Diurnal variations of stratospheric/ mesospheric trace species, ClO, BrO, and HO_2 derived from 4K cooled submm limb sounder ISS/JEM/SMILES

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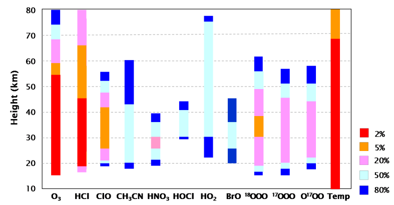
Scientific targets of SMILES

1. **Inorganic Chlorine chemistry**
   - **ClO to HCl ratio**
     (O_3 trend in the US)
   - **HOCl production**
     (O_3 trend in the LS)
   - **Global ClO**
     (background ClO)
2. **Bromine budget (very short-lived source gas issue)**
3. **HO_x budget**

etc.

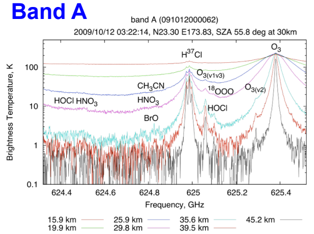
Simulated SMILES observation performance



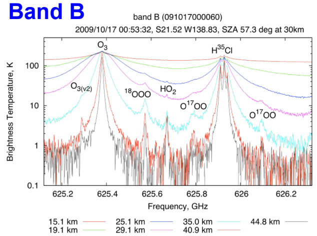
Error estimation for the mid-latitude case based on the single scan measurement

Two Bands among Band A, B, C can be observed.

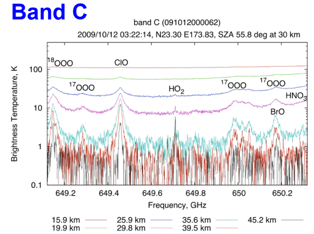
Band A



Band B



Band C



Frequency region has been selected by engineering interest, as high as possible, but 625-626 GHz region is the only frequency to measure HCl below 1 THz.

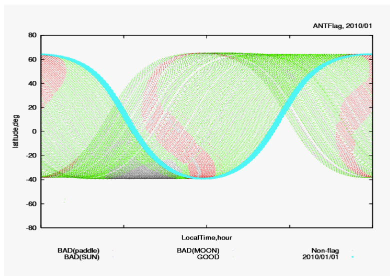
At 600 GHz troposphere is opaque in limb.

Tsys ~ 350 K, and Noise floor is ~0.4 K, given by

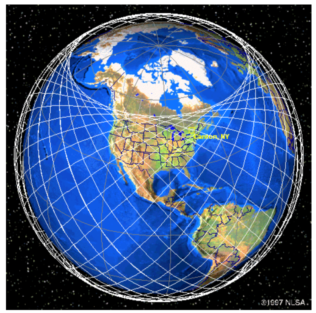
$$NE\Delta T_B = \frac{T_{sys} + T_{Atm}}{\sqrt{\Delta\nu \bullet \tau}}$$

ISS Orbit plane rotates in ~90 days, 45 days for diurnal coverage. It will be good platform for diurnal variation study and solar occultation, such as ISS/SAGE-III (2015 ?).

Actual Local Time Coverage of SMILES in January 2010. Blue: January 1st. Red: not observed.



ISS orbit
- Low altitude: 350 km
- Moderate inclination: 51.2°



Japanese HTV vehicle (big Beer can) just docke

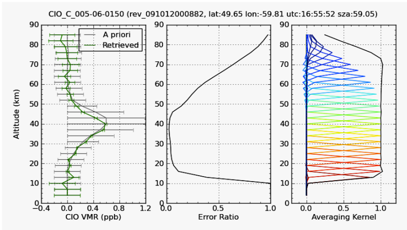
ClO

Retrieval, validation, diurnal cycle, and [night]/[day] within Arctic polar vortex

