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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ELEGANCE-GHG - ESA Living Planet Fellowship

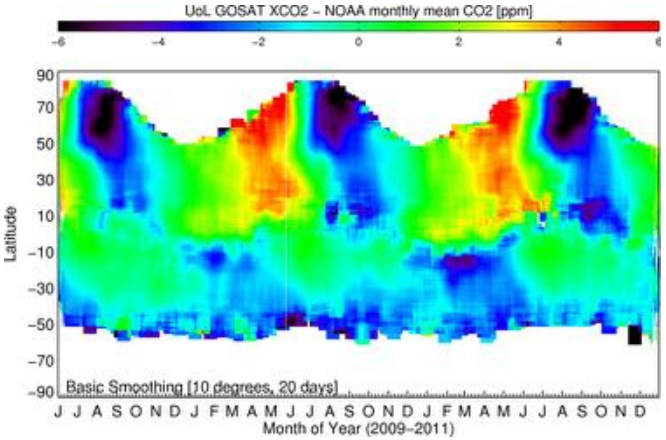
- **2-Year ESA Living Planet Fellowship co-funded by UK NCEO**
- **Objectives:**

1) To identify and quantify the **spatial-temporal anomalies** in satellite remote sensing data of atmospheric **XCO_2 and XCH_4** 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 XCO_2 and XCH_4 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 CH_4 and CO_2 and the underlying carbon cycle.



Hovmoller (time/latitude) plot to show the current UoL GOSAT XCO_2 data product from June 2009 to December 2011 detrended by subtracting the NOAA globally averaged marine surface monthly mean CO_2 value. The northern hemispheric growing season is clearly evident but in the southern hemisphere an enhancement in the CO_2 uptake over Australia is observed in 2011 relative to 2010.

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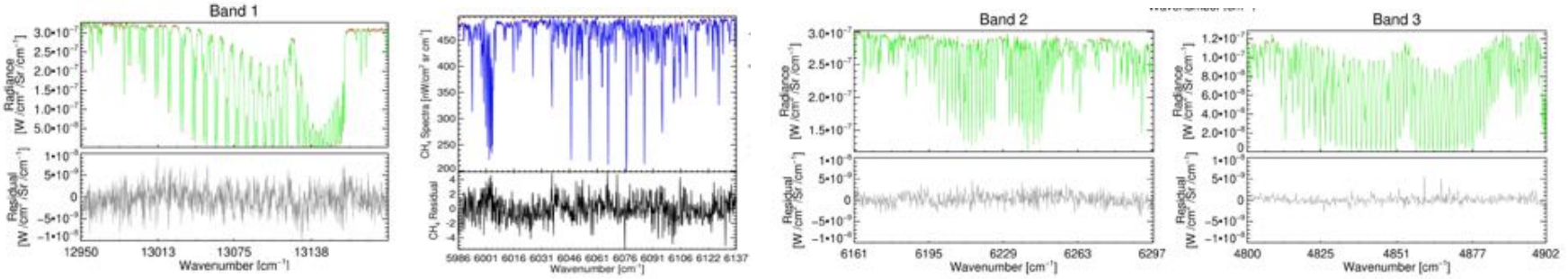
The X_{CO2} and X_{CH4} Retrieval

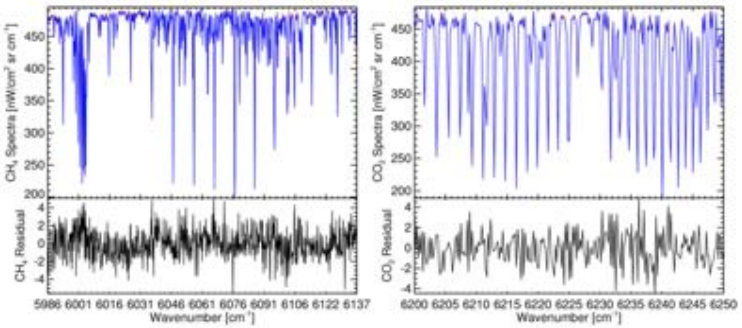
Full physics CO_2 and CH_4 retrieval:

- 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)
- $XCH4_{proxy} = XCH4_{retrieved}/XCO2_{retrieved} * XCO2_{model}$



- 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)

