Albedo error propagation into XCO_2 in the near infrared

Susan S. Kulawik[1], James McDuffie[2], Chris W. O'Dell[3], Annmarie Eldering[2]

[1] BAER Institute, 625 2nd Street, Suite 209, Petaluma, CA, USA

[2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

[3] Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO, USA

ABSTRACT This work explores the best representation of albedo in the near infrared. We use the Reusable FRamework for Atmospheric Composition (ReFRACtor) version of the OCO-2 radiative transfer to generate synthetic radiances to test the retrieval of radiances generated from the ECOSTRESS spectral library. We use the MUlti-SpEctra, MUltiSpEcies, Multi-SEnsors (MUSES) retrieval system, previously utilized in the visible, thermal, and UV spectral regions, e.g. AIRS, OMI, CrIS, and TES.

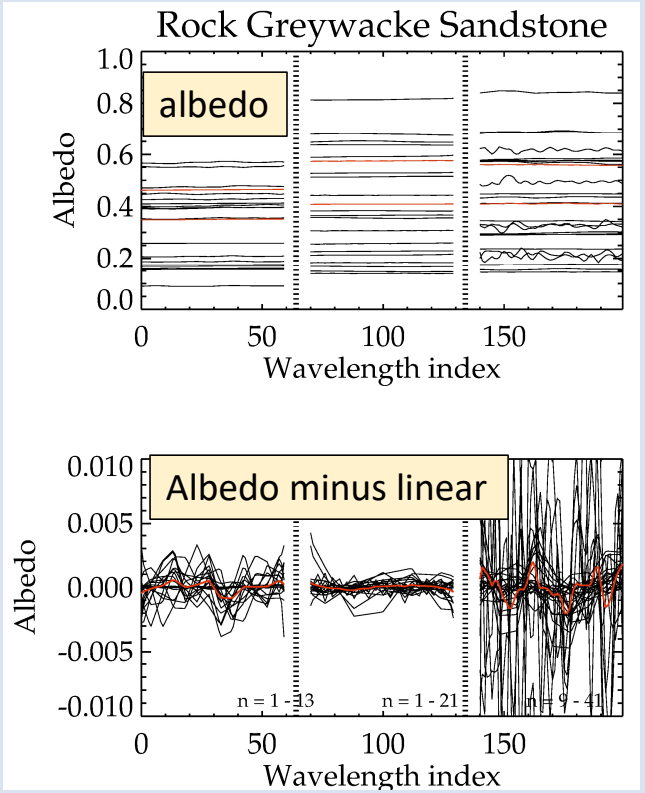
Findings Rock / soil ECOSTRESS samples in have more structure than the current v10 quadratic parameterization, and can propagate into ~7 ppm XCO_2 error. Vegetation and manmade have less structure but still result in ~1.8 ppm XCO_2 error. We test a 30-parameter albedo parameterization on a set of 25 widely varying OCO-2 observations, and find reasonable results versus TCCON but additional study is needed.

Funded by OCO-2/3, and OCO-2 ROSES

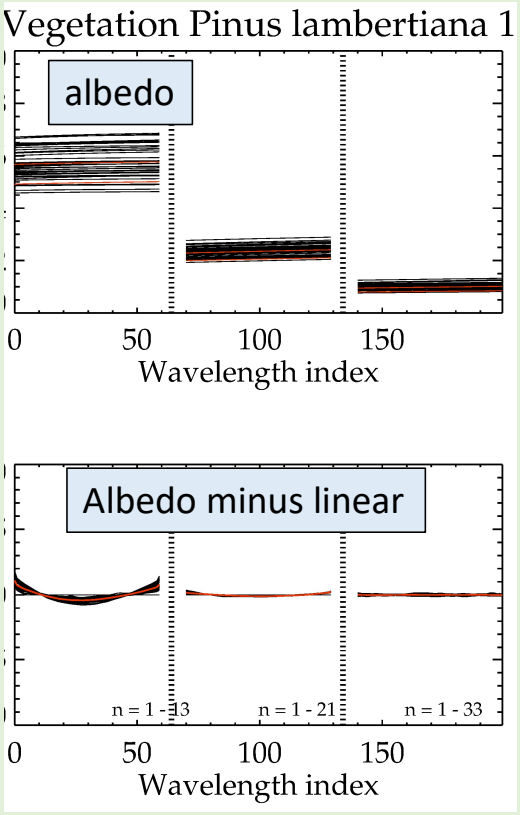
Albedo variability in the NIR

- ECOSTRESS spectral library
- Earth-based samples (soil, rock, manmade, vegetation)
- Examples at right

