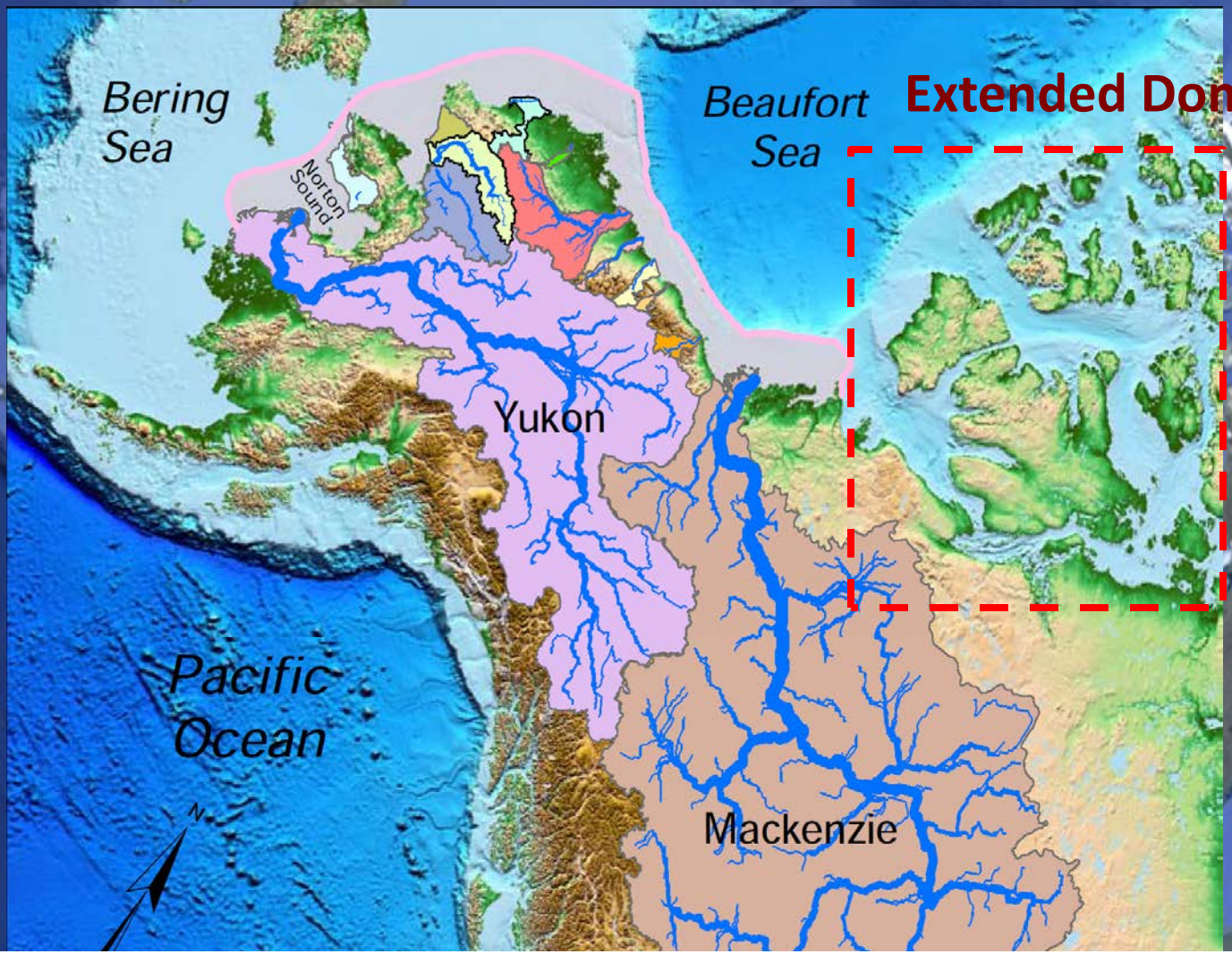
Large globally important rivers, regionally important rivers including smaller tundra rivers, coastal lagoons, erosional bluffs

