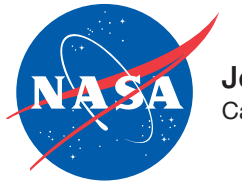

Jet Propulsion Laboratory
California Institute of Technology

A Citrus Census

With Discriminative Representations for Multiple Endmember Spectral Mixture Analysis

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Agenda

1. Introduce a new application: Mapping residential citrus

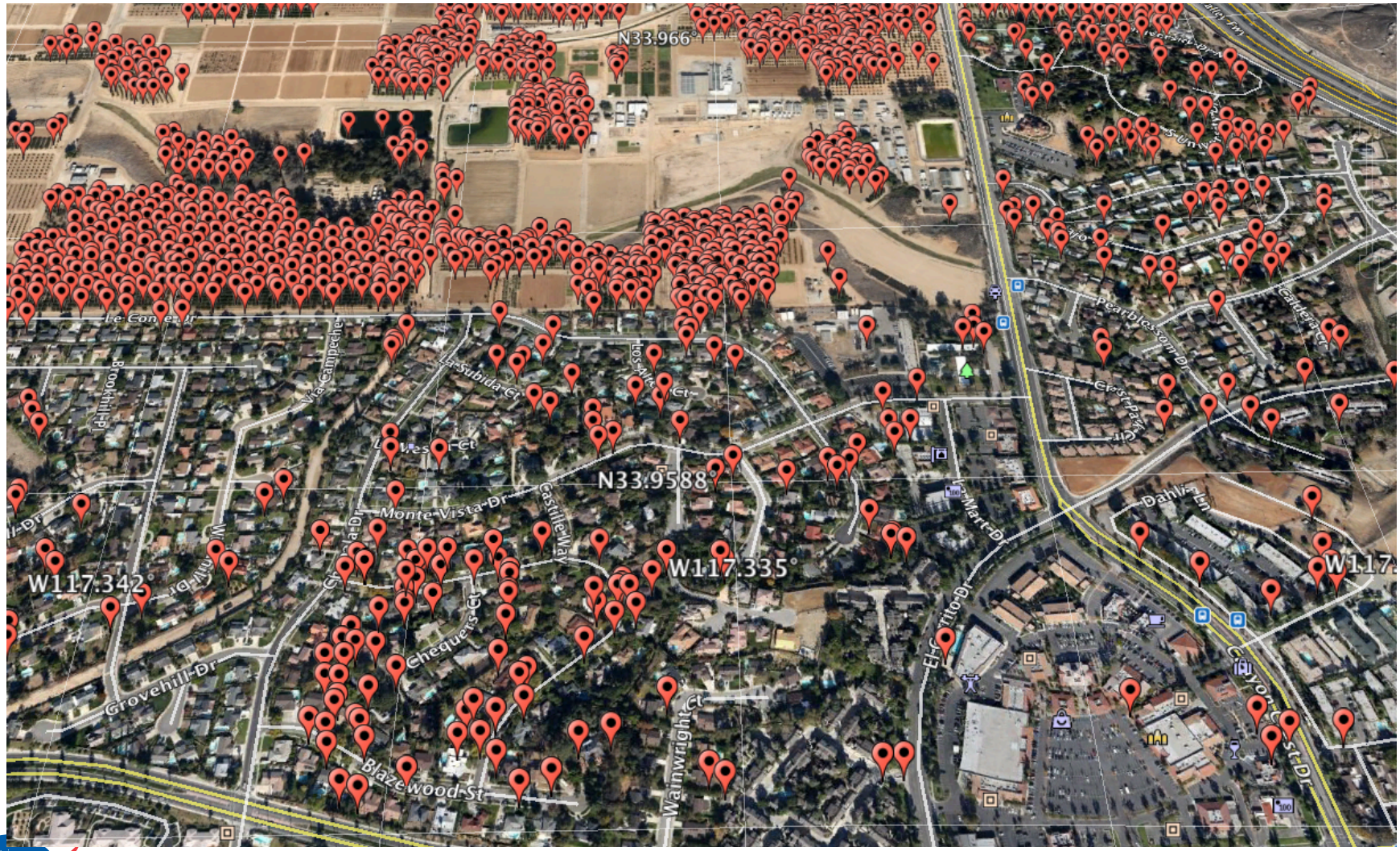
2. Describe our MESMA preprocessing: Multiclass LDA

Motivation

Huanglongbing (HLB) costs hundreds of millions of dollars in damages to Florida and Texas orchards.

Early detection in California is critical to an effective response, but 50% of citrus is outside commercial groves

Mapping concept



Mapping concept

Sponsored by California Citrus Research Board

AVIRIS-C flew over LA citrus hotspots (~20 flightlines)

Aim to detect and identify individual plants

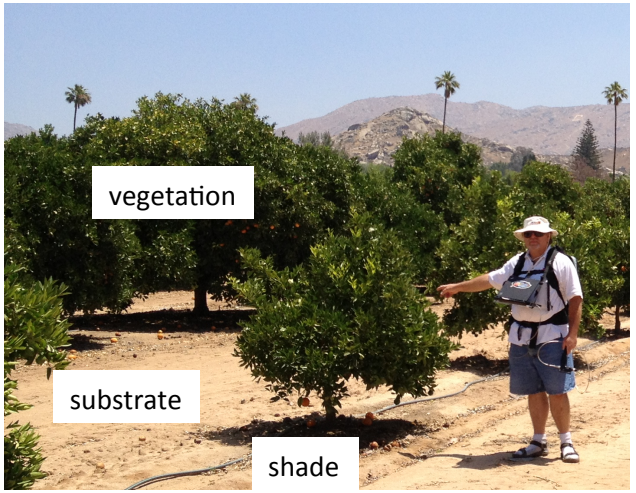
Challenges:

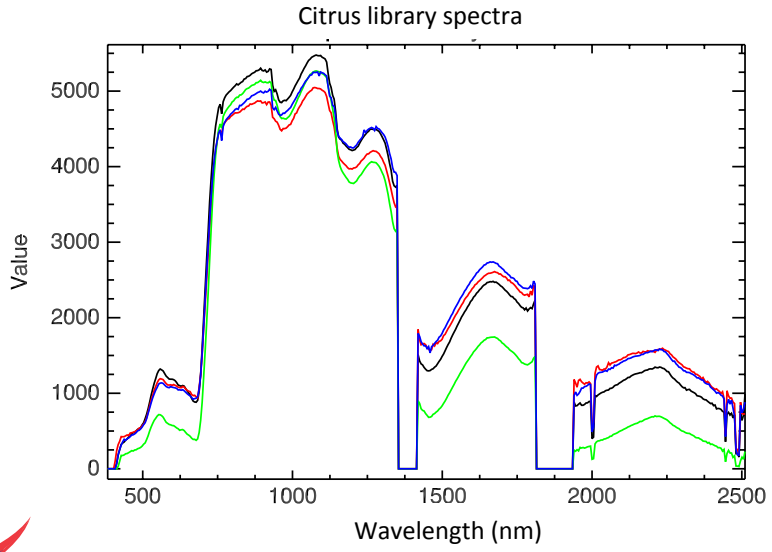
- Diverse species in urban environment (one vs. many classification)
- Complex illumination and substrate

