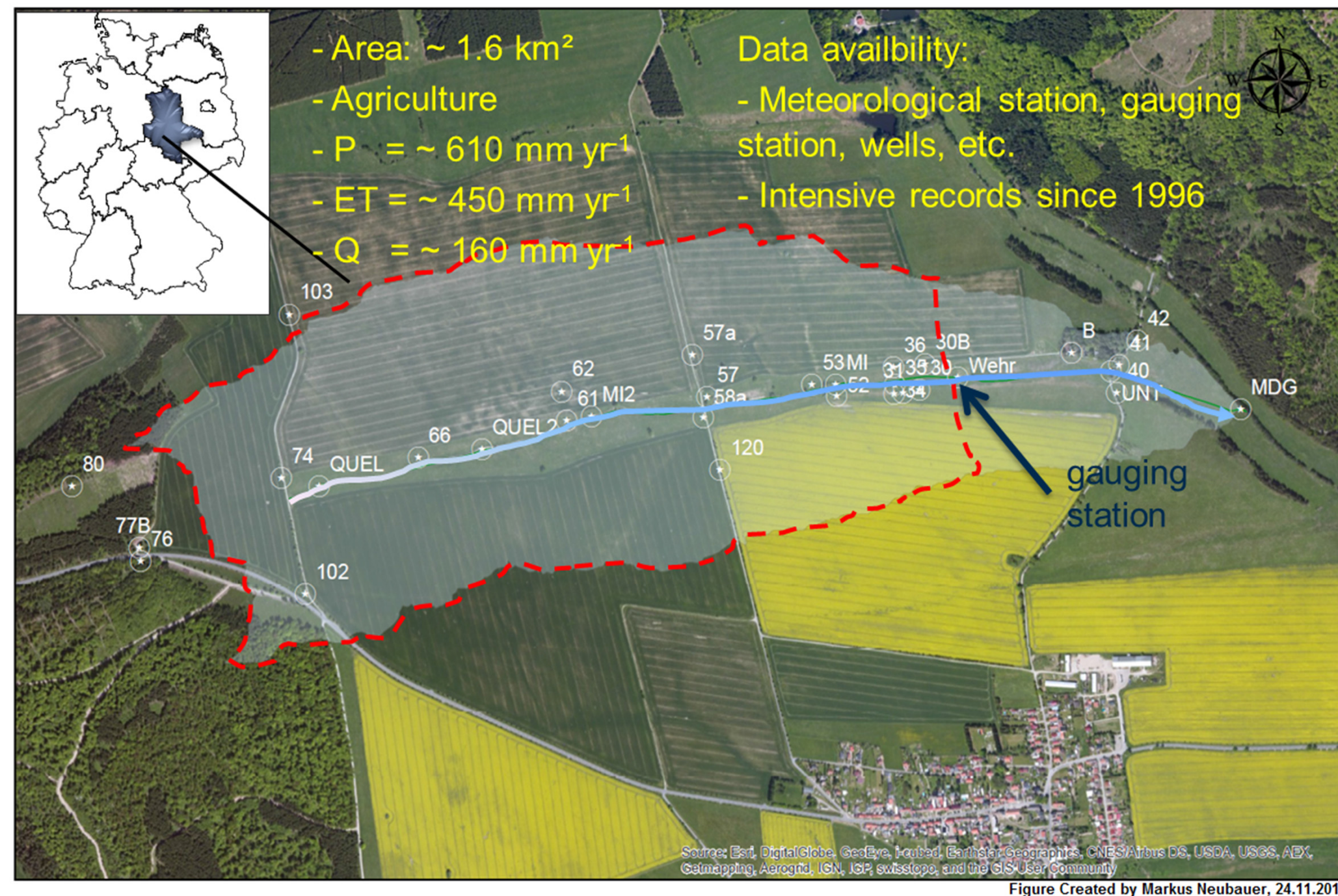# Using a physically-based water flow model to explore the dynamics of transit times and mixing in a small agricultural catchment

