Development of wildfire detection algorithm

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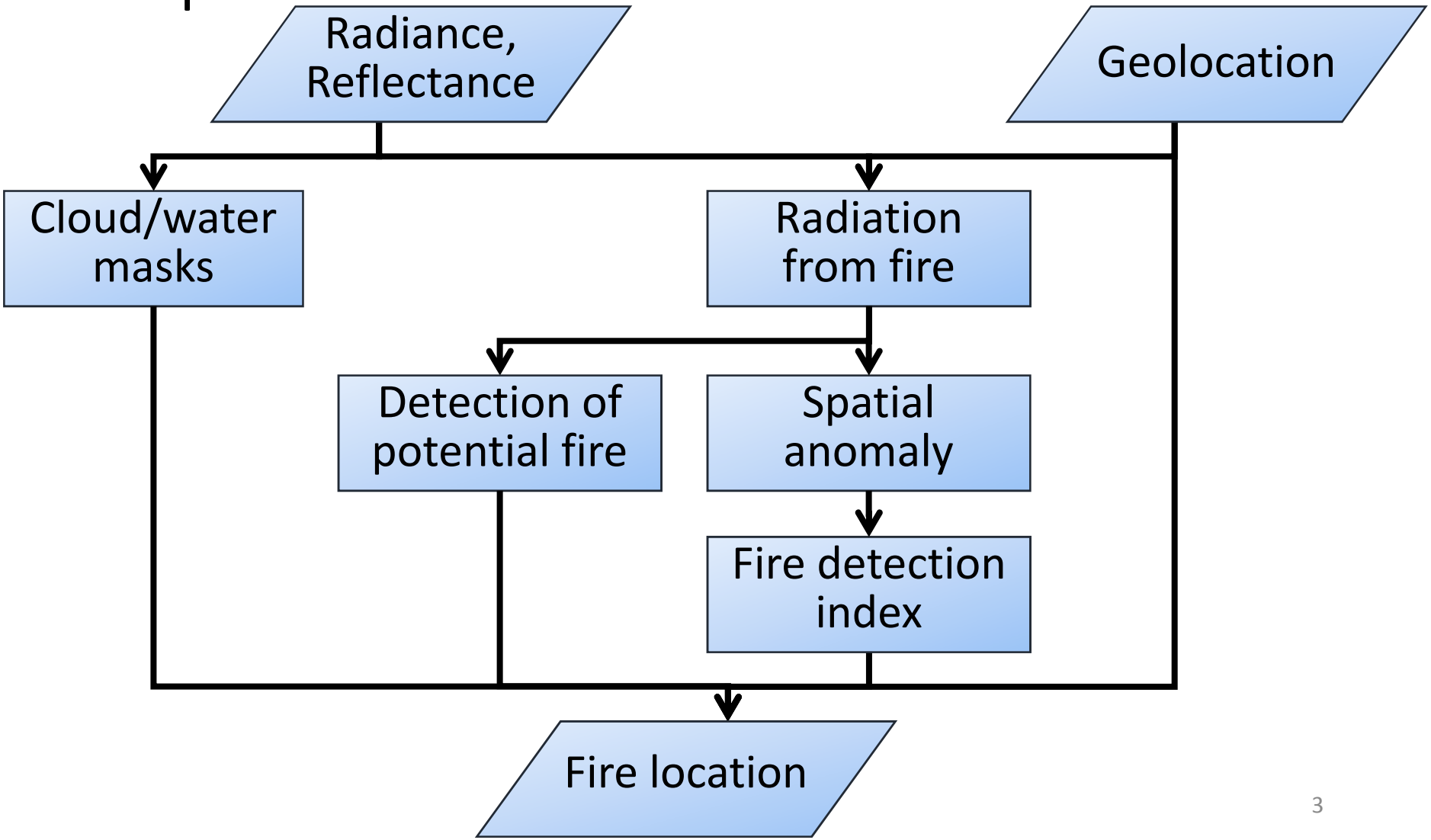
Topics

- In Previous RA
  - MODIS 2.2 / 1.6μm with 1km/500m resolution
  - A fire radiation index in 4μm is estimated by multiple regression with 2.2 / 1.6μm
- In This RA
  - Simulation by ASTER
  - TIR fire detection algorithm (feedback from CIRC)
  - Validation dataset
    - Utilization of human eye
    - Gathering high resolution imagery

Flow of proposed algorithm in previous RA



Proposed algorithm (1)

$$\text{Fire} = (\underline{\text{ABS}} \vee (\underline{\text{CT1} \wedge \text{PF}})) \wedge (\underline{\neg \text{Mask}})$$

Fixed threshold — **Contextual threshold** — **Cloud, water, desert, sun glint**

Examine the pixel further

Fixed threshold

$$\text{ABS} = (\text{Findex}_{2.2} > 0.35)$$

Contextual thrs.

$$\text{CT1} = (\text{Findex}_{2.2} > 0.20) \wedge N\text{valid} > 0.25N\text{all}$$

Potential fire pixel detection

$$\text{PF} = ((0 < \text{FireRad}_{1.6}) \vee (0 < \text{FireRad}_{2.2})) \wedge (0.5 > \text{Ref}_{0.86}) \wedge (0.5 > \text{NDSI}) \wedge \begin{pmatrix} (0.3 < \text{FireRad}_{2.2}) \\ \vee (0.2 < \text{FireRad}_{2.2} \wedge 6\sigma[\text{FireRad}_{2.2}] < \Delta[\text{FireRad}_{2.2}]) \\ \vee (0.1 < \text{FireRad}_{2.2} \wedge 8\sigma[\text{FireRad}_{2.2}] < \Delta[\text{FireRad}_{2.2}]) \end{pmatrix}$$

