OCO-2 Glint Pointing Strategy and Results

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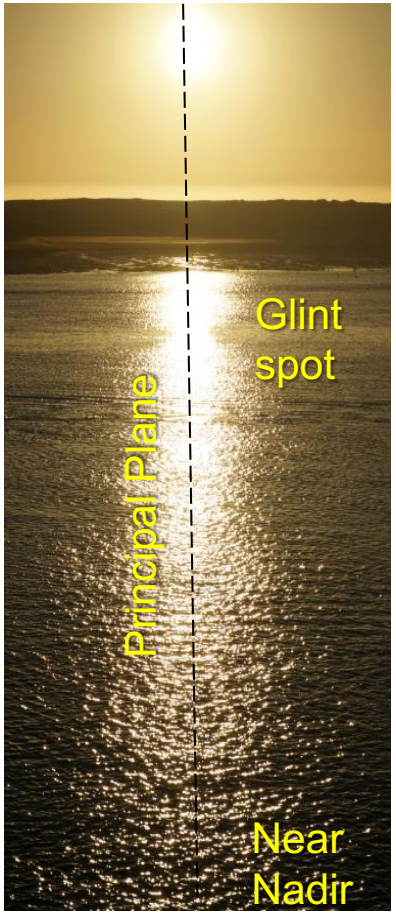
Glint Off-pointing

- 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 solar zenith angle, 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
     - At this distance, the maximum footprint size is < 2 times larger than the nadir footprint.



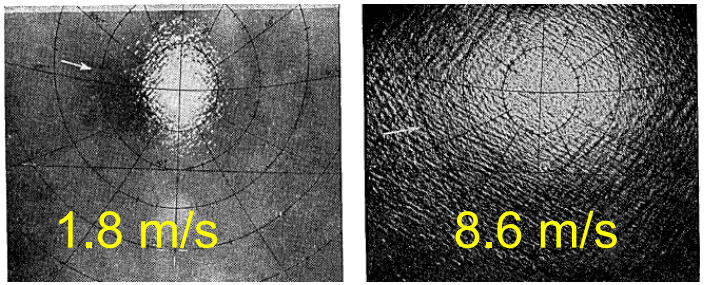
Explaining the Observations
Modeling Glint: The Cox-Munk Model

Cox and Munk, JOSA, 54, (1954)

- Provides a simple statistical description of the reflectance from the ocean surface
- waves are modeled as a distribution of planar facets
- Widely used to interpret satellite observations (e.g. forms the basis of winds estimates from radar scatterometry)
- Key formula: width of the mean square slope distribution, σ^2

  $$\sigma^2 = 0.003 + 0.00512 * \text{Wind}$$

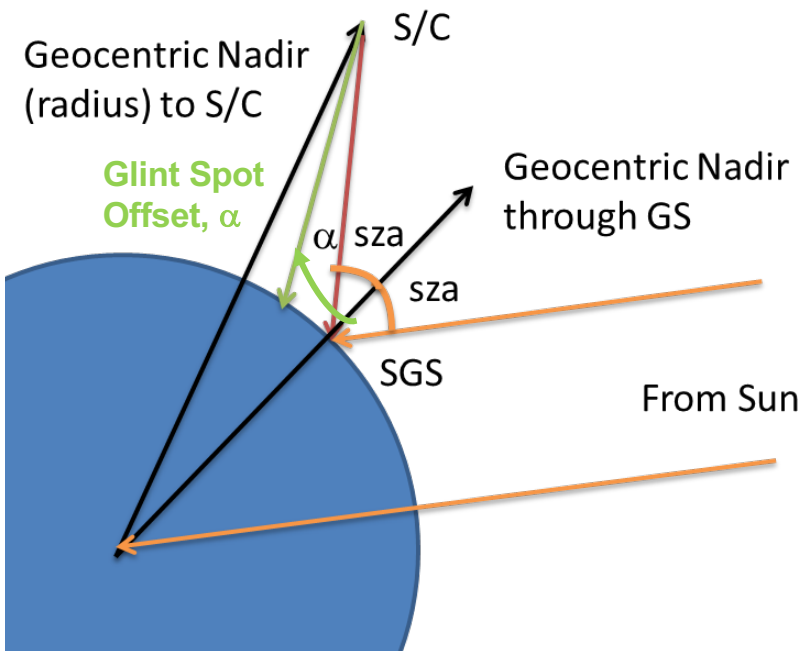
  – There is some uncertainty in the zero-wind intercept



Glitter (glint) distributions viewed at nadir for a solar zenith angle of 20^o (Cox and Munk, 1954).

