



ICMGP 2024
CAPE TOWN • SOUTH AFRICA • 21 - 26 JULY

Combining Mercury Stable Isotopes and Sea Ice Biomarkers to Provide New Insights into the Role of Sea Ice in Mercury Contamination in Arctic Seabirds

Charrier Julie

David Amouroux, Guillaume Massé, Océane Asensio, Marta Cruz-Flores, H. Grant Gilchrist, Gaël Guillou, David Grémillet, Sveinn A. Hanssen, Vincent Klein, Thomas Lacoue-Labarthe, Oliver P. Love, Børge Moe, Reyd A. Dupuis-Smith, Grigori Tertitski, Emmanuel Tessier, Jérôme Fort



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Hg

Mercury (Hg) is a **toxic** contaminant distributed **worldwide**

Hg⁰

Atmospheric Global Circulation

Mercury (Hg) is a **toxic** contaminant distributed **worldwide**

Hg^0

Atmospheric Global Circulation

Mercury (Hg) is a **toxic** contaminant distributed **worldwide**

Rivers MeHg Hg^{2+}



Atmospheric Global Circulation

Mercury (Hg) is a **toxic** contaminant distributed **worldwide**

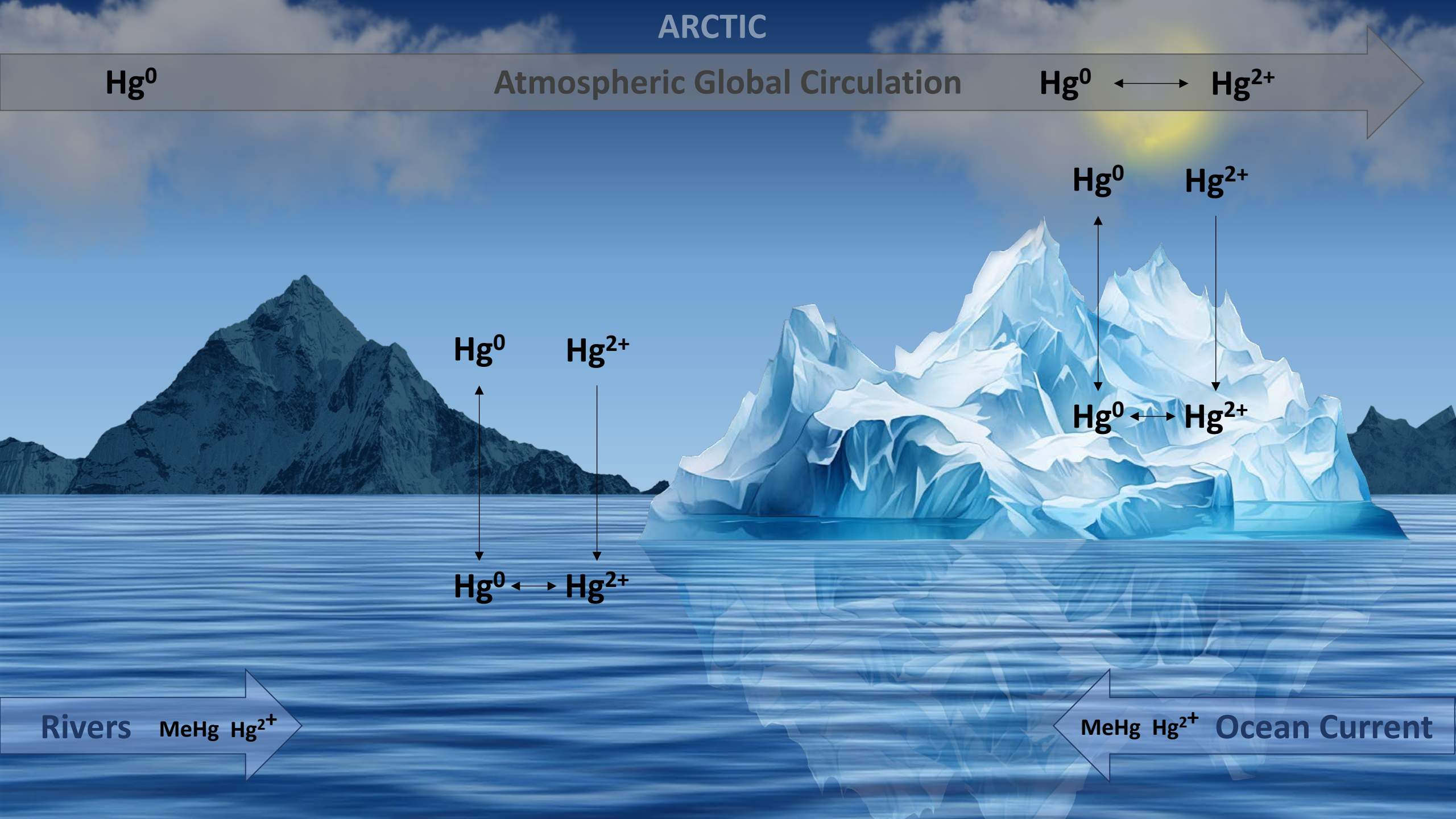
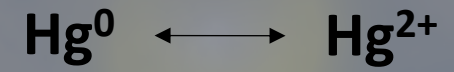
Rivers MeHg Hg^{2+}

MeHg Hg^{2+} Ocean Current

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Atmospheric Global Circulation



Rivers MeHg Hg^{2+}

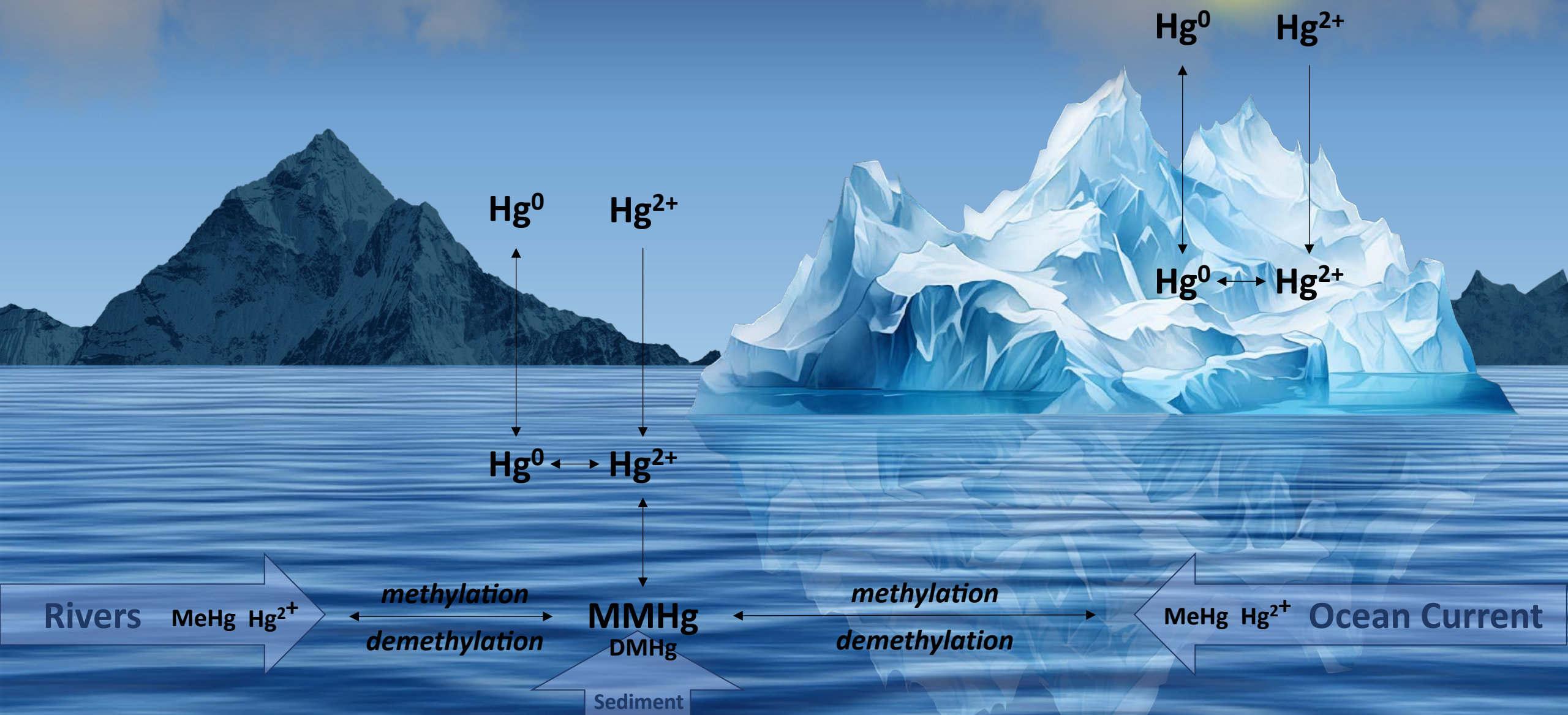
MeHg Hg^{2+} Ocean Current

ARCTIC

Hg^0

Atmospheric Global Circulation

$\text{Hg}^0 \longleftrightarrow \text{Hg}^{2+}$



Rivers

MeHg Hg^{2+}

methylation
demethylation

MMHg
DMHg

Sediment

methylation
demethylation

MeHg Hg^{2+}

Ocean Current

ARCTIC

Hg^0

Atmospheric Global Circulation

$\text{Hg}^0 \longleftrightarrow \text{Hg}^{2+}$

Bioaccumulation & Biomagnification

Hg^0

Hg^{2+}

Hg^0

Hg^{2+}

Hg^0

Hg^{2+}

Rivers

MeHg Hg^{2+}

methylation
demethylation

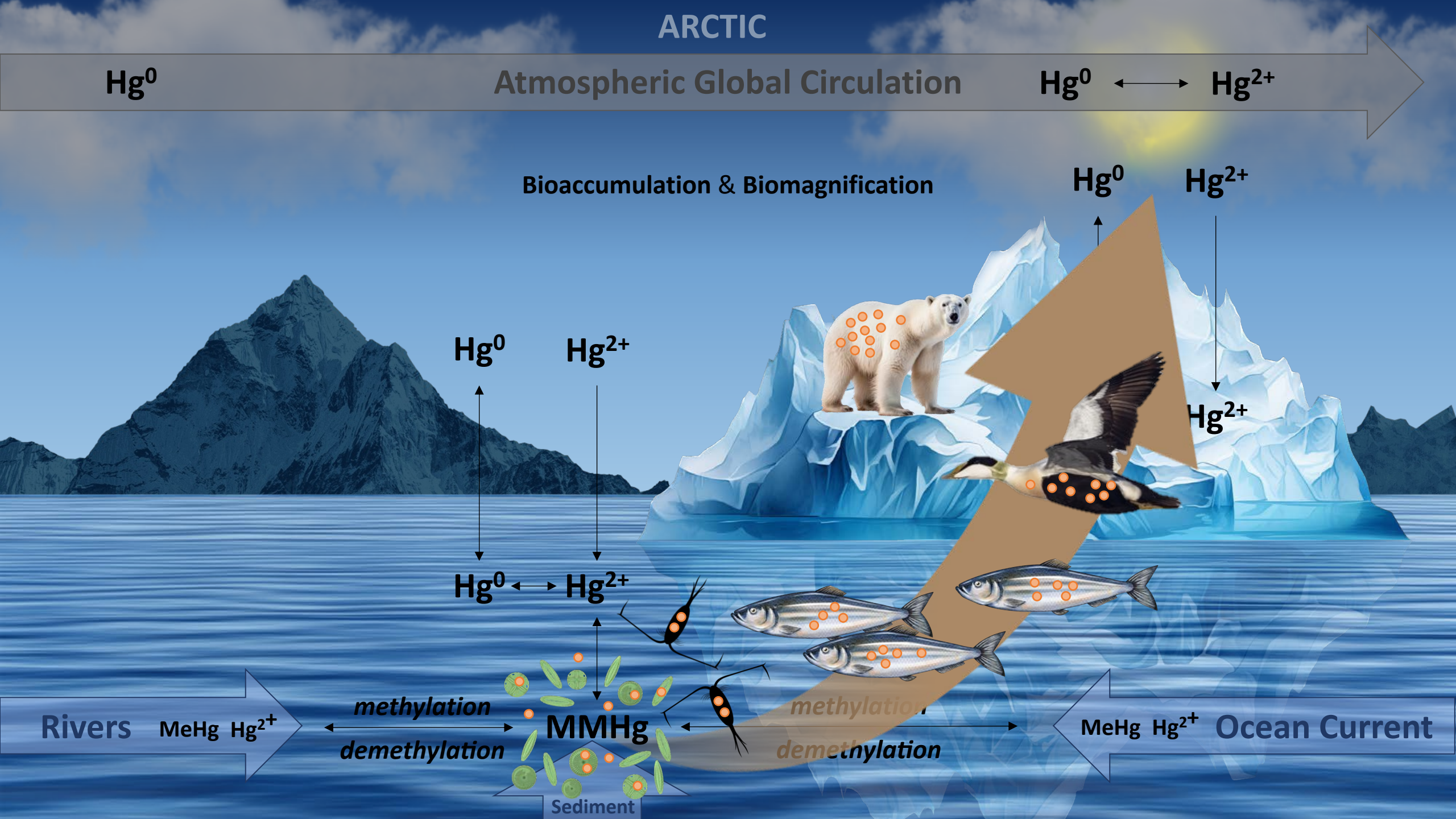
MMHg

methylation
demethylation

MeHg Hg^{2+}

Ocean Current

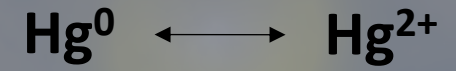
Sediment



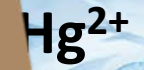
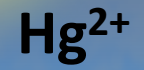
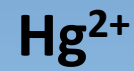
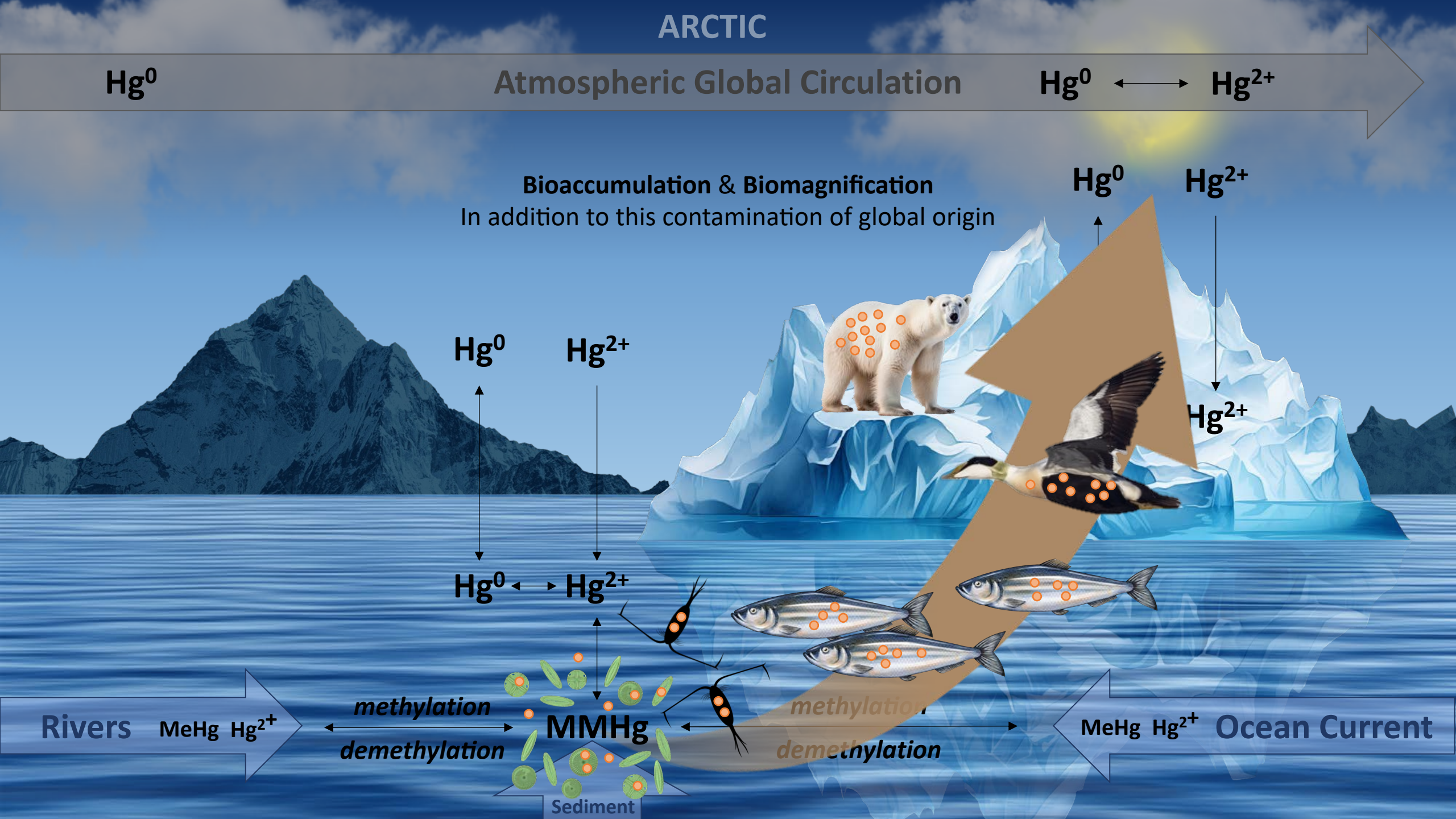
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Atmospheric Global Circulation



