BRDF Models to Reduce Biases in Orbiting Carbon Observatory-2 (OCO-2) Retrievals

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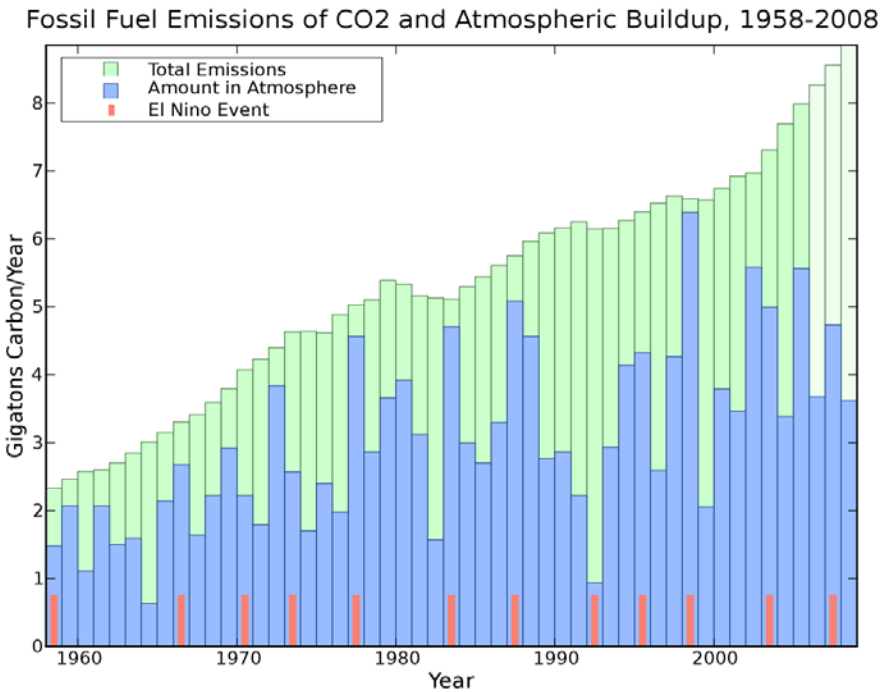
The Mystery of the Missing CO_2

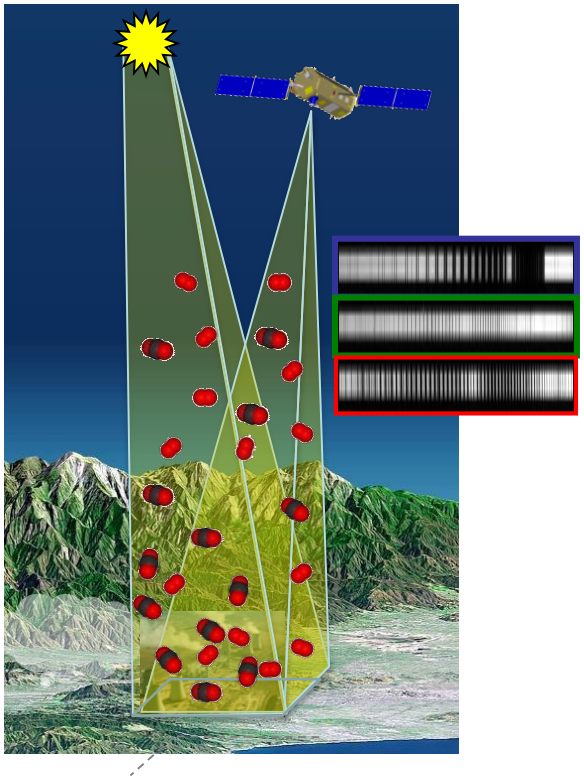
- **Humans have added >200 Gt C to the atmosphere since 1958**
- **Less than half of this CO_2 is staying in the atmosphere**
- **Where are the *sinks* that are absorbing over half of the CO_2?**
  - **Land or ocean?**
  - **Eurasia/North America?**
- **Why does the CO_2 buildup vary from year to year with nearly uniform emission rates?**
- **How will these CO_2 sinks respond to climate change?**



?

