Do clouds cause backgrounds in near-horizon radio neutrino experiments?

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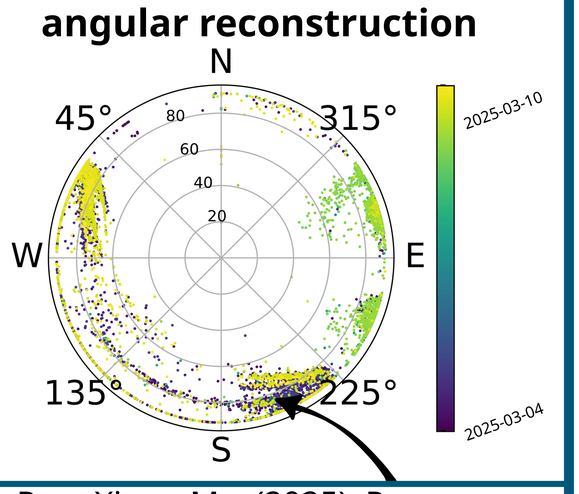
Background mitigation is vital for neutrino hunting

The radio background at radio telescopes presents plenty of transient signals near the horizon. These signals, which cause interference, are difficult to reconstruct but beg for identification.

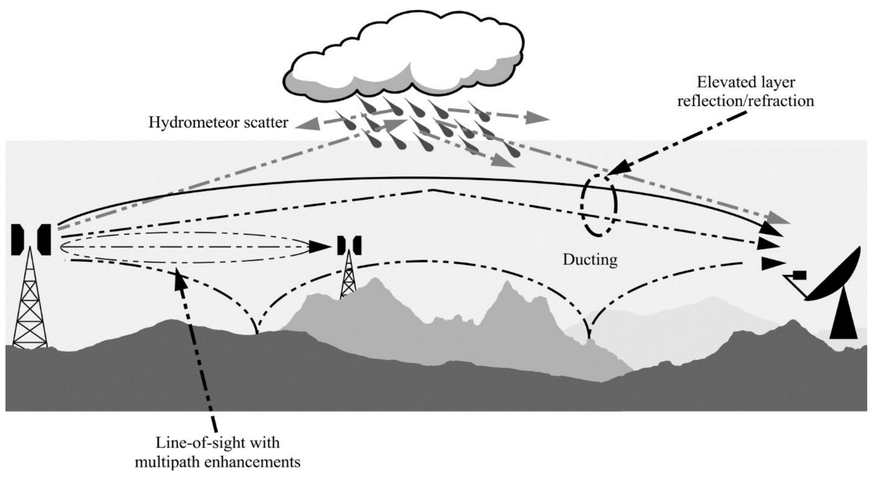
Our hypothesis is that these signals are caused by low-altitude clouds that produce sporadic radio reflections.

GRANDProto300 angular reconstruction



PengXiong Ma. (2025). Progress of the GRANDProto300 Project.

Long-range, transient propagation mechanisms



International Telecommunication Union (ITU) P.452-02.

In this work hydrometeors such as raindrops, snowflakes, ice grains etc., are modeled to investigate how radio signals are affected by surrounding weather conditions.

The radar technique

Normally used to indentify targets, radars transmit electromagnetic waves and aim to interpret the echoed signal. The strength of that echo is captured by the Radar Cross Section.

The **power received** from a volume containing rain is found via the bistatic radar equation[3]:

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma_{RCS}(\theta, \phi)}{64\pi^3 R_{\mathrm{TX}}^2 R_{\mathrm{RX}}^2}$$

where:
- P_tG_t = effective isotropic transmitted power,
- R_{TX} and R_{RX} = distances of transmitter and receiver from target.

3. Barclay, L. (2003). Propagation of Radio Waves.

Radar modeling: MARES

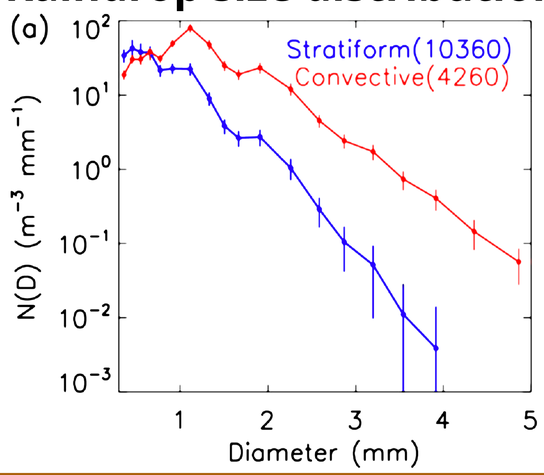
Macroscopic Approximation to the Radar Echo Scatter (MARES)[4] is a modeling software aimed to describe the radar scattering problem, applied here to collections of hydrometeors. The **bistatic angle θ** is the angle between the incoming wave from the transmitter and the scattered wave towards the receiver.

4. Huesca, Santiago, E. (2024). Understanding RADAR echoes from high-energy particle cascades. [PhD thesis]

Hydrometeor scattering theory

We assume a volume of identical spherical water droplets, with size equal to the measured average mass-weighted diameter (~1 mm). Hydrometeor scattering for λ~1 m operates in the radar Rayleigh regime, which accounts for small targets D‹‹λ.