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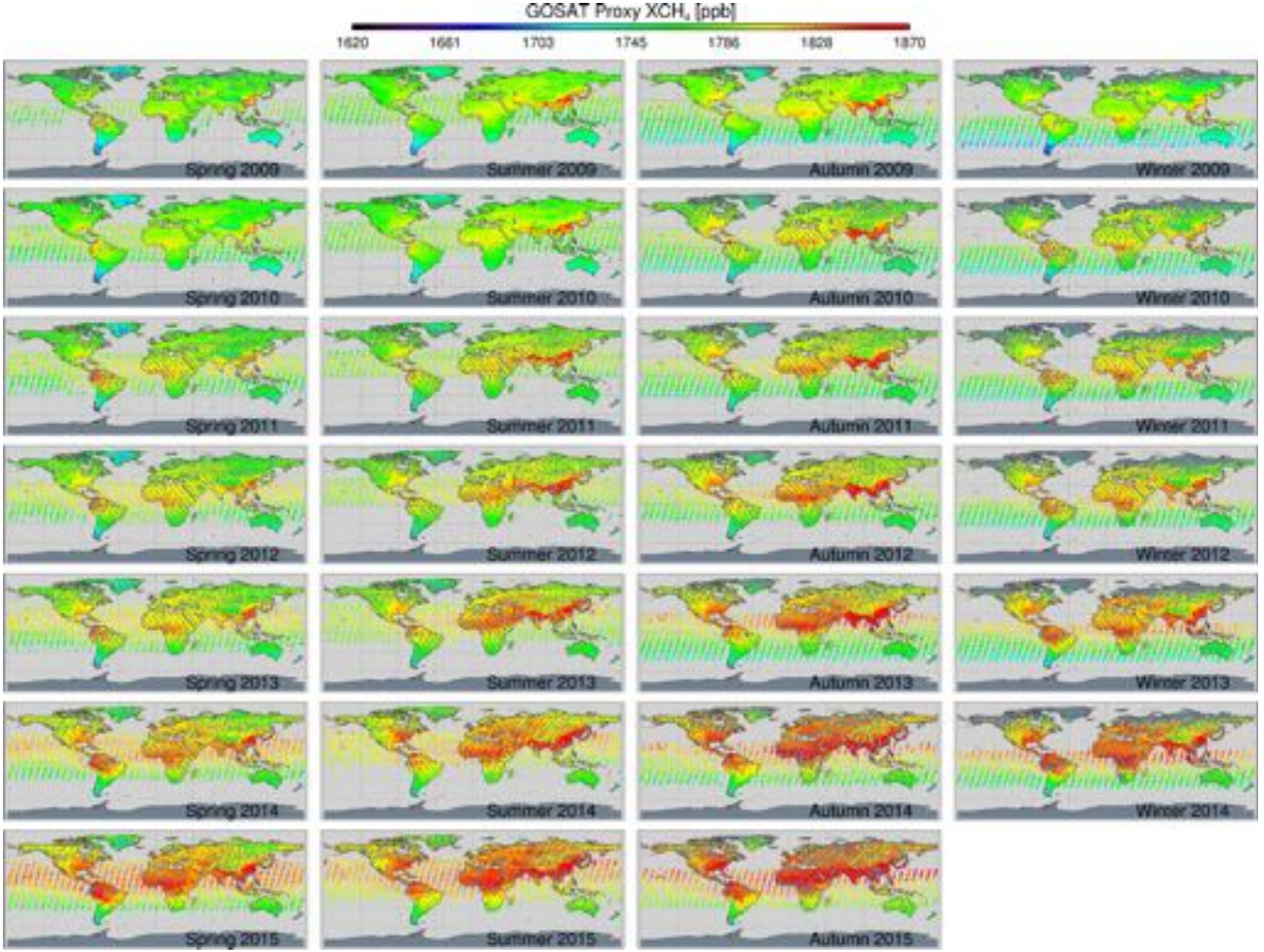

