National Aeronautics and Space Administration

Carbon Cycle Science Benefits of Increased GHG Sampling by Panchromatic Fourier Transform Spectrometer (PanFTS)

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Program: FY23 Strategic Initiatives Research and Technology Development

Strategic Focus Area: Earth System Explorer – Science Definition and Technology Maturation | **Strategic Initiative Leader**: Sabrina M Feldman

Background and Objectives: This proposal focuses on concept and technology maturation for ESE and EV class missions focusing on GHGs. Our concept considers panFTS in different orbits (HEO, GEO, MEO) to optimize C cycle science return at regional- to global- scale. Our GHG ESE concept maturation objectives aim to resolve long-standing questions about C emissions resulting from emerging tipping points in critical ecosystems in Arctic and tropical regions. We address these critical questions using retrieval and flux OSSEs, leveraging PanFTS multi-spectral (SWIR + TIR) retrievals of multiple species (CO2, CH4, CO, SIF, wind), and sub-daily to daily spatially resolved mapping. Our objectives are to: (1) Quantify grid scale flux uncertainty reduction, (2) Determine the detectability of abrupt GHG emissions, and (3) Optimize PanFTS instrument design to achieve pan-Arctic and global GHG science.

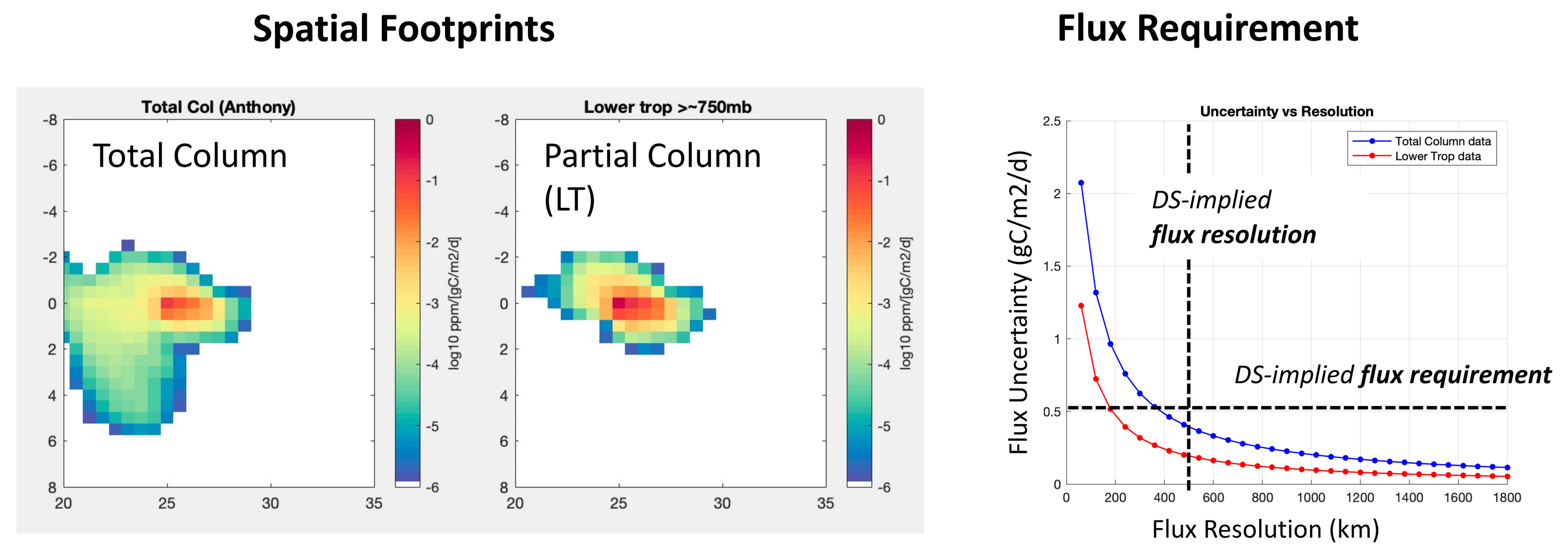
Approach and Results: Our technical approach consists of 4 steps:

1. GHG Retrieval OSSE (Fig 1), 2. Flux Localization OSSE (Fig 2), 3. Flux Inversion OSSE (Fig 3), 4. PanFTS Trade Studies (Fig 4).

