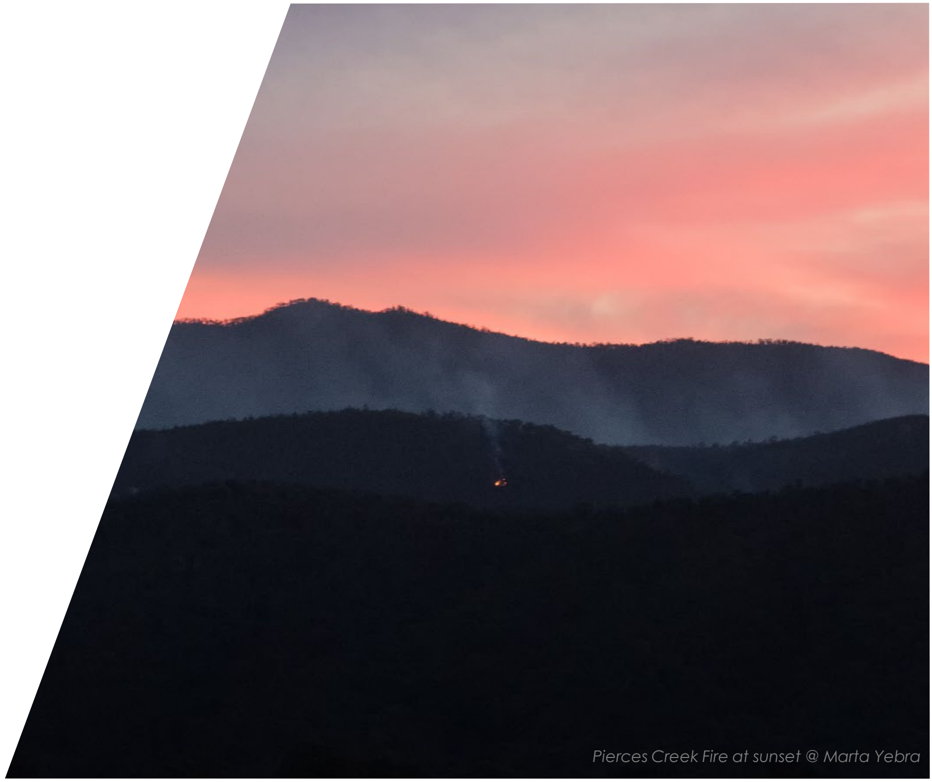
Towards comprehensive characterisation of flammability and fire danger

In the Australian Flammability Monitoring System

@anu_wald


Pierces Creek Fire at sunset @ Marta Yebra

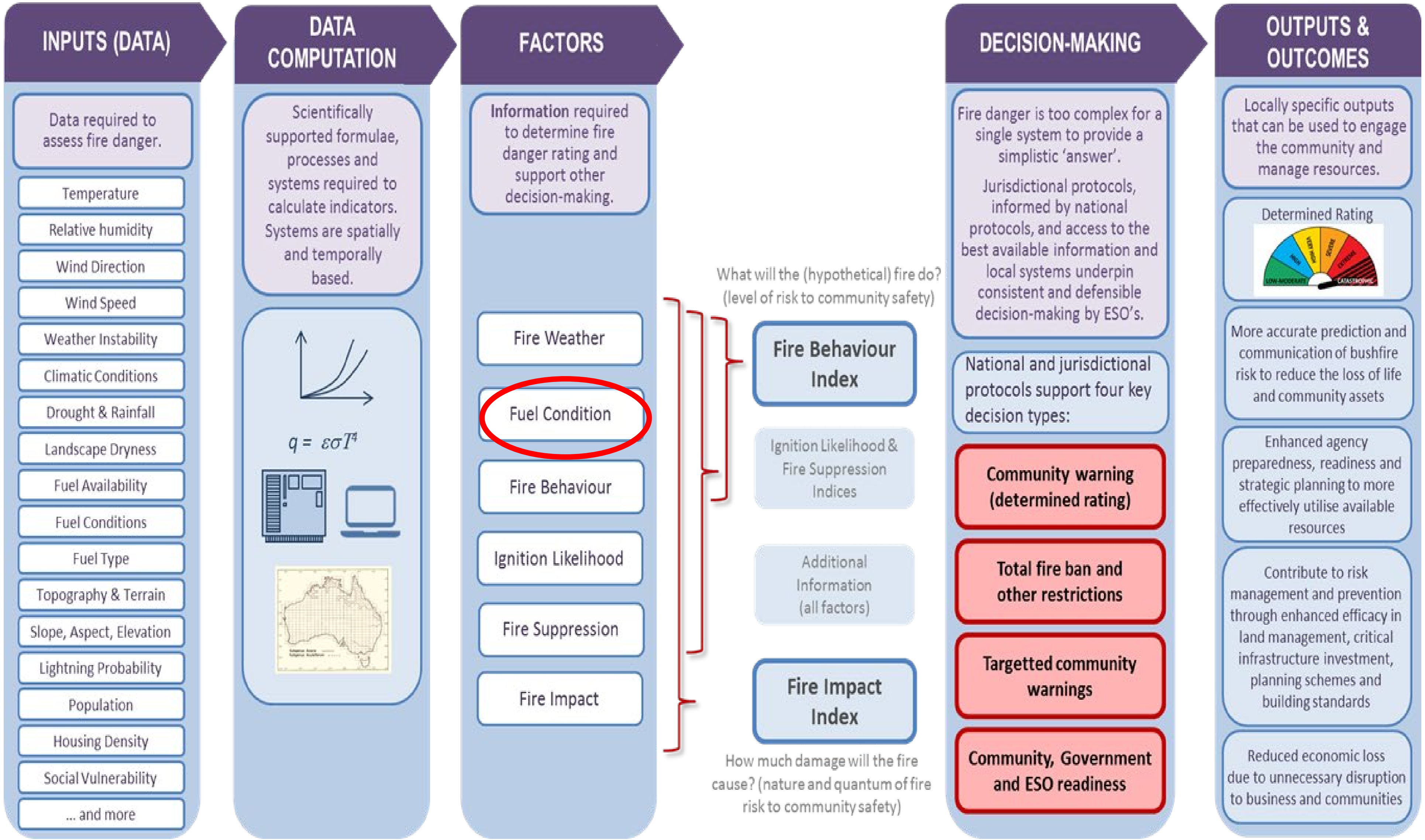
Albert van Dijk, Marta Yebra, Geoff Cary, Sami Sha
Centre for Water and Landscape Dynamics
Australian National University
Bushfire and Natural Hazards CRC

bushfire&natural HAZARDSCRC

Australian Government
Department of Industry, Innovation and Science

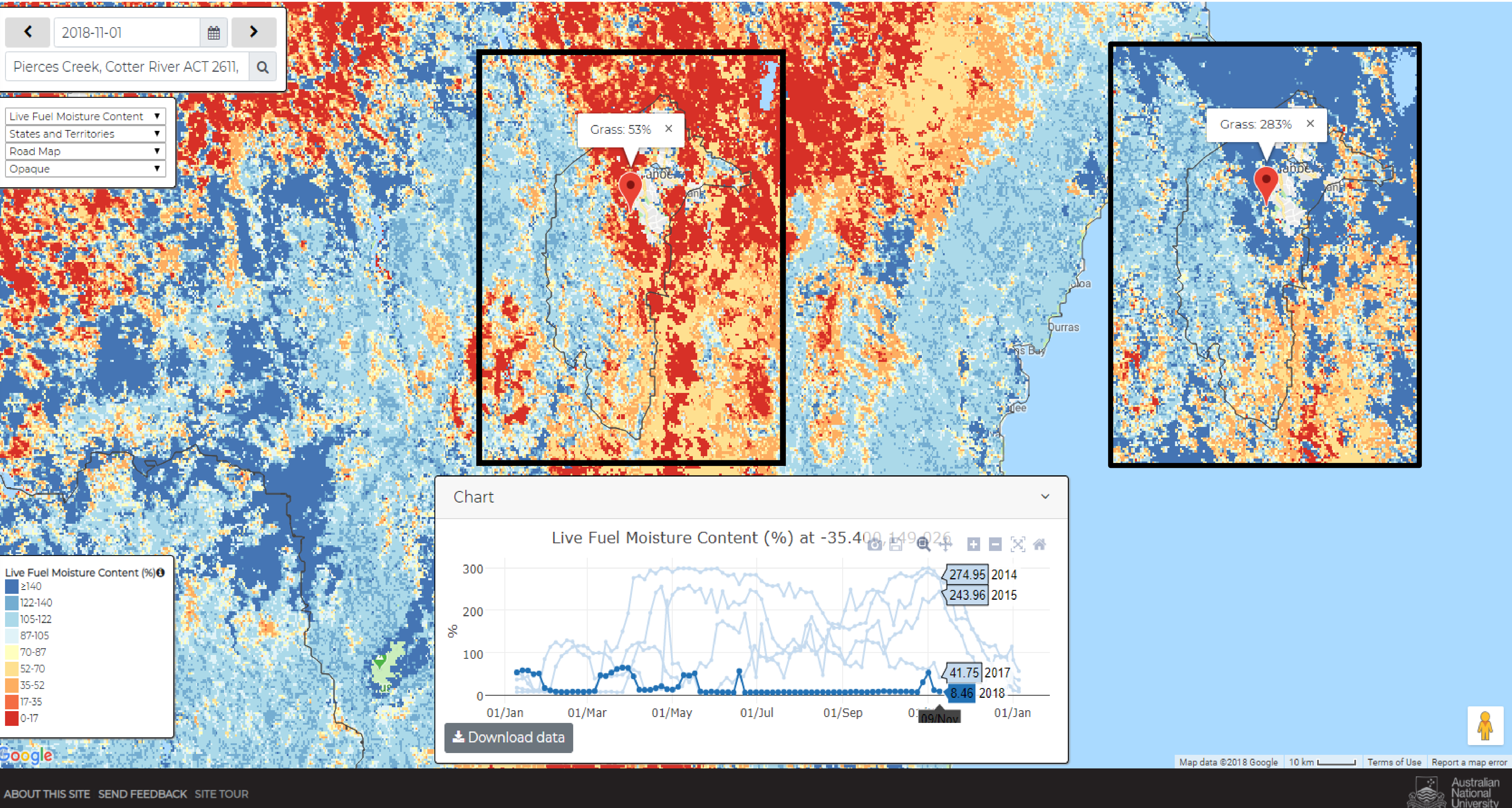
Business Cooperative Research Centres Programme

