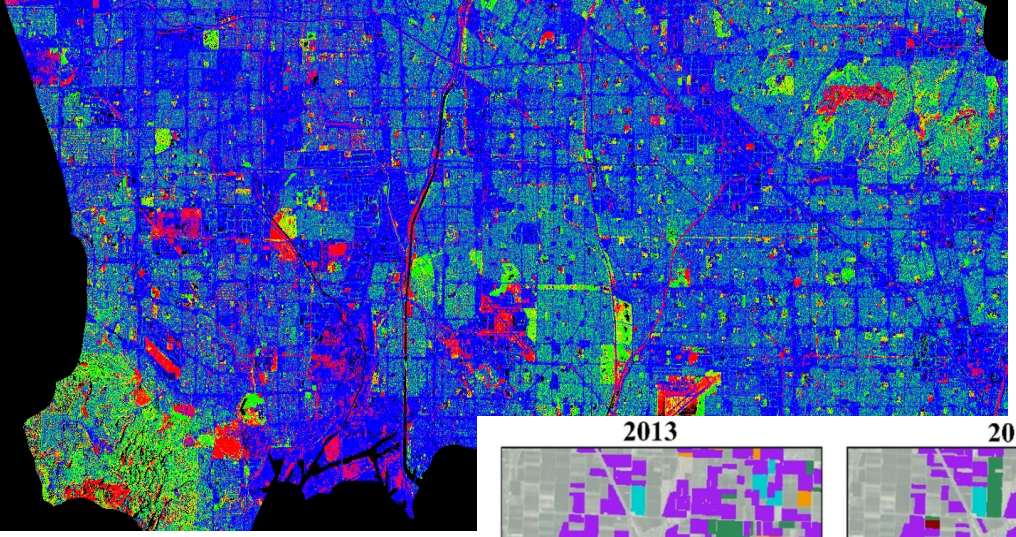
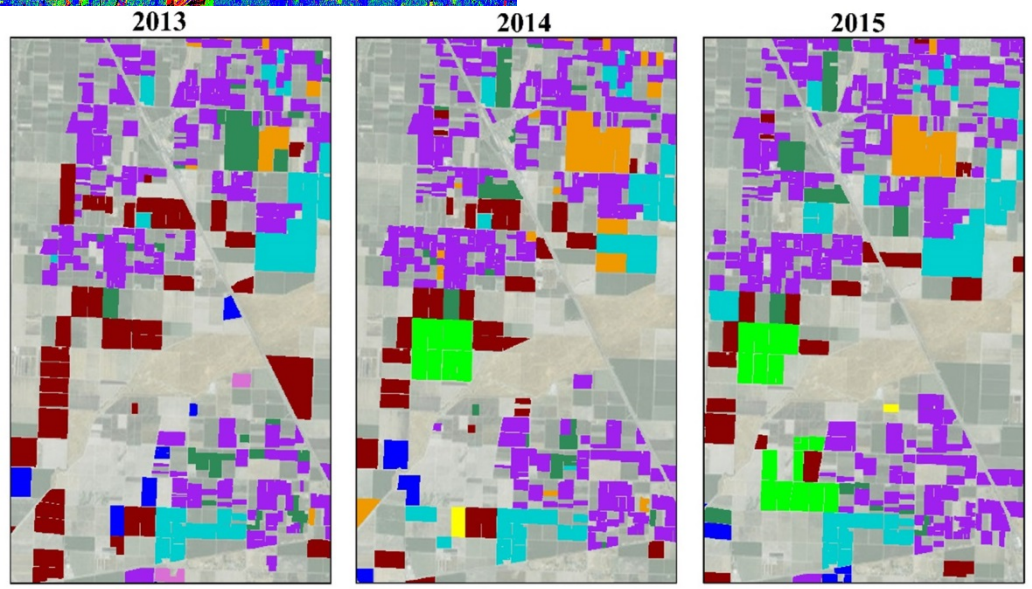
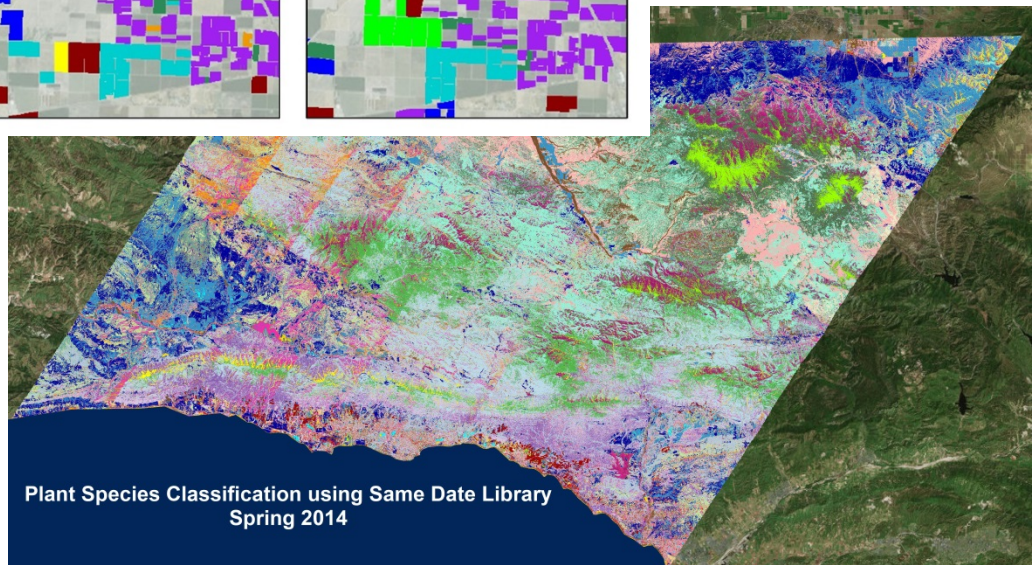
Combined VSWIR-TIR analysis of vegetation in natural, urban and agricultural settings from the HyspIRI airborne campaign





Dar A. Roberts, Susan Meerdink, Sarah Shivers, Erin Wetherley

NASA HyspIRI Preparatory Program
NASA ESSF Program
NSF GRF Program
Jet Propulsion Laboratory



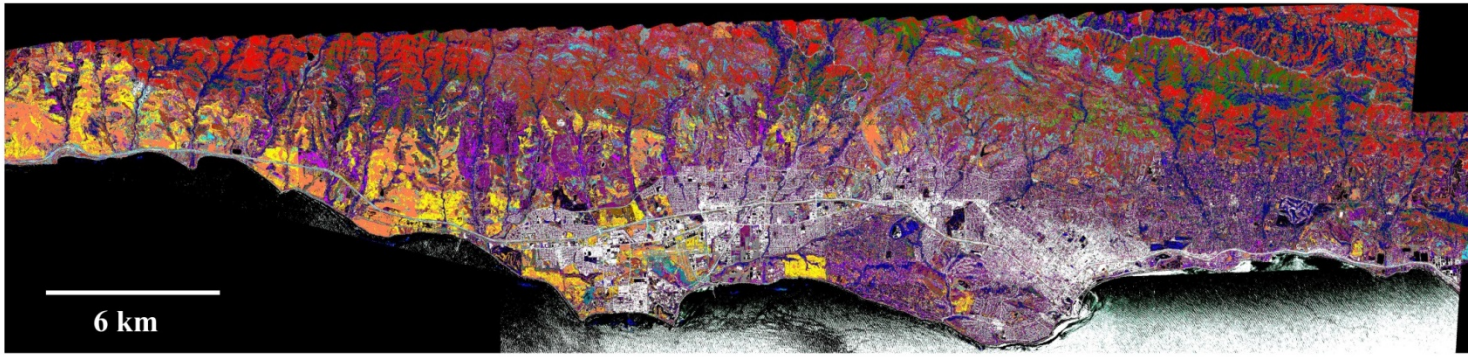
Broad Research Questions

- **What are the synergies between the VSWIR and TIR for vegetation analysis?**
  - **What is the potential of VSWIR fractions combined with LST?**
- **Can we map plant species over large areas over multiple years and seasons using imaging spectrometry?**
  - **What is the potential of developing a global spectral library?**

Outline

- **Developing a VSWIR-TIR model**
  - **Roberts et al., 2015 (RSE/ESA)**
- **Applying a VSWIR-TIR model**
  - **Agricultural Settings: Shivers et al. (in prep)**
  - **Urban Settings: Wetherley et al. (2018)**
- **Mapping plant species over large areas and multiple seasons and years**
  - **Santa Barbara Flight Box: Meerdink et al. (in prep)**
- **Thoughts and conclusions**

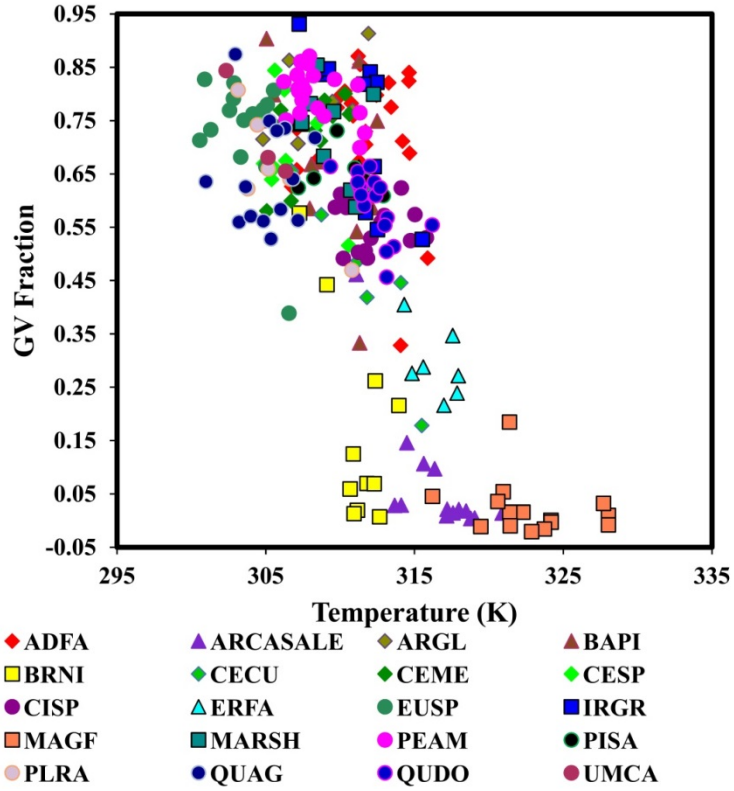
Developing the Model



Legend

ADFA	CEME	MAGF	QUDO
ARCA-SALE	CESP	MARSH	UMCA
ARGL	CISP	PEAM	ROCK/SOIL
BAPI	ERFA	AGRES	URBAN
BRNI	EUSP	PLRA	UNCLASSIFIED
CECU	IRGR	QUAG	

- An inverse relationship exists between GV fraction and LST
- Plant species cluster uniquely in the GV-LST space



Roberts et al., 2015 (RSE)

