EUMETSAT MICROWAVE SOUNDER CONSTELLATION: THE EPS-STERNA PROGRAMME

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Overview of EPS-Sterna Programme

- EUMETSAT identified a constellation of small microwave sounding satellites, complementing the reference EUMETSAT Polar System (EPS-SG) Microwave Sounder (MWS), as a potential additional contribution to the realisation of the WMO Integrated Global Observation System (WIGOS) Vision 2040, in line with objective 4 of the EUMETSAT strategy "Destination 2030".
- EPS-Sterna will be a EUMETSAT programme;
  EUMETSAT will be responsible for the overall system, the development and provision of the ground segment, the procurement of the launch services, the LEOP, the system operations including the management of the constellation.
- The EPS-Sterna space segment will be procured in cooperation with ESA, capitalising on their experience from the Arctic Weather Satellite (AWS) mission.

Arctic Weather Satellite (AWS)

- AWS was launched on 16 August 2024
- Its performance has been extensively analysed by industry, ESA, EUMETSAT and selected partners in the Scientific Advisory Group (SAG).
- The success of the AWS in-orbit demonstration represents an opportunity to expand the product envelope of the EPS-SG mission for its users, by implementing the EPS-Sterna.
- AWS considered as a Proto Flight Model
  – only minor modifications are expected for the EPS-Sterna constellation.

Objectives of EPS-Sterna Programme

- To expand and complement microwave sounding observations from EUMETSAT EPS-SG, the NOAA JPSS and the CMA FY polar-orbiting, meteorological satellites.
- To improve accuracy of global **Numerical Weather Prediction** models by increasing the number of microwave sounding observations by providing atmospheric water vapour and temperature profiles in clear and cloudy air;
- To contribute to **Nowcasting** applications at high latitudes through an increase in the frequency of microwave observations;
- To contribute to **Climate Monitoring** by adding to the existing record data with increased spatial-temporal sampling.

EPS-Sterna operational mission lifetime will be 13 years with the **initial constellation expected in 2029**.

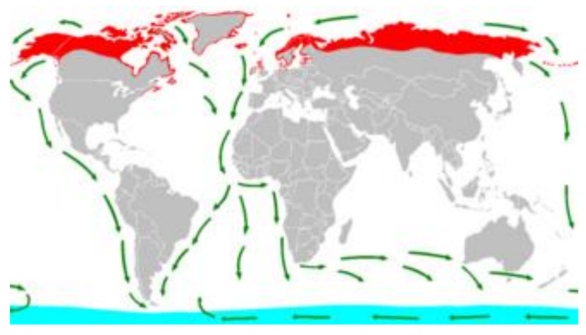

Fig 1: The Arctic Terna – Latin: Sterna Paradisaea
(migrates between Arctic and Antarctic - sees most daylight of any species)
By Andreas Trepte - CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=364093