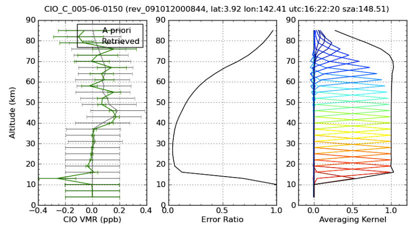
Single Scan Retrieval of ^{35}ClO

BAND C, *a priori* = MLS

Daytime ClO Retrieval Example. (19-70km, ~.01 ppb precision in strstosphere)



Nighttime ClO Retrieval Example

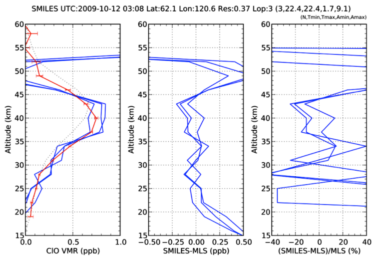


Validation of SMILES ClO with MLS 2.2

MLS coincidence, ΔSZA < 2°, **SMILES ver.150 release candidate.**

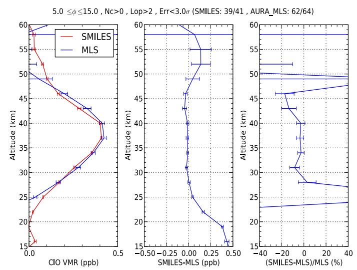
SMILES ClO (since ISAS L2 ver. 32) is adequate for science application.

Coincidence event on Oct. 12, 2009 SMILES, MLS at 62.1°N 120.6°E (The first coincidence).



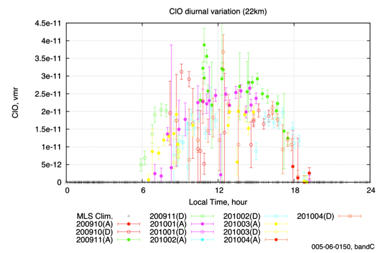
Coincidence Statistics 5N-15N, 39 SMILES vs. 62 MLS profiles.

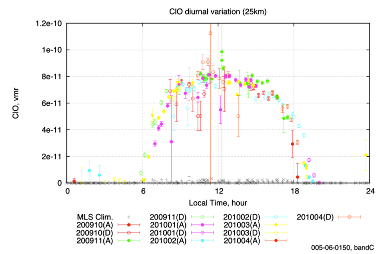
< 10% agreement with MLS 2.2 between 25-42 km

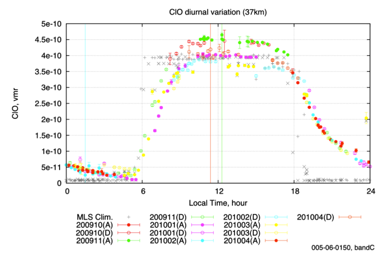


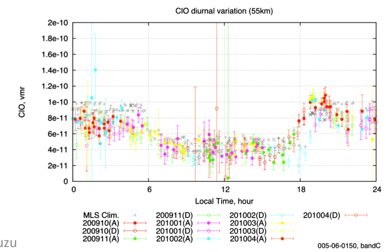
Diurnal variation at equatorial region (10N-10S)

22 km, 25 ppt ?, 25 km, 80 ppt, 37 km, 400 ppt, 55 km

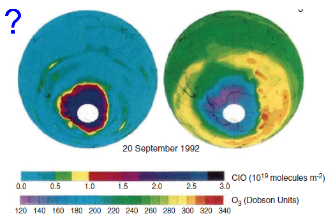






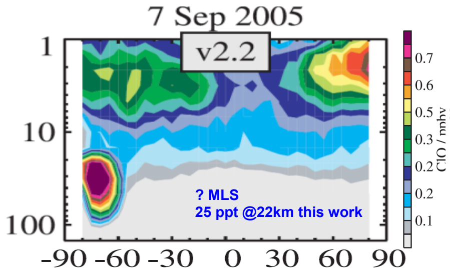


Global ClO distribution

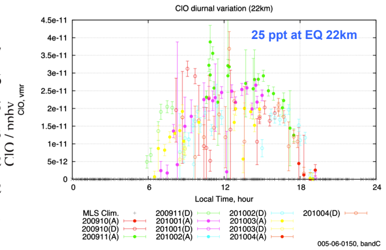


The background ClOx level is important to quantify the in-situ O3 loss at mid-latitudes. However, its global distribution has not been observed with high precision.