Region	Date	CO2		CH4	
		DOFS 1x/3x	Precision % 1x/3x	DOFS 1x/3x	Precision % 1x/3x
		SWIR			
Arctic	March	0.8/1.0	0.5/0.3	1.0/1.3	0.6/0.6
	June	0.9/1.2	0.4/0.3	1.0/1.4	0.6/0.6
Tropics	March	1.1/TBD	0.3/0.3	1.2/1.8	0.6/0.6
	Sept	1.1/TBD	0.3/0.3	1.3/1.9	0.6/0.6
		SWIR + TIR			
Arctic	March	1.5/**2.5**	0.3/0.3	1.2/1.7	0.8/0.7
	June	1.5/**2.3**	0.4/0.3	1.3/**2.1**	0.7/0.7
Tropics	March	**2.1/3.1**	0.3/0.2	**1.9/2.9**	0.8/0.6
	Sept	**2.1/2.9**	0.3/0.2	**1.9/2.9**	0.8/0.6

Figure 1. Summary of PanFTS GHG retrieval performance in the Arctic and tropics. Degrees of Freedom of vertical signal (DOFs) and precision shown for single (1x) and 3x3 aggregated (3x) footprints. This shows improvements in the number of DOFs and increased precision using combined bands (SWIR+TIR, bottom) and spatial aggregation.

GGH Retrieval OSSE. Incorporate Pan-FTS configuration into RTM and retrieval simulation, combining TIR and SWIR bands to retrieve column and partial column CO_2 & CH_4. The combined daytime SWIR+TIR bands achieve 2-3 DOFs and 0.25-0.4% precision at 12 x 12 km with 7.5 minute/FOV stare time in Arctic and tropical environments.



Flux Localization OSSE. Leverage analytical Jacobian analysis to quickly and efficiently test propagation of measurement error to flux, and better determine GHG measurement requirements for SATM traceability. Our results show a reduction in flux footprint and uncertainty at finer flux resolution for lower troposphere partial columns.

Figure 2. Flux-Concentration Jacobians help determine differences in spatial footprint and flux uncertainty for column vs partial columns. This type of simplified and rapid analysis is useful for defining GHG measurement requirements for SATM traceability.

