Active wildfires characterization from space: explaining the complementary value of hyperspectral PRISMA data

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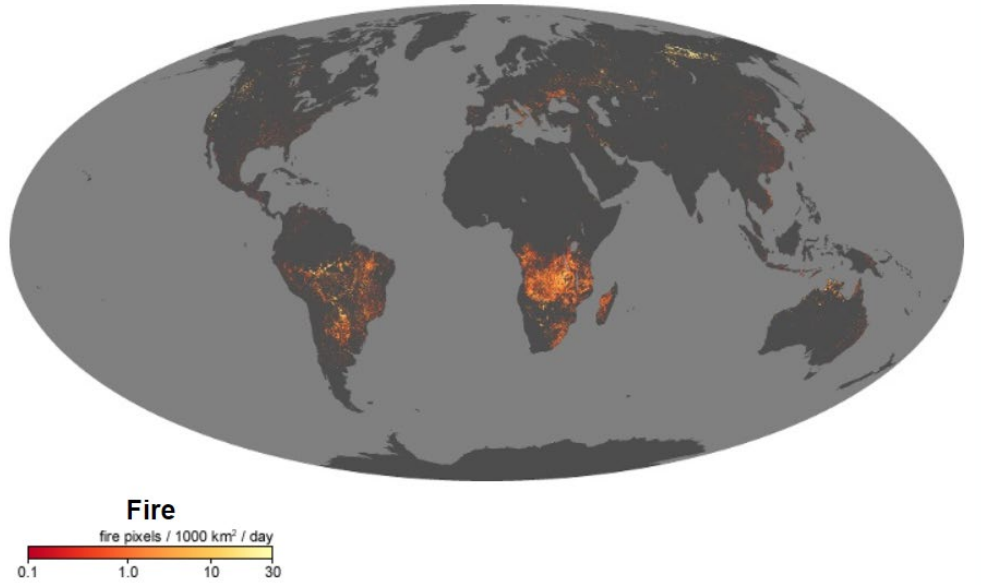
Overview

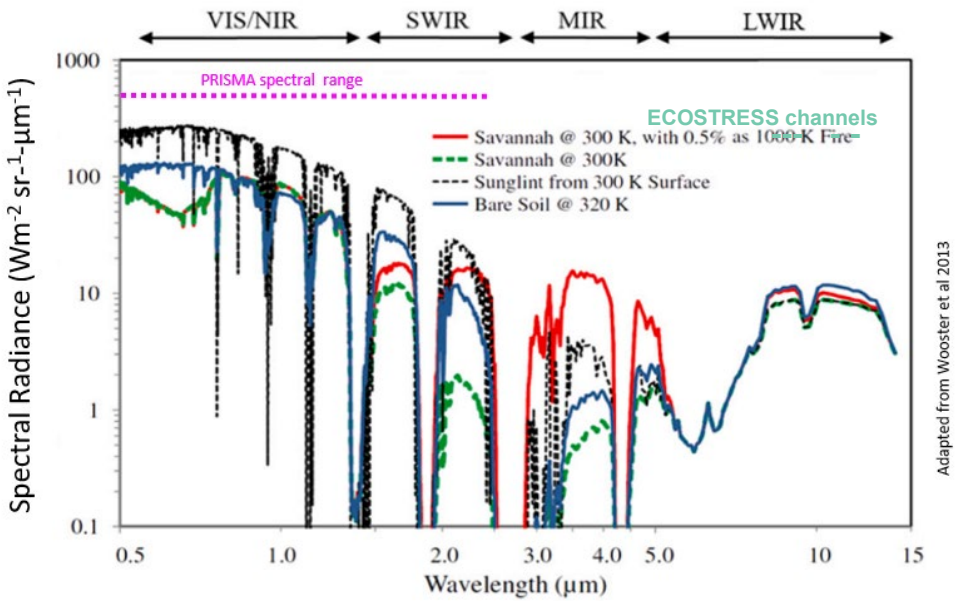
- Framework
- Benefits and limitation
- Active fire characterization techniques: HFDI, CNN classification and temperature
- Case studies
- PRISMA complmentarity
- Remarks

Fire



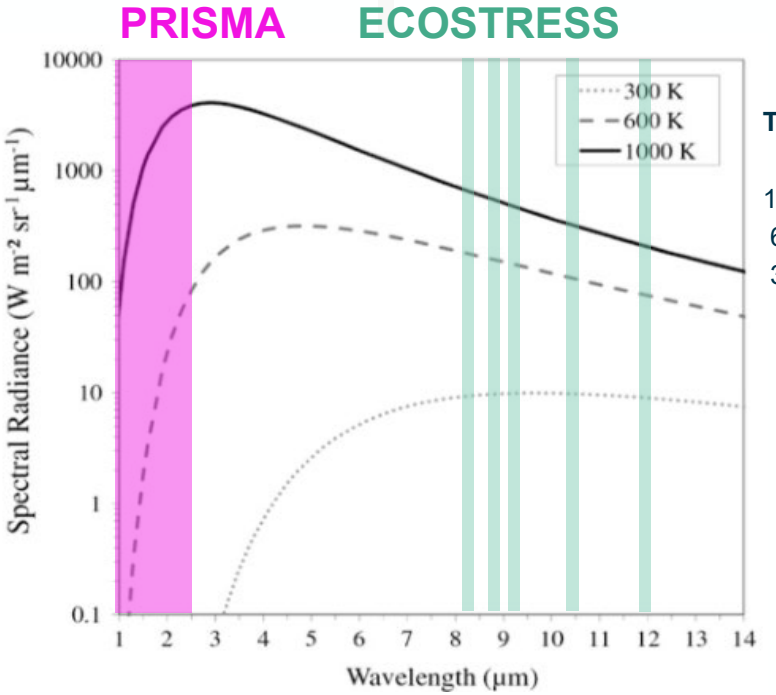
August 2021 active fire map based on MODIS observations White pixels show as many as 30 fires in a 1,000-square-kilometer area per day. Orange pixels show as many as 10 fires, while red areas show as few as 1 fire per day.
Credits FIRE Earth Observatory NASA
https://earthobservatory.nasa.gov/global-maps/MOD14A1_M_FIRE

