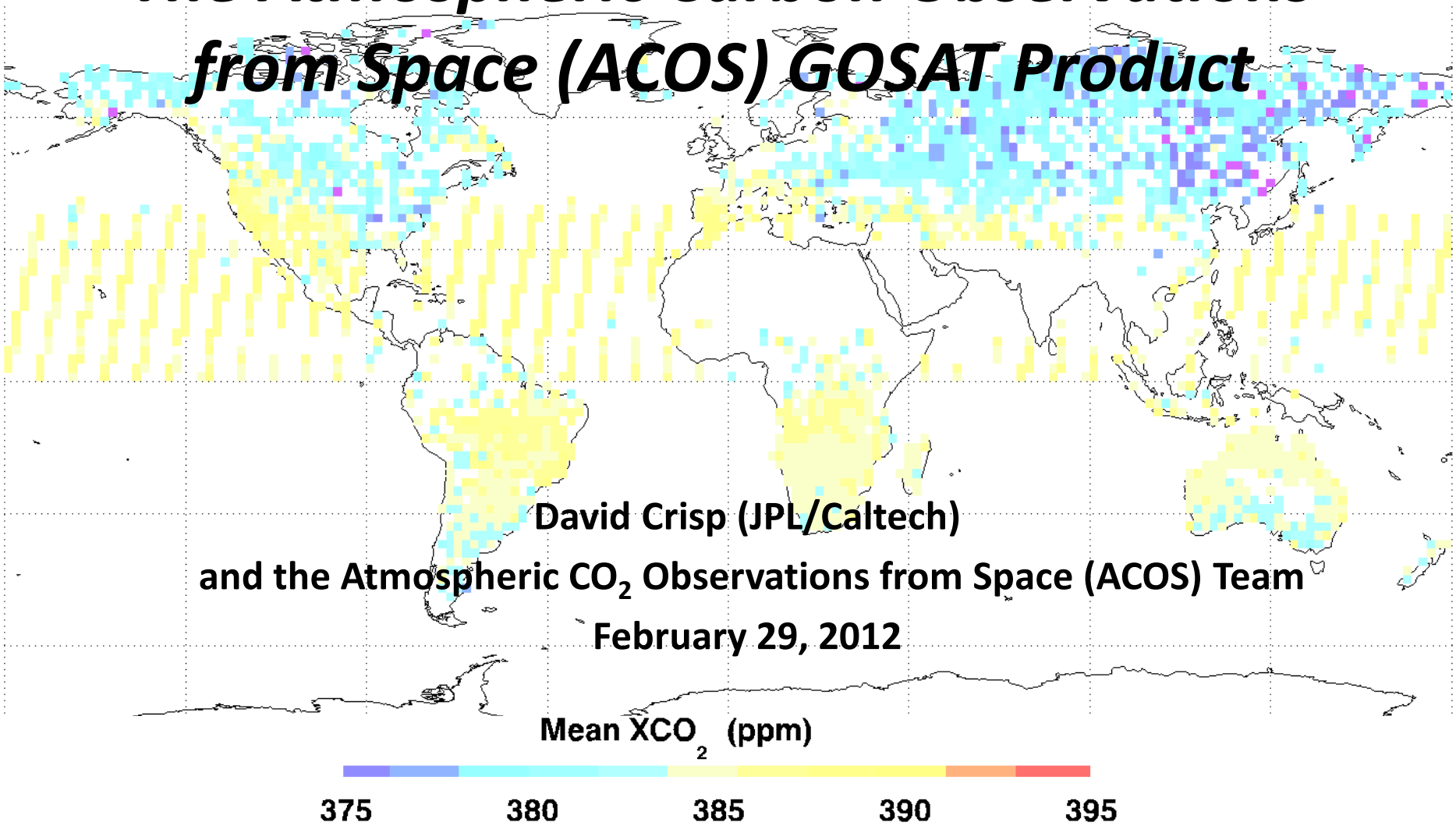
The Atmospheric Carbon Observations from Space (ACOS) GOSAT Product



David Crisp (JPL/Caltech)

and the Atmospheric CO_2 Observations from Space (ACOS) Team

February 29, 2012

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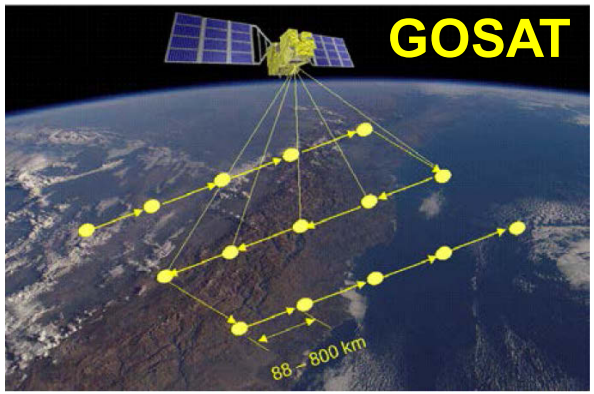
GOSAT-OCO Collaboration

The OCO and GOSAT teams formed a close partnership during the implementation phases of these missions to:

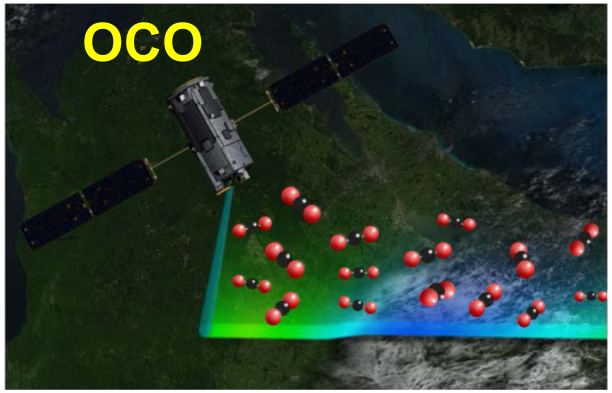
- Cross calibrate the OCO instrument and TANSO-FTS
- Cross validate OCO and GOSAT X_{CO2} retrievals against a common standard

The primary objectives of this partnership were to:

- Accelerate understanding of this new data source
- Facilitate combining results from GOSAT and OCO



