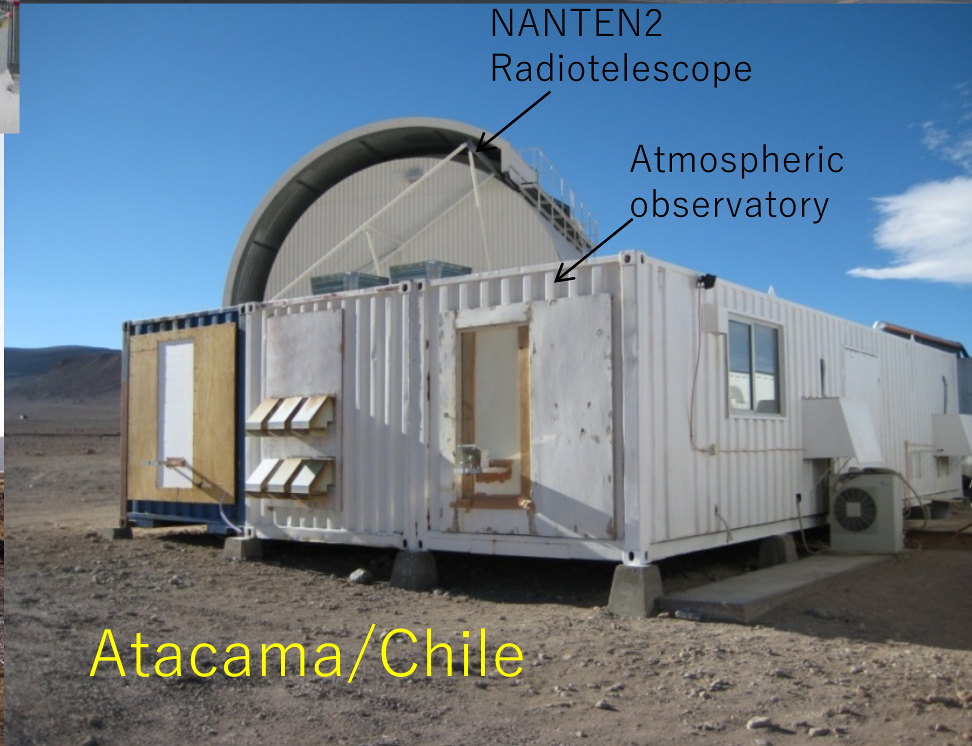
Japanese Activities

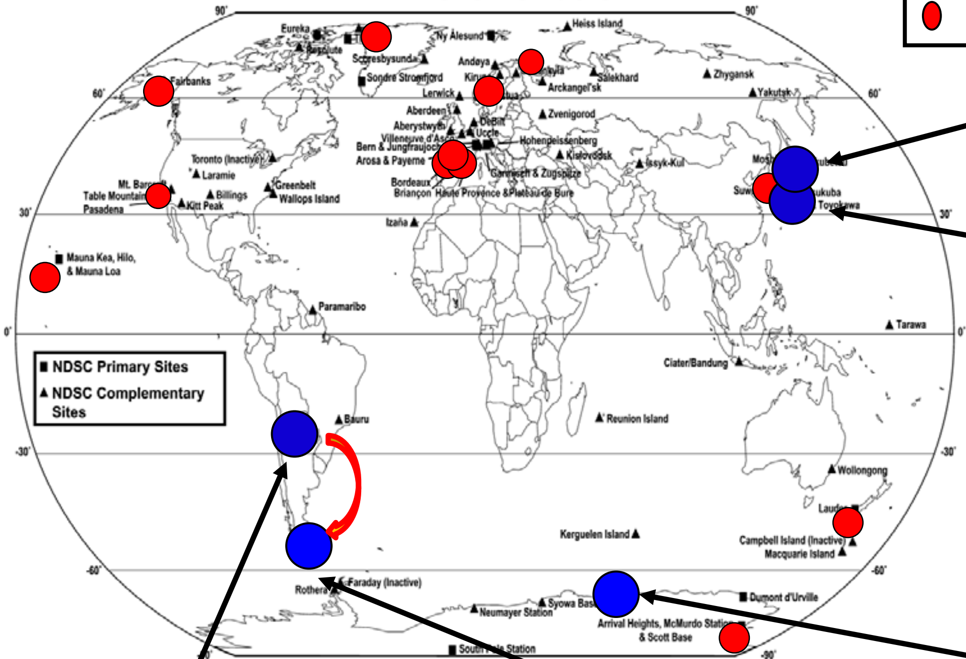
A. Mizuno & T. Nagahama
(STEL, Nagoya University)



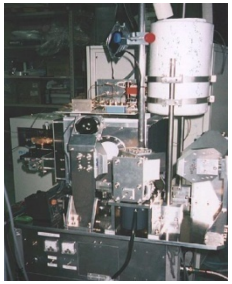
mm-wave observing stations

Microwave-Instruments

Nagoya
Others

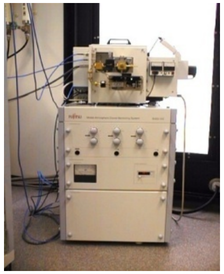


Rikubetsu
(NIES,Nagoya)
43.5N, 143.8E



Since 1999

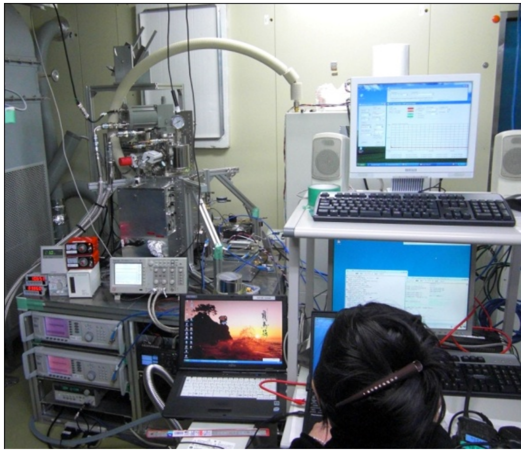
Tsukuba
(NIES, Nagoya)
36.1N, 140.1E



1995-2011

SIS mixer receiver
100GHz /250GHz

Syowa Station
(Nagoya, NIPR)
69.0S, 39.6E Since 2011



Rio Gallegos
(Nagoya, CEILAP)
51.6S, 69.3W
Since 2011

Atacama highland
(Nagoya)

23.0S, 67.7W
Since 2005

Rikubetsu in Japan (1999 -)

Major objective

Monitoring of long-term and short-term variation of Ozone vertical profiles

Main Spec.

Main target : O_3

SIS mixer

Freq.coverage : ~ 100 – 115 GHz

1999 -2005: narrow-band tunable mixer (8-series junctions)

2005 - : broad-band 2SB (sideband-separating) mixer (parallel twin junctions)

AOS spectrometer

1999 -2005: 500MHz bandwidth, 500kHz resolution

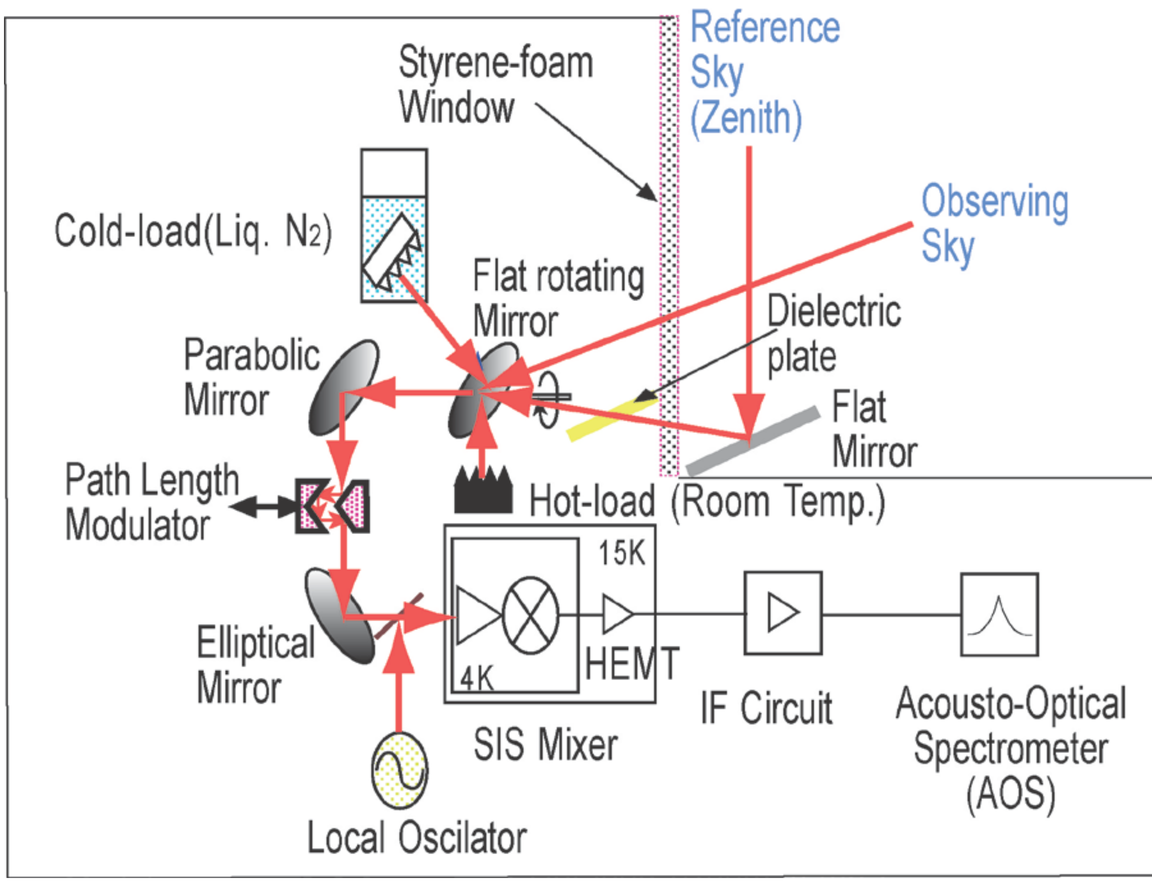
2005 - : 1GHz bandwidth, 1MHz resolution

Rikubetsu spectroscopic radiometer

Major objective

Monitor the long-term and short-term variation of vertical profile of Ozone

Block Diagram

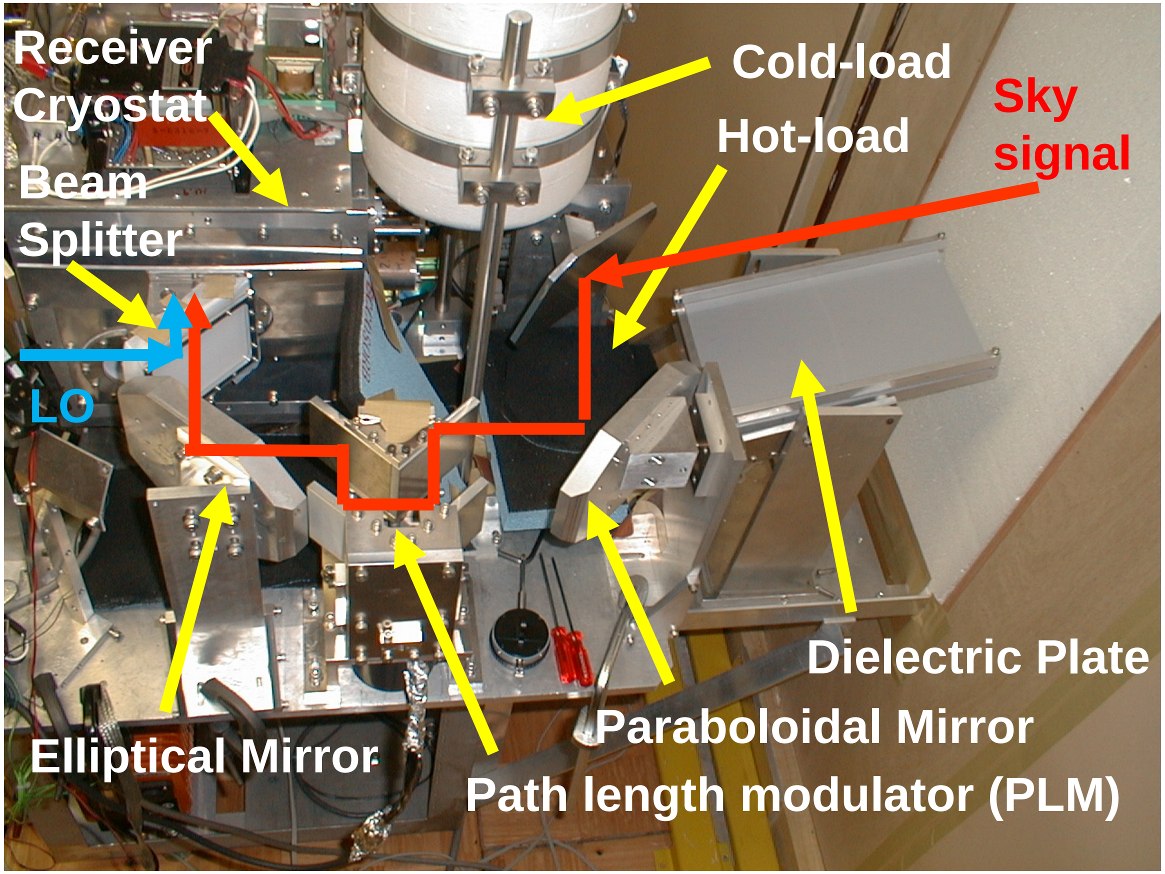


1999: Start operation
- tunable SIS mixer
- ($\Delta\nu$ ~ 500MHz)
- cold-load switching

2005: Receiver and AOS replacement for wideband operation ($\Delta\nu$ ~1GHz)

