Analysis of Arctic stratospheric minor gases by combined use of JEM/SMILES and ACE-FTS

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Outline and Summary

- JEM/SMILES observed atmospheric minor constituents including ClO [Sagawa et al., AMTD, 2013] and HOCl with high accuracy/precision in 2009/2010.
- Both of the single-shot data from SMILES and ACE-FTS have enough precision for scientific use; combined use of them enables a detailed analysis of Cl partitioning.
- Decrease of SMILES HNO_3 and HCl and increase of ClO under cold conditions suggest the existence of PSCs.
- Data with high ClO enhancement experienced below or around Tice.
- Single-shot measurements of HCl, $ClONO_2$, ClO, HOCl from SMILES and ACE-FTS show a detailed pattern of the time evolution of Cl partitioning.
- In Nov. and Mar., Cly_obs. and Cly_calc. correlated very well. In Jan., Cly_obs. was much lower than Cly_calc. inside the vortex, suggesting the existence of ClOClO.

JEM/SMILES and ACE-FTS

- **ISS/JEM/SMILES (Superconducting Submillimeter-Wave Limb-Emission Sounder)**

SMILES is the first sensor to use a superconductive low-noise receiver with a mechanical 4-K refrigerator in space. SMILES was developed by a joint project of JAXA and NICT to monitor global distributions of stratospheric/mesospheric trace gases.

Observation period: Oct. 12, 2009 - Apr. 21, 2010
Data version*: L2r v2.1.5 Latitudes*: north of 50ºN
Data used*: ClO, HOCl, HNO_3*, HCl*, and DMP data for EqL

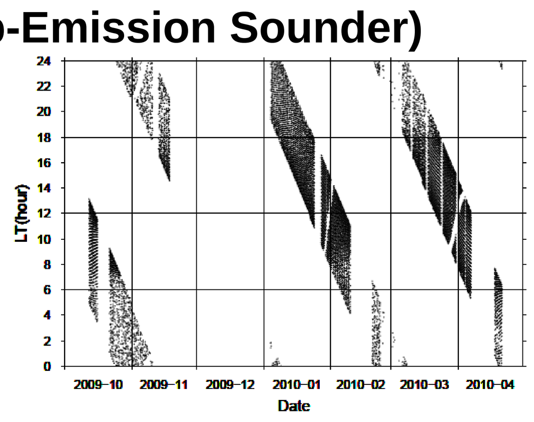


Fig. 1 Local time of SMILES Band C (ClO measurement) observation.

- **SCISAT-1/ACE-FTS (Atmospheric Chemistry Experiment-FTS)**

Launch: Aug. 13, 2003 [e.g., Bernath, 2006] Data version*: L2 v3.0
Latitudes*: north of 50ºN Data used*: HCl, $ClONO_2$, N_2O, and meteorological data

Analysis

SPIRAL

SPIRAL is a trajectory analysis tool which was developed in Nara Women's University in 2006 [Kawagishi, 2006]. It is based on e.g., EORC-TAM [Matsuzono et al., 1998] and flexibly designed to use various types of meteorological datasets such as ECMWF/ERA-40, NCEP, and MERRA. In this analysis, we use NCEP/NCAR Reanalysis 1 data.

We calculated 7-days backward trajectories at the SMILES observation points and the four surrounding points and the two upper/lower points of the each observation point both on 475 K and 525 K (seven points (x 2) in total for each SMILES measurement). If the distance between the trajectory of observation point and that of the other six points was larger than 600 km, we assumed the trajectories to be invalid.

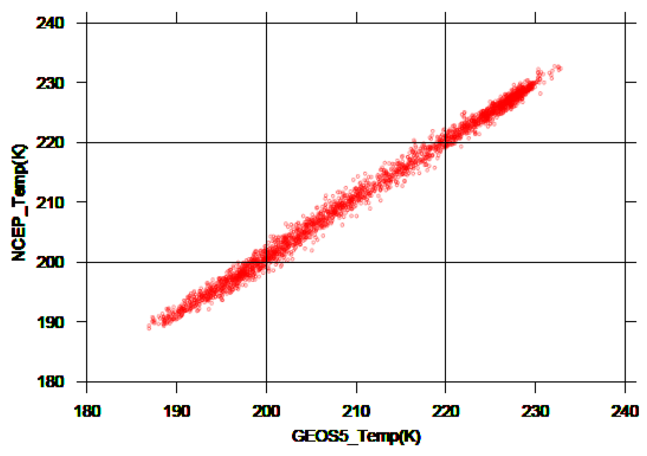


Fig. 2 Comparisons between NCEP T (SPIRAL) and GEOS-5 T (SMILES) at SMILES observation points in January 2010.

