Spectral analysis of biomass burning potassium emission signatures from current airborne to next generation hyperspectral missions.

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forest fire in Nurallao, Sardinia in Cagliari province of Italy taken by Joseph Loddo

Overview

ASI-AGI project
Fire detection indeces for PRISMA

- Introduction
- PRISMA mission
- ASI-AGI project
- Spectral features of fires
- Fire localization by K emission
- Multiple scale approach
- Summary

Wildfire Europe

European Forest Fire Information System
Supporting the Member States in forecasting forest fire danger and assessing fire damage

Fires affect the global climate through processes such as trace gas and aerosol production, and by changes to terrestrial carbon dynamics.

• Fires consume trees and other forest resources that may otherwise be harvested.

• Fires are a source of severe local air pollution for residents nearby.
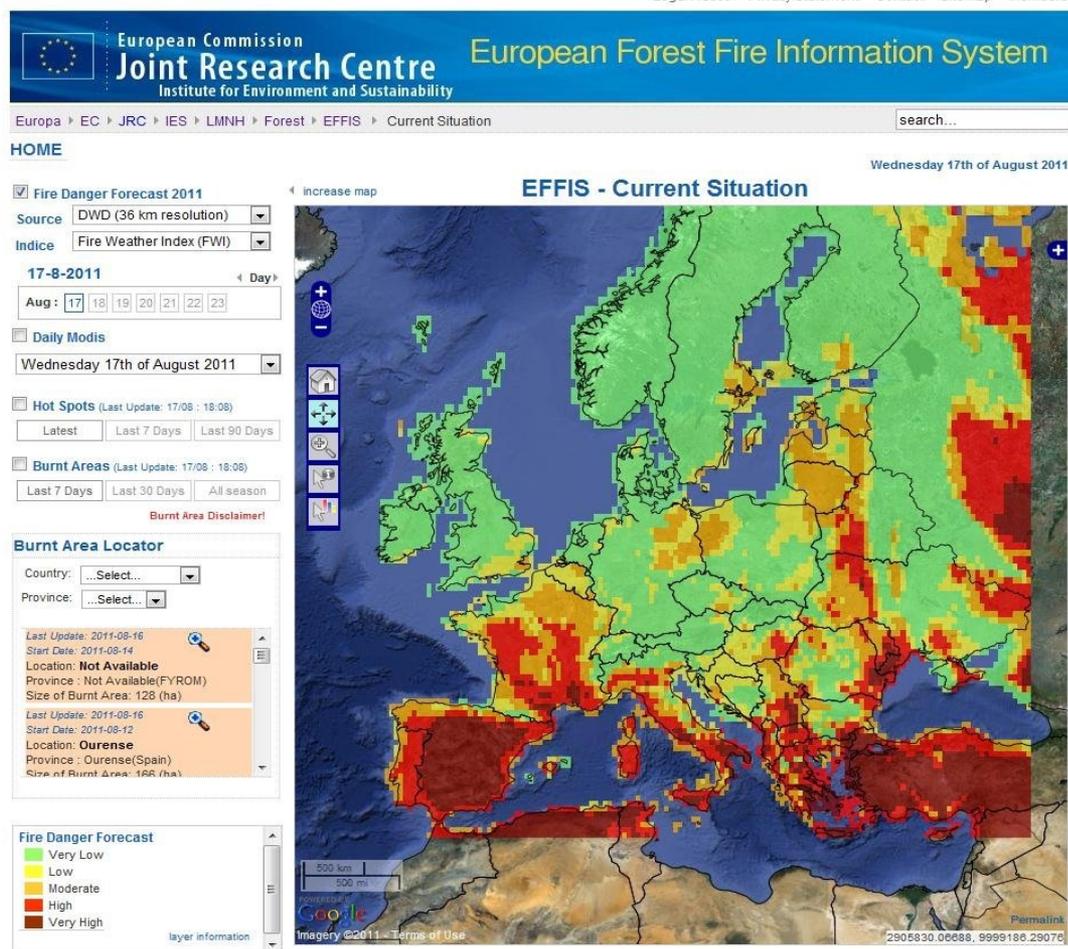
Wildfire in Italy

- From January 2013:**1.850** occurred in Italy
- **Area: 13.630 hectar=3368acres [6.370 hectar=15740ac woodland and 7.260hectar=17939ac no woodland.**
- **Up to 14 August 2013 high crisis level interested Puglia (356), Sardegna (262), Sicilia (242), Campania (183), Piemonte (106) e Calabria (98).**
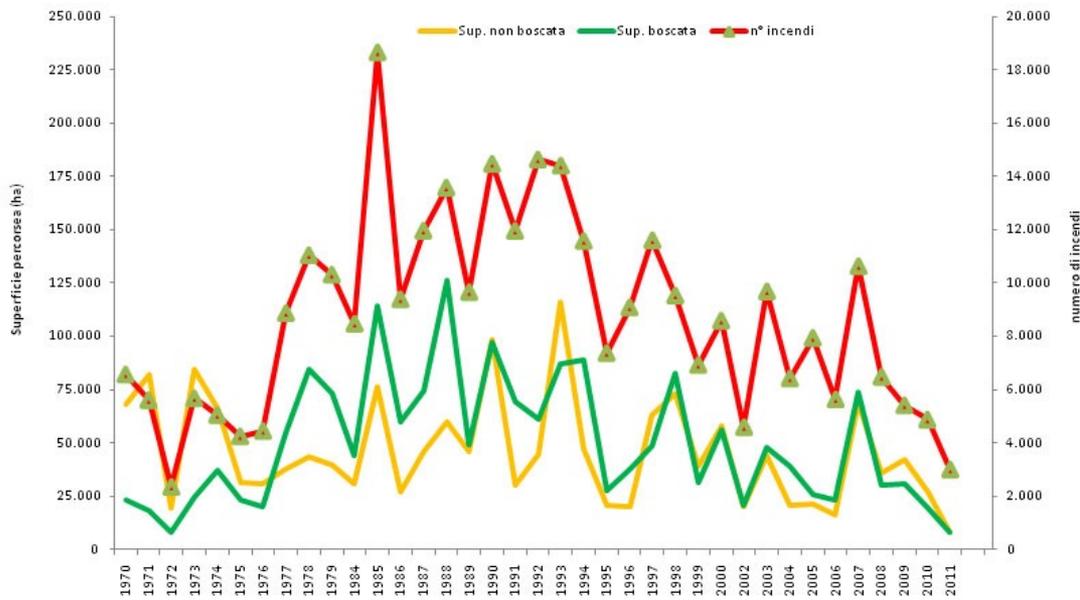
Lovreglio R et al.   2012