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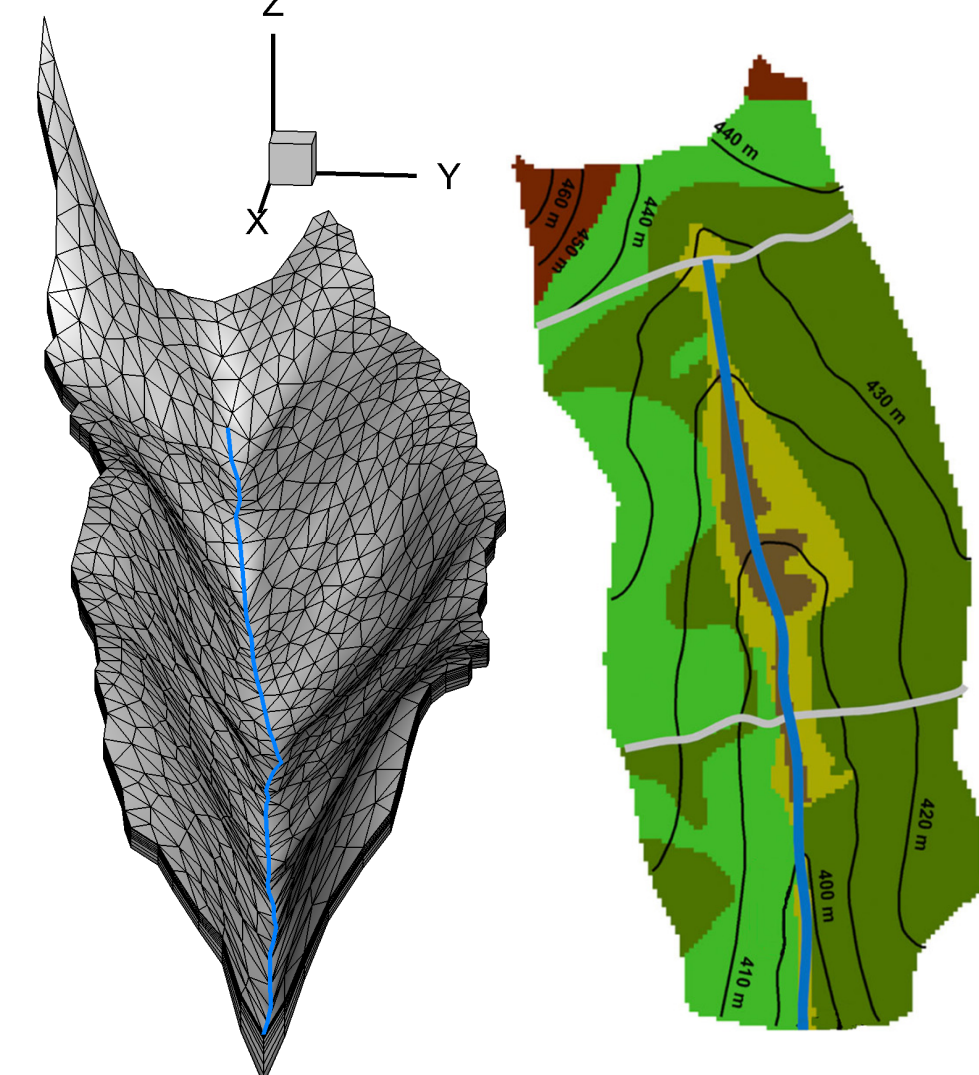Department of Hydrogeology, Helmholtz-Zentrum für Umweltforschung GmbH - UFZ, Leipzig, Germany

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Introduction

Study site: catchment Schäfertal

- Area: ~ 1.6 km²
- Agriculture
- P = ~ 610 mm yr^{-1}
- ET = ~ 450 mm yr^{-1}
- Q = ~ 160 mm yr^{-1}

Data availbility:
- Meteorological station, gauging station, wells, etc.
- Intensive records since 1996

gauging station

Method

Flow modelling:

Boundary conditions:
- Daily $P(t)$, 1998 -2007
- Daily $ET_{pot}(t)$, 1998-2007, estimated using Hydrus
- Daily $T(t)$, 1998-2007, for snow melt process
- Critical depth for outlet

Calibration:
- Using PEST
- to Discharge, water level
- 54 optimized parameters: K, porosity, roughness, parameters of snow melt & ET