Index for fire detection

$$\text{Findex}_{2.2} = \underline{\text{FireRad}_{2.2} - \overline{\text{FireRad}_{2.2}}} - \max\left(0.04, 0.6 * \left(\text{FireRad}_{1.6} - \overline{\text{FireRad}_{1.6}}\right)\right)$$

Anomaly of estimated radiation from fire

Estimated 4μm radiation from fire

$$\text{FireRad}_{2.2} = \text{Rad}_{2.2} - 0.218\text{Ref}_{\text{RED}} - 0.0514$$

$$\text{FireRad}_{1.6} = \text{Rad}_{1.6} - 0.634\text{Ref}_{\text{NIR}} + 0.137\text{Ref}_{\text{RED}} - 0.030$$

Proposed algorithm (2)

$$\text{Mask} = \text{adjCloud} \vee (0 < N\text{bkgwater}) \vee \text{SunGlint} \vee \text{Desert}$$

No cloud **No neighbor water** **No Sun glint** **No desert**

$$\text{SunGlint} = [\text{same as MOD14}]$$

$$\text{Desert} = (0.1N\text{valid} < N\text{fire}) \wedge (4 < N\text{fire} > N\text{valid}) \wedge (0.15 < \text{Ref}_{\text{NIR}}) \wedge (2 > \text{FireRad}_{2.2} - \overline{\text{FireRad}_{2.2}}) \wedge (0.1 > \sigma[\text{FireRad}_{2.2}])$$

$$N\text{bkgwater} = N\begin{bmatrix}(0 > \text{NDVI}) \\ \wedge (0.15 > \text{Ref}_{0.86}) \\ \wedge (0.15 > \text{Ref}_{2.2})\end{bmatrix}$$

$$\text{where}\begin{bmatrix}\text{FireRad}_{2.2} \le 0.5 \\ \text{FireRad}_{1.6} \le 0.3\end{bmatrix}$$

$$N\text{valid} = N\begin{bmatrix}\text{FireRad}_{2.2} \le 0.5 \\ \text{FireRad}_{1.6} \le 0.3\end{bmatrix}$$

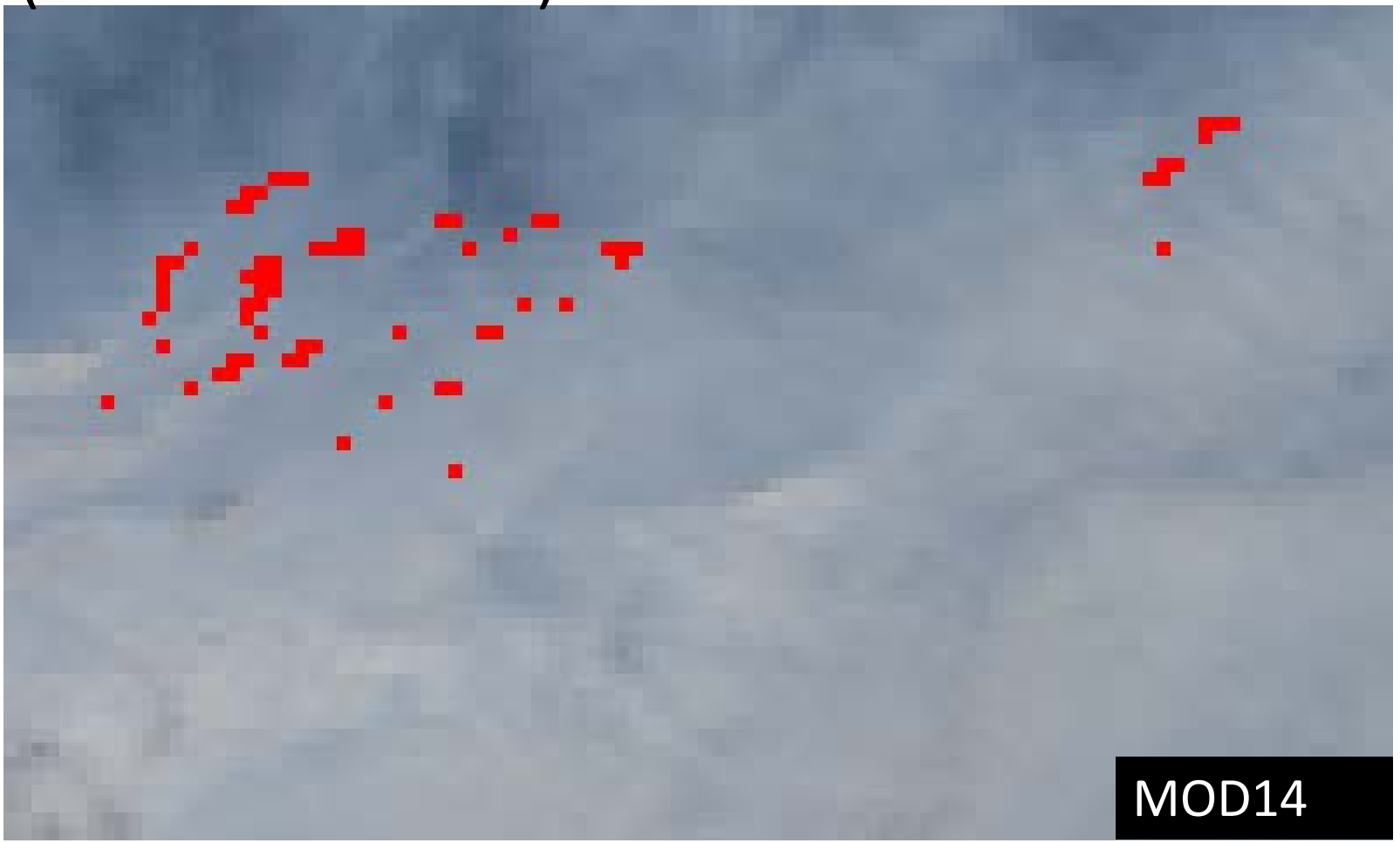
$$\text{Cloud} = 15/16 < (0.6+0.7\max(0,\min(2,\text{Cloud}_1))) \times (1.0+0.5\max(0,\min(2,\text{Cloud}_2))) \times (0.6+0.7\max(0,\min(2,\text{Cloud}_3)))$$

$$\text{Cloud}_1 = 0.6 + 0.7\max(0,\min(2,(2.42 + 3.83(\text{planck}(\text{BT}_{11\mu},\lambda_{12\mu}) - \text{Rad}_{12\mu}))))$$

