New submillimetre airborne instrument for cloud measurements

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Introduction

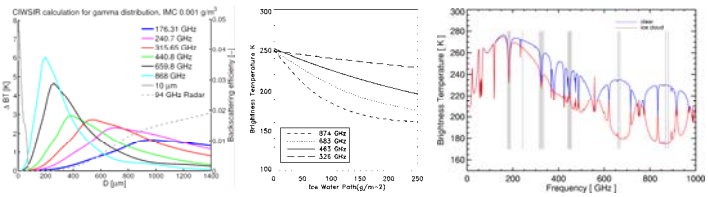
Sub-millimetre wavelength measurements can give additional information for the retrieval of cirrus ice cloud properties and provide alternative channels to the traditional microwave precipitation observations.

An ESA study is underway to develop an airborne instrument which will demonstrate these principles for future satellite missions. This work follows on from recommendations made following the unfunded CIWSIR and GOMAS satellite proposals. Here, we highlight the airborne instrument concepts.

Cirrus properties in climate models

- 20% of Earth is covered by cirrus
- Large impact on global radiative budget
- Effect dependent on optical properties of the ice particles
- Currently large uncertainties in GCMs (Global Climate Models), e.g. IWP (Ice Water Path)
- Current measurements limited:
  - Infrared and visible — sensitive to thin cirrus and particle diameter < ~50µm
  - Microwave (< 190 GHz) — sensitive only to large ice particles (> ~200 µm)
- Millimetre and sub-millimetre can fill the gap and provide information on the intermediate ice cloud types and crystal habits.

Sub-millimetre sensitivity to cirrus

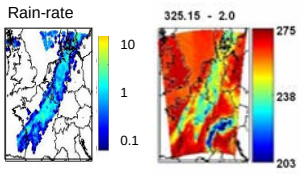


Frequency dependence of Brightness Temperature depression (ΔBT) and brightness temperature as a function of ice particle size (D) and ice water path.

(Buehler et al, QJRMS, 2007)

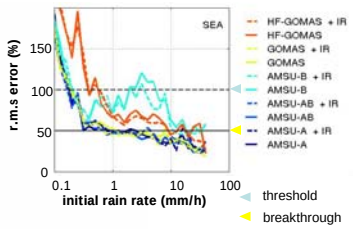
Example of the variability in brightness temperature between clear sky and ice cloud. Large differences are seen particularly in the high frequency "window" regions.

Precipitation retrieval capability



Example of simulation: rain-rate, as provided by the cloud model and brightness temperatures computed from the hydrometeor profiles at 325GHz.

(Defer et al, JGR, 2008)



Performance of the rain-rate retrieval schemes for different frequency sets, with or without infrared channel, quantified by r.m.s errors (in %) as function of the rain-rate.

Now-casting of extreme weather events

- Microwave measurements have direct relation with precipitation
- Currently only available on low-orbit satellites
  - Temporal sampling of the same area is limited
- Geostationary satellites offer quasi-continuous cover of large areas
  - For adequate spatial resolutions antenna is large
  - (e.g. 80 km resolution at 54GHz requires 3 m antenna)
- Possible solution: observe at higher frequencies (requiring smaller antenna)

Potential aircraft platforms

- Medium to high altitude airborne platform
  - Observations from above the cloud
- Large payload capacity
- Range of auxiliary instruments
  - Validation of sub-mm retrievals

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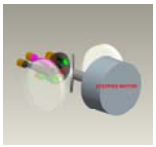
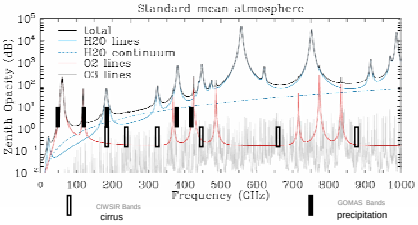
Potential instrument concept

Instrument schematic



Feedhorns directly illuminate heterodyne detectors removing the requirement for lossy quasi-optics. Pointing optics will select the atmospheric view angle and provide a means of onboard calibration by viewing two blackbodies at different but known temperatures.

Frequencies of maximum channel selection



Potential channels

Channel centre	Feature	Dual polarisation
50 GHz	O_2	
118.7 GHz	O_2	
183.3 GHz	H_2O	
243.2 GHz	window	yes
325.2 GHz	H_2O	
340.0 GHz	window	yes
380.2 GHz	H_2O	
424.8 GHz	O_2	
448.0 GHz	H_2O	
664.0 GHz	window	yes
874.4 GHz	window	yes

The final selection of channels and polarisations will be optimised for the demonstrator concept. However, a fuller complement of channels for subsequent scientific use could be realised with additional collaboration and funding.

Current status

- ESA optimisation and design study for demonstrator instrument in progress.
- Potential continuation of ESA funding for instrument build and flight campaigns.
- Opportunities for partners to enhance the instrument for maximum scientific use.

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