Defining human-relevant Arctic extremes

Lessons from the field & the need for integrative climate indices (climate models as tools for societally relevant science)

Laura Landrum (CGD) &
Rachel McCrary (RAL)

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Extremes

”Extreme conditions” may or may not be geophysical “extremes”

Humans experience climate change

- Extreme events
- Chronic exposure to extremes (e.g. multiple hurricane events – migration)
- Chronic exposure to new conditions (e.g. new “hydroclimate” that is different than historically, impacting agriculture)
- Compounding conditions (e.g. increase in storms in addition to increasing sea levels compound risk to coastal flooding)

How can climate models provide useful information on these?

Reframe and define climate indices?

How can we quantify, test and validate these?

"in the field"
Two primary National Science Foundation projects/programs

Study of Environmental Arctic Change (SEARCH)

Navigating the New Arctic
("Current and future Arctic community vulnerabilities to sea -ice change and economic expansion" strategic planning award; work with the NNA community office; mentoring REU students)

- Meetings & workshops in person and remotely, scientists, policy makers, community members
- community visits (NW AK – Nome, Teller, Kotzebue)

Human-relevant “extremes”: examples from the Arctic

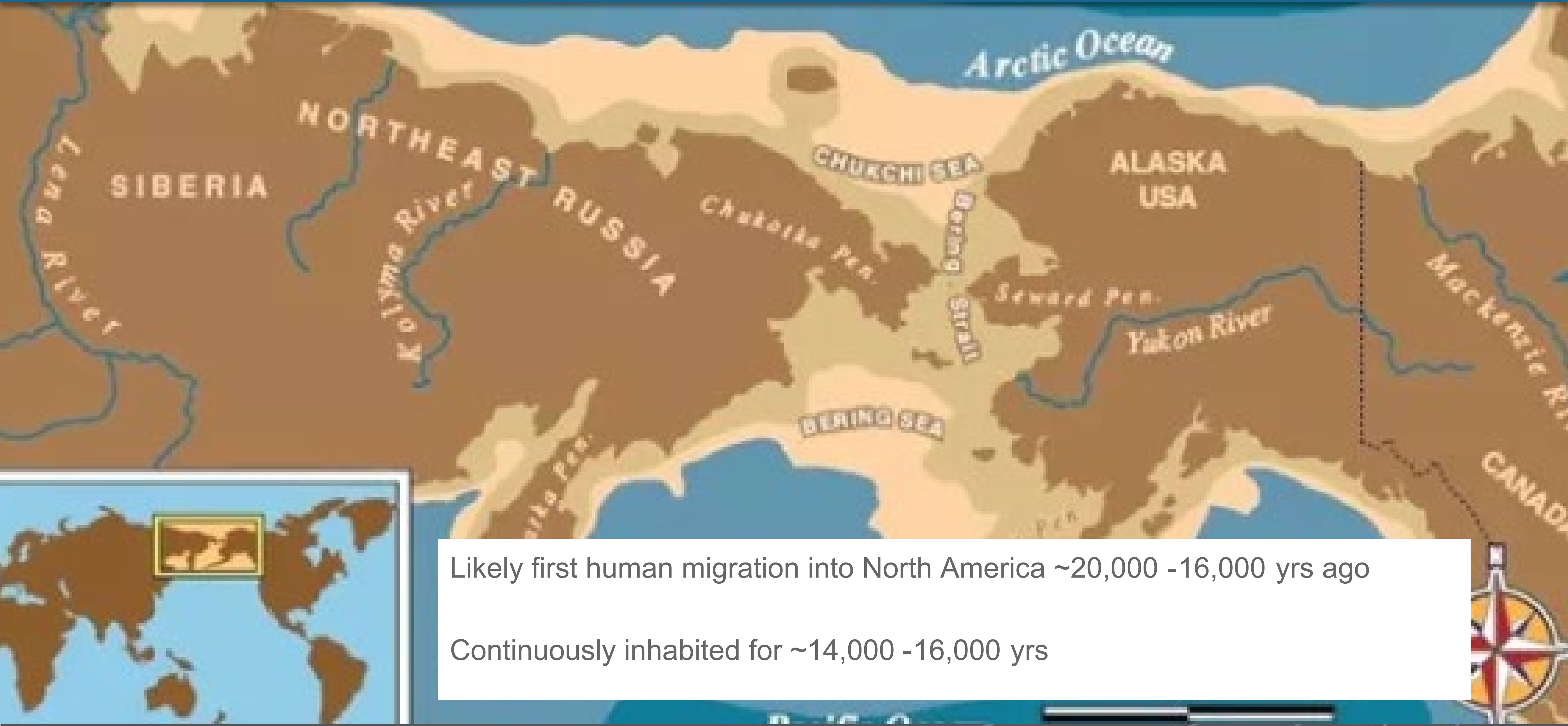
1. Setting the stage: Beringia

2. Examples
   - **Extreme changes and subsistence harvest:**
     St Lawrence Island: Walrus; Kotzebue: Bearded Seals
   - **Extreme (and non-extreme!) events compounded by extreme changes:**
     coastal erosion, Typhon Merbock
   - **Cascades, tipping points**
     marine ecosystems, hazardous algal blooms, Bering & Chukchi Seas

3. Climate indices, metrics, ideas from other disciplines

4. Summary/discussion

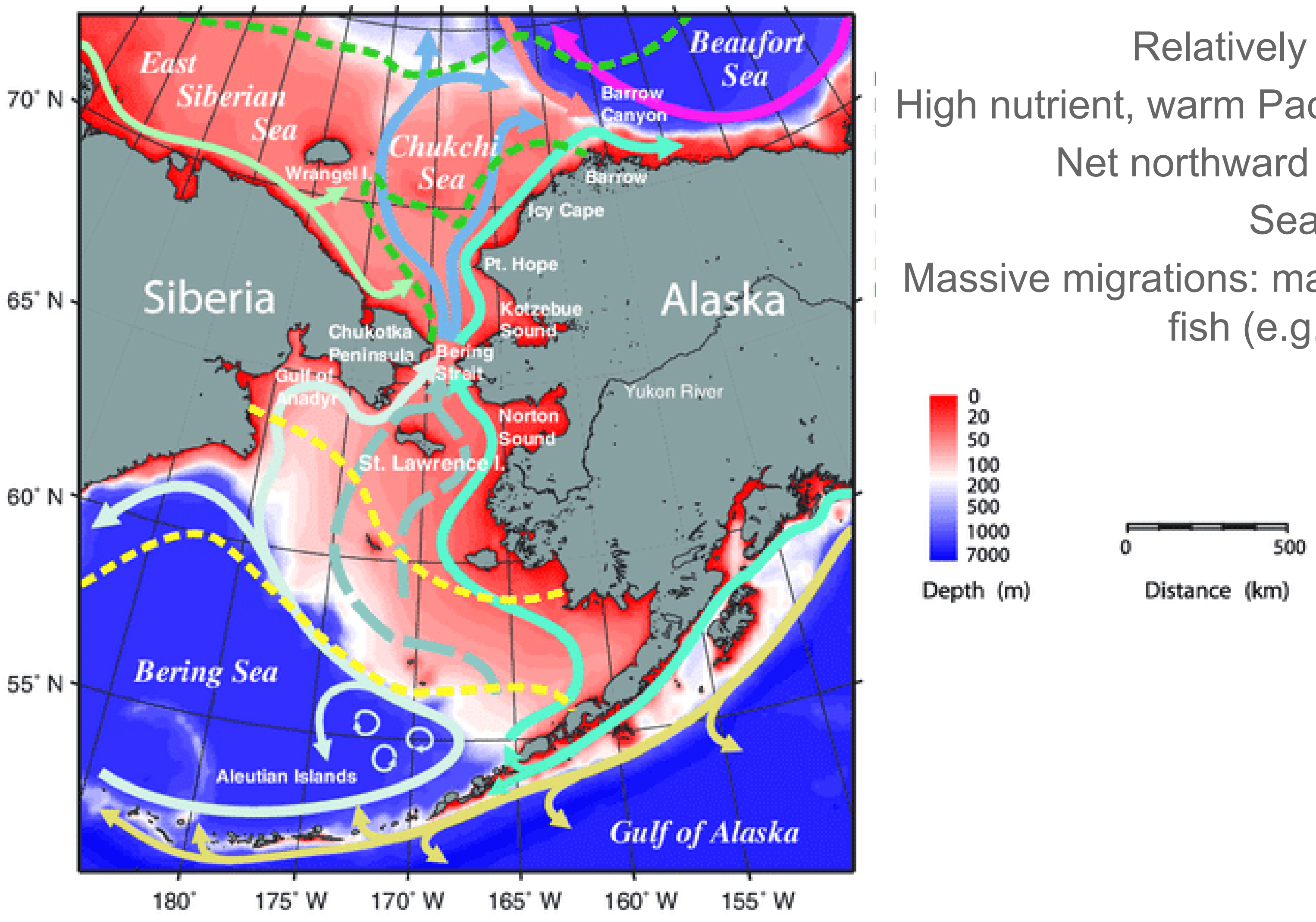
BERINGIA



Likely first human migration into North America ~20,000 -16,000 yrs ago

Continuously inhabited for ~14,000 -16,000 yrs

BERINGIA



Relatively shallow (continental shelf)

High nutrient, warm Pacific water entrance to the Arctic ocean

Net northward flow through the Bering Strait

Seasonal sea ice cover

Massive migrations: marine mammals (whales, seals, walrus), fish (e.g. salmon), caribou, birds

Setting the stage: coastal AK communities Bering Sea -Chukchi Sea

Outside goods and services available only via plane or boat (seasonal) NO ROADS
Most food is traditional (hunting, gathering)
Supplemented by grocery stores
Very expensive

Most harvesting occurs with motorized vehicles (boats, snowmachines – "snowmachine era" started and "dog sled" era ended in 1960s)
Fuel is very expensive

Larger and $-resource wealthy communities have running water

Food preservation and storage also critical for survival
Shore fast ice critical for food processing (e.g. seals – need 10 days of shore fast ice to properly dry & cure at cold temperatures before storing)
Long term food storage – ice cellars (permafrost, sea ice, snow – components)

