The characteristics of atmospheric SF_6 in the Korean Peninsula during 2017-2020

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Sulfur Hexafluoride (SF_6) is almost entirely anthropogenic GHG, which has 22,500 times greater GWP than CO_2 (100-year) and have extremely long atmospheric lifetime of several hundreds to thousands of years.

NIMS/KMA has measured atmospheric SF_6 in Korean Peninsula since 2007 and by now, operated 3 background GHG monitoring stations in Anmyeondo (AMY), Jeju Gosan (JGS) and Ulleungdo (ULD) that monitors inflow and outflow of atmospheric SF_6 of Korea Peninsula.

Figure 1. Three atmospheric background SF_6 monitoring stations in Korea Peninsula (AMY, JGS, ULD).

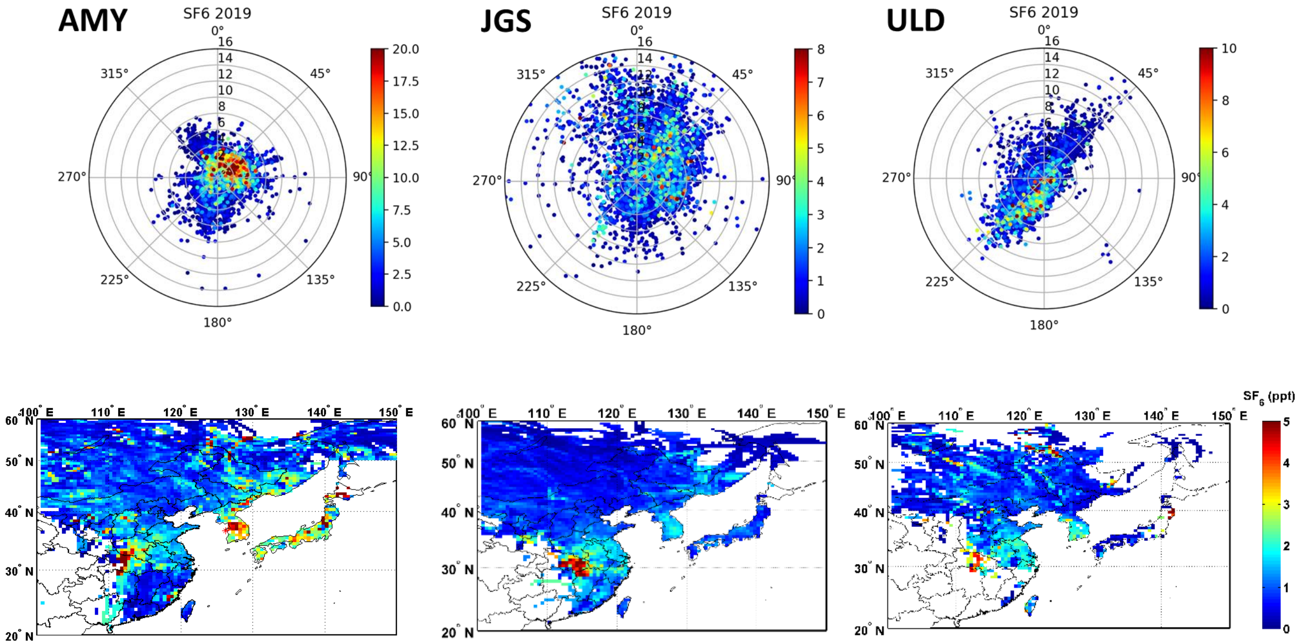

Figure 3. (Upper) The enhancement of atmospheric SF_6 in AMY, JGS, ULD in 2019 is analysed by wind speed and wind direction. (Bottom) Emission source regions and emission strength are analyzed by HYSPLIT model.

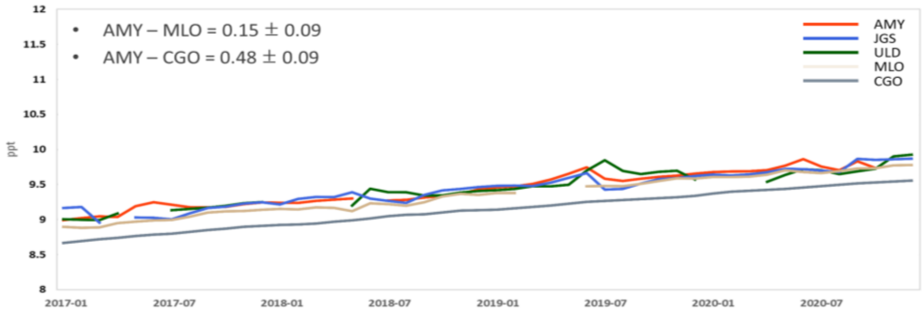

Figure 2. The trends of atmospheric background mole fractions of SF_6 AMY, JGS, ULD, MLO and CGO.

The atmospheric SF_6 of AMY, JGS and ULD shows annual increase rate of ±0.3 ppt yr^{-1} in accordance to trends of global monitoring stations. During 2017 – 2020 period, high SF_6 enhancement of AMY, JGS and ULD assumes to be influenced by local/regional source as well as long-range transport from central and eastern China and Japan. From the analysis of continuous monitoring data, COVID-19 lockdown effect was noticed during 2019-2020 in all monitoring stations.

EGU 2023, Vienna, Austria 26 April 2023

National Institute of Meteorological Sciences

European Geosciences Union

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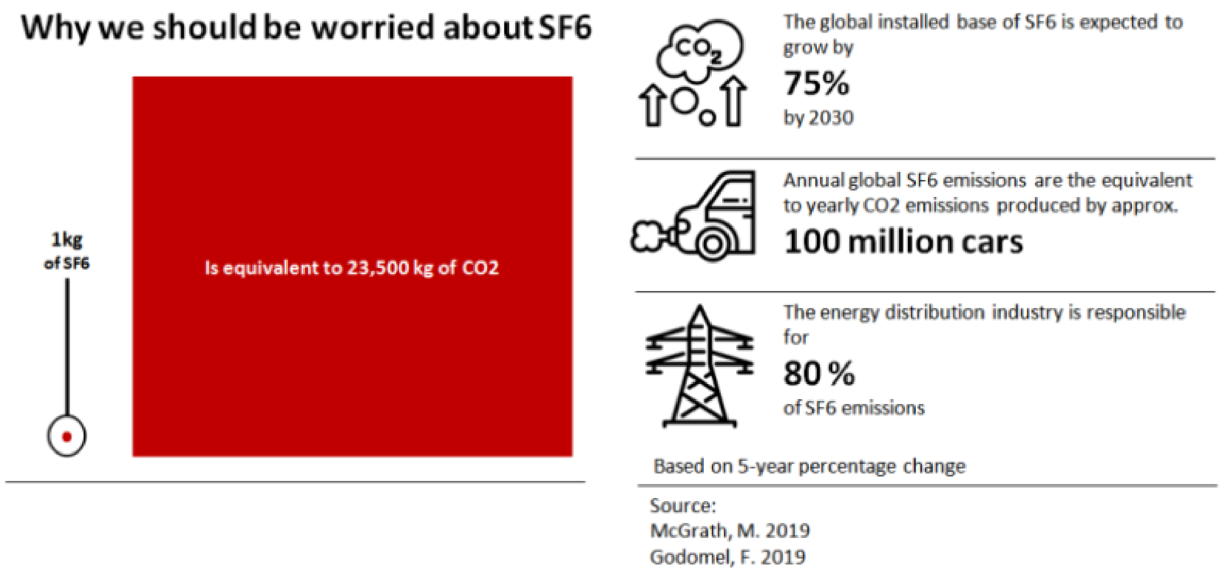
1. Introduction

Why is Sulfur hexafluoride (SF_6) important?

- Almost entirely anthropogenic greenhouse gas;
- 22,500 times greater GWP(Global Warming Potential) than CO_2 (100-year);
- Only sinks by photolysis and electron capture reactions in the mesosphere;
- "Extremely long atmospheric lifetimes" of several hundreds to thousands of years.

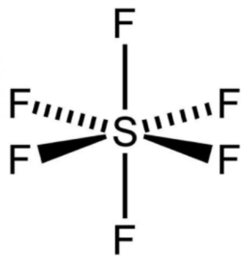


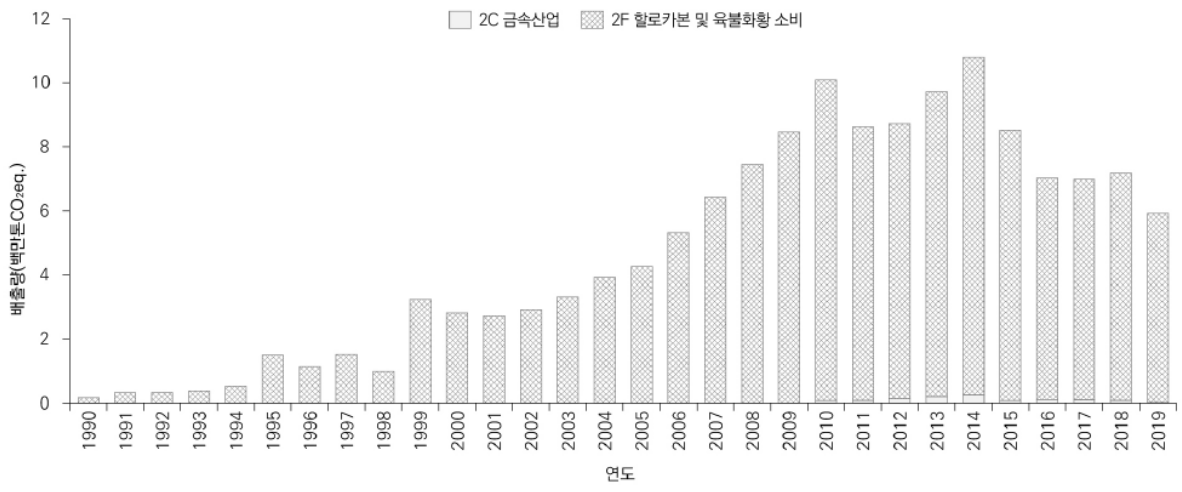
Energypost.eu (2019.11.25) Grid switchgear uses SF6, the world's most potent greenhouse gas. How do we regulate it?

