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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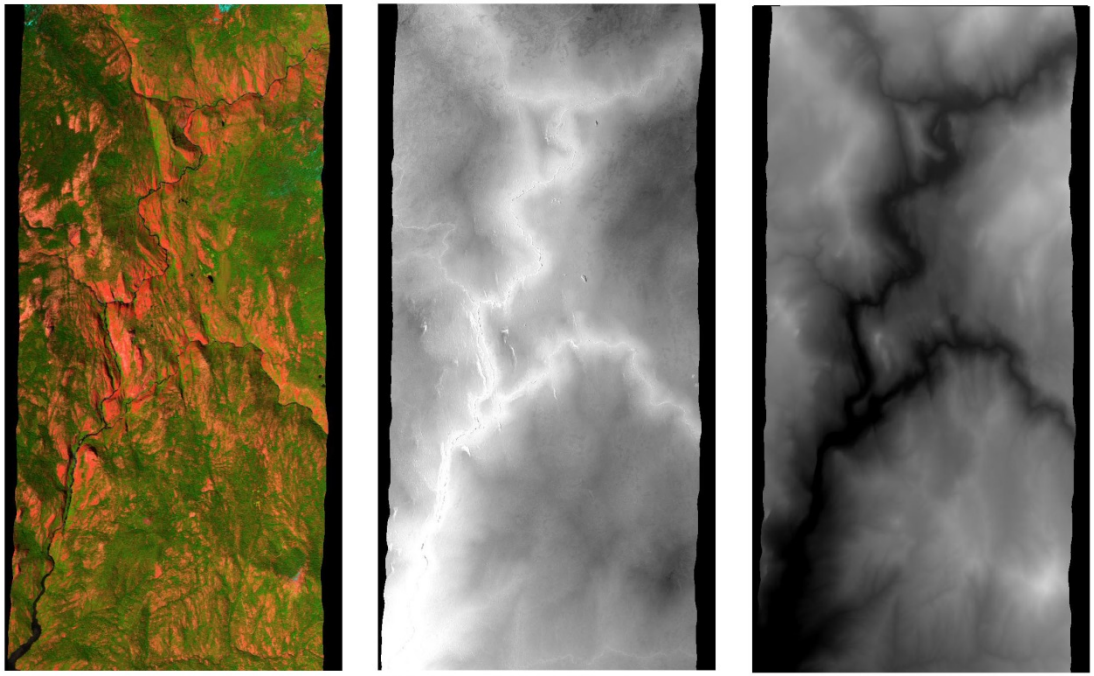


1650, 830, 650 nm RGB | Water Vapor (0.12 to 1.185 cm) | Elevation (1200 to 3120 m)

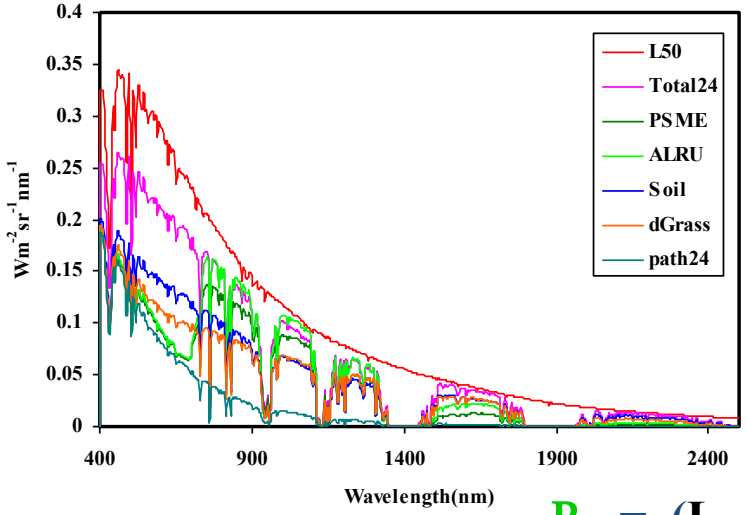
Acknowledgements: NASA HyspIRI Preparatory Program

Outline

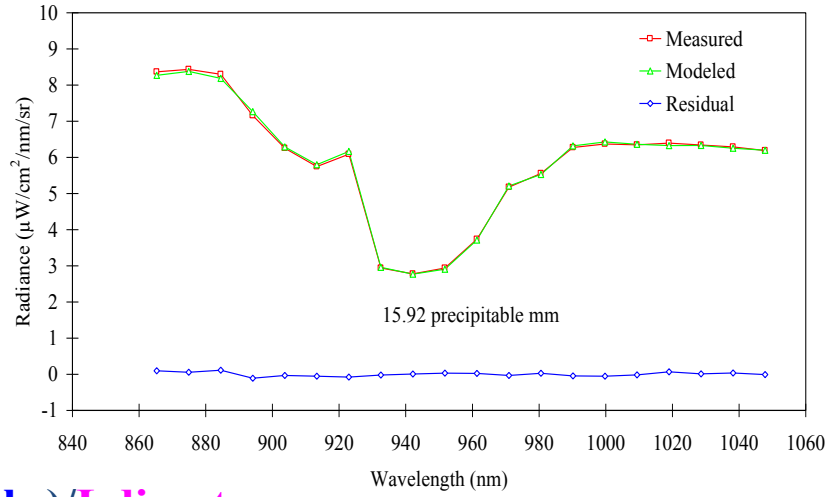
- **Background**
- **Research Questions**
- **Study Site**
- **Reflectance**
- **Water Vapor Artifacts**
- **Water Vapor vs Elevation**
- **Summary**

