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MULTI-TEMPORAL AND -SPATIAL REMOTE SENSING IMAGERY TO MONITOR FLAMMABILITY IN AUSTRALIA

Marta Yebra, Albert Van Dijk and Geoff Cary

Fenner School of Environment & Society, Australian National University
Bushfire and Natural Hazards Cooperative Research Centre

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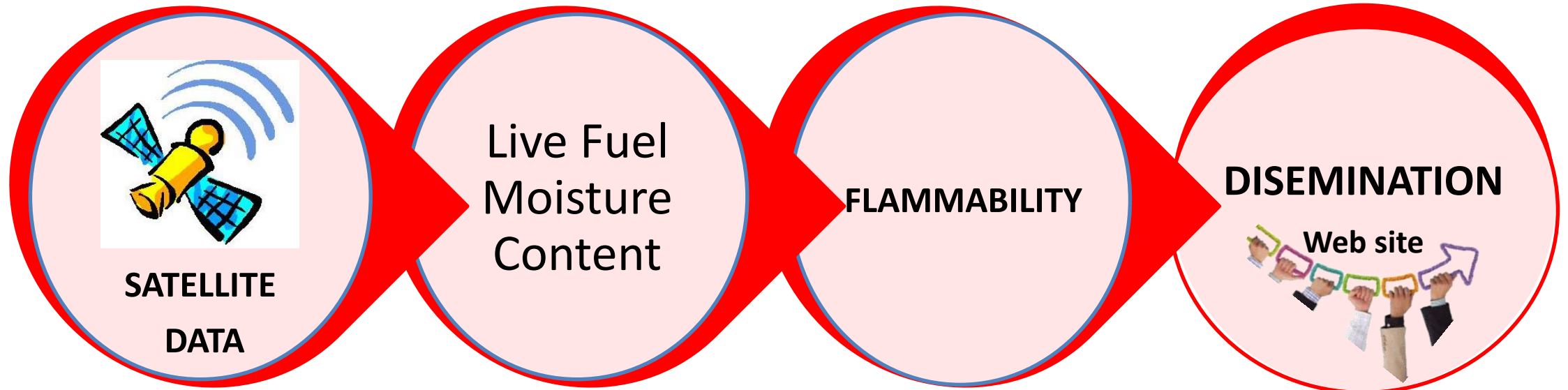
ANU
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THE AUSTRALIAN FLAMMABILITY MONITORING SYSTEM (AFMS)

First **continental-scale** web site providing spatial information on landscape-scale **live fuel moisture content and flammability** derived from **satellite observations (currently MODIS)**



LIVE VERSUS DEAD FUEL MOISTURE

- **LIVE fuel moisture:**

- FMC of Living plants (grass, shrub, forest)
- Typically ranges 30-300%
- Varies over space, species and seasons

- **DEAD fuel moisture**

- FMC of Dead plants, forest litter, slash, etc.
- Typically <30% in absence of surface free water
- Can change quickly over time and space



Coupling Litter and Soil Moisture Dynamics For Dead Fuel Moisture Content Forecast

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This research aims to figure out the role of soil moisture in determining dead fuel moisture content forecast by coupling litter and soil moisture dynamics.

INTRODUCTION

Dead fuel moisture content (FMC) is critical for fire ignition and is an input to most fire danger and fire behavior predictions. Therefore, several models have been developed for dead FMC forecast. These models range from empirical regression functions against weather variables to physical-based models which use water and energy conservation equations. However, none of these models consider the role of soil moisture dynamics in determining FMC. This research aims to figure out how soil moisture content affect FMC forecast by coupling litter and soil moisture dynamics.

METHOD

A process-based model named Kaba model (Matthews, 2006) that simulates physical process for litter fuel moisture prediction and a grid-distributed biophysical model the Australian Water Resources Assessment system Landscape model [AWRA-L] (Van Dijk, 2010) for water resources prediction are chose for the coupling.

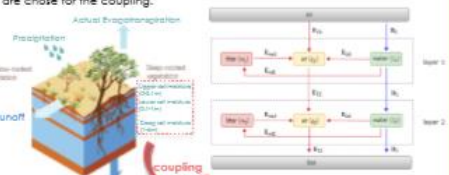


Fig 2. Model structure of water balance in Kaba model: top layer includes litter, water and air and the water content of them are w_l , w_s and w_a , respectively. Red arrows represent vapor flux between materials; $v_{l,s}$ vapor flux between litter and soil, $v_{s,a}$ vapor flux between water and air, $v_{l,a}$ and turbulent vapor flux b_l and blue arrows represent liquid drainage d_l .

CASE STUDY: VICTORIA

- Study area and sampling (Dec.2011~Apr.2013) locations (Fig 3)




Fig 3. Locations of samples

- Input Data
 - ✓ Daily max and min temperature (BOM 5km)
 - ✓ Daily 3pm vapour pressure (BOM 5km)
 - ✓ Daily rainfall (BOM 5km)
 - ✓ Daily radiation (BOM 5km)
 - ✓ Daily mean wind speed (McVicar et al. (2008), 5km)
 - ✓ Daily soil water storage (Van Dijk, 2010).

PRELIMINARY RESULTS

Table 1. Statistics analysis before and after coupling soil-litter vapor flux exchange

Soil-Litter Flux	R ²	N	Before		After	
			Mean	Stdev	Mean	Stdev
Surfex	0.28	45	0.05	0.05	-0.24	0.11
1m	0.44	45	0.05	0.05	-0.17	0.17
Surfex	0.28	45	0.05	0.05	-0.24	0.11
1m	0.44	45	0.05	0.05	-0.17	0.17

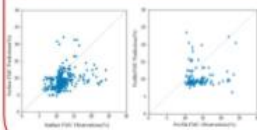








Fig 4. Comparing between observations and model predictions for values >0.05

CONCLUSION AND FUTURE WORK

- Soil water content can influence FMC predictions especially the profile FMC.
- The current research is a preliminary test for coupling, which only considers vapor flux between soil and litter, and future research will focus on improvement of the coupling method.

END USER STATEMENT:

