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

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1 Overview

Motivation

✓ Shallow groundwater interacts with the hydrologic cycle by influencing evapotranspiration and providing long-term storage.

✓VIC and many LSMs do not explicitly incorporate shallow groundwater.

✓This might impact an LSM's to estimate drought duration (i.e., agricultural and hydrologic drought conditions may last longer than meteorological drought if the aquifer is drawn-down significantly; or the presence of aquifer storage may buffer against severe precipitation deficits).

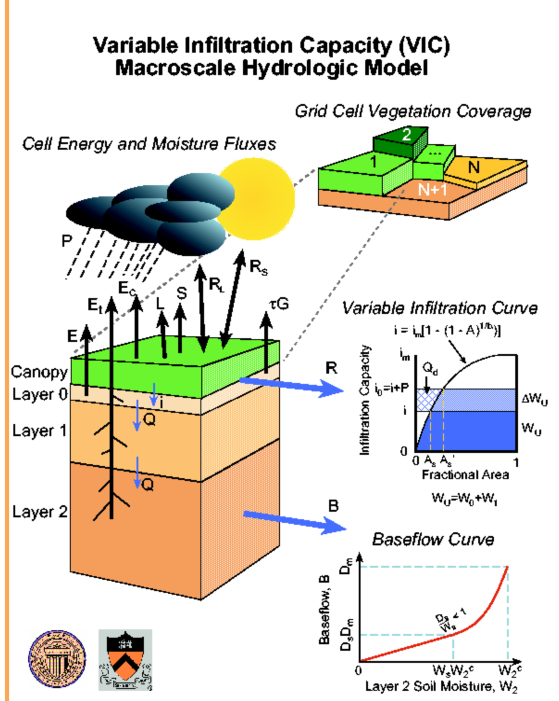
2 Modeling Approach

✓Replace baseflow component in Variable Infiltration Capacity model (VIC; Liang et al., 1994) with the SIMple Groundwater Model (SIMGM; Niu et al., 2007).

✓Calibrate soil parameters (ARNO baseflow parameters,) for VIC model with no groundwater and with groundwater (SIMGM baseflow parameters, specific yield).

✓Depth of lowest two soil layers and variable infiltration capacity curve exponent calibrated for both models.

✓Calibration performed on daily flow and natural log of daily flow using MOCOM-UA algorithm.

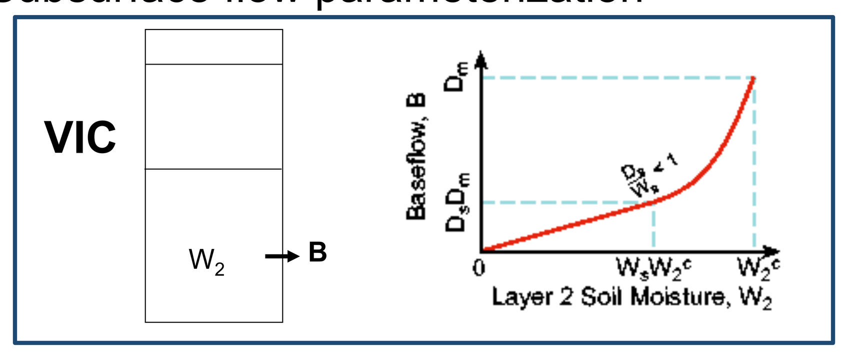


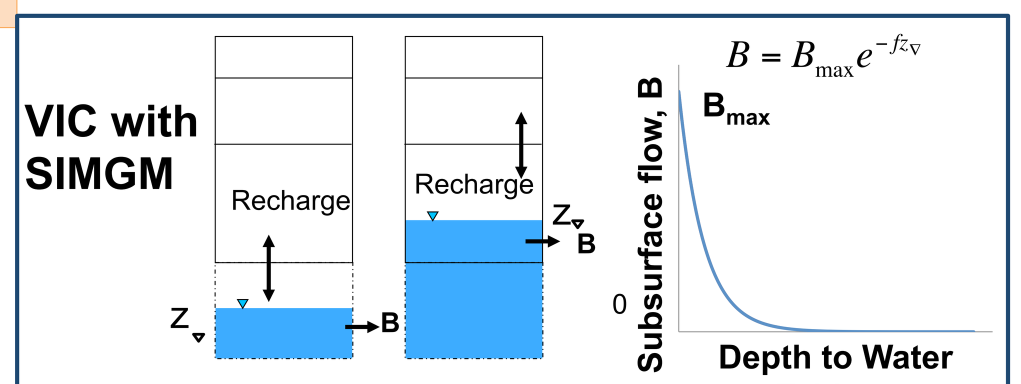
Commonalities:

1)Forcings: Precipitation, Tmax, Tmin, Wind
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





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

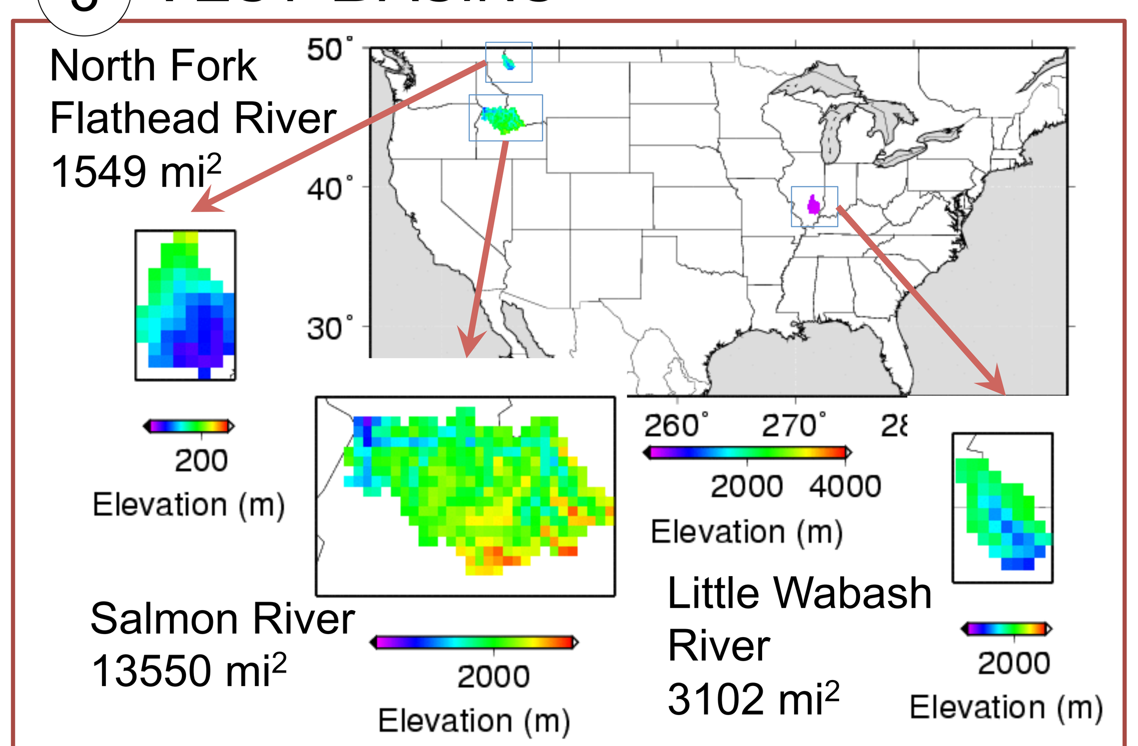
$$B = B_{max} e^{-f z_\nabla}$$

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

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

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

3 Test Basins



Sites selected for variety in topography, hydroclimatology, and vegetation

✓Salmon--mostly grass, shrub, and crop land

✓North Fork Flathead--forest, grass, and shrub land

✓Little Wabash--mostly forest

4 Results

Annual Cycle

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

Runoff-Baseflow Partitioning

— Runoff (gw)
— Baseflow (gw)
— Runoff (no gw)
— Baseflow (no gw)
··· Streamflow (obs)

