

# Earth Systems Processes

Artist: Ian van Coller

## Key Message 3.1

### Human Activities Have Caused the Observed Global Warming

Human activities—primarily emissions of greenhouse gases from fossil fuel use—have unequivocally caused the global warming observed over the industrial era. Changes in natural climate drivers had globally small and regionally variable long-term effects over that period.

## Key Message 3.2

### The Estimated Range of Climate Sensitivity Has Narrowed by 50%

Recent improvements in the understanding of how climate feedbacks vary across timescales have narrowed the estimated likely range of warming expected from a doubling of atmospheric carbon dioxide by 50% to between 4.5°F and 7.2°F (*high confidence*).

## Key Message 3.3

### New Data and Analysis Methods Have Advanced Climate Science

A number of scientific developments have enabled deeper understanding of climate processes and their responses to human influence. Observational records have lengthened, and new observing systems have come online. New scenarios of socioeconomic development, and their associated emissions and land-use changes, drive updated climate projections from Earth system models. Large ensemble simulations from multiple models have enabled scientists to better distinguish anthropogenic climate change from natural climate variability. More targeted model evaluation techniques are using observations to narrow the estimated range of future climatic changes. Finally, advances in methods for extreme event attribution enabled scientists to estimate the contributions of human influence to some types of individual extreme events in near-real-time.

### Key Message 3.4

## Humans Are Changing Earth System Processes

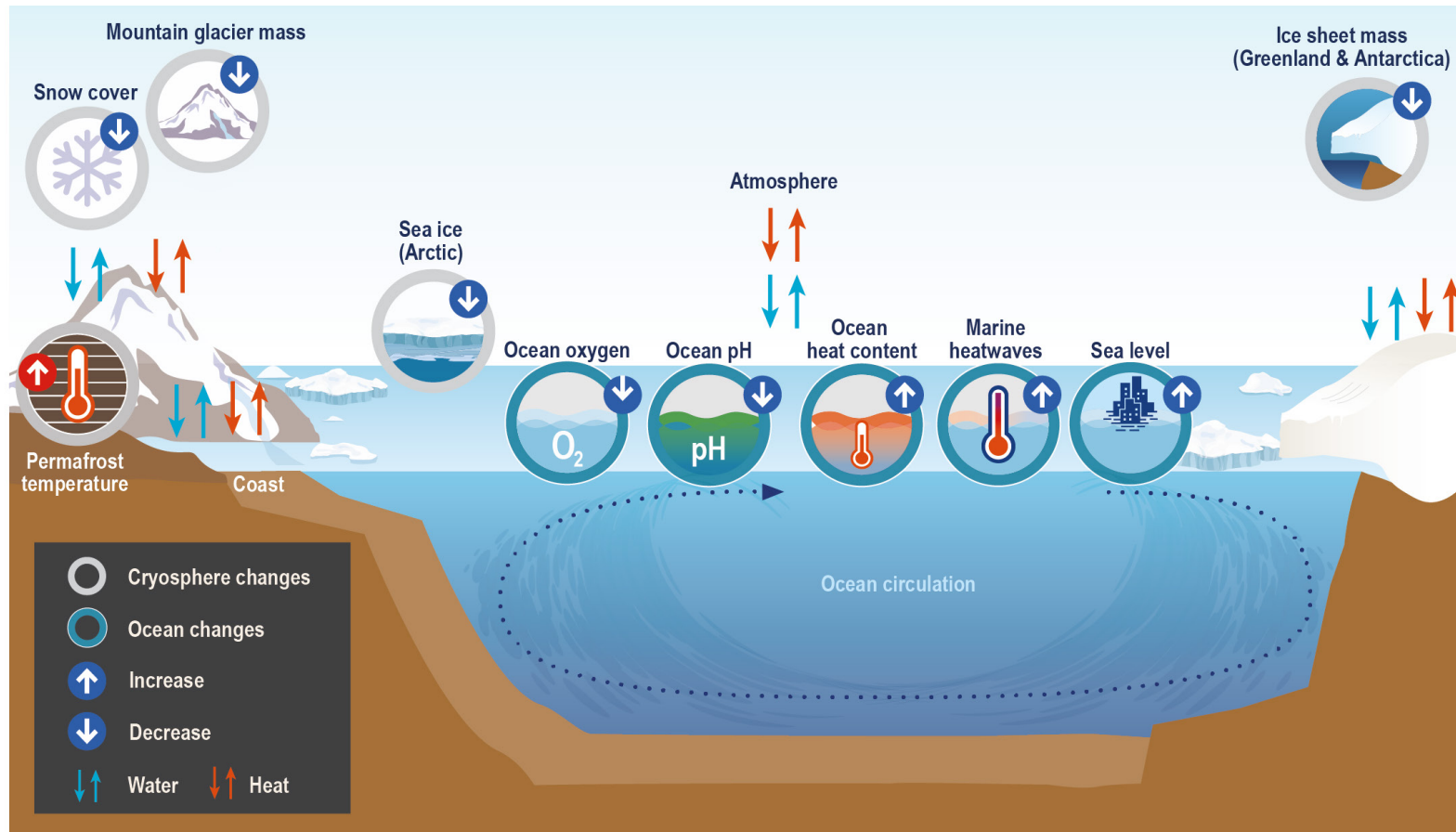
Human activities cause changes throughout the Earth system, including the land surface, cryosphere, ocean and atmosphere, and carbon and water cycles. The magnitude, and for some processes the direction, of these changes can vary across regions, including within the US. These changes also occur against a background of substantial natural climate variability.

### Key Message 3.5

## Humans Are Changing Weather and Climate Extremes

Human activities are affecting climate system processes in ways that alter the intensity, frequency, and/or duration of many weather and climate extremes, including extreme heat, extreme precipitation and flooding, agricultural and hydrological drought, and wildfire (*medium to high confidence*).

## Changes in Ocean, Cryosphere, and Coastal Processes



Climate change has multiple effects on the ocean, atmosphere, and cryosphere and their complex interactions.

**Figure 3.9.** The figure shows important physical processes that play a role in the ocean and cryosphere, along with their linkages. Associated climate change-related effects, including sea level rise, increasing ocean heat content, ocean acidification, marine heatwaves, and ice mass loss, are also shown. The arrows indicate an exchange taking place between ice, ocean, and atmosphere. Adapted with permission from Figure TS.2 in IPCC 2019 (See full chapter for detailed citation).

### Recommended Citation

Leung, L.R., A. Terando, R. Joseph, G. Tselioudis, L.M. Bruhwiler, B. Cook, C. Deser, A. Hall, B.D. Hamlington, A. Hoell, F.M. Hoffman, S. Klein, V. Naik, A.G. Pendergrass, C. Tebaldi, P.A. Ullrich, and M.F. Wehner, 2023: Ch. 3. Earth systems processes. In: *Fifth National Climate Assessment*. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. <https://doi.org/10.7930/NCA5.2023.CH3>