Radiative Transfer Solution for Reflectance in the VSWIR

Models and Measurements

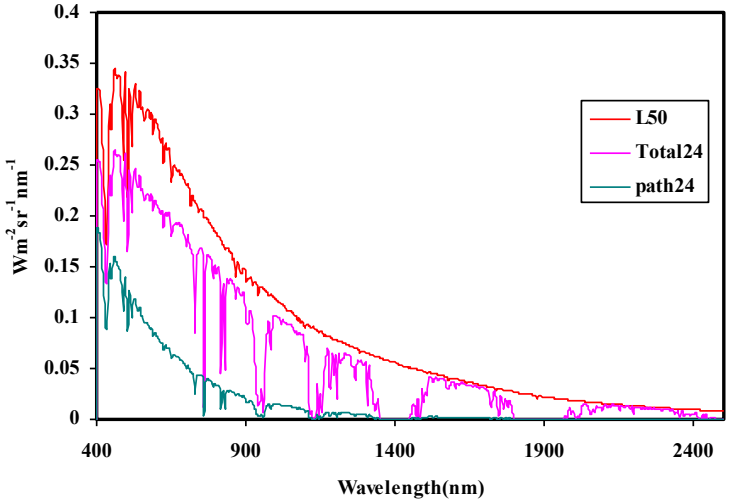


Spectral Fit in Water Vapor Band

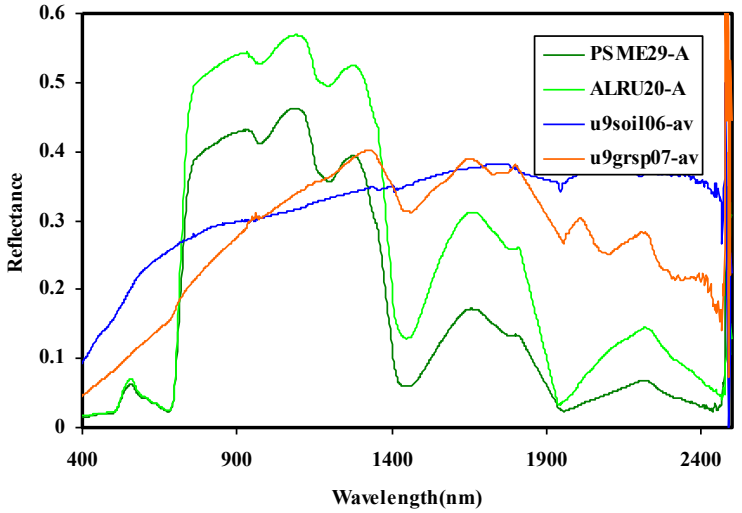


$$P_\lambda = (L_{\lambda s} - Lpath_\lambda)/Ldirect_\lambda$$

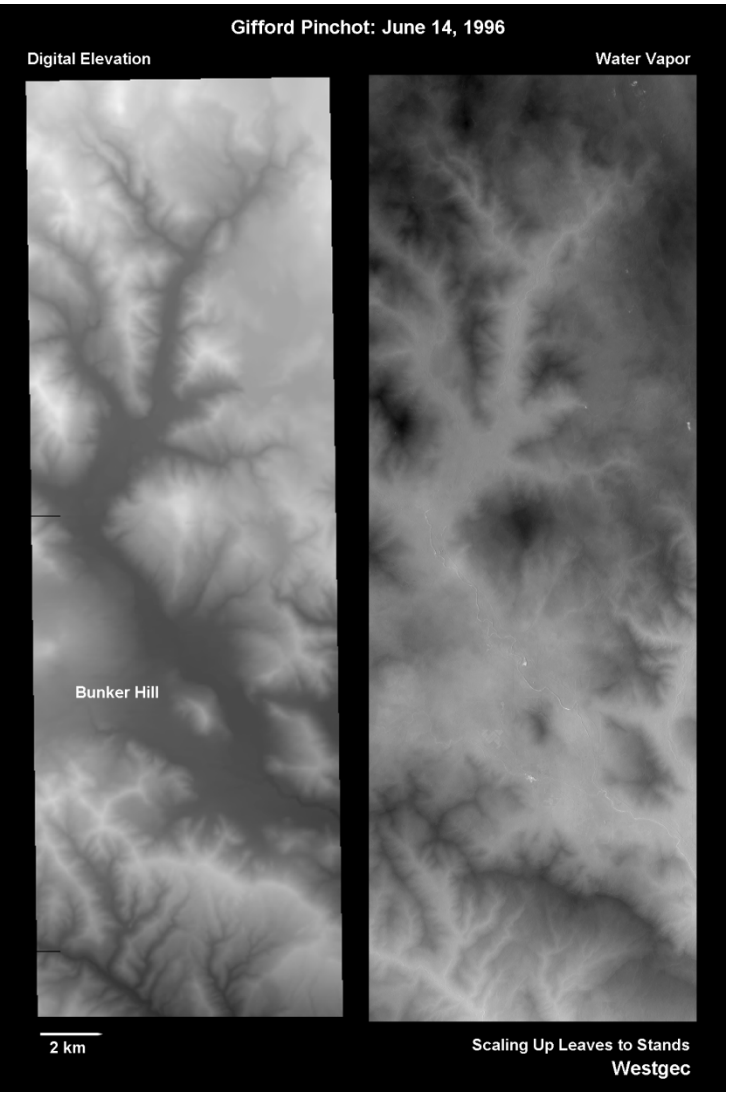
Modeled Radiance

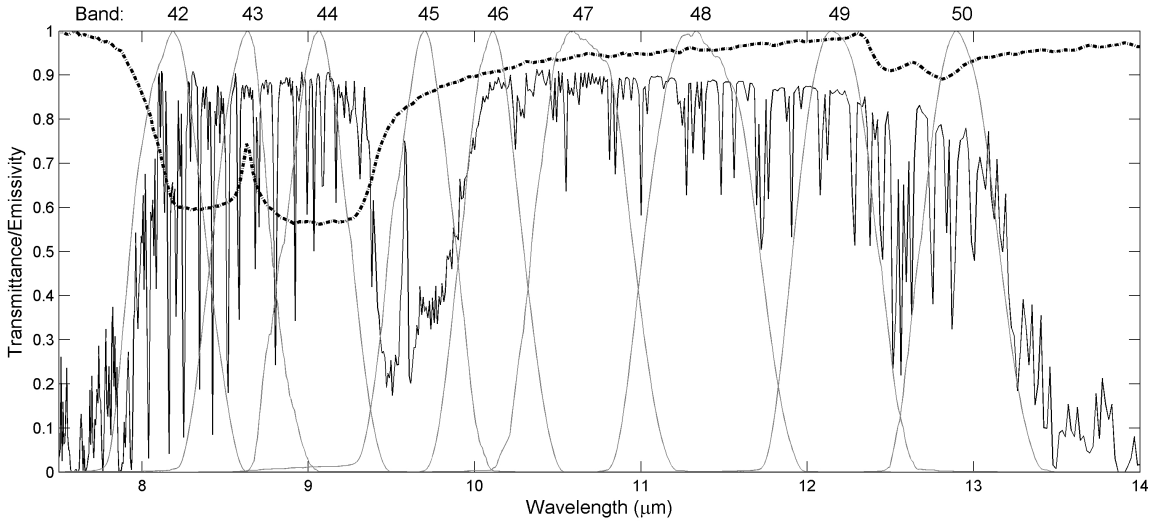


Retrieved Reflectance



VSWIR-TIR Synergies: Atmospheric



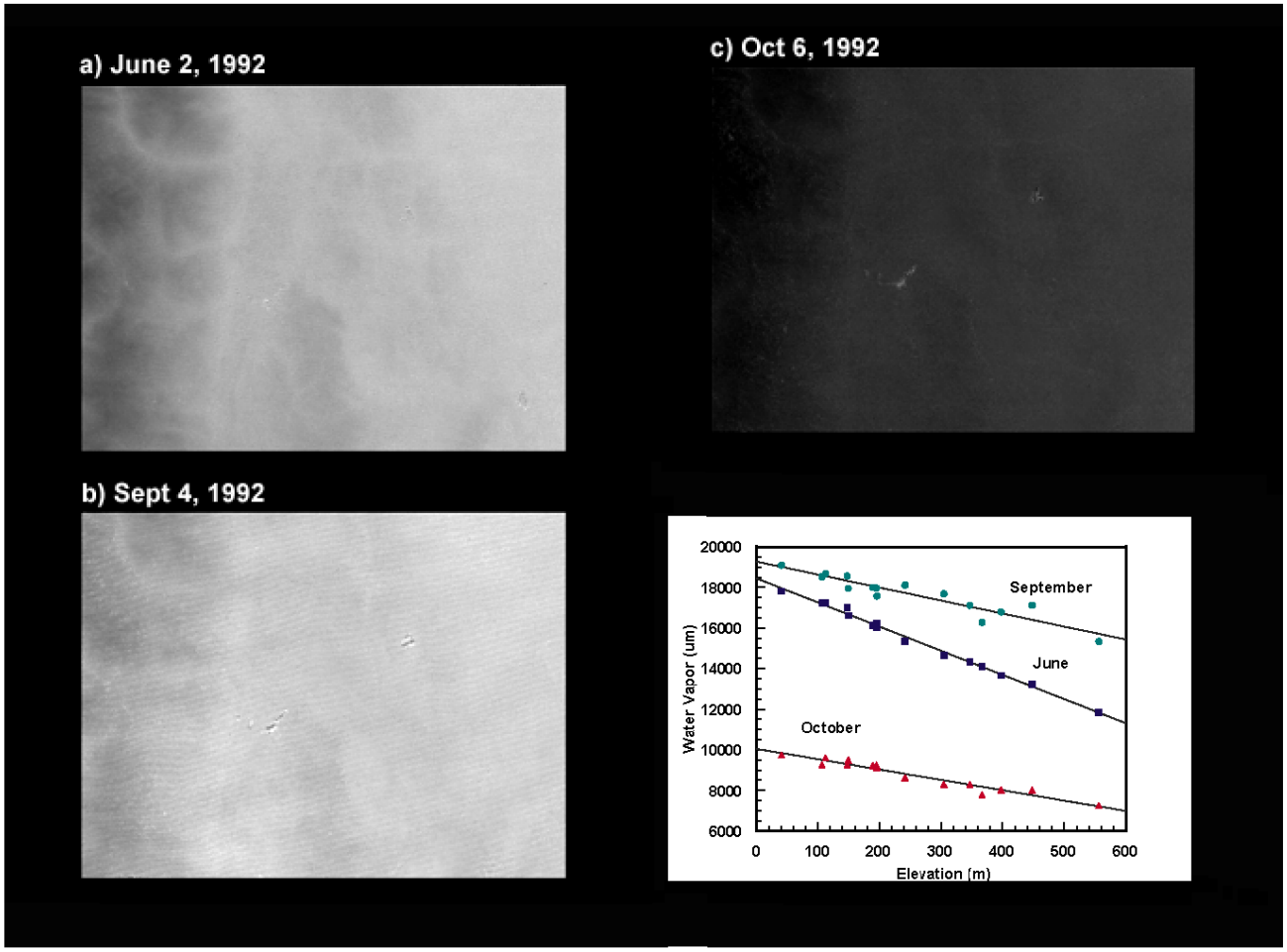


Modtran transmission spectrum. Quartz (dashed). MASTER bands (Gaussian plots)

