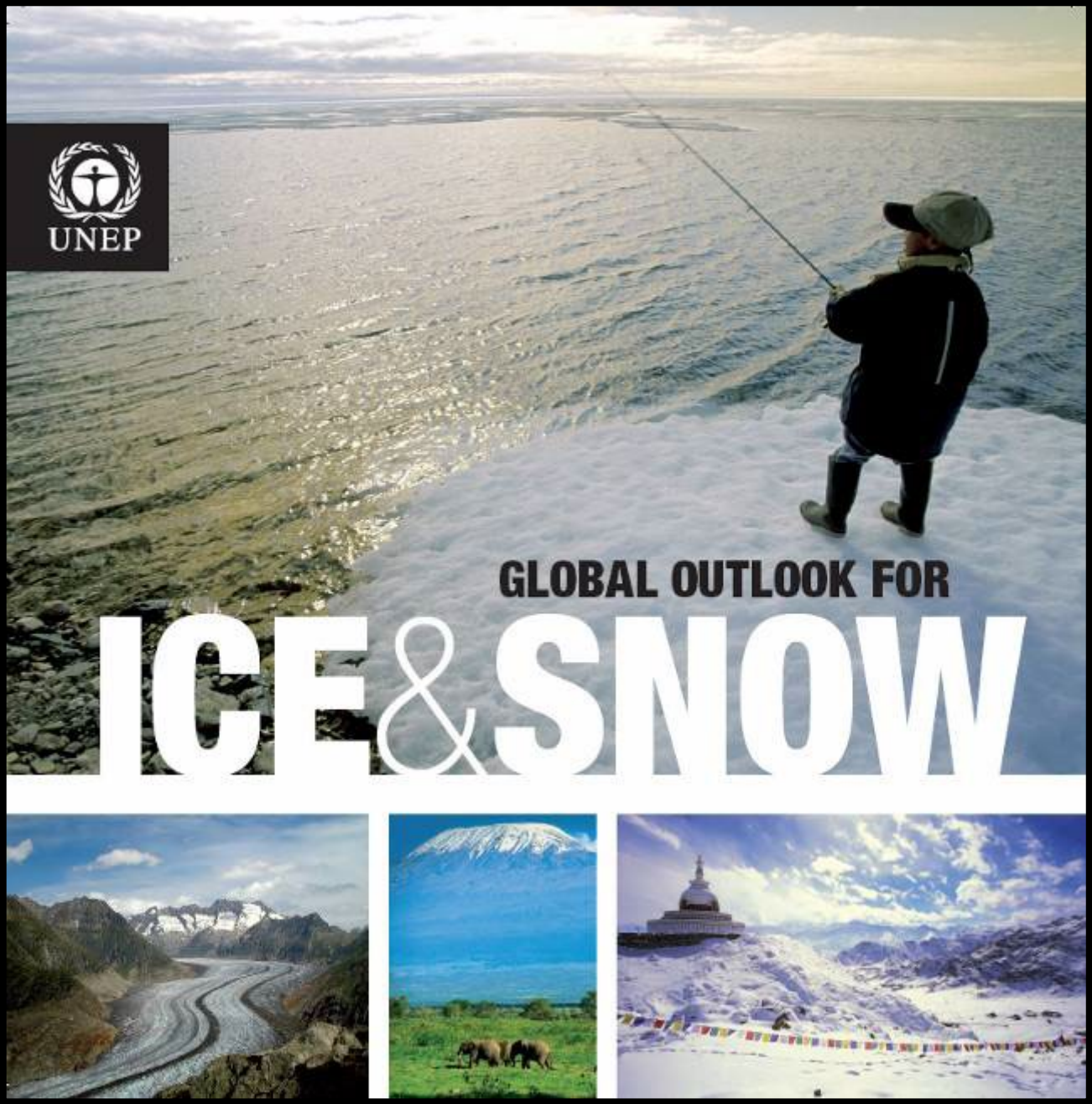
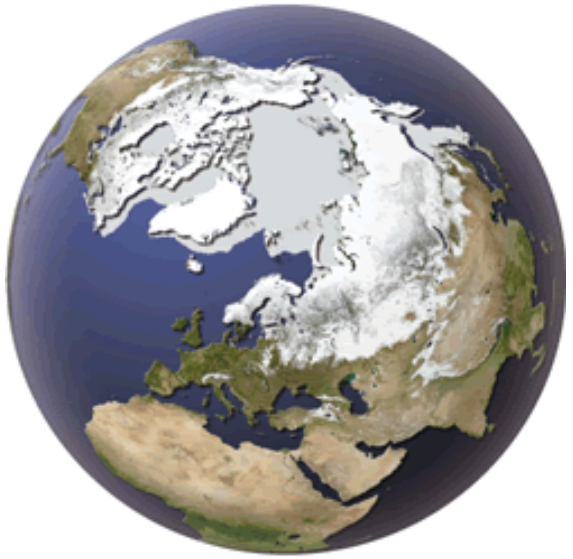


United Nations Environment Programme - 2007

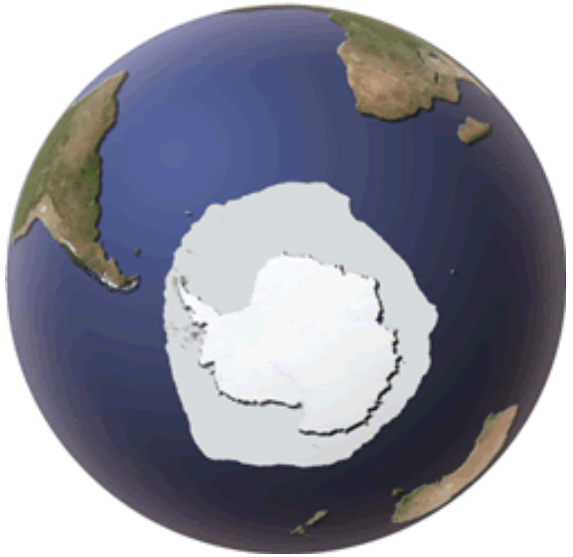
Components of the Cryosphere

- **Snow**
- **Ice in the sea**
- **Ice on land**
  huge ice sheets, and the smaller glaciers and ice caps
- **Frozen ground**
- **River and lake ice**

Northern Hemisphere
March



Southern Hemisphere
September



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Why are Ice and Snow Important to Us?

- **Ice and snow are important in many regions of the world**
  - for biodiversity, water supplies, livelihoods, culture, recreation…
  - because they influence flood risk, construction, transportation, agriculture, resource extraction…

Armin Rose/iStockphoto.com

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Why are Ice and Snow Important to Us?

- **Ice and snow are important factors in global processes**
  - Climate
  - Carbon balance
  - Sea level

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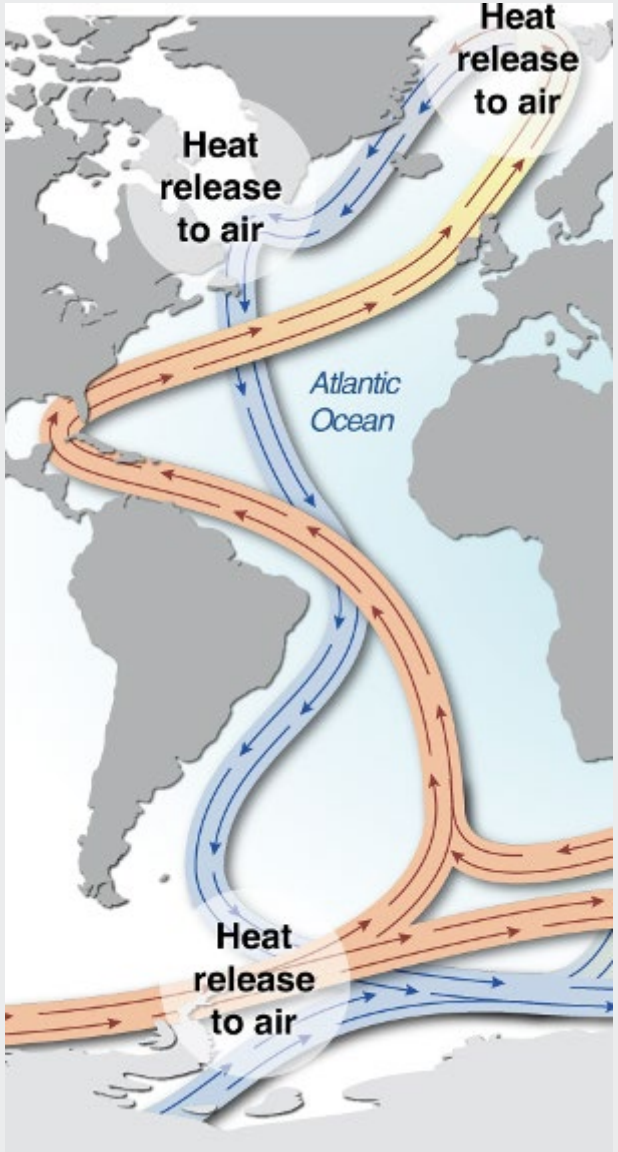
Why are Ice and Snow Important to Us?

- **Ice and snow affect the global distribution of heat**
  - Ocean currents distribute heat: thermohaline circulation depends on deep, cold water formed in the polar regions.
  - Melting ice weakens this process.



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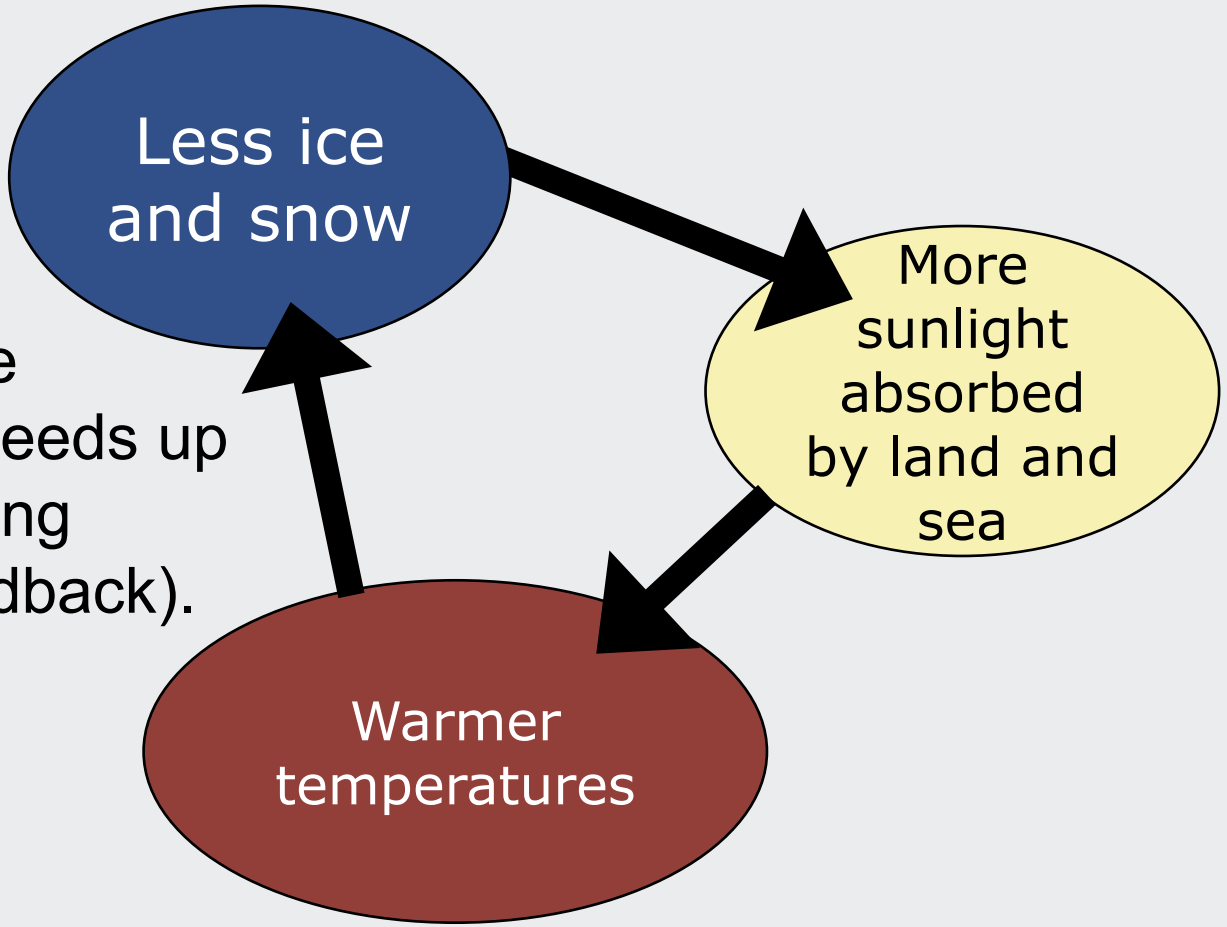
Positive feedback of melting ice and snow

The bright surface of ice and snow cover reflects sunlight and cools the planet.



Melting of ice and snow speeds up global warming (positive feedback).

