Assessing the Thomas Wildfire with Sentinel-2 Imagery

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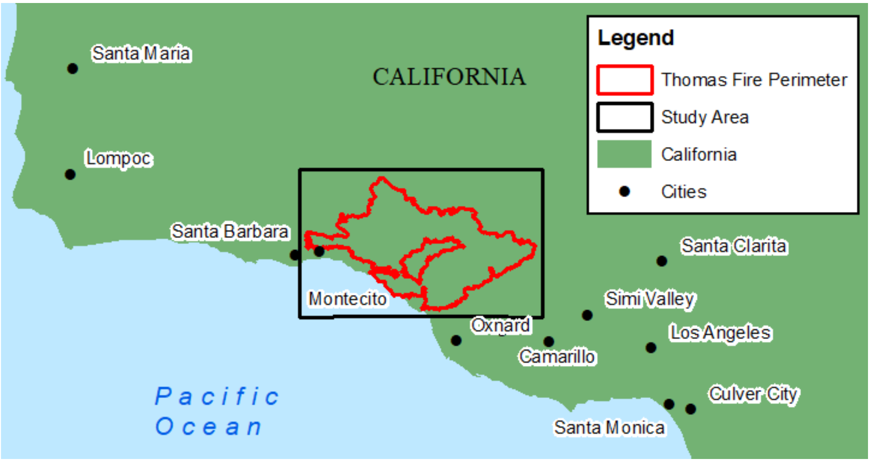
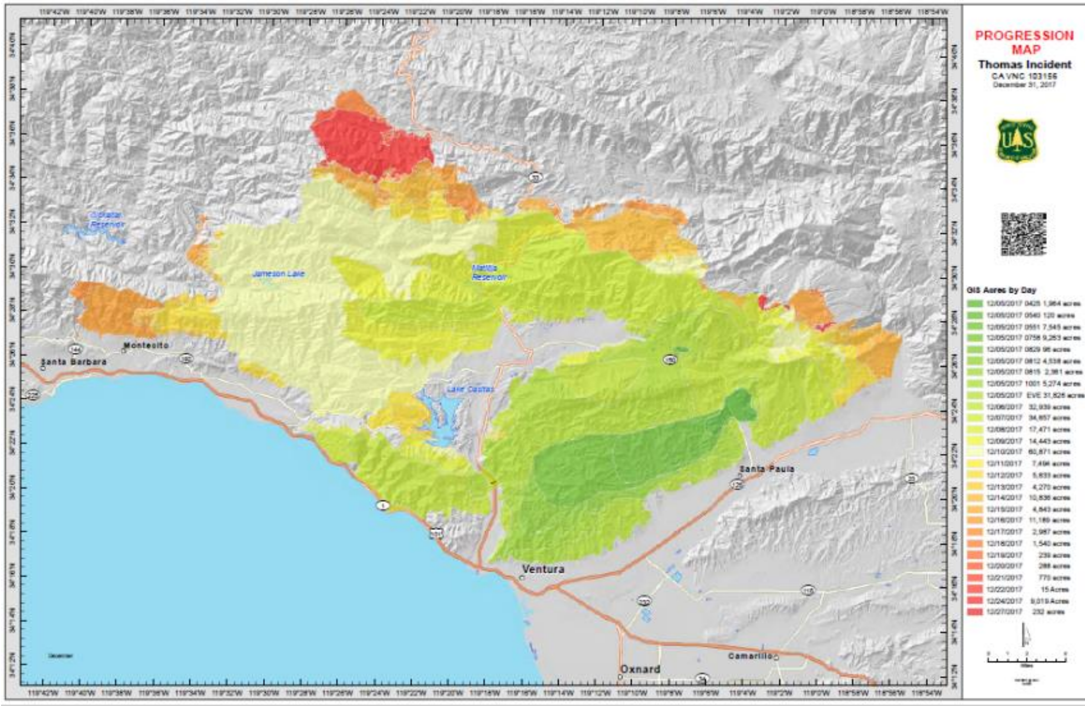
18 APRIL 2018



Overview

- Background/Problem
- Research Questions
- Data
- Methods
- Results/Discussion
- Challenges



