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Tracing Carbon in the Sky: CO_2 and CH_4 Isotope Signatures under Dust and Fire Events at the POT Station, Part of the CIAO Observatory (CNR-IMAA)

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ISOTOPIC CARBON MONITORING

- Instrument for stable carbon isotope analysis of CO_2 and CH_4, purchased with ITINERIS
- ICOS tower and lines used for the instrument implementation
- 2 ITINERIS TNAs for gaining expertise on isotope analysis
- 1 high-resolution isotopic dataset
- 2 papers

Lapenna, E. et al. *Atmosphere,* **2025**

Buono, A. et al. (2025). Dataset. ITINERIS HUB

Buono, A. et al. *Atmosphere,* **2025**

Zaccardo, I. et al. *In preparation*

Which Are Stable Carbon Isotopes?

- Carbon atoms with different neutron numbers but the same atomic number
- Non-radioactive and do not decay over time
- **Useful for source apportionment**

- ^{12}C (about 98.9%)
- ^{13}C (about 1.1%)

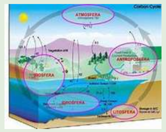
→

- Ratio of ^{13}C to ^{12}C ($^{13}C/^{12}C$)in a sample
- Vienna Pee Dee Belemnite (VPDB) Reference standard
- Delta values **$\delta^{13}C$–CH_4, $\delta^{13}C$–CO_2 (‰)**

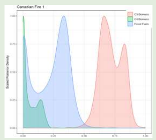
$$\delta^{13}C = \left(\frac{(^{13}C/^{12}C)_{sample}}{(^{13}C/^{12}C)_{standard}} - 1 \right) \times 1000$$

The Role of Isotopic Analysis in Atmospheric Research

Identifying Emission Sources



Studyng Carbon Exchange between Atmosphere, Biosphere and Oceans



Improving Climate Models for Source Apportionment and Greenhouse Gas Inventories

Isotopic Fingerprints of Natural and Anthropogenic Emissions

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$\delta^{13}C–CH_4$

- **Atmospheric background: ~ –47‰**
- **Biogenic sources:**
  wetlands, rice paddies, ruminants → **–65‰ to –55‰**
- **Fossil fuel sources:**
  fugitive emission→ **–55‰ to –25‰**
  incomplete combustion (natural gas, coal, oil)→ **–29‰ to –13‰**
- **Biomass burning (CH_4):**
  Variable depending on vegetation type → **–30‰ to –20‰**

$\delta^{13}C–CO_2$

- **Atmospheric background: ~ –7.5‰**
- **Fossil fuel combustion:**
  Coal, gasoline, natural gas → **–30‰ to –28‰**
- **Biomass burning:**
  -C_3 vegetation (e.g., trees, shrubs) → **–35‰ to –25‰**
  -C_4 vegetation (e.g., savanna grasses) → **–16‰ to –12‰**

Can Saharan Dust Intrusions Alter the Isotopic Composition of CH_4 and CO_2?

