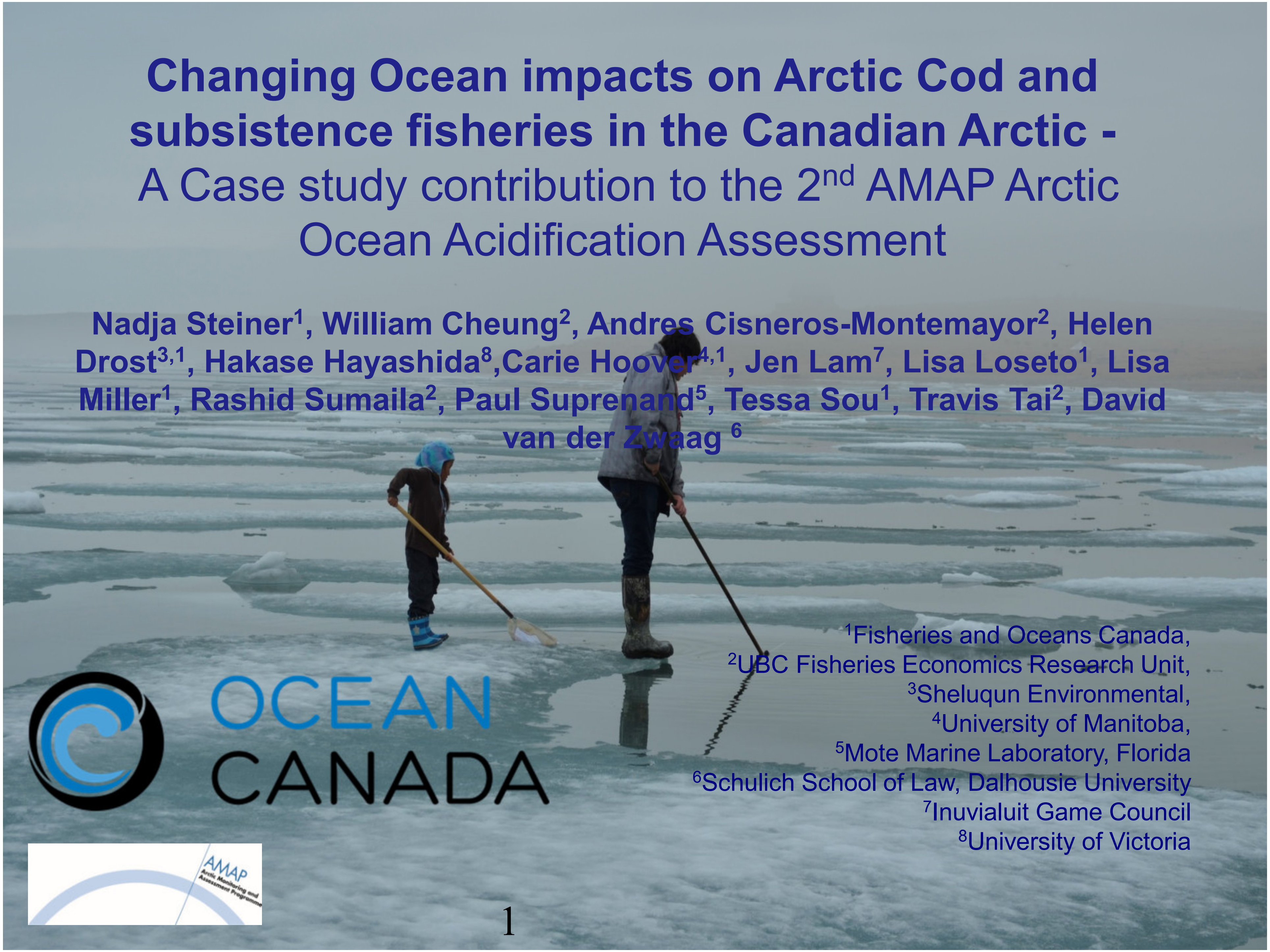

Changing Ocean impacts on Arctic Cod and subsistence fisheries in the Canadian Arctic - A Case study contribution to the 2nd AMAP Arctic Ocean Acidification Assessment

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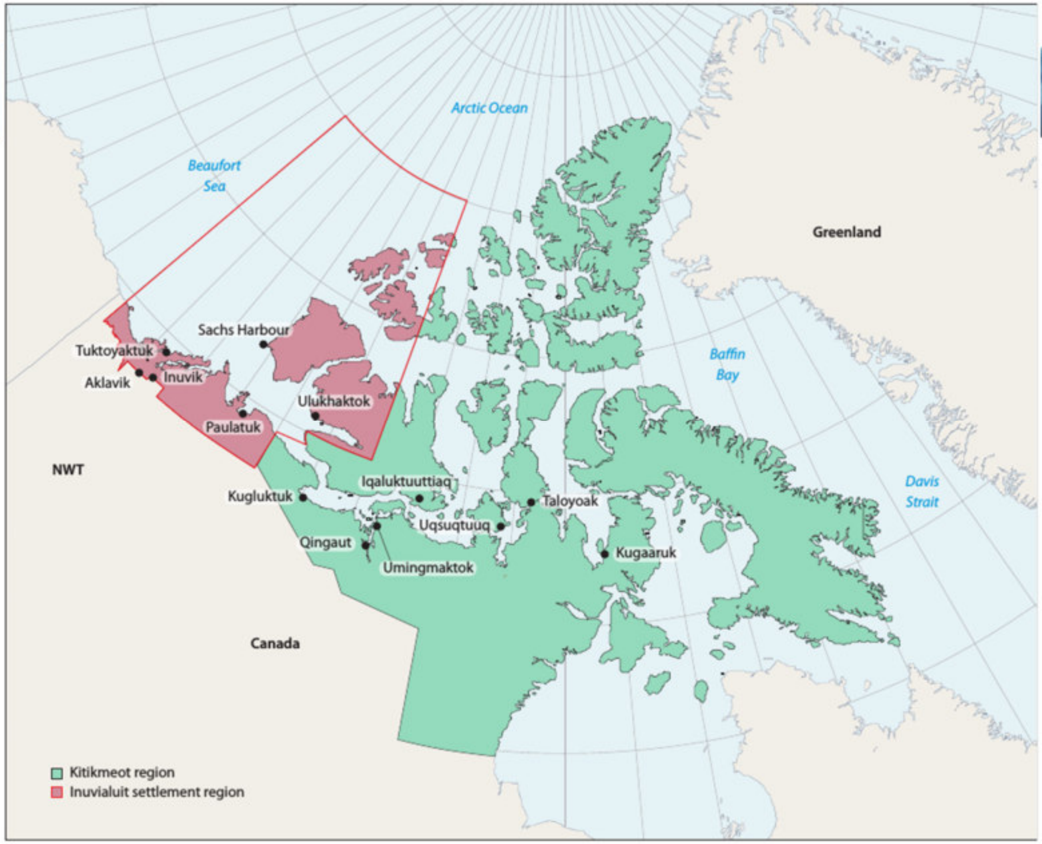
AMAP Arctic Monitoring and Assessment Programme



Inuit peoples maintain their link to their traditional way of life through their harvesting practices (hunting, fishing, trapping). Foods harvested from the land and ocean are an integral dimension of their diet and harvest byproducts support economies based on arts and culture

Focus region:
Western Arctic Bioregion in Canada -
Inuvialuit Settlement region (NWT), Kitikmeot region (Nunavut)