Background/Problem

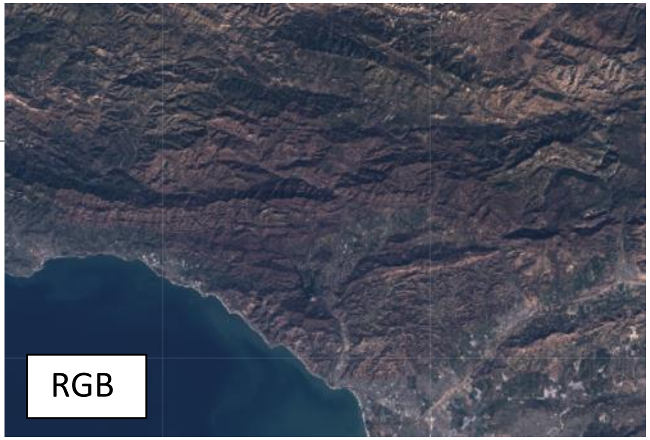
- Wildfire is a common hazard to western U.S. communities
  - Debris-flow risk elevated for locations downstream of burn scars
- Potential for increase in both wildfire and high-intensity precipitation events in the future due to changes in climate
- Thomas Fire in southern California burned from 4 Dec 17 to 12 Jan 18
  - Largest California wildfire in modern history - 281,893 acres
  - 100,000 people evacuated
  - Over 1,300 structures destroyed

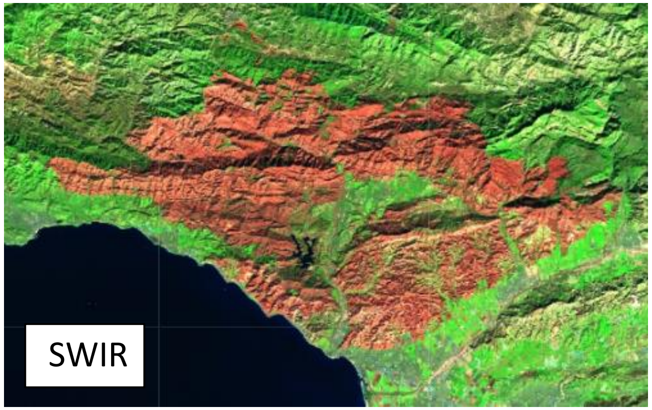
- Heavy rains in Montecito, California on 9 Jan 18
  - Intense rainfall brought 13.7 mm (0.54 in) in 5 min
  - Resulting debris-flows killed 21 people
  - Damaged or destroyed 561 structures

Research Questions

- Can analysis of remotely sensed imagery, combined with DEM, soil, and precipitation data, help **identify** burn areas and debris-flow risk following the Thomas wildfire?

- Does the application of model-based precipitation forecasts further **improve** the debris flow risk assessment for the Montecito area?





Data - Imagery

- Sentinel-2 Multispectral Imager (MSI)
- European Space Agency, acquired via Google Earth Engine
  - 13 Bands spanning visible, NIR, SWIR wavelengths
  - Variable resolution of 10, 20, 60m (band-dependent)
  - Top-of-Atmosphere reflectances scaled by 10,000

Name	Resolution	Wavelength	Description
B1	60 m	443 nm	Aerosols
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Red Edge 1
B6	20 m	740 nm	Red Edge 2
B7	20 m	783 nm	Red Edge 3
B8	10 m	842 nm	NIR
B8a	20 m	865 nm	Red Edge 4
B9	60 m	940 nm	Water vapor
B10	60 m	1375 nm	Cirrus
B11	20 m	1610 nm	SWIR 1
B12	20 m	2190 nm	SWIR 2

Data - Other

- DEM from USGS National Map (1/9 arc-second, ~ 10m)
- Soil erodibility from NRCS State Soil Geographic Data Base
- Precipitation observations from National Weather Service
- High-Resolution Rapid Refresh (HRRR) model data from HRRR Archive at University of Utah
- Fire perimeter and watershed outlets from USGS

Methods

- Normalized Burn Ratio:

$$NBR = \frac{NIR - SWIR}{NIR + SWIR}$$

- Difference NBR (dNBR) to classify burn severity:
  - Pre-fire NBR – Post-fire NBR

- Change Detection:
  - dNBR at multiple dates to identify regrowth

- Supervised Classification:
  - Maximum Likelihood
  - Neural Network

Methods

- Debris-flow likelihood by USGS methodology (Staley et al., 2016)

