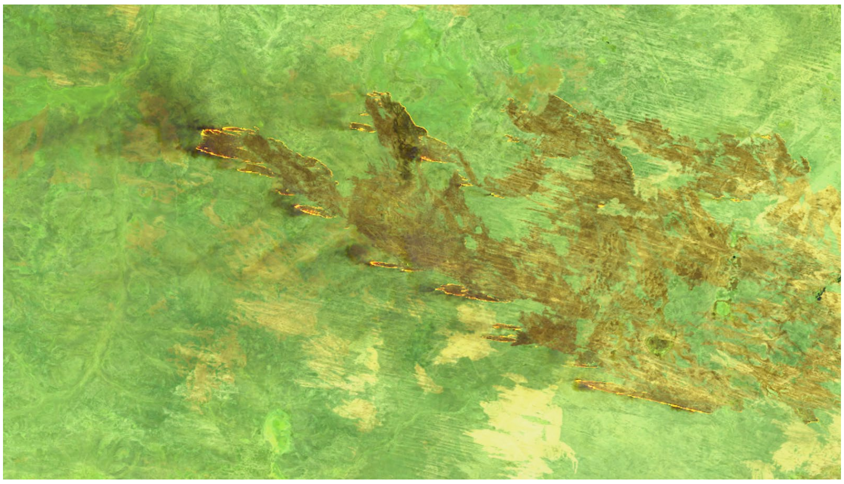
AUSTRALIAN FIRE PATTERN ANALYSES USING MODIS HOTSPOTS



Part 6: BEYOND MODIS - VIIRS

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The real value from analyses of the last two decades' satellite data is that it shows where to look for future trends arising from climate change. As we end the MODIS Era and enter the VIIRS Era it is vital that we get the transition right.

This report reviews aspects of the two main classes of satellites used fire effect monitoring: (1) geostationary weather satellites, which orbit 36,000km above Earth, and produce a steady stream of imagery; and (2) low-earth orbit satellites, which typically pass overhead twice a day but may pass over at an angle more often.

GEOSTATIONARY WEATHER SATELLITES

Satellite	Longitude	Owner
Meteosat-9	45.5˚ E	EUMETSAT, ESA
Meteosat-10	0˚	EUMETSAT, ESA
Meteosat-11	9,5˚ E	EUMETSAT, ESA
Meteosat 12	0.3˚ W	EUMETSAT, ESA
INSAT-3DS	82˚ E	ISRO
INSAT 3DR	74˚ E	ISRO
FY-2G	99.5˚ E	CMA, NRSCC
FY-2H	79˚ E	CMA, NRSCC
GEO-KOMPSAT-2A	128.2˚ E	KMA, KARI, ME, MLTM (S. Korea)
GEO-KOMPSAT-2B	128.2˚ E	KMA, KARI, ME, MLTM (S. Korea)
Himawari-9	140.7˚ E	JMA
GOES-18 (GOES West)	137˚ W	NOAA, NASA
GOES-16 (GOES East)	75.2˚ W	NOAA, NASA (GOES-19 replacing)

AHI/ABI (Himawari & GOES) Spectral Channels

http://www.data.jma.go.jp/mscweb/en/himawari89/index.

Channel	Resolution at nadir	Wavelength (μ)	Key Use
1	1 km	0.47	Visible – Blue
2	1 km	0.51	Visible – Green
3	0.5 km	0.64	Visible – Red
4	1 km	0.86	NIR
5	2 km	1.6	NIR
6	2 km	2.3	NIR
7	2 km	3.9	MWIR – fire detection
8	2 km	6.2	MWIR – water vapour
9	2 km	6.9	MWIR – water vapour
10	2 km	7.3	MWIR – water vapour
11	2 km	8.6	LWIR
12	2 km	9.6	LWIR
13	2 km	10.4	LWIR – thermal infrared
14	2 km	11.2	LWIR
15	2 km	12.4	LWIR
16	2 km	13.3	LWIR

Both families of satellites use the same sensor platform (and other sensors not relevant here) , although there are some differences in ABI.

