NASA MODIS
Global Fire Monitoring
and its applications in
Northern Eurasia

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University of Maryland
Joint NASA LCLUC Science Team Meeting and
GOFC-GOLD/NERIN, NEESPI, MAIRS Workshop
MODIS instrument

- Moderate Resolution Imaging Spectroradiometer (MODIS)
- On board two polar orbiting satellites
  - Terra launched in 1999
  - Aqua launched in 2002
MODIS data acquisition

- Global twice daily imaging (Terra and Aqua)
- Overpass overlaps over higher latitudes – multiple imaging opportunities
- A large number of bands at different resolutions
- Specifically designed bands for fire monitoring purposes
MODIS bands 1-19

<table>
<thead>
<tr>
<th>Primary Use</th>
<th>Band</th>
<th>Bandwidth</th>
<th>Spectral Radiance</th>
<th>Required SNR</th>
</tr>
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<tbody>
<tr>
<td>Land/Cloud/Aerosols Boundaries</td>
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<td>620 - 670</td>
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<td>662 - 672</td>
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<td>673 - 683</td>
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<td></td>
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<td>862 - 877</td>
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<td>18</td>
<td>931 - 941</td>
<td>3.6</td>
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<td>19</td>
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### MODIS bands 20-36

<table>
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<tr>
<th>Primary Use</th>
<th>Band</th>
<th>Bandwidth</th>
<th>Spectral Radiance</th>
<th>Required NE[delta]T(K)</th>
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</thead>
<tbody>
<tr>
<td>Surface/Cloud Temperature</td>
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<td>0.45(300K)</td>
<td>0.05</td>
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<td>21</td>
<td>3.929 - 3.989</td>
<td>2.38(335K)</td>
<td>2.00</td>
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<tr>
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<td>22</td>
<td>3.929 - 3.989</td>
<td>0.67(300K)</td>
<td>0.07</td>
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<td>23</td>
<td>4.020 - 4.080</td>
<td>0.79(300K)</td>
<td>0.07</td>
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<tr>
<td>Atmospheric Temperature</td>
<td>24</td>
<td>4.433 - 4.498</td>
<td>0.17(250K)</td>
<td>0.25</td>
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<tr>
<td></td>
<td>25</td>
<td>4.482 - 4.549</td>
<td>0.59(275K)</td>
<td>0.25</td>
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<td>Cirrus Clouds Water Vapor</td>
<td>26</td>
<td>1.360 - 1.390</td>
<td>6.00</td>
<td>150(SNR)</td>
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<td>27</td>
<td>6.535 - 6.895</td>
<td>1.16(240K)</td>
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<td>7.175 - 7.475</td>
<td>2.18(250K)</td>
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<tr>
<td>Cloud Properties</td>
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<td>8.400 - 8.700</td>
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<td>Ozone</td>
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<td>Surface/Cloud Temperature</td>
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<td>10.780 - 11.280</td>
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<td>32</td>
<td>11.770 - 12.270</td>
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<td>Cloud Top Altitude</td>
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<td>13.185 - 13.485</td>
<td>4.52(260K)</td>
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<td>13.485 - 13.785</td>
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<td>13.785 - 14.085</td>
<td>3.11(240K)</td>
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<td>36</td>
<td>14.085 - 14.385</td>
<td>2.08(220K)</td>
<td>0.35</td>
</tr>
</tbody>
</table>

1. Bands 1 to 19 are in nm; Bands 20 to 36 are in μm
2. Spectral Radiance values are (W/m² - μm-sr)
3. SNR = Signal-to-noise ratio
4. NE[delta]T = Noise-equivalent temperature difference

Note: Performance goal is 30-40% better than required
MODIS fire data products

- Global algorithms – different performance in different areas
- Standard products – science datasets
- Fire was a priority in instrument design and product development
### MODIS Products Table

These links will direct you to specific information and access points for each of the MODIS Land Products distributed from LP DAAC.

