Potential of HyspIRI for post-fire assessments

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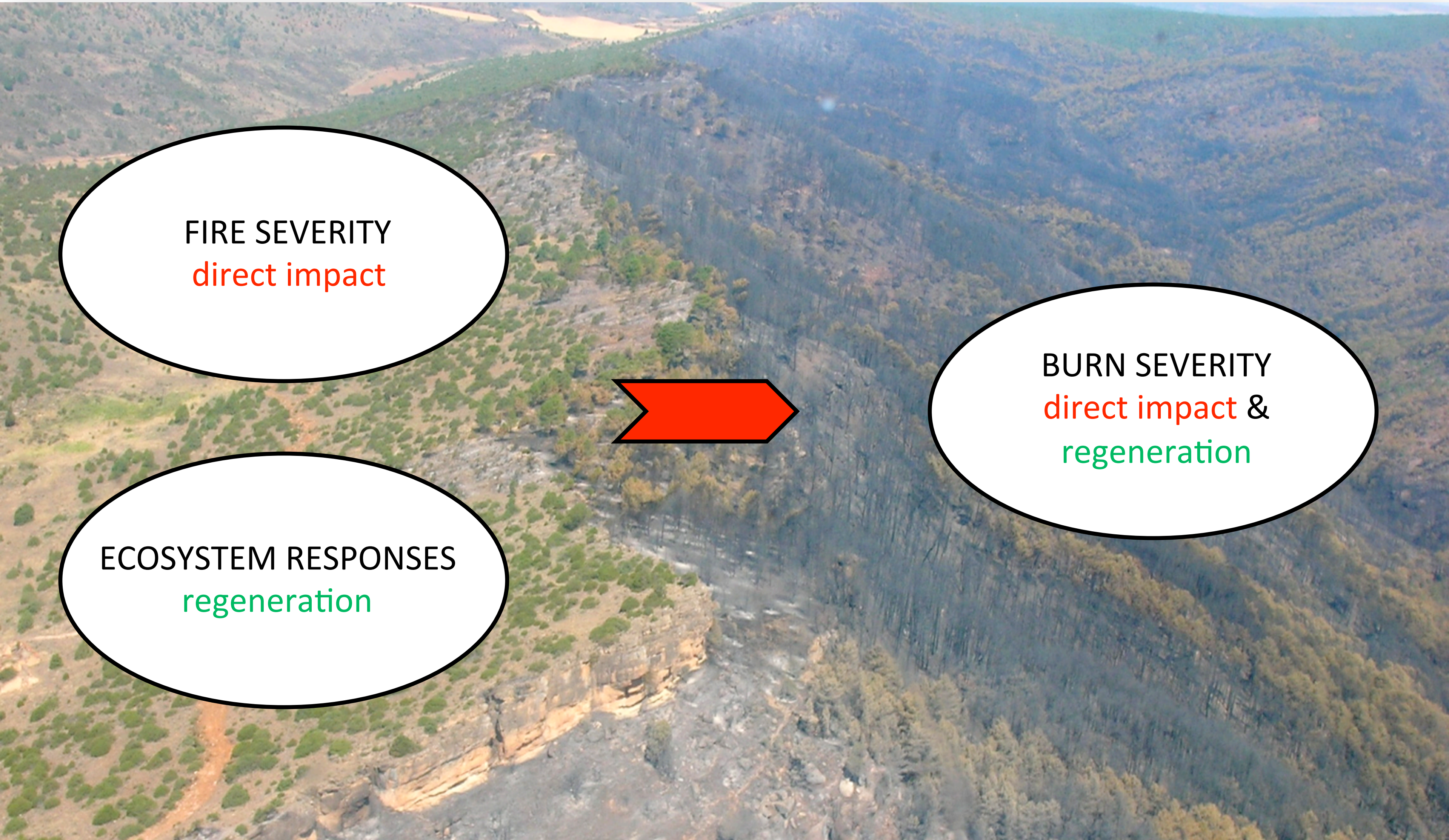
Some terminology

Veraverbeke, S., Lhermitte, S., Verstraeten, W.W., & Goossens, R., (2010). *The temporal dimension of differenced Normalized Burn Ratio (dNBR) fire/burn severity studies: the case of the large 2007 Peloponnese wildfires in Greece*. Remote Sensing of Environment 114, 2548-2563

SEVERITY: degree of environmental change caused by a fire



Importance

Trace gas emission estimates and carbon sequestration → Earth's carbon budget

Post-fire management (erosion prevention, rehabilitation)

Are they changing?

