SBG Ground Segment Science Data Analysis

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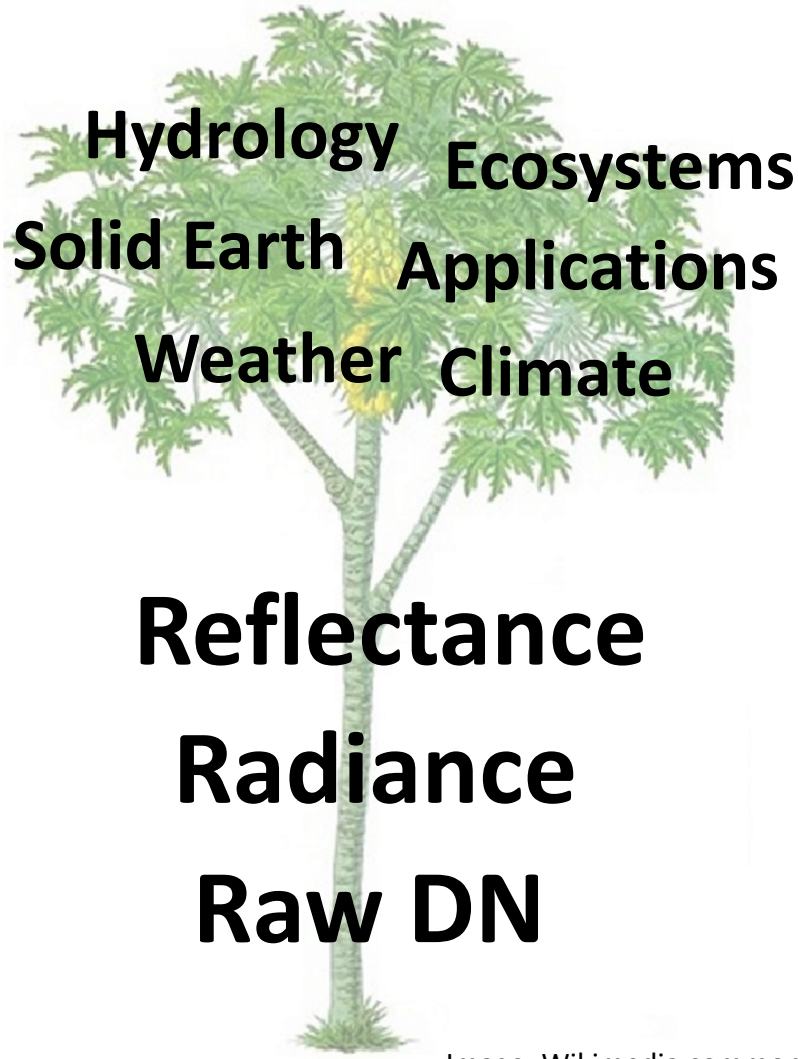

Image: Wikimedia commons

Agenda

- SBG as an information machine
- SDS-relevant questions for the architecture study
- SDS-relevant algorithm properties

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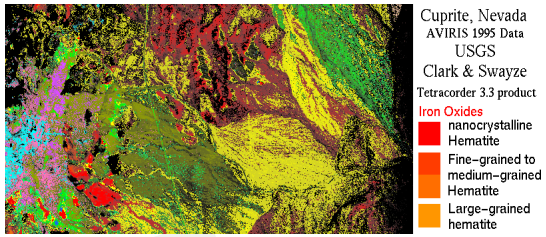
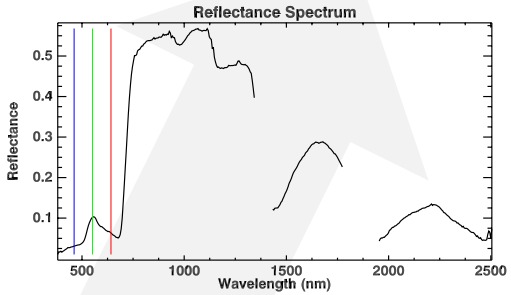
Functional elements of surface analyses

L3: Orthorectified Radiance at sensor mW/nm/cm^2/sr

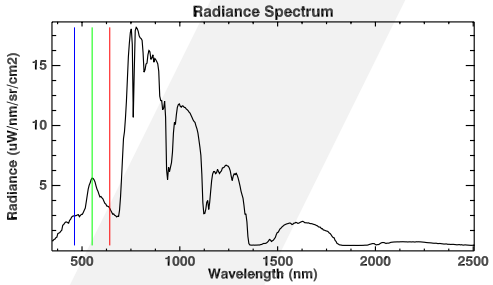


L2: Lambertian Reflectance (VSWIR) Emissivity/Temp (TIR)

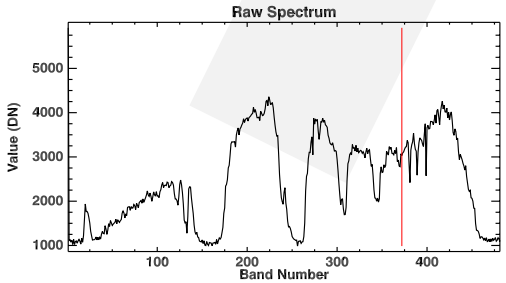


[Gao et al., 1993; Green et al., 1998, Thompson et al., 2015, 2018]

L1: Orthorectified Radiance at sensor mW/nm/cm^2/sr



L0: Raw Digital Numbers



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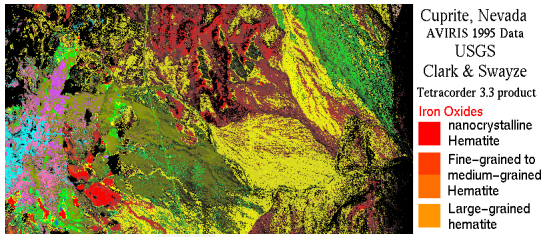
Approximate data volumes (VSWIR)

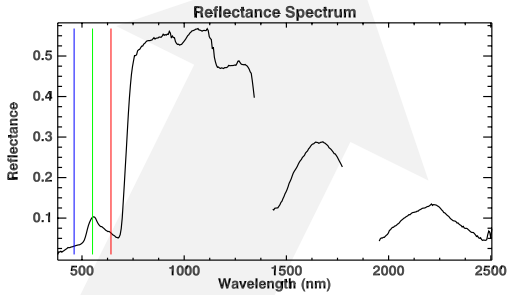
For a 10% acquisition duty cycle, we should expect over 70 TB of data per day of L0-L2 data

