Sept 6th
2021

A MICROWAVE RADIOMETER FOR THE SENTINEL-3 NEXT GENERATION TOPOGRAPHY (S3-NGT) MISSION

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Abstract

- ESA is planning the development of the Sentinel-3 Next Generation Topography (S3-NGT) Space Component, providing enhancement as well as continuity of the current Sentinel-3 capability.

- The payload complement will include a Microwave Radiometer that will provide an essential wet tropospheric correction (WTC), which is the largest source of uncertainty in sea level estimate. The WTC needs to be improved spatially and temporally to comply with the main requirements of next generation altimetry missions.

- This paper presents an overview of the requirements for a next generation MWR and the preparations being undertaken in the UK to meet the future challenges.

  - Currently, parallel Phase AB1 mission studies for S3NG-T are in competition and under adjudication, so this has constrained the content of this presentation today.

Background to WTC

- **The wet tropospheric correction (WTC) or path delay is a major source of uncertainty in altimetry budget error, due to its large spatial and temporal variability: this is why most altimetry missions include a microwave radiometer.**

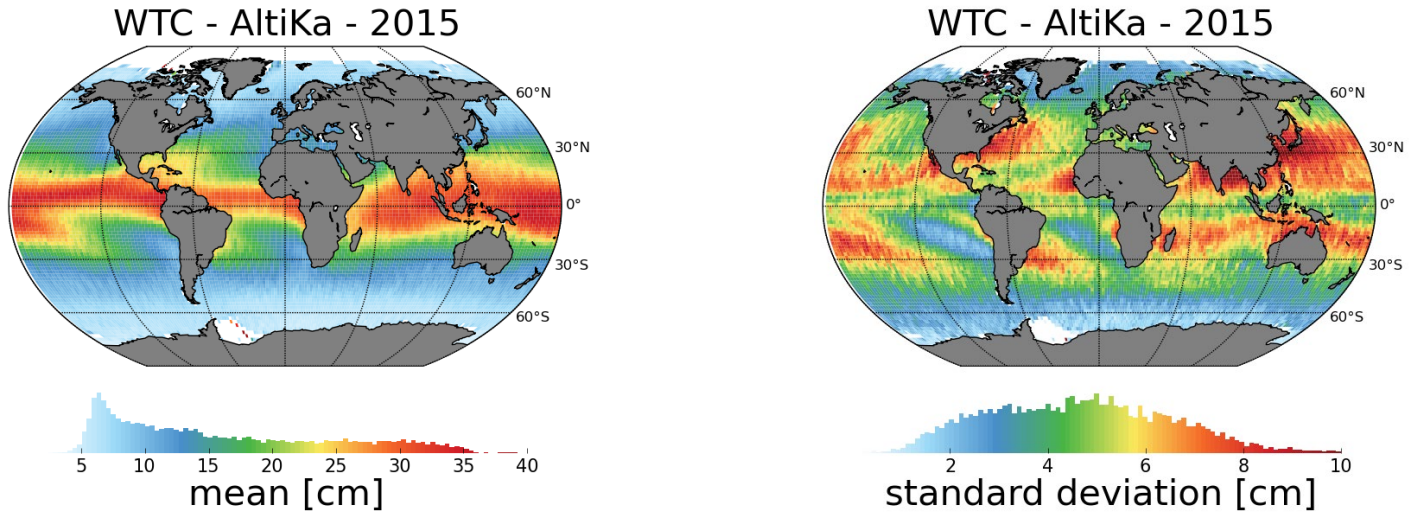


Figure 1 : The wet tropospheric correction retrieved with AltiKa radiometer for the year 2015. Right: gridded averaging over a 2°x2° map; Left: standard deviation over the same grid.

- **The commonly agreed requirement on WTC for current missions is to retrieve WTC with an error better than 1cm rms (NRT) and <0.7cm (STC) or (NTC).**

Background : Increasing Demands on WTC

- For several generations of radar altimeter missions , a dual band radiometer has been incorporated into the payload configuration based upon 23.8GHz and 36.5GHz with medium spatial resolution (~25km).

- With a dual band approach, additional surface corrections need to be obtained by the altimeter σ_0, the SST and the atmospheric temperature lapse rate. However in comparison with AMR-C it is known that not all global zones respond to this approach. Adding 18.7GHz to the "LF" complement would provide the necessary surface emissivity.

- Over the years with continual improvements in the radar altimetry measurement technique, more accurate altimetry data is available for coastal and inland waters. Nevertheless, the quality of data in those areas is degraded with respect to that of the open oceans due to the rather wide field of view of the current microwave radiometers (~25 km) with the resultant lack of spatial discrimination. Furthermore current microwave radiometer observations over those waters are subject to contamination by land brightness temperatures which fall within the radiometer footprint. Such that the accuracy of the WTC degrades ~30km from a coastline. Yet the coastal regions have significant socio-economic strategic importance.

- And now the most recent developments for a next generation radar altimeter now include a swath capability which further challenges an accompanying MWR.

