Trust, Uncertainty and Society

The Public Perception of Scientific Uncertainty in the Climate Science Debate

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Overview

I  Uncertainty in measurement
   Perceptions

II Uncertainty in prediction
   Perceptions

III Some climate science
   Perceptions

IV Climate change
   Perceptions
   A provocative idea
I Uncertainty in measurement

- Measuring temperature
  - 19 °C
  - (19 +/- 1) °C

- Conclusions
  - Not very accurate (10% error)
  - Observer-independent
  - Knowledge of uncertainty key (18.3 °C?)

- Strategies
  - Different instrument? Reduced uncertainty?
Perceptions

- **Uncertainty is not peripheral**
  
  Core part of experimentation  
  Not very well understood in SSK  

- **Random vs systematic error**
  
  Quantifying the error  
  The BEST project (2011)  

- **Comparisons**
  
  Uncertainties in economics  
  Uncertainties in accountancy  
  
  **Growth forecast: (2 +/- 0.5) %**

Harry Collins, Trevor Pinch
II Uncertainty in prediction

“Prediction is very difficult, especially about the future”
- Niels Bohr (Yogi Berra)

“Balderdash”
- CO’R, WEXT Conference, 2017

Some events more predictable than others
*Tomorrow will be Saturday etc.*

Laws of science are laws of prediction
Perceptions

- **Laws of science are predictive**
  *Orbits of planets, solar eclipses*

- **Not just a theory…**
  *Logical framework*
  *The role of observational evidence*

- **Central role for prediction**
  *Discriminating between theories*
  *Core aspect of science*

*Technology!*
Some climate science

- **Theory**
  - Global models not complicated
  - Main factors well understood (unlike big bang)

- **Observables**
  - Air temperature, ocean temperature
  - Sea level, ice-melt

- **Long-term variations**
  - 1950-2010 vs 1900-1950

- **Large planetary areas**

Climate ≠ weather
Only three factors in global climate!

- **The sun**
  *Solar cycles, earth’s orbit*

- **The albedo effect**
  *Different for different planets*
  *Earth: ~ 30%*

- **The atmosphere**
  *Trapping of reflected heat*

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**Table 4.1** Data on the four inner planets in our solar system

<table>
<thead>
<tr>
<th>Planet</th>
<th>Solar constant (W/m²)</th>
<th>Albedo</th>
<th>Observed surface temperature (K)</th>
<th>Inferred n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>10,000</td>
<td>0.1</td>
<td>452</td>
<td>0.052</td>
</tr>
<tr>
<td>Venus</td>
<td>2,650</td>
<td>0.7</td>
<td>735</td>
<td>82</td>
</tr>
<tr>
<td>Earth</td>
<td>1,360</td>
<td>0.3</td>
<td>289</td>
<td>0.65</td>
</tr>
<tr>
<td>Mars</td>
<td>580</td>
<td>0.15</td>
<td>227</td>
<td>0.22</td>
</tr>
</tbody>
</table>
The greenhouse effect

- Atmosphere is transparent to solar radiation but absorbs infra-red
- Radiation from earth **absorbed**
  Re-emitted towards earth
- Atmosphere acts as blanket
  Earth is warmed by sun + atmos
A little chemistry…

Nitrogen ($N_2$): 78%
Oxygen ($O_2$): 21%
Argon (Ar): 1%

• Do not absorb in UV or IR
• Do not warm surface

• Not greenhouse gases
• Play little role in climate
Earth’s greenhouse gases

1. **Water vapour** ($H_2O$): [0.2 – 4.0 %] at surface
   Evaporation from oceans, decreases rapidly with height

2. **Carbon dioxide** ($CO_2$): 0.04% (390 ppm)
   Animal and plant exhalation, emissions from fossil fuels

3. **Methane** ($CH_4$): 1.8 ppm
   From wetlands, animals, agriculture, fossil fuels

4. **Nitrous oxide** ($N_2O$): 0.3 ppm
   Fertilizer and natural sources

$CO_2$ = most abundant non-condensing GHG
Recording CO$_2$

- **Keeling Curve (1950 - )**
  
  *CO$_2$ emissions increasing?*
  
  *Clear trend (Mauna Loa)*

- **Expected effects?**
  
  *Enhanced greenhouse effect*
  
  *Some absorption (50%)*
  
  *Climate sensitivity?*

- **Alternative models of gw**
  
  *Need 2 theories!*
CO₂ and fossil fuels

- Fossils formed when plants buried before respiration
- Stored in rock reservoirs; subject to intense heat and pressure
- Digging up and burning fossilized carbon releases energy
- Also releases CO₂ into atmos.

Flux from fossil fuels: 6 GtC/yr

- Much larger than volcano cycle
- Buildup of CO₂ in atmos.
- Increase of (40 +/- 0.5) % from 1850
Identification of CO₂

- **Compare CO₂ rise with fossil fuel use**
  *Strong correlation*

- **Measure age of CO₂**
  *Radioactive dating using C13 and C14*
  *Significant portion millions of years old*

- **Conclude CO₂ rise from fossil fuels**
IV Climate change

1. Surface temperature record
   - one test of climate change
   - oldest measurements, largest dataset
   - average of many stations around globe

**Relative measurement**
- measure relative to benchmark
- temperature anomaly
- ground data + satellite data

1906-2005: + 0.74 °C/century
1950-2005: + 1.3 °C/century

Rate increasing
2. Ocean temp record
   1-4 km depth
   Mixed layer and deep ocean

   • Rising over the past few decades
     Small rise
     Large heat capacity of water
     Large oceans

   • Most warming occurs in oceans
     Heat ≠ temperature
Ice-melt (land and sea)

- Glacier melt
- Ice sheet melt (both poles)
- Sea-ice melt (arctic)

