National Aeronautics and Space Administration

Exploiting Spatio-Temporal Dependence in Multi-Footprint Remote Sensing Retrievals

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Program: FY22 SURP
Strategic Focus Area: Uncertainty Quantification

Objectives

- Develop statistical methodology and efficient computational tools for multi-footprint joint retrievals of atmospheric and surface properties from remote-sensing data
- Applicable to multiple current and future Earth science missions
  - Trace gas retrievals from Orbiting Carbon Observatory-2/3 (OCO-2/3)
  - Joint surface/atmosphere retrievals for Surface Biology and Geology (SBG)
- Science objectives for these and other Earth-observing missions focus on quantities of interest (QOIs) that exhibit correlation in space and/or time

Background

- Single-footprint retrieval errors are often spatially correlated
- Multi-footprint strategy allows simultaneous inference for a small area of footprints (Fig. 1).

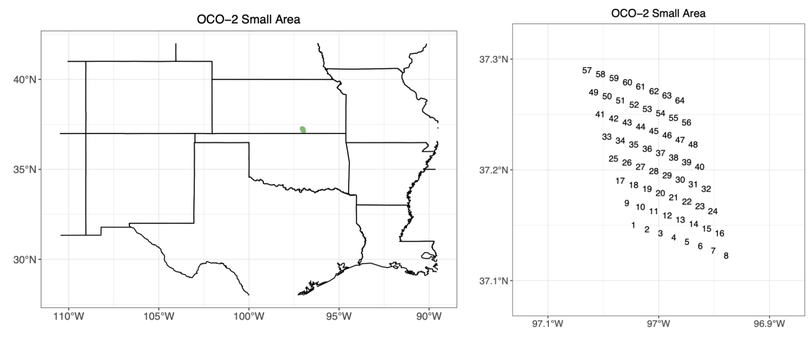

Figure 1: Example multi-footprint scenario for OCO-2. Left: A small portion of an individual OCO-2 orbit (in green) over southern Kansas with m = 64 footprints. Right: A zoomed-in view of the locations of the nearby footprints.

Approach, Results, Significance

- Multi-footprint approach uses a multivariate spatial statistical model as prior distribution
  - Spatial correlation can be state-dependent
- Within-footprint correlation for OCO-2/3 exhibits block structure for state vector groups (Fig. 2)
- Team has enabled retrieval simulation experiments with ReFRACtor retrieval software package (Fig. 3)
- In FY23, retrieval simulation experiments are planned using spatially-correlated states
  - Results to be compared with linear model case of [1] (Fig. 4)
  - Enable multi-footprint retrieval capability for OCO-2 small areas

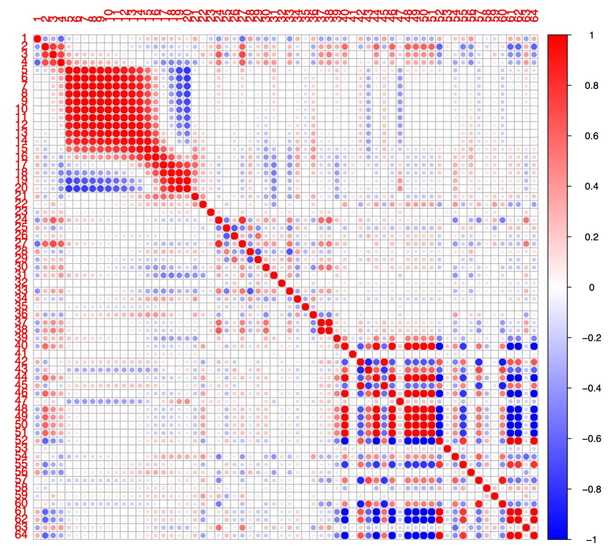

Figure 2: Estimated within-footprint correlation structure for OCO-2 retrieved states. Strongest correlations (in red) in top left block correspond to the vertical profile of atmospheric CO_2.

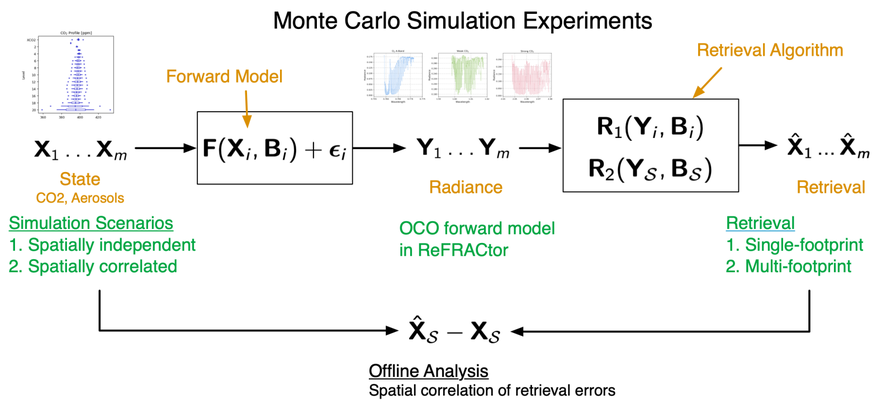

Figure 3: Schematic diagram of simulation experiment framework for single and multi-footprint retrievals. Collections of spatially independent or correlated states are generated and used in the OCO forward model in the ReFRACtor software.

Figure 4: Spatial correlation of retrieval errors for total column CO_2 under three retrieval strategies, from [1]. The operational one-at-a-time retrieval (center) yields strongly correlated retrieval errors.

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References:

[1] Jonathan Hobbs, Matthias Katzfuss, Daniel Zilber, Jenný Brynjarsdóttir, Anirban Mondal, and Veronica Berrocal, "Spatial Retrievals of Atmospheric Carbon Dioxide from Satellite Observations," Remote Sensing **13** (2021). doi: 10.3390/rs13040571

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