JEM/SMILES L2 data processing system on ISAS/JAXA

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1: FUJITSU FIP, 2: ISAS/JAXA, 3:TOME R&D, 4:RISH, 5: NICT

Contents

- Outline of the SMILES Level 2 data processing system (DPS-L2) in ISAS/JAXA
- Retrieval algorithm of the DPS-L2
- Study of the observation capability for target species.
- Improvements of the level 2 data.

◆ Recent status of the Level 2 products is NEXT talk.

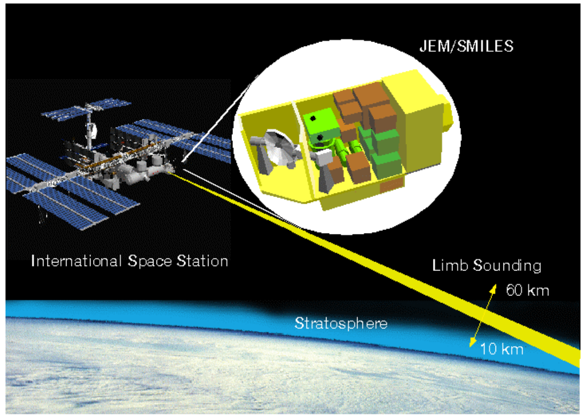
Outline of JEM/SMILES

■ The Superconducting Submillimeter-wave Limb-Emission Sounder (SMILES) had been launched and aboard the Japanese Experiment Module (JEM) of the International Space Station (ISS) in **Sep, 2009**.

■ The SMILES carries 4K cooled **Superconductor-Insulator-Superconductor (SIS) mixers** to demonstrate a highly sensitive instrument for submillimeter limb-emission sounding.

◆ Global test observation : Oct.12.

◆ Operational observation : Nov. 6.



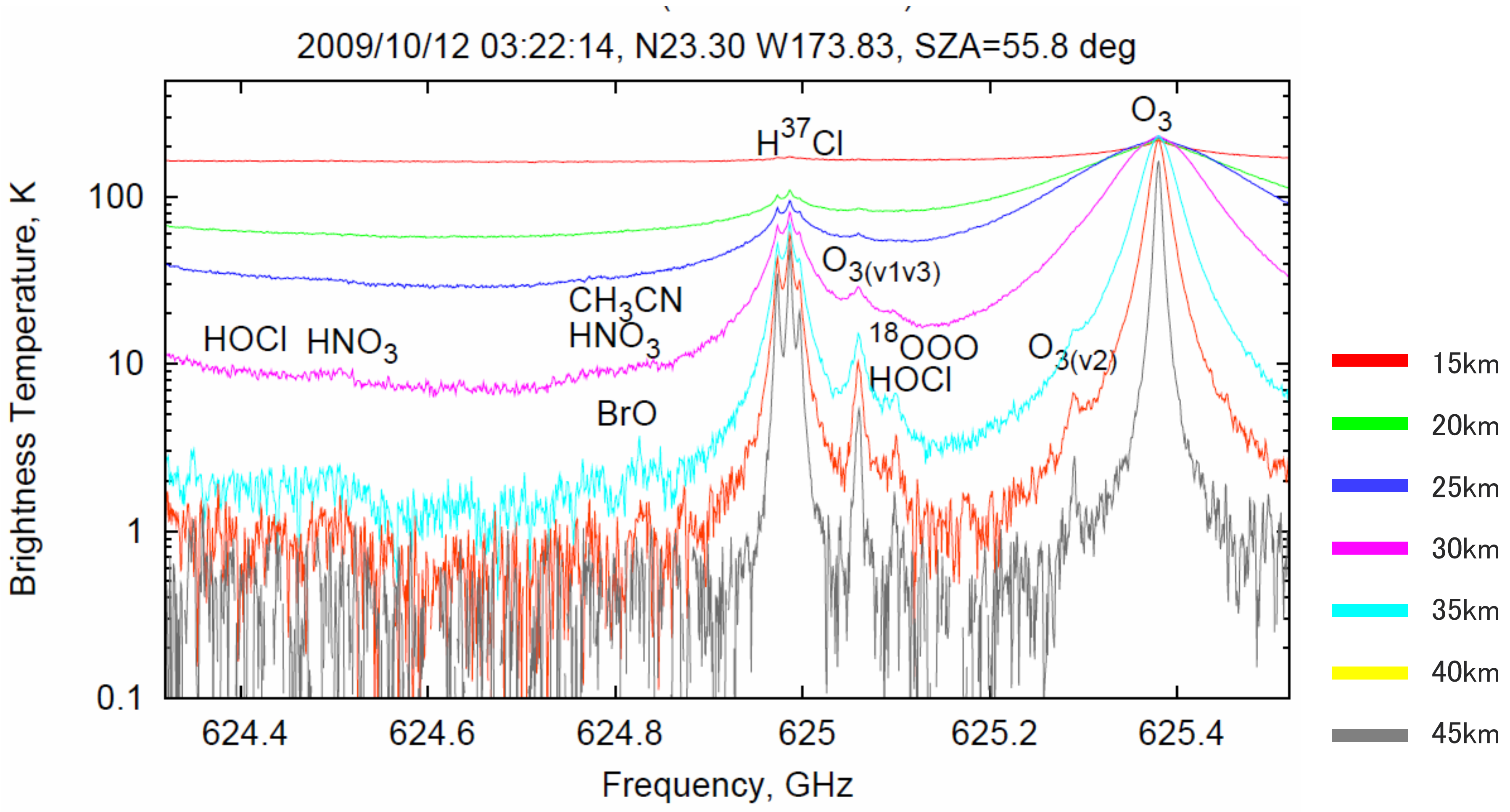
Standard products

O_3, HCl, ClO, HNO_3, CH_3CN, HO_2, HOCl, BrO, O_3 isotopes
(in the middle atmosphere)

JEM/SMILES Specifications

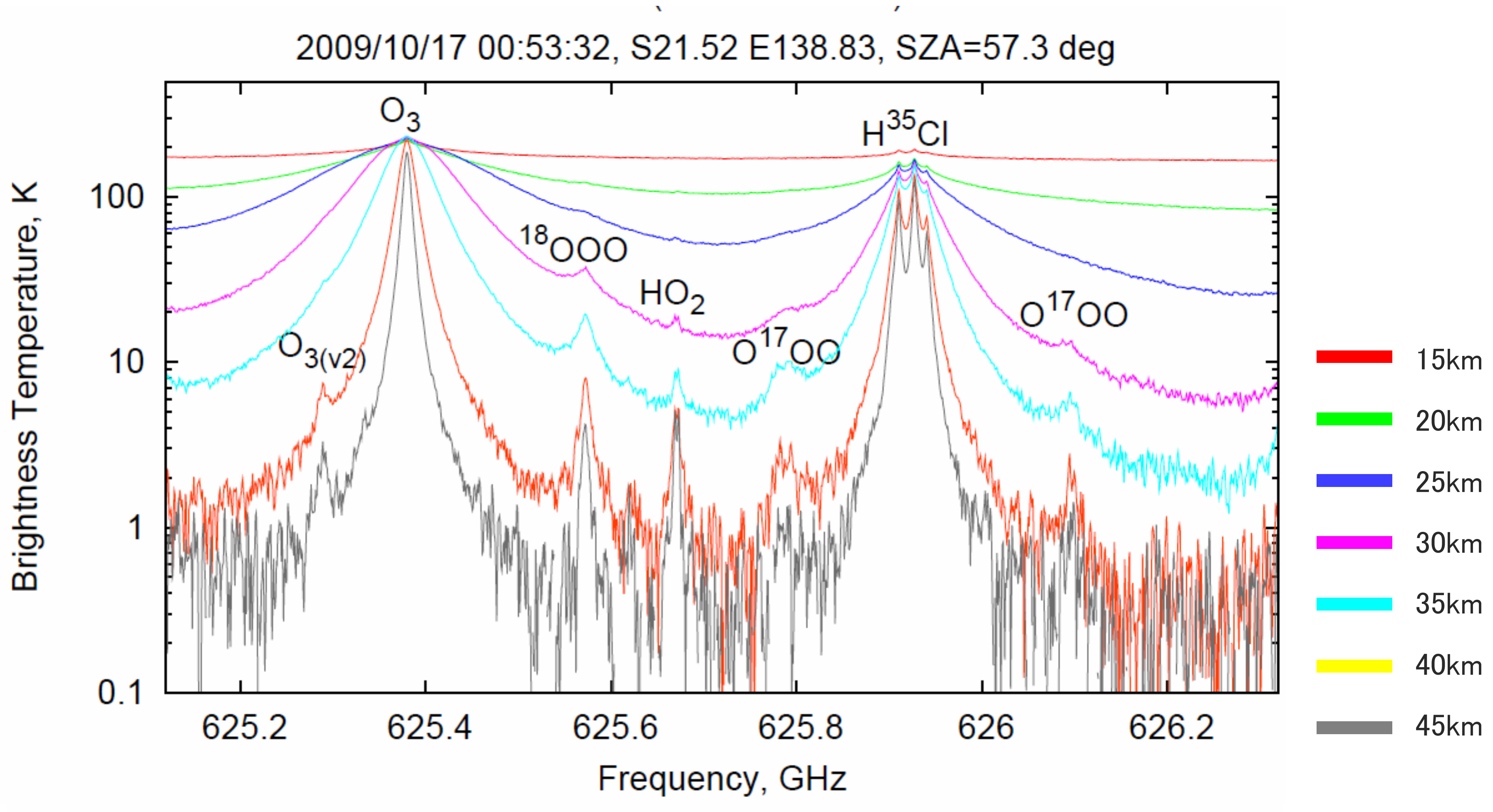
Type	**Parameters**
Frequency bands	Band A (624.32 – 625.52 GHz) Band B (625.12 – 626.32 GHz) Band C (649.12 – 650.32 GHz)
System noise temperature	Less than 500 K
Instrumental height resolution	3.5 - 4.1 km (nominal)
Frequency resolution	1.8 MHz (FWHM)
Channel separation	0.8 MHz /channel
Observation altitude range	10 - 60 km (nominal)
Global coverage	38S - 65N (nominal)
Observation azimuth angle	-10 – 95 degree (0=north)
Processing time	53 s / scam
Integration time	0.5 s for each observation point

Observation band A (09101200062)



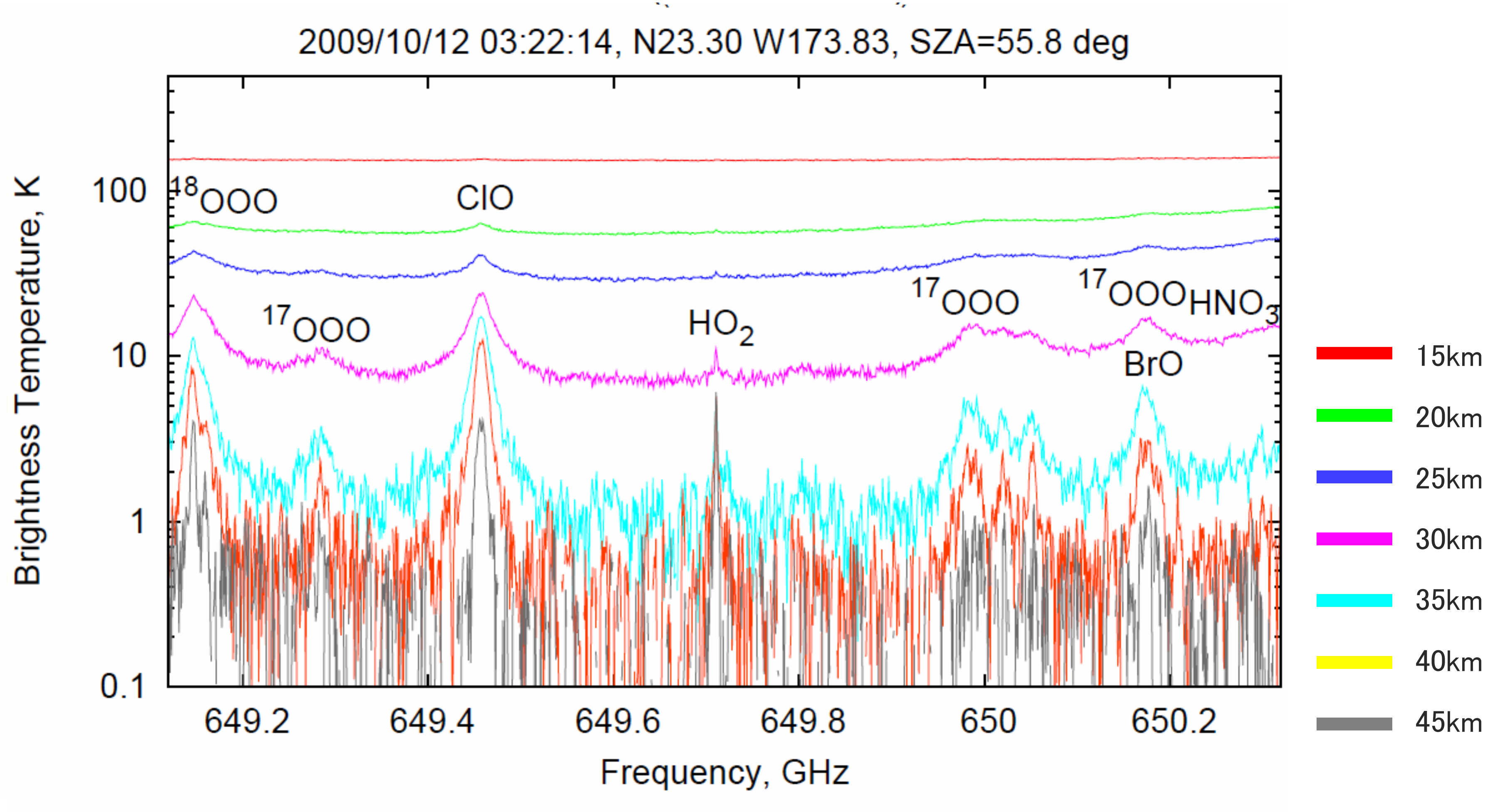
- Strong lines:: O3 and HCl, Weak lines:: HOCl, HNO3, CH3CN and BrO (band A only : CH3CN, HOCl)
- BrO line is superimposed on HNO3 lines. Other major HNO3 line is only one and it is not clearly. So, BrO retrieval is difficalt problem.

