The Climate Crisis
The world is now 1°C (1.8°F) warmer
Global Surface Temperature relative to 1880-1920 mean

Jim Hansen: http://www.columbia.edu/~mhs119/Temperature/
Jean-Baptiste Joseph Fourier (1768-1830)
French mathematician, physicist

- Calculated that Earth should be considerably colder than it is.
- He considered that Earth's atmosphere might act as an insulator.
- First recognition of Greenhouse Effect
John Tyndall (1820–1893) *Irish physicist*

- First to measure heat trapping by atmospheric gases
- Identified the role of CO$_2$ in absorbing heat
- Proved what Greenhouse Effect was real
Svante Arrhenius
(1859–1927) Swedish chemist/physicist

- First to conclude that burning coal could cause global warming.
- Suggested that human emissions would be strong enough to prevent the world from entering a new ice age, and that a warmer Earth would be needed to feed the rapidly increasing population.
Guy Stewart Callendar (1897–1964) English engineer

- Discovered temperature increase from nineteenth century
- Correlated with measurements of CO$_2$
- Concluded that CO$_2$ causing climate change.
Charles David Keeling (1928-2005) American chemist

- 1961 showed that CO₂ levels were rising steadily.
- Now the longest continuous record of CO₂ in the world showing that it has grown from 315 ppm in 1958 to 409 ppm in 2018.
60% of the warming is due to human greenhouse gas emissions
18% results from deforestation
18-22% of global warming comes from industrial meat production
0.5 to 1.1°C warmer if not for aerosols

https://e360.yale.edu/features/air-pollutions-upside-a-brake-on-global-warming
We have exceeded natural levels of carbon dioxide by 45%, highest in millions of years.

![CO2 level graph](graph.png)


Tripati, A.K., et al., 2009, Coupling of CO$_2$ and Ice Sheet Stability Over Major Climate Transitions of the Last 20 Million Years, Science, 04 Dec 2009 : 1394-1397
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>Duration</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 – Large regions too hot to support life, ice melt unstoppable, super-heatwaves, super-storms, socio-economic fabric at risk

2°C - Paris Accord, heatwaves every summer, SLR 1-2m

1°C – extreme weather, ocean changes, SLR 1m
Global Warming is changing our world.
One third of the world’s population is now exposed to deadly heat waves.

Half of human population live with water scarcity.

By 2050 this will increase to 5 billion people.
2017 - 124 million in 51 countries faced acute food insecurity

- Increase of 11 million from 2016
- Triggered by extreme climate events — mainly drought
- In 18 countries, these conditions drove rising conflict, leading to further hunger

Food Crises Intensifying Because of Climate Change and Conflict

By Agnieszka De Sousa
March 22, 2018, 2:17 AM HST

- More lives at risk from lack of food, according to UN and EU
- Food crises set to become more acute, EU commissioner warns

Global food crises are poised to worsen in some areas as conflict and climate change weigh down production, according to analysts at the United Nations and...
Extreme heat leads to drought and famine – driving people from their homelands
Drought in Syria led to civil war and terrorism.

...worst drought in the instrumental record, causing widespread crop failure and a mass migration of farming families to urban centers.

...the drought had a catalytic effect, contributing to political unrest.

Climate change in the Fertile Crescent and implications of the recent Syrian drought

Colin P. Kelley, Shahrzad Mohrtadi, Mark A. Cane, Richard Seager, and Yoshia


Edited by Brian John Hopkins, Imperial College London, London, United Kingdom, and approved January 6, 2015 (received for review November 16, 2014)

Significance

There is evidence that the 2007–2010 drought contributed to conflict in Syria. It was the worst drought in the instrumental record, causing widespread crop failure and a mass migration of farming families to urban centers. Centuries-long observed trends in precipitation, temperature, and sea-level pressure, supported by climate model results, strongly suggest that anthropogenic forcing has increased the probability of severe and persistent droughts in this region, and made the occurrence of a 5-year drought as severe as that of 2007–2010 2 to 3 times more likely than by natural variability alone. We conclude that human influences on the climate system are implicated in the current Syrian conflict.