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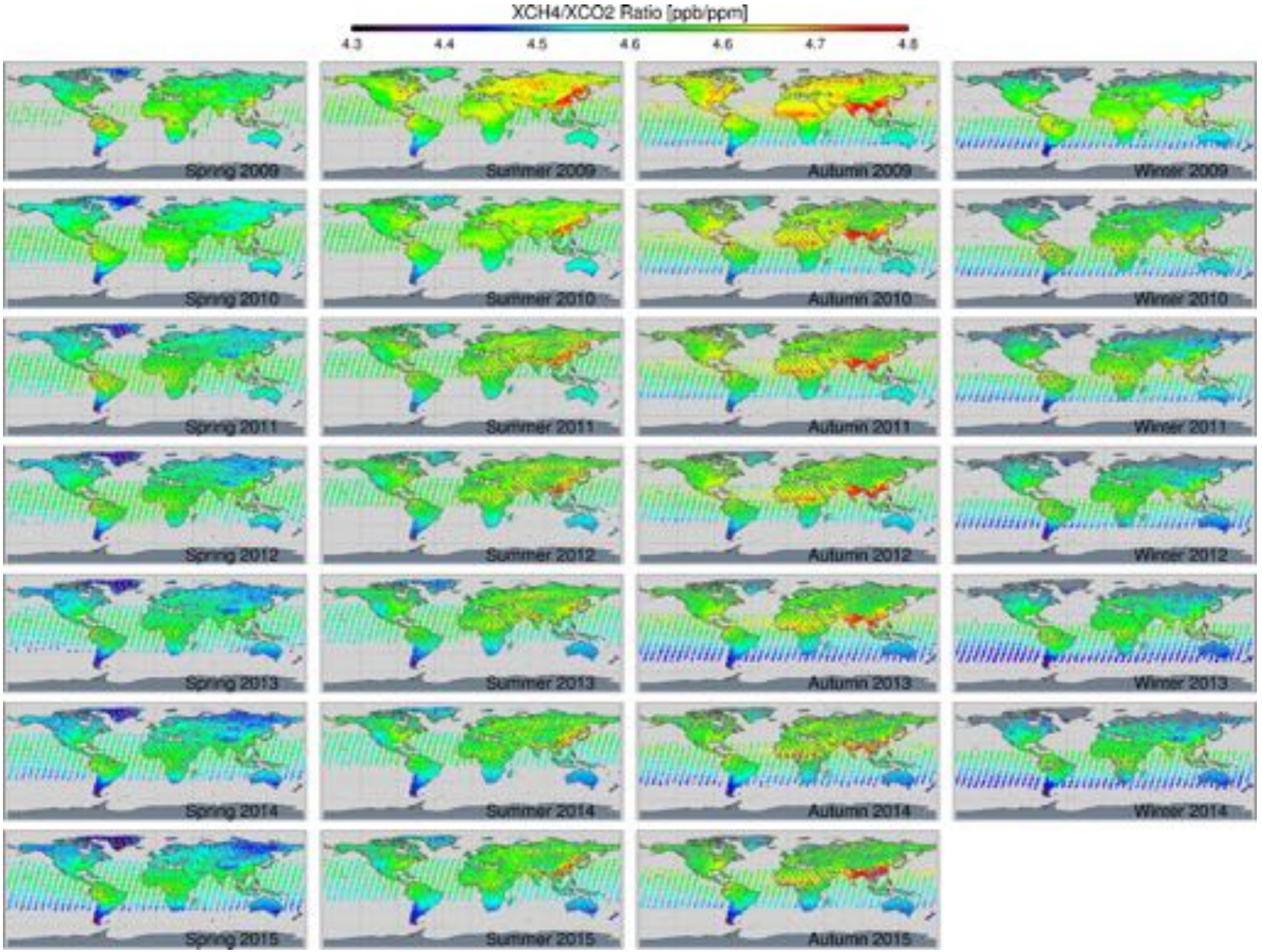

