# Update on Validation of OCO-2 Observations of Column-Averaged Mole Fractions of Carbon Dioxide (XCO2)

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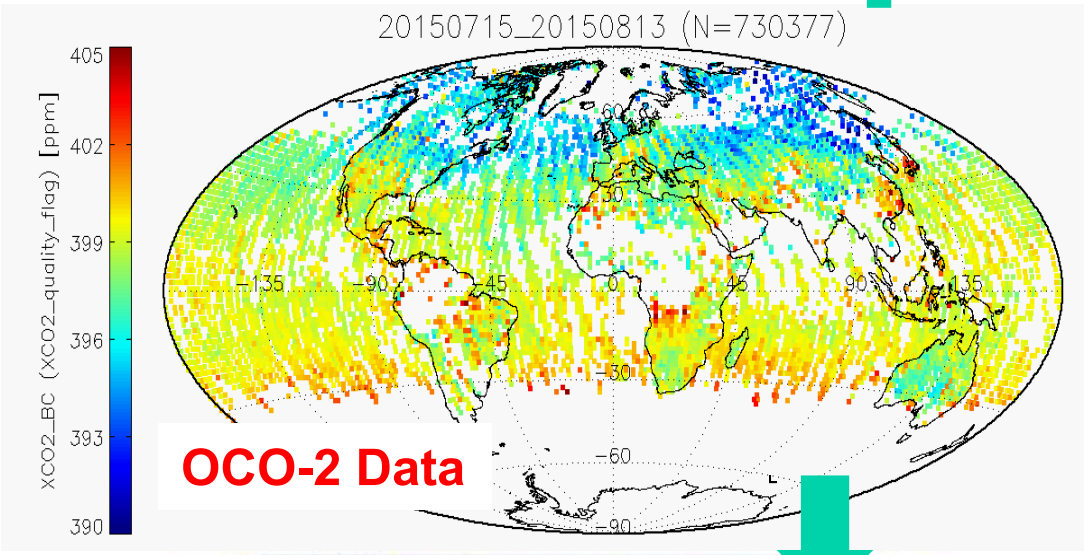
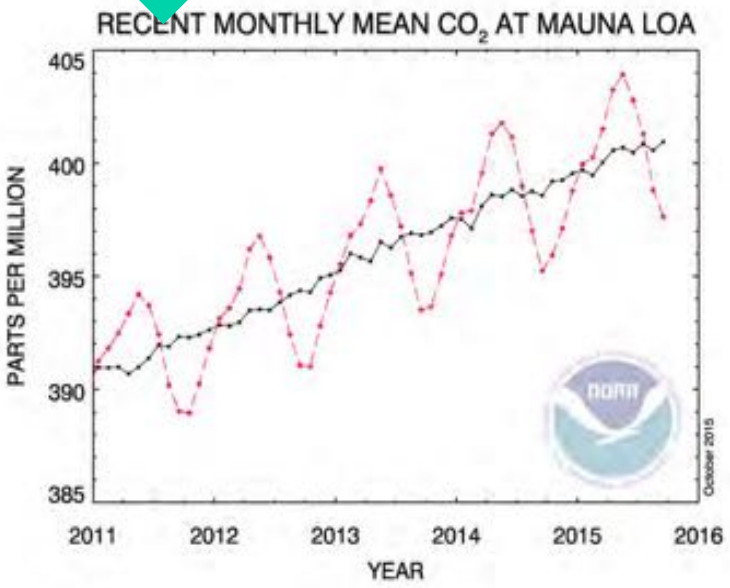
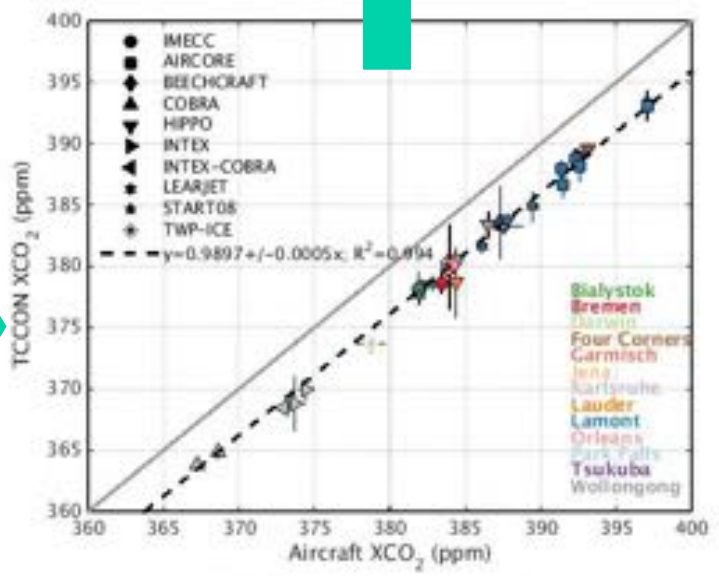
# OCO-2 Validation Plan

NOAA Surface Data
(WMO Standard)








Aircraft Data (WMO Standard)



Watching the Earth breathe.... mapping CO2 from space.
Orbiting Carbon Observatory

# OCO-2 Target Mode Observations & Updates

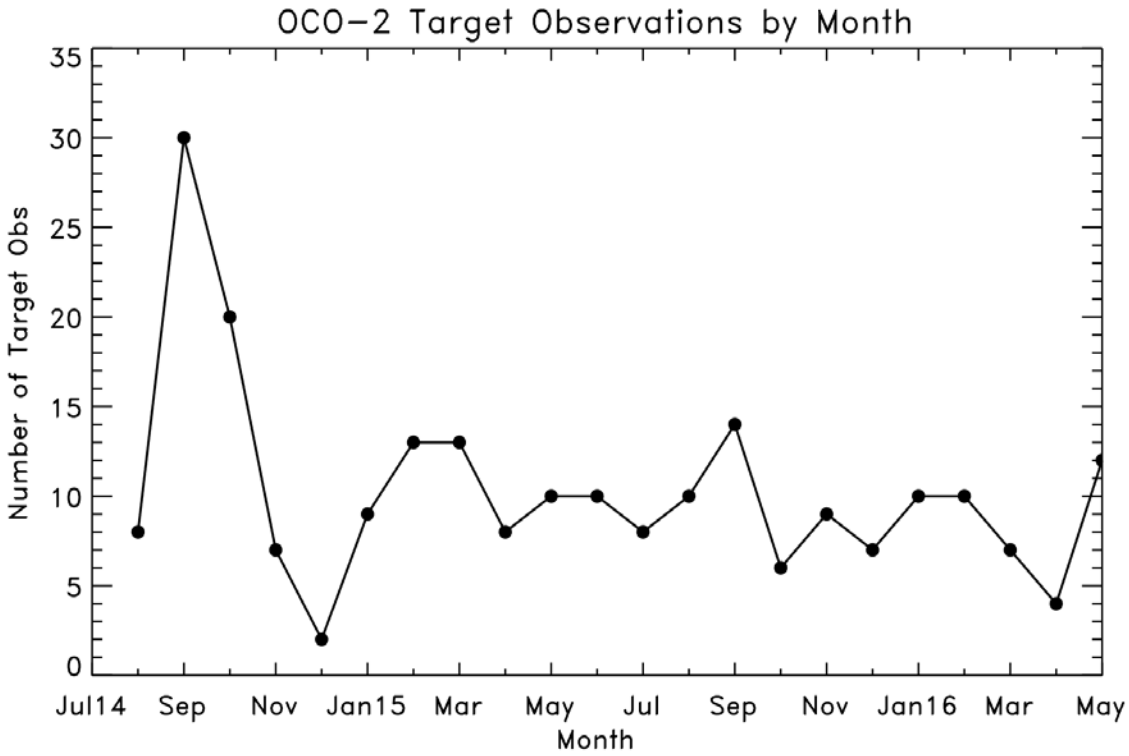
Jet Propulsion Laboratory
California Institute of Technology

| Site | # Obs | May 2016 | Last Obs |
|---|---|---|---|
| Anmyeondo | 3 | 1 | 2016-05-19 04:46:57 |
| Ascension Island | 5 | 0 | 2015-02-24 14:39:01 |
| Bialystok | 7 | 0 | 2016-02-17 11:02:22 |
| Boulder | 0 | 0 | None |
| Bremen | 2 | 1 | 2016-03-17 12:10:17 |
| Caltech | 14 | 0 | 2015-08-21 21:15:08 |
| Darwin | 12 | 0 | 2016-05-22 05:04:16 |
| Dryden (Armstrong) | 13 | 0 | 2016-02-24 20:56:40 |
| Eureka | 4 | N/A | 2015-06-28 17:06:58 |
| Izana | 4 | 0 | 2016-02-22 14:31:29 |
| Karlruhe | 7 | 1 | 2016-05-07 12:40:13 |
| Lamont | 23 | 1 | 2016-05-05 19:25:02 |
| Lauder | 14 | 0 | 2016-04-10 02:39:40 |
| Manaus | 4 | 0 | 2015-07-29 17:40:51 |
| Mexico City | 3 | 0 | 2016-01-24 19:56:38 |
| Orleans | 12 | 0 | 2016-01-21 12:58:01 |
| Paris | 2 | 1 | 2016-03-11 12:46:07 |
| Park Falls | 13 | 1 | 2016-05-18 18:56:21 |
| Poker Flat | 0 | 0 | None |
| Railroad Valley | 24 | 1 | 2016-05-14 20:59:48 |
| Reunion Island | 18 | 0 | 2016-05-11 10:17:10 |
| Rikubetsu | 1 | 0 | 2016-04-20 03:40:49 |
| Saga | 2 | 1 | 2016-03-02 04:33:27 |
| Sao Paulo | 1 | 0 | 2016-02-03 17:03:55 |
| Shanghai | 3 | 0 | 2016-02-07 05:22:09 |
| Sodankyla | 5 | 1 | 2016-03-21 10:10:56 |
| Tsukuba | 11 | 1 | 2016-05-13 03:45:09 |
| Wollongong | 15 | 1 | 2016-05-16 03:57:22 |

