CQ2 - Wildfires

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and by many others (see slides for credit)

Outline

- Overarching question and associated subquestions
- Science traceability matrices (VQ4 and TQ2)
- Associated science
- Decadal Survey relevance
- Level 2 and Level 3 products
- Validation

Overarching question

- How are fires and vegetation composition coupled?

Thematic subquestions

- CQ2a: How do the timing, temperature, and frequency of fires affect long-term ecosystem health?
- CQ2b: How do vegetation composition and fire temperature impact trace-gas emissions?
- CQ2c: How do fires in coastal biomes affect terrestrial biogeochemical fluxes into estuarine and coastal waters and what is the subsequent biological response?
- CQ2d: What are the feedbacks between fire temperature and frequency and vegetation composition and recovery?
- CQ2e: How does vegetation composition influence wildfire severity?
- CQ2f: On a watershed scale, what is the relationship of vegetation cover, clay-rich soils, and slope to frequency of debris flows?

Science traceability matrices – (VQ4 2/1)

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
VQ4. Changes in Disturbance Activity: How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?				
How do patterns of abrupt (pulse) disturbance vary and change over time within and across ecosystems?	Measure changes in fractional cover (from clearing, logging, wetland drainage, fire, weather related, etc.) at the seasonal and multiyear time scales, to characterize disturbance regimes in global ecosystems (e.g., conditional frequencies and/or return intervals for VQ1 ecosystem classes).	Measure spectral signature in the VSWIR region at high precision and accuracy. - Detect fractional surface cover changes > 10%. - Sufficient precision and accuracy for spectral mixture algorithms to give insight to subpixel events. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Cloud-free measurement at least once per season.	Spectral measurement from 400 to 2500 nm at 10 nm (terrestrial): 380 to 900 nm at 10nm with additional SWIR for AC (coastal aquatic): > 95% Spectral cal uniformity: SNR 600 VNIR, 300 SWIR (23.5ZA 0.25R): 14 bit precision: >95% abs cal: > 98% on-orbit stability: no saturation of ecosystem targets: <2% polarization sensitivity 380 to 700 nm: >99% linearity 2 to 98% saturation: <= 60 m spatial sampling: >95% Spectral IFOV uniformity: <20 day revisit to minimize cloud obscuration:	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcals: ~700mbs downlink: >3X zero loss compression: ~11 am sun sync LEO orbit: Radiometric calibration: accurate enough to simulate historical satellite data through band synthesis. Atmospheric Correction: AC validation: Geolocation: 10 m (1 sigma). Ground processing: Seasonal latency:
How do climate changes affect disturbances such as fire and insect damage? [DS 196]	Measure changes in vegetation canopy cover, pigments, and water content in ecosystems globally at the seasonal and multiyear time scale. Make measurements in such a way that they are backward compatible with pre-existing estimates and algorithms (e.g., band synthesis for historical vegetation indexes), as well as allowing more advanced algorithmic approaches.	Measure characteristic changes or differences in plant pigments (10% changes in total chlorophyll, carotenoids, anthocyanins) and water content. Measure PV, NPV and Soil (+/- 5%) using full VSWIR and SWIR algorithms. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Cloud-free measurement at least once per season. VNIR-SWIR spectra suitable for band synthesis consistent with historical data.	Spectral measurement from 400 to 2500 nm at 10 nm (terrestrial): > 95% Spectral cal uniformity: SNR 600 VNIR, 300 SWIR (23.5ZA 0.25R): 14 bit precision: >95% abs cal: > 98% on-orbit stability: no saturation of ecosystem targets: <2% polarization sensitivity 380 to 700 nm: >99% linearity 2 to 98% saturation: <= 60 m spatial sampling: >95% Spectral IFOV uniformity: <20 day revisit to minimize cloud obscuration:	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcals: ~700mbs downlink: >3X zero loss compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction: AC validation: Geolocation: Pointing strategy to minimize sun glint: Avoid terrestrial hot spot: Ground processing: Seasonal latency:
What are the interactions between invasive species and other types of disturbance?	Measure the distribution and cover of key invasive species that introduce novel life histories or functional types, in concert with disturbance measurements. Measure (disturbance related) changes in vegetation canopy cover, pigments, and water content in ecosystems globally at the seasonal and multiyear time scale.	Measure spectral signature in the VSWIR region at high precision and accuracy. -Sufficient precision and accuracy for spectral mixture algorithms to give insight to subpixel events. -Measure species-type and functional type using full spectrum. -Measure PV, NPV and Soil using full VSWIR and SWIR algorithms. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Cloud-free measurement at least once per season.	Spectral measurement from 400 to 2500 nm at 10 nm (terrestrial): > 95% Spectral cal uniformity: SNR 600 VNIR, 300 SWIR (23.5ZA 0.25R): 14 bit precision: >95% abs cal: > 98% on-orbit stability: no saturation of ecosystem targets: <2% polarization sensitivity 380 to 700 nm: >99% linearity 2 to 98% saturation: <= 60 m spatial sampling: >95% Spectral IFOV uniformity: <20 day revisit to minimize cloud obscuration:	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcals: ~700mbs downlink: >3X zero loss compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction: AC validation: Geolocation: Pointing strategy to minimize sun glint: Avoid terrestrial hot spot: Ground processing: Seasonal latency:

Science traceability matrices – (VQ4 2/2)

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
VQ4. Changes in Disturbance Activity: How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?				
How are human-caused and natural disturbances changing the biodiversity composition of ecosystems, e.g.: through changes in the distribution and abundance of organisms, communities, and ecosystems?	Measure the composition of ecosystems and ecological diversity indicators globally and at the seasonal and multiyear time scale.	Measure spectral signature in the VSWIR region at high precision and accuracy. -Sufficient precision and accuracy for spectral mixture algorithms to give insight to subpixel events. -Measure species-type and functional type using full spectrum. -Measure PV, NPV and Soil using full VSWIR and SWIR algorithms. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure temporally to have high probability to achieve seasonal measurements.	Spectral measurement from 400 to 2500 nm at 10 nm (terrestrial): > 95% Spectral cal uniformity: SNR 600 VNIR, 300 SWIR (23.5ZA 0.25R): 14 bit precision: >95% abs cal: > 98% on-orbit stability: no saturation of ecosystem targets: <2% polarization sensitivity 380 to 700 nm: >99% linearity 2 to 98% saturation: <= 60 m spatial sampling: >95% Spectral IFOV uniformity: <20 day revisit to minimize cloud obscuration:	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar ca [illegible] 6 per year vcals: ~700mbs downlin [illegible] 3X zero loss compression: ~1 [illegible] c LEO orbit: Radiometric [illegible] Atmospheric Correction: [illegible] n: Geolocation: Pointing [illegible] inimize sun glint: Avoid [illegible] ot spot: Ground proc [illegible] al latency:
How do climate change, pollution and disturbance augment the vulnerability of ecosystems to invasive species? [DS 114,196]	Measure disturbances and ecosystem status. Measure invasive trends. Measure at the seasonal to multiyear time scale.	Measure spectral signature in the VSWIR region at high precision and accuracy. -Sufficient precision and accuracy for spectral mixture algorithms to give insight to subpixel events. -Measure species-type and functional type using full spectrum. -Measure PV, NPV and Soil using full VSWIR and SWIR algorithms. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure temporally to have high probability to achieve seasonal measurements.	Spectral measurement from 400 to 2500 nm at 10 nm (terrestrial): > 95% Spectral cal uniformity: SNR 600 VN [illegible] 300 SWIR (23.5ZA 0.25R): 1 [illegible] precision: >95% abs cal: > 98% [illegible] stability: no saturation of [illegible] targets: <2% polarization [illegible] 380 to 700 nm: >99% line [illegible] saturation: <= 60 m [illegible] ng: >95% Spectral IFOV [illegible] 0 day revisit to minimize [illegible] ation:	[illegible] ectance in the solar reflected [illegible] for elevation angles >20: [illegible] us cal/val program: Monthly lunar [illegible] Daily solar cals: 6 per year vcals: [illegible] 00mbs downlink: >3X zero loss compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction: AC validation: Geolocation: Pointing strategy to minimize sun glint: Avoid terrestrial hot spot: Ground processing: Seasonal latency:
What are the effects of disturbances on productivity, water resources, and other ecosystem functions and services? [DS 196]	Measure disturbances and productivity indicators including ecosystem function and services on the seasonal to multiyear time scale	Measure spectral signature in the VSWIR region at high precision and accuracy. -Sufficient precision and accuracy for spectral mixture algorithms to give insight to subpixel events. -Measure species-type and functional type using full spectrum. -Measure PV, NPV and Soil using full VSWIR and SWIR algorithms. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure temporally to have high probability to achieve seasonal measurements.	Spectral m [illegible] m 400 to 2500 nm at 1 [illegible] strial): > 95% Spectral cal [illegible] ty: SNR 600 VNIR, 300 SWIR (2 [illegible] A 0.25R): 14 bit precision: >95% abs cal: > 98% on-orbit stability: no saturation of ecosystem targets: <2% polarization sensitivity 380 to 700 nm: >99% linearity 2 to 98% saturation: <= 60 m spatial sampling: >95% Spectral IFOV uniformity: <20 day revisit to minimize cloud obscuration:	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcals: ~700mbs downlink: >3X zero loss compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction: AC validation: Geolocation: Pointing strategy to minimize sun glint: Avoid terrestrial hot spot: Ground processing: Seasonal latency:
How do changes in human uses of ecosystems affect their vulnerability to disturbance and extreme events? [DS 196]	Measure status of ecosystems globally and relation to disturbances and major events at the seasonal to multiyear time scale.	Measure spectral signature in the VSWIR region at high precision and accuracy. -Sufficient precision and accuracy for spectral mixture algorithms to give insight to subpixel events. -Measure species-type and functional type using full spectrum. -Measure PV, NPV and Soil using full VSWIR and SWIR algorithms. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure temporally to have high probability to achieve seasonal measurements.	Spectral measurement from 400 to 2500 nm at 10 nm (terrestrial): > 95% Spectral cal uniformity: SNR 600 VNIR, 300 SWIR (23.5ZA 0.25R): 14 bit precision: >95% abs cal: > 98% on-orbit stability: no saturation of ecosystem targets: <2% polarization sensitivity 380 to 700 nm: >99% linearity 2 to 98% saturation: <= 60 m spatial sampling: >95% Spectral IFOV uniformity: <20 day revisit to minimize cloud obscuration:	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcals: ~700mbs downlink: >3X zero loss compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction: AC validation: Geolocation: Pointing strategy to minimize sun glint: Avoid terrestrial hot spot: Ground processing: Seasonal latency:

VSWIR/TIR coregistration!

Science traceability matrix

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
TQ2. Wildfires: What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?				
How are global fire regimes (fire location, type, frequency, and intensity) changing in response to changing climate and land use practices? [DS 198] (feedbacks?)	Fire monitoring, fire intensity	Detect flaming and smoldering fires as small as ~10 sq. m in size, fire radiative power, fire temperature and area, 4-10 day repeat cycle	Low and normal gain channels at 4 and 11 µm (possible dual gain for 11 um). Low-gain saturation at 1400 K, 1100 K, respectively, with 2-3 K NEdT; normal-gain NEdT < 0.2 K. Stable behavior in the event of saturation. 50-100 m spatial resolution. Accurate inter-band coregistration (< 0.25 pixel). Opportunistic use of additional bands in 8-14 µm region.	Daytime and nighttime data acquisition, direct broadcast and on-board processing, pre-fire and post-fire thematic maps, opportunistic validation. Low Earth Orbit[illegible]
Is regional and local fire frequency changing? [DS 196]	Fire detection	Detect smoldering fires as small as ~10 sq. m in size, 4-10 day repeat cycle over the duration of the mission	Low and normal gain channels at 4 and 11 µm (possible dual gain for 11 um). Low-gain saturation at 1400 K, 1100 K, respectively, with 2-3 K NEdT; normal-gain NEdT < 0.2 K. Stable behavior in the event of saturation. 50-100 m spatial resolution. Accurate inter-band coregistration (< 0.25 pixel). Opportunistic use of additional bands in 8-14 µm region.	Daytime and [illegible]ata acquisition, direct br[illegible] and on-board processi[illegible]re and post-fire themat[illegible]ps, opportunistic valid[illegible] Earth Orbit.
What is the role of fire in global biogeochemical cycling, particularly trace gas emissions? [DS 195]	Fire detection, fire intensity, fire monitoring, burn severity, delineate burned area	Detect flaming and smoldering fires as small as ~10 sq. m in size, fire radiative power, 4-10 day repeat cycle; fire temperature and area.	Low and normal gain channels at 4 a[illegible] µm (possible dual gain for 11 um). L[illegible] saturation at 1400 K, 1100 K, re[illegible] with 2-3 K NEdT; normal-gain N[illegible] K. Stable behavior in the even[illegible]tion. 50-100 m spatial resolutio[illegible] inter-band coregistration [illegible] pixel). Opportunistic use of [illegible]bands in 8-14 µm region.	[illegible]aytime and nighttime data acquisition, pre-fire vegetation cover, condition and loads for fuel potential. Requires fuel fire modeling element.
Are there regional feedbacks between fire and climate change? [DS 196]	Extent of fire front and confirmation of burn scars	Detect flaming and smoldering fires as small as ~10 sq. m in size, fire radiative power, 4-10 day repeat cycle; fire temperature and area.	Low and normal gain cha[illegible]nels at 4 and 11 microns. Low-gain saturation at 1400 K, 1100 K, respectively, with 2-3 K NEdT; normal-gain NEdT < 0.2 K. Stable behavior in the event of saturation. 50-100 m spatial resolution. Accurate inter-band coregistration (< 0.25 pixel).	Daytime and nighttime data acquisition, pre-fire vegetation cover, condition and loads for fuel potential. Requires fuel fire modeling element.

Point spread (line spread) function!

Alignment with decadal survey panel reports

- Land-use change, ecosystem dynamics and biodiversity
  - distribution and changes in ecosystem function
    - disruption in carbon cycles
    - early detection of such events
  - changes in disturbance cycles
    - related to climate change and changes in water cycle
- (Solid earth hazards, natural resources and dynamics)
  - (relevance through post-fire effects (e.g. debris flow))
- Climate variability and change
  - Fire Disturbance: “major climate variable”; GCOS Essential Climate Variable – CEOS, GTOS, GOFC-GOLD relevance
  - “Will droughts become more widespread in the western United States, Australia, and sub-Saharan Africa? How will this affect the patterns of wildfires?”

Combined use of VSWIR and TIR data

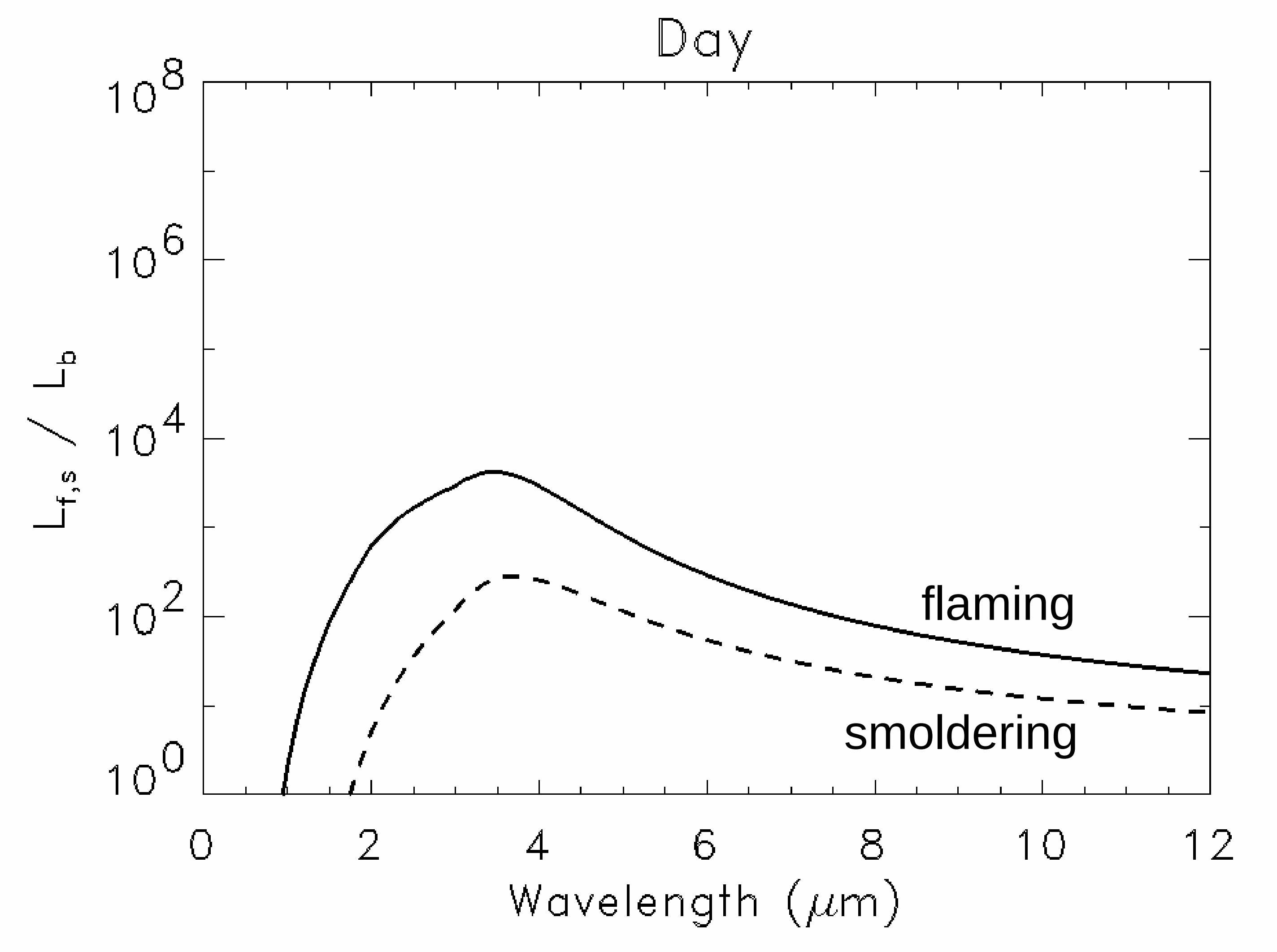
- Pre-fire fuel properties combined with VNIR/SWIR or TIR estimates of active fire properties
  - fuel types, fuel loads
  - VSWIR derived live fuel moisture, vegetation stress etc.
  - surface temperature, ET
- Detection/characterization of the combustion process
  - improved fire temperature and area estimation using VSWIR and TIR
    - including cross-calibration over VSWIR swath
  - improved characterization of smoke emission
- Post-fire impacts
  - fire affected area
  - burn severity
  - amount of material burned
  - hydrophobicity
  - types of ash
  - land cover change
  - nutrient transport

Data fusion?