1. Introduction

Why is Sulfur hexafluoride (SF_6) important?

- Chemically stable, non-flammable and highly electronegative with excellent dielectric property;
- Commonly used in electrical switch gear, transformer, substations as an electrical insulation, arc quenching and cooling medium;
- Mostly used in thin film transistor liquid crystal display (TFT-LCD) manufacturing, plasma etching processes in the semiconductor industry





| 그림 2-24 | 산업공정 분야 SF_6 배출량(1990–2019)

| 표 2-22 | 산업공정 분야 SF_6 배출량(1990–2019)

(단위: 백만톤 CO_2eq.)

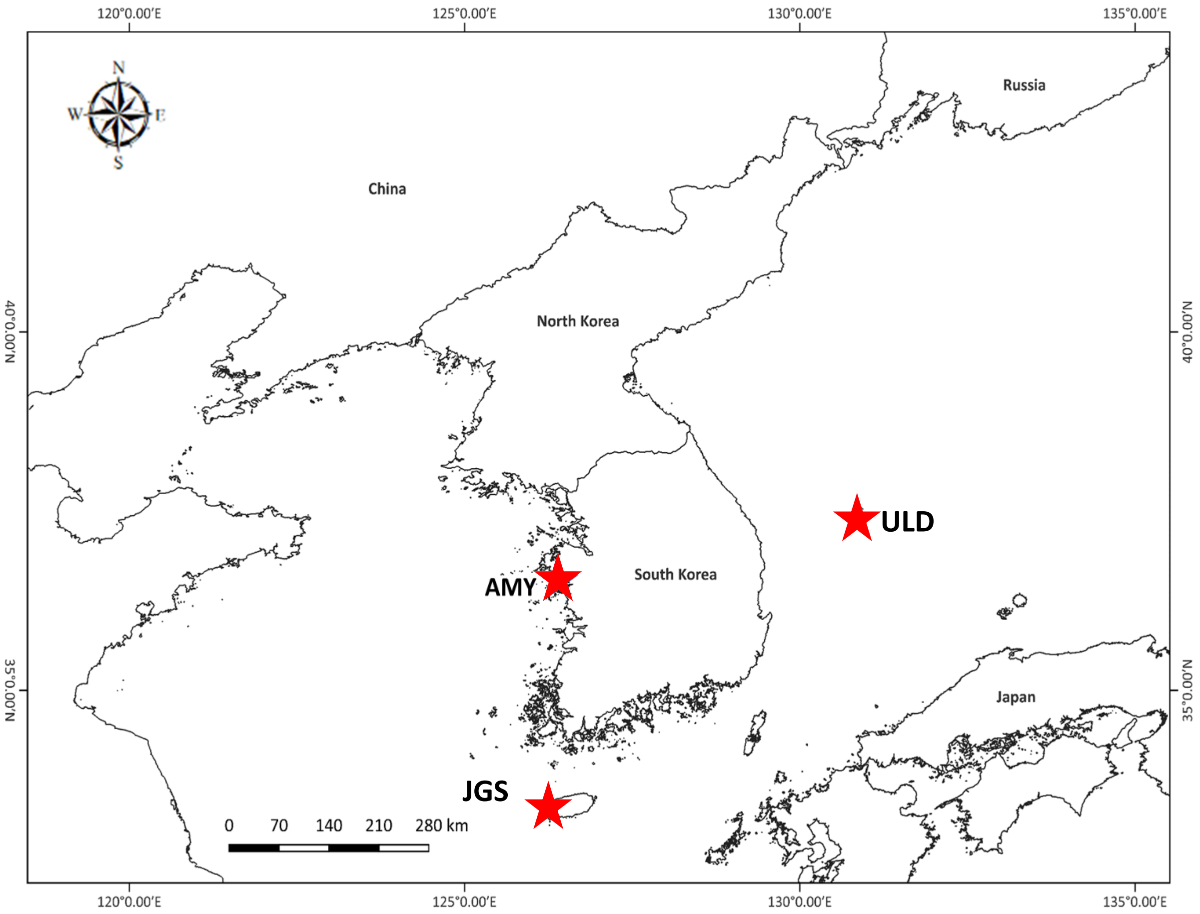
부문	1990	1995	2000	2005	2010	2015	2017	2018	2019
2C 금속산업	NE	NE	NE	NE	0.1	0.1	0.1	0.1	0.02
2F 할로카본 및 SF_6 소비	0.2	1.5	2.8	4.3	10.0	8.4	6.9	7.1	5.9
SF_6 합계	**0.2**	**1.5**	**2.8**	**4.3**	**10.1**	**8.5**	**7.0**	**7.2**	**5.9**

※ NE(Not Estimated): 배출·흡수활동 및 공정이 있으나 산정하지 아니하는 경우

2022 National Inventory Report (GIR)

2. Measurement

In situ atmospheric SF_6 measurement



- Anmyeondo(AMY): 1st in-situ atmospheric SF_6 measurement since 2007.
- Jeju Gosan(JGS) & Ulleungdo(ULD) started the atmospheric SF_6 measurement in 2017.
- As a GAW regional station, AMY & JGS monitors regional scale information than global stations.
- 3 stations Locate at the boundaries of Korean Peninsula

2. Measurement

In situ atmospheric SF_6 measurement

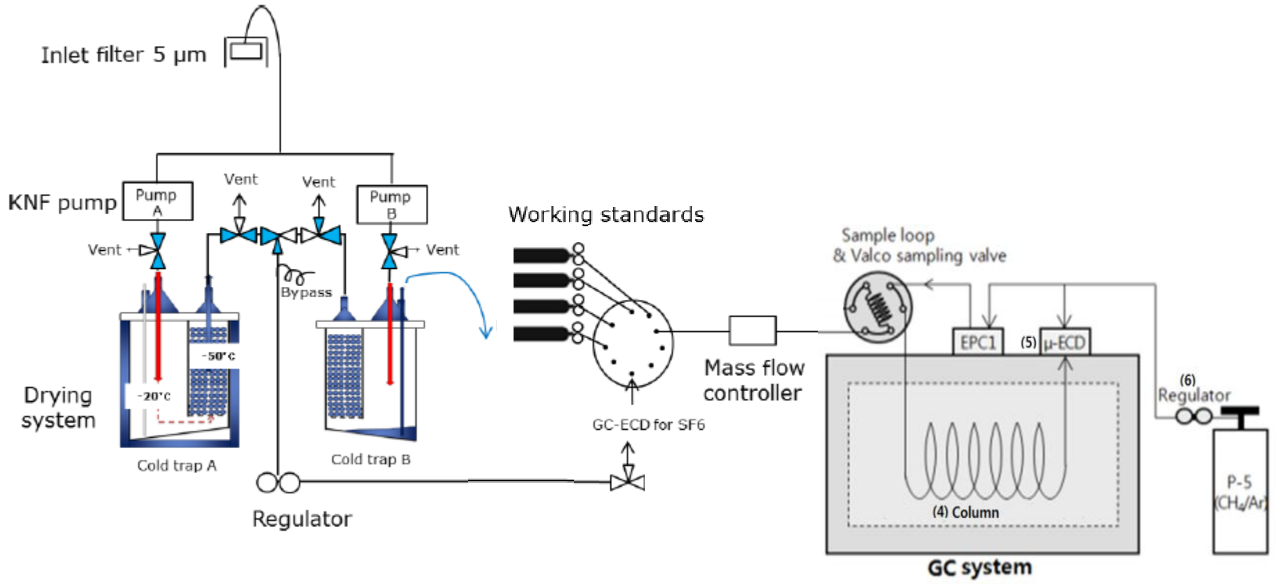


Figure 2. Schematic of the in situ system when the drying system is at the state described in Step 3 in AMY, JGS, and ULD.

- Air sample is introduced from the inlet on the 40m height tower to the detector passing through drying system
- Gas Chromatography with Electron Capture Detector(GC-ECD): High-energy β electrons generated by the decay of a radioisotope (^{63}Ni) used as the primary source of ionizing radiation.
- A data system records the size of the signal and plots it against elapsed time to produce a chromatogram.