… more than a year of AVIRIS-NG airborne operations

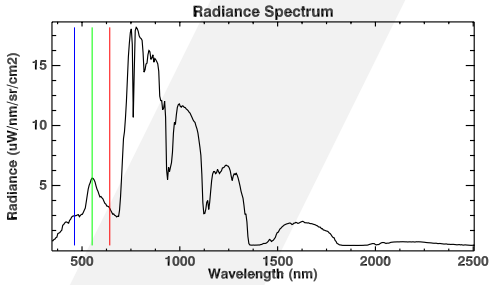
L3: ? GB per acquisition second



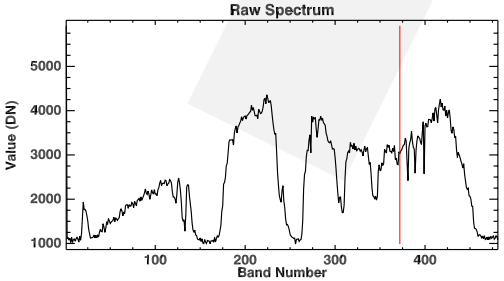
L2: 3 GB per acquisition second



L1: 3 GB per acquisition second



L0: 3 GB per acquisition second



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Roles of the Science Data System

- **Provide data products that are**
  - **Common across many science themes**
  - **Fundamental to SBG success**
  - **Require special expertise or resources**
  - **Benefit from standardization**
- **Provide "off ramps" for regional- or investigation-specific algorithms**

Four tiers of NASA commitment

1. **Standard algorithm, distributed globally** (example: L1 calibrated radiances)

2. **Standard algorithm, distributed for some subset** (example: coastal L3 maps)

3. **Customizable algorithm, computed on-demand with user input** (example: enhanced atmospheric correction)

4. **DIY** algorithm and computation (outside SBG remit)

Four tiers: examples

	I	II	III	IV
	Standard	Standard	Customizable	DIY
	Global	Subset	On demand	
L1	Radiances Orthorectification			
L2	Atmospheric correction (Lambertian) Cloud masks	Specific BRDF Glint corrections	Custom Aerosol prior or BRDFs?	
L3		Terrestrial or Aquatic ecosystem traits, Snow products, Benthic maps, etc.	Custom local canopy or phytoplankton models, etc.	Trace greenhouse gas detection

Agenda

- SBG as an information machine
- SDS-relevant questions for the architecture study
- SDS-relevant algorithm properties

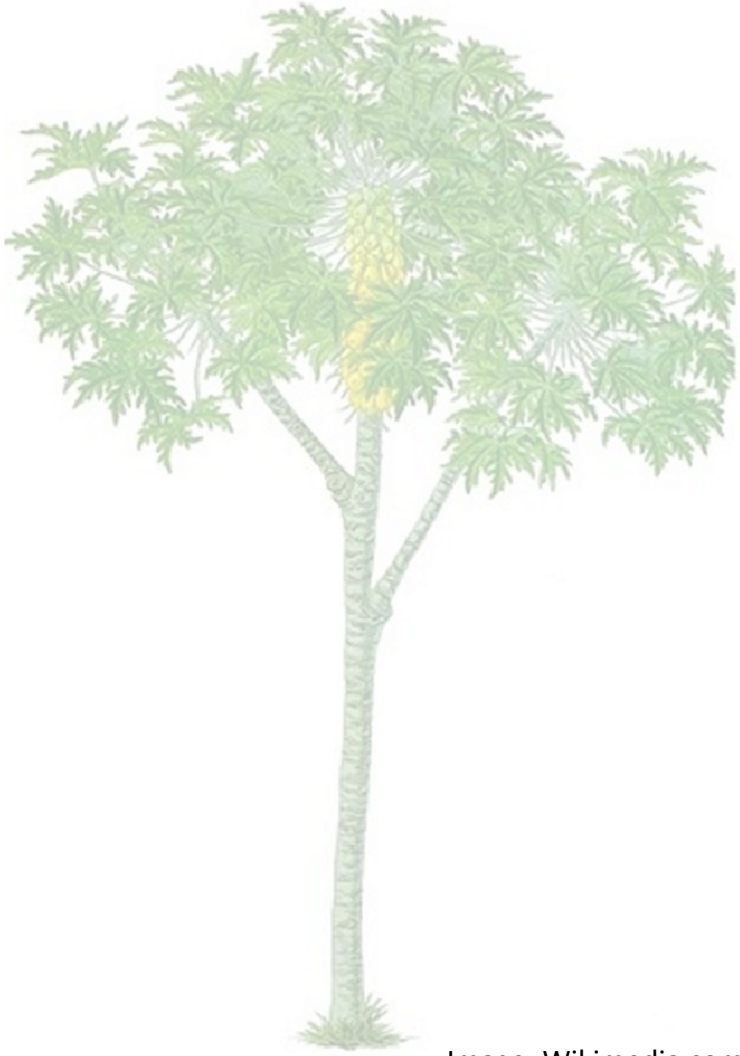


Image: Wikimedia commons

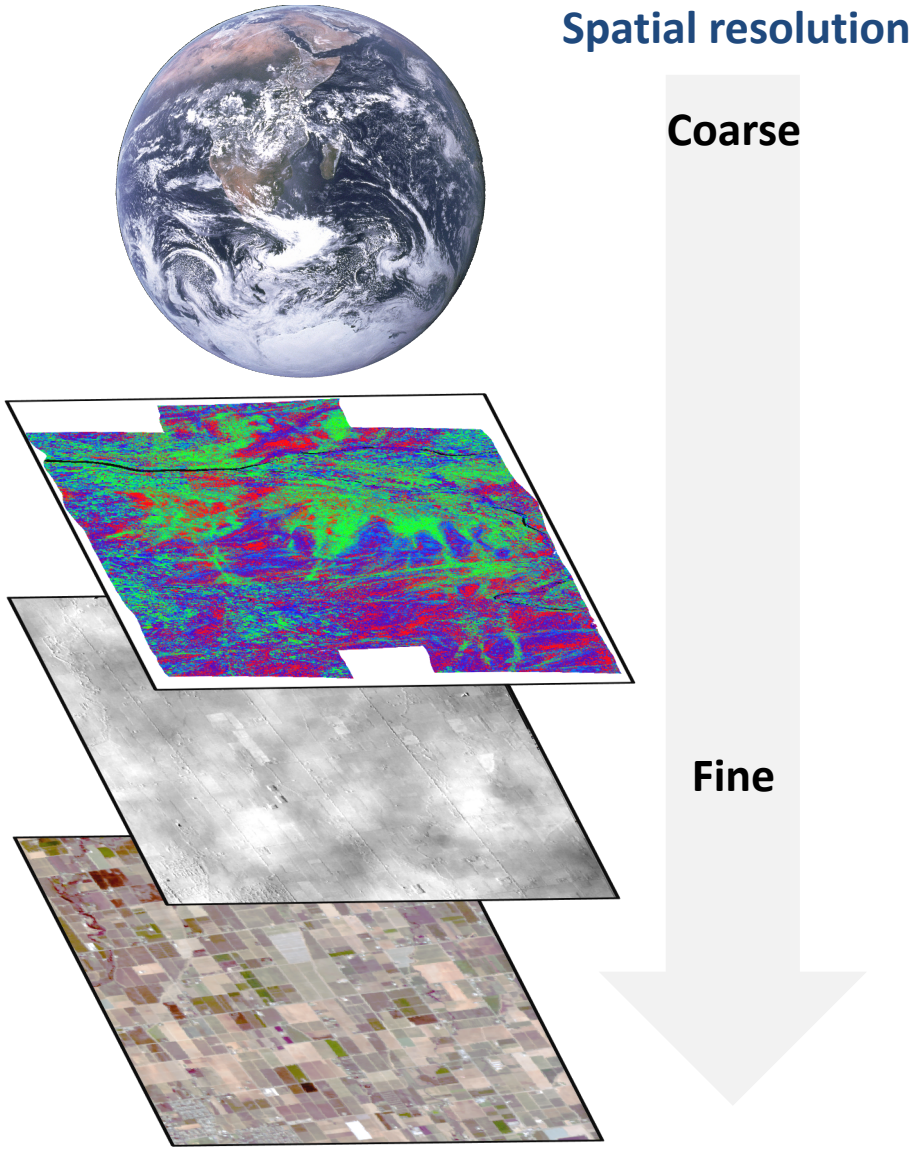
Parallelizability

Global scale
- L4+ ESMs (1km grid?)

