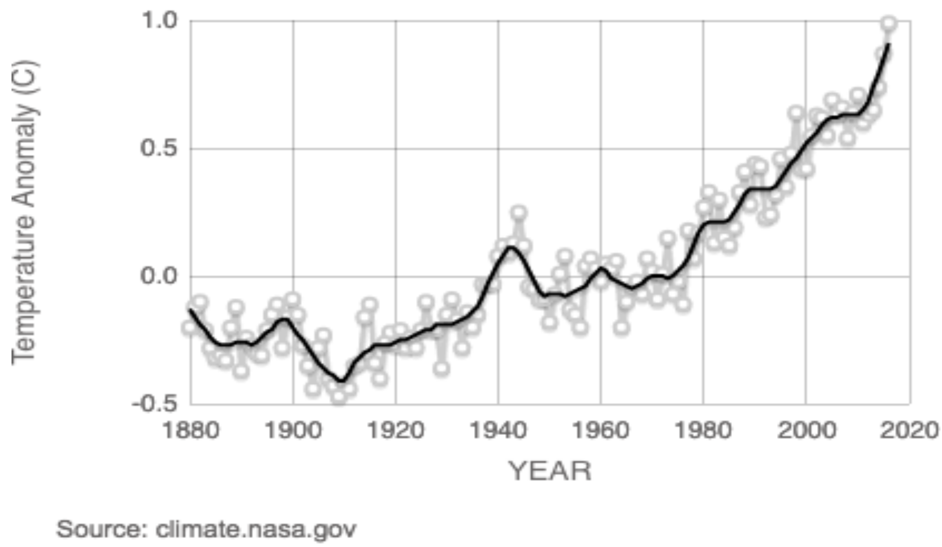
Unit 2
Global warming Trend and Effects

Today's topics:

- Global Temperature Rise
- Oceans Warming
- Shrinking Ice Sheets
- Glacial Retreat
- Decreased Snow Cover
- Sea Level Rise
- Declining Arctic Sea Ice
- Ocean Acidification

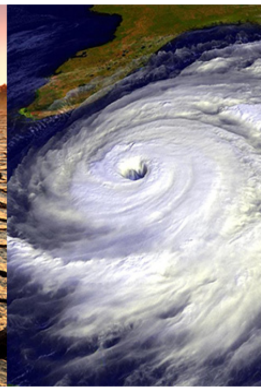
Global warming Trend and Effects

The effects of global warming are the environmental and social changes caused (directly or indirectly) by human emissions of greenhouse gases. There is a scientific agreement that climate change is occurring, that human activities are the primary driver. Many impacts of climate change have already been observed, including glacier retreat, changes in the timing of seasonal events (e.g., earlier flowering of plants), and changes in agricultural productivity.



Data source: NASA's Goddard Institute for Space Studies (GISS). Credit: NASA/GISS

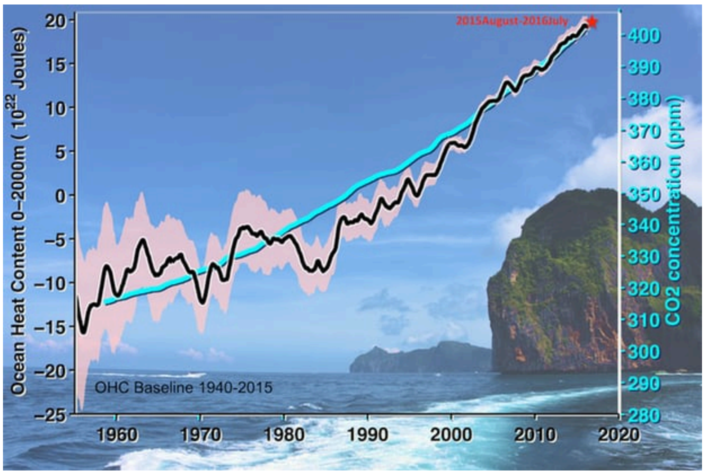
1. Global Temperature Rise (Temperatures will continue to rise)



Because human-induced warming is covered on a naturally varying climate, the temperature rise has not been, and will not be, uniform or smooth across the country or over time. The potential future effects of global climate change include more frequent wildfires, longer periods of drought in some regions and an increase in the number, duration and intensity of tropical storms.