Lee, H., Han, S. O., Ryoo, S. B., Lee, J. S., & Lee, G. W. (2019). The measurement of atmospheric CO_2 at KMA GAW regional stations, its characteristics, and comparisons with other East Asian sites. Atmospheric Chemistry and Physics, 19(4), 2149-2163.
Coakely Jr, J. A., Bernstein, R. L., & Durkee, P. A. (1987). Effect of ship-stack effluents on cloud reflectivity. *Science*, 237(4818), 1020-1022

2. Measurement

In situ atmospheric SF_6 measurement

- Traceable to WMO/GAW Standard Scale
  - WMO X2014

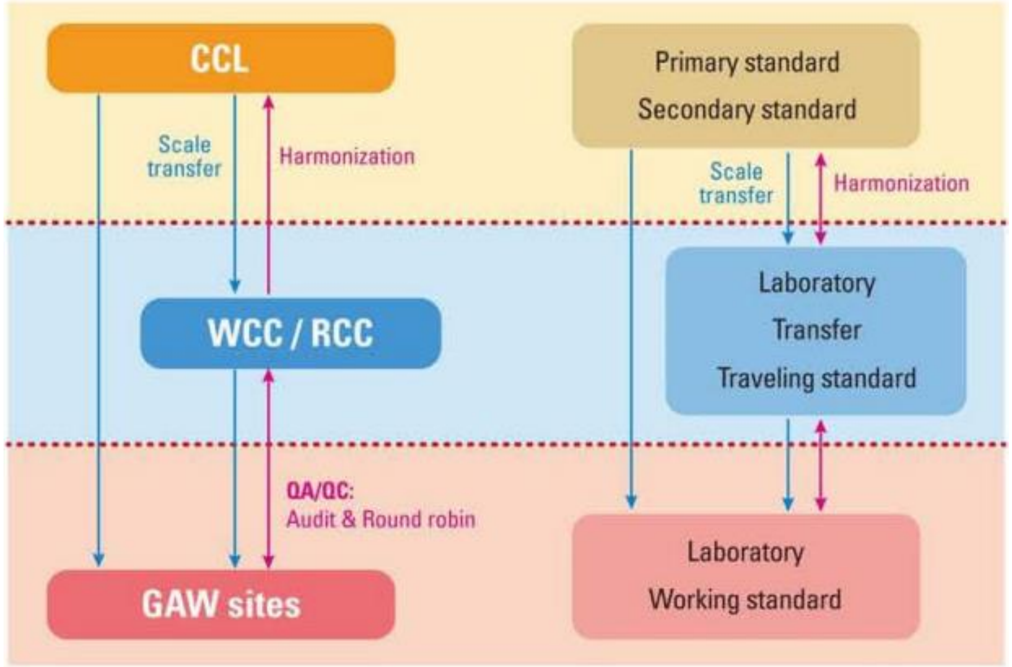


Figure 1. WMO traceability hierarchy.

- 1-point calibration

$$C_{sample} = \frac{R_{sample}}{R_{STD}} \times C_{STD} \times f_{drift}$$

$$f_{drift} = \frac{(2 \times R_{STD'})}{(R_{STD'} + R_{STD''})}$$

- R_{STD}: Response value of Standard gas
- C_{STD}: Certified value of Standard gas
- R_{sample}: Response value of Sample
- C_{sample}: Certified value of Sample
- f_{drift}: Function of drift correction

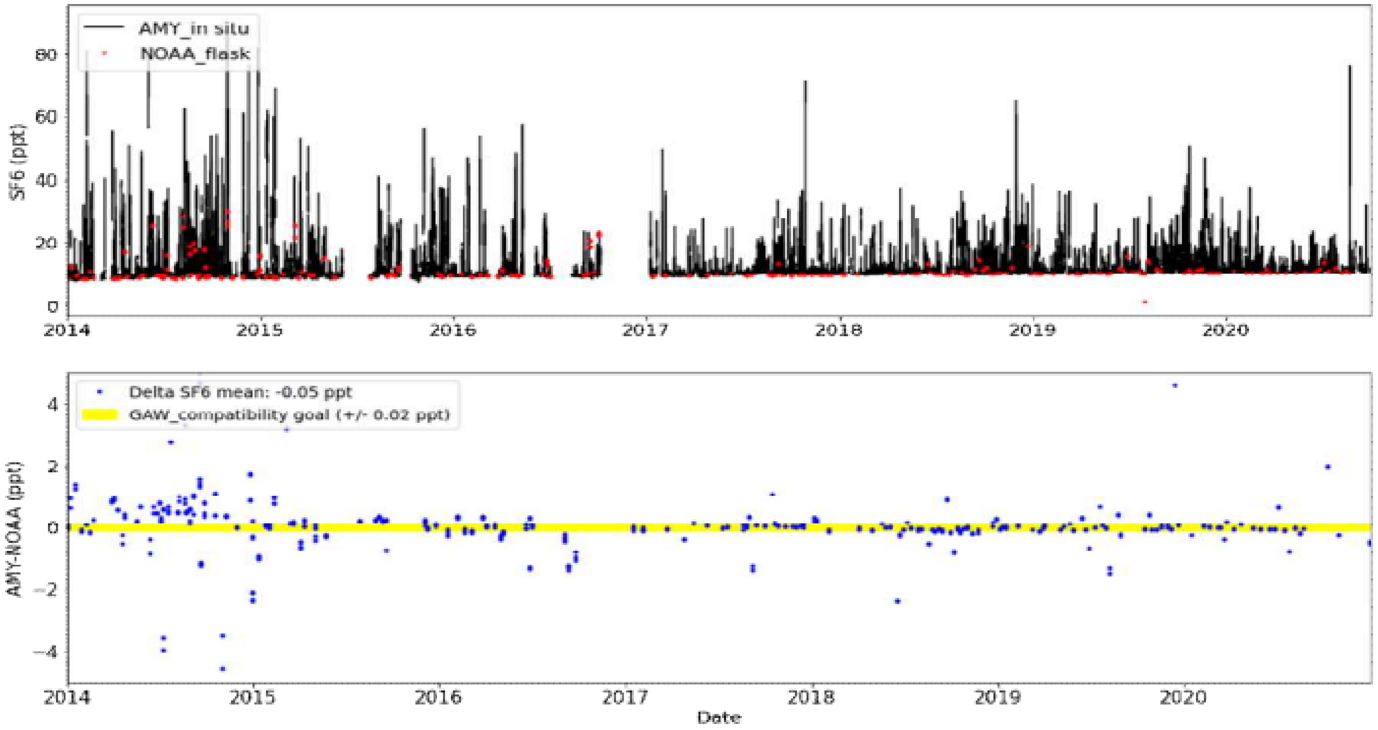
2. Measurement

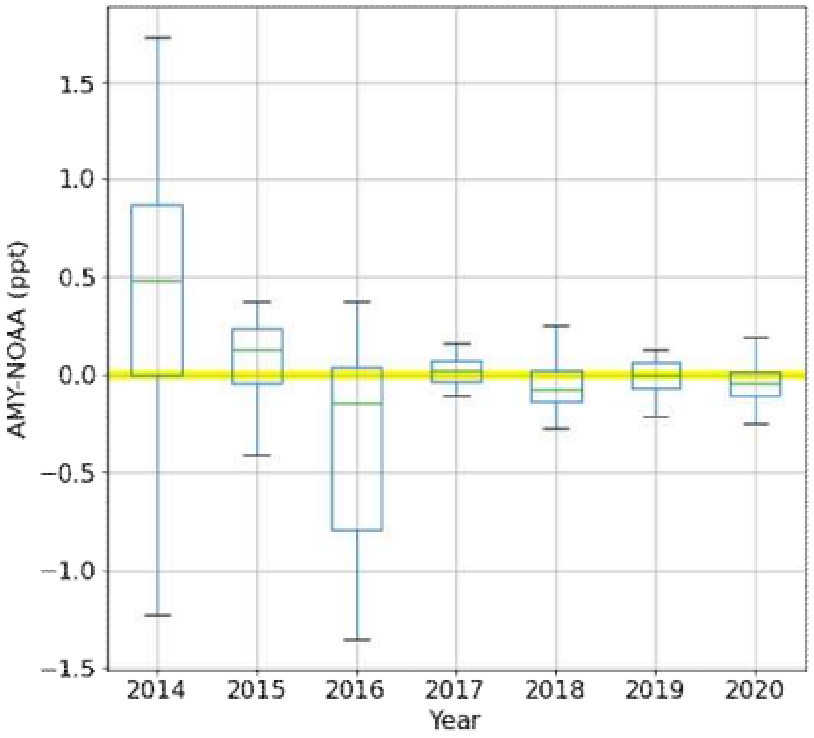
Quality Assurance/Quality Control

Data level		Data	Period	DB table	Note
L0	L0	Raw data	-	PM10_132	
L1	L1A	Automatic QC	hour	L1_PM10_132	6 QC flag
	L1B	Manual QC by observer			Station and instrument flag and observer information
	L1C	Manual QC by researcher			QA flag and researcher information
L2	L2H	Hourly	Day	L2H_PM10_132	Quality assured statistics
	L2D	Daily		L2D_PM10_132	
	L2M	Monthly		L2M_PM10_132	
	L2Y	Yearly		L2Y_PM10_132	
L3	L3H	Hourly background	day	L3H_CO2_132	
	L3D	Daily background		L3D_CO2_132	
	L3M	Monthly background		L3M_CO2_132	

