Design-based validation of the MODIS Global Burned Area Product

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http://modis-fire.umd.edu/MCD45A1.asp
Recall – global burned area algorithm

• Rolling BRDF based expectation change detection

• Semi-Physically based; less dependent upon imprecise but noise tolerant classification techniques; very few thresholds

• Automated, without training data or human intervention

• Applied independently per pixel to daily gridded MODIS 500m land surface reflectance time series

=> globally map 500m location and approximate day of burning
Conceptual Scheme (one pixel, time series)

\[ \rho \]

observed

time

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MODIS burned area validation
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Conceptual Scheme

$\rho$

time

observed

t-1

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Conceptual Scheme

\[
\rho \quad \text{BRDF Inversion window} \quad t-1 \quad \text{observed}
\]

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Conceptual Scheme

BRDF Inversion window

\( \rho \) observed
\( \hat{\rho} \) predicted

\( \rho(t|t-1) \)

t-1

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Conceptual Scheme

BRDF Inversion window

\( \rho_{(t|t-1)} \) observed
\( \rho_{(t|t-1)} \) predicted

t-1

time

\( \rho \)

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Conceptual Scheme

\[ \rho \]

BRDF Inversion window

- observed
- predicted

\[ \rho \text{ (t+1|t)} \]

\[ \rho \text{ (t+1|t)} \]

time

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...looking at images:

Predicted Reflectance
...looking at images:

Predicted Reflectance

Observed Reflectance

BRDF predicted 1.24 micron reflectance (500m) day 275

Observed 1.24 micron reflectance (500m) day 275

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...looking at images:

- **Predicted Reflectance**
  - BRDF predicted 1.24 micron reflectance (500m) day 275

- **Observed Reflectance**
  - Observed 1.24 micron reflectance (500m) day 275

**MODIS burned area validation**
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...looking at images:

### Predicted Reflectance

- BRDF predicted 1.24 micron reflectance (500m) day 275

### Observed Reflectance

- Observed 1.24 micron reflectance (500m) day 275

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**Probability of change:**

\[ Z\text{-score} = \frac{\text{predicted-observed}}{\text{error}} \]
• Algorithm run globally for first time in MODIS C5 - purposefully running to map burned areas conservatively
• Collection 5.1 currently being processed – will replace C5
• Product redesign and integration with active fires for C6

• **Validation:** CEOS Stage 2 for C5.1
• **Validation:** CEOS Stage 3 for C6
Components of the validation

The global burned area product provides information that is

- temporal (day of detection)
- spatial (location and areal extent)

Two separate validation procedures
Validation of Burned Area Product

Temporal Reporting Accuracy

• To date we have concentrated on product spatial reporting accuracy

• The product also reports the ~day of detection

• The nominal uncertainty due to the daily rolling BRDF inversion window is 8 days

• Temporal product accuracy increasingly relevant to user community
  – near real time air quality
  – atm. transport models (weather on day of burn, plume injection height)
  – some regional assessment applications (nat. resource, disaster management)
• MODIS active fire product
  - validated to stage 3
  - very low commission error
  - date & time of active fire detection defined by orbit overpass

GoFC-Fire IT 2013
MODIS Burned Area Temporal Reporting
Validation Approach

Comparison at all global locations where there is a burned area detection and an active fire detection

- Active Fire (Terra or Aqua)
- Burned area
MODIS Burned Area Temporal Reporting Validation Approach

Comparison at all global locations where there is a burned area detection and an active fire detection within 90 days.

- Green circle: Active Fire (Terra or Aqua)
- Red circle: Burned area
MODIS Burned Area Temporal Reporting
Validation Approach

Comparison at all global locations where there is a
burned area detection and an active fire detection

90 days

\[ \Delta t \]

Active Fire (Terra or Aqua)

Burned area

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Time difference analysis
global, 6 years

Median: -1 day

50%: 1 day
75%: 4 days
Consistent annual results
Median difference

50% of deviation from the median

% of pixels within the nominal 8 day uncertainty

Boschetti et al, 2010
Validation of spatial extent

• Based on CEOS Cal Val Protocol for the Production and standardization of validation reference data (community accepted standard).