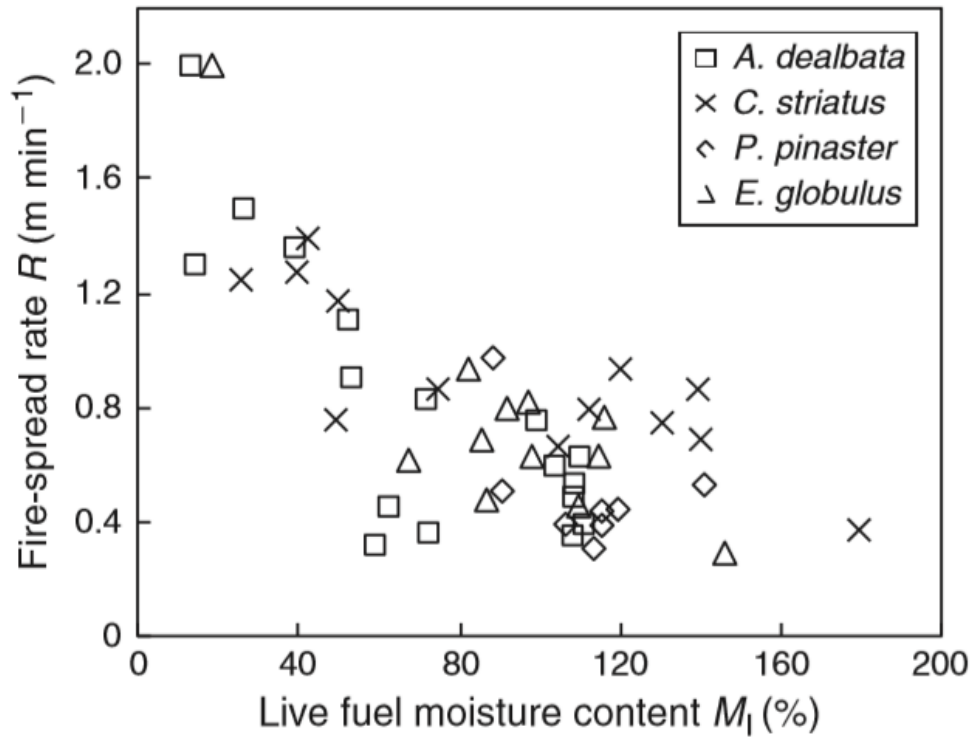







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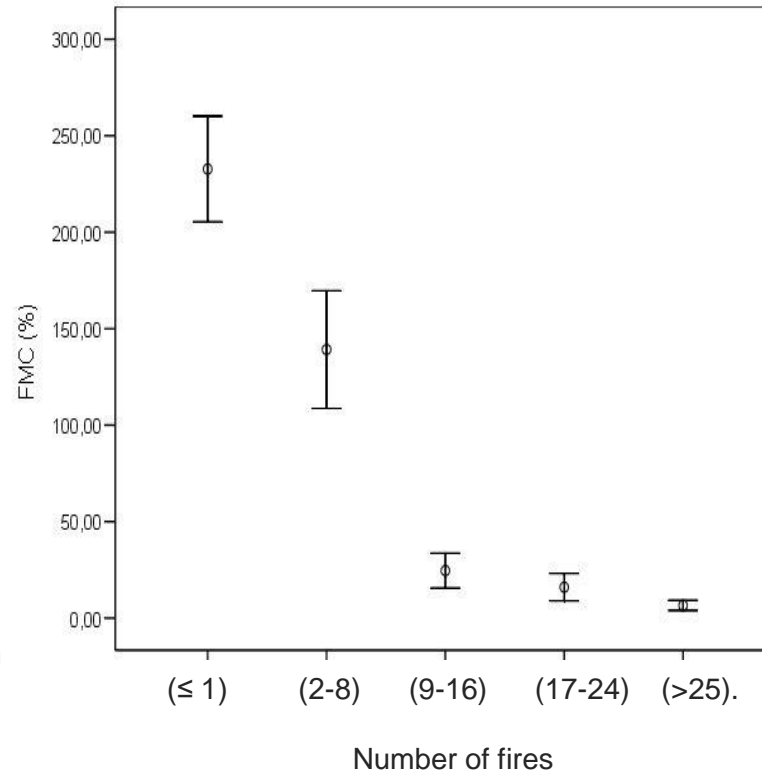
WHY MONITORING LIVE FUEL MOISTURE CONTENT?

Forest



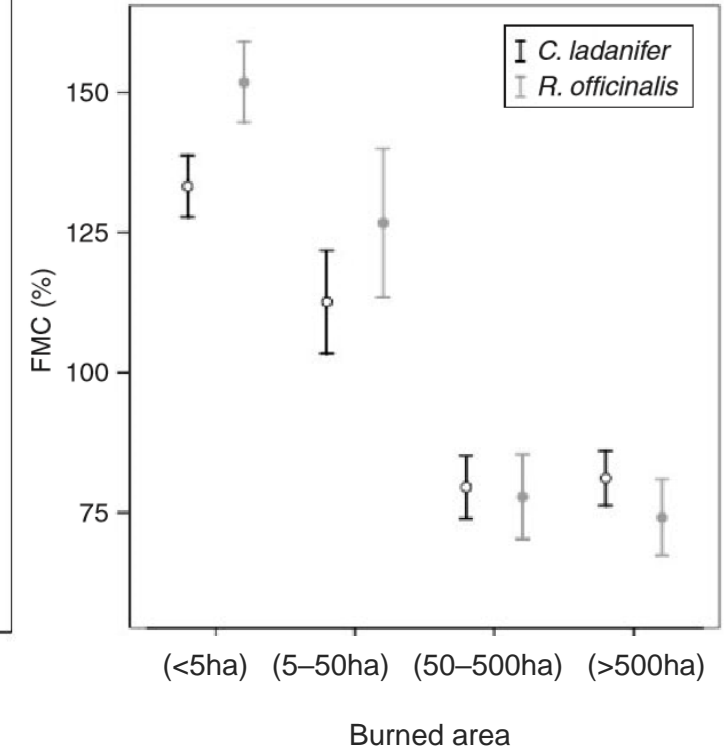
Rossa *et al.*, 2016, IJWF

Grass



Chuvieco *et al.* 2009, IJWF

Mediterranean Shrub



WHY CREATE A WEB SITE?

To make spatially- and temporally- explicit information on live FMC and flammability **easier and faster to access**

Automated, Systematic, Real time, Nation-wide

Planning and prevention

Assist with **scheduling prescribed burns**: drier FMC in a forest may indicate more potential to scorch the canopy

Preparedness

Amend preparedness levels in relation to Fire Danger Rating in response to lower than average landscape dryness conditions

Response

Highlight potential for **anomalies in predicted rate of spread**: for lower FMC a fire may spread faster than predicted

DATA CURRENTLY DISPLAYED

Layer	Method	Resolution		Latency	Reference
		Spatial	Temporal		
Live FMC (%)	Inversion of physical models using MODIS reflectance data (water inside the fuels absorbs solar energy in the short wavelength water bands)	500 m	Daily	2 days	Yebra <i>et al.</i> 2018
Uncertainty (%)	Standard deviation of 40 best FMC estimates				
Flammability Index (0-1, unitless)	Logistic regression models between fire occurrence from the MODIS burned area product (binary dependent variable) and predictor variables derived from FMC estimates (independent variable)				
Soil moisture at 0-10 and 10-35 cm	BoM's JASMIN modelling system	5km	7 days	7 days	Dharssi <i>et al.</i> 2017

Australian Flammability Monitoring System



< 2018-09-01 >

Search (lat/lon or address) 🔍

- Live Fuel Moisture Content ▼
- States and Territories ▼
- Road Map ▼
- Opaque ▼