- Pre-fire
  - vegetation condition, vegetation stress, fire weather, fire danger
- Combustion process
  - 19-day VSWIR/TIR fire characterization
- Fire dynamics
  - spread rate, fireline intensity, flame length
    - active fire + fuel + weather + modeling
- Post-fire
  - VSWIR/TIR burned area / burn severity

Daytime Fire Sensitivity

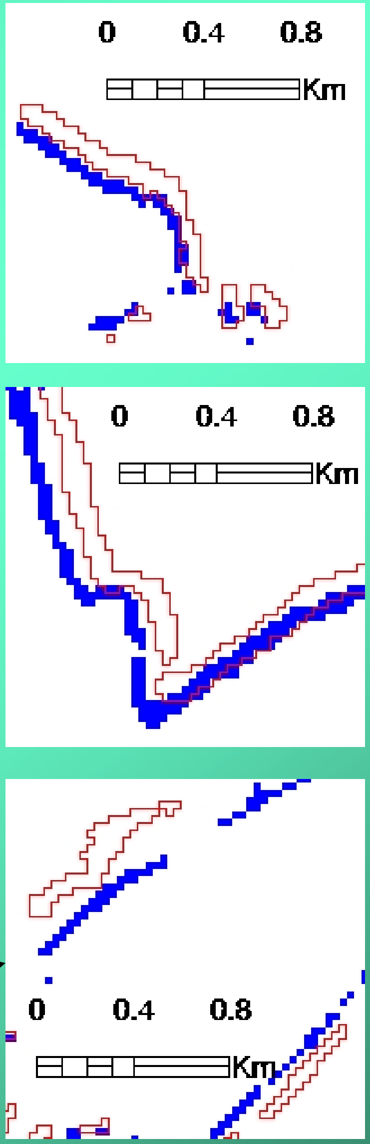
Sensitivity



Giglio et al. (2008)

Fire spread: same-day ETM+ and ASTER

Location on map	Date	WRS-2 path/row	ASTER time (UTC)	Vegetation type
1	8/13/2001	229/067	14:27:35	forest interface
			14:27:43	forest interface
			14:27:52	forest interface
2	8/29/2002	224/064	13:49:16	forest interface
			13:49:25	forest interface
			13:49:34	forest interface
3	8/29/2002	224/067	13:50:27	forest interface
			13:50:36	forest interface
			13:50:45	forest interface
4	8/29/2002	224/071	13:51:55	cerrado
			13:52:04	cerrado
			13:52:13	cerrado
5	8/31/2002	222/066	13:37:36	cerrado
			13:37:45	cerrado
			13:37:54	cerrado
6	10/5/2002	227/068	14:08:52	forest interface
			14:09:01	forest interface
			14:09:10	forest interface
			14:09:19	forest interface
7	10/17/2002	231/067	14:33:18	forest interface
			14:33:27	forest interface
			14:33:36	forest interface
8	1/28/2003	232/058	14:35:59	grassland
			14:36:08	grassland