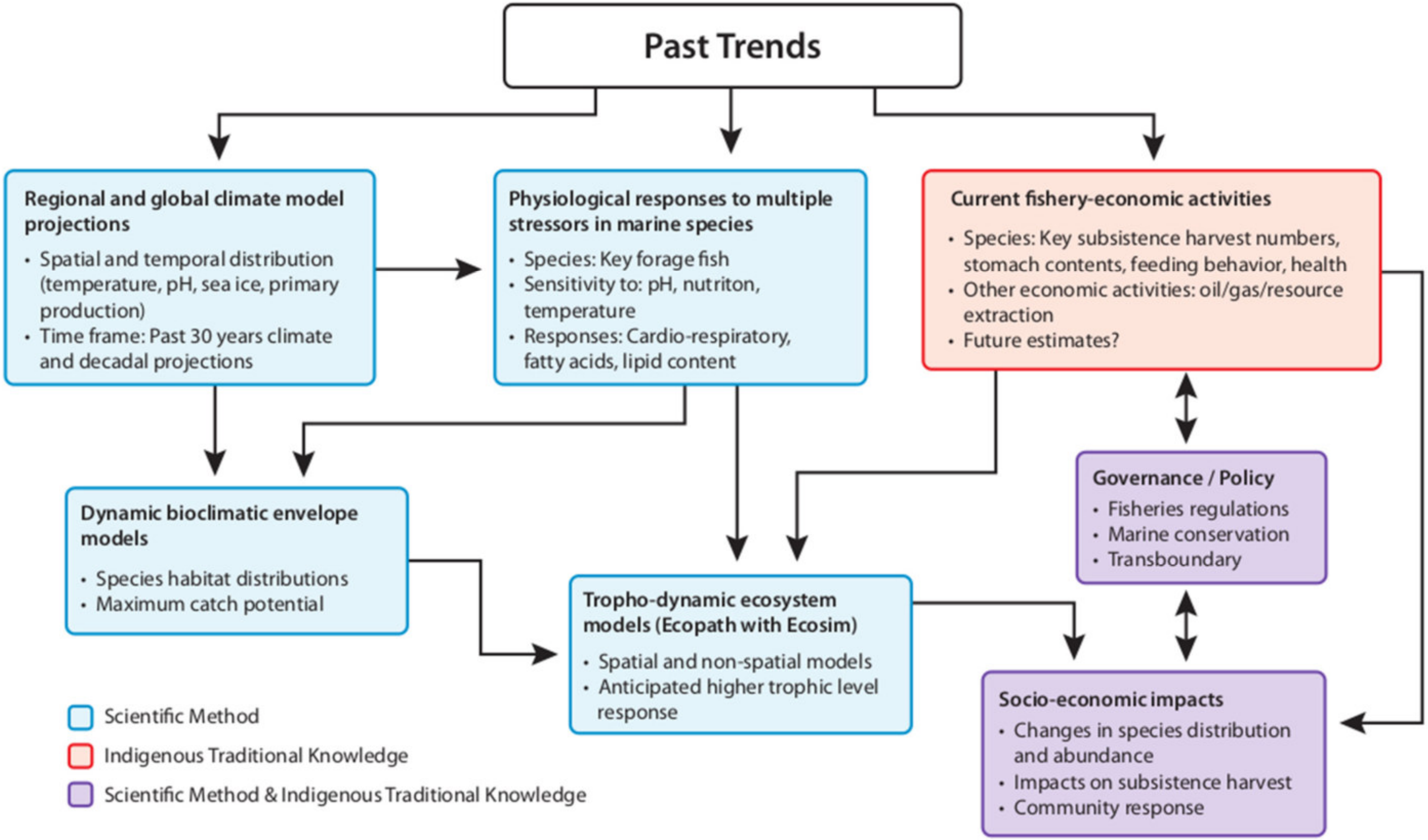
Focus species: Arctic cod (boreogadus saida)

Why Arctic cod?

- **Key forage species** for many subsitence species, e.g. Beluga, Char, Ringed Seals, Bowhead
- **high abundance & biomass**
- transfer energy from zooplankton to mega fauna
- **Ice associated** young
- **Link with climate models** more direct
- comparatively well studied, including the recent Beaufort Sea Marine Fishes Project

Stomach analysis show changes from predominantly Arctic cod to zooplankton and sandlance suggesting a potential shift
(Lea, Harwood, pers. comm.)

Photos: H.Drost


Past Trends
Regional and global climate model projections
• Spatial and temporal distribution (temperature, pH, sea ice, primary production)
• Time frame: Past 30 years climate and decadal projections
Physiological responses to multiple stressors in marine species
• Species: Key forage fish
• Sensitivity to: pH, nutriton, temperature
• Responses: Cardio-respiratory, fatty acids, lipid content
Current fishery-economic activities
• Species: Key subsistence harvest numbers, stomach contents, feeding behavior, health
• Other economic activities: oil/gas/resource extraction
• Future estimates?
Governance / Policy
• Fisheries regulations
• Marine conservation
• Transboundary
Dynamic bioclimatic envelope models
• Species habitat distributions
• Maximum catch potential
Tropho-dynamic ecosystem models (Ecopath with Ecosim)
• Spatial and non-spatial models
• Anticipated higher trophic level response
Socio-economic impacts
• Changes in species distribution and abundance
• Impacts on subsistence harvest
• Community response
Scientific Method
Indigenous Traditional Knowledge
Scientific Method & Indigenous Traditional Knowledge

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UBC University Of B.C.