Global climate change has already had observable effects on the environment. Glaciers have shrunk, ice on rivers and lakes is breaking up earlier, plant and animal ranges have shifted and trees are flowering sooner. Effects that scientists had predicted in the past would result from global climate change are now occurring: loss of sea ice, accelerated sea level rise and longer, more intense heat waves.

2. Warming Oceans

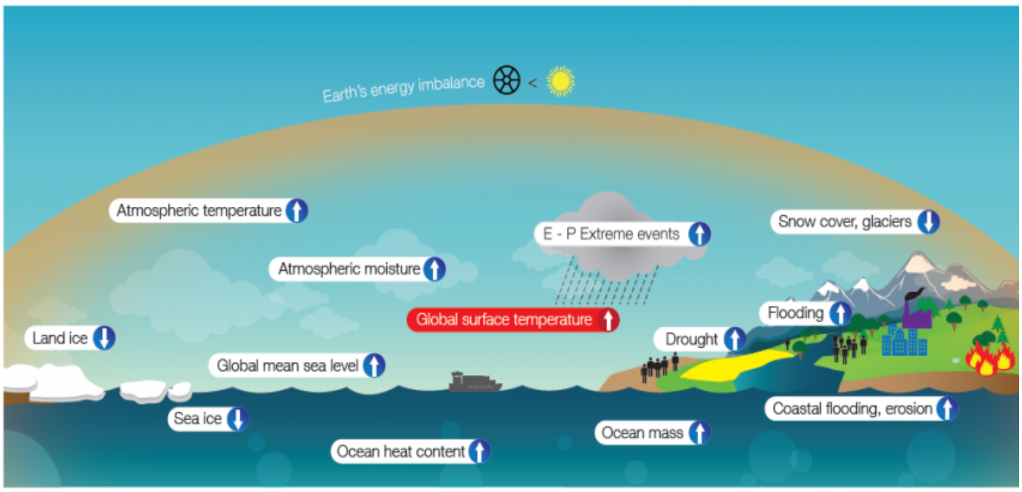


Increases in ocean heat content since 1950s. Illustration: Cheng, L., K. E. Trenberth, J. Fasullo, J. Abraham, T. P. Boyer, K. von Schuckmann, and J. Zhu (2017), Taking the pulse of the planet, Eos, Vol. 98.

- The ocean absorbs most of the excess heat from greenhouse gas emissions, leading to rising ocean temperatures.
- Increasing ocean temperatures affect marine species and ecosystems. Rising temperatures cause coral bleaching and the loss of breeding grounds for marine fishes and mammals.
- Rising ocean temperatures also affect the benefits humans derive from the ocean – threatening food security, increasing the prevalence of diseases and causing more extreme weather events and the loss of coastal protection.
- Achieving the mitigation targets set by the Paris Agreement on climate change and limiting the global average temperature increase to well below 2°C above pre-industrial levels is crucial to prevent the massive, irreversible impacts of ocean warming on marine ecosystems and their services.
- Establishing marine protected areas and putting in place adaptive measures, such as precautionary catch limits to prevent overfishing, can protect ocean ecosystems and shield humans from the effects of ocean warming.

Why is it important?

Ocean warming leads to DE oxygenation – a reduction in the amount of oxygen dissolved in the ocean – and sea-level rise – resulting from the thermal expansion of seawater and continental ice melting. The rising temperatures, coupled with ocean acidification (the decrease in pH (Potential of Hydrogen ion) of the ocean due to its uptake of CO_2), affect marine species and ecosystems and, consequently, the fundamental benefits humans derive from the ocean.



- *Impact on marine species and ecosystems*

Marine fishes, seabirds and marine mammals all face very high risks from increasing temperatures, including high levels of mortalities, loss of breeding grounds and mass movements as species search for favorable environmental conditions. Coral reefs are also affected by increasing temperatures, which cause coral bleaching and increase their risk of mortality.

- *Impact on humans*

Referred by the Food and Agriculture Organization of the United Nations estimates that marine and freshwater capture fisheries and aquaculture provide 4.3 billion people with about 15% of their animal protein. Fisheries and aquaculture are also a source of income for millions of people worldwide. By altering distributions of fish stocks and increasing the vulnerability of fish species to diseases, ocean warming is a serious risk to food security and people's livelihoods globally. Economic losses related to ocean warming are likely to run from tens to hundreds of millions of dollars.

