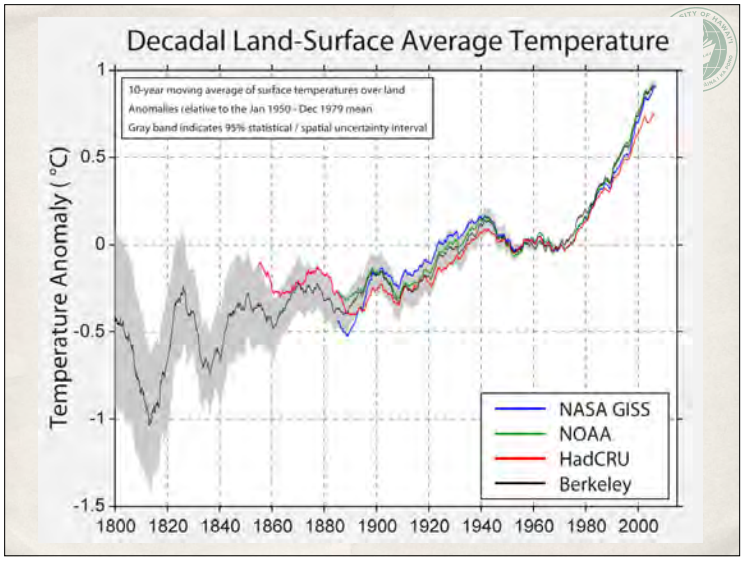
Global Climate Change

"Warming of the climate system is unequivocal, since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased."

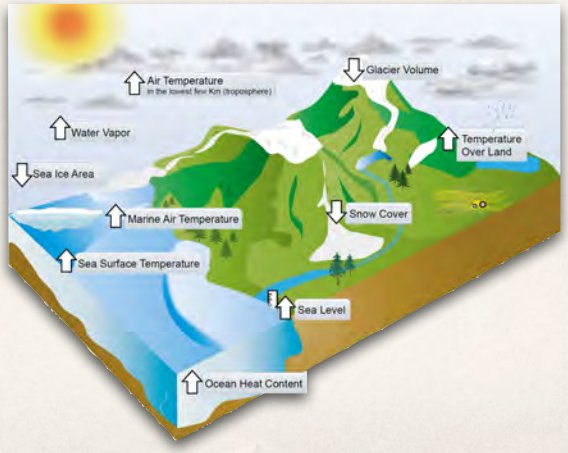
Intergovernmental Panel on Climate Change (IP
5th Assessment report, 2013

BERKELEY EARTH SURFACE TEMPERATURE

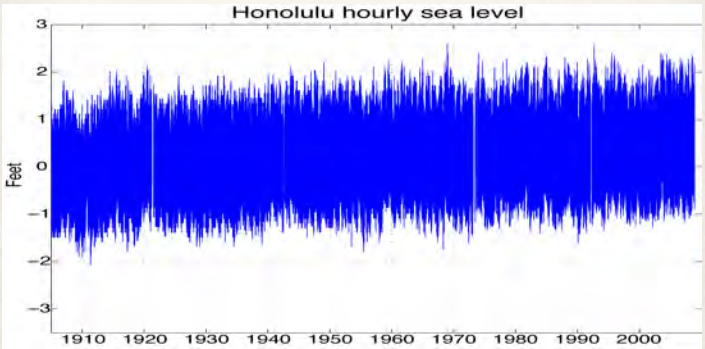
Berkley Earth is an independent non-profit funded by groups across the political spectrum



