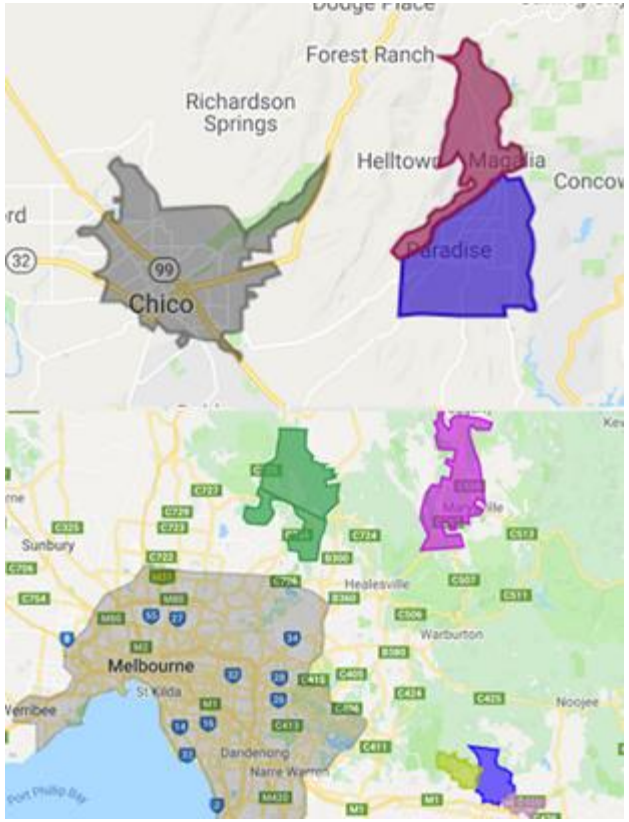
Institute of Industrial Science, the University of Tokyo
W. Takeuchi Lab.
Remote sensing of environment and disaster

THE UNIVERSITY OF TOKYO

Fire Risk Mapping to Predicted Urban Expansion in Wild-Urban Interfaces

in Southern Victoria, Australia and California, United States



Alexander Taniguchi-Wiegman
Undergraduate, 4th year
Thesis Defense Presentation

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Key Findings

- Relatively speaking, since 2000, California is at higher vulnerability for these fires than Victoria. This is due to environmental variables – despite the population and area of exposure being much lower than my region of interest in southern Victoria (currently and in 2040).

- Victoria hasn't changed as dramatically (since 2000) in environmental vulnerability, but it has a higher exposure (due to having more widespread area of fire *and* to having greater chance for novel urbanization up to 2040.)

- Fire stations are reasonably dense in both regions, though some increase in their number will most likely be needed in the future due to potential for urban expansion and densification.

Background

"Three for the show"

All Section Sub-Titles: Inspired by *Rocky and Bullwinkle* alternative titles

How a Wildfire Spreads

No.	Variable of Criteria	Normalized weights	Percent (0-100)
1	Fire Hotspot [Severity]	0.10	10
2	Land Cover Class	0.09	9
3	Settlements and Infrastructure	0.09	9
4	Air temperature	0.08	8
5	Rainfall	0.08	8
6	Soil moisture	0.08	8

This ranking shows some of the criteria that are most likely to influence the spread of a fire.

Hazard factor

Exposure factor

Vulnerability factor

Source: Lutz et al. (2011); Nasanbat et al. (2016)

Model of Risk: Hazard – Exposure - Vulnerability

- As long ago as 1980, UN Disaster Relief Organization defines risk includes societal exposure and vulnerability, in addition to hazard.

Managing Disaster (IPCC) and *Municipal Emergency Plan (*Victoria) say

- Hazard is any dangerous situation - natural or artificial - which causes harm or damage to people, societies, or the environment.
- Exposure is the number of percent of people or assets consistently within a region of hazard.
- Vulnerability are factors – human and environmental - that makes society more prone to be damaged, when exposed to the hazard.

- My thesis assumes humans can more easily control their level of vulnerability than that of their exposure.

Source: IPCC (2012); Colac Otway Shire (2014)

Research Question and Methods

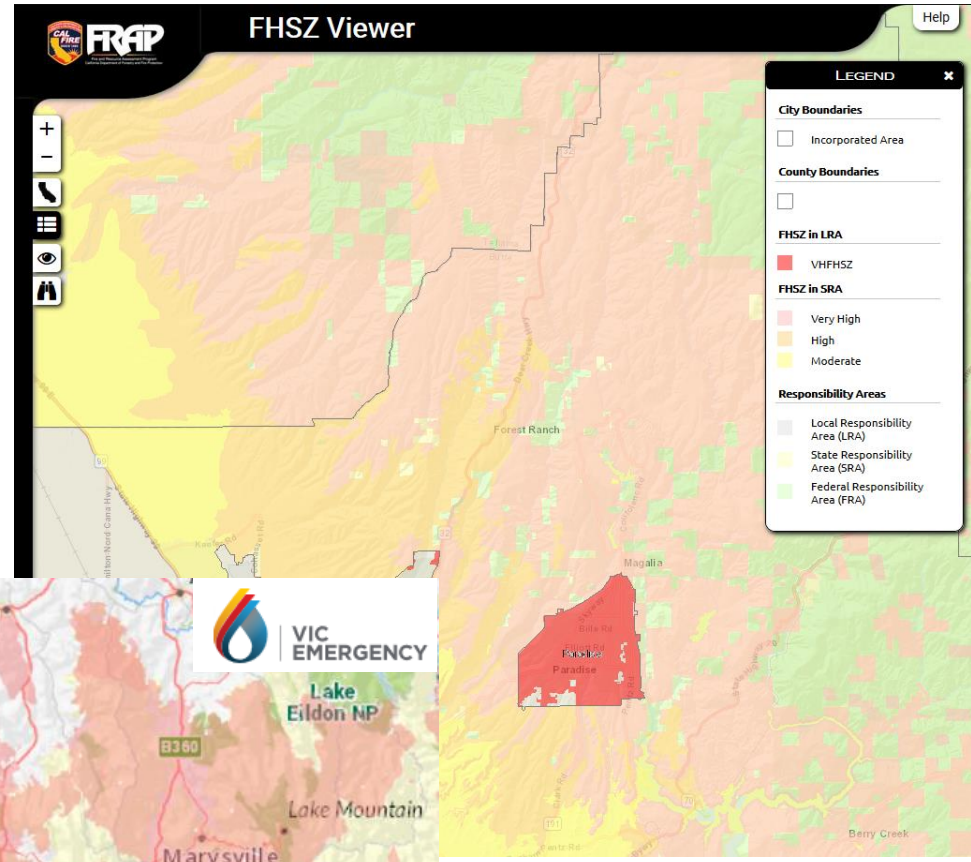
"I've grown accustomed to the place"

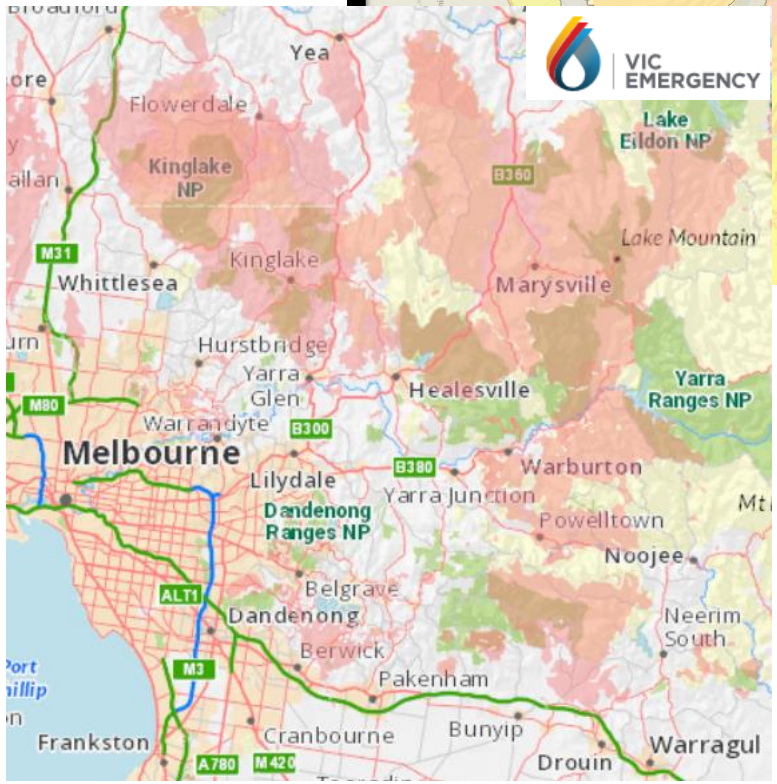
Research Question

- If (a) in present-day we have fire risk maps which give historical and current-risk scores to regions, and

  (b) we know that many cities are expanding into what was previously unused wildlands or forests;

  Then would predictive urban modeling overlaid with contemporary exposure and vulnerability factors give us a glimpse into the future of fire risk for previously destroyed urban regions situated at the edge of such wildlands?



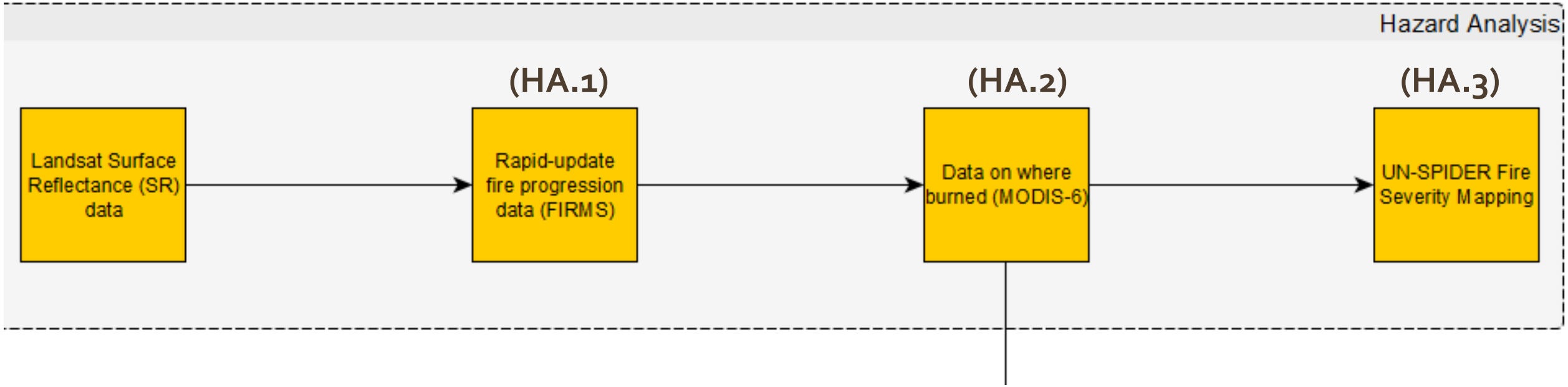


Objectives

See where urban development may occur and determine if "at risk". By that,

- (1) Measure hazard time-progression and area affected from fire-progression and classify burn severity for each of the fire-cases that defined these regions.
- (2) Classify the distinct classes of barren/burnt, urbanized, green-covered, and water-covered land cover. Also show the potential exposure by overlaying the burnt areas from these fires to the simulations of urbanization in 2040.
- (3) Compare environmental vulnerability before and after these fires with changes in temperature, soil moisture, wind direction, and precipitation.
- (4) Calculate a relative density between the location of current (2019) fire stations and the burnt areas from the fires that defined these regions to show if there is any unseen direct social vulnerability.