2SB SIS mixer

Rikubetsu spectroscopic radiometer

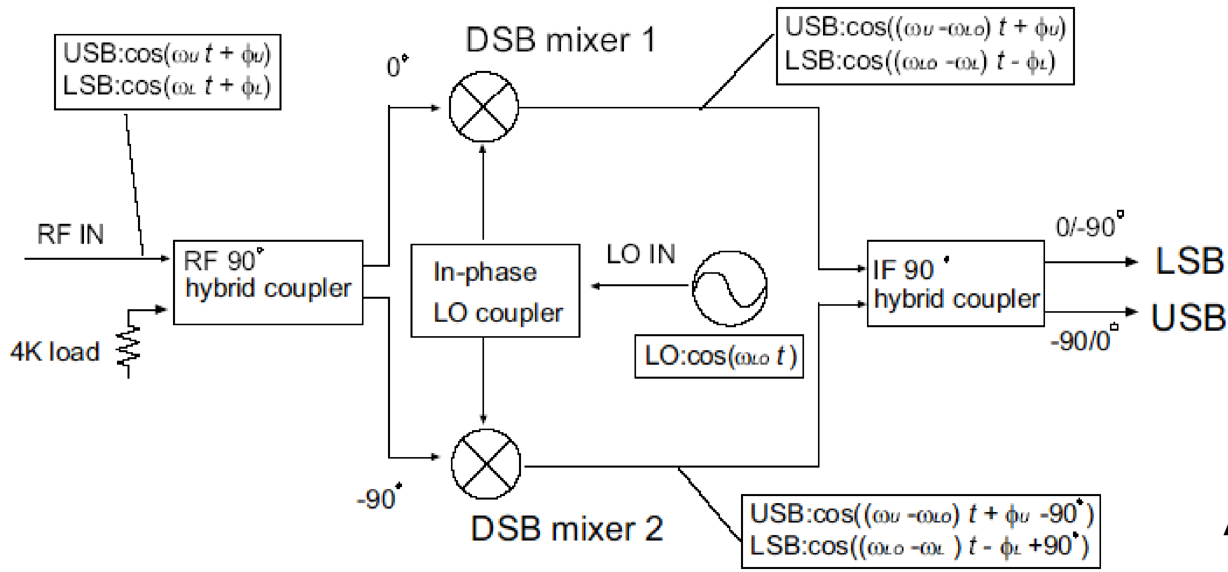


1999: Start operation
tunable SIS mixer
($\Delta\nu$ ~ 500MHz)
cold-load switching

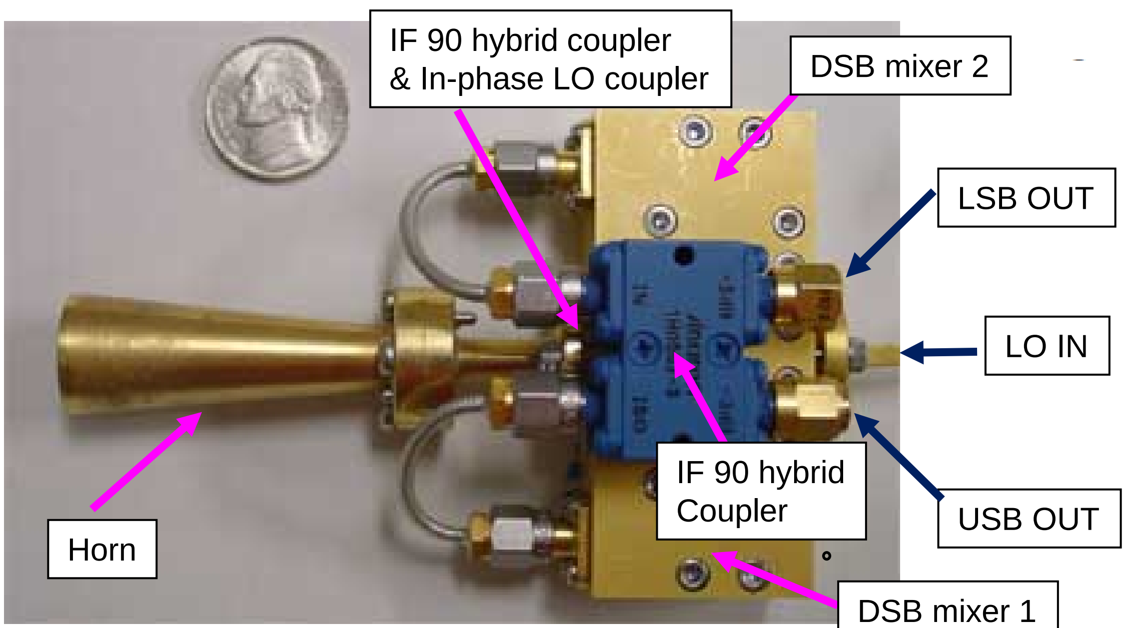
2005: Receiver and
AOS replacement
for wideband operation
($\Delta\nu$ ~1GHz)

2SB SIS mixer

2SB SIS mixer : Side-band separation mixer



Asayama et al. (2004)



Advantages :

(compared with quasi-optical sideband filter)

- No standing-wave
- No additional space

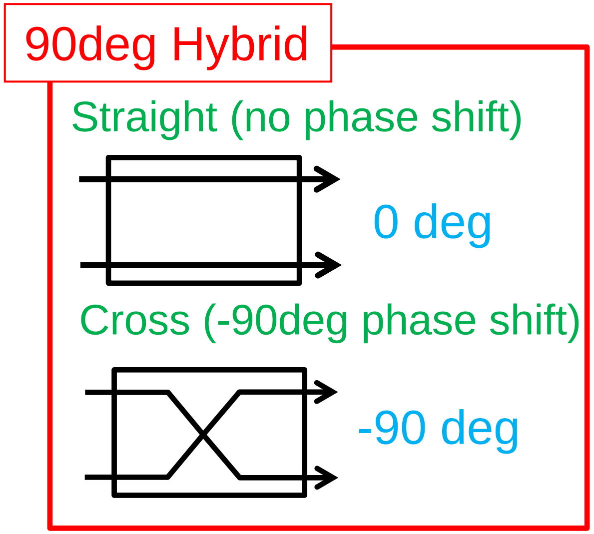
Requirement :

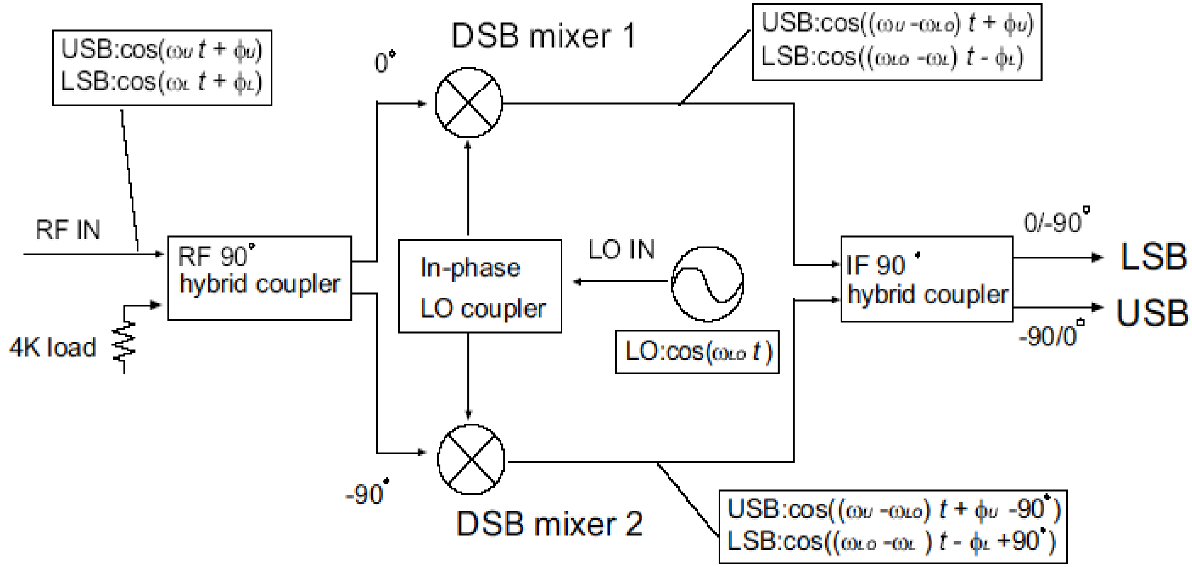
- High equality and stability between the two DSB mixers

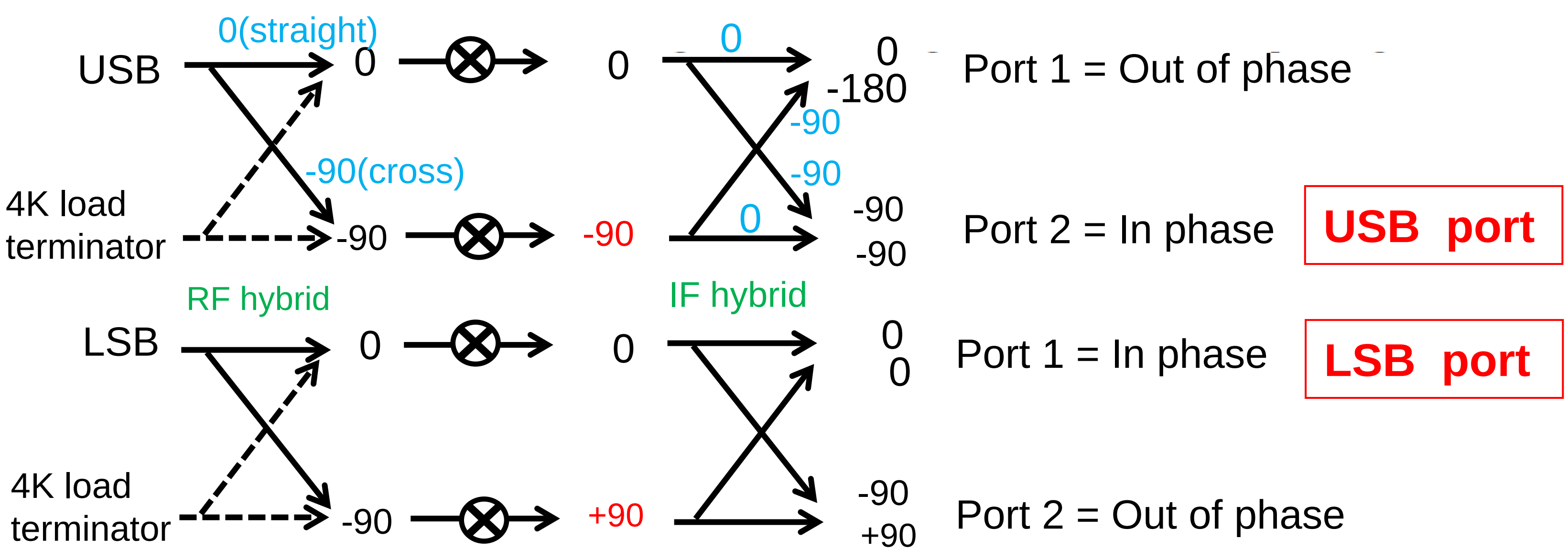
Problem :

- Disruption of the balance leads to change the sideband ratio

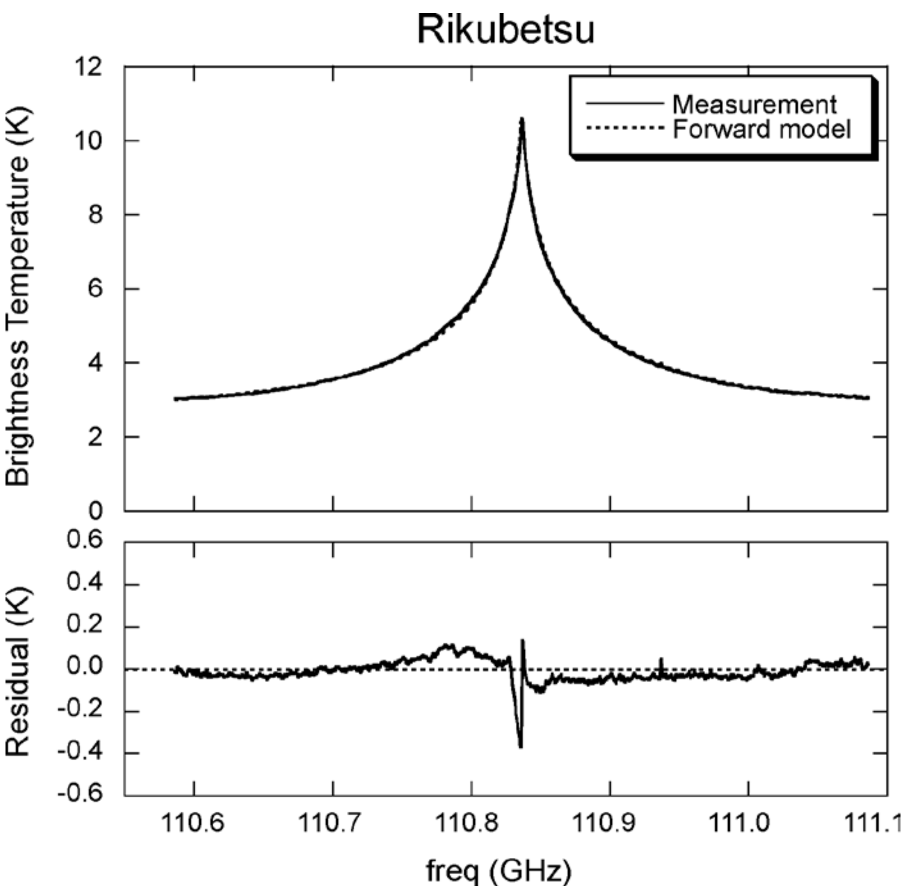
2SB SIS mixer : Side-band separation mixer

