The OCO-2 and OCO-3 missions:
Status, results and plans

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Jet Propulsion Laboratory, California Institute of Technology

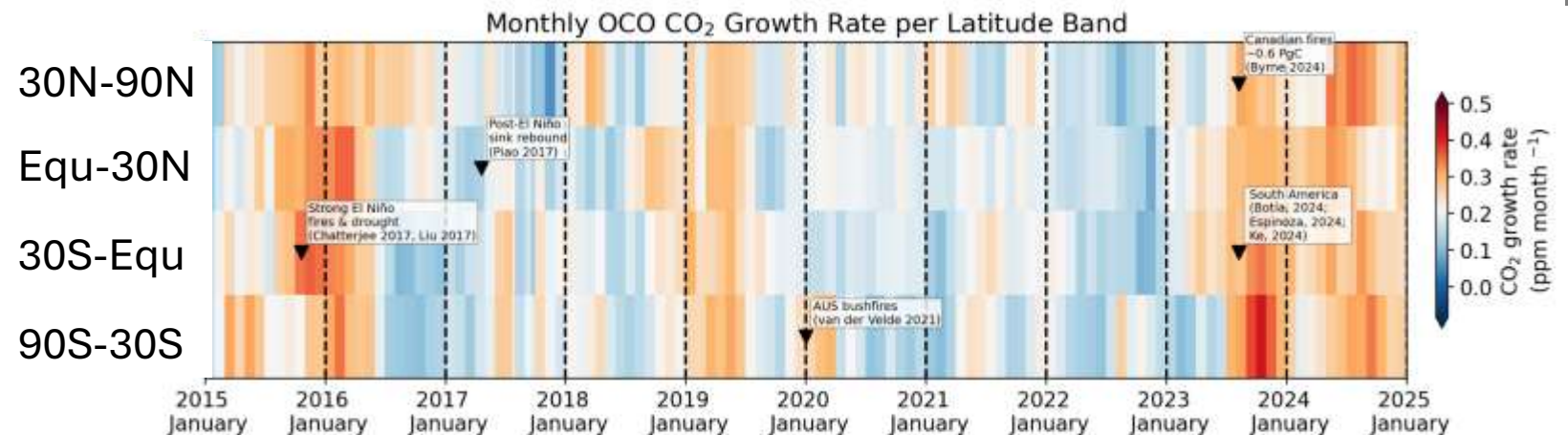And the OCO-2/OCO-3 Project Teams, Science Team!

NASA **Jet Propulsion Laboratory**
California Institute of Technology

Tracking the whole-atmosphere CO$_2$ growth rate in near real time

CO$_2$ growth rate calculated using OCO-2 data
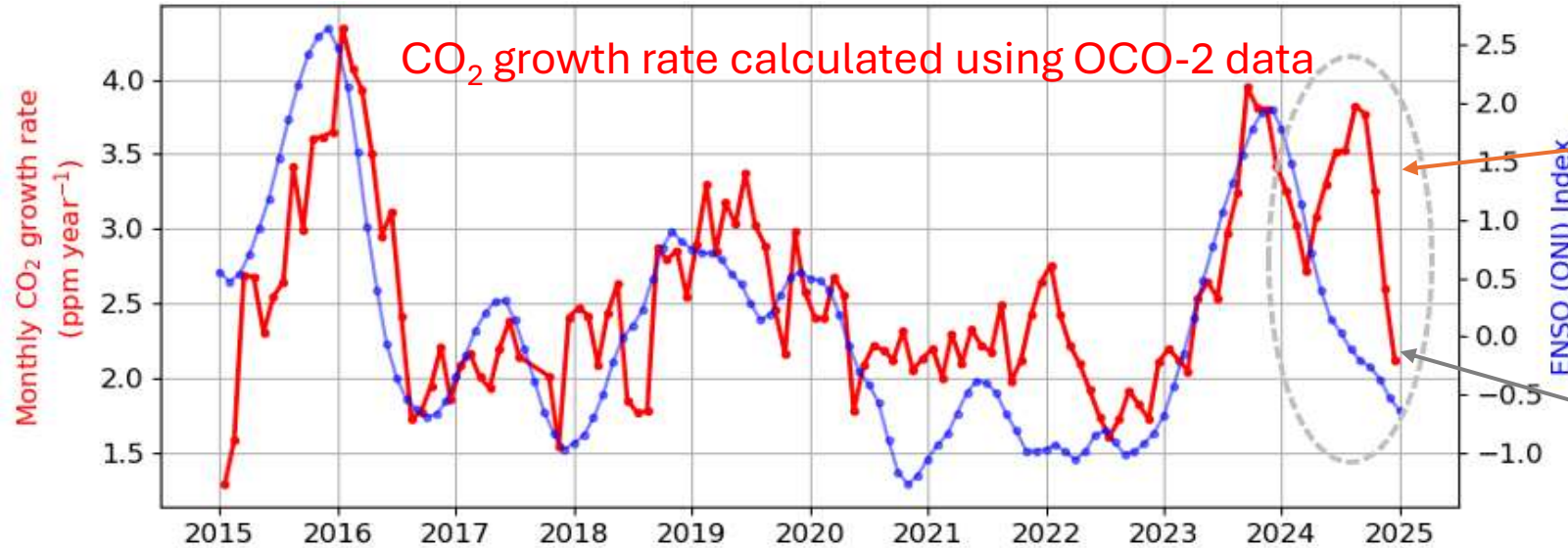
CO$_2$ growth rate for 2024: One of the highest on record

(Both for NOAA ground-based record and for satellite record)

Strongly decoupled from ENSO index, likely that anomaly originated in the Southern Tropics

- Pandey et al. (2024) **AGU Advances**, 10.1029/2023AV001145

- Pandey et al. (*in preparation*)