Multiple scenes, one domain
- Regional L4 Analyses
- Time series
- Possibly lower spatial resolution

Multiple spectra, one scene
- Some L2, e.g. atmospheres
- Some L3, e.g. biodiversity

Independent spectra
- L1 radiance
- Basic L2
- Basic L3



AVIRIS-C RGB and H_2O field from [Thompson et al., *Surveys in Geophys.* 2019]

Open source code is critical

- Makes algorithm assumptions explicit
- Key to grow the research community
- Speeds development and rollout
- Enables division of labor across analyses
- Use state-of-practice community tools
- Long term governance is cheap but must be supported

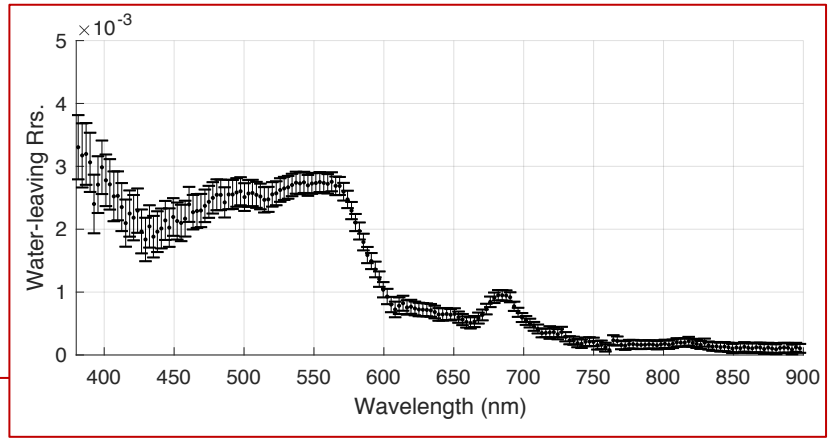
Uncertainty Quantification (UQ)

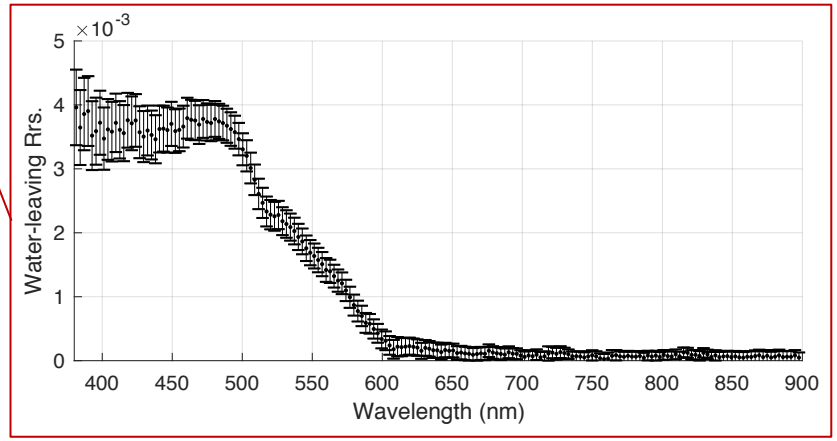
A product produced and incorporated by some algorithms

Reported with each estimated quantity

Requires some support in data formats and algorithms

Should account for covariance structure





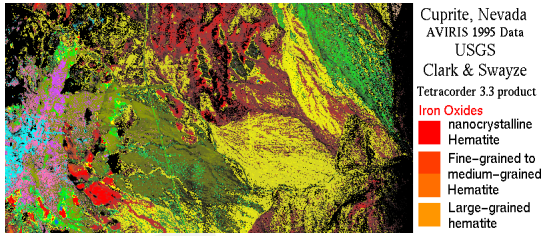
Uncertainty Quantification (UQ)

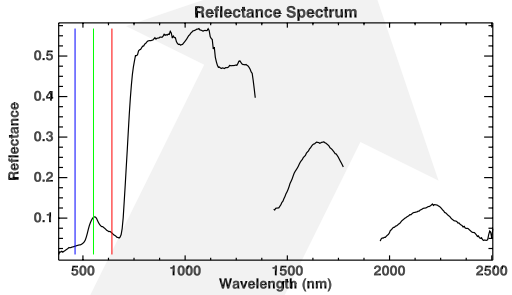
Enables:

1. **Scientific hypothesis testing with a formal understanding of the observation system**
2. **Principled synthesis of sensors, spatial, and temporal locations**
3. **Improved accuracy**
4. **Decision support – the answer doesn't have to be perfect if you can bound the error**

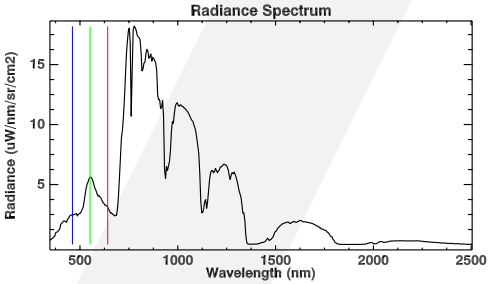
Sources of uncertainty

L2 -> L3: Model generalization specific to each science theme

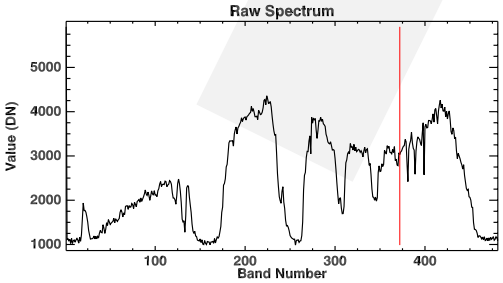




L1 -> L2: Atmospheric unknowns, RTM modeling and inversion approximations (BRDFs, decouplings, glint, atmospheric vertical profiles, etc).

