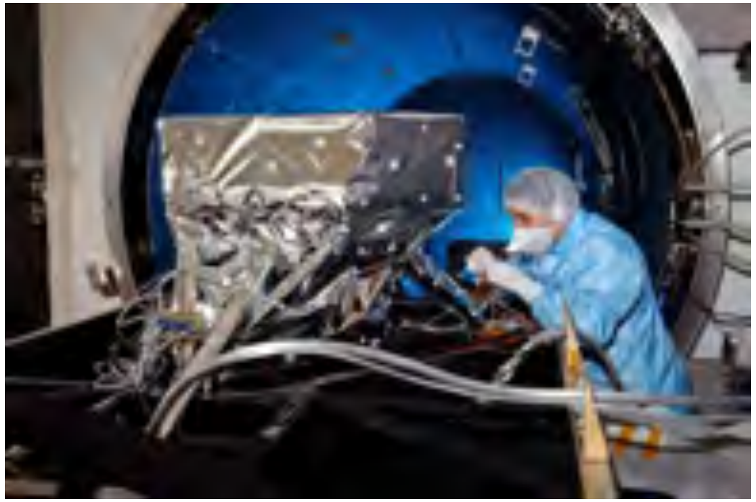
“BAROADAR: Global Surface Air-Pressure Mission”



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RAL Space

Science and Technology Facilities Council

Met Office

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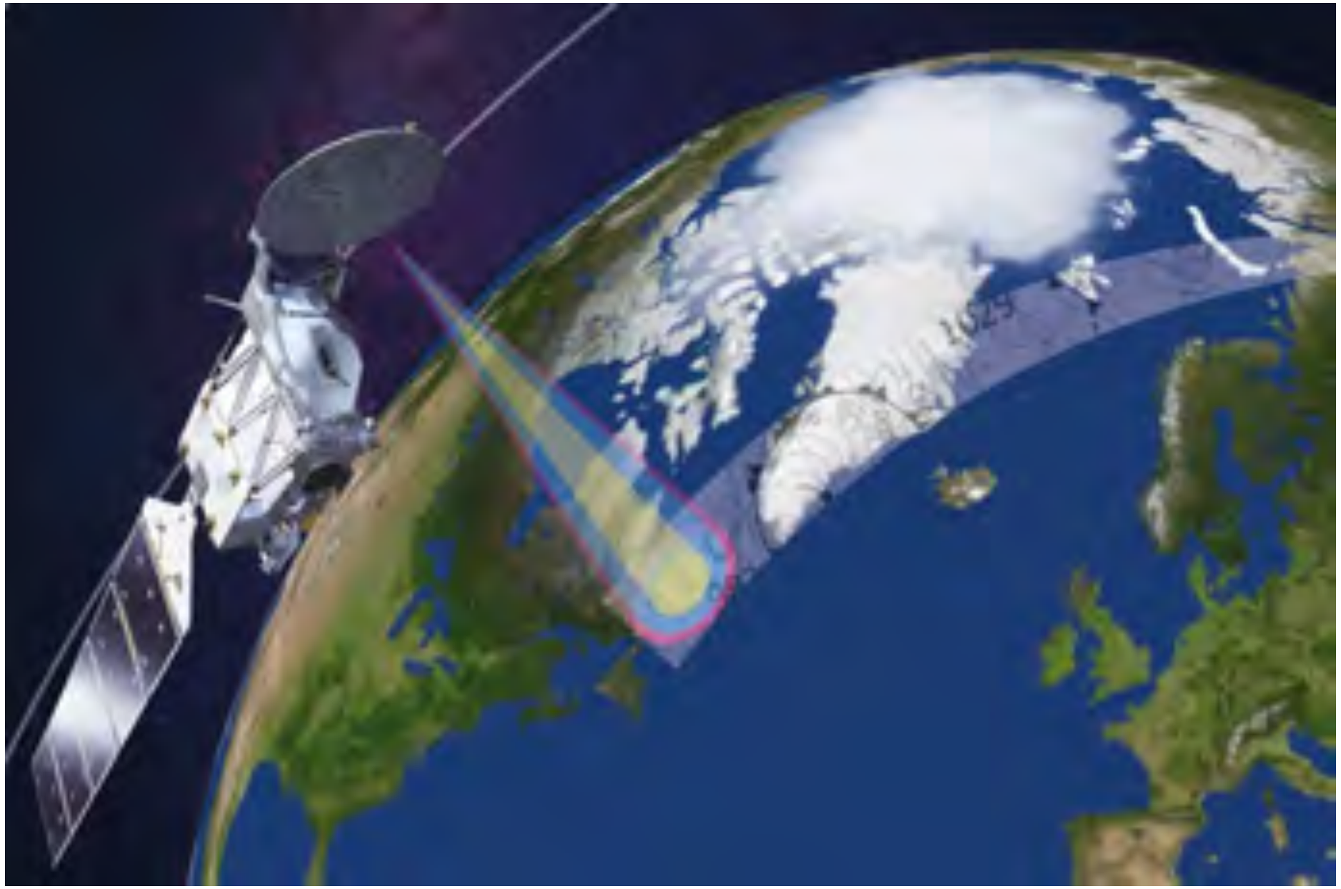
BARODAR: BAROmetric Differential Absorption Radar

BARODAR is an **EO** mission based on **active system** to provide global, regular, and consistent **surface pressure** data for **the first time from space**.

