Spatial and temporal resolution of satellite-based biomass burning emission inventories for the global aerosol model (GOCART)

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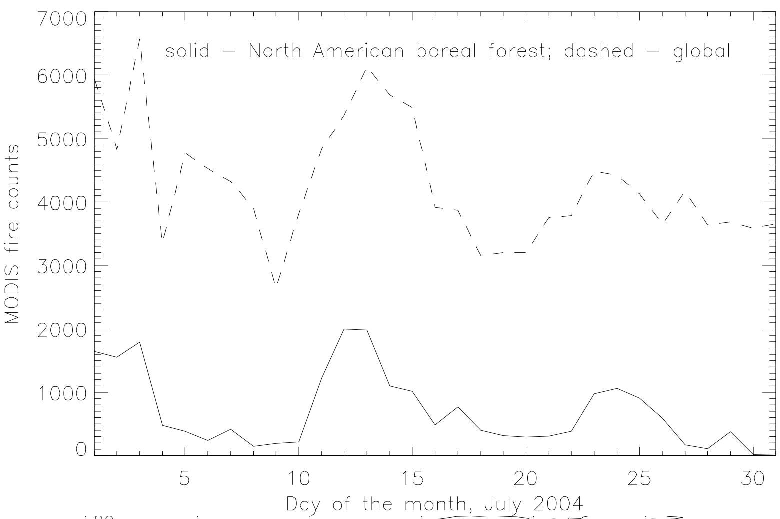
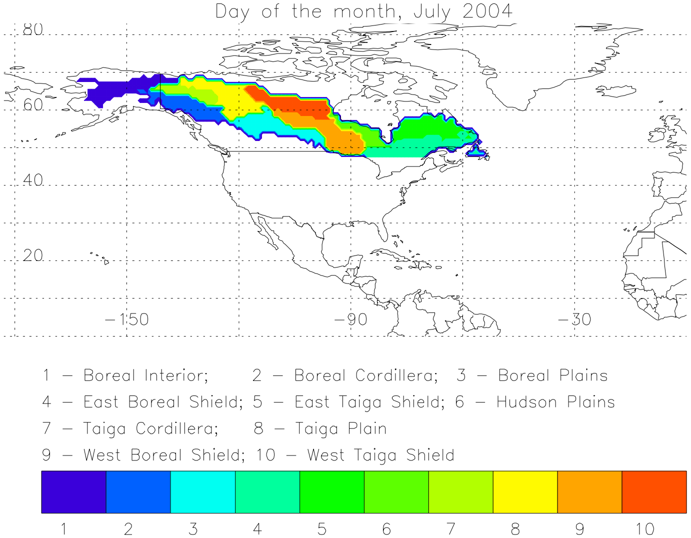
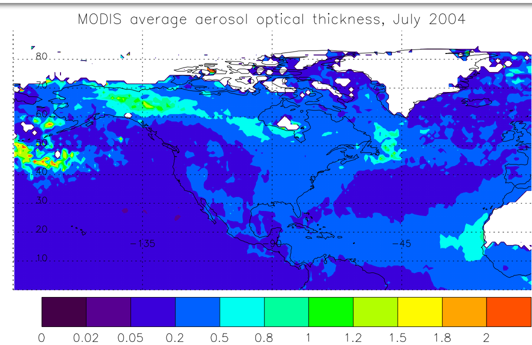
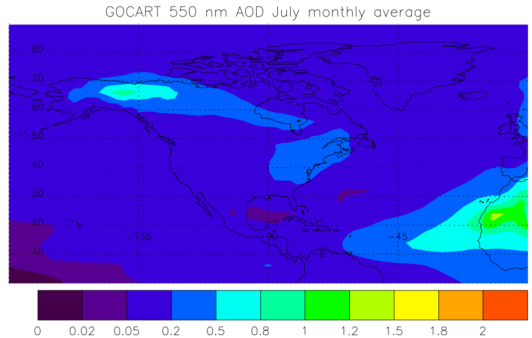
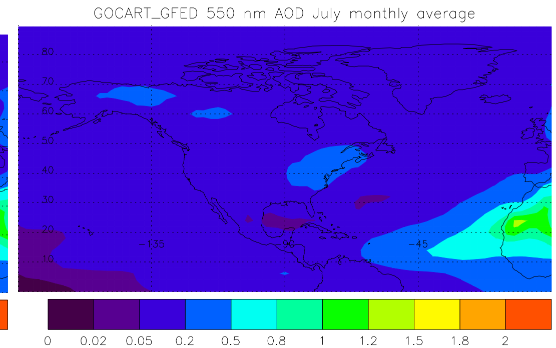
Motivation