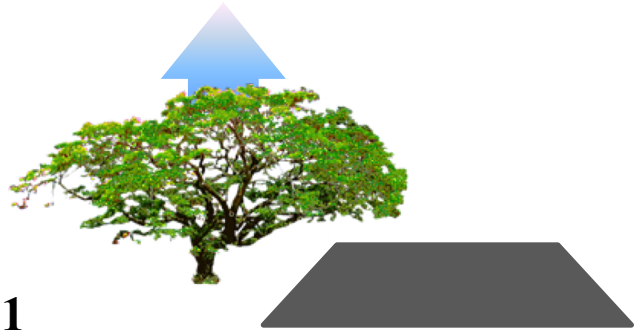
Subpixel Temperature Modeling

VSWIR Fraction

Pure oak endmember (303 K)

Pure road endmember (323 K)

Modeled mixed pixel (309 K)



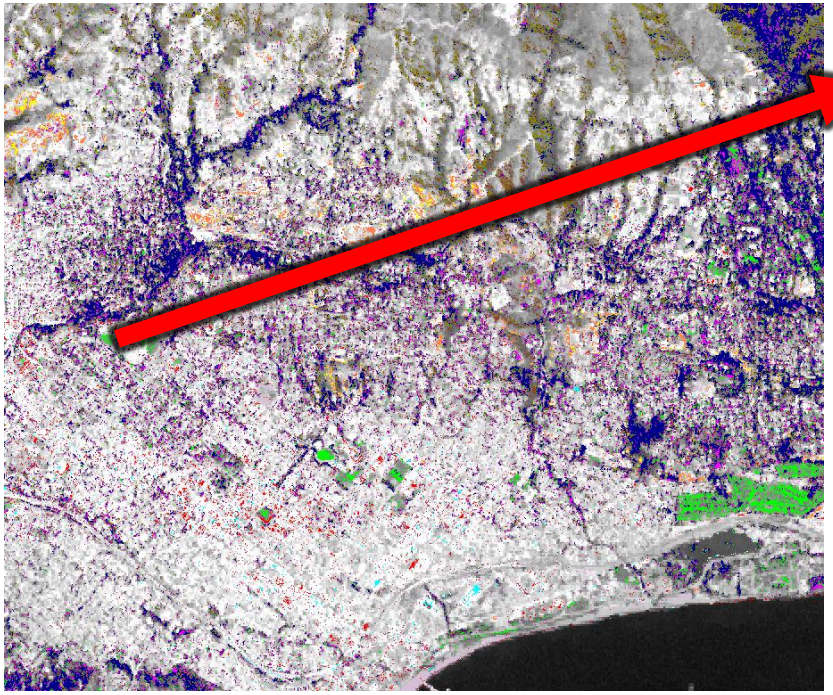
Measured mixed pixel (314 K)

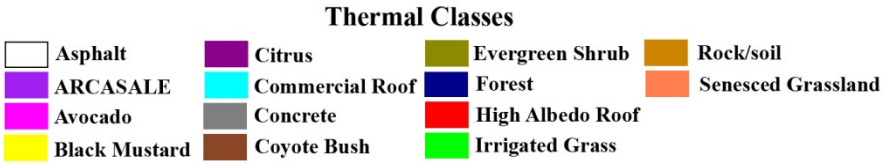
Residual = $LST_{measured} - LST_{modeled} > 1$

- **Oak suffering heat stress?**
- **Lower albedo/hotter road?**
- **Non-linearity?**

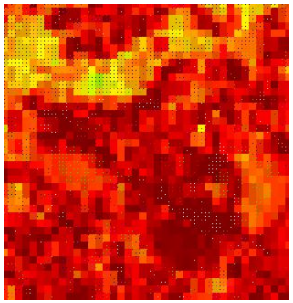
Roberts et al., 2015 (ESA)

Subpixel Temperature Modelling

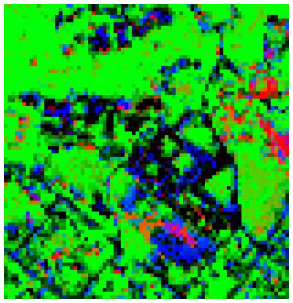




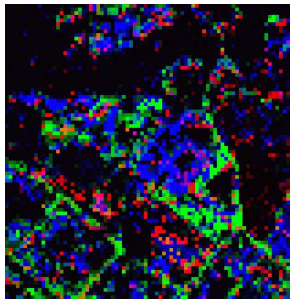
- VSWIR Fractions from AVIRIS
- LST from MASTER
  - Isolated for each thermal class
  - Limited to 100% cover



$LST_m =$



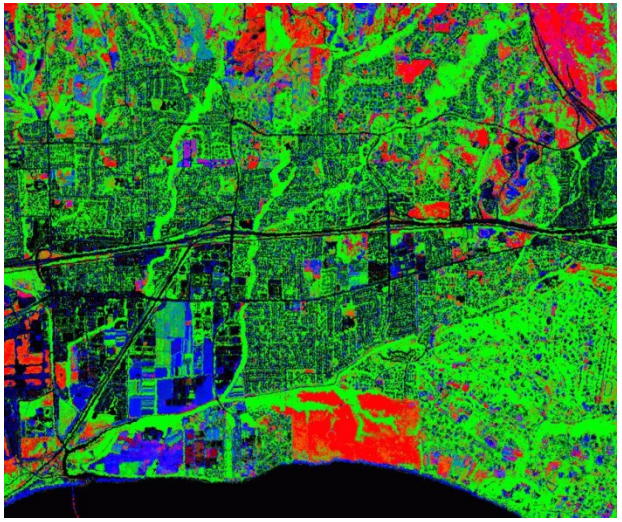
$f_{gv}*LST_{gv}+$
$f_{npv}*LST_{npv}+$
$f_{soil}*LST_{soil}+$

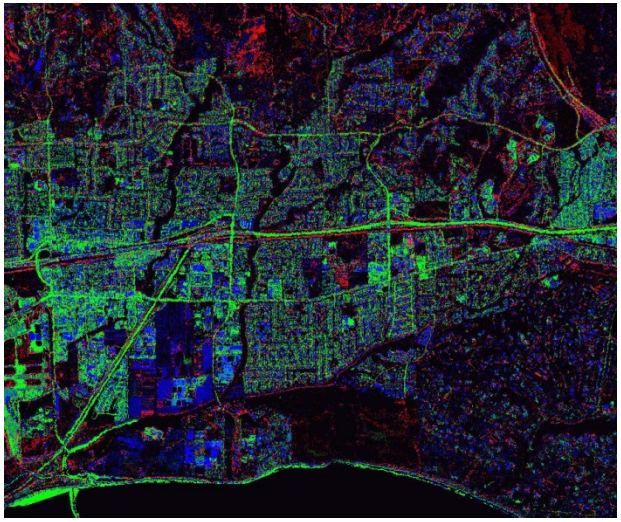


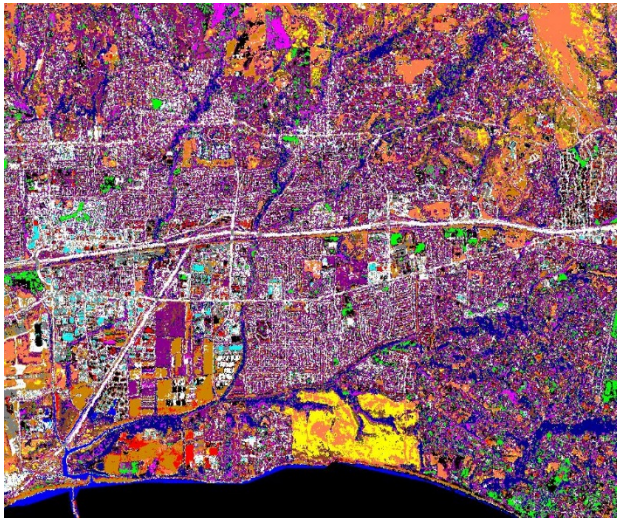
$f_{rock}*LST_{rock}+$
$f_{paved}*LST_{paved}+$
$f_{roof}*LST_{roof}$

LST (thermal class)

Roads, Mustard and Orchards

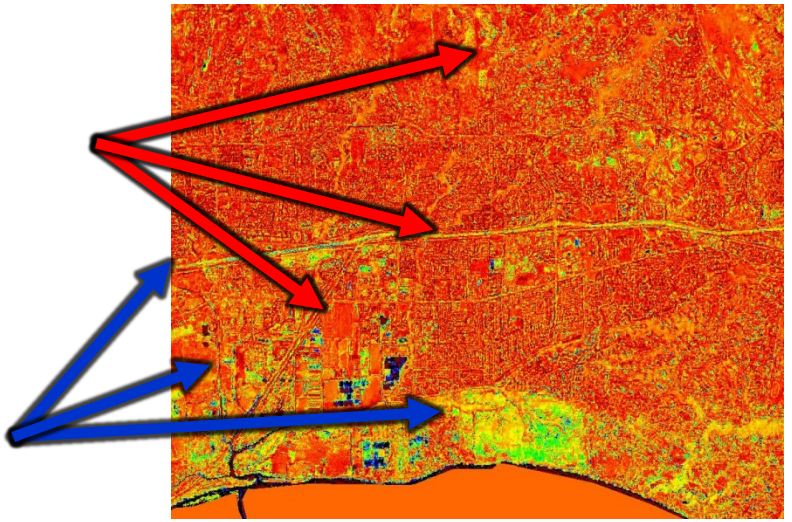




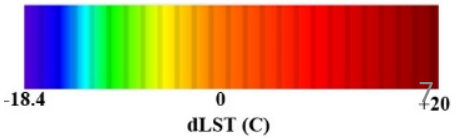


Senesced Mustard is cool (<-6 C)
East-west large roads are cool (<-5 C)
Concrete is cool (< -3 C)

Citrus and Avocado are warm (> 5 C)
North-south large roads are warm (> 2 C)

