

# Supplementary Material

## 1 SUPPLEMENTARY DATA

### 1.1 Ground-based observations at Mt. Tokachi

Here we list the results of the ground-based observations of SO<sub>2</sub> flux measured at Mt. Tokachi by the traverse methods using a car or on foot. Mt. Tokachi has two main craters named Taisho crater and 62-2 crater. After 2014, in this study, the data were collected only by the walking traverse method using miniature ultraviolet spectrometers (USB2000+ and Flame-S, Ocean Optics, Inc.). Wind speed was measured with a portable anemometer around the craters.

**Table S1.** The SO<sub>2</sub> flux of Mt. Tokachi obtained with the ground-based observations

| Date      | Average | Min. | Max. | Reference             |
|-----------|---------|------|------|-----------------------|
| 2003/7/7  | 210     | 60   | 400  | Mori et al. (2006)    |
| 2006/7/9  | 130     | 40   | 260  | M. Ohwada, pres, comm |
| 2014/7/4  | 30*     | 15*  | 64*  | This study            |
| 2015/10/5 | 410     | 180  | 680  | This study            |
| 2016/9/24 | 520     | 510  | 530  | This study            |
| 2017/6/26 | 220     |      |      | This study            |
| 2019/6/12 | 33*     | 29*  | 37*  | This study            |

. \*The SO<sub>2</sub> flux only from Taisho crater was measured.

