A Preview of the OCO-2 Spatial and Temporal Sampling Strategy

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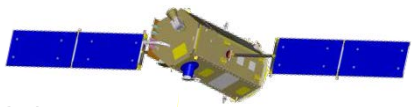
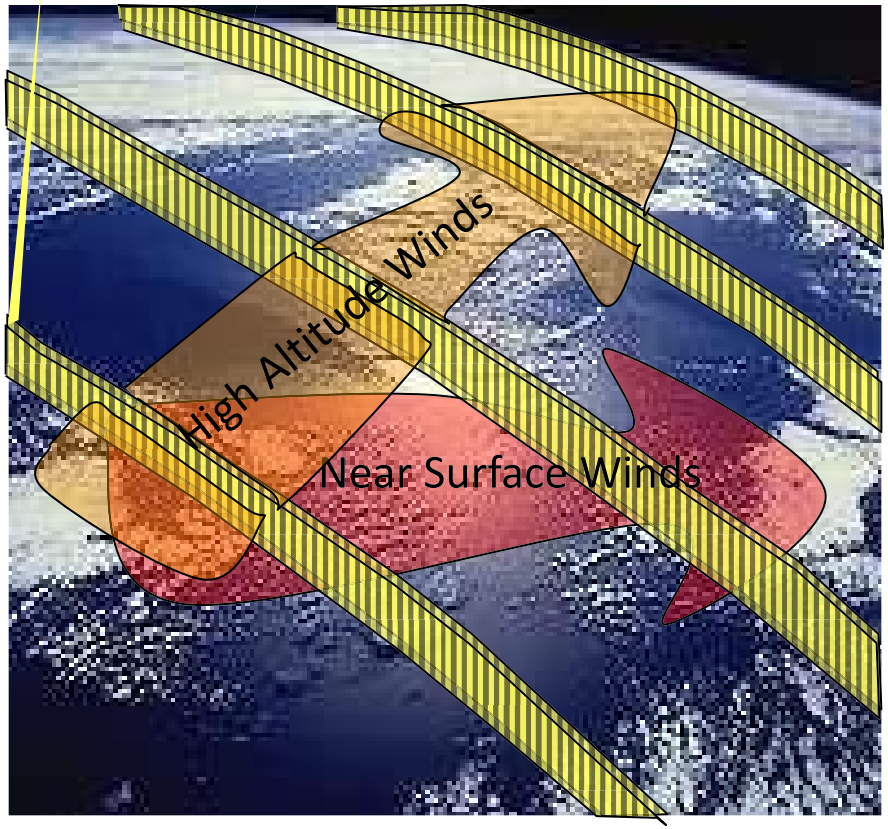
OCO-2 Spatial Sampling Approach

