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 not been affected by the fire.

\[ \rho_{\text{fire}} = f \cdot \rho_{\text{burned}} + (1 - f) \cdot \rho_{\text{unburned}} \]

\( f \): % pixel affected by fire
\( cc \): radiometric combustion completeness.

Assume \( \rho_{\text{unburned}} \approx \rho_{\text{...}} \), the pre-fire pixel reflectance

\[ \rho_{\text{pre}} - \rho_{\text{post}} = f \cdot (\rho_{\text{burned}} - \rho_{\text{...}}) \]

⇒ A linear spectral model of reflectance change, not of reflectance!
⇒ We could solve for \( f \) if we had a model for \( \rho_{\text{burned}} \)
⇒ \( \rho_{\text{burned}} = 0 \) ⇒ \( f \) = 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.

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

\[ \rho_{\text{burned}} = a_0 + a_1 \cdot \lambda + a_2 \cdot \lambda^2 \]

⇒ 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/STake5, 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 ⇒ \( \rho_{\text{pre}}^{(N(BA))} \)
  > Fit linear kernel models to post-fire obs ⇒ \( \rho_{\text{post}}^{(N(BA))} \)

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

Application to MODIS data

Regional evolution of \( fcc \)

NHAFL SHAF

BOAS BONA

TENA AUST

The spectral model parameters

Simple, linear spectral model of reflectance change for fire scenes.
  > Adapts to different short-term post-burn conditions.
  > Simple implementation 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, miombo, ...) Exposed soils Grassly savannas, croplands.

Some points of interest...

Contact e-mail: j.gomez-dans@ucl.ac.uk