

Supplementary Information

Dual-band information helps constrain canopy water content and temperature retrievals from vegetation optical depth

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Text S1

Ulaby & El-Rayes (1987) introduced a linear model for the dielectric constant of vegetation as an additive mixture of three components, a residual component and the dielectric constants of free water and bound water. The dielectric constant of free water is represented using the single-Debye dielectric model with an additional conductivity term to account for the fact that free water in vegetation contains low concentrations of salts and sugars. The dielectric constant of bound water is expressed using a Cole-Cole dispersion equation. The residual component, as well as the relative amounts of free and bound water are parameterized as empirical formulations of gravimetric water content (Ulaby & Long, 2014). These dielectric models provide a straightforward way to estimate the potential impacts of changes in water content, temperature, and vegetation volume on canopy transmissivity. This method has been applied in the retrieval of leaf fuel moisture content (Chaparro et al., 2024; Humphrey and Frankenberg, 2023).

Figure S1 to S13

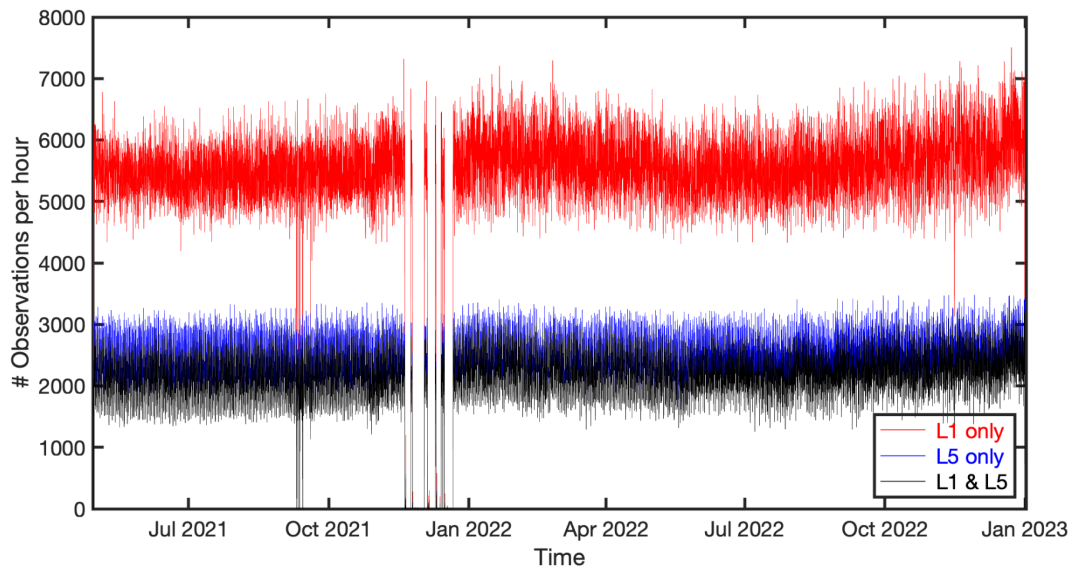


Figure S1 Number of tracked observations per hour. The line colors indicate cases where the L1 band is available, the L5 band is available, and both the L1 band and L5 bands are available.

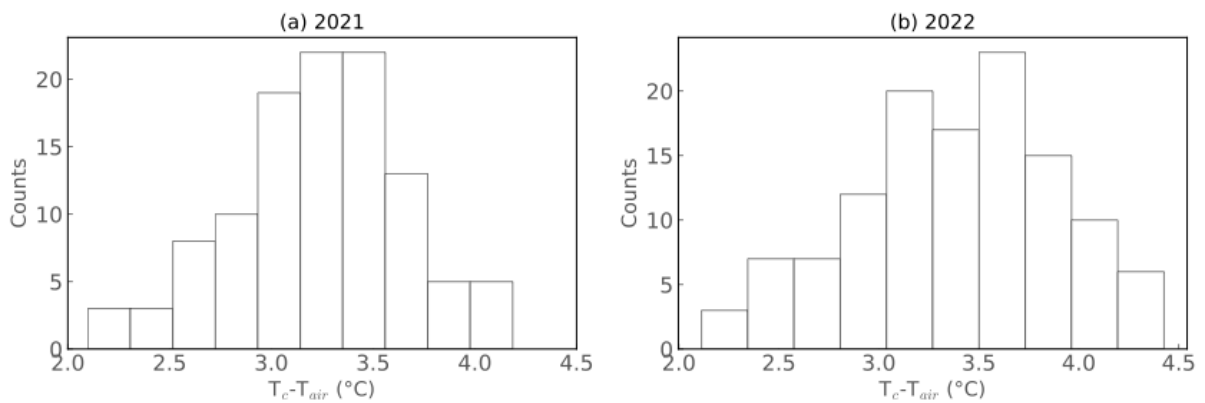


Figure S2 The frequency distribution of difference between T_c and T_{air} . T_c is obtained from outgoing long-wave radiation.

