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Remote sensing in support of groundwater studies

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Groundwater provides drinking water to approximately one third of Canadians and up to 80 percent of the rural population. The protection of clean water supplies is a national priority. This project addresses the government need to better understand the dynamics and vulnerability of groundwater resources through developing remote sensing-based modelling tools and data products for key regional aquifers.

Objectives

The main objective of this project is to support the Earth Sciences sector Groundwater Geoscience Program, which maps groundwater resources, assesses key regional aquifers in Canada and manages and disseminates groundwater information. Specifically, this project focuses on

- aquifer characterization, which includes surface biophysical parameters mapping, soil hydraulic parameter and soil moisture mapping, and aquifer specific yield mapping
- groundwater dynamics and surface water-groundwater interactions, which include groundwater recharge mapping and assessment, water budget and seasonal change quantification, and ecosystem and climate change impacts and feedbacks
- model development and calibration/validation for assessing the aquifer water dynamics using remote sensing data

Methods

Our methods focus on developing remote sensing-based tools for mapping surface hydrological-related parameters of vegetation and soil, as well as models for simulating groundwater and surface interactions under changing environmental conditions. In situ gravity measurements and GRACE satellite data are also used to retrieve total change in water storage. The Ecological Assimilation of Land and Climate Observations (EALCO) model developed at Canada Centre for Remote Sensing (CCRS) assimilates the previously mentioned remote sensing products in assessing aquifer groundwater dynamics.

Results

The project team members and partners continue research and development on methods and prototype products in three areas:

- surface parameters retrieval and validation. A wide range of satellite sensors are used to retrieve hydrological-related parameters of vegetation and soil at different scales, which includes Landsat TM, AVHRR, MODIS, VEGETATION, ENVISAT-ASAR and MERIS, RADARSAT-1 and -2. The parameters related to vegetation include land cover, land use and the leaf area index (LAI). Figure 1 shows the LAI derived from MERIS observations over southern Ontario.[1] The retrieved parameters related to soil include soil texture, permeability and soil water content, from both optical and radar satellite sensors. Figure 2 shows an example of a soil moisture product that was estimated by using RADARSAT-2 fully polarimetric data from and dual polarization over Chateauguay, Quebec. Validations and quality control of the products are conducted through field campaign for each aquifer. These parameters contribute to the water modelling and aquifer assessment.
- total water storage change quantification by using in situ and satellite gravity measurements. Local-scale total water storage change is studied through micro-gravity survey that uses absolute and relative gravitometers over selected aquifers. National-scale total water storage change is studied by using the GRACE satellite measurement. Figure 3 shows the total water storage changes of North America over 2007. These studies contribute to the groundwater storage analysis through integrating with soil water studies that use both field observation and model simulation.
- model and algorithm development for groundwater assessment through integrating the above remote sensing products and other ancillary data. The EALCO model developed at CCRS assimilates the Earth Observation (EO) products mentioned above to simulate the water cycle and assess aquifer recharge (see Figure 4). The EALCO model includes dynamic coupling of surface radiation, energy, water, carbon and nitrogen cycles. Its mechanistic representation of the surface physical, physiological, and biogeochemical processes enables users to study the many impacts and feedback of climate and ecosystem management on surface water and groundwater interactions.

Research continues on enhancing the model's capability in assimilating new remote sensing products and on how to calibrate/validate the model by using local aquifer parameters,[2,3,4] thereby increasing the accuracy of the regional groundwater recharge estimates. EALCO simulates the surface water-groundwater interactions to support assessments of water availability, sustainable yield and vulnerability of regional aquifers under projected climate change and land use scenarios. The current effort of the modelling work is focused on the Waterloo Moraine in southern Ontario.

For more information about available data and model products, contact Shusen Wang.