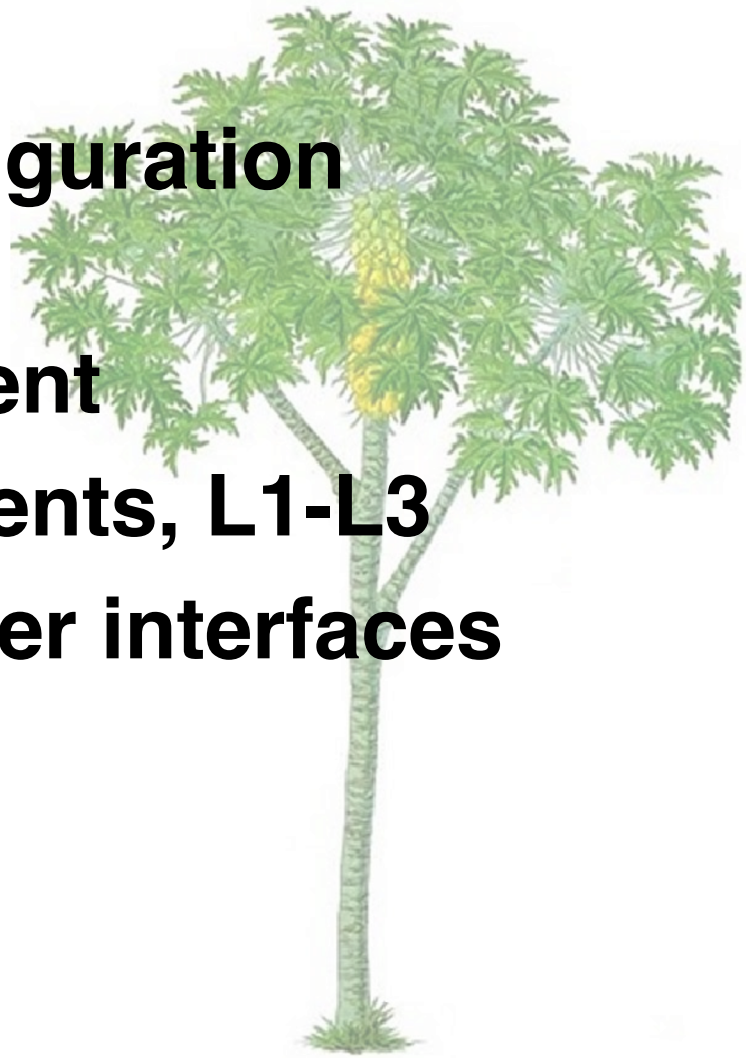


L0 -> L1: Calibration, signal dependent noise, signal independent noise



Ingredients of the SDS

- Discovery
- Workflow and configuration management
- Process management
- Data analysis elements, L1-L3
- Distribution and user interfaces



Next steps

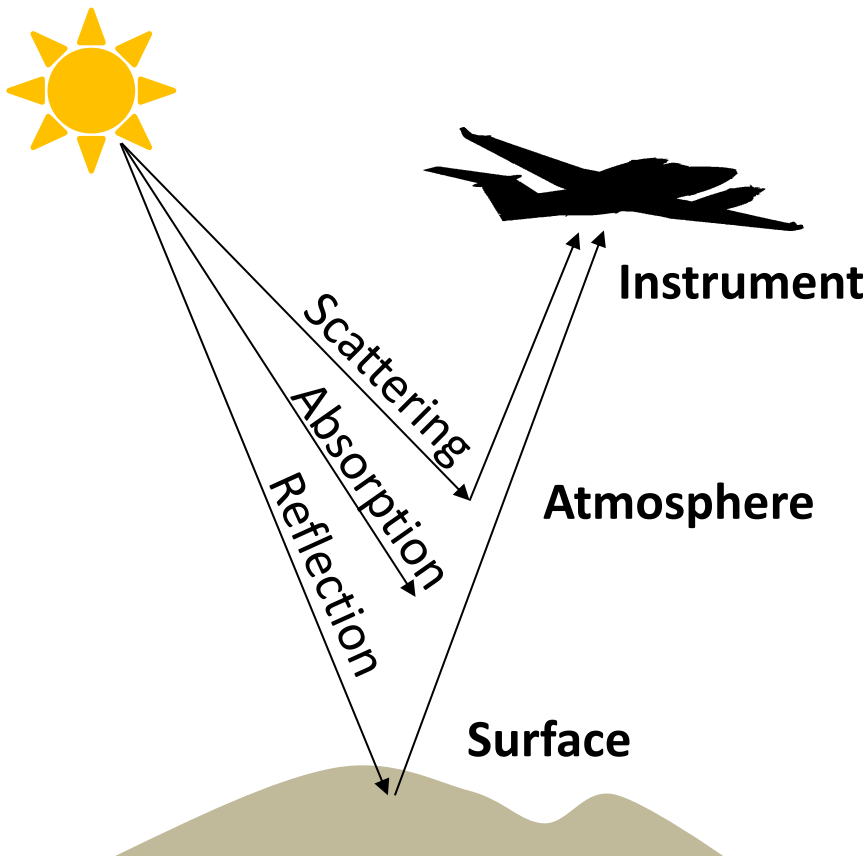
- **Algorithm classifications**
  I. Standard, global
  II. Standard, subsets
  III. On-demand settings, subsets
  IV. DIY
- **Phase II**
  – Characterize computational and storage requirements
  – Refine algorithm TRL assessment
  – Determine formats for uncertainty reporting

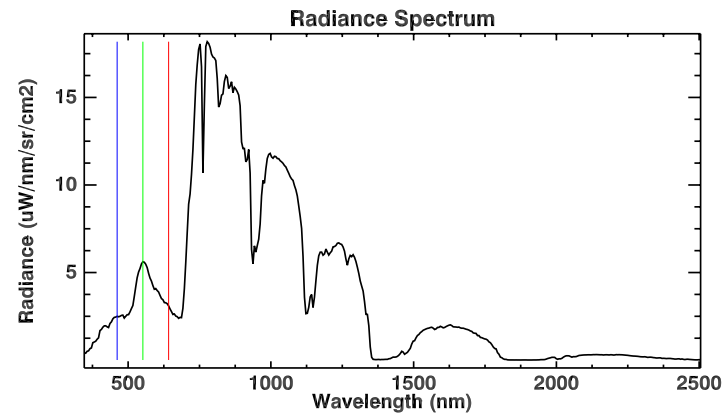
Questions?

