Early Estimation of Fire-Risk in the Eastern Mediterranean and Socioeconomic Informed Communications of Actionable Strategies

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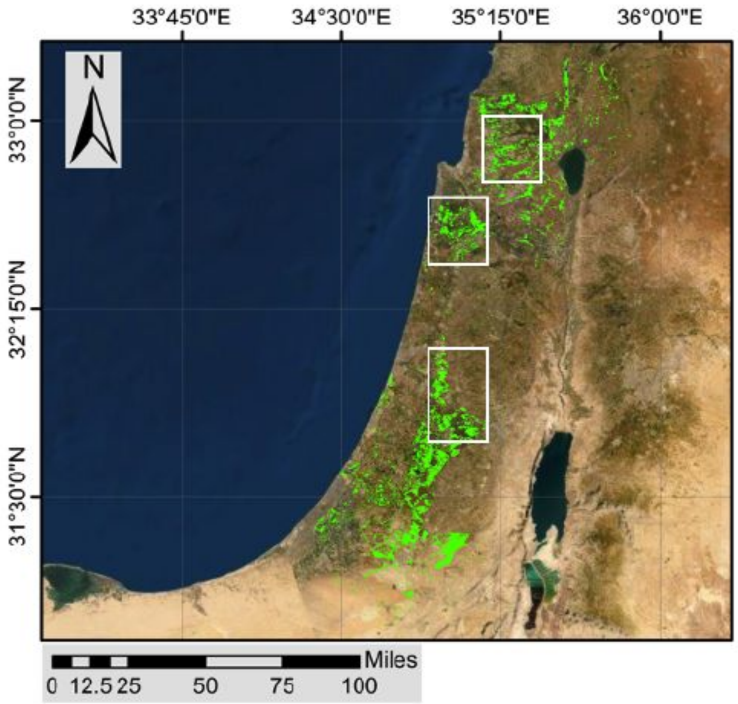
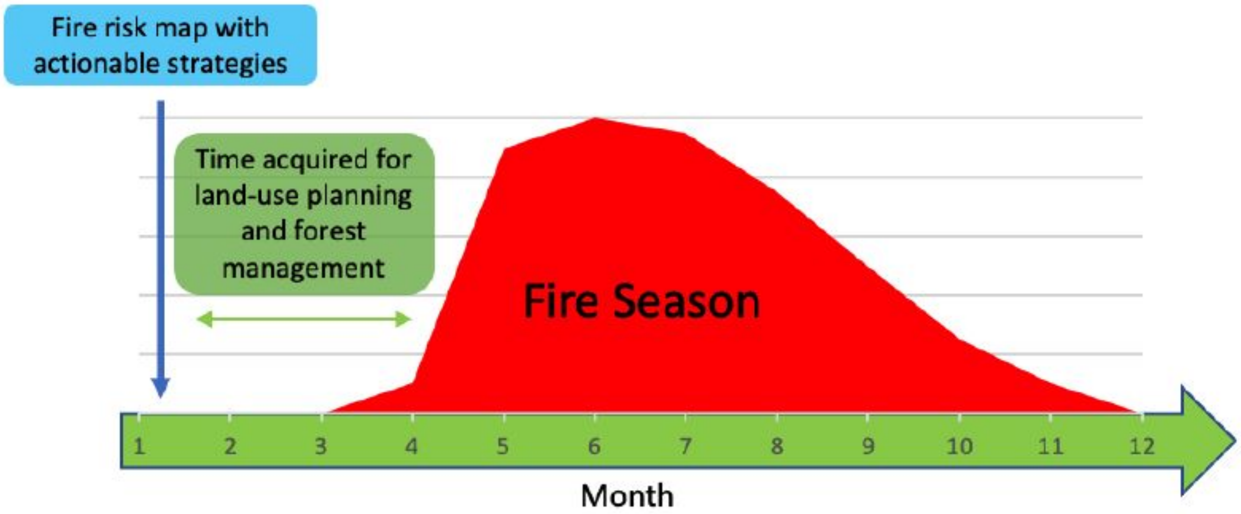
Wildfire in Israeli Forests

- Increased severity in the last 2 decades
- Wildfire risk factors
  - Forest conditions
  - Multi-year droughts
- Current products
  - Not high-resolution
  - No early predictions