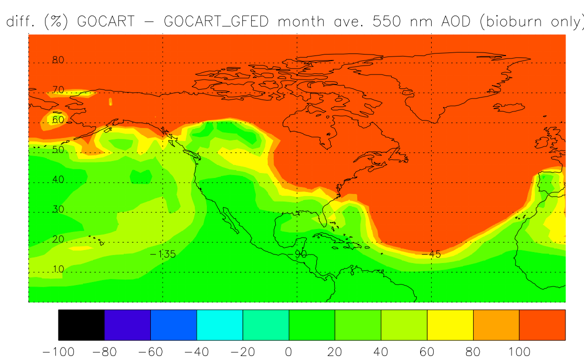


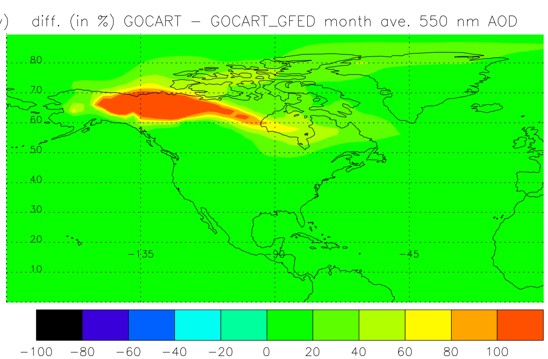












A. Soja, 2006, pers. Comm.

Estimating biomass burning emissions

Bottom-up approach

Dry Mass (DM)

$M_j = A * B * C * F_j$ (Seiler & Crutzen, 1980)

- M_j – mass of emitted gas/aerosol species j ; (g)
- A – burned area; (m^2)
- B – density of available biomass (kg/m^2)
- C – combustion completeness (unitless fraction)
- F_j – species-specific emission factor; (g_j / kgDM)

$M_j = C_j * FRE$ (Ichoku & Kaufman 2005)

- Mj – mass of emitted gas/aerosol species j ; (g)
- *FRE* – fire radiative energy; (W)
- C_j – species-specific emission coefficient; (kg_j /W) (0.*368* × *10*$^{-6}$ *Wooster et al., 2005)*

Top-down approach

- *INVERSE MODELING* - estimate source strength starting from resultant measurements of
  - CO by MOPITT (Arellano et al, 2004);
  - AOD by MODIS & AERONET (Dubovik et al., 2008)

Estimating Burned Area (*A*)

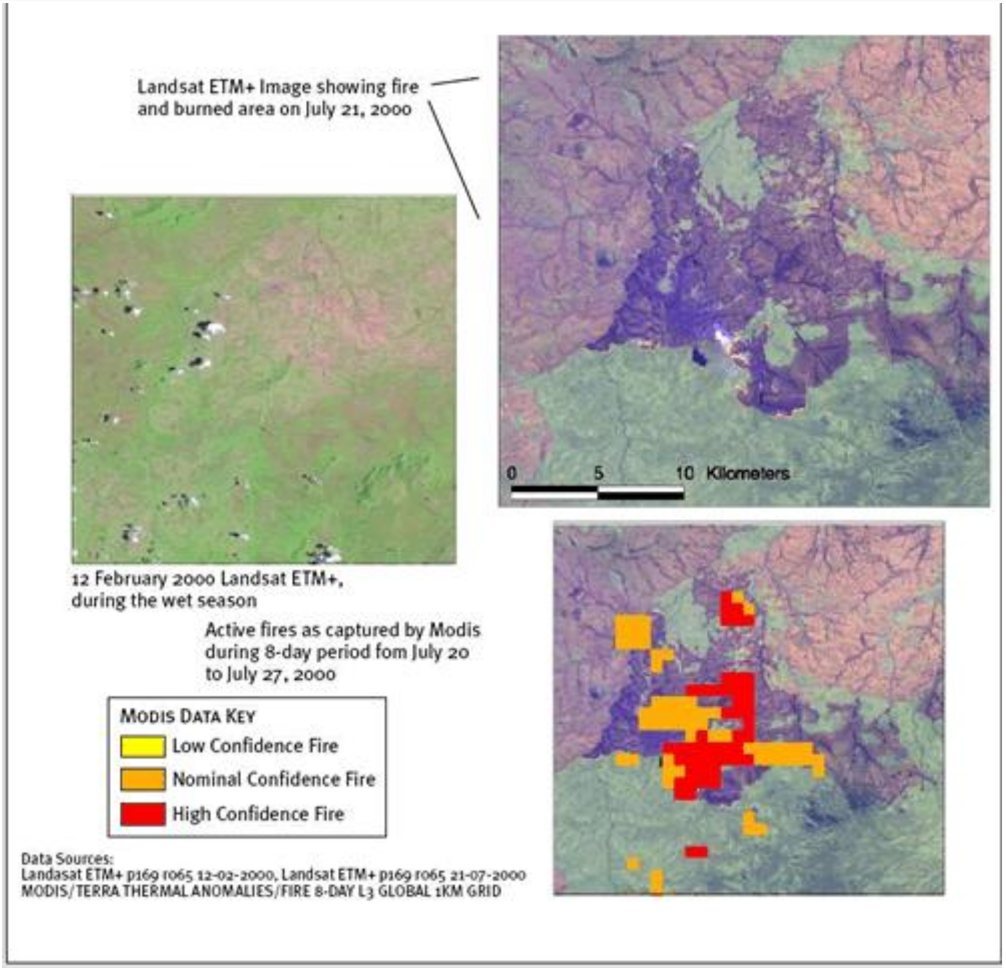
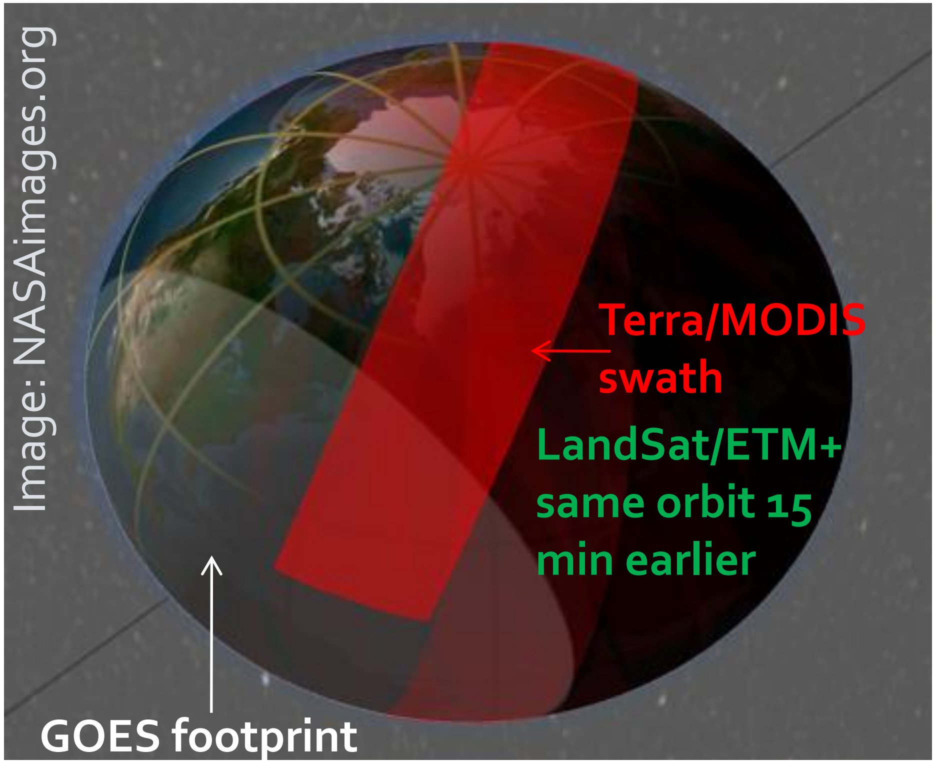


