Activities in microwave radiometry at the Institute of Applied Physics University of Bern

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NDACC workshop, Bern, 8. Jan. 2013

Outline

Microwave radiometers from IAP

- **Bern**
  - GROMOS: GROund based Microwave Ozone monitoring System 
  - TROWARA: TROpospheric WAter Radiometer for IWV and ILW
  - TEMPERA: TEMPerature RAdiometer

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    ☞ Talk by J.J.Oh and S.Ka

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  - MIAWARA-C: MIddle Atmospheric WAter vapour RAdiometer for CAmpaigns
  - WIRA: WInd RAdiometer
  - GROMOS-C: under construction

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- **Payerne**: MeteoSwiss
  - SOMORA: Stratospheric Ozone MOnitoring RAdiometer
    ☞ Talk by Eliane Maillard

Microwave radiometers in the alpine regione

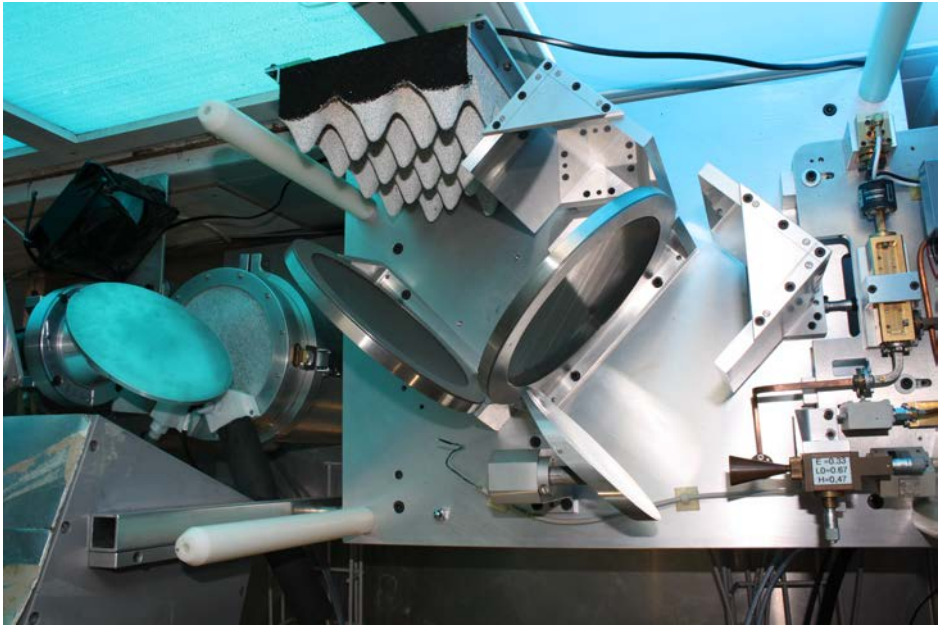
Location of instruments

O_3 measurements from Bern with GROMOS

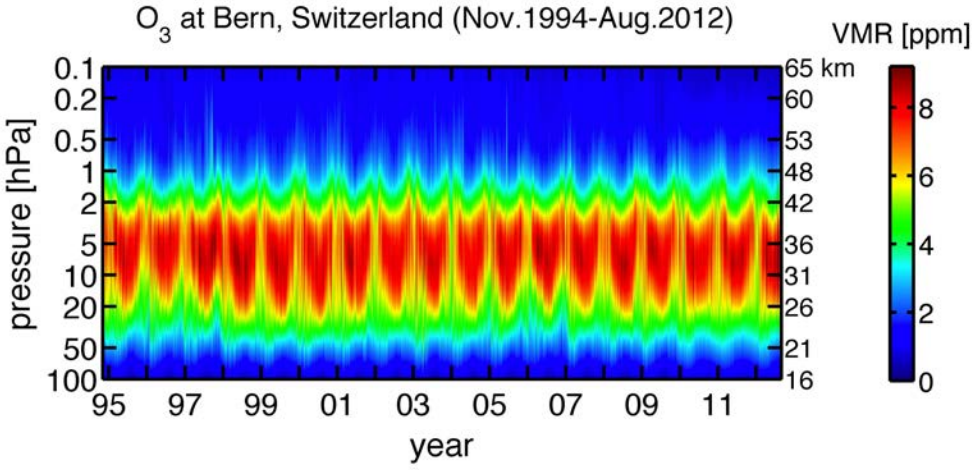
- O_3 at 142.175GHz
- operational since 1994
- total power radiometer with MPI
- observation at 42° elevation
- T_{sys}=2250K SSB uncooled
- calibration with ambient and LN2 load (automatic refill)
- O_3 profiles every 3 minutes
- originally 48 filters in filter bench
- refurbishment with digital FFT spectrometer in 2009
- 32000 channels over 1 GHz
- refurbishment with new operating software Labview

GROMOS frontend

▸ VNC-GROMOS



The GROMOS data set



☞ Data set allows studies of ozone variability over many time scales

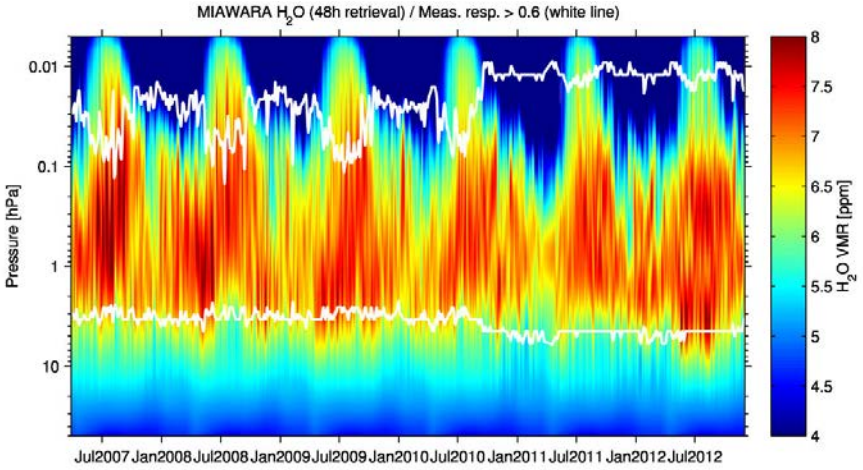
Zimmerwald observatory ▸ MIAWARA

Key characteristics of MIAWARA

VNC-MIAWARA

- H_2O at 22.235 GHz
- corrugated horn with 6° HPBW and plane mirror
- T_{sys} ≈135K SSB uncooled
- balancing operation with reference at zenith with absorber bar
- observation at around 20° elevation (adjusted for balance)
- AOS and CTS spectrometers at the beginning
- now FFT spectrometer with 16000 channels and 62 kHz resolution
- calibration with load at ambient temperature and sky at 60° as cold load determined by tipping curve

