Activity on the definition of the AWS high frequency channels: Proposal

Patrick Eriksson
Dept. of Space, Earth and Environment
Chalmers University of Technology
SE-412 96, Gothenburg, Sweden

1 Objectives

Our understanding is that the main objectives of the study are:

- Demonstrate that channels around 325.15 GHz provides a basis for cloud filtering/correction of data measured around 183 GHz, that is equivalent or better than what can be achieved with a channel at 229 GHz (as found on the MicroWave Sounder, MWS).
- Suggest specifications of 325 GHz channels considering the specific constraints of the AWS project. Matching in terms of weighting functions between 183 and 325 GHz channels could be relevant in this context.

If feasible, other ways to compare the 229 and 325 GHz options should be considered, such as degree of freedom in the measurements.

2 Reference documents and data

The study report by Sreerekha et al. (2008) will be used as reference with respect to cloud filtering using 229 GHz through a scattering index (SI) approach. It should be considered if the specifications of the 325 GHz channels could be the same as applied for ICI (Ice Cloud Imager), that are based on Buehler et al. (2012).

Omnisys will be consulted when it comes to technical assumptions and constraints. It is assumed that channels at 89, 166 and 183 GHz will be placed as for MWS, except that AWS 183 GHz channels will be single sideband (covering the lower MWS band). If needed, assumptions for a 229 GHz channel will be taken from the MWS science plan. Required input from Omnisys includes: minimum and maximum intermediate frequency (IF) for 325 GHz channels, maximum number of channels inside this range and expected receiver noise temperature at 166, 183 and 325 GHz.

3 Cloud filtering and correction

As mentioned, Sreerekha et al. (2008) suggested a SI-based cloud filtering approach for MWS, using data from 229 GHz. SI-type cloud filtering based on 183 GHz data alone can also be performed (Buehler et al. 2007). However, the cloud filtering performed operationally for NWP (numerical weather prediction) seems to mainly be based on deviations between observations and clear-sky simulations based on the background field (e.g. Chambon et al. (2015)). The aim of both these approaches is just to reject data with a cloud impact exceeding some brightness temperature threshold. This means that even if these cloud filtering methods would work perfectly, they will still cause a bias in filtered data. This is the case as the presence of clouds gives throughout a decrease in 183 GHz radiances (maybe except for outermost channels and very dry conditions). Expressed differently, compared to the true cloud and noise free brightness temperature, the filtered data will have an uncertainty distribution that is non-Gaussian. On one side the distribution will be determined by the measurement noise. On the other side, the distribution will be a combination of measurement noise and the cloud impacts that are below the threshold value. The mean of this distribution will deviate from zero. This is not optimal but likely the best that can be achieved with present sensors.

The 325 GHz transition is of similar strength as the 183 GHz one (though a bit weaker and more highly affected by continuum absorption). On the other hand, the impact of high altitude cirrus clouds should be considerably higher. Weak cloud impact should mainly end up in the Rayleigh domain, where scattering follows λ^4. For 325 vs. 183 GHz, this gives a factor very close to 10. That is, if a high cloud gives a 5 K impact on a channel around 325 GHz the impact for a channel around 183 GHz with similar (clear-sky) weighting function should be about 0.5 K. The impact at 183 GHz can not be detected, due to thermal noise and modelling uncertainties, while the impact at 325 GHz should be possible to estimate. Further, the estimated 325 GHz cloud impact could even be used to compensate for the cloud impact at 183 GHz.

This later approach, i.e. to perform a cloud correction of 183 GHz data, will be the primary option for this study. If successful, this will provide 183 GHz data that are more useful for NWP and stand-alone 1DVAR that rely on "clear-sky" data. At least the resulting data should have a lower bias than the existing approaches. The precision will depend on situation and the method for cloud correction should preferably also provide a case-specific uncertainty estimate.

The suggested cloud correction scheme could be seen as forming clear-sky "super-channels" by combining measurements at 183 and 325 GHz. This would have the advantage that NWP systems not yet prepared for 325 GHz, could still make use of these data early on. For situations where 325 GHz lacks cloud impacts, theoretically the super-channels could have a resulting NEDT (Noise Equivalent Delta Temperature) lower than the one of 183 GHz, as the combination of 183 and 325 GHz together gives a higher effective bandwidth. In practice this can be hard to achieve due to a higher noise at 325 GHz and modelling uncertainties, and the comment was added mainly to illustrate the approach.