Bioaccumulation & Biomagnification
In addition to this contamination of global origin



Rivers



methylation
demethylation

MMHg

Sediment

methylation
demethylation



Ocean Current

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Accelerated melting of **sea ice cover**



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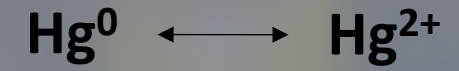
Accelerated melting of **sea ice cover**
Sea ice is central to the **Arctic Hg biogeochemical cycle**



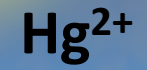
ARCTIC



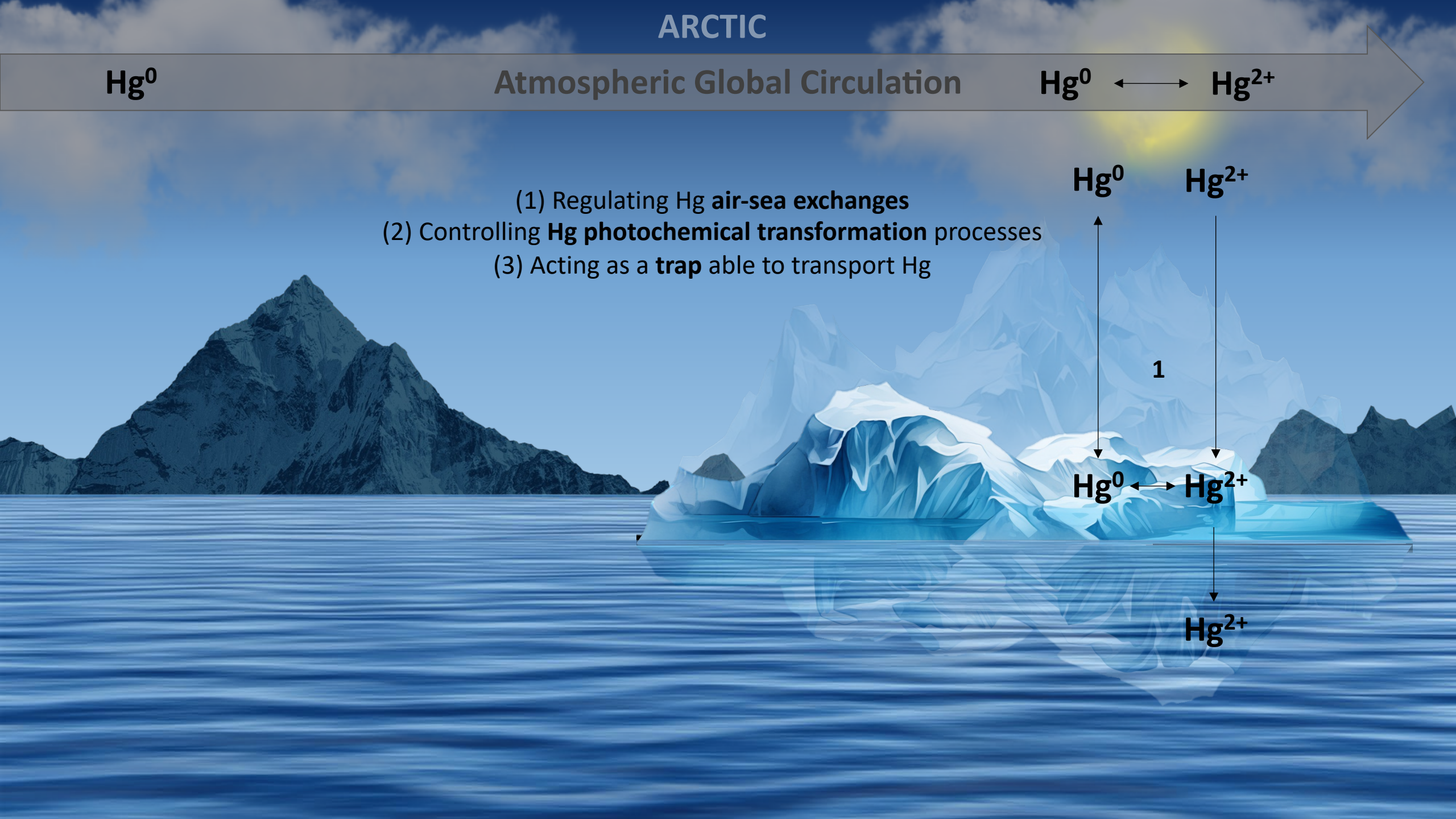
Atmospheric Global Circulation



- (1) Regulating Hg air-sea exchanges
- (2) Controlling Hg photochemical transformation processes
- (3) Acting as a trap able to transport Hg



1



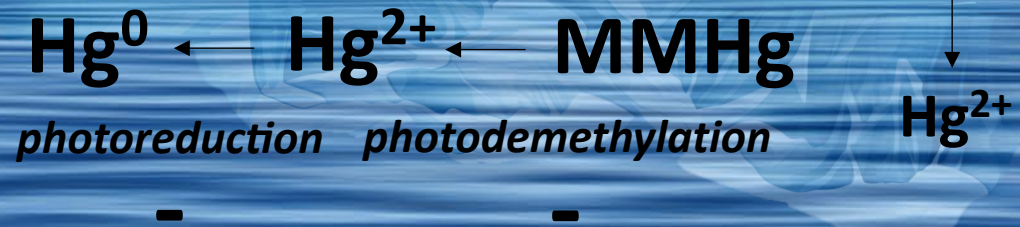
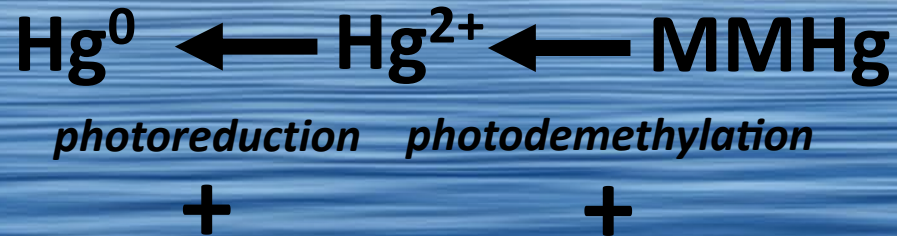
ARCTIC

Hg^0

Atmospheric Global Circulation

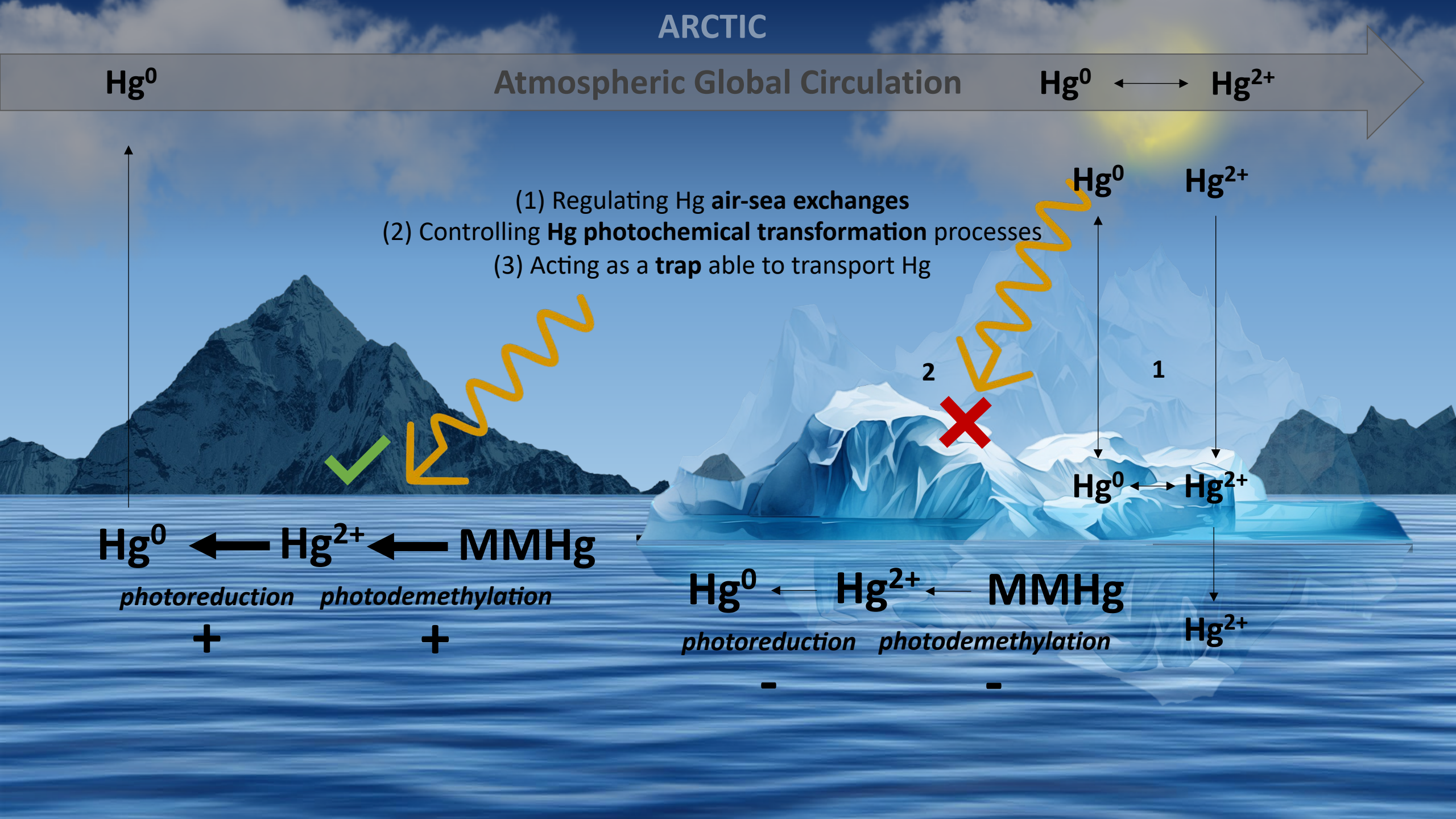
$\text{Hg}^0 \longleftrightarrow \text{Hg}^{2+}$

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Hg^0 Hg^{2+}

$\text{Hg}^0 \longleftrightarrow \text{Hg}^{2+}$



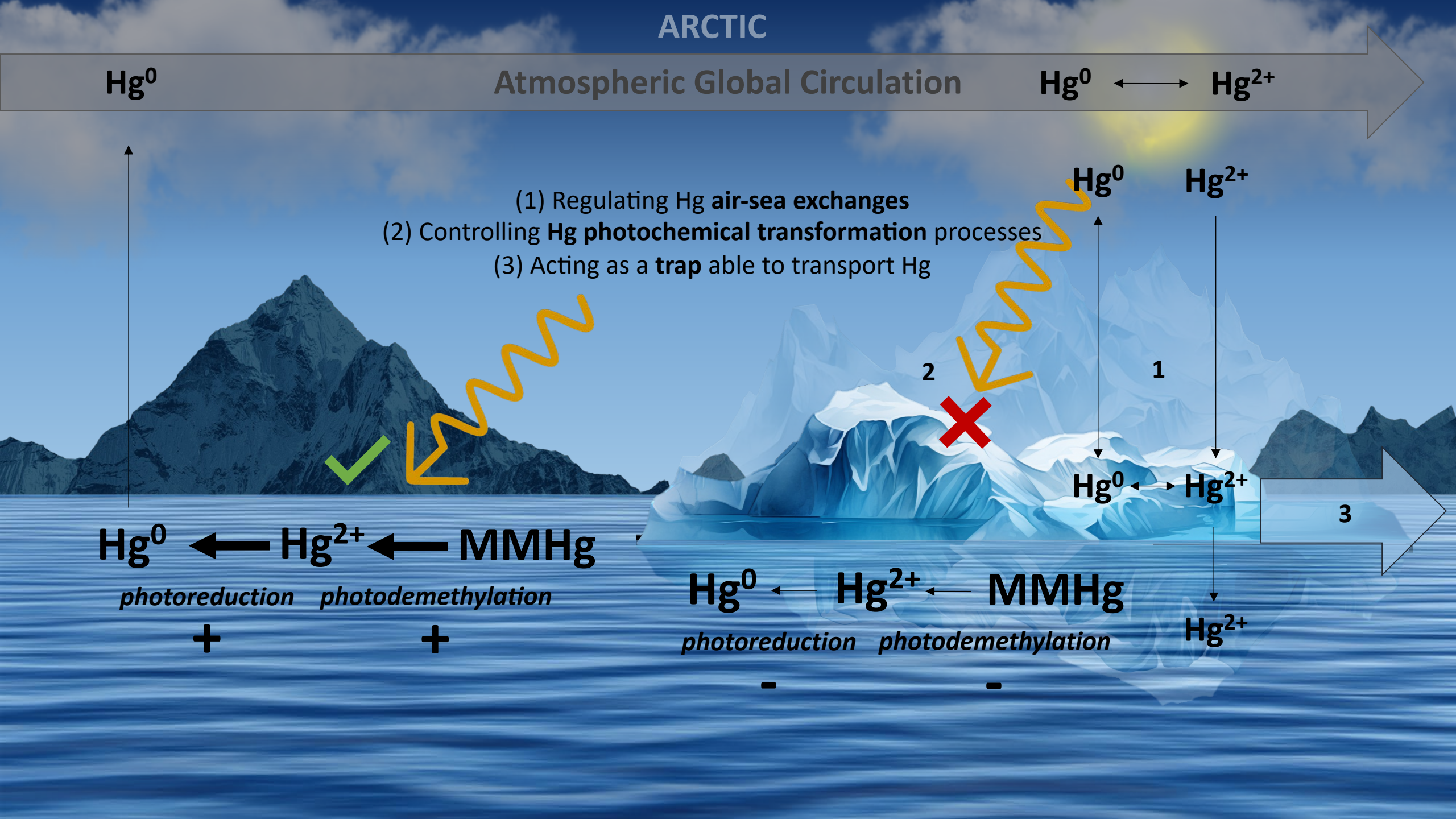
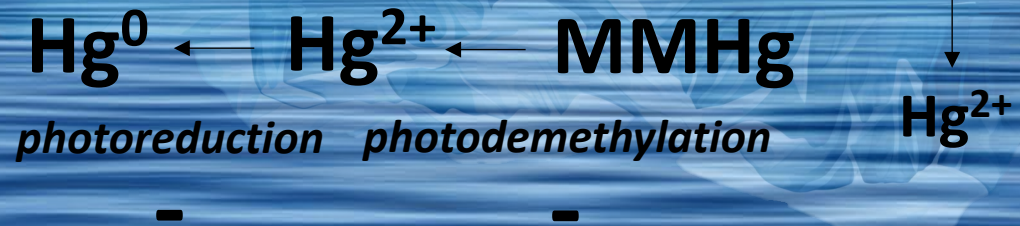
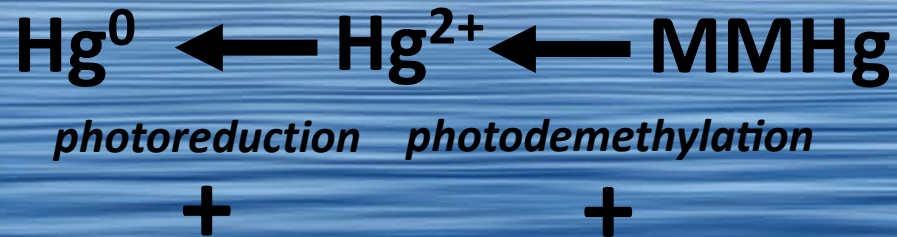
ARCTIC