Water vapor data set of MIAWARA



Data analysis by Dominik Scheiben

MIAWARA-C: MIddle Atmospheric WAtervapor RAdiometer for Campaigns: worldwide at nice places

- easy to set-up, needs 220V and internet, remotely operated
- equipped with own weather station
- Campaigns so far at:

Zugspitze	14. Jan. - 22. April 2009
Table mountain	17. Sept. - 31. Oct. 2009
Zimmerwald	15. July 2010 - 9. May 2011
Sodankylä	15. Jan. - 17. June 2010 and 14. June 2011 until present

webcam MIAWARA-C

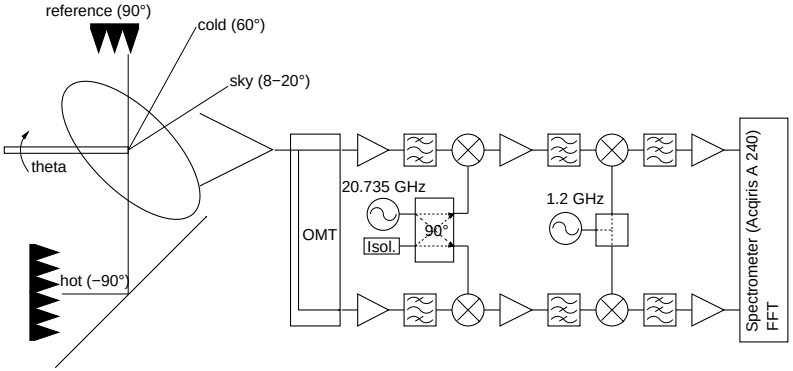
Maido, La Reunion summer 2013 -

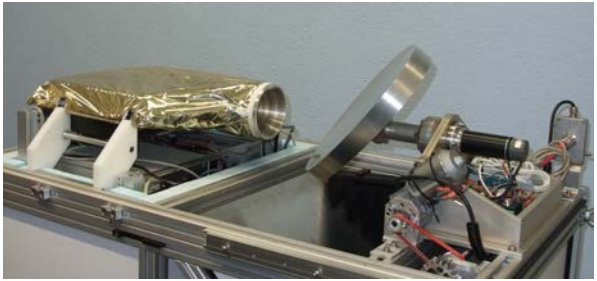
Key characteristics of MIAWARA-C

VNC-MIAWARA-C

- H_2O at 22.235 GHz
- choked Gaussian horn combined with a parabolic mirror with 5° HPBW
- T_{sys} ≈135K SSB uncooled
- dual polarization receiver
- balancing operation with reference at zenith with absorber bar
- observation at around $10 - 18°$ elevation (adjusted for balance)
- FFT spectrometer with with usable BW of 400 MHz and 30.5 kHz resolution
- calibration with load at ambient temperature and sky at 60° as cold load determined by tipping curve

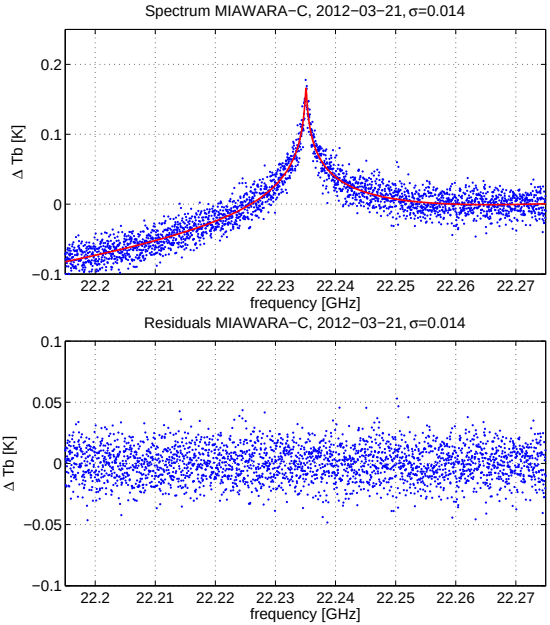
A closer look at MIAWARA-C





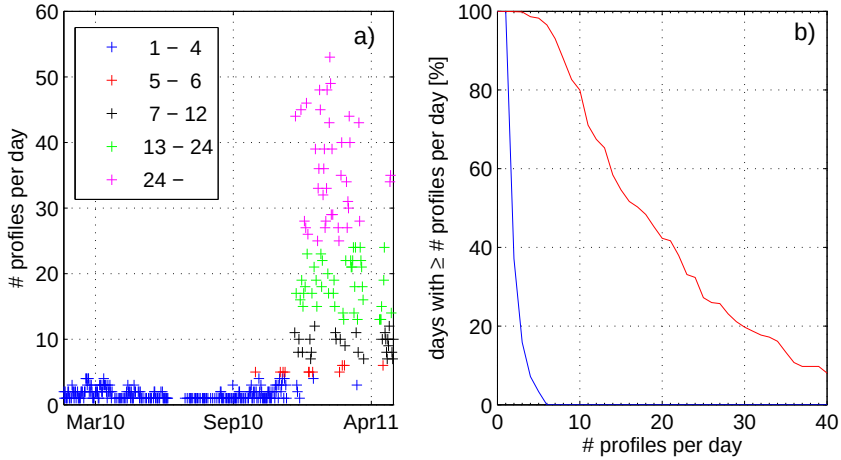
A closer look at MIAWARA-C

Spectra and residuals



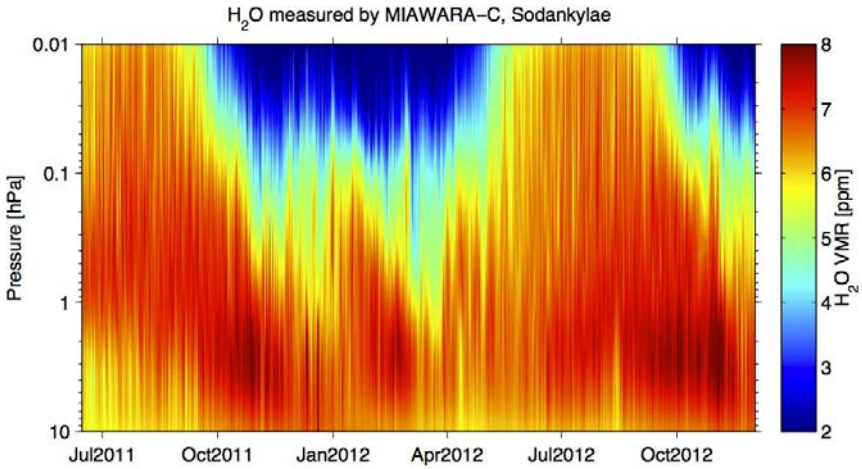
MIAWARA-C: Upgrade enables good temporal resolution