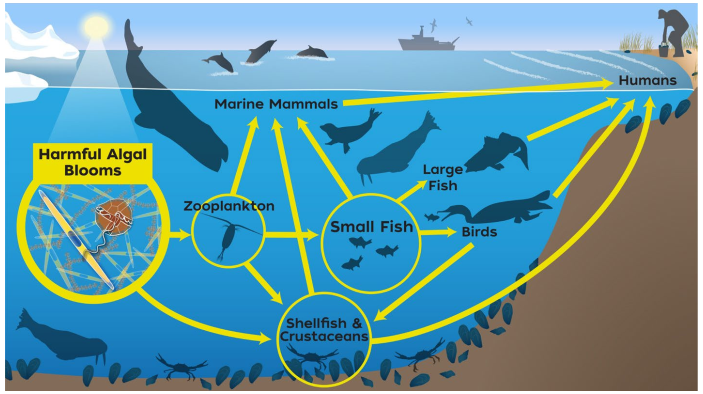
Examples

Extreme Changes

Subsistence Harvest
Walrus (St Lawrence Island)
Bearded Seals (Kotzebue)

Extreme changes + Extreme events

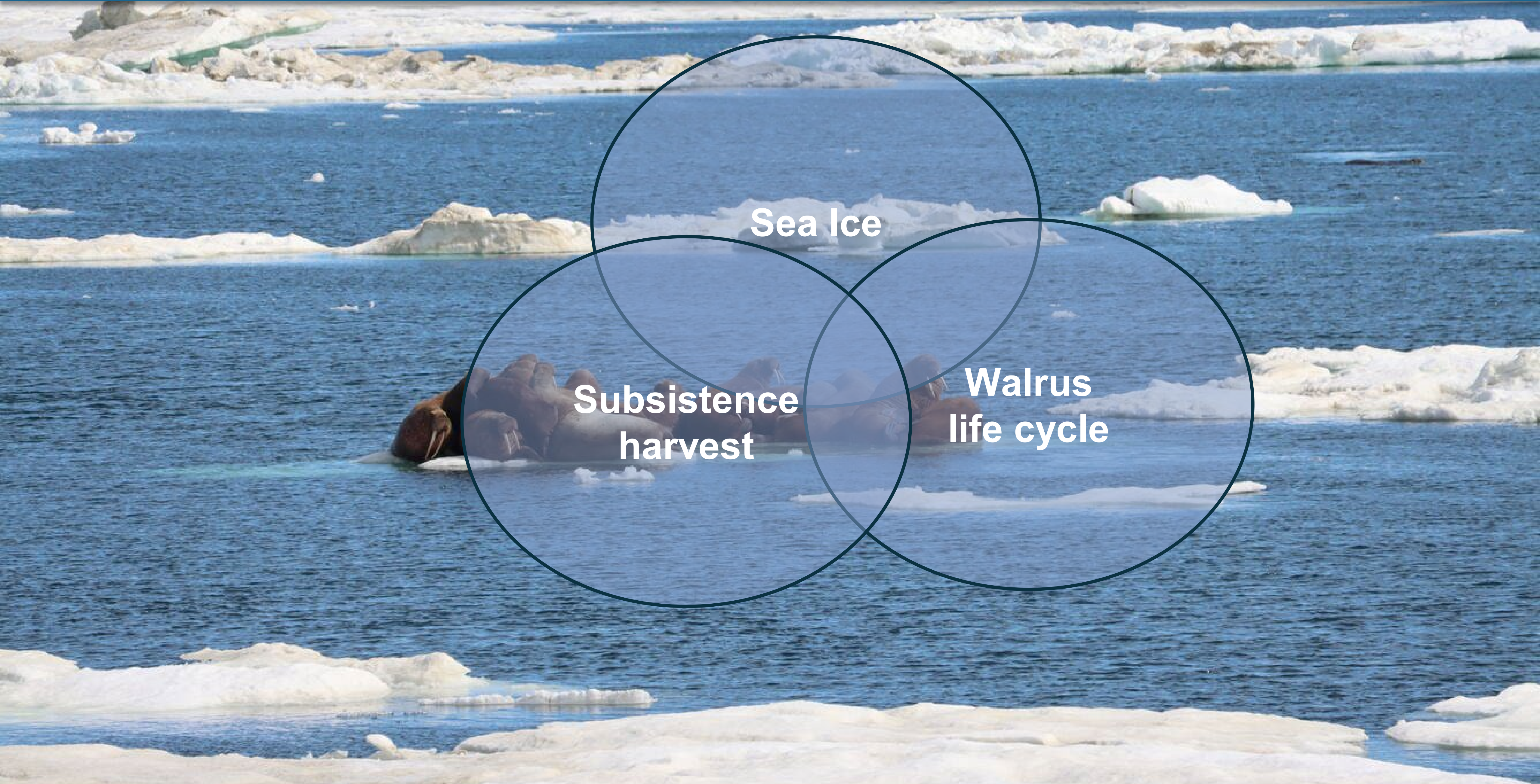
Coastal erosion in Arctic AK
(Typhoon Merbock)



Tipping points & cascades

Harmful Algal Blooms (HABs) and trophic changes
in Arctic marine ecosystems

Extreme changes and subsistence harvest: Walrus Accessibility



Extreme changes and subsistence harvest: Walrus Accessibility

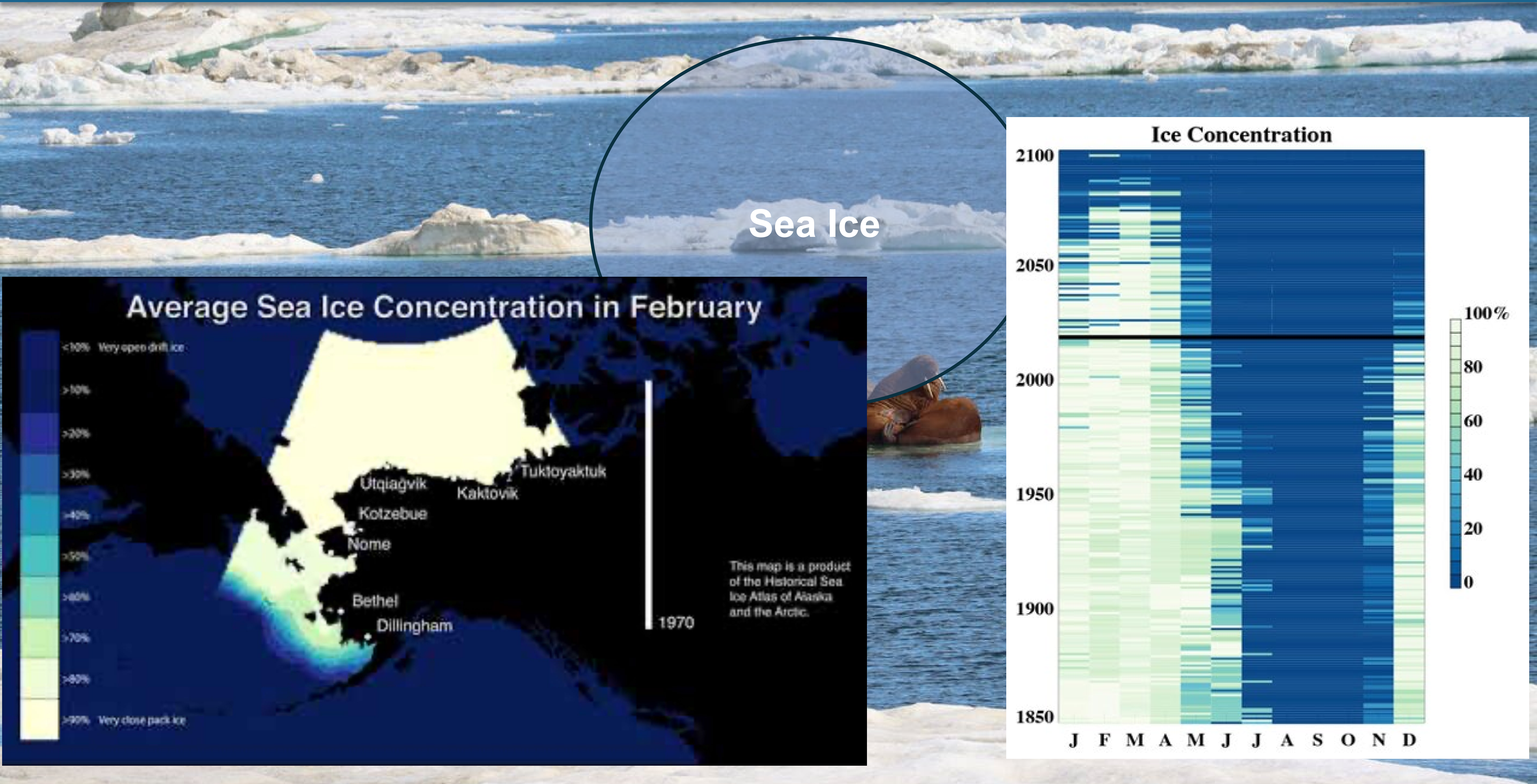
19 communities in AK and 18 in Russian far east depend on walrus (food, culture, economies, etc.) and have for 1000s of years

Accessibility to walrus are changing – hunting access, walrus migration and locations, hunter safety

Example here from St Lawrence Island (Gamble, Savoonga)

Fig. 5.1 Map of the study region and the two villages on St. Lawrence Island, Alaska. The *black squares* identify the 75 × 75 km satellite subregions for Gambell and Savoonga and the *shaded areas* the ice edge for March, May, and July 2007

Extreme changes and subsistence harvest: Walrus Accessibility



Extreme changes and subsistence harvest: Walrus Accessibility

Pacific Walrus

Migrate – Bering Sea (summer) Chukchi Sea (summer)