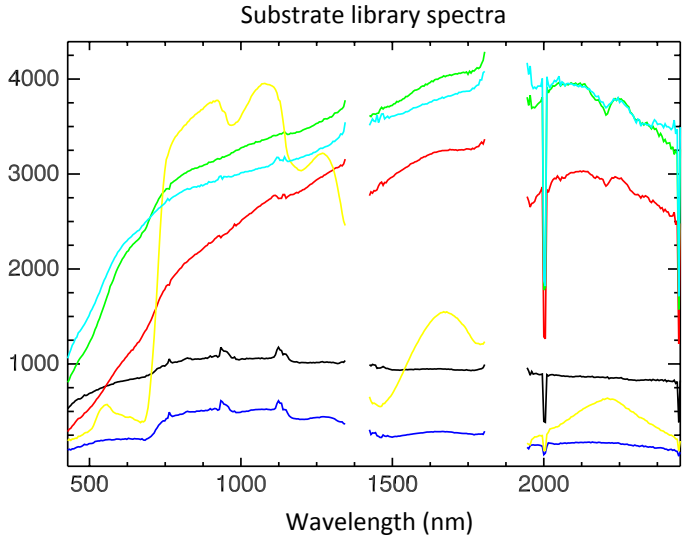
Our spectral mixture model

Each spectrum is a combination of three MESMA components:

1. Vegetation
2. Substrate
3. Shade (photometric)



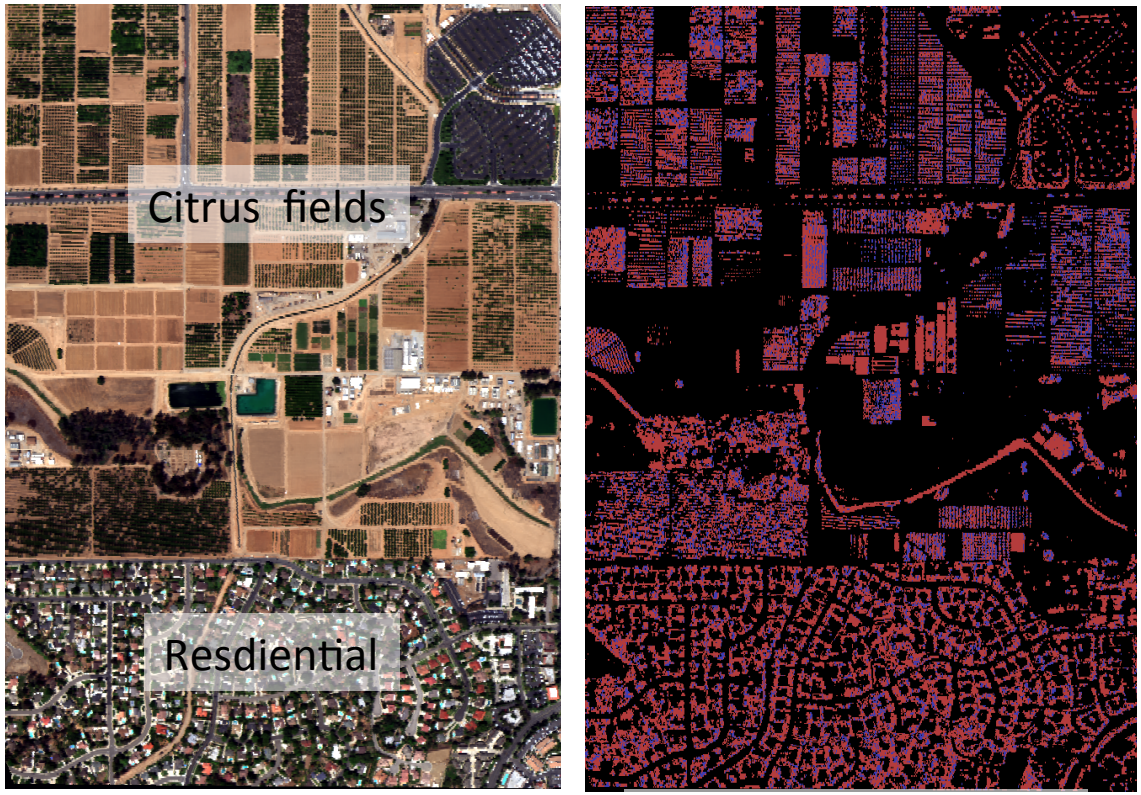




Initial result for AVIRIS-C data

Original UCR scene

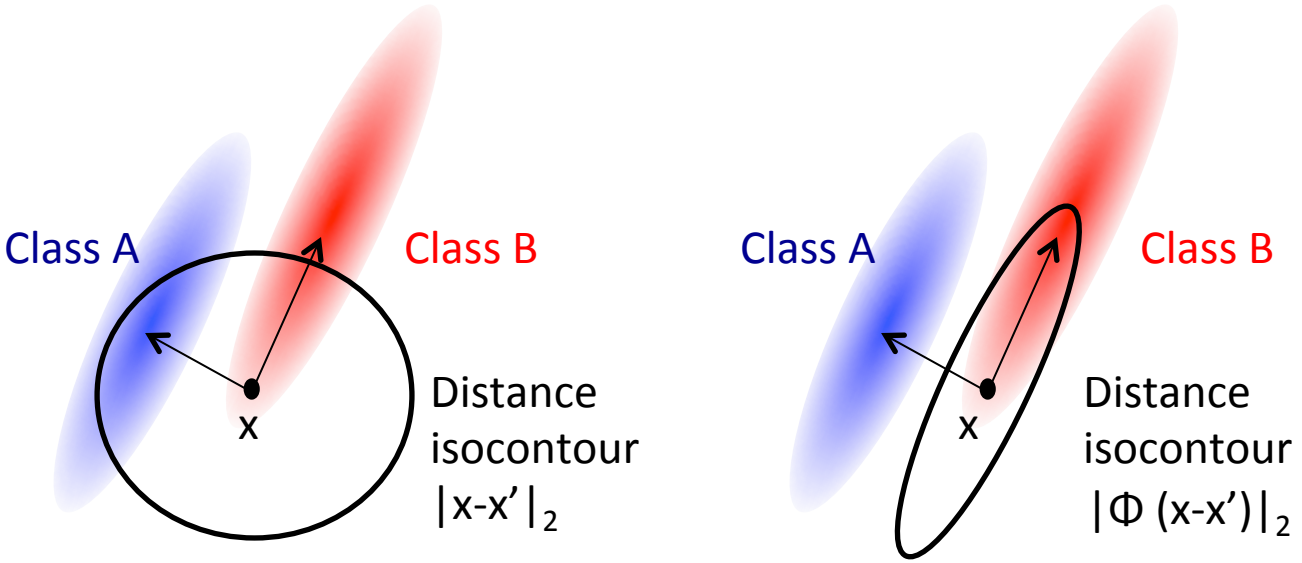
MESMA (library via CoB)



Citrus Non-citrus

Non-isotropic distance metrics

- Standard least-squares solutions use an *isotropic* error function (all bands weighted equally)
- However, errors are correlated due to structure in noise and class distributions
- Can we capture this intuition to improve performance?