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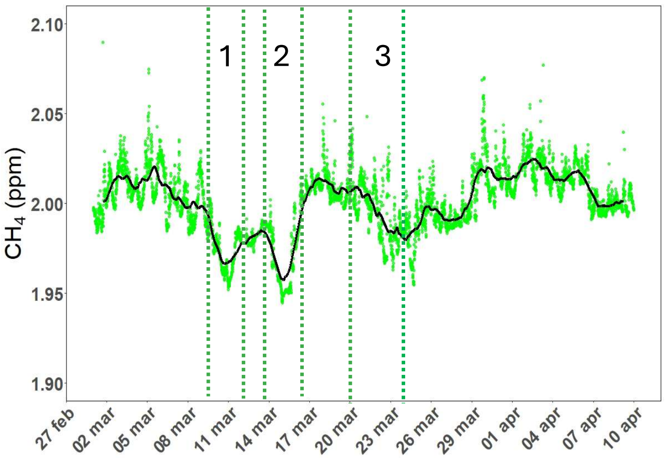
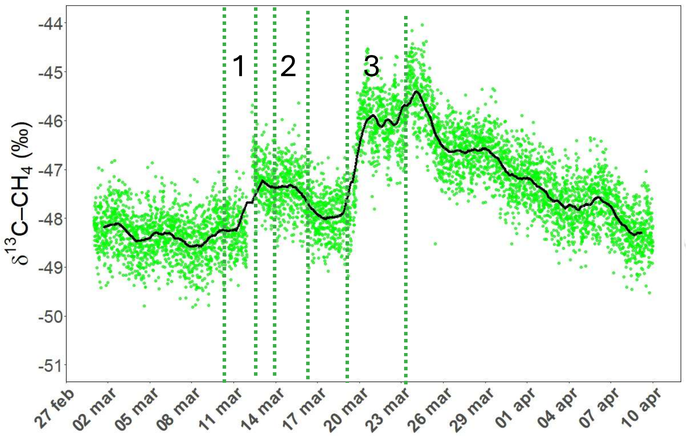
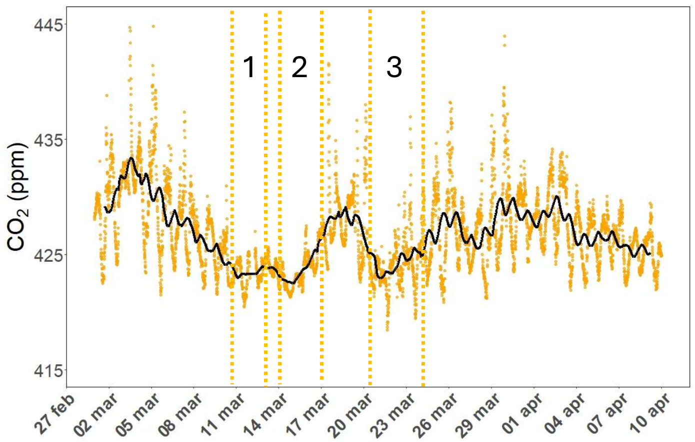
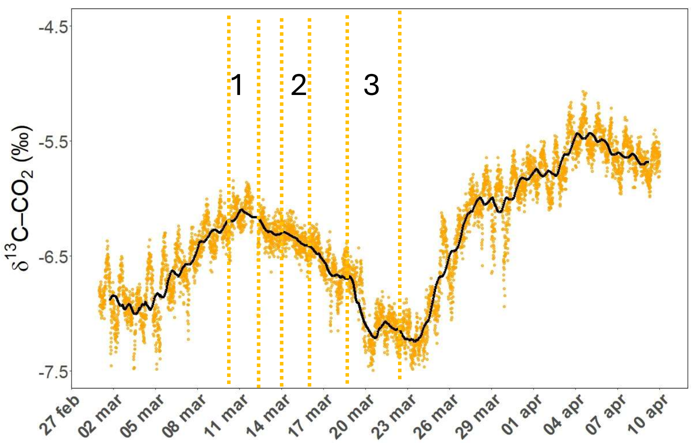




- **CH_4 ↓** → Decrease in mole fractions suggests isotopic fractionation
- **$\delta^{13}C$–CH_4 ↑** → Enrichment indicates enhanced oxidation linked to mineral aerosols.

MDSA mechanism by Marten et al. (2023)





- **CO_2 ↑** → Increased concentrations due to reduced photosynthesis (radiative suppression).
- **$\delta^{13}C$–CO_2 ↓** → Decline reflects lower $^{12}CO_2$ uptake during dust events.