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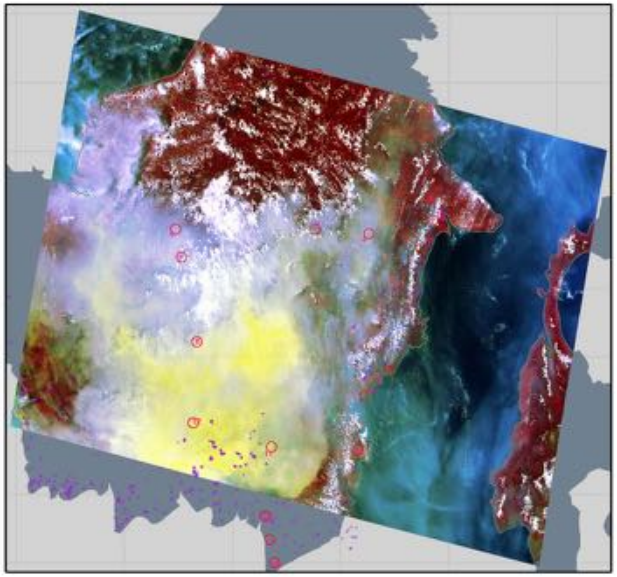
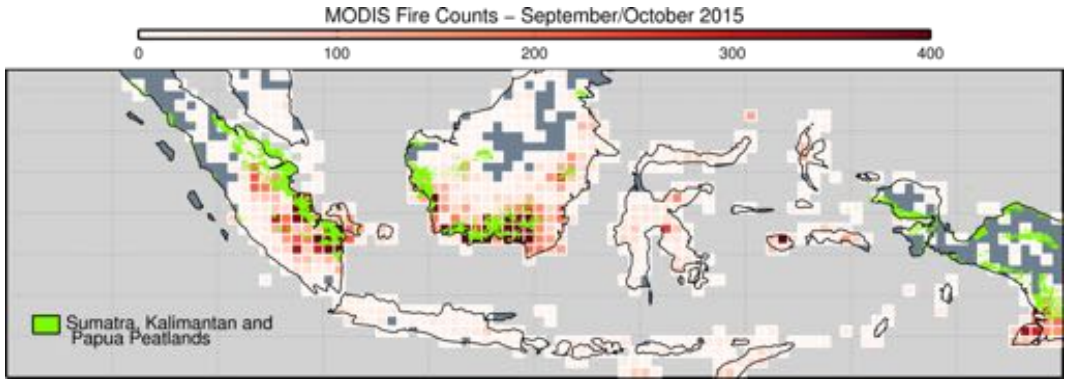
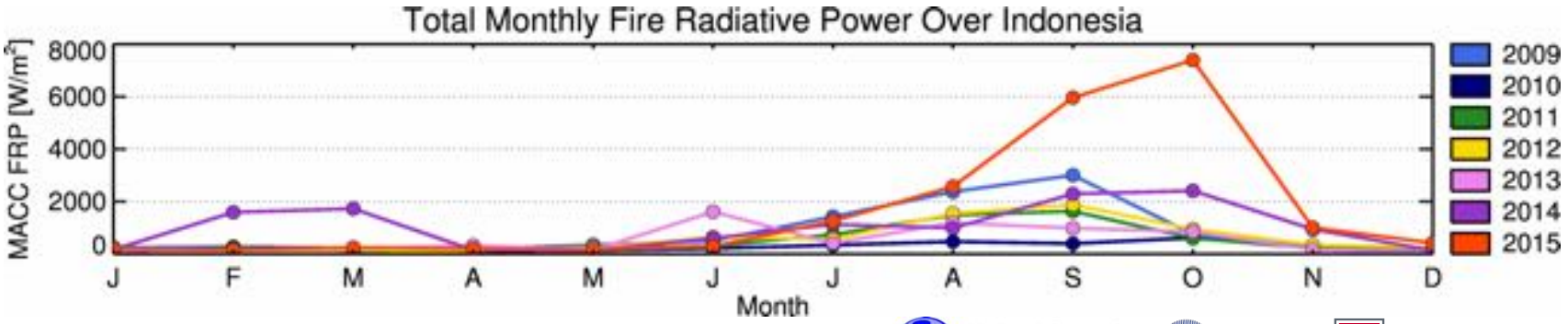
Indonesian fire emissions during the current El Nino