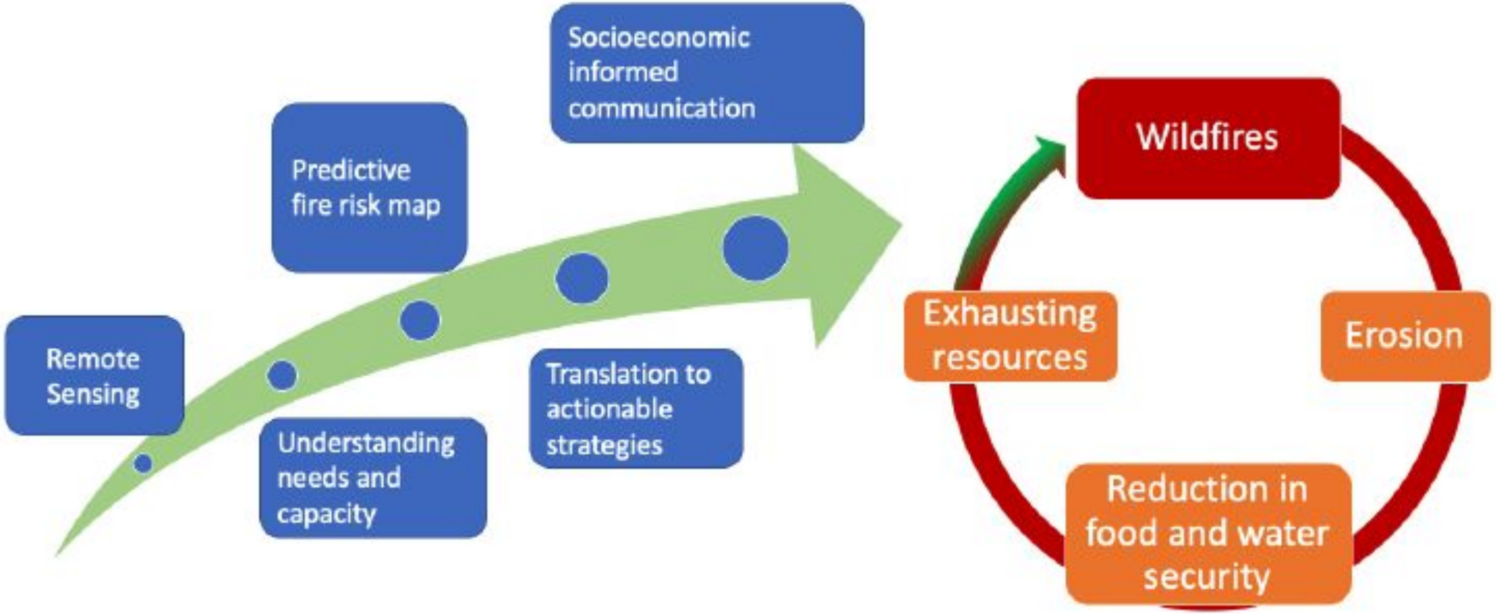
Early Prediction of Fire Risk

Allows for planning and applying mitigation strategies



Early intervention, tailored to the user

Breaking the cycle



PLAN

Objective: To revolutionize vegetation mapping using orbital remote sensing by improving atmospheric correction retrievals and producing "intrinsic" surface reflectance signatures that are better suited for mapping vegetation traits with fine spectral signatures.

Problems

Sources of Uncertainty

- Topographic effects in processing pipelines are often addressed with post-hoc correction, if addressed at all.
- Inaccurate reflectance products used for vegetation trait models lead to biased surface maps and errors in downstream analysis.
- Downstream analysis is prone to errors due to the aforementioned issues.

Post-hoc Topographic Correction

Atmospheric Correction

Topographic Correction

Calibration □ Radiance Measurement → "Apparent" Surface Reflectance → "Intrinsic" Surface Reflectance □ Applications

Determine Atmospheric Conditions (water, aerosols)

Compensate for the effects of Topography

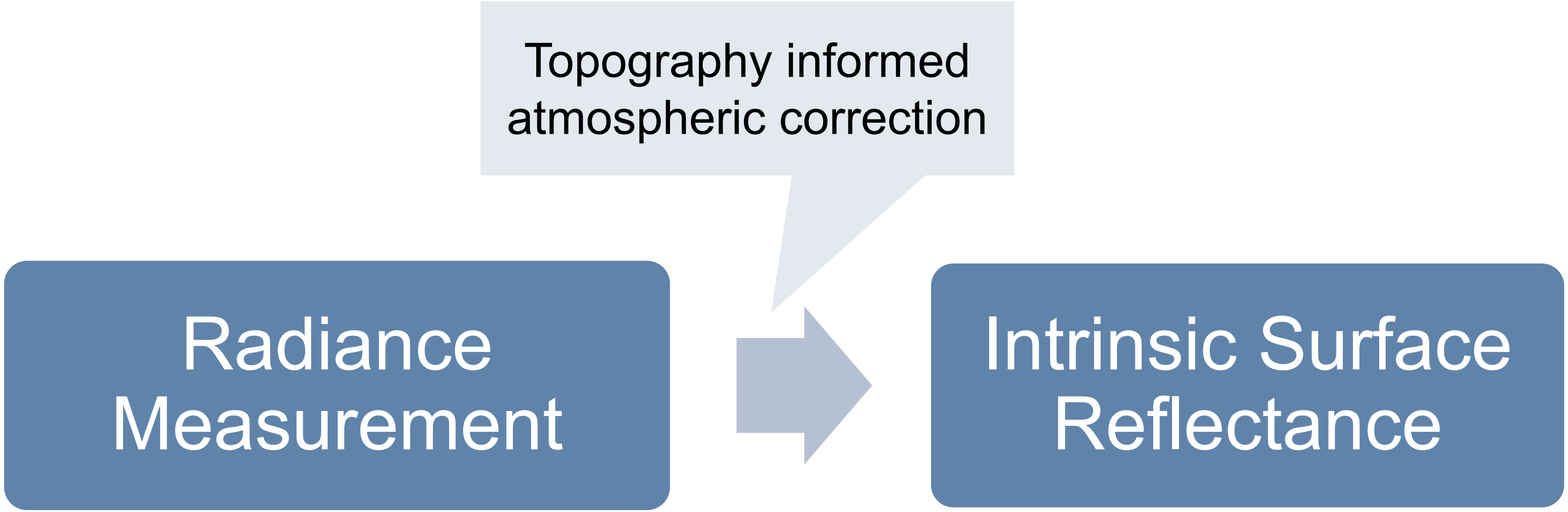
Solution

Unified Atmospheric-Topographic Correction

Implemented topographic effects dynamically within the atmospheric correction → Reduce reflectance and atmosphere errors → Improve downstream vegetation trait maps