Coincidence criteria for SMILES and ACE-FTS

Distance:
Latitude: < 2º degree, Longitude: < 3º degree,
Altitude: < 1 km (*not interpolated to PT in the case of combined use of SMILES and ACE-FTS.)
Time: < 6 hour

Tice calculation

$$\mathrm{Tice} \approx \frac{1.814625\ln(\mathrm{pw}) + 6190.134}{29.120 - \ln(\mathrm{pw})}$$

T > 115 K, pw = partial pressure of atmospheric H_2O (Here, 5 ppmv fixed.) [Murphy and Koop, 2005]

Cly calculation

$$\mathrm{Total\_Cl} = \mathrm{Total\_Cl\_0}*(1-g*\mathrm{calc\_age\_of\_airmass}(N_2O));$$
$$\mathrm{Cly} = \mathrm{Total\_Cl}-(215.4721-1.7262*N_2O+0.03922*N_2O*N_2O)/1000$$

[Woodbridge et al., 1995]

SMILES: Time-Longitude

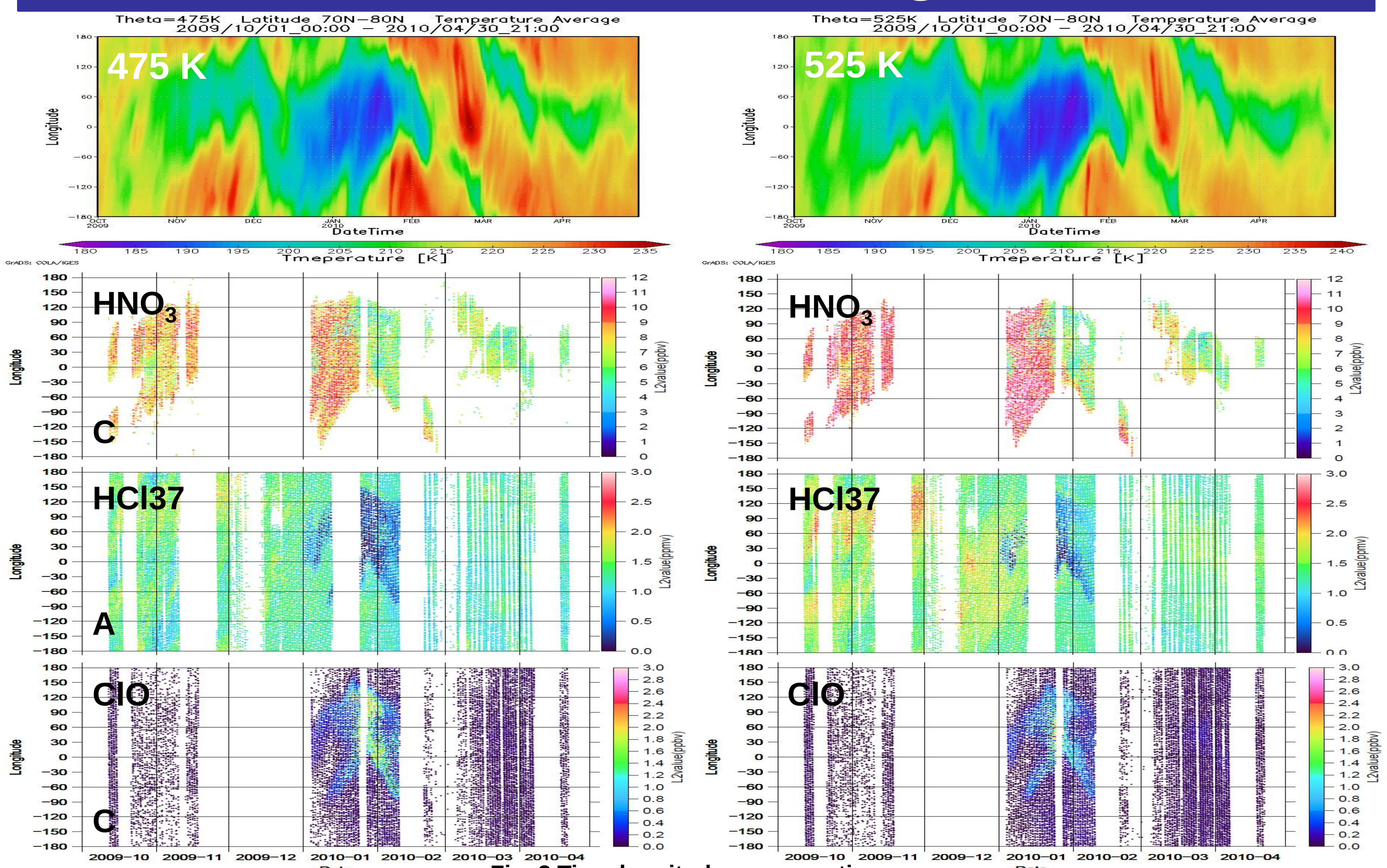


Fig. 3 Time-longitude cross sections.

