OXYGEN LINE-MIXING: CONSOLIDATING A SPECTROSCOPY FOR AMSU-A

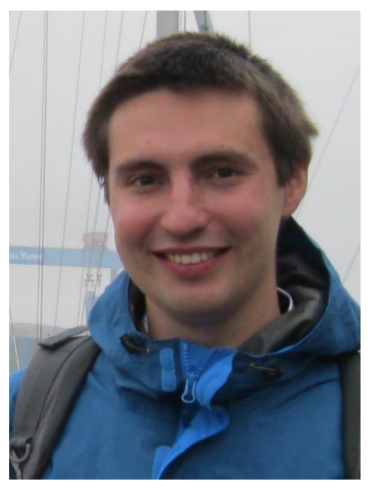
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Oleksandr Bobryshev, Manfred Brath, Stefan A. Buehler

Meteorological Institute, Universität Hamburg

E-mail: oleksandr.bobryshev@uni-hamburg.de

cen
clisap



Introduction

Motivation. The convenient O_2 absorption models, like Millimeter-wave Propagation Model (MPM, Liebe 1987) and it's further development (refinement) by Rosenkranz (1993) and Tretyakov (2005) don't contain the absorption lines data for the sub-mm frequencies (higher than 800 GHz). The advent of new sensors, that measure in the millimeter and the submillimeter spectrum e.g. ISMAR, ICI, MWS, ATMS etc, raise the need for an assessment and practical recommendation of the O_2 absorption model.

Objective: assess the existing O_2 absorption models and recommend the model as the best to use in the milimeter and submilimeter spectrum.

Data

Oxygen models:

- Rosenkranz 1998 (PWR98);
- Tretyakov 2005 (TRE05); Tretyakov_Koshelev 2015 (TRE_KOSH);
- Tretyakov_Makarov_Koshelev (TRE_MAK11);
- AER 2012 (AER-LBLRTM)

Experimental data:

- satellite-based radiometers AMSU-A onboard 4 satellites (NOAA-18, NOAA-19, MetOp-A and MetOp-B (Fig.1)
- Ground-based radiometers RPG HATPRO and HF at Summit Greenland during ICECAPS campaign (Tab.1)
- Radiosonde measurements (mostly, GRUAN-processed).

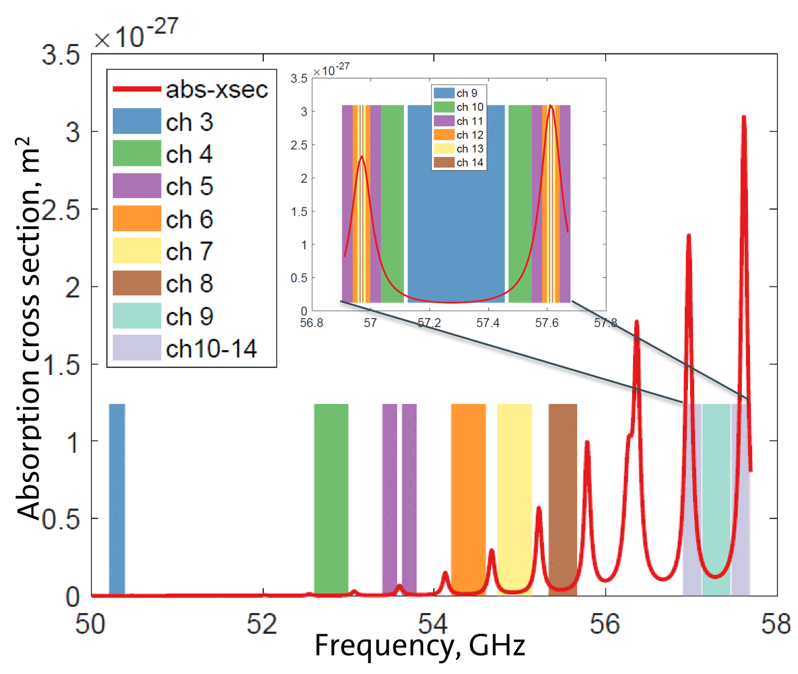


Fig. 1. Central frequency and bandwidth for HATPRO and HF instruments

Table 1. Central frequency and bandwidth for HATPRO and HF instruments

Instrument	HATPRO														HF	
Frequency, GHz	22.2	23	23.8	25.4	26.2	27.8	31.4	51.3	52.3	53.9	54.9	56.7	57.3	58	90	150
Bandwidth, MHz	230	230	230	230	230	230	230	182	179	188	170	704	927	1854	2000	2000

Collocation of point (radiosonde) to area (satellite) measurements

We use radiosonde profiles as an input to the radiative transfer model (RTM) and then compare the output of the RTM with radiometric data, both expressed in units of brightness temperature (T_B). We use different O_2 absorption models (introduced in Data) on the same set of spatially and temporally collocated data, we check the agreement in T_B between the radiosonde and radiometric (satellite and ground-based) data.

