Focussing the Macroscope
Tracking the Earth System’s Vital signs

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Historic Landmark Agreement
• Common Goal - To hold temperatures to well below 2°C relative to preindustrial levels and to pursue efforts to limit the temperature increase to 1.5°C
• Collective Plan - To cut anthropogenic emissions and to achieve a balance with removals by sinks in the second half of C21st
• Cycle of Review and Revision - 2018 stocktake of collective efforts to inform future commitments - repeated every 5 years
‘Truth’ has successfully spoken to ‘Power’
Greatest Collective Action in History
We have Upset the Energy Balance of Our Planet
As the Energy Accumulates …

- The world warms
- Ice & snow melt
- Sea levels rise
- Ocean and atmosphere circulation patterns change
- Extreme weather events increase
- Water cycle accelerates
- Ecosystems respond
- Food and water supplies are affected
- People and species are impacted
Climate to Prosper

Most Complex Object
Characterising the most Complex Object

- Identify and understand components, interconnections, modes of operation
- Select, measure state variables and monitor time-evolution
- ‘Macroscope’ - achieve whole-Earth view with necessary space-time resolution and sampling
Bretherton Diagram
‘Vital Signs’

- Metrics to characterise and track evolution of system, and to support improved communication and dialogue with policy makers, practitioners and the public (‘Dashboard’)
- Risk Indicators to guide mitigation and adaptation policy and actions
Global Surface Temperature

- Characterise ‘global warming’
- Validate climate models
- Demonstrate human influence
- Express climate risk
- Provide basis for UNFCCC negotiations
Global Surface Temperature

Reflections on global climate change
IOP Aug 1991
Bill Mitchell

As a physicist I have worries about the misunderstandings which appear to be arising in the minds of the general public and politicians from the simplifications being introduced into the discussions of global climate change. The system is complex, both (i) thermodynamically, and (ii) in relation to the choice of technical guidelines for the future.

Thermodynamically, the system is not in equilibrium in that there is no single set of thermodynamic parameters which can be used to define it – for example, temperature, pressure. I presume that the mean global surface temperature referred to is

$$
\bar{T} = \frac{\int_{S} T \, ds}{\int_{S} ds}
$$

where $S$ is over the surface of the globe. In the simplified statements, increases in this quantity are discussed (or in some cases for integration over a limited number of surface regions), whereas the important surface profiles are the spatial and temporal variations – for example, $T(r, \theta, \varphi, t)$ which may...
Global Mean Surface Temperature

- Thermodynamically meaningless
- ~94% of energy imbalance enters ocean
- Poor signal-to-noise ratio wrt natural variability
- Data source not designed for climate monitoring
- Socially of limited value cognitively and in terms of threats and impacts
‘Planetary Thermometer’

Global Mean Sea Level
Multiple Indicators

- Global average land surface temperature
- Atmospheric CO₂
- Global sea level
- Arctic summer sea-ice minimum
Climate Change Index

- Global land surface temperature anomaly
- Atmospheric CO₂ content
- Arctic minimum sea ice extent
- Global mean sea level
Socio-Economic Variables

Forecasts of China’s coal consumption versus reality

- Actual (EIA)
- Adams and Shachmurove 2008
- Crompton and Wu 2005
- EIA 2005
- IEA 2004

Coal Consumption (Gt/y)

Risk Assessment

- Manage down the likelihood and impact of greatest risks - increase resilience
- Identify top risks, areas of uncertainty and evaluate changes or trends over time
- Three key areas:
  - Future pathways of global emissions
  - Direct risks of climate response
  - Risks arising from intersection of climate change and human systems
Top Risks

- What do we want to avoid?
  - e.g; high emissions pathway
  - e.g; Arctic methane release
  - e.g; failure of food market / critical infrastructure

- What is the most important uncertainty?

- What measure would serve as best indicator?

- How would we measure and track it?

- What is the worst that could happen?
  - Address low probability, high impact tail risks
# Risk Assessment

<table>
<thead>
<tr>
<th>ENTITY OF CONCERN</th>
<th>THRESHOLD OF NON-LINEAR IMPACT</th>
<th>TOLERABLE PROBABILITY</th>
<th>REGULATING AUTHORITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insurance firm</td>
<td>Insolvency</td>
<td>Less than 1 in 200 years</td>
<td>EU insurance regulations</td>
</tr>
<tr>
<td>Building</td>
<td>Collapse (due to earthquake)</td>
<td>Less than 1 in 500 years</td>
<td>Japanese building codes</td>
</tr>
<tr>
<td>Individual</td>
<td>Death (in the workplace)</td>
<td>Less than 1 in 1000 in a given year</td>
<td>Guidance of UK Health and Safety Executive</td>
</tr>
</tbody>
</table>
Impact
Probability and Time

Can illuminate risk of maximum tolerable impact and action to avoid it
Can illuminate risk of maximum tolerable impact and action to avoid it.
London Risk Management

- 1.25m residents
- £200bn property value
- 400 schools
- 16 hospitals
- 8 power stations, >1000 electricity substations
- 4 world heritage sites plus art galleries, museums and historic buildings
- 35 tube stations
- 51 railway stations
Thames Estuary 2100

Managing flood risk through London and the Thames estuary

TE2100 Plan
November 2012
£10-20bn
Flood defences in London

Interim Defences during Thames Barrier construction

1928 Flood + 1930 Flood Act

Late-C19 update to Flood Act

1879 Flood Act

Ultimate Limit ~ 5m
Long-term MSL Commitment
Key - Thresholds of Impact / Discontinuities
20 Nations commitment to invest substantial public and private investment to accelerate development and deployment of ‘green’ technologies
Success Requires Citizens’ ‘Permissions’
Information Deficit
Climate to Prosper

Storytelling and Legend
Climate to Prosper

Theatre Director

Playwright

Scientist
Climate to Prosper

**The Guardian**

2071 five-star review - urgent call for the greatest collective action in history

*Royal Court, London*

The facts are sombre in Chris Rapley's compelling 75-minute talk on climate change, but his belief in human ingenuity knows no bounds.

Climate change play 2071 aims to make data dramatic.

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"2071 is better than good; it is necessary."

Guardian

2071

The World We’ll Leave Our Grandchildren

Chris Rapley & Duncan Macmillan
Climate to Prosper
What kind of Future do We want to Create?