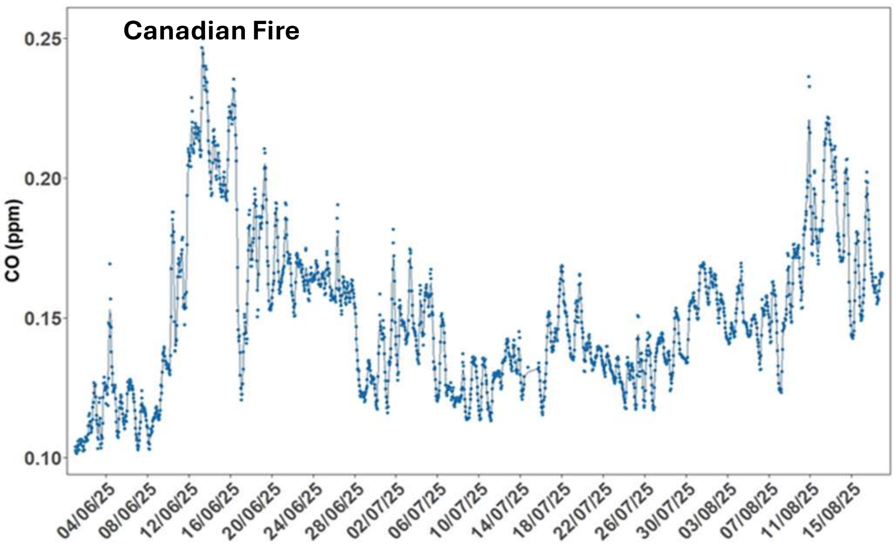
Kinetic Isotopic Effect

Paper under review

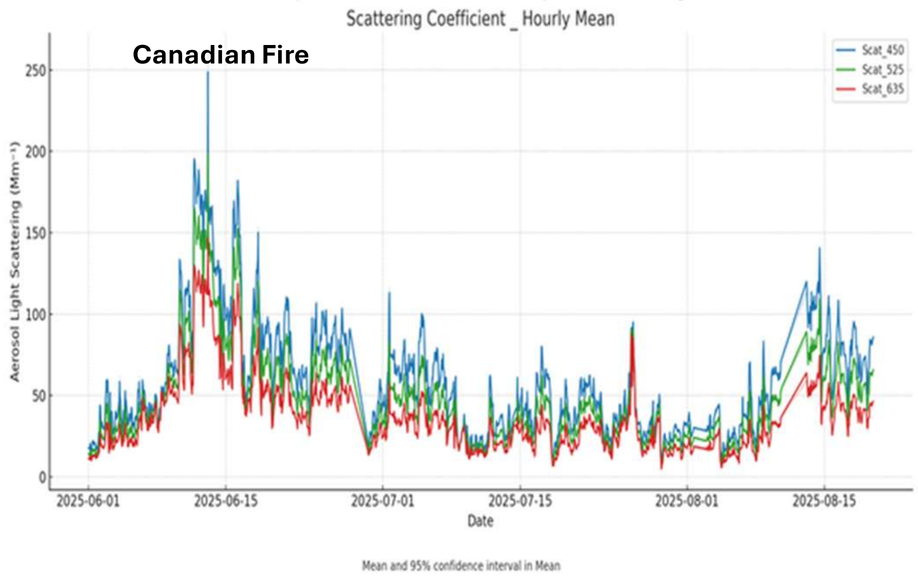
Wildfires Observations, Isotopic Tracers and Source Apportionment

