OCO-2 Science Team Telecon
11 April 2017

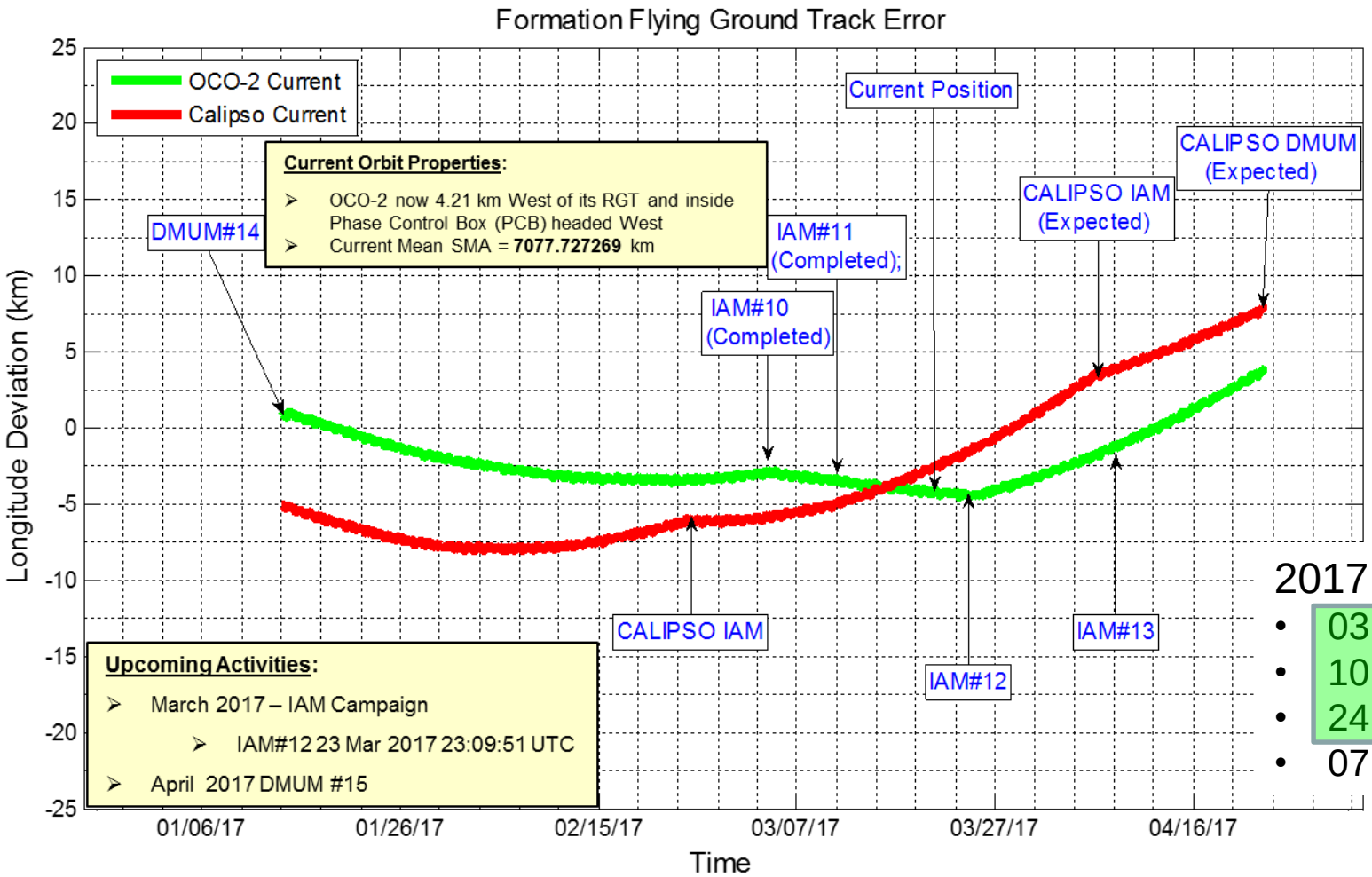
David Crisp for the OCO-2 Science Team
Jet Propulsion Laboratory, California Institute of Technology

Copyright 2017 California Institute of Technology.
Government sponsorship acknowledged.

OCO-2 Status

- Observatory Status: Nominal
  - Inclination Adjust Maneuver (IAM) Sequence in progress
    - First 3 completed, one left – April 7
- Instrument Status: Nominal
  - Recovery from February 21 – March 1, 2017 Decon nominal
- Science and Validation
  - Science Team Meeting 21-23 March
  - V8 testing continues
    - Tests to go – BRDF (final), ZLO correction, Pointing, Cirrus prior
    - New issue – a possible pointing offset?

OCO-2 and CALIPSO Ground Tracks

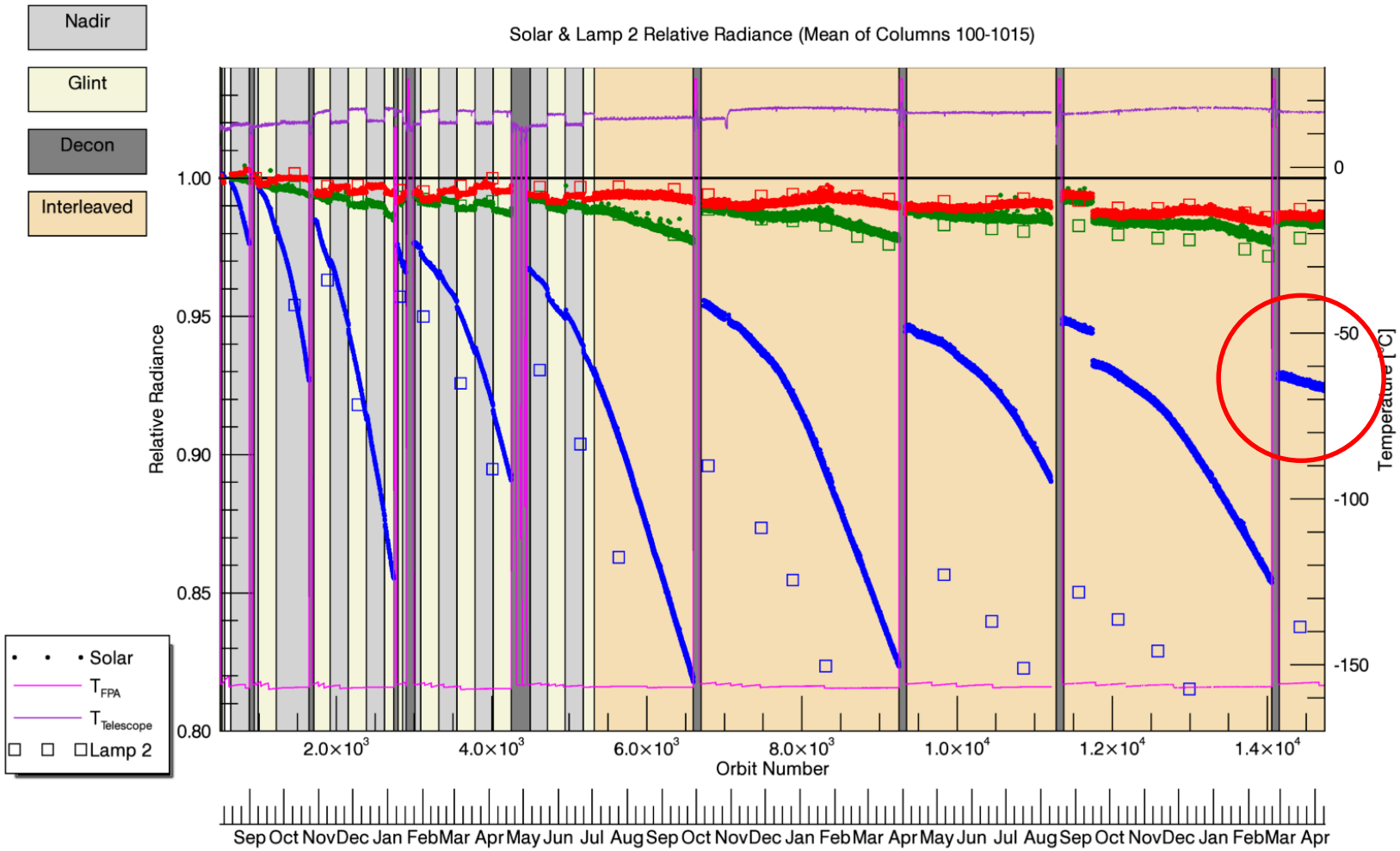


2017 IAM Schedule

- 03 Mar 00:29:12
- 10 Mar 00:35:31
- 24 Mar 00:48:30
- 07 Apr 01:02:49

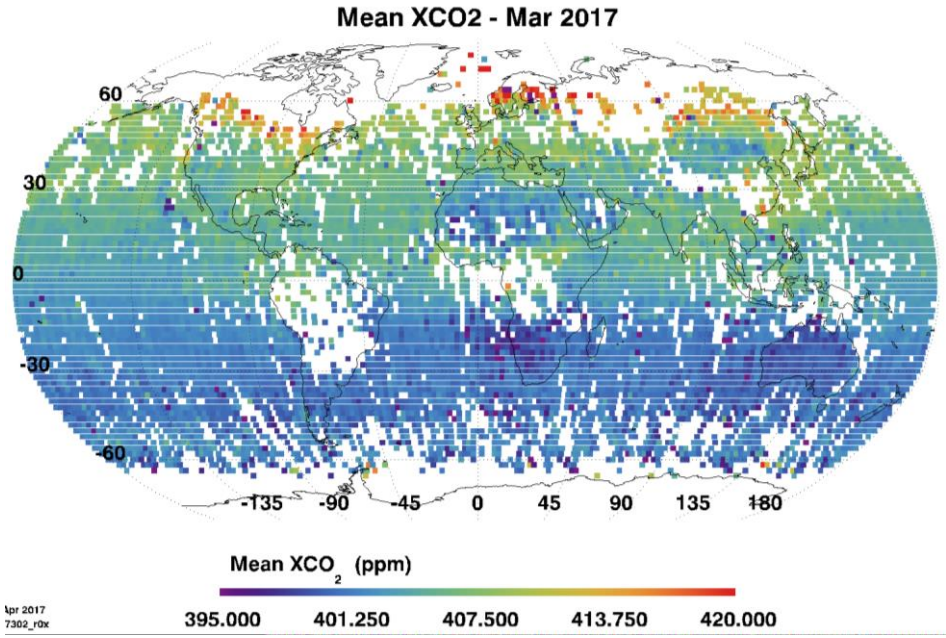
The 2017 IAM series is progressing as planned.

