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Effect of temporal sampling and timing for soil moisture measurements at field scale

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Abstract

Estimating soil moisture at field scale is valuable for various applications such as irrigation scheduling in cultivated watersheds, flood and drought prediction, waterborne disease spread assessment, or even determination of mobility with lightweight vehicles.

Synthetic aperture radar on satellites in low Earth orbit can provide fine resolution images with a repeat time of a few days. For an Earth observing satellite, the choice of the orbit is driven in particular by the frequency of measurements required to meet a certain accuracy in retrieving the parameters of interest. For a given target, having only one image every week may not enable to capture the full dynamic range of soil moisture - soil moisture can change significantly within a day when rainfall occurs. Hence this study focuses on the effect of temporal sampling and timing of measurements in terms of error on the retrieved signal.

All the analyses are based on in situ measurements of soil moisture (acquired every 30 min) from the OzNet Hydrological Monitoring Network in Australia for different fields over several years.

The first study concerns sampling frequency. Measurements at different frequencies were simulated by sub-sampling the original data. Linear interpolation was used to estimate the missing intermediate values, and then this time series was compared to the original. The difference between these two signals is computed for different levels of sub-sampling.

Results show that the error increases linearly when the interval is less than 1 day. For intervals longer than a day, a sinusoidal component appears on top of the linear growth due to the diurnal variation of surface soil moisture. Thus, for example, the error with measurements every 4.5 days can be slightly less than the error with measurements every 2 days.

Next, for a given sampling interval, this study evaluated the effect of the time during the day at which measurements are made. Of course when measurements are very frequent the time of acquisition does not matter, but when few measurements are available (sampling interval > 1 day), the time of acquisition can be important.

It is shown that with daily measurements the error can double depending on the time of acquisition. This result is very sensitive to the phase of the sinusoidal variation of soil moisture. For example, in autumn for a given field with soil moisture ranging from 7.08% to 11.44% (mean and standard deviation being respectively 8.68% and 0.74%), daily measurements at 2 pm lead to a mean error of 0.47% v/v, while daily measurements at 9 am/pm produce a mean error of 0.24% v/v. The minimum of the sinusoid occurs every afternoon around 2 pm, after interpolation, measurements acquired at this time underestimate soil moisture, whereas measurements around 9 am/pm correspond to nodes of the sinusoid, hence they represent the average soil moisture.

These results concerning the frequency and the timing of measurements can potentially drive the schedule of satellite image acquisition over some fields.