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COMPUTATION OF SUBPIXEL FIRE TEMPERATURE WITH MODIS DATA

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ABSTRACT

Fire hot spots have been traditionally detected using the thermal bands of the NOAA-AVHRR sensors. However, AVHRR is primarily designed for measurement of land and sea surface temperature under normal conditions. It has a relatively low saturation level such that fire hot spots easily saturate the sensor. This low saturation level together with the coarse 1-km resolution of AVHRR do not permit the computation of fire temperature and the area of fire. In comparison, the MODIS sensor on-board the Terra satellite has a higher saturation value. It also uses 12 bits (opposed to 10 bits for AVHRR) for signal quantization. Thus, the improved capabilities of MODIS offer an opportunity for the computation of subpixel fire temperature and fire area.

In our model of subpixel fire temperature computation, only a fraction of the hot-spot pixel is assumed to be burning. The rest of the pixel is unburned forest. In the model, the fire area is assumed to occupy a fraction f of the pixel area, with a fire temperature T_f. The background forest occupy a fractional area (1-f), with a temperature T_b. The emissivity ε is assumed to be uniform throughout the whole pixel. The detected radiance L_i of wavelength band-i at the sensor can be expressed in the form,

$$L_i = f\varepsilon B(T_f) + (1-f)\varepsilon B(T_b)$$

where B(T) is the Planck's function for the radiance emitted by a black body at temperature T. If the background temperature T_b and the emissivity ε are known, then the two unknowns in the above equation are the fractional area f and the fire temperature T_f. Hence, if the radiance emitted from a hot-spot pixel is detected at two different bands, then it is in principle, possible to invert the equations to obtain the values of f and T_f.

We have tested the subpixel fire temperature retrieval algorithm using MODIS data acquired on 24 August 2001, 02:31:26 UTC over Kalimantan and northern part of Australia where many hot spots were detected. Two wavelength bands near 4 µm (one of channel 21 or 22, 3.929 – 3.989 µm) and 10 µm (channel 31, 10.780 – 11.280 µm) were used. These channels are within the atmospheric window. Water vapour and aerosol absorption is minimum in this region. Channel 22 saturates at about 335K and channel 21 saturates at about 500K. Channel 22 is less noisy and has a smaller quantization error, hence this channel is used whenever possible. Channel 21 is used in place of channel 22 only when channel 22 saturates or has missing data. An iterative Newton-Raphson method was used for inverting the radiance equations to obtain the subpixel fire temperature and the fractional fire area for each hot spot pixel in the image. A typical value for the emissivity of vegetation was used, and the background temperature for each hot spot pixel was computed using the radiance detected at the 10 µm for the pixels surrounding the hot spot.

The results show that the fire temperature ranges from 700 to 1000K for the test data used. The fire temperature is typically rather small, ranging from 0.002 to 0.01 of the pixel area. The fire area would be grossly estimated if the whole pixel area were used to estimate the fire area.