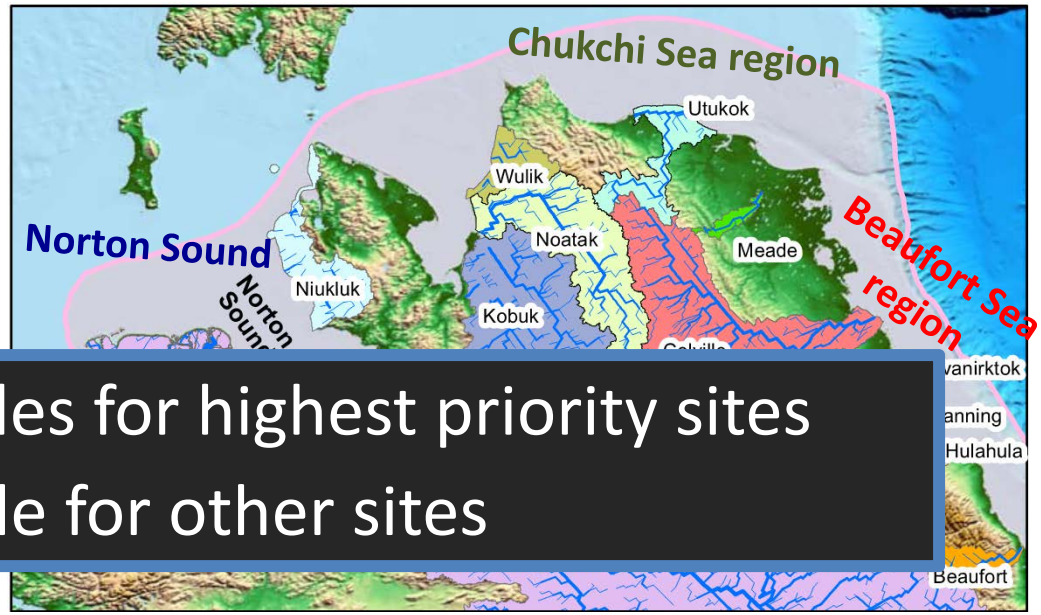


# Field Activities - 1



## Process Studies

- Intensive sampling & experiments from river mouths to mid-shelf for small and large rivers plus coastal erosion sites (lagoons and bluffs).
- **Contrasts:**
  - Particle, sediment, C, nutrient and CDOM loads
  - Timing of peak river discharge
  - Timing of landfast and sea-ice breakup and freeze-up




- Two complete annual cycles for highest priority sites
- One complete annual cycle for other sites

- **Complete seasonality**
  - Continuous measurements with floats, buoys, moorings, AUVs, satellites, …
  - Intensive process studies during key months (plus airborne remote sensing)

| Early March | May-June | July | September | October |
|---|---|---|---|---|
| • End of winter condition | • Peak river discharge<br>• Ice breakup<br>• Under ice blooms | • Under ice blooms<br>• Increasing biological & photochemical activity | • Max open water/min sea ice<br>• Low river discharge<br>• Pre-conditioning of systems prior to winter | • Freeze-up period |

# Field Activities - 2



## Survey Studies

- Assess spatial heterogeneity in physical, biological, and biogeochemical state of different shelf regions
- Determine interactions/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
  - develop and evaluate RS algorithms across a range of

- Surveys conducted during each year of field program
- Utilize ships of opportunity when and where possible

| July-August | September-October |
|---|---|
| • Increasing biological & photochemical activity | • Max open water/min sea ice<br>• Low river discharge<br>• Pre-conditioning of systems prior to winter |

# Integrative Observational Approach

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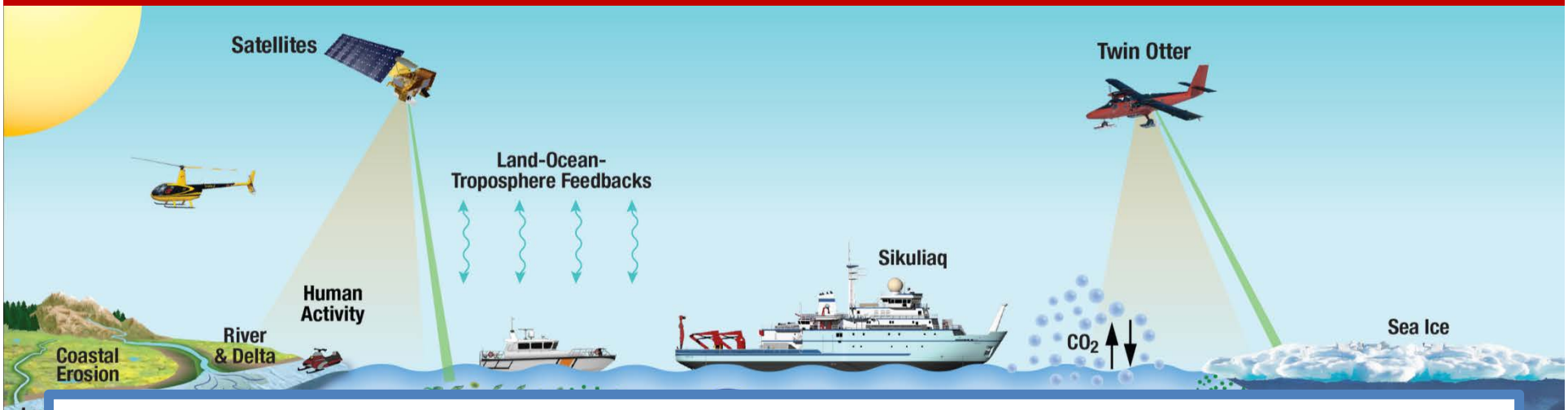


- **Not a traditional oceanographic campaign with a few major cruises**
- Diverse array of measurement approaches proven to be effective in the Arctic for **year-round measurements and sampling**
  - Ice camps, ATVs, sleds (lower river, delta, landfast ice regions)
  - Small boats and small ships (lower river to nearshore seas)
  - 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