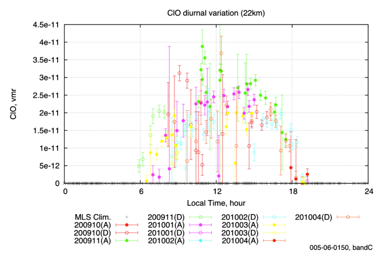
SMILES provides global ClO distribution with high precision. Furthermore, measurements of ClO, HCl, HOCl, and HO_2 can provide important insights into the Cly chemistry.

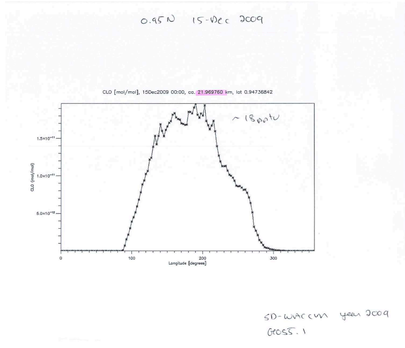


Santee et al., 2008



Comparison 22km ClO with CGCM (WACCAM) at EQ.





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Diurnal variation, previous works and SMILES at 40 km.

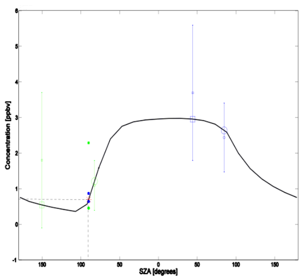
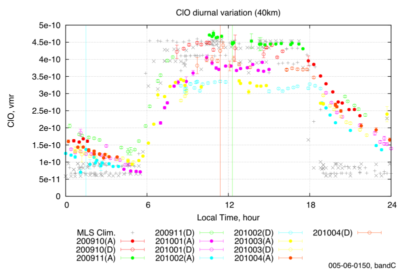


Fig. 6. An illustration of how the scale factors are calculated from Eq. (2) for measurements at $z = 40$ km. ClO diurnal cycle (black line) as a function of time (SZA). Satellite observations $Y_{obs}(\theta_{obs}, z)$ are symbolized by either an open small circle (SMR) or an open small square (MLS). The observations are colour coded such that green = a.m. observations and blue = p.m. observations. The vertical solid lines are the corresponding measurement uncertainties. The large open circles correspond to $Y_{mod}(\theta_{obs}, z)$. The red asterisk is the $Y_{mod}(\theta_{mod}, z)$, where $\theta_{mod} = 90^{\circ}$ a.m. The resulting scaled measurements $Y_{scl}(\theta_{mod}, z)$ are shown as small filled circles (SMR) or squares (MLS). Corresponding scaled measurement uncertainties are not shown.