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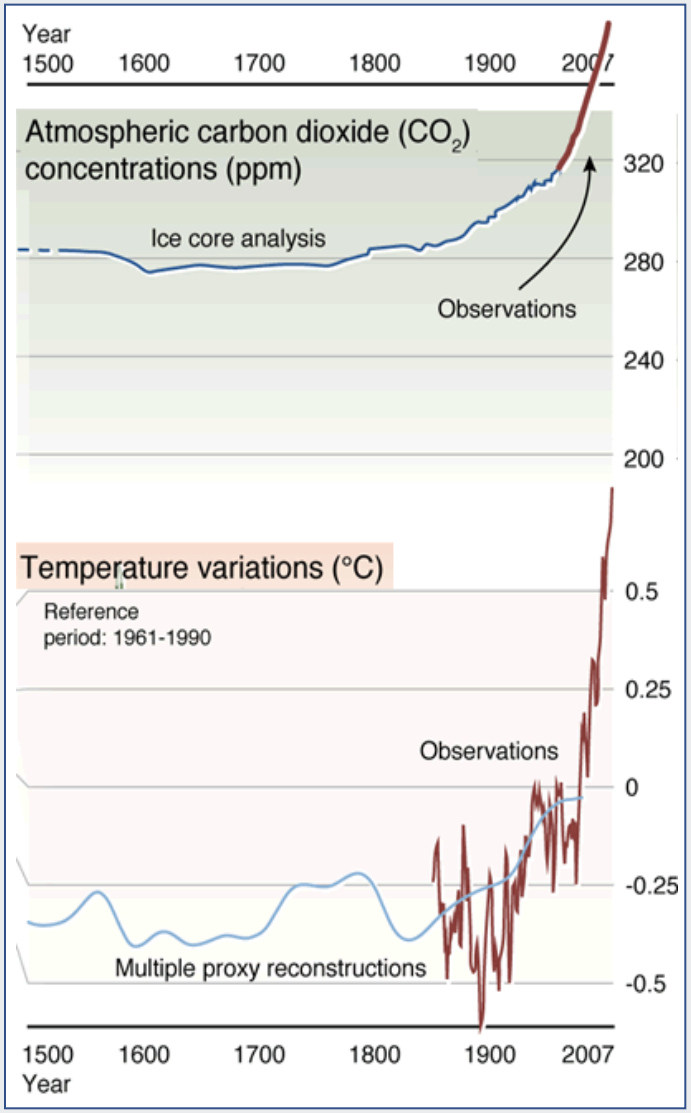
Why are Ice and Snow Changing?

- Temperatures are rising.
- Natural variability influences climate - but most of the recent warming is very likely due to increased greenhouse gas emissions.



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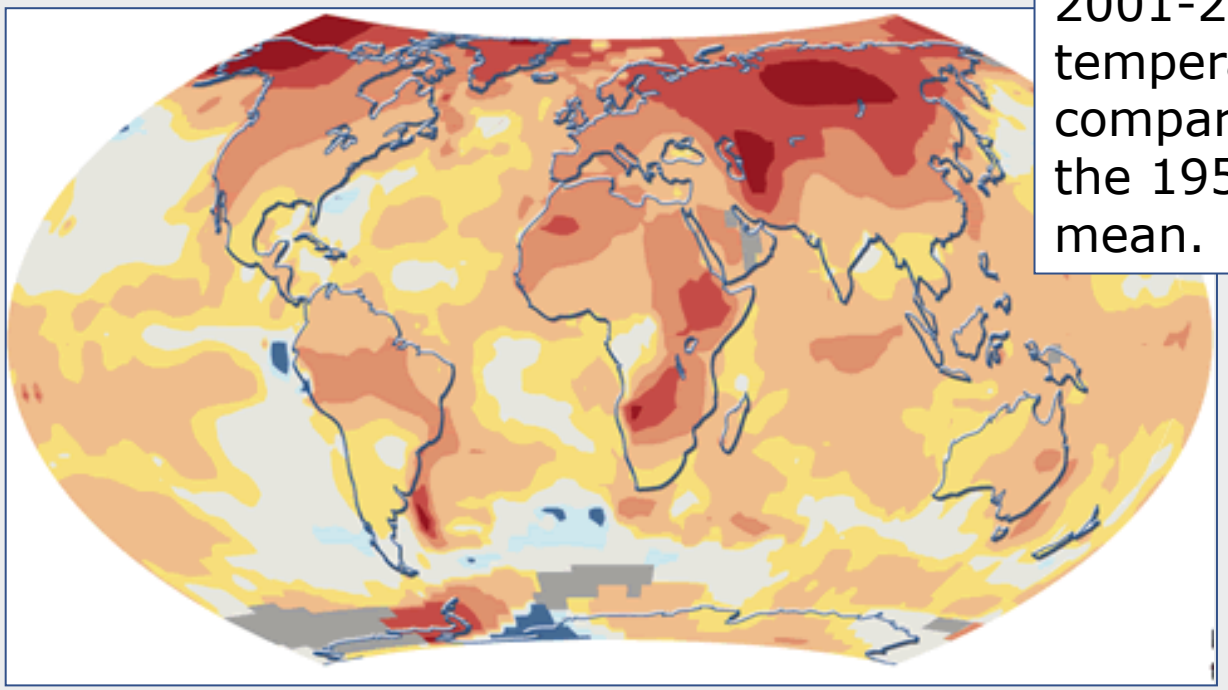

2001-2005 temperatures compared with the 1951-1980 mean.

- The Arctic is warming at almost twice the rate of the rest of the world.
- In many areas the mountains are warming faster than the lowlands.

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Ian Britton/FreeFoto.com

During the 21st century, increases in greenhouse gas emissions will be the most important external influence on ice and snow.

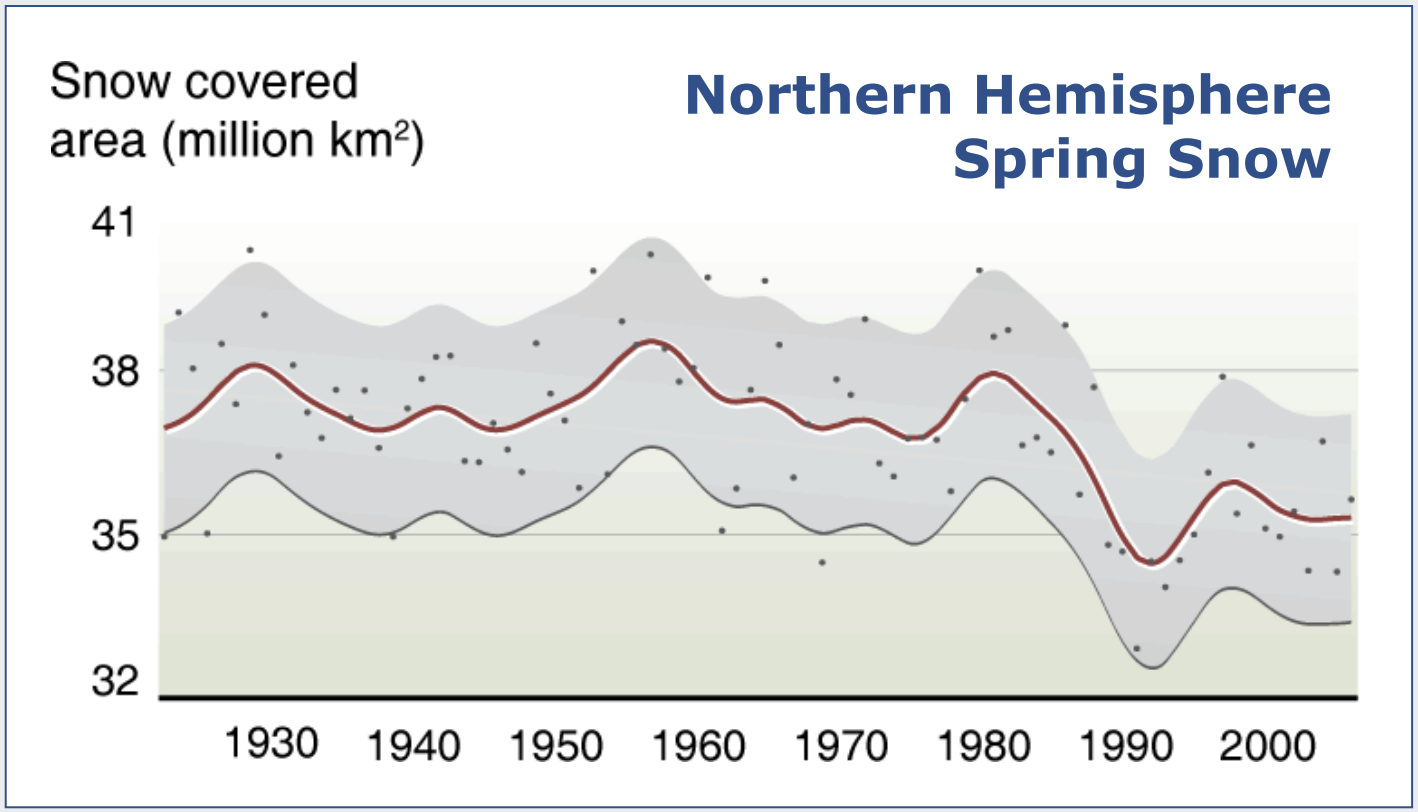
Snow

Snow influences climate because of its insulating properties and because it reflects sunlight.

Less snow leads to acceleration of global warming

Snow: *trends*

Snow cover has declined in the Northern Hemisphere, especially in spring and summer. Mean monthly snow cover is decreasing by about 1.3% per decade.



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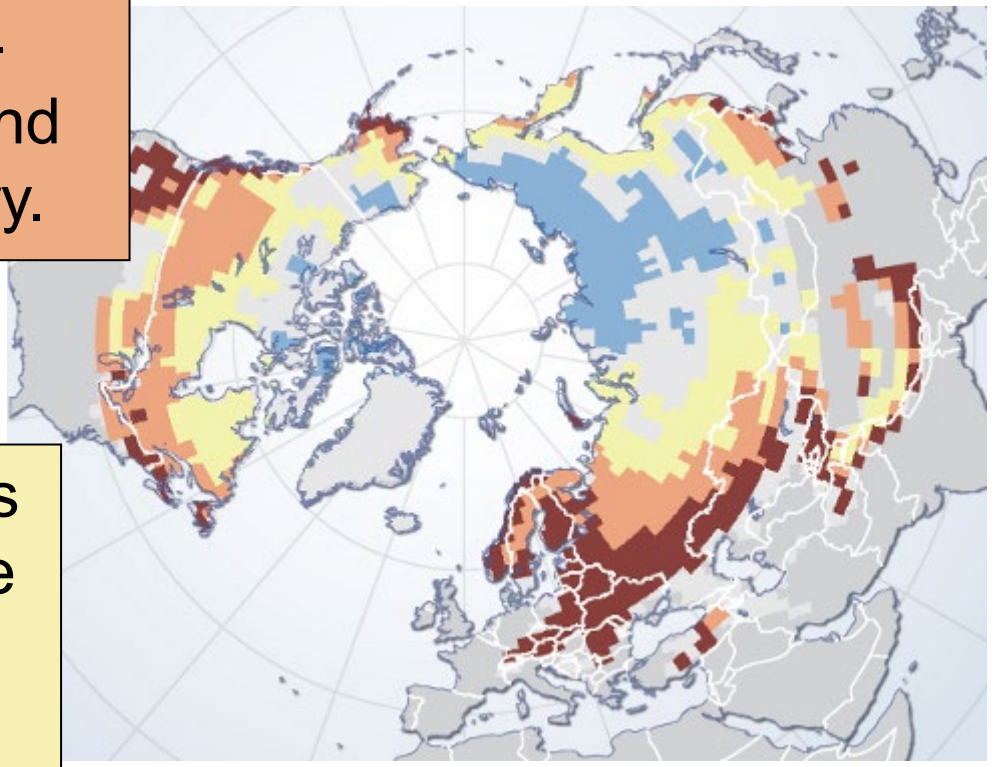
Snow: *outlook*

Major reductions in snow cover are projected for mid-latitudes by the end of the 21st century.

The snow line is projected to rise in many mountain areas



Yellow to red is less snow

Blue is increased snow

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Snow: *impacts*

- Changes in snow cover have a dramatic impact on water resources. Snow in mountain regions contributes to water supplies for almost one-sixth of the world's population.
- Snow is an important ecological factor and changes in snow affect plants and animals

Peter Prokosch

UNEP

Snow: *impacts*

Arctic ecosystems

Changes in snow affect reindeer and caribou and the Arctic indigenous people who depend upon them.

Inger Marie Gaup Eira/www.ealat.org

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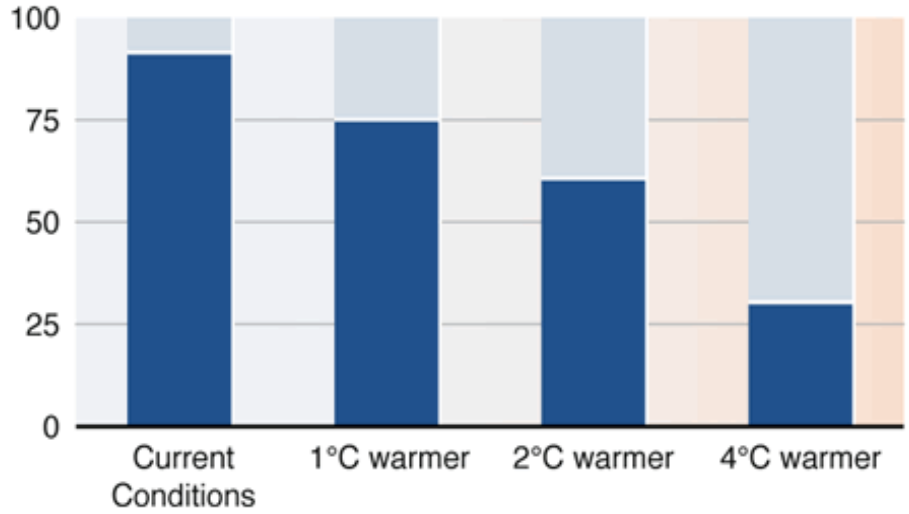
Snow: *impacts*

Winter recreation

Each degree warmer in the winter means poor snow conditions for more ski resorts. Many will be forced to shut down.