## 1.2 Analysed data of satellite observations

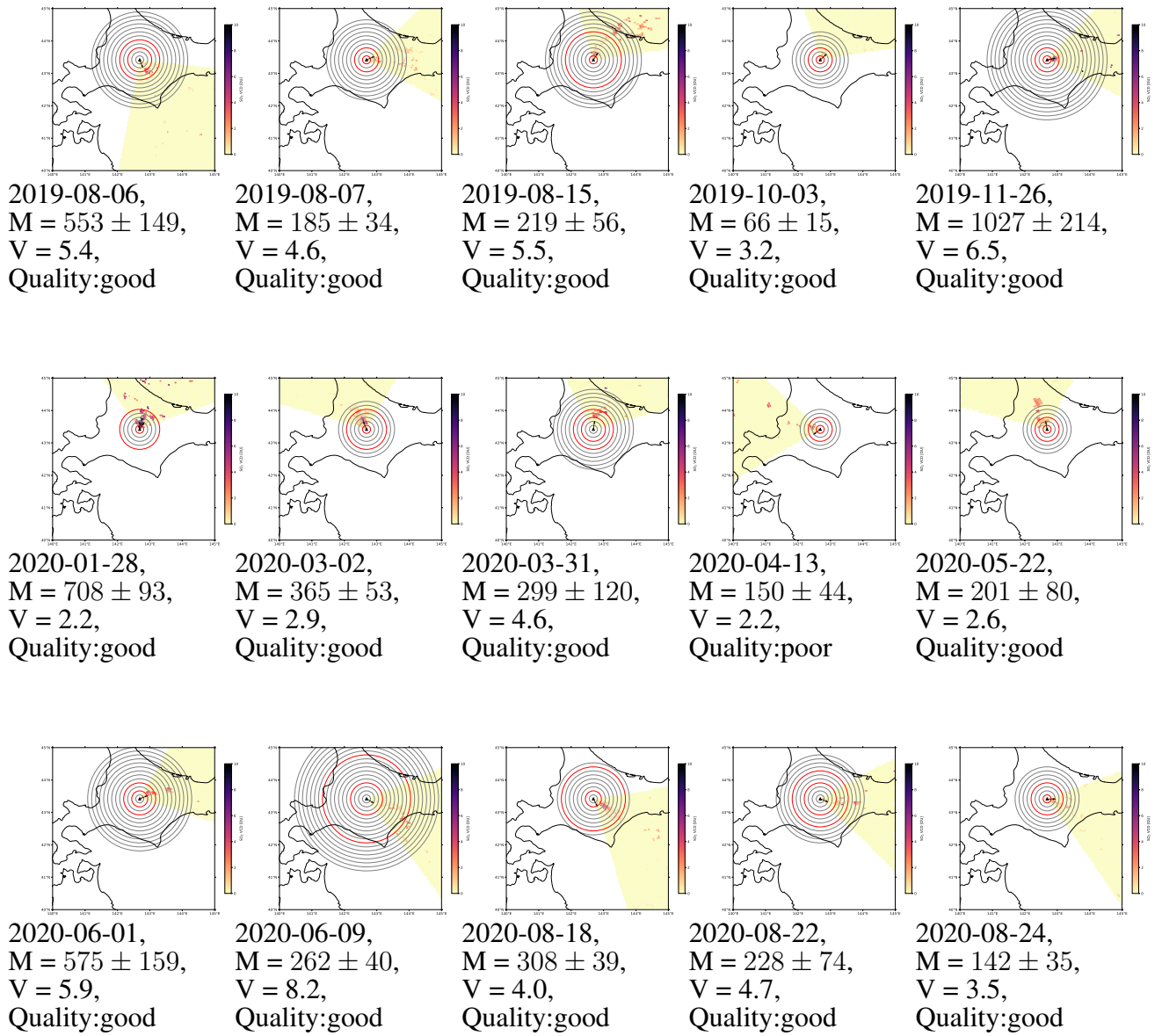


Figure S1: Results of satellite observations. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day, wind velocity V [m/s], and data quality. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.

