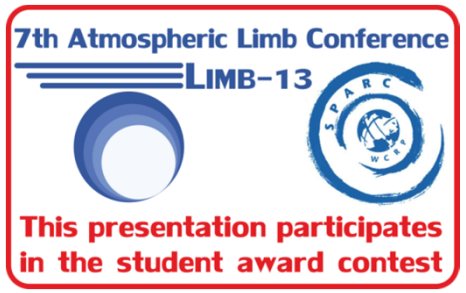


Strato-mesospheric HCl observed by Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES)

○Kengo Yokoyama[1] Hideo Sagawa[2]

Takeshi Manabe[1] Yasuko Kasai[2]

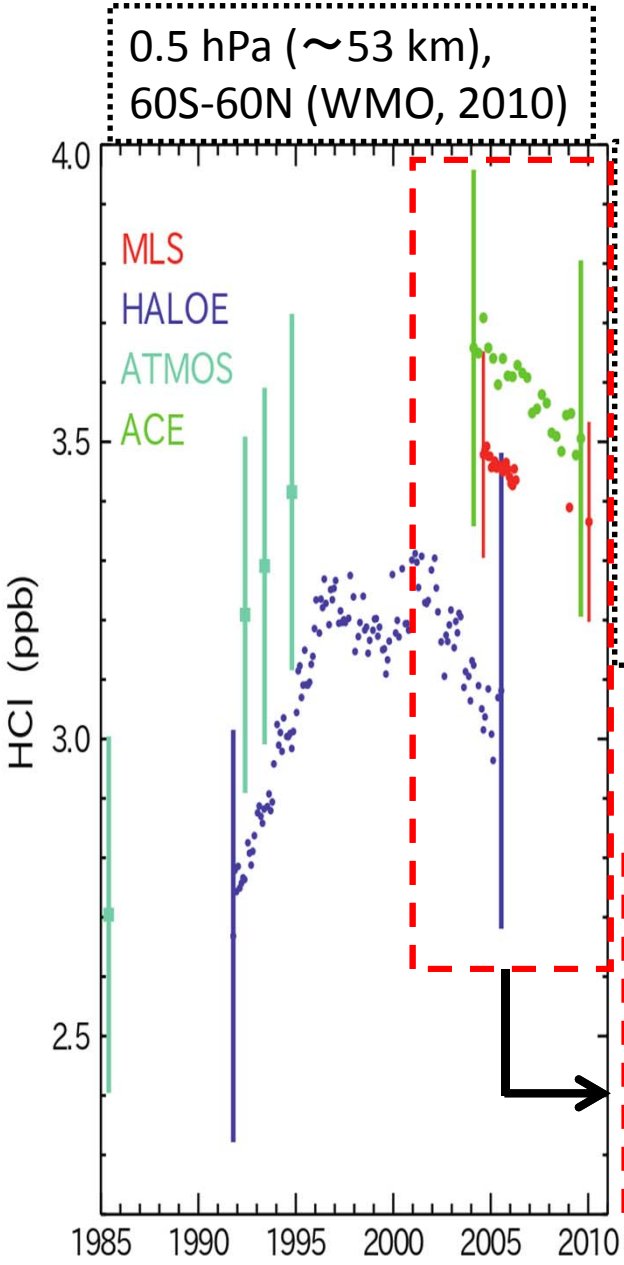
1.Osaka Prefecture University

(Department of Aerospace Engineering)

2. National Institute of Information and Communications Technology

Acknowledgement : Kaley Walker and Lucian Froidevaux

Background



Why HCl, stratosphere and mesosphere?

Almost all of CFCs have been converted to inorganic chlorine in the stratosphere and exist in the form of HCl (HCl/Cly～1.0, above 50 km).

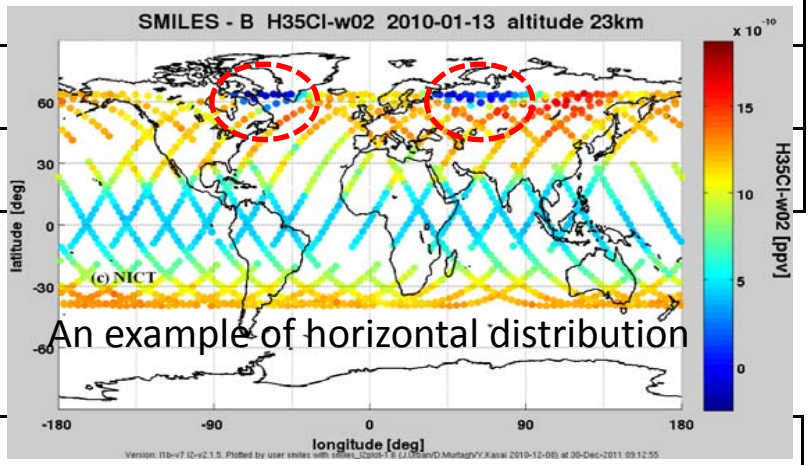
The observation of HCl enables us to estimate the total chlorine content of the atmosphere [Russell et al., 1996, Zander et al., 1996, WMO 2010] .

The decreasing trends of HCl has been observed since 2000. ACE-FTS HCl vmrs are around 5 % and 15 % larger than Aura/MLS and HALOE vmrs, repectively [Froidevaux et al., 2008; Mahiau et al., 2008].

SMILES NICT HCl data

SMILES specifications

Orbit	Inclination angle 51.6° /Non sun-synchronous orbit with an altitude of ~340 – 360 km
Scan altitude	Typically -20 km – 120 km (geometric altitude)
Latitude coverage	38° S – 65° N (nominal)
Frequency resolution	1.0 – 1.2 MHz
Number of samples	1630 scan/day



An example of horizontal distribution

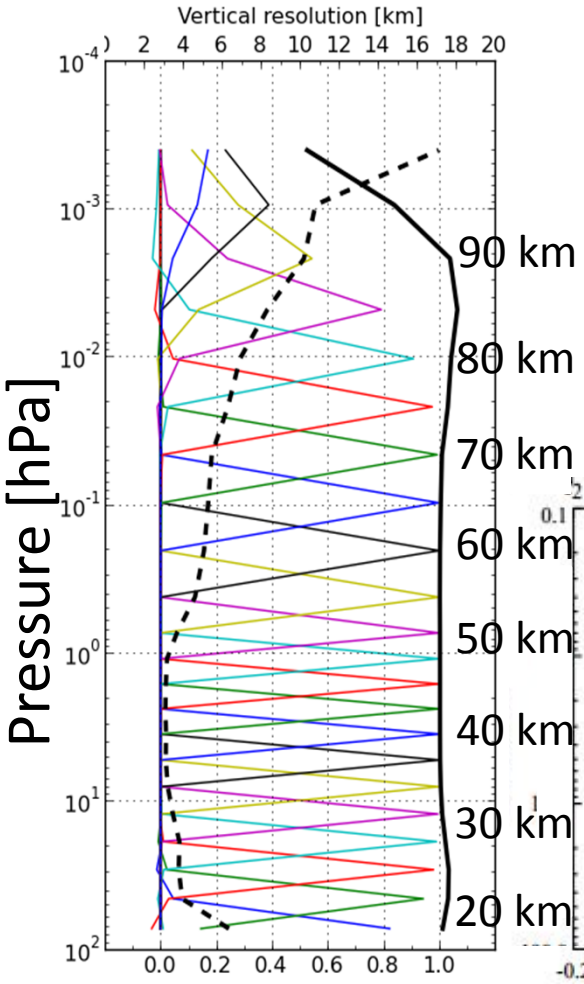
SMILES-NICT product

Version	Notes
2.9.1	・Improvement of the radiance calibration (use L1b 008) and tangent height information [Ochiai et al., 2012]. ・Improvement of the AOS[*1] response function [Mizobuchi et al. 2012].

