Climate Change Impacts in Hawai‘i

Chip Fletcher
School of Ocean and Earth Science and Technology
University of Hawai‘i at Mānoa
Hono‘lulu Climate Change Commission
Rate of CO₂ accumulation is accelerating.
Rate of warming is accelerating.
Currently 1.2°C (2.2°F)
2030 1.5°C (2.7°F)
2045 2.0°C (3.6°F)
The world is now 1.2°C (2.2°F) warmer

https://www.youtube.com/watch?v=Z4bSxb5THm4
Is global warming part of a natural cycle?
Ice Cores contain fossil air bubbles
Melting an ice sample to capture the ancient air it contains
CHANGING OUR ATMOSPHERE
800,000 Years of Carbon Dioxide

Climate cycles ~100,000 yrs

PPM

Carbon dioxide concentration

Ice Ages

Interglacials

2019
415 PPM

1910
300 PPM

800,000
600,000
400,000
200,000
NOW
YEARS BEFORE NOW
Natural Climate Change is fairly well understood

**Orbital Parameters** determine the intensity and duration of Arctic summer and lead to ice ages and interglacials.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Obliquity</td>
<td>41,000 yrs</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>100,000 and 400,000 yrs</td>
</tr>
<tr>
<td>Axial Precession</td>
<td>26,000 yrs</td>
</tr>
</tbody>
</table>
Ice Age
Interglacial
- 3°C – East Antarctic, Permafrost, Winter sea ice
- 2°C – Amazon Forest, Boreal Forest, Oceanic Conveyor Belt, ENSO, Sahel, Greenland Ice Sheet
- 1°C – West Antarctic Ice Sheet, Arctic Sea Ice, Mountain Glaciers, Coral Reefs

Anthropogenic warming

Slow cooling over the Holocene

Holocene Interglacial

Ice Age

Maximum heating from Orbital Parameters

Marcott, S.A., 2013, A Reconstruction of Regional and Global for the Past 11,300 Years, Science, 08 Mar: 1198-1201

What are the impacts of climate change in Hawai‘i?
Hawai`i is getting warmer

100-yr change = +0.52°C (+0.94°F)

Average daily wind speeds are declining

Sea surface temperatures are rising – especially during El Niño.
32 Record Hot Days May 16- June 9, 2019

Recent Records Broken/Tied (Thursday May 16th – Thursday June 9th)

- 5/16/19: Honolulu, 89°
- 5/17/19: Honolulu, 89°
- 5/18/19: Kahului, 91°; Lihue, 85°
- 5/19/19: Lihue, 85°; Honolulu, 89°; Kahului, 92°; Hilo, 87°
- 5/20/19: Kahului, 93°
- 5/21/19: Honolulu, 89°; Lihue, 87°
- 5/22/19: Lihue, 86°; Kahului, 96°; Hilo, 88°
- 5/23/19: Lihue, 86°; Kahului, 95°
- 5/24/19: Lihue, 85°; Honolulu, 90°; Kahului, 94°
- 5/25/19: Lihue, 84°; Honolulu, 91°; Kahului, 93°
- 5/26/19: Kahului, 91°
- 5/28/19: Lihue, 85°; Kahului, 95°
- 5/30/19: Kahului, 93°
- 5/31/19: Kahului, 91°
- 6/4/19: Kahului, 91°
- 6/6/19: Kahului, 95°
- 6/7/19: Honolulu, 91°; Kahului, 95°
- 6/8/19: Honolulu, 90°; Kahului, 91°
- 6/9/19: Kahului, 92°
Hawaiʻi is getting drier

Declining rainfall in wet and dry seasons; affecting all the major islands.
Kona drought has been especially intense
Stream Base Flow

1913-2008 ANNUAL MEDIAN STREAMFLOW, Q$_{50}$

Wildfire is increasing in Hawaiʻi

Trauernicht, C., E. et al. 2015 The contemporary scale and context of wildfire in Hawaii. Pacific Science 69:427-444
Less than half of the landscape in Hawai‘i is still dominated by native plants.
Avian malaria threatens Hawaiian forest birds. The threat increases with rising temperature.