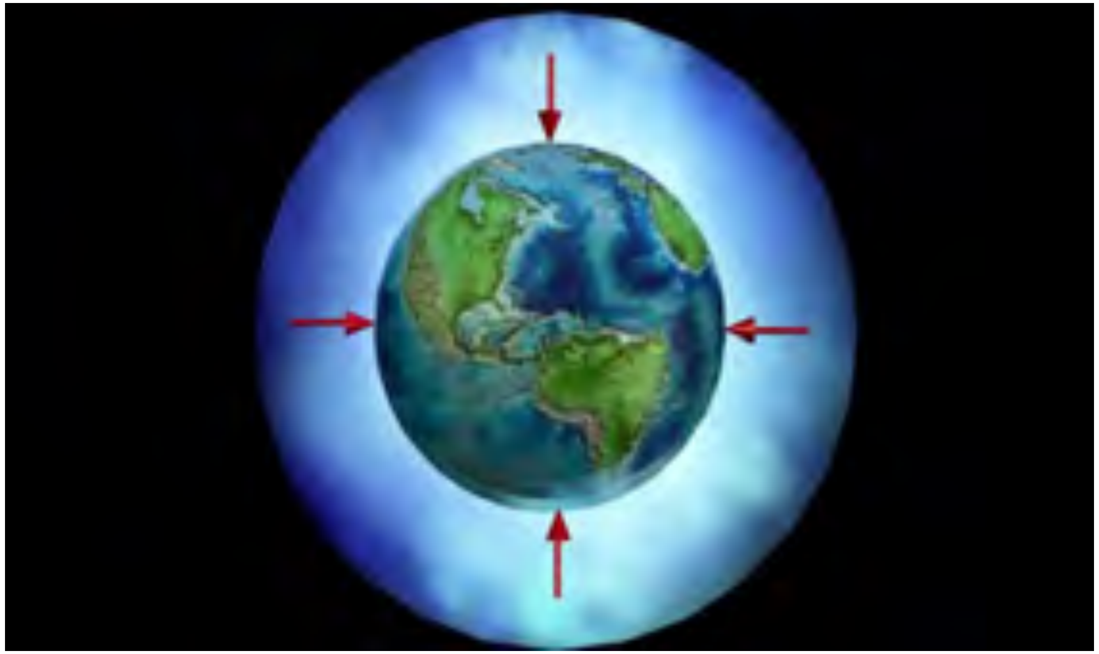
- ❑ Introduction
- ❑ Justification
- ❑ Instrument & Mission Design
- ❑ Future work



Science and Technology Facilities Council

Surface air-Pressure

- Earth’s Atmosphere is **a deep fluid** covering the Earth’s surface.
- Pressure at the surface results from this fluid.
- **Radiative and thermodynamic processes** control this fluid and the atmospheric pressure at the surface.
- Surface pressure **influences, sea height and roughness**. Plays a major role in **storm surges**, and severe flooding.
- Measurements of surface **pressure are critical** in assessing the current state of the **atmosphere and oceans**.



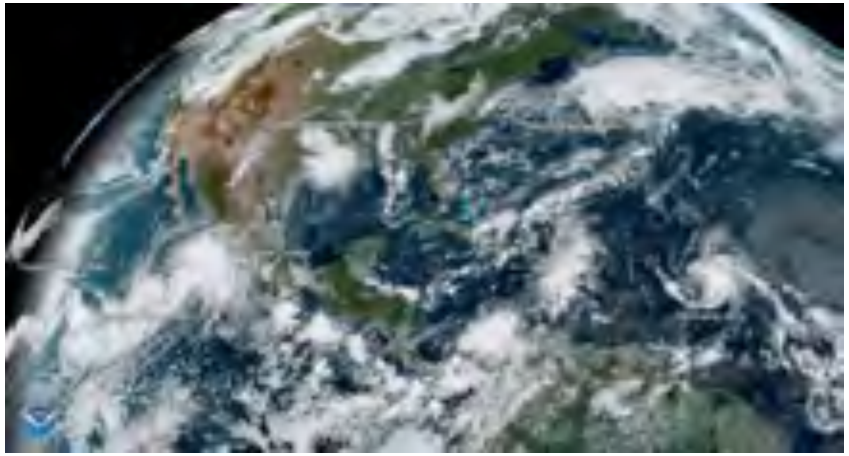
It is the most important parameter used in Numerical Weather Prediction (NWP) Models and Climate Models, General circulations model (GCM) .

Limited measurements on land, and more importantly at sea, limit forecasting capability

Mission justification

- Extreme weather events (**tropical cyclones and hurricanes,** and **floods**) claim many lives, and cause large scale infrastructure damage. Events are becoming **more frequent** and **more intense**, due to **warming climate.**

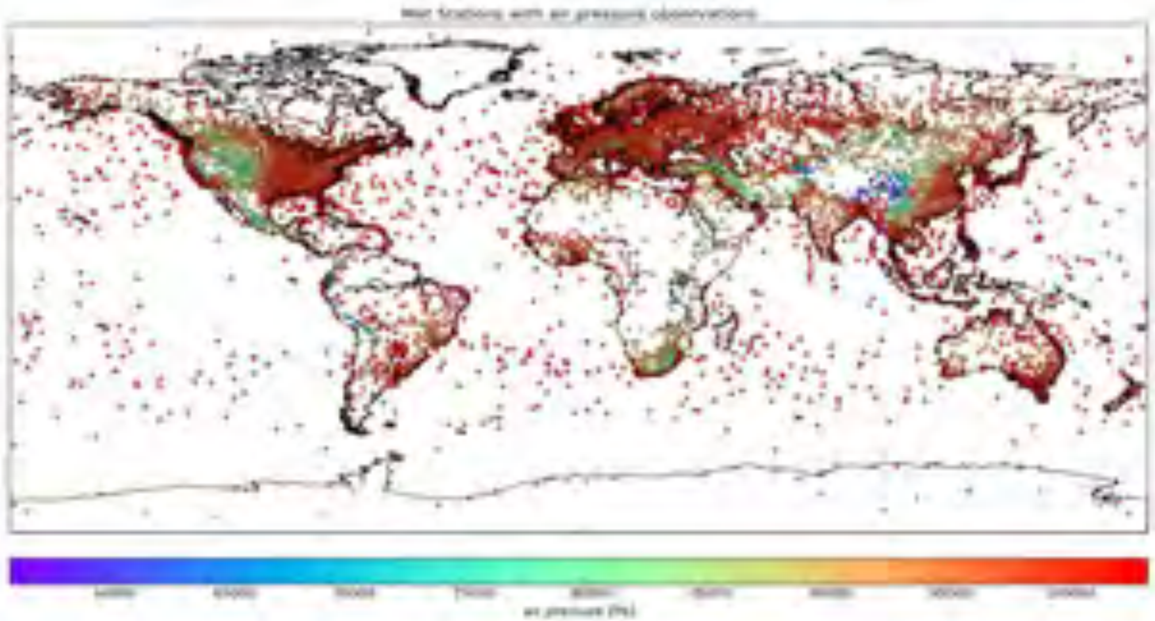
- **Better forecasting** is required for forward planning.
- Routinely measured at **weather stations,** on land, and is monitored by **mooring buoys** on oil rigs and **ships** at sea, but **coverage is sparse.**
- This data is **insufficient for effective forecasting**.
- **Global measurements from space are therefore required.**



