

## SCARBO<sub>n</sub>: Space CARBOn Observatory next step project

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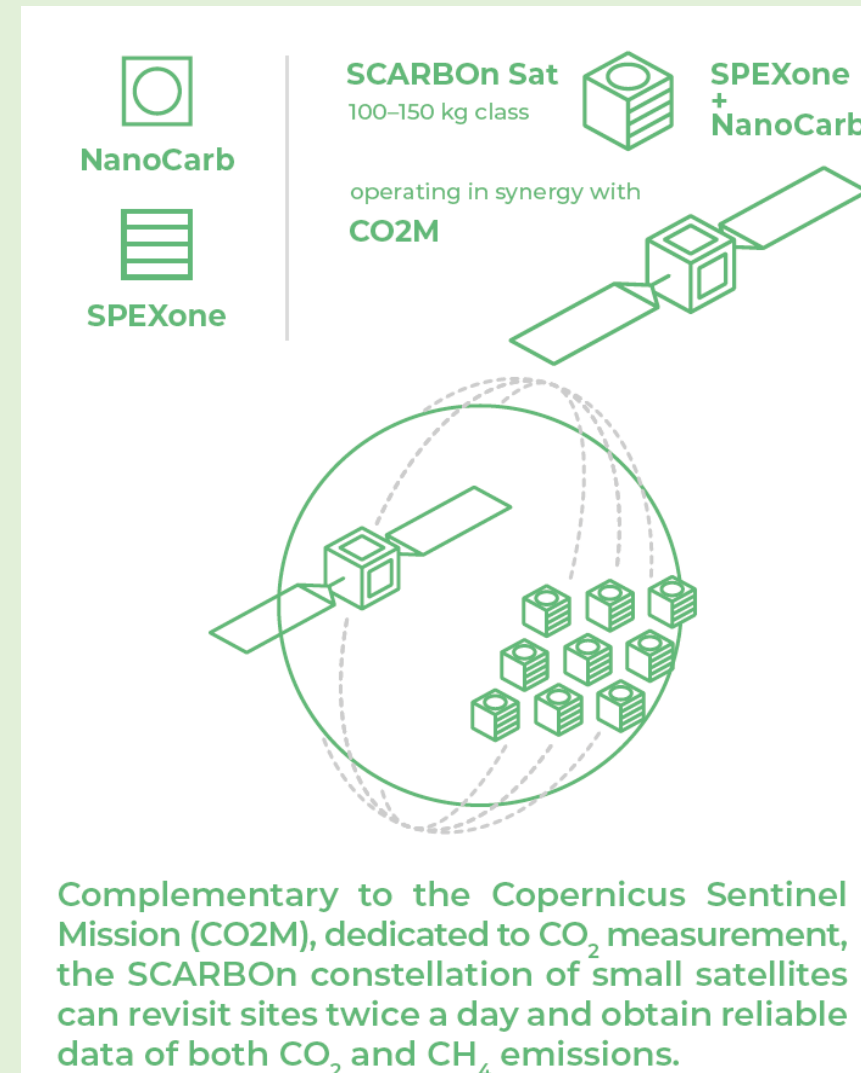
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**Abstract:** SCARBO<sub>n</sub> (Space CARBOn Observatory Next step) is an Innovation Action project funded by the Horizon Europe Programme and led by Airbus Defence and Space. The project brings together space industry partners, SMEs, and research institutes. It aims to mature the SCARBO<sub>n</sub> system, which is based on a constellation of small satellites equipped with a miniaturized static spectrometer (NanoCarb, Patent No.: FR16/56162) combined with aerosol sensors (SPEXone). These instruments will provide accurate daily global measurements to monitor diurnal variations in greenhouse gas (GHG) emissions. These data will contribute to the European Commission's efforts to combat climate change. The SCARBO<sub>n</sub> project focuses on the detailed technical definition of the NanoCarb instrument together with its industrial implementation. It also aims to validate the constellation concept. The overall objective is to achieve operational system availability before the end of the decade. This paper primarily presents NanoCarb, a static Fourier transform spectral imager. Its compactness, robustness, and low mass make it a promising concept for greenhouse gas measurements from space. This concept represents a paradigm shift, as it acquires only portions of interferograms rather than spectral radiances. First, we present the upgraded design of the airborne prototype (NanoCarb-P), which led to a sensitivity increase of approximately a factor of 2 for CO<sub>2</sub> and a factor of 3 for CH<sub>4</sub>. We also present the flight model design (NanoCarb-S), with a specific focus on the evolution of the interferometric core. Furthermore, we discuss how these upgrades enhance NanoCarb performance. The new design improves L2 (total column) performance, reducing random errors in CO<sub>2</sub> retrieval from synthetic data by up to 30% relative to the previous concept. In a case study with synthetic data with the improved and the previous design, we retrieved emissions from a large coal-fired power with improved precision (20% vs 35%) and similar accuracy (-15%).