Rock and soil have fine structure

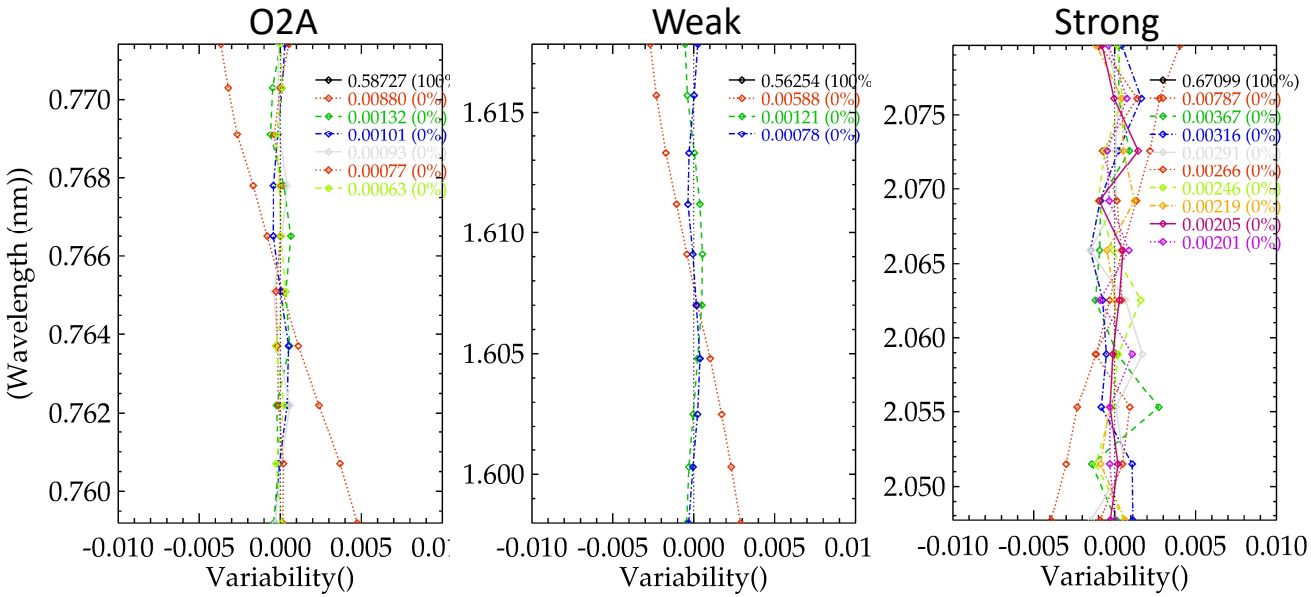


Vegetation has less fine structure



Albedo variations in the NIR

- Use earth-based samples (soil, vegetation, manmade) and calculate covariances
- SVD analysis to see different sizes/shapes of variation
- Wiggles on the order of 0.003. Are these important? (Yes)

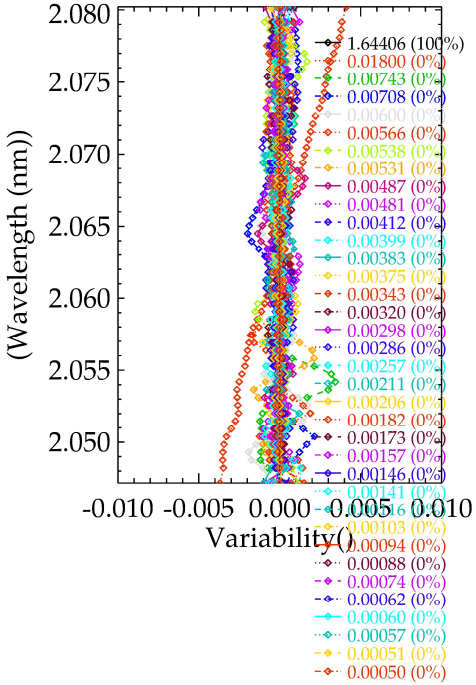


< 10 wavelengths per band

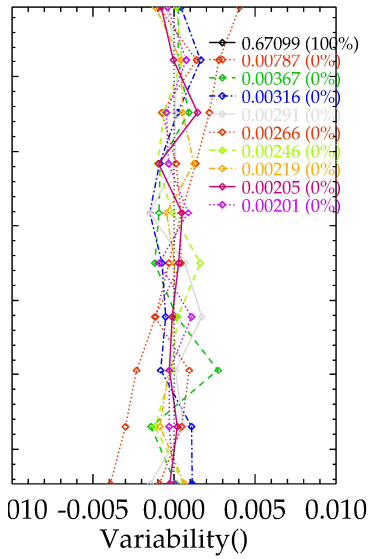
Albedo variability in the NIR

- What representation is adequate?