Independent lines of evidence



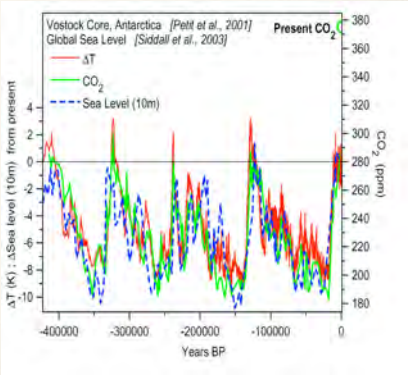
Honolulu sea level gauge



Sea level variations

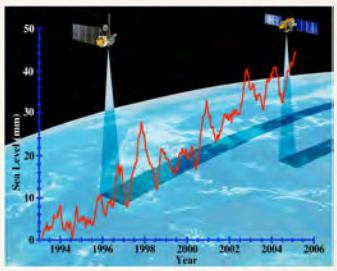
During warm period sea level rises, because ice melts and ocean water expands.

During ice ages sea level goes down, because water is stored as ice on the continents.



Sea level variations

Last couple of decades there have been satellites that measure Sea Surface Height over most of the world's oceans.

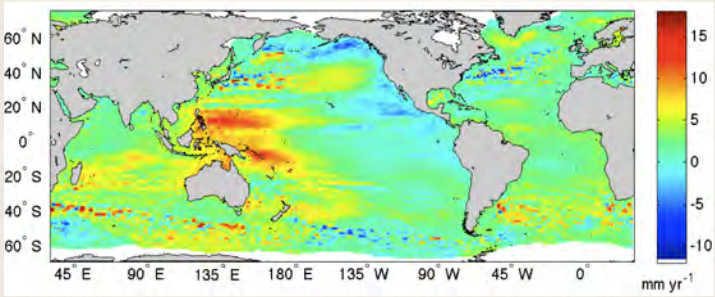


Observed average global sea level rise over this period is 3.1 +/- 0.7 mm/yr (~ 1 inch every 8 years).

Sea level variations

Amount of sea level change varies with location.

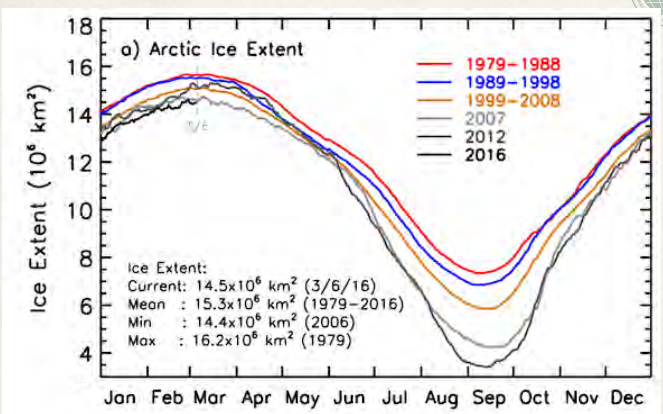
Sea Surface Height trend 1993 to 2009



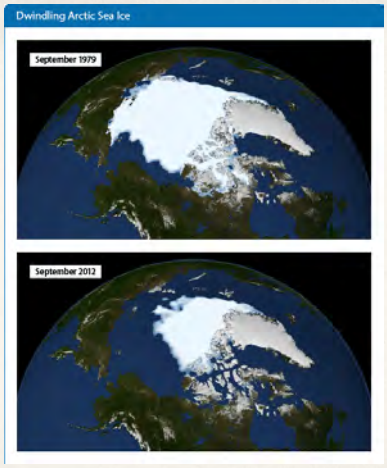
Mark Merrifield (2011)

Water vapor?

- Water vapor is a greenhouse gas.
- In the humid tropics, small addition of CO_2 or water vapor has little effect.
- In cold, dry regions like the poles or upper atmosphere the effect is greater.

