Optimal Band Selection of Multispectral Sensors for Wildfire Detection

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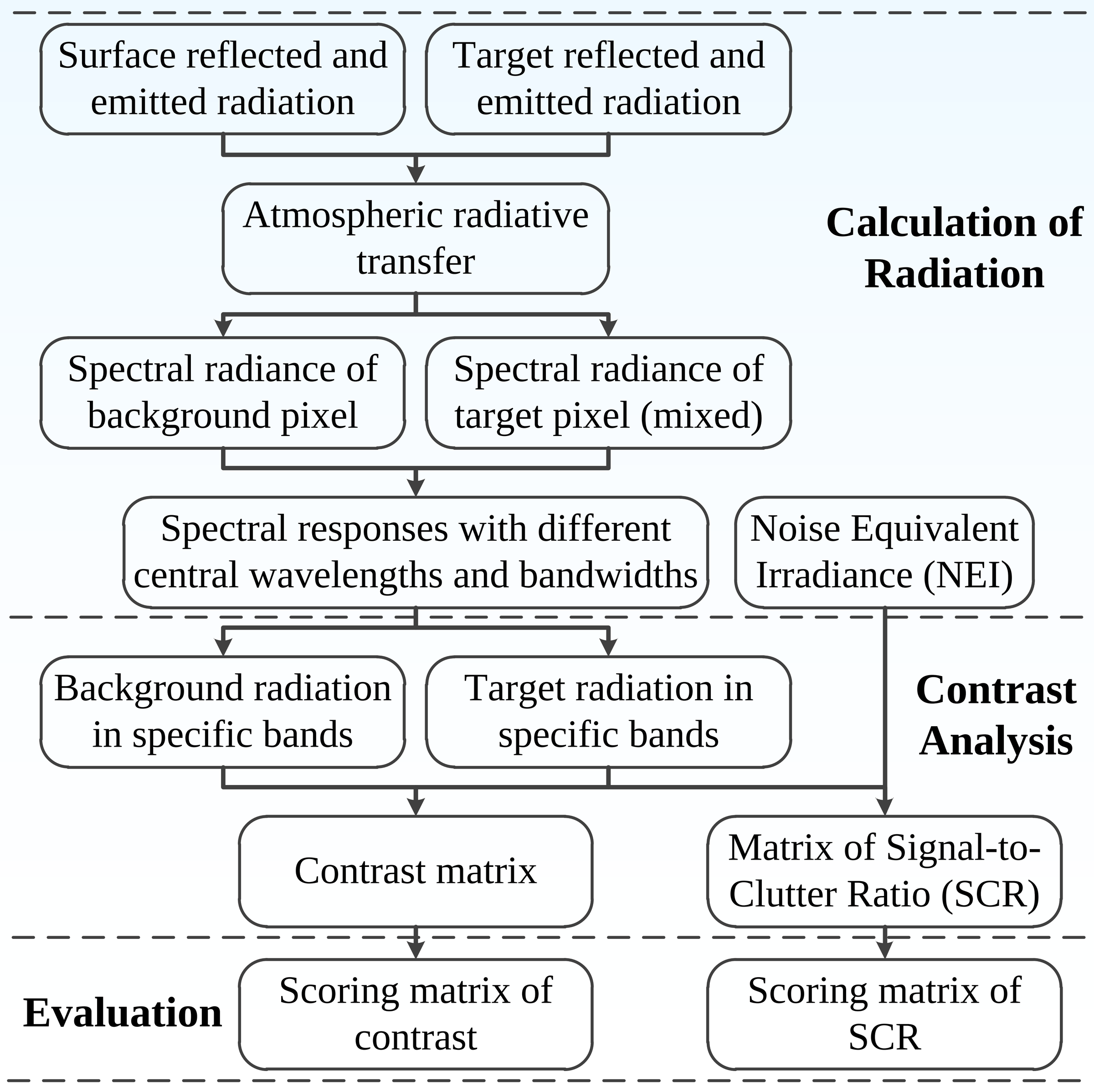
1. Introduction

•The selection of spectral bands is of great important in the design of multispectral sensors.

•The spectral bands of multispectral sensors are decided along with other system parameters before data acquirement.

•An optimal band selection strategy is proposed for multispectral sensors, where the spectral characteristics of the Earth surface, atmosphere and targets as well as the influence of multispectral sensor system are considered.

•To clarify the idea, optimal band selection of a space-based multispectral sensor for wildfire detection is taken as an example.