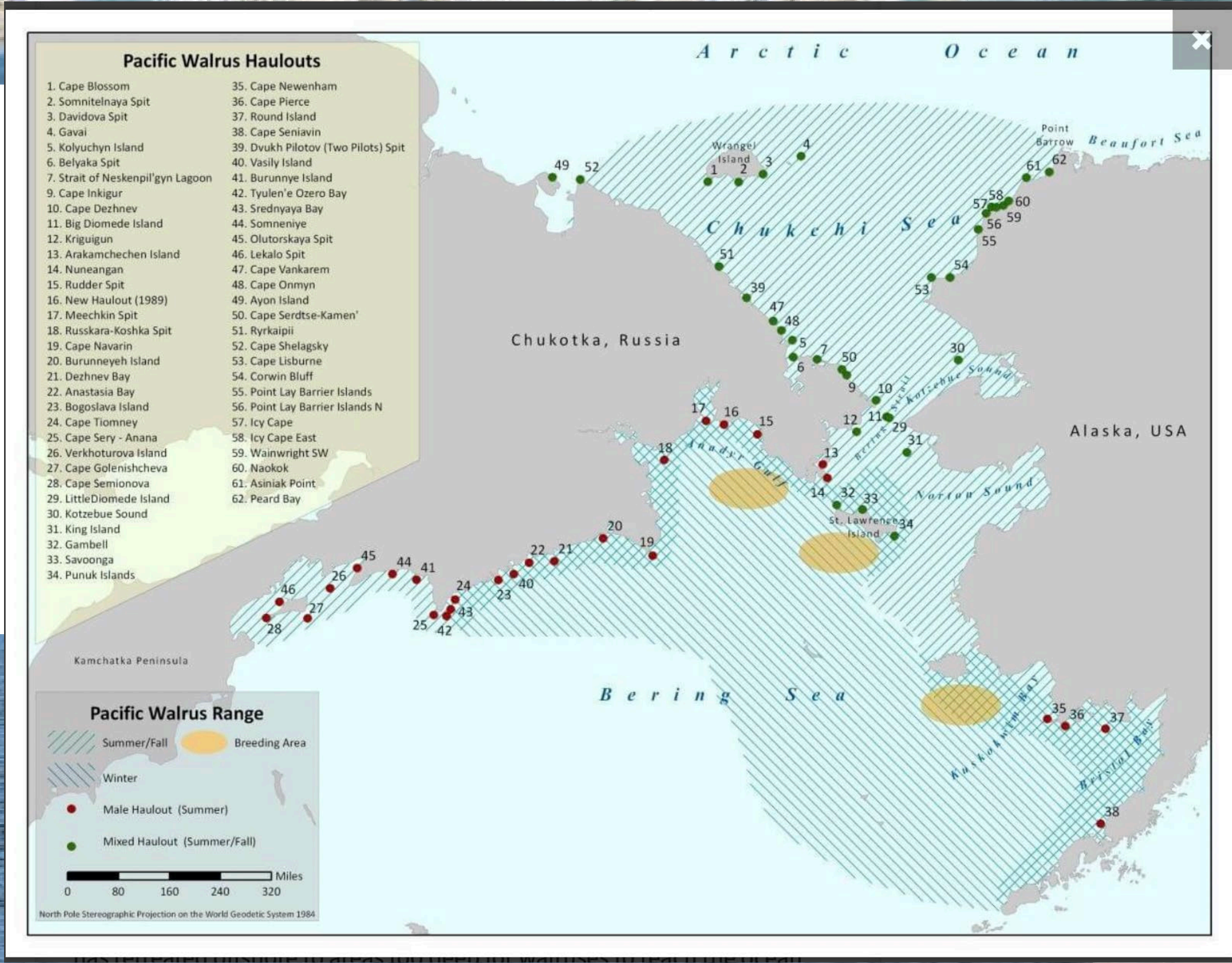
Cannot swim indefinitely – need to haul out (on ice or land)
Haulouts on land – stampeded

Eat clams and other benthic invertebrates

Forage up to ~80 m deep and typically 10-50 m deep

Sea ice – platform for birthing, nursing and pup day-care

Migrate along with seasonal expansion and contraction of sea ice



Extreme changes and subsistence harvest: Walrus Accessibility

Harvesting Walrus, St Lawrence Island, Gambell, Savoonga

Sea Ice:

Complex regional ice conditions

Enough open water for boat access

Enough sea ice for Walrus to rest on sea ice close enough to island to be able to get to (safely)

Sea ice conditions during Walrus migration

Typically >0-30% sea ice concentrations (SIC)
Sea ice dampens waves and makes travel easier

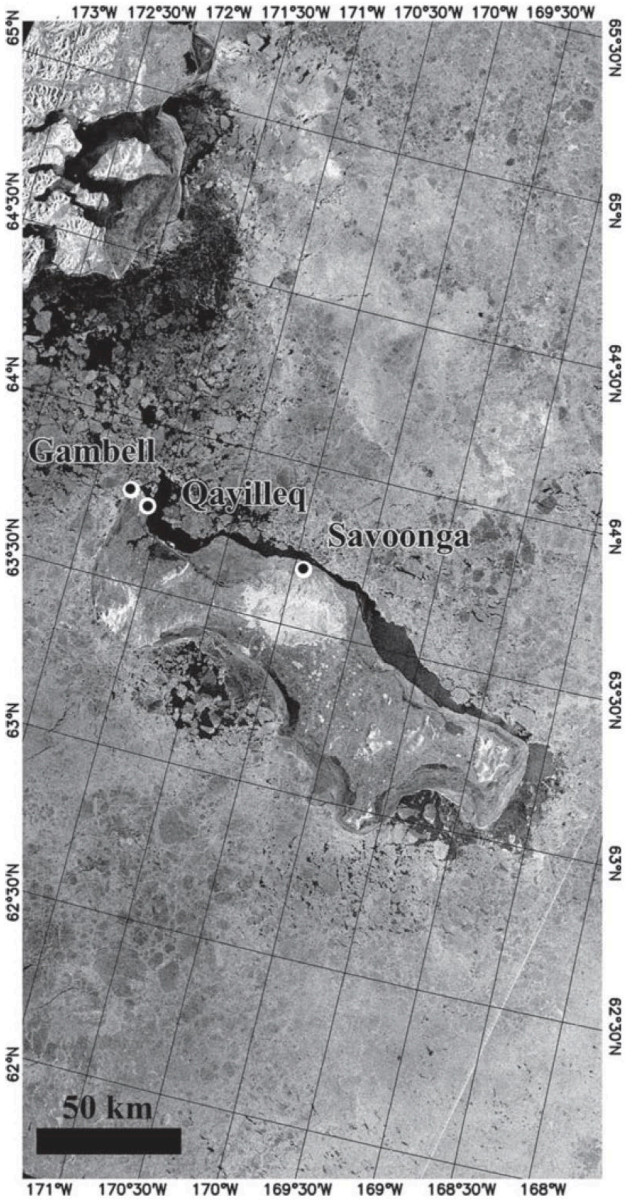


Fig. 5.10 Synthetic aperture radar (SAR) image for April 17, 2008, showing ice conditions around St. Lawrence Island, Alaska (image is 200 × 400 km in size, © Canadian Space Agency) and the locations Gambell, Qayilleq, and Savoonga

Weather

Too quiet and sea ice reforms quickly at the ocean surface (can trap boats)
Too windy and even walrus do not haul out (>~30 m/s)
wind direction – leads open or ice closes (and traps boats) or winds build up sea ice on shore

Winds ~1-9 m/s, visibility ~>6km, air temps. -5° to 5°C

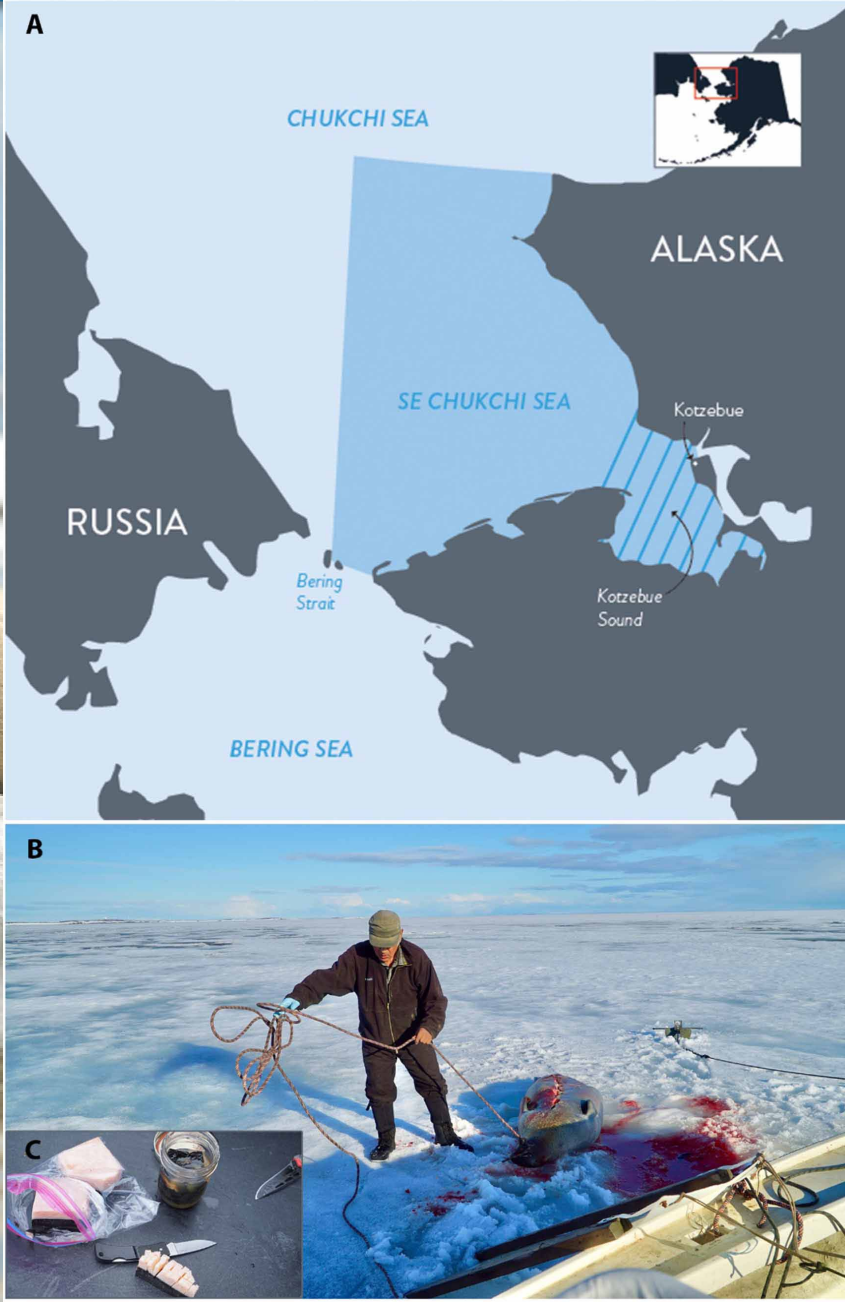
Walrus have become increasingly difficult to access (esp. past 20 yrs).
Longer distances, more fuel (expensive), greater exposure to weather, etc.
Fewer walrus near St Lawrence (10,000 1970s, 1000 1990s

