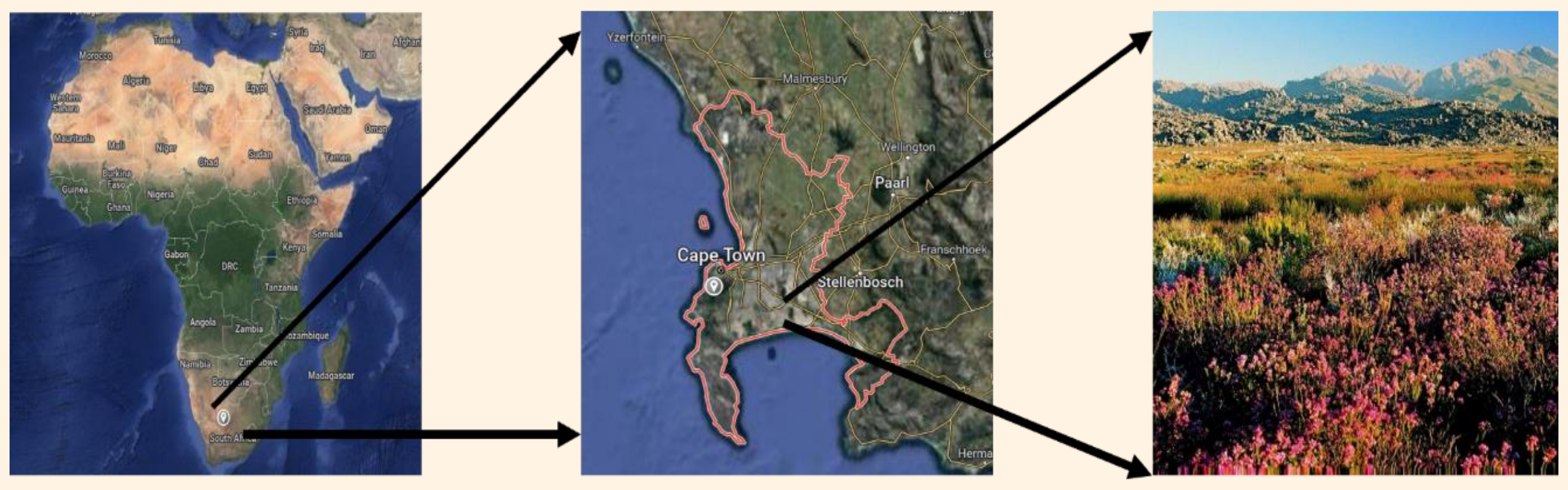
RadSCape: Radiative Transfer Simulation and Validation of the Dynamic Structural and Spectral Properties of the Vegetation of the Cape

Manisha Das Chaity & Jan van Aardt

Rochester Institute of Technology, Rochester, New York, United States

Problem Statement

- **The Greater Cape Floristic Region (GCFR), a mega-diverse Global Biodiversity Hotspot, is threatened by**
  - Habitat loss
  - Habitat fragmentation
  - Altered fire regimes
  - Invasive species
  - Climate change



Images courtesy of Google Earth Engine and Wikipedia

- **Threat management and mitigation requires regularly-updated, spatially-explicit information for the entire region, currently only feasible using satellite remote sensing [1,2,3]**
- **Detecting change in both spectral and structural terms remains challenging, especially for a region like Fynbos (>1300 plant species) [4]**

What We Propose

- **Improve remote measurement & monitoring via a combination of**

Fynbos trait measurements + Radiative transfer modeling in a biophysically- and physics-robust simulation environment

Validated using high spectral resolution and LiDAR remote sensing NASA data from the BioSCape airborne campaigns