Observation band B (091018000060)



- Strong lines:: O3 and HCl, Weak lines:: O3-isotope and HO2 (band B only : O17OO)
- HCl signal in stratosphere is larger than signal in band A.
- Major lines are relatively isolated

Observation band C (091012000062)



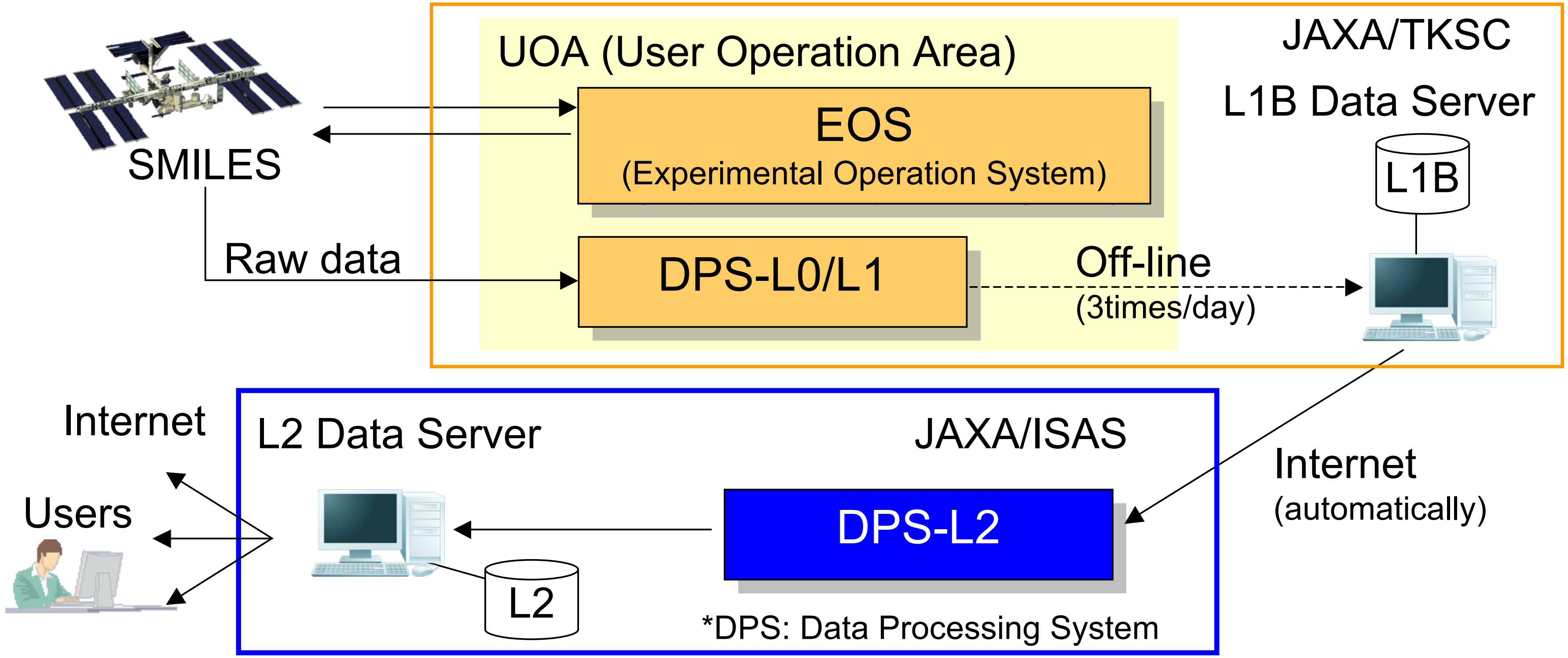
- Strong lines:: ClO, O3-isotope Weak lines: HNO3 HO2, BrO. (band C only: ClO, 17OOO)
- BrO line is superimposed on 17OOO lines. But 17OOO has other 7 strong lines which are isolated from other moleculer's lines. So, Band-C is relatively appropriate to retrieve BrO.

JEM/SMILES Data Sets

Data Type	Description
RAW	Unprocessed mission data at binary packets
Level 0	Reconstructed, unprocessed mission data at binary packets
Level 1b	Calibrated instrument radiances and related data
Level 2	Derived geophysical variables at the same resolution and location as the Level 1 source data
Level 3	Variables mapped on uniform space-time grid scales, usually with some completeness and consistency

Processing

JEM/SMILES Data Flow



- Downlinked raw data from the SMILES will be received by the DPS-L0/L1 at User Operation Area (UOA) on Tsukuba Space Center (TKSC).
- The DPS-L0/L1 processes the raw data consisting of house keeping (HK) data and mission data to brightness temperature (level 1B data) in near-real-time.
- The DPS-L2 produces the vertical profiles of target species called level 2 data in near real time and upload L2 product dataset 5 day after observation (TDB).
- The DPS-L2 distributes the level 2 product to users by a Web server.

Basic Retrieval Algorithm

Optimal Estimation Method （OEM)

- Observation vector：

x：true、**ε**：observation noise 、**f** ：Forward Model

- OEM: *deriving the results which minimize* χ^2

$$\chi^2 = [\mathbf{y} - \mathbf{f}(\mathbf{x})]^{\mathrm{T}} \mathbf{S}_{\mathbf{y}}^{-1} [\mathbf{y} - \mathbf{f}(\mathbf{x})] + [\mathbf{x} - \mathbf{x}_{\mathbf{a}}]^{\mathrm{T}} \mathbf{S}_{\mathbf{a}}^{-1} [\mathbf{x} - \mathbf{x}_{\mathbf{a}}]$$

$\mathbf{x_a}$：a priori, $\mathbf{S_a}$ ：covariance of a priori, $\mathbf{S_y}$ covariance of observation noise

Non-linear case（Levenberg-Marquardt Method）

$$\mathbf{x}_{i+1} = \mathbf{x}_i + (\mathbf{S}_{\mathbf{a}}^{-1} + \mathbf{K}_i^{\mathrm{T}} \mathbf{S}_y^{-1} \mathbf{K}_i + \gamma \mathbf{S}_{\mathbf{a}})^{-1} \left\{ \mathbf{K}_i^{\mathrm{T}} \mathbf{S}_y^{-1} \left[\mathbf{y} - \mathbf{F}(\mathbf{x}_i) \right] - \mathbf{S}_{\mathbf{a}}^{-1} \left[\mathbf{x}_i - \mathbf{x}_{\mathbf{a}} \right] \right\}$$

$\mathbf{K_i}$：Weighting function, γ：Levenberg-Marquardt parameter

References for the SMILES L2 data processing

■C. Takahashi, S. Ochiai, M. Suzuki, Operational Retrieval Algorithms for JEM/SMILES Level 2 Data Processing System, JQSRT (in press)

■K. Imai, M. Suzuki, C Takahahshi, Evaluation of the Voigt algorithms for the ISS/JEM/SMILES L2 data processing system, ASR (in press)

Algorithm for noisy products

- Retrieval profiles of noisy products may include a priori information.
- To avoid the bias from a priori, we retrieve the multi-scan data simultaneously [Livesey,2004].
  - The observation data $\mathbf{y_i}$ (i=1~N), the weighting function $\mathbf{K_i}$, than reference spectra $\mathbf{f_i}$, and the covariance matrix of the measurements $\mathbf{S_{yi}}$ are represented by :

$$\mathbf{y} = \begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \vdots \\ \mathbf{y}_N \end{pmatrix}, \quad \mathbf{f} = \begin{pmatrix} \mathbf{f}_{i1} \\ \mathbf{f}_2 \\ \vdots \\ \mathbf{f}_N \end{pmatrix}, \quad \mathbf{K} = \begin{pmatrix} \mathbf{K}_1 \\ \mathbf{K}_2 \\ \vdots \\ \mathbf{K}_N \end{pmatrix}, \quad \mathbf{S}_y = \begin{pmatrix} \mathbf{S}_{y1} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{S}_{y1} & \mathbf{0} & \vdots \\ \vdots & \mathbf{0} & \ddots & \mathbf{0} \\ \mathbf{0} & \cdots & \mathbf{0} & \mathbf{S}_{y1} \end{pmatrix}$$

- However, these matrixes are too large (ex. $\mathbf{K_i}$ size: 1500x30x30), we calculate $\mathbf{K_i^T S_{yi} K_i}$ (size: 30x30) and $\mathbf{K_i^T S_{yi}(y_i\text{-}f_i)}$ (size:30) for each scan and save to reduce the load of the system.

$$\hat{\mathbf{x}} = \mathbf{a} + \left[\mathbf{S}_a^{-1} + \sum \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} \mathbf{K}_i\right] \left[\sum \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} [\mathbf{y}_i - \mathbf{f}_i(\mathbf{x}_0, \mathbf{b})] - \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} \mathbf{K}_i [\mathbf{a} - \mathbf{x}_0]\right]$$

$$\sum \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} \mathbf{K}_i = \left(\mathbf{K}_1^T \mathbf{S}_{y1}^{-1} \mathbf{K}_1 + \mathbf{K}_2^T \mathbf{S}_{y2}^{-1} \mathbf{K}_2 + \cdots + \mathbf{K}_N^T \mathbf{S}_{yN}^{-1} \mathbf{K}_N\right)$$

$$\sum \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} [\mathbf{y}_i - \mathbf{f}_i(\mathbf{x}_0, \mathbf{b})] = \left(\mathbf{K}_1^T \mathbf{S}_{y1}^{-1} [\mathbf{y}_1 - \mathbf{f}_1(\mathbf{x}_0, \mathbf{b})] + \cdots + \mathbf{K}_N^T \mathbf{S}_{yN}^{-1} [\mathbf{y}_N - \mathbf{f}_N(\mathbf{x}_0, \mathbf{b})]\right)$$

Reference：N J. Livesey and W. Van Snyder, EOS MLS Retrieval Processes Algorithm Theoretical Basis, 2004

Error Analysis

- Retrieval Precision
  - *Measurement error :* decided by the system noise

$$\mathbf{S_m} = (\mathbf{S_a}^{-1} + \mathbf{K}_i^{\mathbf{T}}\mathbf{S_y}^{-1}\mathbf{K}_i)^{-1}\mathbf{K}_i^{\mathbf{T}}\mathbf{S_y}^{-1}\mathbf{K}_i(\mathbf{K}_i^{\mathbf{T}}\mathbf{S_y}^{-1}\mathbf{K}_i + \mathbf{S_a}^{-1})^{-1}$$

  - *Smoothing error :* decided by the atmospheric conditions

$$\mathbf{S_n} = (\mathbf{S_a}^{-1} + \mathbf{K}_i^{\mathbf{T}}\mathbf{S_y}^{-1}\mathbf{K}_i)^{-1}\mathbf{S_a}^{-1}(\mathbf{K}_i^{\mathbf{T}}\mathbf{S_y}^{-1}\mathbf{K}_i + \mathbf{S_a}^{-1})^{-1}$$

- Forward Model parameter error

$$\mathbf{S_f} = \mathbf{G_y}\mathbf{K_b}\mathbf{S_b}\mathbf{K_b^T}\mathbf{G_y^T}$$

  - *Instrumental parameter error*
  - *Spectroscopic parameter error*
  - *Approximation and implementation error*

  etc.

- Forward Model parameter error << Retrieval Precision

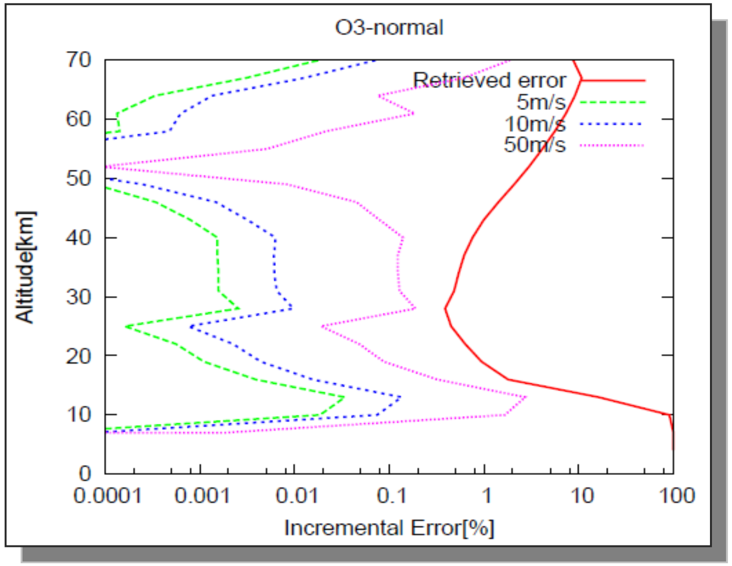
  → High accuracy algorithm is required.

Doppler shift & Instrument Functions

Doppler shift

- Velocity of the ISS : 8 km/s
- Rotation of the earth : 460 m/s (on the equator)
- Wind : ≲100 m/s. (Use GMAO)

Effects of wind



FOV Convolution :

Considering the effects from tilt of ISS

$$T_A(\nu, z_0) = \int_{z_{min}}^{z_{max}} P(z, z_0) \cdot T_p(\nu, z) dz,$$

Fold Sidebands (Single Sideband Separator)

$$T_{mix:i}(\nu, z_0) = \begin{bmatrix} K_{i,a}^{LSB}(\nu_{LO} - \nu_{if}, z_0) \\ K_{i,c}^{LSB}(\nu_{LO} - \nu_{if}) \end{bmatrix}^T \cdot \begin{bmatrix} T_A(\nu_{LO} - \nu_{if}, z_0) \\ T_c(\nu_{LO} - \nu_{if}) \end{bmatrix} + \begin{bmatrix} K_{i,a}^{USB}(\nu_{LO} + \nu_{if}) \\ K_{i,c}^{USB}(\nu_{LO} + \nu_{if}) \end{bmatrix}^T \cdot \begin{bmatrix} T_A(\nu_{LO} + \nu_{if}, z_0) \\ T_c(\nu_{LO} + \nu_{if}) \end{bmatrix}$$

$$K_{i,j}^{LSB,USB}(\nu, T) = \frac{1 + \alpha(T)^2 + 2\alpha(T) cos\left(\frac{m\pi\nu}{\nu_0(T)}\right)}{4}.$$

Channel Average: AOS Response function approximates as Gaussians. And Gaussian parameters depend on channel number.