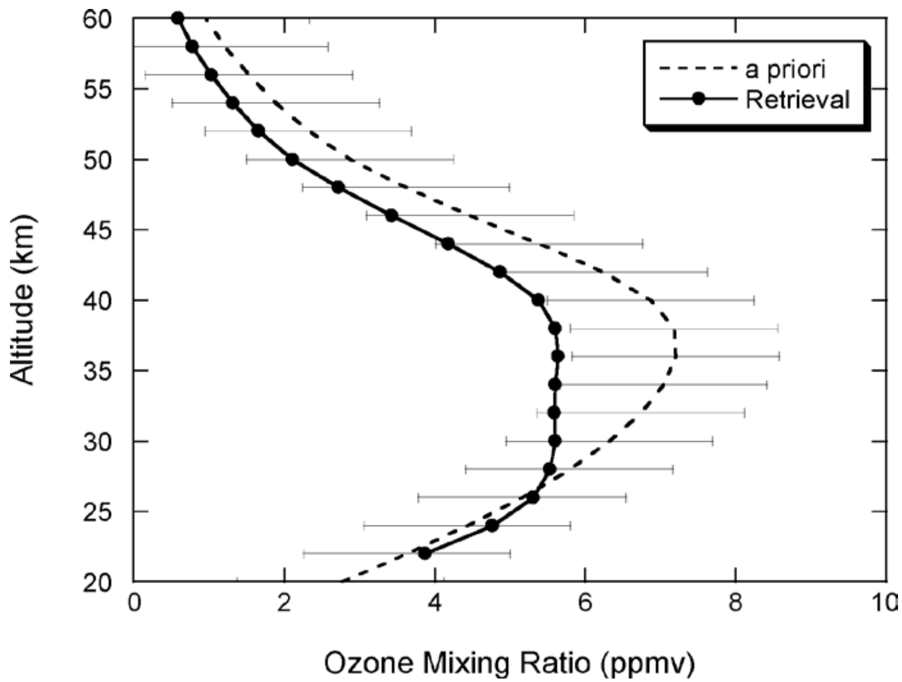




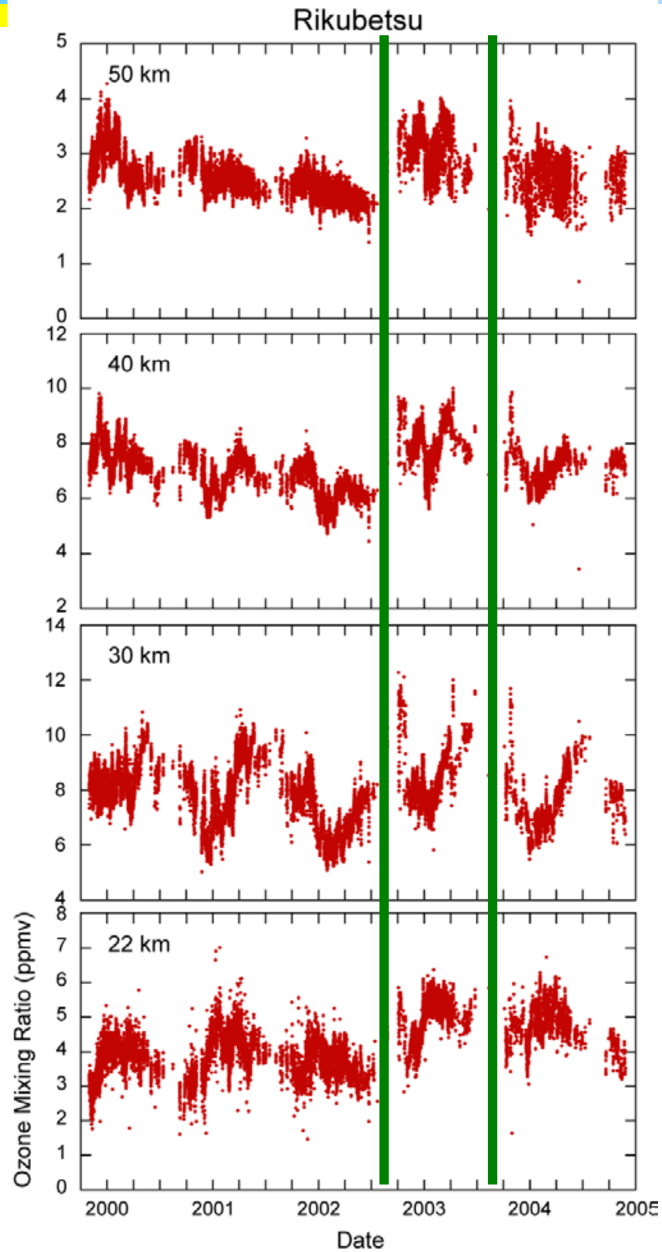


Typical O3 data at Rikubetsu

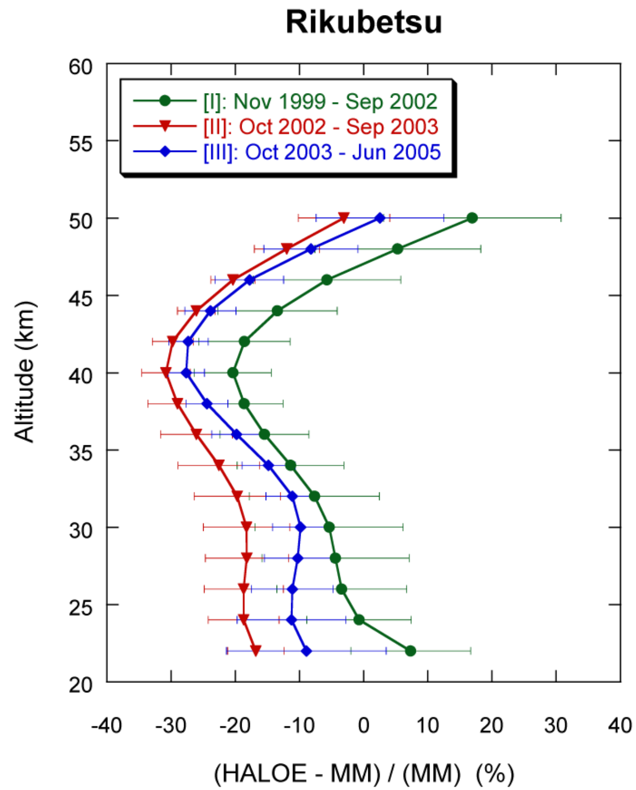




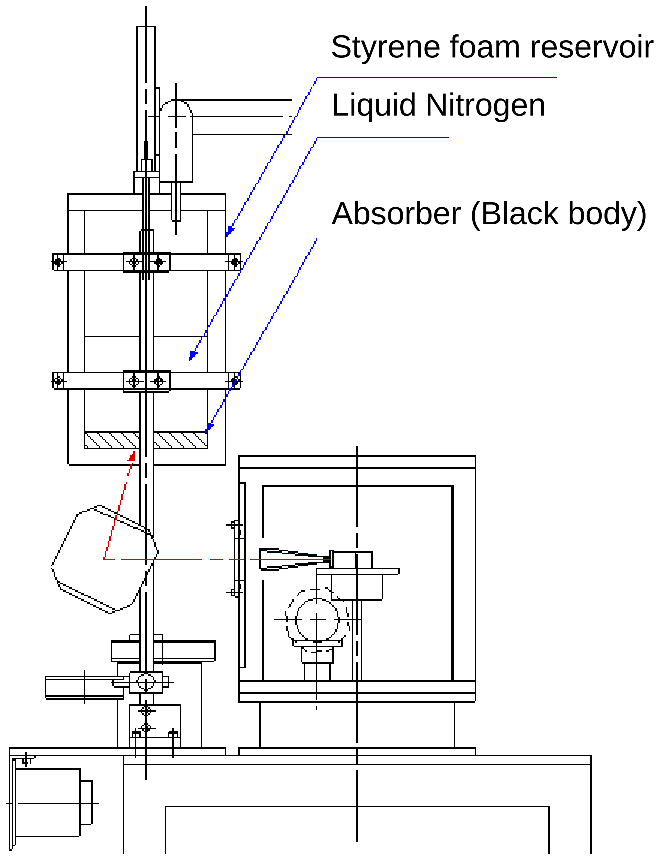
Time-series of vertical O3 profile in Rikubetsu



- Apparent discontinuities were found in the time series data around summer 2002 and autumn 2003



Problem of the cold-load



Previous cold load：
See the cold blackbody through the bottom of the reservoir

The reason of the discontinuities were aging change of the styrene foam of the liquid nitrogen reservoir.

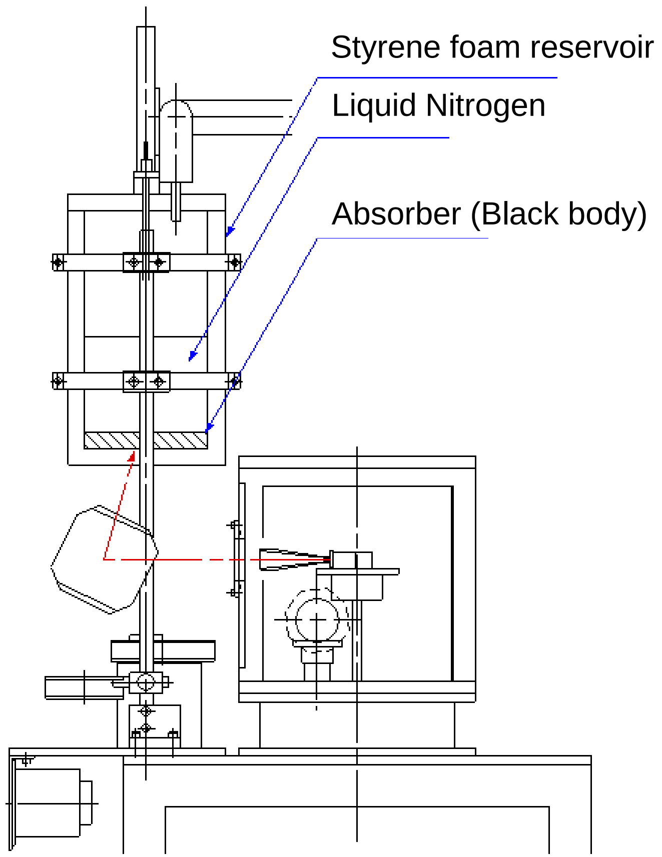
The styrene foam is almost transparent in the mm-wavelength.

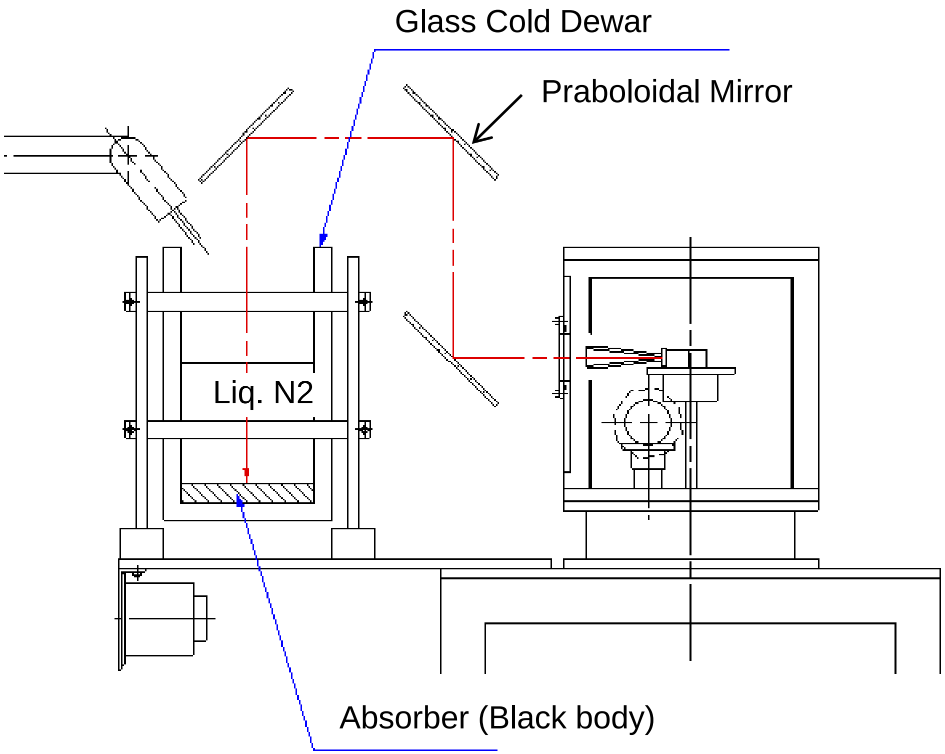
Water vapor in the air penetrated into the styrene foam and was accumulated as time passed.

Absorption coefficient of the reservoir increased.

That increased the equivalent temperature of the cold-load.

