Jet Propulsion Laboratory
California Institute of Technology

HyspIRI-like VSWIR L2 processing: Investigations, Advances, Products

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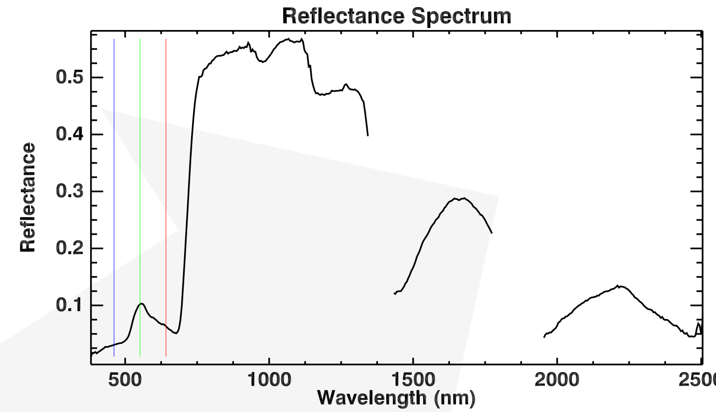
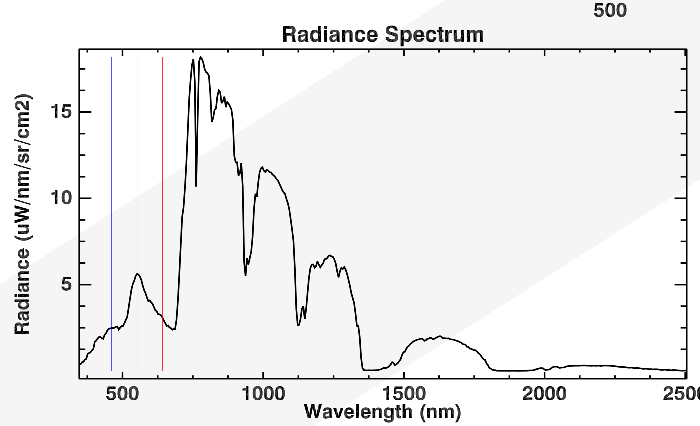
Agenda

- Overview of the HyspIRI data products
- L2 error decomposition
- Recent investigations
  - Radiometric corrections
  - Iterative H_2O path estimation
  - Aerosol estimation

