Simulating large lake-aquifer-systems: Nebraska Sand Hills, USA

Vitaly Zlotnik, Dept. Earth and Atmospheric Sci., Univ. Nebraska-Lincoln, USA
Nathan Rossman, Dept. Earth and Atmospheric Sci., Univ. Nebraska-Lincoln, HDR, Inc. USA
Clinton Rowe, Dept. Earth and Atmospheric Sci., University of Nebraska-Lincoln, USA

Key words: lake-aquifer systems, groundwater flow model, groundwater recharge (GR), GR projections in the 21st century

Introduction

In many regions of the world, such as parts of China, Mongolia, Kazakhstan, a dramatic reduction of areas and numbers of lakes has occurred. In such cases, strong feedbacks between large systems of shallow water bodies (lakes and wetlands) and climate- and human-controlled aquifers are common. Simulation of disparate spatial-temporal scales and data of surface-water bodies and the entire hydrologic system is a grand challenge. The amount of observations in such systems may be overwhelming, yet remains largely inadequate to define the system state and predict the dynamics of the lakes and wetlands. The goal of study is to develop method for estimating the dynamics of lakes and wetlands in the lake-aquifer systems in the 21st century.

Modeling

We explore feasibility of modeling the Nebraska Sand Hills (48,000 sq. km), a large, grass-stabilized dune region containing thousands of small closed-basin lakes and wetlands in hydraulic connection with the Northern High Plains aquifer. Instead of tracking lakes individually, we propose to identify lakes as areas where the simulated regional water table exceeds land surface elevation, and wetlands as areas where the water table is within 3 m from the land surface. For simulations, we used a simplified groundwater flow model of the unconfined aquifer with groundwater recharge (GR) as the major driver of the hydrologic system [1] (Figure 1):

Figure 1. Match of simulated and observed groundwater levels.

Groundwater Recharge

To constrain uncertainty in projections of GR, critical to the existence of lakes and wetlands in the semi-arid climate, we analyzed decadal averages of the difference between precipitation and evapotranspiration under the 21st century GR scenarios. Sixteen downscaled Global Circulation Models (ran through the Variable Infiltration Capacity Land Surface Model) and three greenhouse emission scenarios produced set of 48 GR projections [2], used for
characterizing uncertainty in projections.

Figure 2. GR projections in the Nebraska Sand Hills: median (green), wet (blue), and dry (yellow).

Results and Conclusions

Total baseflow to internal streams, and the area and numbers of lakes and wetlands were obtained using a groundwater flow model for modern conditions and by the end of the 21st century.

- Results indicate mild increase of lake and wetland numbers and total areas for the median GR projection.
- Changes that are more dramatic can be expected if wet or dry GR projections will be realized.
- At intermediate times, some inversions between different projections are possible.
- Our study supports the emerging consensus of the future GR in the High Plains and indicates feasibility of the proposed approach.

References