

**Table S1.** Basic properties of the measured F-gases.

| Categories       | Species         | Total lifetime (year) <sup>a</sup> | ODP <sup>a</sup> | 100-year GWP <sup>a</sup> |
|------------------|-----------------|------------------------------------|------------------|---------------------------|
| HFCs             | HFC-134a        | 14                                 | 0                | 1470                      |
|                  | HFC-23          | 228                                | 0                | 14700                     |
|                  | HFC-125         | 31                                 | 0                | 3820                      |
|                  | HFC-143a        | 52                                 | 0                | 5900                      |
|                  | HFC-32          | 5.3                                | 0                | 749                       |
|                  | HFC-152a        | 1.5                                | 0                | 153                       |
|                  | HFC-227ea       | 38.9                               | 0                | 3580                      |
|                  | HFC-236fa       | 242                                | 0                | 9120                      |
| Other<br>F-gases | PFC-116         | 10000                              | 0                | 9200                      |
|                  | CF <sub>4</sub> | 50000                              | 0                | 6500                      |
|                  | NF <sub>3</sub> | 550                                | 0                | 17000                     |

<sup>a</sup>: The total lifetime, ODP, and 100-year GWP are from the Scientific Assessment of Ozone Depletion: 2022

**Table S2.** Sampling record at Zhongshan Station.

| No. | ID           | Sampling<br>Date | Local<br>Time<br>(UTC+5) | Temperature<br>(°C) | Humidity<br>(%) | Wind<br>Direction<br>(°) | Wind<br>Speed<br>(m/s) | Meteorological Conditions |
|-----|--------------|------------------|--------------------------|---------------------|-----------------|--------------------------|------------------------|---------------------------|
| 01  | C-S-00090677 | 2021/1/15        | 10:00                    | 0.5                 | 55              | 100                      | 14.6                   | cloudy                    |
| 02  | C-S-00091876 | 2021/1/22        | 9:50                     | -2.6                | 51              | 74                       | 4.2                    | sunny                     |
| 03  | C-S-00099991 | 2021/2/5         | 10:32                    | -1.6                | 50              | NE                       | 4.7                    | less cloudy               |
| 04  | C-S-00099992 | 2021/2/19        | 10:30                    | -2.9                | 55              | ENE                      | 4.5                    | cloudy                    |
| 05  | C-S-00091771 | 2021/3/5         | 10:30                    | -1.3                | 51              | E                        | 6.9                    | cloudy                    |
| 06  | C-S-00090633 | 2021/3/19        | 11:30                    | -10.3               | 39              | ESE                      | 5.0                    | sunny                     |
| 07  | C-S-00099993 | 2021/4/2         | 10:39                    | -7.5                | 44              | E                        | 9.0                    | cloudy                    |
| 08  | C-S-00091740 | 2021/4/17        | 9:36                     | -18.1               | 38              | ESE                      | 11.5                   | sunny                     |
| 09  | C-S-00033333 | 2021/4/30        | 10:29                    | -19.7               | 57              | ESE                      | 6.6                    | cloudy                    |
| 10  | C-S-00091742 | 2021/5/15        | 10:29                    | -10.6               | 89              | ESE                      | 2.6                    | light snow                |
| 11  | C-S-00099994 | 2021/5/28        | 10:32                    | -25.2               | 72              | ESE                      | 7.0                    | sunny                     |
| 12  | C-S-00001234 | 2021/6/11        | 10:40                    | -15.0               | 72              | E                        | 5.3                    | light Snow                |
| 13  | C-S-00091868 | 2021/6/25        | 10:32                    | -15.9               | 69              | ESE                      | 15.0                   | blowing snow              |
| 14  | C-S-00099995 | 2021/7/9         | 10:34                    | -7.7                | 66              | ESE                      | 12.3                   | blowing snow              |