Hg^0

Atmospheric Global Circulation

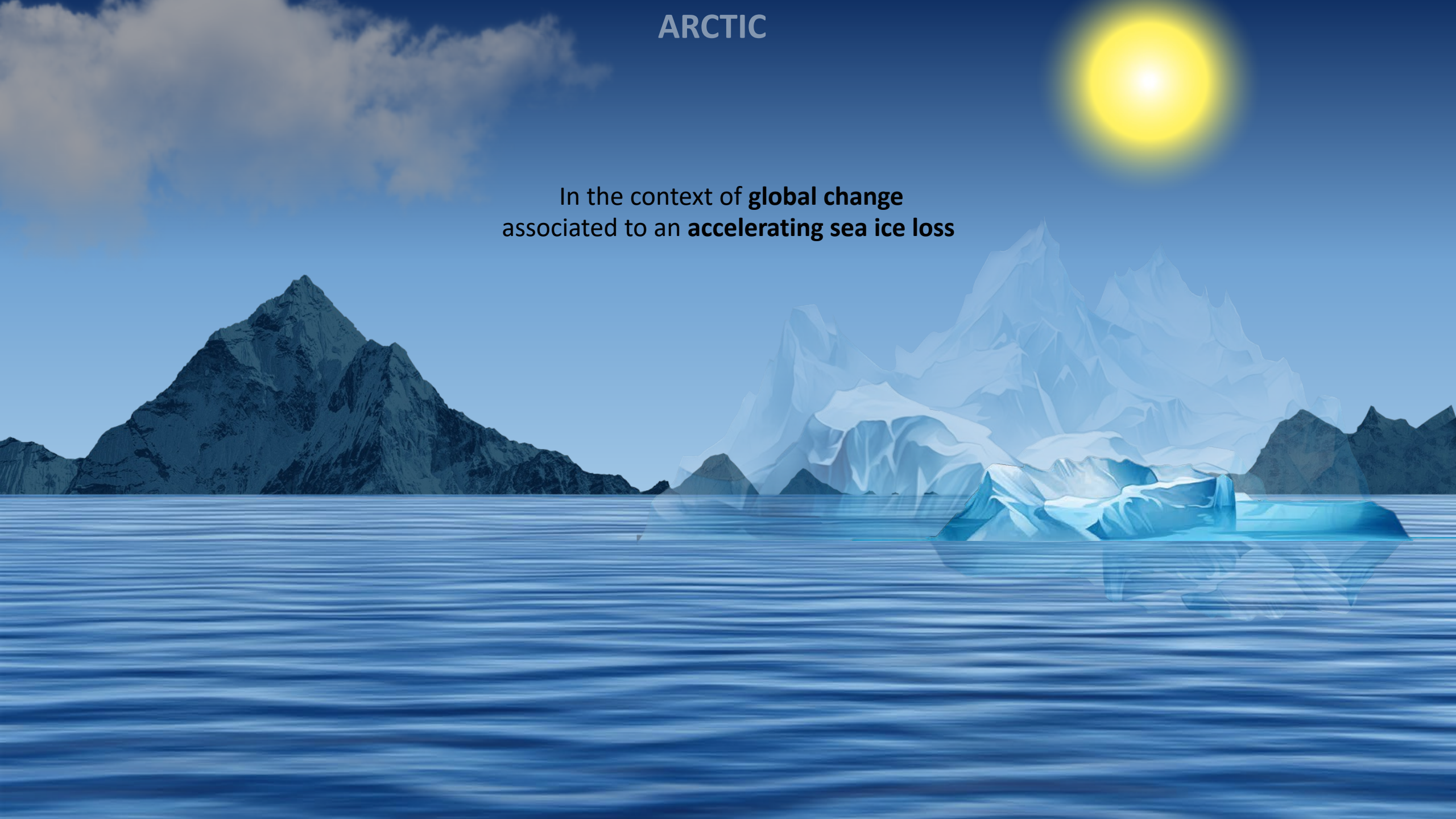
$\text{Hg}^0 \longleftrightarrow \text{Hg}^{2+}$

- (1) Regulating Hg air-sea exchanges
- (2) Controlling Hg photochemical transformation processes
- (3) Acting as a trap able to transport Hg



ARCTIC

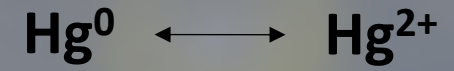
In the context of **global change**
associated to an **accelerating sea ice loss**



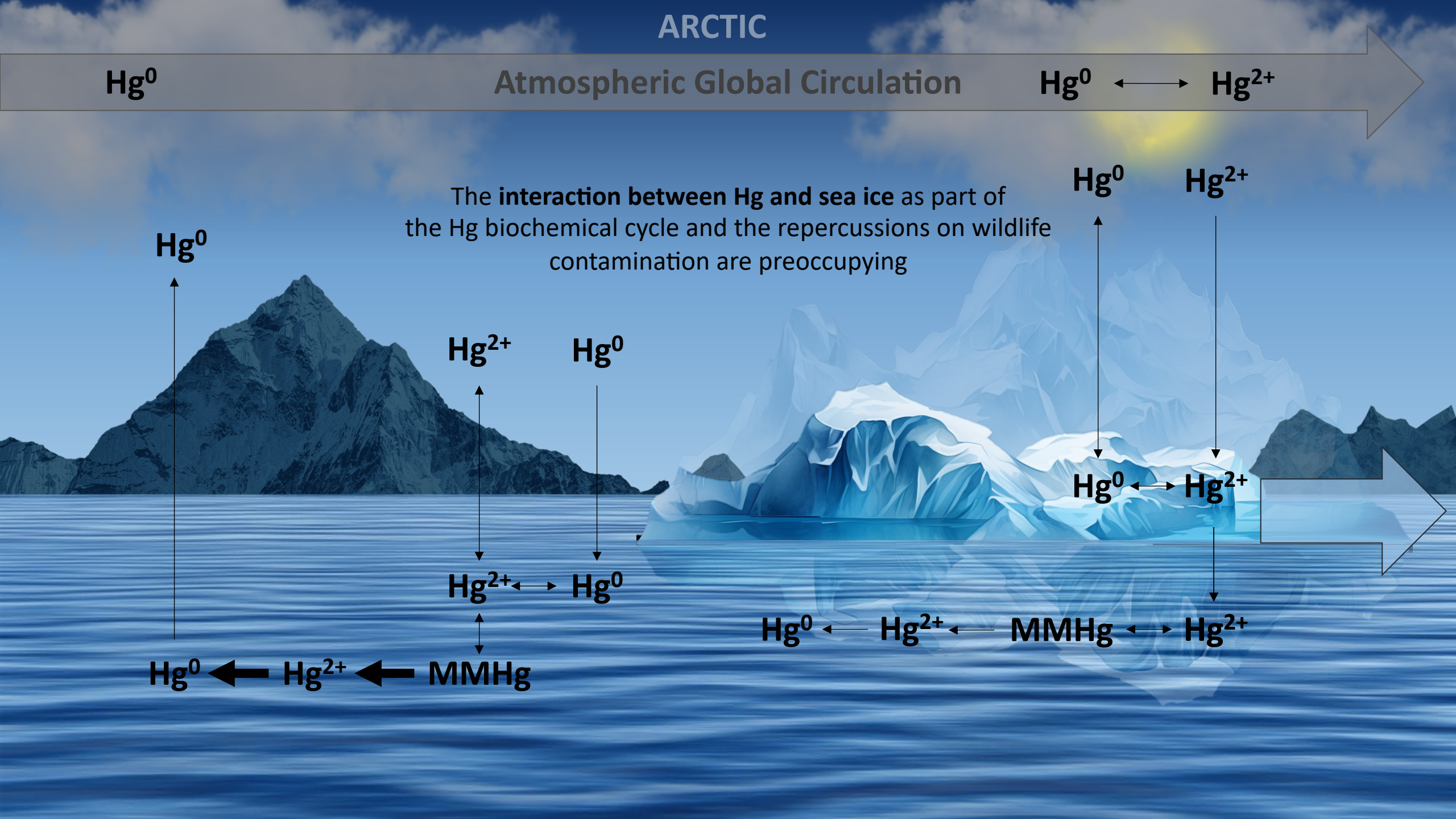
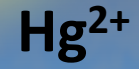
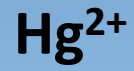
ARCTIC



Atmospheric Global Circulation



The interaction between Hg and sea ice as part of the Hg biochemical cycle and the repercussions on wildlife contamination are preoccupying





The role of sea ice in Hg contamination in Arctic predators?

**Identify the sources of Hg contamination in the Arctic?
Sea ice act as a source of contamination ?**



The role of sea ice in Hg contamination in Arctic predators?
Sea ice biomarkers

Identify the sources of Hg contamination in the Arctic?
Sea ice act as a source of contamination ?

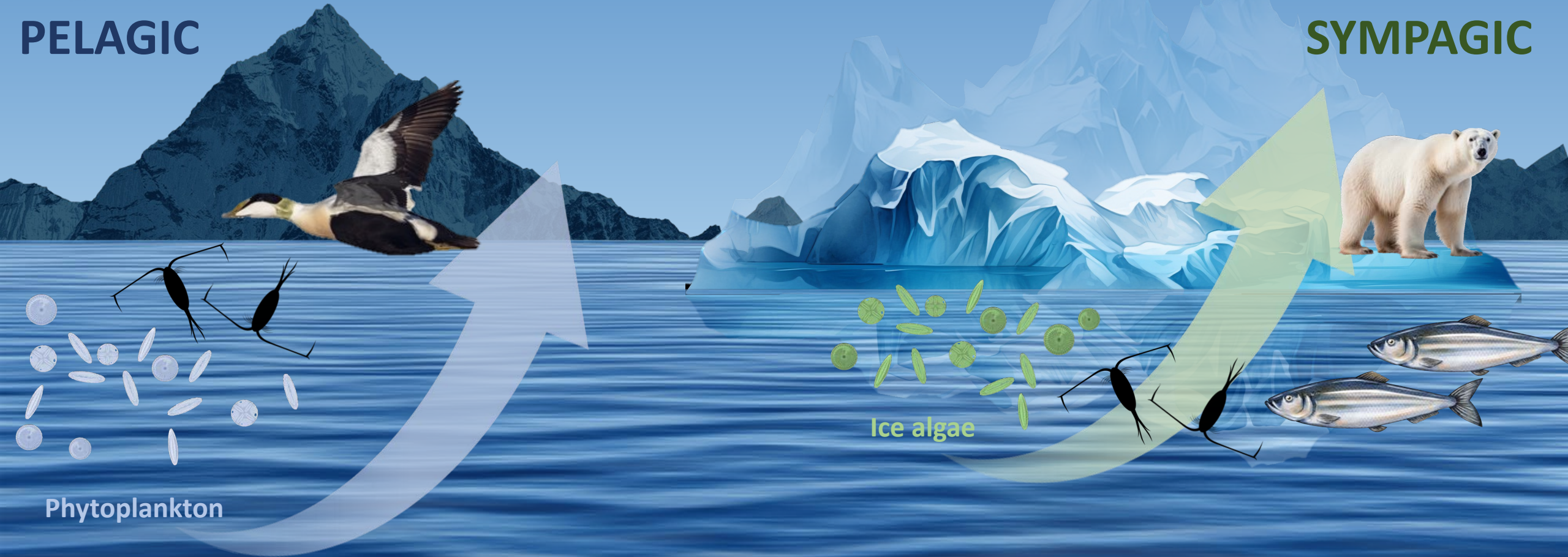
ARCTIC

Indirect interaction between Arctic predators and sea ice

Highly branched isoprenoids alkenes (HBIs)