FIGURE 5.7. A comparison of MODIS Active Fire and Landsat ETM+ data for detecting total area burned by a July 21, 2001 fire in Ruaha National Park, Tanzania. (Map by: J. Forrest, WCS)

http://www.cbd.int/ts32/ts32-chap-5.shtml

- **Ground observations** by forest & fire services
- **Satellite instruments** detect fire-induced spectral changes:
  - Surface reflectance
  - Surface brightness
  - Leaf area index
  - Vegetation indices

Burn area (*A*) detection



Polar Orbiting satellites: MODIS instr.

- **Temporal resolution:**
  - 2-4+ meas. daily
  - products : 1+ days
- **Spatial resolution:**
  - **Fire detection** (thermal channel) – 1 km 100 ha
  - **Burned area** (reflectance from vis & IR channels) – 500 m 25 ha

Geostationary Satellites: SEVIRI instr.

Temporal resolution: 15 min

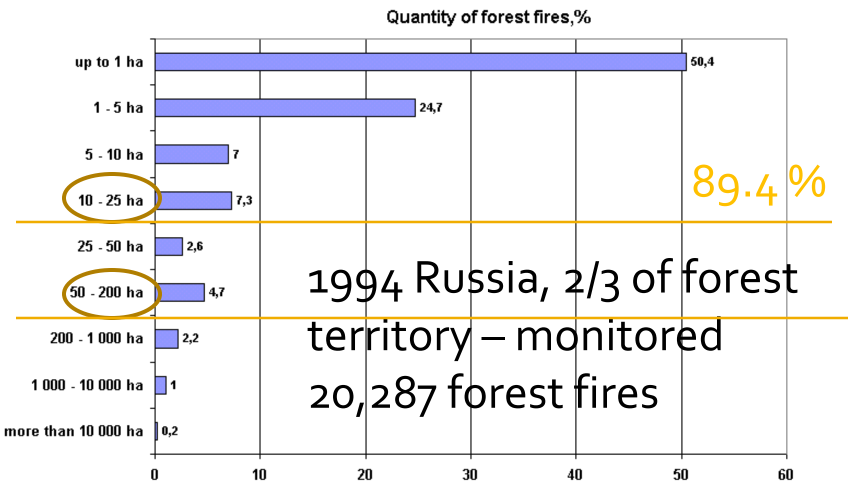
Spatial resolution: 3 km 900 ha

LandSat Enhamced Thematic Mapper (**ETM+)**

Temporal resolution: 16 days

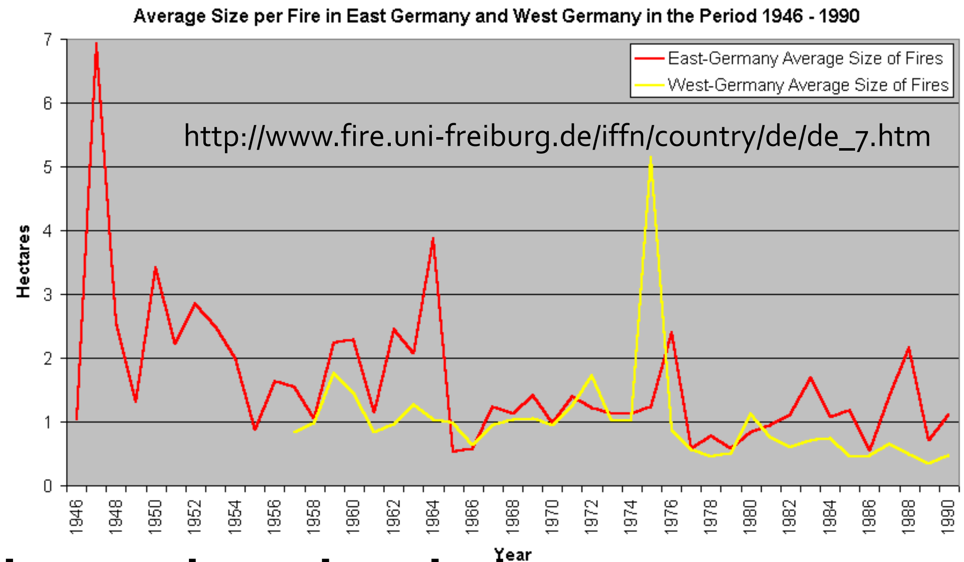
Spatial resolution: 30 – 60 m

Some statistics of fire occurence

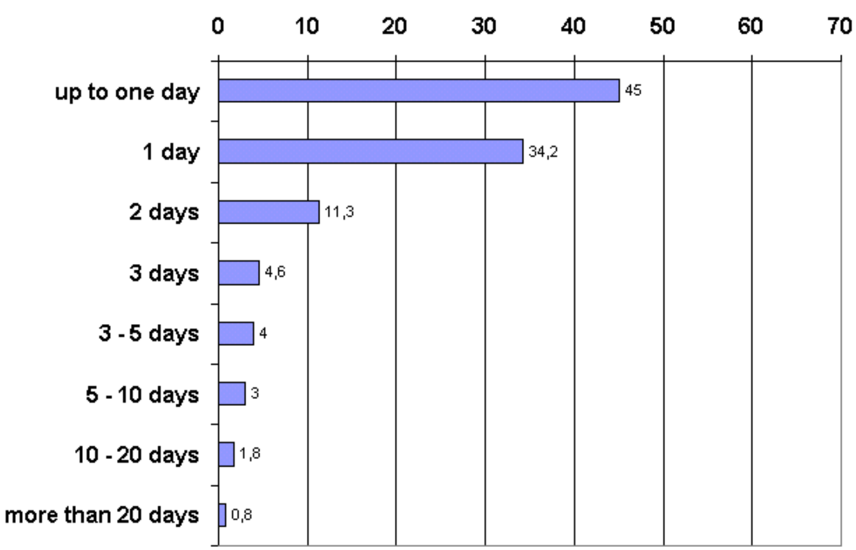


89.4 %

1994 Russia, 2/3 of forest territory – monitored 20,287 forest fires



http://www.fire.uni-freiburg.de/iffn/country/de/de_7.htm

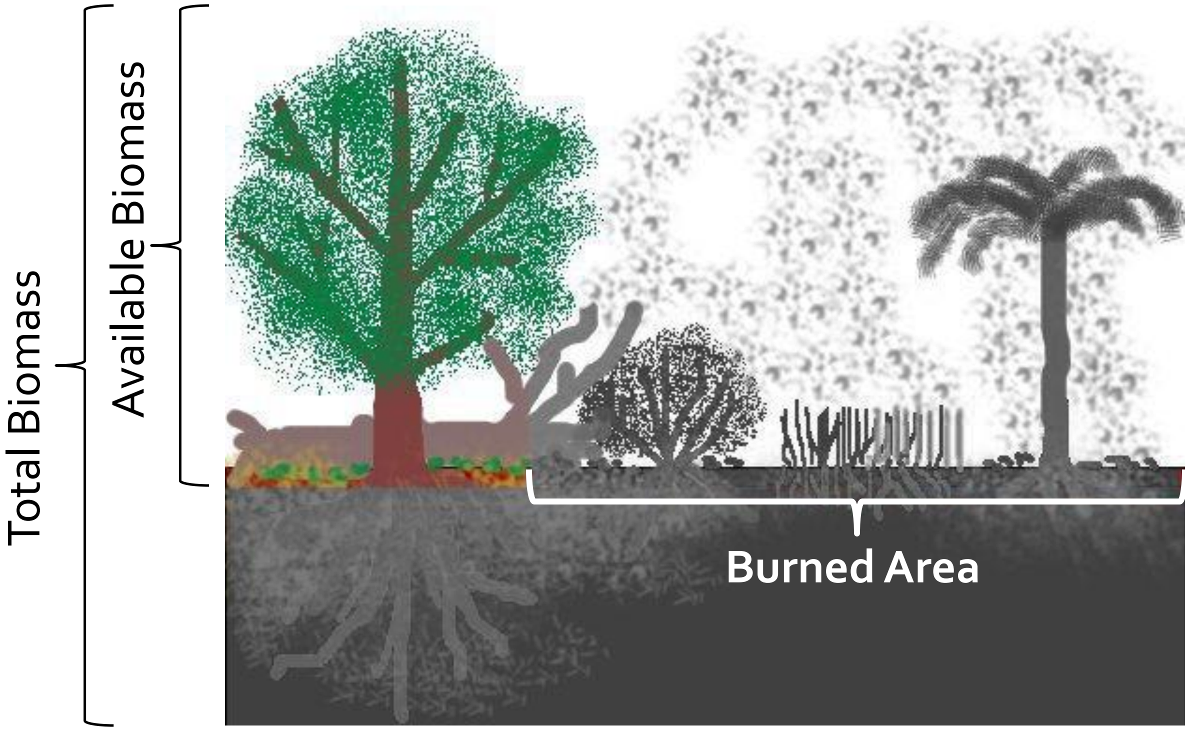


Things to keep in mind:

- Detectable active fire is ~x1000 smaller than the min. detectable burned area (Giglio et al., 2006)
- Active fires and BA are often sub-pixel