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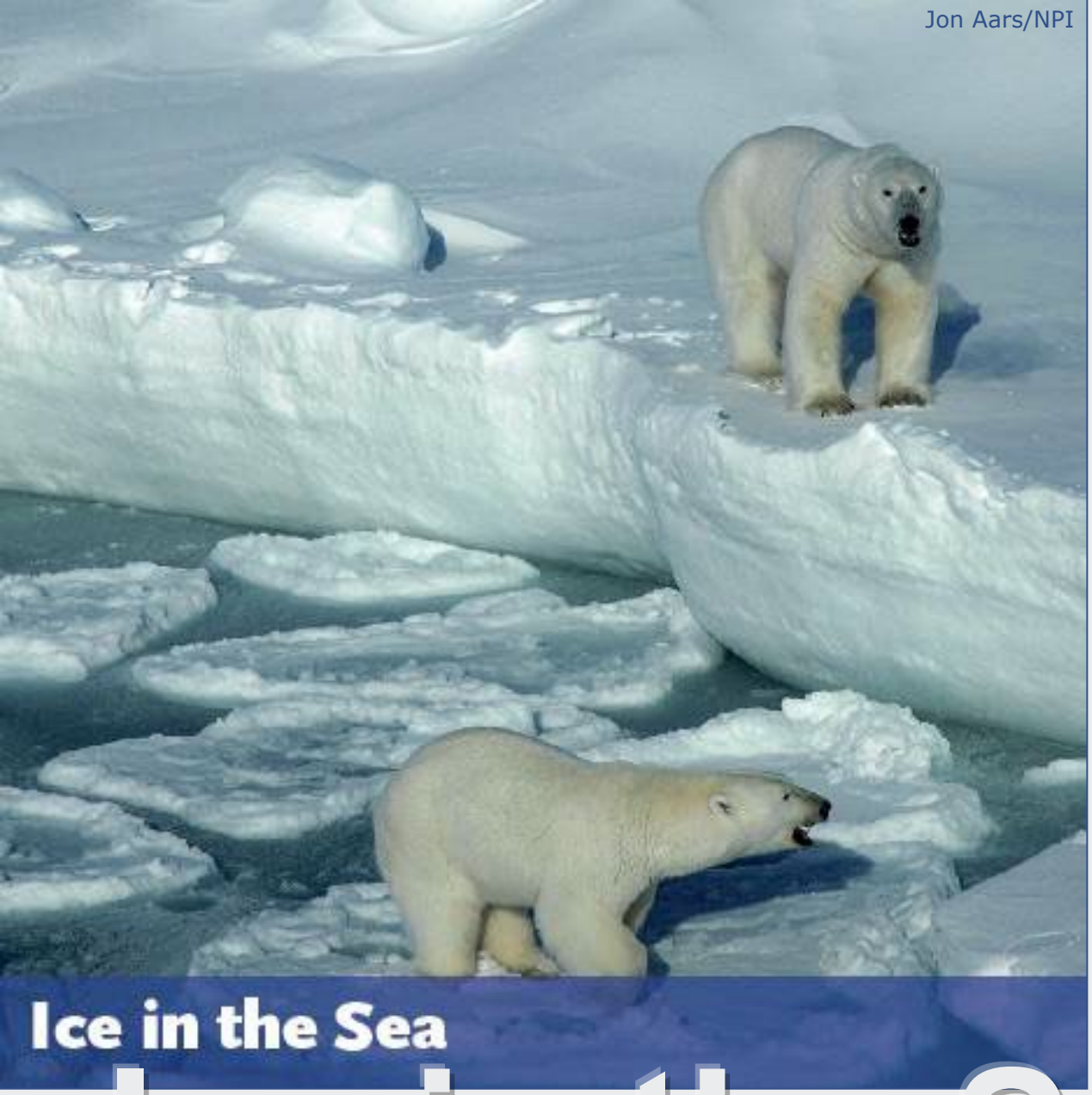
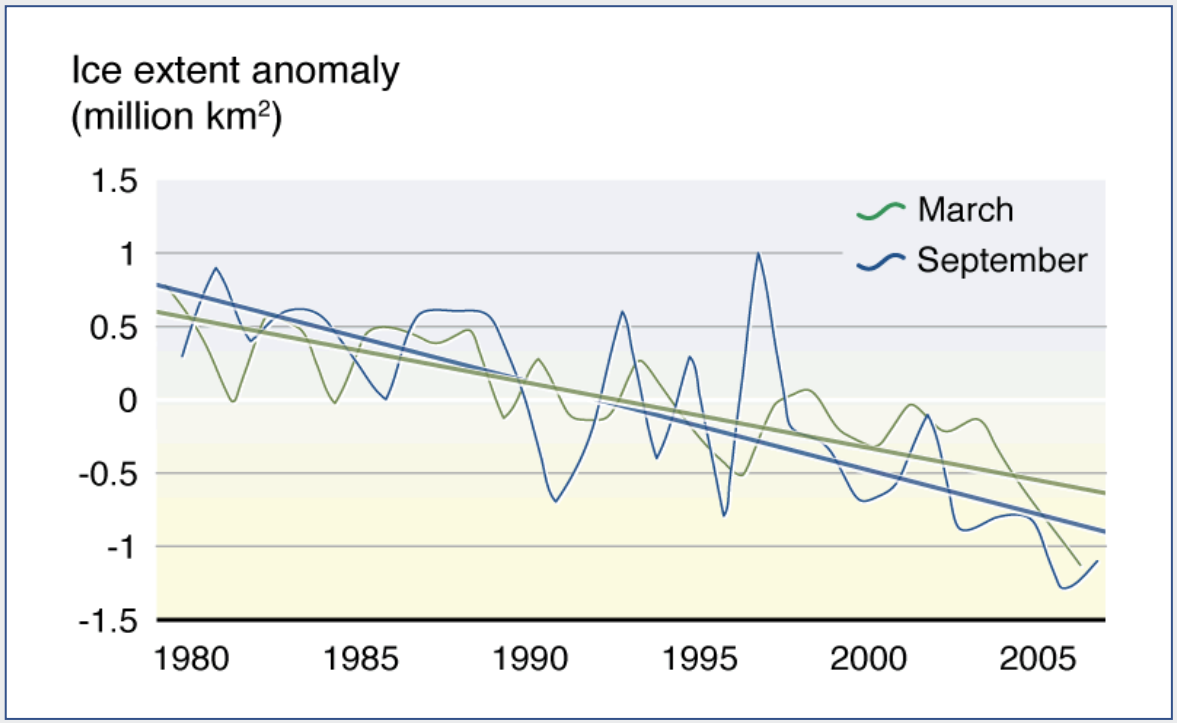


Sea ice influences climate because it reflects sunlight and because it influences ocean circulation.

Less sea ice leads to acceleration of global warming

Ice in the Sea

Sea Ice: *trends*



- Arctic sea-ice cover is shrinking by 8.9% per decade in summer and 2.5% per decade in winter. It is also becoming thinner and there is less multi-year ice.
- Antarctic sea-ice cover is not decreasing.

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Sea Ice: *outlook*

Arctic sea-ice extent and thickness are projected to decline with a possibility of a mainly ice-free Arctic Ocean in summer by 2100 or earlier.

MIenny/iStock

Antarctic sea ice is also projected to decline in this century.

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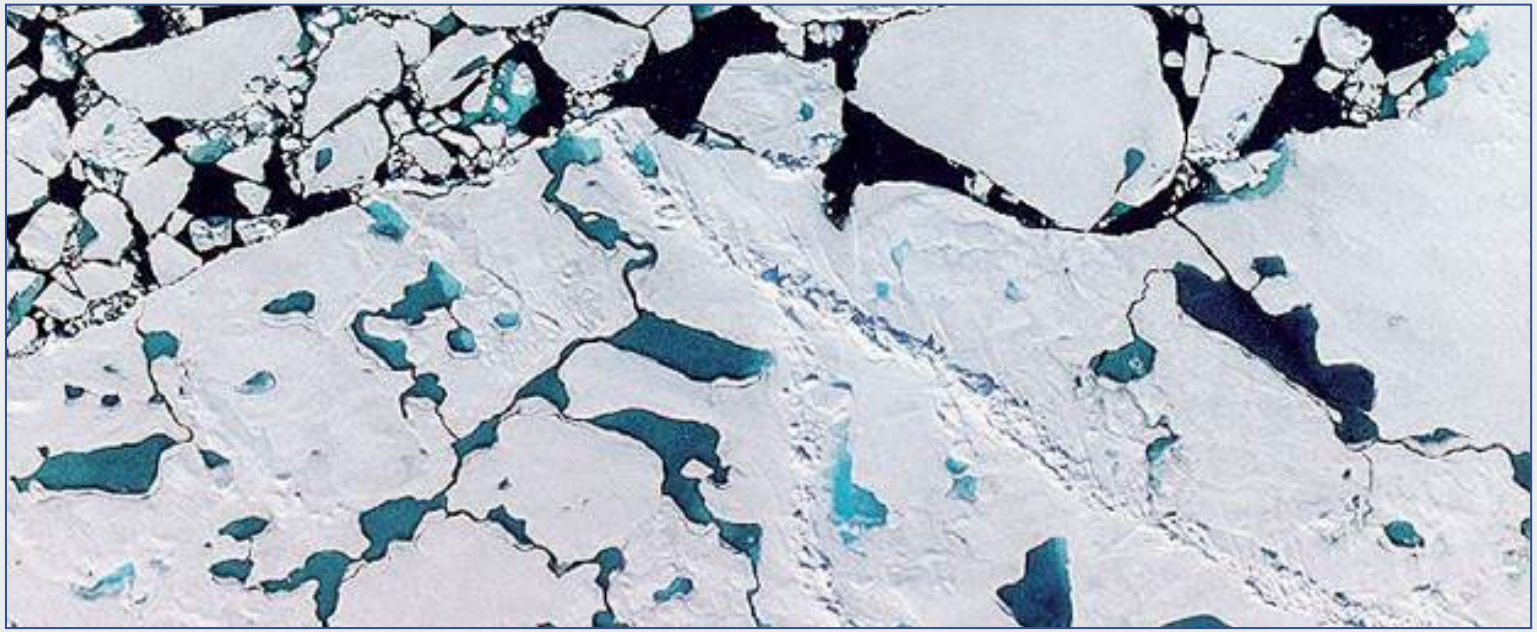
Sea Ice: *impacts*



Don Perovich

- Melting sea ice, in combination with melting glaciers and ice sheets, may cause major changes to global patterns of ocean circulation.
- As with snow, less sea ice increases absorption of heat from the sun, resulting in increased warming

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Sea Ice: *impacts*

Sea ice is habitat for many organisms – from bacteria, algae, sea worms and crustaceans to sea birds, penguins, seals, walrus, polar bears and whales.

Photos: (1,2) Håkon Hop/NPI, (3)www.glaciers-online.net

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Sea Ice: *impacts*

Some sea-ice dependent animals are already at risk and the predicted declines in sea ice may lead to extinctions.