Glint Off-pointing

- OCO-2 does not point directly at the glint spot for glint observations.
  - It points to a surface location that is offset from the true glint spot toward the local nadir by the Glint Spot Offset angle, α
  - The offset increases with the solar zenith angle (SZA) of the glint spot



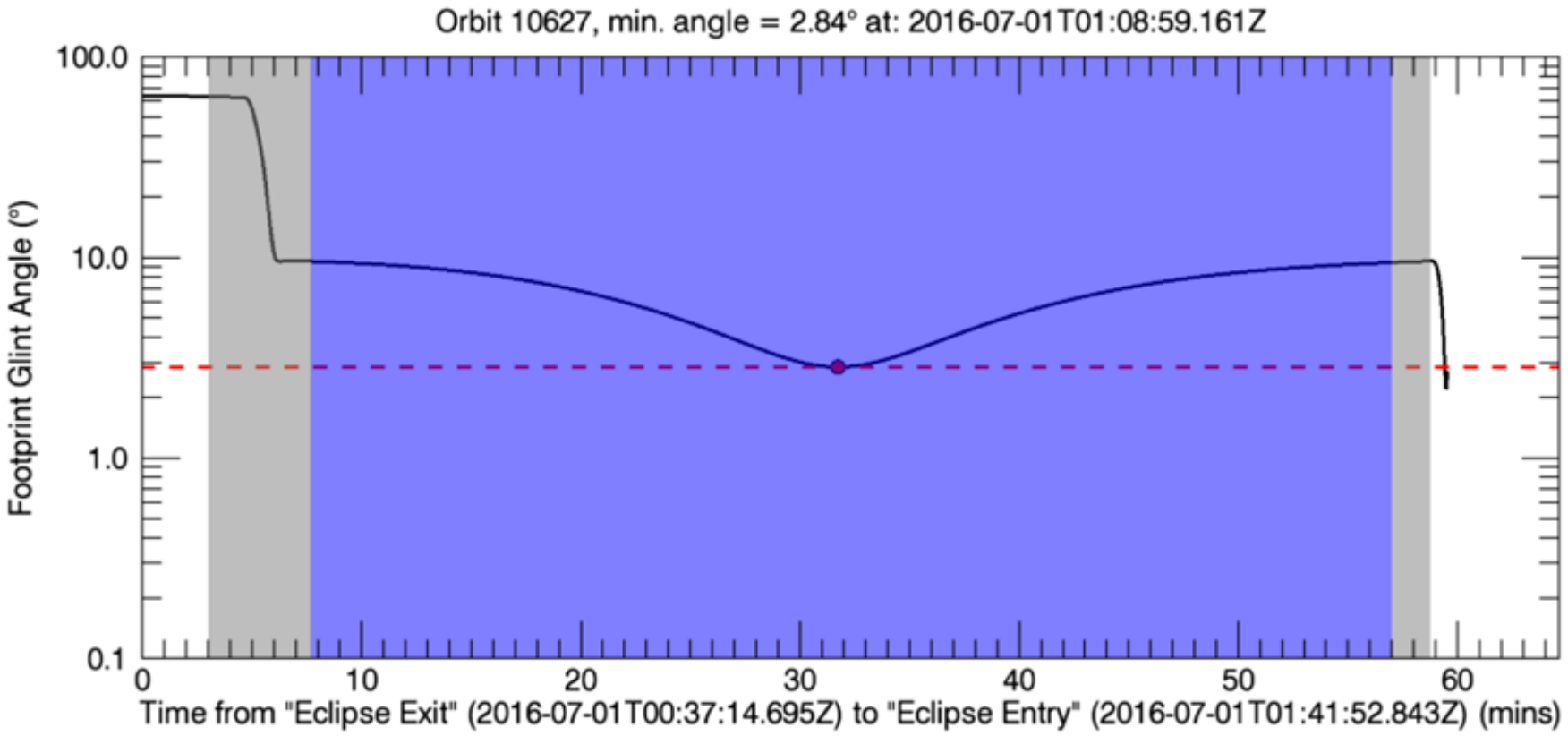
- In the spacecraft coordinate system, the glint spot offset angle:

  $\alpha = M * \sin(SZA)$

- The constant, M is a variable, whose current setting is: M=10°

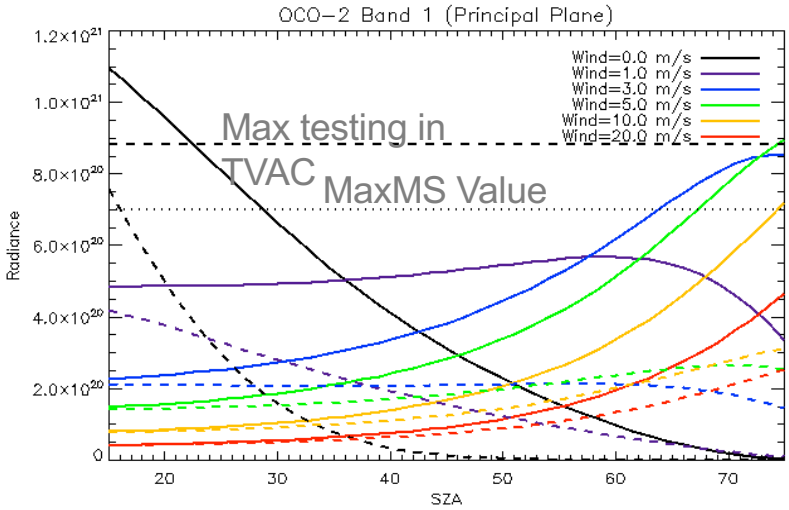
Glint viewing geometry, shown in the principle plane (PP). Orange vectors (parallel rays from Sun) and radius vector to s/c define PP. Red vector is Pointing Vector with no Glint Spot Offset, α. Green vector includes α.

