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Improving Fire Detection: Current GOES to GOES-R

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Background

GOES-R risk reduction requires advance creation of synthetic satellite imagery and using them to create and evaluate new products before satellite launch. The synthetic satellite imagery should realistically represent events for the fields to be useful for pre-launch product development and assessment.

Creation of synthetic imagery requires computation of radiance for high resolution fields. Point spread function that are representative of GOES-R ABI bands are then applied on the high resolution radiance data to create GOES-R footprints.

Fires because of their nature are often smaller in size than a satellite pixel (Nominal GOES-R ABI and current GOES pixels of 2km X 2km and 4km X 4km respectively). The location of a sub-pixel fire within a GOES-R pixel determines its influence on the GOES-R ABI footprint with central locations having higher influence.Therefore a fire of the same size and temperature will result in varying GOES-R ABI pixel brightness temperature based on the location of the fire within the pixel.

Our goal is to investigate the improvement in fire detection and reduction in retrieval uncertainty going from current GOES to GOES-R ABI where the nominal footprint is smaller and the saturation threshold increases to 400 K from 330 K.

General Procedure

Create high resolution point spread function tables (50m X 50 m resolution) for the 3.9 µm channel using a Bessel function.

Use a synthetic atmospheric profile and compute radiances for GOES-R ABI at 3.9 µm for varying surface temperatures representing different fire temperatures.

Use the previously computed radiances and compute radiances for a GOES-R ABI pixel that contain sub-pixel fires. Note that the ABI pixel size varies and different pixel sizes have to be considered for different physical locations.

Create brightness temperature distributions based on probability of sub-pixel fire location within the GOES-R pixel.

Modeling specifics

(a) Point spread function

Use a bessel function to generate a point spread function using current GOES specifications and project it to the selected latitude longitude location. 50 m resolution point spread function is generated in our case. (Zhang et al. 2006)

(b) Radiative transfer computation

Gaseous absorption is computed using CRTM (Mcmillin et al. 1995).

Radiance computations are made using a plane parallel version of the Spherical Harmonics Discrete Ordinate Method (SHDOMPP, Evans 1998) (Greenwald et al. 2002, Grasso et al. 2008).

(c) Brightness temperature distribution based on fire location.

Ambient surface temperature used is 293 K. Fire temperatures are increased by 5 K with maximum fire temperature being around 1550 K.

Fire sizes range from 50m X 50m to 500m X 500 m.

Results

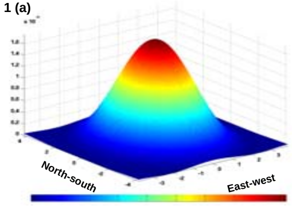


Figure 1(a): This figure represents the normalized probability density function for a GOES-R ABI pixel at 3.9 µm over Kansas representing the point spread function (psf). The nominal pixel size is approximately 2.4 km (East West) X 3.2 km (North-South) while the total area for the psf is 7.6 km X 8.4 km and covers over 99.9% of a bessel function psf.

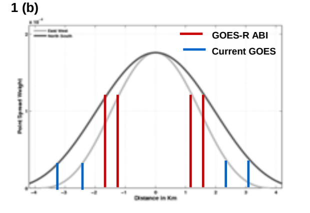
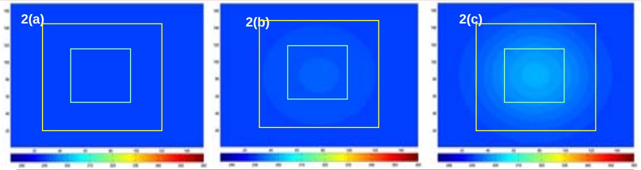
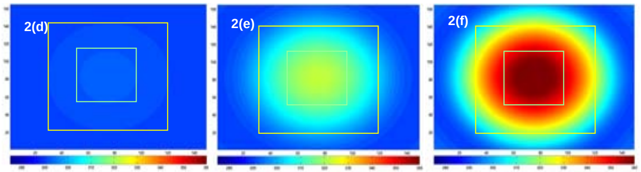


Figure 1(b): This figure represents the East-West and North-South cross-sections of the normalized probability density function for a GOES-R ABI pixel at 3.9 µm over Kansas representing the point spread function (psf). The nominal pixel size for GOES-R ABI is approximately 2.4 km (East West) X 3.2 km (North-South) (in red) while current GOES pixel is represent by double the size (in blue).