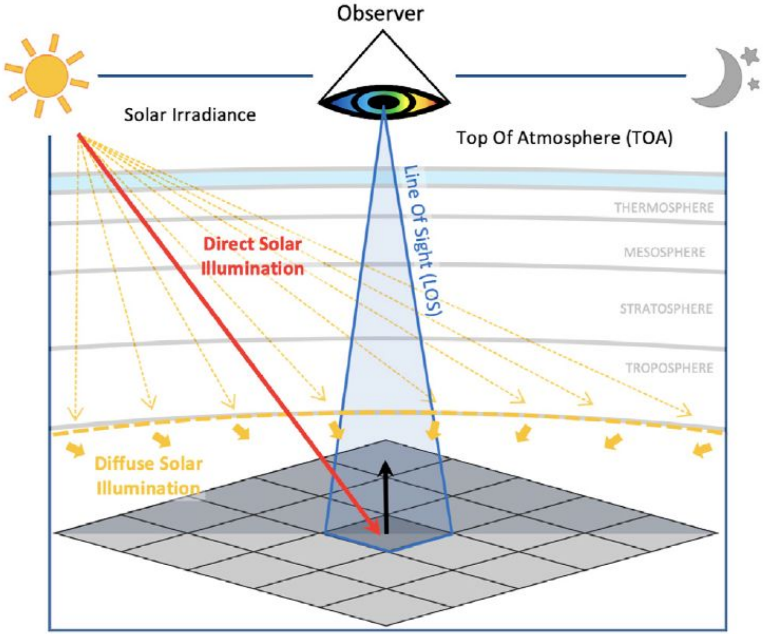
Unified Atmospheric-Topographic Correction

Incorporate topographic effects as a known parameter in the radiance-to-reflectance inversion

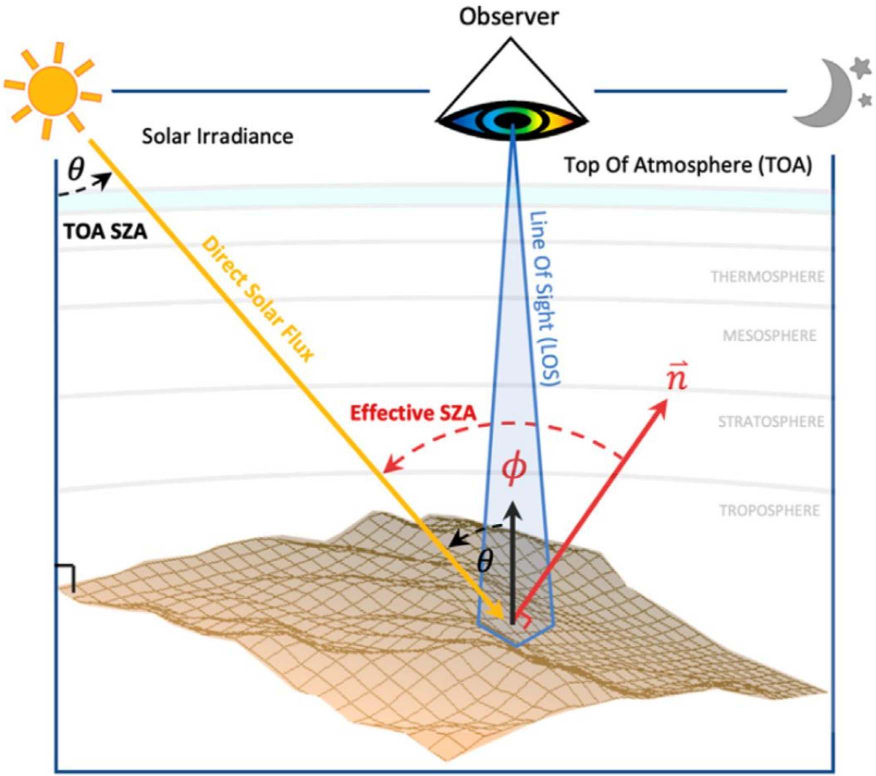


Atmospheric RTM Background

The global flux - sum of direct and diffuse solar illumination

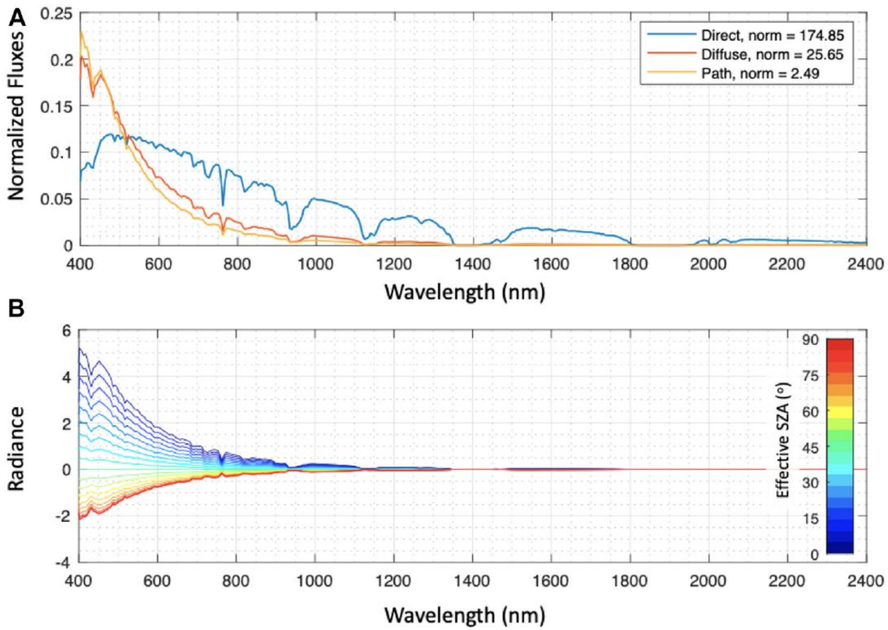


Topography – why it is important



Parameter	Description
	Top of atmosphere solar zenith angle
	Effective solar zenith angle
	The normal vector to the surface
LOS	Line of sight for a given pixel

