FOR 274: Forest Measurements and Inventory

Fire Behavior and Effects

- The Fire Environment
- Fire Intensity Measures
- Radiant Heat Flux
- Severity Assessments

FOR 274: The Fire Environment

Definition: The fire environment includes the weather, fuels, and topography factors that affect the ignition, burn, and spread of the fires.

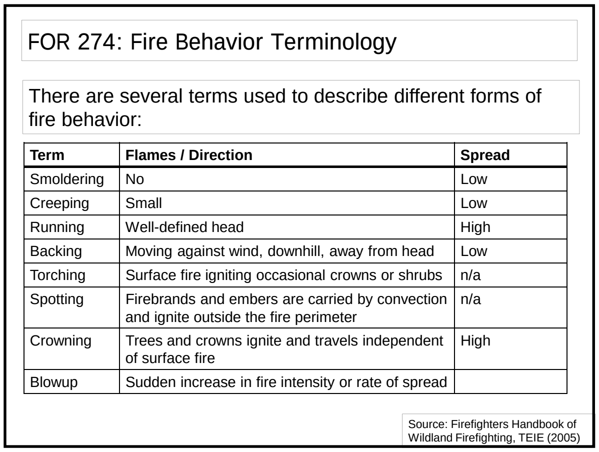
Most important factors are:

Weather: wind, temperature, and relative humidity >> rate of spread, direction of spread, and intensity

Topography: slope and aspect >> direction and rate of spread

Fuels: fuel moisture and fuel temperature >> fire intensity

Source: Firefighters Handbook of Wildland Firefighting, TEIE (2005)

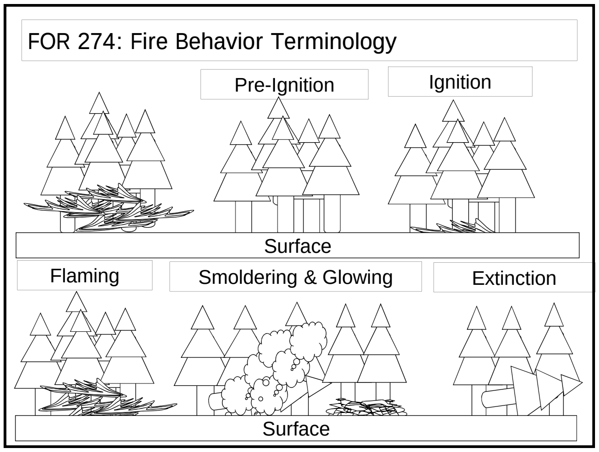


FOR 274: Fire Behavior Terminology

There are several terms used to describe different forms of fire behavior:

Term	Flames / Direction	Spread
Smoldering	No	Low
Creeping	Small	Low
Running	Well-defined head	High
Backing	Moving against wind, downhill, away from head	Low
Torching	Surface fire igniting occasional crowns or shrubs	n/a
Spotting	Firebrands and embers are carried by convection and ignite outside the fire perimeter	n/a
Crowning	Trees and crowns ignite and travels independent of surface fire	High
Blowup	Sudden increase in fire intensity or rate of spread	

Source: Firefighters Handbook of Wildland Firefighting, TEIE (2005)



FOR 274: Fire Behavior Terminology

Pre-Ignition

Ignition

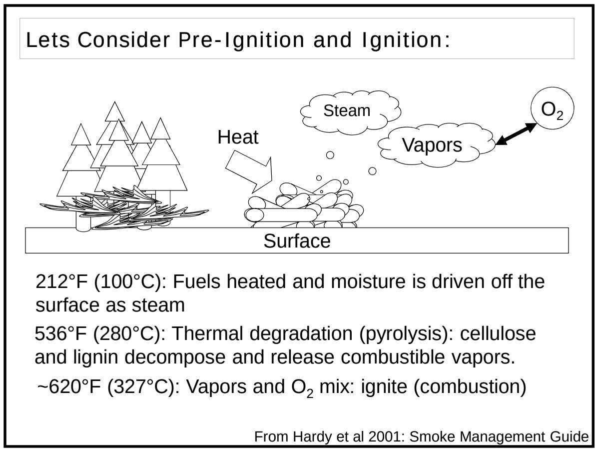
Surface

Flaming

Smoldering & Glowing

Extinction

Surface



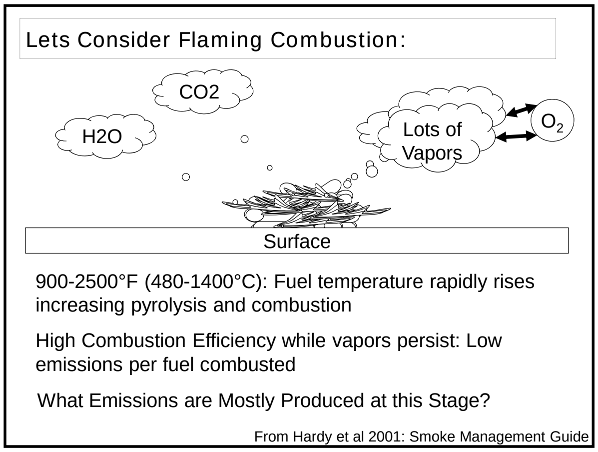
Lets Consider Pre-Ignition and Ignition:

212°F (100°C): Fuels heated and moisture is driven off the surface as steam

536°F (280°C): Thermal degradation (pyrolysis): cellulose and lignin decompose and release combustible vapors.

~620°F (327°C): Vapors and O_2 mix: ignite (combustion)

From Hardy et al 2001: Smoke Management Guide



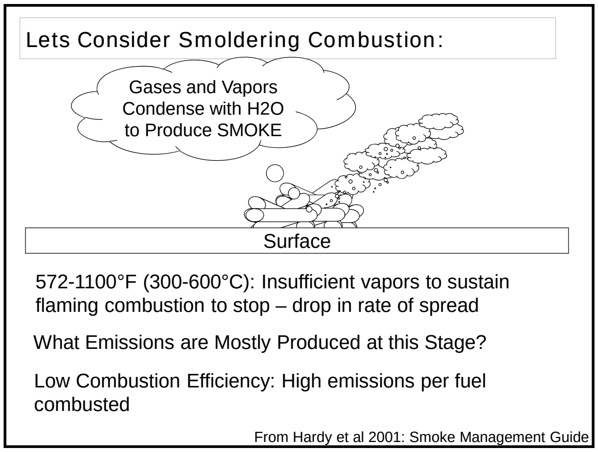
Lets Consider Flaming Combustion:

900-2500°F (480-1400°C): Fuel temperature rapidly rises increasing pyrolysis and combustion

High Combustion Efficiency while vapors persist: Low emissions per fuel combusted

What Emissions are Mostly Produced at this Stage?

From Hardy et al 2001: Smoke Management Guide



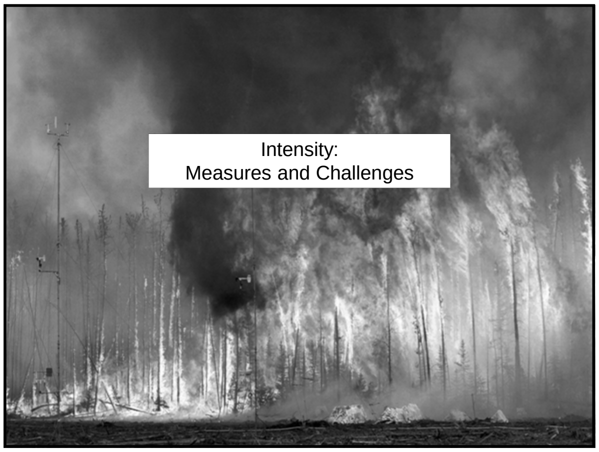
Lets Consider Smoldering Combustion:

572-1100°F (300-600°C): Insufficient vapors to sustain flaming combustion to stop – drop in rate of spread

What Emissions are Mostly Produced at this Stage?