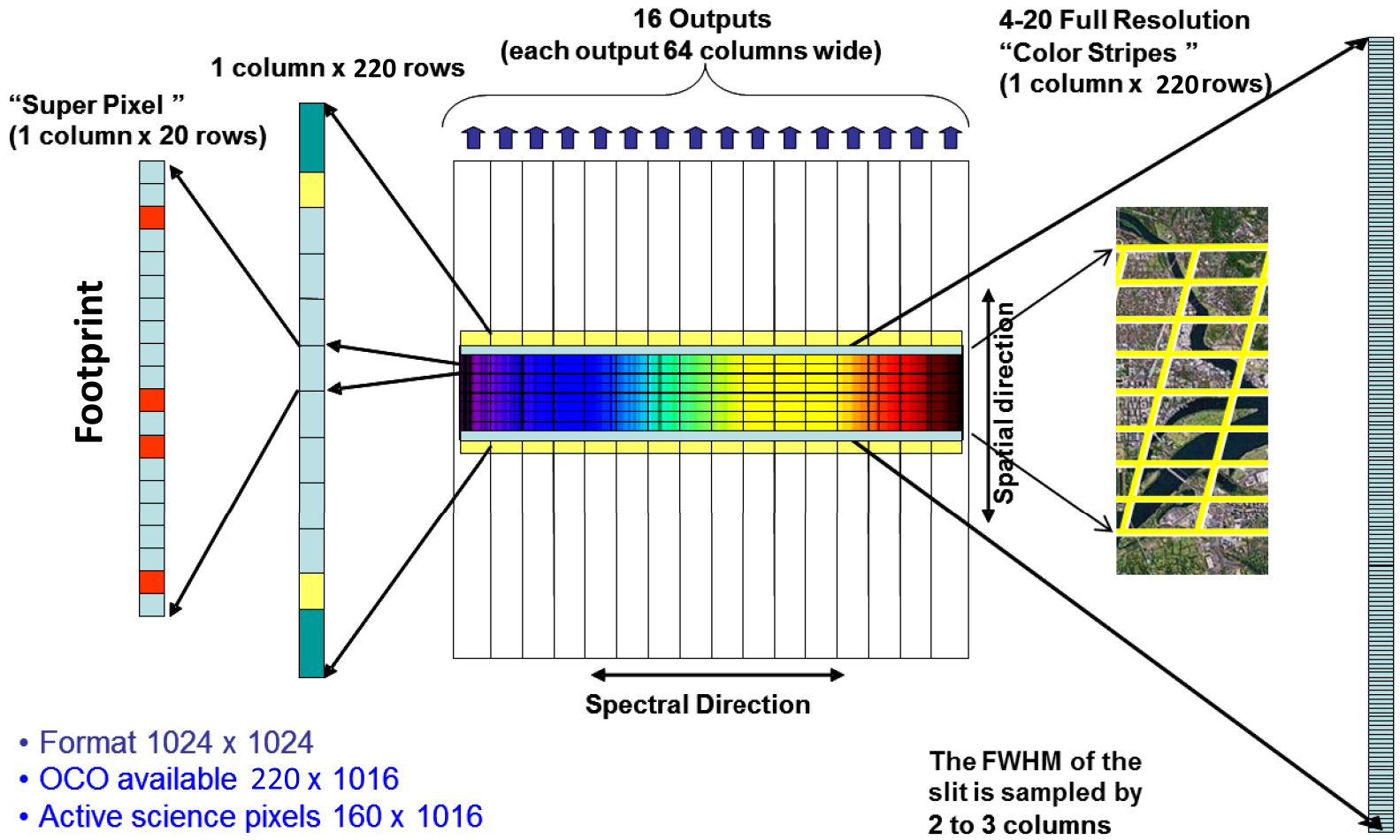
- OCO-2 Orbit Constraints
  - The 705 km altitude, 98.2° inclination
    - global coverage with a 16-day ground track repeat cycle
  - 98.8 minute period: 14.57 Orbits/day
    - ~25° longitude offset between consecutive orbits
    - 1.5° longitude offset between orbit tracks over 16-day repeat cycle
- OCO-2 Sampling Rate/Coverage
  - Glint: ±81° SZA, Nadir: ±85° SZA
  - Collects 24 samples/second along track over land and ocean
    - ~400 samples/degree of latitude on day side of the Earth
    - ~1 million soundings over the globe each day
    - 10-20% of the soundings expected to yield useful X_{CO2} estimates





OCO-2 provides continuous sampling along track but much coarser sampling from track-to-track. Plumes of CO_2 rich/poor air are captured by the column measurements.

Spatial Sampling of the Focal Plane



Every 0.33 seconds, the OCO-2 spectrometer collects:

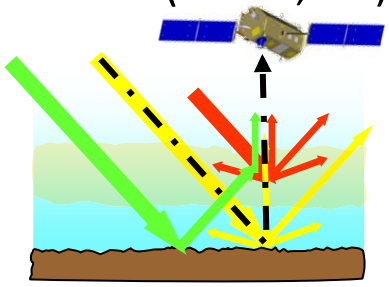
- 1016-color spectra in eight, 0.1° (20-pixel-wide) spatial footprints.
- Up to 20 of the 1016 "Colors" are returned at full spatial resolution – to characterize spatial heterogeneity within each spatial footprint

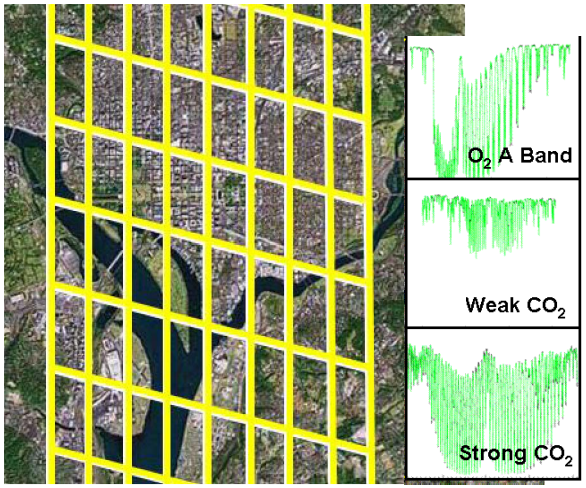
Nadir, Glint, and Target Pointing

Nadir Observations:

+ Small footprint (< 3 km^2)

– Low Signal/Noise over dark surfaces (ocean, ice)

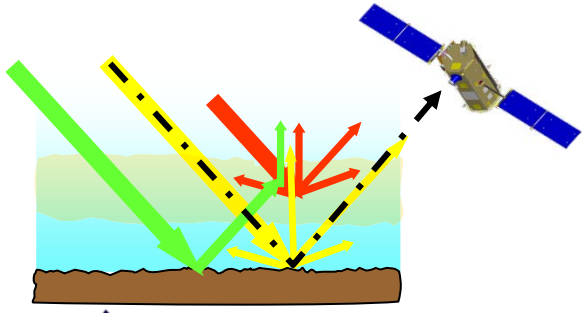


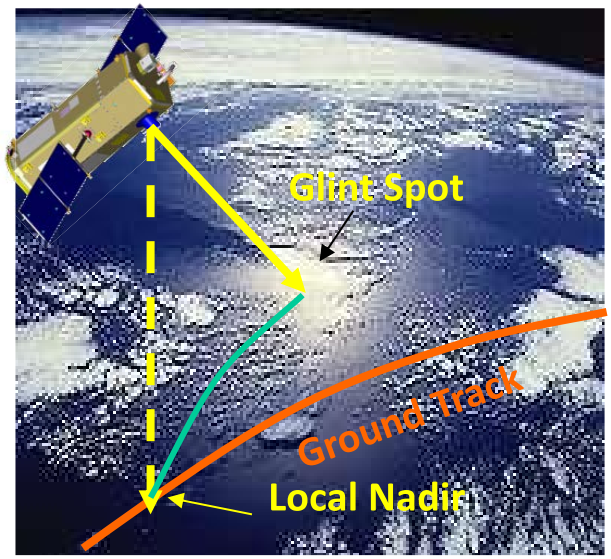


Glint Observations:

+ Improves Signal to Noise ratio over oceans

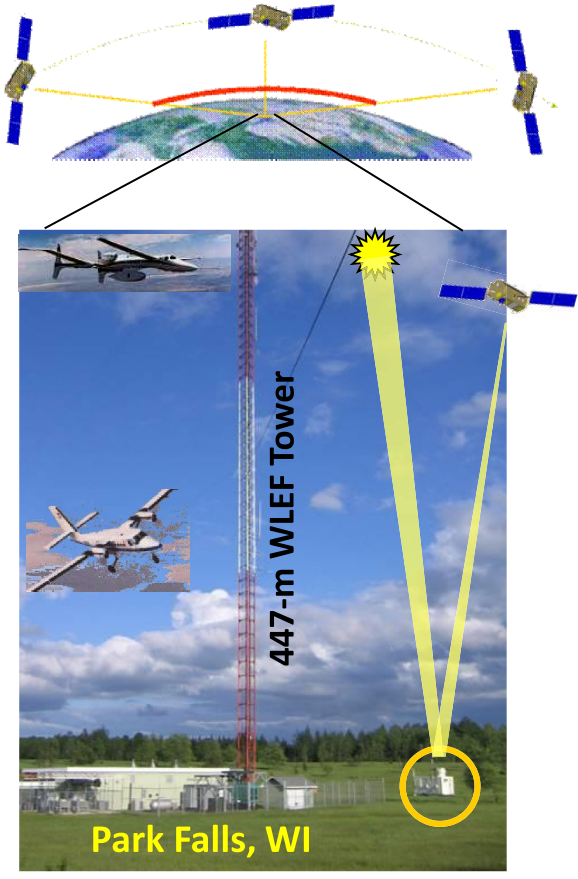
– More cloud interference



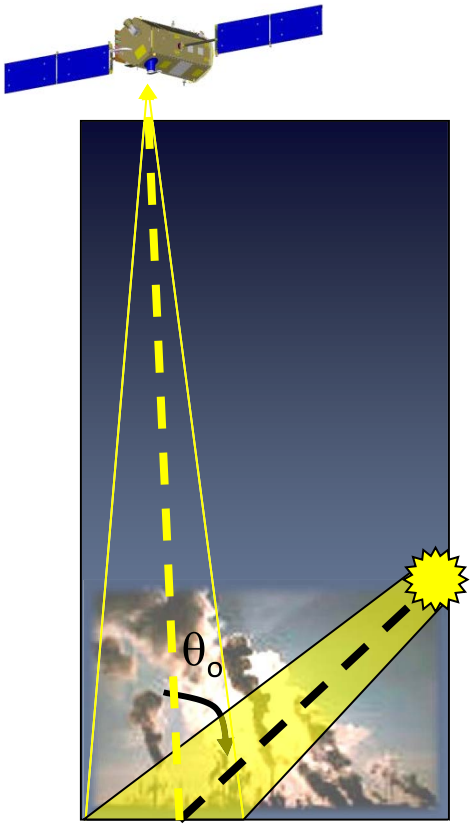


Target Observations:

- Validation over ground based FTS sites, field campaigns, other targets



The OCO-2 Footprint



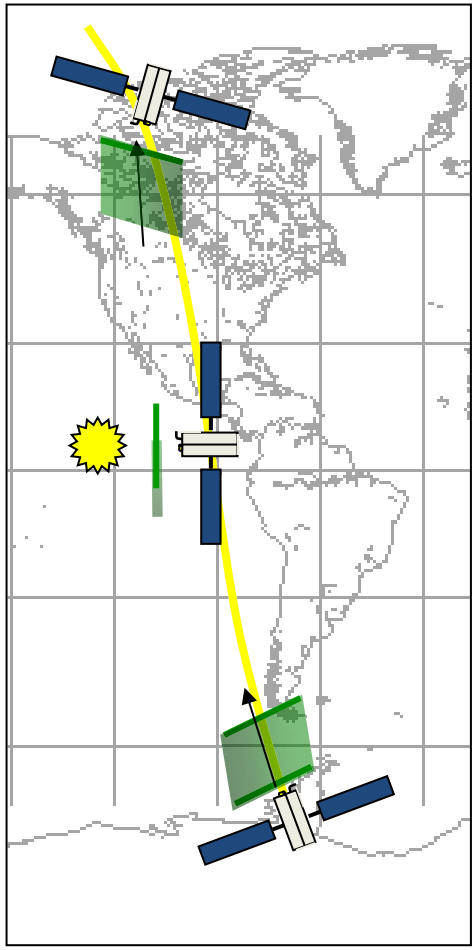
Incoming & outgoing parts of a single Nadir atmospheric footprint.

Atmospheric Footprint

- OCO2 has an "Atmospheric footprint as well as a surface footprint.

