Revolutionising weather forecasting with global surface pressure data from space

The BARODAR (BAROmetric Differential Absorption Radar) mission, led by Science and Technology Facilities Council's (STFC) RAL Space, has the potential to dramatically improve weather predictions and climate monitoring by providing global, regular and reliable surface air pressure data from space for the first time.
This is significant because these pressure measurements are critical for assessing the state of the atmosphere and oceans, and therefore crucial for timely weather prediction.

Currently, ground-based measurements of surface pressure are provided by a network of weather monitoring stations that are predominantly in Europe and North America. There is insufficient coverage across other land areas, and extremely sparse coverage over the oceans which cover about 70% of the Earth's surface.
Accurate global-scale measurement of surface air pressure presents a substantial technical challenge which can only be achieved by remote sensing from space. BARODAR aims to make this possible for the first time.

BARODAR'S challenge

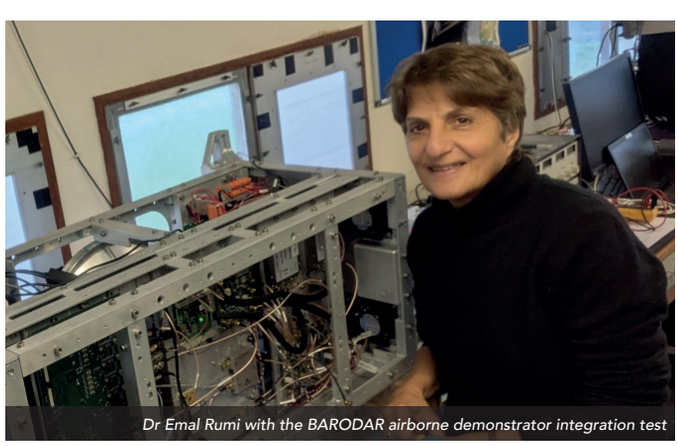
According to the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report[i] [ii] released in 2021, the human-caused rise in greenhouse gases has increased the frequency and intensity of extreme weather events. In July 2023, for the first time in history, the World Health Organization Office for Europe[iii] [iv] declared the climate crisis and extreme weather events a public health emergency in Europe in a bid to improve the coordination of preparedness and response to extreme weather events.
Such events are accelerating the need for more accurate and timely weather forecasting to save lives and protect economies. The BARODAR mission aims to tackle this challenge head on.

"The CEOI funding helped to get the BARODAR project off the ground. We wouldn't be where we are now without the CEOI funding."

Dr Emal Rumi
Principal Investigator and lead research and development of BARODAR

Pressure – a possible solution

The BARODAR concept aims to provide an unprecedented 10km spatial resolution for global surface air pressure measurements, at high accuracy and temporal resolution, for the first time from space.
This is important because surface air pressure measurements support Numerical Weather Prediction, the process of using mathematical models of the atmosphere and oceans to predict the weather.
Currently, air surface measurements are provided by weather monitoring stations on the ground, resulting in insufficient coverage of large parts of the Earth and extremely sparse coverage of the oceans. This is challenging, as the oceans' tight links with the atmosphere makes understanding their behaviour vital for forecasting weather and monitoring climate conditions. Three areas that stand out as particularly problematic are the Southern Ocean, the Arctic and the Antarctic continent. The fact that weather forecasting is less accurate in these areas is partly attributed to the lack of surface air pressure observations.
The need for global-scale measurements of surface pressure from space was discussed by NASA and what is now called RAL Space as far back as the 1980s, but it is only recently that technology has advanced enough to make this a reality.
The retrieval of atmospheric pressure from satellite observations require accurate knowledge of the atmospheric mixing ratio of the spectral feature to be targeted. Molecular oxygen is the only viable candidate, since its mixing ratio is effectively constant over the full range of atmospheric conditions and altitude. The BARODAR method relies on the frequency dependent



Dr Emal Rumi with the BARODAR airborne demonstrator integration test

absorption of mm-wave radar pulses in the upper wing of the 60 GHz oxygen band. The ratio of transmittance of two channels, i.e the differential absorption, is a measure of the total oxygen in the path. Since oxygen is uniformly distributed in the atmosphere, this ratio is related to the total surface pressure. BARODAR includes a third channel to produce another ratio to reduce uncertainty. These measurements do not themselves suffice, however, because they are also sensitive to the cloud cover, atmospheric temperature profile and water vapour content.

