An Assessment of Regional Changes in Atmospheric Scattering and Water Vapor Across a Strong Environmental-Elevational Gradient: First Assessment of the Soda Straw

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Outline

- Background
- Research Questions
- Study Site
- Reflectance
- Water Vapor Artifacts
- Water Vapor vs Elevation
- Summary
Radiative Transfer Solution for Reflectance in the VSWIR

**Models and Measurements**

\[ P_\lambda = \frac{(L_{\lambda_s} - L_{\lambda_{path}})}{L_{\lambda_{direct}}} \]

**Spectral Fit in Water Vapor Band**

15.92 precipitable mm

**Modeled Radiance**

**Retrieved Reflectance**
VSWIR-TIR Synergies: Atmospheric

- Error Sources in Temperature Emissivity Separation
  - Water vapor and ozone (9.6 µm)
  - Uncertainty in water vapor is the largest error source

- Standard Products of Reflectance Retrieval
  - Apparent Surface Reflectance
  - Column Water Vapor
  - Liquid Water

- VSWIR column water vapor can constrain TIR atmospheric correction

DEM (left), AVIRIS derived Water vapor (right)
Temporal Changes in Water Vapor

Theoretical: \( WV(z) = WV(0) \cdot e^{-z/H} \): \( H = 2300 \) km: In practice ~ linear
Slope and intercept vary seasonally with airmasses
Roberts et al., 1997, RSE
Research Questions

• Which reflectance retrieval approach works best?
  – ACORN, ATCOR, AVIRIS-TEAM Product (Standard)
    • Artifacts in reflectance (Path radiance)
    • Artifacts in water vapor

• Which reflectance retrieval approach is most accurate for retrieving water vapor?
  – MODIS column water vapor (MYD05)

• How does water vapor vary regionally and seasonally?
  – Water-vapor-Elevation Conceptual Model
    • Departures: Advected moisture, Evapotranspiration, other?
  – Regional and seasonal models
Study Site

- **The Soda Straw**
  - Elevation Range: 0 to > 4000 m
  - May 2, 2013
    - Run 23: Interior. Run 24: Coastal
  - June 6, 2013
    - Run 5

Source: http://aviris.jpl.nasa.gov/alt_locator/
Data Sets/Processing

• AVIRIS
  – Radiance: 18 m, Surface Elevation (m) (Dennison Code)
  – Reflectance (ACORN5, ATCOR4, Standard)
    • Elevation: Run 23: 1737 m; Run 24: 216 m; Run 5: 82 m
    • All: 940 nm fit region, 50 km visibility, mid-latitude summer
  – Water Vapor (cm)
Water Vapor Accuracy

- MODIS-AVIRIS Water Vapor Comparison

MYD05_L2: 5-2-2013 (1:30 PM)
Artifact Analysis

• AVIRIS Reflectance
  – Select targets covering a range of elevations and cover types
  – Lakes at high and low elevation (dark objects, path radiance)
  – Snow & bare rock
  – Vegetation at a range of elevations

• Water Vapor
  – Dark objects
  – Snow/bright objects
  – Green vegetation
Error Sources: Path Radiance/Transmittance

- ATCOR/ACORN include one surface elevation
  - The path radiance term will either be over or undercompensated
  - Do errors in path radiance correction manifest as errors in reflectance?
Conifer Reflectance

Model Elevation: 1737 m
Crop/Soil Reflectance

Model Elevation: 1737 m
Snow and Rock

Model Elevation: 1737 m

Grain Size Effects on Snow Reflectance (µm)

Wavelength (nm)

Reflectance

350 850 1350 1850 2350

Snow: 3230 m

Bare Rock: 3200 m

1650, 830, 650 nm RGB 1.8 km
Water Vapor: MODIS Analysis

Standard: Lowest slope, highest $r^2$
ACORN: Slope near 1, highest bias
ATCOR: Slope and bias intermediate

940 nm fit should have higher water vapor
Water Vapor Artifacts: Standard

1650, 830, 645 nm RGB

Column Water Vapor
Water Vapor Artifacts: ACORN

ACORN

1650, 830, 645 nm RGB

Column Water Vapor

Water Error
+0.063 cm

Shadow Error
+0.15 cm

Snow Error
-0.14 cm
Water Vapor Artifacts: ATCOR

ATCOR

1650, 830, 645 nm RGB

Column Water Vapor

Water Error Masked

Shadow Error +0.55 cm

Snow Error -0.146 cm
Water Vapor Artifacts: Standard

STANDARD

1650, 830, 645 nm RGB

Column Water Vapor
Water Vapor Artifacts: ACORN

1650, 830, 645 nm RGB

Column Water Vapor
Water Elevation Relationships
May 2, 2013: Run 23

Mono Lake
Water Elevation Relationships
May 2, 2013: Run 23

1650, 830, 650 nm RGB
Water Vapor (classified)

Mono Lake
Water Elevation Relationships
June 6, 2013: Run 5

Mono Lake
Water Elevation Relationships
May 2, 2013: Run 23

Central Sierra Nevada
Water Elevation Relationships
May 2, 2013: Run 23

Central Sierra Nevada
Water Elevation Relationships
June 6, 2013: Run 5

Central Sierra Nevada
Water Elevation Relationships
May 2, 2013: Run 24

Santa Ynez Valley
Water Elevation Relationships
May 2, 2013: Run 24

1650, 830, 650 nm RGB
Water Vapor (0.2 to 0.87 cm)
Elevation (500 to 2000 m)

Santa Ynez Valley
Summary (1)

- Reflectance retrieval is a work in progress
  - Path radiance varies with elevation
    - ACORN and ATCOR use a single elevation
    - Errors manifest as over or under correction in reflectance
    - Standard model and ATCOR appeared to compensate
  - All methods have water vapor artifacts
    - Required for synergies with TIR
    - Manifests as subtle errors in reflectance
    - All approaches were dry compared to MODIS
    - Dark objects are overestimated
      - Standard most sensitive
    - Water vapor underestimated over snow
  - Vegetation
    - ACORN and Standard overestimated water vapor
    - ATCOR underestimates water vapor
Summary (2)

• Ground validation targets are needed
  – Required to assess performance
  – Required for second pass correction
    • The correction is elevation dependent

• Water vapor most often varies linearly with elevation

• Multiple water vapor-elevation relationships are present
  – These vary regionally and seasonally
    • How many are there in a single flight of this length?
  – Departures likely represent advected moisture, local sources, entrainment
    • Can this be translated into meaningful environmental measures such as VPD?

• Questions?