*1: Acousto-optical spectrometer

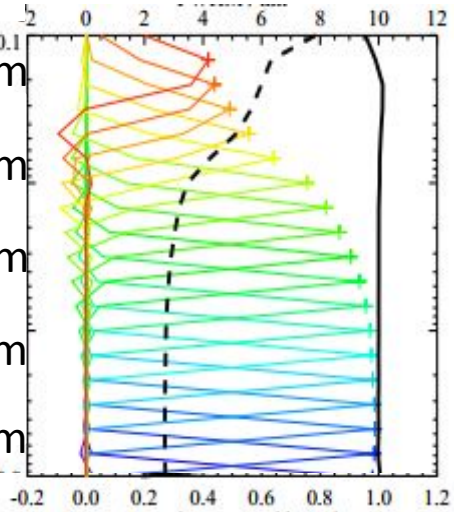
SMILES NICT HCl data

SMILES high-sensitivity



Averaging Kernels of SMILES

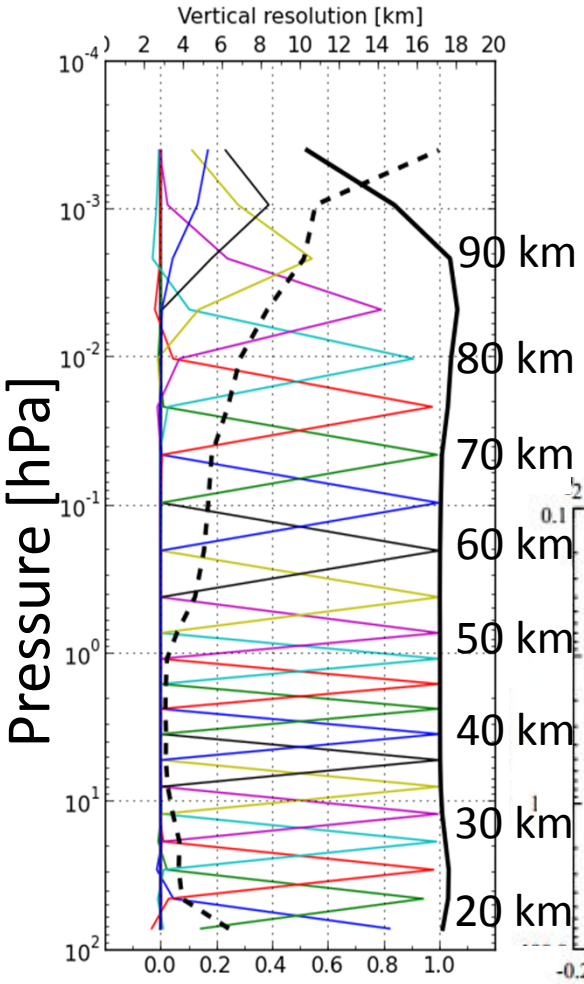
The averaging kernels of SMILES are sharp and the peak values stay at 1.0 (25 hPa - 0.08 hPa, 25 km - 70 km). Measurement error of SMILES is kept less than 2 % between 25 hPa and 0.08 hPa (25 km - 70 km).



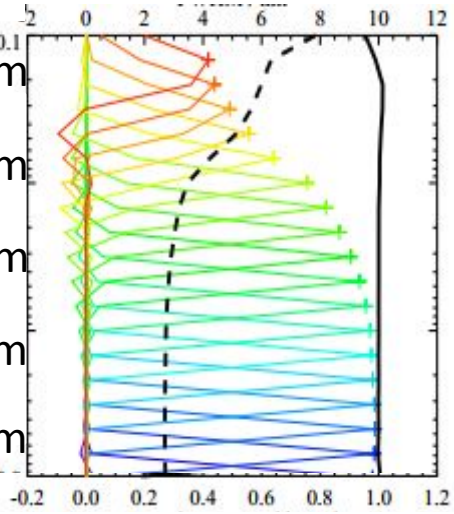
Averaging Kernels of Aura/MLS (Equator, Livesey et al., 2011)

SMILES NICT HCl data

SMILES high-sensitivity



Averaging Kernels of SMILES



Averaging Kernels of Aura/MLS (Equator, Livesey et al., 2011)

The averaging kernels of SMILES are sharp and the peak values stay at 1.0 (25 hPa - 0.08 hPa, 25 km - 70 km). Measurement error of SMILES is kept less than 2 % between 25 hPa and 0.08 hPa (25 km - 70 km).

In this research, we evaluate the accuracy of the SMILES-NICT HCl product through the comparison between SMILES-NICT and other satellite data.

Comparison between SMILES-NICT and SMILES-JAXA, Aura/MLS, ACE-FTS

■Coincidence criteria：

・longitude：±8 deg

・latitude　：±2 deg

・time　　：±5 hours

・closest pair on the same day

■40S-65N

■Aura/MLS(Band 13, v3.3) – SMILES

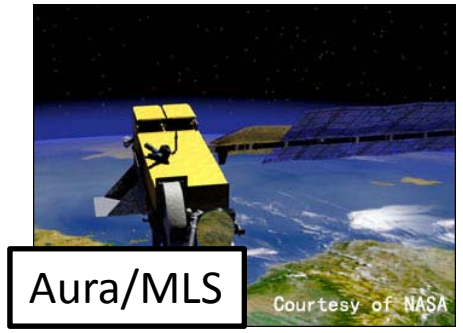
comparison period: 24 Jan., 2010 - 27 Jan., 2010