LOW-EARTH ORBIT SATELLITES

MODIS Spectral Channels

https://lpdaac.usgs.gov/products/modis_products_table/modis_overview

Channel	Range		Key Use
	Reflected (nm)	Emitted (μ)	
1	620-670		Absolute Land Cover Transformation, Vegetation Chlorophyll
2	841-876		Cloud Amount, Vegetation Land Cover Transformation
3	459-479		Soil/Vegetation Differences
4	545-565		Green Vegetation
5	1230-1250		Leaf/Canopy Differences
6	1628-1652		Snow/Cloud Differences
7	2105-2155		Cloud Properties, Land Properties
8	405-420		Chlorophyll
9	438-448		Chlorophyll
10	483-493		Chlorophyll
11	526-536		Chlorophyll
12	546-556		Sediments
13h	662-672		Atmosphere, Sediments
13l	662-672		Atmosphere, Sediments
14h	673-683		Chlorophyll Fluorescence
14l	673-683		Chlorophyll Fluorescence
15	743-753		Aerosol Properties
16	862-877		Aerosol Properties, Atmospheric Properties
17	890-920		Atmospheric Properties, Cloud Properties
18	931-941		Atmospheric Properties, Cloud Properties
19	915-965		Atmospheric Properties, Cloud Properties
20		3.660-3.840	Sea Surface Temperature
21		3.929-3.989	Forest Fires & Volcanoes
22		3.929-3.989	Cloud Temperature, Surface Temperature
23		4.020-4.080	Cloud Temperature, Surface Temperature
24		4.433-4.498	Cloud Fraction, Troposphere Temperature
25		4.482-4.549	Cloud Fraction, Troposphere Temperature
26	1360-1390		Cloud Fraction (Thin Cirrus), Troposphere Temperature
27		6.535-6.895	Mid Troposphere Humidity
28		7.175-7.475	Upper Troposphere Humidity
29		8.400-8.700	Surface Temperature
30		9.580-9.880	Total Ozone
31		10.780-11.280	Cloud Temperature, Forest Fires & Volcanoes, Surface Temp.
32		11.770-12.270	Cloud Height, Forest Fires & Volcanoes, Surface Temperature
33		13.185-13.485	Cloud Fraction, Cloud Height
34		13.485-13.785	Cloud Fraction, Cloud Height
35		13.785-14.085	Cloud Fraction, Cloud Height
36		14.085-14.385	Cloud Fraction, Cloud Height

Note: Reflections are described using nanometres (nm).

1000 nm – 1 μ.