Rising temperatures also affect vegetation and reef-building species such as corals and mangroves, which protect coastlines from erosion and sea-level rise. Rising sea levels and erosion will particularly affect low-lying island countries in the Pacific Ocean, destroying housing and infrastructure and forcing people to relocate.

The rise in sea surface temperatures is causing more severe hurricanes bringing droughts and floods. This can have significant socio-economic and health effects in some regions of the world.

Warming ocean temperatures are linked to the increase and spread of diseases in marine species. Humans risk direct transmission of these diseases when consuming marine species, or from infections of wounds exposed in marine environments.

What can be done?

- *Limiting greenhouse gas emissions*

There is an urgent need to achieve the mitigation targets set by the Paris Agreement on climate change and hold the increase in the global average temperature to well below 2°C above pre-industrial levels. This will help prevent the massive and irreversible impacts of growing temperatures on ocean ecosystems and their services.

• Protecting marine and coastal ecosystems

Well-managed protected areas can help conserve and protect ecologically and biologically significant marine habitats. This will regulate human activities in these habitats and prevent environmental degradation.

• Restoring marine and coastal ecosystems

Elements of ecosystems that have already experienced damage can be restored. This can include building artificial structures such as rock pools that act as surrogate habitats for organisms, or boosting the resilience of species to warmer temperatures through assisted breeding techniques.

• Improving human adaptation

Governments can introduce policies to keep fisheries production within sustainable limits, for example by setting precautionary catch limits and eliminating subsidies to prevent overfishing. Coastal setback zones that prohibit all or certain types of development along the shoreline can minimize the damage from coastal flooding and erosion. New monitoring tools can be developed to forecast and control marine disease outbreaks.

3. Shrinking Ice Sheets

Scientists who assess the planet's health see indisputable evidence that Earth has been getting warmer, in some cases rapidly. Most believe that human activity, in particular the burning of fossil fuels and the resulting buildup of greenhouse gases in the atmosphere, have influenced this warming trend. In the past decade scientists have documented record-high average annual surface temperatures and have been observing other signs of change all over the planet: in the distribution of ice, and in the salinity, levels, and temperatures of the oceans.

4. Glacial Retreat Click HERE

What is a Glacier?

A glacier is a body of snow and ice of sufficient size and mass to move under its own weight. Glacier movement may be detected by the presence of crevasses, cracks that form in the ice as the glacier moves.

Glacial retreat: "With few exceptions, all the alpine glaciers of the world are losing mass and it is predicted that this trend will continue as global warming progresses. Glaciers in alpine areas act as buffers. During the rainy season, water is stored in the glaciers and the melt water helps maintain river systems during dry periods.

The continued glacial retreat will have a number of different quantitative impacts. In areas that are heavily dependent on water runoff from glaciers that melt during the warmer summer months, a continuation of the current retreat will eventually deplete the glacial ice and substantially reduce or eliminate runoff. A reduction in runoff will affect the ability to irrigate crops and will reduce summer stream flows necessary to keep dams and reservoirs replenished. This situation is particularly acute for irrigation in South America, where numerous artificial lakes are filled almost exclusively by glacial melt.

Central Asian countries have also been historically dependent on the seasonal glacier melt water for irrigation and drinking supplies. In Norway, the Alps, and the Pacific Northwest of North America, glacier runoff is important for hydropower.

The potential for major sea level rise *(Topic 6. Sea Level Rise)* depends mostly on a significant melting of the polar ice caps of Greenland and Antarctica, as this is where the vast majority of glacial ice is located.

Everywhere on Earth ice is changing. The famed snows of Kilimanjaro have melted more than 80 percent since 1912. Glaciers in the Himalaya in India are retreating so fast that researchers believe that most central and eastern Himalayan glaciers could virtually disappear by 2035. *Arctic sea ice* has thinned significantly over the past half century, and its extent has declined by about 10 percent in the past 30 years. From the Arctic to Peru, from Switzerland to the equatorial glaciers of Man Jaya in Indonesia, massive ice fields, monstrous glaciers, and sea ice are disappearing, fast.

When temperatures rise and ice melts, more water flows to the seas from glaciers and ice caps, and ocean water warms and expands in volume. This combination of effects has played the major role in raising average global sea level.

