A New BRDF Model to Reduce Biases in Orbiting Carbon Observatory-2 (OCO-2) Retrievals

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OCO-2 Science Viewing Modes

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

Local Nadir

Glint Spot

Ground Track

Park Falls, WI

447-m WLEF Tower

O₂ A Band
Weak CO₂
Strong CO₂
Retrieved albedo correlated with scattering angle => BRDF effects?
BRDF Formulation

\[ BRDF(\lambda) = \left[ w + s(\lambda - \lambda_0) \right] F(p_1, p_2) \]

- \( w \): overall BRDF amplitude
- \( s \): slope of BRDF amplitude
- \( \lambda \): wavelength
- \( \lambda_0 \): 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
Target Mode Tests
Retrieved XCO2

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

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
Glint Mode Tests
XCO2 Difference (Land Glint Only)
BRDF Test  TCCON1 Set

- Black = All Land Data
- Green = Nadir Land
- Blue = Glint Land

Mean diff = 0.042
Diff std. dev. = 0.815
Mean diff(nadir land) = -0.066
Diff std. dev. = 0.741
Mean diff(glint land) = 0.191
Diff std. dev. = 0.887

XCO2 Difference Histogram

26 Jan 2016
Psurf Difference Histogram

BRDF Test TCCON1 Set Lambertian only

Mean diff(land) = -0.153
Diff std. dev. = 1.896
Mean diff(nadir land) = 0.326
Diff std. dev. = 1.759
Mean diff(glint land) = -0.818
Diff std. dev. = 1.879

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Unfiltered Small Area Land Tests
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%)
XCO2
XCO2 Difference
XCO2 Difference Histogram

![BRDF Test UFSA Set](image-url)

- Green = Nadir Land
- Blue = Glint Land

**BRDF Test UFSA Set**

- Black = All Land Data
- Green = Nadir Land
- Blue = Glint Land

Mean diff = 0.038
Diff std. dev. = 0.854
Mean diff (nadir land) = 0.072
Diff std. dev. = 0.719
Mean diff (glint land) = 0.149
Diff std. dev. = 0.961

Mean diff = 0.034
Diff std. dev. = 0.854
Mean diff (nadir land) = 0.071
Diff std. dev. = 0.723
Mean diff (glint land) = 0.142
Diff std. dev. = 0.958
Next Steps

• Re-baseline with new spectroscopic models

• How do we compare Lambertian and BRDF results?

• Implement BRDF model in operational code