Low Combustion Efficiency: High emissions per fuel combusted

From Hardy et al 2001: Smoke Management Guide



Intensity:
Measures and Challenges

FOR 274: Fire Intensity and Rate of Spread

Definition: Fire intensity refers to the rate of energy release during combustion. However different measures exist.

Fire Line Intensity (FLI, kWm^{-1})

Byram (1959) describes this as the energy output from a 1m wide combusting line of fire that extends from the leading edge of the fire front to the rear of the flaming zone

H = Heat Yield or Heat of Combustion (MJ/Kg) = the total possible amount of energy that will be released when a unit mass of the fuel is completely combusted.

w is the "available fuel" – fuel that was consumed by the fire.

r is the rate of spread.

FOR 274: Fire Intensity and Rate of Spread

Fire Line Intensity (FLI, kWm^{-1})

Byram (1959) also presented a version of this formula that uses flame length, L for "savanna fires":

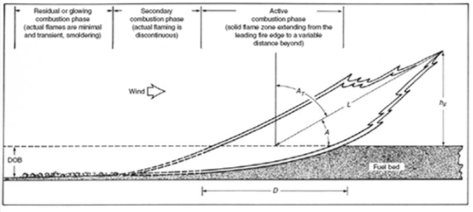
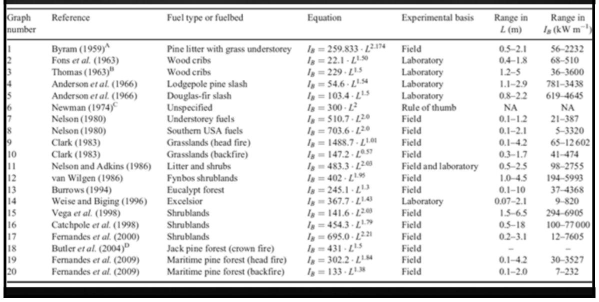


Fig. 3. Cross-section of a stylised, wind-driven surface head fire on level terrain illustrating the energy or heat-release stages during and following passage of the flame front, flame length (L), flame height (h_F), flame angle (A), flame tilt angle (A_T), horizontal flame depth (D), and the resulting depth of burn (DOB) (from Alexander 1982).

FOR 274: Fire Intensity and Rate of Spread

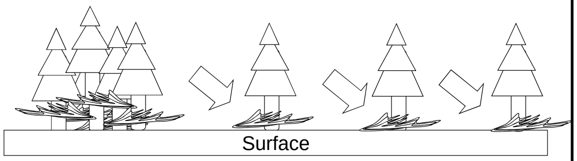
Fire Line Intensity (FLI, kWm^{-1})

Other studies have developed similar flame length fire line intensity relationships (Alexander and Cruz, 2012):

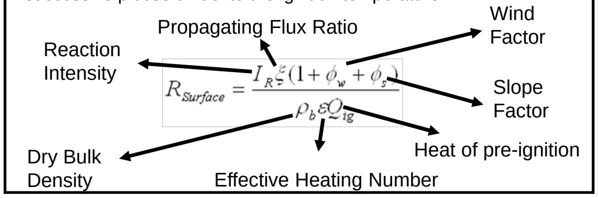


Graph number	Reference	Fuel type or fuelbed	Equation	Experimental basis	Range in L (m)	Range in I_B (kW m^{-1})
1	Byram (1959)[A]	Pine litter with grass understorey	$I_B = 259.833 \cdot L^{2.174}$	Field	0.5–2.1	56–2232
2	Fons *et al.* (1963)	Wood cribs	$I_B = 22.1 \cdot L^{1.50}$	Laboratory	0.4–1.8	68–510
3	Thomas (1963)[B]	Wood cribs	$I_B = 229 \cdot L^{1.5}$	Laboratory	1.2–5	36–3600
4	Anderson *et al.* (1966)	Lodgepole pine slash	$I_B = 54.6 \cdot L^{1.54}$	Laboratory	1.1–2.9	781–3438
5	Anderson *et al.* (1966)	Douglas-fir slash	$I_B = 103.4 \cdot L^{1.5}$	Laboratory	0.8–2.2	619–4645
6	Newman (1974)[C]	Unspecified	$I_B = 300 \cdot L^{2}$	Rule of thumb	NA	NA
7	Nelson (1980)	Understorey fuels	$I_B = 510.7 \cdot L^{2.0}$	Field	0.1–1.2	21–387
8	Nelson (1980)	Southern USA fuels	$I_B = 703.6 \cdot L^{2.0}$	Field	0.1–2.1	5–3320
9	Clark (1983)	Grasslands (head fire)	$I_B = 1488.7 \cdot L^{1.01}$	Field	0.1–4.2	65–12 602
10	Clark (1983)	Grasslands (backfire)	$I_B = 147.2 \cdot L^{0.57}$	Field	0.3–1.7	41–474
11	Nelson and Adkins (1986)	Litter and shrubs	$I_B = 483.3 \cdot L^{2.03}$	Field and laboratory	0.5–2.5	98–2755
12	van Wilgen (1986)	Fynbos shrublands	$I_B = 402 \cdot L^{1.95}$	Field	1.0–4.5	194–5993
13	Burrows (1994)	Eucalypt forest	$I_B = 245.1 \cdot L^{1.3}$	Field	0.1–10	37–4368
14	Weise and Biging (1996)	Excelsior	$I_B = 367.7 \cdot L^{1.43}$	Laboratory	0.07–2.1	9–820
15	Vega *et al.* (1998)	Shrublands	$I_B = 141.6 \cdot L^{2.03}$	Field	1.5–6.5	294–6905
16	Catchpole *et al.* (1998)	Shrublands	$I_B = 454.3 \cdot L^{1.79}$	Field	0.5–18	100–77 000
17	Fernandes *et al.* (2000)	Shrublands	$I_B = 695.0 \cdot L^{2.21}$	Field	0.2–3.1	12–7605
18	Butler *et al.* (2004)[D]	Jack pine forest (crown fire)	$I_B = 431 \cdot L^{1.5}$	Field	–	–
19	Fernandes *et al.* (2009)	Maritime pine forest (head fire)	$I_B = 302.2 \cdot L^{1.84}$	Field	0.1–4.2	30–3527
20	Fernandes *et al.* (2009)	Maritime pine forest (backfire)	$I_B = 133 \cdot L^{1.38}$	Field	0.1–2.0	7–232

FOR 274: Fire Intensity and Rate of Spread

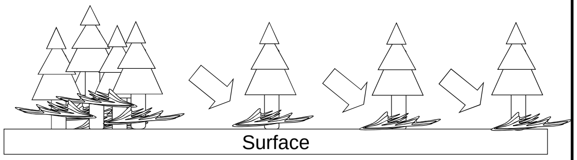


Fire Spread: A series of ignitions where heat from the fire raises successive pieces of fuel to the ignition temperature



$$R_{Surface} = \frac{I_R \xi (1 + \phi_w + \phi_s)}{\rho_b \varepsilon Q_{ig}}$$

FOR 274: Fire Intensity and Rate of Spread



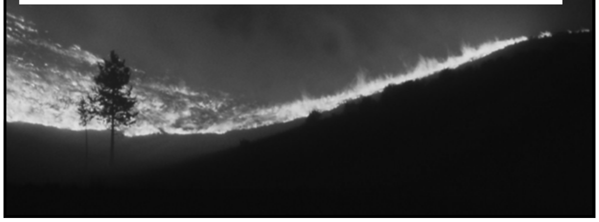
Assumptions of Rothermel's Surface Fire Spread Model:

- Uniform and Continuous Fuels
- Subsequent ignitions not affected by source of 1st ignition
- No extreme wildfire behavior
- Describes fire behavior at flaming front of fire
- Weather and Slope are constant over fire affected area

FOR 274: Flame Temperatures

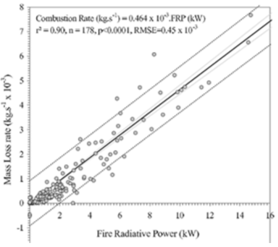
Flame temperature is often measured using thermocouples (Type K). Maximum temperature can be inferred using heat sensitive ceramics and paints.