- **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: $WV(z) = WV(0)*e^{-z/H}$: H=2300 km: In practice ~ linear

Slope and intercept vary seasonally with airmasses

Roberts et al., 1997, RSE

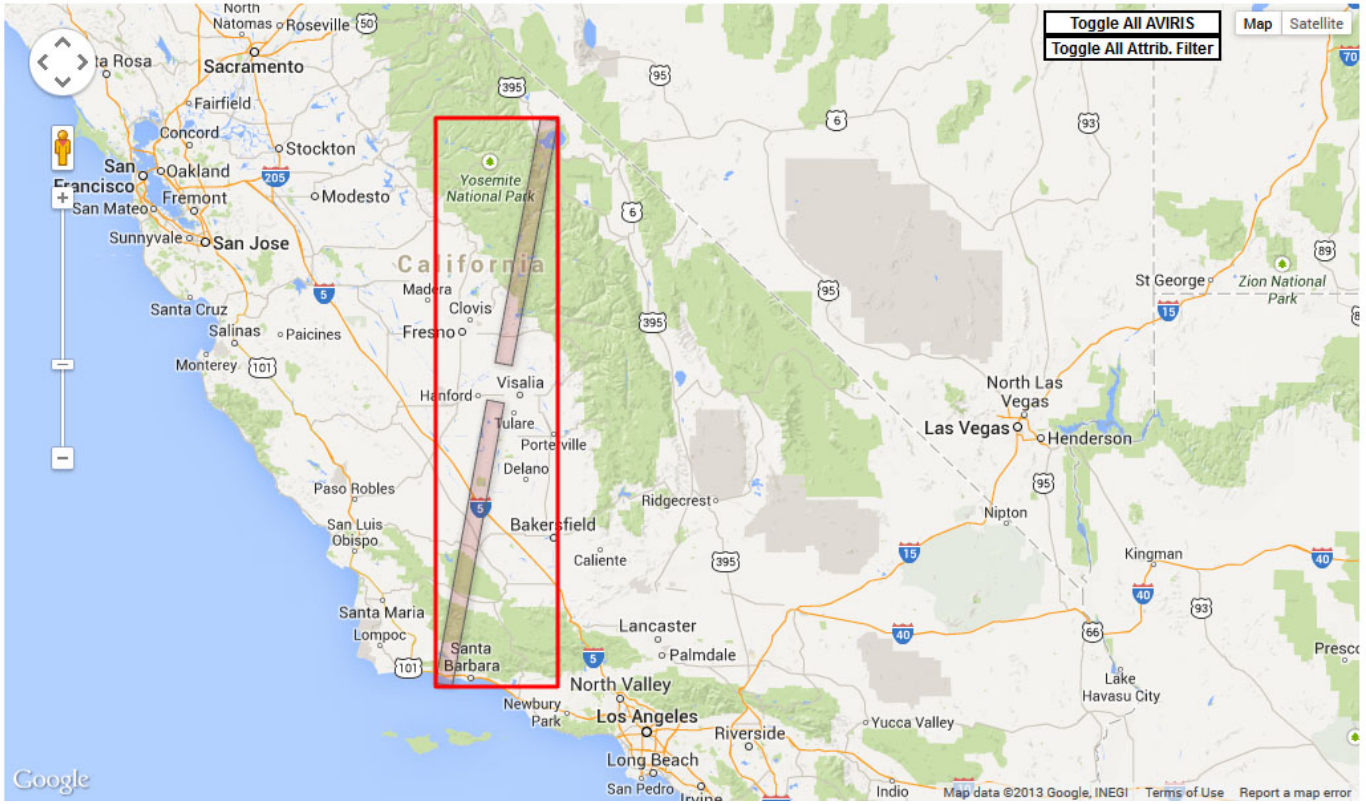
Research Questions

- **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

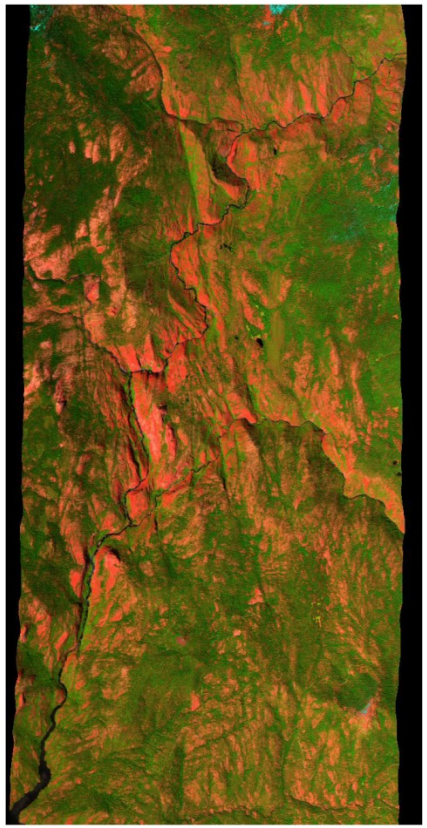
- **The Soda Straw**
  - **Elevation Range: 0 to > 4000 m**
  - **May 2, 2013**
    - **Run 23: Interior. Run 24: Coastal**
  - **June 6, 2013**
    - **Run 5**

