Evaluation of Near-Real-Time Biomass Burning Emissions Estimates derived from MODIS and GOES Active Fire Detections during 2006

Jay Al-Saadi[1], Amber Soja[2,1], Brad Pierce[3,1], Shobha Kondragunta[3], Xiaoyang Zhang[3], Louisa Emmons[4], Christine Wiedinmyer[4], Chieko Kittaka[5,1], Todd Schaack[6], Jim Szykman[7,1]

1 NASA Langley Research Center, Hampton, VA 2 National Institute of Aerospace, Hampton, VA 3 NOAA NESDIS, Camp Springs, MD 4 NCAR, Boulder, CO 5 SSAI, Hampton, VA 6 SSEC, University of Wisconsin, Madison WI 7 US EPA, Research Triangle Park, NC

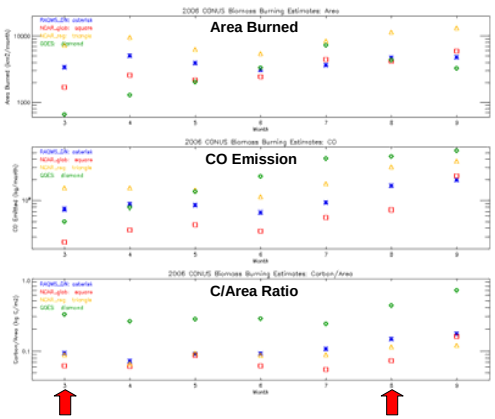
1. Introduction

We intercompare estimates of biomass burning area burned and CO emissions derived from four different techniques using satellite fire detections over the continental US during 2006. Two techniques use daily active detections from MODIS Terra and Aqua, one technique uses the 8-day MODIS Climate Modeling Grid product, and one uses the half-hourly detections from current GOES platforms. The techniques are summarized in the following table. While not "near-real-time", the MODIS Climate Modeling Grid product used in NCAR Global is intended to remove sampling artifacts from polar-orbiting MODIS fire detections, providing a valuable reference in this evaluation.

	NASA Global (RAQMS)	NCAR Global (MOZART)	NCAR Regional	NOAA GOES
Domain	Global	Global	North+Central America	CONUS
Satellite Fire Detection	MODIS Rapid Response	MODIS Climate Modeling Grid	MODIS Rapid Response	GOES processed half-hourly
Area Burned Estimate	1km^2 for each unique Terra+Aqua detect in running 48-hr window	GFEDv2 scaled by Terra 8-day Climate Modeling Grid detects	Vegetated fraction of 1km^2 from combined Terra+Aqua detects	Simulated from WF_ABBA subpixel algorithm
Emissions Estimate	Calculated from fire severity-based carbon consumption databases (severity estimated with Haines Index) and published emission ratios	GFEDv2 scaled by Terra 8-day Climate Modeling Grid detects	Calculated from biomass fuel loading databases, MODIS vegetation products, and published emission ratios	Calculated from fuel loading databases, combustion efficiency parameters, and emission factors from FOFEM model
2006 Dates of Coverage	Feb 1 GOct 15	Jan 1 GDec 31	Jan 1 GDec 31	Mar 1 GSep30
Horizontal Resolution	1 deg x 1 deg	1 deg x 1 deg	1 km (MODIS nadir pixel size)	4 km (GOES nadir pixel size)
Temporal Resolution	Daily	8-days	Daily	Daily
Species available in this intercomparison	CO, NO, area-burned	CO, NO, CO2, CH4, PM2.5, area-burned	CO, CO2, CH4, PM2.5, VOC, NOx, area-burned	CO, area-burned
Other species typically produced	C; other species (NMHC, aerosol) calculated from C	Other species calculated from CO2	PM10, HCN, CH3CN, NH3, SO2, Hg	PM2.5, CH4

2. Time Series of Monthly Totals over CONUS

The figure below shows time series of monthly totals from each of the techniques integrated over the continental United States during 2006. Shown are area burned (top panel), CO emission (middle panel), and ratio of carbon emitted to area burned (bottom panel). Within any particular month there is up to an order of magnitude spread in area burned and CO emission. The three methods using MODIS fire detections have consistent relationships with each other for both area burned and CO emission (values from NCAR Regional are largest of the three and from NCAR Global are smallest of the three). These relationships are consistent with the treatment of MODIS fire detects. The GOES technique shows a stronger seasonal cycle in both area burned and CO emission. The area burned estimates are similar to the MODIS-based estimates from May through August and are lower during March, April, and September. GOES-based CO emissions are largest of all techniques from June through September.
In these mean statistics the GOES technique has a consistently larger carbon emission ratio (bottom panel). The MODIS-based approaches show similar emission ratios to each other in spite of the different methods for determining CO emissions.

