UFZ HELMHOLTZ Centre for Environmental Research

Towards large-scale characterization of subsurface vulnerability due to agrochemical pollutants across Europe

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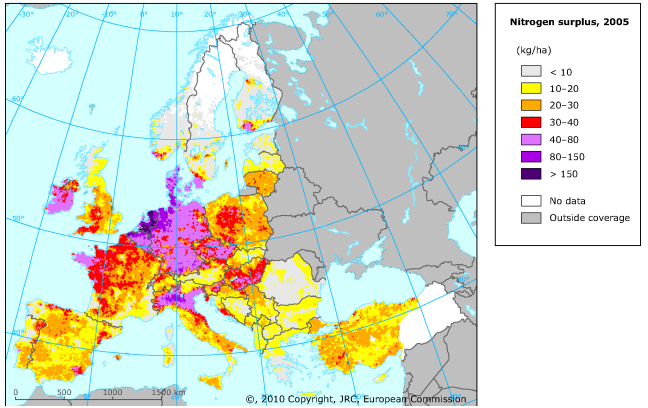
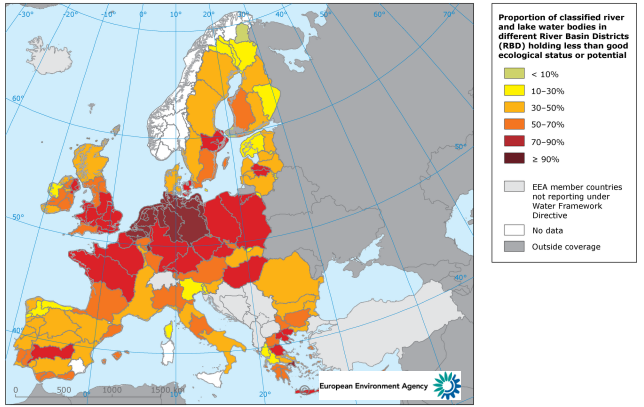
A persistent problem: subsurface contamination

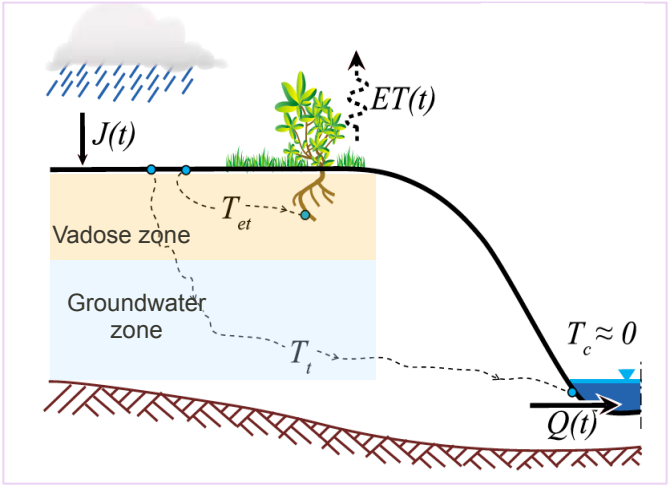
- Subsurface contamination due to diffuse agrochemical pollutants such as pesticides, herbicides, excess nutrients (N, P, K) is a widespread problem in a cultivated areas across Europe.
- Large-scale spatio-temporal patterns emerge from interplay of heterogeneous and dynamic hydrologic and biogeochemical processes in the near-surface critical zone (top one-meter of root-zone soil layer) which contribute to landscape filtering of stochastic hydro-climatic forcing.
- Such outcomes are of interest in characterizing the transient behavior of transport-reaction dynamics operating in the root-zone soil compartment which drive recharge and solute loads to sub-surface compartments (shallow groundwater and eventually to river networks).





Characterization of “intrinsic vulnerability” of a subsurface system

- Our aim here is to provide an effective approach for a large-scale characterization of “intrinsic vulnerability” to identify hotspots/times at a continental scale.
- Intrinsic vulnerability is a system specific property i.e., “*the capacity with which a contaminant introduced at the ground surface can reach and diffuse to subsurface”* (https://water.jrc.ec.europa.eu; NRC 1993).
- This hydrologic transport capacity is reflected in description of transit time distributions (TTDs) – i.e., characterizing the journey of water parcels (and dissolved solutes) from their inception to their release from subsurface to receiving water bodies.
- Our approach relies on recent developments of time-varying TTDs (Botter et al., 2010, 2011).