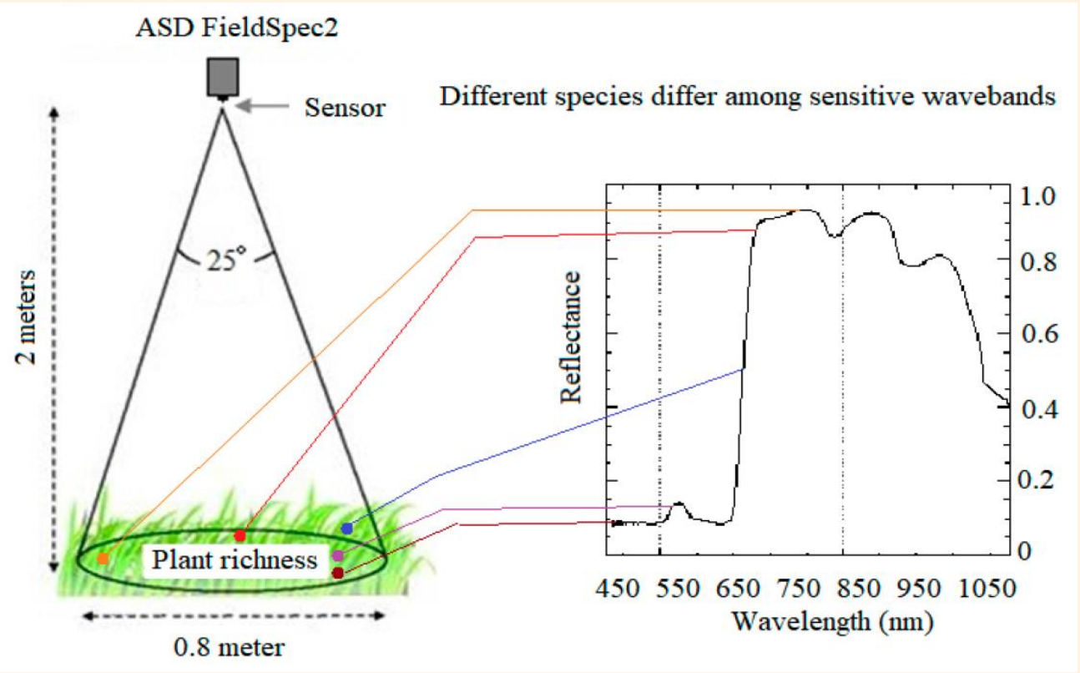
- **A mechanistic linking of structure/spectra-to-traits and an ability to track biodiversity as a function of post-fire recovery**
  - ❖ To improve our understanding of light interactions within the context of fynbos biophysical traits
  - ❖ To inform innovative uses of the remote sensing data for such highly diverse ecosystems at all scales, from airborne to satellite levels

Research Questions

1. How do leaf and canopy traits, both spectral and structural, vary in space and time, in the highly biodiverse GCFR region?
2. How can the coupling of in situ and airborne imaging spectroscopy and LiDAR measurements of fynbos be used to
   a) Improve trait retrievals…
   b) …for scaling to canopy, plot, and landscape levels, using remote sensing data?
3. Can integration of imaging spectroscopy, LiDAR structural retrievals, and radiative transfer modeling provide a more mechanistic approach for remote sensing of post-fire recovery status, in terms of structural and species diversity?
4. Can Objectives (1-3) inform our ability to better detect biodiversity and lead to the definition and refinement of a spectral/structure-trait sensing system in terms of ideal
   - Wavelengths
   - Band passes
   - Ground sampling distance (GSD)
   - Temporal resolution
   - Required structural sensing information?

Methods

1. **Field Sampling**
2. **Digital Imaging and Remote Sensing Image Generation (DIRSIG) Simulation**
3. **Remote Sensing Data**