<table>
<thead>
<tr>
<th>MODIS ID</th>
<th>Platform</th>
<th>Product Type</th>
<th>Resolution</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>MCD45A1</td>
<td>Combined</td>
<td>Burned Area</td>
<td>Tile</td>
<td>Monthly</td>
</tr>
<tr>
<td>MCD45C4</td>
<td>Combined</td>
<td>Nadir BRDF-Adjusted Reflectance</td>
<td>CMG</td>
<td>500m</td>
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<tr>
<td>MOD08A1</td>
<td>Terra</td>
<td>Surface Reflectance Bands 1–7</td>
<td>Tile</td>
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<tr>
<td>MCD14</td>
<td>Terra</td>
<td>Thermal Anomalies &amp; Fire</td>
<td>Swath</td>
<td>1000m</td>
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<td>MCD14A1</td>
<td>Terra</td>
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<td>Tile</td>
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<tr>
<td>MCD14A2</td>
<td>Terra</td>
<td>Thermal Anomalies &amp; Fire</td>
<td>Tile</td>
<td>1000m</td>
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</tbody>
</table>
MODIS Active Fire detections

- MOD(MYD)14 group – Thermal Anomalies and Fire – 1000 m nominal resolution
  - MOD14 – 5 min swath
  - MOD14A1 – tiled daily (LP DAAC)
  - MOD14A2 – tiled 8day
  - MCD14ml – fire detection points
  - CMG – 0.5 degree grid:
    - MOD14C8H – 8-day
    - MOD14CMH - monthly
  - CMG – 0.5 degree grid:
    - MOD14C8H – 8-day
    - MOD14CMH - monthly
MODIS land cover 2005 in IGBP classification: aggregated classes

- forests
- shrublands
- woodlands
- grasslands
- wetlands
- crop complexes
- urban
- snow and ice
- barren
- water

Northern Eurasia
Northern Eurasia

MODIS land cover 2005 in IGBP classification: aggregated classes
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MODIS fire detections

- MODIS active fire detections
MODIS fire detections
Dryland countries of Northern Eurasia
On average fires in drylands ~ 25% of fires in NE
Mean Fire Radiative Power by land cover type. Bar chart showing FRP (W m\(^{-2}\)) for various land cover types over the years 2001 to 2008.
Fire occurrence seasonality

Monthly fire occurrence

Mean monthly fire occurrence
Fire occurrence as a function of land cover and land use
Land cover and land use in dryland countries of NE

- Water
- EN Forest
- DN Forest
- DB Forest
- Mixed Forest
- Closed shrub
- Open shrub
- Woodland
- Savanna
- Grassland
- Wetland
- Crop
- Urban
- Crop mosaic
- Snow
- Bare
Fire occurrence per 1000 km² of different land cover and land use types

Number of fire detections per 1000 km²
MODIS Burned Area products

- MCD45A1 – 500 m combined Terra and Aqua burned area monthly
- MODIS GFED burned area – 500 m annual
- Potential for MODIS regional burned area algorithms
MODIS Sinusoidal grid
Drylands of Northern Eurasia on the MODIS grid:
Analysis area for MODIS tiles h22 – h25 v04-v05 in Lambert Azimuthal Equal Area
MCD45A1: h23v04 Sept 2002
Area burned reported by MCD45 product over tiles h22 – h25, v04 – v05
MCD45A1: known problems
MODIS GFED burned area:
h23v04 August-September 2002
MODIS global burned area products comparison

Annual burned area h23v04

Year
2002 2003 2004 2005 2006 2007 2008
area burned (million ha)
MCD45A1
GFED_DB
MDC45A1 and GFED burned area mapping
Differences: h23v04 2002
MDC45A1 and GFED burned area mapping
Differences: h23v04 2008

[Map showing burned area differences between MDC45A1 and GFED]

- Orange: MDC45A1
- Blue: GFED ba
Satellite Fire Monitoring

- **Data Product Progression**
  - Algorithm Development and Testing (ATBD peer review)
  - Data Set Generation
  - Product Quality Control (QA metadata)
  - Product Validation (independent measurements)
  - Product Documentation and Distribution
  - Algorithm Refinement and Reprocessing
C5 Burned Area Product Validation Protocol

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
Image 1:
Landsat ETM+
Sept. 4th
Yellow vectors = ETM+ interpreted burned areas occurring between the two ETM+ acquisitions
MODIS 500m Burned Areas

Sept. 4 to Oct. 6

White vectors = ETM+ interpreted burned areas occurring between the two ETM+ acquisitions
Landsat ETM+ validation scenes distributed from dry savanna to wet miombo woodland to quantify product accuracy over range of representative biomass burning conditions.