- temporal vs. spatial resolution, different commission and omission errors

http://www.fire.uni-freiburg.de/iffn/country/rus/rus_19.htm

Biomass density (*B*) & Combustion completeness (*C*)



C – combustion completeness (unitless, 0-1)

fcc – fuel carbon content (a.k.a. carbon fraction of the biomass) ~0.45

BA – burned area, m²

F_j – emission factor, g_j/kg_{DM}

R_j – emission ratio, $g_j/kg_{tC\ (CO_2)}$

Available biomass (a.k.a. fuel load) ; kg → C → Potential Dry Mass, kg/m² ⇕ fcc ⇕ Carbon Consumption (CC), kg/m²

→ BA → Dry Mass Burned (DM), kg ⇕ fcc ⇕ Total Emitted Carbon (tC) , kg

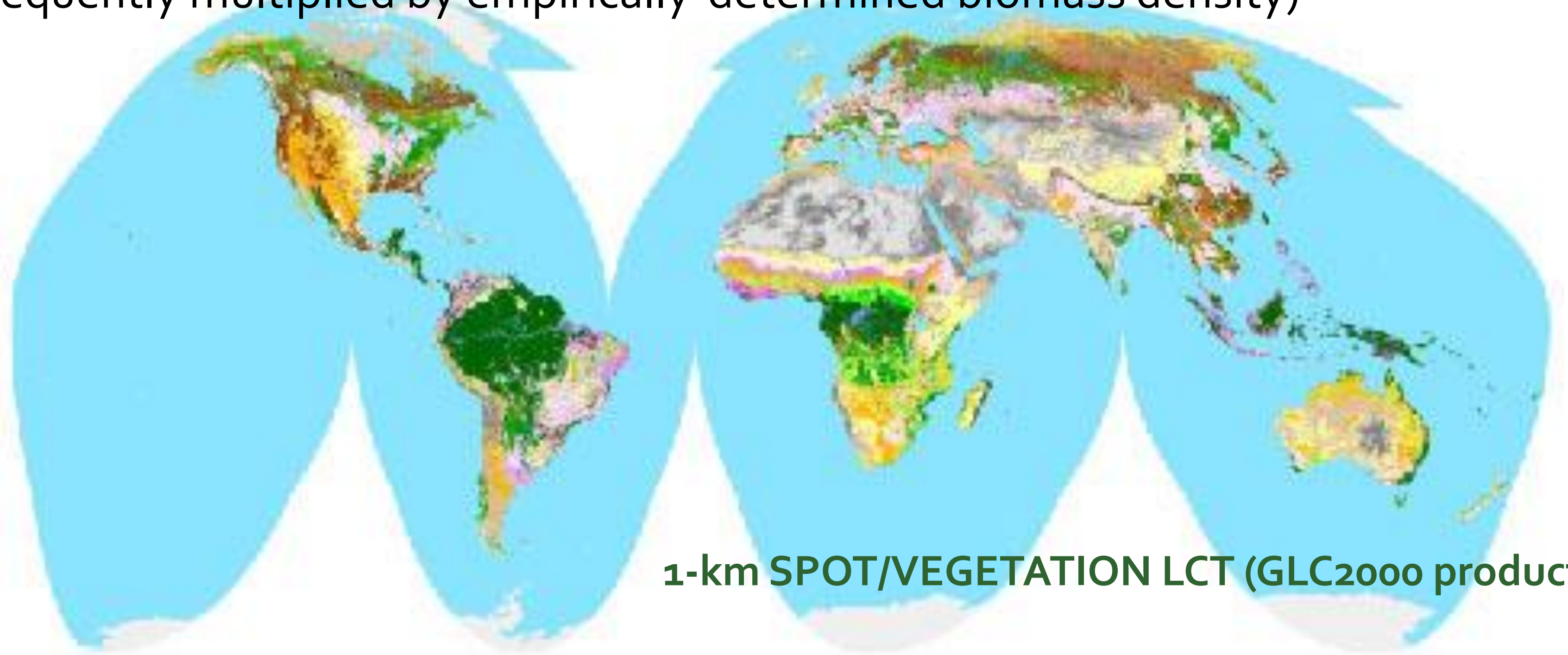
→ F_j / R_j →

- TPM
- BC
- OC
- CO_2
- CO
- CH_4
- NMHC
- NOx
- ...