May 2, 2013



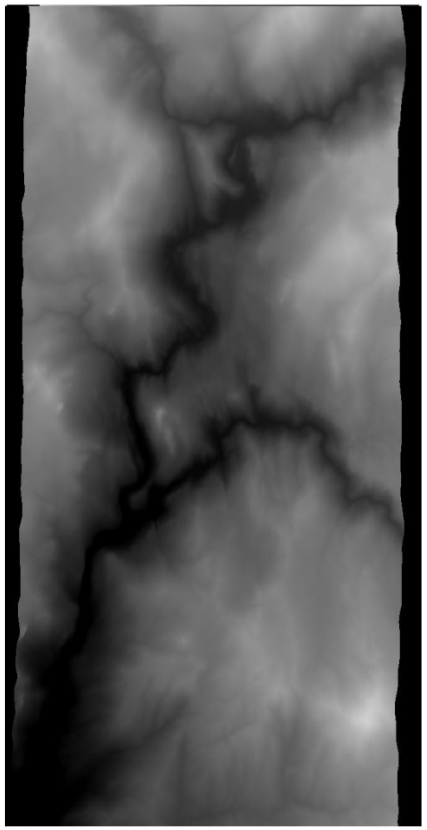
Source: http://aviris.jpl.nasa.gov/alt_locator/

Data Sets/Processing



1650, 830, 650 nm RGB

Water Vapor (0.12 to 1.185 cm)

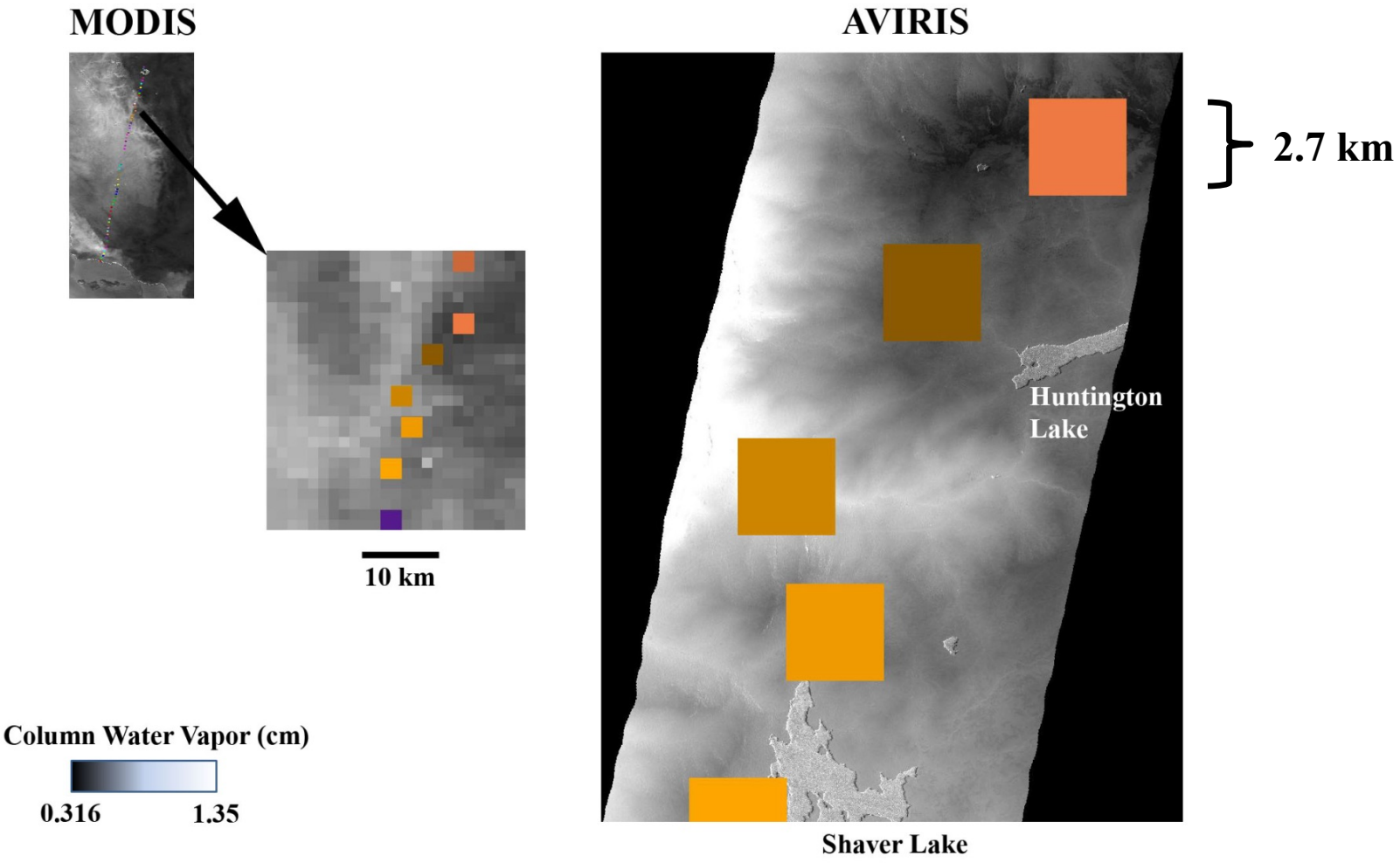


Elevation (1200 to 3120 m)

- **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**

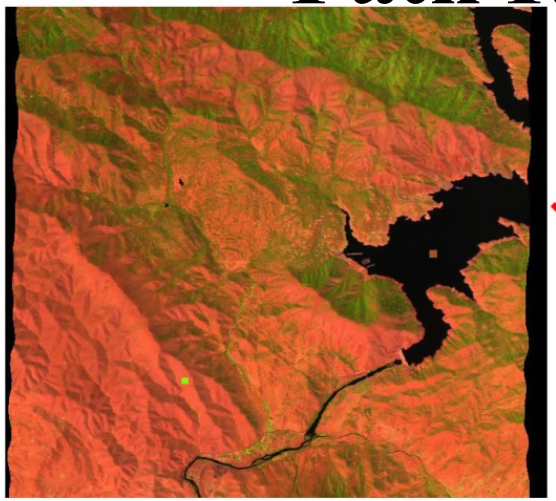


MYD05_L2: 5-2-2013 (1:30 PM)

Artifact Analysis

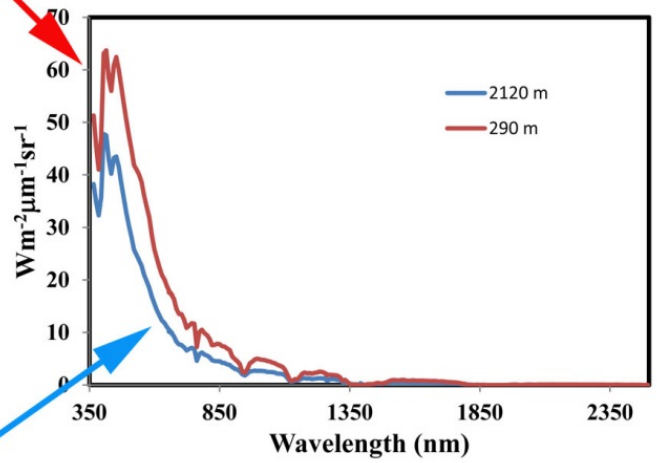
- **AVIRIS Reflectance**
  - **Select targets covering a range of elevations and cover types**
  - **Lakes at high and low elevation (dark objects, path radiance)**
  - **Snow & bare rock**
  - **Vegetation at a range of elevations**
- **Water Vapor**
  - **Dark objects**
  - **Snow/bright objects**
  - **Green vegetation**

Error Sources: Path Radiance/Transmittance



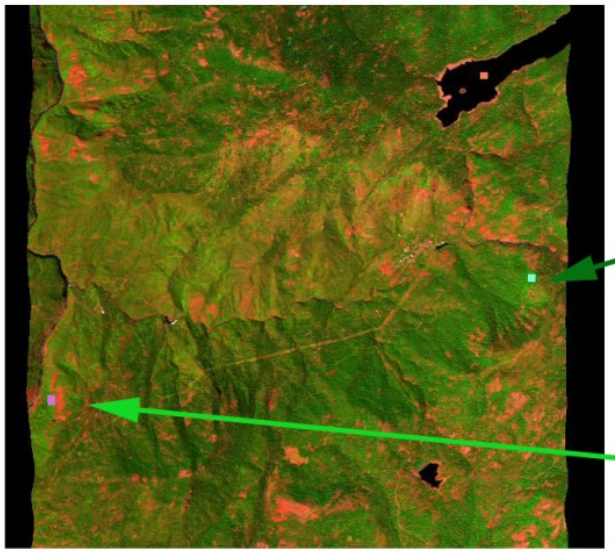
1650, 830, 650 nm RGB

1.8 km



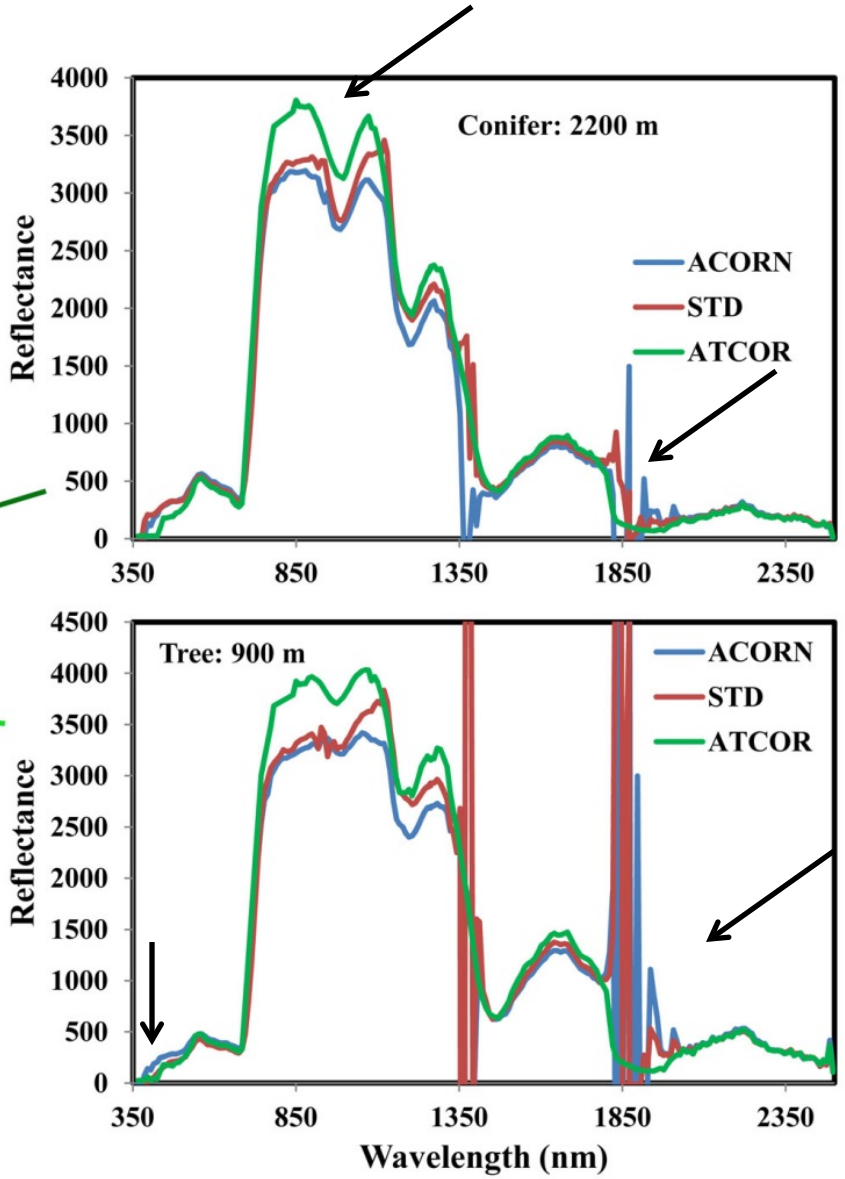
- **ATCOR/ACORN include one surface elevation**
  - **The path radiance term will either be over or undercompensated**
  - **Do errors in path radiance correction manifest as errors in reflectance?**