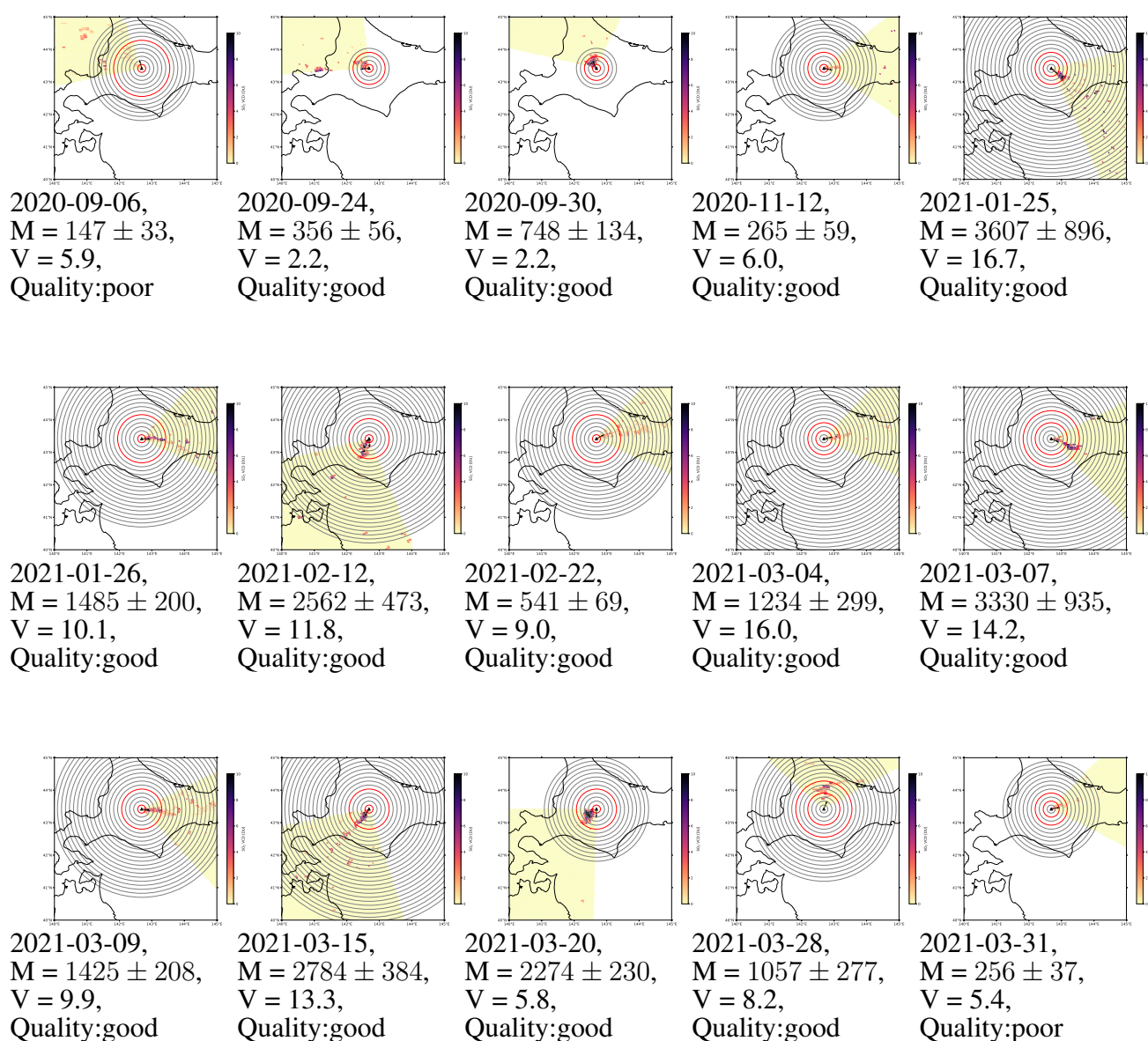


Figure S2: Results of satellite observations. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day, wind velocity V [m/s], and data quality. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.

