Jet Propulsion Laboratory
California Institute of Technology

Joint Estimation of Atmosphere and Surface Reflectance: Initial Results from the AVIRIS-NG India Campaign

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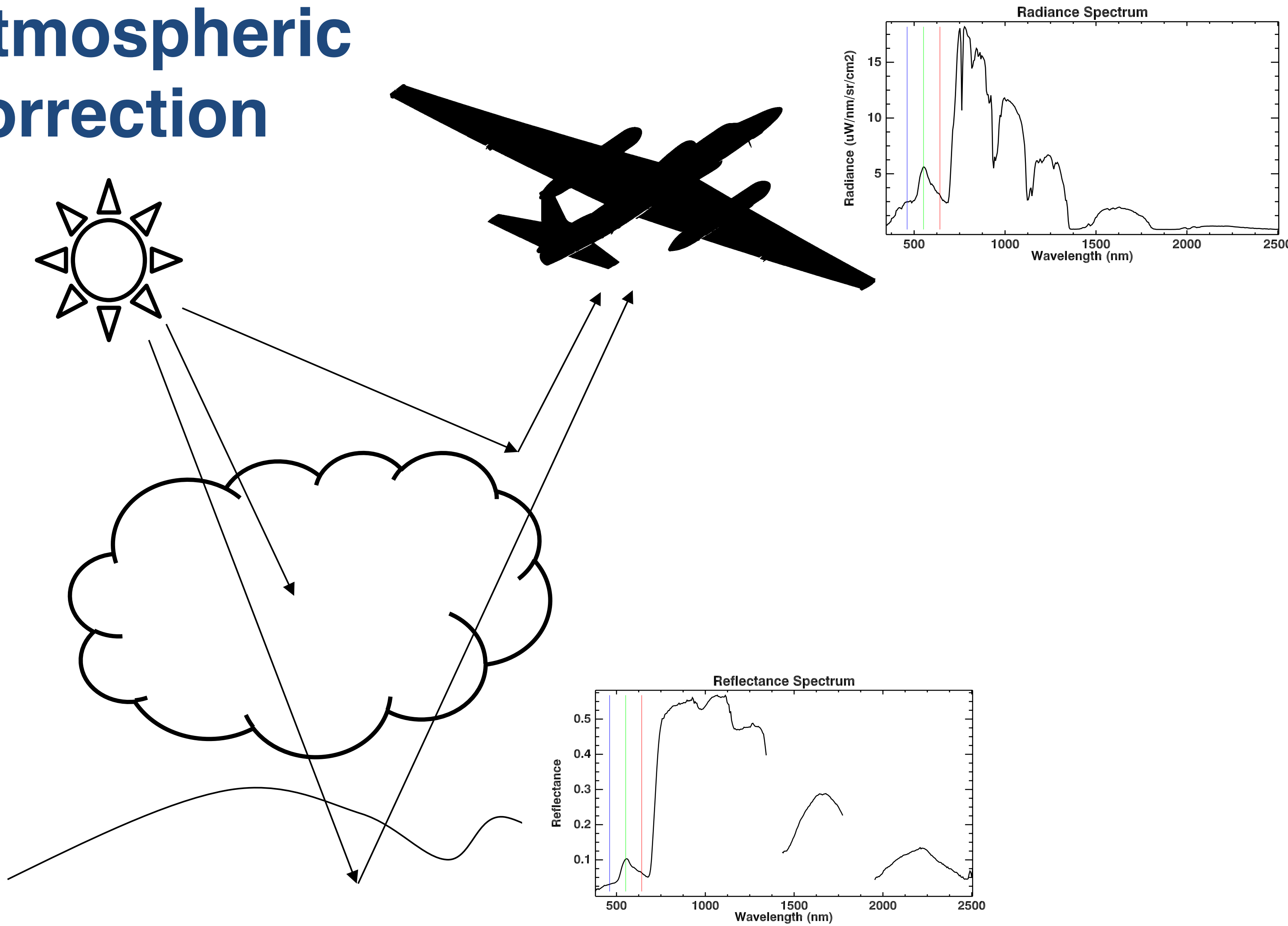
Agenda