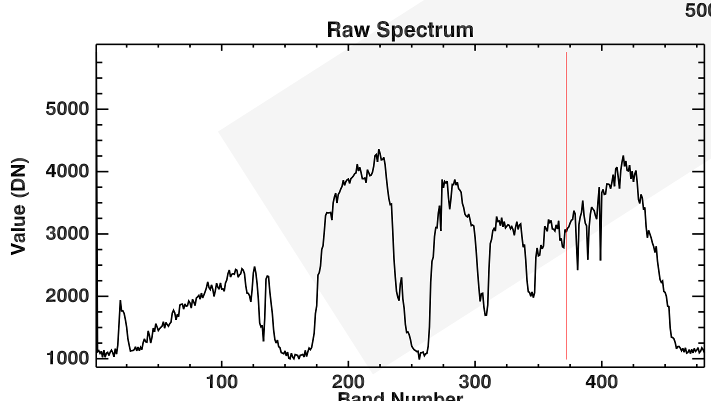
HyspIRI L2 processing objectives



Accurate reflectance measurements



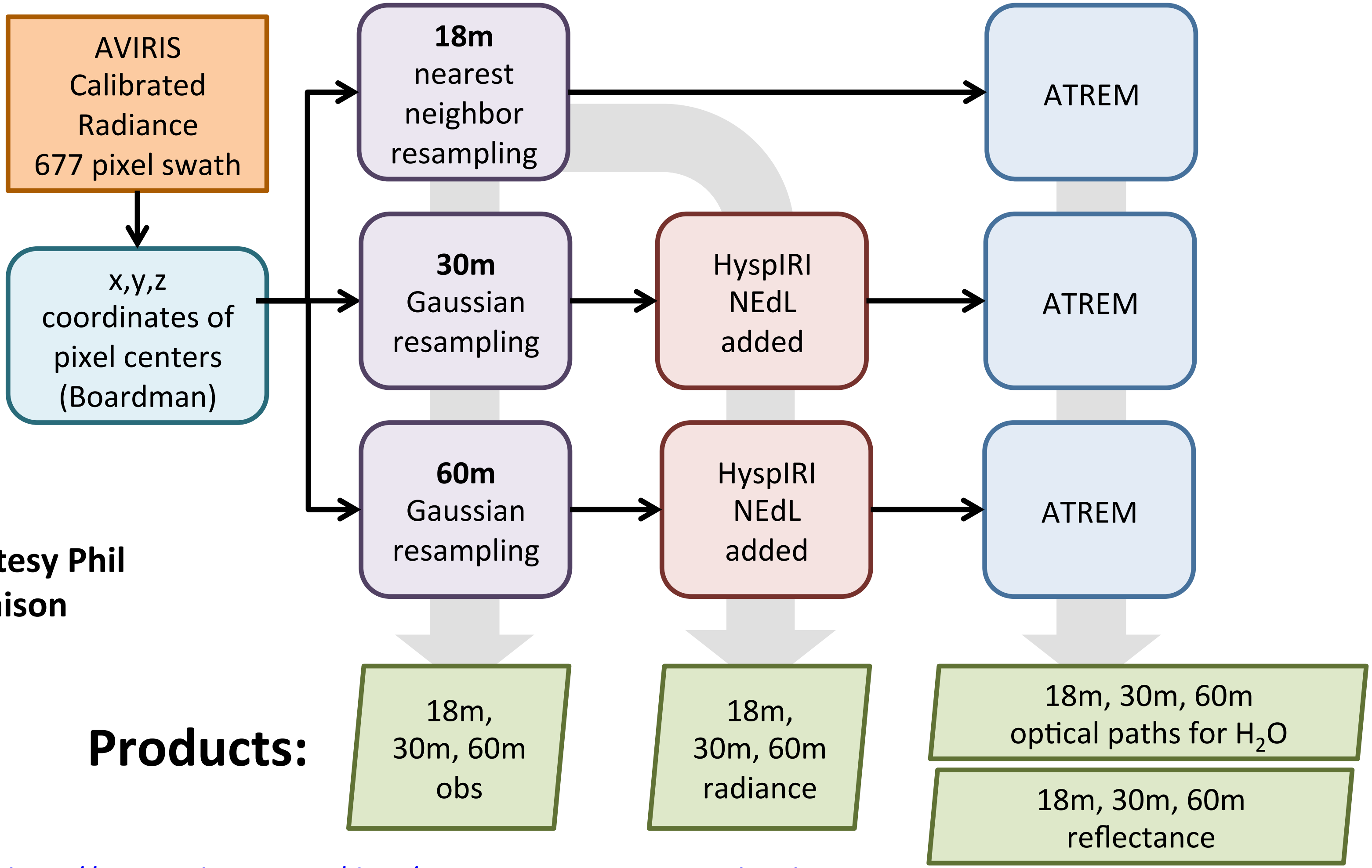
Without in-scene references



At any elevation

Under clear or hazy skies

HyspIRI simulated data products

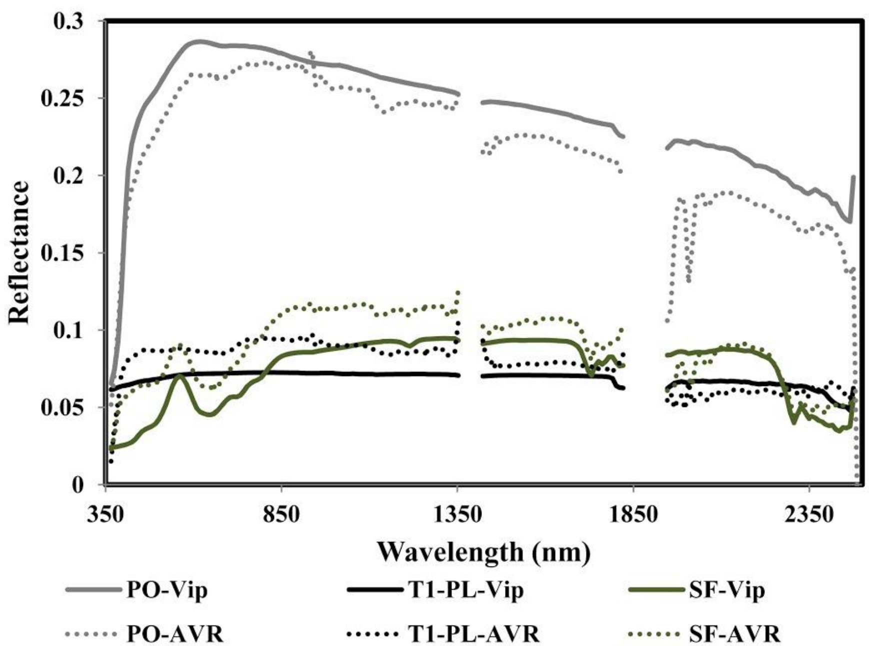


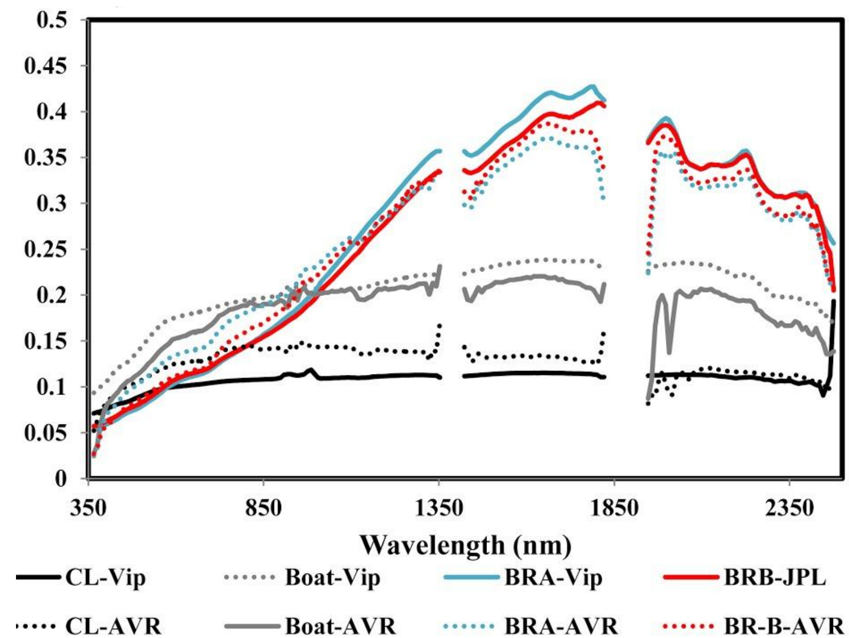
Courtesy Phil Dennison

http://aviris.jpl.nasa.gov/data/AV_HyspIRI_Prep_Data.html

Ground truth validation targets

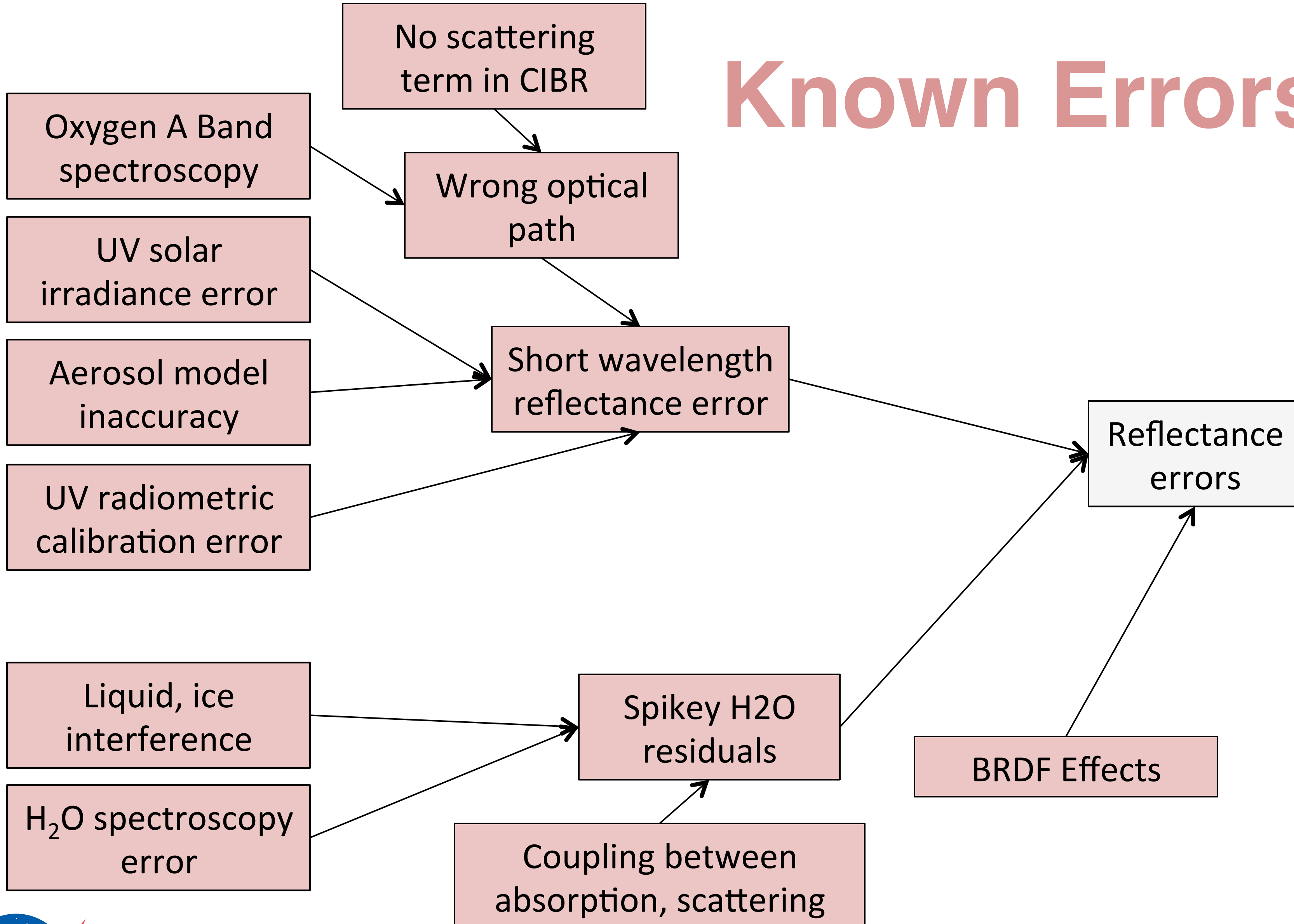
- **Dark targets too bright, bright targets too dark**
- **This suggests uncorrected scattering is a major offender**
- **Accuracy degrades somewhat at short wavelengths**
- **Water vapor maps (not shown) still show some "vegetation bias"**