Photos: (1) Jon Aars/NPI, (2) Georg Bangiord

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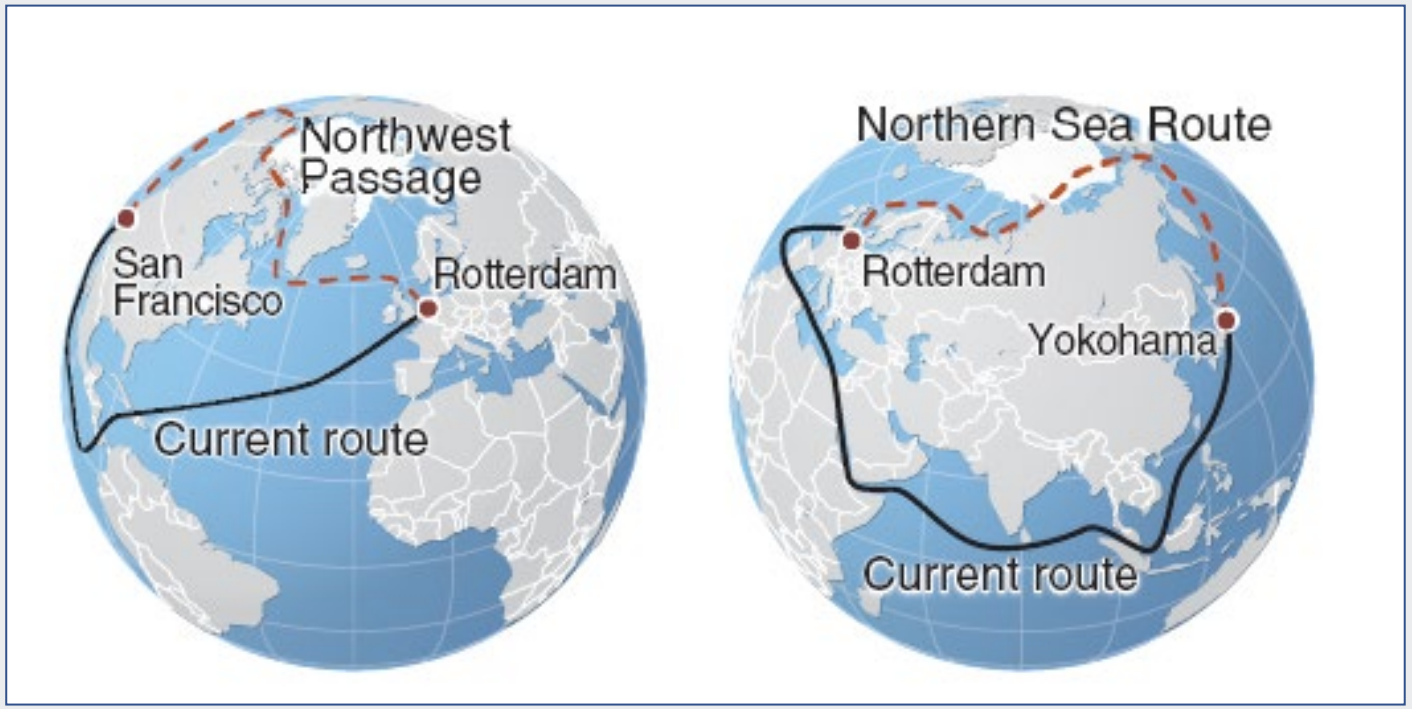
Sea Ice: *impacts*

Shrinking sea ice is affecting Arctic indigenous people and further loss of sea ice threatens livelihoods and cultures.

Bjørn Frantzen

UNEP

Sea Ice: *impacts*



More open water in polar regions will provide easier access to oil and gas reserves and increase shipping and tourism, with accompanying benefits and risks.

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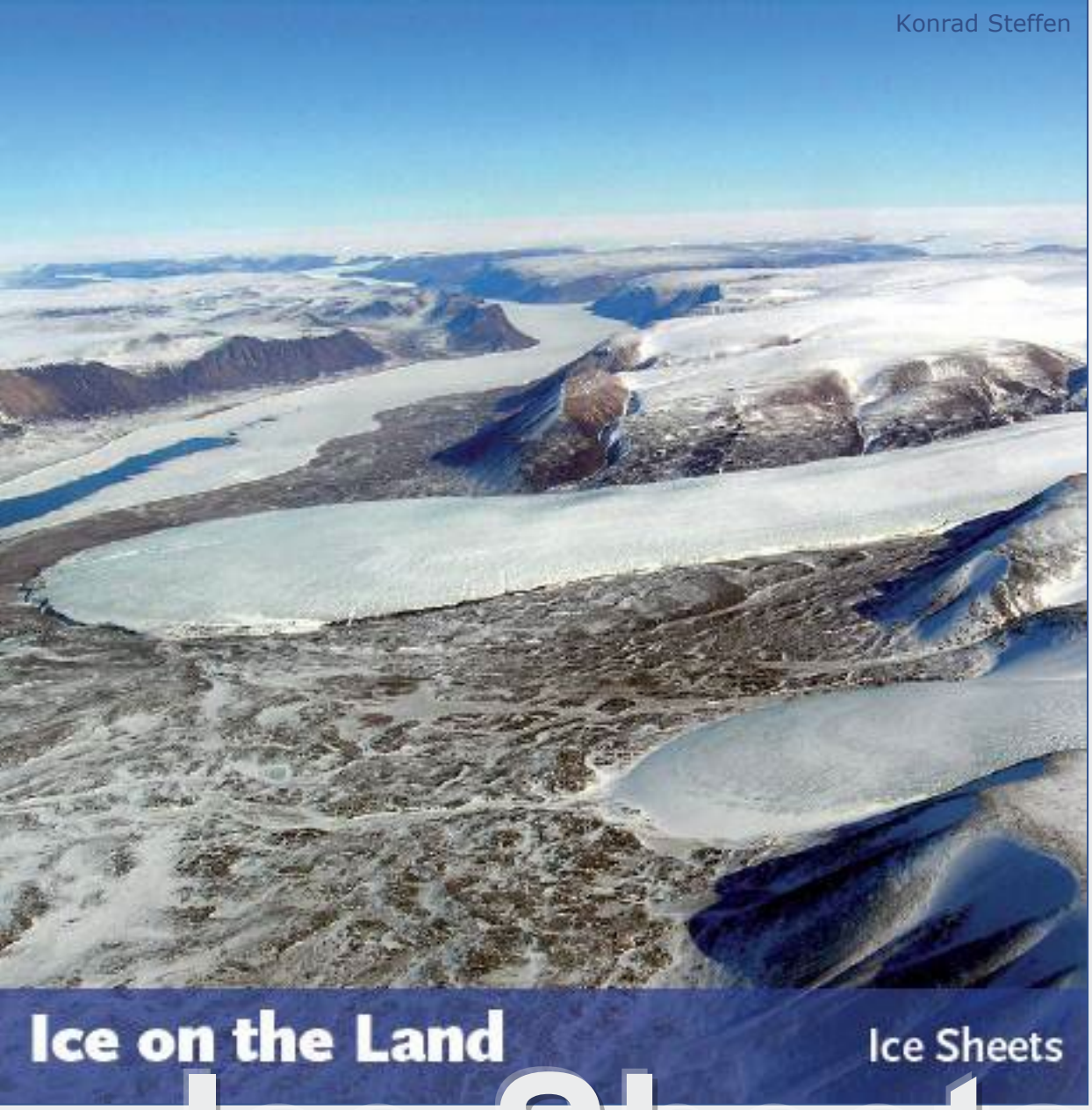


Ice Sheets

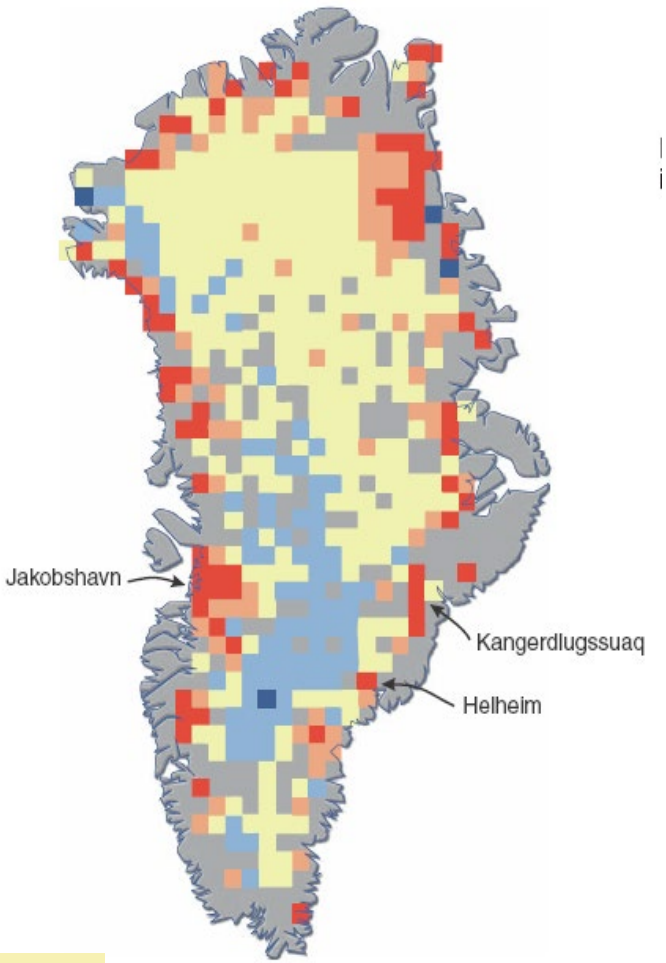
Greenland and Antarctica contain about 99% of the freshwater ice on Earth's surface.

Meltwater from ice sheets contributes to sea level rise.

Ice Sheets: *trends*

- Annual total loss of mass from the Greenland Ice Sheet more than doubled in the last decade of the 20th century and may have doubled again by 2005.
- Warmer summers are increasing melting and ice discharge.

Greenland: recent changes



Yellow = no or little change

Blue = snow accumulation

Red = less mass (melting and discharge of ice)

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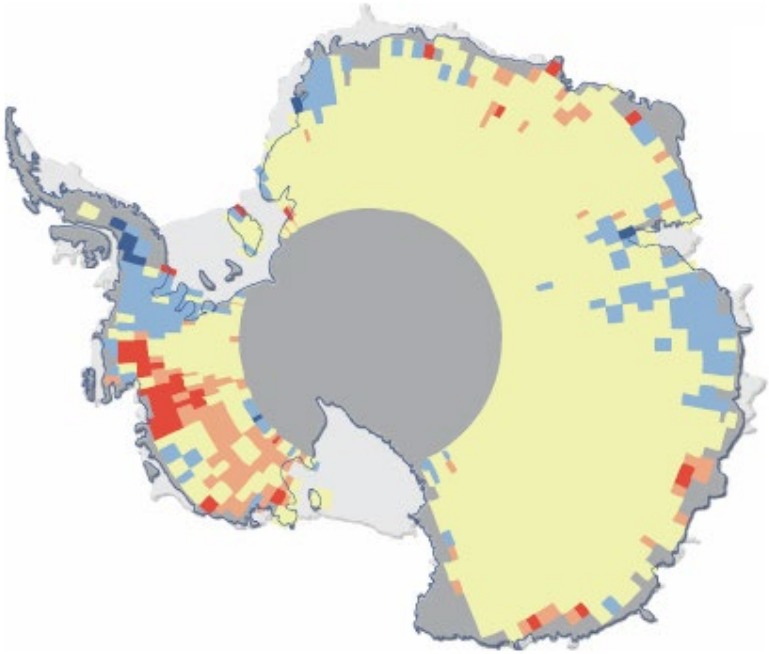
Ice Sheets: *trends*

Antarctica: recent changes



Yellow = no or little change

Blue = snow accumulation

Red = less mass (melting and discharge of ice)

- There is uncertainty concerning recent overall changes in ice mass in the Antarctic Ice Sheet, but there is probably a decline in mass.
- Ice shelves are thinning and some are breaking up.

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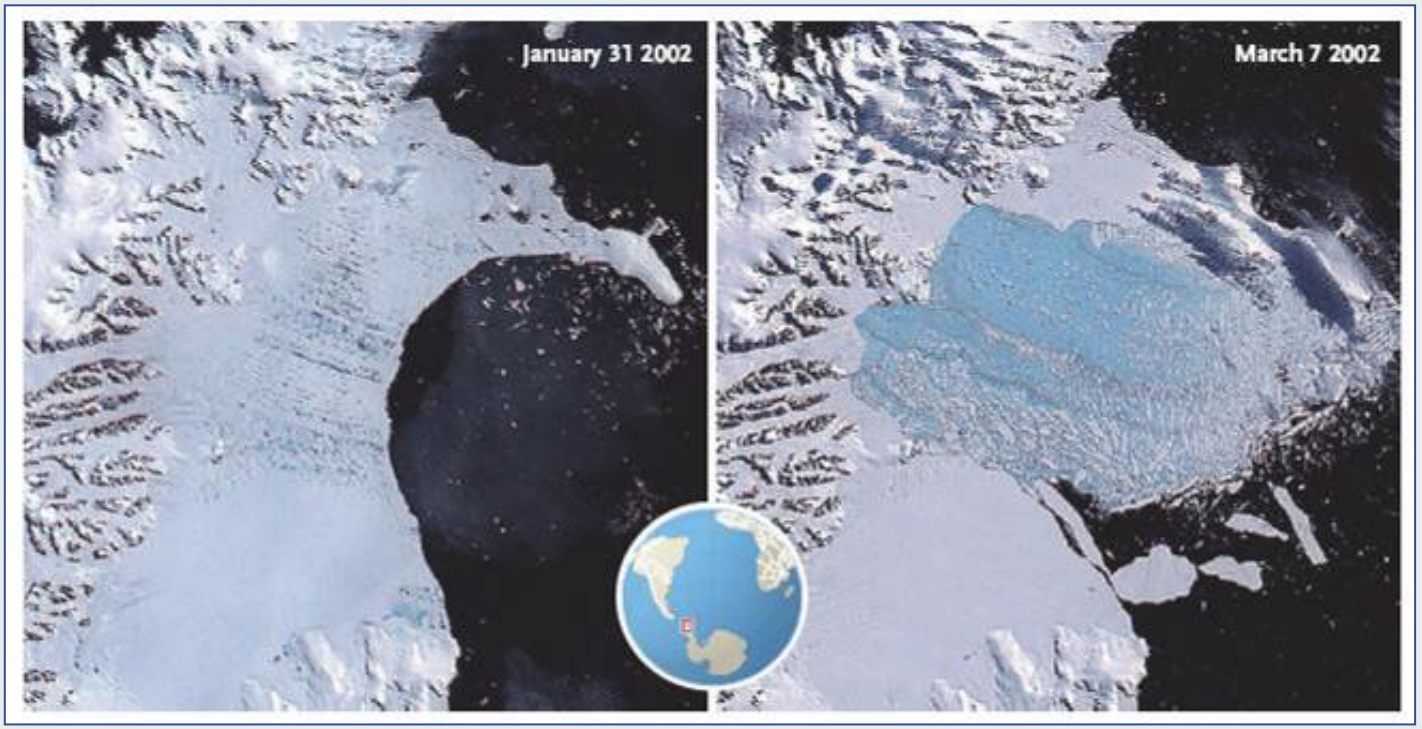
Ice Sheets: *trends*

Surprising changes that models cannot simulate, including thinning of outlet glaciers and ice shelves, have been observed over the past five years.