https://doi.org/10.3390/rs11050588

Field Sampling

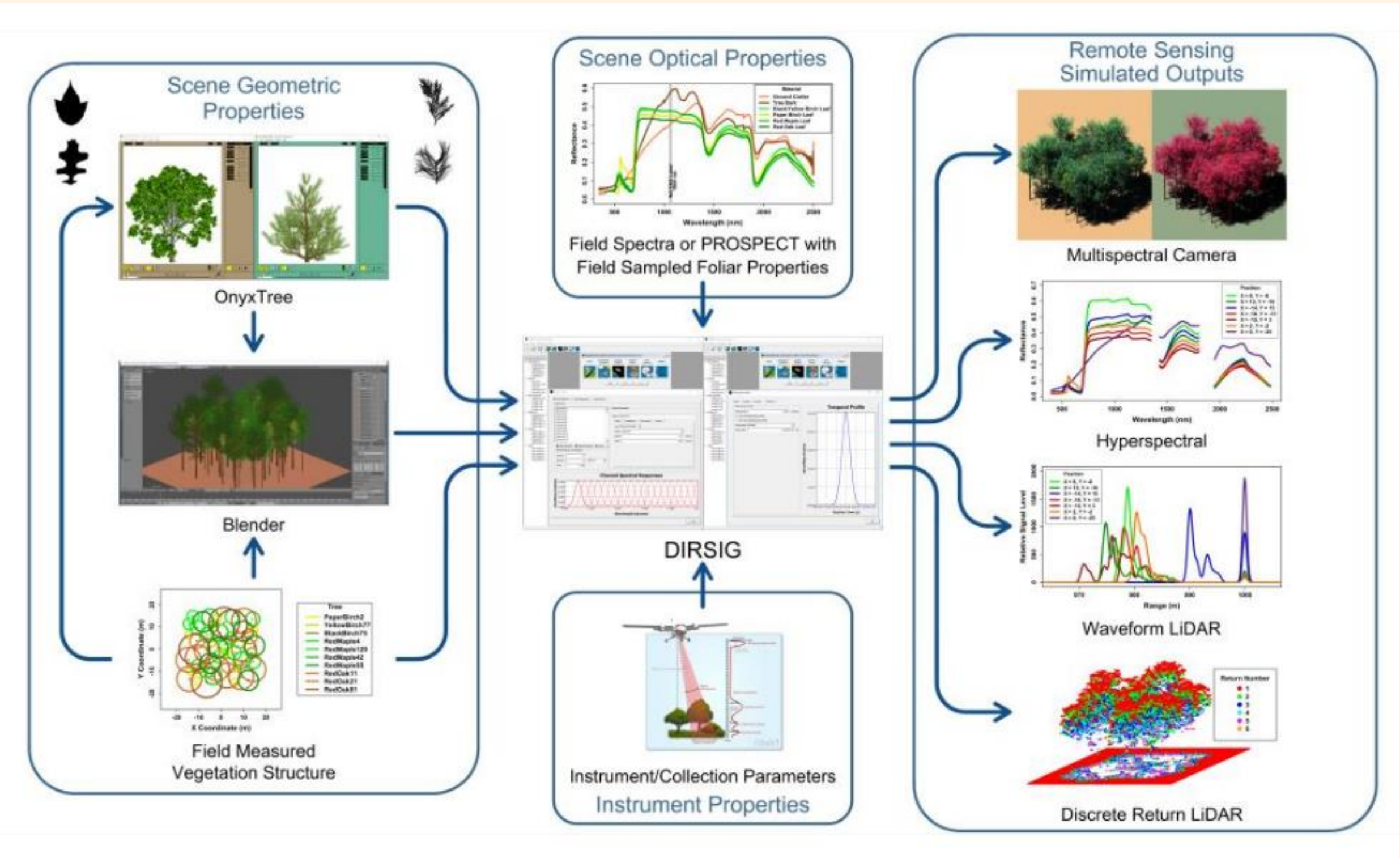
Area: Various BioSCape regions-of-interest
- To capture variability in fynbos species composition and structure for virtual scene development
- Level and status of post-fire recovery status, based on fire history

Dimension: 5-7 plots per study area, with most plots @ 50 m^2, 5m x 5m releves

Instruments:
- Spectral measurements of leaf reflectance (ASD)
- TLS data will be collected using a UMass Boston/RIT developed LiDAR scanner and iPad scanning

DIRSIG Simulation

DIRSIG is a physics-based, first principles, radiometric modeling environment for the creation of synthetic remote sensing imagery that is radiometrically, geometrically, and temporally accurate



(***Left***) A diagrammatic representation of the DIRSIG workflow; (***Top***) a representation of complex, grass-type vegetation (***top-left***) and a Harvard Forest scene (***top-right***) to show potential scene complexity and fidelity

