Ground-based Observation of O_3 and H_2O

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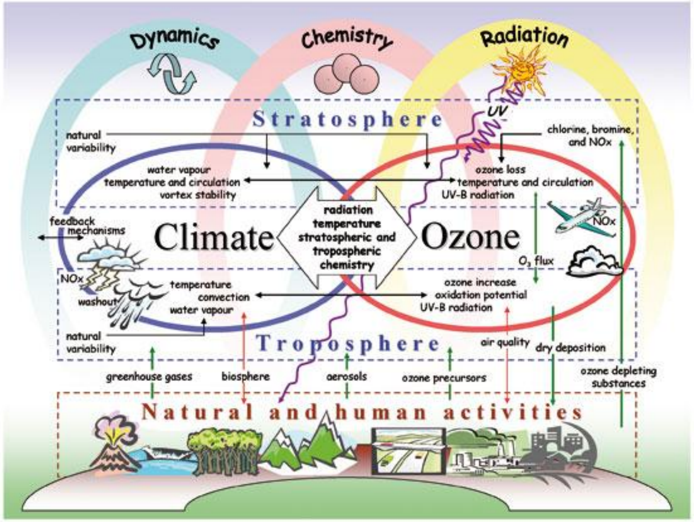
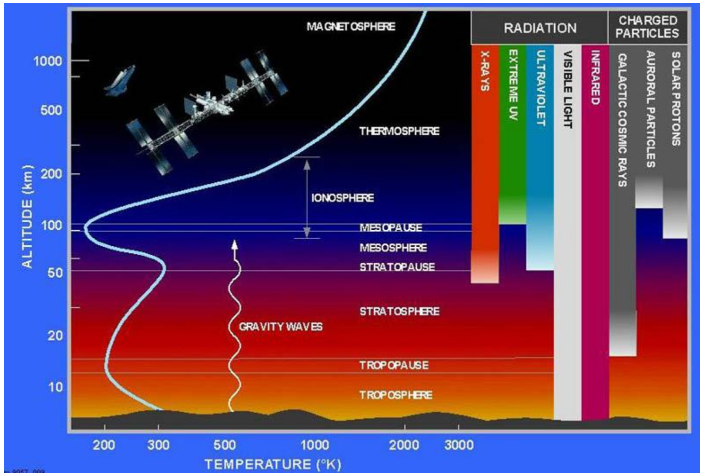
Climate change and the middle atmosphere

■ The middle atmosphere
- Photochemical balance
- Radiative process
- Dynamics, Man-made chemicals

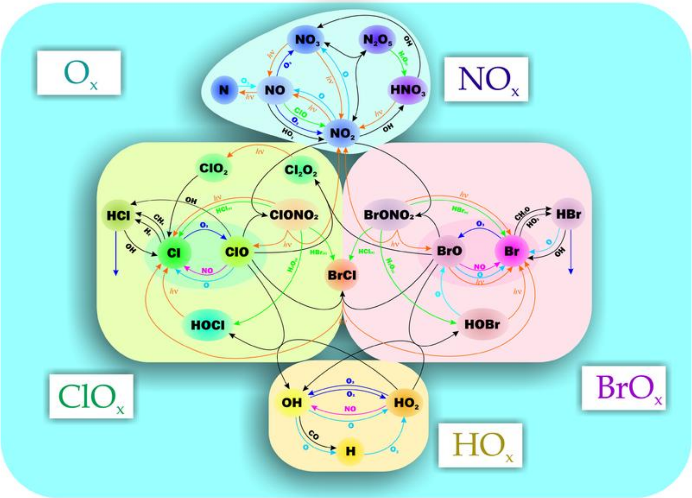
■ Water vapor and Ozone
- the most important green house gas
- a key role in the earths radiative budget
- source of OH (Ozone chemistry)
- Key element for the formation of polar stratospheric clouds



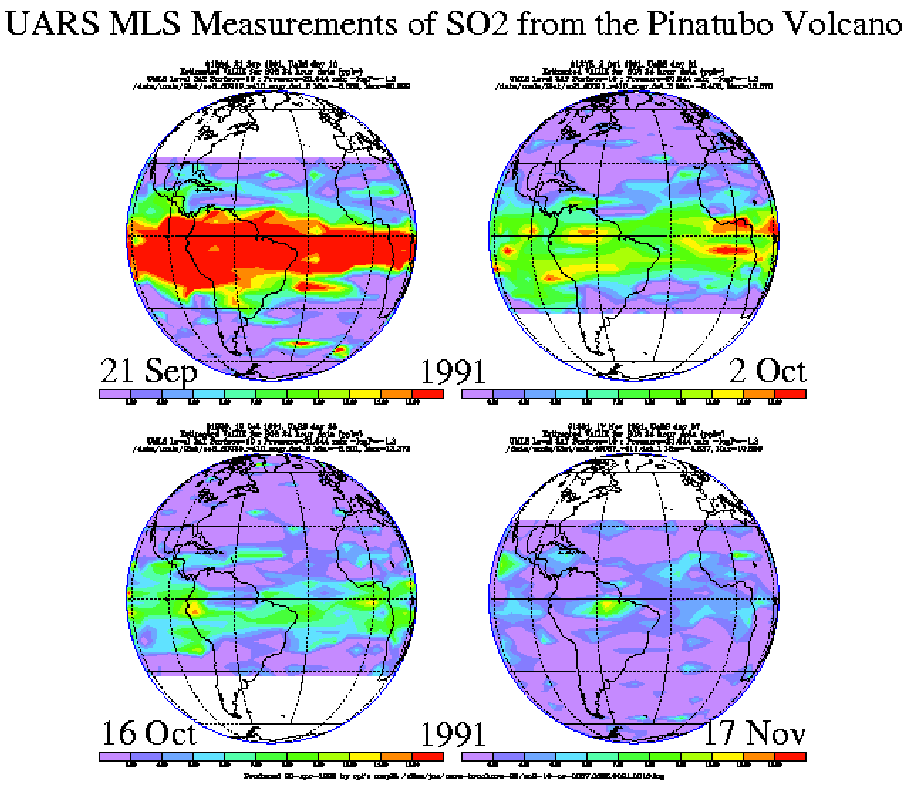
http://www.niwa.cri.nz/__data/assets/image/0005/50675/ozone3_large.jpg