- OCO-2 has executed 227 target observations since Aug 8, 2014
- In July 2015, new (additional) target sites were added:
  - TCCON/Future TCCON: Anmyeondo, Paris, Poker Flat, Rikubetsu, Saga
  - Megacities: Sao Paulo, Shanghai, Mexico City
  - AirCore: Boulder
  - Removed Eureka (Large number of coincidences in nadir/ glint mode due to high latitude location)
- In June 2016, more changes will be made:
  - Add Solar Induced Fluorescence Study Sites: Rosemount, MN and Litchfield, Australia
  - Add OCO-2 Calibration site in Libya
  - Remove Shanghai, Sao Paulo and Manaus
- We can switch out targets for a given orbit (two weeks ahead of time)
  - Example change Orleans to Paris
  - Both must be visible on given orbit
  - Should be transparent to TCCON partners (Notification process is the same)

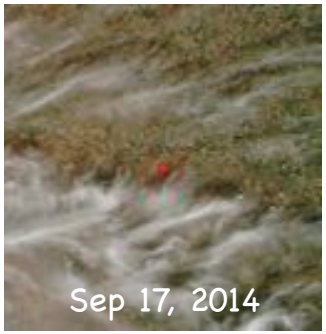
# Criteria for Target Selection

- Operational status of the possible TCCON site
- Weather forecast at the time of target
- Operation mode of the OCO-2 satellite (i.e., nadir or glint)
  - Paths near Reunion Island observed in nadir mode return little data – more likely to attempt a target
- Targeting statistics for the TCCON site
  - How many times has it been targeted?
  - Has it been targeted recently?
  - Is there a seasonal aspect to its availability?
  - Attempting to get most sites at least on a seasonal basis (weather or TCCON/OCO-2 operational status can preclude



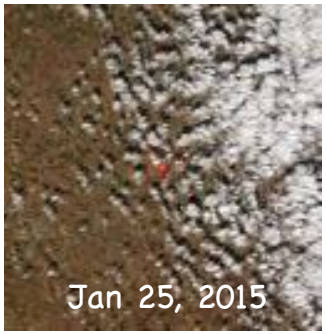
# Target Observations at Lamont (23)