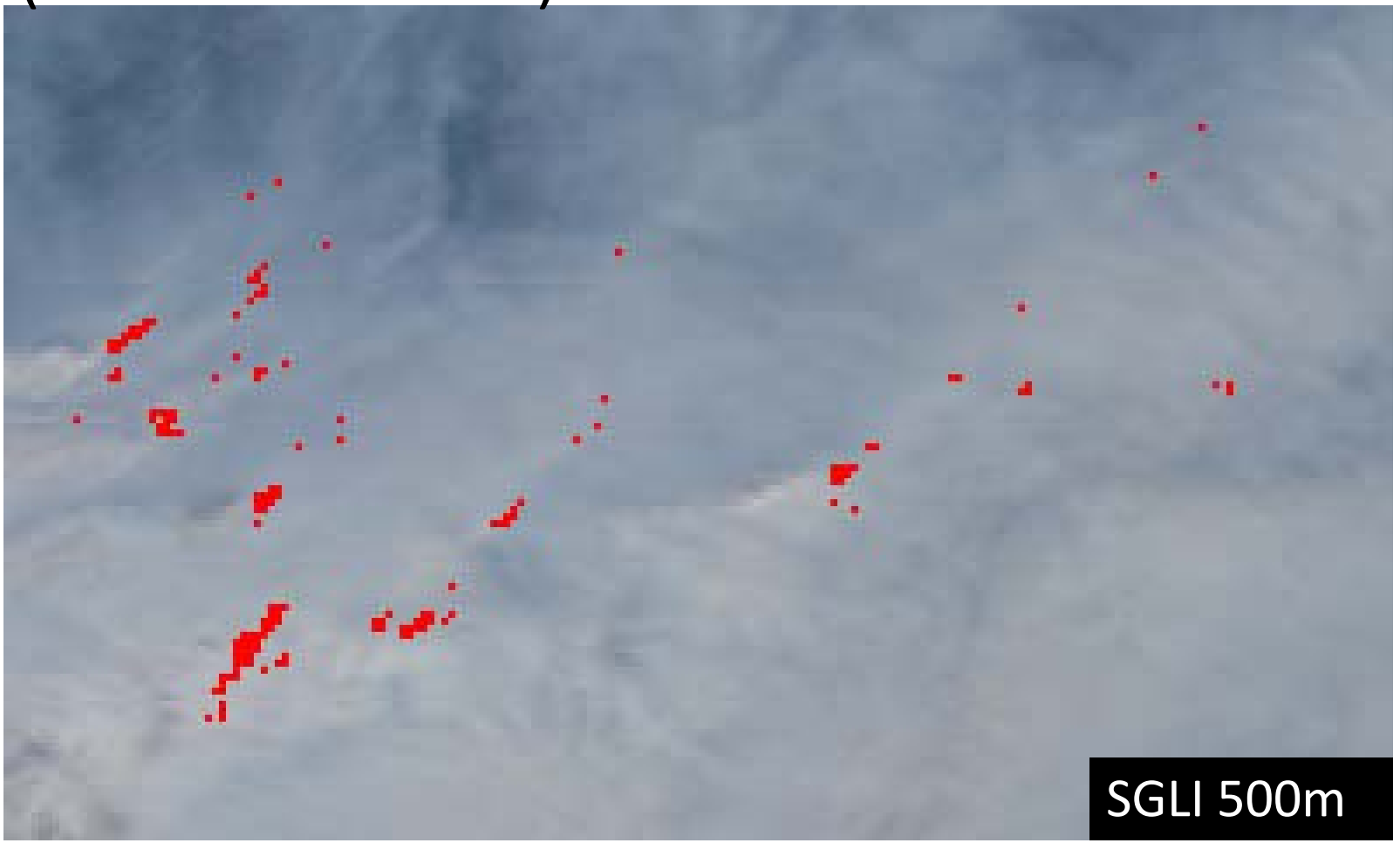
$$\text{Cloud}_2 = 1.0 + 0.5\max\left(0,\min\left(2,\left(-0.66 + 85.56\frac{(\text{Ref}_{\text{BLUE}}+\text{Ref}_{\text{RED}} - 2\text{Ref}_{\text{GREEN}})}{(\text{Ref}_{\text{BLUE}}+\text{Ref}_{\text{RED}})}\right)\right)\right)$$

$$\text{Cloud}_3 = 0.6 + 0.7\max(0,\min(2,(0.00 + 0.10(283\text{K} - \text{BT}_{11\mu}))))$$

