- **We applied end-member mixing to a 10 km² agricultural catchment in a Dutch deep polder**
- **In extension of classical EMMA[1,2], we applied end-member mixing within a Monte-Carlo framework**
- **Borrowing from the GLUE methodology[3], non-behavioural parameter sets were discarded and we analyzed the posterior parameter sets**
- **This approach not only quantified the uncertainty surrounding the analysis, but revealed catchment processes otherwise overlooked**

Deltares

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Uncertainty in mixing models: a blessing in disguise?

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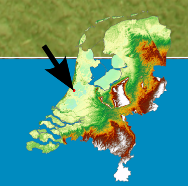

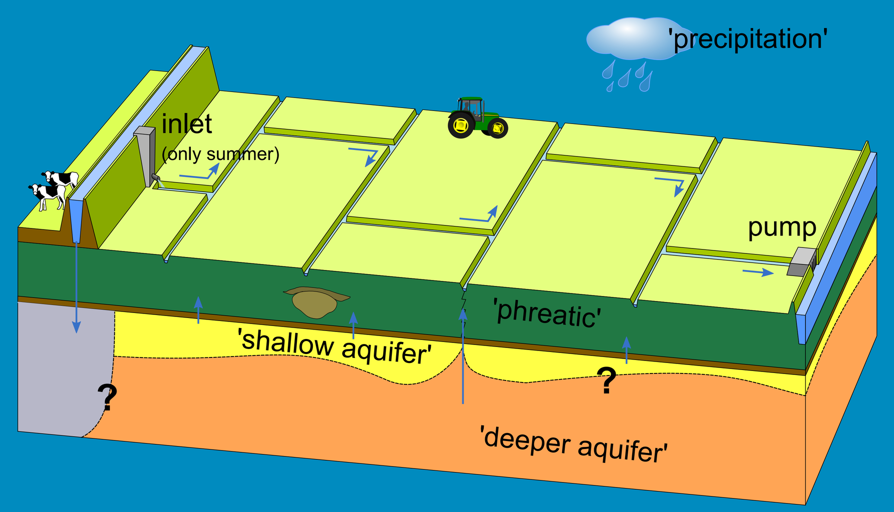

Figure 1: Schematic representation of catchment and discerned end-members (quoted)

Study Area

- 10 km² agricultural catchment
- Dutch coastal zone
- Deep polder, 4 m below MSL
- Artificially drained
- Waterquality affected by brackish seepage

Geohydrology

- 7m confining layer (peat/clay)
- Thick Pleistocene aquifer
- Groundwater saline due to Holocene transgressions
- Groundwater flows upwards
- Seepage mostly concentrated in boils[4]

Methods

Discharge was automatically sampled every pumping cycle from 11 October 2011 onwards. End-members were sampled with different spatial and temporal frequencies.

Samples were analyzed for major anions, cations, alkalinity, pH and EC using standard methods.