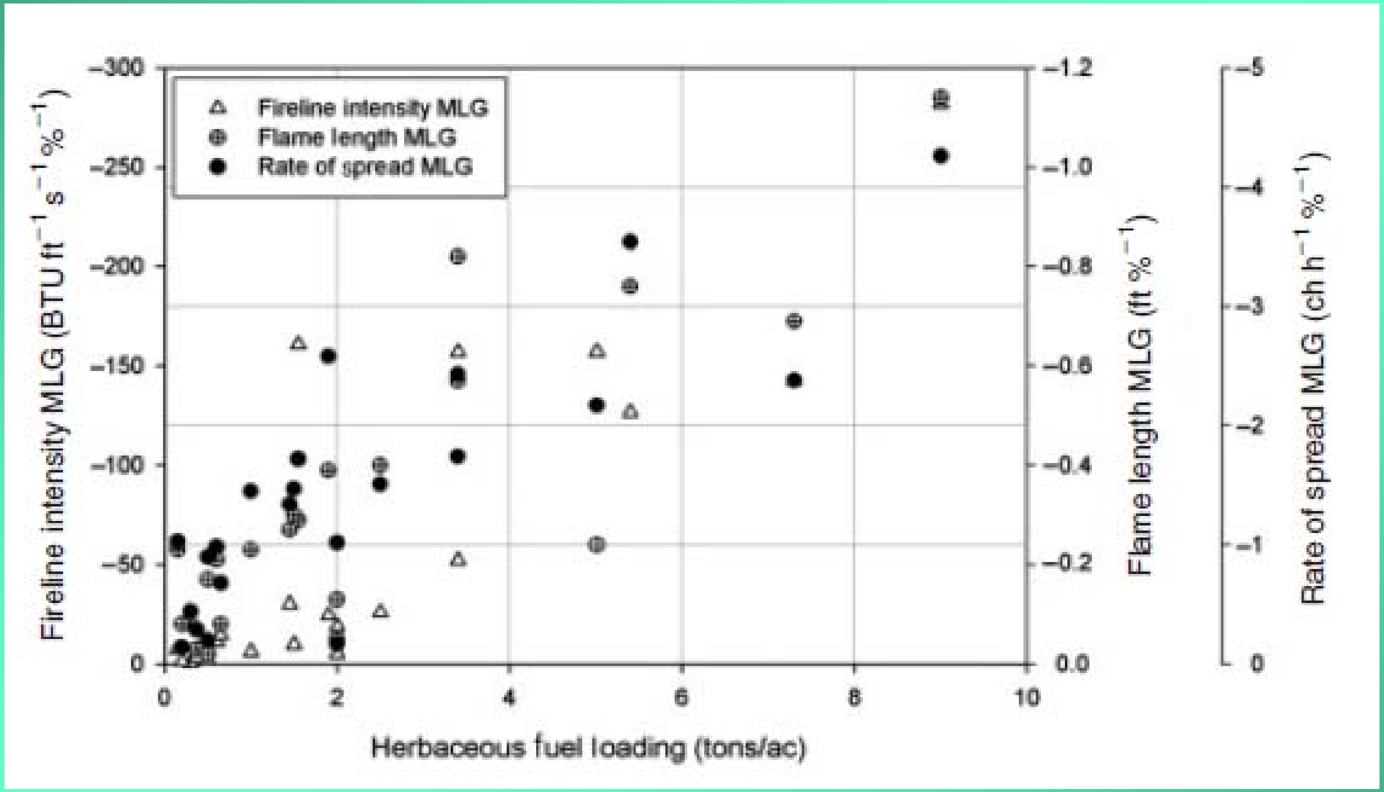
Red: ASTER

Blue: TM+

HyspIRI: fire front + fuel

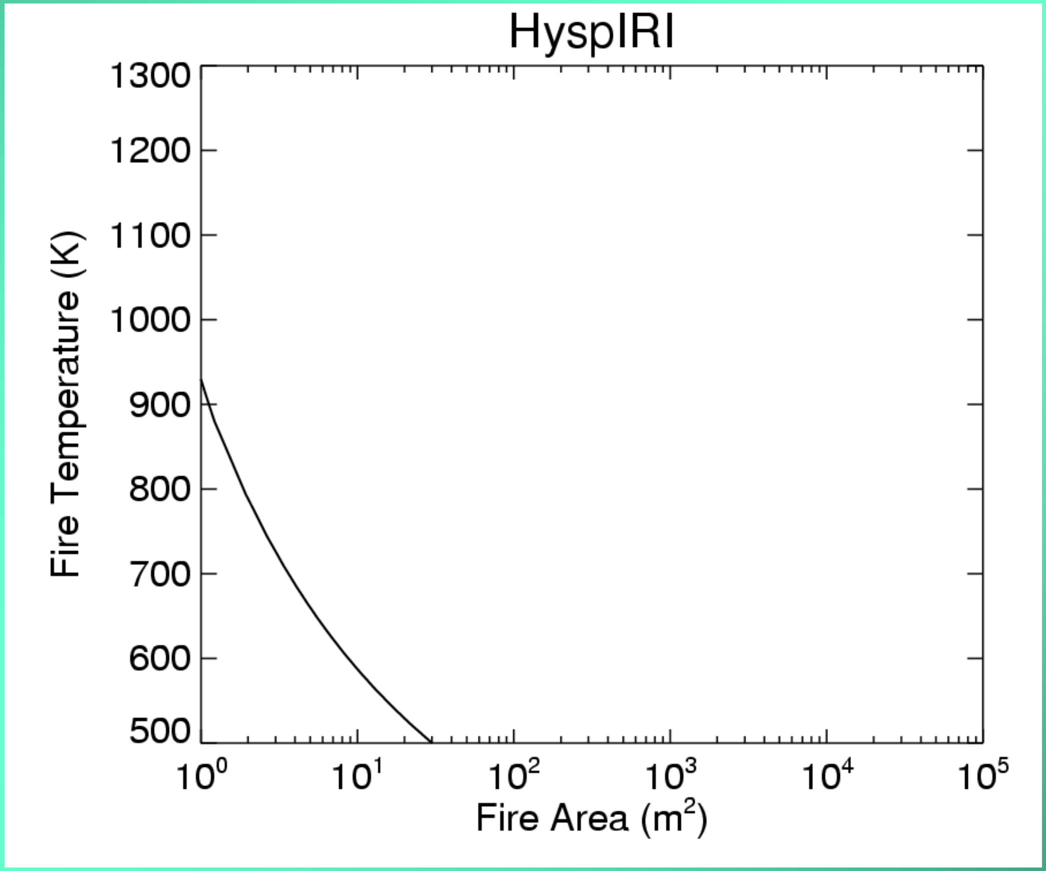
Csiszar and Schroeder, 2008

Fire properties and fuel



Jolly, 2007

HyspIRI detection envelope

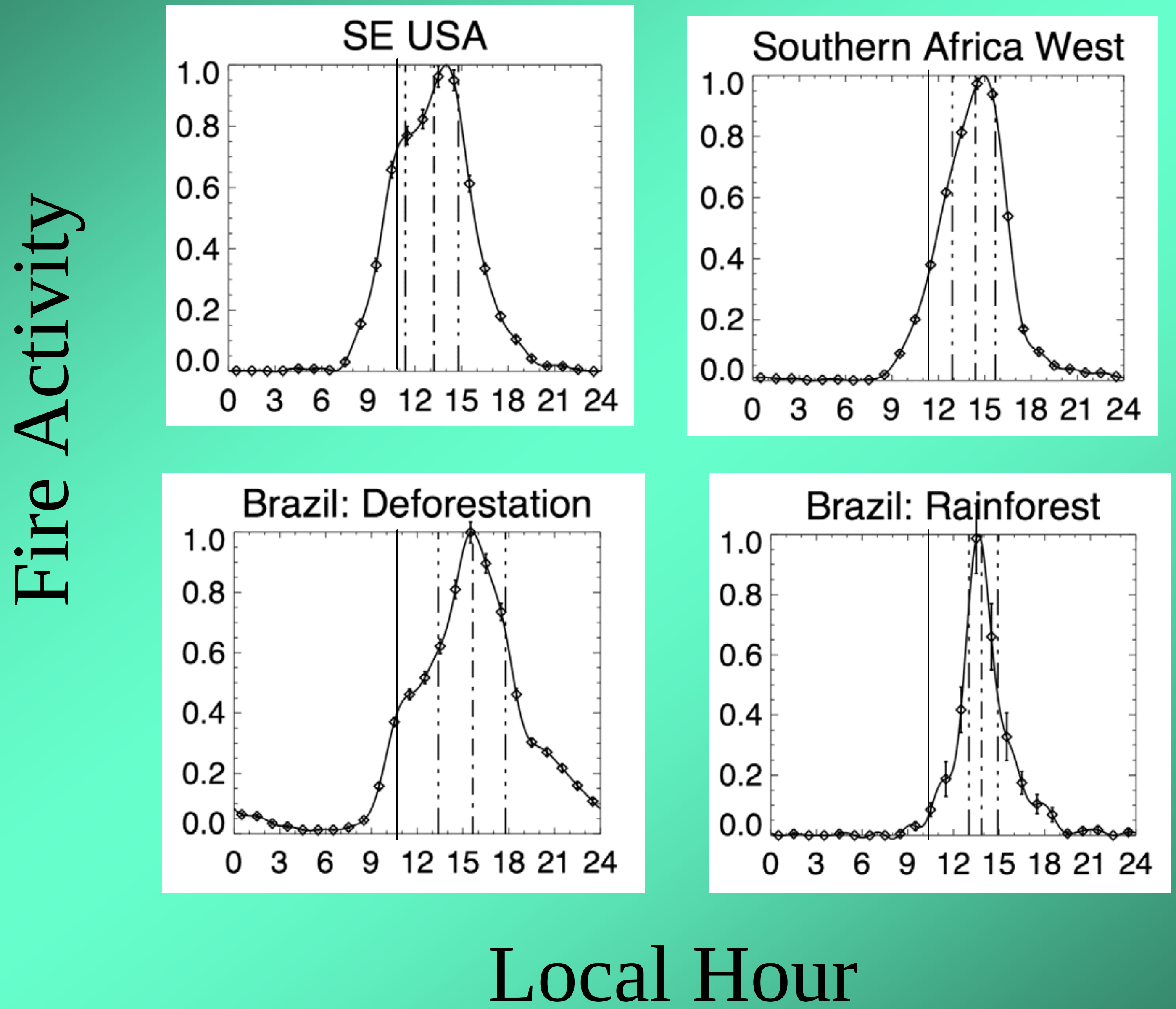


60 m

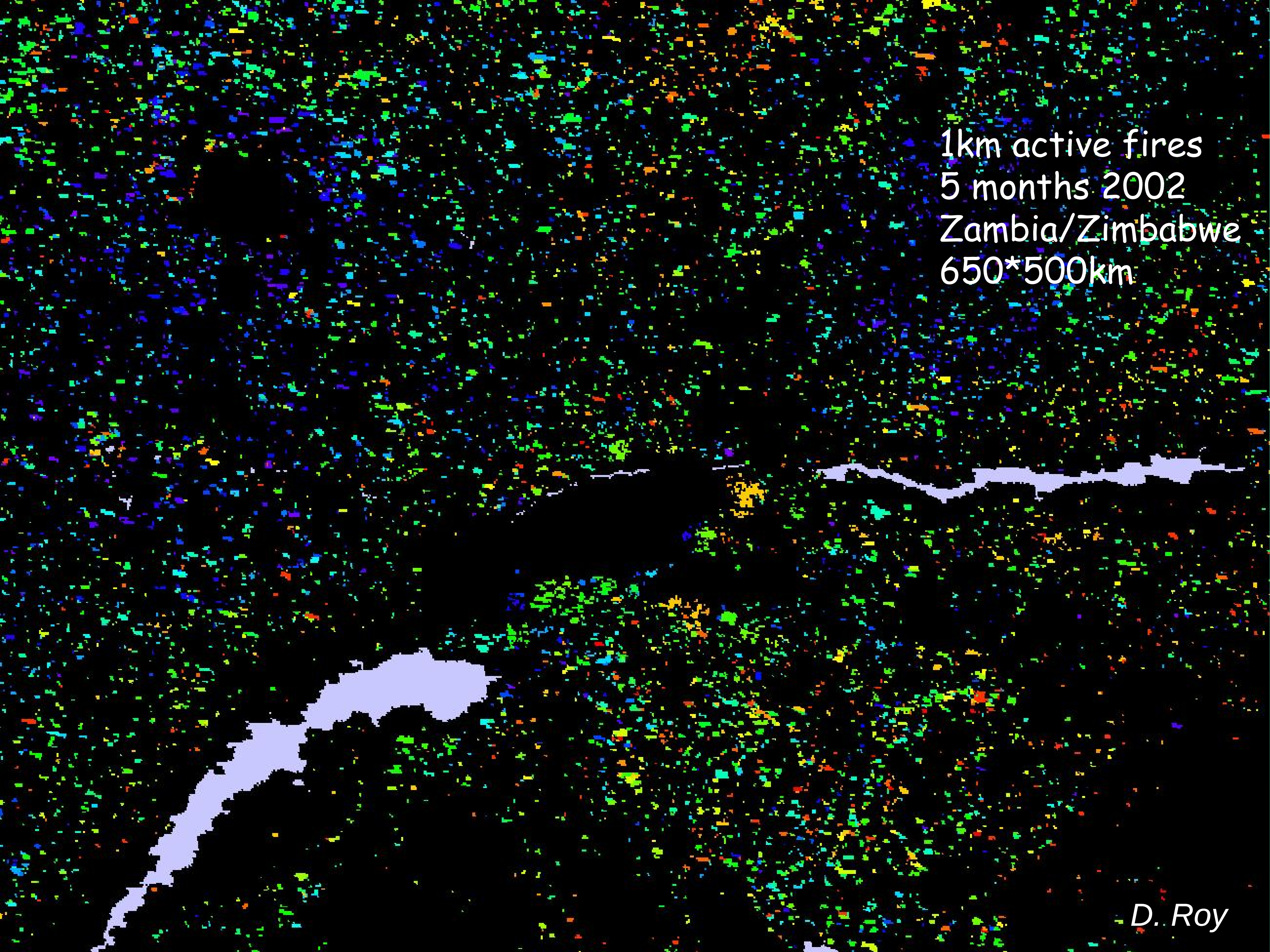
90% probability of detection; boreal forest; nadir view

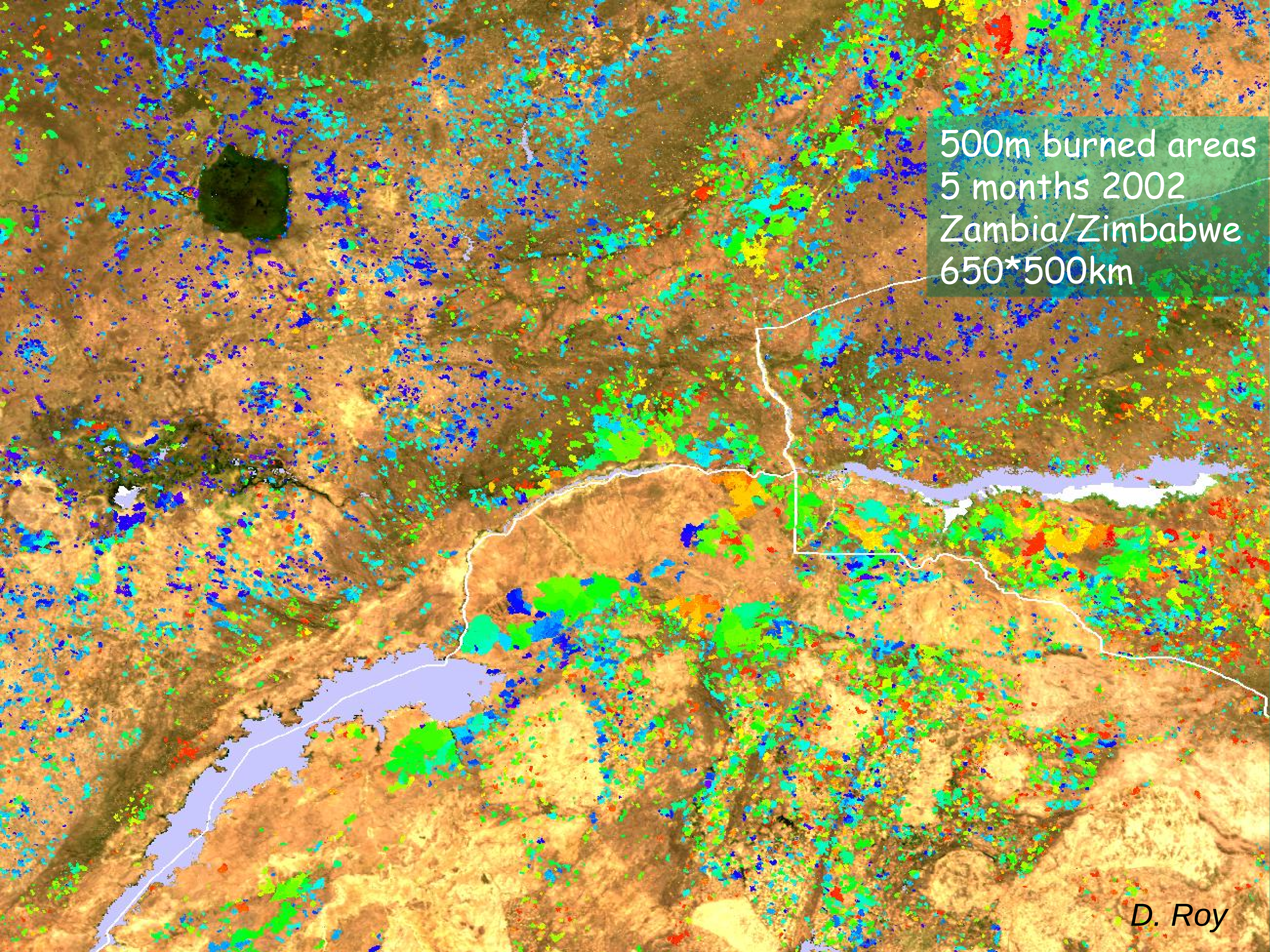
L. Giglio

Example Diurnal Fire Cycles (from VIRS Data)



L. Giglio


1km active fires
5 months 2002
Zambia/Zimbabwe
650*500km
D. Roy

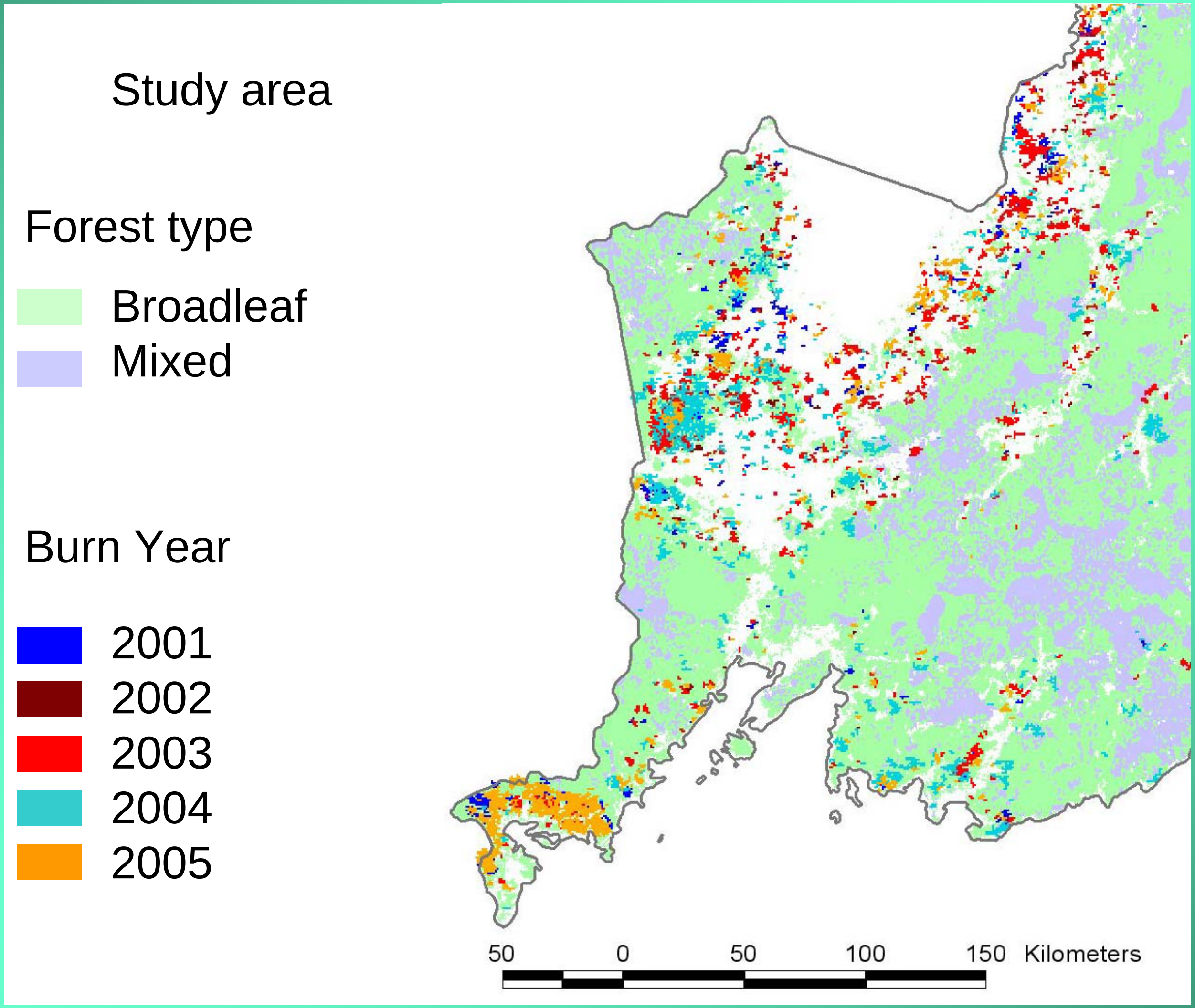

500m burned areas
5 months 2002
Zambia/Zimbabwe
650*500km
D. Roy

CQ2a: How do the timing, temperature, and frequency of fires affect long-term ecosystem health?

Example: Mediterranean Shrublands

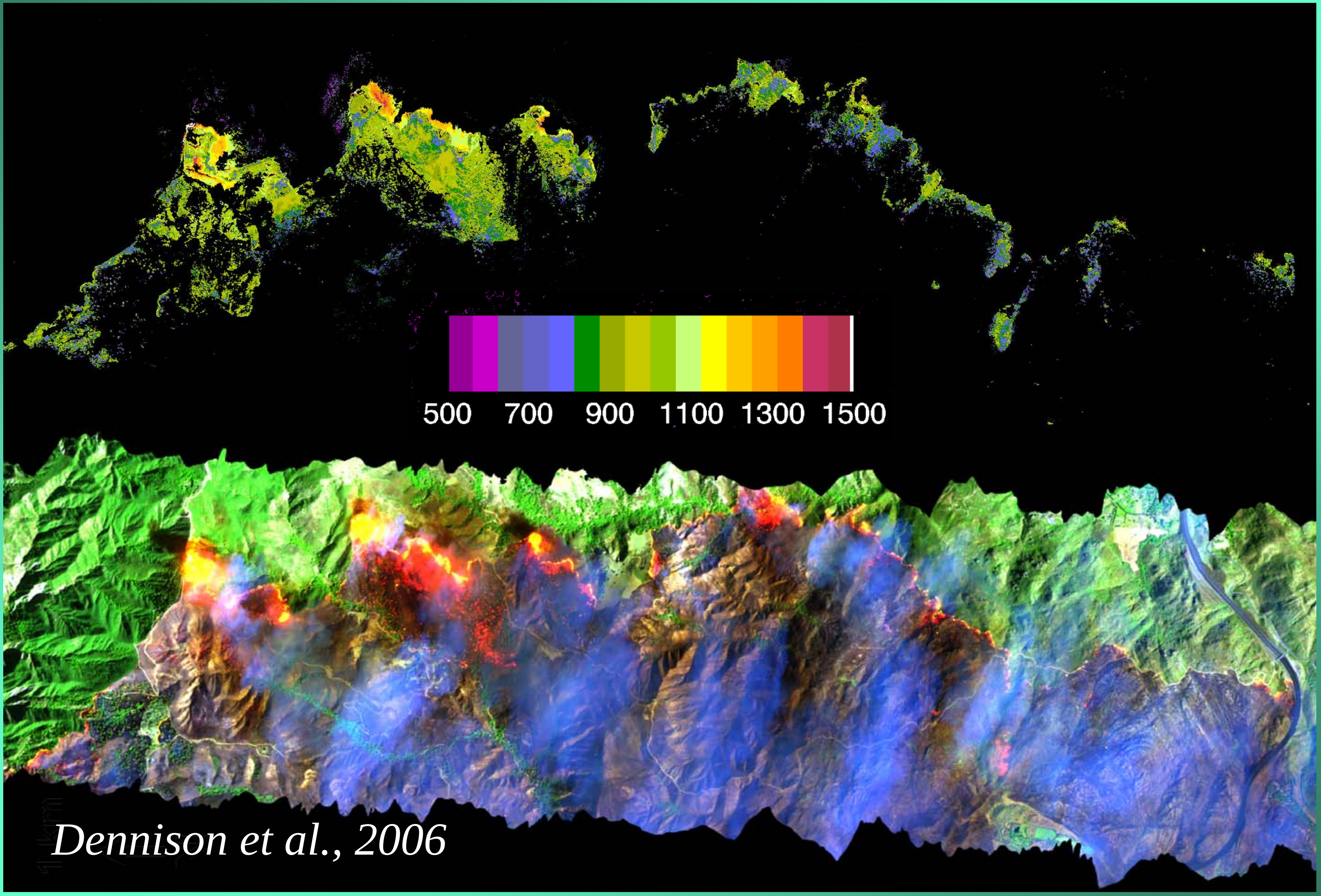
- The shrublands of California (Chaparral) are believed to be much more extensive today than before aboriginal burning and Spanish livestock grazing
- There are two Californian shrubland associations - lowland sage and foothills chaparral consisting of woody shrubs. A <u>twenty year fire cycle</u> provides a sub climax of *chamise* adapted to fire e.g.
  - the plants flammable oils promotes fire
  - the plants sprouts from roots after a burn
  - fire enables cones to disperse seeds

High frequency of low severity fires in the southern RFE may contribute to the observed decline in tiger densities

