Comparison of Current and Future GOES Fire Characterization

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The WildFire Automated Biomass Burning Algorithm

The need to systematically and reliably generate diurnal biomass burning information led to the development of the Wildfire Automated Biomass Burning Algorithm (WF_ABBA) processing system. With inputs consisting of geostationary satellite data, total precipitable water from numerical forecast models, and an ecosystem map, the WF_ABBA is able to detect and characterize fires in near real-time, providing users such as the National Oceanic and Atmospheric Administration and the hazards community with high temporal and spatial resolution fire data. Current Geostationary Operational Environmental Satellite (GOES) data allows for fire detection at a spatial resolution of 4 km, and the WF_ABBA runs every half-hour for both GOES-12 and GOES-10, detecting fires within a satellite zenith angle of 80° (covering the better part of the visible hemisphere). The WF_ABBA algorithm can be extended to any geostationary satellite platform that possesses 3.9 µm and ~11 µm bands which meet certain requirements (ex: high saturation temperatures, good band-to-band co-registration, etc…).

A Brief Primer on Satellite Fire Detection

IR fire detection from satellites takes advantage of the fact that as target temperature increases radiance increases faster at the shortwave end of the spectrum as opposed to the longwave end. By using two windows such as the 3.9 µm and 11 µm fire locations and even characteristics can be determined. Algorithms can determine the radiance due to the fire itself, within limits determined by viewing conditions and satellite characteristics. That fire radiance can be split into instantaneous size and temperature via the Dozier method or converted into fire radiated power (FRP). The key to successfully estimating any of those quantities is to have good radiance information, which requires correcting for atmospheric attentuation, accurately estimating the background temperature, and having good instrument performance (such as low NEDT at high temperatures and a sufficiently high saturation temperature). Every recent and currently planned geostationary satellite has the IR bands necessary for fire detection, though some have limited capabilities due to low saturation temperatures and/or Level 1 data processing which distorts point sources such as fires.

Calculating Fire Radiated Power and Fire Radiated Energy (FRE)

(and why we want to know them)

FRE and its time derivative FRP are by definition related to the temperature and size of a fire:

$$FRP = A\ s\ T^4$$

where A is the area burning, s is the Stephan-Boltzman Constant, and T is the temperature of the fire. The typical unit of FRP is Watts (J/s) and FRE is Joules. For a given material one may assert that the total FRE of a fire is directly related to mass consumed by that material's heat of combustion, which can then be related to PM2.5 and other emissions. Geostationary satellites allow for observations of sufficient frequency to calculate upwardly emitted FRE from satellite-derived FRP. There are two approaches to calculate FRP: use the above definition with the Dozier-estimated instantaneous A and T, or use an approximation such as the relationship:

$$L_4 = aT^4$$

where L_4 is the radiance at ~4 µm, a is a curve-fitting constant, and T is the fire temperature. This relationship is only valid for 600K < T < 1400 K and fires are assumed to emit as gray-bodies. The "radiance method" FRP looks like:

$$FRP = A_{pixel}\ s\ (L_{4,fire} - L_{4,background})/a$$

Which utilizes the aforementioned difference between the fire pixel and the background radiances. A_{pixel} is the area of the satellite pixel.

Typically emissions from fires for an individual species (i) is calculated through the relationship:

$$Emission_i = A_{burned} * B * CE * EF_i$$

where A_{burned} is the area burned, B is the fuel loading in biomass per unit area, CE is the fraction of fuel burned, and EF_i is the emission factor for species i. Combined the terms A_{burned}, B, and CE equal biomass burned (BB):