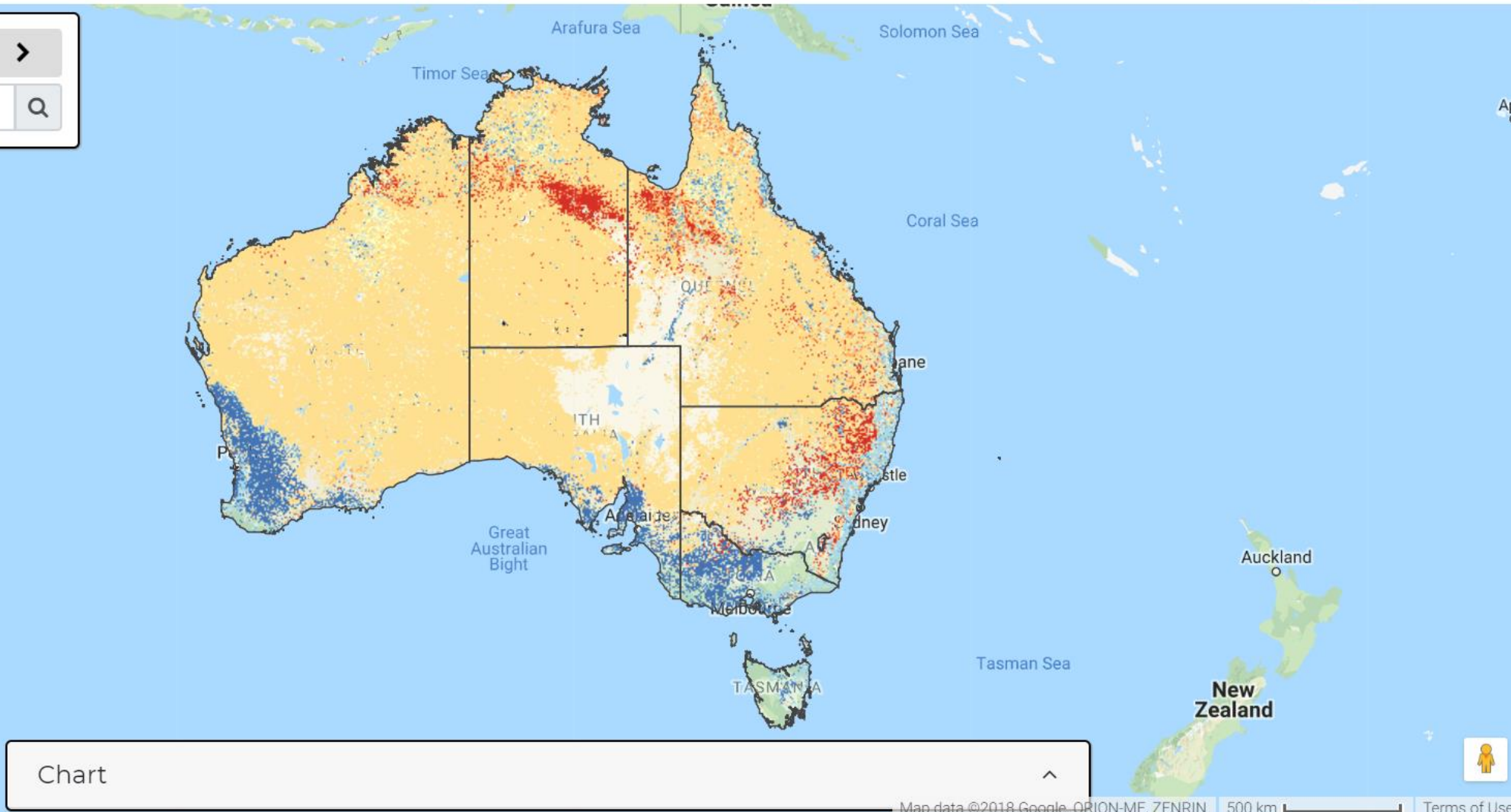
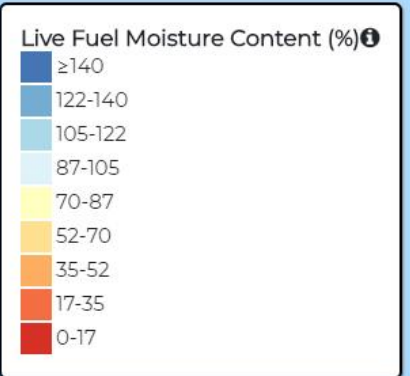
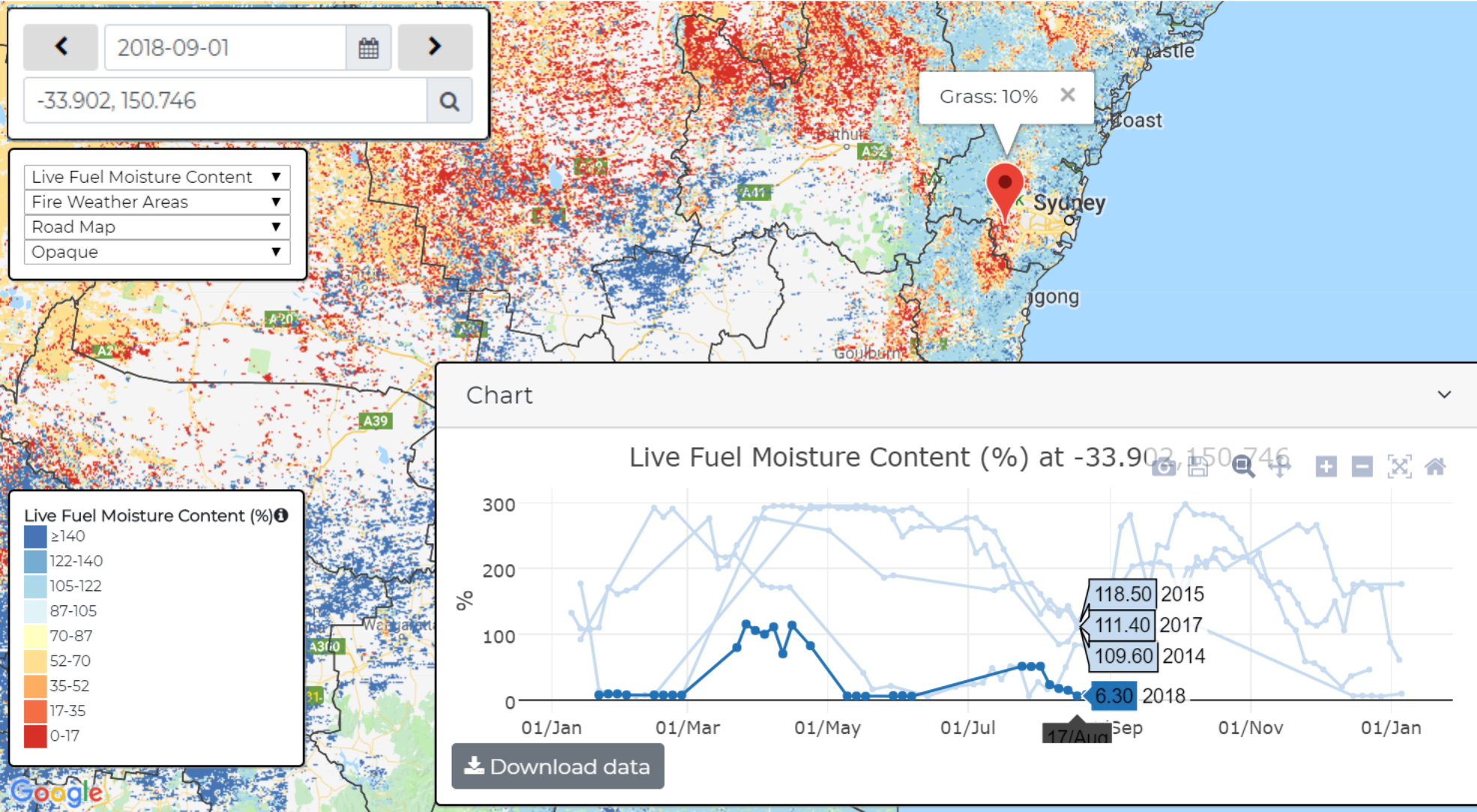