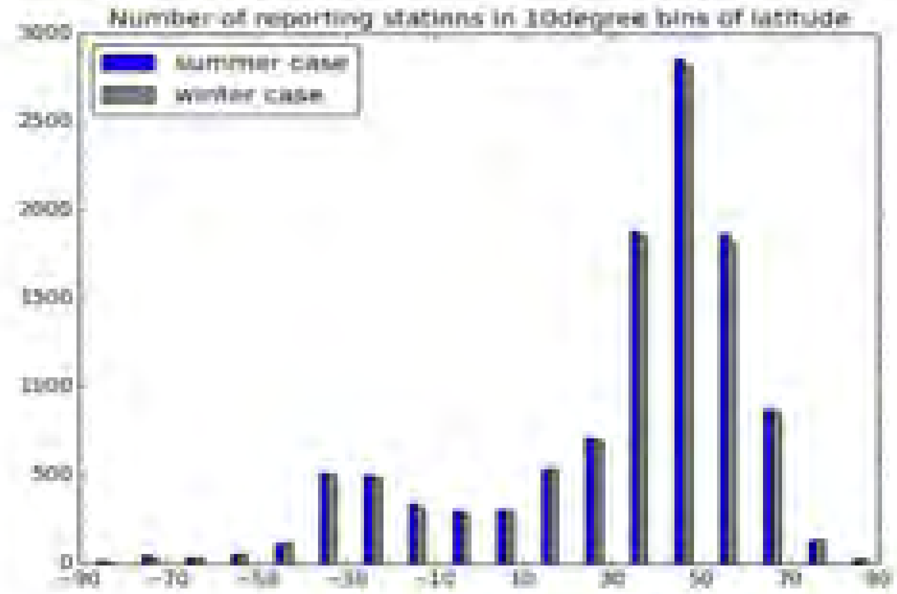
Tropical cyclones in 2019

Year statistics	
Total systems	128
Named systems	83
Total fatalities	1,901 total
Total damage	> $48.92 billion USD

Distribution of in-situ surface-air pressure sensor



Coverage of surface pressure observations for the 00 UTC assimilation cycle on 19th July 2017 in the Met Office global model. Observations are used from 10 236 stations globally, some reporting hourly, giving approximately 40 000 observations assimilated in a 6 hour window. [Credit: Met Office]



Distribution of in-situ stations reporting pressure for 1st Jan 2017 (winter) and 17th July 2017 (summer), based on the observations available from the Met Office operational database received via the WMO Global Telecommunication System. [Credit: Met Office]

- 90% of stations are on **land and concentrated on the Northern Hemisphere**.
- The **network of weather stations** has been **shrinking** over the last decades.
- Ground based instruments are **not homogeneous**, data quality control, installation, maintenance and **calibration** are challenging.
- **Temperature, humidity, wind** are routinely measured from space.
- Surface air pressure was **never measured globally** from space before.

Satellite remote sensing is the only way to provide, global consistence and continuous observations.

Concept design study

- **ESA-**ITT GSP started in 2017.
- Collaboration with the Met Office and NOC
- **Feasibility** and **concept design.**
- Different technologies
- Active Microwave technique
- Weather prediction models under estimate the pressure at the centre of the storm by 5 hPa [Heming2016].
- Antenna Beam Scanning Design study
- Started building radar **instrument bench model.**

A concept design of a potential instrument capable of measuring surface-air pressure from space with sufficient accuracy of (~1 hPa)

Operational and research users requirements

	Numerical weather prediction	Ocean dynamics and sea level	Climate modelling	Gravity monitoring	Atmospheric composition monitoring
Repeat distance/grid (km)	1 - 500	1 - few x 100	Few x 10	200	3 - 100
Repeat rate (hours)	0.5 - 24	0.5 - 12	3 - 24	3 - 6	2 – 4 weeks
Uncertainty ±(hPa)	0.5 - 2.0	0.2 - 10.0	0.5 - 1.0	1 - 2	1