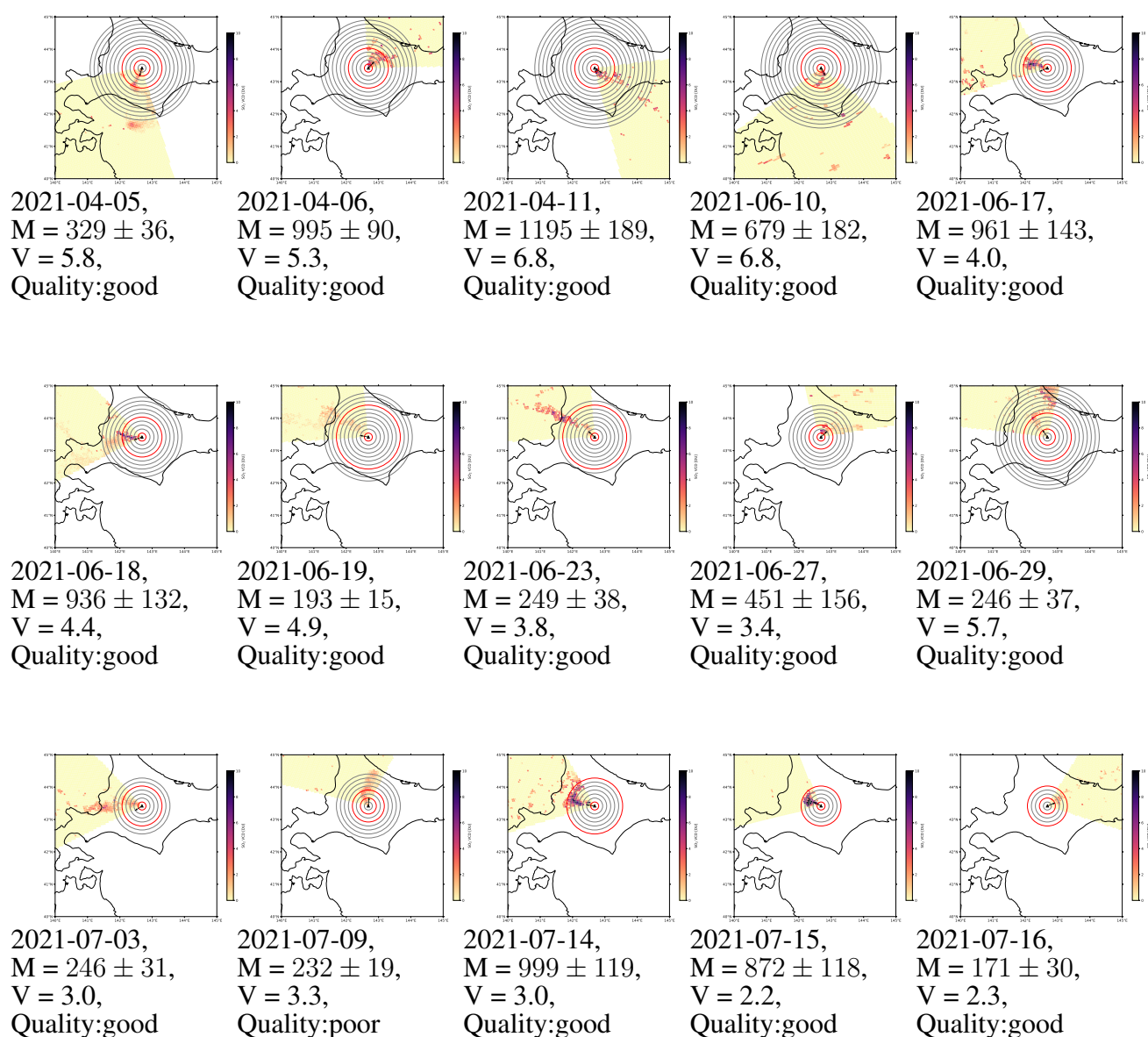


Figure S3: Results of satellite observations. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day, wind velocity V [m/s], and data quality. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.

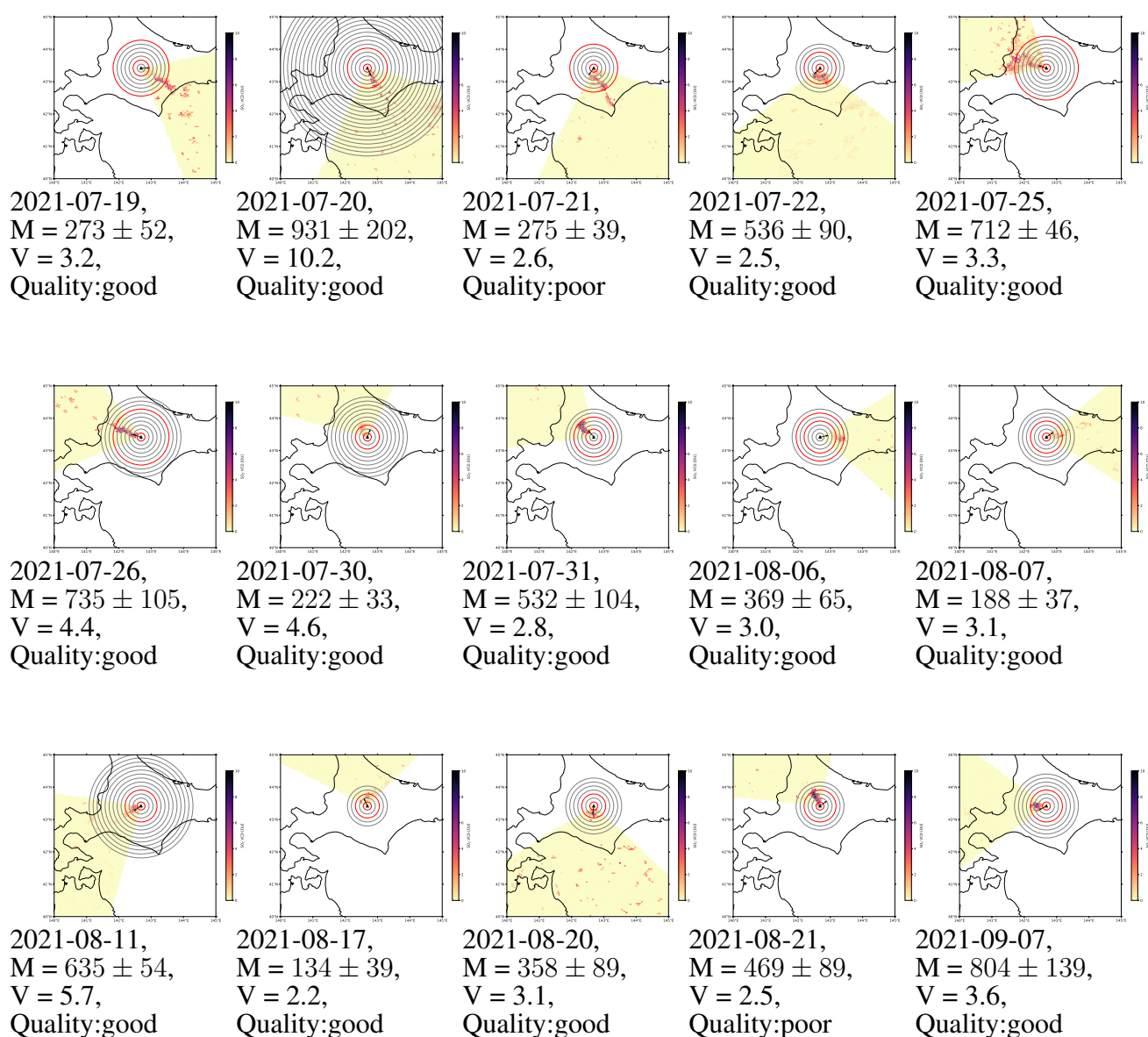


Figure S4: Results of satellite observations. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day, wind velocity V [m/s], and data quality. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.



