The impact of groundwater-land surface interactions on hydrologic persistence in macroscale modeling

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OVERVIEW

✓ Shallow groundwater interacts with the hydrologic cycle by influencing evapotranspiration and providing long-term storage. Like many land surface models (LSMs), the Variable Infiltration Capacity (VIC) model does not explicitly represent shallow groundwater.

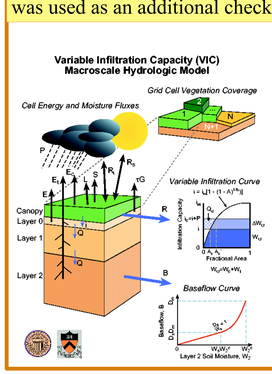
✓This might impact an LSM's ability to estimate drought duration (i.e., hydrological drought conditions may be more persistent than meteorological drought due to groundwater effects, or groundwater effects may buffer against severe precipitation deficits).

✓The objective of this research is to investigate whether incorporating the Simple Groundwater Model (SIMGM) of Niu et al. (2007) into the VIC model will improve our estimates of persistence in VIC's hydrologic states over a set of basins selected to represent varying vegetation and hydroclimatic conditions across the U.S.

MODELING APPROACH

✓Replaced baseflow component in VIC (Liang et al., 1994) with the SIMple Groundwater Model (SIMGM; Niu et al., 2007).

✓Tuned soil parameters (soil layer depth, variable infiltration capacity curve exponent) for VIC model with no groundwater (ARNO baseflow parameters) and with groundwater (SIMGM baseflow parameters). Performed an initial proof-of-concept manual tuning based on monthly flow for the 1990-1995 period. Daily flow was used as an additional check.

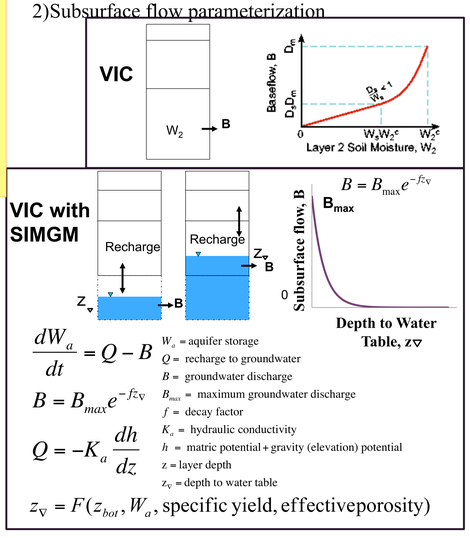


Commonalities:

1) Forcings: Precipitation, Tmax, Tmin from MOPEX
2) Sub-grid cell vegetation, roots distributed in soil layers
3) Surface runoff, Variable Infiltration Curve
4) Soil and canopy evaporation
5) Transpiration from vegetation
6) Snow
7) Energy balance optional
8) Vertical soil moisture drainage

Differences:

1)VIC-SIMGM includes unconfined aquifer
2)Subsurface flow parameterization



$$\frac{dW_a}{dt} = Q - B$$

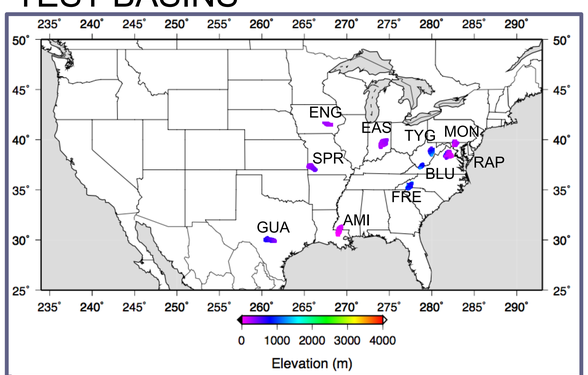
$$B = B_{max} e^{-fz_\nabla}$$

$$Q = -K_a \frac{dh}{dz}$$

$z_\nabla = F(z_{bot}, W_a$, specific yield, effectiveporosity$)$

W_a = aquifer storage
Q = recharge to groundwater
B = groundwater discharge
B_{max} = maximum groundwater discharge
f = decay factor
K_a = hydraulic conductivity
h = matric potential + gravity (elevation) potential
z = layer depth
z_∇ = depth to water table