FIRE SPECTRAL FEATURES



Top-of-atmosphere spectral radiance simulated at four different target pixels (note logarithmic x and y axes) using the MODTRAN 5 radiative transfer code.
in Fig. are shown the simulations for a savannah surface at 300 K; the same surface but with a 1000 K fire covering 0.5 % of the ground field-of-view (FOV), specularly reflected sunglint from a 300 K surface; and solar-heated (320 K) bare soil
The pixel containing the sub-pixel fire shows a signal highly elevated in the MIR (3–5 µm) spectral region compared to all other targets, equivalent to a brightness temperature of around 400 K (Wooster M.J. et al. (2013). https://doi.org/10.1007/978-94-007-6639-6_18)

FIRE THERMAL EMISSION



Thermal emission from:

1000K – FLAME object
600 K - SMOLDERING FIRE
300 K - Ambient background

Wooster et al. 2021

Emitted spectral radiance for Blackbodies at typical flaming (1000K) and smouldering 600K temperature
Atmospheric window are shaded in grey

Benefits and limitations

	PRISMA	EnMap	VIIRS	MODIS	SENTINEL 3	MSG-SEVIRI	LANDSAT 8 -9	Sentinel 2A-B	ECOSTRESS
Spatial resolution	30m	30m	375m- 750m	250m- 500m- 1000m	500m- 1000m	1000m	15m- 30m- 100m	10-20m	50-60m
Spectral coverage	VNIR-SWIR	VNIR-SWIR	VNIR-SWIR-MIR-TIR	VNIR-SWIR--MIR TIR	VNIR-SWIR-MIR- TIR	VNIR-SWIR-MIR- TIR	VNIR-SWIR-TIR	VNIR-SWIR	SWIR –TIR
Number of bands	240	225	21	36	21 +2	12	9 +2	13	1 + 5
Repetition time	5 Days	27days 5 days	Daily	Daily	Daily	15min	8 days	5 days	Variable*
Swath width	30 km (2.77°)	30Km	3060 km	2330-km	1400km (nadir)	Main full Earth imagery (EU-Africa)	185 kilometers	290 km	384 Km
PAN channel	Yes	No	No		No	No	Yes	No	No

Benefits	
Limitations	

* The true revisit period for a given location is variable based on the instrument's orbital cycle aboard the ISS

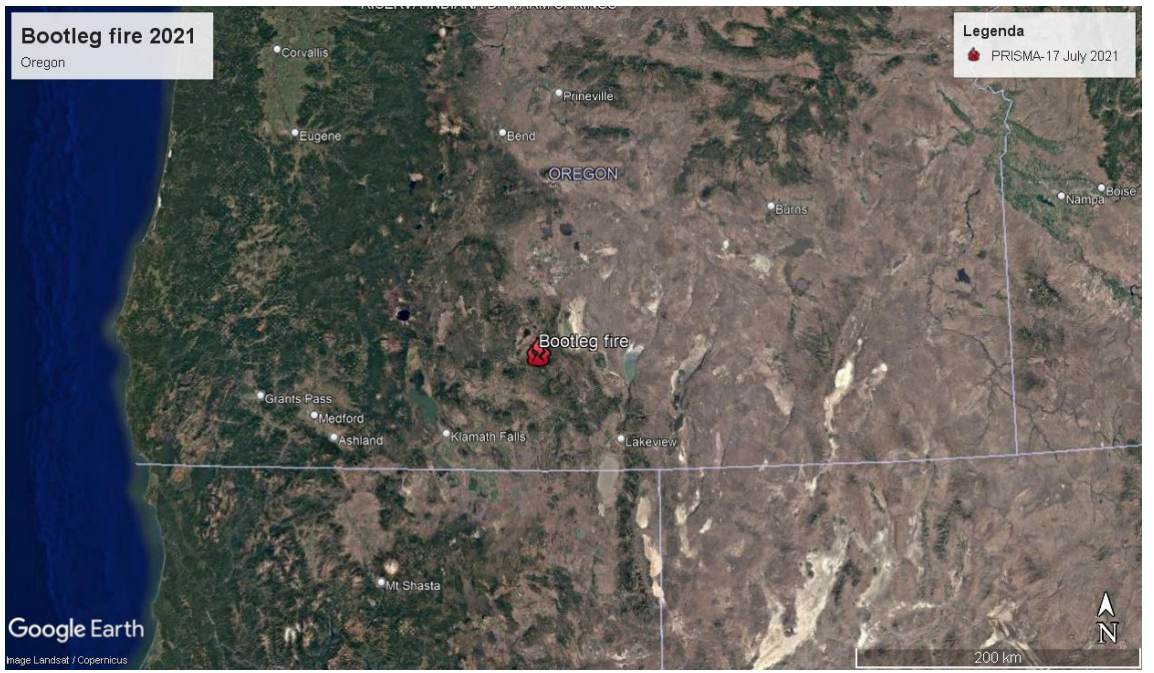
Active fire characterization techniques

Bush fire - NSW 2019 (Australia)