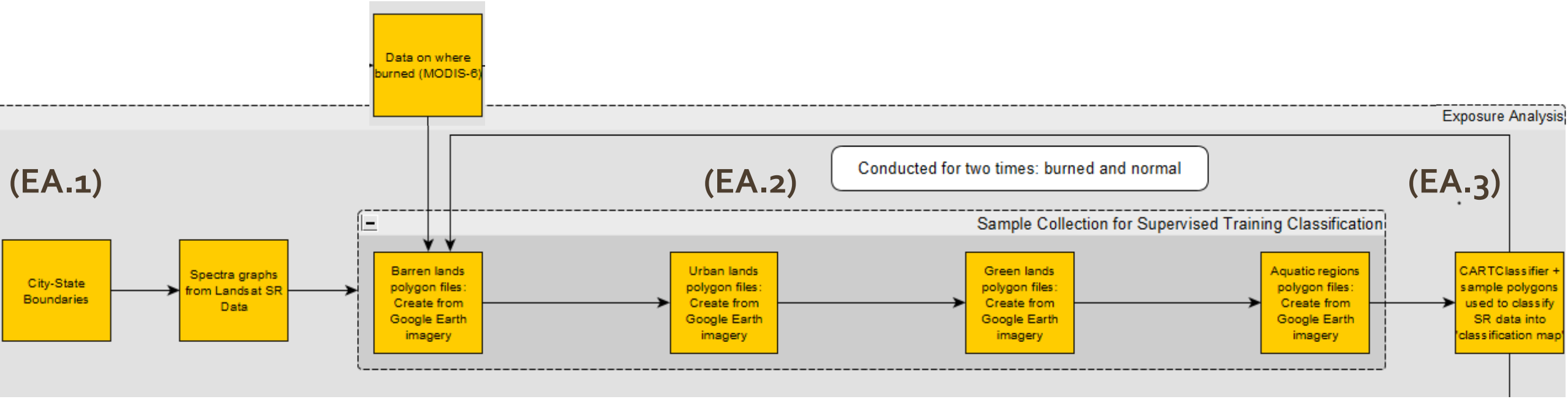
Methodology



First, I looked at the Hazard, paying attention to:

(1) How long did the fire take to burn in each of the towns/cities of interest?
(2) How large of an area was burnt?
(3) Where burned, how severe was it, and how close was it to major population centers?

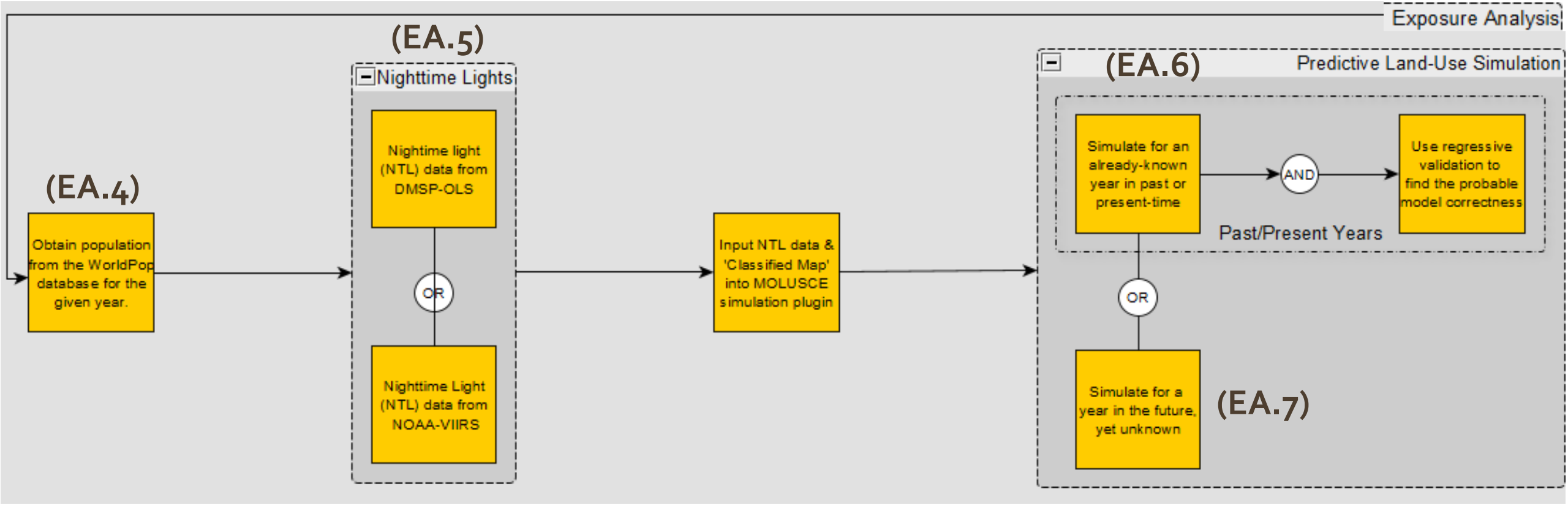
Methodology



Next, I looked at the exposure variables

(1) Where are the administrative boundaries that define where people are living?
(2) Classifying at-surface imagery into distinct classes of landcover usage.
(3) Visualizing the above land usages in each of these regions, during burnt and normal times.

Methodology

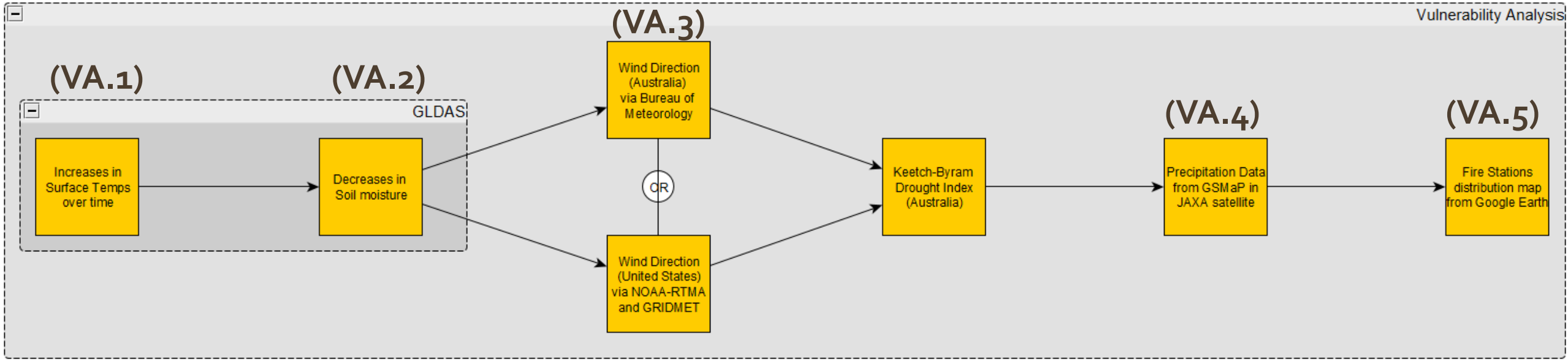


Continuing with exposure:

(4) Obtain population of various regions
(5) Model nighttime lighting (proxy population)

(6) Model known years (e.g. present-day) to test accuracy of the urban modeling program.
(7) Model unknown future years (e.g. 2030, 2040)
- novel areas have 15 sq. km+ in concentrated area

Methodology



Finally, vulnerability of populations:

(1) Visualize and compare average daily temperature.
(2) Visualize and compare average daily soil moisture.
(3) Visualize and compare the wind's direction to fire's directionality for the first day of each fire.
(4) Visualize and compare total annual rainfall.
(5) Measure density of fire stations – compare to average response times and travel speed.

Satellites' Products Used in this Presentation

	Satellite Product (name)	Cadence (days)	Resolution (m)	Purpose
(HA.1)	NASA FIRMS (Fire Information Resource Management System)	1	1000	Daily fire progression over an area [Data available: Nov. 2000 –]
(HA.2) (HA.3)	NASA Moderate-resolution Imaging Spectroradiometer (MODIS) Collection 6 Burned-Area	30/31 (1 month)	500	Cumulative area burned by fires [Data available: Nov. 2000 –]
(EA.7)	NASA/USGS Landsat Surface Reflectance	16	30	Show Earth's surface land cover [Data available: July 1972 –]
(VA.1) (VA.2)	NASA Global Land Data Assimilation Systems (GLDAS-2.1)	0.125 (3 hours)	~27,500 (.25 arc deg)	Temperature, Soil Moisture [Data available: Jan. 2000 –]
(VA.3)	NOAA Real-Time Mesoscale Analysis (RTMA)	~0.04 (1 hour)	2500	Wind Directionality (U.S. only) [Data available: Jun. 2015 –]
(VA.4)	JAXA Global Satellite Mapping of Precipitation (GSMaP)	~0.04 (1 hour)	~11,000 (.1 arc deg)	Precipitation [Data available: Mar. 2000 –]

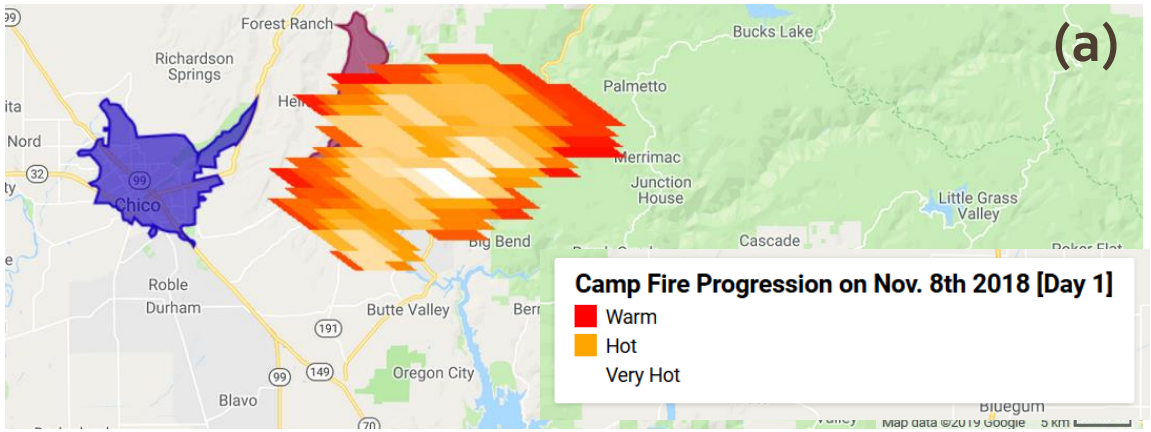
Source: Google Earth Engine Data Catalog

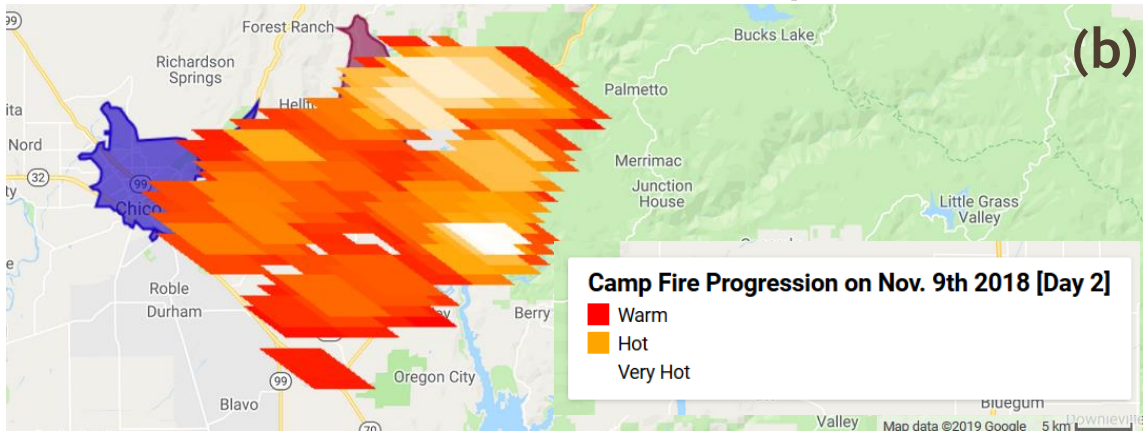
Results

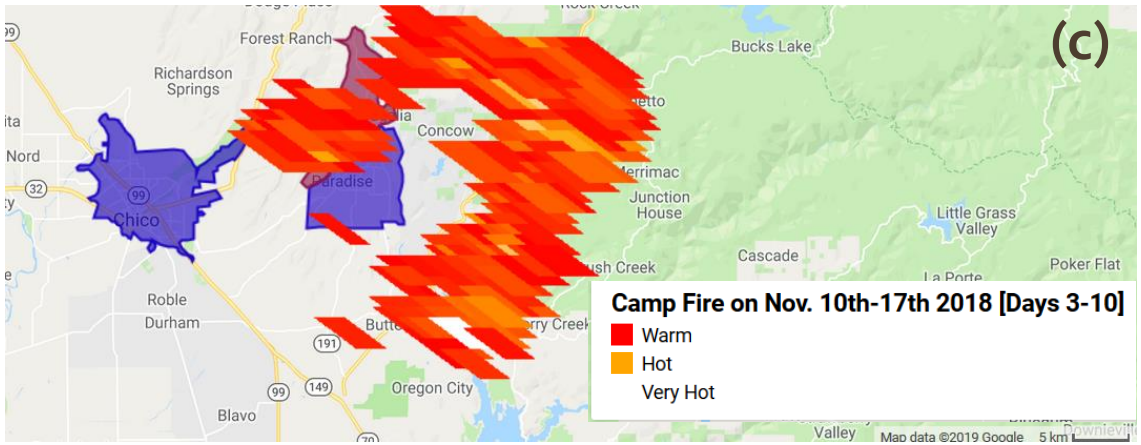
"That's some dandy looking collection you have there"