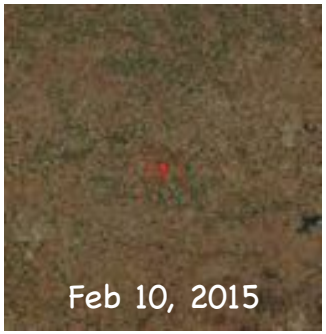


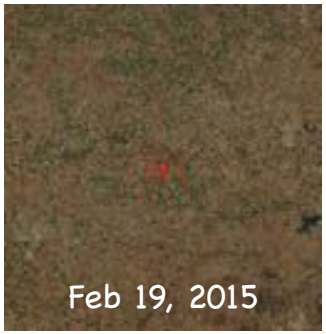



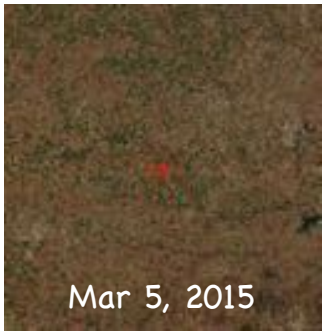


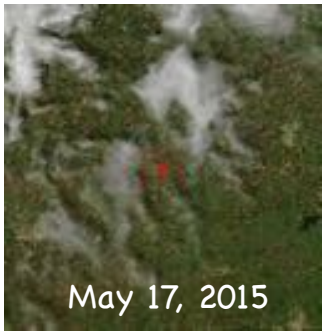




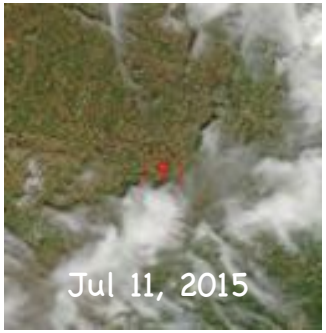



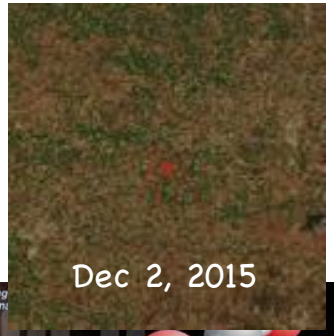



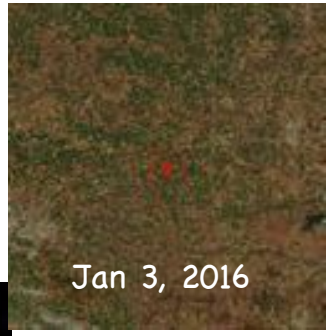


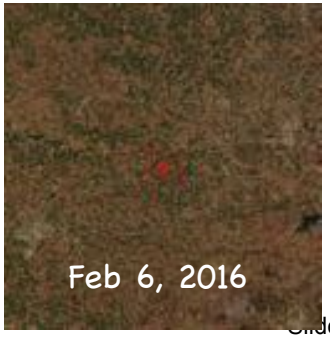






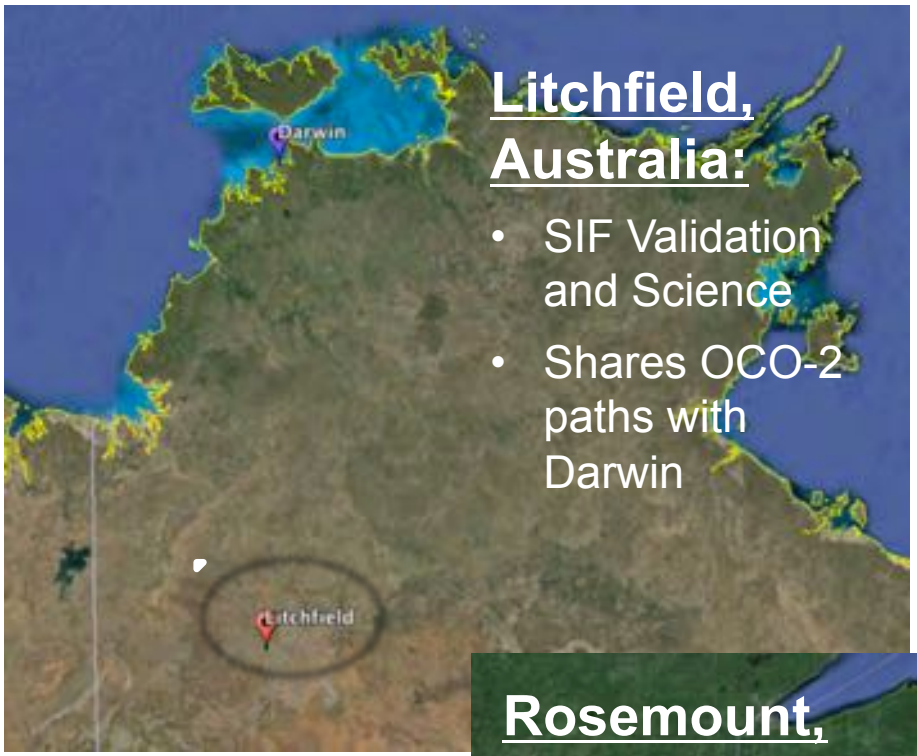





# OCO-2: New Target Locations

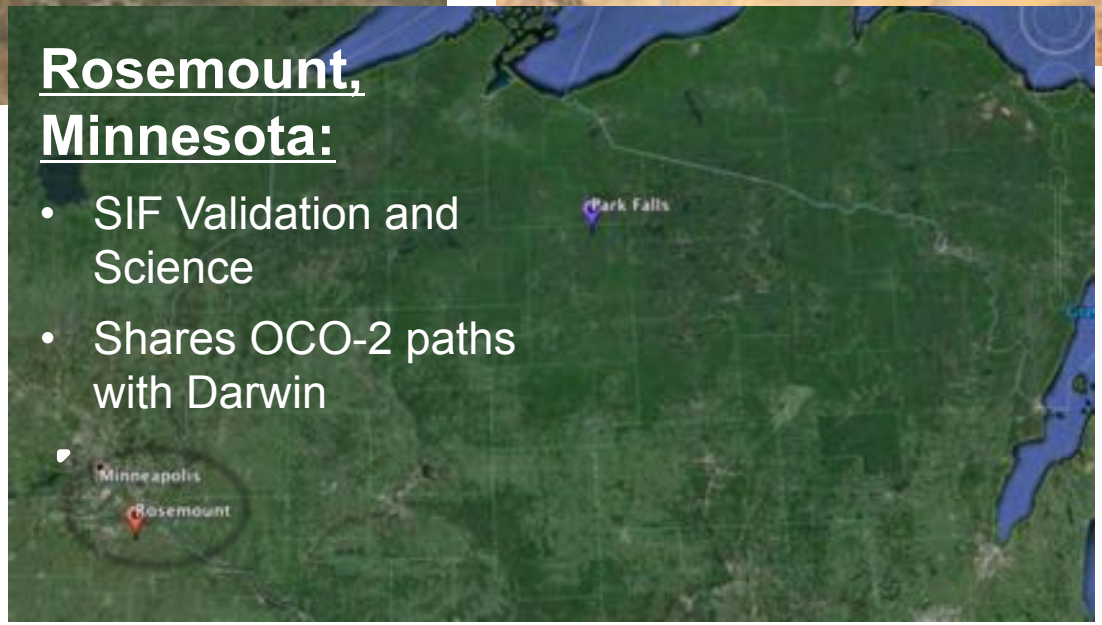



## Litchfield, Australia:

- SIF Validation and Science
- Shares OCO-2 paths with Darwin


## Libya:

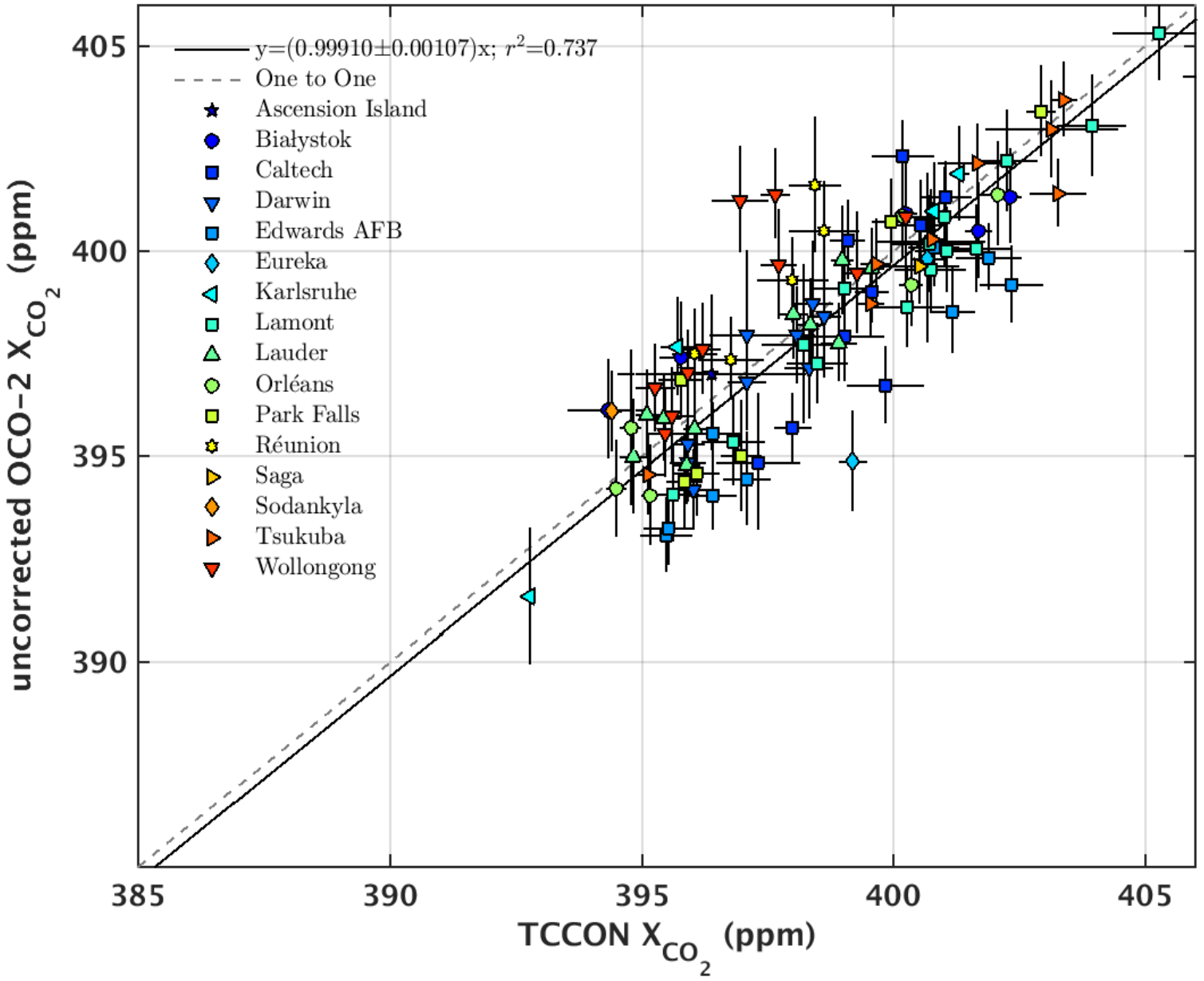
Provides another set of target data for calibration studies



