Climate Change: Past and Future

Dr James Renwick
School of Geography, Environment and Earth Sciences
Victoria University of Wellington
james.renwick@vuw.ac.nz
Origins of climate research

• Late 1700s, moraines and “erratics” –

• Cuvier, Agassiz and Schimper (1830s)

• John Tyndall – greenhouse gases

• James Croll (1870s) - cycles
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Greenhouse gases & ice ages

The “EPICA” Dome C drilling team

- Past atmosphere trapped in bubbles in ice
  - Can track back and find past GHG levels
Greenhouse Gases & Temperature

EPICA Dome C: http://www.iceandclimate.nbi.ku.dk/research/past_atmos/composition_greenhouse/
Long-term changes in Earth’s orbit & the Milankovitch climate cycles

Precession = 20,000 years
Obliquity (tilt) = 40,000 years
Eccentricity = 100,000 years

In combination Milankovitch cycles cause predictable changes in the amount of solar radiation (insolation) received at different latitudes on annual and seasonal timescales.

On long time scales Milankovitch cycles cause the intensity, duration and timing of the seasons to change.

James Croll, c. 1870
Milutin Milankovitch, c. 1910
New Zealand 20,000 years ago

- Sea level 120m lower
- Walk from New Plymouth to Nelson
- Canada under 2km of ice
- Global temperatures 6° lower
- Most of last million years like this
- Why? The distribution of sunlight was different to today

Climate change: Carbon dioxide

Atmospheric concentrations of carbon dioxide, methane, & nitrous oxide have increased to levels unprecedented in at least the last 800,000 years.
Temperature

L–OTI(°C) Anomaly vs 1905–1934

NASA GISS
Ocean warming

Ocean time scale for adjustment: ~1000 years

http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/
Where is global warming going?

Ocean 93.4%

Also a big absorber of CO₂ ➔ “acidification”
Sea level rise

Expansion of water column
Melt of land-based ice

Source: http://www.cmar.csiro.au/sealevel
Alaskan fires: July 2015
Natural variations – El Niño

Weak Trade Winds (SOI -1.6)
• El Niño warms the global atmosphere
**ENSO and NZ**

**El Niño**
- Lower than normal pressures to the south, strong (south)westerlies.

**La Niña**
- Higher than normal pressures to the east/south, weak westerlies, more NE flow.
El Niño and NZ climate

Average Summer Temperature Anomaly during El Niño

Average Summer Percent of Normal Rainfall during El Niño
El Niño and NZ climate
Where to from here?

IPCC (2013)
Stopping at 2°C

How much carbon dioxide can the world emit?

67%

To have a good chance of limiting warming to 2°C, the world can emit no more than a total budget of about 2900 billion tonnes of CO₂.

→ Need ZERO emissions within 50 years
→ Then NEGATIVE emissions after that

By 2011, we had already emitted two thirds of this total budget.

At current rates, we will exceed the total budget around 2035.
Pattern of warming

CMIP5: 2081-2100

(°C per °C global mean change)
Rainfall change

CMIP5: 2081-2100

(% per °C global mean change)

IPCC (2013)
Sea level rise

Negative emissions
future

IPCC (2013)
How warm were the poles, last time we had 400ppm CO₂ (3 m yr ago)?

“Polar amplification”

Global sea levels 10-30m higher than present

Haywood et al., (2012)
Ice shelf buttressing and “marine ice sheet instability”
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Pliocene (3m years ago) ice sheet simulations

Old Model +7m GMSL  
(Pollard and DeConto, 2009, Nature)

New Model +17m GMSL  
(Pollard, DeConto and Alley, 2015)
New Zealand by 2100

- Sea Level ~60-130 cm higher
  - High tide line now = low tide line then
    - Beaches still the same width
    - Commitment to 10m or more rise (centuries)
- ~2-3°C warmer
  - Frosts rare everywhere
    - Impact on agriculture, pests etc
  - Snow line goes up (2° = 300m)
- Gradually rising westerly winds (winter/spring)
  - More often drier (droughtier) in the east
  - More rain in the west, alpine regions
- Changing seasonality critical
The future & “tipping points”

• Higher temperatures, changed rainfall
  – Heatwaves, fires, drought & flood etc
  – Water availability, food security → conflict
  – Permafrost methane?

• Sea level rise of 1m this century
  – Maybe 10-20m commitment
    • Irreversible melting of major ice sheets?
    • 400ppm may be a threshold for marine-based ice on planet Earth

• New Zealand not so badly off in the short term
  – But we live in a connected world...
The future & “tipping points”

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Thank you