Data source: Corpo forestale dello Statottp://www3.corpoforestale.it/

Prisma mission

PRISMA (PRecursore IperSpettrale della Missione Applicativa) Hyperspectral Payload is an Electro-Optical instrument composed of a high spectral resolution spectrometer optically integrated with a medium resolution panchromatic camera.

The instrument is the focus of the Earth Observation PRISMA mission, fully funded by ASI (Agenzia Spaziale Italiana) and developed by a consortium of Italian companies, lead by CGS as S/C responsible. PRISMA is: "a pre-operative small Italian hyperspectral mission, aiming to qualify the technology, contribute to develop applications and provide products to institutional and scientific users for environmental observation and risk management ..."

In this context SELEX Galileo has the full responsibility of the Electro-Optical Payload (**Hyperspectral and Pancromatic cameras**); in addition, SELEX Galileo provides the following items: a) PhotoVoltaic Assembly (PVA); b) Power Control & Distribution Unit (PCDU) for the S/C; c) AA-STR Autonomous Star Tracker for S/C attitude control and is also responsible of Data Products management (Level 0 and Level 1).

PRISMA Mission is based on previous experiences carried out by SELEX Galileo under ASI studies for Earth Observation, namely the programs **HypSEO** phase B (first study) and **JHM** (Joint Hyperspectral Mission) phase A (mission and instruments refinement).

The launcher baseline (which will be provided by the Agency) is **VEGA**, but the Mission design will be compatible also with other launchers to maintain the maximum flexibility.

PRISMA context background

2016-17

2012-15

2008-14

System deployment

Operational mission

Future ...