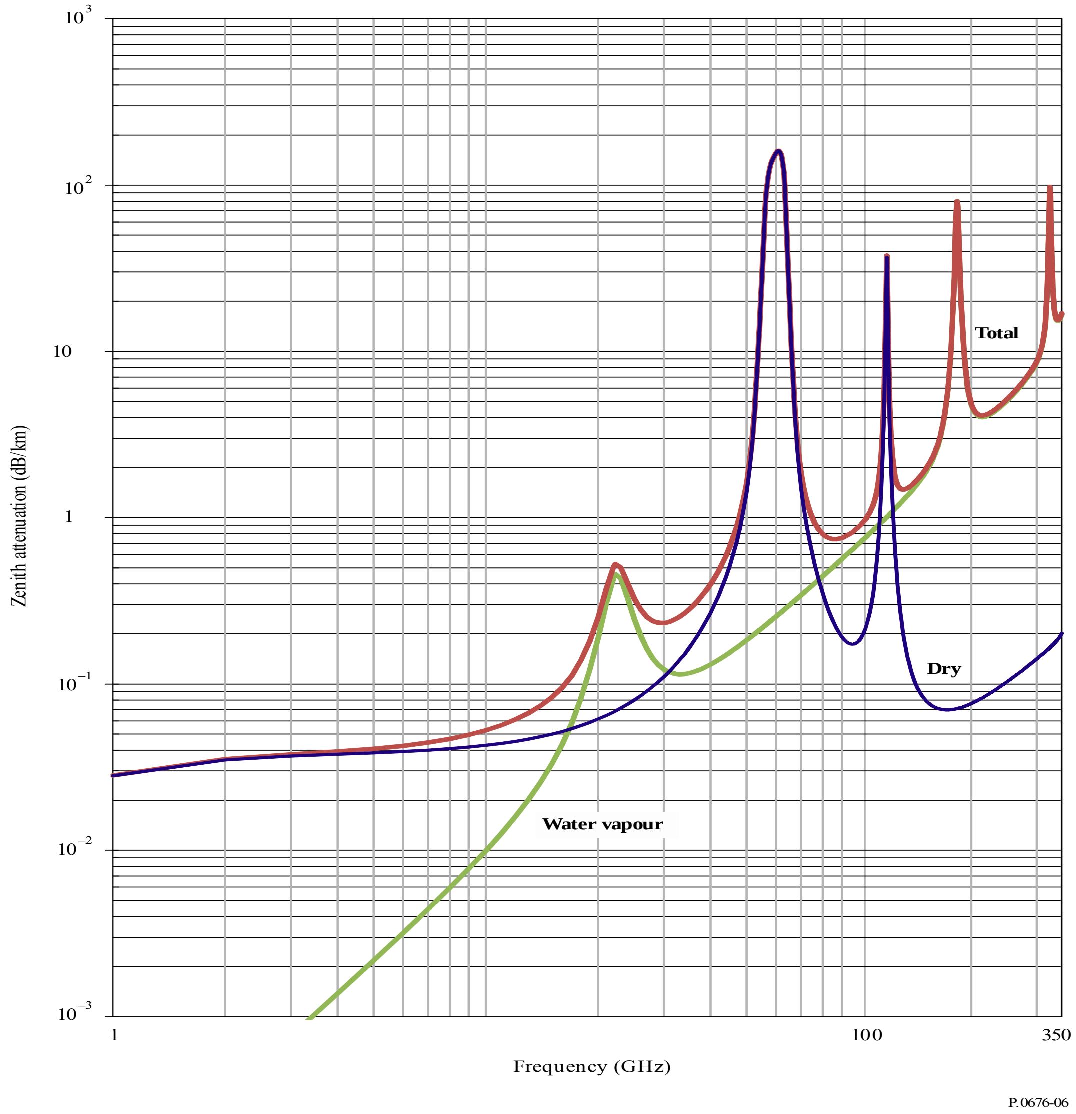
WMO and OSCAR requirements + users survey

- Uncertainties of **±0.5hPa** would be of **significant** benefit for **NWP** and **Climate** Modelling.
- **For oceanographic applications** uncertainty of **± 0.2hPa** is needed for **coastal areas especially** considering storm and hurricane forecasting.
- Achieving this will be a **break through** as **it will satisfy all users** as well as providing accuracy comparable with **the in-situ measurements**.
- Temporal resolution of 6 to 12 hours is reasonable

How to measure surface air-pressure from space

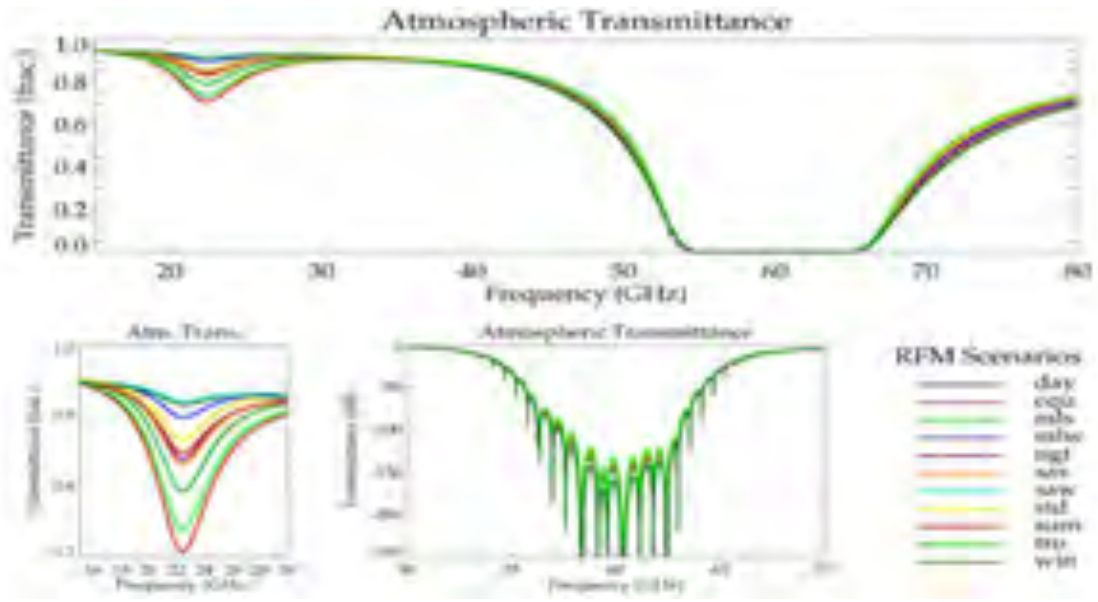
- Electromagnetic waves are absorbed in the atmosphere primarily by **oxygen** and **water vapour**.
- Molecular oxygen **uniquely** has **a constant mixing ratio** over the full range of atmospheric conditions.
- The **total oxygen** is a proxy for atmospheric air pressure measurements.
- A pair of pressure sensing frequencies on the **lower or the upper wing** of the oxygen absorption band provide **distinctive attenuations**.
- The **Differential Absorption Radar (DAR) with 3 channels** provides potential technique for surface pressure measurements.
- Additional measurements in the **water vapour band** is needed to correct for **clouds and precipitation**.