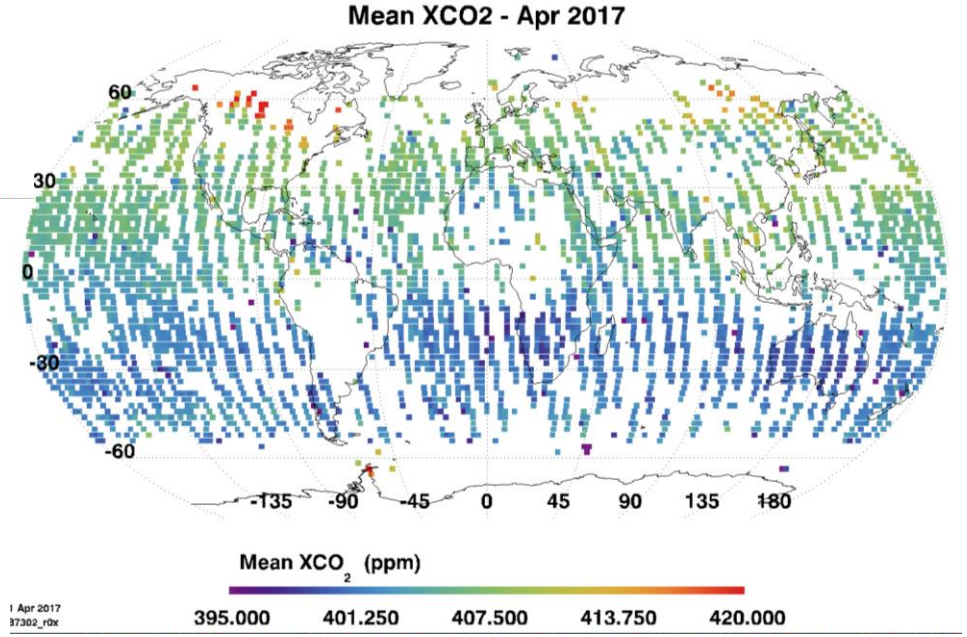
OCO-2 Instrument Trending



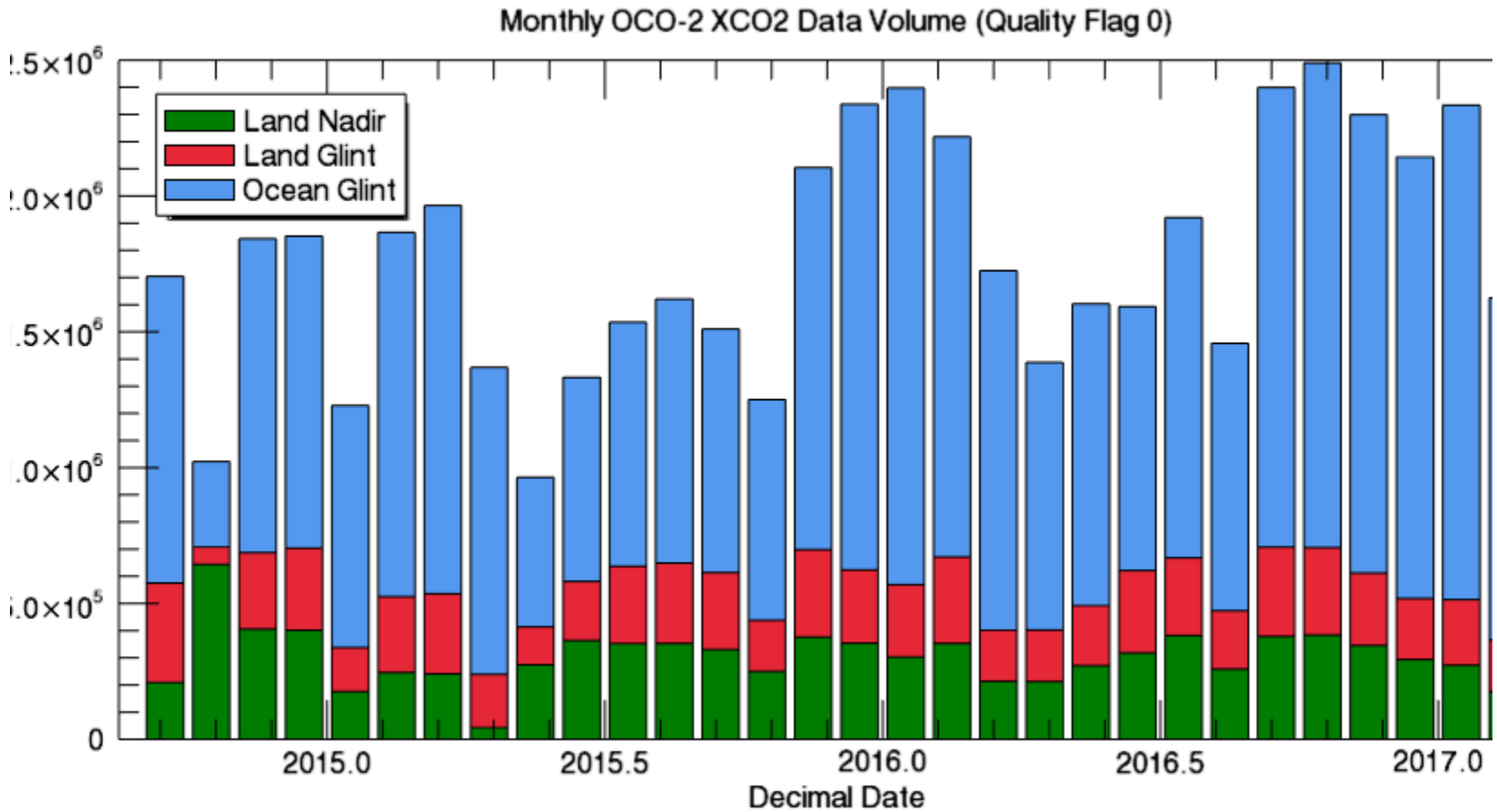
Clean Again

Latest X_{CO2} Data (forward stream)





Data Volume
Chris O'Dell



Plots of monthly data volume clearly show the benefits of the "optimal" viewing mode, which acquires ocean glint on orbits predominately over the Atlantic or Pacific Oceans, which was implemented in November 2015.

March 21-23 Science Team Meeting at Caltech

OCO-2 Science Team Meeting

- Monday 20 March: Breakout Sessions
  - Morning: Validation
  - Afternoon: Flux Inversion
- Tuesday – Thursday 21-23 March Science Team Meeting
  - Plenary Sessions
  - Speed Talks
  - Posters
- Thursday afternoon – ABSCO breakout

- Annmarie has posted the oral presentations on Partnerspace. Contact her if you need access.

- All PI's/Theme Group Leads were asked to send 1-page summaries
  - These are being used to identify emerging themes in research

Combining CALIPSO and OCO-2

A. Merrelli and R. Bennartz, U.Wisc-Madison SSEC & Vanderbilt University

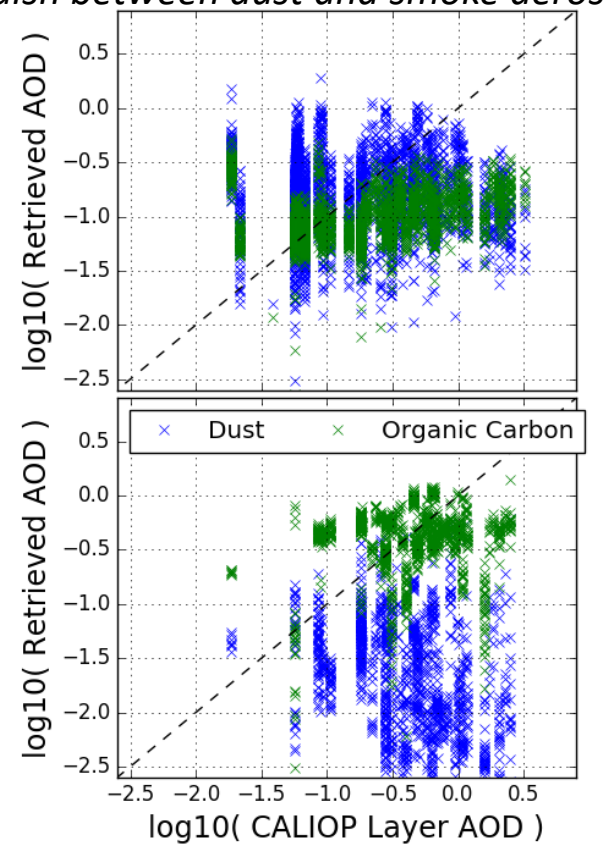
Problem: Aerosols are a known to be a source of bias for XCO2 retrieval. Aerosol optical depth is currently used for bias correction and filtering for OCO-2 nadir mode retrievals.

Approach: The close formation flying between CALIPSO and OCO-2 has aligned the ground footprints extremely well. CALIPSO aerosol retrieval information can be used to test OCO-2 retrievals.

Case Study: OCO-2 overpass of the Ft. McMurray fires. Other instruments (e.g. VIIRS) showed the smoke aerosols were very small particles.

Using CALIPSO aerosol heights as a tight prior constraint for the OCO-2 retrieval, the resulting retrieved optical depths show better resemblance to smoke aerosol

Top: OCO2 B7 Operational retrieval cannot distinguish between dust and smoke aerosol



Bottom: Retrieval with CALIPSO height constraint clearly favors the smoke-like aerosol type

Cloud retrievals from OCO-2

Mark Richardson, Graeme Stephens - JPL

- **Oceanic low clouds cause much spread in climate projections.**
- **OCO-2's A-band spectrometer should allow a retrieval that includes geometric thickness, a ke test of models. This uses "cloudy scene" data that is not exploited in the main OCO-2 products.**
- **A simplified retrieval of optical depth and cloud top pressure has been validated with MODIS and CALIPSO and is under review.**
- **Our optimal estimation scheme has ±2 hPa uncertainty in cloud top pressure or thickness in synthetic tests. We are optimizing to speed retrieval for an operational release collocated with CloudSat/CALIPSO.**

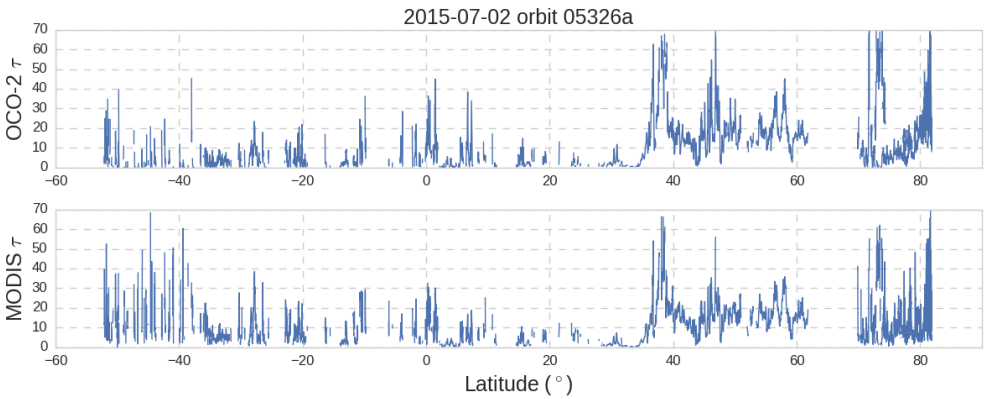
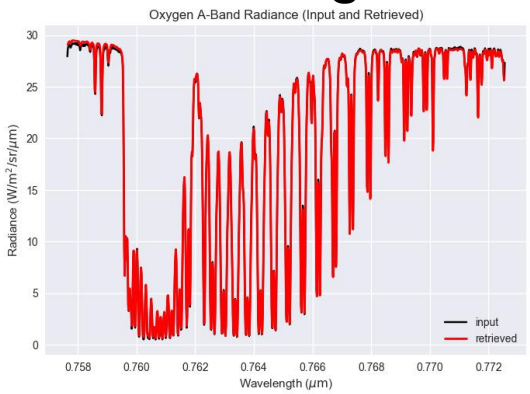


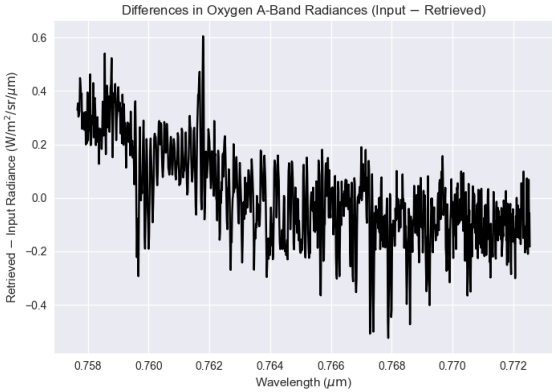
Figure 1 Example of first-step OCO-2 retrieval of cloud *optical* depth (top) versus the collocated MODIS value (bottom), showing that OCO-2 captures the main cloud features through the orbit. Retrieval of cloud *geometric* thickness is under development and requires in-situ data for validation.

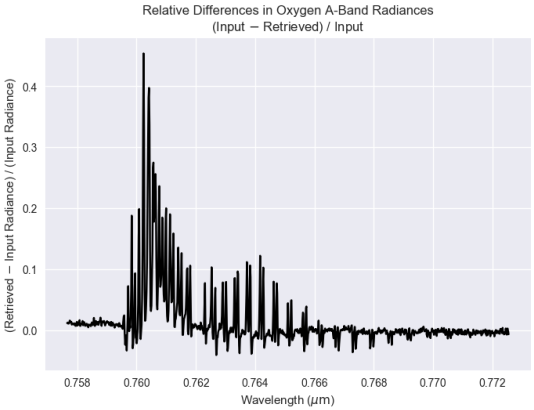
Absorbing Aerosol Retrievals

Anthony Bratt[1], Pengwang Zhai[1], David Winker[2], Yongxiang Hu[2]
[1]UMBC, [2]NASA LaRC

1. Important science question: development of an aerosol absorption algorithm based on co-located OCO2 OAB and CALIPSO measurements.
2. Importance: an aerosol absorption retrieval algorithm purely based on satellite measurements will help reduce uncertainty in aerosol radiative forcing of climate modeling.
3. Approach: we build a forward radiative transfer model for OCO2 OAB and use the Levenberg–Marquardt algorithm for least squares fitting to retrieval aerosol single scattering albedo from co-located OCO2 OAB and CALIPSO measurements.
4. What we learned: the retrieval algorithm is sensitive to spectral dispersion correction, which we will improve in the next stage of retrieval algorithm development.







Improving the OCO-2 Aerosol Parameterization

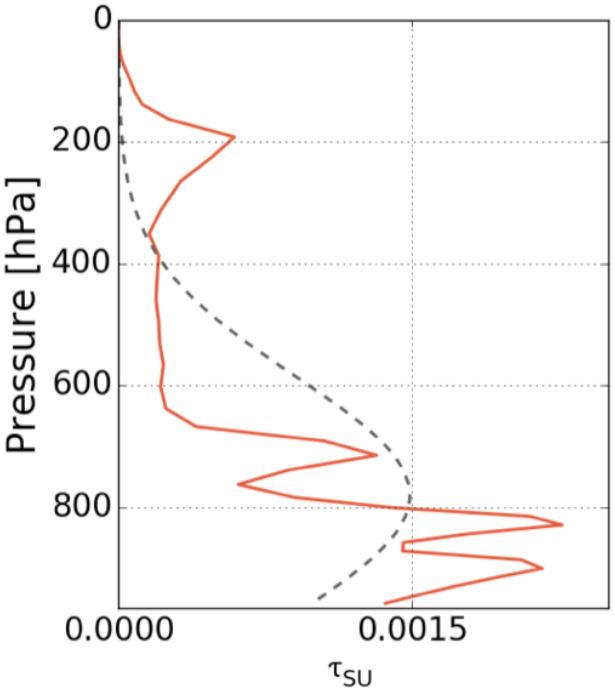
Robert R. Nelson, Chris O'Dell, Heather Cronk, Aronne Merrelli

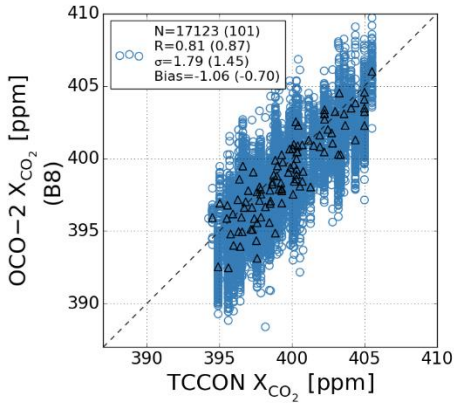
1. Can we improve the retrieved OCO-2 X_{CO2} by making intelligent modifications to the aerosol parameterization?