Benthic Community Dynamics

Float

# Models

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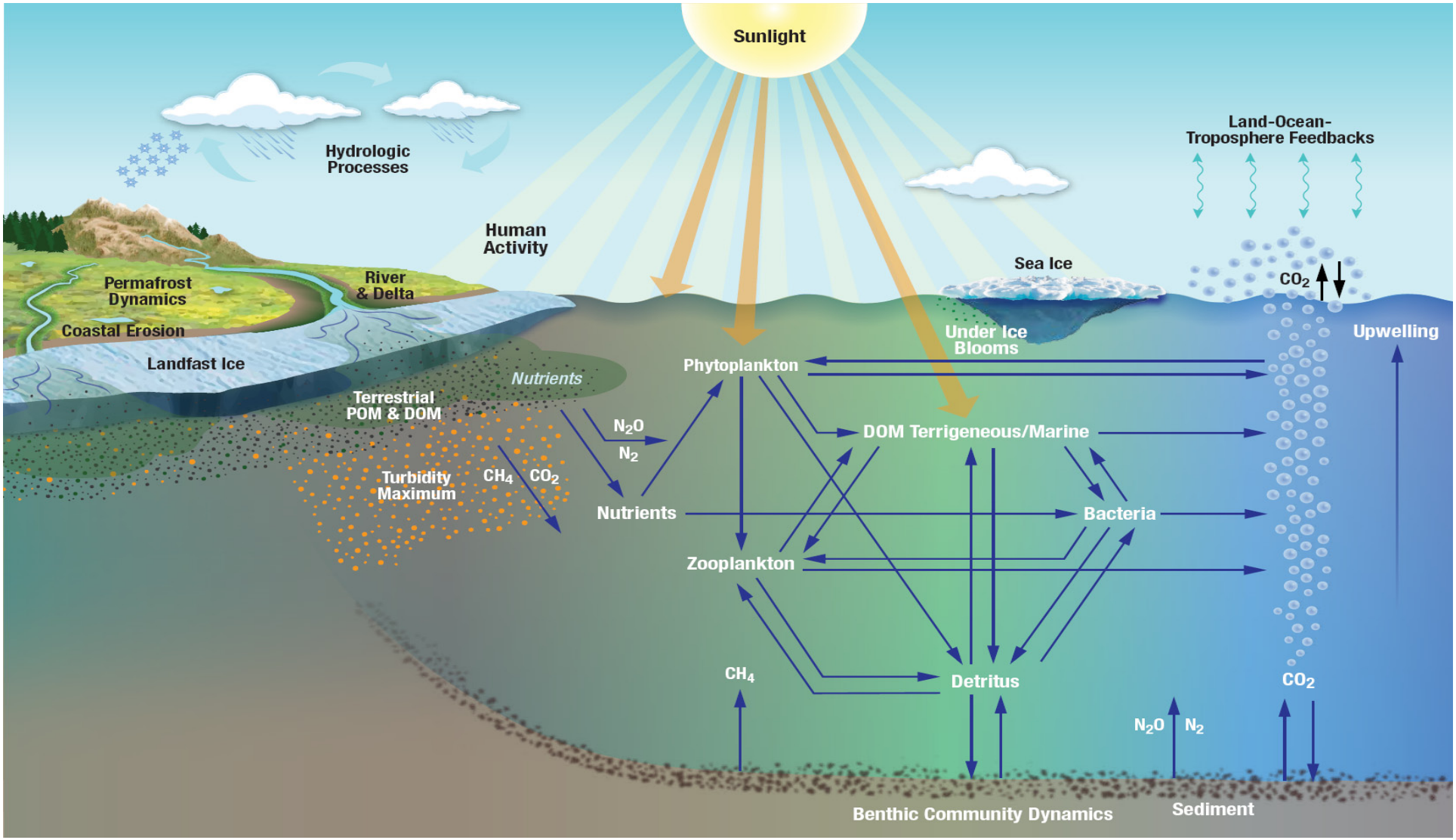
Field studies and measurements planned in coordination with modelers to ensure that uncertainties in model parameters are resolved