S3NG-T Mission Requirements

- **SCIENTIFIC JUSTIFICATION OF S3NG-T MISSION MEASUREMENT REQUIREMENTS well explained in the MRD (ESA-EOPSM-S3NG-MRD-3821)...**
  - **S3NG-T and Copernicus Marine Monitoring And Prediction**
  - **S3NG-T and Copernicus Wave And Wind Monitoring And Prediction .**
  - **S3NG-T and Copernicus Hydrology Monitoring And Prediction.....**
  - **S3NG-T and Copernicus Cryosphere Monitoring And Prediction**
  - **S3NG-T and Copernicus and Climate Monitoring And Prediction .**
  - **S3NG-T and Copernicus Extreme Events, Security And Emergencies**
  - **S3NG-T and Copernicus Applications In Geodesy .. ..**

S3NG-T Mission Objectives

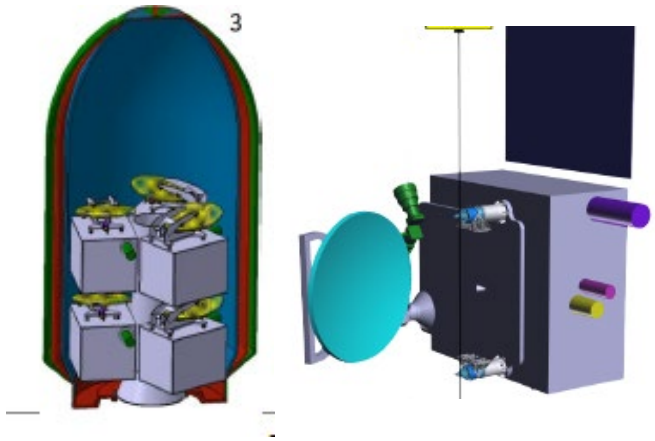
- Considering the User's needs expressed by the European Commission and concisely articulated in RD[01], the aim of the Copernicus Next Generation Sentinel-3 Topography (S3NG-T) Mission is:
  - To ensure continuity of Sentinel-3 in flight performance topography capability in the 2030-2050 timeframe.
- Agree definitions for the meaning of "Continuity" and "Enhanced Continuity" in terms of NG missions were agreed using three "levels" as follows:
  - 1. Baseline continuity: This is the minimum definition for an NG-Mission. Baseline continuity products guarantee the continuity of Level-2 products with the same coverage, revisit, performance, sampling, delivery timeliness of existing topography parameters. Baseline continuity is derived directly from S3 in-flight performance.
  - 2. Enhanced continuity: Level-2 products that meet baseline continuity plus enhanced revisit and effective resolution (i.e. wavelength) and/or coverage, and/or performance, and/or timeliness of existing topography parameters (e.g. SSH, Hs, Sigma0, U10, etc.) to address Copernicus User's Needs.
  - 3. New products: a new Level-2 product to address Copernicus User's Needs providing considerable enhancement over the baseline continuity (e.g. (Directional) Wave Spectra, sea surface height gradients and river gradients. Total Surface Current Velocity measurements are considered out of scope by the European Commission

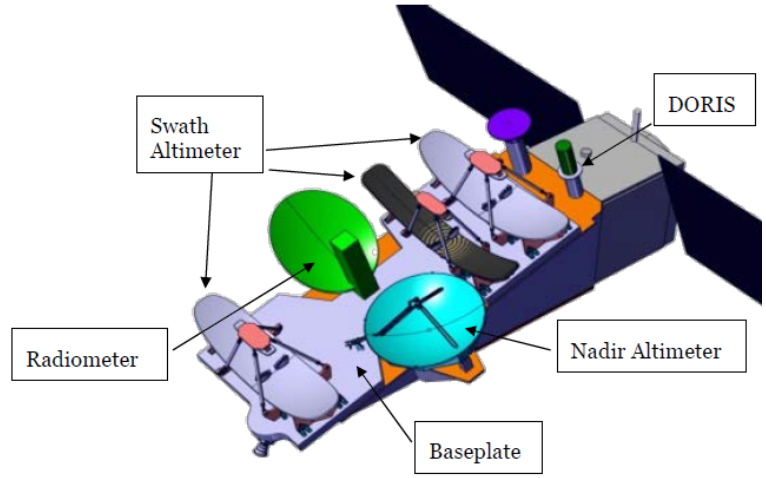
S3NG-T Mission Objectives

- The primary objectives of the S3NG-T mission are to:
  - PRI-OBJ-1. Guarantee continuity of Sentinel-3 topography measurements for the 2030-2050 timeframe with performance at least equivalent to Sentinel-3 in-flight performance2 (‘baseline mission’).
  - PRI-OBJ-2. Respond to evolving user requirements and improve sampling, coverage and revisit of the Copernicus Next Generation Topography Constellation (S3NG-T and Sentinel-6NG)) to ≤50 km and ≤5 days (CMEMS, 2017) in support of Copernicus User’s Needs.
  - PRI-OBJ-3. Enhance sampling coverage, revisit and performance for Hydrology Water Surface Elevation measurements in support of Copernicus Services.
  - PRI-OBJ-4. Respond to evolving user requirements and enhance topography Level-2 product measurement performance.
- The secondary objectives of the S3NG-T mission include:
  - SEC-OBJ-1. Provide directional wave spectrum products that address evolving Copernicus user needs.