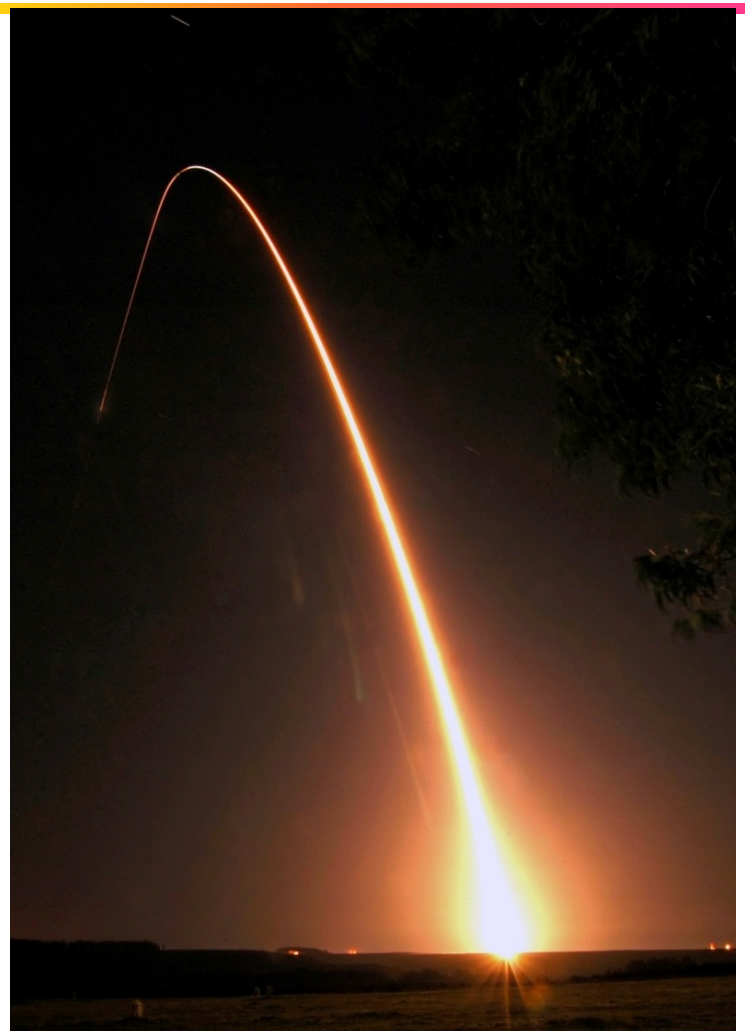
3-day ground track repeat cycle resolves weather



Continuous high resolution measurements along track

The Launch of GOSAT and Loss of OCO

GOSAT launched successfully on 23 January 2009

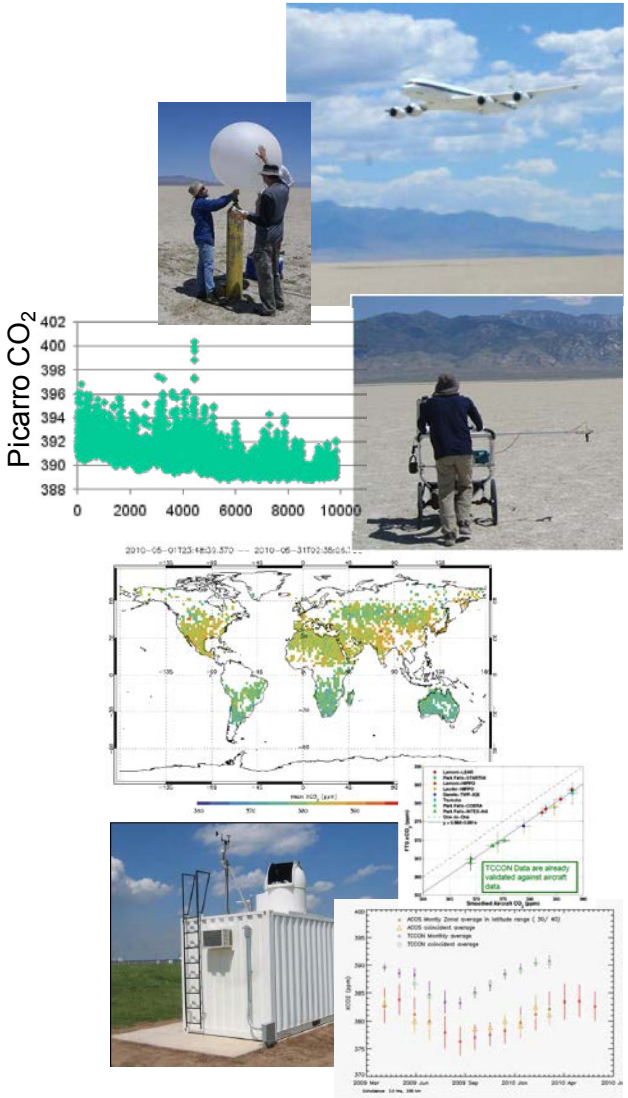


OCO was lost on 24 Feb 2009 when its launch system malfunctioned

The ACOS/GOSAT Collaboration

- Immediately after the loss of OCO, the GOSAT Project manager invited the OCO Team to participate in GOSAT data analysis

- The ACOS team is collaborating closely with the GOSAT teams at JAXA and NIES to:
  - Conduct vicarious calibration campaigns in Railroad Valley, Nevada, U.S.A.
  - Retrieve X_{CO2} from GOSAT spectra
    - Model development & testing
    - Data production and delivery
  - Validate GOSAT retrievals by comparing GOSAT retrievals with TCCON measurements and other data



The ACOS GOSAT Data Product

- The primary purpose of the ACOS effort is to assess
  - The best methods for retrieving X_{CO2} from high resolution spectra, like those from GOSAT, and those expected from OCO-2 and GOSAT-2
  - The use these products in source/sink inversion studies
- The ACOS GOSAT product is therefore more an "Exploratory" product than a production science data product
  - It changes frequently as errors are corrected and new capabilities are added to address known problems
  - It includes large amounts of diagnostic information that may or may not be useful for diagnosing errors and performing source/sink inversions
  - Provides as testbed for assessing instrument design & calibration issues
- The ACOS L2 Products are now being distributed on the Goddard Earth Science Data and Information Services Center (GES DISC) Mirador site.

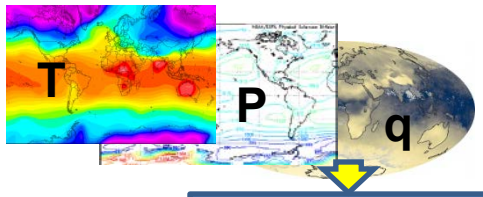
http://mirador.gsfc.nasa.gov/

ACOS GOSAT Versions

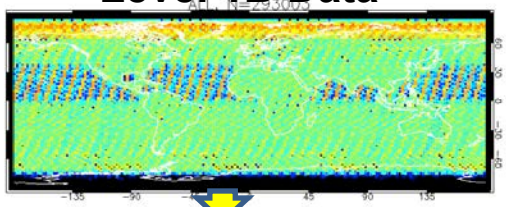
- July 2010: B2.7 – First major release
- December 2010: B2.8
  - Time dependent calibration coefficients (delivered Aug 2010)
  - Implemented pre-screening (cloud screening, latitude filter)
  - Updated convergence criteria
  - Introduced a sounding quality flag
  - Initial glint retrieval results
- October 2011: B2.9
  - Updated time-varying calibration coefficients (delivered Nov 2010)
  - Added geometric correction factors to L1B geolocation
  - Corrected time-dependent noise (consistent with calibration coefficients)
  - Custom glint flag calculation (fixing omitted glint soundings)
  - Cloud screening applied to glint
  - Added Zero-level offset correction to A-band
  - Updated WCO2/SCO2 absorption coefficients, scaled A-band to fix 10 hPa bias
  - Corrected ILS interpolation and other known errors