# Leveraging from ABoVE

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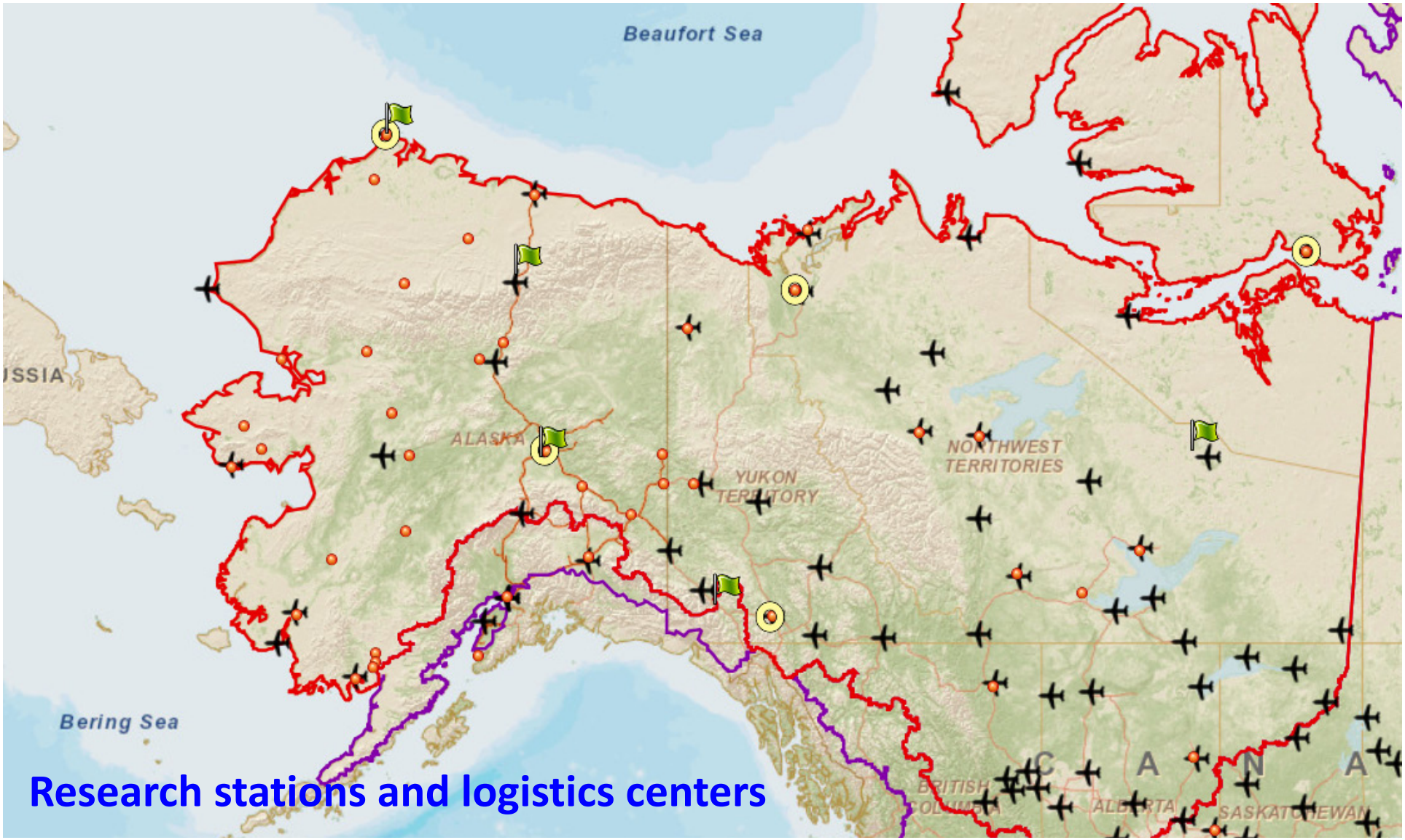
**Terrestrial end-member: The Arctic-Boreal Vulnerability Experiment,** a field campaign by NASA's Terrestrial Ecology Program (2015-2024)



# Notional Timeline

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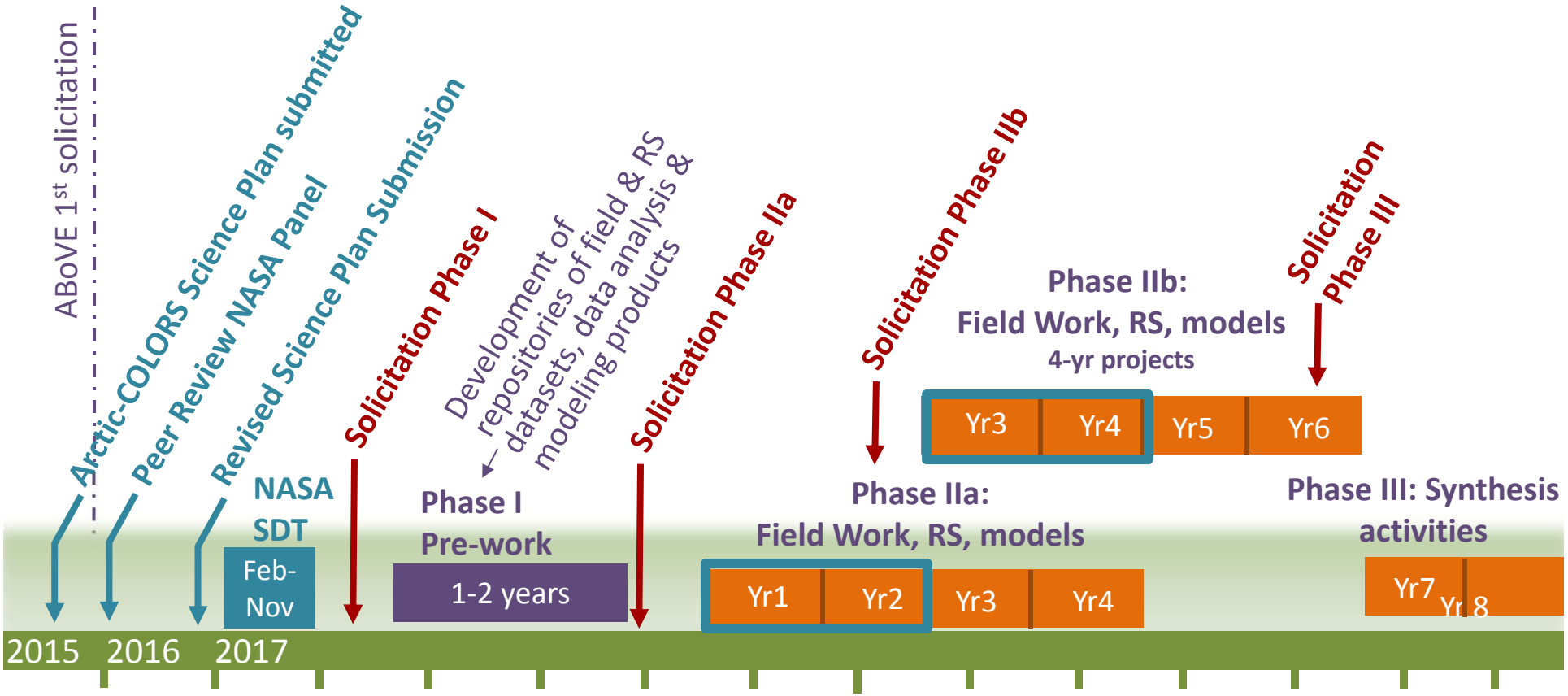
PACE
**Launch in ~Aug. 2022**

