

GLOBAL CLIMATE CHANGE:

The Oceans Take the Heat and Coral Bleaching

Enduring ideas are statements summarizing important concepts, principles and core processes that are central to a discipline. Among enduring ideas we know about climate and climate change are the following:

- Fundamentally, climate is the story of how the solar energy intercepted by Earth is absorbed, scattered, reflected, stored, transformed, put to work, and eventually emitted back to space as infrared radiation.
- Earth's climate evolves through changes in external agents that affect the climate system and the climate system's internal dynamics.
- Earth's climate is undergoing change, as it always has and always will. The climate record shows change can be gradual or abrupt.

With these enduring ideas in mind, we will explore global climate change and impacts based on the observational record. Our goal is to gain an overview of climate change from a planetary perspective.

Evidence of a Warming World:

As we know from the instrument-based observational record from 1880 through 2013 a generally rising global mean surface temperature that unequivocally confirms change in the state of Earth's climate system. Simply stated, it verifies that we live in a warming world.

This global warming results from the addition of extra heat to Earth's climate system, primarily arising from the build-up of heat-trapping gases in the atmosphere.

Numerous research studies, based exclusively on the observational record and fundamental principles of physics and chemistry, have quantified how much heat has been and is being added to Earth's climate system and where it is located. **Figure 1** summarizes where the additional heat responsible for global warming resides in Earth's climate system in recent years.

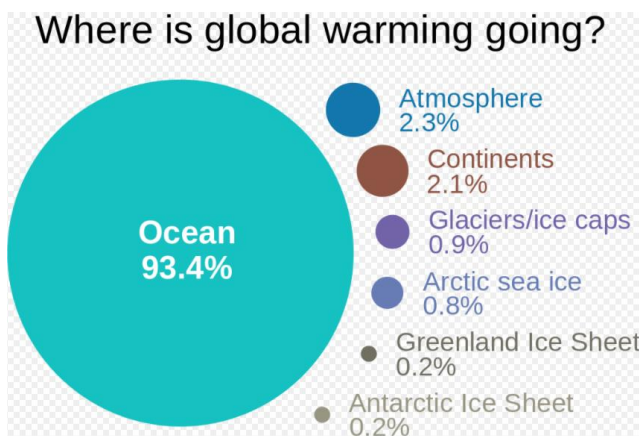


Figure 1. Reservoirs for heat added to Earth's climate system responsible for global warming. [2009 State of the Climate Highlights, NOAA]

1. Figure 1 shows that most of the heat responsible for global warming that has been added to Earth's climate system resides in the [(glaciers, ice caps, and ice sheets)(atmosphere) (continents)(ocean)].

About 71% of Earth’s surface is covered by ocean, which contains 97% of the planet’s water. Because of factors including its fluid motions and ecosystems, the global ocean plays a major role in shaping Earth’s climate, its variability and change. Because of water’s high heat capacity, the ocean holds the heat it accumulates while warming and cooling far more slowly than air. This sluggishness extends the impacts of human activity on the state of the climate for decades, centuries, and millennia into the future. **This is one example that demonstrates what we do today to perturb Earth’s climate system will have far greater consequences on future generations than on us.**

Figure 2 displays the yearly heat content of the top 700 m (2300 ft) of the global ocean from 1955 through 2013 based on departures from the 1971-2000 average as calculated by NOAA. In the figure, the black curve shows the yearly average through 2013. The red curve displays running 3-month averages through October-December 2013, and the blue curve shows the running pentadal (5-year) average from 2009 through 2013.