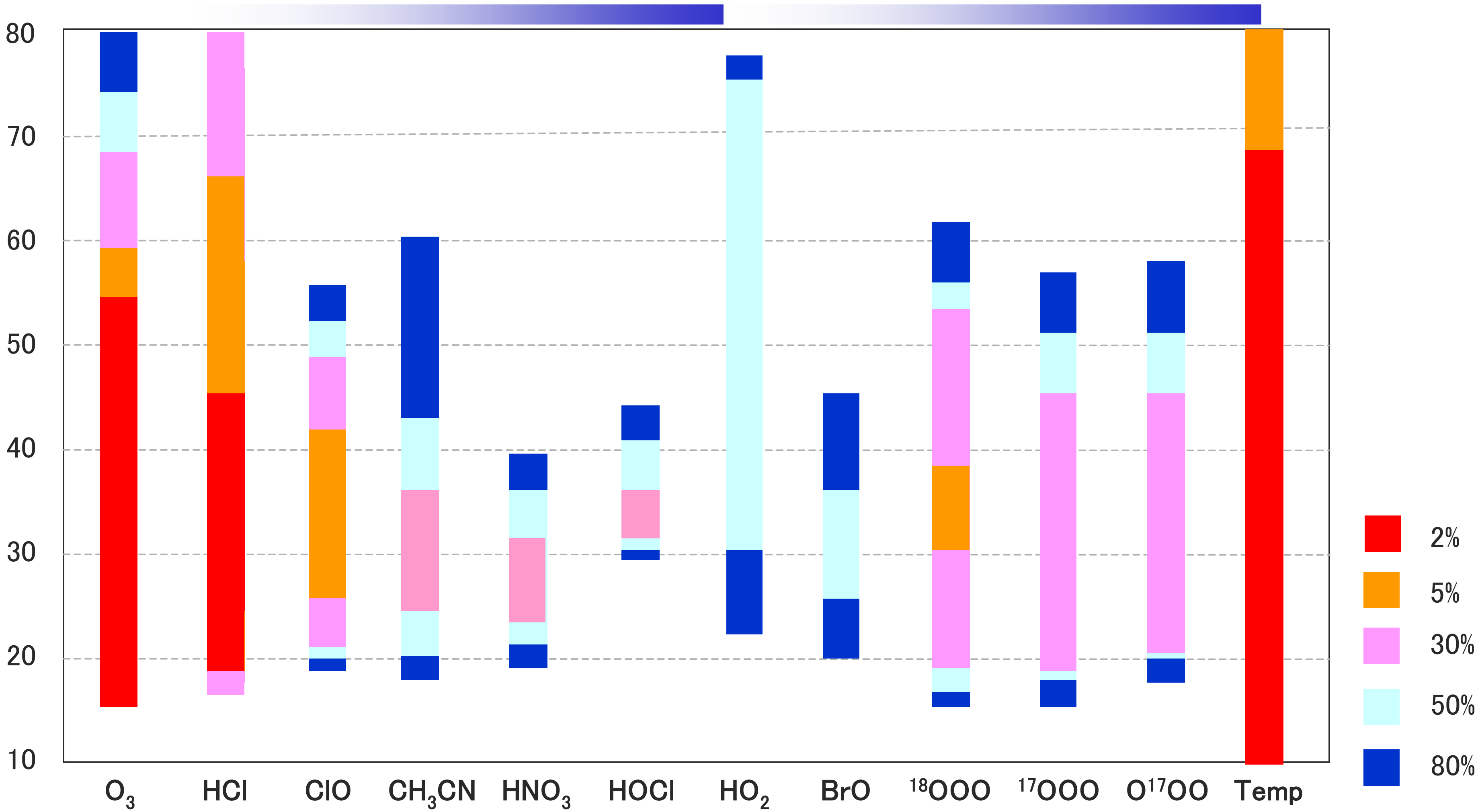
$$T_{AOS(l)}(\nu_j, z_0) = \frac{\int_{\nu_{min}}^{\nu_{max}} H_{AOS(l)}(\nu - \nu_j) \cdot T_{mix(k)}(\nu, z_0) d\nu}{\int_{\nu_{min}}^{\nu_{max}} H_{AOS(l)}(\nu - \nu_j) d\nu}. \quad H_{AOS(l)}(\nu - \nu_j) = \sum_{j-1}^{N_j} \frac{A_{i,j}}{w_{i,j}\sqrt{\pi/2}} \cdot exp\left(-2\frac{(\nu - \nu_j - xc_{i,j})^2}{w_{i,j}^2}\right).$$

A Priori / first guess

Object		Reference data
Tracer constituents	O_3	LBLRTM*1, Aura/MLS*2, CCSR/NIES*3
	O_3 isotopes	*O_3 references with isotopic abundances for HITRAN*
	HCl	LBLRTM*1, Aura/MLS*2, CCSR/NIES*3
	ClO	LBLRTM*1, Aura/MLS*2, CCSR/NIES*3
	CH_3CN	UARS/MLS*4 (, Aura/MLS*2)
	HOCl	LBLRTM*1, Aura/MLS*2, CCSR/NIES*3
	HNO_3	LBLRTM*1, Aura/MLS*2, CCSR/NIES*3
	HO_2	Aura/MLS*2, CCSR/NIES*3
	BrO	Aura/MLS*2, CCSR/NIES*3
Dynamics	Temperature H_2O Wind Pressure	NASA/GMAO*5

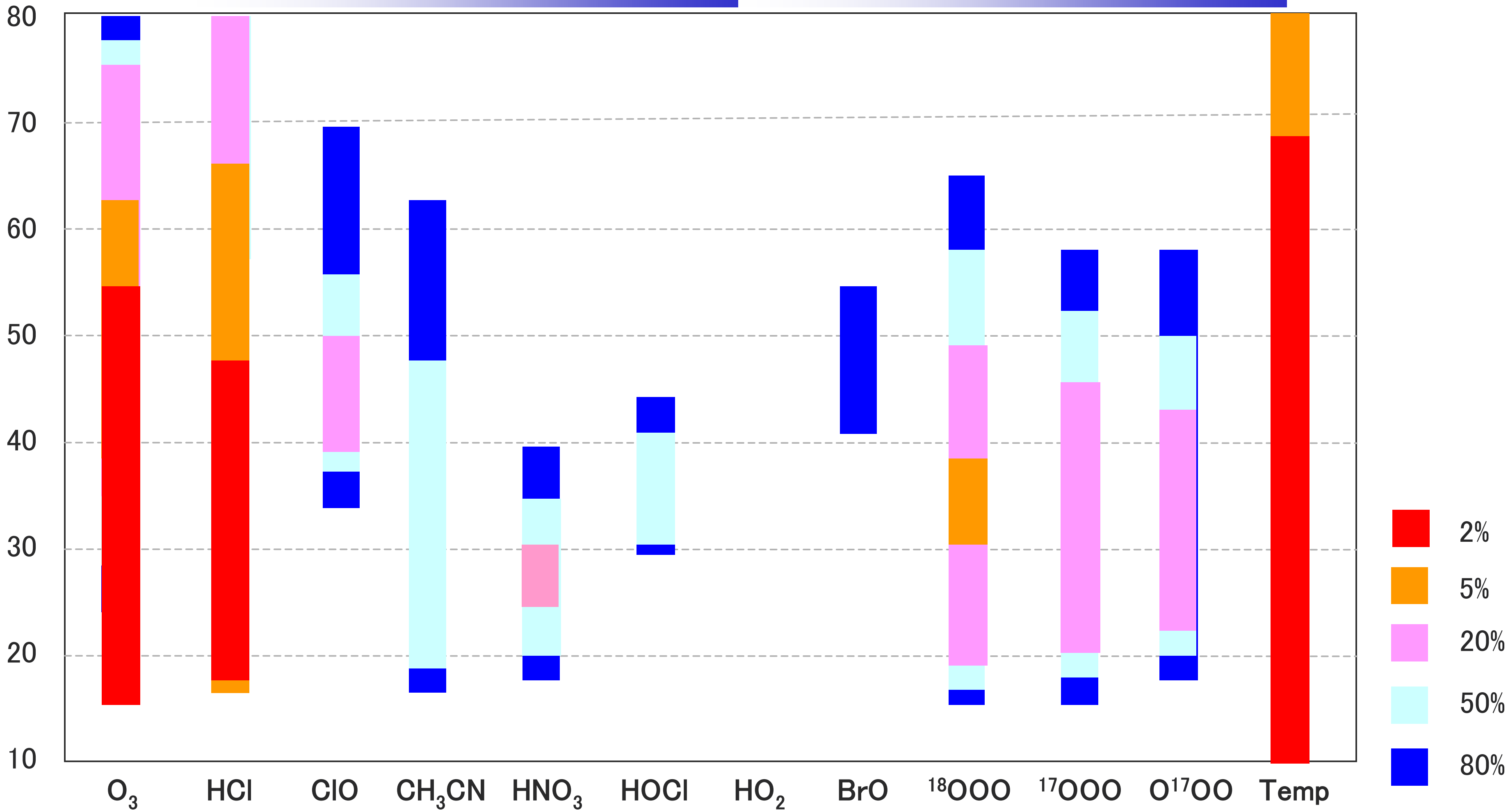
*1: Reference profiles used in Line-by-Line Radiative Transfer Model
*2: Monthly climatology based on measurements by EOAS-Aura/MLS
*3: Monthly climatology based on the CCMVal-REF2 run for 2001-2010 by CCSR/NIES CCM
*4: CH_3CN reference profiles based on measurements by UARS/MLS
*5: Near-realtime analyses produced by NASA/GMAO's GEOS-5 DAS

Retrieval Precision : Day (LT12:00)



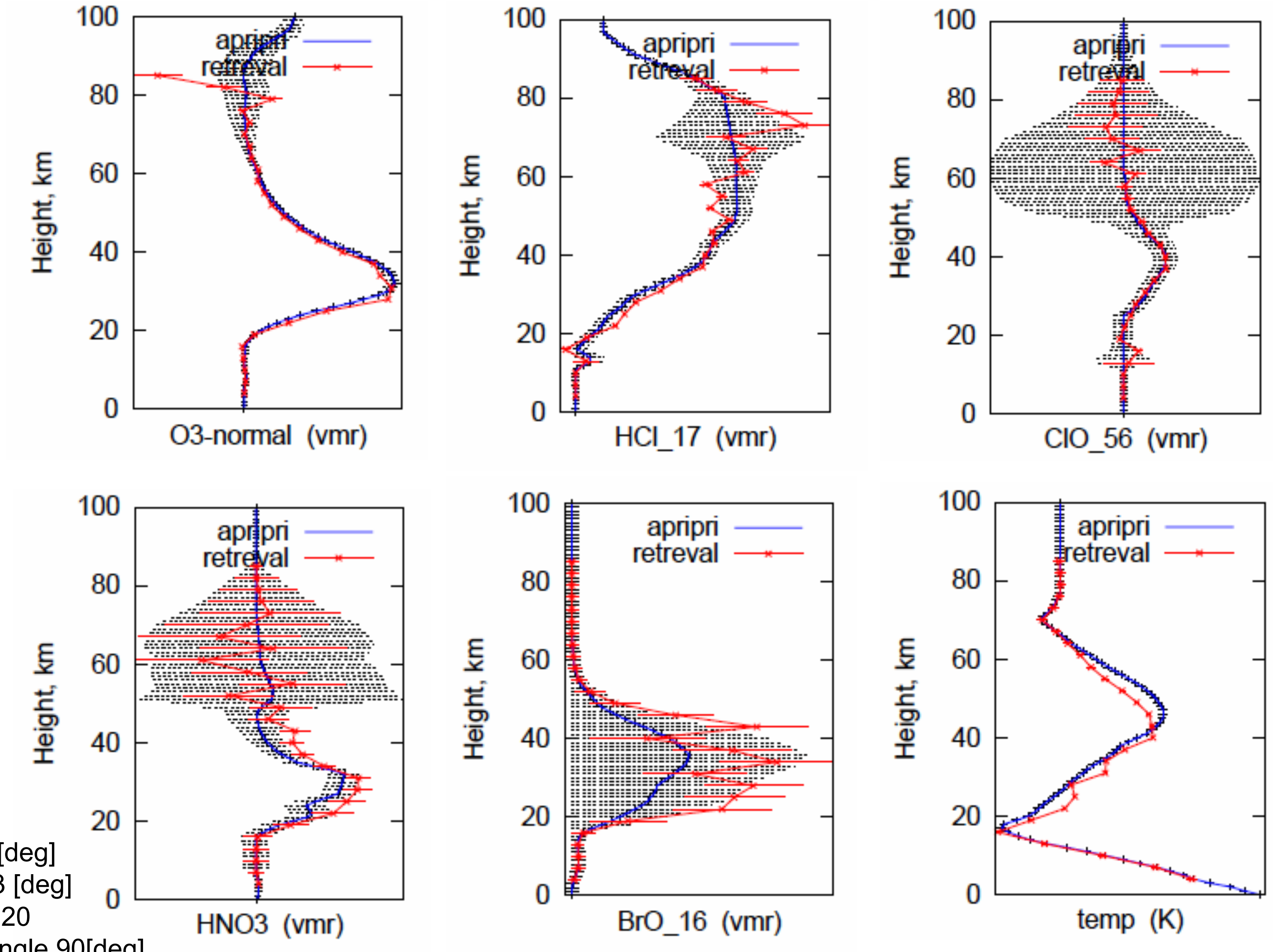
- a priori profiles HOCl, BrO: CCSR/NIES, CH_3CH: UARS/MLS, others: Aura/MLS (40N/March)
- Standard deviation of a priori : 100 %
- Measurement altitude : 0-80km, 2km, Retrieval Altitude: 4-85km, 3km

Retrieval Precision：Night (LT0:00)



- a priori profiles HOCl, BrO: CCSR/NIES, CH_3CH: UARS/MLS, others: Aura/MLS (40N/March)
- Standard deviation of a priori : 100 %
- Measurement altitude : 0-80km, 2km, Retrieval Altitude: 4-85km, 3km

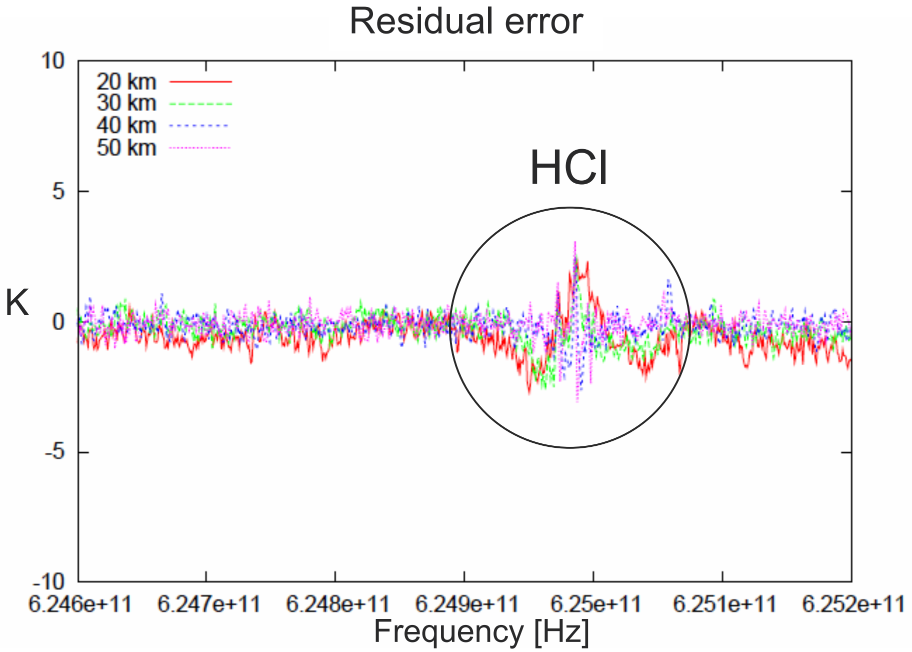
Retrieval Results



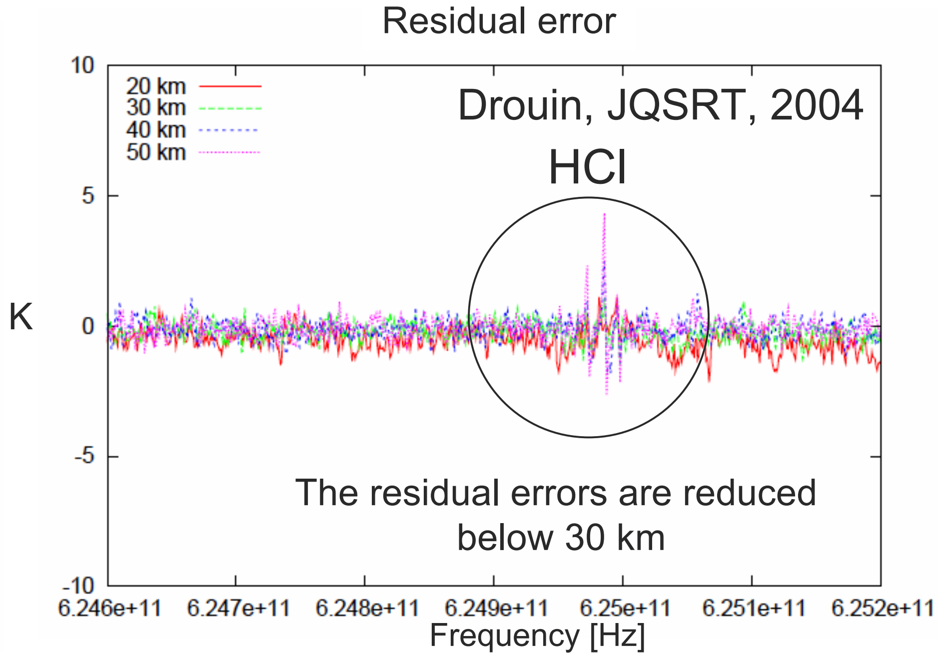
2009.10.12
Latitude 13.6 [deg]
Longitude -5.3 [deg]
Local time 15:20
Solar zenith angle 90[deg]

