The Orbiting Carbon Observatory: Mission Overview

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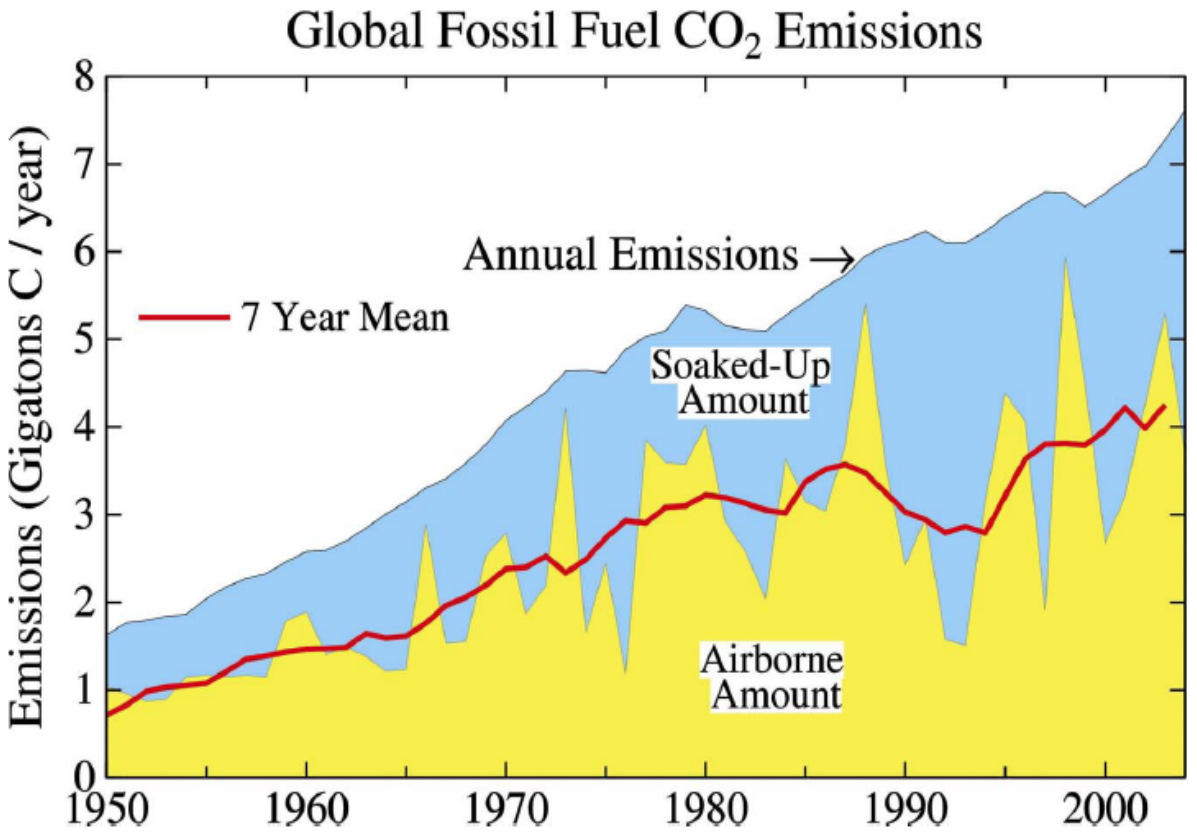
May 2006

Outstanding Questions

- Only ~58% of the CO_2 produced by human activities is remaining in the atmosphere
- Where are the ***sinks*** that are absorbing over 40% of the CO_2 that we emit?
  - Land or ocean?
  - Eurasia/North America?
- Why does CO_2 buildup vary dramatically with nearly uniform emissions?
- How will CO_2 sinks respond to climate change?



Global fossil fuel CO_2 emissions with division into portions that remain airborne or are soaked up by the ocean and land.

Source: Hansen and Sato, *PNAS*, **101**, 16109, 2004.

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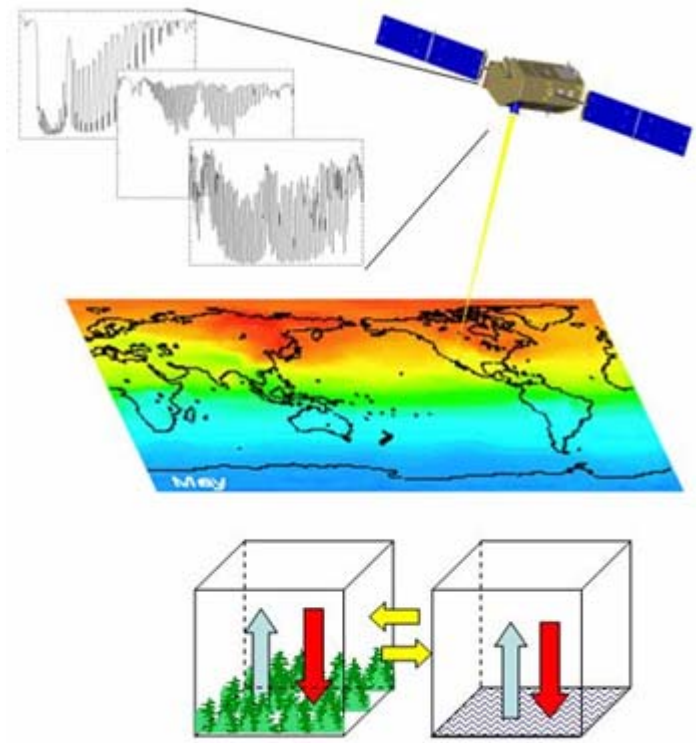
The Orbiting Carbon Observatory (OCO)