|    |              |            |       |       |    |     |      |            |
|----|--------------|------------|-------|-------|----|-----|------|------------|
| 15 | C-S-00099996 | 2021/7/23  | 10:28 | -20.5 | 45 | E   | 6.8  | cloudy     |
| 16 | C-S-00099997 | 2021/8/6   | 10:36 | -27.1 | 67 | 123 | 1.9  | cloudy     |
| 17 | C-S-00091782 | 2021/8/20  | 10:40 | -8.7  | 60 | 106 | 12.9 | cloudy     |
| 18 | C-S-00090704 | 2021/9/3   | 10:37 | -12.3 | 89 | 79  | 8.5  | light snow |
| 19 | C-S-00090650 | 2021/9/17  | 10:36 | -8.8  | 54 | 114 | 12.2 | cloudy     |
| 20 | C-S-00091833 | 2021/10/1  | 9:35  | -7.4  | 90 | 96  | 6.7  | light snow |
| 21 | C-S-00099998 | 2021/10/15 | 10:40 | -9.3  | 61 | 98  | 2.9  | cloudy     |
| 22 | C-S-00099999 | 2021/10/29 | 10:28 | -11.5 | 66 | 71  | 10.9 | cloudy     |
| 23 | C-S-00091774 | 2021/11/12 | 10:24 | -4.0  | 54 | 44  | 3.5  | cloudy     |
| 24 | C-S-00091796 | 2021/11/26 | 10:33 | -5.9  | 51 | 86  | 2.1  | sunny      |
| 25 | C-S-00090688 | 2021/12/3  | 10:20 | 2.3   | 46 | 119 | 3.2  | cloudy     |
| 26 | C-S-00090001 | 2021/12/10 | 10:30 | 1.9   | 58 | 68  | 2.8  | sunny      |

**Table S3.** Accuracy, limit of detection and quantitative method of the mole fraction for each compound by ODS5-pro system.

| Compound        | Limit of Detection(ppt) | Accuracy(%) | Quantify |
|-----------------|-------------------------|-------------|----------|
| HFC-134a        | 0.16                    | -0.02       | A        |
| HFC-23          | 0.08                    | 0.01        | A        |
| HFC-125         | 0.21                    | 0.01        | A        |
| HFC-143a        | 0.18                    | -0.02       | A        |
| HFC-32          | 0.59                    | <0.01%      | A        |
| HFC-152a        | 0.91                    | 0.02        | H        |
| HFC-236fa       | 0.08                    | 0.40        | H        |
| HFC-227ea       | 0.11                    | -0.04       | H        |
| PFC-116         | 0.08                    | -0.16       | A        |
| CF <sub>4</sub> | 0.23                    | 0.04        | A        |
| NF <sub>3</sub> | 0.7                     | 0.02        | H        |
| SF <sub>6</sub> | 0.04                    | -0.07       | A        |

“A” means using the peak area for calculation, “H” means using the peak height for calculation. Data from [Yi et al., 2023](#).

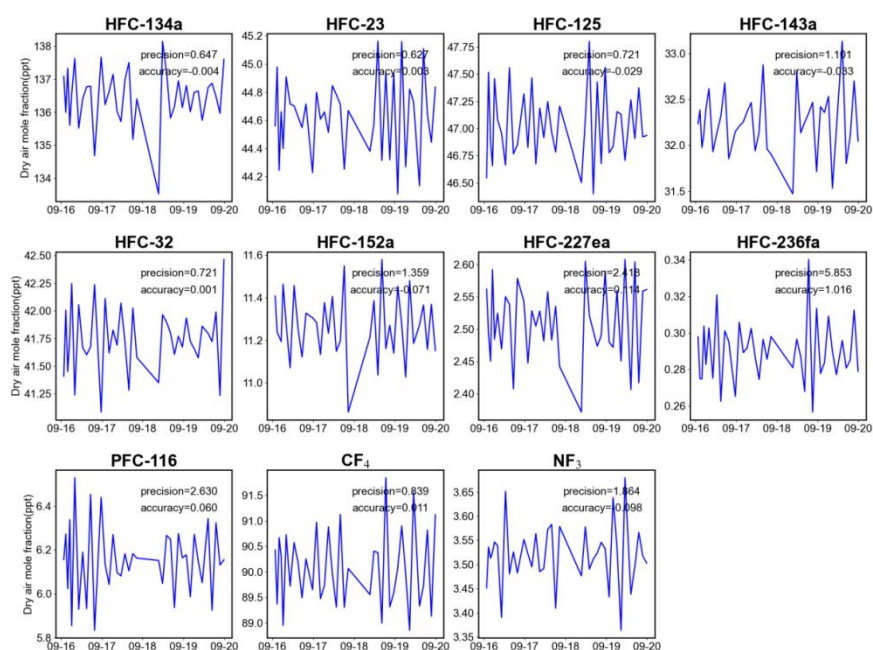
**Table S4.** F-gases concentration(ppt) carried by different trajectory clusters in 2021 at four Antarctic stations.