Spectroscopic parameter error (HCl)

Before the Correction



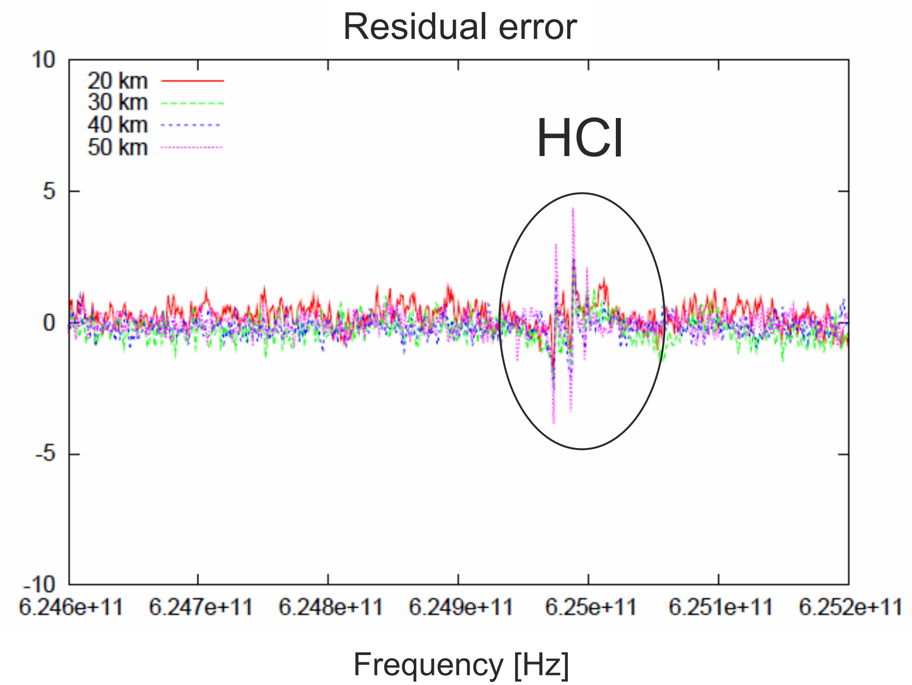
After the Correction



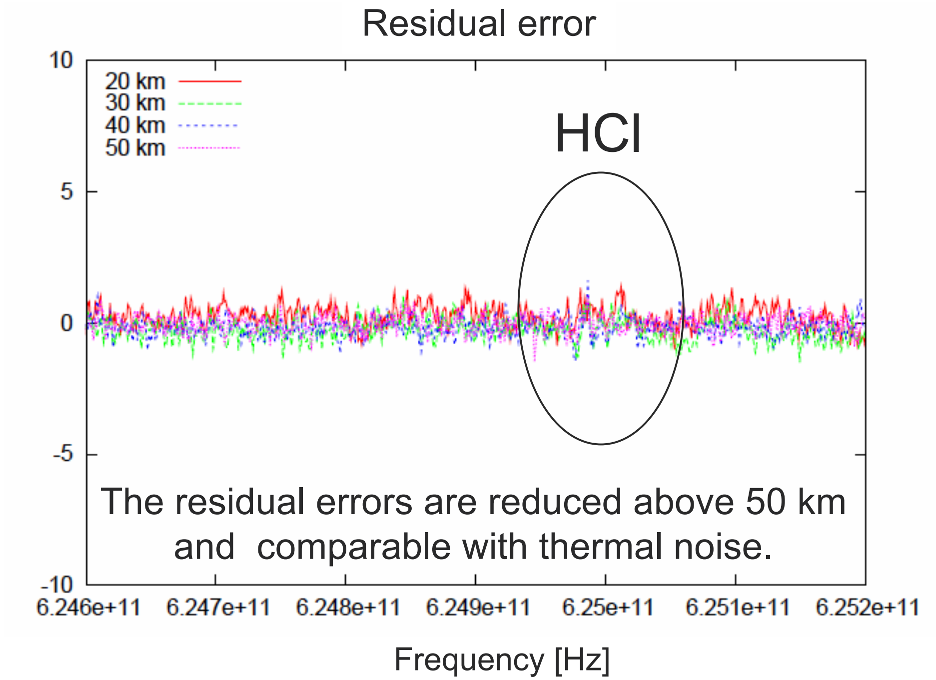
- Residual errors are 3 K around HCl lines at several heights. Below 30km, these errors are large around HCl lines, not other lines.
- Change HCl line parameters
  - include pressure shift effect
  - change temperature dependency of pressure broadening parameter

Doppler Shift by Earth's Rotation Rate

Before the Correction



After the Correction



- SMILES antenna viewing direction is from north-northwest to east. These errors occur when direction is north-northwest (azimuth < 0 deg)
- Effect of Earth rotation rate is estimated by L1B data processing. So we request correction.

Summary

- The DPS-L2 is working as expected. The observation data can be retrieved with minimal loss.

- There are still some systematic errors in retrieval results. We will continue the following estimation and improve the level 2 data.
  - Accuracy of determining tangent heights
  - Error source of the frequency shift
    (Frequency calibration, Wind, etc)
  - Line shape for other molecules

  etc.

Algorithm for noisy products

- To avoid the bias from a priori, we retrieve the multi-scan data simultaneously [Livesey,2004]. i.e. The observation data $\mathbf{y_i}$ (i=1~N), the weighting function $\mathbf{K_i}$, than reference spectra $\mathbf{f_i}$, and the covariance matrix of the measurements $\mathbf{S_{yi}}$ are represented by :

$$\mathbf{y} = \begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \vdots \\ \mathbf{y}_N \end{pmatrix}, \quad \mathbf{f} = \begin{pmatrix} \mathbf{f}_{i1} \\ \mathbf{f}_2 \\ \vdots \\ \mathbf{f}_N \end{pmatrix}, \quad \mathbf{K} = \begin{pmatrix} \mathbf{K}_1 \\ \mathbf{K}_2 \\ \vdots \\ \mathbf{K}_N \end{pmatrix}, \quad \mathbf{S}_y = \begin{pmatrix} \mathbf{S}_{y1} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{S}_{y1} & \mathbf{0} & \vdots \\ \vdots & \mathbf{0} & \ddots & \mathbf{0} \\ \mathbf{0} & \cdots & \mathbf{0} & \mathbf{S}_{y1} \end{pmatrix}$$

- However, these matrixes are too large (ex. K size: 1500x30x30), we calculate $\mathbf{K_i^T S_{yi} K_i}$ (size30x30) and $\mathbf{K_i^T S_{yi} (y_i - f_i)}$ (size:30) for each scan and save to reduce the load of the system.

$$\hat{\mathbf{x}} = \mathbf{a} + \left[\mathbf{S}_a^{-1} + \sum \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} \mathbf{K}_i\right]\left[\sum \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} [\mathbf{y}_i - \mathbf{f}_i(\mathbf{x}_0, \mathbf{b})] - \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} \mathbf{K}_i [\mathbf{a} - \mathbf{x}_0]\right]$$

$$\sum \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} \mathbf{K}_i = \left(\mathbf{K}_1^T \mathbf{S}_{y1}^{-1} \mathbf{K}_1 + \mathbf{K}_2^T \mathbf{S}_{y2}^{-1} \mathbf{K}_2 + \cdots + \mathbf{K}_N^T \mathbf{S}_{yN}^{-1} \mathbf{K}_N\right)$$

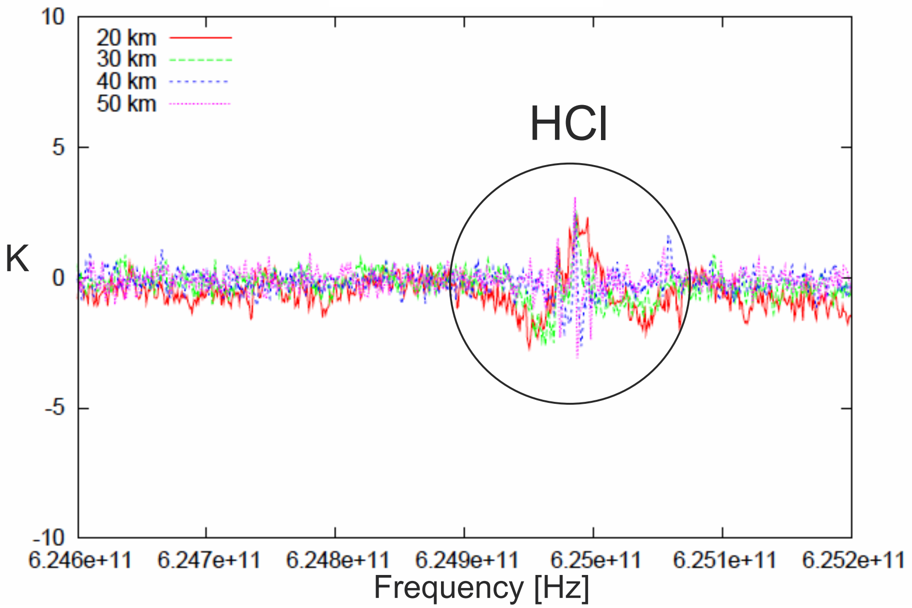
$$\sum \mathbf{K}_i^T \mathbf{S}_{yi}^{-1} [\mathbf{y}_i - \mathbf{f}_i(\mathbf{x}_0, \mathbf{b})] = \left(\mathbf{K}_1^T \mathbf{S}_{y1}^{-1} [\mathbf{y}_1 - \mathbf{f}_1(\mathbf{x}_0, \mathbf{b})] + \cdots + \mathbf{K}_N^T \mathbf{S}_{yN}^{-1} [\mathbf{y}_N - \mathbf{f}_N(\mathbf{x}_0, \mathbf{b})]\right)$$

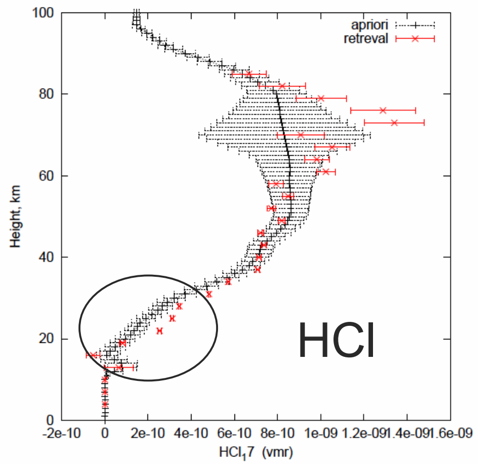
Reference：N J. Livesey and W. Van Snyder, EOS MLS Retrieval Processes Algorithm Theoretical Basis, 2004

Pressure Broadening Parameters (HCl)