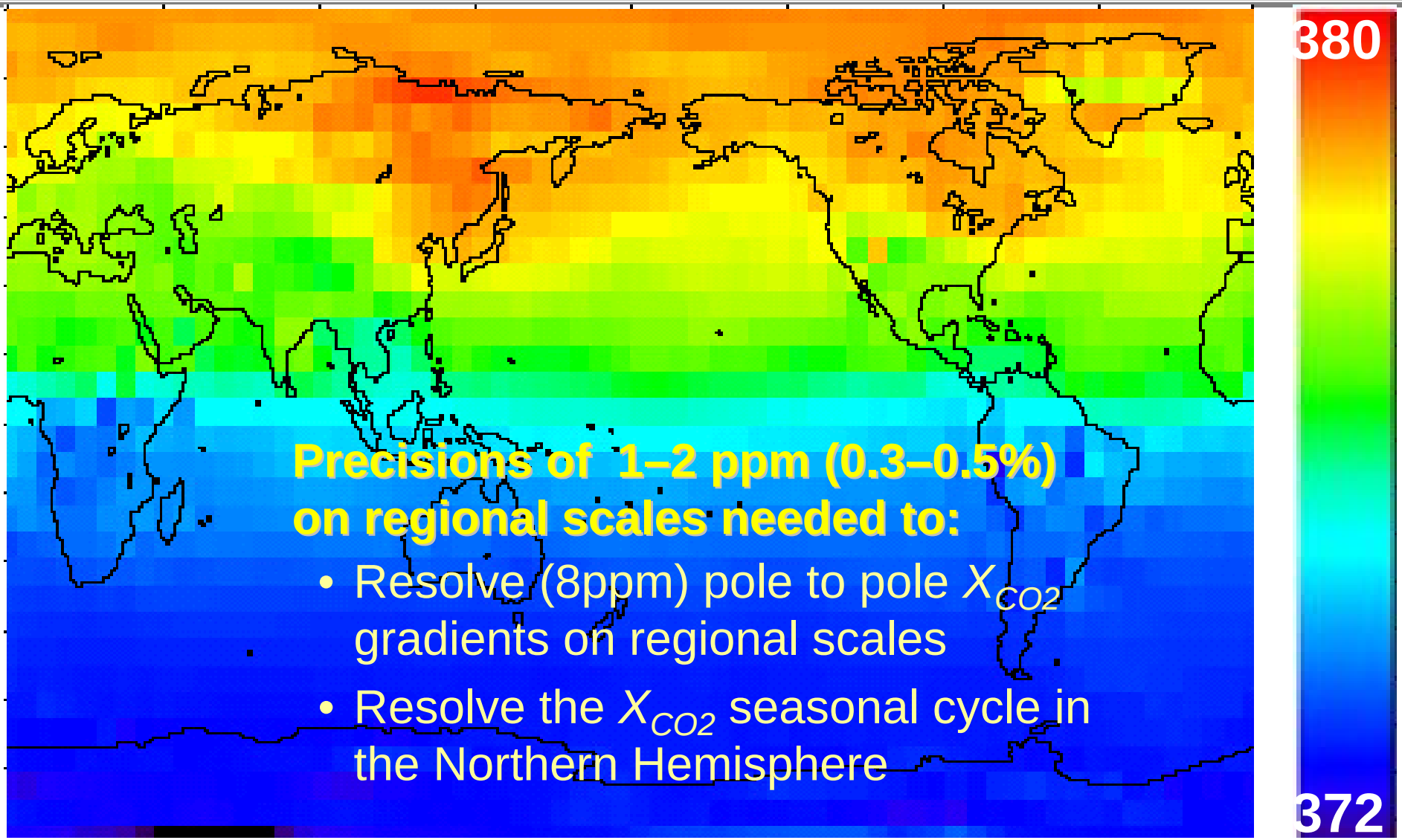
OCO will acquire the space-based data needed to identify CO_2 sources and sinks and quantify their variability over the seasonal cycle

Approach:

- Collect spatially resolved, high resolution spectroscopic observations of CO_2 and O_2 absorption in reflected sunlight
- Use these data to resolve spatial and temporal variations in the ***column averaged CO2 dry air mole fraction, X_{CO2}*** over the sunlit hemisphere
- Employ independent calibration and validation approaches to produce X_{CO2} estimates with random errors and biases no larger than 1 - 2 ppm (0.3 - 0.5%) on regional scales at monthly intervals



Precise Measurements are Needed to Characterize CO_2 Sources and Sinks

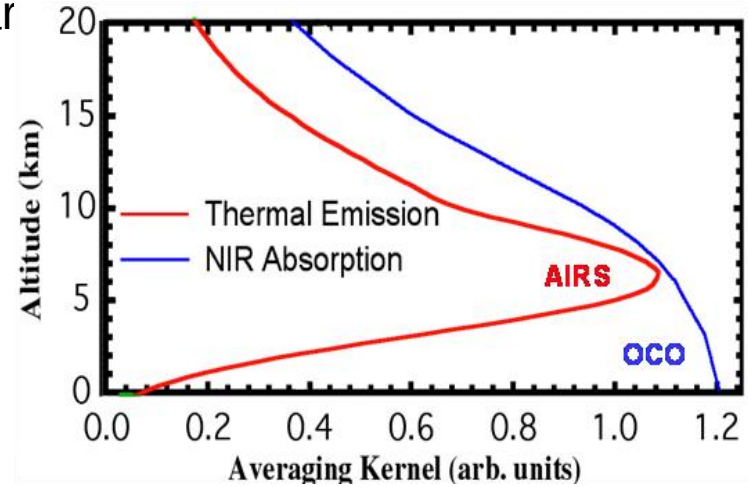


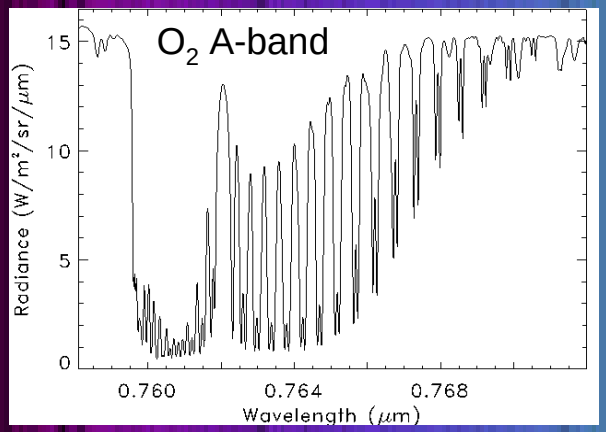
Precisions of 1–2 ppm (0.3–0.5%) on regional scales needed to:

- Resolve (8ppm) pole to pole X_{CO2} gradients on regional scales
- Resolve the X_{CO2} seasonal cycle in the Northern Hemisphere

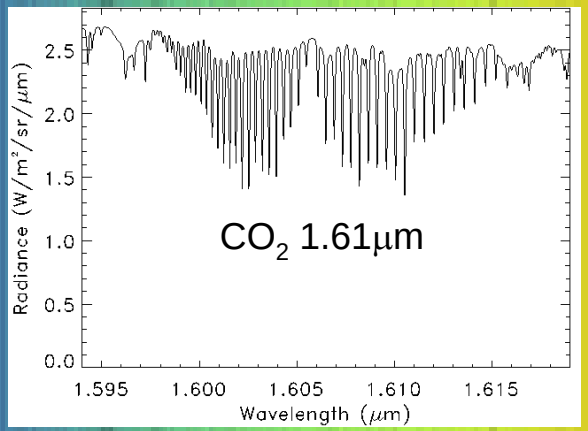
Making Precise CO_2 Measurements from Space

- High resolution spectra of reflected sunlight in near IR CO_2 and O_2 bands used to retrieve the column average CO_2 dry air mole fraction, X_{CO2}
  - 1.61 μm CO_2 band: Column CO_2
  - 2.06 μm CO_2 band: Column CO_2, Aerosols
  - 0.76 μm O_2 A-band: Surface pressure, clouds, aerosols
- Why high spectral resolution?
  - Enhances sensitivity, minimizes biases