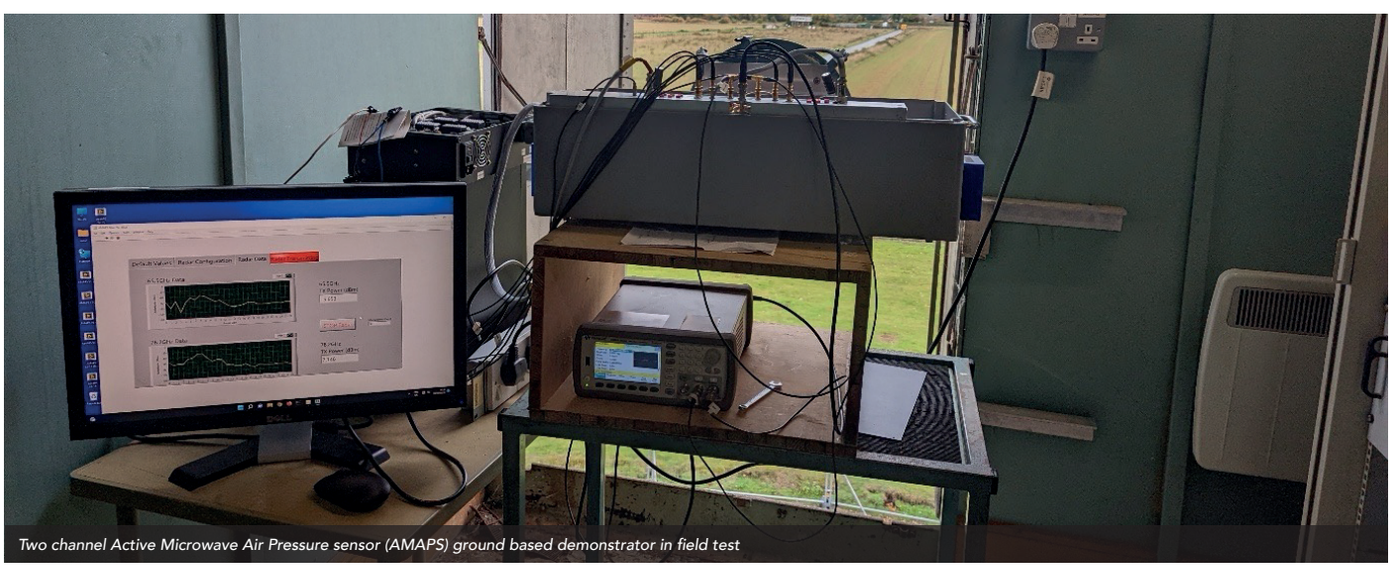
BARODAR's novel instrument design is based on three measurements at separate frequencies, characterising the atmosphere both inside and outside of the oxygen absorption band. BARODAR's pulsed radar operates in two modes: the first mode measures signal returns from the Earth's surface at three different frequencies, providing information for surface air pressure calculations. The second mode transmits longer pulses in the out of band channel for cloud detection, necessary to improve the accuracy of pressure measurements.

BARODAR will fly with a multi-frequency microwave radiometer to sense water vapour, liquid water, and temperature profiles. This atmospheric correction information is required to accurately derive surface pressure and to provide great value due to the co-location in time and space with surface pressure measurements.

The resulting global measurements will improve forecasting and provide early warnings of extreme weather events. This data can be used by governments and communities to help save lives and protect infrastructure, while benefitting key sectors such as agriculture, shipping and the military.

In 2025, the Met Office shared its concerns and latest research into the impact a changing climate is having on global food security. It highlighted that droughts, floods and other extreme weather events are becoming more frequent and severe and such events can destroy crops, erode soil, damage infrastructure and displace communities.[v]

The benefits that improved weather forecasting could have on these areas and others is why the weather forecasting services market is projected to be worth over $3.5billion by around 2030, according to market research carried out by the likes of TERRAWATCH-Space on behalf of STFC and others, including Meticulous Research.[vi]



Two channel Active Microwave Air Pressure sensor (AMAPS) ground based demonstrator in field test

How the CEOI grant helped

Between 2022 and 2024, the CEOI has contributed a total of £350,000 to the BARODAR mission concept development. CEOI initially provided £250,000 which supported the successful build of a ground-based BARODAR demonstrator to test the technology and concept. This funding was divided between RAL Space and two other UK-based companies, NanoAvionics UK and Plextek Services Limited. NanoAvionics UK worked on the mission concept design analysis which examined the coverage achieved using multiple satellites compared to a singular satellite. Plextek Services Limited carried out a study for BARODAR's innovative scanning antennae design concept.