Airborne MASTER

As a surrogate to study HyspIRI's potential…

MASTER
11 VNIR bands
14 SWIR bands
15 MIR bands
10 TIR bands
5-50 m pixel size

HyspIRI
Hyperspectral VSWIR
8 MTIR bands
60 m pixel size

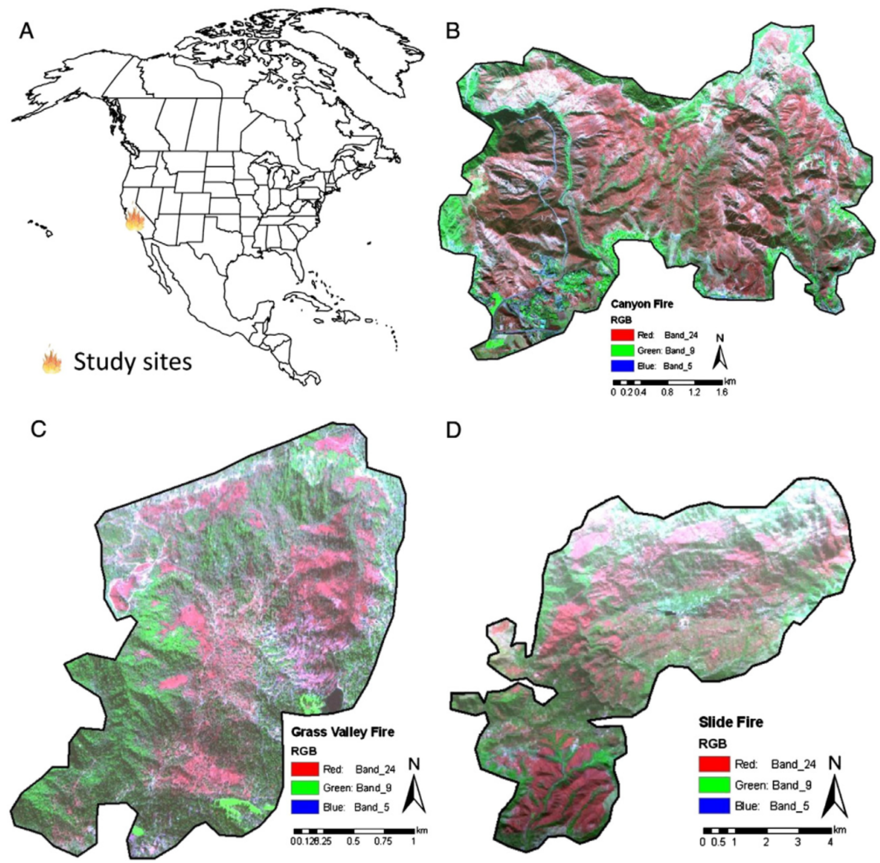
Application 1: Burned area mapping

Whole bunch of indices currently in use, most of them relying on the VSWIR region

e.g. NDVI, NBR, BAI, SAVI, etc.

Which indices are the best to map burned areas?

And what could the MIR-TIR regions add?