ESA's EOPP Phase AB1 SSRD Requirements

- **At least three variants shall be analysed and discussed:**
  - **A constellation of 2 to n satellites hosting a nadir altimeter (besides radiometer and POD instrument),**
  - **A constellation of 2 to m satellites hosting a swath altimeter and a nadir altimeter (besides radiometer, and POD instrument), and**
  - **A constellation of x satellites with nadir altimeter and y satellites with a swath altimeter and a nadir altimeter (besides radiometer and POD instrument).**





- **Recent CDF activities investigated (i) Mini Altimeter Constellation (ii) Swath Altimeter mission.**

S3NG-T MRAD Requirements

JCR SYSTEMS

	Centre Frequency (GHz)	Spatial Resolution (km)		Polarisation (TBC)	NeΔT (K)	Total Standard Uncertainty	Stability K/Yr (TBC)
		Baseline	Goal				
MRAD-1	18.7 (TBC)	≤25km	≤15km	VV	≤0.3	<1K	≤0.1
MRAD-2	23.8	≤25km	≤15km	VV	≤0.3	<1K	≤0.1
MRAD-3	36.5 or 31.4 (TBC)	≤25km	≤15km	VV	≤0.3	<1K	≤0.1
MRAD-4	89.0 (TBC)	≤10km	≤5km	VV	≤0.5	<1K (TBC)	≤0.3
MRAD-5	130.0(TBC)	≤10km	≤5km	VV	≤0.5	<1K (TBC)	≤0.3
MRAD-6	165.5 (TBC)	≤10km	≤5km	VV	≤0.5	<1K (TBC)	≤0.3
MRAD-7	172.311 (TBC)	≤10km	≤5km	VV	≤0.5	<1K (TBC)	≤0.3

- **Additionally dynamic range 2.7- 340K**

- **Indicative apertures if at 750km altitude for a nadir viewing MWR:**

		Spatial Resolution	(m)
MRAD-1	18.7GHz	25km	0.77
MRAD-2	**23.8GHz**	20km	0.75
MRAD-3	**36.5GHz**	20km	0.48
MRAD-4	**89GHz**	10km	0.35
MRAD-5	**130GHz**	10km	0.24
MRAD-6	**165GHz**	10km	0.19
MRAD-7	**183GHz**	10km	0.18

FLUCTUS INFORMUS S.M.T. Consultancies Ltd. TK INSTRUMENTS

UK Involvement

- **The UK has a long standing heritage in humidity sounders having led developments in the past such as AMSU-B for NOAA, MHS for MetOp and currently MWS for MetOP-SG.**
- **Using this experience, JCR Systems has been leading successive radiometer studies, involving both science teams and technologists to develop both the SRL and the TRL in parallel for next generation WTC:**
  - **2013 EOP Sentinel 6 Phase A/B1 study HRMR, eventually supplied by JPL.**
  - **2015 TRP MWR Coastal Altimetry Mission Study**
    - » the initial study into the selection of an enhanced selection of frequency bands
  - **2016 TRP MWR Radiometer Antenna for Coastal Altimetry:**
    - » wholly UK based engineering team, academic & industrial incorporating UK expertise from MWS
    - » Both studies focussed on the addition of millimetre-wave channels including 50.3GHz
  - **2019 EOPP MWR4SAMS Phase 0 Study for Copernicus 2.0**
    - » Incorporating adaptations for swath altimetry missions, using retrieval simulations to refine the radiometer specification, particularly investigating interpolation techniques and the engineering solutions including addition 18.7GHz
  - **2020 EOPP Technology Development Programmes:**
    - » Millimetre-wave Antenna Feed for EO :
    - » Millimetre-wave Internal Calibration Subsystem:

UK Involvement

- **Extending this SRL and radiometer concepts into supporting critical technology developments:**
  - **2020 EOPP Technology Development Programmes:**
    - » Millimetre-wave Antenna Feed for EO : wholly UK based engineering team to design, manufacture and test a compact antenna feed incorporating the additional bands compatible with the existing LF feed.
      - » Led by Thomas Keating supported by SMT Consultancies and JCR Systems
      - » Capitalises upon expertise gained from both MWS and TROPICS antenna feed designs, providing low loss & high port2port isolation.
    - » Millimetre-wave Internal Calibration Subsystem for which JCR Systems are supporting a European consortium from academia & industry to develop a low loss, highly integrated mm-wave calibration switch and noise source which could meet the requirements for a MRAD for a swath mission.

Conclusion

Sub Assembly	Company	Heritage
Millimetre-wave Antenna Feed	Thomas Keating	AMSU-B, MWS, TROPICS
On-Ground & In-Flight Black Body Calibration Targets	RAL Thomas Keating	MWS S3-MWR, ICI
166GHz, 183GHz Receiver Front Ends	RAL	MWS, MWI
Systems Performance Assessment & Verification including Rad-Cal	JCR Systems	AMSU-B, MHS, MWS

- **The UK is well placed to make a significant contribution to the next generation of MWRs for radar altimetry.**
- **Thank you for your attention!**