4 Work plan

For clarity, the work as divided into a number of work packages (WPs). See next page. The work will be performed by (with WP responsibilities inside parenthesises):

- Patrick Eriksson (WP 1.1 and 3.3)
- Simon Pfreundschuh (WP 1.2 and 3.2)
- Inderpreet Kaur (WP 2.1, 2.2, and 3.1)

WP1

WP1.1: Basic preparations

- Contact Omnisys to obtain required technical information.
- Determine the number of monochromatic frequencies needed to represent each channel with sufficient accuracy.
- Compare 183, 229 and 325 GHz brightness temperatures and weighting functions (clear-sky), for a set of climatological atmospheres. Based on this, define preliminary specifications of 325 GHz channels.

WP1.2: Setting up bulk simulations

The task of this WP is to prepare and implement functions for creating a diverse set of simulations, to be used in later WPs. The simulations will be based on CloudSat reflectivities and ERA5 data, and largely follow the "dBZ-based model system" introduced in Ekelund et al. (2020). The main deviations to Ekelund et al. (2020) is that some along-track averaging of CloudSat data will be performed, the mapping from reflectivities will be performed by 1DVAR (and not by "onion-peeling") and that each footprint will be represented with a single pencil beam. To make it easier to streamline the calculations, a switch from Matlab to Python will also be made. Both clear-sky and all-sky data will be generated, using ARTS and its interface to the RT4 scattering solver.

WP2

WP2.1: Bulk simulations

Perform the required number of simulations. Data will be generated for randomly sampled positions, for latitudes up to 60°N/S. Higher latitudes will be avoided initially as that require more care about surface emissivity. Both land and ocean areas will be considered but for land an altitude threshold will be applied, again due to limitations in the knowledge of surface emissivities.

Simulations covering channels at 89, 166, 183, 229 and 325 GHz will be made. A number of scan angles, between nadir and swath edge, will be covered. A first batch of 100 000 simulations will be made. If found necessary, adding more simulations could be possible. If time permits, extending the simulations to higher latitudes could also be considered.

WP2.2: Post-processing of data

Monochromatic data are weighted together to form channel antenna temperatures. For 325 GHz channel data should be formed for some alternative channel specifications, for later comparison between the alternatives. Position, land/ocean, IWP and other data are added, to form a database suitable for the analysis in WP3.

WP3

WP3.1: Cloud correction

A cloud correction scheme of 183 GHz data is developed. The main task if to find a suitable regression approach. In short, the regression shall, based on the simulated 325 GHz data and the antenna temperature of the 183 GHz channel of concern, predict the clear-sky, noise free, value. Different regression schemes and 325 GHZ channel alternatives will be compared by assessing the error of the prediction. The error shall have as low bias and spread as possible. An error model will also be devised and assessed. Tests will be made for lower and higher assumed NEDT, to assess if there is any critical value that should be reflected in the requirements of AWS.

A similar regression will be tested for 229 GHz. If not working well, a perfect version of the approach by Sreerekha et al. (2008) will be used instead for 229 GHz. That is, the assumed error distribution is the one described in Sec. 3,

WP3.2: Measurements degrees of freedom (DoF)

An analysis following the one in Sec. 4.3.2 of Eriksson et al. (2020) for ICI will be made, based on the database of simulations. This WP requires that the database contains data for 89 and 166 GHz, to give a correct view on the value of 229 GHz. This is the case as 229 GHz is a window channel (as 89 and 166 GHz) and there should be redundancy between 229 GHz and the other window channels. In a similar way, 325 GHz will give small increase in the DoF for clear clear-sky situations, due to redundancy with 183 GHz, but should increase the DoF significantly in the presence of ice clouds.

WP3.3: Meetings and reporting

This WP covers to analyse the results to reach a conclusion, as well as reporting the results.

References

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CV: Patrick Eriksson

Personal details

Name	Patrick Eriksson (641125-5539)
Work address	Dept. of Space, Earth and Environment, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden
Phone / email	+46 (0)31 7721832 / patrick.eriksson@chalmers.se

Academic degrees

1999-02-19	PhD in *Environmental Sciences with Specialization in Radio and Space Science* at Chalmers University.
2004-12-17	Docent in *Global environmental measurements* at Chalmers University.
2017-04-26	Professor in *Global environmental measurements* at Chalmers University.