ABoVE
Arctic Boreal Vulnerability Experiment

**Arctic Boreal Vulnerability Experiment 2016-2024**

**Sentinel North** (U. Laval, Canada) ~2017-2023



# Notional Budget

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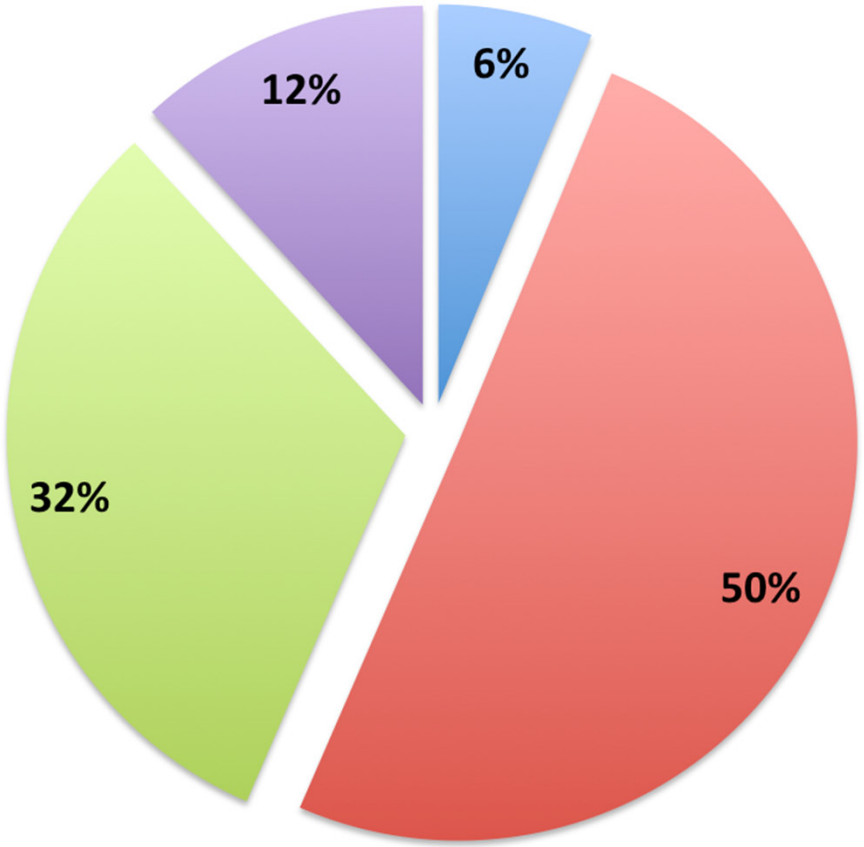
## Total Cost Estimate - ~$80M



# Urgency?



'New normal' (Jeffries et al., 2013): Biophysical changes in the Pacific Arctic region becoming extreme compared to the recent past