- 2019–20 bushfire season was the most widespread, extreme and catastrophic that Australia has ever experienced since European settlement

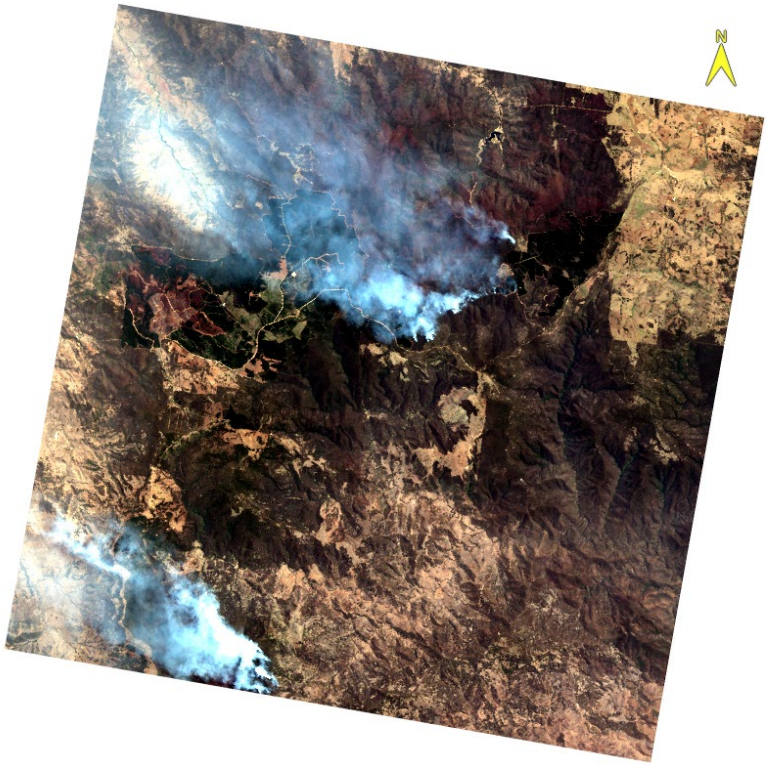
Bootleg fire 2021 (Oregon)

- Started on 6th july 2021 in south Oregon
- Burned 413,765 acres
  (1,674 km^2)

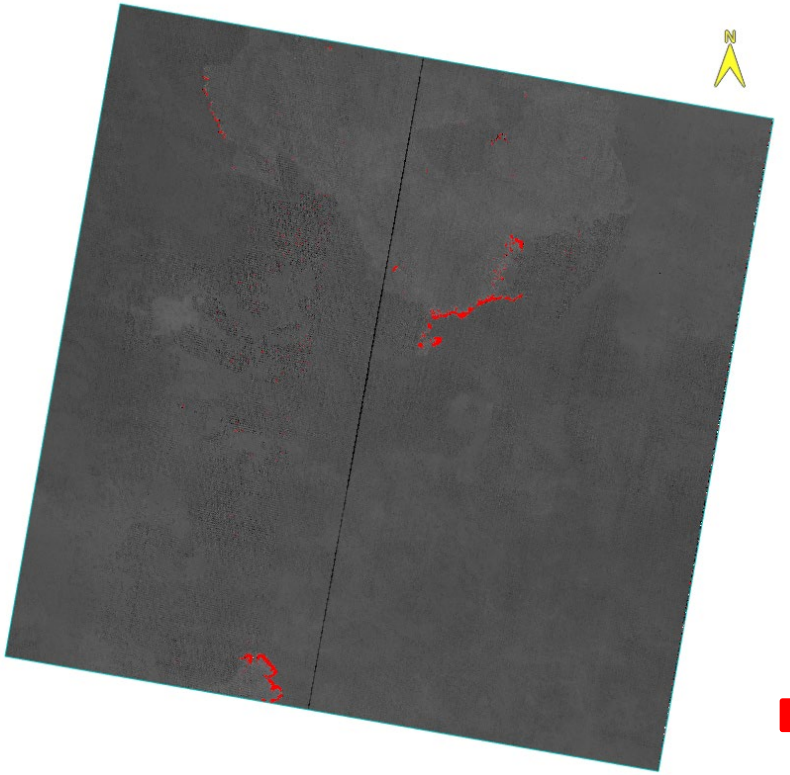


Bush fire - NSW (Australia) - Hyperspectral Fire index

PRISMA: 27 DECEMBER 2019



HFDI



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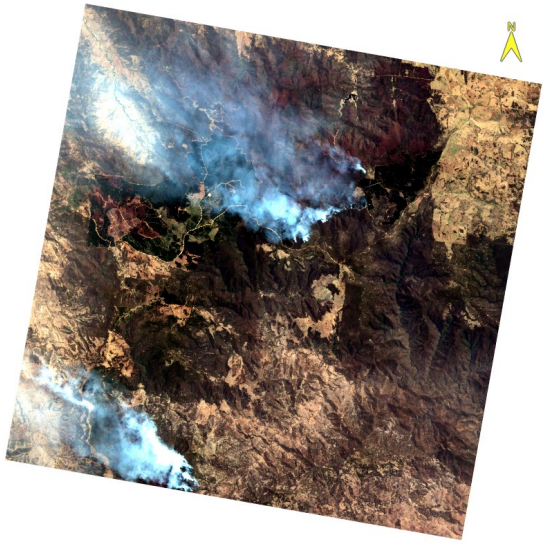
Bush fire - NSW (Australia) - Convolutional Neural Network classification

PRISMA: 27 DECEMBER 2019



Precision, Recall, and F1 scores in the four identified area. The Australia, North-East dataset has been used for training, whereas the others are used as test.