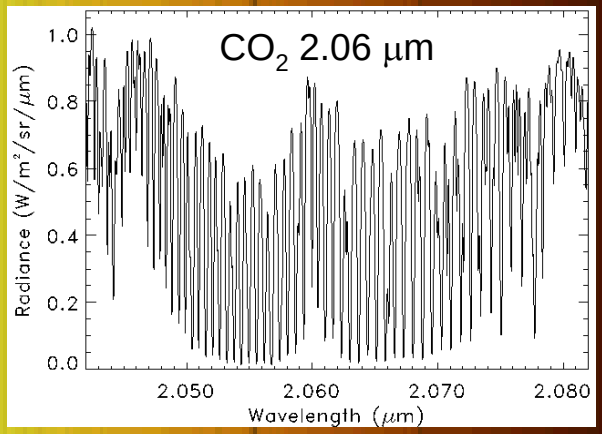




Clouds/Aerosols, Surface Pressure



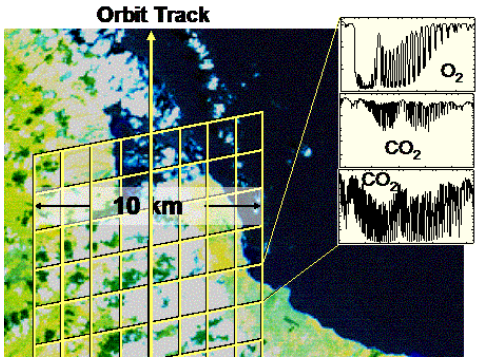
Column CO_2

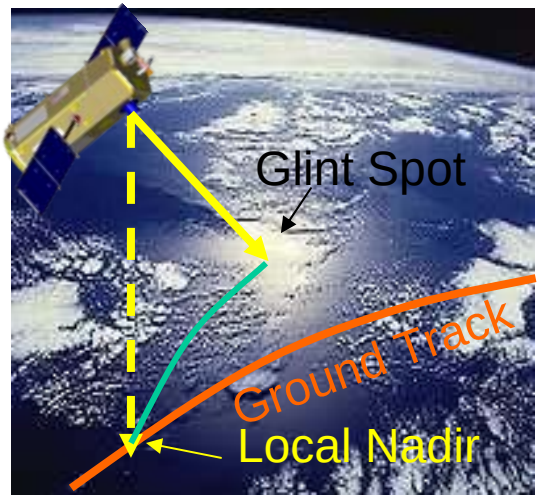


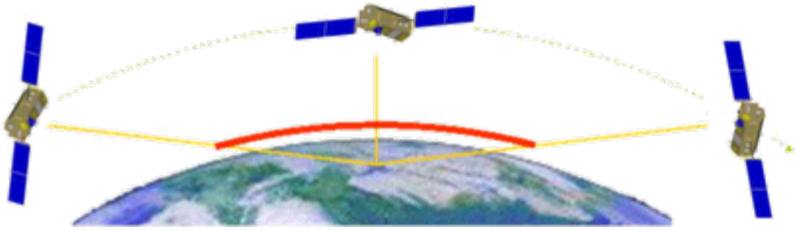
Clouds/Aerosols, H_2O, Temperature

OCO Observing Strategy

- Nadir Observations: tracks local nadir
  - + Small footprint (< 3 km^2) isolates cloud-free scenes and reduces biases from spatial inhomogeneities over land
  - Low Signal/Noise over dark ocean
- Glint Observations: views "glint" spot
  - + Improves Signal/Noise over oceans
  - More interference from clouds
- Target Observations
  - Tracks a stationary surface calibration site to collect large numbers of soundings
- Data acquisition schedule:
  - alternate between Nadir and Glint on 16-day intervals
  - Acquire ~1 Target observation each day

