Working towards a coupled interactive fire-atmospheric-composition model

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Impacts of fire on the atmosphere, land surface, ice surfaces and the ocean (Ward et al., 2012)

Fire in the Earth System

Fire carbonaceous aerosol emissions (Hamilton et al. 2018)
Objectives

→ **Development and application** of a coupled vegetation-fire-composition-climate Earth system model

→ **Quantification of the impacts** of fire variability on atmospheric composition-climate
  - Radiative forcing of climate
  - Fire-composition-climate feedback
S. Mangeon et al. (2016): INFERNO - a fire and emissions scheme
Model Setup

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experiment</th>
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</thead>
<tbody>
<tr>
<td>Model setup basis</td>
<td>UKESM1-AMIP</td>
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<tr>
<td><strong>INFERNO</strong></td>
<td>Diagnostic</td>
<td>Interactive</td>
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<td><strong>Period</strong></td>
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<td>1980-2010</td>
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<td><strong>Biomass emissions</strong></td>
<td>UKESM1 CMIP6</td>
<td>INFERNO (CO, NO\textsubscript{x}, SO\textsubscript{2}, BC, OC)</td>
</tr>
</tbody>
</table>

**Observations dataset** – GFED 4.1s burned area (including small fires) and emissions of burnt Carbon – from 1997 to 2010

Giglio, L. et al. (2013), ‘Analysis of daily, monthly, and annual burned area using the fourth-generation global fire emissions database (gfed4)’
Mean Annual Burnt Area Fraction ($\% \text{year}^{-1}$)

- Agreement with observations on spatial patterns
- Overestimation over N. America
- Underestimation over Africa
Burnt Area fraction Monthly Climatology \((fraction \text{ month}^{-1})\)

- **Northern Hemisphere Africa**
- **Southern Hemisphere Africa**

- UKESM1-AMIP INFERNO Interactive
- UKESM1-AMIP INFERNO Diagnostic
- GFED 4.1s
Mean Annual Carbon emission \((kg \ m^{-2} \ year^{-1})\)

- Agreement with observations on spatial patterns
- Overestimation over N. America, S. America, Africa and Maritime Continent
Emitted Carbon Monthly Climatology \((kg \ m^{-2} \ year^{-1})\)

**Northern Hemisphere Africa**

**Southern Hemisphere Africa**

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**UKESM1-AMIP INFERNO Interactive**

**UKESM1-AMIP INFERNO Diagnostic**

**GFED 4.1s**
What’s wrong?

~80% Broad Leaf Evergreen Tropical
~20% C4 Grass
Atmospheric composition - Troposphere column

**Mass mixing ratio**

UKESM1-AMIP INFERNO Interactive (1980-2010)

- **CO** (mg kg\(^{-1}\))
- **NO\(_x\)** (mg kg\(^{-1}\))
- **O\(_3\)** (µg kg\(^{-1}\))
- **OH** (mg kg\(^{-1}\))

**Difference**

(interactive – diagnostic INFERNO)
Atmospheric composition - Total column

Mass mixing ratio
UKESM1-AMIP INFERNO Interactive (1980-2010)

Difference
(interactive – diagnostic INFERNO)
Impact on clouds and precipitation

Total Cloud

Precipitation
Impact on temperature and soil moisture

1.5 m Temperature

Unfrozen soil moisture
Radiation Balance at TOA ($W m^{-2}$)

**UKESM1-AMIP INFERNO Diagnostic (1980-2010)**

**UKESM1-AMIP INFERNO Interactive (1980-2010)**

**ERF – due to differences in the two experiments**

**ERF per year**

The multi-model global mean $\Delta$ERT is $-0.07 \pm 0.13 Wm^{-2}$.

The associated standard error is 0.02 Wm$^{-2}$

Root mean square $\Delta$ERT is 0.7 Wm$^{-2}$.
Summary

• Implementation of the online coupling to the atmospheric model
  • Allowing for a fire-atmosphere-composition two way interaction
  • Fires change Earth’s radiative balance which feedback to the atmospheric controls of fires

• Biases in underlying vegetation are the main reason for biases in fire emissions
  • Model gives the wrong for the right reason
  • Implications for atmospheric and climate feeding back to fire

Next Steps

• Understand how to improve/constraint the land surface properties
• Evaluation of the impact fires in composition
• Response of fire and compositions in fire
• Climate-fire feedbacks in future climates