HydroGeoSphere integeral modelling:
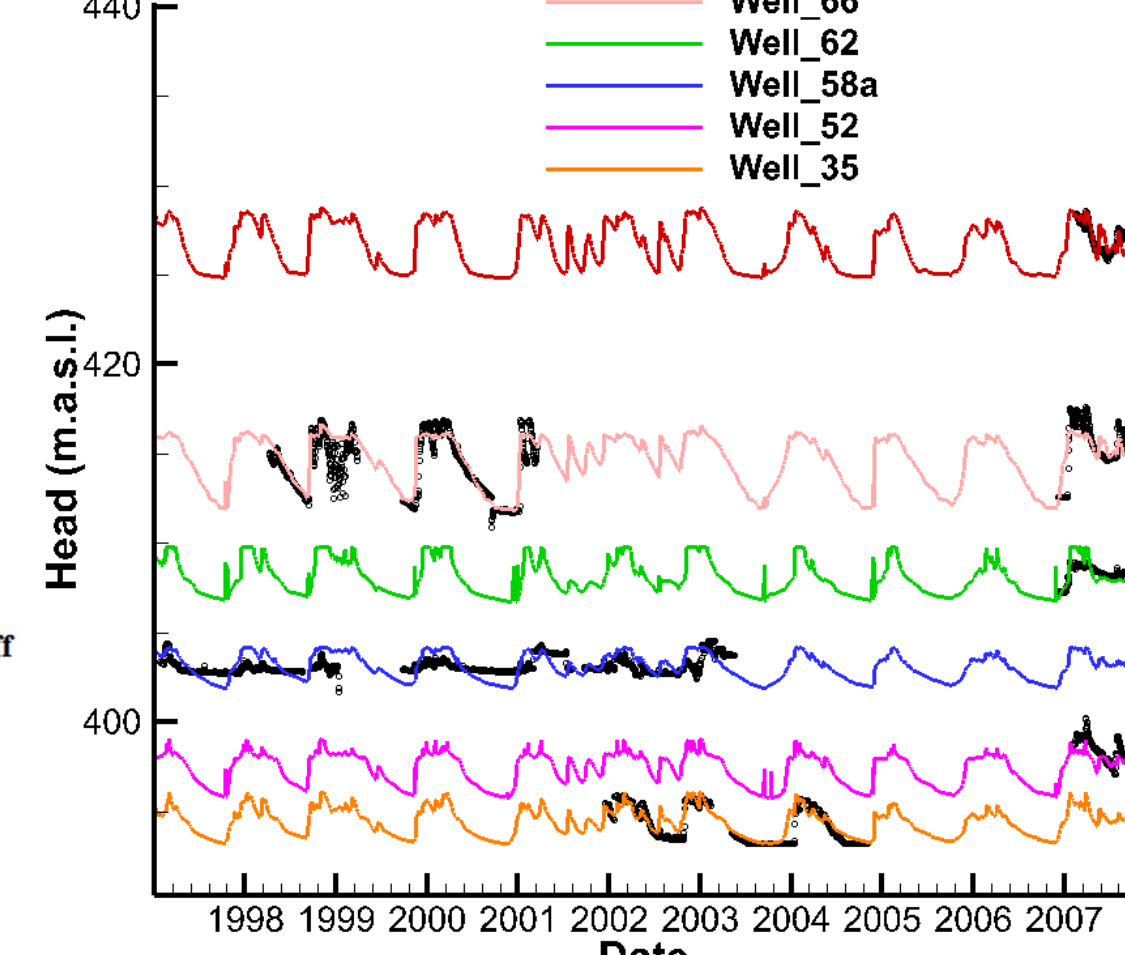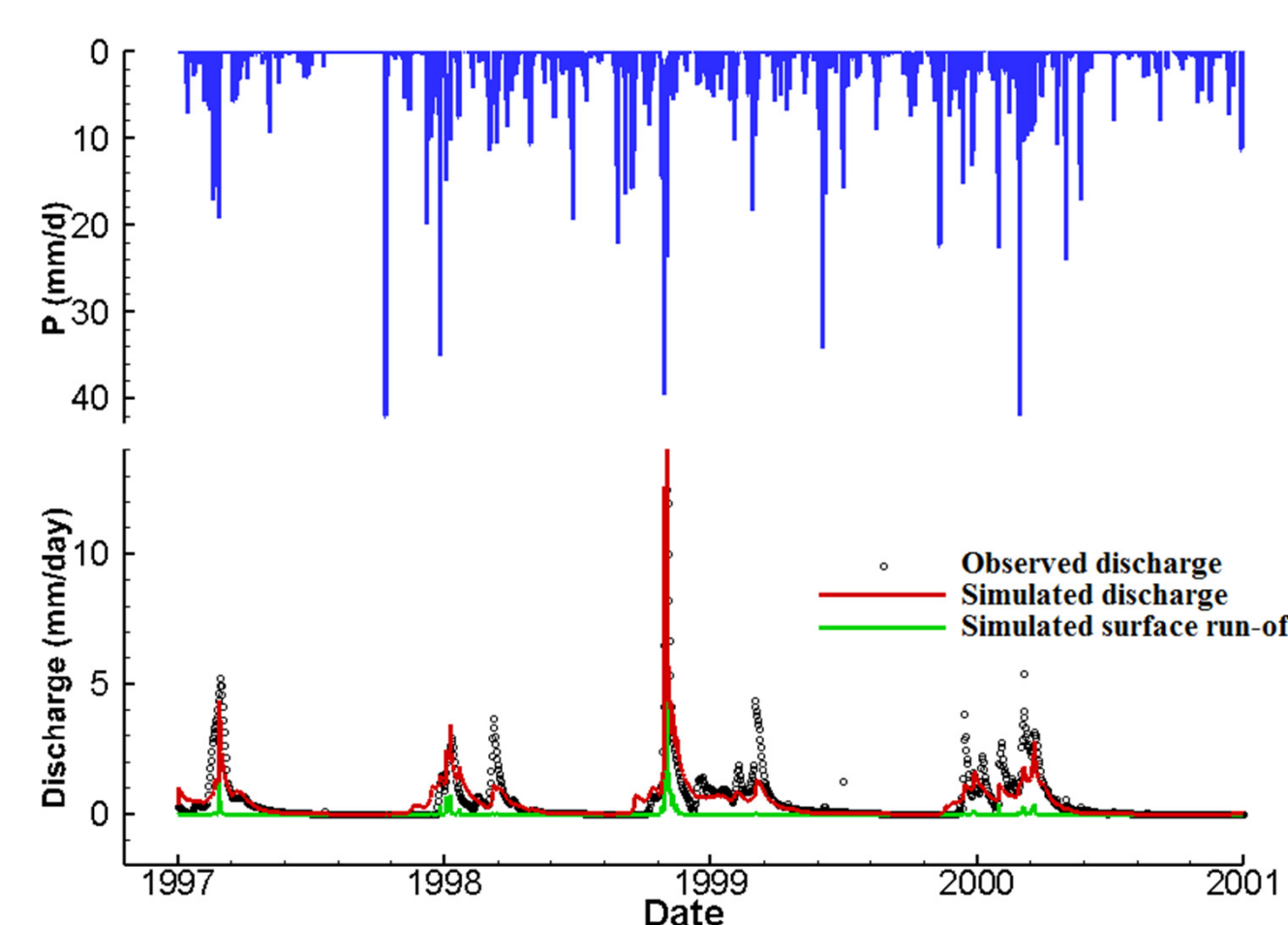- 3D Subsurface
- 2D Surface
- 1D Channel