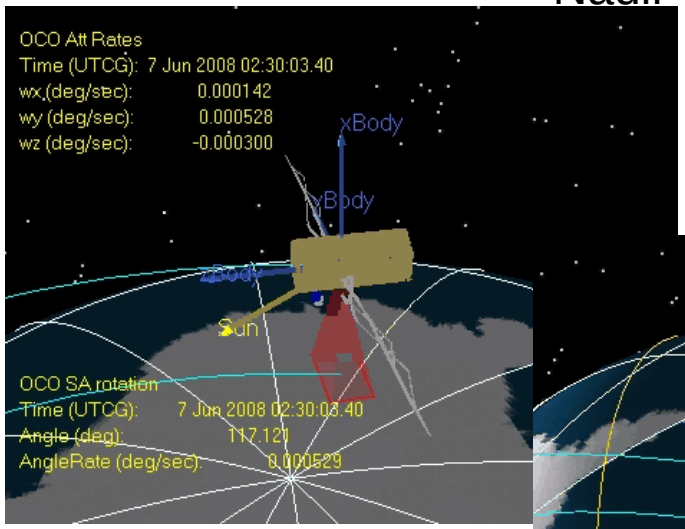




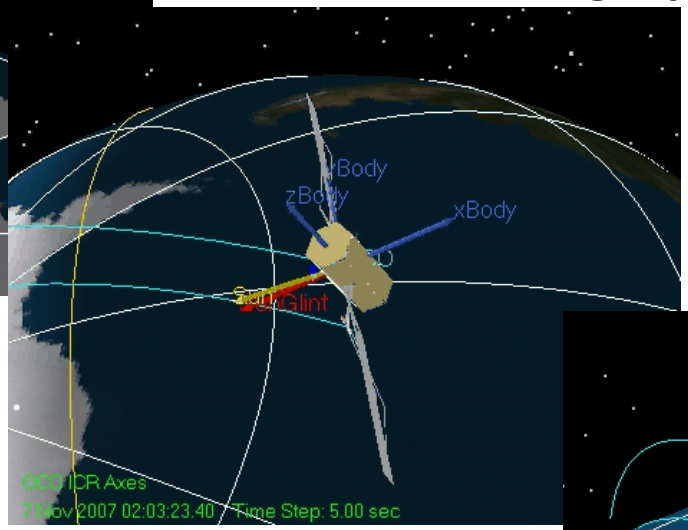


OCO Observing Modes

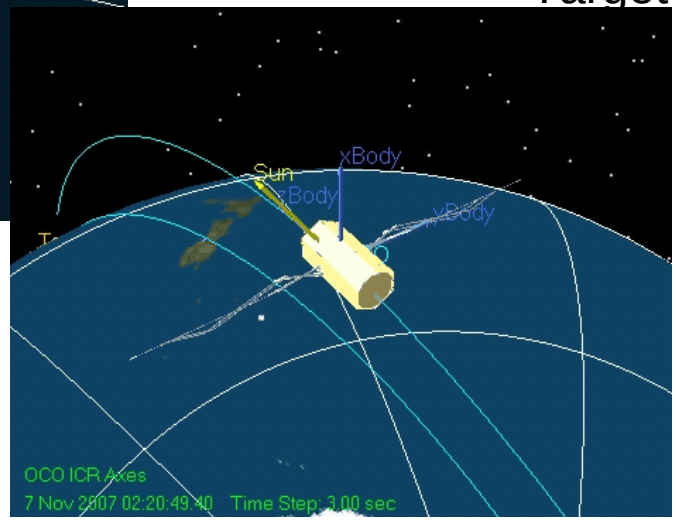
Nadir



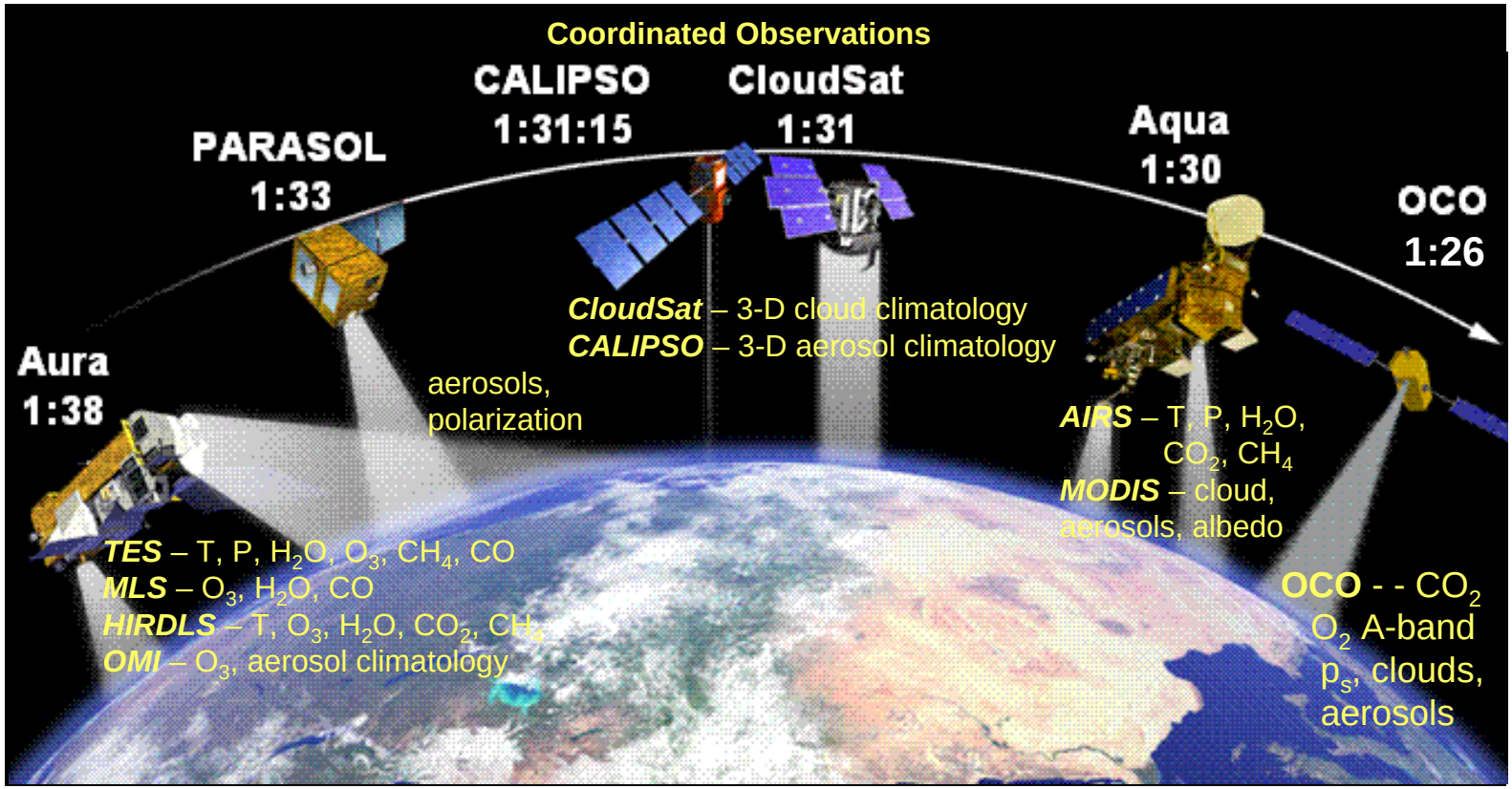
Glint



Target



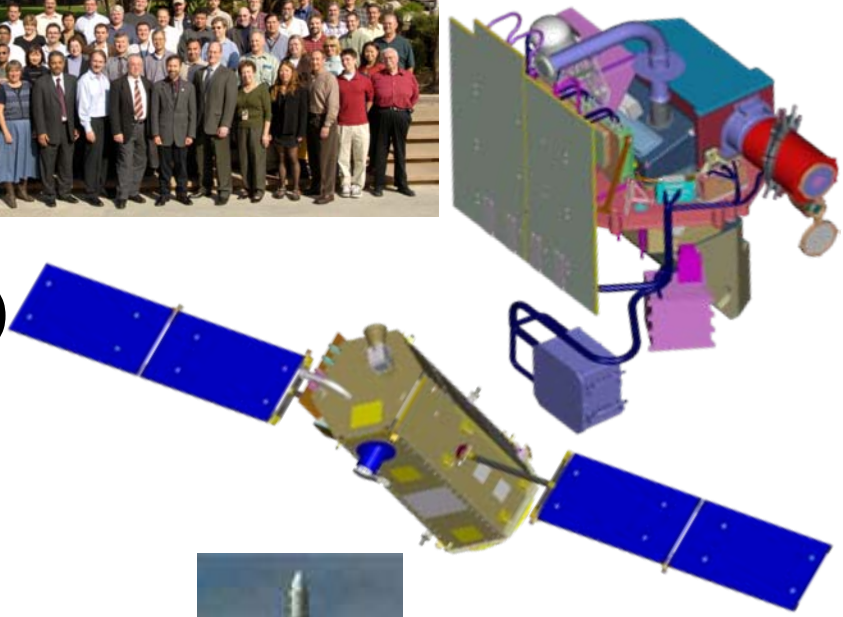
OCO Will Fly in the A-Train



OCO files at the head of the A-Train, 12 minutes ahead of the Aqua platform

- 1:26 PM equator crossing time yields same ground track as AQUA
- Near noon orbit yields high SNR CO_2 and O_2 measurements in reflected sunlight
- CO_2 concentrations are near their diurnally-averaged values near noon
- Maximizes opportunities of coordinated science and calibration activities

OCO Mission Approach



Project Management (JPL)

- Science & Project Team
- Systems Engineering, Mission Assurance
- Ground Data System

Single Instrument (Hamilton Sundstrand)

- 3 high resolution grating spectrometers

Dedicated Bus (Orbital Sciences)

- LEOstar2: GALEX, SORCE, AIM

Dedicated Taurus 3110 Launch Vehicle (Orbital)

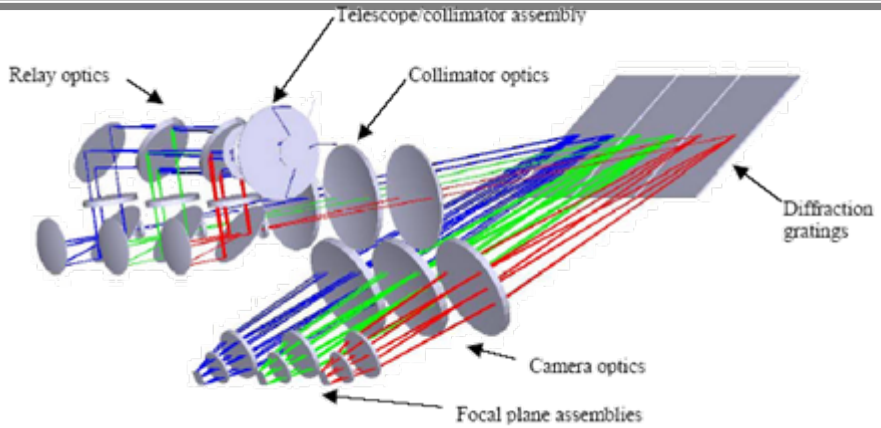
- September 2008 Launch from Vandenberg AFB

Mission Operations (JPL/Orbital Sciences)

