Turbulence intensity retrieval in precipitation via optimal estimation using polarimetric radar

Delft University of Technology

Objectives
- Develop a radar forward model, where as a function of turbulence intensity, a parametric or stochastic solution can be chosen.
- Develop a generalized methodology to retrieve the turbulence intensity from polarimetric radar data.

Introduction

The polarimetric profiling radar at a slant elevation angle is a promising sensor for remote-sensing of particle characteristics (Bringi and Chandrasekar, 2004).

For an accurate turbulence intensity retrieval in rain, often the drop size distribution is crucial.

Optimal estimation

• We estimate the effect of droplet inertia on the radar measurements by solving the equations of motion for an ensemble of droplets for a backcast trajectory.
• We use 3D stochastic turbulence from Maim (1998).
• The inertial velocity term $\vec{v}_I$ is assumed to be small in comparison to the total particle velocity.
• The particle velocity is written as $\vec{v}_p = \vec{v}_I + \vec{v}_d + \vec{v}_z$, where $\vec{v}_I$ is the terminal fall velocity and $\vec{v}_d$ the air velocity. The solution is found by solving the equations of motion for a small trajectory, e.g. for the $z$-direction:

$$ \frac{d}{dt} v_{z,p} = F_{z,p} = \frac{d}{dt} v_{z,I} + \frac{d}{dt} v_{z,d} = \frac{d}{dt} \left( \frac{2}{3} \rho \Omega^2 r \right) + \frac{d}{dt} \left( \frac{2}{3} \rho \Omega^2 r \right) + \frac{d}{dt} \left( \frac{2}{3} \rho \Omega^2 r \right).
$$

Forward model

An ensemble of particles is used to cover a spatial distribution, matching the radar resolution volume and a size distribution.

• Cross sections from Mishchenko (2000) and terminal fall velocities from Khrustovalov and Curry (2005) are used.
• The particle symmetry axis is oriented parallel to the particle motion.
• Turbulence is modelled as an ensemble of isotropic vectors, with the standard deviation of radial speed from White et al. (1999).

Relevance of the DSD on turbulence intensity retrievals. In this schematic $\sigma_v$, the Doppler spectral width or the velocity standard deviation, is the measurement. The contributors to this measurement are antenna motion $\sigma_d$, hydrometeor fall speeds $\sigma_v$, hydrometeor orientations and vibrations $\sigma_I$ and turbulence $\sigma_T$, where $\sigma_I$ is the hydrometeor inertia correction. Note that the turbulence contribution scales with the spatial scale $\sigma \propto L^{1/2}$.

Measurments vs. forward model

• A novel forward model is proposed for retrievals of turbulence intensity profiles, which takes the orientations of particles into account.
• The inertia effect increases the Doppler spectral width.
• Error estimation of the posterior size distribution will improve the interpretation of radar measurements.

Additional Information

Download The model Zephyros, a package for radar simulations and retrievals of wind and turbulence, under development, is written in C with interfaces to Python and Matlab and can be downloaded from:

https://github.com/albertoudenijhuis/zephyros0.4

References

1. V.I. Khvorostyanov and J.A. Curry. Fall velocities of hydrometeors in the atmosphere: Refinements to a continuous analytical power law.

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Contact Information

Email: albertoudenijhuis@gmail.com