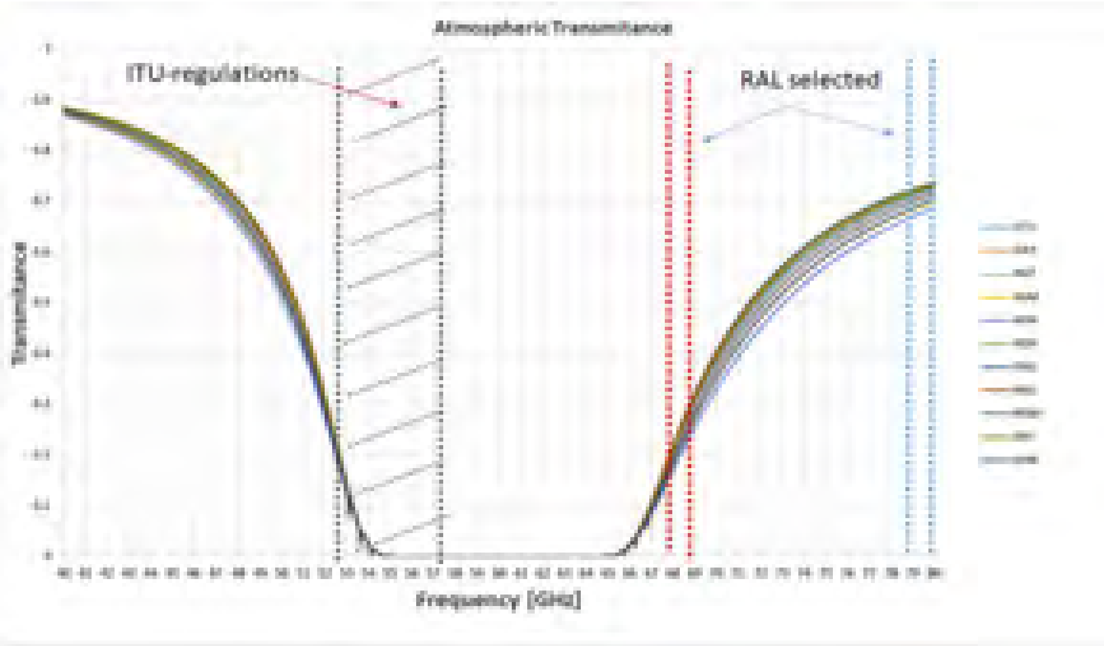
Active Microwave Technique with DAR



Total, dry air and water-vapour zenith attenuation from sea level
(Pressure = 1 013.25 hPa; Temperature = 15°C; Water Vapour Density = 7.5 g/m³), Rec. ITU-R P.676-11