Refurbishment of cold load and its optics

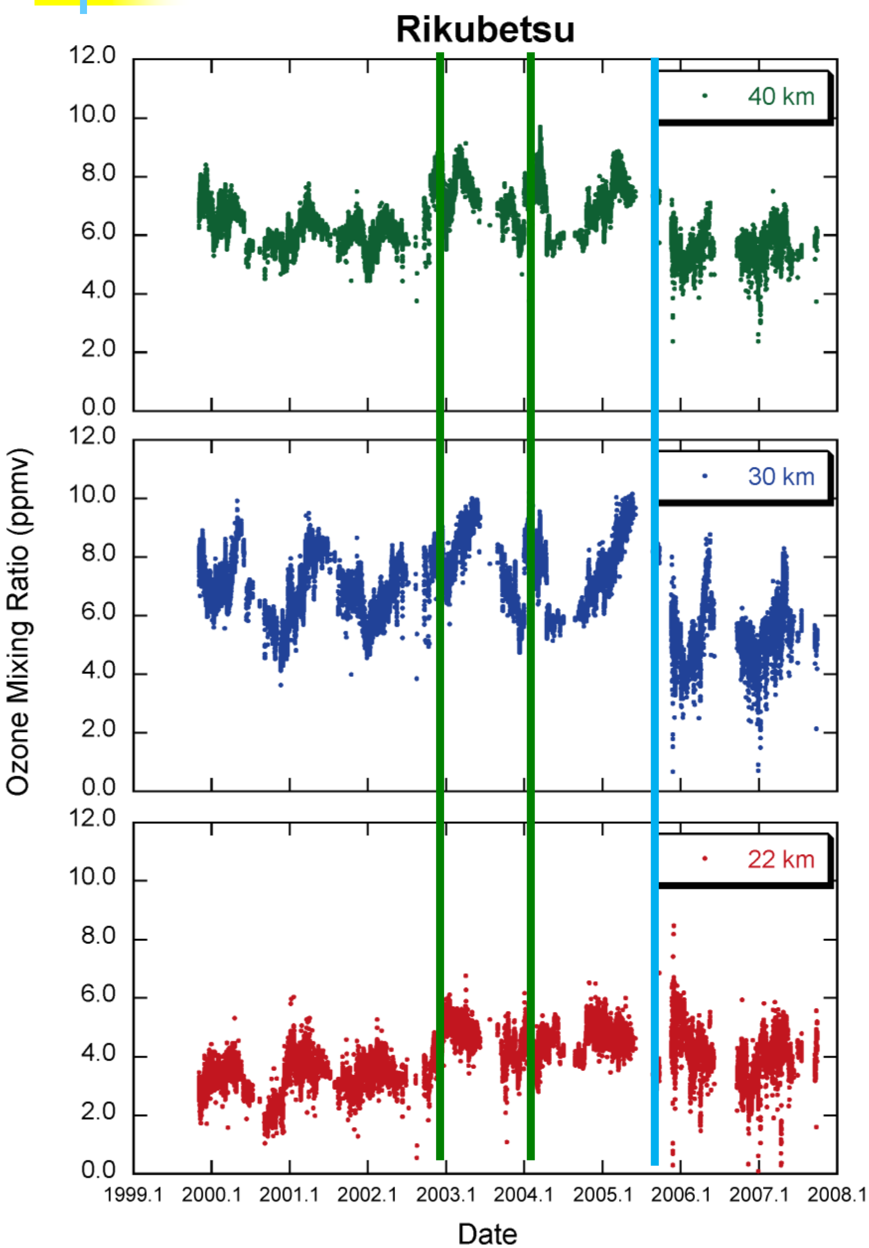




Previous cold load：
See the cold blackbody through the bottom of the reservoir

Alternative cold load：
See the cold blackbody form the upper side of the reservoir

Corrected time series and another problem



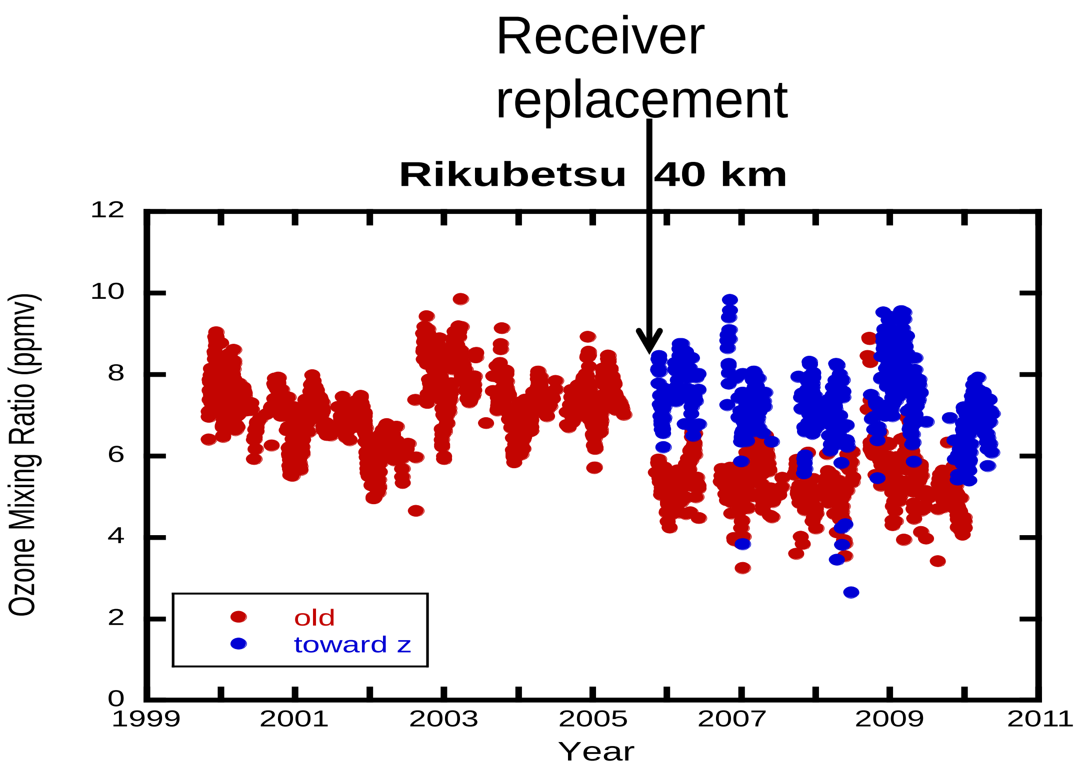
Another discontinuity was found at the end of 2005.

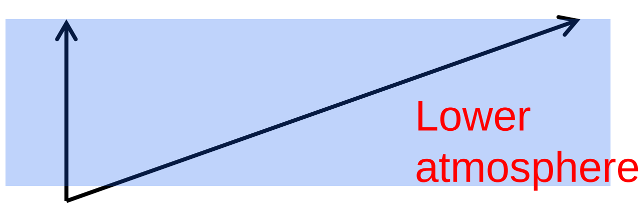
↓

This moment corresponds to the receiver replacement.

Discontinuity at the end of 2005

Saturation (= Gain compression) of the 2SB mixer probably causes this discontinuity





Elevation switching (=low sky elevation) measurement gives small VMR.
VMR derived only by using ref-sky data toward zenith (=high elevation) does not show such a discontinuity.

Thermal emission from lower atmosphere:
El=90deg ➔ Tsky□ 60K
El=20deg ➔ Tsky□ 180K

Previous mixer : 8 series junction
2SB mixer : parallel twin junction

Saturation level ∝ (resistance)^2

Now, developing new 3-series SIS junction for 2SB mixer.

Syowa in Antarctica (2011 -)

Major objective

Monitoring of NOx and Ozone to study the influences of energetic particle precipitation (EPP) on the composition of middle atmosphere in the polar region

Main Spec.

Main target : NO, O_3, etc.

Power-saving & portable Cryostat and Optics

SIS mixer

Freq.coverage : ~ 230 – 260 GHz

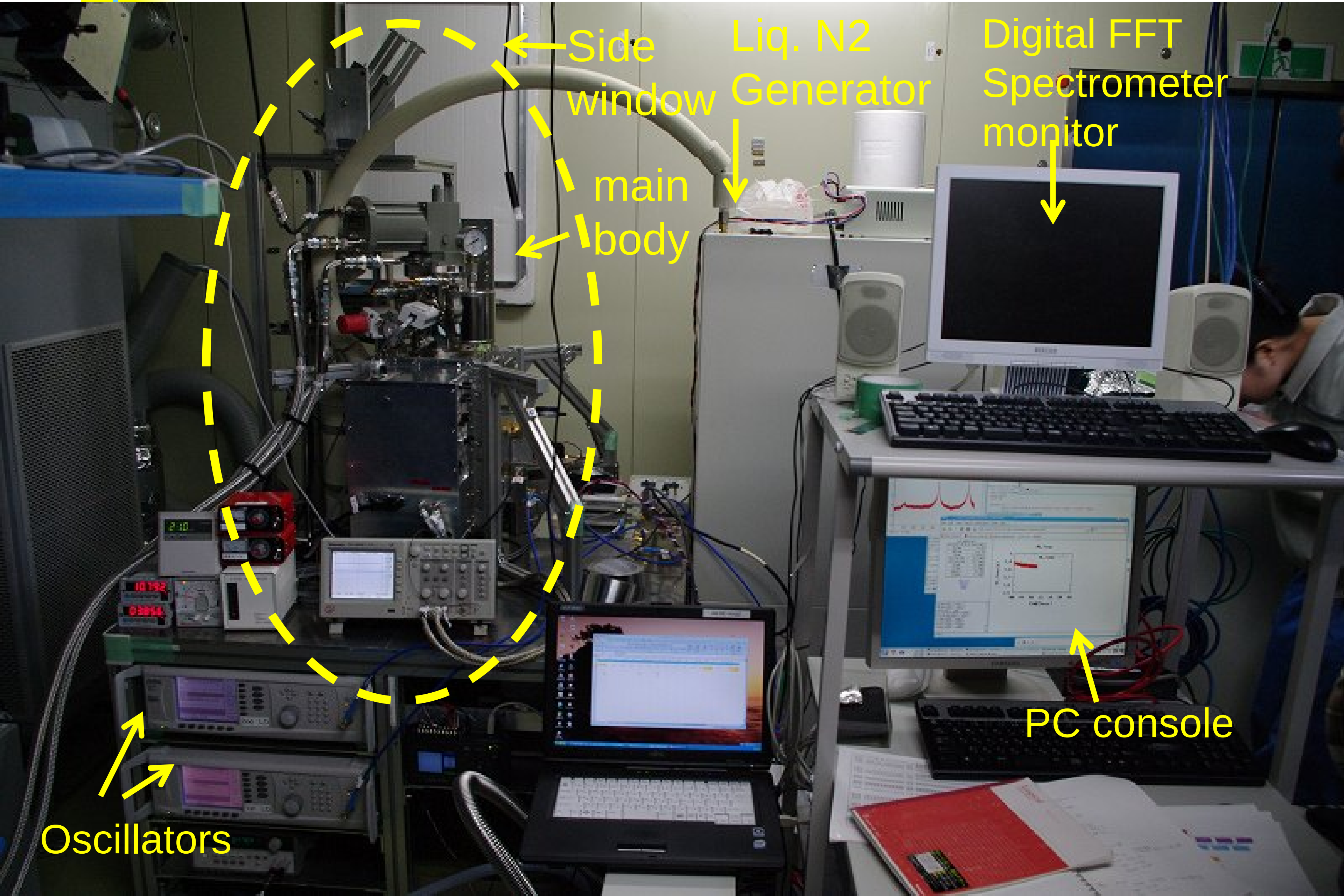
Fixed-tune broadband SIS mixer in DSB mode

(Parallel twin junctions)

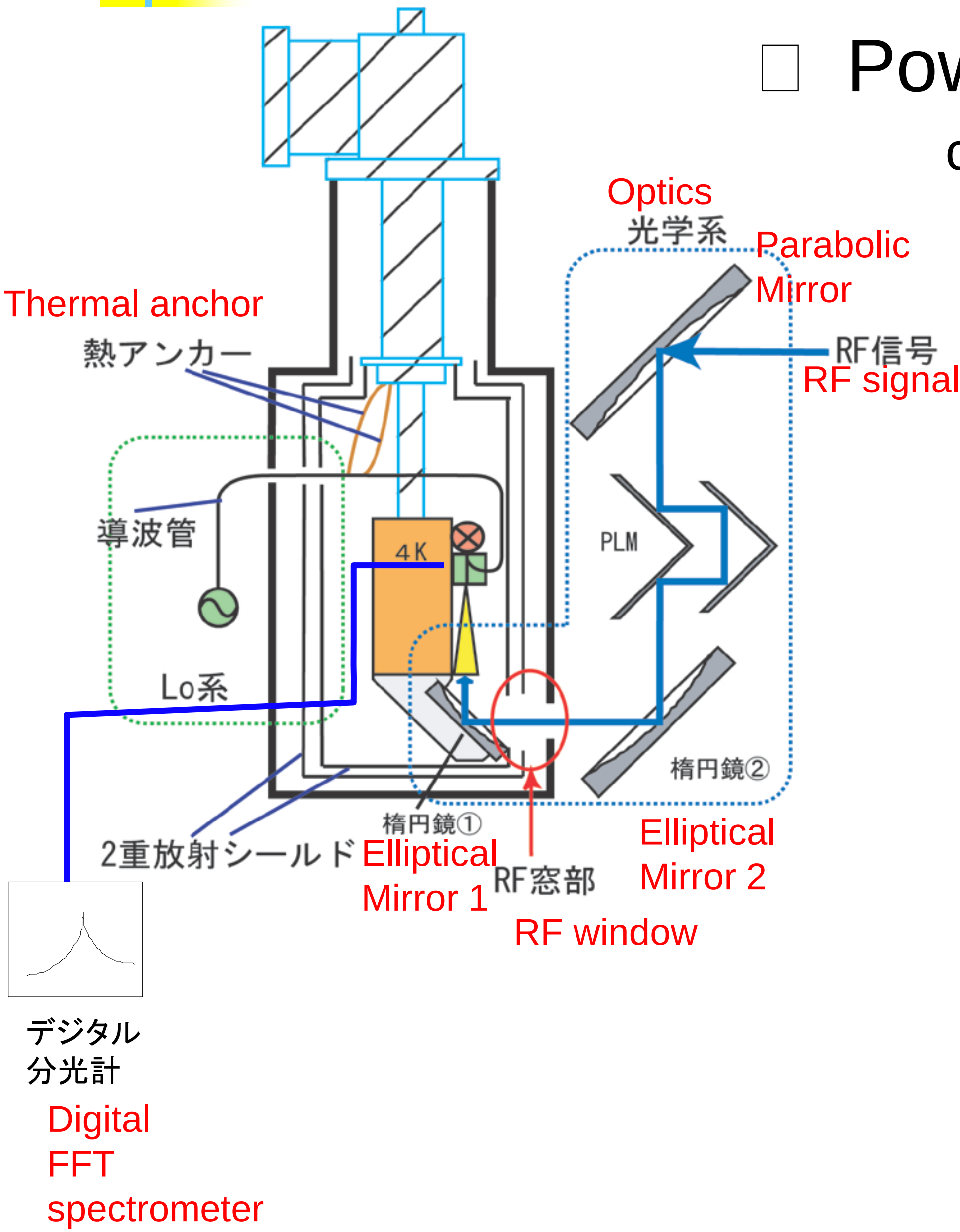
Spectrometer

Digital FFT (1GHz bandwidth, 60kHz resolution)

