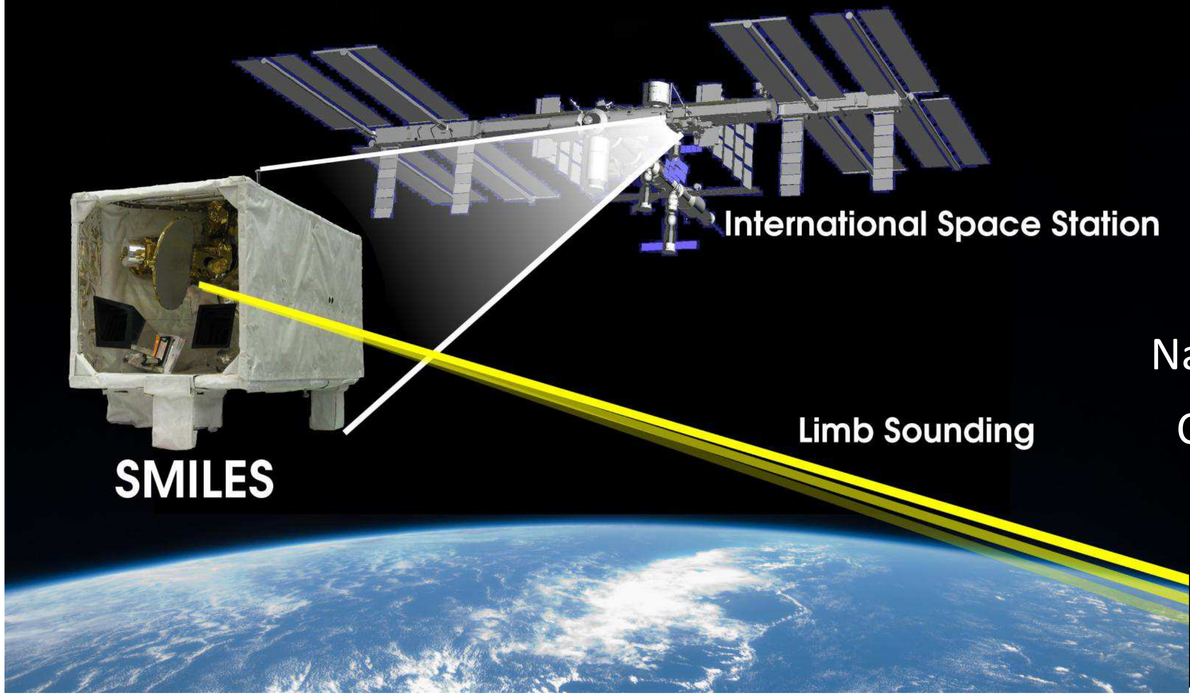
SMILES retrieval and spectroscopy



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Thanks to SMILES colleagues

NICT SMILES members

Leader: Yasko Kasai (NICT/ Tokyo Institute of Tech)
Instrument and L1b: Satoshi Ochiai, Ken Kikuchi, Toshiyuki Nishibori
L2 research: Hideo Sagawa, Tomohiro Sato, Jana Mendrok(Lulea U.), Joachim Urban, Joakim Muller, Donal Murtagh (Chalmers U.)
Validation and Science: Kengo Yokoyama, Kota Kuribayashi, Taka Yamada, Nawo Suzuki, Mona Mahani, Bengt Rydberg
Climatology: Daniel Kreyling
Modeling: Ralph Lehmann,

JAXA SMILES members

Leader: Masato Takayanagi, Masato Shiotani (Kyoto U.)
Instrument: Toshiyuki Nishibori,
L2: Takuki Sano, Makoto Suzuki,

Superconducting Sub**mi**llimeter-Wave **L**imb-**E**mission **S**ounder

What is SMILES?

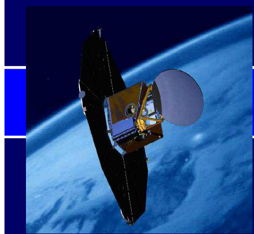
Collaboration project of NICT and JAXA

A instrument sub-mm (600GHz) spectroscopic limb observation from International space station with one order magnitude better sensitivity than past similar satellite measurements measurements station.

Table 1. SMILES instrumental specifications

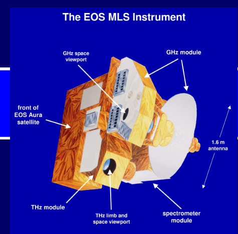
Parameters	Characteristics
Orbit	Inclination angle 51.6° Non sun-synchronous orbit
Scanning geometry	Limb scan
Scan altitude	−20–100 km
Latitude coverage	38° S–65° N (nominal)
Nominal data sampling	103 scans per orbit, 1630 scans per day
Frequency range	624.32 – 625.52 GHz (Band-A) 625.12 – 626.32 GHz (Band-B) 649.12 – 650.32 GHz (Band-C)
Antenna field-of-view	0.089° (HPBW)
Sampling interval	0.056°
Receiver system	SIS mixers and HEMT amplifiers
Spectrometers	Acousto Optical Spectrometers (AOS)
Frequency resolution	1.0–1.2 MHz
Channel separation	0.8 MHz
System noise temperature	315–350 K
Integration time for single spectrum	0.47 s