SMILES: ClO enhancement

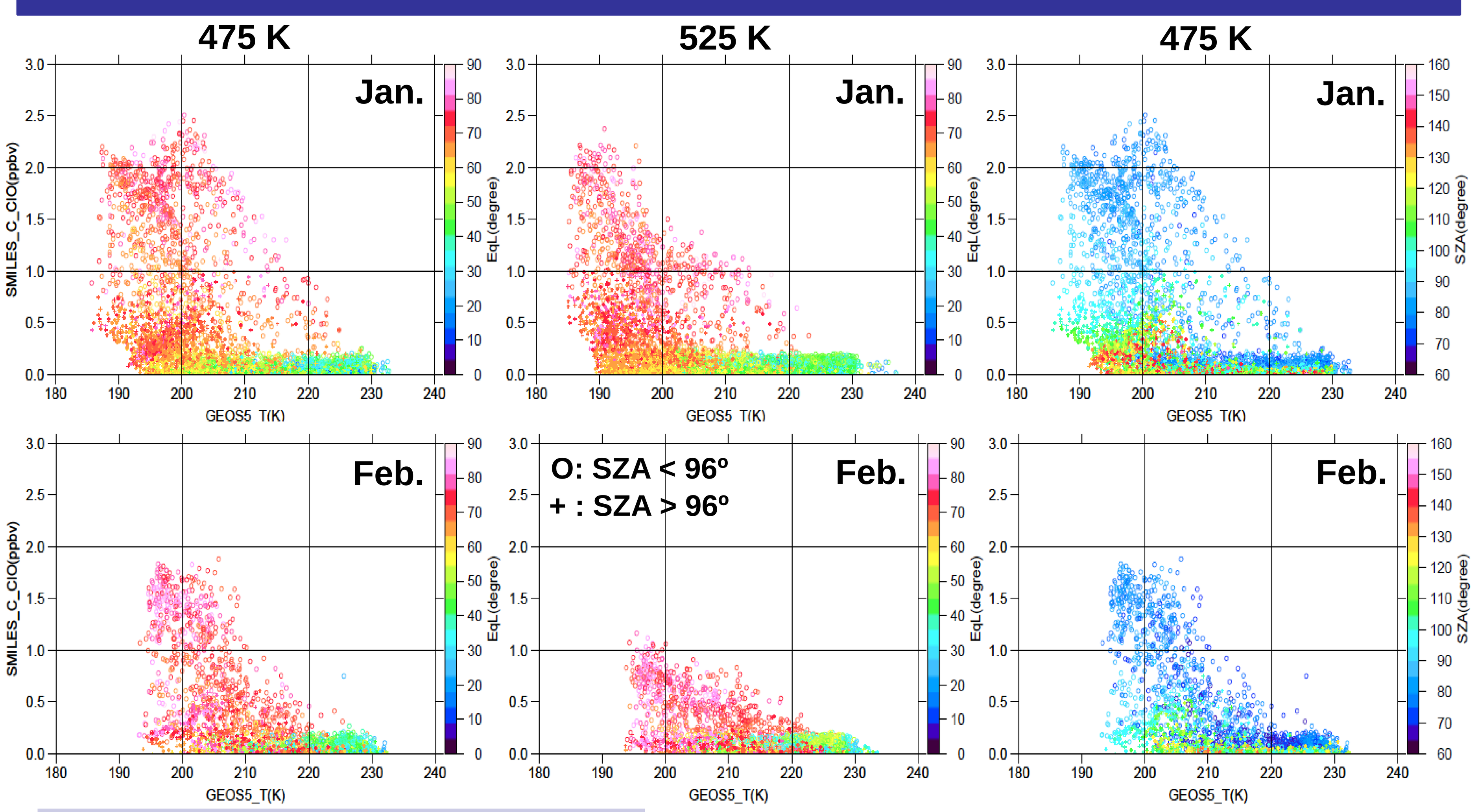


Fig. 4 Scatter plots between SMILES ClO and GEOS5 T.

Data in well-inside vortex show ClO enhancement under rather warmer conditions in January.

SMILES: T history of ClO-enhanced data

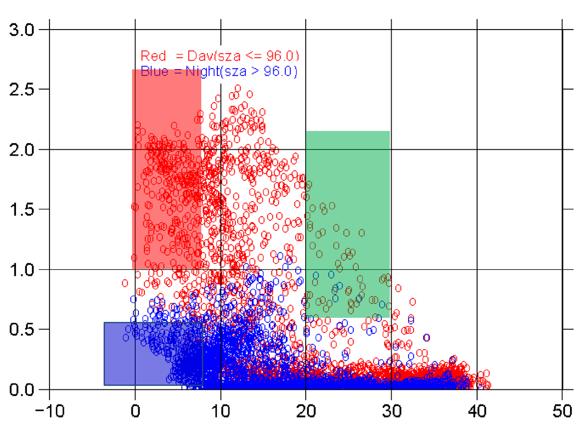


Fig. 5 Similar to Fig. 4, but showing three categories of ClO enhancement.

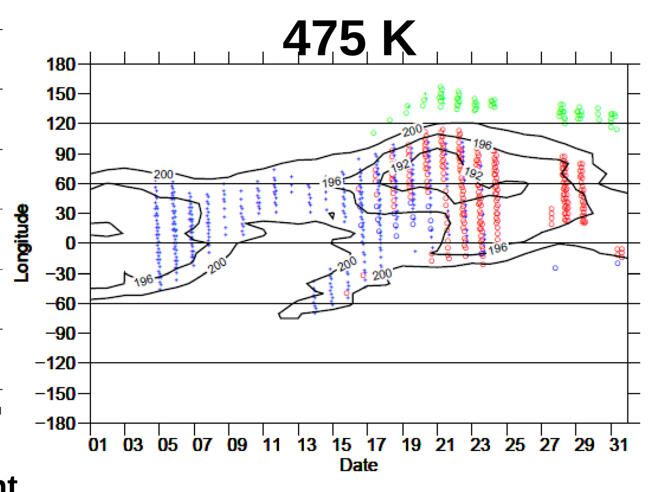