• Sampling and Accuracy measures not included in the protocol yet (current research)

• Prototype of stage 3 validation for global burned area products
Burned Area Product Validation Protocol

• Compare MODIS burned area product with independent spatially explicit burned area data derived from *multitemporal Landsat ETM+ data*

• SAFNet field trip held to develop the mapping protocol and to discuss southern African fire information needs, Zimbabwe-Zambia, July 2000

• SAFNet members map the areas burned between 2+ Landsat acquisitions, augmented by limited fieldwork

• Consensus mapping protocol to ensure regionally consistent independent validation data

• Protocol followed 2000-2002 at ~11 ETM+ scenes/year

Reference dataset produced using pre-burn and post-burn data

Priorities:

1- ensure the accuracy of the reference data: local partners involved in the interpretation of the high resolution data

2- temporal consistency: map the changes between two acquisitions

3- spatial consistency: differentiate between unburned areas and areas that could not be interpreted due to data quality issues, or not visible because of clouds or shadows
Examples: Mapping the changes

Image 1: 10 Sept 2001

Image 2: 12 Oct 2001

Interpretation

MODIS burned area validation
Boschetti, Roy, Stehman
Examples: Mapping the changes

Image 1: 10 Sept 2001

Image 2: 12 Oct 2001

Interpretation

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Image 1:
Landsat ETM+
Sept. 4th
Image 2:
Landsat ETM+
Oct 6th

Yellow vectors = ETM+ interpreted burned areas occurring between the two ETM+ acquisitions

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MODIS 500m Burned Areas

Sept. 4 to Oct. 6

White vectors = ETM+ interpreted burned areas occurring between the two ETM+ acquisitions

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The case for Stage 3 validation

- MODIS Stage 2 validation dataset. 100 Landsat image pairs
Product Intercomparison: in the absence of validation it shows the differences and similarities between products, but it is insufficient to quantify the accuracy
2003 VALIDATION: L3JRC
REGRESSION OVER 5KM X 5KM CELLS
• L3JRC performs very well on MODIS Europe validation dataset.

• Intercomparison: Giglio et al. 2010, shows that L3JRC detects more than MCD45, GFED 2 and GFED 3 in Europe

![Graph showing MODIS burned area validation](image)

• Is the Stage 2 dataset enough to conclude that L3JRC has the right estimate?
• MCD45 also performs well on Stage 2 dataset!

• Stage 3 needed to characterize fully the variability! (sampling in space and time)
Designing a Stage 3 validation dataset
Characteristics of the Stage 3 sampling

- Stratified random sampling
- Total population of the dataset: all the Landsat pairs which respect the CEOS protocol requirements
  - Cloud free
  - Within a set time period (~2 months)
- Stratification
  - In space: sub-continental regions
  - In time: fire seasonality based on MODIS active fire detections
- Number of samples guided by the results of stage 2 validation on C5.1
MODIS-Landsat data fusion for high spatial resolution multi-annual wall to wall burned area mapping of the conterminous United States

Prototype developed under NASA funding
February 2011 – January 2014
7+ Years of Landsat ETM+ WELD products

http://weld.cr.usgs.gov/
Annual
(December 2009 - November 2008)

Alaska ~ 1,700 L1T acquisitions / year
CONUS ~ 8,000 L1T acquisitions / year
Summer
(June, July, August) 2008
Week 28: July 8 - 14 2008
Western US Forests
Western US Forests

107 WELD tiles selected, 1 year of data (52 weekly composites)
Landsat-MODIS fusion

Jan

Dec

MTBS polygons
Conclusions

• Statistically robust sampling is essential for proper characterization of presence/absence of fire, the current validation datasets are biased and are not suitable to detect false positives
• Need to validate separately temporal and spatial aspect
• The method for validation through the interpretation of image pairs has been widely tested and published in peer reviewed literature
• Data availability is the main limiting factor, currently the sampling is prototyped using 2002 SLC-on Landsat 7
• Pathfinding operational validation for future production of ECVs (systematic coverage with LCDM/Sentinel 2)
Thanks