Multiclass Discriminants

- Original idea from Fisher [1936],
- Generalized by Rao [1948]
- Calculates a linear projection maximizing class separation

Within-class scatter

$$\hat{\Sigma}_w = S_1 + \cdots + S_n = \sum_{i=1}^{n} \sum_{\mathbf{x} \in c_i} (\mathbf{x} - \bar{\mathbf{x}}_i)(\mathbf{x} - \bar{\mathbf{x}}_i)'$$

Between-class scatter

$$\hat{\Sigma}_b = \sum_{i=1}^{n} m_i (\bar{\mathbf{x}}_i - \bar{\mathbf{x}})(\bar{\mathbf{x}}_i - \bar{\mathbf{x}})'$$

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Between-class scatter

$$\hat{\Sigma}_b = \sum_{i=1}^{n} m_i (\bar{\mathbf{x}}_i - \bar{\mathbf{x}})(\bar{\mathbf{x}}_i - \bar{\mathbf{x}})'$$

Find Φ to maximize

$$\mathcal{J}(\Phi) = \frac{\left|\Phi^T \hat{\Sigma}_b \Phi\right|}{\left|\Phi^T \hat{\Sigma}_w \Phi\right|}$$

by solving

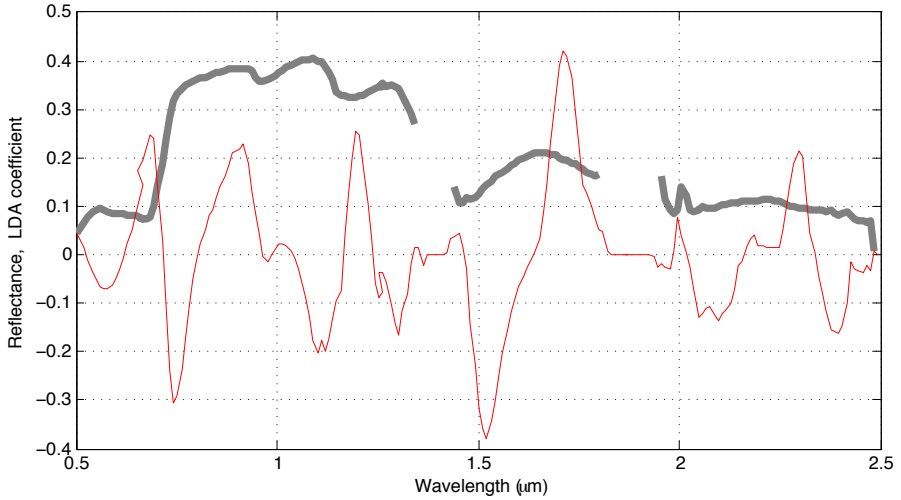
$$\hat{\Sigma}_b \Phi = \lambda \hat{\Sigma}_w \Phi$$

Procedure

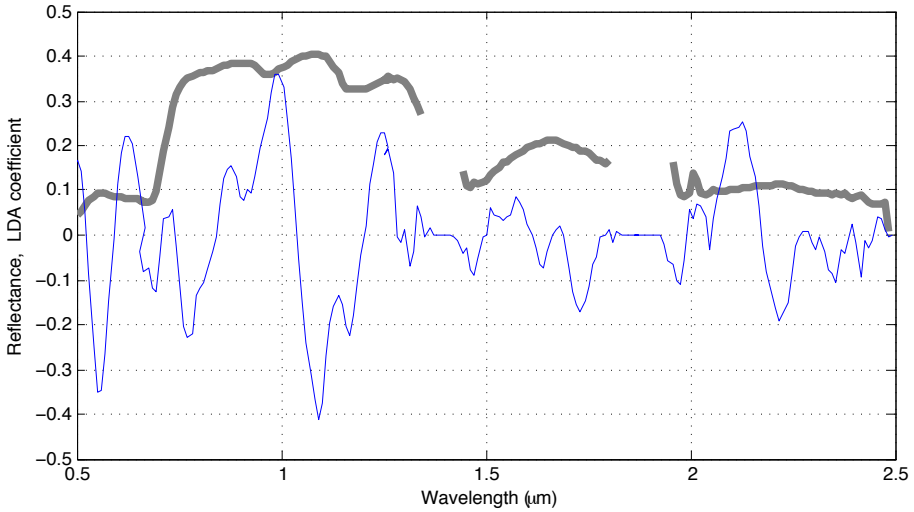
- Collect a training set of 30 canopies
- Learn the 10D linear projection to best separate distinct plants
- Species-specific projections also possible

Example labels

Projection for first dimension Φ_1



Projection for second dimension Φ_1

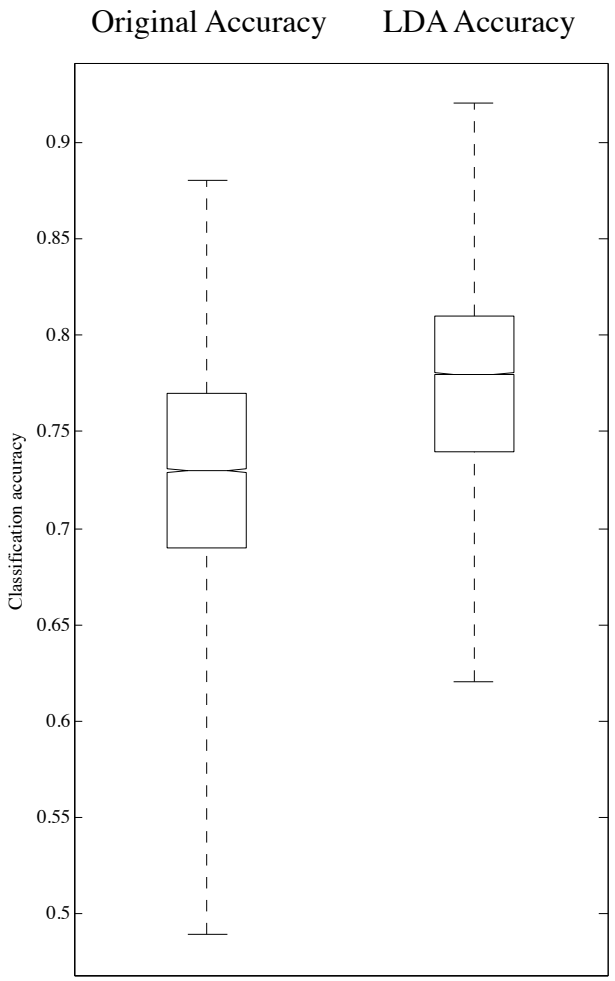


Simulation

Simulated mixtures of citrus and noncitrus spectra with substrate

Unmixed these spectra using a library randomly decimated by 90%

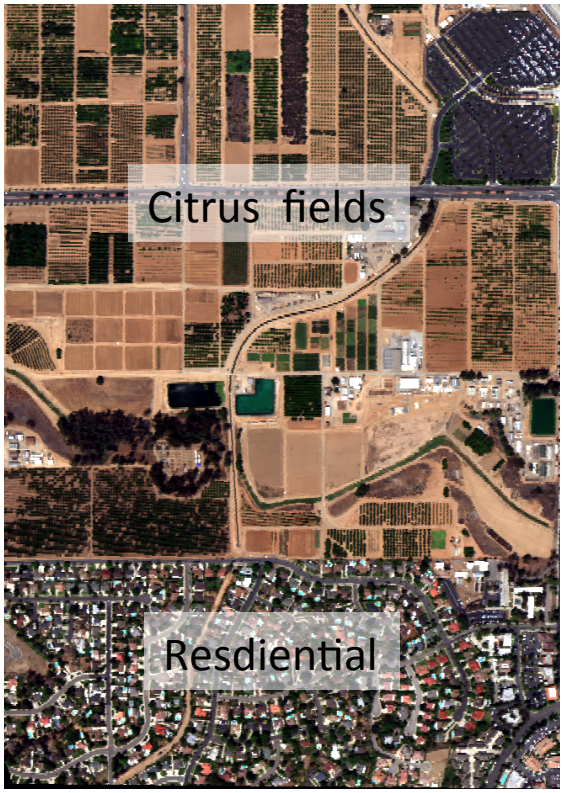
Premultiplication by LDA transform gives a modest but statistically-significant improvement



