Validation of the MODIS active fire products in Siberia with coincident ASTER data

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ABSTRACT - Satellites provide valuable information for the large-scale monitoring of biomass burning in the vast boreal forest region. However, the accuracy of the satellite-derived fire products needs to be determined. An active fire product from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on board the polar orbiter Terra satellite has been available since 2000. A unique feature of the Terra satellite is the availability of coincident high resolution data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). In this study we used the elevated signal in the 30 m resolution ASTER channel 9 at 2.4 µm to characterize fires within the 1-km MODIS pixels. The probability of MODIS detection was determined by logistic regression as a function of sub-pixel fractional fire coverage. The dependence on spatial heterogeneity, found to be significant in an earlier study over Southern Africa, is also examined. Examples of individual fires and summarized statistics are presented for May and August 2001 and May 2002 cases in Siberia. The effects of algorithm changes on product accuracy are also discussed. This work is being undertaken in the framework of the international GOFC/GOLD-Fire program. Involvement of regional scientists in validation of satellite data products is encouraged and will help build a user community informed on the capabilities and limitations of a given product for susbsequent application.

BACKGROUND

- GOFC/GOLD-Fire
  - "Determine product accuracy – operational network of fire validation sites and protocols established providing accuracy assessment for operational products and test bed for new or enhanced products – leading to standard products of known accuracy"
  - "Increase user awareness – increased understanding of the utility of satellite fire products for global change research, resource management and policy (UN, Regional, National, Local)"
- CEOS WGCV LPV subgroup
  - "increase the quality and economy of global satellite product validation *via* developing and promoting international standards and protocols for field sampling, scaling, error budgeting, data exchange and product evaluation"
  - "advocate mission-long validation programs for current and future earth observing satellites"
- MODLAND validation
  - "comparison of data and products from other spaceborne sensors"

METHOD

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer

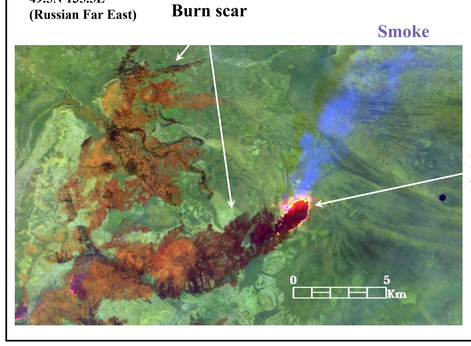
- On board Terra (*not* on board Aqua)

	VNIR	SWIR	TIR
Spectral	1: 0.52 - 0.60	4: 1.600 - 1.700	10: 8.125 - 8.475
	2: 0.63 - 0.69	5: 2.145 - 2.185	11: 8.475 - 8.825
range	3: 0.76 - 0.86	6: 2.185 - 2.225	12: 8.925 - 9.275
	3B*: 0.76 - 0.86	7: 2.235 - 2.285	13: 10.25 - 10.95
		8: 2.295 - 2.365	14: 10.95 - 11.65
(µm)		9: 2.360 - 2.430	
Ground res. (m)	15	30	60
Swath width (km)	60	60	60
Quantization (bits)	8	8	12

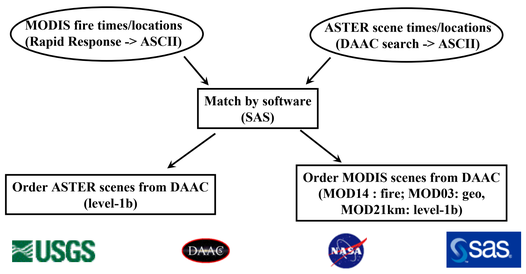
*Backward looking; all other sensors nadir looking

Fire observations with ASTER

May 9 2002
02:01 UTC
49.5N 135.5E
(Russian Far East)

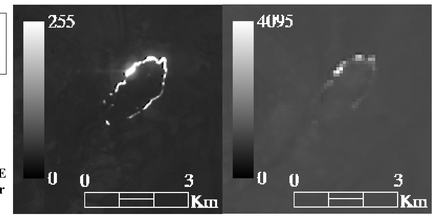


ASTER-MODIS fire coincidence search



ASTER data characteristics

Band selection



May 9 2002
02:01 UTC
49.5N 135.5E
(Russian Far East)

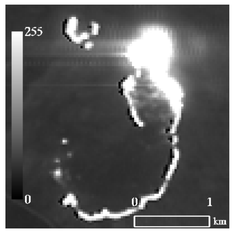
2.4 µm – channel 9 | 8.3 µm – channel 10