Abstract

The Syrian uprising that began in 2011, the greater Fertile Crescent experienced the worst drought in the instrumental record. For Syria, a country marked by poor governance and unsustainable agricultural and environmental policies, the drought had a catalytic effect, leading to political unrest. We show that the recent decrease in Syrian precipitation is a combination of natural variability and a long-term drying trend, and the unusual severity of the observed drought is here shown to be highly unlikely without this trend. Precipitation changes in Syria are linked to rising mean sea-level pressure in the Eastern Mediterranean, which also shows a long-term trend. There has been also a long-term warming trend in the Eastern Mediterranean, adding to the drawdown of soil moisture. No natural cause is apparent for these trends, whereas the observed drying and warming are consistent with model studies of the response to increases in greenhouse gases. Furthermore, model studies show an increasingly drier and hotter future mean climate.
Syrian refugees flooded into Europe by the millions
... creating a backlash among residents
Sebastian Kurz....campaigned on the need for tougher immigration controls, quickly deporting asylum-seekers whose requests are denied and cracking down on radical Islam.

Our basic socio-economic system, and core humanitarian principles are at risk.

As Europeans assess the fallout from the U.K.'s Brexit referendum, they face a series of elections that could equally shake the political establishment. In the coming 12 months, four of Europe's five largest economies have votes that will almost certainly mean serious gains for right-wing populists and nationalists. Once seen as fringe groups, France's National Front, Italy's Five Star Movement, and the Freedom Party in the Netherlands have attracted legions of followers by
Wild fires have increased 9-fold


Flooding is a global problem. Extreme rainfall has increased 12%.
Food is less nutritious. Decreased zinc, iron, and protein.
Climate-related local extinctions have already occurred in hundreds of species, including 47% of the 976 species surveyed.
2017 record highest ocean heat content since records began in 1958

Oceans are more acidic

...West Coast waters dissolving shells of pteropods food for pink salmon, mackerel and herring.
2% decline in dissolved oxygen since 1950

The global percentage of reefs impacted by bleaching tripled through the 28-year record. By 2050 more than 98% of coral reefs will be afflicted by bleaching each year.
Four global bleaching events since 1998, none prior
Ice is melting – 600 billion tons each year and accelerating
Ice is melting – 600 billion tons each year and accelerating
NBC news West Antarctic collapse
nearly every country pledged to keep global temperatures “well below” 2°C and to “pursue efforts to limit the temperature increase even further to 1.5°C”. 
Nations Unies
Conférence sur les Changements Climatiques 2015
COP21/CMP11
Paris, France
After 3 years of flat emissions, a 1.4% increase in 2017.

Global energy-related CO₂ emissions, 2000-2017

After 3 years of flat emissions
1.4% increase in 2017

- **Energy**: Global energy demand increased by 2.1% in 2017, compared with 0.9% the previous year and 0.9% on average over the previous five years.
  - More than 40% of the growth was driven by China and India
  - 72% of the new energy demand was met by fossil fuels
  - 25% by renewables and the remainder by nuclear
  - Energy demand was more than twice the annual average seen over the last decade
  - Driven by: increasing share of sport-utility vehicles and light trucks in major economies and
  - Demand from the petrochemicals sector

- **Oil**: World oil demand rose by 1.6% (or 1.5 million barrels a day)

- **Carbon dioxide (CO2)**: Global energy-related CO2 emissions grew by 1.4%

- **Rise**: Most major economies saw a rise in emissions

- **Decline**: United States, United Kingdom, Mexico and Japan.
  - Largest decline came from the United States, mainly because of higher deployment of renewables.

Carbon Budget – in climate models, there is strong relationship between cumulative emissions, and temperatures

- 1.5°C – 593 billion tons of Carbon (66%)
- 2019
- 2.0°C – 790 billion tons of Carbon (66%)
- 2033 to 2037 (15 to 19 yrs.)

Paris pledges are only 1/3 of what is needed to stop at 2°C
Global energy use to the year 2040

• Global economy grows at 3.4% per year
• Energy demand expands by 30%
  • Global population grows to 9 billion in 2040
  • One-third of growing demand comes from India
  • Urbanization adds a city the size of Shanghai (24 million) every 4 months
• Renewable energy meets 40 percent of the increase
• Oil demand continues to grow at a steadily decreasing pace. Natural gas use rises by 45%
• Fossil fuels hold a steady 75 to 80% market share
• Global emissions of CO2 from fossil fuels alone grows 16% by the year 2040

Negative Emissions

Scenario group
Baseline (3–5.1°C)
6.0 W/m² (3.2–3.3°C)
4.5 W/m² (2.5–2.7°C)
3.4 W/m² (2.1–2.3°C)
2.6 W/m² (1.7–1.8°C)

16% growth to 2040
The likely range of warming is 2.0–4.9°C, with median 3.2°C

- Global scale refugee crisis as the equatorial continents marginally habitable
- Sea level, 10-15m (30-50 ft)
- 2100, 50% more people to feed, 50% less grain to give them.
- Extreme weather disasters, massive floods, heat waves, great tropical cyclones, mega-drought, and torrential rainfall.
- Ironically, this is all taking place in a world of solar panels, wind mills, electric cars, and cleaner air.

