Hydrological Sciences Journal

ISSN: 0262-6667 (Print) 2150-3435 (Online) Journal homepage: https://www.tandfonline.com/loi/thsj20

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To cite this article: J. C. RITCHIE & A. RANGO (1996) Remote sensing applications to hydrology: introduction, Hydrological Sciences Journal, 41:4, 429-431, DOI: 10.1080/02626669609491518

To link to this article: https://doi.org/10.1080/02626669609491518

Published online: 24 Dec 2009.

Remote sensing applications to hydrology: introduction

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This is the first of a proposed series of Special Issues of *Hydrological Sciences Journal* meant to give state-of-the-art overviews of the sciences covered in the different Commissions and Committees of the International Association of Hydrological Sciences (IAHS). The International Committee for Remote Sensing and Data Transmission (ICRSDT) organized this first Special Issue to cover the current research in and operational applications of remote sensing technology in hydrology. The latter applications are becoming more important because remote sensing techniques have the ability: (a) to measure spatial, spectral and temporal information; and (b) to provide data on the state of the Earth's surface. It is also a rapidly changing domain with new sensors, platforms and application techniques being developed to give hydrologists new data and new views of the landscape with which to evaluate the Earth's surface (Rango, 1994; Running *et al.*, 1994). Remote sensing provides observations of changes in hydrological states and variables over both time and space that can be used to monitor hydrological conditions and changes.

Remote sensing has been defined as the science and art of obtaining information about an object, area, or phenomenon through the analyses of data acquired by a sensor that is not in direct contact with the target of investigation. Remote sensing studies include data collected with instruments on the ground (hand-held, truck-mounted, etc.) and on a variety of airborne and spaceborne platforms. Sensors used for remote sensing for hydrological applications cover a broad range of the electromagnetic spectrum. Both active sensors that send a pulse and measure the return pulse and passive sensors that measure emissions or reflectance from natural sources are used. A variety of sensors can provide data on reflective, thermal and dielectric properties of the Earth's surface (Engman & Gurney, 1991). Remote sensing techniques indirectly measure hydrological variables, so the electromagnetic variables measured by remote sensing techniques have to be related to the hydrological variables empirically or with transfer functions. The objective of this Special Issue is to provide an overview of the applications of remote sensing to operational and research hydrology so that those applications can be better understood.

Twelve papers addressing various applications of remote sensing to hydrology are contained in this issue. The first paper describes the applications of remote sensing to estimate precipitation. Several operational programs are currently using remote sensing techniques to estimate precipitation. The availability of satellite-derived rainfall products for meteorologists and hydrologists has expanded rapidly over the last five years. International activities are ongoing to evaluate the performances of algorithms used to estimate precipitation.

While runoff cannot be measured directly with remote sensing, the second paper discusses the use of remotely sensed derived parameters and algorithms as input to operational models for estimating runoff. Parameters estimated with the aid of remotely sensed data are precipitation, interception, evapotranspiration and soil storage. The author gives examples of the use of remotely sensed parameters in runoff estimates.

Applications of remote sensing to snow hydrology are very positive. Operational programmes currently provide snow cover data for North America using AVHRR and GOES data. The Canadian Climate Centre provides microwave-derived snow water equivalent data on the Prairies to operational hydrological forecasters. New combinations of sensors and integration with other data will in the future further improve snow and ice data acquisition by remote sensing techniques.

Several empirical/statistical techniques have been used to estimate daily evapotranspiration operationally using satellite data at regional scales. More physically-based techniques have also been used and these approaches estimate evapotranspiration with the same uncertainty as that of current ground-based measurement techniques. The authors describe many approaches as looking promising, especially those based on surface temperature and vegetation indices.

Surface soil moisture (0-5 cm) can be measured with passive and active microwave instruments that can be implemented on airborne and spaceborne platforms. The greater emphasis on the spatial distribution and temporal behaviour of soil moisture has opened a new area of interest and potential applications for hydrologists.

The application of high spectral and spatial resolution remotely sensed data for estimating water quality variables has developed almost to operational levels. A case study in The Netherlands demonstrated that remote sensing can provide data on various water quality parameters of interest to water districts and managers. Satellite data have also been used to monitor water quality at regional scales.

Image interpretation is used in the qualitative characterization of hydrogeological mapping of features related to groundwater. Recent developments have used thermal and multispectral data to define areas of groundwater recharge and emergence. Other applications of remotely sensed data in groundwater mapping are described.

The next two papers demonstrate applications of remotely sensed data in hydrological models and Geographic Information Systems (GIS). Land use and snow extent are the most commonly used remotely sensed input variables in hydrological models. Most hydrological models in operational use are not designed to use the spatially distributed data that remote sensing can provide.

The authors provide examples of the use of remotely sensed data in hydrological models. However, GIS can play a fundamental role in the application of spatially distributed data to hydrological models. The integration of GIS, database management systems and hydrological models may speed the use of remotely sensed data in hydrological applications and operational programmes.

The two following papers deal with instruments (radar and laser) that are well suited to provide remotely sensed data to be used for understanding hydrological processes across the landscape. Radar can provide much information for studies of the hydrological features because of the sensitivity of radar to moisture state and surface roughness and the ability of radar to penetrate clouds. Laser altimetry can also be an additional tool in the arsenal of remote sensing sensors used to measure hydrological properties across the landscape.

The final paper makes the case that the science of hydrology is data-limited and that future progress in understanding hydrological processes is limited by lack of data. The application of remote sensing to hydrology should provide the spatially distributed data needed by hydrologists to address many unsolved questions in hydrological sciences.

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