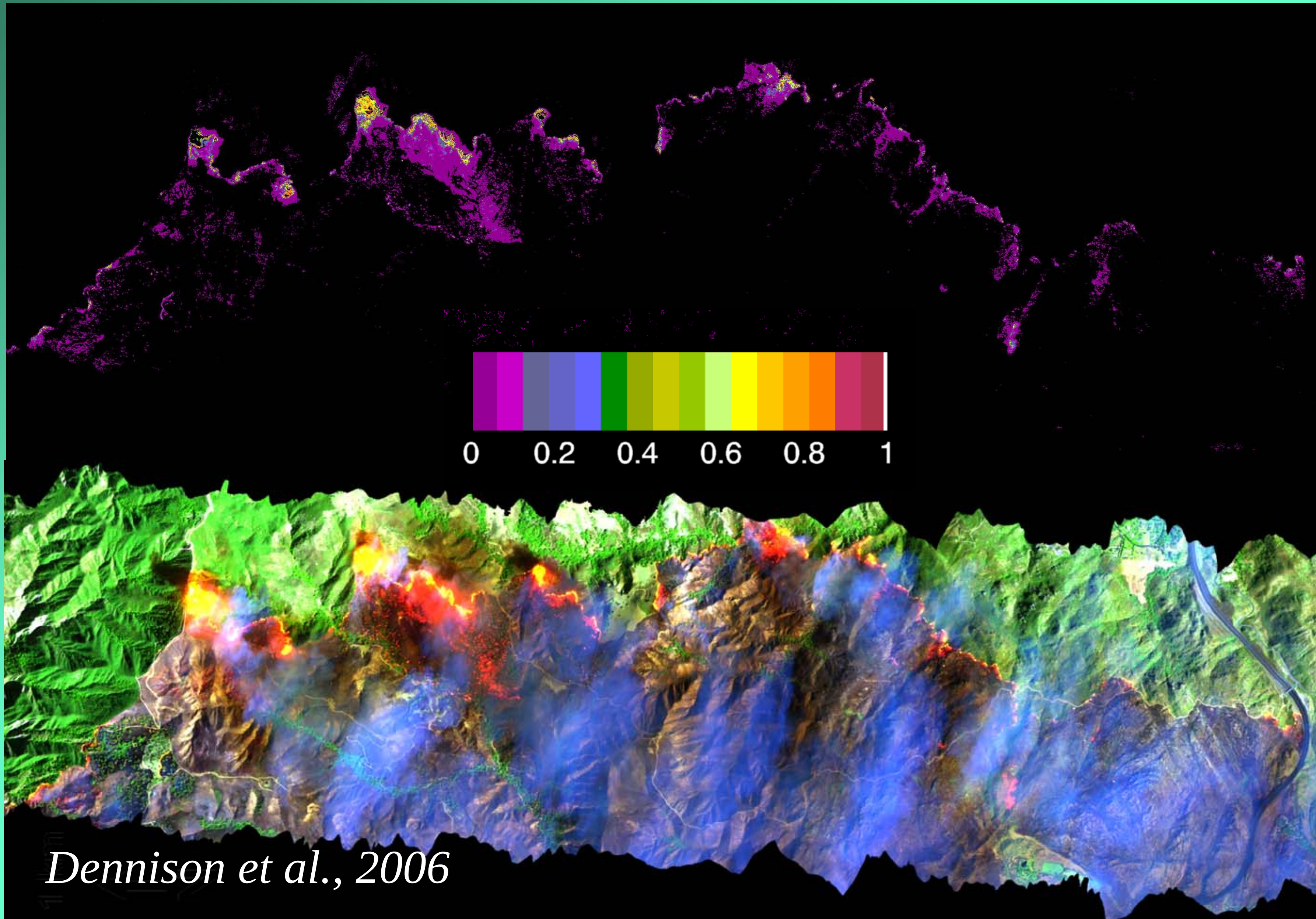


T. Loboda, UMD

Retrieved Temperature Endmembers

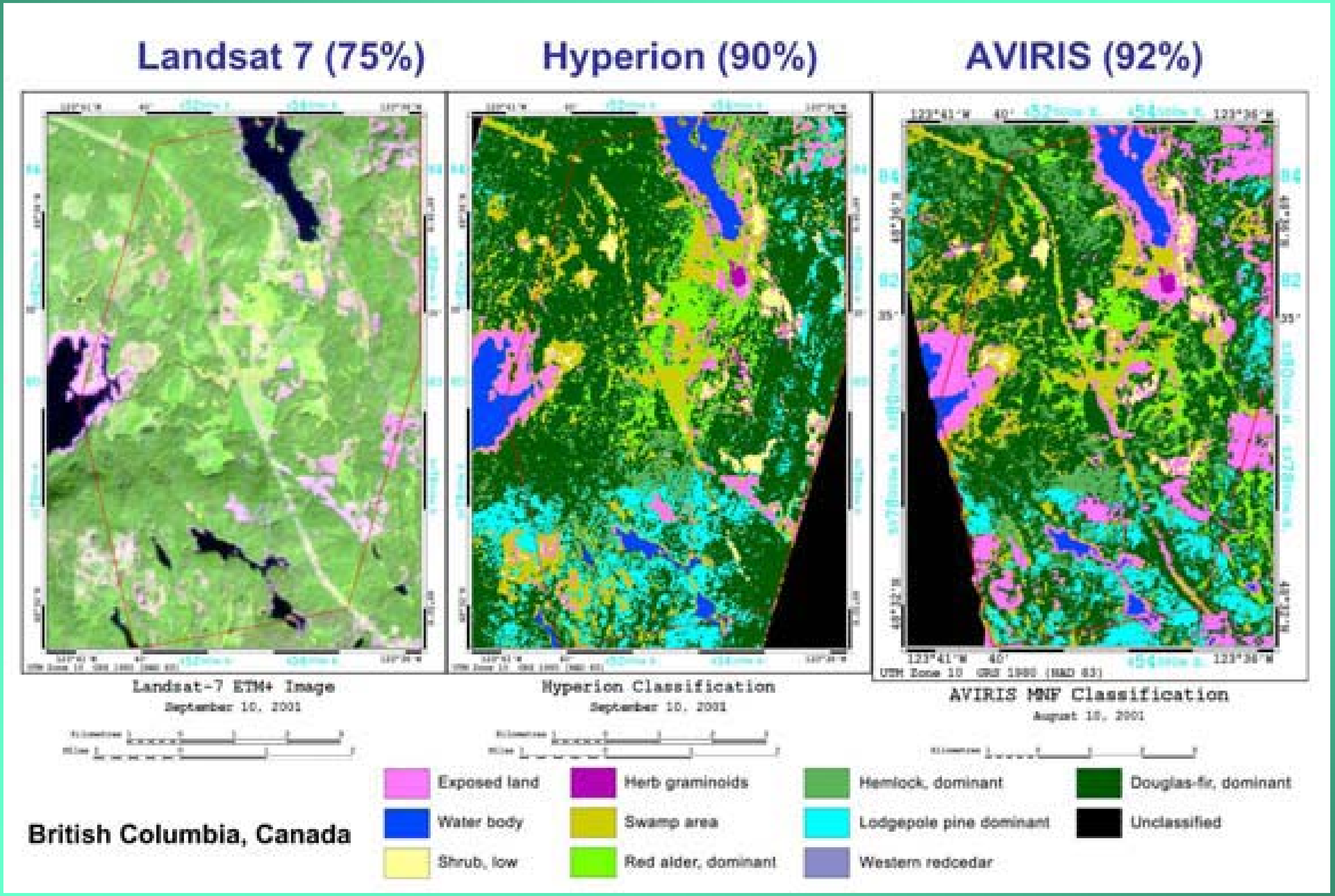


Sub-Pixel Fire Fraction



CQ2b: What are the feedbacks between fire temperature and frequency and vegetation composition and recovery?

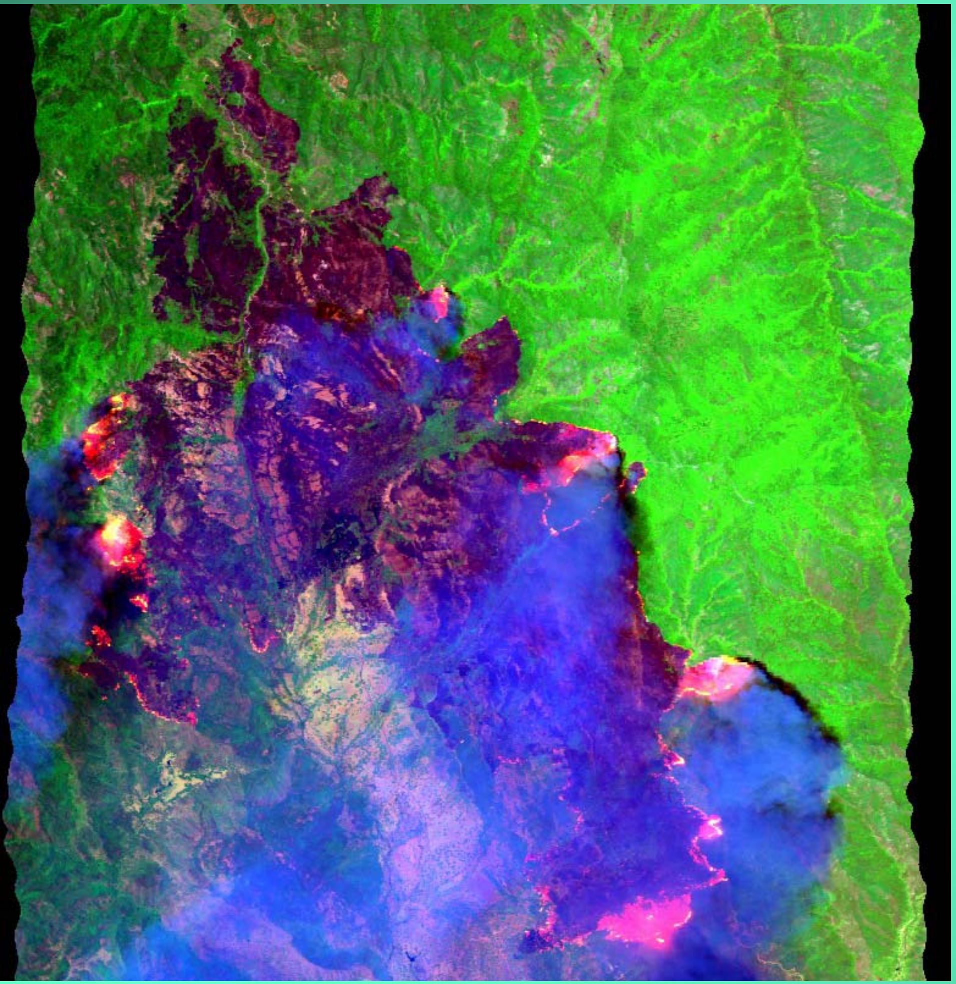
VSWIR: Improved Vegetation Mapping



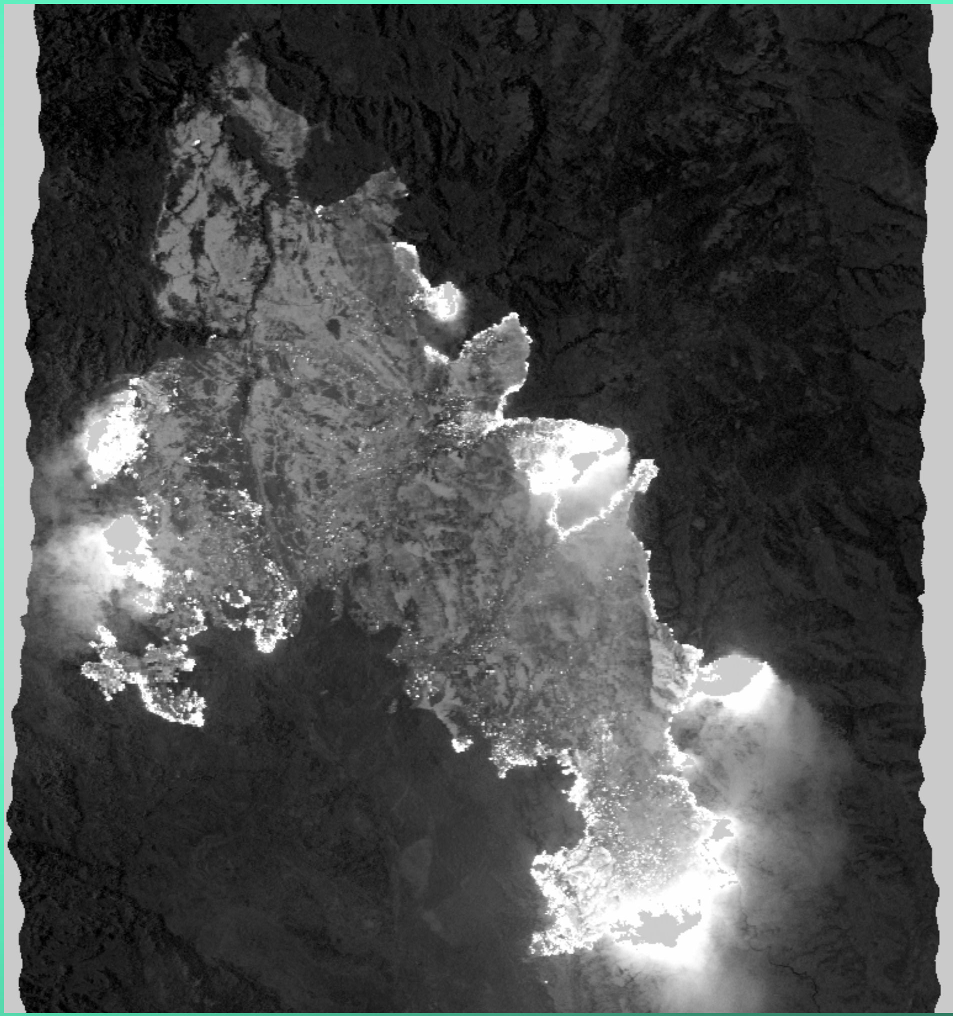
Goudenough et al. (2003)