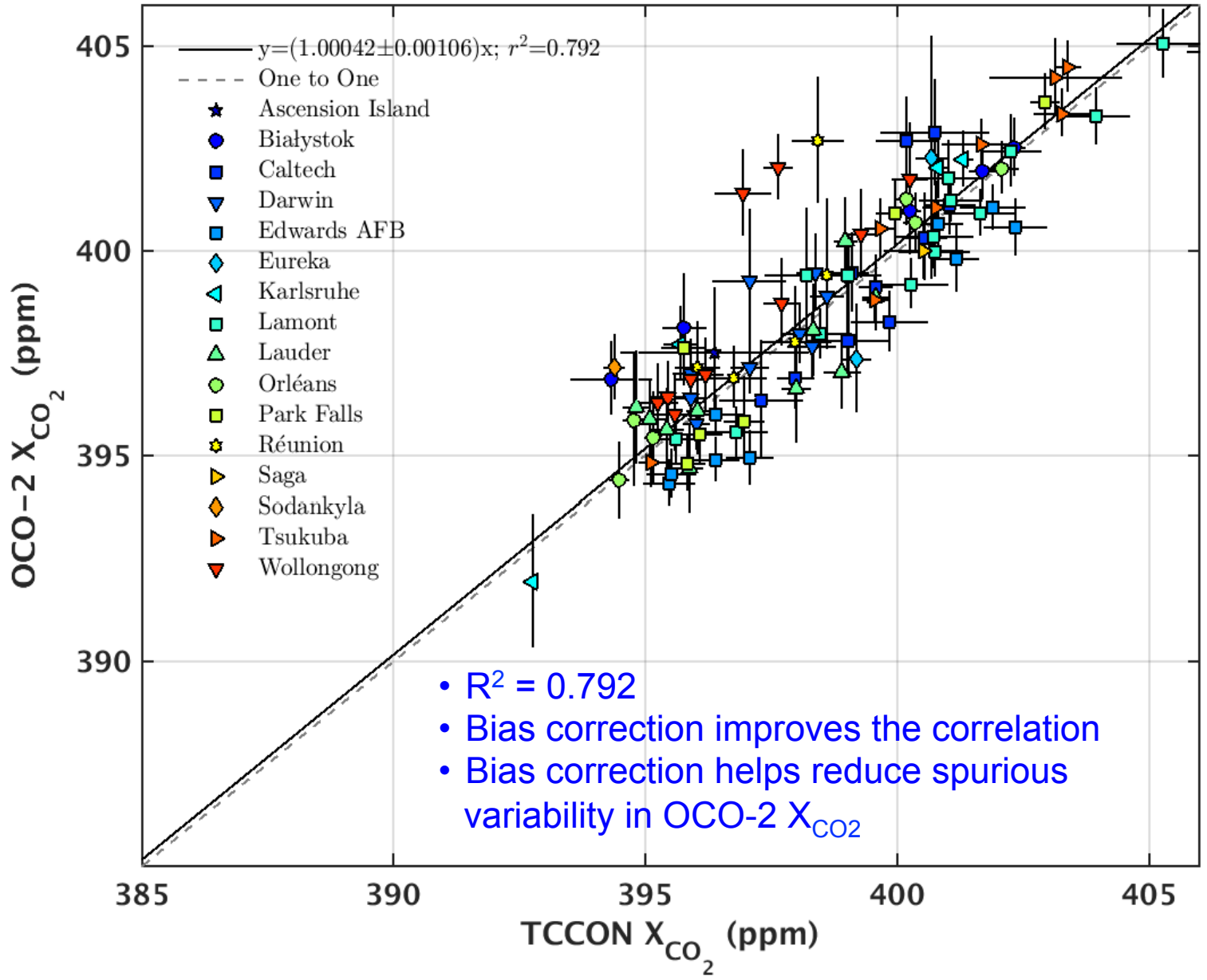

## Rosemount, Minnesota:

- SIF Validation and Science
- Shares OCO-2 paths with Darwin

# OCO-2 Comparison to TCCON Target Mode – No Bias Correction

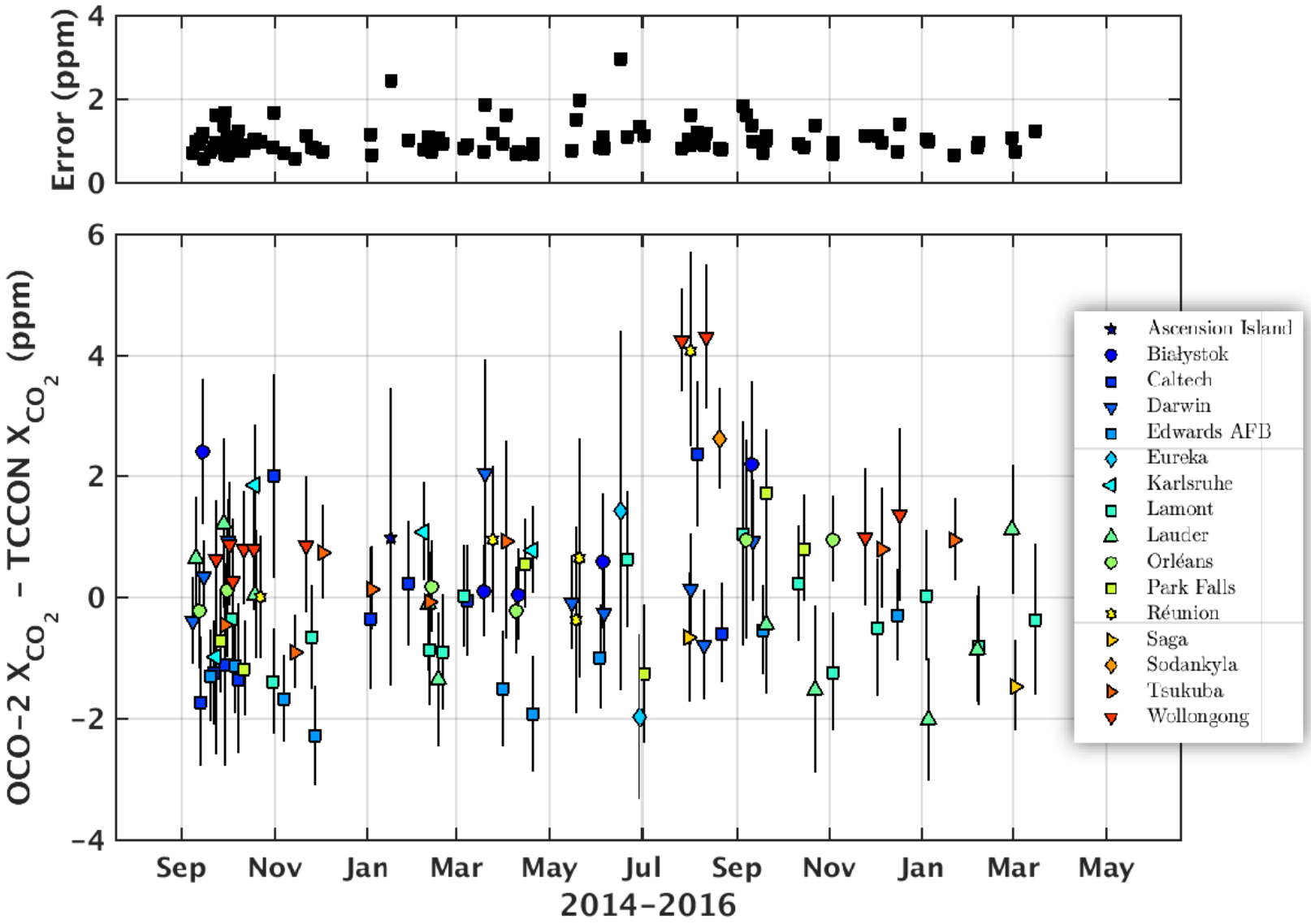


# OCO-2 Comparison to TCCON Target Mode – Bias Corrected



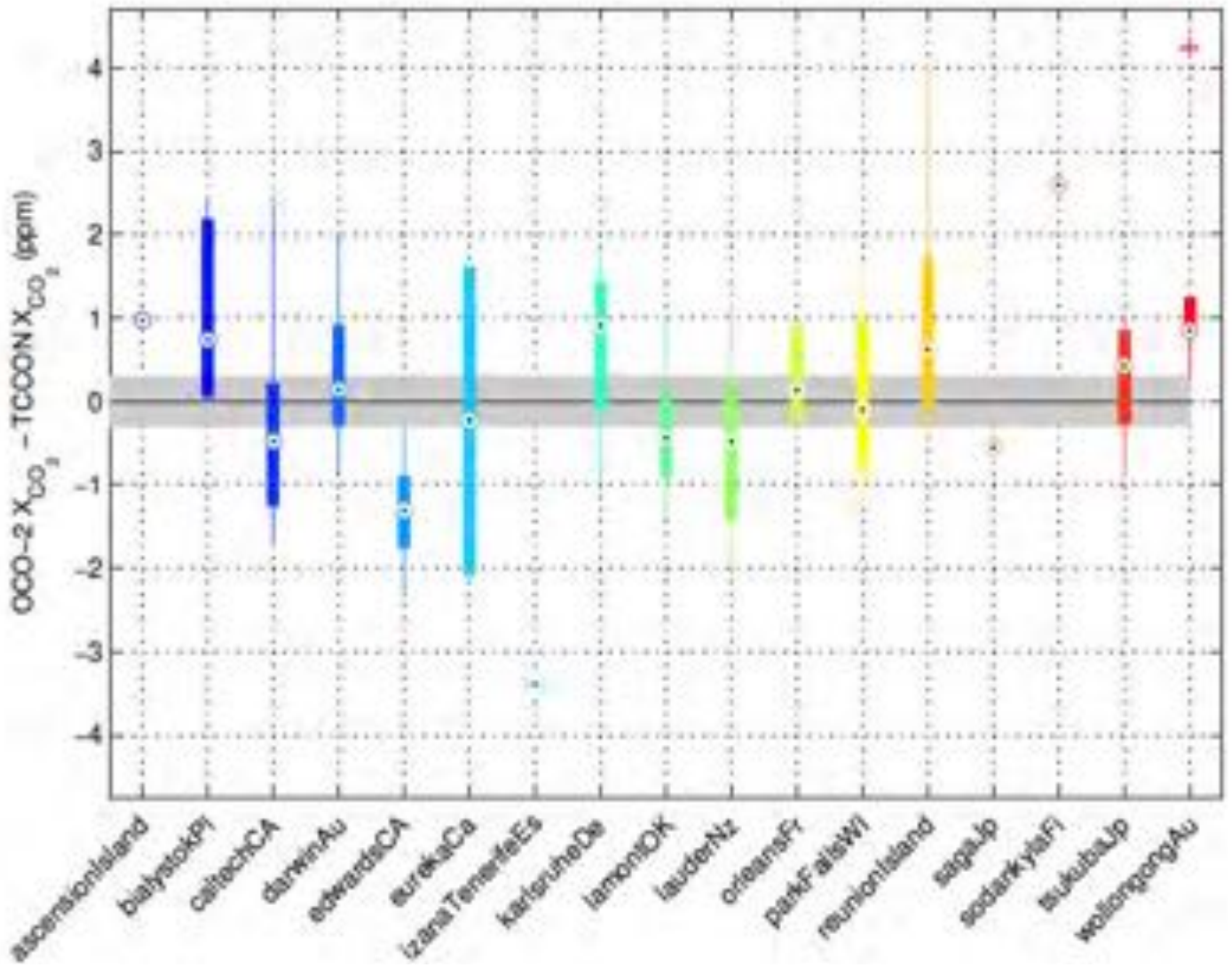

- $R^2$ = 0.792
- Bias correction improves the correlation
- Bias correction helps reduce spurious variability in OCO-2 $X_{CO2}$