Fig. 6 Locations of the categorized data.

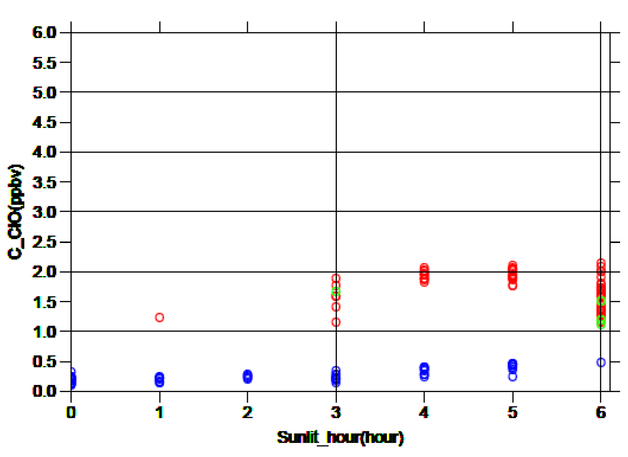


Fig. 7 Accumulated sunlit hours from observation points for the categorized data. Results of only 6 hours from the observation are shown.

red : 1ppbv < ClO, T-Tice < 8K
blue : ClO < 0.5ppbv, 8K < T-Tice
green : 0.5ppbv < ClO, 20K < T-Tice < 30K

Data with ClO enhancement experienced below or around Tice.