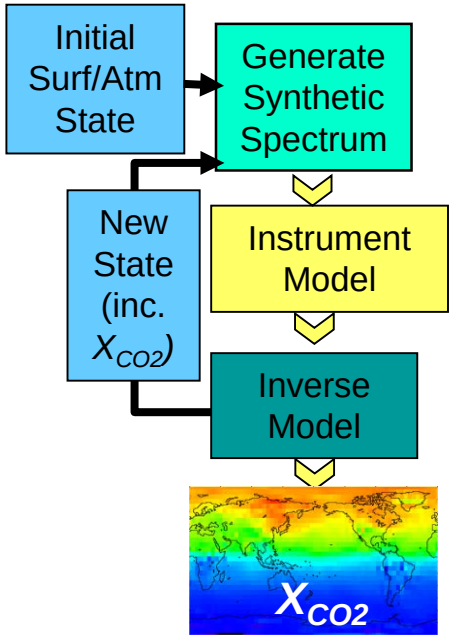
Measuring CO_2 from Space

- **Collect** spectra of CO_2 & O_2 absorption in reflected sunlight over the globe



V&V in Pre-launch Tests

- **Retrieve variations in the *column averaged CO_2 dry air mole fraction, X_{CO2}*** **over sunlit hemisphere**



Documented in L2 ATBD.
Verified with GOSAT data.

- **Validate** measurements to ensure X_{CO2} precision of 1 - 2 ppm (0.3 - 0.5%)

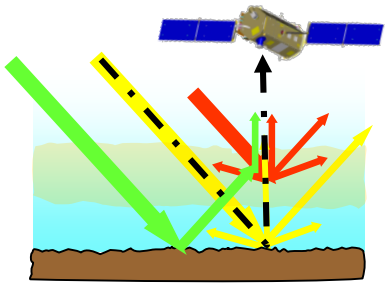
Documented in OCO-2 Validation Plan.
Verified with GOSAT Data

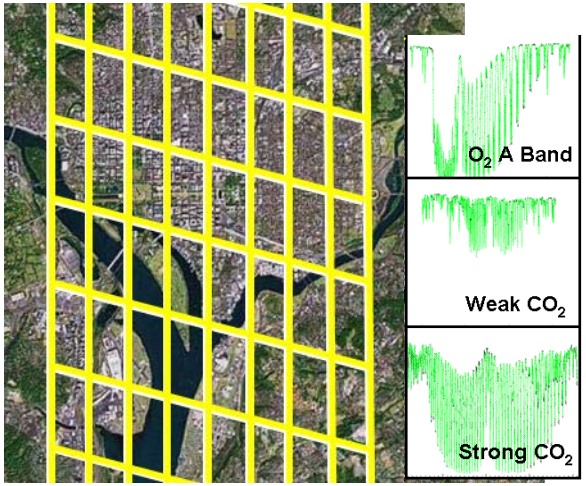
OCO-2 Requires Agile Spacecraft

Nadir Observations:

+ Small footprint (< 3 km²)

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

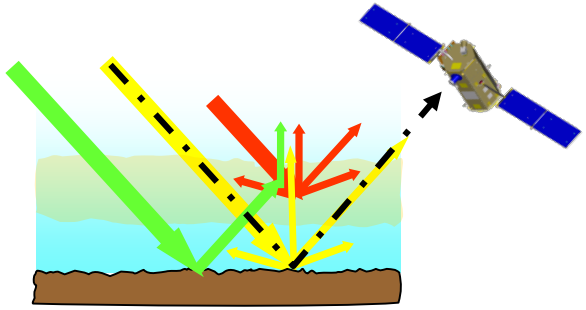


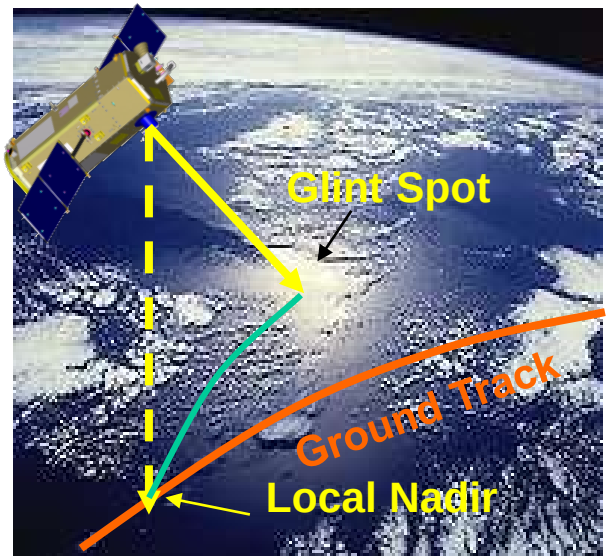


Glint Observations:

+ Improves Signal/Noise over oceans

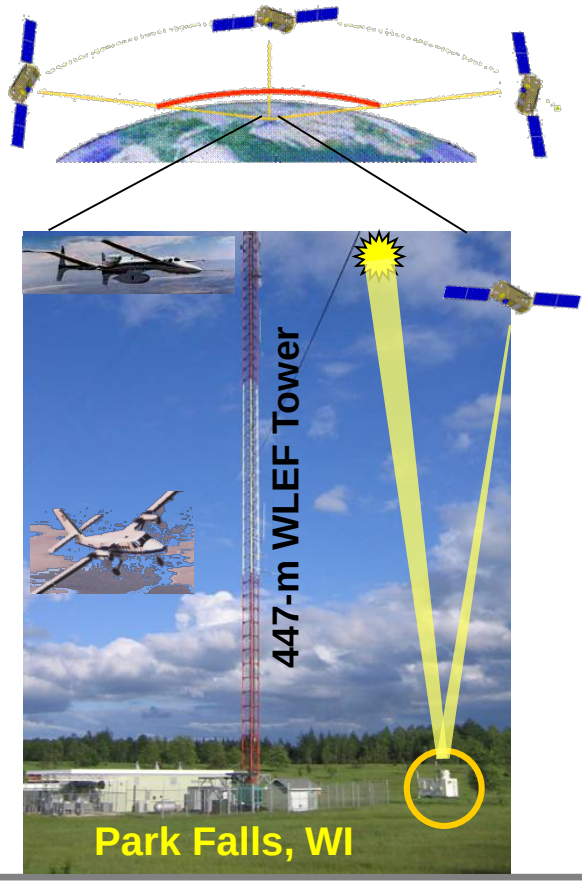
– More cloud interference



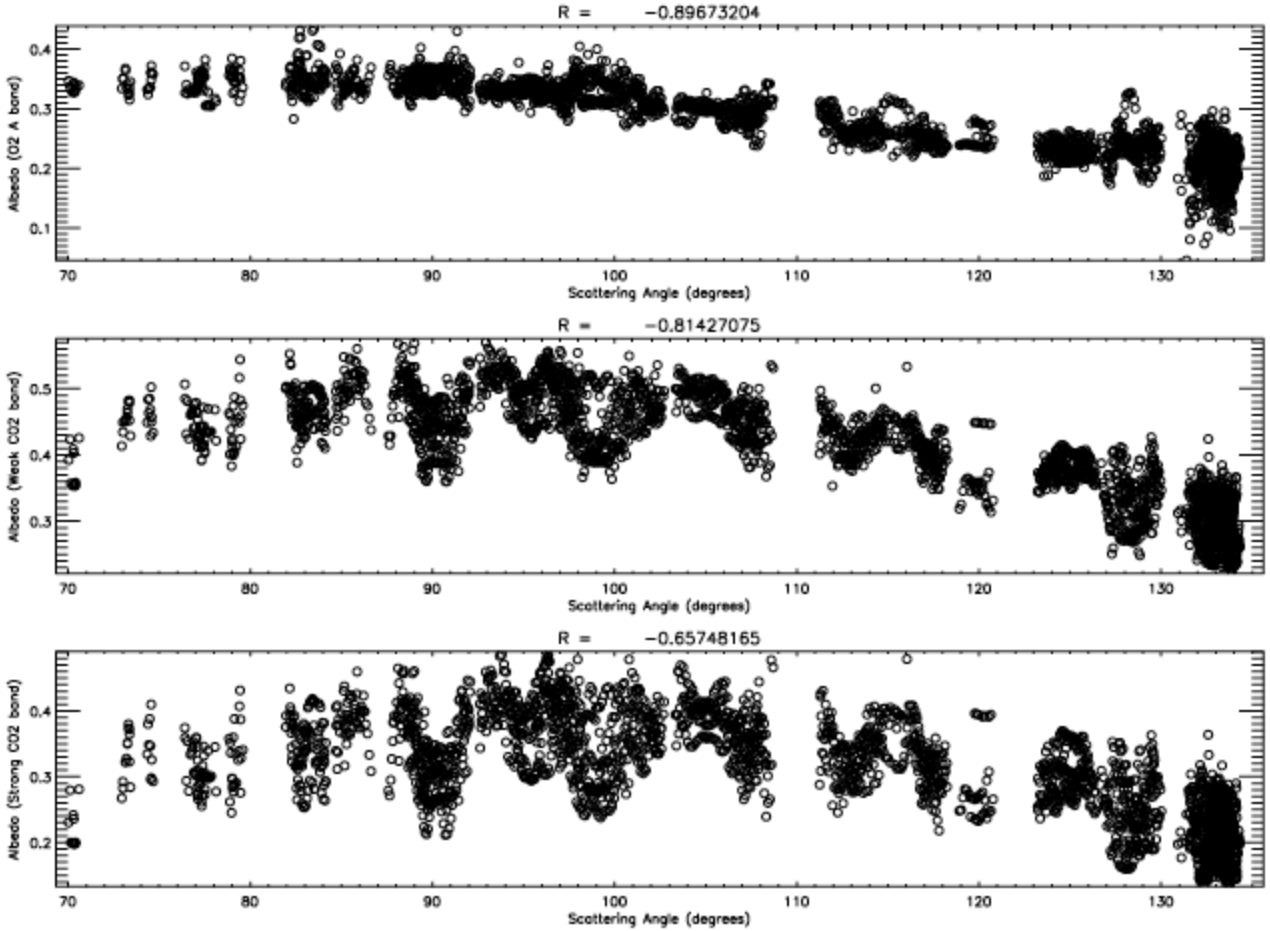


Target Observations:

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



Retrieved Albedo Correlated With Scattering Angle



Retrieved albedo correlated with scattering angle => BRDF effects?

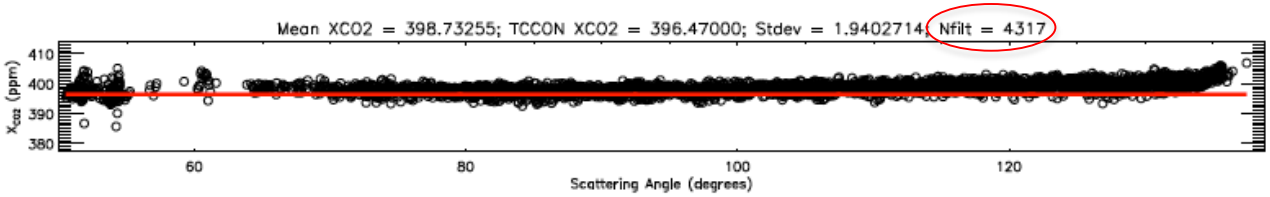
BRDF Formulation

- w: overall BRDF amplitude
- s: slope of BRDF amplitude
- λ: wavelength
- λ_0: central wavelength (where parameters are retrieved)
- F: function describing BRDF shape
- F has slightly different forms for bare soil and vegetated surfaces
- BRDF kernel reduces to Lambertian kernel for certain choice of F
- p_1 and/or p_2 can be retrieved or held fixed