| Site            | ZOS    |       |        | TRL    |        |        | SPO    |       |        | PSA   |       |       |
|-----------------|--------|-------|--------|--------|--------|--------|--------|-------|--------|-------|-------|-------|
| Cluster         | 1      | 2     | 3      | 1      | 2      | 3      | 1      | 2     | 3      | 1     | 2     | 3     |
| HFC-134a        | 112.74 | 112.8 | 113.69 | 111.98 | 111.33 | 112.11 | 113.02 | 112.3 | 112.69 | 86.66 | 86.7  | 86.8  |
| HFC-23          | 35.16  | 35.38 | 35.27  | 34.05  | 33.98  | 34.2   |        |       |        |       |       |       |
| HFC-125         | 34.32  | 34.39 | 34.67  | 34.58  | 34.21  | 34.68  | 32.89  | 32.6  | 33.09  | 32.69 | 32.48 | 32.82 |
| HFC-143a        | 26.45  | 26.53 | 26.75  | 26.73  | 26.45  | 26.61  | 25.65  | 25.44 | 25.84  | 25.34 | 25.24 | 25.41 |
| HFC-32          | 24.37  | 24.4  | 24.83  | 24.16  | 23.77  | 24.21  | 21.02  | 20.92 | 21.53  | 21.02 | 20.41 | 20.46 |
| HFC-152a        | 4.78   | 4.81  | 4.85   | 4.82   | 4.72   | 4.8    | 5.02   | 4.93  | 5.04   | 4.86  | 4.83  | 4.87  |
| HFC-227ea       | 1.87   | 1.88  | 1.88   | 1.87   | 1.86   | 1.88   | 1.78   | 1.78  | 1.79   | 1.75  | 1.74  | 1.74  |
| HFC-236fa       | 0.22   | 0.23  | 0.23   | 0.21   | 0.21   | 0.21   | 0.36   | 0.34  | 0.39   | 0.2   | 0.2   | 0.2   |
| PFC-116         | 5.27   | 5.32  | 5.2    |        |        |        | 5      | 4.98  | 4.99   | 4.96  | 4.87  | 4.86  |
| CF <sub>4</sub> | 86.66  | 86.7  | 86.8   | 86.34  | 86.27  | 86.39  | 86.42  | 86.3  | 86.39  | 86.3  | 86.15 | 86.22 |
| NF <sub>3</sub> | 2.56   | 2.53  | 2.62   |        |        |        | 2.25   | 2.25  | 2.27   | 2.32  | 2.28  | 2.29  |

**Figure S1.** Pictures of collecting ambient air sample using a sampler and canister at Swan Ridge, Zhongshan Station.



**Figure S2.** The precision and accuracy when ODS5-pro system measuring standard gas.



Relative standard deviation (%) represent precision and mean relative error(%) represents accuracy.

**Figure S3.** The scaled residuals from positive matrix factorization (PMF) model.