Syowa Station in Antarctica



Design concept of power-saving SIS radiometer



- Power-saving: ~ 4kW in total

  c.f. 13kW for Rikubetsu-type system

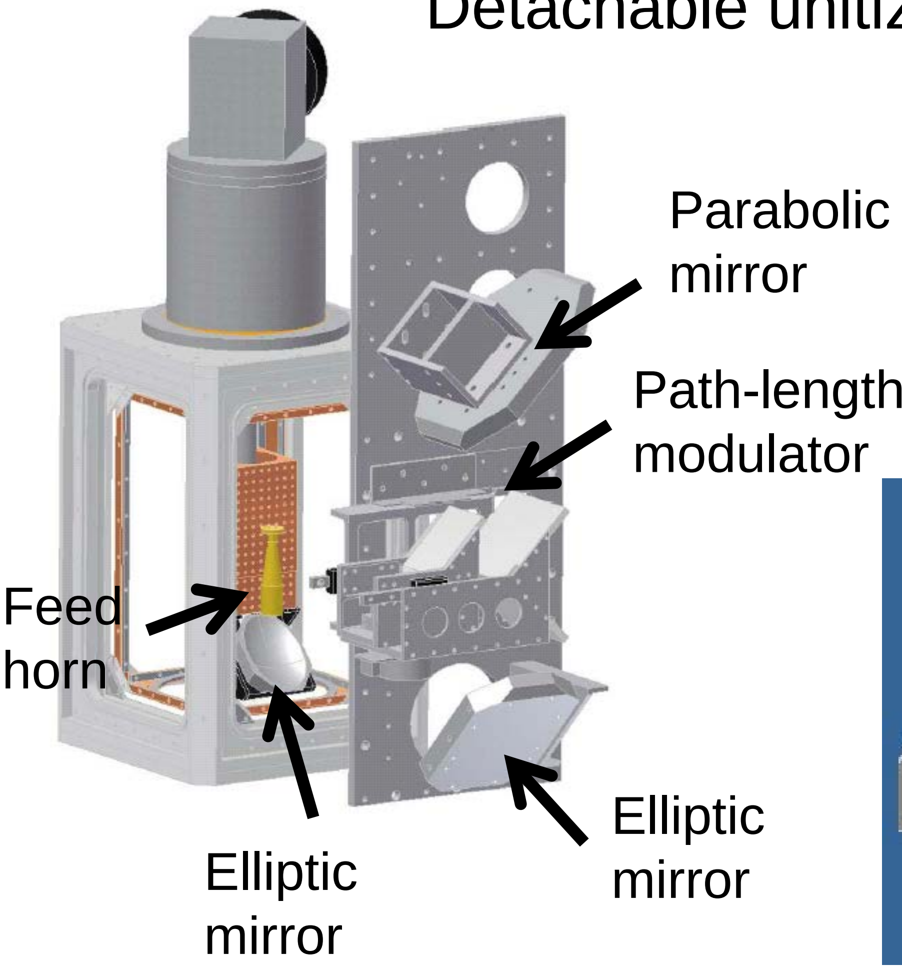
ULVAC GM-type refrigerator
0.3W cooling power
“He-pot” to stabilize temperature

Freq. band :230 – 260GHz
SIS mixer□ PCTJ (by H. Maezawa□
LO: Quinstar Active Multiplier
(13-14GHz x 6)
+ RPG tripler (x3)
input level 6-8dBm

Design concept of power-saving SIS radiometer

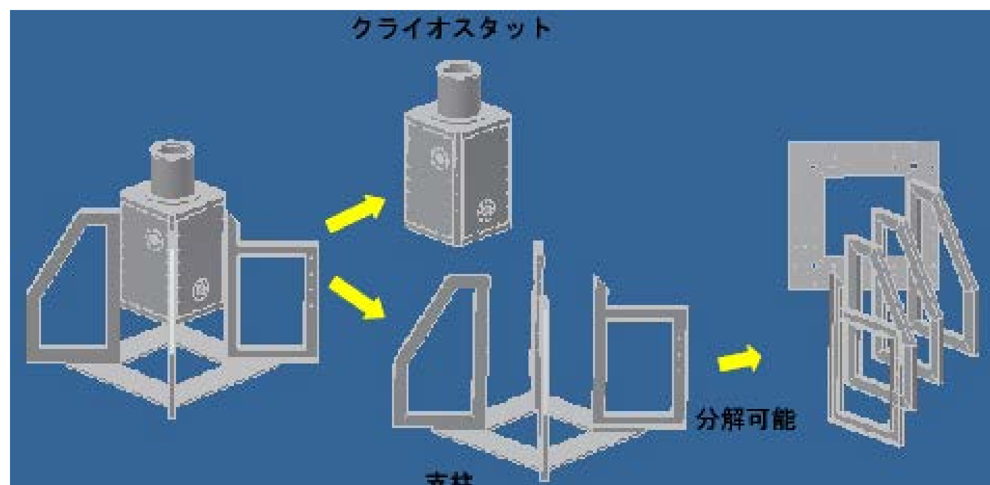
- Portability

Detachable unitized optics

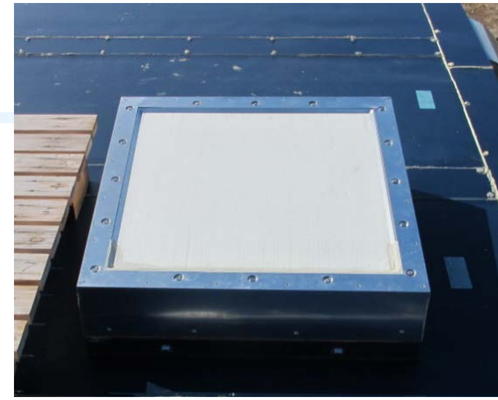


Easy to disassemble, reassemble, and readjust

Detachable supporting legs



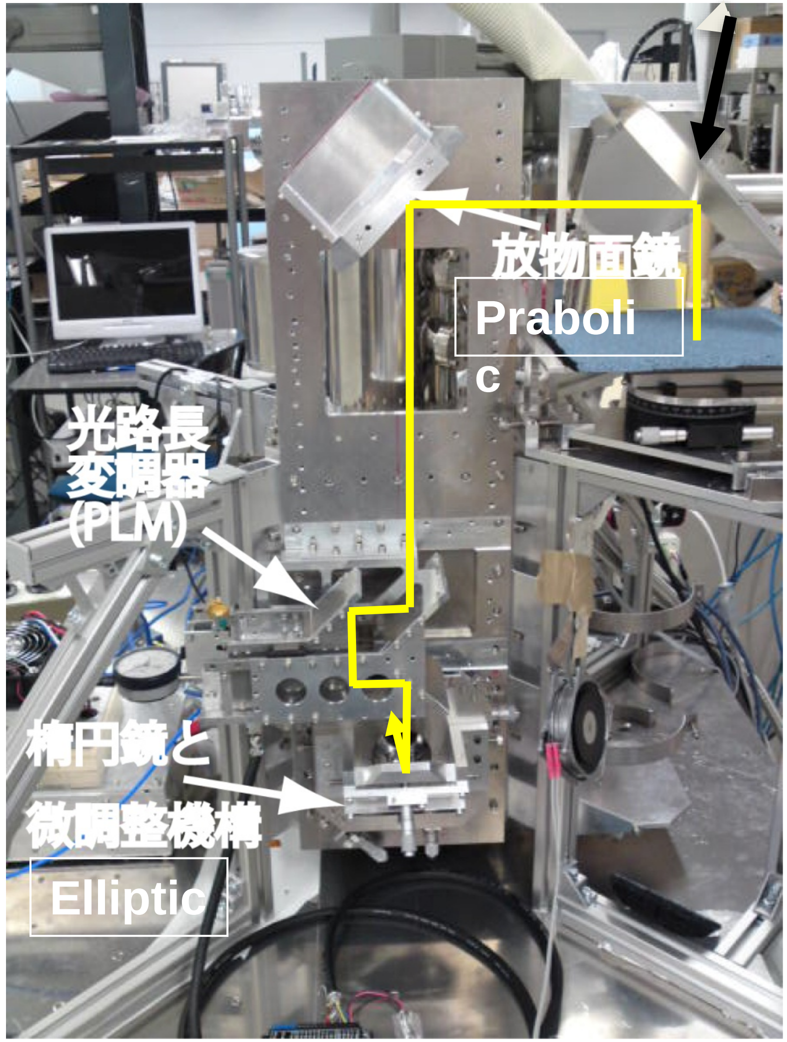
Optics at Syowa

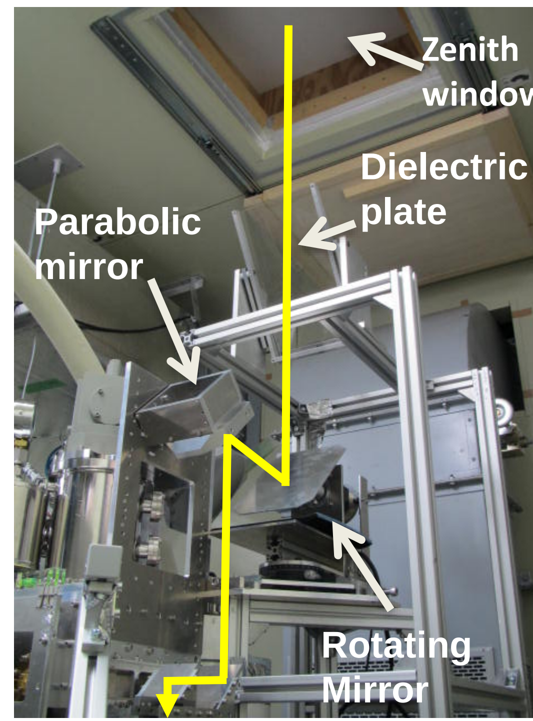


Zenith window on the roof

Inside of the Cryostat

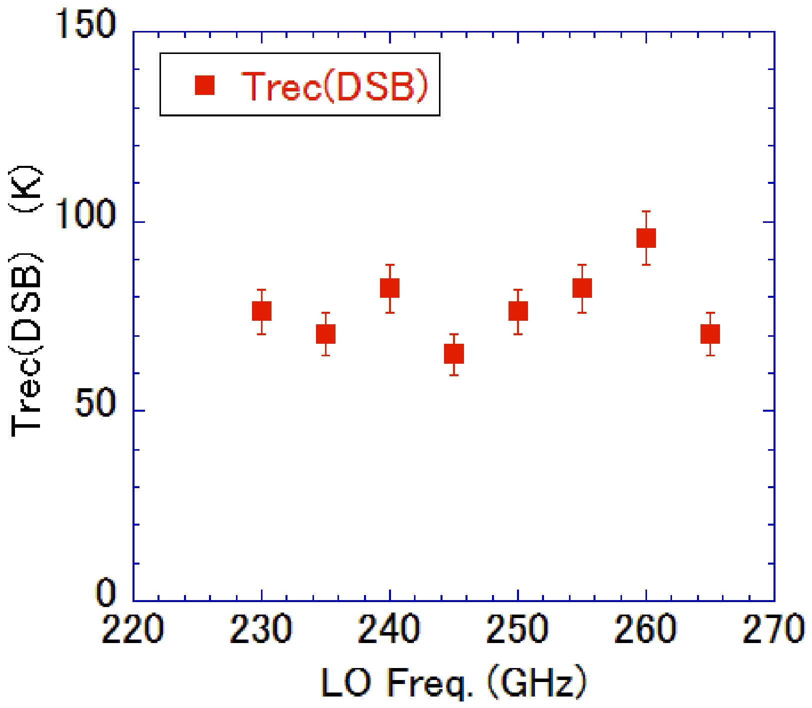
Rotating mirror



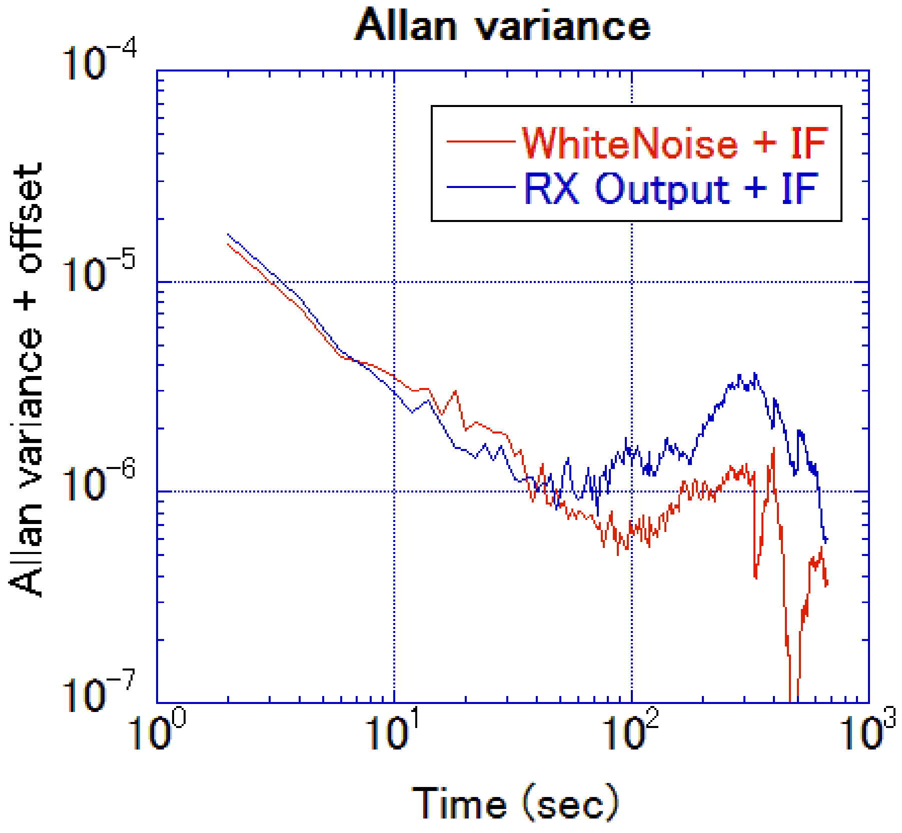


Receiver status after installation at Syowa

Receiver noise temperature



Allan variance

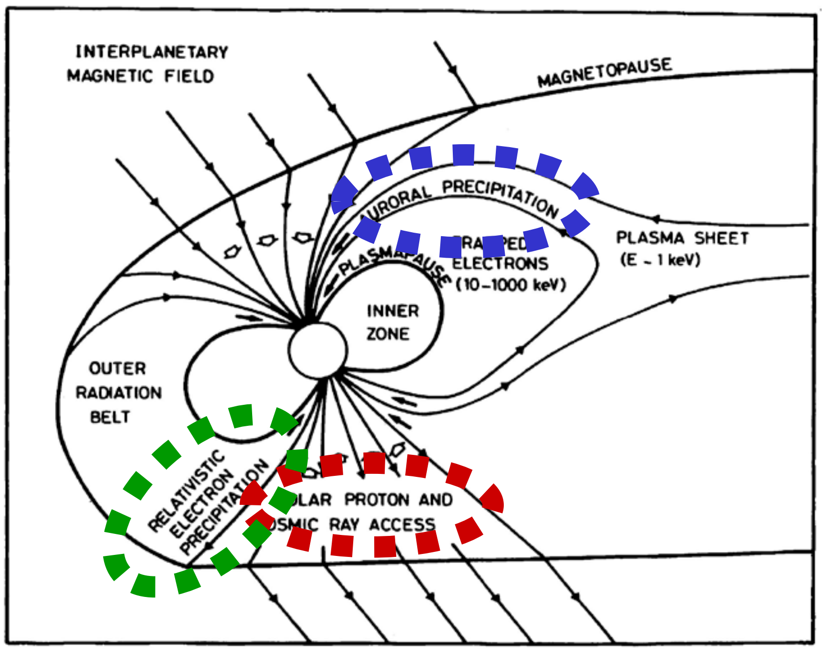


Spectrometer is Digital FFT spectrometer (Acqiris AC240)