Spectral separability measured by:

$$M = \frac{\mu_b - \mu_u}{\sigma_b - \sigma_u}$$

The higher M, the better

Veraverbeke, S., Harris, S. & Hook, S. (2011). *Evaluating spectral indices for burned area discrimination using MODIS/ASTER (MASTER) airborne simulator data*. Remote Sensing of Environment 115, 2702-2709

Application 1: Burned area mapping

Table 3
Spectral indices tested in this study (B: Blue, R: Red, NIR: Near Infrared, SSWIR: shorter short wave infrared, LSWIR: longer short wave infrared, MIR: mid infrared, TIR: thermal infrared, E: emissivity and T_s: surface temperature, see Section 2.3 for specifications on wavelength intervals).

Index	Abbreviation	Formula	Reference
Normalized Difference Vegetation Index	NDVI	$NDVI = \frac{NIR-R}{NIR+R}$	Tucker, 1979
Global Environment Monitoring Index	GEMI	$GEMI = \gamma(1-0.25\gamma)-\frac{R-0.125}{1-R}$ with $\gamma = \frac{2(NIR^2-R^2)+1.5NIR+0.5R}{NIR+R+0.5}$	Pinty and Verstraete, 1992
Enhanced Vegetation Index	EVI	$EVI = 2.5\frac{NIR-R}{NIR-6R-7.5B+1}$	Huete et al., 2002
Vegetation Index 3	VI3	$VI3 = \frac{NIR-MIR}{NIR+MIR}$	Kaufman and Remer, 1994
Soil Adjusted Vegetation Index	SAVI	$SAVI = (1+L)\frac{NIR-R}{NIR+R+L}$ with $L=0.5$	Huete, 1988
Modified Soil Adjusted Vegetation Index	MSAVI	$MSAVI = \frac{2NIR+1-\sqrt{(2NIR+1)^2-8(NIR-R)}}{2}$	Qi et al., 1994
Burned Area Index	BAI	$BAI = \frac{1}{(0.1+R)^2+(0.06+NIR)^2}$	Chuvieco et al., 2002
Global Environment Monitoring Index 3	GEMI3	$GEMI3 = \gamma(1-0.25\gamma)-\frac{MIR-0.125}{1-MIR}$ with $\gamma = \frac{2(NIR^2-MIR^2)+1.5NIR+0.5MIR}{NIR+MIR+0.5}$	Barbosa et al. 1999b
Normalized Burn Ratio	NBR	$NBR = \frac{NIR-LSWIR}{NIR+LSWIR}$	Key and Benson, 2005
Char Soil Index	CSI	$CSI = \frac{NIR}{SWIR}$	Smith et al., 2007
Mid Infrared Burn Index	MIRBI	$MIRBI = 10LSWIR-9.8SSWIR+2$	Trigg and Flasse, 2001
Normalized Difference Vegetation Index Thermal	NDVIT	$NDVIT = \frac{NIR-R\times TIR}{NIR+R\times TIR}$	Smith et al., 2007
Soil Adjusted Vegetation Index Thermal	SAVIT	$SAVIT = (1+L)\frac{NIR-R\times TIR}{NIR+R\times TIR+L}$ with $L=0.5$	Smith et al., 2007
Normalized Burn Ratio Thermal	NBRT	$NBRT = \frac{NIR-LSWIR\times TIR}{NIR+LSWIR\times TIR}$	Holden et al., 2005
Char Soil Index Thermal	CSIT	$CSIT = \frac{NIR}{SWIR\times TIR}$	Smith et al., 2007
Vegetation Index 6 Thermal	VI6T	$VI6T = \frac{NIR-TIR}{NIR+TIR}$	Holden et al., 2005
NIR-SWIR-Emissivity Version 1	NSEv1	$NSEv1 = \frac{NIR-LSWIR}{NIR+LSWIR}\times E$	This study
NIR-SWIR-Emissivity Version 2	NSEv2	$NSEv2 = \frac{NIR-(LSWIR+E)}{NIR+LSWIR+E}$	This study
NIR-SWIR-Temperature Version 1	NSTv1	$NSTv1 = \frac{NIR-LSWIR}{NIR+LSWIR}\times T_S$	This study
NIR-SWIR-Temperature Version 2	NSTv2	$NSTv2 = \frac{NIR-(LSWIR+T_S)}{NIR+LSWIR+T_S}$	This study

Table 4
MODIS/ASTER (MASTER) airborne simulator bands revealing the best spectral separability M for each spectral region. These bands were used to generate the indices listed in Table 3 (B: Blue, R: Red, NIR: Near Infrared, SSWIR: shorter short wave infrared, LSWIR: longer short wave infrared, MIR: mid infrared, TIR: thermal infrared, E: emissivity and T_s: surface temperature, see Section 2.3 for specifications on wavelength intervals).