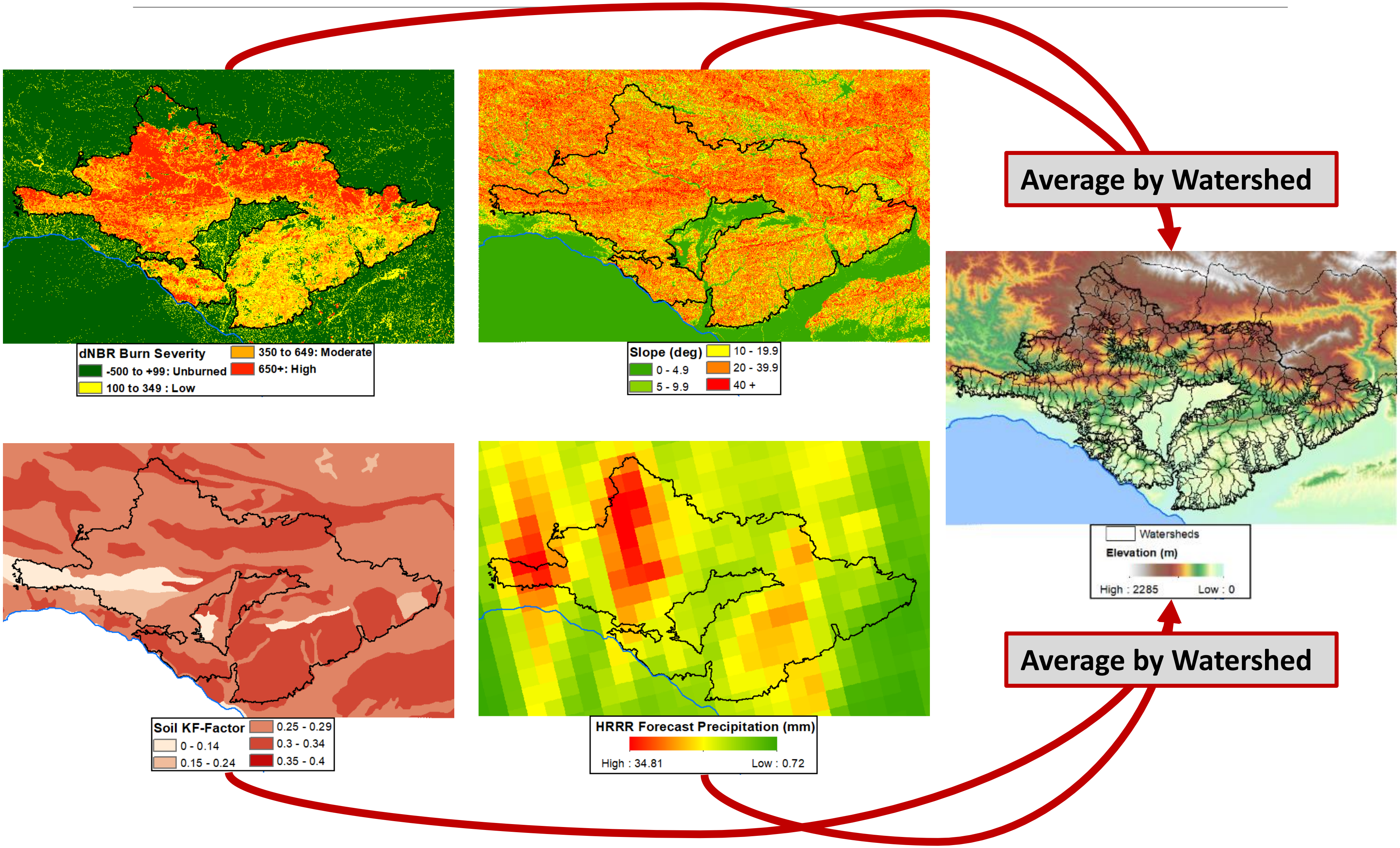
$$P = \frac{e^{\chi}}{1 + e^{\chi}}$$

$$\chi = \beta + C_1TR + C_2FR + C_3SR$$

Parameter	Value
β	-3.63, empirically defined coefficient
C_1	0.41, empirically defined coefficient
T	Proportion upstream area burned at moderate or high severity with slope gradient >= 23 degrees
R	15-minute rainfall accumulation, in mm
C_2	0.67, empirically defined coefficient
F	Mean upstream dNBR/1000
C_3	0.70, empirically defined coefficient
S	Mean upstream Soil KF-Factor (fine-earth soil erodibility)

- DEM used in hydrology workflow:
  - Identified primary streams
  - Identified watershed boundaries
  - Adjusted watershed outlet points to match stream locations