• What is an ice shelf? Watching ice melt: Click HERE

Ice shelves are floating tongues of ice that extend from grounded glaciers on land. Snow falls on glaciers, which flow downstream under gravity. (They're floating ice, connected to the mainland. They receive ice from glaciers flowing into them from the mainland, from accumulation from snow directly onto the ice shelf, and from sea water freezing onto the bottom of the ice shelf). Ice shelves surround 75% of Antarctica's coastline, and cover an area of over 1.561 million square kilometers (a similar size to the Greenland Ice Sheet).

Ice shelves gain mass from ice flowing into them from glaciers on land, from snow accumulation, and from the freezing of marine ice (sea water) to their undersides. Ice shelves are important, because they play a role in the stability of the Antarctic Ice Sheet and the ice sheet's mass balance, and are important for ocean stratification and bottom water formation; this helps drive the world's Thermohaline circulation. Melting from beneath ice shelves is one of the key ways in which the Antarctic Ice Sheet loses mass.

5. Decreased Snow Cover

About 98% of Earth's snow cover is located in the Northern Hemisphere where it can have large impacts on climate variability.

What's Snow Cover got to do with it?

We hear a lot about snow during the winter months, but what makes it an important part of Earth's climate system. That's where snow cover comes in. Snow cover—or the area of land that is covered by accumulated snow at any given time—helps regulate Earth's surface temperature when it is present, and it helps fill rivers and reservoirs once it melts away.

In addition to helping keep the atmosphere cool, snow cover also helps keep the ground warm. Working like an insulating blanket, snow cover holds heat in the ground beneath it and prevents ground moisture from evaporating into the atmosphere. Under just one foot of snow, soil and organisms can be protected from changes in the air temperature above.

While snow cover affects climate, changes in climate also affect snow cover. Overall, warmer temperatures are shortening the amount of time snow is on the ground in the Northern Hemisphere. Recent temperature increases in the Arctic have also led to decreased snow and ice cover in many areas during parts of the year. And, they've also led to earlier melting of snow cover, which are changing when and how much water is available in some rivers and reservoirs as well as lengthening the growing season. Because changes in snow cover can severely impact Earth's environment and ecosystems as well as people's access to water resources, scientists continuously measure how much of the planet is covered by snow. In the long term, this record will help scientists understand how snow cover and Earth's climate are changing, and in the short-term, it can help water resources managers assess and plan for each spring's snowmelt.

- *Snow and Climate - Snow's effect on climate*

Seasonal snow is an important part of Earth's climate system. Snow cover helps regulate the temperature of the Earth's surface, and once that snow melts, the water helps fill rivers and reservoirs in many regions of the world, especially the western United States. (I have mentioned above on the first paragraph). In terms of area, snow cover is the largest single component of the covering as a large scale; snow cover helps regulate the exchange of heat between Earth's surface and the atmosphere, or the Earth's energy balance. On a smaller scale, variations in snow cover can affect regional weather patterns. For instance, in Europe and Asia, the cooling associated with a heavy snowpack and moist spring soils can shift the arrival of the summer monsoon season and influence how long it lasts.

- *Effects of climate on snow*

Changes in climate can affect how much snowfall and influence the timing of the winter snow season. Between 1966 and 2018, the amount of land and sea ice that is snow-covered each year has decreased over many Northern Hemisphere regions, especially during the spring snow felt season. Scientists are modeling how Earth's climate might change over the next 100 years, and the results suggest that snow will cover less of the planet, particularly over Europe and Asia. Climate warming can reduce snowfall, and cause earlier spring melts and shorter snow cover seasons. For instance, warmer air in Alaska has caused the snow to melt earlier each spring, lengthening the snow-free summer season.

Warm periods of spring-like weather during winter may also cause rainfall instead of snowfall, or force unusual melting during a normally cold season. Warmer spring weather in Alaska and in the Canadian Arctic areas has caused more frequent melting and refreezing of snow, as well as more frequent rainfall. This extra water may seem beneficial for vegetation, and consequently for grazing animals. But nighttime temperatures during the Arctic springtime are still low enough to freeze the rain and melted snow, which seals the ground beneath a sheet of ice.