The new Australian Fire Danger Rating System



Australian Flammability Monitoring System

http://www.anuwald.science/afms



AUSTRALIAN FLAMMABILITY MONITORING SYSTEM WEBSITE

Marta Yebra[1,2], Albert I.J.M. Van Dijk [1,2], Geoff Cary[1,2]

[1] Fenner School of Environment and Society, College of Science, Australian National University, ACT
[2] Bushfire and Natural Hazards Cooperative Research Centre, Melbourne, Australia

Information currently displayed

Layer	Method	Resolution		Latency	Reference
		Spatial	Temporal		
Live FMC (%)	Inversion of **physical models** using MODIS reflectance data	500 m	4 days	4 days	Yebra *et al.* 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 and predictor variables derived from FMC estimates			**8 days* forecast**	
Soil moisture at 0-10 and 10-35 cm	BoM's **JASMIN** modelling system	5km	Daily	7 days	Dharssi *et al.* 2017

Uses in fire management

The AFMS is **available to anyone**, including fire and land managers and other industries such as insurance and agricultural sectors and electricity and water suppliers. Individual community members such as farmers could also use the AFMS to assess how dry their property is when preparing for fire season

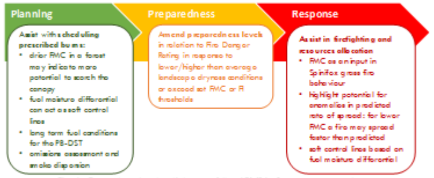


Fig. 1. Current and potential uses of the AFMS in fire management.

New look and Features in http://anuwald.science/afms

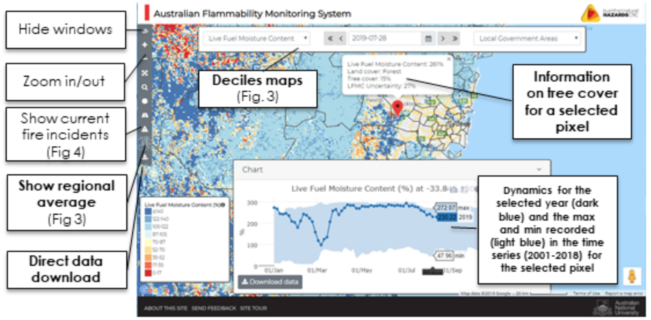


Fig. 2. Live FMC around the Sydney Basin area. The pop-up represents the information on Live FMC, uncertainty in the estimates as well as the land cover and the percentage tree cover for a random pixel.

Fig. 3. Example of the flammability Index decile map averaged by local government areas to identify areas of low or high values, relative to normal conditions at a location and time of year

Fig. 4. Live FMC map showing the fire incidents for the selected day

Future developments

• **Pilot prototype of high-resolution AFMS** using high spatial resolution (<30m) satellite imagery included in the Geoscience Australia Digital Earth Australia (GA-DEA)
• This will facilitate the utilization and sustainability of the AFMS in the longer term if the experimental service we provide gets transitioned to GA

References

• Yebra *et al.* 2018. A fuel moisture content and flammability monitoring methodology for continental Australia based on optical remote sensing. RSE 212, 260-272
• Dharssi, *et al.* 2017, JASMIN: A prototype high resolution soil moisture analysis system for Australia, Research Report No. 026, Bureau of Meteorology.

END USER STATEMENT *'This new technology has enormous potential to improve the efficiency of bushfire operations across Australia and drive an expansion of our capability. The provision of accurate, spatially explicit, near real-time estimates of FMC and flammability would permit more accurate targeting of scarce bushfire fighting resources in time and space. It would no longer be necessary to estimate jurisdiction-wide readiness based on anecdotal extrapolation of conditions at a few locations'.* ***Adam Leavesley, ACT Parks and Conservation Service***

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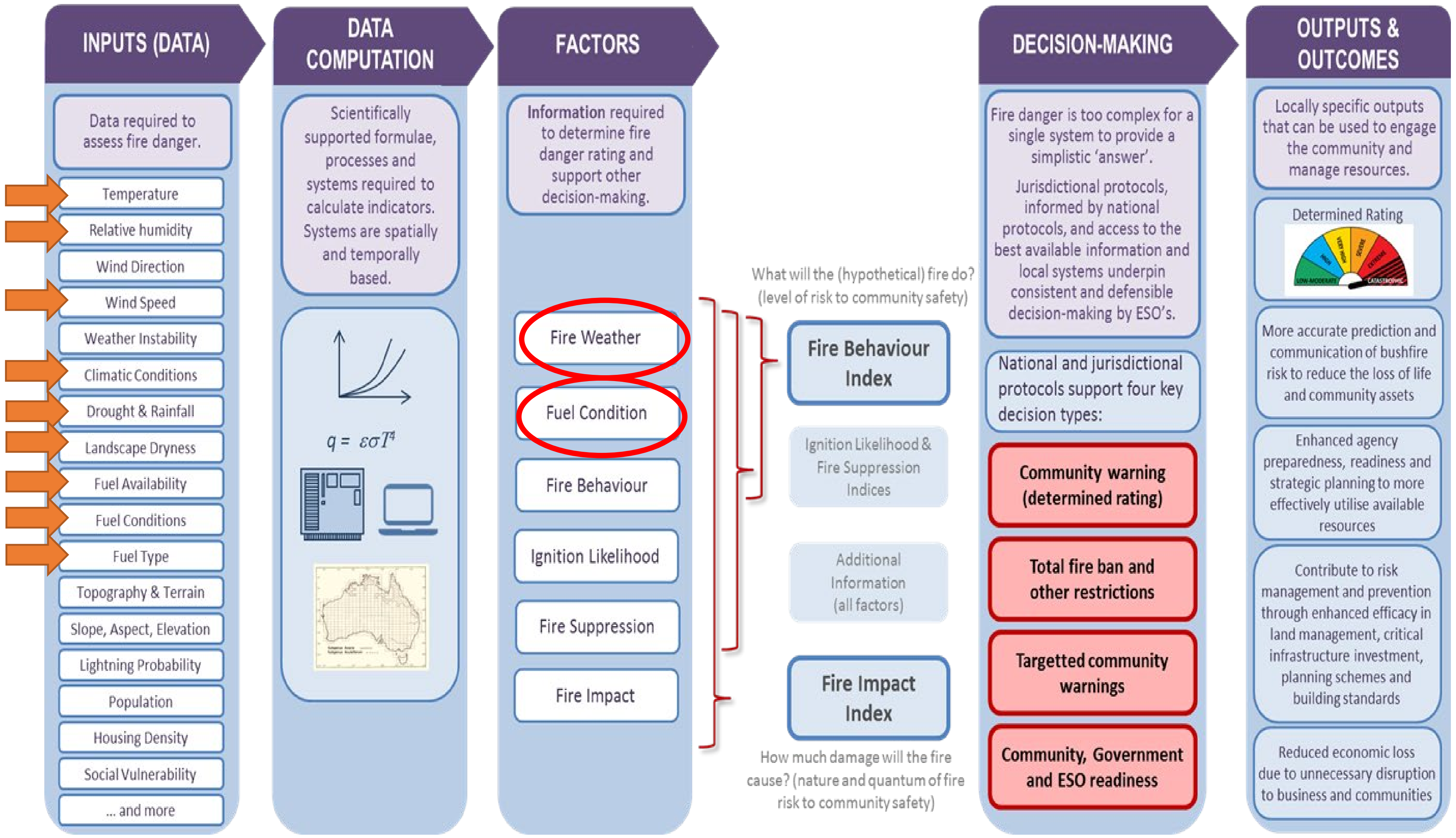
http://www.anuwald.science/afms

The new Australian Fire Danger Rating System



Empirical Fire Danger Index (EFDI)

Method

Day	Lat.	Long.	X (FMC)	Y (fire)
1/1/2003	-30.025	156.025	220	0
1/1/2003	-30.075	156.075	156	1
2/1/2003	-30.025	156.025	182	1
2/1/2003	-30.075	156.075	191	0

