L-BAND H POLARIZED MICROWAVE EMISSION DURING THE CORN GROWTH CYCLE

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Abstract

L-band radiometry is recognized as a technique with a significant potential for providing spatial and temporal soil moisture variations [1, 2]. As a result, satellite missions dedicated to global soil moisture monitoring have been proposed. A 2D-interferometric L-band radiometer has recently been launched onboard the European SMOS (Soil moisture and Ocean Salinity) satellite, [3], and the NASA is in preparation of a similar suite of microwave instruments as a part of the Aquarius and SMAP (Soil Moisture Active/Passive missions, [4] which have anticipated launch dates in 2011 and 2014, respectively. The reliability of soil moisture products derived from these microwave observations will depend, at least in part, on the effectiveness of accounting for vegetation and surface roughness impacts.

From a combined active/passive microwave remote sensing campaign conducted in 2002, hourly L-band H polarized T_B (Brightness temperature) measurements are available for five episodes (> 2.5 days) distributed over the corn growth cycle. These measurements were collected at five incidence angles and three azimuth angles relative to crop row orientation. A labor intensive ground characterization took place on a weekly basis in the direct proximity of the footprints and, at some distance (<100 m), a suite of automated instruments were available to support the microwave data sets. In this investigation, the soil moisture and temperatures measured at preset time intervals have been utilized as input for the τ-ω (Tau-Omega) model to reproduce the measured T_B cycles. Via calibration of the model's vegetation and roughness parameterizations, the impact of the changing canopy structure throughout the season and soil moisture dependence of the h_r are evaluated.

This study shows (see Figure 1) that the empirical parameter b, defining the optical depth or canopy opacity (τ), and its dependence towards the incidence and azimuth angles change both during the growth cycle. The b found for the early growth stage is about three times larger than expected based on the literature, while near peak biomass and at senescence its value is about half. The latter is mainly caused by assuming the scattering within canopy to be negligible by setting the single scattering albedo (ω) equal to zero. The larger b at the beginning of the growth cycle is consistent with a previous report by Wigneron et al. [5].