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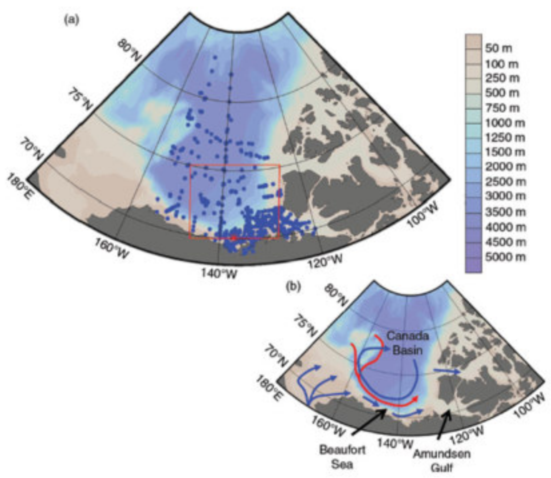
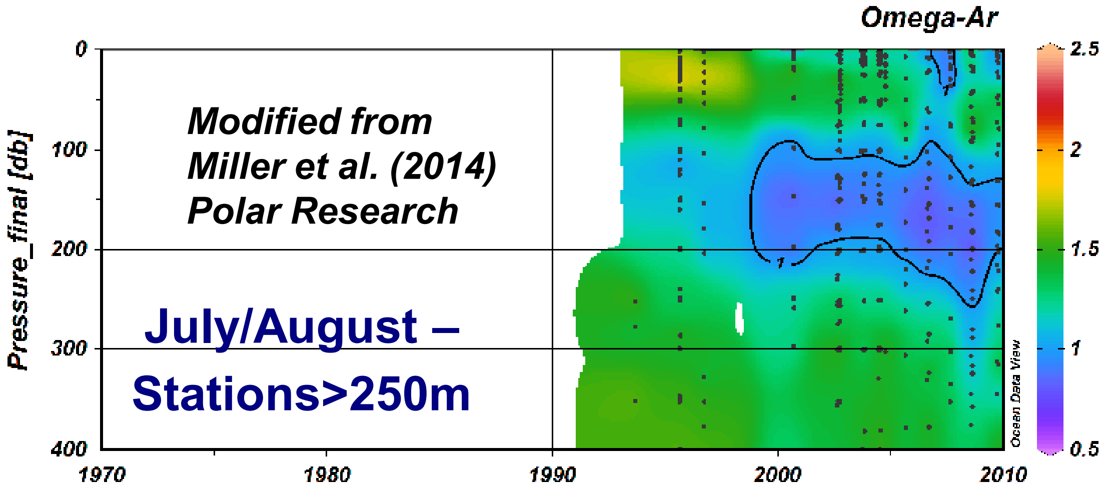
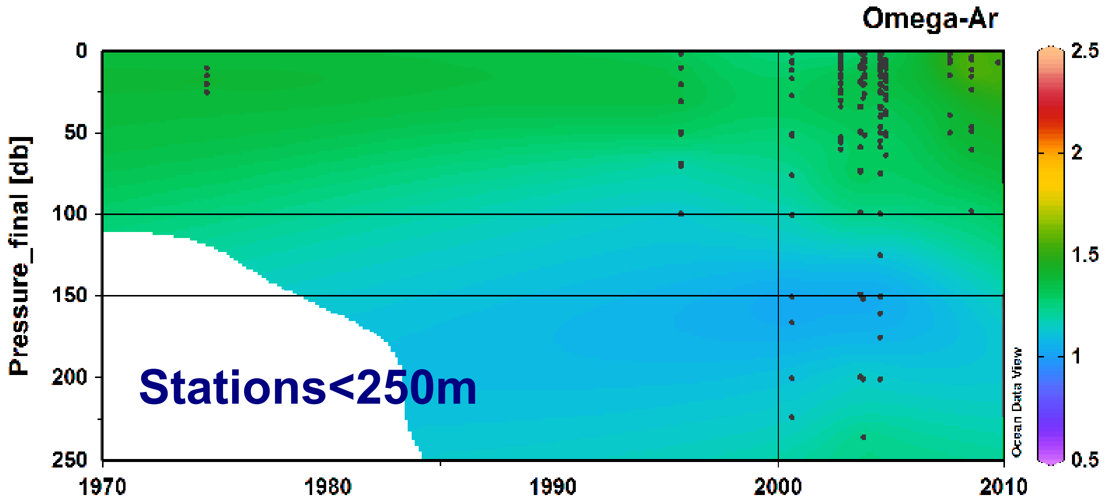
Observed changes in the Western Arctic Ocean

Aragonite Saturation State Ω_a



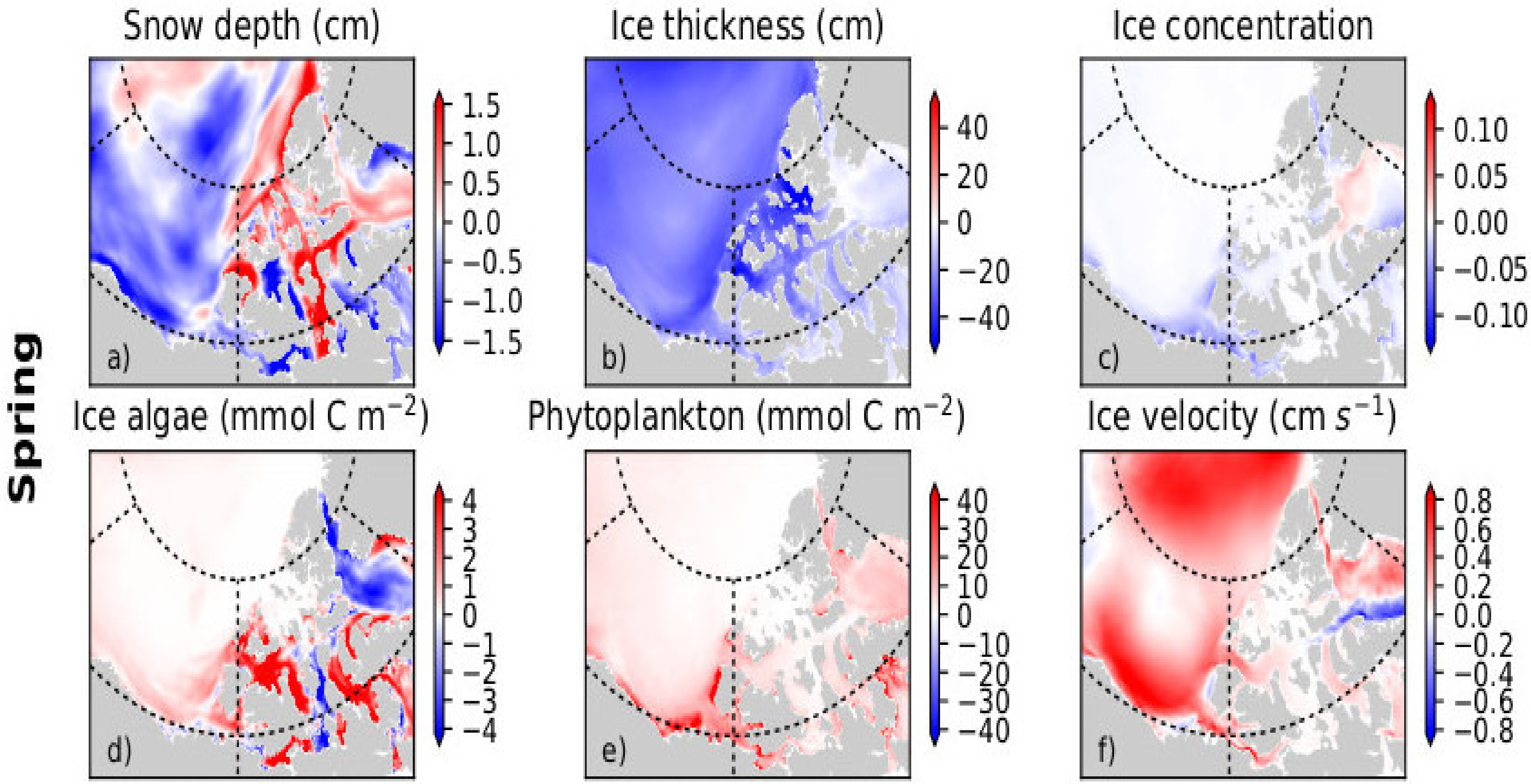
Beaufort Sea and Canada Basin (70-75N, 128-145W)





Canada

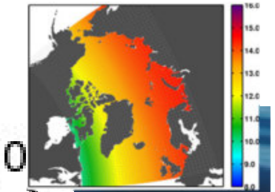
Simulated trends per decade (1979 to 2015)