- 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







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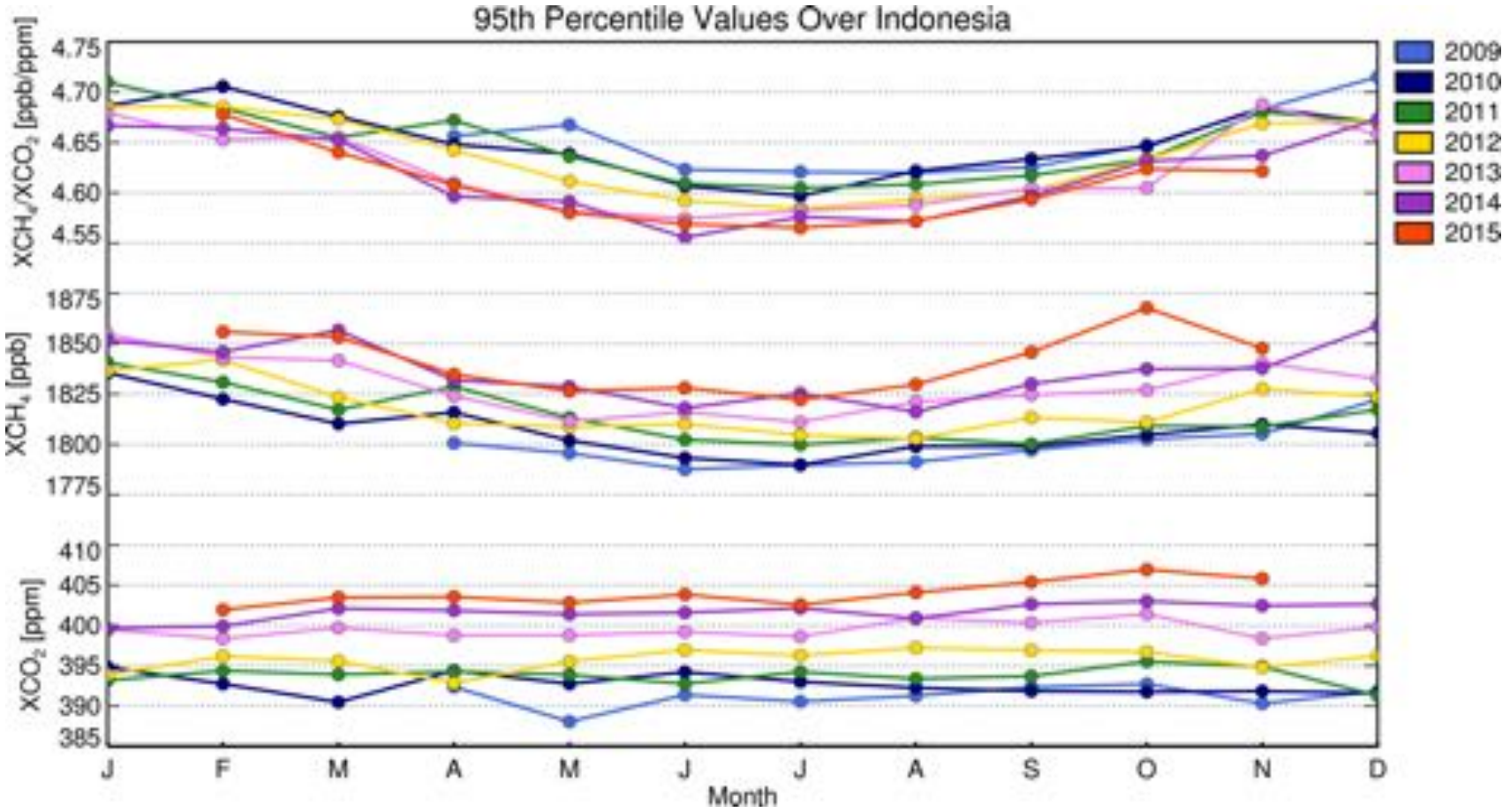
GOSAT observations of GHGs emitted by Indonesian fires

- Emissions of CO_2, and particularly CH_4, were significantly higher than previous years
- October-July differences in 95th-perctile values used to compensate for trend/growth rate.
  - CO_2: 4.35 ppm for 2015 vs a mean of 1.05 ± 1.42 ppm for 2009-2014
  - CH_4: 45.65 ppb for 2015 vs a mean of 11.93 ± 3.60 ppb for 2009-2014