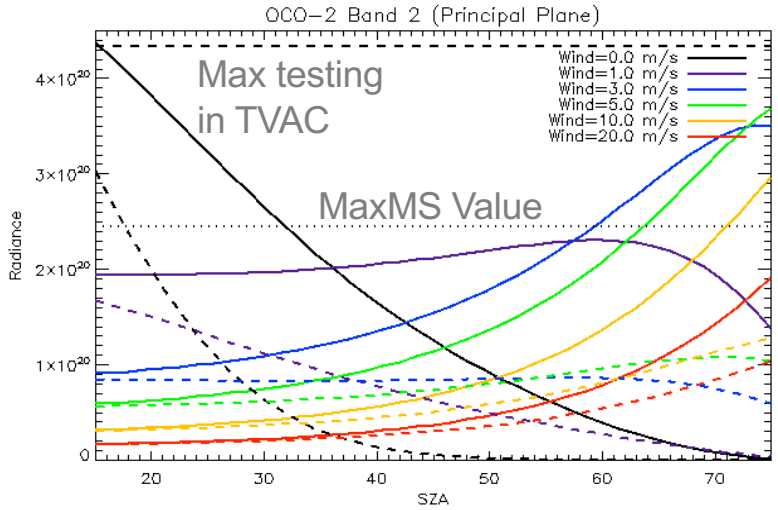
Glint Off-pointing Angles

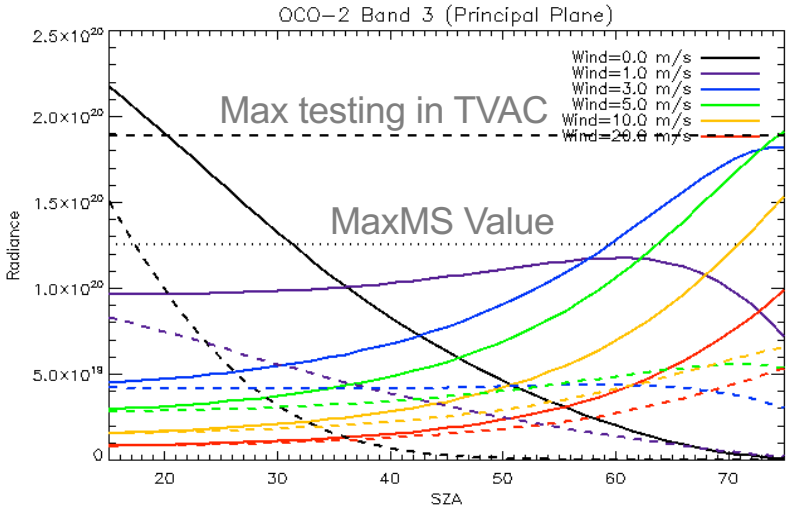


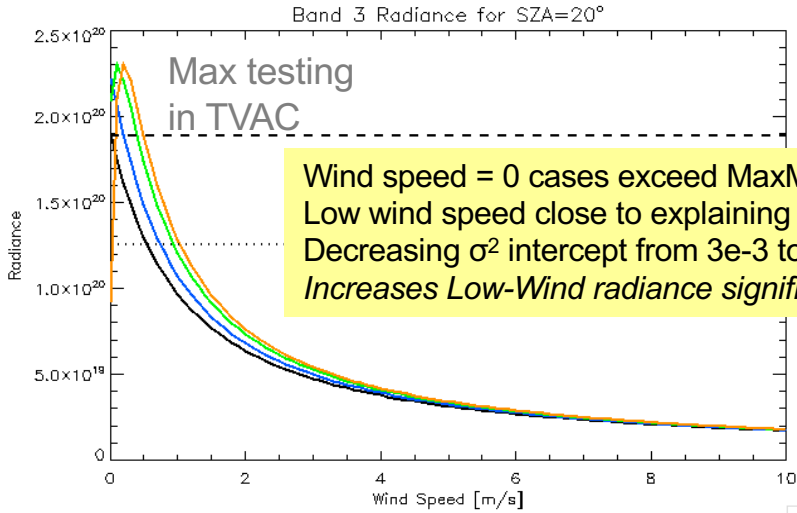
The angular offset between the actual glint spot and the instrument bore sight for an orbit with a minimum glint angle less than 2.8 degrees.

