Matching scales of observed and simulated cloud and precipitation processes seen in the microwave spectrum

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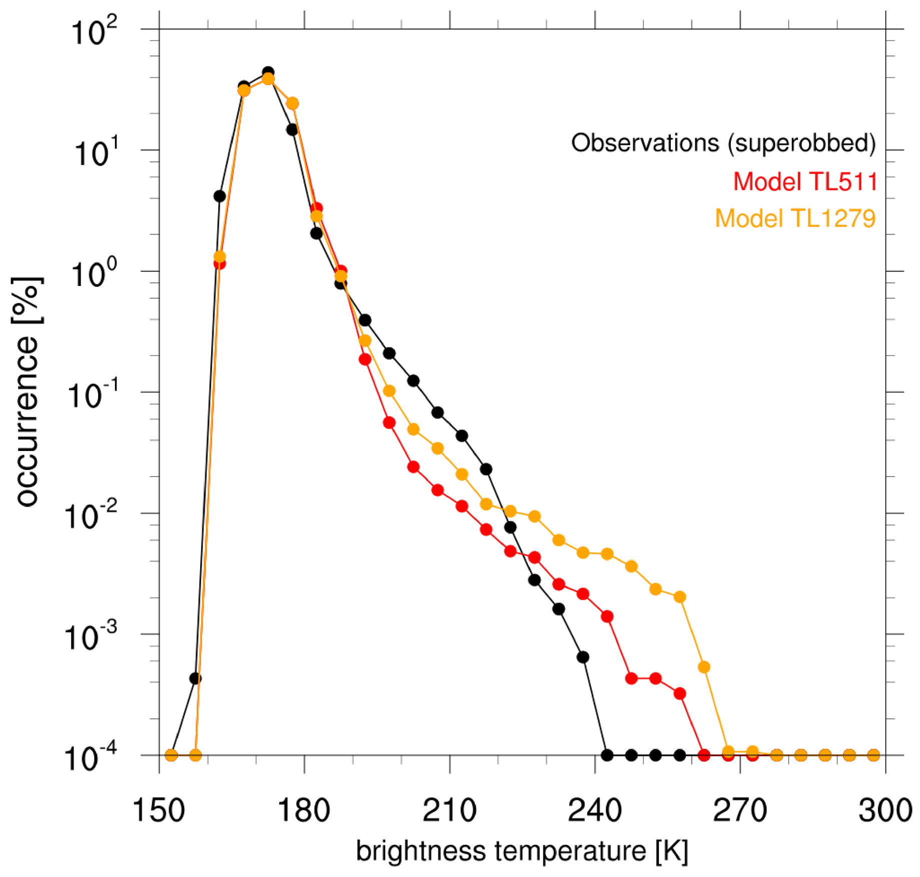
Motivation

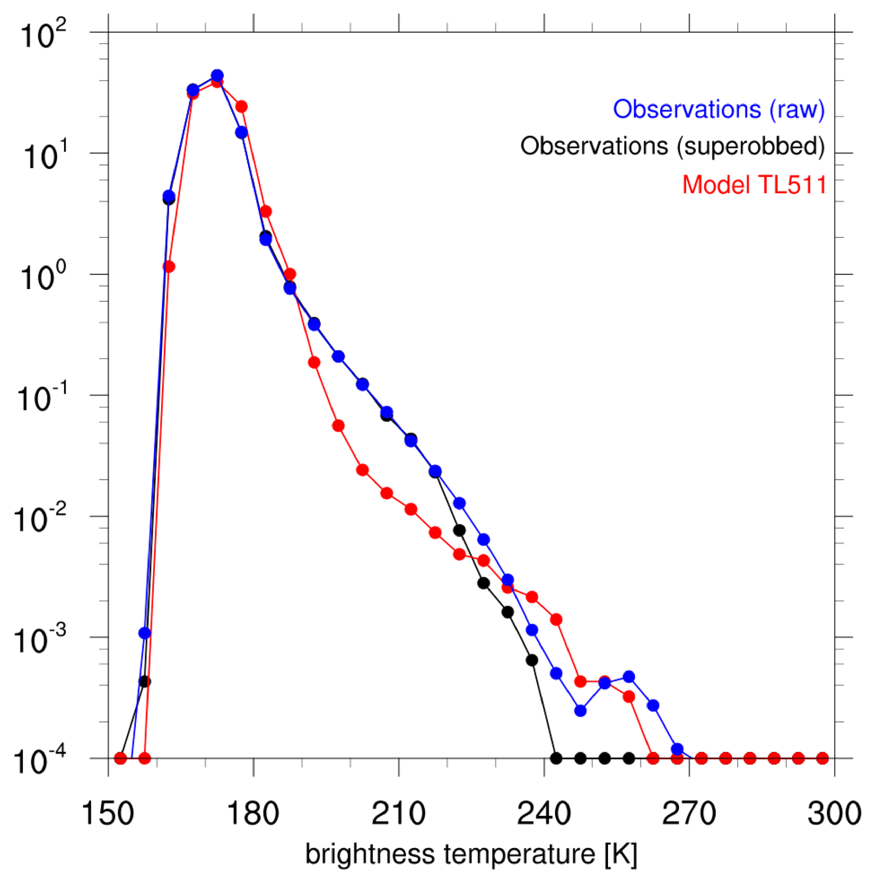
At the ECMWF microwave radiances over ocean are assimilated under clear-sky, cloudy and rainy conditions (all-sky). In order to assimilate the captured cloud- and precipitation systems in the most optimal way it is important to keep the observation error as small as possible. One element of the observation error is the representativeness error, which tells us among other things how well the simulated and observed scales agree with each other. If simulated and observed scales do not agree well a larger representativeness error will be caused and, hence, contributes to a less optimal assimilation of those observations.