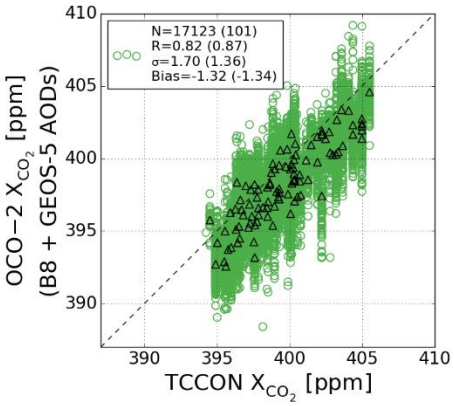
2. Aerosols are one of the largest sources of uncertainty when making CO_2 measurements

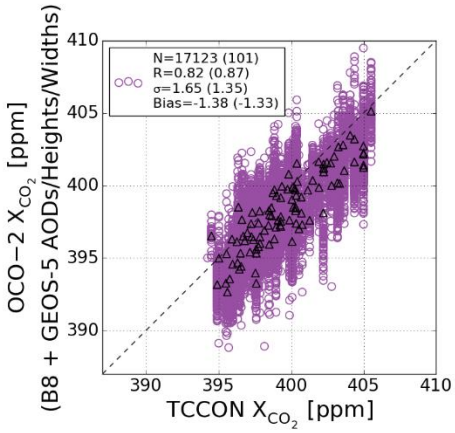
3. Here, we modified the retrieval algorithm to use modeled 3D aerosol fields from GEOS-5 FP-IT →

4. We found an improvement in X_{CO2} against TCCON, suggesting that more realistic aerosols result in a more accurate CO_2 measurement







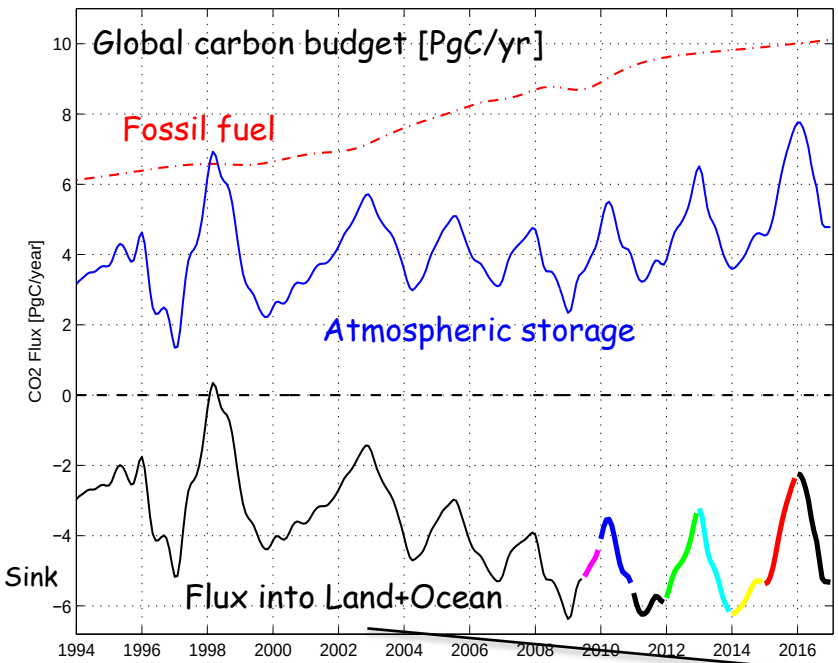


Jet Propulsion Laboratory
California Institute of Technology

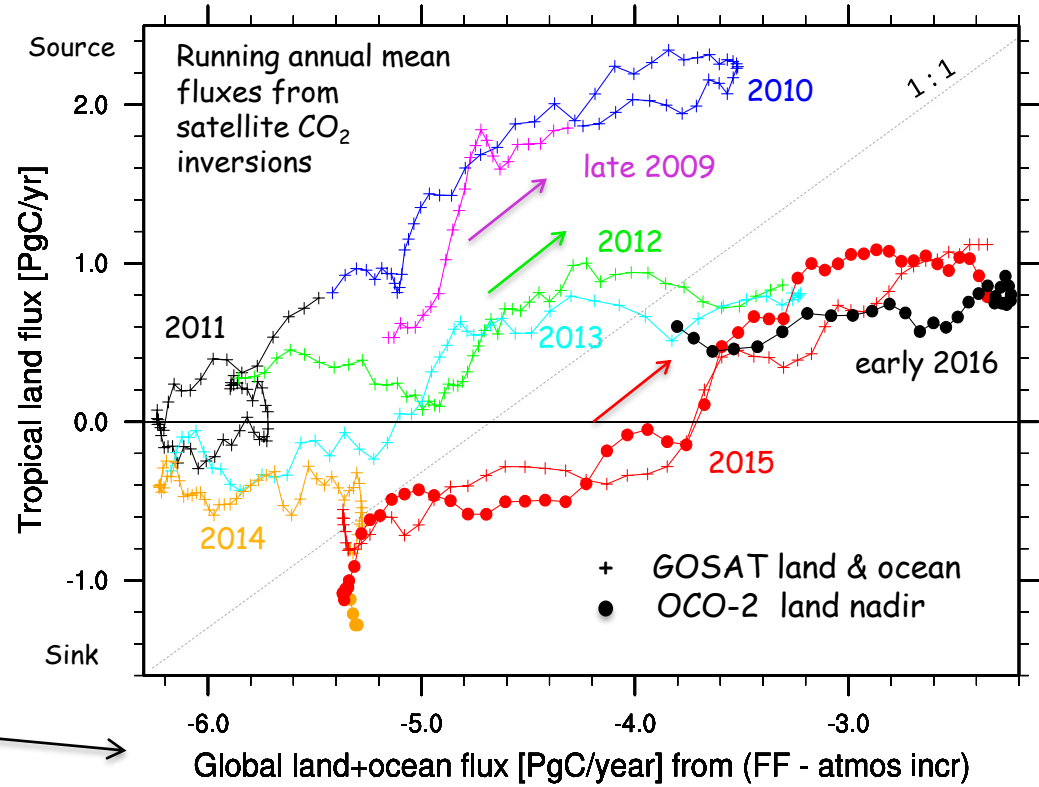
Colorado State University

OCO-2 & GOSAT: tropical land biosphere the main driver of global CO_2 IAV

- To predict future global temperatures, we need to understand what causes observed inter-annual variability (IAV) in CO_2



Land + Ocean = Atmos - FF



- OCO-2: global source of CO_2 during the '15/'16 El Niño came mostly from the tropical land
  - Agrees with ACOS GOSAT during overlap: since OCO-2 avoids clouds better with a smaller FOV, suggests cloud contamination not dominating GOSAT results
- GOSAT: tropical land regions the main driver of global CO_2 IAV since 2009
- ➔ Dense satellite data confirm that tropical land biosphere drives global CO_2 IAV
  - a result obtained 15+ years ago from inversion of *in situ* CO_2 data but never really believed (sparse *in situ* data coverage in tropics + error-prone transport models = shaky result)

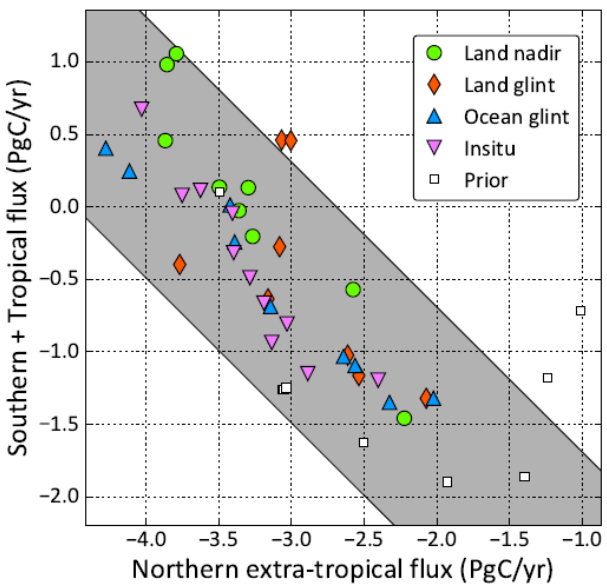
Flux inversion results from PCTM-based 4Dvar system.
David F. Baker
CIRA/Colorado State Univ.

Uncertainty in OCO-2 flux estimates from transport models

Sourish Basu, John Miller, David Baker, OCO-2 flux modelers

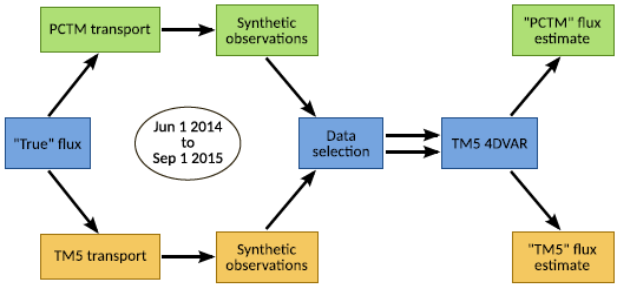
Motivation

Current OCO-based inversions show a large spread in fluxes given the same satellite retrievals (below). What part of this uncertainty is coming from modelled atmospheric transport? Does this limit our ability to harness satellite data?



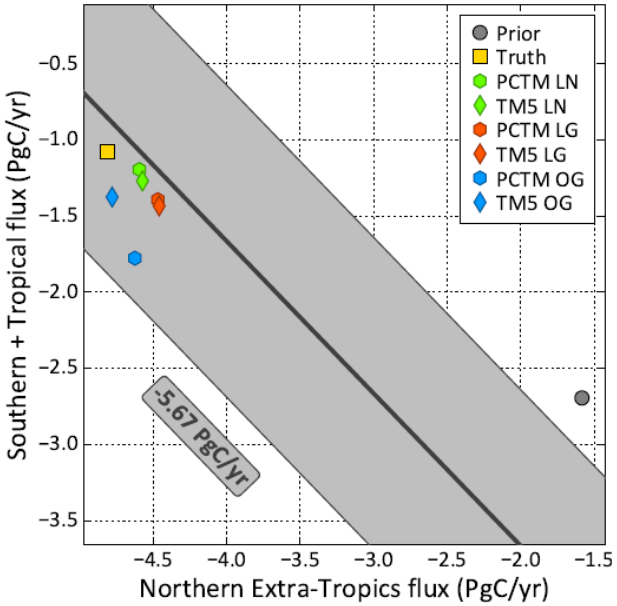
Method

A series of "nature runs" simulated OCO2 XCO_2 retrievals with different transport models (TM5 and PCTM at this point, more to come). The simulated retrievals were assimilated in an OSSE to estimate fluxes. Spread in those fluxes should be a metric of uncertainty in real-data flux estimates due to transport uncertainty.



Preliminary results

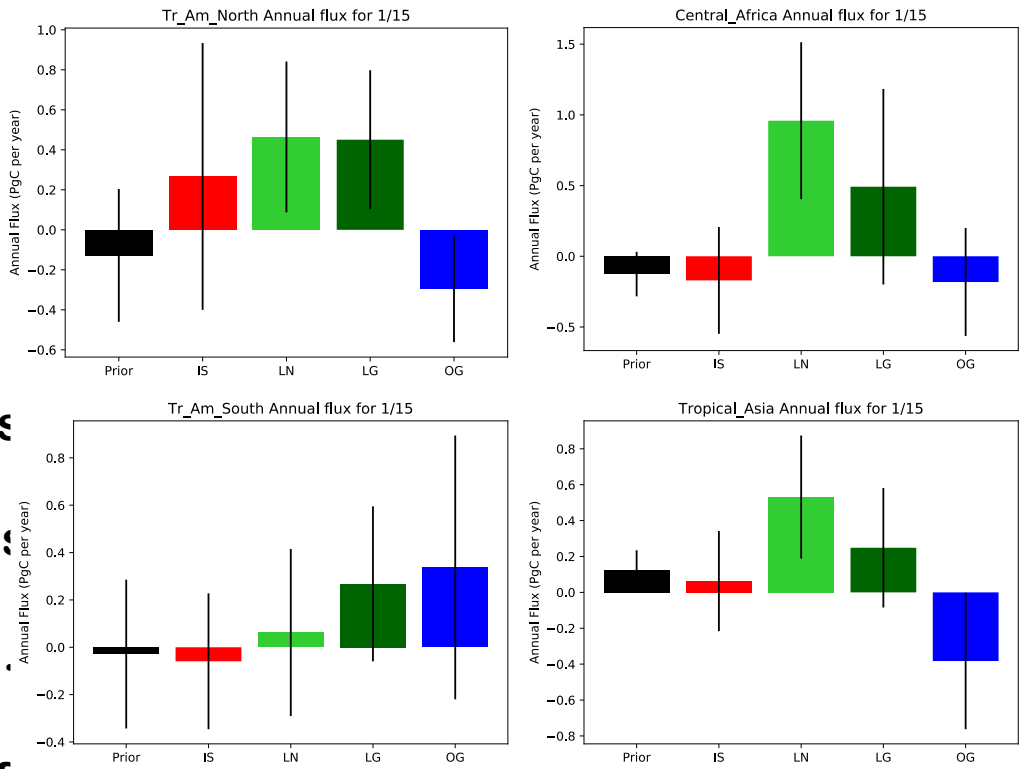
TM5 vs PCTM transport certainly accounts for a part of the inter-model spread in flux estimates. Exact magnitude depends on the flux partitioning. More analysis being done currently to solidify the details.



Were terrestrial ecosystems in the tropics a source of CO_2 in 2015?

- Inter-annual variability in the tropical land fluxes are a driver of global sink variability, and is tied to climate drivers such as ENSO.
- Results from the OCO-2 Flux Model Inter-comparison Project point to a terrestrial ecosystem source for 2015. The largest contributor to this source term is seen to be Central Africa, and other work indicates the cause is drought and high temperatures leading to increased respiration.
- The conclusion is supported by robust seasonality in the suite of models assimilating OCO-2 data as compared to those assimilating in situ observations.