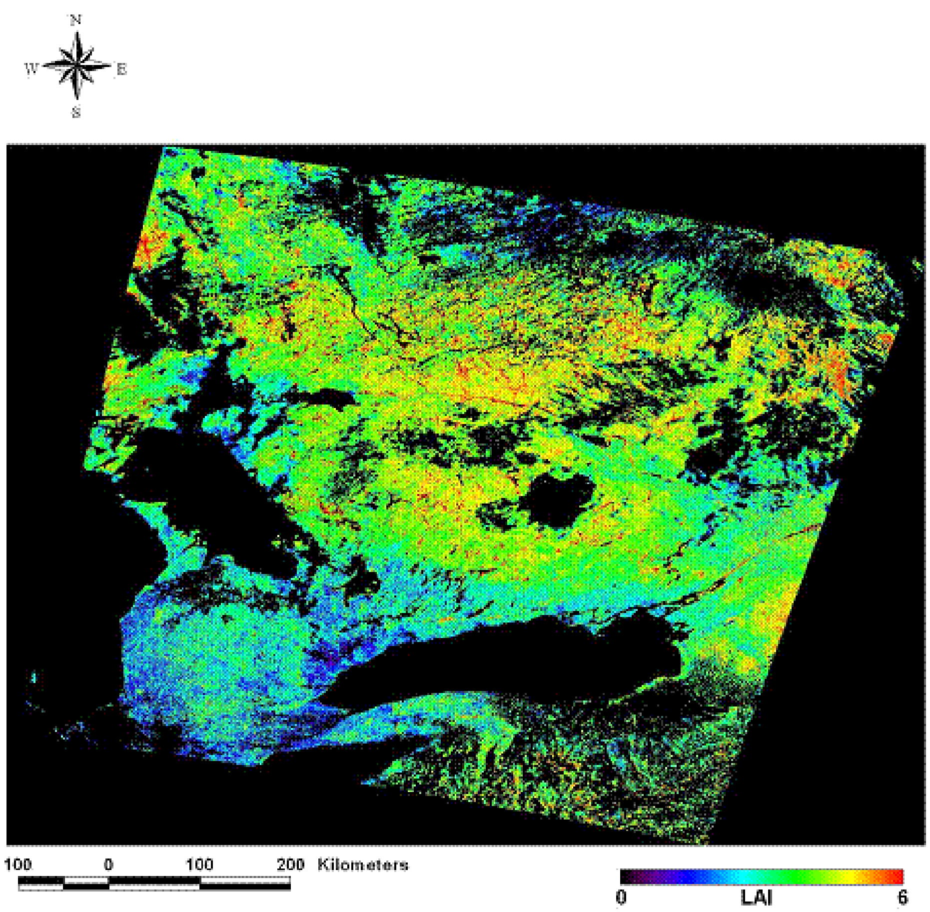

Figure 1. Leaf area index retrieved from MERIS observations over southern Ontario, July 3, 2006

[1] Canisius, F., Fernandes, R. and J. Chen, 2010. "Comparison and evaluation of MERIS FR LAI products over mixed land use regions." *Remote Sensing of Environment*, doi:10.10 16/j.rse.2009.12.010.

[2] Wang, S., 2008. Simulation of evapotranspiration and its response to plant water and CO^{2} transfer dynamics; Journal of Hydrometeorology, vol. 9, p. 426-443, doi : 10,1175/2007JHM918.1.

[3] Wang, S., Yang, Y., Trishchenko, A. P., Barr, A. G., Black, T. A., and H. McCaughey, 2009. "Modelling the response of canopy stomatal conductance to humidity." *Journal of Hydrometeorology*, 10, 521–532, doi: 10.1175/2008JHM1050.1.

[4] Fernandes, R.A., Korolevich, V. and S. Wang, 2007. "Trends in land evapotranspiration over Canada for the period 1960-2000 based on in situ climate observations and a land surface model." *Journal of Hydrometeorology*, 8 (5), pp. 1016-1030.