How well are cloud and precipitation processes resolved?

Model: The current operational IFS model has a TCo1279 resolution, which translates into about 9 km horizontal resolution. That means cloud and precipitation process are effectively resolved by about 25 km.

Observations: In the IFS all microwave radiances are superobbed over an area with a radius of about 60 km.



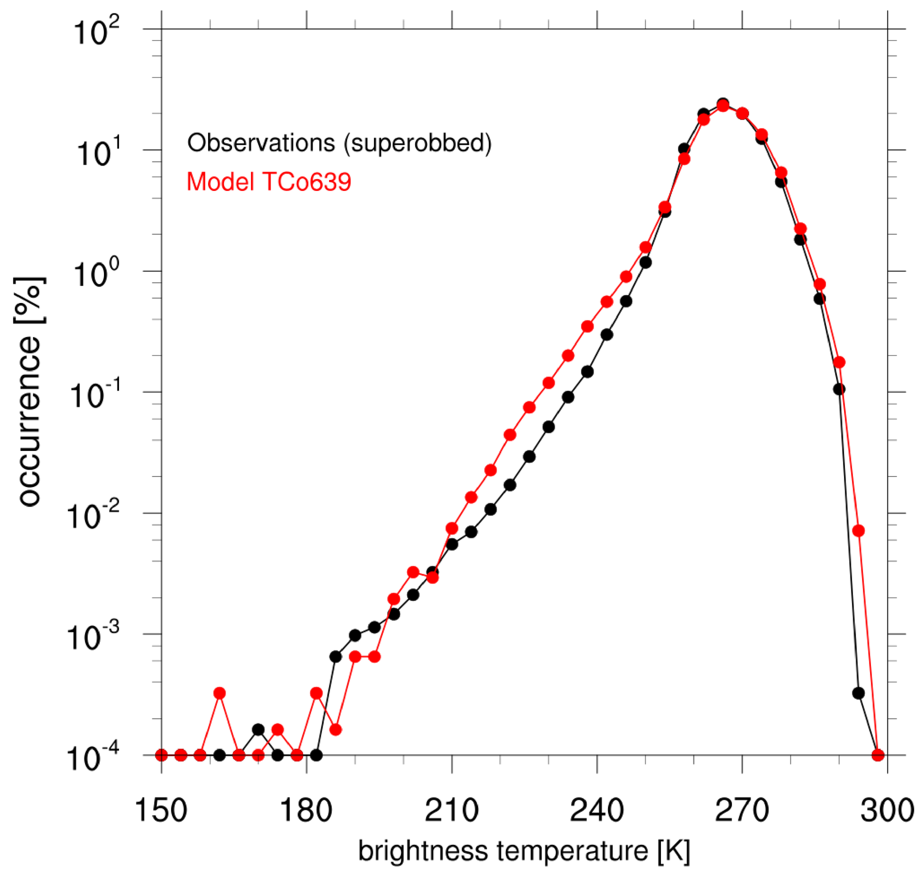


Left Fig.: Histogram of over-ocean brightness temperatures from TMI 10 GHz vertically polarised channel covering August 2013.

It can be seen that a higher simulated or "observed" resolution allows to capture more convective systems (having high brightness temperatures).

Right Fig.: Histogram of over-ocean brightness temperatures from GMI 183 +/- 7 GHz for high latitudes covering August 2016.

Gap between observed and simulated brightness temperatures between 210 K and 250 K in higher latitudes.



Why is superobbing necessary in the first place?