Indians Fire AVIRIS Scene

SWIR Fire Detection Index



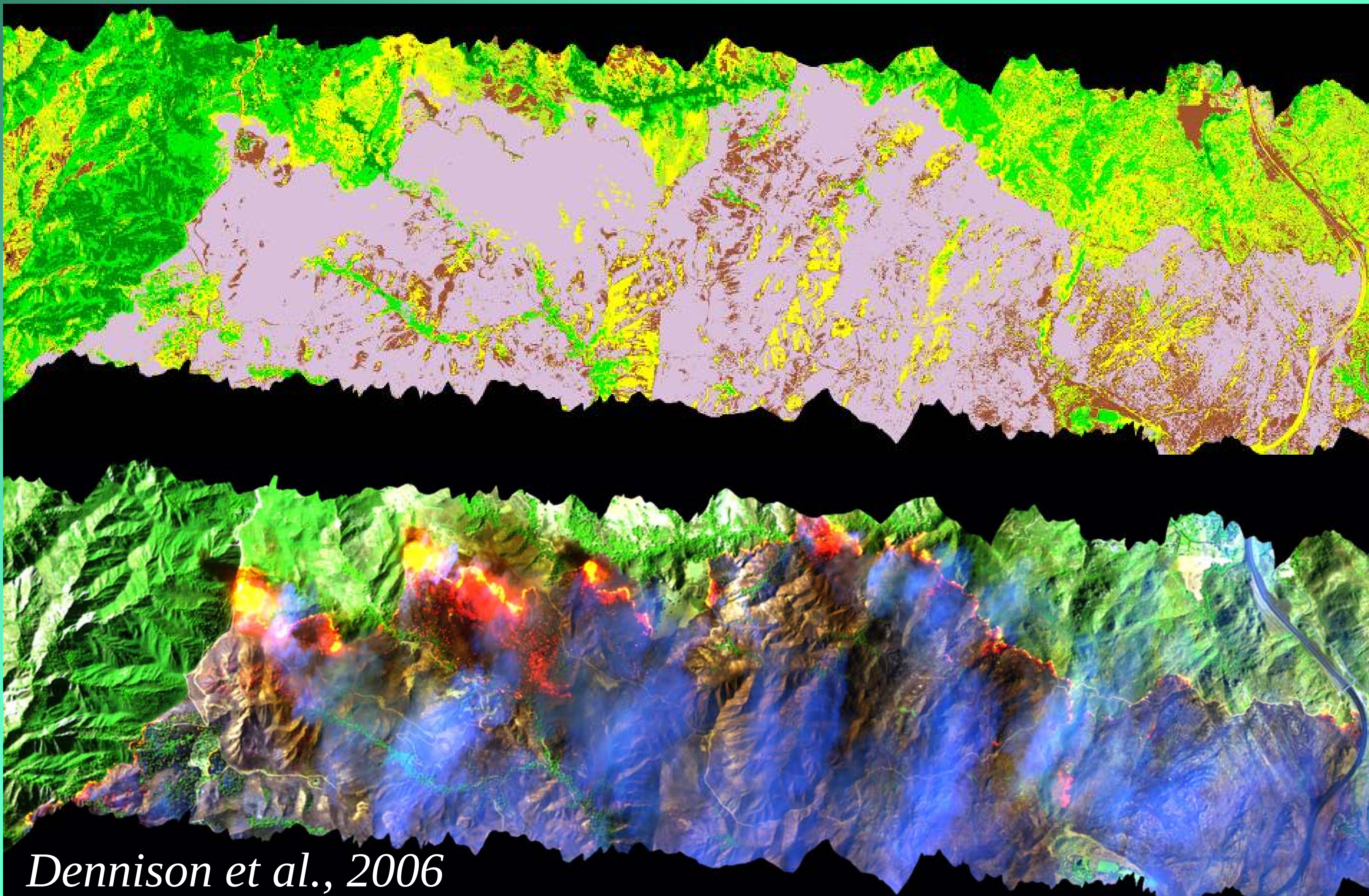
1682 nm **1111 nm** **648 nm**



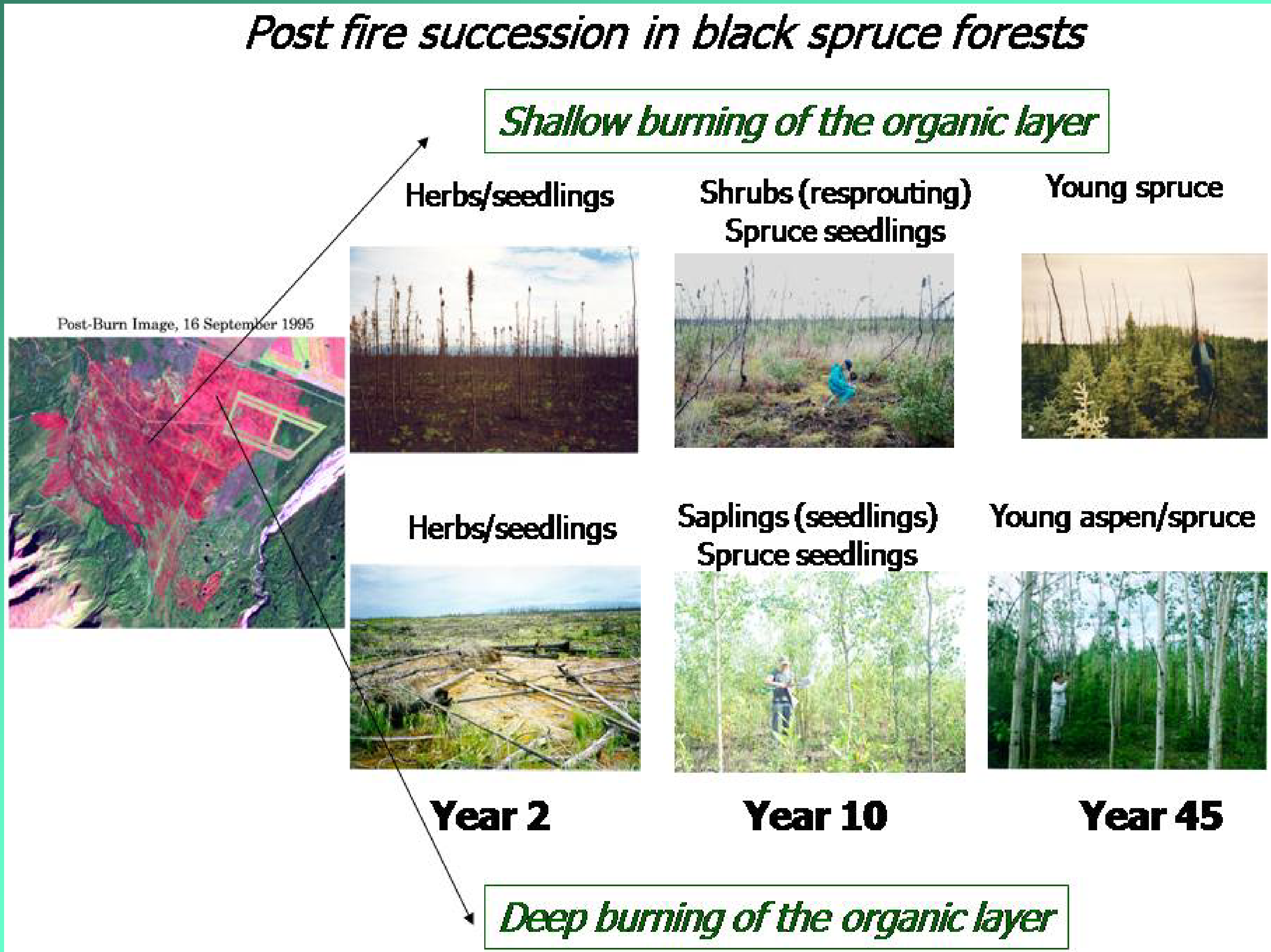
Dennison and Roberts, 2009

Land Cover

Ash
Soil
Riparian
Dense Chap.
Sparse Chap.
Grass



Vegetation recovery



Burn severity!

E. Kasischke, UMD

CQ2c: How do vegetation composition and fire temperature impact trace-gas emissions?

Regional to Global Scale Emission Estimates

RANDERSON ET AL.: C_4 FIRE EMISSIONS

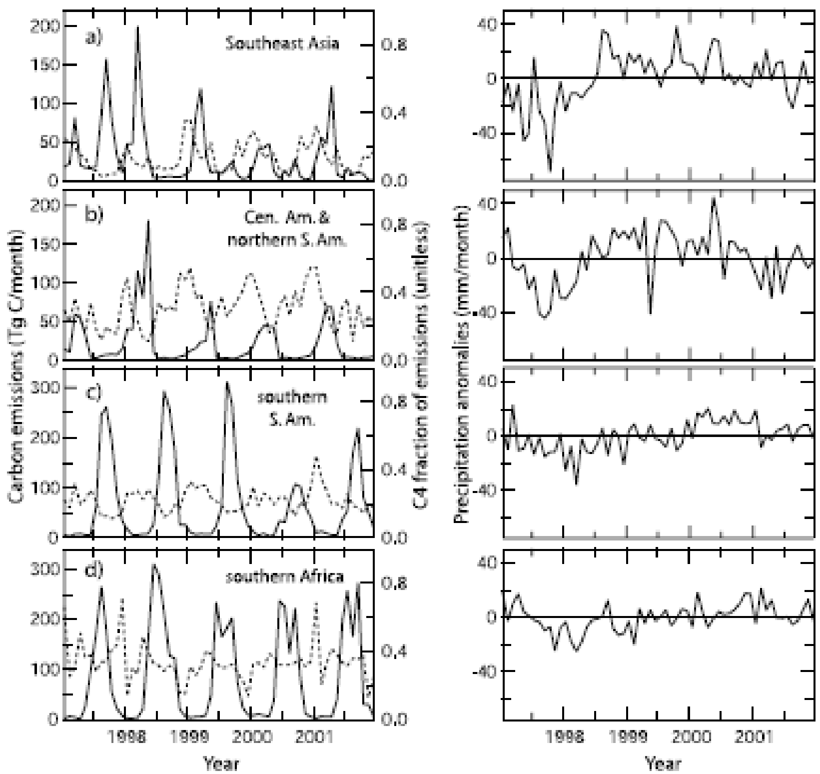
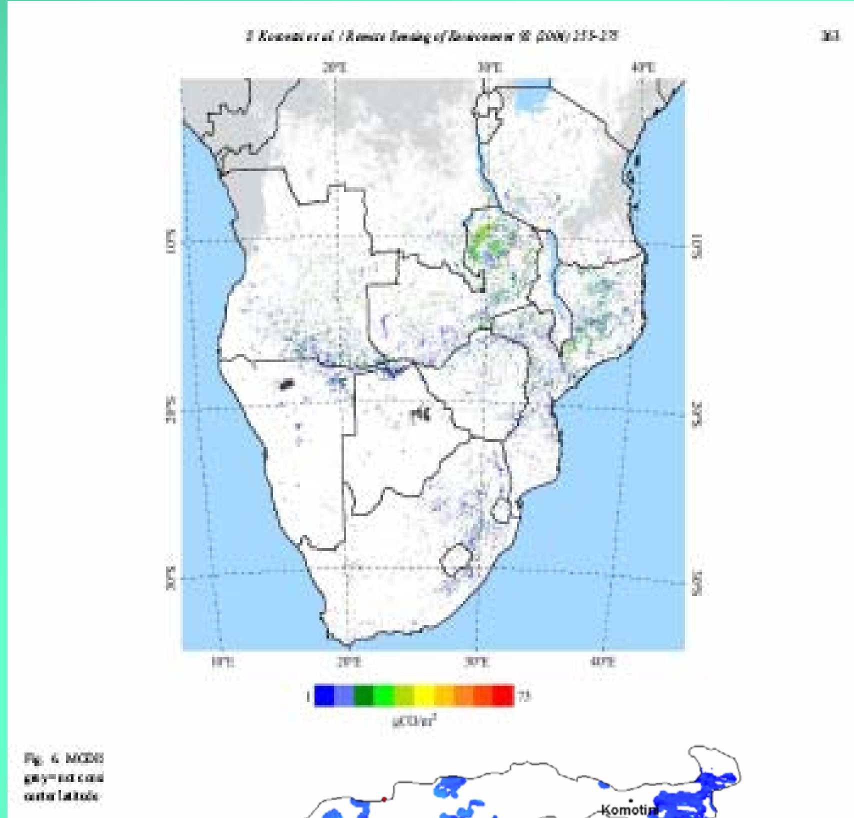
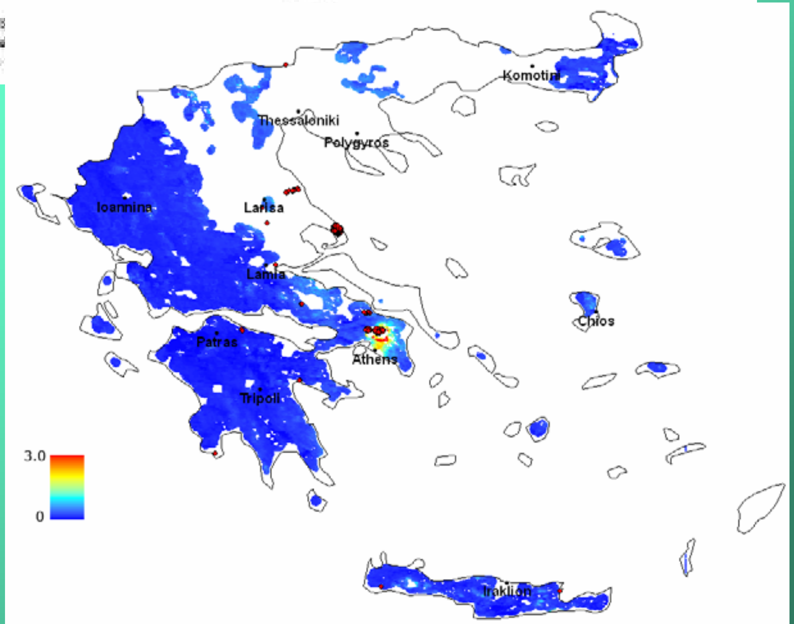


Figure 2. Fire emissions and the C_4 fraction of fire emissions from (a) Southeast Asia, (b) Central and northern South America, (c) southern South America, and (d) southern Africa. Fire emissions (left panel, left axis, solid line) are for total carbon and have units of Tg C/month. The C_4 fraction of fire emissions (left panel, right axis, dashed line) is unitless. Precipitation anomalies for each region (right panel, solid line) have units of mm/month. The precipitation anomalies were constructed by removing a mean seasonal cycle from 1997–2001 from each region.





Canadian Wildland Fire Information System

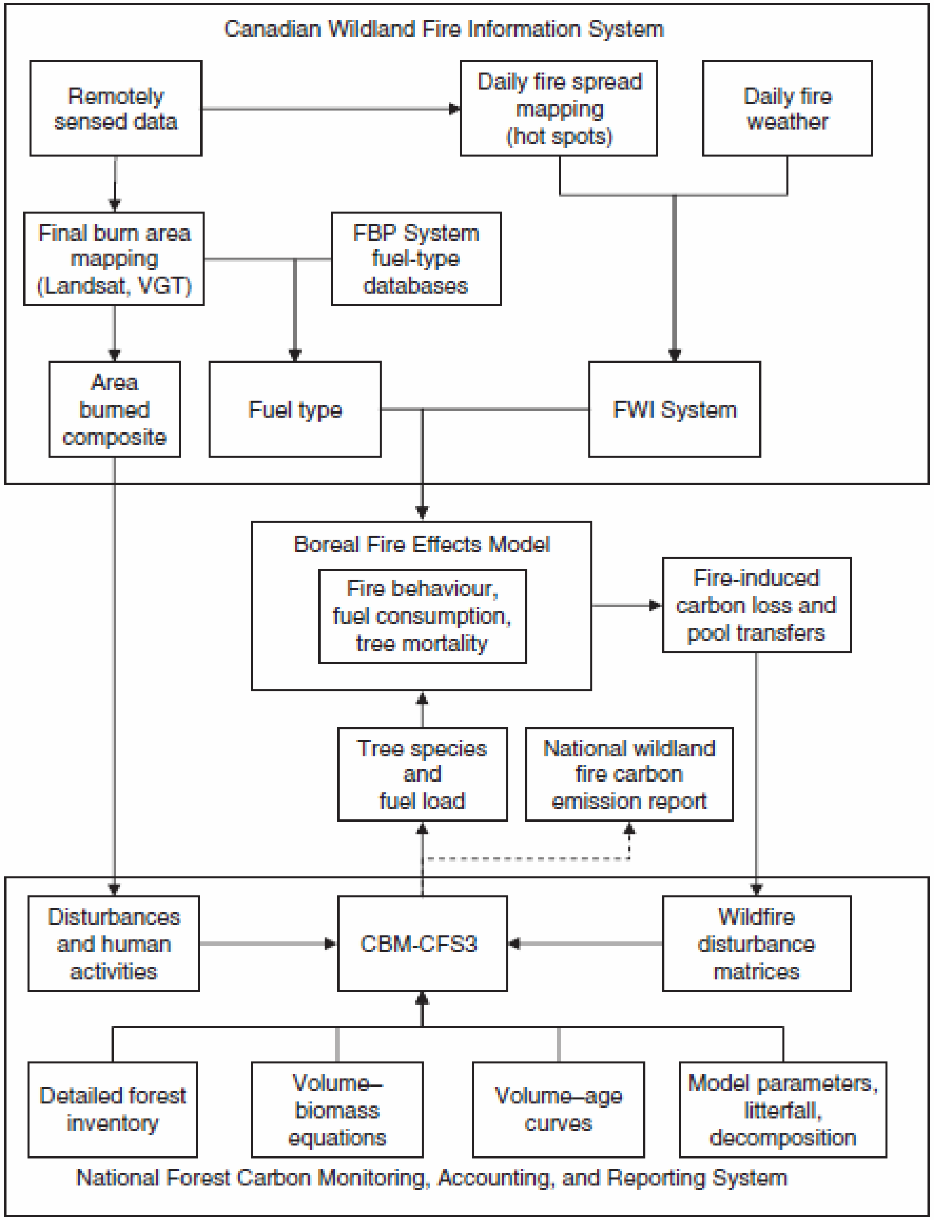


Fig. 1. National framework to estimate annual wildland fire carbon emissions. Dashed line indicates final step. FBP, Fire Behaviour Prediction; VGT, SPOT-VEGETATION sensor; FWI, Fire Weather Index; CBM-CFS3, Carbon Budget Model of the Canadian Forest Sector.

de Groot et al., 2007

Model of Biomass Burning Emissions

$$E = \sum_{k=1}^{K} \sum_{l=1}^{L} \sum_{j=1}^{J} \sum_{i=1}^{I} A_{ijkl} M_{ijk} C_{ijkl} F_{ijkl}$$

E	biomass burning emissions (kg)
A	burned area (km^2)
M	biomass density/fuel loading ($kg.km^{-2}$)
C	fraction of combustion
F	fraction of emission
i, j	fire (pixel) locations
l	fuel type
k	time period

Xiaoyang Zhang, NOAA/NESDIS/STAR

Emission parameters and Vegetation Types

Emission factors (kg species Mg^{-1} biomass burned) assigned to fires in each of the GLC land cover classes

GLC code	CO_2	CO	PM_{10}	$PM_{2.5}$	NO_x	NH_3	SO_2	NMHCs	CH_4
1	1588	117	12.5	9.9	1.3	0.7	0.8	8.1	6.6
2	1588	117	12.5	9.9	1.3	0.7	0.8	8.1	6.6
3	1569	94	12.5	11.2	2.1	0.6	0.8	6.8	4.5
4	1569	89	13.1	12.1	2.5	0.9	0.8	6.1	4.8
5	1569	89	13.1	12.1	2.5	0.9	0.8	6.1	4.8
6	1569	82	15.0	11.5	2.7	0.9	0.8	6.8	4.5
7	1569	82	15.0	11.5	2.7	0.9	0.8	6.8	4.5
8	1569	82	15.0	11.5	2.7	0.9	0.8	6.8	4.5
9	1630	84	6.9	5.6	3.2	0.6	0.5	3.2	3.1
10	1630	84	6.9	5.6	3.2	0.6	0.5	3.2	3.1
11	1630	84	6.9	5.6	3.2	0.6	0.5	3.2	3.1
12	1630	84	6.9	5.6	3.2	0.6	0.5	3.2	3.1
13	1630	90	12.5	9.5	6.5	0.6	0.5	5.0	3.1
14	1630	90	12.5	9.5	6.5	0.6	0.5	5.0	3.1
15	1630	90	12.5	9.5	6.5	0.6	0.5	5.0	3.1
16	1630	90	12.5	9.5	6.5	0.6	0.5	5.0	3.1
17	1630	90	12.5	9.5	6.5	0.6	0.5	5.0	3.1
18	1515	70	6.9	5.7	2.4	1.5	0.4	6.7	2.2
19	1515	70	6.9	5.7	2.4	1.5	0.4	6.7	2.2
20	1569	89	13.1	12.1	2.5	0.9	0.8	6.1	4.8
21	1630	84	6.9	5.6	3.2	0.6	0.5	3.2	3.1
22	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	1630	84	6.9	5.6	3.2	0.6	0.5	3.2	3.1
24	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	1630	84	6.9	5.6	3.2	0.6	0.5	3.2	3.1
26	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	1569	94	12.5	11.2	2.1	0.6	0.8	6.8	4.5
28	1630	84	6.9	5.6	3.2	0.6	0.5	3.2	3.1
29	1588	117	12.5	9.9	1.3	0.7	0.8	8.1	6.6

(from Wiedinmyer et al., 2006, Estimating emissions from fires in North America for air quality model, Atmospheric Environment, 40:3419-3432)

Fuel Combustion Factor

Percent Canopy, Shrub, Grass, or Duff Loading Consumed --- (Anderson et al., 2004)

$$C_L=100*(1-e^{-1})^{mcf}$$

C_L percent of fuel loading consumed for fuel type canopy, shrub, grass, and duff, respectively

mcf moisture category factor

The combustion factor for litter was assumed to be 100%.