As a result of this work, BARODAR moved up to Technology Readiness Level 3.

This work also led to RAL Space successfully applying for €500,000 from the European Space Agency (ESA) to build an airborne demonstrator for the system which is due to be flown in 2026/2027.

CEOI contributed a further £100,000 which enabled RAL Space to work with Airbus and the University of Leicester on a mission proposal for ESA Earth Explorer 12 and to publish an important paper which defined the concept of the BARODAR mission and what it could achieve scientifically.[vii]

In the words of Dr Emal Rumi

Principal Research and Development Engineer at RAL Space

“BARODAR’s global measurements will improve forecasting and will support early warnings for extreme weather events such as flooding, hurricanes and storms. These warnings will help governments and communities to save lives and protect infrastructure from the devastation caused by weather-related damage. This is why BARODAR’s data has huge societal benefits. Its data can help governments, communities and key sectors, such as agriculture, shipping, the military and the sports events industry, to become far more resilient against the impacts of extreme weather.”

Current status of the project

The team at RAL Space has been assembling the airborne demonstrator which is under final test. RAL Space is planning to fly the demonstrator in different weather conditions during 2026/2027.

The purpose of the airborne demonstration is to prove the concept of the space mission and verify the frequency selection of the radar, the technology and the algorithms for pressure retrieval. Measurements will be compared with ground-based pressure measurements to quantify the accuracy of its algorithms going forward.

Following the airborne demonstration of the BARODAR instrument, the team will look at the next steps for the technology. This may include applying for the Earth Explorer 13 mission or building a constellation with a medium-sized satellite. If RAL Space pursues the constellation option, it would aim to start with an inorbit demonstrator featuring one satellite with a view to building up to three satellites to achieve global coverage. If this was successful, the number of satellites could be increased to a maximum of nine satellites.

Dr Emal Rumi Principal Investigator and lead research and development of BARODAR

At a glance

- **Unique global approach** to measure surface air pressure missing information for NWP
- More than **£1.1m** of investment has gone into BARODAR to date
- CEOI has contributed **£350,000** towards the project, STFC has contributed **£200,000** and ESA has contributed around **€700,000**
- BARODAR is a differential absorption pulsed radar operating in the right wing of the Oxygen band
- It will operate on a sun-synchronous (SSO) Dawn-Dusk orbit at around **500km altitude**
- It will conduct nadir looking observations with **2** instruments
- It promises to provide an unprecedented **10km x 10km** spatial resolution for global surface pressure measurements, at high temporal resolution.

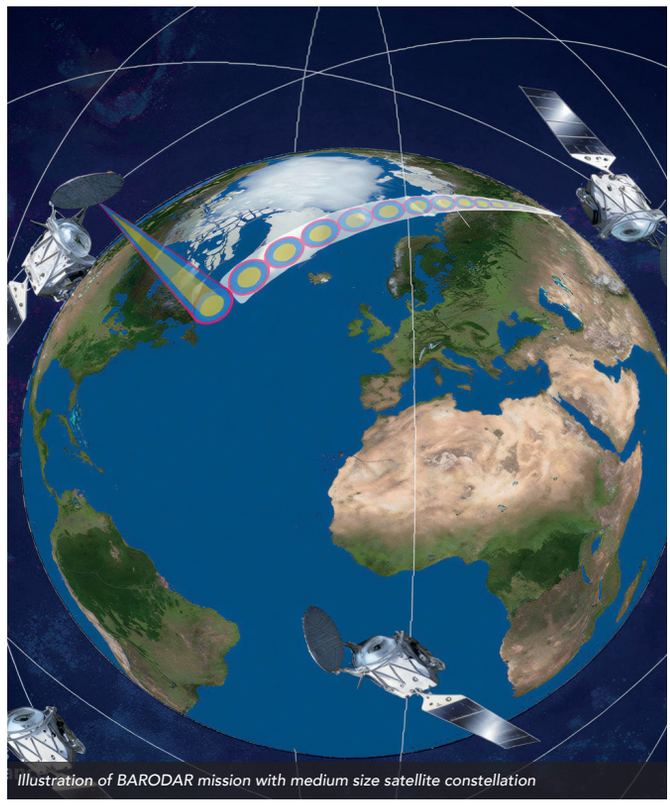


Illustration of BARODAR mission with medium size satellite constellation

"Early-stage funding ensures that organisations can test innovative ideas and derisk new technologies. It is fantastic to see BARODAR through the early development stages where so many ideas and technologies have to be abandoned."

