A simple spectral model of fire impacts

Poster · May 2016

DOI: 10.13140/RG.2.1.4467.0321

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A Simple Spectral Model of Fire Impacts

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Challenges in fire monitoring using optical Earth Observation data

⇝ Monitoring the effect of fire on ecosystems:

- Climate
- Carbon cycle
- Ecology
- Human health & economic activity

⇝ EO only practical way to monitor fires on a global scale.

⇝ Available global Burned Area (BA) products have some important limitations

Binary indicator Presence/Absence of fire, but not information on impact of fire on the vegetation

Coarse spatial resolution No information on subpixel fire heterogeneity.

A linear model of reflectance change

From *Roy & Landmann, (2005)*, the reflectance of a pixel that experiences a fire is a linear combination of

- A fraction of the pixel that has been affected by the fire and
- A fraction of the pixel that has been not affected by the fire.

$$\rho_{+} = fcc \cdot \rho_{burned} + (1 - fcc) \cdot \rho_{unburned}$$

f: % pixel affected by fire

cc: radiometric combustion completeness.

Assume $\rho_{unburned} \approx \rho_{-}$, the pre-fire pixel reflectance

$$\rho_{+} - \rho_{-} = fcc\,(\rho_{burn} - \rho_{-})\,.$$

⇒ A linear spectral model of *reflectance change*, *not* of reflectance!

⇒ We could solve for fcc if we had a model for ρ_{burn}!

⇒ $\rho_{burn} = 0 \rightarrow fcc =$ relative change in reflectance

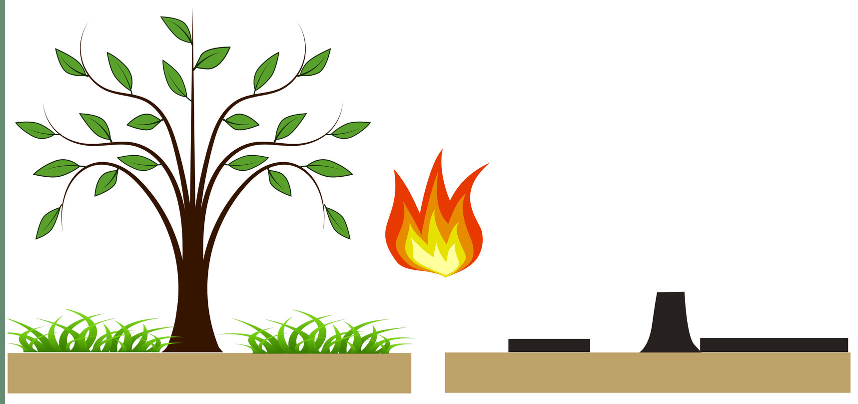
⇝ Contamination effects to look out for

- BRDF effects,
- residual atmospheric effects,
- other changes in the scene, e.g. vegetation regrowth

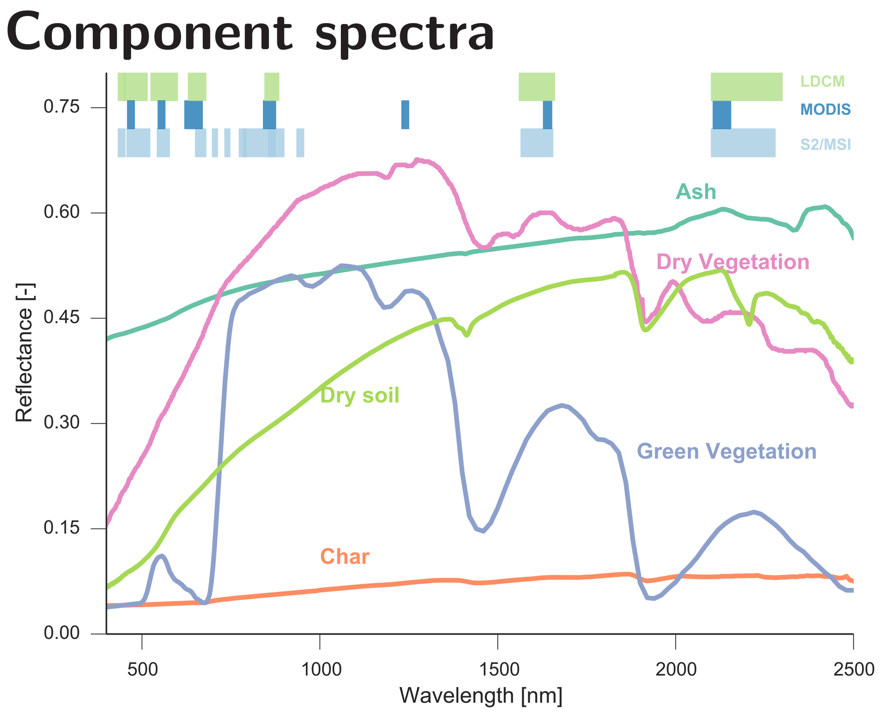
A spectral model of burned scenes

During a fire...