Break-up of the Larsen B Ice Shelf, 2002



NSIDC

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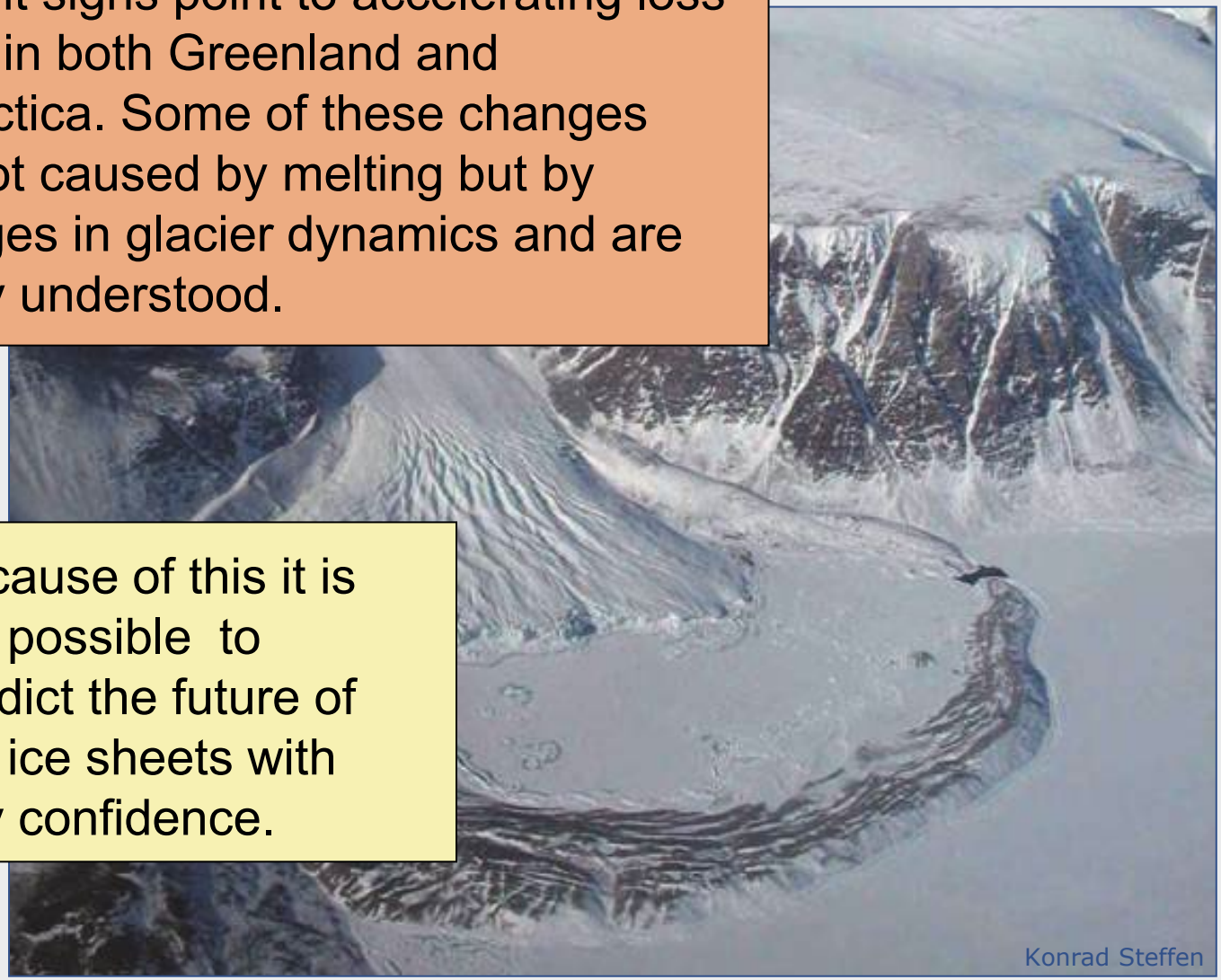
Ice Sheets: *outlook*

Recent signs point to accelerating loss of ice in both Greenland and Antarctica. Some of these changes are not caused by melting but by changes in glacier dynamics and are poorly understood.

Because of this it is not possible to predict the future of the ice sheets with any confidence.



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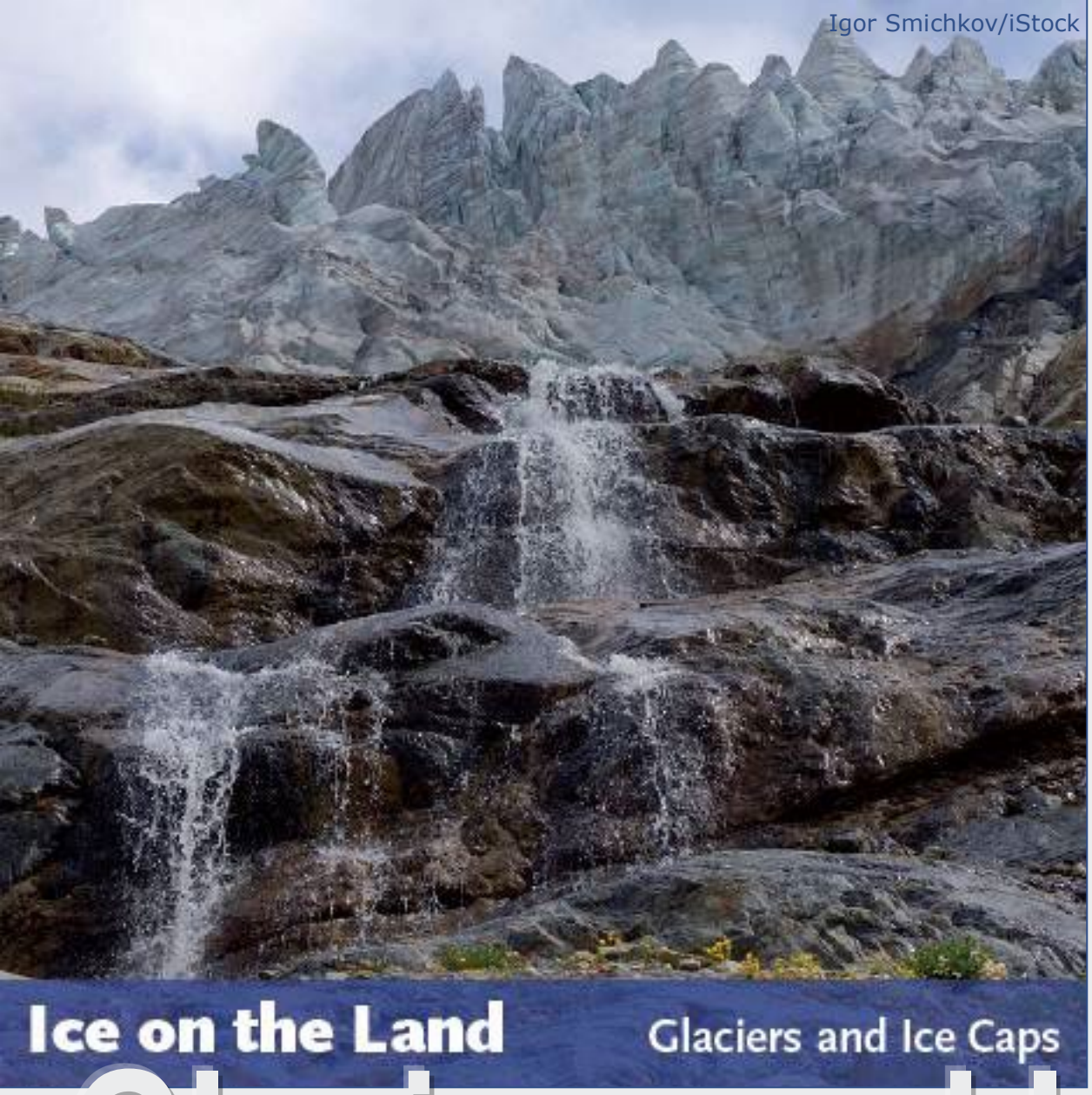

Glaciers and ice caps are important freshwater resources, but also natural hazards.

Glaciers are close to the melting point and react strongly to climate change.

Glaciers and Ice Caps

Glaciers: *trends*

Over the past 100 years, and particularly since the 1980s, there has been worldwide and dramatic shrinking of glaciers, closely related to global warming.

Jürg Alean, SwissEduc (www.swisseduc.ch)/Glaciers online (www.glaciers-online.net)

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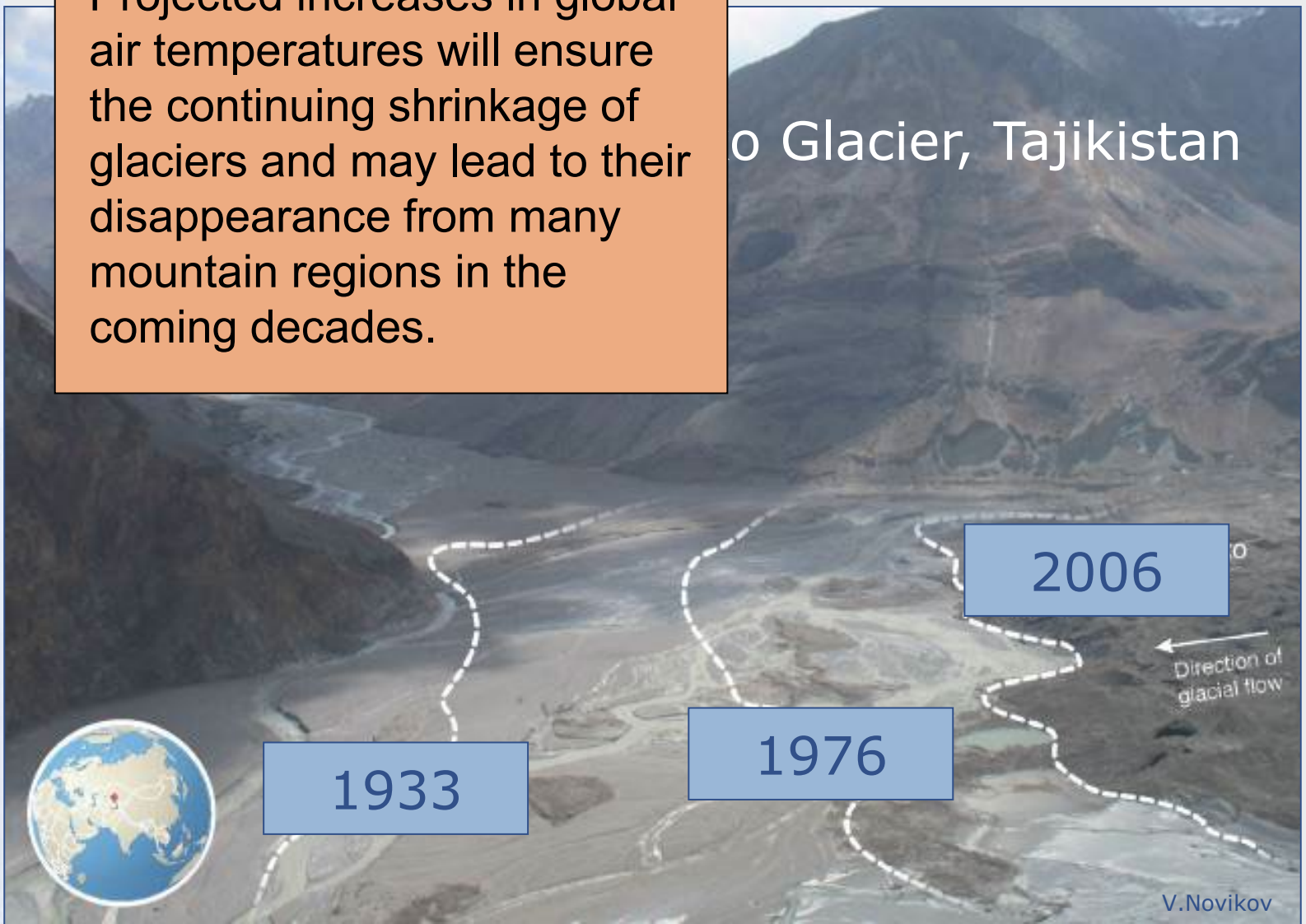
Glaciers: *outlook*

Projected increases in global air temperatures will ensure the continuing shrinkage of glaciers and may lead to their disappearance from many mountain regions in the coming decades.



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Glaciers: *impacts*

Disappearance of glaciers will have major consequences on water resources, especially in the Himalayas – Hindu Kush, the Andes, Rocky Mountains and European Alps.

