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**Hypothesis:** an informal idea that has not been thoroughly tested by the scientific community. Most are discarded.

**Theory:** A hypothesis becomes a theory when it can explain and predict observations and it also has been thoroughly tested by the scientific community. Even theories, over time, can be disproved and discarded.

**Law:** If a theory stands the test of time (years and decades) it may be called a *law* or *unifying theory* and is the closest approximation to "the truth" possible. Keep in mind that it is impossible to prove that a theory is true, only that it is untrue.

**Forcing:** Factors that cause change.

**Feedback:** A process that alters climate changes already underway. *Positive* means increasing change while *negative* means decreasing change.

**Weather:** Short term, random event within the atmosphere.

**Climate:** Long term trend or statistical probability of changes in the atmosphere.

**Anthropogenic:** Originating in human activity.
Since the last major glacial period about 12,000 years ago, climate has been fairly stable.

Humanity has adapted to this climate and our existence is based on this stable climate.

Since the Industrial Revolution, global T has increased by 1°C (1.8°F).
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- IPCC models predict more heat waves and fewer cold snaps with higher emissions of heat trapping gases
- Precisely what is happening in the US (and also globally)
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25 Years of the IPCC
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Video: **Climate Change & Extremes**

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![Graph showing probability of occurrence of cold and hot weather](image)

*Kitchen (2013)*
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Web Alert:

Determining Past Climate

Mann, et al. (2008)
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Ice cores

The ice from the bottom of that core is over 20,000 years old.

Video: Ice Core Data
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Mann, et al. (2008)

Marcott, et al. (2013)
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Video: The Hockey Stick & Climate Wars
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Earth at the last glacial maximum
Kitchen (2013)

65 million years of climate change
Kitchen (2013)
Chapter 1

- Sun’s radiant energy has been fairly constant in the previous millions of years

- **Radiative forcing** is the difference between incoming vs. outgoing radiation

- Humans are causing an increased radiative forcing mostly due to increased greenhouse gases (GHG)

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### Radiative Forcing

<table>
<thead>
<tr>
<th>Emitted compound</th>
<th>Resulting atmospheric drivers</th>
<th>Radiative forcing by emissions and drivers</th>
<th>Level of confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>CO₂</td>
<td>1.68 [1.33 to 2.03]</td>
<td>VH</td>
</tr>
<tr>
<td>CH₄</td>
<td>CO₂, H₂O, O₃, CH₄</td>
<td>0.97 [0.74 to 1.20]</td>
<td>H</td>
</tr>
<tr>
<td>Halo-carbons</td>
<td>O₃, CFCs, HCFCs</td>
<td>0.16 [0.01 to 0.35]</td>
<td>H</td>
</tr>
<tr>
<td>N₂O</td>
<td>N₂O</td>
<td>0.17 [0.13 to 0.21]</td>
<td>VH</td>
</tr>
<tr>
<td>CO</td>
<td>CO₂, CH₄, O₃</td>
<td>0.23 [0.16 to 0.30]</td>
<td>M</td>
</tr>
<tr>
<td>NMVOC</td>
<td>CO₂, CH₄, O₃</td>
<td>0.10 [0.05 to 0.15]</td>
<td>M</td>
</tr>
<tr>
<td>NOₓ</td>
<td>Nitrate, CH₄, O₃</td>
<td>-0.15 [-0.34 to 0.03]</td>
<td>M</td>
</tr>
<tr>
<td>Aerosols and precursors (Mineral dust, SO₂, NH₃)</td>
<td>Mineral dust, Sulphate, Nitrate, Organic carbon, Black carbon</td>
<td>-0.27 [-0.77 to 0.23]</td>
<td>H</td>
</tr>
<tr>
<td>Short-lived gases and aerosols (Cloud adjustments due to aerosols)</td>
<td>Cloud adjustments due to aerosols</td>
<td>-0.55 [-1.33 to -0.06]</td>
<td>L</td>
</tr>
<tr>
<td>Albedo change due to land use</td>
<td>Albedo change due to land use</td>
<td>-0.15 [-0.25 to -0.05]</td>
<td>M</td>
</tr>
<tr>
<td>Natural</td>
<td>Changes in solar irradiance</td>
<td>0.05 [0.00 to 0.10]</td>
<td>M</td>
</tr>
</tbody>
</table>