Spectral region	MASTER band (μm)	M statistic (average over three fires)
B	0.45 to 0.48	0.15
R	0.65 to 0.68	0.13
NIR	0.86 to 0.88	0.64
SSWIR	1.59 to 1.62	0.09
LSWIR	2.31 to 2.36	0.58
MIR	3.54 to 3.64	0.71
TIR	8.51 to 8.76	0.58

Table 5
M values of the spectral indices over the Canyon, Grass Valley and Slide fires. Values higher than one are given in bold. For explanation on the indices, reference is made to Table 3 and Section 2.3.

Spectral indices	Canyon fire	Grass Valley fire	Slide fire	Average over three fires
NDVI	**1.22**	0.42	0.78	0.80
GEMI	0.07	0.04	0.06	0.06
EVI	0.28	0.10	0.04	0.14
VI3	**1.30**	**1.29**	0.83	**1.14**
SAVI	**1.42**	0.55	0.83	0.94
MSAVI	0.23	0.25	0.13	0.21
BAI	0.34	0.47	0.07	0.29
GEMI3	0.04	0.03	0.01	0.03
NBR	**1.46**	**1.00**	0.94	**1.13**
CSI	0.04	0.00	0.00	0.01
MIRBI	0.67	0.76	0.55	0.66
NDVIT	0.92	0.22	0.42	0.52
SAVIT	0.88	0.21	0.41	0.50
NBRT	0.08	0.03	0.16	0.09
CSIT	0.04	0.00	0.00	0.01
VI6T	0.66	0.92	0.36	0.65
NSEv1	**1.47**	0.88	**1.06**	**1.13**
NSEv2	**1.57**	**1.02**	**1.07**	**1.22**
NSTv1	**1.47**	0.88	**1.06**	**1.14**
NSTv2	0.71	0.96	0.41	0.69

Application 1: Burned area mapping

Potential of MIR and TIR data in synergy with the traditionally used NIR and SWIR regions

Slightly better results than NBR

Tough currently unavailable on moderate resolution spaceborne sensors

HyspIRI will meet the requirements

Application 2: Fire severity

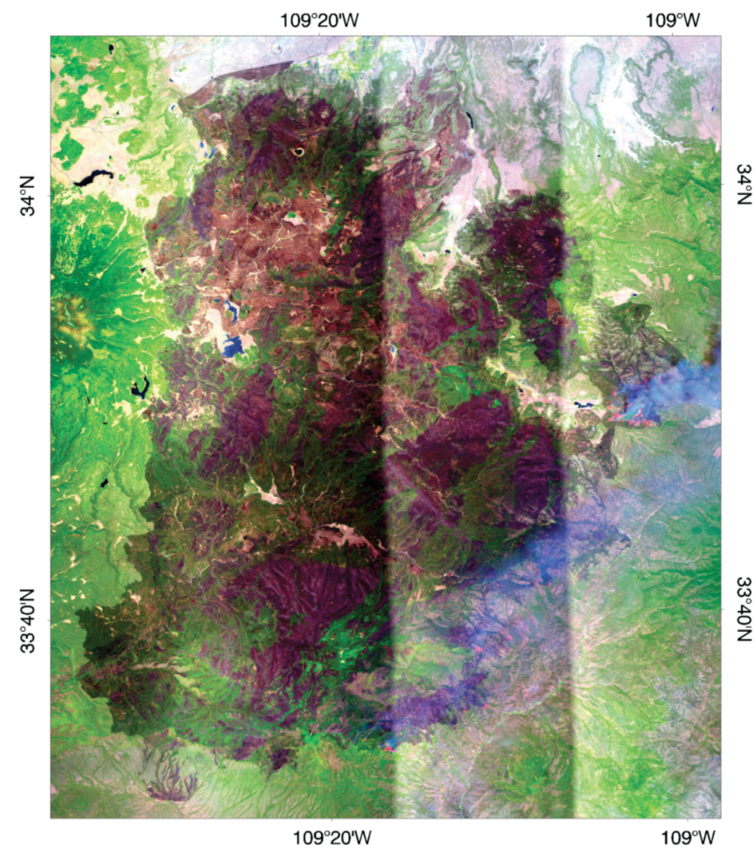
Traditionally assessed with Landsat dNBR