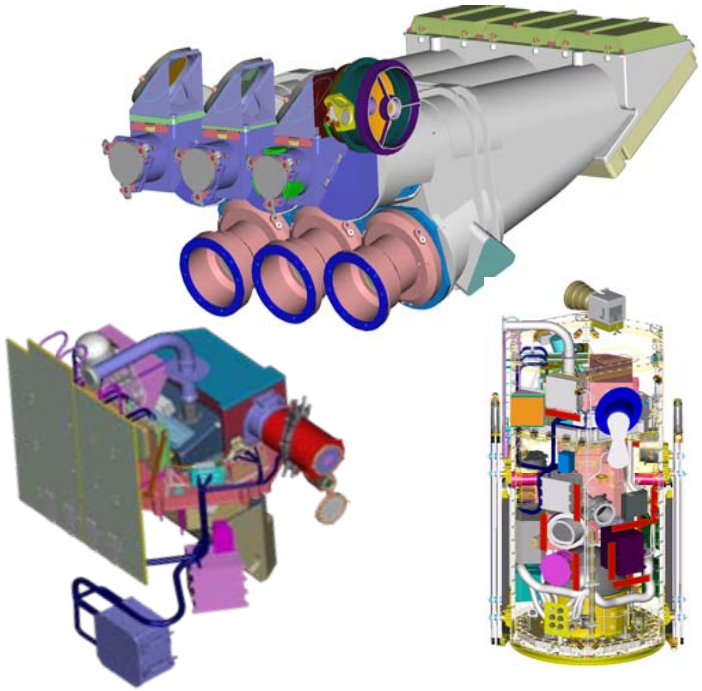
- NASA Ground Network, Poker Flats, Alaska

The OCO Instrument

- **3 bore-sighted, high resolution, grating spectrometers**
  - O_2 0.765 μm A-band
  - CO_2 1.61 μm band
  - CO_2 2.06 μm band

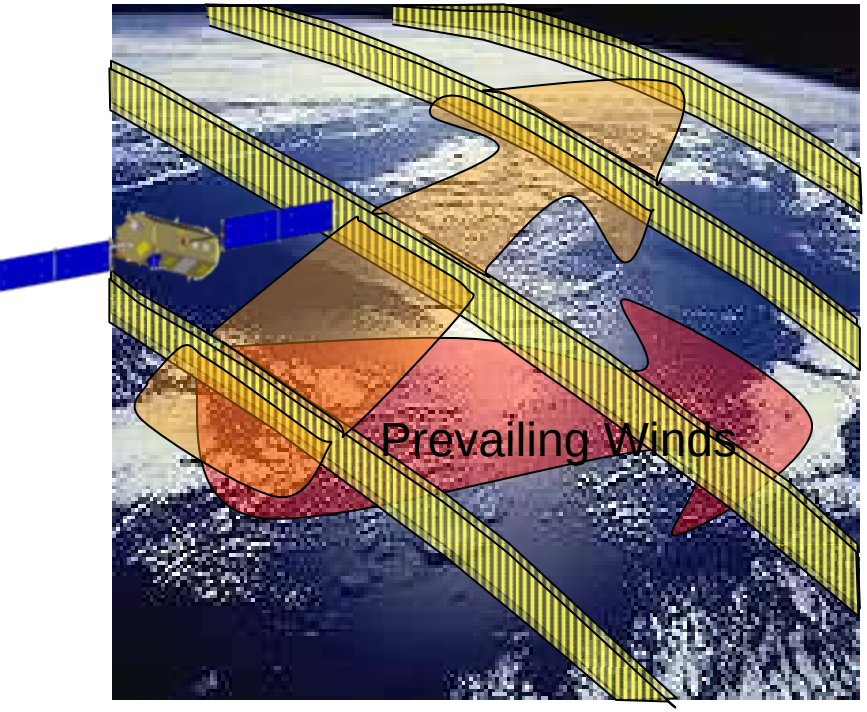


- **Similar optics and electronics**
  - Common 200 mm f/1.9 telescope
  - Spectrometers cooled to < 0 ^{o}C
  - Resolving Power ~18,000/21,000
  - Common electronics for focal planes

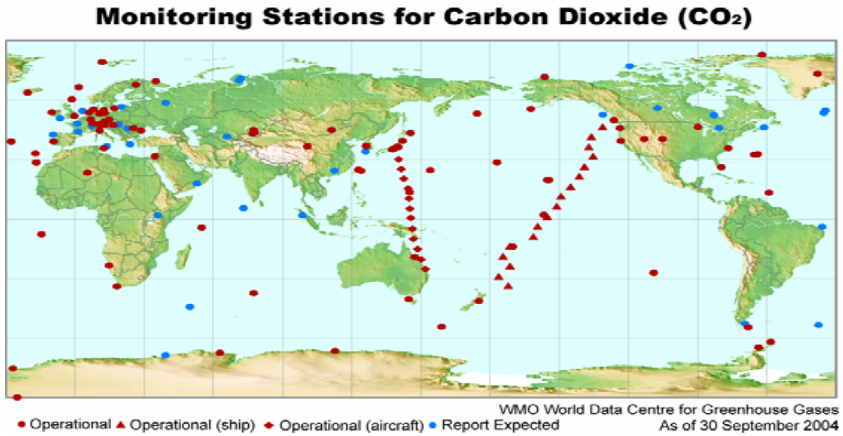


- **Status**
  - Detectors: Delivered in June 2006
  - Gratings: Delivered in June 2006
  - Optical Bench: In process.

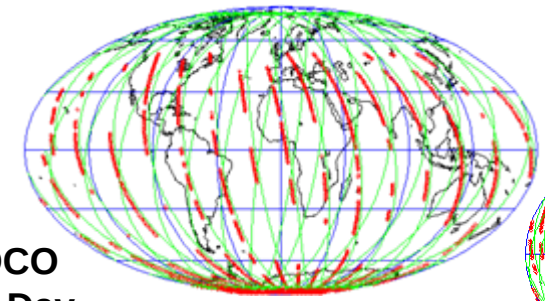
OCO Sampling over a 16-Day Repeat Cycle



Space-based CO_2 column measurements complement surface measurement network.

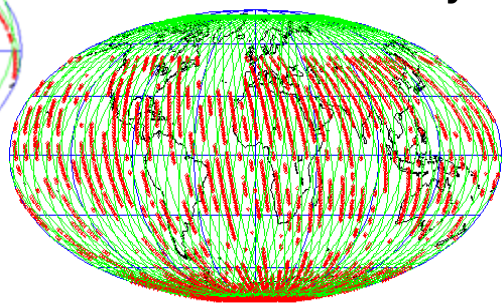


- OCO Sampling Rate/Coverage
  - 12-24 samples/second collected along track over land and ocean
  - Glint: ±75o SZA
  - Nadir: ±85o SZA
  - Longitude resolution 1.5°