Extreme changes and subsistence harvest: Ugruk (Bearded Seals), Kotzebue

Ugruk feed, molt and haul out on ice

Kotzebue Sound – "rest stop" on migration north, following sea ice edge, into the Chukchi sea

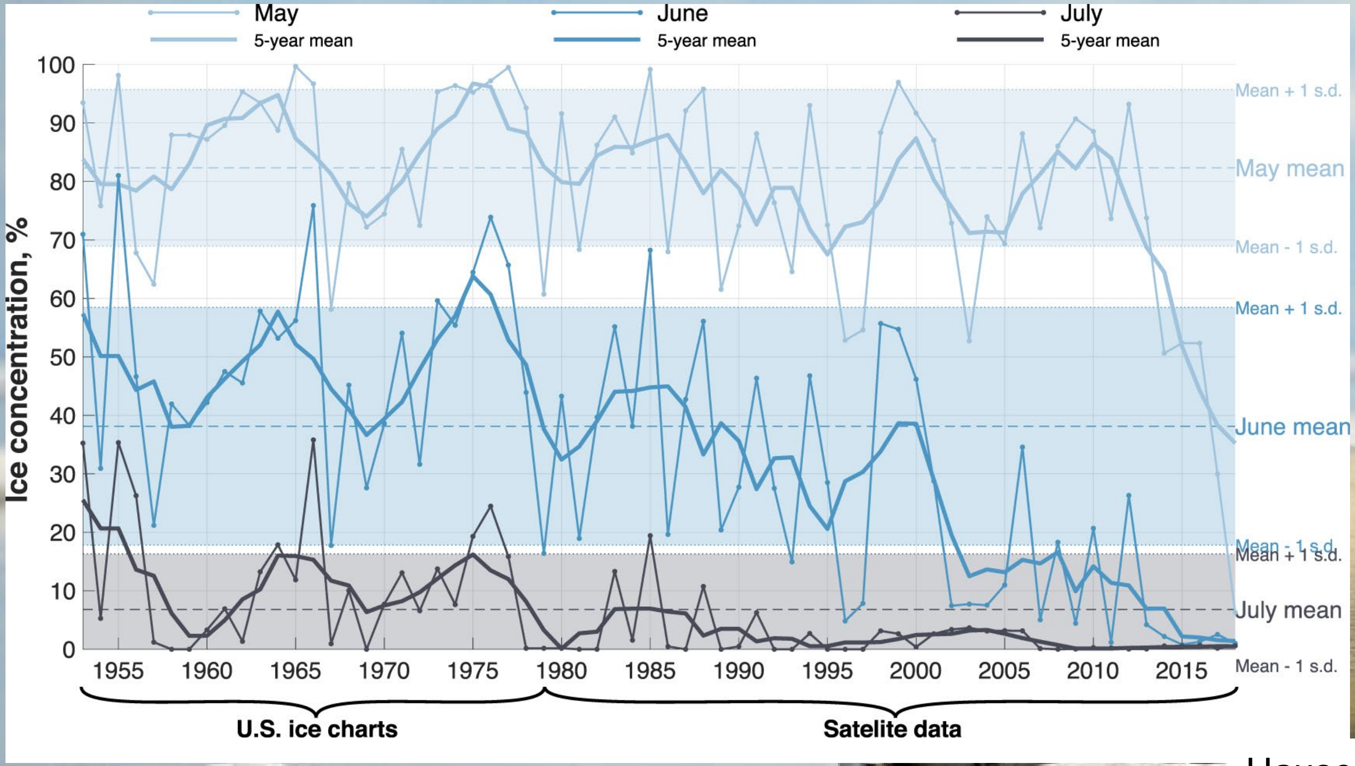
Eat invertebrates (shrimp, crabs, clams..) and some fish

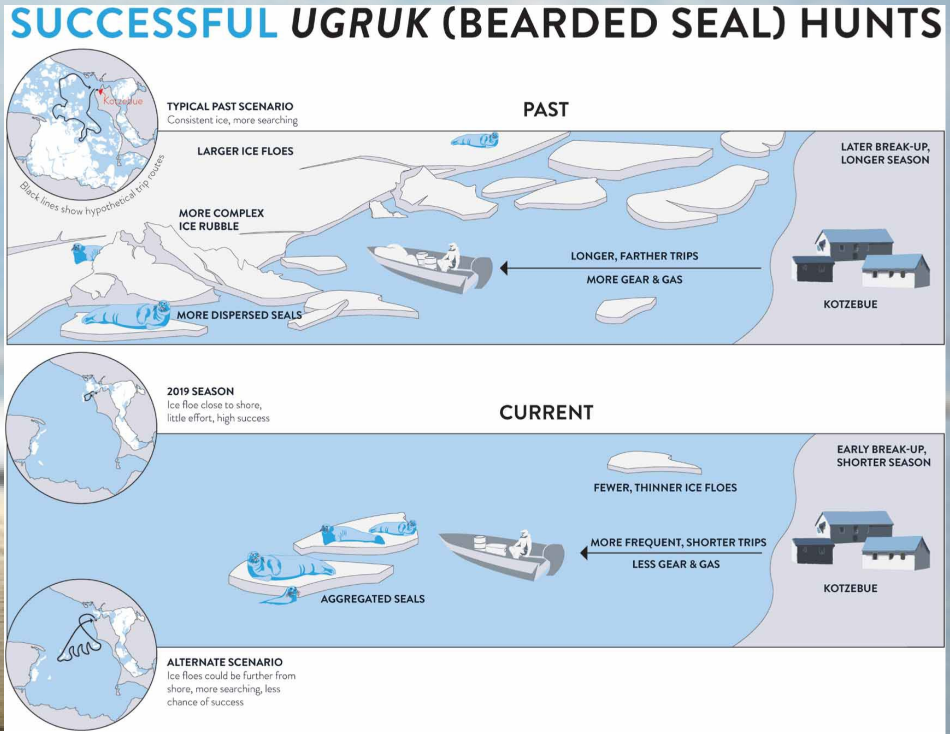


Ice break up events & Ugruk access:

1. km-scale leads/openings (Ugruk enter Kotzebue sound)
2. Opening up of channel (~600m) in front of town through landfast ice (first day of season – boats can get to Kotzebue Sound from town)
3. Absence of sea ice in the inner sound (ugruk no longer close)
4. No detectable sea ice in Kotzebue Sound (only seals are "swimmers")

Extreme changes and subsistence harvest: Ugruk (Bearded Seals), Kotzebue





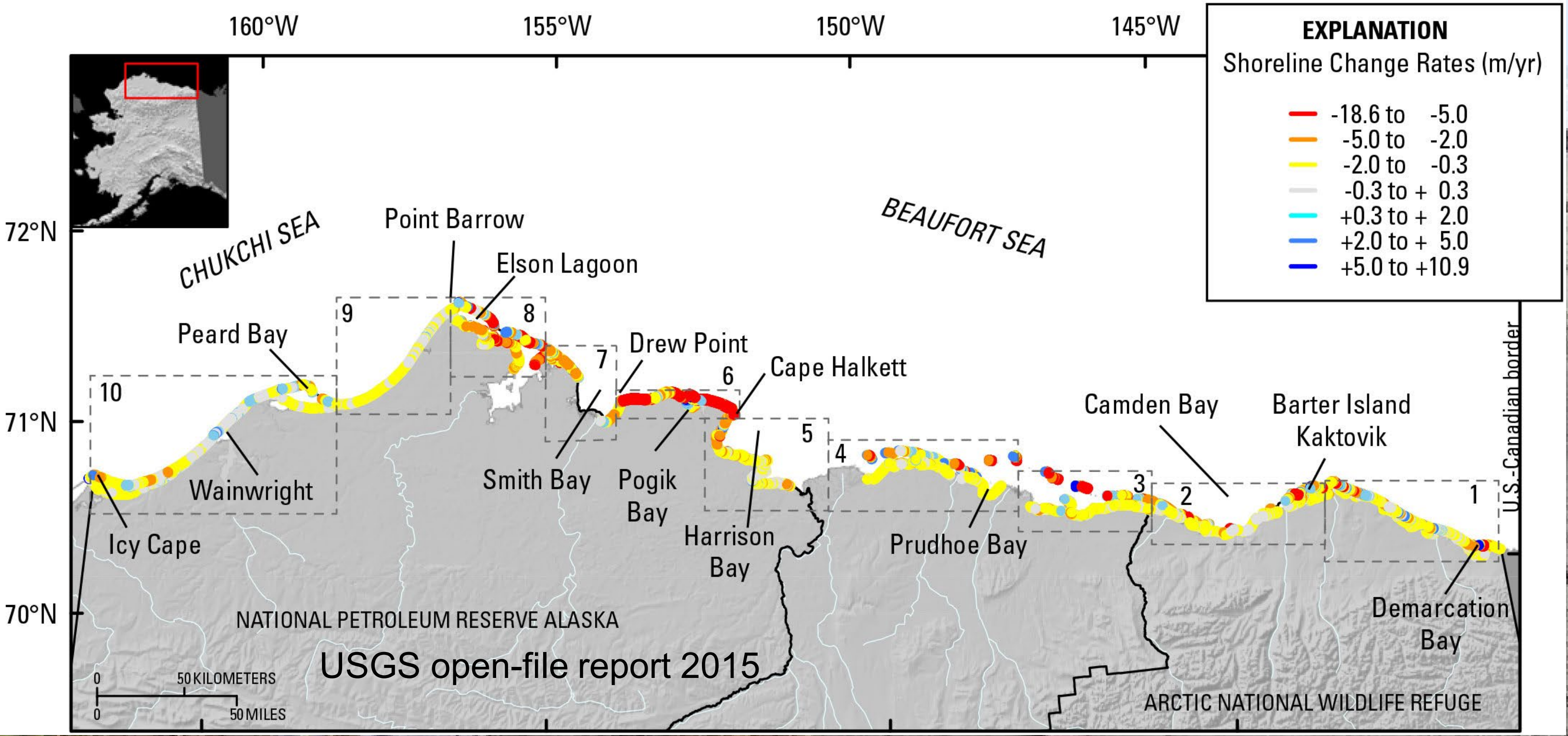
Hauser et al., 2021

Ugruk season duration:

decreased 1 day/ yr, 2003-2019, primarily due to earlier end date (~26 days earlier)