Wildfire Location	Precision	Recall	F1
Australia, North-East	0.98	0.98	0.98
Australia, South	0.98	0.98	0.98
Australia, North-West	1.00	0.95	0.97
Oregon, North-East	0.85	0.79	0.79

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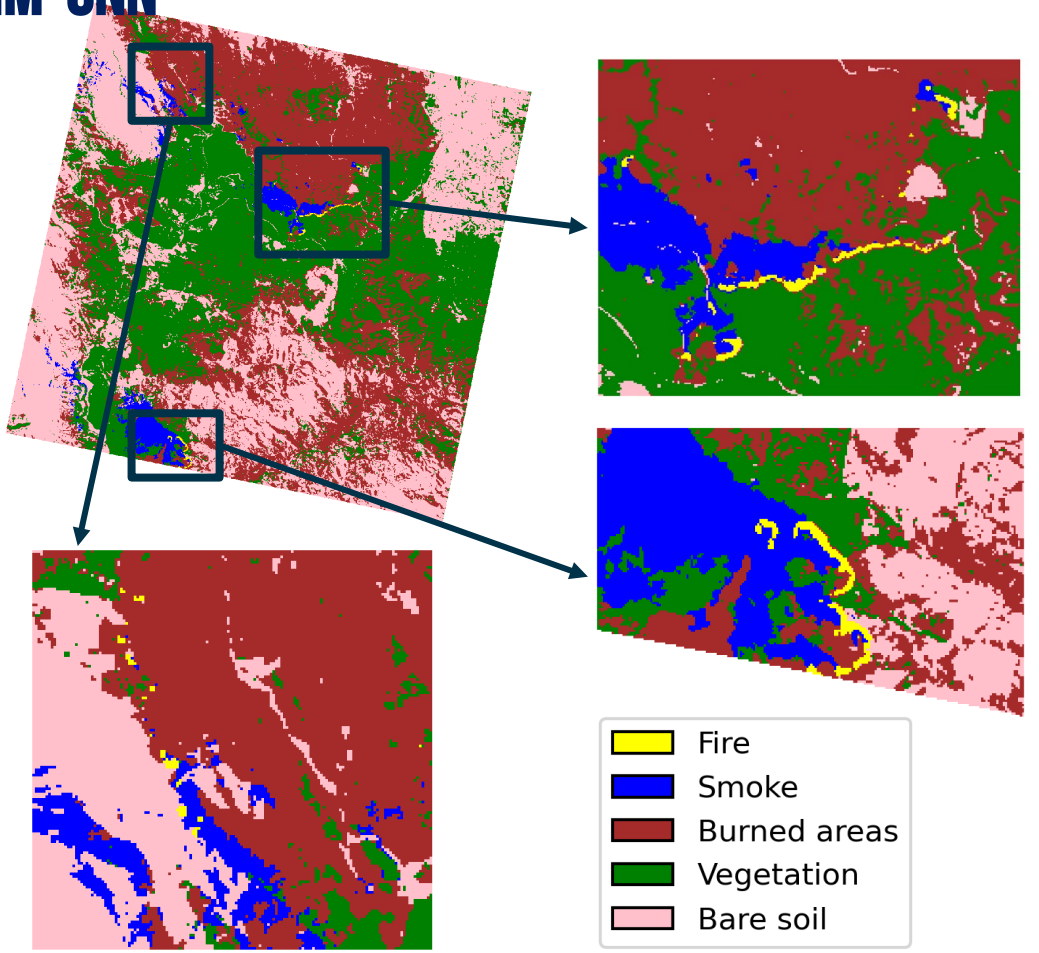
1 DIM CNN