- Defoliation,
- Exposed soil,
- Ash and Char deposition.

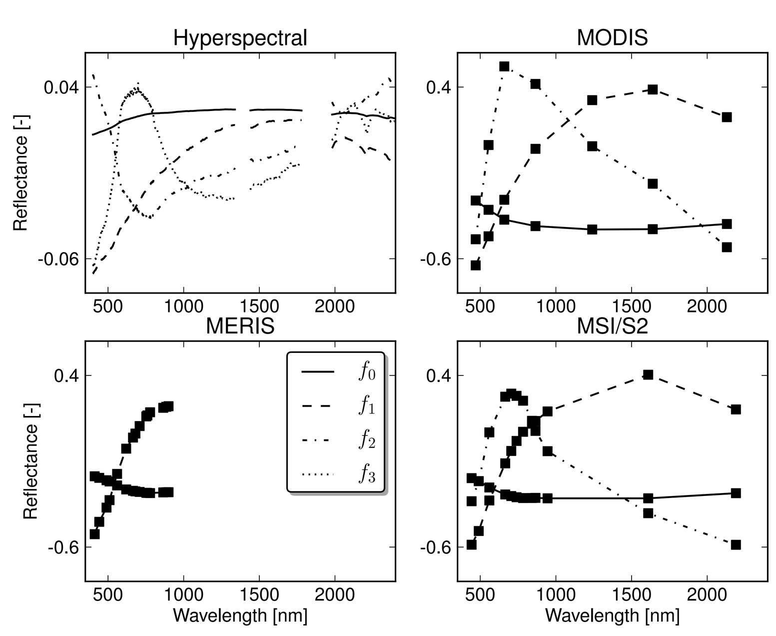


Component spectra



Method:

- Spectral database of soils, burned materials etc
- Different spectral configurations
- Apply PCA for different spectral configurations
- 2 (3 for hyperspectral) endmembers explain $> 75\%$ of variance
- Model good at fitting char, soils and brown veg, bad at green veg.



Model is formalised as a quadratic in wavelength

$$\rho^{\lambda}_{burn} = a_0 + a_1 \cdot s(\lambda)$$

⇒ Requires pre- and post fire reflectance.

⇒ A linear model with 3 parameters

fcc "Impact" of fire

a_0 "Char-like" spectral component

a_1 "Soil-like" spectral component

Applying the fcc model to actual satellite data

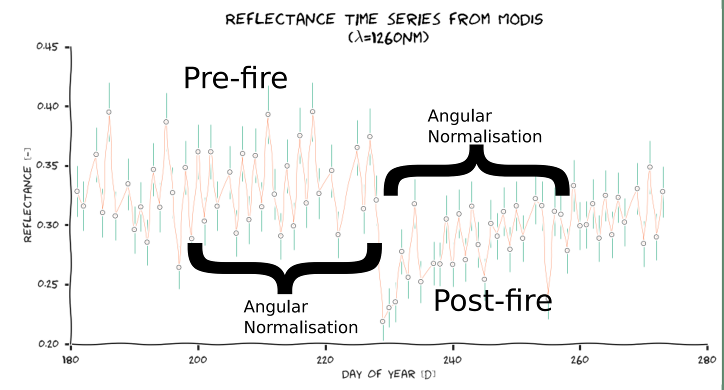
Constant view/illumination short revisit sensors

- Includes SPOT4/5Take5, Sentinel-2, LDCM, ...
- Requires before and after acquisitions
- Burn signal likely to degrade with growing interval between acquisitions.
- Needs careful treatment of atmospheric correction, maybe topographic correction.