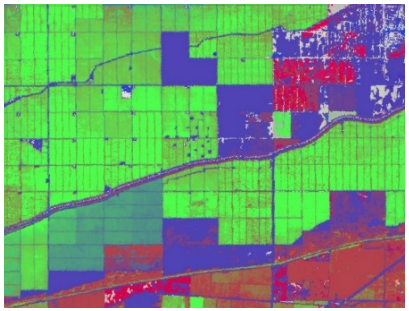


$$LSTresid = LST_{mea} - LST_{mod}$$

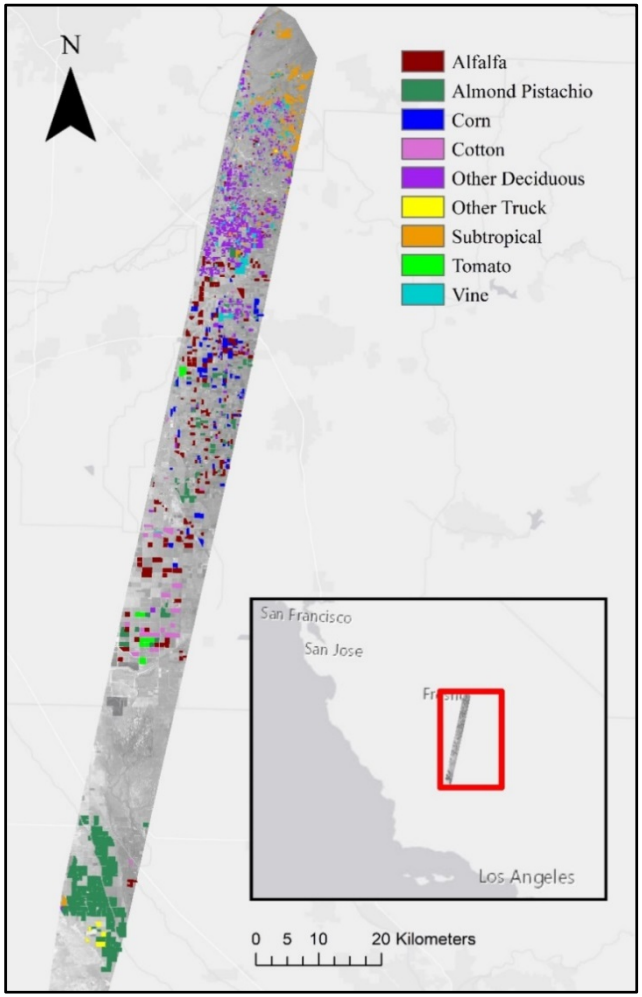


Agricultural Applications: Sarah Shivers

- **Developed a VSWIR-LST model for the Soda Straw analyzed changes in crops 2013-2015**
- **Used MESMA to map fractions of GV, NPV and Soil**



Red: NPV
Green: GV
Blue: Soil



- **Used MESMA results and crop species information to divide GV, NPV, and soil into subclasses expected to have similar thermal properties**
- **Modeled expected temperature using fractional cover and thermal endmembers**

$$LST_{expected} = f_{GV}T_{GV} + f_{SOIL}T_{SOIL} + f_{NPV}T_{NPV}$$

- Citrus
- Perennial Fruits
- Nuts

- MESMA Soil EM 1
- MESMA Soil EM 2
- MESMA Soil EM 3
- MESMA Soil EM 4
- MESMA Soil EM 5
- MESMA Soil EM 6
- MESMA Soil EM 7
- MESMA Soil EM 8
- MESMA Soil EM 9
- MESMA Soil EM 10

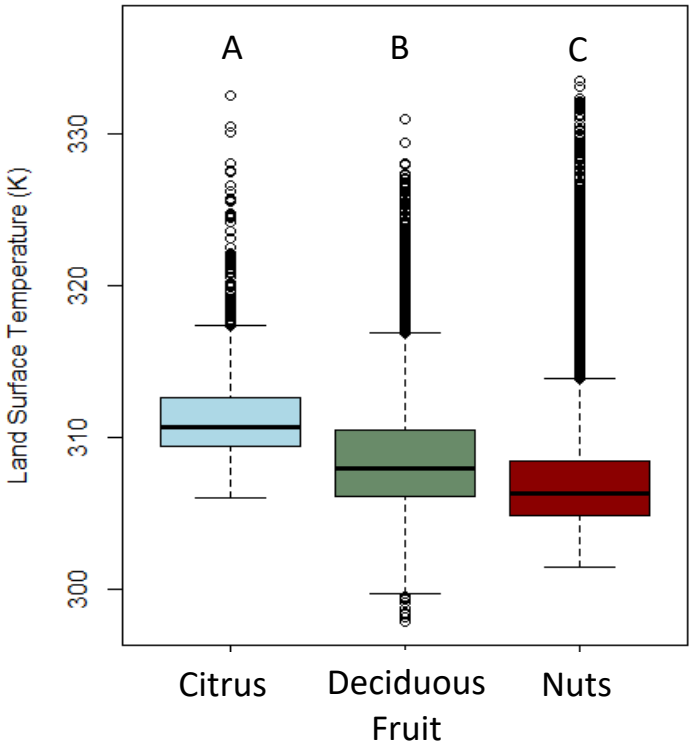
- MESMA NPV EM 1
- MESMA NPV EM 2
- MESMA NPV EM 3
- MESMA NPV EM 4
- MESMA NPV EM 5
- MESMA NPV EM 6
- MESMA NPV EM 7
- MESMA NPV EM 8

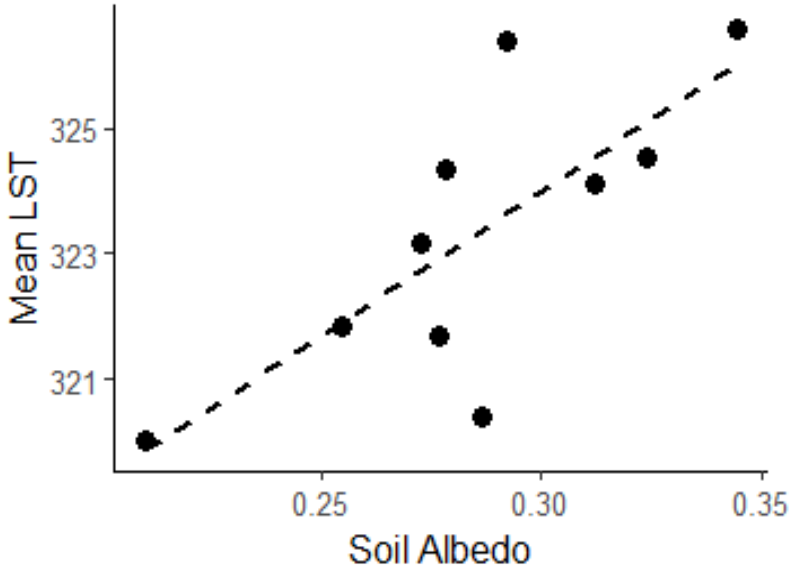
- **Calculated a temperature residual**

$$Residual = LST_{MASTER} - LST_{expected}$$

Shivers et al., in prep

Crop groups and MESMA thermal classes are unique





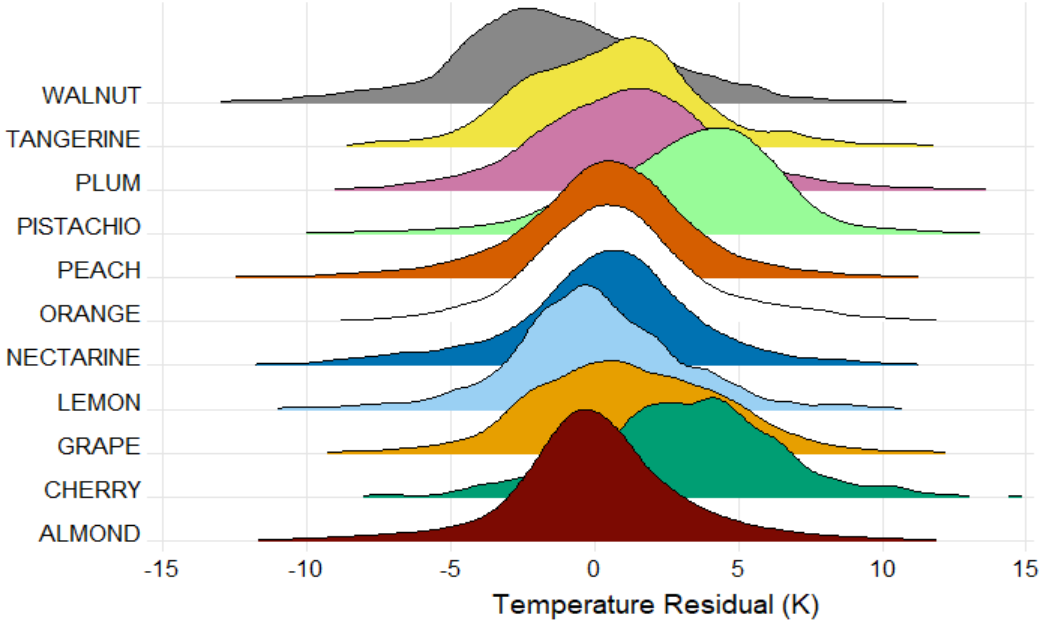
Crop groups show distinct LST distributions

MESMA endmember groups are suitable as thermal classes and show sensitivity to soil moisture

Shivers et al., in prep

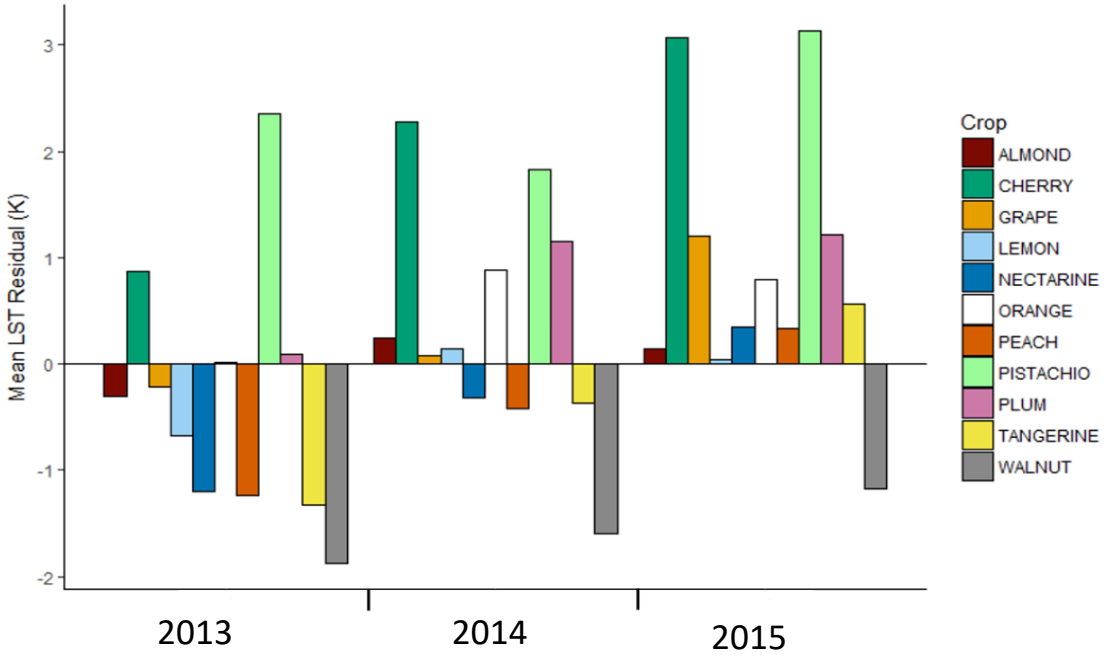
Residuals vary by Crop

Of 11 crops, 7 showed unique LST residual distributions



Residuals increased as the drought progressed

Mean LST residual (K)