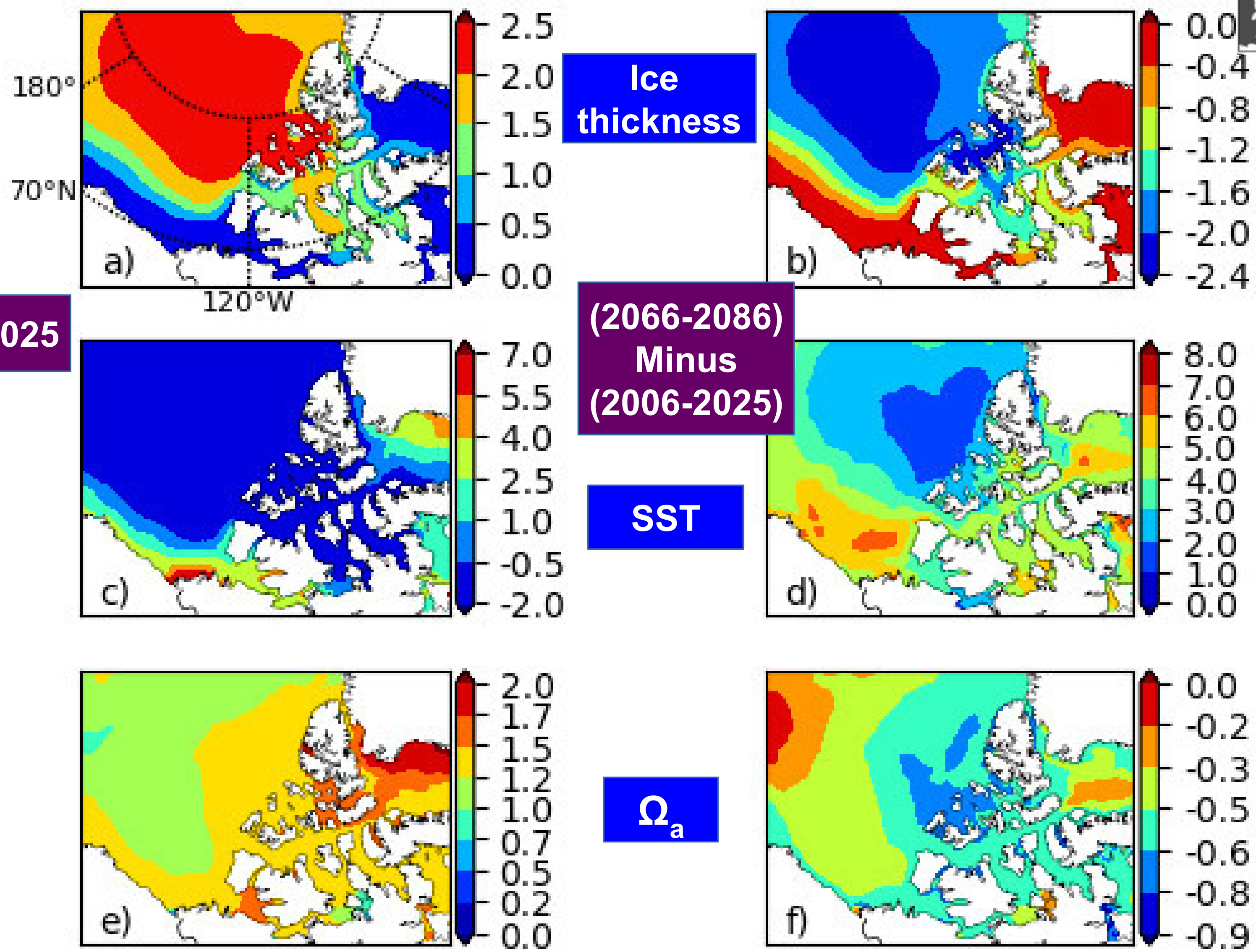


Steiner et al. 2018, Frontiers, submitted

Fisheries and Oceans Canada

High resolution Arctic model – Summer (RCP8.5)





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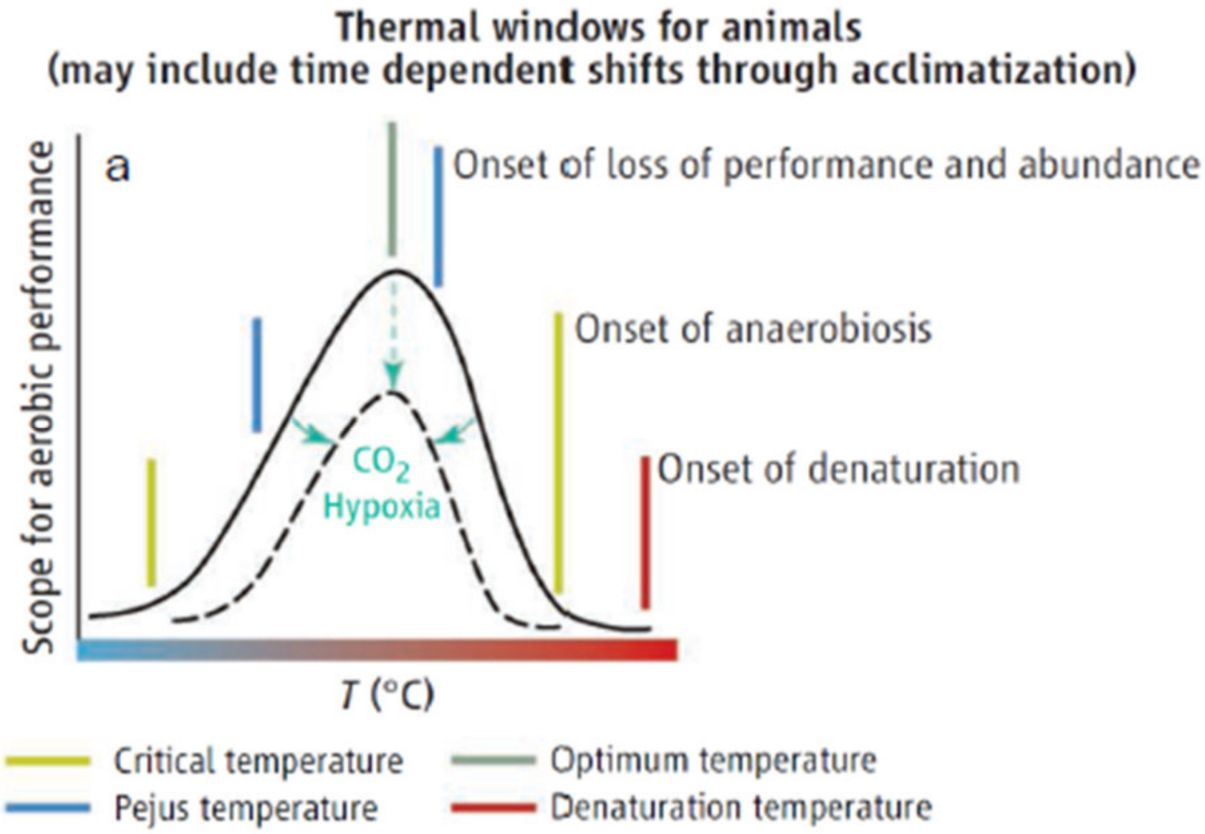
Thermal window for animals



Pörtner & Farrell, 2008:
Animals, including marine species, perform best within a window of optimal temperature.

Additional stressors might compress the optimum window

Acclimation might allow this window to shift (Drost et al. 2015, 2016) but at what energetic cost ?