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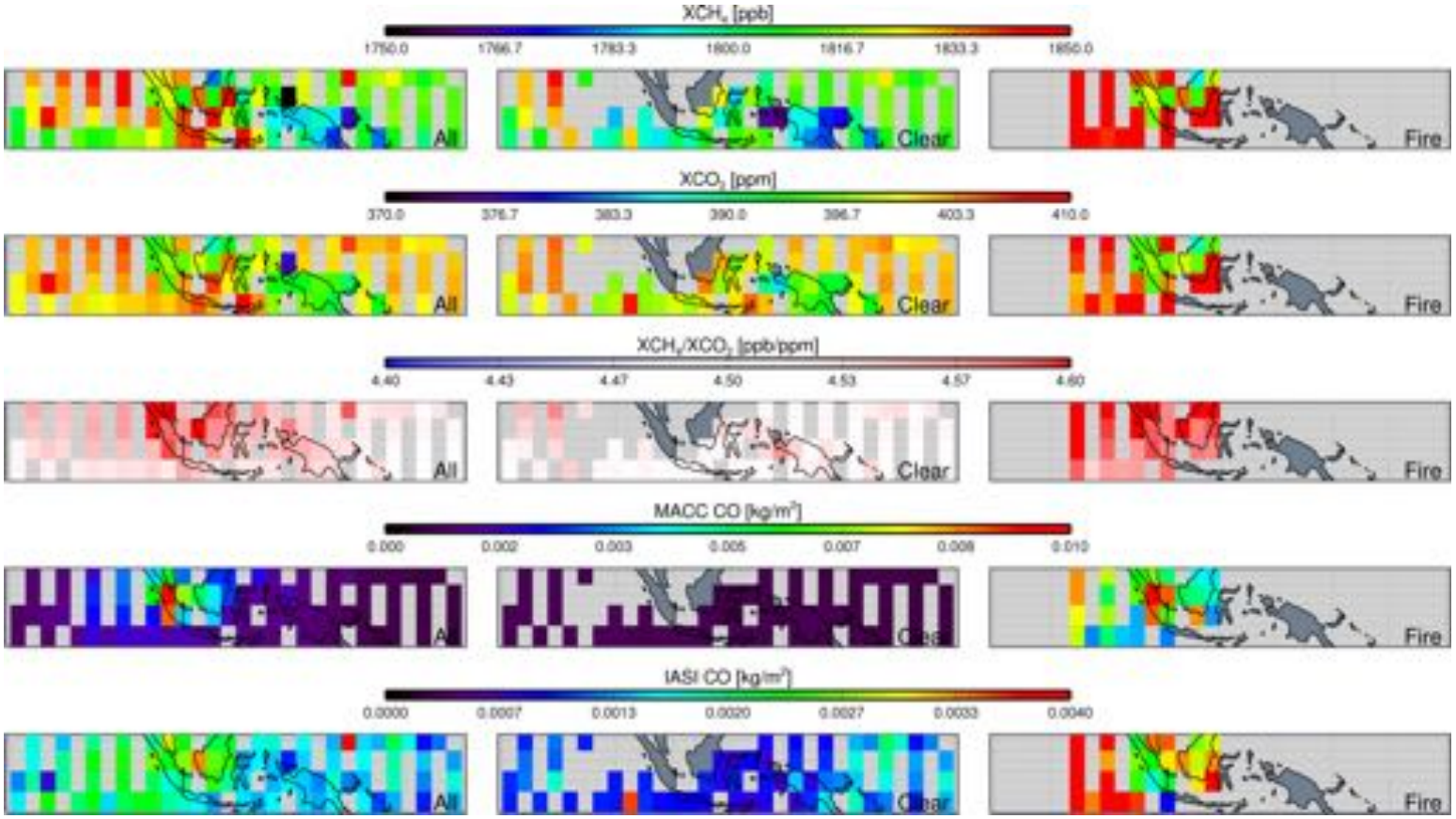
GOSAT observations of GHGs emitted by Indonesian fires

- Significant enhancements in XCH_4, XCO_2 and the XCH_4/XCO_2 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



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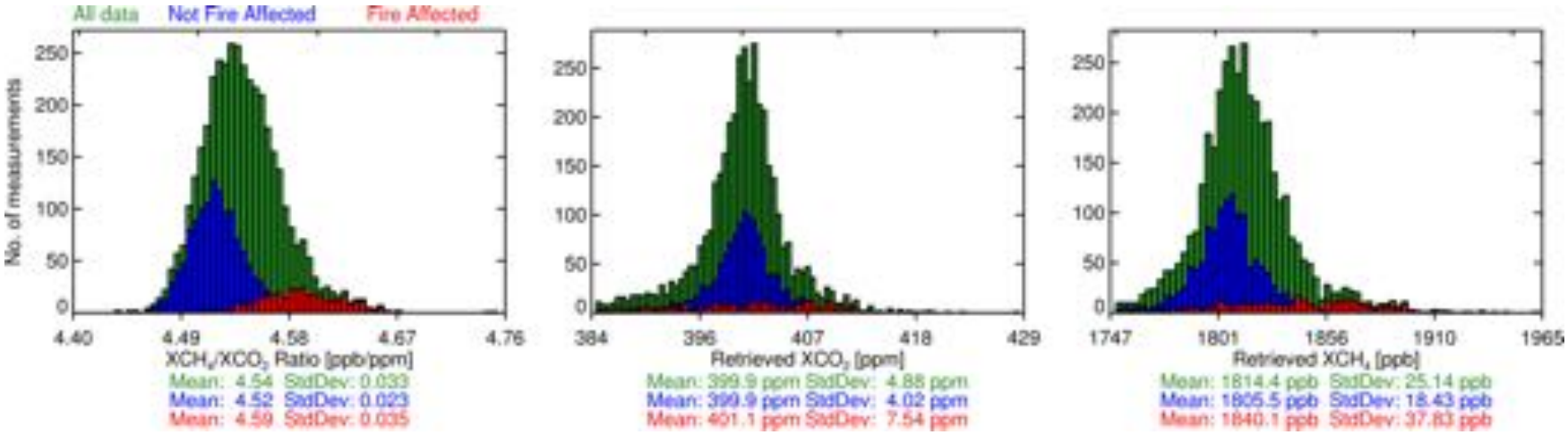
GOSAT observations of GHGs emitted by Indonesian fires