Influence of EPP on the middle atmosphere

EPP =Energetic Particle Precipitation

(e.g. solar proton, relativistic electron)



Energetic particle precipitation

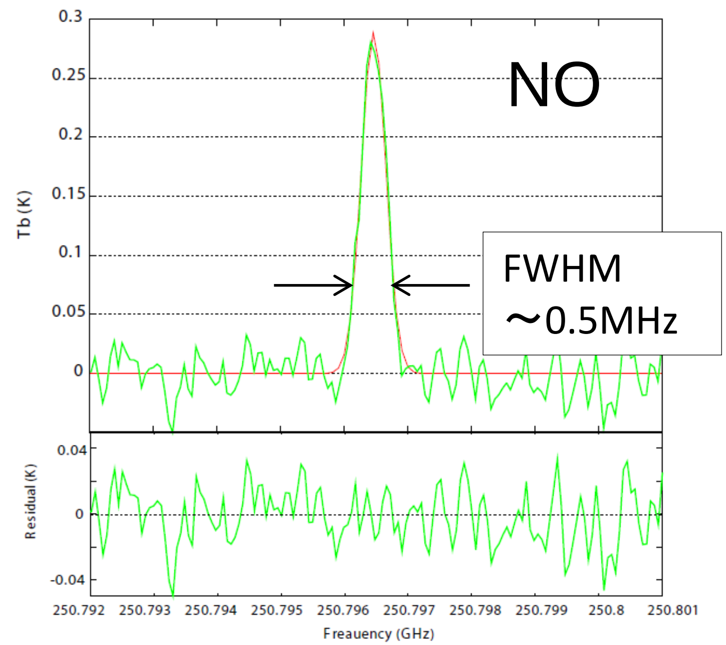
⇒ Ionization of N_2, O_2

⇒ N_2^+, N^+, O^+, O_2^+, …

⇒ HO_x, NO_x production

⇒ Ozone depletion

by HOx, NOx catalytic cycle



Gaussian fitted spectrum and its residual

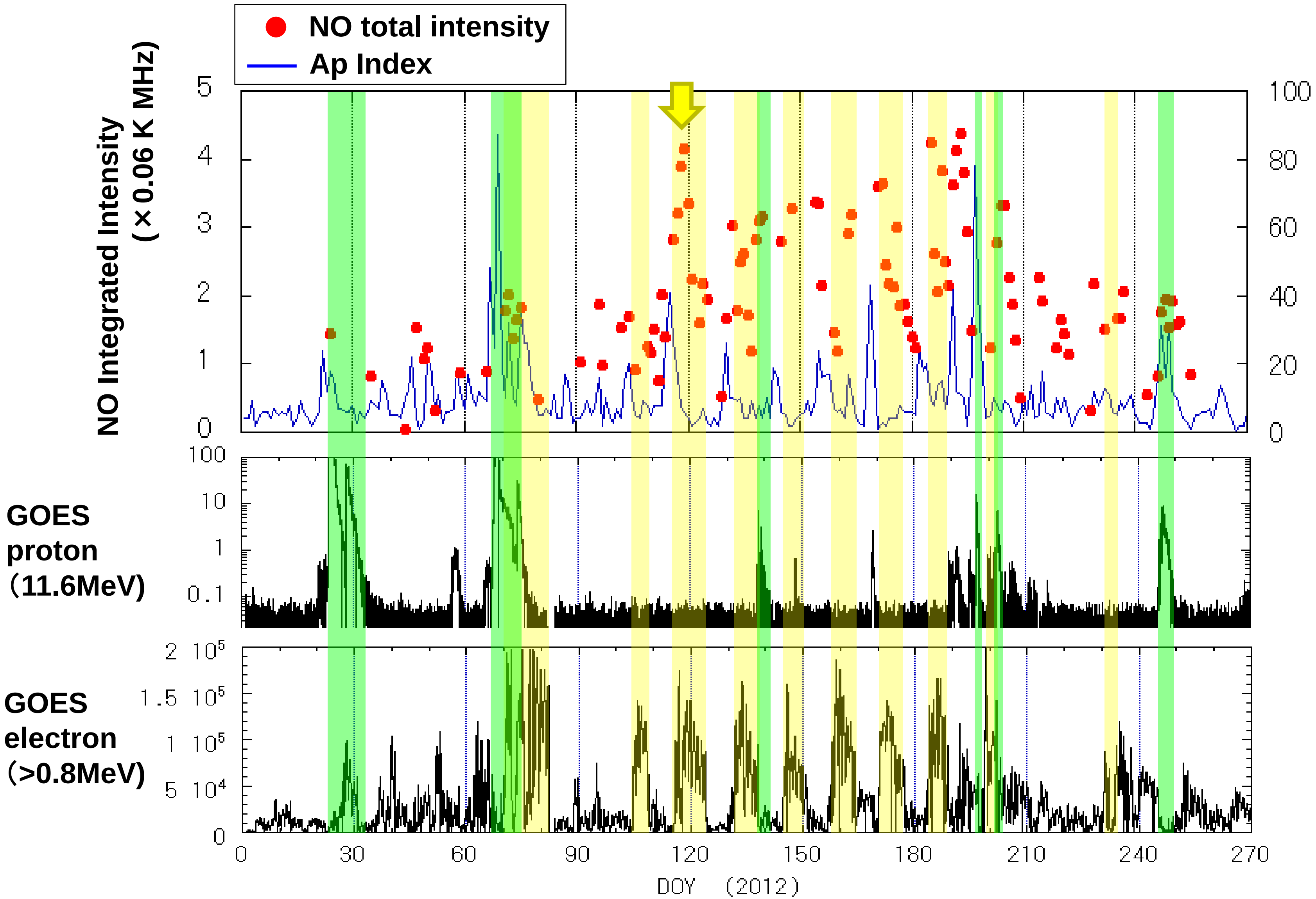
- Well fitted by single Gaussian
- Full width of Half maximum is ~ 0.5 MHz

NO spectrum is emitted above ~ 60-70 km

Temperature derived from Doppler width is ~ 250K

Emitting region is upper mesosphere or lower thermosphere

NO intensity variation and EPP signatures



Atacama in Chile (2004 -)

Major objective

Monitoring of very rare molecules such as $H_2{}^{18}O$, ClO, etc.
Study of the EPP effects near the Brazilian Geomagnetic Anomaly region.

Main Spec.

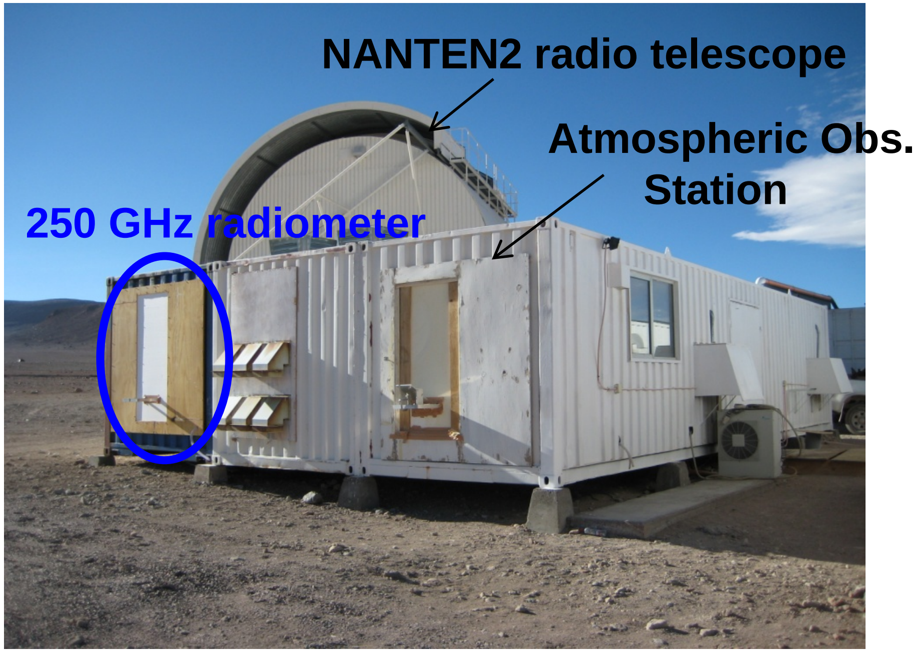
Main target : NO, NO_2, $H_2{}^{18}O$, ClO, O_3, etc.
Rikubetsu-type Cryostat and Optics
SIS mixer
- Freq.coverage : ~ 180 – 260 GHz
- Fixed-tune SIS mixer in DSB mode (Parallel twin junctions)

Spectrometer
- 2004 -2009: AOS (1GHz bandwidth, 1MHz resolution)
- 2009 - : Digital FFT (1GHz bandwidth, 60kHz resolution

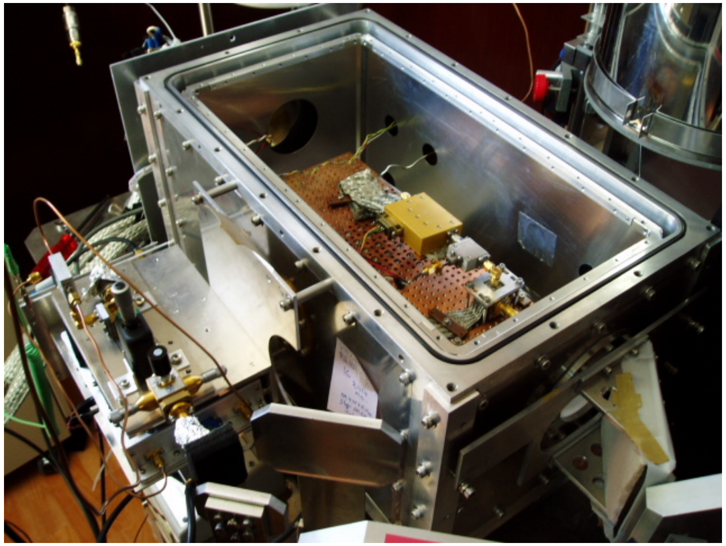
2010-2012 : Stop operation
2013 spring: Restart operation

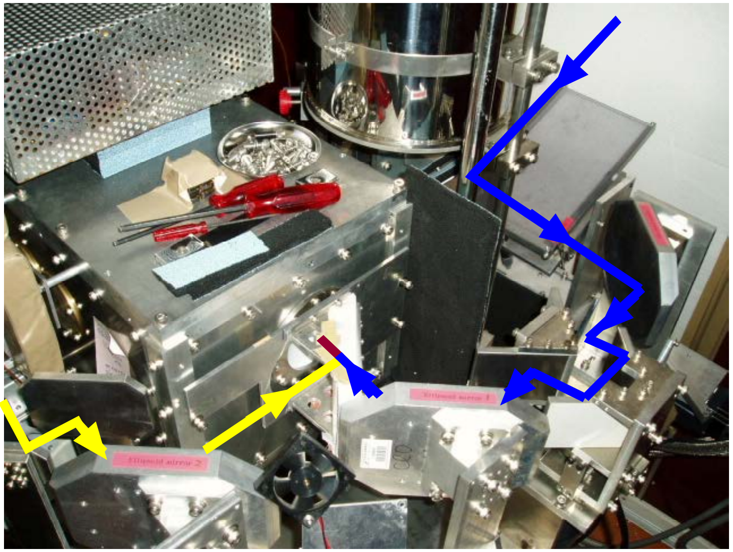
Atacama in Chile

Very small atmospheric water vapor attenuation at millimeter wave length because of high altitude (4,800m).



Rikubetsu-type optics and cryogenics.
DSB mixer.