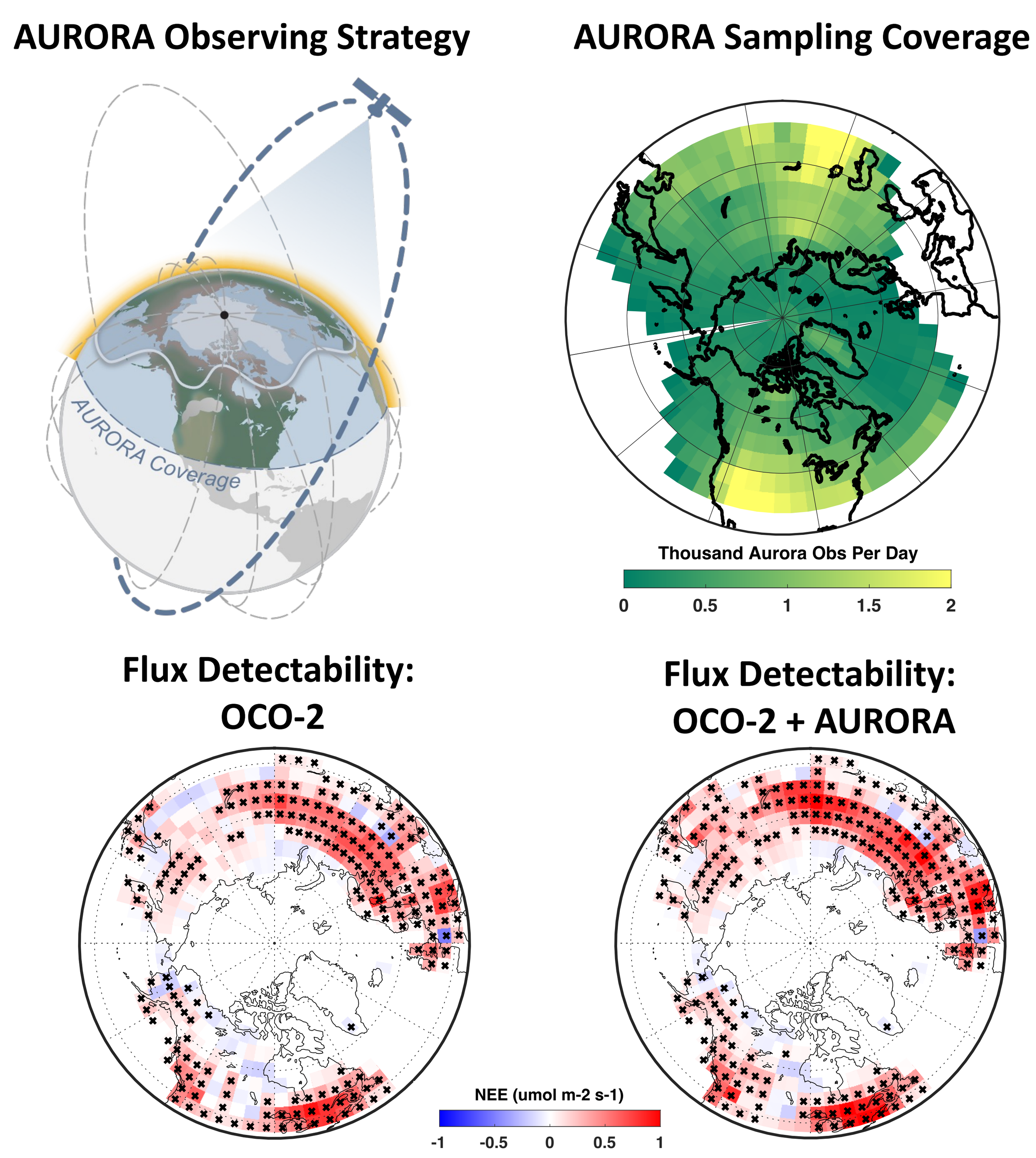


Figure 3. Illustration of AURORA GHG Mission concept for detecting carbon cycle changes in northern high latitude Arctic ecosystems.

Flux Inversion OSSE. Use CMS-Flux inversion system to assimilate PanFTS column retrievals to quantify flux retrieval and uncertainty reduction relative to OCO-2. High frequency AURORA sampling of the pan-Arctic improves detectability of fall emissions relative to OCO-2 alone.