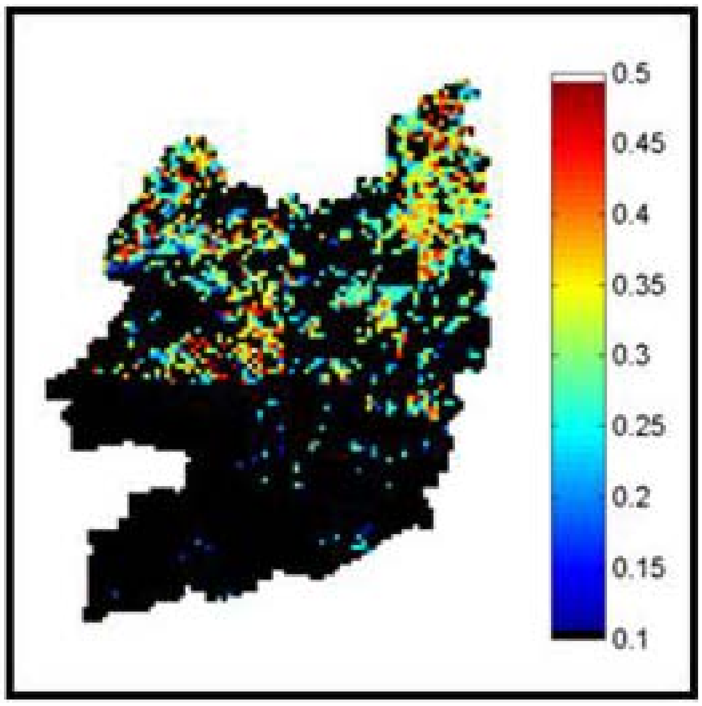

Figure 2. Soil moisture estimated by using RADARSAT-2's fully polarimetric data and dual polarization

Figure 2 shows the soil moisture estimated by using RADARSAT-2's fully polarimetric data and dual polarization over Chateauguay, Quebec. The approach is based on the converging solution of the integrated equation model on which the solution to a common roughness is extrapolated.

The vegetation effect on soil moisture estimations is obvious because of the multiscattering effect and attenuation of the scattered signal. By using the polarimetric information and signal decomposition technique, it is possible to quantify the backscattered energy generated by the vegetation layer.

Reducing the total backscattered intensity by this volumetric contribution produces information that is closely related to the soil surface. By using this methodology, it has been possible to generate absolute surface soil moisture maps for every RADARSAT-2 fully polarimetric acquisition.

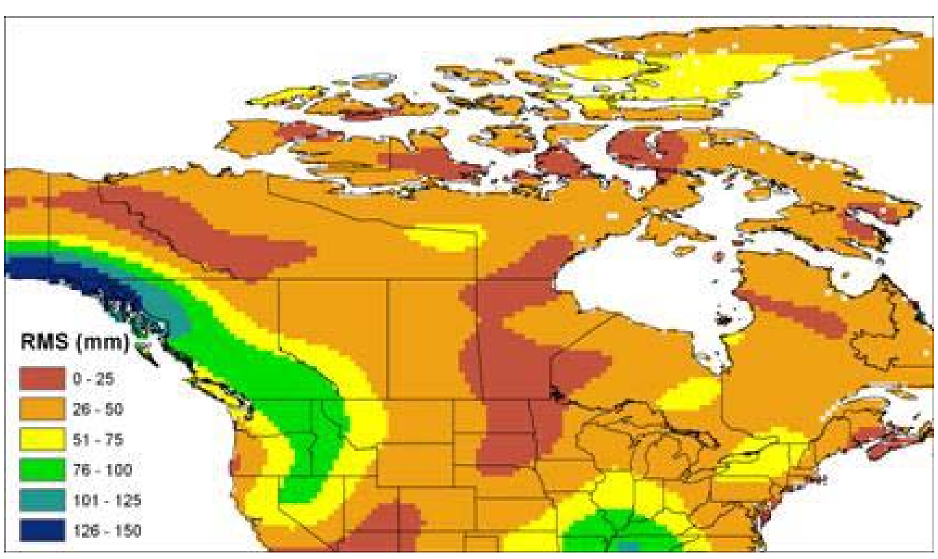

Figure 3. Root-mean-squares map of water storage changes in water thickness equivalent

Figure 3 is a root-mean-squares map of the total water storage changes in water thickness equivalent (millimetres), with respect to the annual mean field derived from GRACE for the 12 months of 2007.

