FLEXible Emission Estimates?

How hyperspectral EO of landscape fires could map proportions of flaming and smouldering combustion to improve fire emission estimation

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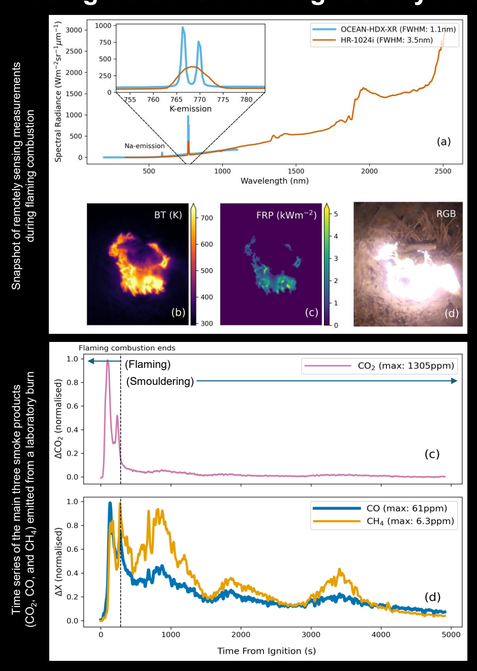
Laboratory investigation

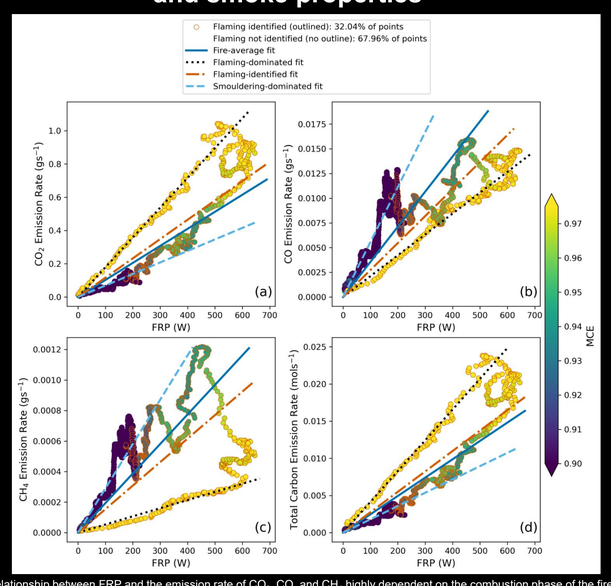
The chemical makeup and production rate of smoke produced by fire is strongly dependant on combustion phase (i.e., the amount of flaming and smouldering activity).

However, there is currently no routine EO technique to distinguish flaming from smouldering fires.

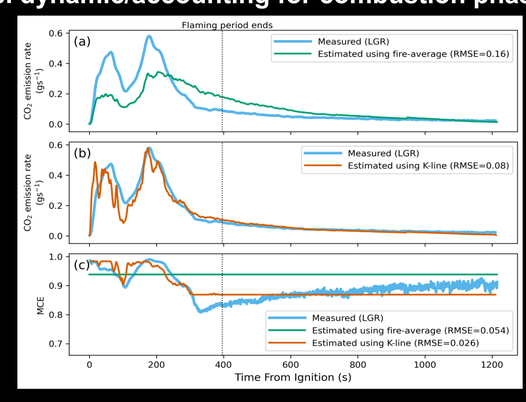
1. Intensively measured laboratory burns using EO sensors and gas analysers → **2. Determined relationships between the EO-derived fire characteristics and smoke properties** → **3. Compared emission estimations (static/fire-average vs. dynamic/accounting for combustion phase)**

Find out more about the laboratory experiments (Owsley-Brown et al., 2024) here





Relationship between FRP and the emission rate of CO_2, CO, and CH_4 highly dependent on the combustion phase of the fire, with distinct linear relationships for purely flaming (high MCE) and purely smouldering combustion (low MCE).



The K-line (emission lines in the NIR produced by thermally excited potassium atoms in burning biomass) effectively identified flaming combustion.

A dynamic emission estimation approach using the K-line—tailoring emission factors to the contribution of flaming and smouldering combustion—was compared to the currently used fire-average method with static emission factors for smoke emissions estimates.

This new dynamic method improved: CO_2 estimation by 42%, CO by 10%, CH_4 by 15%, and Modified Combustion Efficiency (MCE, a parameter indicating the ratio of CO_2 and CO in the plume) by 46%.