Monthly OCO CO$_2$ Growth Rate per Latitude Band

Pandey et al. (2024). The plot uses JPL OCO-2 (all) XCO$_2$ data.
Colorscale is centered (white) at the mean growth rate.
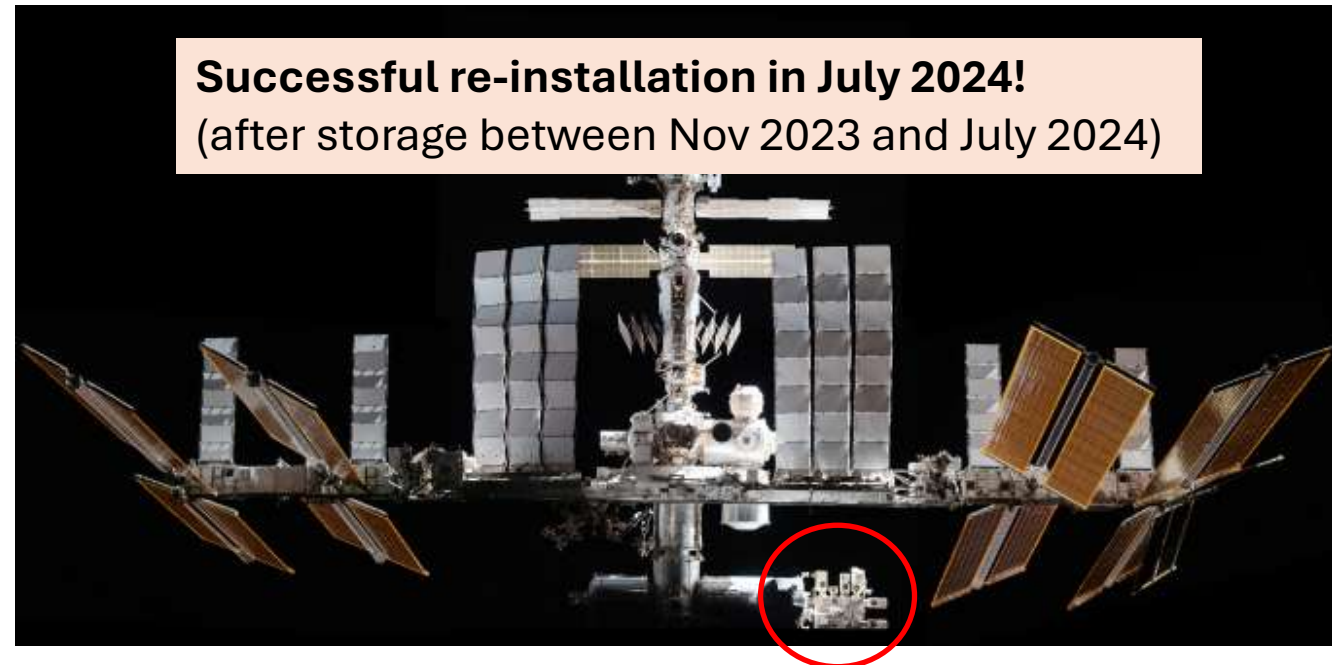
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The OCO-2 and OCO-3 missions

Orbiting Carbon Observatory-2 (OCO-2)

- Launched July 2, 2014
- Free flying spacecraft
- Sun-synchronous polar orbit

Orbiting Carbon Observatory-3 (OCO-3)

- Launched May 4, 2019
- International Space Station (ISS)
- ± 52° inclined orbit

Successful re-installation in July 2024!
(after storage between Nov 2023 and July 2024)

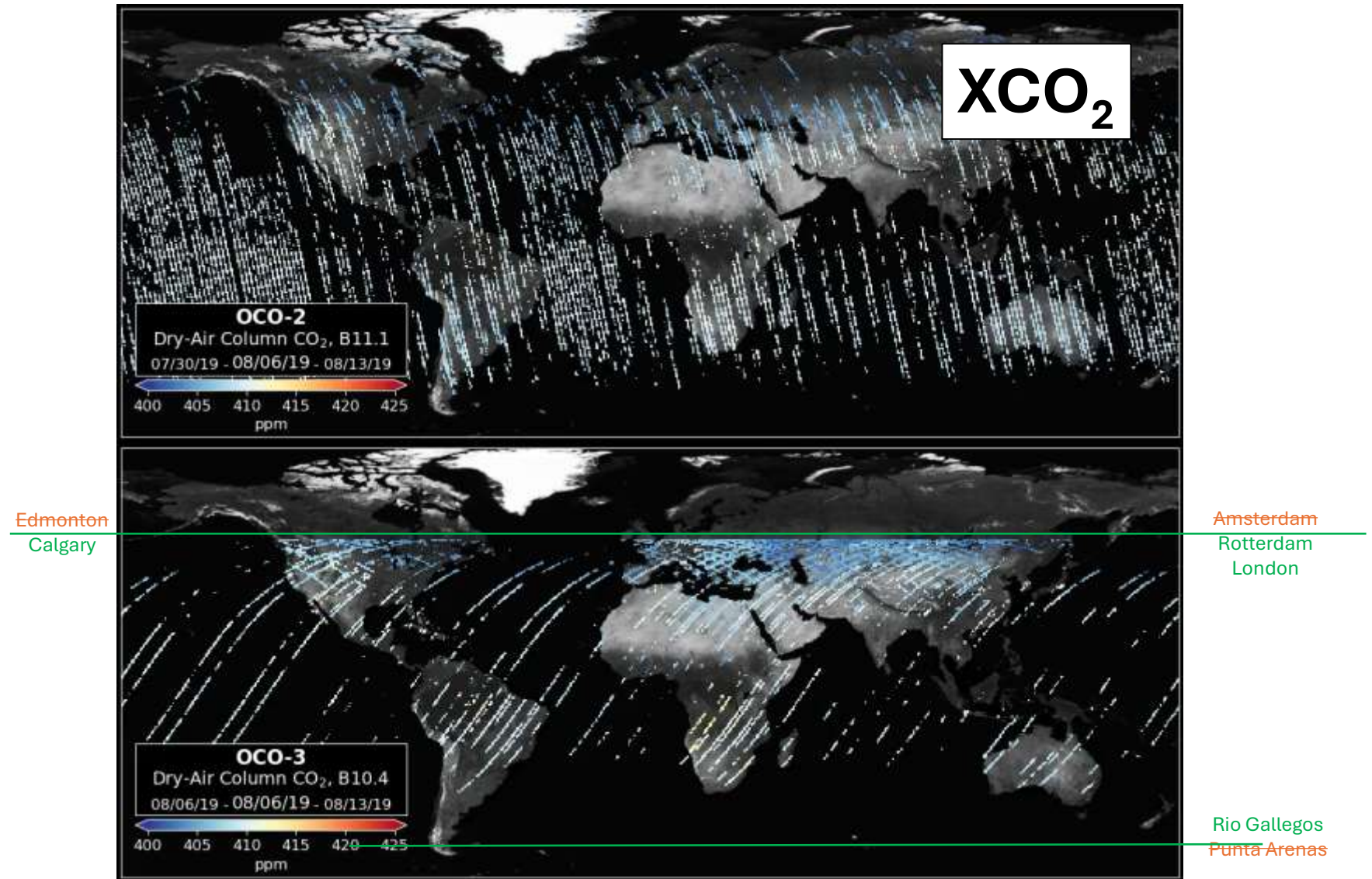**OCO-2 and OCO-3 data products are publicly available via the NASA GES DISC**