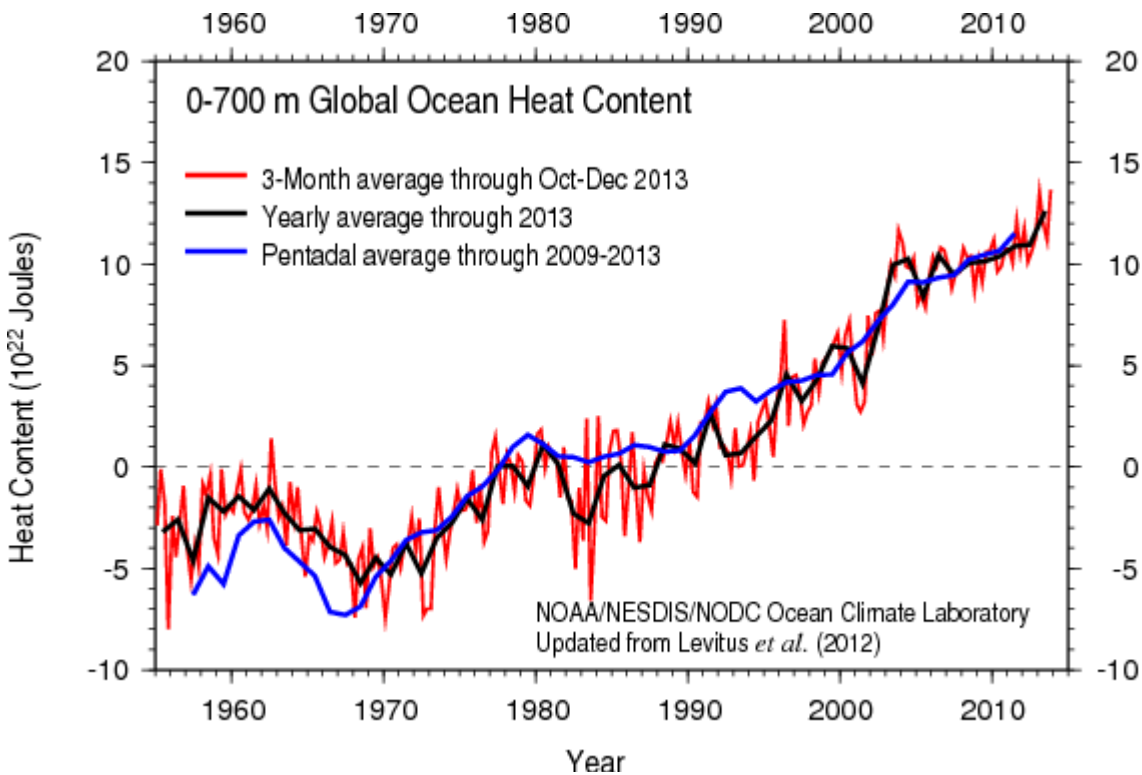


Figure 2. Heat Content in the top 700 m of the Ocean, 1955-2013. [NOAA]

2. Figure 2 confirms that from the late 1960s until 2013 the overall trend of 0-700 m global ocean heat content was **[(downward)(no change)(upward)]**.

3. In addition to revealing overall trends in the change of global ocean heat content, the Figure 2 heat-content yearly-average curve suggests a variability pattern (from one curve crest to the next) often lasting **[(two to several years)(one or two decades) (several decades)]** in length. This implies the presence of internal processes at work in the Earth’s climate system that are not directly related to the system’s astronomically determined boundary conditions.

A Global-scale Climate Change Impact Example: Coral Bleaching

Many changes have been directly observed in the global climate over the past century or so, with more significant changes evident in recent decades. Of the many that could be cited, a striking example is the increasing frequency that coral reefs around the world experience high enough water temperatures to produce *coral bleaching*. Coral bleaching results from conditions that cause coral death, and the loss of vibrant ocean ecosystems and their fisheries that feed millions of people. As the world ocean continues to warm, an increase in the number and intensity of coral bleaching episodes is inevitable.

Corals are marine colonial organisms. Most reef-building corals contain brightly colored photosynthetic algae, called zooxanthellae, that live in their tissues. The corals and algae have a symbiotic relationship, each benefiting the other, and many are unable to survive unless together. When corals become physically stressed, they expel their algae and become stark white, appearing bleached. Without zooxanthellae, corals will starve to death.

Corals are vulnerable to bleaching when the sea-surface temperature (SST) exceeds what they would normally experience during the hottest month of the year. NOAA's *Coral Bleaching HotSpots* report, which is updated every 3 or 4 days, shows where temperatures exceed coral's limits. **Figure 3** shows the worldwide HotSpots on 12 September 2013, near the end of the Northern Hemisphere summer. The HotSpot value of 1.0 C° is a threshold for thermal stress leading to coral bleaching. To highlight this threshold, values of 1.0 C° or greater are displayed in yellow to red on the map.

