THE FUTURE OF GROUNDWATER MODELING: LARGE-SCALE, INTEGRATED, AI-ENABLED

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Groundwater modeling has advanced greatly since the early days of regional flow models and contaminant transport codes. Models such as MODFLOW and MT3DMS have helped us understand aquifer dynamics, contaminant transport, and groundwater management from site to regional scales. Today, however, the purposes and scope of groundwater models are changing. Groundwater is no longer only a local water-supply or contamination issue; it is playing an increasingly important and dynamic role in the global water cycle, with major implications for long-term water security.

This presentation will discuss three trends shaping the future of groundwater modeling. The first is the move toward larger scales, including emerging efforts to better represent groundwater processes at continental and global scales, so that models can more effectively quantify depletion, groundwater–surface water interactions, and groundwater's role in drought resilience, sea-level rise, and climate adaptation. The second is the development of more integrated models that connect groundwater with surface water, land use, soil erosion, nutrient and carbon cycling, biogeochemistry, ecosystems, and management decisions, as many groundwater challenges have become multidisciplinary. The third is the growing use of AI to accelerate simulation, learn from sparse monitoring networks, and support contaminant risk assessment and sustainable water management.

We will illustrate these trends with our recent work in China, including national-scale groundwater depletion analysis, integrated watershed modeling, and AI-assisted flow and transport simulation. These examples show that the central challenge for the field lies in combining physics-based, system-integrated models with AI-enabled, data-driven approaches. This combination will allow groundwater models to play a more direct role in decisions related to water and food security, environmental quality, ecosystem sustainability, and climate resilience.