- Using this categorisation, the histograms of the XCH_4/XCO_2, XCO_2 and XCH_4 show distinct distributions, especially for the XCH_4/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



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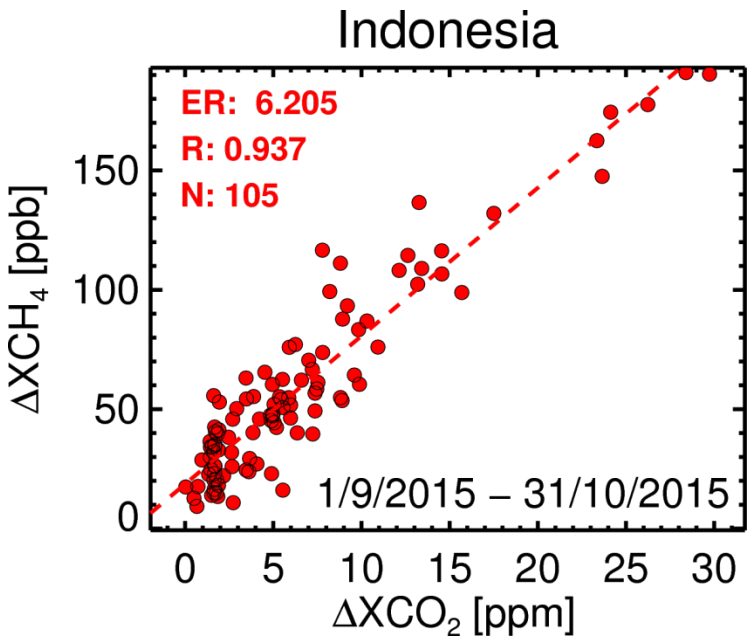
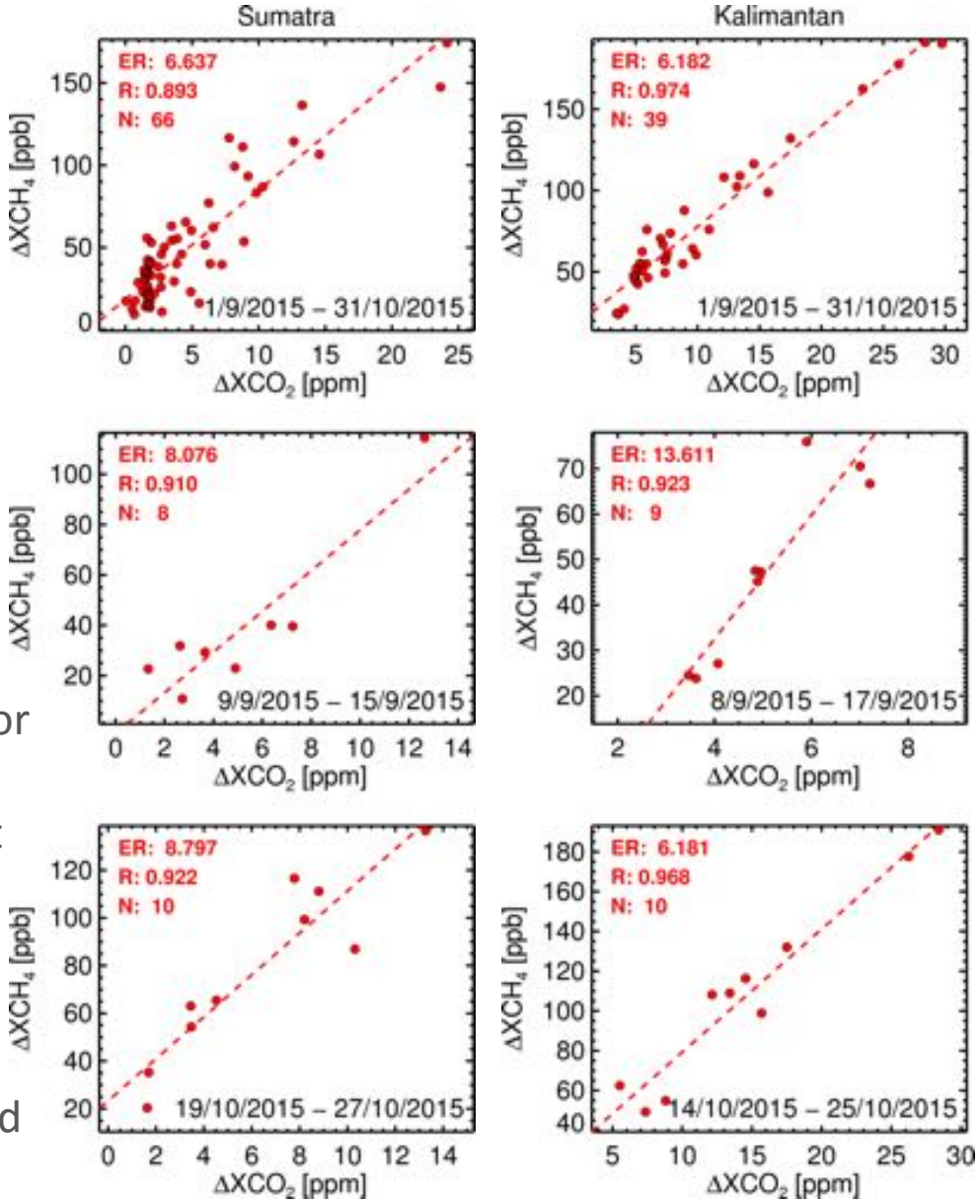
Determining CH4/CO2 Emission Ratios