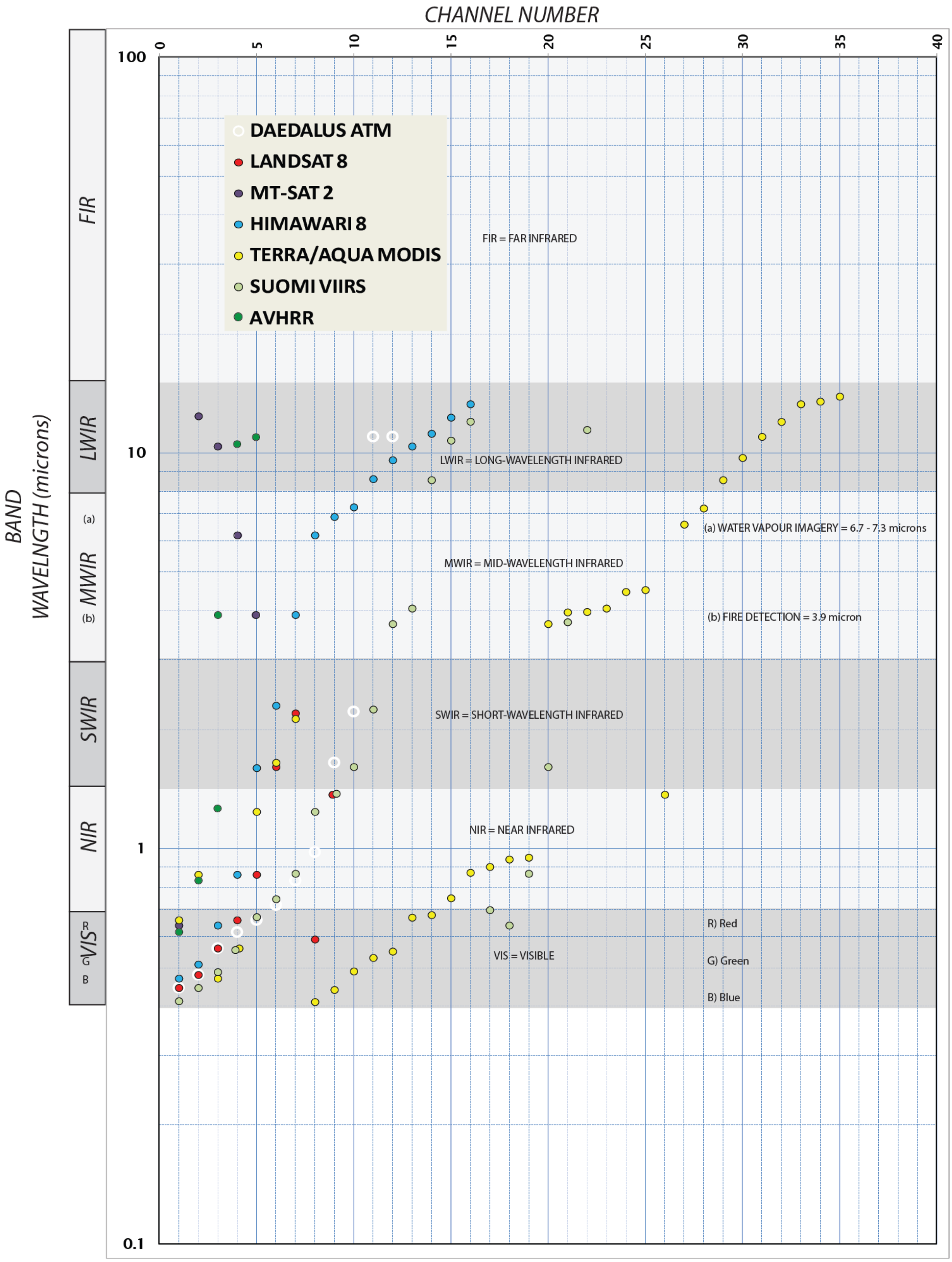
VIIRS Spectral Channels

https://lpdaac.usgs.gov/products/modis_products_table/modis_overview

Channel	Range		Key Use
	Reflected (nm)	Emitted (μ)	
1	412		Chlorophyll
2	445		Chlorophyll
3	488		Visible – Blue
4	555		Visible – Green
5	672		Visible – Red
6	746		Visible – Blue
7	865		Aerosol Properties, Atmospheric Properties
8	1240		Leaf/Canopy Differences
9	1378		Cloud Fraction (Thin Cirrus), Troposphere Temperature
10	1610		
11	2250		
12		3.70	Forest Fires & Volcanoes
13		4.05	Cloud Temperature, Surface Temperature
14		8.55	Surface Temperature
16		10.76	Cloud Temperature, Forest Fires & Volcanoes, Surface Temp.
17		12.01	
18		0.7	
19		0.64	
20		0.86	
21		1.61	
22		3.74	Cloud Temperature, Surface Temperature
23		11.45	
30		9.580-9.880	Total Ozone
31		10.780-11.280	
32		11.770-12.270	Cloud Height, Forest Fires & Volcanoes, Surface Temperature
33		13.185-13.485	Cloud Fraction, Cloud Height
34		13.485-13.785	Cloud Fraction, Cloud Height
35		13.785-14.085	Cloud Fraction, Cloud Height
36		14.085-14.385	Cloud Fraction, Cloud Height

Note: Reflections are described using nanometres (nm).

1000 nm – 1 μ.



CHANNEL NUMBER
BAND
WAVELENGTH (microns)
FIR
LWIR
MWIR
SWIR
NIR
VIS
DAEDALUS ATM
LANDSAT 8
MT-SAT 2
HIMAWARI 8
TERRA/AQUA MODIS
SUOMI VIIRS
AVHRR
FIR = FAR INFRARED
LWIR = LONG-WAVELENGTH INFRARED
(a) WATER VAPOUR IMAGERY = 6.7 - 7.3 microns
MWIR = MID-WAVELENGTH INFRARED
(b) FIRE DETECTION = 3.9 micron
SWIR = SHORT-WAVELENGTH INFRARED
NIR = NEAR INFRARED
R) Red
VIS = VISIBLE
G) Green
B) Blue

An example of the difference between MODIS and VIIRS data can be seen through a fire activity mapping technique called a BUFEGRAM. This aggregates hotspots into cells of a regular grid and analyses patterns using number of hotspots ,number of days with hots, and the distribution of FRP with respect to thresholds. Cells are classified into one of four classes:

- Edge burning – low activity levels (mapped in grey).
- Prolonged burning, over a large number of days (mapped in green).
- Headfire run, with FRP concentrated into a short time span (mapped in orange).
- Blow-Up Fire Event (BUFE), with elevated FRP in a very short time period (mapped in red).

