Exploitation of X-band space-borne synthetic aperture radar for highly-resolved precipitation retrieval over land within GPM

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Numerous studies, conducted as part of the Tropical Rainfall Measurement Mission (TRMM) program, have demonstrated the benefits of space-borne precipitation measurements. The NASA Global Precipitation Measurement (GPM) mission is an outgrowth of TRMM that will provide improved precipitation measurements and it will extend those measurements to higher latitudes. The forthcoming GPM will seek data from a constellation of satellites to provide measurements of precipitation that expand the coverage provided by the well-instrumented core satellite. The analysis of X-band Synthetic Aperture Radar (SAR) data is aimed to explore the advantage of resources that will already be placed in orbit by European and other space agencies for other purposes. The TerraSAR-X (TSX) will be launched by the Deutsches Zentrum f. Luft u. Raumfahrt (DLR) and the Constellation of Small Satellites for Mediterranean basin Observations (COSMO-SkyMed, CSM) will be launched by the Agenzia Spaziale Italiana (ASI). Both have been launched in June 2007 and both will operate in the X-band. Additional X-band SARs will be launched in the coming decade.

C-band and L-band SARs have a long heritage of Earth observation. Recent studies showed that X-band SARs are more sensitive to rainfall effects than SARs operating at longer wavelengths because the rainfall reflectivity at X-band is enhanced by ~ 12 dB and the attenuation increases by ~ 4 dB compared to C-band reflectivities and attenuation. The main scientific benefit that will accrue from the use of X-band SARs will be the measurement of precipitation over land where microwave radiometers have had limited success. X-band SAR precipitation retrievals will be especially valuable over mountainous terrain where ground based radars are obstructed. The high spatial ($\sim$100m) resolution of those radars will provide new insights into the structure of precipitating clouds.

Beam filling has introduced ambiguities in precipitation estimates derived from microwave radiometry. The spatial resolution of X-band SARs is better than about 100m; much smaller rain cells can thus be observed from space-borne observations. Combin-

ing X-band SAR and microwave radiometric data enables such beam filling problems to be addressed. Unlike the TRMM Precipitation Radar (PR), which provides highly resolved vertical precipitation profiles, TSX and CSM will mainly measure the slant-path integrated scattering and attenuation of precipitation. These satellites will also measure the differentially-polarized phase shift produced by precipitation in the slant path. However unlike microwave radiometers, contrast between rain and land background signals will be sufficient to measure terrestrial rainfall. Marine precipitation has been observed by previous space-borne X-band SARs. Because it appears to be difficult to separate the effects of downbursts, wind roughening and rain impact on the sea surfaces from signals produced by hydrometeors, we have deferred the retrieval of maritime rainfall until we have demonstrated the utility of terrestrial precipitation retrievals.

In this work we illustrate a model-based investigation on the potentials of X-band space-borne SARs to detect and retrieve rainfall over land. In order to show this, a vertically-inhomogeneous horizontally-finite rain cloud model is set up coupled with an electromagnetic surface and volume scattering model. The effect of the slant-view geometry is taken into account in order to deal with possible overlay phenomena. The rain-cloud model is varied to evaluate the sensitivity of the normalized radar cross section (NRCS), measured from satellite SARs, to snowfall and rainfall intensity. Dual-polarized horizontal and vertical absorption and scattering are also considered. The bounded random variation of cloud parameterizations is accomplished to generate a training data set for an inversion algorithm. Both a semi-empirical and statistical retrieval schemes have been formulated and tested in order to give a rough estimate of rainfall accuracy. Mission constraints, derived from nominal specifications of both TSX and CSM, will be discussed and some case studies, obtained from 1994 Shuttle missions, will be also analyzed.