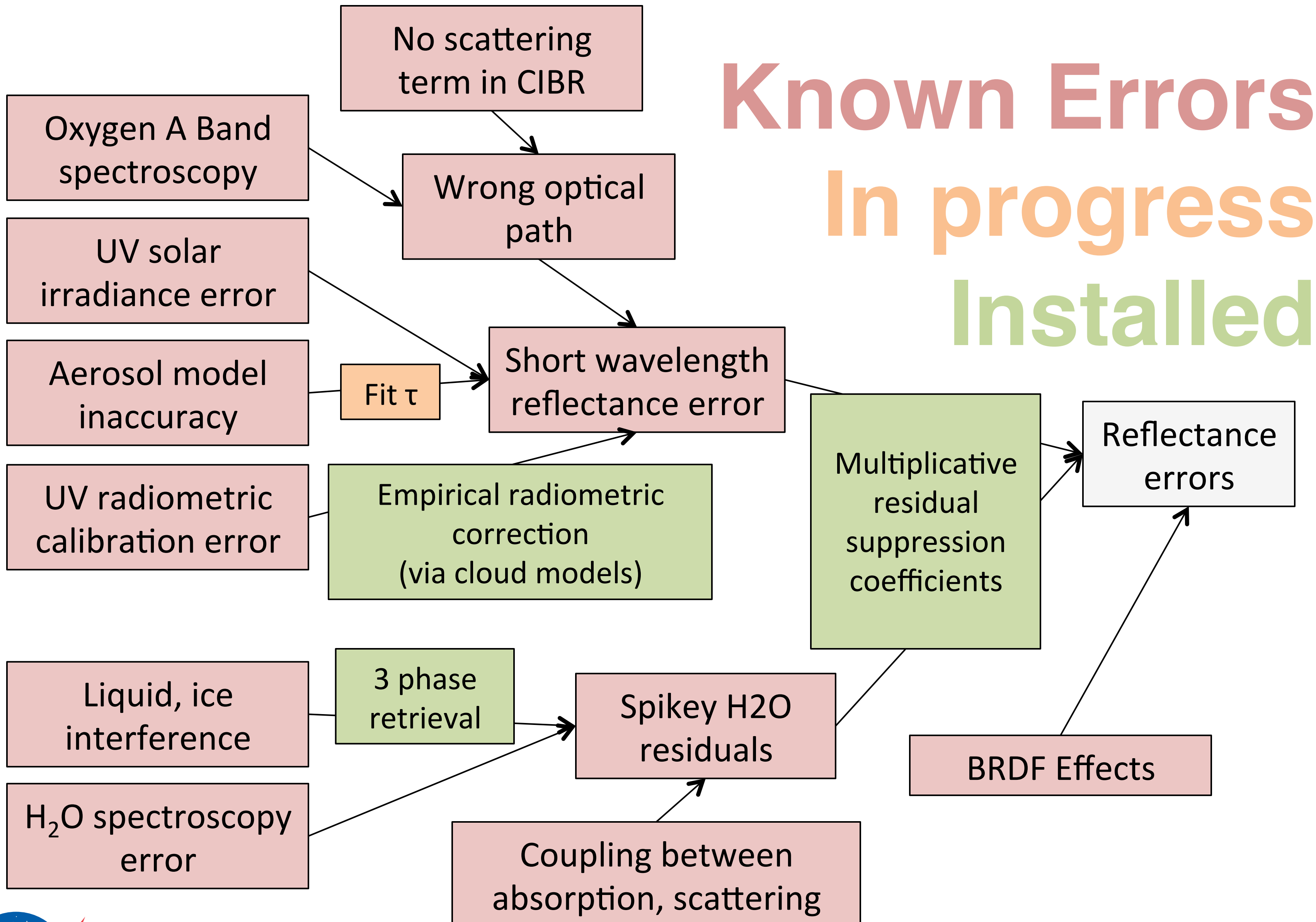




Courtesy Dar Roberts

Known Errors




Known Errors
In progress
Installed
No scattering term in CIBR
Oxygen A Band spectroscopy
Wrong optical path
UV solar irradiance error
Aerosol model inaccuracy
Fit τ
Short wavelength reflectance error
UV radiometric calibration error
Empirical radiometric correction (via cloud models)
Multiplicative residual suppression coefficients
Reflectance errors
Liquid, ice interference
3 phase retrieval
Spikey H2O residuals
BRDF Effects
H_2O spectroscopy error
Coupling between absorption, scattering

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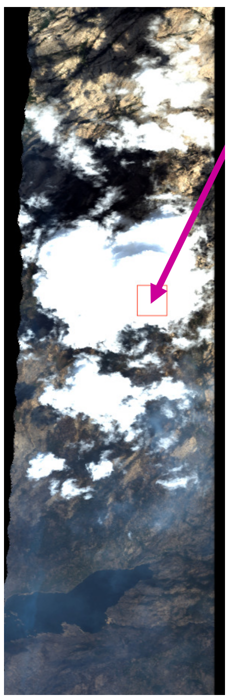
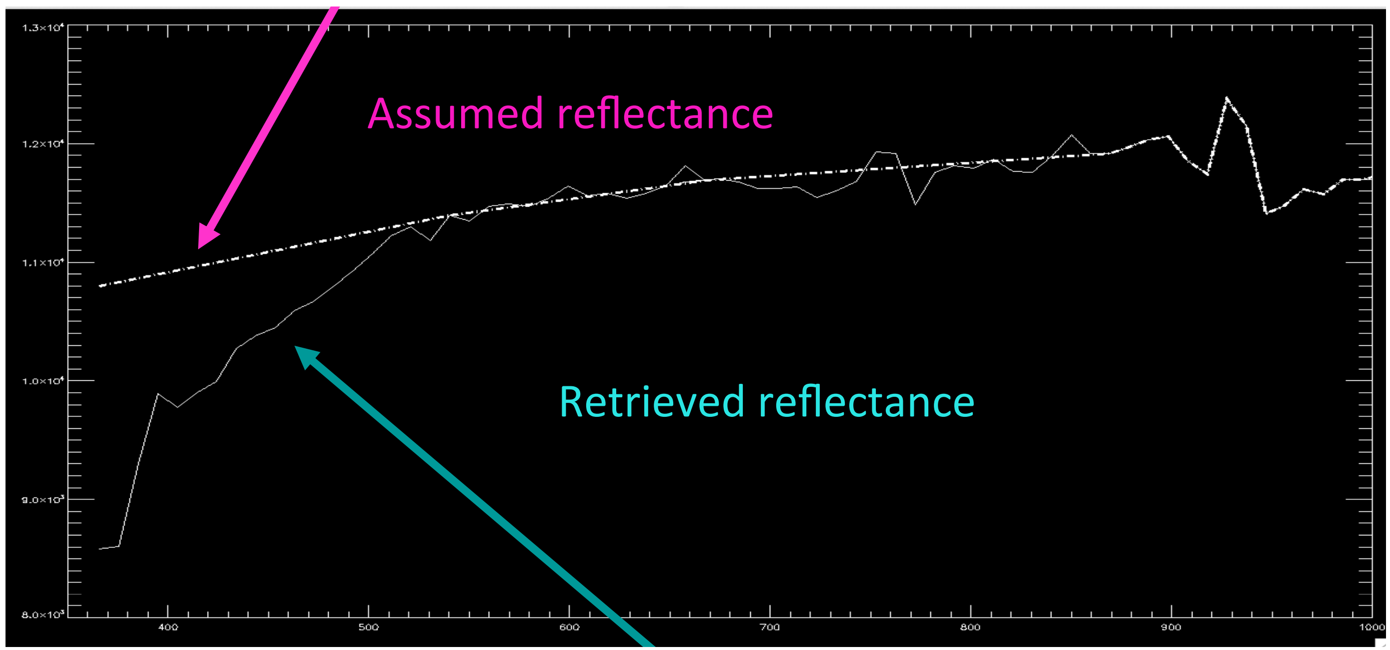
1. Radiometric corrections

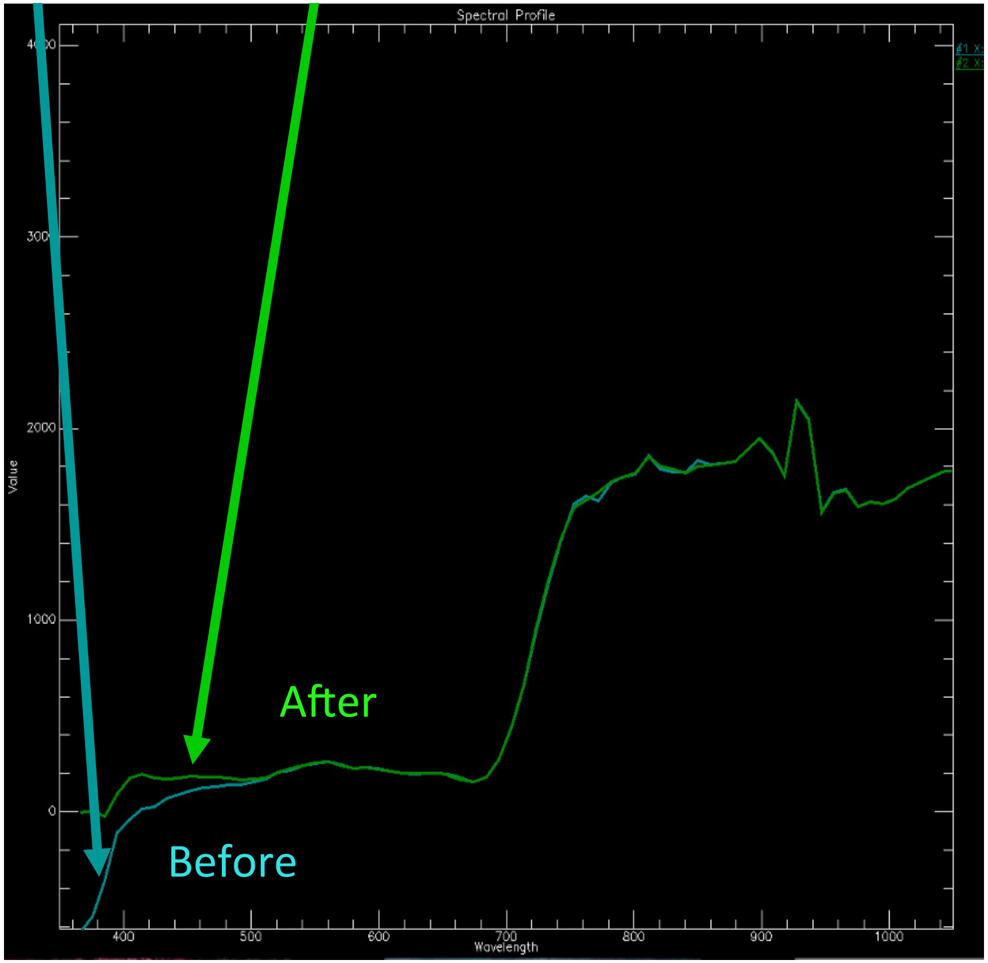
- Clouds are assumed smooth in the UV.
- This leads to a radiometric gain estimate