Dr Emal Rumi, Principal Research and Development Engineer at RAL Space

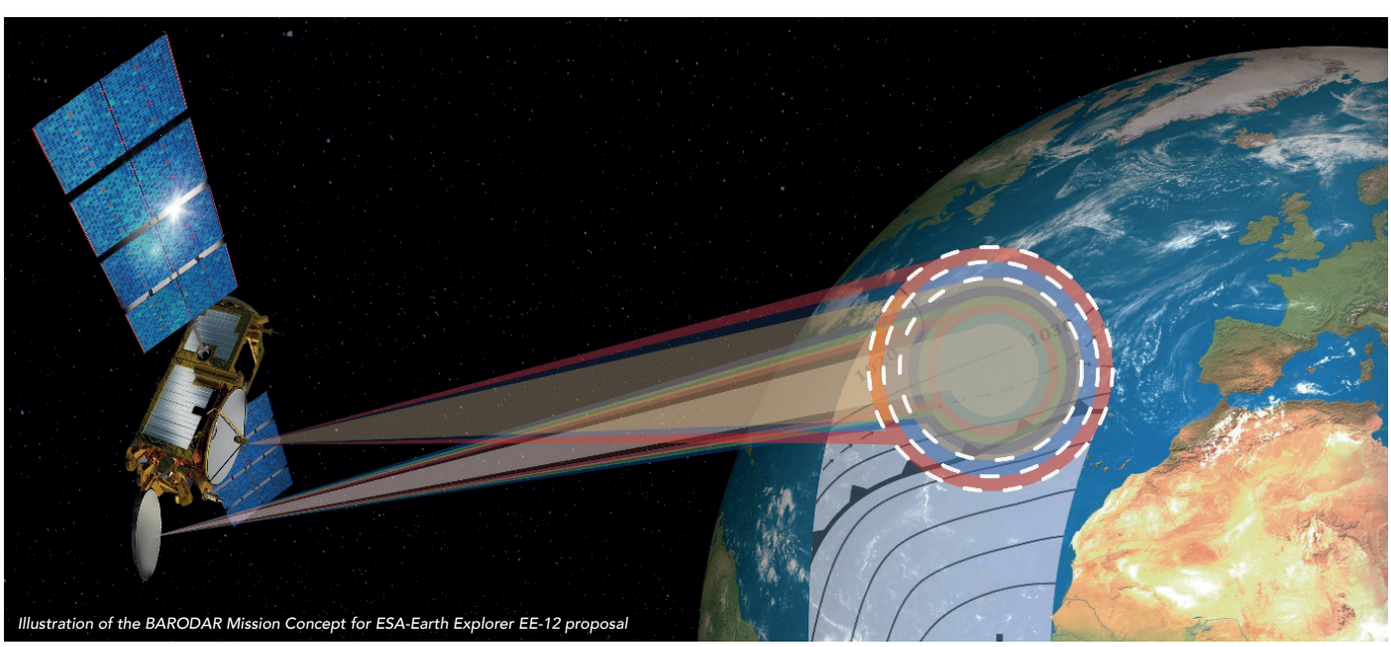


Illustration of the BARODAR Mission Concept for ESA-Earth Explorer EE-12 proposal

[i] https://science.nasa.gov/climate-change/extreme-weather/#:~:text=As%20the%20climate%20changes%2C%20the,responding%20to%20extreme%20weather%20events.
[ii] https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/
[iii] https://www.who.int/europe/emergencies/situations/climate-crisis-extreme-weather
[vi] https://climate.copernicus.eu/esotc/2023/extreme-weather-and-human-health
[v] https://www.metoffice.gov.uk/blog/2025/how-weather-affects-food-production
[vi] https://www.meticulousresearch.com/product/weather-forecasting-services-market-5449?utm_source=Globnewswire&utm_medium=Paid&utm_campaign=Product&utm_content=08-03-2023
[vii] https://ceoi.ac.uk/eo-missions/earth-explorer-12/barometric-differential-absorption-radar-barodar/