1. Extract X-Y data pairs

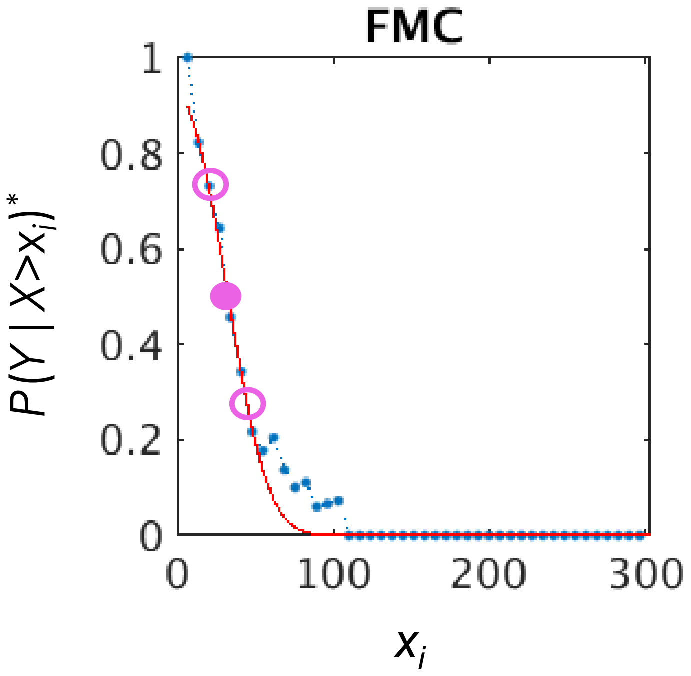
For all grid cells corresponding to a region and fuel type of interest, and for each day:

- Record if a fire event occurred
- Record the value of selected predictor variables (e.g., *FMC*)

Calculate daily time series of region-average *Y* and *X*

2. Calculate Empirical Probability Function

- For different x_i calculate cumulative conditional probability $P(Y|X>x_i)$, that is, the mean fire probability *Y* for all days with $X>x_i$
- Divide by the 'unconditional' marginal probability $P(Y)$ to get $P(Y|X>x_i)^*$ starting from 0 and ending at 1



3. Fit a Factor FDI function:

Normal cumulative distribution function:

- Mean (μ) or <u>*threshold value*</u> equals x_i with $P(Y|X>x_i)=0.5$
- Standard deviation (σ) or <u>*sharpness*</u> calculated from x_i with $P(Y|X>x_i)$ values of 0.25 and 0.75 (the inter-quartile range)

Data: fire occurrence, fuel type and regions

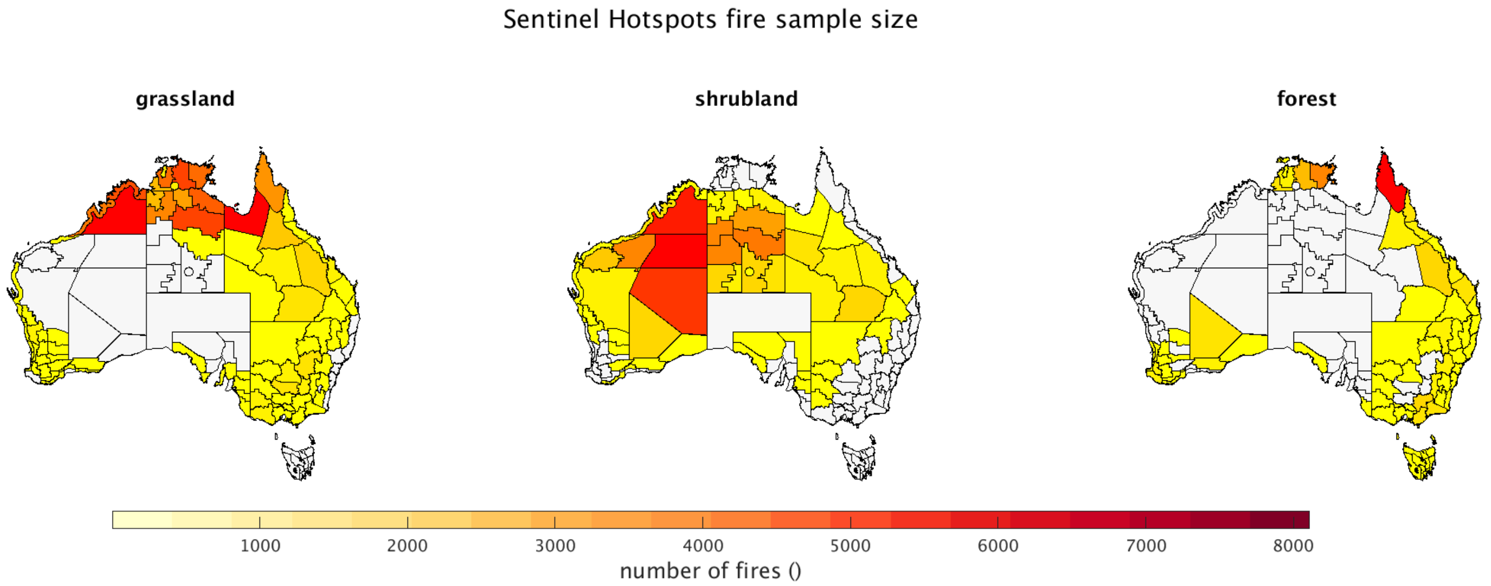
Fire occurrence: GA Sentinel Hotspots fire detection system MODIS and other satellite sensors.

- Max fire intensity (temperature) resampled to daily, 0.025° (~2.5 km) grids
- Grids available from Australia's Environment Explorer, www.ausenv.online)
- Used >80 °C temperature threshold to resample to binary (yes/no) fire occurrence.

Fuel type: Current AFMS land cover classification ('grass', 'shrub', 'forest')

Fire weather areas (FWA): To account for regional characteristics of fire regime, fuel type etc.

Availability of data depends on FWA size, dominant land cover and fire frequency



Data: FDI predictors

Fuel condition

- MODIS-derived life fuel moisture content (***LFMC***, % water / dry mass) (~500 m)

BoM Landscape water balance model (AWRA) predictions (~5 km):

- Top soil moisture (***w0***, fraction of plant available water capacity)
- Shallow soil moisture (***ws***, " ")
- Deep soil moisture (***wd***, " ")

Fire weather

BoM daily gridded climate data (~5 km):

- Maximum temperature (***Tmax***, °C)
- Daily mean wind speed (***Uavg***, m/s)

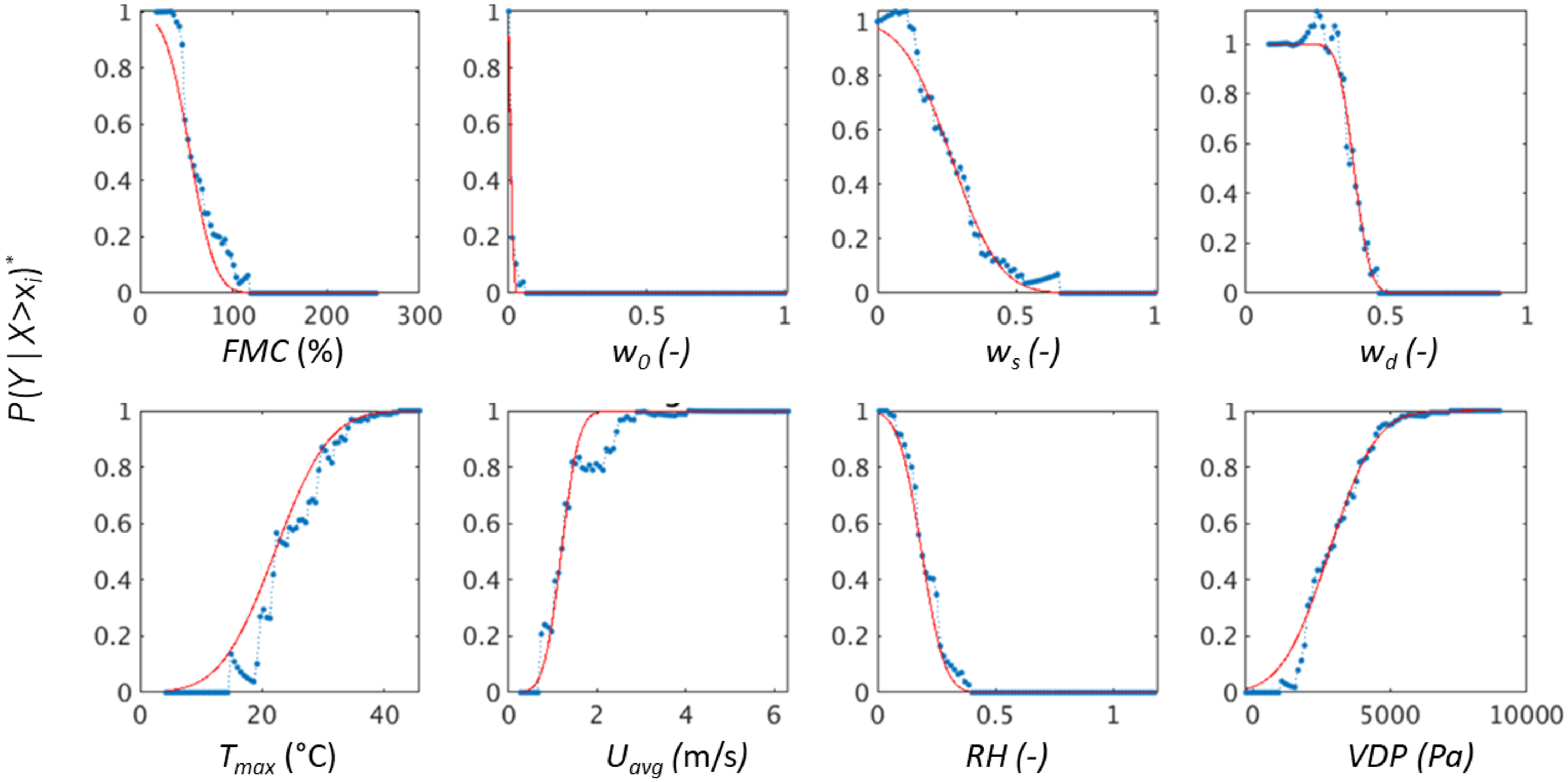
Calculated from *Tmax* and Vapour pressure at 3pm