Combustion factor for Coarse Woody Detritus (CWD):

$$C_w=0.6(0.31+(0.03*(0.31-mcf)))$$

Anderson et al. 2004 Fire Emission Production Simulator (FEPS) User's Guide (version1.0)

Emission Factor (kg/kg)

	Wet CH4	Moderate CH4	Dry CH4
Litter, w	0.001	0.001	0.001
Wood 1-3”	0.0022	0.0022	0.0022
Wood >3”	0.0054	0.0041	0.0035
Herbs and shrubs	0.005	0.005	0.005
Duff	0.0058	0.0063	0.0063
Canopy	0.005	0.005	0.005

Anderson et al. 2004 Fire Emission Production Simulator (FEPS) User’s Guide (version1.0)

Emission Factor (kg/kg)

	Wet CO	Moderate CO	Dry CO
Litter, w	0.0262	0.0262	0.0262
Wood 1-3”	0.0557	0.0557	0.0557
Wood >3”	0.1345	0.1029	0.0872
Herbs and shrubs	0.1246	0.1246	0.1246
Duff	0.1443	0.1581	0.1581
Canopy	0.1246	0.1246	0.1246

Anderson et al. 2004 Fire Emission Production Simulator (FEPS) User’s Guide (version1.0)

Live fuel moisture content

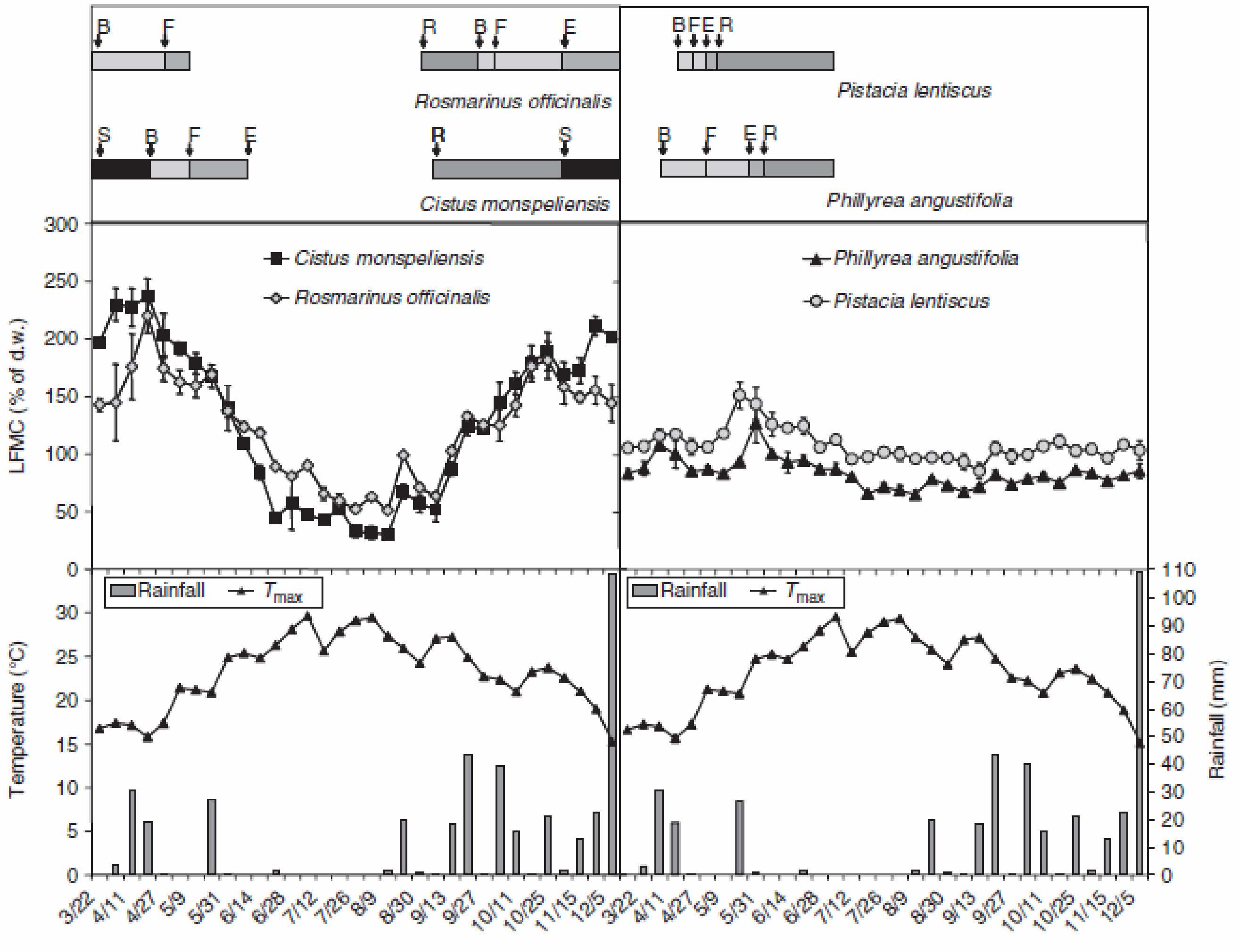
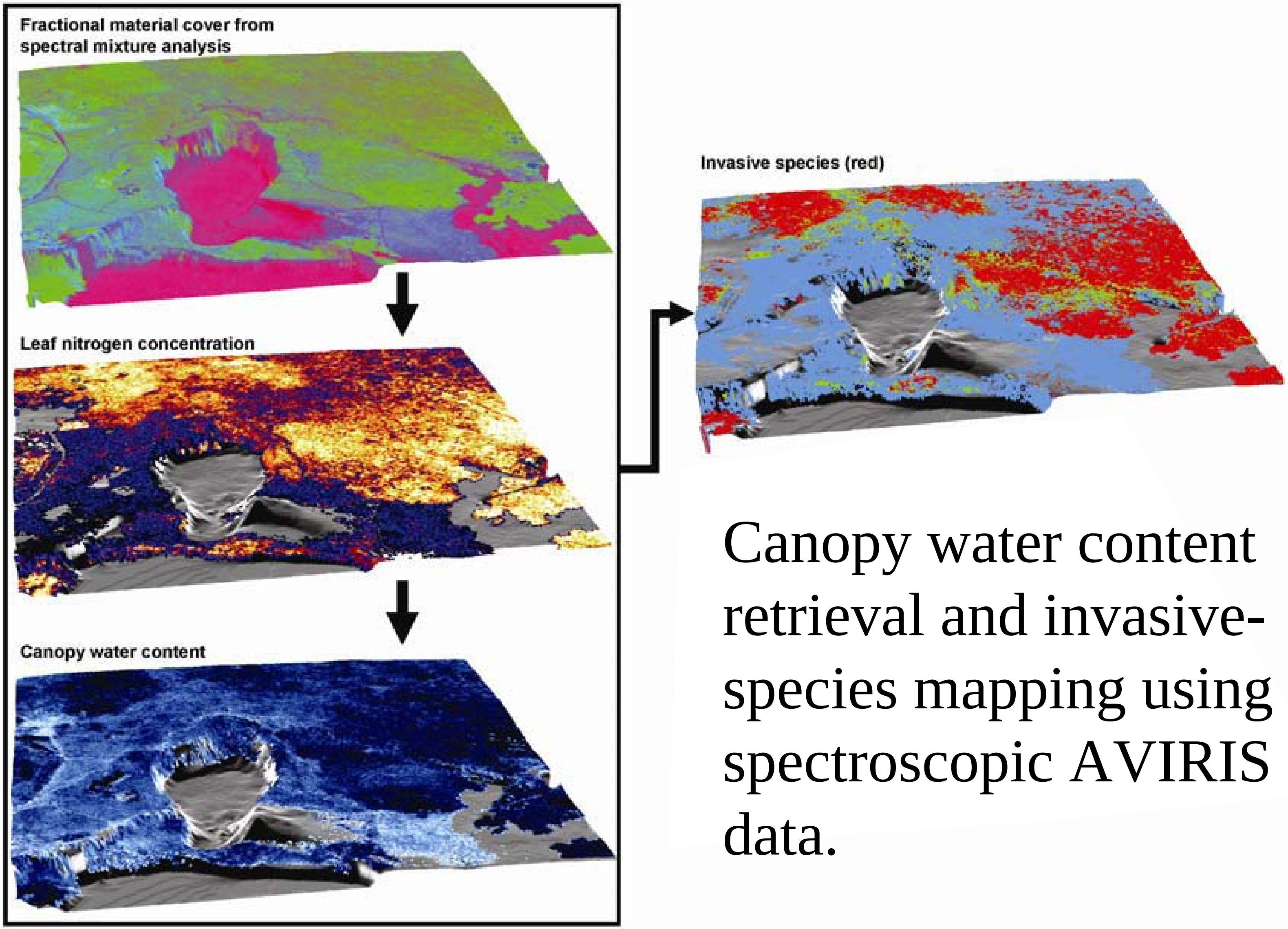


Fig. 2. Phenological diagrams (top) and live fine fuel moisture content (LFMC) (middle) of four shrub species during the period late March through December 2005. Rainfall totals cumulated between sampling dates and mean values of daily maximum air temperature (T_{max}) calculated over ten days before samplings are also shown (bottom). B, beginning of flowering; E, end of flowering; F, full flowering; R, resprouting; S, shoot elongation.

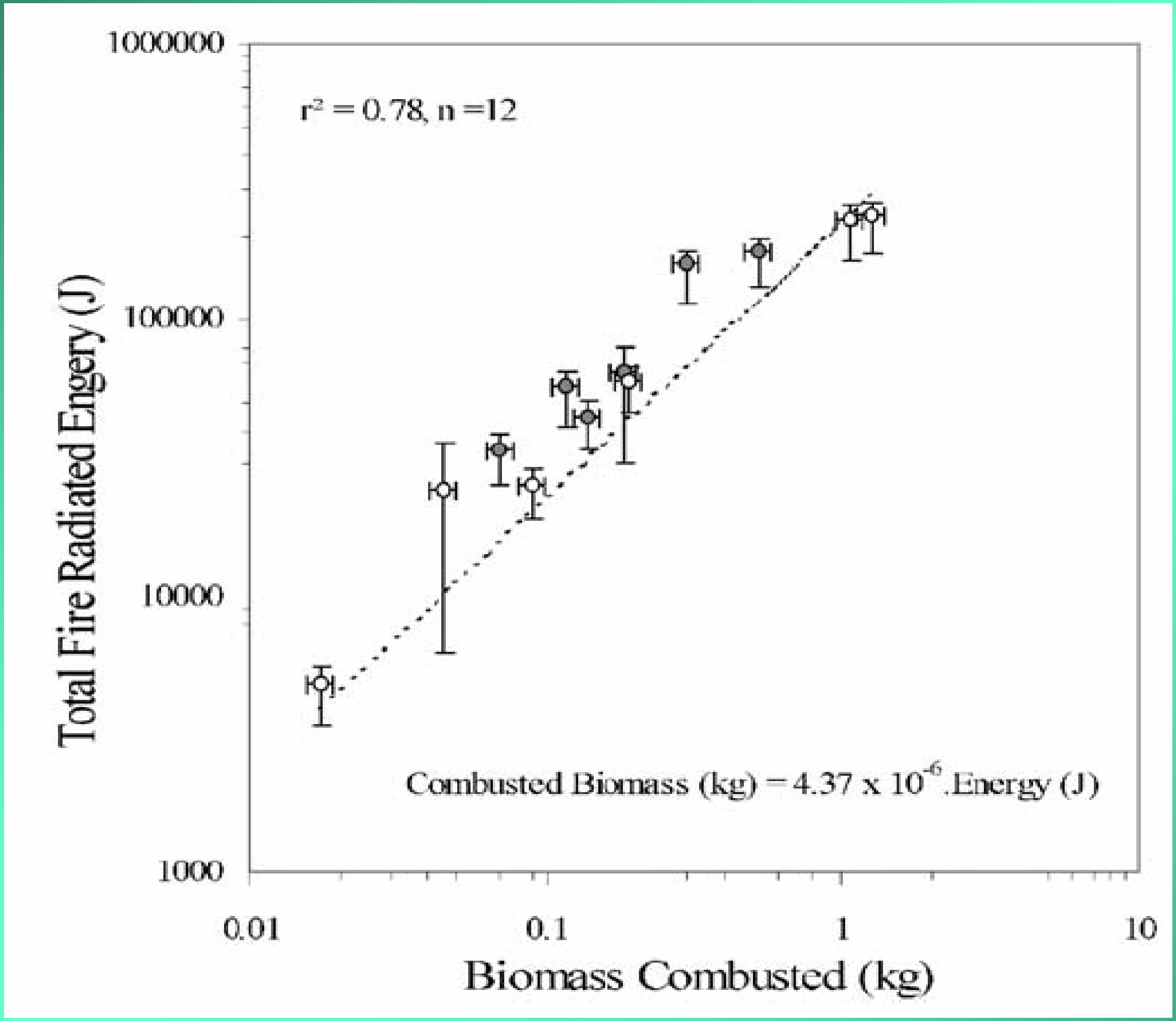
Pellizzaro et al., 2007



Canopy water content retrieval and invasive-species mapping using spectroscopic AVIRIS data.

Asner and Vitousek (2005)

