Investigating the dynamics of transit times and subsurface mixing of a small agricultural catchment using physically-based numerical model



J. Yang, I. Heidbüchel, A. Musolff, F. Reinstorf, J. H. Fleckenstein | Helmholtz Centre for Environmental Research GmbH - UFZ

Introduction Results Age dynamics Study site: catchment Schäfertal Median age of discharge Median age of storage 160 Median age of ET Strong seasonal fluctuations in age Wetting 140 F of Storage, Discharge and ET. **Age (day)**08 08 Discharge younger than storage in the wet and the drying periods ET younger than Storage Meteorological station Gauging station Stream Model area - - - Cross-section Month Area: ~ 1.4 km2 $P = ^{610} mm/yr$ Meteorological station, **Dynamics of Discharge/ET selection preferences** ET = ~ 450 mm/yr Agriculture gauging station, wells, etc SAS functions indicate a seasonal Q = ~ 160 mm/yr Intensive records since 1996 shift in selection preferences For discharge: Dry Method Wetting Preference for young water in Overall wet period, preference shift Flow modelling: gradually to older water as the 3.5 HydroGeoSphere Boundary conditions: young water catchment transitions into the preferred integeral modelling: Daily P(t), ET_p(t) drying, dry and wetting periods. young water 3D Subsurface Daily T(t) Dominated by wet period preferred 2D Surface Critical depth outlet 1D Channel For ET: 1.5 Calibration: Strong preference for young Properties: For Q, water level, water in dry period. Approaching 10 zones for 0.5 0.5 using PEST uniform selection in wet period. subsurf. property 54 optimized Dominated by drying period 7 zones for surface parameters: K, & ET → land use porosity, roughness, N-NO₃ export patterns parameters of snow melt & ET Shallow flowpaths (a) A wet day (Feb. 2000) High connectivity Drying to hillslopes Dry Wetting (fertilizer) r = 0.67Shorter delivery Well 52, R²=0.52 time Well 35, R²=0.53 Age of discharge (day) 30 60 90 180 365 (b) A dry day (Jul. 2000) Deeper flowpaths Low connectivity RTDs, TTDs computing: Longer delivery **Residence Time Transit Time** Flow 200 100 150 time Median age of discharge (day) Distributions (RTDs) model Distributions (TTDs) Velocity field , Mass balance Stor. (mm) Stor. (mm) **Particle** An approach to model N-NO₃ export 140 120 tracking (undergoing work) Mobilization **RTDs** depends on flow rate/ ~12 kg/ha/yr ~26 kg/ha/yr **TTDs Mobilization Transport** Age (day) Age (day) Soil: **Stream water Groundwater:** fractoinal StorAge Selection (fSAS) functions ω_0 immobile N-NO₃ mobile N-NO₃ • Dilution • Basic annual input Denitrafication Surplus (decay) groundwater darcy flow rate (mm/yr) $\omega_Q(Ps, t) = \frac{TTDs}{RTDs}$ Storage Storage observed N-NO₃ Discharge simulated N-NO, SAS function 25000 describes which 20000 (m³/day) fraction of the storage well-mixed, no younger water older water prefered preference prefered 15000 is preferentially sampled by discharge (i.e. mixing) Q $P_s = 0$: youngest water in storage 2000 2004 2006 2008 $P_s = 1$: oldest water in storage **Date**

References:

van der Velde, Y., Torfs, P. J. J. F., van der Zee, S. E. A. T. M., & Uijlenhoet, R. (2012). Quantifying catchment-scale mixing and its effect on time-varying travel time distributions. Water Resources Research, 48, W06536.

Yang, J., Heidbüchel, I., Musolff, A., Reinstorf, F., & Fleckenstein, J. H. (2018). Exploring the dynamics of transit times and subsurface mixing in a small agricultural catchment. Water Resources Research, 54. https://doi.org/10.1002/2017WR021896

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH - UFZ