Available Biomass: satellite-based classification of land cover

- 17 standard land cover types incl. 11 veg. types

defined by the International Geosphere- Biosphere Programme (IGBP)
(subsequently multiplied by empirically-determined biomass density)



1-km SPOT/VEGETATION LCT (GLC2000 product)

MODIS (500 m - 0.5°, yearly)
SPOT/VEGETATION (1 km, “yearly”)

Figure from http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php

Available Biomass estimates: biogeochemical models

CASA model (Carnegie Ames Stanford Approach) (GFED3: Van der Wef et al, 2010)
→ 0.5°, monthly
Simulates biomass dynamics
Estimates fire emissions from fraction of carbon pool combusted (estimates combustion completeness) , and LCT-dependent emis. factors
Inputs: temp., precipitation 1°x1°
solar radiation (1 km - 2°,daily – climatology)
LCT (500 m)

Emission factors

- Usually static (no time resolution)
- Derived from biomass burning in the lab or in field experiments
- Currently globally possible F_j for each of 11 vegetation types (GLC, Liousse et al.)

- $F_{OC} = \sim 4\text{-}8\ g/kg_{DM}$
- $F_{BC} = \sim 0.6\text{-}1\ g/kg_{DM}$
- $F_{CO_2} = \sim 1600\ g/kg_{DM}$

Excited about the new (since Andreae & Merlet, more comprehensive compilation of emission factors!

$M_j = ABCf_i$

- Resultant resolution of the BB emissions inventories, possible down to 500 m (finest of all parameters) daily
- Sub-daily (diurnal cycle) possible

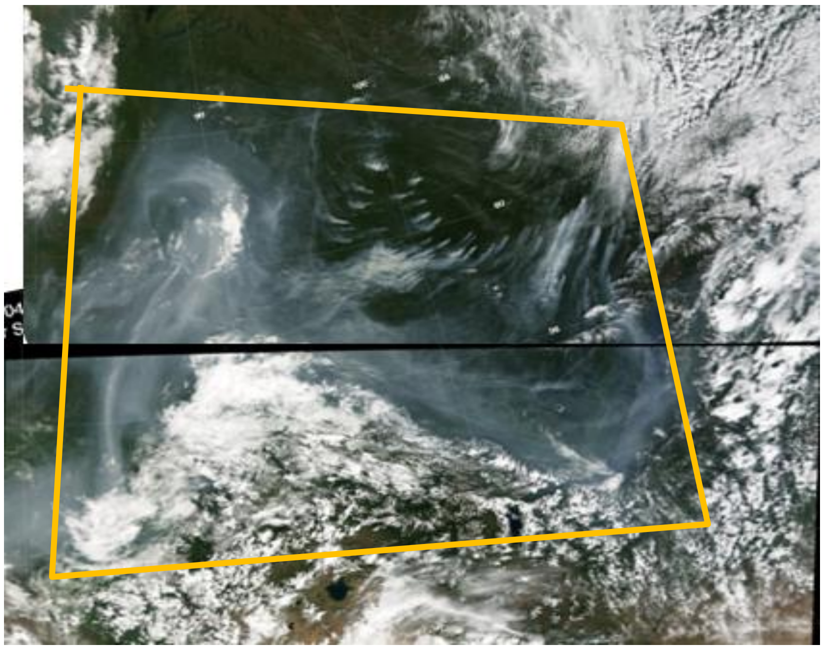
- Emission datasets are usually aggregated to a coarser spatial grid (0.5+ °) to meet the needs of the global modeling community

GOCART model resolution

is determined by meteorological fields

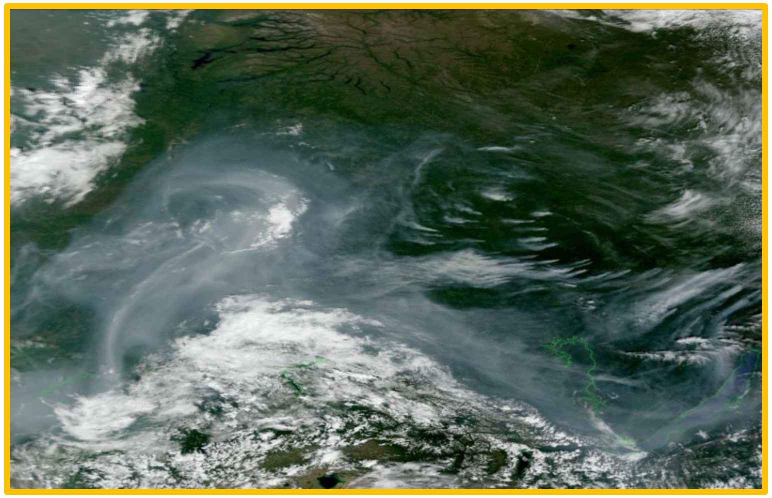
GEOS-4	**GEOS-5**
1° lat x 1.25° lon	0.5° lat x 0.625° lon
55 (30) vertical layers	72 (47) vertical layers
30 min time step	30 min time step