Methods

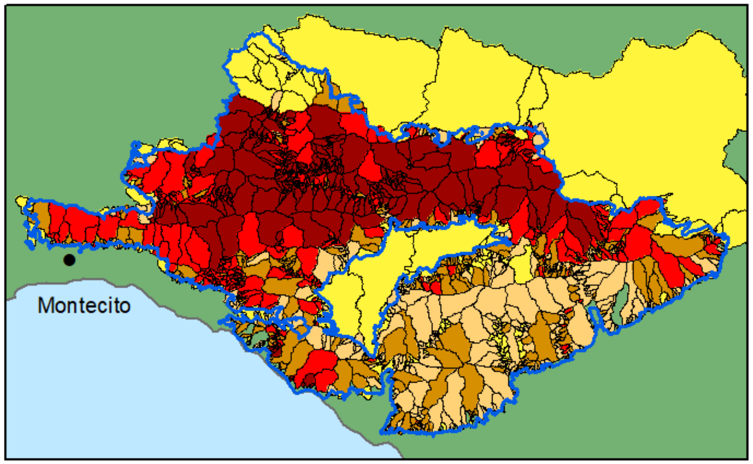


dNBR Burn Severity
-500 to +99: Unburned
100 to 349 : Low
350 to 649: Moderate
650+: High
Slope (deg)
0 - 4.9
5 - 9.9
10 - 19.9
20 - 39.9
40 +
Average by Watershed
Watersheds
Elevation (m)
High : 2285
Low : 0
Soil KF-Factor
0 - 0.14
0.15 - 0.24
0.25 - 0.29
0.3 - 0.34
0.35 - 0.4
HRRR Forecast Precipitation (mm)
High : 34.81
Low : 0.72
Average by Watershed

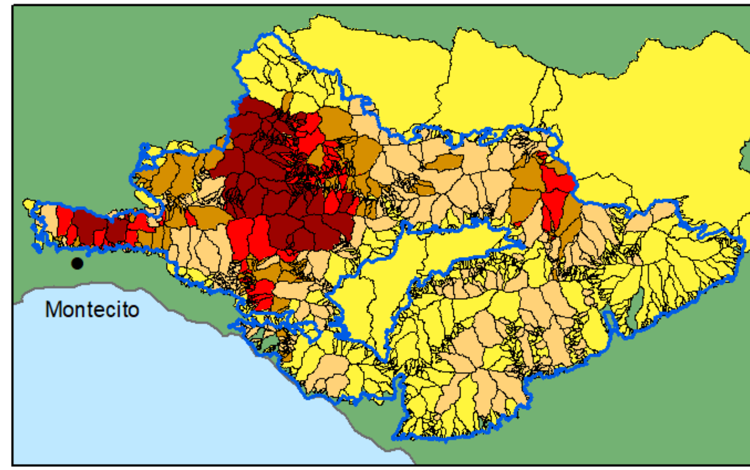
Results: Debris-Flow Probability

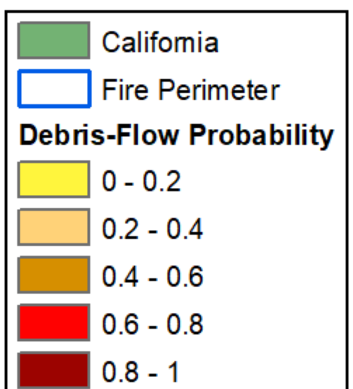
- Logistic regression approach ID’d debris-flow threat in Montecito
- HRRR model provided even better spatial results; less over-forecasting

Probability based on uniform 6 mm rainfall

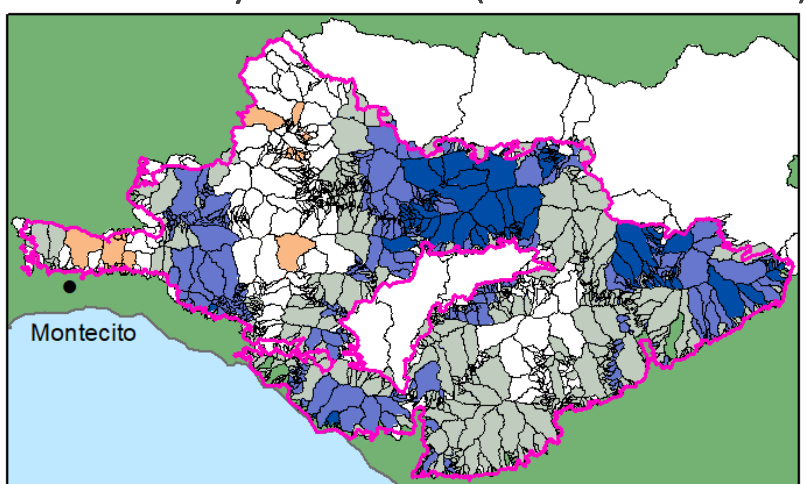


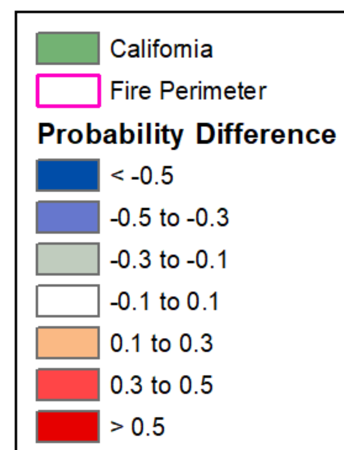
Probability based on HRRR rainfall forecast