2001



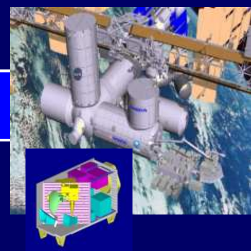
Odin/SMR
Tsys: 3000K
(SSB@500GHz)

2004

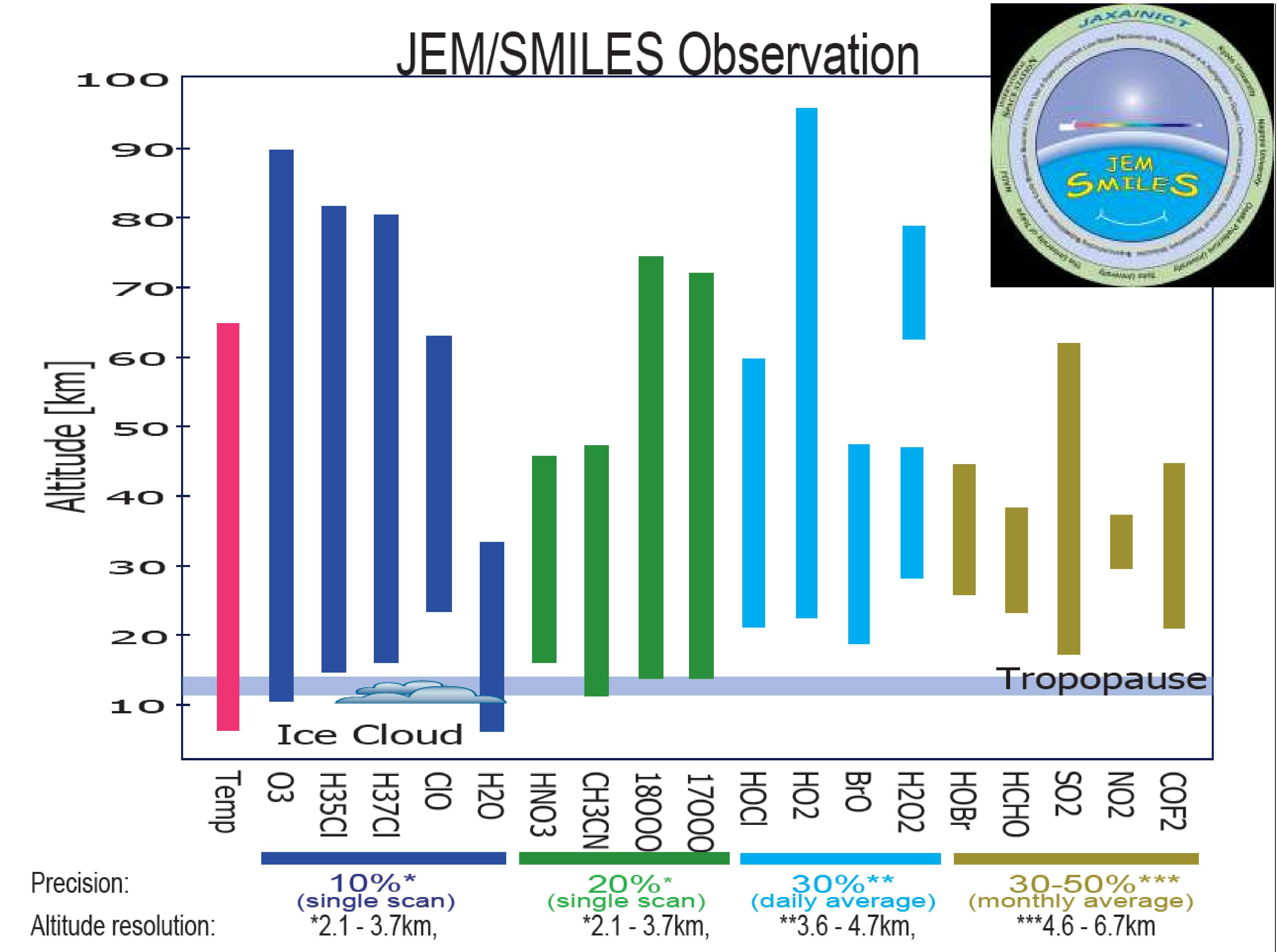


Aura/MLS
Tsys: 6000K
(DSB@650GHz)

