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Editorial

Advances in Remote Sensing and Modeling of Terrestrial Hydrometeorological Processes and Extremes

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Remote sensing is an indispensable tool for monitoring and detecting the evolution of the Earth's hydrometeorological processes. Fast-growing remote sensing observations and technologies have been a primary impetus to advancing our knowledge of hydrometeorological processes and their extremes over the last decades. Meanwhile, integrating the hydrological-meteorological processes and bridging traditional disciplines are emerging as the frontier of hydrological and meteorological studies. These progresses opened new opportunities to advance the studies of modeling and forecasting climate change related extremes for adaptation and mitigation of hydrometeorological hazards. This special issue gathers a number of contributions in remote sensing and modeling of hydrometeorological processes and extremes, including retrieval methods, validation of satellite retrieval results, hydrological modeling, application of parallel computing in model optimization, and analysis of spatiotemporal changes in hydrological regimes. The investigated hydrologic variables in these studies contain precipitation, evapotranspiration, stream flow, and water storage.

Remote sensing of actual evapotranspiration (ET) has been a hot topic in the past two decades. Many ET retrieval algorithms have emerged and formed many different types of approaches, including the thermal remote sensing based surface energy balance approaches [1, 2], process-based Penman-Monteith methods [3–5], land surface temperature-vegetation index space models [6, 7], maximum entropy production model [8], and water balance method [9]. In this special issue, a couple of studies are also devoted to this research effort. X. Pan et al. applied a recently developed nonparametric ET retrieval model in a semiarid region of China and evaluated it against observations from six eddy-covariance flux sites that represent desert, Gobi, cropland, orchard, vegetable field, and wetland. The ET retrieval model ingests net radiation, surface air temperature, land surface temperature, and soil heat flux, which can be provided or estimated by satellite remote sensing, to estimate ET without the need of parameterizing surface resistance. This model is simple but generally effective in the study region, making it potentially applicable for a larger region. Z. Sun et al. investigated the relationship between ET and remotely sensed land surface temperature (LST) under energy- and water-limited conditions in Mongolia. Their study demonstrates that ET and LST have a general negative relationship under the water-limited condition in a dry and cold climate, but the relationship between ET and LST varies under the energy-limited condition. This study suggests that LST-based ET retrieval needs to account for different ET behaviors under energy- and water-limited conditions in the dry and cold regions.

It has been about fifteen years since the launch of the Gravity Recover and Climate Experiment (GRACE) satellite in March 2002. It provides the very first global continuous monitoring of near-surface mass, in particular terrestrial water storage, and has revealed major changes across a range of timescales including strong seasonal shifts, interannual variations, and apparent trends [10]. In this special issue, J. T. Fasullo et al. utilized both GRACE observations and model simulations from the CESM1-CAM5 Large Ensemble (LE) to examine changes in global terrestrial water storage (TWS) during the GRACE era (2003–2014). They found that trends in the LE TWS simulations are dominated by internal variability rather than by the forced response, with TWS anomalies in much of the Americas, eastern Australia, Africa, and southwestern Eurasia largely attributable to the negative phases of the Pacific Decadal Oscillation and Atlantic Multidecadal Oscillation. They also concluded that it is inappropriate to attribute trends mainly to anthropogenic forcing despite the similarities between observed trends and the model-inferred forced response. Their findings highlight the challenge of detecting anthropogenic climate change in temporally finite satellite datasets and underscore the benefit of utilizing models in the interpretation of the observed record.

Investigation and attribution of changes in the hydrologic regimes and extremes also draw much attention from the hydrometeorology community and are another important study area. R. C. Balling Jr. et al. examined trends in extreme precipitation in Iran from 1951 to 2007 using observation-based APHRODITE daily rainfall data. They used seven different indices of extreme precipitation, including annual precipitation total, number of days above a certain threshold, maximum precipitation received over a certain period of time, maximum one-day precipitation, and number of days with precipitation above the 90th percentile, to quantify the characteristics of the precipitation regime in Iran. They further conducted the trend and principal component analyses of these index time series. Their results show that all seven indices show an upward trend through the study period, indicating increase in total rainfall and rainfall extreme, which may be related to the climate change in this region. Meanwhile, the upward trend in extreme precipitation exhibits a strong southwest-to-northeast gradient across Iran. In another study, J. Wang et al. investigated the impact of projected climate change in the next 50 years on hydrologic extremes in the upper Yellow River Basin of China based on statistical analysis and hydrologic modeling. This basin is an important region in China for providing hydropower. Their results show that the values of different long duration (15, 30, and 60 days) rainfall extremes for several given probabilities in this basin will slightly rise in the future. Correspondingly, long durance flood volume extremes will increase as well. These results suggest that planning for flood control, hydropower production, agriculture irrigation, and ecosystem preservation in this region needs to take these changes into account.

Advances in the runoff generation mechanisms and their representations in the hydrologic and land surface models are important for improving the accuracy of modeling land surface hydrologic fluxes. P. Huang et al. compared the applicability of saturation-excess mechanism, infiltration-excess mechanism, and their combination in a semiarid basin. Based on these runoff yield concepts and GIS and remote sensing techniques, they designed an event-based spatial combination modeling framework and developed two spatial combination models that account for spatial distribution and variability of runoff generation processes from saturation-excess and infiltration-excess mechanisms. The results demonstrate that delineation and differentiation of different runoff generation processes across the space certainly help to improve the accuracy of simulations relative to applying single runoff yield mechanism.

Utilizing advanced computational technologies to facilitate modeling efficiency and application is another interesting study area. For example, SCE-UA is a well-known, robust global optimization method. However, it has a high computational load, which prohibits the application of SCE-UA to high-dimensional and complex problems. G. Kan et al. proposed two parallel SCE-UA methods and implemented them on Intel multicore CPU and NVIDIA many-core GPU using OpenMP and CUDA Fortran, respectively. The parallel methods are not only reliable but also highly efficient, which can largely reduce the time consumed for model calibration and optimization.

There is no doubt that there are much more studies that represent recent advances and research directions in remote sensing and modeling of terrestrial hydrometeorological processes and extremes. However, the papers collected in this special issue cover a wide range of research topics and shed light on some of recent progresses and ideas in the field. It will serve as valuable asset for the scientists and engineers in hydrometeorology and related fields.

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