PELAGIC

SYMPAGIC



Phytoplankton

Ice algae

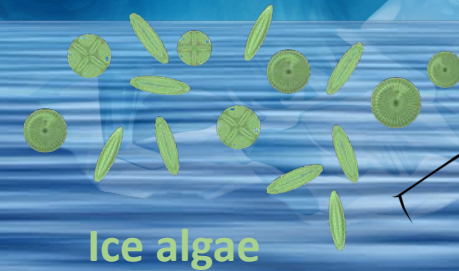
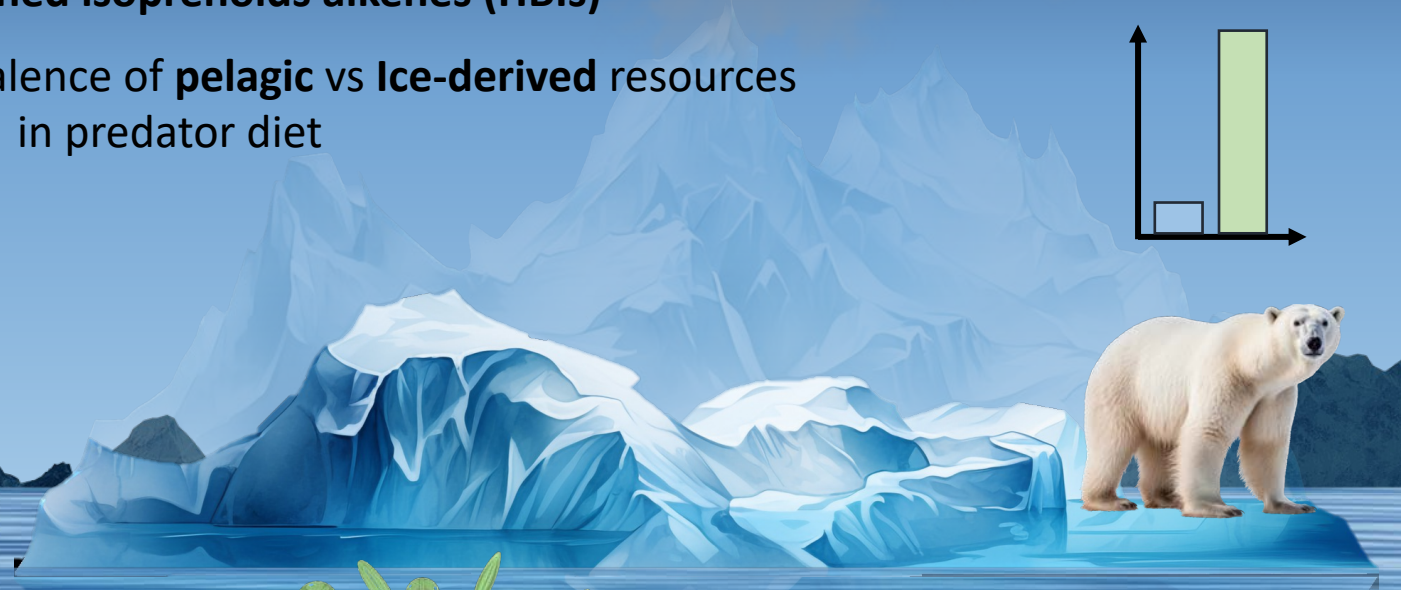
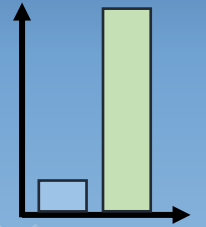
ARCTIC

Indirect interaction between Arctic predators and sea ice

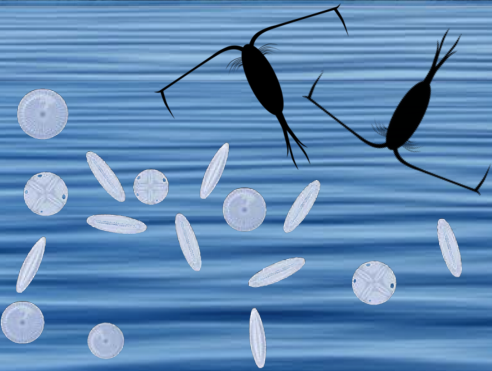
Highly branched isoprenoids alkenes (HBIs)

Estimation of the prevalence of **pelagic** vs **Ice-derived** resources in predator diet

SYMPAGIC



Ice algae



Phytoplankton

ARCTIC

Indirect **interaction** between top Arctic **predators** and sea ice

PELAGIC

SYMPAGIC

Highly branched isoprenoids alkenes (HBIs)

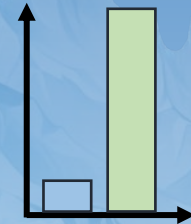
Estimation of **pelagic** vs **Ice-derived** resources

Proportion of sea ice particulate organic carbon (*i*POC)



0%

100%





The role of sea ice in Hg contamination in Arctic predators?

**Identify the sources of Hg contamination in the Arctic?
Sea ice act as a source of contamination ?**



The role of sea ice in Hg contamination in Arctic predators?

Identify the sources of Hg contamination in the Arctic?

Sea ice act as a source of contamination ?

Hg stable isotopes

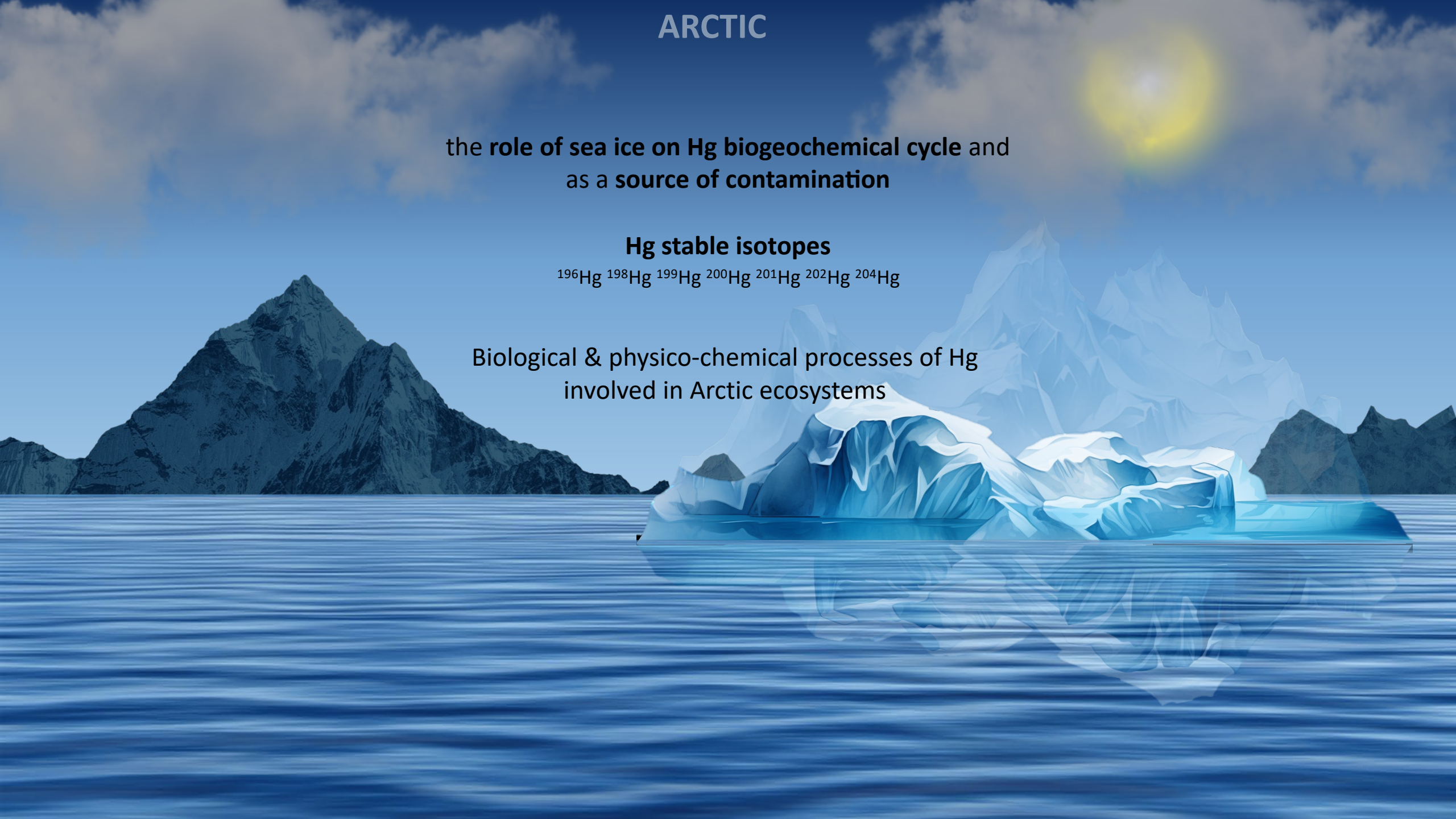
ARCTIC

the role of sea ice on Hg biogeochemical cycle and
as a source of contamination

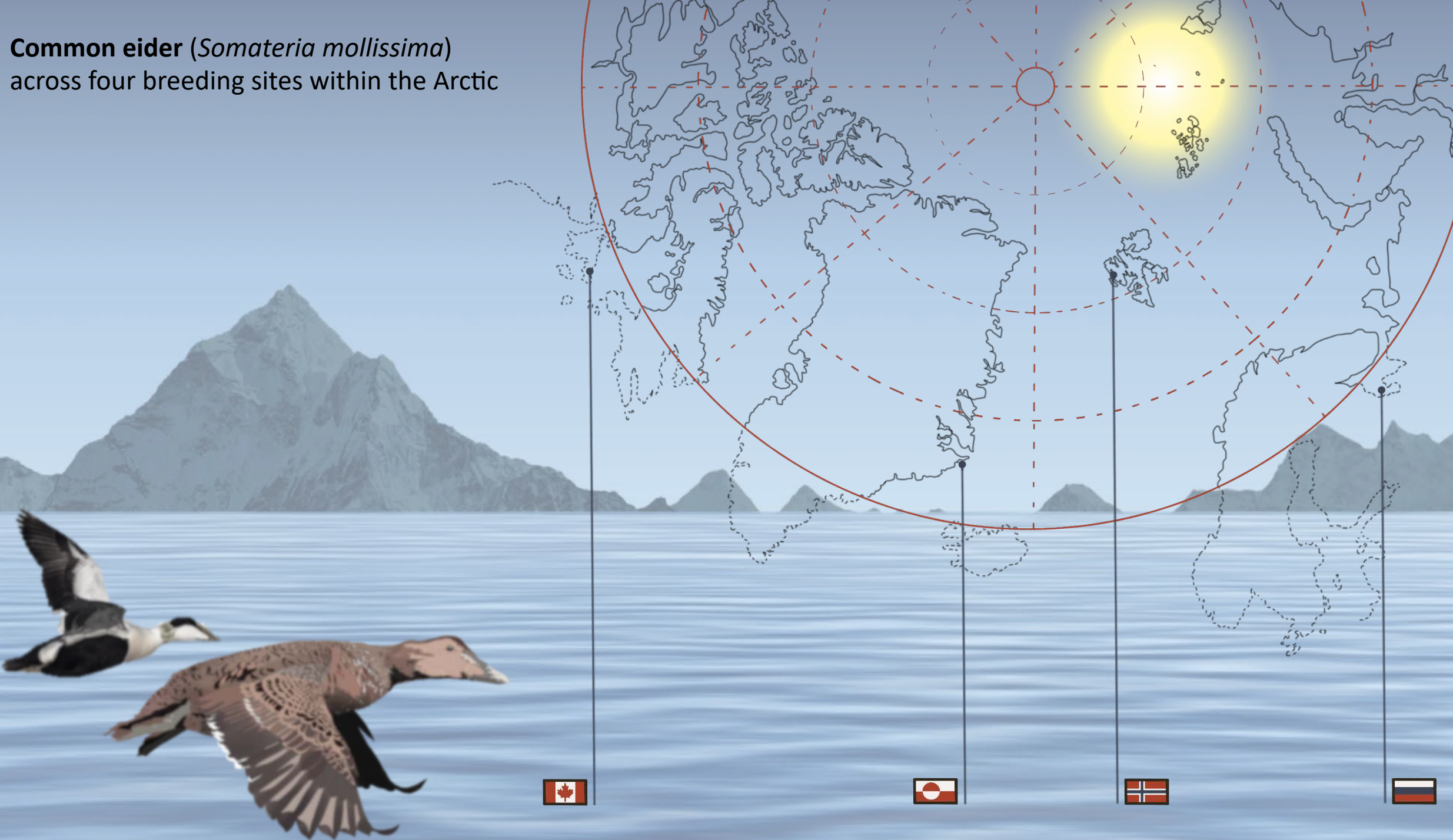
Hg stable isotopes

^{196}Hg ^{198}Hg ^{199}Hg ^{200}Hg ^{201}Hg ^{202}Hg ^{204}Hg

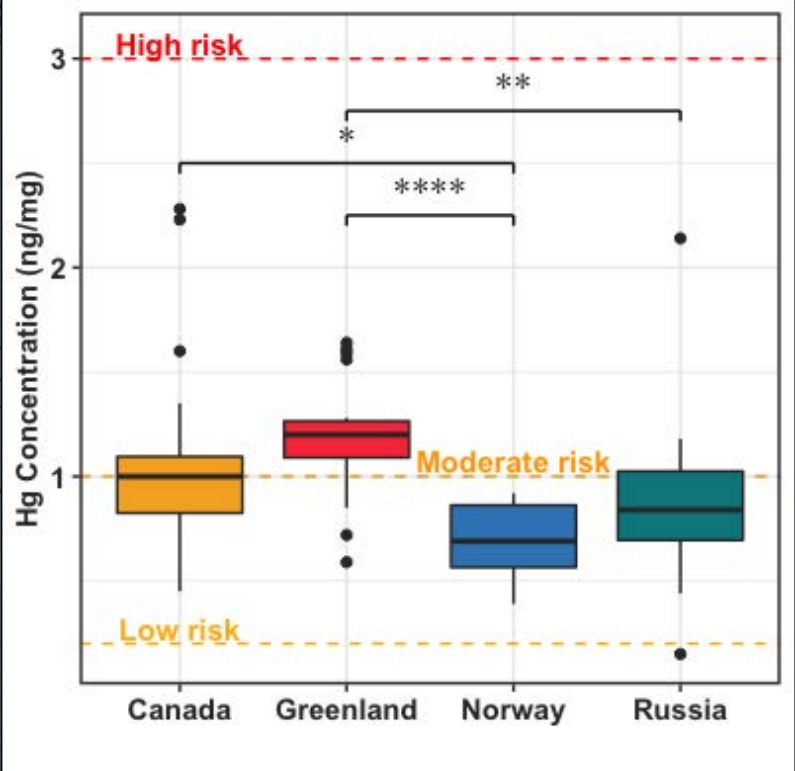
Biological & physico-chemical processes of Hg
involved in Arctic ecosystems



Common eider (*Somateria mollissima*)
across four breeding sites within the Arctic



Common eider (*Somateria mollissima*)
across four breeding sites within the Arctic