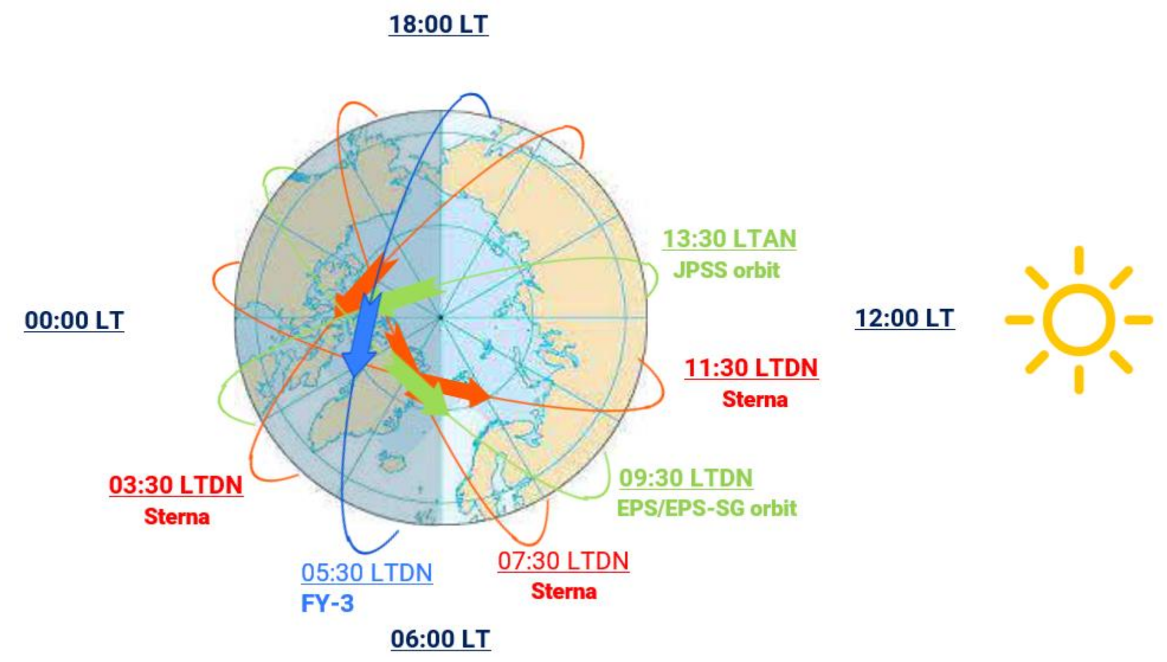

Fig 2: EPS-Sterna Proposed Orbital Configuration – 3 Planes x 2 Satellites

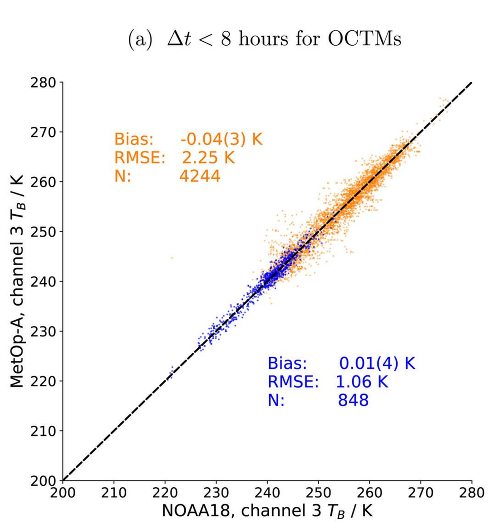

Fig 3: OCTM matchups of MHS 183±1GHz on NOAA 18 v. Metop A (orange)
Blue points mark classic SNO matchups. (From Buehler et al. 2020 – [1])

Scientific Support

- Collaboration with ECMWF on assimilation
  - and monitoring
- Developing Inter-Calibration
  + Uncertainty Framework
  - SNO method
  - OCTM "Warm SNOs" [1]
  - Vicarious inter-calibration
  - NWP Double-differencing
- Scoping L1C product to remap feedhorns
- Scoping L1D product for limb-compensation

EPS-Sterna Constellation Configuration

- 3 Sun-synchronous orbital planes at 595 km altitude
- Inclination: 97.8°
- Repeat cycle per individual satellite: 9 days
- Nominal constellation: 6 satellites
- 2 Satellites per each orbital plane phased at 180°
- Orbits selected in order to minimize global time-to-coverage by complementing EPS-SG and+ JPSS
- LTDN 03:30, 07:30, 11:30

EPS-Sterna Time-to-Coverage

- *Time-to-Coverage* requirement is one of the key drivers of the constellation
- It is defined as the time required to cover 90% of the globe with Sterna observations
- The Sterna constellation shall achieve 90% of global coverage over the repeat cycle in 5 hours (T), 4 hours (O), 3 hours (B)

Constellation performance

- Time to achieve 90% coverage:
- EPS-Sterna only: 3.1-4.7 hours
- EPS-Sterna + EPS-SG +JPSS: 2.4-3.8 hours