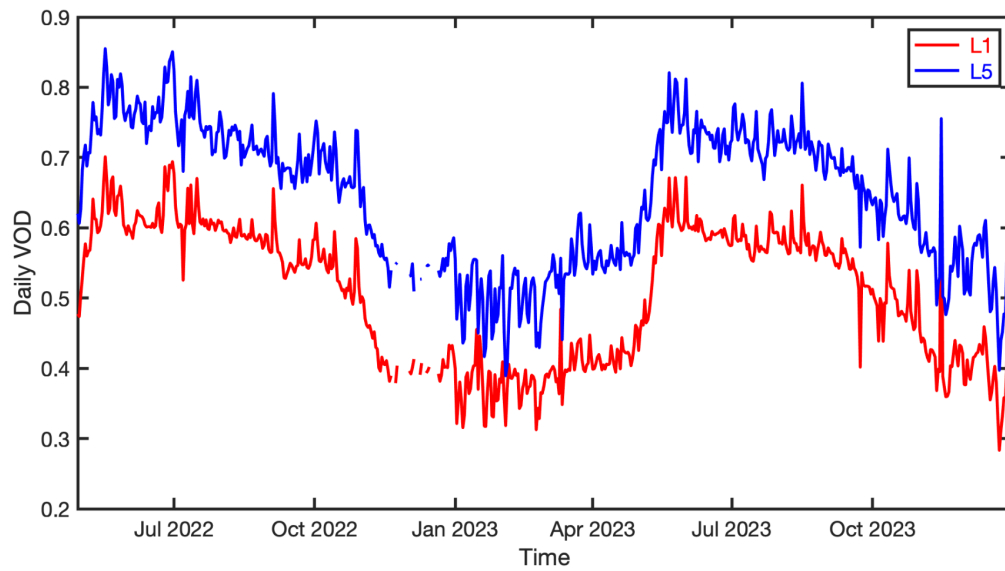


Figure S3 Time series of daily averaged Vegetation Optical Depth VOD (during the study period).