- Relative Humidity (***RH***, %)
- Vapour pressure deficit (***VPD***, Pa)

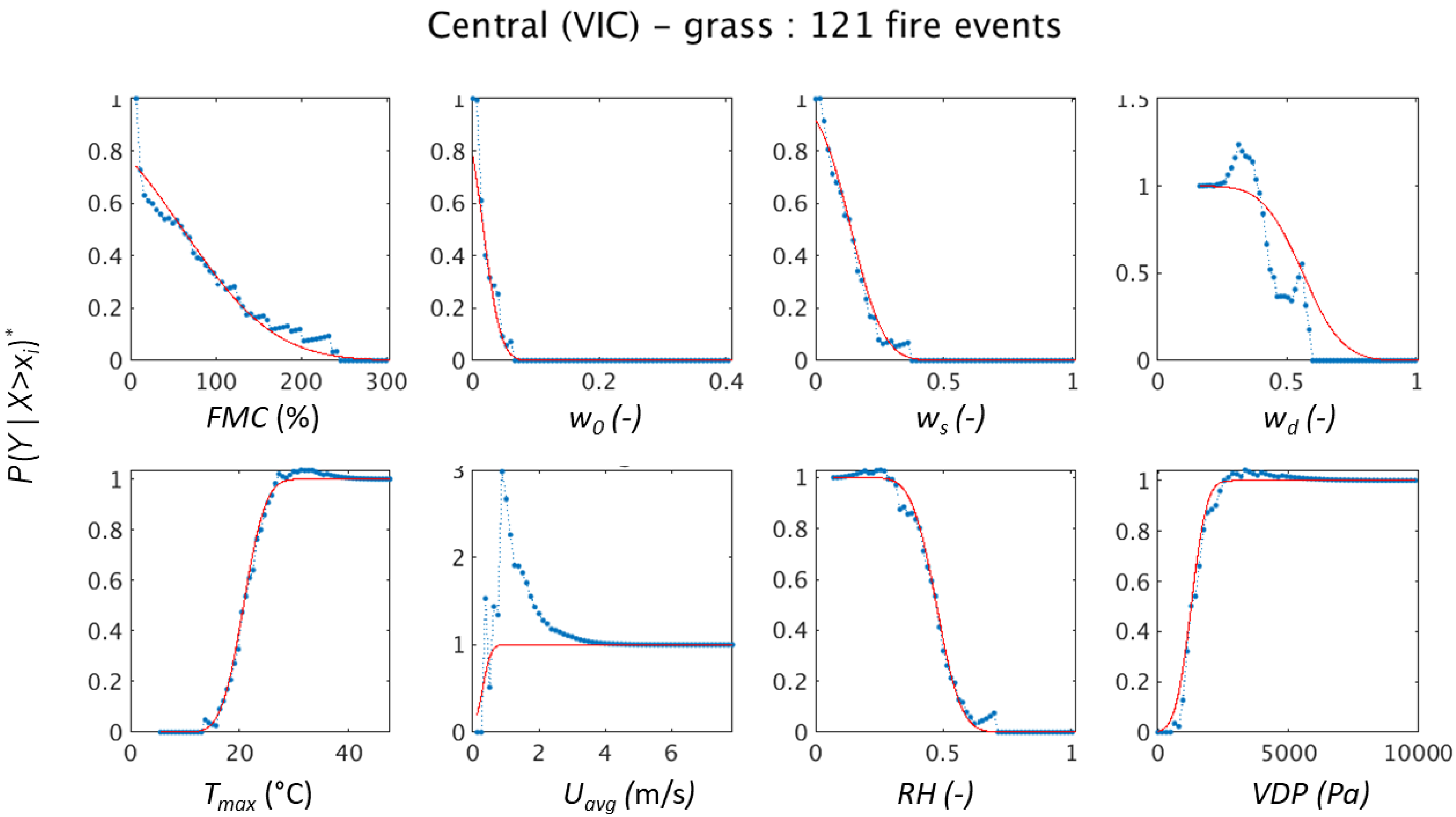
All data available for 2003-2017 and resampled to the 2.5 km and daily time step resolution of the fire data.

Examples

Darling Downs and Granite Belt (QLD) – forest : 153 fire events



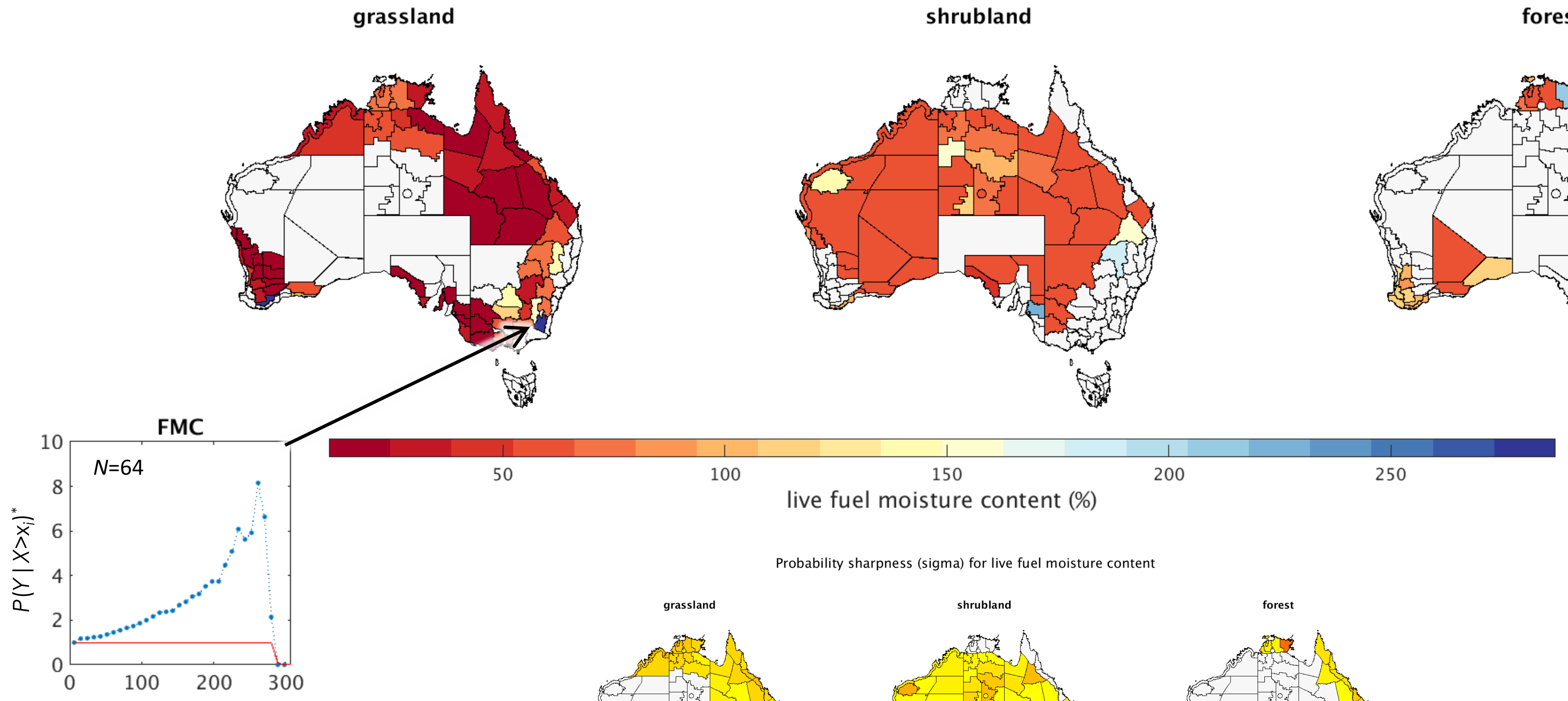
Examples



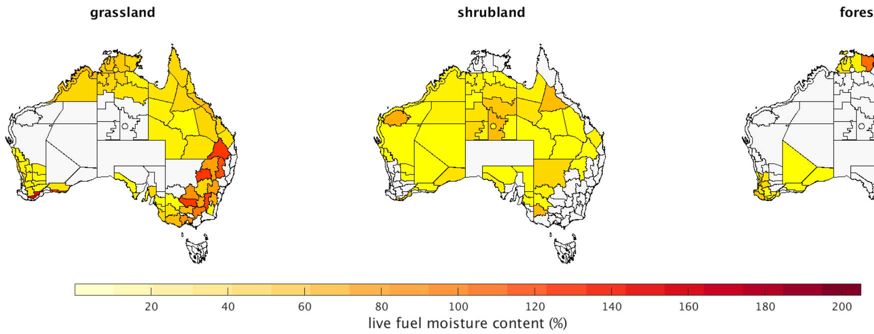
Central (VIC) – grass : 121 fire events
P(Y | X>x_i)*
FMC (%)
w_0 (-)
w_s (-)
w_d (-)
T_max (°C)
U_avg (m/s)
RH (-)
VDP (Pa)

