Technology Market Case Study No. 11

GRaCE: G-band Radar for Cloud Evaluation

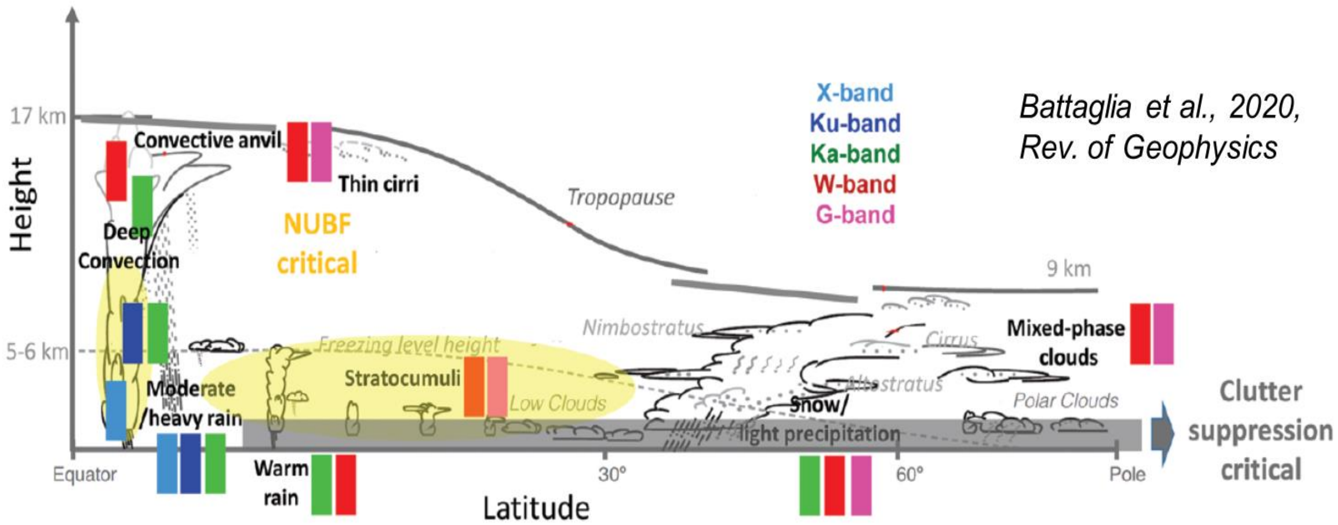
The Challenge

Measuring hydrometeors (rain, snow, hail, etc.) from space is essential for environmental science as ground estimates don't provide adequate temporal and spatial coverage. Neither do they provide information on precipitation in 3D, an aspect critical to understanding the thermodynamics of latent heat release in the atmosphere.

But why do we need remote sensing estimates of precipitation when current Numerical Weather Prediction (NWP) models both estimate and forecast the occurrence of hydrometeors?

1. Below basic-scale level, models still struggle to provide accurate estimates of precipitation for hydrological applications. Forecasts are improving fast, but there are still many situations with a low degree of predictability, affecting the overall consistency of estimates.
2. A reference metric is needed to assess model performance.
3. As models are heavily tuned to observed conditions, remote precipitation estimates are required to fine-tune the multitude of empirical parameters embedded in all models.
4. In weather forecasting, including precipitation data in models is known to improve accuracy.
5. Remote estimates of precipitation are necessary to improve our understanding of the physics behind the precipitation processes.

Without observations, microphysics parameterizations of hydrometeors cannot be improved. Detailed observations in 4D (3D plus time) are critical for deriving parameters from first principles, a must in order not to tie those parameters to specific atmospheric conditions.