Total melt → sea level rise 100m
Sea levels

Test for sea level rise:

- Melting of land ice
- Thermal expansion of water
- Changes in water stored on land

Results

- Sea level risen by + 15 cm/cent
- Past 40 years: + 1.8 cm/decade
- Past 10 years: + 3.1 cm/decade

Global annual average sea-level anomaly
GW summary

**Observations**
- Surface temperature (land, sea): up
- Ocean energy: up
- Ice-melt (land): up
- Ice-melt (sea): up
- Sea level: up

**Clear trend in different variables**
- Independent lines of evidence
- Different datasets/teams
- Different uncertainties/errors

**Concordance**
The future (IPCC)

**Continued emissions**

*Four scenarios (A2 = BAU)*

**Committed warming**

*Already in the pipeline*

**Future warming**

*2-6 °C by 2100*

*Depends on climate sensitivity*

**Alarmist?**

*Feedbacks not included*
Climate feedbacks

- **Reduced albedo effect**
  *Melting of ice sheets reduces reflectivity*

- **Reduced permafrost**
  *Releases methane and CO₂*

- **Ocean vents**
  *Release of methane from ocean vents*

- **Tipping points**
  *Past climates show accelerated warming*
Expectations

- **Increased drought, desertification**  
  *Africa, Australia, USA*

- **Increased flooding**  
  *China, India, Bangladesh*  
  *Robinson: poorest worst affected*

- **Frequent extreme events**  
  *Warmer air holds more moisture*

- **Global refugee problem**  
  *Not acknowledged*
A problem of perception

- **Media discussions poor/biased**
  - Opinionism vs journalism (weather)
  - Critical thinking and The History Boys

- **Resistance from industry**
  - Lobbyists, propagandists

- **Resistance from politics**
  - Conservative, nationalist values

- **Clear effect**
  - Low acknowledgement of problem

‘It’s just a theory’
Prognosis

- **A clear and present danger**
  Well understood (unlike big bang model)

- **Urgent action required**
  Sluggish

- **Problem of perception**
  Climate vs weather
  Vested interests, politics

- **Prognosis poor**
  No solution without trust
  No trust without knowledge?
What should be shown

1. Measure $E_{out}$ of atmosphere
   - Function of wavelength, time
   - Satellite measurements (1970 - )
     - Clear dip in microwave region
     - Clear increase in dip over 4 decades

2. Measure $T$ of atmosphere
   - Function of height
   - Stratospheric cooling

Clear signals of enhanced greenhouse effect
Climate and tobacco

- Dangers of smoking understood early on
  *Research results clear from 1950s*

- Strongly contested by tobacco industry
  *Industry experts, scientists*

- Media wars, PR wars
  *Doubt is our product*

- Same tactics for climate science
  *Heartland Institute*

*Countdown issue?*
The longterm future

- **Continued emissions**
  
  Slow removal of $CO_2$ from atm/bios/ocean system

- **Peak warming**
  
  Fossil fuels finite: peak around 2100
  Some delay due to fracking
  Major new threat to climate

- **Future warming**
  
  Climate for the next thousand years
Fixing climate

- **Reduce GHG emissions**
  - Reduce fossil fuel use
  - Remove fossil fuel subsidies
  - Reduce hydraulic fracking

- **Impose international targets**
  - Developed vs developing nations
  - Concerted global action

- **Invest in renewable energy**
  - Increase subsidies for renewables
  - Create climate of investment
  - Economics based on sound science

Unsound science
Renewables

- Nuclear energy
- Biofuels
- Wind energy
- Solar energy
- Tidal energy
- Long-term promise?
- Hydroelectric
- 2nd, 3rd generation

Sources of energy
- Nuclear
- Natural gas
- Renewable
- Oil

%
- Nuclear: 37%
- Natural gas: 21%
- Renewable: 25%
- Oil: 9%
- Coal: 8%

Renewable energy as share of total primary energy consumption, 2010

- Biomass and biofuels: 14%
- Hydroelectric: 20%
- Wind: 1%
- Geothermal: 3%
- Solar/photovoltaic: 1%
- Percentage of renewable energy: 21%
Climate controversy

- **Hockey-stick controversy**
  *Medieval warm period inaccurate?*
  *Contested by conservative think tanks*

- **Complex science**
  *Ice cores, tree rings, ocean sediments*
  *Vindicated by many studies*

- **Climategate controversy**
  *Hacked emails - fake controversy*
  *Exploited by conservative media*
  *Prevented agreement at COP 2009*
The future

$$\text{CO}_2 \text{ emitted} = \text{pop} \times \text{affluence} \times \text{tech}$$

*IPAT*

- $P \times A = \text{energy required}$
  - *Population growth*
  - *Affluence growth*

- Technology = GHG emitted/$$
  - *Carbon intensity x energy intensity*
  - Tends to decrease

**Net effect: large increase in emissions**
Climate change?

- **Long-term variation**
  
  *Is the global climate of 1955-2015 different from 1900 - 1955?*

- **Observational parameters**
  
  *Air temperatures; ocean temperatures*
  
  *Ice-melt (land, sea); sea level*

- **Climate science**
  
  *Basic principles*
  
  *What do we expect?*

Climate ≠ weather

Heat ≠ temperature
Conclusions

1. Multiple lines of evidence for warming
   Surface temps, ocean temps, sea-level rise, ice melt

2. Multiple lines of evidence for enhanced GHG effect
   CO\textsubscript{2} increase, radioactive dating, wavelength of absorbed radiation, stratospheric cooling

Conclude: (IPCC 2007)
Most of the warming since 1950 very likely (90\% prob) due to increase in GHG conc
Expect rise of 2-6 °C by 2050