2. Radiant Calculation Model

A. Background Radiation

• When no target exists in an IFOV, the corresponding pixel in multispectral images is defined as the background.

$$I_b = \frac{\cos\theta_v \cdot \Delta A_s \cdot \Delta\Omega_b}{\pi} \cdot \sum_{\lambda_1}^{\lambda_2} \left(R(\lambda) \cdot E_b(\lambda) \right) \cdot \Delta\lambda$$

• For the Earth observational sensors, the background radiation consists of two components.

$$E_b(\lambda) = E_p(\lambda) + E_g(\lambda)$$

$$E_g(\lambda) = \left[E_0(\lambda) \cdot \tau_s(\lambda) \cdot \rho_r(\lambda) + \varepsilon_g(\lambda) \cdot B(\lambda, T_g) \right] \cdot \tau_v(\lambda)$$

• The spectral irradiance coming from atmosphere E_p and the transmittances τ_s, τ_v can be calculated using atmospheric radiative transfer models.

B. Target Radiation

• Target may not locate at the same distance as the background.

$$I_t = \frac{\cos\theta_v \cdot \Delta A_s \cdot \Delta A_t}{\pi \cdot l^2} \cdot \sum_{\lambda_1}^{\lambda_2} \left[R(\lambda) \cdot E_t(\lambda) \right] \cdot \Delta\lambda$$

• The projected area of target is much smaller than GIFOV. When a target exists in an IFOV, the corresponding pixel in the multispectral image is defined as a target pixel.

$$I_m = I_b + I_t$$

3. Contrast Analysis for Band Selection

A. Contrast Analysis for a single target

•The definition of contrast is given as

$$C = \left(I_m - I_b \right) / I_b$$

•The contrast is related to the spectral radiant exitance of the target and the background, the projected areas, and the spectral response. In the case of fire detection, the background area ΔA_b can be calculated as $\Delta A_b = \Delta\Omega_b \cdot l^2$.

$$C = \frac{I_t}{I_b} = \frac{\Delta A_t}{\Delta A_b} \cdot \frac{\sum_{\lambda_1}^{\lambda_2} \left[R(\lambda) \cdot E_t(\lambda) \right]}{\sum_{\lambda_1}^{\lambda_2} \left[R(\lambda) \cdot E_b(\lambda) \right]}$$

•The uniform background radiation can be suppressed to improve Signal to Clutter Ratio (SCR) for point target detection.

$$\mathrm{SCR} = \frac{I_m - \bar{I}_b}{I_b - \bar{I}_b} = \frac{\phi_t}{\phi_b}$$

•Detection performance depends upon the spectral response characterized by the central wavelength and the bandwidth. For an arbitrary target, the contrast defined can be represented as a two dimensional matrix varying with the central wavelength and the bandwidth.

$$\mathbf{C} = \begin{bmatrix} C_{11} & \cdots & C_{1N} \\ \vdots & \ddots & \vdots \\ C_{M1} & \cdots & C_{MN} \end{bmatrix}_{M \times N}$$

•Elements in the contrast matrix **C** are obtained via compromising the contrast of different surface types.

$$C_{ij} = \frac{1}{n} \sum_{k=1}^{n} C_k$$

•According to the land cover classification map of the International Geosphere Biosphere Programme (IGBP), 17 types of surface are considered in the analysis.

B. Contrast Analysis for multiple targets

•When multiple targets are considered, the contrast matrix is graded quantitatively.

$$P_{ij}^{(k)} = \begin{cases} 1 - a + a \cdot \dfrac{C_{ij}^{(k)} - \gamma}{\max\limits_{ij}(\mathbf{C}^{(k)} - \gamma)}, C_{ij}^{(k)} > \gamma \\ 0, C_{ij}^{(k)} \le \gamma \end{cases}$$

