The FY-3D Global Active Fire product: Principle, Methodology and Validation

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1. Introduction of satellite fire monitoring
2. Theory and method for wild fire detection
3. Validation of FY-3D fire product
4. Application examples of fire monitoring
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## Table. Parameters of FY-3D/MERSI compared with MODIS/Aqua in fire monitoring

| Satellite | Series     | Observation frequency | Resolution (m) | Sensitivity (m²) |
|-----------|------------|-----------------------|----------------|-----------------|
| FY-3C     | Polar orbit| 2                     | 1000           | 70              |
| FY-3D     | Polar orbit| 2                     | 1000           | 70              |
| FY-3E     | Polar orbit| 2                     | 1000           | 70              |
| NPP       | Polar orbit| 2                     | 375/750        | 15/45           |
| NOAA-20   | Polar orbit| 2                     | 375/750        | 15/45           |
| TERRA     | Geostationary| 2                      | 1000           | 60              |
| AQUA      | Geostationary| 2                      | 1000           | 60              |
| FY-4A     | Geostationary| >200                   | 2000           | 250             |
| FY-4B     | Geostationary| 96                     | 2000           | 200             |
| Himawari-8| Geostationary| 144                    | 2000           | 200             |

| Channel | Wavelength/μm | Waveband              | Resolution/km |
|---------|---------------|-----------------------|---------------|
| MERSI   | MODIS         | MERSI                 | MODIS         | MODIS        | MODIS      | MODIS  | MODIS  |
| 1       | 3             | 0.470                 | 0.469         | Visible light| 0.25       | 0.50   |
| 2       | 4             | 0.550                 | 0.555         | Visible light| 0.25       | 0.50   |
| 3       | 1             | 0.650                 | 0.645         | Visible light| 0.25       | 0.25   |
| 4       | 2             | 0.865                 | 0.859         | Near infrared| 0.25       | 0.25   |
| 20      | 20            | 3.800                 | 3.750         | Medium infrared| 1.00     | 1.00   |
| 21      | 23            | 4.050                 | 4.050         | Medium infrared| 1.00     | 1.00   |
| 24      | 31            | 10.800                | 11.030        | Far infrared  | 0.25       | 1.00   |
| 25      | 32            | 12.000                | 12.020        | Far infrared  | 0.25       | 1.00   |
The fires mainly occurred in Northeast, South, Southwest and North China, such as JiLin, GuangXi, YunNan and other provinces.
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The Sensitivity of satellite infrared channel.

According to Wine's law of radiation:

$$\lambda_m \cdot T = 2897.8 \text{ (}}\mu\text{m} \cdot \text{K})$$

when temperature of blackbody goes up, the wavelength of peak radiation moves to shorter waves of the spectrum.

The temperature of forest fire and grass land fire is around 600K to 1200K, and their wavelength of peak radiation is around $2.5$ to $4.5\mu_m$. The temperature of ground surface is about 300K, the wavelength of peak radiation is about $10\mu_m$. 
2. Theory and method for wild fire detection

Figure. Planck radiances function curve for temperatures from 300K to 1000K. For a given increase in temperature, the increase in area under the channel 3 segments of the curves is much greater than under the channel 4 segments.
2. Theory and method for wild fire detection

(1) Cloud mask

| number | conditions |
|--------|------------|
| 1      | $T_{\text{Mir}} - T_{\text{far1}} < 4K$ |
| 2      | $T_{\text{Mir}} - T_{\text{far1}} > 20K$ \& $T_{\text{Mir}} < 285K$ \& $T_{\text{far1}} < 280K$ |
| 3      | $R_{\text{Vis}} > 0.28$ |
| 4      | $T_{\text{far1}} < 265K$ |
| 5      | $T_{\text{Mir}} < 270K$ \& $T_{\text{far1}} - T_{\text{far2}} < 4K$ |
| 6      | $T_{\text{far1}} < 270K$ \& $T_{\text{far1}} - T_{\text{far2}} > 60K$ |
| 7      | $T_{\text{Mir}} < 320K$ \& $T_{\text{Mir}} < T_{\text{Mir,TH}}$ |
| 8      | $R_{\text{Vis}} > 0.28$ \& $T_{\text{Mir}} < 320K$ |

(2) Fire pixels identification

1) $T_{3.9} > T_{3.9bg} + n_1 \times \delta T_{3.9bg}$

2) $\Delta T_{3.9_{11}} > \Delta T_{3.9bg_{11bg}} + n_2 \times \delta T_{3.9bg_{11bg}}$

(3) Sub-pixel fire spot area estimate

$$N_{imix} = P \times N_{hi} + (1 - P) \times N_{bg}$$

$$= P \times \frac{C_1 V_i^3}{C_2 V_i \cdot e^{T_{hi} - 1}} + (1 - P) \times \frac{C_1 V_i^3}{C_2 V_i \cdot e^{T_{bg} - 1}}$$

(4) Calculation fire radiation power

$$FRP = P \times S_{\lambda, \varphi} \times \sigma T^4$$
2. Theory and method for wild fire detection

Density map of global fire spots based on FY-3D (2019-06)