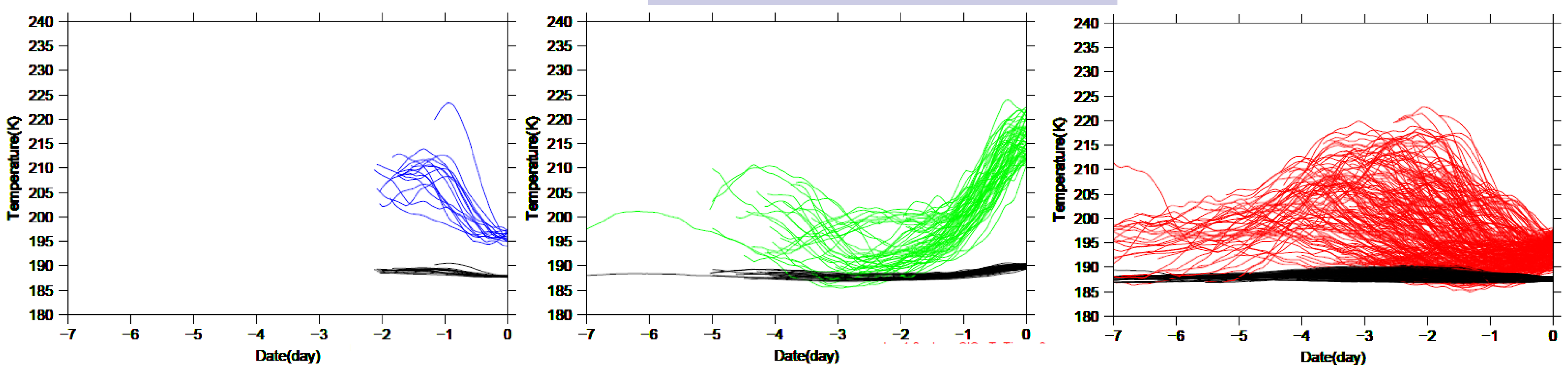
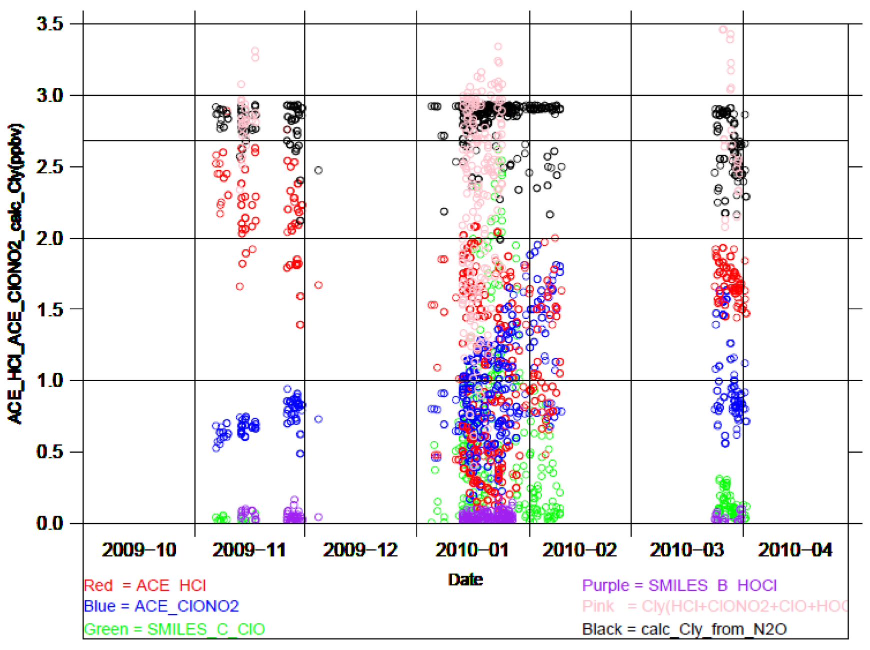


Fig. 8 7-days backward trajectories of the categorized data.