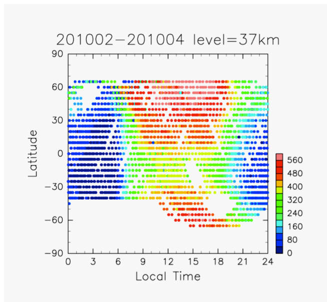


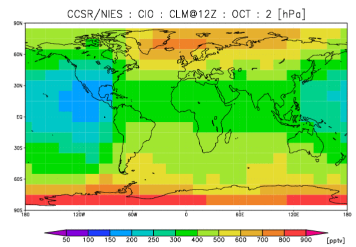
A. Jones et al, ACPD 2010

Diurnal variation of ClO

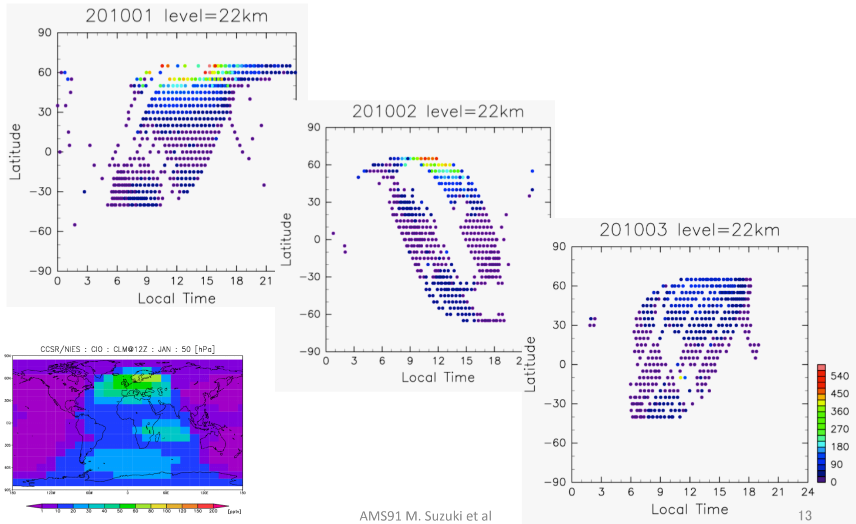
SMILES at 37 km

CCSR/NIES Model Calculation at 2 hPa





Diurnal variation of ClO at lower altitude
SMILES 22km, CCSR/NIES 50 hPa



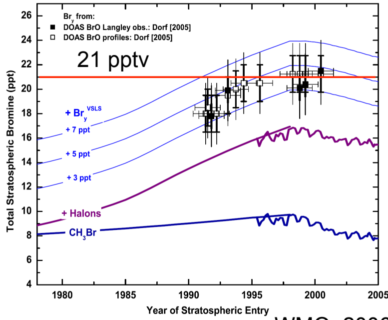
BrO

BrO retrieval

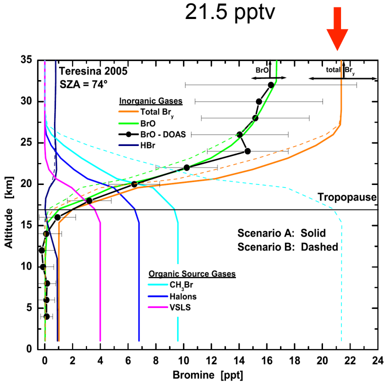
Diurnal variation

Bromine budget

21.5 pptv



WMO, 2006

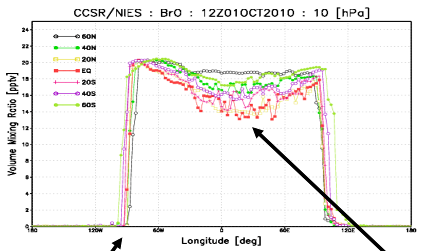


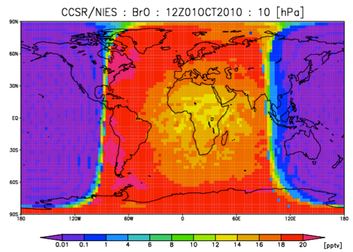
Dort et al., 2008

BrO measurements suggest that in addition to long-lived source gases (halons and methyl bromide), very short-lived ($\tau < 6$ months) source (CH_2Br_2, $CHBr_3$, etc.) gases likely contribute to Br_y by about 5 pptv. This difference can be important for O_3 in the LS.

Diurnal Variation of BrO

Akiyoshi et al.





$BrONO_2 + hv \rightarrow Br + NO_3$

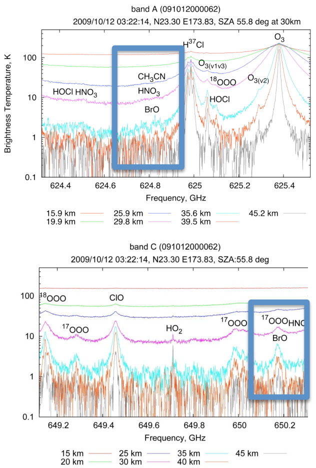
$BrO + NO \rightarrow Br + NO_2$
$BrO + hv \rightarrow Br + O$