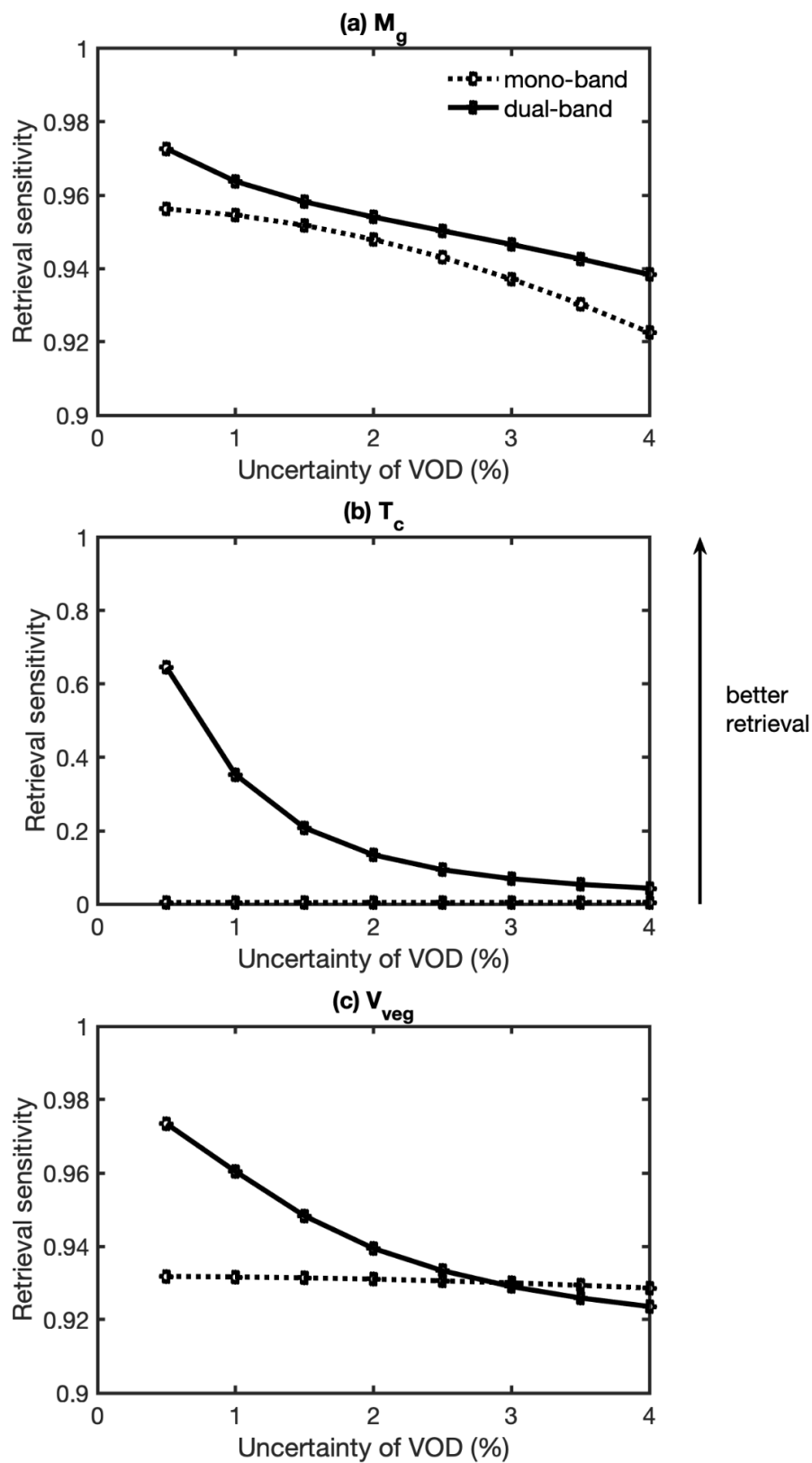


Figure S4 Retrieval sensitivity of water content, temperature, and vegetation volume. This metric reflects how changes in true state variables are translated into changes in the retrieved variables.