OCO-2 and OCO-3: Complementary coverage and sampling

OCO-2

- "Pole-to-pole" coverage, depending on season;

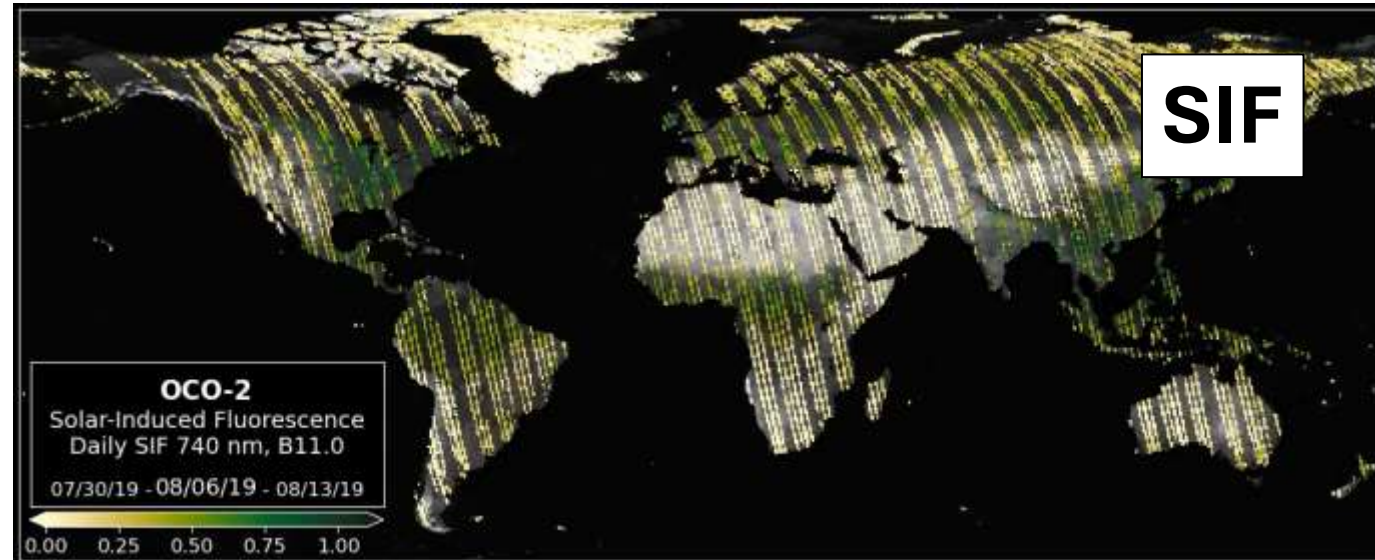- Fixed 1330h equator crossing time (and local overpass time)

OCO-3

- Coverage limited to ±52º latitude, changing with season;

- Observations span all times of day

XCO$_2$

OCO-2
Dry-Air Column CO$_2$, B11.1
07/30/19 - 08/06/19 - 08/13/19
400 405 410 415 420 425
ppm

OCO-3
Dry-Air Column CO$_2$, B10.4
08/06/19 - 08/06/19 - 08/13/19
400 405 410 415 420 425
ppm

Edmonton
Calgary

Amsterdam
Rotterdam
London

Rio Gallegos
Punta Arenas

Videos from Thomas Kurosu/JPL

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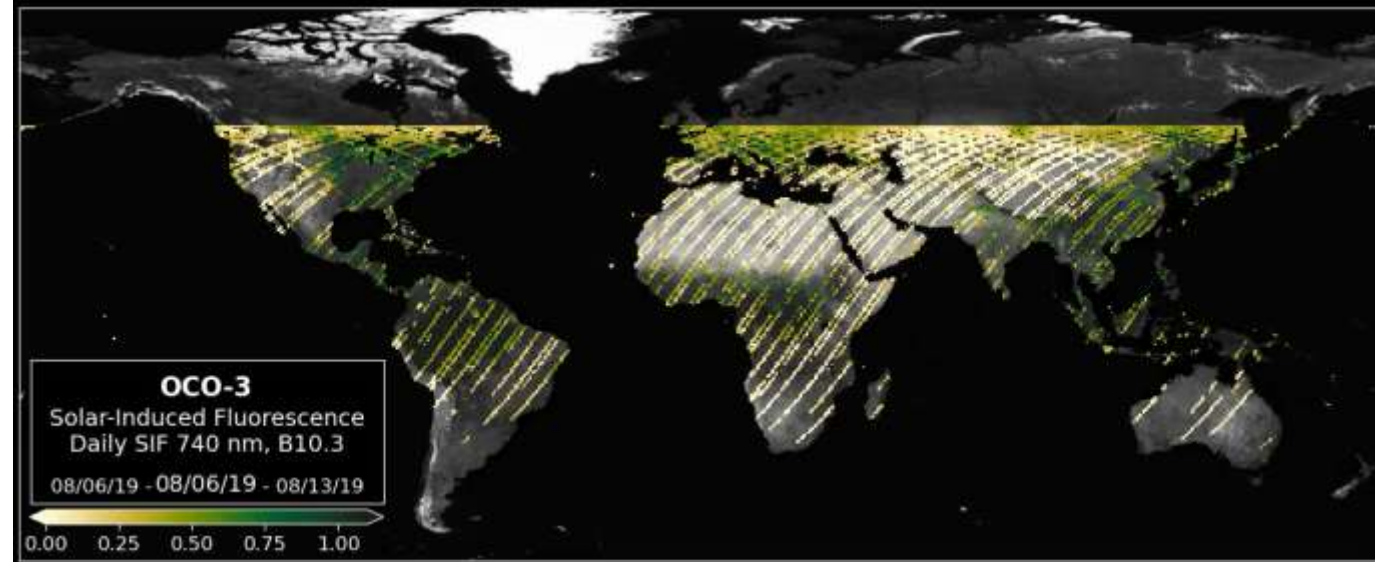# OCO-2 and OCO-3: Complementary coverage and sampling

OCO-2

- "Pole-to-pole" coverage, depending on season;

- Fixed 1330h equator crossing time (and local overpass time)

