Rainfall Measurements from the TerraSAR-X Satellite

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Introduction

“Global non-hydrostatic numerical weather prediction (NWP) models coupled with ocean and land models are essential as the spatial resolution of models continues to increase, especially with grid spacing less than 10 km. High-resolution non-hydrostatic models (with grid spacing around 2 km) remove the dependence of the model on convective parameterizations, which has been a major barrier for progress in weather forecasting... Observations remain inadequate to optimally run and evaluate most high-resolution models and determine forecast skills at various temporal and spatial scales.” [1]

This need can be met for rainfall measurements by the use of data from the Synthetic Aperture Radar (SAR) as these provided by the TerraSAR-X that is operated by the German Space Agency, DLR. [2]

Rainfall retrieval method

The Normalized Radar Cross Section (NRCS) of rain is the term of a term that represents the attenuated scattering from the surface, 
\[ \sigma_0 = \sigma_v + \text{volumetric scattering term} \]

\[ \sigma_v = \int_0^\infty \frac{d^0_r e^{-2z}}{d(z/e)} dz \]

where \( d_0 \) is the volumetric reflectivity and \( e \) is the specific attenuation and \( d^0_r \) is the background surface NRCS

As the scan moves from left to right the NRCS first increases due to scattering by incipient hydrometeors and rain. The NRCS then decreases as the backscattered radiation is attenuated by the rain. That NRCS reduction continues until the radar pulse emerges from the distant side of the rain cloud. The NRCS then rises as the rain attenuation occurs over path lengths until it return pulse no longer passes through the rain cloud, whereupon the NRCS returns to its background value.

Rainfall was previously observed in X-band SAR imagery obtained from STS-X and in 1994, [3]

Sample images

Rain over Land:

As the NRCS increases, the raindrop size increases and the NRCS reaches its maximum at the radar wavelength. This is due to the increase in the effective cross section of the raindrop. The NRCS then decreases as the raindrops become too large to scatter at the radar wavelength. The NRCS then increases as the raindrops become too small to scatter at the radar wavelength. The NRCS then decreases as the raindrops become too small to scatter at the radar wavelength. The NRCS then increases as the raindrops become too small to scatter at the radar wavelength.

Rain over the Sea:

The sea surface NRCS is affected by sea surface waves and wind impact, moreover \( d^0_r \) may be sufficiently small so that \( \sigma_0 = \sigma_v \) and rain may thus brighten the NRCS compared to the background.

Another interesting case arises when the sea surface is completely calm, as was case when the CRP oil spill damped capillary waves so that \( \sigma_0 = \sigma_v \).