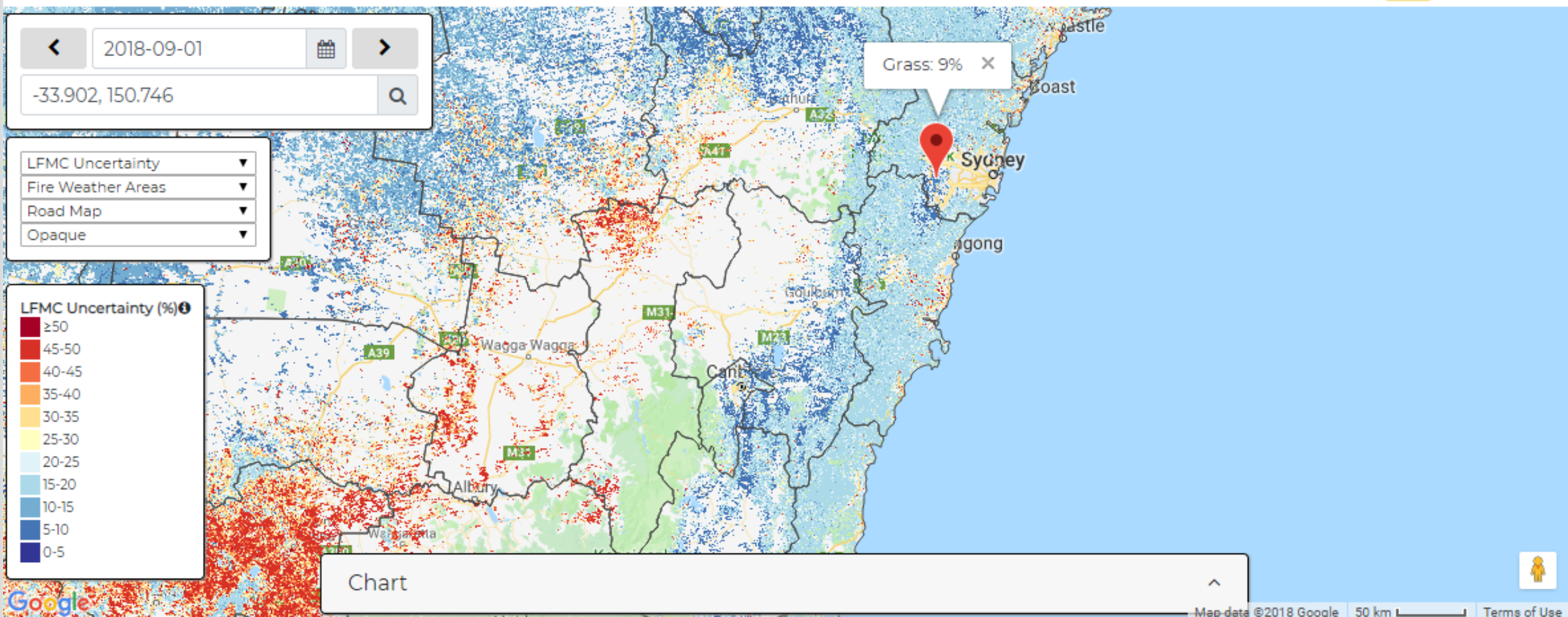
Chart ^



Map data ©2018 Google, ORION-ME, ZENRIN 500 km Terms of Use



Australian Flammability Monitoring System

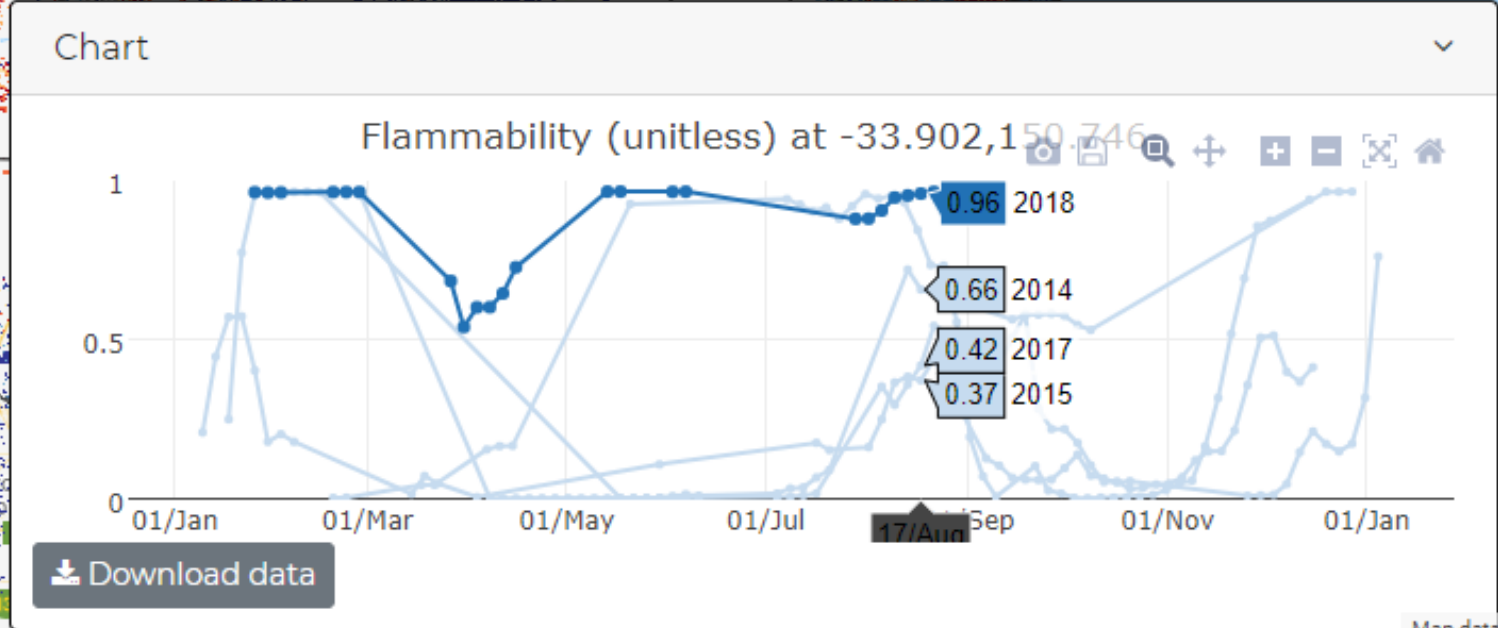
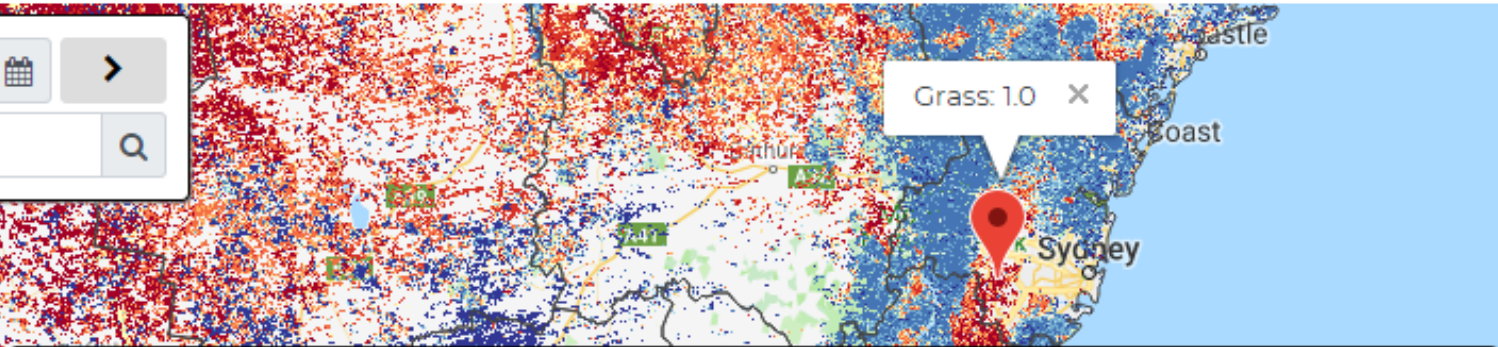
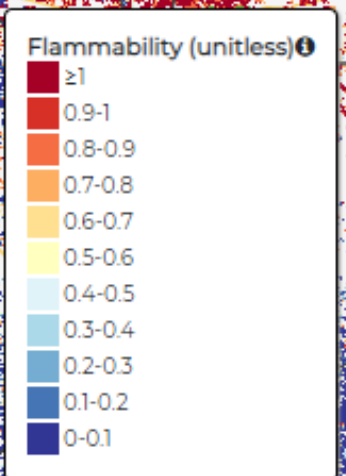