Properties:
- 10 zones for subsurface property
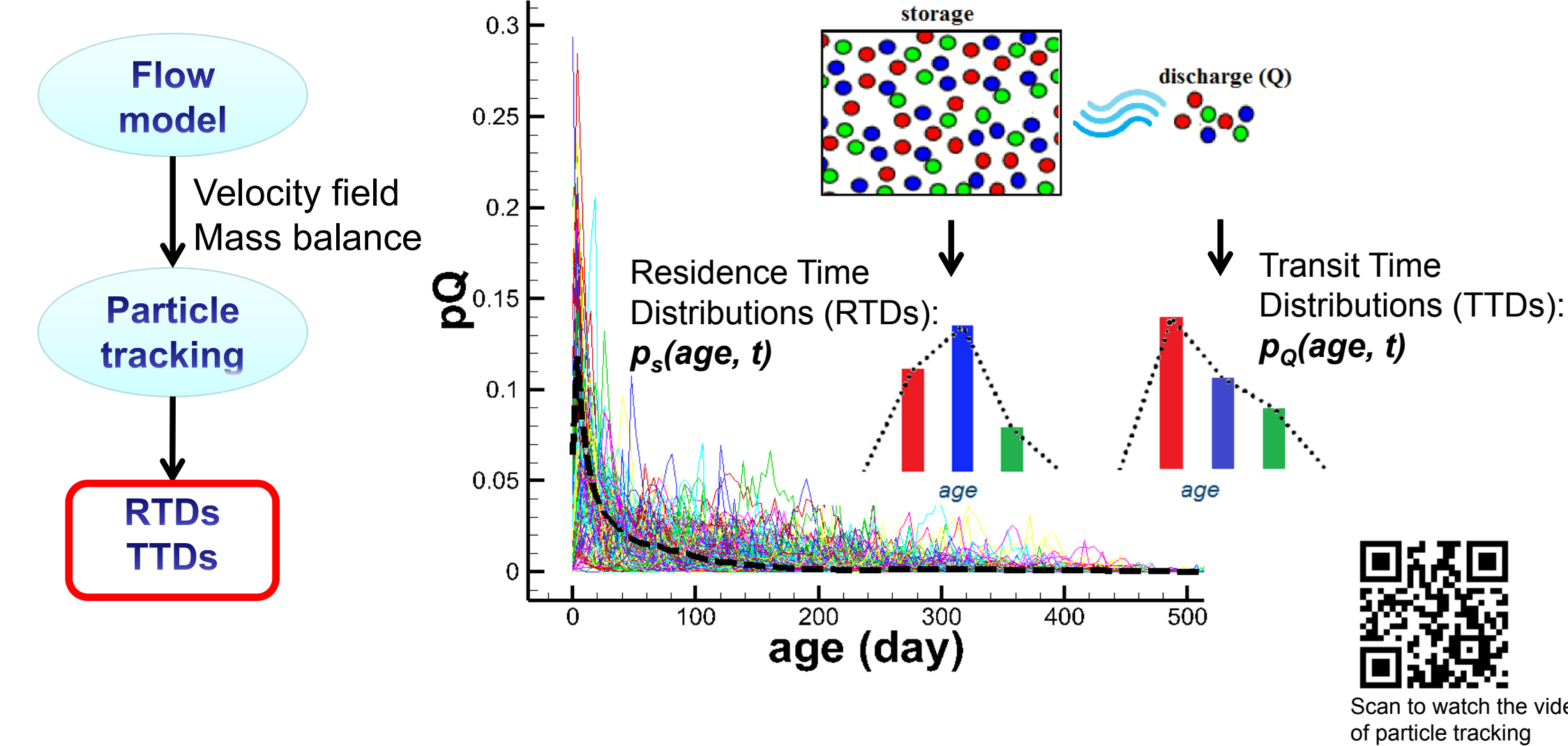- 7 zones for surface and ET according land usage