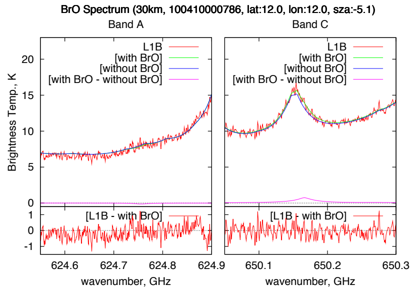
$Br + O_3 \rightarrow BrO + O_2$
$Cl + O_3 \rightarrow ClO + O_2$
$BrO + ClO \rightarrow Br + Cl + O_2$

$BrO + HO_2 \rightarrow HOBr + O_2$
$HOBr + hv \rightarrow OH + Br$

$Br + O_3 \rightarrow BrO + O_2$
$OH + O_3 \rightarrow HO_2 + O_2$

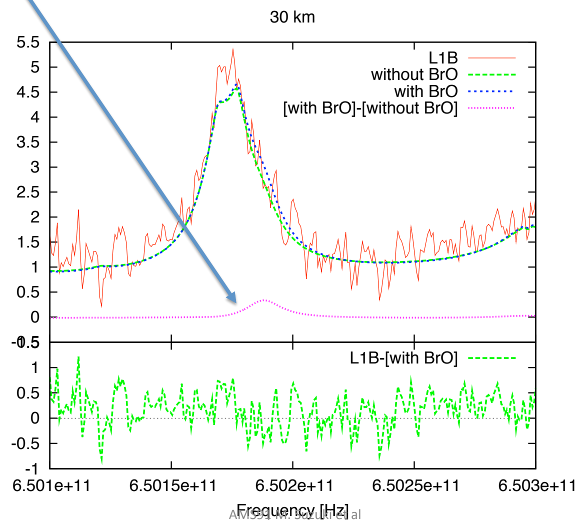
Band A: ^{81}BrO is not good.
Band C: ^{81}BrO is workable.





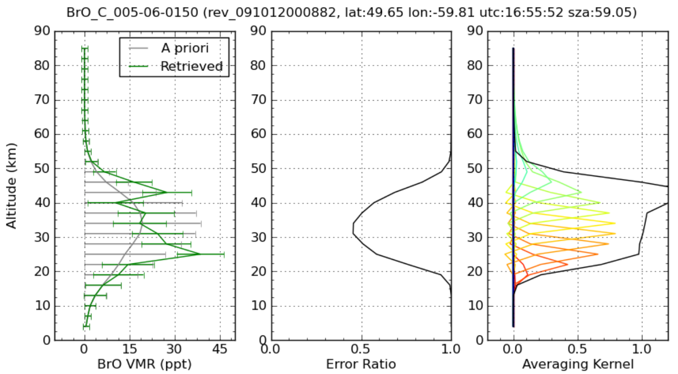
Band A (Left) BrO is clearly below detection limit. Only Band C BrO can be used for science applications.
650 GHz is not suitable for BrO retrieval. (Urban 2003)

BrO: Spectrum fitting at Band C



Single Scan Retrieval of BrO

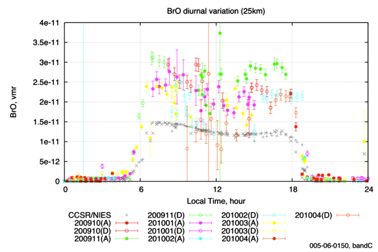
BAND C, *a priori* = NIES/CCSR 3D

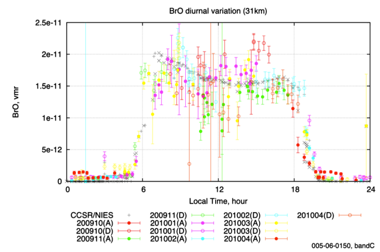


BrO diurnal variation at equatorial region (10S-10N), ver. 150

25 km, 20-30 ppt
higher group: Nov. Jan., lower: Apr.