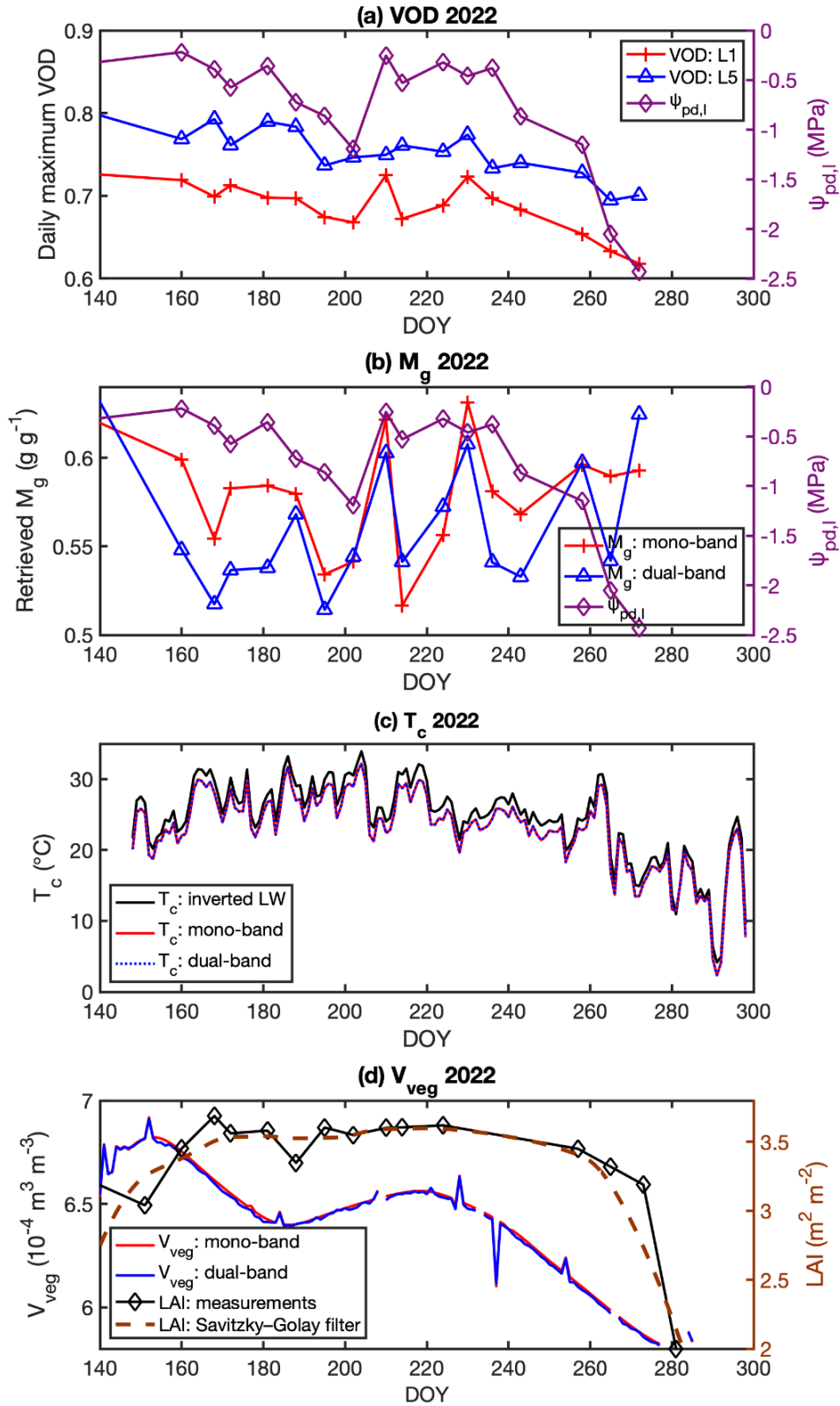


Figure S5 Similar to Figure 4 but showing time series for 2022.