Retrieving X_{CO2} from GOSAT Spectra

Interpolated Meteorology

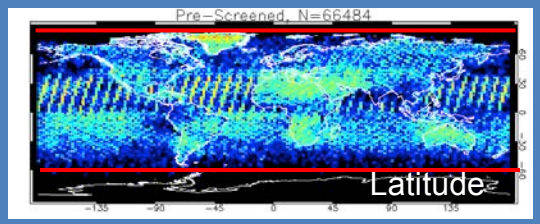


Level 1B Data



- Evolved from the OCO Retrieval Algorithm
  - Optimal Estimation
  - "Full Physics"
  - 3-band (ABO2, WCO2, SCO2)

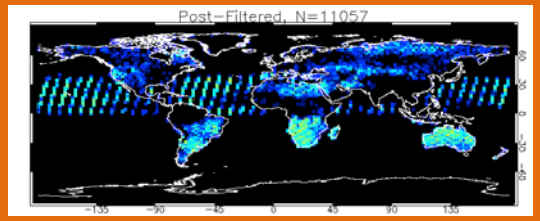
Pre-Processing Filter



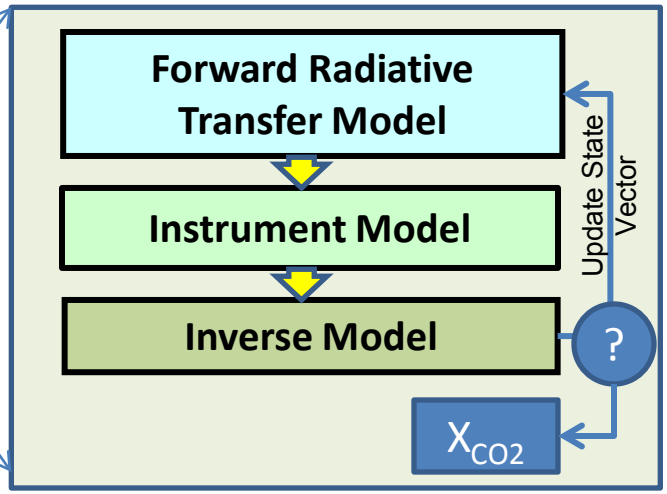
Cloud

X_{CO2} Retrieval Algorithm

Post-Processing Filter



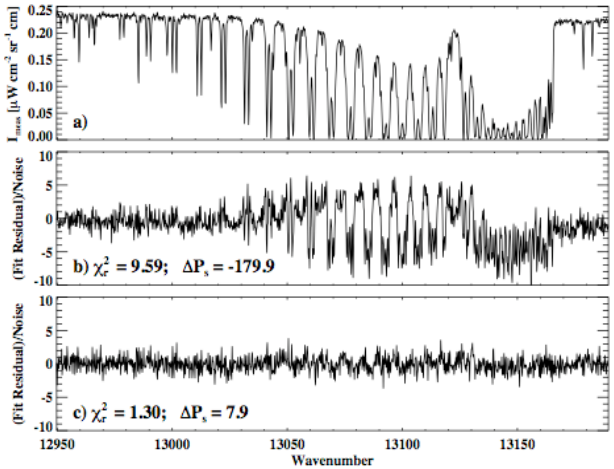
χ^2
Δp
τ_{aer}
σ_{XCO2}



Pre-Processing Filters

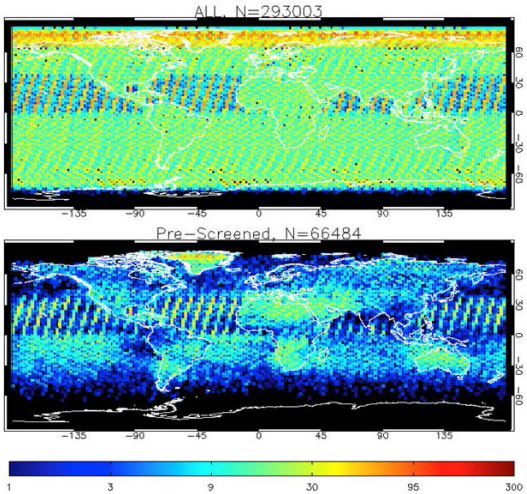
- The ACOS GOSAT Pre-Processing Filters screen the L1B data to screen out
  - Soundings acquired at solar zenith angles > 75°
  - Soundings contaminated by optically-thick clouds

- A Spectroscopic cloud screening algorithm based on the O_2 A-band is currently being used for GOSAT retrievals
  - Fits a clear sky atmosphere to every sounding in the O_2 A band.
  - High values of χ^2 and large differences between the retrieved surface pressure and the ECMWF prior indicate the presence of clouds