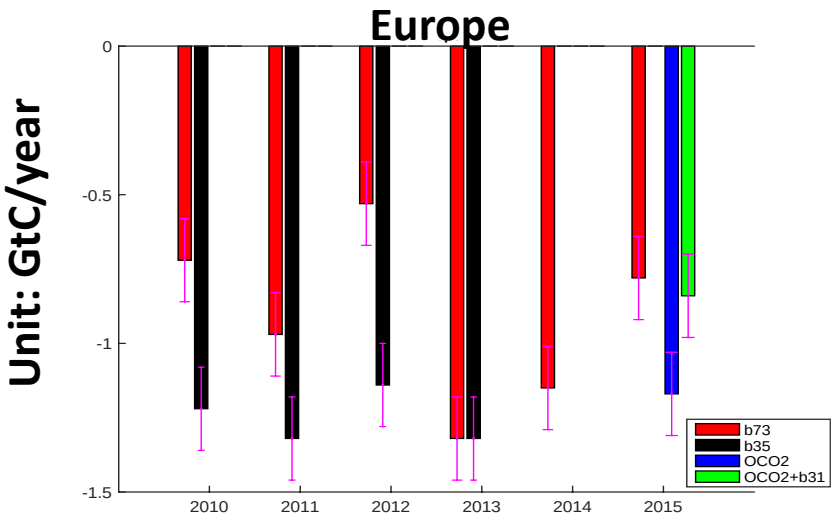
Sean Crowell and the OCO-2 Flux MIP Team



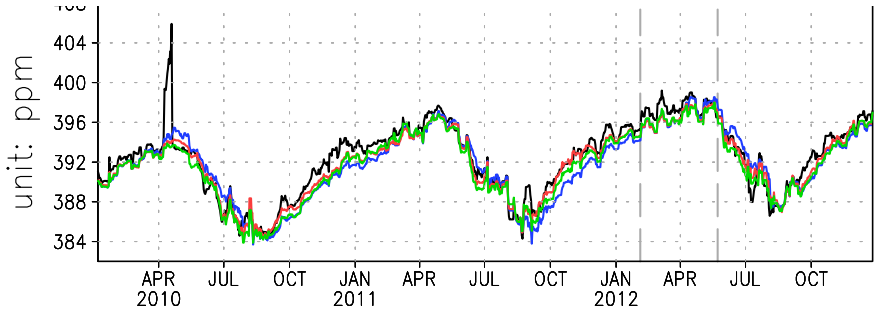
Sensitivity of posterior fluxes to satellite observation datasets

(Junjie Liu and the OCO-2 Flux Team)

- **Questions:**
  - how sensitive of regional flux estimation to different versions of retrieval products?
  - can current validation strategies falsify one estimate from another?
- **Significance:** Robustness of posterior fluxes and effective validation are preconditions for broader use of top-down flux inversion results in the carbon cycle science community.
- **Methods:** Compared the posterior fluxes constrained by ACOS-GOSAT b3.5, ACOS-GOSAT b7.3, and two OCO-2 b7br products, and validated the posterior CO2 concentration against independent aircraft observations
- **Conclusion:** The regional flux differences constrained by different versions of retrievals are larger than the estimated uncertainty, and validation against independent aircraft observations fails to falsify one estimate from another.

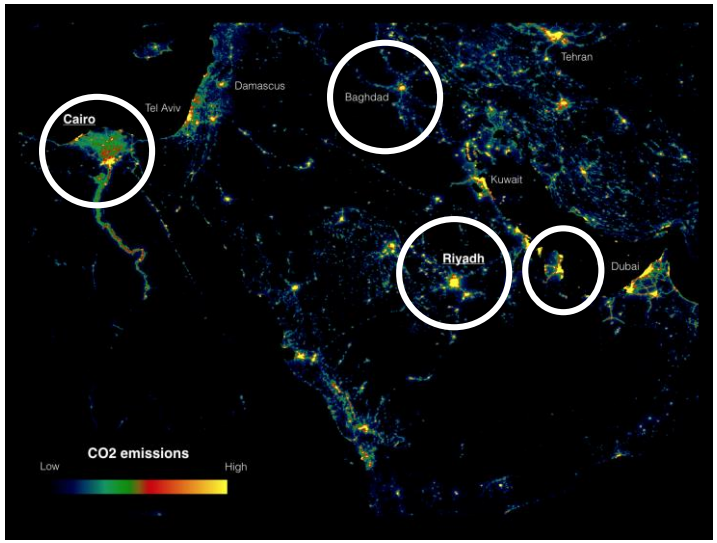


2km-3km average, black : aircraft ; prior (blue), rms=1.5; b35(red), rms=1.2 ppm; b73 (green), rms=1.3 ppm

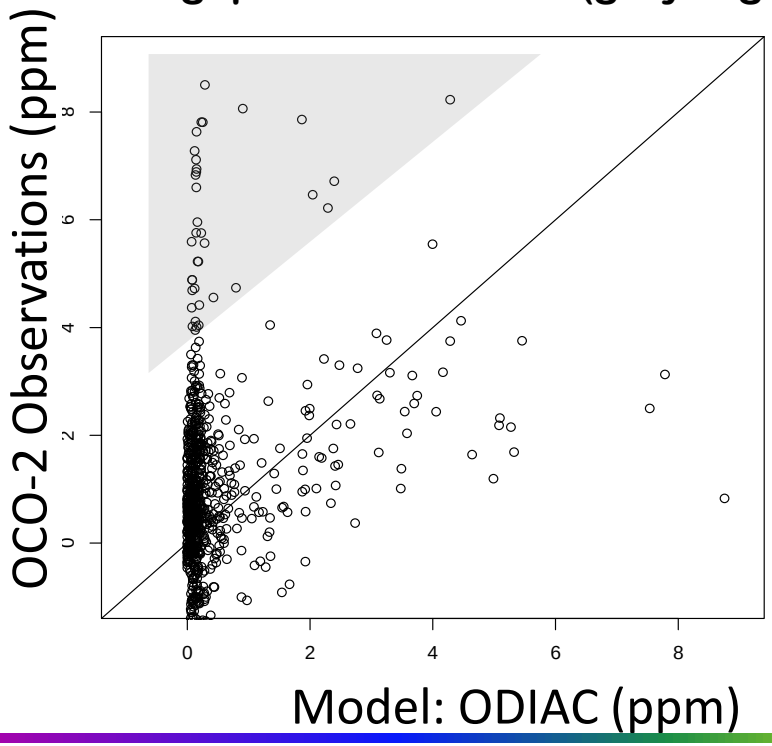


Quantifying global megacity CO_2 emissions: the Middle East

Emily Yang, Eric Kort, Xinxin Ye, Thomas Lauvaux, Dien Wu, John Lin, Tom Oda
U. Michigan, PSU, U. Utah



Simulation-Model comparison illustrating fidelity of approach (linear relationship) and gaps in inventories (gray region).



- **Question:** Can we improve anthropogenic emissions estimates from intense emitting regions with high uncertainties?
- **Motivation:** Anthropogenic emissions and uncertainties are increasing and this compromises our ability to understand carbon cycle feedbacks.
- **Approach:** Combine OCO-2 observations with Lagrangian models.
- **Preliminary result:** Approach demonstrates fidelity in the Middle East. Illustrates potential of denser XCO_2 observations near urban regions (such as provided by OCO-3).

What is the flux of CO_2 from the South Coast Air Basin?

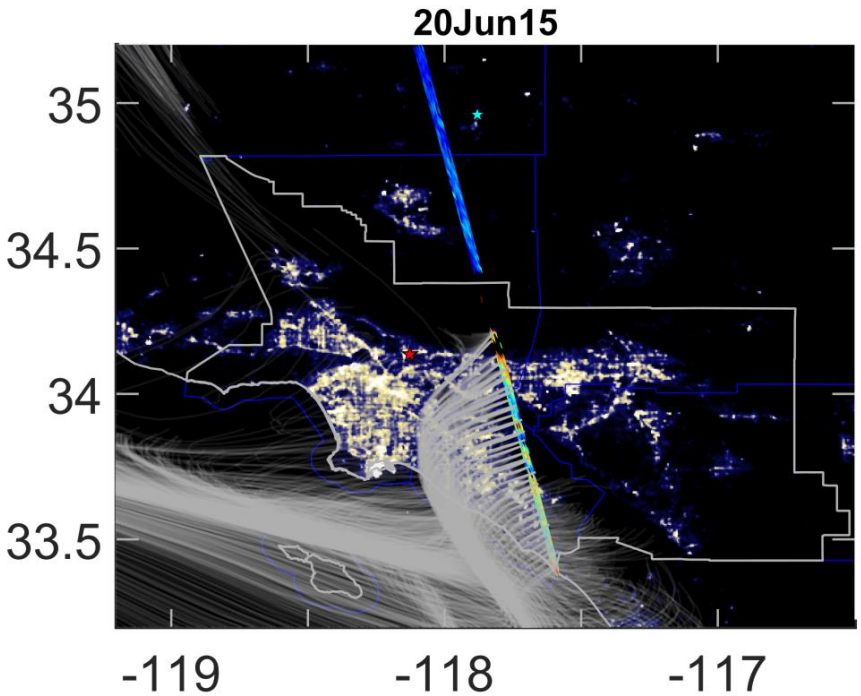
J. K. Hedelius, C. M. Roehl, P. O. Wennberg, D. Wunch, P. W. Hillyard, J. R. Poldolske, & L. T. Iraci

- Primary urban fossil fuel CO_2 emissions are ~43% of global. Most city reports are bottom-up (BU). Top-down (TD) estimates can be used to verify reports.

- 1st order estimate used a nightlight prior, and HYSPLIT back trajectories, along with OCO-2 observations in an inversion to get the annual flux

Source	Tg CO_2 yr^{-1}
CARB (BU)	167 ± 25
OCO-2 & HYSPLIT (TD)	190 ± 38
TCCON & HYSPLIT (TD)	201 ± 40

- Next steps – test different inputs to improve accuracy, computational time, and scalability of estimate.

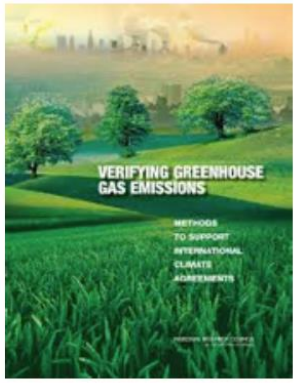


- Nightlight map of SoCAB. OCO-2 nadir path shown along with HYSPLIT trajectories for every 5th sounding.

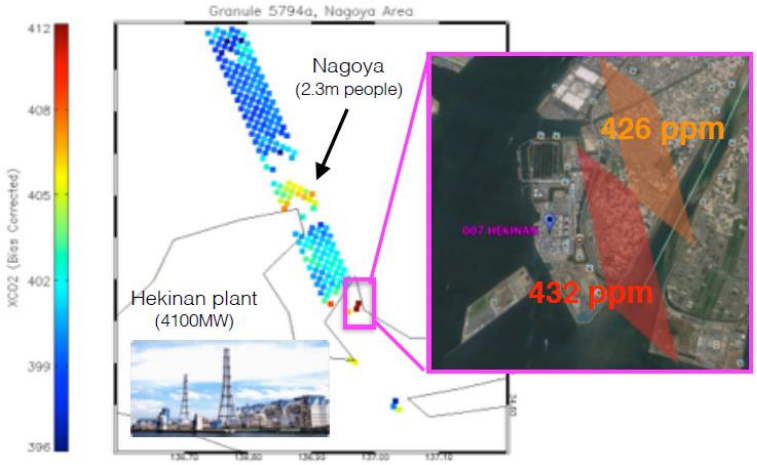
OCO-2 confirms reported power plant emission

T. Oda, C. W. O'Dell, C. Frankenberg et al.

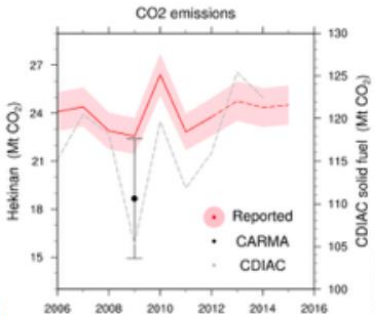
1. Background: Carbon satellite can be one of future tools to help/guide emission management (e.g. MRV).

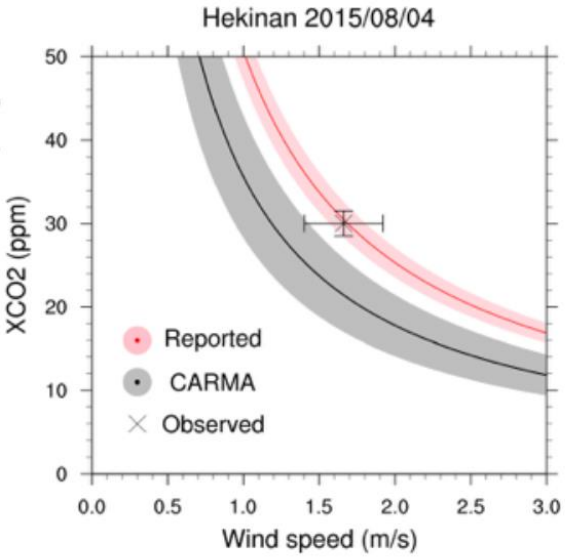


2. Observation: OCO-2 observed large anomaly at the largest, Japanese coal-fired power plant.



3. Analysis The anomaly was not consistent with the emission estimate from a global database, but projected value of the projected, self-reported emission.