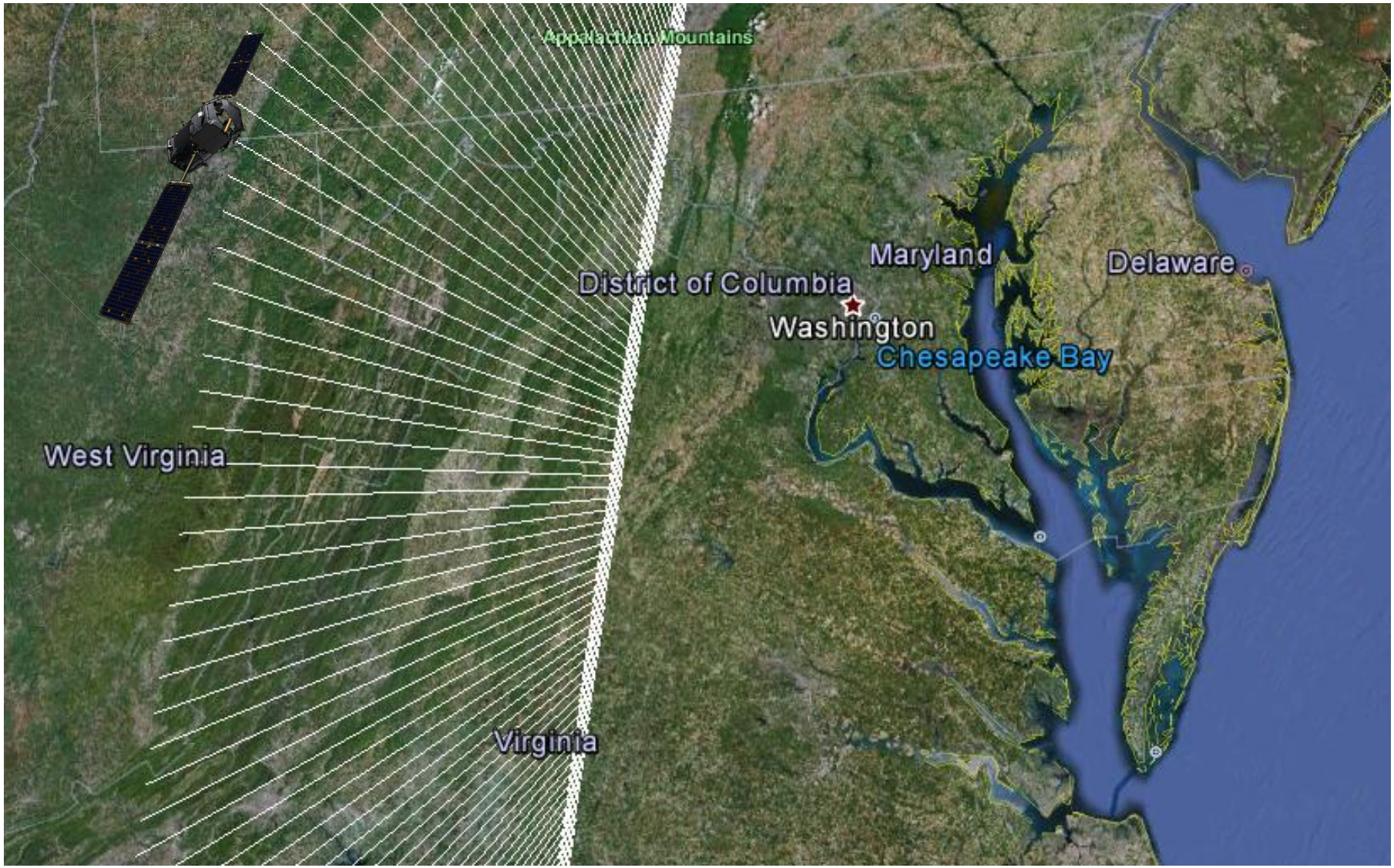
OCO-2 Azimuth Slew:

- The azimuth orientation of the OCO spacecraft varies along the orbit track to
  - Maintain alignment of the spectrometer slits orthogonal to the plane defined by the sun-surface spacecraft
  - Maintain constant power on the solar panels
- This approach produces an footprint shape and size that varies along the orbit



Slit and Footprint orientation and overlap changes as a function of position along orbit track.