BUFEs often need to be augmented with separate mapping data, as they often leave too little heat to trigger the satellite hotspot detection algorithm.

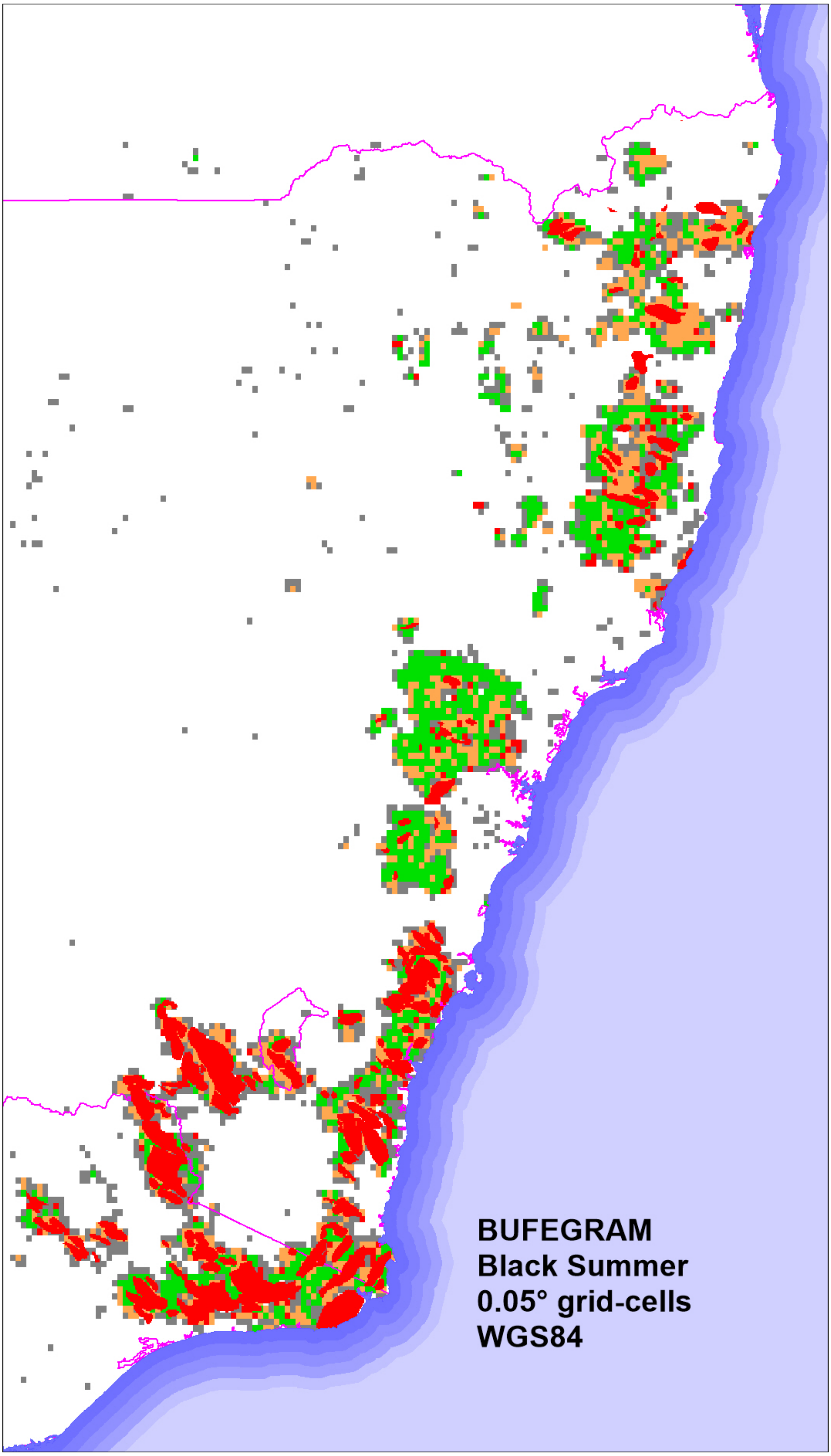
BUFEGRAMs do not show fire spread isochrones or direction, rather they classify the manner in which fire spreads. This can be valuable intelligence for learning how to optimise future incident strategies and tactics, as those suited for one class may be completely unsuited, if not dangerous, for another. Gaining an understanding of where on the landscape and where in a fire's life cycle the classes occurred will be valuable.