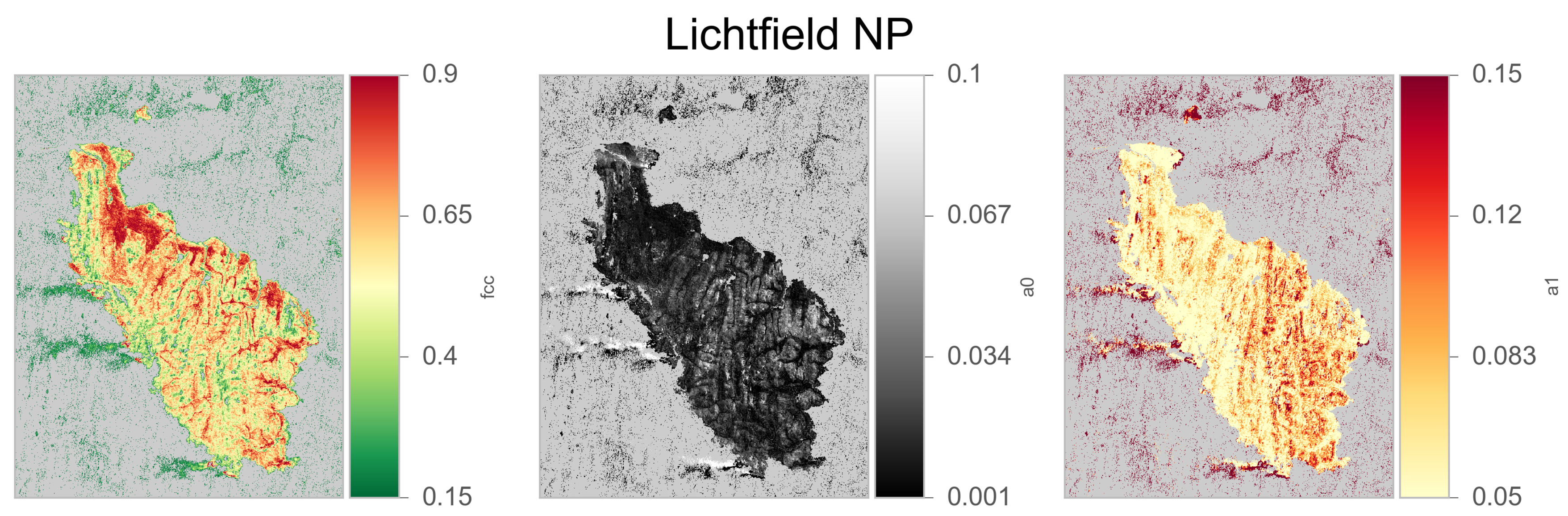
Wide swath sensors (MODIS, VIIRS, ...)

Need to account for BRDF effects in data.

- BA product indicates day of burn (DoB)
- Fit linear kernel models to pre-fire obs ⇒ $\rho_{-}^{(NBAR)}$
- Fit linear kernel models to post-fire obs ⇒ $\rho_{+}^{(NBAR)}$