Number of retrieved profiles per day



MIAWARA-C provides valuable datasets

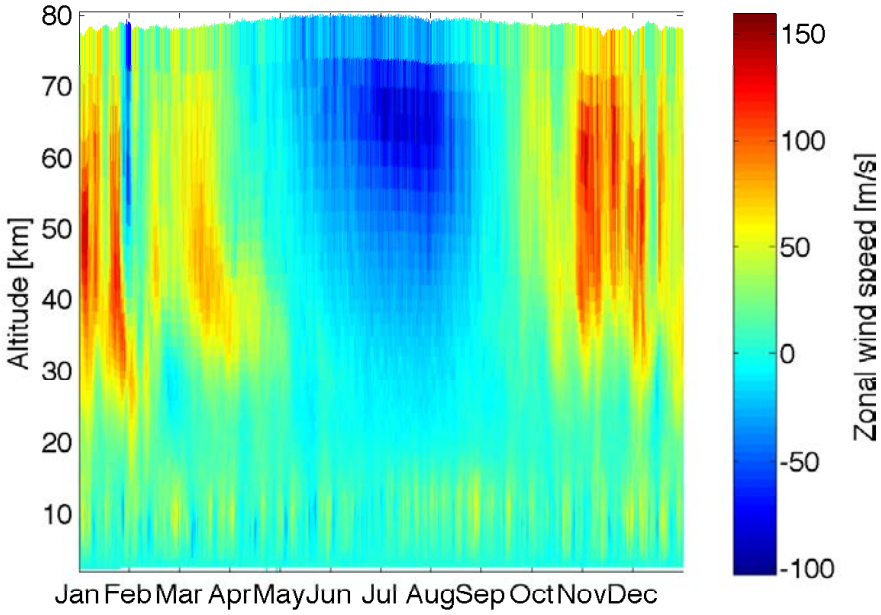
Water vapor profiles measured at Sodankylä, 67N