The model that shows the lowest bias and the lowest standard deviation is regarded as the best one.

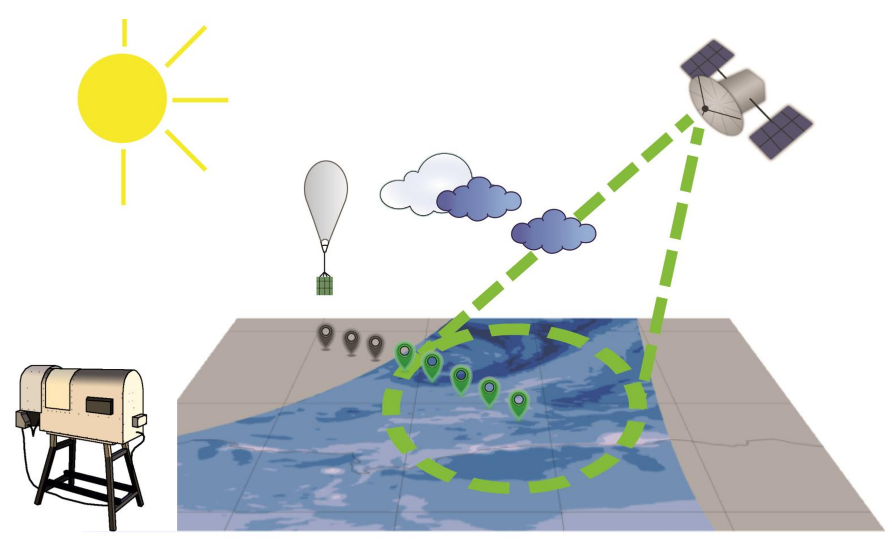


Fig. 2. Area satellite measurements and point-profile measurements of radiosonde

Selection of the data

Spatial-temporal collocations are a big problem by itself. The different nature of the remote and in-situ measurements brings another dimension when discussing the agreement.

We have applied the following filters to the data:

Satellite data:

- Time difference ± 3 hours from the radiosonde launch time
- Target area concept: as T_B of pixels that surround the closest match point can differ a lot we compute the mean value of all the pixels whose centers are closer than 50 km from the average position of the radiosonde launch point (black circle on Fig. 3)

Radiosonde:

- Drift during ascent from the launching point < 15 km
- Average position of the radiosonde between 700 and 300 hPa

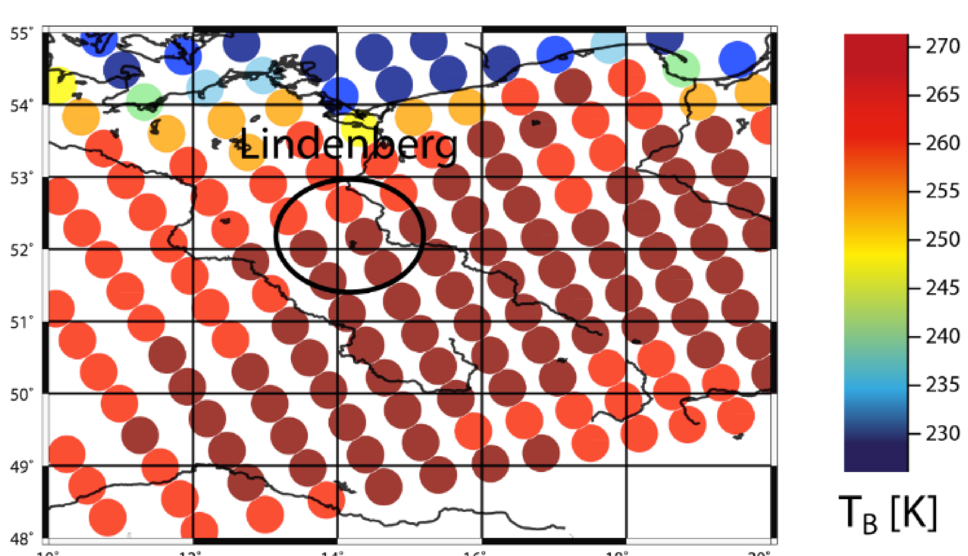


Fig.3. Satellite pixels around the Lindenberg radiosonde launching site. Target area concept

Theoretical difference between the O_2 models

What is line mixing? Oxygen rotational transition lines blend together and form a wide band ranging from 50 to 70 GHz. Because of the mixing effect, the resulting intensity differs from a simple sum of Van Vleck-Weisskopf profiles of the isolated line [4]. Thus the name – line-mixing.