Australian Flammability Monitoring System

< 2018-09-01 >

-33.902, 150.746

- Flammability
- Fire Weather Areas
- Road Map
- Opaque



< 2018-07-28 >

-33.902, 150.746

Soil Moisture 0-10cm (JASMI) ▾

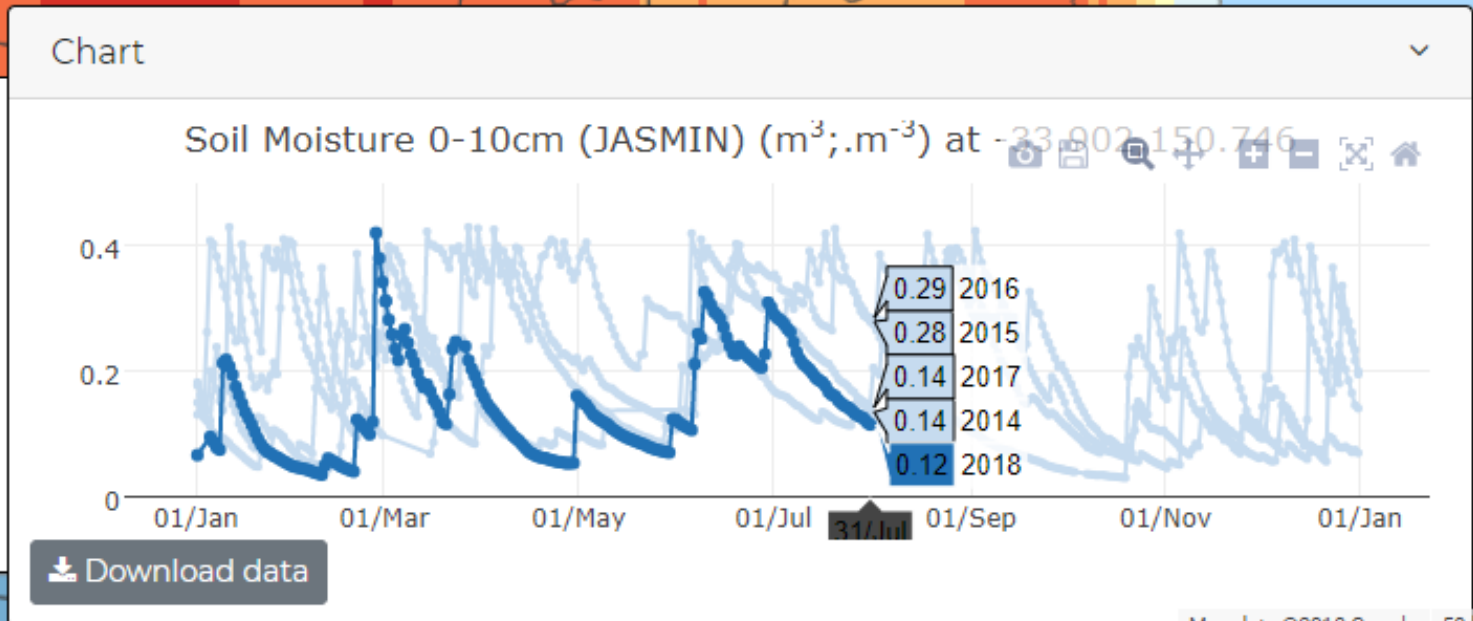
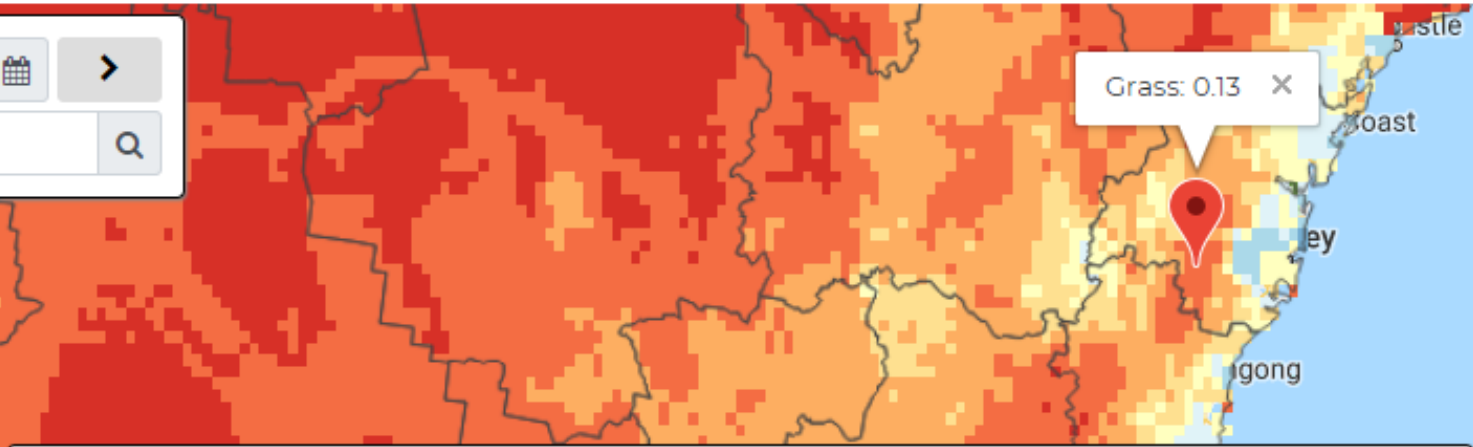
Fire Weather Areas ▾