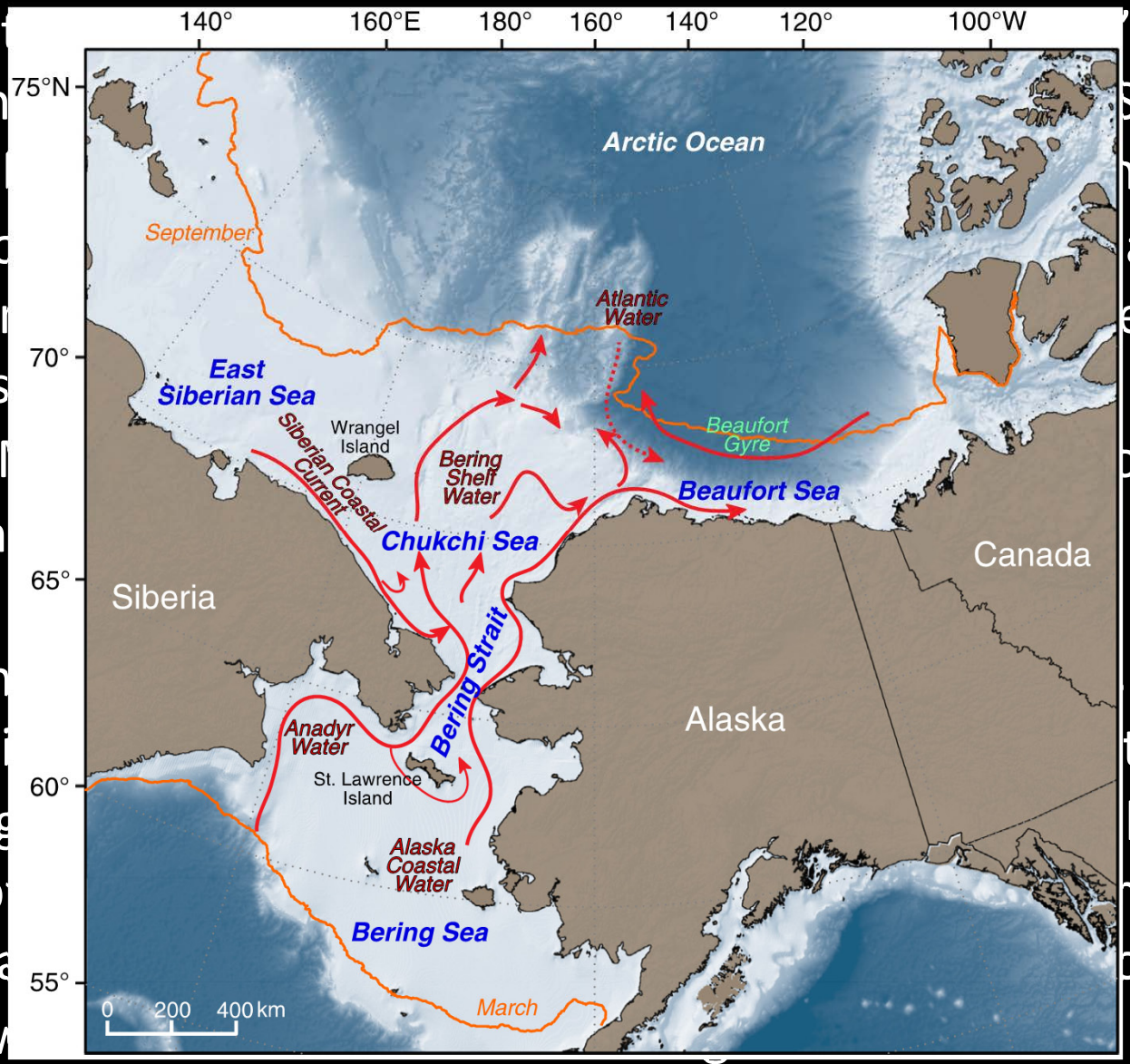
- Sea ice loss during summer (50% by area; 75% by volume)
  - Light penetration has increased
    - Higher NPP (1998-2012) esp. within interior shelves (Beaufort and East Siberian; less in Chukchi)
    - Surface sea layer experiencing more warming
      - Delays fall freeze-up; Accelerates sea-ice retreat
- >50% increase in mean transport across Bering Strait (2001-2011)
- Multi-year ice almost entirely disappeared
  - Recent strong easterly winds in Eastern Beaufort result in advection of warm, fresh water from Mackenzie River plume.
- Arctic ecosystems shifting from benthic- to pelagic-dominated

- *Synthesis of Arctic Research (SOAR) in marine ecosystems of the Pacific Arctic Progress in Oceanography 136; Moore & Stabeno 2015; Arrigo et al. 2015; Frey et al. 2015; Wood et al. 2015*
- *Bélanger et al. 2012*

# Why coastal domain?



- Riverine coastal domain hypothesis (Carmack et al. 2015)
  - Cont… flowing alon… Sea and to the … …hena)
  - Yuko… …al pulses of warr… …eaufort seas…
    - M… …organisms.
- Macken… …past decade…
- Sagavan… …increased suggesti… …the past.
- Thawing… …l undoub… …nts, organic matter a… …oastal seas.
- Not as w…