Shorter season adaptations

Extreme events compounded by extreme changes: coastal erosion



USGS open-file report 2015

Increasing rates of coastal erosion

Decreasing sea ice

(more open water, increased exposure to waves, increased fetch and wave energy)

Permafrost thaw

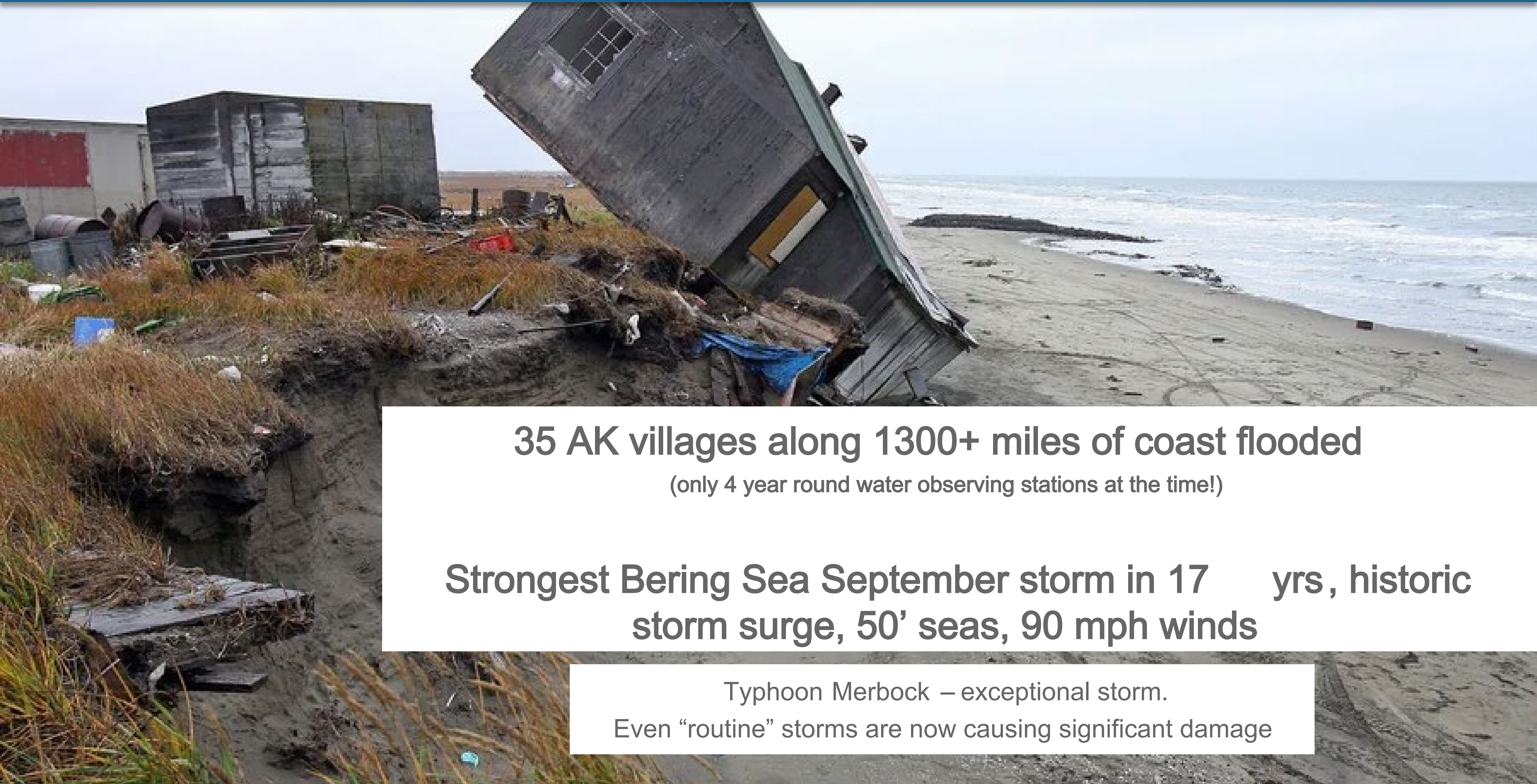
Increased Arctic storms

(magnitude, frequency)

Increased sea levels

(higher storm surge)

Extreme events compounded by extreme changes: Typhoon Merbock, Sept. 2022



35 AK villages along 1300+ miles of coast flooded

(only 4 year round water observing stations at the time!)

Strongest Bering Sea September storm in 17 yrs, historic storm surge, 50’ seas, 90 mph winds

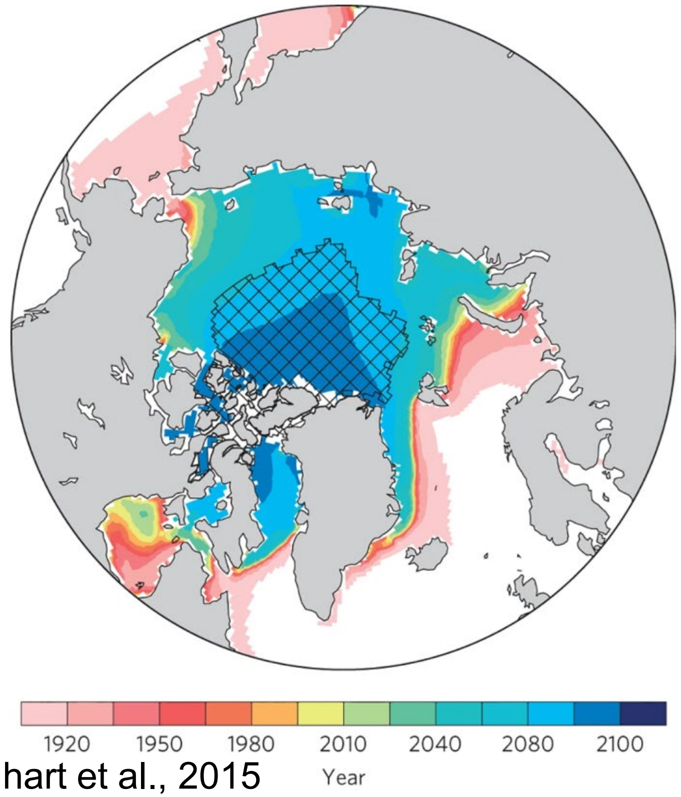
Typhoon Merbock – exceptional storm.

Even “routine” storms are now causing significant damage

Extreme events compounded by extreme changes: coastal erosion

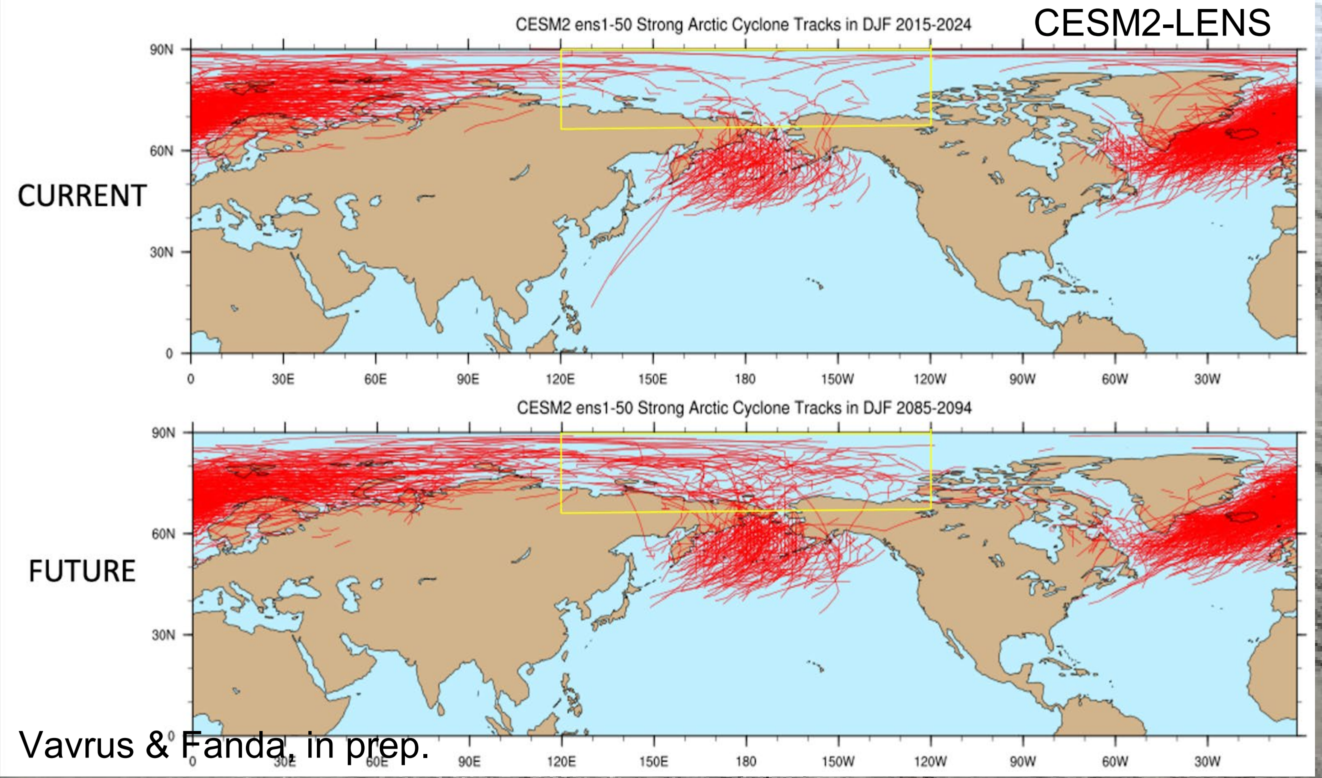
Figure 2: Last year with ice coverage for 182 days.