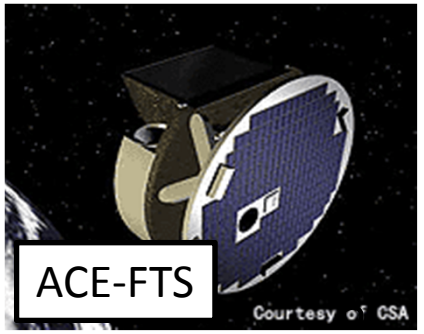
total coincidences: 2473 profiles

■ACE-FTS(v3.0) – SMILES

comparison period：Oct., 2009 – Apr., 2010

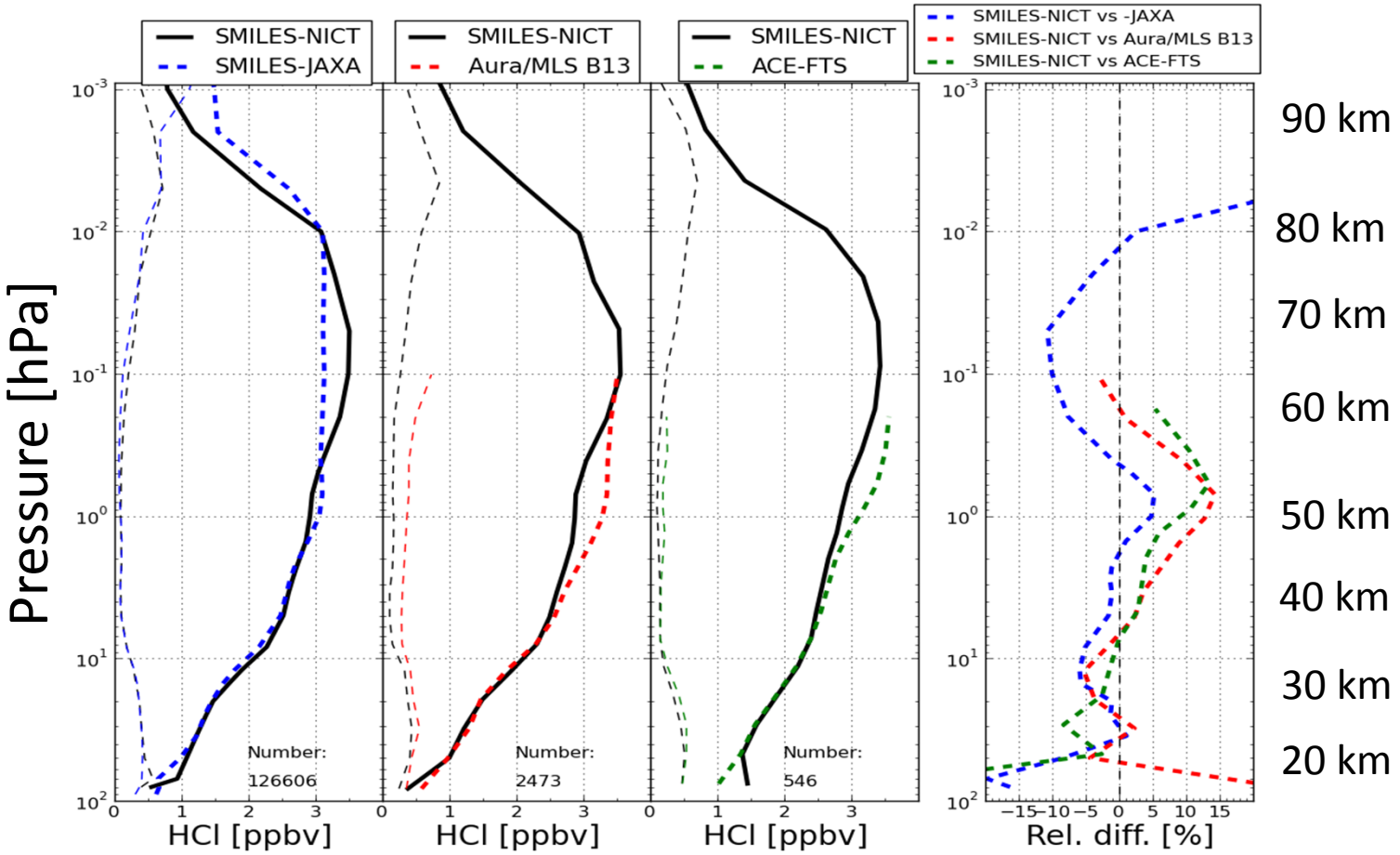
total coincidences: 546 profiles





Comparison between SMILES-NICT and SMILES-JAXA, Aura/MLS, ACE-FTS

Latitude:40S-65N,Period: Oct. 2009–Apr. 2010, SMILES BandB



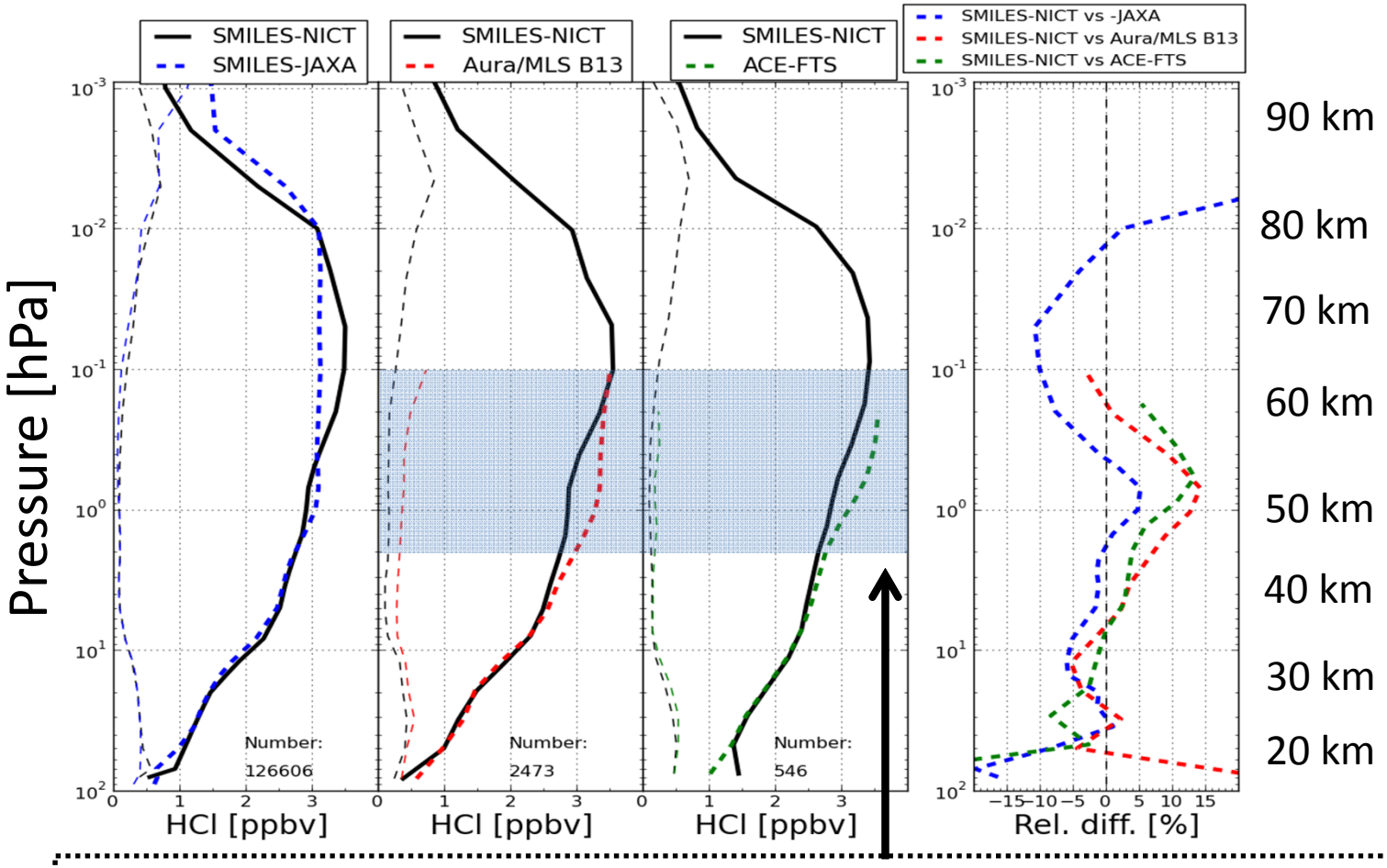
SMILES-JAXA version:
008-11-0502

Rel. Diff. = mean(($HCl_{com.ins.}$ - $HCl_{SMILES-NICT}$)/ $HCl_{SMILES-NICT}$)

※$HCl_{com.ins.}$: $HCl_{SMILES-JAXA}$ or $HCl_{Aura/MLS}$ or $HCl_{ACE-FTS}$

Comparison between SMILES-NICT and SMILES-JAXA, Aura/MLS, ACE-FTS

Latitude:40S-65N,Period: Oct. 2009–Apr. 2010, SMILES BandB



Pronounced discrepancies are found in the area between 2.0 hPa and 0.1 hPa (45 km – 65 km). We denote this area the “island” in this research.

Comparison between SMILES-NICT and SMILES-JAXA, Aura/MLS, ACE-FTS

Summary of differences	0.5 hPa(~53km) Abs. Diff. [ppbv] [*1]	0.1 hPa (~65km) Abs. Diff. [ppbv] [*1]
SMILES-JAXA	0.1	- 0.4
Aura/MLS	0.4	- 0.1
ACE-FTS	0.4	-

HCl is one of the indicators of the effect of the CFC releases. It is important to perform the accuracy assessment of SMILES-NICT product. We evaluate the effects of several parameters in the retrieval processing for the “island” discrepancies at 0.5 hPa.

*1 : Abs. Diff. = mean($HCl_{com.ins.} - HCl_{SMILES\text{-}NICT}$)

Rel. Diff. = mean(($HCl_{com.ins.} - HCl_{SMILES\text{-}NICT}$) / $HCl_{SMILES\text{-}NICT}$)

※$HCl_{com.ins.}$: $HCl_{SMILES\text{-}JAXA}$ or $HCl_{Aura/MLS}$ or $HCl_{ACE\text{-}FTS}$

Presumed parameters related to the SMILES HCl profile for the “island” discrepancies (2.0 – 0.1 hPa, 45 km – 65 km)

Parameters	**SMILES-NICT 2.9.1**	**Uncertainty / Alternative configuration**
Tangent height	Fix to the information based on the SMILES-Star tracker.	Retrieved from SMILES O_3 line [#1]
AOS response function	Triple Gaussian model [#2]	±2% uncertainty
Air pressure broadening coefficient (γ)	JPL Spectroscopic Catalogue [#3]	±4% uncertainty [#3]
Temperature	Retrieved from SMILES O_3 line	Fix to the a priori state from the GEOS-5 model
HCl apriori	Based on early-1990's climatology (1.73 ppbv at 0.5 hPa)	Aura/MLS HCl measurement (3.36 ppbv at 0.5 hPa)