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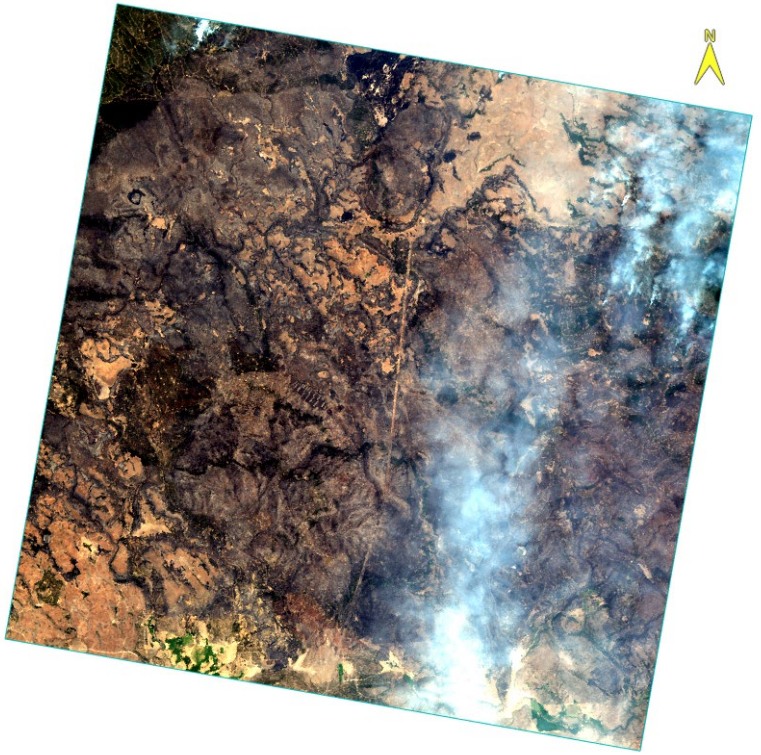
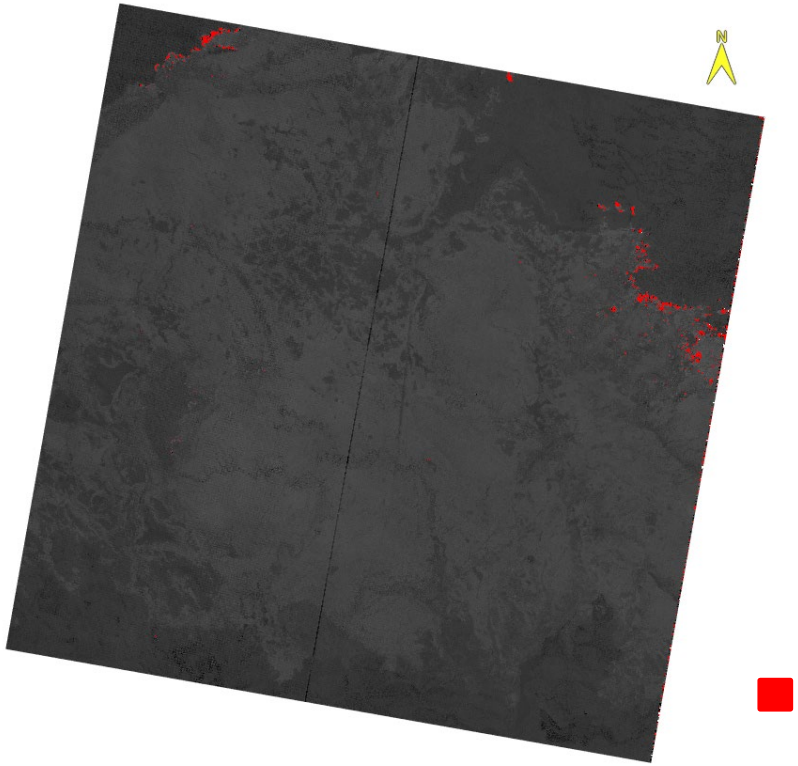
OREGON case study: - Hyperspectral Fire index

PRISMA: 17 JULY 2021



HFDI



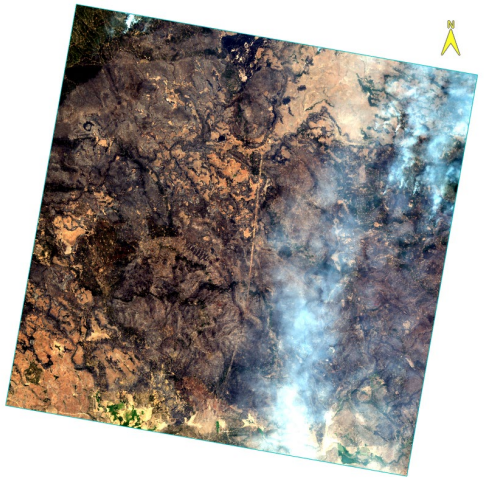
Forest Fire Front

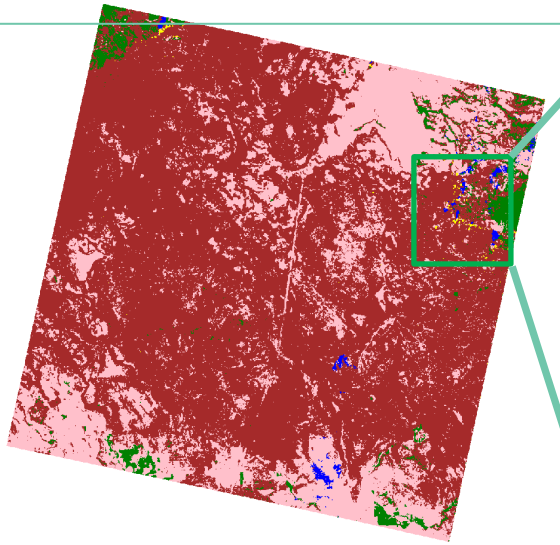
The threshold values are in the range expected by Dennison 2009 with -0.1 for likely detection and -0.178 for threshold ash-background.

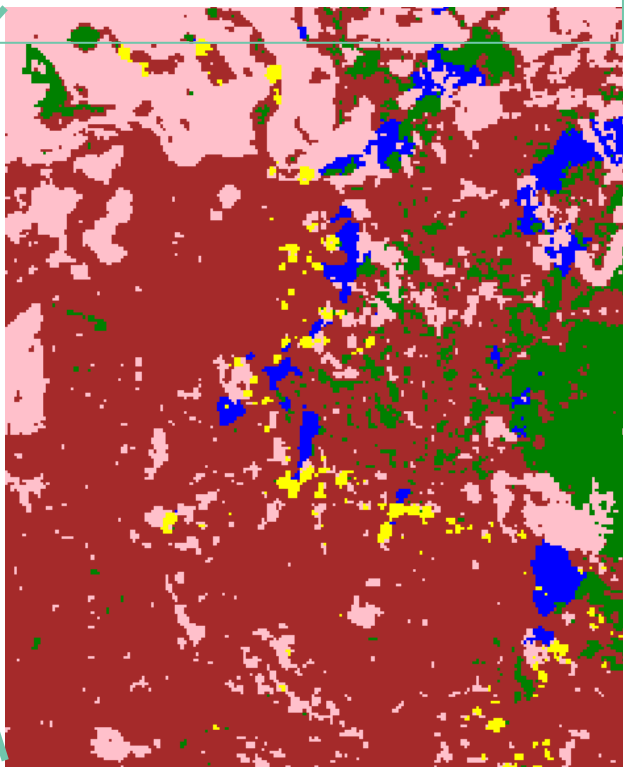
OREGON Transfer learning - Australia Oregon confusion matrix