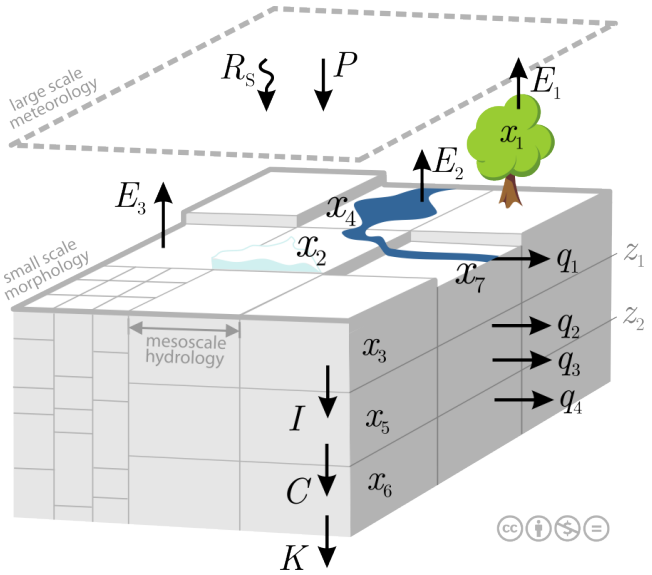


Hillslope representation of TTs (from Botter, et. al., WRR 2010)

National Research Council (NRC; 1993) Ground Water Vulnerability Assessment: Contamination Potential under Conditions of Uncertainty. National Academy Press, Washington DC.
Botter, et al., WRR (2010)
Botter, et al., GRL (2011)

Characterization of travel times (TTs)

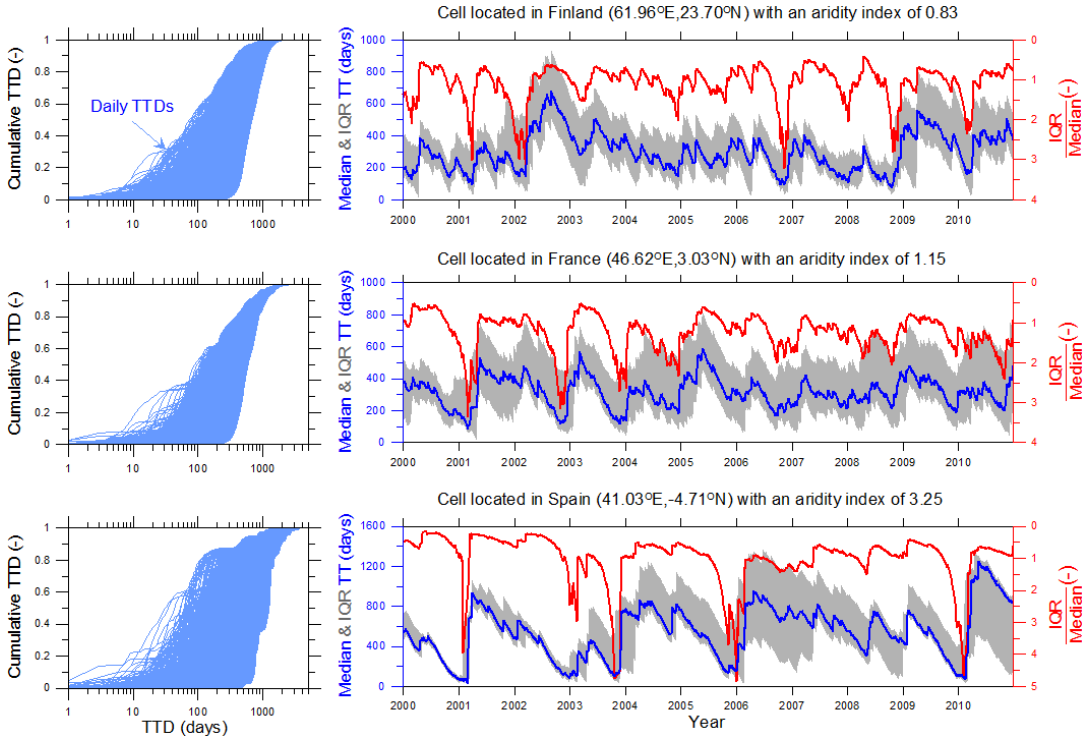
- We focus on characterizing TTs in the **root-zone** – the most dynamic and active part of the subsurface.
- Following Botter et al., (2010), we derived grid-wise estimates of the daily TTDs for water (and dissolved solute) particles leaving the root-zone soil layer.
- We use the Europe-wide estimates of spatially resolved hydrologic fluxes and storages from a well-established mesoscale Hydrologic Model (mHM; www.ufz.de/mhm).
- Here we focus on upper 1-2 meters of soil coloum – in mHM represented as multi soil layers with x3 as soil moisture, ET – evapotranspiration, P+M as combined rain and snowmelt; and I – as exfiltration from soil layers.