OCO-3

- Coverage limited to ±52º latitude, changing with season;
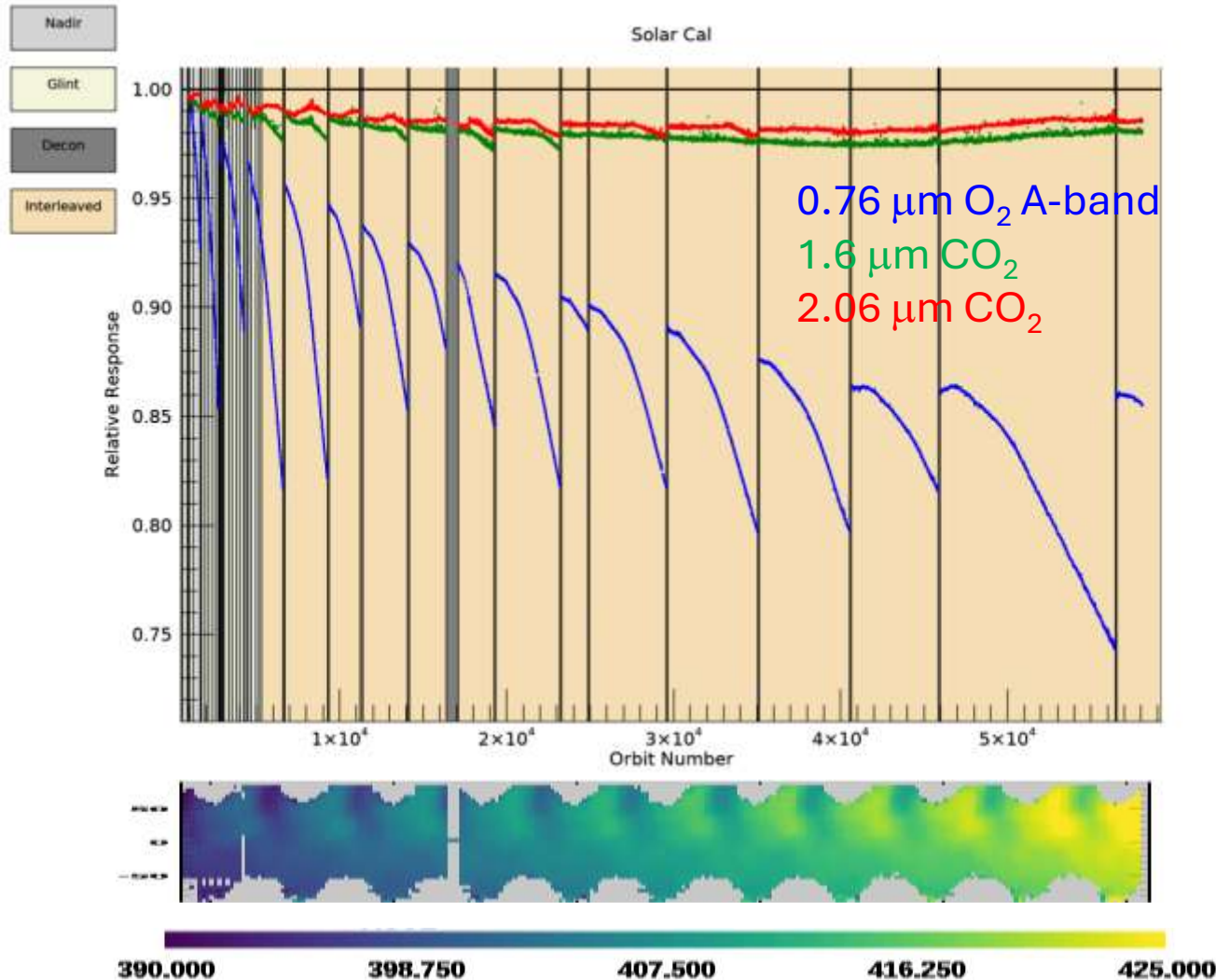
- Observations span all times of day

Videos from Thomas Kurosu/JPL

OCO-3 Snapshot Area Maps (SAMs)

- Collects data over an ~80 km × 80 km area in 2 minutes
- Complements the near-global nadir & glint measurements


OCO-3 SAMs/Targets, 26 July 2019 - 2 June 2025, N = 21020
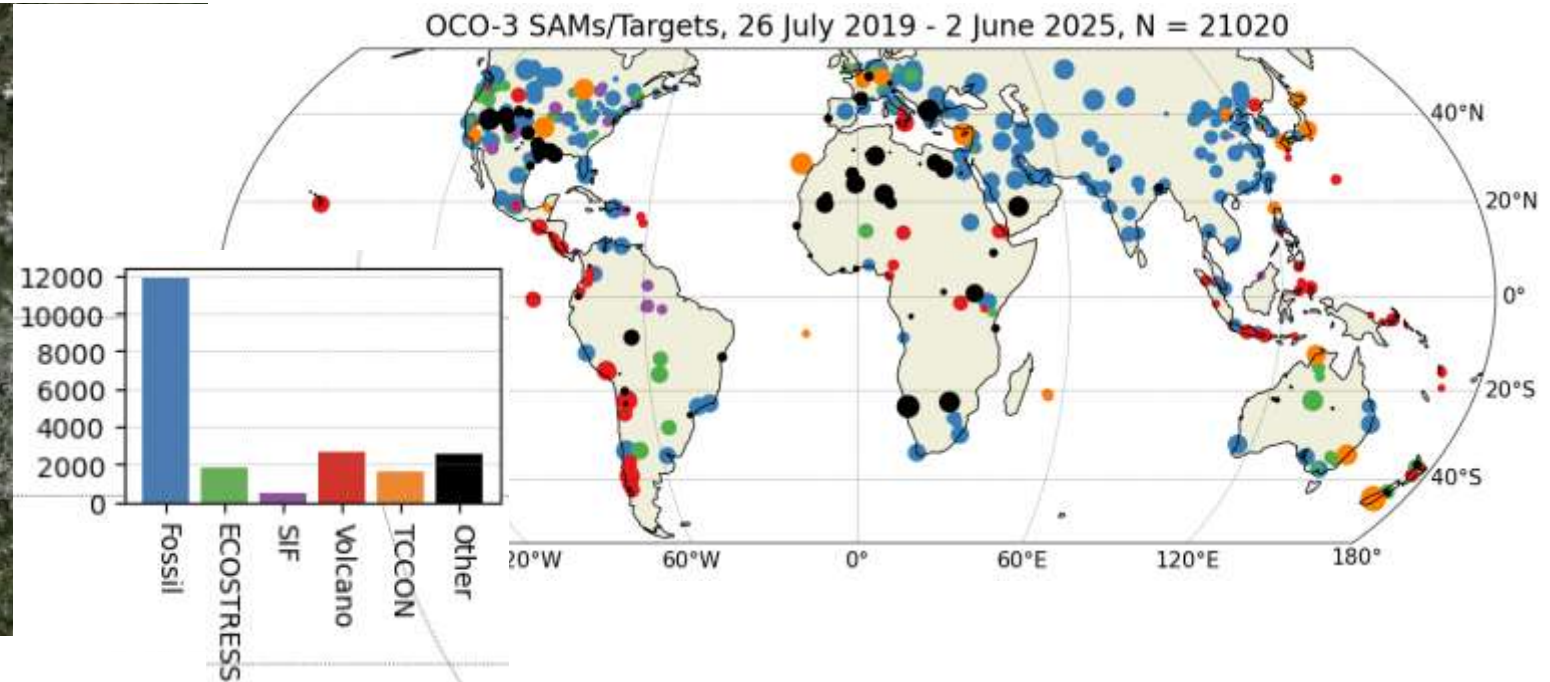
See R. Nelson/A. Chatterjee talk on Tuesday!