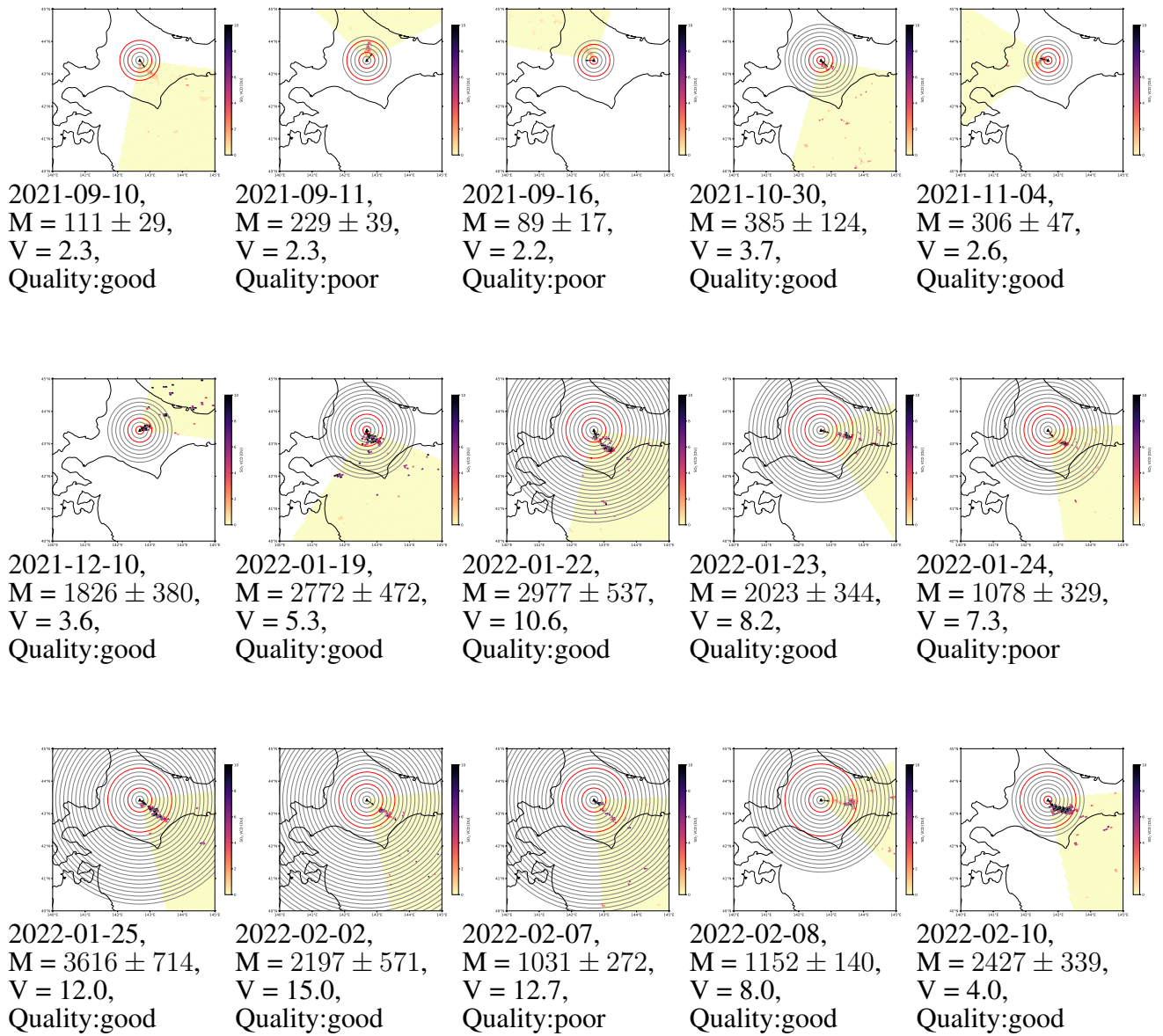


Figure S5: Results of satellite observations. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day, wind velocity V [m/s], and data quality. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.