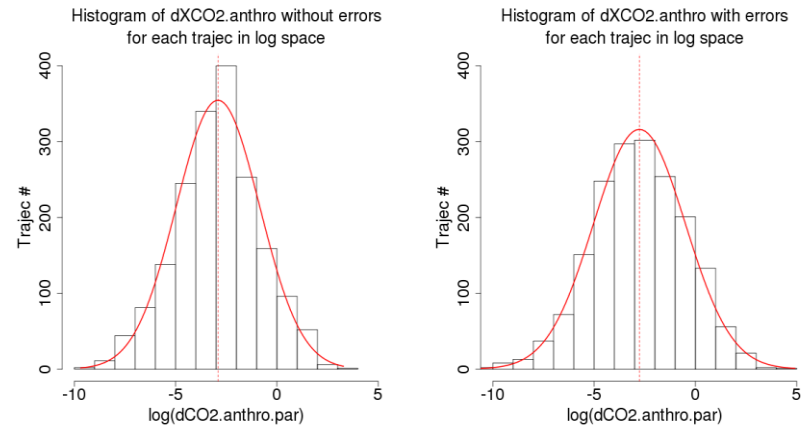


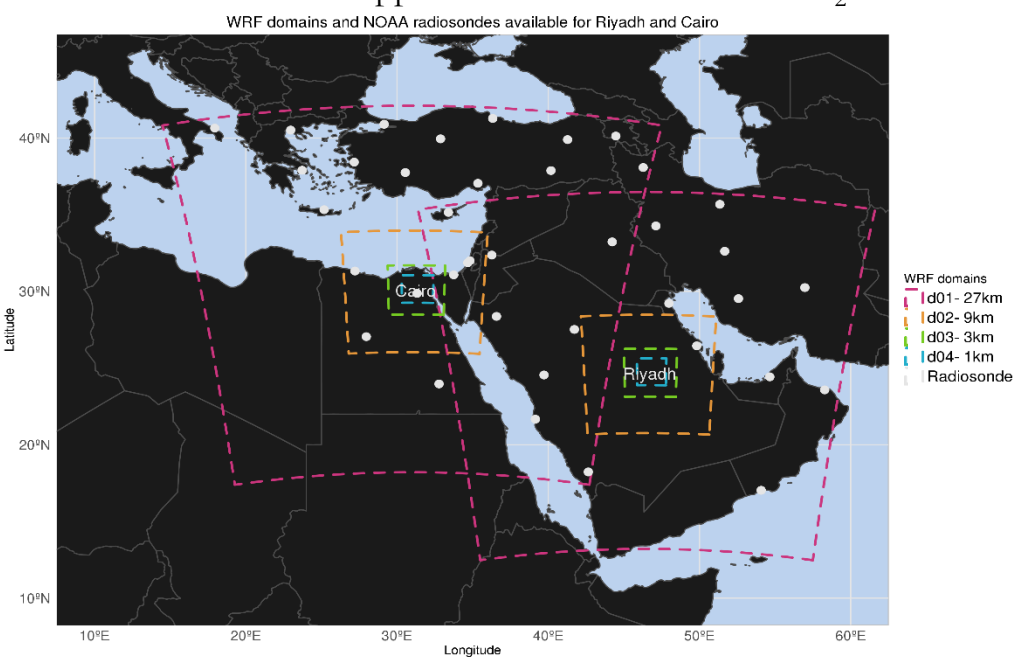
4. Conclusions: OCO-2 demonstrated the capability of carbon-observing satellites for 1) detecting an emission signature even from a single emission source (emission attribution) and 2) confirming the reported emission. A similar instrument with an improved observation strategy (e.g. OCO-3) should enable the community to study more toward establishment of space-based MRV tool.

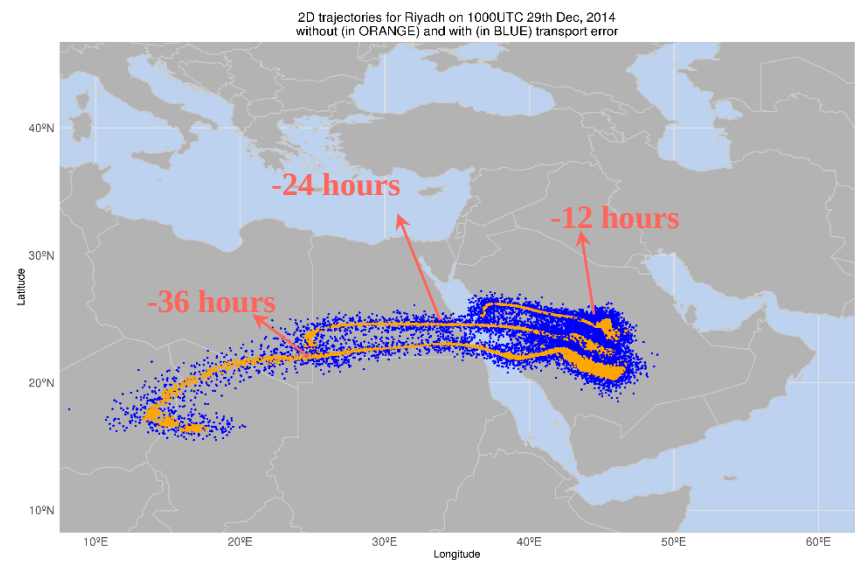
Transport error in WRF-STILT

Dien Wu, John Lin , Tomohiro Oda, Xinxin Ye, Thomas Lauvaux, Emily Yang, Eric Kort

To evaluate WRF wind errors, we compared WRF-interpolated u,v winds at several levels against winds measured from NOAA radiosonde profiles. Generally, anthropogenic emissions are more of point sources emissions, where STILT trajectories either "hit-or-miss" emissions. And $dXCO_2$.anthro for all particles displayed as log-normal distributions. Thus, we extended the method originated from *Lin and Gerbig*, [2005], and performed a log transform to calculate the variance difference in log-space, which can later be used for estimate an upper and lower limits on $dXCO_2$.







Quantification of Urban Biogenic CO_2 Fluxes

Xinxin Ye, Thomas Lauvaux, PennState University;
Eric Kort, Emily Yang, University of Michigan; Tom Oda, NASA Goddard; Dien Wu, John Lin, University of Utah

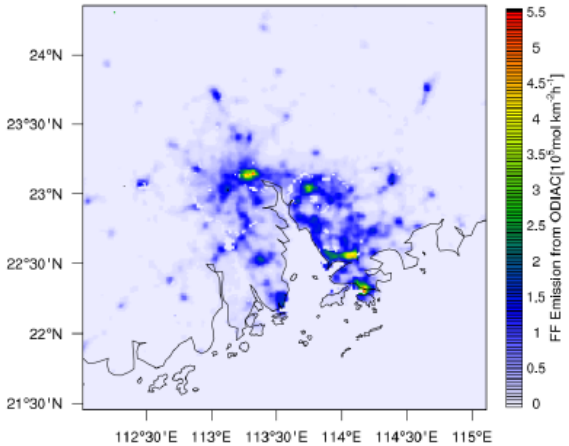
Goal: Assess the green fraction of urban CO_2 budgets in high-resolution inversions

Problem: Vegetation absorbs or releases CO_2 in and around cities but are not represented in inventory products like ODIAC.

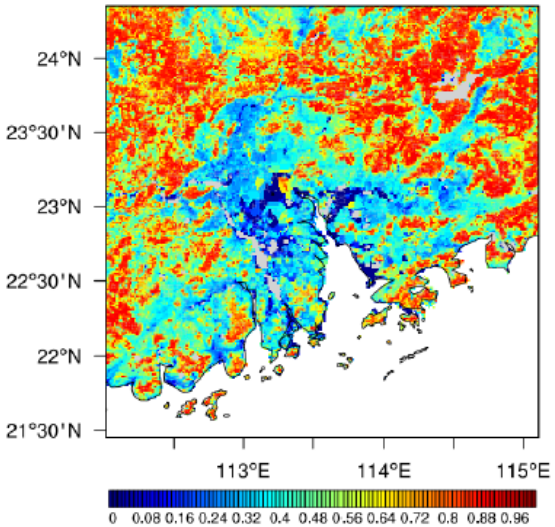
Question: How to account for the urban biogenic signals in XCO2 retrievals over large cities?

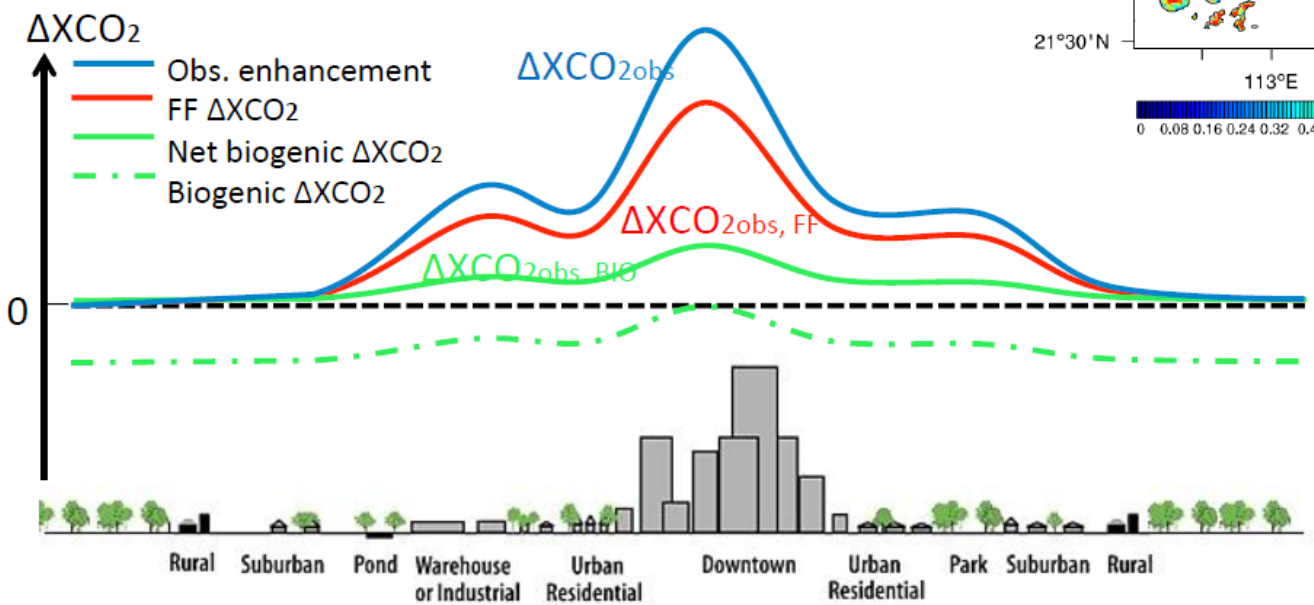
Example: Pearl River Delta region

FF CO_2 Emission (ODIAC)



MODIS Green vegetation fraction





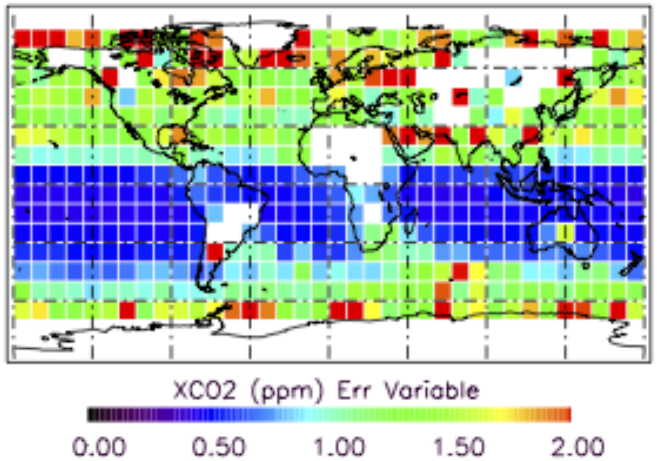
A Path to Improved Operational XCO_2 Error Estimates

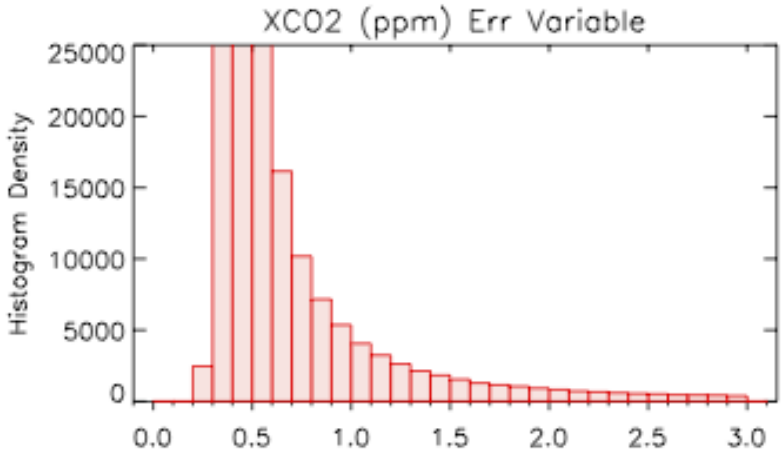
Brian Connor

- What are the uncertainties in each X_{CO2} sounding, and how are they correlated?
- This is essential for data users to know, to get the most benefit to their own science studies using OCO-2 data
- The uncertainties should be:
  1. Calculated for every sounding independently
  2. Error correlation between any two soundings well characterized
  3. Consistent with comparisons to validation data after 'bias correction'
- We are able to estimate 'variable error' for any sounding by a well established and documented procedure of linear error analysis
- We have demonstrated the calculation of error correlations between any 2 geographic regions
- The following slide demonstrates the above 2 points for a large sample of sea-glint data
- Comparisons with validation data are needed; we believe they can be used to develop a field of error estimates consistent with the validation data while incorporating the geographic variation and correlation of the linear error analysis
- Such estimates will provide an answer to the question in the first bullet