OCO 1-Day

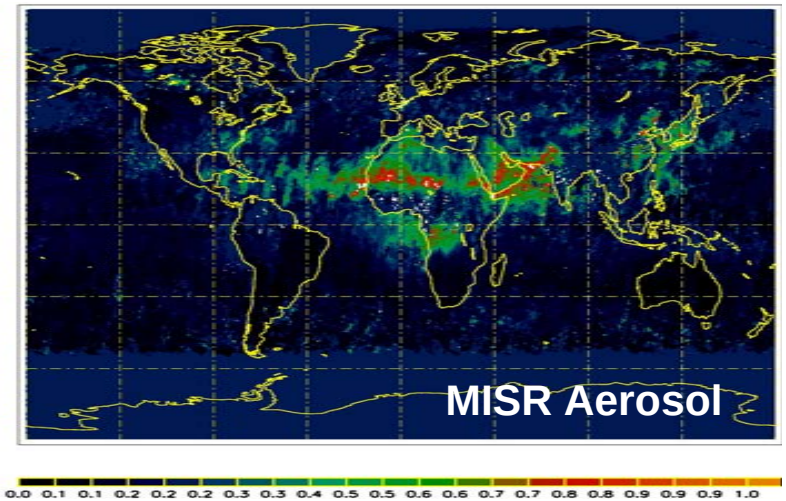
OCO 3-Days

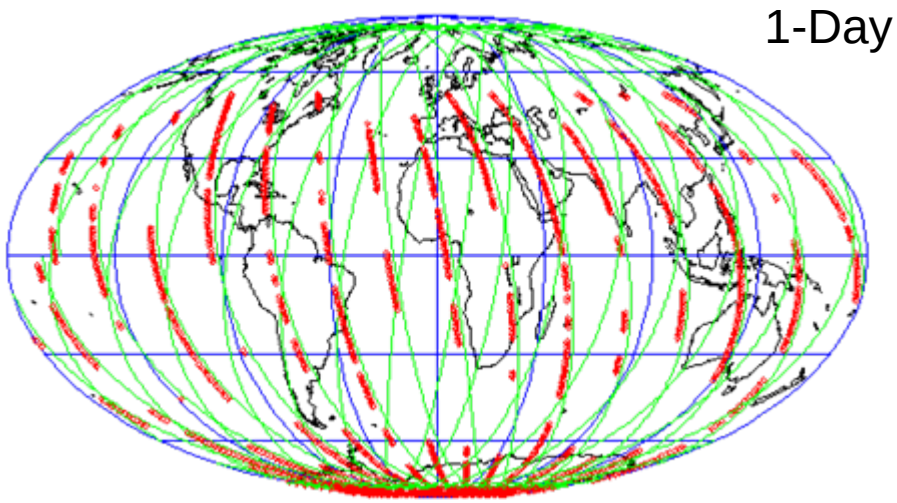


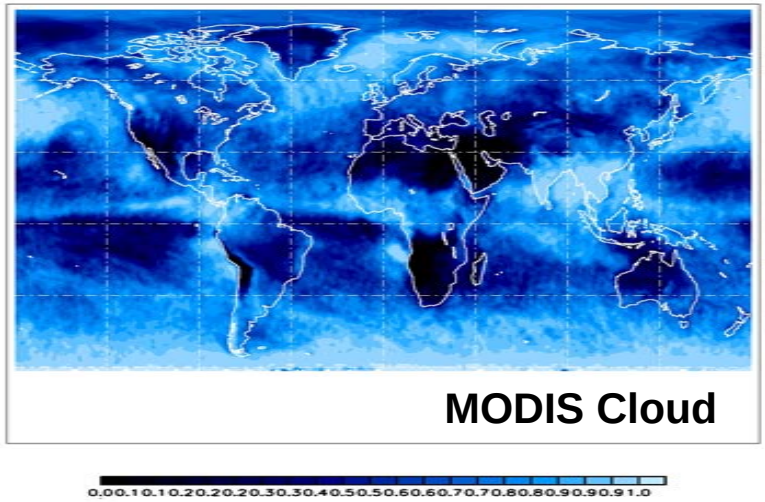
OCO Sampling: Clouds reduce number of usable samples

Chevallier et al. 2006

Spatial/Temporal Sampling Constraints



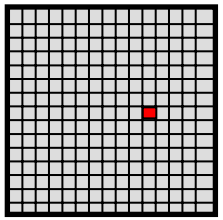




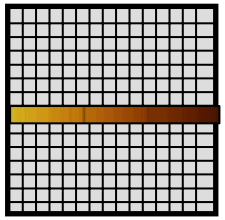
Factors Limiting Sampling Density

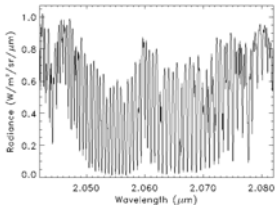
- **Orbit ground track**
- **Clouds and Aerosols**
  - **OCO can collect usable samples only in regions where the cloud and aerosol optical depth < 0.3**
- **Low Surface Albedo**
- **Others?**