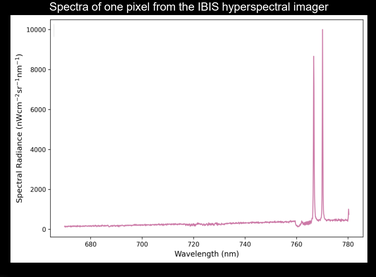
Airborne data

Find out more about the FIDEX (validation of the Sentinel-3 FRP product) campaigns here

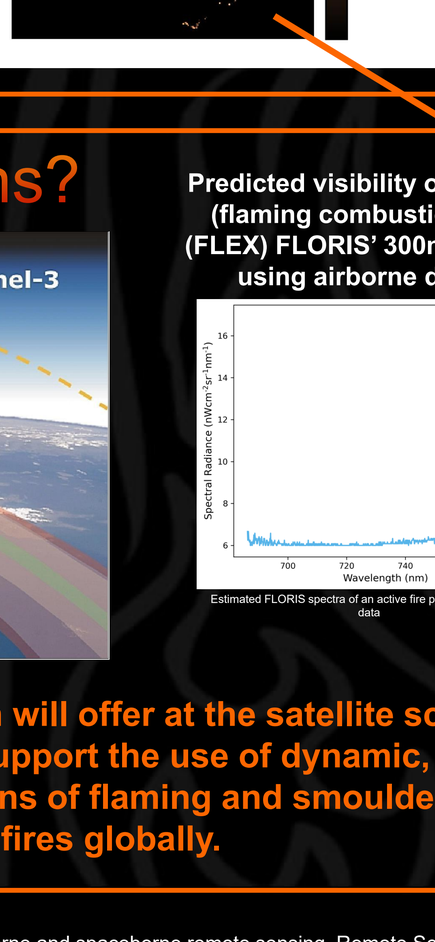
MIR thermal camera used to map fire radiative power (FRP), which can be used to estimate combustion rate.

NIR hyperspectral imager used to map K-line, which can be used to identify flaming combustion.

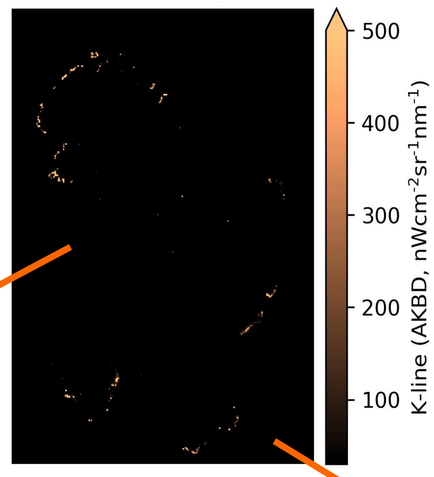
Spectra of one pixel from the IBIS hyperspectral imager



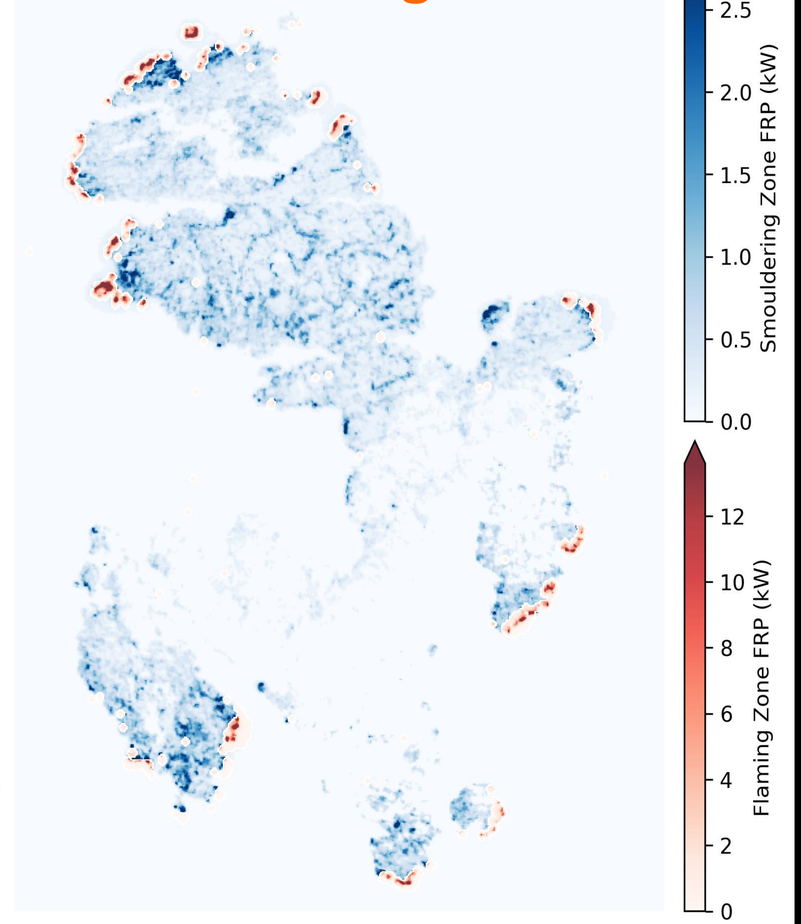
InfraTec ImageIR 8300 hp (mounted on Twin Otter) used to retrieve FRP