1. Joint retrieval of surface and atmosphere
2. Examples from the AVIRIS-NG India campaign
3. Going beyond lookup tables

Atmospheric correction



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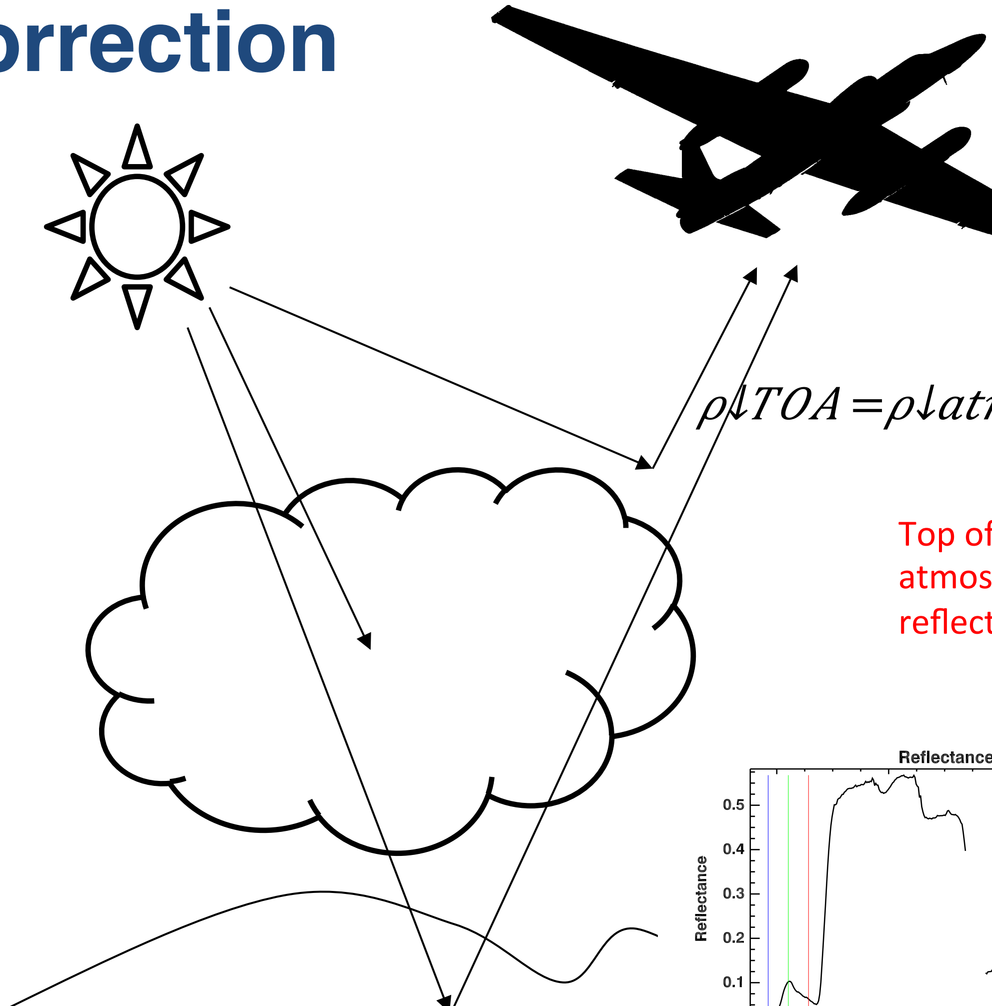
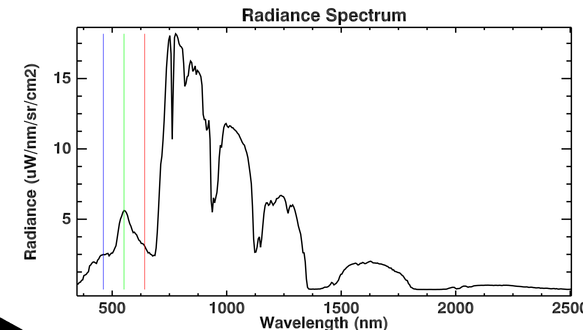