Regional differences (LFMC)

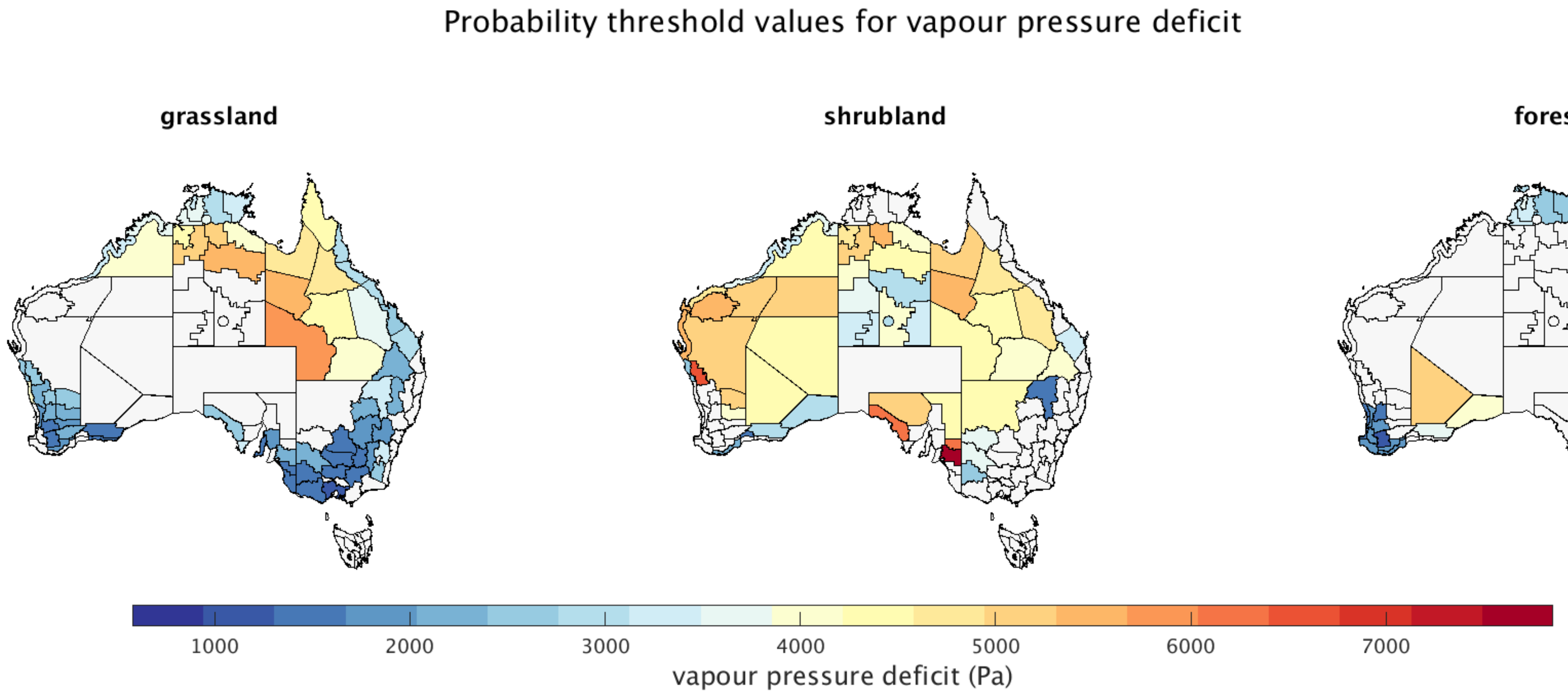
Probability threshold values for live fuel moisture content

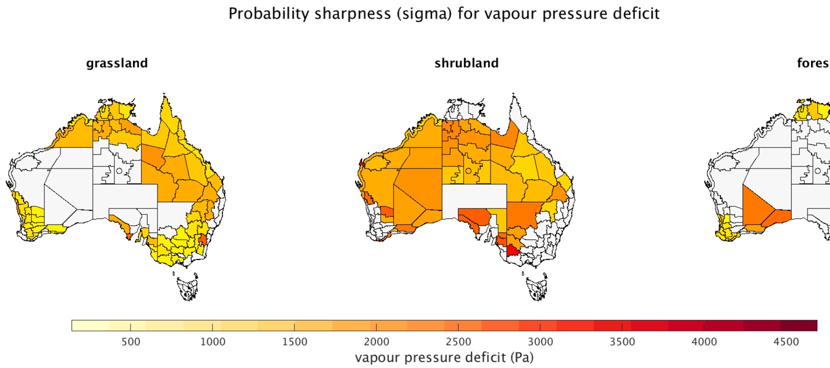


Probability sharpness (sigma) for live fuel moisture content



Regional differences (VPD)





Composite Empirical Fire Danger Index (EFDI)

Calculate

- Calculate Factor FDI for each of the n_X=8 predictor variables
- Multiply the probabilities and raise to the power $1/n_X$ (assumes strong cross-correlation)
- Result is an observation-based regional EFDI for each day

Evaluate

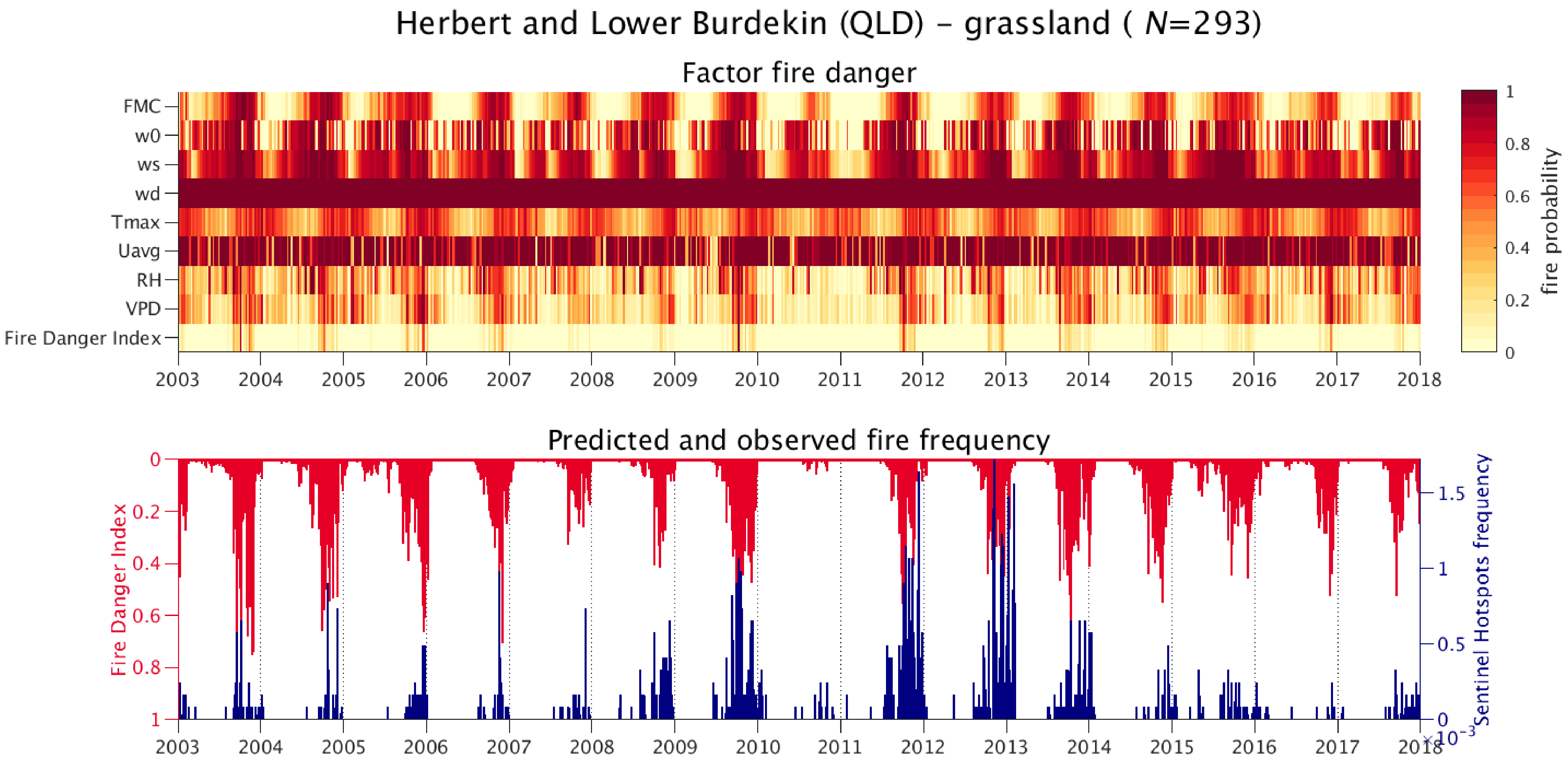
- Compare predicted EFDI time series of fire frequency across the region and fuel type