OCO-2: Continuing to age like a fine wine!

Solar Cal

Nadir
Glint
Decon
Interleaved

0.76 μm O₂ A-band
1.6 μm CO₂
2.06 μm CO₂

- Instrument and spacecraft are in excellent health

- Outgassing/icing effects continue to slow as the mission extends in time

Lamp 1   Solar   Lunar

OCO3 SNO   Vicarious   Cloud   PICS   Ocean
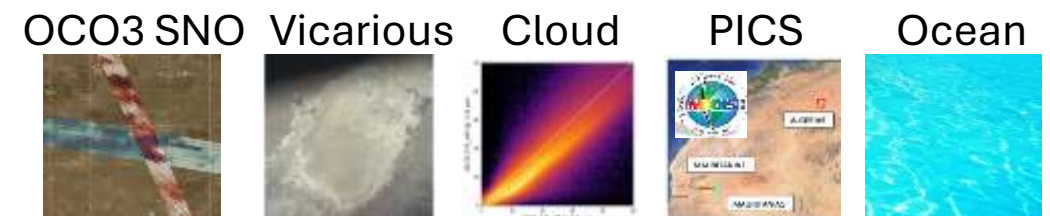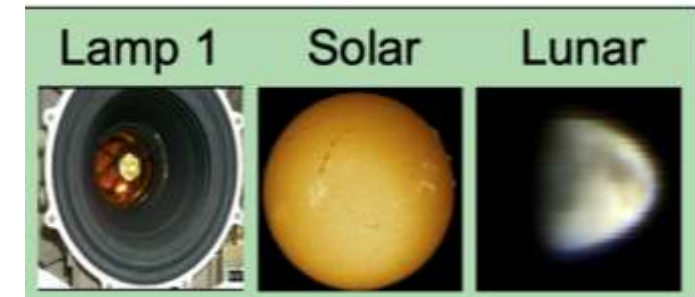
Figures: R. Rosenberg and the OCO-2 cal team

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OCO-3: With age (and v11) comes wisdom

- OCO-3 instrument is in excellent health!

- OCO-3 v11: Consistency with OCO-2 v11.2 L2 algorithm, plus OCO-3-specific improvements to L1B calibration and geolocation compared to v10


Keller et al., 2025

Taylor et al., in prep
Thanks to B. Fisher.
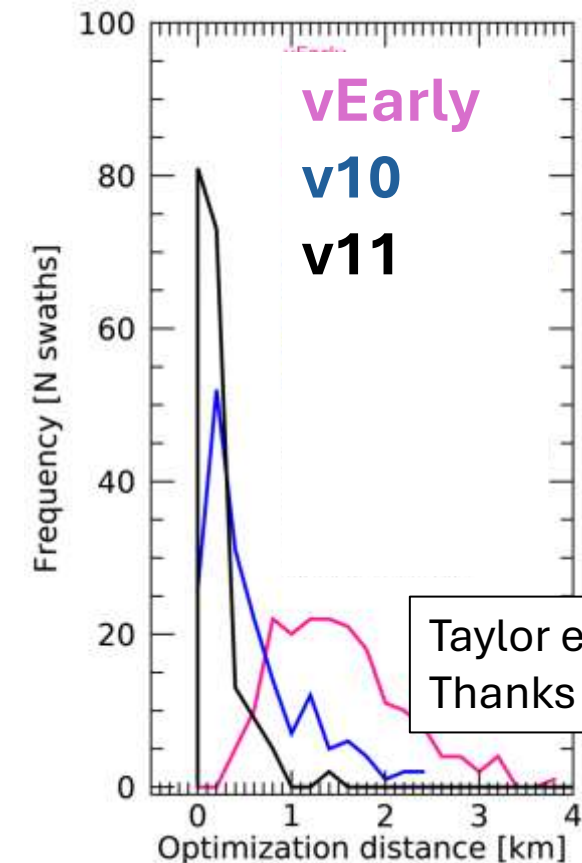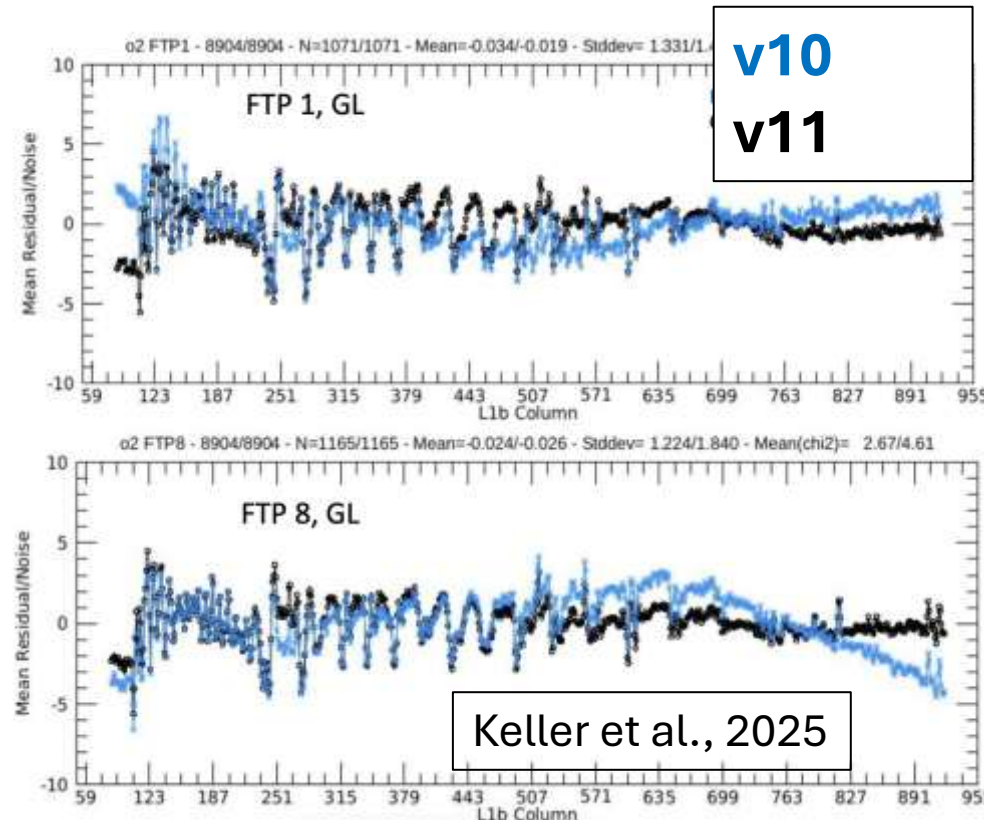
Level 2 XCO$_2$ and SIF products

- Latest and greatest Level 2 data versions: <u>**v11.2**</u> for OCO-2, <u>**v11**</u> for OCO-3
  - Consistent algorithm used for OCO-2 and OCO-3!