From: Mapping the future expansion of Arctic open water



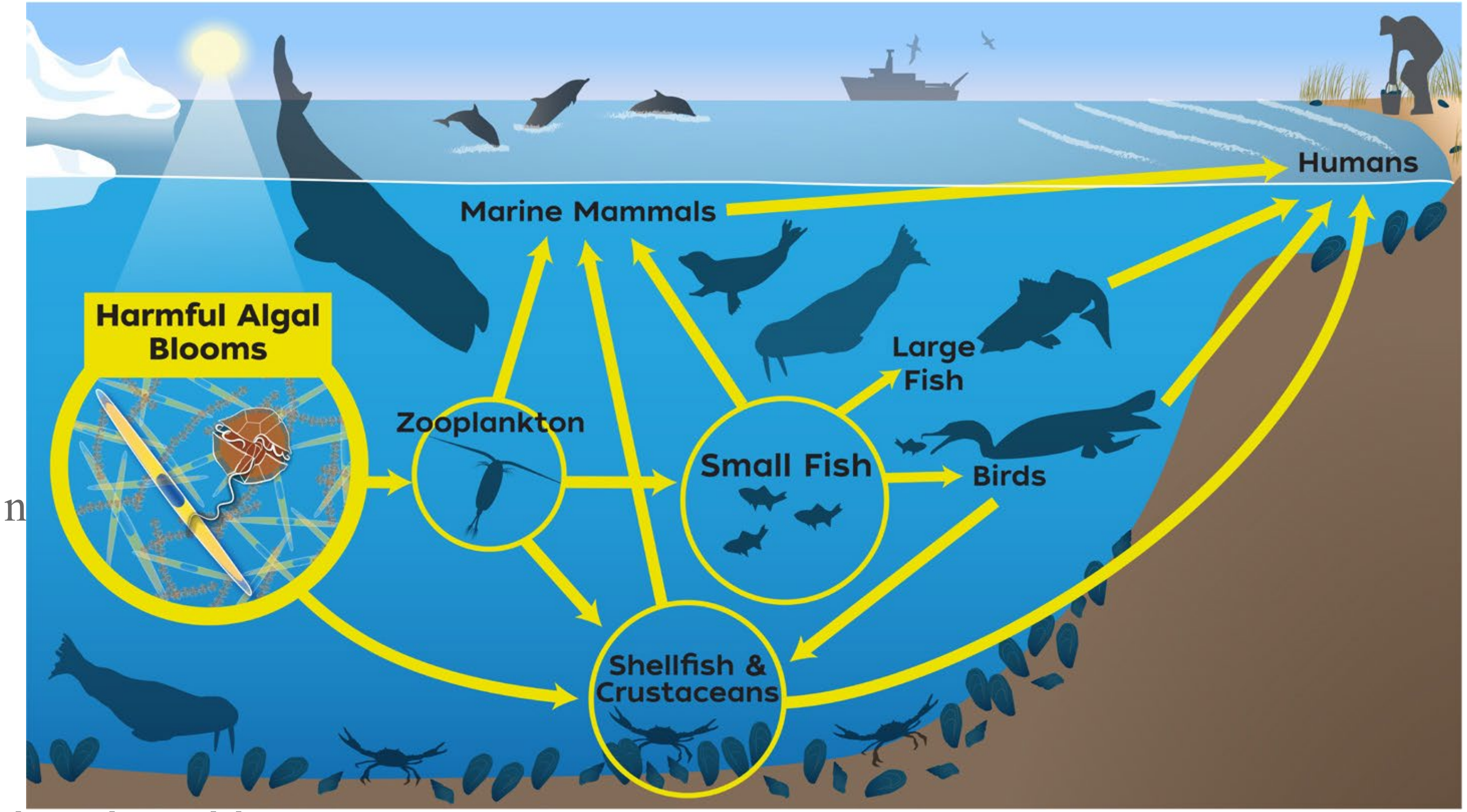
Barnhart et al., 2015

Climate models project increasing loss of sea ice, more open water days, and increasing number of strong cyclones tracking into the Arctic.



Vavrus & Fanda, in prep.

Cascades and tipping points: marine ecosystems, Harmful Algal Blooms



Harmful Algal Blooms (HABs)

Emerging threat in Artic ecosystems

2 primary toxins:

- Saxitoxins (*Alexandrium catenella*)
- Domoic acid (DA)

Cause paralytic and amnesic shellfish poison

Bioaccumulate in food web

Significant risk when SSTs 8°C and higher

Arctic coastal communities highly vulnerable

Marine resources critical (food, culture, health & well being)