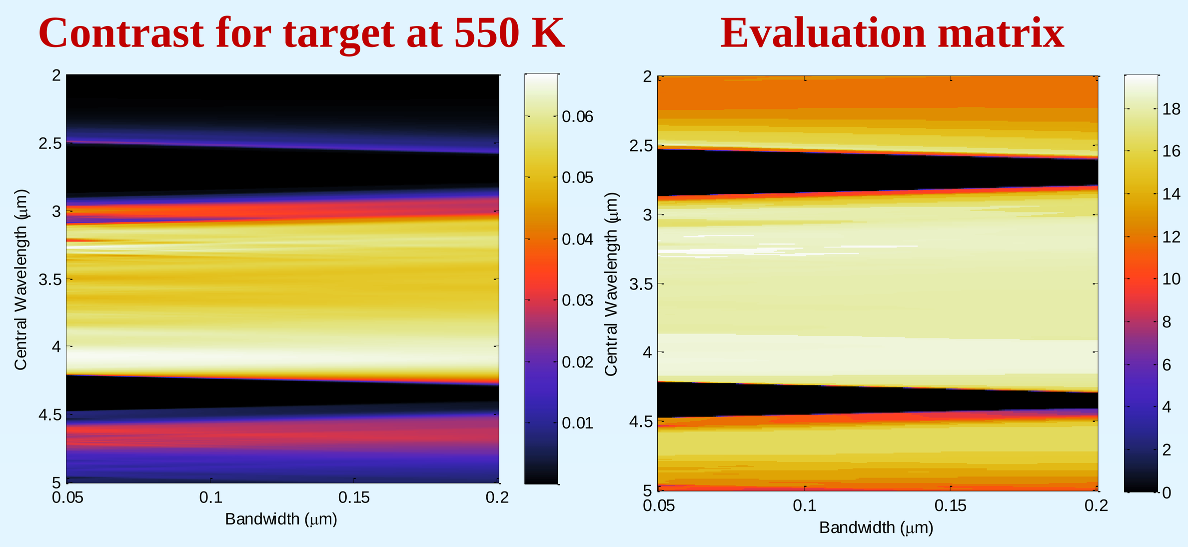
$$\mathbf{P}^{(k)} = \begin{bmatrix} P_{11}^{(k)} & \cdots & P_{1N}^{(k)} \\ \vdots & \ddots & \vdots \\ P_{M1}^{(k)} & \cdots & P_{MN}^{(k)} \end{bmatrix}_{M \times N}$$

•A scoring matrix of SCR can be obtained in a similar way.

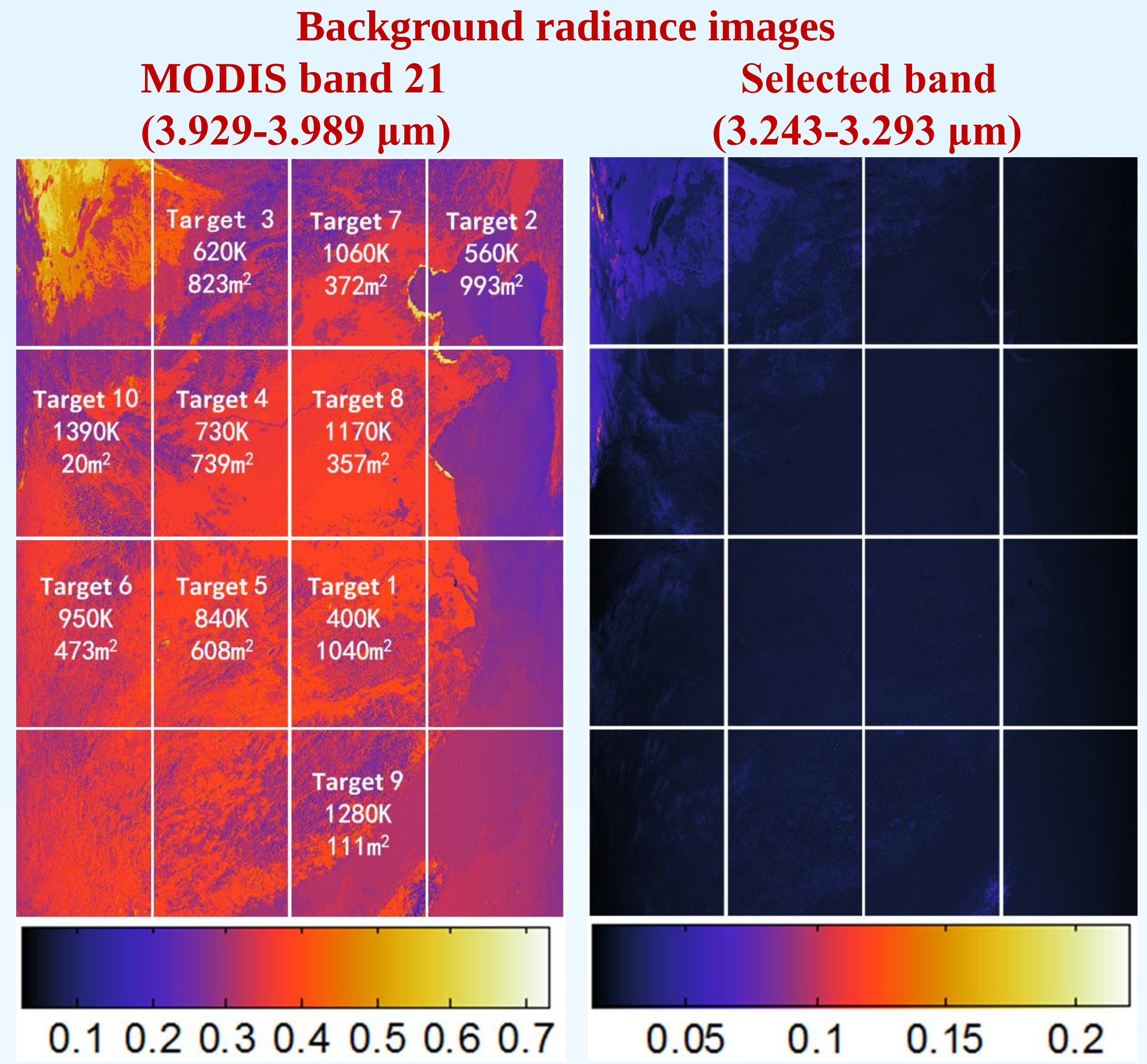
4. Implication of Band Selection Strategy for Wildfire Detection