+ TBD

System consolidation and development

System design and development

PRISMA

2006-07

System architecture & preliminary design

User Needs - consolidation

JHM

2000-02

Critical technologies developments

System architecture & preliminary design

User Needs

Hypseo
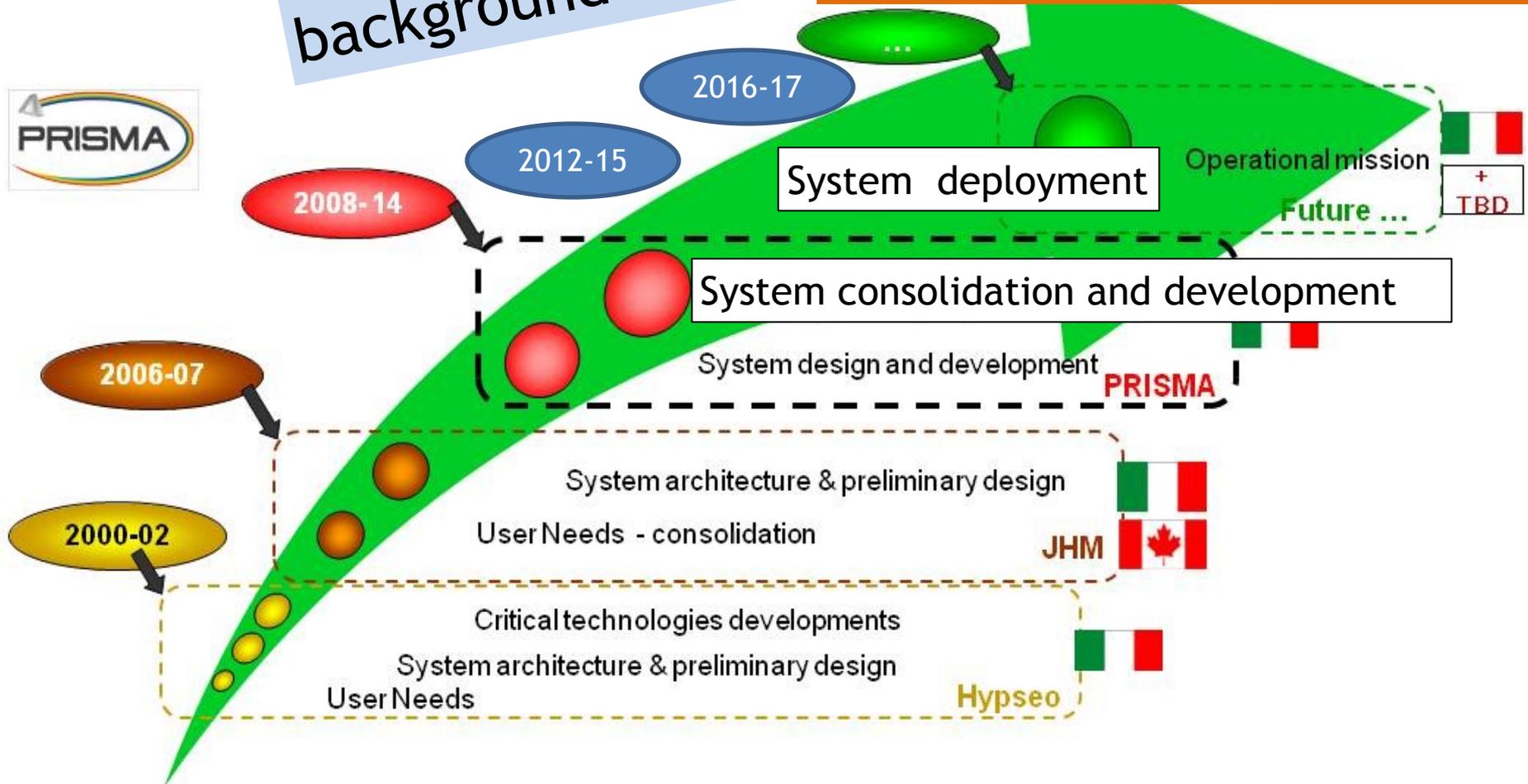
Prisma mission

Orbit	sun synchronous
Orbital Altitude	615 Km
Inclination	97.851°
LTDN	10:30 a.m.
Orbital period	about 97 min (5819.7 sec)
Average eclipse duration	about 34 min (2048sec)
Beta Angle	from 16.1 to 26.6 deg
Repeat cycle	29 days (430 orbits)
Relook time	7 days
Area Of Interest (AoI)	longitude from 10°W to 50°E, latitude from 30°N to 70°N
Outside AoI	40° latitude window per orbit at every latitude in the range 70°N – 60°S
Swath / GSD	30 Km / 30m
Off- Nadir	18.2°
AoI access duration	Average Duration 8.44 min Maximum Duration 11.19 min
Lifetime	5 years
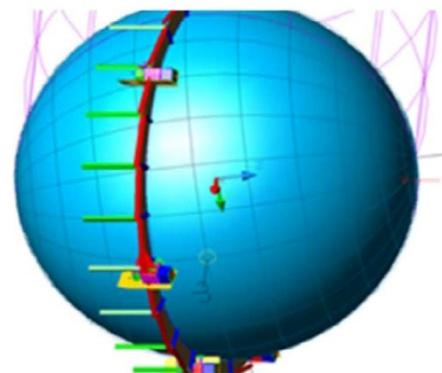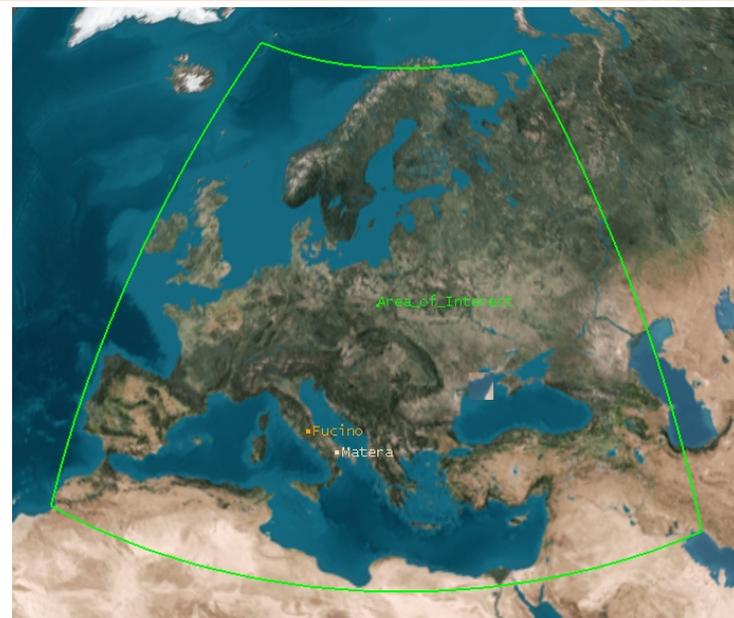
PRISMA Mission Overview

(Courtesy of SELEX-GALILEO)

Prisma mission

Instrument characteristics

| Reference Orbit Altitude	615 Km
Swath / FOV	30 Km / 2.77°
GSD	Hyperspectral: 30 m PAN: 5 m
Spatial Pixels	Hyperspectral: 1000 PAN: 6000
Pixel Size	Hyperspectral: 30x30 μm PAN: 6.5x6.5 μm
Spectral Range	VNIR: 400 – 1010 nm SWIR: 920 – 2500 nm
Spectral Sampling Interval (SSI)	≤ 11 nm
Spectral Width	≤ 12 nm
Cross-Track Variation of Centre Wavelength (Smile)	< +/- 0.1 SSI
Spatial registration of spectral sampling (incl. Keystone)	≤ 0.1 pixel
Spectral Calibration Accuracy	+/-0.1 nm
Radiometric Quantization	12 bit
VNIR SNR	> 200:1 on 400 – 1000 nm > 600:1 @ 650 nm
SWIR SNR	> 200:1 on 1000 – 1750 nm > 400:1 @ 1550 nm > 100:1 on 1950 – 2350 nm > 200:1 @ 2100 nm
PAN SNR	> 240:1
Absolute Radiometric Accuracy	Better than 5%
Aperture Diameter	210 mm
MTF	VNIR @ Nyquist Frequency > 0.3 SWIR @ Nyquist Frequency > 0.3 PAN @ Nyquist Frequency > 0.2
Cooling System	Passive Radiator
Lifetime	5 years

- Area of interest:
  - Re-look time: < 7 days
  - Response time: < 14 days
- Mission modes:
  - Primary: User driven
  - Secondary: Data driven (background mission)

Swath / FOV: 30 km / 2.45°

Aperture diameter: 210mm

Absolute radiometric accuracy: <5%
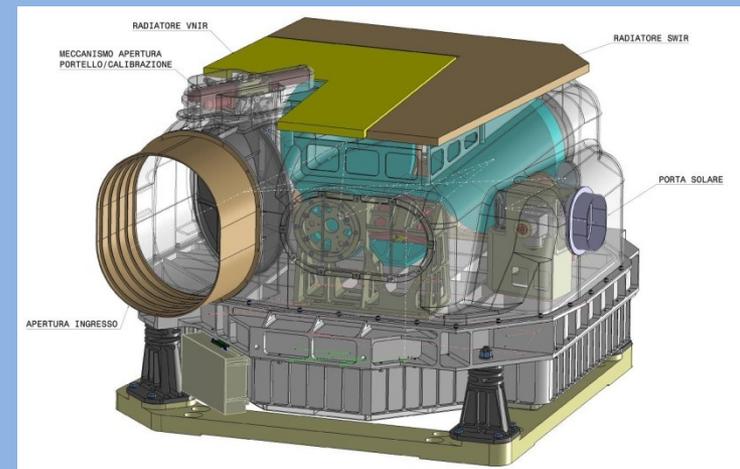
Courtesy of SELEX-GALILEO