Probability difference (HRRR – uniform)



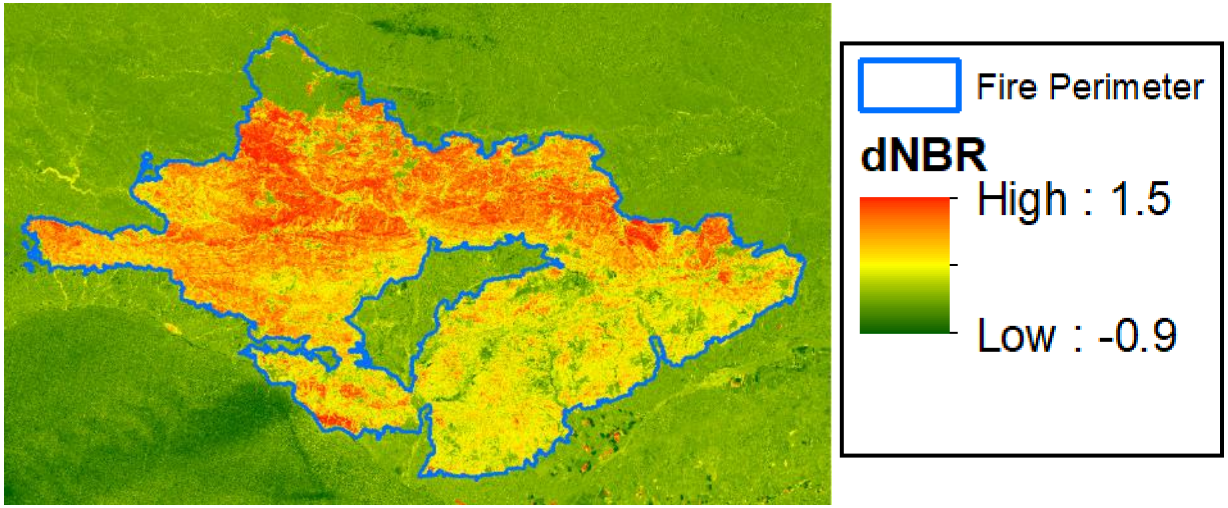


Results: NBR calculation

Pre-fire SWIR Image: 03 Dec 2017

Post-fire SWIR Image: 22 Jan 2018

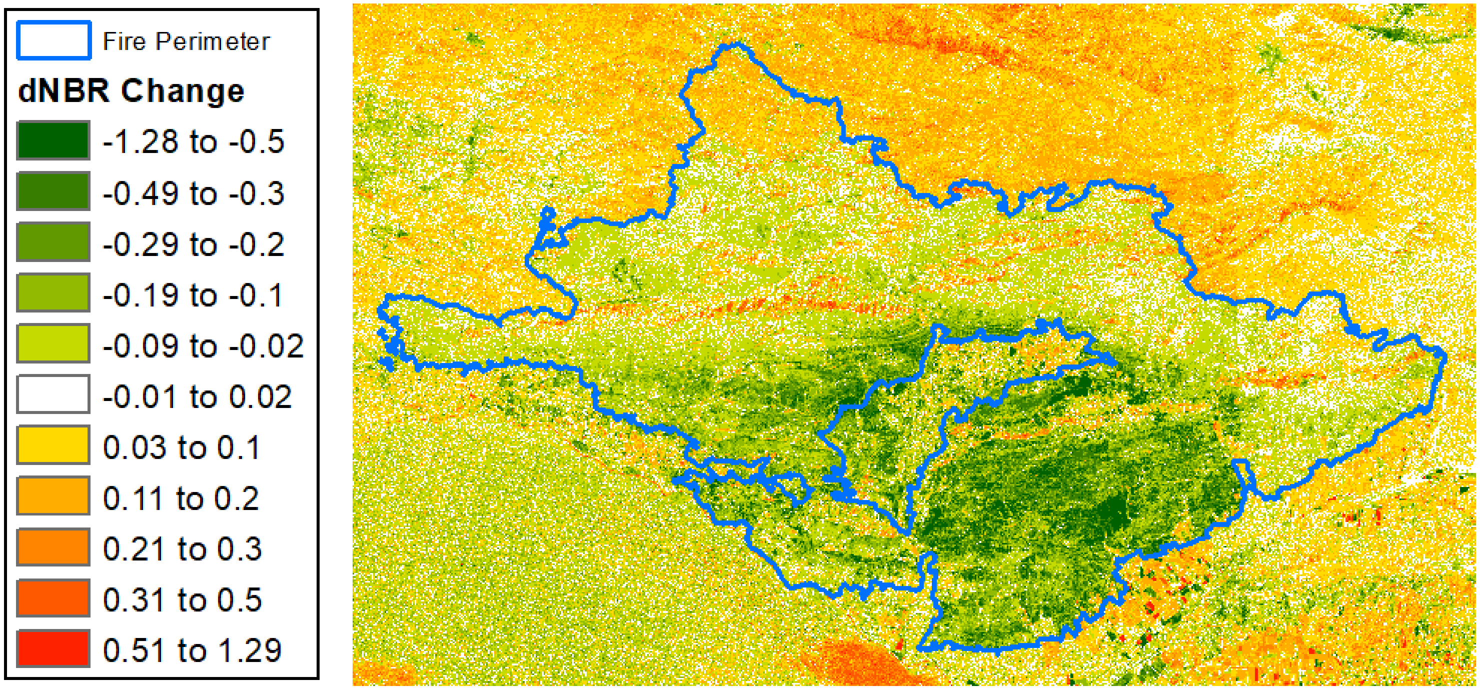
dNBR Image: preNBR – postNBR



Results: NBR change detection