2. Measurement

Quality Assurance/Quality Control



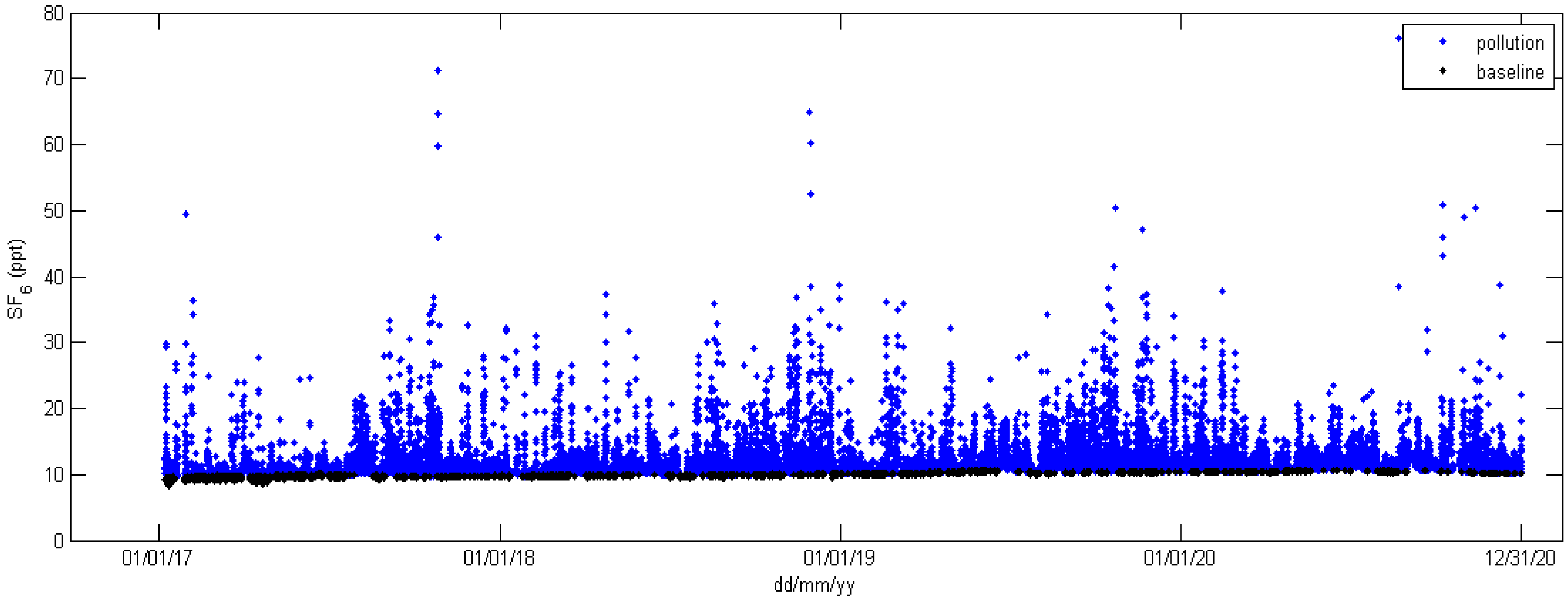


- Regularly(weekly) compares measurements of AMY with NOAA GML/ESRL by flask sampling since 2013.
- The difference between the in situ real time measurement data and NOAA flask sampling results becomes within the network compatibility goal range (±2 ppt) from 2017.

Lee, H., Han, S. O., Ryoo, S. B., Lee, J. S., & Lee, G. W. (2019). The measurement of atmospheric CO_2 at KMA GAW regional stations, its characteristics, and comparisons with other East Asian sites. Atmospheric Chemistry and Physics, 19(4), 2149-2163.

3. Results

(1) Background and Enhancement of SF_6 mole fraction (ppt)

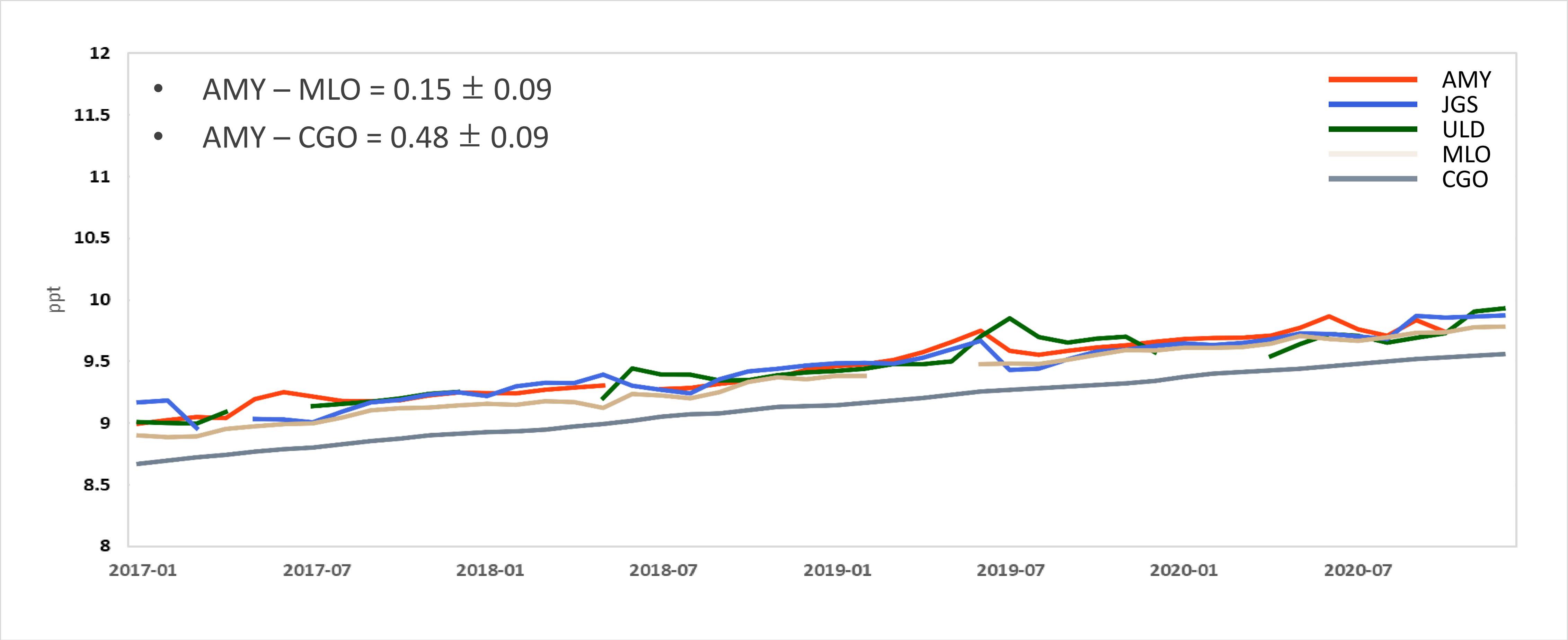


※ Background calculation (O’Doherty et al., 2001)

1) Quadratic fitting curve with ± 60d minimum value
2) Calculate the median value of residuals of fitting value
3) Calculation of the standard deviation (σ) of the values lower than the median
4) Background concentration is selected if it is lower than the sum of the median value + 3σ

3. Results

(2) SF_6 mole fraction trend in Korea compared to Global trend

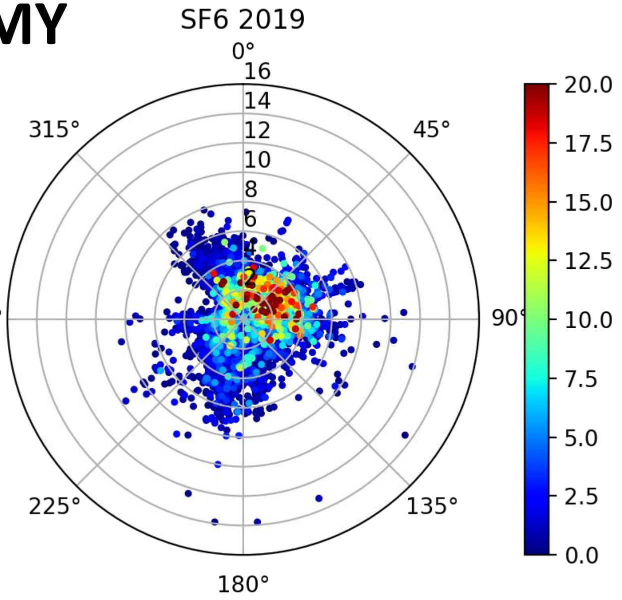


3. Results

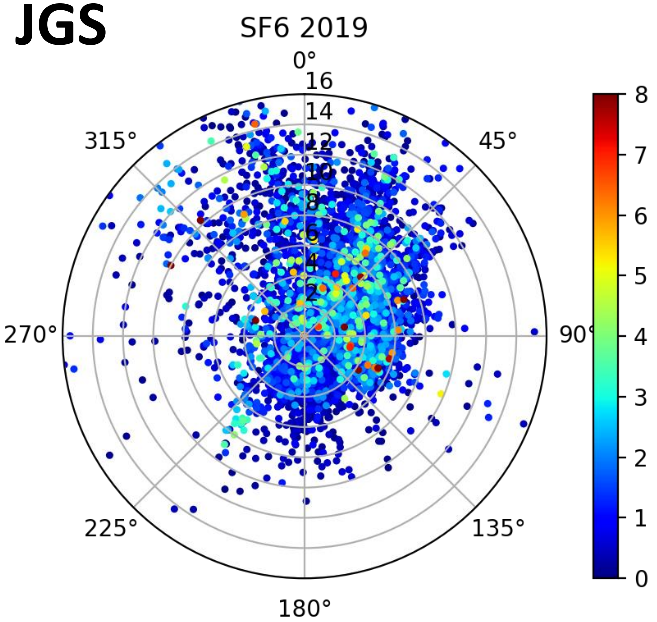
(3) Enhancement of SF_6 by wind direction and wind speed

- **AMY:** high SF_6 case occurred with winds from **0 to 90°** with the speed **< 5 m/s**.
- **JGS:** high SF_6 occurred with winds from **0 to 135°** with the speed **< 8 m/s** and **270 to 360 °** with the speed **over 10 - 12 m/s**
- **ULD:** high SF_6 occurred with winds from **180 to 270°** with the speed **< 8 m/s**.