Data analysis by Brigitte Tschanz

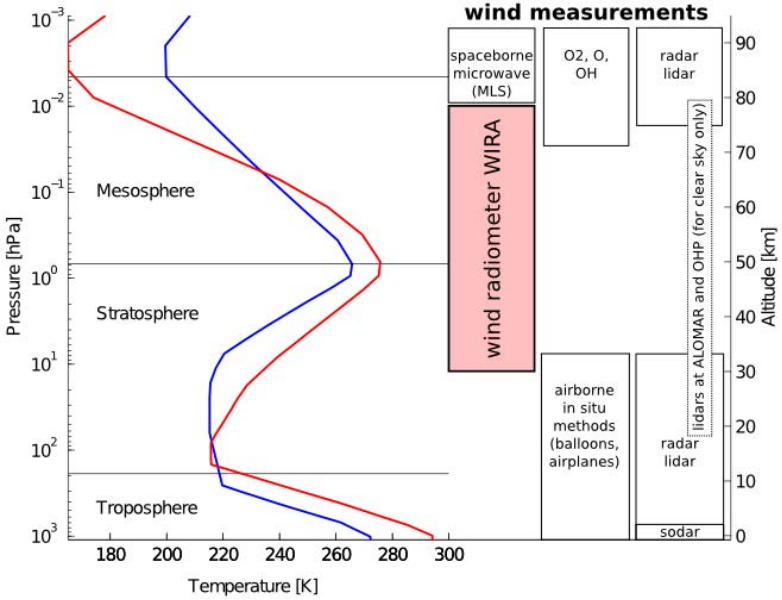
Microwave wind radiometer

The atmospheric wind field at midlatitudes



Motivation for wind measurements

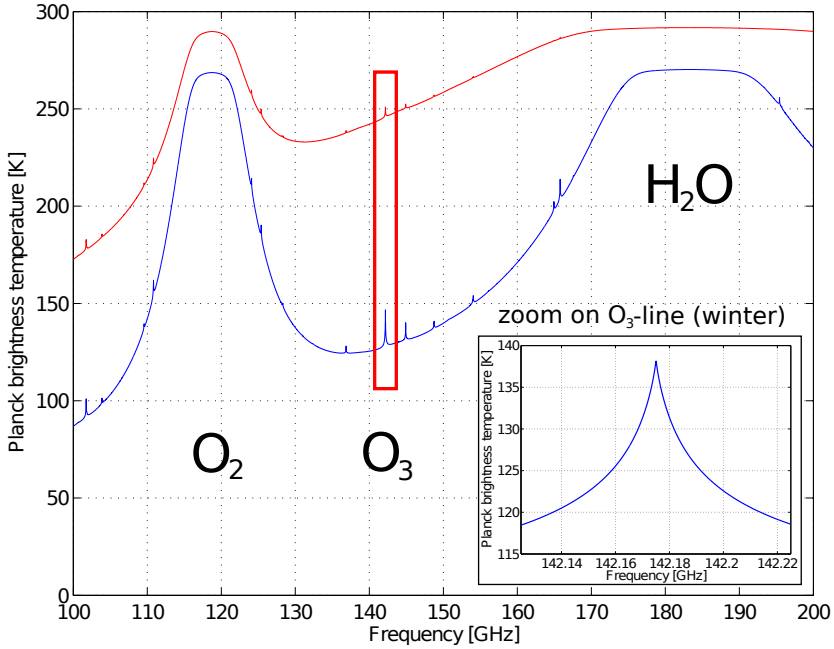
What is available by now



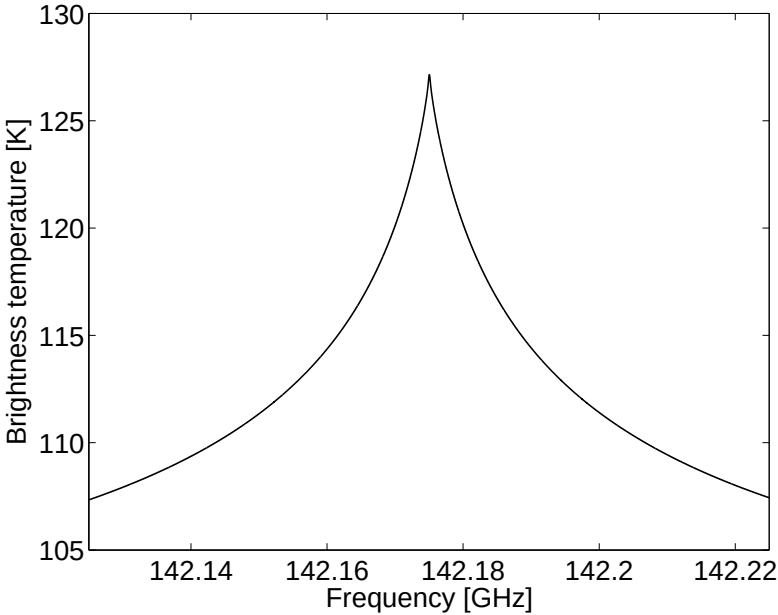
The measurement principle

- Doppler effect: $\Delta\nu = \frac{v_{LOS}}{c}\nu_0$
  where $v_{LOS} = v \cdot \cos\epsilon$ with ϵ: elevation angle
- Frequency $\nu_0 = 142.17504$ GHz from the rotational transition of the ozone molecule
- Ozone emission line is pressure broadened $\rightarrow$ altitude information
- Measure ozone spectra in opposite observing directions using a heterodyne receiver
- Deduce wind speed from frequency shift between the spectra

Atmospheric emission spectra in μwave region



Influence of wind on the ozone emission spectrum



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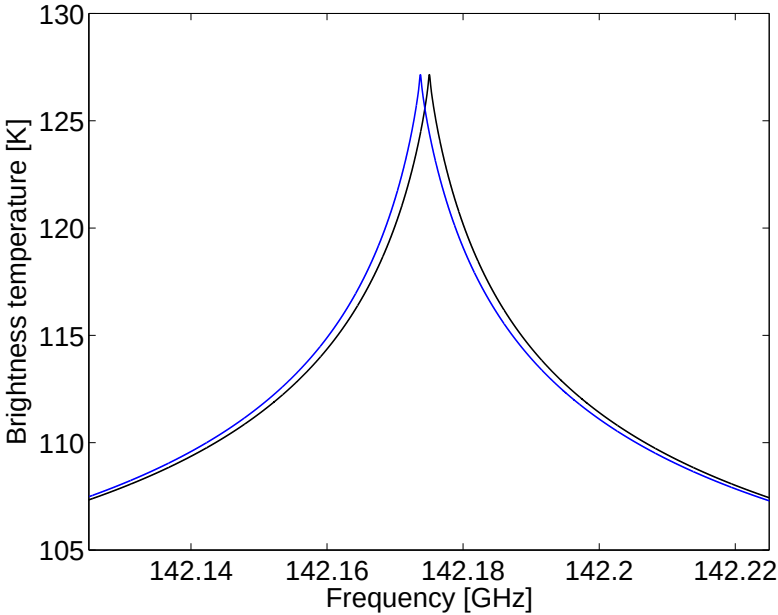

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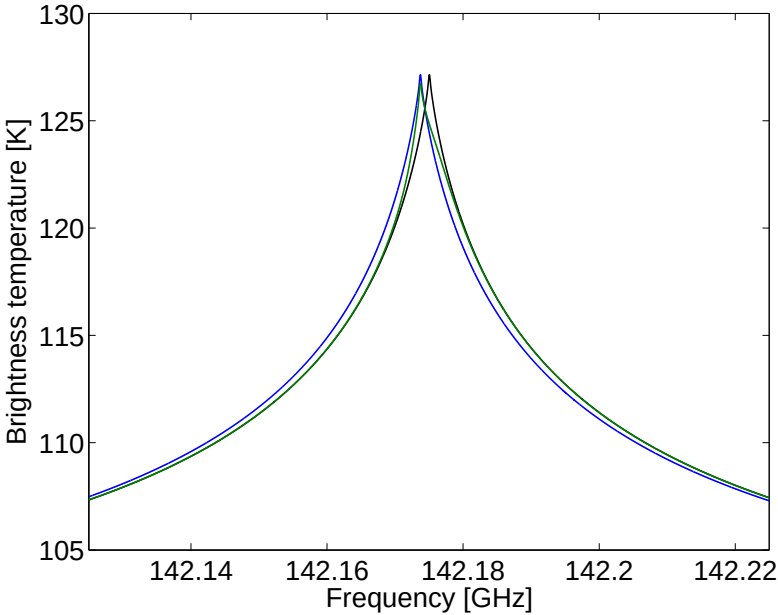