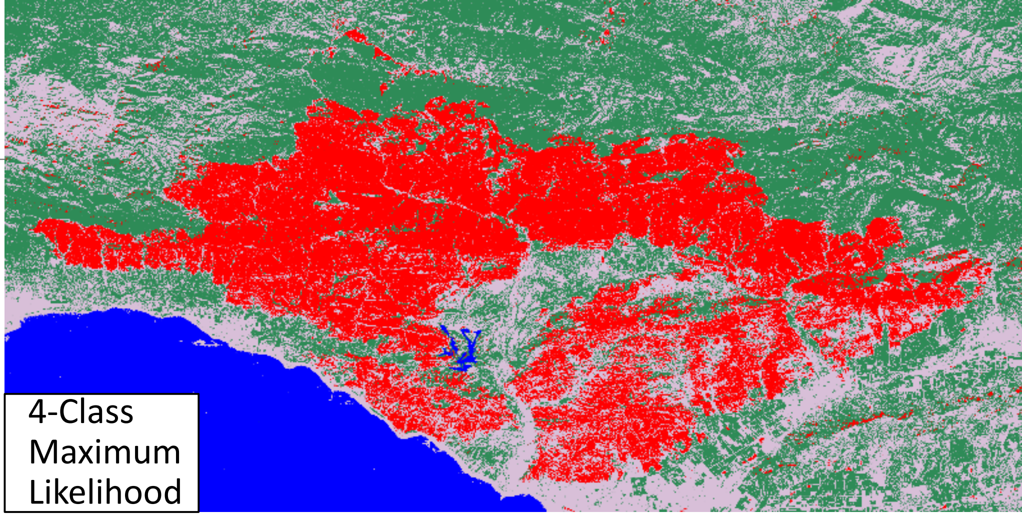
- dNBR re-evaluated on 8 March and 28 March
- Change detection performed to detect decrease in burn severity due to regrowth
  - New image – old image
  - Negative values indicate regrowth, positive values mostly anomalous