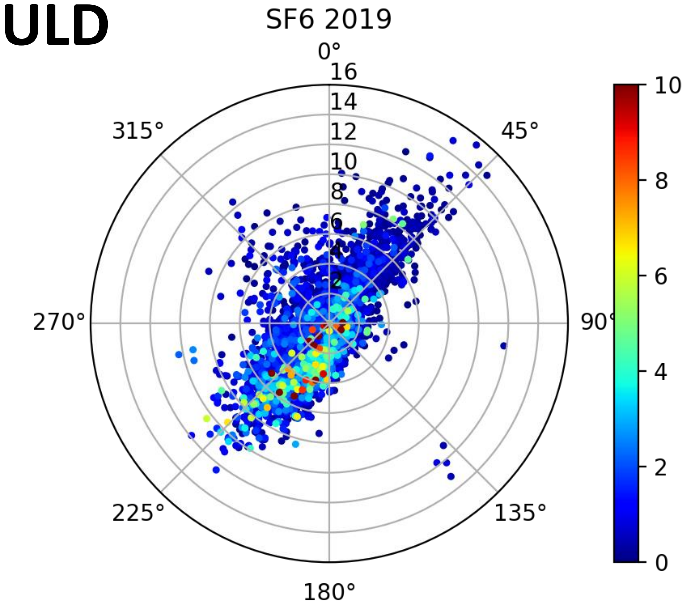
AMY



JGS

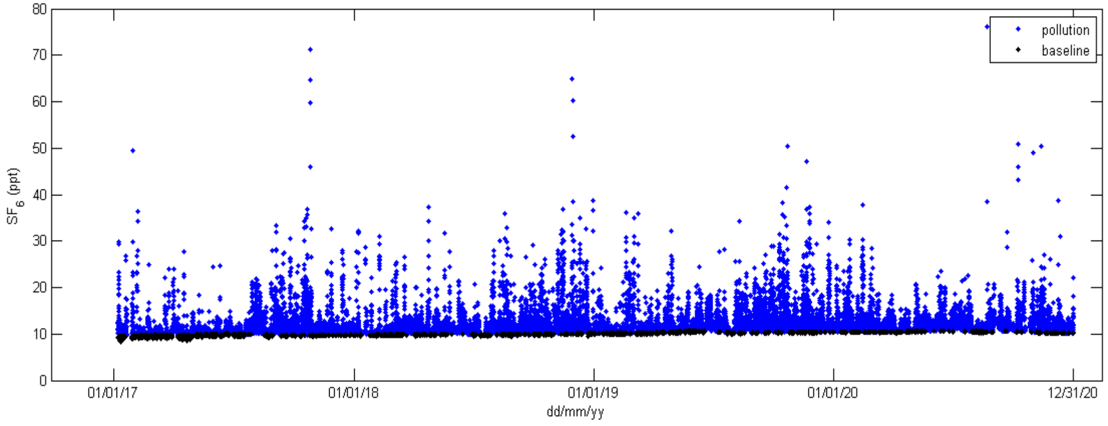


ULD



3. Results

(4) Emission source distribution identification



$$C_{(i,j)} = \sum_{a=1}^{t} (C_a) T_{(i,j,a)} \Big/ \sum_{a=1}^{t} T_{(i,j,a)}$$

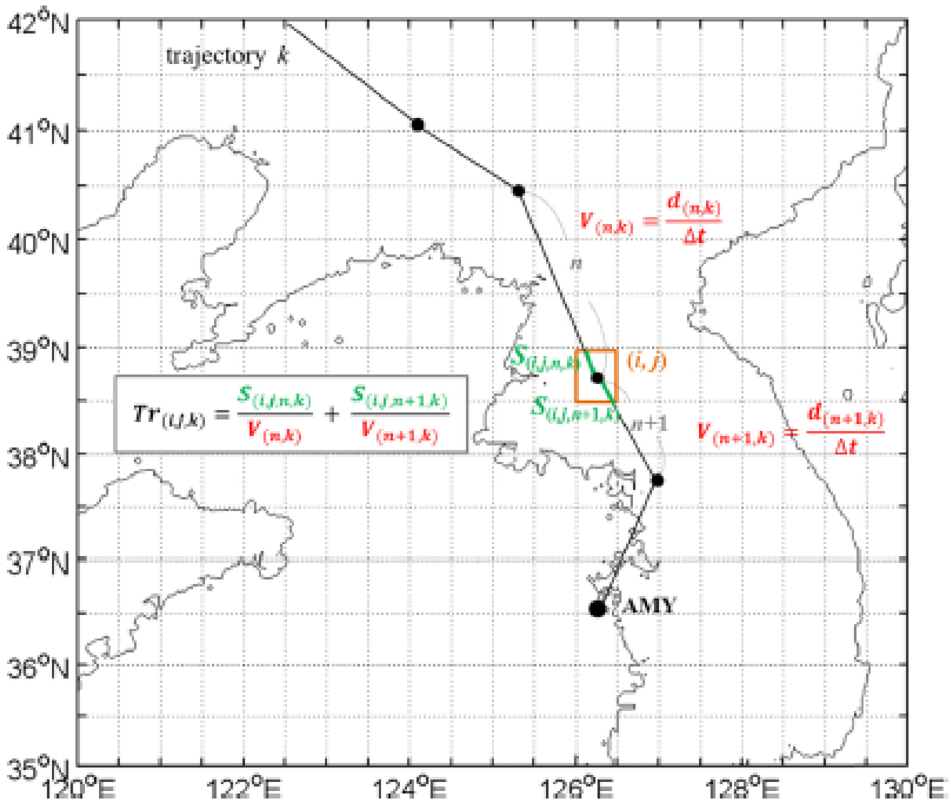


Fig. 1. Illustration of residence time calculation on a grid cell (*i*, *j*) of a HYSPLIT back-trajectory arriving at Anmyeon-do (AMY).

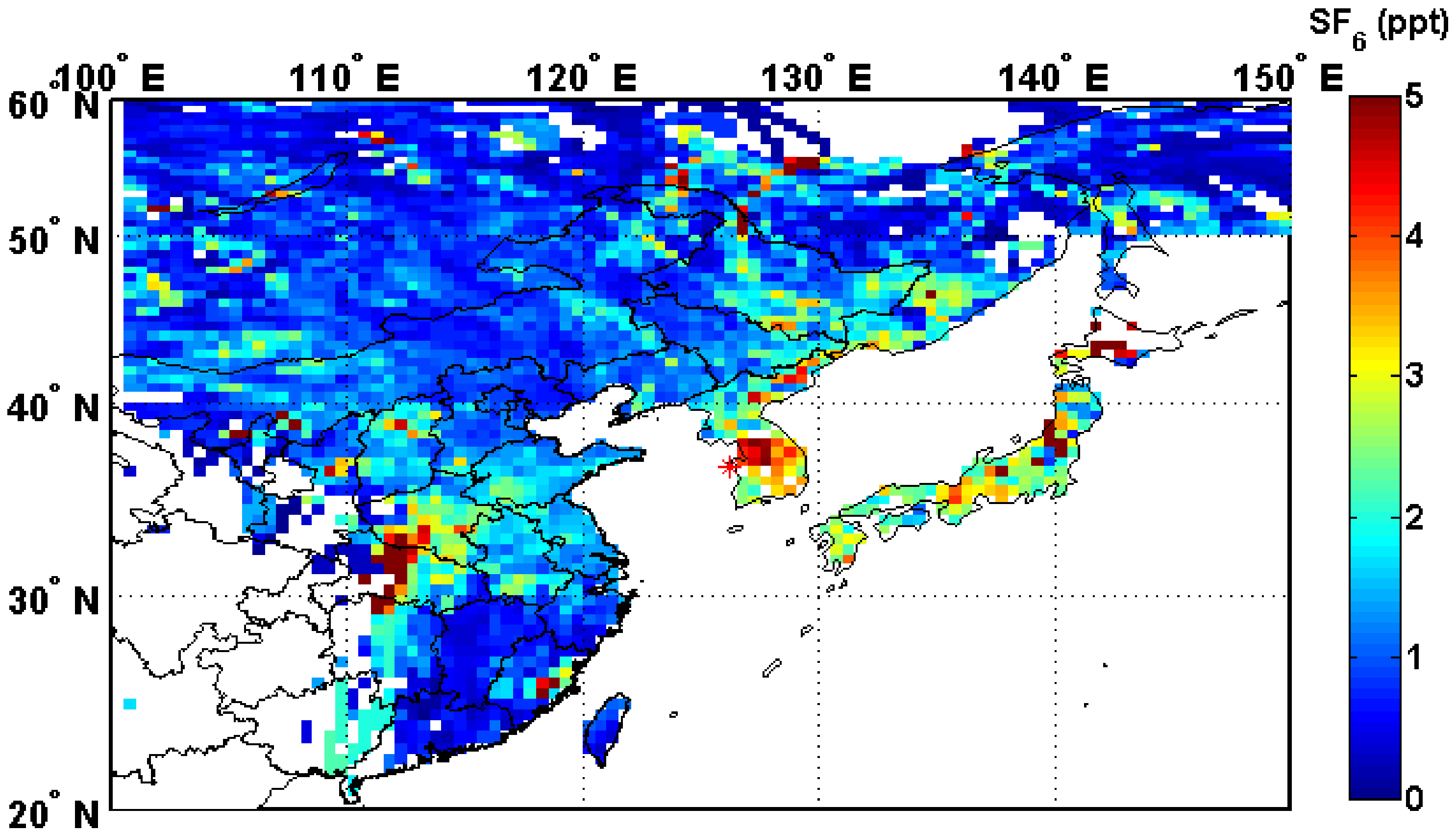
- Combine the high frequency data and air mass residence time with single particle Lagrangian model of HYSPLIT in each grid cell to identify the potential emission source regions