$$Emission_i = BB * EF_i$$

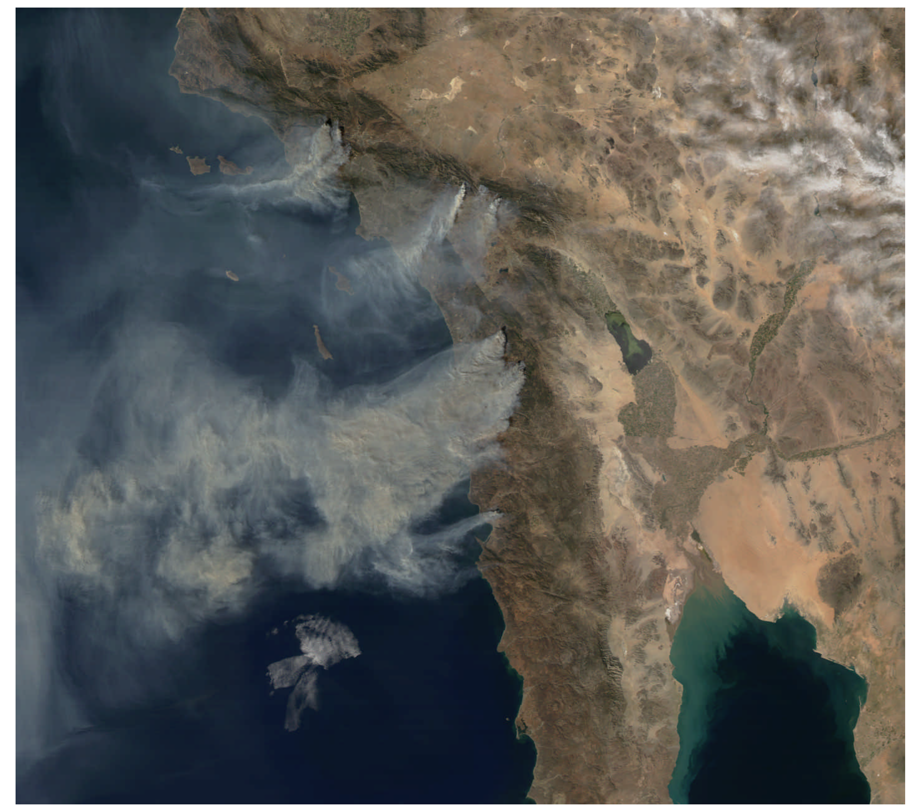
and BB is proportional to FRE, thus:

$$Emission_{i,k} = ß_k * FRE * Ef_{i,k}$$

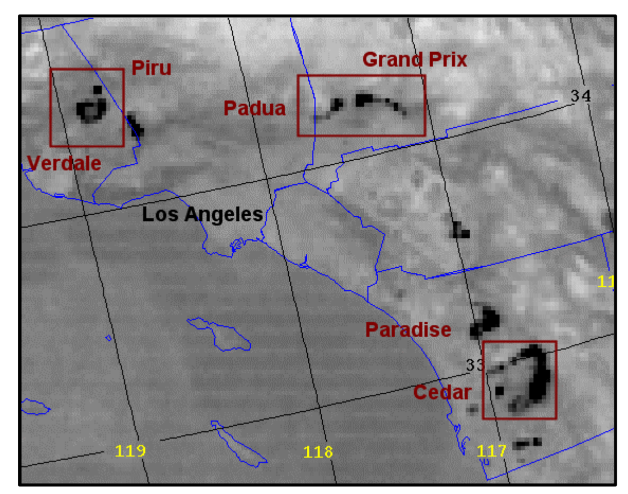
Where $ß_k$ is the constant relating *satellite-detectable* FRE to the heat of combustion of a specific material k. Wooster et al. determined $ß_k$ to be 0.368 for *Miscanthus* and found no evidence to suppose that $ß_k$ varies significantly with vegetation type.