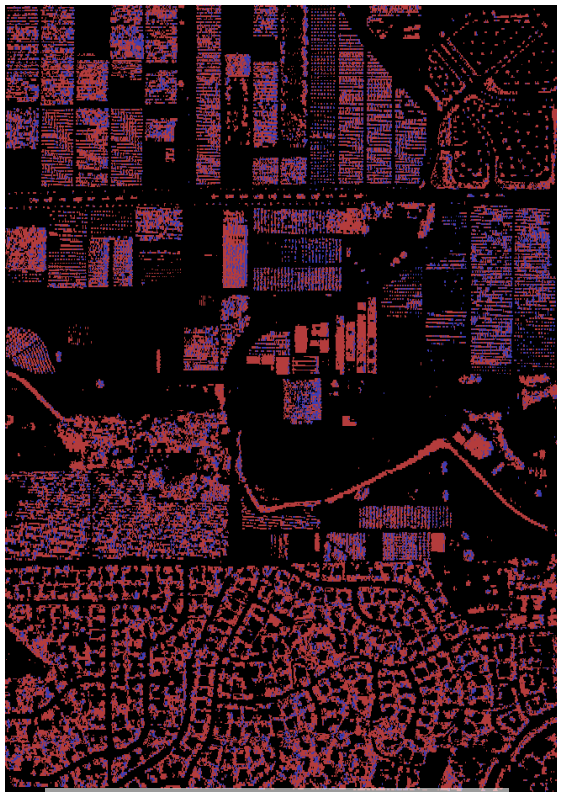
Impact of MDA (AVIRIS-C)

In practice the improvement is significant

Original scene

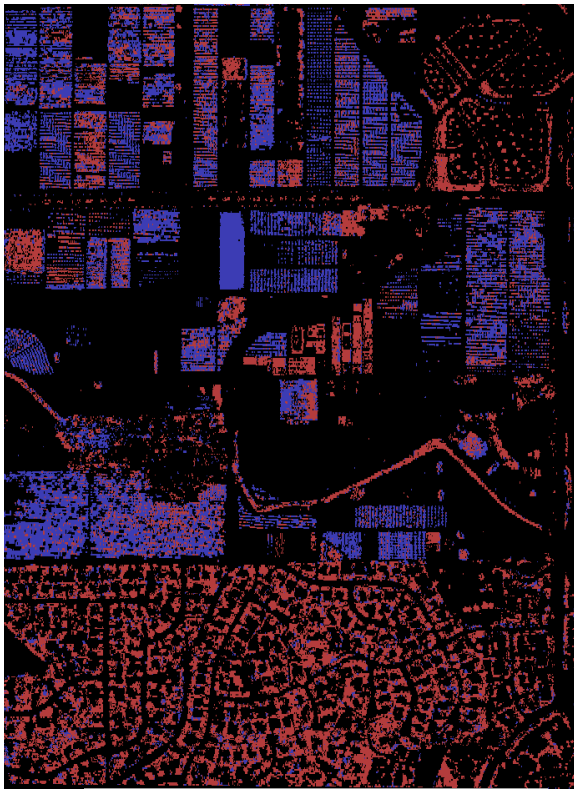


MESMA (library via CoB)



