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

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This document has been reviewed and determined not to contain export controlled technical data.
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
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

Radiance Measurement

“Apparent” Surface Reflectance

Determine Atmospheric Conditions (water, aerosols)

Topographic Correction

“Intrinsic” Surface Reflectance

Compensate for the effects of Topography

Applications

Calibration
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
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<tbody>
<tr>
<td>Top of atmosphere solar zenith angle</td>
<td></td>
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<tr>
<td>Effective solar zenith angle</td>
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<td>The normal vector to the surface</td>
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<tr>
<td>LOS</td>
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<td>Line of sight for a given pixel</td>
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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

\[ F_0: l_{\text{obs}} = l_p + \frac{e_g(0)}{1 - s \rho_s} t^\top \rho_s, \text{ where} \]
\[ e_g(0) = e_0 \mu_\theta \pi^{-1} (t^\top_{\text{dir}} + t^\top_{\text{diff}}). \]

Treats all pixels as flat

Aware

\[ F_1: l_{\text{obs}} = l_p + \frac{e_0 \pi^{-1} \mu_\phi t^\top_{\text{dir}} + e_0 \pi^{-1} \mu_\phi t^\top_{\text{diff}}}{1 - s \rho_s} \rho_s t^\top. \]

Dynamically incorporates topography
Topography Naïve vs. Topography Aware

Naïve

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

\[ e_g(0) = e_0 \mu_\theta \pi^{-1}(t^\downarrow_{dir} + t^\downarrow_{dif}). \]

Aware

\[ F_1: l_{obs} = l_p + \frac{e_0 \pi^{-1} \mu_\phi t^\downarrow_{dir} + e_0 \pi^{-1} \mu_\theta t^\downarrow_{dif}}{1 - s\rho_s} \rho_s t^\uparrow. \]
Relative Errors in Radiance
Homogeneous and Symmetric Target
Beckman Auditorium Roof

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Homogeneous and Symmetric Target

Beckman Auditorium Roof

- 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

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Experiment with Temporal Repeats

The Valencia Site
Results

Decorrelation of Reflectance from Topography


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Retrieval of $\cos(i)$ from radiance

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Estimating $\cos(i)$

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
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 types 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