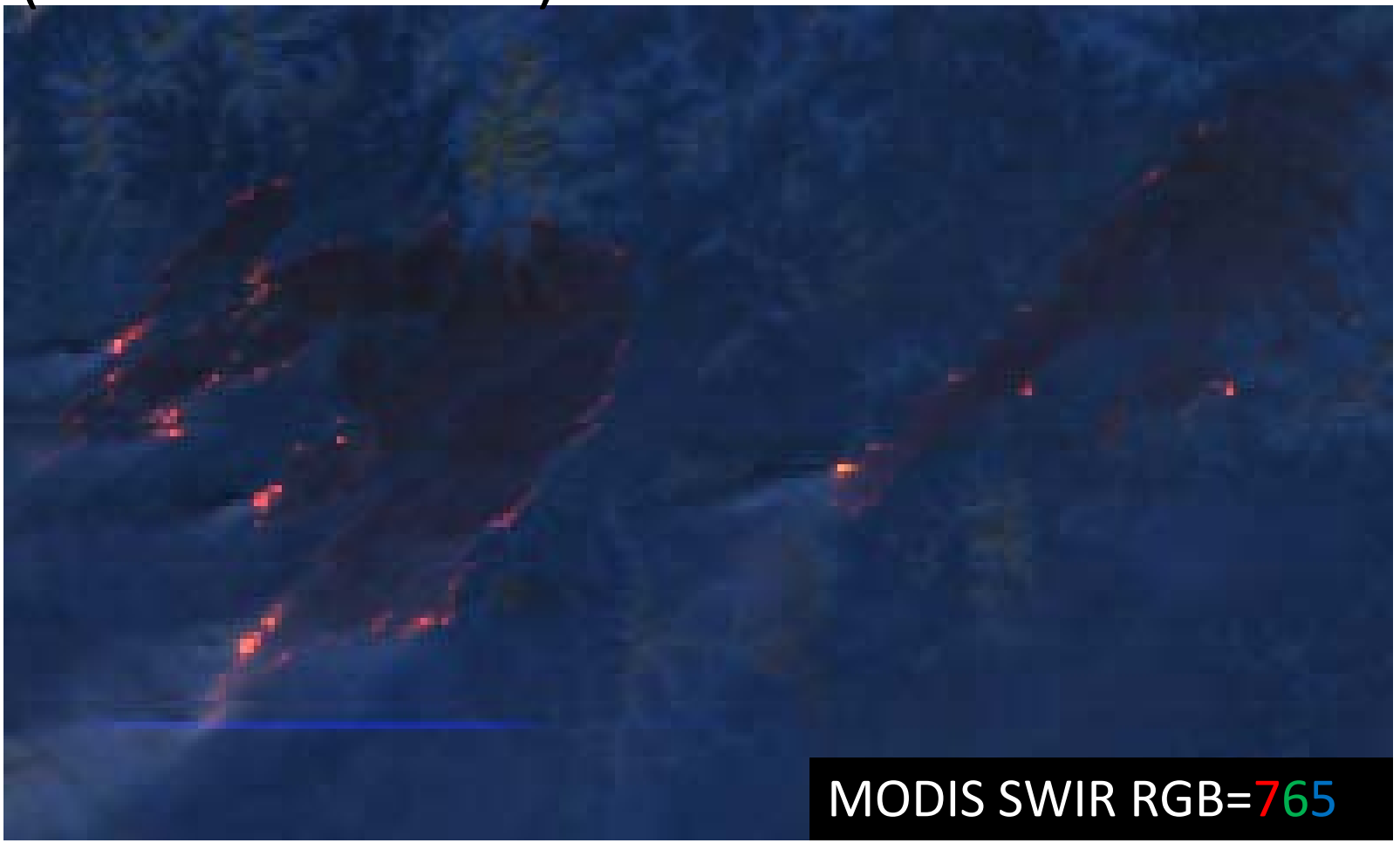
Wildfire detection result (2004 Alaska)



Wildfire detection result (2004 Alaska)



Wildfire detection result (2004 Alaska)



In Previous RA

- Development of wild fire detection algorithm
  - using 2.2 / 1.6µm with 1km/500m resolution
  - Regression of 4µm fire radiation with 2.2 / 1.6µm
- Result
  - **Succeeded to detect wildfire** somehow.
  - **Only 10-15% of HS are detected** with 500m/1km data comparing to MOD14
- Next step
  - Simulation by ASTER
  - TIR (feedback from CIRC)
  - Ground truth dataset