Conifer Reflectance



1650, 830, 650 nm RGB

1.8 km

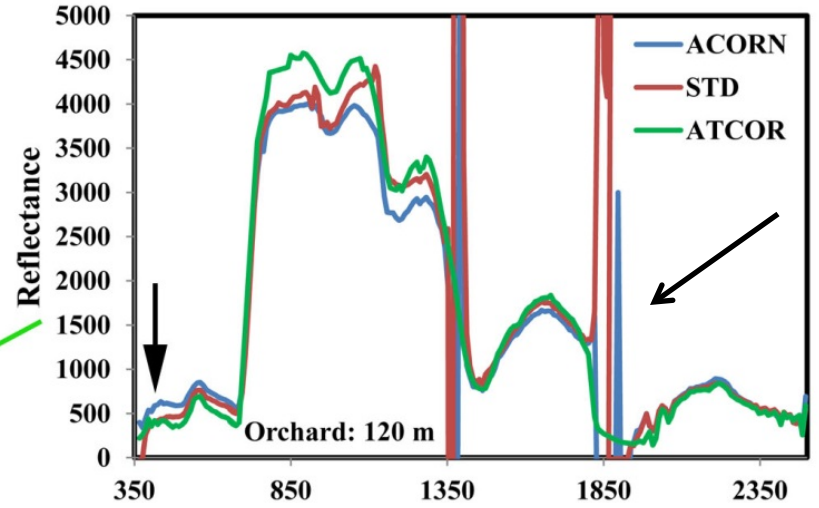


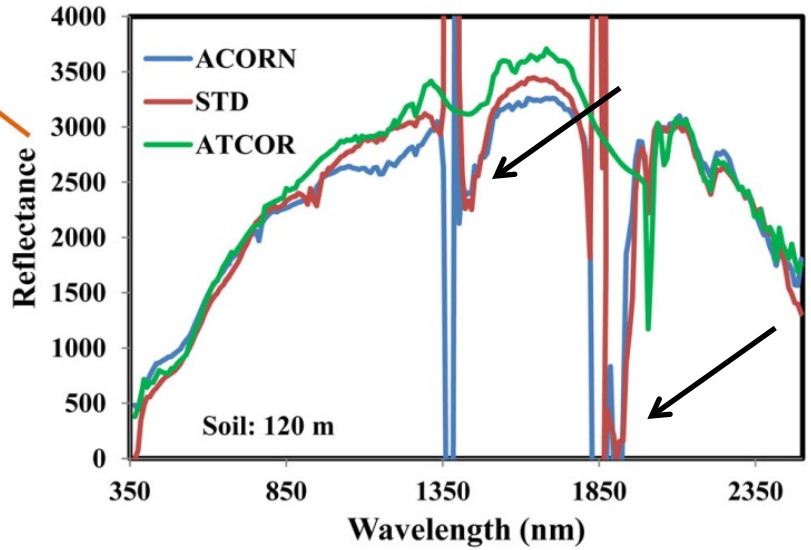
Model Elevation: 1737 m

Crop/Soil Reflectance

1650, 830, 650 nm RGB

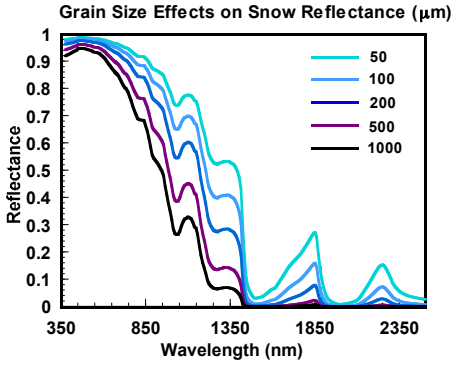
1.8 km

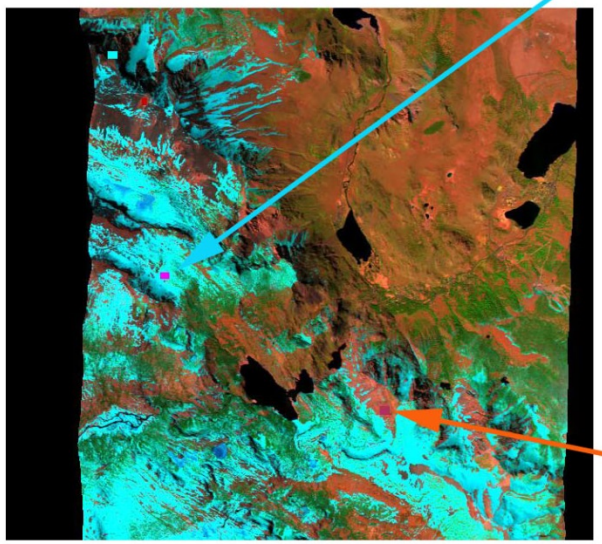




Model Elevation: 1737 m

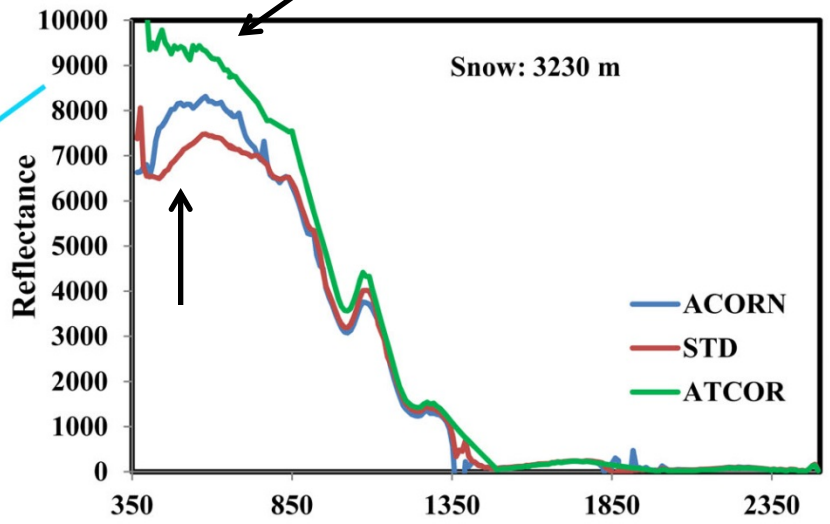
Snow and Rock

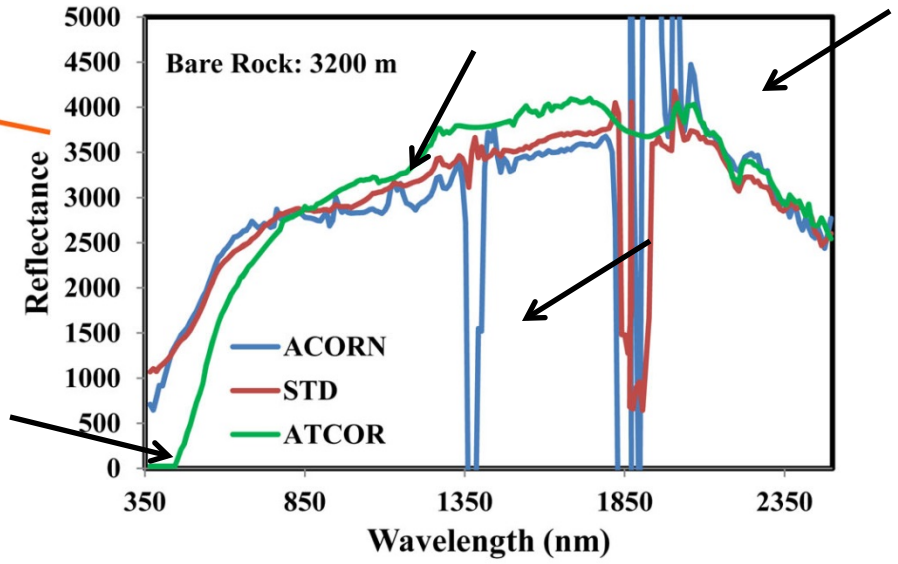




1650, 830, 650 nm RGB

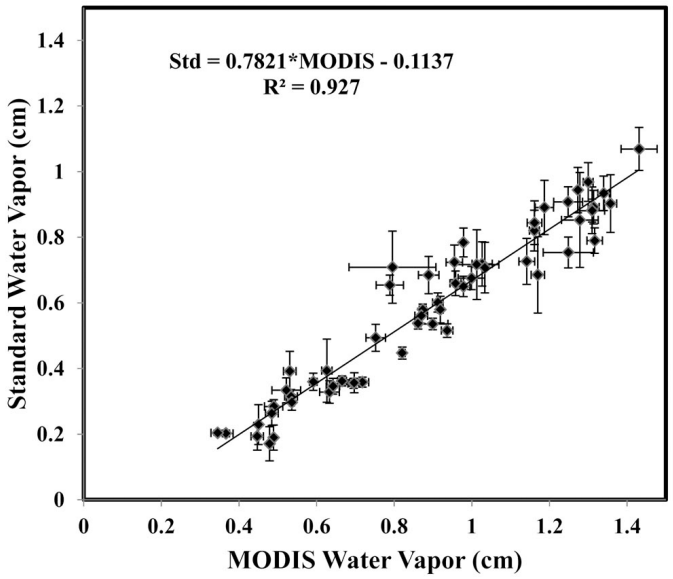
1.8 km

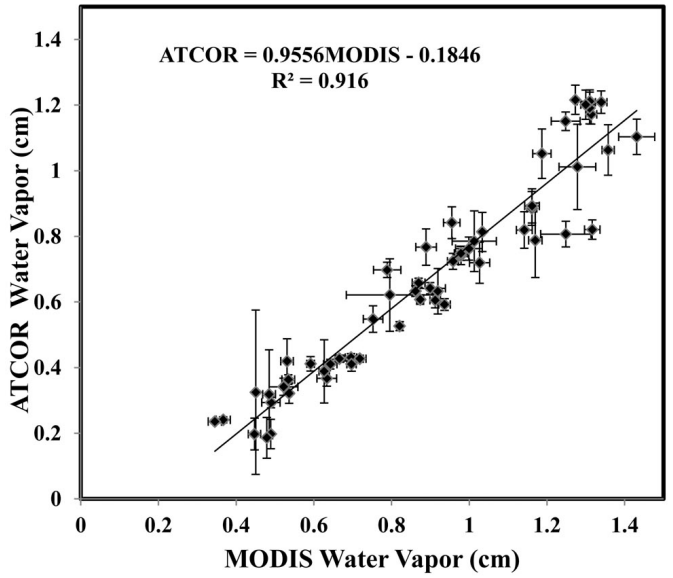


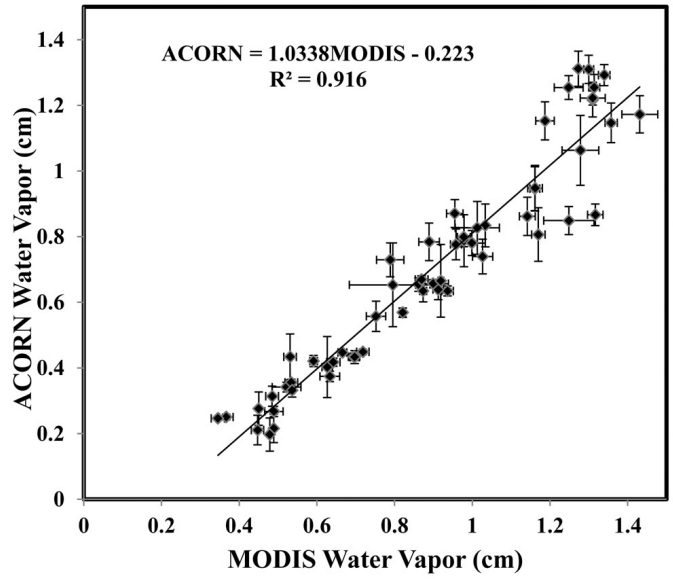


Model Elevation: 1737 m

Water Vapor: MODIS Analysis





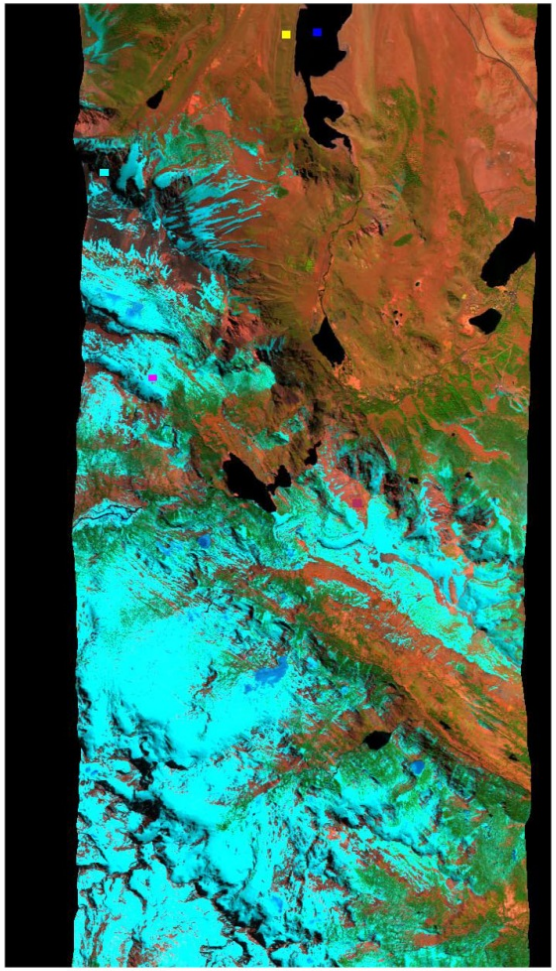


Standard: Lowest slope, highest r^2
ACORN: Slope near 1, highest bias
ATCOR: Slope and bias intermediate

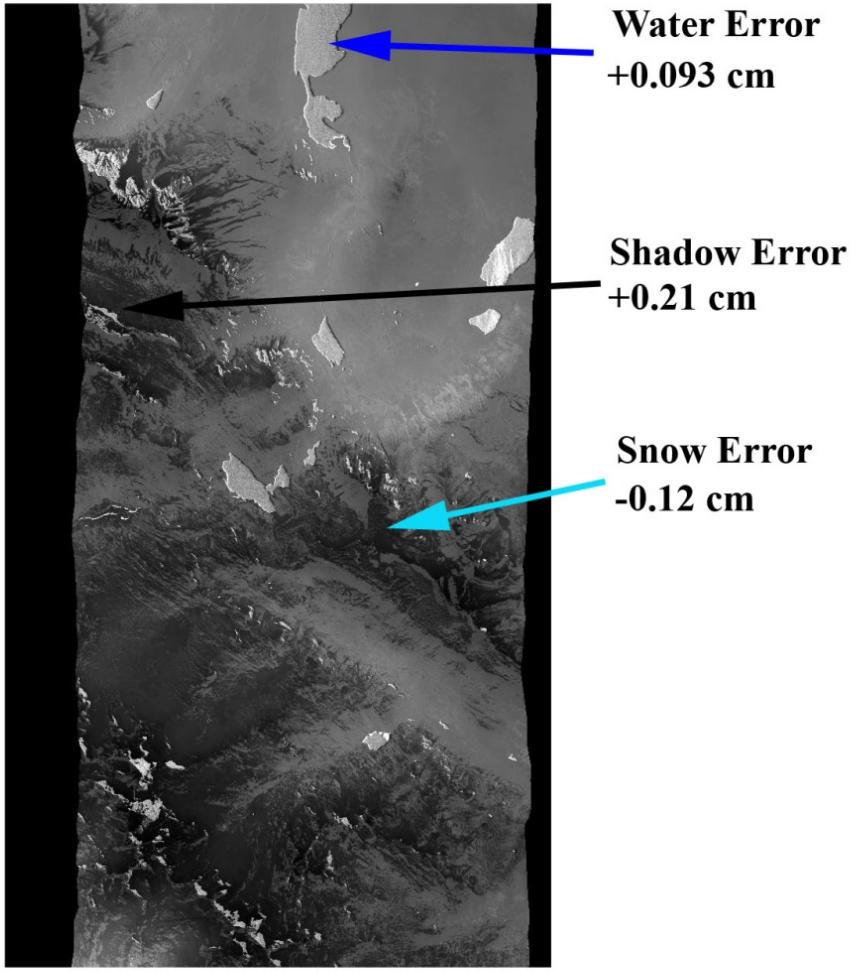
940 nm fit should have higher water vapor