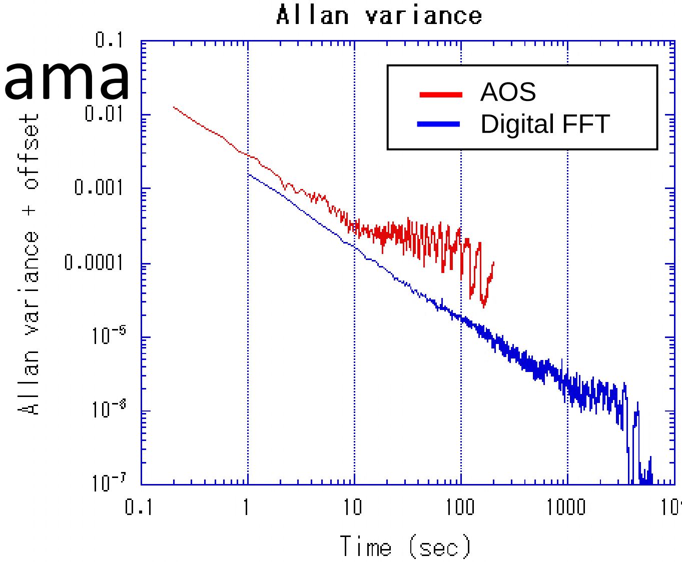




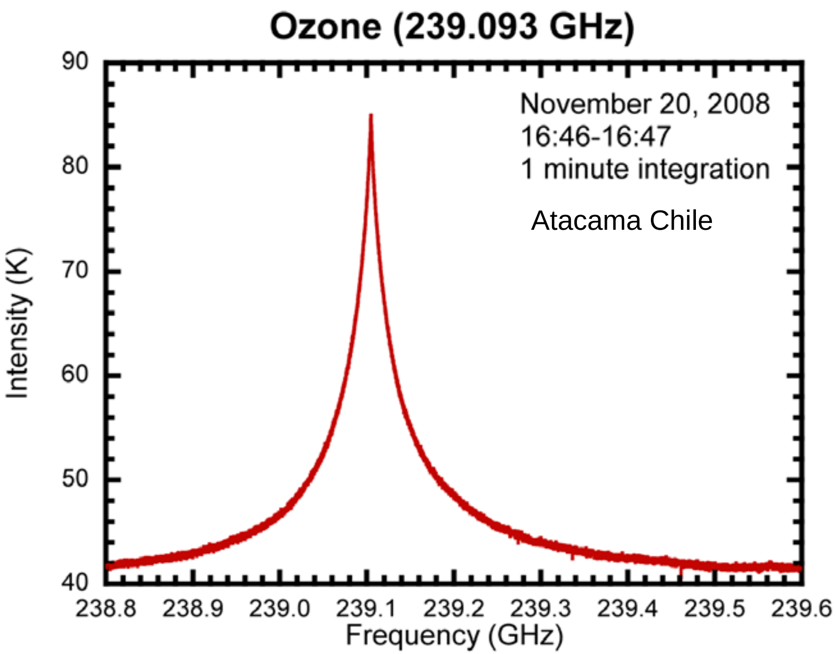
Digital FFT Spectrometer in Atacama

Digital FFT spectrometer (DFS)

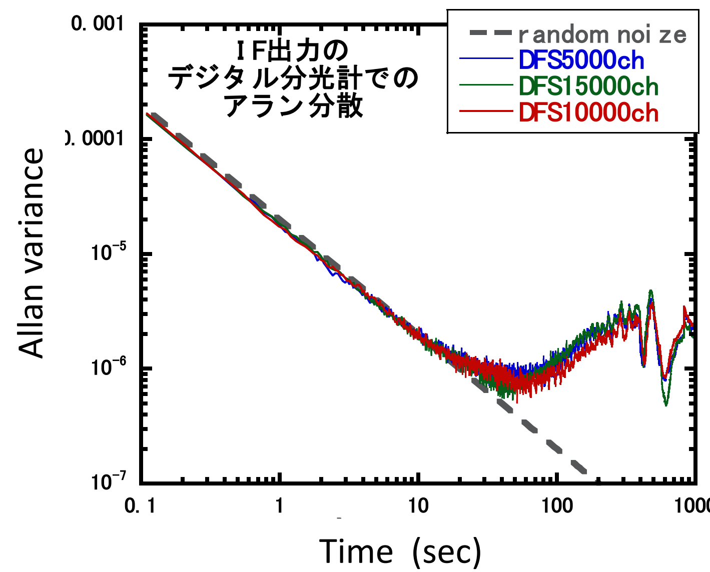
- (Acqiris AC240)
- BW = 1 GHz
- Δf = 61 kHz
- N = 16384 ch



Stability of the DFS compared with previous AOS



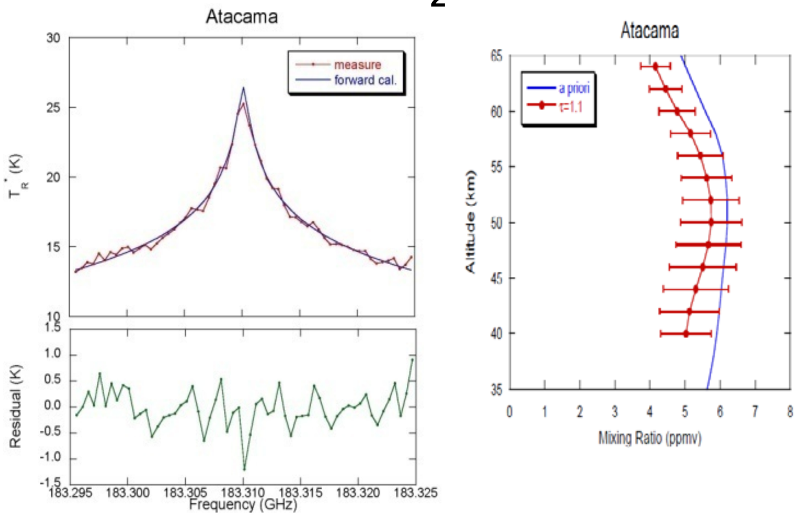
Ozone spectrum obtained with the DFS



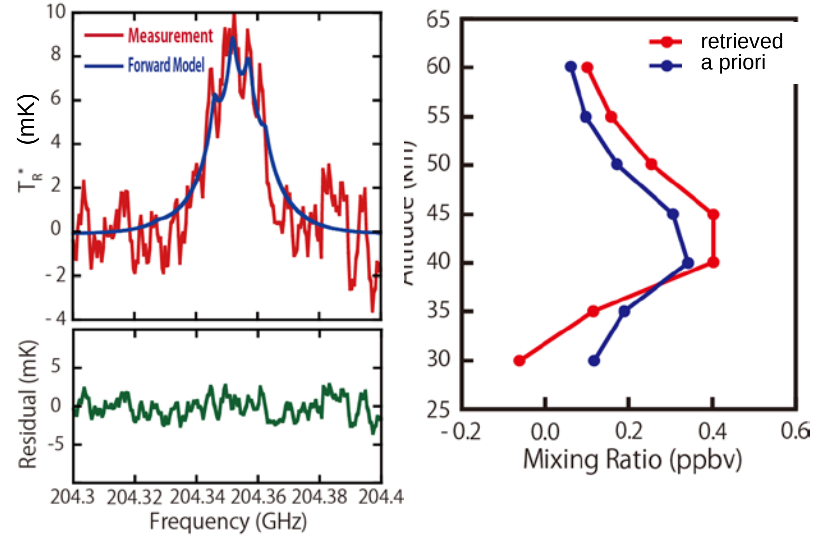
Stability of the whole radiometer system

Molecular spectra obtained in Atacama

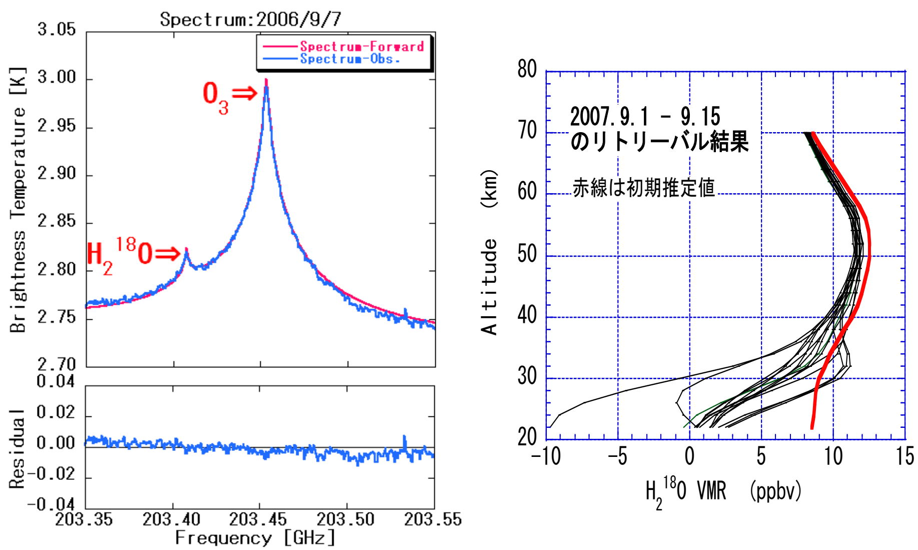
183GHz H_2O



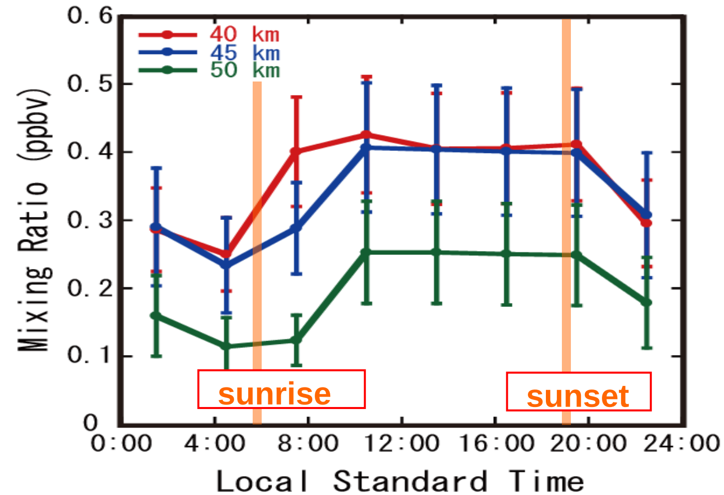
204GHz ClO



203GHz $H_2^{18}O$

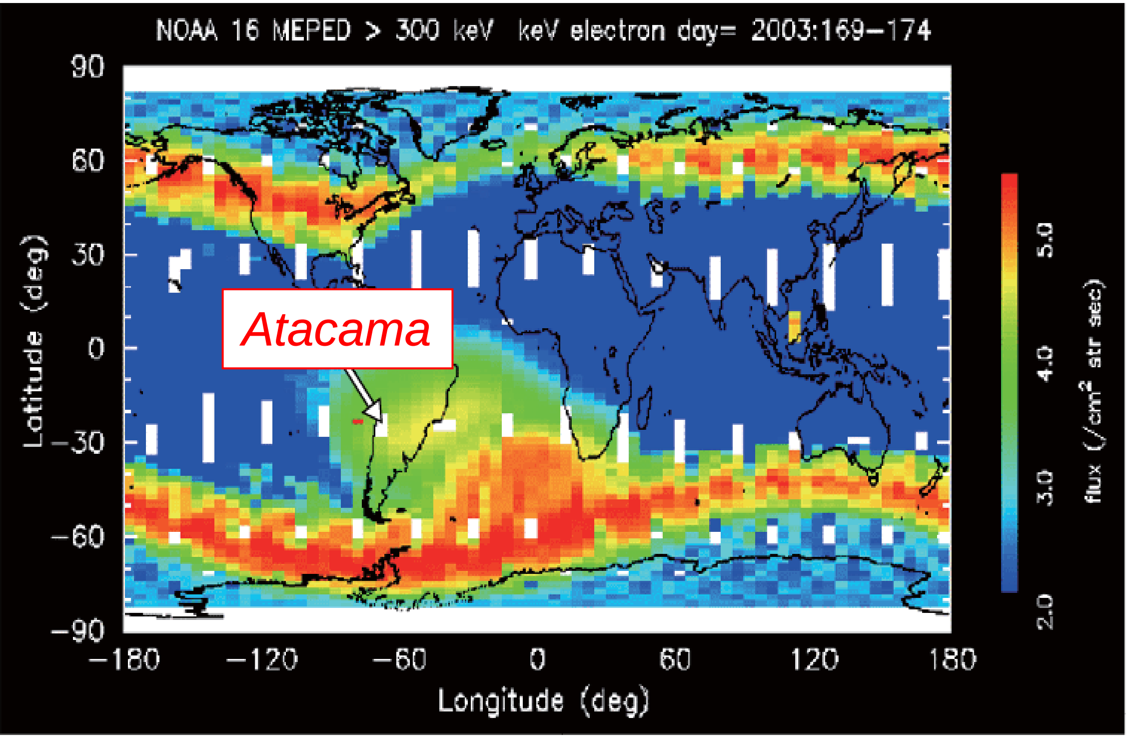


ClO diurnal variation



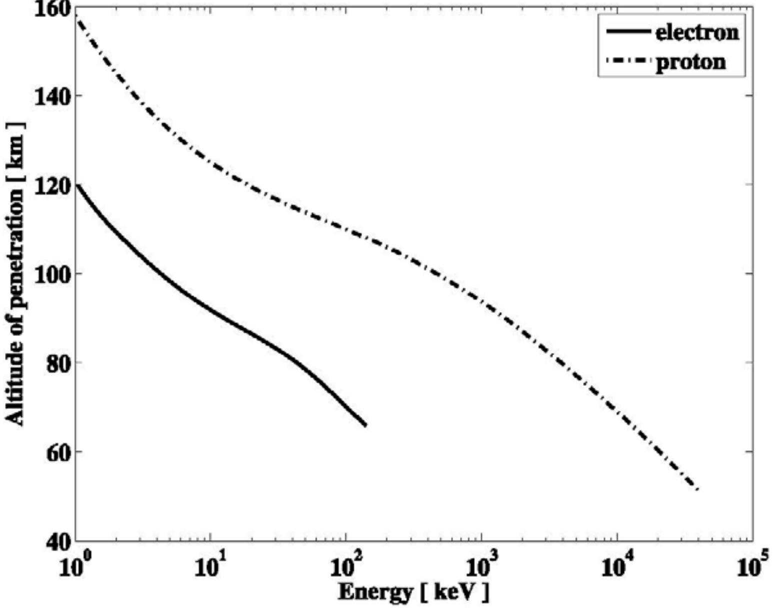
Search for the EPP effect in the mid-latitude region

- Atacama is close to the Brazilian geomagnetic anomaly
  ➔ Large amount of relativistic electron precipitation from radiation belt is expected.
- High energy electron (200-300keV) will be penetrate into ~60km
- Solar activity will be maximum around 2013
- Correlation study of EPP effects with Syowa observation



Distribution of high energy electron more than 300 keV at 800 km at the solar proton event of October 2003 (Courtesy of Dr. Miyoshi, STEL, Nagoya U.)