Wooster, M. J., G. Roberts, and G. L. W. Perry, 2005: Retrieval of biomass combustion rates and totals from fire radiative power observations: FRP derivation and calibration relationships between biomass consumption and fire radiative energy release. J. Geo. Res., Vol. 110, D24311, doi:10.1029/2005JD006318

Comparison of GOES-12 and GOES-R ABI Fire Characterization



Above:MODIS True color composite
Below: Simulated GOES-R ABI 3.9 micron data
Date: 27-October-2003 Time: 09:50 UTC



MODerate-resolution Imaging Spectroradiometer (MODIS) observations of the large, destructive fires of October 2003 in Southern California were used to simulate current GOES-12 Imager and future GOES-R Advanced Baseline Imager (ABI) fire characterization capabilities. Instantaneous sub-pixel mean fire temperature and area were derived using the Dozier technique. For this case study GOES-12 and GOES-R were assumed to be located directly over the fires to limit issues introduced by re-mapping data.

FRP was derived from the Dozier output only following the relationship shown on the lower left of this poster. Saturation in the 3.9 micron band on GOES-12 inhibited determination of FRP for 20% of the fire pixels. Only 4% of the ABI fire pixels were saturated. ABI was also able to characterize more of the variability in fire intensity.

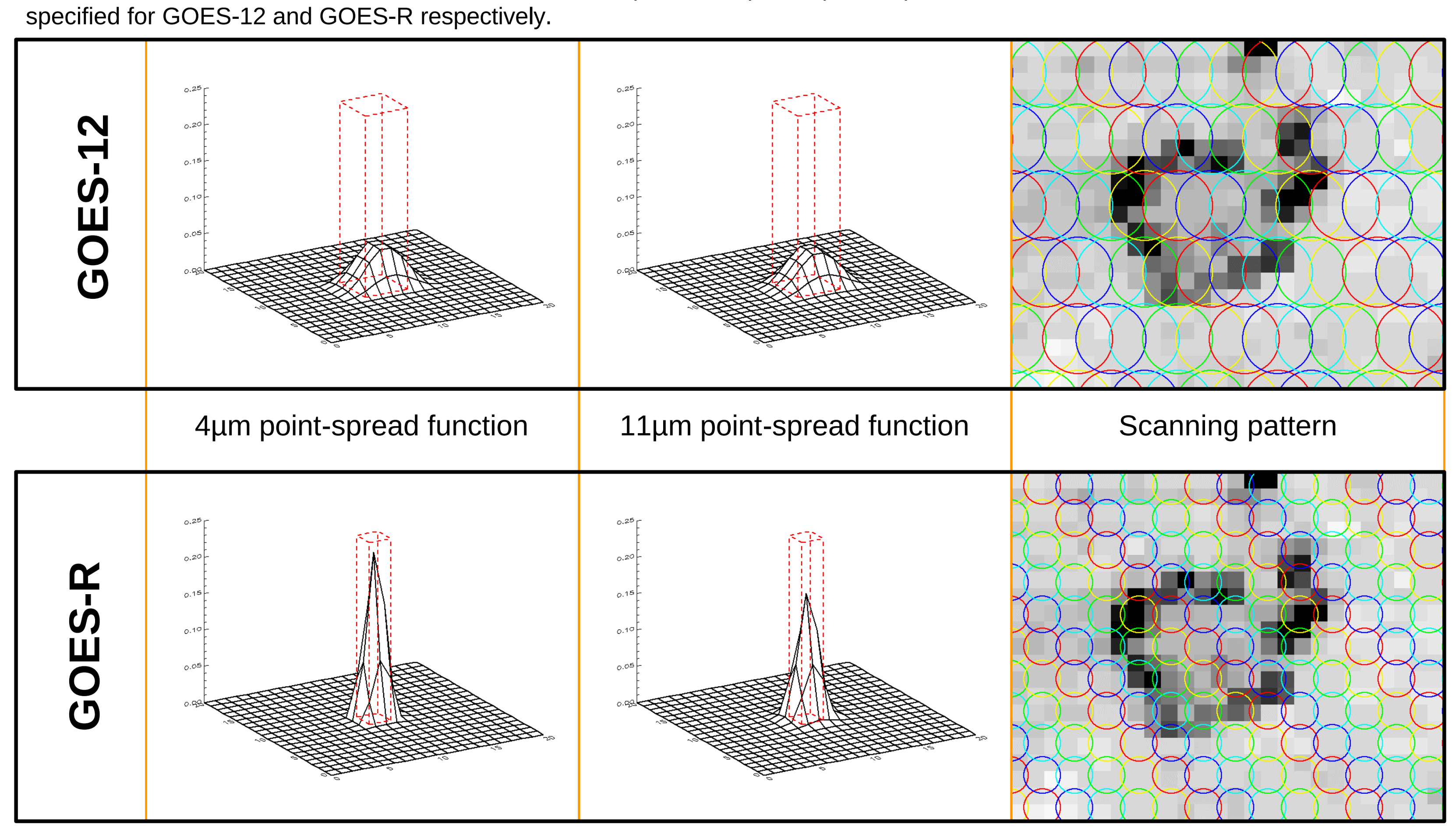
Mean fire pixel FRP:

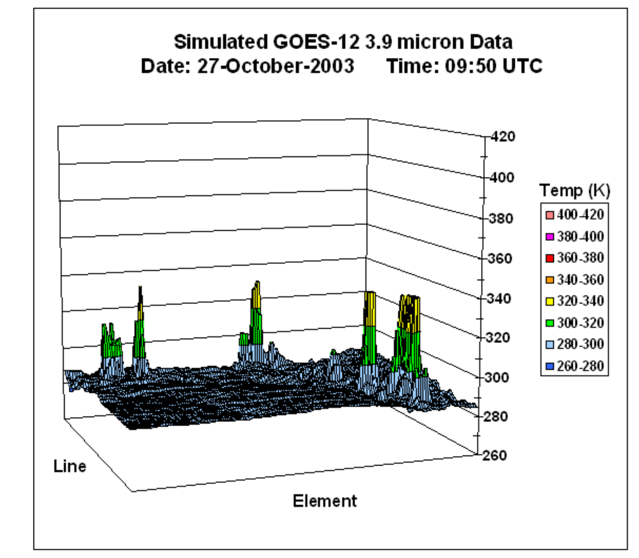
GOES-R ABI: 46 Wm^{-2}
GOES-12 : 24 Wm^{-2}

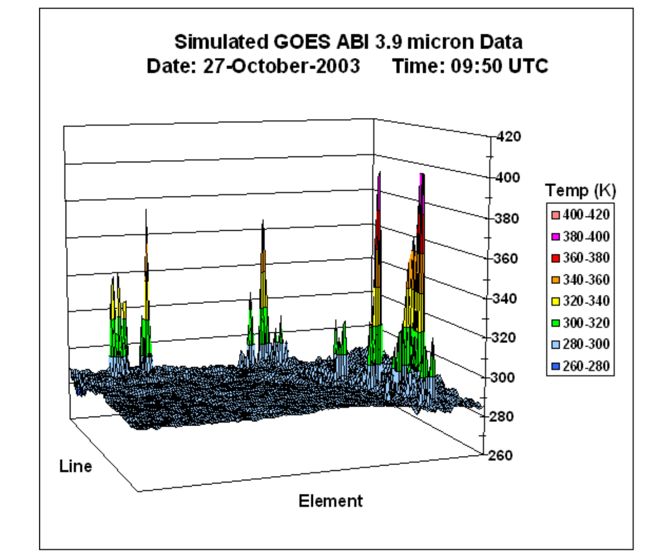
The mean FRP is greater for GOES-R ABI because several of the hotter fires were included in the average, fires that were not processed due to saturation on GOES-12.