### SCARBO<sub>n</sub> Mission

- A small satellite constellation
- Innovative sensors:
  - NanoCarb sensor for CO<sub>2</sub> and CH<sub>4</sub> detection
  - SPEXone aerosol detector for enhanced accuracy
- Swath: 200km and GSD: 2 x 2 km
- SSO orbits on different orbital planes allowing for different local times of observation
- Complementarity with institutional programs (e.g. CO2M, MicroCarb, TANGO) contributing to a European GHG monitoring system



### SCARBO<sub>n</sub>: Space CARBOn Observatory next step (2024-2027)

- EU Horizon Europe-funded project developing an innovative satellite system for GHG (Green House Gases) emissions monitoring
- Successor to the HE2020 SCARBO project which laid the technological foundation for SCARBO<sub>n</sub>
- Coordinated by Airbus Defence and Space (with nine EU-based partners)
- Addresses the challenge of GHG emission monitoring from space by leveraging innovative space-based sensors, thereby significantly contributing to climate change mitigation through enhanced data accuracy and reliability
- The NanoCarb instrument and the SCARBO<sub>n</sub> constellation aim to achieve operational system availability by the end of the decade.

### NanoCarb: at the Heart of SCARBO<sub>n</sub> Mission

#### Principle

- Miniaturized (~15x4x4 cm<sup>3</sup>) imaging spectrometer
- Full static Fourier Transform Spectrometer
  - Each FP thickness chosen to target a particular Optical Path Difference (OPD)
  - Focal Plan Array (FPA) intensity modulated by low finesse Fabry-Perot array
  - Snapshot acquisition mode

2 airborne demonstrators (CO<sub>2</sub>, CH<sub>4</sub>)