# OCO-2 Comparison to TCCON Target Mode – Time Series



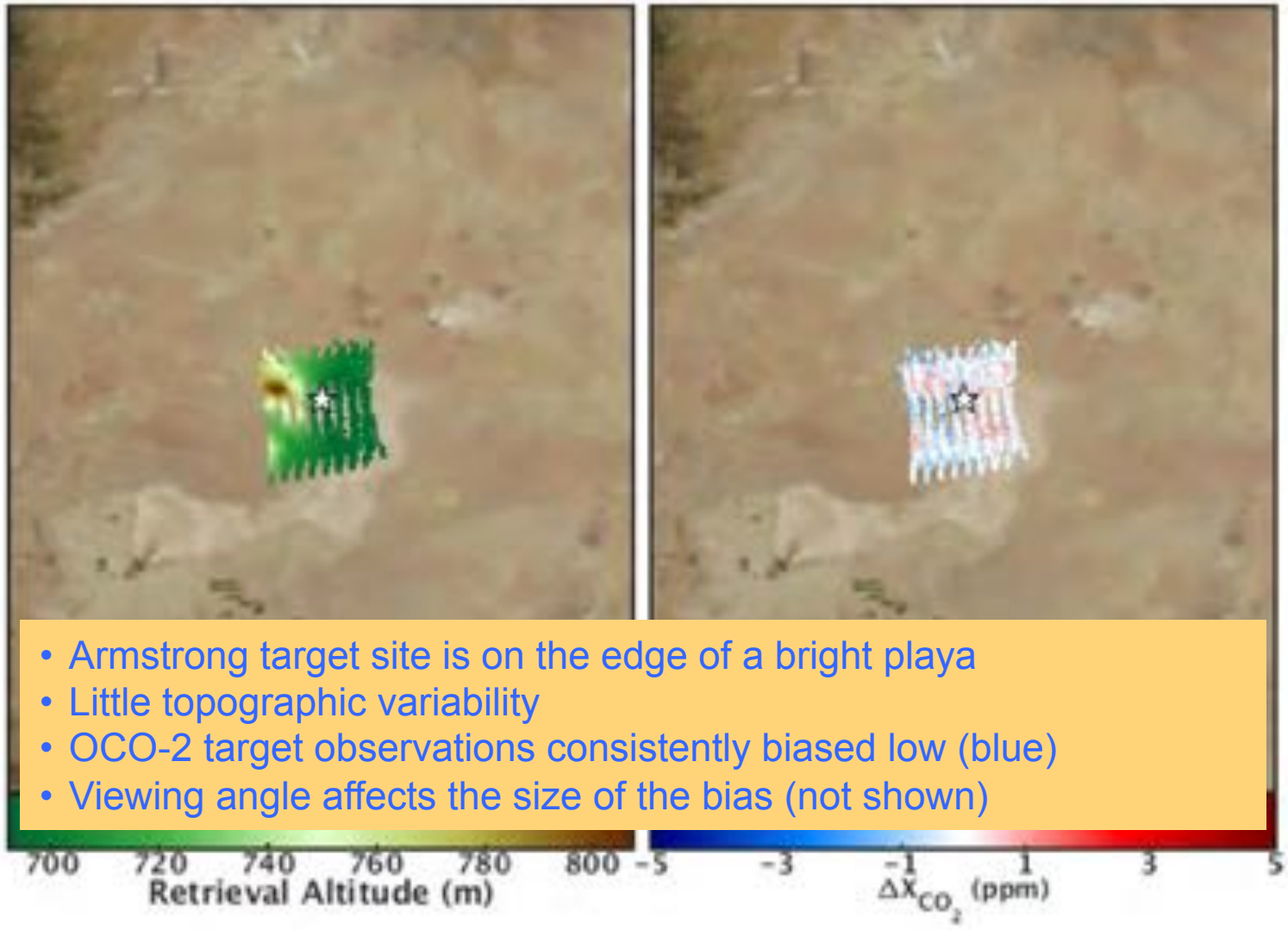

**There is no clear time dependence in $\Delta X_{CO_2}$ or in the errors**

# OCO-2 Comparison to TCCON Target Mode – By Station



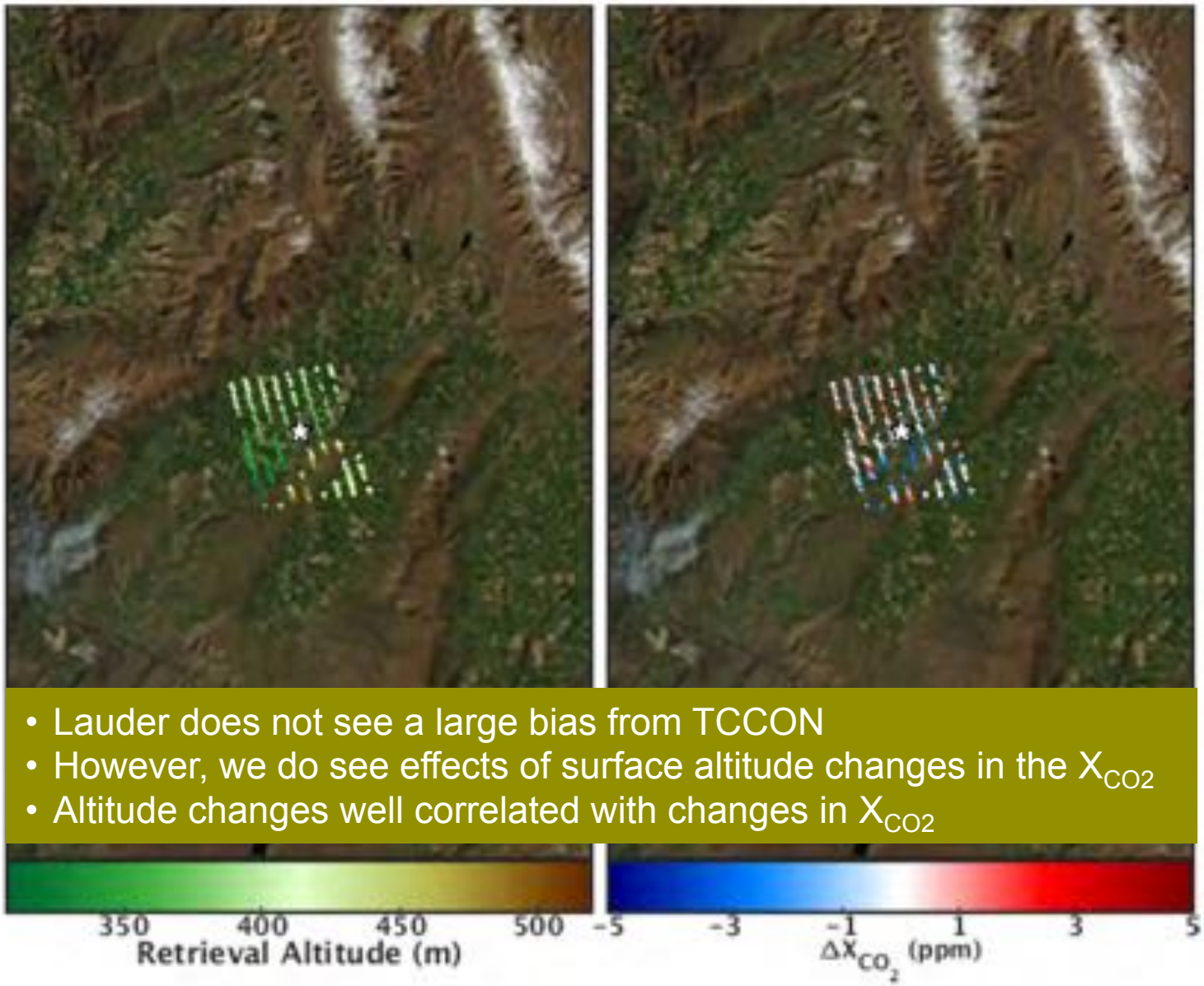

- Site dependent differences from the “One to One” plot
- Differences < 0.3 ppm could be attributable to TCCON site to site biases
- Sites with possible surface property related biases: Armstrong/Edwards and Wollongong