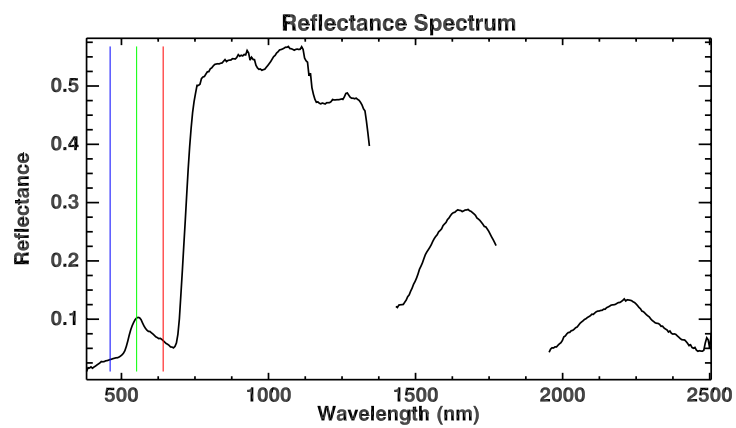
Image: Wikimedia commons

Backup

From radiance to reflectance







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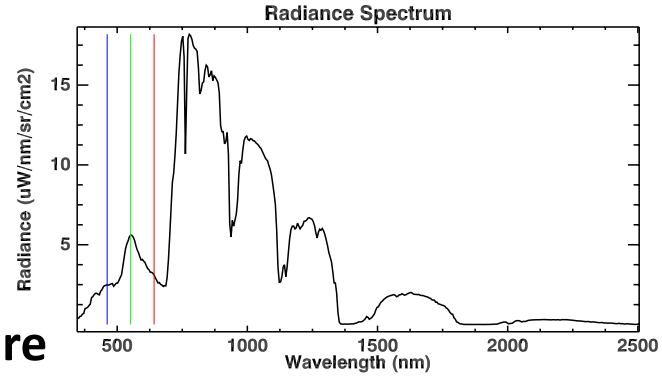
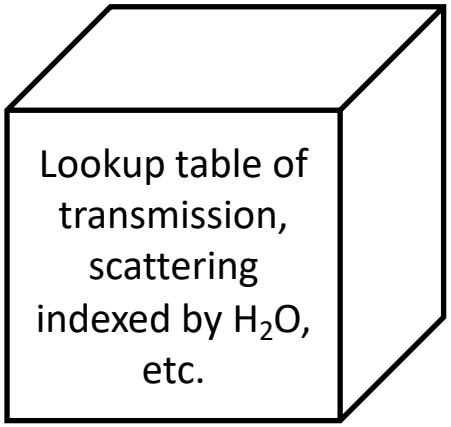
Conventional atmospheric correction: A sequential process



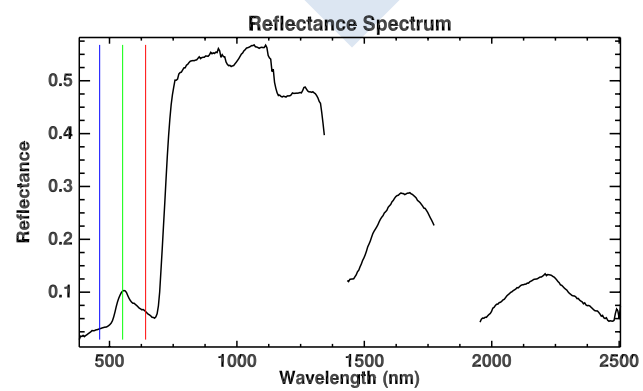
2. Estimate atmosphere (typically by band ratios)



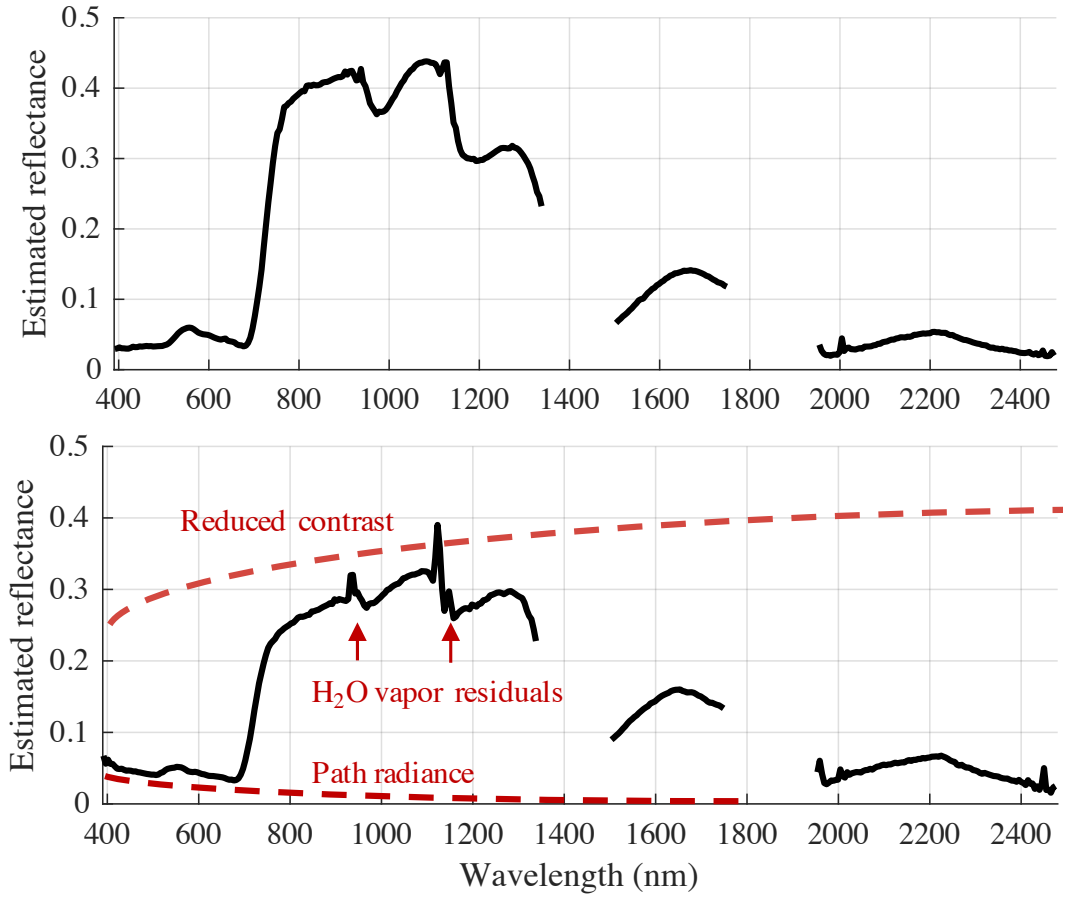
1. In advance, do RTM calculations

3. Algebraic Inversion

$$\overbrace{\rho^*_{obs}}^{\text{measurement}} = \rho_a + \frac{T\overbrace{\rho_s}^{\text{reflectance}}}{1 - S\rho_s}$$