OCO Data Hierarchy

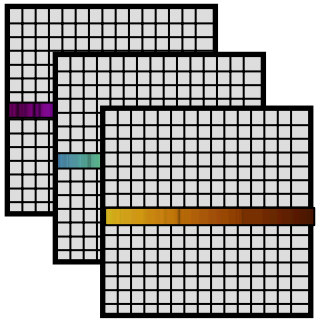


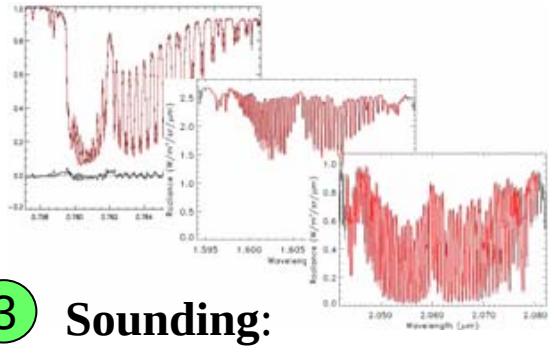
1 **Pixel**



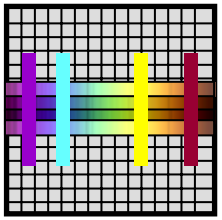


2 **Spectrum**

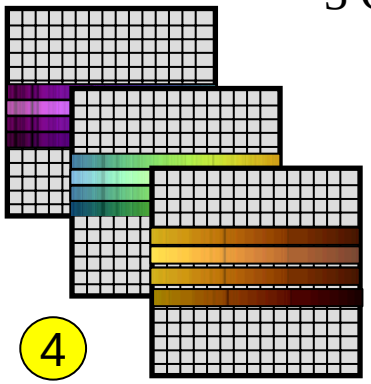




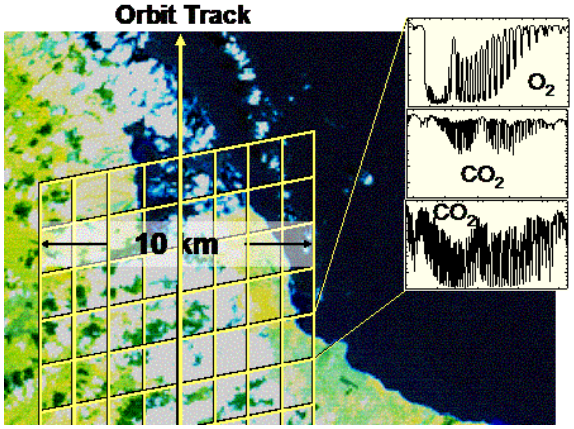
3 **Sounding**:
3 Collocated Spectra

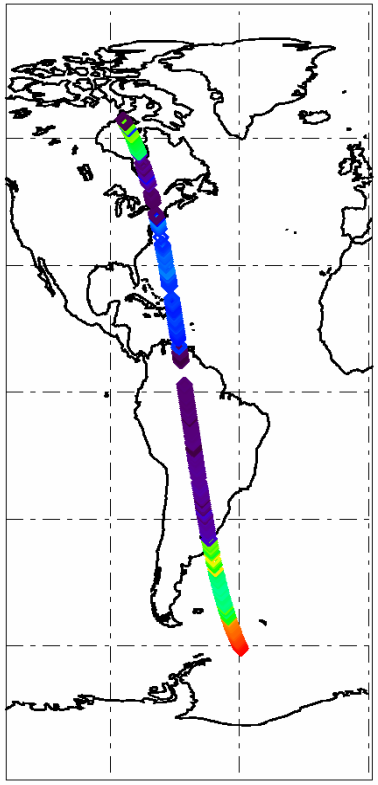


5 **4 (20) Full Res Color Stripes**



4 **Frame**:
4 (8) Cross-Track Soundings



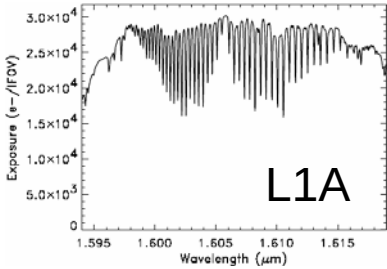


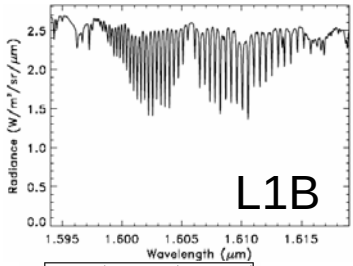
6 **Granule**:
All ~30,000 Soundings recorded each orbit

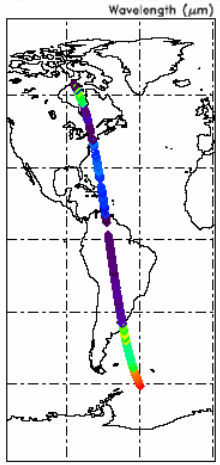
Summary of Data Products

0010011010001

- **Four major products**
  - **Level 0 – Time-ordered science and housekeeping data**
    - Raw data, excluding spacecraft packet information for data transfer to ground
  - **Level 1A - Parsed and merged science and instrument housekeeping telemetry**
    - Data subdivided into discretely named elements
    - Data from all three spectrometers correlated in a single frame
    - Corresponding temperature and voltage measures from housekeeping merged into appropriate frame
  - **Level 1B - Spatially ordered, Geolocated, calibrated spectra**
  - **Level 2 - Geolocated retrieved state vectors with column averaged CO_2 dry air mole fraction**







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OCO Data Product Volumes

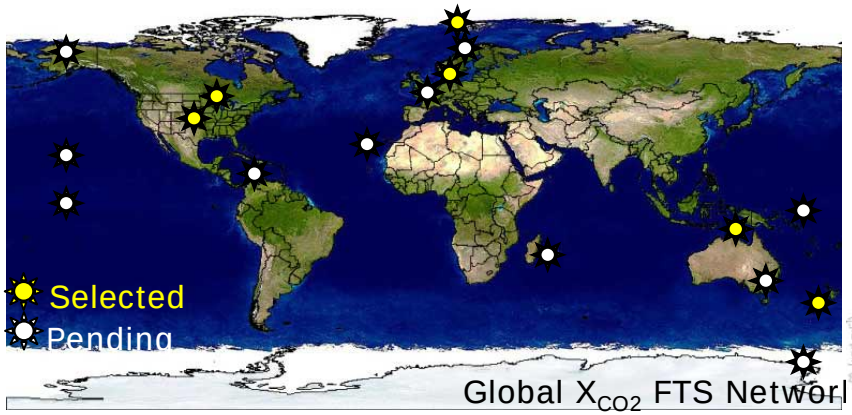
Product	Daily Volume (Gbytes)	Mission Volume (Tbytes)
Science Telemetry	4.843	3.455
Housekeeping Telemetry	0.186	0.133
OCO Level 0	4.406	3.141
OCO Level 1A	4.479	3.193
OCO Level 1B	9.090	6.480
Level 2	0.226	0.161
Total	23.230	16.563

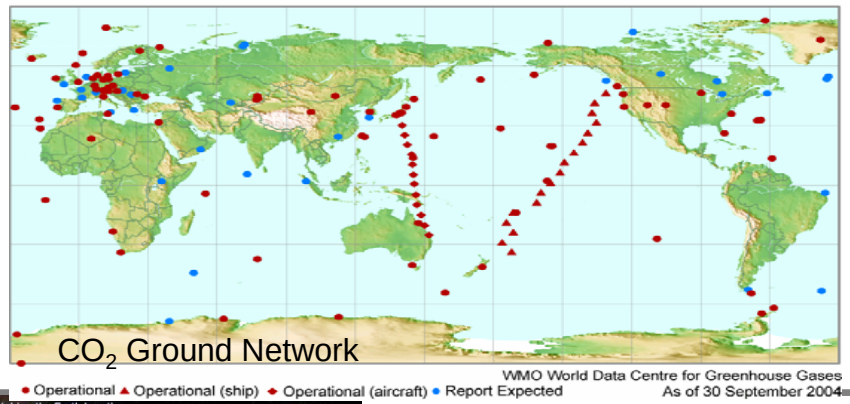
OCO can collect up to 8 cross-track soundings per frame.
Volumes quoted here assume 4 cross-track soundings per frame.

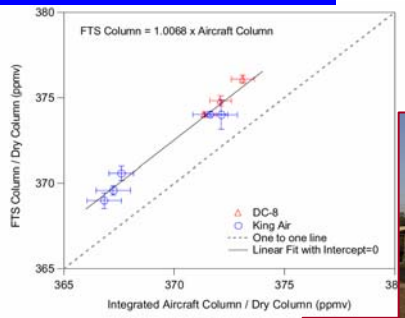
Space-based X_{CO2} Validation Strategy Ensures Accuracy and Early Acceptance

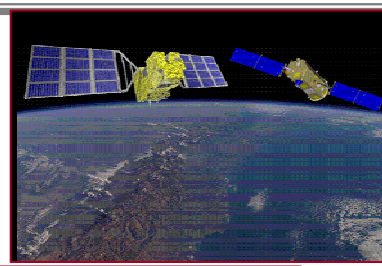
A common validation approach will speed acceptance of OCO and GOSAT data by the Science Community

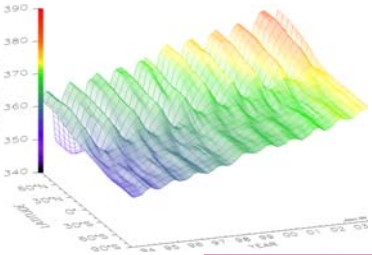
- The space-based measurements must be validated against the surface CO_2 standard