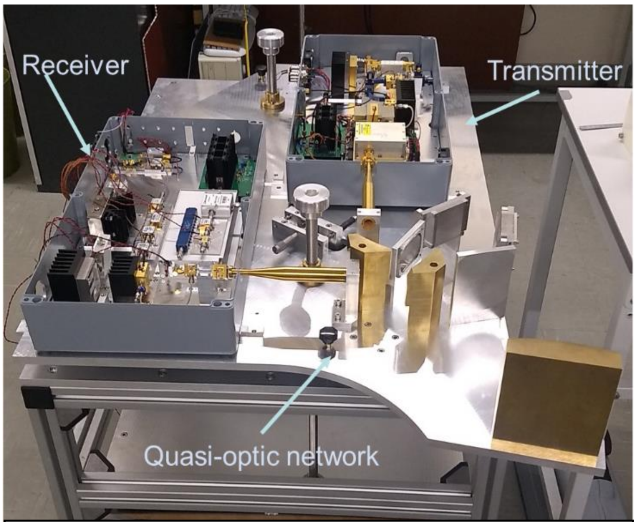
A combination of multi-frequency (Doppler) radars with frequencies ranging from 10 to above 200 GHz allows characterizing from heavy precipitation particles to small-size ice crystals. Inclusion of G-band is highly beneficial in three areas: boundary layer clouds, cirrus and mid-level ice clouds and precipitating snow.

There are three frequency bands commonly used for weather radars. S-band (2700–2900 MHz) is deployed mostly in tropical and temperate climate areas, e.g. in areas where hurricanes, tornadoes, large hail and monsoon or heavy rain are common. C-band (mainly 5600-5650 MHz), is used in climates where attenuation (weakening of radar return signal) by intervening heavy rain or large hail is a very minor issue. X-band (9300-9500 MHz) is used mainly in shorter-range hydrological and meteorological applications such as urban and mountain valley hydrology.

Improvements in data resolution, sensitivity and accuracy require significantly higher radar frequencies (shorter wavelengths) which in turn require new technologies to deliver.

The Solution

The short wavelength of a 200 GHz space radar provides enhanced global information on the distribution of small droplets in the atmosphere. When operated in tandem with existing lower frequency space radars, the dual wavelength observations will enable atmospheric scientists to better characterize the microphysical properties of hydrometeors in water and ice clouds.



200 GHz Hardware Prototype.
Courtesy: STFC RAL Space

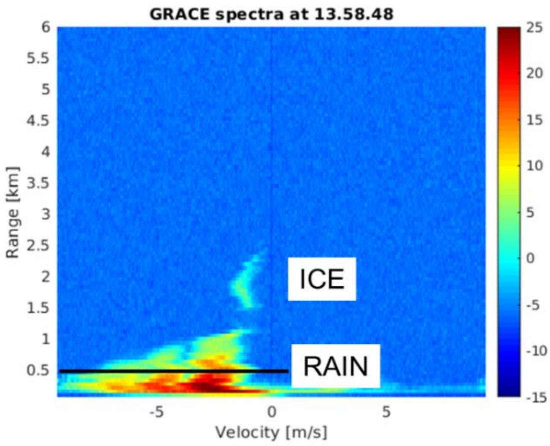
The project has developed a ground based science and technology demonstrator which has three key subsystems.

A *quasi-optic network* allows the transmitter and receiver to share a common antenna. Corrugated feedhorns are used with a measured single pass insertion loss at 200 GHz of ≈ 0.35 dB, and a network insertion loss at 200 GHz of ≈ 1.2 dB. The reflective polarisation rotation gives Tx to Rx isolation > 60 dB, and prevents a high power transmitter destroying the receiver.

The *high power solid state transmitter* uses a 100 GHz QuinStar power amplifier and teratech frequency doubler to generate pulse lengths 10 ns to 300 ns via fast pin switch at 33 GHz. The range resolution is 3 m to 100 m and peak transmitted power is 80 mW.

A state of the art *sensitive super-heterodyne I & Q receiver* utilises a 200 GHz subharmonic mixer from MetOp-SG instrumentation with a conversion loss ≈ 6 dB and noise temperature ≤ 600 K.

The hardware is now completed and the instrument has been deployed at the Chilbolton Observatory. First 200 GHz atmospheric returns have been obtained, and comparison with a co-located kW pulsed radar allows a sensitivity estimation of 0 dBz at 4 km altitude. The first-ever 200 GHz Doppler spectra has been extracted through processing of IQ data.