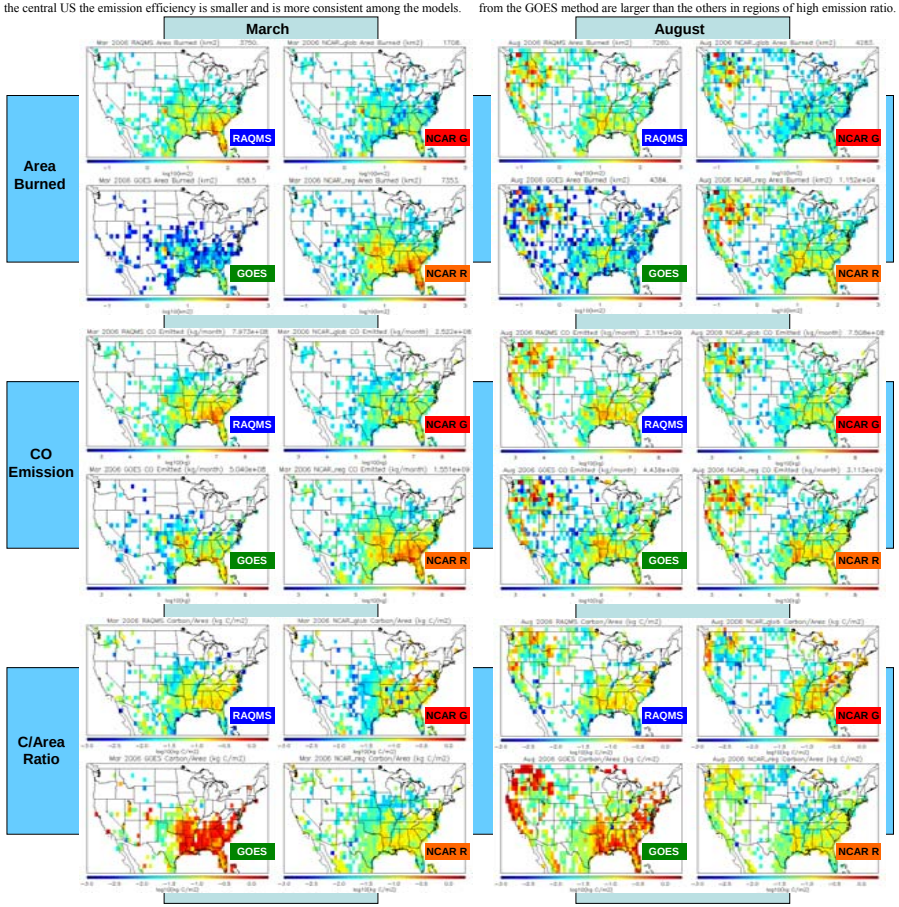


Next we focus on two months to analyze details of these comparisons. We look at March (the time of the NASA INTEX-B campaign), a period of large disagreement in both area burned and CO emission, and August (during the TexAQS campaign), a period of better agreement in area burned, larger CO emissions, and large range of CO emission estimates.

3. CONUS 1-degree Maps: Monthly Area Burned, CO Emission, and Carbon Emission per Unit Area Burned

During March spatial patterns are reasonably consistent as all methods show that most burning is occurring in the southeastern and south central US with peak burning in north Texas and the Florida panhandle. GOES has fewer detections in the northern US. GOES area burned estimates are smaller than MODIS-based estimates in the southeast and are often smaller than 1km^2. Much of this burning is associated with small-scale agricultural fires. CO emissions appear more consistent among the techniques than the area estimates. Largest emissions and largest differences are in the southeast. Order-of-magnitude differences are apparent in carbon emissions per unit area through most of the southeast, where GOES values are typically the highest, values from RAQMS and NCAR Regional are similar to each other, and values from NCAR Global show the most heterogeneity. In the central US the emission efficiency is smaller and is more consistent among the models.

During August the GOES method is detecting more small fires in the Midwest, Plains, and Rocky Mountain regions associated with very small burn areas. All methods appear to produce similar area-burned estimates in regions with large area burned (Northwestern States). Again there is good spatial consistency in CO emissions among the techniques as regions of high emissions (northwest and southeast) are similarly captured by all methods. In the 1-degree cells with highest emissions the GOES values are typically the largest, followed by NCAR Regional. All methods show high carbon emission ratios in the southeast and Pacific northwest. Beyond this spatial similarity there is less consistency among the techniques in the actual values of this ratio than is seen in March, although in both months the values from the GOES method are larger than the others in regions of high emission ratio.

