SMAP RADAR PROCESSING AND CALIBRATION

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1. INTRODUCTION

The Soil Moisture Active Passive (SMAP) mission is part of the NASA space-based Earth observation program, and consists of an L-band radar and radiometer scheduled for launch into sun synchronous orbit in late 2014. A joint effort of the Jet Propulsion Laboratory (JPL) and the Goddard Space Flight Center (GSFC), the SMAP mission draws heavily on the design and risk reduction heritage of the Hydrosphere State (Hydros) mission [1], [2]. The SMAP science and applications objectives are to: 1) understand processes that link the terrestrial water, energy and carbon cycles, 2) estimate global water and energy fluxes at the land surface, 3) quantify net carbon flux in boreal landscapes, 4) enhance weather and climate forecast skill, and 5) develop improved flood prediction and drought monitoring capability.

To meet these science objectives, SMAP ground processing will combine the attributes of the radar and radiometer observations (in terms of their spatial resolution and sensitivity to soil moisture, surface roughness, and vegetation) to estimate soil moisture with 4% volumetric accuracy at a resolution of 10 km, and freeze-thaw state at a resolution of 1-3 km. Model sensitivities translate the soil moisture accuracy to a radar backscatter accuracy of 1 dB (1σ) at 3 km resolution and a brightness temperature accuracy of 1.3 K at 40 km resolution. This paper will describe the level 1 radar processing and calibration challenges and the choices made so far for the algorithms and software implementation.

2. RADAR PROCESSING ALGORITHM

To obtain the desired high spatial resolution the level 1 radar ground processor employs synthetic aperture radar (SAR) imaging techniques. Part of the challenge of the SMAP data processing comes from doing SAR imaging on a conically scanned system. The radar echo energy will be divided into range/Doppler bins using correlation processing algorithms described in many textbooks (eg., [3], [4]). A more detailed discussion of the performance and design issues for a conically scanned radar using SAR techniques is presented in [5].

2.1. Radar Resolution

The varying size and shape of range/Doppler cells on the surface are an important feature of a conically scanned radar system. Figure 2 in [5] shows the range/doppler structure underneath the conically scanning SMAP radar. SAR processing produces resolution cells bounded by iso-range and iso-doppler lines with spacing determined by the chirp bandwidth and the beam dwell time over a particular point. Resolution cells are relatively square rectangles in the side-looking position, but become

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elongated parallelograms in highly squinted positions. For SMAP, projected range resolution is about 250 meters, while azimuth resolution varies from 400 meters at the swath edge (500 km cross-track) down to about 1.2 km at the inner edge of the usable swath (150 km cross-track). In the nadir gap region, iso-range and iso-doppler lines are approximately parallel, and only range slicing can be done. Here, azimuth resolution degrades to the beamwidth. The SMAP concial scan maintains an incidence angle of 40 degrees, and the actively imaged area is thus an annulus covered by the beam footprint. The swath is filled in by repeated conical scans which slightly overlap along the nadir track.

2.2. Correlation Processing

The conical scan motion limits the dwell time for a particular point on the surface to about 32 ms. Such a relatively short synthetic aperture time permits the decoupling of range and Doppler processing using the rectangular algorithm and the use of time domain azimuth correlation techniques while still meeting latency requirements. Time domain correlation simplifies the azimuth processing algorithm while accomodating the rapid variation of Doppler around the conical scan.

3. CALIBRATION

Radiometric calibration of the SMAP radar means measuring, characterizing, and where necessary correcting the gain and noise contributions from every part of the system from the antenna radiation pattern all the way to the ground processing algorithms. Knowledge of the antenna gain pattern will be important to both active and passive calibration. The SMAP antenna pattern will be computed using an accurate antenna model, and then validated post-launch using homogeneous external targets such as the Amazon rain forest to look for uncorrected gain variation. Noise subtraction is applied after image processing using measurements from a noise only channel. Variations of the range/Doppler cell area will be tabulated and parameterized to meet latency and accuracy requirements. Variations of the internal electronics are tracked by a loopback measurement which will capture most of the time and temperature variations of the transmit power and receiver gain. Corrections from temperature models of components outside the loopback path will also be applied.

Long-term variations of system performance due to changes in the loopback path or in components outside the loopback path will be tracked and corrected using stable external reference targets. The Amazon rain forest has been used by prior missions for this purpose with a residual variation around 0.2 dB [6]. More recently, unpublished data from the Aquarius mission has shown that a model-corrected global ocean measurement can also be used as a stable reference level.

4. RADIO FREQUENCY INTERFERENCE

Radio frequency interference (RFI) signals are expected in the L-band frequency window used by the SMAP radar because many other users also operate in this band. Both ground-based sources and space-based sources can cause RFI. A team at JPL has investigated the occurence, detectability, and correction of RFI signals using operating airborne and space-based L-band radars (such as UAVSAR and ALOS/PALSAR). Results of this study are reported in [7] and [8]. Based on results of this study, SMAP L1 radar processing will use a ”Slow-Time Thresholding” or STT algorithm to handle RFI contamination. The STT technique looks at the slow-time series associated with a given range sample, sets an appropriate threshold, and identifies any samples that rise above this threshold as RFI events. The RFI events are removed and the data are azimuth compressed without those samples. Studies have indicated that up to 15 azimuth samples can be excised without generating azimuth side-lobes that cause errors above 0.4 dB. A survey of a limited PALSAR data set shows that the vast majority of scenes have five or fewer RFI events that would be excised by STT, leaving a residual σ_0 error of less than 0.1 dB.

5. FARADAY ROTATION CORRECTION

Faraday rotation affects L-band signals by rotating the polarization vector during propagation through the ionosphere. This mixes HH, VV, HV, and VH results with each other introducing another source of error. The SMAP radar is not fully polarimetric so the radar data do not provide a correction by themselves. Instead a correction must be derived from other sources. There are two basic approaches. One is to apply the Faraday correction produced by the radiometer which uses its third Stokes channel to estimate the amount of Faraday rotation. The result is expected to be more than accurate enough to meet the radar error budget for Faraday corrections; however, it will require radar processing to wait for radiometer processing to complete first thus introducing more latency.

The second approach, which we will adopt for L1 radar processing, is to use estimates of Faraday rotation derived from externally supplied measurements of the ionosphere total electron content (TEC). These measurements, which use GPS signals in the same band, are available from several sources on a daily basis. A numerical study performed by O. Kwoun assessed the impact expected from Farady rotation on SMAP data using long term models of the ionsphere, and the expected performance of the Faraday rotation correction derived from GPS-based measurements of TEC. If we assume no Faraday rotation correction, then 3% of the AM co-pol backscatter measurements, and 2% of the AM cross-pol measurements will not meet requirements. All of the PM measurements are expected to meet requirements. The PM data show less effect from Faraday rotation because the latitude restriction eliminates the most heavily impacted locations. If a Faraday rotation correction is applied using the GPS-based measurements of TEC, then all measurements are expected to meet the Faraday correction residual error budget.

6. REFERENCES

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