These work by changing color when a certain temperature is met or by breaking (ceramics)



FOR 274: Radiant Energy Release

Alternative measures of the energy release from fires are the Fire Radiative Power (FRP) and the Fire Radiative Energy (FRE).



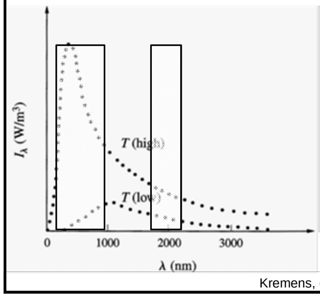
$$M_c = \frac{FRE}{F_r\, H_c}$$

In the equation:
- H can be calculated via using a bomb calorimeter
- FRE is the fire radiative energy released
- Fr is the fraction of the total energy release (per unit area) that is apportioned to radiation.

Wooster et al. *JGR*, 110, D24311, doi:10.1029/2005JD006318 (2005)

FOR 274: Radiant Energy Release

To get at FRE we use the Stefan-Boltzman Law. In wildland fires, the T^4 relationship, ensures that the radiation from the hot fires (>900K) dominates over any cooler background emissions.



In recent years, Fire Radiative Power has been estimated using:

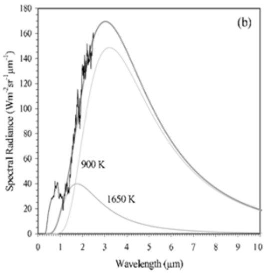
$$FRP = \frac{A_{sampl}.\sigma.\varepsilon}{a.\varepsilon_{MIR}}(L_{MIR,fire} - L_{MIR,bg})$$

Alternatively, field based FRE is usually calculated by determining the brightness temperature via dual band thermometry.

Kremens, et al, (2010), Wooster et al (Springer, in press)

FOR 274: Radiant Energy Release

To get at FRE we use the Stefan-Boltzman Law. In wildland fires, the T^4 relationship, ensures that the radiation from the hot fires (>900K) dominates over any cooler background emissions.



Step 1. Integrate the Stefan-Boltzman equation over the 2 bands

Integrate over MWIR (2.5-9 um)

$$W(T)_{\lambda_1\lambda_2} = 2\pi\varepsilon hc^2 \int_{\lambda_1}^{\lambda_2} \frac{d\lambda}{\lambda^5\left(e^{\frac{hc}{\lambda kT}} - 1\right)}$$

$$W(T)_{\lambda_3\lambda_4} = 2\pi\varepsilon hc^2 \int_{\lambda_3}^{\lambda_4} \frac{d\lambda}{\lambda^5\left(e^{\frac{hc}{\lambda kT}} - 1\right)}$$

Integrate over LWIR (6.5-14 um)

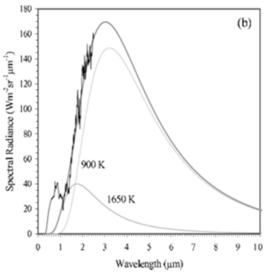
Fit these using the approximate analytic form:

$M = cT^n$, where $n < 4$

Kremens, Smith, and Dickinson, JFE, (2010)

FOR 274: Radiant Energy Release

To get at FRE we use the Stefan-Boltzman Law. In wildland fires, the T^4 relationship, ensures that the radiation from the hot fires (>900K) dominates over any cooler background emissions.



Step 2. Calculate the radiant (brightness temperature), T

$$R(T) = \left(\frac{W(T)_{\lambda_1 \lambda_2}}{W(T)_{\lambda_3 \lambda_4}}\right)$$

Step 3. Determine the emissivity. Large hot flames ~0.15, warm soils ~ 0.85 (Kremens et al 2010). Alternatively, the product of eA can be calculated:

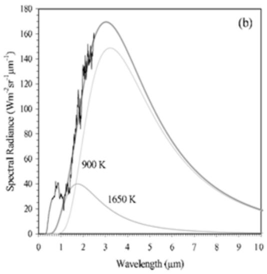
$$\varepsilon A = \frac{W(T)_{LWIR}}{C(T^n + T_s^n)}$$

C is a calibration parameter and T_s is the temperature of the sensor.

Kremens, Smith, and Dickinson, JFE, (2010)

FOR 274: Radiant Energy Release

To get at FRE we use the Stefan-Boltzman Law. In wildland fires, the T^4 relationship, ensures that the radiation from the hot fires (>900K) dominates over any cooler background emissions.



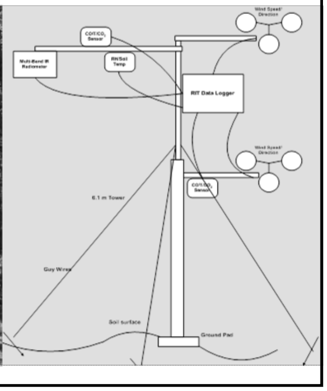
Step 4. FRE is then calculated through the Stefan-Boltzman Law

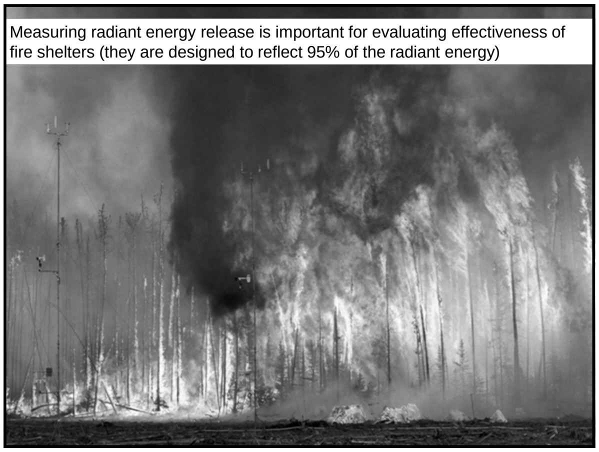
$$P = \varepsilon A_f \sigma T^4$$

A_f is the fraction of unit area (i.e. of a pixel) occupied by the fire

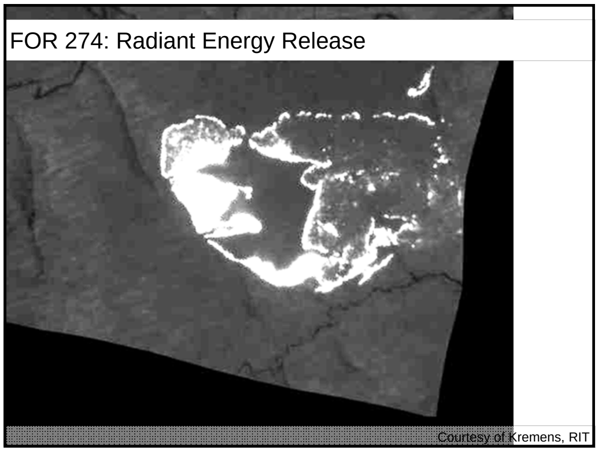
Kremens, Smith, and Dickinson, JFE, (2010)