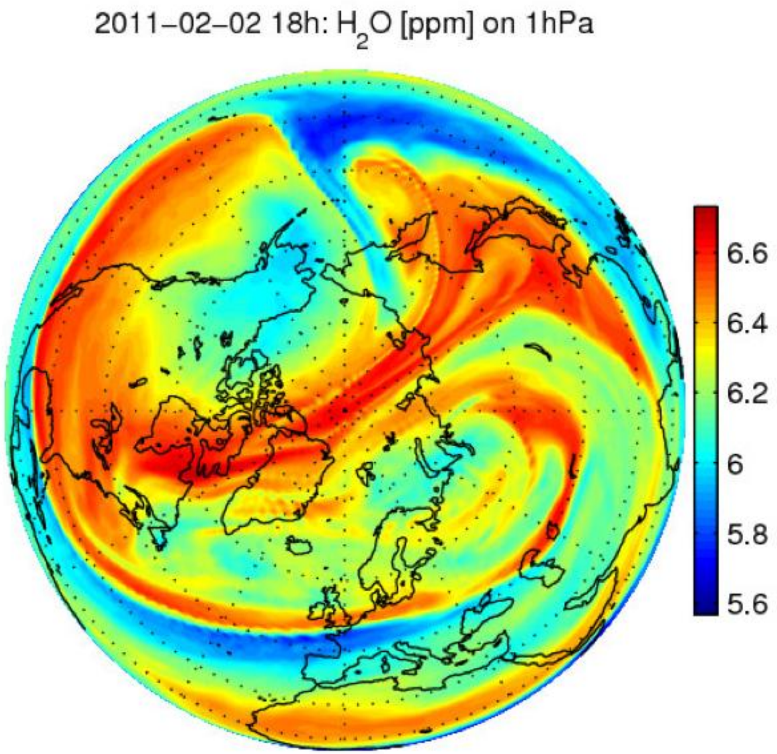


http://www.redorbit.com/education/reference_library/atmosphere/21/index.html



The middle atmosphere

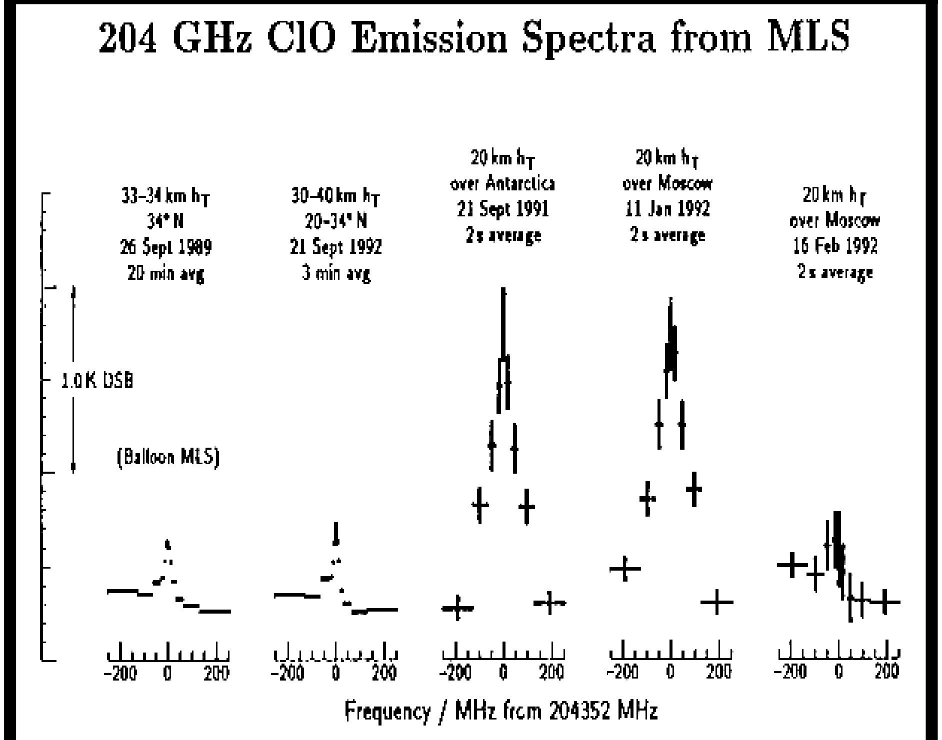




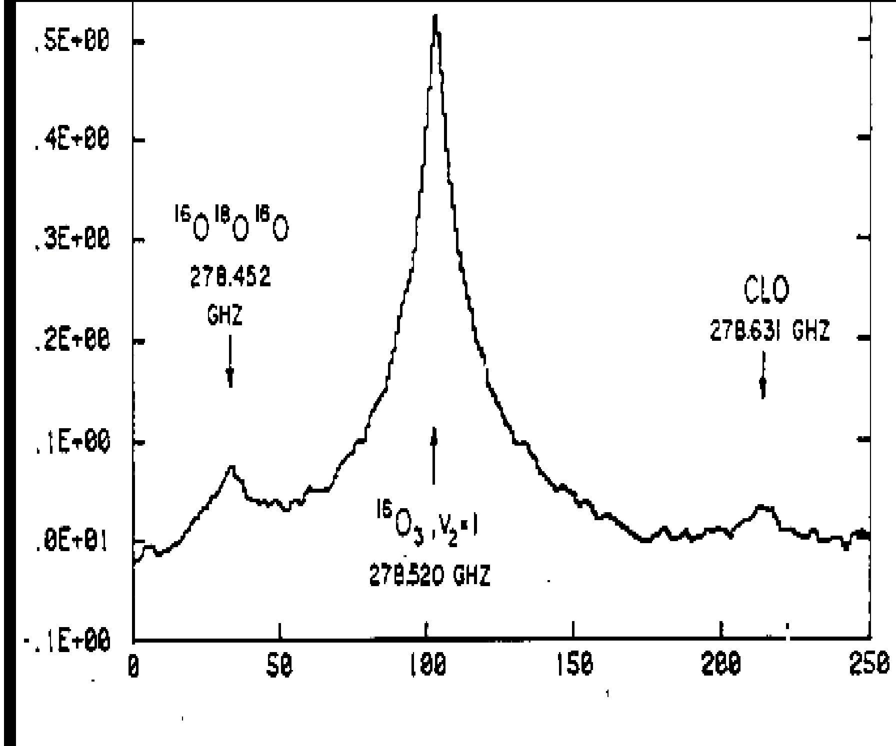
Water vapor as the tracer of
a sudden stratospheric warming

Microwave observation

Microwave Limb Sounder (MLS)