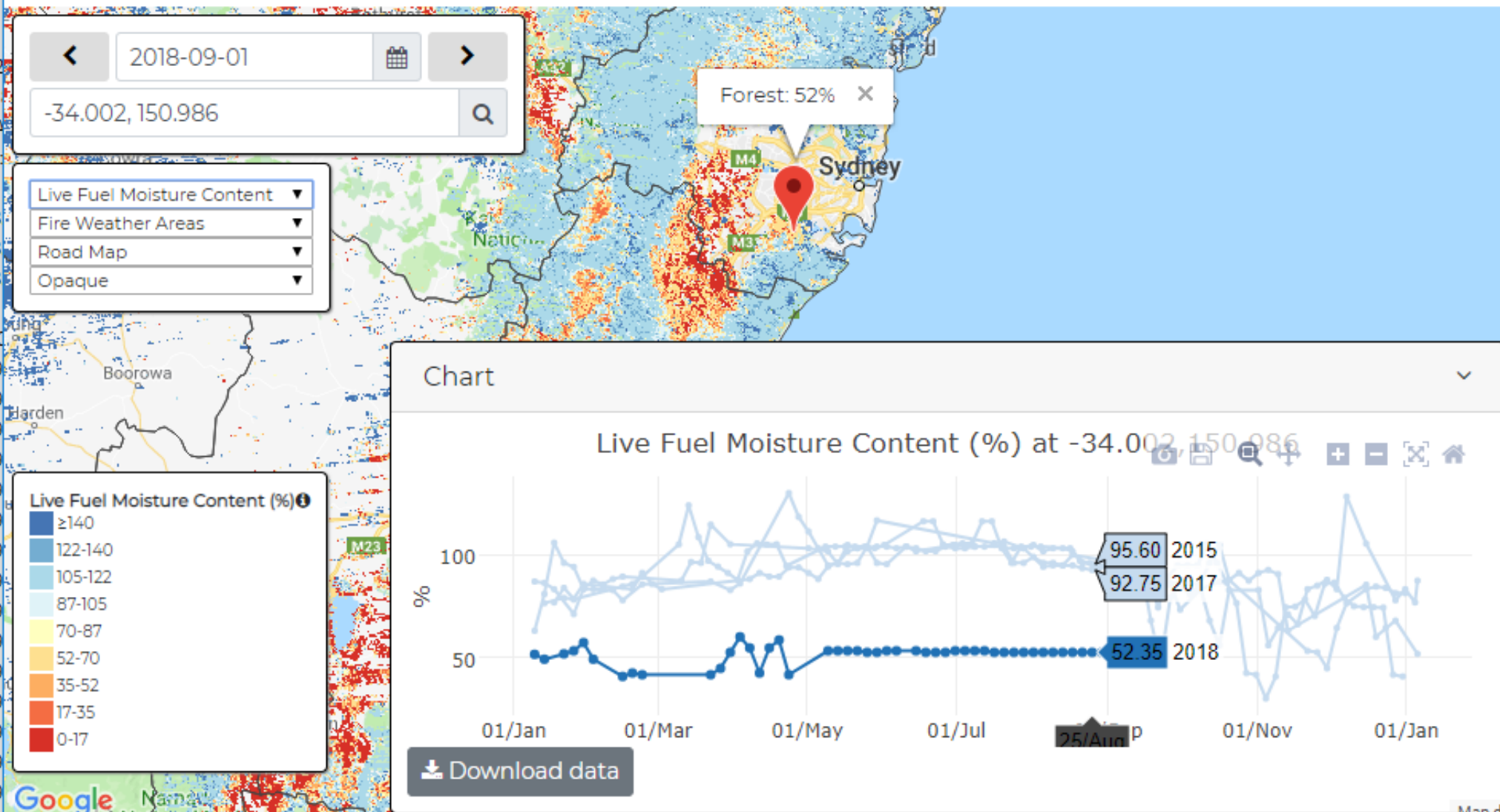
Road Map ▾

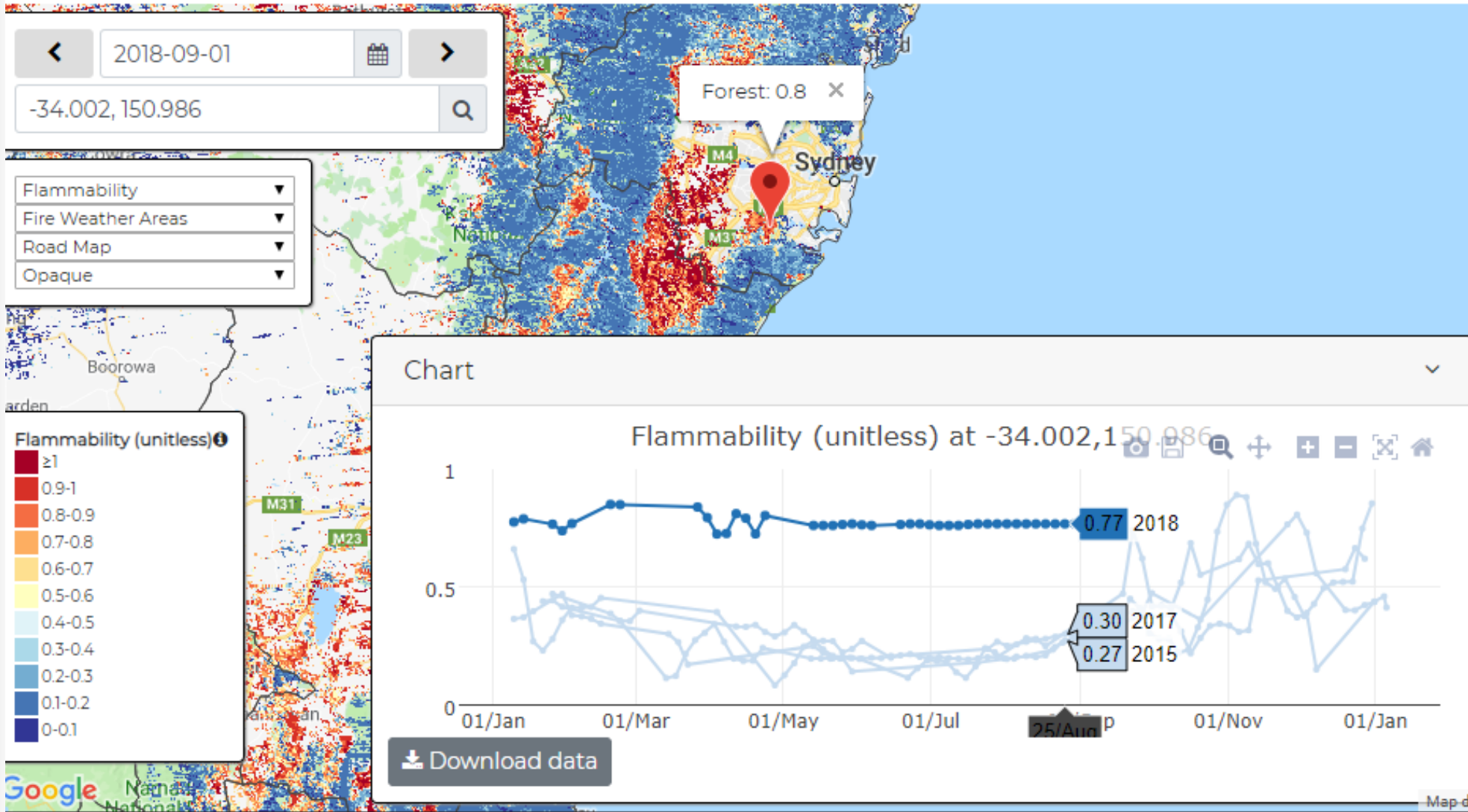
Opaque ▾

Soil Moisture 0-10cm (JASMIN) ($m^3 \cdot m^{-3}$)

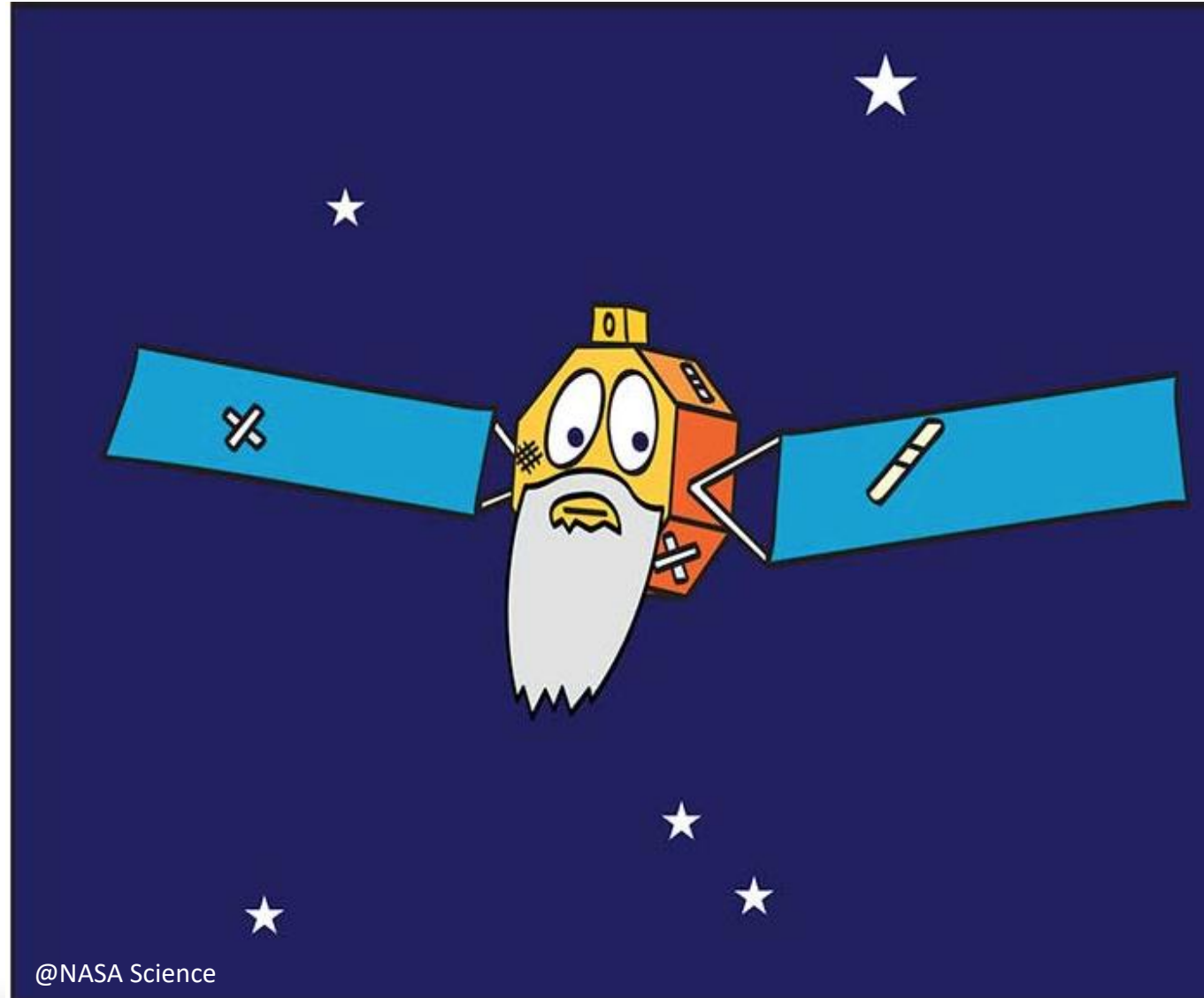
- ≥0.5
- 0.45-0.5
- 0.4-0.45
- 0.35-0.4
- 0.3-0.35
- 0.25-0.3
- 0.2-0.25
- 0.15-0.2
- 0.1-0.15
- 0.05-0.1
- 0-0.05