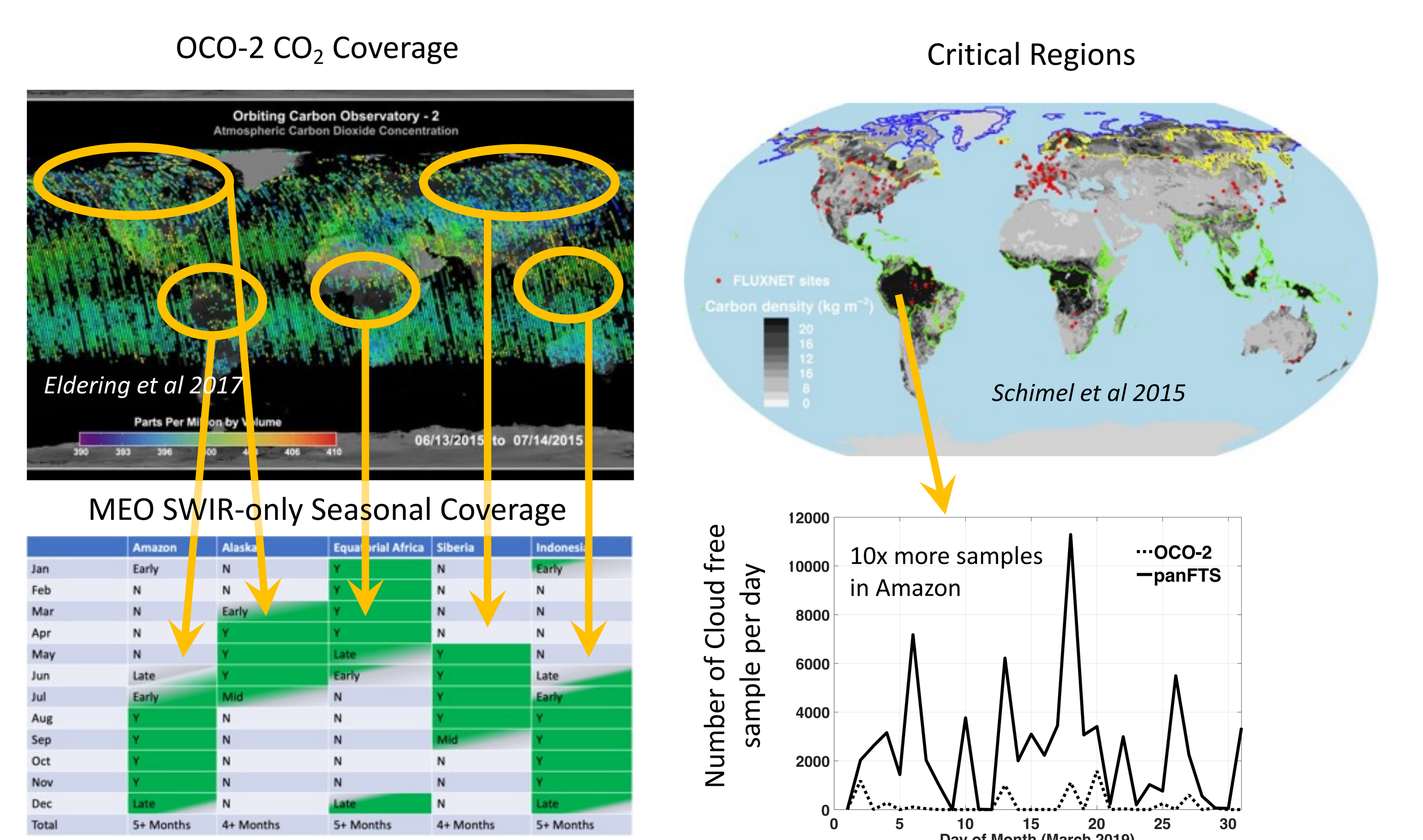


Figure 4. Global observing strategy for a PanFTS in MEO GHG mission concept. The mission design is optimized to target critical regions and critical seasons.

PanFTS Trade Studies show that PanFTS is ideally suited for a MEO GHG mission due to high altitude (~37000 km) vantage, wide spatial & spectral coverage of iFTS, and slow ground speed relative to LEO. The SWIR-only PanFTS improve cloud free sampling in Amazonia relative to relatively infrequent sampling from LEO

Significance/Benefits to JPL and NASA: Retrieval OSSE's demonstrate the potential of the JPL designed multi-spectral panFTS to retrieve sub-daily maps of CO2 and CH4 vertical profiles (2+ DOFs) at sub-daily frequency in the tropics and Arctic. This offers advanced GHG spectral, spatial, and temporal sampling relative to PoR. Increased sampling of the pan-Arctic improves C flux detectability, thus reducing uncertainty in carbon-climate feedback.

National Aeronautics and Space Administration

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California Institute of Technology
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www.nasa.gov

Clearance Number: CL#
Poster Number: RPC#

Publications:

Parazoo, N.C., G. Keppel-Aleks, S. Sander, B. Byrne, V. Natraj, M. Luo, JF Blavier, R. Nassar, L. Dorsky, Increased spaceborne sampling of X_{CO2} improves detectability of carbon cycle seasonal transition in Arctic-Boreal ecosystems, Submitted to GRL

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