Figure: Chris O'Dell, CSU

- **Forward stream**
  - Subset of soundings, **latency < 1 week**
  - Products removed from GES DISC site on rolling basis
  - **New!** **Bias-corrected forward stream L2 products**
    - Intended for users who need low latency
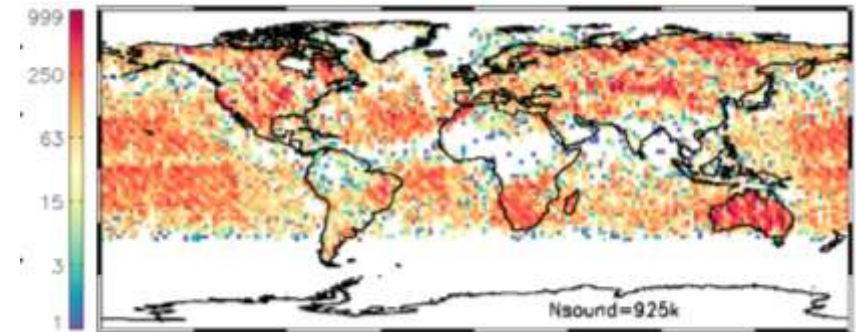
OCO-2 coverage, forward stream (06/22)

- **Retrospective stream**
  - All "cloud-free" soundings processed, monthly cadence
  - Full record available at GES DISC site
  - L2 **Lite** products: Bias correction, quality filter applied
    - Recommended for most users
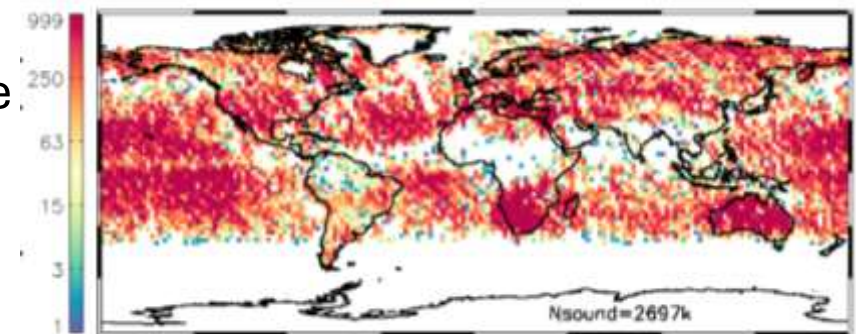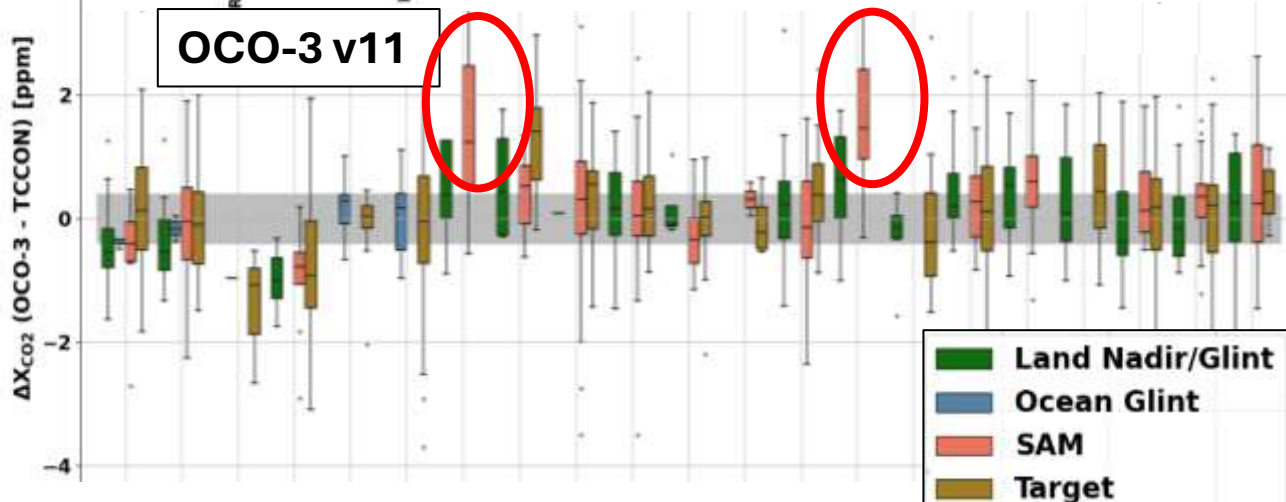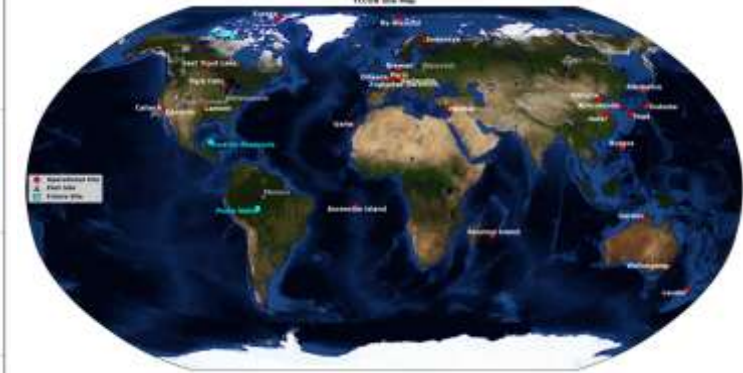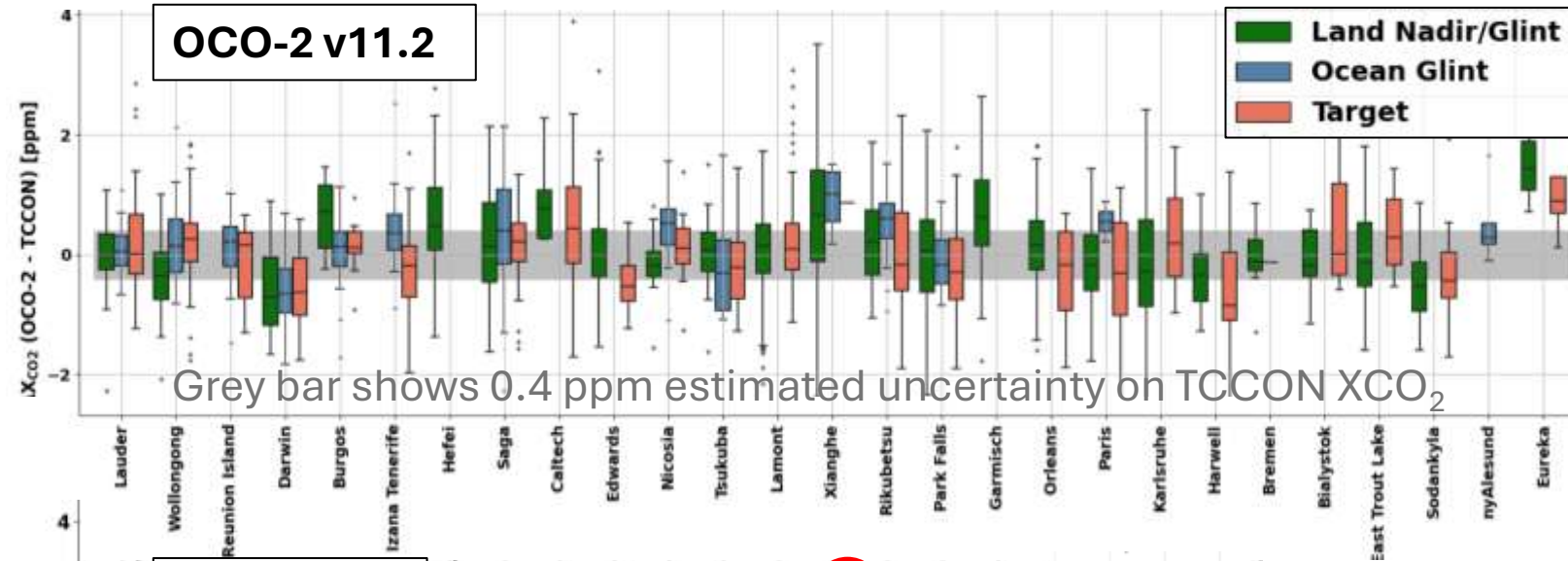
OCO-2 coverage, retrospective stream (06/22)