The recently published Intergovernmental Panel on Climate Change (IPCC) projections to 2100 give likely ranges of global temperature increase in four scenarios for population, economic growth and carbon use. However, these projections are not based on a fully statistical approach. Here we use a country-specific version of Kaya’s identity to develop a statistically based probabilistic forecast of CO₂, emissions and temperature change to 2100. Using data for 1960-2010, including the UN’s probabilistic population projections for all countries, we develop a joint Bayesian hierarchical model for Gross Domestic Product (GDP) per capita and carbon intensity. We find that the 90% interval for cumulative CO₂ emissions includes the IPCC’s two middle scenarios but not the extreme ones. The likely range of global temperature increase is 2.0–4.9°C, with median 3.2°C and a 5% (1%) chance that it will be less than 2°C (1.5°C). Population growth is not a major contributing factor. Our model is not a “business as usual” scenario, but rather is based on data which already show the effect of emission mitigation policies. Achieving the goal of less than 2°C warming will require carbon intensity to decline much faster than in the recent past.

The IPCC has issued projections of climate change based on four different pathways for emissions and land use up to 2100, each one in turn based on a different socioeconomic scenario for the world’s future and developed by a different research group. They are called representative concentration pathways (RCPs) and were selected so as to represent the scientific literature as of 2007 and to span a range of radiative forcings by 2100. The RCP2.6 scenario was designed to represent very low greenhouse gas concentration levels, RCP4.5 and RCP8.5 are stabilization scenarios, and RCP6.0 represents rising radiative forcing. The RCPs were not to be interpreted as forecasts. The two key socioeconomic driving forces of the RCPs are population and GDP, and the RCPs draw on population information up to 2010. The UN has recently issued new population projections to 2100, reflecting data up to 2015. These are probabilistic projections based on a Bayesian model. The UN’s predictive distribution for world population in 2100 has a median of 11.2 billion and a 90% interval from 9.7 to 12.9 billion. Three of the four RCPs are based on population in 2100 below the lower fifth percentile; only one higher is the high-emissions RCP8.5. This raises the question of the impact of the higher projected future population on climate. The availability of probabilistic population projections now (unlike when the RCPs were formulated) makes it more feasible to develop a statistical forecasting model for the key drivers, as advocated by Moss and Schneider. We use a simple form of the Kaya identity, which expresses future emission levels in a country as a product of three components: population, GDP per capita, and CO₂ emissions per capita. This is a specific version of the IFAT equation, Impact = Population × Affluence × Technology. We use data from 1960 to 2010 on GDP per capita and carbon intensity for most countries. We build a joint Bayesian hierarchical statistical model for GDP per capita and carbon intensity in most countries, and combine it with the UN probabilistic population projections to produce a predictive distribution of quantities of interest to 2100. We develop a probabilistic forecast of global temperature increase by combining them with the relationship between cumulative CO₂, emissions and temperature used by the IPCC. For GDP per capita we use a Bayesian hierarchical model for all countries based on the idea of a world technology frontier (represented by the US for the period of our data), towards which countries may converge; see Supplementary Fig. 1. The frontier model is modelled by a random walk model with constant drift. This allows countries with high current growth rates to continue growing fast in the short to medium term, while avoiding unrealistically high long-term forecasts.