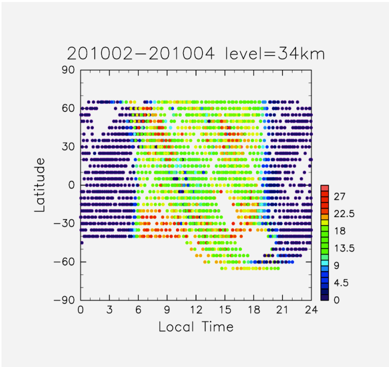
31 km, 10-20 ppt



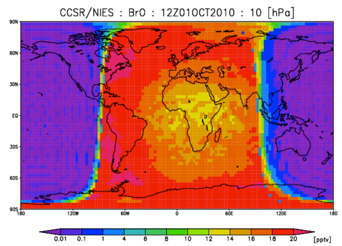


Diurnal variation of BrO

SMILES, Feb.-Apr. 34km



CCSR/NIES CGCM 10 hPa

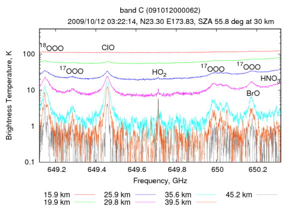


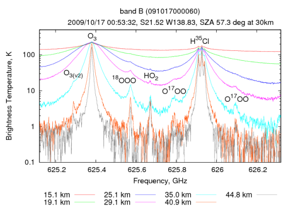
HO_2

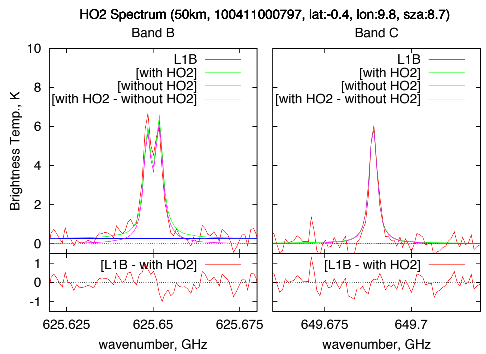
Band B, C: Internal Consistency Check for HO_2

Band B and C, HO_2 Spectral Fitting.

For ISAS operational L2, Band C HO_2 looks more stable.



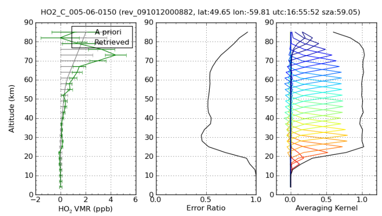




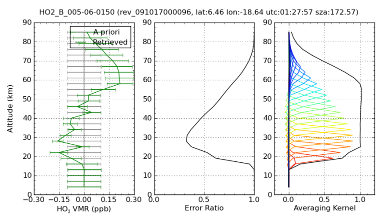
Single Scan Retrieval of HO2

BAND C, a priori = NIES/CCSR 3D

Oct. 12, 2009, SZA=59.1°, 49.7°N



Oct. 17, 2009. SZA=172.6°, 6.5°N



Validation with MLS HO_2 (underway)

MLS HO_2 averaged 2879 profiles in 29N-39N (Picket et al 2008)

SMILES single scans (9 profiles)

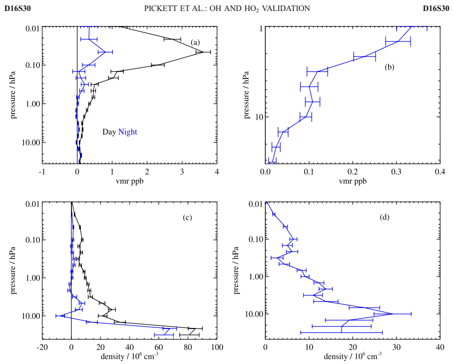
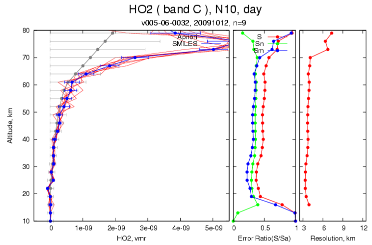
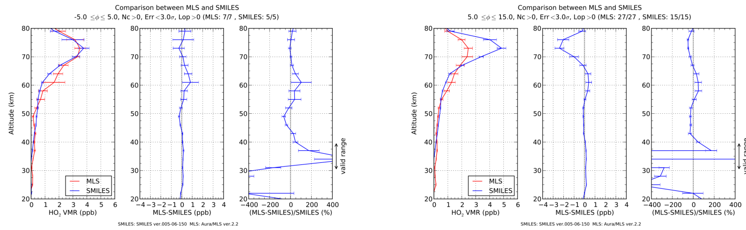