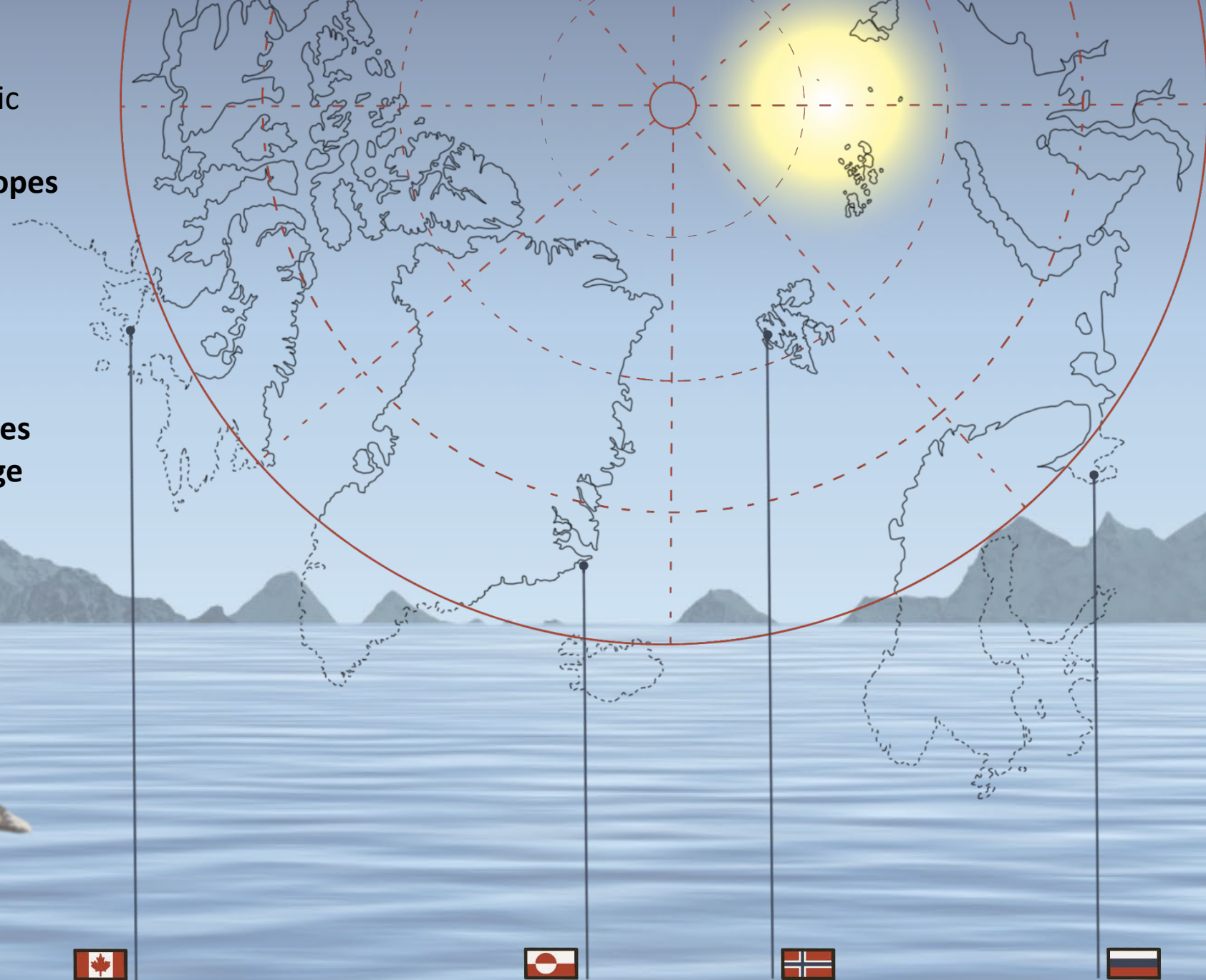


Common eider (*Somateria mollissima*)
across four breeding sites within the Arctic

Sea ice biomarkers and Hg stable isotopes
in blood samples

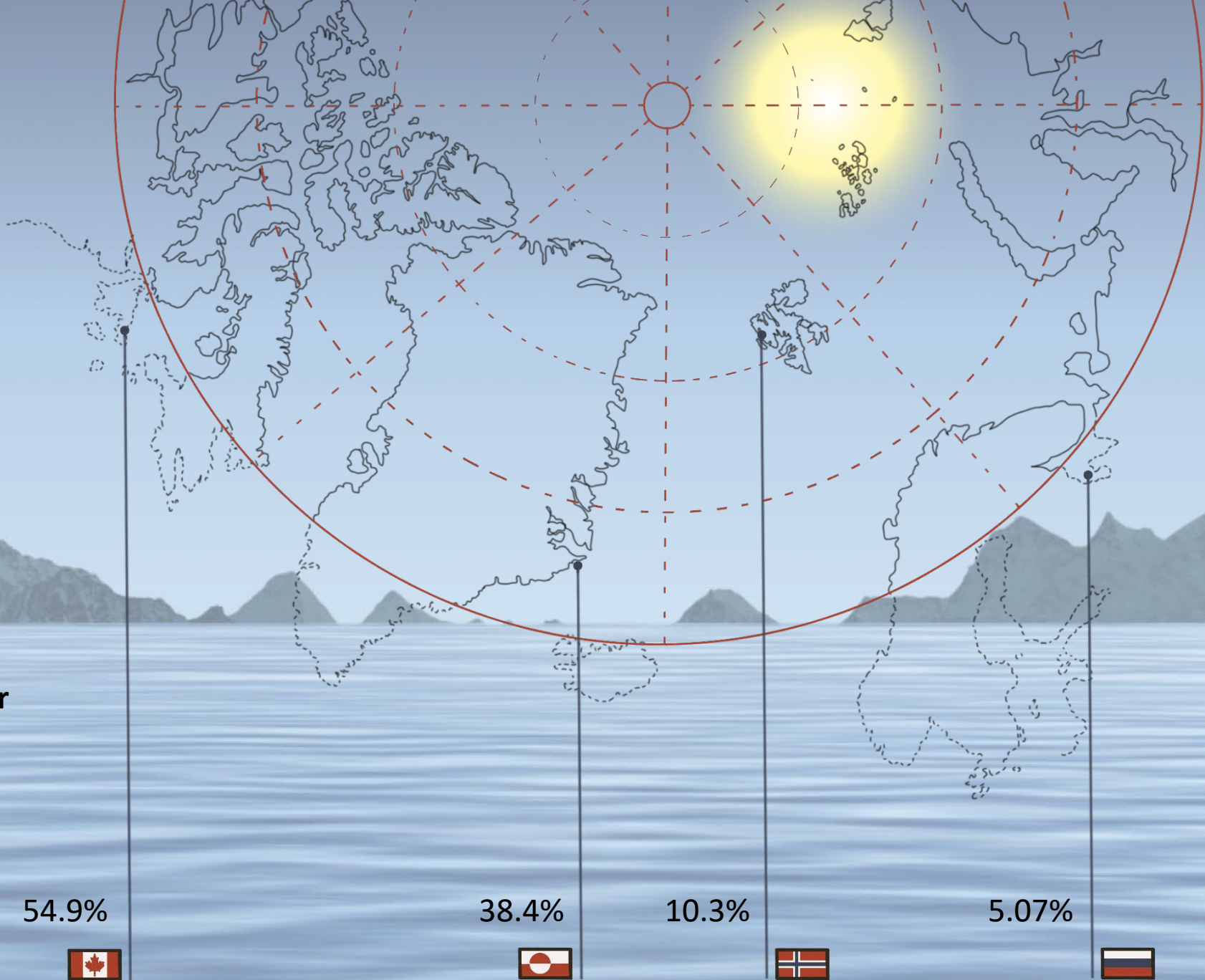


1. The use of sea ice-associated resources by eiders, relatively to sea ice coverage
2. Identify sources of Hg contamination.





Influence of sea ice cover on the prey diet of common eider?

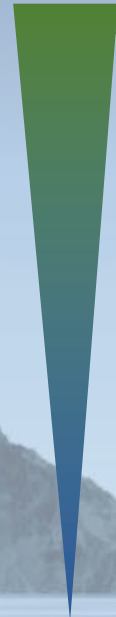


Different sea ice concentration during the sampling period of June

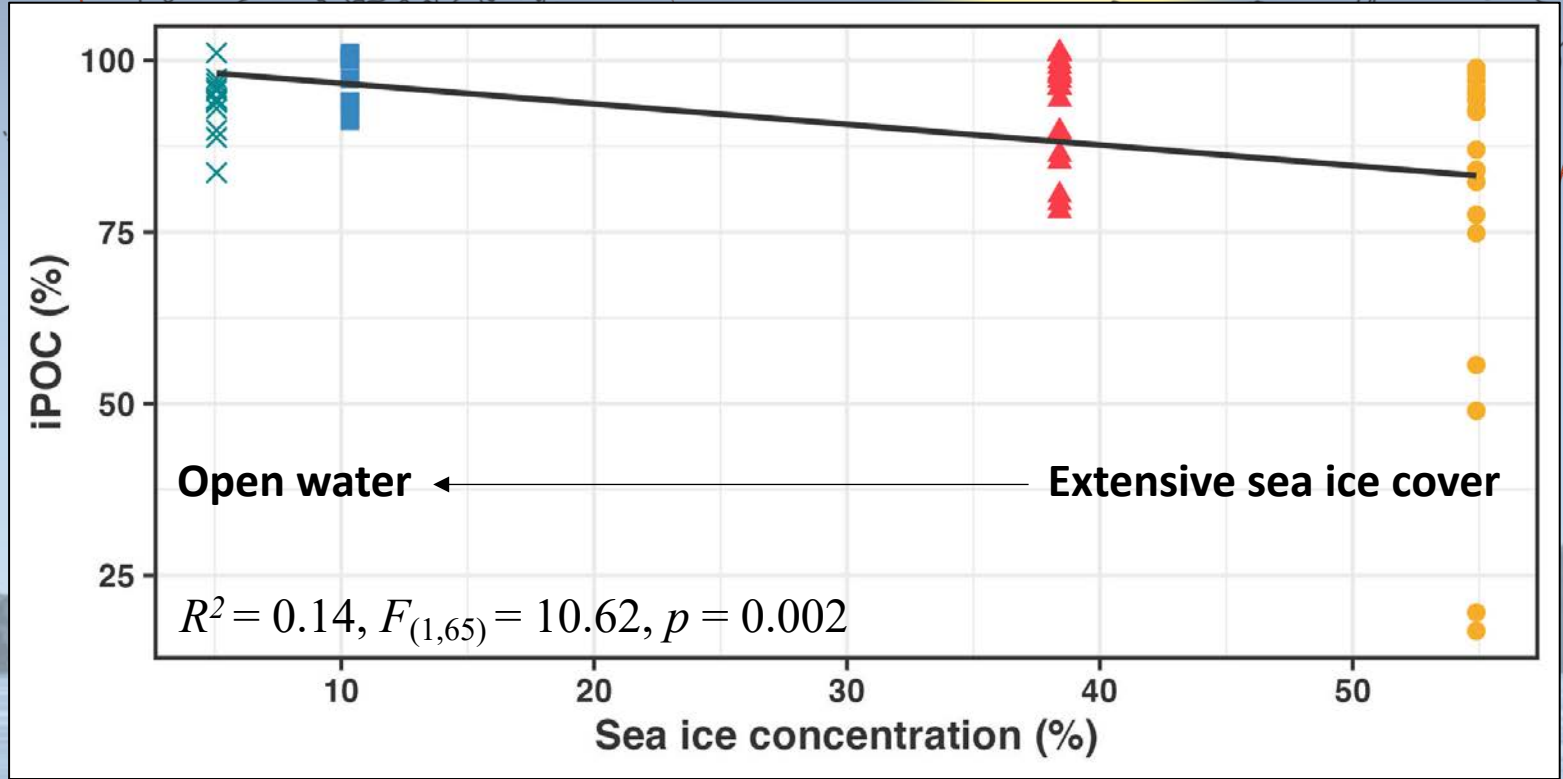
From **extensive** cover to **open water**



sympagic



pelagic



The proportion of sea ice particulate organic carbon was correlated with sea ice melt stages

54.9%



38.4%



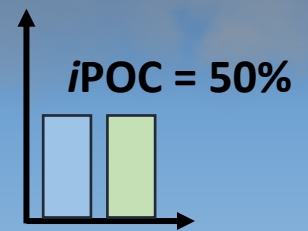
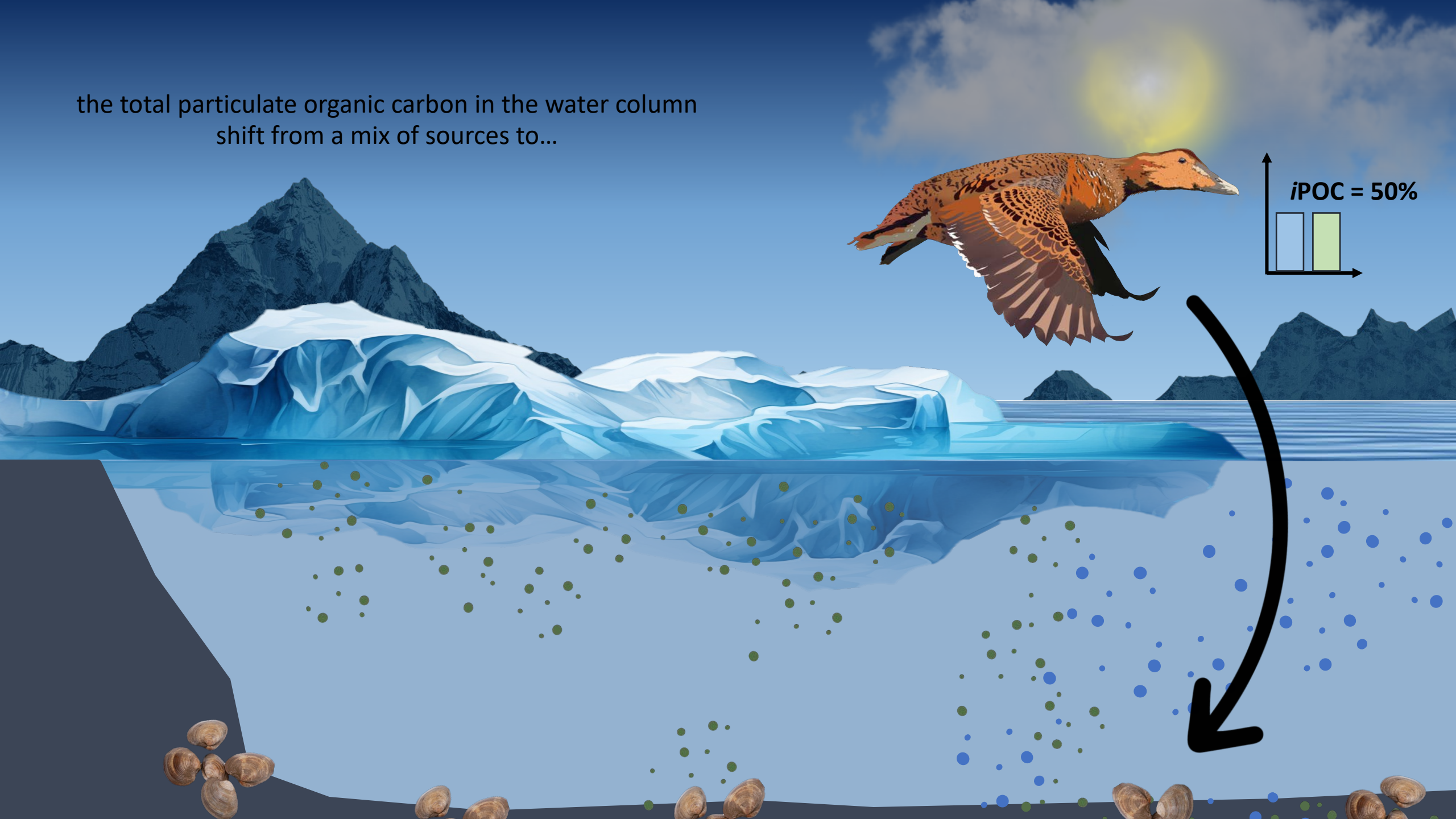
10.3%