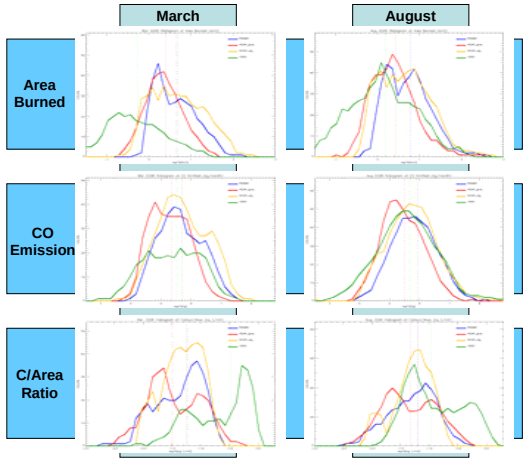


Variation in the Carbon Emission per Unit Area is highlighting differences in deriving area burned estimates from instantaneous fire detections, in the details of the emission models (including ecosystem and vegetation dependences of emission factors and fuel loadings), or both. Comparison with the MODIS Land Cover Map shown to the right indicates that largest differences are associated with evergreen forests in the Pacific Northwest and with forest ecosystems and crop land in the Southeast.

4. Histograms of 1-degree Area Burned, CO Emission, and Emission Ratio

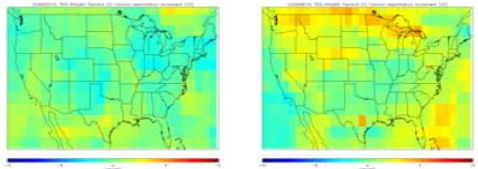
The March area-burned distribution from GOES has a different shape than the MODIS estimates, skewed toward smaller values with a median of 0.15 km^2. Median values for the MODIS techniques are 2.5-5 km^2. Histogram shapes are more consistent for CO emission than Area though clearly GOES has fewer 1-degree cells in which fires are detected. The carbon emission ratio histograms show an appearance of bimodality in all four techniques. GOES has a distinct population of points with high ratios, consistent with the large ratios found in the southeastern US. On these logarithmic scales, the rightmost (largest) values in the histograms control the total monthly values shown in the time series at the bottom left of this poster.

The shapes of the area histograms are more similar in August than March because the peak in the GOES distribution has shifted to larger values and all methods show a tail of high values associated with large fires in the Northwest. The CO emission distributions have similar shapes although the GOES and NCAR Regional distributions are broader than the others and the peak in the NCAR Global distribution is skewed toward smaller values. The emission ratios are quite different from those in March. The GOES distribution is still bimodal but the dominant peak occurs at values similar to NCAR Regional and RAQMS. The NCAR Global distribution is the least changed from March to August.



5. Evaluation of CO Emissions

A global reanalysis with the RAQMS model, using RAQMS emissions shown here, has recently been completed in which CO observations from the TES instrument on the Aura satellite have also been assimilated. The assimilation increment (assimilation result minus model first guess) provides a qualitative evaluation of the biomass burning CO emissions in regions where CO variability is primarily a result of biomass burning. These figures show mean daily TES-RAQMS CO assimilation increments during March (left panel) and August (right panel) expressed as a percentage of the total column amount. Positive values indicate that TES observations are larger than the model first guess. In March the burning emissions are largest in the southeast and the model first guess CO is 0-2% lower than TES (positive assimilation increment) through much of the region, suggesting that the daily variation and magnitude of the RAQMS burning emissions are realistic but could have a low bias. During August, when largest burning emissions are in the northwest, assimilation increments over burning locations range from zero to 3%, suggesting that the RAQMS emissions have a low bias for these fires.



6. Conclusions

- Estimates of the total area burned and total CO emissions (e.g., the time series) are dominated by the largest fires.
- Over CONUS there is a wide spread in area burned estimates with a significant fraction of GOES area-burned estimates smaller than 1km^2. The GOES technique employs a sub-pixel algorithm to infer instantaneous fire sizes while the MODIS-based techniques assume a burn area on the order of 1km^2 is associated with fire detections.
- CO emissions are more consistent than area estimates over CONUS. This is a result of significant differences among the techniques in net CO emission rates per unit area within some ecosystems and vegetation classes. Visual inspection of ecozone maps suggests largest differences are associated with forested land. We have yet to determine whether these differences are associated with estimates of area burned, CO emission, or both.
- Evaluation of a 2006 RAQMS model reanalysis with TES CO observations suggests these RAQMS CO emissions have realistic temporal variation with a low bias over regions of largest burning.