mHM (www.ufz.de/mhm)

Samaniego.,et al. WRR (2010) JHM(2013) HESS(2017)
Kumar, et al., WRR (2013a,b),
Rakovec et al., JHM (2016) WRR (2016) JGR (2019)

Space-time variability of TTs



Humid

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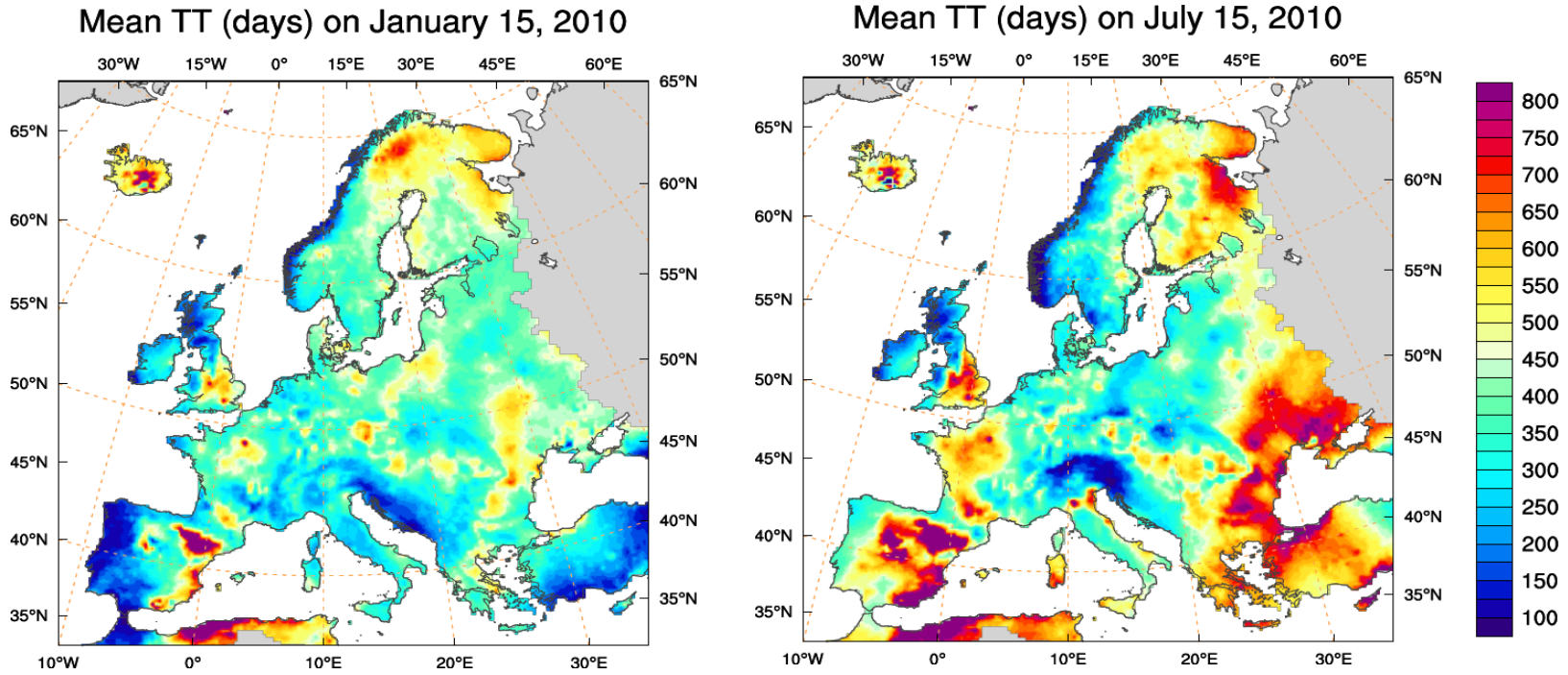
Recognition of the time-varying feature of TTs