Arctic key marine species physiological limits database - extract

ID	Species common name:	Critical lower °C	Lower pejus °C	Optimum °C	Upper pejus °C	Critical upper °C	Key reference(s) for temperature limit justifications
3	Pacific Herring		Adults = 4.7C	Adults= 6.5-10.5C		Spawning = 10C Larvae= 13.3C (@25ppm)	Akderdice and Velsen, 1971
4	Spot Prawn	Adults = 3C	Adults = 5C	Adults = 7-11C Larvae = 0-18C	Eggs = 13-15C	Adults = 21C Larvae = 15.2C	King, MSc Memorial U. 1997
14	Arctic cod	-1.9C (assumed)	Adults: Acclimation 0.5C = 0.2C Acclimation 3.5C = 1.6C Acclimation 6.5C = 5.4C	Larvae (acclimation 3.5C) = 3.3C Adults: Acclimation 0.5C = 1.0C Acclimation 3.5C = 3.5C Acclimation 6.5C = 5.4C	Spawning = 3.5C Adult Heart rate (Tmax): Acclimation 0.5C = 10.8C Acclimation 3.5C = 12.3C Acclimation 6.5C = 10.9C	LOE-Adults (acclimation 0C) = 14.9C Acclimation 3.5C = 15.5C Acclimation 6.5C = 17.1C	Drost et al., 2014; Kunz et al., 2016; Laurel et al., 2015
33	Caplin	-1.5C	0C	Spawning: 2.5-10.8C Egg-hatching: 1-19C Larvae: 4.5-9C Juveniles:5-7C Adults= -1-6C	Juveniles: 10C, Adults: 14C,		(Ref#6) (Ref#7) (Ref#9) (Ref#10) Ref#4,
51	*L. helicina* pteropod	Adults = -1.9C	Adults = -0.4	Adults = 4C	Adults = 7C		Encyclopedia of life, Species ID.org

88 species identified, 16 with T threshold info, 2 with T acclimation info,
6 with info on acidification – huge gaps - high uncertainty – need focused testing!

Steiner et al. 2018, DFO Fisheries Report

Canada

Changes in Body condition of Arctic species

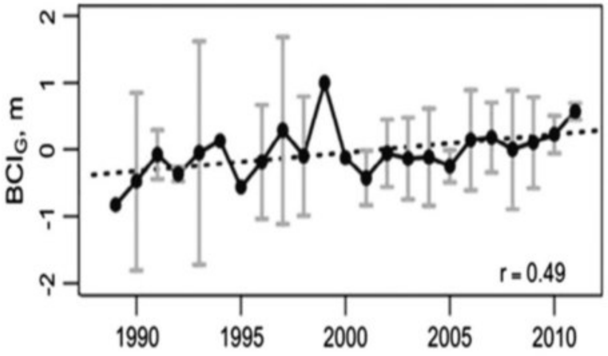


Fig. 2. Trend in BCI (body condition index based on axillary girth only) for fall subadult bowhead whales (1989–2011, $n = 100$). Data point for each year is the mean for all whales landed for that given fall season. Error bars represent the 95% confidence interval for the whales sampled that year (adapted from George et al. (2015)).

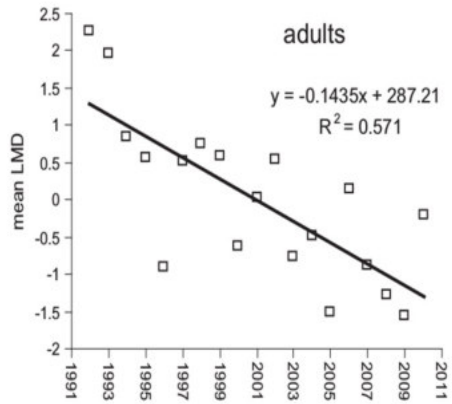


Fig. 4. Temporal trend in mean annual body condition indices of adult ringed seals sampled near Ulukhaktok, NT, June–July, 1992–2010 (adapted from Harwood et al. (2012a)).

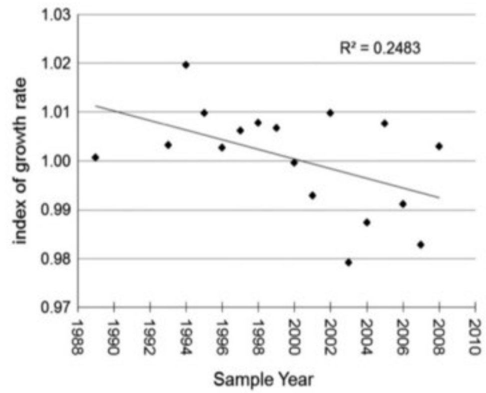
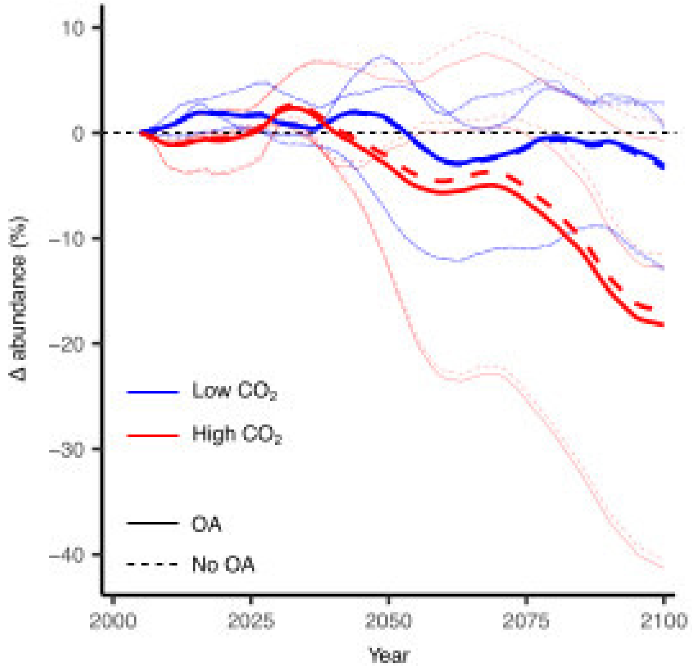


Fig. 5. Temporal trend in size-at-age (growth rate) of belugas landed in Delta and Paulatuk subsistence harvests, 1989, and 1993–2008 (adapted from Harwood et al. (2014)).

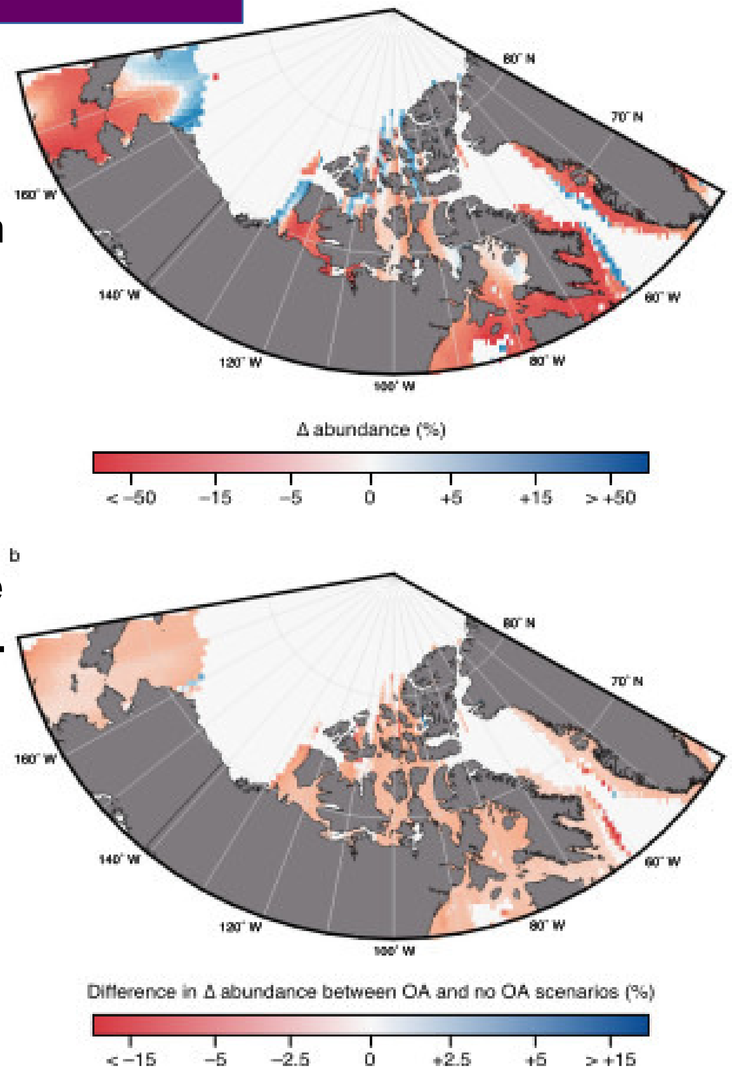
Increased body condition for subadult bowhead whale, Arctic Char: linked to retreating ice and increase in zooplankton production – feed on Arctic cod and other forage species