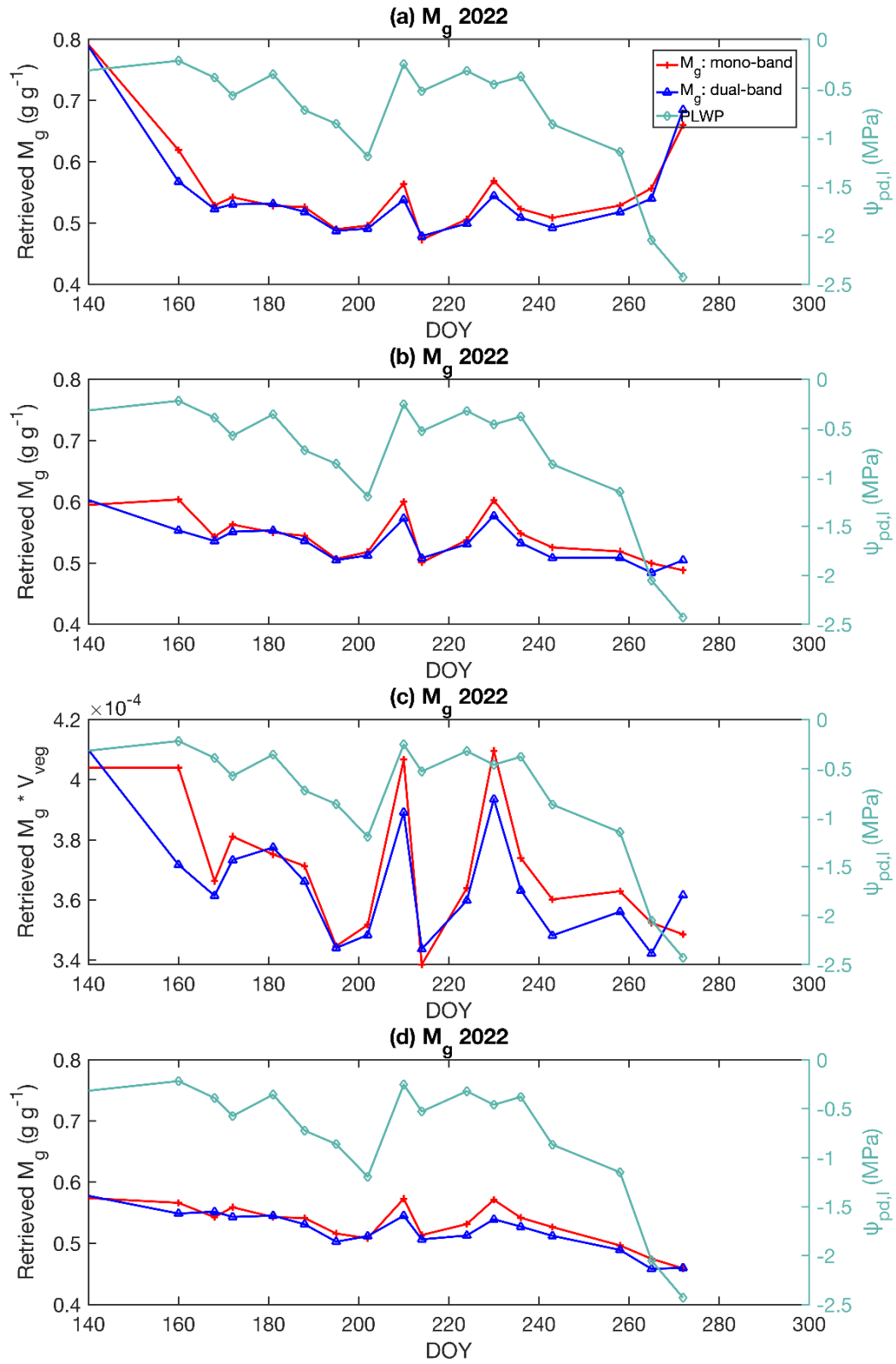


Figure S6 Similar to Figure 5 but showing time series for 2022.

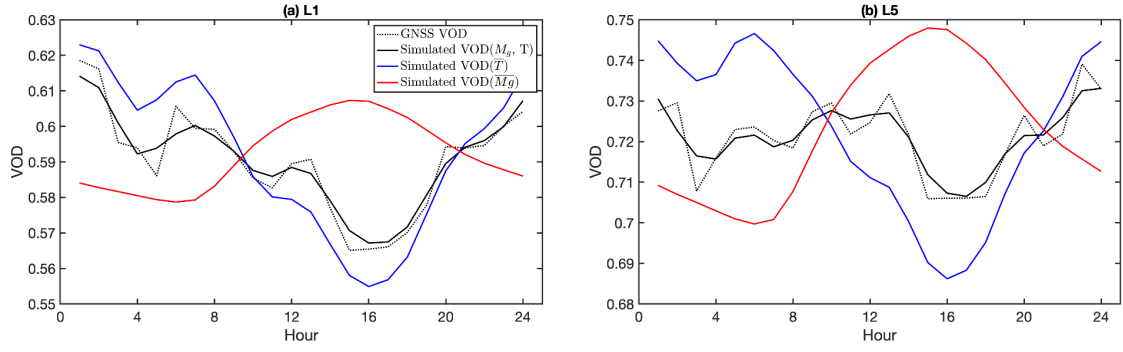


Figure S7 The relative importance of water content and temperature on VOD retrieved from (a) L1 band, and (b) L5 band. Averaged GNSS VOD diurnal cycle during August is shown as dashed line. $VOD(M_g, T)$: simulated VOD with both M_g and T varying. $VOD(\bar{T})$: simulated VOD with varying M_g and a fixed mean temperature for this period as input. $VOD(\bar{M}_g)$: simulated VOD with varying T and a fixed mean M_g for this period as input.

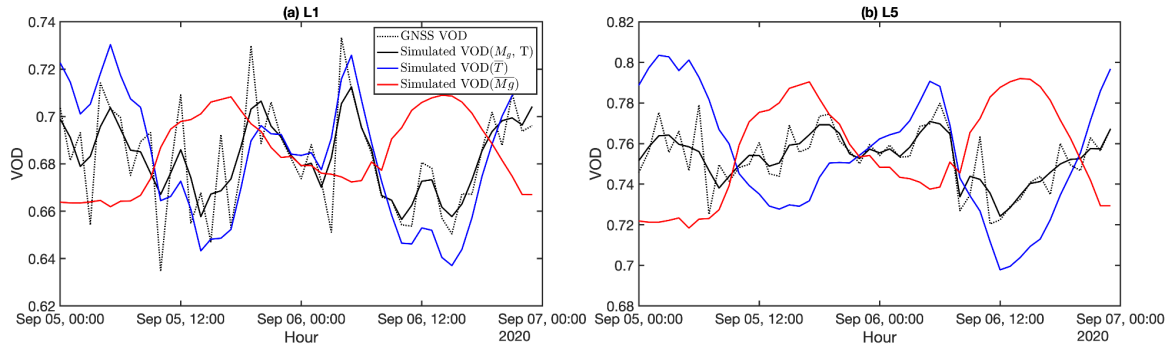


Figure S8 GNSS measurements and modeled hourly VOD responses to moisture (M_g) and temperature (T) during the record-breaking heatwave on September 5-6, 2020 in Los Angeles. (a) L1 band, (b) L5 band. $VOD(M_g, T)$: simulated VOD with both M_g and T varying. $VOD(\bar{T})$: simulated VOD with varying M_g and a fixed mean temperature for this period as input. $VOD(\bar{M}_g)$: simulated VOD with varying T and a fixed mean M_g for this period as input.