2009

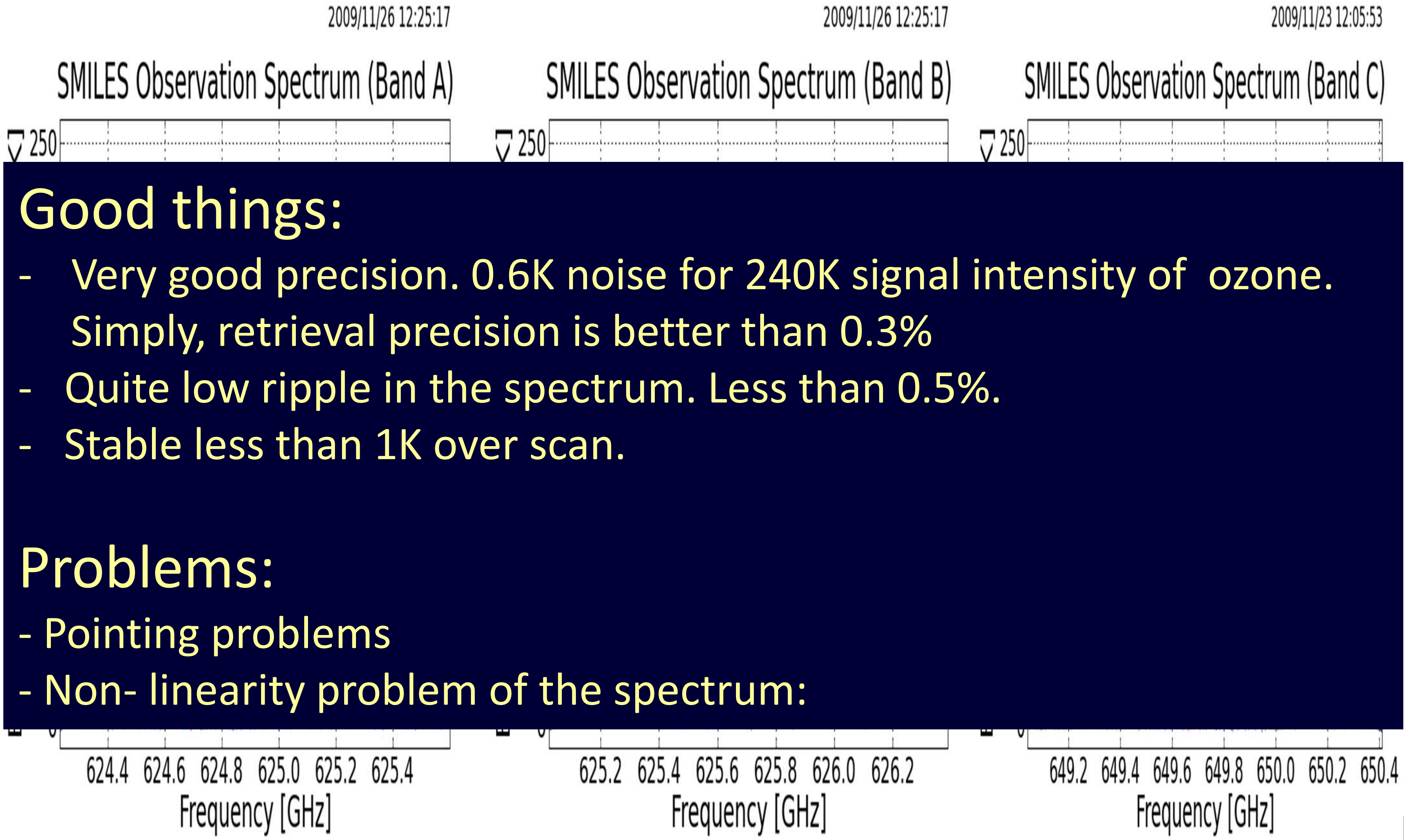


JEM/SMILES
Tsys: 350K
(SSB@650GHz)



JEM/SMILES Observation
JAXA/NICT
JEM SMILES
Altitude [km]
100
90
80
70
60
50
40
30
20
10
Tropopause
Ice Cloud
Temp
O3
H35Cl
H37Cl
ClO
H2O
HNO3
CH3CN
18OOO
17OOO
HOCl
HO2
BrO
H2O2
HOBr
HCHO
SO2
NO2
COF2
Precision:
Altitude resolution:
10%*
(single scan)
*2.1 - 3.7km,
20%*
(single scan)
*2.1 - 3.7km,
30%**
(daily average)
**3.6 - 4.7km,
30-50%***
(monthly average)
***4.6 - 6.7km

Observed Spectrum



Good things:

- Very good precision. 0.6K noise for 240K signal intensity of ozone. Simply, retrieval precision is better than 0.3%
- Quite low ripple in the spectrum. Less than 0.5%.
- Stable less than 1K over scan.