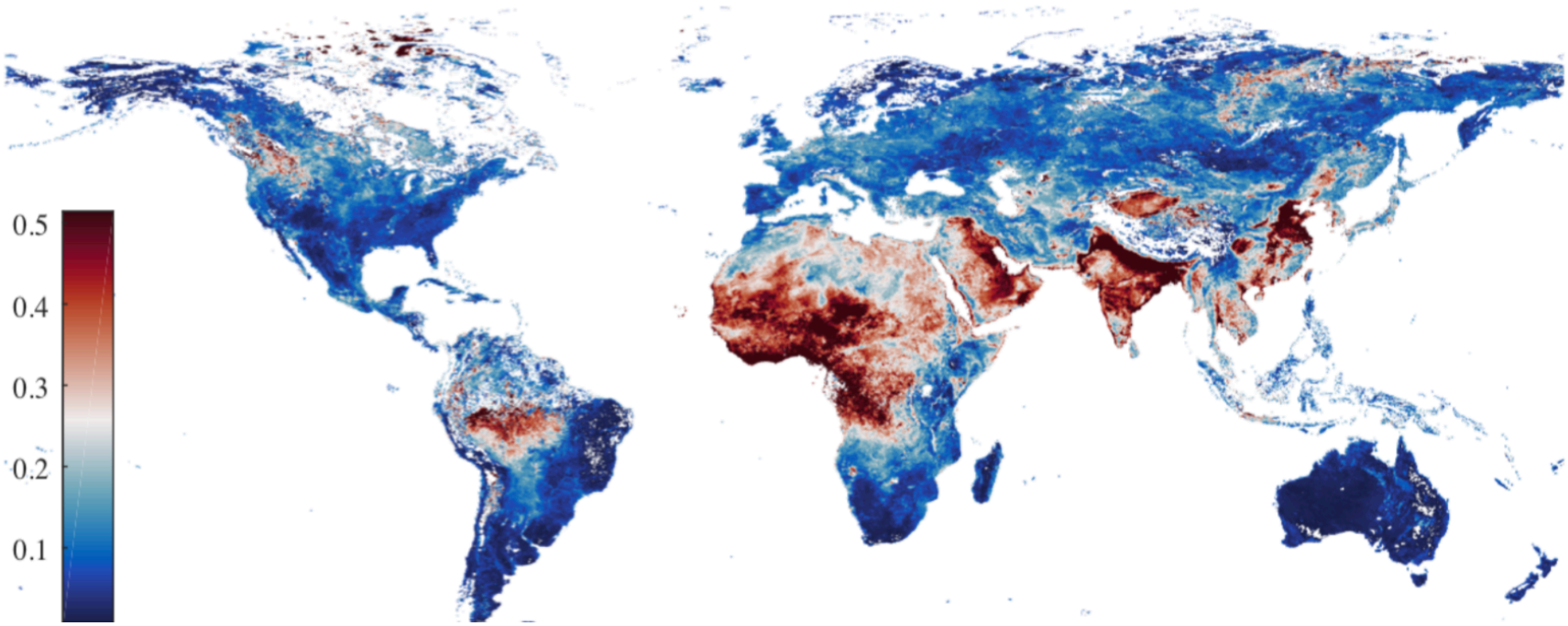


Global spectroscopy missions are an atmospheric correction challenge



Thompson et al., (in review)

Global spectroscopy missions are an atmospheric correction challenge



Annual average AOD

Thompson et al., (in review)

Optimal Estimation : Simultaneous fit of surface, instrument and atmosphere

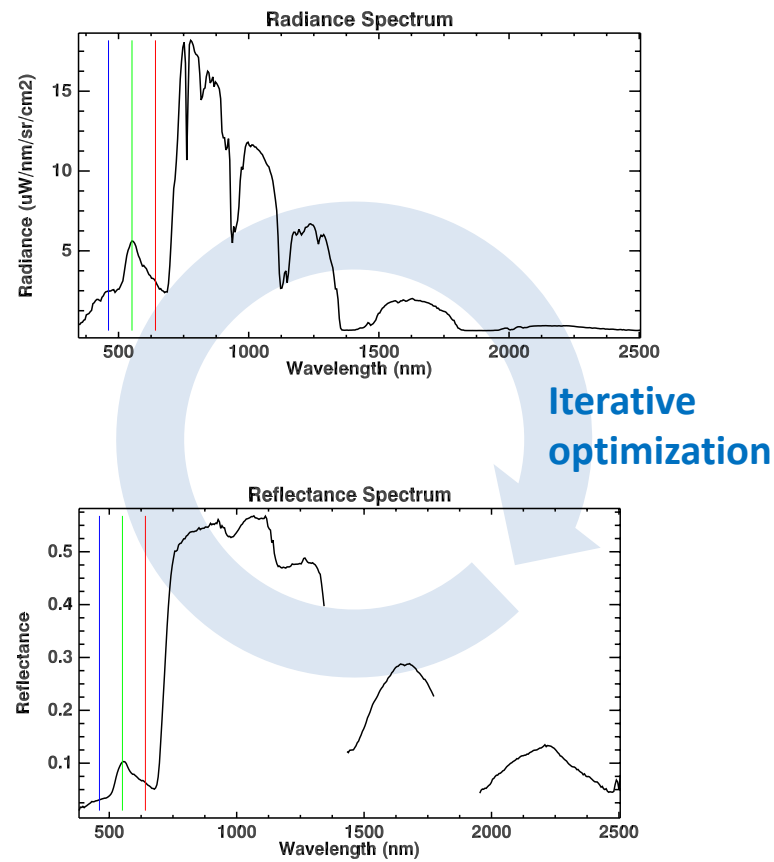
[Thompson et al., *Remote Sensing of Environment* 2018, 2019a, 2019n]

Bayesian *Maximum a Posteriori* estimate using a combined model of surface, atmosphere, instrument