Himalayas – Hindu Kush: major rivers draining glaciers and populations in their basins

River	Total population
Tarim	8 067 000
Syr Darya	20 591 000
Amu Darya	20 855 000
Indus	178 483 000
Ganges	407 466 000
Brahmaputra	118 543 000
Yangtze	368 549 000
Huang He (Yellow river)	147 415 000
Salween	5 982 000
Mekong	57 198 000

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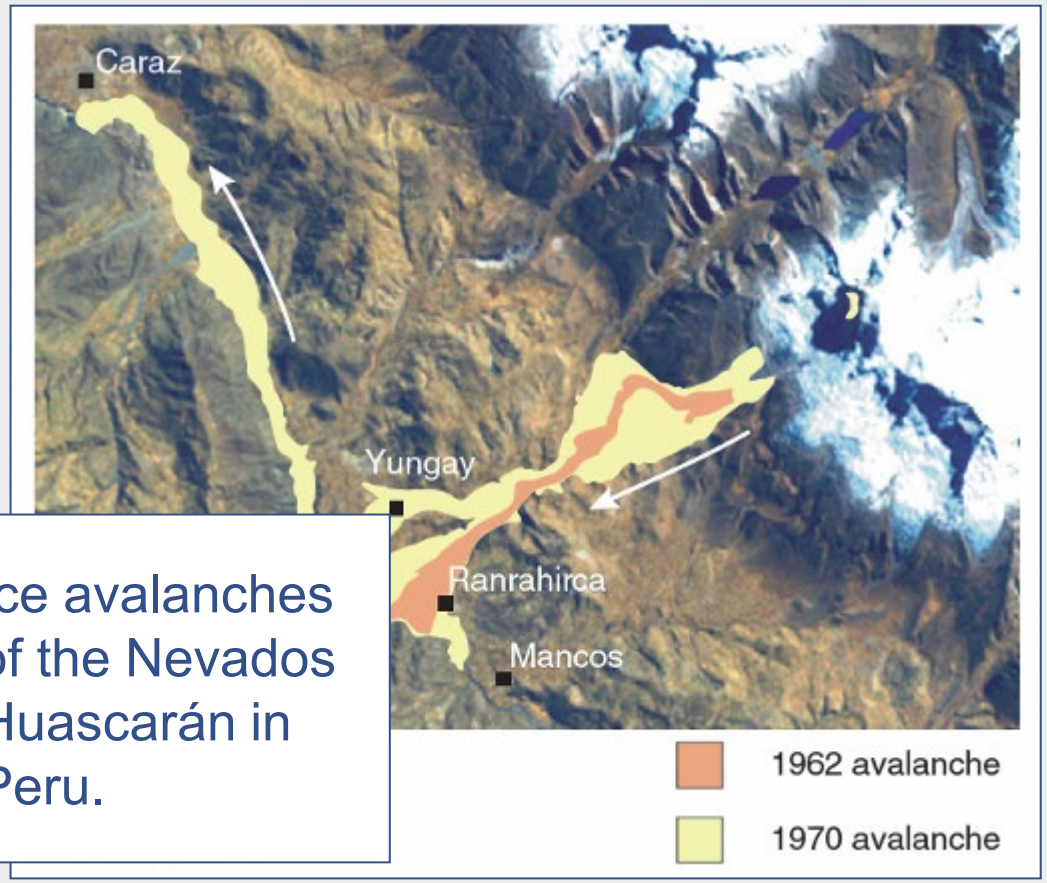
Glaciers: *impacts*

Shrinkage of glaciers leads to ice instability and formation of ice and debris dams, resulting in more flooding, debris flows and ice avalanches.



Ice avalanches of the Nevados Huascarán in Peru.

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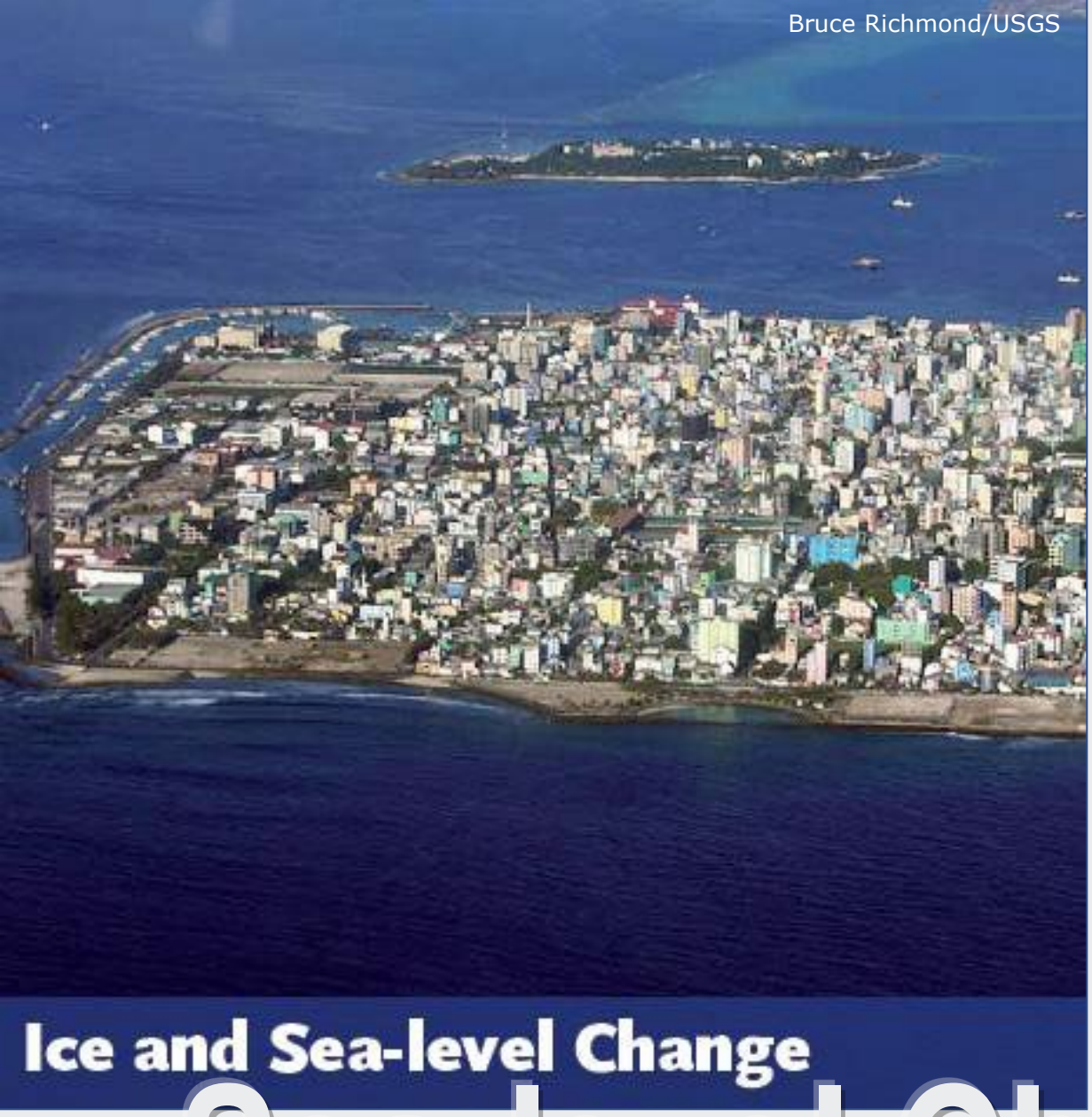


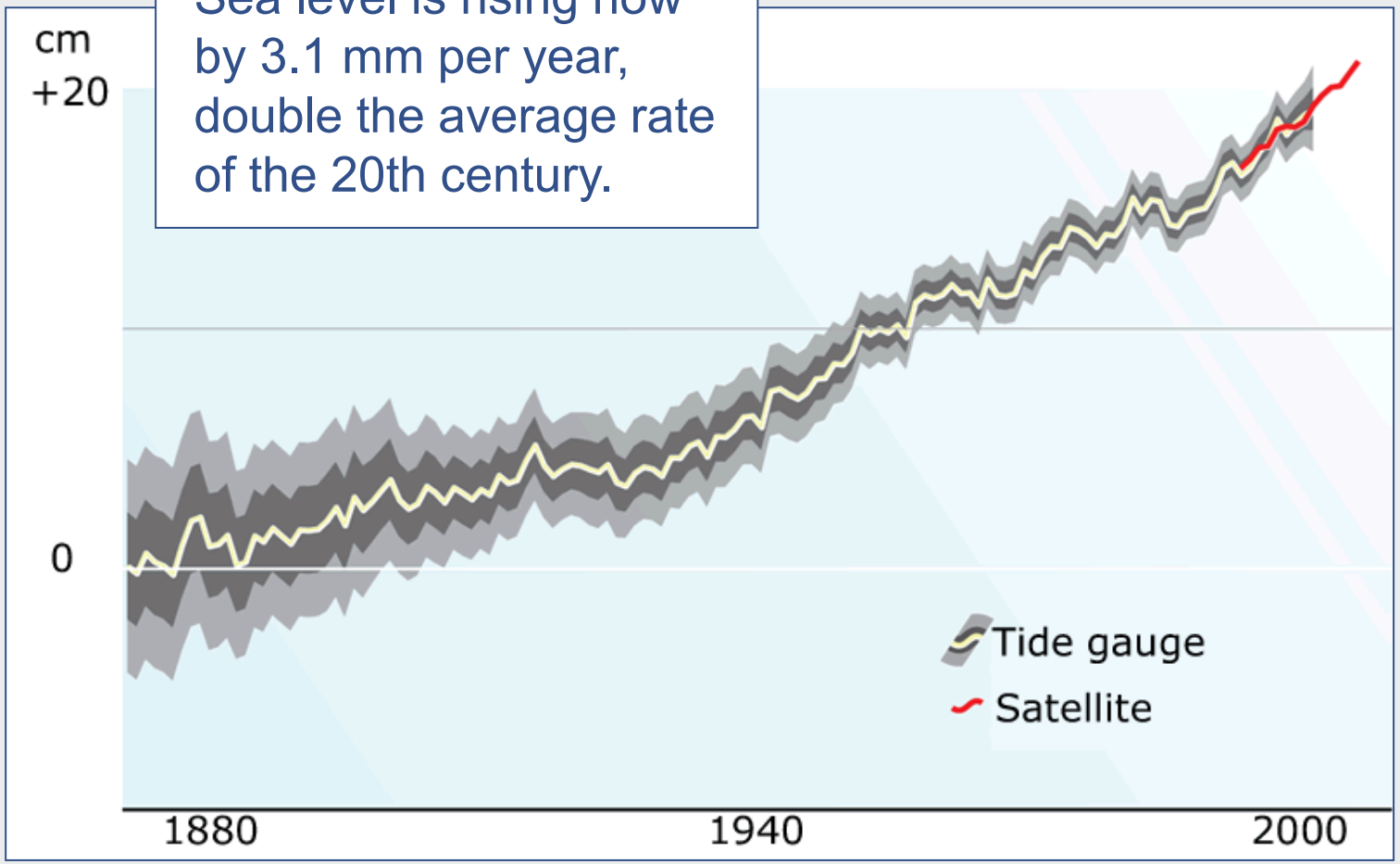
Meltwater from ice sheets, glaciers and ice caps contribute to sea-level rise.

How much the sea level rises relative to the adjacent coast varies from place to place.

Sea-level Change

Sea Level Rise: *trends*

Sea level is rising now by 3.1 mm per year, double the average rate of the 20th century.



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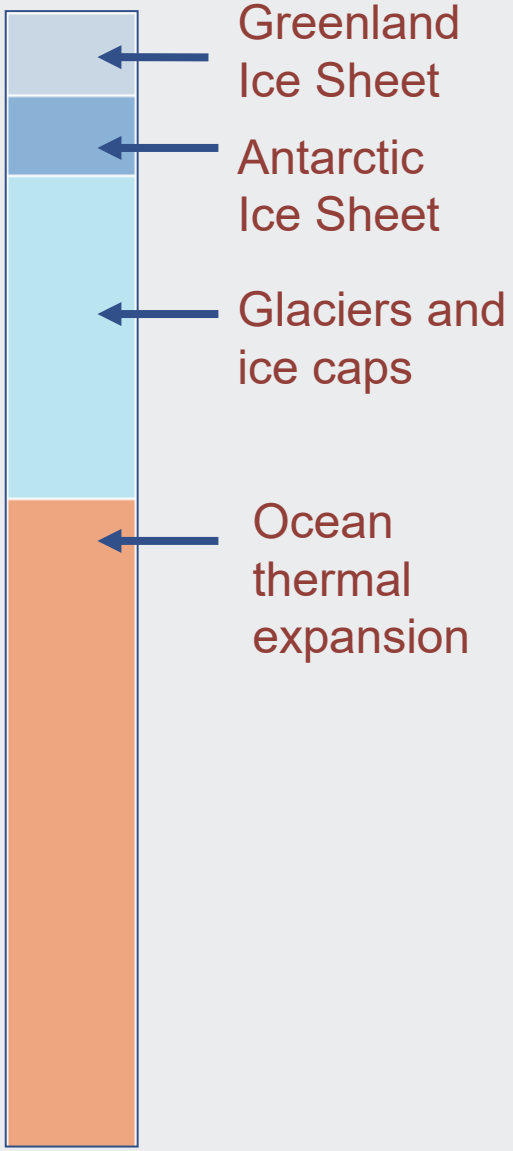
Sea Level Rise: *outlook*

Contributions to sea-level rise



The contribution from meltwater to sea level rise can be expected to accelerate as more land ice melts.

In the long run, the ice sheets have the potential to make the largest contribution to sea-level rise.