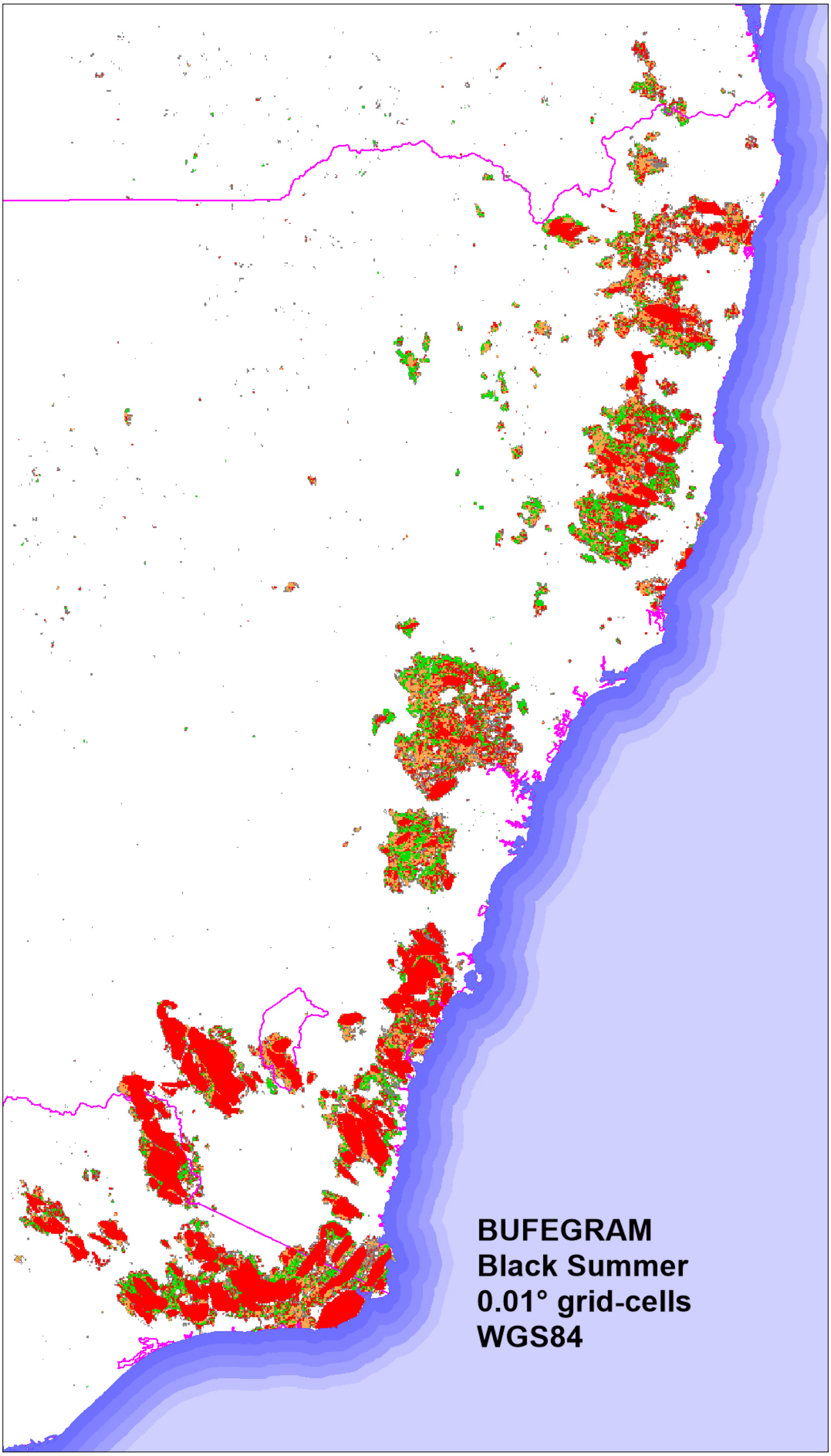
The entirety of Black Summer data were used to generate BUFEGRAMs, using MODIS data on a 0.05° grid and using VIIRS data on a 0.01° grid.