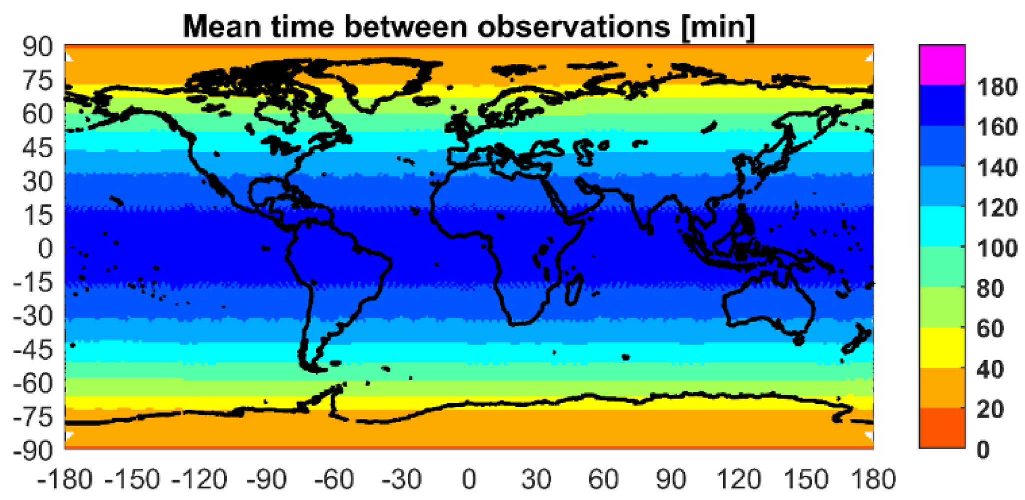

Fig 4: Mean time between observations: 20 min-3 hours
(with 6 EPS-Sterna satellites in 3 orbital planes)

EPS-Sterna Spacecraft

- Three axis stabilised with electric propulsion
- Mass: 120 - 135 kg
- Volume: 1x 0.7 x 0.9m
- Power (nominal): ca. 220 W
- Science data : L band
- Command and Control: S band
- Carries single instrument:-

Fig 5: Artist Impression of EPS-Sterna Satellite – courtesy of ESA

EPS-Sterna Microwave Radiometer

- Cross-track scanning
- 19 channels: 50.3 – 325 GHz
- Mass: 30 kg (MWS on EPS-SG ~150 kg)
- Power: ~35 W (MWS ~120W)
- Data rate: 60 kbps
- Scan period: 1.19s (constant rate ~50 rpm)
- Scan angle: ±54.42°
- 145 Earth views, oversampled at <100GHz
- Swath ~ 2000 km

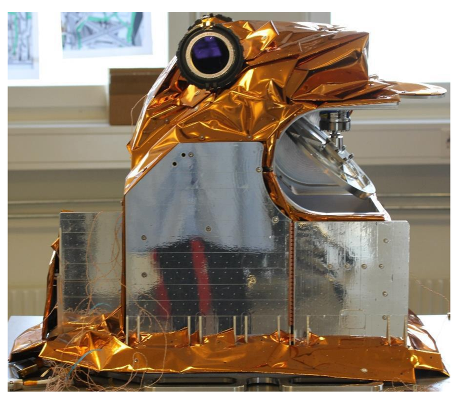

Fig 6: AWS Microwave Radiometer – courtesy of ESA

Channel name	Centre Frequency [GHz]	Bandwidth [MHz]	NEΔT [K]	Footprint at nadir	Application
STERNA-11	50.3	180	<0.6	≤ 40 km (±25%)	Temperature Sounding
STERNA-12	52.8	400	<0.4		
STERNA-13	53.246	300	<0.4		
STERNA-14	53.596	370	<0.4		
STERNA-15	54.4	400	<0.4		
STERNA-16	54.94	400	<0.4		
STERNA-17	55.5	330	<0.5		
STERNA-18	57.290344	330	<0.6		
STERNA-21	89	4000	<0.3	≤ 20 km (±25%)	Window and Cloud detection
STERNA-31	165.5	2800	<0.6	≤ 10 km (±25%)	Window/humidity sounding
STERNA-32	176.311	2000	<0.7		
STERNA-33	178.811	2000	<0.7		Humidity sounding
STERNA-34	180.311	1000	<1		
STERNA-35	181.511	1000	<1		
STERNA-36	182.311	500	<1.3		
STERNA-41	325.15±1.2	(2x) 800	<1.7	≤ 10 km (±25%)	Humidity sounding/cloud detection
STERNA-42	325.15±2.4	(2x) 1200	<1.4		
STERNA-43	325.15±4.1	(2x) 1800	<1.2		
STERNA-44	325.15±6.6	(2x) 2800	<1		