OCO-2 Nadir Ground Track



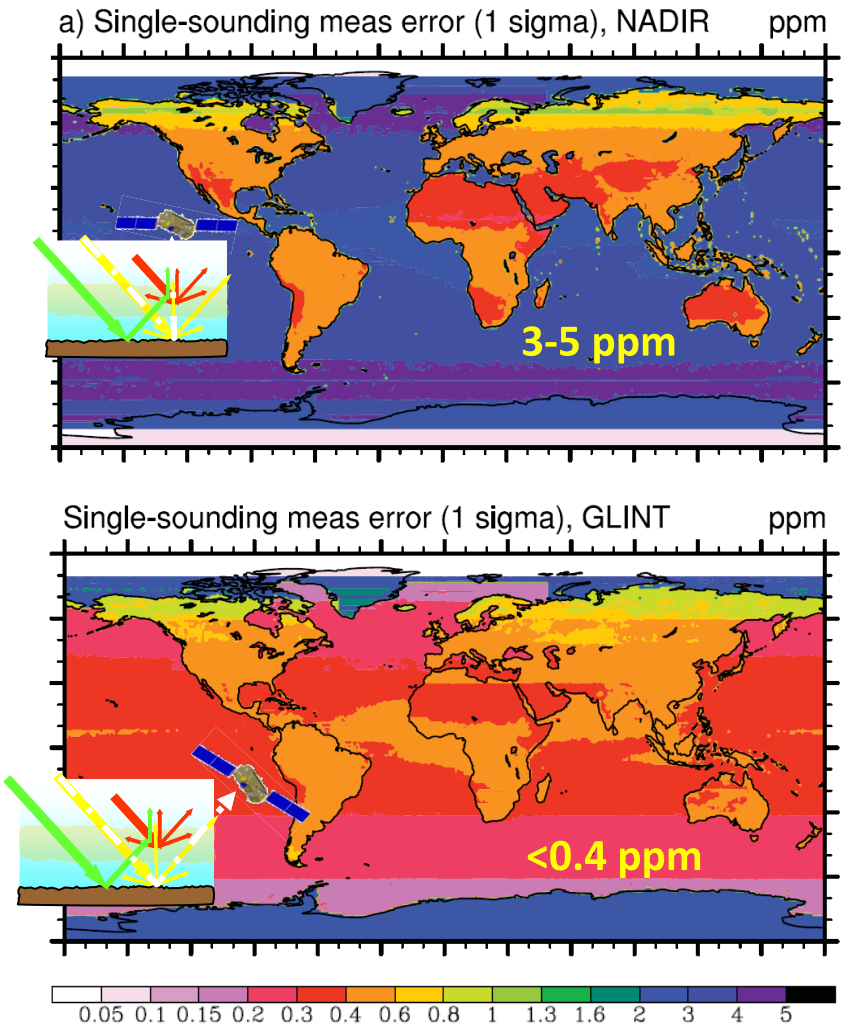
Coverage: The need for Glint

- The ocean covers 70% of the Earth and absorbs and emits 10 times more CO_2 than all human activities combined
- Coverage of the oceans is essential to minimize errors from CO_2 transport in and out of the observed domain

Near IR solar measurements of CO_2 over the ocean are challenging

- Typical nadir reflectances: 0.5 to 1%
- Most of the sunlight is reflected into a narrow range of angles, producing the familiar “glint” spot

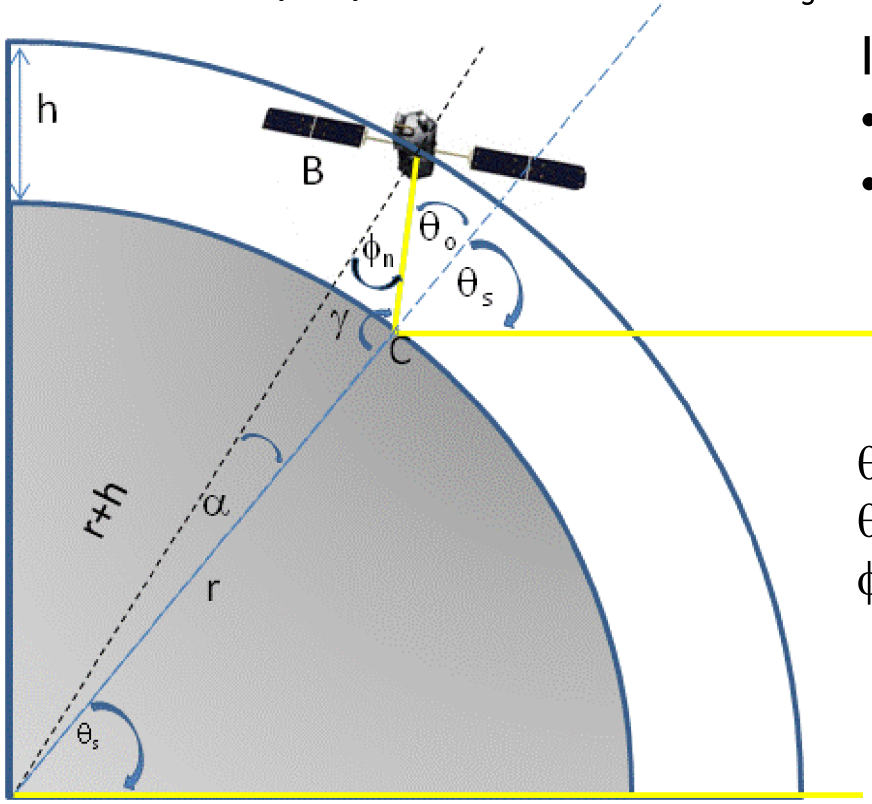
Glint and nadir measurements can be combined to optimize sensitivity over both oceans and continents



OCO single sounding random errors for nadir and glint [Baker et al. ACPD, 2008].