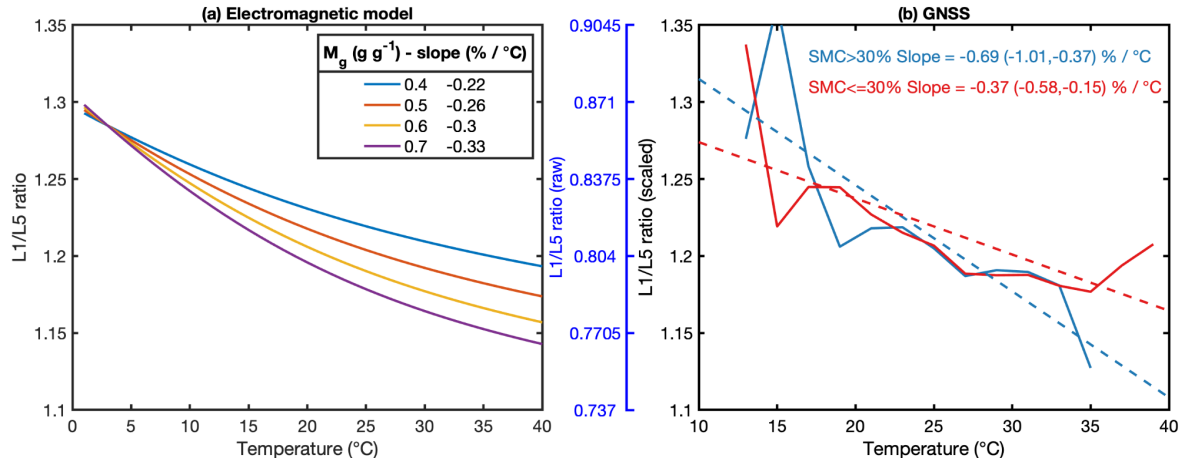


Figure S9 Similar to Figure 7 but using an ordinary linear regression.