Courtesy Bo Cai Gao

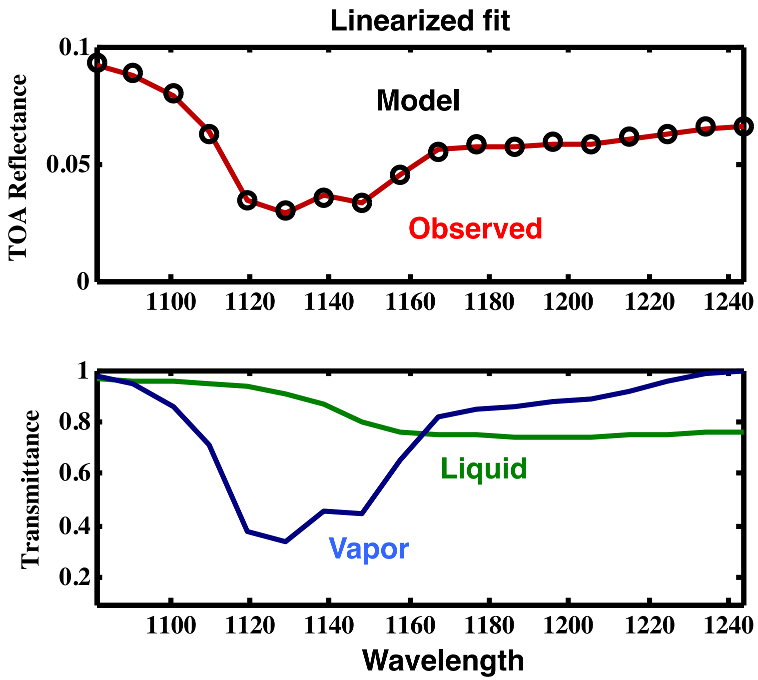
Typical vegetation spectra



Courtesy Bo Cai Gao

2. Reducing bias in H_2O vapor maps

Courtesy Elyse Pennington (poster at this workshop)



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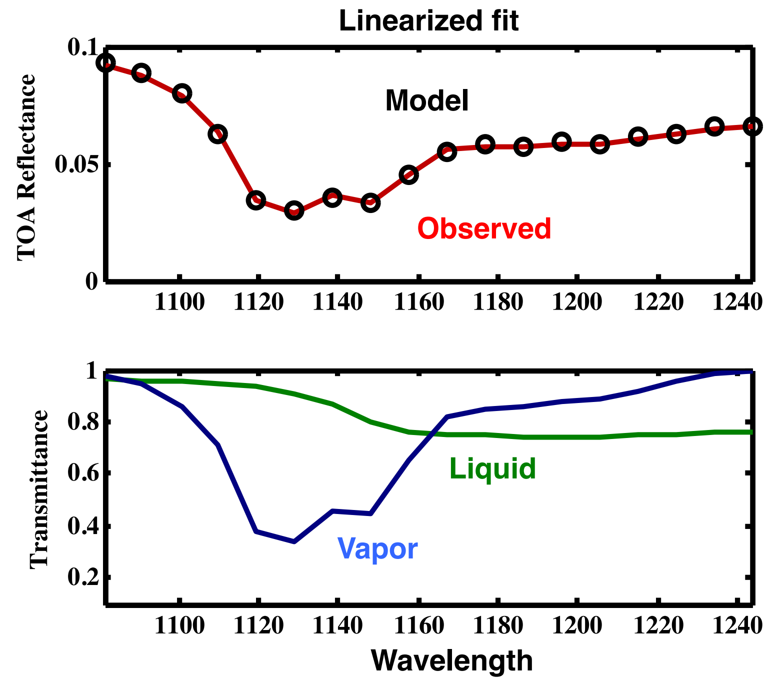
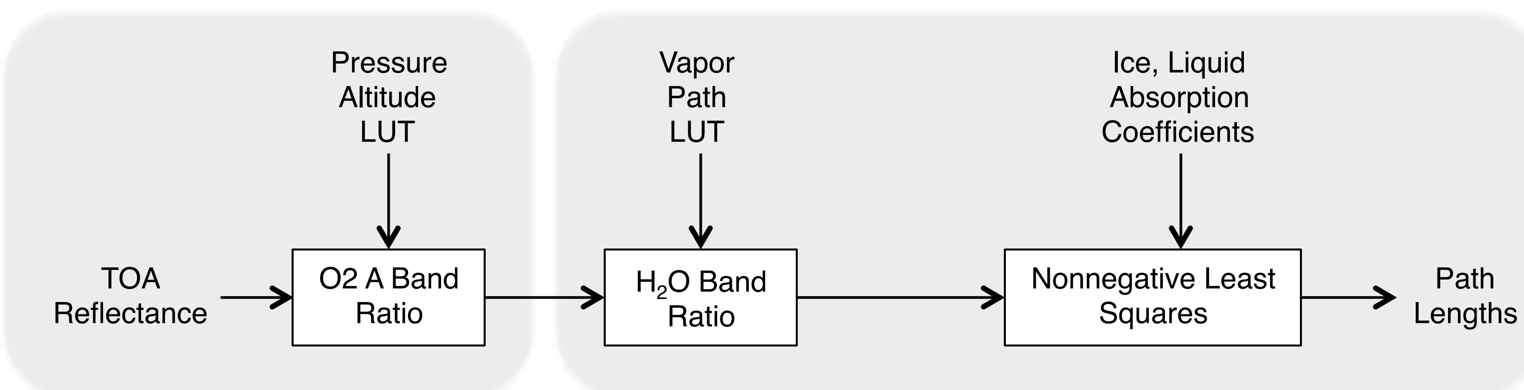