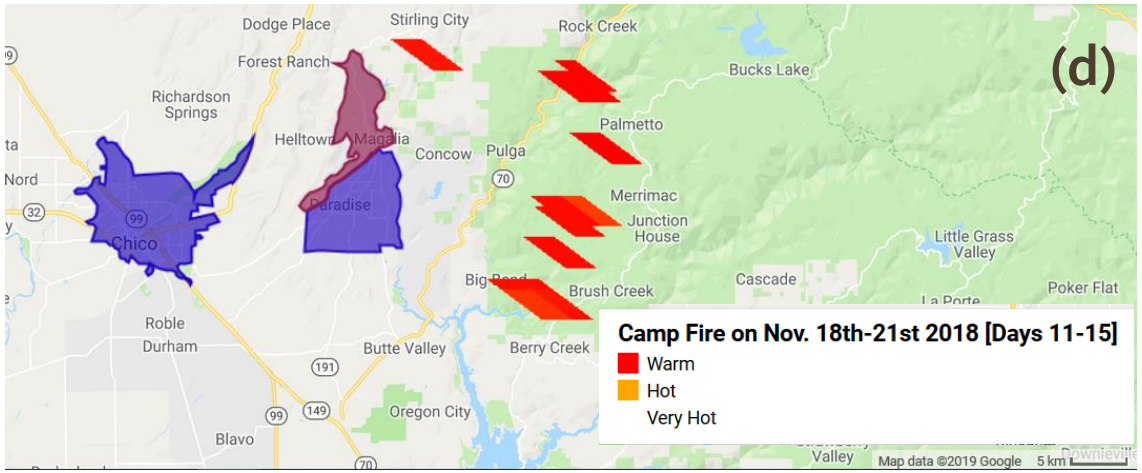
Warm = 300-370 K
Hot = 370-440 K
Very Hot = 440-510K

Time Progression of Camp Fire (HA.1)









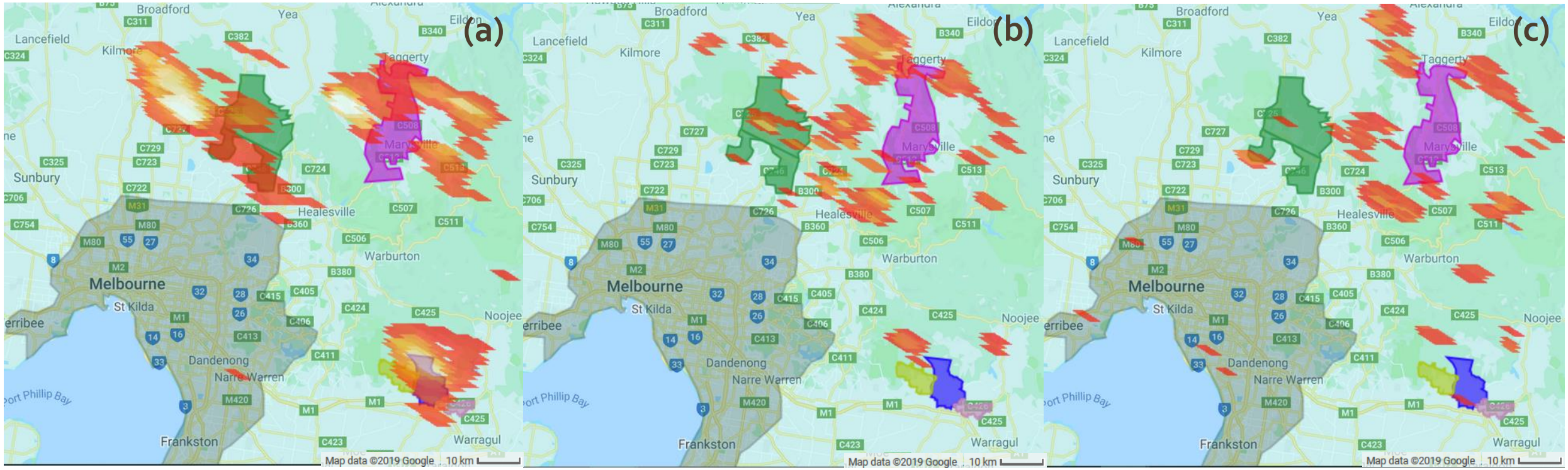
*After the first two days, the fires had mostly left the towns.
It continued in the forests until the just past a 2nd week.

Source: FIRMS (NASA)

Warm = 300-370 K
Hot = 370-440 K
Very Hot = 440-510K

Time Progression of Black Saturday Fires (HA.1)

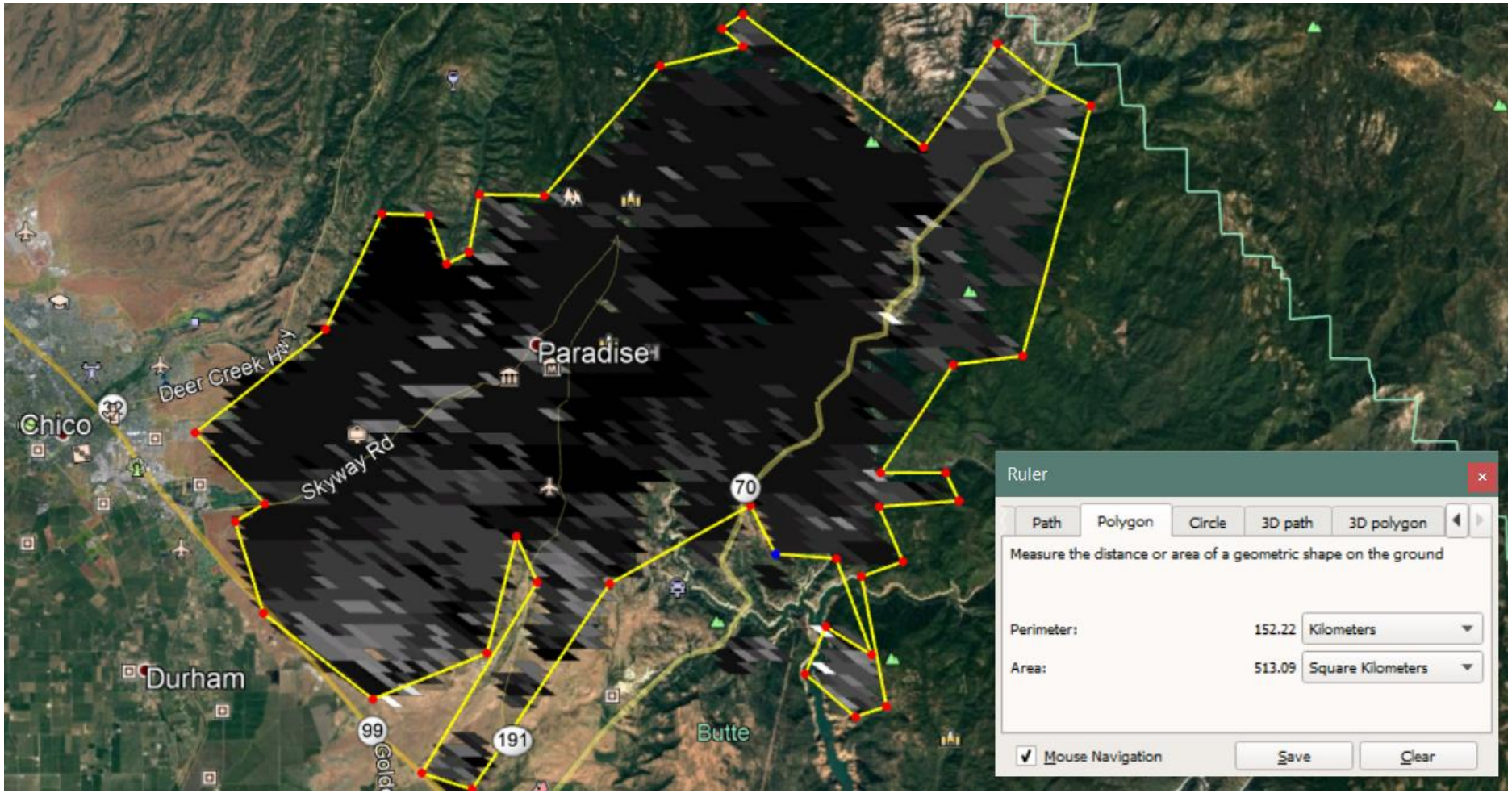
Feb. 7th, 2009 [Day 1] **Feb. 8th-11th, 2009 [Day 2-5]** **Feb. 12th-15th, 2009 [Day 6-9]**



*After the first week, the fire left the towns.
It continued in the forests until the end of the 5th week.

Source: FIRMS (NASA)

Hazard: Size of Burned-Area [California, USA] (HA.2)

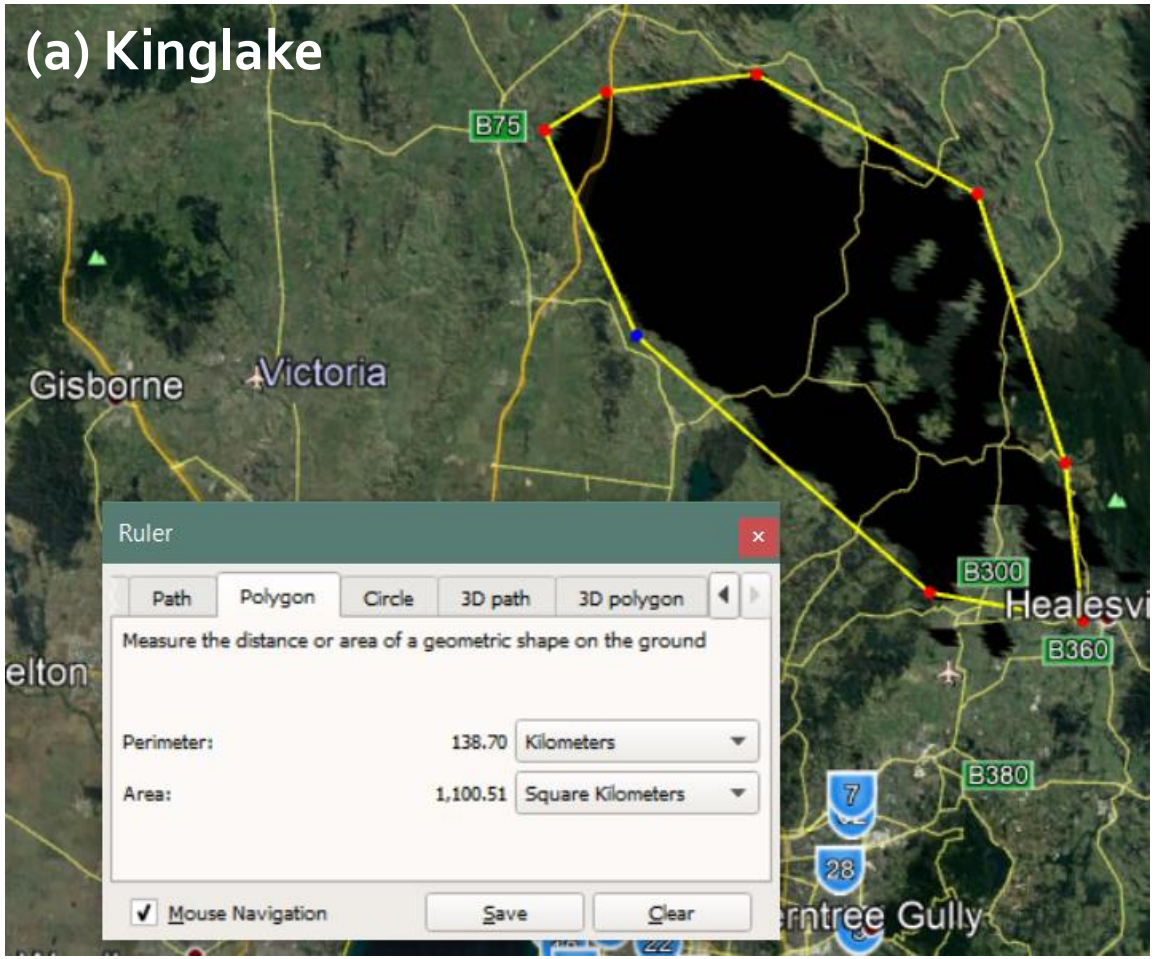


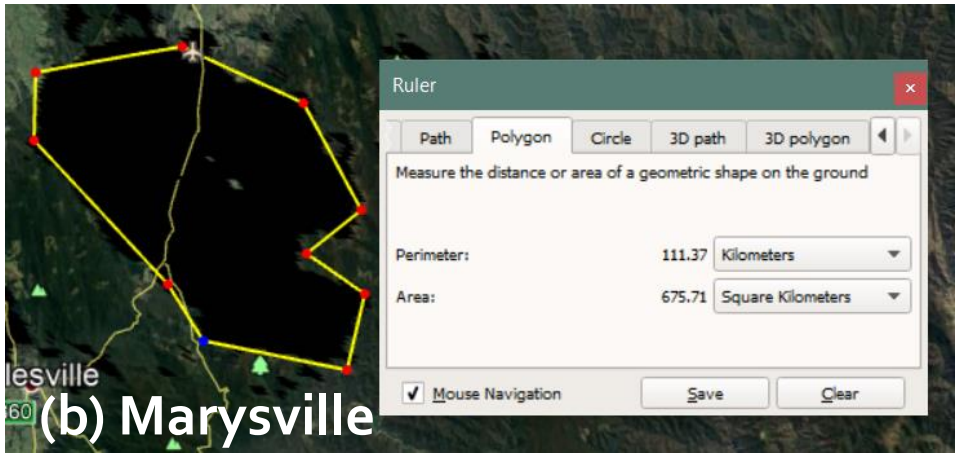
Total within Region of Interest: ~515 sq. km.