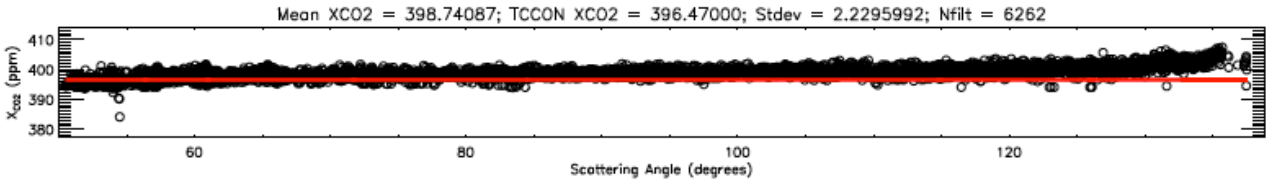
Retrieved XCO2

Number of filtered, converged scenes

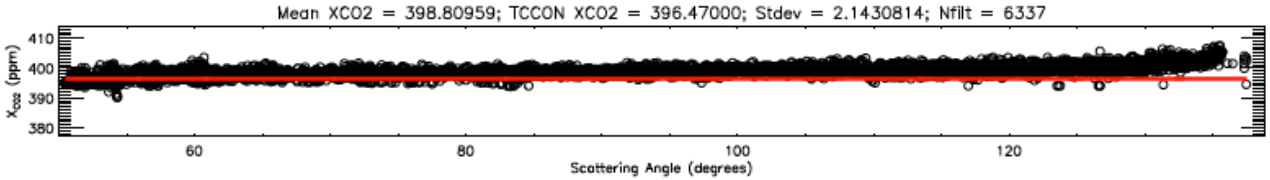
Lambertian



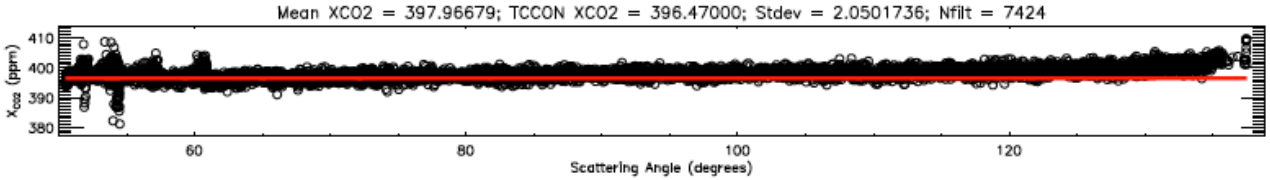
Soil BRDF, p_1, p_2 retrieved



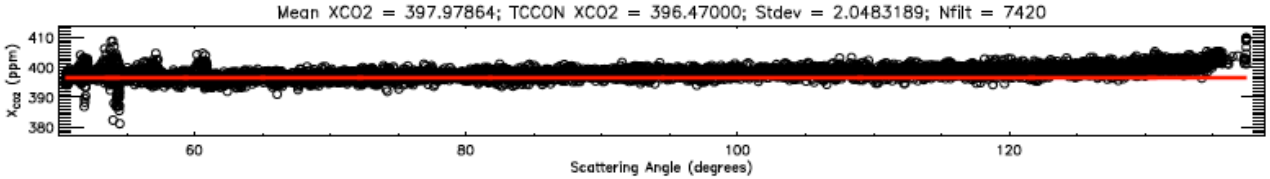
Veg BRDF, p_1, p_2 retrieved



Soil BRDF, p_1, p_2 not retrieved



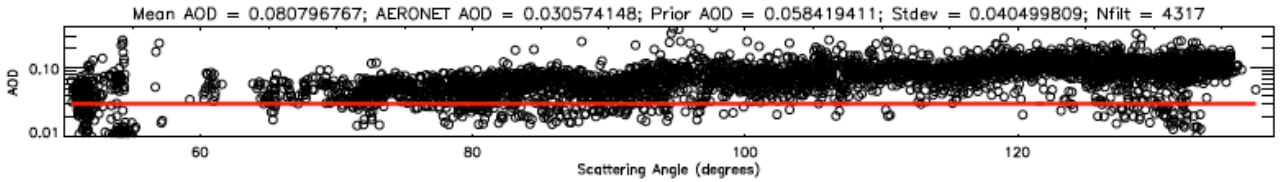
Veg BRDF, p_1, p_2 not retrieved



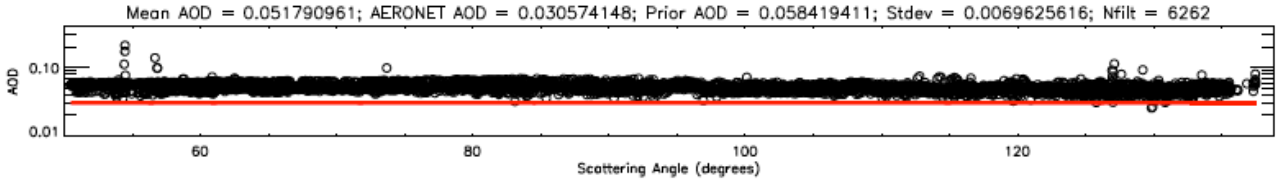
X_{CO2} closer to TCCON value for BRDF models, especially when BRDF shape is fixed