Spectral effects of Topography



- The direct flux is directional and scaled by the cosine of ESZA
- The diffuse flux and the path radiance are not directional and are not affected by the ESZA

Topography Naïve vs. Topography Aware

Naïve

$$F_0\colon \boldsymbol{l}_{obs} = \boldsymbol{l}_p + \frac{\boldsymbol{e}_g(0)}{1 - s\boldsymbol{\rho}_s}\boldsymbol{t}^{\uparrow}\boldsymbol{\rho}_s, \text{ where}$$
$$\boldsymbol{e}_g(0) = \boldsymbol{e}_0\mu_\theta\pi^{-1}\left(\boldsymbol{t}^{\downarrow}_{dir} + \boldsymbol{t}^{\downarrow}_{dif}\right).$$

Treats all pixels as flat

Aware

$$F_1\colon \boldsymbol{l}_{obs} = \boldsymbol{l}_p + \frac{\boldsymbol{e}_o\pi^{-1}\mu_\phi\boldsymbol{t}^{\downarrow}_{dir} + \boldsymbol{e}_o\pi^{-1}\mu_\theta\boldsymbol{t}^{\downarrow}_{dif}}{1 - s\boldsymbol{\rho}_s}\boldsymbol{\rho}_s\boldsymbol{t}^{\uparrow}.$$

Dynamically incorporates topography

Topography Naïve vs. Topography Aware

Naïve

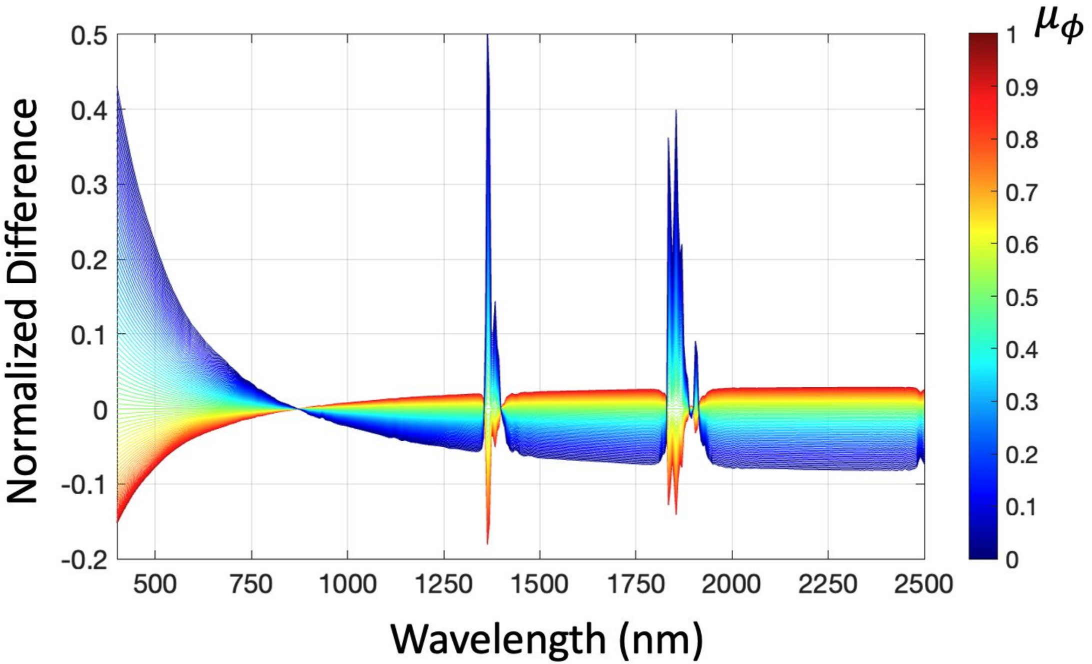
$$F_0:\ l_{obs} = l_p + \frac{e_g(0)}{1 - s\rho_s} t^{\uparrow} \rho_s, \text{ where}$$

$$e_g(0) = e_0 \mu_\theta \pi^{-1} \left(t^{\downarrow}_{dir} + t^{\downarrow}_{dif} \right).$$

Aware

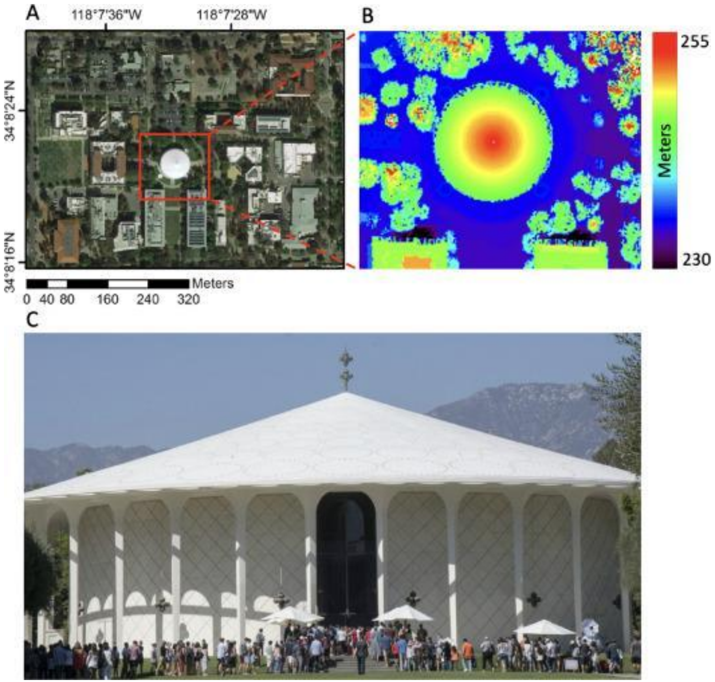
$$F_1:\ l_{obs} = l_p + \frac{e_o \pi^{-1} \mu_\phi t^{\downarrow}_{dir} + e_o \pi^{-1} \mu_\theta t^{\downarrow}_{dif}}{1 - s\rho_s} \rho_s t^{\uparrow}.$$