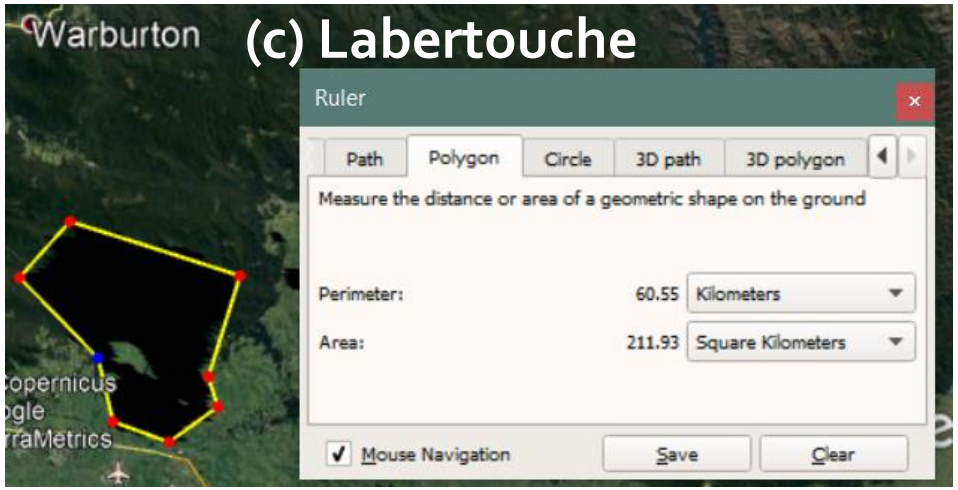
As the area was mostly burnt within 2.5 days, average speed of fire was 206 sq. km/ day.

Source: Google Earth, MODIS Collection 6

Hazard: Size of Burned-Area [Victoria, Australia] (HA.2)







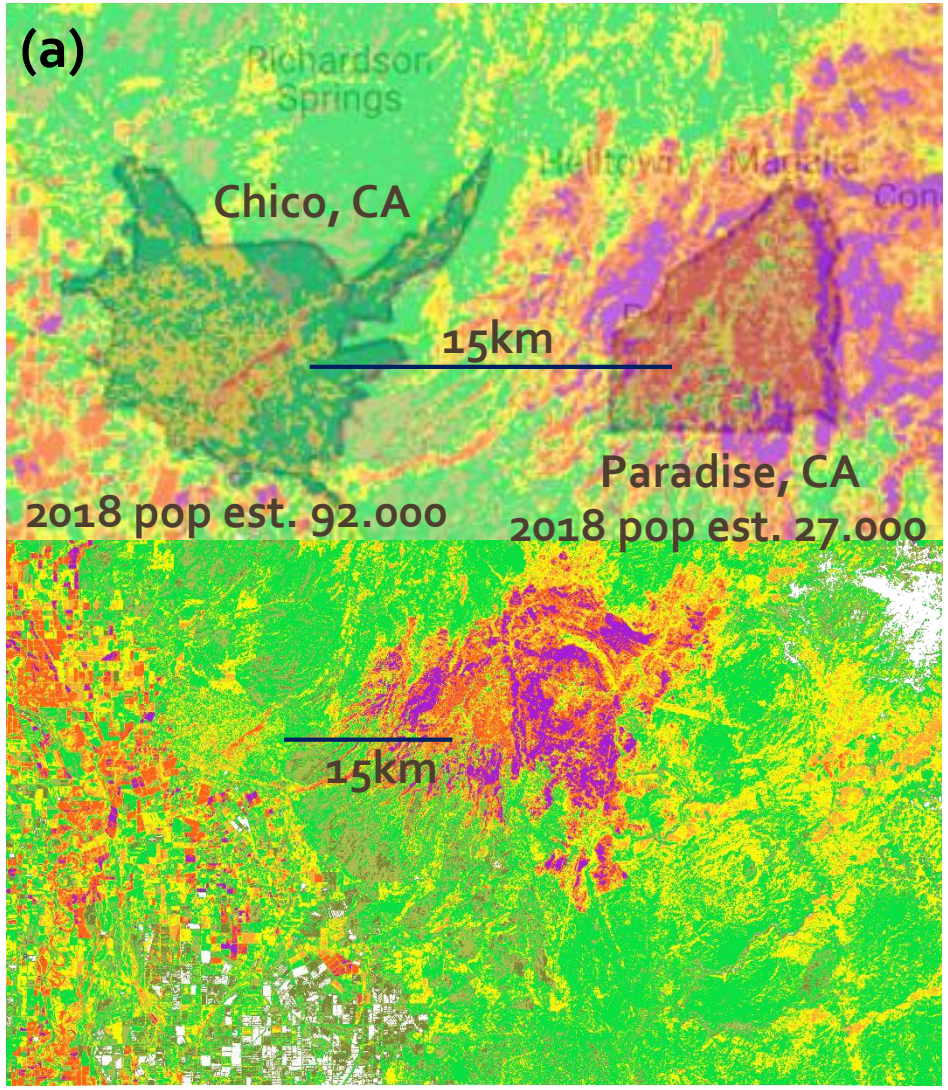
Total within Region of Interest: ~1975 sq. km.

As the area was mostly burnt within 7 days, average speed of fire was 282 sq. km/ day.

Source: Google Earth, MODIS Collection 6

Burned Area Severity Maps

(HA.3)

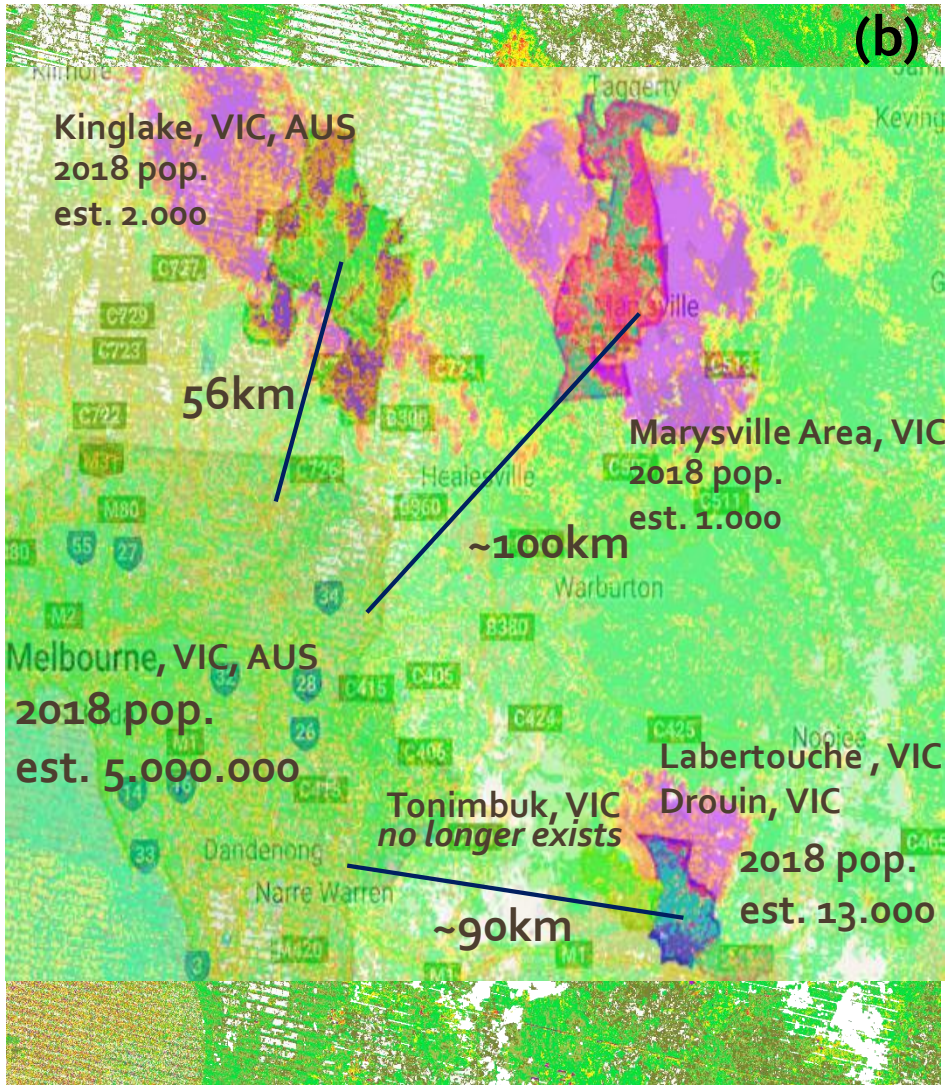


Classes calculated using UN-SPIDER method of arithmetic average of 'Very-Near Infrared' (~850nm) and 'Shortwave Infrared 2" (~2200nm).

[This looks at damage to vegetation in the region.]

dNBR Classes

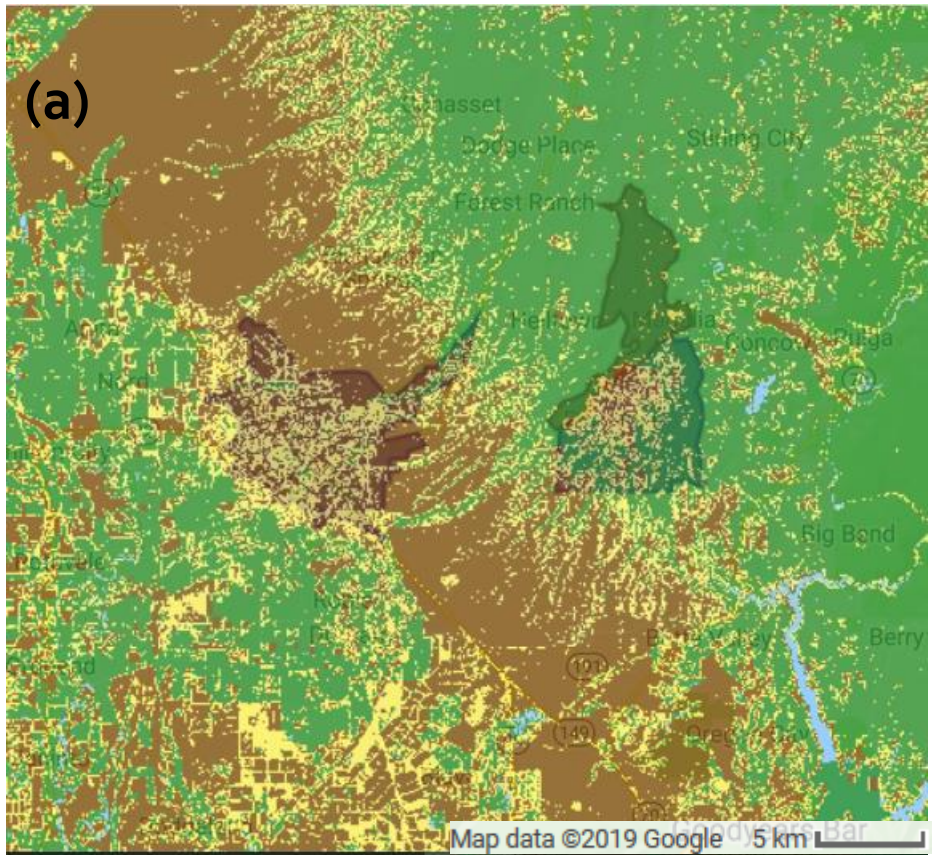
- Enhanced Regrowth, High
- Enhanced Regrowth, Low
- Unburned
- Low Severity
- Moderate-low Severity
- Moderate-high Severity
- High Severity
- N/A (likely masked by cloud)