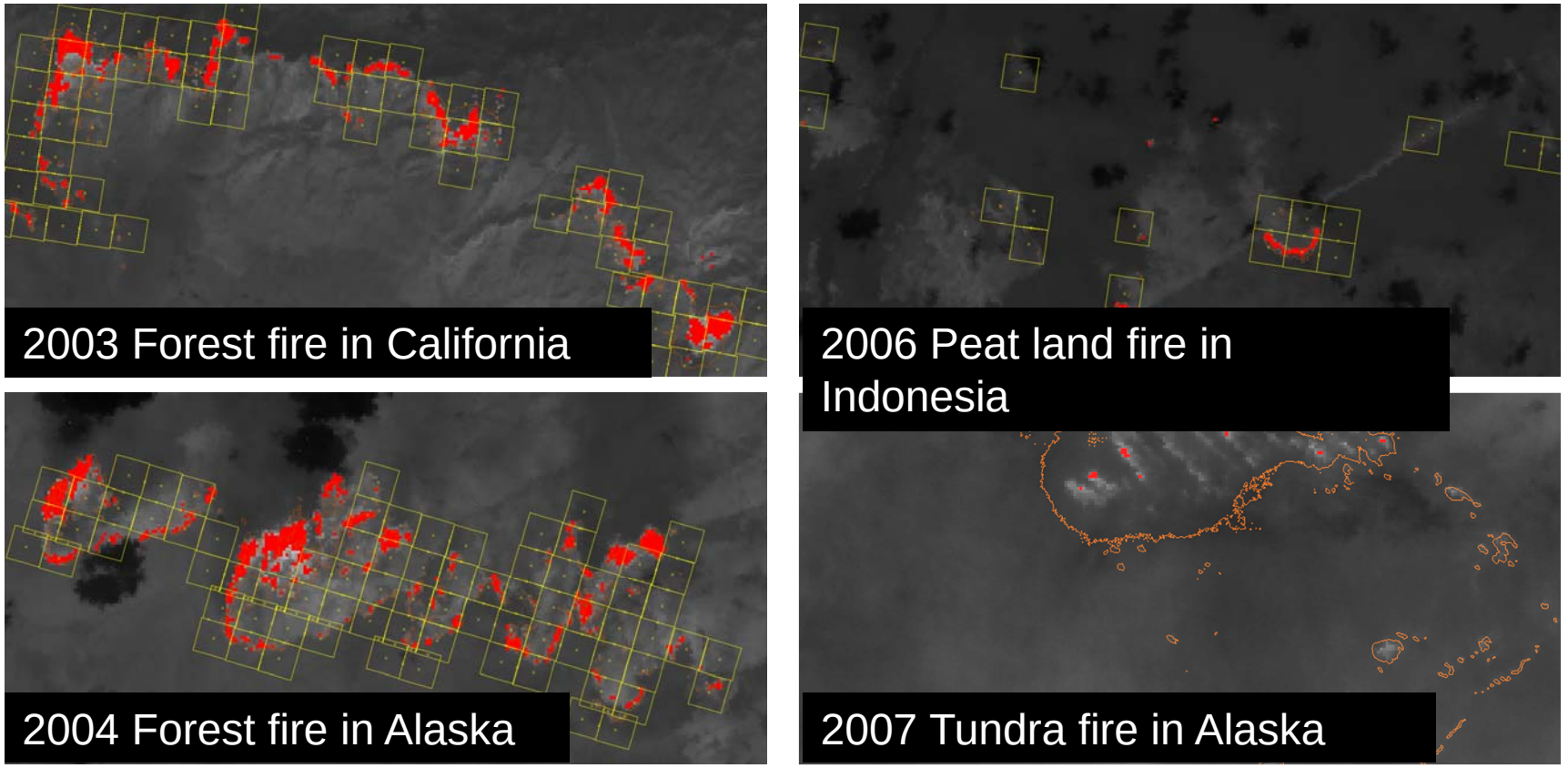
2013-1-18 Daytime MODIS obs.	MOD14	SGLI 500m	SGLI 1km
#HS	2961	445	375.
True fire	---	378	314
False Alarm	---	67	61
Missed fire	---		2647

Improvement of fire detection using TIR

- Existing regression of 4µm fire radiation with 2.2/1.6µm
- Simulation by ASTER

- **TIR fire detection** algorithm (feedback from CIRC)

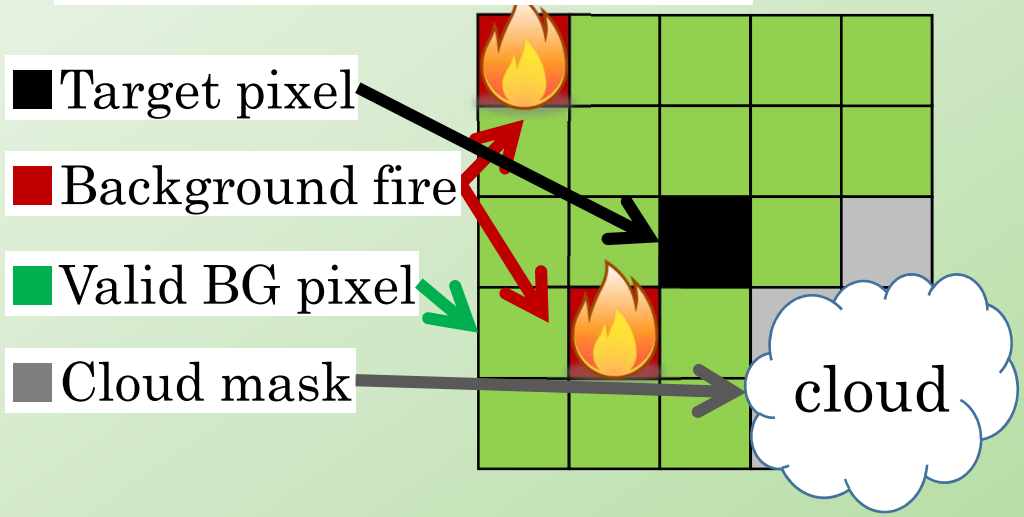
Simulated fire detection with high-res. TIR images.



Wildfire detection only with 90m resolution ASTER 11um channel.

Wildfire detection using TIR

Current Algorithm for CIRC



Fire pixel is detected utilizing spatial anomaly of Brightness temperature. However, threshold for cloud mask or background fire is fixed value.

Contextual Threshold

■Fire: $L_{11\mu} > 1.5 + \overline{L_{11\mu}}$

■有効背景画素の平均輝度 [W/m2/um/str]