Caveats

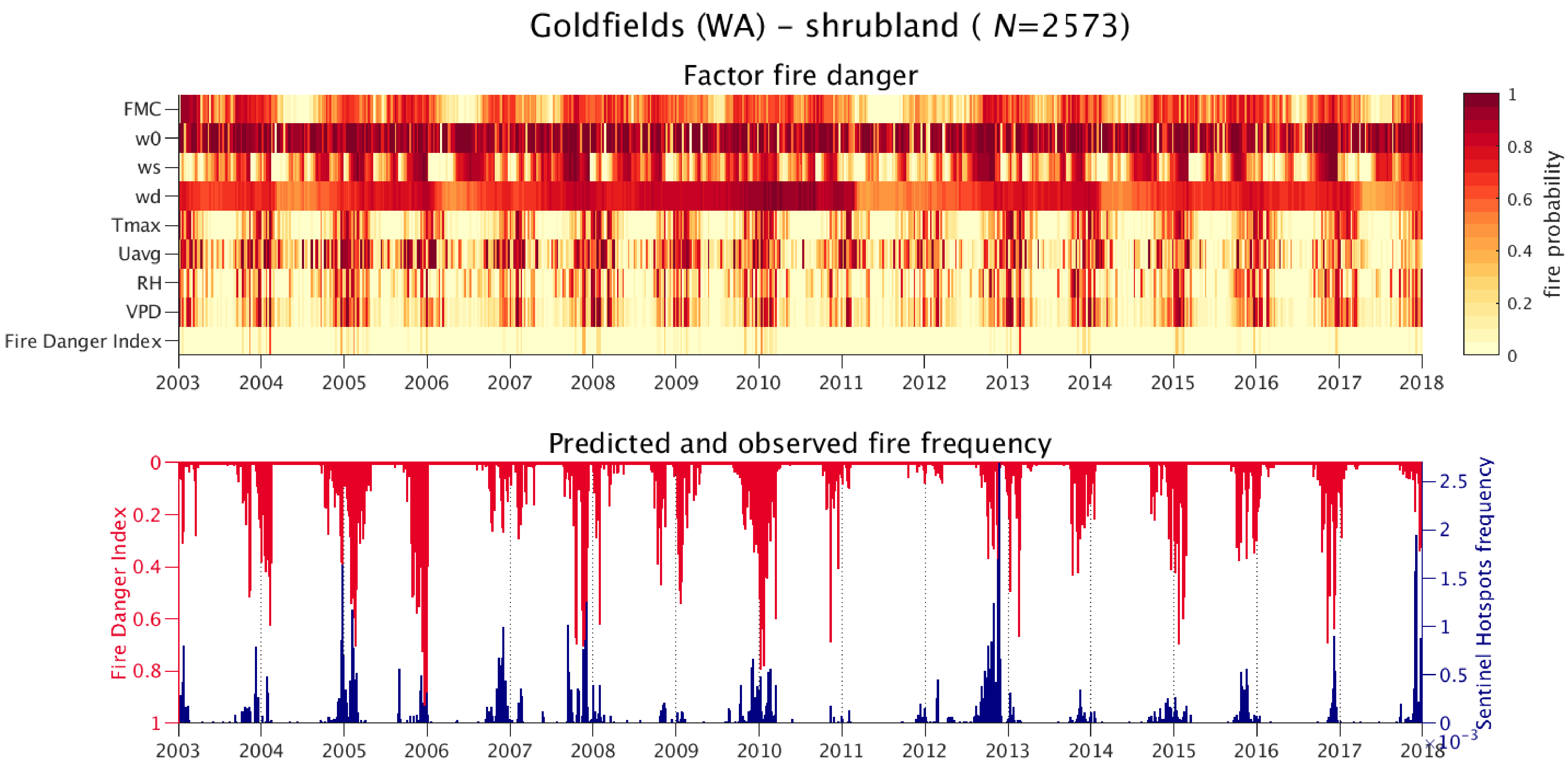
- "fire" = fire as detected by Sentinel Hotspots
- noise does occur
- can includes residue burning, prescribe burning etc., if large and hot enough
- ignition probability cannot be considered
- evaluation against same dataset so not independent (but still informative)
- the correlations between factors is assumed

Evaluation example

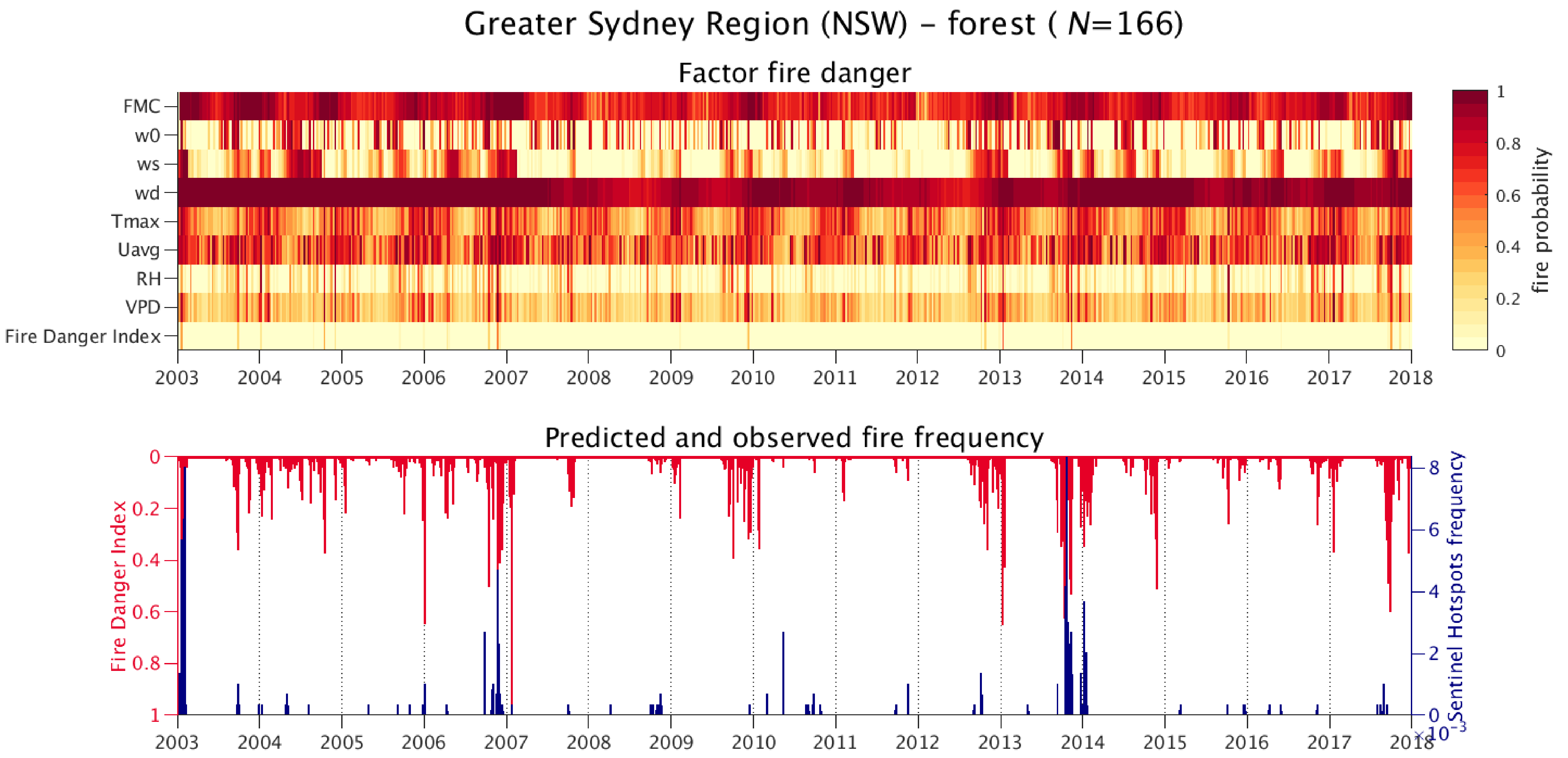
Temporal variability in the predicted probability is a measure of predictive power