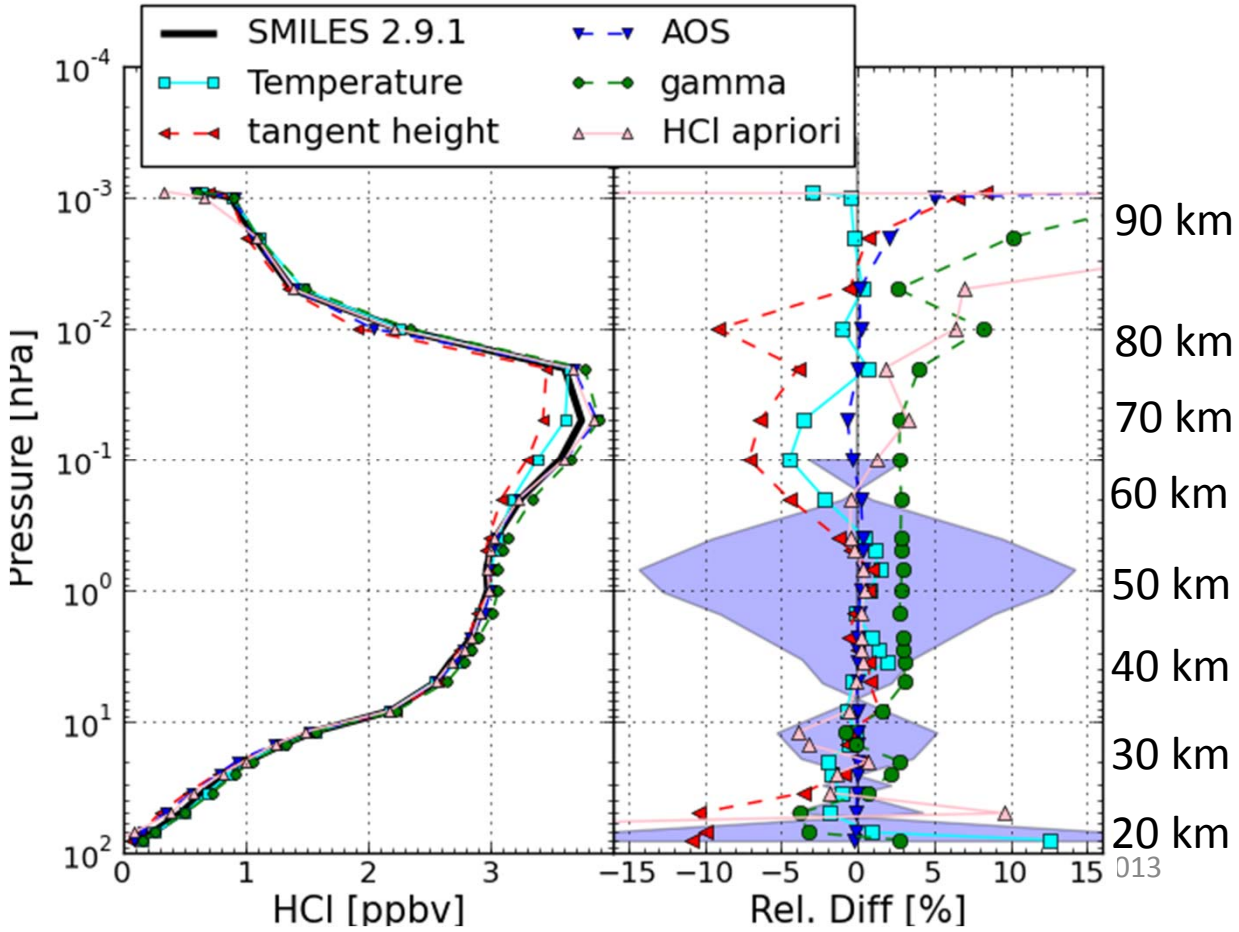
AOS: Acousto-optical spectrometer

#1: Baron et al., 2011・ #2: Mizobuchi et al., 2012・#3：Drouin et al., 2004

Effects of parameters for the SMILES HCl profile for the “island” discrepancies (2.0 - 0.1 hPa, 45 km – 65 km)

Summary of effects of parameters

Retrieval tests of 10 scans were performed with modifying parameters in the retrieval model.



Left: HCl profiles retrieved with modifying each parameter.

Right: Relative differences from the nominal 2.9.1 configuration.

- Rel. Diff. = mean((HCl_{test} – $HCl_{2.9.1}$)/ $HCl_{2.9.1}$)
- HCl_{test} : Retrieved with one of the alternative parameters

Effects of parameters for the SMILES HCl profile for the "island" discrepancies (2.0 - 0.1 hPa, 45 km – 65 km)

	0.5 hPa (~53km)		0.1 hPa (~65km)	
Summary	**Abs. Diff. [ppbv]**	**Rel. Diff. [%]**	**Abs. Diff. [ppbv]**	**Rel. Diff.[%]**
Observed differences	-	-	-	-
SMILES-JAXA	0.1 [*1]	3 [*1]	-0.4 [*1]	-10 [*1]
Aura/MLS	0.4 [*1]	10 [*1]	-0.1 [*1]	-3 [*1]
ACE-FTS	0.4 [*1]	12 [*1]	-	-
Considered Parameters	-	-	-	-
Tangent height	~ 0.0 [*2]	~ 0.0 [*2]	0.15 [*2]	4.5 [*2]
AOS response function	~ 0.0 [*2]	~ 0.0 [*2]	~ 0.0 [*2]	~ 0.0 [*2]
Air pressure broadening coefficient (γ)	0.1 [*2]	3 [*2]	0.1 [*2]	3 [*2]
Temperature	0.03 [*2]	1 [*2]	0.07 [*2]	2 [*2]
HCl apriori	~ 0.0 [*2]	~ 0.0 [*2]	~ 0.0 [*2]	~ 0.0 [*2]
Total	0.1 [*3]	3 [*3]	0.2 [*3]	5.5 [*3]

⇨ We found none of the considered model parameters can explain the "island" discrepancies.

*1 : Abs. Diff. = mean($HCl_{com.ins.}$ - $HCl_{SMILES\text{-}NICT}$)
Rel. Diff. = mean(($HCl_{com.ins.}$ - $HCl_{SMILES\text{-}NICT}$)/ $HCl_{SMILES\text{-}NICT}$)
※$HCl_{com.ins.}$: $HCl_{SMILES\text{-}JAXA}$ or $HCl_{Aura/MLS}$ or $HCl_{ACE\text{-}FTS}$

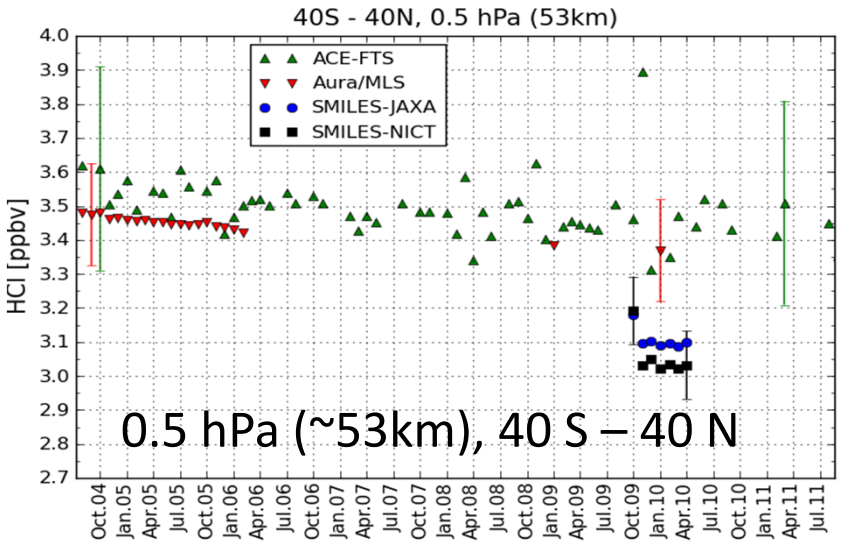
*2: Abs. Diff. = abs(mean(HCl_{test} – $HCl_{2.9.1}$))
Rel. Diff. = abs(mean((HCl_{test} – $HCl_{2.9.1}$)/ $HCl_{2.9.1}$))
HCl_{test} : Retrieved with one of the alternative parameters