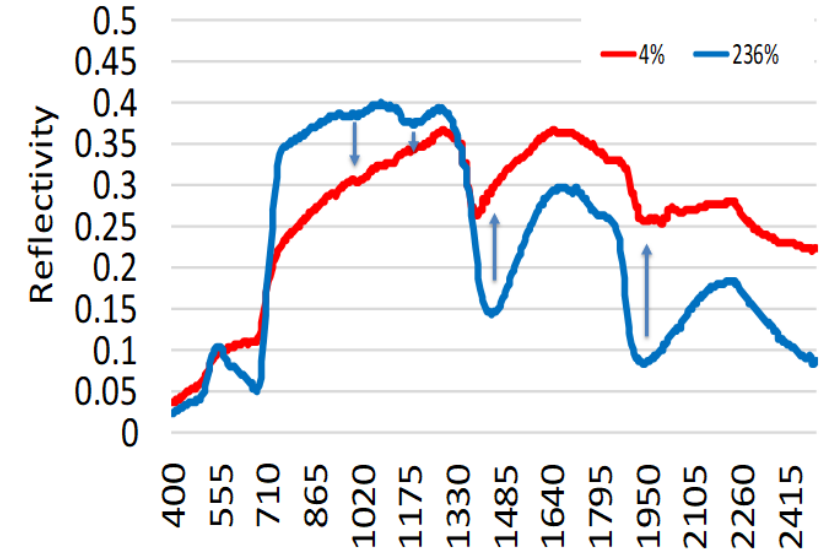
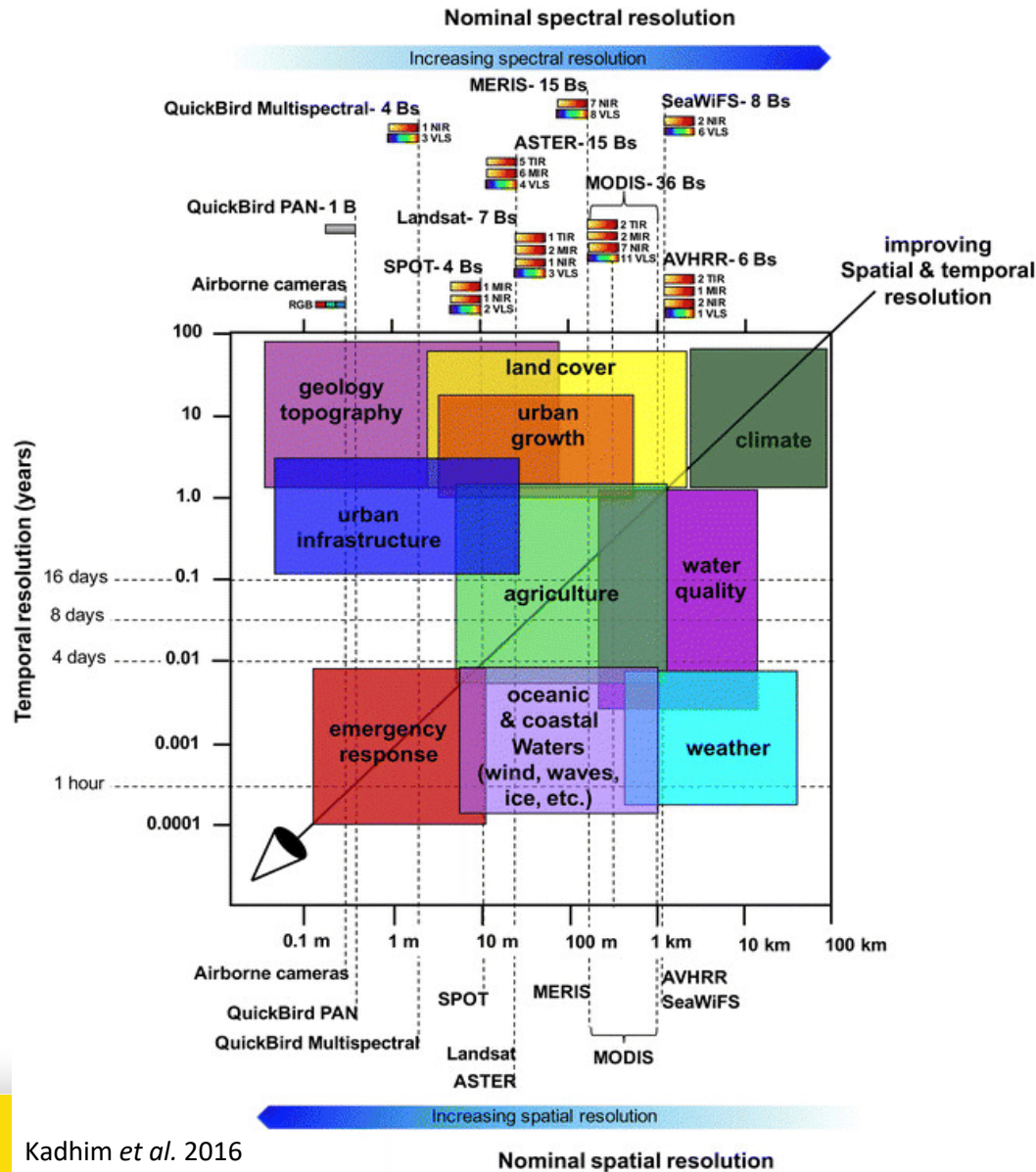




EVENTUALLY ALL SATELLITES GROW OLD, WEAR OUT, AND DIE



PLANNING FOR CONTINUITY

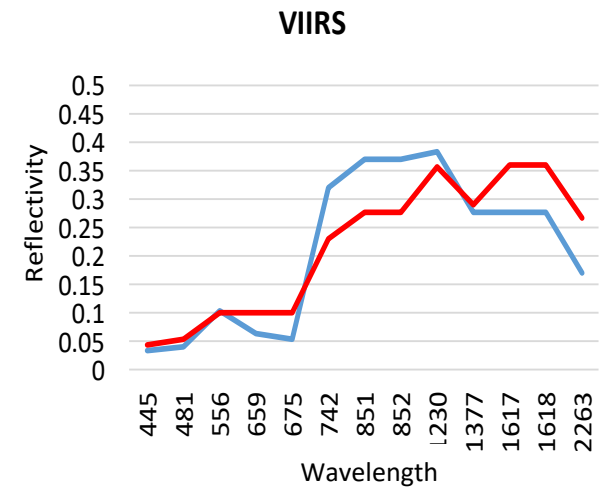
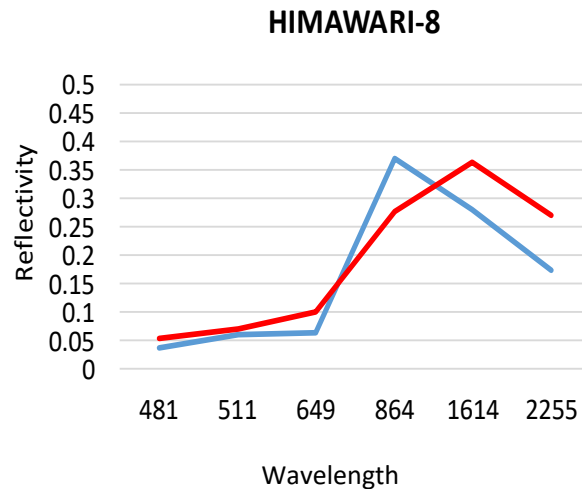
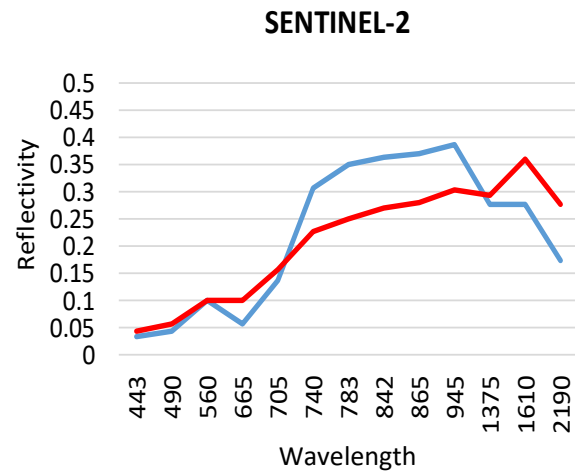
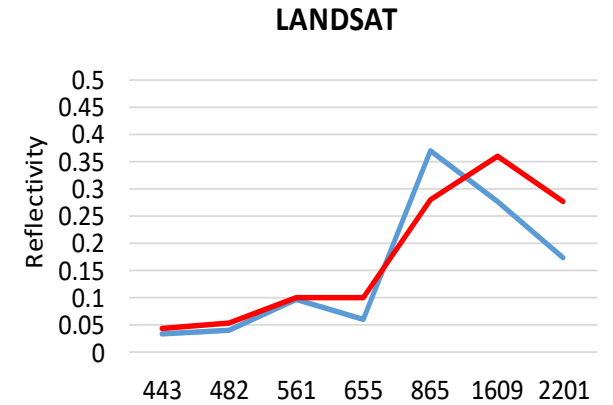
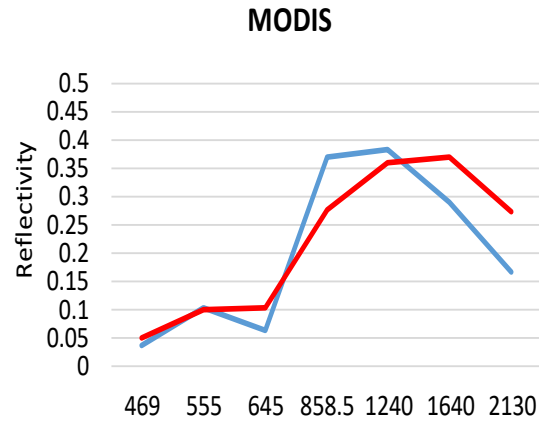
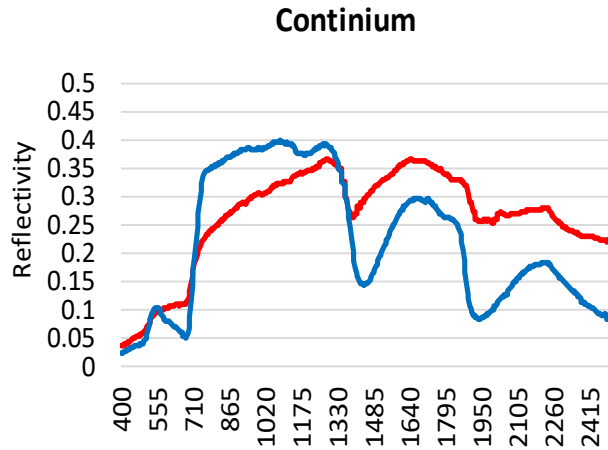