Transmission

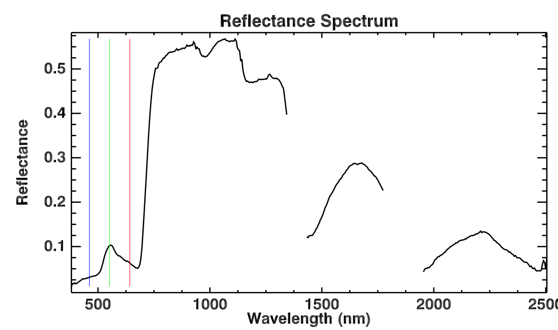
path reflectance

$$\rho_{TOA} = \rho_{atm} + T\rho_s / 1 - S\rho_s$$

Top of atmosphere reflectance

Spherical albedo

Surface reflectance

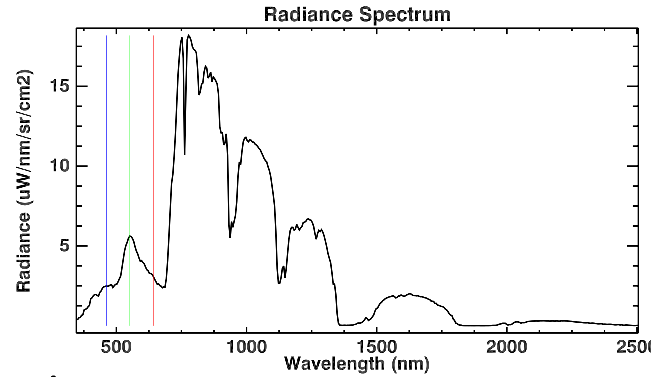


Conventional approach: sequential estimation of atmosphere and surface

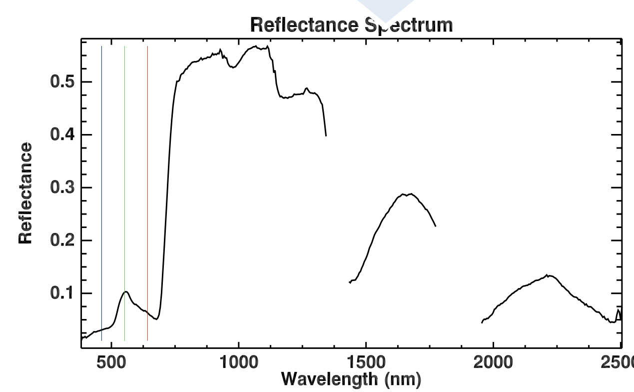
1. In advance, do RTM calculations

Lookup table for T, S, $\rho\downarrow atm$ indexed by H_2O, etc.

2. Estimate atmospheric state from radiance



3. Algebraic Inverson



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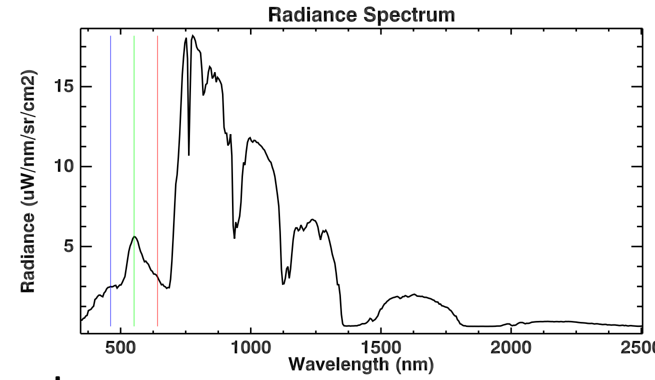

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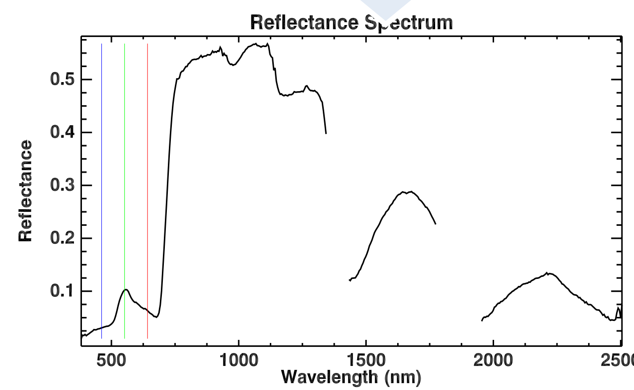

Challenging to disentangle atmosphere & surface effects

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Simultaneous estimation of atmosphere & surface