Why "OCO-2 v11.2" but "OCO-3 v11"?

- **OCO-2** v11 → v11.1: Switch to Copernicus Digital Elevation Map

- **OCO-2** v11.1 → v11.2: Transition from GEOS-FPIT to GEOS-IT met fields
  - Date of GEOS-IT transition: 2nd April 2024
  - Users should be aware: Transition introduces subtle but non-zero discontinuity in record
    - Mitigated, but not fully addressed, by v11.2 Lite reprocessing for pre-2024 data
    - To fully address this, a full L2FP reprocessing would be required
  - For more info, see OCO-2 Data User Guide
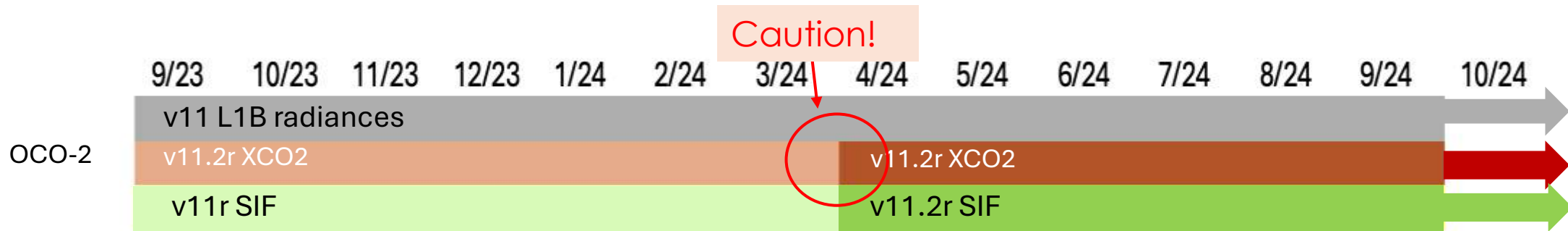
- **OCO-3 v11 is fully consistent throughout the record**
  - OCO-3 v11 processing started later, was able to "bake in" these DEM, GEOS-IT updates

Validation against TCCON (GGG2020): Agreement < 1 ppm

OCO-2 v11.2

Land Nadir/Glint
Ocean Glint
Target

Grey bar shows 0.4 ppm estimated uncertainty on TCCON XCO_2

X_{CO2} (OCO-2 - TCCON) [ppm]

Lauder, Wollongong, Reunion Island, Darwin, Burgos, Izana Tenerife, Hefei, Saga, Caltech, Edwards, Nicosia, Tsukuba, Lamont, Xianghe, Rikubetsu, Park Falls, Garmisch, Orleans, Paris, Karlsruhe, Harwell, Bremen, Bialystok, East Trout Lake, Sodankyla, nyAlesund, Eureka

OCO-3 v11

ΔX_{CO2} (OCO-3 - TCCON) [ppm]

Land Nadir/Glint
Ocean Glint
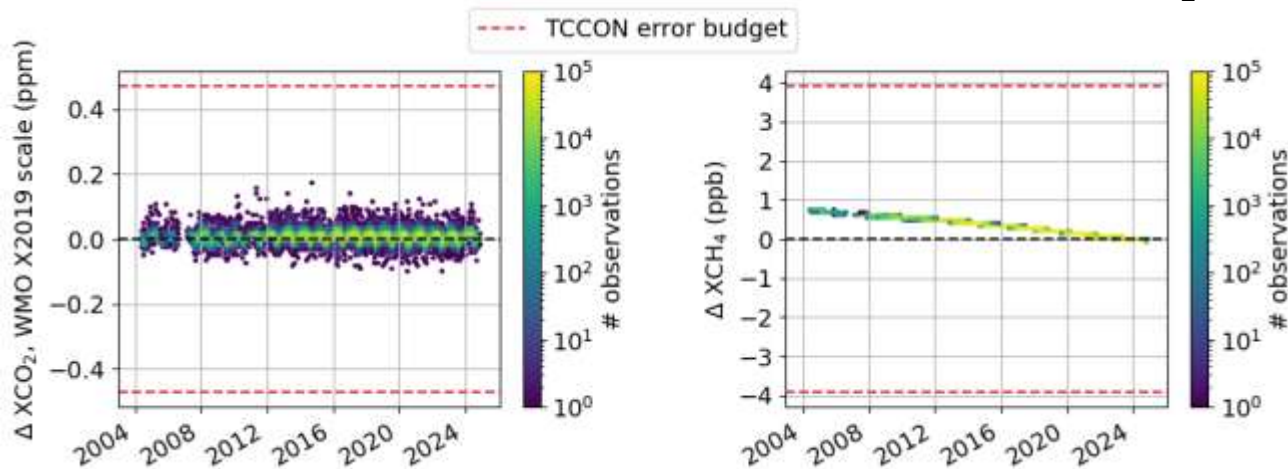SAM
Target

Outliers: SAMs over Hefei, Xianghe

Comparisons with TCCON are stable across the record. (Das et al. (2025), in prep)

See S. Das/M. Sha talk on Tuesday!