FOR 274: Radiant Energy Release



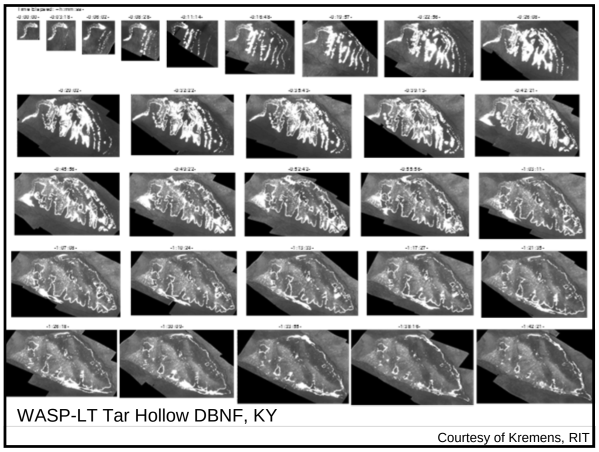


Measuring radiant energy release is important for evaluating effectiveness of fire shelters (they are designed to reflect 95% of the radiant energy)



FOR 274: Radiant Energy Release

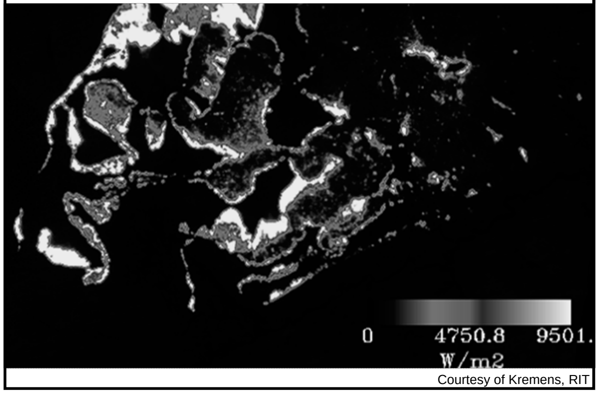
Courtesy of Kremens, RIT



WASP-LT Tar Hollow DBNF, KY

Courtesy of Kremens, RIT

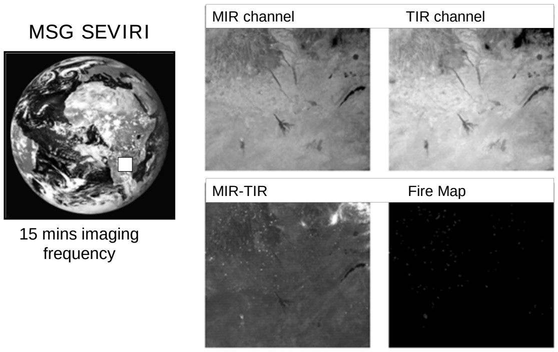
FOR 274: Radiant Energy Release



Courtesy of Kremens, RIT

FOR 274: Radiant Energy Release

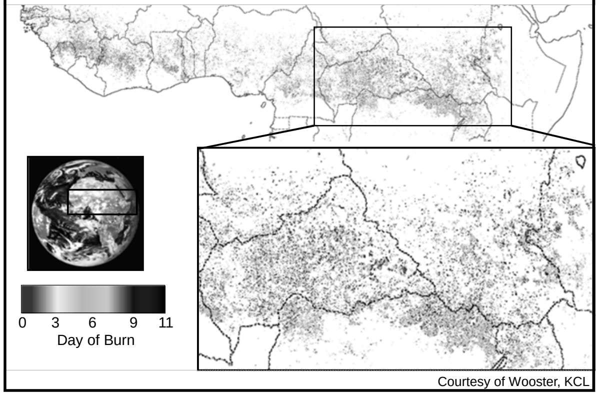
MSG SEVIRI



15 mins imaging frequency

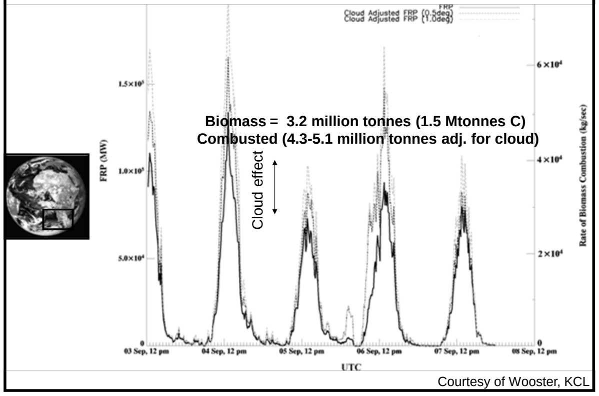
Courtesy of Wooster, KCL

FOR 274: Radiant Energy Release



Courtesy of Wooster, KCL

FOR 274: Radiant Energy Release

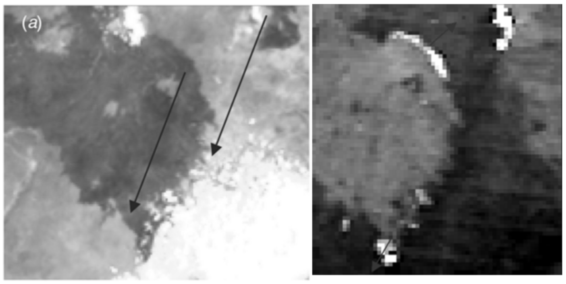


Biomass = 3.2 million tonnes (1.5 Mtonnes C)
Combusted (4.3-5.1 million tonnes adj. for cloud)

Courtesy of Wooster, KCL

FOR 274: Radiant Energy Release

Head and Backing Grassland Fires



Smith AMS, Wooster MJ (2005) Remote classification of head and backfire types from MODIS fire radiative power observations. *International Journal of Wildland Fire* **14**, 249-254.

FOR 274: Radiant Energy Release

Field

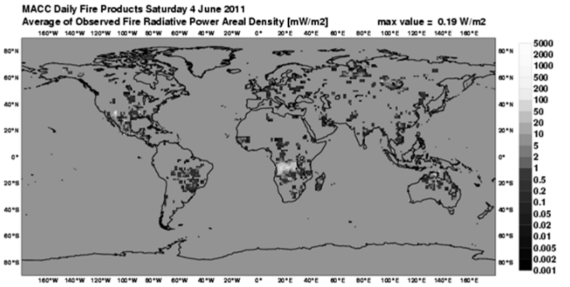
	FLI (kW m^{-1})	Reference
Headfire	4048–10 906	Stocks *et al.* (1996)
	93–3644	Trollope *et al.* (1996)
	2810 ± 893	Trollope (1996)
	43–9476	Hely *et al.* (2003)
	130–9274	Smith (2004)
Backfire	20–160	Trollope *et al.* (1996)
	77 ± 29	Trollope (1996)

Image

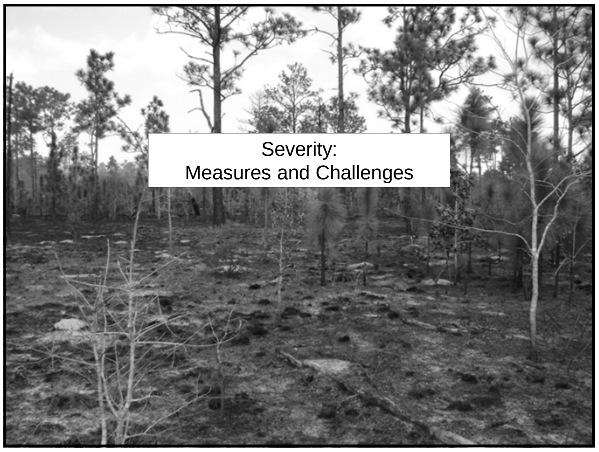
	ΣFRP (MW)	Radiative FLI (kW m^{-1})	Fire front length (km)
Mean Head	3405	153	16.9
Range Head	12 132	[illegible]	38.3
Mean Back	88	17	6.0
Range Back	91	[illegible]	3.4
Head : Back mean ratio	38.5	9.3	2.8

FOR 274: Radiant Energy Release

We are at the stage that FRP/FRE maps are being used to infer biomass burned in fires at the global scale.