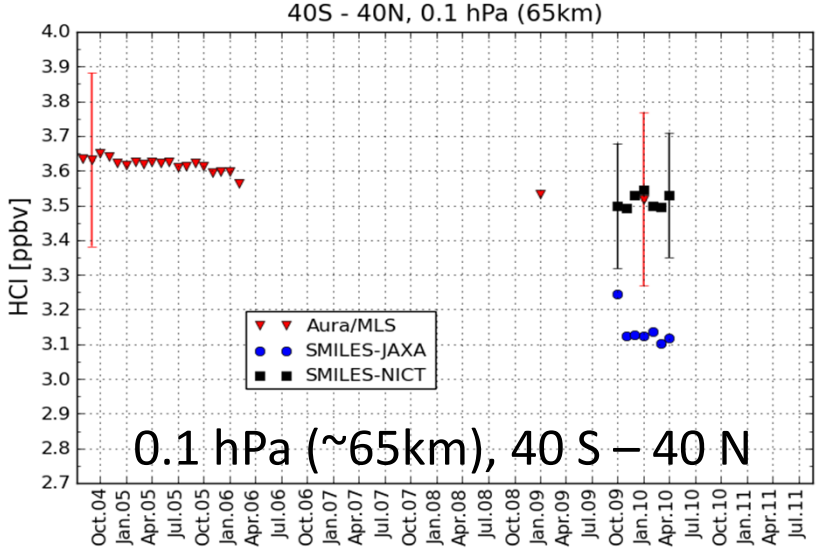
*3 : $\Delta HCl_{total\_abs.diff} = \sqrt{\Delta HCl^2_{\tan gentheight} + \Delta HCl^2_{AOS} + \Delta HCl^2_{\gamma} + \Delta HCl^2_{temperature} + \Delta HCl^2_{apriori}}$, (root sum square)

$\Delta HCl_{total\_rel.diff} = \Delta HCl_{total\_abs.diff} / HCl$

Time series of HCl at 0.5 hPa and 0.1 hPa (53 km and 65 km)

Aug 2004 – Aug 2011, Monthly averaged plot





SMILES-NICT HCl vmrs

Pressure [hPa]	HCl [ppbv]
0.5 hPa (~53 km)	3.04 ± 0.1
0.1 hPa (~65 km)	3.50 ± 0.2

Averaged data from Oct 2009 through Apr 2010

■At 0.5 hPa (53 km)

SMILES-NICT vmr on Oct 2009 is larger than that on other month.

■At 0.1 hPa (65 km)

SMILES-NICT agrees with Aura/MLS, but the deviation of monthly averaged plots of SMILES-NICT is a bit large. (We assume the effect of SSW for SMILES-NICT data.)

Summary

■25 hPa – 2 hPa (25 km - 45 km)

SMILES-NICT agrees within 5 % with Aura/MLS and ACE-FTS.

■2 hPa – 0.1 hPa (45 km - 65 km)

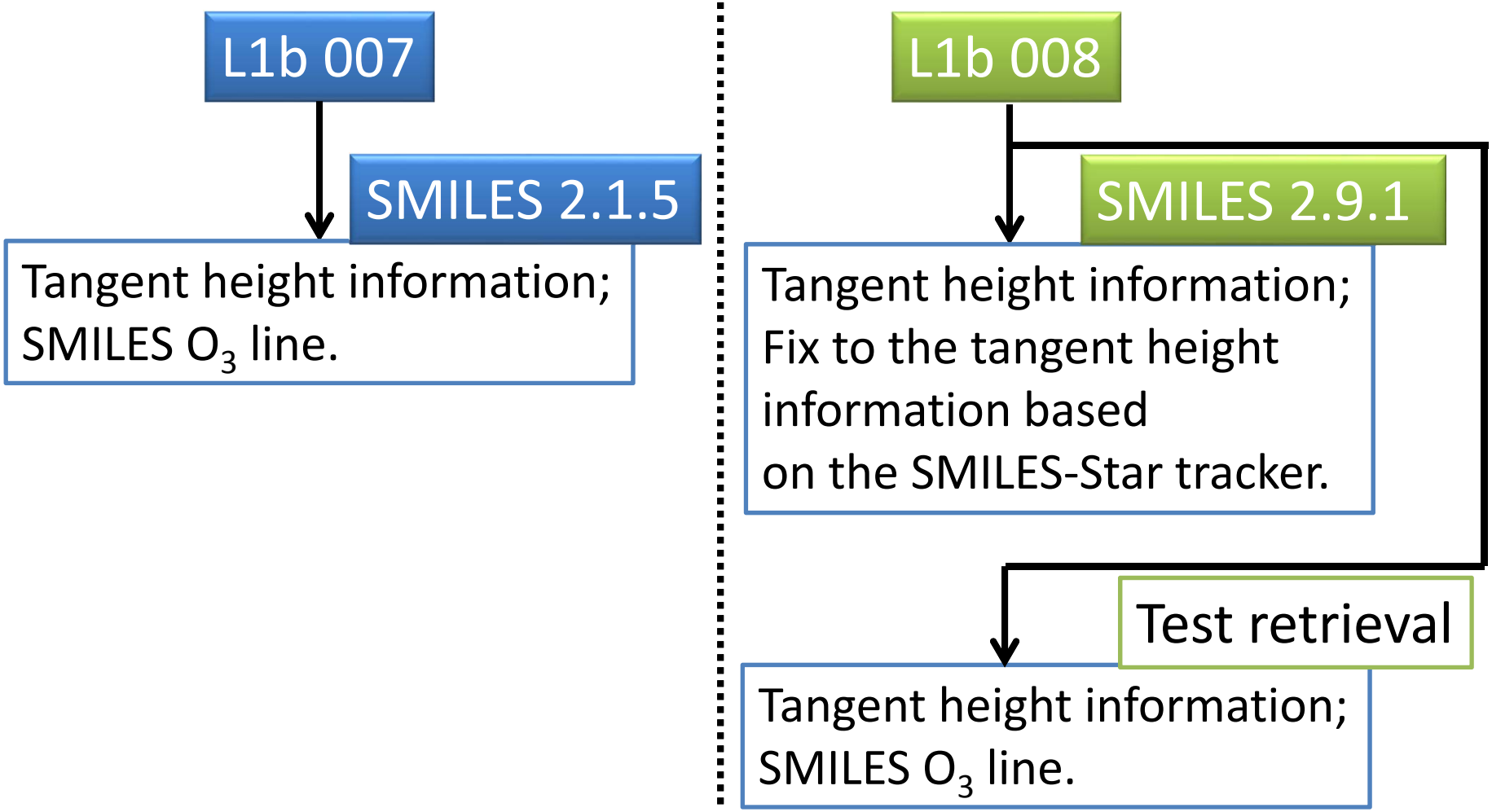
The SMILES-NICT HCl product is smaller than those of Aura/MLS and ACE-FTS by 0.4 and 0.4 ppbv at 0.5 hPa (~53km), respectively .
We found none of the considered parameters in the SMILES forward and inversion model can explain this discrepancy.

SMILES-NICT agrees with Aura/MLS at 0.1 hPa (~65 km). The deviation of monthly averaged plots of SMILES-NICT is a bit large.
(We assume the effect of SSW for SMILES-NICT data.)