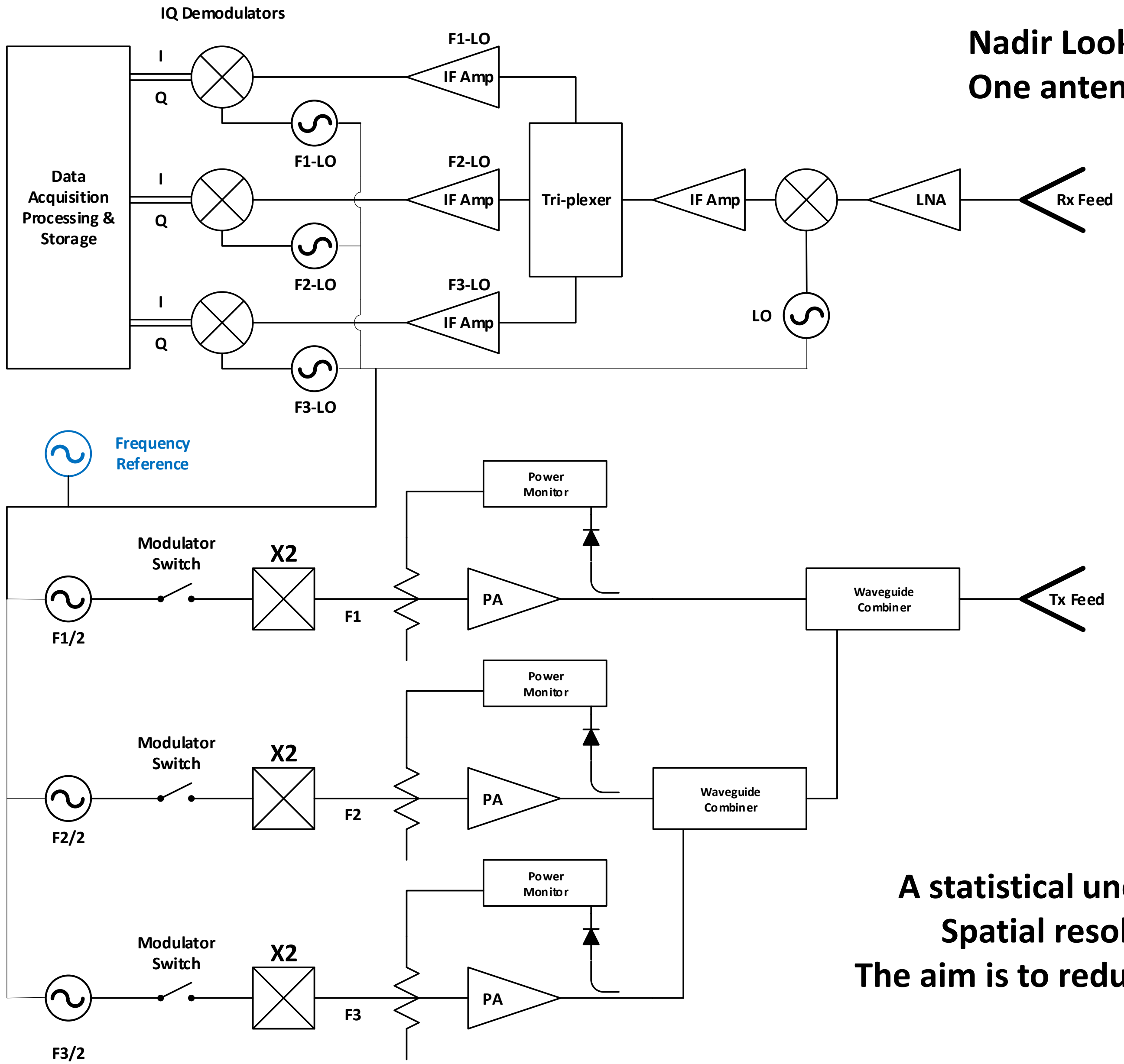
Frequency selection criteria



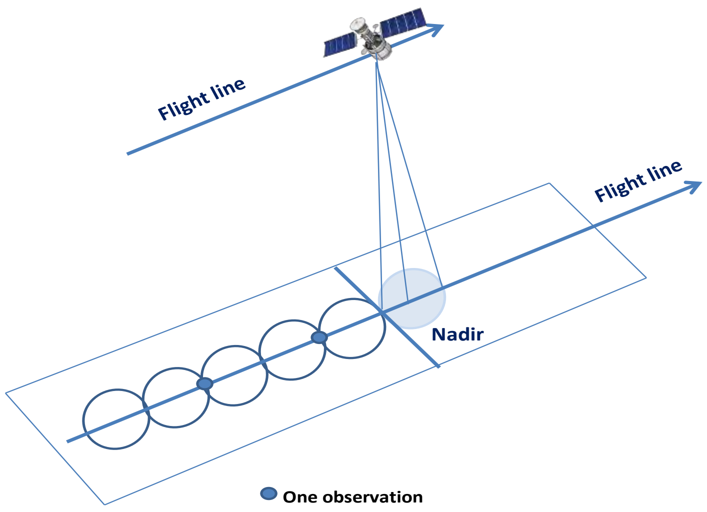


- Outside the ITU astronomy allocated bands.
- Strong correlation with column O2 amount
- Close enough to use the same antenna.
- Careful selection to increase attenuation ratio of a pair.
- Not too deep in the oxygen band to maintain good SNR.

Three channels radar transceiver

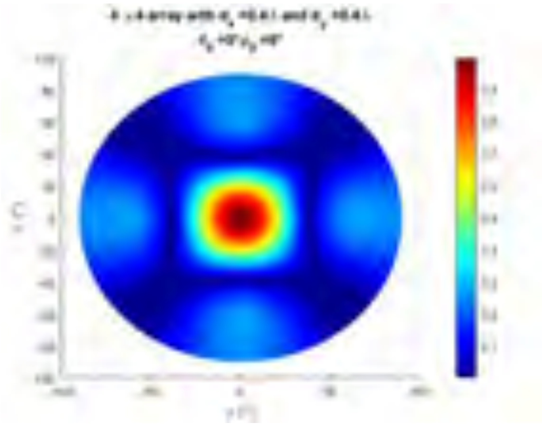


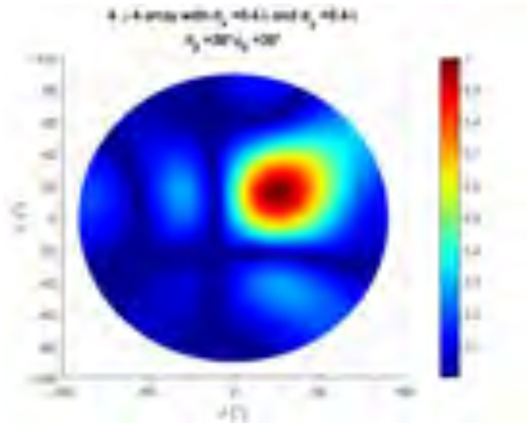
Nadir Looking observation with pulsed radar at 500km altitude.
One antenna for transmit and receive of the 3 channels.



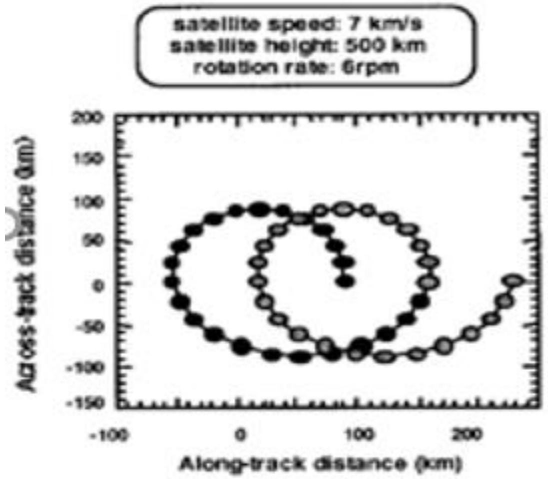
A statistical uncertainty of 0.33%, ±1.65hPa with base-line design.
Spatial resolution of 4km across swath and 8km along track.
The aim is to reduce uncertainty, by antenna beam scanning technique.