Radiance vs Wind Speed and Off-pointing Angle, M





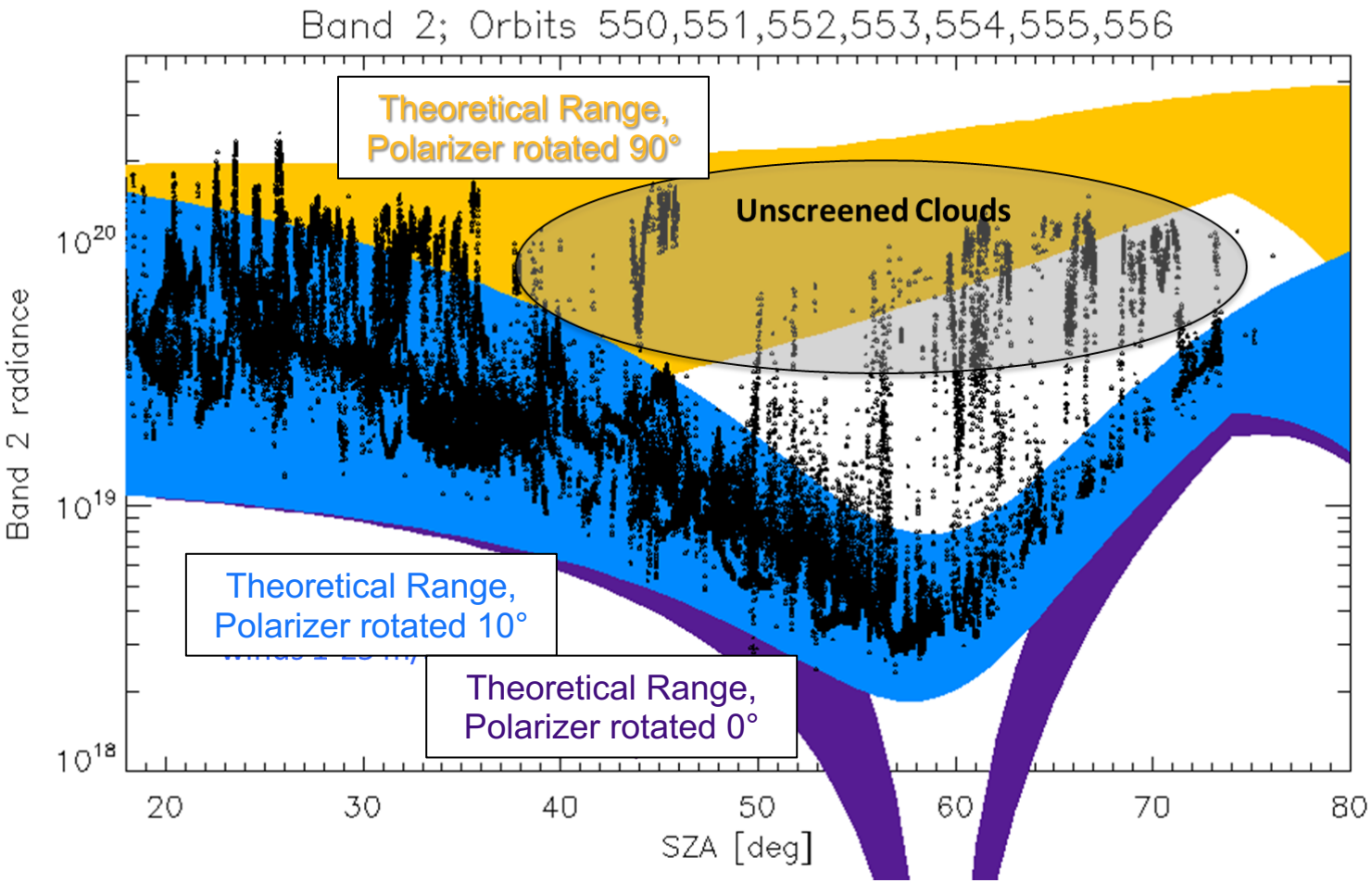




Wind speed = 0 cases exceed MaxMS.
Low wind speed close to explaining event:
Decreasing σ^2 intercept from 3e-3 to 0.5e-3:
Increases Low-Wind radiance significantly

