Antarctic Climate Change and the Environment
A synopsis and recommendations for action

Hans-O. Pörtner,
XLIV Antarctic Treaty Consultative Meeting
Observations of increasing human impacts on the Antarctic

- Ocean warming
- Ice melt
- Ocean acidification
- Ocean oxygen loss
- Fishing, Pollution, Tourism
- Invasive species
- Human activities
...Will we be able to keep the (global) benefits of a stable Antarctic?

- Stable sea level
- Engine of global ocean circulation
- Biodiversity distribution and pump
- Reducing climate change through heat and carbon uptake (cooling of the planet)
The Antarctic may seem far away, but it provides crucial services to all life around the world... and can provide challenging feedbacks... Our actions today determine its future as well as ours.
…in the global context
From the latest IPCC reports &
SCAR ACCE decadal synopsis
The ocean is projected to transition to unprecedented conditions

- **Ocean heat content** (0–2000 m depth)
  - as $10^{21}$ Joules (right axis)

- **Global mean sea surface temperature**

- **Marine heatwave days**

- **Surface pH**

Changes relative to 1986–2005:
- Historical (observed)
- Historical (modelled)
- Projected (RCP2.6)
- Projected (RCP8.5)
Ongoing changes reflect the crucial role of the Southern Ocean in the global climate system ... at the expense of climate impacts on marine ecosystems.
Processes contributing to global sea level rise (metres)

... according to present knowledge... we have choices between below 1 metre or several metres by 2300 due to

- Thermal expansion
- Glacier melt
- Ice sheet melt

~1.5°C
High uncertainty in the Antarctic contribution to global sea level rise. The most significant global influence of Antarctic changes will be on mean sea level rise and its influence on society and nature in all coastal regions.

Ice sheet contributions to global mean sea level rise have increased, but the contribution so far has been small. E.g. due to ice cliff instability.
Extreme sea levels rise progressively at most locations

- Historical Centennial Events (HCE) become more common
- Many low-lying coastal cities and small islands will be exposed to risks of flooding and land loss annually by 2050
Local extreme sea levels that historically occurred once per century (historical centennial events, HCEs) are projected to become at least annual events at most locations during the 21st century, causing severe impacts depending on the level of exposure.

**Black dots:** Locations where HCEs already recur annually

**White dots:** Locations where HCEs recur annually after 2100
The IPCC concept of risk

Climate action entails risk reduction by adaptation and mitigation .... considering limits to adaptation

Evaluating risks

Limits to Adaptation
- E.g. physical, ecological, technological, economic, political, institutional, psychological, and/or socio-cultural

Level of added impacts/risks
- **Very high**: Purple: Very high probability of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.
- **High**: Red: Significant and widespread impacts/risks.
- **Moderate**: Yellow: Impacts/risks are detectable and attributable to climate change with at least medium confidence.
- **Undetectable**: White: Impacts/risks are undetectable.

Confidence level for transition
- ••••• = Very high
- •••• = High
- •• = Medium
- • = Low
  |- = Transition range

**see figure caption for definition**
Global and regional risk provide orientation for action (adaptation/mitigation)

... avoiding high risk by keeping global warming below 1.5°C
Due to the current trajectory of human-derived GHG emissions, the atmosphere and ocean will continue to warm, the ocean will continue to acidify, atmospheric and ocean circulation patterns will be altered, the cryosphere will continue to lose ice in all forms, and sea level will rise.

SCAR ACCE Decadal Synopsis
Antarctic contributions to global change support the synthetic view by IPCC 2022:

From current imbalance ... ... towards a sustainable future

The risk propeller shows that risk emerges from the overlap of:
- Climate hazard(s)
- Vulnerability
- Exposure

... of human systems, ecosystems and their biodiversity

Future Climate Change
Limiting Global Warming

Climate Resilient Development
Human health & well-being
Equity, justice

Ecosystem health
Planetary health

Governance
Finance
Knowledge and capacity
Catalysing conditions
Technologies

Livelihoods, Ecosystem Services

Societal Energy Industry | Urban, Rural & Infrastructure

Ecosystems Transitions
Land | Freshwater Coastal | Ocean
Ecosystems and their biodiversity

conserve, restore
Ecosystem based approaches

provision

Livelihoods, Ecosystem Services

IPCC WGII AR6 SPM Figure 1
Impacts in the Antarctic
Antarctic changes:

Projected Temperature changes over land

ΔT °C
relative to
1986–2005

8°C
6°C
4°C
2°C
0°C

+2°C
Global warming level

+4°C
Global warming level

(i)

(l)
Life on Land is changing

- The Antarctic Peninsula and parts of West Antarctica are seeing increases in the abundance and distribution of a variety of Antarctic plants
- Growth rates have increased
- Species replacement has occurred in East Antarctica and the Dry Valleys
- Future changes in ranges and populations are uncertain with little long-term data

Forecast:
- The number and distribution of invasive species will increase
Antarctic changes:

Projected Sea Surface Temperatures (SSTs) – approaching and surpassing the thermal tolerance limits of marine fauna
Observations, modelling and global assessments describe significant changes in Antarctic physical and living systems. Antarctic species and systems are highly vulnerable.