- **ETM+ scene**: ~185 * 185 km
- **Each ETM+ scene** has a local SAFNet collaborator
- **11 scenes** = ~3% of southern African surface

MODIS 1km land cover product: of the 17 MODIS land cover classes, predominant classes illustrated include: evergreen broadleaf forest (dark green), barren or sparsely vegetated (gray), woody savannas (light green), open shrublands (cream), grasslands (light brown), savannas (orange), croplands (yellow), cropland/natural vegetation mosaic (olive brown), urban (red).
MODIS Burned Area product Validation

The slope of the regression line is 0.75, The intercept is -0.005 and the r2 is 0.746
Specialized regional product development

- Best results in spatial and inventory accuracy
- Factors in regional specifics
  - Fire occurrence
  - Land surface imaging
Regional specifics of land surface imaging: Alaska solar elevation
Regional specifics of land surface imaging: Alaska – clear surface
MODIS-based algorithms used to estimate burned area in Alaska

MTBS

MODIS active fires

Provisional burned area product

Direct Broadcast algorithm

Regional algorithm

Regional algorithm (adjusted)
Comparison of burned area estimates from various MODIS–based algorithms during 2004 fire season in Alaska against MTBS scars (n = 67)

- **Active Fire**: $y = 0.797x$, $R^2 = 0.9844$
- **Direct Broadcast**: $y = 0.7637x$, $R^2 = 0.9228$
- **Provisional Burned Area**: $y = 0.3016x$, $R^2 = 0.7777$
- **Regional adjusted**: $y = 0.9494x$, $R^2 = 0.9924$
MODIS in Giovanni: online visualization

September 10, 2009: Giovanni Users - the annual NASA data center user satisfaction survey is underway! Using Giovanni does not require submission of an email address to the GES DISC, so if you would like to help us improve Giovanni and our other data services, [click here for instructions on how to receive an invitation] to take the survey.

Northern Eurasia Earth Science Partnership Initiative
Monthly Products

This instance focuses on monthly atmospheric, land surface and cryospheric products for supporting Northern Eurasia Earth Science Partnership Initiative (NEESPI) project. Information of the NEESPI project can be found at the supporting [website]. For help on how to use this Giovanni instance, please see the [NEESPI help page].

Other NEESPI products are available in Giovanni: [Daily data]

ACKNOWLEDGMENT: The NASA NEESPI Data and Services Center project is supported by NASA HQ through ROSES 2005 NNH05ZDA001N-ACCESS.
Northern Eurasia Earth Science Partnership Initiative
Daily Products

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Other NEESPI products are available in Giovanni: Monthly data

Select:

- Parameters

  Display: Data Product Info  Units

Atmospheric Measurement

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data Product Info</th>
<th>MODIS-Terra Ver. 5</th>
<th>MODIS-Terra Ver. 6</th>
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<td>MODIS_D3051</td>
<td>2003/01/04 - 2009/09/06</td>
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</table>
Relationship between precipitation and fire occurrence in boreal forests

Area-Averaged Time Series (GPCP, Jdeg.002)
(Region: 120E-130E, 55N-65N)

Area-Averaged Time Series (MODV1.005)
(Region: 120E-130E, 55N-65N)

Area-Averaged Time Series (MOD14CM1.004)
(Region: 120E-130E, 55N-65N)

Area-Averaged Time Series (MOD14CM1.004)
(Region: 120E-130E, 55N-65N)
Relationship between precipitation and fire occurrence in dry lands
Conclusion

- MODIS fire products are
  - Standard
  - publicly available
  - Free of charge

- We need community help to improve algorithm performance through joint validation efforts