Climate Change Part 1: Causes and Consequences

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Droughts. Royal Lake floods. Record-setting heat waves. Snowmageddon. The derecho. Superstorm Sandy. Are these weather events resulting from climate change? In this special series, we'll explore climate change theory, learn how you can prepare for a warmer world, and steps to slow or even reverse this problem. Planetary topics might seem pretty intense for community newsletters until one realizes the long, global reach of each neighborhood and land steward.

Introduction

"Anthropogenic (or human-induced) climate change" is the technical term applied to the modern era's abnormally altered climate created by human activity; the shortened "climate change" name will be applied in this article. One of climate change's repercussions is a warmer atmosphere, popularly called "global warming." As the name suggests, global warming involves the entire planet's temperature trends over an extended time period. The heating takes place unevenly; for example, the poles are experiencing higher temperature increases from their normal baselines compared to equatorial regions. Some places may even experience cooler temperatures due to wind and precipitation shifts brought by warming elsewhere. Neither a single weather event nor the climatic history at a sole location can be held as a climate change example.

Gradual climate change is a normal part of Earth's history. As the climate shifts from hot, humid epochs to ice ages and back, the flora and fauna adapt to the new conditions, migrate to more preferential areas, or become replaced by newly evolving species. In any case, the net species and ecological niches filled remain relatively constant, resulting in balanced ecosystems. Occasionally, a catastrophic event occurs, such as asteroid impacts or colossal volcanic eruptions, driving a huge percentage of species to extinction (more on extinctions later). This die-off pace exceeds the rate surviving species can evolve into the newly vacant niches, resulting in ecological imbalances.

We are in the midst of a rapid climate change period caused by human activities releasing heat-trapping (aka "greenhouse") gases. Naturally-produced greenhouse gases [e.g., water vapor; carbon dioxide (CO_2) from volcanoes, oceans, wildfires, and respiration; methane from anaerobic decomposition], provide the biosphere with thermal stability. Though less than natural sources, anthropogenic greenhouse gases tip the balance, causing higher temperatures. Table 1 summarizes the major pollutants fueling the current climate change. The U.S.'s 2010 greenhouse gas total was over 6.8 billion metric tons worth of CO_2 heat-trapping potential!

Table 1. Based on USEPA data summaries for 2010 (published in the DRAFT of Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011), this table summarizes the three major anthropogenic greenhouse gases, their primary sources, heat retention potential relative to CO_2, and life in the atmosphere. The final 2% (not shown here) are other emissions, such as fluorinated gases.

Greenhouse Gas	Primary Source(s)	Percent of Output	CO_2 Equivalent	Years In Atmosphere
CO_2	• Burning fossil fuels • Other, non-fossil fuel sources	• 80% • 4%	1X	50-200
Methane	Industry, livestock (cattle), fossil fuel systems and mining, and rotting garbage	10%	21X	12
Nitrous Oxide	Fertilizers, agriculture	4%	300X	120

Scientists trace greenhouse gas production from the dawn of civilization (clearing land for agriculture, domesticating and expanding livestock herds) to modern eras based on the air trapped in snowfall. Over the centuries, accumulating snow in alpine and polar regions compress into glacial ice. Just like radioactive isotope ratios enable ancient organic materials to be dated via carbon-14 content, the glacier bubbles also hold measurable isotopes. Combining these data with historic records, tree ring growth, and ocean sediments demonstrate the correlation between extra atmospheric greenhouse gas and a hotter planet. Only in the past 200 years or so have human population sizes and emissions per person compound into major climatic problems.

Too Much Greenhouse Gas Production In Too Little Time
Earth has great ways of scrubbing naturally produced greenhouse gases: water vapor soon cools, condenses, and precipitates; CO_2 dissolves into oceans (more than is released) and is absorbed by forest plants. Nature cannot keep up with removing extra CO_2, especially with heavy deforestation rates. The outcome of overloading anthropogenic greenhouse gas is Earth quickly heats. With reduced—and the eventual loss—of Arctic sea ice, Earth forfeits significant reflectivity or “albedo,” and sunlight no longer bounces out to space. The dark water absorbs more solar energy and increases polar temperatures. That sea ice loss does nothing to the global sea level. However, the warm, open water heats the surrounding land, further accelerating the glacier and ice shelf melt; that water flows into the oceans and elevates sea levels. Furthermore, warmer poles means thawing permafrost, which currently locks frozen vegetation. Without permafrost, microbes decompose the organic material, resulting in more methane and CO_2 release, not to mention all of the buildings, roads, bridges, and other infrastructure buckling under soft, unstable ground.

A warming planet enables more tropical organisms—even unwanted ones—to survive further north. Frosty climates prevent northern spreads of certain pests, such as disease-spreading mosquitoes and invasive tropical species (e.g., fire ants, giant African land snails, Burmese pythons, Eucalyptus trees). Losing mountaintop ecosystems is another climate change repercussion. Increasing highland temperatures may displace cool-dependent organisms from their habitat island. These organisms must jump to a higher mountain range, head north, or perish.

Most organisms recognize new seasons through either temperature or daylight changes. Which one an organism responds matters little when all other members in the environment have their behaviors synchronized so that at approximately this date, a certain flower blooms or another animal hatches. Global warming would mean that thermally activated organisms would go about life earlier in the year, but the daylight-driven critters stay on their scheduled timelines. If climate change shifts the timings of interdependent organisms from the two groups (e.g., migrating animals miss a flower’s bloom so the flower slips past pollination and the animal starves, an insect egg hatches before host leaves sprout), the environment becomes imbalanced. The worst-case scenario leads to extinctions and collapsing ecosystems.