*Carmack et al. 2015; Moore & Stabeno 2015; Wood et al. 2015*

# Why NASA?



- Remo… esser… Arcti… the
  - N… S

| Sensor | Ocean Color Data Time Series | Spatial Resolution at nadir | Ocean Color Spectral Bands (nm) | Global Coverage | Agency |
|---|---|---|---|---|---|
| **SeaWiFS** | 9/1997 to 12/2010 | ~1 x 1 km | 412, 443, 490, 510, 555, 670, 765 | 2-day | NASA/Geo Eye |
| **MODIS-Aqua** | 6/2002 to present | ~1 x 1 km | 412, 443, 469, 488, 531, 547, 555, 645, 667, 678, 748 | 2-day | NASA |
| **MODIS-Terra** | 2/2000 to present | 1 x 1 km | 412, 443, 469, 488, 531, 547, 555, 645, 667, 678, 748 | 2-day | NASA |
| **MERIS** | 6/2002 to 4/2012 | 300 x 300 m | 412, 443, 490, 510, 560, 620, 665, 681, 709 | 2-3 day | ESA |
| **VIIRS on Suomi NPP** | ~2/2012 to present | 750 x 750 m across full swath | 410, 443, 486, 551, 671 | Twice/day | NOAA/NASA |
| **OLI** | 3/2013 to present | 30 x 30 m | 443, 482, 561, 655 | ~16 days; ~5 days at ~73oN | NASA/USGS |
| **OLCI** | Launch 2015 | 300 x 300 m | 400, 412.5, 442.5, 490, 510, 560, 620, 665, 681, 709, 754 | 2-3 days | ESA |
| **MSI** | 6/2015 to present (Sentinel 2A)<br><br>Launch mid-2016 (Sentinel 2B) | 10 to 60 m | 443, 490, 560, 665, 705, 740, 783 | ~10 days per sensor | ESA |
| **SGLI** | Launch Dec. 2016 | 250 x 250 m | 380, 412, 443, 490, 530, 565, 670, 763 | 2-day | JAXA |
| **PACE OCI** | Notional launch March 2022 | ~1 x 1 km or better | Hyperspectral 350-800 | 2-day | NASA |

Remote sensing observations from a range of platforms (airborne, space-based)

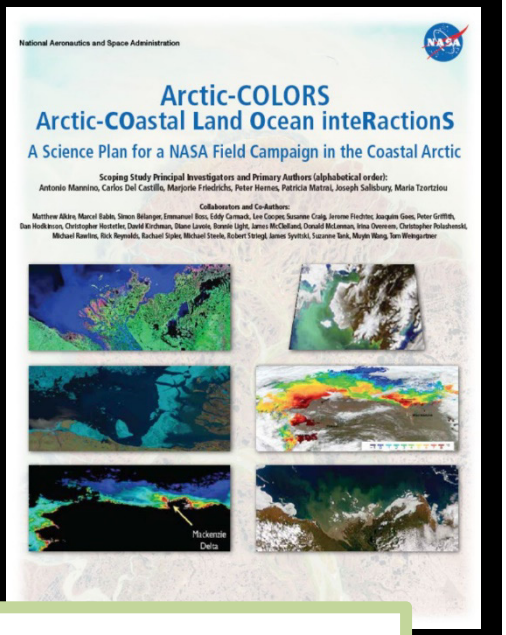
~30 years of Ocean Color Data from 1997 to the conclusion of Arctic-COLORS

# Why NASA?



- Remote sensing (RS) from satellite and airborne platforms are essential for capturing the spatial and temporal variability of the Arctic coastal study domain (past and present).
  - NASA has the satellites, airplanes, airborne sensors and RS data processing and distribution capability to enable A-C.
- The development/parameterization and robustness of models necessary to address the goals of A-C will be accelerated with NASA remote sensing observations.
- Synergies with ABoVE and other NASA field campaign and modeling programs
- NASA coordinated activities in collaboration with programs and scientists in Canada can make significant progress on A-C goals.
- A more complete understanding of the Pacific Arctic coastal zone is possible with complementary efforts supported by NSF, NOAA, BOEM, USGS, North Pacific Research Board, DOE, etc.

# *Scoping Study Timeline*




**2014** Kick-off in January 2014

- 1st Team Workshop in June
- 2nd Team Workshop in November

**2015**

**Panel Comment:** "An Arctic coastal experiment represents an important and timely opportunity for [NASA] because of the rapidly changing Arctic Environment."

**201**

**Panel Conclusion:** Arctic-COLORS is of potential high merit, but needs further study/planning to resolve science or other issues.