CANDIDATE SENSORS

Satellite Sensor	Spatial resolution (m)	Temporal resolution	Spectral resolution		Functional period
			Spectral range (nm)	Multi-spectral Bands	
MODIS	500	1-2 days	458-2155	7	2000-present
Landsat-8 OLI	30	16 days	433-1390	8	2013-present
VIIRS	750	Daily	4412-2250	10	2011-present
Himawari-8	2000	10 minutes	470-2256	6	2014-present
Sentinel-2A/2B MSI	20	5 day	442-2202	13	2017-present

SPECTRAL RESOLUTION OF CANDIDATE SENSORS

FMC — 4% — 236%



PERFORMANCE OF CANDIDATE SENSORS TO RETRIEVE FMC

Sensor	Slope	intercept	R ²	RMSE	RMSEs	RMSEu	n
Landsat-8 OLI	1.2	-21	0.8	24	7	23	6178
Sentinel-2A/2B MSI	1.2	-22	0.8	23	7	21	6178
VIIRS	1.2	-18	0.8	19	6	18	6178
Himawari-8	1.2	-19	0.7	26	6	25	6178
MODIS	1.14	-16	0.7	24	5	24	6178

PATH FORWARD



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AUSTRALIAN FLAMMABILITY MONITORING SYSTEM VERSION 1.0 – USER FEEDBACK AND PRIORITIES FOR FURTHER DEVELOPMENT

Marta Yebra, Albert van Dijk and Geoff Cary
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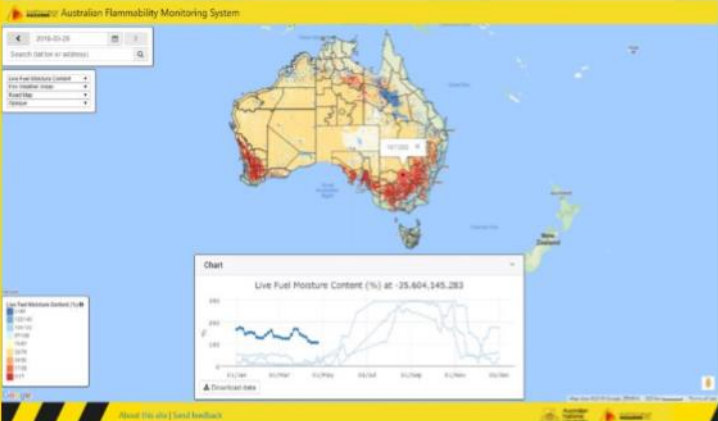



TABLE 1. SUMMARIZES THE USER FEEDBACK AND PRIORITIES FOR FURTHER DEVELOPMENT


THEME	FEEDBACK	SOLUTION
Web Service Enhancement	Pixels are not square	Change in the projection
	The system needs to better represent the interaction between vegetation types with vastly different FMC dynamics and the scale of the coloured classification	Map the different fuels (grass, shrub and forest) separately Display decile maps in addition to absolute values
	It is confusing to know what the FMC and FI products inform in a multilayer forest in relation to what the satellite senses	Make it easy to identify from what layer the FMC is being calculated by adding additional contextual or fire danger factor data layers that are already available online.
	Data needs to be integrated into the users' GIS systems	Allowing direct data downloads for a region of interest as GeoTIFF
	More regular updates of data displayed are needed	Automate this process
Understanding and usability	Users want to make more use of the information displayed on the AFMS	Invest more time working with the end users and develop specific, operational applications and integrate the information displayed in the AFMS into current decision processes and tool.
	Users want to learn more about integrating AFMS products into their current systems	Develop use examples or instruction videos for new website users that explain the strengths and limitations of the data (based on our conversation with end users)
	Users would like to use FMC in the current grass fire spread model	Relate grass moisture content to curing
Algorithm development	Explore other satellite data sources to allow finer spatial and temporal resolution.	Suitability study of different satellite data sources

AFMS; TAKE HOME MESSAGE

- **First Australia-wide** system providing **near-real time** estimates of live FMC and flammability **predictions** one week ahead at 500m based on MODIS.
- Offers flexibility to incorporate other relevant spatial information that might be currently available (e.g. soil moisture)
- **VIIRS** (750m, daily), **Sentinel-2** (20m, 5 days) and **Himawari-8** (2km, 10 min) will ensure **continuity** at the same time than provide **finer spatial and temporal resolutions**.
- AFMS can **help fire managers** in their prescribe burning efforts, improved awareness of fire hazards and pre-positioning of firefighting resources
- **Seeking your inputs to improve data usability!!**

MORE INFO

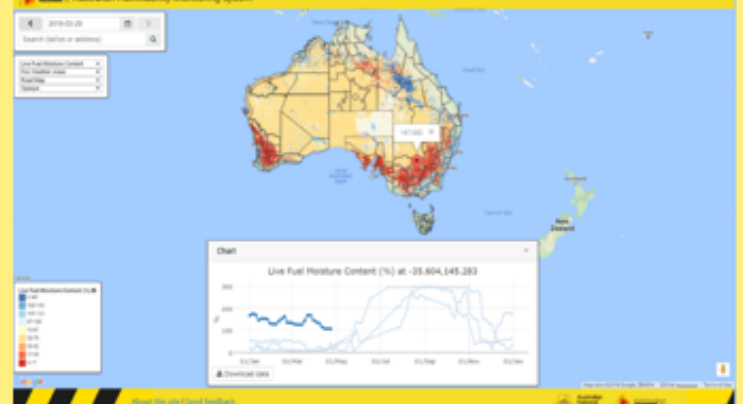
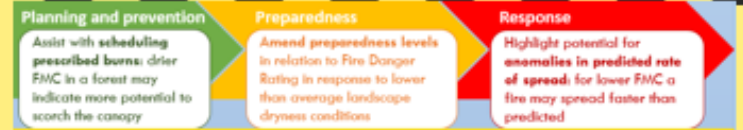
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 ELSEVIER


Remote Sensing of Environment

Volume 212, June 2018, Pages 260-272



A fuel moisture content and flammability monitoring methodology for continental Australia based on optical remote sensing

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AFAC Webinar: Australian Flammability Monitoring System

132 views

AFAC news
Published on Apr 3, 2018

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Link to data:
<http://dapds00.nci.org.au/thredds/catalog/ub8/au/FMC/catalog.html>

ACKNOWLEDGMENTS

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Web developers; Pablo Rozas, Zac Hatfield Dodds, Joel Rahman, Chris Tapper



THANKS!

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