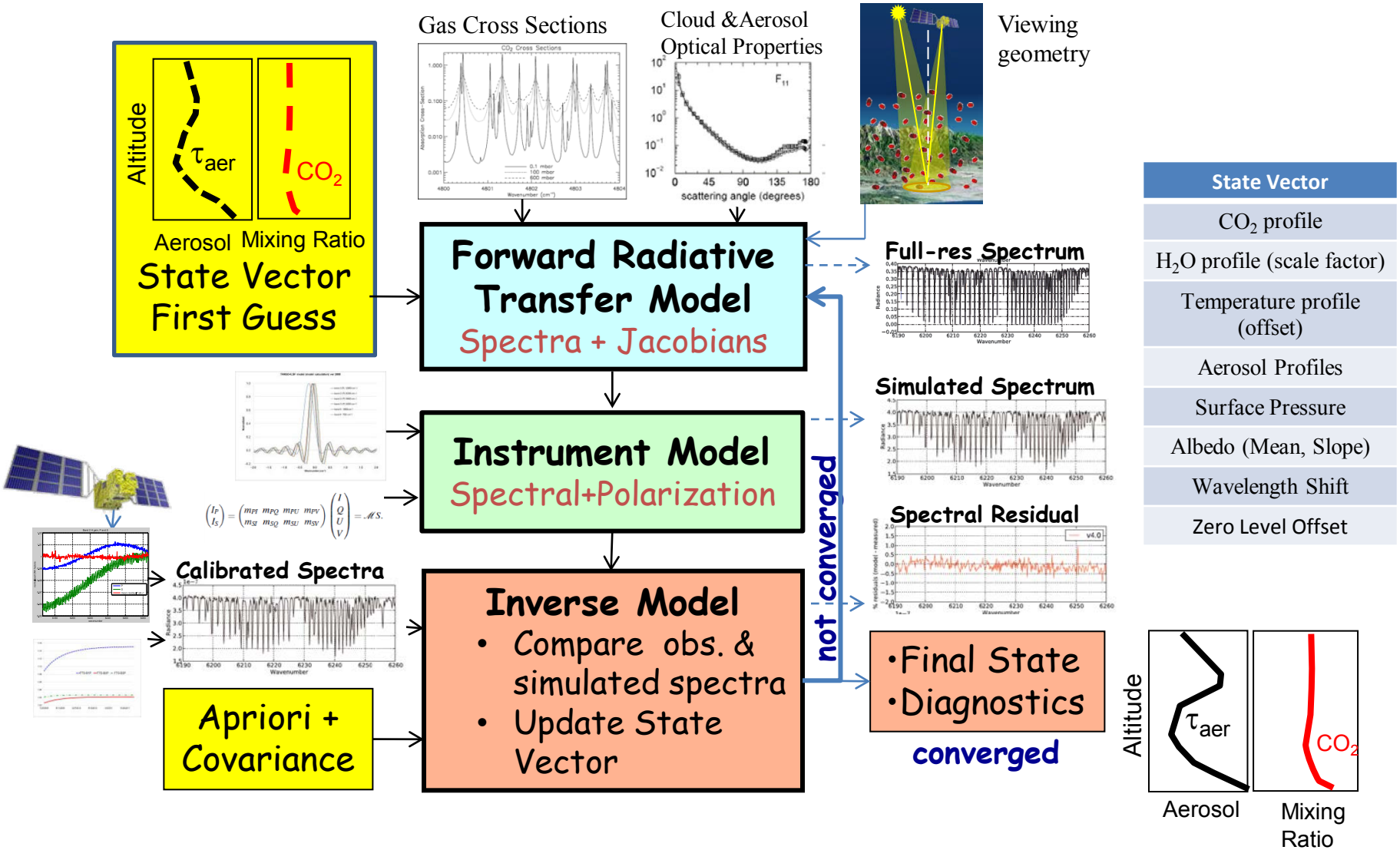


Example A-Band fit

- Poor fit ($\chi^2 = 9.6$) indicates presence of cloud
- Small residuals and good agreement between retrieved and ECMWF surface pressure indicates cloud free

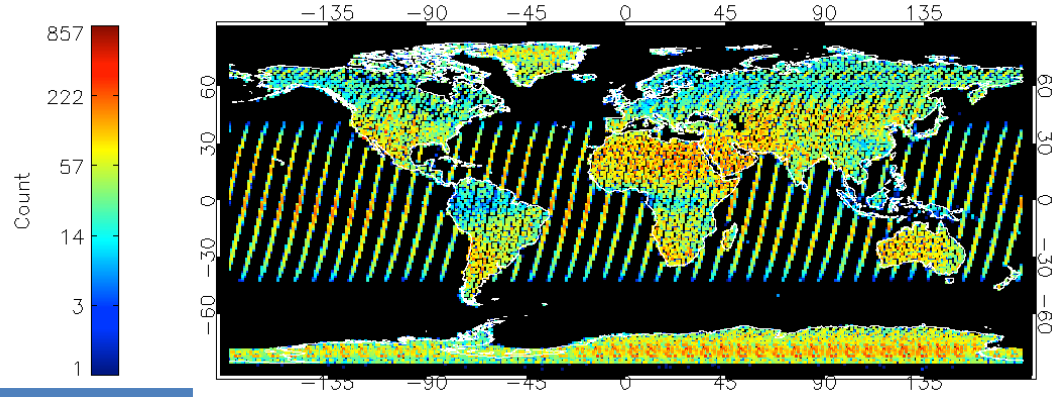


The ACOS X_{CO2} Retrieval Algorithm



Post-Processing Filters

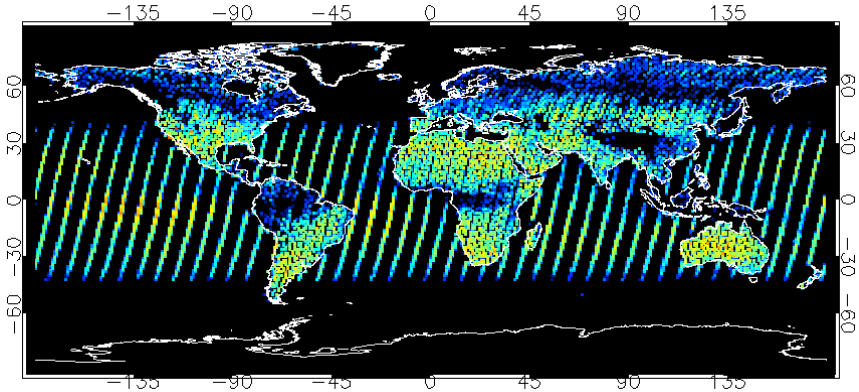
Post Processing filters use diagnostic information from the retrievals to identify unreliable soundings, so that they can be screened from further use.