Fire detection: Band 9 > 200 and Band 9 > Band 1 ← Detect hotspots; ← Remove false alarms from reflective clouds and sun-glint

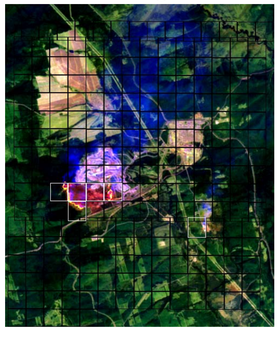
Sensor artifacts

May 9 2002
02:01 UTC
51.5N 136.25E
(Russian Far East)

saturation
blooming
spikes
near-zero counts



Collocating ASTER and MODIS data

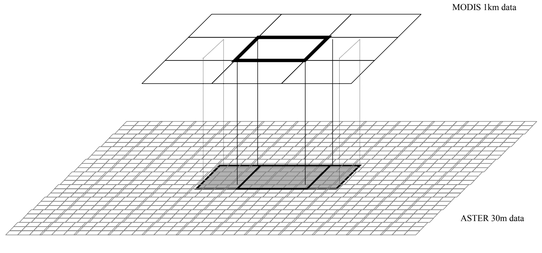


White gridcells indicate MODIS version 4 detection

shift/overlap from MODIS scanning pattern

May 30 2001
04:35 UTC
57.25N 103.6E
(Central Siberia)

ASTER binary masks within MODIS footprints



For 2x1 along-scan along-track areas to account for MODIS triangular response

MODIS active fire products considered

- Level 2 fire products for 5-minute orbital segments
  - Version 3: currently operational, persistent false detections caused by absolute thresholds
  - Version 4: new algorithm, relies heavily on contextual tests – by the end of 2002 the entire data record will be reprocessed

Statistical summaries within MODIS footprints

Fractional area: number of ASTER fire pixels

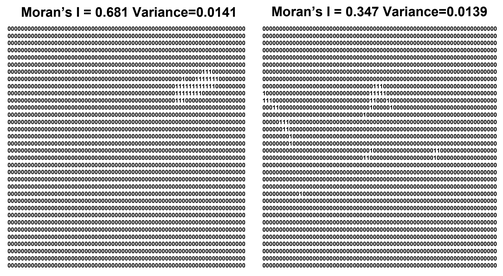
Fire heterogeneity: Moran's *I*

$$\text{Moran's I} = n \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}(y_i-\mu)(y_j-\mu)}{\left(\sum_{i=1}^{n}(y_i-\mu)^2\right)\left(\sum\sum_{i\neq j} w_{ij}\right)}$$

n: number of ASTER pixels covered by a MODIS pixel
w_{ij}:1 for the eight adjacent pixels and 0 for all others
y_i:is value of the ASTER fire pixel (either 0 or 1) for pixel *i*
μ: mean of ASTER fire map for the area represented by the MODIS pixel

Binary ASTER fire masks

Moran's I = 0.681 Variance=0.0141 | Moran's I = 0.347 Variance=0.0139



Total number of ASTER fire pixels = 34

Statistical method for comparison

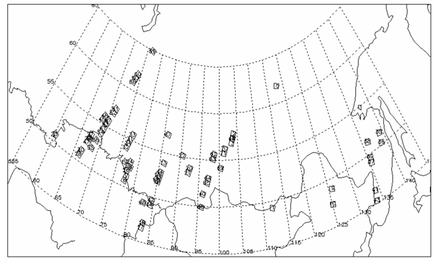
MODIS "fire/no fire" ⟷ statistical summaries from binary ASTER fire mask

	Fixed effect models (within-scene variability only)	Random effect models (include between-scene variability also)
Model 1	$\pi(x_i)=\frac{e^{\beta_0+\beta_1 x_i}}{1+e^{\beta_0+\beta_1 x_i}}$	$\pi(x_{ij})=\frac{e^{(\beta_0+b_{0j})+(\beta_1+b_{1j})x_{ij}}}{1+e^{(\beta_0+b_{0j})+(\beta_1+b_{1j})x_{ij}}}$
Model 2	$\pi(x_i,m_i)=\frac{e^{\beta_0+\beta_1 x_i+\beta_2 m_i}}{1+e^{\beta_0+\beta_1 x_i+\beta_2 m_i}}$	$\pi(x_{ij},m_{ij})=\frac{e^{(\beta_0+b_{0j})+(\beta_1+b_{1j})x_{ij}+(\beta_2+b_{2j})m_{ij}}}{1+e^{(\beta_0+b_{0j})+(\beta_1+b_{1j})x_{ij}+(\beta_2+b_{2j})m_{ij}}}$

i denotes MODIS pixel; *j* denotes ASTER scene
x: count of ASTER fire pixels within MODIS pixel
m: Moran's *I* within MODIS pixel
π: probability that MODIS pixel is flagged as "fire"
β_0 , β_1 , β_2: fixed effects parameters estimated from the data population
b_0 ,b_1 ,b_2: random effects parameters associated with experimental units drawn at random