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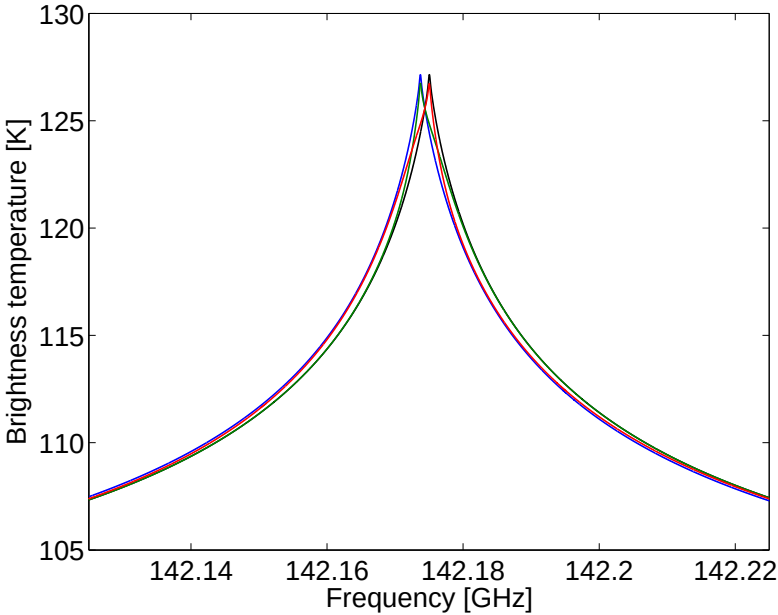
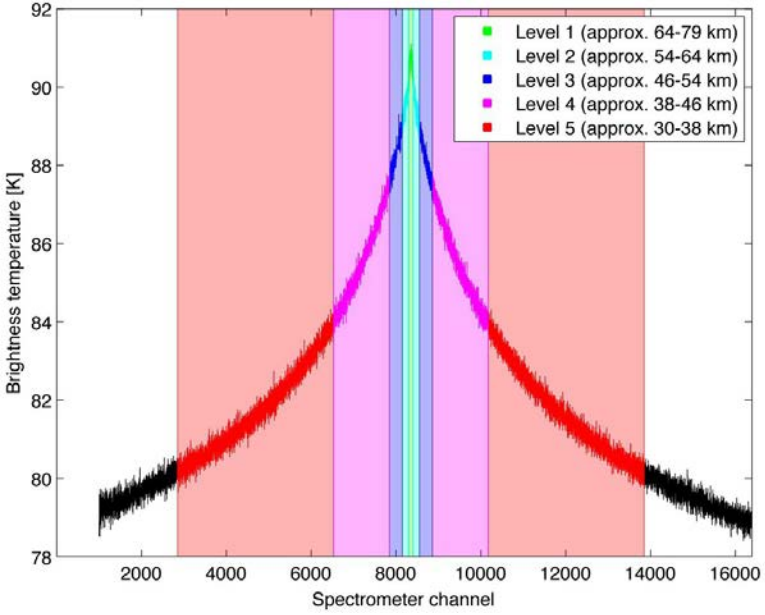
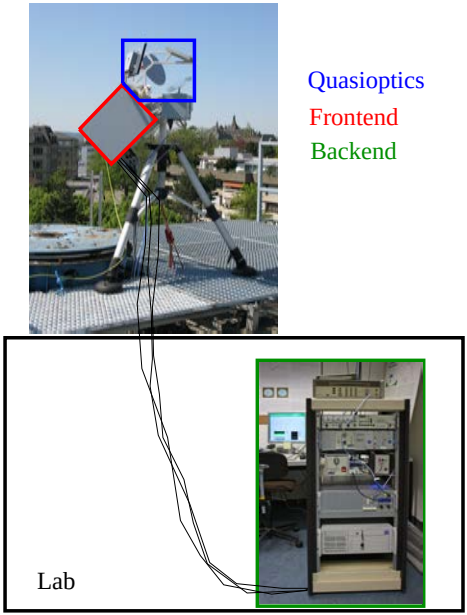


Altitude dependent information

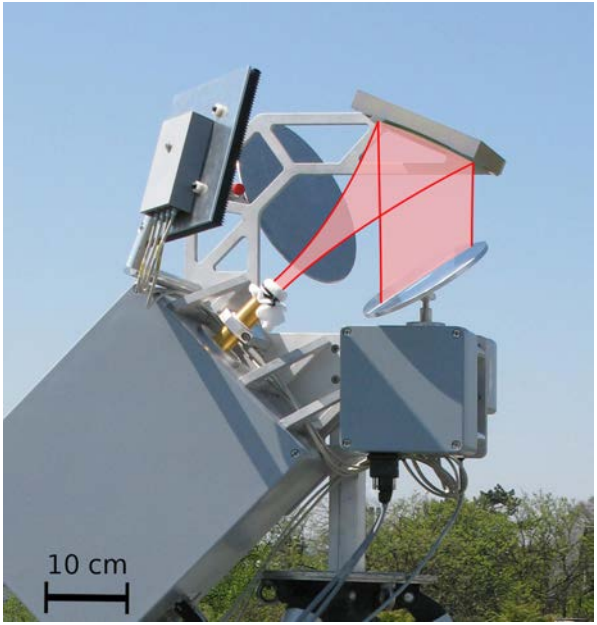


The instrument

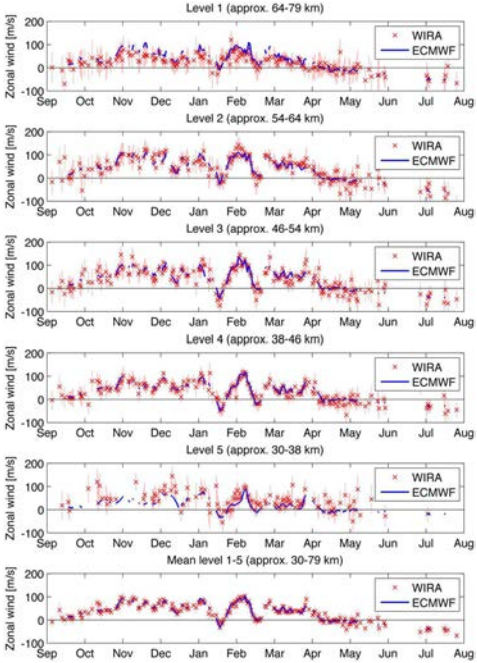
▸ VNC-WIRA



The quasioptics



Zonal wind observed over Bern



Status of WIRA today

Instrument paper is published

Atmos. Meas. Tech., 5, 2647–2659, 2012
www.atmos-meas-tech.net/5/2647/2012/
doi:10.5194/amt-5-2647-2012

Atmospheric Measurement Techniques

First middle-atmospheric zonal wind profile measurements with a new ground-based microwave Doppler-spectro-radiometer

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Upgrade: Receiver equipped with an amplifier at 142 GHz in front of the mixer

before: $T_{sys} = 880$ K DSB (≈ 1760 K SSB) now: $T_{sys} = 740$ K SSB

→ 2.4 times better signal to noise ratio in spectra
→ 2.4 times smaller error for wind measurements
→ 5.6 times less integration time for the same wind error

WIRA is now operating at Observatoire de Haute Provence ▸ webcam-WIRA

Temperature profiling using oxygen line

Waters 1973, Nature

Ground-based Measurement of Millimetre-wavelength Emission by Upper Stratospheric O_2

J. W. WATERS

Research Laboratory of Electronics and Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

Measurements from ground level of 53 GHz radiation from molecular oxygen in the stratosphere, using a very precise radiometer, can be used to give stratospheric temperatures.