Subsurface Storage Partitioning

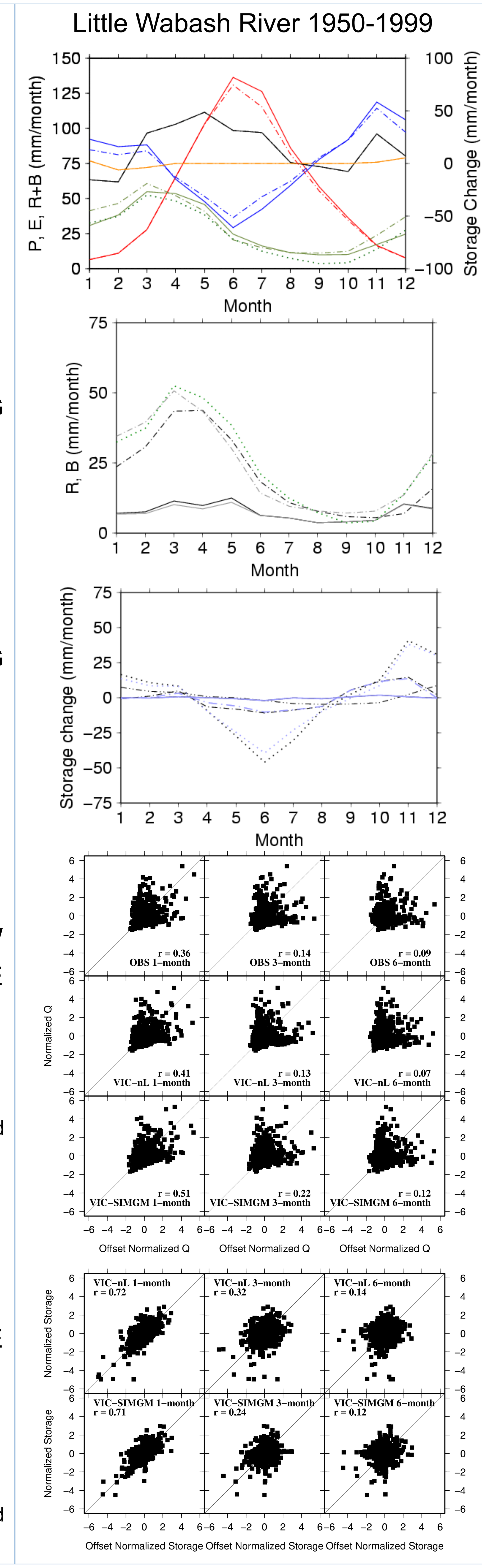
— Soil layer 1 (gw)
— Soil layer 2 (gw)
— Soil layer 3 (gw)
— Aquifer (gw)
— Soil layer 1 (no gw)
— Soil layer 2 (no gw)
— Soil layer 3 (no gw)