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Sea Level Rise: *outlook*

For the next few decades the rate of sea-level rise is partly locked in by past emissions.

Sea-level in the late 21st century and beyond is critically dependent on future greenhouse gas emissions.

Bruce Miller

IPCC projections are for a global sea level rise of 20 to 80 cm over the 21st century. The upper bound is very uncertain.

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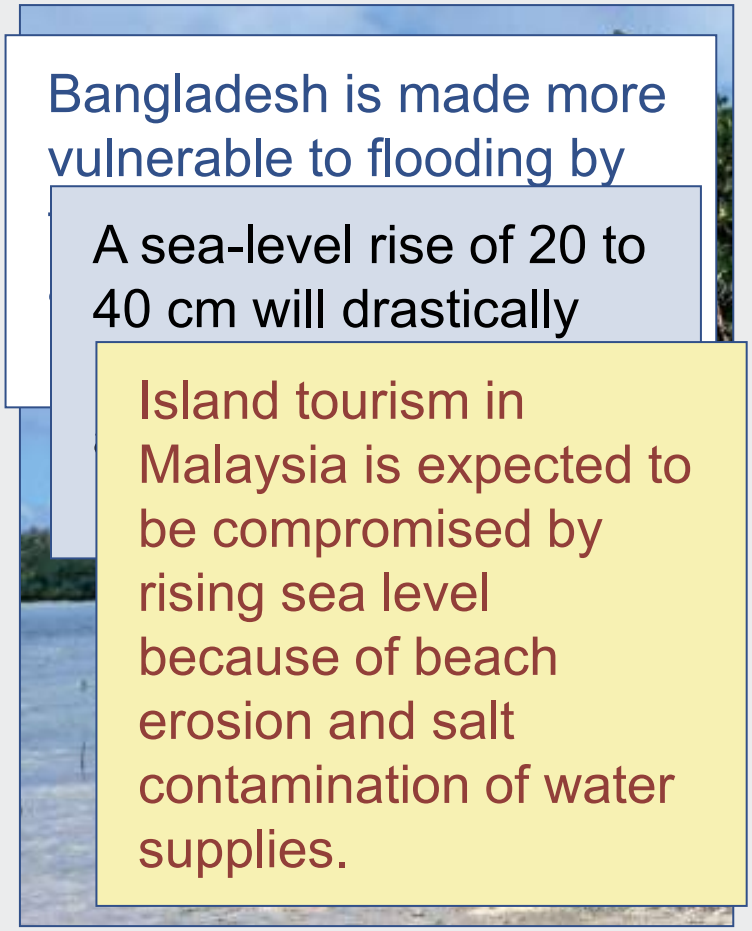
Sea Level Rise: *impacts*

The impacts of sea-level rise in any region will depend on many interacting factors, such as

- whether the coastal region is undergoing uplift or subsidence;
- how much development has altered natural flood protection, like coastal vegetation.



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Sea Level Rise: *impacts*

Magnitude of the issue

Rising sea levels, combined with increased extreme events, will potentially affect millions of people on small islands and at and near coasts world-wide.

Asia: a one metre sea-level rise would affect

- Land: 900,000 km^2
- People: over 100 million
- Economic activity: over US$400 billion in GDP

Veer

UNEP

Sea Level Rise: *adaptation and mitigation*

- A wide range of adaptation and mitigation measures will be required to assist people with the consequences of sea-level rise.
- These measures require cooperation among nations, and among governments, private sector, researchers, NGOs and communities

Patrick Nunn

Restoring shoreline vegetation, Fiji

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Sea Level Rise: *adaptation*

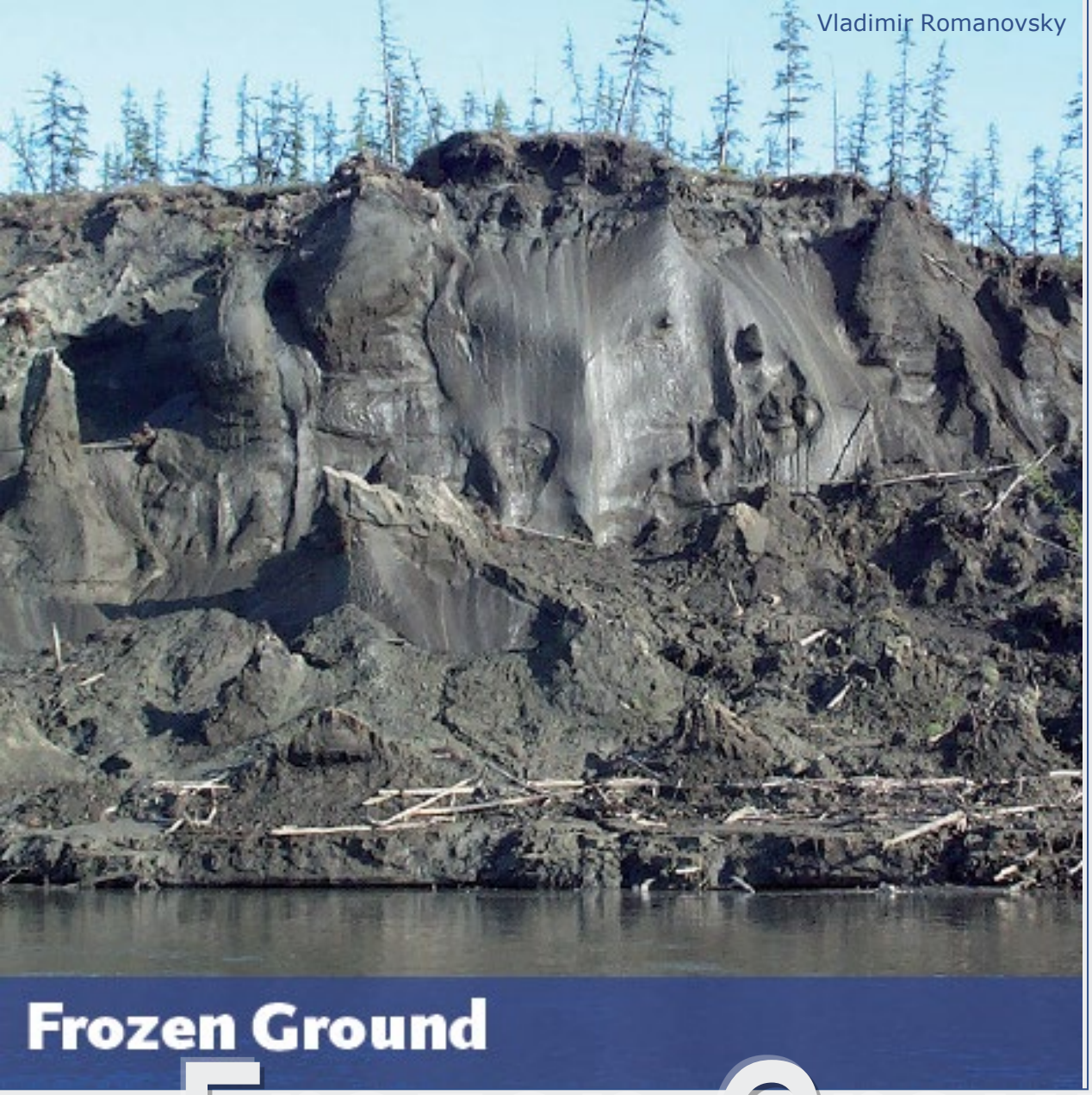
Adaptation Strategies:

- Accommodation: increase resilience, for example through providing storm shelters and warning systems
- Protection: such as barriers, dykes and vegetation
- Planned retreat: for example, designate no-build areas or setbacks from coasts

Patrick Nunn

The Environment Agency

UNEP



Frozen Ground

Permafrost occupies up to 24% of land in the Northern Hemisphere.

Permafrost is also under parts of polar seas, in mountain regions and Antarctica.

Permafrost: *trends*

- Permafrost temperatures have increased during the last 20-30 years in almost all areas of the Northern Hemisphere.
- Warming is reported from areas of mountain permafrost.
- Widespread thawing is not yet occurring.

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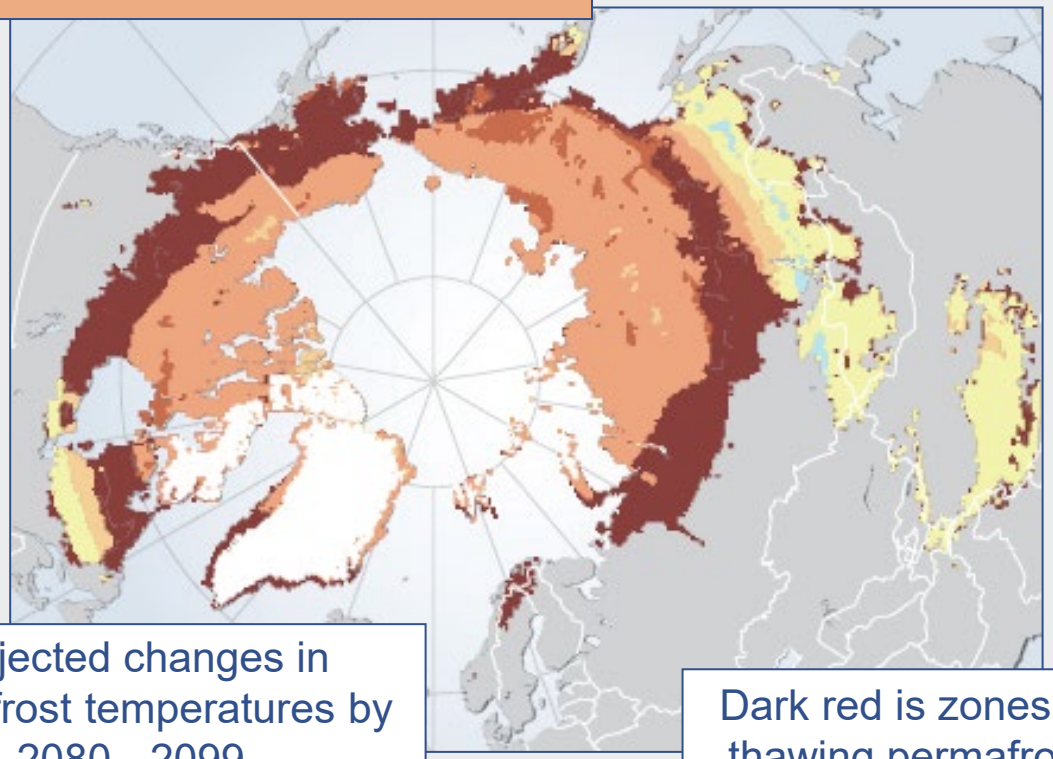
Permafrost: *outlook*

Permafrost thawing is expected to occur across the subarctic by the end of the 21st century.



Projected changes in permafrost temperatures by 2080 - 2099

Dark red is zones of thawing permafrost

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Permafrost: *impacts*

- When permafrost thaws carbon is released in the form of greenhouse gases, accelerating global warming.
- Thawing of ice-rich permafrost results in the land surface subsiding.
- On a large scale, permafrost thawing changes ecosystems – for example, changing forest to wetland.

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Permafrost: *impacts*

- Construction and everyday use of permafrost can result in permafrost thawing – damaging the infrastructure. Warming may accelerate this.
- Good engineering practices prevent permafrost thawing.

Roger Asbury/iStock Photo

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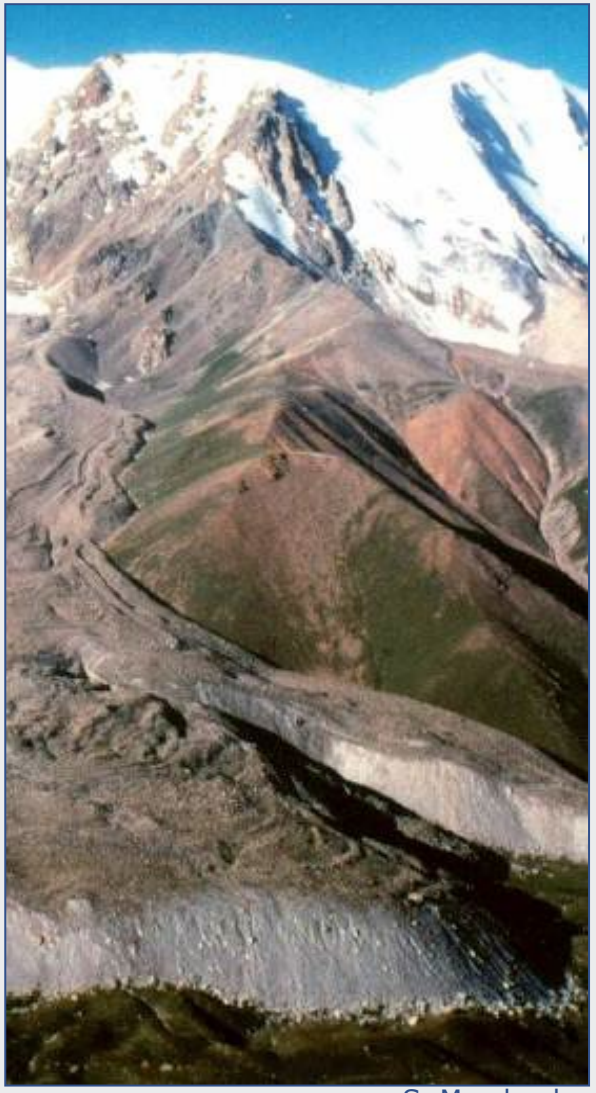
Permafrost: *impacts*

- In mountainous areas, thawing permafrost increases risk of landslides and rock falls and has impacts on infrastructure.
- Permafrost in China has degraded over the past 40 years and is projected to decrease by 30-50% in this century.