### Total Anthropogenic RF relative to 1750

- 2011: 2.29 [1.13 to 3.33] (H)
- 1980: 1.25 [0.64 to 1.86] (H)
- 1950: 0.57 [0.29 to 0.85] (M)
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- Sun’s radiant energy has been fairly constant in the previous millions of years

- Radiative forcing is the difference between incoming vs. outgoing radiation

- Humans are causing an increased radiative forcing mostly due to increased greenhouse gases (GHG)

Figure 10.5 | Assessed likely ranges (whiskers) and their mid-points (bars) for attributable warming trends over the 1951–2010 period due to well-mixed greenhouse gases, other anthropogenic forcings (OA), natural forcings (NAT), combined anthropogenic forcings (ANT) and internal variability. The Hadley Centre/Climatic Research Unit gridded surface temperature data set 4 (HadCRUT4) observations are shown in black with the 5 to 95% uncertainty range due to observational uncertainty. In this record (Morice et al., 2012).
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**Attribution of Surface Temperature trends since 1950**

> 50% warming due to human activity

PDF derived from IPCC Fig. 10.5

Best guess ~110%
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Text Book Animation: Global Warming, Climate Change (CH.3)

Web Alert:

**Impact of Greenhouse Gases**
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- Greenhouse gases allow sunlight (visible-shortwave) to freely pass through to the surface

- Greenhouse gases slow the heat (infrared-longwave) leaving the Earth

- End result: a warmer climate

**Web Alert:**

**Impact of Greenhouse Gases**

NASA (2010)
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• Climate change from these cycles take millions of years
• Mountain building enhances precipitation
• Precipitation removes CO₂ which then enters oceans
• Shelled creatures absorb that CO₂ into shells
• Dead shells put CO₂ into sea floor
• Sea floor subducts, heats up, and melts
• CO₂ added back to atmosphere via erupting volcanoes

Web Alert: Ruddiman (2008)

Climate Change: Natural Causes
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Video: Plate Tectonics
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Kitchen (2013)
Earth 255 million years ago
Web Alert:

**Climate Change: Natural Causes**

- Climate change from these Milankovitch cycles range between 41,000 to 100,000 years
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• Ocean conveyor moves heat around and causes climate changes on time scales of decades to centuries

• Volcanoes and El Niños change climate on 1-5 year intervals
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Volcanoes and El Niños change climate on 1-5 year intervals

Kitchen (2013)
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Kitchen (2013)
Why Climate Models Should Have Accurate Future Projections

- Climate models are based upon well-established laws of physics and use a wealth of actual observations
- These models are able to simulate the current climate
- These models are able to simulate past climate

Web Alert:

Climate Models & Accuracy
Various emission scenarios result in different levels of global warming

A1F1 is the **warmest world** and that is the path we are on now
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IPCC (2013) now uses **Representative Concentration Pathways (RCPs)** instead of previous A & B carbon emission scenarios. There are four pathways: RCP8.5, RCP6, RCP4.5 and RCP2.6 - the last is also referred to as RCP3-PD.

We are currently tracking along RCP8.5
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- Society quickly becomes vulnerable at global T increases above 2°C
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Web Alert: Modern Day Climate Change

How do we know the world is warming?

Air Temperature over Ocean
Humidity
Temperature of the Lower Atmosphere
Arctic Sea Ice
Snow
Glaciers
Ocean Heat Content
Sea Surface Temperature
Global Sea Level
Air Temperature over Land
What can we do?

USGCRP Climate Literacy Guide, 2009

NCDC (2010)
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Web Alert:

Global Cooling?
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IPCC (2013)
Climate change is caused by natural and human forcing

Before 1975, natural and human forcing appear to have shared responsibility for the post-IR global warming

Since 1975, most of the global warming is due to human activities, primarily emissions of GHGs