Climate changes (1900 to 2000) due to human activity

<table>
<thead>
<tr>
<th>Phenomenon^a and direction of trend</th>
<th>Likelihood that trend occurred in late 20th century (typically post 1960)</th>
<th>Likelihood of a human contribution to observed trend^b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmer and fewer cold days and nights over most land areas</td>
<td>Very likely^c</td>
<td>Likely^d</td>
</tr>
<tr>
<td>Warmer and more frequent hot days and nights over most land areas</td>
<td>Very likely^c</td>
<td>Likely (nights)^d</td>
</tr>
<tr>
<td>Warmer spells/heat waves. Frequency increases over most land areas</td>
<td>Likely</td>
<td>More likely than not</td>
</tr>
<tr>
<td>Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas</td>
<td>Likely</td>
<td>More likely than not</td>
</tr>
<tr>
<td>Area affected by droughts increases</td>
<td>Likely in many regions since 1970s</td>
<td>More likely than not</td>
</tr>
<tr>
<td>Intense tropical cyclone activity increases</td>
<td>Likely in some regions since 1970</td>
<td>More likely than not</td>
</tr>
<tr>
<td>Increased incidence of extreme high sea level (excludes tsunamis)^e</td>
<td>Likely</td>
<td>More likely than not</td>
</tr>
</tbody>
</table>

Virtually certain > 99%
Very likely > 90%
Likely > 66%
More likely than not > 50%

IPCC 2007

Climate Models

• What is a climate model?
• How long have they been around?
• How good are they?
Climate Models

• What is a climate model?
  – Mathematical representations of the atmosphere, ocean, sea ice and land surface
  – For each component, the model is based on the laws of physics and chemistry. For example,
    • the models conserve energy, mass, momentum. The obey the laws of physics (e.g., $F=ma$) and chemistry
    • Radiation (solar and terrestrial) is based on detailed theory (quantum mechanics).
    • Concentrations of some gases are prescribed because they change very very slowly ($N_2$, $O_2$, Ar, CFCs, etc)
    • Other gases are sometimes prescribed and sometimes calculated by the laws of chemistry and thermodynamics
  – The equations are hopelessly complicated to solve by pen and pencil (“analytically”), so we solve them numerically
  – The equations can’t be solved at a molecular level, so the climate system is chopped up regular chunks
Climate Models

- The current size of a chunk of atmosphere, land, ocean or sea ice is about 150km x 150km

The vertical extent of a box is typically:
- Atmosphere/Ocean: 80-500m
- Sea Ice: 50cm
- Land: 10cm

Climate Models

- The physical and chemical laws are solved in each of these chunks.
  - Within each chunk, there are things that are not explicitly modelled (e.g., clouds) but must be approximated ("parameterized") as a function of the average state of the chunk (e.g, the fraction of clouds in the chunk as a function of the chunk’s temperature, pressure, wind, humidity)
Climate Models

- Information in one chunk affects another because of motion
  - Wind (atmosphere)
  - Flow (ice, rivers, groundwater movement)
  - Currents (ocean)

- Motion, in turn, is due to pressure differences that result from temperature differences

- These calculations require enormous computer resources
  - For example, a 100 year run of a typical IPCC AR4 climate model takes
    * Nine months on the world’s fastest machines
    * 10,000 Gbytes of disk space (minimal output)

Climate Models

- What is a climate model
- How long have they been around?

Climate Models are based on the laws of physics and chemistry, and used for ~40 years for various problems.
Climate Models

• What is a climate model?
• How long have they been around?
• How good are they?
  – Some examples from 14 of the 23 climate models used in the most recent IPCC report: Assessment Report #4 (AR4) in 2007.

Annual Average Surface Temperature

Observed

Model Average

°C

IPCC 2007
Annual Average Surface Temperature

- Contoured = Observed
- Shaded = error in ‘average of the models’ (simulated minus observed)
- Error in typical model

“Annual Cycle*” in Temperature

* Multiply by ~3 to get approximately the difference in July and January temperature

Observed

Mean Model

Model Average

IPCC 2007
"Annual Cycle*" in Temperature

* Multiply by ~3 to get approximately the difference in July and January temperature

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