Source: Landsat 7/8 , US Census Bureau, Australian Bureau of Statistics

Urban Predictions: 2030 (EA.7)

California, United States



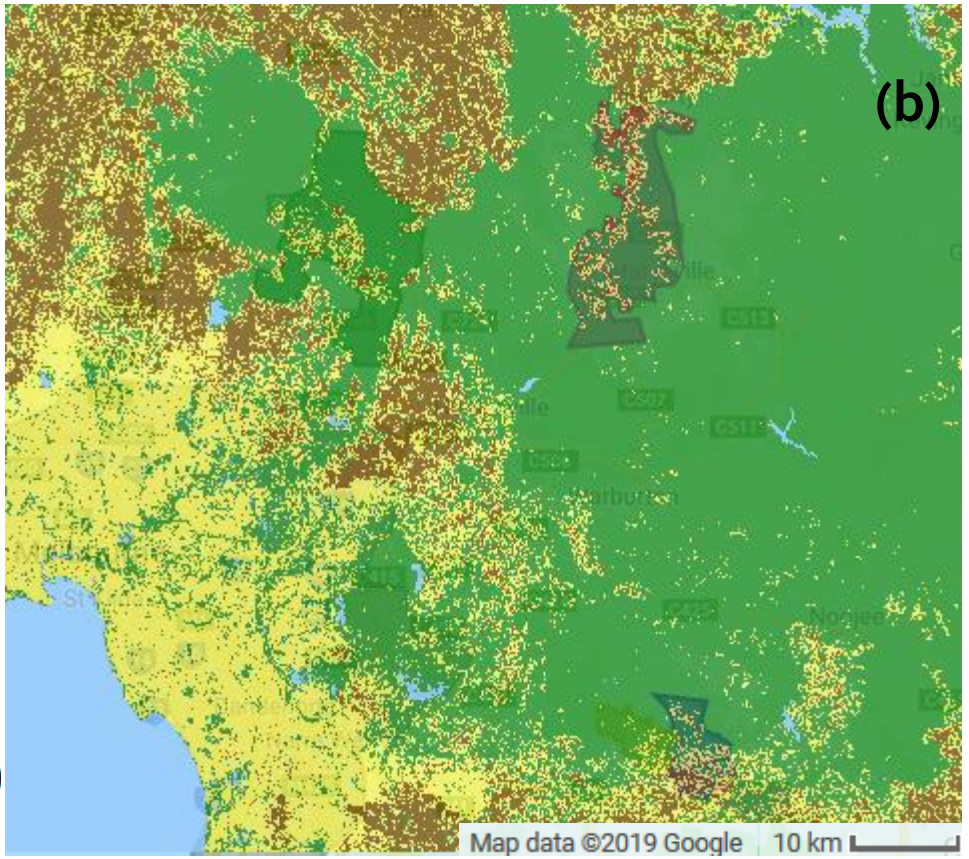
Simulation Image, created from 2006 and 2018 images

Base-images from Landsat.

Land-Cover classes

- Barren
- Urban
- Greenery (Forest / Grass / etc)
- Water

Victoria, Australia

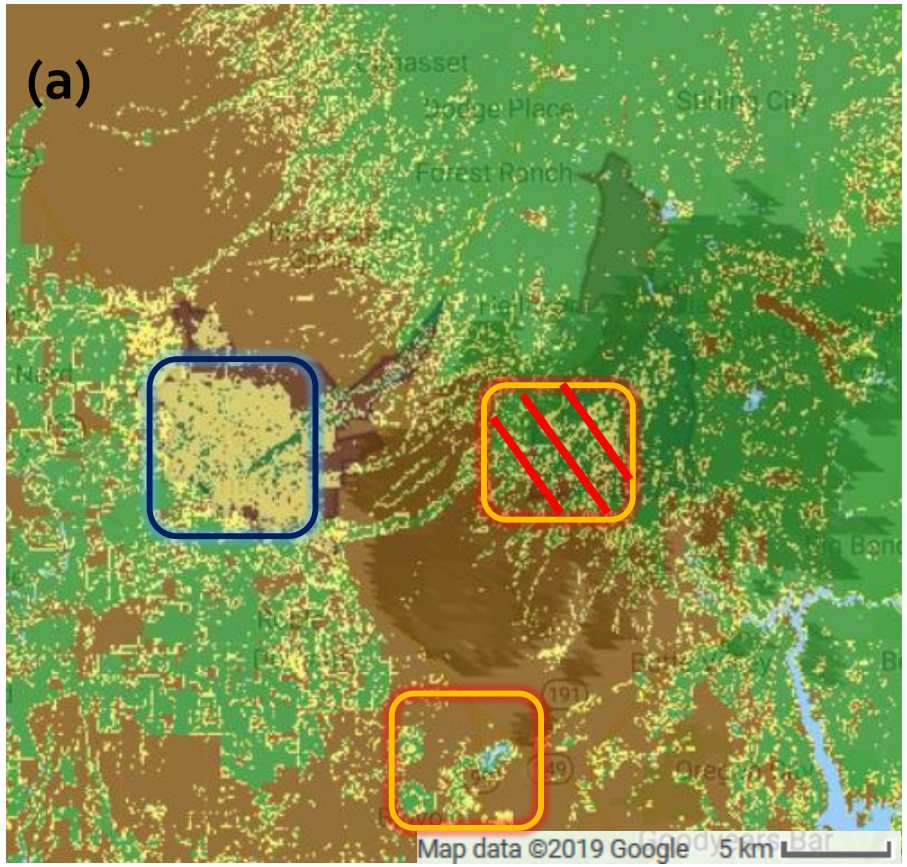


Simulation Image, created from 2008 and 2019 images

Source: Landsat 7 / 8

Urban Predictions: 2040 (EA.7)

California, United States



New/Renewed urban area

Densification in an existing urban area

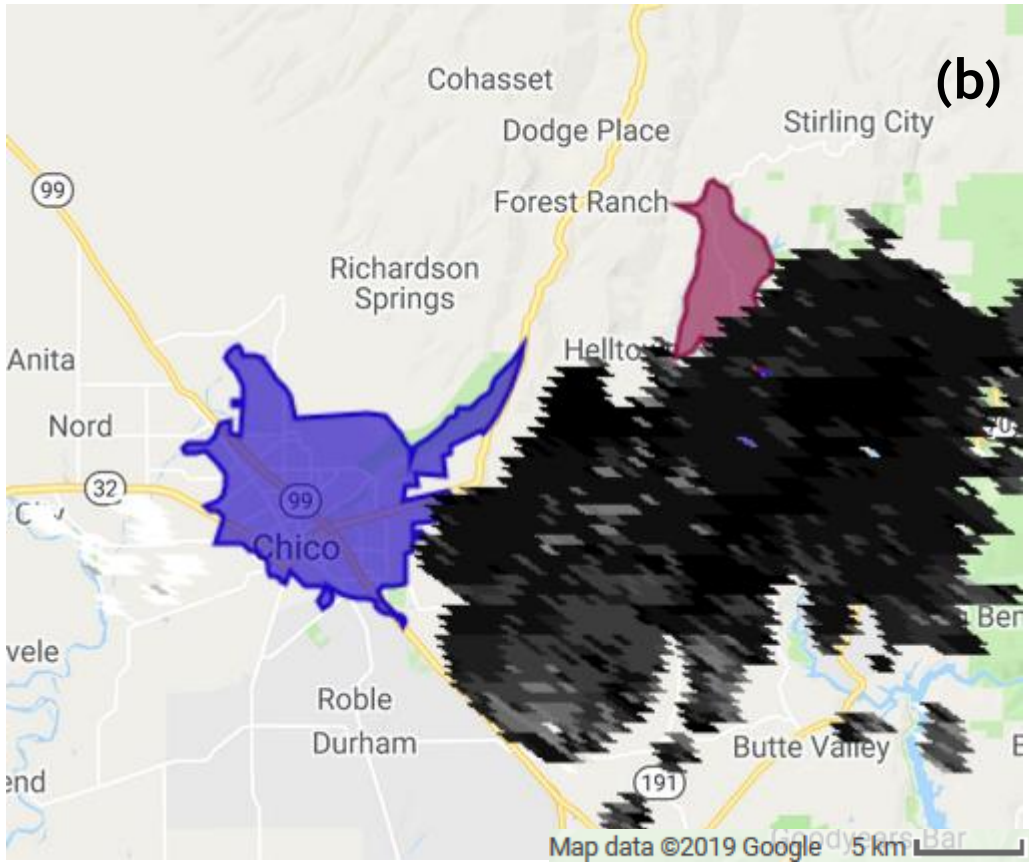
Areas in or adjacent to

or

zone of exposure

Land-Cover classes

- Barren
- Urban
- Greenery (Forest / Grass / etc)
- Water



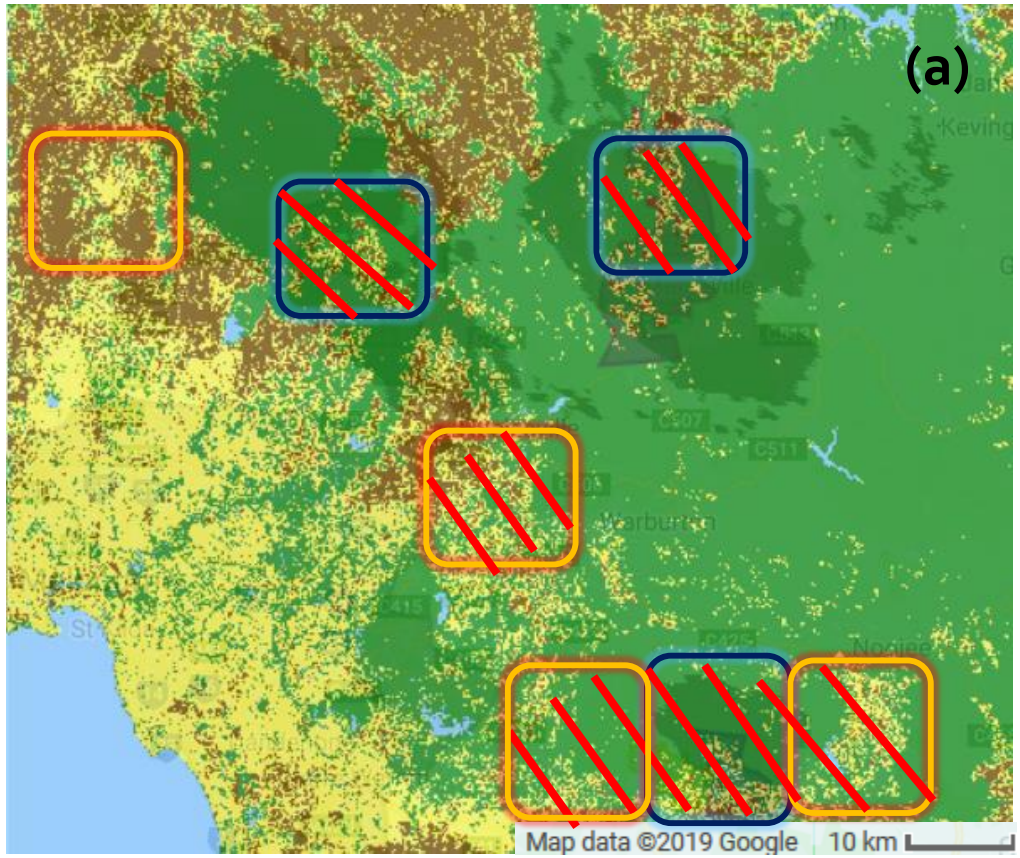
Simulation Image, created from 2006 and 2018 images

Burned Area Image, for comparison

Source: Landsat 7 /8, MODIS Collection 6

Urban Predictions: 2040 (EA.7)