Decrease for adult ringed seal, beluga whale, black guillemot – Arctic cod preference

Dynamic Bioclimatic Envelope Model (DBEM) Changes in abundance of Arctic cod



* Mean of 3 different Earth System Models for high CO2 emission scenario (RCP8.5)
* OA impact expressed via growth and survival
* Changes are by 2100 relative to the 2001-2010 average.



Ecopath Model: **A sudden decrease in the energetic contributions from Arctic Cod with a warming Beaufort Sea causes higher trophic level predators (Beluga Whales, Ringed Seals, Arctic Char) to alter their prey, possibly shifting to sub-Arctic species such as Capelin.**

Key Points

Climate change and ocean acidification will likely cause significant changes in species composition, potentially leading to changes in ecosystem structure and in Inuit subsistence fisheries:

Warming waters and sea-ice retreat are likely to lead to increased productivity and a greater potential harvest, commercial or otherwise, with acidification having a modest negative effect primarily on invertebrate harvests.

The abundance of Arctic cod could decline, while other forage species, such as capelin and sandlance, are likely to migrate northwards into the region. This could affect its predators, including culturally important species hunted by Inuit (e.g. ringed seals, beluga). If subsistence species are able to adapt to alternate prey, climate change impacts will likely be positive.

Uncertainty is high for species responses to acidification, particularly in combination with other stressors. There is a need for multi-stressor research into how (Arctic-specific) species are likely to respond. => Monitoring and laboratory research into physiological responses and genetic adaptation will be key in improving predictions. Uncertainties remain with respect to future emissions as well as model responses.


Monitoring environmental conditions
In combination with the food chain
Photo: Leukos
Photo: G.Divoky, North Slope Borough
Photo: George Divoky
Photos: H.Drost

Key Points - continued

Ecosystem changes should be monitored in such a way that allows for the identification and differentiation of the impact of each stressor on the ecosystem, as well as the potential synergistic effects of multiple combined stressors (monitoring environmental conditions and the food chain). There is need for a unified monitoring program to harmonize and support adaptation actions in the Arctic. This includes actively involving local communities in monitoring and research projects.

=> Lack of certainty about the interplay between biological changes and social and economic impacts of ocean acidification should not preclude action. Adaptation actions should be directed towards providing communities with flexibility, adaptability and economic and ecological resilience in the face of change and uncertainty. Proper measures must be taken to ensure the sustainability of these marine resources and to consider the ecological, social, cultural, and economic impacts of any actions.


Community based water sampling, Anguniaqvia
Niqiqyuam MPA,(Darnley Bay) March 2017:
Canadian Ranger Ocean Watch (CROW)
DFO/DND - local HTCs
Thanks.... nadja.steiner@canada.ca

Extra Slides

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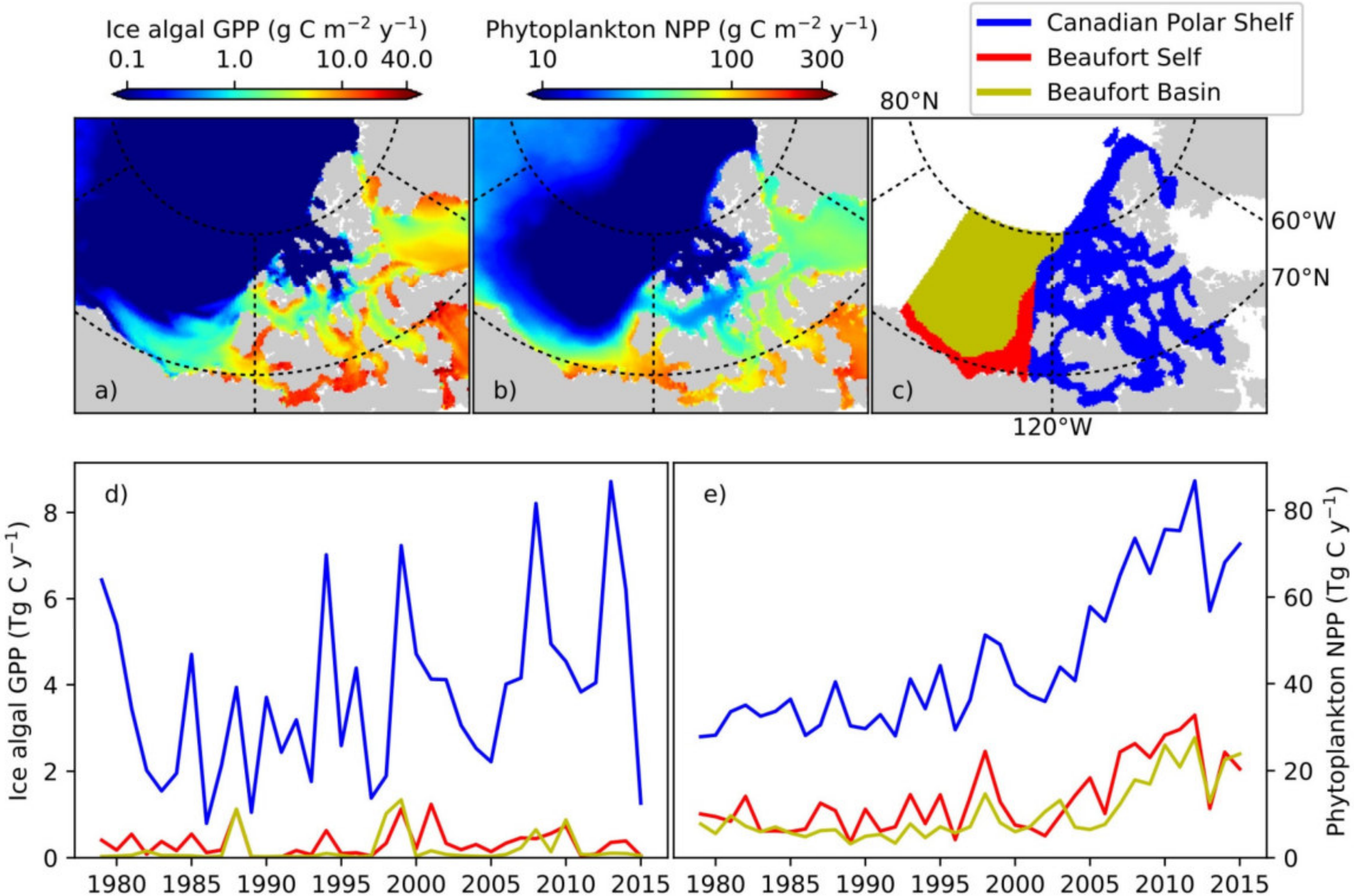