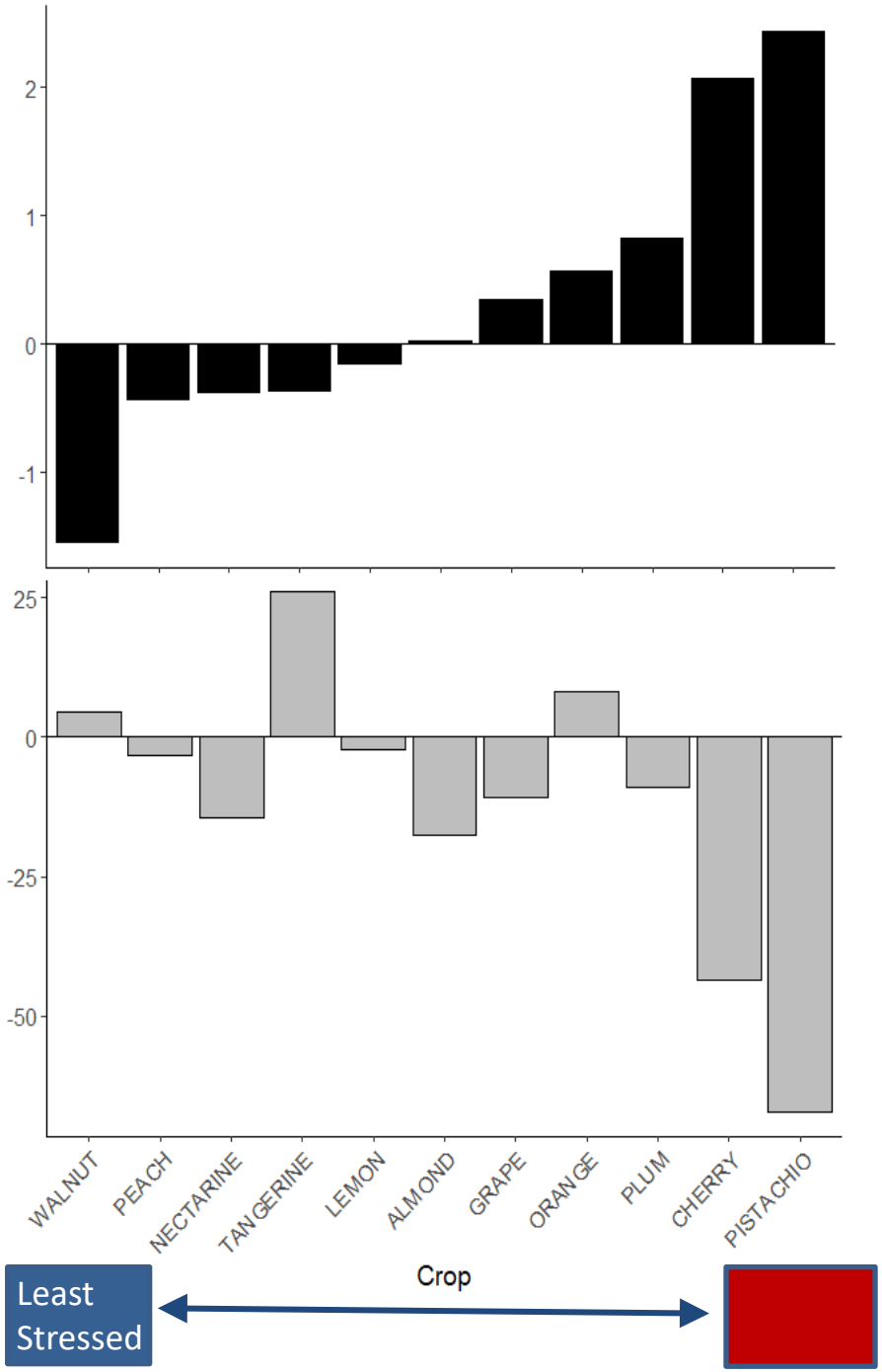
Shivers et al., in prep

LST Residuals reflect crop yield

Crops with the highest positive temperature residuals, also had the largest reductions in yield during the study period

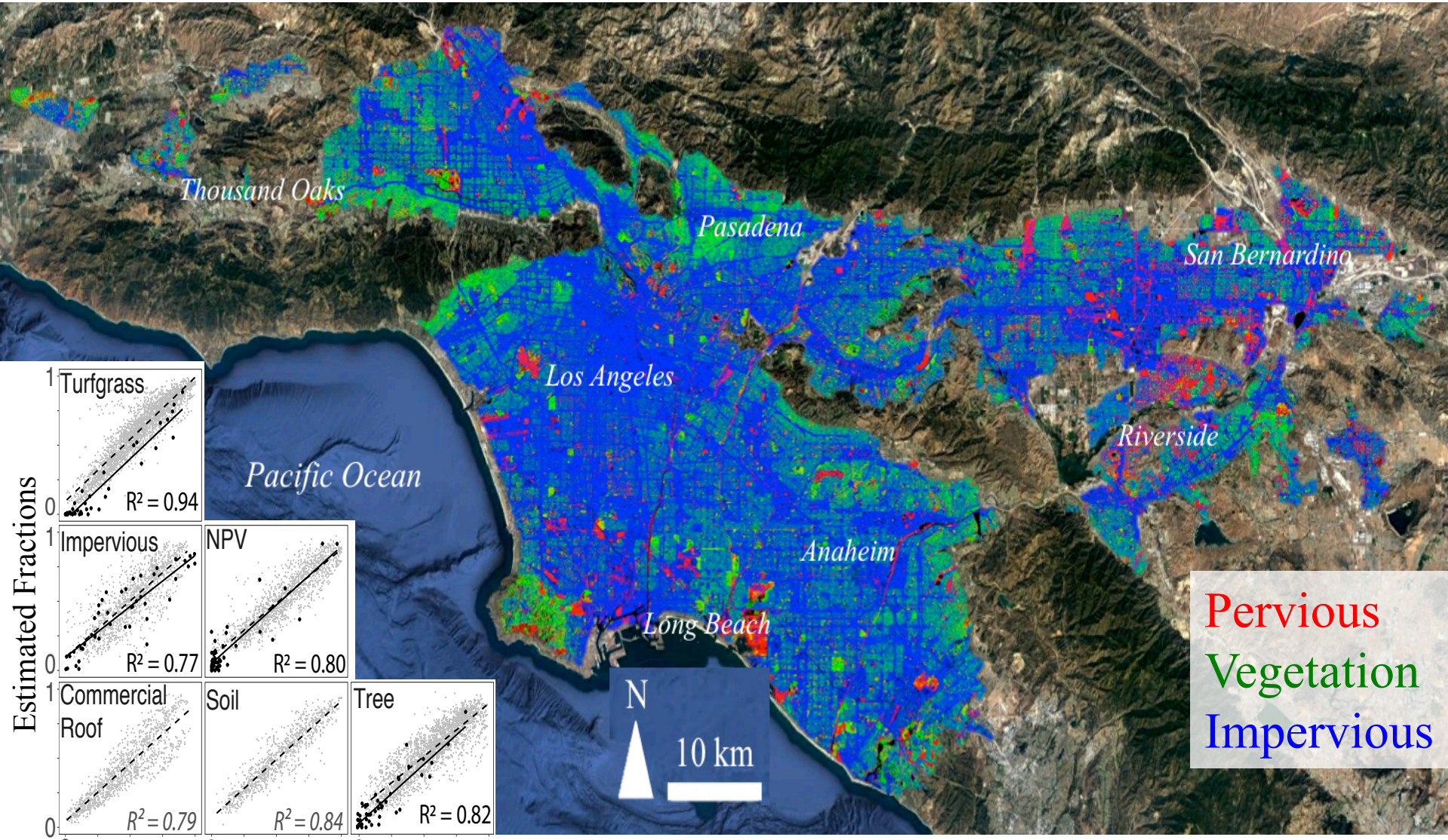
Average LST Residual (K) from 2013, 2014, & 2015

Percent Change in Yield Per Hectare From 2013 to 2015



Shivers et al., in prep

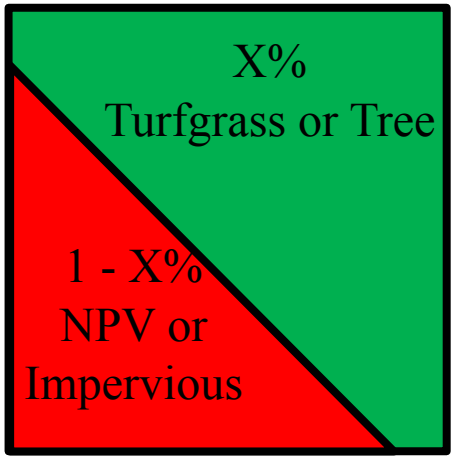
Wetherley, Erin B., Joseph P. McFadden, and Dar A. Roberts. 2018. "Megacity-Scale Analysis of Urban Vegetation Temperatures.", RSE, 2018