Retrieved AOD

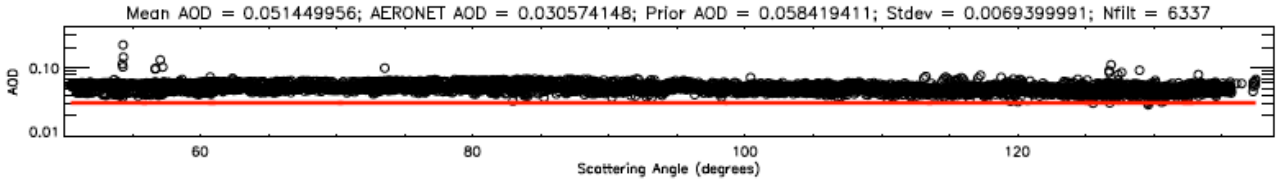
Lambertian



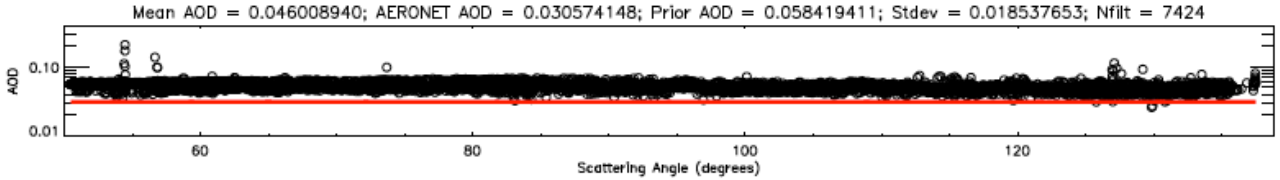
Soil BRDF, p_1, p_2 retrieved



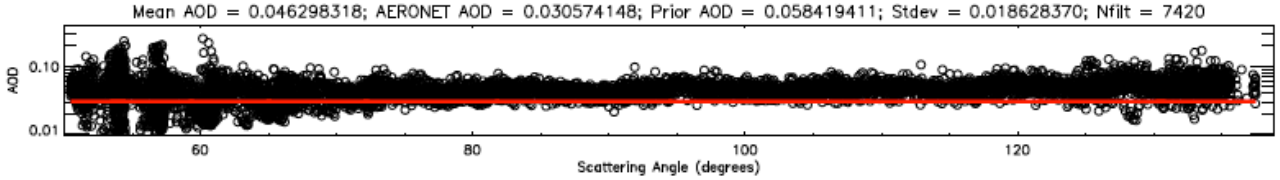
Veg BRDF, p_1, p_2 retrieved



Soil BRDF, p_1, p_2 not retrieved



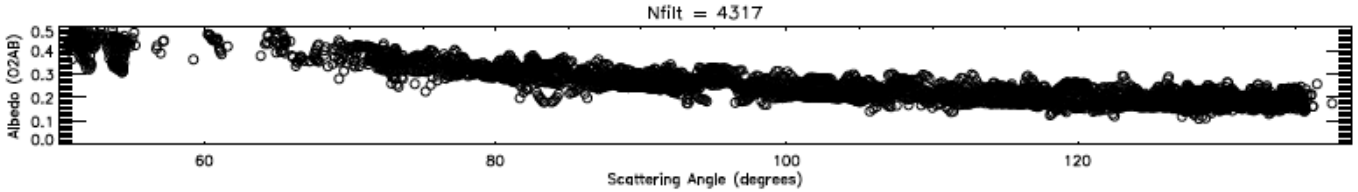
Veg BRDF, p_1, p_2 not retrieved



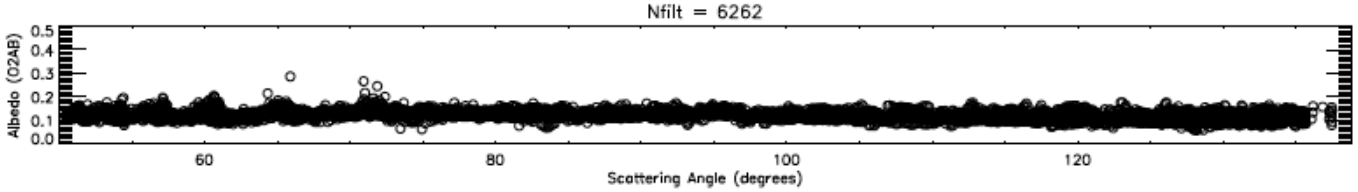
AOD closer to AERONET value, and uncorrelated with scattering angle, for BRDF models