Before the Correction

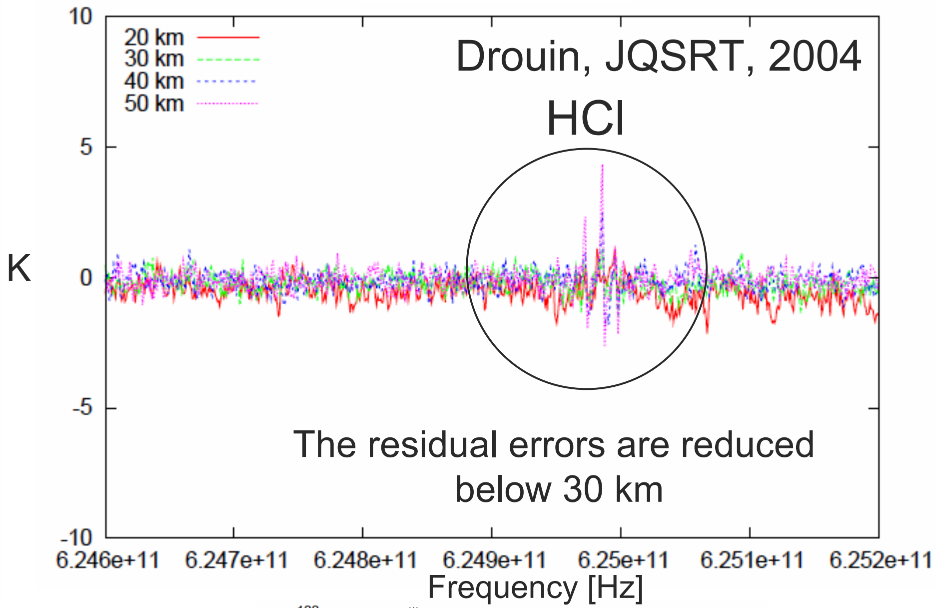
Residual error

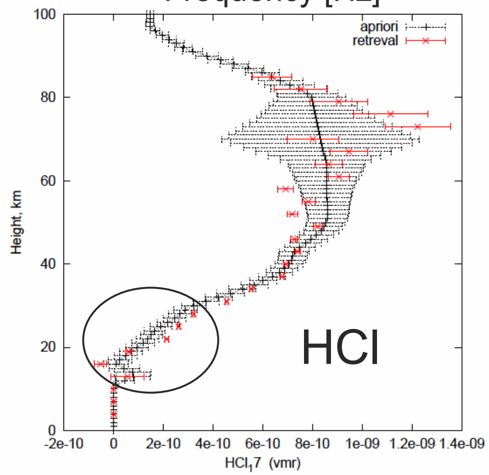




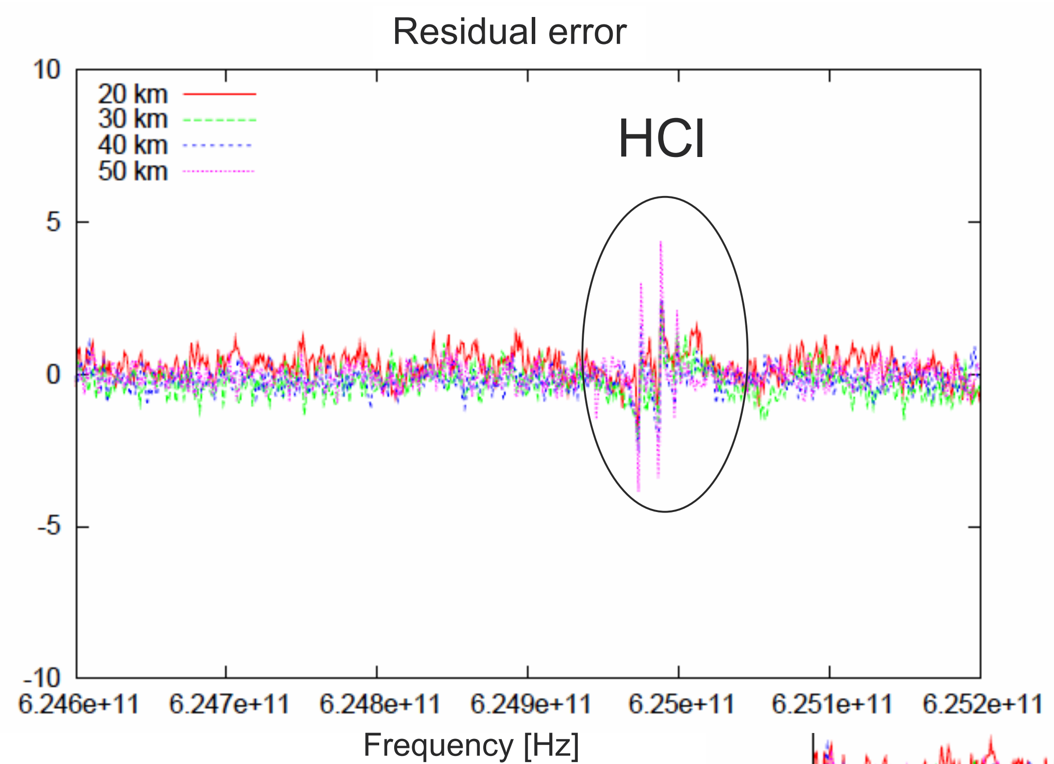
After the Correction

Residual error



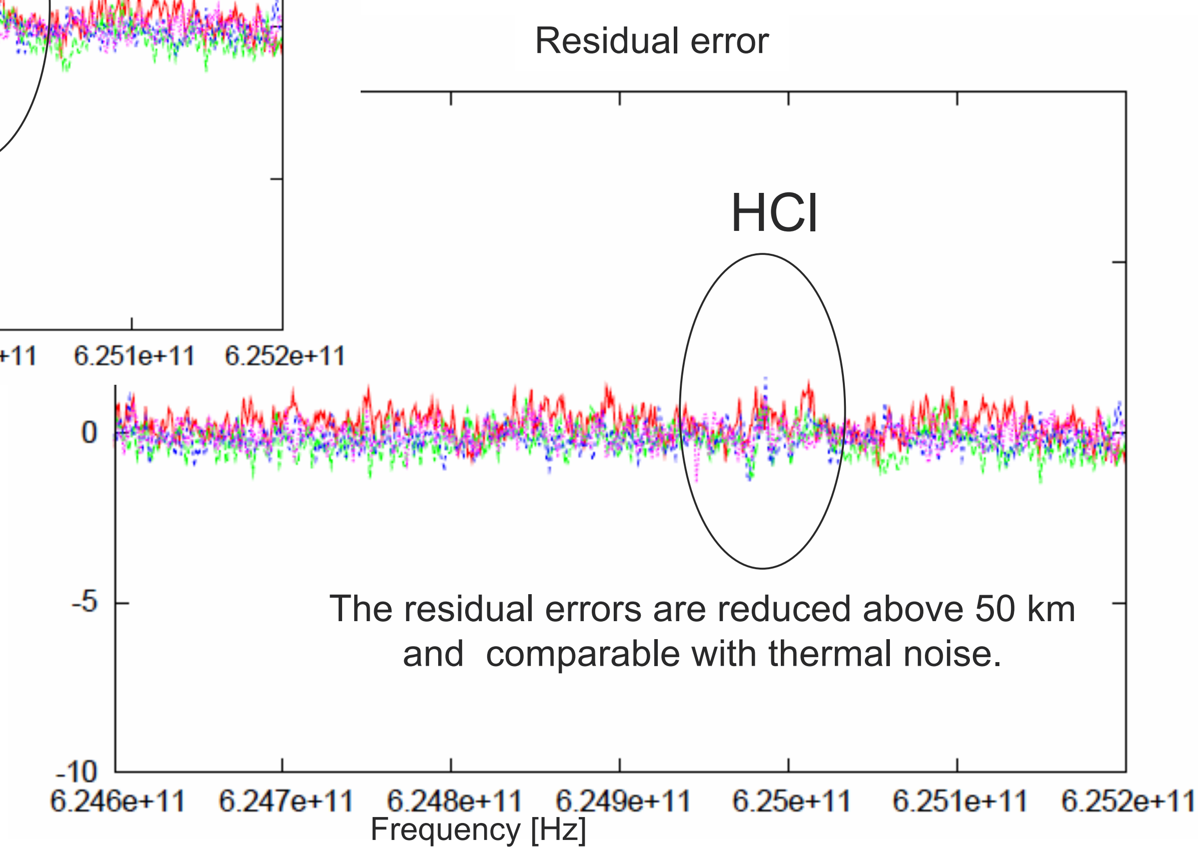


Doppler Shift by Earth's Rotation Rate



Before the Correction

After the Correction



The residual errors are reduced above 50 km and comparable with thermal noise.

Doppler shift & Instrument Functions

- **Doppler shift**
  - Velocity of the ISS : 8 km/s
  - Rotation of the earth : 460 m/s (on the equator)
  - Wind : ≲100 m/s. (Use GMAO)
- **FOV Convolution :**

  Considering the effects from tilt of ISS

$$T_A(\nu, z_0) = \int_{z_{min}}^{z_{max}} P(z, z_0) \cdot T_p(\nu, z) dz,$$

- **Fold Sidebands (Single Sideband Separator)**

$$T_{mix:i}(\nu, z_0) = \begin{bmatrix} K_{i,a}^{LSB}(\nu_{LO} - \nu_{if}, z_0) \\ K_{i,c}^{LSB}(\nu_{LO} - \nu_{if}) \end{bmatrix}^T \cdot \begin{bmatrix} T_A(\nu_{LO} - \nu_{if}, z_0) \\ T_c(\nu_{LO} - \nu_{if}) \end{bmatrix} + \begin{bmatrix} K_{i,a}^{USB}(\nu_{LO} + \nu_{if}) \\ K_{i,c}^{USB}(\nu_{LO} + \nu_{if}) \end{bmatrix}^T \cdot \begin{bmatrix} T_A(\nu_{LO} + \nu_{if}, z_0) \\ T_c(\nu_{LO} + \nu_{if}) \end{bmatrix}$$

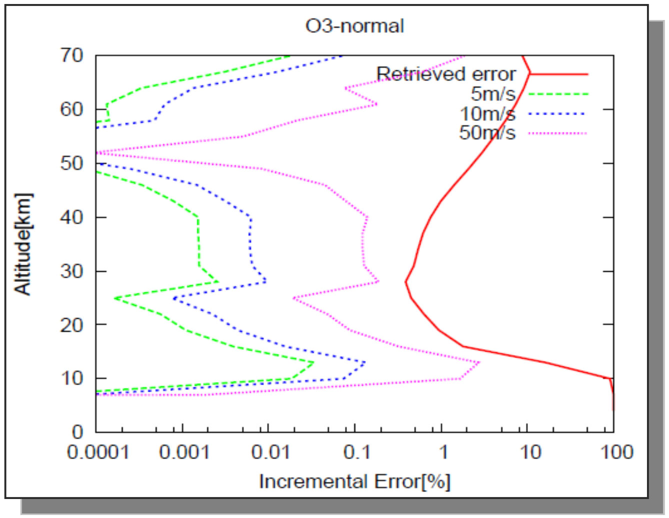
$$K_{i,j}^{LSB,USB}(\nu, T) = \frac{1 + \alpha(T)^2 + 2\alpha(T) cos\left(\frac{m\pi\nu}{\nu_0(T)}\right)}{4}.$$

- **Channel Average:** *Considering channel dependence*

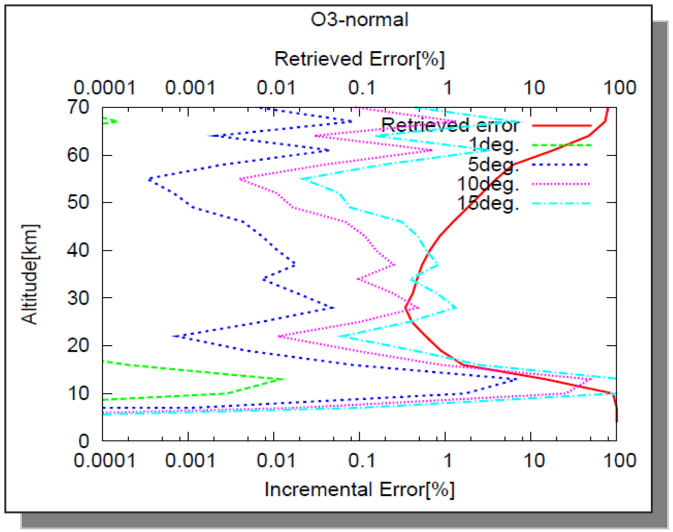
$$T_{AOS(l)}(\nu_j, z_0) = \frac{\int_{\nu_{min}}^{\nu_{max}} H_{AOS(l)}(\nu - \nu_j) \cdot T_{mix(k)}(\nu, z_0) d\nu}{\int_{\nu_{min}}^{\nu_{max}} H_{AOS(l)}(\nu - \nu_j) d\nu}.$$

$$H_{AOS(l)}(\nu - \nu_j) = \sum_{j-1}^{N_j} \frac{A_{i,j}}{w_{i,j}\sqrt{\pi/2}} \cdot exp\left(-2\frac{(\nu - \nu_j - xc_{i,j})^2}{w_{i,j}^2}\right).$$

Effects of wind



Effects of tilt of antenna scan axis



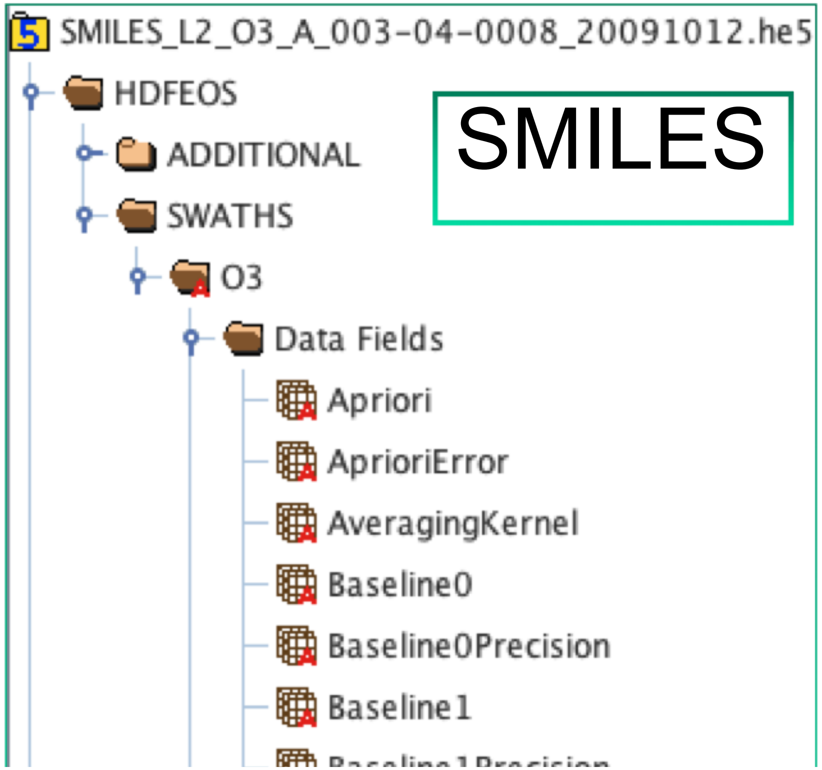
L2 Product dataset

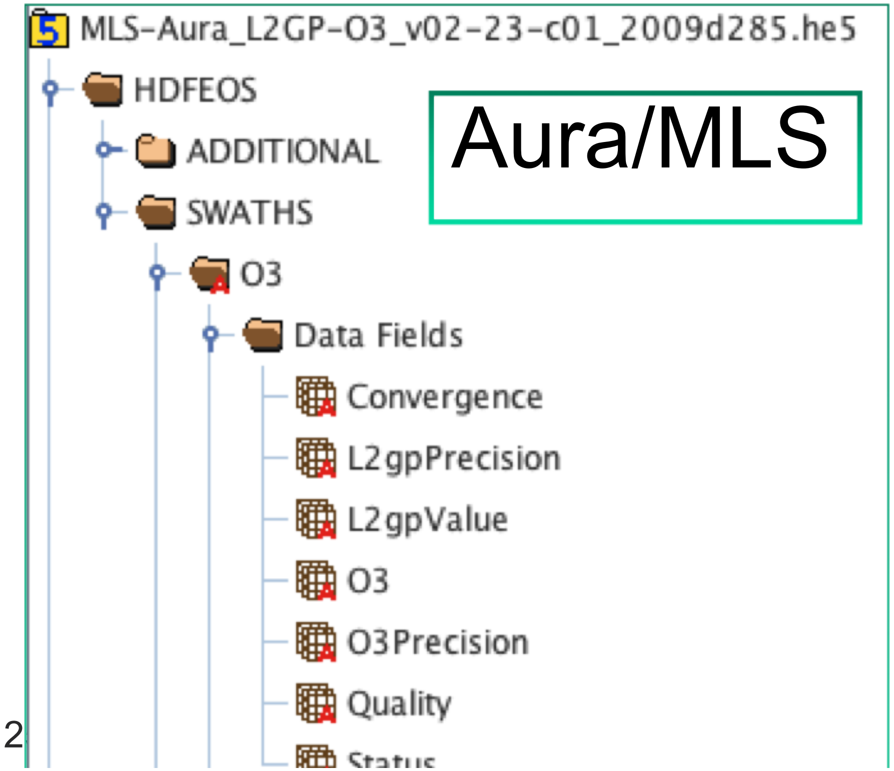
Data: profile, precision, location, time, status….