Global extreme rainfall has increased 12\%
Global extreme rainfall has increased 12%
O‘ahu, April 2018
State of Emergency, $124 million
Short steep watersheds with heavy development promote flooding.
O‘ahu, April 2018
Water in Wailupe Gulch rose 8 ft
Kaua‘i, April 2018
49.69 inches in 24-hour, national record
Kauaʻi, April 2018
Hanalei River rose 15 feet
Kauaʻi, April 2018
Hanalei River jumped its bank and carved a new channel
Hurricanes and Climate Change

• Warmer water = More fuel
• Larger
• More rain
• Stronger wind = Higher category
• Slower = More damage
• Higher storm surge
• Shifting away from equator

1994 hurricane season
2018 hurricane season
Projected increase in tropical cyclones near Hawaii

Hiroyuki Murakami, Bin Wang, Tim Li & Akio Kitoh

Abstract

Projections of the potential impacts of global warming on regional tropical cyclone activity are challenging owing to multiple sources of uncertainty in model physical schemes and different assumptions for future sea surface temperatures. A key factor in projecting climate change is to derive robust signals of future changes in tropical cyclone activity across different model physical schemes and different future patterns in sea surface temperature. A suite of future warming experiments (2075–2099), using a state-of-the-art high-resolution global climate model, robustly predicts an increase in tropical cyclone frequency of occurrence around the Hawaiian Islands. A physically based empirical model analysis reveals that the substantial increase in the likelihood of tropical cyclone frequency is primarily associated with a northwestward shifting of the tropical cyclone track.
Hurricane Michael, Florida Panhandle, October, 2018
Hurricane Michael, Florida Panhandle, October, 2018
Global weather disasters have doubled in two decades

Worldwide Extreme Weather Catastrophes
1980-2016

- Red: Extreme temperatures, droughts, fires
- Blue: Floods, mudslides
- Orange: Storms

Number of Events

Data: Insurance Information Institute, January 2017
Oceans are hotter, more acidic, with 2% less oxygen.
Reefs are projected to decline to 10-30% of former cover at 1.5°C and to less than 1% at 2°C

By 2050 >98% of coral reefs will be afflicted by annual bleaching
Invasive Species
Reef Collapse

Antarctic ice melt has ‘tripled over the past five years’

Greenland faces a 66% chance that melting will become unstoppable at 1.8°C
Mountain Glaciers lost 9,625 billion tons of ice since 1961, raising sea level almost 1 ft

The ocean is 40% hotter than previously thought.
How high will SL rise by 2100?

- Antarctic ice loss
- Greenland ice loss
- Mountain glacier ice loss
- Thermal expansion

0.8m + 0.8m + Thermal expansion = 1m by 2100

10% chance of sea level exceeding 6.5 ft by 2100

"Coastal decisions require long lead times. It would be nice if we could wait for the science to clear up, but we can't."

"If you knew there was a 10% chance a plane would crash, you wouldn't get on it. It's the same with sea level rise,"
Sea Level Rise: 4 ft (MHHW)

Flood Component
- Coastal
- Drainage
- Groundwater

Flood Depth
- 0 m
- 1 m

Drainage Failure
Impassable Roadway

Miles
Sea Level Rise:
5 ft (MHHW)

Flood Component
Coastal
Drainage
Groundwater

Flood Depth
Coastal
Drainage
Groundwater

1 m
0 m

Drainage Failure
Impassable Roadway
Rain + High Tide = Flooding
Department of Transportation

- 140 miles
- 120 bridges
- 10-15% all roads
- $7.5M per lane mile
- $14M per bridge
- $15B total
Coastal Erosion and Beach Loss
Summer wave run-up 2ft
Summer wave run-up 3ft
Are global CO$_2$ emissions decreasing?
CO₂ emissions are rising at record levels

http://www.globalcarbonproject.org
Global emissions must be cut 50% by 2030

Hawaii is in a strong position to lead the world

- HECO has 7 new projects approved by the PUC
- One of these will be the single largest solar and storage deployment in U.S. history
- Phase II will replace our 180 MW coal plant and build a stand-alone 200 MW battery that will feed peak demand at less than current pricing.
- Farmers, cattle ranchers, and fish farms are going carbon negative and increasing our food security
- Seawater air conditioning is a cutting edge advancement
- Grid modernization strategy is installing “smart meters” to create new records of efficiency.