To model carbon intensity, we note that most countries have reached a peak intensity; subsequently their carbon intensity has been trending downwards, as illustrated in Fig. 1. Note that we posit a peak and subsequent decline in CO₂ emissions per unit of GDP; this is different from the Environmental Kuznets Curve hypothesis that CO₂ emissions per capita peak and then decline, which has not been established despite much research. We modelled carbon intensity using a Bayesian hierarchical model for most countries estimated using the post-peak data. For each country, intensity is modelled as a linear trend plus an autoregressive random process. Our model incorporated a within-country correlation between model errors in GDP per capita and carbon intensity, estimated to be −0.16. We found no significant correlation between model errors in population and either of the other two components. An advantage of a fully statistical model is that it can be assessed by prediction validation experiments; we carried out several. In the first one, we fitted the model using only data from 1950 to 1980, generated predictive distributions for the following 30 years, and compared them to what actually happened. We repeated forecasts through 2010 for data up to 1990 and 2000, respectively. Illustrative results for world CO₂ emissions are shown in Fig. 2. The percentile of the UN’s predictive distributions (97 billion); the only one higher is the high-emissions RCP8.5. The largest deviation from our median forecast in these validation experiments is in prediction of the rapid uptick in CO₂ emissions from 2000 to 2010. This decade of rapid emissions, driven in China by exceptionally rapid growth, nevertheless lies within our 90% intervals for all three predictive validation experiments.

The results of these validation exercises by country are shown in Supplementary Table 1, while the results for the five IPCC regions are shown in Supplementary Fig. 2. These indicate that the model is
We need to bend the curve of carbon, and reach zero emissions by 2050.
Halving emissions each decade
Sea Level Rise
Nerem et al (2018) Climate-Change-driven accelerated sea level rise detected in the Altimeter era, PNAS.
NOAA – 6 scenarios

NOAA Global Mean Sea Level (GMSL) Scenarios for 2100

- High scenario, 6.5 ft
- Intermediate-high scenario, 5 ft
- Intermediate scenario, 3.3 ft

Graph showing global mean sea level trends from 1800 to 2100 with projections for RCP 2.6, RCP 4.5, and RCP 8.5.
GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES

Silver Spring, Maryland
January 2017

noaa National Oceanic and Atmospheric Administration
U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

Photo: Ocean City, Maryland

Table 5. GMSL rise scenario heights in meters for 19-year averages centered on decade through 2200 (showing only a subset after 2100) initiating in year 2000. Only median values are shown.

<table>
<thead>
<tr>
<th>GMSL Scenario (meters)</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>2060</th>
<th>2070</th>
<th>2080</th>
<th>2090</th>
<th>2100</th>
<th>2120</th>
<th>2150</th>
<th>2200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0.03</td>
<td>0.06</td>
<td>0.09</td>
<td>0.13</td>
<td>0.16</td>
<td>0.19</td>
<td>0.22</td>
<td>0.25</td>
<td>0.28</td>
<td>0.30</td>
<td>0.34</td>
<td>0.37</td>
<td>0.39</td>
</tr>
<tr>
<td>Intermediate-Low</td>
<td>0.04</td>
<td>0.08</td>
<td>0.13</td>
<td>0.18</td>
<td>0.24</td>
<td>0.29</td>
<td>0.35</td>
<td>0.4</td>
<td>0.45</td>
<td>0.50</td>
<td>0.60</td>
<td>0.73</td>
<td>0.95</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.04</td>
<td>0.10</td>
<td>0.16</td>
<td>0.25</td>
<td>0.34</td>
<td>0.45</td>
<td>0.57</td>
<td>0.71</td>
<td>0.85</td>
<td>1.0</td>
<td>1.3</td>
<td>1.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Intermediate-High</td>
<td>0.05</td>
<td>0.10</td>
<td>0.19</td>
<td>0.30</td>
<td>0.44</td>
<td>0.60</td>
<td>0.79</td>
<td>1.0</td>
<td>1.2</td>
<td>1.5</td>
<td>2.0</td>
<td>3.1</td>
<td>5.1</td>
</tr>
<tr>
<td>High</td>
<td>0.05</td>
<td>0.11</td>
<td>0.21</td>
<td>0.36</td>
<td>0.54</td>
<td>0.77</td>
<td>1.0</td>
<td>1.3</td>
<td>1.7</td>
<td>2.0</td>
<td>2.8</td>
<td>4.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Extreme</td>
<td>0.04</td>
<td>0.11</td>
<td>0.24</td>
<td>0.41</td>
<td>0.63</td>
<td>0.90</td>
<td>1.2</td>
<td>1.6</td>
<td>2.0</td>
<td>2.5</td>
<td>3.6</td>
<td>5.5</td>
<td>9.7</td>
</tr>
</tbody>
</table>
Marine and Groundwater Inundation
Sea Level Rise +0.32 m
NOAA Monthly Maximum Tide Stage (MMT)