ASI-AGI

- National competition for 5 scientific projects
- Duration: 4 years
- 2 main tasks:
  - Research on specific theme reffering to the ASI list of applications using simil-PRISMA data and, ~~after launch~~, PRISMA data
  - Scientific support to ASI PRISMA project team
- Identification of 5 Principal Investigators (PIs) in a Scientific Advisory Team
- Common Kick Off: 14/04/2011

Hyperspectral systems analisys for integrated geophysical applications (ASI-AGI) -INGV

PRISMA DATA SIMULATION

COMMON UTILITIES

GEOMORPHOLOGY AND SPECTROSCOPY

VOLCANIC APPLICATIONS

FIRE APPLICATONS
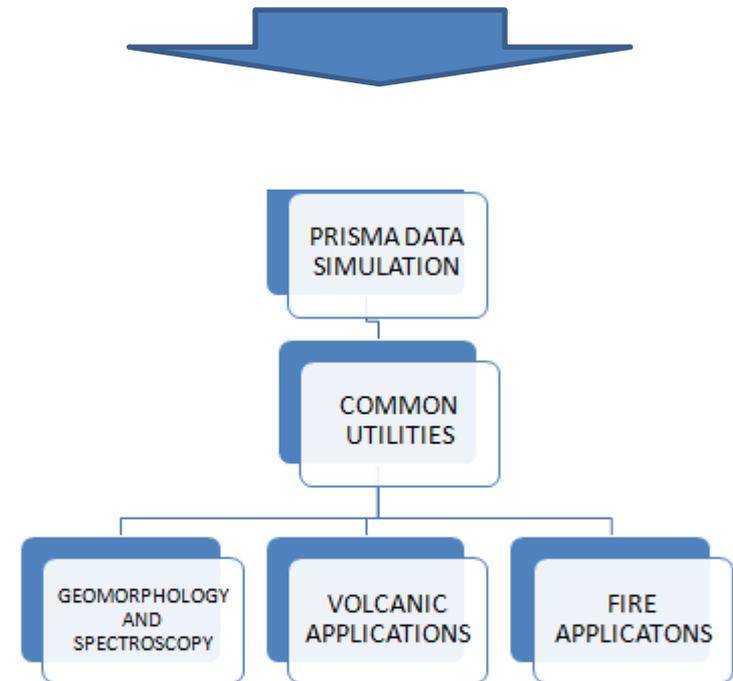
Fire Energy Emissions

Thermal remote sensing studies of actively burning wildfires are usually based on the detection of Planckian energy emissions in the MIR (3-5 μm),

LWIR (8-14 μm)

and/or SWIR (1.0-2.5 μm) spectral regions
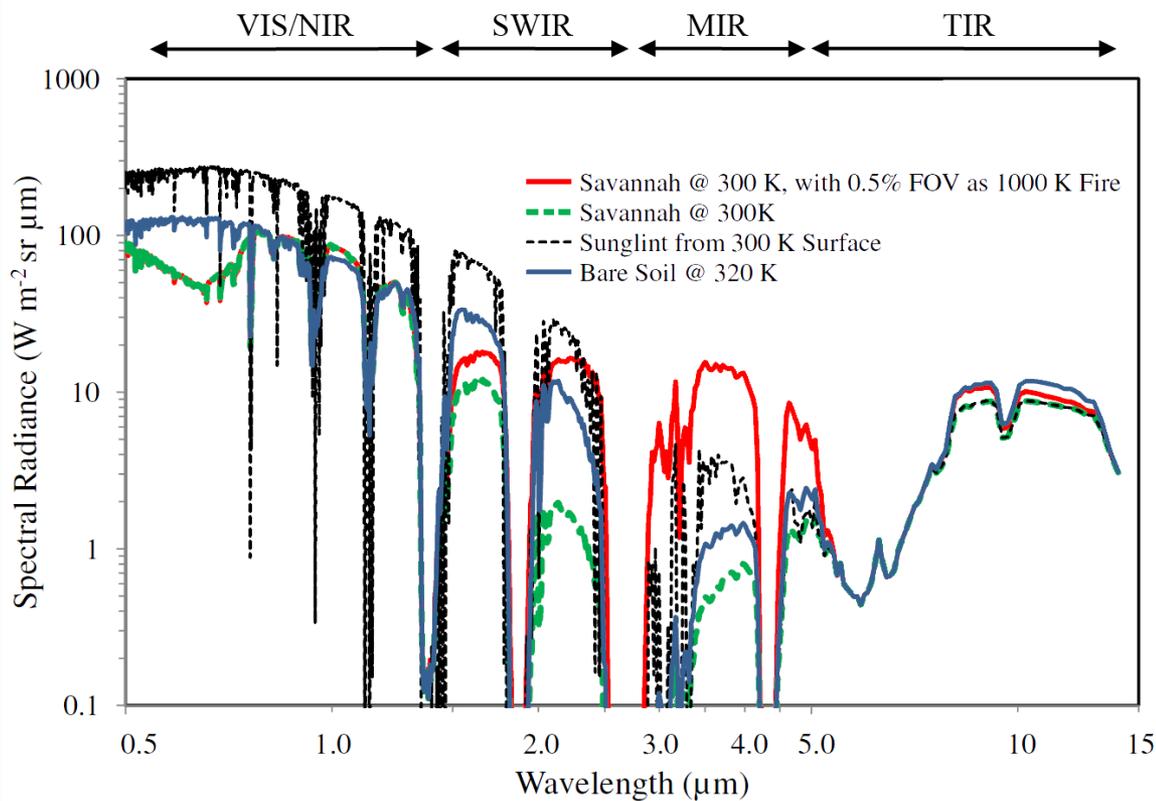
K emission

