Validation of Electromagnetic Wind Radar Simulator Based on LES with Scanning X-band Radar Measurements and Meteorological Data

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Context and Results

Context:
An electromagnetic radar simulator was developed by UCL in the framework of FP7 UFO project. Results of the simulation were compared with measurements using a scanning X band radar developed by Thales and meteorological data provided by Meteo France.

The simulator is developed for radar cross section, wind and energy dissipation rate (EDR) retrieval, in clear air and in the presence of rain. It is based on the refractive index calculated from Large Eddy Simulations (LES) of the turbulent atmosphere in the boundary layer. The refractive index is then used for the calculation of the radar cross section of the turbulence as well as the power received by the radar and the Doppler spectrum. EDR is estimated from the simulated Doppler spectra.

Radar Simulator

Simulator Geometry Configuration

Input:
A set of LES (simulated by iMMC, UCL) with different stratification levels and energy dissipation rates (EDR) (with or without raindrops). LES introduced as a box with values of parameters at equidistant grid nodes.

Radar Signatures Simulation

Scattering mechanism:
1. Bragg scattering on clear air turbulence (inhomogeneities of the refractive index of the air)
2. Rayleigh/Mie scattering on the raindrops
3. Radar Cross Section (RCS)

Calculation of the radar signatures:
1. I/Q of the scattered signal
2. Doppler spectrum of the scattered signal
3. Radar Cross Section (RCS)

Output parameters estimation:
1. Energy dissipation rate
2. Wind velocity and direction

Radar Measurements vs. Meteorological Data

EDR from X-band Thales Radar Measurements

- In the scanned sector from ~4.5 km to 25 km around Toulouse airport
- 3 elevation angles: 2˚; 3.5˚; 5˚
- 10 days of measurements

EDR from Meteo France Meteorological Data

- Latitude from 43.24˚ to 44.04˚
- Longitude from 0.94˚ to 1.84˚
- Step 0.05˚
- Altitudes from 10 m up to 500 m with a step of 10 m
- Pressure, temperature, humidity, turbulence kinetic energy, EDR, u- and v-wind components

EDR from radar measurements is the estimate of the real EDR

Scatter plot of EDR values retrieved from the simulator against input LES EDR

Assumption that Bragg wavelength belongs to the inertial subrange

Transition from the inertial subrange to dissipative range

Scatter plot of EDR from radar measurements against meteorological EDR

- Statistics of EDR obtained on 30 minutes intervals
- Wind shear contribution estimated and removed from the Doppler spectrum width
- 29/04 – low reflectivity

There is no “ground truth value for EDR”

a. Meteorological data is the output of the Weather Prediction Model (HARMONIE-AROME) model based on meteorological observations assimilation
b. Radar measurements is the estimate of the real EDR