Relative Errors in Radiance



Homogeneous and Symmetric Target

Beckman Auditorium Roof



Homogeneous and Symmetric Target

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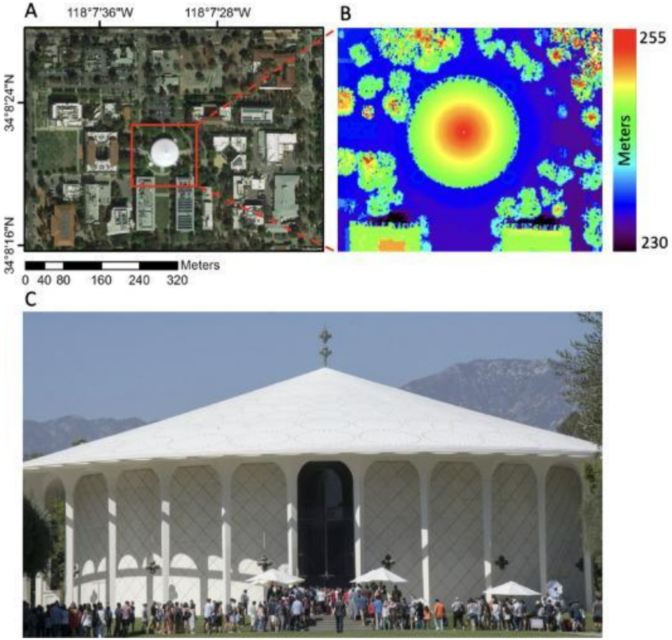
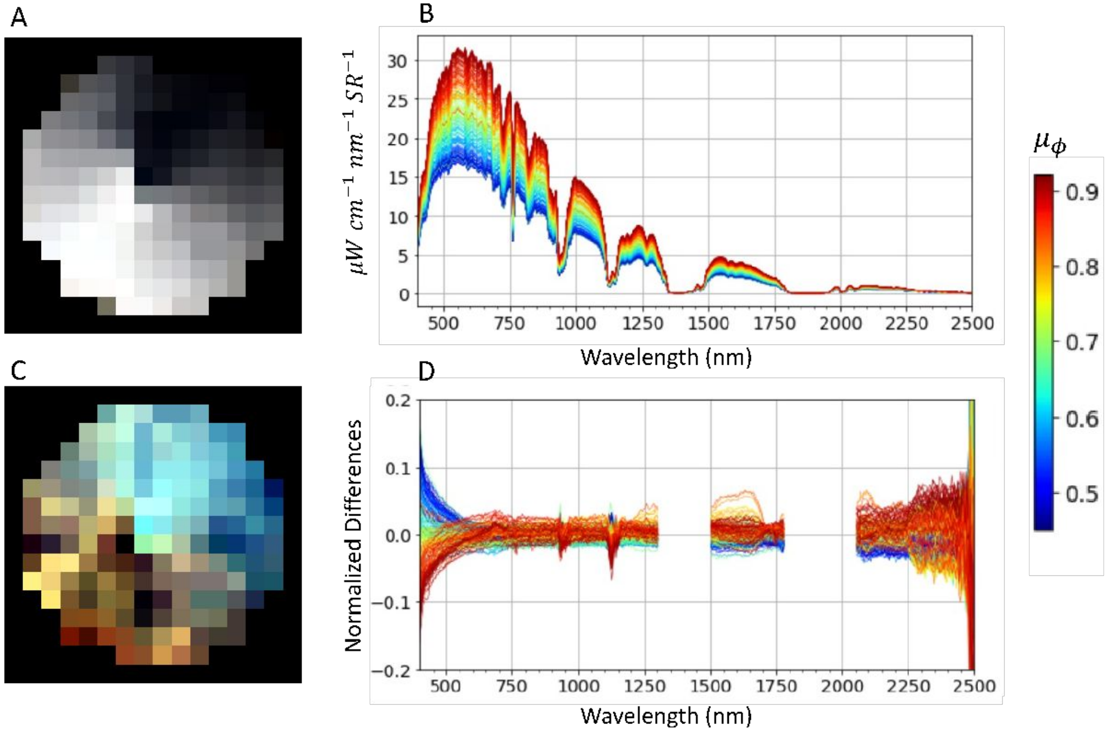
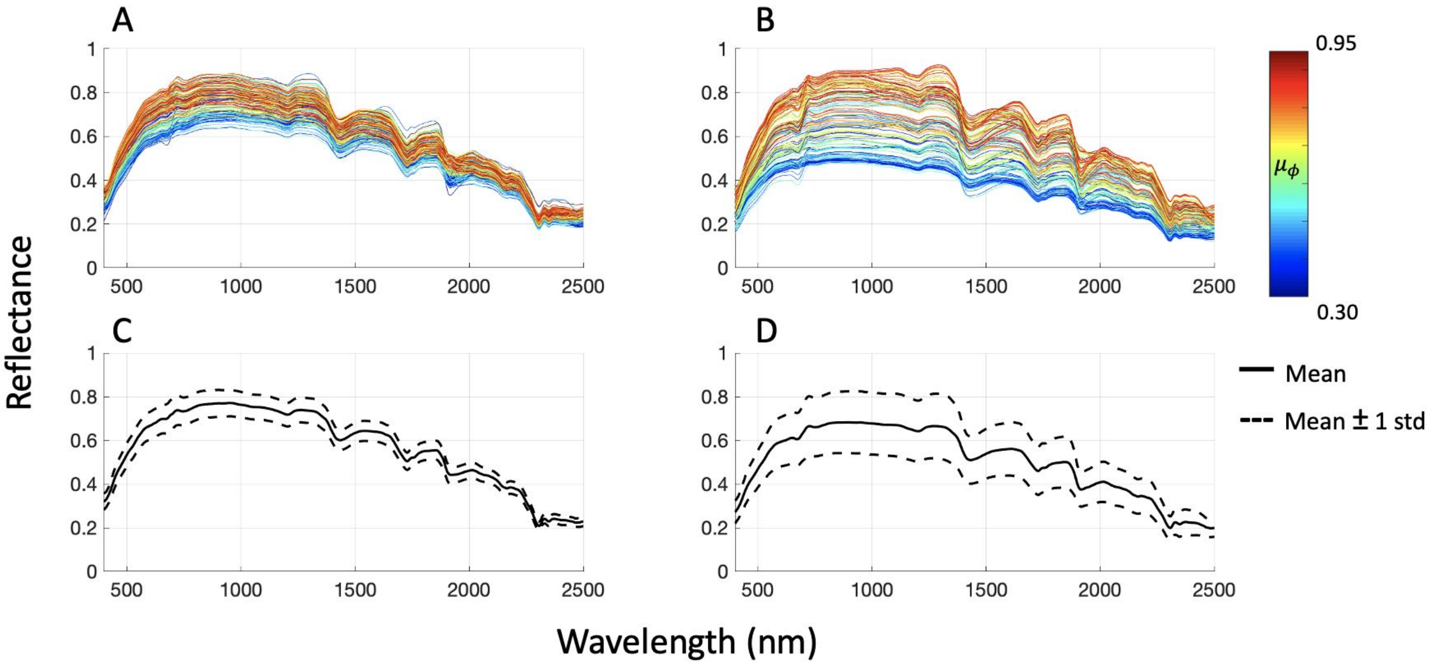