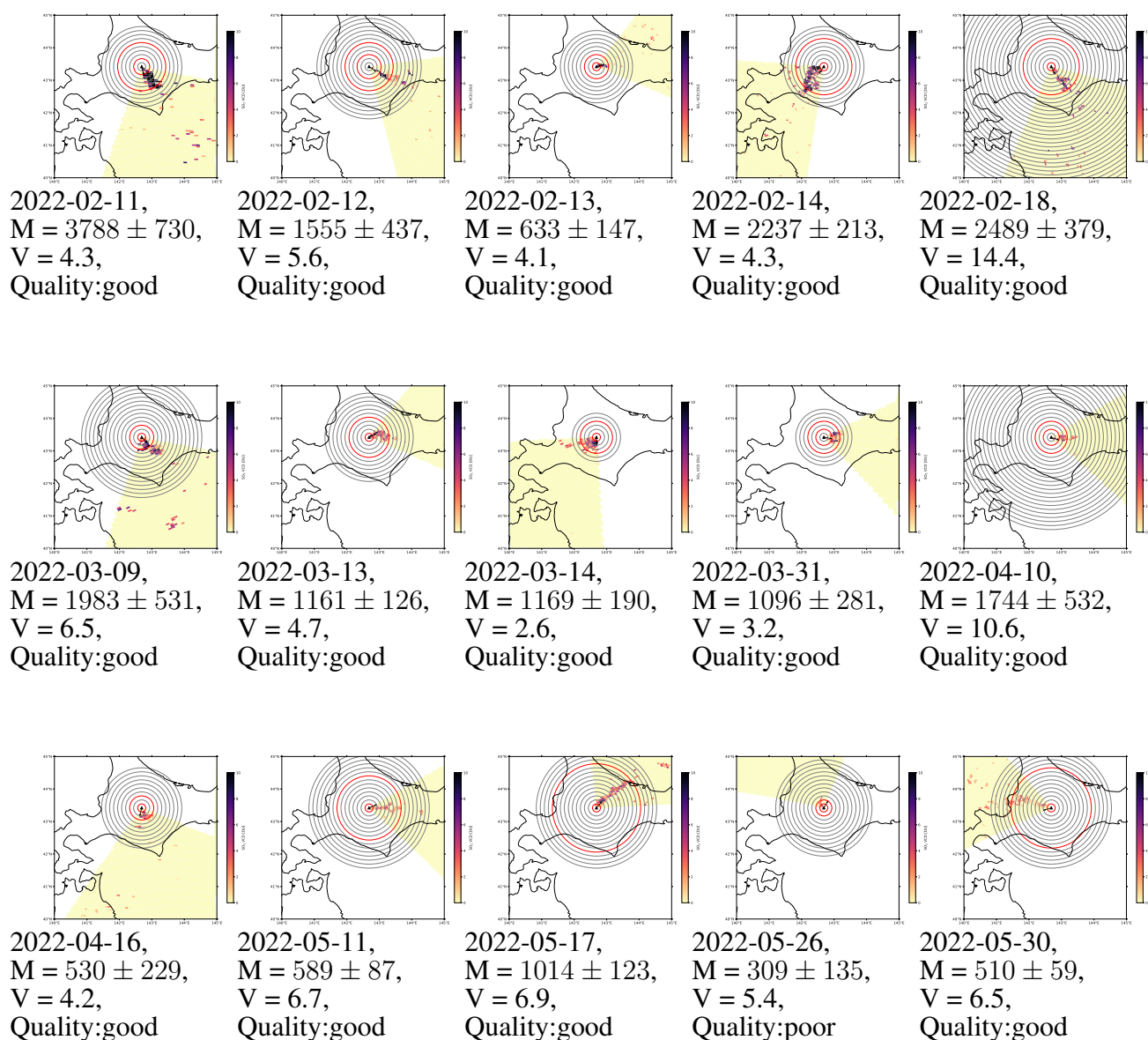


Figure S6: Results of satellite observations. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day, wind velocity V [m/s], and data quality. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.