Improves atmospheric correction accuracy

Rigorous uncertainty accounting

Optimal weighting of information from instrument vs. domain knowledge



https://github.com/isofit/isofit

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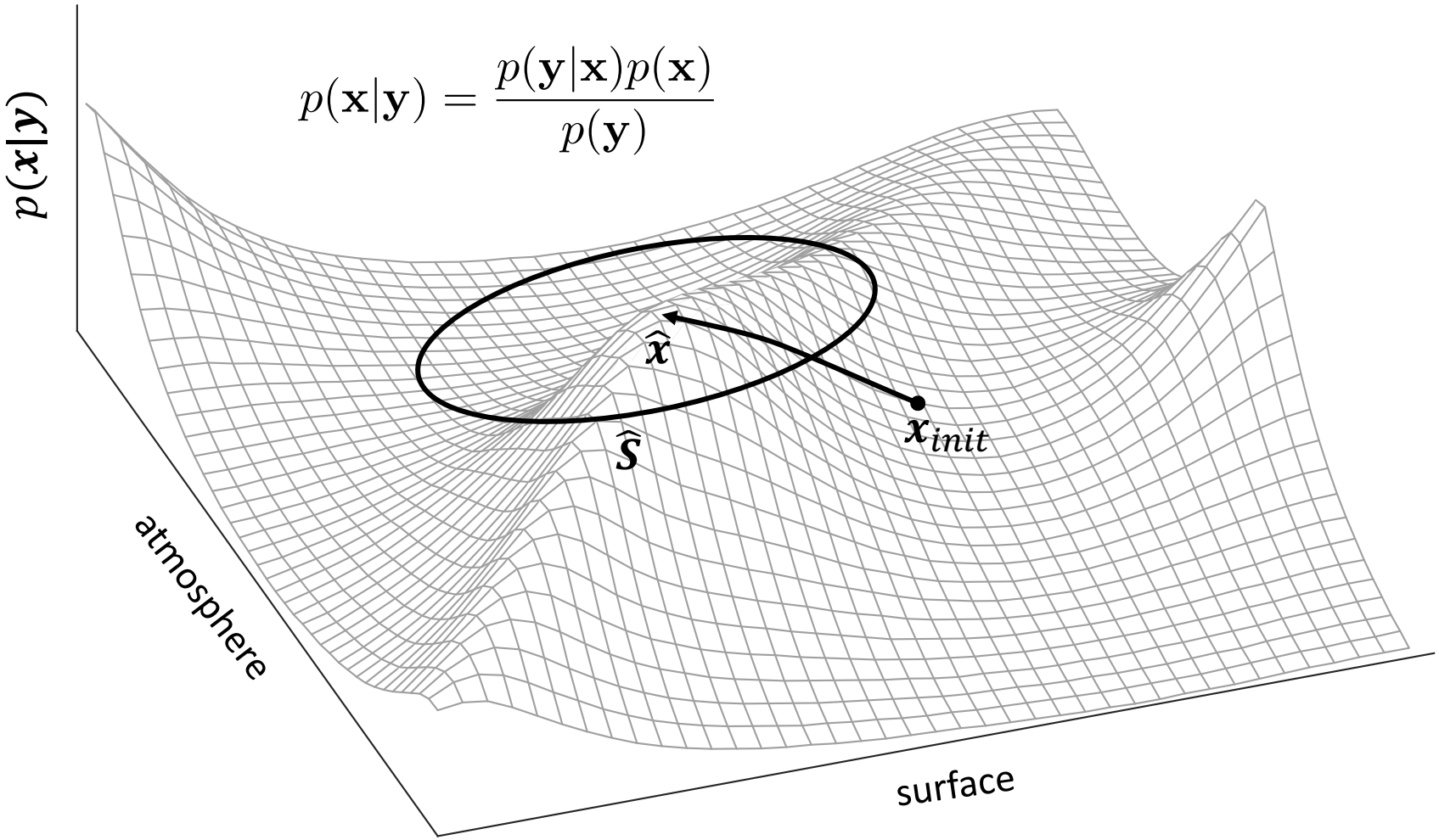
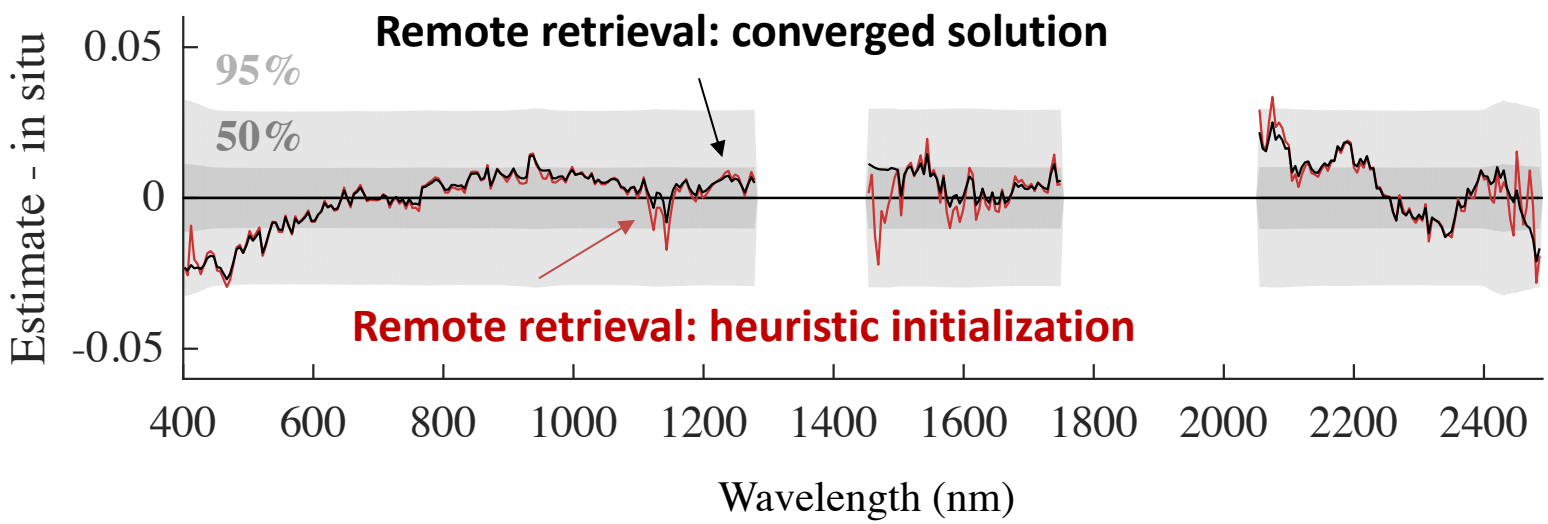
Maximum A Posteriori estimation



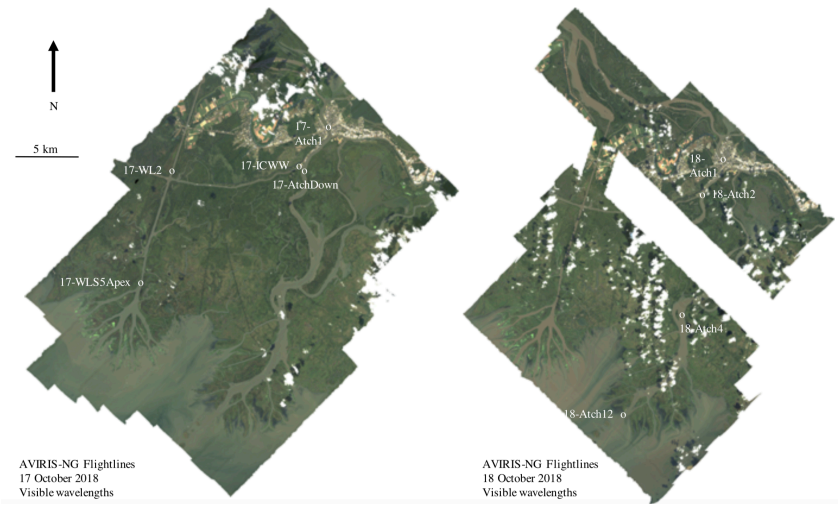
Posterior uncertainty compared to actual discrepancies

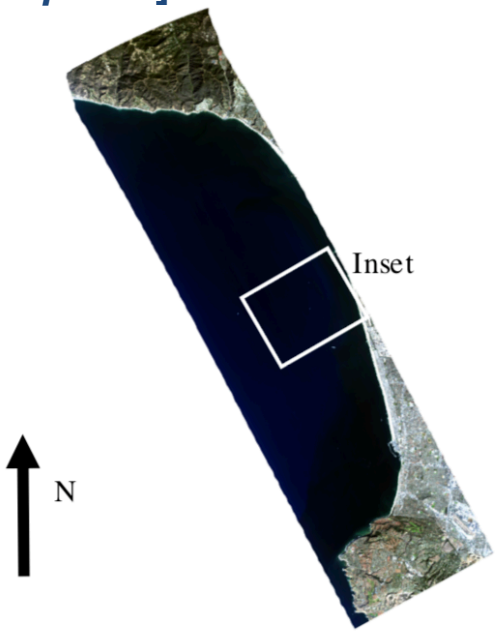
[Thompson et al., *Remote Sensing of Environment* 2018]

