Atmospheric CH$_4$ and CO$_2$ enhancements and biomass burning emission ratios derived from satellite observations of the 2015 Indonesian fire plumes

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- Objectives:

1) To identify and quantify the spatial-temporal anomalies in satellite remote sensing data of atmospheric XCO₂ and XCH₄ and to interpret them in the context of surface characteristics such as land-cover and vegetation.

2) To investigate the key physical climatic drivers for observed atmospheric XCO₂ and XCH₄ anomalies and to assess the representation of these coupling processes in current land system models.

3) To improve our understanding of the role of wetland inter-annual variability on the methane cycle.

4) To quantify the influence that disturbances (such as biomass burning and land-use change) have on the inter-annual variability of atmospheric CH₄ and CO₂ and the underlying carbon cycle.
The $X_{\text{CO}_2}$ and $X_{\text{CH}_4}$ Retrieval

Full physics CO$_2$ and CH$_4$ retrieval:
- Simultaneous multi-band fit to retrieve CO$_2$ and CH$_4$ together with additional aerosol, surface and atmospheric variables (Boesch et al., 2013, Cogan et al., 2012)

CH$_4$ proxy retrieval:
- CO$_2$ column from spectrally-close window is used as proxy for the unknown light path for the CH$_4$ retrieval (Frankenberg et al., 2008, Parker et al., 2011)
- $X_{\text{CH}_4}^\text{proxy} = \frac{X_{\text{CH}_4}^\text{retrieved}}{X_{\text{CO}_2}^\text{retrieved}} \times X_{\text{CO}_2}^\text{model}$

- Very simple, fast retrieval
- Reduced sensitivity to aerosols/clouds and instrument calibration
- Model for atmospheric CO$_2$ can introduce regional errors (Parker et al, 2015)
Indonesian fire emissions during the current El Nino

- Current El Nino event led to extremely large fire activity in September/October 2015 over Indonesia
- Majority of burning occurred in regions dominated by carbon-rich peatland
- Fire activity was significantly higher than any observed in last 6 years
GOSAT observations of GHGs emitted by Indonesian fires

- Emissions of CO₂, and particularly CH₄, were significantly higher than previous years.
- October-July differences in 95th-percentile values used to compensate for trend/growth rate.
  - CO₂: 4.35 ppm for 2015 vs a mean of 1.05 ± 1.42 ppm for 2009-2014
  - CH₄: 45.65 ppb for 2015 vs a mean of 11.93 ± 3.60 ppb for 2009-2014
GOSAT observations of GHGs emitted by Indonesian fires

- Significant enhancements in XCH₄, XCO₂ and the XCH₄/XCO₂ ratio
- Separated data into “All”, “Clear” and “Fire” categories using MACC CO and GOSAT aerosol information
- Clear westward transport of fire emissions, consistent with wind vectors
GOSAT observations of GHGs emitted by Indonesian fires

- Using this categorisation, the histograms of the $\text{XCH}_4/\text{XCO}_2$, $\text{XCO}_2$ and $\text{XCH}_4$ show distinct distributions, especially for the $\text{XCH}_4/\text{XCO}_2$ ratio.
- We are observing significantly enhanced GHG emissions due to the Indonesian fires driven by the current El Nino.
- The next step is to determine the fire emission ratio.

![Graphs showing histograms of GHG emissions](image-url)
Fire emission ratios (ERS) are important for calculating emission factors which are ultimately used to determine the amount of gas being emitted by the fire.

The ability to determine large-scale emission ratios from satellite data allows the combustion behaviour of very large regions of burning to be characterised and understood in a way not possible with ground-based studies.
Same methodology applied to Southern Africa and the Amazon, both of which underwent significant burning during the same time period.

The ER is capable of discerning the combustion characteristics of the fire. A higher ER (i.e. more CH$_4$ relative to CO$_2$) is indicative of smouldering combustion, whereas a lower emission ratio indicates more complete combustion from flaming fires.

The ERs we derive from GOSAT are consistent with the expectation that the Indonesian peat-land burning involves smouldering combustion, Southern African is much more dominated by flaming processes, with the Amazon showing a combination of both.

ERs are also very consistent with previous in-situ measurements (e.g. Wooster et al. observed a value of 4.3 ppb/ppm over African Savannah)
Summary and Outlook

- Work on the El Nino driven Indonesian fires was successful with paper submitted to ACPD:
  - For the first time, we use satellite observations of CH$_4$ and CO$_2$ from GOSAT made in large scale plumes from the 2015 El Nino-driven Indonesian fires to probe aspects of their chemical composition.
  - We demonstrate significant modifications in the concentration of these species in the regional atmosphere around Indonesia, due to the fire emissions.
  - We determine the CH$_4$/CO$_2$ fire emission ratio for the entire 2-month period of the most extreme burning (September-October 2015), and also for individual shorter periods where the fire activity temporarily peaks.
  - We find the range of our satellite-derived Indonesian ERs to be relatively closely matched to that of a series of “close-to-source” ground-based sampling measurements made on Kalimantan at the height of the fire event.
  - The ability to determine large-scale emission ratios from satellite data allows the combustion behaviour of very large regions of burning to be characterised and understood in a way not possible with ground-based studies, and which can be logistically difficult and very costly to consider using aircraft observations.
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