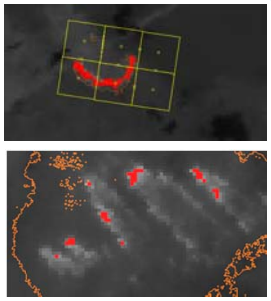
■Cloud: $BT_{11\mu} < 0℃$

■BG fire: $70℃ < BT_{11\mu}$

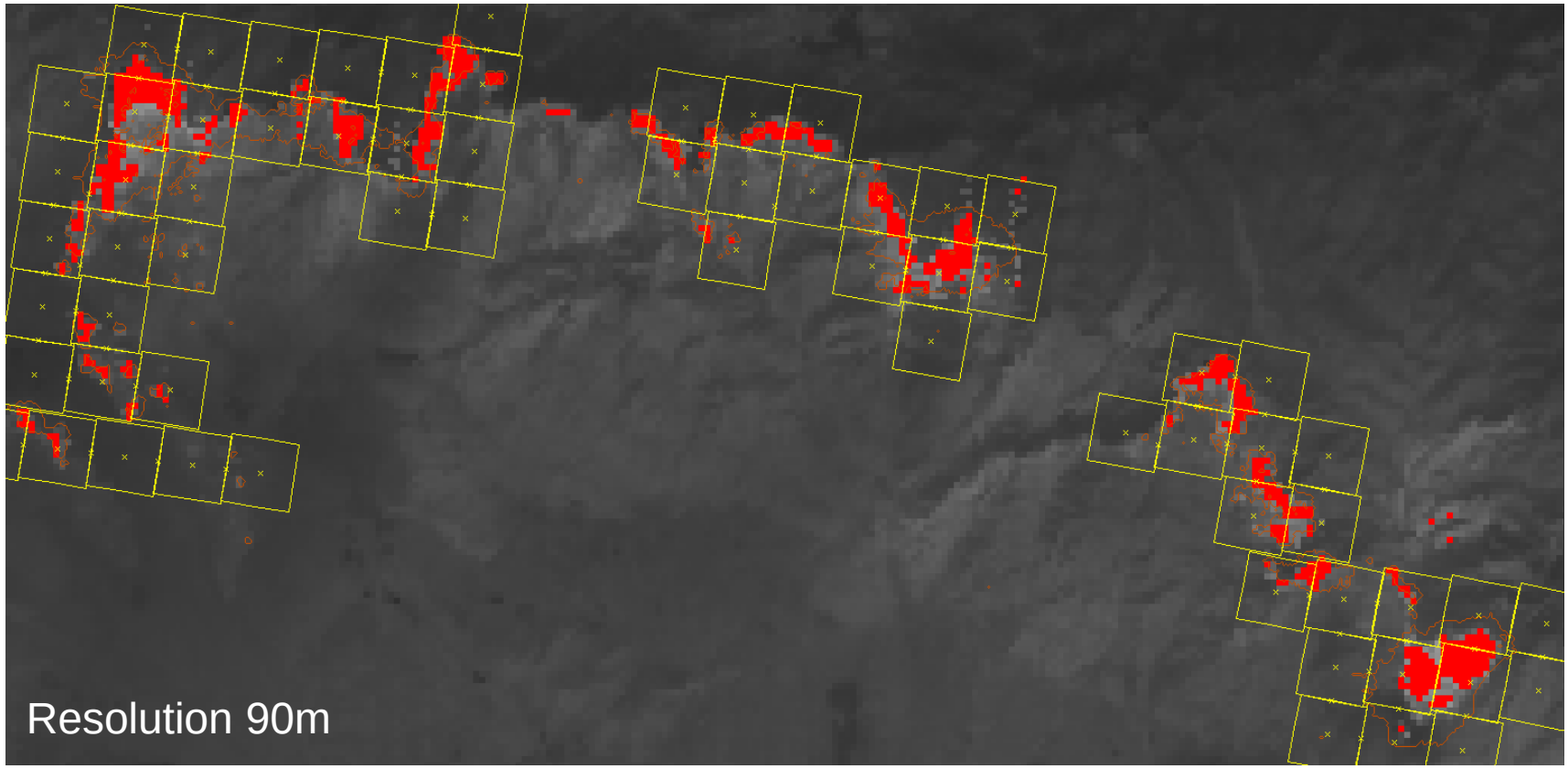
■Valid BG: Non-cloud, fire

Under construction

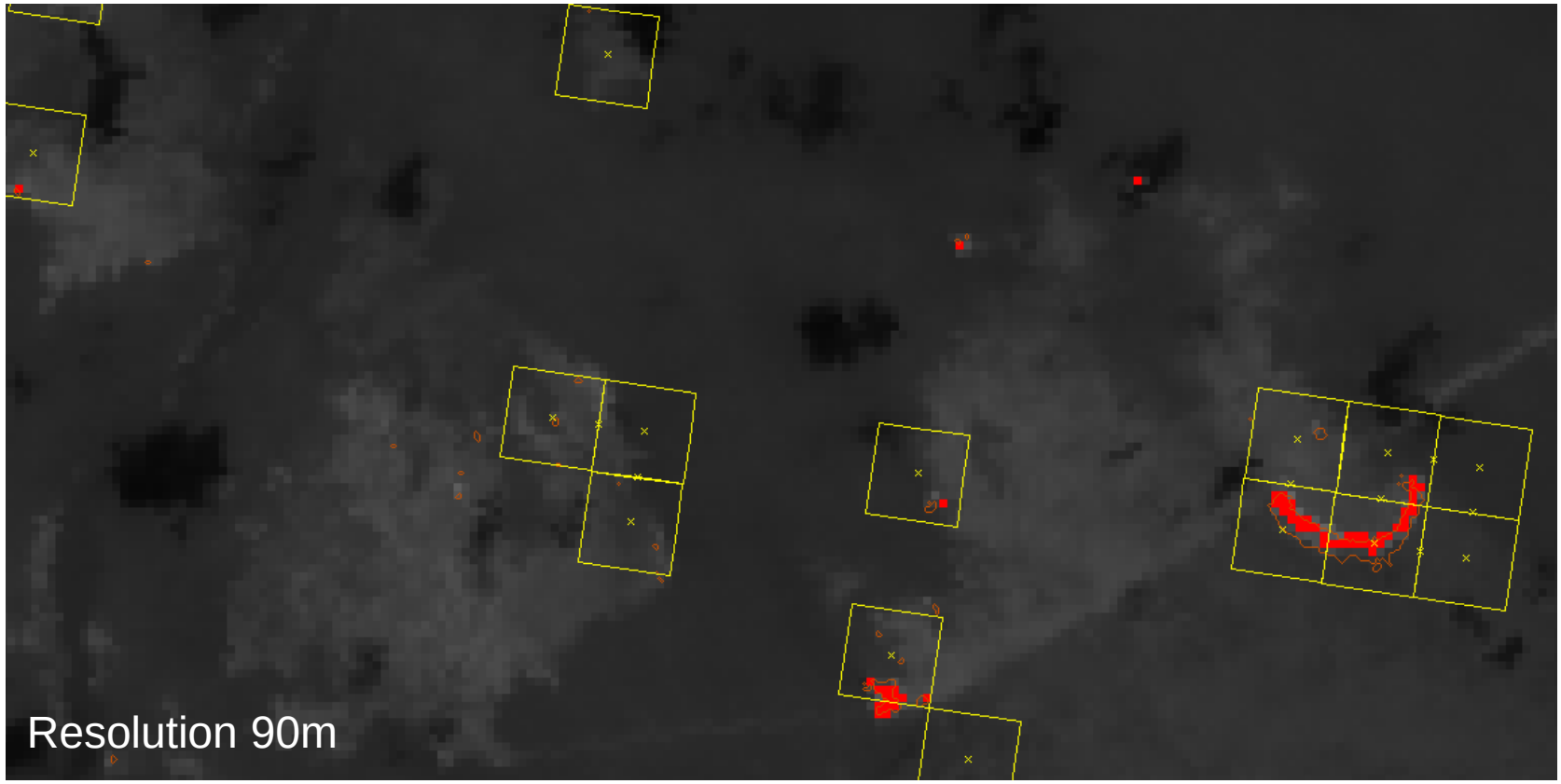
■雲マスクと■背景火災画素の判別に固定閾値を用いている。
本来は地域や季節で変化するため精度制約要因となっている。
→地域や太陽エネルギー等により調整し、精度向上を図る
→成果はGCOM-C1にも応用



Sensitivity of fire detection with various resolution (CA)



Sensitivity of fire detection with various resolution (INA)



Summary of fire detection with Thermal Camera

- 90～270m resolution enable us to detect fires with MOD14 sensitivity.
  - TIR fire detection algorithm has certain performance
- Performance for low temperature fire should be improved.
  - Better potential fire detection
  - Better cloud masks
  - Farther improvement of threshold