Victoria, Australia



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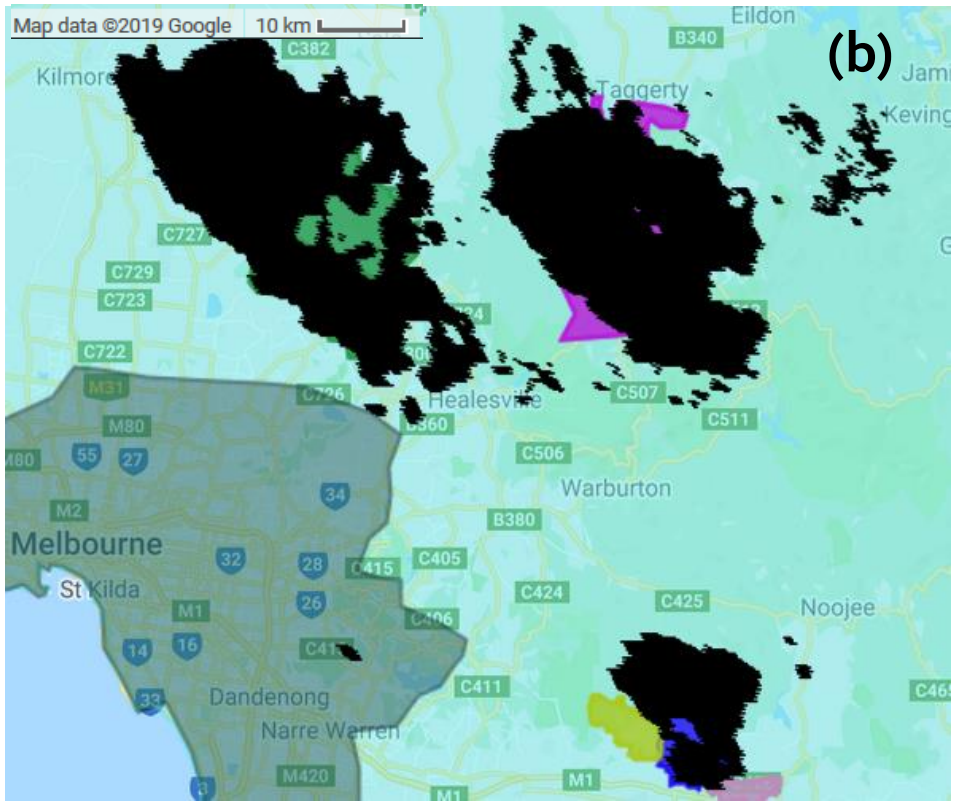


Simulation Image, created from 1998 and 2019 images

Burned Area Image, for comparison

Source: Landsat 7 /8, MODIS Collection 6

Urban Prediction (EA.7)

Notes on measurements

- California sees no new urban expansion as of 2040, within the already known zone of exposure (defined by the area that burned).

- Victoria also sees novel urban expansion in areas which are currently adjacent (but not within) such zones of exposure.

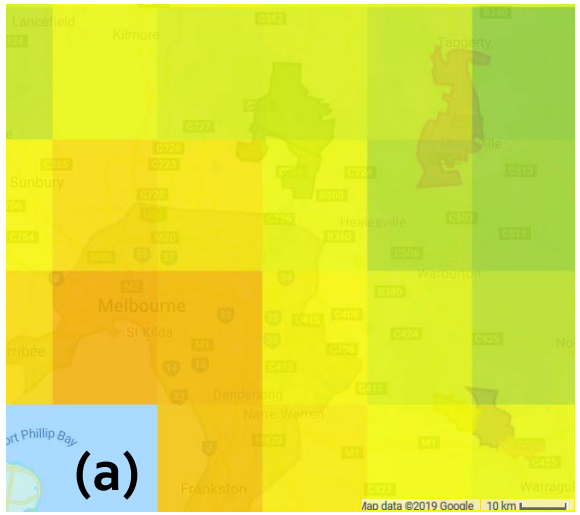
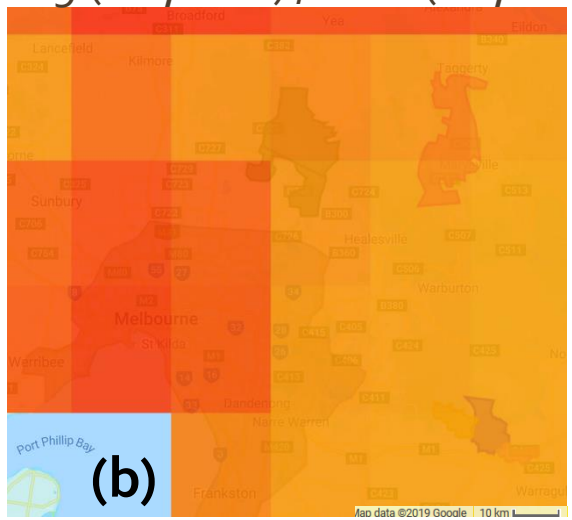
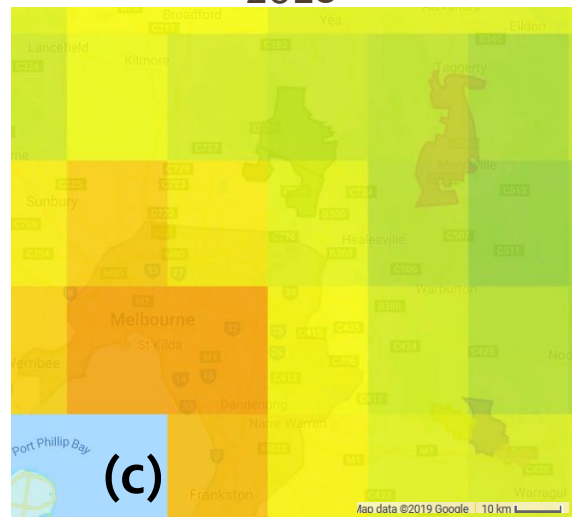
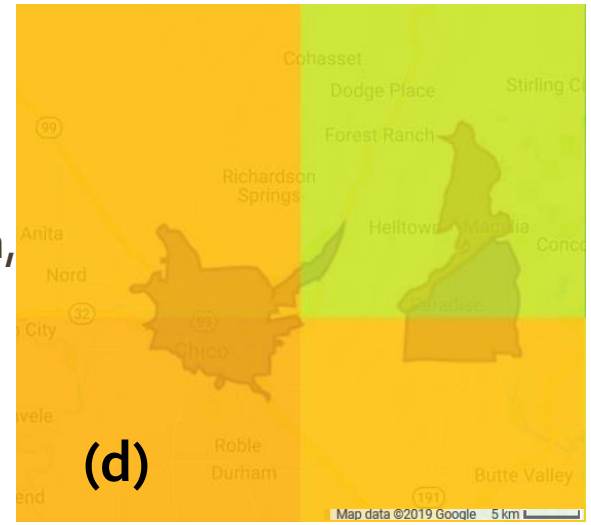
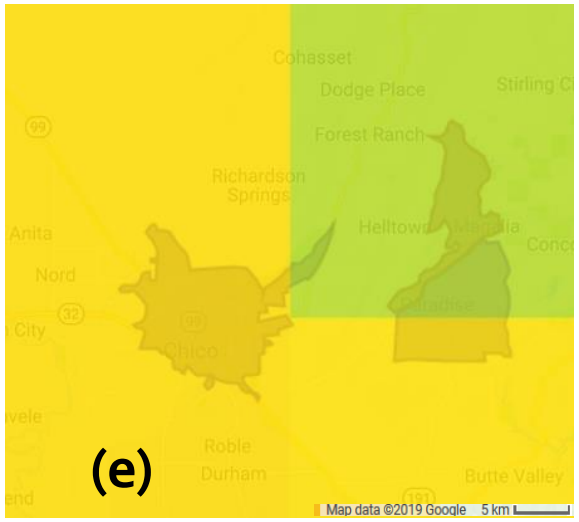
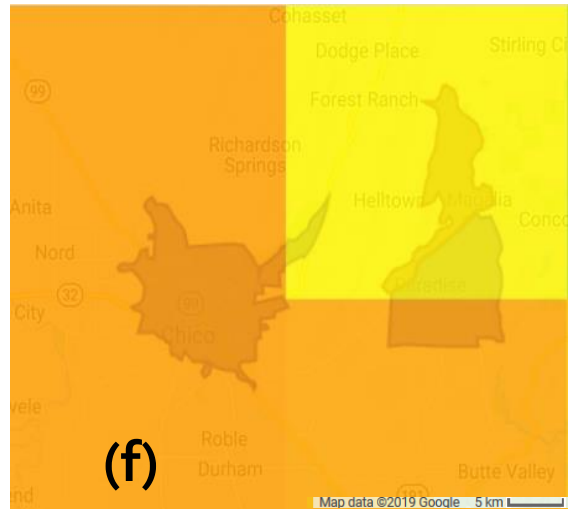
- The urban prediction algorithm was tested for the already known year of 2018. While urban area was most likely over-predicted (cf. noisy-appearance of simulation):

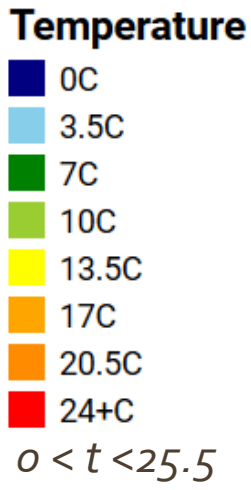
  Victoria's 2040 simulation was at up to 80.26% accurate (with Landsat 8).

  California's 2040 simulation was up to 79.06% accurate (with Landsat 7).

Source: MOLUSCE

Average At-Surface Soil Temperature (over 1 year) (VA.1)

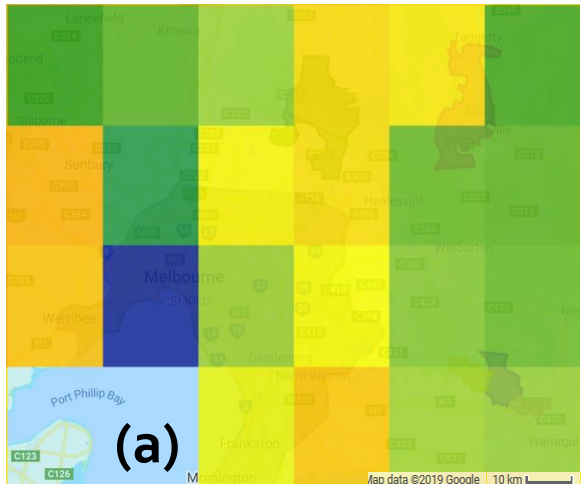
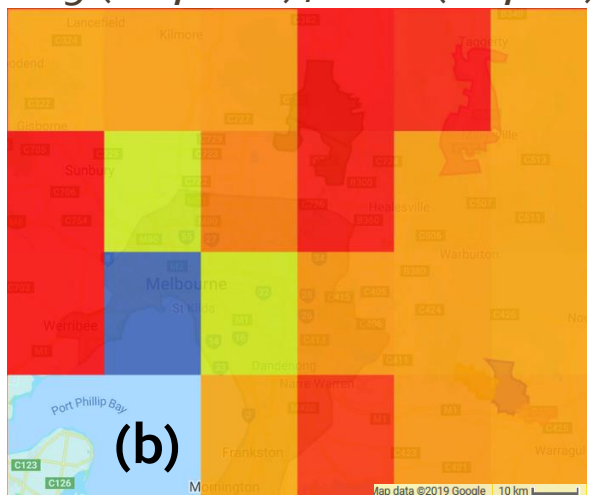
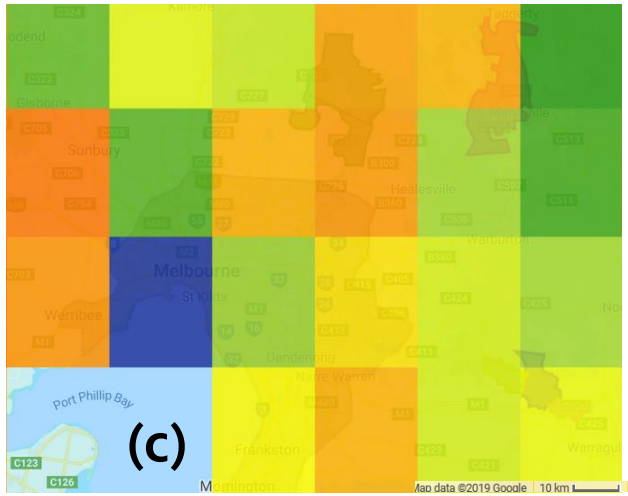
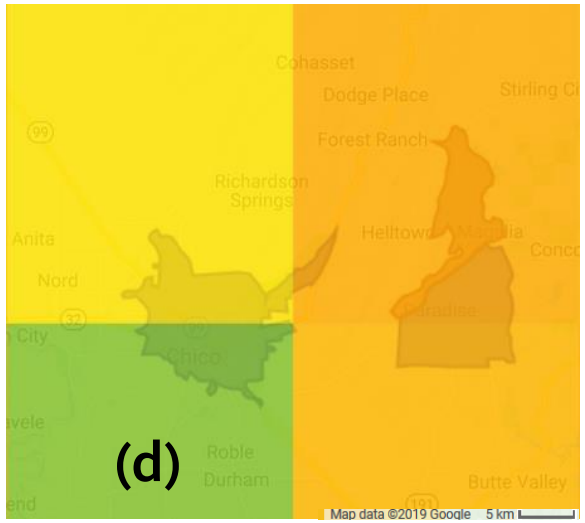
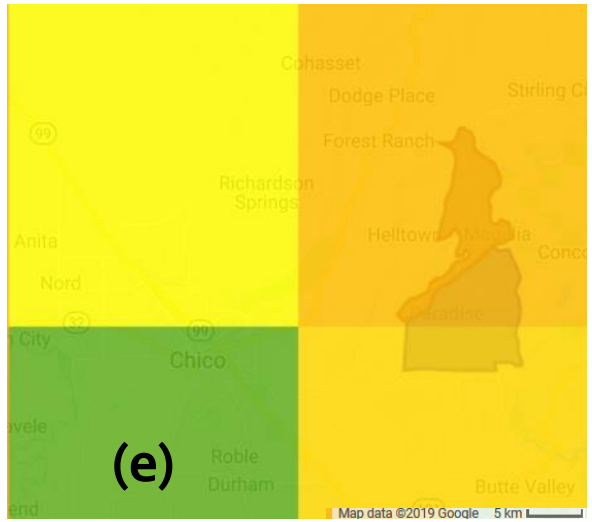
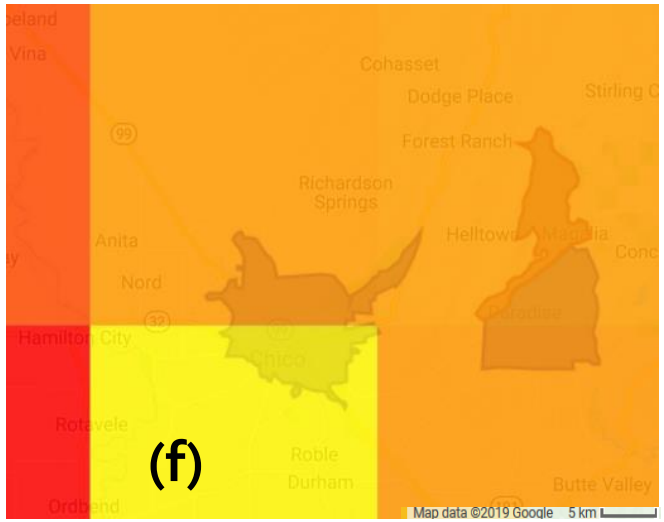
	2000	2009 (Vic, AUS) / 2010 (CA, US)	2018
Victoria, Australia			
California, United States			