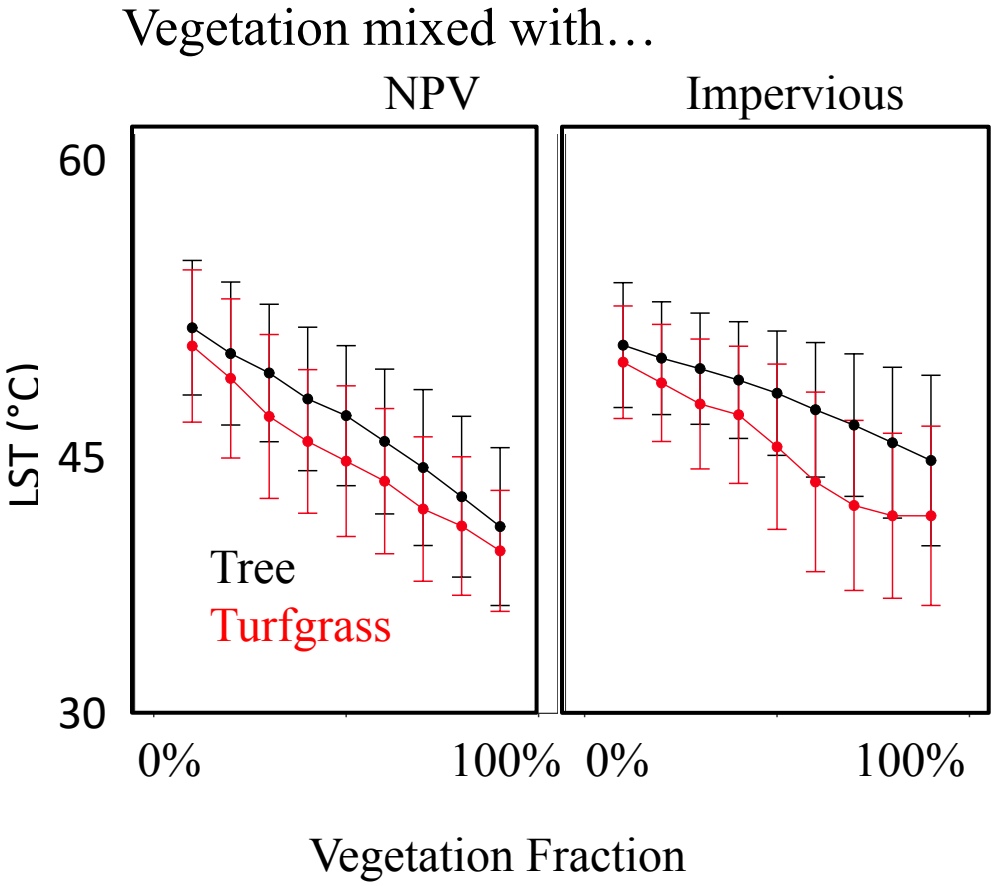
Study Area = 4,466 km^2

Modeling LST by Plant Type & Material

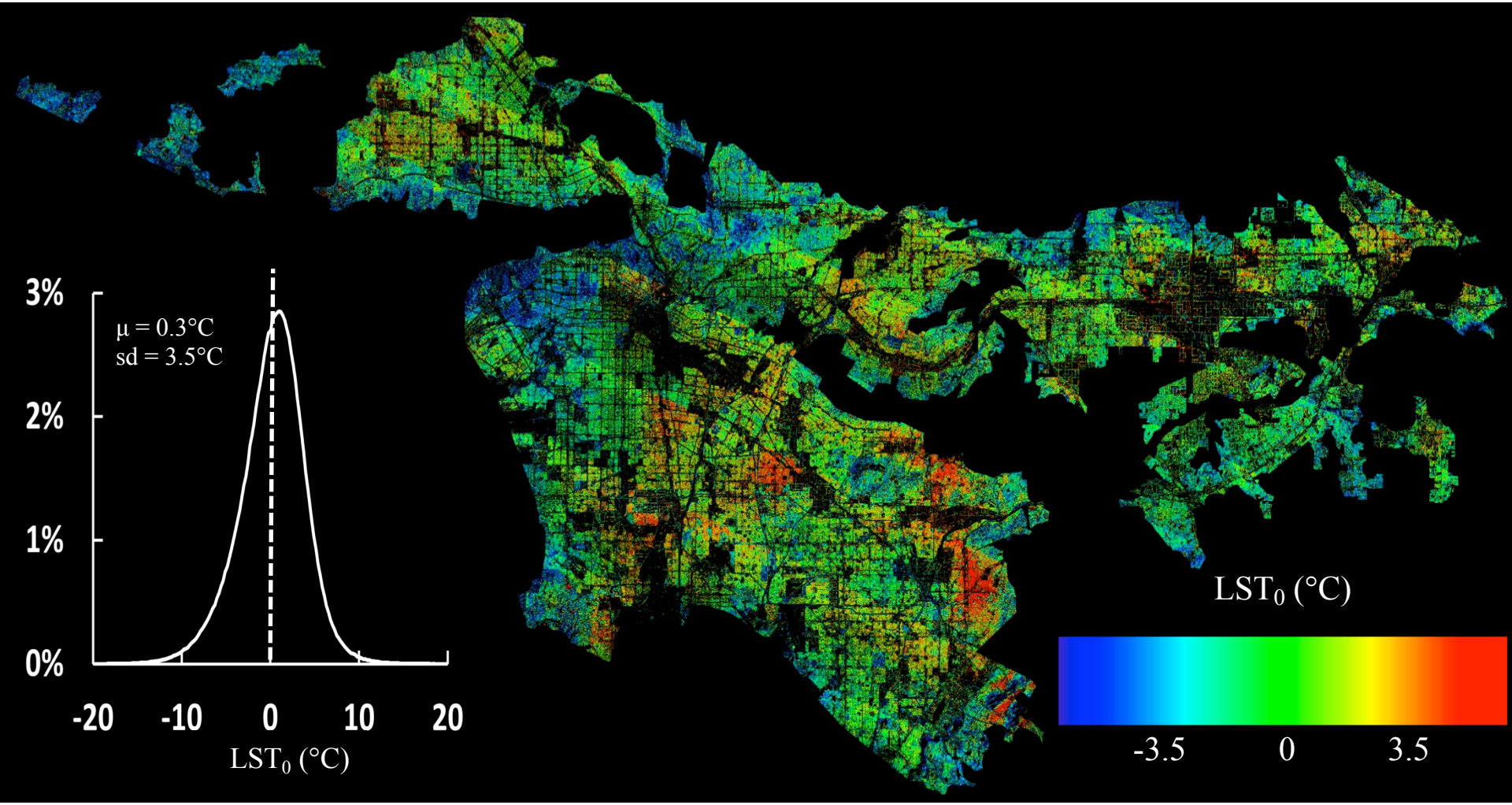
- 1,756,302 Mixed Pixels
- 4 Mixture Types



+LST

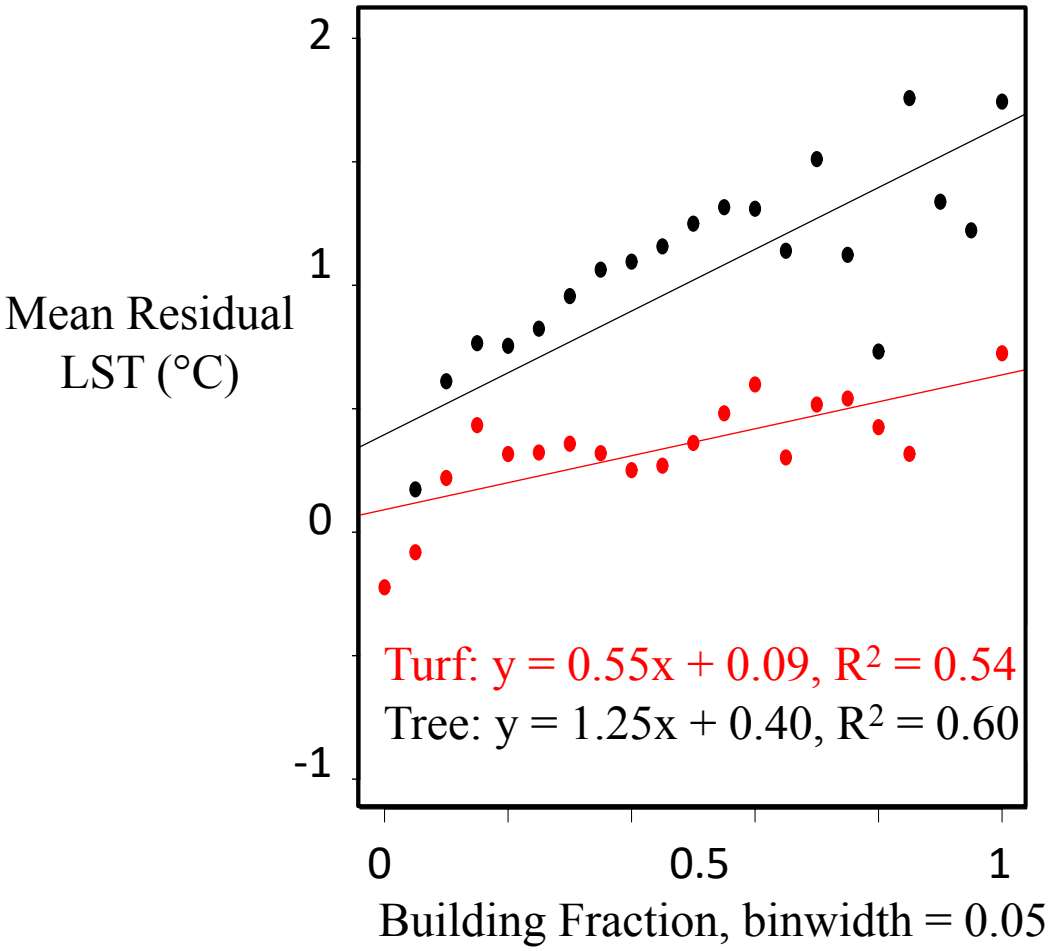


Subtracting modeled from measured vegetation LST reveals ~15°C of variability independent of fraction & plant type.



Examining other sources of temperature variability across LA, including…

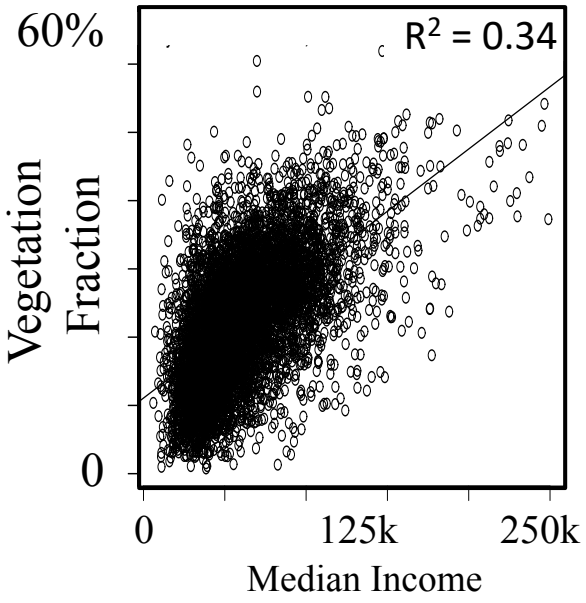
Building Fraction (LA County GIS)



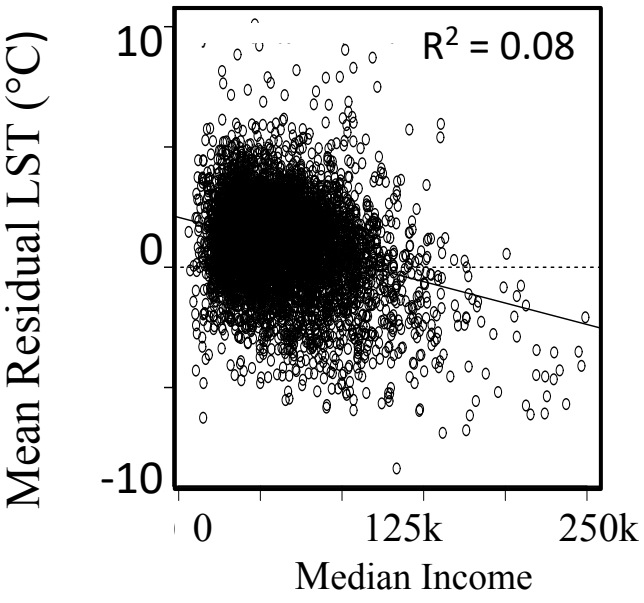
Building Fraction has a 3x greater effect on measured tree LST compared to turfgrass LST.