TCCON GGG2020.1 status

Changes to Xgases from implementation of time-varying O_2 DMF

Progress:
- ✓ Consistent time-varying O_2 DMF for all Xgases
- ✓ N_2O T-dependent bias reduction
- ✓ Track use of alternate CO priors
- ⧗ Upgrade public file creation to support above
- ⧗ Generate alternate pre-Apr 2024 CO priors

Changes to XN_2O from implementation of T-dependent bias reduction
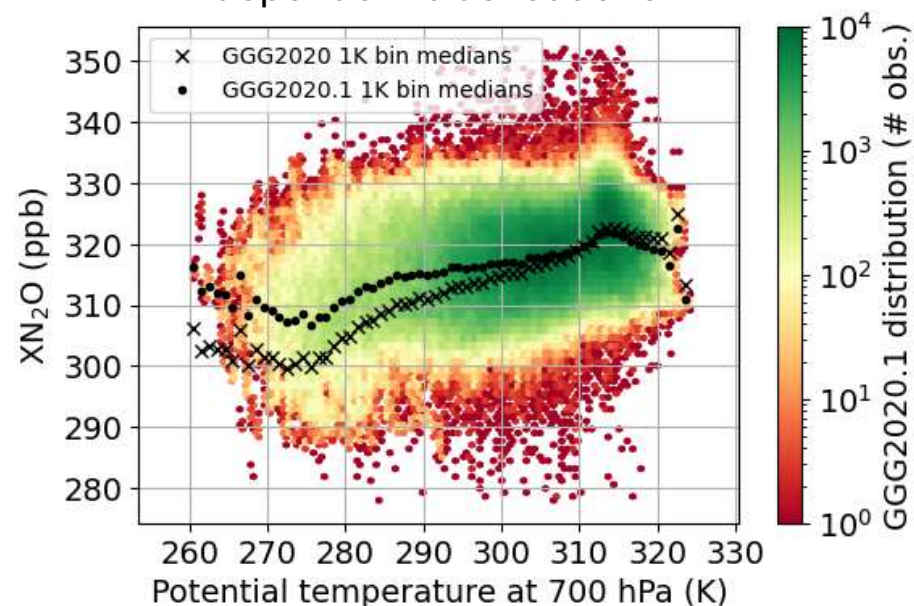
- Impact of new time-varying O_2 DMF is much smaller than the TCCON error budget, benefit is to long timeseries analyses
- XN_2O bias reduction reduces temperature dependence in the common temperature ranges, future work needed to address the coldest temperatures

- Updating TCCON infrastructure to ensure that the GGG2020 to GGG2020.1 processing is applied correctly is taking longer than expected
  - First of three components almost complete
- Aiming now to have development complete by Sep. 2025.
- Sites that wish to use improved CO priors will need time after the GGG2020.1 release to reprocess

"Can I use OCO-2 and OCO-3 together?"

Yes!

- Direct comparisons for XCO2:
  - **OCO-3 v11 agrees with OCO-2 v11.2 to better than 0.5 ppm for co-located soundings**
  - **This is well within the agreement of either sensor with TCCON.**
  - Taylor et al. (2025), in prep
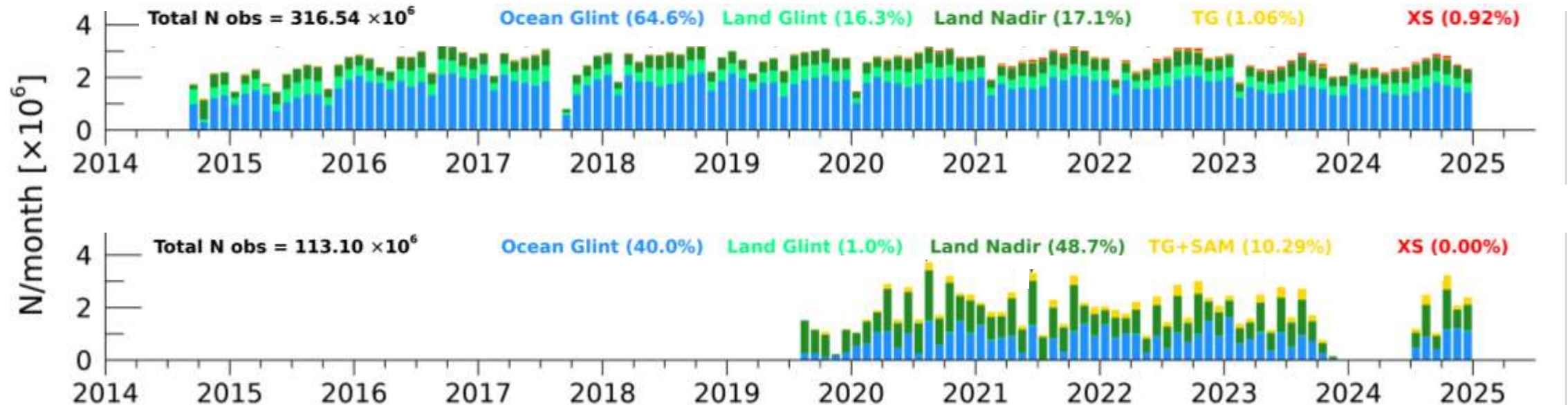
Closing remarks

- **OCO-2 and OCO-3 are both in excellent health**

- With OCO-2 v11.2 and OCO-3 v11, L2 products are now in step

- Accuracy and precision of XCO_2 products:
  - < 1 ppm for **both missions**

- Characterization of a new instrument/data product can take some time….

- XCO_2 and SIF datasets from OCO-2 and OCO-3
  - Shining new light on **natural** and anthropogenic components of carbon cycle

- **Length of the record and quality of the data products are key**
  - Particularly for studies of the natural carbon cycle