Kasier et al. Biogeosciences, (2012)



Severity: Measures and Challenges

Defining Severity

Severity is, by nature, a value laden term, with negative perceptions often applied.

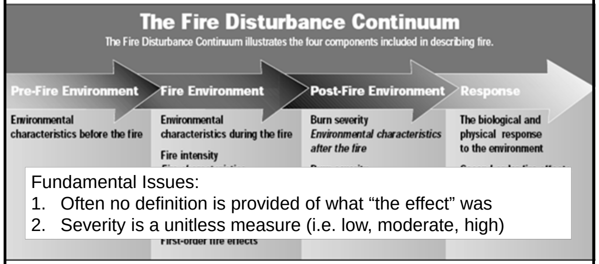
- Negative Connotations: severity = bad

The problem is that although some fires may “appear” severe, they might not be ecologically bad for the ecosystem.

Many definitions exist:
* Fire duration and heat transfer
* Vegetation mortality
* Change in surface reflectance
* Alteration in soil properties
* Changes in the litter and duff layers
* Impacts on seed banks

Defining Severity

Fire and burn severity are used inconsistently in the fire ecology and remote sensing literature.

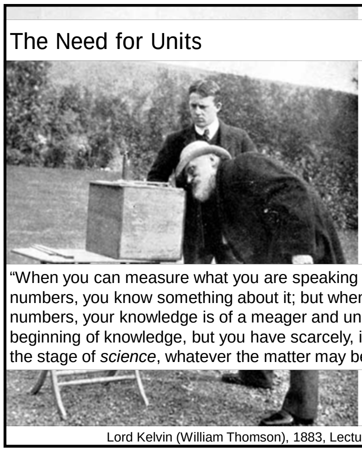


Fundamental Issues:

1. Often no definition is provided of what “the effect” was
2. Severity is a unitless measure (i.e. low, moderate, high)

Jain et al (2004), Lentile, Holden, Smith, et al. IJWF (2006)

The Need for Units



“When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of *science*, whatever the matter may be.”

Lord Kelvin (William Thomson), 1883, Lecture on "Electrical Units of Measurement"

Field Measures of Severity

FIREMON LA Form

BURN SEVERITY -- COMPOSITE BURN INDEX (BI)

The CBI field measure of severity was developed to calibrate the dNBR severity spectral index.

- Measures scaled 0-3
- 15m radius plots
- Used 5 Strata:
  - Soil
  - Understorey
  - Shrubs / saplings
  - Sub-canopy trees
  - Overstorey

The CBI is now a part of FIREMON, a national protocol developed by the US forest service for measuring and monitoring vegetation and forests.

Field Measures of Severity

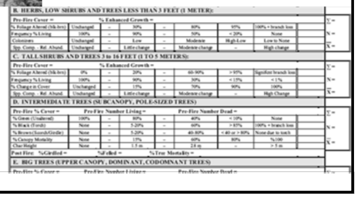
CBI Measures:

- Soil Measures (0-3)
  - change in color
  - change in cover
  - post-fire erosion
  - fuel consumed (1,10,100 hr)
- Understory (0-3)
  - Amount of veg. Consumed
  - Changes in species composition
  - Colonizing species?

Field Measures of Severity

CBI Measures:

- Overstorey (0-3)
  - % Torch (black)
  - % Scorch (brown)
  - % Green (unburned)
  - Height of bole char



B. HERBS, LOW SHRUBS AND TREES LESS THAN 3 FEET (1 METER):									
Pre-Fire Cover = % Enhanced Growth =									Σ =
% Foliage Altered (blk-brn)	Unchanged	–	30%	–	80%	95%	100% + branch loss		N =
Frequency % Living	100%	–	90%	–	50%	< 20%	None		
Colonizers	Unchanged	–	Low	–	Moderate	High-Low	Low to None		$\bar{X}$ =
Spp. Comp. - Rel. Abund.	Unchanged	–	Little change	–	Moderate change	–	High change		
C. TALL SHRUBS AND TREES 3 to 16 FEET (1 TO 5 METERS):									
Pre-Fire Cover = % Enhanced Growth =									Σ =
% Foliage Altered (blk-brn)	0%	–	20%	–	60-90%	> 95%	Significant branch loss		N =
Frequency % Living	100%	–	90%	–	30%	< 15%	< 1%		
% Change in Cover	Unchanged	–	15%	–	70%	90%	100%		$\bar{X}$ =
Spp. Comp. - Rel. Abund.	Unchanged	–	Little change	–	Moderate change	–	High Change		
D. INTERMEDIATE TREES (SUBCANOPY, POLE-SIZED TREES)									
Pre-Fire % Cover = Pre-Fire Number Living = Pre-Fire Number Dead =									Σ =
% Green (Unaltered)	100%	–	80%	–	40%	< 10%	None		
% Black (Torch)	None	–	5-20%	–	60%	> 85%	100% + branch loss		N =
% Brown (Scorch/Girdle)	None	–	5-20%	–	40-80%	< 40 or > 80%	None due to torch		
% Canopy Mortality	None	–	15%	–	60%	80%	%100		$\bar{X}$ =
Char Height	None	–	1.5 m	–	2.8 m	–	> 5 m		
Post Fire: %Girdled = %Felled = %Tree Mortality =									
E. BIG TREES (UPPER CANOPY, DOMINANT, CODOMINANT TREES)									
Pre-Fire % Cover = Pre-Fire Number Living = Pre-Fire Number Dead =									

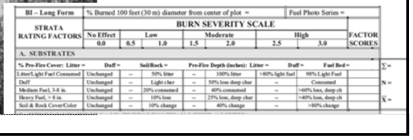
Field Measures of Severity

The Good:

- Very fast and easy to understand method
- Does not require any knowledge of the pre-fire condition. It “assumes” you can estimate the conditions based on what you see around you.

The Bad:

- Ocular assessments
- User dependent
- Some measures are very hard to estimate



BI – Long Form	% Burned 100 feet (30 m) diameter from center of plot =						Fuel Photo Series =		
STRATA RATING FACTORS	BURN SEVERITY SCALE							FACTOR SCORES	
	No Effect	Low		Moderate		High			
	0.0	0.5	1.0	1.5	2.0	2.5	3.0		
A. SUBSTRATES									
% Pre-Fire Cover: Litter = Duff = Soil/Rock = Pre-Fire Depth (inches): Litter = Duff = Fuel Bed =									Σ =
Litter/Light Fuel Consumed	Unchanged	--	50% litter	--	100% litter	>80% light fuel	98% Light Fuel		
Duff	Unchanged	--	Light char	--	50% loss deep char	--	Consumed		N =
Medium Fuel, 3-8 in.	Unchanged	--	20% consumed	--	40% consumed	--	>60% loss, deep ch		
Heavy Fuel, > 8 in.	Unchanged	--	10% loss	--	25% loss, deep char	--	>40% loss, deep ch		$\bar{X}$ =
Soil & Rock Cover/Color	Unchanged	--	10% change	--	40% change	--	>80% change		

Field Measures of Severity

The Ugly:

- These estimates are done after the fire (often in an area unseen before the fire)
- Many of these field measures are <u>not measurable</u> by satellites sensors (which is unfortunate given CBI was developed as ground validation for the dNBR spectral index…)

The Ugliest:

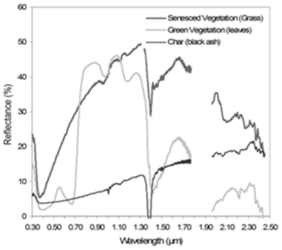
Given there is often no pre-fire data, how do you know whether effects are caused by the fire; and even if you know they are, what magnitude of those effects are due to the fire?