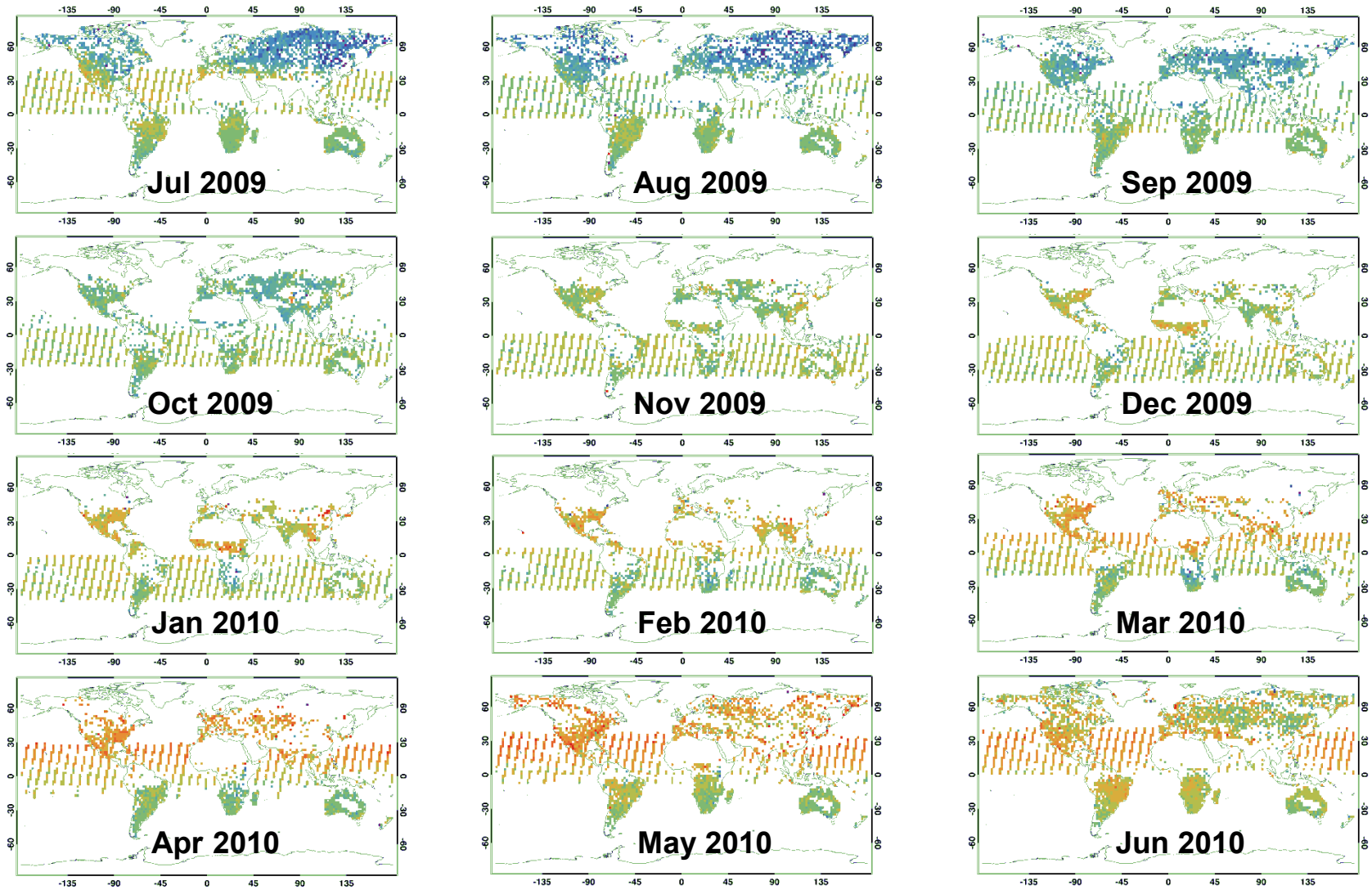
Screening Parameter	Criteria
Cloudy	0
Convergence reached?	1 or 2
χ^2 ABO2	< 1.4
χ^2 WCO2, SCO2	< 2.0
Total Aerosol Optical Depth	< 0.15
Surface Pressure Difference	$-10 < dP_{surf} < 10$ hPa
Albedo SCO2	> 0.05
Blended Albedo	< 1.0
X_{CO2} A Posteriori Error	< 1.3 ppm
Number of Diverging Steps	≤ 1

Above: All cloud-free soundings processed by the L2 algorithm.

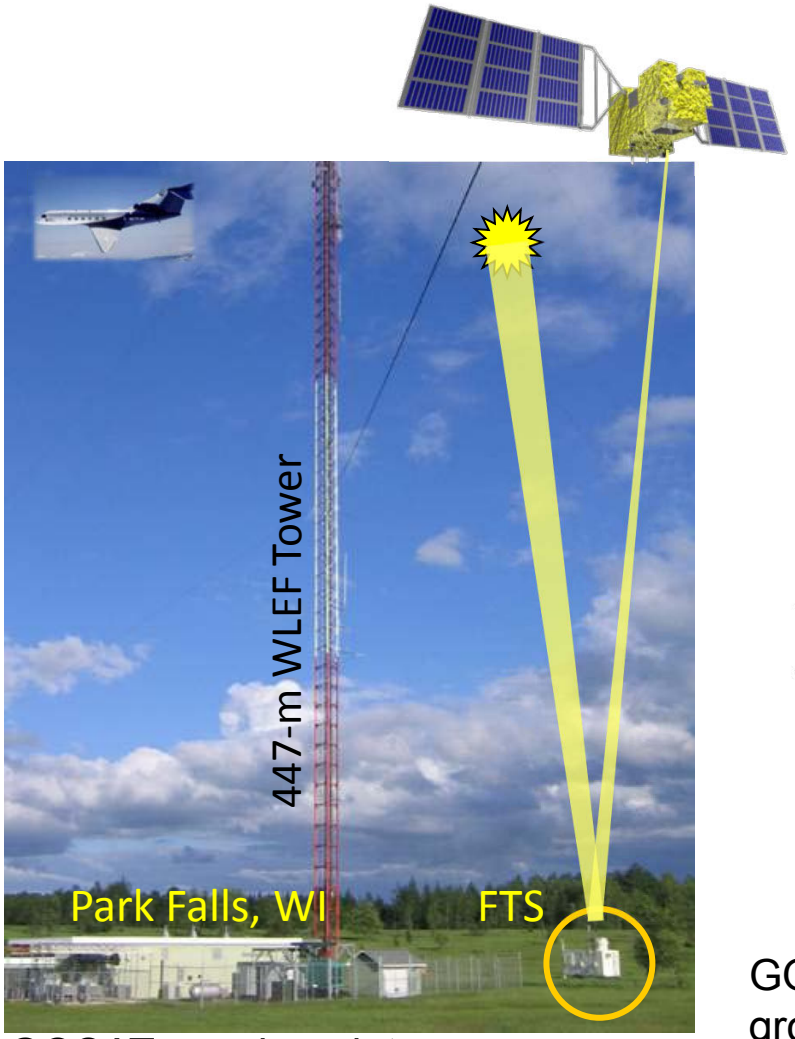
Below: Soundings that passed all Post-Processing filters



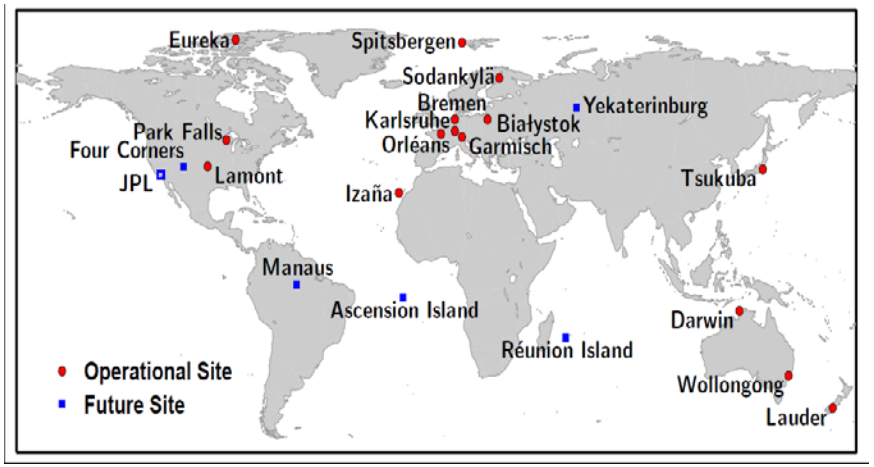
ACOS GOSAT X_{CO2} Seasonal Cycle (H-Gain Only)