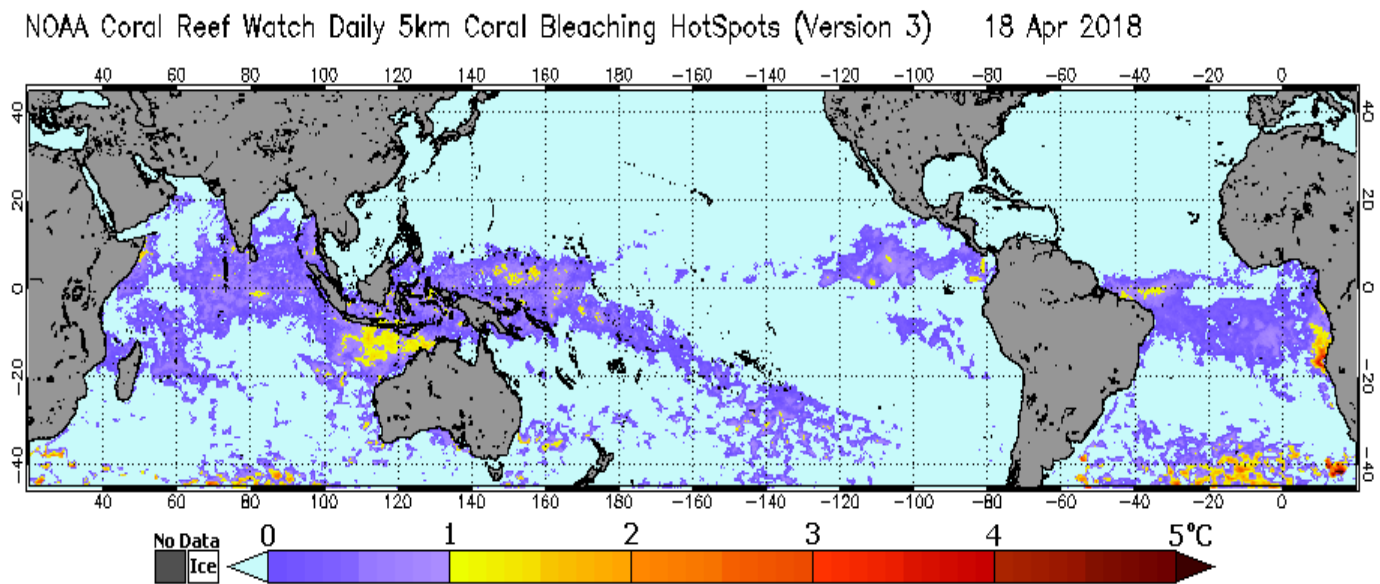


Figure 3. NOAA Global Coral Bleaching HotSpots on 18 April 2018. The more red the color, the greater the coral bleaching threat.

4. Figure 3 shows extensive coral bleaching HotSpot in the [(Arabian Sea)(Gulf of Mexico) (Benguel Current area off western Africa)] in mid-September 2013.

5. **Figure 4** is an experimental NOAA product that assigns alert level to places experiencing coral bleaching stress. The figure shows the general area identified in Item 4 above as having alert locations as high as [(**Watch**)(**Warning**)(**Alert Level 1**)]. This level indicates bleaching is likely.

NOAA Coral Reef Watch Daily 5km Bleaching Alert Area 7d Max (Version 3) 18 Apr 2018

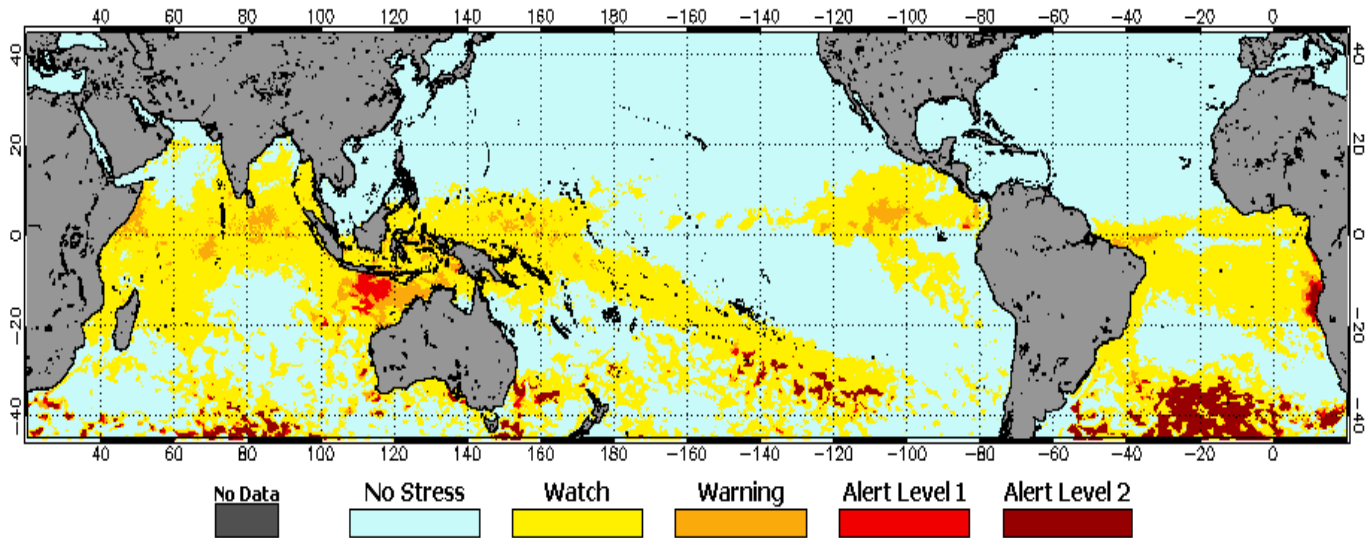


Figure 4. NOAA Coral Reef Watch (CRW) Bleaching Alerts, 18 April 2018.

You can track current conditions or impacts of coral bleaching and possible relationships to global warming by going to: <http://coralreefwatch.noaa.gov/satellite/index.php>