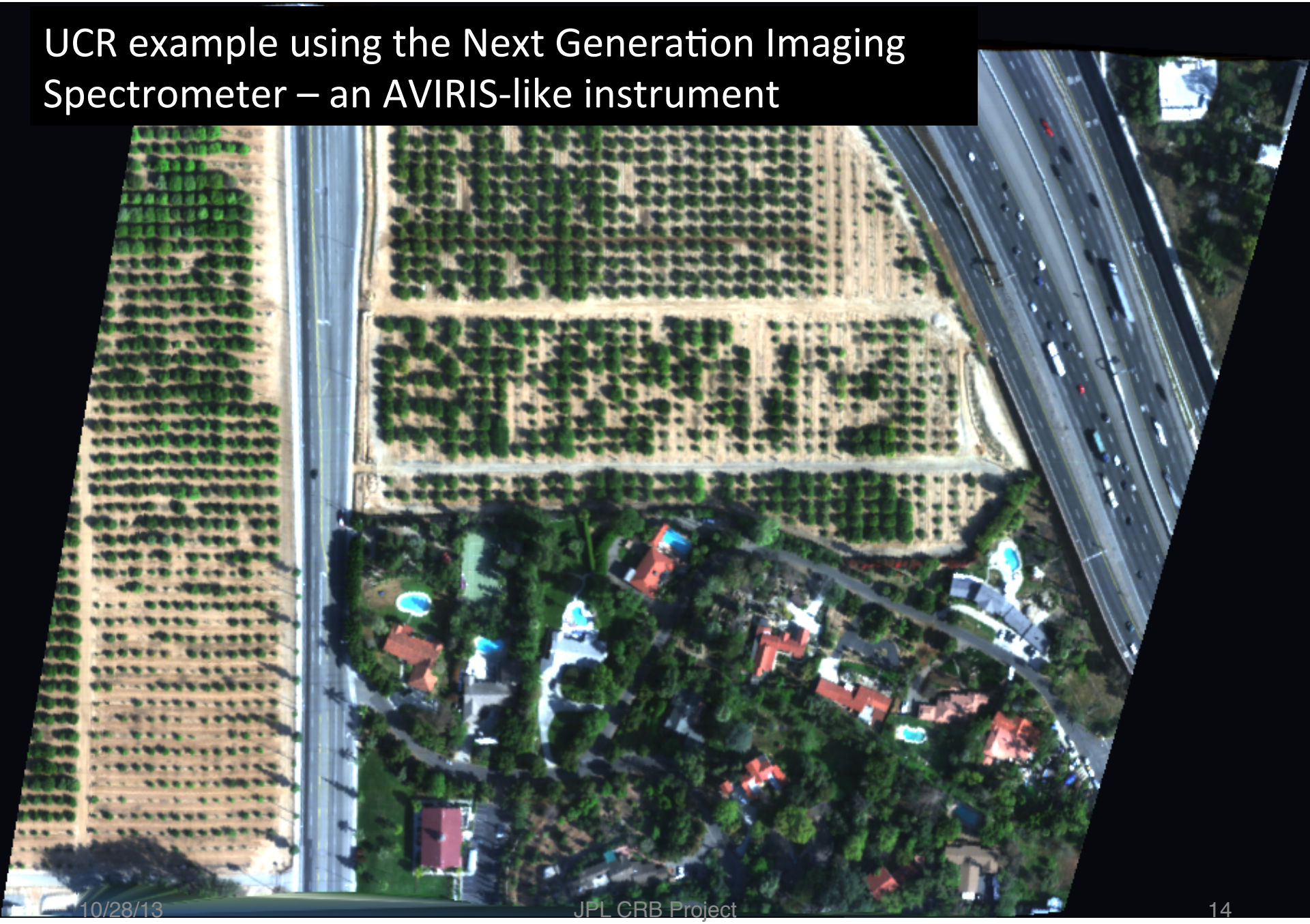
Citrus Non-citrus

With MDA pre-transform



Citrus Non-citrus

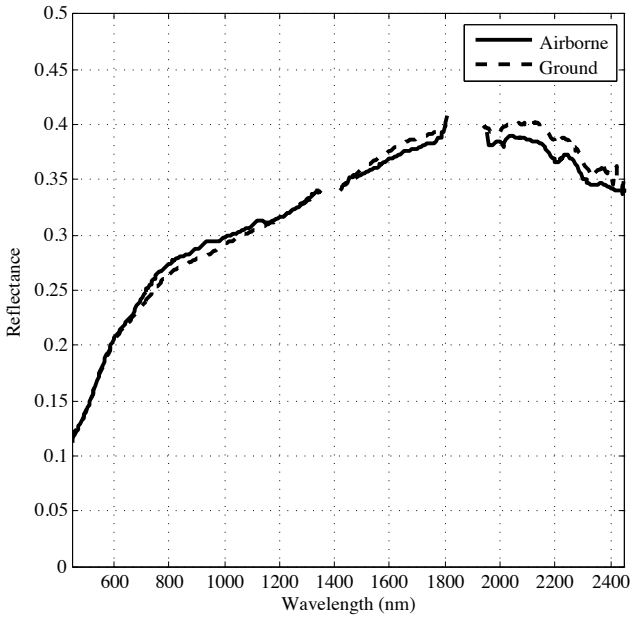
UCR example using the Next Generation Imaging Spectrometer – an AVIRIS-like instrument



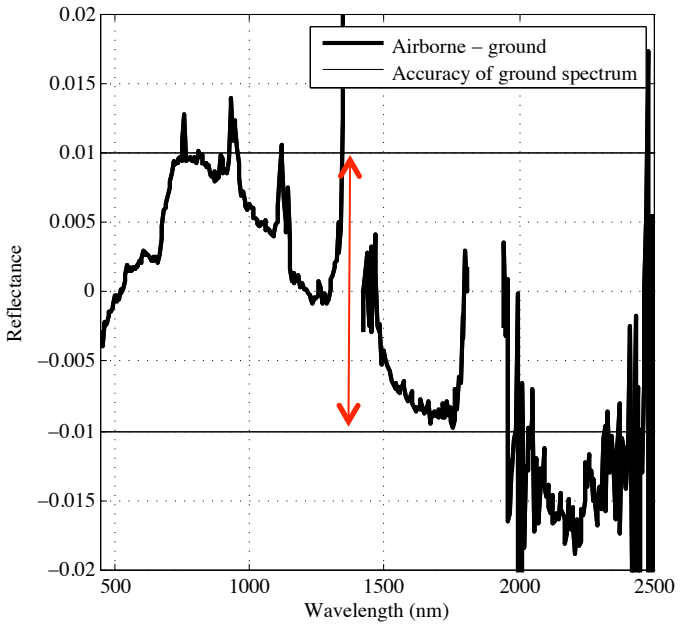
Reflectance correction using in situ spectra