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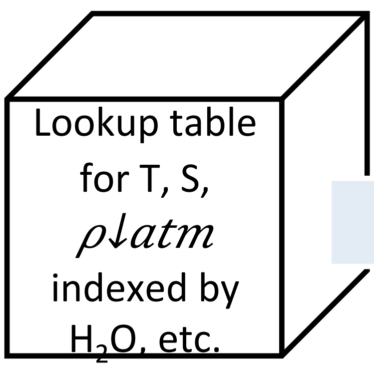
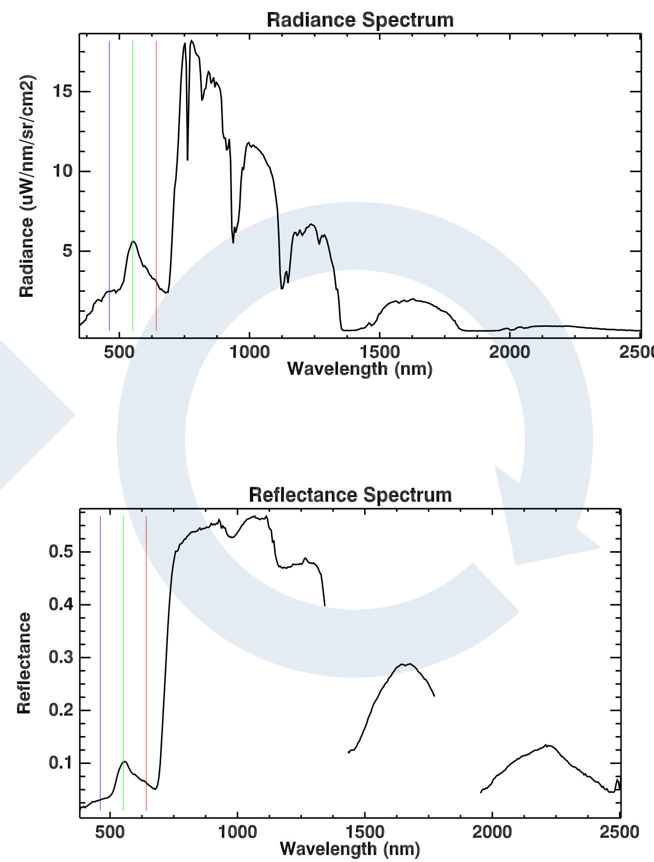


2. Iterative optimization of surface & atmosphere model



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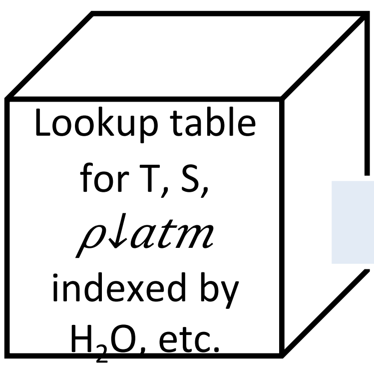

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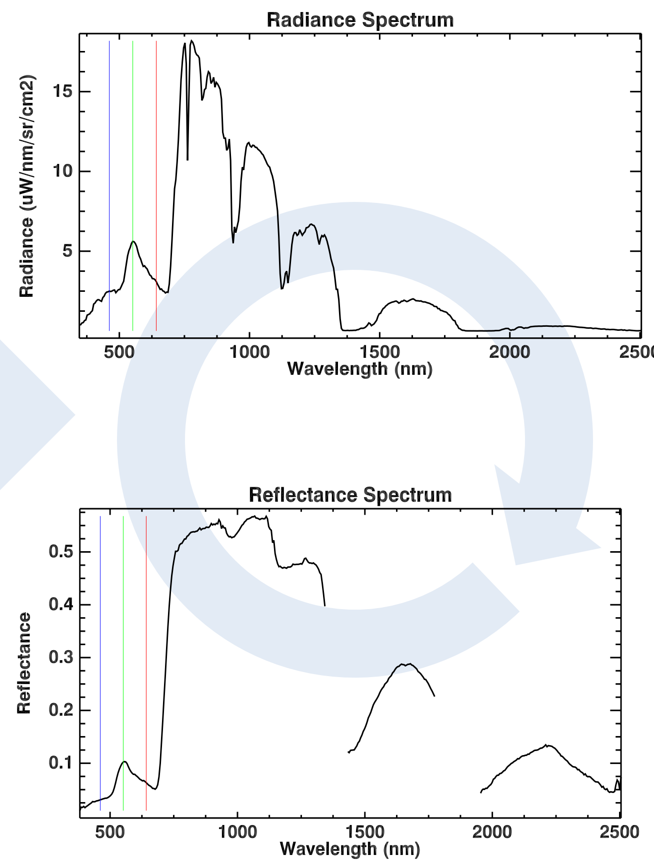

Can estimate spectrally-smooth atmospheric effects

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Enables Optimal Estimation

[Rodgers et al., 2000]

- Measurement model:

$$\mathbf{y} = \mathbf{F}(\mathbf{x}) + \epsilon$$

Radiance measurement

RTM prediction

random error

- For covariances **S,** the iterative loop minimizes the error:

$$\chi^2(\mathbf{x}) = \underbrace{(\mathbf{F}(\mathbf{x})-\mathbf{y})^T \mathbf{S}_\epsilon^{-1} (\mathbf{F}(\mathbf{x})-\mathbf{y})}_{\text{Model match to measurement}} + \underbrace{(\mathbf{x}-\mathbf{x}_a)^T \mathbf{S}_a^{-1} (\mathbf{x}-\mathbf{x}_a)}_{\text{Bayesian prior}}$$