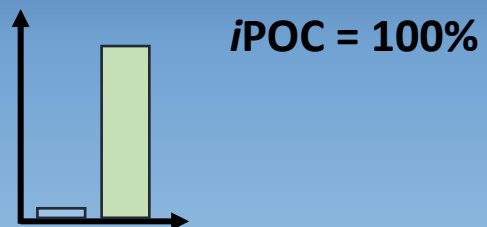
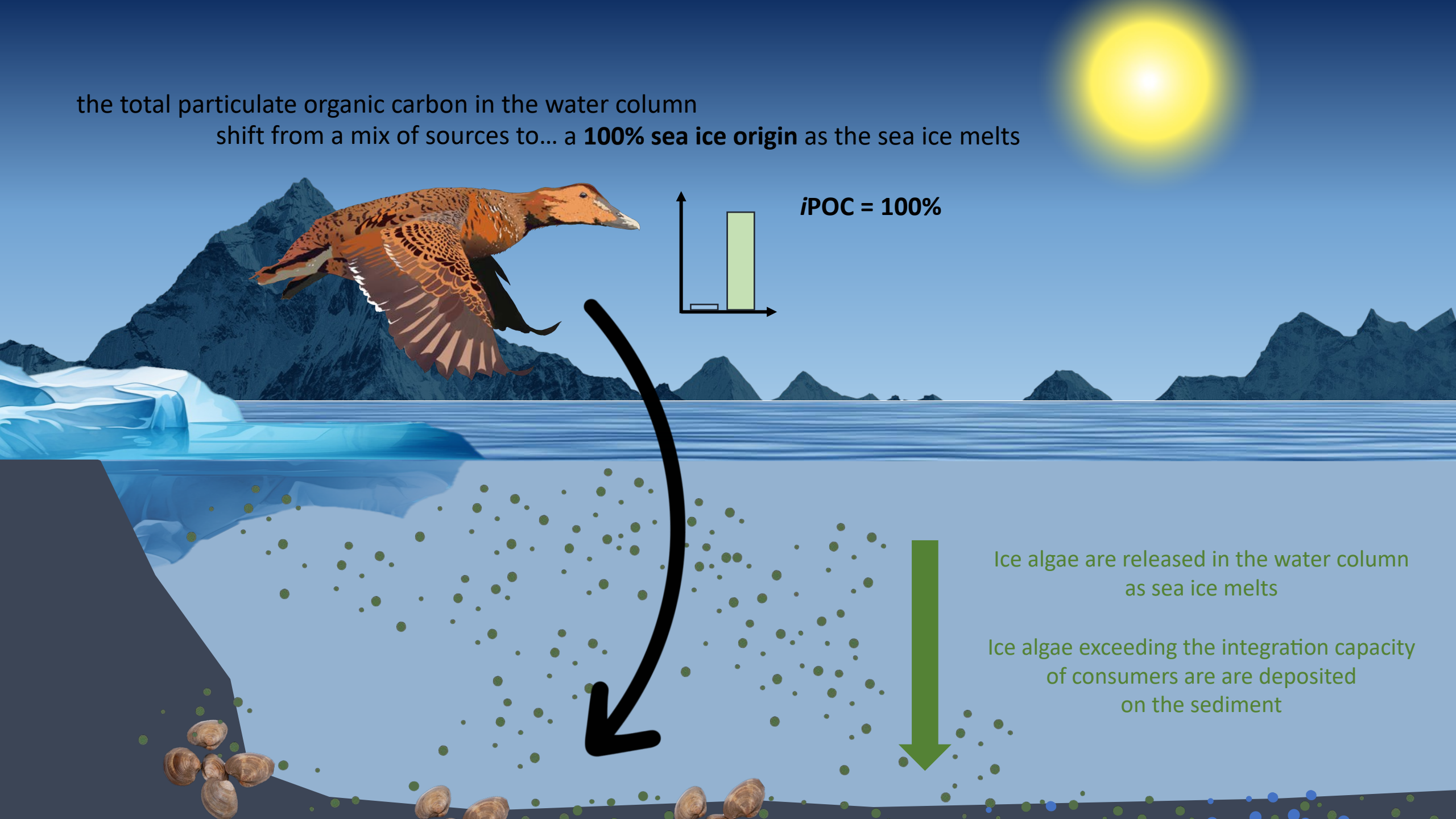
5.07%



the total particulate organic carbon in the water column
shift from a mix of sources to...



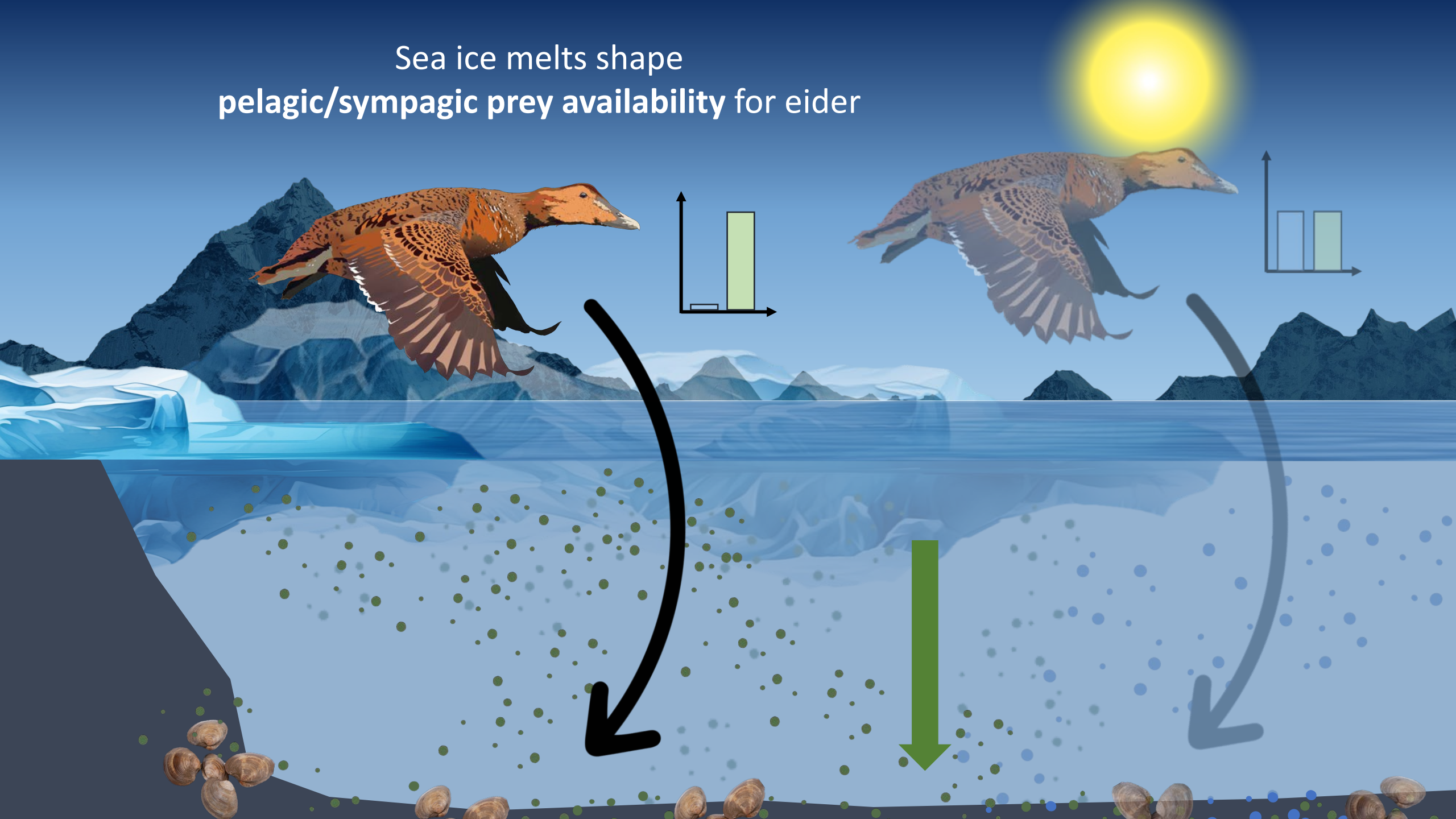
the total particulate organic carbon in the water column
shift from a mix of sources to... a **100% sea ice origin** as the sea ice melts



Ice algae are released in the water column
as sea ice melts

Ice algae exceeding the integration capacity
of consumers are deposited
on the sediment

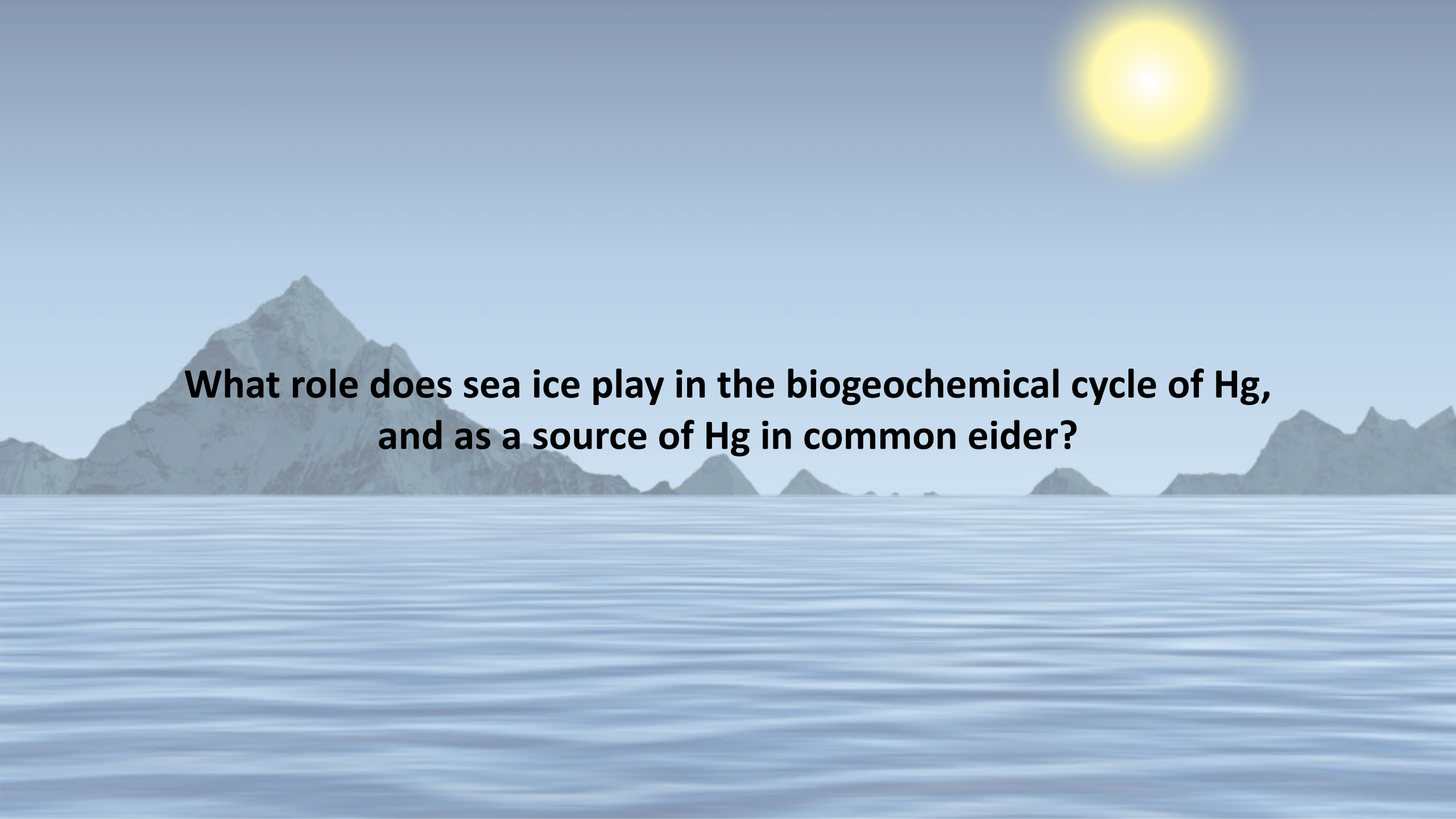
Sea ice melts shape
pelagic/sympagic prey availability for eider





Influence of sea ice cover on the prey diet of common eider?

The gateway to Hg contamination...

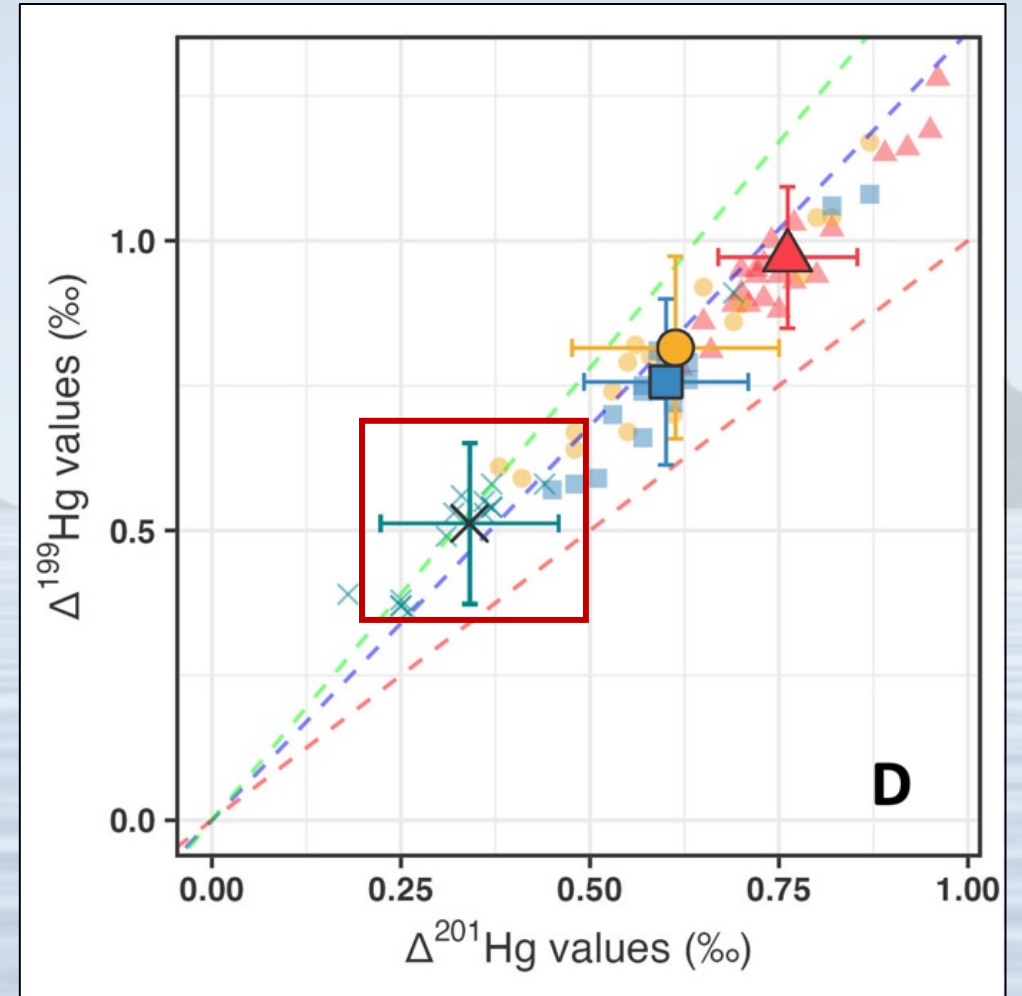


**What role does sea ice play in the biogeochemical cycle of Hg,
and as a source of Hg in common eider?**

The sources of Hg contamination : Hg Odd-MIF

- Odd-MIF values was significantly **lower in Russian eiders** compared to other sites
- Very low values of odd-MIF were also reported in terrestrial geological matrices, and sediments
- Region with large riverine discharge