Examining other sources of temperature variability across LA, including…

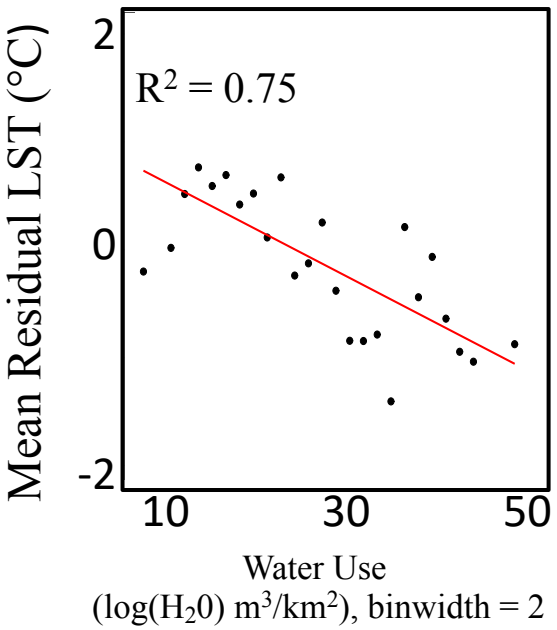
Vegetation Management



Wealthier areas in L.A. have more vegetation.



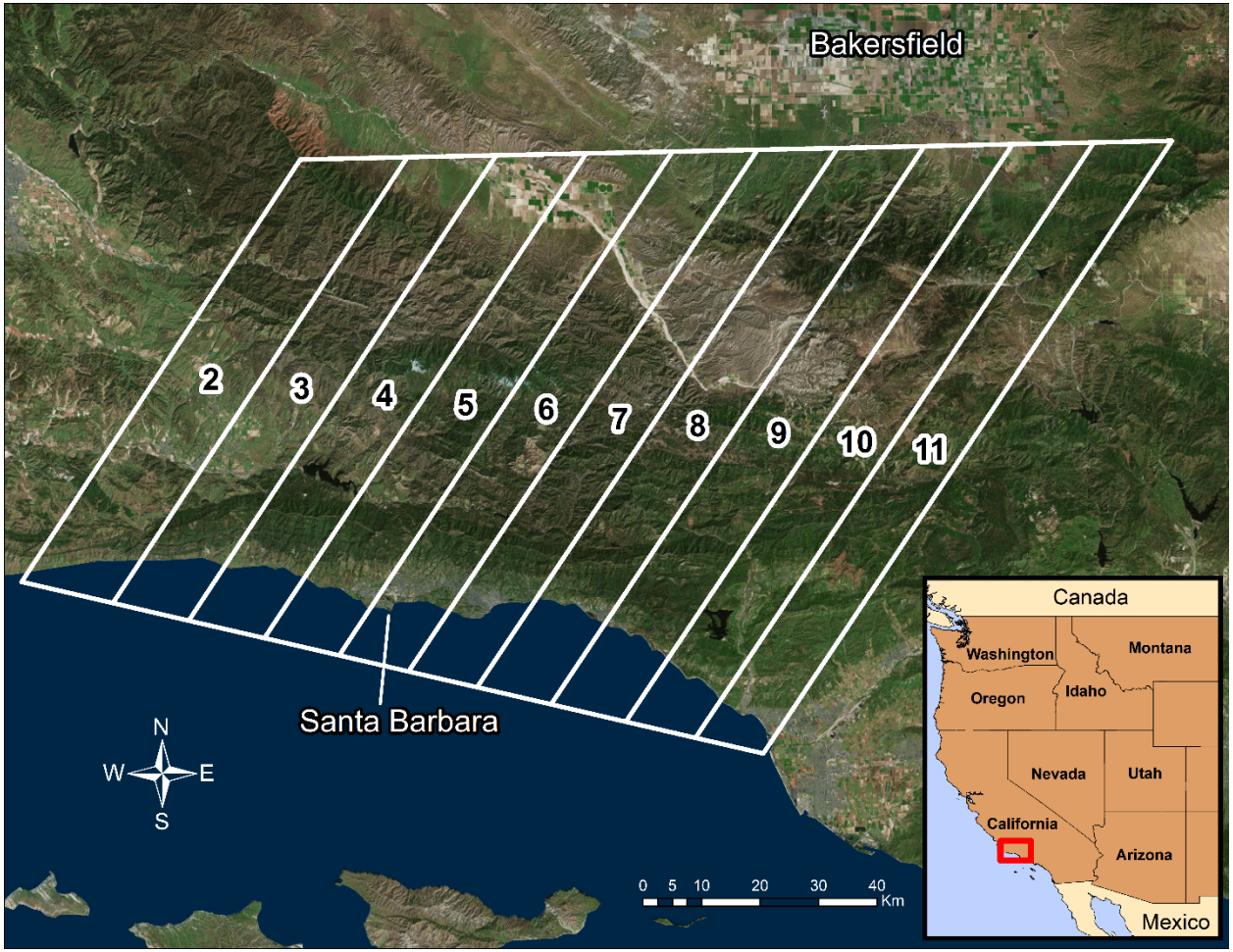
For each $10,000 increase in median income, vegetation LST decreased by 0.23°C.



Areas with more outdoor water use are cooler!

Classifying California plant species across seasons

Susan Meerdink, Dar Roberts, Paul Gader, Keely Roth, Jennifer King,
Zachary Tane, and Alexander Koltunov

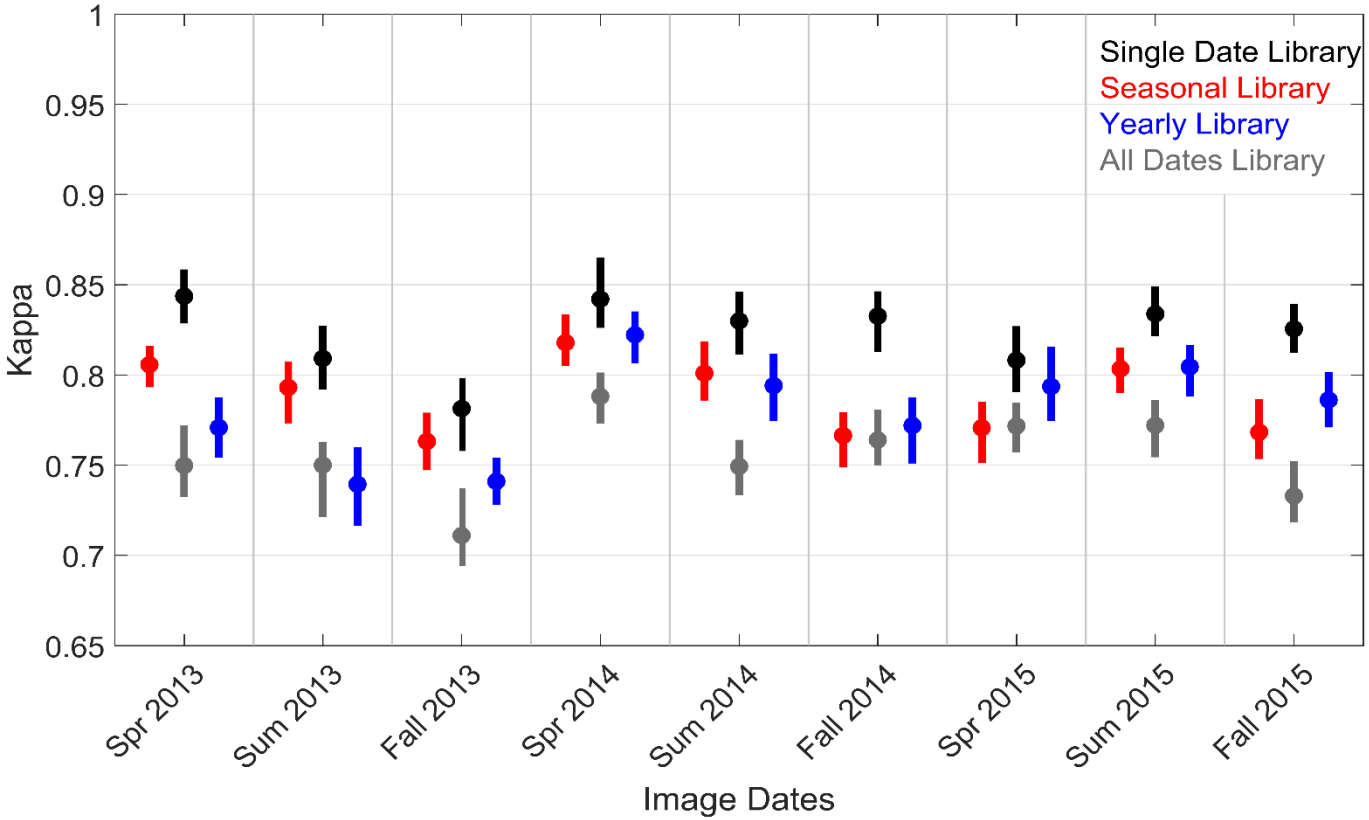


Imagery	
2013 Spring	04/11/13
2013 Summer	06/06/13
2013 Fall	11/25/13
2014 Spring	04/16/14
2014 Summer	06/06/14
2014 Fall	08/29/14
2015 Spring	04/16/15
2015 Summer	06/02/15
2015 Fall	08/24/15

Total of 88 Images

- Approach:
- Spectral libraries from reference
- polygons
- Mapping using CDA/LDA

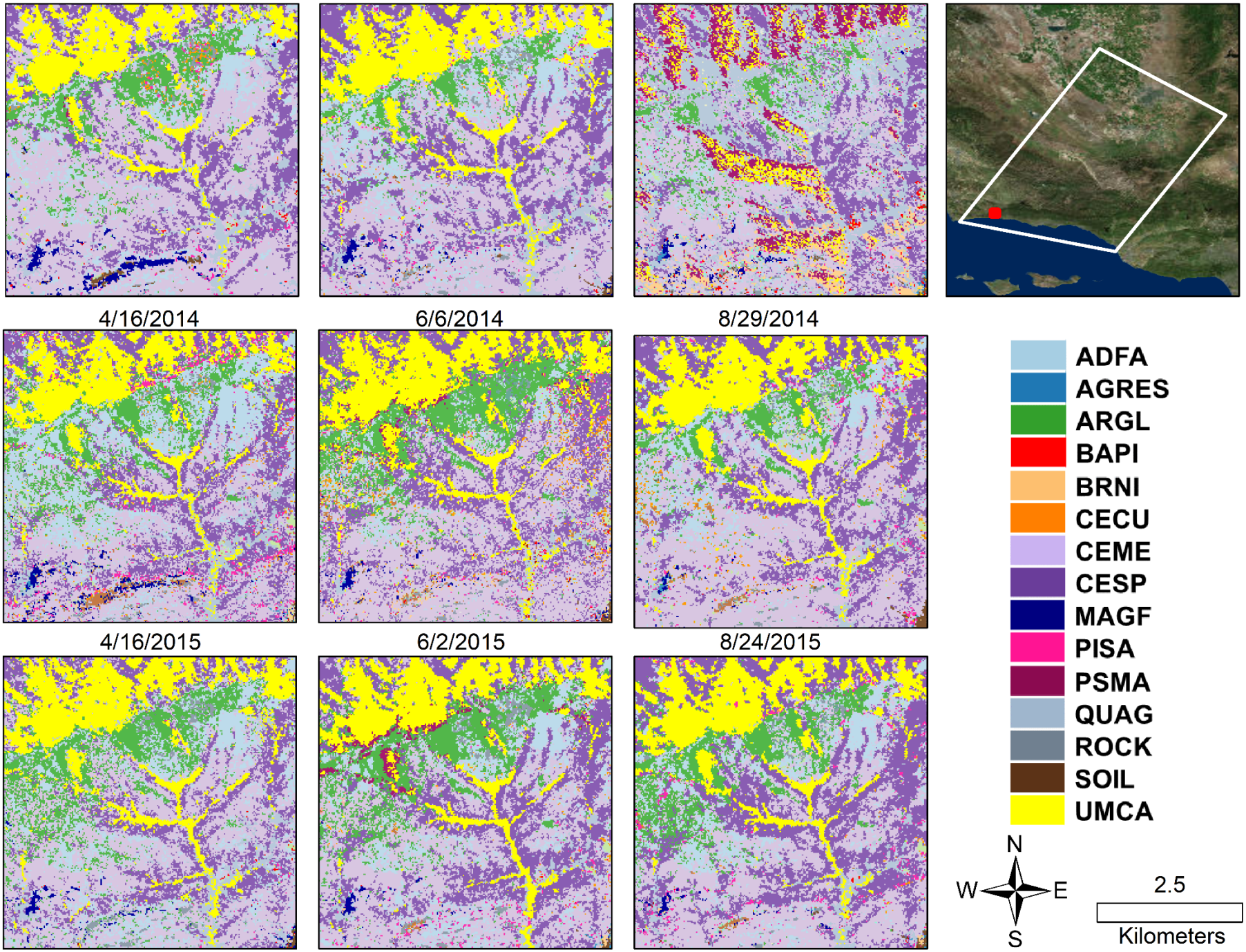
Single Date Libraries Outperform all Other Libraries