$$NBR = \frac{NIR - LSWIR}{NIR + LSWIR}$$

Caveats

- bi-temporal differencing requires image-to-image normalization
- rapid assessments over active fires impeded as the NIR band is affected by smoke

MASTER imagery over the active Wallow fire, AZ

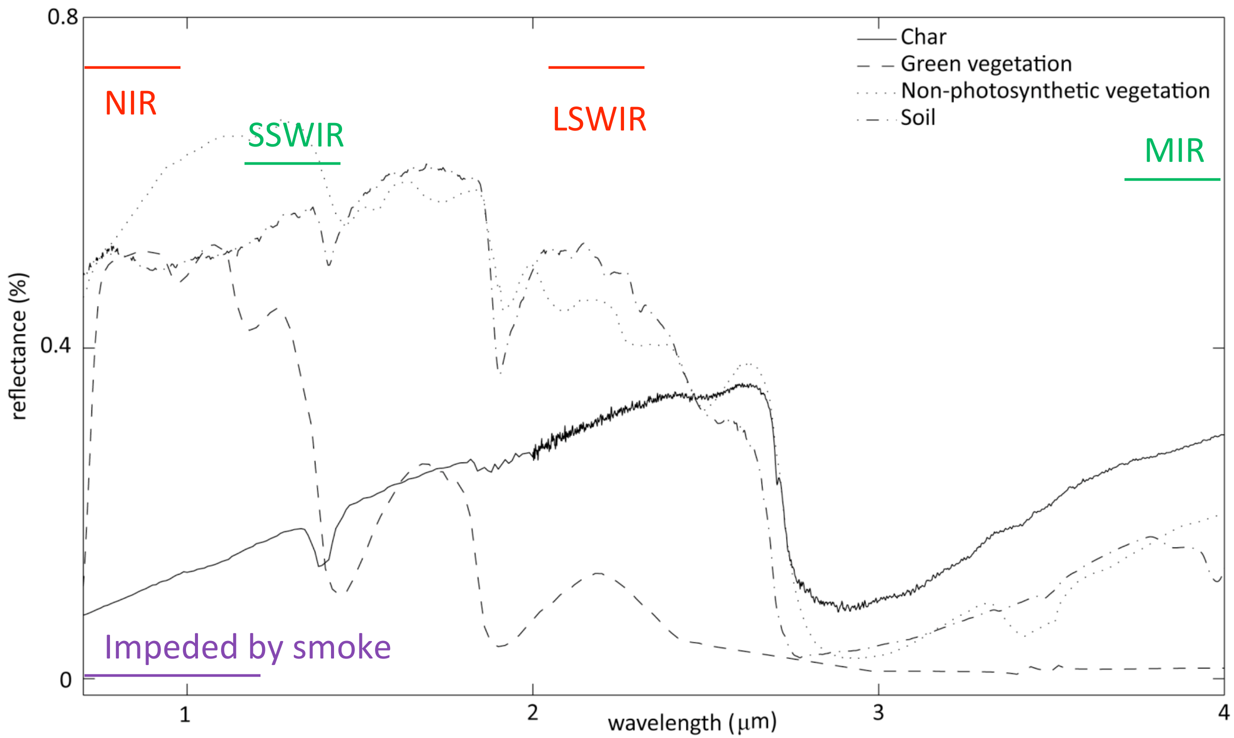


Application 2: Fire severity

We want maximal discrimination between fire-related and non-fire related terrain features

Does NBR do so?