The extra CO_2 may help plants grow a bit faster and fuller than previously observed. A six-year investigation at Duke University (published in 2006)—complete with chambers simulating a higher CO_2 world—made headlines after revealing how CO_2-rich air stimulates poison ivy growth. In elevated CO_2, it both outpaced other test plants and increased the itchy urushiol production. Another high CO_2 consequence: ocean acidification. As oceans absorb CO_2, the gas reacts with seawater, forming carbonates and carbonic acid. Too much carbonic acid decreases the pH of the ocean, harming sea life. This acidification especially hurts calcareous algae, shellfish, and corals—the latter already suffer bleaching from higher sea temperatures. Without coral and their reefs, many marine species will lose their habitat and coastlines sacrifice protection against storms and pounding waves.

Other Expected Impacts
On a hotter planet, anticipate extreme weather. The extra heat will increase evaporation rates, raising humidity. Water vapor quickly reaches saturation levels and heavy rains trigger flooding; cooler latitudes could see more winter snows. Meanwhile, other areas experience drought and crop failure. In part because of environmental and agricultural problems, radical weather patterns spur regional instability, which is why the U.S. military seriously studies climate change. Since people develop too close to water, more tax dollars will be selectively spent on dikes, levies, sea gates, and other pricy coastal protection measures. Other areas will be left to flood.

Many people wonder if Superstorm Sandy’s damage is linked to global warming. The answer is a complex yes, no, and maybe. The elevated sea levels are definitely from a warmer world with less water locked in glaciers and ice shelves. Higher seas meant the storm surge flooded more elevated land than a same sized surge would 100 years ago. The "no" comes from the storm making landfall less than 24 hours after the full moon. When the earth, moon, and sun align during the full and new moons, the tidal flux is at its highest and called a "spring tide." Climate change had nothing to do with this astronomical coincidence. The "maybe" concerns the storm's intensity. Climate models predict larger, more powerful storms than previously experienced. Factors potentially contributing to Sandy's strength include warming seas, converging storm systems, and simple bad luck.

Why Ecosystem Imbalances and Extinctions Are "Bad Things"

Without high biodiversity levels, ecosystems fall off balance. The initial belief was only a handful of species crucially influence a habitat's wellbeing. Now we know these keystone species comprise a much larger number. Many people understand basic food chain concepts (plants feed herbivores, smaller carnivores prey upon herbivores, and top predators eat lower animals). For many years, the lowest organisms were deemed crucial foundations to the web of life. These days, we see plenty of examples where higher trophic species are equally important to an ecosystem's health as the basal plants and microbes. Wolf eradication brought habitat imbalance with huge deer and elk populations. Reintroducing wolves to Yellowstone National Park restored that ecosystem and improved biodiversity; water quality improved as diverse native vegetation returned and stabilized riparian areas. On the other hand, northern Virginia's limited hunting and frequent vehicle collisions are poor deer controlling substitutes for filling a major predator void. As a result, excessive deer browsing is one factor significantly altering the forests' health as we learned how it impacts box turtles in the *Habitat Islands* article (March 2013). Fortunately, wolf reintroduction reset balance, at least in Yellowstone. When massive extinctions occurred in the past, eventually other organisms evolved to fill vacant niches, but that recovery takes about 4-5 million years. This estimate comes mostly from the fossil record and studies on vulnerable, isolated localities (e.g., the Galápagos Archipelago); in some case, measuring DNA mutations in semi-conserved genes provides species divergence time estimates.

A note about the recent buzz on bringing back extinct species: we can hope this technology may some day rightfully return species lost through human ignorance. The result should be whole genome (include native mitochondrial or chloroplast DNA in addition to nuclear DNA) replicates of the extinct species and not a hybrid or chimera of other organisms. Traditional conservation efforts are far more cost-effective than letting species die and then try recovering them—think of the old adage "an ounce of prevention is worth a pound of cure." Anyway, that organism still needs a suitable habitat or its resurrection will be in vain.

Food For Thought

Most people now accept that human-induced climate change is real and any remaining naysayers need to wake up. We are part of this planet and the planet is part of us. What we do and how we act has worldwide ramifications just as global warming impacts us and every other living creature. Part 2 will explore ways to prepare for climate change and show how each person is empowered to combat this crisis.

Additional reading for the general public:

- http://climate.nasa.gov/
- http://environment.nationalgeographic.com/environment/global-warming/
- http://www.defenders.org/climate-change/climate-change-101
- http://www.epa.gov/climatechange/basics/
- http://www.ncdc.noaa.gov/cmb-faq/globalwarming.html
- http://www.nwf.org/Wildlife/Threats-to-Wildlife/Global-Warming.aspx
- http://www.ucsusa.org/global_warming/science_and_impacts/impacts/early-warning-signs-of-global-9.html

Kunzig, Rob. 2012. Antarctic methane could escape, worsen warming. *National Geographic News*. http://news.nationalgeographic.com/news/2012/08/120831-antarctica-methane-global-warming-science-environment/

Perkins, Sid. 2013. Global temperatures are close to 11,000-year peak. *Nature* doi:10.1038/nature.2013.12564 http://www.nature.com/news/global-temperatures-are-close-to-11-000-year-peak-1.12564

Staudt, Amanda, Corey Shott, Doug Inkley, and Isabel Ricker. 2013. *Wildlife in a Warming World*. National Wildlife Federation. On-line report: http://www.nwf.org/~/media/PDFs/Global-Warming/Reports/NWF_Wildlife-Warming-World_Report_web.pdf?dmc=1&ts=20130317T1732102725

Scientific and peer reviewed resources:

- Atmospheric Physics and Chemistry Group: http://www.projects.science.uu.nl/atmosphereclimate/publications.php
- Intergovernmental Panel on Climate Change: http://www.ipcc.ch/

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