THIS article reports measurements at sea level of upper stratospheric thermal emission from five high-rotational, millimetre-wavelength, magnetic dipole transitions of molecular oxygen, and discusses use of the emission lines for remote sensing of upper stratospheric temperatures. One of the lines, the 27−,

Molecular oxygen has a band of spectral lines near 60 GHz (5 mm wavelength) and a single line at 118 GHz produced by changes in orientation of its electronic spin relative to its rotation. The individual spin-rotation lines are designated N_+ or N_-, where N is the rotation quantum number which must be odd for $^{16}O_2$ in the $^3\Sigma_g^-$ electronic ground state, and where the subscript indicates whether the change in total angular momentum of the molecule during an emission transition is $+1$ or -1. Each $N_\pm$ line has $3(2N\pm1)$ Zeeman components spread over $\sim\pm1$ MHz by the terrestrial magnetic field. Near the centre of the 60 GHz band the terrestrial atmosphere is quite opaque, but on the band edges thermal emission, originating in the upper stratosphere where the lines are relatively narrow, can penetrate the lower atmosphere and can be measured at the ground.

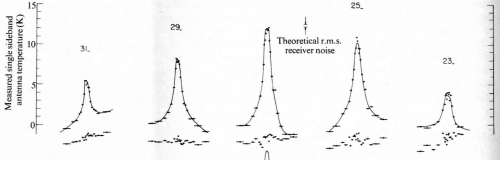
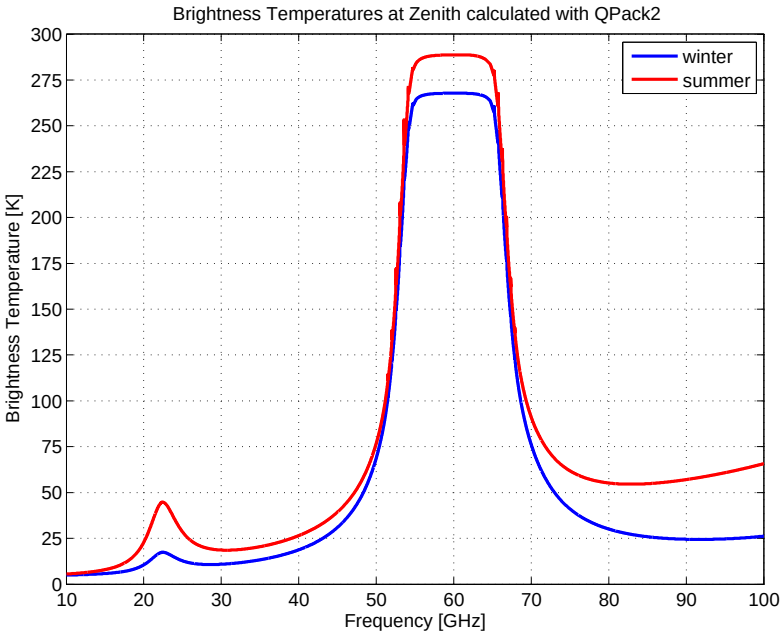
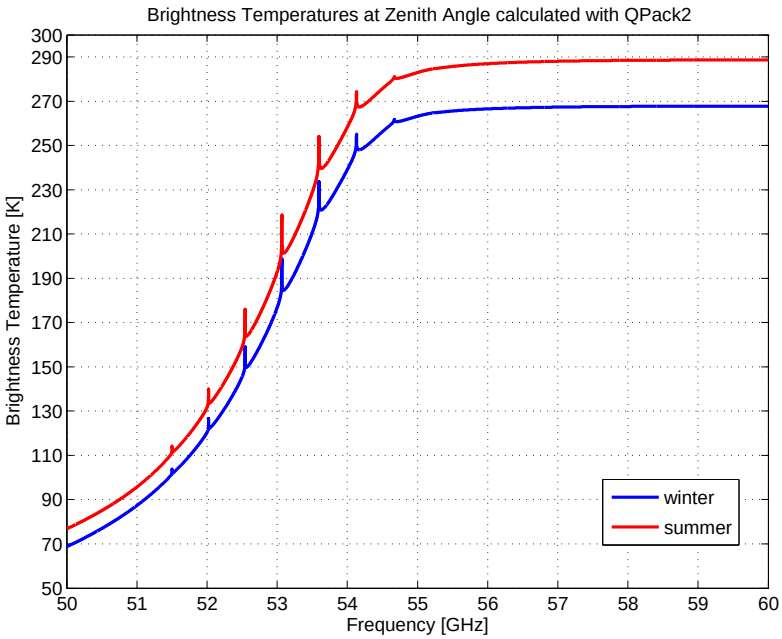


Fig. 1 Measured (upper) and calculated (lower) atmospheric zenith emission. Each measured line and the instrumental baseline shown beneath it represent integration for 16 min. The measurements were made during the week of August 30