Thank you for your attention

Supplement Slide

The tangent height information



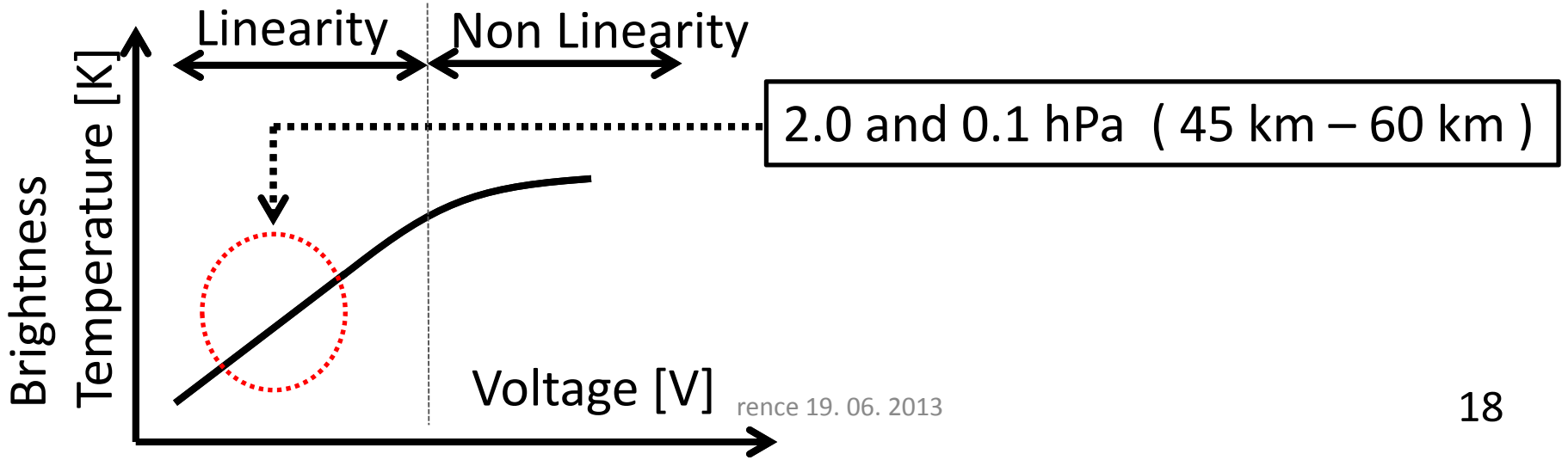
The effect of pressure shift

At 0.5 hPa, pressure shift is 0.05 MHz (= 50 kHz).
This value is smaller than the frequency resolution of SMILES (1.0 – 1.2 MHz). Then, we assume that we can ignore the effect of the pressure shift.

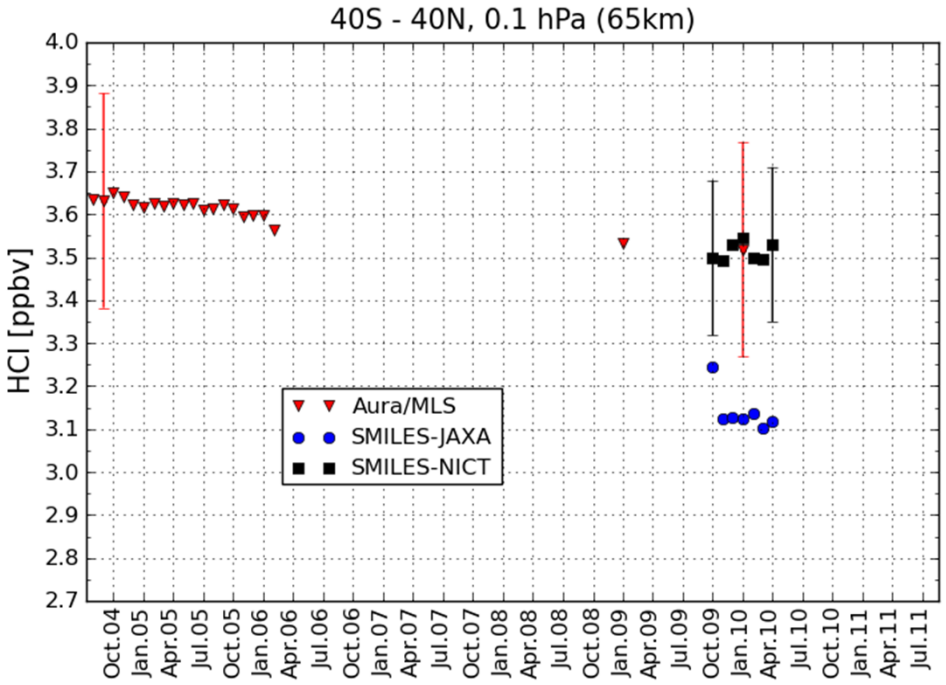
Error sources for the difference between SMILES and Aura/MLS, ACE-FTS

L1b non linearity

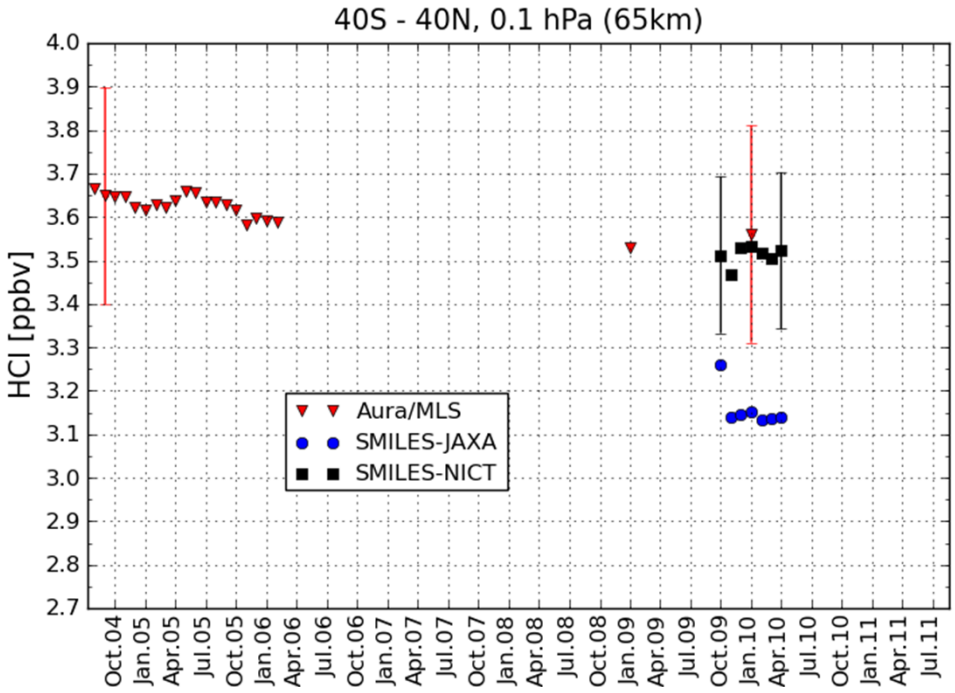
"L1b non linearity" causes a issue in converting from voltage data to brightness temperature data.



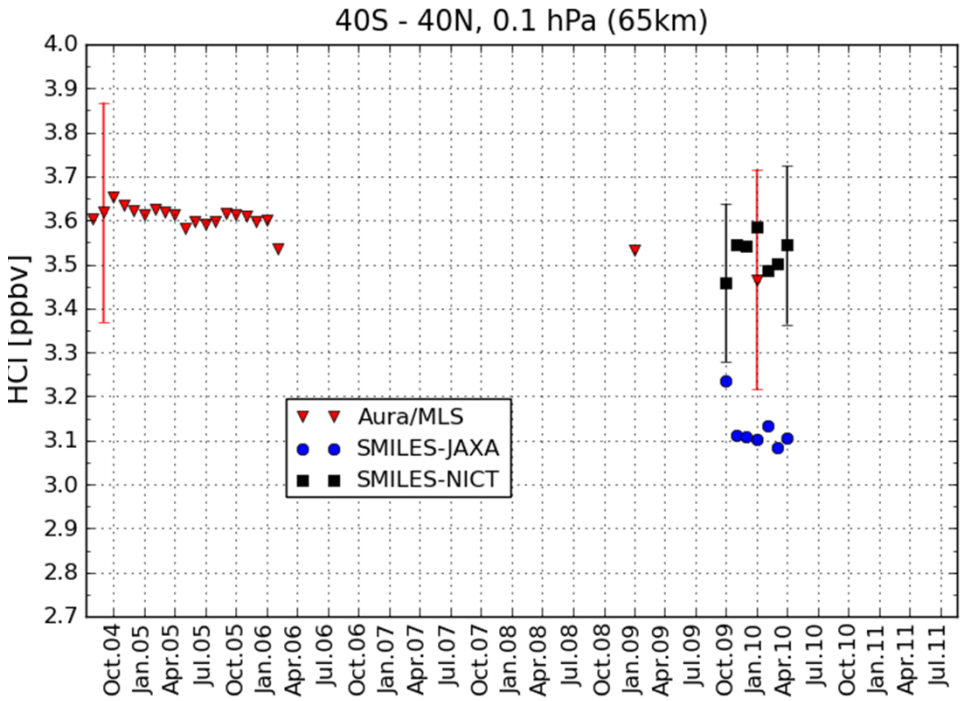
0.1 hPa (65 km) 40S -40 N daytime + night