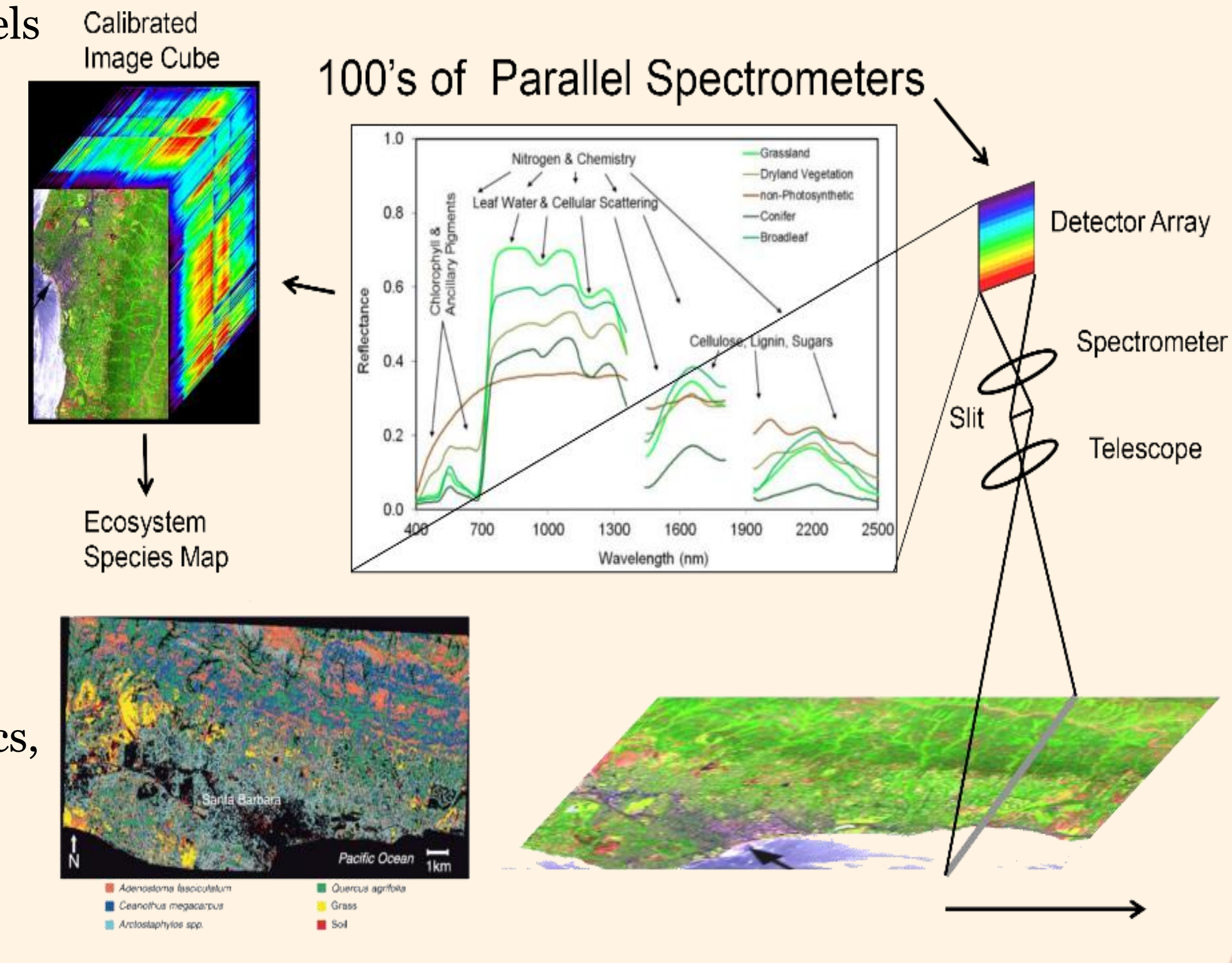
Remote Sensing Data

AVIRIS-NG: 5-10m pixels
LVIS: 5-20m footprints

i) To validate the simulation scene

ii) To extend fine-scale field-level spectral or structural and trait observations to landscape levels