Table 1: Characteristics of EPS-Sterna Microwave Radiometers

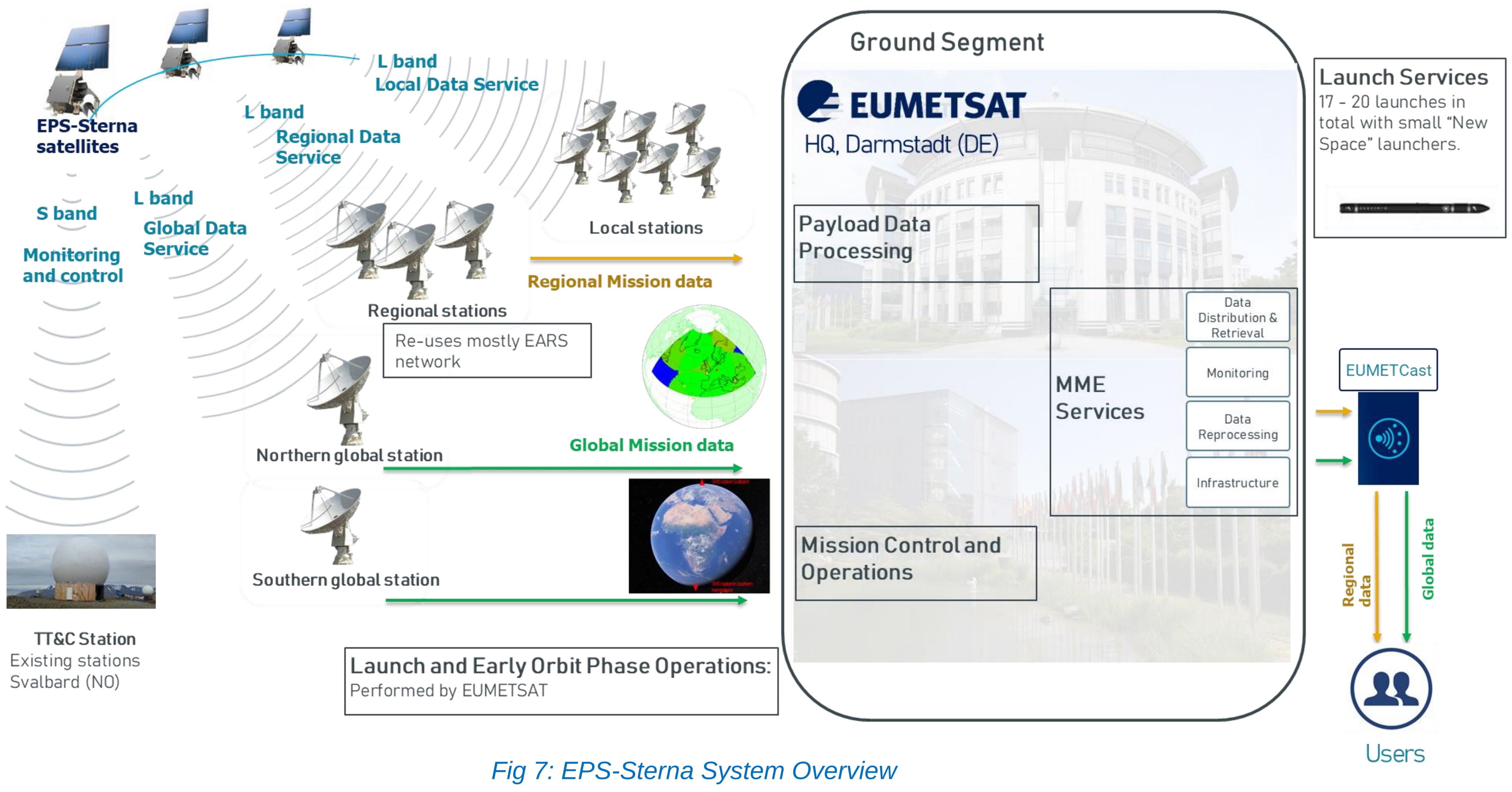

Fig 7: EPS-Sterna System Overview

Expected Benefits to NWP

- NWP Impact assessments confirm that impacts on global NWP are substantial (the order of one Metop satellite) [2]
- Additional substantial impacts expected on regional, short-range forecasts and Nowcasting [3]
- Performance/measurement accuracy are drivers of the magnitude of impacts - Meeting instrument performance specifications is important