The resolution of microwave radiance observations depends on their frequency, with low frequencies having a large footprint and high frequencies having a small footprint. **A clever superobbing strategy matches these different resolutions to one scale which is "resolved" by the model.**

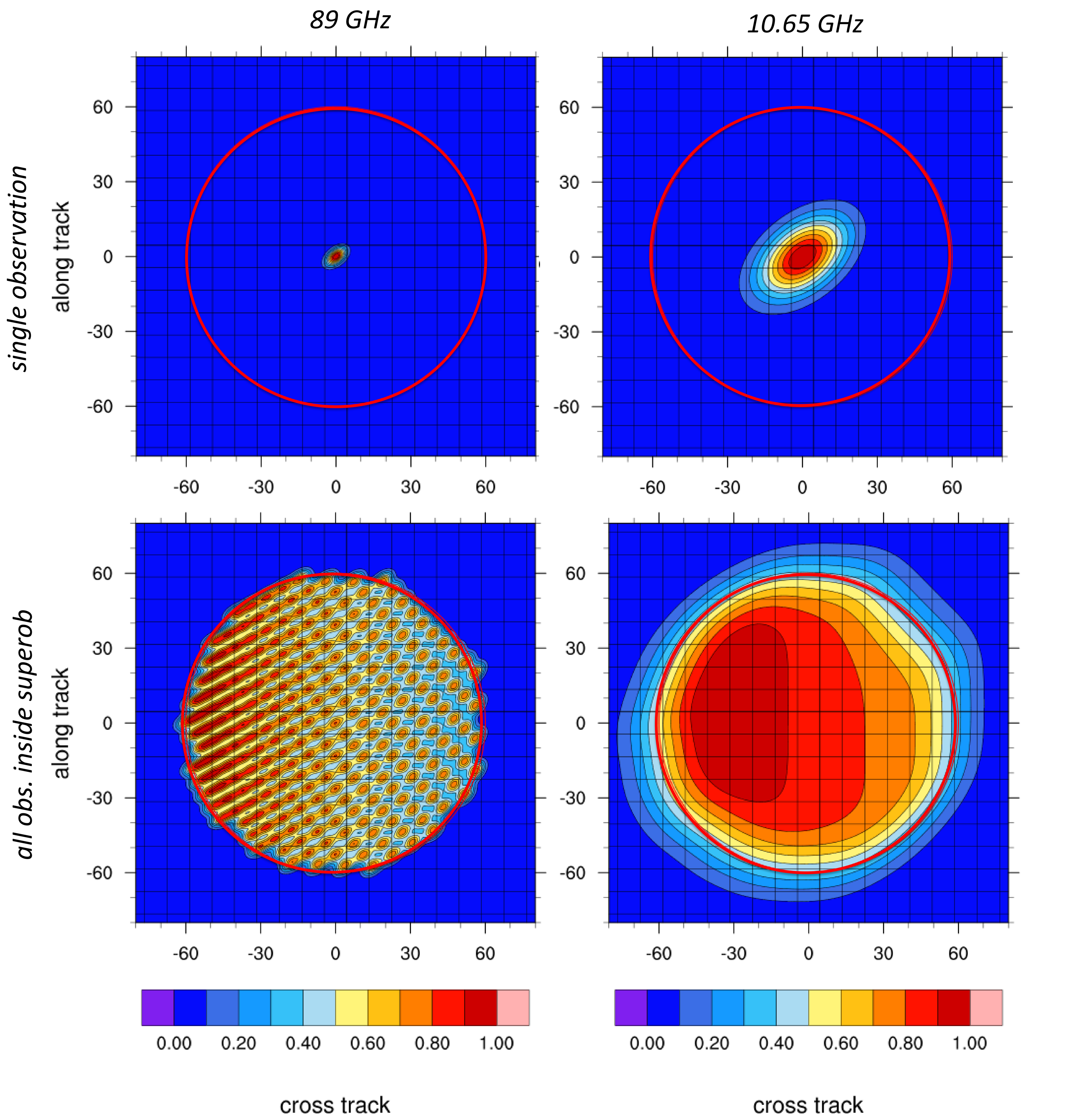


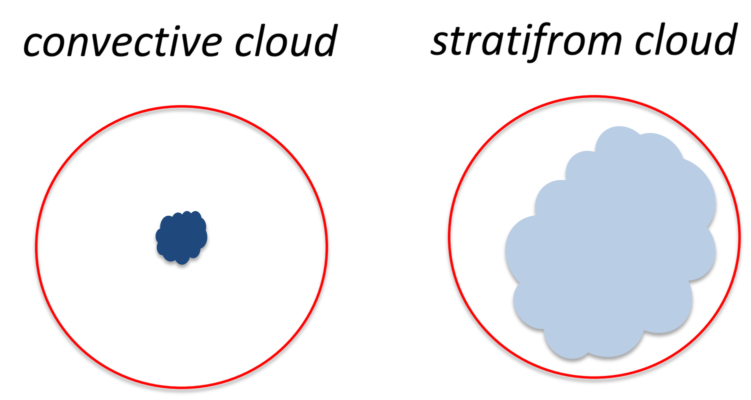
Fig.: Theoretical response function for a single GMI observation **(top)** and all GMI observations inside a superob (red circle) of r = 60 km **(bottom)** at 89 GHz **(left)** and at 10.65 GHz **(right)** with a overlaid model grid of 9 km x 9 km. At 89 GHz the FOV is 7.2 km x 4.4 km and at 10.65 GHz the FOV is 32.1 km x 19.4 km (cross-scan x along scan) [Petty and Bennartz, 2017]

More than just model resolution...