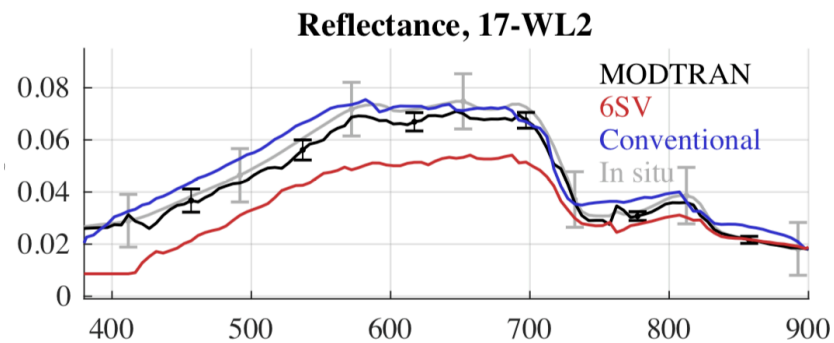


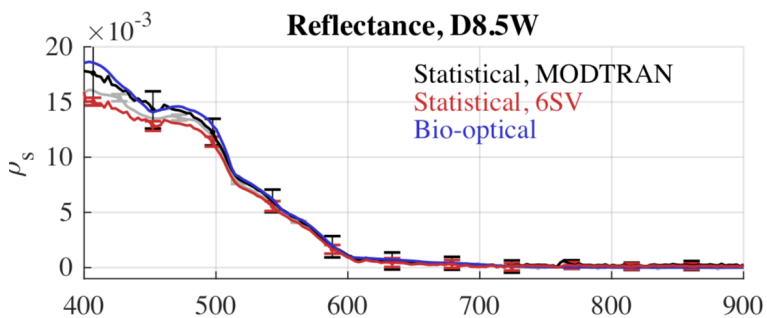
Coastal environments

[Thompson et al., *Remote Sensing of Environment* 2019, *in press*]



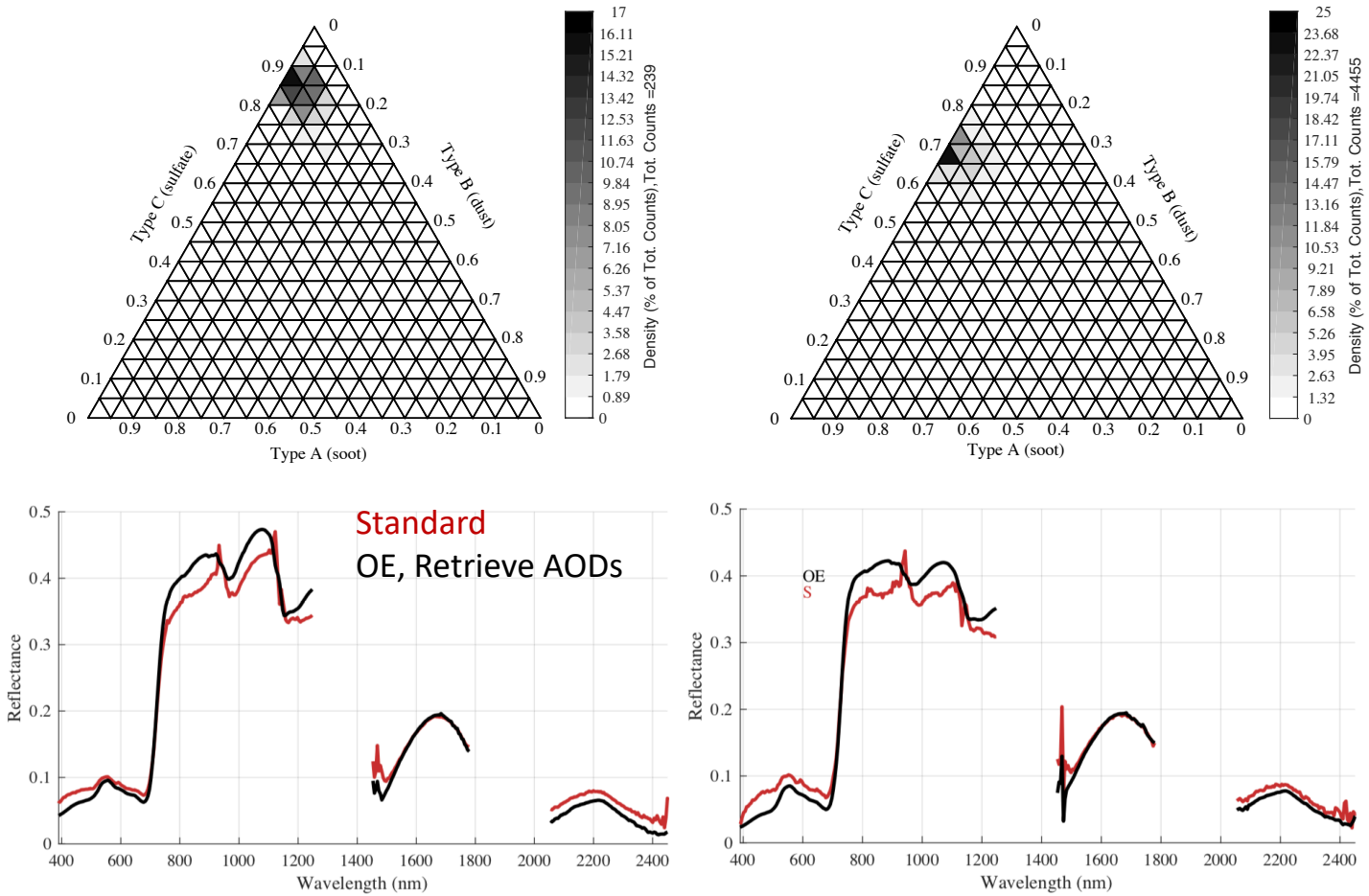






Challenging atmospheres

[Thompson et al., *Remote Sensing of Environment,* 2019, in press]



More resources

Two posters in this meeting

Thompson et al. (2018), “Optimal Estimation for Imaging Spectrometer Atmospheric Correction,” *Remote Sensing of Environment*, 216.

Thompson et al. (2019), “A unified approach to estimate land and water reflectances with uncertainties for coastal imaging spectroscopy,” *Remote Sensing of* Environment, in press.

Thompson et al. (2019), “Optimal Estimation of Spectral Surface Reflectance in Challenging Atmospheres,” *Remote Sensing of* Environment, in press.

https://github.com/isofit/isofit