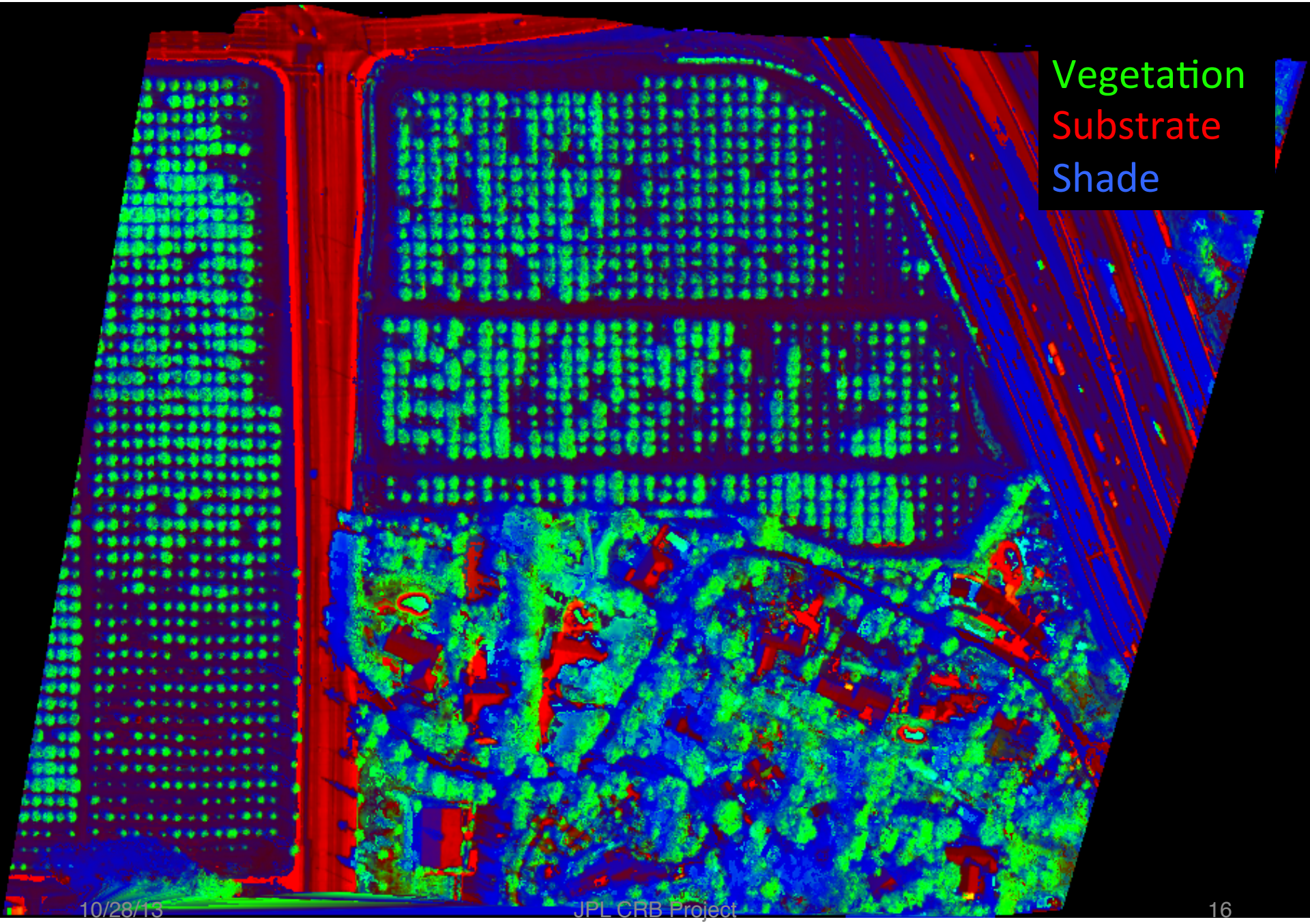
In situ measurement

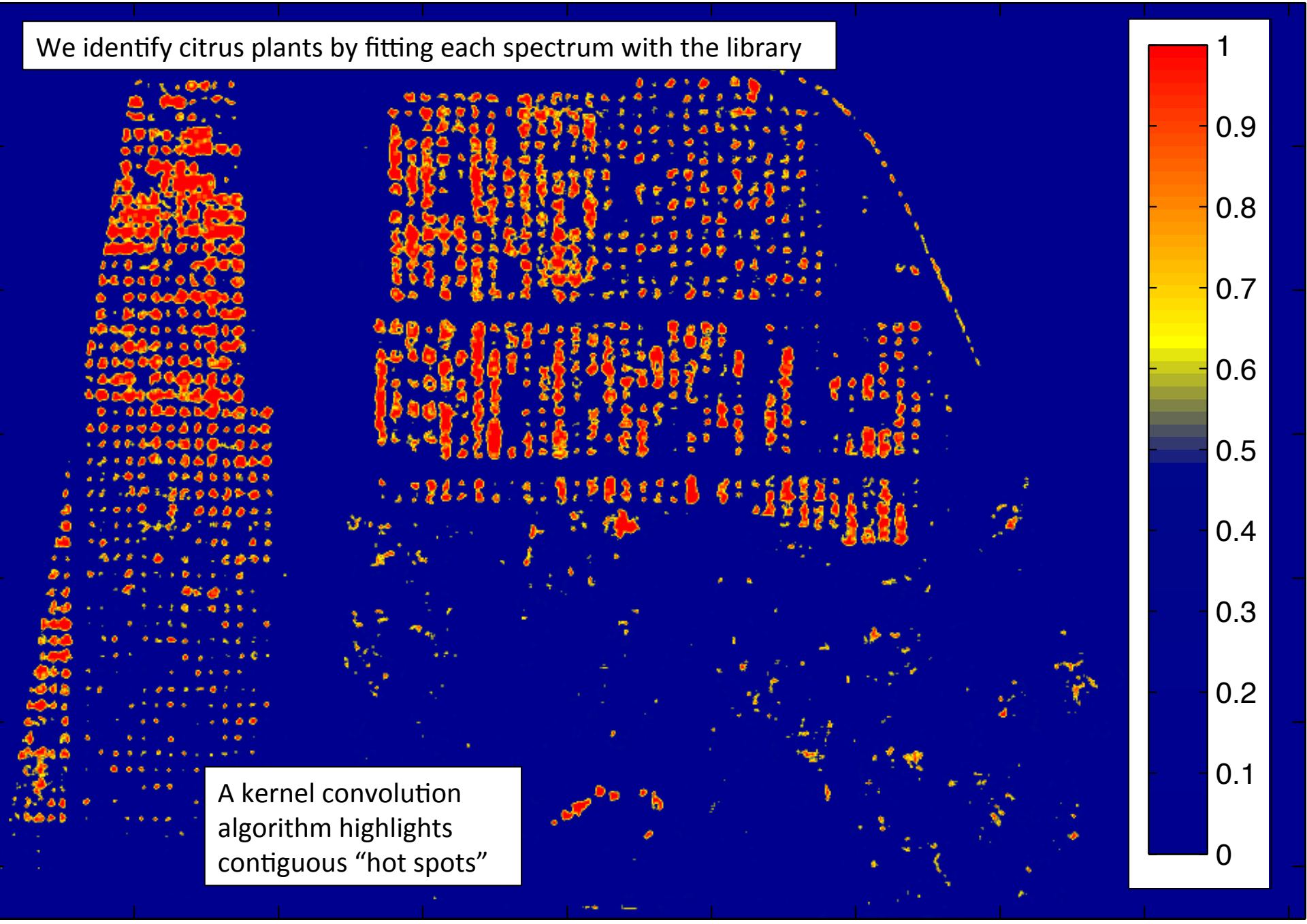
Field 18 road

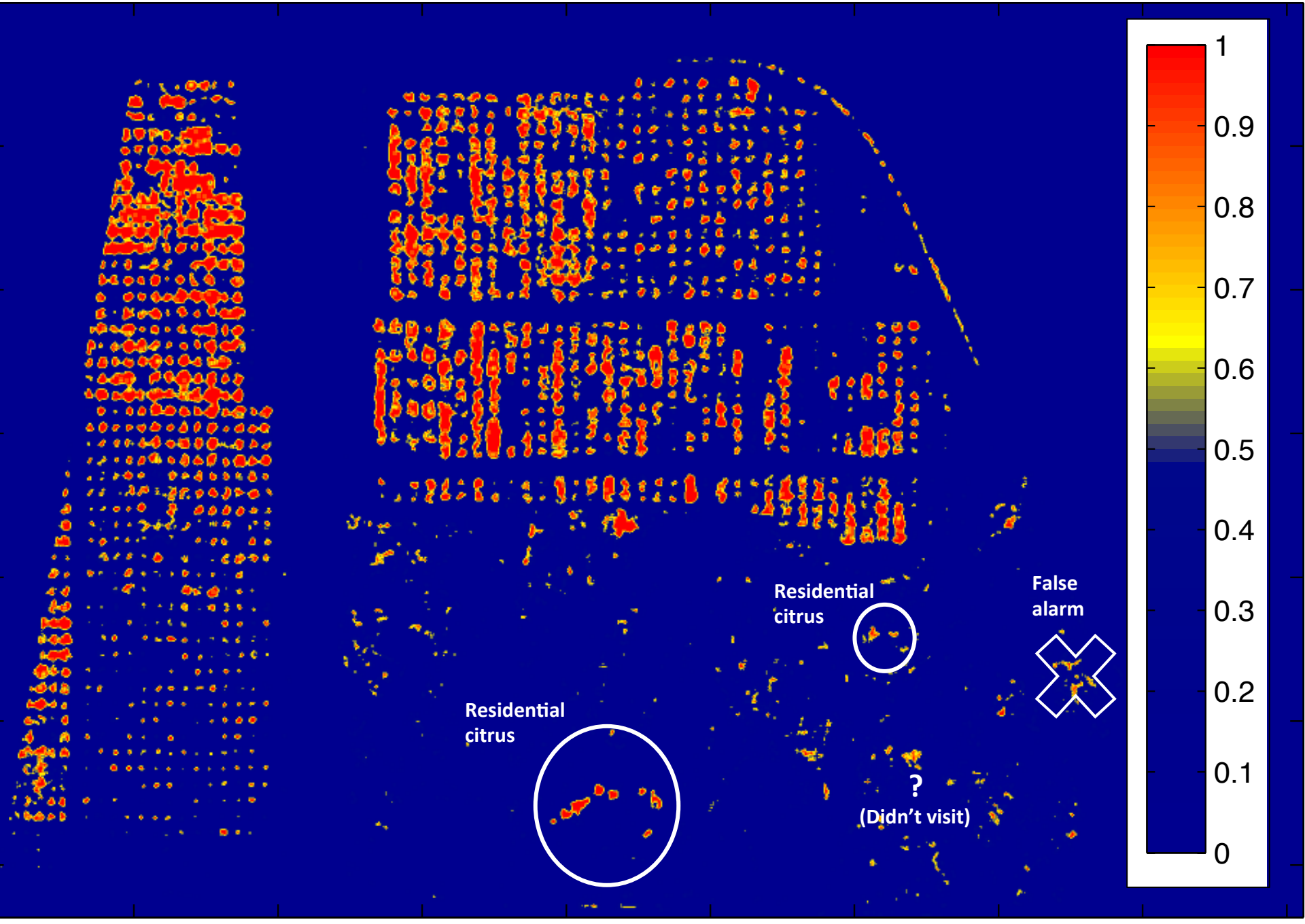


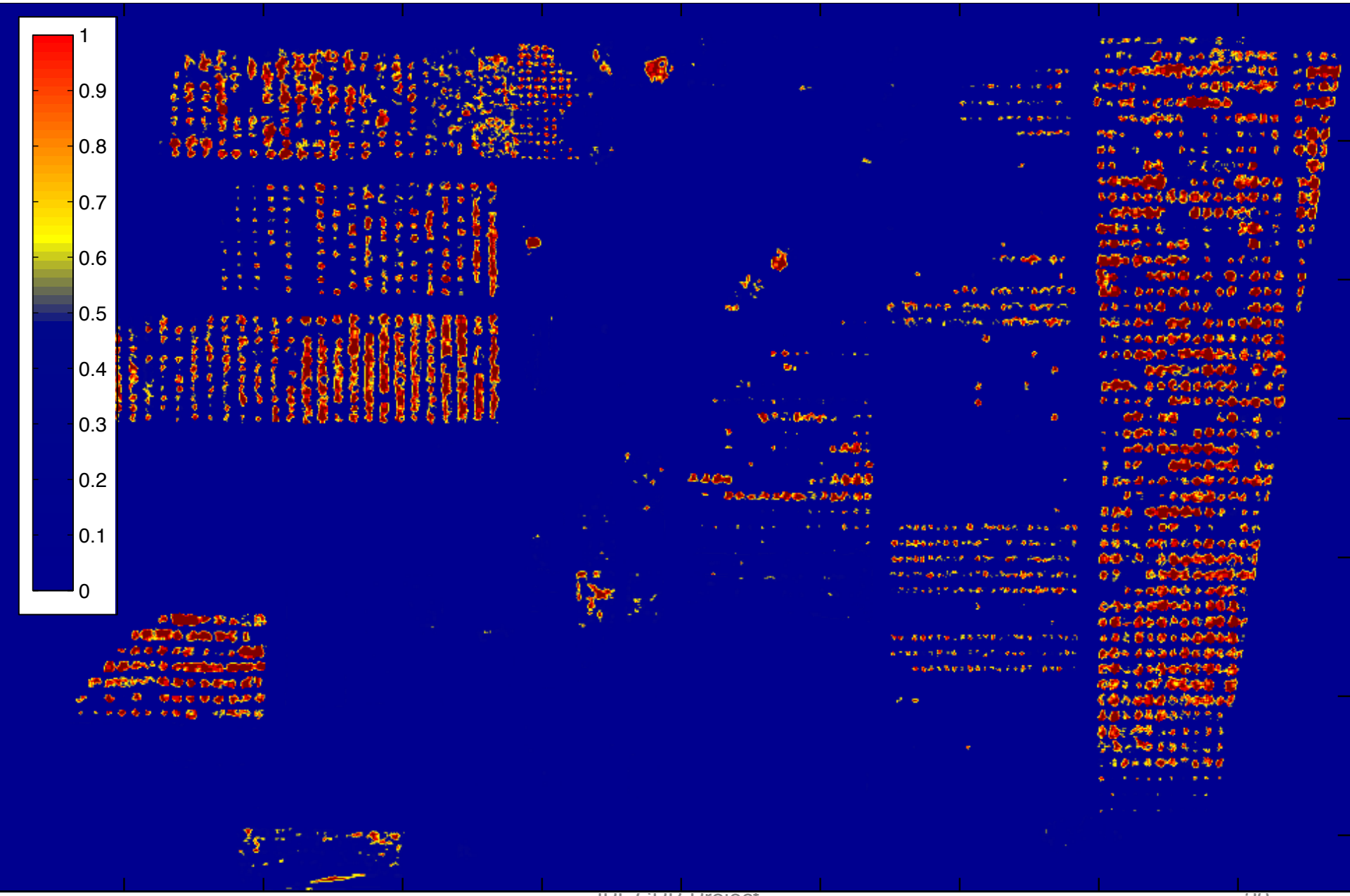
Agreement, and in situ radiometric accuracy