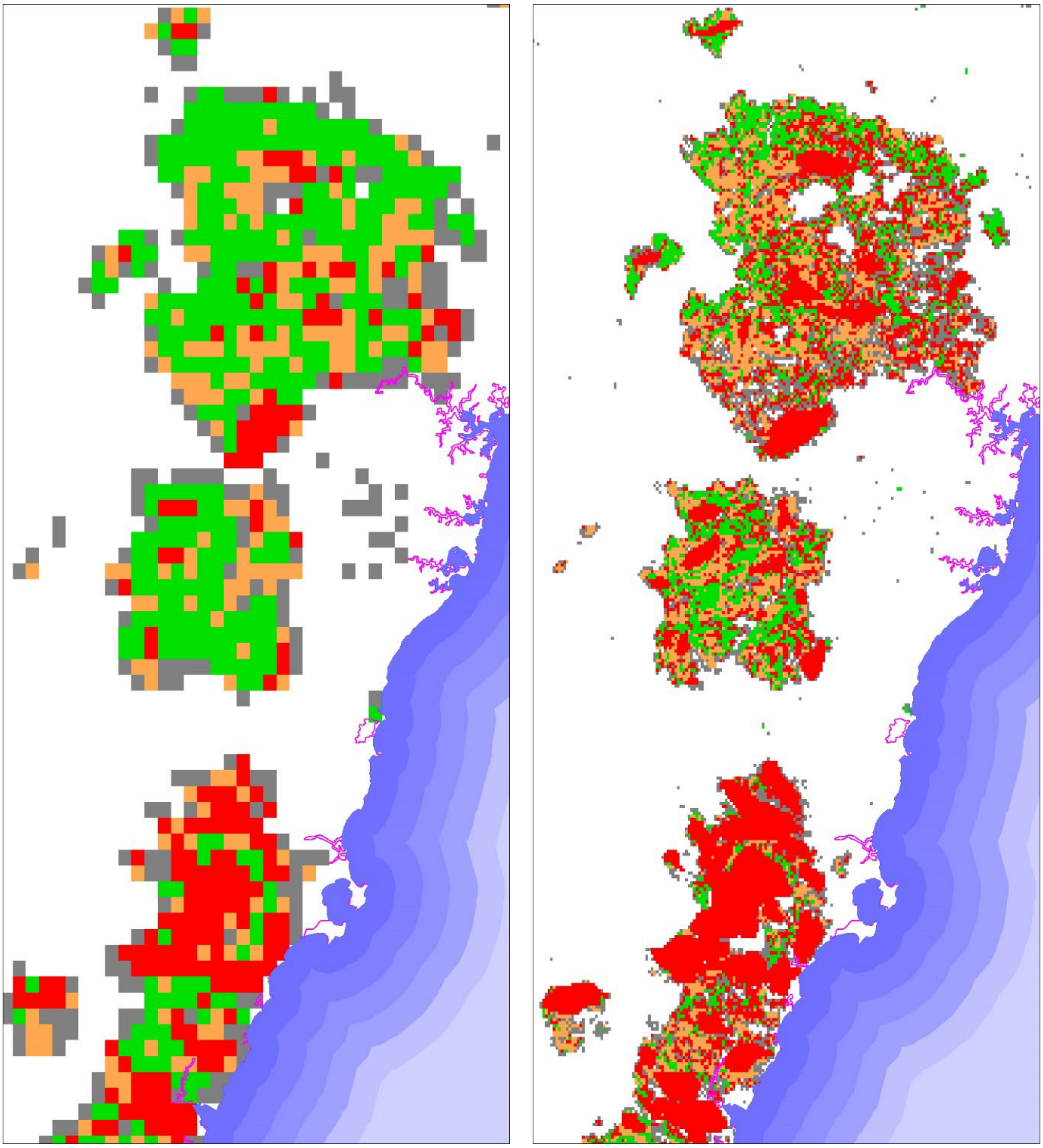
The comparison below shows the difference between the two sensor types. Also shown are the results from a subset area. These examples do not claim to be optimised, rather they show a shift in resolution that may be possible, but may also be too confusing to be of value. This raises the caveat that switching to VIIRS has to be done carefully, and new products must be tailored to end-user needs.