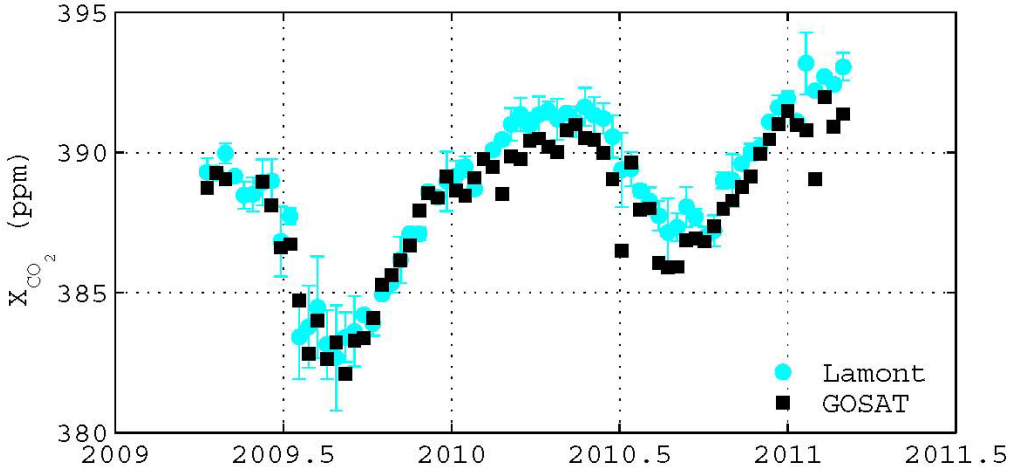


Validating GOSAT Products against TCCON



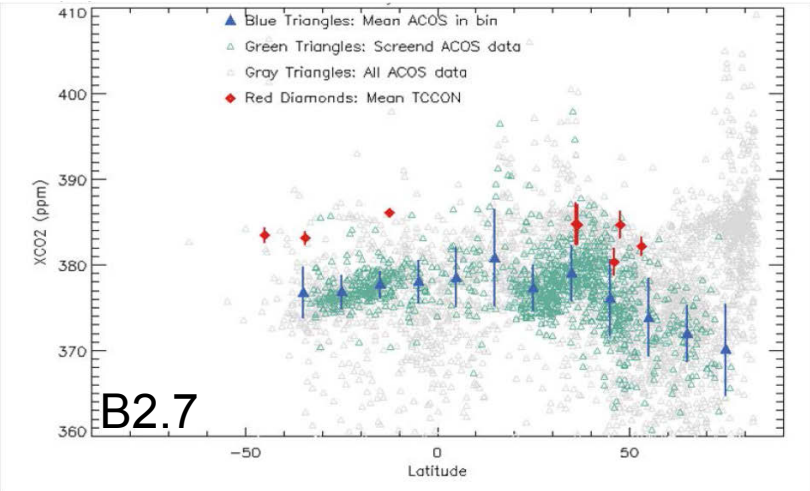
GOSAT acquires data over TCCON Stations

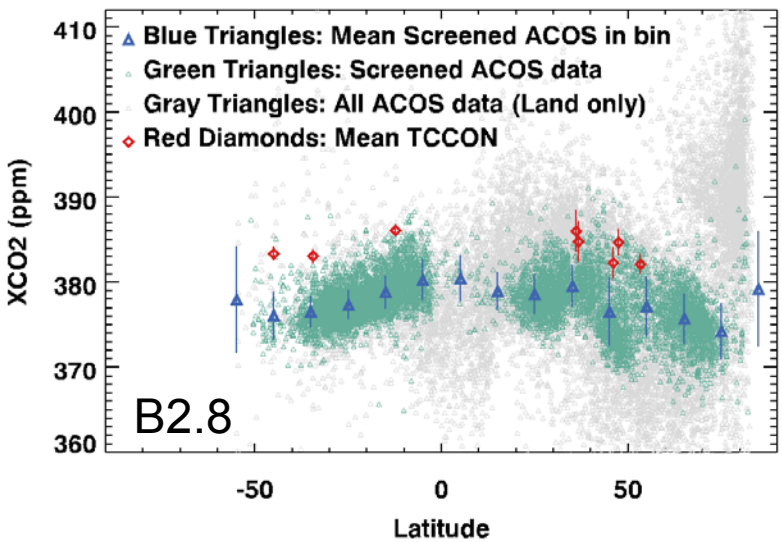


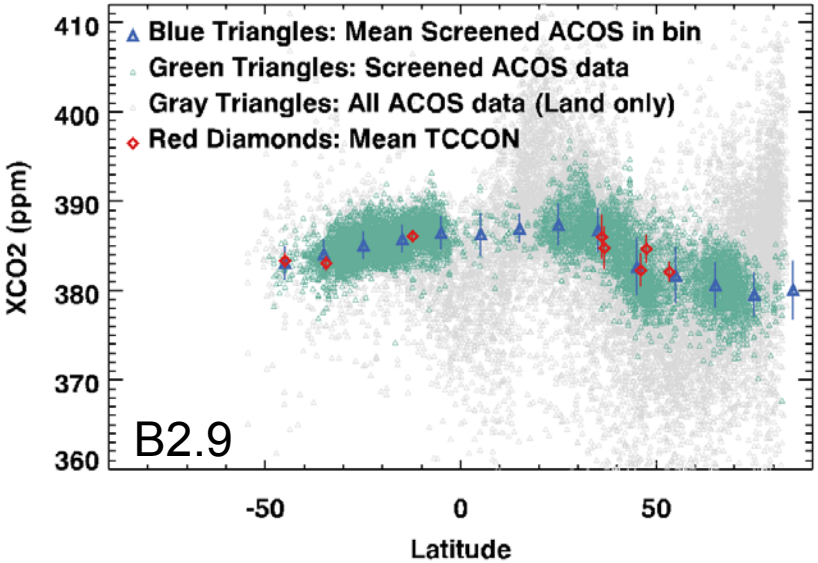


GOSAT X_{CO2} retrievals are compared with those from the ground based Total Carbon Column Observing Network (TCCON) to verify their accuracy