-Methodology-

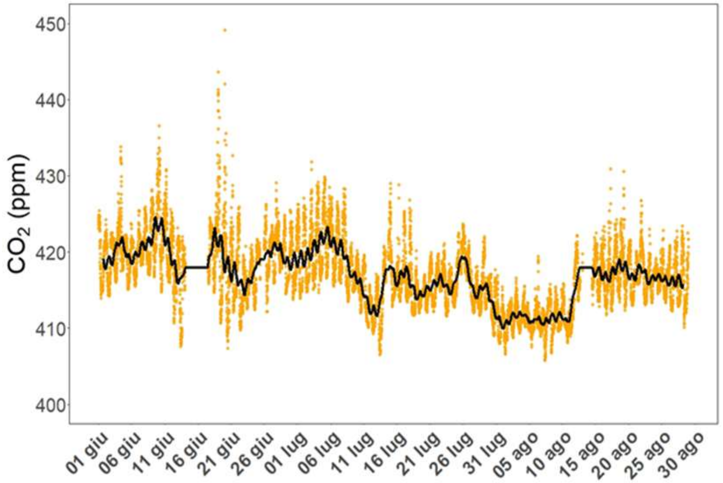
1. – CO Peak Detection

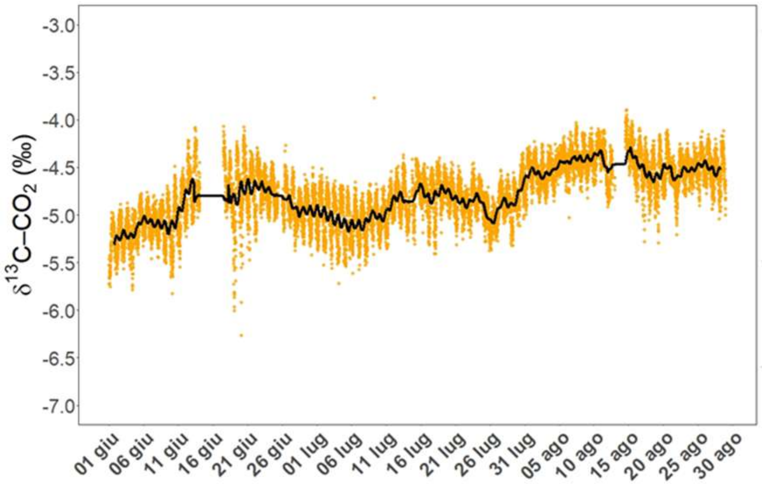


2. – Peaks in scattering coefficients

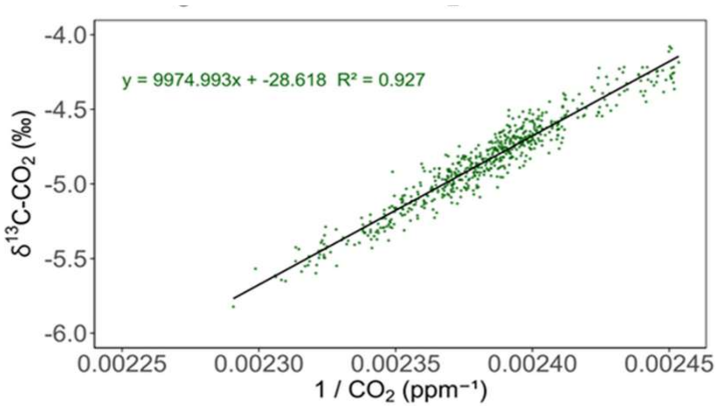


3. High-Frequency Isotopic Monitoring

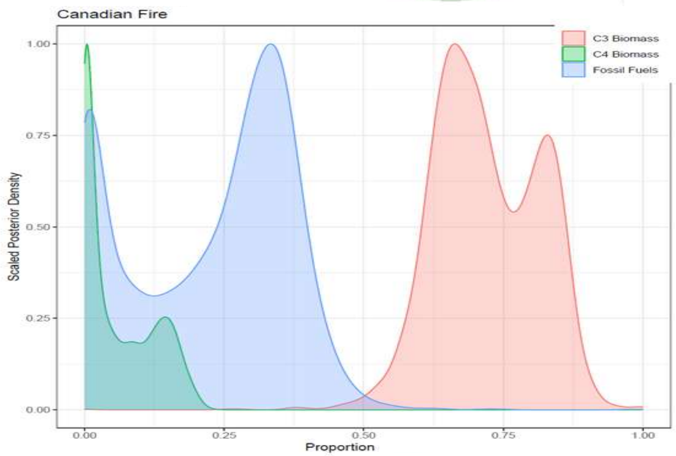




4. Keeling Plot Construction



5. Bayesian Mixing Model (MixSIAR)



Perspectives

- **Expand Temporal Coverage** Extend isotopic monitoring across multiple seasons to capture long-term trends and variability.
- **Model Coupling** Combine isotopic data with atmospheric transport models to improve spatial resolution of source apportionment.
- **Policy Relevance** Translate findings into actionable insights for climate mitigation strategies and emission inventories.
- **Cross-Station Collaboration** Enhancing collaborative efforts within the emerging national consortium for isotope monitoring

THANKS!

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