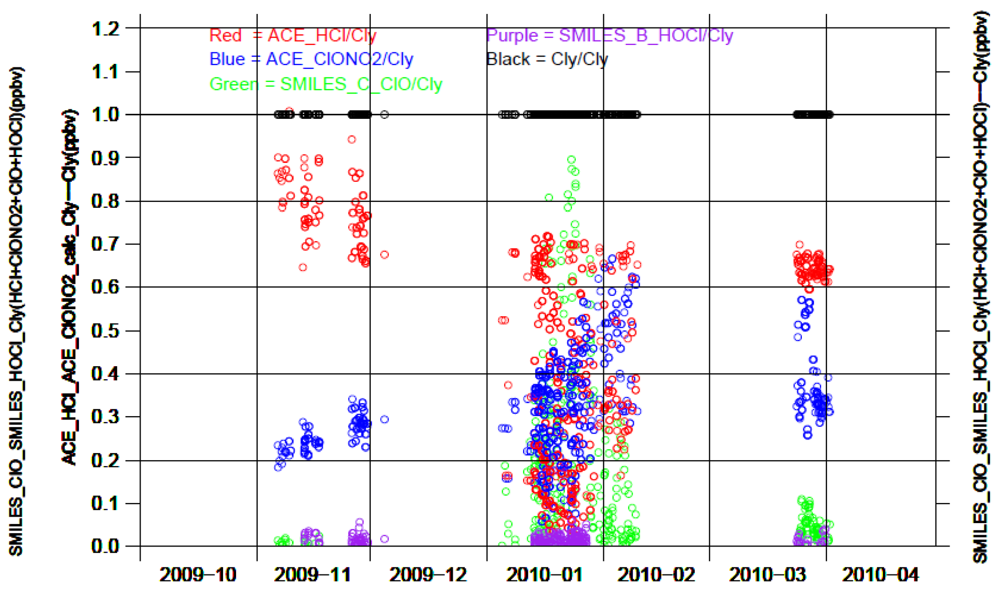
SMILES & ACE-FTS: Cl partitioning

20.5 km, only inside vortex (at ACE-FTS observations)



red : ACE-HCl
blue : ACE-$ClONO_2$
green : SMILES-ClO
purple : SMILES-HOCl
pink : Cly_obs.
black : Cly_calc.

Fig. 9 Time-series of Cl compounds (HCl, $ClONO_2$, ClO, HOCl) and Cly. Two types of Cly are shown: Cly_obs. is the sum of the above compounds and Cly_calc. is calculated on the basis of N_2O.