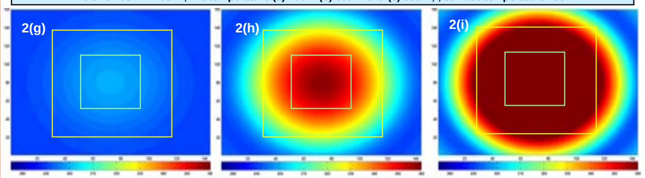
Brightness Temperature distribution based on location, size and temperature of subpixel fire within a 3.9 µm GOES-R ABI (green box) and current GOES pixel (yellow box)



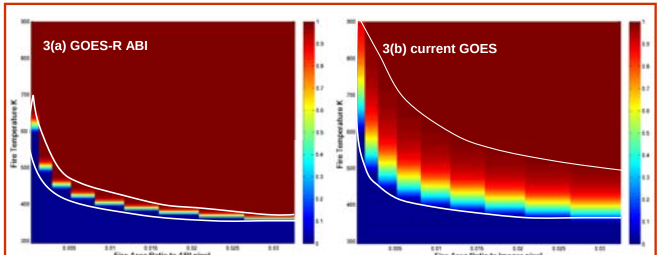
Fire size 50m X 50 m; fire temperature (a) 400 K (b) 600 K and (c) 800 K; surface temperature 293 K



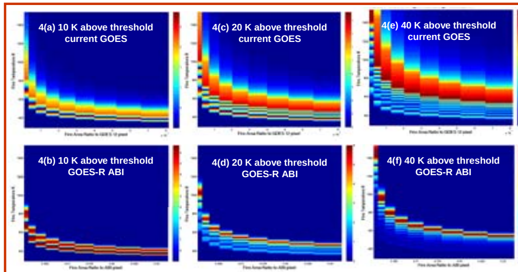
Fire size 250m X 250 m; fire temperature (a) 400 K (b) 600 K and (c) 800 K; ; surface temperature 288 K



Fire size 500m X 500 m; fire temperature (a) 400 K (b) 600 K and (c) 800 K; surface temperature 288 K



Probability that a fire of a particular size (x-axis) and temperature (y-axis) can be detected if it lies within a (a) GOES-R pixel and (b) a current GOES pixel. The brightness temperature at 3.9 µm of the background is 290 K and the detection threshold is taken to be 2 K. Figures 3(a) and 3(b) were created using information from the complete set represented in Figure 2. It is easily seen that smaller fires at lower temperatures will be detected by the GOES-R ABI instrument when compared with a current GOES pixel. Also the probability band (enclosed by white lines) is smaller for GOES-R ABI indicating less retrieval uncertainty than current GOES.



Normalized probability distribution of fire size and temperature for current GOES and GOES-R ABI when pixel brightness temperature is

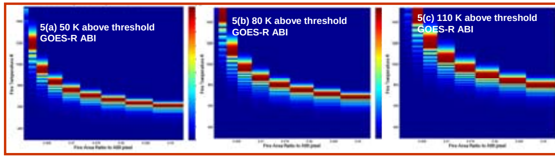
(a &b) 10 K,

(c&d) 20 K and

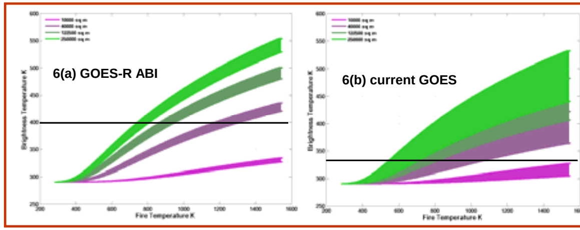
(e &f) 40 K

above the 290 K background.

Note the larger spread in current GOES showing that a smaller pixel size will lead to significantly lower detection uncertainty. Also note the current GOES saturation of 330 K is shown here while the next figure shows the 400 K ABI threshold.



Normalized Probability of fire size and temperature for GOES-R ABI when pixel brightness temperature is (a) 50 K (b) 80 K and (c) 110 K above the 290 K background. Note the higher temperatures that GOES-R ABI can detected compared to current GOES.



Spread in brightness temperature of pixel depending on location of sub-pixel fire within the (a) GOES-R pixel and (b) current GOES pixel. Four different fire sizes are shown. The thick black line shows the saturation thresholds for GOES-R ABI and current GOES.

Conclusions and future work

Point spread functions for the GOES-R ABI channels were created at high resolution using a Bessel function.

The impact of point spread function on sub-pixel fires has been shown to be significant for the 3.9 µm GOES-R ABI band.

Improvement in spatial resolution from current GOES to GOES-R ABI results in a reduction in the minimum size and temperature of fires that can be detected .

Improvement in spatial resolution also lead to a reduction in the uncertainty in the size and temperature of the fire being detected and retrieved.

Raising the 3.9 µm saturation brightness temperature threshold from 330 K to 400 K will result in a significant improvement in the capability to retrieve hotter and larger fires.

Overall it is seen that the improvement in spatial resolution and the saturation threshold from current GOES to GOES-R ABI extends the dynamic range of fire size and temperature retrieval in both directions.

The availability of the 2.25 µm channel on GOES-R provides an additional channel that will extend the dynamic range for fire retrieval to even larger and hotter fires that appear saturated at 3.9 µm

References:

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