→ **Influenced by riverine inputs** ✓

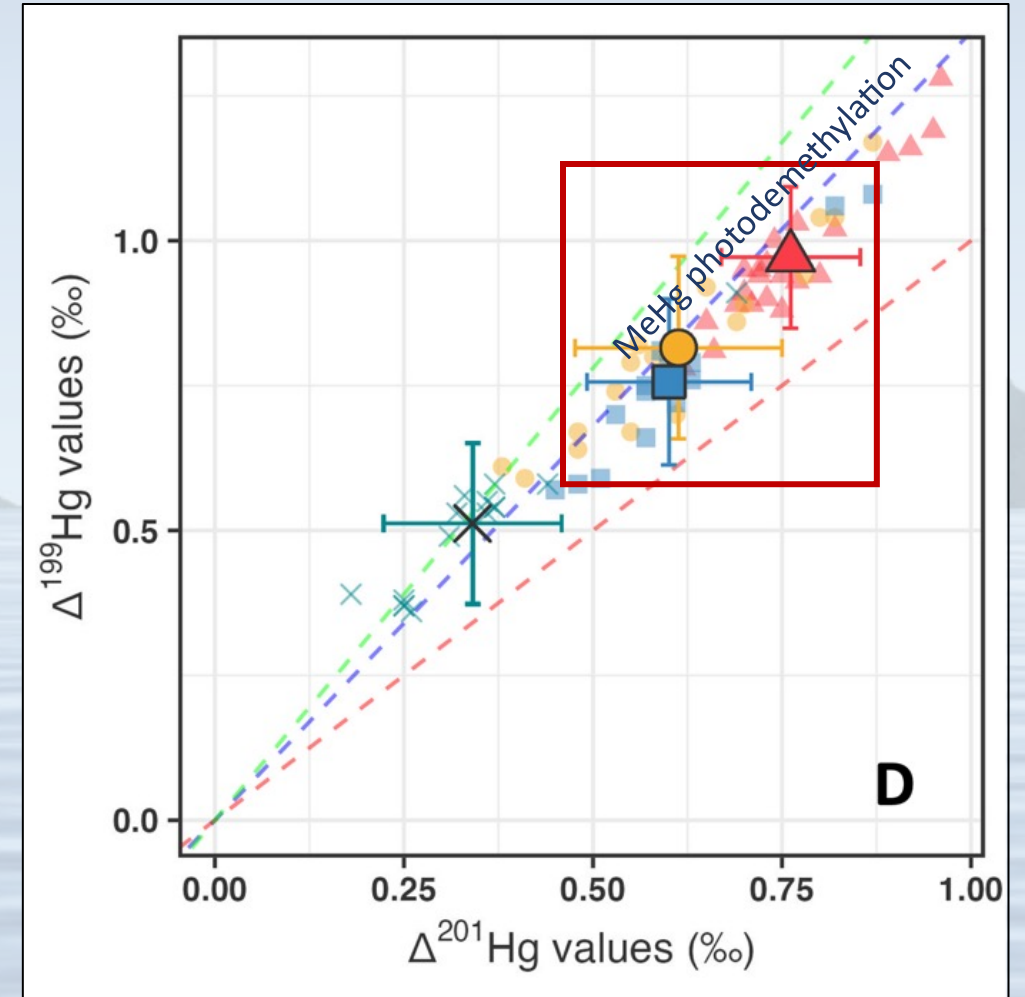


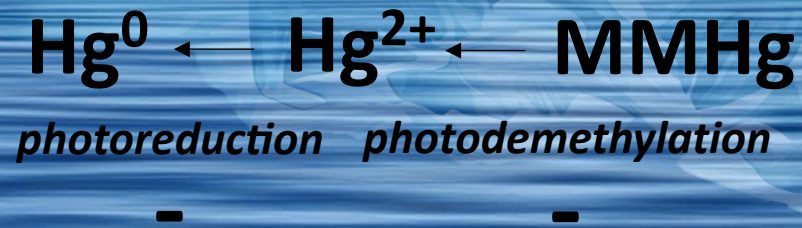
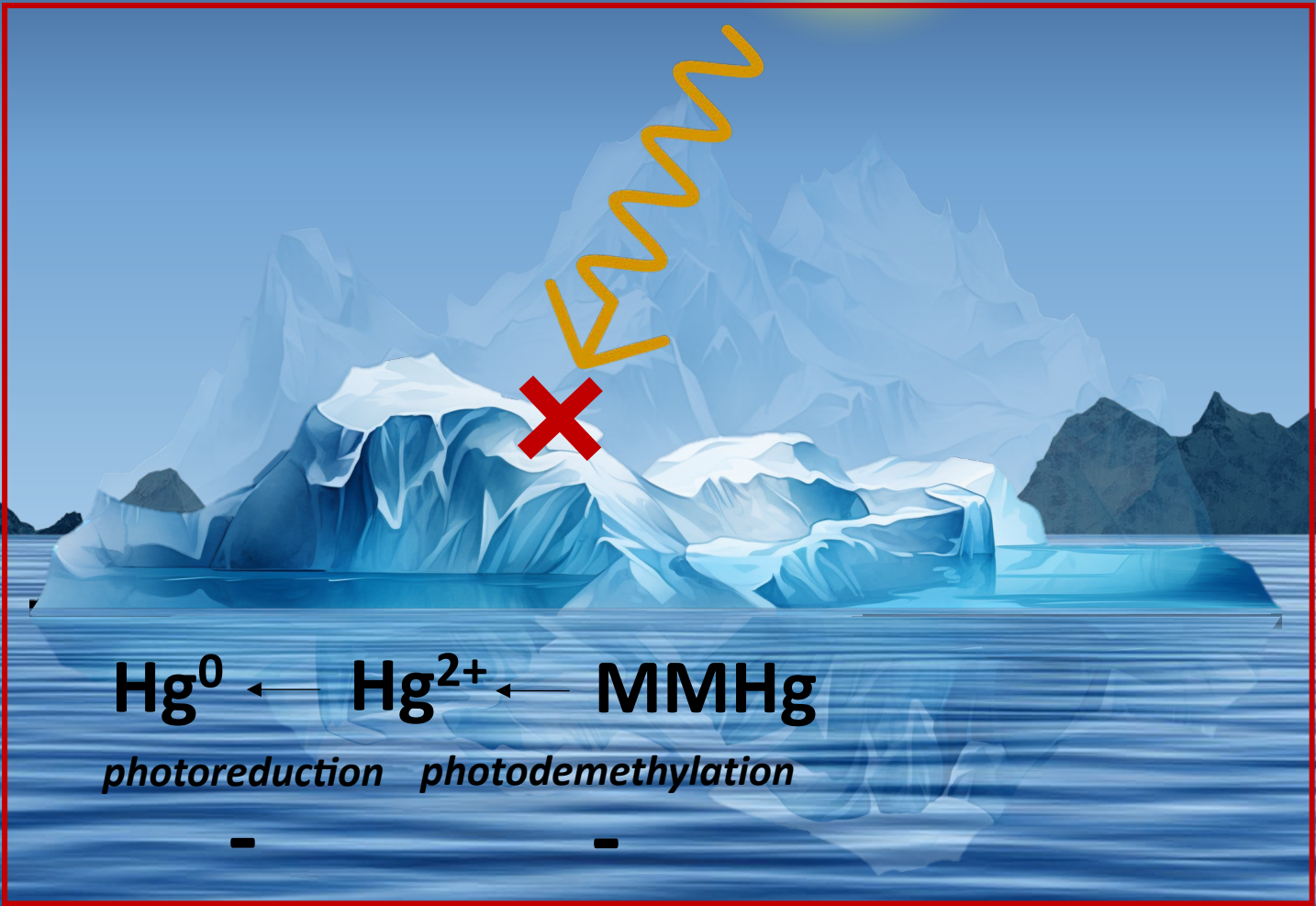
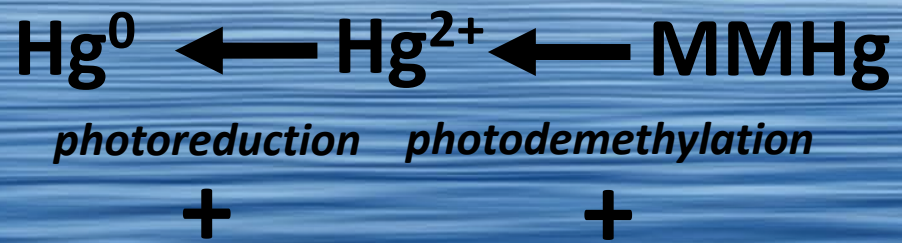
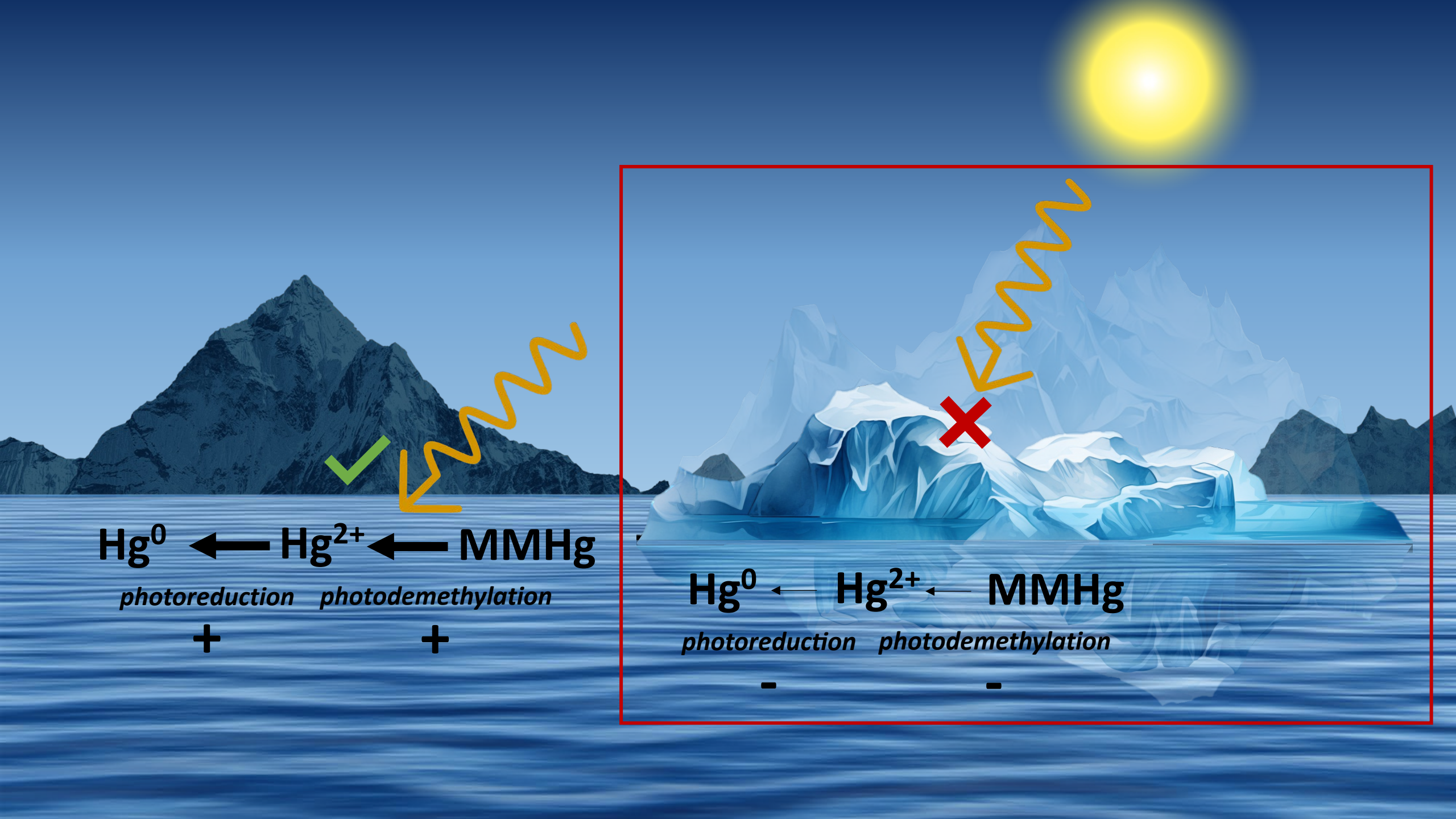
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➔ **Influenced by riverine inputs** ✓

- Odd-MIF ratio in the three other sites were closed to 1.36, the ratio related to **MMHg photodemethylation** in aqueous systems
- Low odd-MIF values, suggesting the **photodemethylation process was limited**





The sources of Hg contamination : Hg Odd-MIF

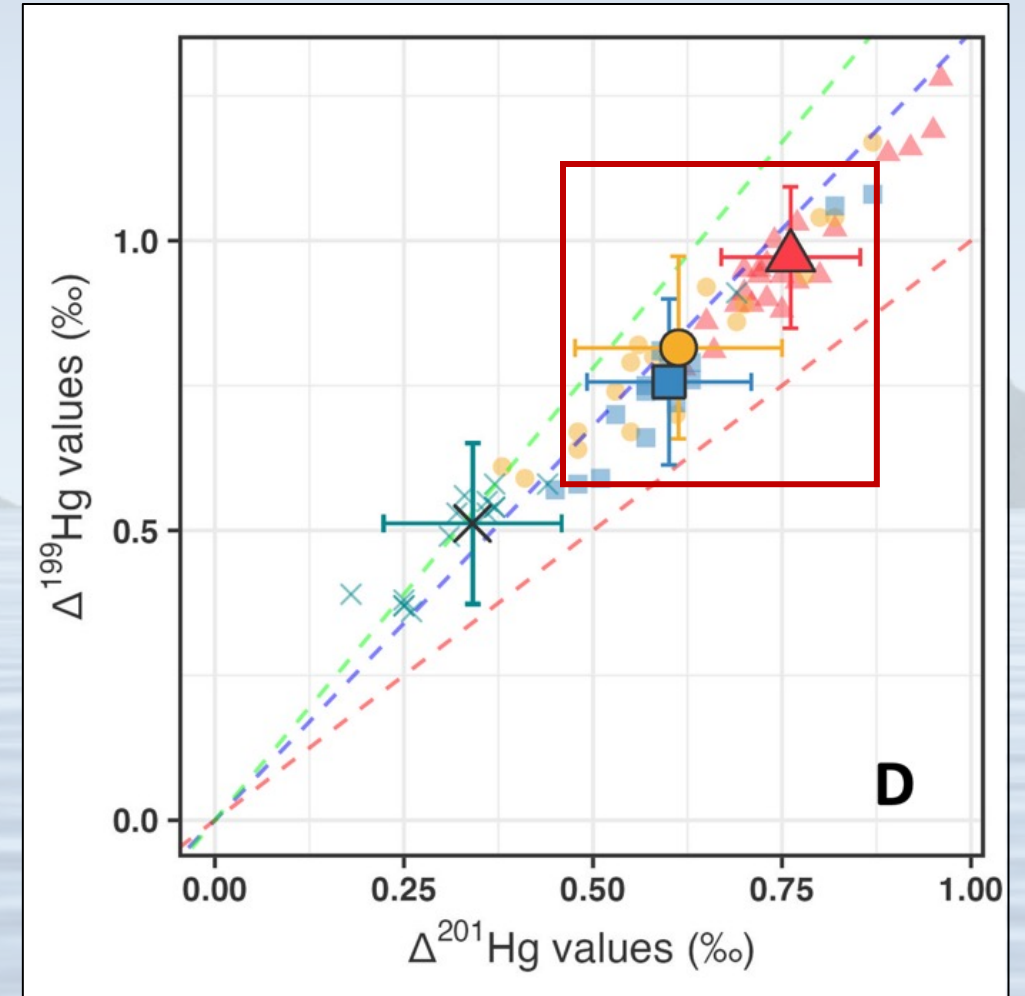
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Influenced by riparian inputs ✓

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Influence of sea ice cover ✓

Could sea ice act as a source of Hg ?