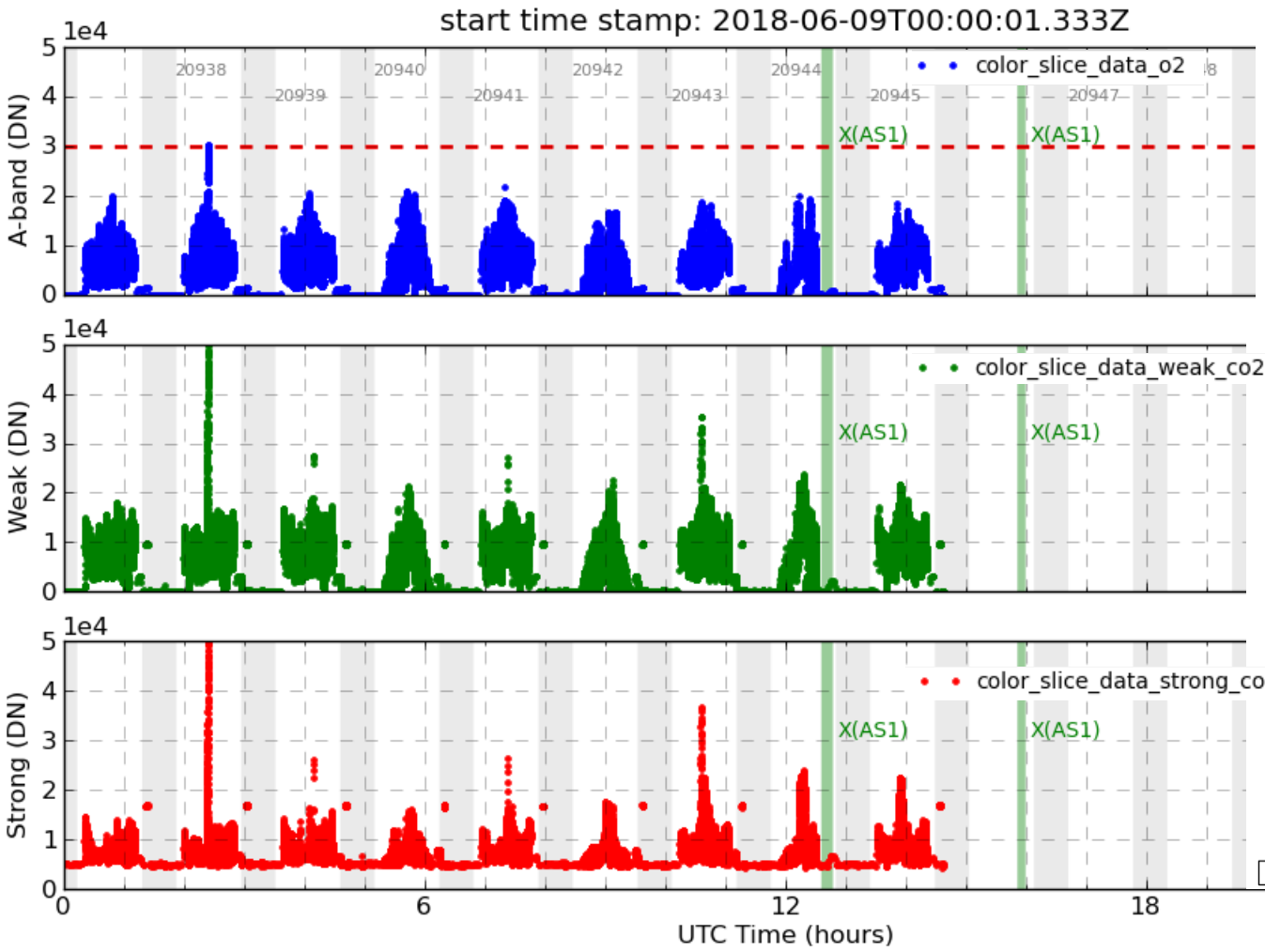
—— M=10° - - - M=15°

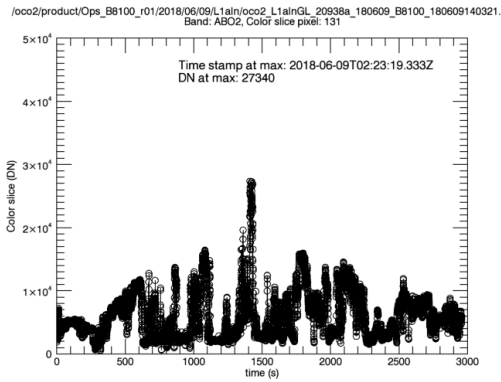
Predicted and Observed Radiances

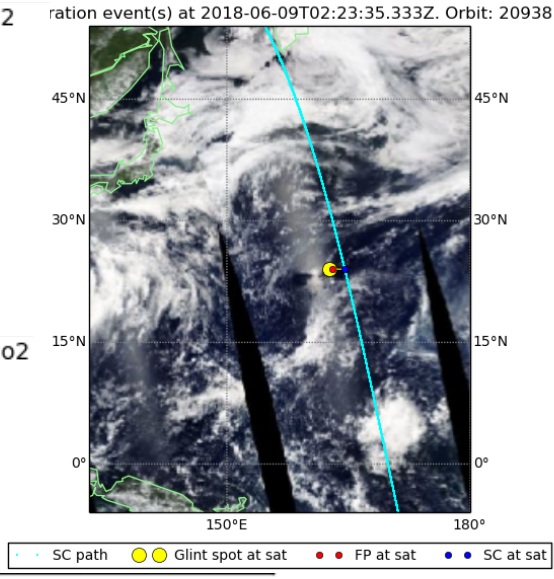


Theoretical Range covers wind speed from 1 to 25 m/s

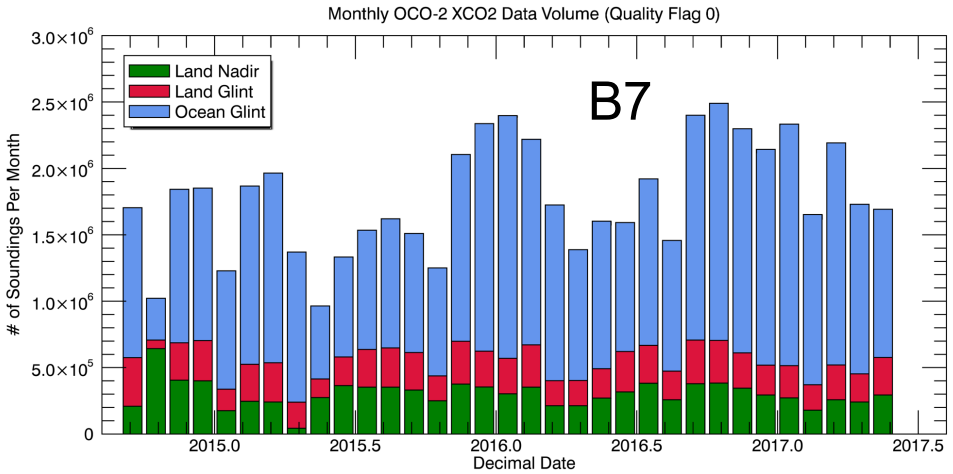
