A Hyperspectral Microwave Sounding Mission for Australia

The Bureau of Meteorology

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1 Introduction

In 2022, the Bureau began working with the Australian Space Agency and the Australian National Concurrent Design Facility at the University of New South Wales Canberra Space [1] to design three satellite missions to support our operational requirements. One of the instruments chosen is a Hyperspectral Microwave Sounding Mission, due to the criticality of microwave sounding data for Bureau numerical weather prediction (NWP) performance.

This poster summarises the user requirements for microwave sounding to meet our future NWP and tropical cyclone nowcasting and monitoring needs, and will provide an overview of the proposed mission, along with results of our user requirements survey. We would like to thank the ITSC members who contributed to the survey, and hope that it may inform the development of the future global microwave sounding observing network.

Proposed areas for improvements over existing instrumentation:

- Higher vertical resolution via software-controlled digital spectrometer "hyperspectral" sounder, also delivering better possibilities for RFI mitigation
- Higher temporal resolution: via a constellation of low-earth orbit satellites.
- Pathfinder instrument is proposed for Sun Synchronous Orbit with LTAN 05:30
- Better spatial resolution – lower orbit delivering smaller footprints.
- Better noise performance through new technology Low Noise Amplifiers etc.

2 Mission aim and objectives

The aim of the Microwave Sounding Mission (MSM) is to provide high-quality microwave-sounding measurements of the atmosphere with global coverage and sub-daily revisit in the Australian region and adjacent Antarctic territory to address Bureau customer needs for increasingly accurate numerical predictions and severe weather monitoring capability.

ID	Parameter	Objective-O	Breakthrough-B	Threshold-T	Notes
MSM-USR-01	Spectral Bands	50-70 GHz, 90 GHz, 183 GHz, Plus: 118 GHz, 150GHz Plus: 31.4 GHz,36-7 GHz, 23.8 GHz, 19 GHz OR: Complete spectral coverage between 19 and 183 GHz	50-60 GHz, 90 GHz, 183 GHz, Plus: 118 GHz, 150 GHz	50-60 GHz, 90 GHz, 183 GHz	
MSM-USR-02	Number of channels	Approx. 1800	Approx. 1100	Approx. 400	
MSM-USR-03	Spectral resolution ν /Δν	5000 (T) 4575 (WV)	2500 (T) 1830 (WV)	1250 (T) 915 (WV)	
MSM-USR-04	Spatial Coverage	Global	Global	Full coverage of Australia, including its surrounding area	
MSM-USR-05	Swath width	>=2200 km (tied to orbit height and viewing geometry)	>=2052 km (tied to orbit height and viewing geometry)	>=1800 km (tied to orbit height and viewing geometry)	
MSM-USR-06	Noise Level (NEΔT)	≤ ATMS actual * 0.5 for spectrum integrated to ATMS SRF and IFOV	≤ ATMS actual * 0.66 for spectrum integrated to ATMS SRF and IFOV	≤ ATMS actual for spectrum integrated to ATMS SRF and IFOV	See Appendix B for more details on achievable noise performance.
MSM-USR-07	Spatial resolution (footprint)	≤5 km at nadir	≤15 km at nadir for temperature sounding. ≤7 km at nadir for humidity.	≤25 km at nadir for temperature sounding. ≤15 km at nadir for humidity.	Assumed a 10 km resolution throughout this study, acknowledging this requires a detailed design of the antenna. This is relevant to the data budget.
MSM-USR-08	Geolocation accuracy	≤10% spatial resolution	≤ 17% spatial resolution	≤25 % spatial resolution	The attitude knowledge system was sized to determine the spacecraft's attitude within 1 km on the ground.
MSM-USR-09	Viewing Geometry	Up to +/-55°, multiple view angles per ground footprint	Up to +/-55°	Up to +/-55°	The objective requirement requires a conical scanner which was ruled out in section 5.2.2.
MSM-USR-10	Polarization	Low-frequency channels (≤37 GHz) polarised	Single linear polarization changing with scan angle (as ATMS)	Single linear polarization changing with scan angle (as ATMS)	Not discussed in detail in this study.
MSM-USR-11	Spatial sampling	Oversampling (Nyquist at minimum)	Contiguous Footprints	Non-contiguous	A conservative sampling frequency of 200 Hz was assumed.
MSM-USR-12	Calibration mechanism	2-point calibration -40 to -50 dB return loss from onboard source	2-point calibration -40 to -50 dB return loss from onboard source	2-point calibration	
MSM-USR-13	Calibration accuracy	≤0.2 K	≤0.5 K	≤1 K	
MSM-USR-14	Temporal Refresh	Sub-hourly	≤Every 3 hours	≤Every 6 hours *for single pathfinder, once every 12 hours is acceptable*	
MSM-USR-15	Instrument lifetime	7 years	5 years	3 years *for a single pathfinder, a 2year lifetime is acceptable*	
MSM-USR-16	Global data timeliness	90% within 1 hour	90% within 2 hours	NRT - 90% within 3 hours 30 mins *for single pathfinder, there is no NRT timeliness requirement*	
MSM-USR-17	Local data timeliness	90% within 10 mins	90 % within 15 mins	90 % within 20 mins	

