What's Happening to the Cryosphere?

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Last fall in Innsbruck, Austria I presented results of research I conducted with Protect Our Winters (POW) at the International Snow Science Workshop on the economics of snow sports. There, I met a French snow scientist who asked me to join his team as a contributing author on a chapter on High Mountain Areas in IPCC's next research effort. **The IPCC Special Report on Oceans and the Cryosphere** came out this September and is such an important work that I wanted to highlight some of its main findings. While I am a social scientist and not a scientist, I've attempted to summarize the science as well to help ensure its information is absorbed by as much of society as possible.

Our engagement with new climate change information depends on how it coheres with our existing perception of how the world works. I want to acknowledge this and distill the report down into digestible chunks that various communities can relate to. For the AAC, distributing information on the alpine environment makes sense. We are all aware of the changes we have seen in the mountains – from rain in winter to shrinking glaciers. How these collective changes are impacting our global environment is what the report investigates.

It is the first IPCC report to examine climate change impacts to the farthest corners of the Earth, from the highest alpine regions to the deepest oceans. The cryosphere is the frozen part of the Earth: ice, snow, glaciers and permafrost. Cryosphere is widespread in polar regions and high mountains. Frozen regions are thawing and impacts are far-reaching. Land and sea ice are melting at accelerating rates. There is rapid surface melt of glaciers and decline in snow cover, especially at lower elevations. The permafrost is melting, with permafrost temperatures increasing to record high levels.

While melting of sea ice does not contribute to sea level rise (as it displaces the same amount of water), melting of land ice and glaciers does. Polar ice sheet loss has overtaken warming ocean expansion and glacial melt as the main cause of sea-level rise. The two largest ice sheets on Earth — the Antarctic ice sheet and the Greenland ice sheet — are melting at accelerating rates. Mass loss from the Antarctic ice sheet from 2007-2016 tripled relative to 1997 –2006, while mass loss doubled from the Greenland ice sheet. To understand how enormous the Antarctic ice sheet is, if it melted completely, sea level would rise by 200 ft. It covers an area larger than the U.S. and Mexico combined.

Arctic sea ice is melting at unprecedented rates. The Arctic Ocean is one of the fastest-changing places on the planet. Loss of sea ice and reduced snow cover decrease the planet's albedo, or reflectivity. This results in an increase in the amount of heat absorbed by the planet, worsening the warming trend. Wildfires across the Arctic and northern expanses will continue to increase for the rest of the century.

Loss of glacial mass and snow cover is diminishing drinking water sources for millions and is contributing to species decline in endemic and native species, such as some coldwater fish (e.g. trout), large mammals and species whose traits directly depend on snow (e.g. snowshoe hares). Water quality is decreased from release of heavy metals, particularly mercury, and other legacy contaminants stored in glaciers. Human health is also negatively impacted, especially for indigenous populations. Food availability (from fishing, hunting and agricultural yields), has been disrupted along with an increased risk in food and waterborne diseases and mental health. Communities in which snow and glaciers hold spiritual significance are experiencing deep losses.

Shrinking glaciers and snow cover have many impacts to recreation. They pose challenges to winter recreationists and to ski resorts, forcing some out of business and increasing financial risks, especially for lower elevation resorts. Many resorts are responding by increasing snowmaking capabilities, which may be effective for a while but may not be feasible in the long term as temperatures exceed minimum temperatures needed for snowmaking. By 2050, only 10 to 13 out of 21 prior Olympic Winter Games locations are projected to have adequate snow reliability, depending on emissions scenario. Cryosphere decline has also reduced some opportunities for ice-climbing. In summer, cryosphere changes are impacting glacier-related activities such as hiking, skiing and climbing and mountaineering. Hiker and climber safety is being compromised along established trails and common access routes. In response, several routes have been relocated and some ladders and fixed anchors have been installed. New opportunities are presented in some locations where visitors are attracted by 'last chance' opportunities to view a glacier or to view the loss of a glacier. Trekking in the Himalaya has been negatively affected and the reduced water availability affects the ability of hotels and campsites to serve visitors.

Permafrost holds double the amount of carbon currently in the atmosphere. As it thaws, enormous quantities of carbon and methane are released – we're talking 10s to 100s of billions of tonnes of CO2 - which further contribute to global warming. Contaminants are also released, affecting water quality. Permafrost thaw is also affecting recreationists: rock falls on and off glaciers are increasingly observed, threatening the safety of hikers and mountaineers, especially in Switzerland and New Zealand. Permafrost thaw, along with glacier retreat, have induced major changes to iconic mountaineering routes in the Mont-Blanc area including reduced route safety and shift in the climbing season.

Sea level rise is the biggest impact of cryosphere loss to oceans. The report reveals that sea level rise is happening faster than anticipated. If global warming is kept to 2 degrees C, the oceans will rise 0.39 meters (1.27 feet) by 2100. If not, they could rise .84 meters (2.8 feet) or higher, depending on the stability of the Antarctic ice shelf. These estimates are higher than previous IPCC reports. That's one thing about these IPCC reports – they report on consensus, which is typically conservative.

The ocean has been acting like a sponge, absorbing heat and CO2 to regulate global temperatures. But it can't continue like it has and is projected to transition to unprecedented conditions. It is challenged by three major climate change-induced stressors: warming, loss of oxygen, and acidification. Oceans have absorbed 90 percent of the excess heat generated around the world over the last 50 years. Since 1993, the rate of ocean warming has more than doubled. As oceans warm, so do their ability to fuel stronger tropical cyclones, and keep those cyclones spinning further and further from the equator. Heatwaves - which we usually think of as happening just on land - have doubled in frequency in the ocean. They have increased in intensity and last much longer than heat waves on land. They kill kelp forests and bleach coral, resulting in loss of many fish and other species. The warming ocean has reduced oxygen (as warmer liquids can't hold as much gas) and led to more stratified layers that don't mix as much, resulting in less oxygen mixing down to deeper water and less nutrients coming up to the surface. This is a challenge to most marine life and has resulted in dead zones reinforced by expanding algal blooms. As the ocean loses oxygen, it's becoming more acidic as it absorbs more C02. Acidic oceans are more hostile to corals and shellfish, as it decreases the concentration of carbonate, a key ingredient to building shells. These climate-change stressors occur alongside other human impacts, such as overfishing, excessive nutrient loads (eutrophication), and plastic pollution. In sum, the world's oceans are stressed to the point of having reached or are near reaching critical tipping points.

The report concludes that the speed and intensity of the future impacts from ocean and cryosphere change depend critically on the quantities of greenhouse gas emissions we chose to continue to release. So, it is a positive that we actually have control over how severe the impacts of climate change will get. We will continue to experience significant changes, but impacts will be much less severe if emissions are significantly reduced. Reducing other pressures such as pollution and overfishing, and increasing habitat and wetland restoration can ease impacts. Improving education and using scientific knowledge alongside local and Indigenous knowledge can support the development of solutions that help communities adapt to changes and respond to challenges ahead.

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