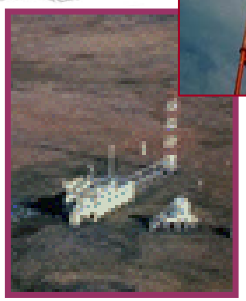


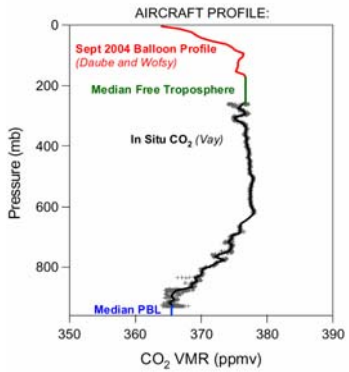












JPL Orbital Hamilton Sundstrand
A United Technologies Company

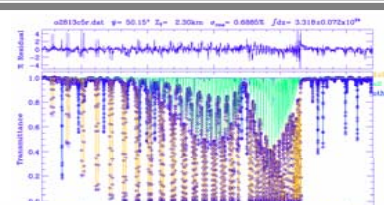
Ground-Based FTS – the Transfer Standard

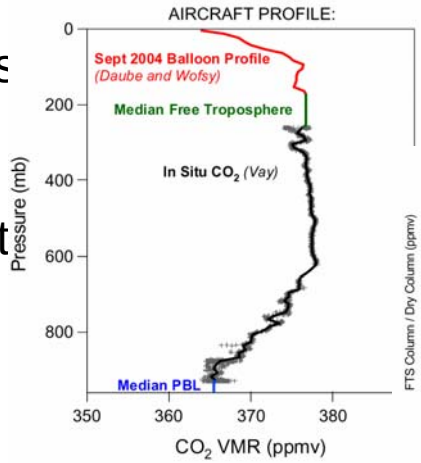
- OCO will use the WMO surface CO_2 standard, which is based on flask and tower measurements from the NOAA network

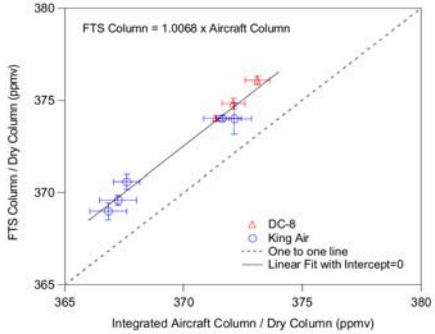
- Ground based Fourier transform spectrometers will be used as a transfer standard
  - Same retrieval code used to retrieve X_{CO2} from the FTS and space-based instrument

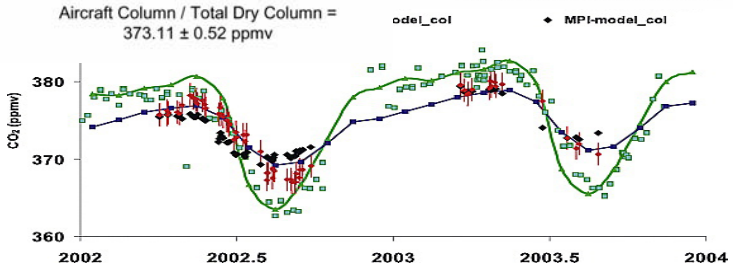
- To validate the FTS transfer standard, FTS X_{CO2} retrievals are being compared to:
  - Surface and tower *in situ* CO_2
  - Integrated column CO_2 from *in situ* aircraft profiles

- FTS X_{CO2} performance monitoring:
  - Instrument Line Shape (HCl gas cell)
  - Pointing (Doppler shift, telluric/solar lines)
  - XO_2, surface pressure and H_2O



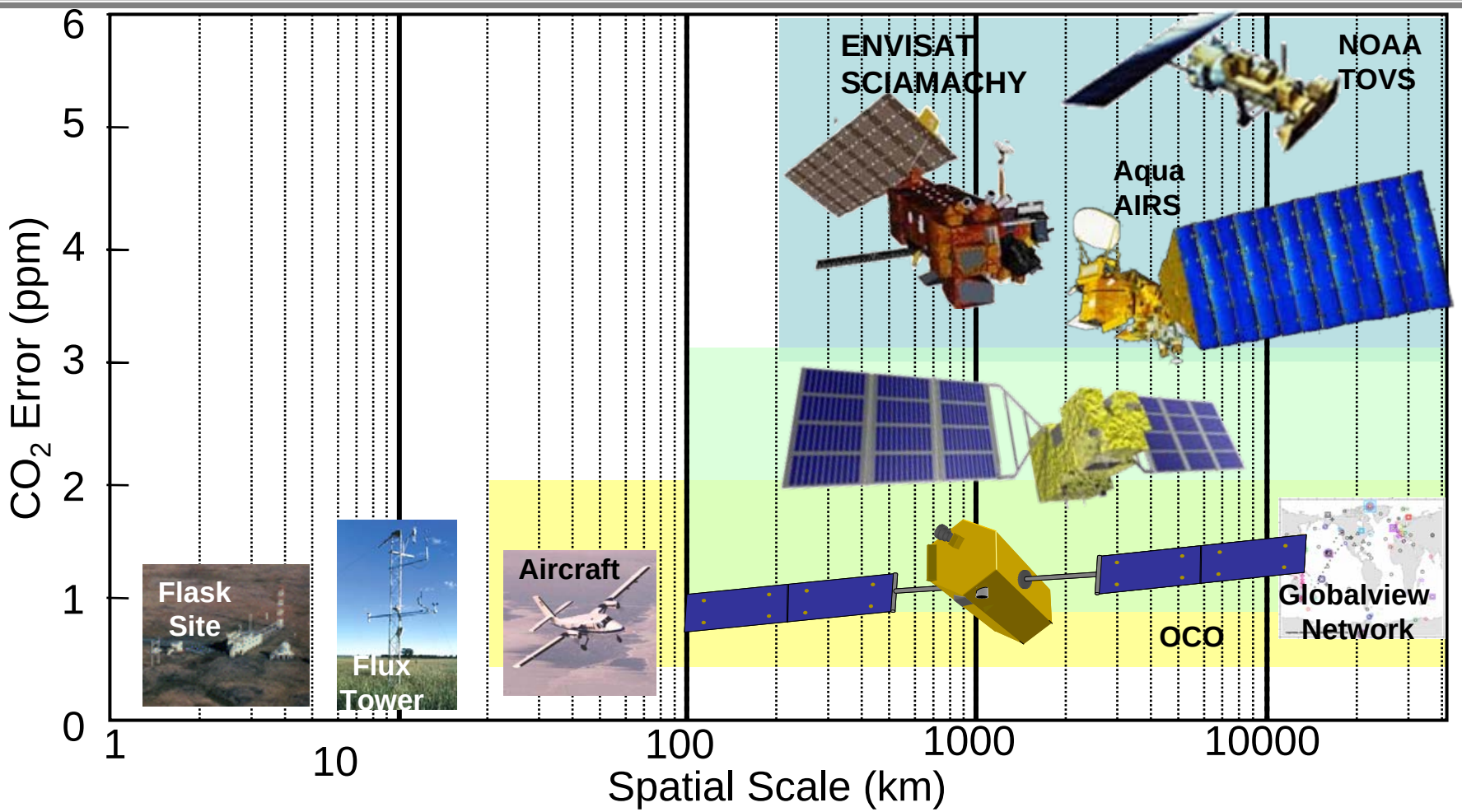






Observations at 79°N (Spitsbergen) FTS
Notholt et al., GRL, 2005

OCO Fills a Critical Measurement Gap



OCO will make precise global measurements of X_{CO2} over the range of scales needed to monitor CO_2 fluxes on regional to continental scales.