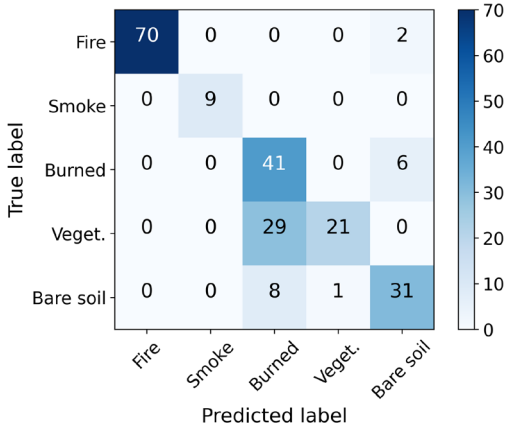
PRISMA: 17 JULY 2021

1 DIM, CNN









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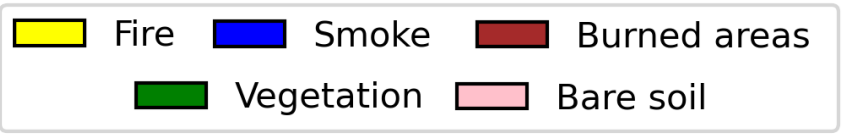

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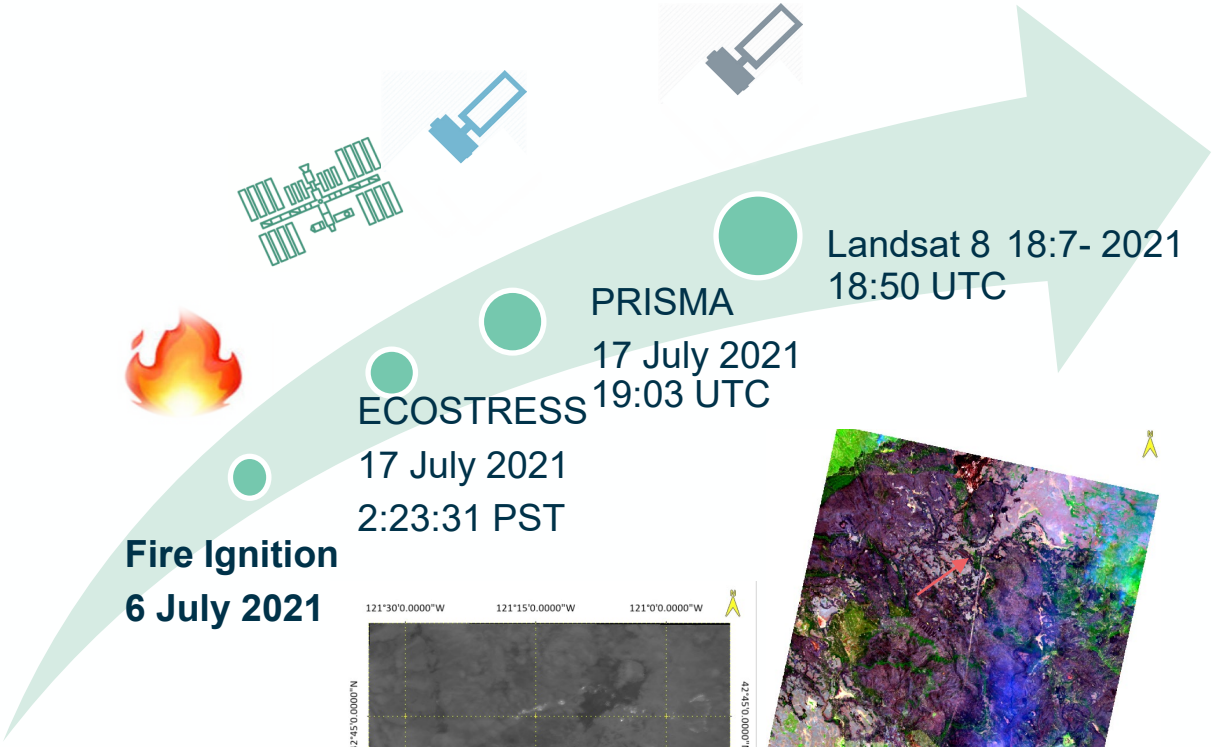
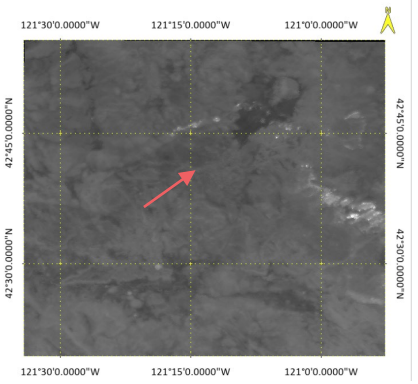
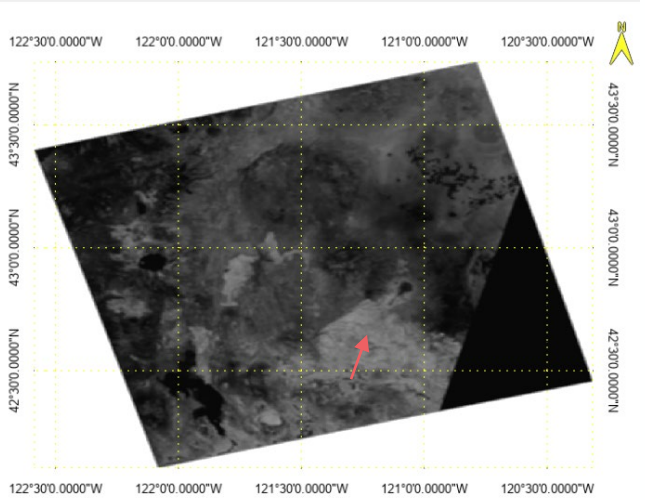
Satellite complementarity