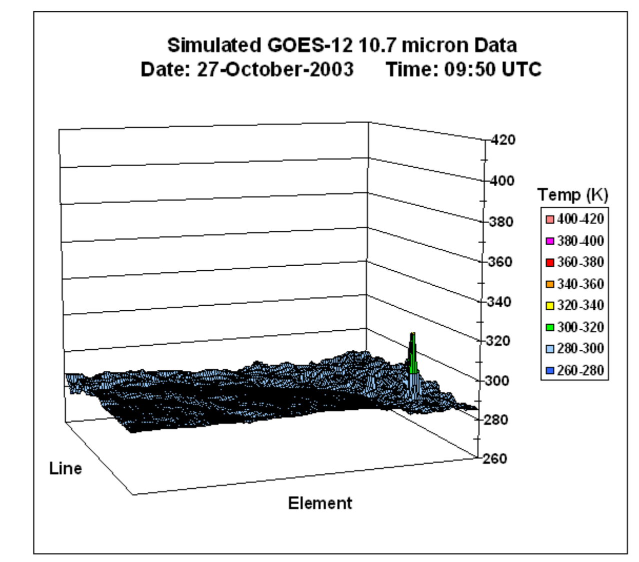
GOES-R ABI vs GOES I-M Imagers: Spatial response and sampling differences

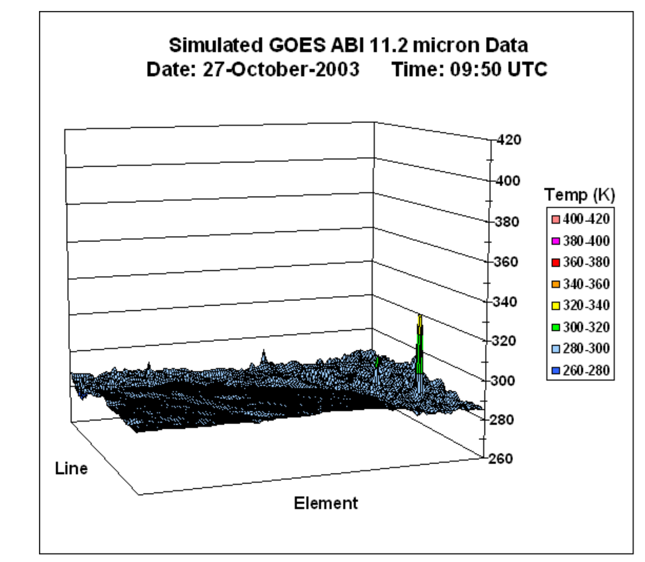
The plots below show the spatial response of each instrument with each gridpoint representing 1 km^2 at the sub-satellite point. The scanning pattern represents an approximation of the size and sampling for both sensors overlaid on the MODIS 3.9 µm image of the Verdale fire. GOES-R is expected to have minimal oversampling compared to current GOES, which oversamples by approximately 2:1 in the East-West direction. The red boxes on the spectral response plots represent the nominal 4 km and 2 km field-of-view specified for GOES-12 and GOES-R respectively.