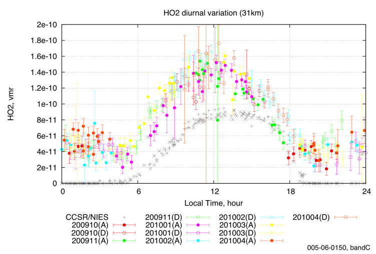
Figure 7. Zonal mean of retrieved HO_2 and its estimated precision for 20 September 2005 averaged over 29°N to 39°N. The average includes 2879 profiles. (a) Plot of vmr versus pressure for day (black) and night (blue) overpasses. (b) The same data plotted as a day-night difference for the stratosphere. (c) The same data converted to density units. (d) The day-night differences for the data in Figure 7c.

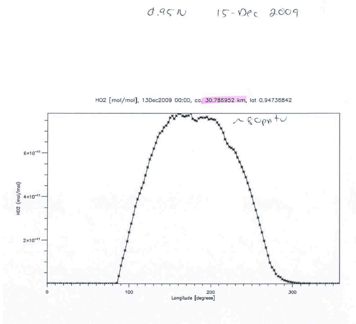


HO_2 validation, d|SZA|<2°
Left EQ (-5~5°), Right (+5~+15°)



SMILES HO2 comparison with CGCM
SMILES 150 ppt, WACCAM 80 ppt at 31km





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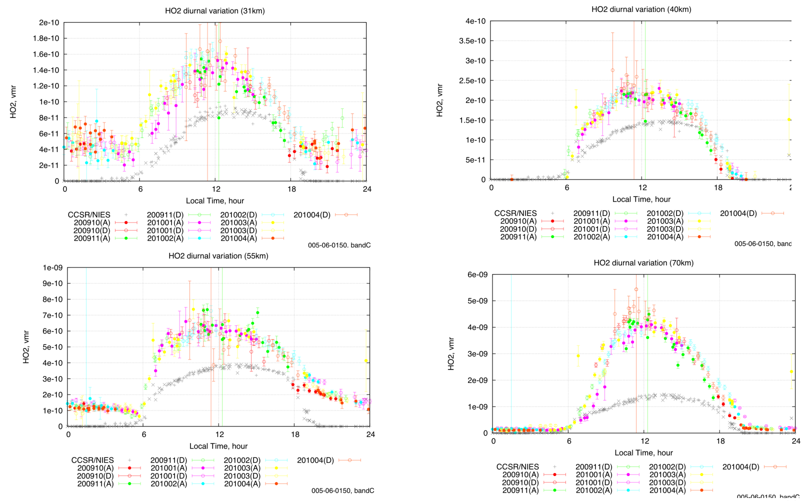
HO_2 Diurnal variation: 31km (150 ppt), 40 km (200-250 ppt), 55 km (0.6-0.7 ppb), and 70 km (4-4.5 ppb) at Equatorial region



Conclusion

- **SMILES can produce diurnal variation products of ClO, HO_2,, and BrO as stated in the mission proposal.**
- **It will open up new opportunity to study chemical mechanisms of stratosphere and mesosphere, which has been mostly tested models and limited observations.**
- **ClO looks to be usable for science immediately, since ver. 0032.**
- **HO_2, and BrO should be checked some more time before science application.**
  - **We found not proper AOS instrument function: affecting all products above 50 km.**
  - **BrO retrieval is very difficult and tricky in stratosphere.**

- **Late proposal to SMILES RA is open !**
  - **Some coordination might happen**
  - **Sep. 13-14 at Tsukuba Japan. (Local meeting, but non Japanese are all welcome)**