Retrieved Albedo

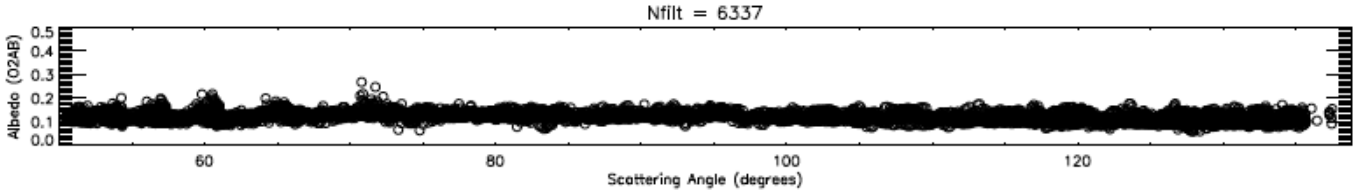
Lambertian



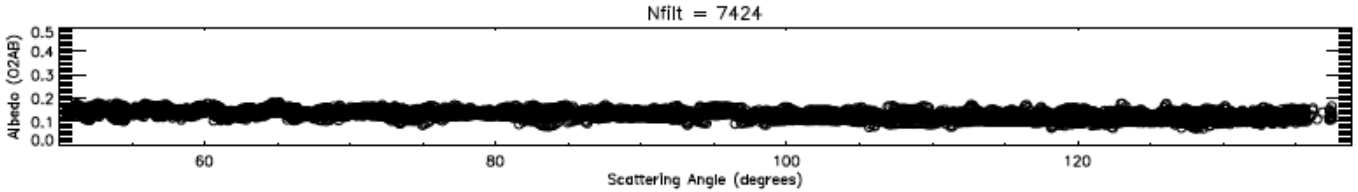
Soil BRDF, p_1, p_2 retrieved



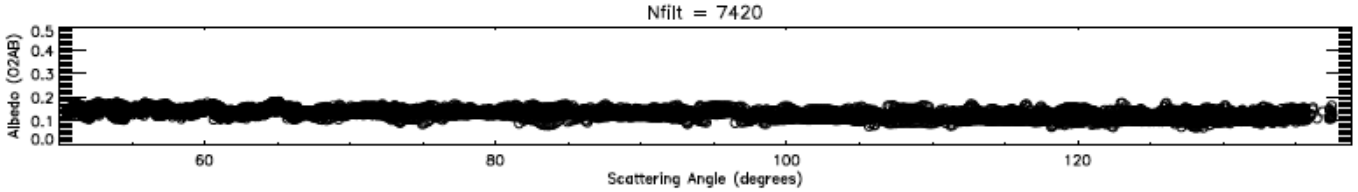
Veg BRDF, p_1, p_2 retrieved



Soil BRDF, p_1, p_2 not retrieved



Veg BRDF, p_1, p_2 not retrieved



Albedo uncorrelated with scattering angle for BRDF models; BRDF models also produce more filtered, converged soundings

Convergence Statistics

- **Number of soundings**
  - **B7 Baseline: 41873**
  - **Soil: 42551**
  - **Vegetation: 42550**

- **Converged**
  - **B7 Baseline: 36035 (86.06%)**
  - **Soil: 42539 (99.97%)**
  - **Vegetation: 42541 (99.98%)**

- **Good Quality**
  - **B7 Baseline: 12958 (30.95%)**
  - **Soil: 15239 (35.81%)**
  - **Vegetation: 15210 (35.75%)**

Next Steps

- **Re-baseline with new spectroscopic models**
- **How do we compare Lambertian and BRDF results?**
- **Implement BRDF model in operational code**