Problems:

- Pointing problems
- Non- linearity problem of the spectrum:

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Atmospheric Measurement Techniques Discussions
Open Access

Validation of stratospheric and mesospheric ozone observed by SMILES from International Space Station

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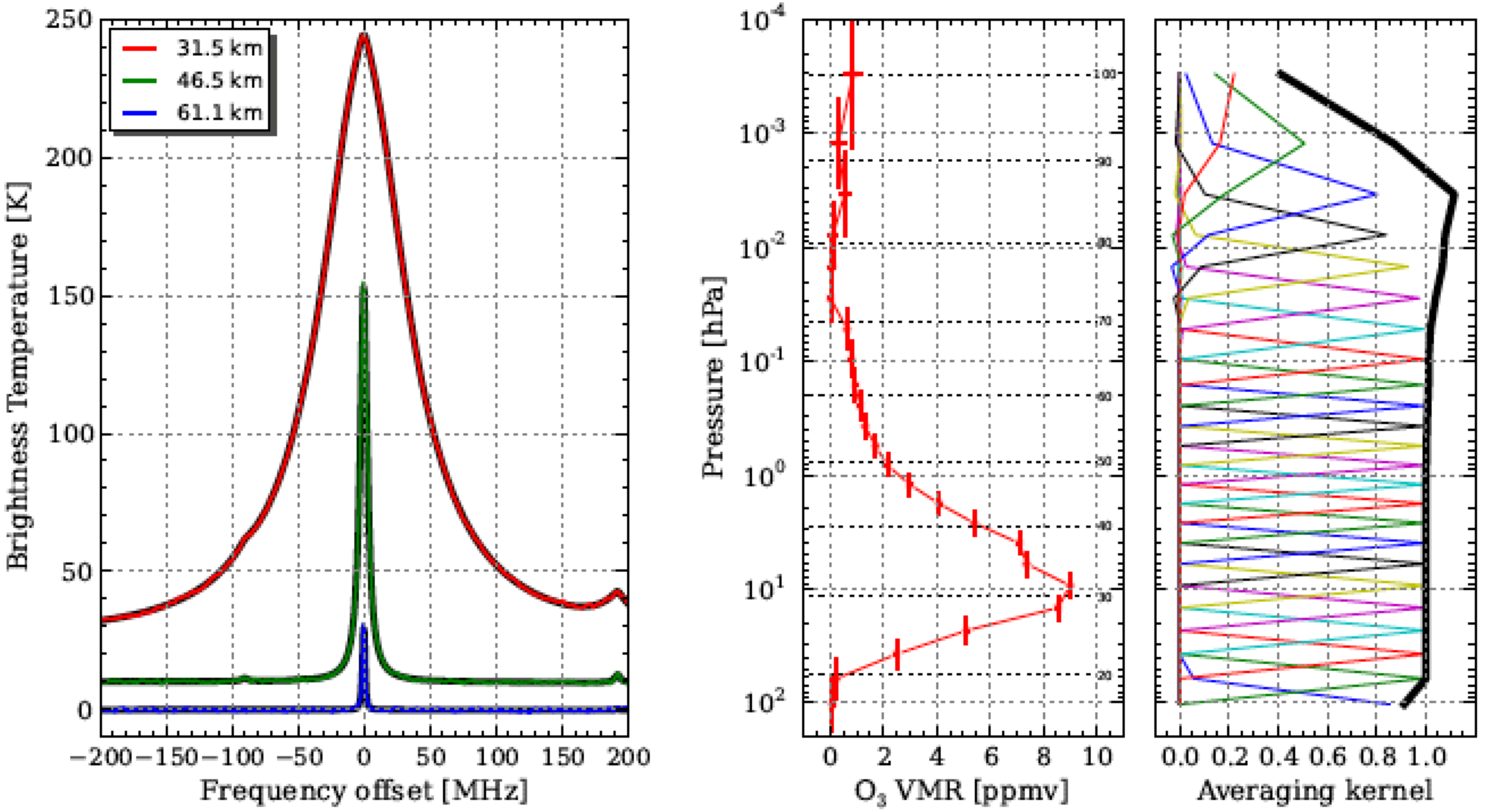
Ozone spectrum and its sensitivity



Retrieval precision is better than 0.3%

Error source of ozone is NOT coming from spectrum noise.

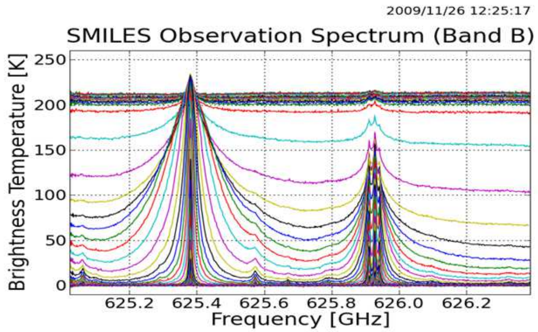
L2 analysis of SMILES Ozone spectrum

What we have to care for the SMILES retrieval

1. SMILES Characteristics: Ultra good signal to noise ratio

→ Required 'accurate' (about 0.3%)

- instrumental functions.
- radiative transfer calculation including spectroscopic parameters.



2. ISS problem: Large uncertainty of the tangent hei and SMILES has no O2 observation.

→ Required appropriate retrieval method.

3. Characteristics of Heterodyne passive sub-mm sensor

Not accurate calibration (compared solar occultation) and problems, such as non-linearity of the spectrum, are exist.

L1b spectrums: non-linearity + tangent height

version 007: Certain problems

version 008 : Less problem. Certain improvement.