Advantages

- **Permits atmosphere/surface coupling, relaxes Lambertian assumption**
- **Retrieve aerosol parameters** using information across the VSWIR range, improving accuracy of aerosol correction.
- **Incorporates ancillary measurements** in a principled way via the prior distribution
- **Degree of Freedom (DOF) analysis** permits a rigorous analysis of VSWIR atmospheric information content
- **Posterior uncertainty estimates** for use in downstream analyses.

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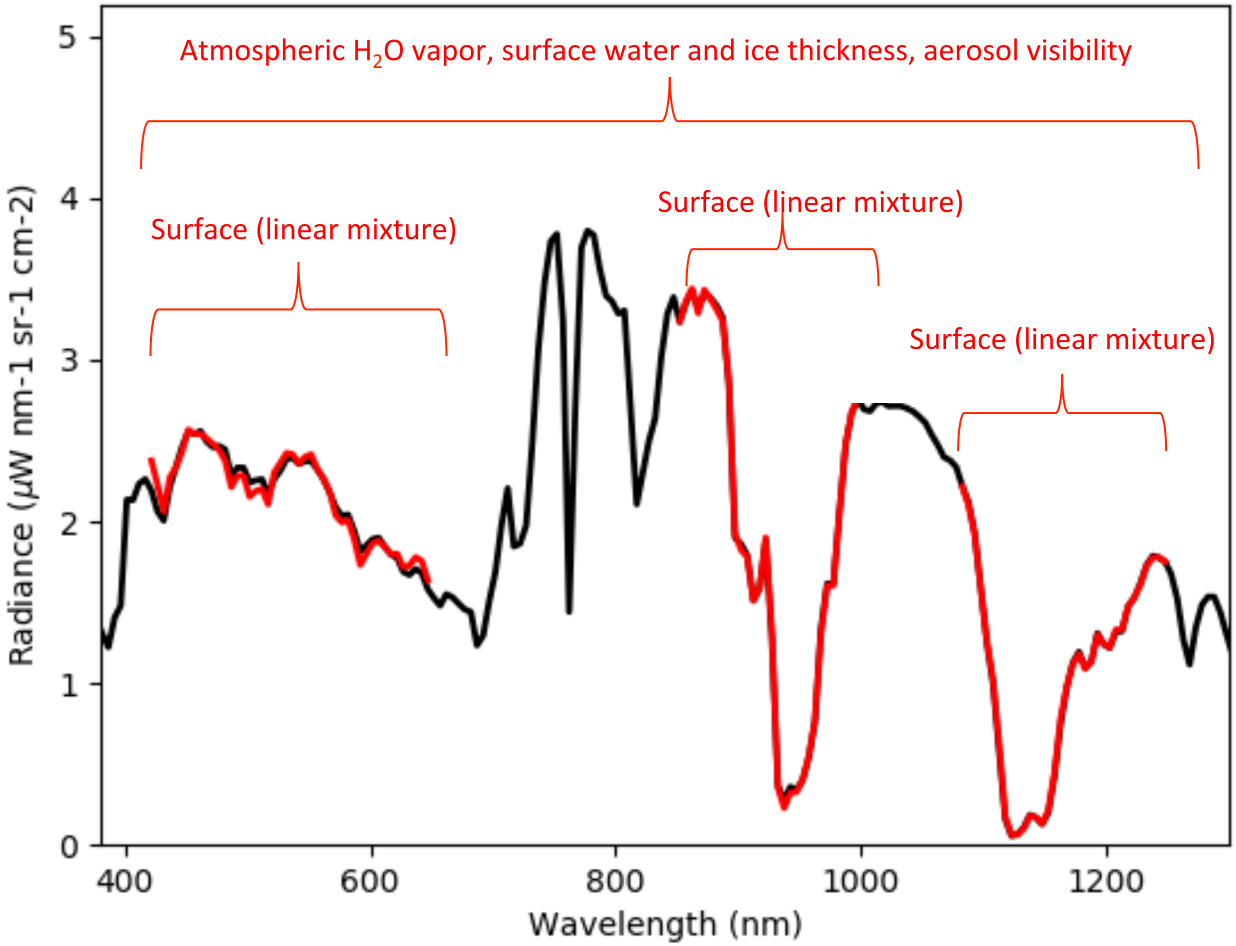
Hyderabad spectrum fit example