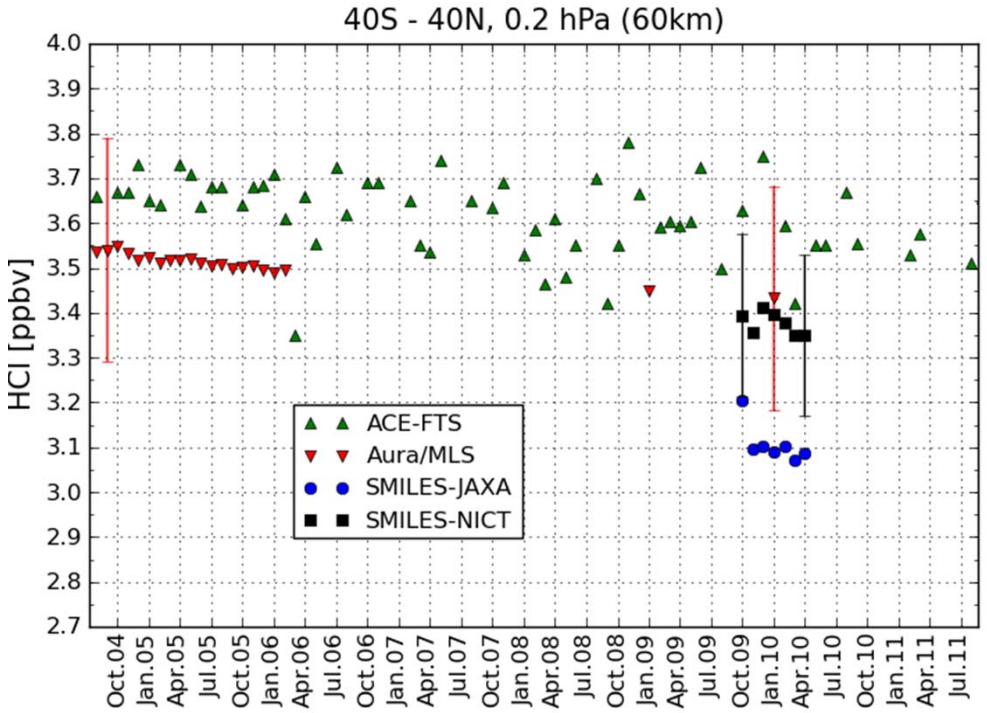
0.1 hPa (65 km) 40S -40 N daytime



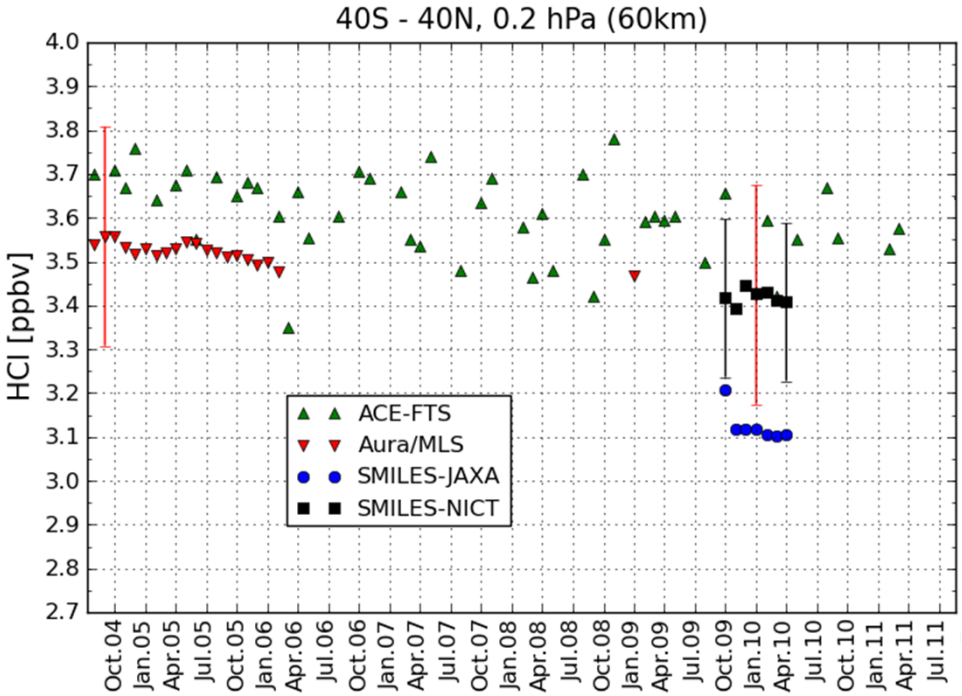
0.1 hPa (65 km) 40S -40 N night



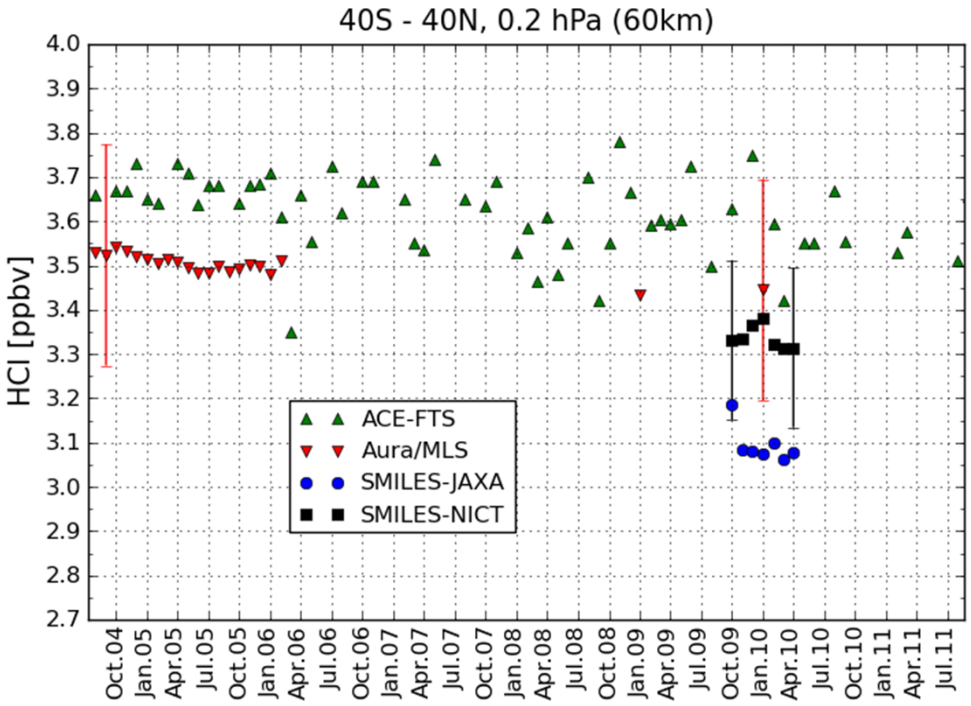
0.2 hPa (60 km) 40S -40 N daytime + night



0.2 hPa (60 km) 40S -40 N daytime



0.2 hPa (60 km) 40S -40 N night



Summary	0.5 hPa (~53km)		0.2 hPa (~60km)	
	Abs. Diff. [ppbv]	Rel. Diff.[%]	Abs. Diff. [ppbv]	Rel. Diff.[%]
Observed differences	-	-	-	-
SMILES-JAXA	0.1 [*1]	3 [*1]		
Aura/MLS	0.4 [*1]	10 [*1]		
ACE-FTS	0.4 [*1]	12 [*1]		
Considered Parameters	-	-	-	-
Tangent height	~ 0.0 [*2]	~ 0.0 [*2]	0.15	4.5
AOS response function	~ 0.0 [*2]	~ 0.0 [*2]	~ 0.0 [*2]	~ 0.0 [*2]
Air pressure broadening coefficient (γ)	0.1 [*2]	3 [*2]	0.1	3
Temperature	0.03 [*2]	1 [*2]	0.07	2
HCl apriori	~ 0.0 [*2]	~ 0.0 [*2]	~ 0.0 [*2]	~ 0.0 [*2]
Total	0.1 [*3]	3 [*3]	0.2	5.5

We found none of the considered model parameters can explain the "island" discrepancies.