Parameter	Thresholds used	
	MODIS	VIIRS
Sensor min ground resolution, IR (km)	1.0	0.75
Grid-cell size used (degrees)	0.05	0.01
Approximate area, km^2	25	1
Mean of daily max FRP (MW)	68	15
Max of daily max FRP (MW)	150	30
Count of hotspots	15	5
Count of days with fire activity	6	3

In the first graphic, fire north of the Hunter River is dominated by headfire runs, fire down to the Shoalhaven River is dominated by prolonged burning, while fire further south is dominated by BUFEs. These patterns have major impacts on suppression difficulty, risk levels, and recovery extent. In the higher resolution second graphic the pattern is less evident.

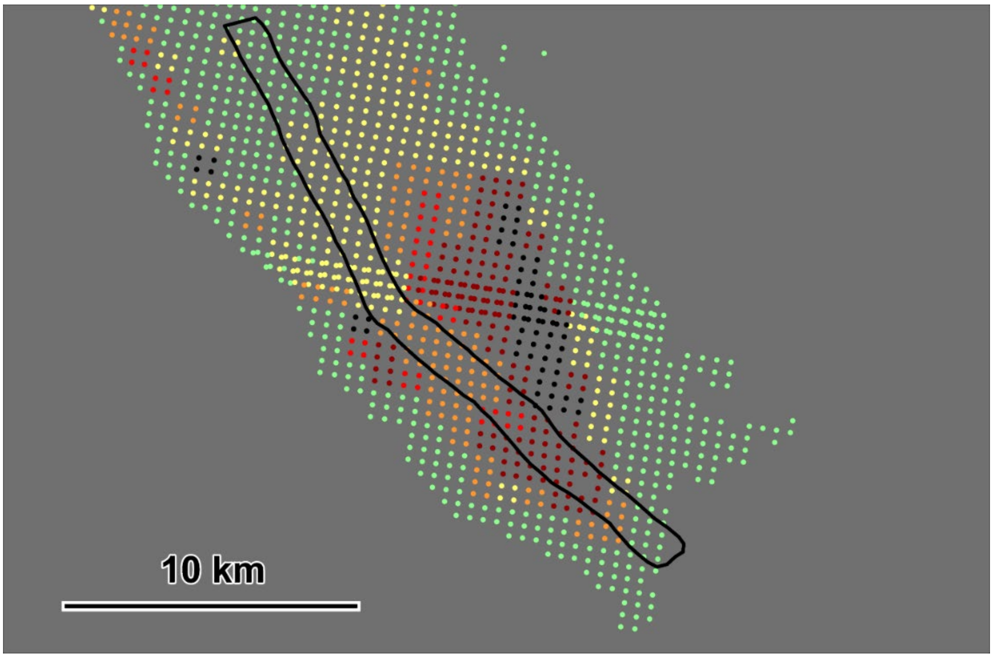

BUFEGRAM
Black Summer
0.05° grid-cells
WGS84


BUFEGRAM
Black Summer
0.01° grid-cells
WGS84



Comparison of MODIS (left) and VIIRS (right) BUFEGRAMs. These span from Wollemi – Yengo NPs in the north, through Blue Mountains NP to Morton and Deua NPs in the south.

It is clear the extrapolating MODIS lessons forward into VIIRS data analysis will not be straightforward. There will ultimately be over six years of overlap, and the recalibration of techniques will need as much of that data as possible, to span wet years and dry years, and all other types of year.



Above: Blow-up fire event hotspot transect, night of30 December 30/12/22019 with a NW north-westerly wind. The colour scheme legend for the dots is: Green = 0 to 20 MW (MegaWatts), Yellow = 25 to 50 MW, Orange = 50 to 75 MW, red = 75 to 100 MW, Dark red = over 100 MW.

Data source: NASA Fire Information for Resource Management System FIRMS.

The fire shown above contained 242 hotspots. The hotspot Fire Radiative Power values were aggregated (summed) along that transect into 0.01° segments. The FRP trace along the transect is shown below.

The map shows the hotspots dataset from the 2 VIIRS sensors and provides a snapshot of the fire's behaviour at the time of overflight (halfway between midnight and sunrise).

Analysis (right) shows a likely resolution of a major spotfire about 3km ahead of the main run. This indicates that there was a major fire run that included dense fire spotting that quickly merged, forming a head fire that took a long time to burn-out (estimated to be about 2 hours). The Y-axis, in Megawatts , is a reminder of the extraordinary power of large fire runs.