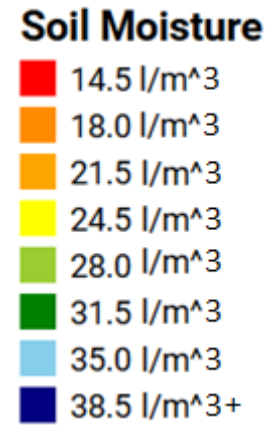


Victoria sees a sudden increase in temperature just prior to Black Saturday Fire; California sees it gradually worsen.

Source: GLDAS (NASA, NOAA, US Air Force)

Average At-Surface Soil Moisture Maps (over 1 Year) (VA.2)

	2000	2009 (Vic, AUS) / 2010 (CA, US)	2018
Victoria, Australia			
California, United States			



$14.5 < m < 39.5$

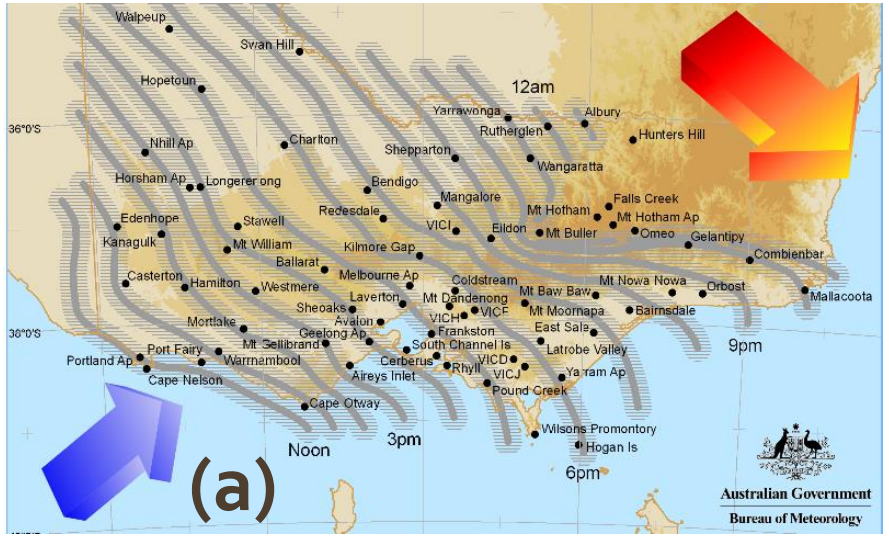
Victoria sees a sudden decrease in soil moisture only prior to Black Saturday; California sees a gradual and then sudden decrease.

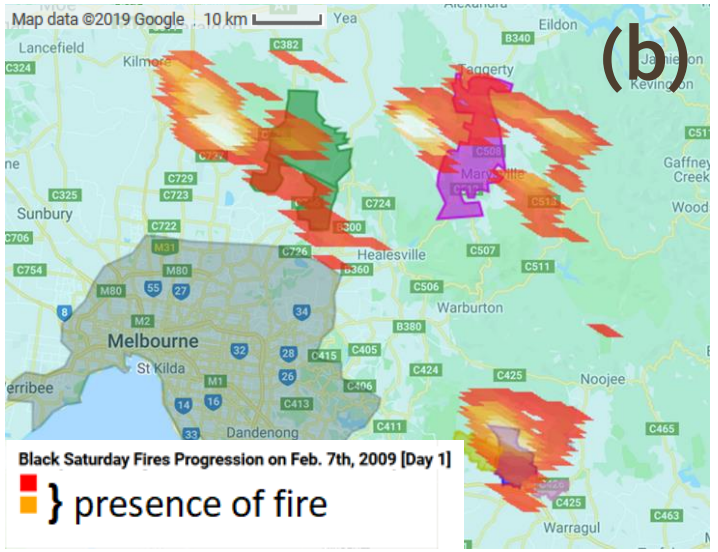
Source: GLDAS (NASA, NOAA, US Air Force)

Wind Direction for the First-Day of Each Fire

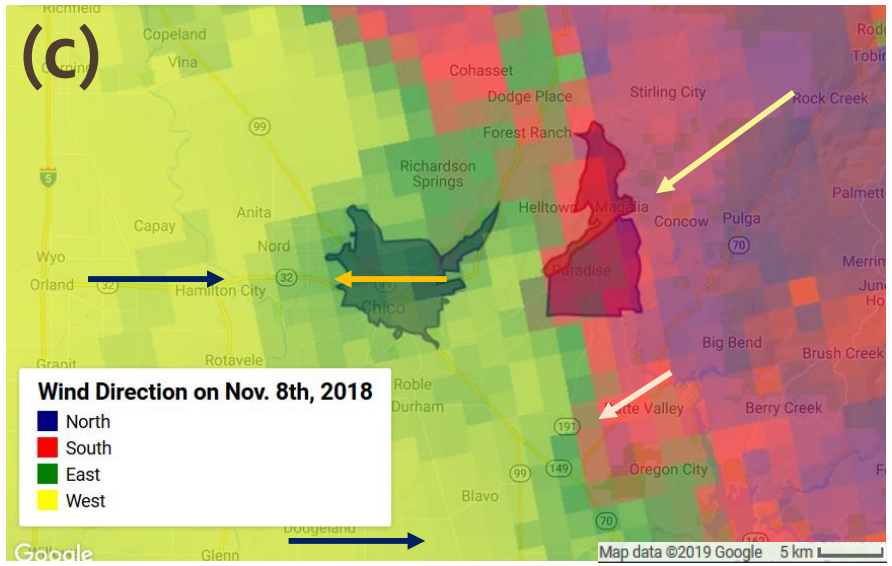
(VA.3)

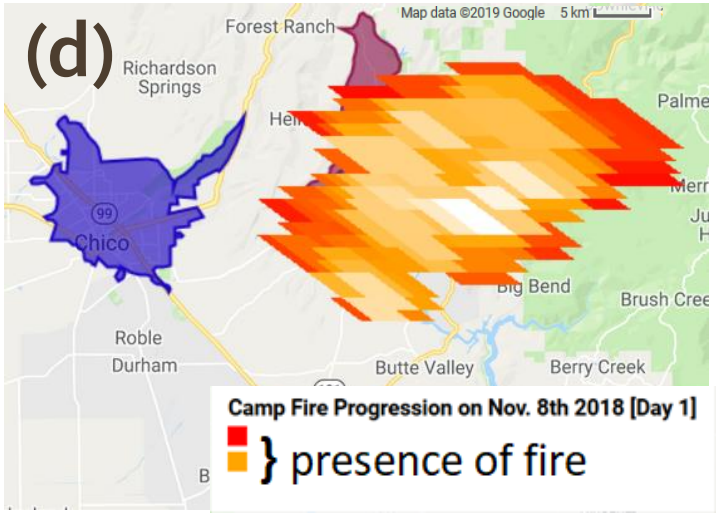
Victoria, Australia (Feb. 7, 2009)





California, USA (Nov. 8, 2018)





Generally speaking, we see in both regions that wind clearly defines if the fire will (or will not!) spread in some given direction.

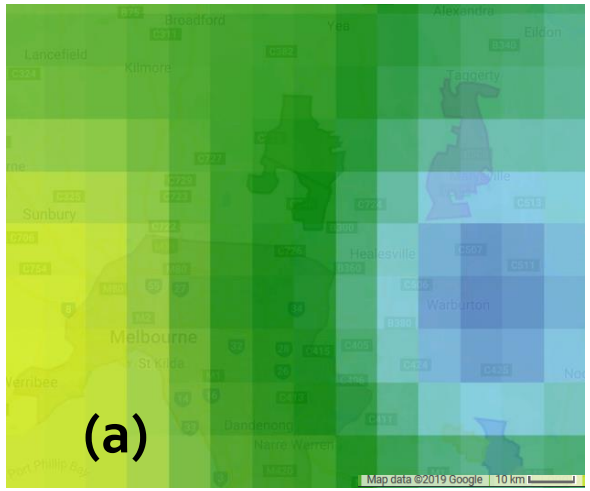
Source: Australian Bureau of Meteorology, RTMA (NOAA), FIRMS (NASA)

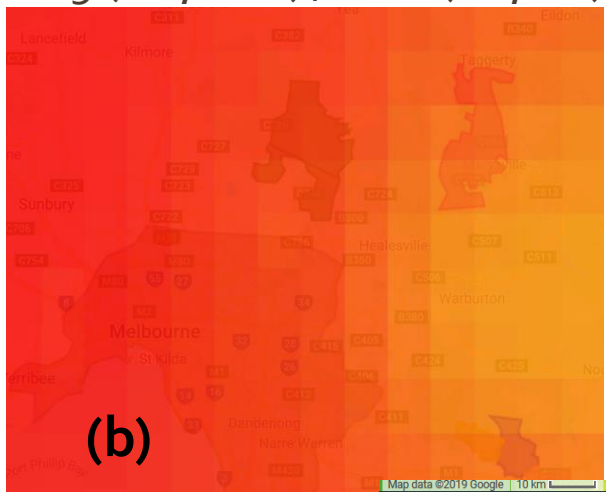
Yearly Cumulative Rainfall Maps

(VA.4)