TCCON Comparisons



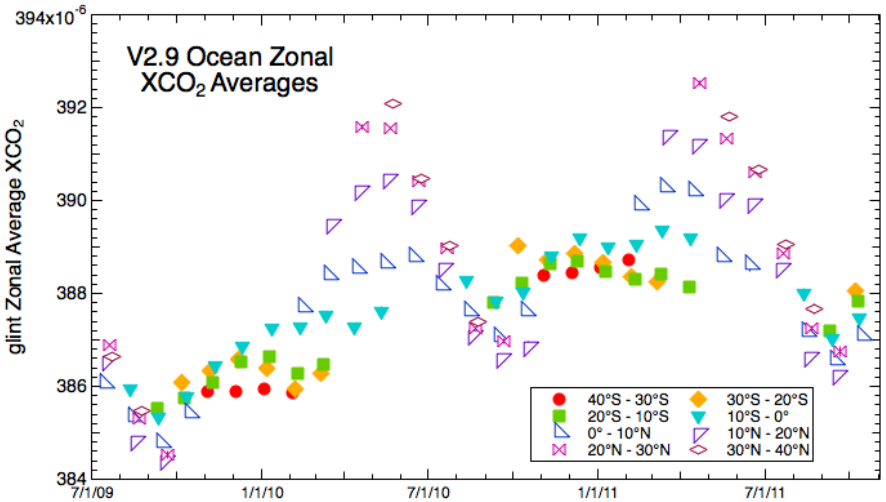


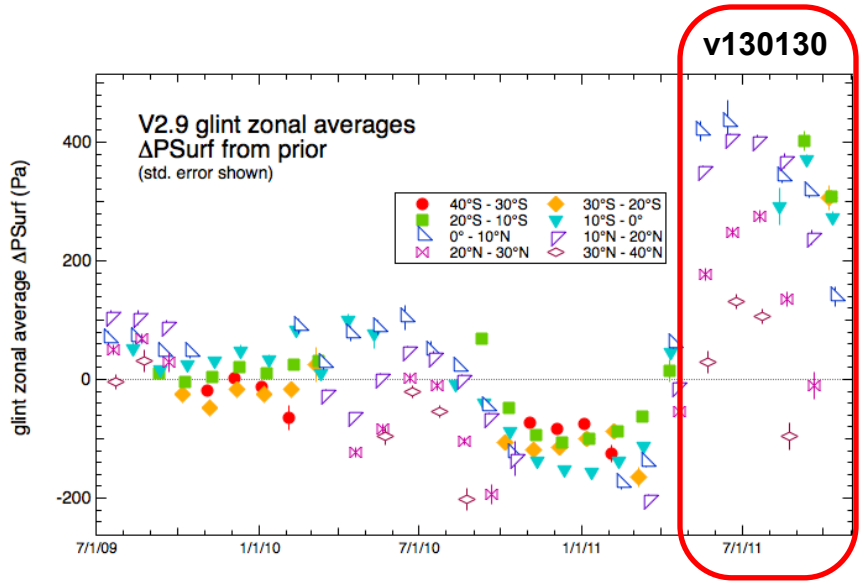


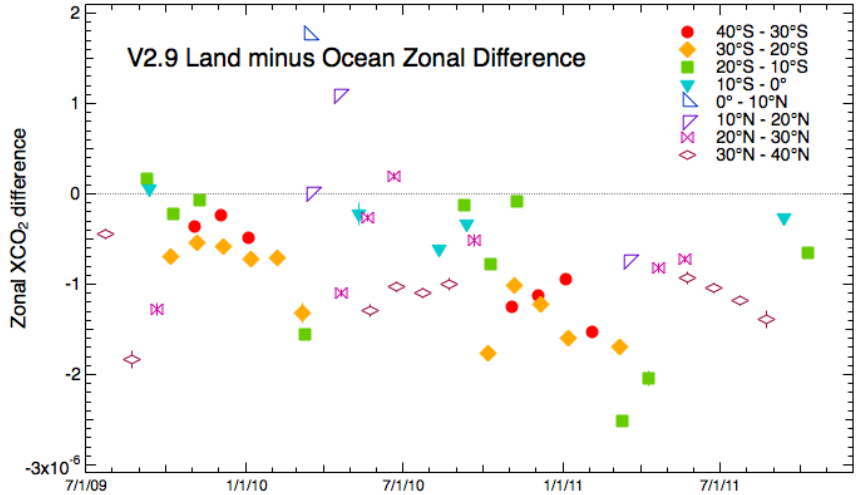
As the algorithms and screening methods improve, we find:

- Increasing yields
- Reduced bias (relative to TCCON)
- Reduced scatter

A First Look at Ocean Glint







ACOS GOSAT B2.9 Processing History

as of 2/23/2012

Build 2.09.01 ACOS Production & Delivery Status

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
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February																															
March																															
April					D	D	D	D	D										D	D	D	D	D	D	D	D	D	D	D	D	
May	D	D	D																												
June			D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
July	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
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October	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
November	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
December	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
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March	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
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June	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
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December	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
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March	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
April	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
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June	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
July	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
August	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
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October	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
November	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
December	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D															
January 12																															
February																															