Trending Glint Exposures





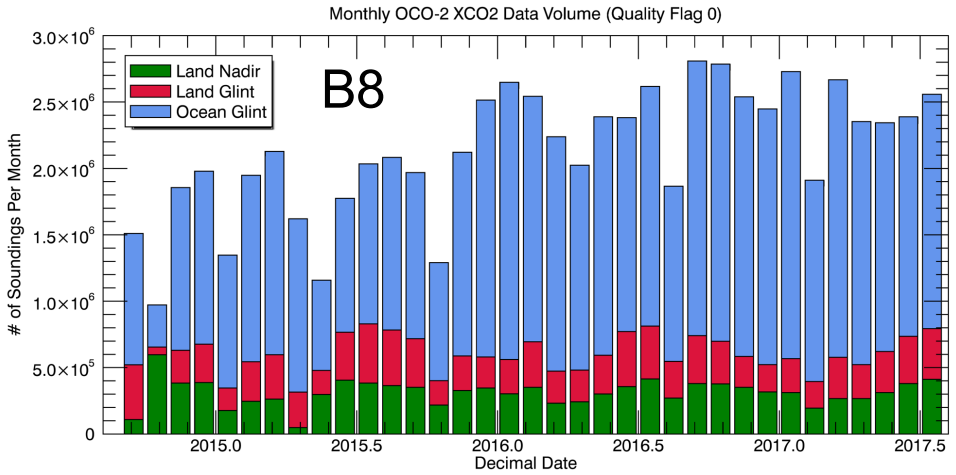


Actual Yields for Nadir and Glint Observations

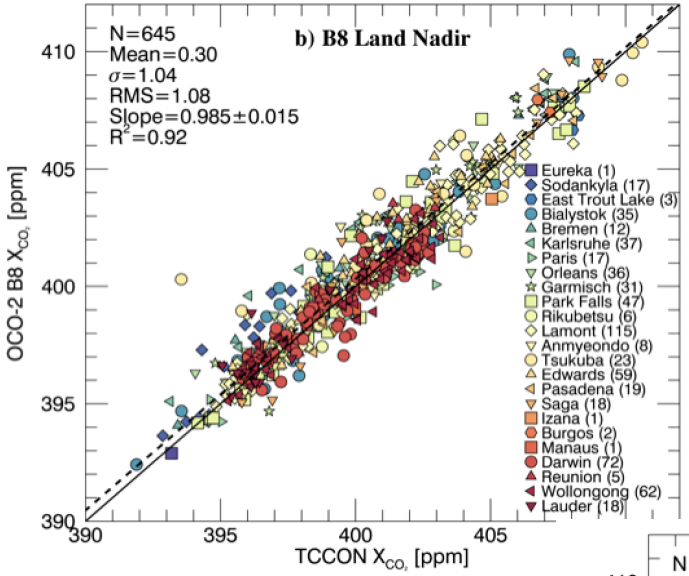


The sounding yield for B7 was ~7% (2 million soundings/month) once the optimal observing scheme was implemented.