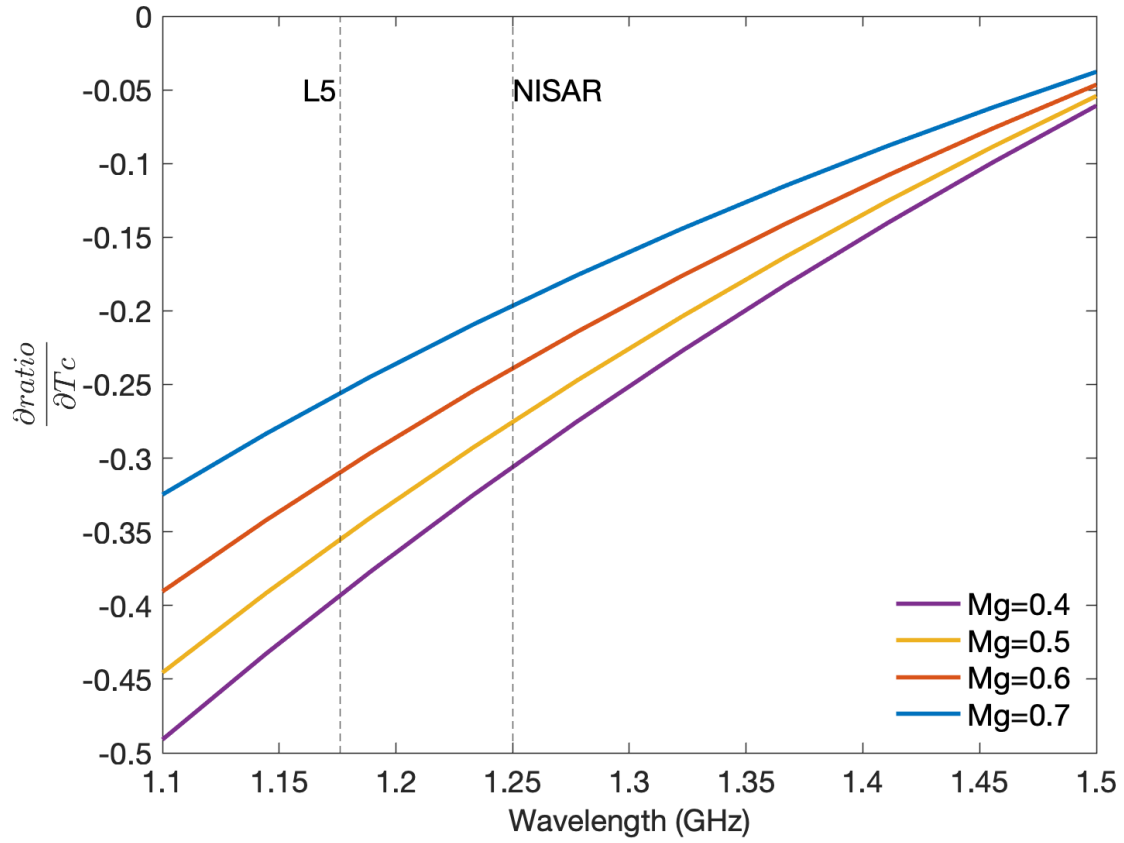


Figure S10 Temperature dependencies across wavelengths. Wavelength is shown on the X axis. The slope between the VOD ratio from two bands and temperature is shown on the Y axis.

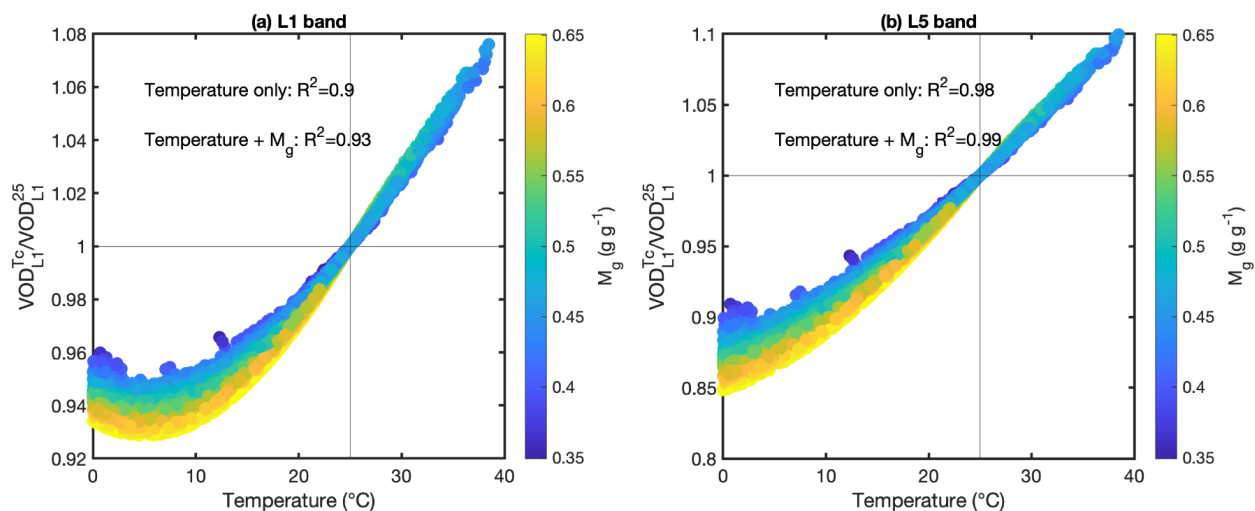


Figure S11 The relationship between the scaling factor used to standardize the VOD to 25°C .