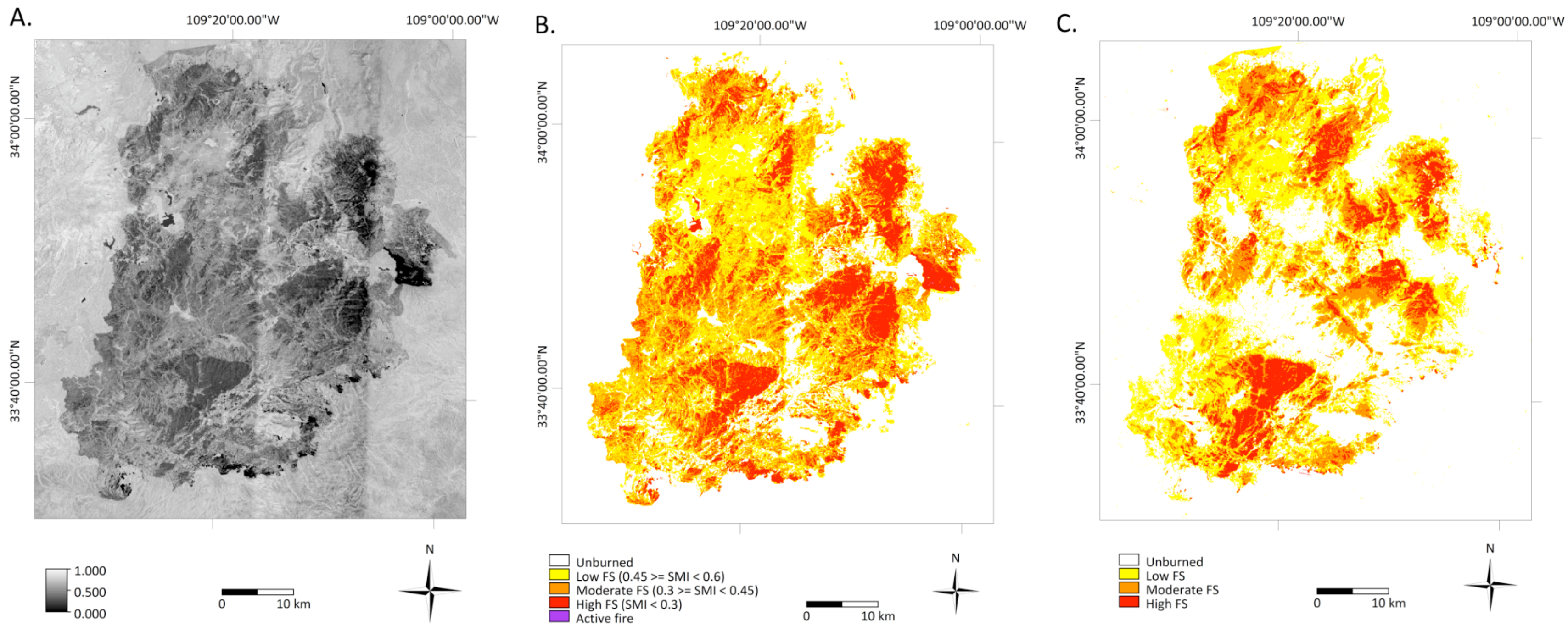
An alternative index, unimpeded by smoke, the SWIR-MIR index: $SMI = \frac{SSWIR - MIR}{SSWIR + MIR}$