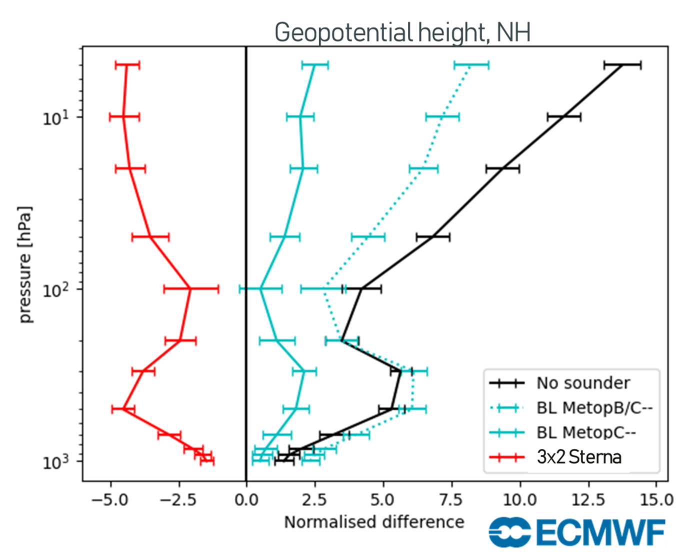

Fig 8: Vertical profiles of EDA spread reduction for the geopotential height, comparing nominally operational 6 EPS-Sterna constellation (red line), removal of all MW sounding data (black line) and experiments that change the number of Metop platforms

Benefit from adding more MW observations

- Additional microwave data continues to reduce Ensemble Data Assimilation (EDA) spread – i.e. improve uncertainties [2]
- Reference (6 satellite) EPS-Sterna constellation performs very well
- Results with simulated data consistent with results from existing real data
- Significant additional impact adding Sterna constellation to baseline observing system

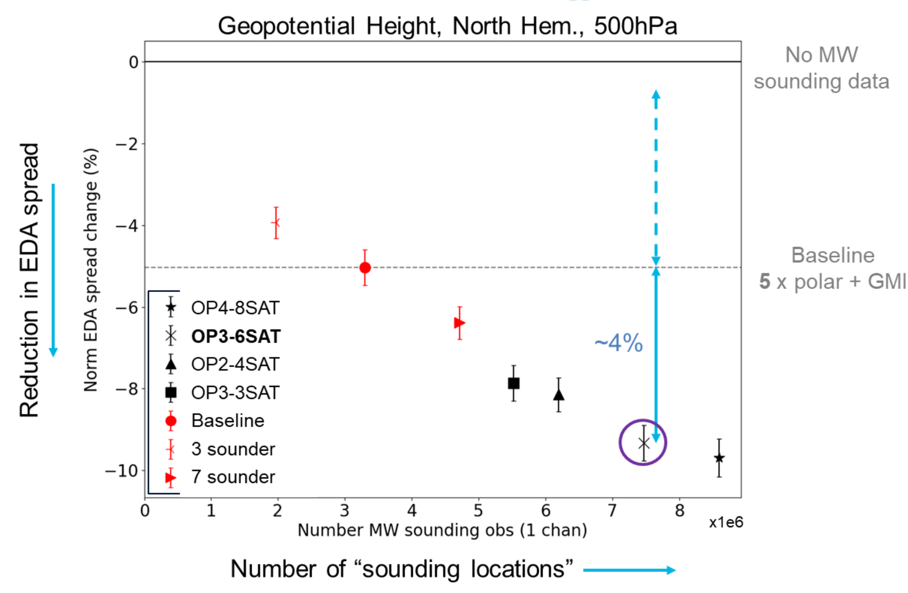

Fig 9 : Percentage EDA spread reductions with increasing observation numbers for 500hPa geopotential height relative to No MW Sounders for EPS-Sterna constellation options and experiments changing number of MW sounders

References

[1] Buehler, S. A., Prange, M., Mrziglod, J., John, V. O., Burgdorf, M., & Lemke, O. (2020). Opportunistic constant target matching—A new method for satellite intercalibration. Earth and Space Science. 7, e2019EA000856. https://doi.org/10.1029/2019EA000856

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[3] Bengt Rydberg, Adam Dybbroe, Nina Håkansson, Günther Haase, and Daniel Johnson, EPS-Sterna impact assessments for precipitation nowcasting, EUMETSAT Study Contract Report, https://www.eumetsat.int/media/52111

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