1 file /　day　/ molecule (11MB / day)

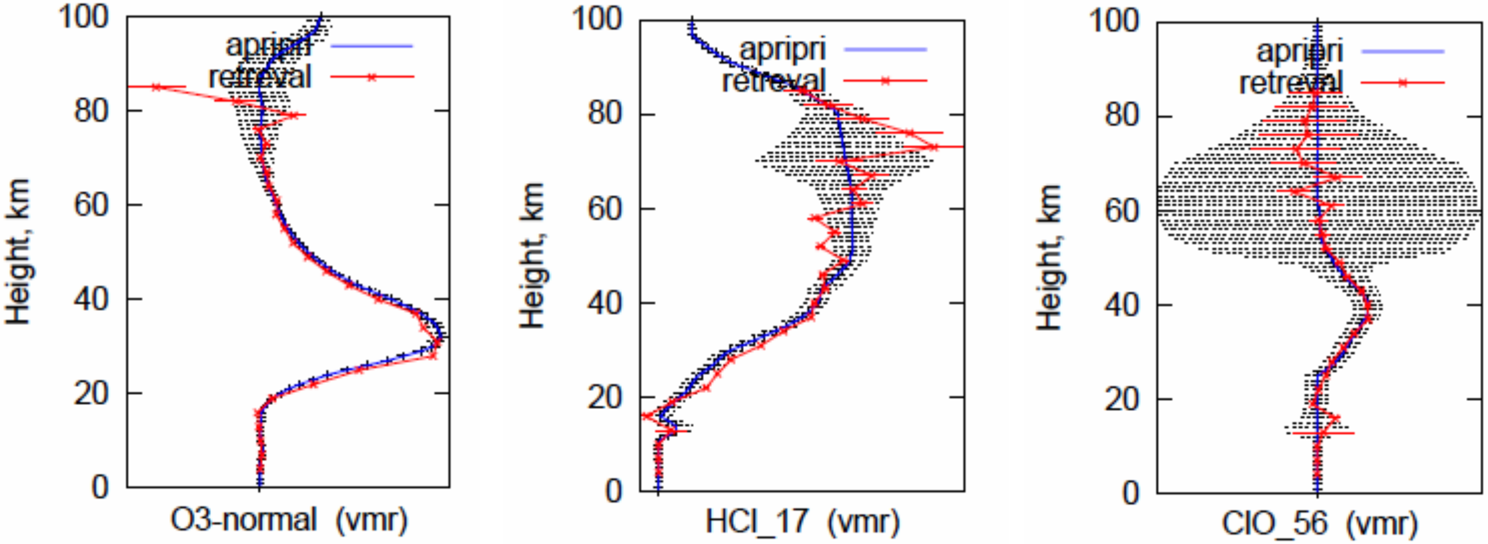
Data format: EOS-HDF (version 5)

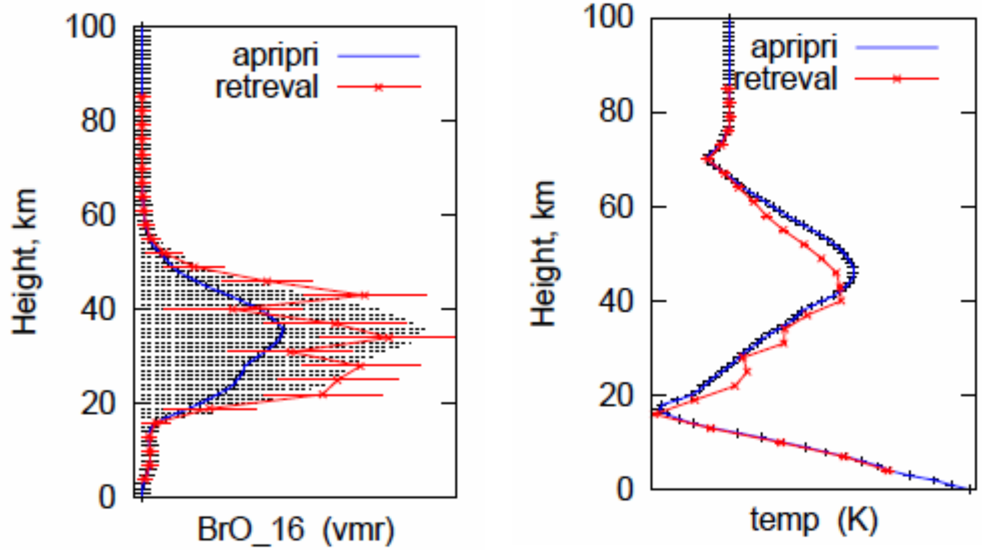
→ Compatible format with Aura/MLS





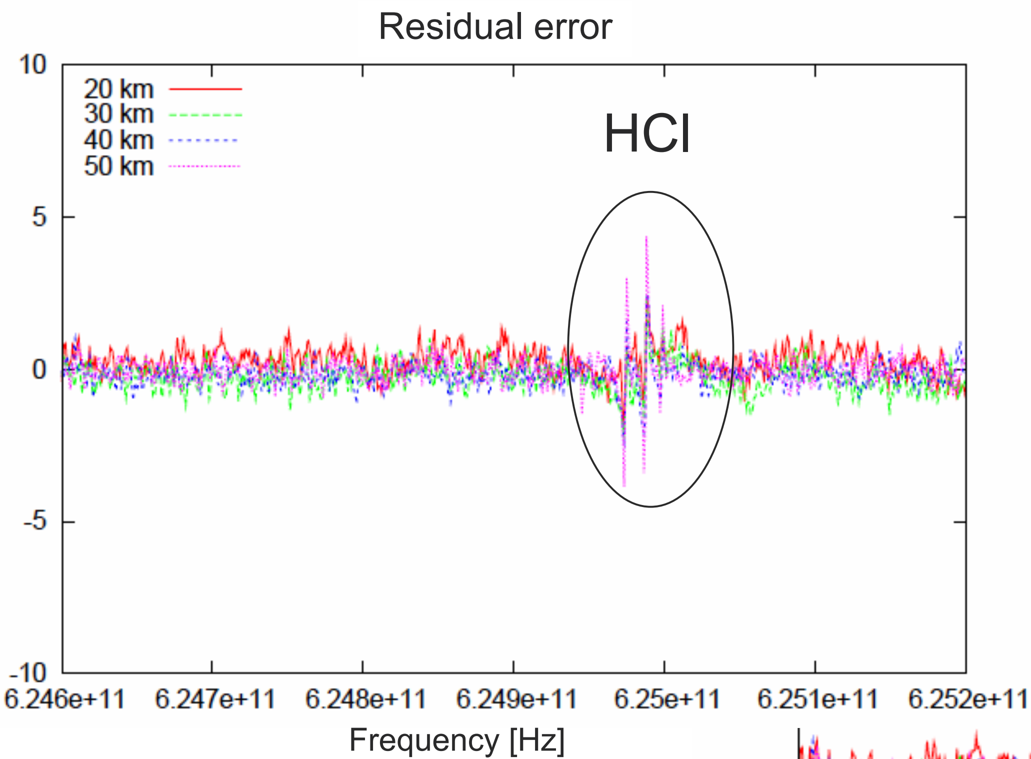
Retrieval Results





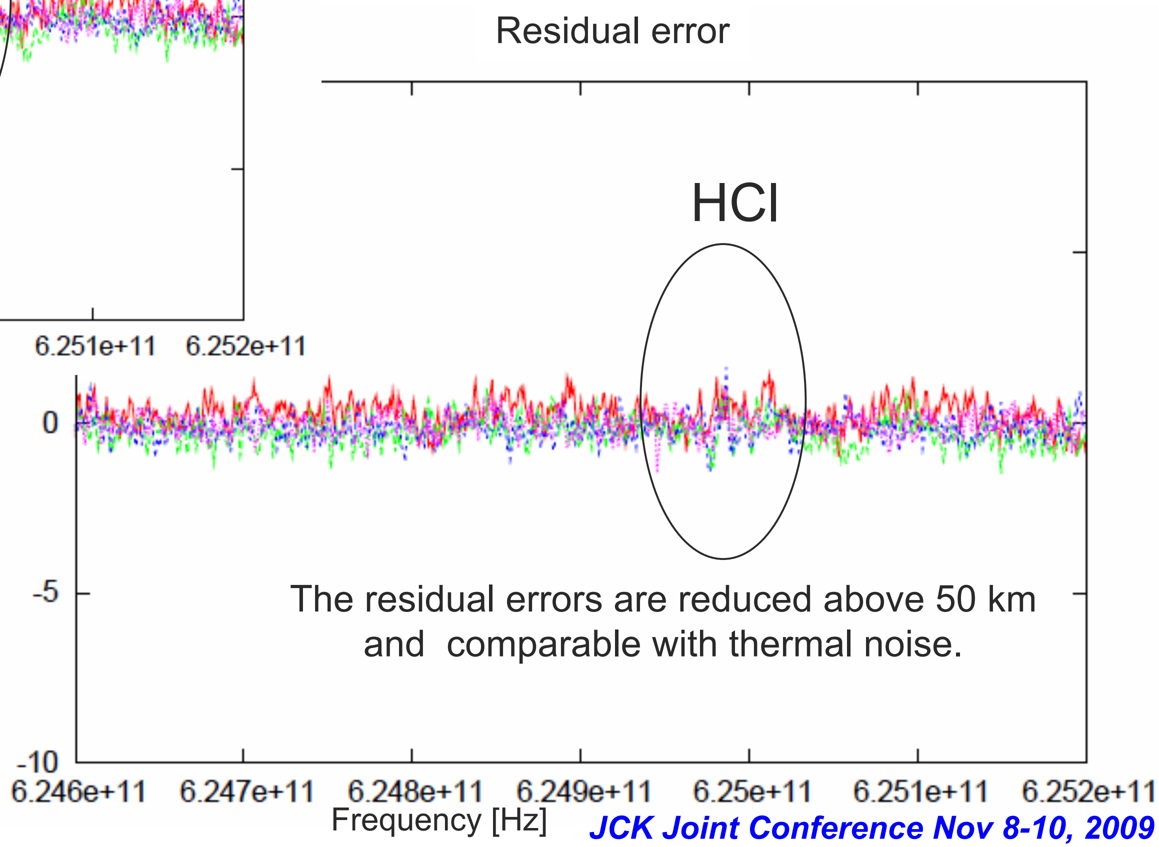
2009.10.12
Latitude 13.6 [deg]
Longitude -5.3 [deg]
Local time 15:20
Solar zenith angle 90[deg]

Doppler Shift by Earth's Rotation Rate



Before the Correction

After the Correction



Algorithm for Noisy Product

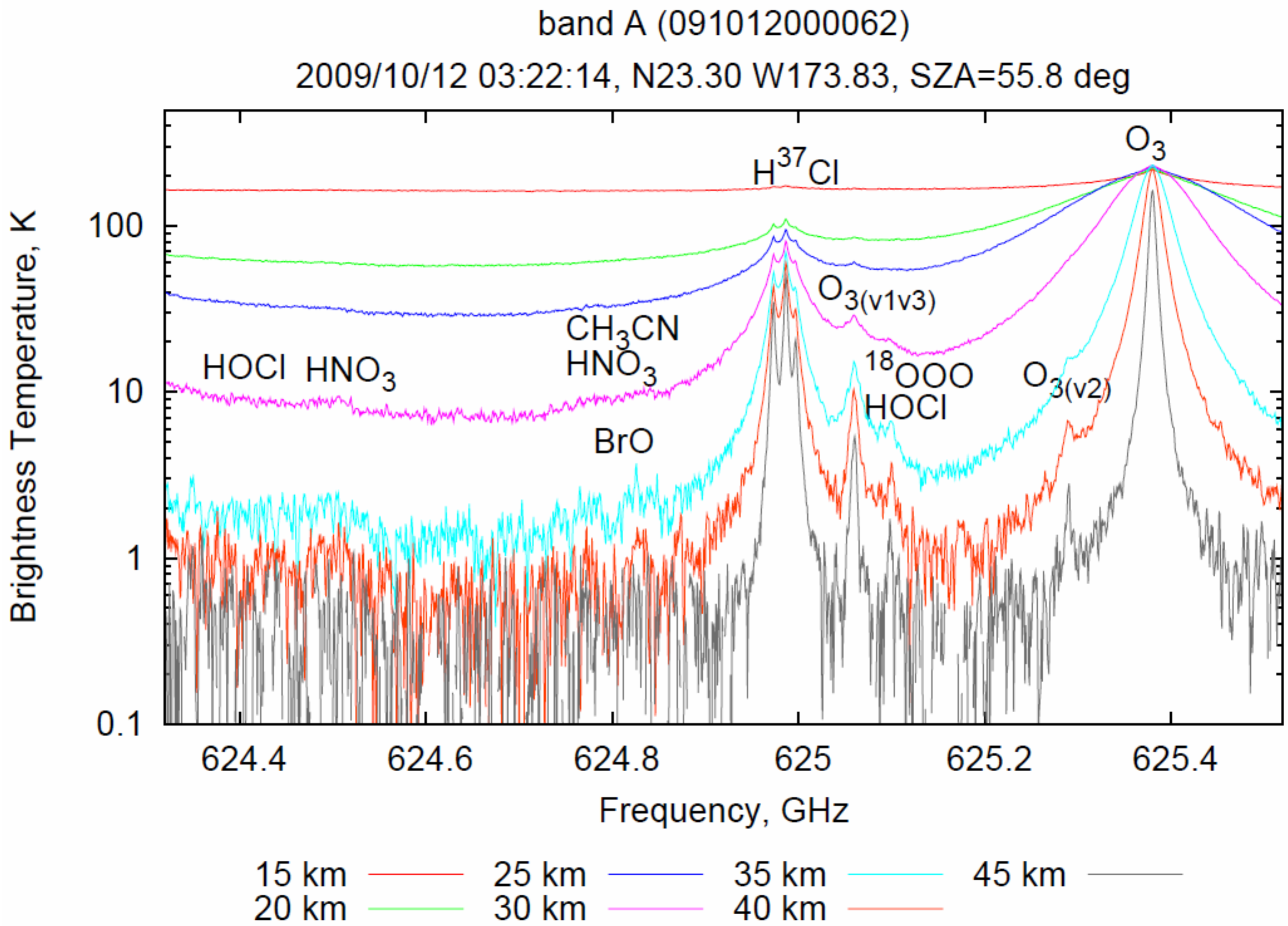
- To avoid the bias from a priori, we retrieve the multi-scan data simultaneously [Livesey,2004]. i.e. The observation data $\mathbf{y_i}$ (i=1~N), the weighting function $\mathbf{K_i}$, the reference spectra $\mathbf{f_i}$, and the covariance matrix of the measurements $\mathbf{S_{yi}}$ are represented by :

$$\mathbf{y} = \begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \vdots \\ \mathbf{y}_N \end{pmatrix}, \quad \mathbf{f} = \begin{pmatrix} \mathbf{f}_{i1} \\ \mathbf{f}_2 \\ \vdots \\ \mathbf{f}_N \end{pmatrix}, \quad \mathbf{K} = \begin{pmatrix} \mathbf{K}_1 \\ \mathbf{K}_2 \\ \vdots \\ \mathbf{K}_N \end{pmatrix}, \quad \mathbf{S}_y = \begin{pmatrix} \mathbf{S}_{y1} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{S}_{y1} & \mathbf{0} & \vdots \\ \vdots & \mathbf{0} & \ddots & \mathbf{0} \\ \mathbf{0} & \cdots & \mathbf{0} & \mathbf{S}_{y1} \end{pmatrix}$$

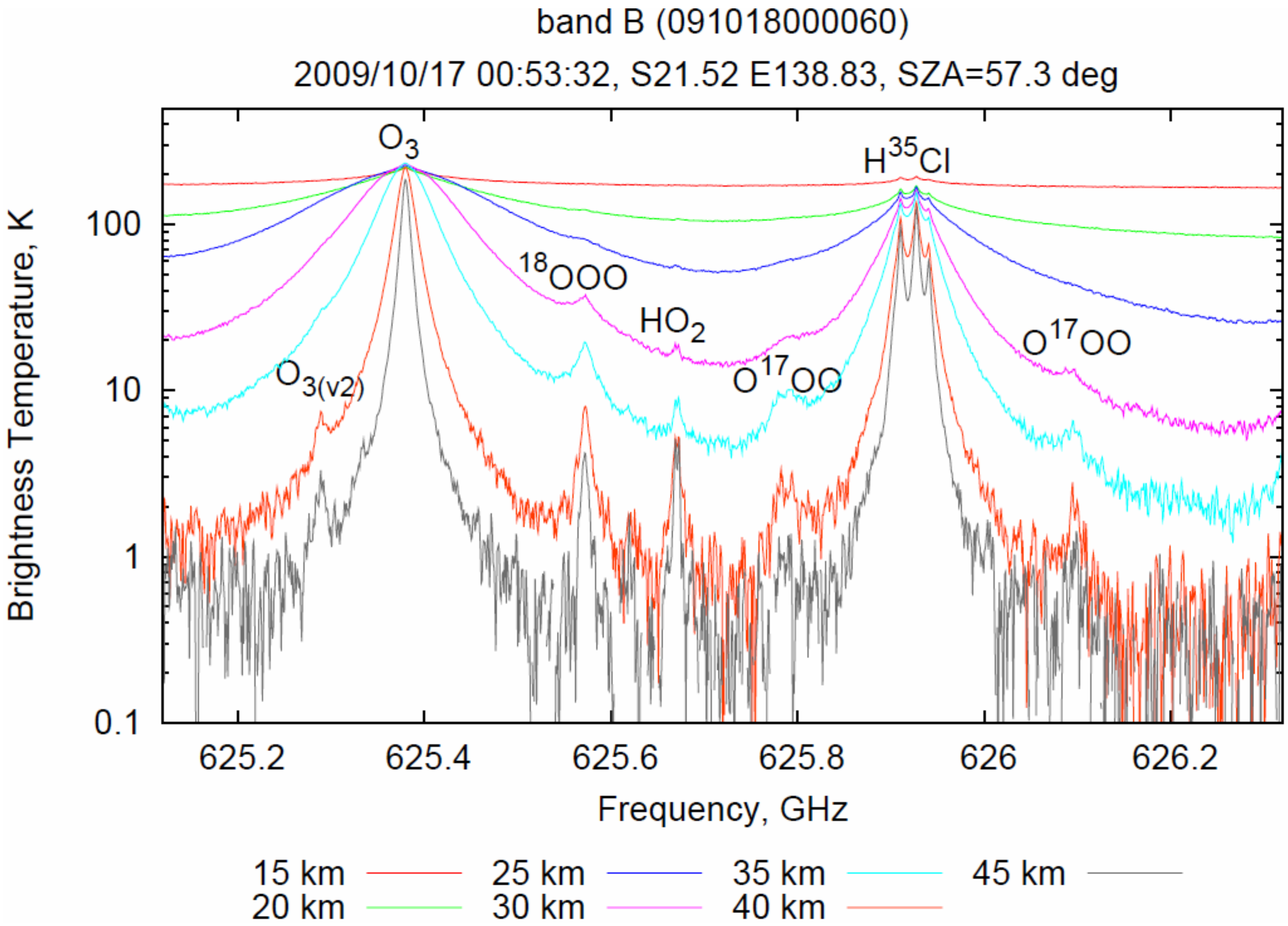
- To reduce the load of the system, we calculate below matrices and vectors, $\mathbf{K_i^T S_{yi} K_i}$ and $\mathbf{K_i^T S_{yi}(y_i-f_i)}$ foe each scan and save, because the size of these matrices and vectors are small.