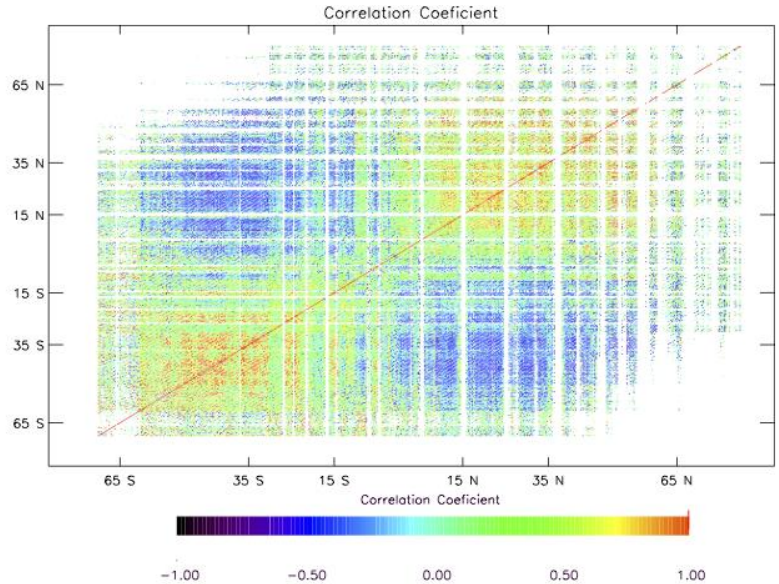
Sea Glint Variable Error

Brian Connor





- Net Variable Errors are 0.8 ± 1.0 ppm over the sea
- Much smaller in 10° N – 40° S than elsewhere
- Aerosol is the main source
- Consistent positive correlations within each hemisphere
- Consistent anti-correlations between hemispheres

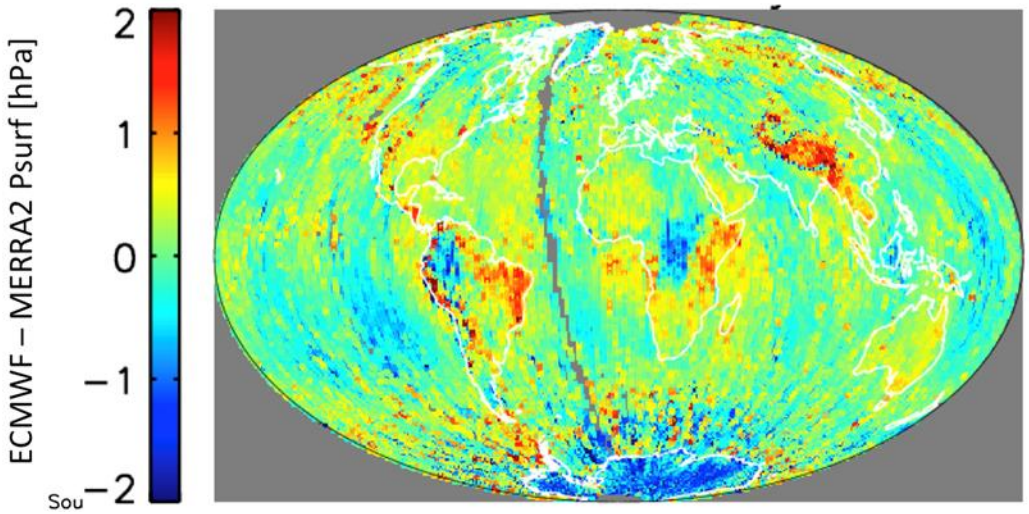


V8 Testing Highlights

- Issue still in work

Prior Meteorology Update
Chris O'Dell

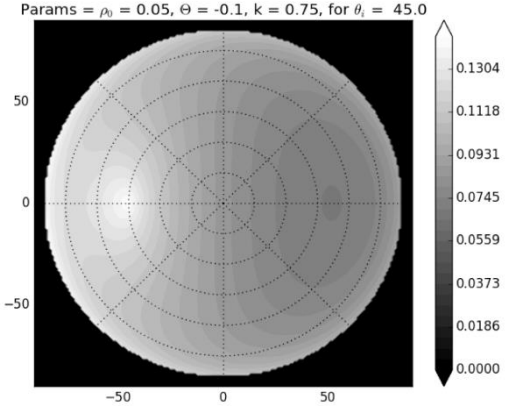
- Switching prior meteorology from ECMWF to GEOS5 FP-IT.
  - ECMWF 0.25x0.25 deg, updates every 6 months
  - GEOS5 0.5x0.5 deg, more stable
- Small but nonzero differences in retrieved XCO2, primarily driven by surface pressure differences.

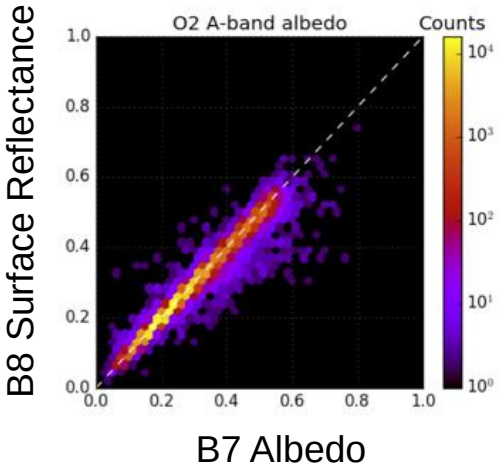


BRDF Update
Chris O'Dell

- Use a non-Lambertian model with a fixed directional parameterization (RPV model with parameters for soil)
- Tests showed that our spectra typically have little to no information on the BRDF shape
- Still effectively retrieve mean & spectral slope of reflectance, but now as scaling factors to new BRDF (shape) model.
- BRDF model provides more consistency for target observations, but little change in retrieved XCO2.
- Still updating implementation to correct errors – results pending.

RPV Kernel, SZA=45°

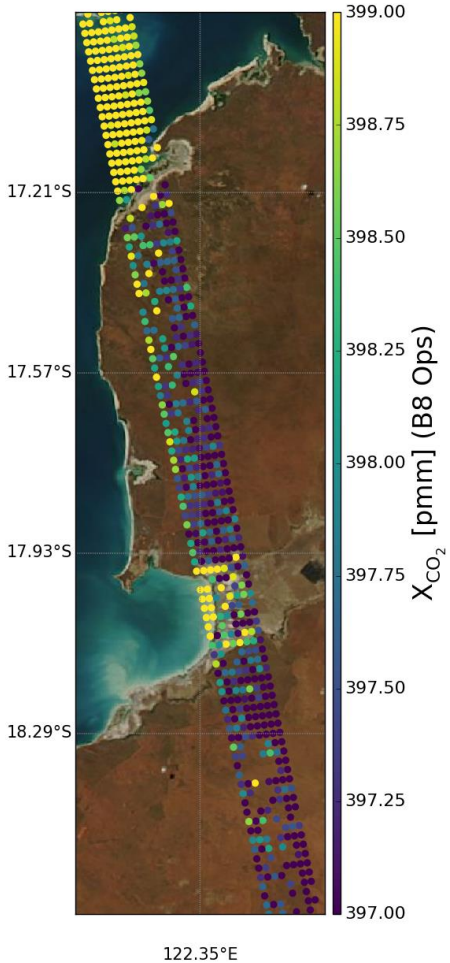




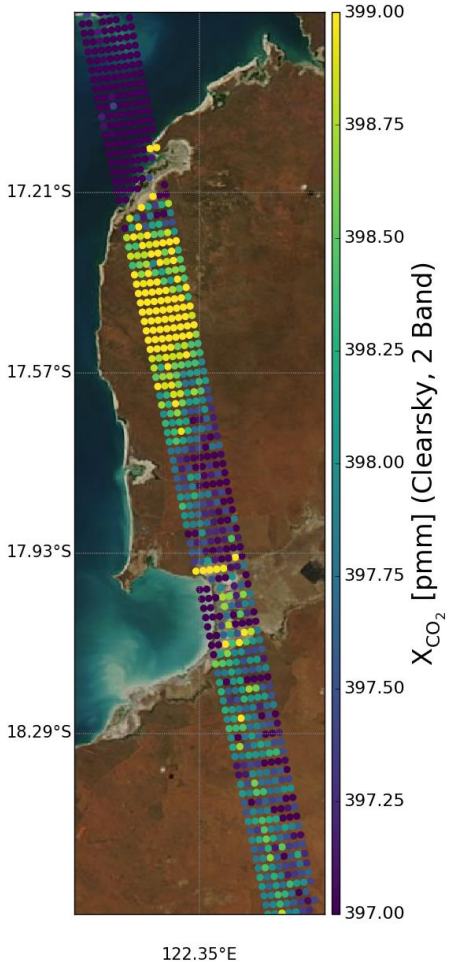
Ocean/Land Biases

Rob Nelson and Chris O'Dell

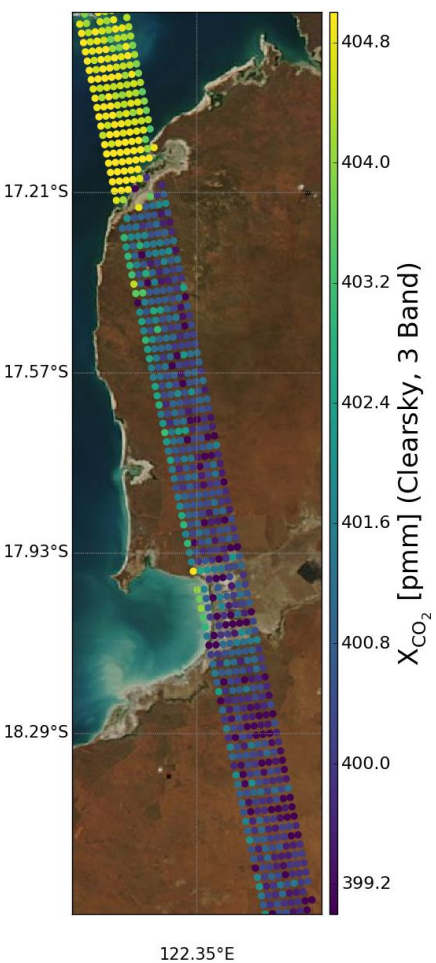
Ops



Clear-sky;
Psurf fixed



Clear-sky;
Psurf retrieved



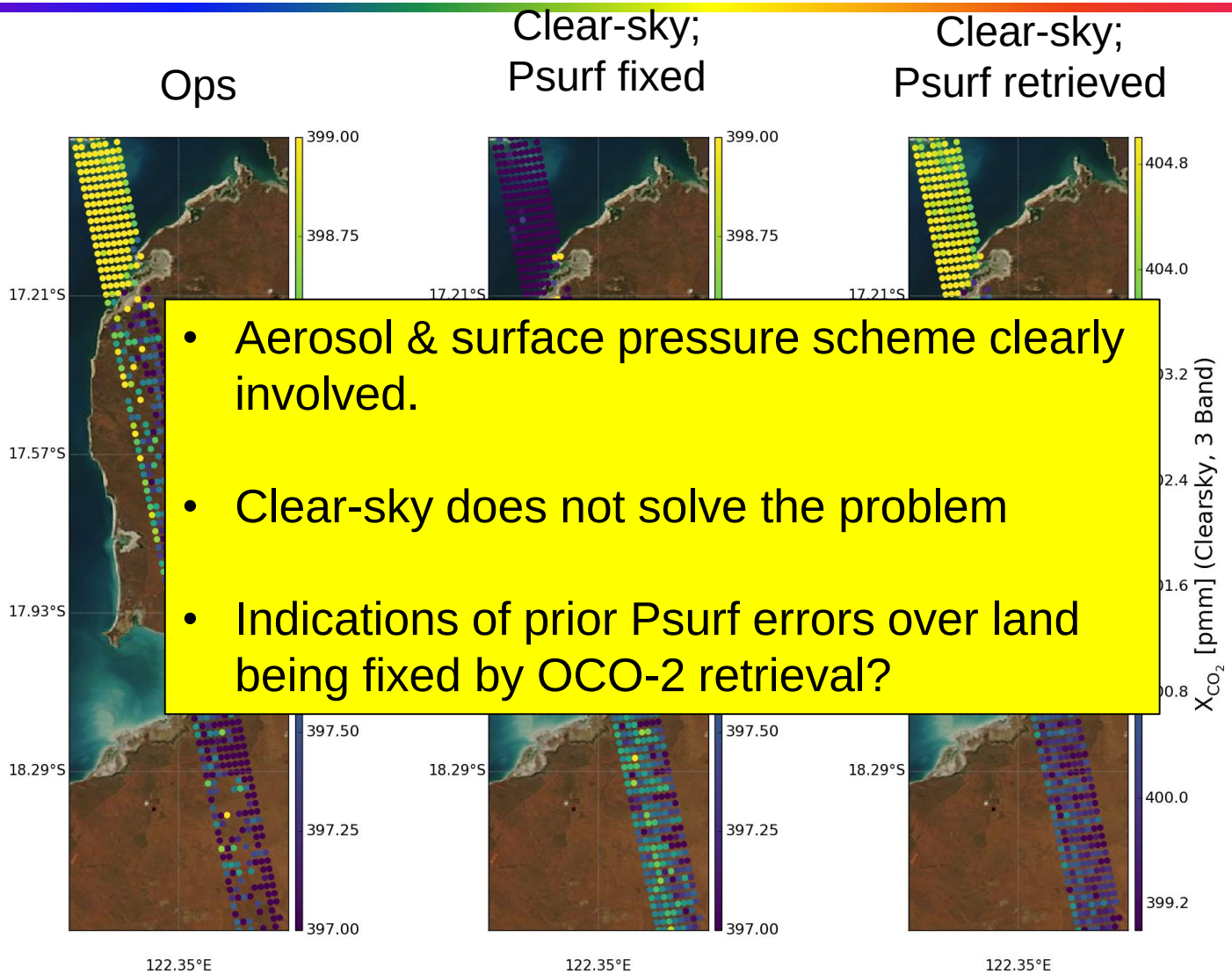
A new tool has been developed to overlay OCO-2 tracks on MODIS images.