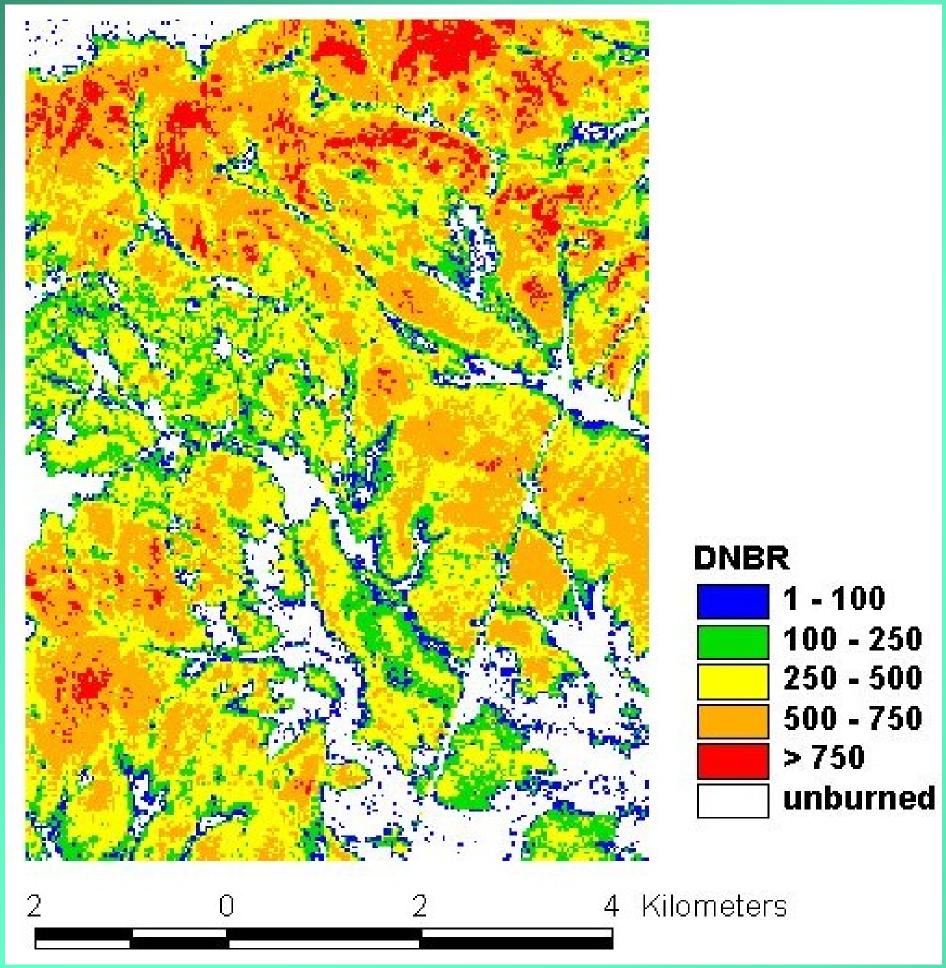
Fire Radiative Energy

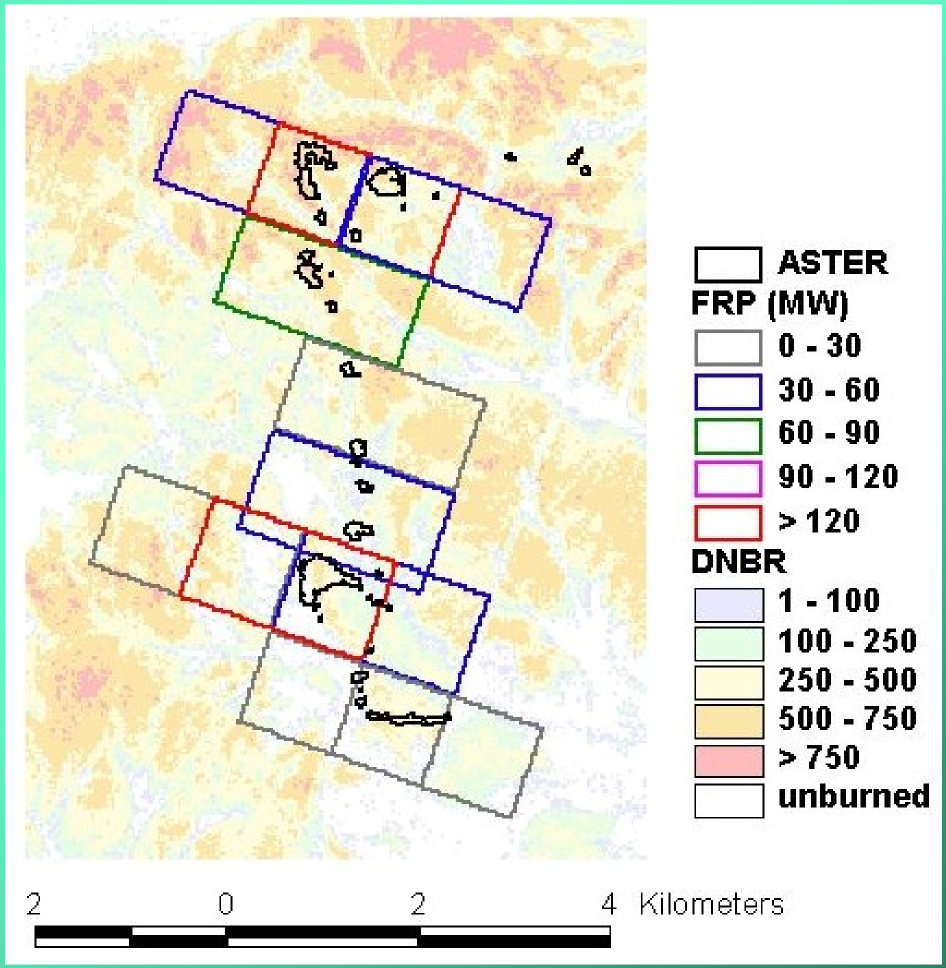


alternative approach for estimating fire emissions

Wooster et al 2002 and 2003

Combined evaluation of the combustion process

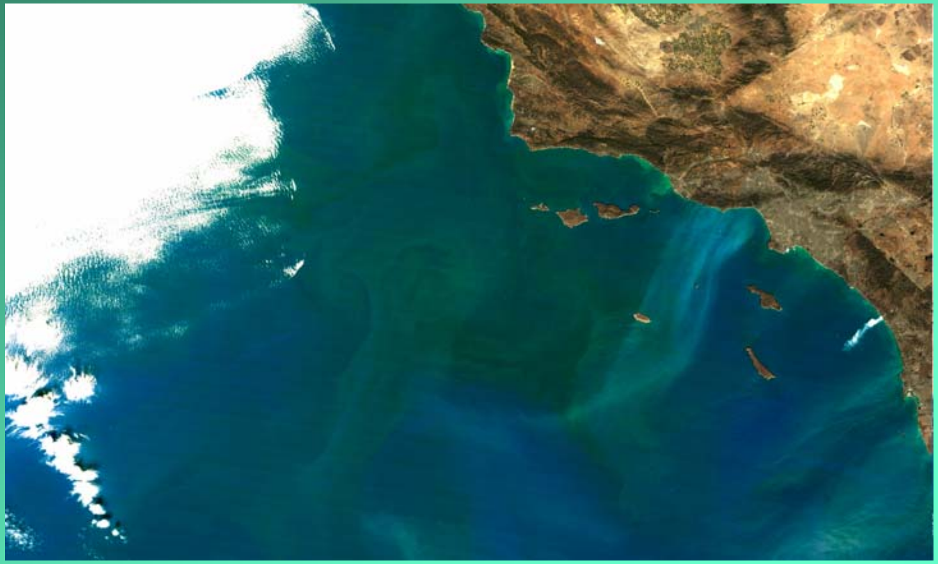




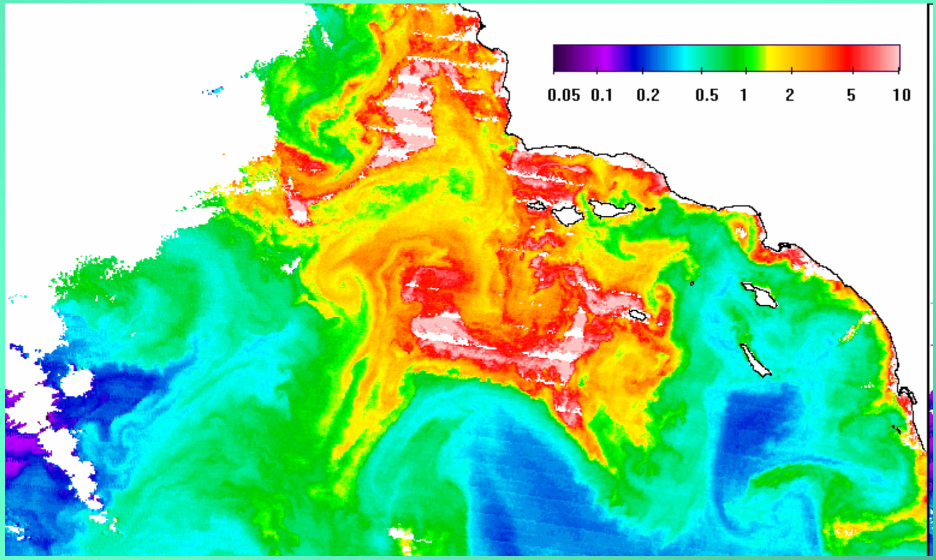
Csiszar et al., 2005

CQ2d: How do fires in coastal biomes affect terrestrial biogeochemical fluxes into estuarine and coastal waters and what is the subsequent biological response?

Nutrient transport into coastal waters -> phytoplankton bloom



MODIS bands 1,4,3 RGB



Chlorophyll-a concentration [mg m^{-3}]

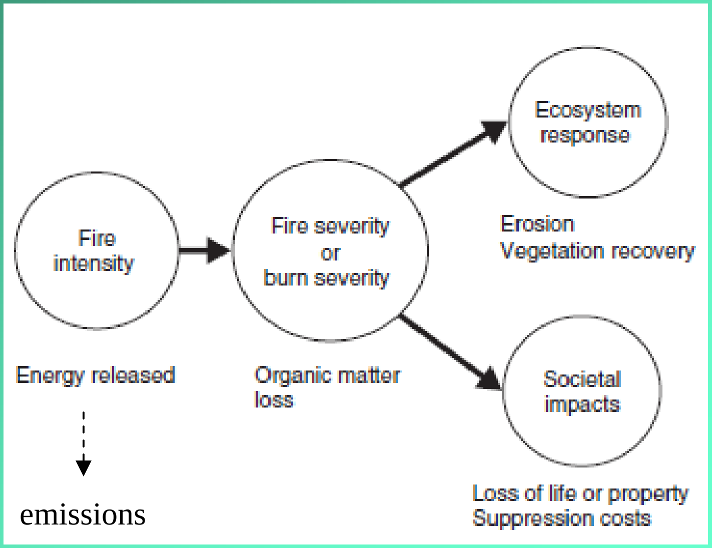
(a) better characterization of smoke amount/composition
- indirect: VSWIR (Fuel burned) + TIR (combustion process)
- direct: VSWIR – smoke/aerosol characterization

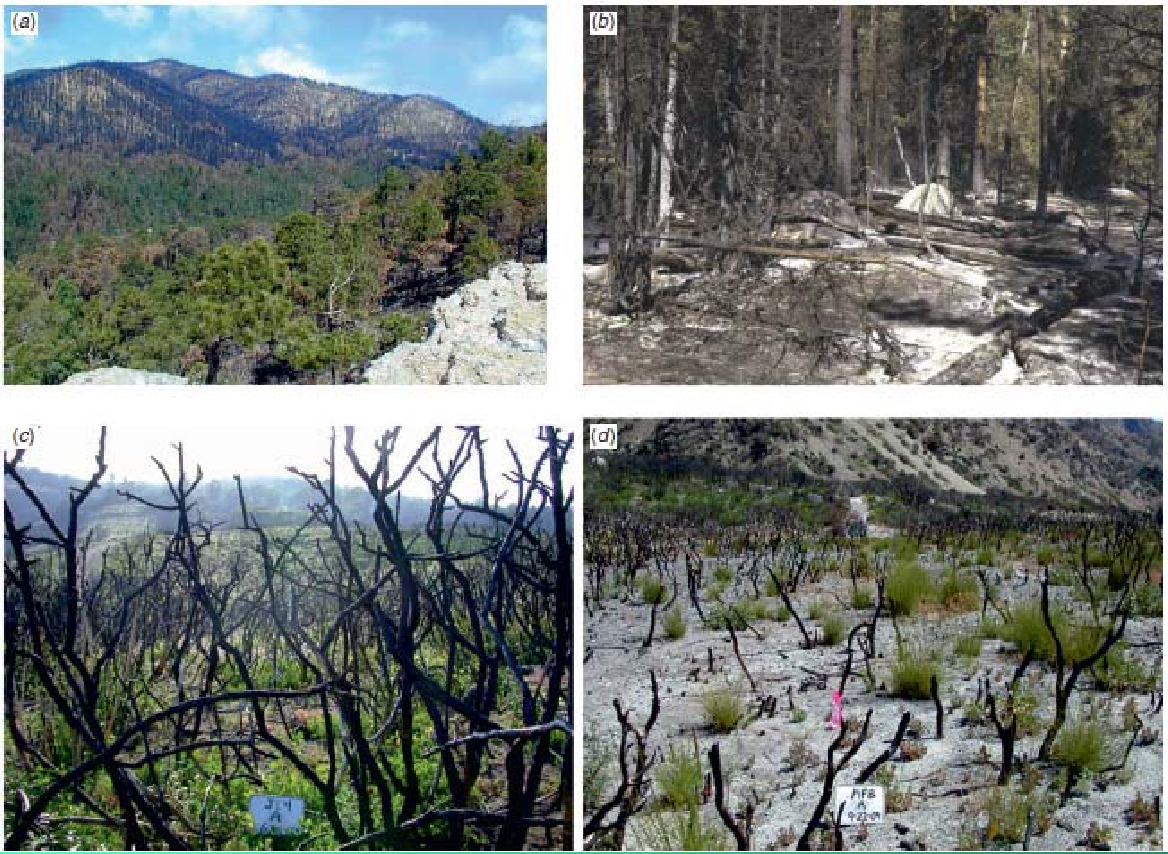
(b) better characterization of runoff/discharge
- ash type / burn severity

Imagery courtesy Mati Kahru, Scripps Photobiology Group

CQ2e: How does vegetation composition influence wildfire severity?

