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Estimating groundwater levels from a simple water balance and evapotranspiration calculated with remotely sensed data

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Identifying groundwater recharge and discharge areas across a basin is critical for getting a throughout understanding of a basin groundwater/surface water system. Groundwater levels have been used extensively to estimate groundwater recharge rates at local scale, however those estimates are much needed at regional scales for implementing effective water resources and agricultural management strategies. In hydrology, there is a growing number of applications of remotely sensed information to estimate surface variables. Nevertheless, groundwater and soil moisture were the last variables to benefit from satellite technology. The objective of this study is to use evapotranspiration ET estimated by the Argentinean National Agricultural Institute (INTA – http://www.evapotranspiracion.org.ar) based on the NDVI and the surface temperature provided by NOAA AVHRR imagery, hereafter called Et remote, to infer the temporal evolution of groundwater levels in extensive areas of central Argentinean plains. INTA ET maps are reported only for Spring and Summer months. The value at each pixel of 1.1 km x 1.1 km, represents the maximum ET for a 7-10 day period, expressed in mm/month.

The analysis was performed for the period January 2005 to March 2009, first for Spring and Summer months, accumulating weekly ET maps to obtain a monthly value.

A preliminary validation of the resulting map was carried out on a pixel-to-point basis at a site within the study area by contrasting ET remote with ET estimations obtained with Thornthwaite. The differences between the two were no greater than 20-25 %. Once the validation procedure was considered satisfactory, the difference between monthly precipitation P and ET remote was calculated and contrasted against changes in measured phreatic levels from one month to the next. Both, manual and automatic water level data were used. A linear correlation was achieved, with a correlation coefficient of 0.8.

Before inferring the temporal evolution of groundwater levels for the study period, it was necessary to complete the ET remote times series for those months not provided by INTA. Previous studies by other authors computed actual ET by means of the Priesty-Taylor, Mankkink and Penman-Monteith formulae for the period 1978/1982. With those values, an average monthly actual ET was defined, later made dimensionless against the maximum monthly value, i.e. January. The resulting dimensionless coefficients for Fall and Winter months were multiplied by the ET remote for January of each year analyzed (2005 to 2009), in order to complete the ET series for the full period.

The ET series so obtained was used in a simplified monthly water balance to infer the temporal evolution of water table levels at the validation site. The water balance was based on the hypothesis that, being a flat area, vertical flow processes predominate over overland flow processes on a monthly time scale. Considering the simplifications set forth in the methodology, estimated groundwater levels resulting from the application of the water balance matched observed groundwater levels remarkably well from the study period. The maximum difference between measured and estimated groundwater levels was 1.32 m and the minimum 0 m, with an average error of 0.36 m. It is worth noting that the depth to the water table for the period of analysis ranged from 3.98 m to 7.63 m. At present, the methodology is being replicated at other validation points to reduce uncertainties of the method and build confidence on the approach before constructing a reliable evolutionary water levels map at regional scale. The idea is to benefit from properly validated satellite technology in areas of scarce point data for estimating hydrological variables at regional scales avoiding costly field surveying.