Climate Objectives and Feedback Effects on Future Emissions

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NERC Programme – Understanding the Pathways to and Impacts of a 1.5°C Rise in Global Temperature

- Evidence for the UK Committee on Climate Change, with regard to their statutory advice on national carbon budgets.
- Input to the special report of the Intergovernmental Panel on Climate Change (IPCC): “Impacts of global warming of 1.5°C above pre-industrial levels …..”, publication in 2018

Three projects with common methods (JULES-IMOGEN) formed an “Intra-Consortia”

**CLIFFTOP**
Climate feedbacks from wetlands and permafrost thaw in a warming world
Garry Hayman, Sarah Chadburn, Eddy Comyn-Platt, Toby Marthews, Eleanor Burke, Nic Gedney, Eleanor Blyth and Hanna Lee

**CLUES**
Climate, Land-Use, and Ecosystem Services at 1.5°C
Anna Harper, Peter Cox, Stephen Sitch, Tim Lenton, Tom Powell, Jo House, Chris Huntingford

**MOC1.5**
Methane, Ozone and the Carbon Budget for 1.5°C
Bill Collins, Peter Cox, Stephen Sitch, Jason Lowe, Chris Webber, Chris Huntingford
Intra-Consortia Baseline Scenario

JULES Key Features:
• 14 Soil Carbon Layers
  • Chadburn et al., 2015; Burke et al., 2017
• 13 PFTs and LULUC projections
  • Anna Harper et al., 2016.
• Wetland Methane Feedback
  • Gedney et al, 2004 (and 2017 in review)
• Ozone damage
  • Scaled to CH$_4$ for future projections
CLIFFTOP Layered Soil Carbon

- Better representation of respiration and input litter flux.
  - Burke et al. (2017b) demonstrated improved Soil Carbon stock estimates

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CLIFFTOP Layered Soil Carbon

• Better representation of respiration and input litter flux.
  • Burke et al. (2017b) demonstrated improved Soil Carbon stock estimates
• Better representation of methanogenesis
• Better representation of permafrost
  • Permafrost thaw feedback
    • Is carbon released as carbon dioxide or methane?
    • Does the temperature pathway chosen affect this?

CLIFFTOP Wetland Methane

- Orginal Methane Emission Scheme (Gedney et al, 2004):
  \[ E_{CH4} = k \cdot f_{wetl} \cdot C_s \cdot Q_{10} (T_{soil})^{0.1(T_{soil}-T_0)} \]
  
  - \( f_{wetl} \) - Fraction of Wetland (TOPMODEL)
  - \( C_s \) - Static (HWSD) or Dynamic (TRIFFID) Soil Carbon
  - \( T_{soil} \) - Soil Temperature
  - \( k \) and \( Q_{10} \) are the tunable scaling factor and temperature sensitivity

CLIFFTOP Wetland Methane

• Layered Methane Emission Scheme (Chadburn, in preparation):

\[ E_{CH4} = k \cdot f_{wetl} \cdot \sum_{Cs \, pools} \kappa_i \cdot \sum_{z=0m}^{z=3m} e^{-\tau z} C_{s,z} \cdot Q_{10}(T_{soil,z} - T_0)^{0.1} \]

- \( z \) – Depth in soil column
- \( i \) – Carbon pool (DPM, RPM, BIO and HUM)
- \( f_{wetl} \) - Fraction of Wetland (TOPMODEL)
- \( C_s \) - Dynamic Soil Carbon (TRIFFID)
- \( T_{soil} \) - Soil Temperature
- \( k \) and \( Q_{10} \) were tuned for each GCM

• Wetland Methane Feedback:
  - Anomaly in wetland emission included, Gedney et al. (2004 & 2017, in review).
  - Does not increase temperature but reduces atmospheric CO2.
## Results - Permafrost

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Surface</th>
<th>1m</th>
<th>2m</th>
<th>3m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Industrial</td>
<td>187</td>
<td>1080</td>
<td>1380</td>
<td>1530</td>
</tr>
<tr>
<td>Present Day</td>
<td>180</td>
<td>987</td>
<td>1250</td>
<td>1460</td>
</tr>
<tr>
<td>1.5°C</td>
<td>159</td>
<td>860</td>
<td>1090</td>
<td>1330</td>
</tr>
<tr>
<td>1.5°C overshoot</td>
<td>156</td>
<td>806</td>
<td>1050</td>
<td>1260</td>
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<tr>
<td>2°C</td>
<td>155</td>
<td>778</td>
<td>1030</td>
<td>1240</td>
</tr>
</tbody>
</table>

### Global Cover (Mha)

- **Surface**: 187
- **1m**: 1080
- **2m**: 1380
- **3m**: 1530

### Maps

- **Pre Industrial**
- **Present Day**
- **1.5°C**
- **1.5°C overshoot**
- **2°C**
Results - Permafrost

![Bar chart showing carbon stores in permafrost](image)

- **Soil Carbon**
- **Defrosted Permafrost Carbon**
- **Permafrost Carbon**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Carbon Store (GtC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Industrial</td>
<td>2000</td>
</tr>
<tr>
<td>1.5°C (2100)</td>
<td>2000</td>
</tr>
<tr>
<td>1.5°C Overshoot (2100)</td>
<td>2000</td>
</tr>
<tr>
<td>2.0°C (2100)</td>
<td>2000</td>
</tr>
</tbody>
</table>
Results – Carbon Budgets

The graph illustrates the carbon stores in different compartments over time and under various climate scenarios. The bars represent carbon stores in vegetation, soil, and atmosphere for different periods:

- **Pre-Industrial**
- **Present Day (2015)**
- **1.5°C (2100)**
- **1.5°C Overshoot (2100)**
- **2.0°C (2100)**

The carbon data is measured in GtC (Gigatons of Carbon) and CO₂ (parts per million). The graph shows a comparison of carbon stores and CO₂ levels across these timeframes and scenarios.
Results – Carbon Budgets

Baseline Scenario
- 1.5°C (2100): 375 GtC
- 1.5°C Overshoot (2100): 540 GtC
- 2.0°C (2100): 640 GtC

Methane Feedback
- 1.5°C (2100): 310 GtC
- 1.5°C Overshoot (2100): 467 GtC
- 2.0°C (2100): 560 GtC

Additional Reductions
- 17.3%

Relative to present day
Summary and Future work

- Permafrost extent is reasonably similar for the 1.5°C and 2°C targets in 2100.
  - This will change when we run the model out to 2200 and beyond.
- Considering natural wetland methane feedbacks will mean the permitted anthropogenic emissions are 17% less to achieve the 1.5°C target.

- Need to re-run with corrected LULUC setup
- Submit Carbon Budgets paper by end of October
- A wealth of data to mine to study the impacts of these targets after we get our initial results out.