# Target Observation – Armstrong FRC



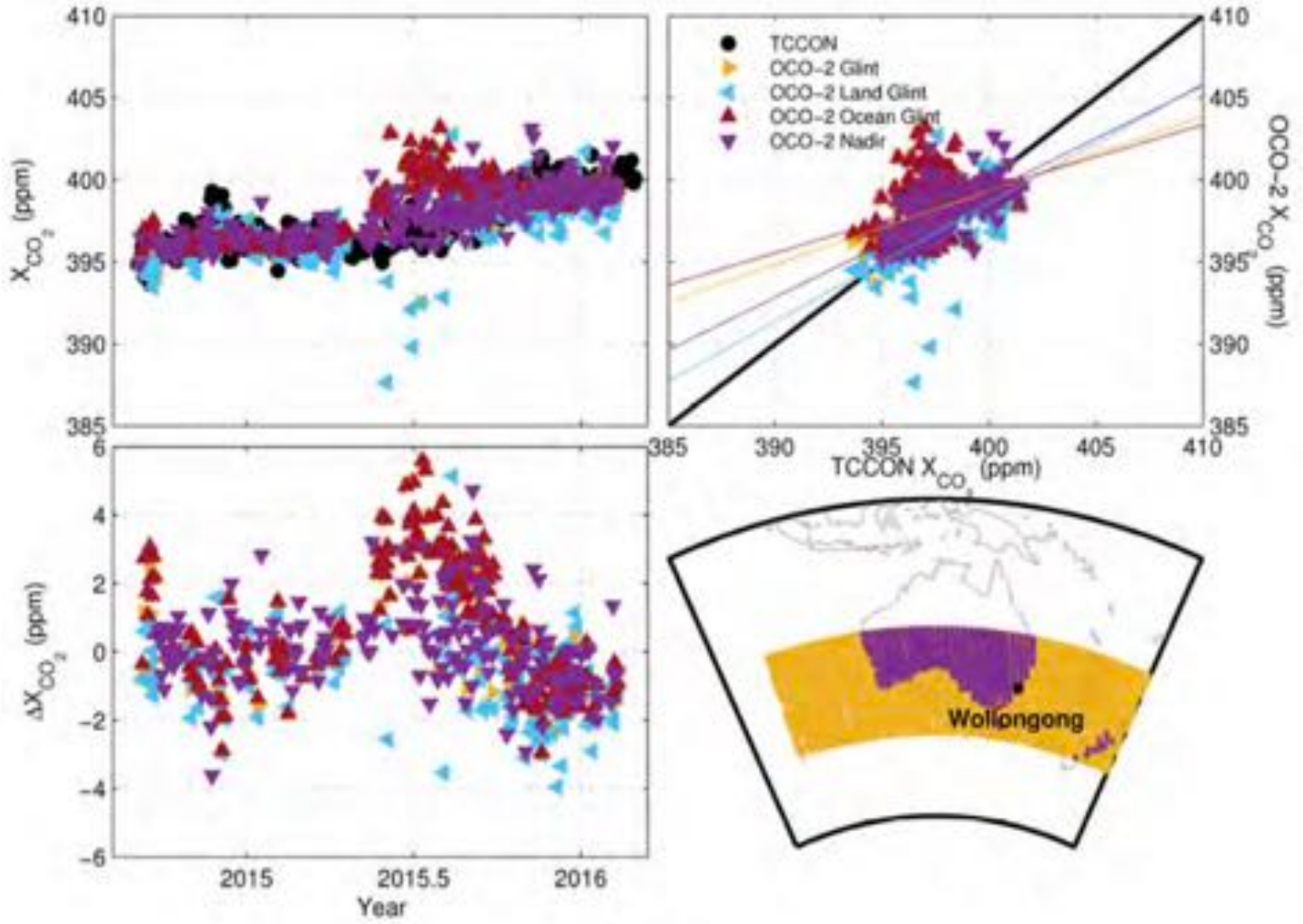

- Armstrong target site is on the edge of a bright playa
- Little topographic variability
- OCO-2 target observations consistently biased low (blue)
- Viewing angle affects the size of the bias (not shown)

# Target Observation – Lauder



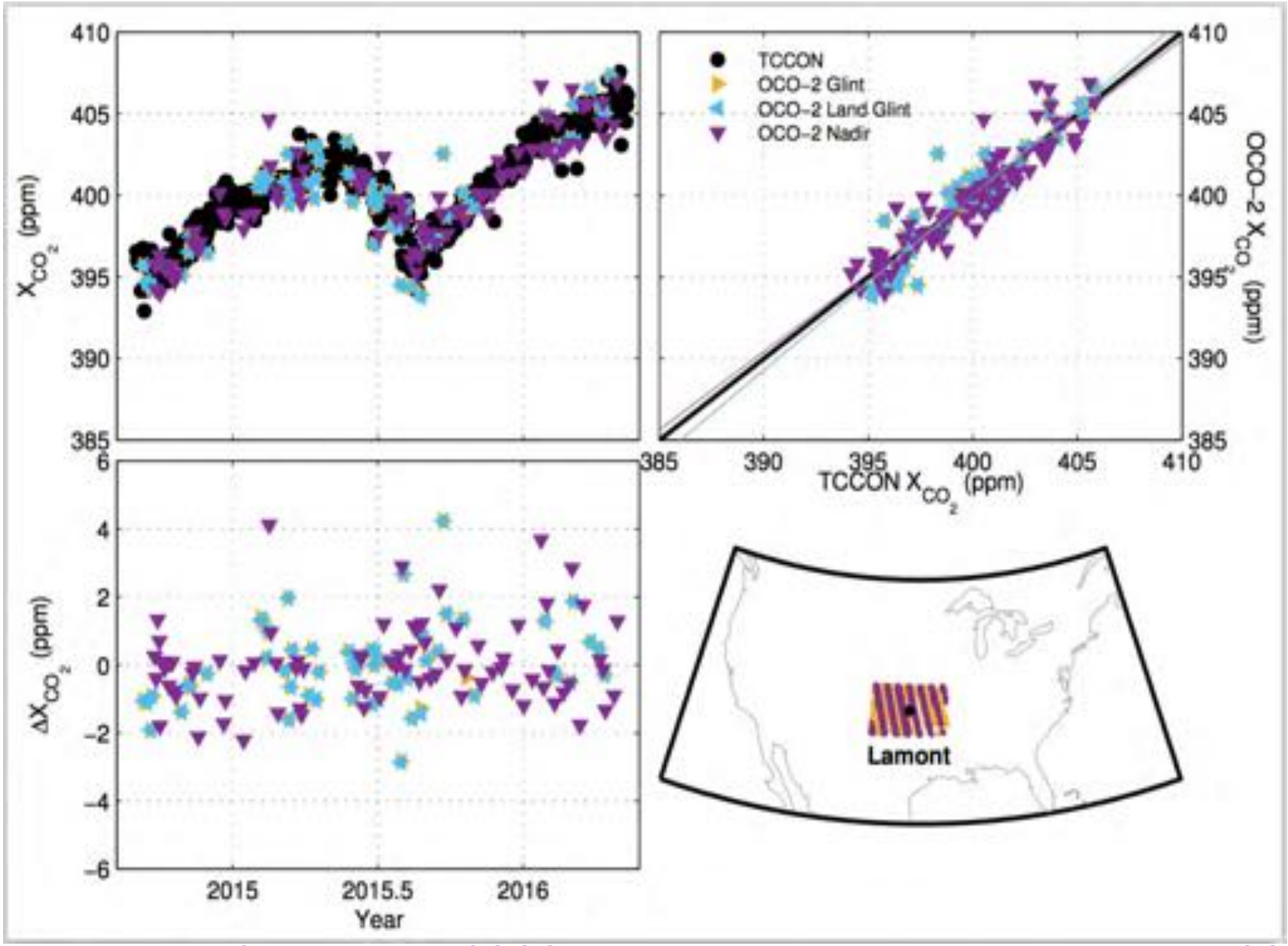

- Lauder does not see a large bias from TCCON
- However, we do see effects of surface altitude changes in the $X_{CO2}$
- Altitude changes well correlated with changes in $X_{CO2}$

# OCO-2 Comparisons of Glint and Nadir Data to TCCON Data - Wollongong



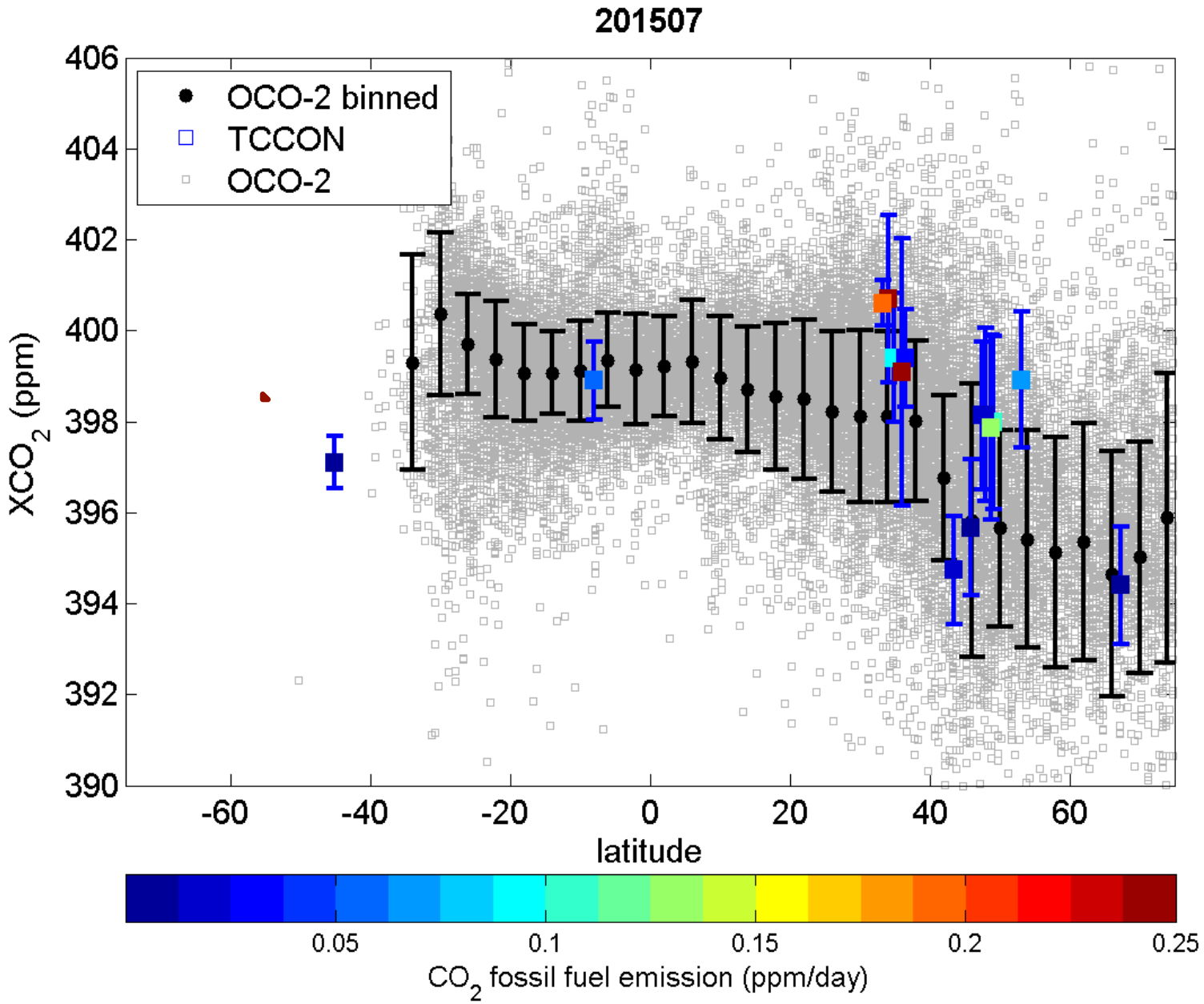

- Comparison of OCO-2 glint/ocean, glint/land and nadir data to TCCON
- Helped show bias in high latitude glint/ocean data during July-Sep 2015