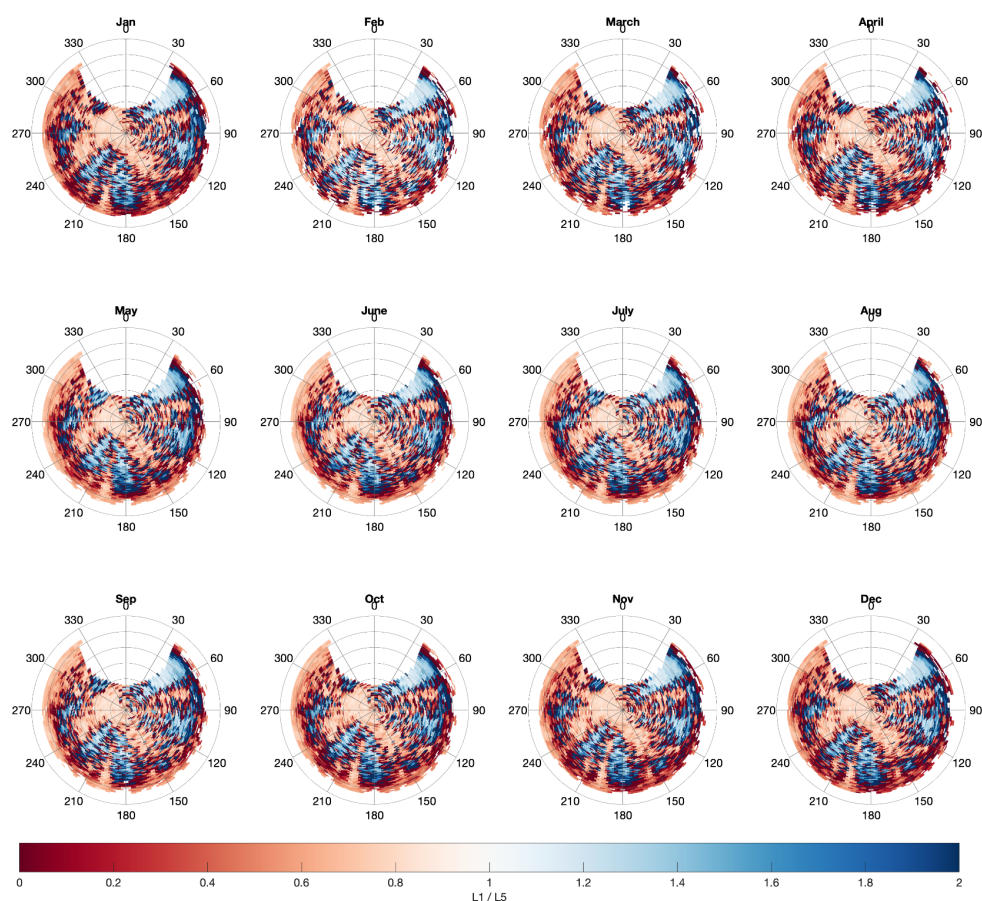


Figure S12 Sky plot illustrating the magnitude bias of VOD from GNSS signals.

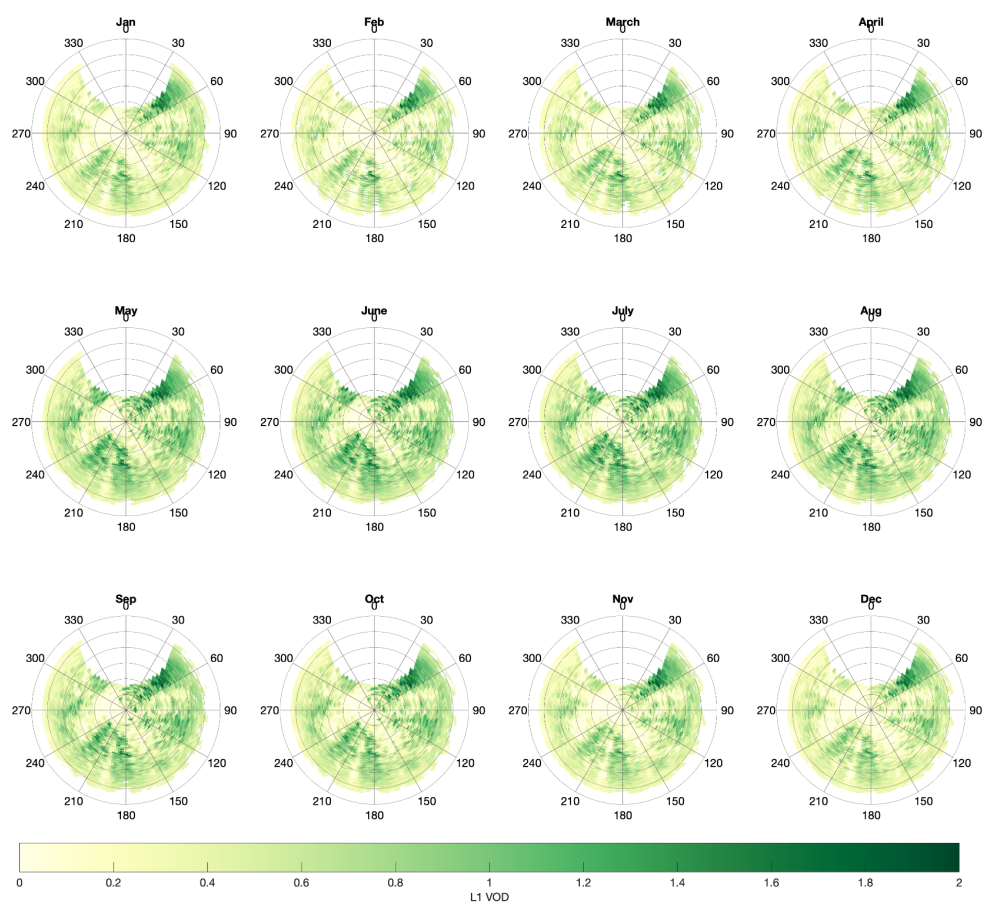


Figure S13 Sky plot illustrating the VOD at the L1 band.