Error source for SMILES ozone

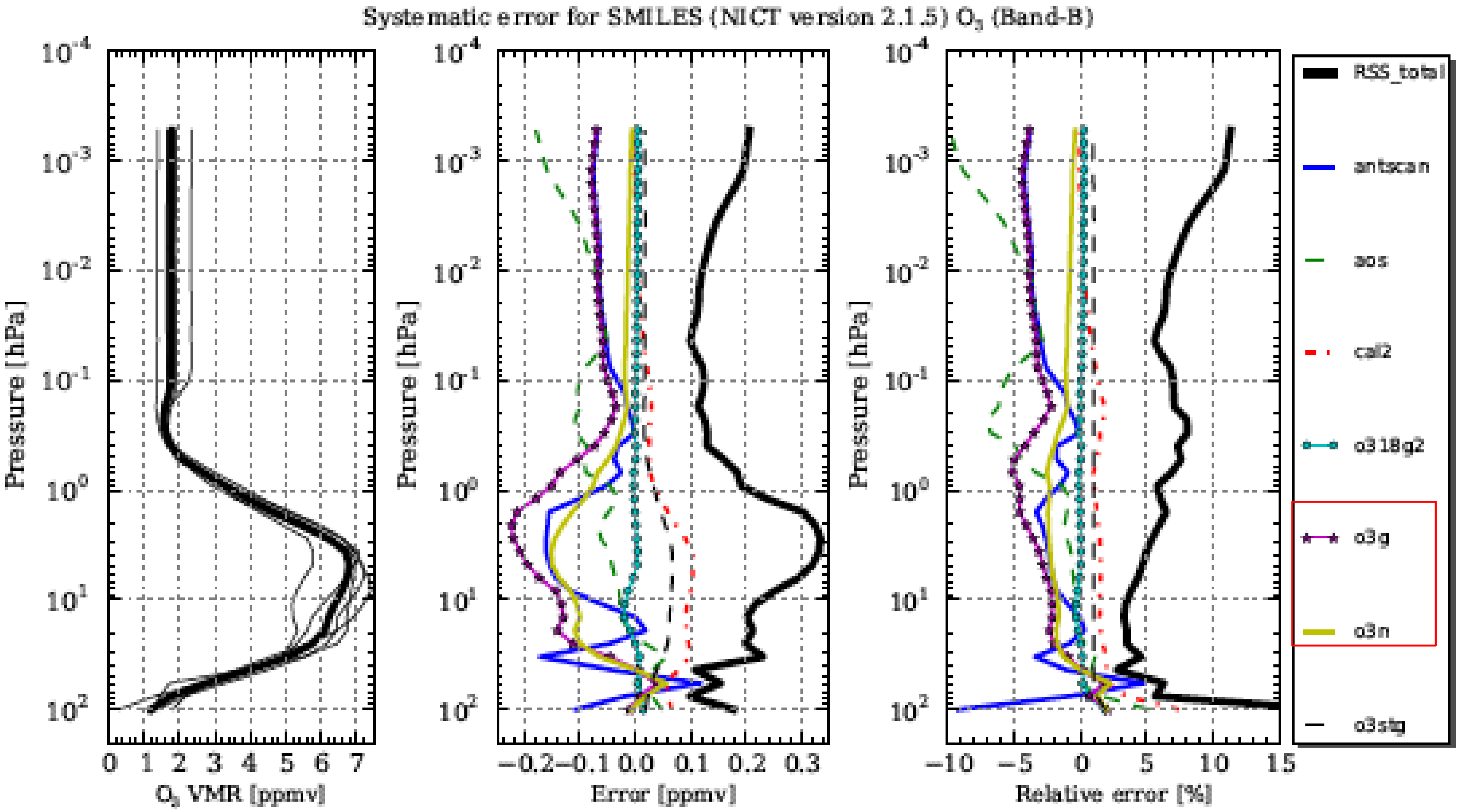
Table 3. Systematic errors and their perturbations considered in this study. For each error source, the corresponding label in Fig. 3 is indicated in the parentheses. The resulting error values at the O_3 peak level (8.3 hPa or 36 km) are given in the right column.

Error source	Perturbation	Error on O_3 at 8.3 hPa
Spectroscopic parameters of O_3 625.371 GHz		
Line intensity (O3stg)	1 %	1.0 %
Air pressure broadening, γ (O3g)	3 %	−2.2 %
Temperature dependence, n, of O3g (O3n)	10 %	−1.8 %
Impact from other species		
$H^{35}Cl$-625.901 GHz γ (HCl35g)	3 %	0.01 %
$H^{35}Cl$-625.901 GHz n (HCl35n)	10 %	0.01 %
$H^{37}Cl$-624.964 GHz γ (HCl37g)	3 %	0.02 %
$H^{37}Cl$-624.964 GHz n (HCl37n)	10 %	0.01 %
$O_3v_{1,3}$-625.051 GHz γ (O3v13g)	3 %	0.01 %
$OO^{18}O$-625.091 GHz γ (O318g)	3 %	0.01 %
$OO^{18}O$-625.563 GHz γ (O318g2)	3 %	−0.2 %
Dry air continuum (DRY)	20 %	−0.05 %
Instrumental functions		
Image side-band (SSB)	see below[1]	−0.08 %
AOS response function width (AOS)	10 %[2]	−0.4 %
Antenna FOV drift (ANTSCAN)	see below[3]	−1.8 %
Calibration		
Non-linearity gain correction (CAL2)	20 %[4]	1.5 %
Total (RSS_total)		3.8 %