General flow chart for generating FY-3D fire spot products
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Verification methods

\[ \sqrt{(lat1 - lat2)^2 + (long1 - long2)^2} \leq 0.02^\circ \]

(1) Assessment of FY-3D fire products based on visual interpretation

| Region                      | GFR-based fire spots | Not match | Accuracy (%) |
|-----------------------------|----------------------|-----------|--------------|
| South-central Africa        | 1429                 | 77        | 94.6         |
| East-central South America  | 204                  | 12        | 94.1         |
| Siberia                     | 32                   | 3         | 90.6         |
| Australia                   | 85                   | 7         | 91.8         |
| Indo-China Peninsula        | 438                  | 32        | 92.7         |
| Overall                     | 2188                 | 131       | 94.0         |

Observation positions from FY-3D MERSI-II

Clean sky
3. Validation of FY-3D fire product

(2) Cross-validation between FY-3D and MODIS global fire products

1) Validation in different months

| Time   | Match | Mismatch | Total  | Consistence (%) |
|--------|-------|----------|--------|------------------|
| 201901 | 70799 | 14188    | 84987  | 83               |
| 201902 | 66849 | 14717    | 81566  | 82               |
| 201903 | 105176| 22576    | 127752 | 82               |
| 201904 | 94474 | 39250    | 133724 | 71               |
| 201905 | 75703 | 17135    | 92838  | 82               |
| 201906 | 174587| 33862    | 208449 | 84               |
| 201907 | 362108| 39683    | 401791 | 90               |
| 201908 | 315182| 51627    | 366809 | 86               |
| 201909 | 226363| 47607    | 273970 | 83               |
| 201910 | 115975| 33956    | 149931 | 77               |
| 201911 | 102240| 27732    | 129972 | 79               |
| 201912 | 157464| 28461    | 185925 | 85               |
| Total  | 1866920| 370794   | 2237714| 83.4             |
2) Validation on different underlying surfaces

| ID | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 11 | 50  | 76  | 86  | 81  | 68  | 66  | 54  | 77  | 80  | 85  | 73  | 56  |
| 14 | 64  | 57  | 73  | 81  | 71  | 64  | 56  | 79  | 85  | 73  | 73  | 57  |
| 20 | 72  | 67  | 78  | 83  | 78  | 68  | 64  | 81  | 87  | 73  | 77  | 79  |
| 30 | 65  | 63  | 77  | 84  | 82  | 84  | 84  | 77  | 83  | 83  | 79  | 75  |
| 40 | 94  | 88  | 75  | 84  | 85  | 74  | 72  | 76  | 83  | 80  | 82  |     |
| 50 | 61  | 72  | 82  | 88  | (87)| 86  | 85  | 71  | 81  | 79  | 80  | 66  |
| 60 | 90  | 85  | 75  | 87  | 86  | 89  | 89  | 82  | 82  | 79  | 86  | 89  |
| 70 | 56  | 79  | 80  | 87  | 82  | 90  | 73  | 86  | 82  | 77  | 49  | 66  |
| 90 | 35  | 57  | 62  | 56  | 97  | 98  | 91  | 85  | 64  | 72  | 82  | 56  |
| 100| 49  | 59  | 71  | 59  | 82  | 93  | 87  | 92  | 70  | 75  | 70  | 66  |
| 110| 84  | 84  | 73  | 67  | 80  | 92  | 84  | 88  | 84  | 86  | 86  | 81  |
| 120| 83  | 81  | 77  | 65  | 86  | 93  | 86  | 85  | 51  | 84  | 88  | 87  |
| 130| 87  | 85  | 85  | 87  | 84  | 86  | 85  | 76  | 85  | 87  | 82  | 84  |
| 140| 76  | 66  | 78  | 80  | 76  | 85  | 78  | 80  | 26  | 82  | 87  | 87  |
| 150| 77  | 71  | 77  | 60  | 81  | 87  | 58  | 71  | 24  | 75  | 88  | 92  |
3. Validation of FY-3D fire product

The global monitoring area is divided into Africa, America, Asia, Europe, and Oceania. The verification demonstrates the results with the highest consistence (over 80%) are found in Africa and Asia, and those in America, Europe, and Oceania show the consistence over 70%.

China’s regional consistency of results in China is lower than other continents, only 65%.
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FY-3D Monitor wildfires in California

New South Wales, Australia

FY-3D fire monitoring in South America
4. Application examples of fire monitoring

FY-3D fire monitoring in The Mediterranean Sea compare 2021 to 2020

FY-3 fire monitoring in Arctic Circle compare 2018 to 2017
4. Application examples of fire monitoring

Multi-source satellites in fire monitoring

FY-4A monitoring the evolution of fire in Mongolia from April 19 morning to afternoon

FY-4B monitoring the fire 2022/4/19 15:45

FY-3D monitoring the fire area 2022/4/19 13:00

GF-4 monitoring the fire area 2022/4/22

FY-3E monitoring the fire 2022/4/19 17:25
The Fengyun-3D (FY-3D) global active fire product: principle, methodology and validation

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Viewed (geographical distribution)

FY-3D fire product download address:
http://data.nsmc.org.cn/PortalSite/Data/Satellite.aspx?currentculture=en-US

The End
Thanks for your attention!