Glint Off-Pointing

- The OCO-2 instrument does not point directly at the glint spot.
- Instead, the instrument bore site is pointed to a footprint along the principle plane between the apparent glint spot and local nadir.
- The spacecraft pointing offset increases with solar zenith angle (SZA),
  - Offset is proportional to $A \times \sin \theta_s$, where θ_s is the SZA at the glint spot



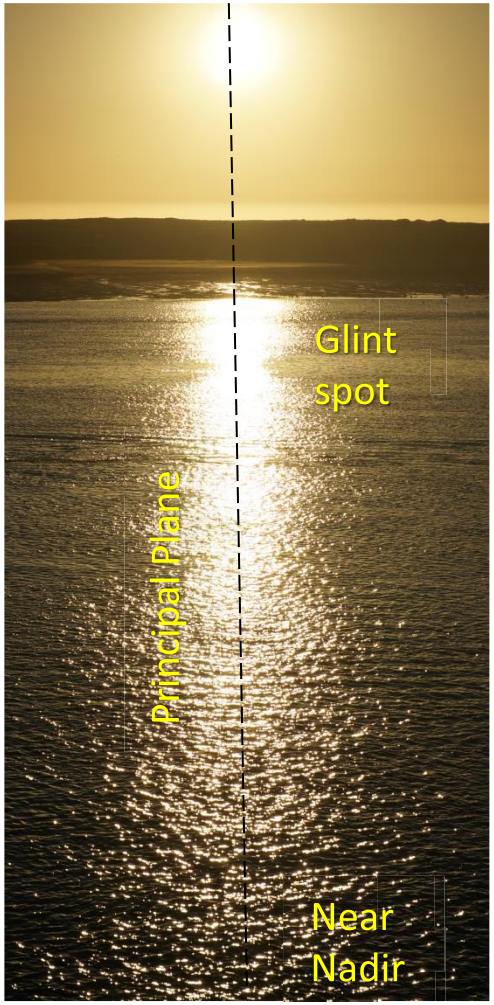
In Glint mode,

- $\theta_o < \theta_s$
- $\phi_n = \phi_{glint} - A \sin \theta_s$

θ_s: Solar zenith angle at surface footprint
θ_o: Observation zenith angle
ϕ_n: Spacecraft nadir observation angle