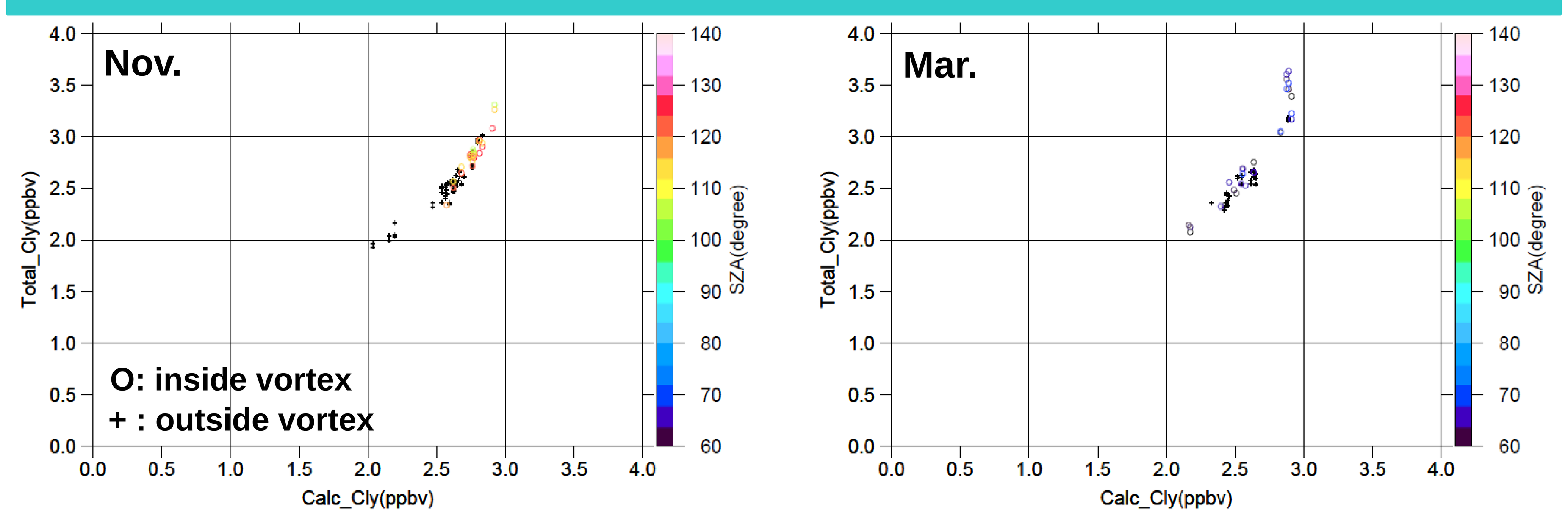


red : ACE-HCl
blue : ACE-$ClONO_2$
green : SMILES-ClO
purple : SMILES-HOCl
black : Cly_calc.

Fig. 10 Similar to Fig. 9, but representing the ratio between the each Cl compound and Cly_calc.

Each SMILES and ACE-FTS single-shot measurement enables to analyze Cl partitioning. $ClONO_2$ was higher in late winter and spring.

SMILES & ACE-FTS: Cly_obs. vs. Cly_calc.



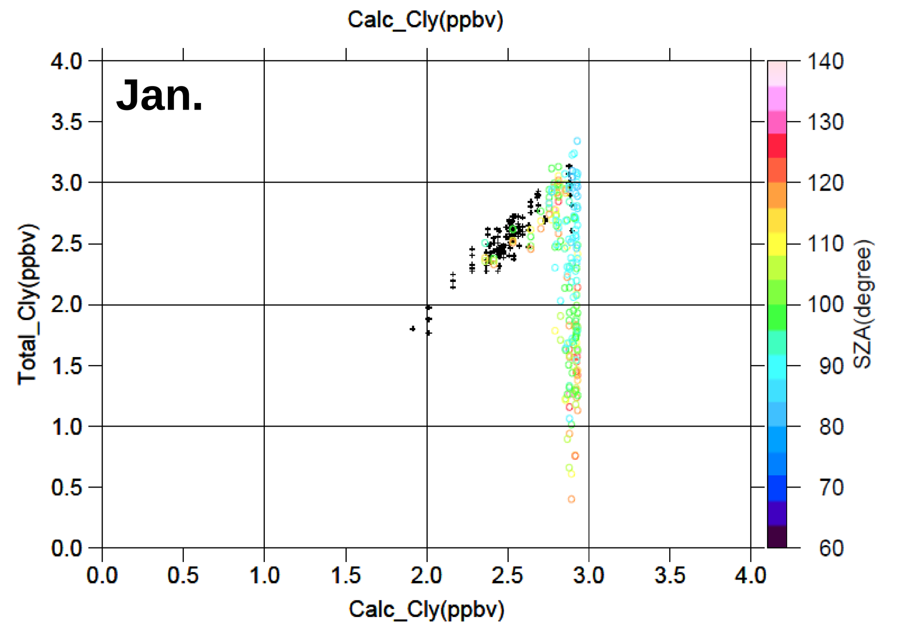


Fig. 11 Scatter plots between Cly_obs. and Cly_calc. both inside and outside vortices.

In Nov. and Mar., Cly_obs. and Cly_calc. correlated very well. In Jan., Cly_obs. was much lower than Cly_calc. inside the vortex, suggesting the existence of ClOClO.

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