Microwave Ground-Based radiometer



Instruments for the atmosphere

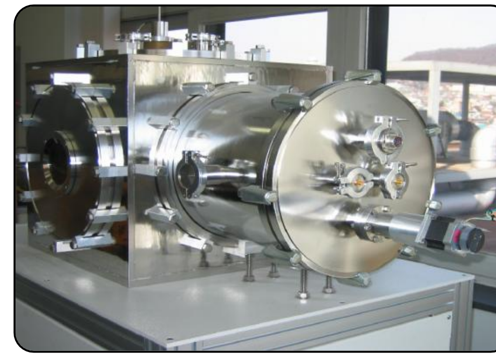
◆ **SORAS (*Stratospheric Ozone RAdiometer in Seoul*)**

- ➢ Radiometer to detect the microwave thermal emission from stratospheric ozone at 110 GHz
- ➢ Long term monitoring of stratospheric ozone change
- ➢ Feature
  - Acquirement of real-time data (unconstraint from atmospheric condition and from day and night)
  - Economical competitive power
  - The first microwave system using direct amplification at room temperature in Korea

◆ **SWARA (*Seoul WAter vapor RAdiometer*)**

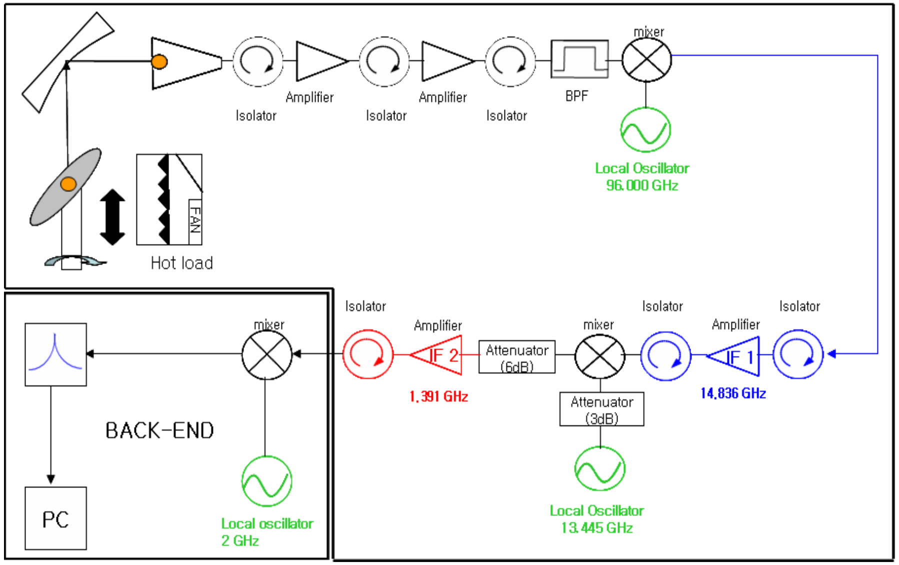
- ➢ Ground-based receiver to detect the 22 GHz signal of water vapor in stratosphere
- ➢ The first microwave radiometer for stratospheric water vapor in Asia
- ➢ Water vapor in stratosphere : the important molecule causing global warming in stratospheric chemical mechanism
- ➢ Co-work with Bern University (Switzerland)

◆ **FTMW (*Fourier-Transform MicroWave spectroscopy*)**



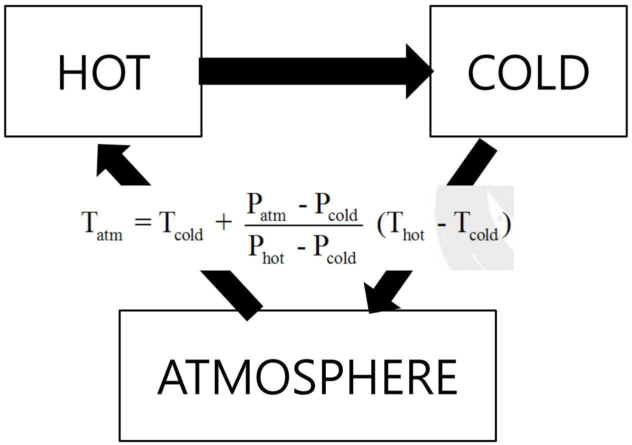
- ➢ Research of atmospheric chemistry
  - Mechanism of the stratospheric ozone destruction
  - Reaction intermediate, dimeric complexes
  - Molecular structures, internal motions within van der Waals complexes, hydrogen-bonded molecular species
- ➢ Configuration & Operation principle
  - Configuration : vacuum chamber, Febry-Perot Cavity, microwave circuit, analysis system

110 GHz Ozone Radiometer

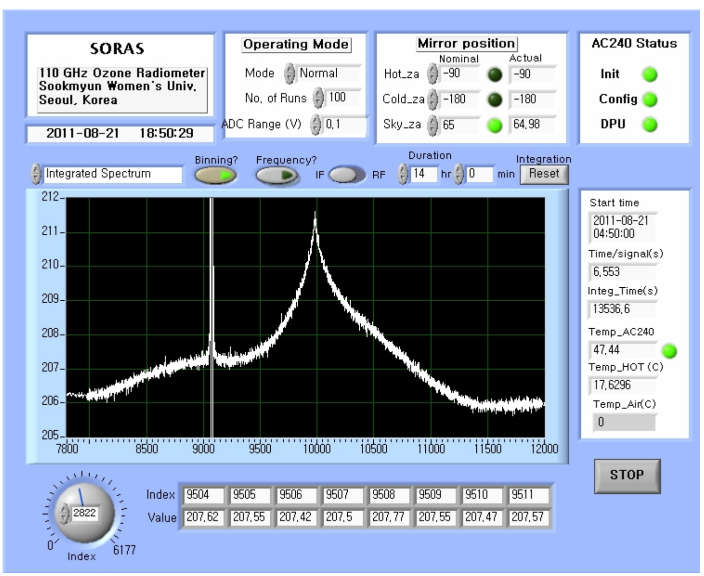


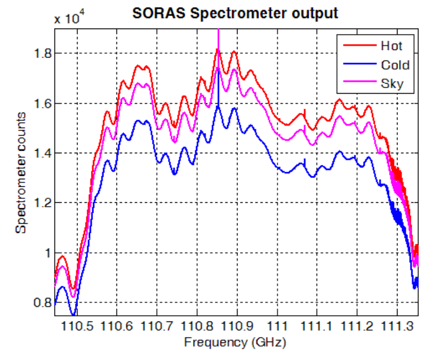
- Target molecule : Ozone (615-606 transition)
- Center frequency : 110.836 GHz
- Total power method (Hot (CV3 absorber at RT) – Cold (Liquid nitrogen) – Atmosphere (65 degrees (zenith angle))
- Operation time : ~ 14 hrs / day
- AC 240 FFT spectrometer of 1 GHz bandwidth and 61 kHz resolution