TEST BASINS



Sites selected from MOPEX data set for variety in topography, hydroclimatology, and vegetation

CONCLUSIONS

Including a shallow, lumped, unconfined aquifer model:

✓Had little effect on overall model performance in terms of streamflow

✓Found that baseflow tends to dominate streamflow signal for most of these basins (only shown for French Broad), regardless of model used

✓Resulted in slight summertime transpiration increases for most basins (except Bluestone)

✓Led to only slightly higher lagged-correlation (as a measure of persistence) for monthly streamflow for the French Broad River, and increased the lagged-correlation for end-of-month storage on the French Broad River

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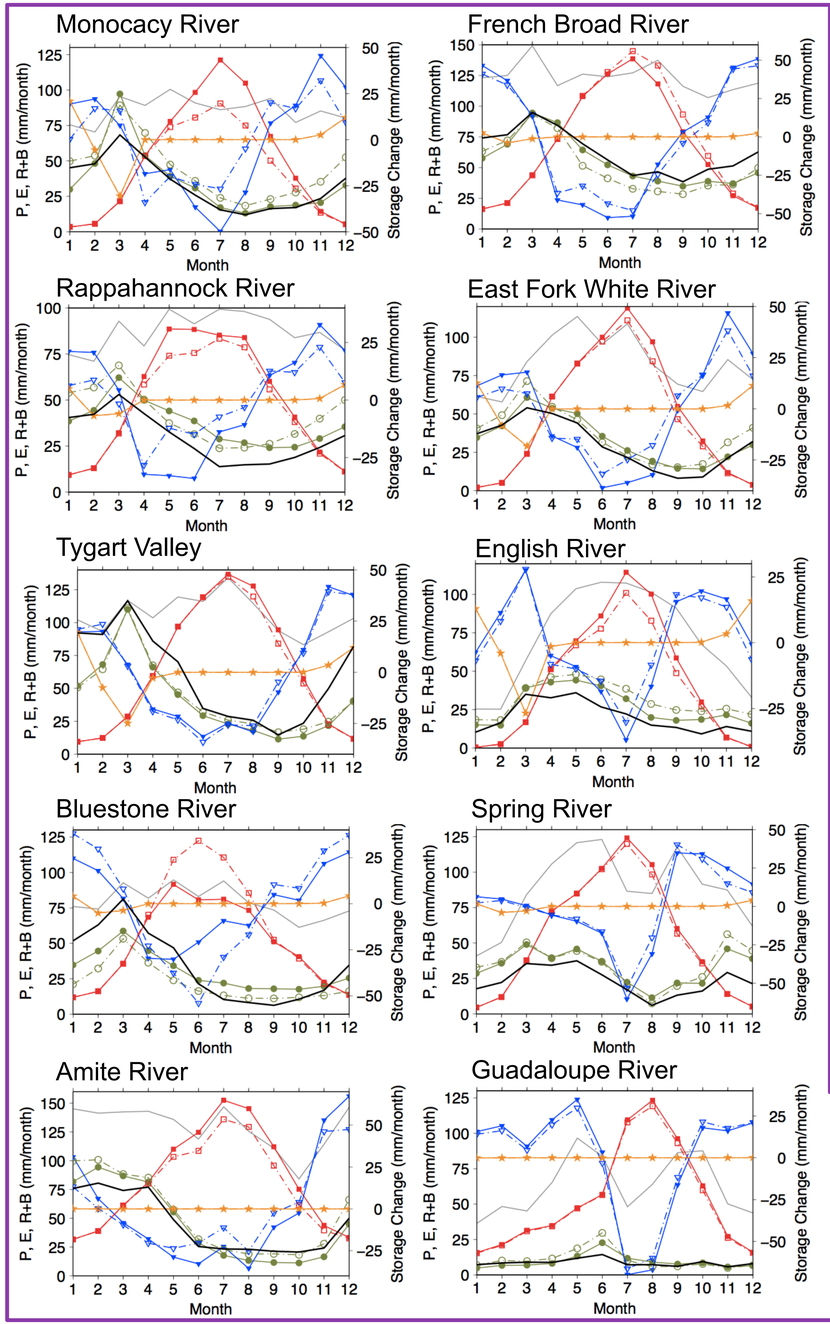
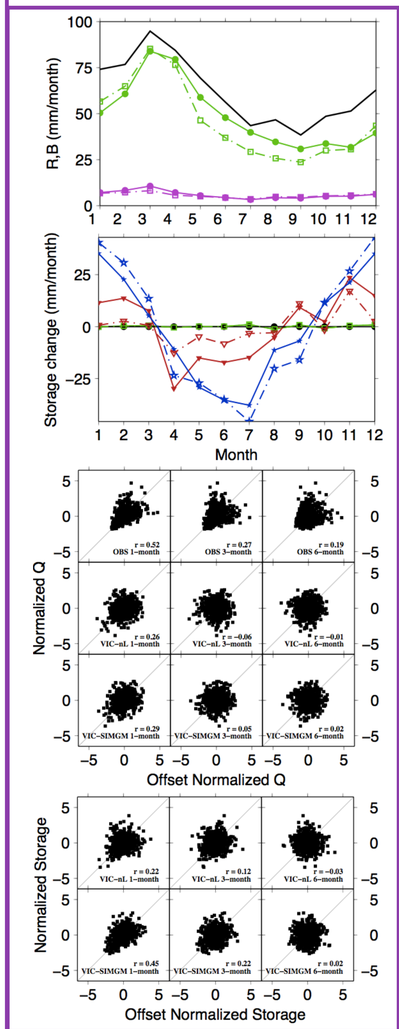
RESULTS