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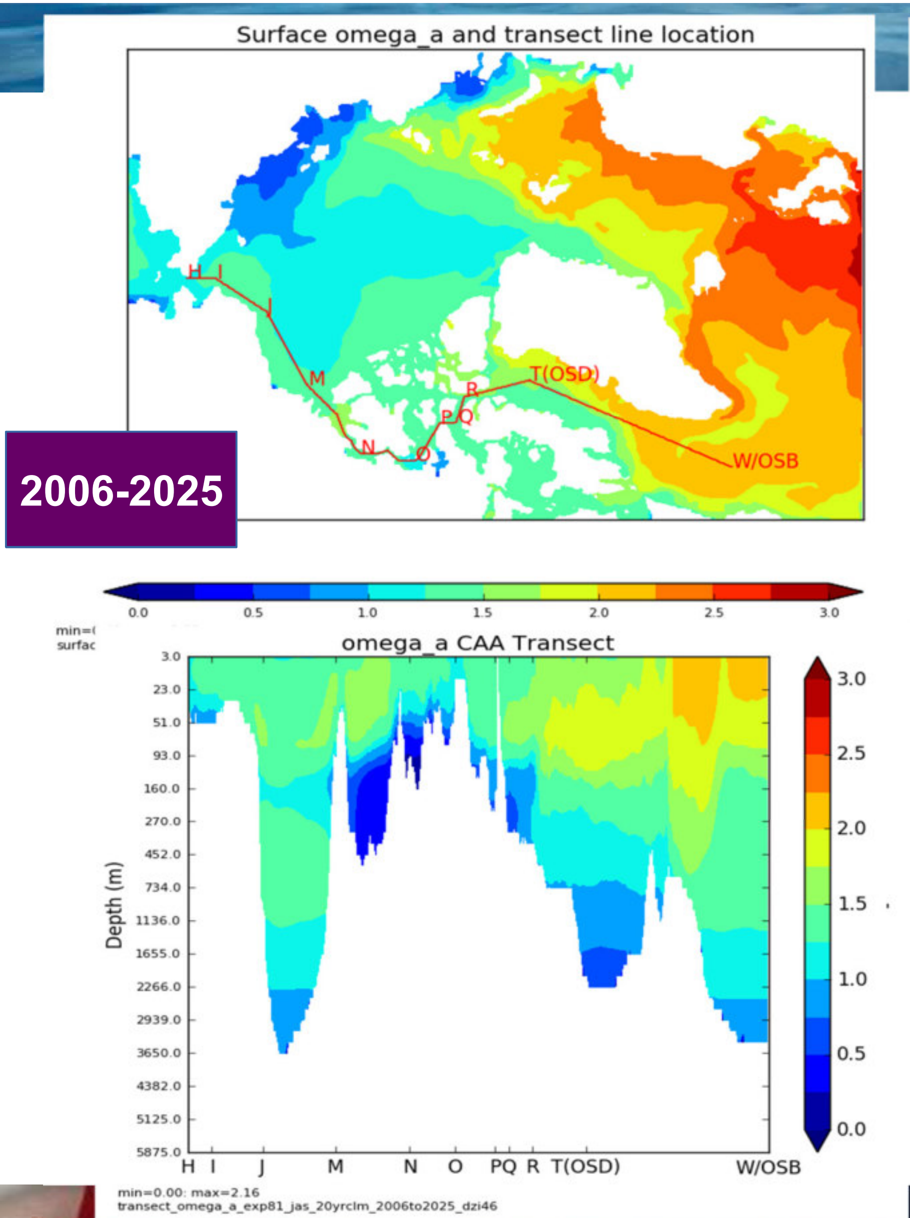
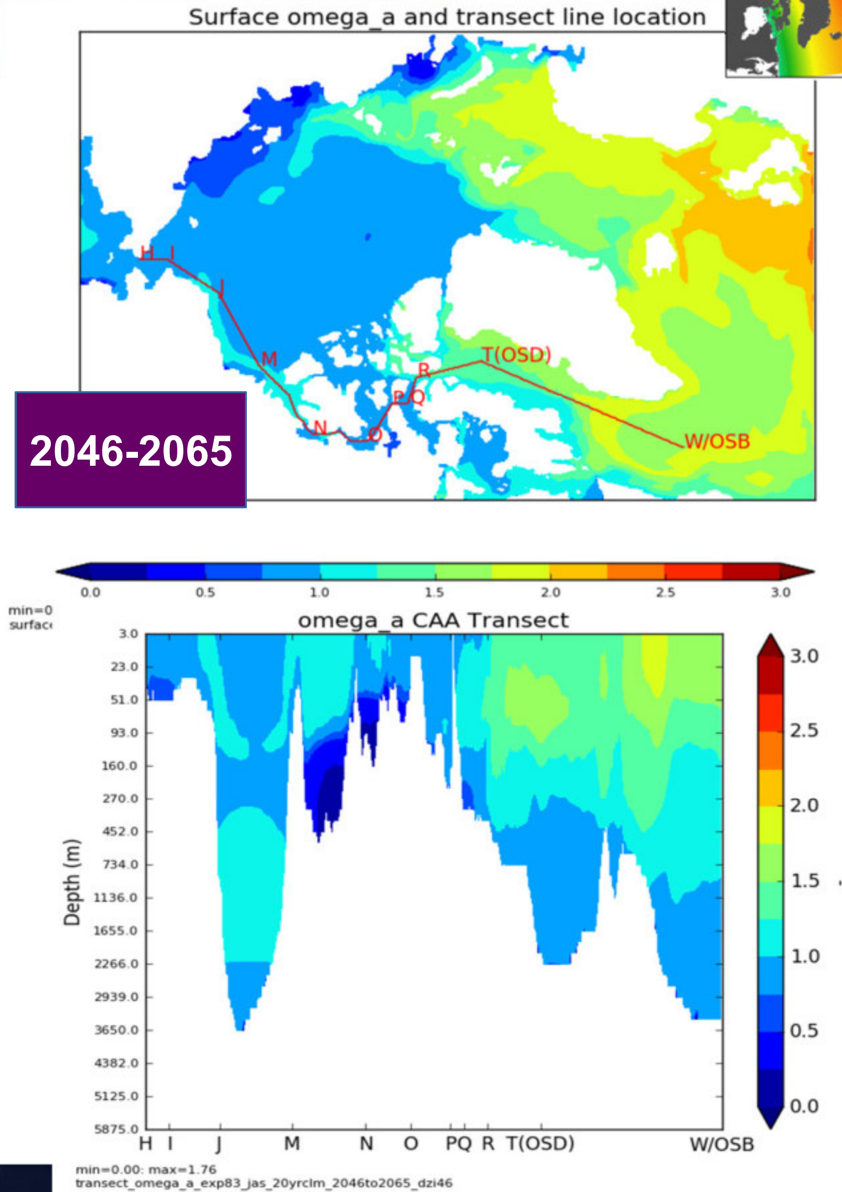
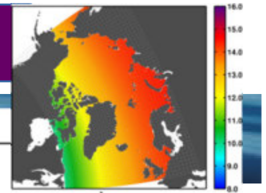
High resolution Arctic model: Projected Omega_a – Summer (RCP8.5)