Penetration depth of proton and electron



Renard et al. 2006 GRL

Rio Gallegos in Argentina (2011 -)

Major objective

Monitoring of time variation of ozone vertical profiles around the boundary region of ozone hole.

Main Spec.

Main target : O_3

Rikubetsu-type Cryostat and Optics

SIS mixer

Freq.coverage : 2011 ~ 209 GHz

2012 ~ 111 GHz

Fixed-tune broadband SIS mixer in DSB mode

(Parallel twin junctions)

This year DSB ➔ 2SB

Spectrometer

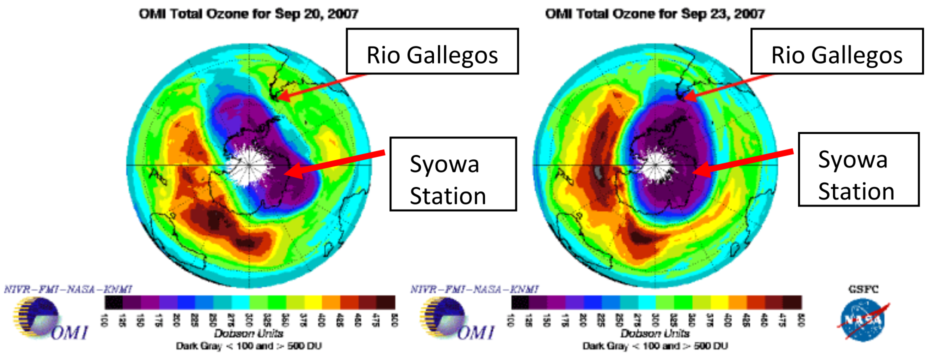
Digital FFT (1GHz bandwidth, 60kHz resolution)

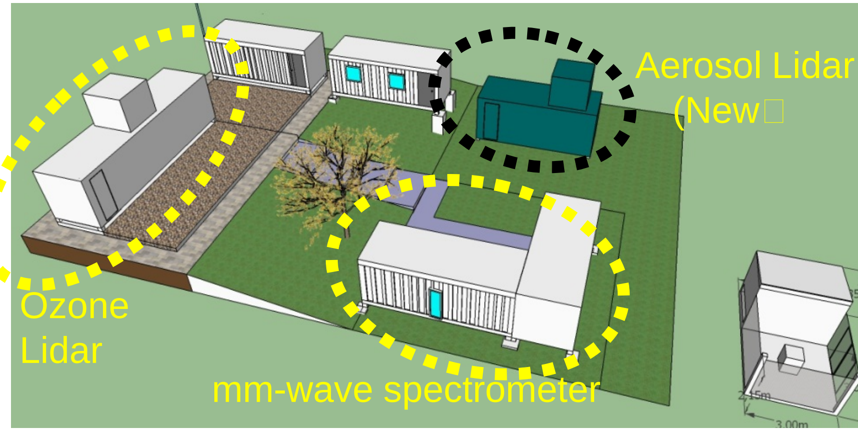
Ozone observation in Rio Gallegos

SATREPS
Science and Technology Research Partnership for Sustainable Development Program

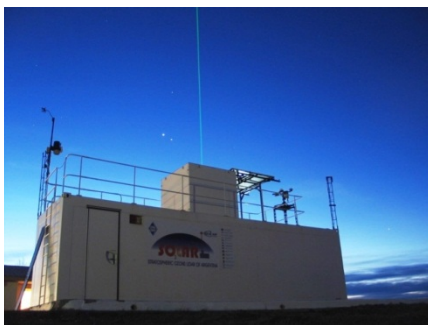
supported by JICA and JST

Collaboration with CEILAP In Argentina
(Laser and Application Rresearch Center)
Magellan Univ. in Chile





Atmospheric Observatory Patagonia Austral
In Rio Gallegos, Argentina

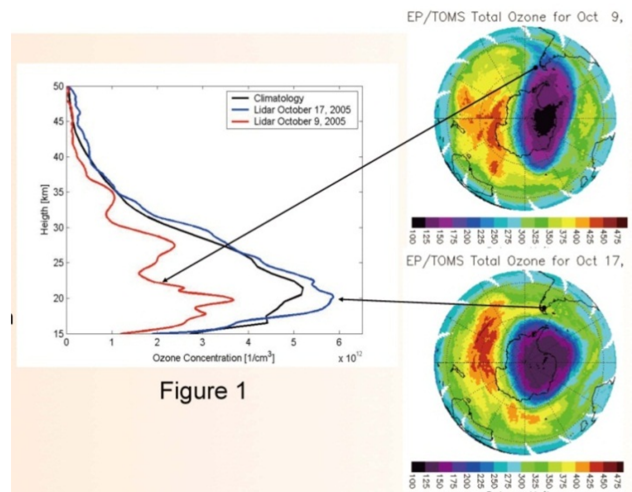


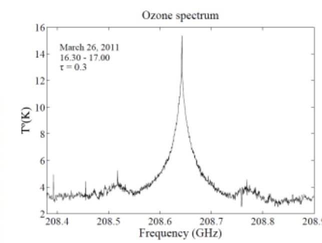
Ozone Lidar (Argentina)

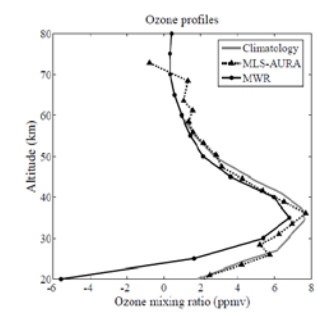
Ozonesonde (Chile)

UV measurements (CL & AR)

mm-wave (Japan)







Ozone vertical profile obtained by Lidar（left）
Ozone vertical profile obtained by mm-wave (right)

Main specification

	Receiver	Freq. (main target)	Spectrometer	Refrigerator	calibration
Rikubetsu [1] Japan (1999 -)	SIS mixer (2SB)	100-115 GHz (O_3)	AOS (1.0GHz, 1.0MHz)	GM-JT	Hot-cold (liq N_2)
Atacama Chile (2004 -)	SIS mixer (DSB)	230-260 GHz (NO, O_3, ClO)	Digital FFT (1.0GHz, 60kHz)	GM-JT	Hot-cold (liq N_2)
Syowa [2] Antarctica (2011 -)	SIS mixer (DSB)	230-260 GHz (NO, O_3, ClO)	Digital FFT (1.0GHz, 60kHz)	GM	Hot-cold (liq N_2)
RioGallegos [3] Argentina (2011 -)	SIS mixer (DSB)	100-115 GHz (O_3)	Digital FFT (1.0GHz, 60kHz)	GM-JT	Hot-cold (liq N_2)
Tsukuba [1] Japan (1995 – 2010)	SIS mixer (2SB)	100-115 GHz (O_3)	AOS (1.0GHz, 1.0MHz)	GM-JT	Hot-cold (liq N_2)

(1) operated by National Institute for Environmental Studies (NIES), Japan until 2011

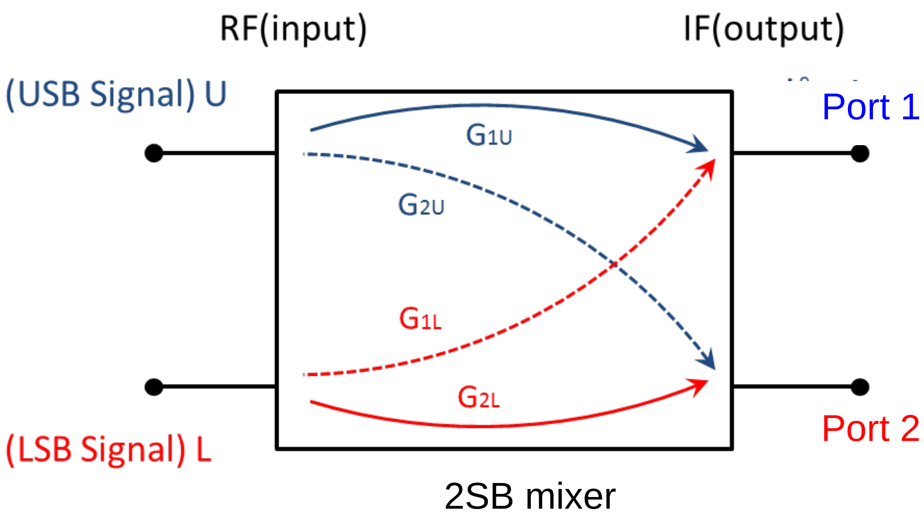
(2) operated in collaboration with National Institute of Polar Research (NIPR), Japan

(3) operated in collaboration with Laser Research and Application Center (CEILAP), Argentina

Kerr's method

Kerr et al., ALMA MEMO 357, 2001

Relationship of the mixer gain of the 2SB mixer



Sideband ratio at port 1 $R_1 = \frac{G_{1U}}{G_{1L}}$

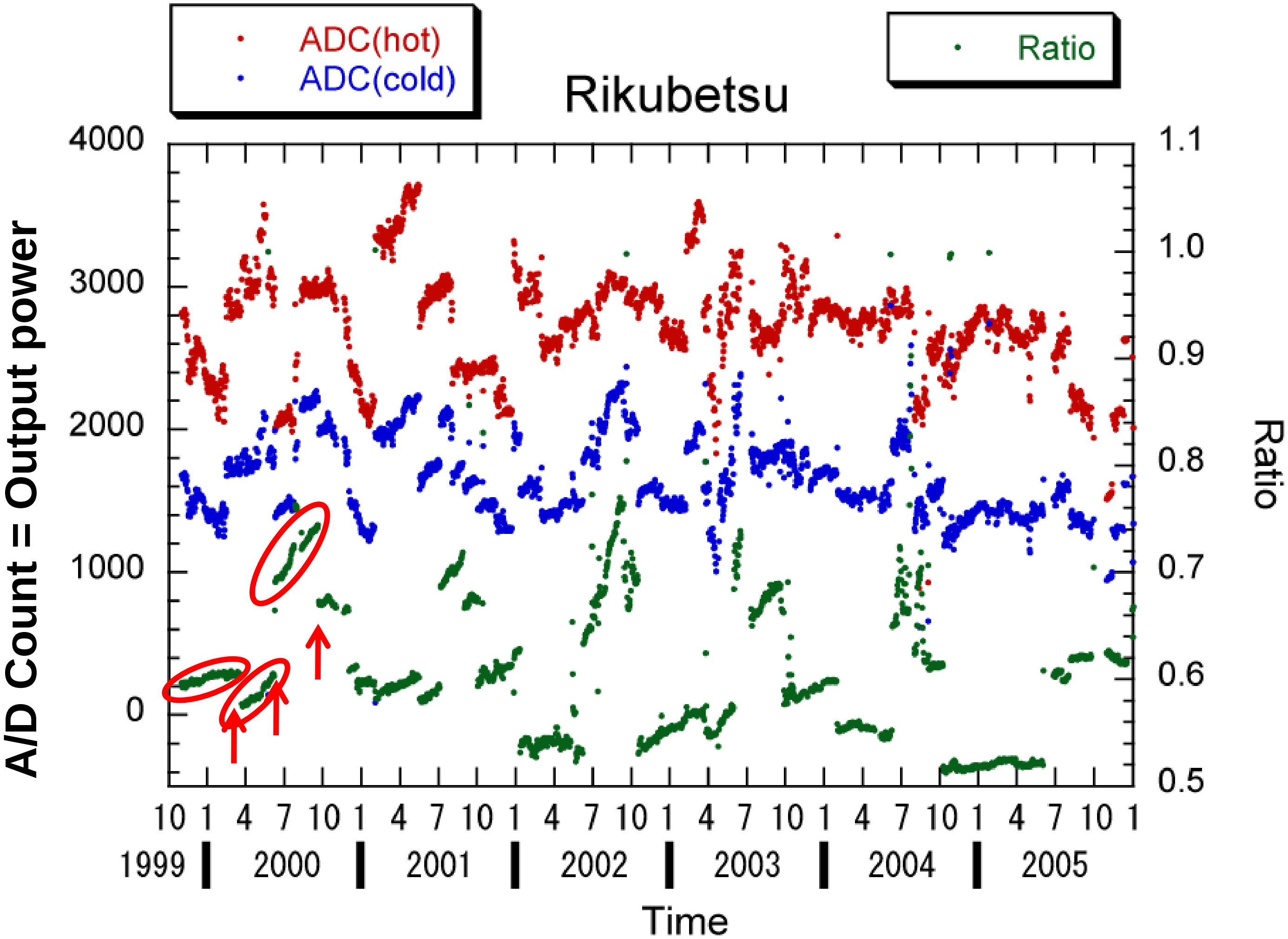
Sideband ratio at port 2 $R_2 = \frac{G_{2L}}{G_{2U}}$

4 unknown variables: $G_{1U} \cdot G_{1L} \cdot G_{2U} \cdot G_{2L}$
→If we make 3 equations of Gain factors, then we can obtain the ratio.

G_{1U} : Gain at output port 1 for USB signal input
G_{2U} : Gain at output port 2 for USB signal input
G_{1L} : Gain at output port 1 for LSB signal input
G_{2L} : Gain at output port 2 for LSB signal input

The effect of water vapor in the styrene foam reservoir

- The output power (P) changes along with the receiver gain variation
- But P(cold)/P(hot) should be constant, if the load temperatures do not change



$$R \equiv \frac{P_{cold}}{P_{hot}}$$

$$= \frac{G(T_{cold} + T_{sys})}{G(T_{hot} + T_{sys})}$$

T_{sys} :
Receiver system noise
~ almost constant

T_{hot} is almost constant (within ~0.3%)

⇩

Time variation of the ratio (R) corresponds to the variation of T_{cold}

⇩

Intensity correction by using the ratio, R