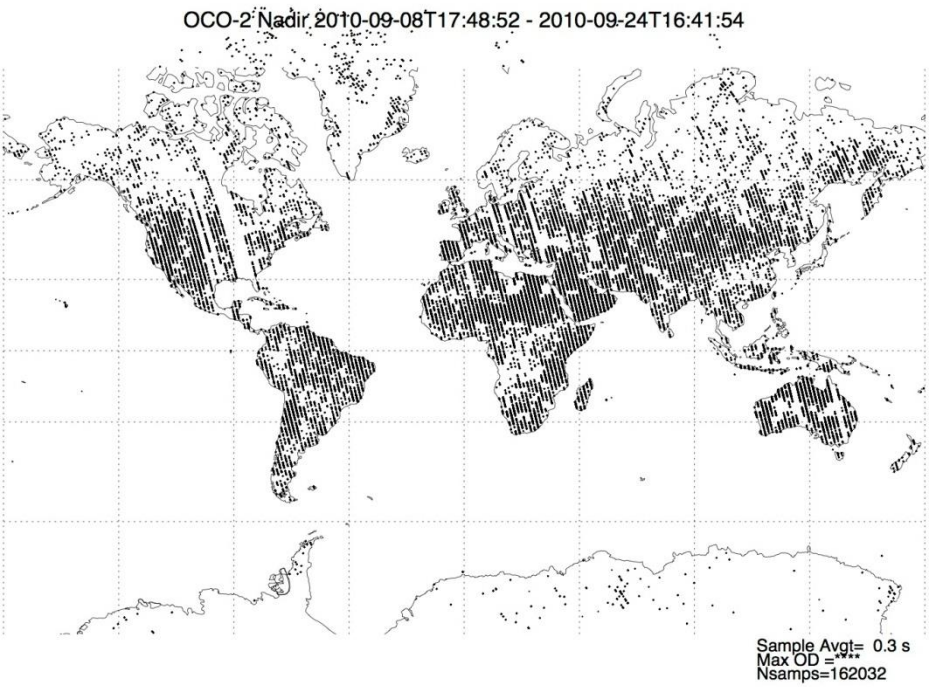
Glint Off-Pointing

- The glint spot is elongated along the principal plane between the true specular angle and the local nadir
- Off-pointing toward the local nadir has 4 advantages:
  1. Prevents instrument bore site from staring at the sun as the observatory approaches the terminator.
  2. Reduces the intensity of the glint at the highest latitudes, reducing dynamic range needed
  3. Extends the range of latitudes that can be observed for a given maximum θ_s
     - The nominal range of solar latitudes recorded in glint mode by OCO-2 is ±81°
  4. Reduces the maximum target distance (and number of air masses) at the highest glint angles observed
     - The distance to the surface at ± 81° is ~1230 km
     - The maximum footprint size is < 2 times larger than the nadir footprint.

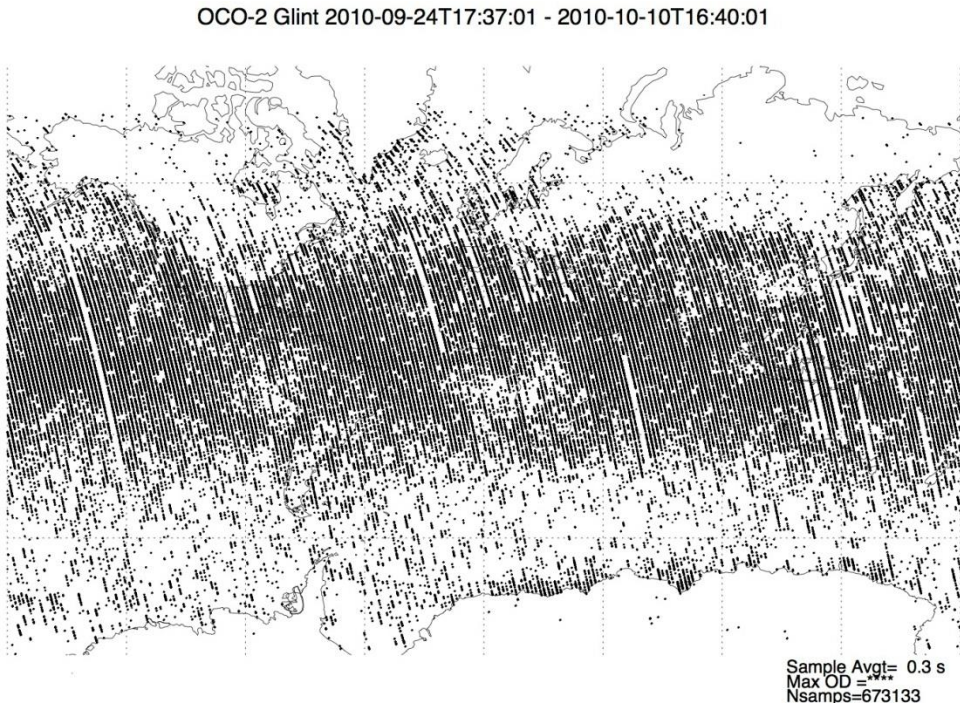


Nadir vs. Glint Simulations

- OCO-2 will collect ~380 Soundings/degree of latitude (>10^6 soundings/day)
- OCO-2 will obtain Nadir and Glint observations of the sunlit hemisphere on alternate 16-day ground track repeat cycles.



Nadir observations provide better coverage over continents



Glint observations provide better coverage over oceans

Target Mode

Summary of Observing Modes

For routine science observations, the OCO-2 spacecraft bus points the instrument bore sight either at the local nadir (θ_s < 85º) or at the glint spot (θ_s < 81º) and collects ~10^6 soundings/day over the sunlit hemisphere.

- Nadir observations: expected to yield more spatially-homogeneous optical paths in partially cloudy regions and over topographically rough land regions
- Glint observations are expected to yield (much) higher SNR over dark ocean or ice covered surfaces.
- For both glint and nadir observations, the spacecraft performs a yaw maneuver to orient the long axis of the spectrometer slits perpendicular to the principle plane
- The nominal plan is to alternate between glint and nadir observations on alternate 16-day ground repeat cycles, but this strategy may be modified to maximize coverage

Target observations: For calibration and validation, the spacecraft bus can also point the instrument bore sight at a stationary surface target

- Collects up to 12,000 soundings at observing zenith angles from ±75º