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Summer Institute Abstracts

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Evaluating the Groundwater-surface Water Exchange on Streamflow Prediction of the National Water Model in the Northern High Plains Aquifer

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Currently, the National Water Model (NWM) only considers a one-way flux between the stream and the aquifer, where water can enter the stream from the groundwater but water cannot leave the stream. Consequently, streamflow does not have a mechanism for losing water in the downstream direction. A losing stream can occur where the stream stage is higher than the surrounding groundwater table as a result of natural topography, drought, or groundwater pumping. The purpose of this study is to evaluate the lack of a losing stream mechanism on the National Water Model's streamflow prediction skill in hydrologic extremes. Using the Northern High Plains Aquifer (NHPA) as a case study area, this study identifies losing stream reaches using USGS gage data, a groundwater availability model, and Normalized Difference Vegetation Index (NDVI) from remote sensing. While losing streams are traditionally identified using field techniques like seepage meters and soil temperature, this study utilized identification techniques with high spatial and temporal resolution. Hydrographs comparing the National Water Model and USGS gages losing stream reaches were created for both flood and drought events. For flood events, the lack of bank storage as a losing stream mechanism resulted in National Water Model flood data were flashier food response characterized by an earlier peak offset and overestimated peak discharge. For drought conditions, the omissions of a mechanism for the water to exit the stream prevents the stream from doing dry and thus the National Water Model predicted streamflow in streams that had actually gone dry. On average, the groundwater availability model shows that the losing mechanism contributes to a streamflow loss of 10% per mile in losing reaches, contributing to a volume loss of 1% per mile over the entire Northern High Plains Aquifer. By incorporating an average simple losing mechanism of 1% per mile, the National Water Model could improve the magnitude of streamflow prediction during hydrologic extremes.

Evaluating Alternative Groundwater Discharge Estimations for Improved National Water Model Forecasting

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Freshwater is essential to human civilization, and groundwater amounts to approximately 30% of the overall freshwater available on earth [1,2]. The National Center for Atmospheric Research (NCAR) along with National Weather Information Service (NWIS) and National Oceanic and Atmospheric Administration (NOAA) released version 1.2.0 of the National Water Model (NWM) in October, 2017. The NWM utilizes a conceptual (not physically-explicit) model for estimating groundwater discharge (baseflow) to streams, and this non-linear method only expresses a part of the interaction between groundwater and surficial hydrology. This research evaluates the current representation of groundwater in the NWM with a case study of two watersheds located within the Northern High Plains region. A comparison between USGS observed streamflow and baseflow, and the NWM output showed that the NWM does a much better job of predicting streamflow and baseflow in the clayey catchment than in the sandy catchment. Based on the results of this analysis, Rorabaugh' and SWAT baseflow alternative functions were analyzed for representing the interactions between reservoir storage and baseflow. By comparing baseflow hydrographs derived from each alternative formulation, potential improvements to the NWM baseflow estimation were investigated. The results show that the magnitude and duration of NWM baseflow can be better correlated with observed baseflow with the use of the suggested alternative solutions.

Discerning When to Initiate Hyper-resolution Modeling in Low Gradient Watersheds through Dynamical Forcings

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Floods are the most frequent natural disasters that occur in the United States, annually costing hundreds of lives and billions of dollars. NOAA's National Water Model is a hydrologic model that simulates real time and forecasted streamflow and other hydrologic information for 2.7 million river reaches across the contiguous United States. This model has proven beneficial in forecasting when and where flooding can be expected as it operates at a spatial resolution of 250 m. However, in topographically complex regions and areas that experience precipitation induced flooding, a finer resolution is necessary to better predict flood extent and depth. This study aims to determine when it is imperative to run a hyper-resolution model (<100 m) to more accurately determine the impacts of flood events thereby enhancing lead time for residents. A 2D physics-based hydrologic model, the Gridded Surface/Subsurface Hydrologic Analysis (GSSHA) model, was employed to determine the difference between a hyper-resolution grid (50 m) and the NWM standard (250 m) on inundation extent and depth in Brownsville, Texas. Atmospheric forcing data based on 2, 25, and 100 year precipitation events was used to run the model at rainfall intensities of 6 and 24 hours. Results indicated that the 250 m resolution seemed to overestimate flooding extent and contained a lower peak discharge, whereas the 50 m resolution was able to better identify potential inundated areas, but estimated larger overland depth values. Additionally, an analysis of variance (ANOVA) test suggested that rain intensity had a larger significance in determining the number of inundated pixels. Ultimately, the data showed that hyper-resolution modeling in complex terrains could be preferable in forecasting floods driven by low intensity precipitation events.