3 User requirements and survey results

Various efforts internationally have set out the needs for microwave sounding in support of NWP. Three main resources have been studied:

- WMO observation requirements (noting that these are not mission requirements, and not even satellite requirements) [2]
- NOAA Future Satellite Architecture requirements for microwave SounderSat missions [3]
- EUMETSAT MWS user requirements [4]

We conducted a user requirements and preference survey at Bureau from 1 -9 September 2022. This provided opportunity for general discussion and questions, a survey was sent to both internal and external experts, and to the global satellite NWP DA community (total 36 participants, among 13 were from Bureau).

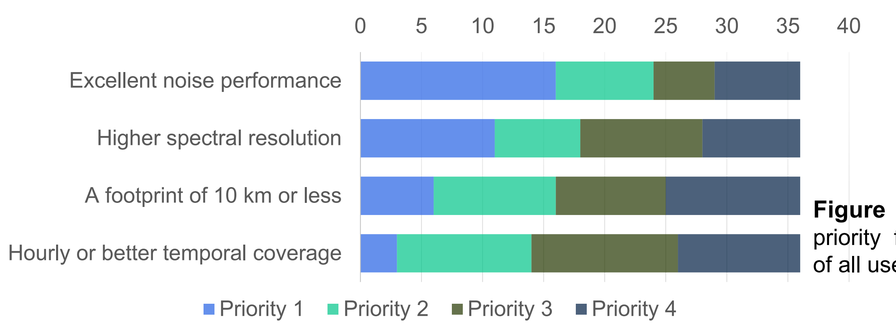

Figure 1: The rank of priority from the survey of all user's.

Figures 1-3 show the rank of priority from the survey. From these figures it shows ~44.5% of participants prefer lower NEΔT and other noises as a very high priority for an MWS mission, and 30.6% rank that user's want a higher spectral resolution. The hourly temporal coverage is not the first choice by most participants in the rank of priority or choice (high: ~30.6%, medium: ~33.3%, and lower priority: ~27.8%).

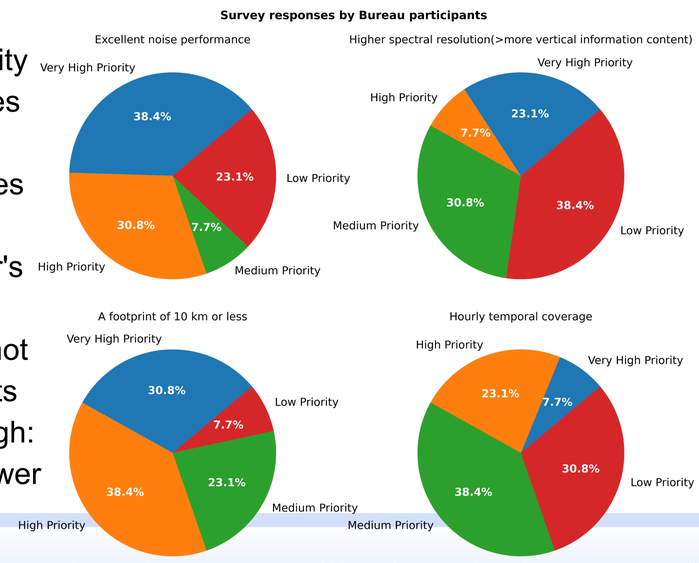

Figure 2: The rank distribution of priority from Bureau user's

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The mission's footprint size has

4 Summary and future work

- In the 2021 Earth Observation Roadmap [5] developed by the Australian Space Agency, the Bureau articulated an ambition for Australian operational meteorological satellite sensing capabilities in the 2030s. To achieve this ambition, the Bureau undertook a preliminary investigation into possible satellite mission pathfinders to build towards this capability.
- Overall, survey evidence suggested that future MWS missions should prioritize the instrument's noise performance first.
- The next step is to conduct simulation-based impact assessments and information content study based on the preferable requirements parameters suggested by the users.

References:

[1]
[2] https://space.oscar.wmo.int/observingrequirements
[3] Kalluri, S., 2021. Satellite Microwave Sounding Measurements in Weather Prediction: A Report of The Virtual NOAA Workshop on Microwave Sounders.
[4] MWS Science Advisory Group: "EPS-SG MicroWave Sounder (MWS) Science Plan", 2019, https://www-cdn.eumetsat.int/files/2020-04/pdf_science_epssg_mws_plan.pdf
[5] https://www.industry.gov.au/publications/earth-observation-space-roadmap-2021-2030