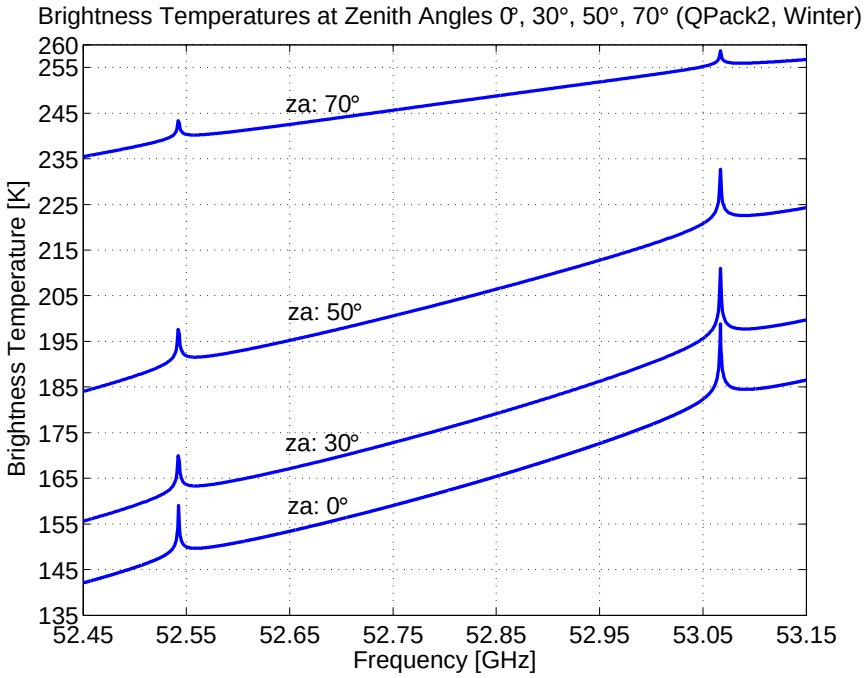
Calculated microwave spectra



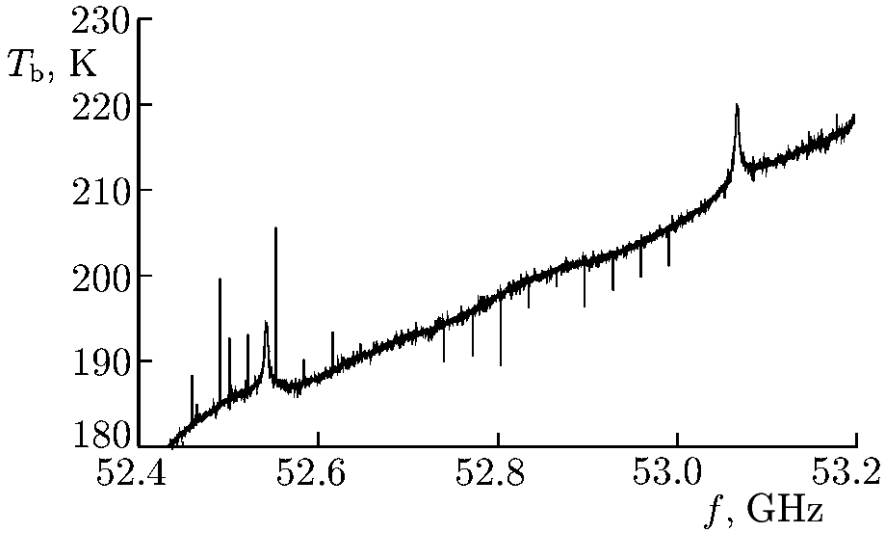
Spectra around oxygen line complex at 60 GHz



Emission lines around 53 GHz (Winter)



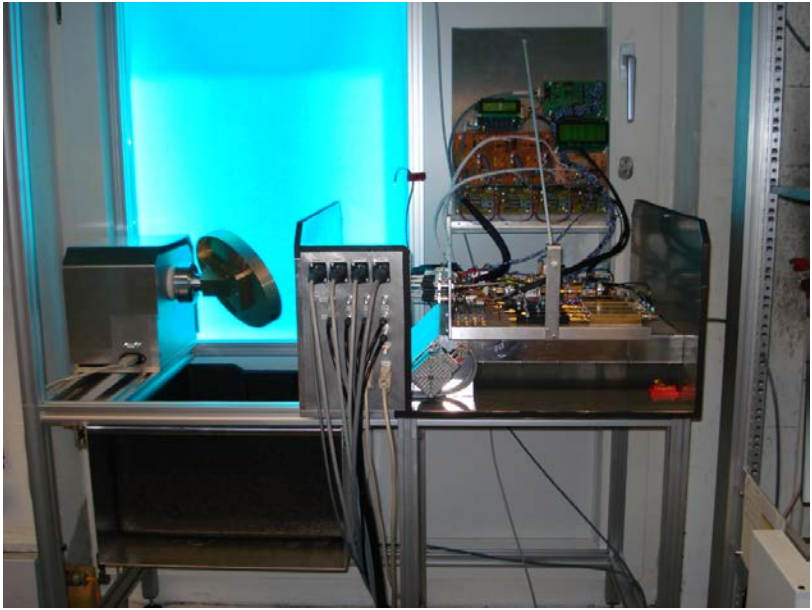
Measurements by Shvetsov et al., 2010



[A. A. Shvetsov et al., *Radiophys. & Quantum Electr.* Vol. 53, No. 5-6, 2010]

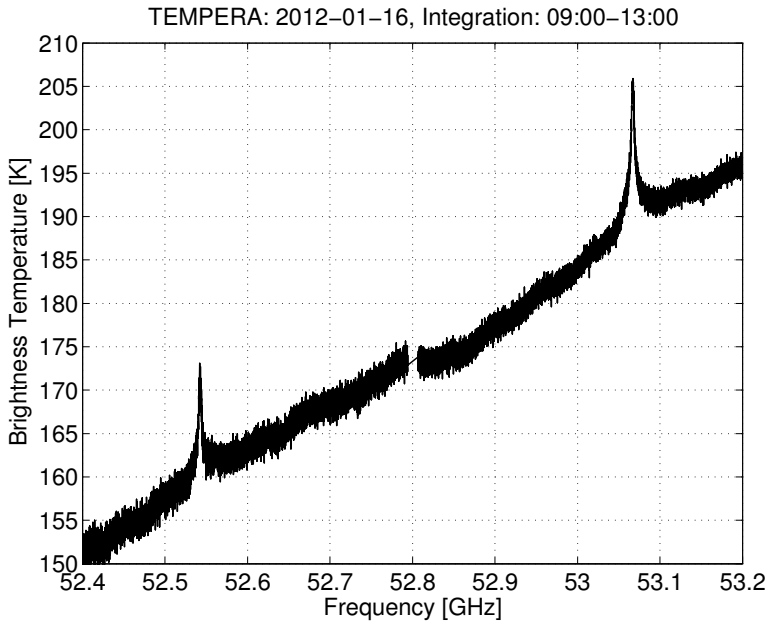
TEMPERA (**TEMPE**rature **RA**diometer)