Soil Type
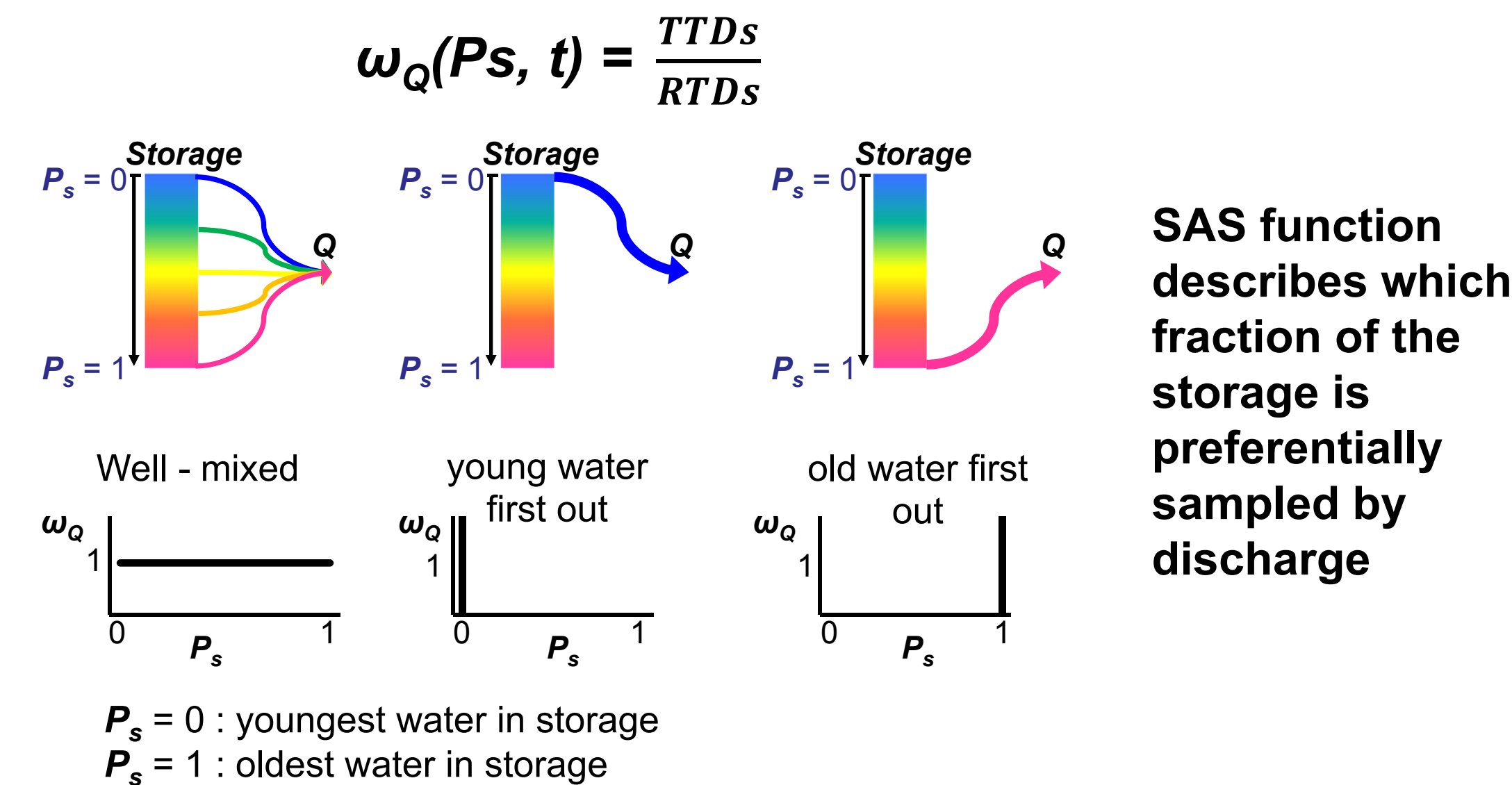- Cambisol
- Gleyic Cambisol
- Luvisol
- Fluvisol
- Gleysol