2000 | 2009 (Vic, AUS) / 2010 (CA, US) | 2018

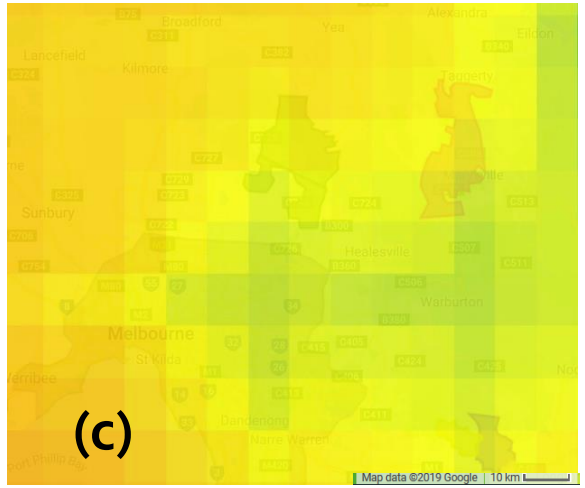
Victoria, Australia





Cumulative Rain
0 mm
15 mm
30 mm
45 mm
60 mm
75 mm
90 mm
105 mm+

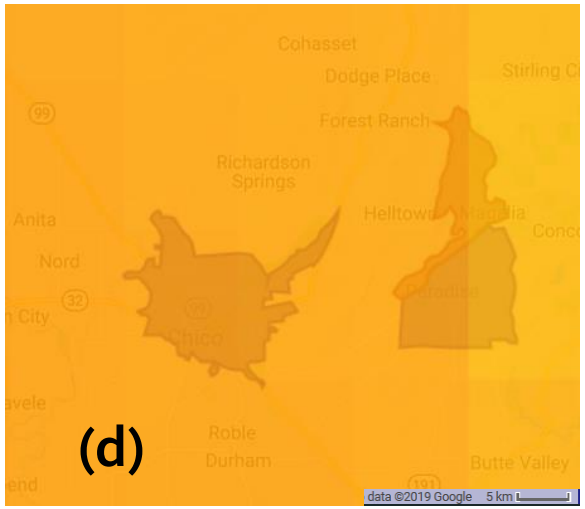
0 < r <112, 2009

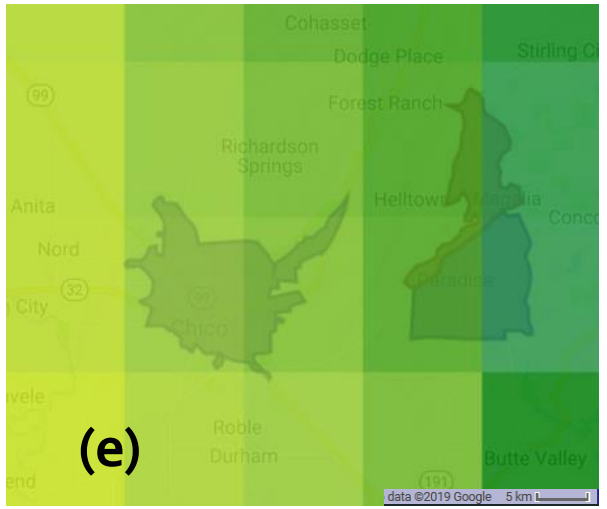


Cumulative Rain
0 mm
215 mm
430 mm
650 mm
60 mm
865 mm
1080 mm
1300 mm+

0 < r <1315, 2000&2018

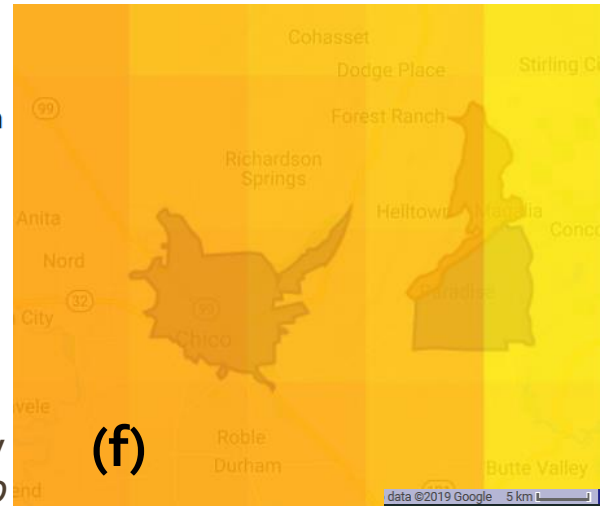
California, United States





Cumulative Rain
0 mm
300 mm
600 mm
900 mm
1200 mm
1500 mm
1800 mm
2100 mm+

0 < r <2190, 2000&2010



Cumulative Rain
0 mm
260 mm
515 mm
770 mm
1030 mm
1285 mm
1540 mm
1800 mm+

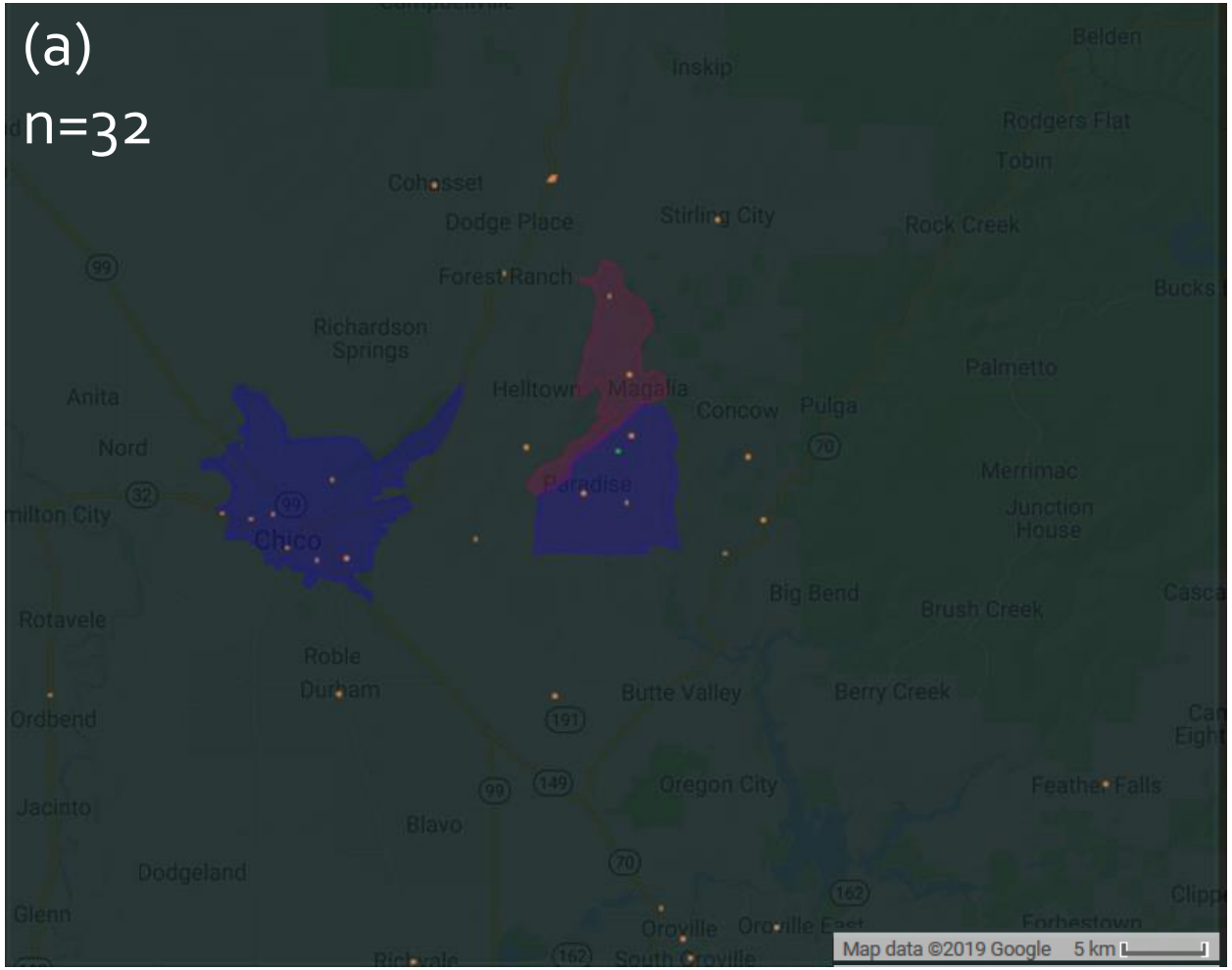
0 < r <1825, 2018

Victoria sees a sudden spike in no rain just prior to Black Saturday Fire, California sees variable (though worse overall) rainfall.

Source: GSMaP (JAXA)

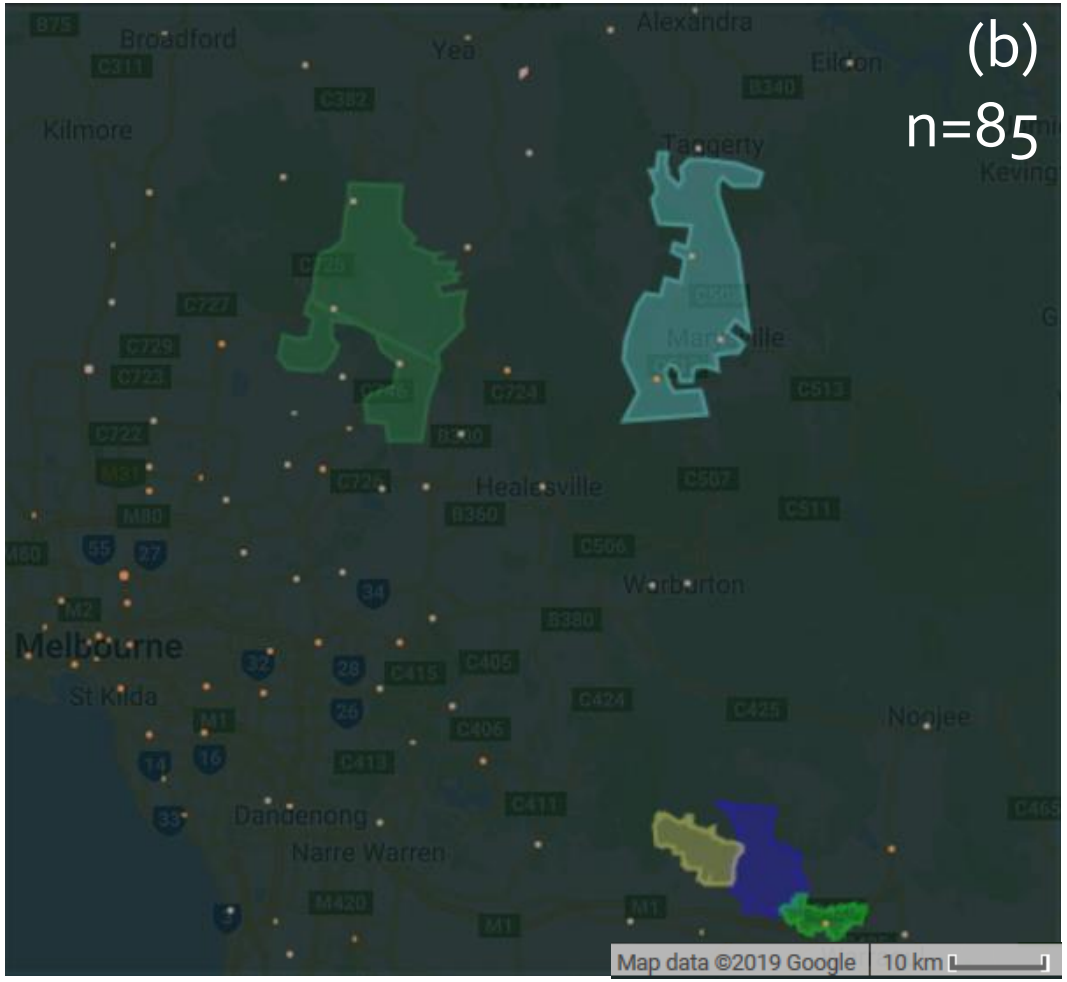
Locations of Firefighting Stations

California, United States ~200 sq. km / station



(VA.5)

Victoria, Australia ~141 sq. km / station [~400 sq. km / station not including Melbourne]



Both regions theoretically have enough fire stations to respond "in-time" to habitats, though a future increase is encouraged.

Source: Google

Conclusions

"In Remembrance"

Conclusion

- In California …

  (a) Exposure is relatively low and unchanging in 2040 simulations. New urbanization very limited.

  (b) Environmental vulnerabilities show slight effects for temperature, clear effects for the other variables.

  (c) Approx. 200 sq. km. is in zone for each fire station. At 67.5 km/ hr (average of in-city and expressway speed) to respond in 15 minutes, circular area of 223 sq. km. can be responded to. Hence, sufficient.

- In Victoria …

  (a) Exposure in 2040 is somewhat elevated, due to novel urbanization.

  (b) Environmental vulnerabilities show clear effect for all factors before the fires in 2009. Currently, temperature is about the same as 2000 but moisture and rainfall are slightly decreased.

  (c) Approximately every 400 sq. km has a fire station. At 75 km / hr (average of in-city and expressway speed) to respond in 20 minutes, a circular area of 490 sq. km can be responded to. Theoretically sufficient.