Pressure Altitude Retrieval **H2O Retrieval**



Pressure Altitude Retrieval **H2O Retrieval**

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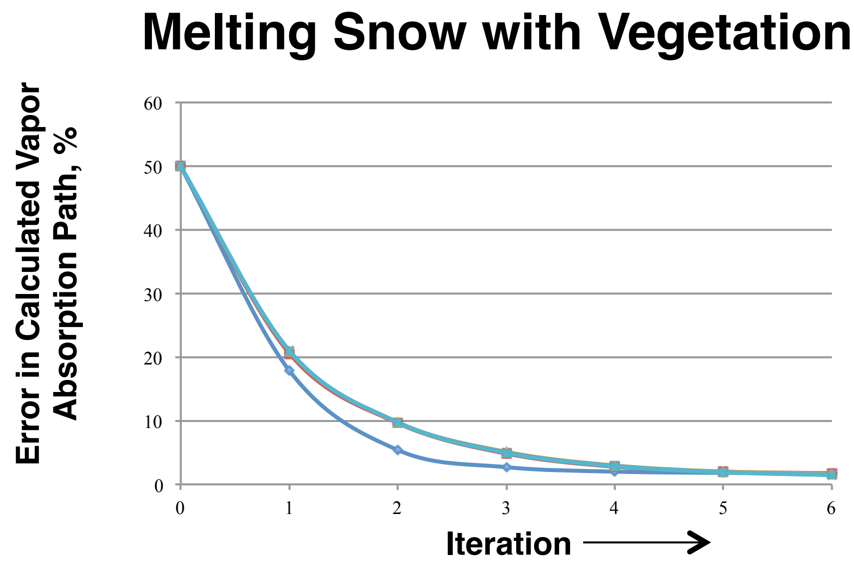
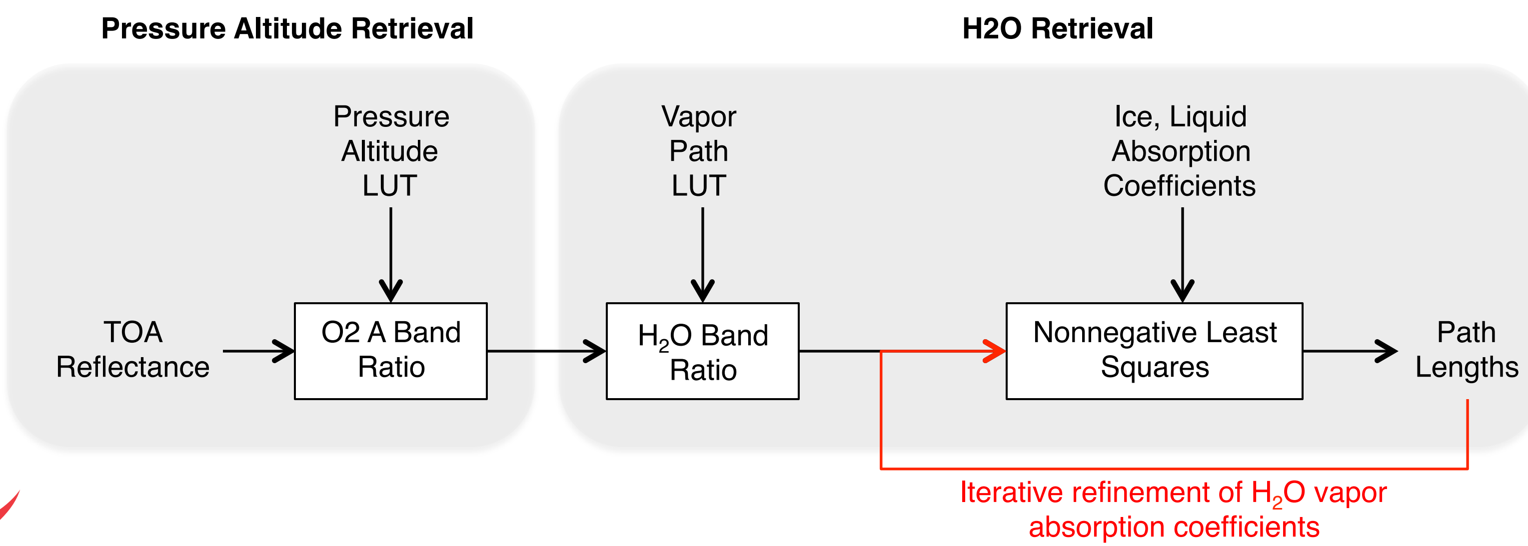
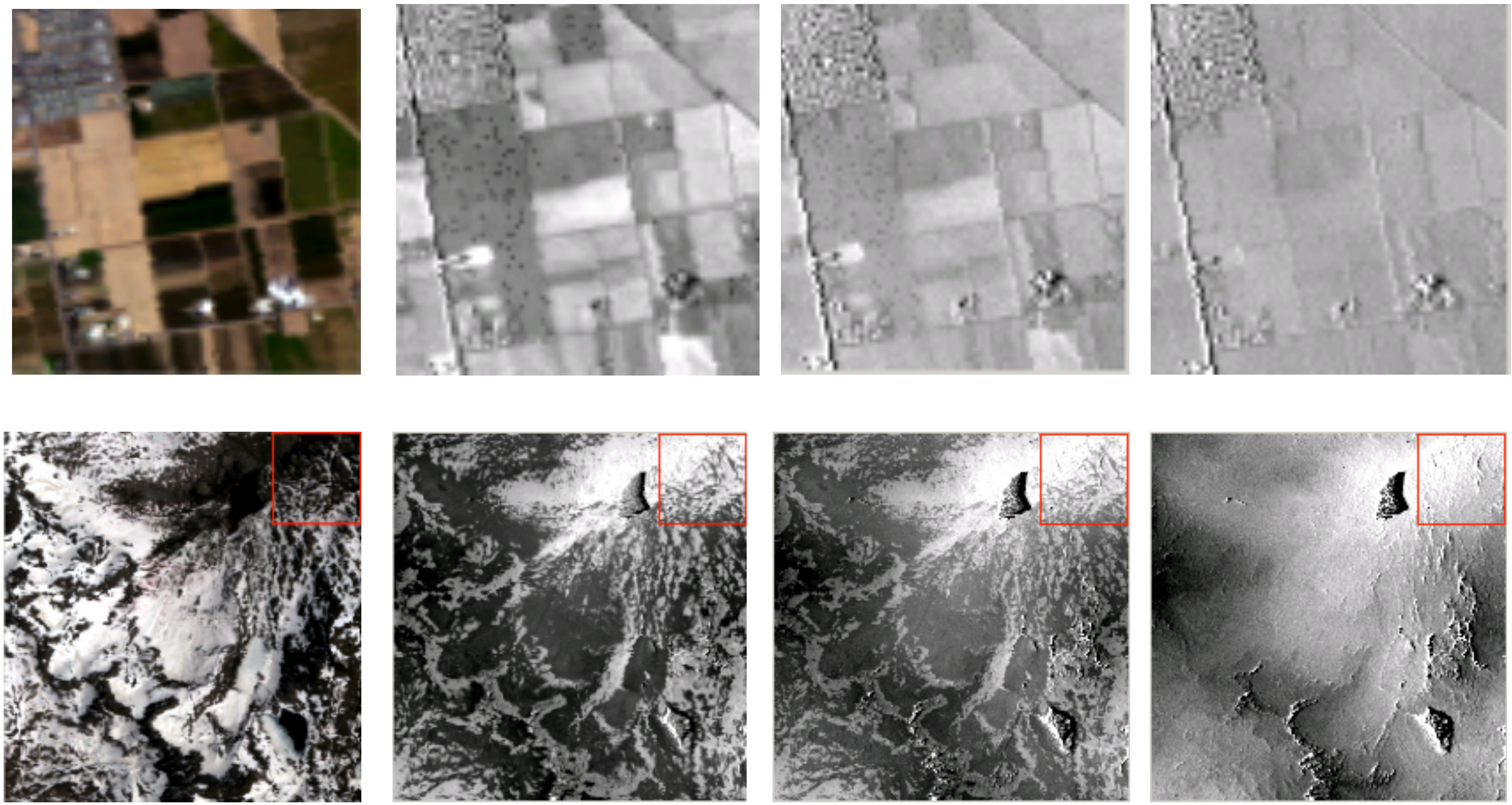




Better H_2O Vapor Maps

RGB | **Initial guess** | **One fitting iteration** | **Converged**



3. Bayesian estimation of aerosol parameters

$$P(R,\theta|L) = P(R)\;P(\theta)\;\underbrace{P(L|\theta,R)}_{\text{L2 algorithm}}\;Z$$

Reflectance

Aerosols

Radiance

3. Bayesian estimation of aerosol parameters

$$P(\underset{\text{Reflectance}}{R},\underset{\text{Aerosols}}{\theta}\,|\,\underset{\text{Radiance}}{L}) = \underbrace{P(R)}_{\text{Prior for reflectance, via historical data}}\ \underbrace{P(\theta)}_{\text{Prior for aerosols}}\ \underbrace{P(L|\theta,R)}_{\text{L2 algorithm}}\ \underbrace{Z}_{\text{Normalizing constant}}$$

3. Bayesian estimation of aerosol parameters

$$P(R,\theta|L) = \underbrace{P(R)}_{\text{Prior for reflectance, via historical data}}\ \underbrace{P(\theta)}_{\text{Prior for aerosols}}\ \underbrace{P(L|\theta,R)}_{\text{L2 algorithm}}\ \underbrace{Z}_{\text{Normalizing constant}}$$