Fuel **biomass** is largely composed of **carbon (~50%), hydrogen (5.5%), oxygen (41%),** and **nitrogen (3.5%),** and the **molecular combustion products are dominantly CO_2, H_2O, CO, CH_4, and various nitrogenous compounds** (Levine, 1991)

However, in addition to their primary C, H, O and N constituents, vegetation contains many trace elements and some of these (Na, K, P) display narrow and unique spectral emission lines when heated to high temperatures.
The main trace element resulting in the appearance of spectral emission lines appears to be Potassium
(K), with features at 766.5 nm and 769.9 nm

NIR

Oxygen absorption lines
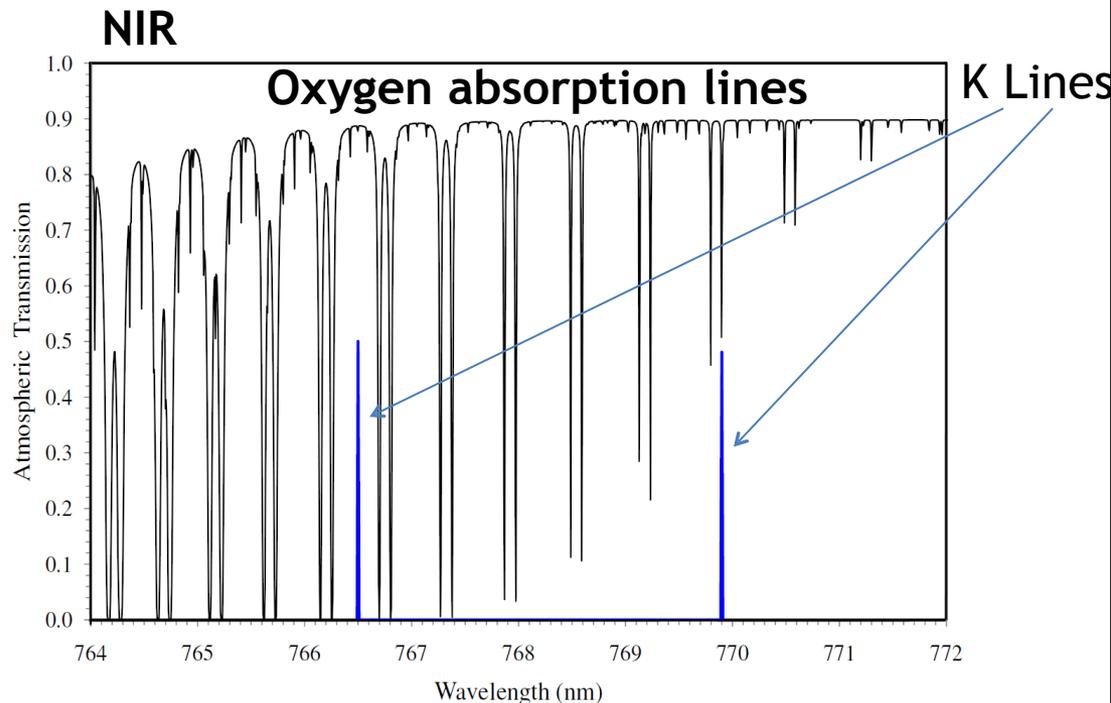
K Lines

Potassium Emission Line (Simulation) Simulated Earh atmosphere. Transmission was calculated as viewing the Earth from100 kmelevation at nadir and assuming a US 1976 Standard Atmosphere and a 23 km rural aerosol. Simulation wasconducted at 0.1 cm−1 wavenumber resolution using the high spectral resolution mode of MODTRAN 5.2 (Berk et al., 2008)

Multiple scale approach

- Potassium Emission   for forest fire localization at:
- Lab. Scale
- Airborne
- Satellite scale

Lab.scale experimen

| Sensor	Spatial resolution	Central band
Hyperion	*30m*	*772nm*
HyspIRI	*60m*	*770nm*
PRISMA	*30m*	*770nm*

GER 3700 field spectroradiometer fitted with a 10° FOV foreoptic and measuring across the 0.4–2.5 µm spectral region (using a 1.5 nmsampling interval in the K-line spectral region),
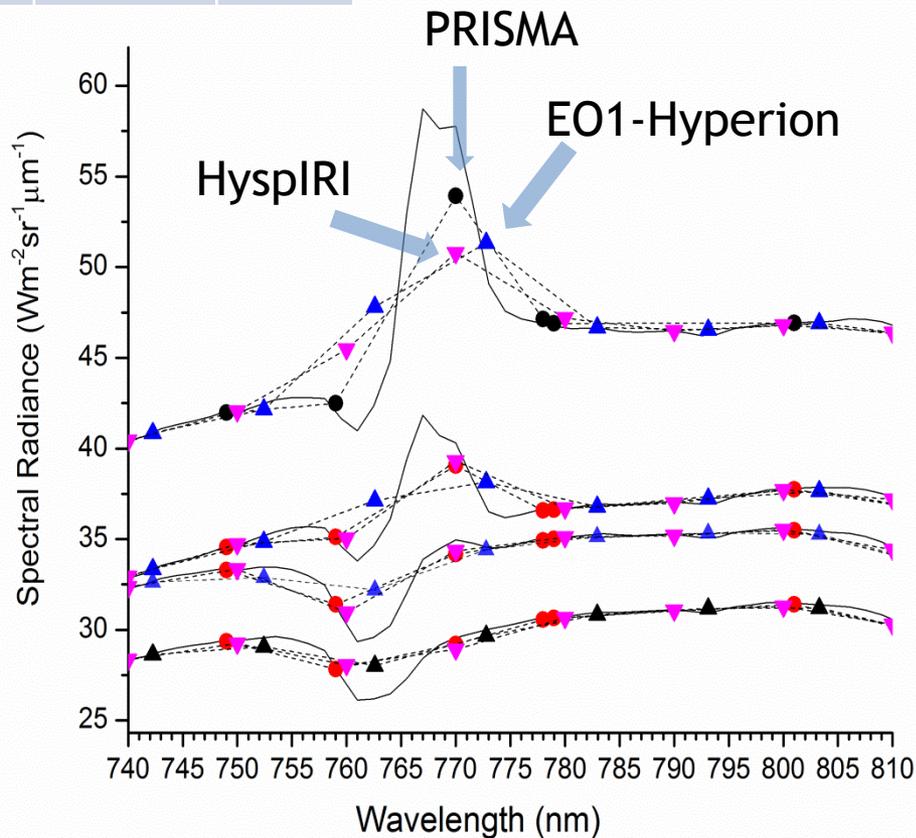
Flaming