Water Vapor Artifacts: Standard

STANDARD



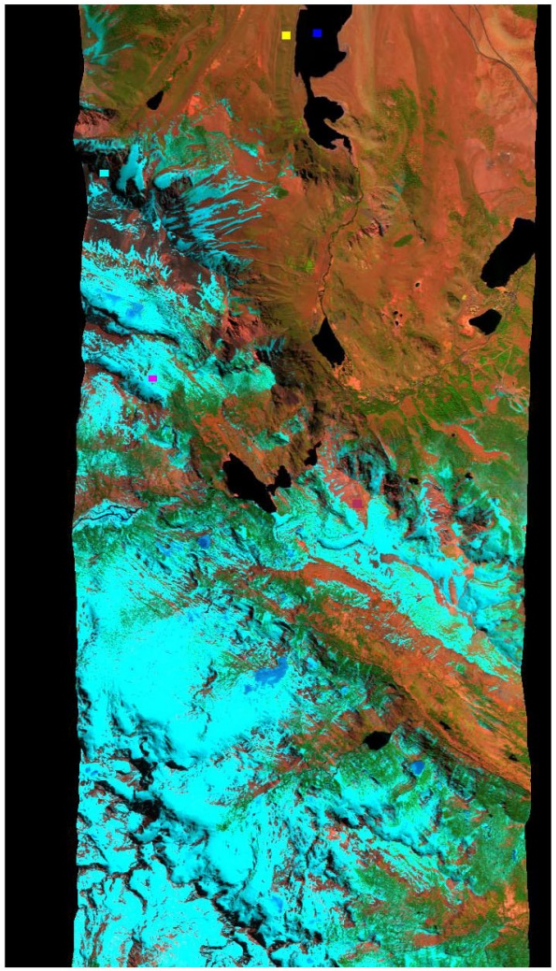
1650, 830, 645 nm RGB



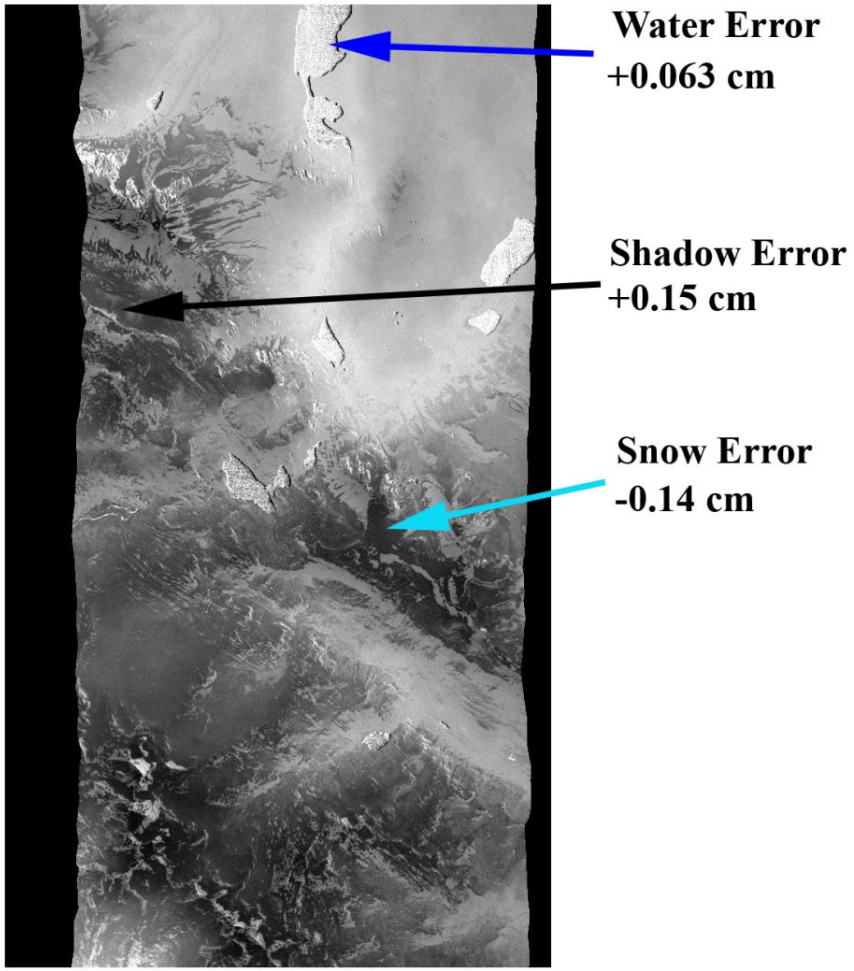
Column Water Vapor

Water Vapor Artifacts: ACORN

ACORN



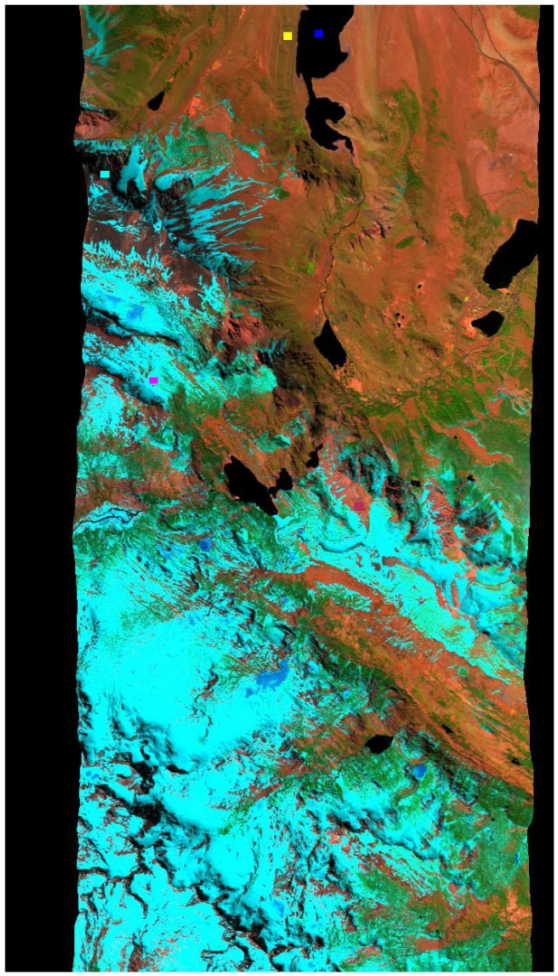
1650, 830, 645 nm RGB



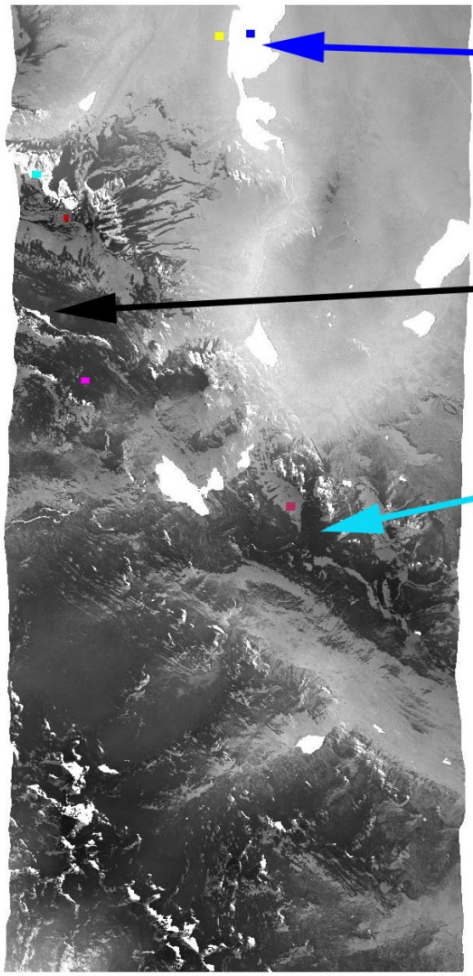
Column Water Vapor

Water Vapor Artifacts: ATCOR

ATCOR



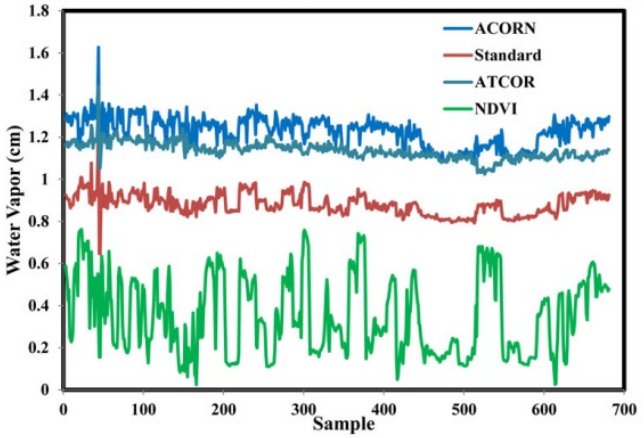
1650, 830, 645 nm RGB



Column Water Vapor

Water Vapor Artifacts: Standard

STANDARD

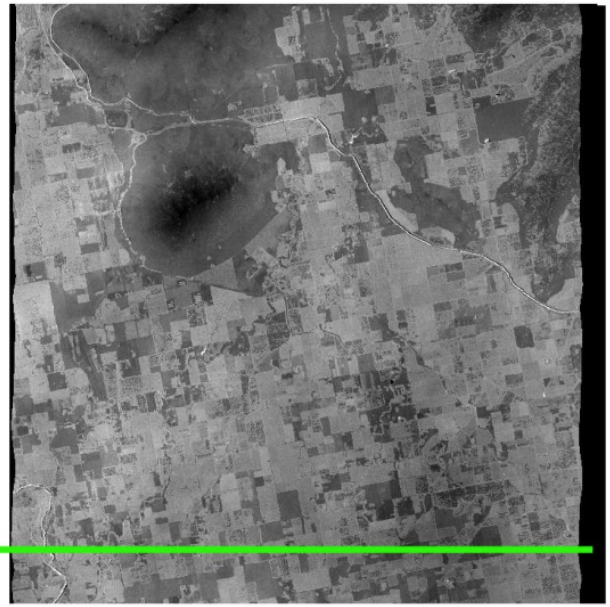


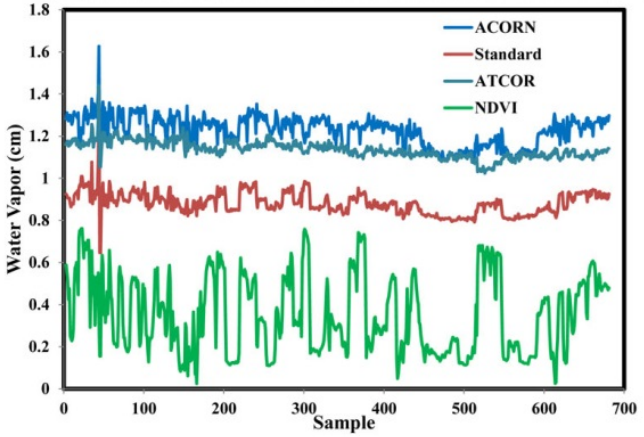
1650, 830, 645 nm RGB

Column Water Vapor

Water Vapor Artifacts: ACORN

ACORN





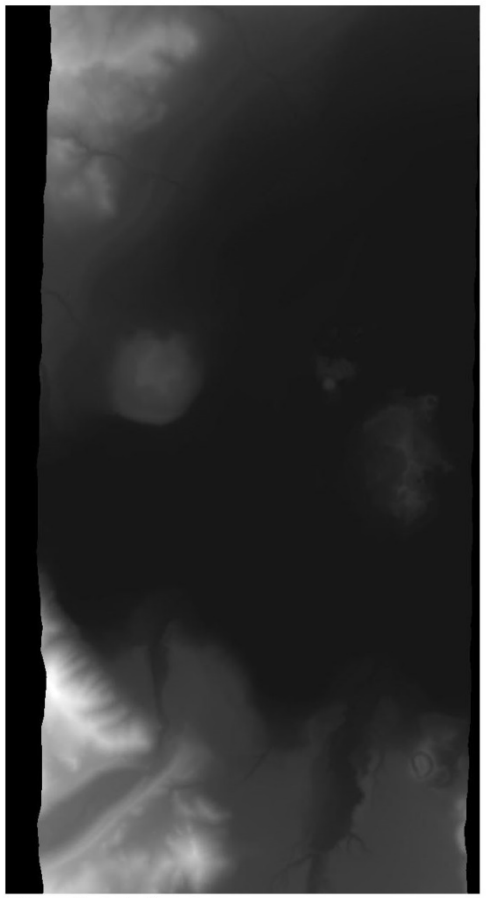
1650, 830, 645 nm RGB

Column Water Vapor

Water Elevation Relationships
May 2, 2013: Run 23

1650, 830, 650 nm RGB

Water Vapor (classified)

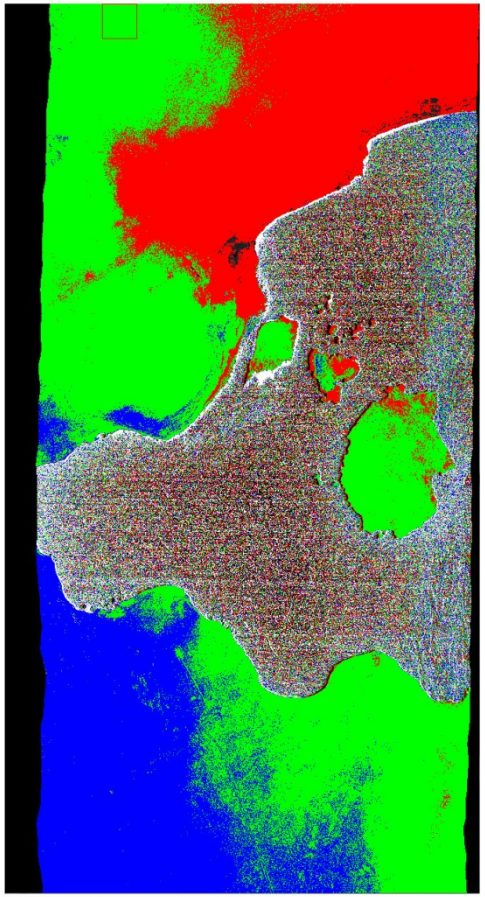


Elevation (m)

