Geophysical Research Abstracts
Vol. 12, EGU2010-5578, 2010
EGU General Assembly 2010

The NASA Dual-Frequency Dual-Polarized Doppler Radar (D3R) System For GPM Ground Validation

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Following on the successful introduction of single-frequency (Ku-Band) weather radar onboard the Tropical Rain Measuring Mission (TRMM) satellite in 1997, the Global Precipitation Measurement (GPM) mission attempts to advance further the goal of making global scale precipitation observations by deploying the next generation of satellite-borne weather radars. The GPM satellite will carry a Ka-Ku band Dual-frequency Precipitation Radar (DPR) that can make measurements of parameters directly related to the microphysics of precipitation (such as raindrop size distribution). The Dual-Frequency Dual-Polarized Doppler Radar (D3R) is a ground validation radar, as a part of the GPM Ground Validation (GV) program, to enable both physical validation support in terms of understanding the microphysical description of the observations as well as algorithm retrieval implications. This paper provides a scientific and technical overview of the D3R system as well as major challenges.

The preferred frequency bands of operation for precipitation surveillance in ground radar systems have been nearly non-attenuating frequencies (such as S-, C-band) or short-range measurements of attenuating frequencies (as in X band). However, it is not practical to use traditional ground radar frequencies for precipitation observations in space-borne radars. The GPM mission has embarked on a dual-frequency approach at Ku- and Ka-band for characterizing precipitation. Moving to higher frequencies to observe precipitation though has its own challenges namely, attenuation due to precipitation and reduced Doppler velocity Nyquist limits. Ground radar measurements enjoy the advantage of coincident microphysical observations available to interpret radar signatures but they are currently unavailable at Ku- and Ka-band. An important broader science goal of the NASA D3R is to enhance the database of dual-frequency radar observations on the ground, in conjunction with existing observations, in order to provide a dataset for physical validation basis. Another major advantage of the ground radar observations is the ability to use dual-polarization techniques to yield enhanced microphysical characterization similar to what has been done at lower frequencies. In addition, self-consistency of dual-polarization and dual-frequency observations presents an enhanced level of interpretation, while also providing independent rainfall estimates on the ground. With the ground-based D3R, an independent estimation of hydrometeor classification and drop size distribution retrievals can be done to understand the error structure of retrievals.

The dual-frequency ground-based radar provides for various options, including polarimetry and Doppler capabilities. Hence, the name D3R or Dual-frequency Dual-polarized Doppler Radar. Another important engineering aspect of a dual-frequency system is the level of "integration". This can range from a design where two separate radar units operate independently to the one that employs a common reference system for dual-transmitters on a single dual-frequency aperture. The first generation version of the D3R falls somewhere in the middle, i.e., a common platform transmitter illuminating two distinct but aligned antennas. Most of the engineering challenges stem from making precipitation measurements on the ground at a highly attenuating frequency. In order to support the development, extensive numerical evaluations have been carried out to document the extinction statistics of propagation through precipitation. One of the novel aspects of this system is that it employs a solid-state transceiver which supports the deployment in different climactic locations. Thirdly, the dual-frequency dual-polarization operation at higher frequencies involves non-Rayleigh scattering mechanisms and presents different precipitation signatures compared to the conventional S- or C- band observations. The expected observations for this radar based on such scattering and precipitation models are also presented in this paper.