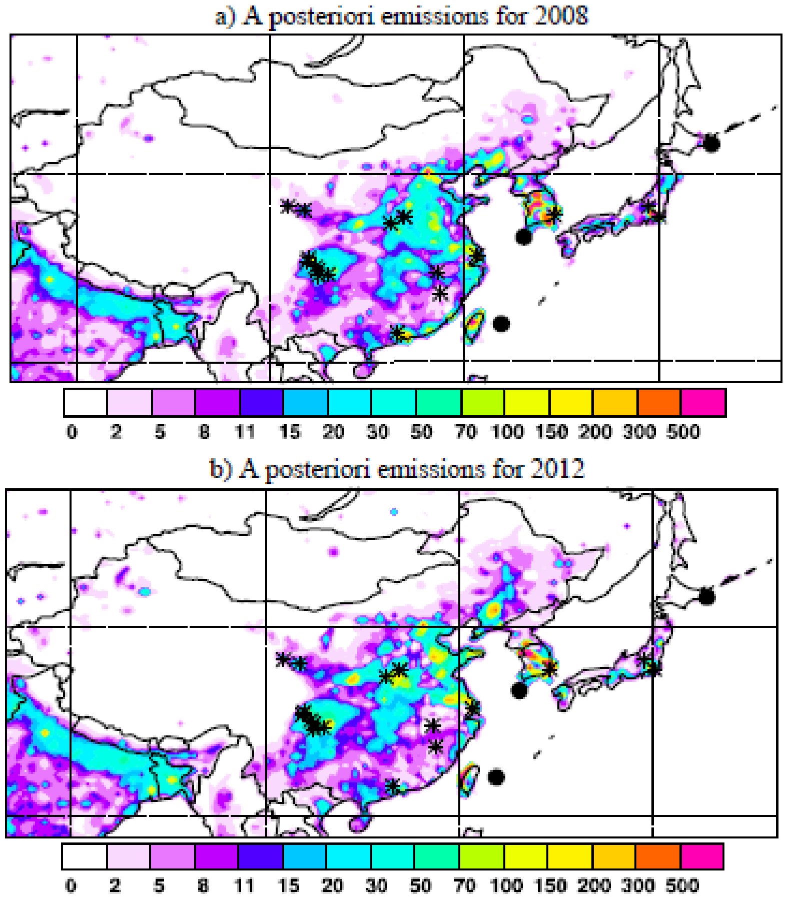
(Li et al., 2014) Illustration of residence time calculation on a grid cell (I, j) of a HYSPLIT back-trajectory arriving at AMY.

3. Results

(4) Emission source distribution identification of AMY

- Regional potential Source Strength (ppt) is from north eastern area (Industrial field)
- Long-range transport from central China and Japan is assumed



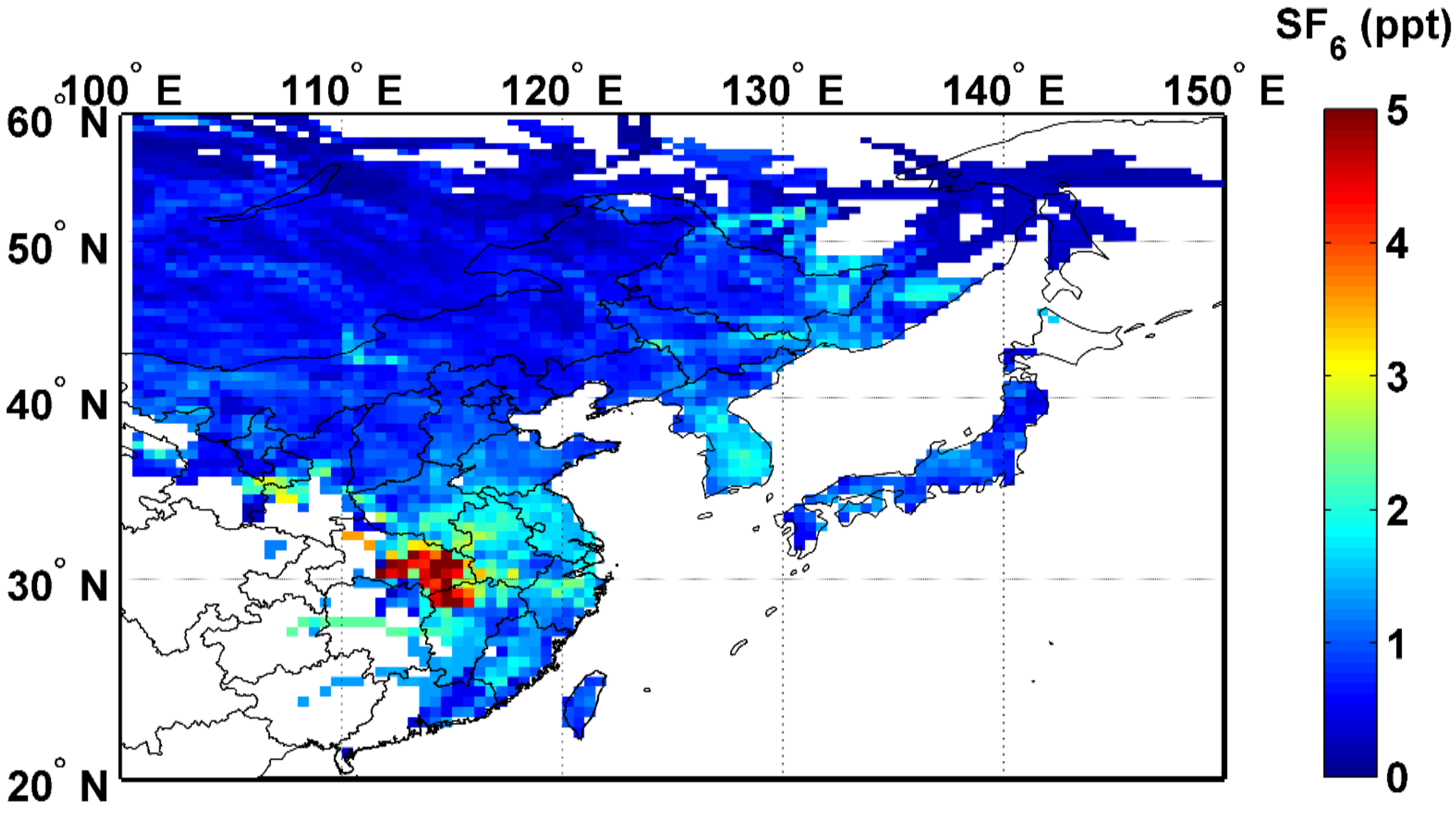


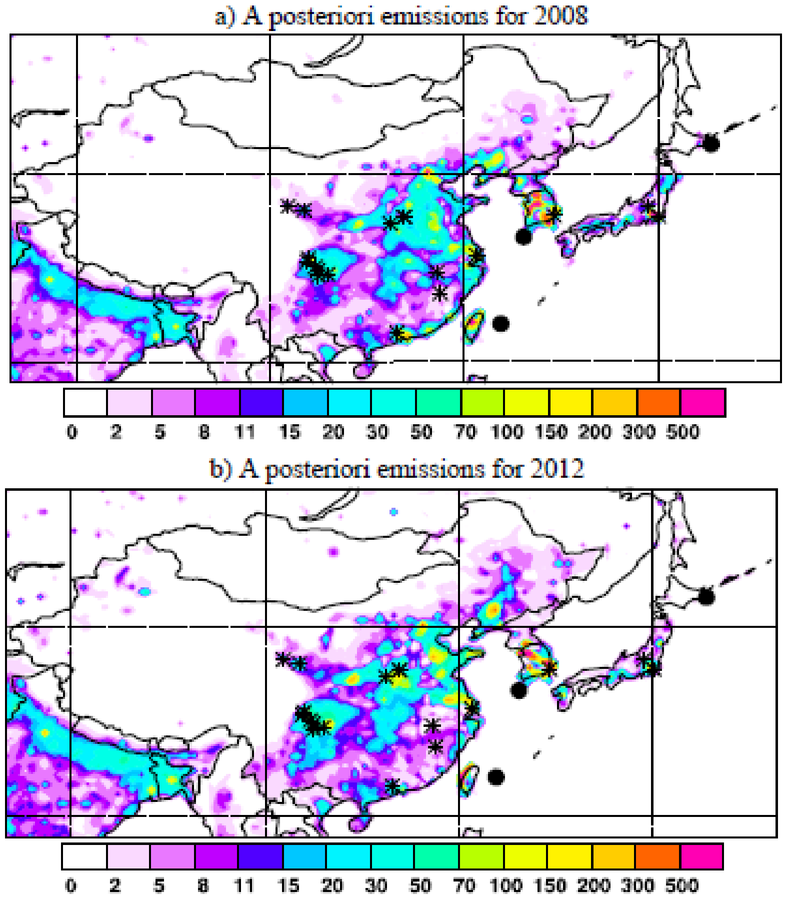
(Fang et al., 2014) Maps of the posteriori SF6 emissions for 2008 (top panel) and 2012 (bottom panel). Black dots denote the location of measurement stations. Asterisks mark the locations of factories in East Asia known to have produced SF6 around the year 2008.