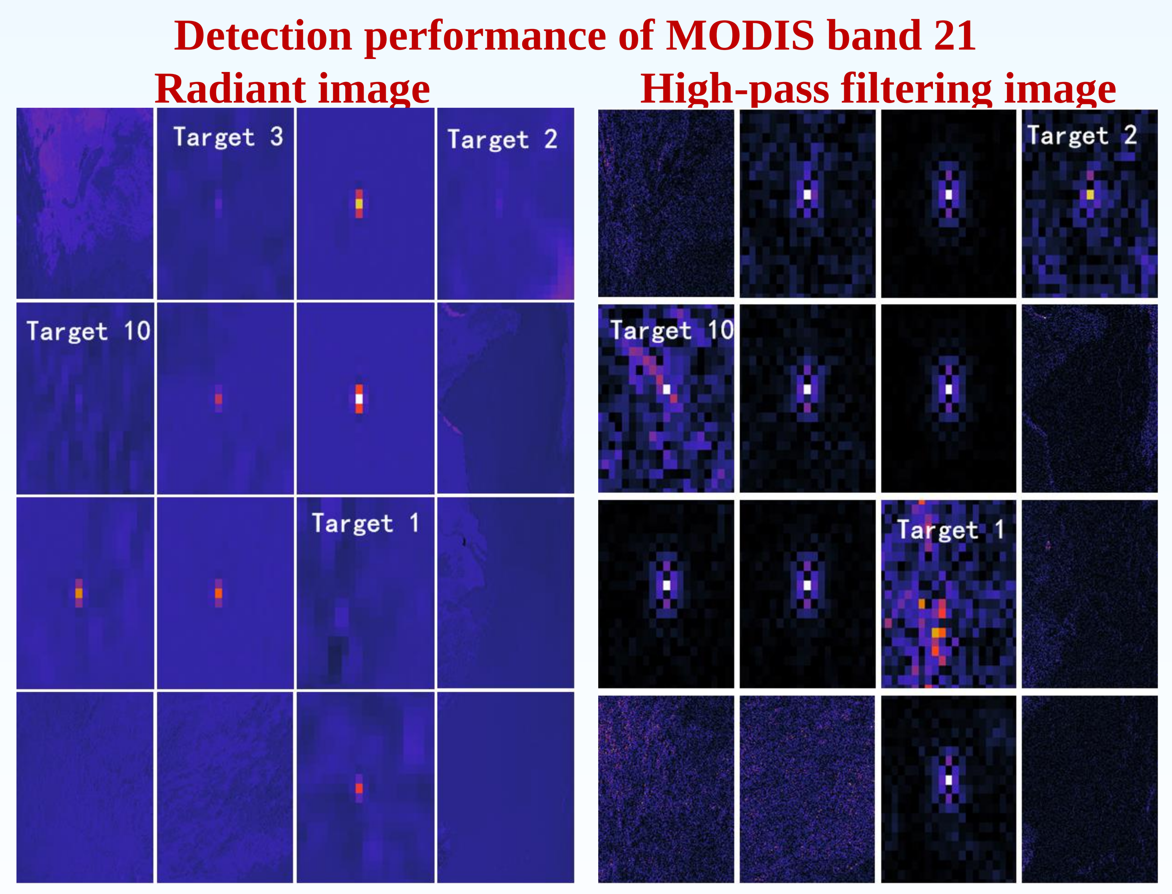
•Target temperature from 500 K to 1500 K in step of 50 K.