Reflectance

Aerosols

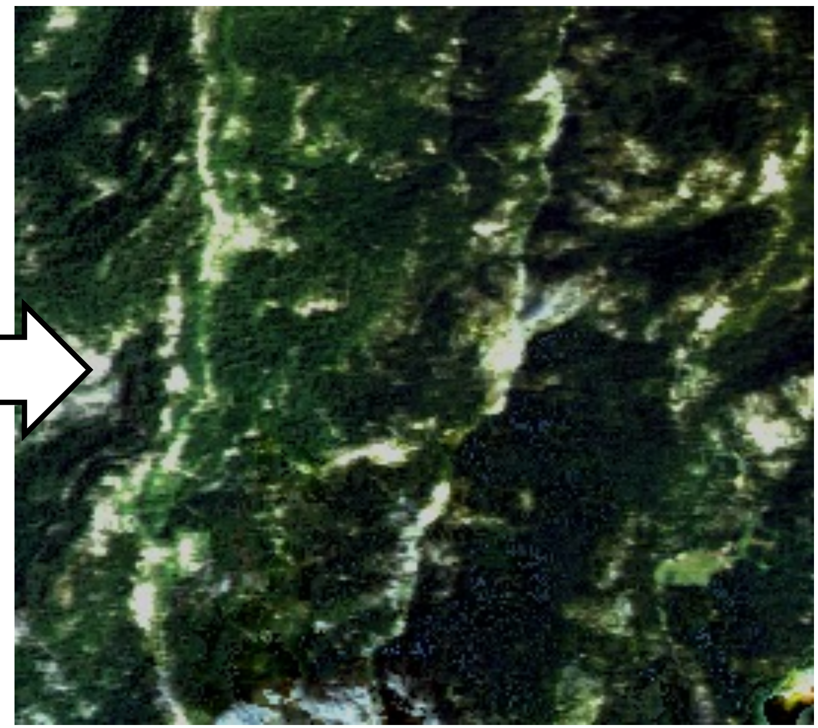
Radiance

1. **In advance, model the distribution of valid surface reflectances (Gaussian Mixture Model)**
2. **At runtime, generate reflectance *hypotheses* based on many aerosol parameters**
3. **Calculate the probability of each hypothesis**

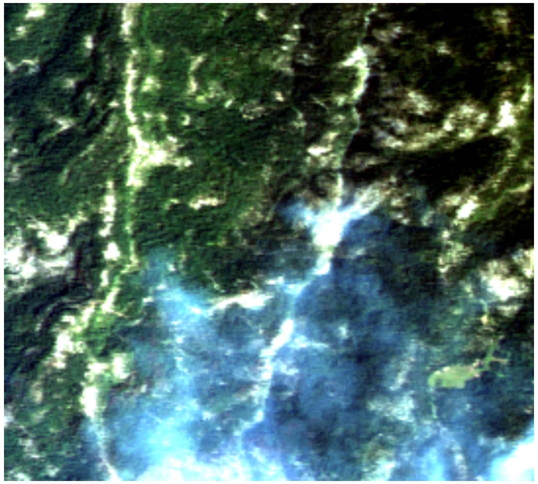
3. Bayesian estimation of aerosol parameters

Original image, Yosemite rim fire f130913

Corrected

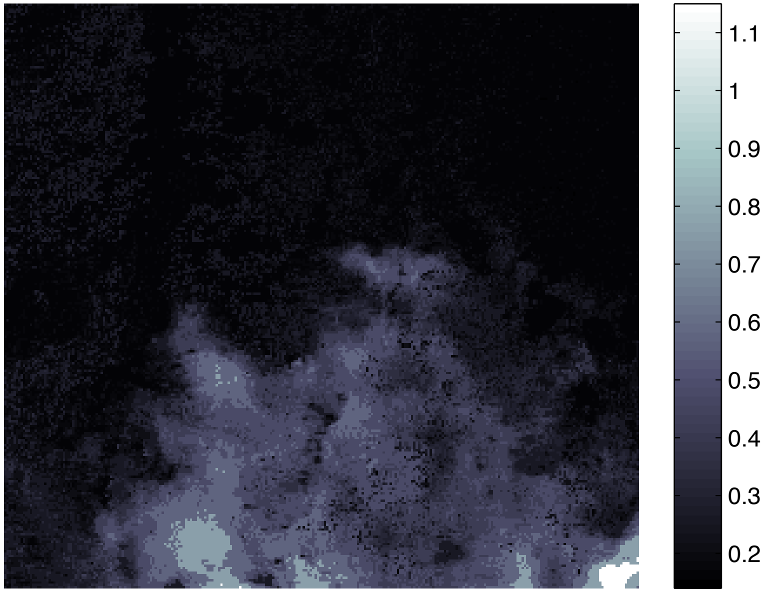


Retrieved Aerosol Optical Depth

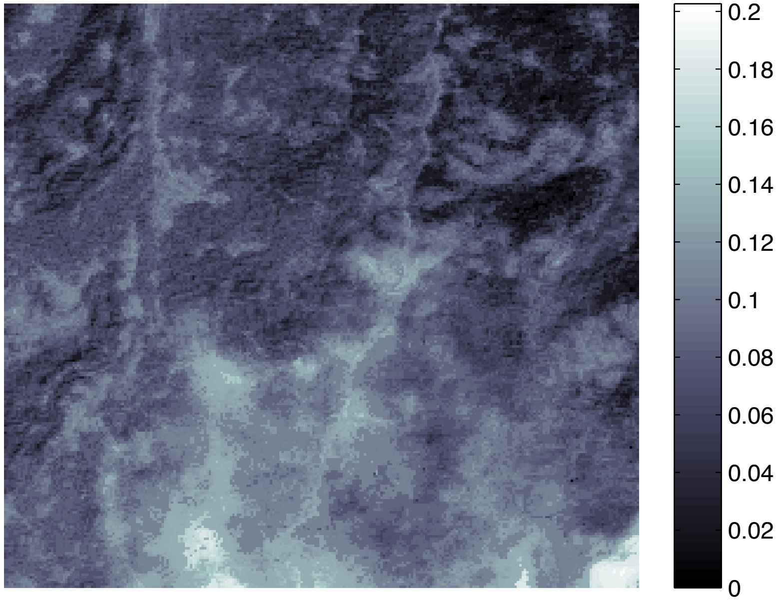


The retrieval has highest confidence over dark vegetated regions. It has lower confidence inside smoke, or over bright bare surfaces.