# OCO-2 Comparisons of Glint and Nadir Data to TCCON Data - Lamont




- More typical of comparison of OCO-2 glint/ocean, glint/land and nadir data to TCCON

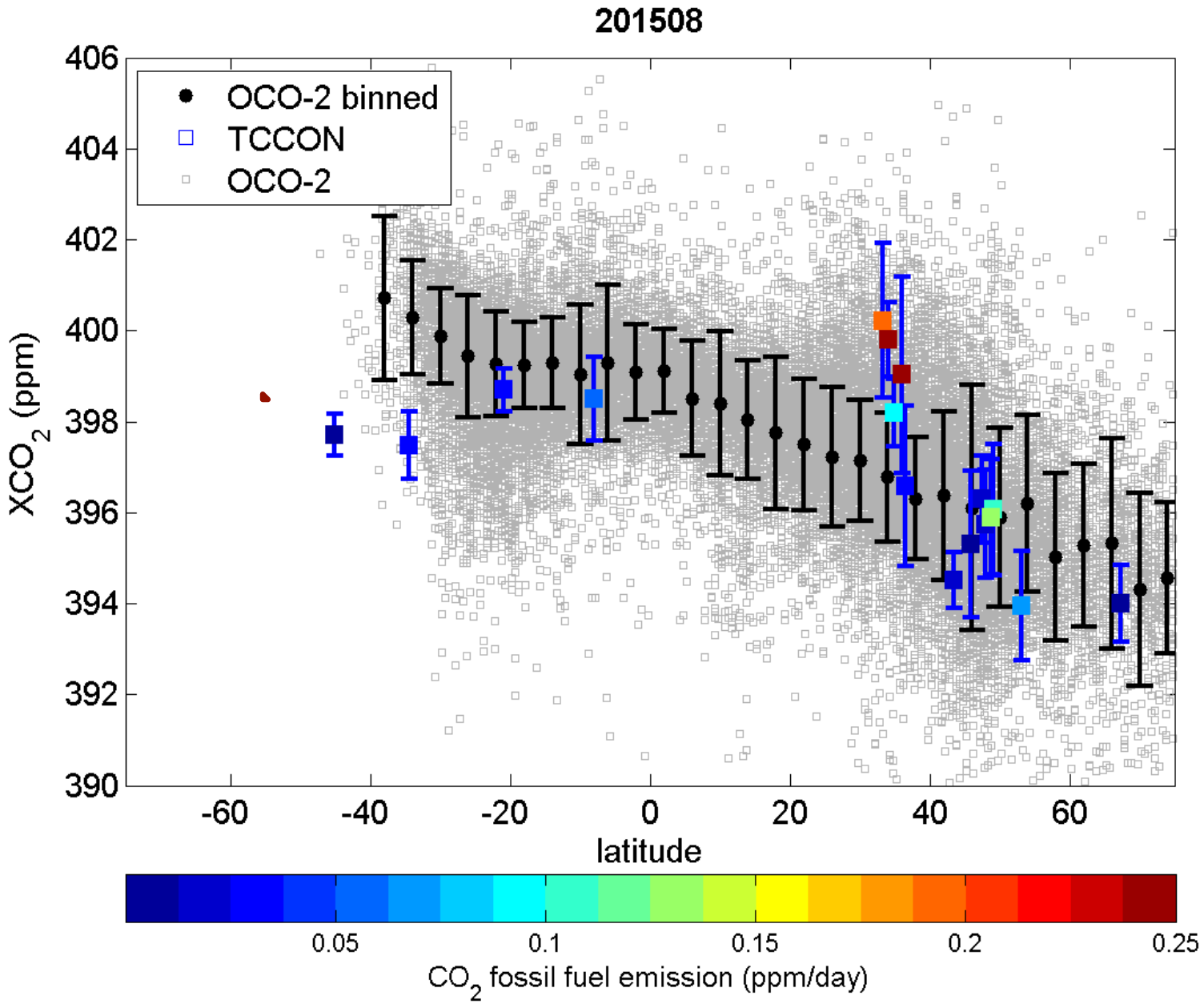
# OCO-2 and TCCON – Latitude Plots
# July 2015



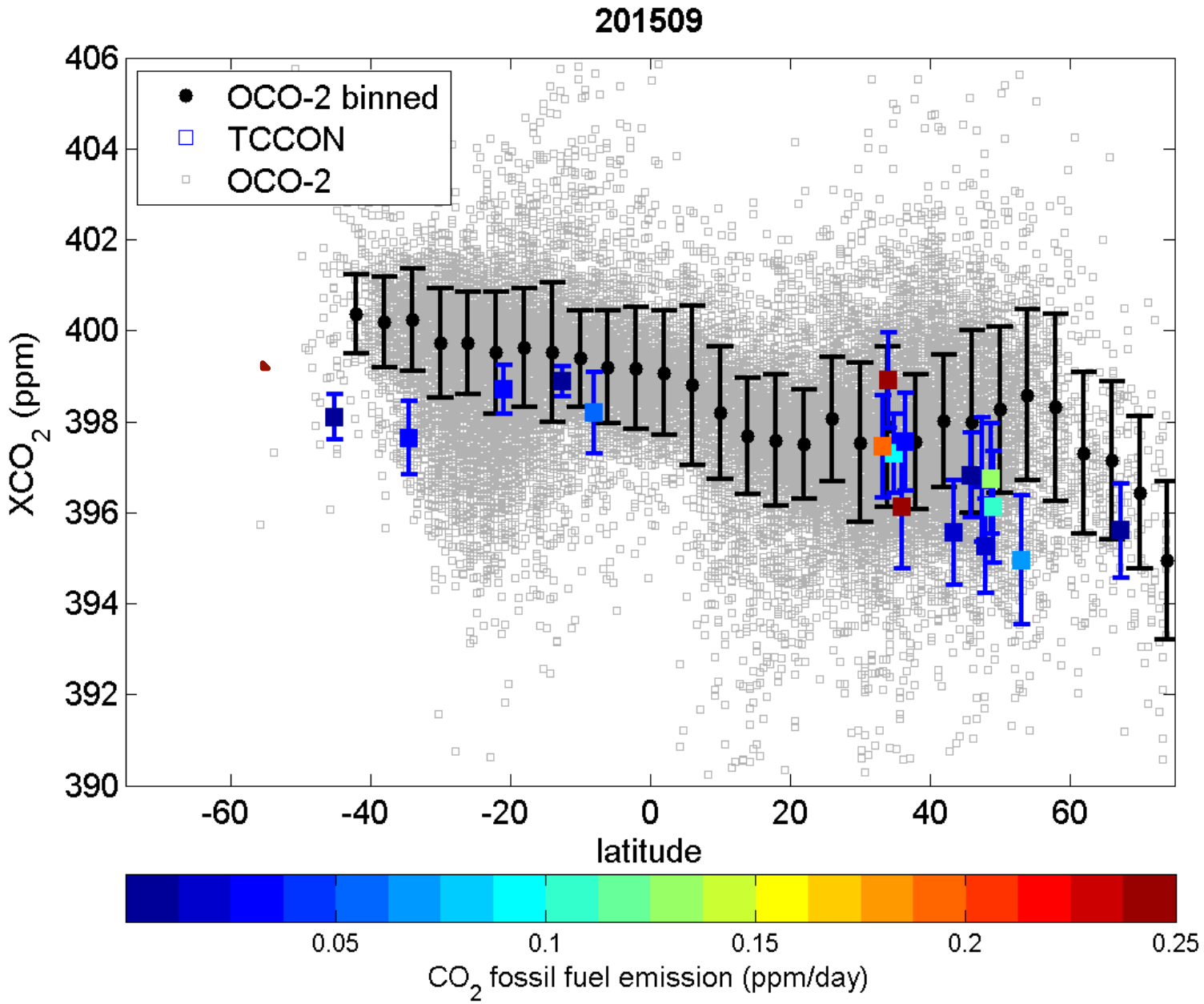

TCCON monthly means (squares) colored by estimated CO2 emissions with 50 km of site