RTDs, TTDs computing:

Flow model → Velocity field / Mass balance → Particle tracking → RTDs TTDs

Residence Time Distributions (RTDs): $p_s(age, t)$

Transit Time Distributions (TTDs): $p_Q(age, t)$

Scan to watch the video of particle tracking

StorAge Selection (SAS) functions: $\omega_Q(P_s, t)$:

$$\omega_Q(Ps, t) = \frac{TTDs}{RTDs}$$

Well - mixed   young water first out   old water first out

P_s = 0 : youngest water in storage
P_s = 1 : oldest water in storage

SAS function describes which fraction of the storage is preferentially sampled by discharge

Results

Age distribution (30 Nov. 1998)

Saturation   age   velocity

Time = 699 d   Time = 699 d   Time = 699 d

Scan to watch the video

Age variation:

- Very young discharge and storage (mean ages less than 1 year)
- Discharge younger than storage overally
- Younger discharge and storage in wet time, older in dry time

Overall:
91 d
66 d
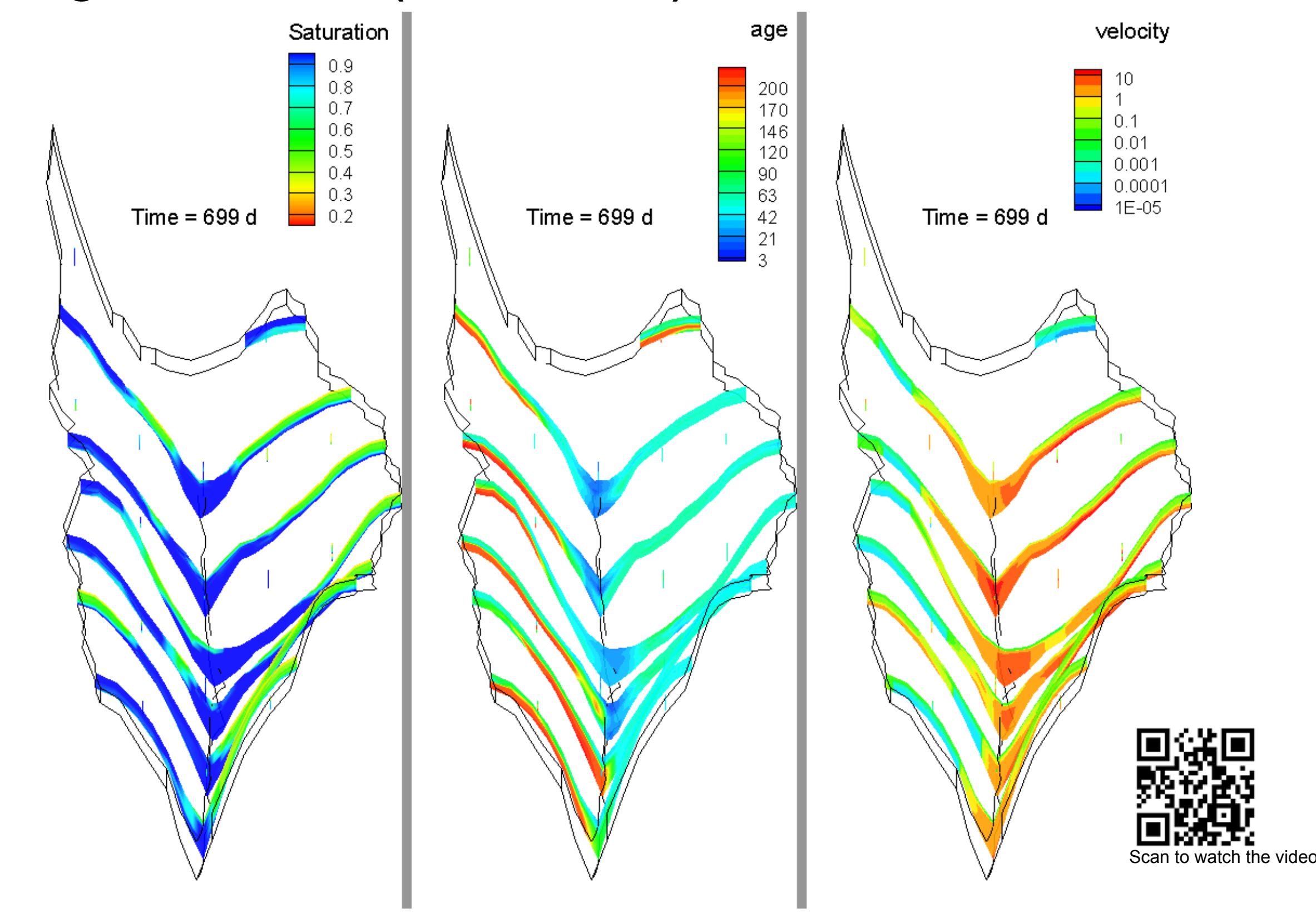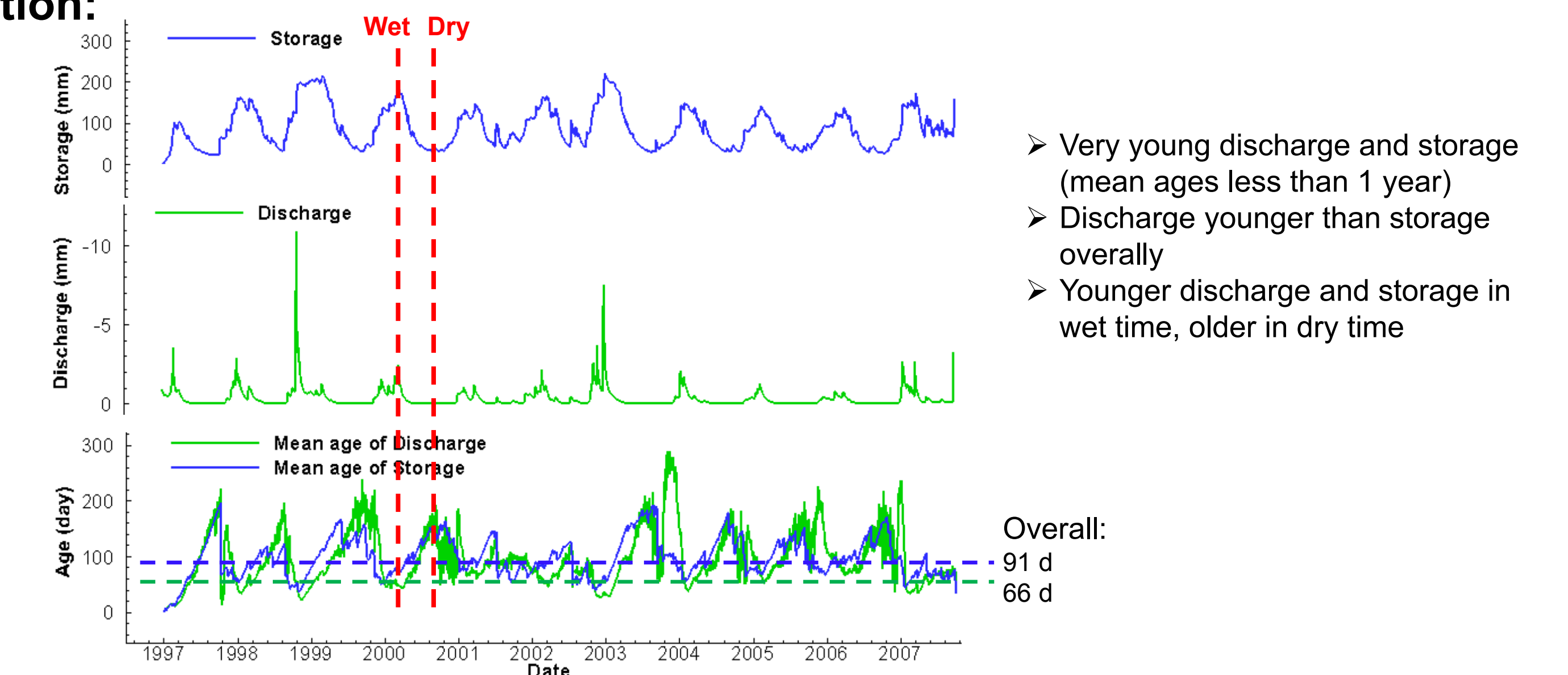
Age variation in year & Shift of discharge sampling preference in year:

- Variation between wet and dry months
- Younger discharge from January to June

A day of high storage (30 Nov. 1998)   A day of low storage (31 Jul. 1998)

Quick shallow flow path   Deeper flow path

(Crosssectional view)

Darcy velocity (m/d)

- SAS functions shift between two phases.
  Phase 1:
  - Older water preferred, July - December, 10% of annual discharge
  Phase 2 (dominating):
  - Younger water preferred, January - June, 90% of annual discharge

- Active quick shallow flow path triggers: **Phase 1** → **Phase 2**
- Deactive quick shallow flow path triggers: **Phase 2** → **Phase 1**

Age variation between years & Shift of discharge sampling preference between years:

- Discharge much younger than storage in wet years (1999, 2003), compared to dry years

- Higher posibility to discharge young water in wet years

- SAS functions shift from wet years to dry years
- Higher posibility to discharge young water in wet years
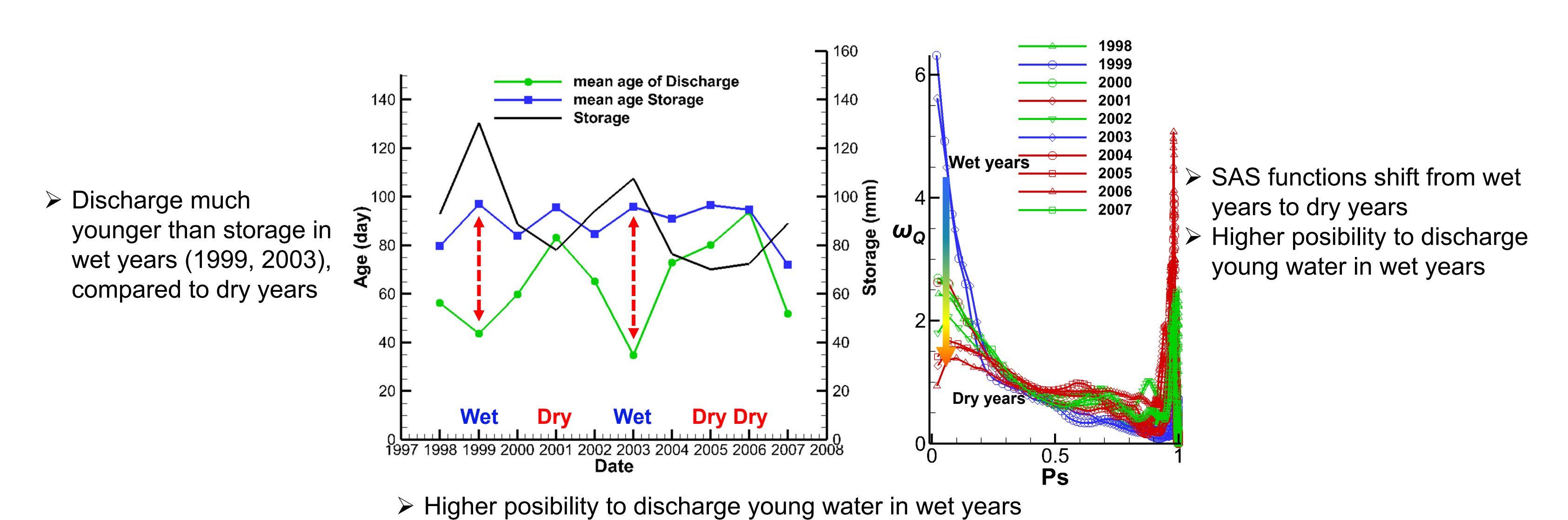
References:

Rinaldo, A., Benettin P, Harman CJ, Hrachowitz M, McGuire KJ, van der Velde Y, Bertuzzo E, Botter G, 2015. Storage selection functions: A coherent framework for quantifying how catchments store and release water and solutes. Water Resource Research. 51, 4840–4847.

Harman CJ, 2015. Time-variable transit time distributions and transport: Theory and application to storage-dependent transport of chloride in a watershed. Water Resource Research. 51, 1-30.

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