Reference：N J. Livesey and W. Van Snyder, EOS MLS Retrieval Processes Algorithm Theoretical Basis, 2004

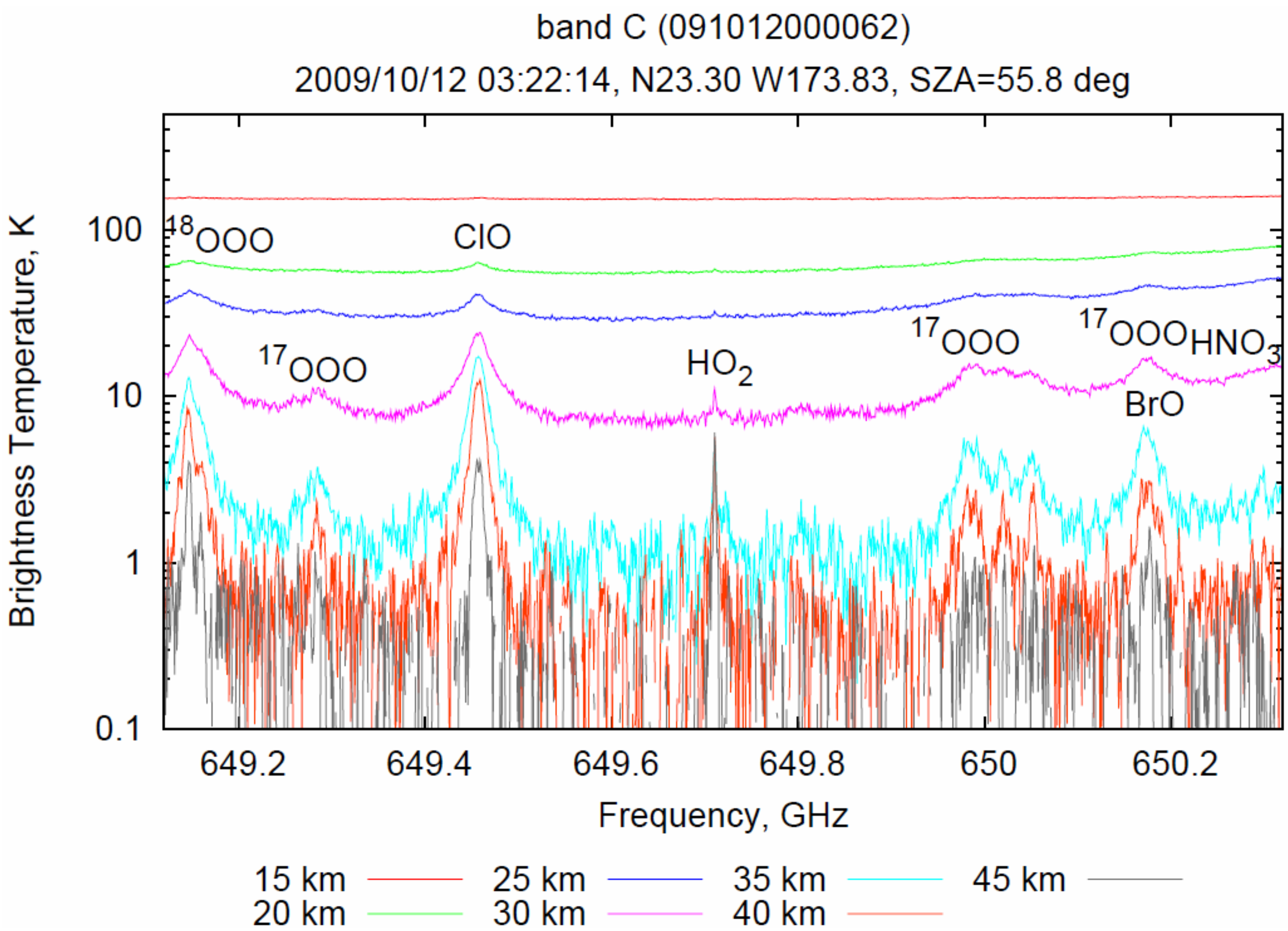
SMILES Level 1B Data – Band A



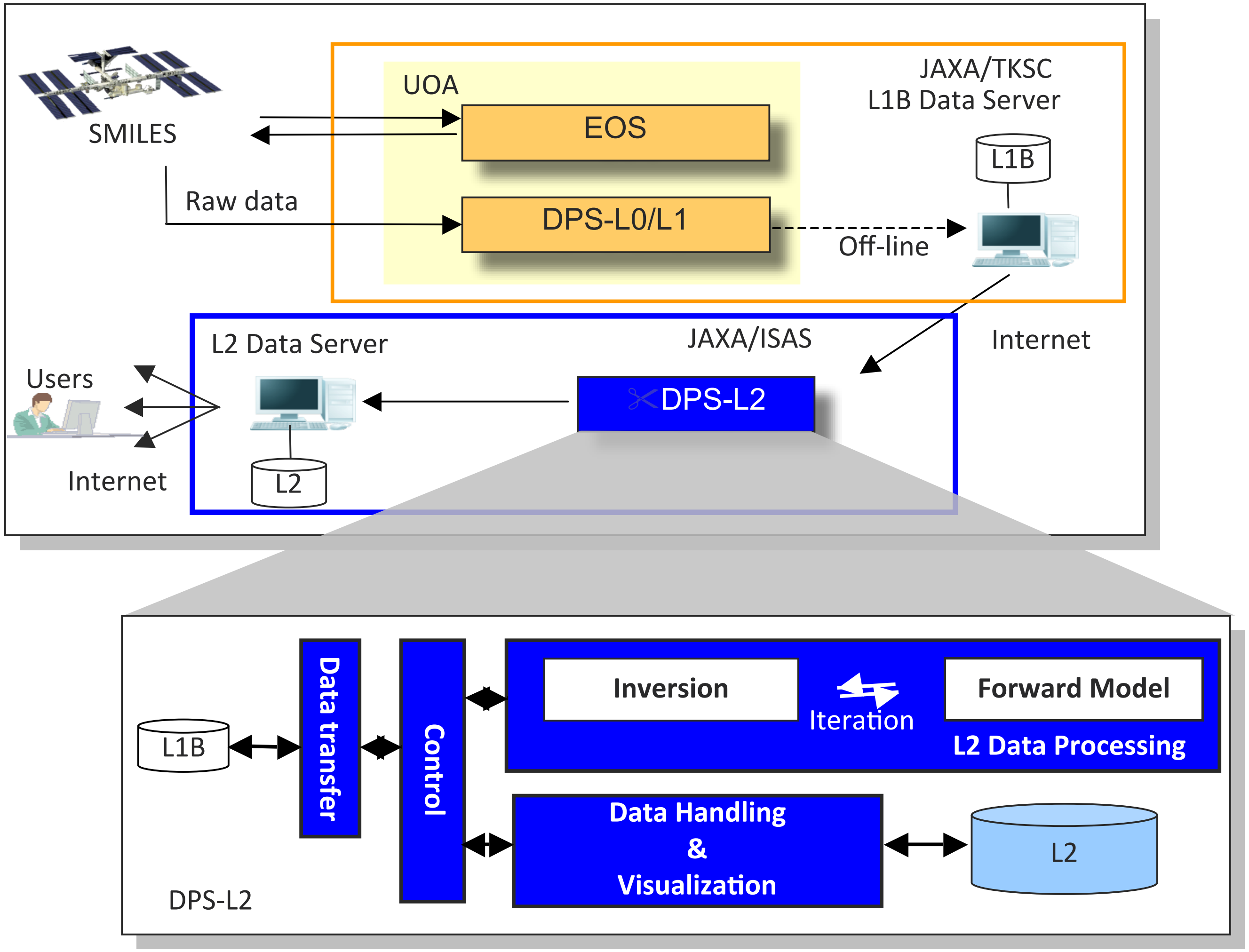
SMILES Level 1B Data – Band B



SMILES Level 1B Data – Band C



JEM/SMILES Data Flow

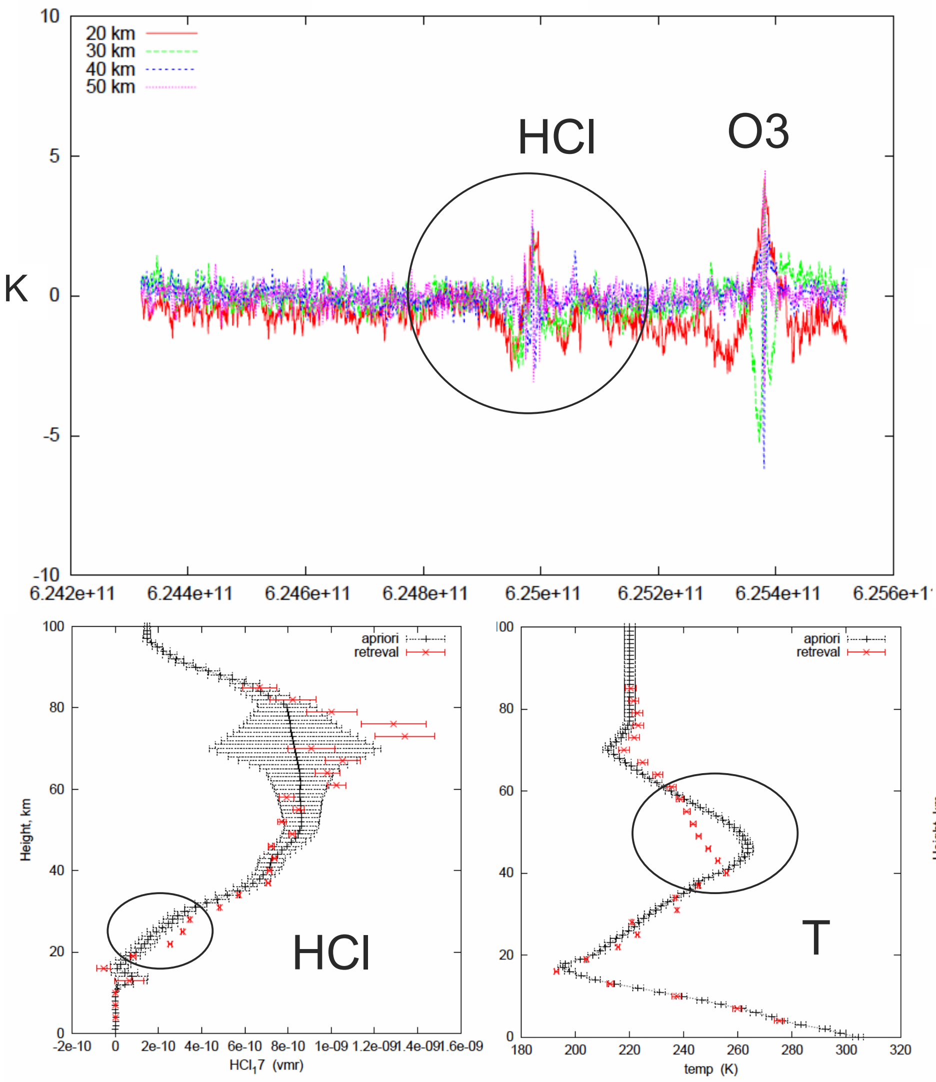


- Downlinked raw data from the SMILES will be received by the DPS-L0/L1 at User Operation Area (UOA) on Tsukuba Space Center (TKSC).
- The DPS-L0/L1 processes the raw data consisting of house keeping (HK) data and mission data to brightness temperature (level 1B data) in near-real-time.
- The DPS-L2 produces the vertical profiles of target species called level 2 data in near real time and distributes the level 2 data to data users by a Web server.