Raindrop size distribution

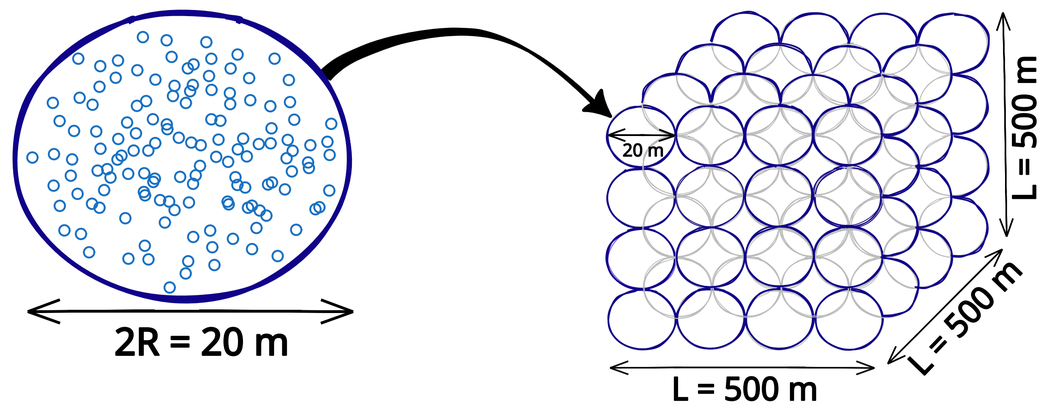


Abin, T. (2021). Characterization of raindrop size distributions and its response to cloud microphysical properties.

To cope with the large amount of water droplets in a cloud, the simulation is split in two steps:

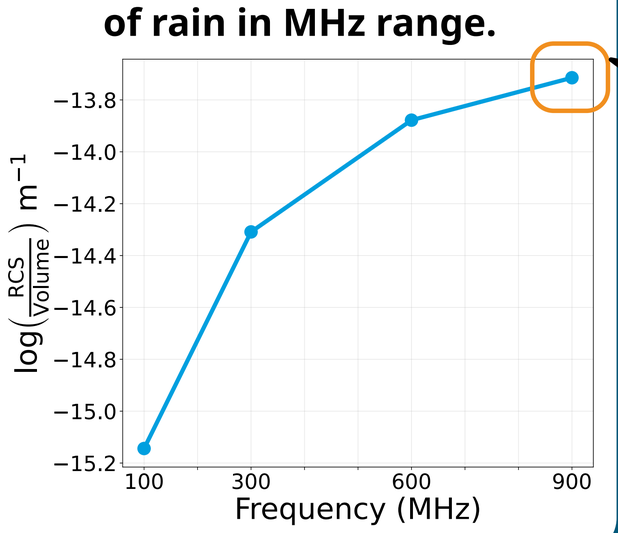
1) simulation of one small volume of raindrops,

2) simulation of a cloud as a collection of small volumes.



Results

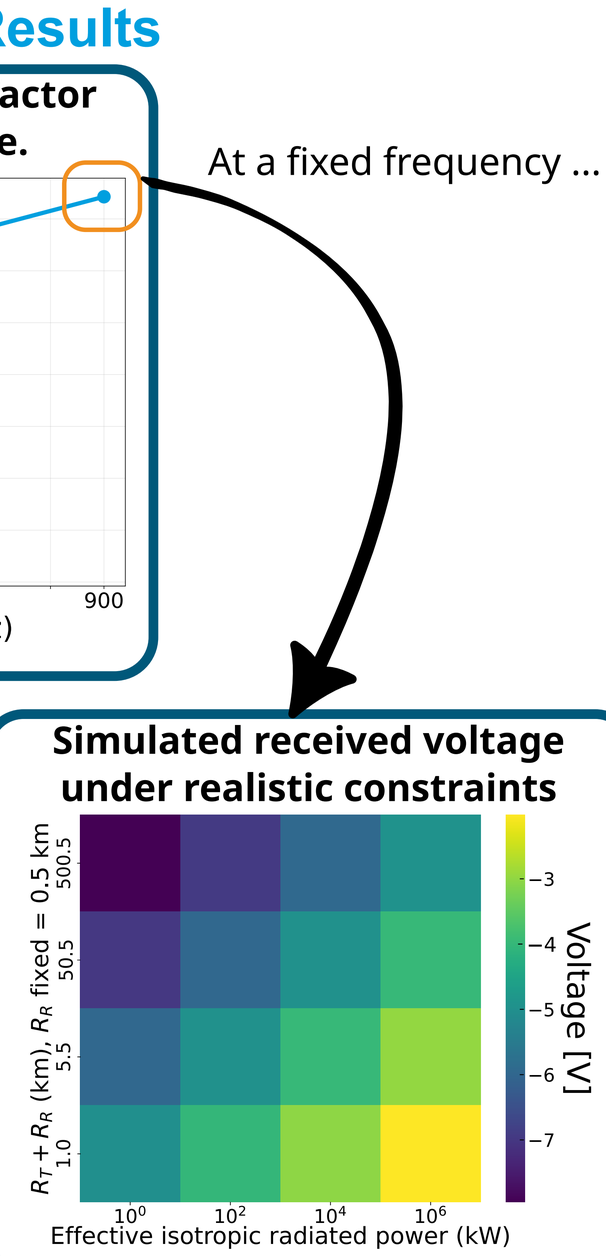
Simulated reflectivity factor of rain in MHz range.



At a fixed frequency ...

... the received voltage is a function of :
- geometry:
  scattering angle θ = 7°,
  polarization angle Φ = 90°,
- effective size = 500 m^3,
- gain $G_r = 10^6$,
- load resistance R = 50 Ω,
- transmitted power,
- distances R_{TX} and R_{RX}.

Simulated received voltage under realistic constraints



Conclusions: Clouds are possible sources of radio backgrounds, but further research is needed. For in-depth analysis, read: Cantarini, G. (2025). Modeling the reflection of radio signals from atmospheric clouds as a near-horizon background for astroparticle observatories. [Master thesis]

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