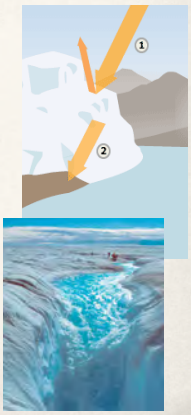


http://neptune.gsfc.nasa.gov/csb/index.php?section=234

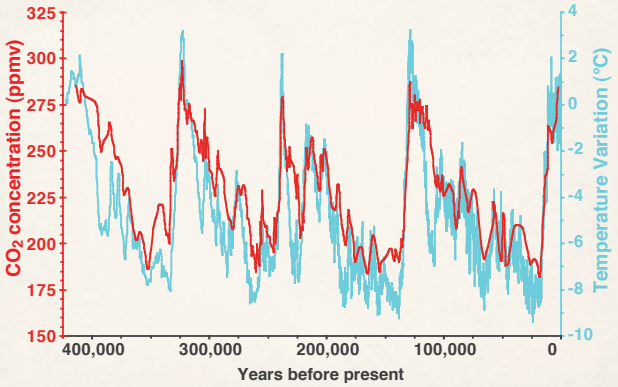


Positive Feedback

1) Light colored ice reflects back the Sun's energy efficiently.
2) Exposed land is darker and absorbs more energy; warming.
3) **As the ice** melts, more land is exposed. This absorbs more heat, melting more ice, and causing further warming**.**



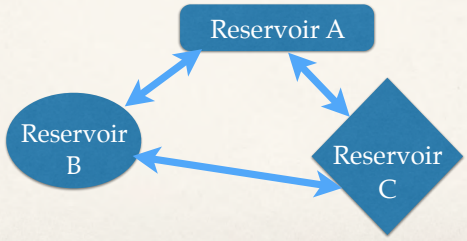
CO_2 & Temp from Vostok ice core



Temperature from Oxygen isotope ratio.

Cycles & Reservoirs

- Material is transferred between reservoirs as part of a cycle.
- Elements on Earth are from when the Earth was accreted (~4.5 billion years ago).
- Cycles interconnect.



Carbon reservoirs

Reservoir	Amount
Carbonate Sediments	150,000
Soils (dissolved carbon)	25,000
Oceans and Freshwater (dissolved CO_2)	140
Biomass (living material)	30
Fossil fuels (plus organic carbon in sediments)	27
Atmospheric CO_2	2

Amounts are in units of 10^{12} tons of CO_2 equivalent.

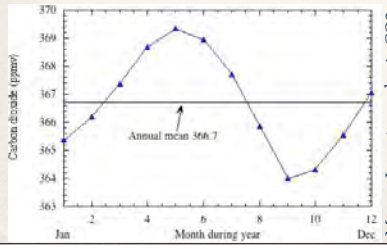
Carbon reservoirs

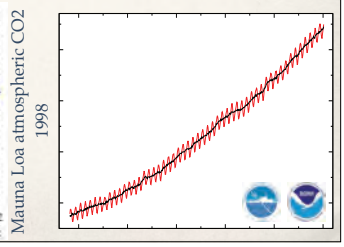
Reservoir	Amount
Carbonate Sediments	150,000
Soils (dissolved carbon)	25,000

- The two largest reservoirs (carbonate sediments and soils) are not believed to have change much in the last 240 years.

Carbon reservoirs

- The total size of the biomass reservoir probably hasn't changed much over last ~200 years. Increases in human population and agriculture offset by deforestation etc.
- Annual cycle of plant growth and death moves CO_2 from atmosphere to biomass and back.





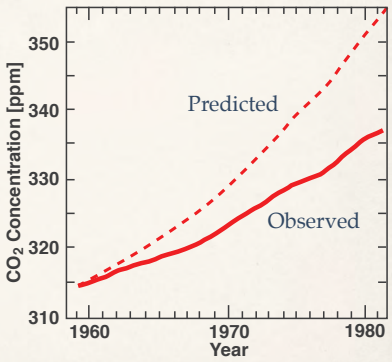
Carbon reservoirs

That leaves

Reservoir	Amount
Carbonate Sediments	150,000
Soils (dissolved carbon)	25,000
Oceans and Freshwater (dissolved CO_2)	140
Biomass (living material)	30
Fossil fuels (plus organic carbon in sediments)	27
Atmospheric CO_2	2

Carbon reservoirs

Observed atmospheric CO_2 levels are smaller than predicted from oil, coal production records.