Mixed<

Mixed

Smoulderin

PRISMA

EO1-Hyperion

HyspIRI

spectrum 1

88s

spectrum 2

180s

spectrum 3

455s

spectrum 4

1490s

Airborne –satellite data set

- **Sim.Ga (ITA)**→ VIS 400-1000nm (spectral sampling 1.2nm), SWIR 1000-2400nm (5.4nm)

- **ARSF(UK)**   → AISA-EAGLE, VNIR 400 - 970 nm, (spectral sampling 1.25 nm),

 AISA –Hawk: 970nm 2500nm spectral sampling, 6.3 nm.

Potassium Emission (Airborne) 1

FRP derivation via spectral fitting

- **SimGa** acquisition over wildfilre over Latium Region on August 14 2006
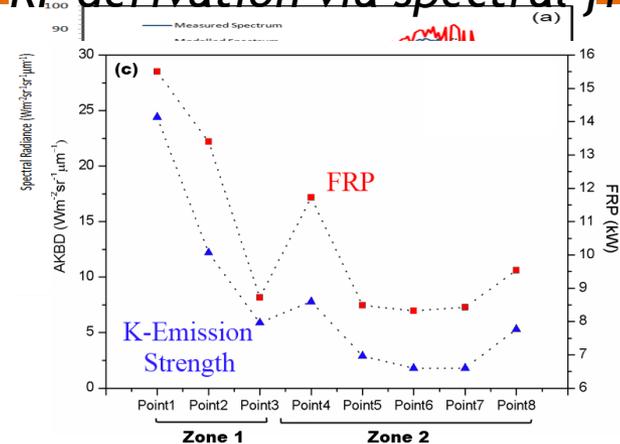
'Advanced' K Band Difference $(AKBD) = Max|BandK_i| - Bkg$

True colour composite

0.7m VIS Hyper   0.7m AKBD Hyper   30m   30m   60m
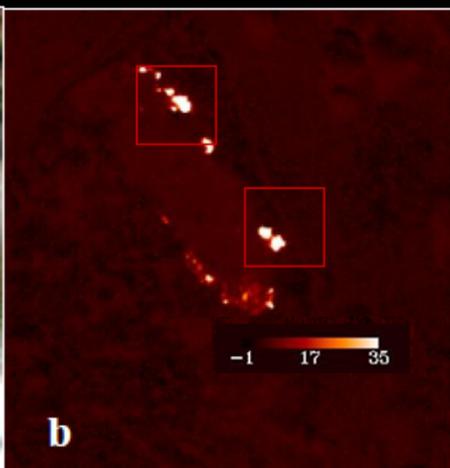
AKBD-Hyperion simulated   AKBD- PRISMA simulated   AKBD- HyspIRI simulated
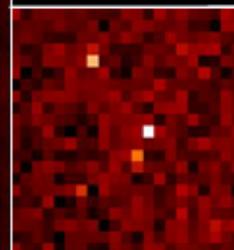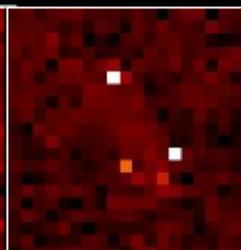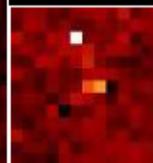
Potassium Emission (Airborne) 2