[1] Difference between the cases considering the realistic rejection rate for the image side-band signal and an ideal one.
[2] Perturbation added on the FWHM of the response function.
[3] Difference between the cases with and without considering the drift of the antenna FOV during 0.47 s.
[4] Perturbation added on the gain compression factor.

Improvement from spectrum L1b v007 -> 008

Ozone spectrum and its sensitivity



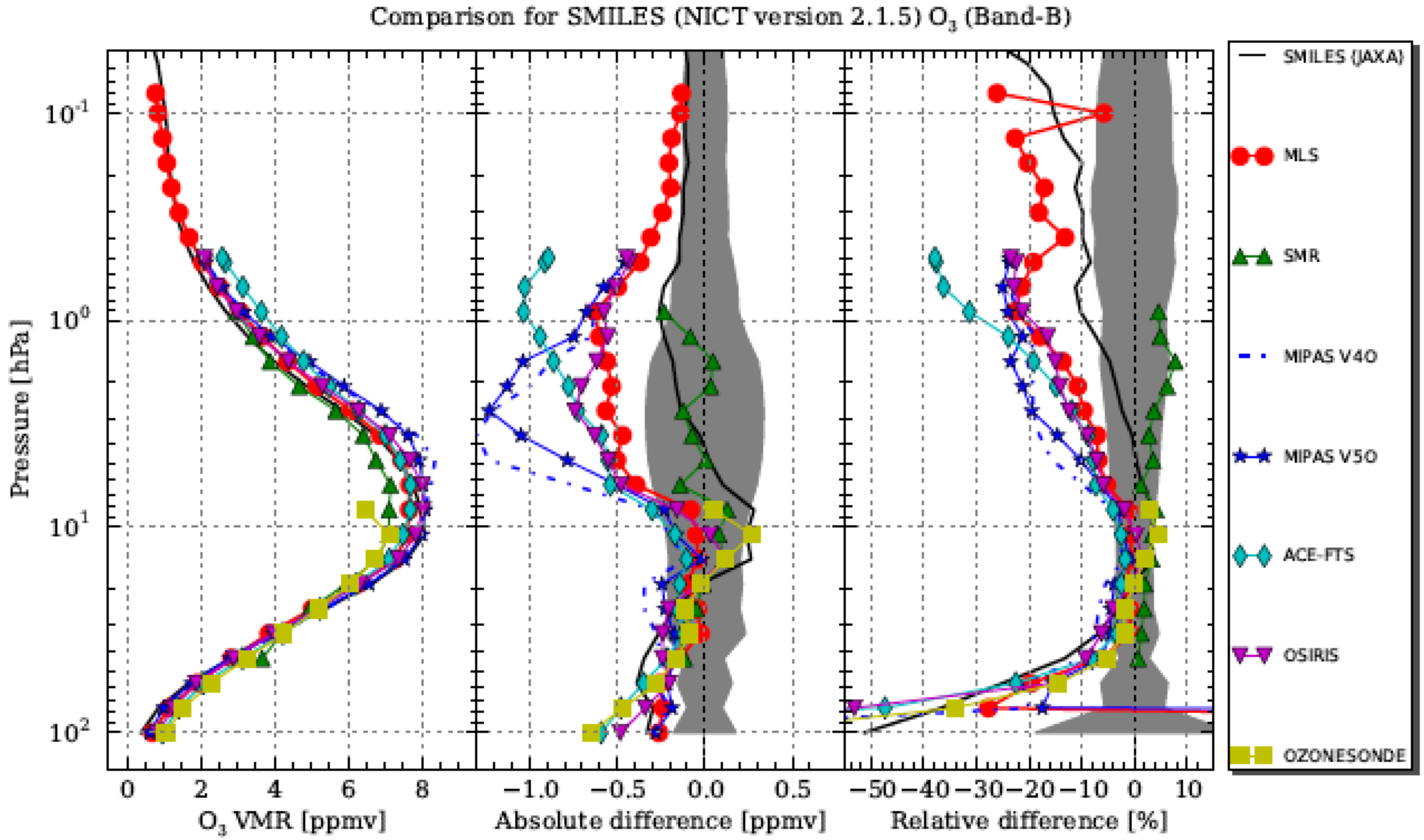
Largest error source is the spectroscopic parameters for ozone.