*1 : Abs. Diff. = mean($HCl_{com.ins.} - HCl_{SMILES\text{-}NICT}$)
Rel. Diff. = mean(($HCl_{com.ins.} - HCl_{SMILES\text{-}NICT}$)/ $HCl_{SMILES\text{-}NICT}$)
※$HCl_{com.ins.}$: $HCl_{SMILES\text{-}JAXA}$ or $HCl_{Aura/MLS}$ or $HCl_{ACE\text{-}FTS}$

*2: Abs. Diff. = abs(mean($HCl_{test} - HCl_{2.9.1}$))
Rel. Diff. = abs(mean(($HCl_{test} - HCl_{2.9.1}$)/ $HCl_{2.9.1}$))
HCl_{test} : Retrieved with one of the alternative parameters

*3 : $\Delta HCl_{total\_abs.diff} = \sqrt{\Delta HCl^2_{\tan gentheight} + \Delta HCl^2_{AOS} + \Delta HCl^2_{\gamma} + \Delta HCl^2_{temperature} + \Delta HCl^2_{apriori}}$,

$\Delta HCl_{total\_rel.diff} = \Delta HCl_{total\_abs.diff} / HCl$

Comparison between SMILES-NICT and SMILES-JAXA, Aura/MLS, ACE-FTS

Summary of differences	0.5 hPa(~53km)		0.1 hPa (~65km)	
	Abs. Diff. [ppbv] [*1]	Rel. Diff. [%] [*1]	Abs. Diff. [ppbv] [*1]	Rel. Diff. [%] [*1]
SMILES-JAXA	0.1	3	- 0.4	-10
Aura/MLS	0.4	10	- 0.1	-3
ACE-FTS	0.4	12	-	-

HCl is one of the indicators of the effect of the CFC releases. It is important to perform the accuracy assessment of SMILES-NICT product. We evaluate the effects of several parameters in the retrieval processing for the “island” discrepancies at 0.5 hPa.

*1 : Abs. Diff. = mean($HCl_{com.ins.} - HCl_{SMILES\text{-}NICT}$)

Rel. Diff. = mean(($HCl_{com.ins.} - HCl_{SMILES\text{-}NICT}$) / $HCl_{SMILES\text{-}NICT}$)

※$HCl_{com.ins.}$: $HCl_{SMILES\text{-}JAXA}$ or $HCl_{Aura/MLS}$ or $HCl_{ACE\text{-}FTS}$

Contents

- Background
- SMILES NICT data
- Comparison between SMILES and other satellite instruments
- Effects of parameters for the SMILES HCl profile
- The time series of HCl at 53 km
- Summary

What is MAXI ?

SMILES HCl measurement

SMILES-NICT HCl product and SMILES-JAXA product

There are two kinds of SMILES HCl products. The main purpose developing level 2 products with two different algorithms retrieved from same L1b is to conduct researches on the SMILES measurements more accurately through comparing the two L2 processing.

Scientific consideration

The contribution of very short-lived (VSL) gases to stratospheric chlorine

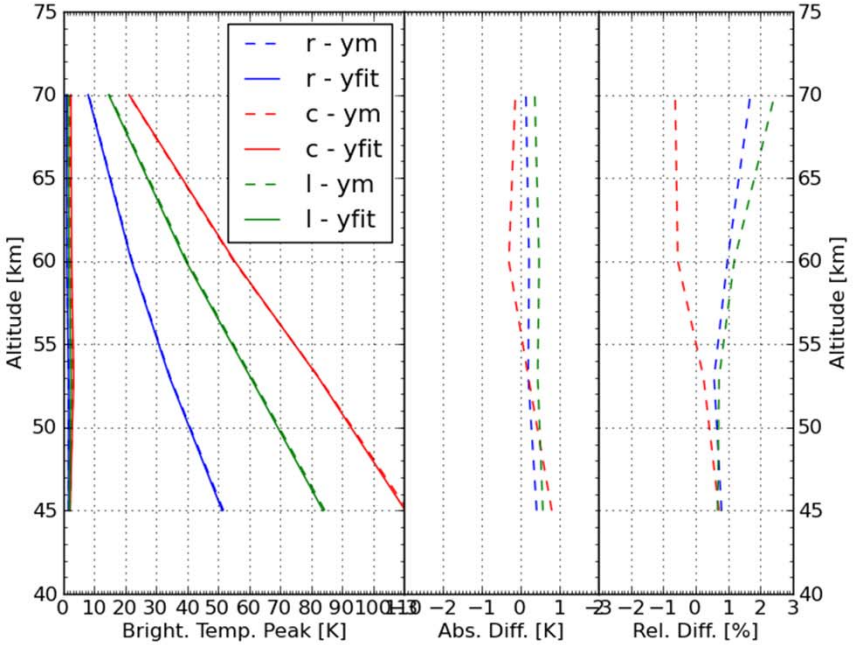
It is unclear how much VSL compounds contribute to stratospheric Cl_{TOT} [Kindler et al., 1995]. The uncertainty is from them is ~50 pptv. Satellite results do not make a judgment on possible chlorine contributions from VSL compounds, because of the absolute uncertainties in the measurements and differences between the datasets. While HALOE data are consistent with no chlorine contribution from VSL gases, the Aura/MLS, ACE-FTS, and ATMOS data suggest a significant contribution [Froidevaux et al., 2006].

→ The precision in the upper stratosphere of the SMILES-NICT HCl product for one scan is about 20 pptv. SMILES has potential to reveal the effect of VSL compounds in the stratosphere.

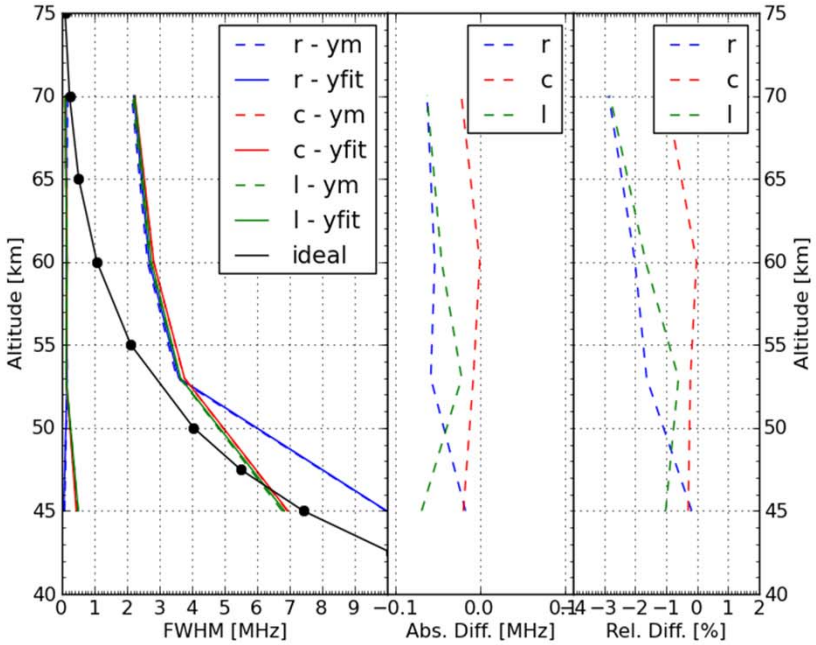
(「Cly ~ HCl じゃないかもしれない」という指摘は，VSLに起因するものかを笠井さんに確認)

The goodness of fitting

Brightness Temperature Peak



FWHM



Abs: mean(ym – yfit)
Rel: mean((ym – yfit) / yfit)