Smith et al. (2009); Roy et al (2012)

Remote Measures of Severity

The widely applied Normalized Burn Ratio (NBR) takes advantage of how TM bands 4 and 7 change following a fire.

$$\mathbf{NBR} = \rho_4 - \rho_7 / \rho_4 + \rho_7$$



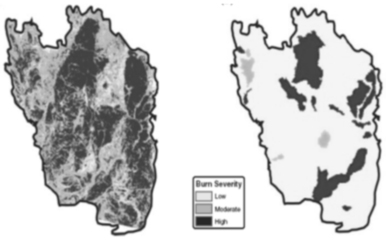
For both green and senesced vegetation, replacement of the vegetation by charred surfaces results in a significant drop in NIR reflectance.

In TM band 7, charcoal and soil often have a higher reflectance than green vegetation.

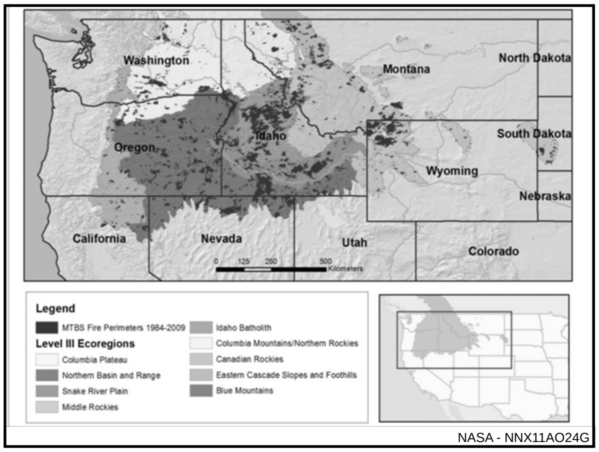
Remote Measures of Severity

The Differenced Normalized Burn Ratio (dNBR) is a change detection method that calculates the difference between post- and pre-fire NBR values as a measure of severity.

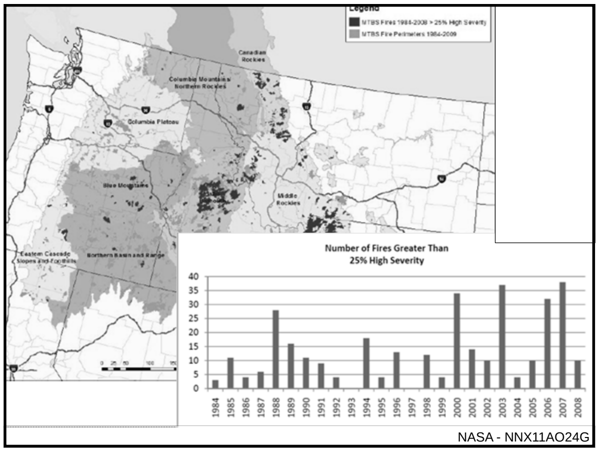
$$\mathbf{dNBR = NBR_{pre} - NBR_{post}}$$



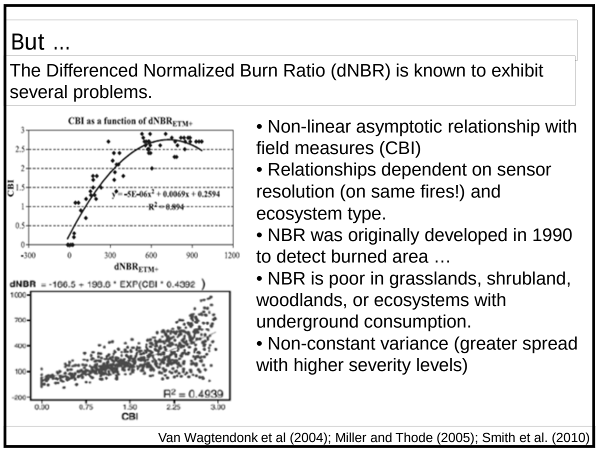
Most people use a post-fire image from 1 year post-fire. This mainly represents the canopy condition after tree mortality has occurred.



NASA - NNX11AO24G



NASA - NNX11AO24G

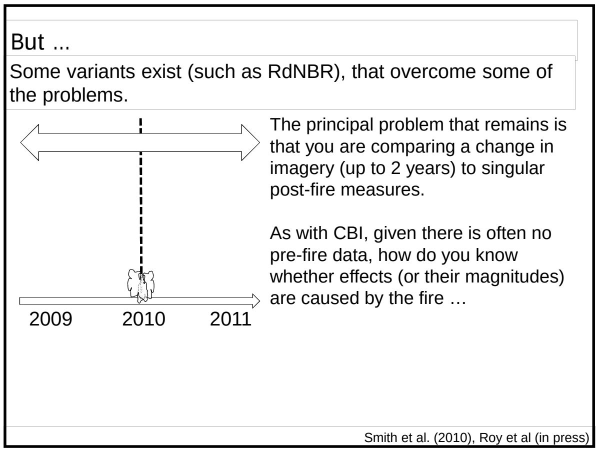


But …

The Differenced Normalized Burn Ratio (dNBR) is known to exhibit several problems.

- Non-linear asymptotic relationship with field measures (CBI)
- Relationships dependent on sensor resolution (on same fires!) and ecosystem type.
- NBR was originally developed in 1990 to detect burned area …
- NBR is poor in grasslands, shrubland, woodlands, or ecosystems with underground consumption.
- Non-constant variance (greater spread with higher severity levels)

Van Wagtendonk et al (2004); Miller and Thode (2005); Smith et al. (2010)



But ...

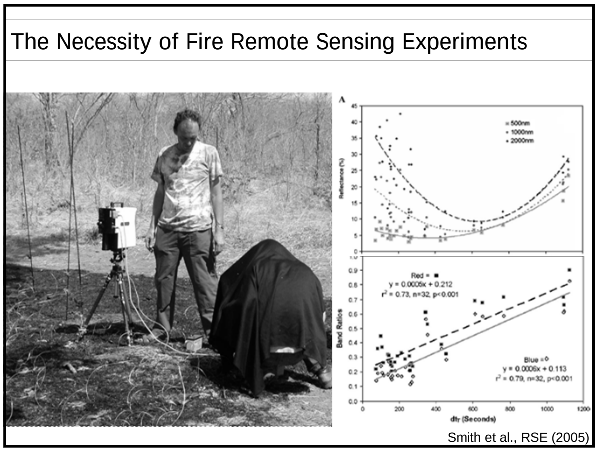
Some variants exist (such as RdNBR), that overcome some of the problems.

The principal problem that remains is that you are comparing a change in imagery (up to 2 years) to singular post-fire measures.