Clear land-ocean biases exist even in very clear conditions

Surface pressure is clearly a part of the problem, but does not explain the whole problem

Ocean/Land Biases

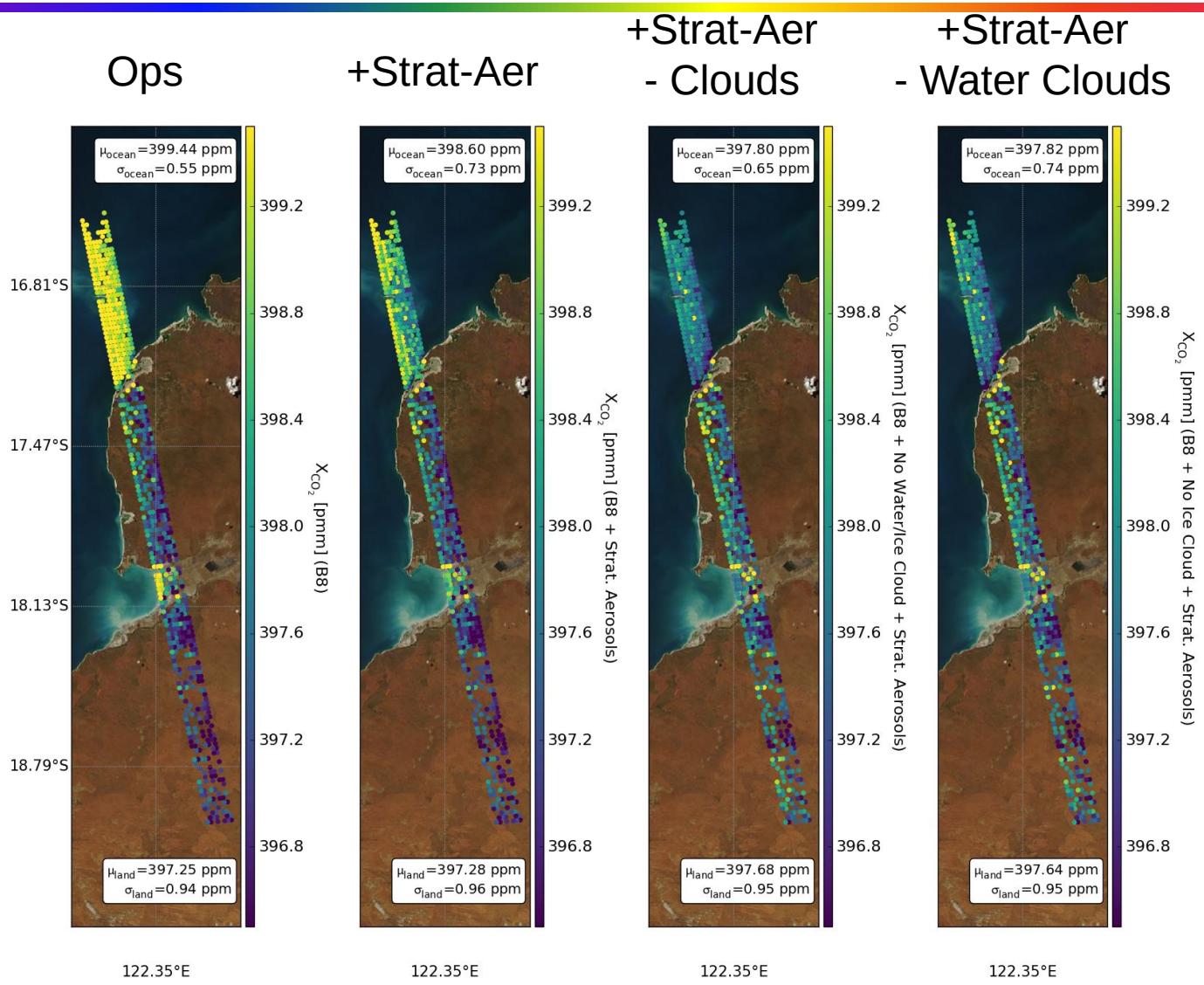
Rob Nelson and Chris O'Dell



- Aerosol & surface pressure scheme clearly involved.
- Clear-sky does not solve the problem
- Indications of prior Psurf errors over land being fixed by OCO-2 retrieval?

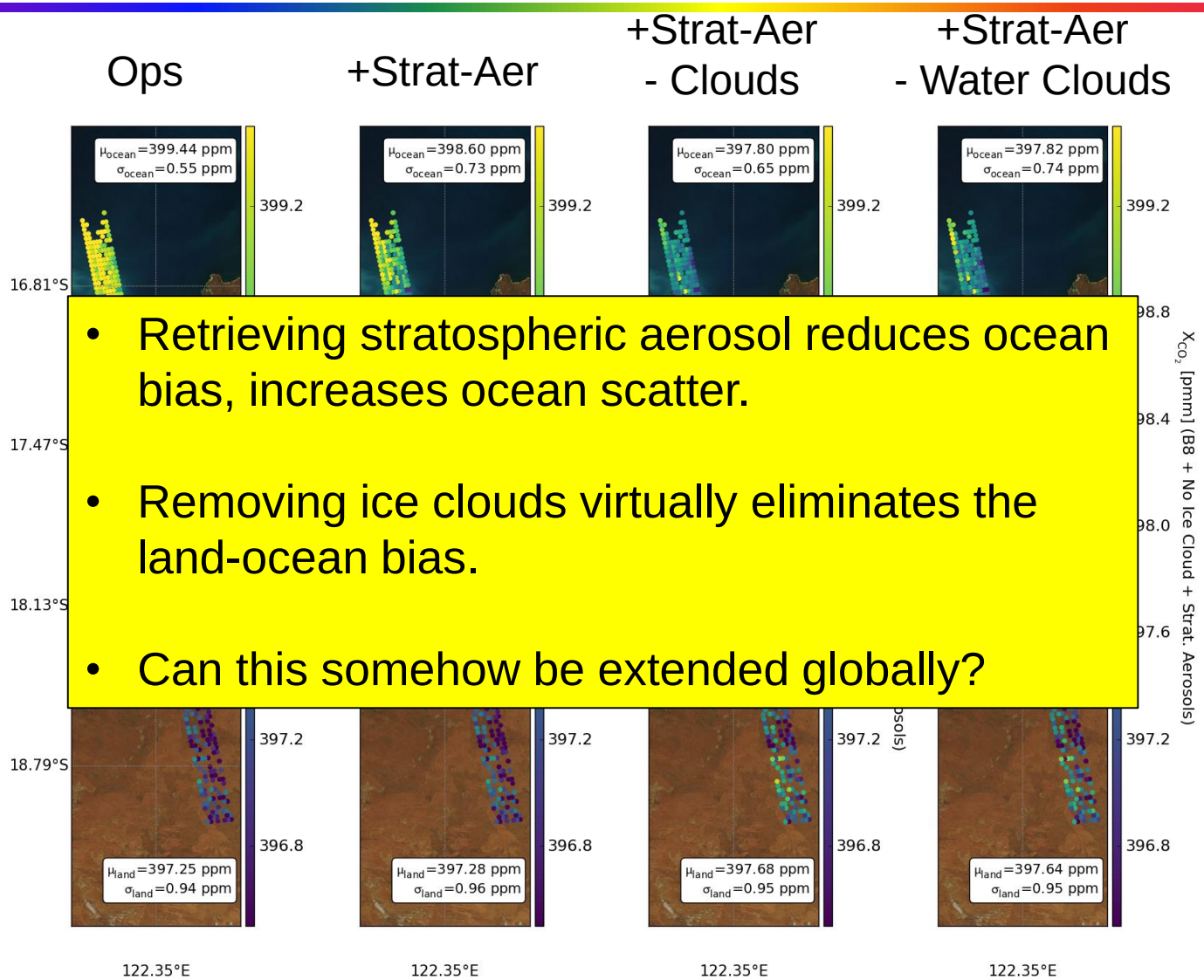
Alternate Retrievals (Nelson)

Rob Nelson and Chris O'Dell



Alternate Retrievals (Nelson)

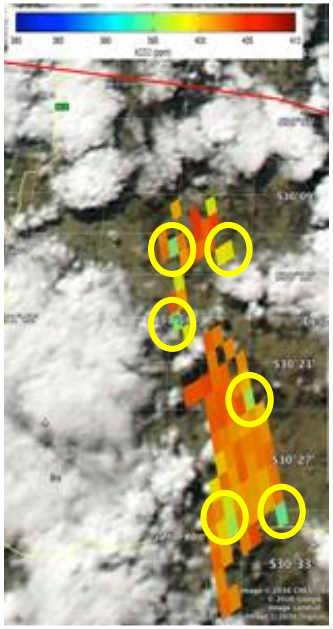
Chris O'Dell

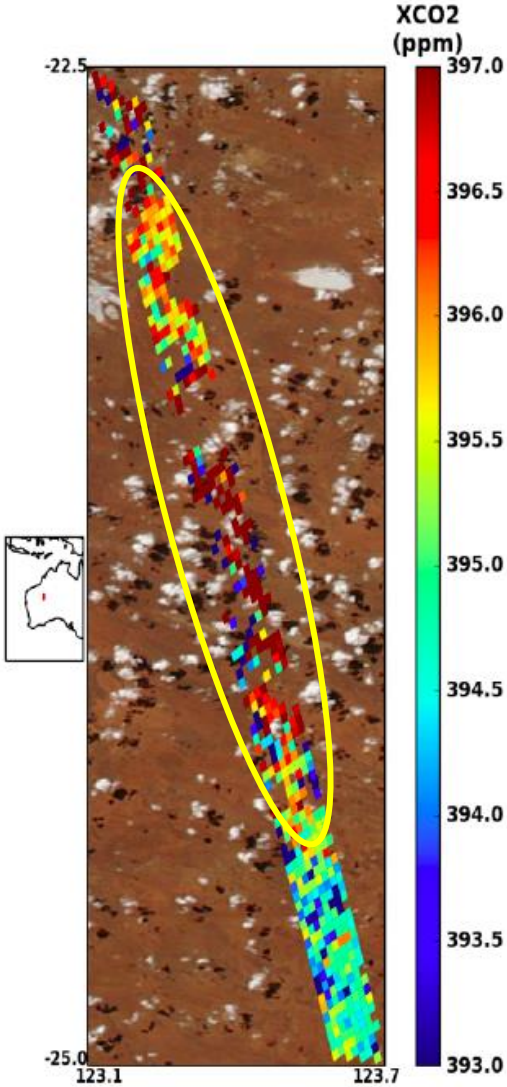


- Retrieving stratospheric aerosol reduces ocean bias, increases ocean scatter.
- Removing ice clouds virtually eliminates the land-ocean bias.
- Can this somehow be extended globally?

B8 needs better cloud filtering

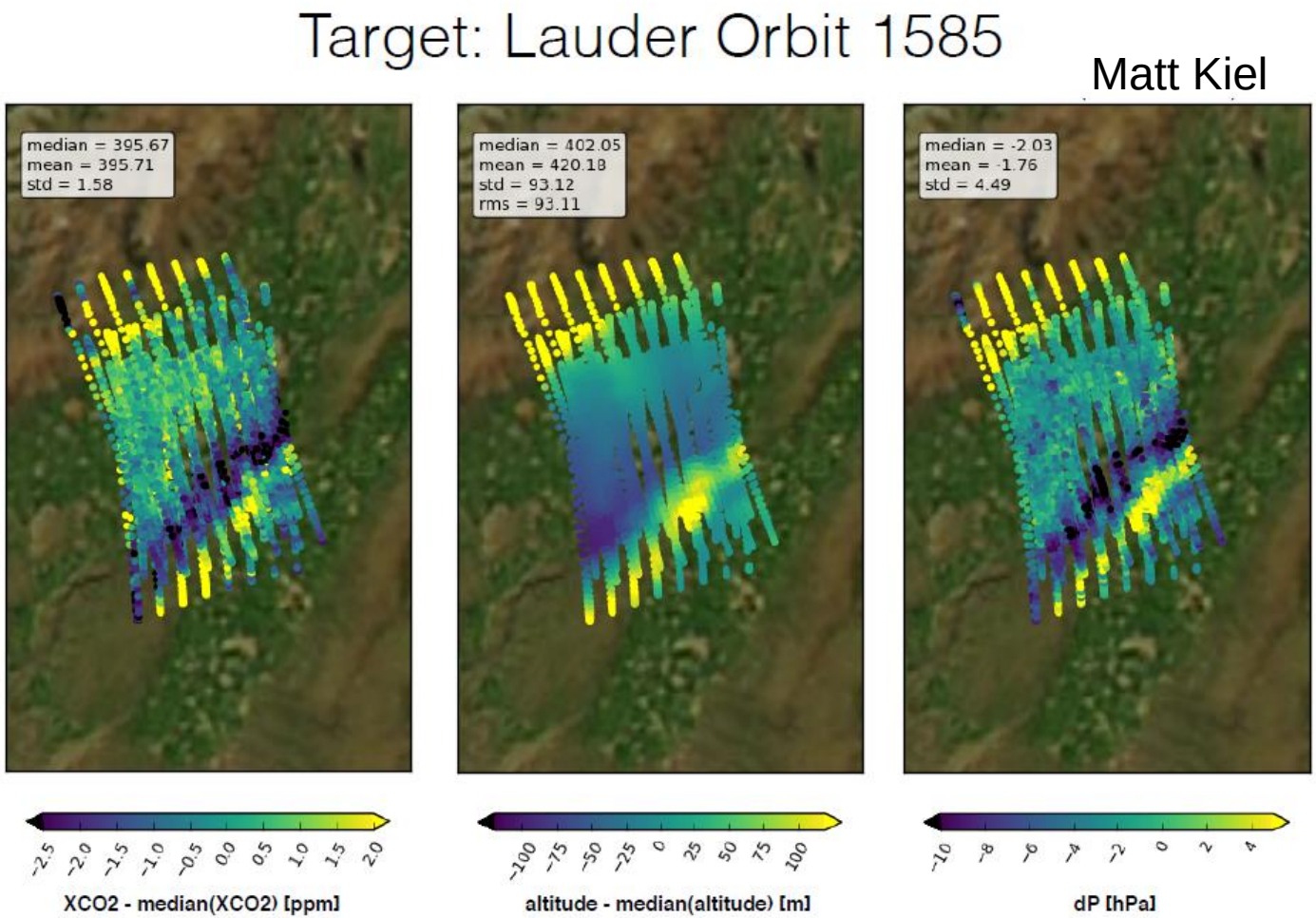
Tommy Taylor and Chris O'Dell





- Many obviously cloud-contaminated cases remain in the "good" v7 data.
- No obvious way (yet) to fix the retrievals in these cases.
- Work will be starting soon on filtering this out, many ideas floating around.