So some CO_2 must be going in to the ocean.

1750 to 2011 GHG totals

375 GtC

180 GtC

240 GtC

155 GtC

160 GtC

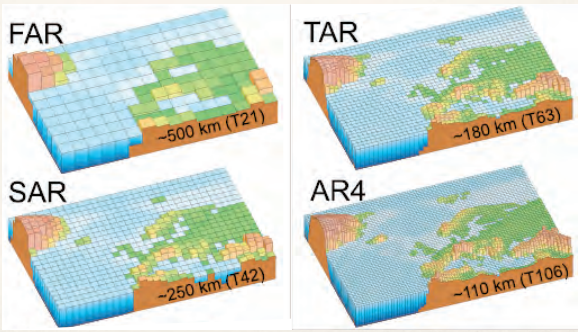
Models

Climate models are of necessity *gross simplifications of reality*, so how can we be sure they give us realistic predictions?

We compare them with the past behavior of the planet, as found in paleoclimate records such as sediments and ice cores. If the models correctly predict what has already happened, we can have more confidence in their forecasts.

Models

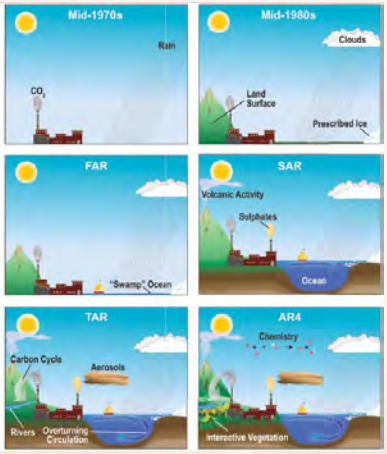
As computers improve the resolution and complexity of models can increase.



IPCC 2007

Models

IPCC 2007



More physical processes added, as we get a better understanding of their physics.

Summary of Local Impacts of Climate Change to Hawai'i

The rate of **warming air temperature** in Hawai'i has quadrupled in the last 40 years to over 0.3°F (0.17°C) per decade. This warming could cause thermal stress for plants and animals, and heat-related illnesses in humans as well as expanded ranges for pathogens and invasive species.

A decrease in the prevailing northeasterly trade winds, which drive orographic precipitation on windward coasts, has been recorded in Hawai'i over the last 40 years.

Hawai'i has seen an overall **decline in rainfall** in the last 30 years, with widely varying precipitation patterns on each island. It is projected that Hawai'i will see more drought and heavy rains causing more flash flooding, harm to infrastructure, runoff, and sedimentation.

Declining precipitation trends have caused a **decrease in stream base flow** over the last 70 years, and could reduce aquifer recharge and freshwater supplies and influence aquatic and riparian ecosystems and agriculture.

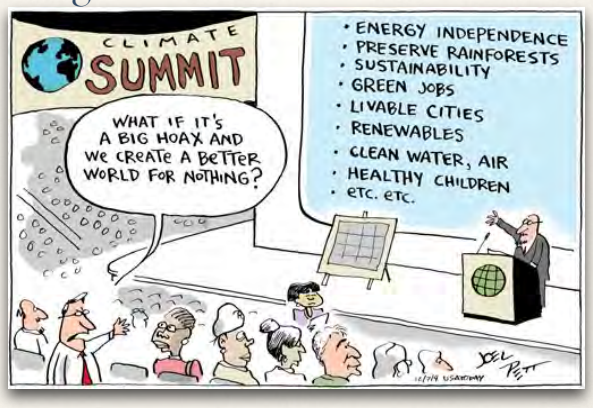
Sea surface temperatures have warmed between 0.13°F and 0.41°F (0.07°C and 0.23°C) per decade in the Pacific for the last 40 years. This trend is projected to accelerate, warming by 2.3°F to 4.9°F (1.3°C to 2.7°C) before the end of the century. This warming can influence ocean circulation and nutrient distribution.