The first two models (PWR98 and TRE05) are so-called full-models: they contain both line and continua absorption. These two models are greatly based on the MPM89, but with updated coefficients. TRE_KOSH and TRE_MAK11 models include, to the extent of our knowledge, the newest lab measurements and include 1st and 2nd order line-mixing coefficients.

We conducted a set of monochromatic calculations for the top-of-the-atmosphere (TOA) T_B at 50 to 70 GHz with the step of 10 MHz for each O2 model (Fig. 4) on the set of atmospheric profiles specifically selected for the intercomparison of radiative transfer models by F.Garand in 2001. ΔT_B is obtained by taking the difference to the model and then averaging we get the mean. We choose the PWR98 model to serve as a reference, as it is most commonly used. On Fig.5 oxygen absorption cross-section difference is presented. The reference is PWR98 model.

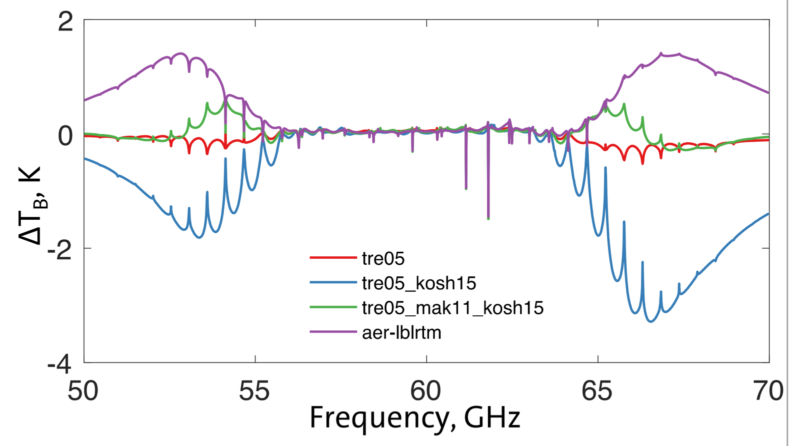


Fig. 4. ΔT_B for the spectrum calculated with ARTS, using 5 Oxygen models. Reference model PWR98. ΔT_B mean over 42 Garand atmospheres

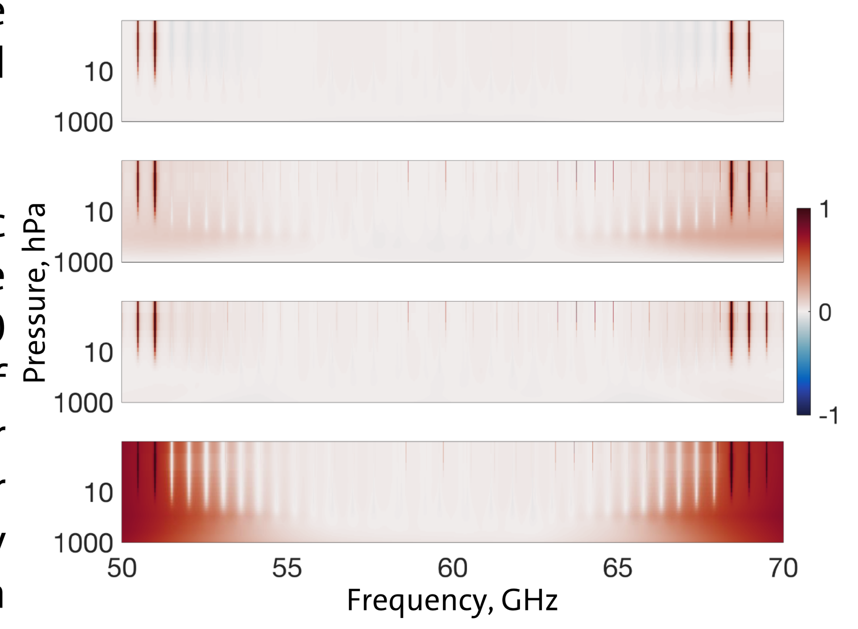


Fig. 5. Absorption cross-sections difference for the oxygen models based on the FASCODE subtropical winter atmosphere. PWR98 is the reference model

Closure study using satellite–radiosonde and ground based–radiosonde

Table 2. An overview of the data used in the study. The positions of the radiosounding stations, number of satellite-radiosonde and ground-based-radiosonde matchups and time range when they occur. All the data presented after all filters are applied.