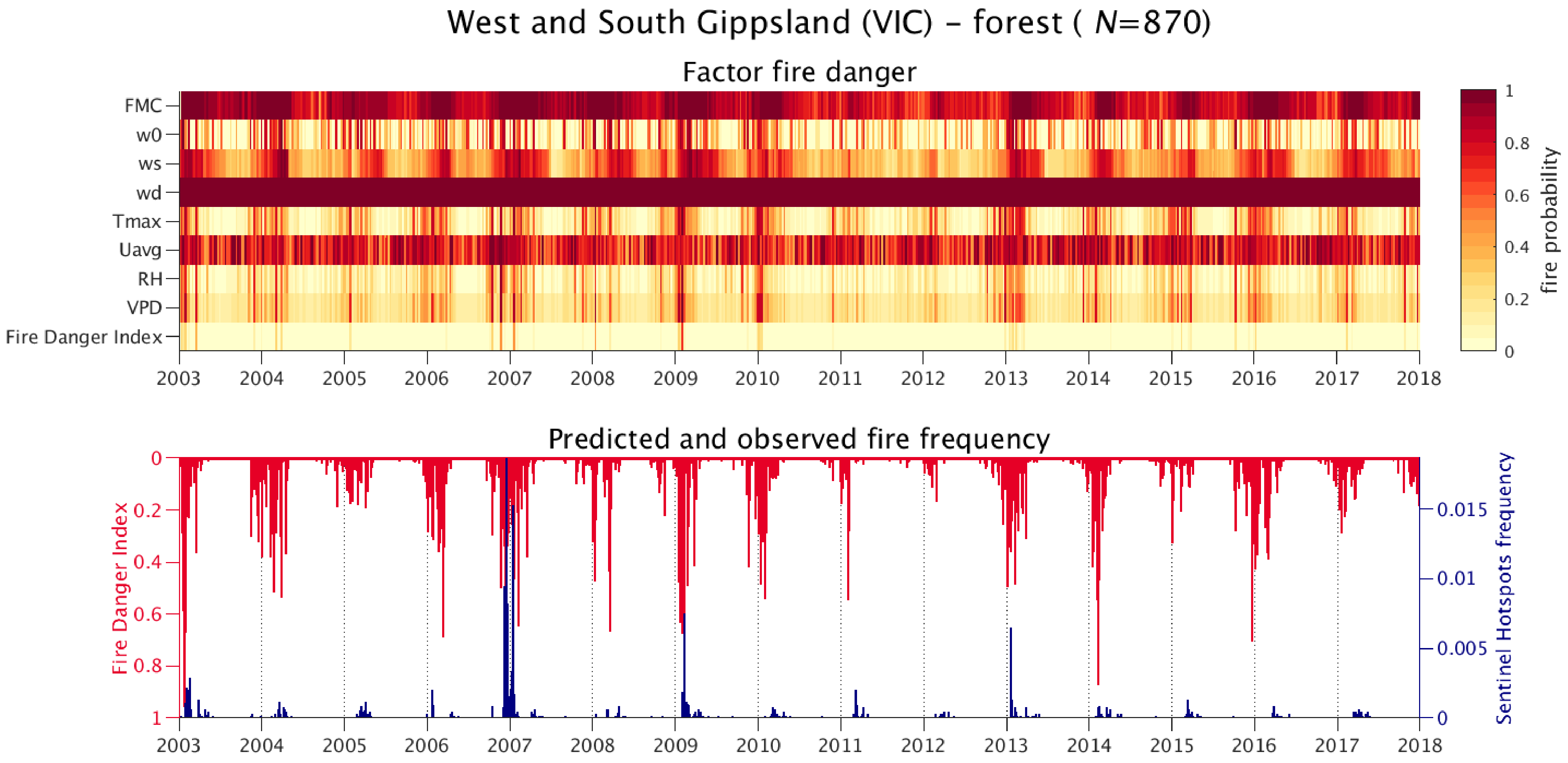
Evaluation example



Evaluation example



Evaluation example



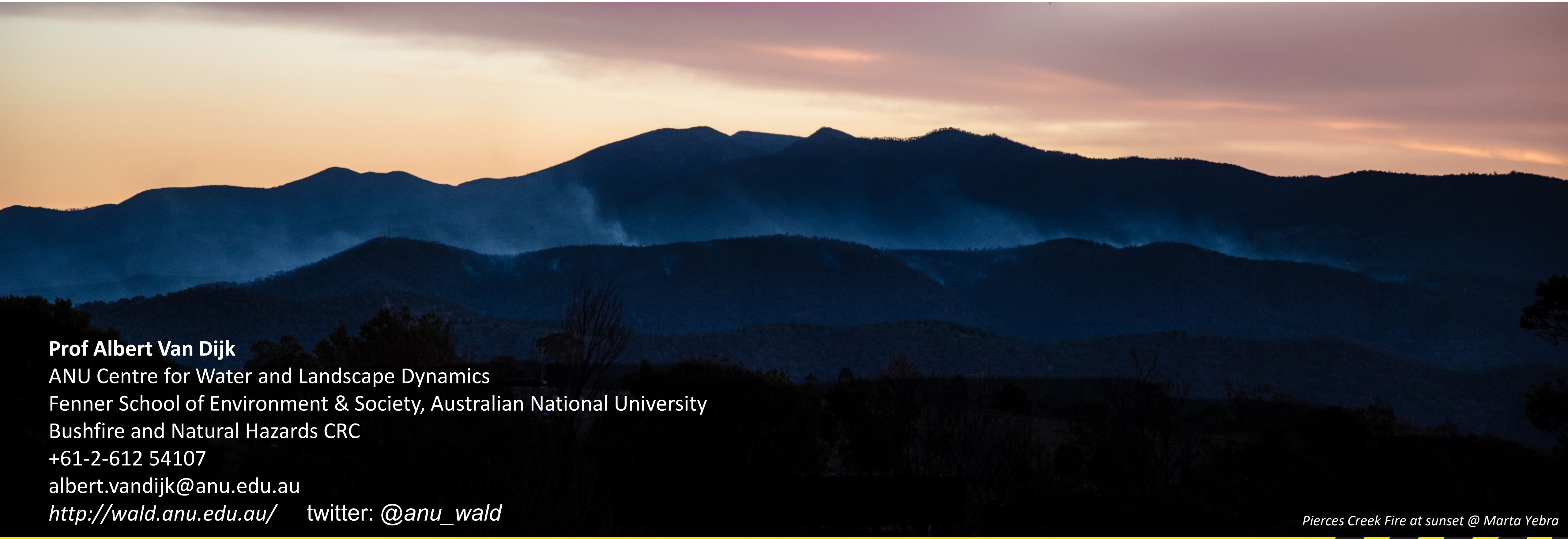
Take home messages

- Methodology to develop Empirical Fire Danger Index from ‘Big Data’
- Based on observations from GA Sentinel Hotspots
- Predictors tested to far relate to fuel condition and fire weather
- Temporal variability in predicted probability is a measure of predictive power
- Early results very promising

Prospects

- Formal skill comparison vs. MacArthur FFDI/GFDI
- EFDI could be produced daily at 500-m as part of AFMS
- Address sources of error (e.g., small sample size)
- Explore sophistications (e.g., Bayesian Belief Networks)
- Extend to EFDI forecasts using BoM ACCESS weather forecasts
- Inform the new National Fire Danger Rating System?

Thank you



Prof Albert Van Dijk
ANU Centre for Water and Landscape Dynamics
Fenner School of Environment & Society, Australian National University
Bushfire and Natural Hazards CRC
+61-2-612 54107
albert.vandijk@anu.edu.au
http://wald.anu.edu.au/ twitter: *@anu_wald*