3. Results

(4) Emission source distribution identification of JGS

- Central China is estimated as a major sources of enhancement of JGS by long-range transport



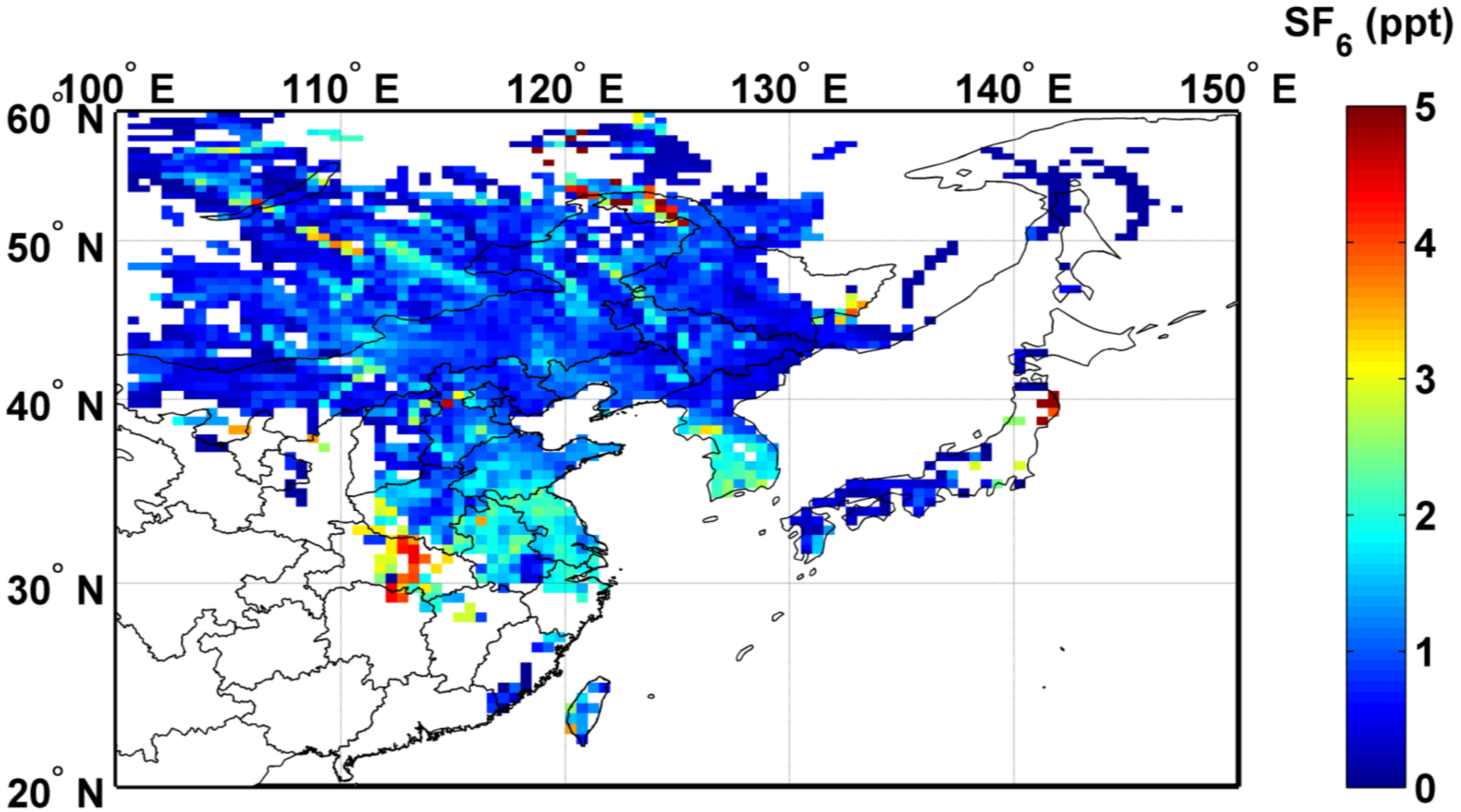


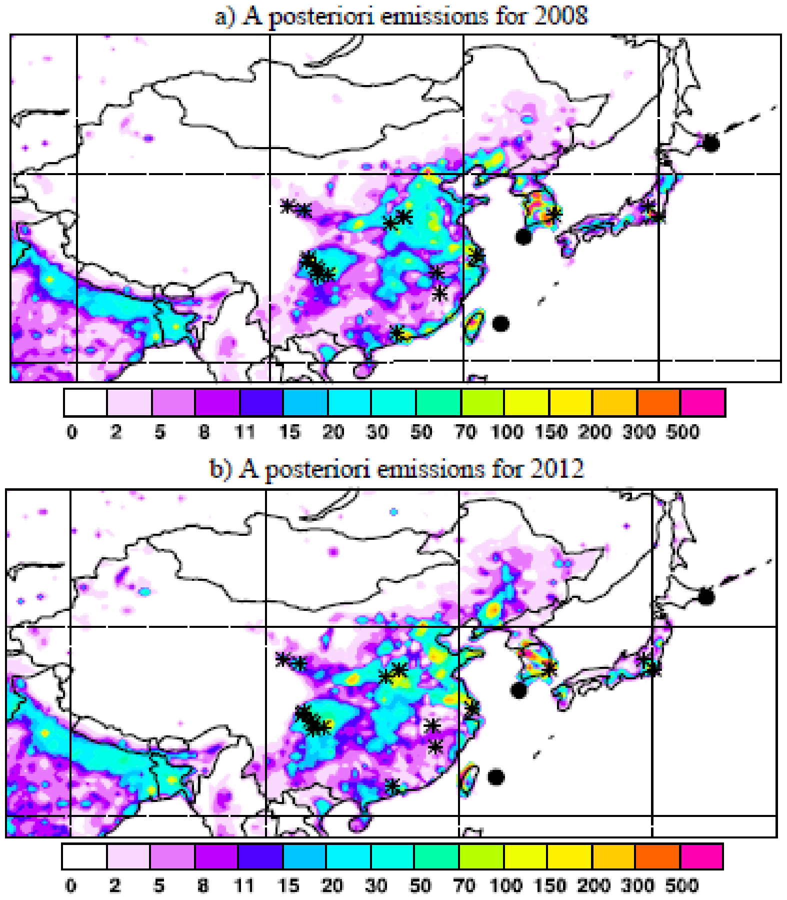
(Fang et al., 2014) Maps of the posteriori SF6 emissions for 2008 (top panel) and 2012 (bottom panel). Black dots denote the location of measurement stations. Asterisks mark the locations of factories in East Asia known to have produced SF6 around the year 2008.

3. Results

(4) Emission source distribution identification of ULD

- Influence of southern Korean Peninsula appears Long-range transport from central China and Japan is assumed (Northern China and Mongolia as well)



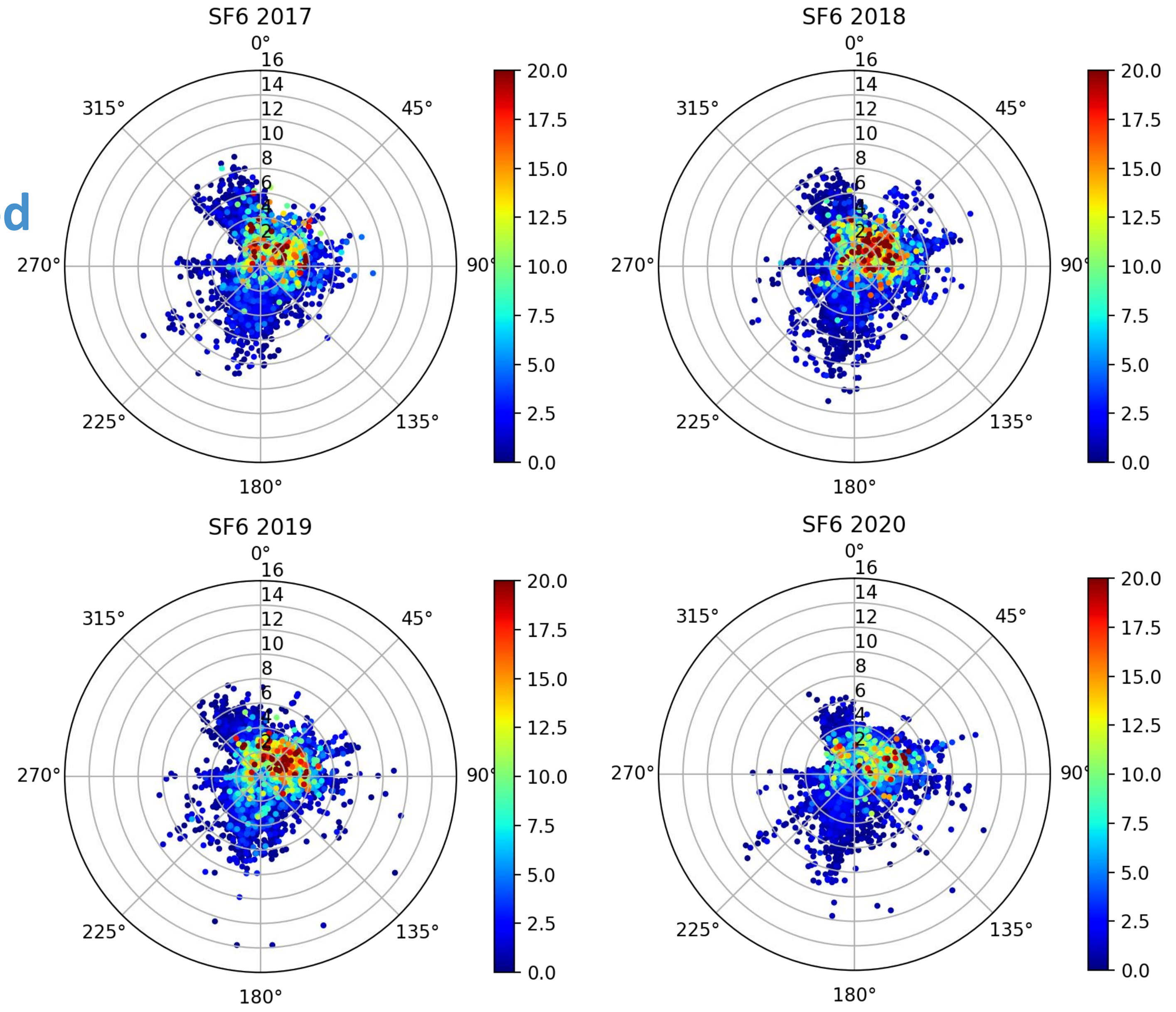


(Fang et al., 2014) Maps of the posteriori SF6 emissions for 2008 (top panel) and 2012 (bottom panel). Black dots denote the location of measurement stations. Asterisks mark the locations of factories in East Asia known to have produced SF6 around the year 2008.