Sensitivity of Urban Flooding to Subsurface Storm Drainage Systems in Low-Gradient Watersheds

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In order to facilitate the National Water Center's mission to pursue hyper resolution hydrologic/hydraulic modeling, this work presents an urban flood inundation study using hyper resolution models to quantify the effects of subsurface storm drainage infrastructure. As urban populations increase globally, cities change natural flooding mechanisms through increased impervious land cover, detention and retention ponds, and storm sewer networks. Such expansion affects flood characteristics such as peak magnitude, time to peak, and the inundation area. This study addresses the sensitivity of these variables to the inclusion of subsurface storm drainage systems in hyper-resolution modeling. Using the Gridded Surface-Subsurface Hydrologic Analysis (GSSHA) Model in the Town Resaca basin in Brownsville, Texas, we show that including the storm sewer infrastructure is both feasible and beneficial for accurate flood inundation mapping in urban areas. At storm return periods above 5 year and 25 year for floods and flash floods, respectively, the additional benefit in flood inundation accuracy is decreased. However, even at higher return periods, hyper resolution models of storm sewers can be a critical addition to urban flood inundation studies.

Using Dimensionless Scaling Parameters as Decision Metrics in a Heterogenous Hydraulic Routing Scheme

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Homogeneous hydraulic routing schemes are subject to a trade-off between computational accuracy and resource consumption. In operational environments, such as with the National Water Model (NWM), accuracy coupled with robustness and efficiency is of utmost importance, while resources are highly constrained. A heterogeneous routing scheme could theoretically give operational centers the advantage of preserving accuracy while conserving resources by only implementing the Dynamic Wave method when it provides a significant increase in accuracy. This study proposes that there are instances when the Dynamic Wave method is not necessary to produce sufficiently accurate results, and that dimensionless scaling parameters can be used to initiate transitions between the Dynamic, Diffusive, and Kinematic Wave routing methods. A framework is constructed to investigate the relationships between the terms of the Saint-Venant momentum equation and Dimensionless Scaling Parameters (DSPs). The framework automates simulation of the MESH model to produce a sample of points spanning a range of hydraulic scenarios. The workflow then analyzes that sample, both visually and statistically. It is seen that the full Dynamic Wave provides unique accuracy over the Diffusive and Kinematic Wave methods for only ~5% of sample cases, and the Diffusive wave provides unique accuracy over the Kinematic Wave for ~75%. Histograms at different positions relative to transition thresholds show variable ranges for DSPs, primarily the Courant and Froude number, and may be interpreted as a justification for a routing scheme decision. Principal component analysis reveals redundant DSPs and demonstrates potential to statistically relate DSPs and terms of the momentum equation. Future work may utilize the framework established to capture a sample more indicative of the population and incorporate considerations for additional DSPs.

Incorporating Realistic Channel Geometry into Continental-Scale Hydrological Modeling

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A key element in hydraulic modeling is the specification of representative channel geometry, without which hydraulic properties will never be accurate. As a result, it is difficult to obtain reliable estimates of bankfull discharge and stage at which flooding commences. The traditional solution to the geometry problem has been topographic and bathymetric surveying, and floodplains have become increasingly resolved with the advent of lidar. For continental-scale hydrology and hydraulics, however, the large amount of high resolution data required, as well as the massive computational effort needed to effectively incorporate such data, has led to simplifying assumptions such as rectangular or trapezoidal channels for long river reaches. The National Water Model (NWM) uses the simplified trapezoidal channel representation for 2.7 million river reaches, over which it forecasts water discharge for the entire continental United States. This has created uncertainties in when to initiate hydraulic predictions. The aim of this study is to 1) evaluate the NWM predictions with the current trapezoidal channel representation and with real channel geometry (using HEC-RAS), and 2) to suggest an improved representation of channel geometry while maintaining parsimony. As a preliminary analysis, the HEC-RAS model outputs of discharge and stage were compared with the USGS observed records for three cases: trapezoidal, real, and proposed generalized geometry representations. A brief analysis of NWM Muskingum-Cunge routing parameters for varied geometry cases was also undertaken. Statistical analyses show that more realistic channel geometry not only improves the HEC-RAS outputs of stage and flow, but also improves NWM routing parameters, indicating the potential for geometric improvements to enhance the current NWM products.

Exploration of Citizen Science Data and Potential Application to the National Water Model

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The National Water Model (NWM) is a hydrologic model that simulates observed and forecast streamflow for approximately 2.7 million streams, based on an observational network of nearly 8,000 United States Geological Survey (USGS) stream gages [1]. This observational data network could be increased by integrating crowdsourced distributed hydrologic measurements on ungauged streams. Citizen Science (scientific work undertaken by members of the general public) engages the larger water community (at national, regional, and local scales), but comes with uncertainty [2]. In order to investigate this uncertainty, a decision tree method was applied to evaluate existing citizen science data of stream stage base on the CrowdHydrology network. Quality control (QC) flags were developed for data measurements to pass from L1 (raw dataset), to L2 (flagged dataset), to L3 (corrected dataset). QC flags were tested with synthetically generated crowdsourced stream stage measurements and unaltered USGS gage height. This methodology was than applied to CrowdHydrology sites and compared to co-located pressure transducer measurements. Error estimates were calculated to determine uncertainty in the in the citizen science data at these sites. Using this methodology, the NWM can incorporate crowdsourced data as independent verification and validation points to increase accuracy in forecast predictions. In addition, this research advances the Office of Water Prediction's goal of supporting a water-resilient nation by involving the public in the collaborative research process; allowing for better informed water management decisions, promoting water resource awareness / education, and increasing public trust.