Invasion/expansion of crabs as crushing predators due to warming

High thermal vulnerability

Retreating, variable sea ice

Marine fauna is threatened by climate change
Antarctic changes:
Projected Sea Ice extent, variability, stability
Antarctic changes:
Ice and krill dependent species are threatened

• Affecting birds and marine mammals in the Southern Ocean, as well as their patterns of activity.
98% of emperor penguin colonies could be extinct by 2100 depending on sea ice instability and melt.

Compound risks for...

MARINE LIFE

Seabirds and mammals have experienced population declines and increases, range shifts, and changing life histories.

Population changes for birds and seal populations will continue.

Southward movement of krill has occurred and is forecast to continue.

Acidification has had mixed and negative impacts. Ongoing impacts will be negative.

Fish will be negatively impacted.

Changes to benthic systems are largely unknown. Changes in distributions are forecast.

Invasions

Few currently but forecast to increase.

EMPEROR PENGUIN EXTINCTION RISK

Under business-as-usual climate scenarios.

[SCAR update]
Risks for Antarctic Sea Ice Ecosystems and Fisheries in relation to global warming levels

The color gradient indicates the level of additional risk to society as a function of global temperature change. Confidence is provided for the change of risk level at given temperature ranges.
Comparing the Arctic and Antarctic:

Critical risk levels to sea ice ecosystems, marine mammals and sea birds have been or are about to be surpassed in both systems.

(a) Global surface temperature change
Increase relative to the period 1850–1900

Projections for different scenarios
SSP1-1.9
SSP1-2.6 (shade representing very likely range)
SSP2-4.5
SSP3-7.0 (shade representing very likely range)
SSP5-8.5

1.5°C
2.0°C

Global and regional risks for increasing levels of global warming

Summary for Policymakers

- Mortality projections include demographic trends but do not include future efforts to improve air quality that reduce ozone concentrations.
- Increase relative to the period 1850–1900

Comparing the Arctic and Antarctic:

- Biodiversity
-过渡范围
- 风险水平
- 1.5°C
- 2.0°C

- 冰层生态系统
- 海鸟

- SSPI-1.9
- SSPI-2.6（代表非常可能的范围）
- SSPI-2.6
- SSPI-3.7（代表非常可能的范围）
- SSPI-5.8

历史平均温度升高的范围在2011–2020为0.95–1.20°C

1.09°C

分配给风险水平的过渡范围

- 低
- 非常高

非常高的

低

非常高的

历史平均温度升高的范围在2011–2020为0.95–1.20°C

- 抗议性适应
- 不充分的适应

- 不充分的适应

- 不充分的适应
Research Recommendations
Research needs while taking urgent climate action

The Antarctic: A role model for conservation?

Protection of the Southern Ocean:
Spatial requirements (matching the 30 to 50% overall)?
• Regionalization?
• Spatial heterogeneity?
• Migration patterns and corridors?
• Comparative understanding of the spatial needs for biodiversity (e.g. biodiversity pump) across latitudes?
• Cryptic species?

Ecological consequences of:
• Life history specializations and vulnerabilities
• Physiological specializations and vulnerabilities
• Seasonality
Explaining marine biodiversity across latitudes … and in the Antarctic

Lacking: Mechanism-based understanding of biodiversity distribution

The Antarctic in a global context

Antarctic: Diverse, highly endemic fauna

[IPCC WGII AR6, Chhaya et al. 2021]
The Antarctic in a global context

Explaining the ecological consequences
• of physiological specialization, trade-offs and constraints?
• of climate-induced biodiversity shifts?
• of extirpations and extinctions
Topics for Antarctic action and research, e.g.:

- Setting up a network for Antarctic conservation
- Stabilizing the role of the Southern Ocean in climate change mitigation
- Considering the adaptation limits of Antarctic organisms
- Maintaining a future for Antarctic biodiversity
Research needs while taking urgent climate action

- Long-term observatories: atmospheric, cryospheric, oceanography and biology
- Experimental studies
- Modelling approaches

…through:
- coordinated, international and transdisciplinary research efforts by all Antarctic Training Programs;
- Development of an appropriately-resourced scientific workforce for the future
Policy Recommendations
Rapidly changing Antarctic and Southern Ocean environments require similarly rapid environmental governance responses, including potential changes to agreements that have previously taken many years to reach.

SCAR ACCE Decadal Synopsis
Policy recommendations

Governance for managing climate impacts in Antarctic environments is considered **poorly developed**, despite its importance for decision-making.

Communicate the urgency of drastic emission reductions, to ensure that Antarctic and Southern Ocean environments including cryosphere are preserved.

Meet the growing management difficulties, logistic challenges and research requirements, elicited by changes to the Southern Ocean and its ecosystems.

Continue support for research delivering evidence-informed options, for the reduction of uncertainties and for climate change mitigation & adaptation actions.
Climate change is a threat to human well-being and planetary health.

Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all.

IPCC AR 6 WGII
Thank you!