Specim AisaIBIS (mounted on Twin Otter) used to map flaming combustion



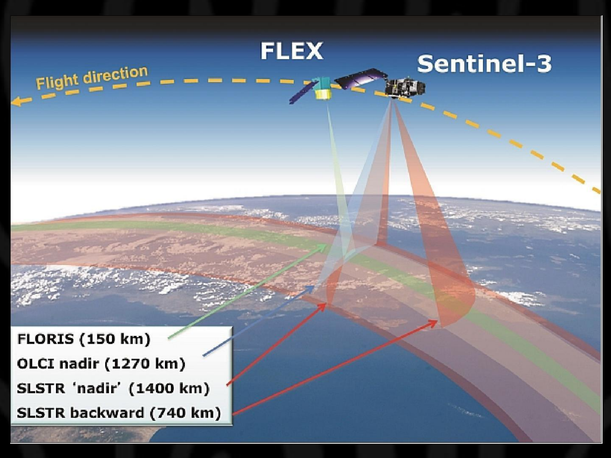
Map of Flaming and Smouldering Zones



Can this be applied to satellite observations?

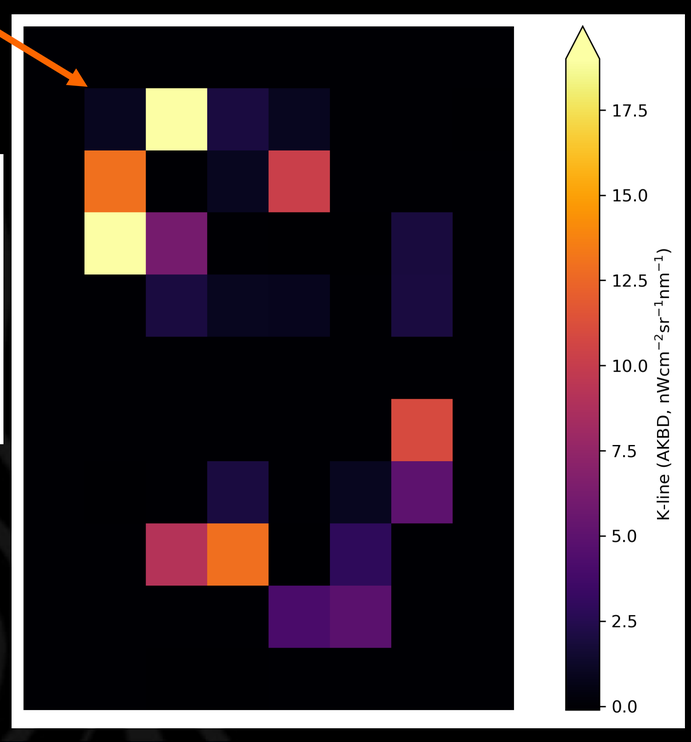
While the K-line has been detected from space (Amici et al., 2011), current sensors lack either the spectral or spatial resolution to consistently map the K-line.

However, ESA's upcoming FLEX mission will not only be able to provide high resolution measurements of the K-line, but these will also be collocated with FRP measurements from Sentinel-3.



Predicted visibility of K-line (flaming combustion) in (FLEX) FLORIS' 300m pixels using airborne data

Estimated FLORIS spectra of an active fire pixel using airborne data



While some uncertainty remains about the improvements this approach will offer at the satellite scale, these complementary FRP and K-line measurements are planned to support the use of dynamic, or FLEXible, emission estimates that more accurately reflect the proportions of flaming and smouldering combustion during smoke production from landscape fires globally.

References:

Amici, S., Wooster, M. J., and Piscini, A.: Multi-resolution spectral analysis of wildfire potassium emission signatures using laboratory, airborne and spaceborne remote sensing, Remote Sensing of Environment, 115, 1811–1823, https://doi.org/10.1016/j.rse.2011.02.022, 2011.

Owsley-Brown, F., Wooster, M. J., Grosvenor, M. J., and Liu, Y.: Can the remote sensing of combustion phase improve estimates of landscape fire smoke emission rate and composition?, Atmos. Meas. Tech., 17, 6247–6264, https://doi.org/10.5194/amt-17-6247-2024, 2024.