S. Marchenko

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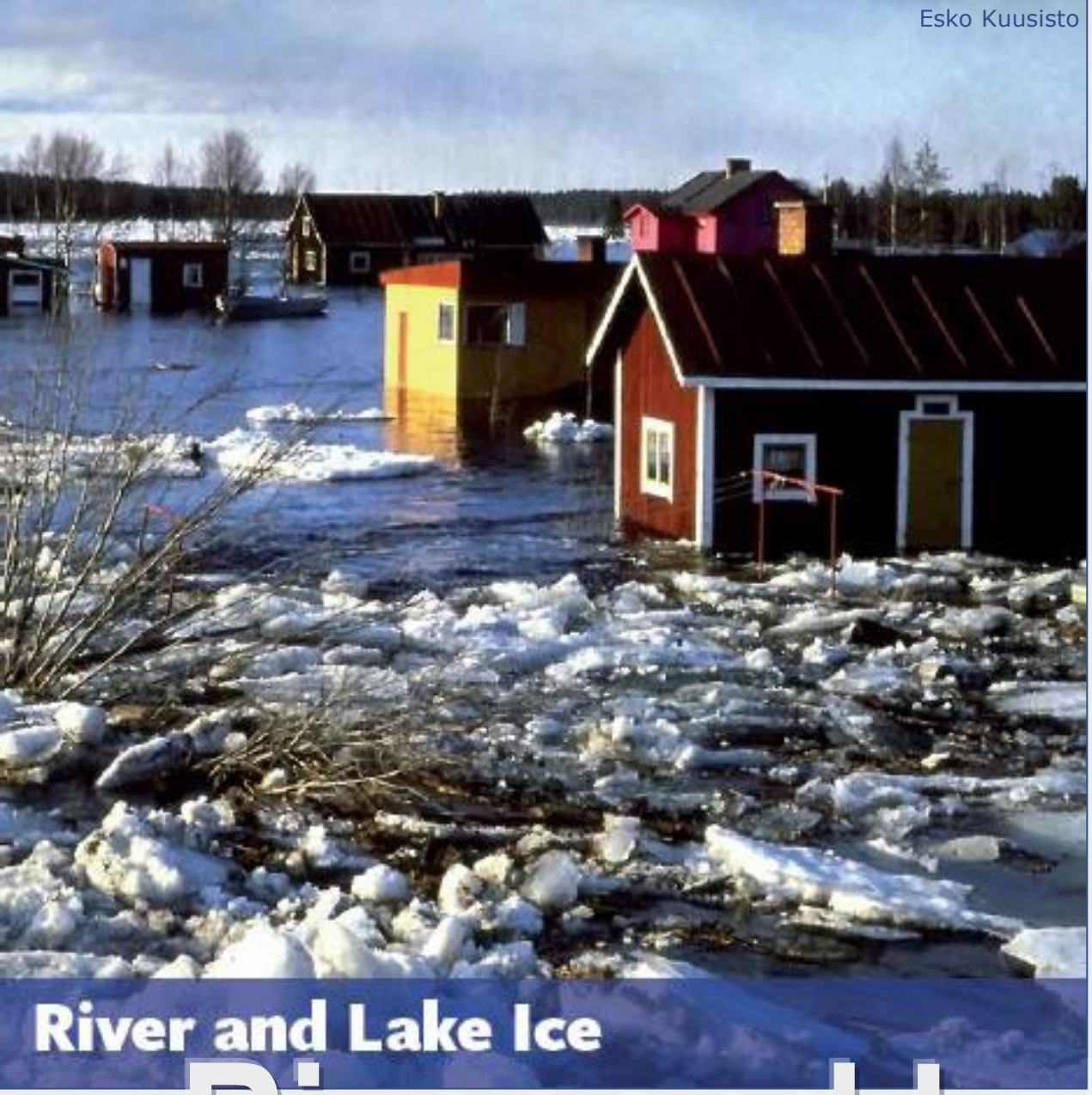

Floating freshwater ice is a key component of cold-regions river and lake systems, mainly in the Northern Hemisphere and mountain regions.

River and Lake Ice

River and Lake Ice: *trends*

- Changes that have largely mirrored rising air temperatures are affecting river and lake ice.
- Main change is earlier spring break up and, to a lesser degree, later autumn freeze up.

R. Borgström

UNEP

River and Lake Ice: *outlook*

The trend to longer ice-free periods is projected to continue, with the amount of change projected for each region being related to the amount of warming forecast.

R. Borgström

UNEP

River and Lake Ice: *impacts*

T.D. Prowse

In remote areas frozen rivers and lakes are used as transport corridors and longer ice-free periods mean reduced or more expensive access to communities and industrial developments.

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River and Lake Ice: *impacts*

Many northern indigenous people depend on frozen lakes and rivers for access to traditional hunting, fishing, reindeer herding or trapping areas.

Shari Gearheard

UNEP

River and Lake Ice: *impacts*

Dörte Köster

- Spring break up often causes damming of rivers by ice, resulting in costly flooding.
- Lowered temperature gradients on northward-flowing Northern Hemisphere rivers may result in reduced flooding.
- This has potential negative ecological consequences where annual flooding maintains important wetlands.

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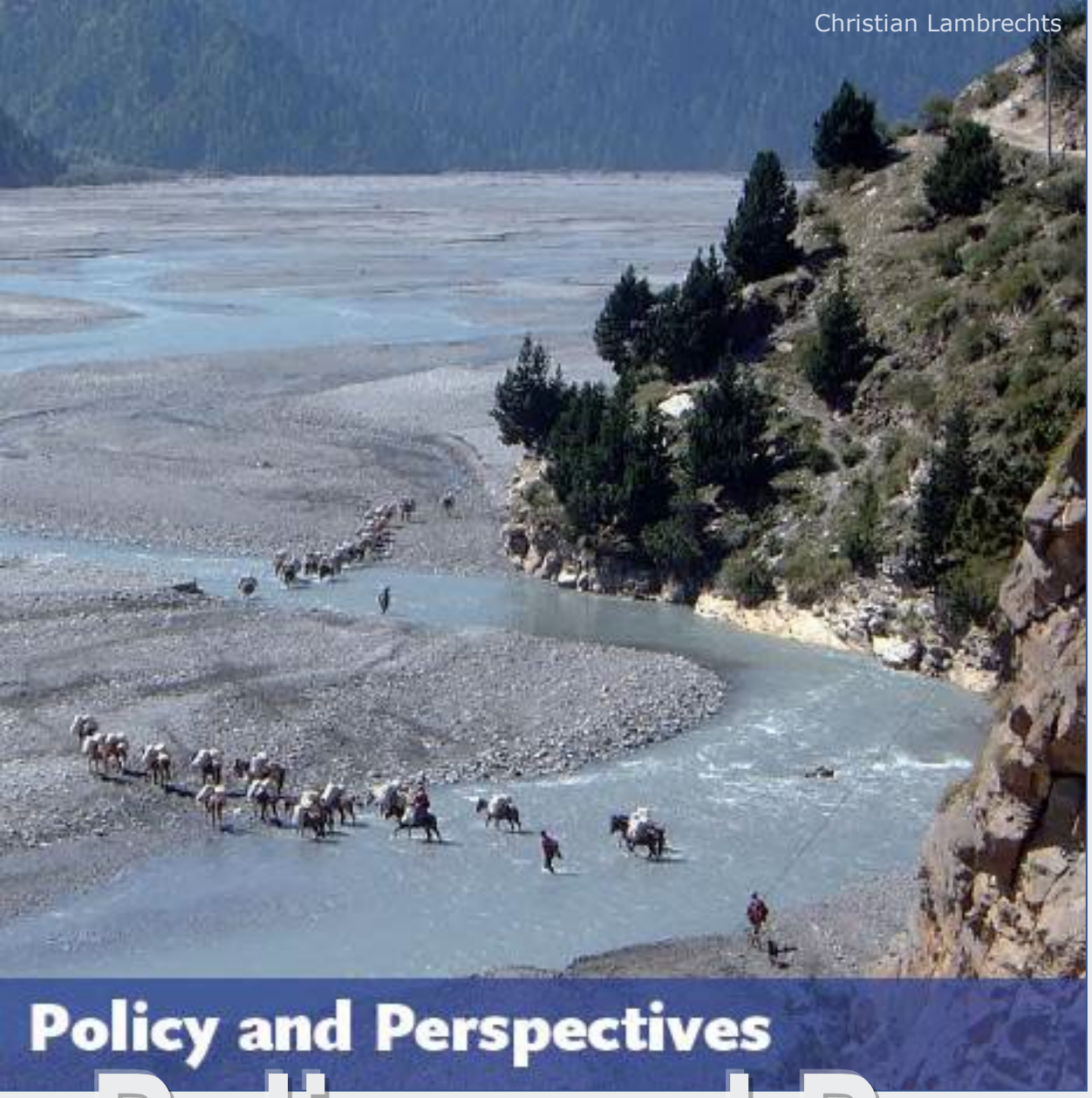

Policy and Perspectives

The underlying theme of the Global Outlook for Ice and Snow is that changes are now observed in ice and snow and bigger changes are projected.

This raises policy issues at global, regional and local scales.

Policy: *global*

- Mitigating climate change by reducing greenhouse gas emissions is the main global policy response.
- IPCC 4th Assessment: to avoid further and accelerated global warming with major negative consequences, greenhouse gases must stop increasing and start decreasing no later than 15 to 25 years from now.

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Policy: *regional*

- Adaptation policy must be tailored to regions and this requires regional scientific knowledge and impact assessment.
- **Arctic:** key policy issues: retreating sea ice and implications for shipping and exploitation of oil and gas reserves, accompanied by issues of jurisdiction and regulation for environmental protection.

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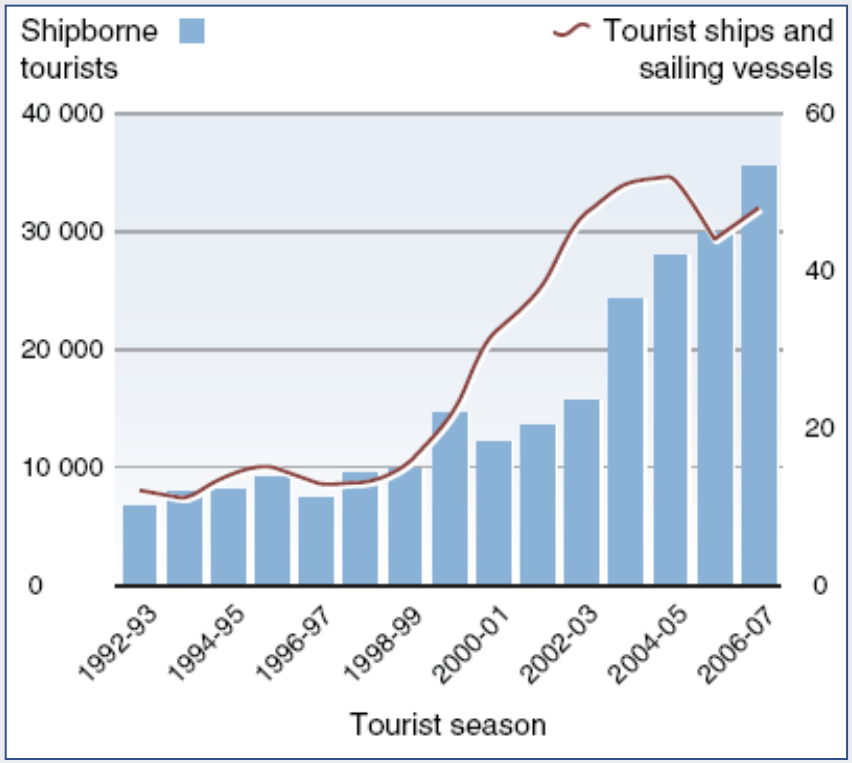
Policy: *regional*



- **Antarctic:** a key policy issue: decreasing sea ice could contribute to rapid expansion of tourism industry: potential negative impacts and need for regulatory regime.

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Policy: *regional*

Falk Kienas/iStock

- **Himalayas – Hindu Kush:** a key policy focus: changes in snowfall and glaciers potentially increasing floods and leading to water shortages affecting hundreds of millions of people: strategies for water management and land use planning to reduce vulnerability.

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Stine Rybråten

Policy: *local*

- Impacts of changes in ice and snow are already major concerns in many Arctic communities. Issues include erosion of coastal infrastructure and access to subsistence resources.
- Expansion of shipping and oil and gas development will bring both local opportunities and potential negative economic and social effects. Most Arctic communities lack capacity to cope effectively with these stresses.

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Perspectives

Indigenous communities say "all things are connected" - the land to the air and water, the earth and the sky, the plants to the animals, the people to the spirit.

If marine mammal populations are no longer accessible to our communities, what can replace them?

ARCTIC

Pacific Island countries are some of the most vulnerable communities in the world and are already experiencing the effects of climate change.

SMALL ISLANDS

What happens to the snows that feed these rivers due to global warming will determine the future of the billion people who live downstream. Think of that next time you stop at a petrol station.

HIMALAYAS

UNEP