dNBR change from 22 Jan to 28 Mar 2018



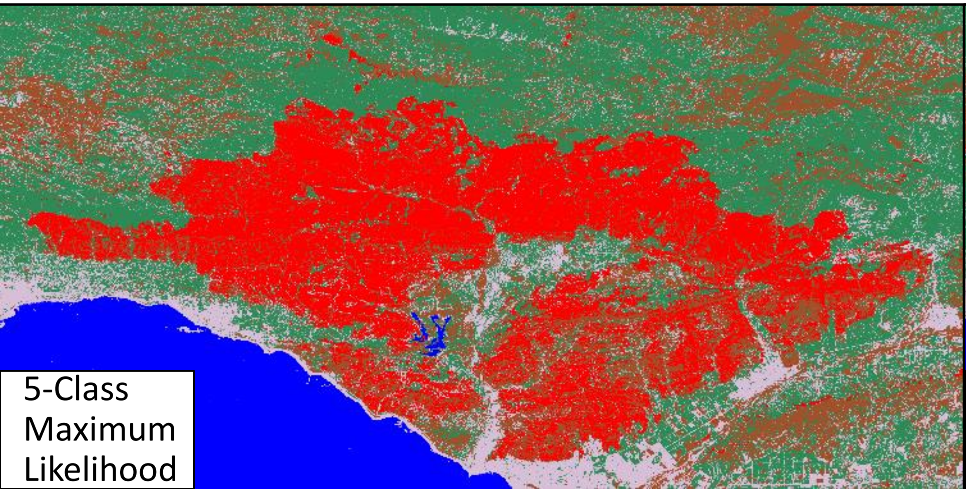
Results: Supervised Classification

- Burn Area
- Vegetation
- Water
- Urban

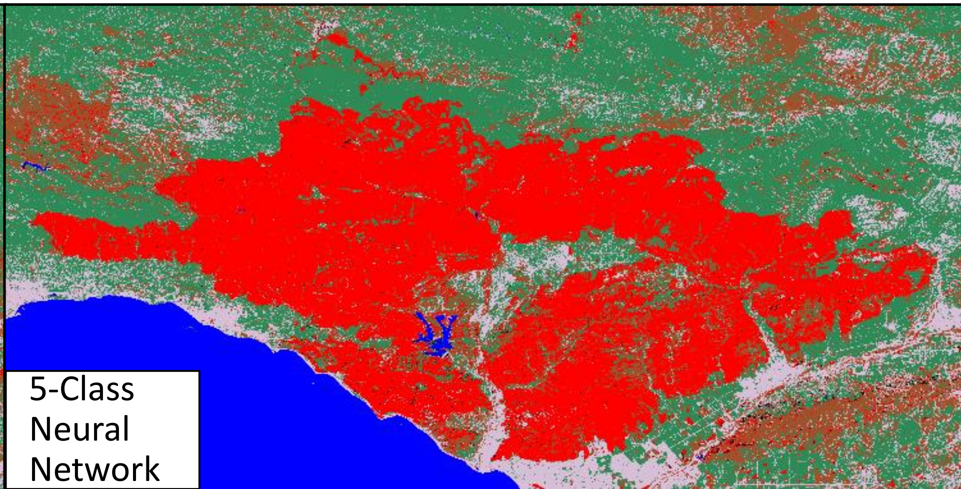


4-Class Maximum Likelihood

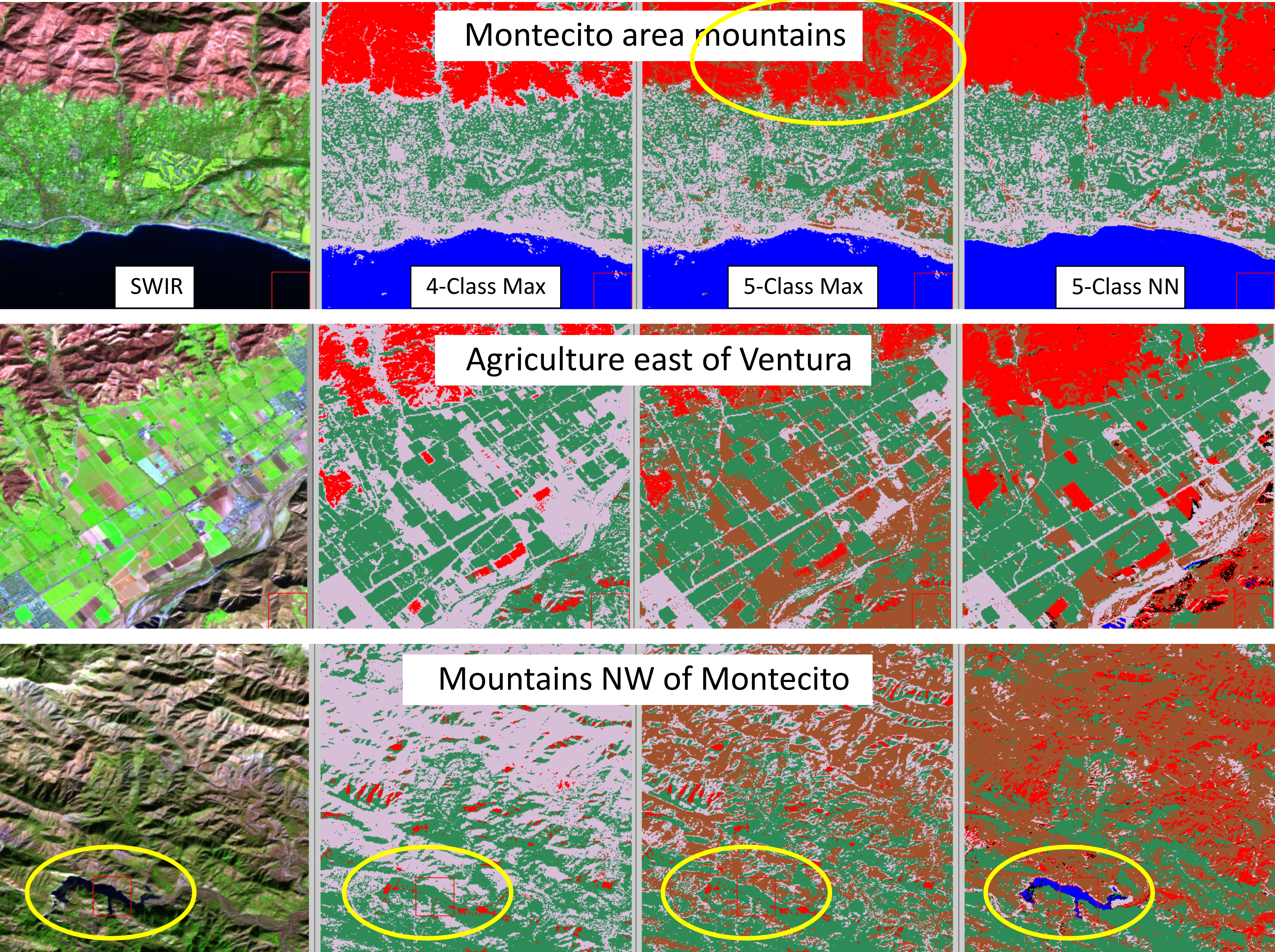
- Unclassified
- Burn Area
- Vegetation
- Water
- Urban
- Soil/NPV