- Symmetric cone (Right-Cone) shape
- Relatively smooth surface
- Same surface material throughout
- Taller than its surrounding
- High resolution lidar available
- AVIRIS-NG radiances available

Empirical Evidence over Beckman Auditorium

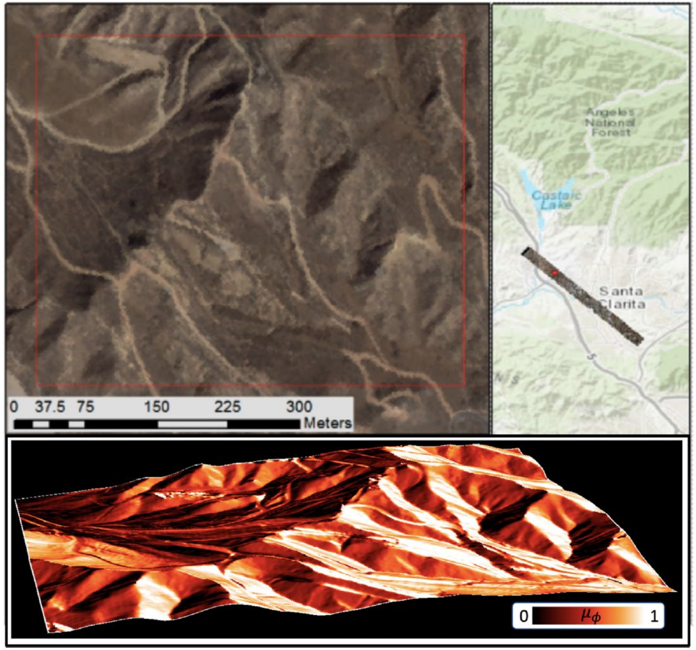


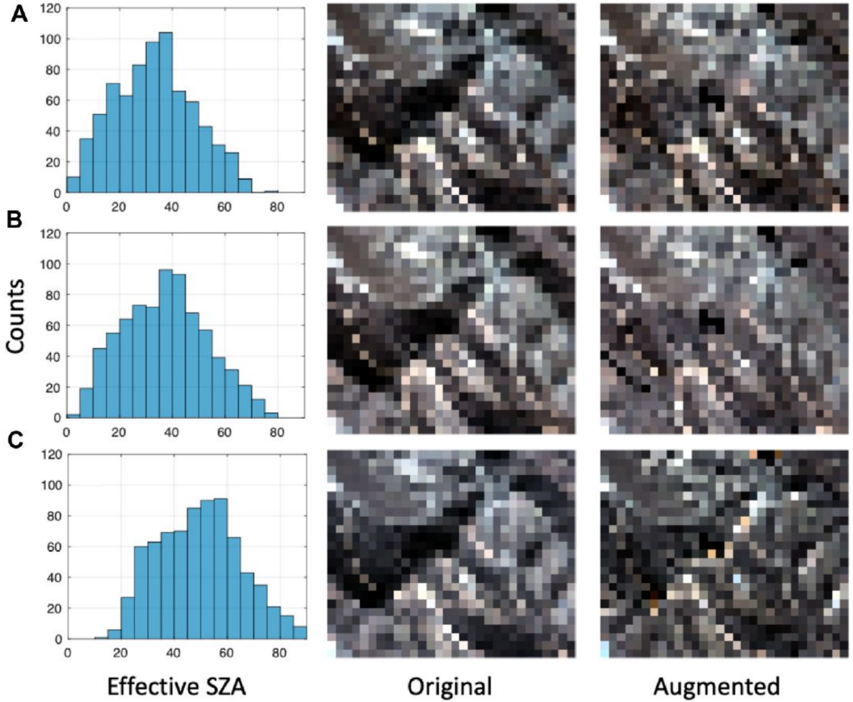
Error in Reflectance over Homogeneous Surface