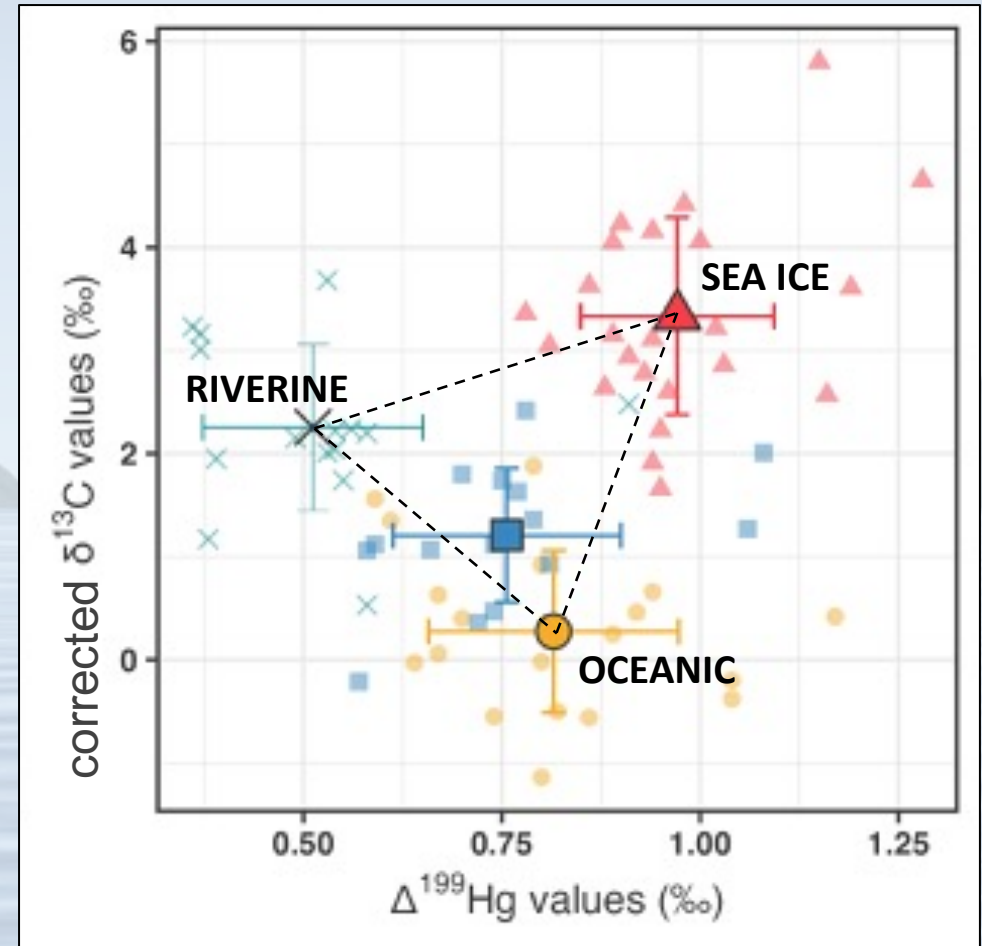
The sources of Hg contamination : Hg Odd-MIF and carbon isotopic composition

- Canada
- ▲ Greenland
- Svalbard
- × Russia

Sea ice-derived $\delta^{13}\text{C}$

The carbon isotopic composition is heavier when originating from sea ice

To discriminate Hg sources of oceanic from sea ice reservoirs



Pelagic $\delta^{13}\text{C}$

The sources of Hg contamination : Hg Odd-MIF and carbon isotopic composition

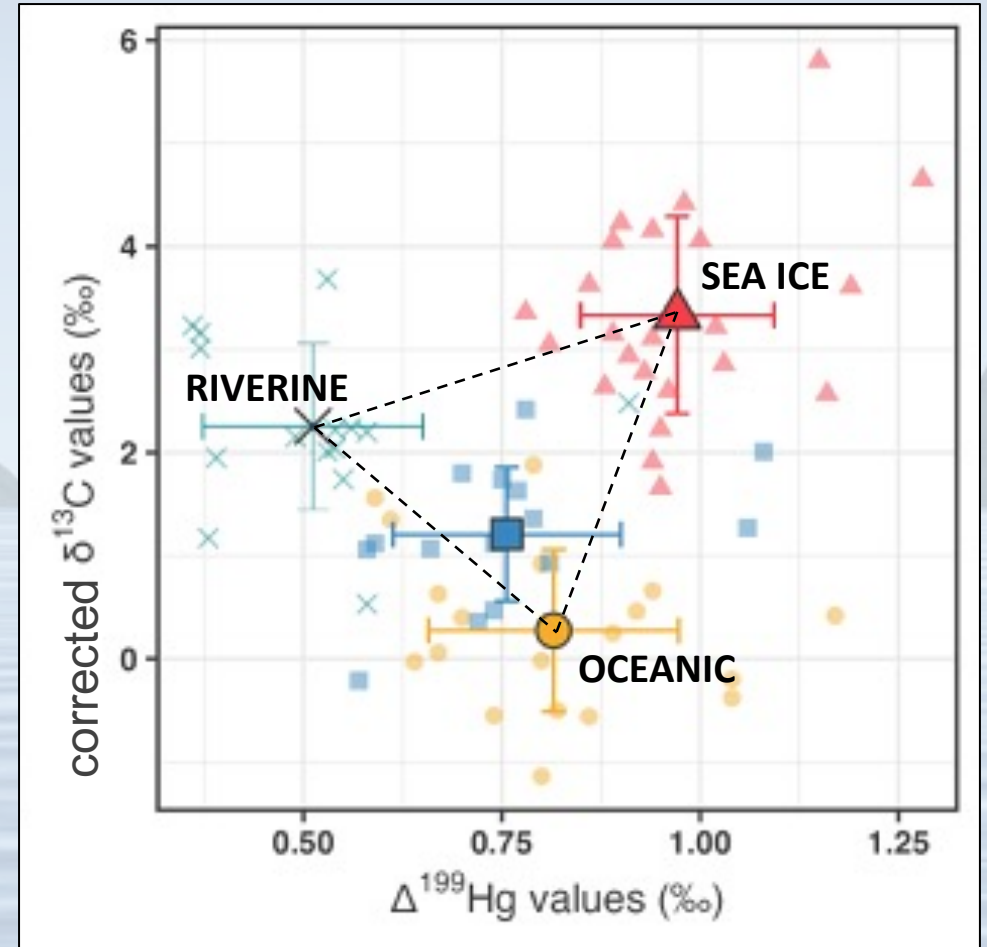
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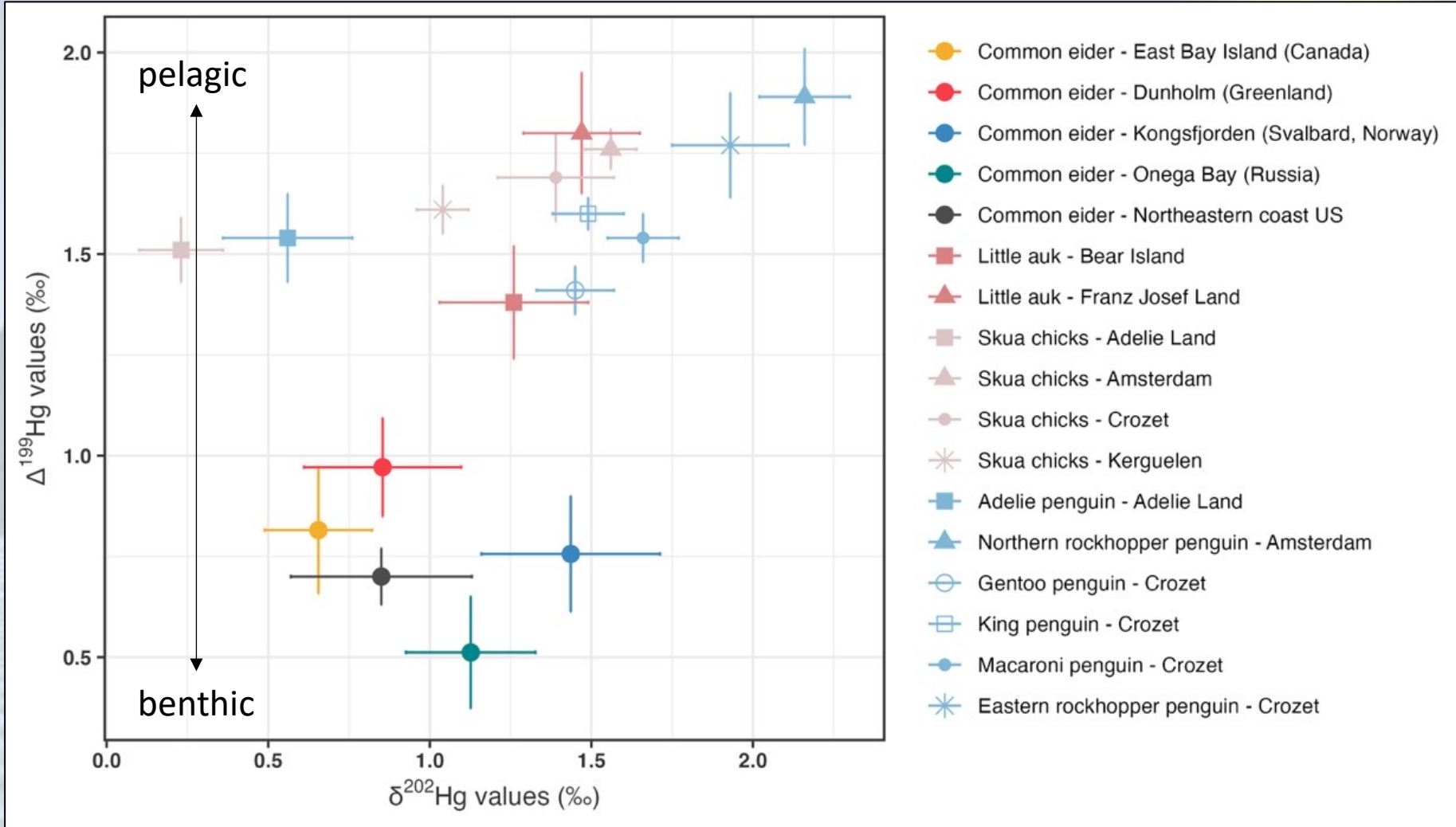
The carbon isotopic composition is heavier when originating from sea ice

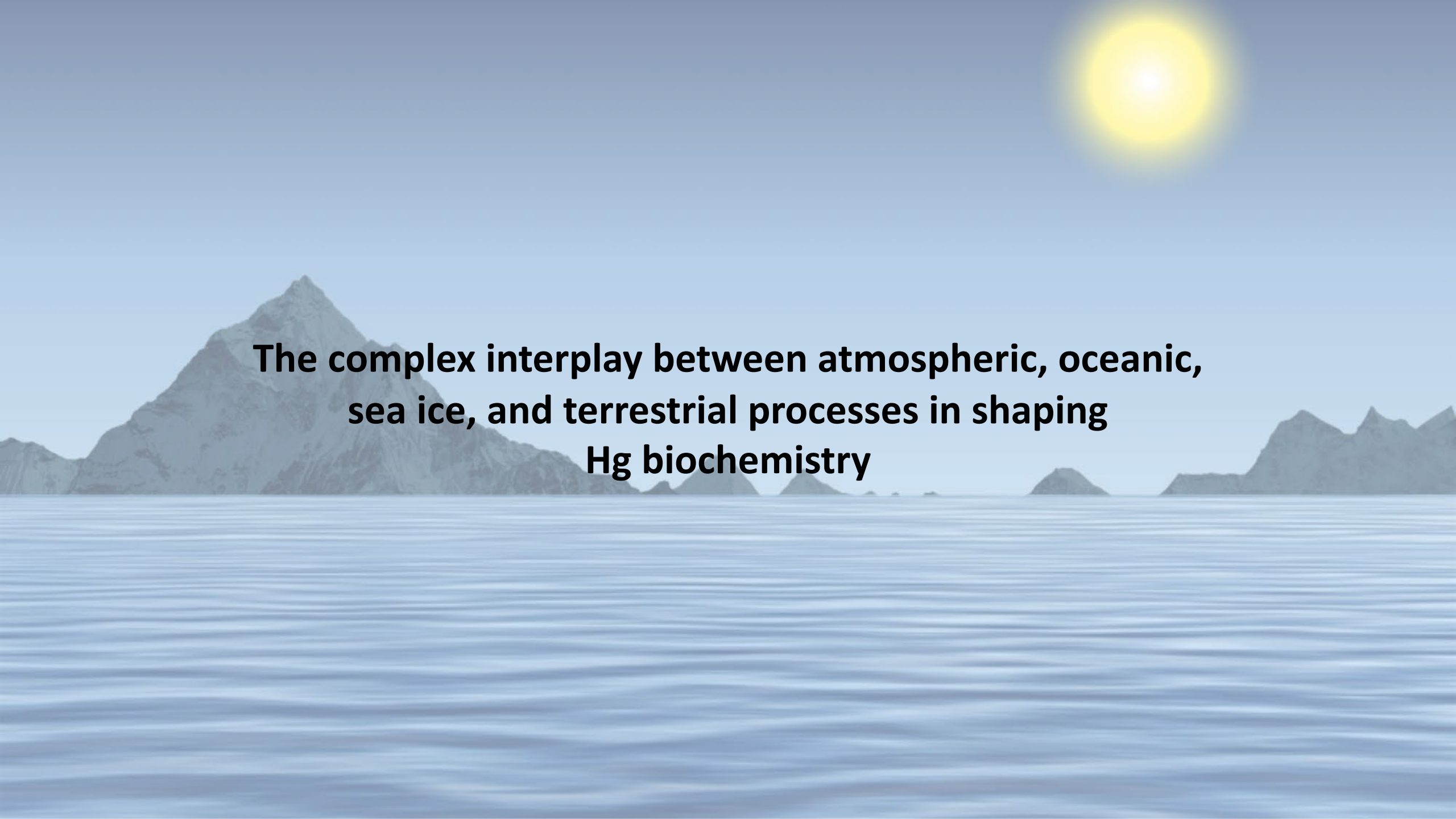
To discriminate Hg sources of oceanic from sea ice reservoirs

Variable contribution of Hg reservoirs
(oceanic vs terrestrial) to biota contamination

Via **3 input fluxes**
(oceanic, riverine input, and sea ice melt)







**The complex interplay between atmospheric, oceanic,
sea ice, and terrestrial processes in shaping
Hg biochemistry**



ICMGP 2024

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Thanks for listening