Ozone measurement

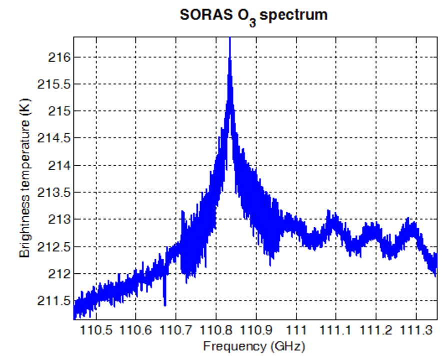


$$T_{atm} = T_{cold} + \frac{P_{atm} - P_{cold}}{P_{hot} - P_{cold}} (T_{hot} - T_{cold})$$

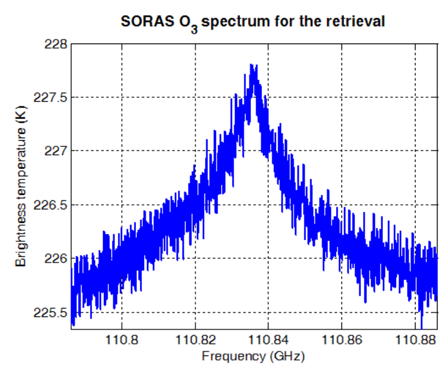




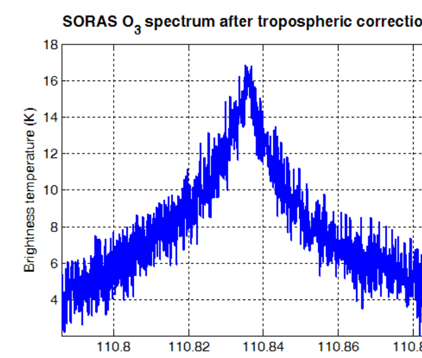
① Signals from 3 materials



② Calculated spectrum

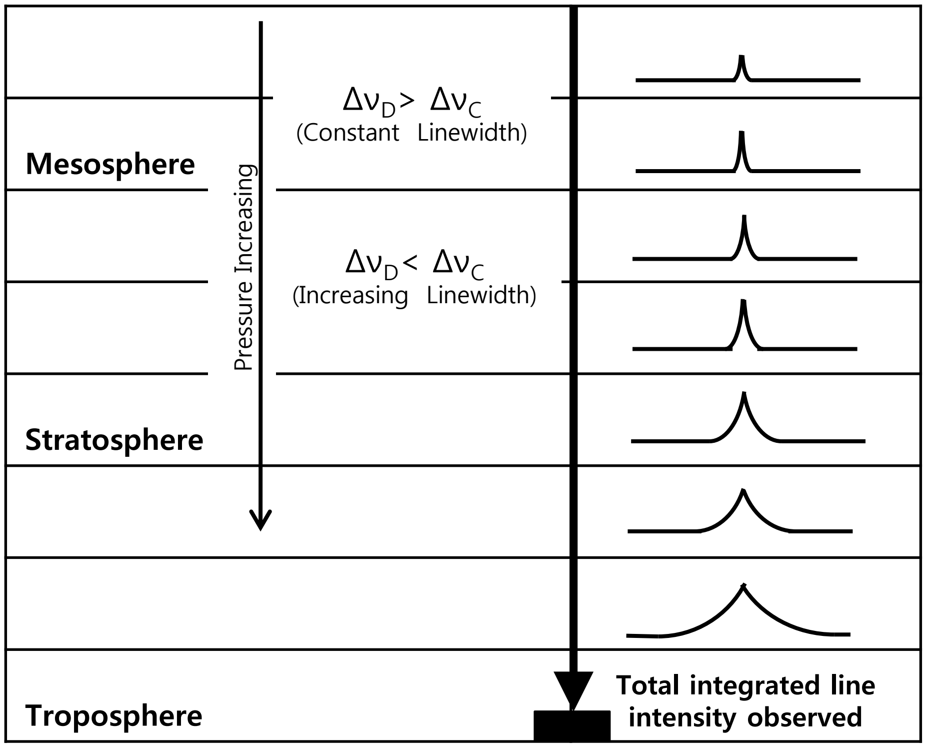


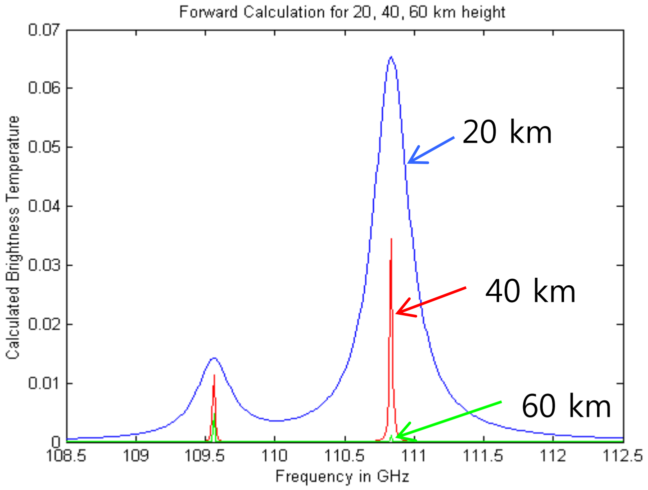
③ Selecting center area (±50 MHz) for the retrieval