Fire intensity, fire severity

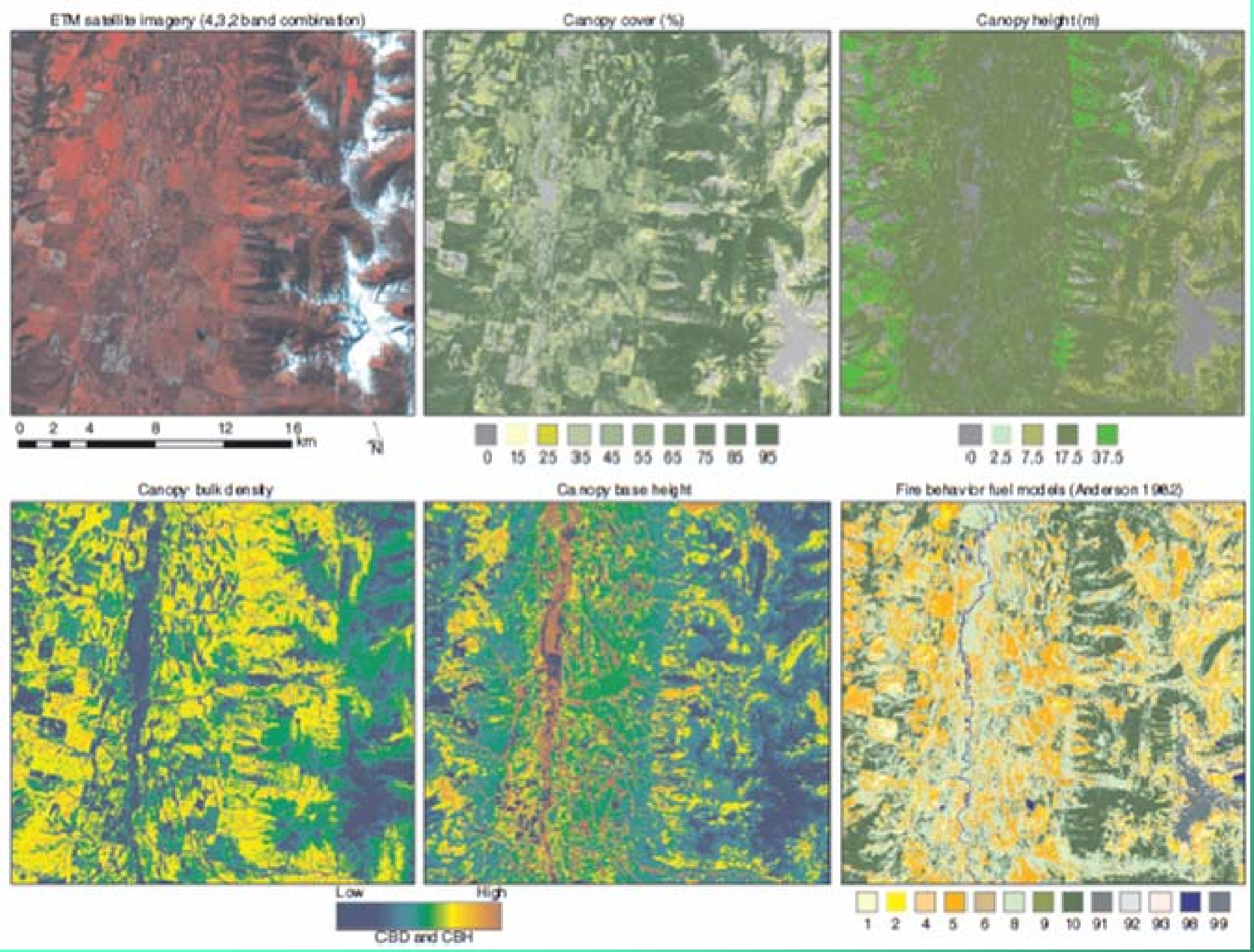




Keeley, 2009

Variations of burn severity

LANDFIRE: fuel characterization



Reeves et al., 2009

NBR/dNBR in Boreal Alaska

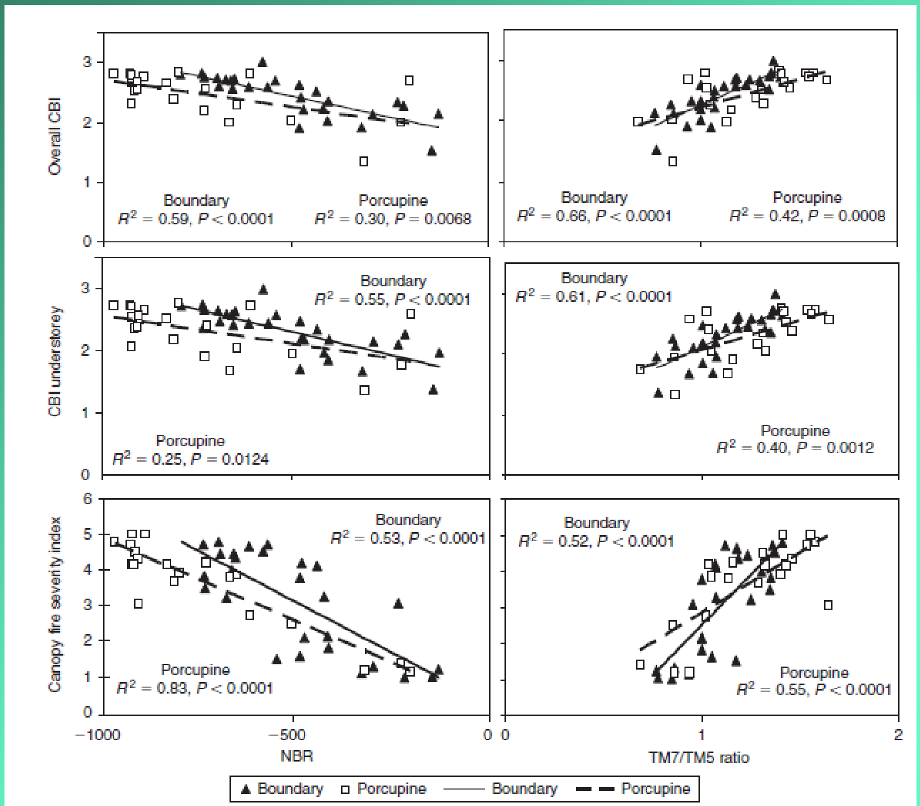
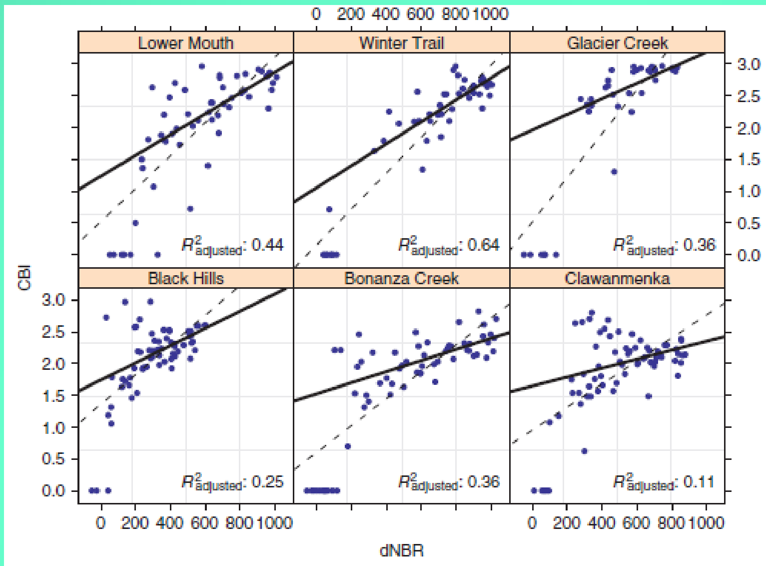
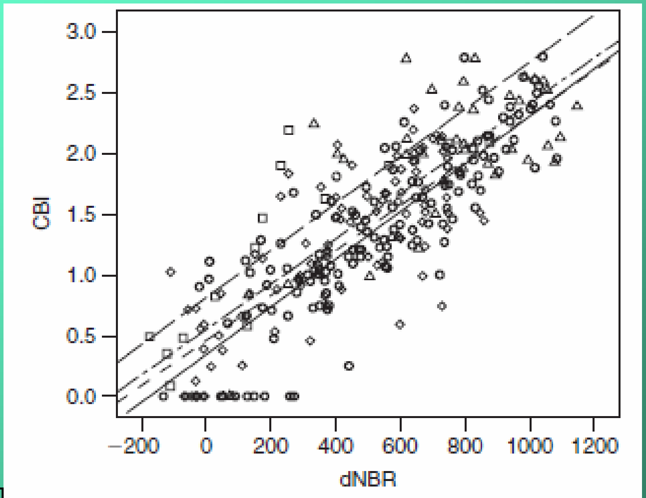


Fig. 6. Single-date comparison of the NBR and 7/5 ratio indices *v.* three different ground measures of fire severity for data from the Boundary and Porcupine Fires. These plots represent those indices that showed the greatest potential to estimate fire severity.

Hoy et al., 2009



Murphy et al., 2009

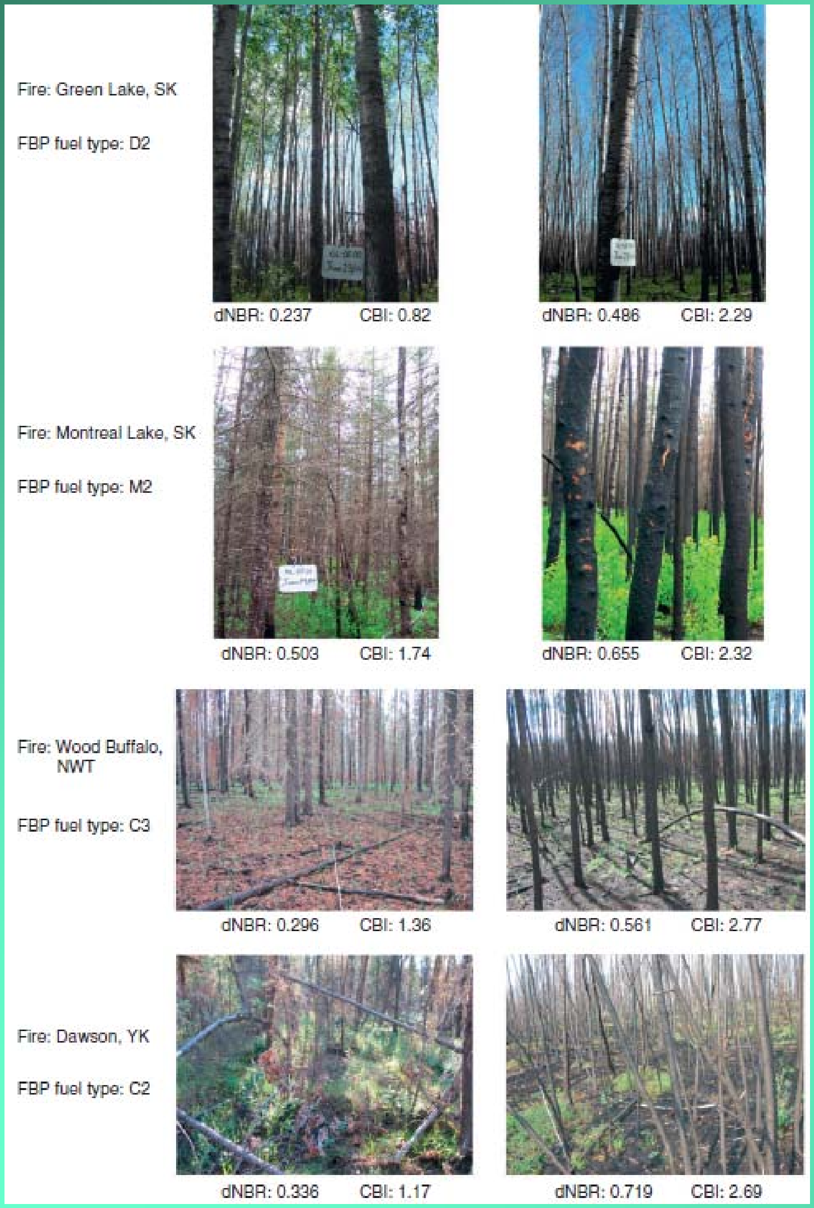


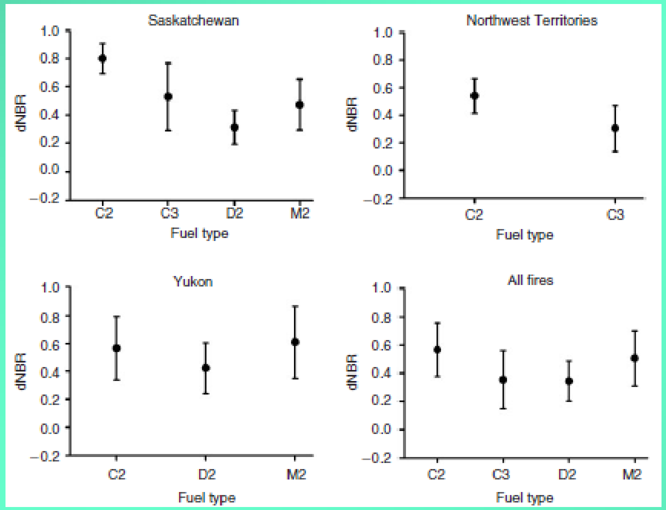
Allen et al., 2008

Also, dependence on image acquisition dates (phenology, illumination angle) (Verbyla et al., 2009).

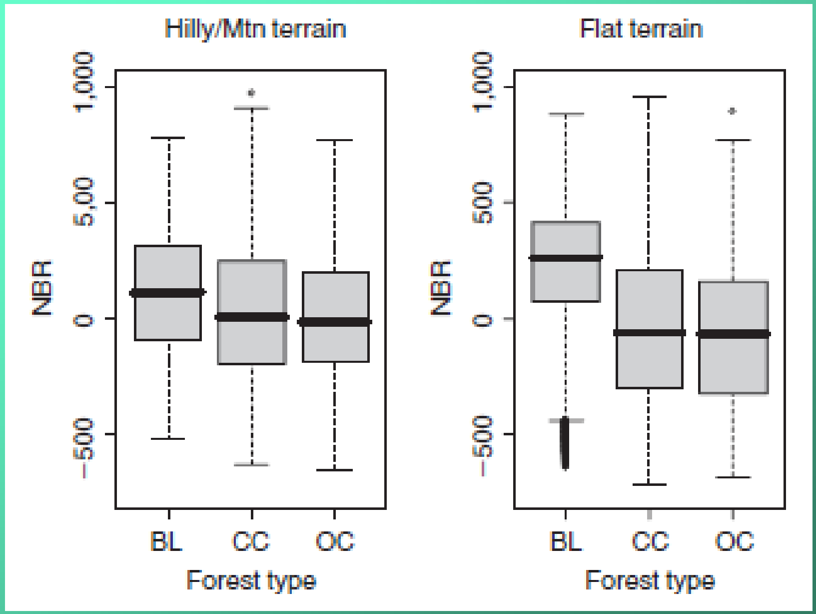
Also: French et al., 2008

Fuel type and burn severity





Hall et al., 2008



Duffy et al., 2006

CQ2f: On a watershed scale, what is the relationship of vegetation cover, clay-rich soils, and slope to frequency of debris flows?

Impacts on soils

- Water runoff and soil erosion
- Need for rapid post fire assessment and treatment

Southern California Wildfires: Oct 21, 2003

280,000 ha burned
22 fatalities
~$2B in direct losses

Southern California Wildfires: Nov, 2007

210,000 ha burned
6 fatalities
~$1.5B in direct losses

Southern California setting:

- Steep, tectonically-active mountain ranges
- Deeply-incised, tightly-confined channels
- Abundant, readily-eroded materials
- The occasional rainstorm
- A population at risk from debris flows

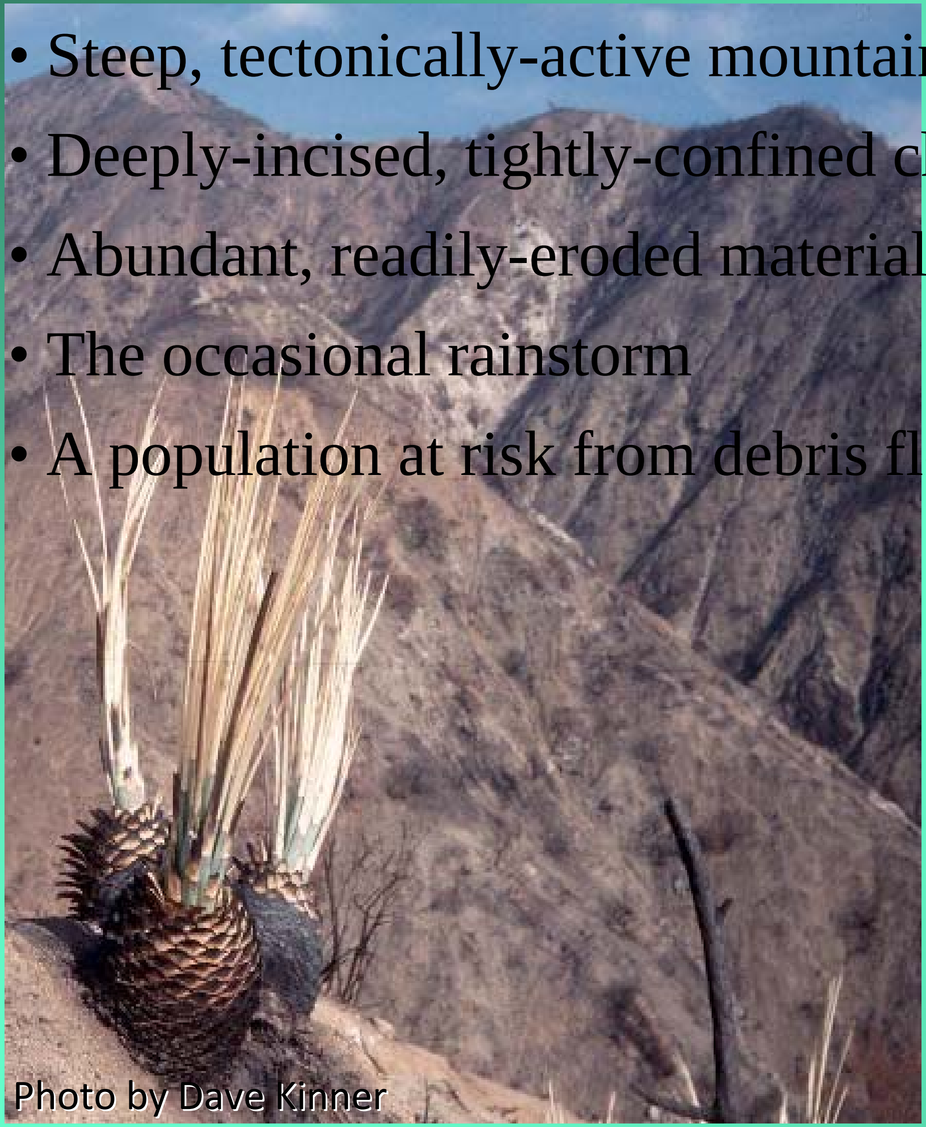


Photo by Dave Kinner

(Susan Cannon, USGS)

Southern California setting:

Debris-flow probability =

$$e^x/1+e^x$$

x = f(length of the longest flow path in the basin,

- change in basin elevation,
- percentage of the basin burned at high and moderate severity,
- percentage of the burned basin with gradients GE 30%,
- soil clay content and erodibilty,
- storm duration and

average storm rainfall intensity)

(Susan Cannon, USGS)

USGS science for a changing world

Intermountain west setting:

Debris-flow probability =

$$e^x/1+e^x$$

x = f(percentage of the basin area with gradients GE 30%,

• basin ruggedness (change in basin elevation divided by the square root of the basin area),

• percentage of the basin burned at high and moderate severity,

• soil clay content and liquid limit,

• average storm rainfall intensity)

(Susan Cannon, USGS)

Level 2 VSWIR/(M)TIR data products

- Pre-fire multi-spectral products
  - Level 2
    - orbital mask
    - 19-day (monthly?) composites with time stamp
  - Level 3
    - spatially (and temporally) aggregated for
      - input to fire danger models
      - climate models/studies

Level 2 VSWIR/(M)TIR data products

- Active fire detection and characterization
  - Level 2
    - orbital mask
    - fire characteristics (FRP, area/temperature)
  - Enhanced products from Level 2
    - cluster size
    - cluster shape
    - cluster mean temperature and variability
    - fuel characteristics and condition
    - statistical distributions
  - Level 3
    - spatially aggregated (grid size/aggregation period TBD)
    - seasonal (?) temporal composite
      - fire pixel density
      - gridded mean fire temperature
      - gridded mean FRP

Level 2 VSWIR/(M)TIR data products

- Post-fire multi-spectral products
  - Level 2
    - orbital mask
    - 19-day (monthly?) composites with time stamp
  - Level 3
    - spatially (and temporally) aggregated for
      - input to emission models
      - climate models/studies

Validation

- Pre-fire
  - validation activities for general vegetation characterization products
    - add fire-specific variables as applicable
- Active fire
  - higher resolution imagery, in-situ, post-fire confirmation
  - opportunistic validation through agency data
- Post-fire
  - EOS/CEOS validation activity and protocol – data intensive
  - increased role of in-situ
- Logistical issues for active fire and post-fire because of dynamic nature of fire activity