Global **ocean acidity has increased** by 30% due to marine uptake of CO_2, correlating to a pH change of 0.1. Acidification is expected to continue, with additional pH changes between 0.1 and 0.4 by the end of the century. Ocean acidification could trigger a wide range of impacts on marine biota, including inhibiting shell and skeleton growth in corals, shellfish, and plankton.

Sea level has risen over the last century on each island at rates varying from 0.5-1.3 inches (1.5-3.3 centimeters) per decade, which has contributed to shoreline recession. Accelerating rates of sea-level rise have been detected in global sea level data. Rates of rise are projected to continue to accelerate, resulting in a 1-3 foot (approximately 0.3-1 meter) rise, or more, by the end of the century. Sea-level rise will exacerbate coastal inundation, erosion and hazards, leading to the degradation of coastal ecosystems, beach loss, and increasing damage to infrastructure in low-lying areas.

Threats to human health posed by Hawai'i's warming climate may include increased heat-related illness and wider ranges of vector-borne diseases such as dengue fever.

'No regrets' actions



Some key ideas

- Climate change is a natural process that has happened for millions of years.
- The climate system includes many cycles linked together.
- Human activities are increasing the rate of climate change.
- Carbon reservoirs, which components have changed over the last few hundred years.
- Climate change is not just warming - its much more complicated.
- 2012 was a record low for Arctic Sea Ice.
- Polar regions are most sensitive to climate change.
- Positive feedback reinforces the cycle.

Summary of Local Impacts of Climate Change to Hawai'i

The rate of **warming air temperature** in Hawai`i has quadrupled in the last 40 years to over 0.3°F (0.17°C) per decade. This warming could cause thermal stress for plants and animals, and heat-related illnesses in humans as well as expanded ranges for pathogens and invasive species.

A decrease in the prevailing northeasterly trade winds, which drive orographic precipitation on windward coasts, has been recorded in Hawai`i over the last 40 years.

Hawai`i has seen an overall **decline in rainfall** in the last 30 years, with widely varying precipitation patterns on each island. It is projected that Hawai`i will see more drought and heavy rains causing more flash flooding, harm to infrastructure, runoff, and sedimentation.

Declining precipitation trends have caused a **decrease in stream base flow** over the last 70 years, and could reduce aquifer recharge and freshwater supplies and influence aquatic and riparian ecosystems and agriculture.

Sea surface temperatures have warmed between 0.13°F and 0.41°F (0.07°C and 0.23°C) per decade in the Pacific for the last 40 years. This trend is projected to accelerate, warming by 2.3°F to 4.9°F (1.3°C to 2.7°C) before the end of the century. This warming can influence ocean circulation and nutrient distribution.

Global **ocean acidity has increased** by 30% due to marine uptake of CO_2, correlating to a pH change of 0.1. Acidification is expected to continue, with additional pH changes between 0.1 and 0.4 by the end of the century. Ocean acidification could trigger a wide range of impacts on marine biota, including inhibiting shell and skeleton growth in corals, shellfish, and plankton.

Sea level has risen over the last century on each island at rates varying from 0.5-1.3 inches (1.5-3.3 centimeters) per decade, which has contributed to shoreline recession. Accelerating rates of sea-level rise have been detected in global sea level data. Rates of rise are projected to continue to accelerate, resulting in a 1-3 foot (approximately 0.3-1 meter) rise, or more, by the end of the century. Sea-level rise will exacerbate coastal inundation, erosion and hazards, leading to the degradation of coastal ecosystems, beach loss, and increasing damage to infrastructure in low-lying areas.

Threats to human health posed by Hawai`i's warming climate may include increased heat-related illness and wider ranges of vector-borne diseases such as dengue fever.