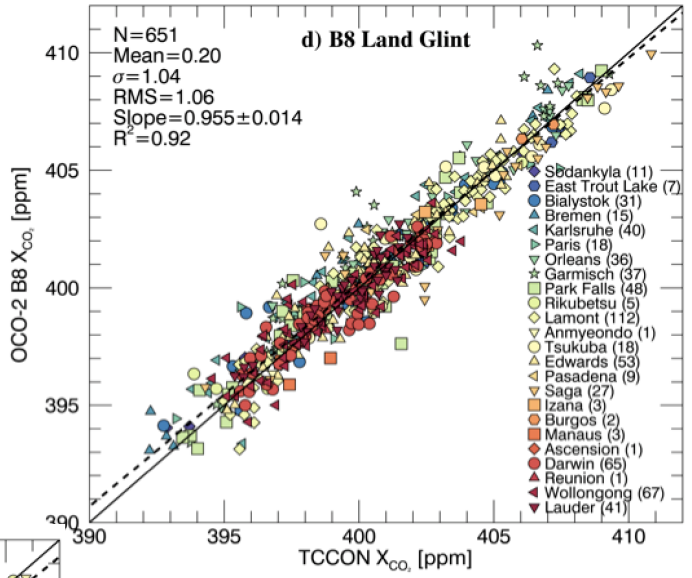
Improvements in the cloud screening algorithm and other changes in the L2 algorithm increased the B8 yield to > 8%, with the largest changes seen in the tropics and at at high latitudes



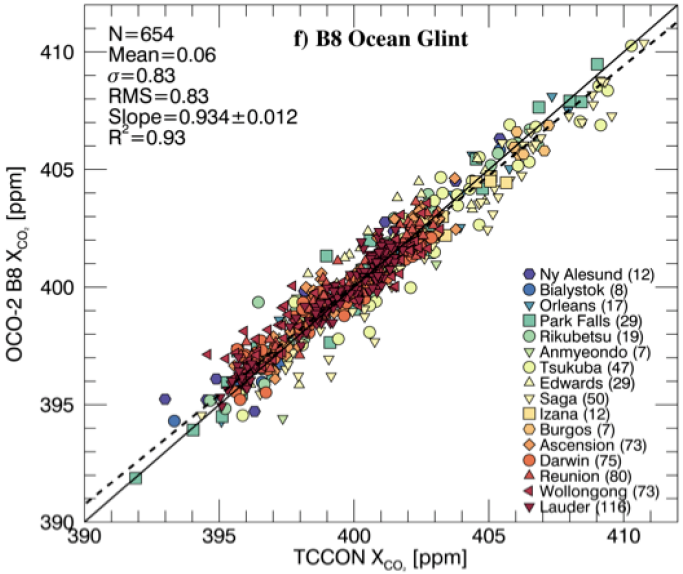
Error Statistics vs TCCON



In comparisons with TCCON and other truth proxies, there is no statistical difference between land nadir and land glint products for v8.



In comparisons to TCCON and other truth metrics, the OCO-2 v8 ocean glint product outperforms the land nadir and glint products



Summary

- OCO-2 switches between nadir and glint observations on alternating orbits, except for orbit tracks that are predominately over ocean, which are always observed in glint
  - This approach provides good coverage over both land and ocean at monthly intervals
- >70% of the successful soundings are glint soundings over ocean
- With the glint off-pointing strategy, the glint airmass and footprint size is never more than twice as large as that in nadir
- Ocean glint soundings have better error statistics than the nadir soundings over land when compared to TCCON or other standards
  - Ocean glint: mean bias = 0.06 ppm, standard deviation = 0.83 ppm
  - Land nadir: mean bias = 0.3 ppm, standard deviation = 1.04
  - Land glint: mean bias = 0.2 ppm, standard deviation = 1.04
- There is no statistical difference between land nadir and land glint observations