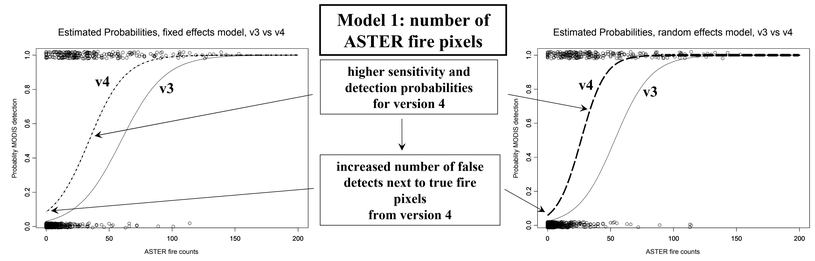
DATA

Coverage of ASTER scenes used for statistical analysis



1-4: May 2001; 5-23: August 2001; 24-71: May 2002

RESULTS



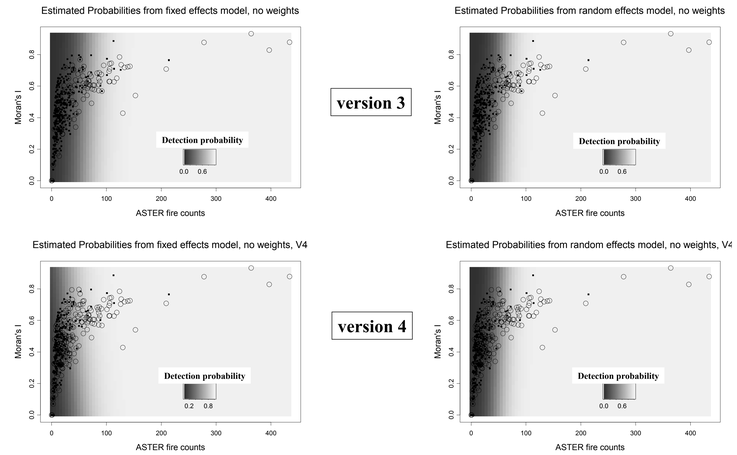
Model 1: number of ASTER fire pixels

higher sensitivity and detection probabilities for version 4

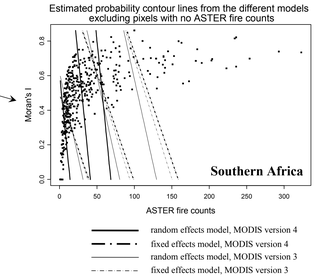
increased number of false detects next to true fire pixels from version 4

Somewhat higher detection probabilities for random effects model for version 4

Model 2: number of ASTER fire pixels + Moran's *I*



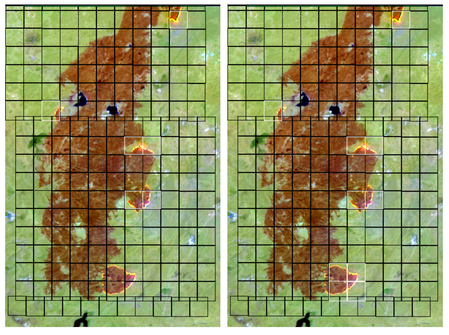
Very weak dependence on Moran's *I* found: different from earlier finding over Southern Africa



The three lines shown for each model represent, from left to right, the modeled probability at .05, .50, and .95.

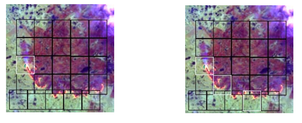
Effects of MODIS algorithm change

August 4 2001 06:02 UTC, 50.9N 77.6 E (Northern Kazakhstan)



Version 3 | Version 4

May 8 2002 06:13 UTC, 55.2N 77.3 E (Western Siberia)



Version 3 | Version 4

ASTER RGB images. White squares show MODIS fire pixels.

SUMMARY

- detection probabilities from the logistic regression models presented characterize well omission errors; for commission errors other variables may be needed
- there is some sensitivity to model formulation and data sampling
- dependence on sub-pixel heterogeneity is much weaker than in Southern Africa
- MODIS version 3 -> version 4 algorithm change had a positive effect on fire product accuracy
- "false alarms" next to valid fire pixels remain
- in Siberia, a large number of small fires remain undetected by MODIS