Experiment with Temporal Repeats

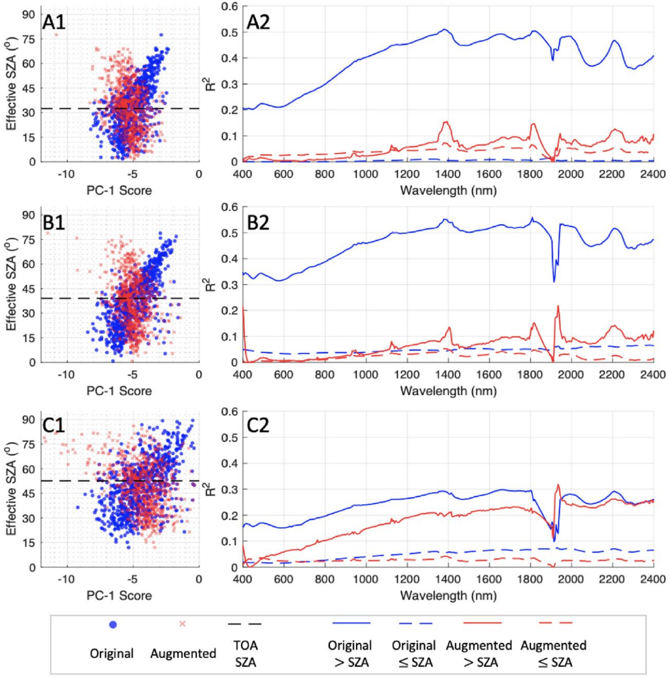
The Valencia Site



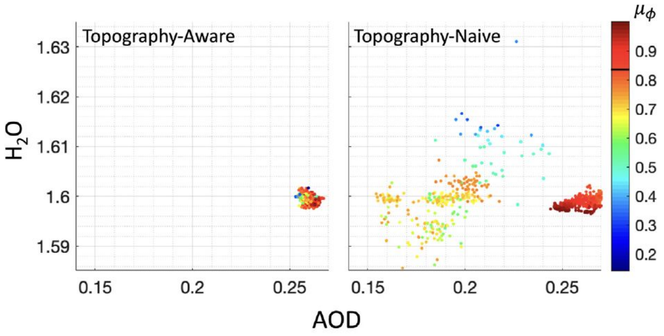


Results

Decorrelation of Reflectance from Topography

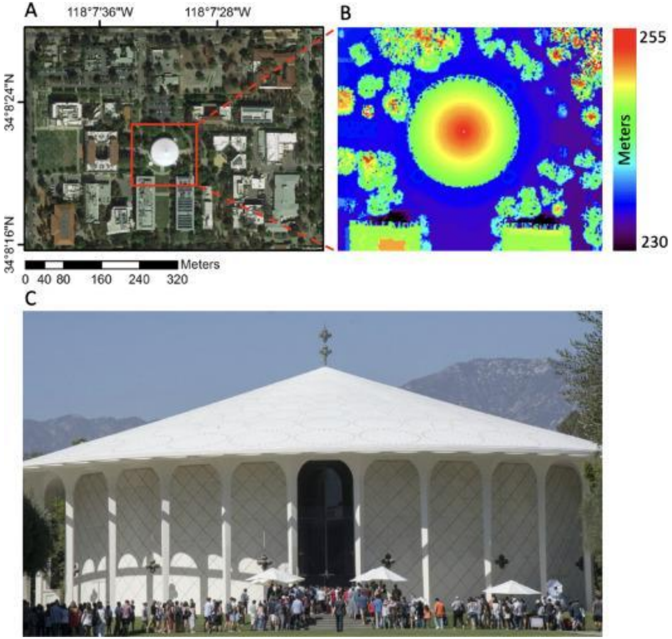


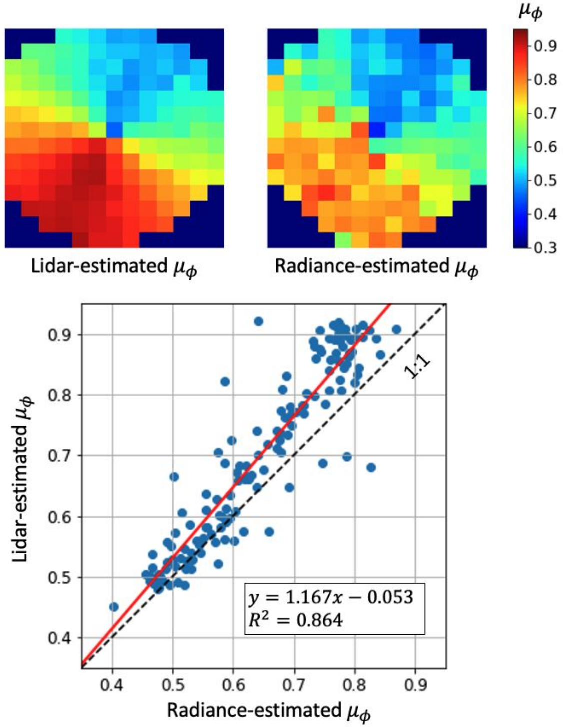
Smaller Errors in Atmosphere



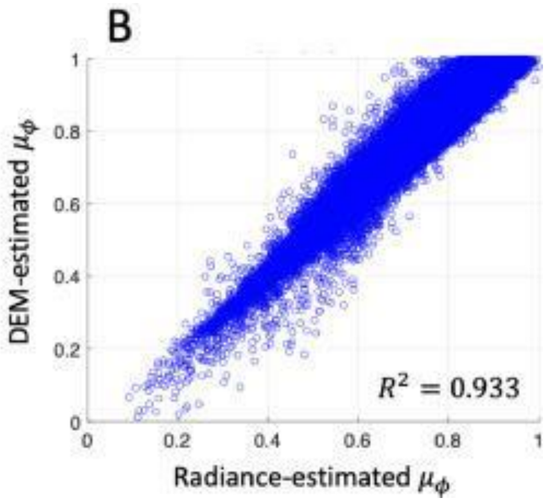
Carmon, Nimrod, et al. "Unified Topographic and Atmospheric Correction for Remote Imaging Spectroscopy." *Frontiers in Remote Sensing* 3 (2022): 916155.

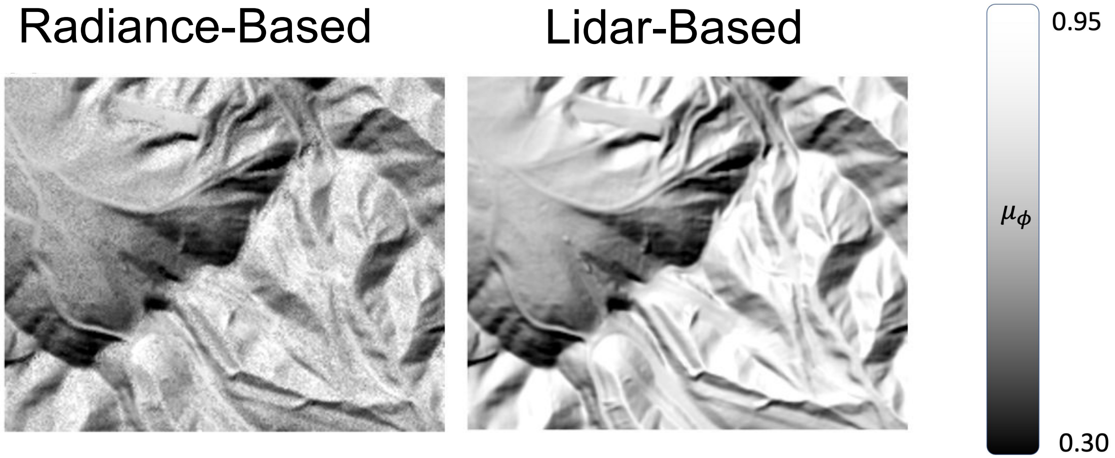
Retrieval of cos(i) from radiance





Estimating cos(i)





Carmon, Nimrod, et al. "Shape from spectra." *Remote Sensing of Environment* 288 (2023): 113497.

Case Study – Israeli Forest

Example with EMIT measurements

Experimental Design (ongoing)
1. Process EMIT L1B Radiance to 'intrinsic' surface reflectance using developed algorithm
2. Apply vegetation trait models on both standard L2A product and on intrinsic reflectance
3. Evaluate and compare performance, capture results in manuscript and submit

Short Term Next Steps

1. Implement PROSAIL algorithm into pipeline
2. Tie PROSAIL trait maps to fire event record from JNF
3. Estimate precursor vegetation traits and train a predictive model

Questions and Discussion