L1B Version

- GOSAT v050
- GOSAT v080
- GOSAT v100
- GOSAT v110
- GOSAT v130

- B2.09 L1B
- B2.09.01 L2

D Delivered

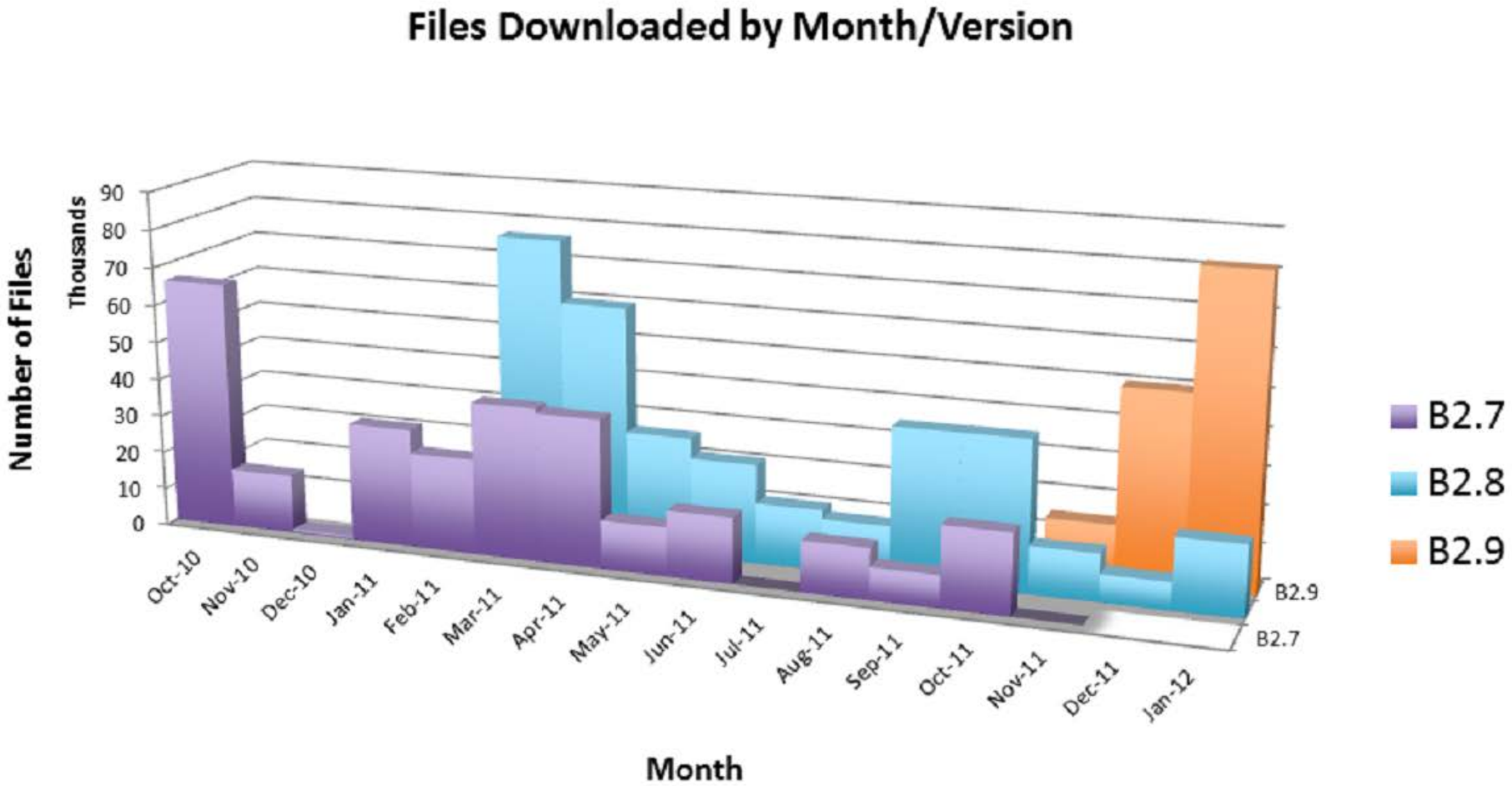
Areas Currently Under Investigation

- Instrument calibration anomalies still limit accuracy
  - Time Dependent throughput variations
  - Non-linearity in Band 1 (O_2 A-band)
  - H-Gain vs M-Gain biases
  - Time dependent errors in pointing

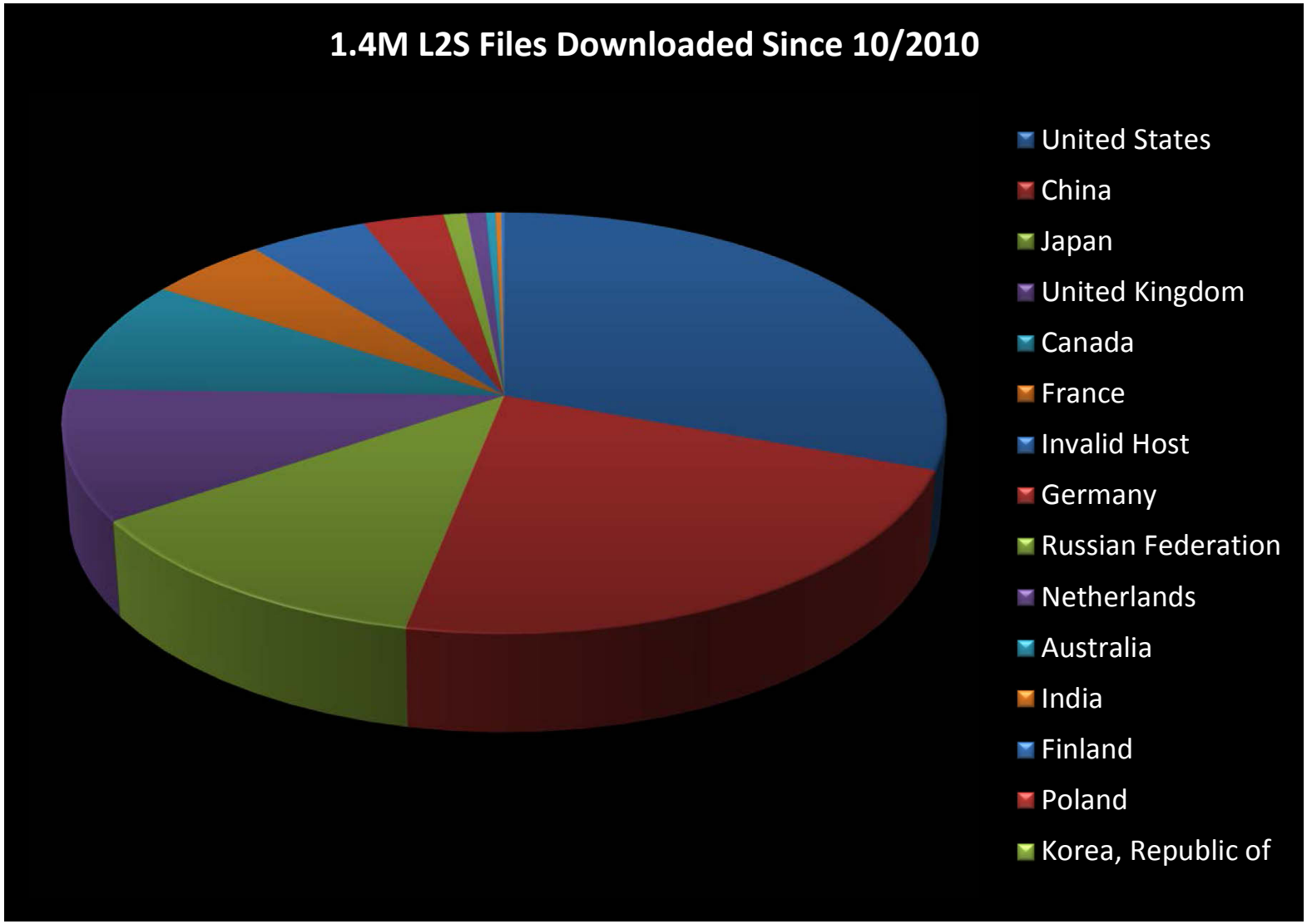
- Retrieval algorithm shortcomings contribute to regional scale bias
  - Gas absorption coefficients: Laboratory studies ongoing
  - Solar model: Small errors in solar lines and solar continuum
  - Aerosol optical properties and vertical distribution
  - Chlorophyll fluorescence neglected
  - Ocean Glint vs Land bias

We are going to hear more about some of these issues here

ACOS Data Downloads



ACOS Downloads by Country



Conclusions

- The ACOS/GOSAT retrieval algorithm is:
  - currently in place and is generating an exploratory GOSAT X_{CO2} product
    - April 2009 – December 2011 delivered to JAXA and to the GES DISC
  - still evolving, to address known errors and biases
- Validation of GOSAT X_{CO2} retrievals against TCCON results
  - Indicate errors < 2 ppm (0.5%) on regional scales over much of the globe
  - are providing valuable insights into the causes of regional-scale bias
- Additional efforts are needed to improve the spatial coverage and yield
- Ongoing efforts to improve the accuracy of the L1B product, the absorption coefficients of CO_2, O_2, and other gases, and the aerosol retrieval approach are expected to yield additional reductions in bias and random error
- Lessons learned from this experience are expected to substantially accelerate the delivery of high quality products from the OCO-2 and GOSAT-2