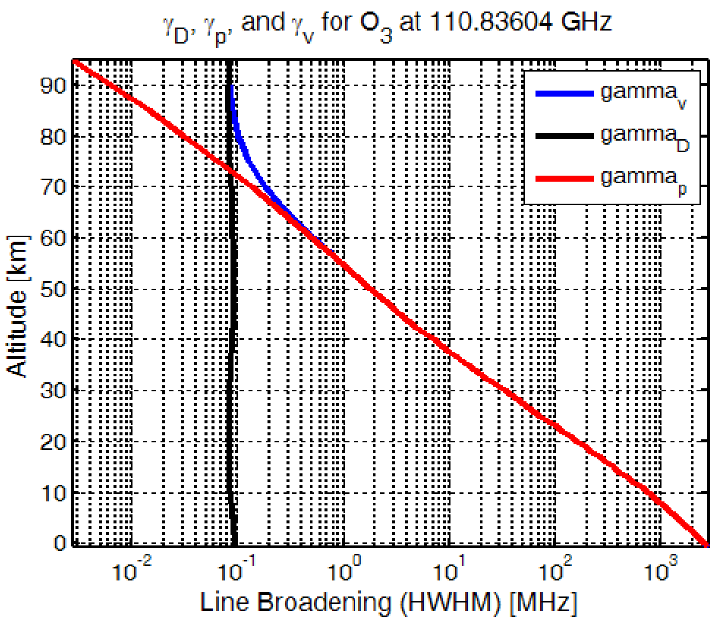


④ Tropospheric correction

Spectrum shape variation

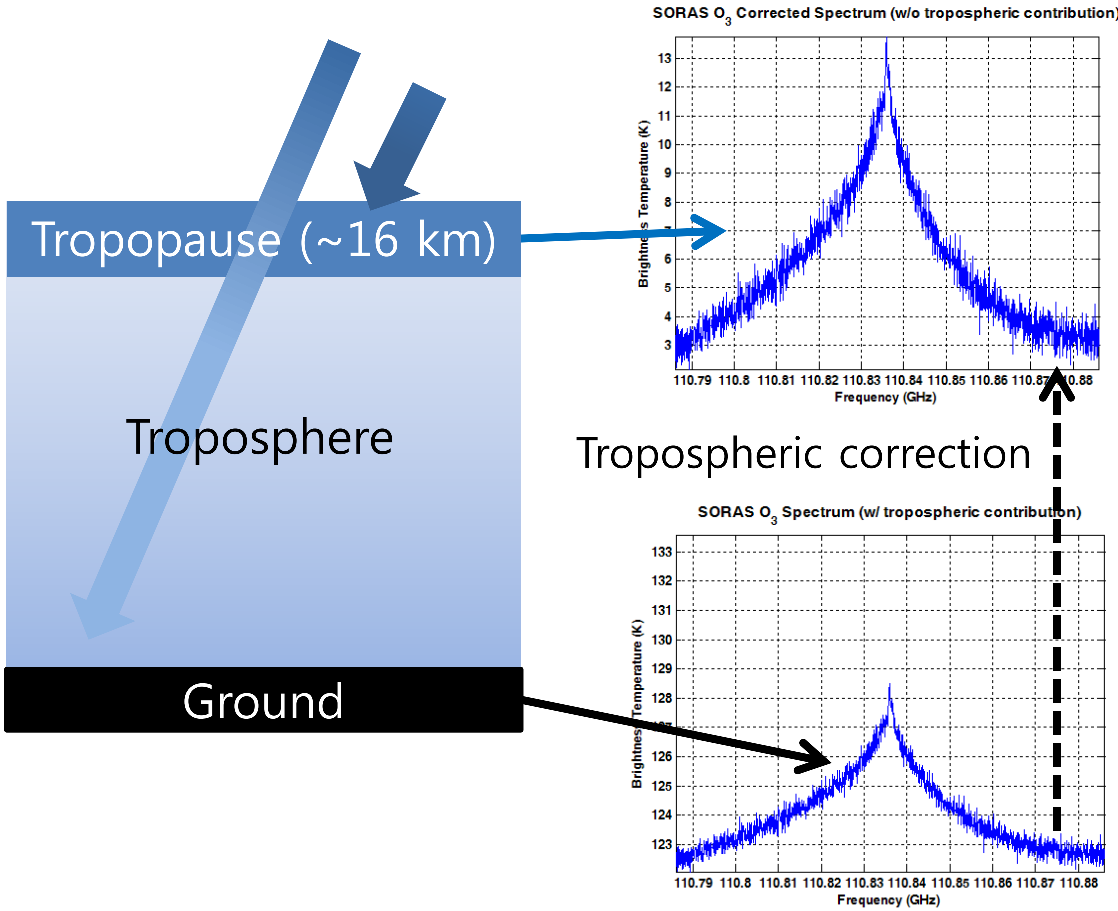






Retrieval of ozone radiometer

- Tropospheric correction



(1) Assume the atmosphere consists of the troposphere and the stratosphere.
$[\ T_{B,ground} = T_{B,\ tropo} + T_{B,strato}]$

(2) $T_{B,ground} = T_{eff}(1-\chi)+T_{B,O3}\chi$
- T_{eff} : effective tropospheric temperature (~ 270 K)
- χ : atmospheric transmission

(3) At the farthest filter channel,
$T_{B,tropo} = T_{B0} + T_{B,strato} \sim= T_{B0}$
$T_{B0} = T_{eff}(1-\chi)$

(4) $X = 1- T_{B0}/T_{eff}$

(5) $T_{B0} =[T_{B,}-T_{eff}(1-\chi)]/\chi$

(Carlos M. Puliafito, *Remote sensing of environment*, 94(2005))

Inverse Method

❖ Inversion Problem

- Mathematically ill-posed problem
- Non-linear problems in radiative transfer equation