A new radiometer at IAP, Bern

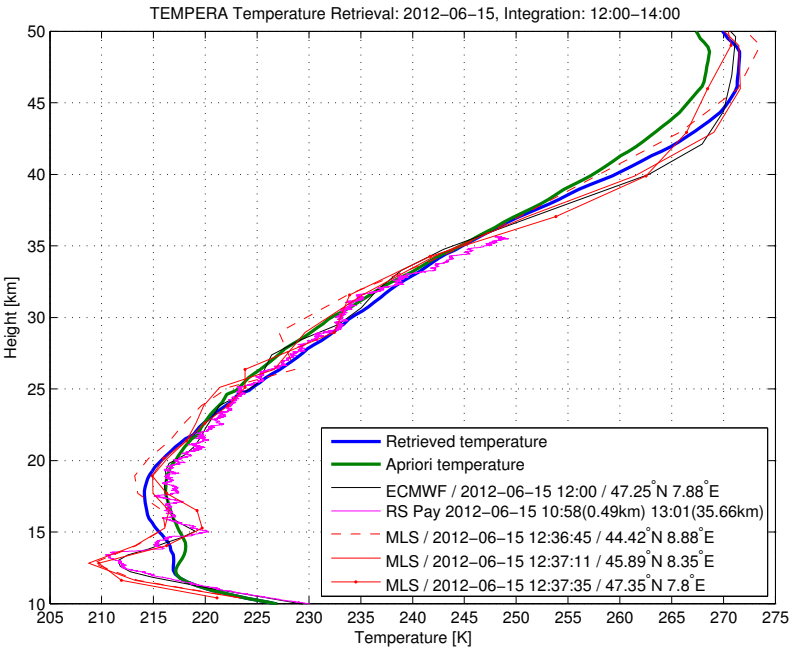


Measured O_2 spectra by TEMPERA at Bern

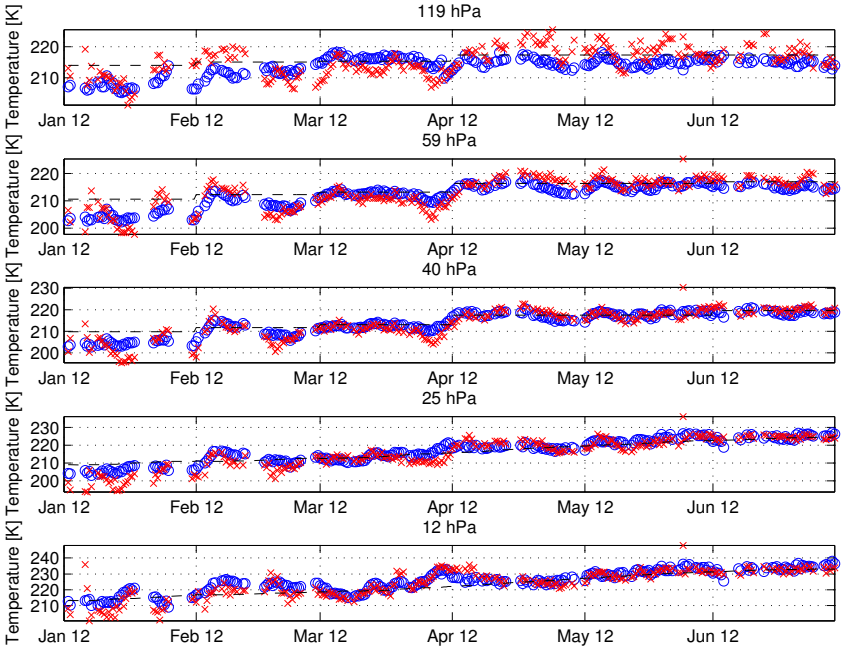
▸ VNC-TEMPERA



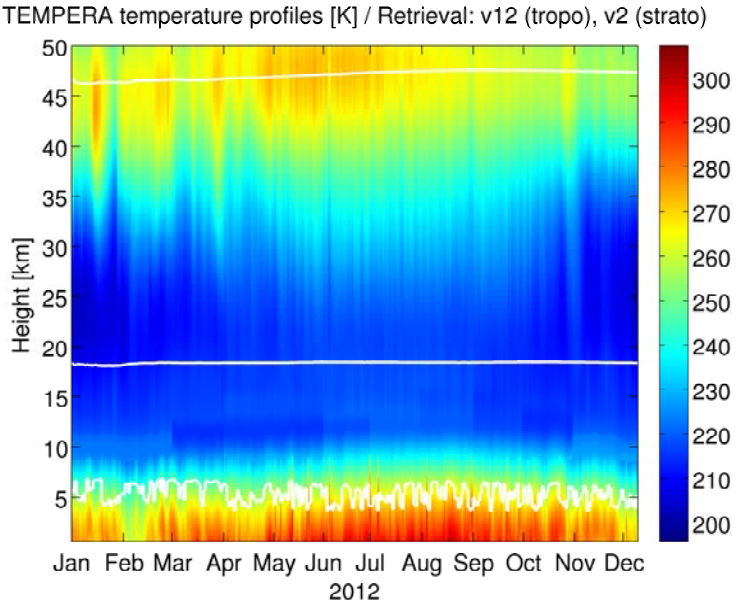
Retrieved temperature profile in the stratosphere



Comparison of TEMPERA with sondes at Payerne



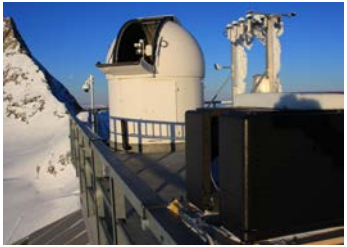
Retrieved T- profiles in 2012

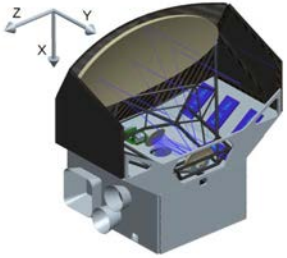


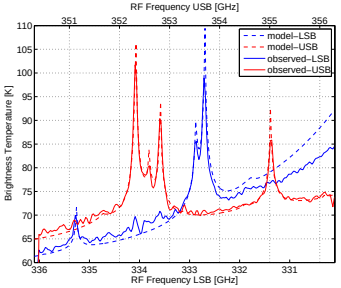
white lines indicate masurement response of higher than 60%

STEAMR: The Stratosphere -Troposphere Exchange and Climate Monitor Radiometer for ESAs PREMIER mission

A prototype of a new sub-mm satellite sensor ▸ STEAMR







Data analysis by Matthias Renker

Conclusions and Outlook

- Microwave instruments from IAP measure H_2O, O_3, IWV, ILW, wind and T
- 4 instruments belong to NDACC
- Data sets allow to investigate atmospheric phenomena over many time scales
- Campaign instrument for H_2O, wind and in the future also for O_3