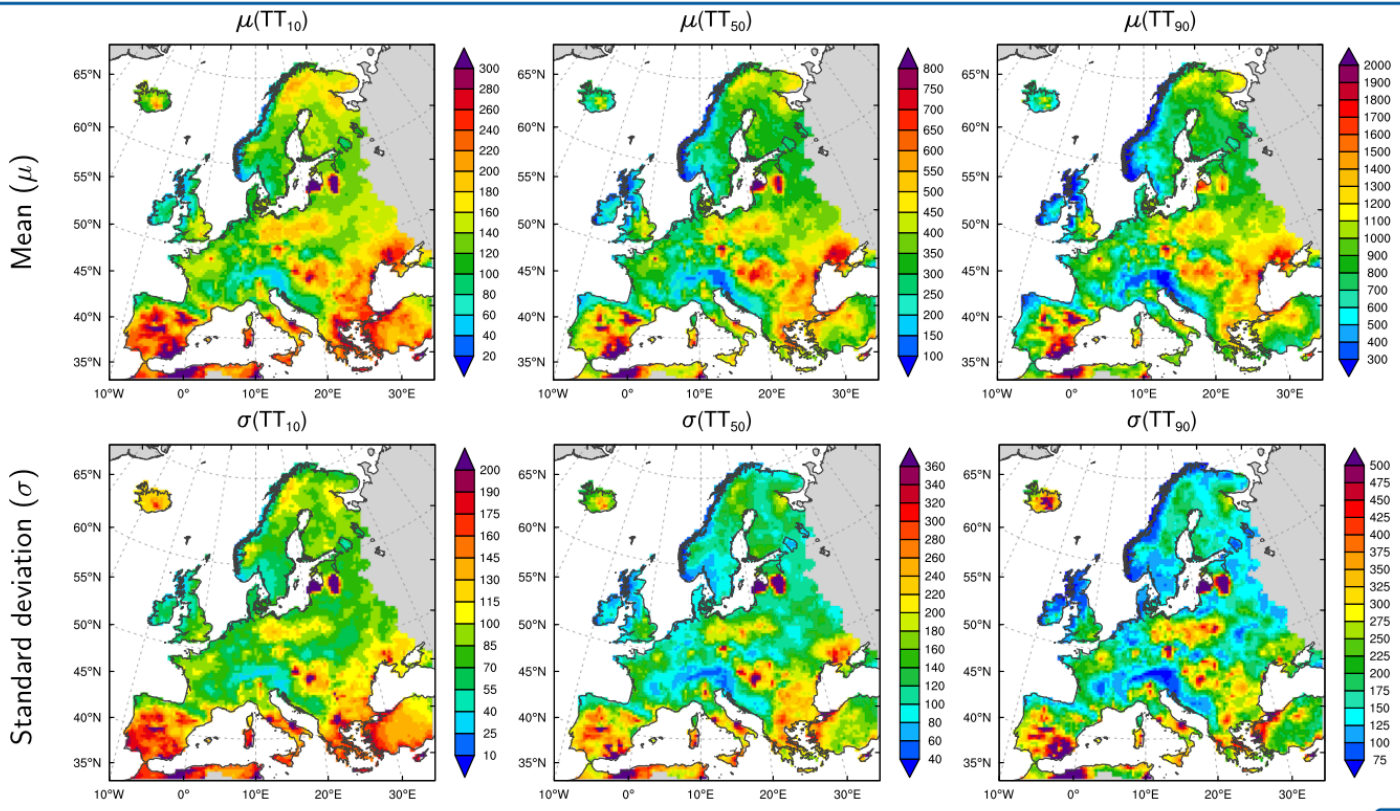
Space-time variability of TTs



Recognition of the space and time-varying feature of TTs

Summary of TTD statistical moments

(as mean and standard deviation of the daily TT_{10}, TT_{50} and TT_{90} [days])



Some take-home messages

- Combining recent developments in existing modeling approaches allow for the quantification of travel times at larger scales (Europe).

- Travel times characterizing the “intrinsic vulnerability” of a hydrologic system are highly heterogeneous in **space and time**; and therefore vulnerability assessments should therefore consider these dynamic aspects of hydrologic transport behaviors.