- 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.

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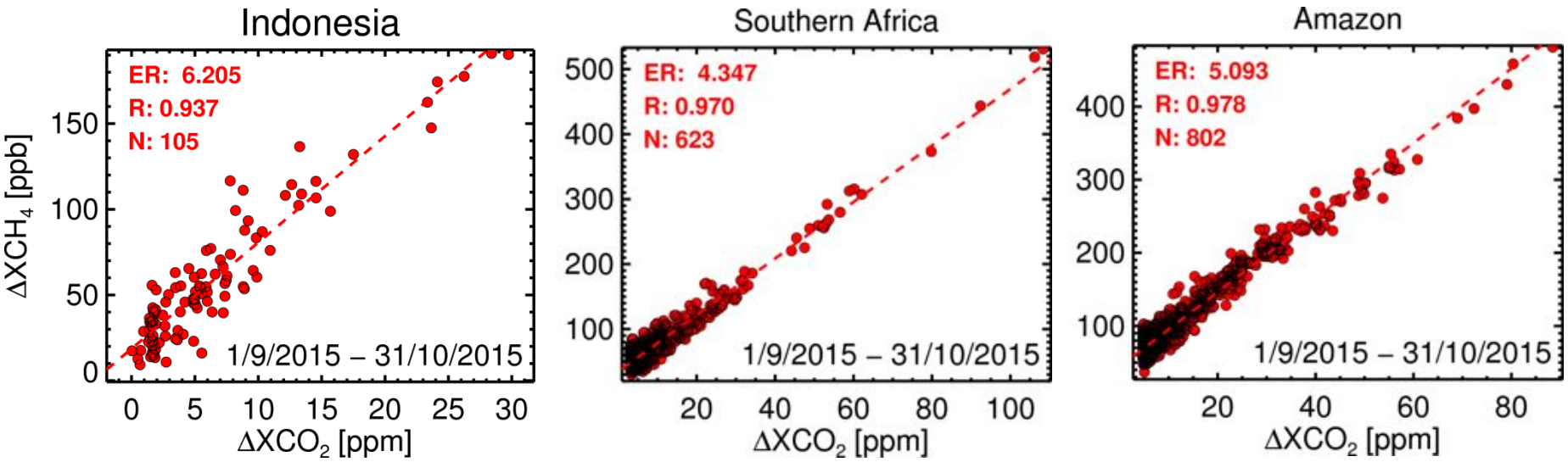
Characterising Combustion



- 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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- NASA FIRMS for the MODIS Active Fire Detections
- EUMETSAT for the IASI CO Level 2 data

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