SMILES Pressure Broadening Parameters

Complete | stimated/some measurement | No observation

	Frequency [GHz]	γ(air) [MHz/Torr]	n	δ0 Pressure shift [MHz/Torr]	s	Current Accuracy	Required Accuracy	References
H_2O	620.701	4.379	---	---	---	2%	1%	Y. kasai, to be published
O_3	625.372	2.99[a] 2.906[b]	0.93[a] 0.723[b]	0	0	4% 2%	1%	[a]M.M. Yamada *JQSRT, Vol.95, 221-230(2005),* [b]BJDrouin, *JMS, Vol.251, 194-202(2008)*
O_3	650.732	3.006	0.598	---	---	2%	1%	[b]BJDrouin, *JMS, Vol.251, 194-202(2008)*
O_3 isotopes	Many	3.10 (647.691 GHz)	---	0	0	5%	0.50%	M.M. Yamada *JQSRT, Vol.95, 221-230(2005),*
$H^{35}Cl$	625.919	3.42	0.73	0.146	0.4047	4%	1%	BJDrouin, *JQSRT, Vol.83, 321-331(2004),*
$H^{37}Cl$	624.978	3.42[a] 3.51[b]	0.73[a] ---	0.146[a] 0.123[b]	0.4047[a] ---	4% ?	1%	[a]BJDrouin, *JQSRT, Vol.83, 321-331(2004),* [b]Ozeki et al., private communication
ClO	649.451	2.86	0.77	0	0	3%	1%	MLS Spectroscopic catalog (2010 Nov 10) ~~J. J. Oh and E. A. Cohen~~
HO_2	625.660	3.00	---	0	0	0	3%	B.J.Drouin, MLS clear sky production forward model2002)
	649.702	2.74	-0.2	0	0	4%	3%	M.M.Yamada (Thesis) should confirm
H_2O_2	625.044	3.71	---	0	0	2.4%	3%	T. O. Sato *JQSRT, Vol.111,* 821-825(2010),
HOCl	625.076	3.881	0.650	-0.076	0.397	4.6%	3%	635GHz B.J.Drouin, *JQSRT, Vol.103,* 558-564*(2007)*
BrO	624.768	3.05	0.80	0	0	3%	5%	M.M. Yamada *JQSRT, Vol.82, 391-399(2003),*
	650.179	3.03	0.81	0	0	3%	5%	M.M. Yamada *JQSRT, Vol.82, 391-399(2003),*
HNO_3	624.484	4.09	0.70	-0.13	0	0	3%	T.O.Sato. Estimated from the paper, J. Atm.Chem., Vol.51, 161-205, (2005). Line shift parameters were taken from the thesis of Miriam von Konig (U. of Bremen).
	624.776	4.09	0.70	-0.13	0	0	3%	
	625.345	4.33	0.70	-0.13	0	0	3%	
	650.288	4.09	0.70	-0.13	0	0	3%	
CH_3CN	624.819	4.79	---	---	0	---	3%	B.J.Drouin, MLS clear sky production forward model2002) Different
	624.926	4.81			0		3%	

Summary of comparison between SMILES and other measurements

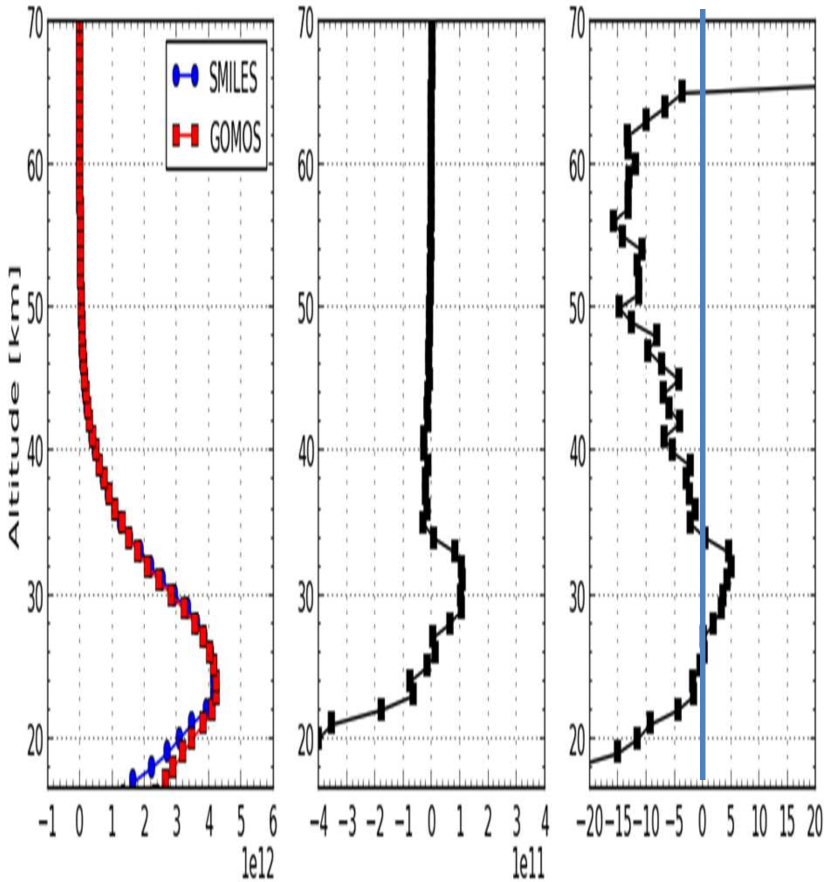


SMILES agree well in the stratosphere, had negative trend above 1hPa due to the problems of non-linearity and tangent height problem.

