A Sub-Pixel-Based Calculation of Fire Radiative Power from MODIS Observations: Retrieval, Validation, and Sensitivity Analysis

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I. Introduction and Motivation

Using satellite, airborne, and meteorological data, this study develops and validates a new sub-pixel-based calculation of fire radiative power (FRP) for fire pixels detected at 1 km2 spatial resolution by the MODerate Resolution Imaging Spectroradiometer (MODIS) fire detection algorithm. A two-component model (Dozier method) for retrieving sub-pixel fire area fraction and temperature has been available since 2001. However, in the current investigation, modifications are made to the retrieval to account for atmospheric effects by implementing output from a radiative transfer model at 3.96 and 11 µm (MODIS fire detection channels). In addition, two clustering techniques are implemented to mitigate errors that may exist when using individual pixels. The FRP, in combination with retrieved fire cluster area, allows the calculation of fire radiative power from MODIS observations in 2007.

II. MODIS Sub-Pixel Retrieval and Case Study Specifics

Calculations per MODIS fire pixel (orange in flow chart):

\[ L = P(\lambda) \cdot T + (1-P(\lambda)) \cdot T_b \]

where \( L \) = radiance, \( \lambda = 3.96 \) and 11 µm, \( \lambda = 11 \) µm, \( T \) = fire temperature, \( T_b \) = background temperature at 4 and 11 µm, \( P(\lambda) = 1 - \exp(-\alpha \cdot d) \)

\( \alpha = 0.003 \) for 3.96 µm and 0.079 for 11 µm

The MODIS FRP Validation Model Advantages

- Quantitative retrieval of the intensity
- Proportional to amount of biomass
- Proportional to amount of smoke released
- Low spatial footprint

III. Validation of Retrieved Fire Area

Incorporating the high-resolution data (≥1 km2) obtained from the Autonomous Modular Sensor (AMS), flown aboard NASA’s Ikhana Unmanned Aerial System (UAS) (Peterson et al., Submitted), the MODIS FRP was compared to fire product background temporal and spatial resolutions (Peterson et al., Submitted)

\[ FRP = \text{(fire area fraction) \cdot fire temperature) \cdot fire area \cdot background temperature} \]

IV. Indirect Effects on Retrieved Fire Area

Performing the MODIS Fire Retrieval

- MODIS Pixel #1
- MODIS Pixel #2
- MODIS Pixel #3

V. Clustering-Level Comparisons

- The clustering-level results highlight the importance of averaging to reduce the random errors, highlighted in Section IV, such as the distribution of sub-pixel fires, point-spread-function effects, and comigration errors.

VI. Sub-Pixel MODIS FRP, vs. the Current MOD14 FRP (FRP\text{MOD})

- FRP is strongly correlated to the current MOD14 FRP, but it also contains additional information.

VII. Sensitivity to Background Temperature

Figures 1-7. (Top) Validation of MODIS FRP, and FRP\text{MOD} for cluster and pixel area.

VIII. Concluding Remarks

This study developed a MODIS sub-pixel retrieval for fire area and temperature, which are used to calculate FRP. The retrieval was designed for any MODIS granule and a radiative transfer model was used to account for atmospheric effects. Over the next decade, the new generation of satellite sensors, such as VIIRS and GOES-R, will replace the current generation, including MODIS. Therefore, the sub-pixel algorithm is designed for easy application to all future sensors, provided the basic spectral properties are similar.

Essential References


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