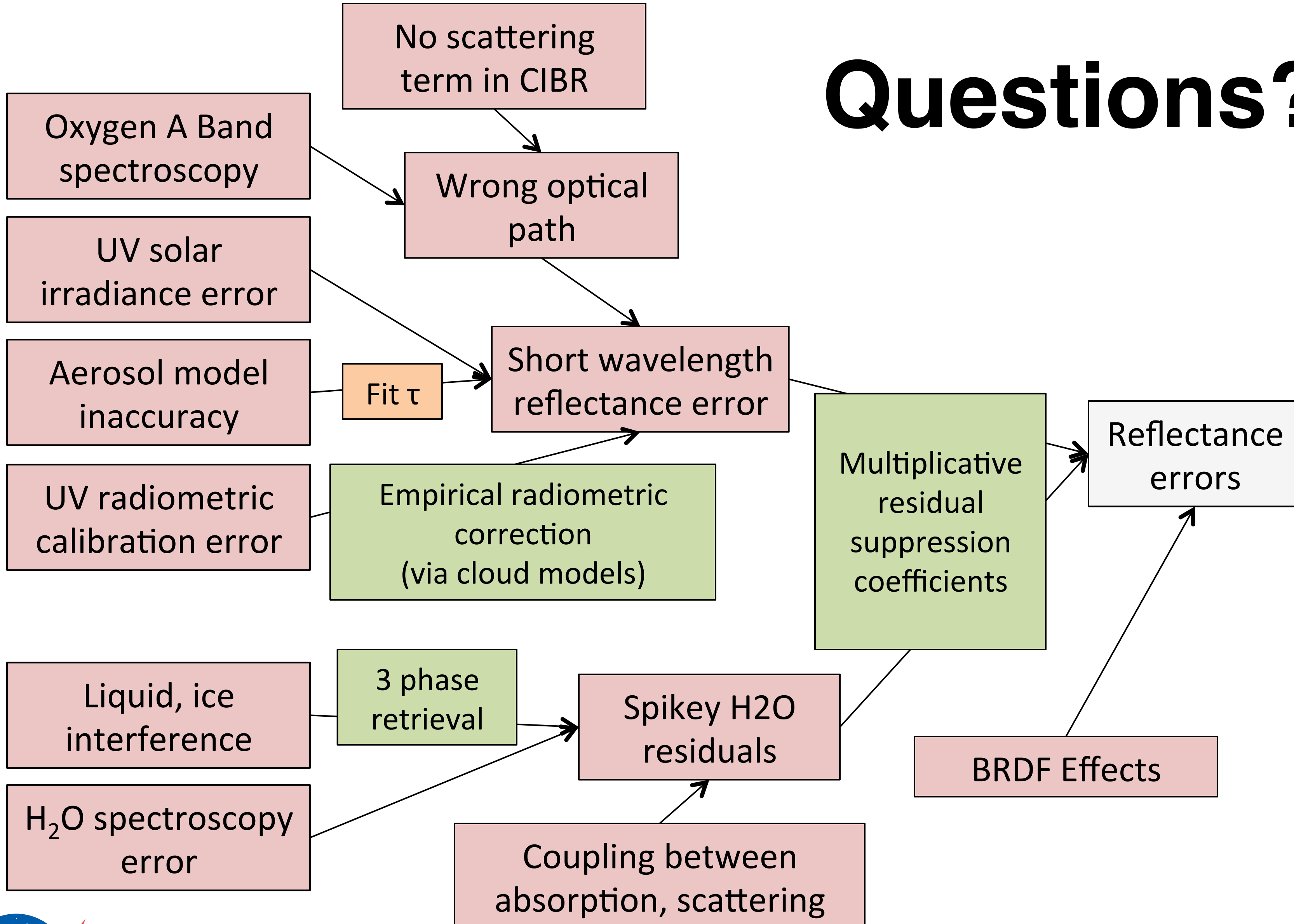
Most probable AOD



Posterior Standard Deviation



Questions?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Coupling between absorption, scattering

Thanks!

Ian McCubbin, Didier Keymeulen, Brian Bue, Sarah Lundeen, Mark Helmlinger, Scott Nolte and the AVIRIS team…

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Backup slides

L2 Surface reflectance

Solar spectrum F (modified Kurucz)

Top of atmosphere apparent reflectance ρ

$$\rho = \frac{\pi L}{F\ cos(\theta)}$$

Retrieve pressure altitude, H_2O vapor, liquid by fitting absorption features

Gaseous transmission T_g

Aerosol particle type distribution, AOD at 550nm

Calculate molecular & aerosol scattering w/6s radiative transfer code

Aerosol transmission $T_d T_u$, Spherical sky albedo s, Path reflectance r_a

Reflectance spectrum

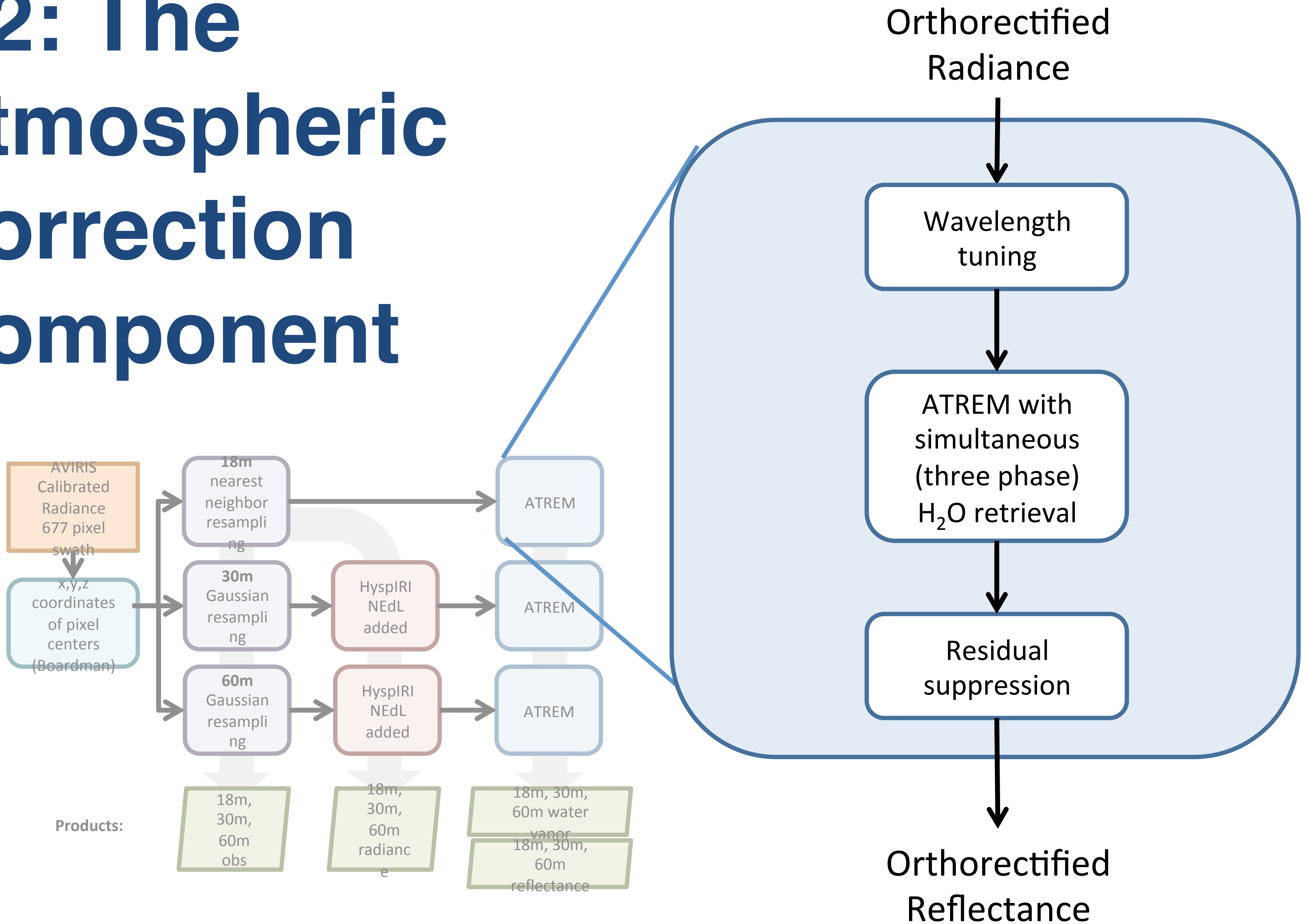
$$r_s = \frac{\rho/T_g - r_a}{T_d T_u + s(\rho/T_g - r_a)}$$