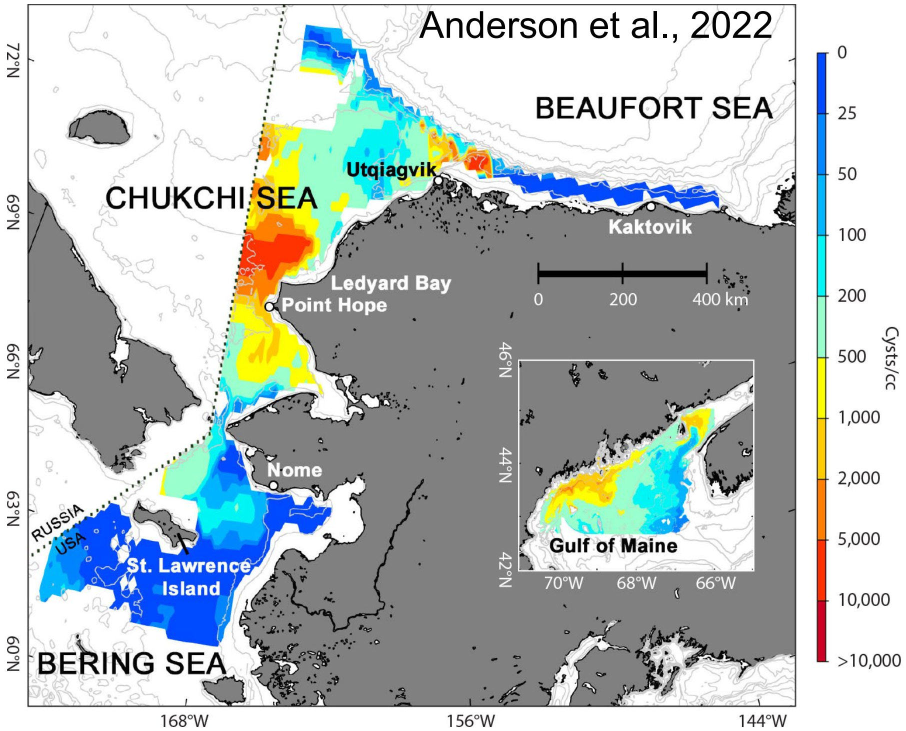
Difficult logistical access

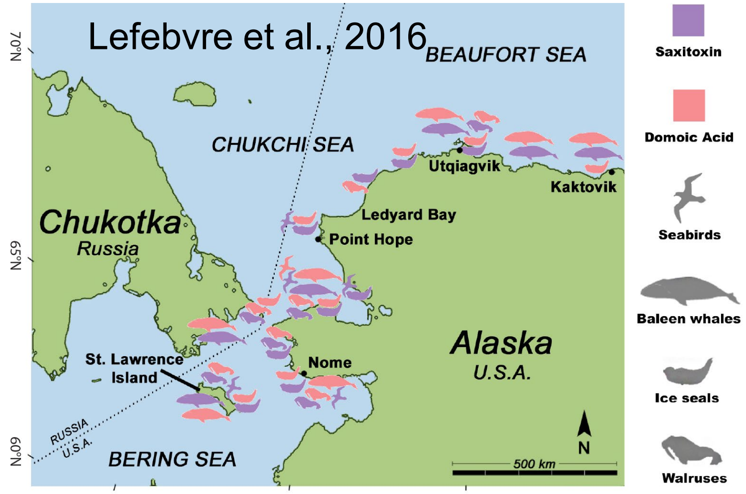
Lack of response infrastructure

Extreme regional warming

Ecosystem shifts

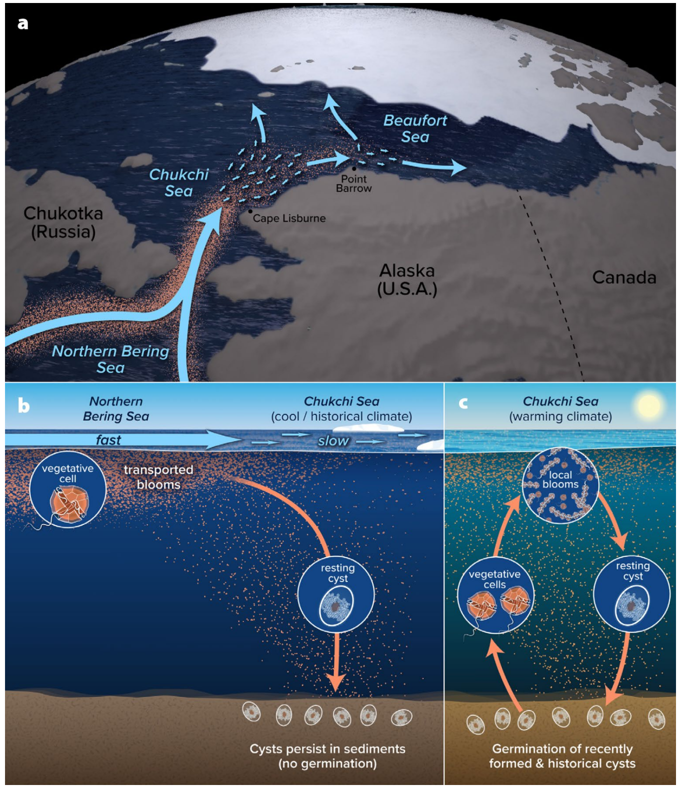
Tipping points: Harmful Algal Blooms





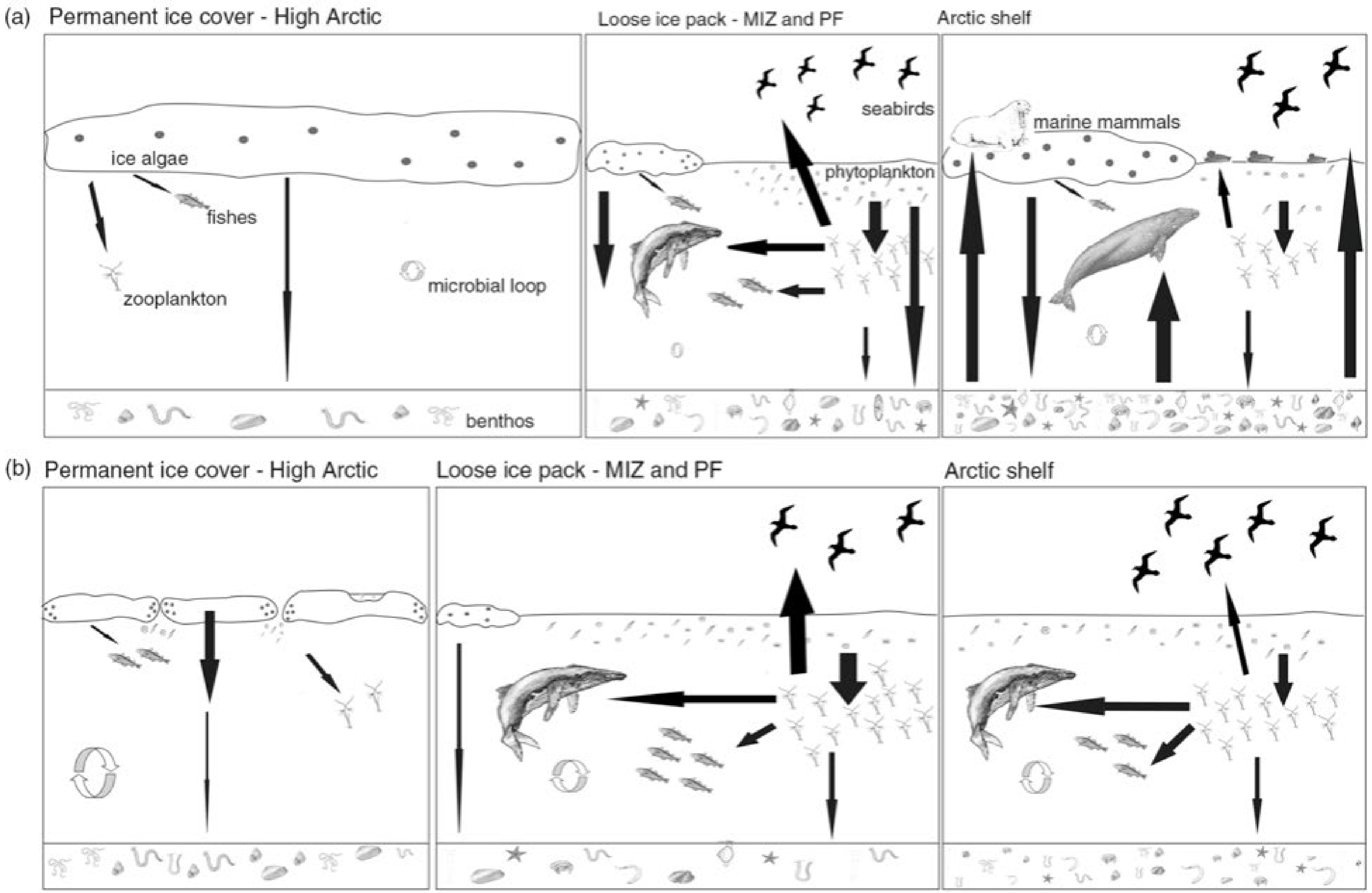
Alexandrium catenella

- **Historically not significant** food safety concern (north of Bering Strait) – bottom waters too cold for cysts to germinate
- Ocean temperatures warming
- **Massive**, persistent cyst bed in Chukchi Sea much higher density than Gulf of Maine (known region of annually recurrent, dangerous blooms)
- Presumably extends west (Russia)
- cysts can survive 100+ yrs



Anderson et al., 2022

Cascades: marine ecosystems



Kedra et al., 2015

"Borealization" of Arctic marine food webs

Large piscivorous & semipelagic boreal species replacing small benthivorous Arctic species

Will profoundly impact ecosystem functioning in the Arctic

Climate-driven

Ideas from other disciplines: chronic exposure, climate indices, metrics

“Climate Risk”

Can we identify applicable, standard methodology/protocols for assessing weather and climate risk:

for Arctic communities?

to assess climate models?

Photo courtesy of North Slope Borough

“Climate Risk”

b) AR6 and future of the IPCC Risk Framework

Risk as a probability of hazard happening, times magnitude of consequences

“Climate Risk”

Hazard

“**Shock**” immediate, destructive but short lived (e.g. meteorological extreme, Typhoons)

“**Stressor**” slower onset, long term adverse effects (e.g. sea level rise, warming temperatures)

b) AR6 and future of the IPCC Risk Framework

Risk as a probability of hazard happening, times magnitude of consequences

"Climate Risk"

b) AR6 and future of the IPCC Risk Framework

Exposure

Likelihood that an individual, community, organization, etc. will experience a hazard

Risk as a probability of hazard happening, times magnitude of consequences

"Climate Risk"

b) AR6 and future of the IPCC Risk Framework

Vulnerability

How well equipped the individual, community, organization, sector, etc. is to withstand exposure to the hazard

Risk as a probability of hazard happening, times magnitude of consequences

Ideas from other disciplines: chronic exposure, climate indices, metrics

"Climate Risk"

Vulnerability

How well equipped the individual, community, organization, sector, etc. is to withstand exposure to the hazard

Responses

Adaptation, mitigation

Risk as a probability of hazard happening, times magnitude of consequences

Ideas from other disciplines: chronic exposure, climate indices, metrics

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Hazard

"**Shock**" immediate, destructive but short lived (e.g. meteorological extreme, Typhoons)

"**Stressor**" slower onset, long term adverse effects (e.g. sea level rise, warming temperatures)

Exposure

Likelihood that an individual, community, organization, etc. will experience a hazard

Climate models well suited to assess?

Vulnerability

How well equipped is the individual, community, organization, sector, etc. can withstand exposure to the hazard

Responses

Adaptation, mitigation

Risk as a probability of hazard happening, times magnitude of consequences

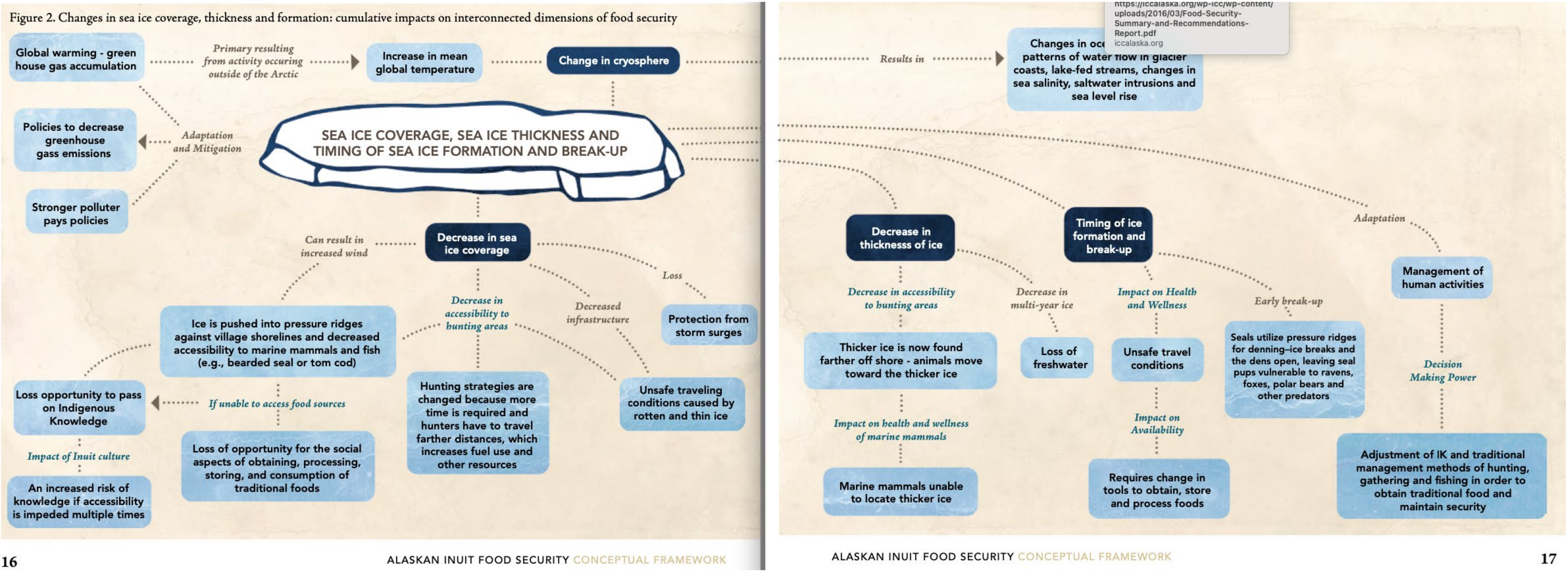
Summary/Discussion

- Arctic communities are experiencing – and will continue to experience – a range of climate hazards.
- Hazards types are both “shock” and “stressor”
- Arctic communities speak about environment in integrative, holistic terms and perspectives
- Climate scientists speak about climate change often in mathematical and reductionist terms
- Climate models are skilled at statistics of changing climate
- Bridging the gap: creating quantifiable, verifiable, useful indices (defined by both communities – Arctic residential and western scientific)