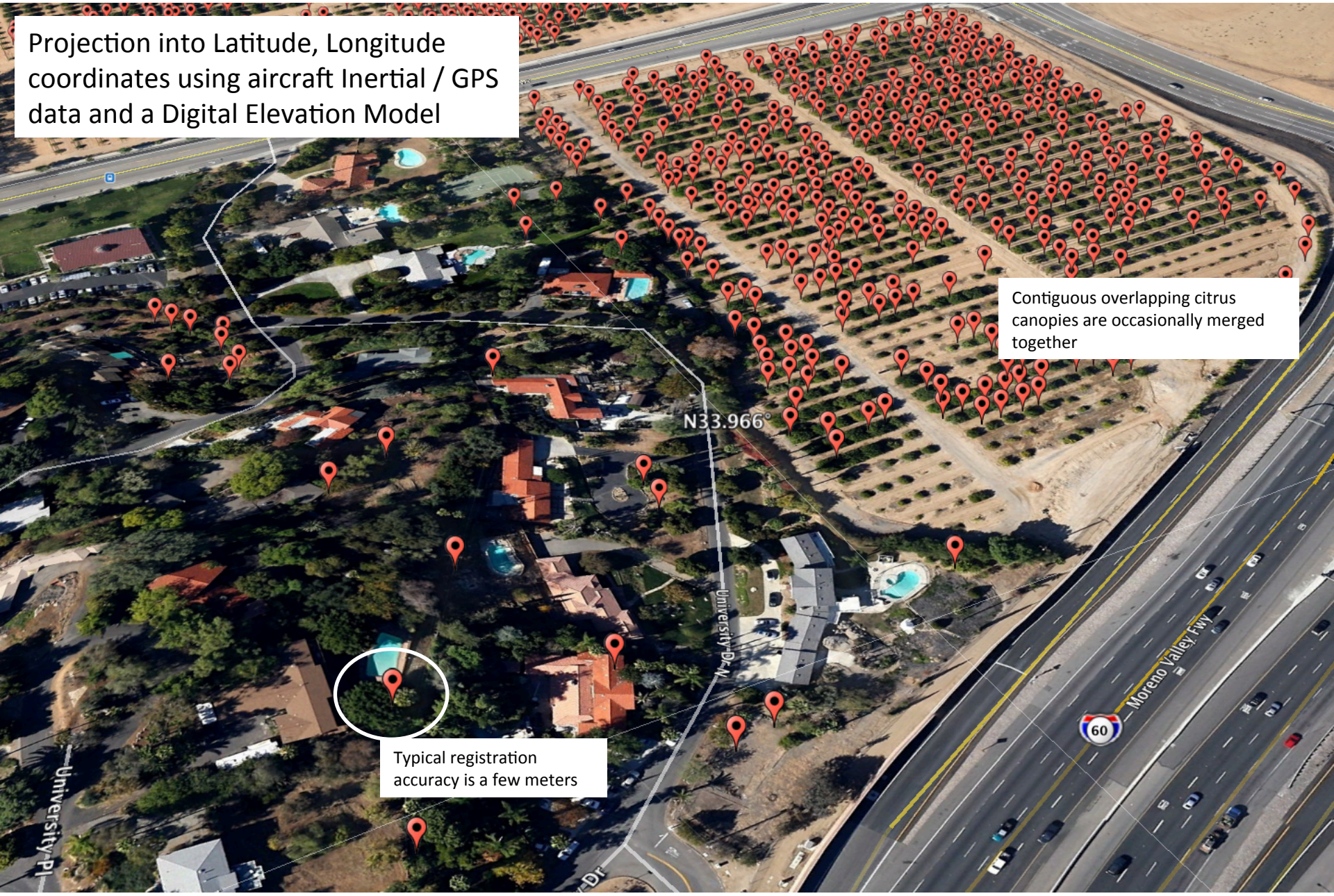



Vegetation
Substrate
Shade


We identify citrus plants by fitting each spectrum with the library
A kernel convolution algorithm highlights contiguous “hot spots”
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