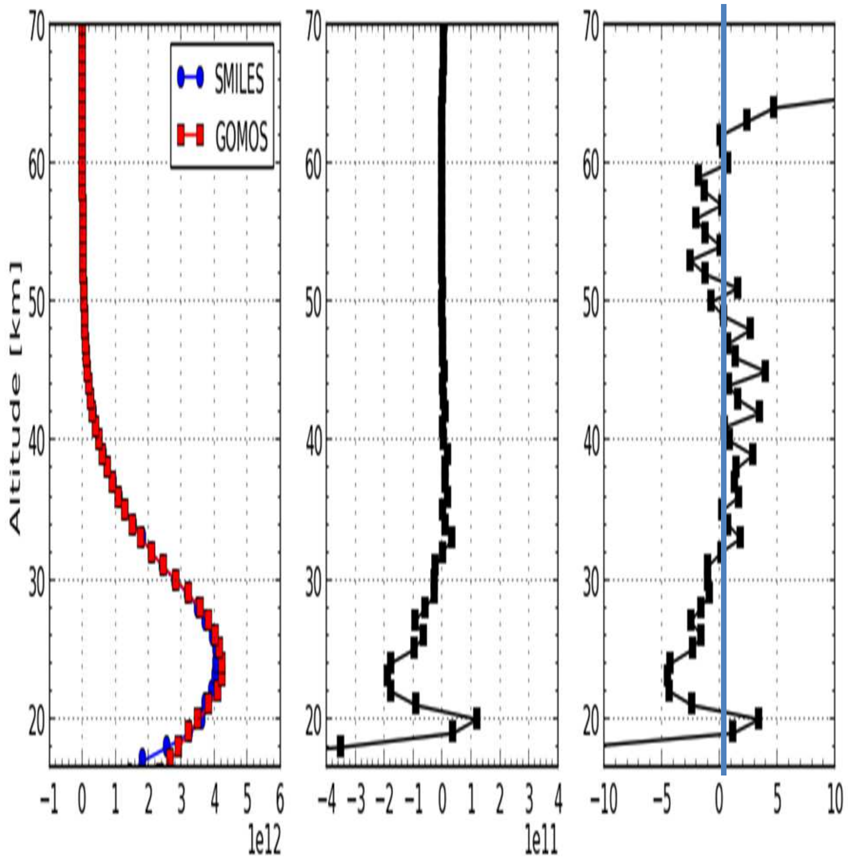
Thanks to Johanna Tamminen and Kyrölä Erkki

GOMOS-SMILES comparisons

L1b 007

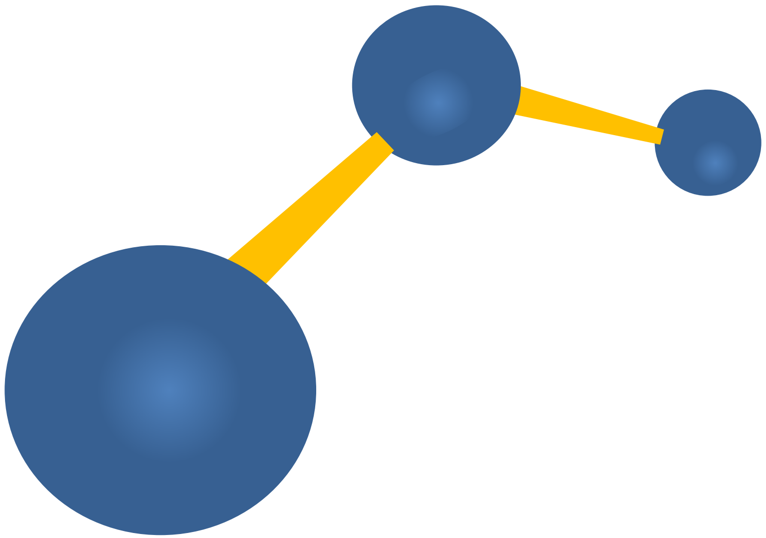


L1b 008



Development of retrieval algorithm for SMILES observation of δ^{18}OOO from stratosphere to mesosphere

Tomohiro Sato and Yasko Kasai
Tokyo Institute of Technology and NICT



Scientific requirement from SMILES team

- Accurate spectroscopic parameters (gamma, n) better than < 1 %.

- Absorption cross section for ozone isotopomers including Asym-18/17 O3, Sym-18/17 O3.

- More close collaboration with laboratory cross section measurement team for isotope study.