DIAGNOSIS OF DIFFERENCES IN BEHAVIOR OF HYDROLOGIC STATE OF FRENCH BROAD RIVER



RUNOFF-BASEFLOW PARTITIONING

- Runoff (gw)
- Runoff (no gw)
- Baseflow (gw)
- Baseflow (no gw)
- Streamflow (obs)

SUBSURFACE STORAGE PARTITIONING

- Soil layer 1 (gw)
- Soil layer 2 (gw)
- Soil layer 3 (gw)
- Aquifer (gw)
- Soil layer 1 (no gw)
- Soil layer 2 (no gw)
- Soil layer 3 (no gw)

STREAMFLOW PERSISTENCE

Lag-correlation in monthly streamflow with lag time of 1 month on left, 3 months in center, and 6 months on right. Each dot is a normalized streamflow value plotted against the normalized streamflow 1, 3, and 5 months later.

SUBSURFACE STORAGE PERSISTENCE

Lag-correlation in monthly total subsurface storage with lag time of 1 month on left, 3 months in center, and 6 months on right. As above but with end-of-month subsurface storage.

ANNUAL CYCLE

- Precipitation
- Evaporation
- Runoff+Baseflow
- Subsurface change
- SWE change
- no gw
- gw
- Streamflow (obs)

REFERENCES

✓Liang, X., D. P. Lettenmaier, E. F. Wood, and S. J. Burges, 1994: A Simple hydrologically Based Model of Land Surface Water and Energy Fluxes for GSMs, *J. Geophys. Res., 99(D7), 14,415-14,428.*

✓Niu, G.-Y., Z.-L. Yang, R.E. Dickinson, L.E. Gulden, H. Su, 2007. Development of a simple groundwater model for use in climate models and evaluation with Gravity Recovery and Climate Experiment data, *J. Geophys. Res., 112*, D07103, doi:10.1029/2006JD007522.