• **Eagle Aquisition** over prescribed fire
March 2010
Plot size di 80mx40m
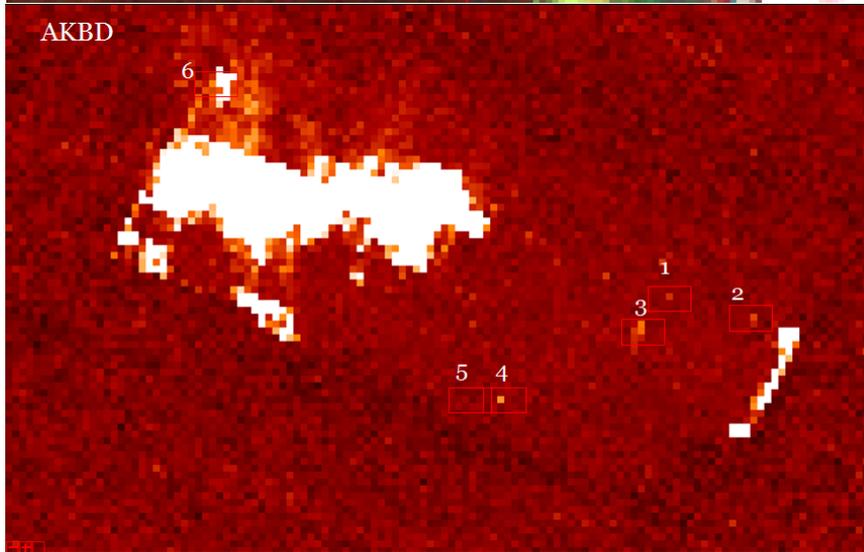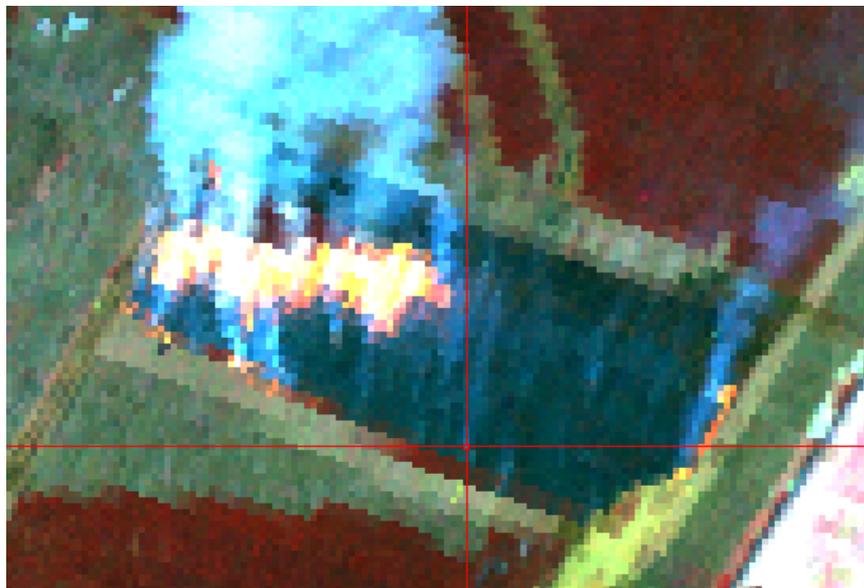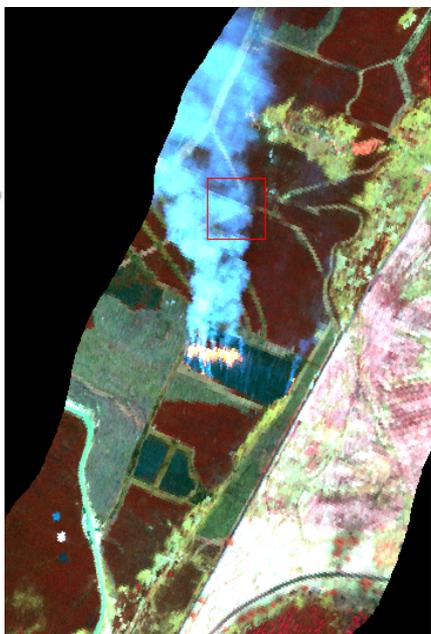
Plot size di 80mx40m
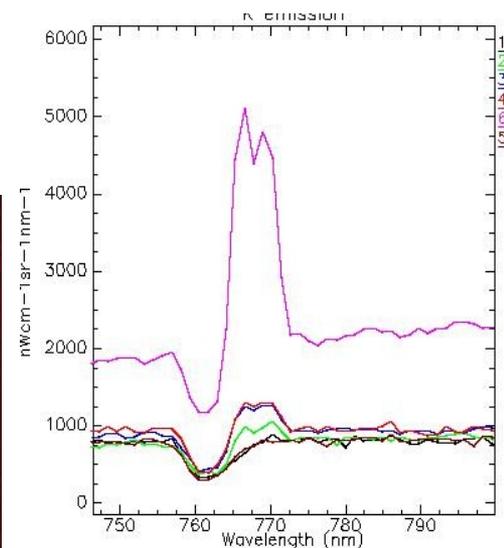
Eagle AKBD at different spatial resolution