ACQUISITION TIMELINE

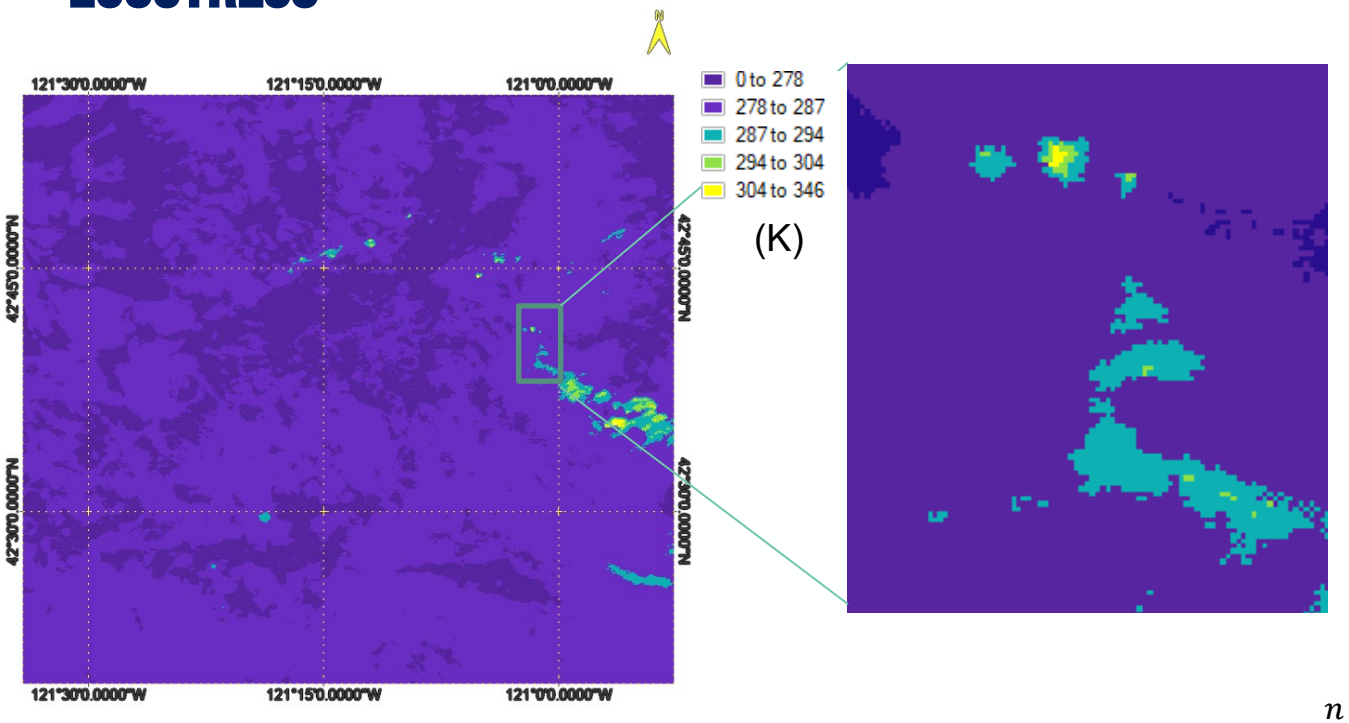






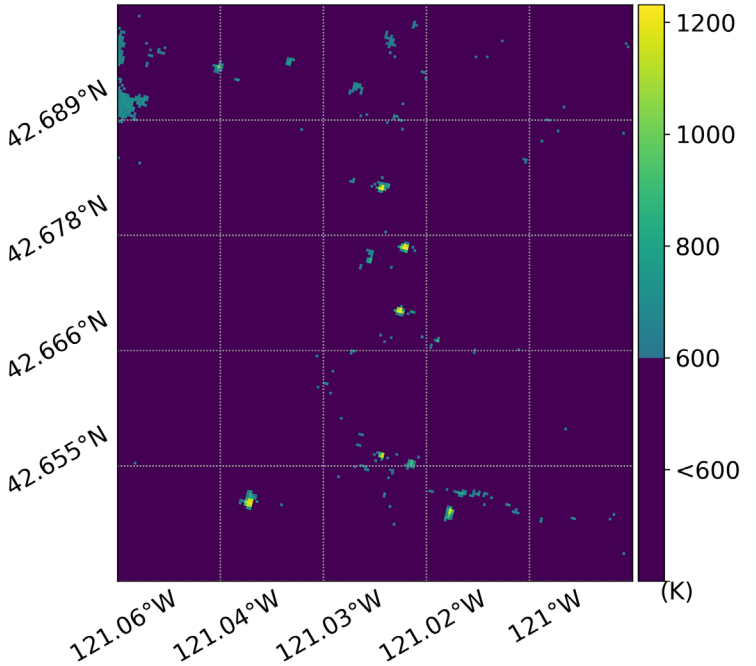
PRISMA vs ECOSTRESS -Temperature maps

ECOSTRESS



Spot fire T> 304 C
Intense heat 294<T>304K
Saturation 573K
Thesholds adapted by Miller L., Coleman A., 13 August 2021, at ECOSTRESS