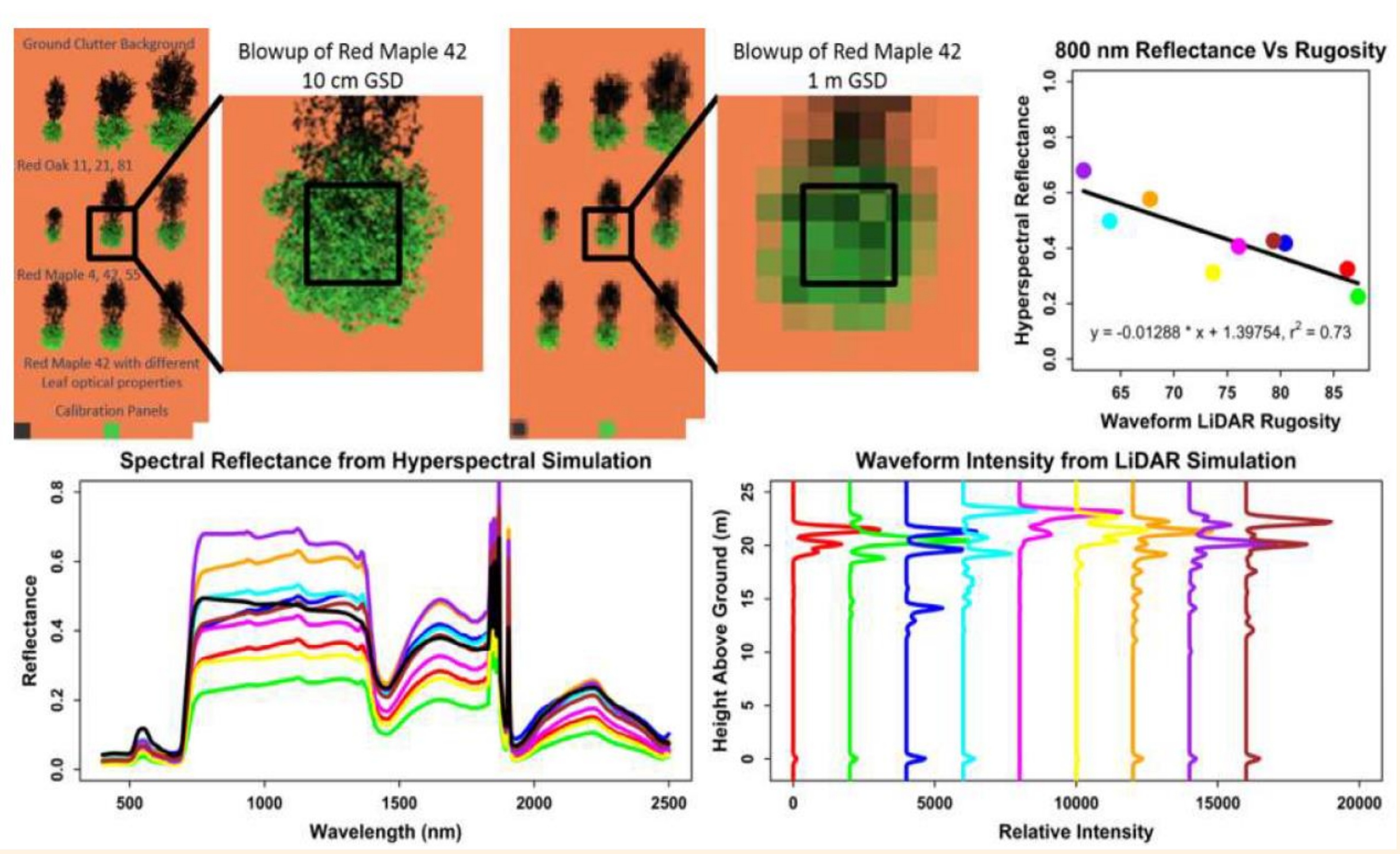
iii) To develop initial system parameters specs, validated against observed airborne data sets



https://avirisng.jpl.nasa.gov/aviris-ng.html

Expected Results

- ☐ A simple tree farm scene is shown (***top-left***)
- ☐ This allows for the spectral reflectance to be plotted on a per-pixel basis, for a Red Maple in this case (***top-center*** & ***bottom-left***)
- ☐ Corresponding LiDAR waveforms for the same area also can be extracted (***bottom-right***). These waveforms illustrate the structural differences within the canopy, where some waveforms are more complex than others
- ☐ Reflectance at 800 nm vs. rugosity is shown as a demonstration of relating LiDAR-based structure to imaging spectrometer data (***top-right***)



In short, we can use such simulations to answer questions related to spectral-structural trait interactions, scaling, and system development

Acknowledgements

NASA ROSES Award #80NSSC22K0831

References

1. Moncrieff, G. R. Locating and Dating Land Cover Change Events in the Renosterveld, a Critically Endangered Shrubland Ecosystem. Remote Sensing 13, 834 (2021).
2. Ntshanga, N. K., Procheş, S. & Slingsby, J. A. Assessing the threat of landscape transformation and habitat fragmentation in a global biodiversity hotspot. Austral Ecol. n/a, (2021).
3. Skowno, A.L., Jewitt, D. and Slingsby, J.A., 2021. Rates and patterns of habitat loss across South Africa's vegetation biomes. South African Journal of Science, 117(1-2), pp.1-5
4. Slingsby, J. A. et al. The assembly and function of Cape plant communities in a changing world. in Fynbos (eds. Allsopp, N., Colville, J. F. & Verboom, G. A.) 200–223.
5. DIRSIG5: Next-Generation Remote Sensing Data and Image Simulation Framework Adam A. Goodenough and Scott D. Brown.

RIT | College of Science
Chester F. Carlson Center for Imaging Science