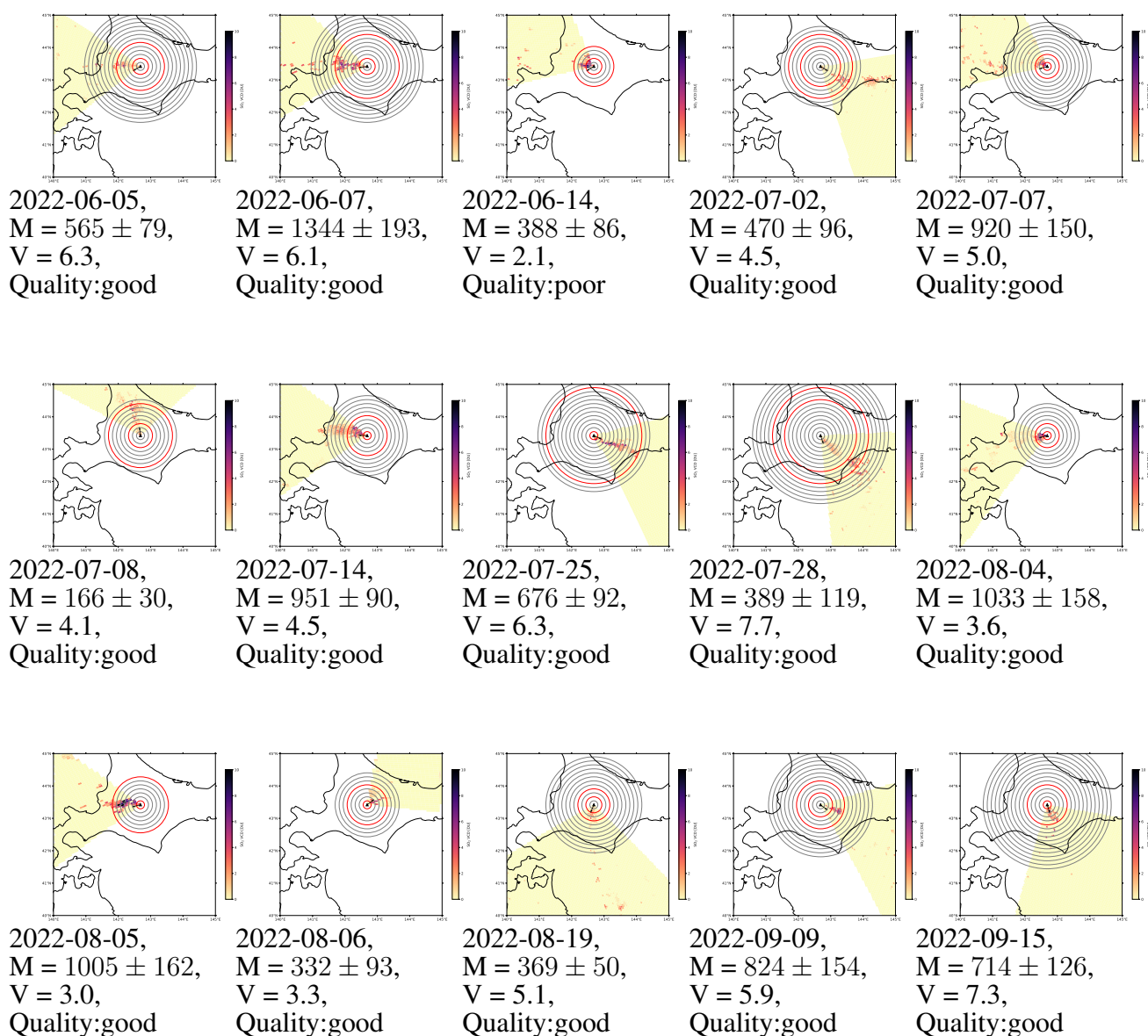


Figure S7: Results of satellite observations. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day, wind velocity V [m/s], and data quality. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.