Illustrates the SH bias in the glint data

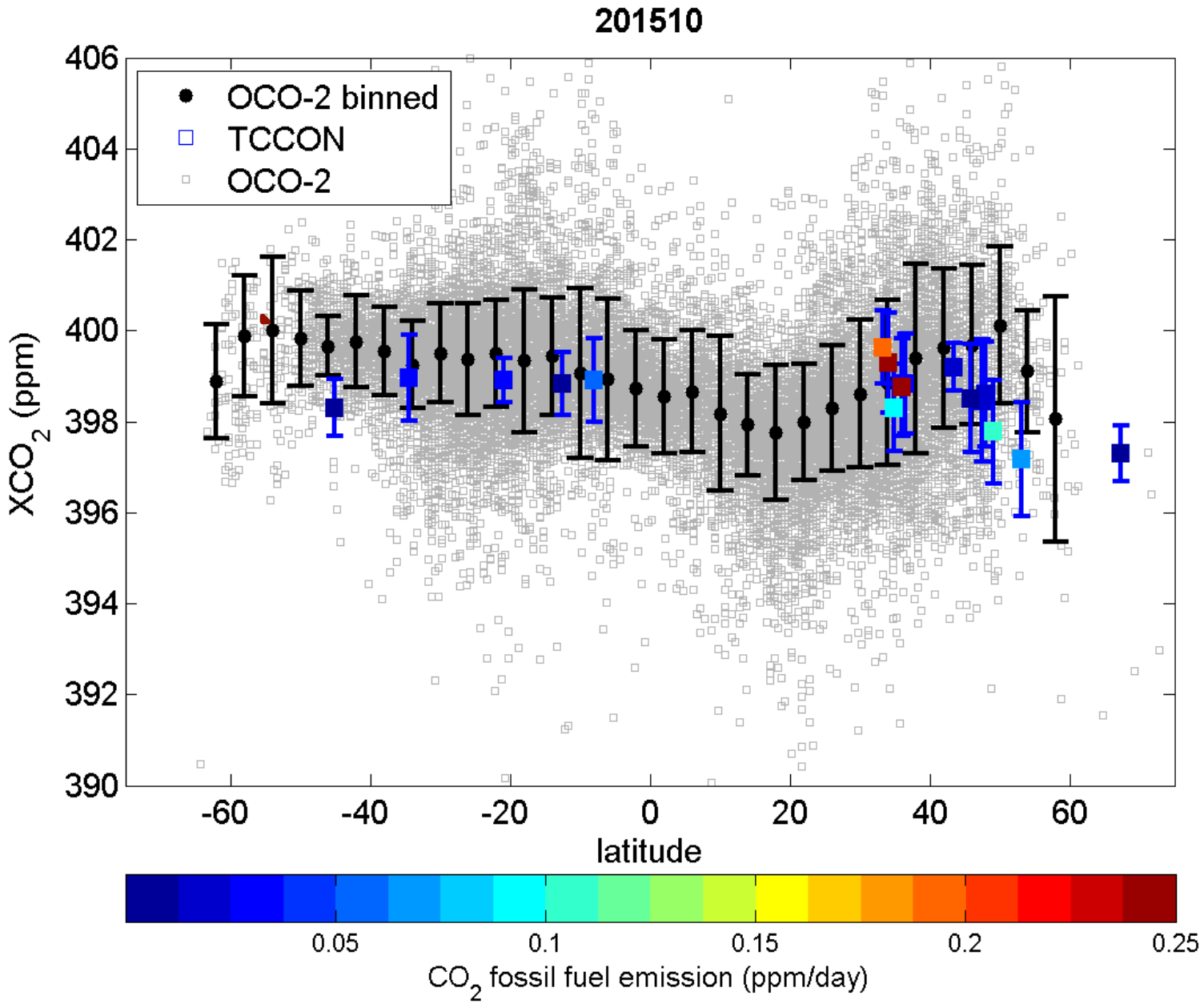
# OCO-2 and TCCON – Latitude Plots
# August 2015



# OCO-2 and TCCON – Latitude Plots September 2015



# OCO-2 and TCCON – Latitude Plots
# October 2015



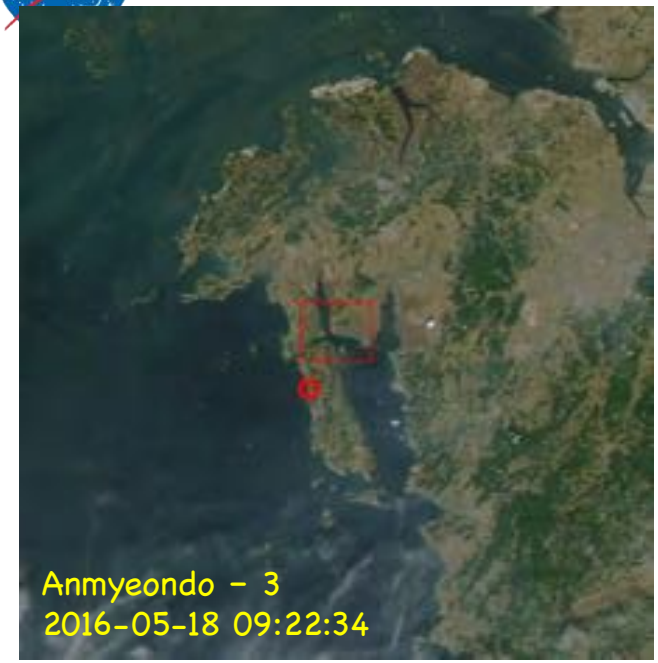
# Summary

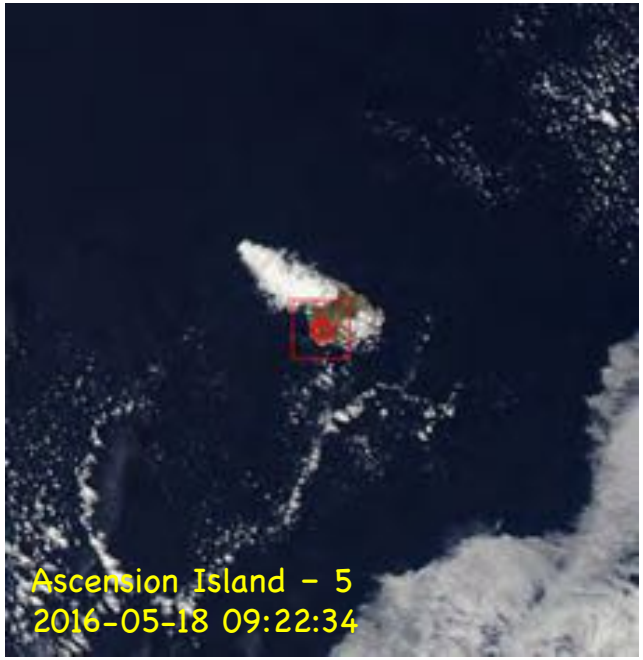
- Comparisons to TCCON data are the basis for the OCO-2 Validation Plan
- The correlation between non-bias corrected OCO-2 data and TCCON is ~ 0.7
- Correlation is improved (~0.8) with bias correction (Mandrake et al., 2015)
- Bias correction helps reduce spurious variability in OCO-2 $X_{CO2}$
- There is no clear time dependence in $\Delta X_{CO2}$ or in the errors
- Site dependent differences < 0.3 ppm could be attributable to TCCON site to site biases
- Larger differences are seen at sites with possible surface property related biases: Armstrong/Edwards and Wollongong
- Comparisons at Lauder show effects of surface altitude changes on the $X_{CO2}$
- Armstrong target site is on the edge of a bright playa: OCO-2 target observations consistently biased low (blue)
- Comparison of OCO-2 glint/ocean, glint/land and nadir data to TCCON also very useful
  - Helped show bias in high latitude glint/ocean data during July-Sep 2015
- Continue to look at the TCCON comparisons with data from all OCO-2 modes
- Looking at model results to help pinpoint other possible issues

# OCO-2 Science Team Activities: Validation

- Aircraft Campaigns (Past, Current and Future)
  - HIPPO: 2009-2011
  - FLAGG-MD: 2015
  - ORCAS: January 2016
  - KORUS-AQ: April – June 2016
  - AJAX Flights (California and Western US): Several flights in Spring 2016 and more planned in 2016
  - JPL CFIS Instrument Campaigns: June
  - ACT-America: July 18 - August 28 and continues in 2017
  - ATom: July 28 - August 22 and continues in 2017
- Observational campaigns at Railroad Valley, Sodankyla, Manaus
- Analyses with portable FTS (EM-27)
- Comparisons to global models and model mean values
- Flux inversion group activities and feedback to Validation team

# OCO-2 Target Sites (TCCON)



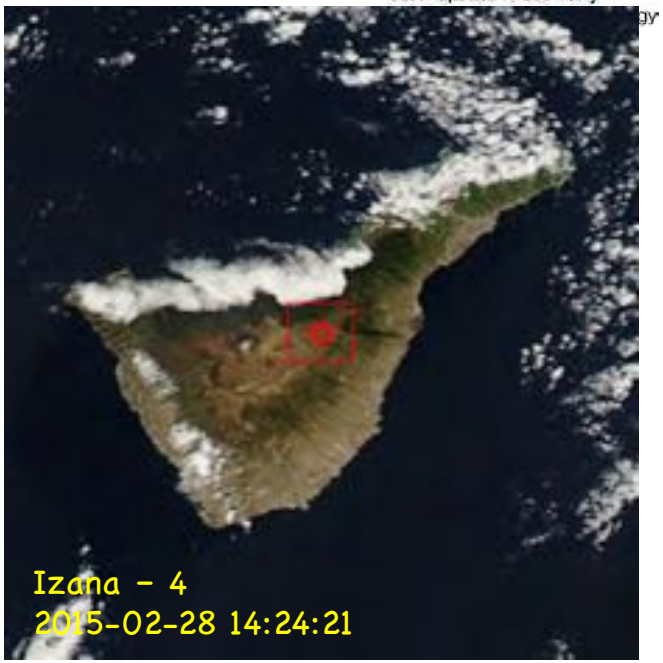







# OCO-2 Target Sites (TCCON)








# OCO-2 Target Sites (TCCON)



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