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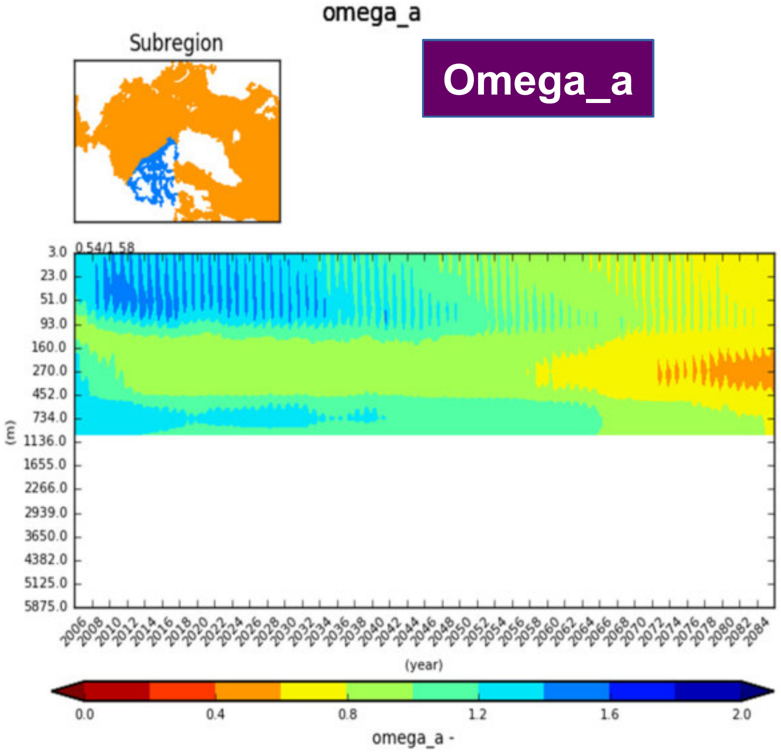
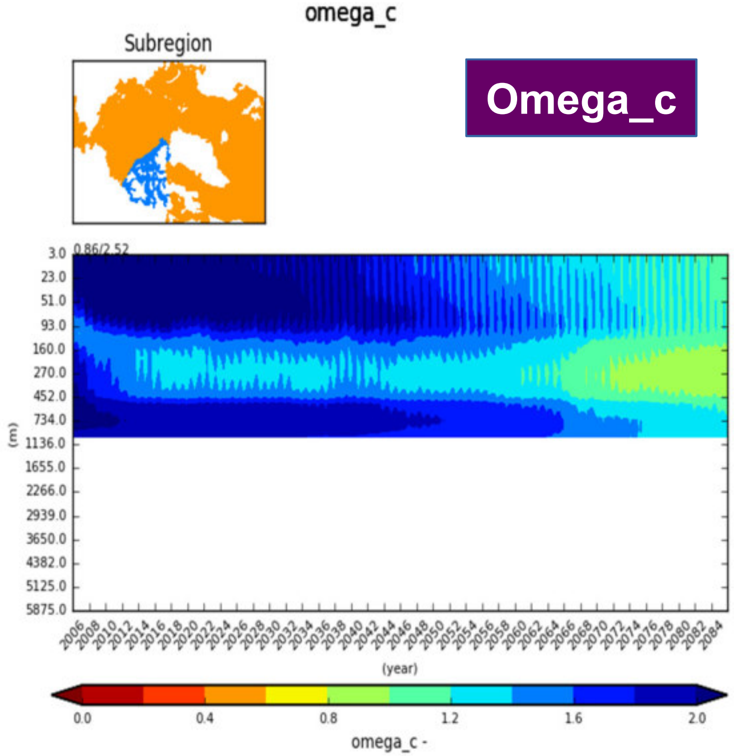
Projected ocean acidification (High emission RCP8.5)





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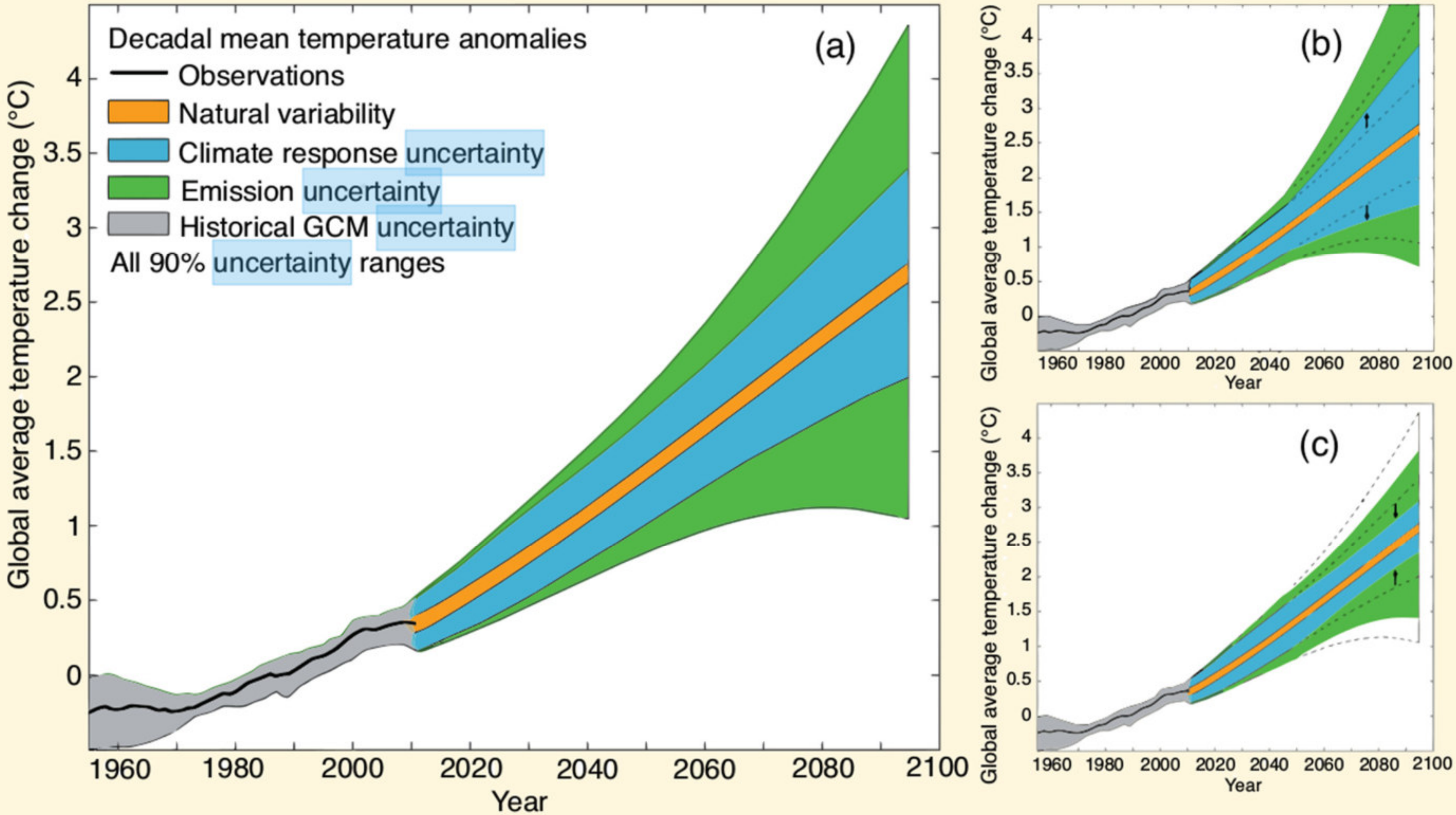
Climate Model Uncertainties – Regional Downscaling



Cubasch et al. 2013, IPCC