Pressure Broadening Parameters

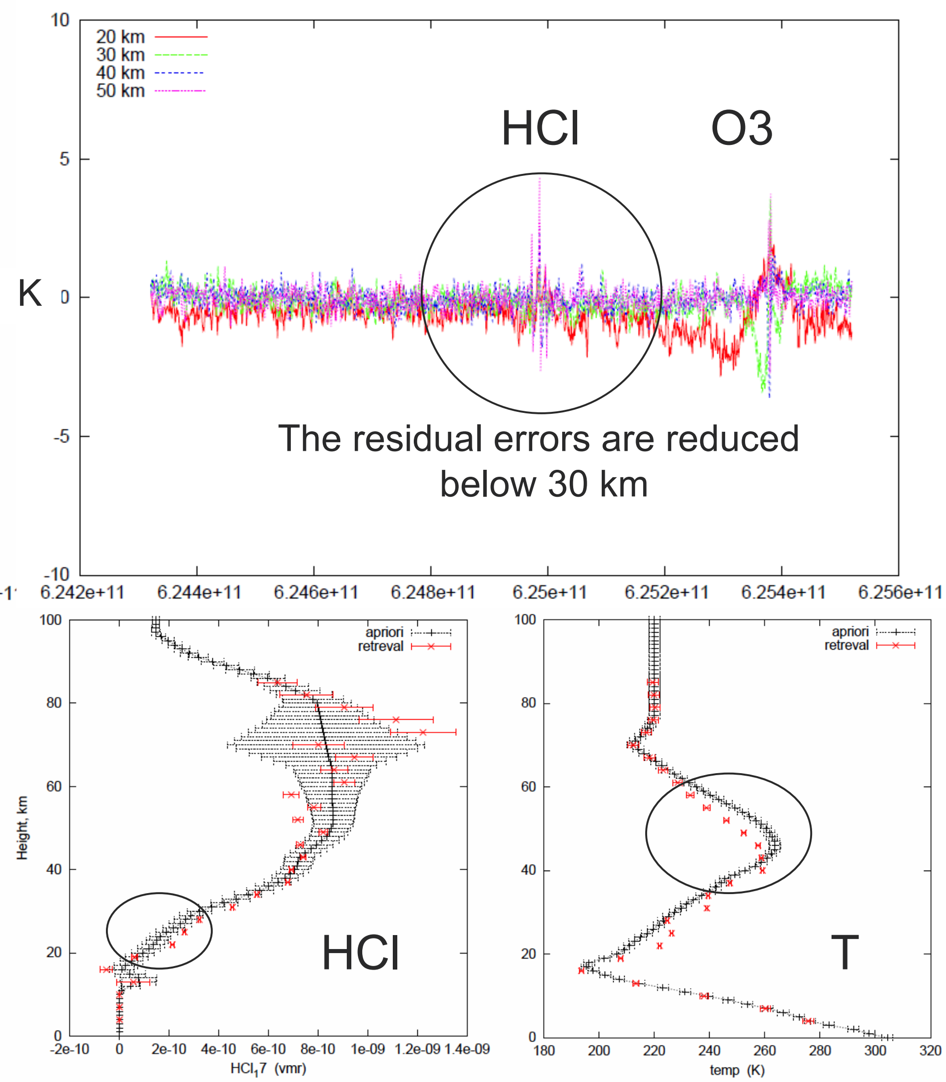
Before the Correction

Residual error



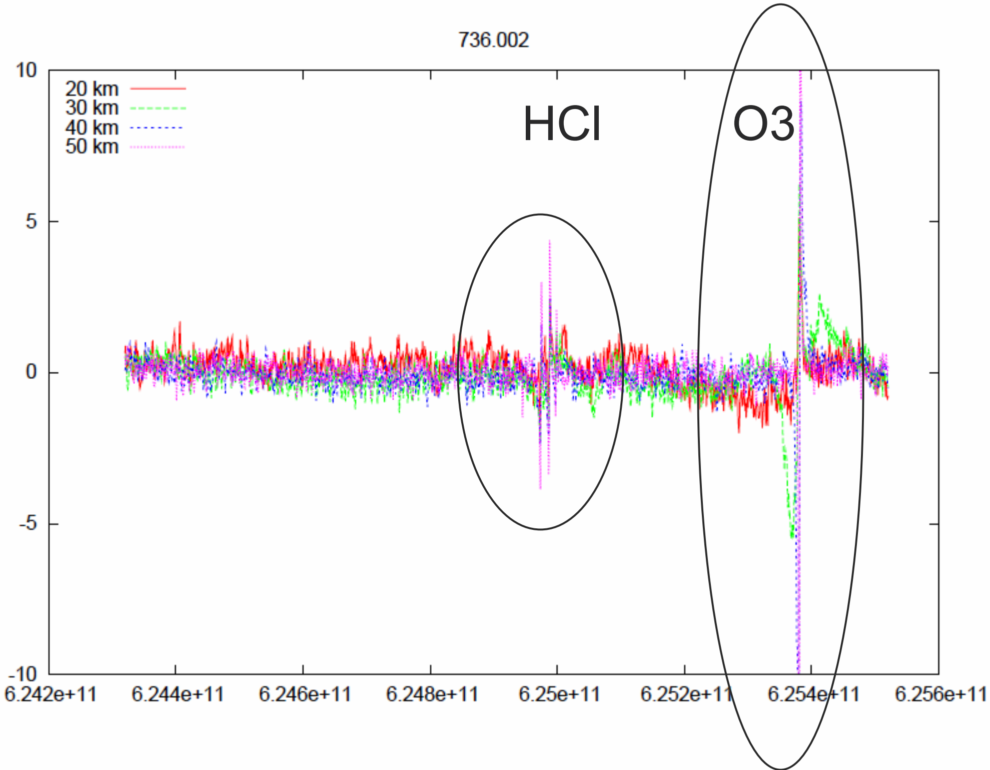
After the Correction

Residual error



Earth's Rotation Rate

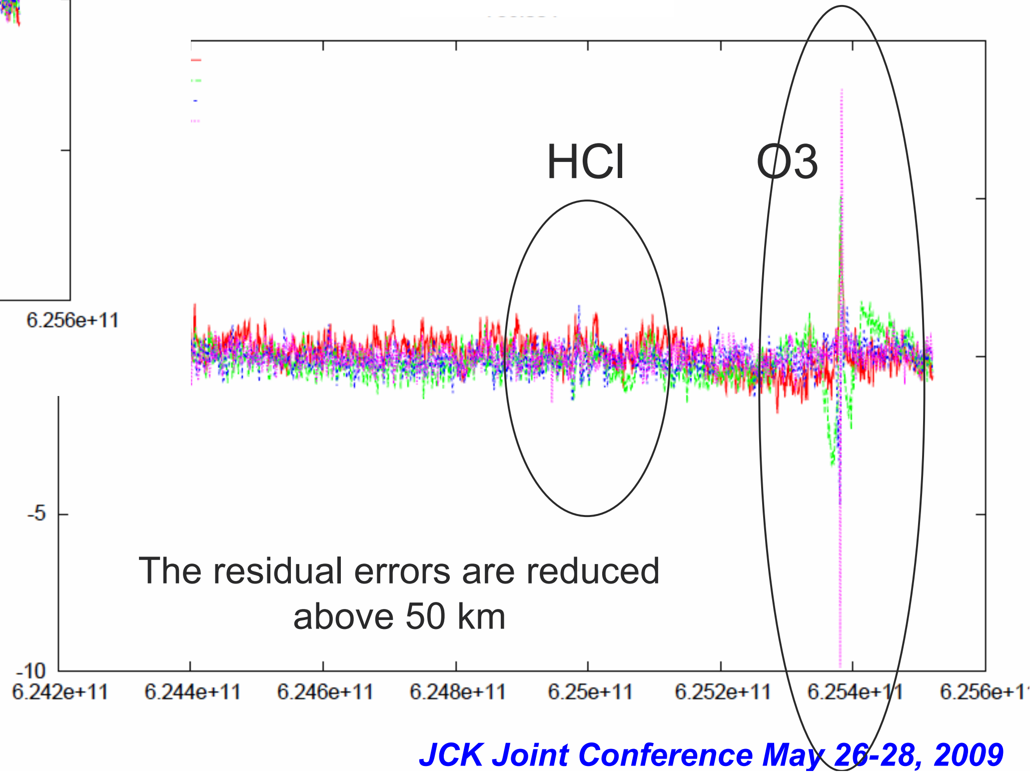
Residual error



Before the Correction

After the Correction

Residual error



The residual errors are reduced above 50 km

Doppler shift & Instrument Functions

Doppler shift

- Velocity of the ISS : 8 km/s
- Rotation of the earth : 460 m/s (on the equa
- Wind : ≲100 m/s. (

FOV Convolution :

Considering the effects from tilt of ISS

$$T_A(\nu, z_0) = \int_{z_{min}}^{z_{max}} P(z, z_0) \cdot T_p(\nu, z) dz,$$

Fold Sidebands (Single Sideband Separator)

$$T_{mix:i}(\nu, z_0) = \begin{bmatrix} K_{i,a}^{LSB}(\nu_{LO} - \nu_{if}, z_0) \\ K_{i,c}^{LSB}(\nu_{LO} - \nu_{if}) \end{bmatrix}^T \cdot \begin{bmatrix} T_A(\nu_{LO} - \nu_{if}, z_0) \\ T_c(\nu_{LO} - \nu_{if}) \end{bmatrix} + \begin{bmatrix} K_{i,a}^{USB}(\nu_{LO} + \nu_{if}) \\ K_{i,c}^{USB}(\nu_{LO} + \nu_{if}) \end{bmatrix}^T \cdot \begin{bmatrix} T_A(\nu_{LO} + \nu_{if}, z_0) \\ T_c(\nu_{LO} + \nu_{if}) \end{bmatrix}$$

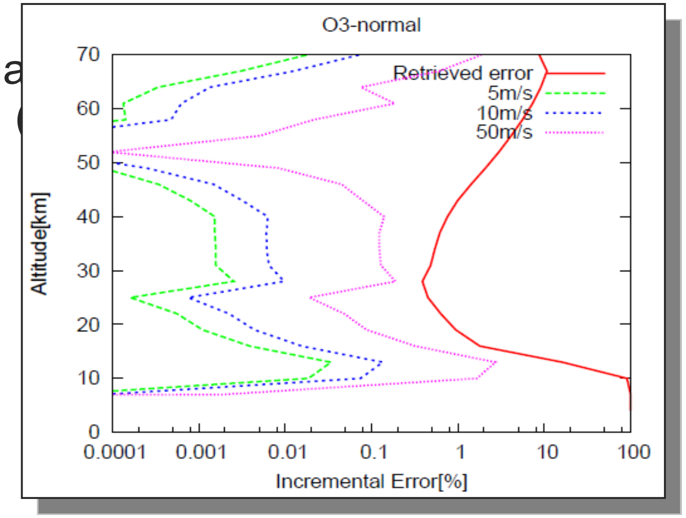
$$K_{i,j}^{LSB,USB}(\nu, T) = \frac{1 + \alpha(T)^2 + 2\alpha(T) cos\left(\frac{m\pi\nu}{\nu_0(T)}\right)}{4}.$$

Channel Average: *Considering channel dependence*

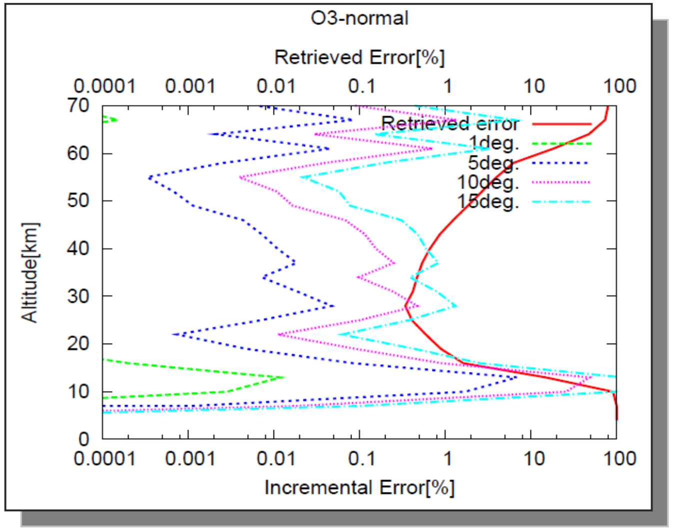
$$T_{AOS(l)}(\nu_j, z_0) = \frac{\int_{\nu_{min}}^{\nu_{max}} H_{AOS(l)}(\nu - \nu_j) \cdot T_{mix(k)}(\nu, z_0) d\nu}{\int_{\nu_{min}}^{\nu_{max}} H_{AOS(l)}(\nu - \nu_j) d\nu}.$$

$$H_{AOS(l)}(\nu - \nu_j) = \sum_{j-1}^{N_j} \frac{A_{i,j}}{w_{i,j}\sqrt{\pi/2}} \cdot exp\left(-2\frac{(\nu - \nu_j - xc_{i,j})^2}{w_{i,j}^2}\right).$$

Effects of wind



Effects of tilt of antenna scan axis

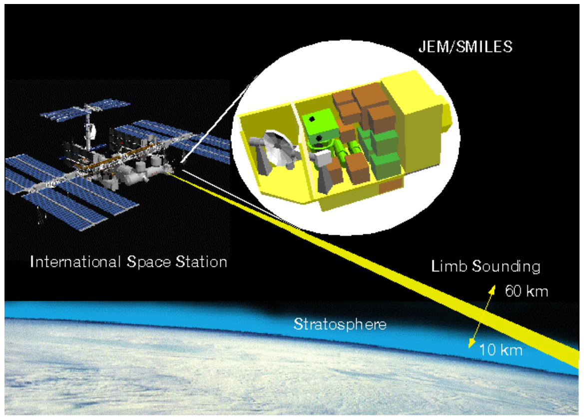


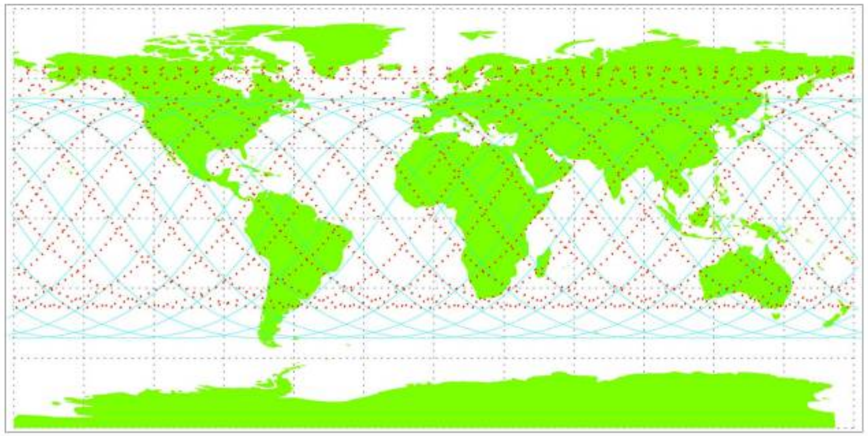
Outline of JEM/SMILES

- The Superconducting Submillimeter-wave Limb-Emission Sounder (SMILES) had been launched and aboard the Japanese Experiment Module (JEM) of the International Space Station (ISS) in **Sep, 2009**.
- The SMILES carries 4K cooled **Superconductor-Insulator-Superconductor (SIS) mixers** to demonstrate a highly sensitive instrument for submillimeter limb-emission sounding.
  - Nominal latitude coverage: **38S - 65N**
  - Observation number : 1600 / day (105 observation / orbit, 15.5 orbit / day)
  - Observation band number: 3 (band A, B, C)

Standard products

O_3, HCl, ClO, HNO_3, CH_3CN, HO_2, HOCl, BrO, O_3 isotopes
(in the middle atmosphere)





Contents

- Outline of the SMILES Level 2 data processing system (DPS-L2) in ISAS/JAXA
- Retrieval algorithm of the DPS-L2
- Study of the observation capability for target species.
- Improvements of the data quality by using Level 1B data (calibrated spectra)

- Recent status of the Level 2 products
- Distribution system of the Level 2 data

Etc.

- S6-05 Masato SHIOTANI*, Masahiro TAKAYANAGI and JEM/SMILES MISSION TEAM: CURRENT STATUS OF SUPERCONDUCTING SUBMILLIMETER-WAVE LIMB-EMISSION SOUNDER (SMILES)
- S6-06 **Chikako TAKAHASHI*, Chihiro MITSUDA, Makoto SUZUKI, Yoshitaka IWATA, Hiroo HAYASHI, Koji IMAI, et al.: CAPABILITY STUDY FOR ATMOSPHERIC MINOR SPECIES WITH JEM/SMILES**
- S6-07 Yasuko KASAI*, Philippe BARON, Jana MENDROK, Satoshi OCHIAI, Takeshi MANABE, et al.: OBSERVATION CAPABILITIES OF SUPERCONDUCTIVE SUBMILLIMETER-WAVE LIMB-EMISSION SOUNDER (SMILES) ONBOARD INTERNATIONAL SPACE STATION
- S6-08 **Chihiro MITSUDA*, Chikako TAKAHASHI, Makoto SUZUKI, Hiroo HAYASHI, Takuki SANO, et al.: DEVELOPMENT OF JEM/SMILES LEVEL 2 DATA PROCESSING SYSTEM**