Residual suppression based on a reference target

Corrected reflectance spectrum

David.R.Thompson@jpl.nasa.gov

L2: The atmospheric correction component



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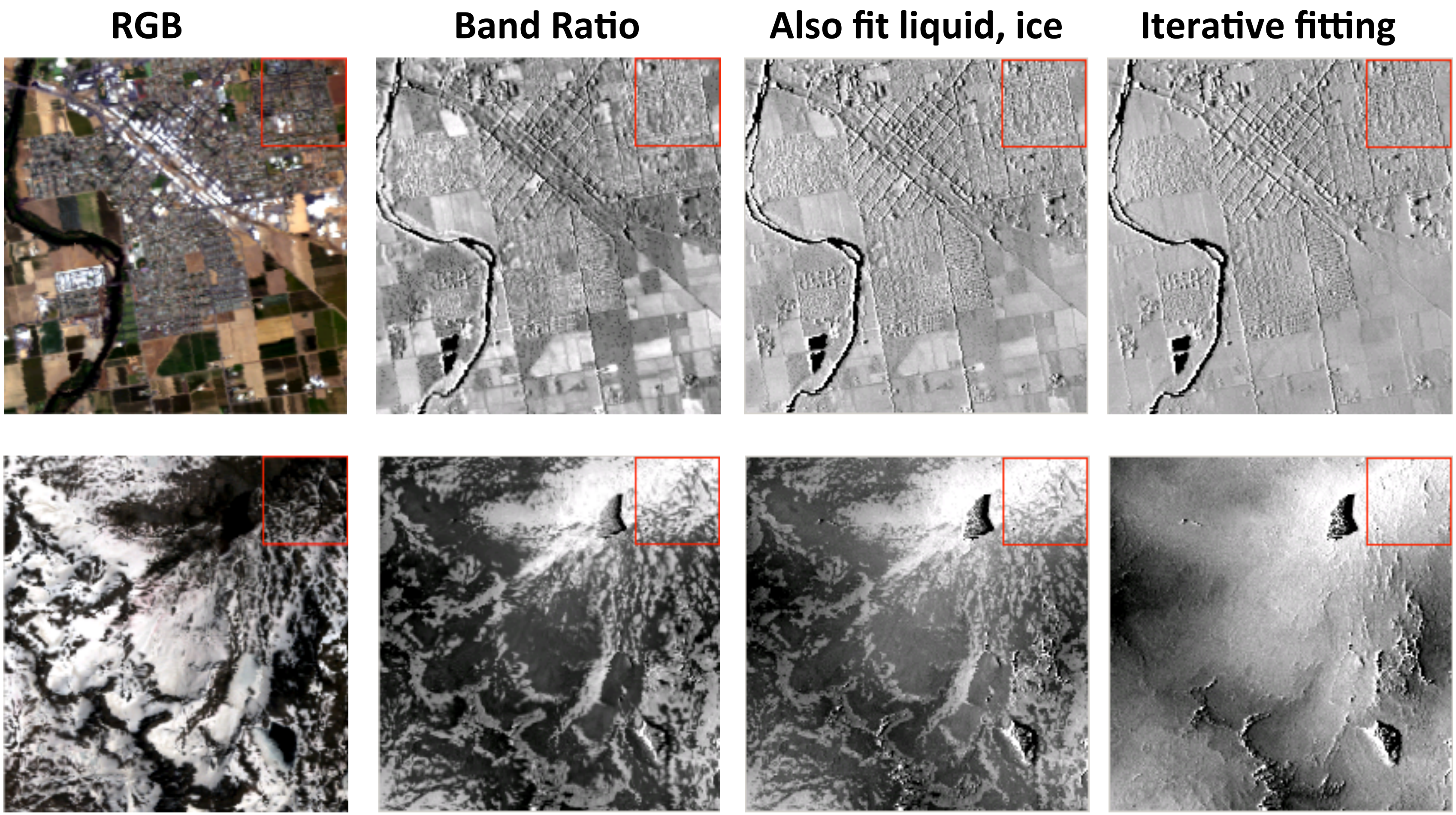
Better H_2O Vapor Maps



The ATREM Approach

Apparent reflectance | Radiance | Solar flux

$$r^{*}_{obs}\,(l,q,f,q_o,f_o) = p\,L_{obs}(l,q,f,q_o,f_o)\ \ /\ [m_o\,F_o(l)],$$

Path reflectance | Surface reflectance | Atmospheric transmittance

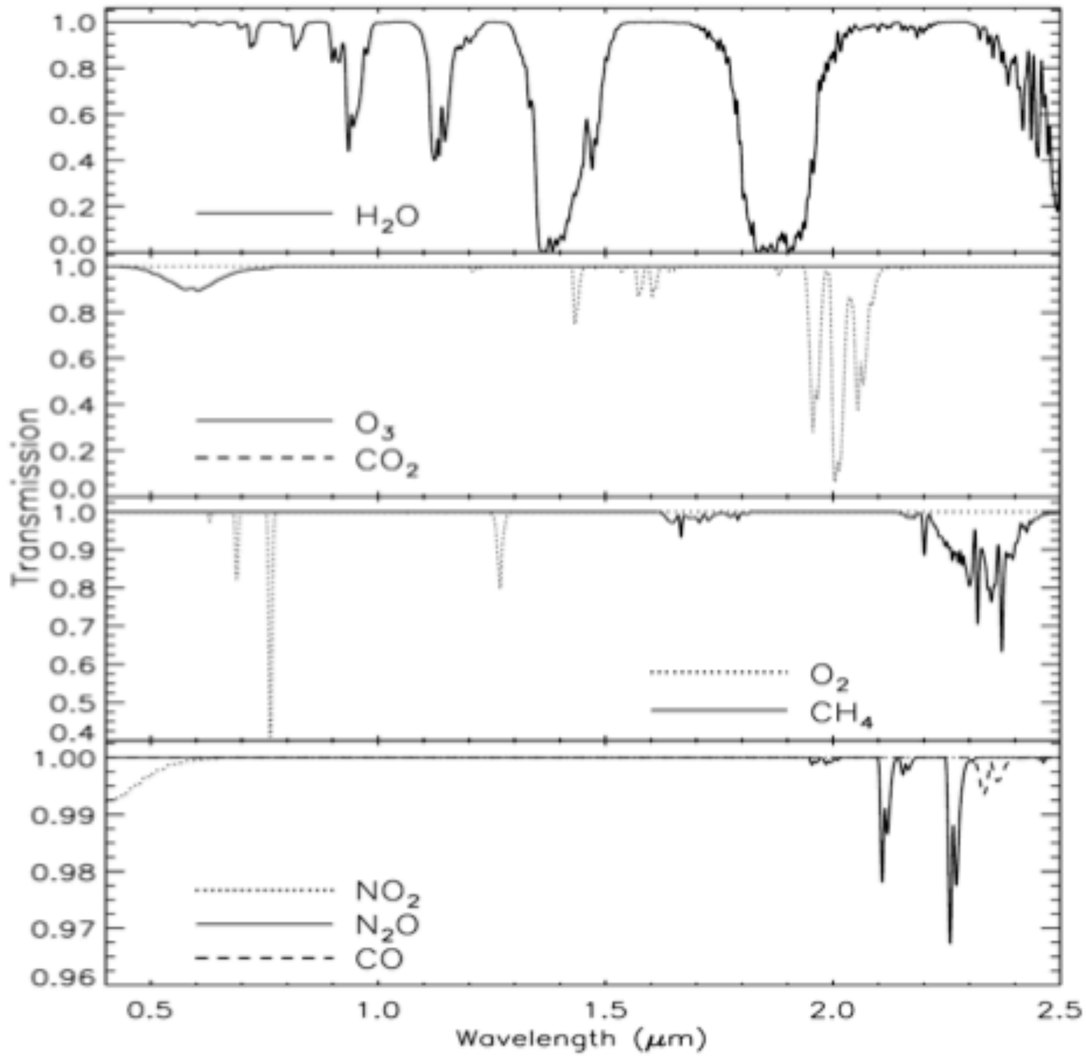
$$r^{*}_{obs}\,(l,q,f,q_o,f_o) = [r^{*}_{atm}(l,q,q_o,f_o) + t_d(l,q_o)\ t_u(l,q)\ r(l)/(1 - s(l)r(l)\ )]\ T_g(l,q,q_o),$$

Scattering terms from 6s code

$$r\ = (r^{*}_{obs}/T_g - r^{*}_{atm})\ /\ [t_d\,t_u + s\,(r^{*}_{obs}/T_g - r^{*}_{atm})\ ].$$

From [Gao and Green 2010]

Typical transmittance



Absorption is modeled for 7 gases

ATREM retrieves water vapor for each pixel using 0.94 and 1.14 μm H_2O band depths

Vertical profiles use 20-layer atmospheres

[Gao and Green 2010]

3. Bayesian estimation of aerosol parameters

1. **In advance, model the distribution of valid surface reflectances (here a Gaussian Mixture Model)**
2. **At runtime, generate reflectance hypotheses based on different aerosol parameters**
3. **Calculate the probability of each hypothesis**

$$P(R,\theta|L) = P(R)\ P(\theta)\ P(L|\theta,R)\ \ Z$$

3. Bayesian estimation of aerosol parameters

1. In advance, model the distribution of valid surface reflectances (here a Gaussian Mixture Model)
2. At runtime, generate reflectance hypotheses based on different aerosol parameters
3. Calculate the probability of each hypothesis

$$\underbrace{P(R,\theta|L)}_{\substack{\text{Joint estimation}\\ \text{of reflectance R}\\ \text{and aerosols }\theta\\ \text{given radiance L}}} = \underbrace{P(R)}_{\substack{\text{Prior for}\\ \text{reflectance,}\\ \text{modeled from}\\ \text{historical data}}} \; \underbrace{P(\theta)}_{\substack{\text{Prior for}\\ \text{aerosols}}} \; \underbrace{P(L|\theta,R)}_{\substack{\text{Nonstochastic,}\\ \text{via L2}\\ \text{algorithm}}} \; \underbrace{Z}_{\substack{\text{Normalizing}\\ \text{constant}}}$$

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