- MMT = 49 cm above MSL
- MHHW = 33 cm above MSL

1 ft – 2030 to 2040
Sea Level Rise +0.60 m
NOAA Monthly Maximum Tide Stage (MMT)

MMT = 49 cm above MSL
MHHW = 33 cm above MSL
3 ft – 2060 to 2070

Sea Level Rise +0.98 m
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 49 cm above MSL
MHHW = 33 cm above MSL
Sea Level Rise +1.22 m (4 ft)
NOAA Monthly Maximum Tide Stage (MMT)

MMT = 49 cm above MSL
MHHW = 33 cm above MSL
5 ft – 2090 to 2100

Sea Level Rise +1.52 m (5 ft)
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 49 cm above MSL
MHHW = 33 cm above MSL
Summer wave run-up 2ft
Summer wave run-up 3ft
Coastal Erosion
Today
18 buildings (10%) 0.04 miles of road
1 ft SLR
109 buildings (60%) 0.2 miles of road
Coastal roads are threatened by erosion on every island.
Hawaii will need $15 billion to protect highways from sea level rise.

$7.5 million for every mile of road that must either be raised, pushed back or relocated in the next 50 to 100 years.

$40 million for every mile of bridge.
Ewa Beach 3.2 ft SLR

- Coastal erosion with 3 ft SLR
- Annual wave inundation with 3 ft SLR
- Groundwater and storm drain flooding with 3 ft of SLR
Punalu'u
“If you wage war with water, you will lose.”

Yield and elevate
Hope? ...... ACTION!
Wind is the most competitively priced technology in most markets.
Solar Power is the fastest-growing source of new energy worldwide.

Renewable Energy accounted for two-thirds of new power added to the world’s grids in 2016.

**Time to shine: Solar power is fastest-growing source of new energy**

Renewables accounted for two-thirds of new power added to the world’s grids last year, says International Energy Agency.

Solar power was the fastest-growing source of new energy worldwide last year, outstripping the growth in all other forms of power generation for the first time and leading experts to hail a “new era”.

Renewable energy accounted for two-thirds of new power added to the world’s grids last year, says International Energy Agency.
17 states, >36% of US population, >$7 trillion dollars, equivalent to world’s third largest country

STATES UNITED FOR CLIMATE ACTION

In response to the U.S. federal government’s decision to withdraw the United States from the Paris Agreement, Governors Andrew Cuomo, Jay Inslee, and Jerry Brown launched the United States Climate Alliance – a bipartisan coalition of governors committed to reducing greenhouse gas emissions consistent with the goals of the Paris Agreement. Smart, coordinated state action can ensure that the United States continues to contribute to the global effort to address climate change.

The Alliance has three core principles:

- **States are continuing to lead on climate change:** Alliance states recognize that climate change presents a serious threat to the environment and our residents, communities, and economy.

- **State-level climate action is benefitting our economies and strengthening our communities:** Alliance members are growing our clean energy economies and creating new jobs, while reducing air pollution, improving public health, and building more resilient communities.

- **States are showing the nation and the world that ambitious climate action is achievable:** Despite the U.S. federal government’s decision to withdraw from the Paris Agreement, Alliance states continue to be leaders in addressing climate change.

U.S. Climate Alliance members represent more than 40% of the population of the United States.

News

U.S. Climate Alliance asks Congress to protect critical funding for renewable energy and energy efficiency research and development

Feb 16, 2018

Julie Cerqueira named new executive director of the U.S. Climate Alliance

Jan 30, 2018
Help us draw the line on climate change.

Join Blue Planet Foundation on Saturday, April 21, 2018, from 9:00 AM to 12:00 PM for the Blue Line Project—a locally powered movement to raise awareness about the impacts of climate change.
There is something everyone can do

• Volunteer on weekends
• Eat a more vegetable-based diet
• Use cars and airplanes less
• Plant trees and help DLNR with watershed work
• Have smaller families
• Spread the word
• Create art about climate change
• Contact your elected official and ask what they are doing?
• Eat and buy more locally produced foods and goods
• Support urban farming at parks and wetlands (Lo‘i Kalo mini-park)
• Tap into climate change news:
  • Climate Progress https://thinkprogress.org/climate/
  • Inside Climate News https://insideclimatene ws.org
  • The Daily Climate http://www.dailyclimate.org