	NIR	SSWIR	LSWIR	MIR	*NBR*	*SMI*
Char	0.107	0.235	0.316	0.241	*-0.494*	*-0.013*
Green vegetation	0.517	0.225	0.124	0.012	*0.612*	*0.899*
Non-photosynthetic vegetation	0.577	0.595	0.453	0.122	*0.120*	*0.660*
Soil	0.501	0.610	0.494	0.139	*0.007*	*0.629*

Application 2: Fire severity

SMI | SMI-approach | BARC-approach



		BARC approach			
		Unburned	Low FS	Moderate FS	High FS
SMI approach	Unburned	0.54	0.03	0.01	0.00
	Low FS	0.08	0.08	0.03	0.01
	Moderate FS	0.04	0.04	0.04	0.02
	High FS	0.02	0.02	0.03	0.03

Total agreement	0.68
Kappa coefficient	0.43

Application 2: Fire severity

Benefits of SMI:
- not impeded by smoke
- mono-temporal

→ Allows timely assessments

Further testing required (field data, different ecosystems)

Tough currently unavailable on moderate resolution spaceborne sensors

HyspIRI will fill the gap

Application 2: Further research

92 GeoCBI (Composite Burn Index) plots, sampled August 2-15, 2011

$$GeoCBI = \frac{\sum_{m_1}^{m_n} CBI_m \cdot FCOV_m}{\sum_{m_1}^{m_n} FCOV_m}$$

where m refers to each vegetation stratum and n is the number of strata

GeoCBI 3

GeoCBI 2.39

GeoCBI 1.14

Stratum	Burn severity scale						
	No effect	Low		Moderate		High	
	0	0.5	1	1.5	2	2.5	3
Substrates				FCOV			
Litter (l)/Light Fuel (lf) Consumed	0 %	--	50 % l	--	100 % l	> 80 % lf	98 % lf
Duff	0 %	--	Light char	--	50 %	--	Consumed
Medium/Heavy Fuel	0 %	--	20 %	--	40 %	--	> 60 %
Soil & Rock Cover/Colour	0 %	--	10 %	--	40 %	--	> 80 %
Herbs, low shrubs and trees less than 1 m				FCOV			
% Foliage Altered	0 %	--	30 %	--	80 %	95 %	100 %
Frequency % Living	100 %	--	90 %	--	50 %	< 20 %	0 %
New sprouts	Abundant	--	Moderate-high	--	Moderate	--	Low-none
Tall shrubs and trees 1 to 5 m				FCOV			
% Foliage Altered	0 %	--	20 %	--	60-90 %	> 95 %	branch loss
Frequency % Living	100 %	--	90 %	--	30 %	< 15 %	< 1 %
LAI Change %	0 %	--	15 %	--	70 %	90 %	100 %
Intermediate trees 5 to 20 m				FCOV			
% Green (Unaltered)	100 %	--	80 %	--	40 %	< 10 %	none
% Black/Brown	0 %	--	20 %	--	60-90 %	> 95 %	branch loss
Frequency % Living	100 %	--	90 %	--	30 %	< 15 %	< 1 %
LAI Change %	0 %	--	15 %	--	70 %	90 %	100 %
Char Height	none	--	1.5 m	--	2.8 m	--	> 5 m
Big trees >20 m				FCOV			
% Green (Unaltered)	100 %	--	80 %	--	50 %	< 10 %	none
% Black/Brown	0 %	--	20 %	--	60-90 %	> 95 %	branch loss
Frequency % Living	100 %	--	90 %	--	30 %	< 15 %	< 1 %
LAI Change %	0 %	--	15 %	--	70 %	90 %	100 %
Char Height	none	--	1.8 m	--	4 m	--	> 7 m

Summary

Current post-fire effects rely heavily on the VSWIR region, especially NBR

MIR and TIR data can add valuable information

Tough the VSWIR-MIR-TIR combination is current not available in moderate resolution (< 100 m)

The VSWIR-MTIR synergy will be available on HyspIRI


DON'T START FIRES YOU CAN'T STOP
BE FIREWISE.
FIREWISE
WILDFIRE
MOVES
QUICKER
THAN YOU
THI