ang20151218t105122



Hyderabad spectrum fit example
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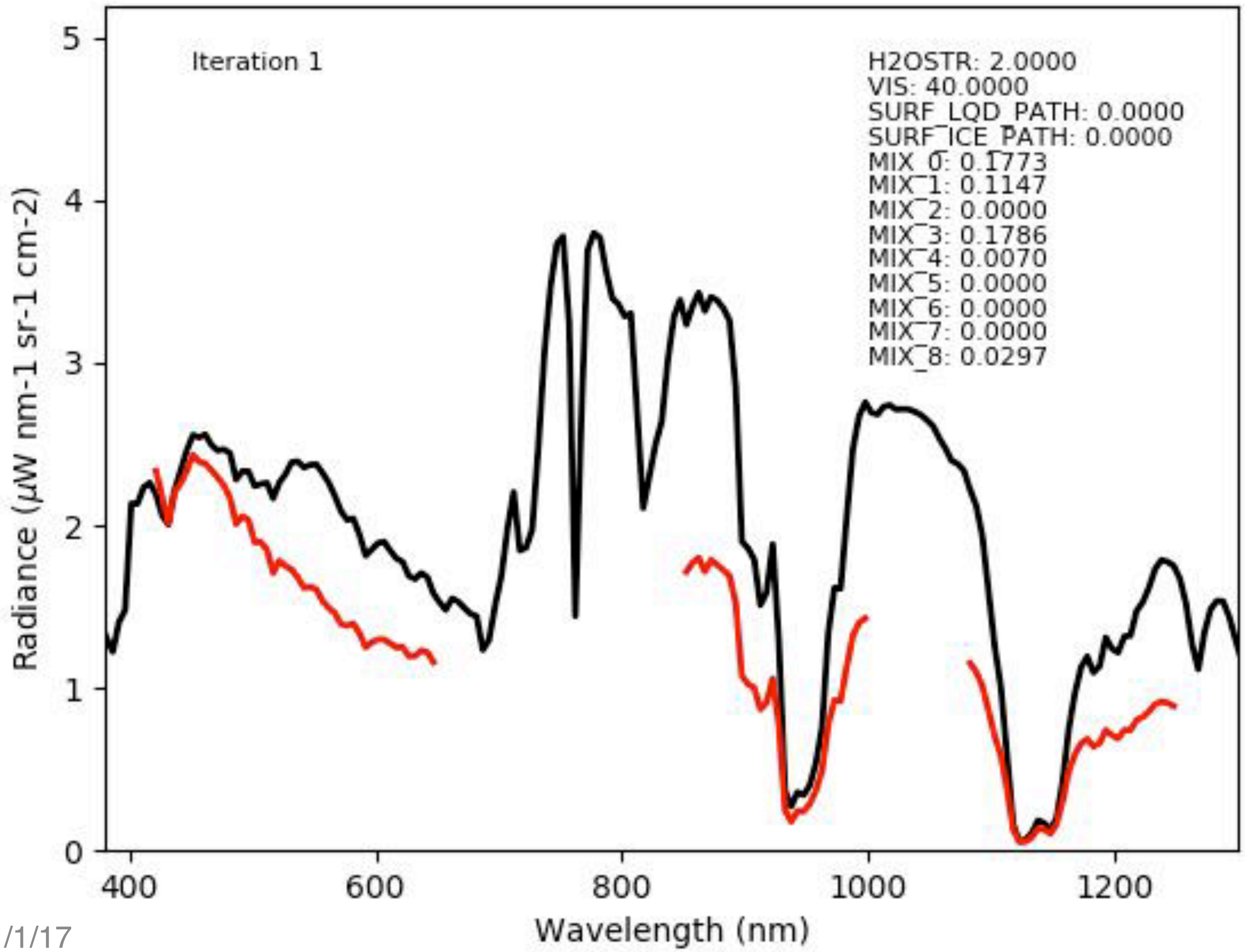
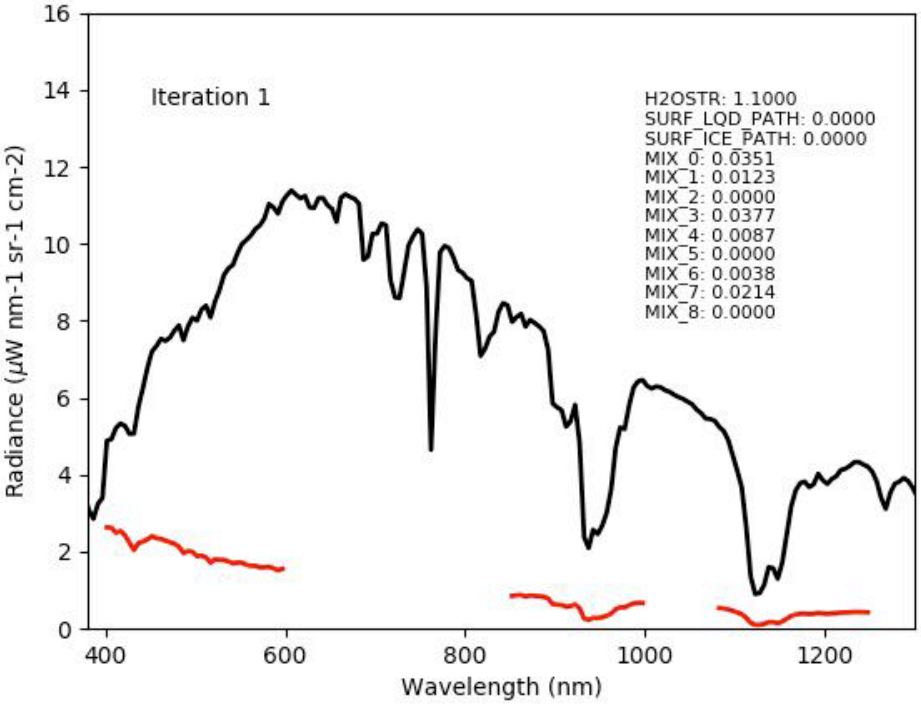