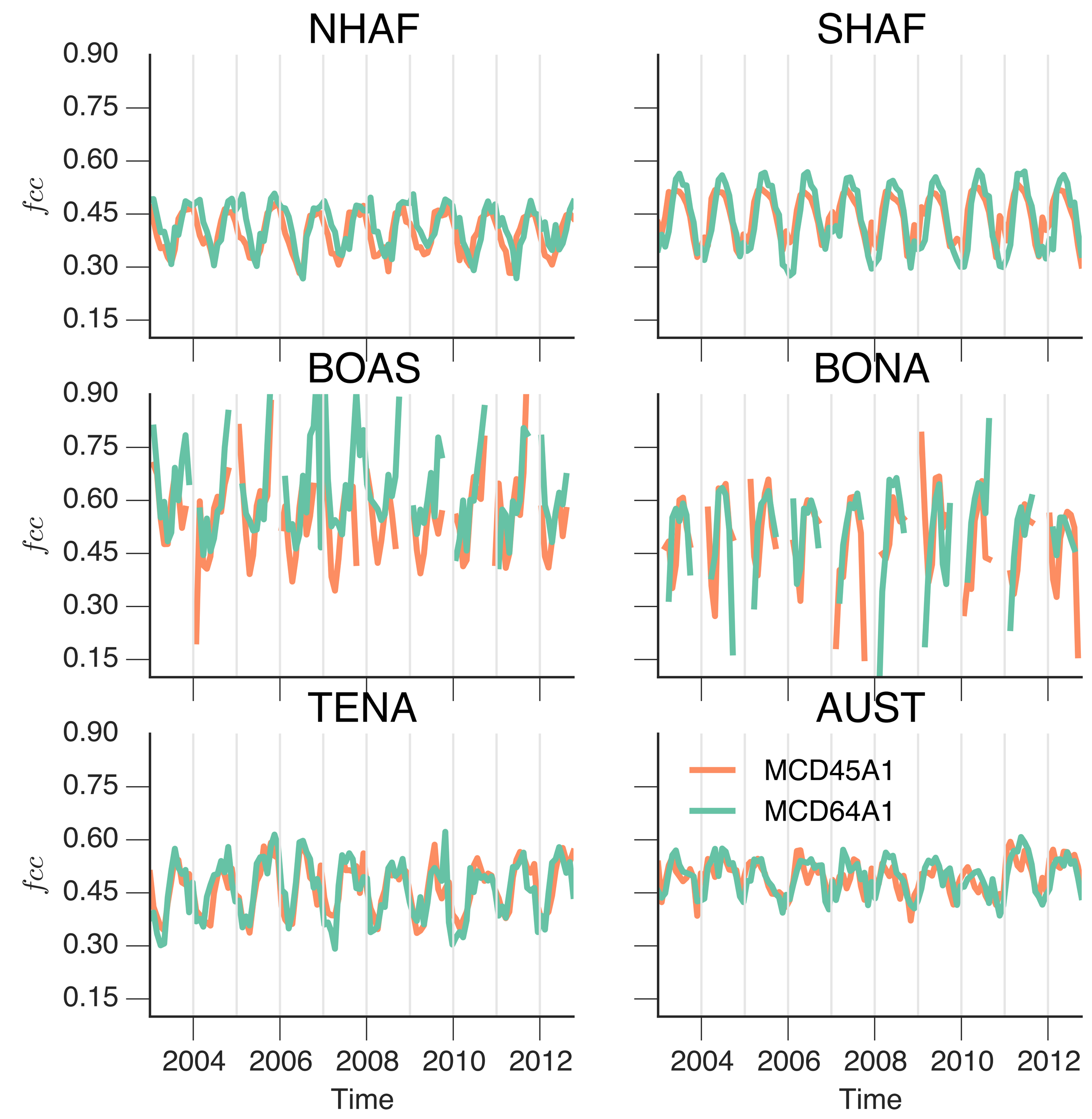


Application of the fcc model to SPOT5/Take5, 5 day revisit

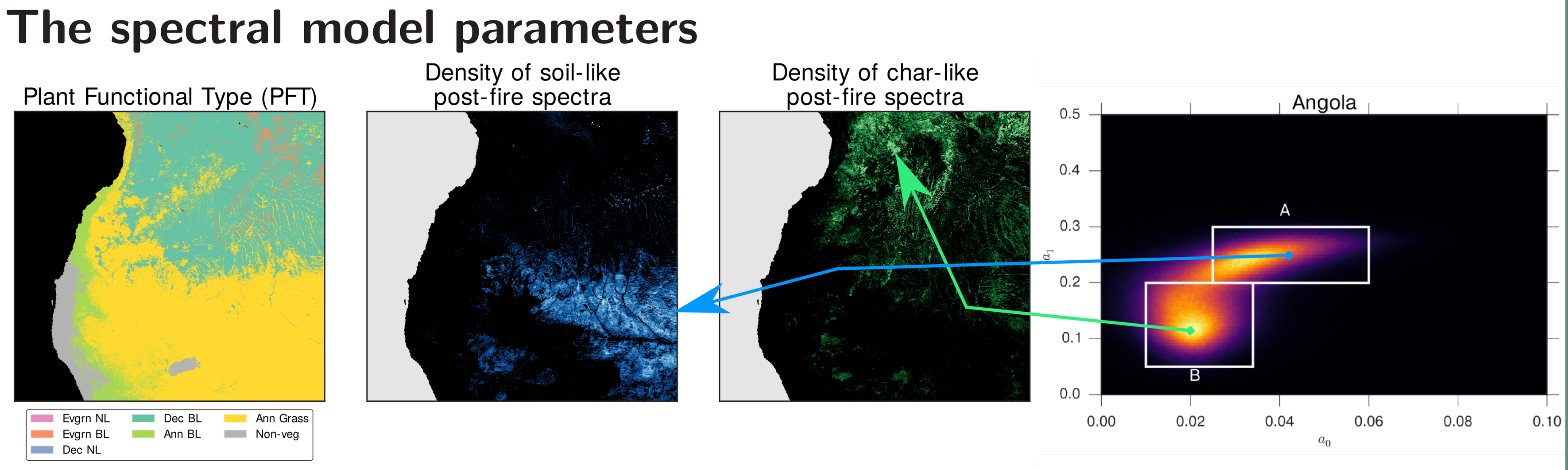


Application to MODIS data

Regional evolution of fcc



The spectral model parameters



Some points of interest...

- Simple, linear spectral model of reflectance change for fire scenes.
  - Adapts to different short-term post-burn conditions.
  - Simple implemenation for either high resolution or moderate resolution data.
- Successfully fits burned areas⇒ basis for new, robust BA algorithms
- Model parameters are spectral invariants ⇒ Blending different sensors.
- Tool to assess BA products, and why they work (or not!).
- fcc might be a useful indicator of fire impact in emissions calculations.
- fcc shows seasonal dynamics over all biomes.
- Average fcc is typically < 0.6 ⇒ If $fcc \sim f$,⇒ underestimation of emissions!
- Spectral model parameters are consistent with

  Char&Ash deposition In wooded areas (boreal forests, miombos, ...)

  Exposed soils Grassy savannas, croplands.

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