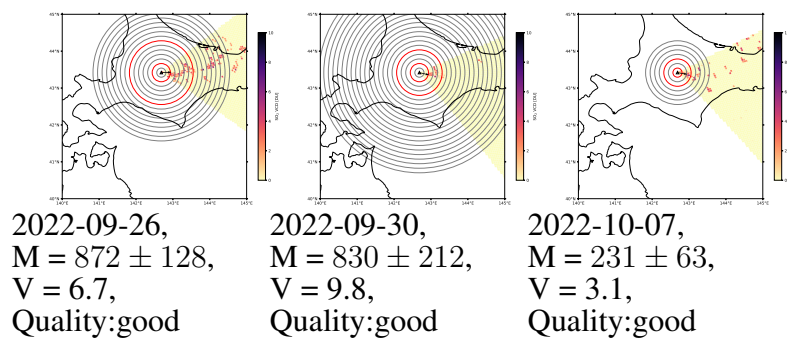


Figure S8: Results of satellite observations. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day, wind velocity V [m/s], and data quality. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.

### 1.3 Analysed data of satellite observations in winter by new method

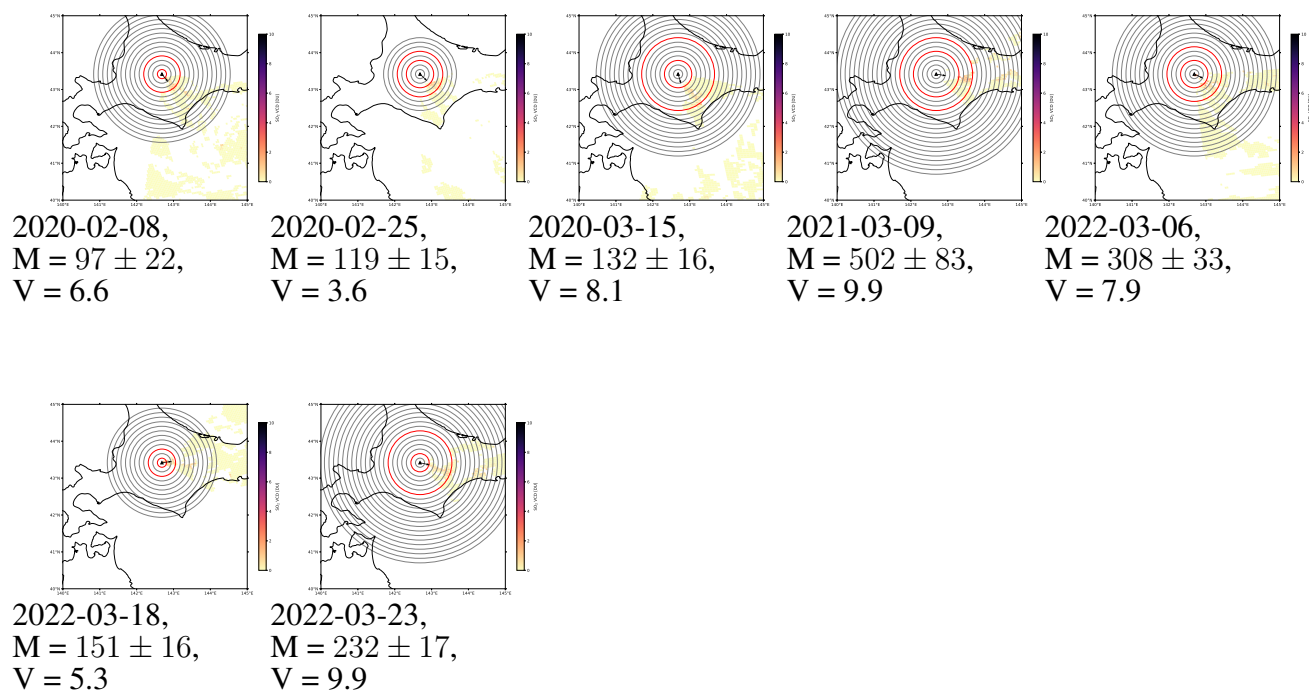


Figure S1: VCD maps masked pixels with cloud fraction less than 0.5 for the new method. Each caption shows Date of data, SO<sub>2</sub> flux [tons/day] of the day and wind velocity V [m/s]. Color scale represents Vertical Column Density of SO<sub>2</sub>. Circles are time windows. We integrated VCDs between two red circles. Black arrow represents the wind direction.