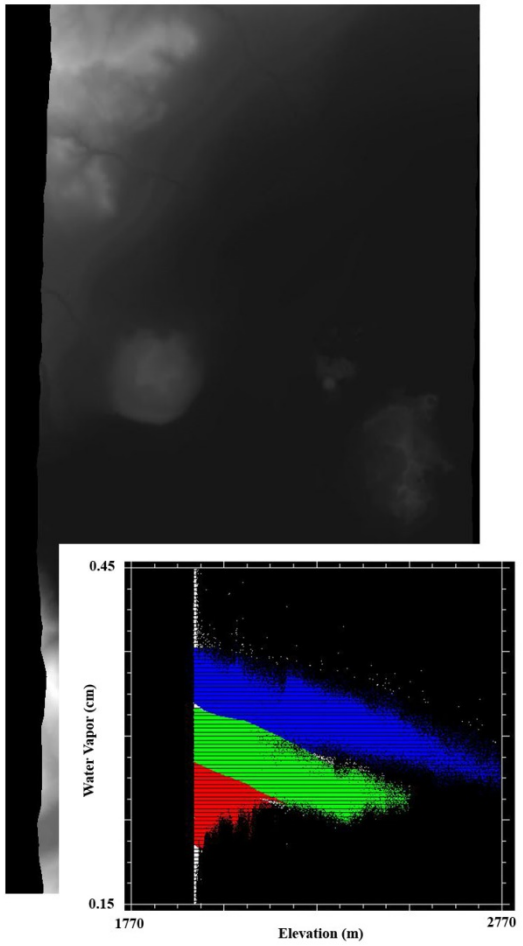
Mono Lake

Water Elevation Relationships
May 2, 2013: Run 23

1650, 830, 650 nm RGB



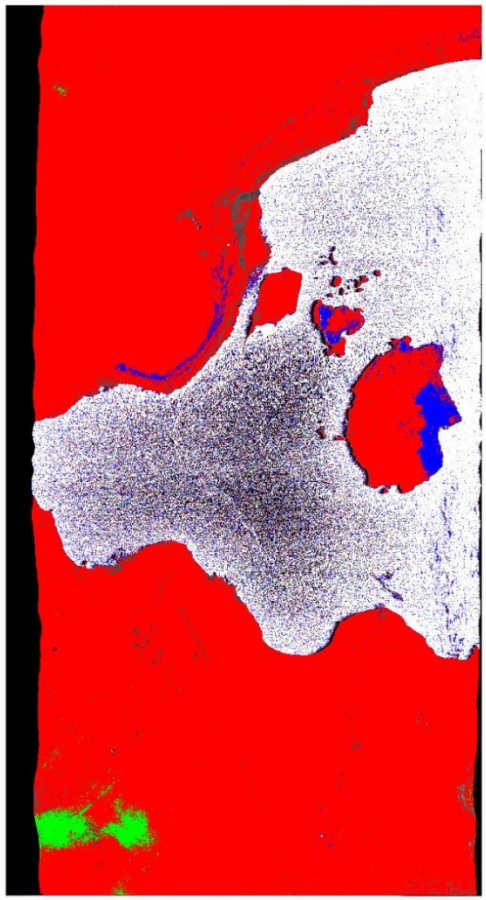
Water Vapor (classified)



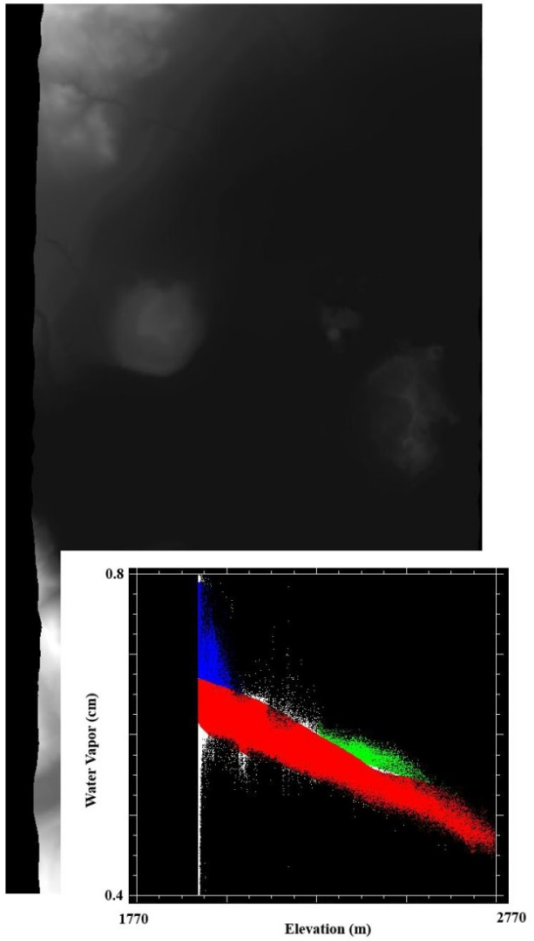
Mono Lake

Water Elevation Relationships
June 6, 2013: Run 5

1650, 830, 650 nm RGB

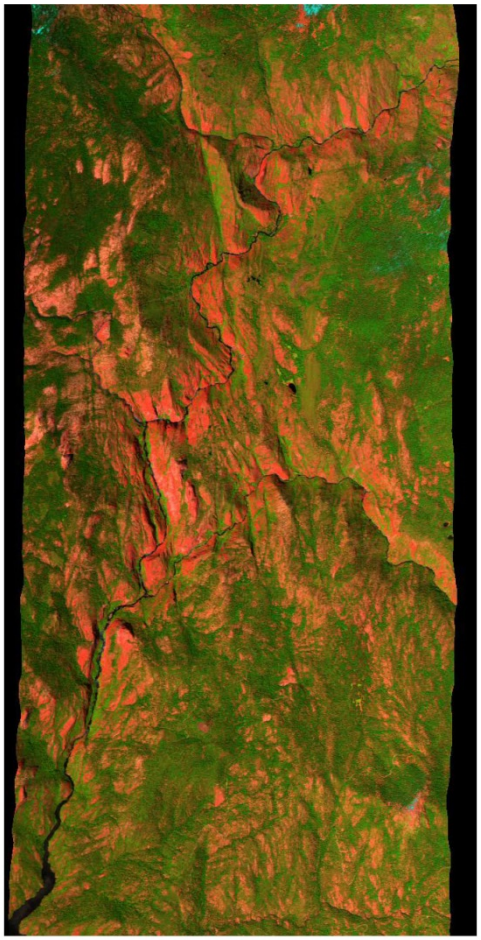


Water Vapor (classified)



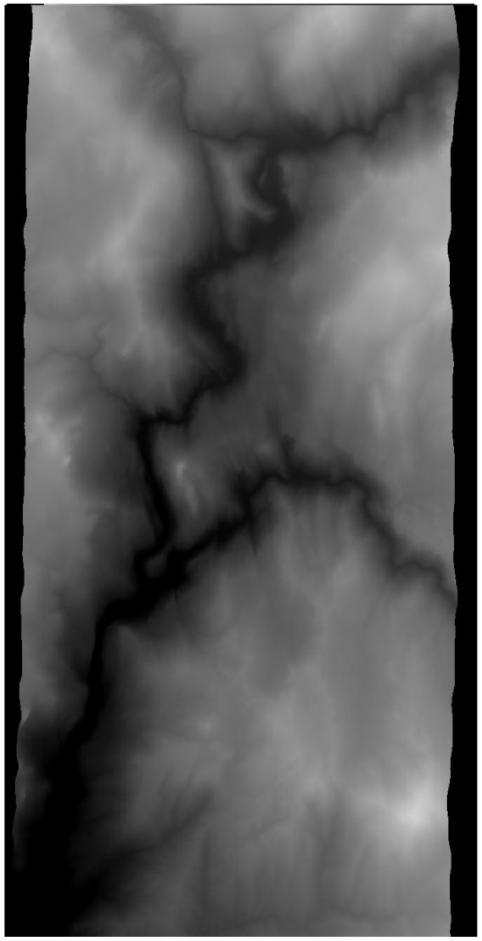
Mono Lake

Water Elevation Relationships
May 2, 2013: Run 23



1650, 830, 650 nm RGB

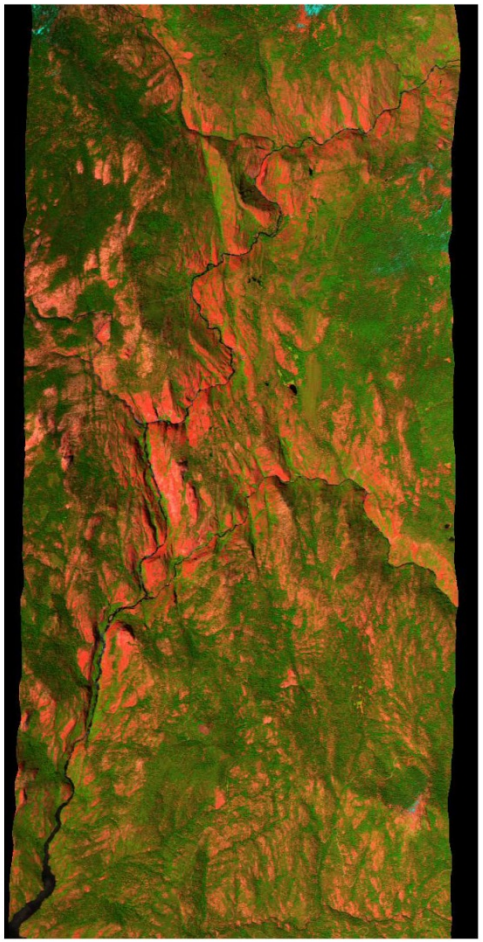
Water Vapor (0.12 to 1.185 cm)



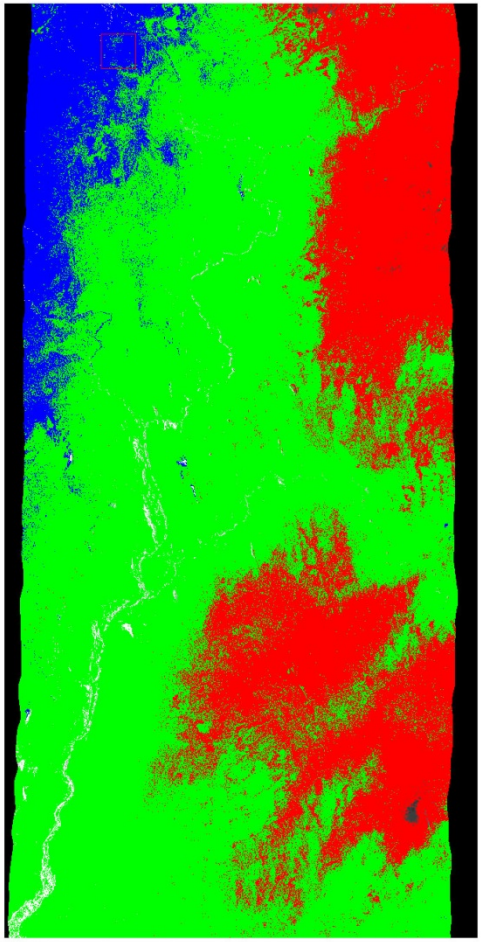
Elevation (1200 to 3120 m)