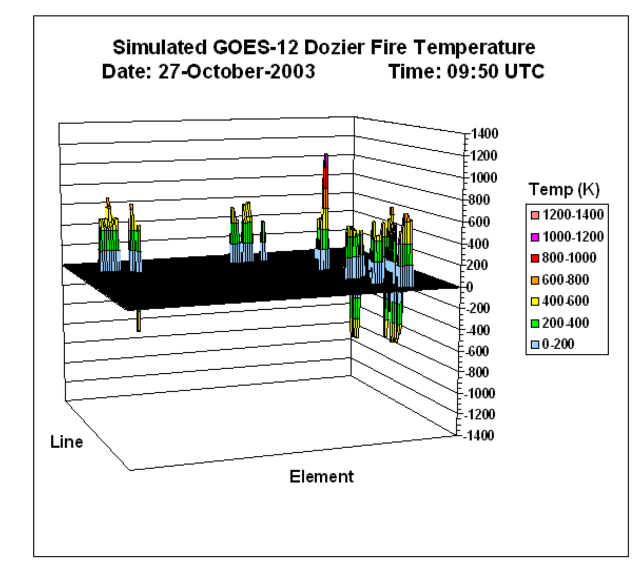


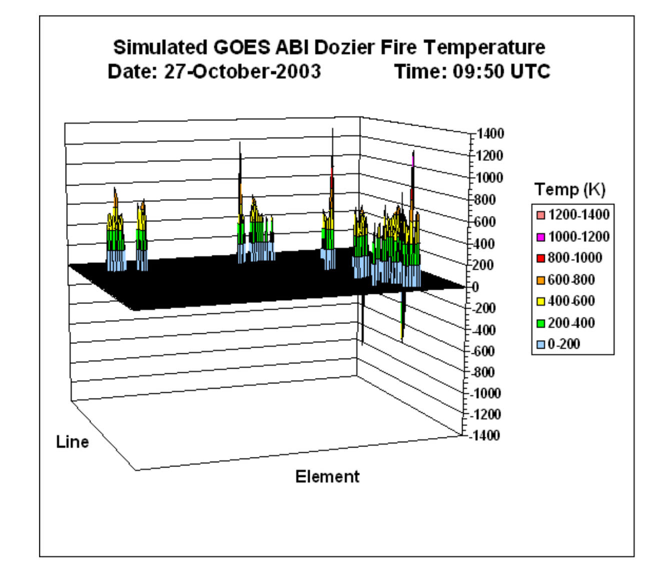


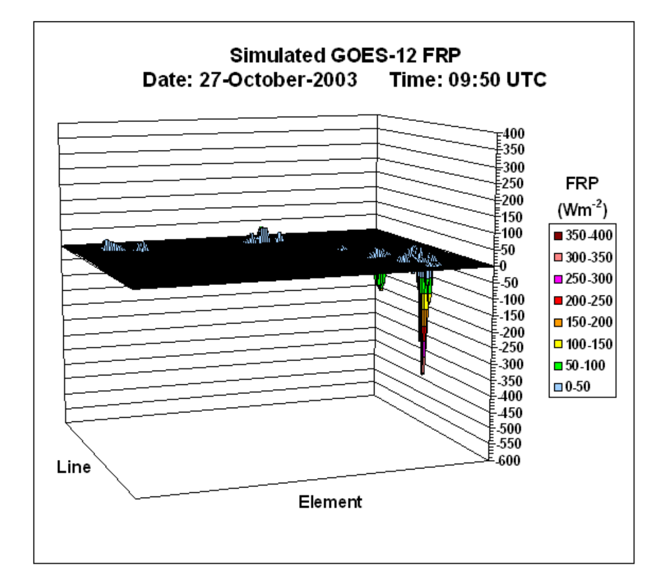


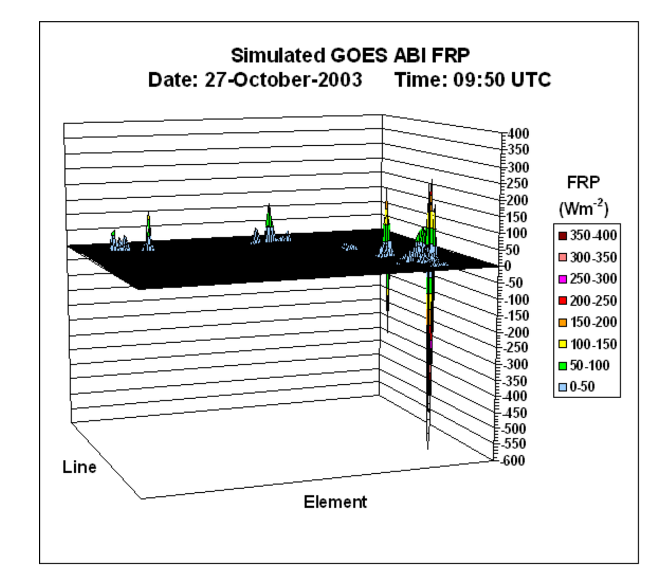












Note: Non-saturated MODIS simulated data were used to calculate instantaneous fire temperature and FRP for saturated GOES-12 and GOES-R ABI data. These estimates are denoted as negative values in the graphs to give an indication of the information lost.

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