A standard approach to solve such problems is the optimal estimation method

❖ Inverse Method

$$\hat{x} = Ax + (I - A)x_a + G\epsilon$$

Rodgers' optimal estimation method

- Bayes' Theory

$$P(x|y) = \frac{P(y|x)P(x)}{P(y)}$$

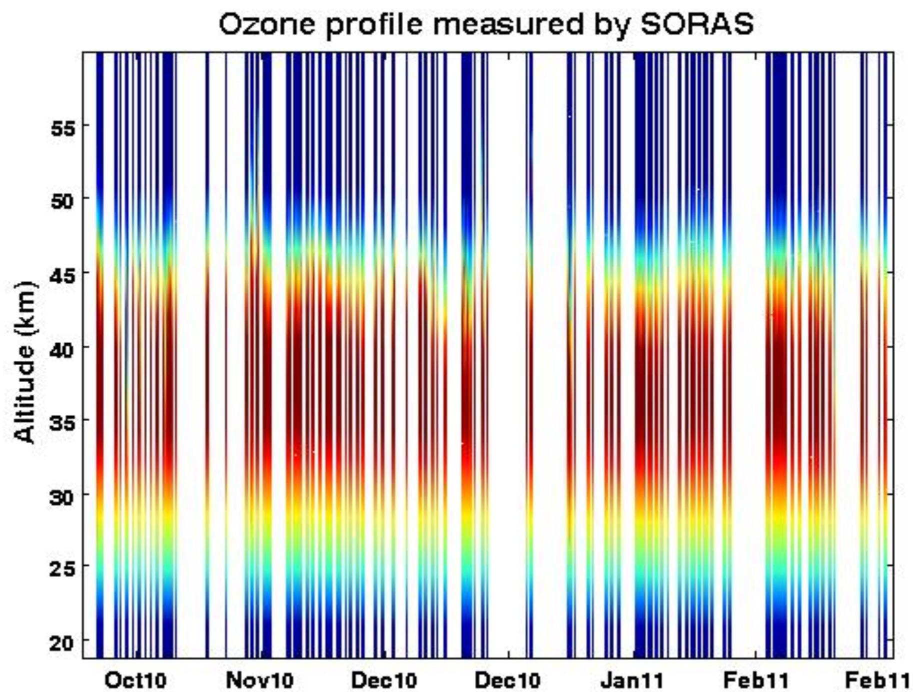
Settings for ozone retrieval

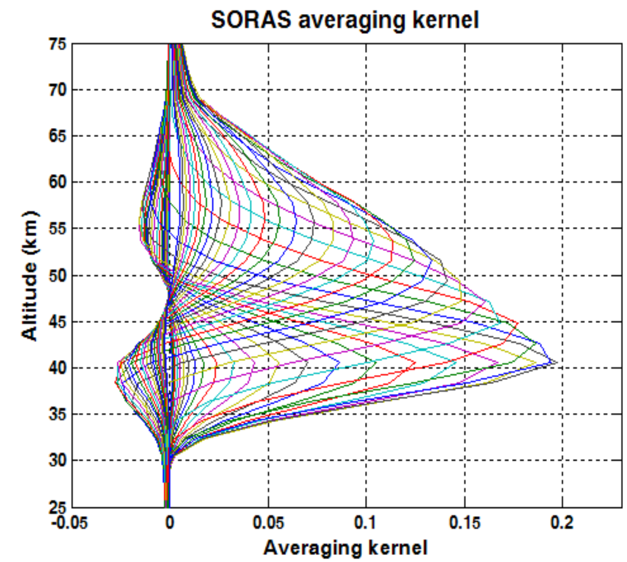
- Retrieval

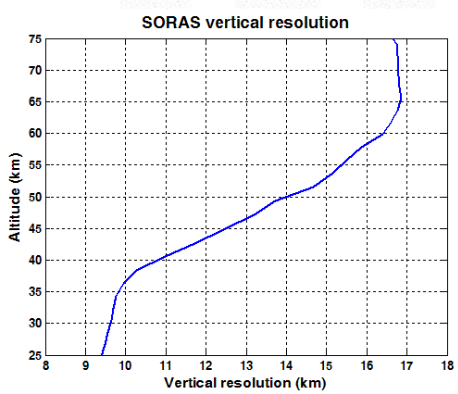
Target molecule	Ozone
Operating program	ARTS + Qpack (Optimal estimation method)
Spectral catalog	JPL + HITRAN08
Line shape function	Voigt Drayson
a priori profile	US Standard atmosphere
Atmospheric profile	AURA MLS Temperature data
Spectrum noise level	0.5
baseline fitting	polynomial and sinusoidal

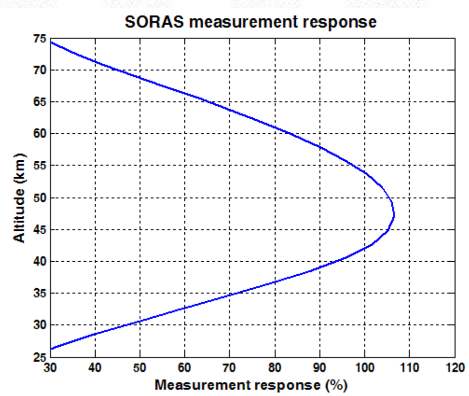
Spectroscopy		
center frequency	110.83604 GHz	JPL
pressure shift of center frequency	0 Hz/Pa	HITRAN08
line intensity	3.567795883E-17 m^2/Hz	JPL
Ref. Temp. for line intensity	300 K	JPL
lower state energe	3.495627626E-22 J	JPL
air broadended width	24676 Hz/Pa	HITRAN08
self broadened width	31362 Hz/Pa	HITRAN08
AGAM Temp. Exponent	0.76	HITRAN08
SGAM Temp. Exponent	0.76	HITRAN08
Ref. Temp. for AGAM, SGAM	296 K	HITRAN08