- Planning to submit Revised Science Plan by December 2016

# Panel Recommendations

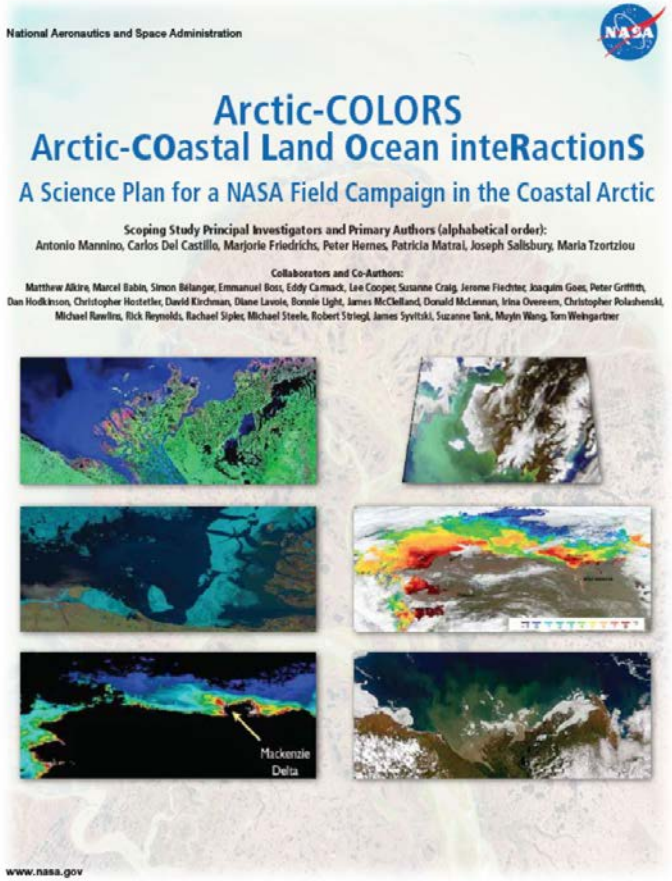


- More **specificity in overarching aim and science questions**
  - Fundamental Ecosystem Processes or Carbon Budgets?
  - Top level questions need more focus
- Identify **most important ecological problems or biogeochemical processes** and what measurements needed
- **Stronger linkage to past and on-going work** in the Arctic
- More detail on how particular **risks** will impact the ability to address specific science questions.
  - Expand on synergies with other programs that would mitigate risk
- More traceable Science Traceability Matrix (STM)
  - Modular structure to clarify risks and **de-scoping options**

# What's Next



- Solicit input from the community on overarching science aim and science questions, processes, domain, etc.
  - Conduct an open community workshop
- Revise the Science Plan and submit to NASA by Dec 2016
- NASA HQ will conduct a programmatic review
- NASA solicits SDT to develop the implementation plan



# Focusing Science Goal & Questions

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REVISED Overarching Science Goal:
to quantify the biogeochemical response of the Arctic nearshore ecosystem to rapidly changing terrestrial fluxes and ice conditions.

1. **Must establish a baseline (past & present)**
2. **Study and predict changes into the future**

**Open Community Workshop at WHOI on July 28-29**
following OCB Workshop

# Science Themes

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***Hypothesis – It is not too late to establish a baseline for characterizing biological and biogeochemical conditions in the nearshore Arctic.***

1. Effect of Land on Sea (rivers, thawing permafrost, coastal erosion)

2. Effect of Ice on Sea (snow, landfast ice, sea ice)

3. Effects of future warming land on sea and future melting ice on Sea – seasonal and interannual first, and then future scenarios/predictions

# Science Questions

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## 1. Effect of Land on the Sea

- How does variability in riverine fluxes affect biogeochemical transformations in the nearshore zone?

- How do freshwater carbon, nutrient and sediment loadings to the coastal zone change as a result of permafrost thawing within the watershed?

- How do freshwater carbon, nutrient and sediment loadings to the coastal zone change as a result of coastal erosion?

- Is the relative magnitude of inputs from rivers, thawing permafrost and coastal erosion changing across the coastal Arctic seasonally and interannually?

# Science Questions

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## 2. Effect of Ice on the Sea

- How does the coastal snow and ice cover impact nearshore net ecosystem productivity by controlling rates of transport/mixing and by modulating light availability?

- What controls do ice/snow conditions impose on terrestrial fluxes into the nearshore environment?

- Seasonality: How does the timing of sea ice formation/retreat, length of sea ice cover and ablation, snow accumulation, and the morphology of the coastal ice zone influence coastal ecology and biogeochemistry?

# Science Questions

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3. Effects of future warming land on sea and future melting ice on the Sea

- What is the future biogeochemical response of the Arctic nearshore ecosystem to rapidly changing riverine inputs, permafrost and coastal erosion?

- What is the future biogeochemical response of the Arctic nearshore ecosystem to rapidly changing sea-ice, land-fast ice and snow?

- How would net ecosystem productivity in the Arctic nearshore environment respond to changing scenarios of terrestrial fluxes and ice conditions?

*Those who live in, work and engage with the Arctic have the most at stake in a rapidly changing environmental context*

*Their input will be sought early in the research planning to inform and refine critical research targets, during field program, and later to ensure findings are communicated effectively.*


Contact us: arctic-colors@lists.nasa.gov

Programmatic Questions: paula.bontempi@nasa.gov; 202-358-1508

# BACKUP

Please, provide feedback:
arctic-colors@lists.nasa.gov

**http://arctic-colors.gsfc.nasa.gov**


Programmatic Questions: paula.bontempi@nasa.gov; 202-358-1508

# Notional Timeline from Report

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