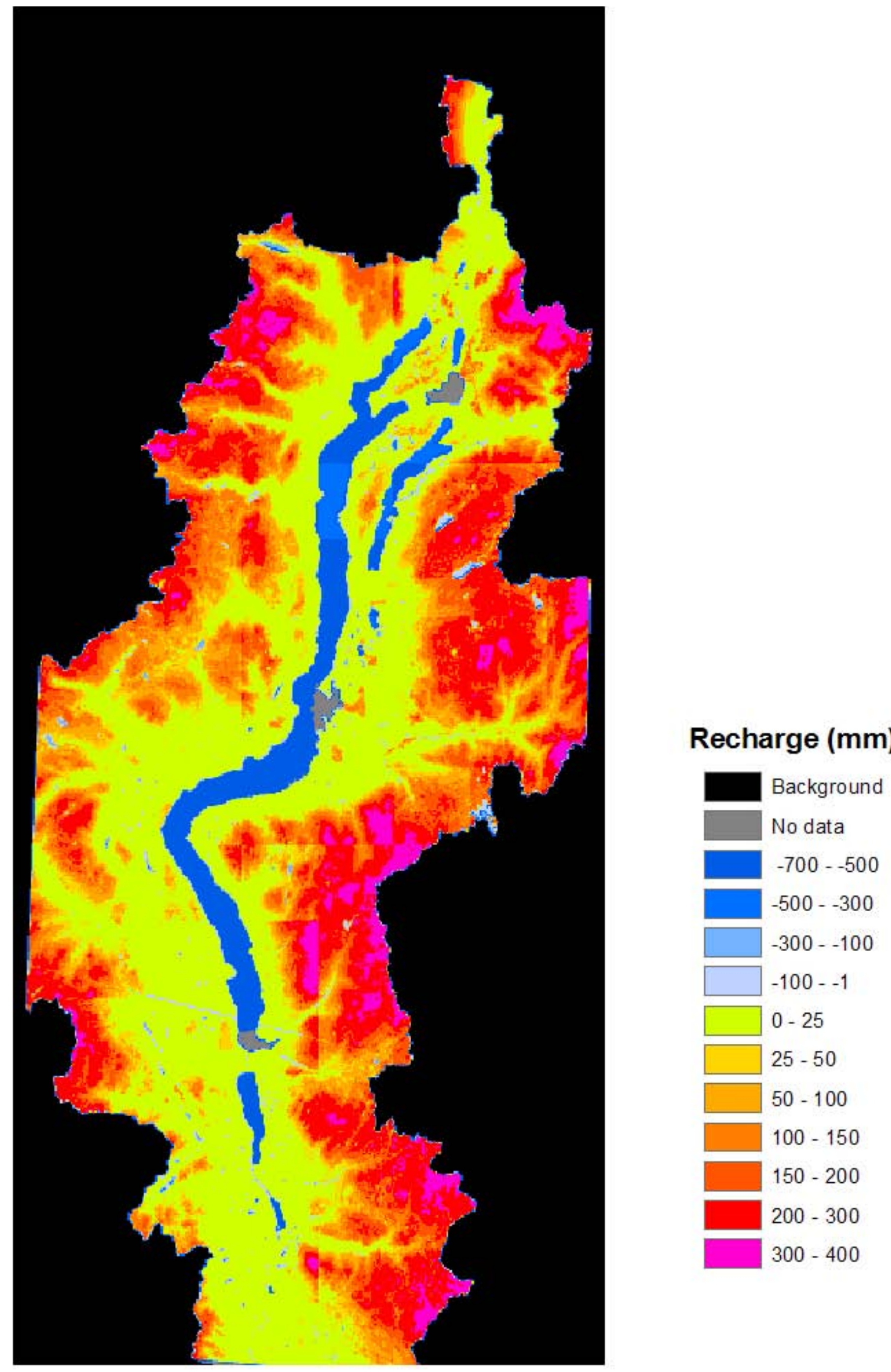

Figure 4. Annual diffuse recharge simulated over the Okanagan basin using the EALCO model

In Figure 4, note that the effect of groundwater-supported evapotranspiration is excluded in this simulation.

Acknowledgement

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References

Canisius, F., Fernandes, R. and J. Chen, 2010. "Comparison and evaluation of MERIS FR LAI products over mixed land use regions." *Remote Sensing of Environment*, doi:10.10 16/j.rse.2009.12.010.

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