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

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Mixed Pixels – a Problem

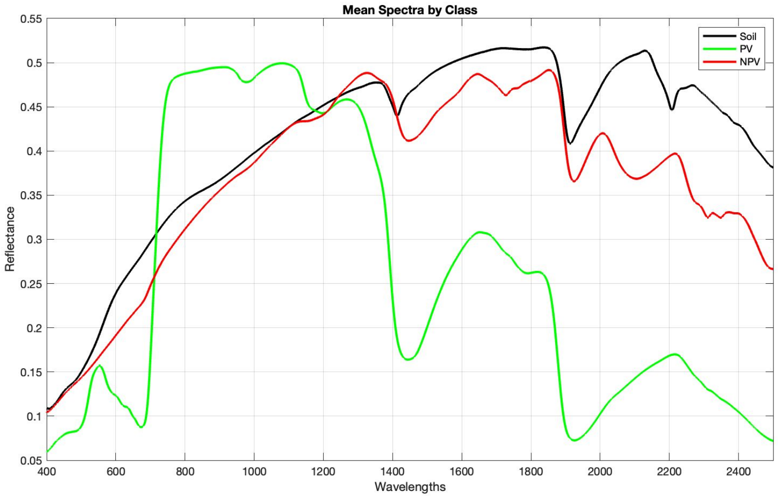
- Biogeophysical models simulate reflectance for a given endmember
- Remote-sensing pixels are usually a mixture of multiple endmembers
- Applying an endmember model on a mixture results in errors

The at-sensor signal for a given pixel arises from multiple type of surfaces: soil, green vegetation, dry vegetation
The different spectral signatures of the endmembers must be decomposed and retrieved individually to eliminate prediction errors
Traditional approaches first estimate the pixel-level reflectance, the "unmix" using linear methods

Our Solution

Dimension Reduction to Emphasize the Analysis of Mixtures (DREAMS)

- We implement a reflectance mixture model within the atmospheric correction routine
- We use dimension reduction (PCA) to formulate low-rank models of three endmembers (Soil, PV, NPV)
- We then optimize for their parameters within the atmospheric correction, simultaneously with endmember fractions and atmospheric variables
- This model can estimate both the endmember spectral signature and endmember fraction for each pixel in the image, directly from radiance



Capturing uncertainty due to DEM errors