Continued Climate-Induced Changes in the Cryosphere Will Cause Irreversible Impacts Across the Globe

Higher levels of CO_2 emissions and warming (including 2°C) will substantially increase the risk of crossing irreversible Cryosphere thresholds. Lower levels of emissions and warming will in turn substantially decrease this risk. We must limit temperature rise to 1.5°C and below.

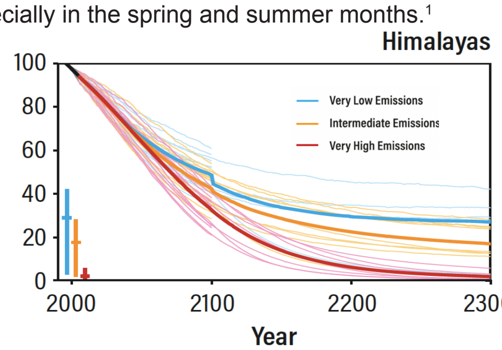
Climate change has brought about significant negative changes in the global Cryosphere, be it snow, ice or permafrost; in both mountain and polar regions. These changes are evident at the local, regional and global levels; including decrease in snow cover; loss of mass from ice sheets, land glaciers and sea ice; permafrost thaw and degradation; and changes in both polar oceans, including acidification, freshening, and disturbances in ocean currents.[1]

Such changes in the Cryosphere however have their greatest human and ecosystem impacts outside of mountain and polar regions; not least because of permafrost carbon emissions, and sea-level rise from melting of mountain glaciers and polar ice sheets.

The Human Impacts of Cryosphere Loss

Mountain Glaciers and Snow

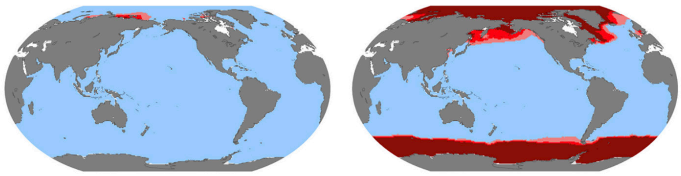
Loss of mountain glaciers and snow, especially in mid-latitude and tropical regions, impacts more than **three billion people**. Current changes are especially acute in the northern Andes, western U.S., Scandinavia, and the Alps; where where the **availability of freshwater, including for economic activities such as agriculture, power generation and tourism, depend on a rapidly shrinking mountain cryosphere**. Changes in the Hindu Kush Himalaya have negative direct and indirect impacts on over two billion people; ranging from **changes in water availability, to flooding and landslides from a deadly combination of extreme rainfall and heightened meltwater**, especially in the spring and summer months.[1]



The water towers of the Himalayas preserve far more ice at 1.5°C compared to 2°C. Based on Marzeion et al. (2012)

Polar Oceans

Because high latitude and polar waters absorb CO_2 more rapidly, the important fisheries in and near the polar regions, for example the North Sea, Barents Sea and Southern Ocean, already are seeing seasonal impacts of ocean acidification.[4] A combination of freshening waters from melt of glaciers and the Greenland Ice Sheet, warmer waters, and the invasion of more mid-latitude species **threaten polar marine ecosystems and local/regional fishing industries**.[2]



Difference between acidification conditions in a 1.5°C world (RCP2.6) (left map), and a 4°C world (RCP8.5) (right map) by 2100. Red shows "undersaturated aragonite conditions", a measure of ocean acidification meaning that shelled organisms will have difficulty building or maintaining their shells, leading to potential decline of populations and dietary sources for fish, with loss of biodiversiry towards simplified food webs. Image source: IPCC SROCC (2019).

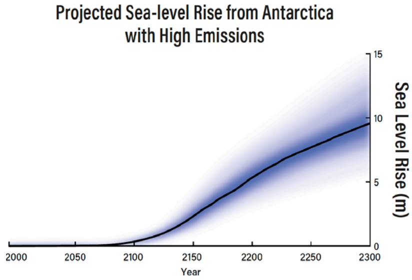
These threats will grow should CO_2 emissions and atmospheric concentrations of greenhouse gases continue to rise. We note that at current rate of increase (≈2.5ppm/year), 450ppm will be exceeded in the 2030's – a level that marine scientists identified already in 2009 as a limit that should not be exceeded, due especially to damaging acidification impacts in polar regions.[5]

Irreversible Sea-level Rise and Other Negative Impacts from Cryosphere Loss

ONE WAY

Most importantly, nearly all of these damaging global impacts from the Cryosphere are essentially irreversible and permanent on human timescales: they will remain for decades, centuries and even millennia. This is especially true with emissions scenarios that contain an overshoot of the maximum global temperature rise set in the Paris Agreement (well below 2°C/1.5°C, with regard to pre-industrial levels).

Indeed, limiting temperature rise to 1.5°C will significantly reduce the risks and negative impacts due to changes in the Cryosphere, with substantial differences between a 1.5°C and a 2°C temperature peak. These include more frequent, intense and longer extreme weather events at 2°C; the potential at 1.5°C to slow multi-meter sea-level rise from Greenland and Antarctica; and preservation at 1.5°C of remnants of mid-latitude glaciers/snowpack that will largely disappear at 2°C, and equally preservation at 1.5°C of two-thirds the ice in the Himalayan region. Permafrost thaw and carbon emissions that require offset for more than a century will also be on a smaller scale at 1.5°C. Preservation of Arctic summer sea ice would occur most years at 1.5°C, versus ice-free conditions for several months each summer by 2°C, with potential for major global climate feedbacks.[6,7]



Models taking into account ice sheet collapse properties project potentially rapid sea-level rise from Antarctica under very high emissions. Adapted from DeConto e al. (2021).

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