PRISMA



$$L_{\lambda,m} = \sum_{i=1}^{n} p_{i,fire} L_{\lambda}(T_i) + \sum_{j=1}^{m} p_{j,bkg} L_{j,bkg}$$

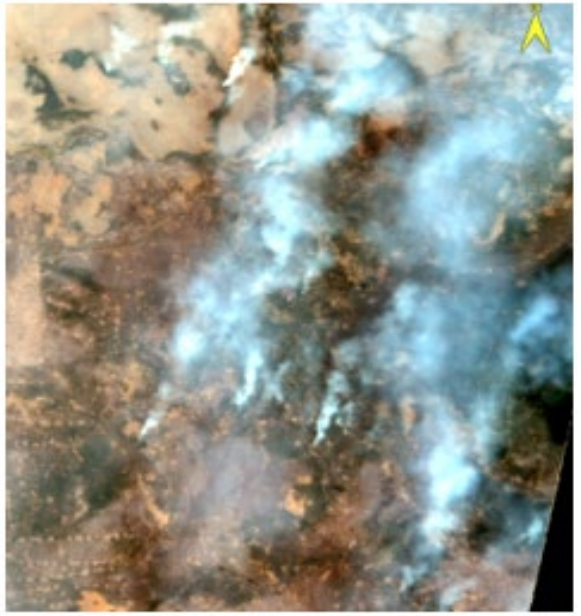
Temperature by using the PRISMA level 2B images (BOA radiance) and a linear mixture model (Waigl 2019). The pixel signal $L_{\lambda,m}$ is expressed as a weighted average of n sources $L_{\lambda}(T_i)$ (represented as black bodies) and m background signals $L_{j,bkg}$ (chosen as other pixels in the same image). The summation is weighted by means of the parameters p. A least square method is used to estimate the parameters p_i, p_j and the temperatures T_i:

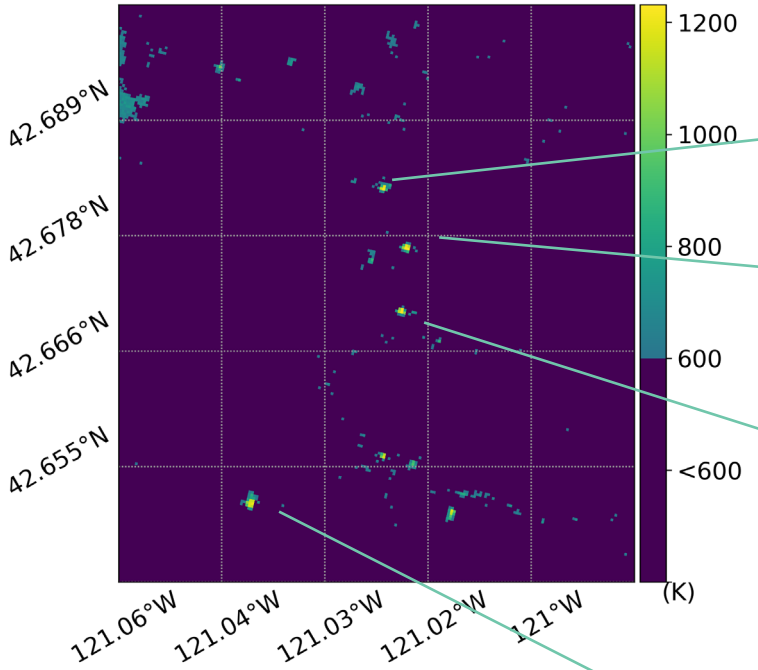
Qualitative validation

PRISMA PANSHARP VISIBLE

TEMPERATURE MAP

PRISMA PANSHARP NIR

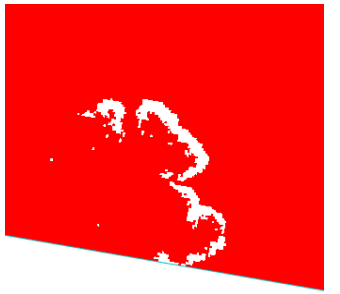




Remarks

- Characterization of a phenomena beyond the main PRISMA mission goals.
- Characterization of active fires in terms of fire front and temperature
- PRISMA derived front fire consistent with ECOSTRESS
- Temperature of hot spot consistent with ECOSTRESS

VIIRSS
350m



PRISMA
30m

Benefits

Sinergy with TIR data
Sinergy with hyperspectral missions
High resolution very detailed location of the front
Temperature can be linked to the fire impact and used for FRP
Potential operative application

Challenges

Coding processing time
Background identification
Having acquisition very near to PRISMA
Validation measurements

Thanks for listening!

Acknowledgements

We thanks ECOSTRESS team for sharing the data to the community

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HD-7: Aiding active landscape fire detection from space with ASI PRISMA: unlocking the complementary value of hyperspectral PRISMA data

Get in touch

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Fire

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