Desalpar calibration / validation site
ang20160210t061239



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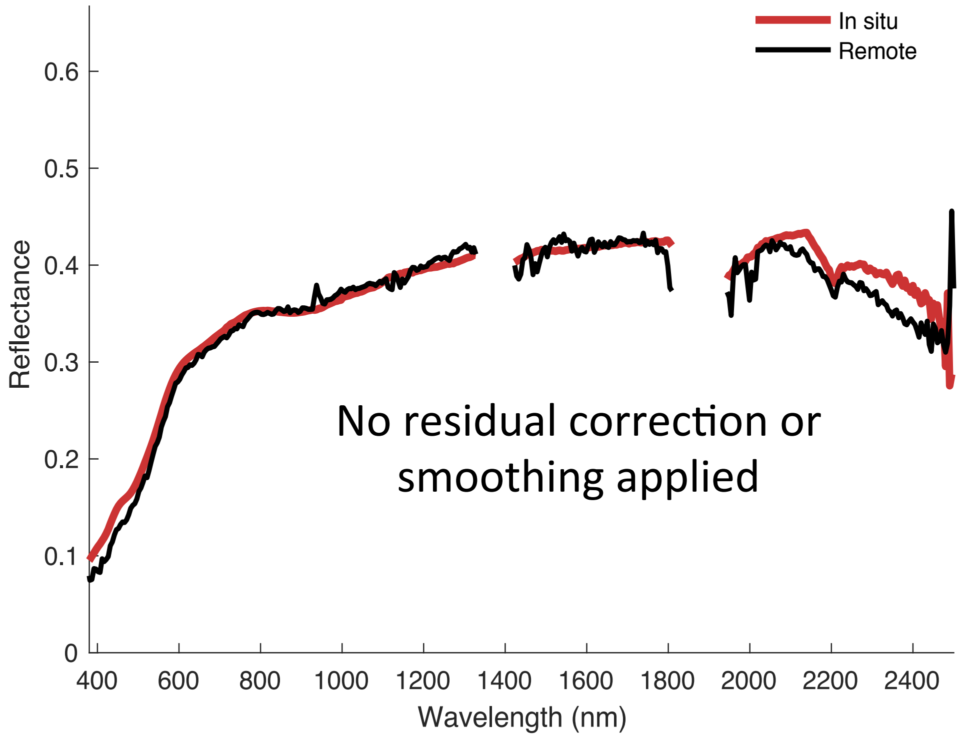