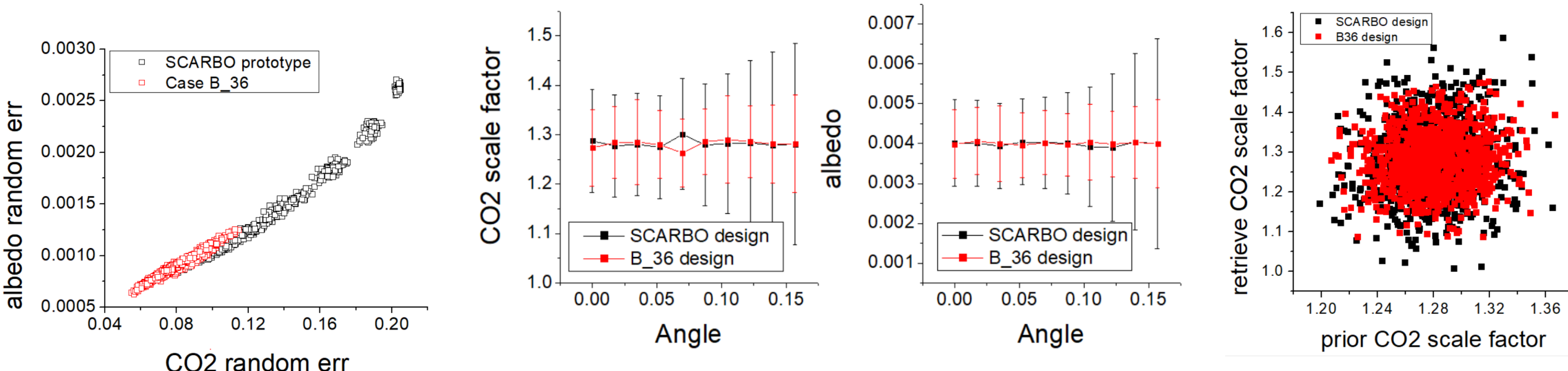
Nanocarb-S Space model: 4 channels



Band	Main target	Spectral range
B1	Surface pressure	12940-13175 cm <sup>-1</sup>
B2	CO <sub>2</sub>	6180-6200 cm <sup>-1</sup>
B3	CH <sub>4</sub>	6000-6200 cm <sup>-1</sup>
B4	CO <sub>2</sub>	4820 - 5010 cm <sup>-1</sup>

### Nanocarb-S design upgrade

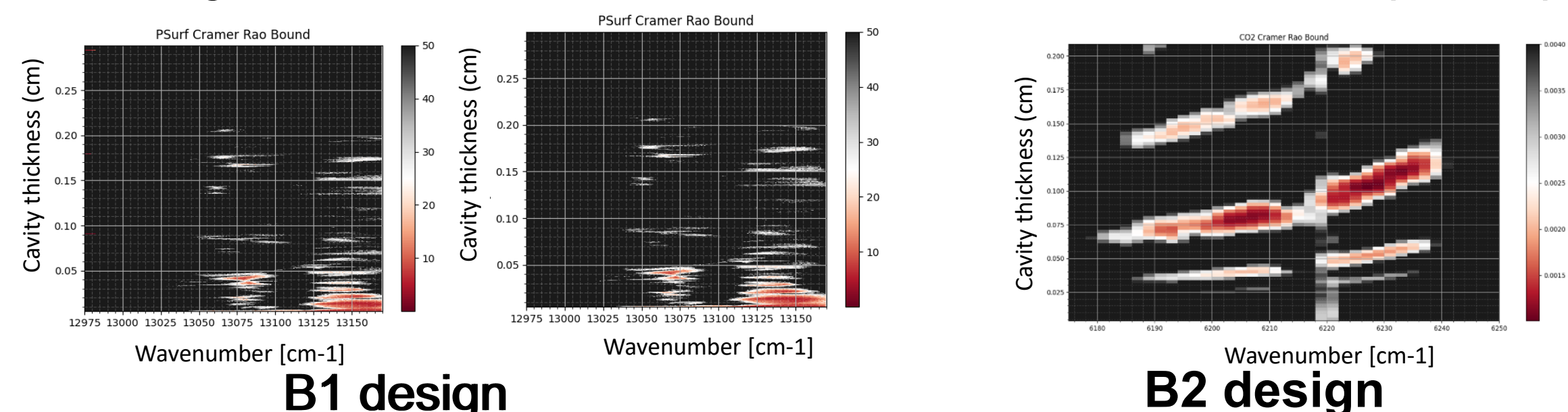
New design of the 2 airborne prototype based on a co-conception approach



- Up to 2x sensitivity improvement over the original SCARBO system
- Stable performance across varying incidence angles
- Reduced correlation between surface albedo and CO<sub>2</sub> retrievals