Pierces Creek Fire at sunset @ Marta Yebra

The Australian Flammability Monitoring System

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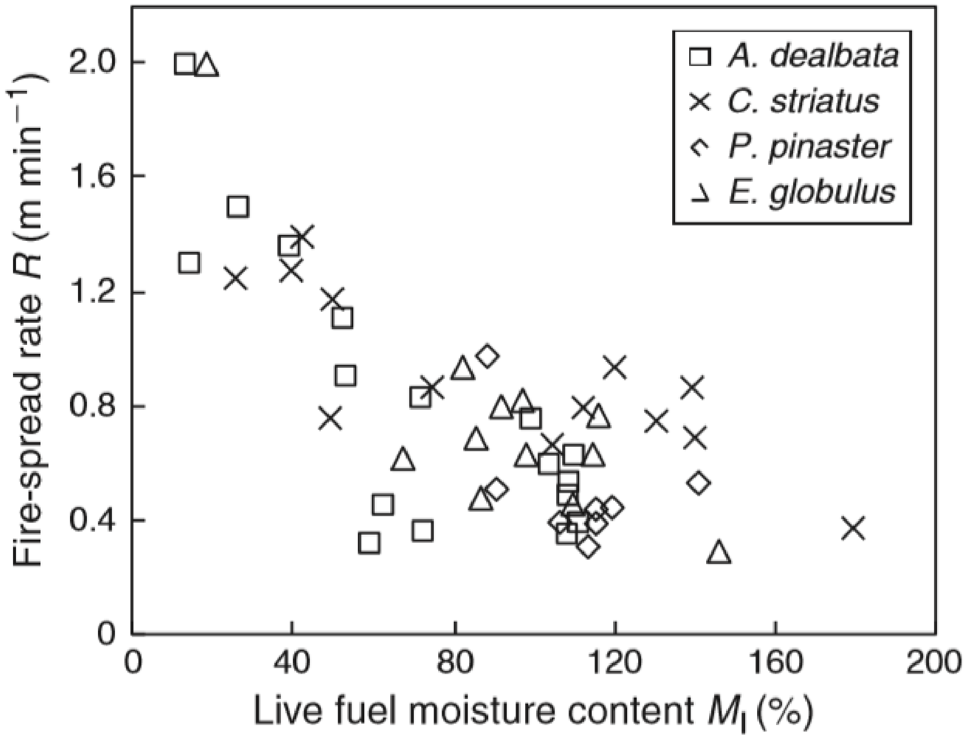
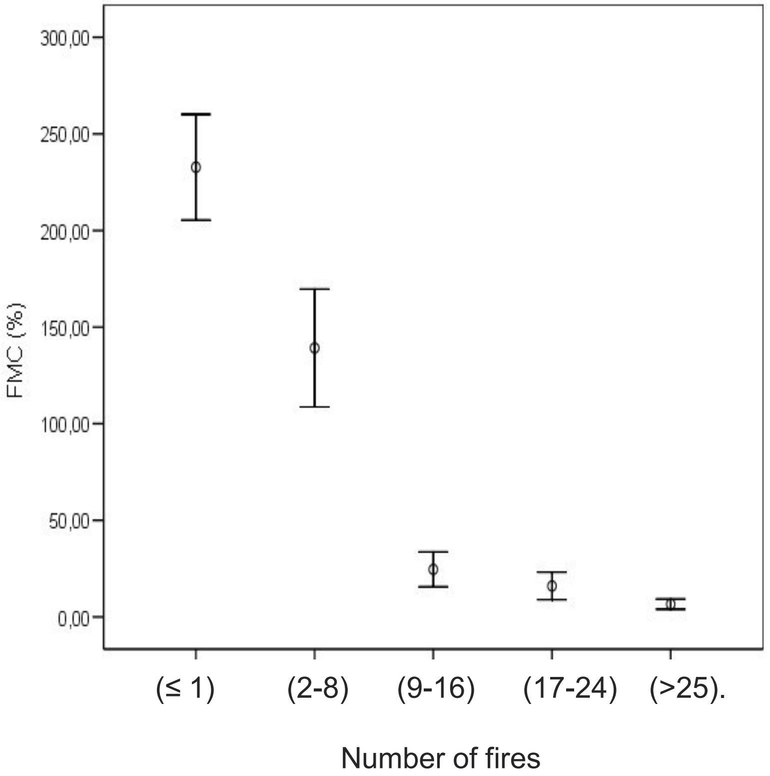
Why monitor live fuel moisture content?

Forest

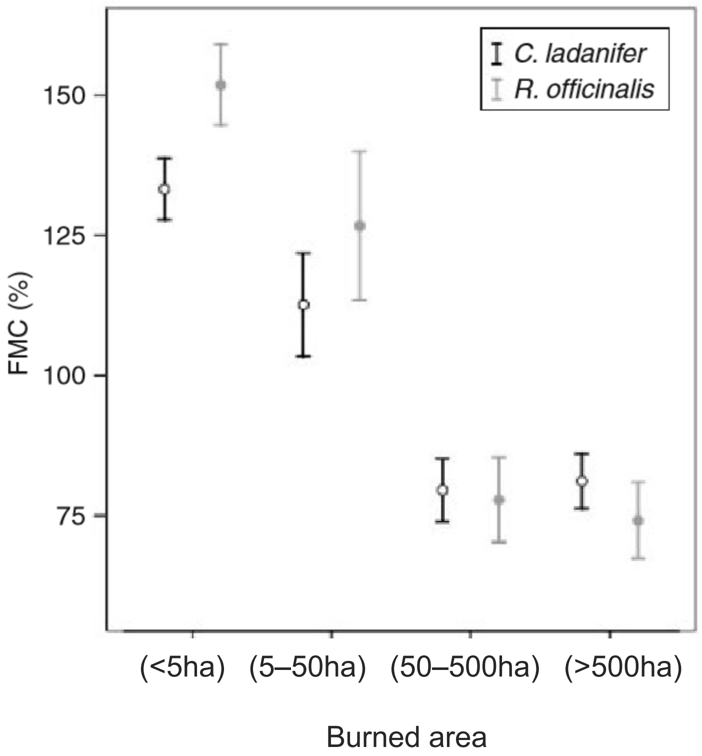


Rossa *et al.*, 2016, IJWF

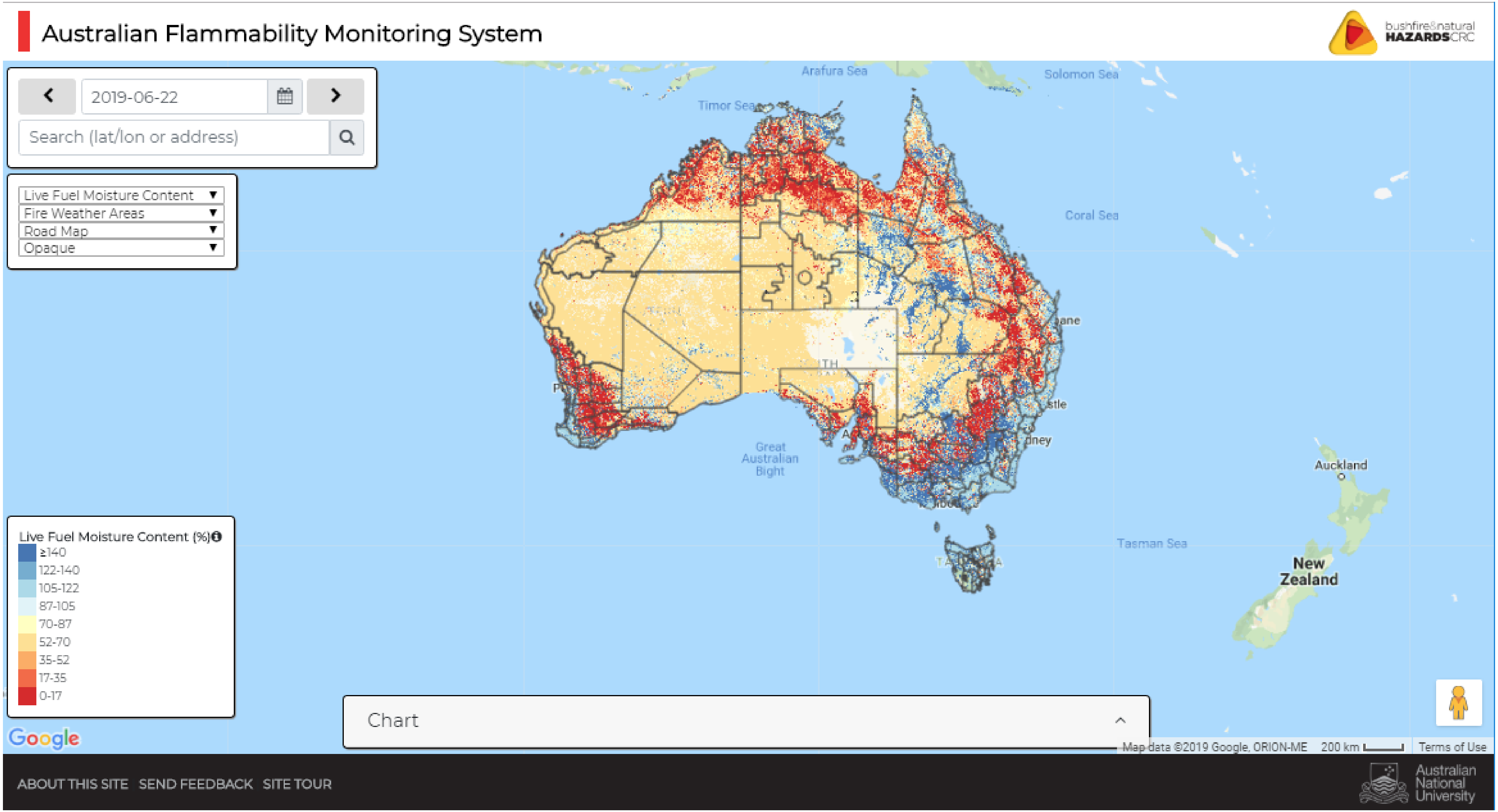
Grass



Mediterranean Shrub



Chuvieco *et al.* 2009, IJWF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bushfire&natural HAZARDSCRC
2019-06-22
Search (lat/lon or address)
Live Fuel Moisture Content
Fire Weather Areas
Road Map
Opaque
Arafura Sea
Solomon Sea
Timor Sea
Coral Sea
Great Australian Bight
Tasman Sea
Auckland
New Zealand
Live Fuel Moisture Content (%)
≥140
122-140
105-122
87-105
70-87
52-70
35-52
17-35
0-17
Chart
Map data ©2019 Google, ORION-ME
200 km
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How the system is currently or intended to be used

Spatially-explicit knowledge of FMC and flammability must be a key aim for fire managers

Planning

Assist with **scheduling and plan prescribed burns:**

- drier FMC in a forest may indicate more potential to score the canopy
- fuel moisture differential can act as soft control lines
- long term fuel conditions for the PB-DST
- emissions assessment and smoke dispersion

Preparedness

Amend preparedness levels in relation to Fire Danger Rating in response to lower/higher than average landscape dryness conditions or exceed set FMC or **FI** thresholds

Response

Assist in firefighting and resources allocation

- FMC as an **input in Spinifex grass** fire behaviour
- Highlight potential for **anomalies in predicted rate of spread:** for lower FMC a fire may spread faster than predicted
- soft control lines based on fuel moisture differential