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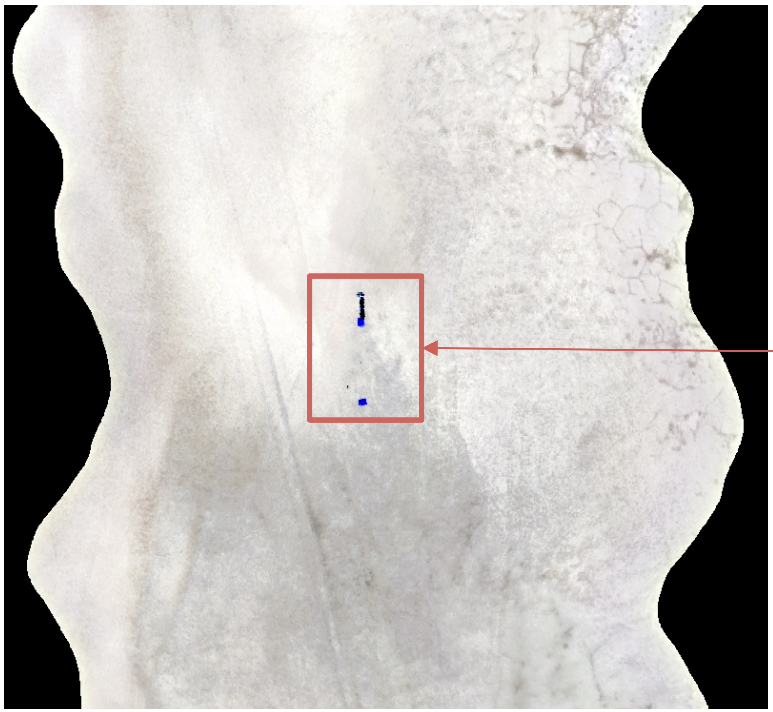
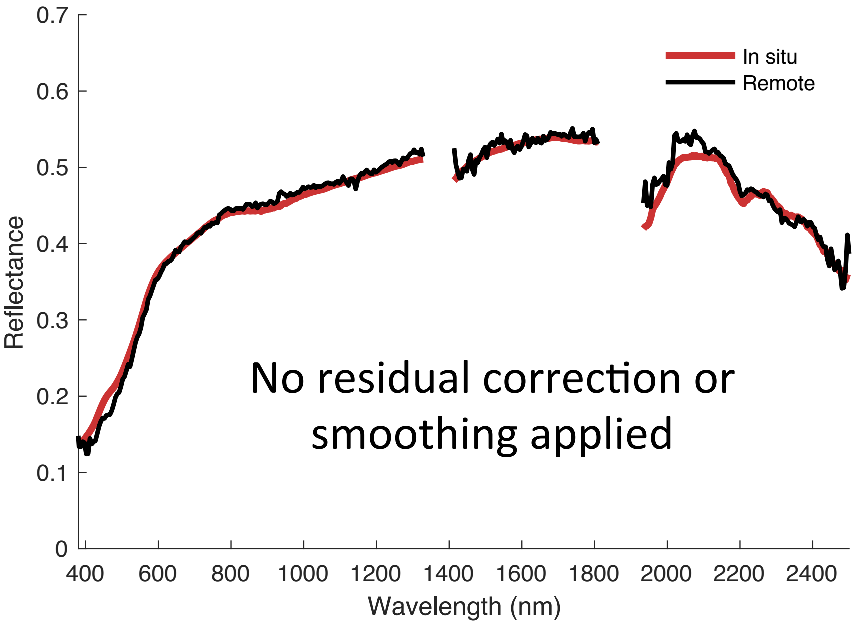
Ivanpah calibration / validation site

ang20170328t212316





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Fast Radiative Transfer

- Two-stream exact-single-scattering (2S-ESS) model (Spurr and Natraj, 2011)
  1. 2S computes the approximate multiple scattering field
  2. ESS calculates the single-scatter field.
- Incorporates state of art representations
  - Nakajima-Tanaka (N-T) correction
  - Delta-M scaling
- For calculations in a 20-layer atmosphere with 100 spectral points, 2S is ~800 times faster compared to DISORT with eight discrete ordinates in the half-space.
- **Accurate to within 0.1% of an "exact" RT model, but with computational speed comparable to two-stream models.**

Joint surface and atmosphere estimation

- Elegant unified model
- Flexibility for large, diverse state vectors
- Can model coupled atmosphere & surface, non-Lambertian reflectance
- Can estimate spectrally-smooth atmospheric effects
- Principled statistical foundation, uncertainties
- Path to overcome lookup table simplifications thanks to emerging RTM technologies

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Thanks!

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The AVIRIS-NG Team, including Sarah Lundeen, Brian Bue, Winston Olson-Duvall, Ian McCubbin, Mark Helmlinger, and others

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