Publications

About 110 journal articles (see www.researcherid.com/rid/A-5321-2009) and a number of other publications. H-index is 23/30 and i10-index 61/76 according to WoS/Google Scholar.

Teaching and student advising

Organisation	In charge of Atmosphere and Environment PhD school (2008-2010).
Main teacher	Remote sensing (RRY055, master level, 2003 onward). Inversion theory for atmospheric sounding (PhD course, given irregularly). Computer programming (LEU483, undergraduate level, 2019 onward). “Jorden som system” (course in development, start 2021).
Lecturing	In several other courses, older or given irregularly.
Master theses	Adviser to about 14 theses.
PhD students	Main/co-adviser to eight/four students. Examiner for two (not finished).

Examples on commissions, memberships, . . .

MWI/ICI	Member of ESA/EUMETSAT Science Advisory Group for MWI and ICI. These two satellite instruments will be part of Metop second generation.
AMT	Associate editor for EGU journal Atmospheric Measurement Techniques.
Referee	Reviewed articles for ACP, AMT, Atmosphere, BAMS, GI, GMD, JGR, JQSRT, IJRS, I3ETGRS, GRL and RS.
Department	Been teaching staff chairman and member of departmental advisory team.
University	Member of faculty senat.
PhD thesis	Been in six PhD thesis defence grading committees.

Project experience

ARTS	Organisation and development of a state-of-art (open source) software. This software package is used in ∼20 research institutes and has ∼200 citations.
Qpack	Development and support of this retrieval package accompanying ARTS.
Research	Leader of several national research projects (VR, SNSB and NRFP).
Odin-SMR	Development of operational retrievals, characterisation of instrument responses and geophysical interpretation of results.
Workshops	Organiser of seven international workshops.
ESA studies	Participated in ≈17 ESA studies, with with a leading role at several occasions.
EUMETSAT	Project leader for study on development of a microwave single scattering database, as well as definintion of ATBD for Metop ICI retreivals of IWP. Participated in study on remapping of MWI and ICI L1 data.

Inderpreet Kaur

Info

Address

Gothenburg, Sweden

Phone

+46 733282663

Email

ikaur1985@gmail.com

Skills

Programming Skills: Python, Matlab, Fortran, matplotlib, GrADS

verison control with git

Links

Orcid

LinkedIn

Languages

English

● ● ● ● ●

Swedish

● ● ○ ○ ○

Hindi

● ● ● ● ●

Profile

Researcher in Atmospheric Science with 6+ years experience in geophysical parameter retrieval, model/algorithm development, analysis of geophysical datasets and data-validation

Employment History

Postdoctoral Researcher, Chalmers University of Technology

Mar 2020 — Present Gothenburg, Sweden

- *Measurements of precipitation by applying machine learning techniques*

Postdoctoral Researcher, Max Planck Institute for Chemistry

Nov 2017 — Feb 2019 Mainz, Germany

- *Development of a new Global Fire Assimilation System (GFAS-CLIM) specially adapted for climate applications using retrospective analyses (Kalman Smoother)*
- *Bias mitigation in MODIS FRP observations*

Pre/Post-doctoral Researcher, Basque Centre for Applied Mathematics

Oct 2014 — Jun 2016 Bilbao, Spain

- *Modeling of stochastic processes in an Eulerian fire propagation model : LSFire+ through a probabilistic approach*
- *Parametrisation of fire-spotting behaviour in wildfires*

Junior Research Fellow, Space Applications Centre, ISRO

Nov 2009 — Feb 2014 Ahmedabad, India

- *Retrieval of Atmospheric Motion Vectors from Indian geostationary missions:* Kalpana-1, INSAT3D
- *Numerical Weather Prediction (NWP) using WRF-3DVar*
- *Data validation against model, satellite and in-situ observations*
- *Assisting real-time operational retreival of AMVs*

Education

Gujarat University, PhD

Apr 2011 — Mar 2016 Ahmedabad, India

Thesis title: *Estimation of winds using satellite observations and their application in tropical atmospheric processes*

Panjab University, M Sc (Physics)

Aug 2006 — Aug 2008 Chandigarh, India