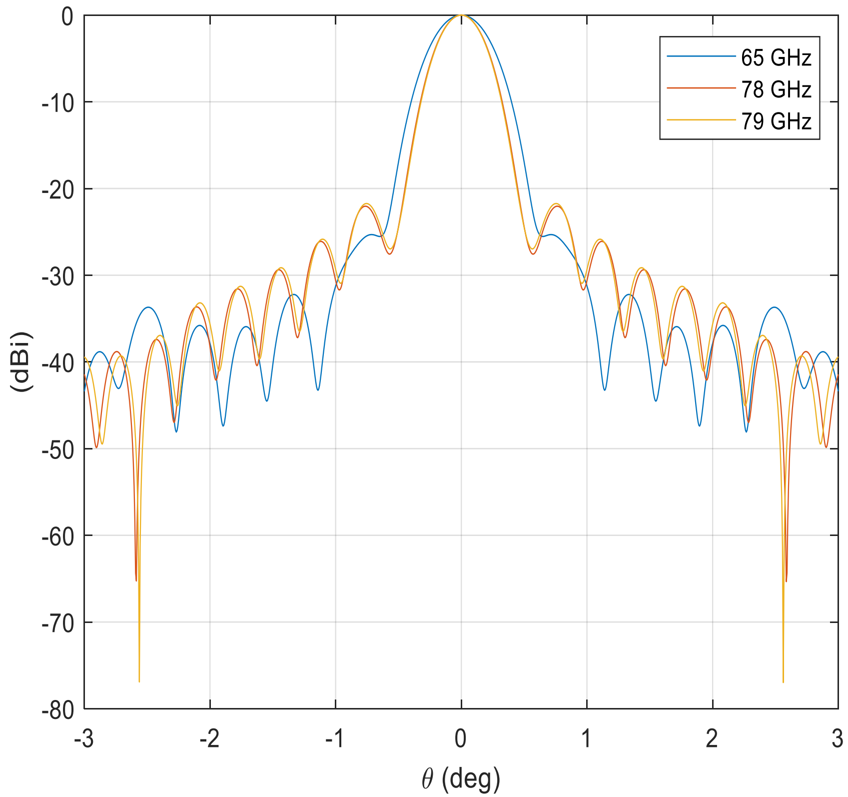
Conical beam scanning antenna





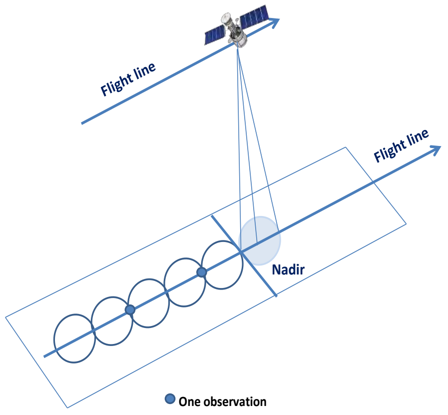
Overall system dimensions (HxWxL)	1.2 m × 0.7 m × 0.8 m
Magnification	15
f1	53.33
f2	800 mm
Diameter sub-reflector M1	100 mm
Diameter main reflector M2	700 mm
M1 to M2 vertex separation distance	853.33 mm
Offset of M1 lower edge to common axis	44.18 mm
Offset of M2 lower edge to common axis	662.74 mm
Angle between reflectors	45°
Number of elements	4 × 4
Array dimensions	46.4 mm × 46.4 mm
M2 Beamwidth (FWHM)	~0.44°
Footprint diameter	3.2 - 3.8 km
Sidelobe level	<-20 dB
Directivity	~61 dBi