First-ever rain Doppler spectra at G-band
Courtesy: STFC RAL Space

Support from CEOI

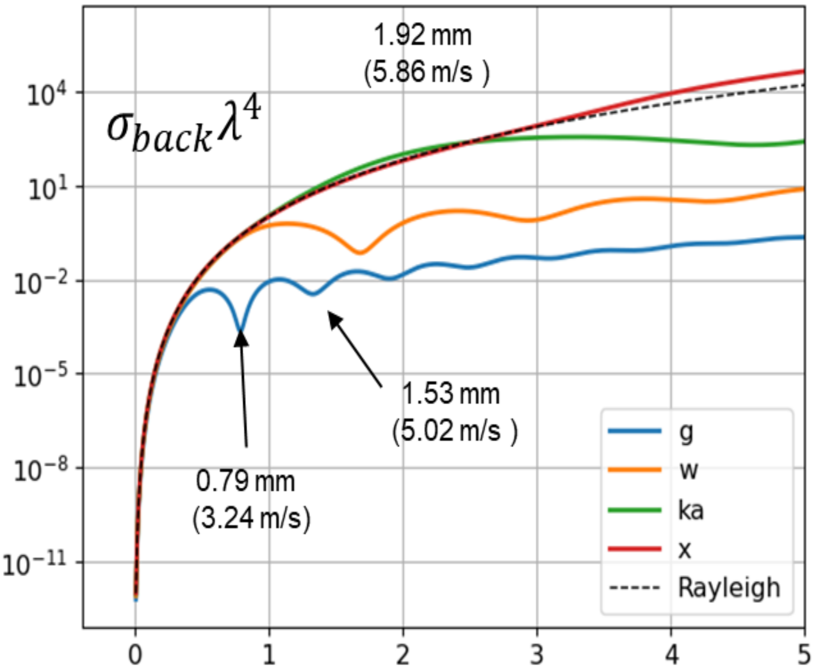
CEOI provided funding to a consortium of STFC RAL Space (project lead), Thomas Keating Ltd., and the Universities of Leicester and St Andrews, through the CEOI 11th Call to build and demonstrate a prototype instrument. The target technology readiness level was TRL 5/6 and the advances will put UK in a strong position to bid for future flight and terrestrial missions.

Relation to previous CEOI projects

Previous CEOI funding of the University of Leicester and RAL Space partners, under the POLYDOROS and HIDRA4PPM grants, has contributed to the technical and scientific foundations for the 200 GHz radar.

Wider Deployment

Due to the small wavelength, radar sensors at 200 GHz and above produce resolutions which could previously only be achieved with laser measuring systems. The 200-GHz frequency band is particularly attractive as it offers range measurements with micrometre precision and a well-focused beam. It also offers imaging radar scanners which produce images with millimetre spatial resolution through SAR processing or real aperture scanning (in reflection or transmission).



First-ever rain Doppler spectra at G-band
Courtesy: STFC RAL Space

This opens up completely new applications for millimetre wave technology. These convincing characteristics and the potential of these frequency bands do, however, involve very sophisticated high frequency techniques and, hence, very expensive sensors.

Measuring precipitation from space is also fundamental for activities such as hydropower planning, dam operations, freshwater availability management, agriculture, forestry, and natural resources management.

The Future

Further development work on the system is underway funded by a follow-on GRACES NERC grant, with Universities of Reading and Leicester. Strong export possibilities/contract are under negotiation for spacecraft demonstrator in Shanghai, China, and ESA is now funding the University of Leicester to undertake a study for deploying a G-band radar in space.

CEOI

Centre for Earth Observation Instrumentation (CEOI) works with UK academia and industry. Its objective is to develop a world leading, internationally competitive, UK Earth Observation (EO) instrument and technology R&D capability, enhanced through teaming of scientists & industrialists. CEOI is funded by the UK Space Agency with parallel technology investment from industry.

Further information on this & other technologies funded by CEOI can be found at ceoi.ac.uk, or contact: CEOI Director, Chris Brownsword: Tel: +44 (0)7825762527, email cbrownsword@QinetiQ.com.