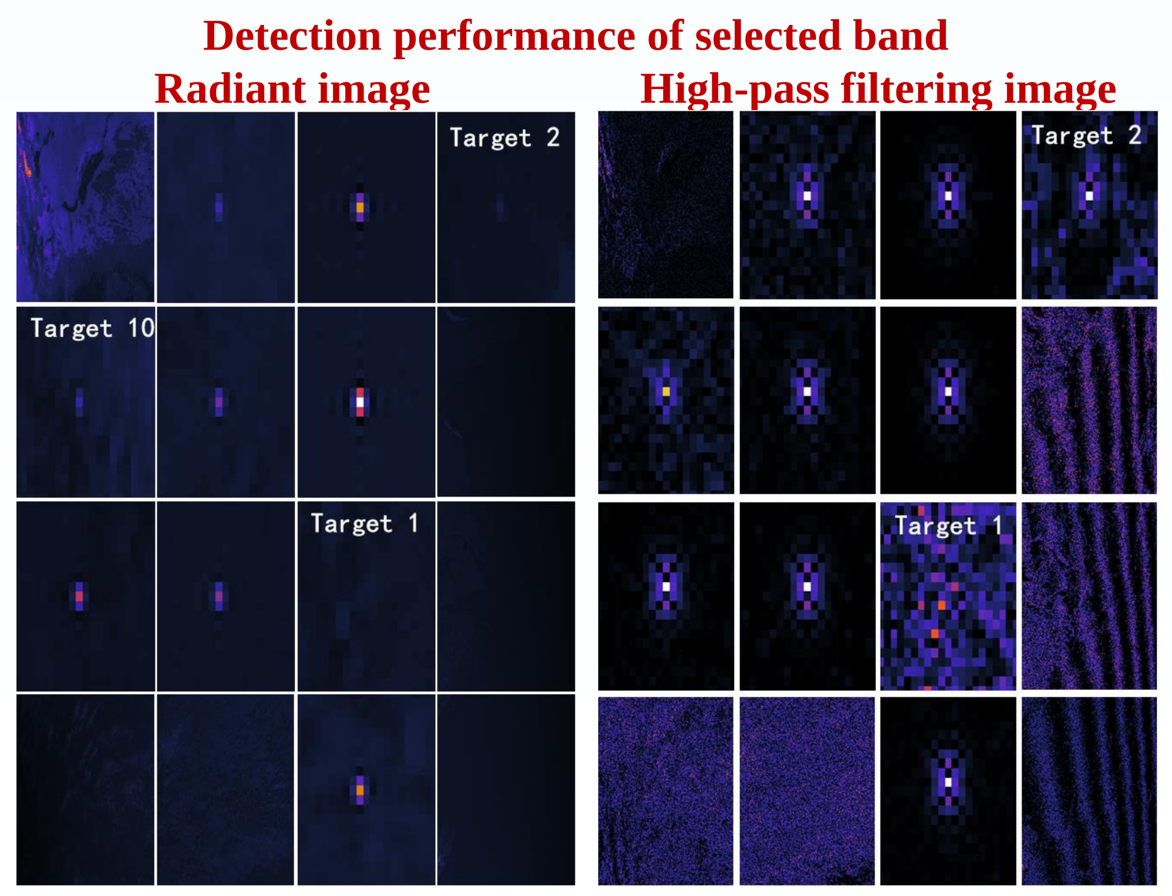
•The spectral radiance are calculated at a spectral resolution of 1 nm.



•The band located at 3.268 μm with a bandwidth of 0.05μm is selected.







5. Summary

An optimal band selection strategy was proposed for multispectral sensors. In order to detail the idea, the strategy was adopted in optimal band selection of space-based multispectral sensors for wildfire detection. The settings of the MODIS were used in the image simulation to demonstrate the usefulness of the proposed strategy. The simulation results show that the detection performance of a multispectral sensor can be improved via spectral band optimization and background radiant suppression.