Central Sierra Nevada

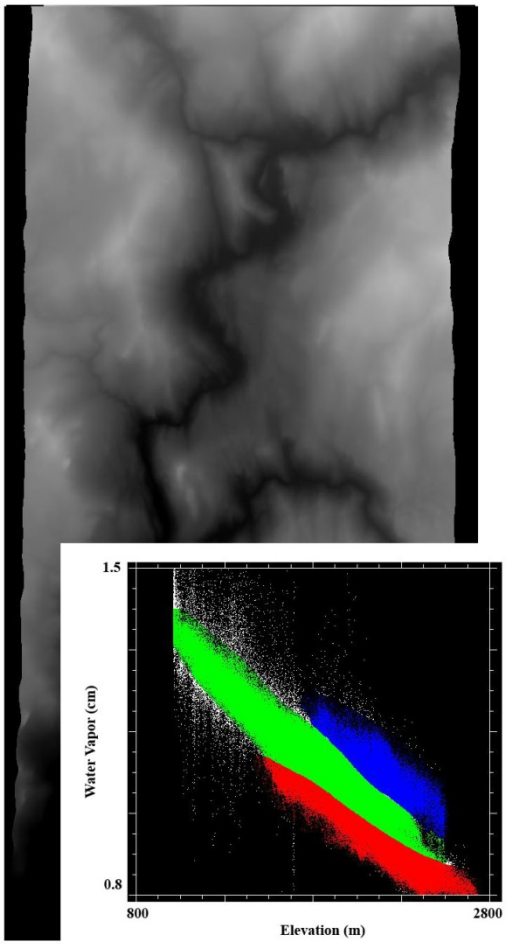
Water Elevation Relationships
May 2, 2013: Run 23



1650, 830, 650 nm RGB



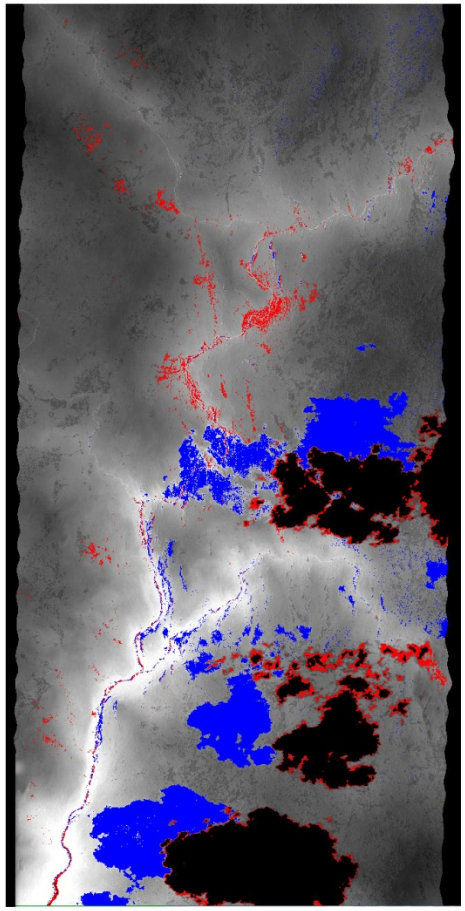
Water Vapor (classified)



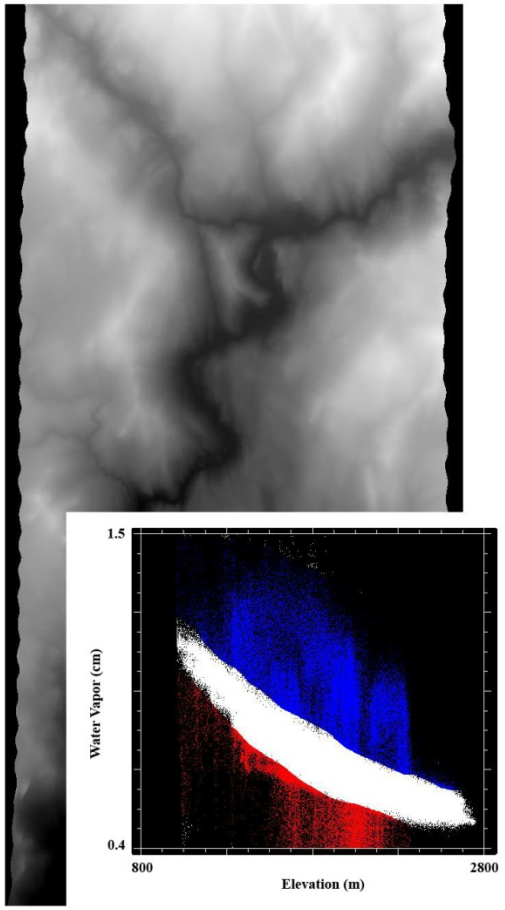
Central Sierra Nevada

Water Elevation Relationships
June 6, 2013: Run 5

1650, 830, 650 nm RGB



Water Vapor (0.4 to 1.04 cm)

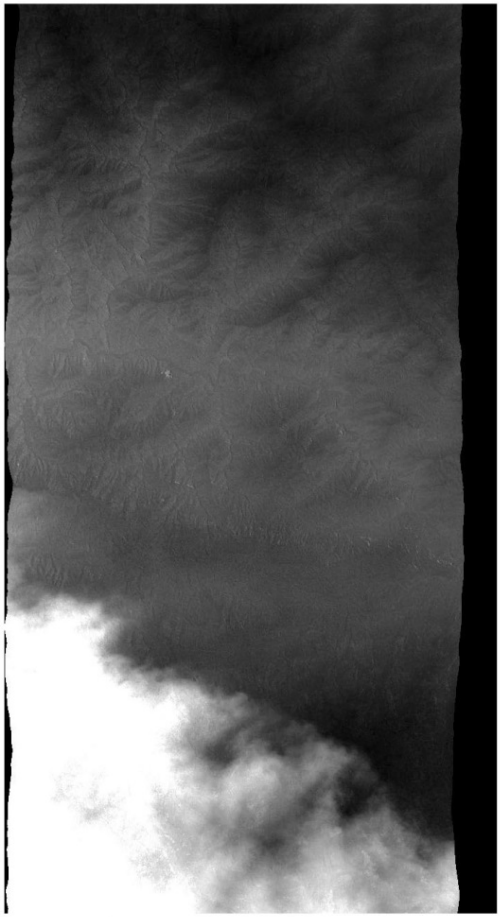


Elevation (1200 to 2800 m)

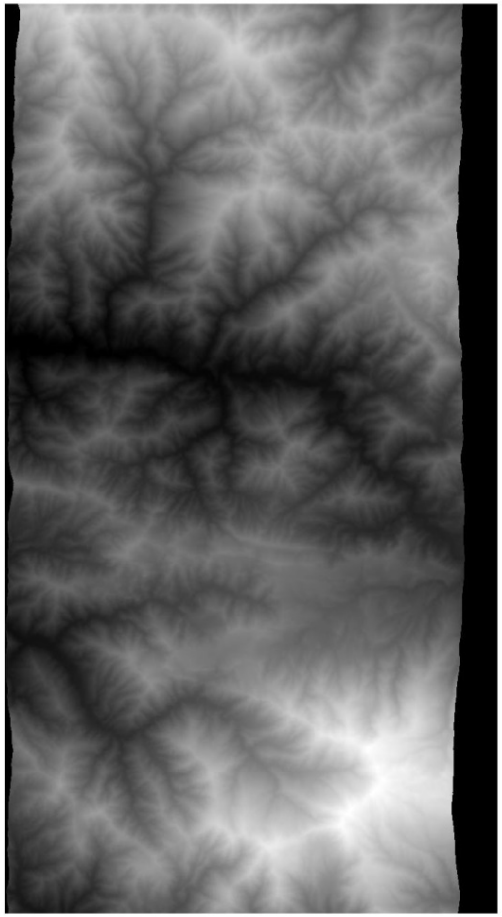
Central Sierra Nevada

Water Elevation Relationships
May 2, 2013: Run 24

1650, 830, 650 nm RGB



Water Vapor (0.2 to 0.87 cm)

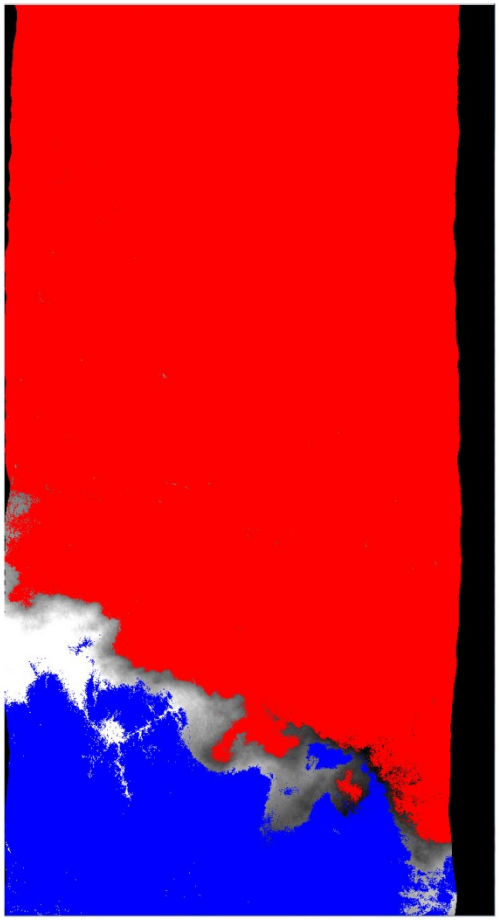


Elevation (500 to 2000 m)

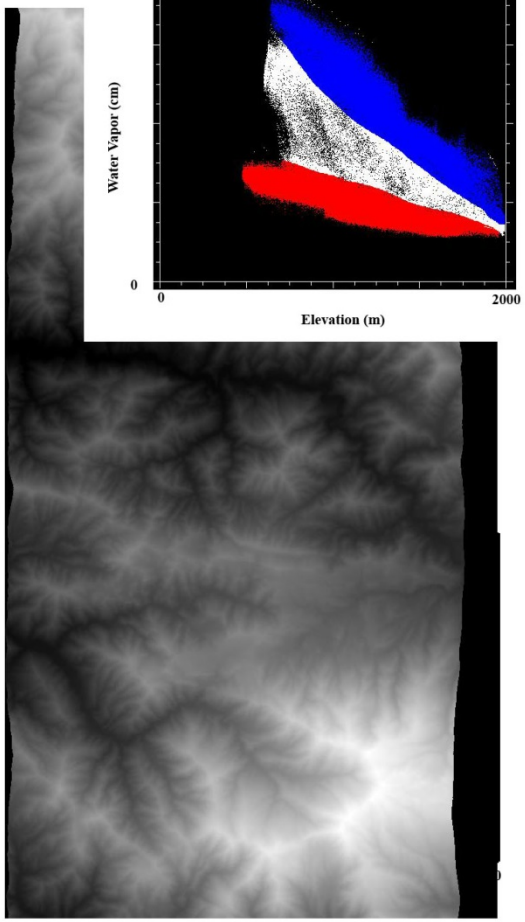
Santa Ynez Valley

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 understimates 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?**