Changes in the amount of snow covering the ground, and changes in how the snow melts in the spring, *will affect the water supplies that people use* for things like farming and making electricity. Retreating glaciers and decreasing snowpack are prompting concerns about dwindling water supplies throughout India and southwest Asia. Ski resorts located in temperate mountain ranges, like those located in western North America, New Zealand, and the European Alps, already experience winter temperatures that are only slightly below freezing, and even a small increase in air temperature may shorten the ski season, or cause complete ski area closures.

6. Sea Level Rise Click HERE

Sea level rise is caused primarily by two factors related to global warming: the added water from melting ice sheets and glaciers and the expansion of seawater as it warms. (The summary is the two major causes of global sea level rise are thermal expansion caused by warming of the ocean (since water expands as it warms) and increased melting of land-based ice, such as glaciers and ice sheets). The oceans are absorbing more than 90 percent of the increased atmospheric heat associated with emissions from human activity.

With continued ocean and atmospheric warming, sea levels will likely rise for many centuries at rates higher than that of the current century. In the United States, almost 40 percent of the population lives in relatively high-population-density coastal areas, where sea level plays a role in flooding, shoreline erosion, and hazards from storms.

Sea level rise at specific locations may be more or less than the global average due to local factors such as land subsidence from natural processes and withdrawal of groundwater and fossil fuels, changes in regional ocean currents, and whether the land is still rebounding from the compressive weight of Ice Age glaciers. In urban settings, rising seas threaten infrastructure necessary for local jobs and regional industries. Roads, bridges, subways, water supplies, oil and gas wells, power plants, sewage treatment plants, landfills—virtually all human infrastructure—is at risk from sea level rise. Click HERE

But some information has mentioned that the rise in sea levels is linked to three primary factors, all induced by this ongoing global climate change:

- Thermal Expansion:

When water heats up, it expands. About half of the past century's rise in sea level is attributable to warmer oceans simply occupying more space.

▪ Melting Glaciers and Polar Ice Caps:

Large ice formations, like glaciers and the polar ice caps, naturally melt back a bit each summer. In the winter, snows, primarily from evaporated seawater, are generally sufficient to balance out the melting. Recently, though, persistently higher temperatures caused by global warming have led to grater than average summer melting as well as diminished snowfall due to later winters and earlier springs. This imbalance results in a significant net gain in the ratio of runoff to ocean evaporation, causing sea levels to rise.

▪ Ice Loss from Greenland and West Antarctica:

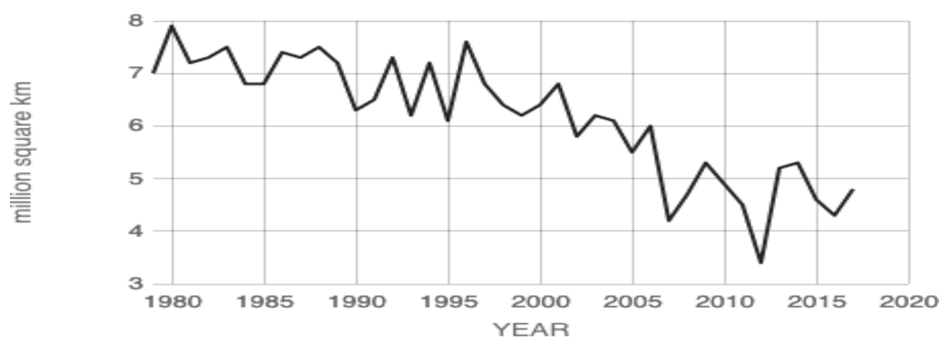
As with the glaciers and ice caps, increased heat is causing the massive ice sheets that cover Greenland and Antarctica to melt at an accelerated pace. Scientists also believe melt water from above and seawater from below is seeping beneath Greenland's and West Antarctica's ice sheets, effectively lubricating ice streams and causing them to move more quickly into the sea. Higher sea temperatures are causing the massive ice shelves that extend out from Antarctica to melt from below, weaken, and break off.

When sea levels rise rapidly, as they have been doing, even a small increase can have devastating effects on coastal habitats. As seawater reaches farther inland, it can cause destructive erosion, wetland flooding, aquifer and agricultural soil contamination, and lost habitat for fish, birds, and plants.