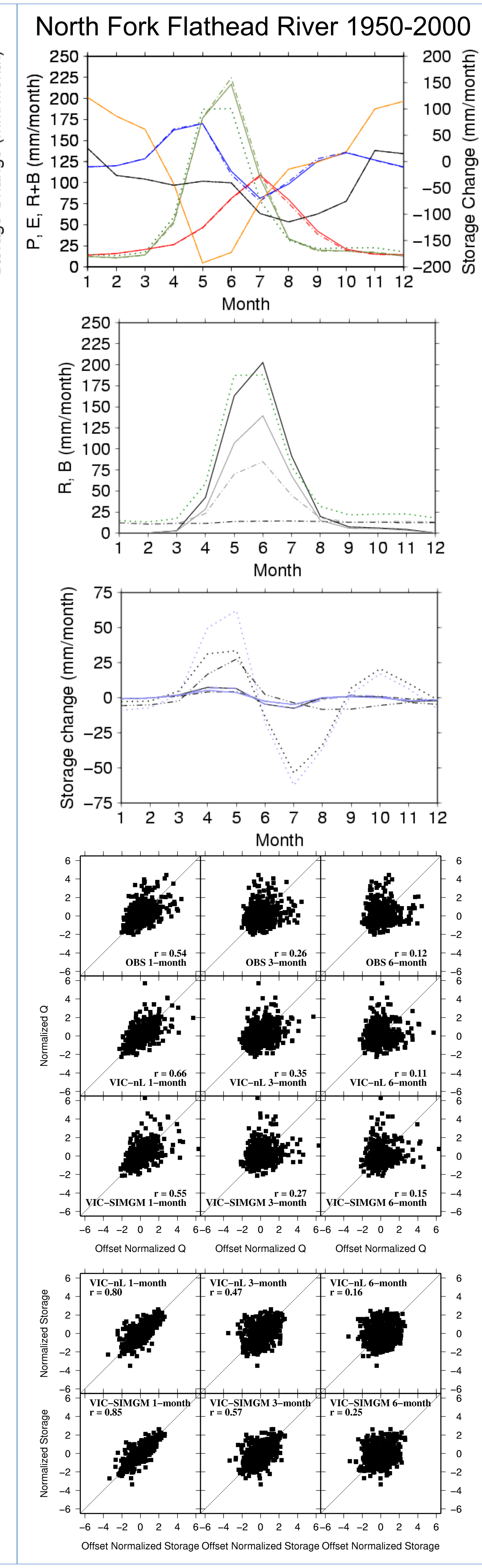
Streamflow Persistence

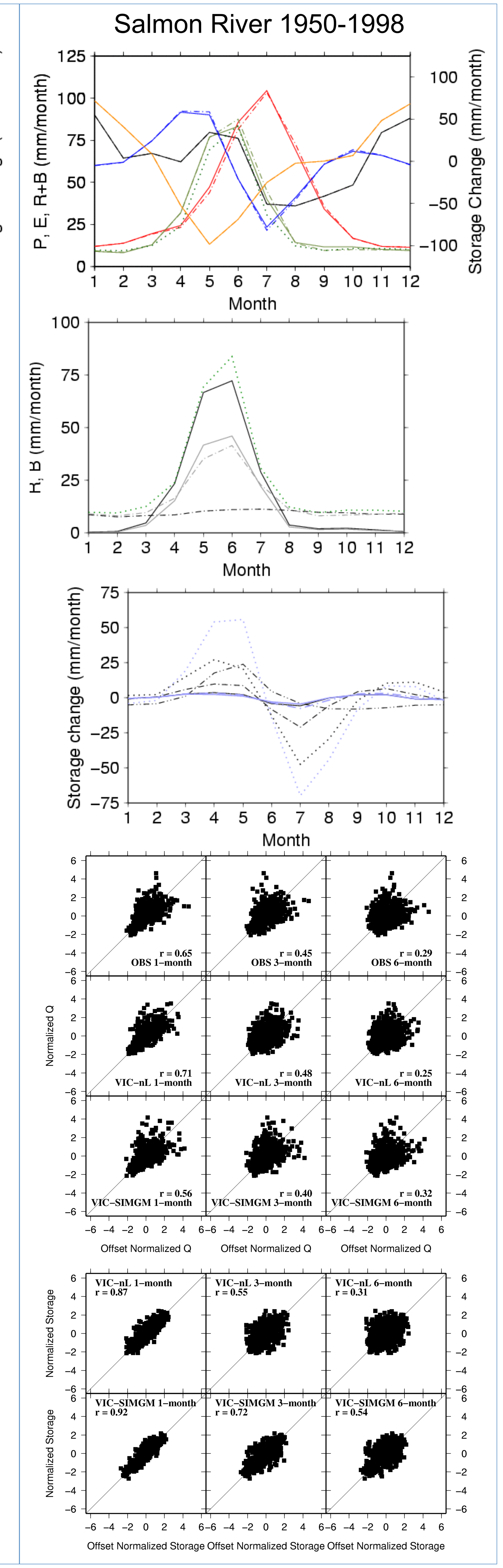
Lag-correlation in monthly streamflow with lag time of 1 month on left, 3 months in center, and 6 months on right

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







5 Conclusions

Including a shallow, lumped, unconfined aquifer model:

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

✓Flattened seasonal cycle in baseflow in western basins

✓Resulted in slight summertime transpiration increases, particularly in forested basins

✓Increased the magnitude of storage change in the deepest soil layer, particularly in western basins

✓Led to only slightly higher lagged-correlation (as a measure of persistence) for both monthly streamflow and soil moisture, more so than observed for Q

6 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.