### Nanocarb-S design upgrade

New design of the 4 band of Nanocarb-P based on a co-conception approach

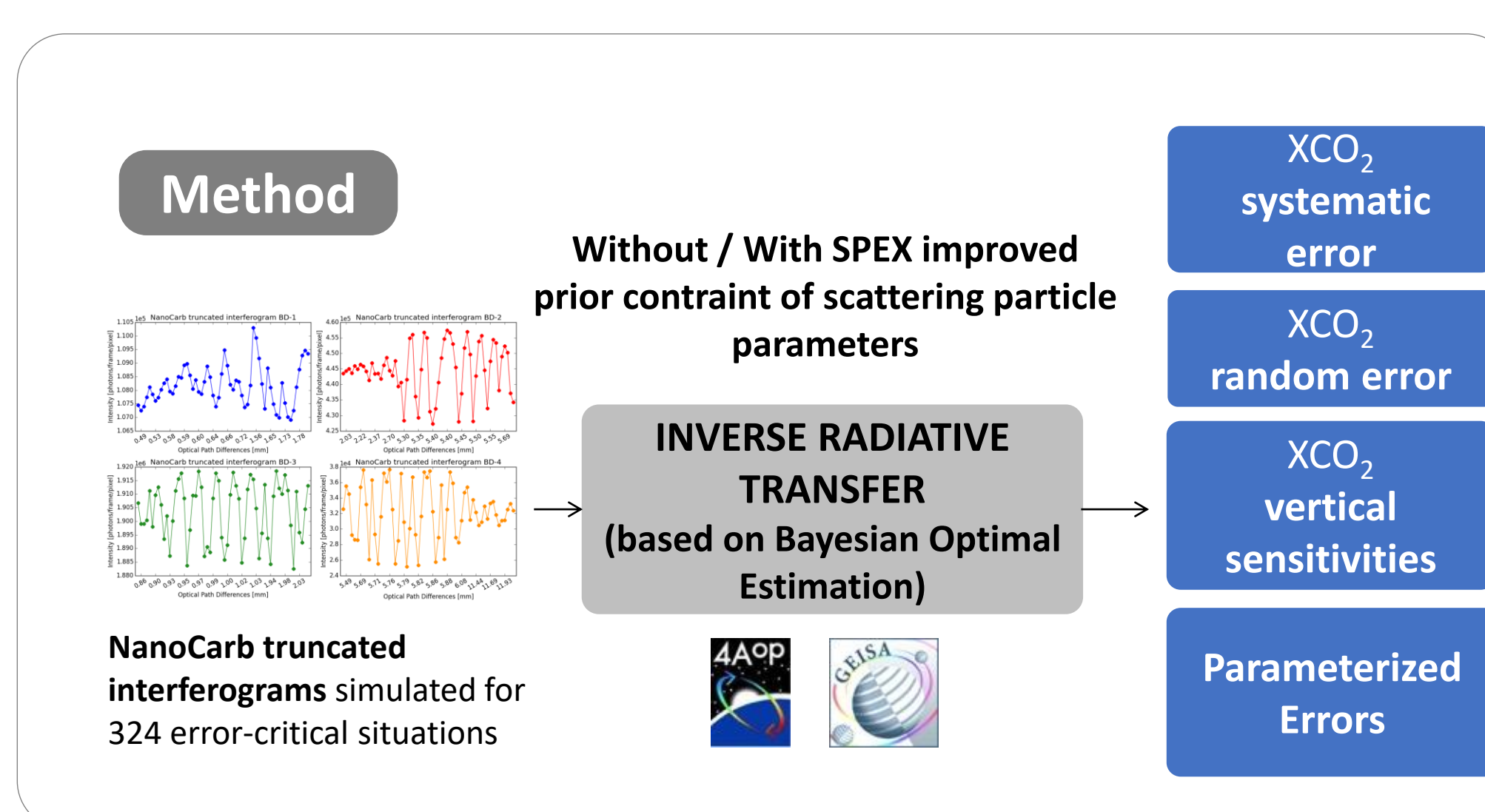


#### References

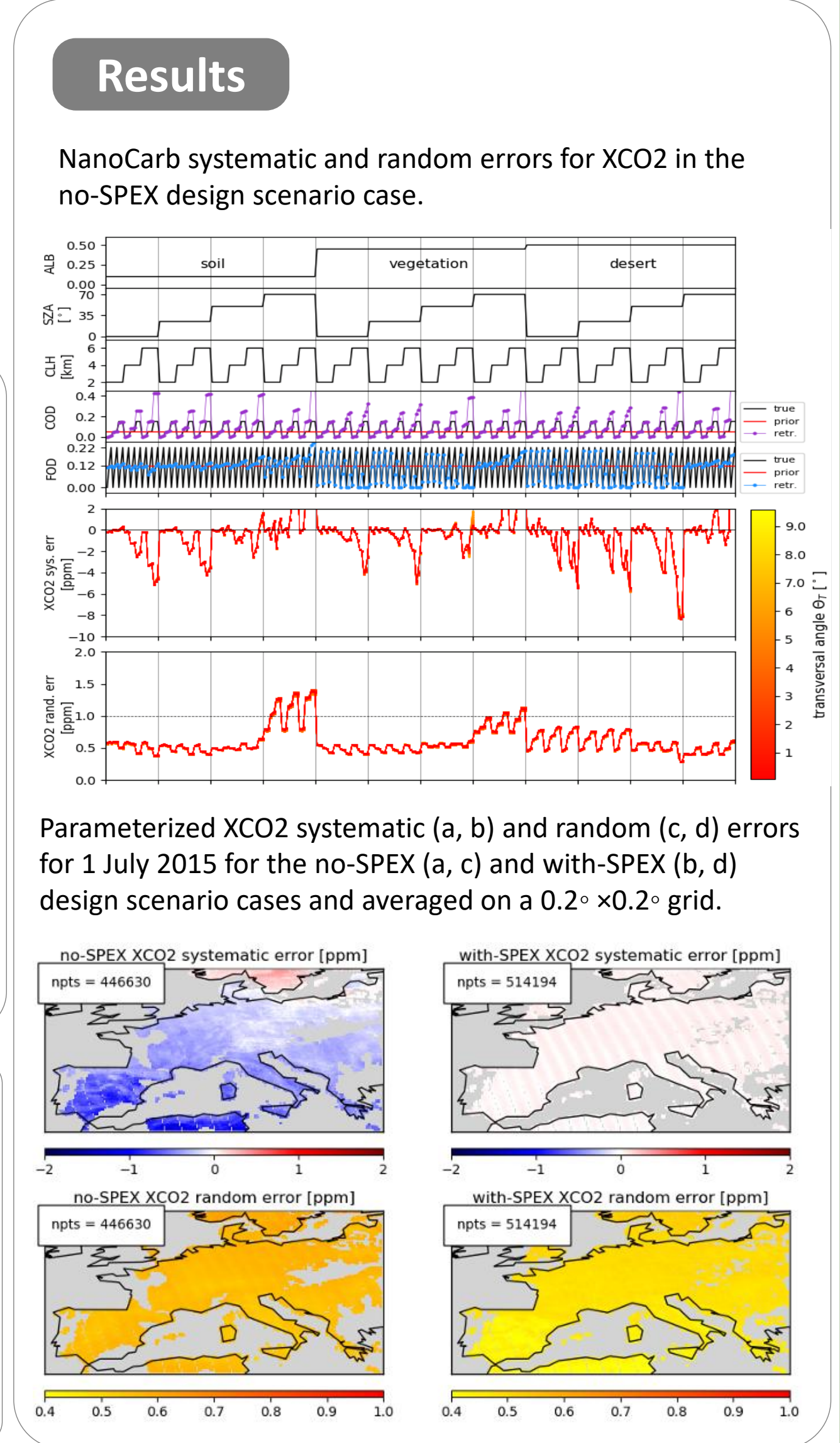
- L. Brooker Lizon-Tati, S. Val Serra, H. Bovensman, C. Crevoisier, M. Dogniaux, L. Croizé, Y. Ferrec, E. Le Coarer, S. Gousset, B. Sic, M. Smit, and the SCARBO consortium, SCARBO: A constellation of small satellites for the monitoring of anthropogenic greenhouse gases, 73rd International Astronautical Congress (IAC), Paris, France, 18-22 September 2022.
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- M. Dogniaux, C. Crevoisier, S. Gousset, E. Le Coarer, Y. Ferrec, L. Croizé, L. Brooker (2021), The Space CARBOn Observatory (SCARBO) concept: Assessment of XCO<sub>2</sub> and XCH<sub>4</sub> retrieval performance. Atmospheric Measurement Techniques Discussions, 1-38