7. Declining Arctic Sea Ice (Arctic Sea Ice Minimum)

Arctic sea ice reaches its minimum each September. This graph shows the average monthly Arctic sea ice extent each September since 1979, derived from satellite observations. The animated time series below shows the annual Arctic sea ice minimum since 1979, based on satellite observations. The 2012 sea ice extent is the lowest in the satellite record.

Arctic surfaces reflect the sun’s heat back out to space, and cool the surface. The decline of Arctic sea ice in recent decades has occurred at a more rapid rate than predicted by most climate change models. Many scientists suspect that the deterioration results from a combination of global warming and other climate cycles.



Source: climate.nasa.gov

Teasing apart the natural and human-caused parts of sea ice decline will help to predict future sea ice conditions in Arctic summer. Forecasting sea ice conditions is relevant for shipping, climate science, Arctic biology and even tourism. It also helps to understand why sea ice declines may be faster in some decades than others.

8. Ocean Acidification

Ocean acidification and its effects-Oceans absorb a substantial proportion of the CO_2 emitted into the atmosphere by human activities, with potentially negative effects on shell-forming organisms.

- Increasing CO_2 in the atmosphere due to human activities not only affects the climate; it also has direct, chemical effects on ocean waters.
- Associated chemical reactions can make it difficult for marine calcifying organisms, such as coral and some plankton, to form shells and skeletons, and existing shells become vulnerable to dissolution.

- The impacts of acidification will extend up the food chain to affect economic activities such as fisheries, aquaculture and tourism. Wherever there are marine calcifying organisms, there are risks from ocean acidification.

- Human activities release CO_2 into the atmosphere, which leads to atmospheric warming and climate change, as explained in caused of climate change. Around a third to a half of the CO_2 released by human activities is absorbed into the oceans. While this helps to reduce the rate of atmospheric warming and climate change, it also has a direct, chemical effect on seawater, which we call *ocean acidification.*

What are the effects of ocean acidification on marine organisms and ecosystems?

Ocean acidification reduces the amount of carbonate, a key building block in seawater. This makes it more difficult for marine organisms, such as coral and some plankton, to form their shells and skeletons, and existing shells may begin to dissolve.

The present-day pH of seawater is highly variable, and a single organism can cope with fluctuations of different pH levels during its lifetime. The problem with ocean acidification is the sustained nature of the change, as the risk comes from the lifetime exposure to lower pH levels. The rapid pace of acidification will influence the extent to which calcifying organisms will be able to adapt.

The impacts of ocean acidification are not uniform across all species. Some algae and seagrass may benefit from higher CO_2 concentrations in the ocean, as they may increase their photosynthetic and growth rates. However, a more acidic environment will harm other marine species such as molluscs, corals and some varieties of plankton. The shells and skeletons of these animals may become less dense or strong. In the case of coral reefs this may make them more vulnerable to storm damage and slow the recovery rate.

Marine organisms could also experience changes in growth, development, abundance, and survival in response to ocean acidification. Most species seem to be more vulnerable in their early life stages. Juvenile fish for example, may have trouble locating suitable habitat to live.

Despite the different responses within and between marine groups, positive or negative, research suggests that ocean acidification will be a driver for substantial changes in ocean ecosystems this century. These changes may be made worse by the combined effect with other emerging climate-related hazards, such as the decrease of ocean oxygen levels – a condition known as ocean DE oxygenation –that is already affecting marine life in some regions.

What are the effects on human societies?

Changes in marine ecosystems will have consequences for human societies, which depend on the goods and services these ecosystems provide. The implications for society could include substantial revenue declines, loss of employment and livelihoods, and other indirect economic costs. Socioeconomic impacts associated with the decline of the following ecosystem services are expected:

- Food: Ocean acidification has the potential to affect food security. Commercially and ecologically important marine species will be impacted, although they may respond in different ways. Molluscs such as oysters and mussels are among the most sensitive groups.
- Coastal protection: Marine ecosystems such as coral reefs protect shorelines from the destructive action of storm surges and cyclones, sheltering the only habitable land for several island nations. This protective function of reefs prevents loss of life, property damage, and erosion.
- Tourism: This industry could be severely affected by the impacts of ocean acidification on marine ecosystems (e.g. coral reefs).
- Carbon storage and climate regulation: The capacity of the ocean to absorb CO_2decreases as ocean acidification increases. More acidic oceans are less effective in moderating climate change.

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