PASSAGE 4

How Will Melting Ice Sheets Affect Us?

Variation is normal. During the last ice age, for example, ice sheets also covered much of North America and Scandinavia. Why is what's happening now different from what happened in the past? "It's different because we are adding an additional factor: extra warming," says geophysicist Isabella Velicogna. "We have a trend in temperature that doesn't look like it's going to slow down or stop." As she points out, many changes are already irreversible. "Once the mountain glaciers disappear, they're gone. Once it becomes so warm that no more sea ice forms in the summer, sea ice will form only in the winter and it won't be thick enough to last through the summer."

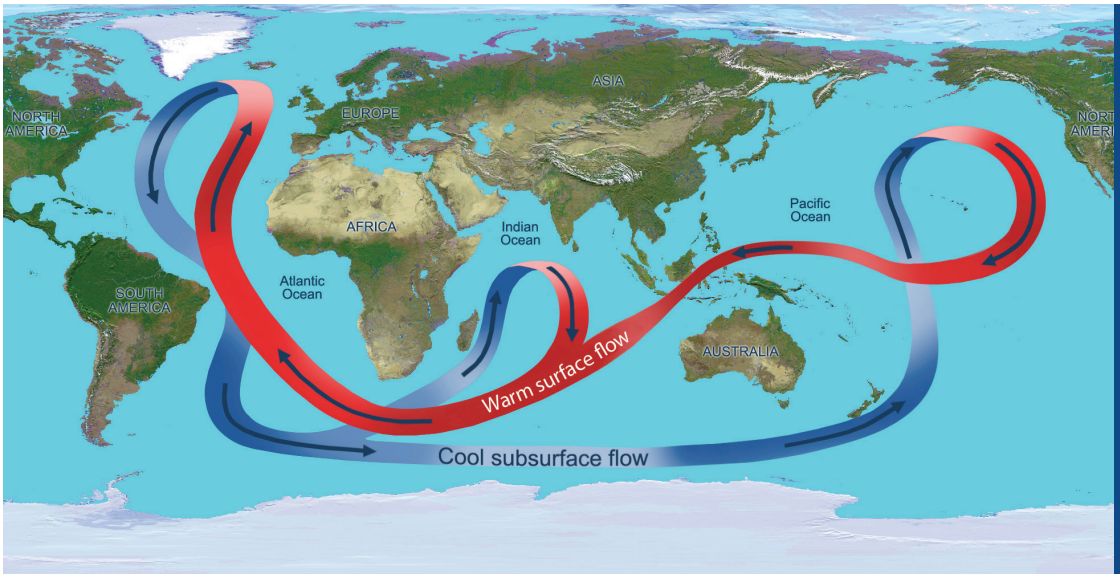
So far the effect has been small, and "maybe it will continue that way for the next ten years," says Velicogna. "The full effects of ice shelves breaking are difficult to predict. But even at present rates, a big part of Greenland will be gone by 2100 for sure, and probably also a big part of Antarctica. Nature has shown us that things can happen very, very fast." We do know that land ice affects many Earth systems, and that its loss will have far-reaching effects.

Climate will be affected by changes in ocean circulation and albedo

Ocean circulation: A constantly moving system of deep-ocean currents, called the global ocean conveyor belt (see figure below), is driven by density gradients in ocean waters. These differences in density are created by temperature (cold water is more dense than warm water) and salinity (salt water is more dense than fresh water). When sea ice forms and the top layer of seawater freezes into pure crystals of ice, the ocean gets a little bit saltier.

Around Greenland, the warm salty waters of the northeast-flowing Gulf Stream merge with cold waters flowing south from the Artic. The collision produces a vast quantity of cold, salty water that is dense enough to sink to great depths. This deep current spreads southward through the deep Atlantic all the way to the Southern Ocean.

Large-scale ocean circulation plays a fundamental role in Earth's climate because it transfers huge quantities of heat around the globe. It generally stabilizes climate over



The global ocean conveyor belt circulates the surface and deep sea currents over incredible distances.

Image source: NASA

hundreds to thousands of years, but it may also cause abrupt change. Past climate records indicate that the circulation system may have occasionally slowed or stopped, then restarted abruptly (within a few years), implying that it has had something to do with the rapid and dramatic shifts in climate experienced by Greenland, northern Europe, and other places in the North Atlantic over the last 75,000 years. A massive influx of fresh water from ice sheets will affect this balance.

Albedo: This is a measure of the reflectivity of the earth's surface. Ice, especially with snow on top of it, has a high albedo and reflects a lot of sunlight back into space. That's how land ice in polar regions helps keep the planet cool. Land and water, on the other hand, are darker and have a lower albedo. The ocean, for example, reflects only six percent of the incoming sunlight. As sea ice shrinks, darker land or water is exposed, absorbs more sunlight, and heats up. This creates a feedback loop: a response to a change that influences the change itself. Less ice increases warming, which melts ice faster, which increases warming, and so on.

Rising sea level poses unprecedented challenges

Glaciers all over the world are melting. Although they don't hold much water on a global scale, they provide fresh water to local communities and their loss is devastating. The Greenland and Antarctic ice sheets, on the other hand, are massive repositories, making sea level rise the most direct and alarming effect of melting.

Between 2002 and 2009, the Greenland Ice Sheet lost ice at a rate of 230 ± 33 gigatons/year, and the Antarctica Ice Sheet at a rate of 143 ± 73 gigatons/year. The total loss for the period corresponds to an average sea level rise of 1.1 ± 0.2 millimeters/year. While this corresponds to only 11 centimeters of sea level rise in a century, the rates of ice loss have been increasing. Consequently, the rate of sea level rise has itself been rising by the substantial amount of 0.17 millimeters each year.