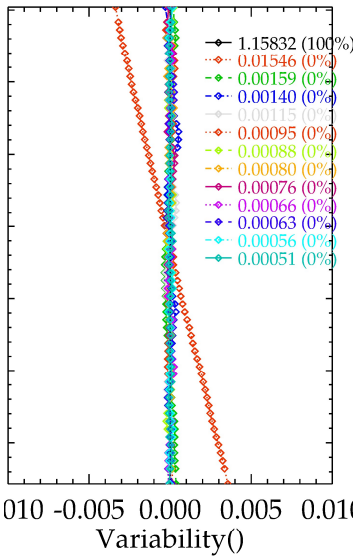
60 wavelengths per band
soil,rock,veg,snow,manmade



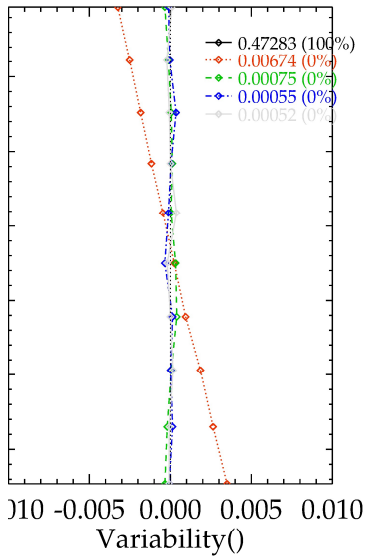
10 wavelengths per band
soil,rock,veg,snow,manmade



60 wavelengths per band
vegetation, snow, manmade



10 wavelengths per band
vegetation, snow, manmade



Propagation of albedo error into XCO_2

Method

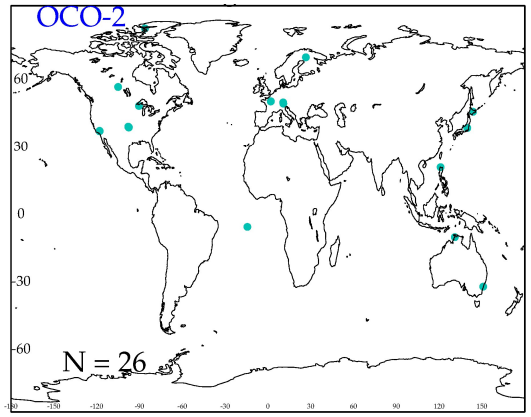
- The propagation of error is achieved by using a 30-wavenumber piecewise linear albedo as the "full state" and the 2nd order polynomial as the retrieved state
- The a priori covariances estimated from ECOSTRESS are propagated through the retrieval system. This results in "mapping error" discussed in Bowman et al. (2006)
  - $Error = (\mathbf{I} - \mathbf{M}\boldsymbol{A_{zx}})\boldsymbol{S_{a,xx}}\,(\mathbf{I} - \mathbf{M}\boldsymbol{A_{zx}})^{T} + \mathbf{G}_z^T e \mathbf{G}_z$
  - where $\mathbf{A_{zx}} = \left(\boldsymbol{K_z^T K_z} + \boldsymbol{constraint}\right)^{-1} \boldsymbol{K_z^T K_x}$

Findings

- The XCO2 mapping error resulting from the ECOSTRESS albedos is 7.6 ppm. This is high due to the inclusion of soil & rock albedos in the a priori covariance. When rock and soil are removed, the estimated error is 1.8 ppm. This is high but close to observed raw OCO-2 errors.
  - "pure" albedos will not occur in the 2 x 3 km oco-2 footprints
  - Can mix in fractions of albedo types to generate a more realistic covariance
- The XCO_2 error estimate when a piecewise linear albedo is retrieved is 1.6 ppm

Testing 30-parameter albedo retrievals

- 25 widely varying land observations (right)
  - Wide range of albedos, temperature, water, CO_2
  - Close to TCCON sites
- Effect on DOFs of adding 30-parameter albedo to state (right):
  - minor effect on CO_2 DOFs -- surprisingly
- Retrievals have improved metrics
  - |chi|: 1.90 -> 1.81
  - |co2_grad_del|: 41 -> 22 ppm
  - |PSUR – prior|: 3.5 -> 3.2 hPa
- Comparison to TCCON (no bias correction, no AK, no filtering)
  - Slightly worse comparison to TCCON: 2.64 -> 2.69 ppm stdev for single observations
  - Have not optimized albedo constraints
  - OCO-2 ROSES project will start work on this:
    - year 1: simulated observations (from co-I Chris O'Dell)
    - year 2 + 3: selected overpasses and target locations
    - year 2 + 3: also add in 3-d cloud retrievals (with Sebastian Schmidt, Co-I)



Effect on DOFs

TATM 1.23 → 1.12
H2O 2.18 → 2.15
CO2 1.95 → 1.89
PSUR 0.86 → 0.86
AEROD 4.76 → 4.77
AERP 0.87 → 0.85
AERW 0.00 → 0.00
ALBBRDF 5.97 → 30.00
DISP 6.00 → 6.00
EOF 9.00 → 9.00