As with CBI, given there is often no pre-fire data, how do you know whether effects (or their magnitudes) are caused by the fire …

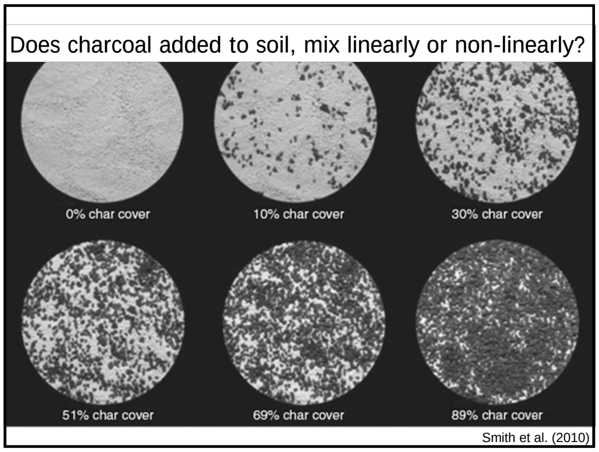
Smith et al. (2010), Roy et al (in press)

What We Need:
More remote sensing research to directly connect spectral properties to changes in surface properties



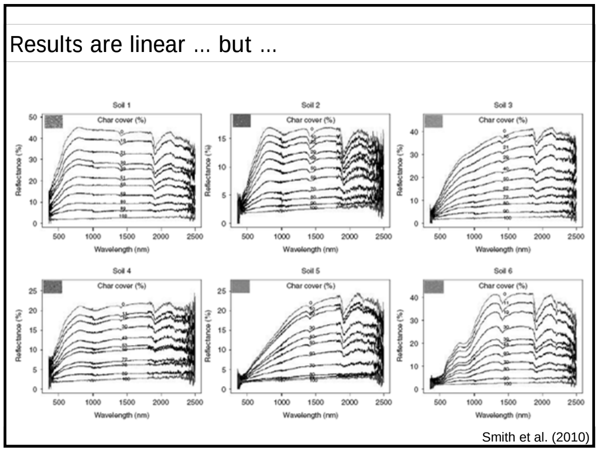
The Necessity of Fire Remote Sensing Experiments

Smith et al., RSE (2005)



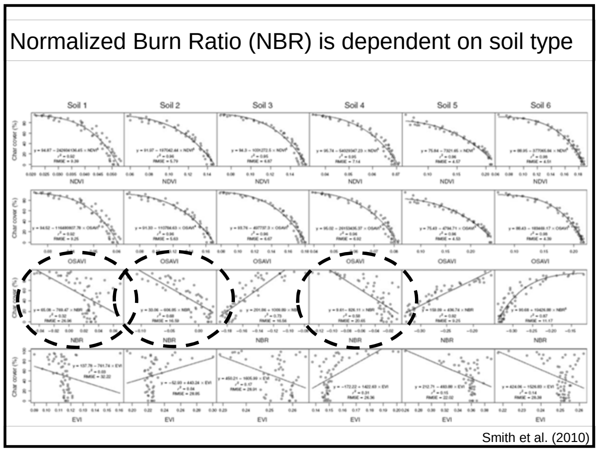
Does charcoal added to soil, mix linearly or non-linearly?

Smith et al. (2010)



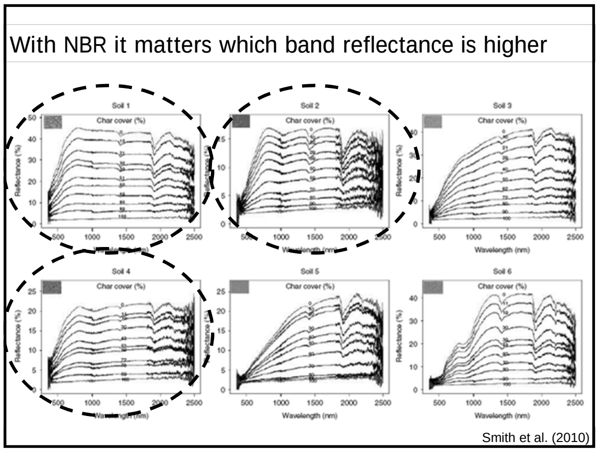
Results are linear … but …

Smith et al. (2010)



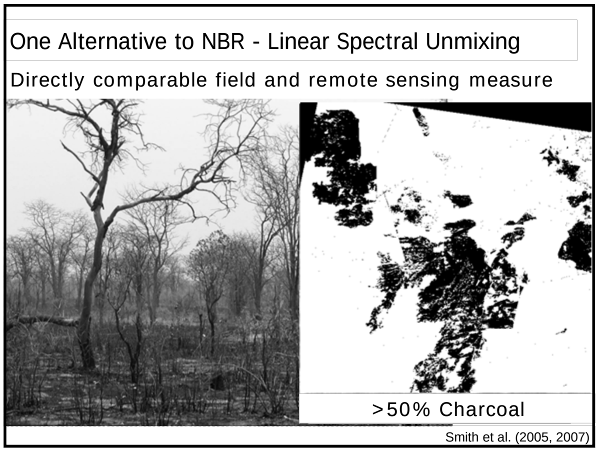
Normalized Burn Ratio (NBR) is dependent on soil type

Smith et al. (2010)



With NBR it matters which band reflectance is higher

Smith et al. (2010)

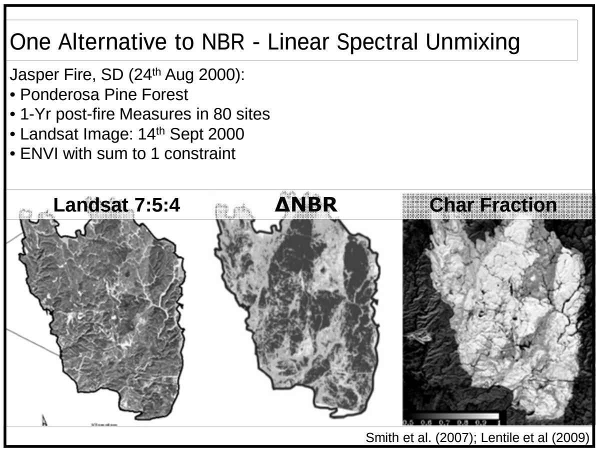


One Alternative to NBR - Linear Spectral Unmixing

Directly comparable field and remote sensing measure

>50% Charcoal

Smith et al. (2005, 2007)

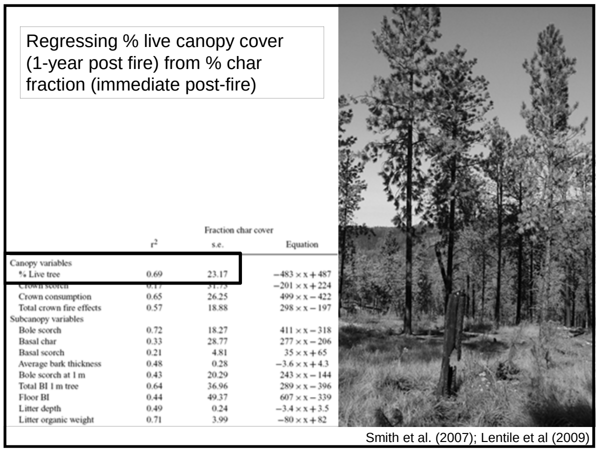


One Alternative to NBR - Linear Spectral Unmixing

Jasper Fire, SD (24th Aug 2000):
- Ponderosa Pine Forest
- 1-Yr post-fire Measures in 80 sites
- Landsat Image: 14th Sept 2000
- ENVI with sum to 1 constraint