AKBD a diverse risoluzioni spaziali

1m/px

20m/px

30m/px
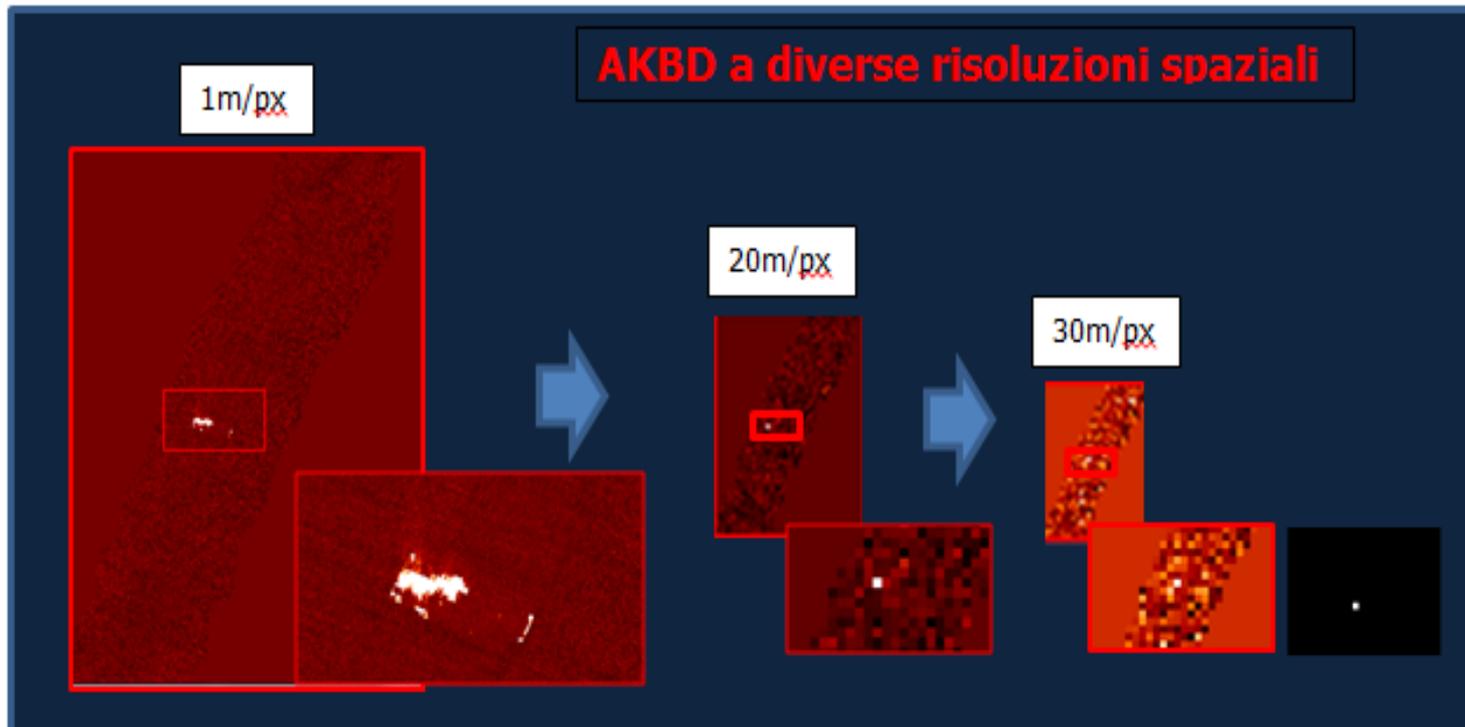
Satellite scale: Hyperion

EO1-Hyperion [220 bands VNIR (70 bandsi, 356 nm - 1058 nm), SW (172) bands, 852 nm - 2577 nm), spatial resolution 30m, spectral rsolution 10nm,
772nm, SNR 161 (550 nm); 147 (700 nm); 110 (1125 nm); 40 (2125 nm)

ASPEN Arizona	July 3 2003
Wedge Canyon	July 29, 2003.
California	October 23 2007
Russia Yakutsk	on May 24, 2011
Station fire Arcadia California	September 3, 2009

Data	Lat. Lon.	Località
1 luglio 2012	38.8° 104.9°	Waldo Canyon
12lluglio 2012	57.3° 91°	Krasnoyarsk (siberia)
5 luglio 2012	33.3° -108.9°	New Mexico
5 Aprile 2011	30.2° 95.8°	Texas
3 Dicembre 2010	32.7° 35.0°	South Haifa (Israel)
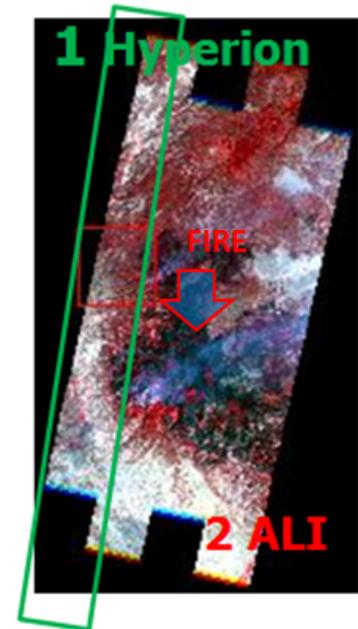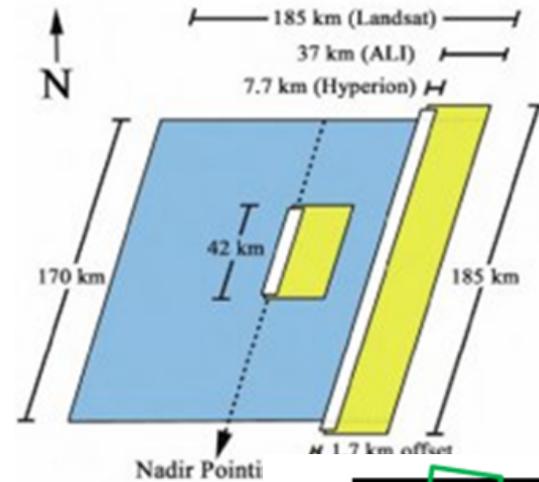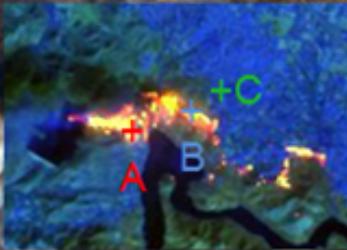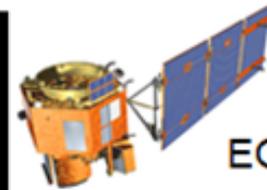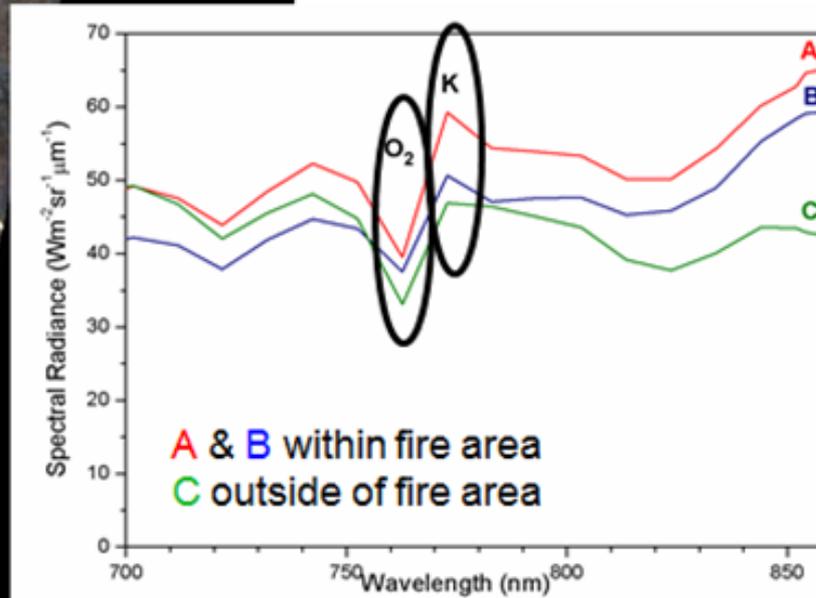
2007 "Witch" Wildfire (lat. 33.0 ° N, lon. 117.2 ° W)

Summary

Atomic emission spectroscopy is a potential method for fire detection based on high spectral resolution NIR measures

K-emission signal from fires is unique, works day/night.

May provide info. related to fire emission source strength.

PRISMA sensor has spectral bands conviniently located for K emission detection.

Resolution increases fire localization for fire small fire.

Further step consists in considering effect of sensor transfer function and atmosferic effects

Thanks for your attention!