As discussed, model resolution is essential for the resolved cloud and precipitation processes. Nevertheless, the details of how these processes are represented by the observation operator in brightness temperature space is also very important. Taking into account subgrid variability of hydrometeors is necessary due to the nonlinearity of radiative transfer in cloudy and precipitating conditions.

Beamfilling effect [e.g. Kummerow 1998]

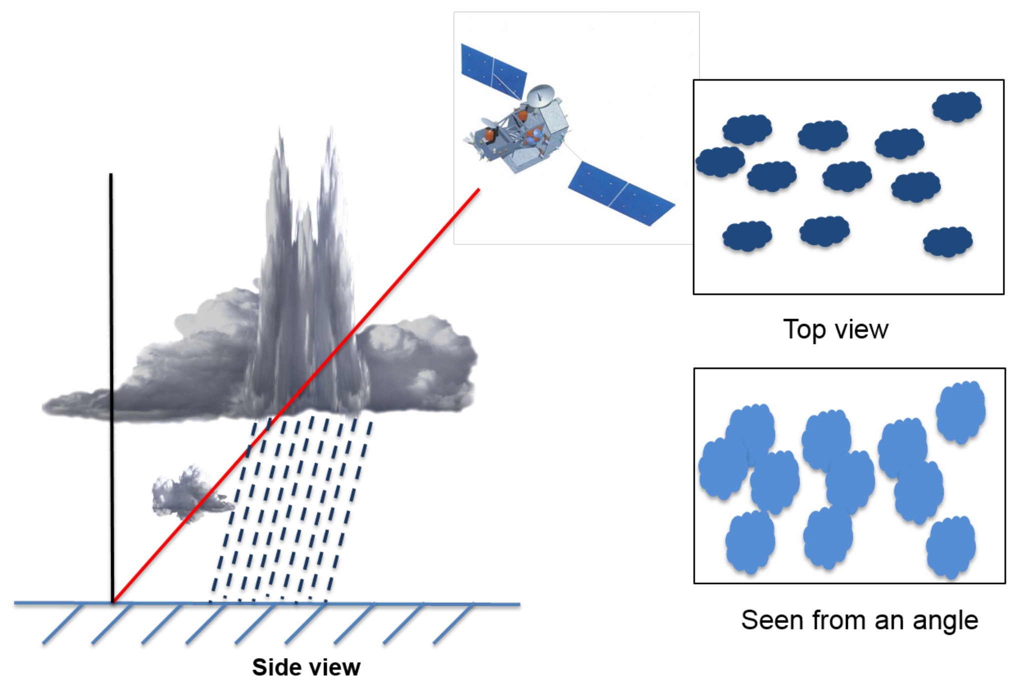
Schematic: This example shows how the same cloud liquid water is distributed differently within superob (red circle). **The convective cloud case would give a lower brightness temperature than the stratiform cloud case**.



Projection effect

Schematic: Side view shows the profile which is used (black) and which should be used (red) in the observation operator. This leads to differences in how much cloud can be seen (right panel).

The projection effect can induce differences of 10 to 20 K in brightness temperatures [Bauer et al, 1998; Bennartz and Greenwald, 2011]



Ongoing work at ECMWF

- Take into account FOV for microwave radiances if available
- Reducing **superob** size to match simulated scales better
- **Beamfilling and projection effect:** Working on a reliable estimation of subgrid-cloud and precipitation fraction from forecast model by using a cloud generator to fill a number of vertical sub-columns, and then to trace slanted independent columns through these [e.g Bauer et al., 1998]

Petty and Bennartz, 2017: "Field-of-view characteristics and resolution matching for the Global Precipitation Measurement (GPM) Microwave Imager (GMI)", AMT (10), p745–758.
Kummerow, 1998: "Beamfilling Errors in Passive Microwave Rainfall Retrievals", Journal of Applied Meteorology (37), p356 -370.
Bauer et al, 1998: "Correction of three-dimensional effects for passive microwave remote sensing of convective clouds", Journal of Applied Meteorology (37), p1619–1632.
Bennartz and Greenwald, 2011: "Current problems in scattering radiative transfer modelling for data assimilation", QJRMS.(137), p1952–1962.