This data visualization shows the changes in elevation over the Greenland Ice Sheet from 2003-2006. The pink and red regions indicate a slight thickening, while the blue and purple shades indicate a thinning of the ice sheet.

Image Source: NASA / GSFC

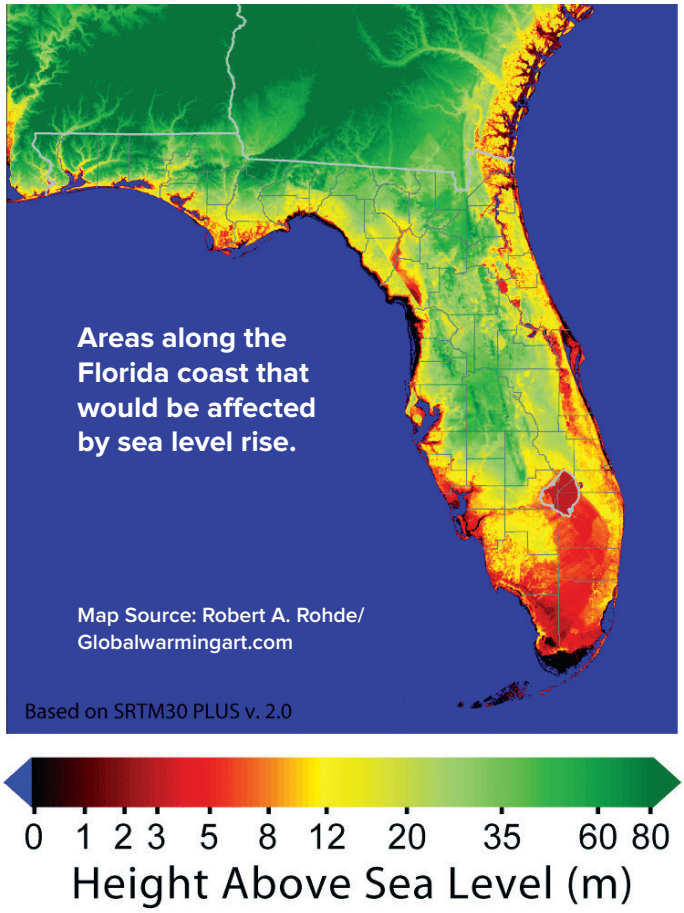
Estimating the amount of sea level rise —and the effects

Plausible estimates for the 21st century indicate that sea level could rise as much as two meters, although most estimates are lower and all are highly uncertain. If the ice sheets continue to melt into the ocean at the present rate, they'd contribute to a sea level rise of one meter by the year 2100. This would be enough to submerge large areas of coastline around the world. As Velicogna puts it, "One meter of sea level rise affects not only the coast but 10 kilometers inland. The surface is going to change, the vegetation is going to change, the animals that live there are going to change." Ecosystems will have to rapidly adapt, and massive numbers of people will be displaced.

Ten percent of the world's population lives in coastal regions within a 10-meter (33-foot) elevation of sea level. Most of the world's largest cities are at or near sea level, including New York, Miami, New Orleans, Bangkok,

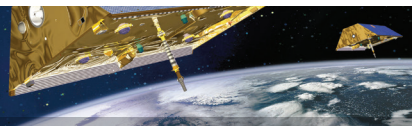
Shanghai, and Kolkata. Rising oceans threaten entire nations, including the Netherlands, the Maldives, and much of Bangladesh. A sea level rise of just 0.5 meters (1.7 feet) in a century would expose most of these populations to flooding (mainly as a result of coastal erosion), as well as to flooding during storm surges and unusually high tides. By the end of the 21st century the number of people worldwide who live along coastlines less than 5 meters above sea level is estimated to increase from 200 million to 400-500 million.

The Greenland Ice Sheet holds enough ice to raise sea level by seven meters were it all to melt. This is enough of a rise to submerge most of Florida. The West Antarctic Ice Sheet contains enough ice to raise sea level by five meters, the East Antarctic Ice Sheet enough to raise it another five. A sea-level rise of 10 meters would flood areas where 25 percent of the U.S. population currently resides, largely in the Gulf and East Coast States. If both ice sheets were returned to the ocean, it would raise sea level by over 75 meters. These changes are unlikely and would in any case take centuries, but need to be taken into consideration



Satellite data will become critically important to managing Earth's water

Can ecosystems adapt? What will the consequences of displacing hundreds of millions of people be? What will it cost? We have no answers unless we can estimate the rate and amount of sea level rise. That's where GRACE and its successors come in. Climate change unfolds over decades, centuries, millennia. "We need three, four, five decades of this kind of information to truly understand the behavior of Earth's water," says Famiglietti. While GRACE's satellites likely won't last that long, climate scientists hope future missions will keep the water data flowing. This unprecedented view of our water planet could prove critical in the effort to anticipate and manage the consequences of climate change for people worldwide. "The problem isn't which factors are natural and which are not," says Velicogna. "The problem is the consequences."



PASSAGE 4

Stop & Think Questions

Based on the Text

1. What are some possible consequences of the loss of land ice from Greenland and Antarctica?

Final Discussion

2. Considering all four passages and science practices listed below, how does the investigation of ice sheets in Greenland and Antarctica provide examples of how scientists work?
   - Asking questions
   - Developing and using models
   - Planning and carrying out investigations
   - Analyzing and interpreting data
   - Using mathematics and computational thinking
   - Constructing explanations
   - Engaging in argument from evidence
   - Obtaining, evaluating, and communicating information.
3. What actions can be taken to minimize the effects of melting ice sheets at the poles?