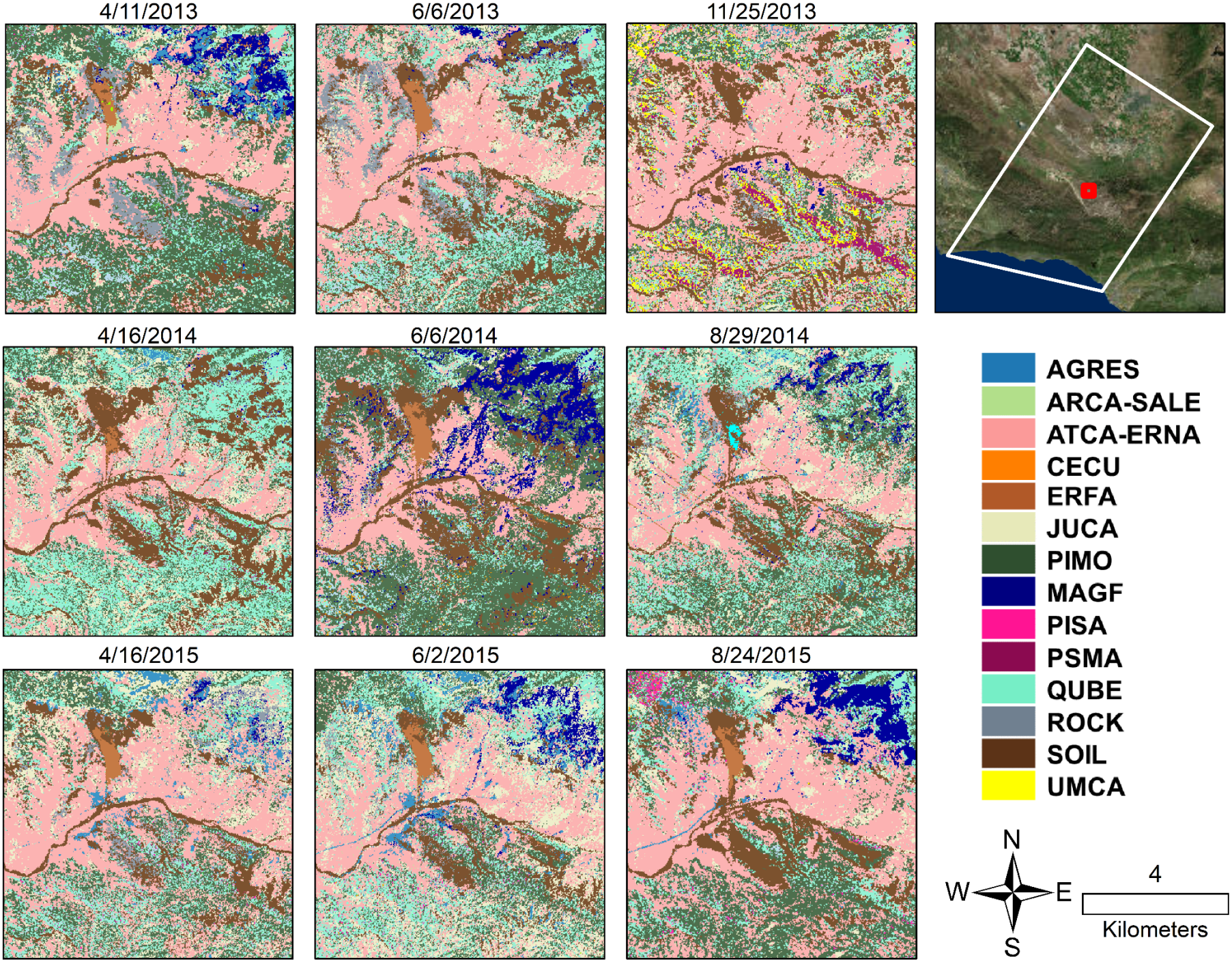


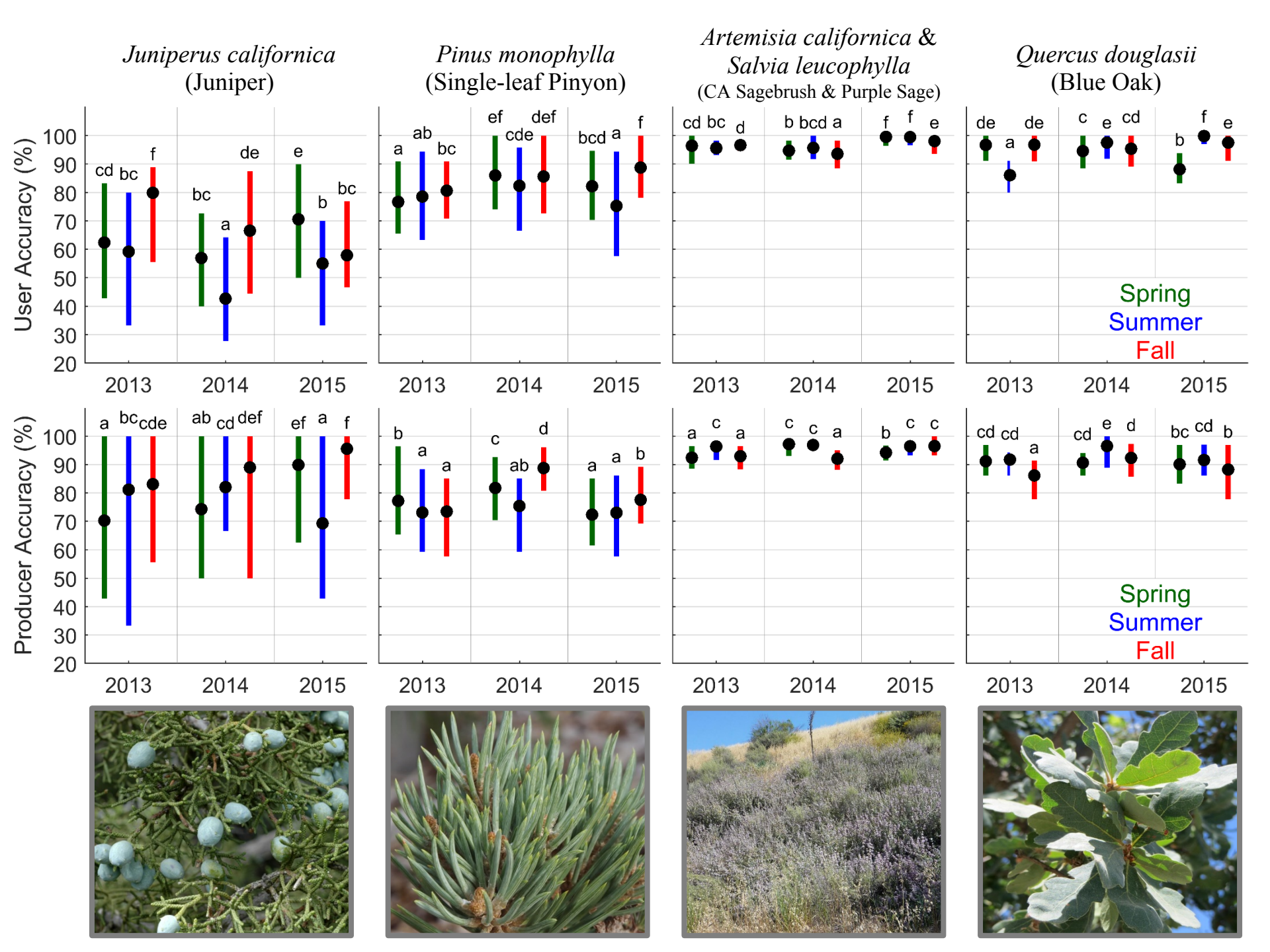
Example of classifying Fall 2015 imagery:

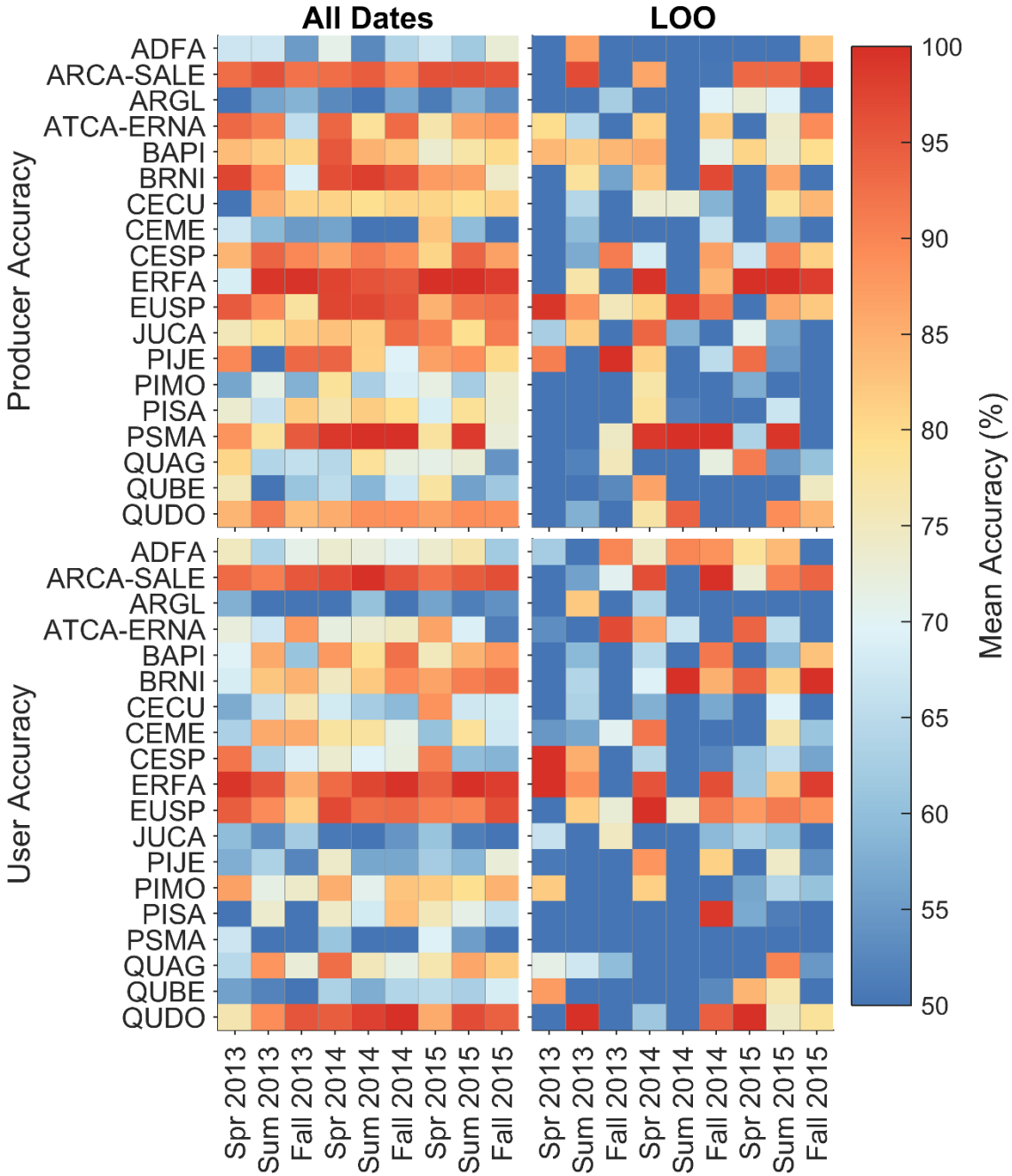
Single Date Library:
Fall 2015
Seasonal Library:
Fall '13/ '14/ '15
Yearly Library:
Spr./Sum./Fall '15
All Dates Library:
All 9 Image Dates

Single Date Library	Seasonal Library	Yearly Library	All Dates Library
0.78 – 0.84 mean kappa	0.76 – 0.82 mean kappa	0.74 – 0.82 mean kappa	0.71 – 0.79 mean kappa
Spring 2013 & 2014 highest accuracy	Kappa loss ranging 0.02 - 0.07	Kappa loss ranging 0.01 – 0.08	Kappa loss ranging 0.03 – 0.10


4/11/2013
6/6/2013
11/25/2013
4/16/2014
6/6/2014
8/29/2014
4/16/2015
6/2/2015
8/24/2015
ADFA
AGRES
ARGL
BAPI
BRNI
CECU
CEME
CESP
MAGF
PISA
PSMA
QUAG
ROCK
SOIL
UMCA
N
W
E
S
2.5
Kilometers


4/11/2013
6/6/2013
11/25/2013
4/16/2014
6/6/2014
8/29/2014
4/16/2015
6/2/2015
8/24/2015
AGRES
ARCA-SALE
ATCA-ERNA
CECU
ERFA
JUCA
PIMO
MAGF
PISA
PSMA
QUBE
ROCK
SOIL
UMCA
N
W
E
S
4
Kilometers


Juniperus californica
(Juniper)
Pinus monophylla
(Single-leaf Pinyon)
Artemisia californica &
Salvia leucophylla
(CA Sagebrush & Purple Sage)
Quercus douglasii
(Blue Oak)
User Accuracy (%)
Producer Accuracy (%)
Spring
Summer
Fall
2013
2014
2015



Libraries perform poorest when Applied to data sets excluded From training

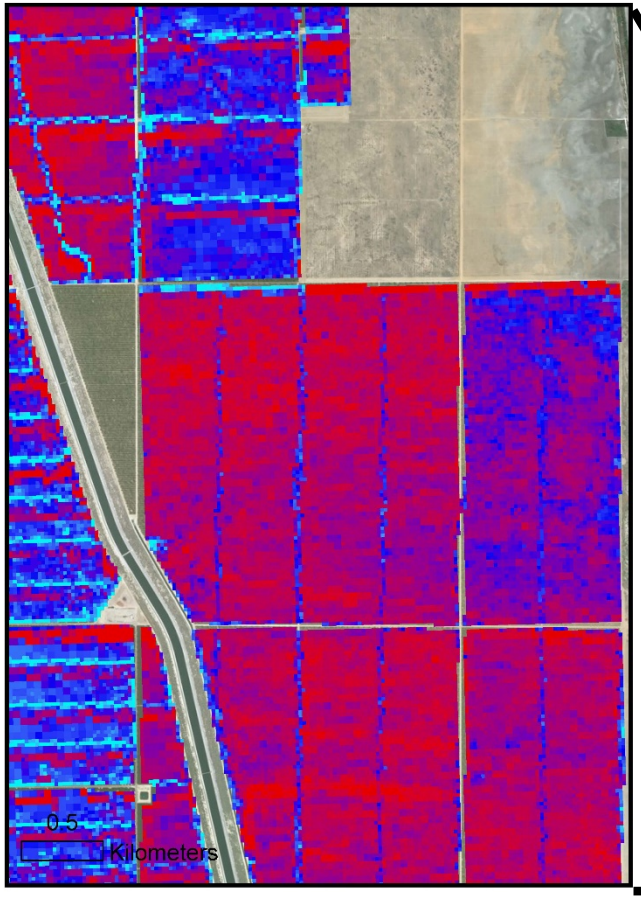
Overall Kappa Classification Accuracy

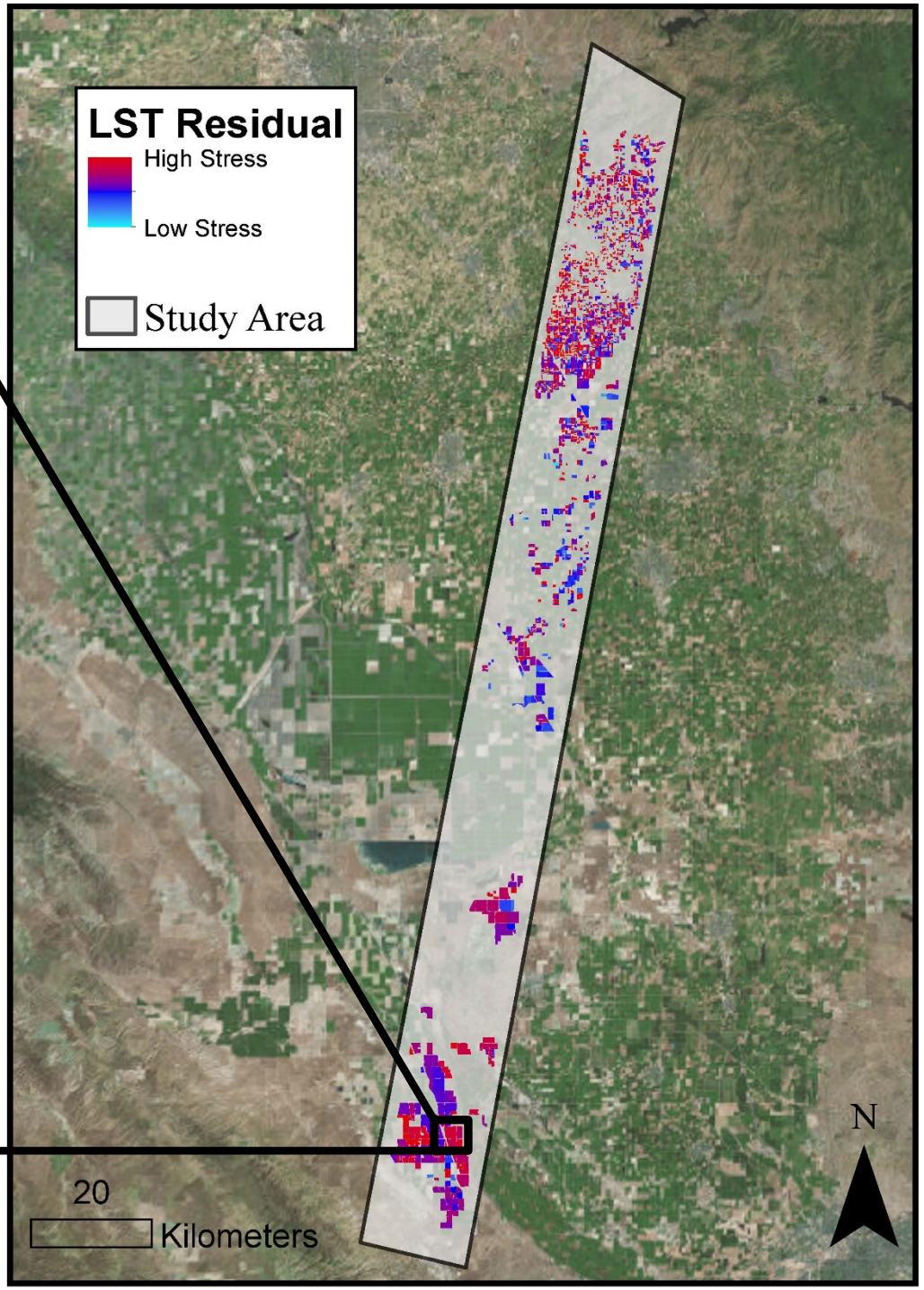
Image Date	All Dates	Leave One Date Out
2013 Spring	0.75	0.44
2013 Summer	0.75	0.58
2013 Fall	0.71	0.42
2014 Spring	0.79	0.62
2014 Summer	0.75	0.31
2014 Fall	0.76	0.58
2015 Spring	0.77	0.56
2015 Summer	0.77	0.70
2015 Fall	0.73	0.57

Conclusions and Thoughts

- The hyperspectral VSWIR-LST residual model has considerable promise
  - Does not require simultaneous observations
  - Broad applications in multiple ecosystems
- Plant species can be mapped over large areas and multiple dates
  - Highest accuracies were achieved when image dates and libraries were the same
  - Seasonal libraries outperformed yearly, multi-year libraries
  - Existing spectral libraries may not be transferable across dates
    - Develop geodatabase of reference species locations
  - A spaceborne system will likely outperform airborne data
    - Improved sun-sensor geometry
    - Fewer cross track/cross flight line artifacts

Identify within-field stress





Backup