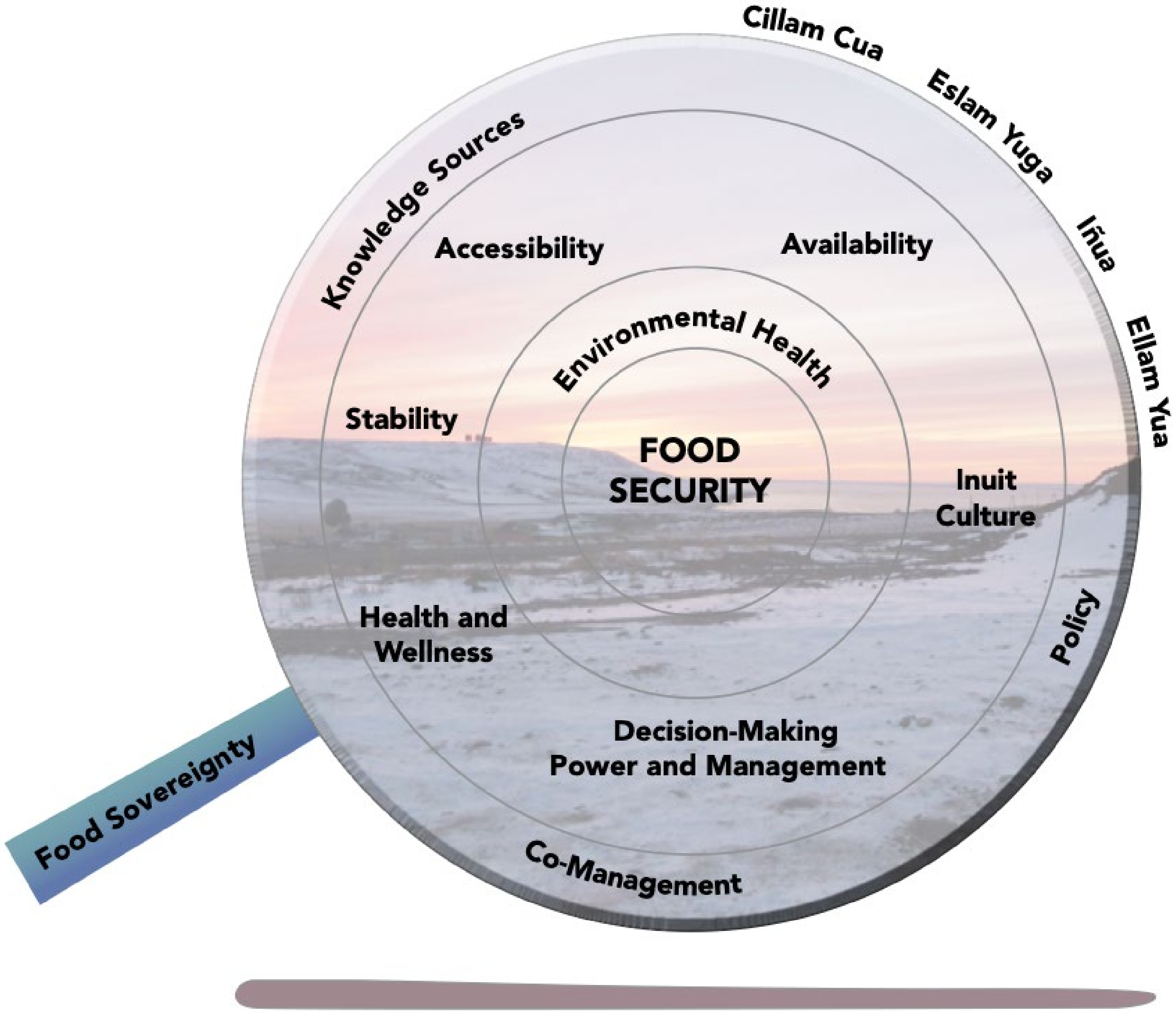
Thank you!

Inuit Circumpolar Council Alaska

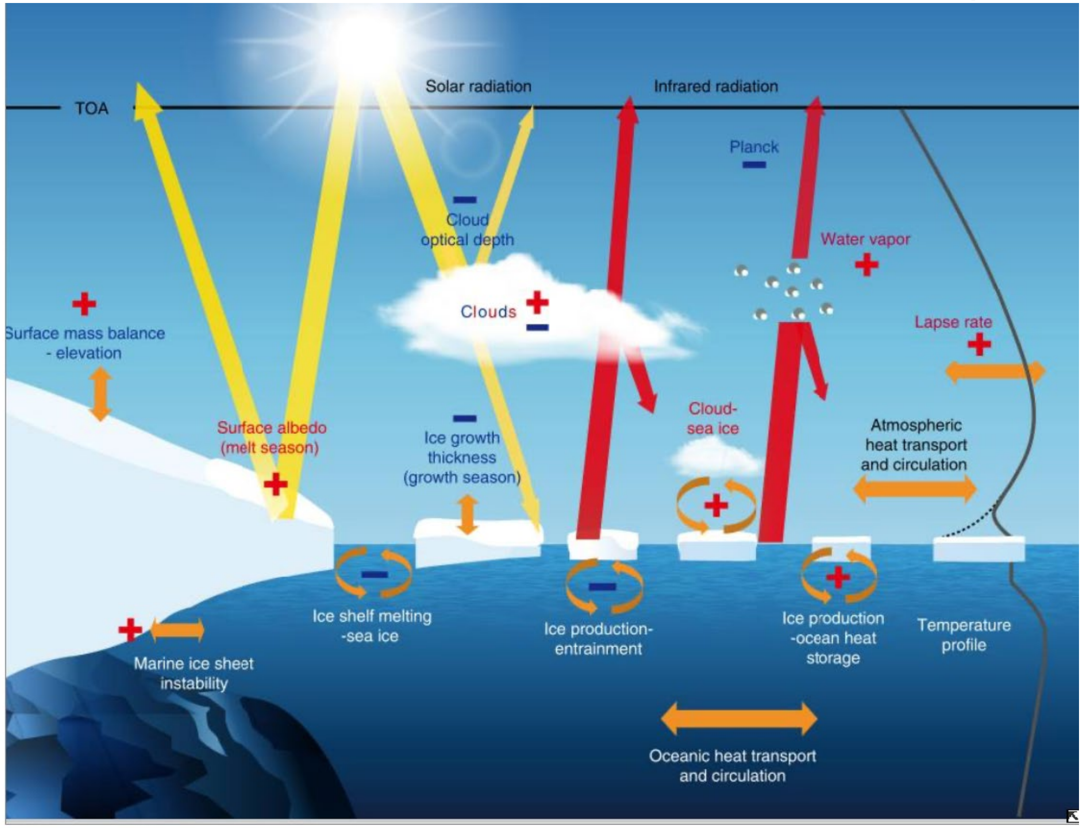
Sea Ice (food sovereignty framework)



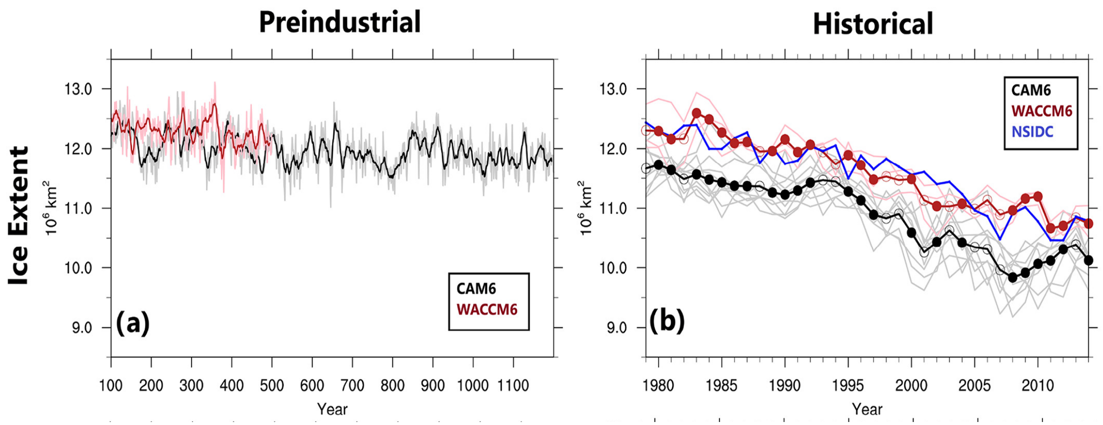
Inuit Circumpolar Council Alaska

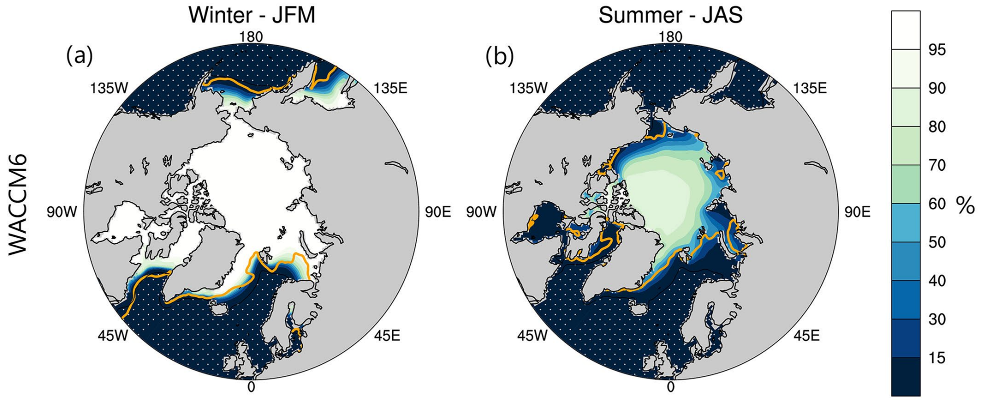


Sea Ice (climate modeling framework)



Goose et al., 2018, Nat.Comm.





DuVivier et al., 2020, JGR Oceans, **125**

Example Vulnerability Assessment Frameworks

climate risk/vulnerability assessment resources:

USAID Climate Vulnerability Assessment Technical Report
U.S. Climate Resilience Toolkit
NOAA's Adapting to Climate Change: A Planning Guide for State Coastal Managers
Florida Adaptation Planning Guidebook

Compound and Cascading Risk - risks are not isolated

Compound risks:

A single event or overlapping events cause multiple hazards to interact, which creates a larger overall impact than the sum of the individual hazard impacts

Arctic Examples:

Extreme winds from typhoon coincide with higher sea levels, lower wave damping and coastal protection from diminished sea ice cover, and rising sea levels.

Cascading risks:

An extreme event triggers a sequence of secondary events causing additional disruptions

Arctic example:

Rising ocean temperatures can contribute to increased risk of Alexandrium cysts to germinate with consequences for entire food web, community food safety, etc.

Example Vulnerability Assessment Frameworks

- The following slides summarize key information from the following climate risk/vulnerability assessment resources:

- USAID Climate Vulnerability Assessment Technical Report
- U.S. Climate Resilience Toolkit
- NOAA's Adapting to Climate Change: A Planning Guide for State Coastal Managers
- Florida Adaptation Planning Guidebook

U.S. Climate Resilience Toolkit - Steps to Resilience

- Understand Exposure
- Assess Vulnerability & Risk
- Investigate Options
- Prioritize & Plan
- Take Action

This circular representation of the Steps reflects the iterative nature of enhancing climate resilience. Adaptation planners may need to return to previous steps repeatedly to consider changing vulnerabilities, even as they take steps to build resilience and reduce risk. The central gear of engagement shows the importance of continuing to work with the full range of stakeholders.