Ozone temporal variation





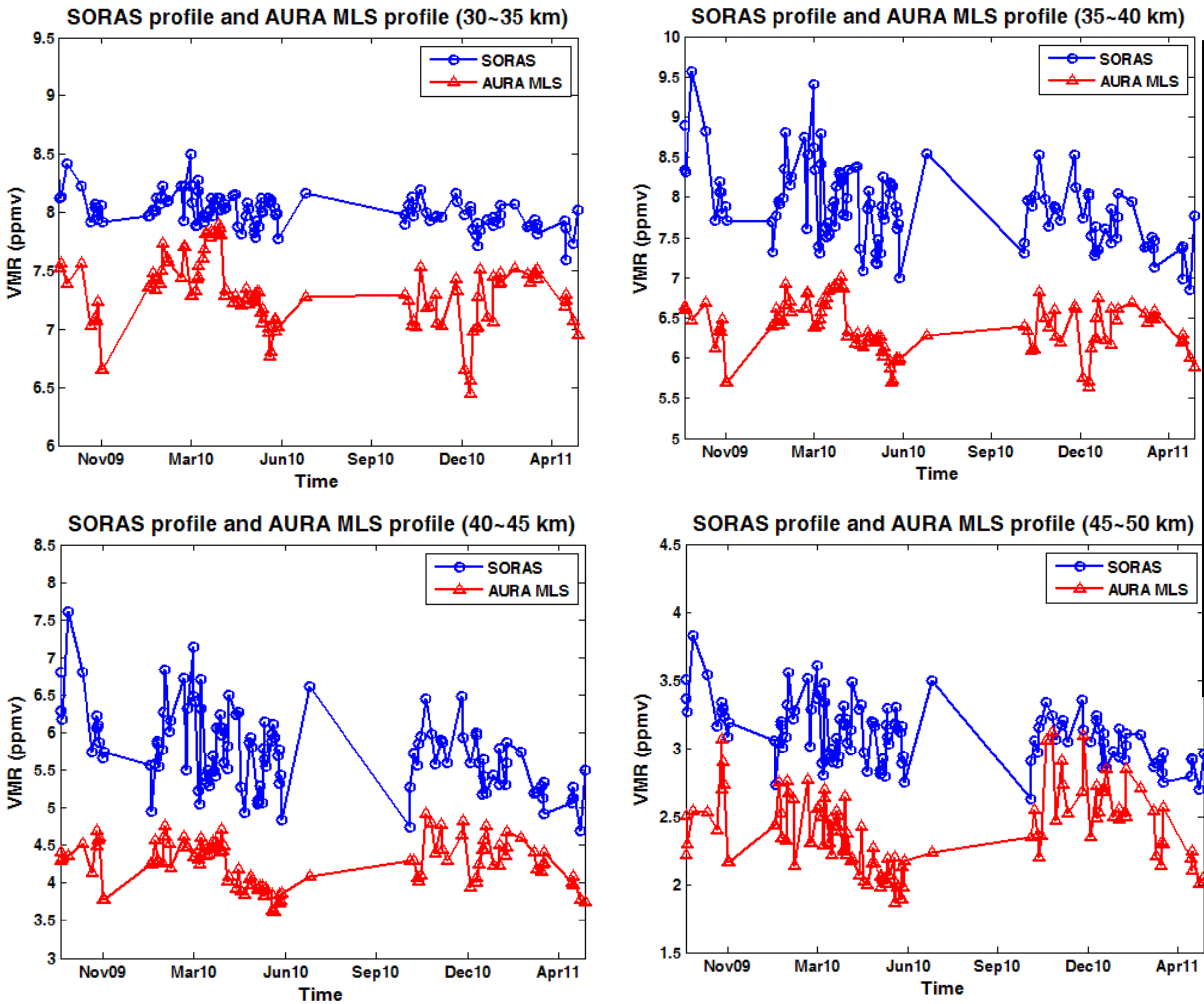




SORAS measurement contributes to the retrieval over 50 % between 30 km and 68 km.

Vertical resolution : 10~17 km

Validation with AURA MLS

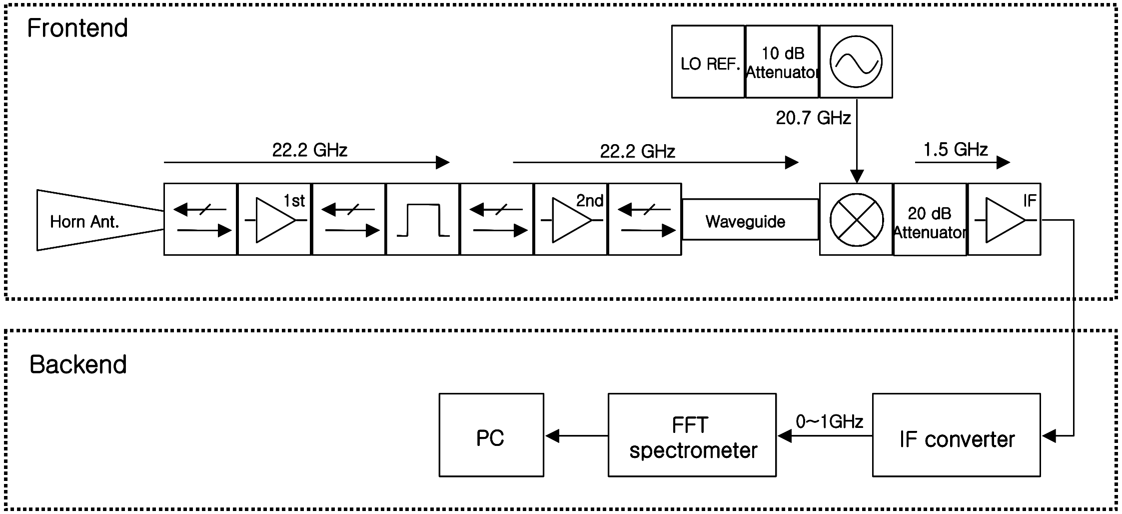


To validate SORAS retrievals, the comparison was performed with AURA MLS data convolved with SORAS averaging kernels.

$$X_{convolved} = X_a + A_{SORAS}(X_{MLS} - X_a)$$

SORAS retrieval shows higher concentration than AURA MLS ozone data.

22 GHz Water vapor Radiometer



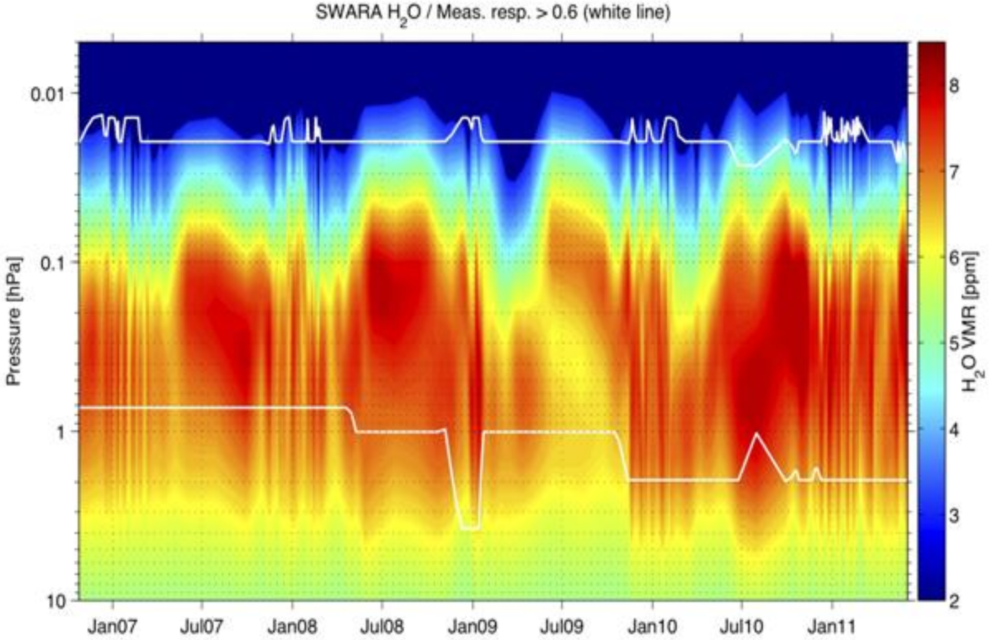
- Target molecule : Water vapor (616-523 transition)
- Center frequency : 22.235 GHz
- Tipping curve calibration + Balancing calibration
- Operation time : 24 hrs (except rainy time)
- AC 240 FFT spectrometer of 1 GHz bandwidth and 61 kHz resolution