Residential citrus
Residential citrus
False alarm
?
(Didn't visit)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

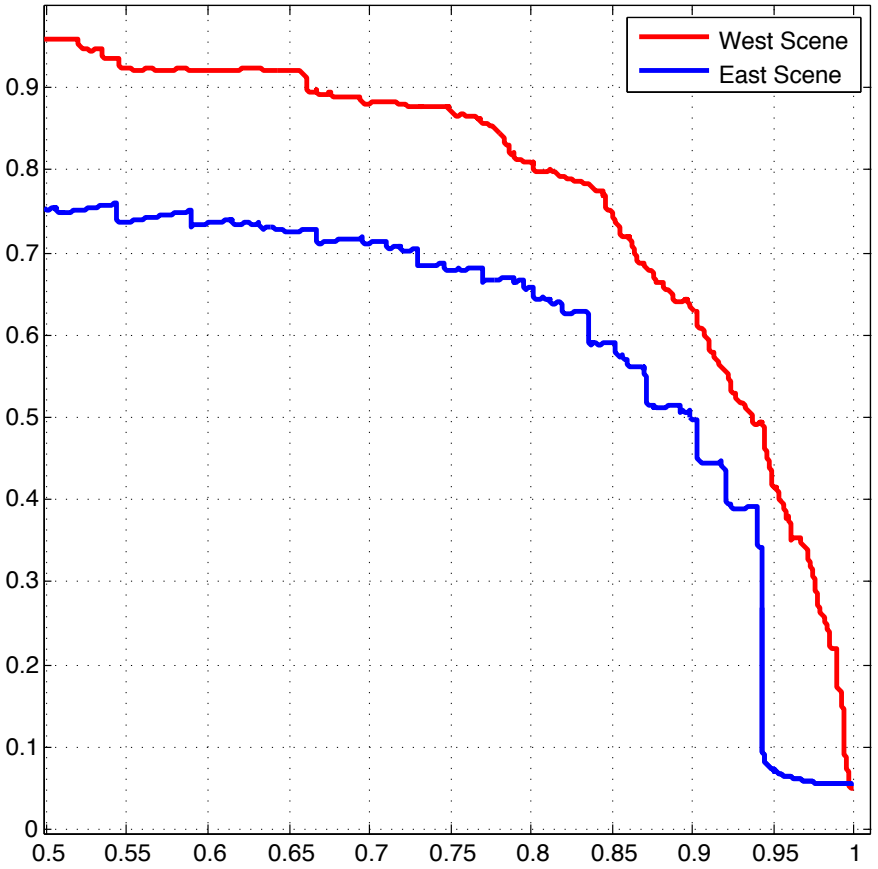

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


Projection into Latitude, Longitude coordinates using aircraft Inertial / GPS data and a Digital Elevation Model
Contiguous overlapping citrus canopies are occasionally merged together
N33.966°
University Dr N
Moreno Valley Fwy
60
Typical registration accuracy is a few meters
University Pl

Performance for citrus plant detection

Detection performance

Assumes 5% of trees are citrus



Precision

What fraction of detections are real?

Recall What fraction of the total citrus is detected?

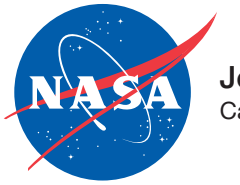
Confusion matrices

East Scene

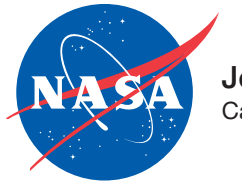
		Actual: Non-citrus	Actual: Citrus
Predicted	Non-citrus	350	156
Predicted	Citrus	31	966

West Scene

		Actual: Non-citrus	Actual: Citrus
Predicted	Non-citrus	395	243
Predicted	Citrus	23	1260



Questions?



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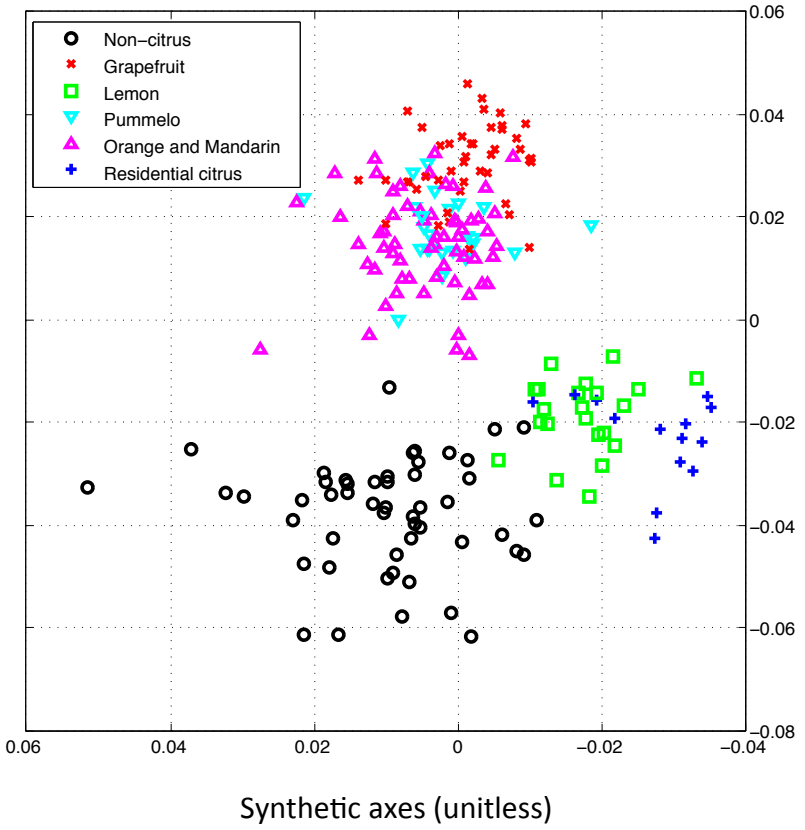
Backup slides

Examples of residential citrus from UCR neighborhood survey

We use Linear Discriminant Analysis to represent the spectral data in a way that emphasizes cross-plant differences

Discriminant Analysis suggests the spectra are:

- Somewhat similar to cultivated citrus plants
- Distinct from non-citrus residential plants



Spectral derivatives

Suggest several candidate diagnostic features