Station	Location		Time range	# of collocations				
	Lat	Lon		NOAA-18	NOAA-19	MetOp-A	MetOp-B	HATPRO & HF
Lindenberg, Germany	52.21°	14.12°	2009-2015	1068	1126	147	547	-
Lamont, OK, US	36.60°	-97.49°	2009-2015	382	218	16	167	-
Manus	-2.06°	147.42°	2011-2014	805	786	71	423	-
Nauru	-0.52°	166.92°	2011-2013	65	51	-	57	-
Barrow, AK, USA	71.32°	-156.61°	2009-2015	3	80	-	20	-
Greenland, Summit	72.60°	38.42°	2010-2015	-	-	-	-	3418

There are many satellite-radiosonde matchups. The big unkown is the surface emissivity, as for AMSU-A frequencies the atmosphere is effectively transparent for many precipitable water columns. That is why we could use only channels 8,9,10 and 11 of AMSU-A instrument.

Contrary, the comparison of the simulated radiosonde data with ground-based radiometry (Fig. 6) has no such problem. All the oxygen model give comparable agreement, with some outlier at HATPRO channels 8,9 and 15 (HF channel) values for the AER-LBLRTM and TRE_KOSH models.

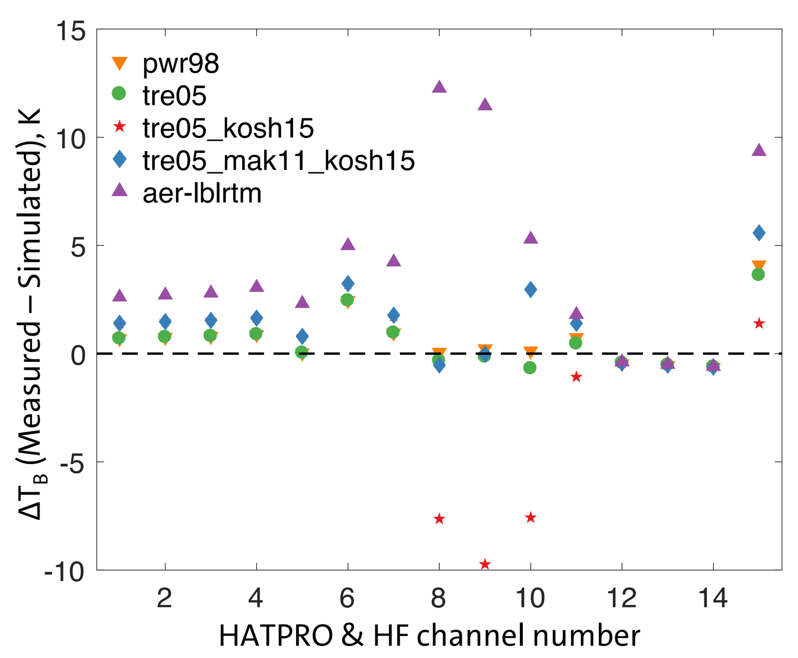


Fig. 6. Mean value ΔT_B difference (measured (radiometer) minus simulated (radiosondes) over 3418 matchups.

Conclusions and further work

- PWR98 and TRE05 do not contain O_2 absorption lines higher than 800 GHz thus cannot be used for higher frequencies;
- Better understanding of LBLRTM spectroscopy database and oxygen model is needed;
- We intend to include ATMS data in the analysis;
- Regular measurements of surface emissivity are desirable for the reference radiosonde stations;
- We thank Dave Turner for providing us with HATPRO data.

Contact: Alex Bobryshev, Meteorological Institute, Center for Earth System Research and Sustainability, Universität Hamburg
Bundesstraße 55, 20146 Hamburg. E-mail: oleksandr.bobryshev@uni-hamburg.de

References:

1. Bobryshev, O. et al. (**in review** 2017), Is there really a closure gap between 183.31 GHz satellite passive microwave and in-situ radiosonde water vapor measurements?, *IEEE T. Geosci. Remote.*
2. Eriksson, P., S. A. Buehler, et al. (2011), ARTS, the atmospheric radiative transfer simulator, Version 2, *J. Quant. Spectrosc. Radiat. Transfer*, *112*(10), 1551–1558
3. Tretyakov, M. Y. et al. (2005), 60-GHz oxygen band: precise broadening and central frequencies of fine-structure lines, absolute absorption profile at atmospheric pressure, and revision of mixing coefficients," *J. Molec. Struct.*, vol. 231, pp. 1–14.
4. Makarov, D. S., et al. (2011), 60-GHz oxygen band: Precise experimental profiles and extended absorption modeling in a wide temperature range, *J. Quant. Spectrosc. Radiat. Transfer*, *112*(9), 1420–1428