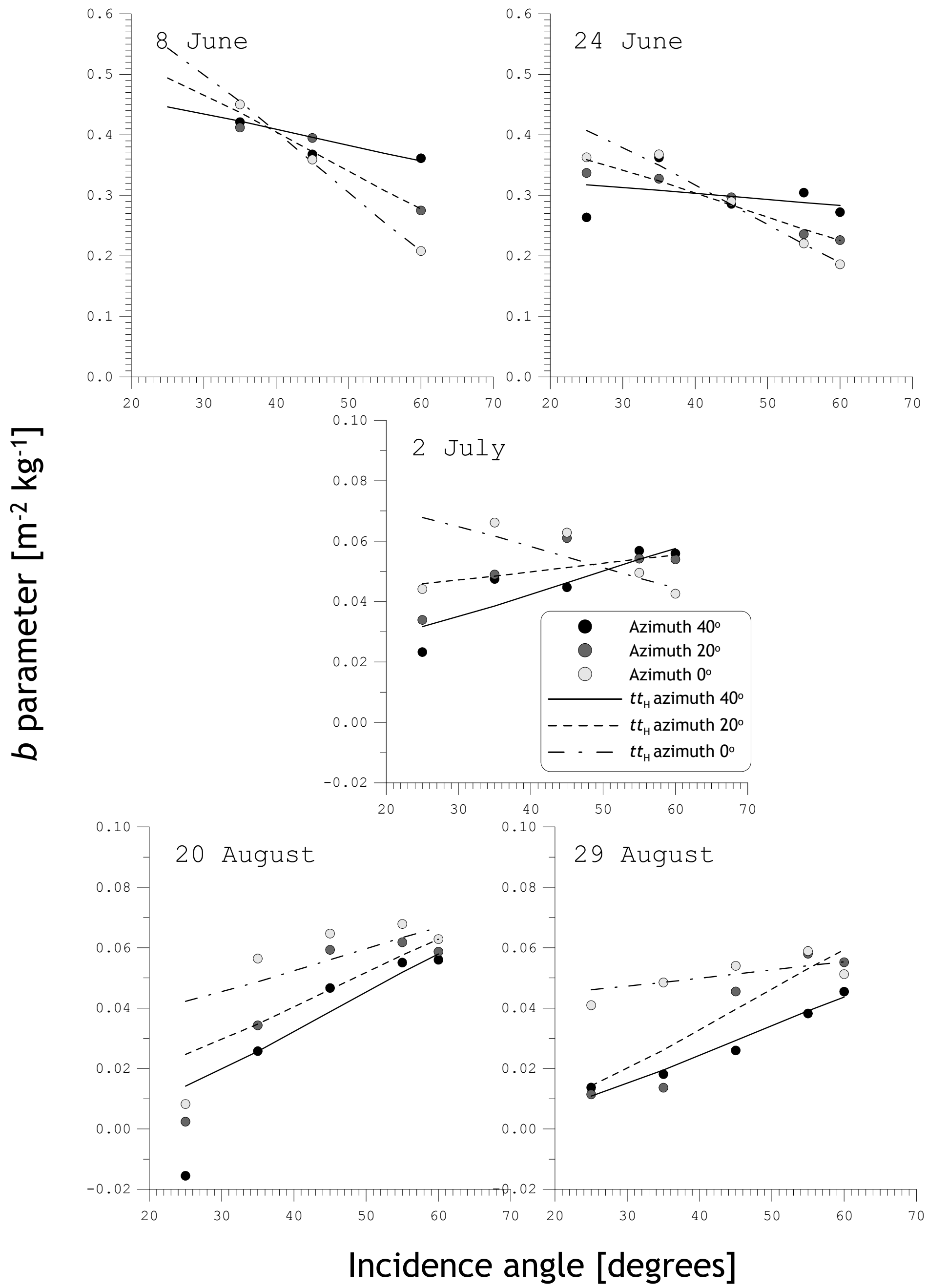

Figure 1: *b* values plotted against the incidence angle for the three azimuth positions obtained for the five episodes; 8 and 24 June (early growth stage, $W < 1.0$ kg m^{-2}), 2 July (near peak biomass, $W = 4.2$ kg m^{-2}), 20 and 29 August (senescence, $W < 2.7$ kg m^{-2}). $W \sim$ vegetation water content.

Interesting is the changing angular dependence of the *b* along the season shown in Figure 1. In general, the *b* parameter decreases with the incidence in the early growth phase, which might be attributed to the predominant vertical structure of the corn plants at this stage. Closer to peak biomass the leaves develop in the horizontal direction and form a closed canopy, which is associated with the observed weakening of the angular dependencies as the leaf coverage attenuates angular dependent contributions. These attenuating effects of the leaves disappear at senescence as the foliage loses its water and, thus, the influence exerted by the stalks increase. For this growth stage, an increase of the b with the incidence is observed when the ω is taken equal to zero, which is most notable when viewing across the rows.

However, it is found that when assuming a single b value (0.15 $m^2\ kg^{-1}$) for all incidence angles, the optimized ω's are well above zero and fairly independent of the incidence angle. Larger ω's are obtained for the across row than for along row view direction. These results suggest that scattering within a corn canopy is primarily induced by stalks, which becomes particularly important at senescence. As such, the change in the scattering cross sections of the vertically oriented corn stalks with azimuth explains the dependence of the ω on the crop row orientation. The assumption $\omega = 0.0$ requires an angular dependent b parameter for reproducing the T_B measurements at senescence. On the other hand, this study also shows that the parameterization (tt_H) proposed by Wigneron et al. [6], and included in L-MEB [7], is able to replicate the angular dependence of b observed for different azimuthal angles during various growth stages.

In addition, calibration of the regression coefficients defining the relationship between soil moisture and the roughness parameter (h_r) indicate that the effective roughness increases as the soil dries. This dependence of h_r is found to be responsible for significant uncertainties particularly in the mid soil moisture range. Previously, similar h_r increments in response to a soil moisture decrease were associated with a spatial heterogeneity of the dielectric properties [e.g. 8]. The typically large spatial variability in the mid soil moisture range explains the larger uncertainty imposed by the soil moisture dependence of h_r under those conditions, which is supported by the findings of Panciera et al. [9].

In summary, this investigation of L-band H polarized demonstrates that the b parameter (or τ) and its angular dependence change over the season, and that during a considerable part of the dry-down cycle, the h_r increases as the soil moisture content decreases. Discussion of the relative importance of these two sources of uncertainty suggests that at the start of the crop development ($W < 1.0$ kg m^{-2}) an imperfect parameterization of the angular dependence of b can account for about a 10 % error in T_B simulations, while this source of uncertainty causes errors up to 27 % at senescence. On the other hand, the soil moisture dependence of h_r accounts for an error of about 38 % at beginning of the growth cycle. Encouraging is that near peak biomass neither the angular dependence of the b nor the soil moisture dependence of h_r is found to degrade the reliability of T_B simulations significantly. This means that the commonly adopted assumptions (e.g. angular dependence of τ_{nad} (tt_H) = 1 and $\omega = 0.0$) are reasonable for peak biomass. Therefore, it may be hypothesized that the uncertainties discussed above affect mostly the soil moisture retrievals at the start and end of the growth cycle. Including a soil moisture dependent h_r parameterization and accounting for the changing angular dependencies of the empirical b parameter can assist in developing more robust soil moisture products.

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