### Status on Nanocarb performance assesment

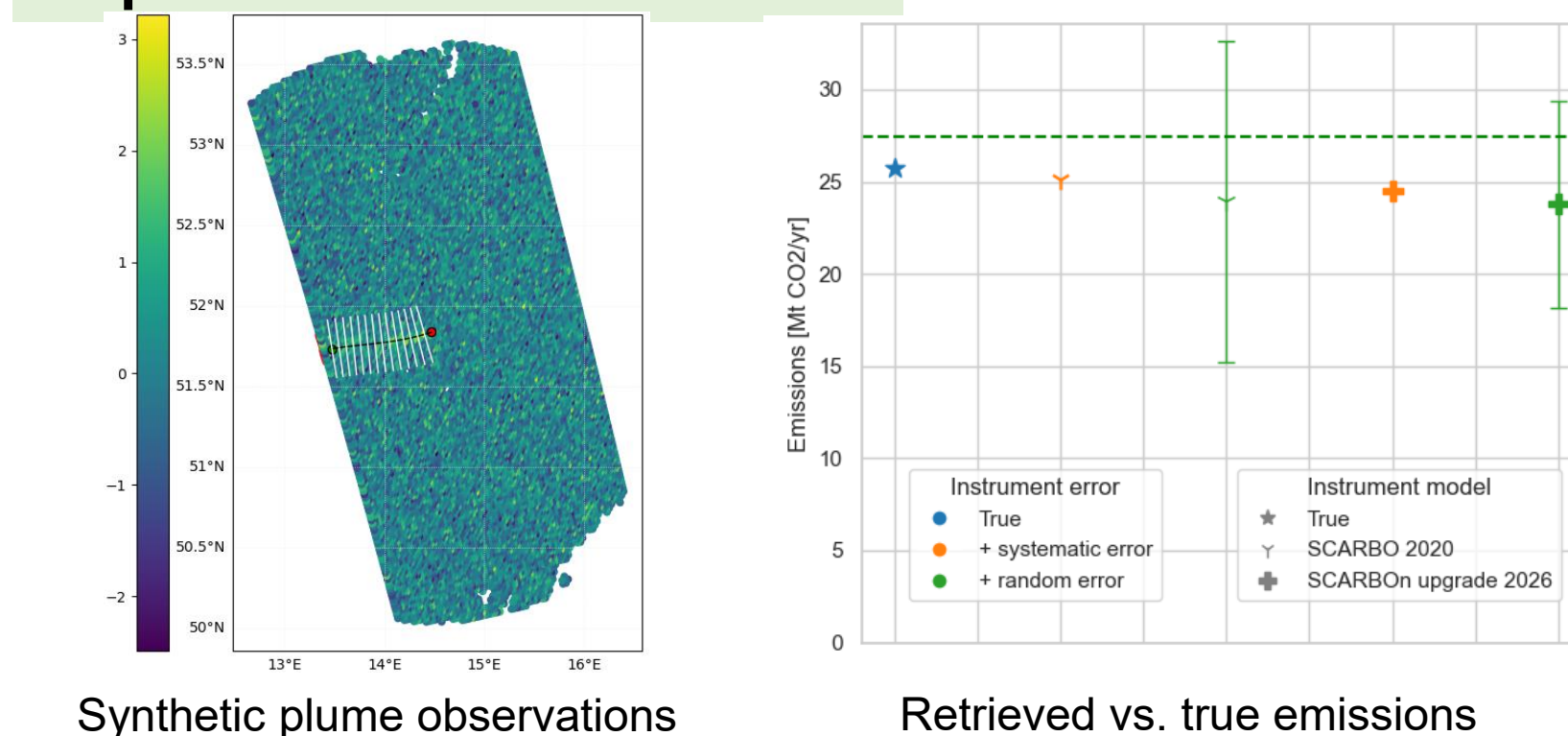
Following the methodology of Dogniaux et al., 2021, SCARBO<sub>n</sub> L2 performance assessment is conducted using an optimal estimation scheme applied to truncated interferograms simulated for 324 representative scenarios, covering various surface types, solar zenith angles and fine/coarse aerosol configurations. The resulting errors are then parameterized to derive L2 random and systematic error maps.



- Main conclusions on the performance assessment are:**
- Significant reduction in the random error (~30%) and in the FOV-dependent effects on L2 errors compared with the previous concept.
  - The resulting random error is lower than 0.7ppm for most of the cases
  - Coupling Nanocarb with SPEXone allows to decorrelate satisfactorily the systematic error from aerosol properties



#### L4 performance assessment



- Case study: retrieve CO<sub>2</sub> emissions of a power plant from synthetic measurements. Compare instrument models before and after SCARBO<sub>n</sub> design upgrades
- Method: Cross-sectional flux method
- Result: The uncertainty of retrieved emissions is dominated by random over systematic L2 errors. After the design upgrade, random emission uncertainty is reduced by 40%.