Case study:
Fires in Russia 20 July 2006



MODIS visible image
Sinusoidal projection

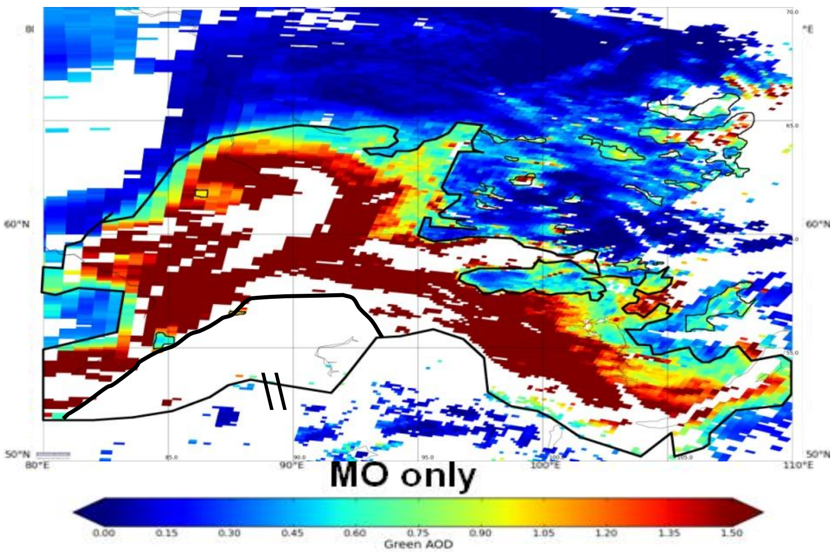
70 N



50 N

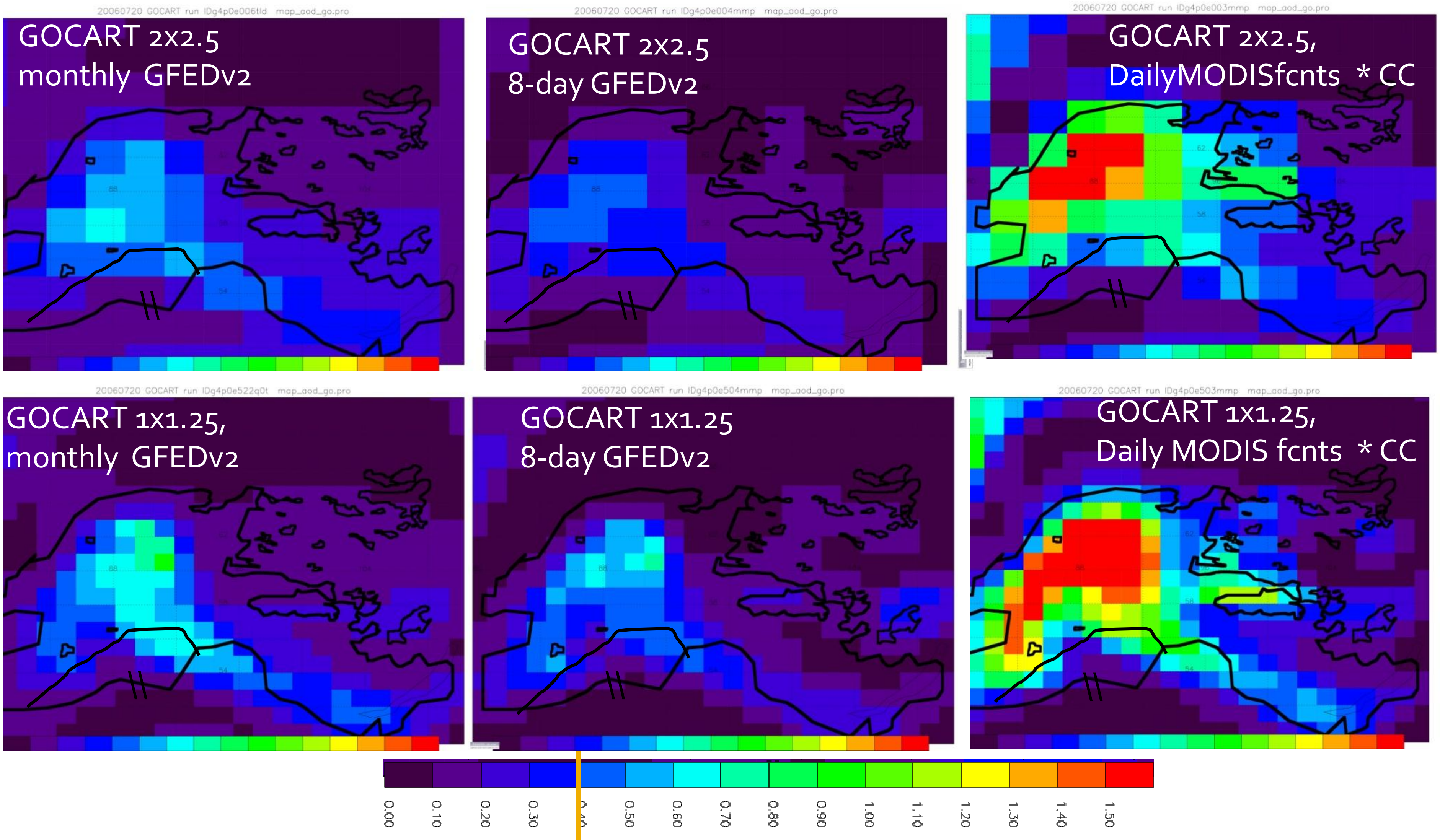
80 E

110 E



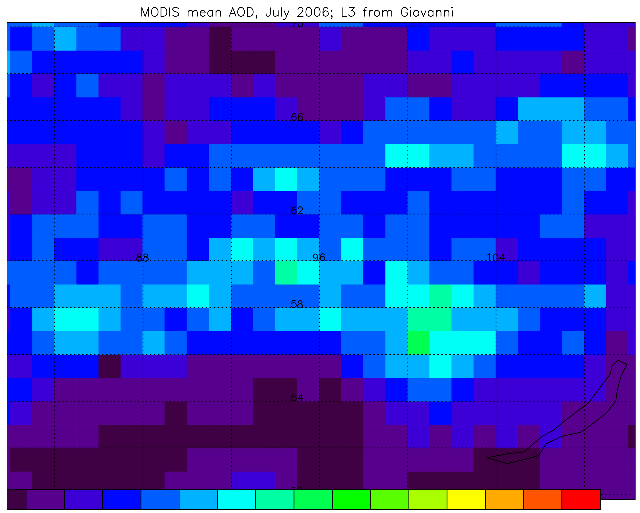
Study area
Cylindrical equidistant projection

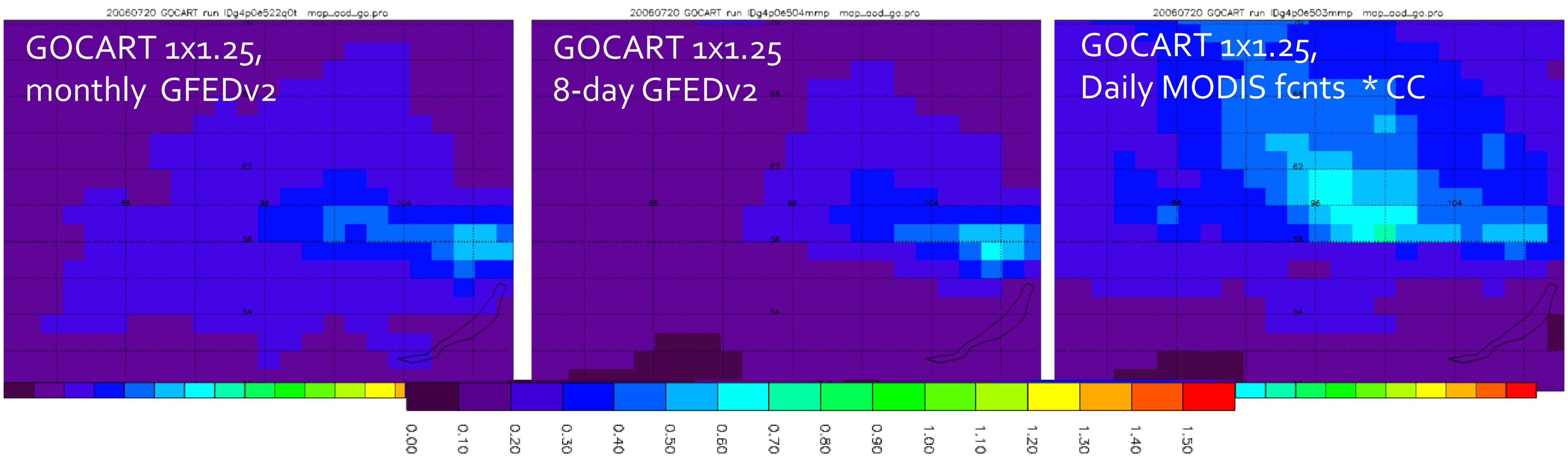
GOCART AOD



GOCART 2x2.5
monthly GFEDv2
GOCART 2x2.5
8-day GFEDv2
GOCART 2x2.5,
DailyMODISfcnts * CC
GOCART 1x1.25,
monthly GFEDv2
GOCART 1x1.25
8-day GFEDv2
GOCART 1x1.25,
Daily MODIS fcnts * CC
0.00
0.10
0.20
0.30
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
1.50

MODIS AOD and GOCART AOD
July 2006 month averages





Summary

- Finer resolution emission input into the model produces AOD output, which compares better with MODIS AOD
- Current spatial resolution of inventories are well compatible with the global models, finer temporal resolution is desired

Concluding remarks

- I'm playing with GOCART and different daily emission inputs with case studies - also explore model capabilities and regional differences & importance
- We use MODIS fire counts as daily BA estimate, but keep in mind the shortcomings
- Expecting GFED3 daily
- Also, waiting for an updated emission factors dataset
- Diurnal cycle & shorter than daily input – work in progress (FLAMBE looks attractive, E. Elicott)
- Global distribution of plume vertical resolution based on observations is a long shot – parameterizations are being developed

Acknowledgements

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