Evidence of a Pointing or Slit Misalignment Offset??

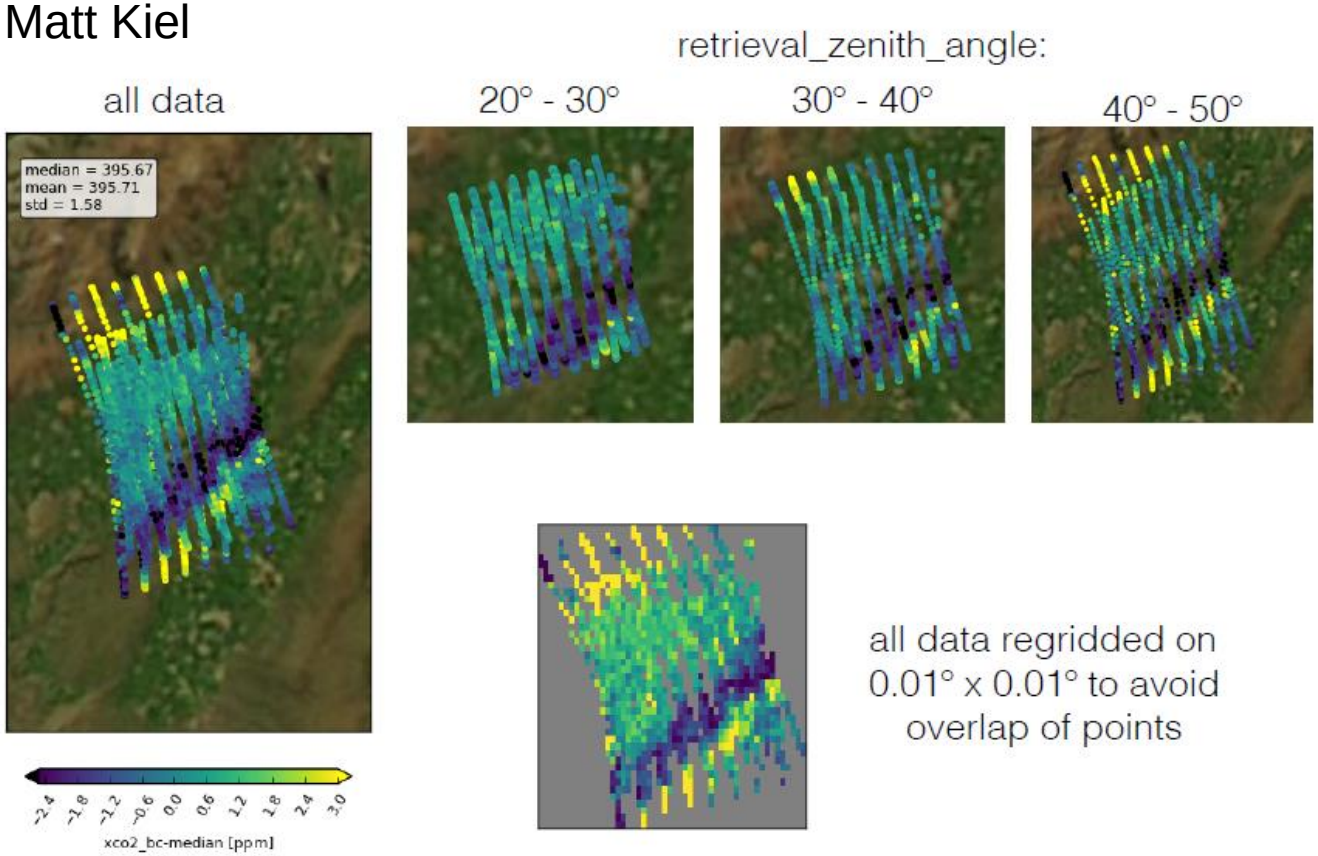


Target observations at Lauder show biases that are correlated with topography. This issue has long been recognized but is now receiving more attention.

Amplitude of Bias varies with Observation Angle

Viewing geometry - LauderNz_1585

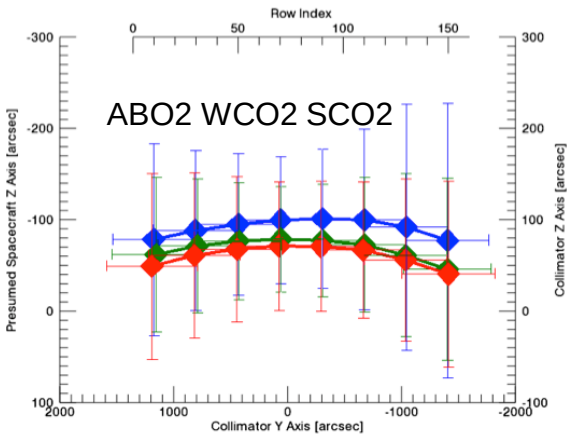
Matt Kiel



Larger biases are seen at larger observation angles.

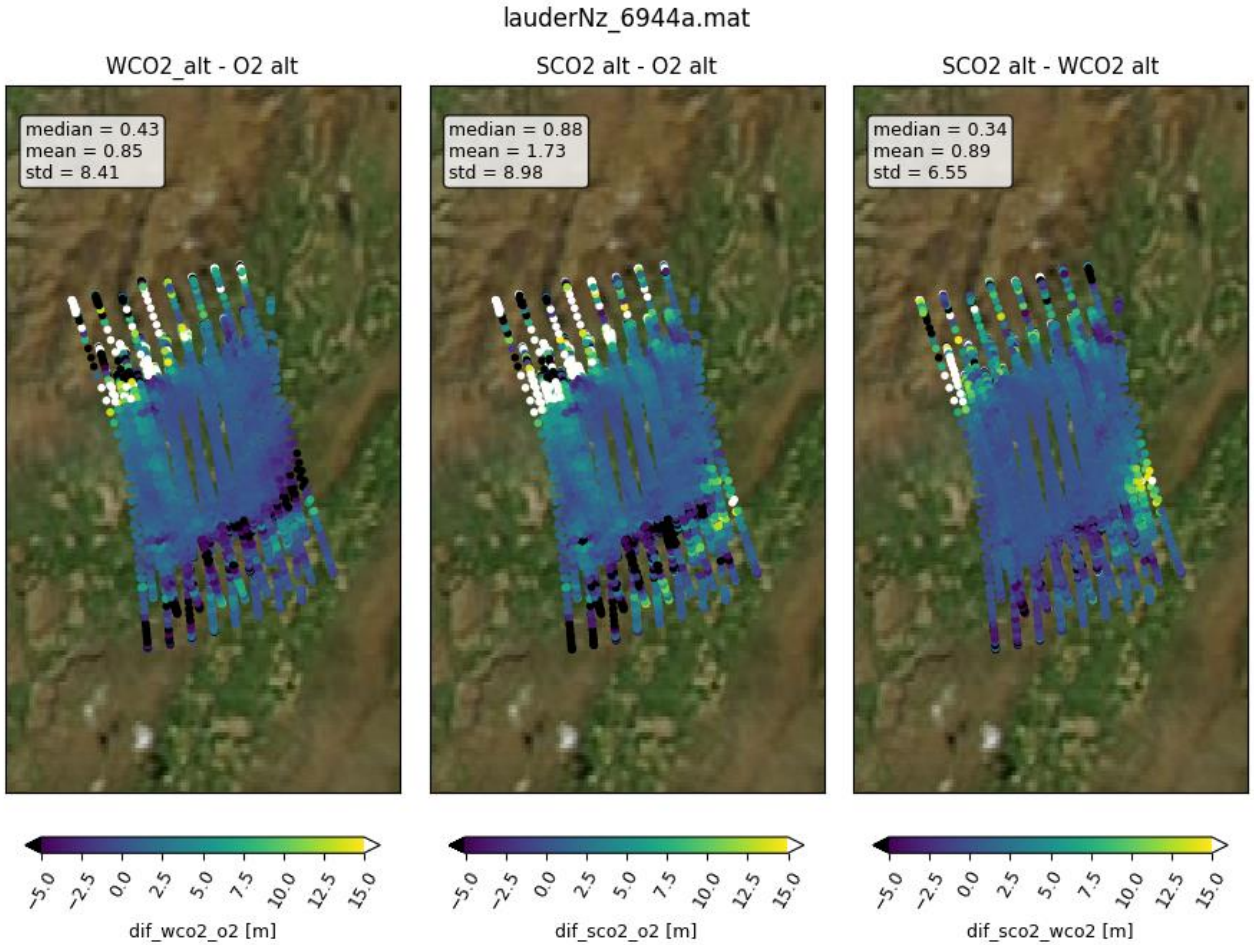
This is consistent with a pointing error in the cross-slit (pitch) direction because the observation angle is correlated with distance from the target. The spatial offset associated with a fixed angular error increases with distance ($S=R\theta$)..

Could This Be a Slit Misalignment Issue?



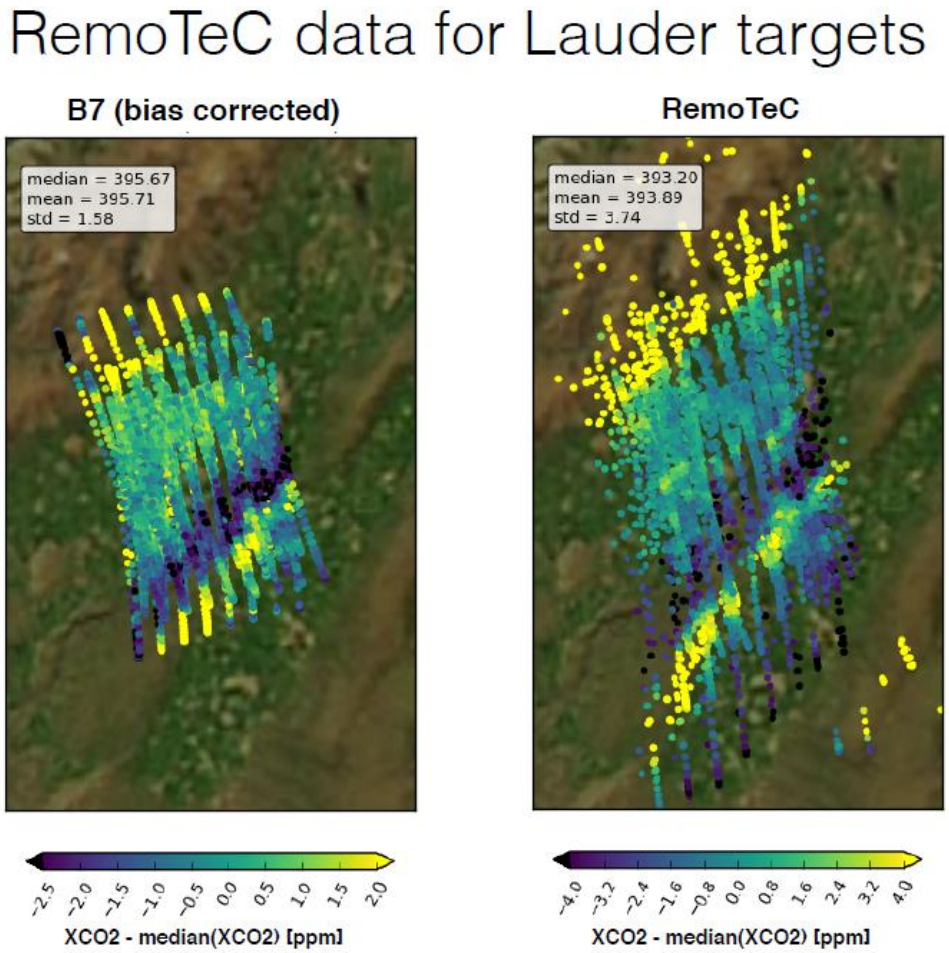
The ABO2 slit is offset from the CO2 slits by ~30 arcsec (0.14 mrad or 100 m at nadir).

This produces small impacts on the usual 2.25-km-long glint and nadir footprints, but can affect target footprints, which are typically < 1 km.



Differences between the altitudes of the 3 footprints. The SCO2 and WCO2 are similar, but both can differ from the ABO2 by up to 20 m.

Similar Results Seen in RemoTeC Retrievals



The amplitude and spatial distribution of the biases in the B7 product are similar those seen in XCO2 estimates from RemoTeC.

RemoTeC does not perform a surface pressure retrieval, and uses ABO2 results only for retrieving thin clouds and aerosols.

How would the misalignment of the ABO2 slit produce similar biases in the RemoTeC results?

Matt Kiel

Upcoming Activities

- 10-13 April: GAW Symposium, WMO, Geneva
- 19-21 April: A-Train Symposium, Pasadena, CA
- 23-28 April: EGU, Vienna
- 25-27 April: CEOS SIT, Paris, France
- 20-25 May: JpGU, Chiba, Japan
- 23-24 May: NOAA ESRL GMD Annual Meeting, Boulder CO
- 6-8 June: IWGGMS, Helsinki
- 28-30 June: CEOS VC-AC, CNES HQ, Paris
- 6-11 August, AOGS, Singapore
- 21-25 August, ICDC10, Interlaken, Switzerland