Results

(5) Enhancement change of SF6 during COVID-19 lockdown period

- At AMY, high SF_6 occurred when winds mainly come from 0 to 90° with the speed < 5 m/s



Results

(5) Enhancement change of SF6 during COVID-19 lockdown period

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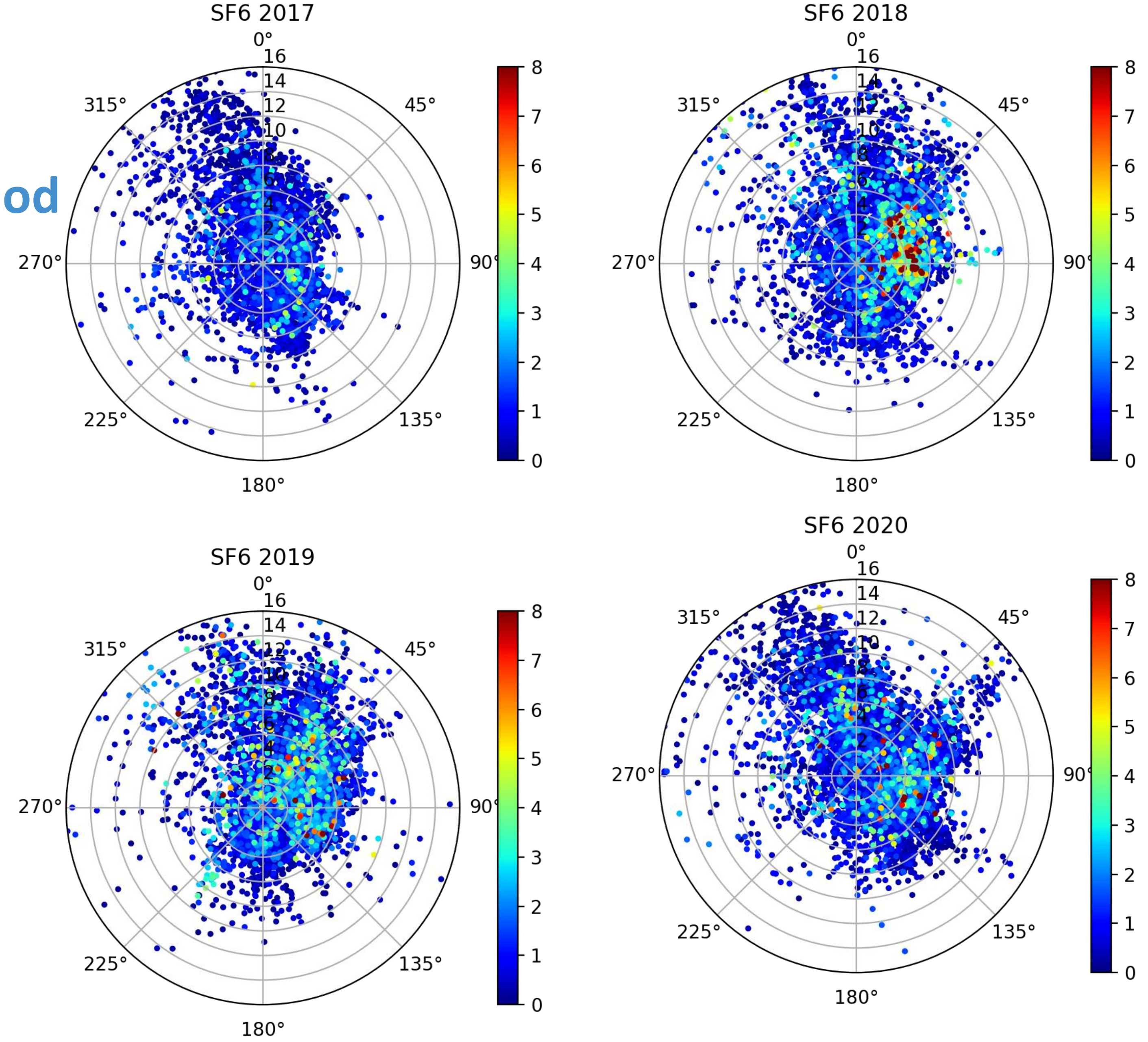
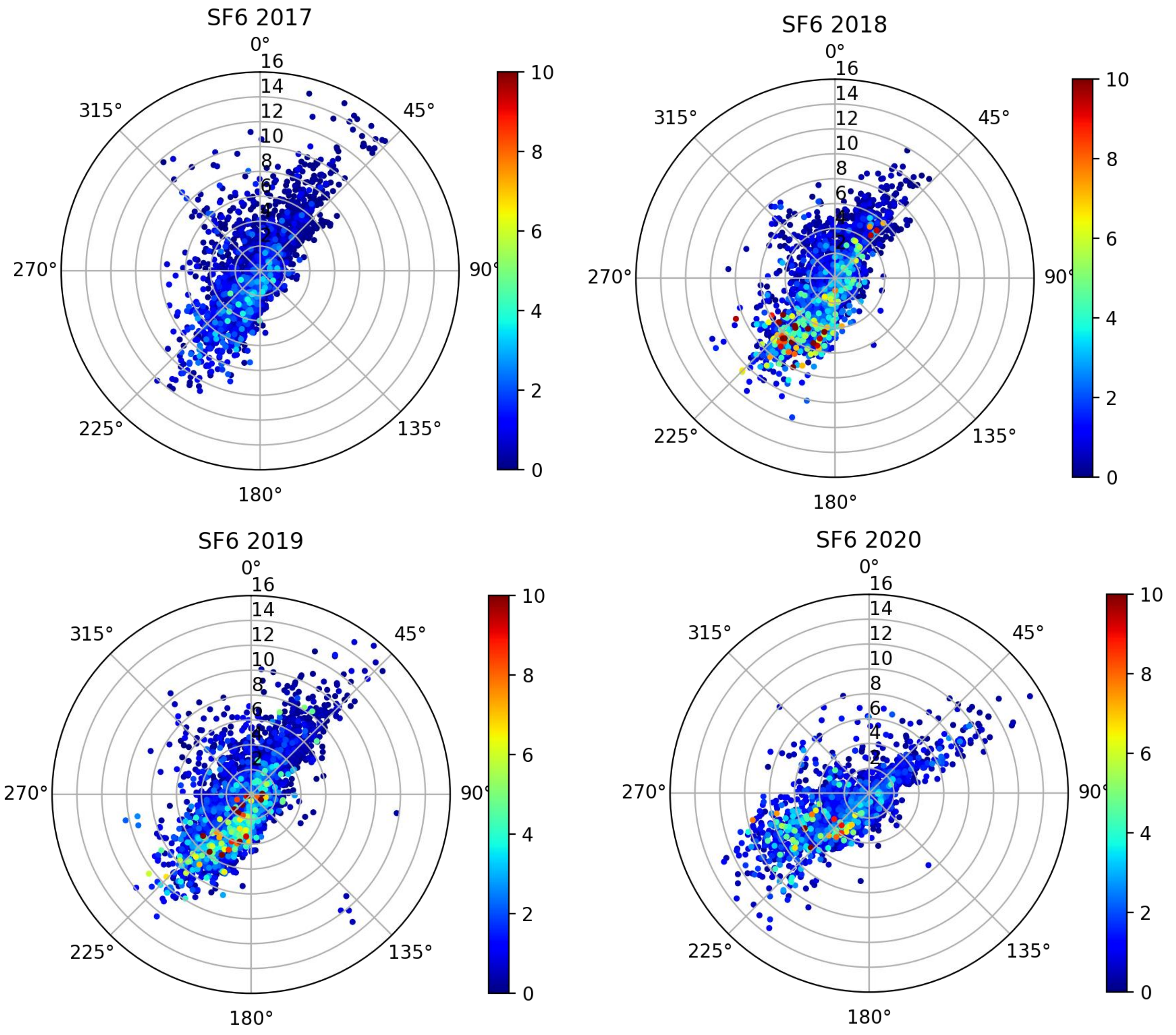


Results

(5) Enhancement change of SF_6 during COVID-19 lockdown period

- At ULD, high SF_6 occurred when winds mainly come from 0 to 90° with the speed < 5 m/s



Summary and discussion

- AMY, JGS and ULD produces atmospheric SF6 data of quite good quality as they are in accordance to trends of global monitoring stations.
- During 2017 – 2020 period, high SF_6 enhancement of AMY assumes to be influenced by local/regional source as well as long-range transport.
- Through the result from the identification potential emission sources, central part of Korea, China and Japan are assumed to be major SF6 emission sources.
- The data observed from 3 stations would be profitable to monitor the changes of SF_6 in and out of Korean peninsula, also in East Asia.
- Estimating sources and emissions by inversion modeling would be the next step.

감사합니다