Landsat 7:5:4 **ΔNBR** **Char Fraction**

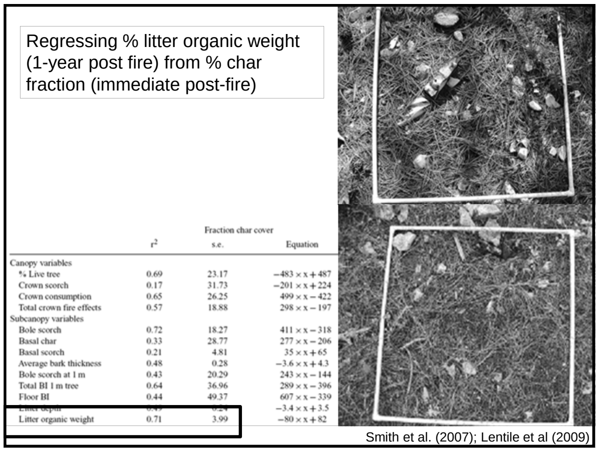
Smith et al. (2007); Lentile et al (2009)



Regressing % live canopy cover (1-year post fire) from % char fraction (immediate post-fire)

	Fraction char cover		
	r^2	s.e.	Equation
Canopy variables			
% Live tree	0.69	23.17	$-483 \times x + 487$
Crown scorch	0.17	31.73	$-201 \times x + 224$
Crown consumption	0.65	26.25	$499 \times x - 422$
Total crown fire effects	0.57	18.88	$298 \times x - 197$
Subcanopy variables			
Bole scorch	0.72	18.27	$411 \times x - 318$
Basal char	0.33	28.77	$277 \times x - 206$
Basal scorch	0.21	4.81	$35 \times x + 65$
Average bark thickness	0.48	0.28	$-3.6 \times x + 4.3$
Bole scorch at 1 m	0.43	20.29	$243 \times x - 144$
Total BI 1 m tree	0.64	36.96	$289 \times x - 396$
Floor BI	0.44	49.37	$607 \times x - 339$
Litter depth	0.49	0.24	$-3.4 \times x + 3.5$
Litter organic weight	0.71	3.99	$-80 \times x + 82$

Smith et al. (2007); Lentile et al (2009)



Regressing % litter organic weight (1-year post fire) from % char fraction (immediate post-fire)

	Fraction char cover		
	r^2	s.e.	Equation
Canopy variables			
% Live tree	0.69	23.17	$-483 \times x + 487$
Crown scorch	0.17	31.73	$-201 \times x + 224$
Crown consumption	0.65	26.25	$499 \times x - 422$
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Smith et al. (2007); Lentile et al (2009)

Linking Intensity to Severity:

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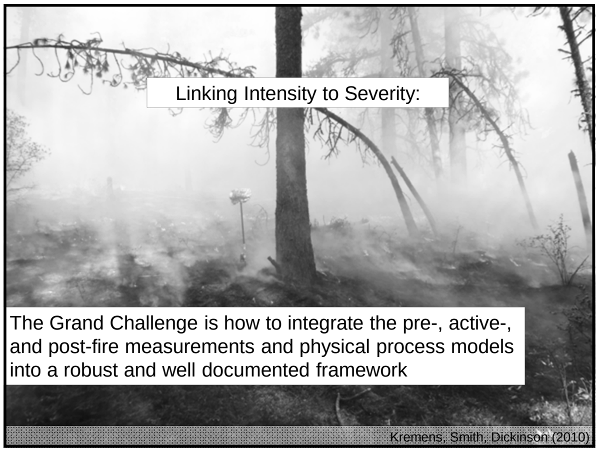
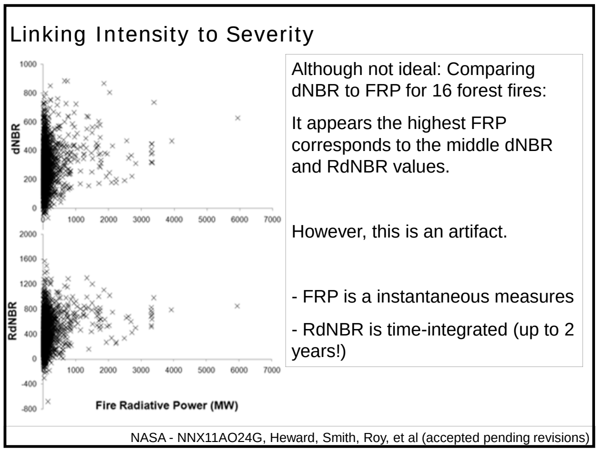


Linking Intensity to Severity:

The Grand Challenge is how to integrate the pre-, active-, and post-fire measurements and physical process models into a robust and well documented framework

Kremens, Smith, Dickinson (2010)



Linking Intensity to Severity

Although not ideal: Comparing dNBR to FRP for 16 forest fires:

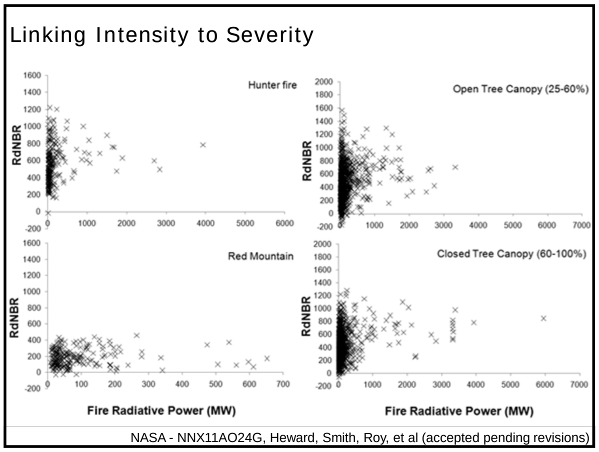
It appears the highest FRP corresponds to the middle dNBR and RdNBR values.

However, this is an artifact.

- FRP is a instantaneous measures

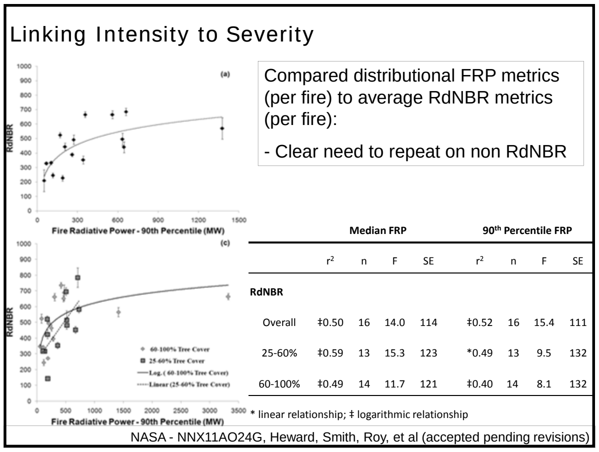
- RdNBR is time-integrated (up to 2 years!)

NASA - NNX11AO24G, Heward, Smith, Roy, et al (accepted pending revisions)



Linking Intensity to Severity

NASA - NNX11AO24G, Heward, Smith, Roy, et al (accepted pending revisions)



Linking Intensity to Severity

Compared distributional FRP metrics (per fire) to average RdNBR metrics (per fire):

- Clear need to repeat on non RdNBR

	Median FRP				90th Percentile FRP			
	r^2	n	F	SE	r^2	n	F	SE
RdNBR								
Overall	‡0.50	16	14.0	114	‡0.52	16	15.4	111
25-60%	‡0.59	13	15.3	123	*0.49	13	9.5	132
60-100%	‡0.49	14	11.7	121	‡0.40	14	8.1	132

* linear relationship; ‡ logarithmic relationship

NASA - NNX11AO24G, Heward, Smith, Roy, et al (accepted pending revisions)

Any Questions?