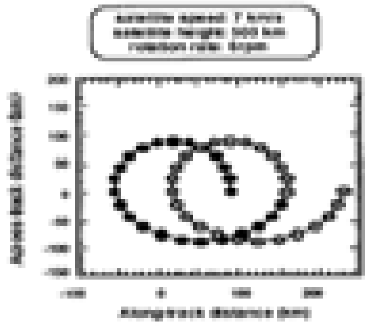
System design specifications

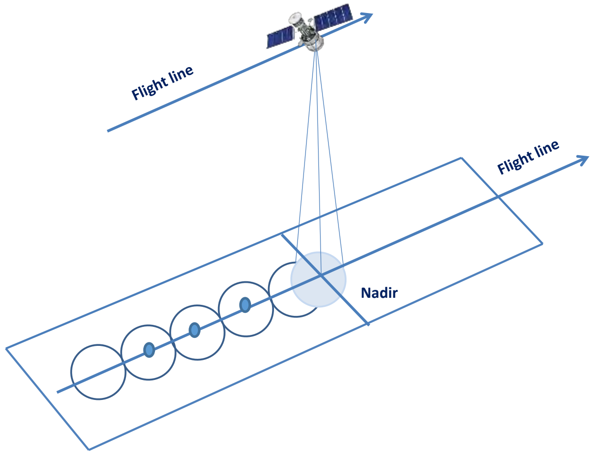
Base-line design



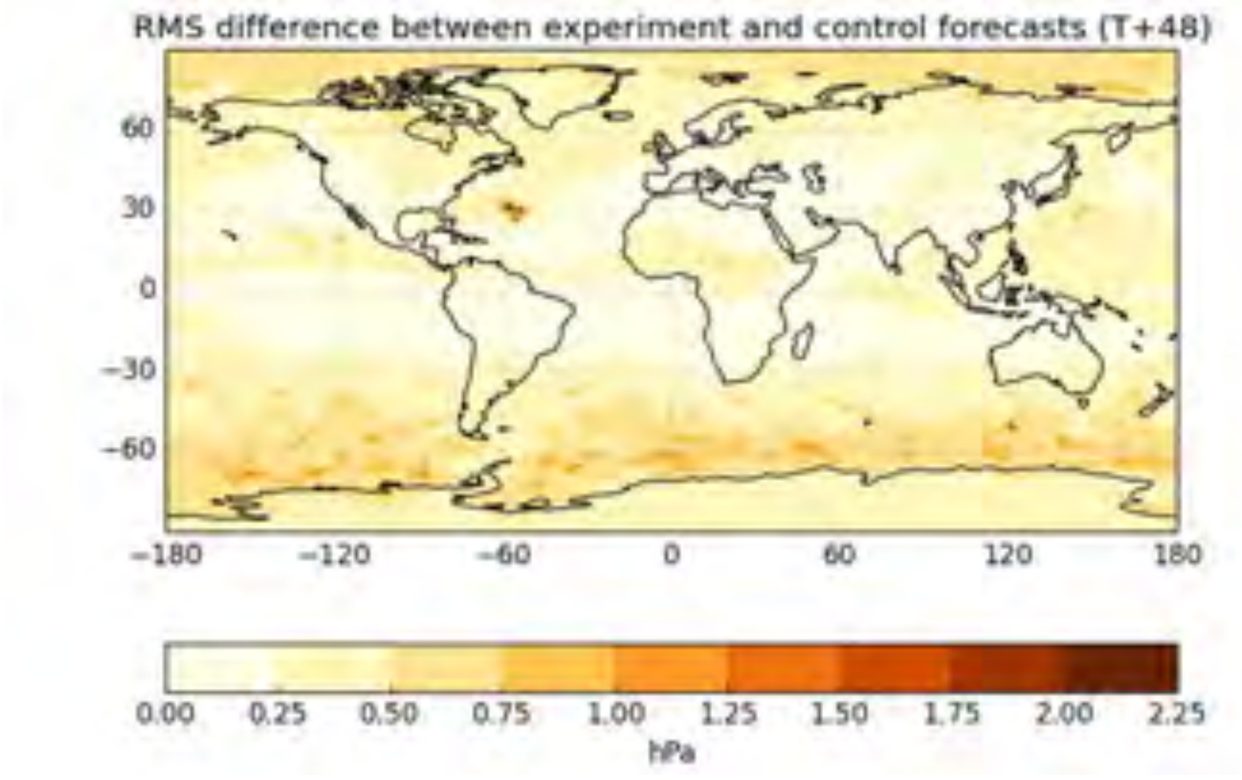
Parameter	Base-line design	Improved design	Unit
Instrument	3 frequency radar	3 frequency radar	
TX power	5	5	W
Antenna diameter	0.5	0.5	m
Altitude	500	500	km
Pulse width	10	10	µs
Bandwidth	100	100	kHz
Spatial resolution	4 (swath) x 8 (along)	4 (swath) x 4 (along)	km
Repeat Rate	12 to 24	12 to 24	hr
Statistical accuracy for 1σ	0.33	0.05	%
Statistical accuracy per channel	±1.65	±0.28	hPa

Improved design

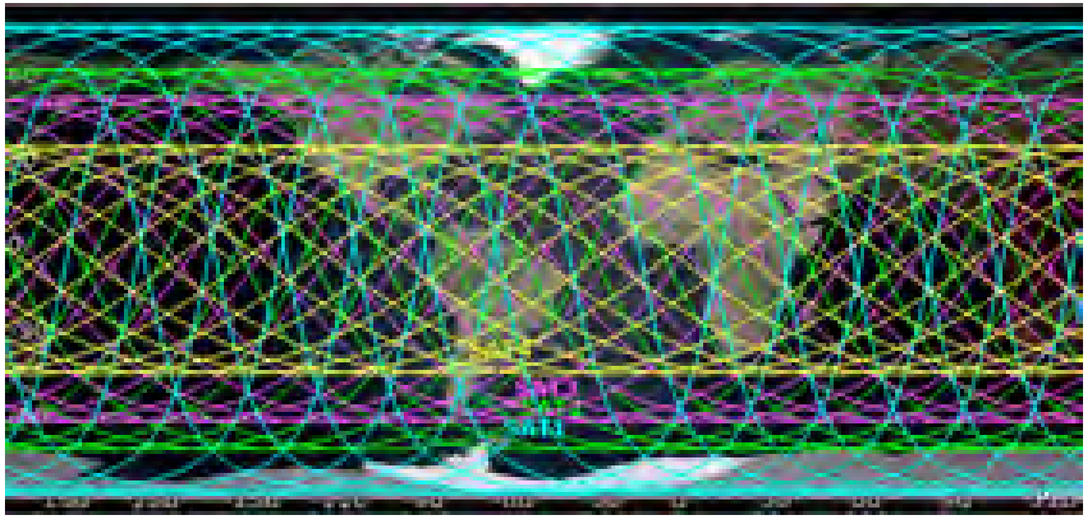




Mission impact



Root mean square difference between surface pressure forecasts (units hPa) from the no marine pressure experiment compared to a control run. Forecast lead time is 48 hours. [Credit: Met Office]



Satellite	Orbit Altitude (km)	Orbit Inclination (degree)	RAAN (degree)
Satellite 1	500 km	97.4065	0
Satellite 2	500 km	113	11.5
Satellite 3	500 km	123	19.5
Satellite 4	500 km	140	14

- The **polar regions** proved to be the most sensitive to including pressure observation.
- This has influenced the orbit design to **include high latitudes orbits.**

Summary and future roadmap

- There is a gap in pressure data globally.
- **BARODAR** mission will provide global, consistence and regular observation for surface air-pressure.
- Dramatically improve weather and climate prediction to save lives and infrastructure.
- **Future roadmap**:
  - Complete and test radar bench model. Funded until October 2021.
  - Seeking **partners** and **funding** for
    - Air-borne model, recommended by ESA
    - In-orbit demonstrator, recommended by ESA

FAAM: Facility for Airborne Atmospheric measurements

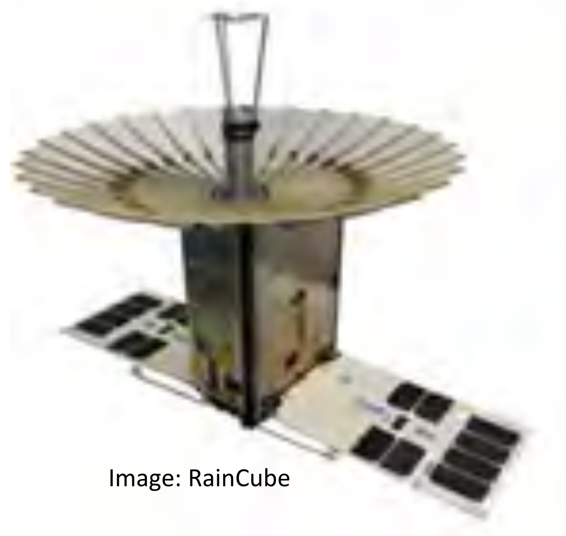


Image: RainCube

BARODAR

Thank you

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