5-Class Maximum Likelihood



5-Class Neural Network


Montecito area mountains
SWIR
4-Class Max
5-Class Max
5-Class NN
Agriculture east of Ventura
Mountains NW of Montecito

Results: Supervised Classification

- Overall Accuracy & Kappa:

Measure/Name	4-Class Max	5-Class Max	5-Class NN
Overall Accuracy	98.45%	97.22%	98.20%
Kappa Coefficient	0.9751	0.9591	0.9735

- User’s Accuracy:

User's Accuracy/Name	4-Class Max	5-Class Max	5-Class NN
Burn Area	98.37%	98.09%	93.56%
Vegetation	99.66%	99.45%	99.69%
Water	100.00%	100.00%	100.00%
Urban	89.01%	96.85%	96.91%
Soil/NPV		81.87%	98.61%
Average	96.76%	95.25%	97.75%

- Producer’s Accuracy:

Producers's Accuracy	4-Class Max	5-Class Max	5-Class NN
Burn Area	95.67%	89.83%	99.65%
Vegetation	95.92%	95.52%	98.35%
Water	99.98%	99.98%	100.00%
Urban	99.52%	98.18%	98.77%
Soil/NPV		99.17%	85.17%
Average	97.77%	96.54%	96.39%

Results: Class Confusion

- 4-Class Max:
  - Burn areas incorrectly classified as Urban (4.3%)
  - Urban very overclassified – led to addition of soil class
  - Urban pixels bleed into the ocean along coastline

- 5-Class Max:
  - Burn areas incorrectly classified as Soil/NPV (9.6%)
  - Urban pixels still bleed into the ocean along coastline

- 5-Class NN:
  - Soil incorrectly classified as Burn area (14%)
  - Burn areas generally overclassified (in mountains, shadows, agriculture)
  - Very good with water and coastline

Project Challenges

- Gathering and pre-processing data
  - Dealing with data sizes (800 MB) and formats (.jp2 vs .tif vs .img)
  - Stitching tiles together – Google Earth Engine very helpful
  - Finding cloud-free images

- Atmospheric correction
  - Unable to implement method for Sentinel-2 imagery
  - Abandoned after speaking with Phil Dennison, due to common use of TOA reflectances for burn identification with NBR/dNBR

- Supervised classification
  - Challenge to identify land cover in parts of imagery
  - Vegetation vs. soil in mountainous areas, due to reflections and shadows

Sources

(1) Brewer, D., et al., 2005. Classifying and Mapping Wildfire Severity: A Comparison of Methods, *Photogrammetric Engineering & Remote Sensing*, 71(11): 1311-1320.

(2) National Weather Service, Los Angeles. 2018. NWS Los Angeles Twitter Page. https://twitter.com/NWSLosAngeles/status/950785251520995333 (last accessed 10 April 2018).

(3) National Weather Service California Nevada River Forecast Center. 2018. NWS CNRFC Twitter Page. https://twitter.com/NWSCNRFC/status/951127915013509121 (last accessed 10 April 2018).

(4) Staley, D. M., et al., 2016. Prediction of spatially explicit rainfall intensity-duration thresholds for post-fire debris-flow generation in the western United States, *Geomorphology*, 278: 149-162.

(5) Thomas Fire Watershed Emergency Response Team: Final Report. 26 February 2018. *Cal Fire,* 1-241.

Questions?