Abrupt Impacts of Climate Change: Anticipating Surprises

Committee on Understanding and Monitoring Abrupt Climate Change and Its Impacts; Board on Atmospheric Sciences and Climate; Division on Earth and Life Studies; National Research Council

December 2013

Summary

	Potential Abrupt Climate Change or Impact and Key Examples of Consequences	Current Trend	Near Term Outlook (for an Abrupt Change within This Century)	Long Term Outlook (for a Significant Change[1] after 2100)	Level of Scientific Understanding	Critical Needs (Research, Monitoring, etc.)
...in the Ocean (cont.)	**Decrease in ocean oxygen (expansion in oxygen minimum zones (OMZs))** • Threats to aerobic marine life • Release of nitrous oxide gas—a potent green house gas—to the atmosphere	Trend not clearly detected	**Moderate**	High	Low to Moderate	• Expanded and standardized monitoring of ocean oxygen content, pH, and temperature • Improved understanding and modeling of ocean mixing • Improved understanding of microbial processes in OMZs
Abrupt Changes in the Atmosphere	**Changes to patterns of climate variability (e.g., ENSO, annular modes)** • Substantial surface weather changes throughout much of extratropics if the extratropical jetstreams were to shift abruptly	Trends not detectable for most patterns of climate variability Exception is southern annular mode—detectable poleward shift of middle latitude jetstream	**Low**	Moderate	Low to Moderate	• Maintaining continuous records of atmospheric pressure and temperatures from both in-situ and remotely sensed sources • Assessing robustness of circulation shifts in individual ensemble members in climate change simulations • Developing theory on circulation response to anthropogenic forcing
Abrupt Changes in the Atmosphere	**Increase in intensity, frequency, and duration of heat waves** • Increased mortality • Decreased labor capacity • Threats to food and water security	Detectable trends in increasing intensity, frequency, and duration of heat waves	**Moderate** (Regionally variable, dependent on soil moisture)	High	High	• Continued progress on understanding climate dynamics • Increased focus on risk assessment and resilience
Abrupt Changes in the Atmosphere	**Increase in frequency and intensity of extreme precipitation events (droughts/floods/ hurricanes/major storms)** • Mortality risks • Infrastructure damage • Threats to food and water security • Potential for increased conflict	Increasing trends for floods Trends for drought and hurricanes not clear	**Moderate**	Moderate / High	Low to Moderate	• Continued progress on understanding climate dynamics • Increased focus on risk assessment and resilience

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Abrupt Changes at High Latitudes	**Increasing release of carbon stored in soils and permafrost** • Amplification of human-induced climate change[3]	Neutral trend to small trend in increasing soil carbon release	**Low**	High	Moderate[4]	• Improved models of hydrology/cryosphere interaction and ecosystem response • Greater study of role of fires in rapid carbon release • Expanded borehole temperature monitoring networks • Enhanced satellite and ground-based monitoring of atmospheric methane concentrations at high latitudes
	Increasing release of methane from ocean methane hydrates • Amplification of human-induced climate change	Trend not clearly detected	**Low[5]**	Moderate	Moderate[6]	• Field and model based characterization of the sediment column • Enhanced satellite and ground-based monitoring of atmospheric methane concentrations at high latitudes
	Late-summer Arctic sea ice disappearance • Large and irreversible effects on various components of the Arctic ecosystem • Impacts on human society and economic development in coastal polar regions • Implications for Arctic shipping and resource extraction • Potential to alter large-scale atmospheric circulation and its variability	Strong trend in decreasing sea ice cover	**High**	Very high	High	• Enhanced Arctic observations, including atmosphere, sea ice and ocean characteristics • Better monitoring and census studies of marine ecosystems • Improved large-scale models that incorporate the evolving state of knowledge
	Winter Arctic sea ice disappearance • Same as late summer Arctic sea ice disappearance above, but more pronounced due to year-round lack of sea ice	Small trend (Decreasing but not disappearing)	**Low**	Moderate	High	• Same as late summer Arctic sea ice disappearance above

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Abrupt Changes in Ecosystems	**Rapid state changes in ecosystems, species range shifts, and species boundary changes** • Extensive habitat loss • Loss of ecosystem services • Threats to food and water supplies	Species range shifts significant; others not clearly detected	**Moderate**	High	Moderate	• Long term remote sensing and in situ studies of key systems • Improved hydrological and ecological models
	Increases in extinctions of marine and terrestrial species • Loss of high percentage of coral reef ecosystems (already underway) • Significant percentage of land mammal, bird, and amphibian species extinct or endangered[7]	Species and population losses accelerating (Portion attributable to climate is uncertain)	**High**	Very high	Moderate	• Better understanding of how species interactions and ecological cascades might magnify extinctions intensity • Better understanding of how interactions between climate-caused extinctions and other extinction drivers (habitat fragmentation, overexploitation, etc.) multiply extinction intensity • Improved monitoring of key species

Levels of carbon dioxide and other greenhouse gases in Earth's atmosphere are exceeding levels recorded in the past millions of years, and thus climate is being forced beyond the range of the recent geological era. Lacking concerted action by the world's nations, it is clear that the future climate will be warmer, sea levels will rise, global rainfall patterns will change, and ecosystems will be altered.

However, there is still uncertainty about how we will arrive at that future climate state. Although many projections of future climatic conditions have predicted steadily changing conditions giving the impression that communities have time to gradually adapt, for example, by adopting new agricultural practices to maintain productivity in hotter and drier conditions, or by organizing the relocation of coastal communities as sea level rises, the scientific community has been paying increasing attention to the possibility that at least some changes will be abrupt, perhaps crossing a threshold or "tipping point" to change so quickly that there will be little time to react. This concern is reasonable because such abrupt changes—which can occur over periods as short as decades, or even years—have been a natural part of the climate system throughout Earth's history. The paleoclimate record—information on past climate gathered from sources such as fossils, sediment cores, and ice cores—contains ample evidence of abrupt changes in Earth's ancient past, including sudden changes in ocean and air circulation, or abrupt extreme extinction events.

One such abrupt change was at the end of the Younger Dryas, a period of cold climatic conditions and drought in the north that occurred about 12,000 years ago. Following a millennium-long cold period, the Younger Dryas abruptly terminated in a few decades or less and is associated with the extinction of 72 percent of the large-bodied mammals in North America.

Some abrupt climate changes are already underway, including the rapid decline of Arctic sea ice over the past decade due to warmer polar temperatures. In addition there are many parts of the climate system that have been thought to be possibly prone to near-future abrupt change that would trigger significant impacts at the regional and global scale.

For some of these potential changes, current scientific understanding is insufficient to say with certainty how significant the threat is. In other cases, scientific research has advanced sufficiently that it is possible to assess the likelihood, for example the probability of a rapid shutdown of the Atlantic Meridional Overturning Circulation (AMOC) within this century is now understood to be low.

In addition to abrupt changes within the climate system itself, gradual climate changes can cross thresholds in both natural systems and human systems. For example, as air and water temperatures rise, some species, such as the mountain pika or some ocean corals, will no longer be able to survive in their current habitats and will be forced to relocate or rapidly adapt. Those populations that cannot do so quickly enough will be in danger of extinction. In addition, human infrastructure is built with certain expectations of useful life expectancy, but even gradual climate changes may trigger abrupt thresholds in their utility, such as rising sea levels surpassing sea walls or thawing permafrost destabilizing pipelines, buildings, and roads.