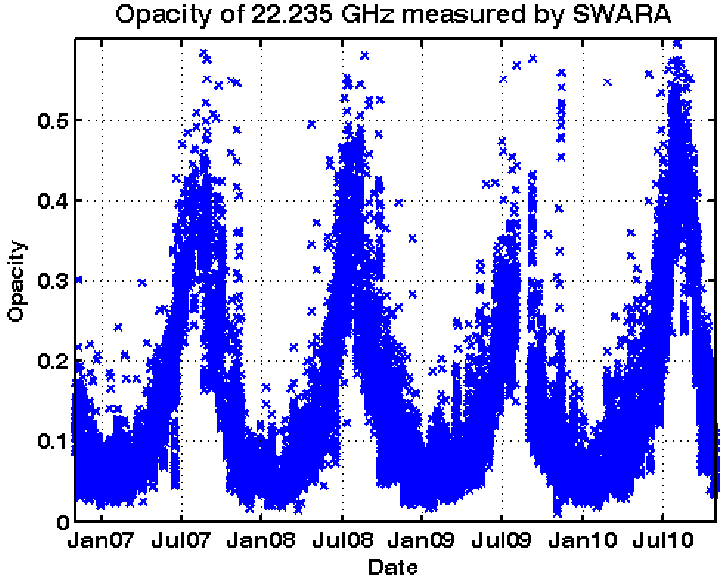
Settings for water vapor retrieval

Target molecule	Water vapor
Operating program	22.235 GHz
Spectral catalog	JPL + HITRAN06
Line shape function	Voigt Drayson
a priori profile	US Standard atmosphere
Atmospheric profile	AURA MLS Temperature data
Spectrum noise level	0.01
baseline fitting	polynomial and sinusoidal

Spectroscopy		
center frequency	22.235080 GHz	JPL
pressure shift of center frequency	0 Hz/Pa	HITRAN06
line intensity	1.324E-18 m^2/Hz	JPL
Ref. Temp. for line intensity	300 K	JPL
lower state energe	8.870E-21 J	JPL
air broadended width	27871 Hz/Pa	HITRAN06
self broadened width	105538 Hz/Pa	HITRAN06
AGAM Temp. Exponent	0.64	HITRAN06
SGAM Temp. Exponent	0.64	HITRAN06
Ref. Temp. for AGAM, SGAM	296 K	HITRAN06

Retrieval of water vapor radiometer

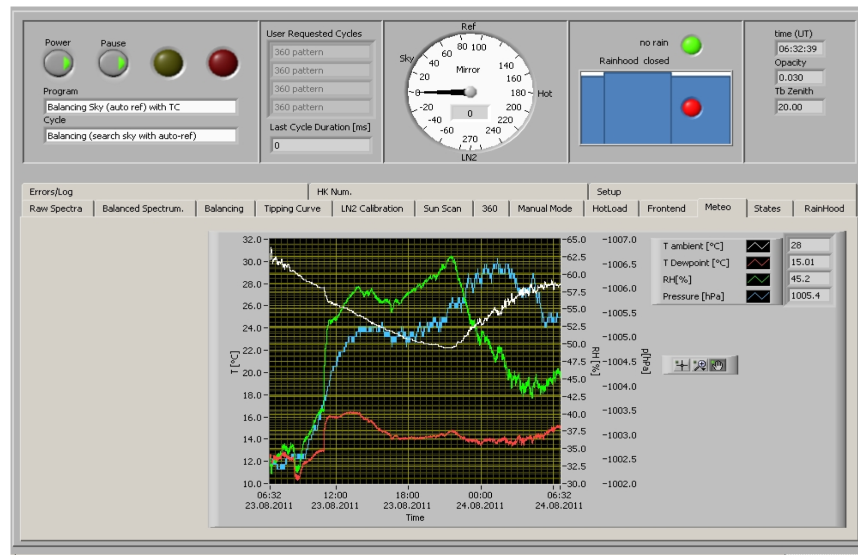




SWARA system upgrade

- SWARA has been operated since Oct. 2006.
- Upgrade of the SWARA (Jun. 2011)
  - The motors moving a mirror and the operating software are replaced.

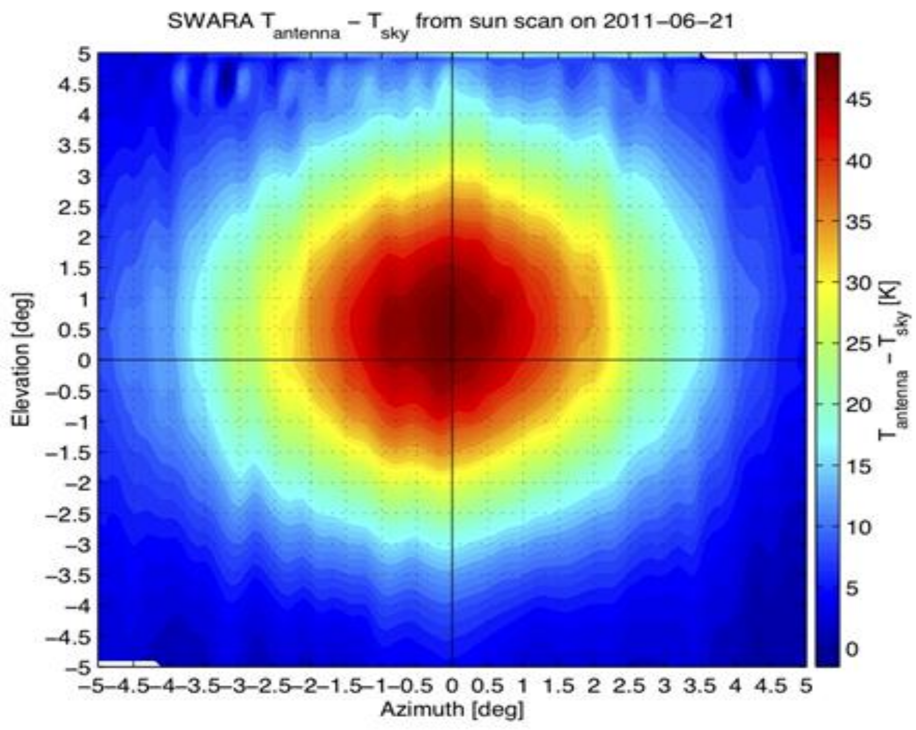
Smooth, silent and fast movement



Many tabs to monitor the status of SWARA.
Faster the balancing calibration

SWARA system upgrade

- Test of the antenna offset (Sun scan method)



Sun scan method
- Indirect method measuring an antenna pattern
- Easy test to determine the antenna pointing offset if the exact coordinate of the sun is known at the test time.

SWARA pointing offset is about 0.5 degrees.

Webcam service

http://swaracam.sookmyung.ac.kr

http://swaracam2.sookmyung.ac.kr

Future work

- Ozone retrievals improvement
- Ozone retrieved data validation
- SWARA new program routines adapted for the upgraded system
- Water vapor retrievals improvement
- Instruments upgrade