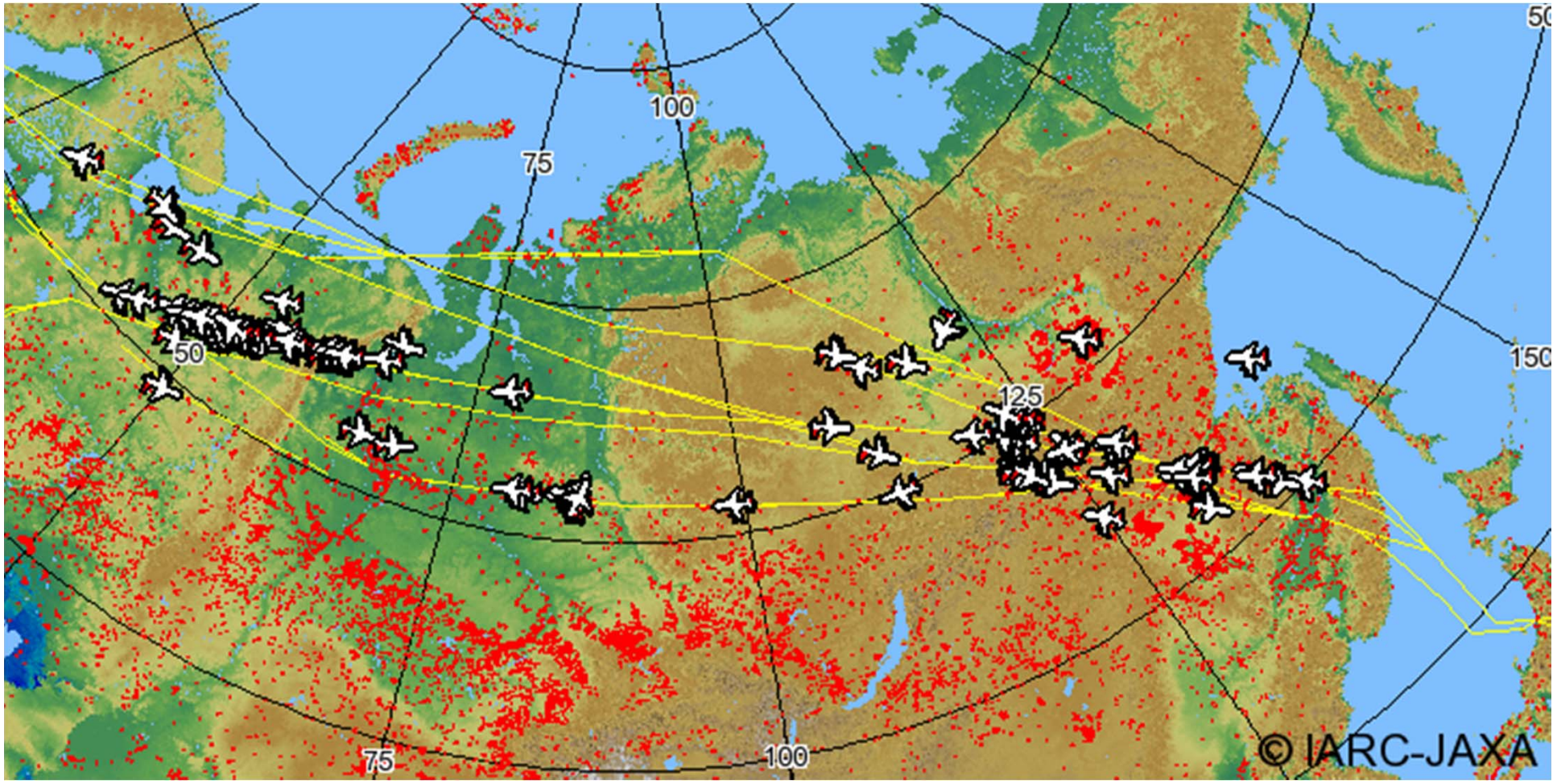
Ground truth dataset

- Collection of high resolution IR imagery
  - ASTER
  - LANDSAT
- Utilization of human eye
  - JAL wildfire observation
  - Around 200 reports / year
  - Location, time, phenomena

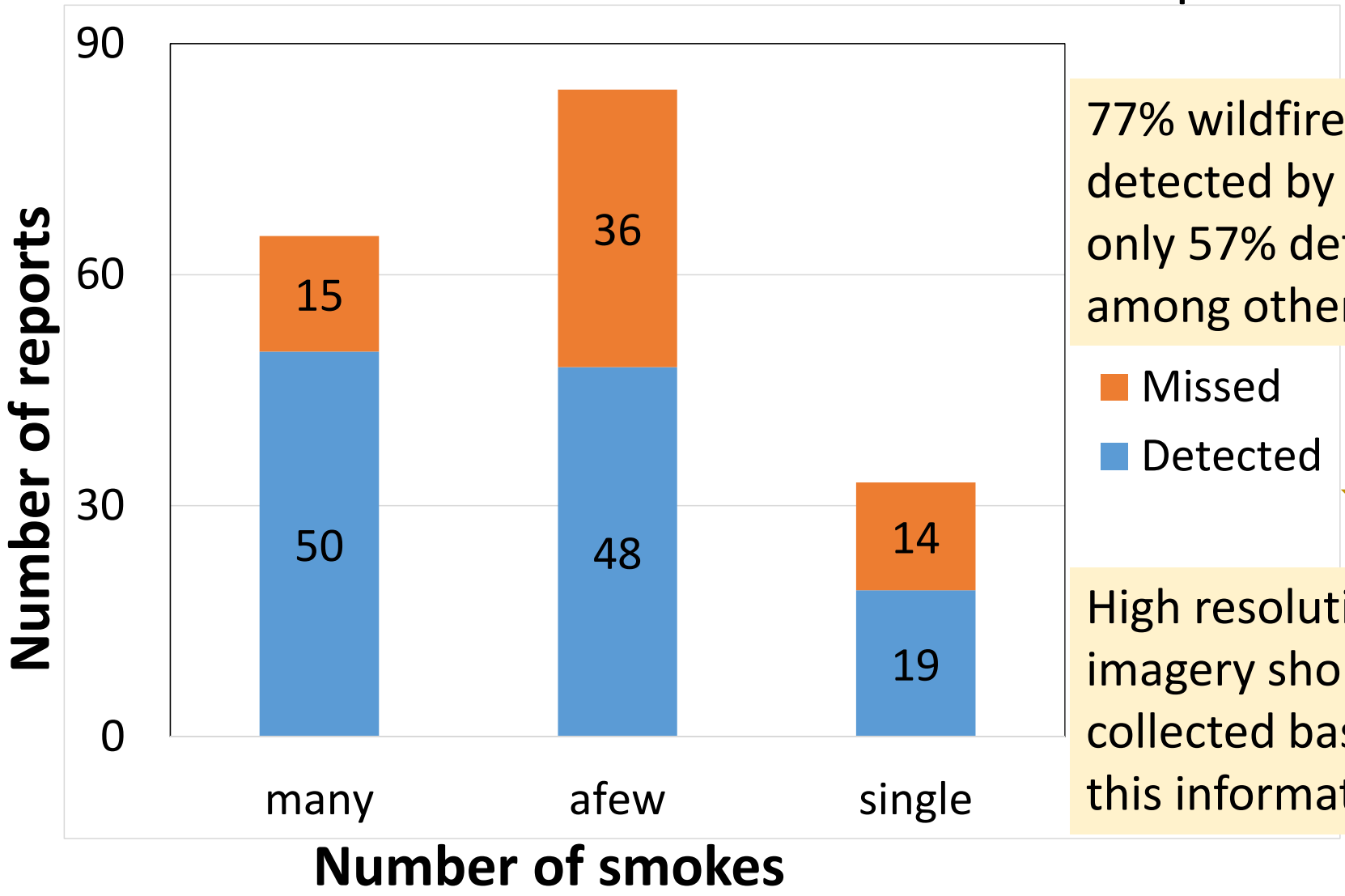
JAL wildfire monitoring reports in 2013

Route	Reports
Total	199
Europe	143
America	45
SE Asia	9
Oceania	2

Geospatial distribution of wildfire by JAL reports and by MODIS



Wildfire detection score correlates to “number of smokes” on fire reports



77% wildfires are detected by MODIS, only 57% detected among other fires.

High resolution IR imagery should be collected based on this information

Summary

- In Previous RA
  - A fire radiation index in 4μm is estimated by multiple regression with 2.2 / 1.6μm
- In This RA
- TIR can be used with a certain performance
  - Threshold should be tuned for SGLI
- Validation dataset (Utilization of human eye)
  - JAL fire observation can be used to gather L8 / ASTER wildfire scenes