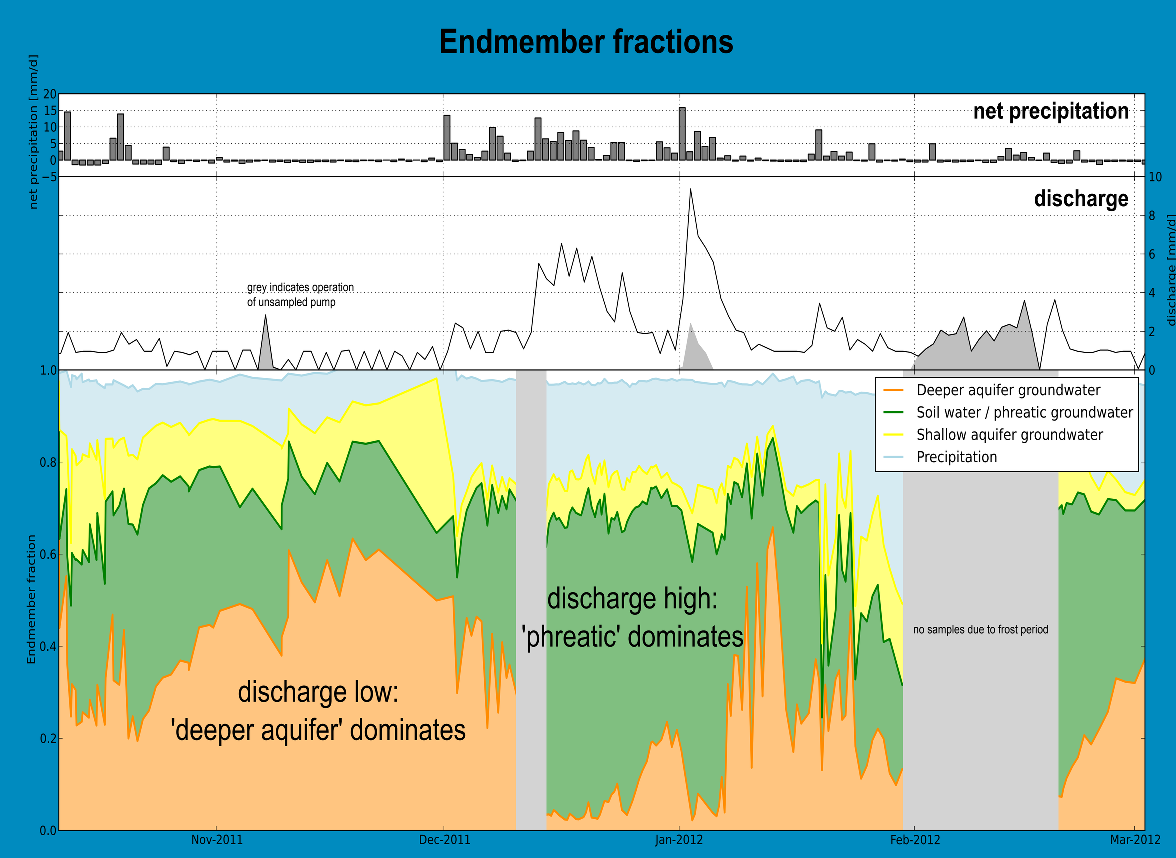

Figure 2: Net precipitation, discharge and calculated median end-member contributions

Mixing model approach

The diagnostic tools of Hooper[2] were first applied to choose suitable solutes and dimensionality.

Distribution functions for solutes were constructed from the variation between samples (end-members), or the analytical uncertainty (stream water). All concentrations were standardized by the mean and standard deviation of the stream water data set.

In a Monte-Carlo approach, end-member and stream water concentrations were randomly selected from the distributions. End-member fractions were calculated using the least squares solution to the overdetermined problem.

Parameter sets were deemed behavioural when ∑ residuals ≤ n solutes * 0.1 (10% of standardized st. deviations)

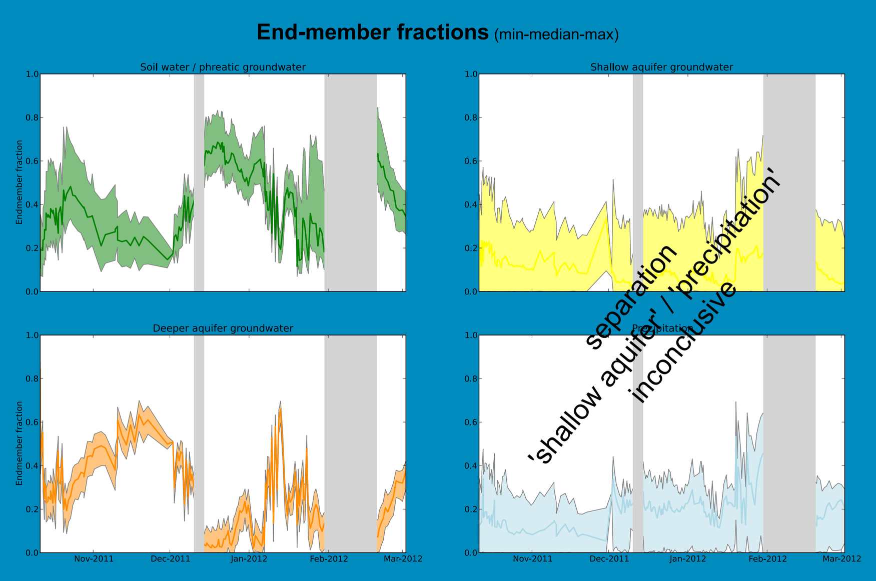

Figure 3: End-member fractions including uncertainty range (min - median - max)

Results

Figure 2 shows the catchment response based on the end-member analysis. During low-flow periods the contribution of the deeper aquifer water dominates, whereas phreatic groundwater dominates the stream water after precipitation events.

The uncertainty surrounding the calculated end-member fractions is shown in Figure 3. The contribution of the deeper groundwater end-member is the most certain, shallow aquifer and precipitation the least certain.

Figure 4 shows the posterior behavioural concentration distribution of the solutes of the end-member 'Phreatic groundwater'. Sulphate, silicium, calcium and strontium were reasonably well identified, apparent from the decrease in the posterior concentration range. Chloride and bromide however were not, as their concentration range is far below the range in the end-member 'Deeper aquifer groundwater'.

The identified solutes show a feasible temporal pattern: if the contribution of 'Phreatic groundwater' increases during wet periods, concentrations of sulphate and strontium decrease, signaling the influence of precipitation infiltrating in the soil.

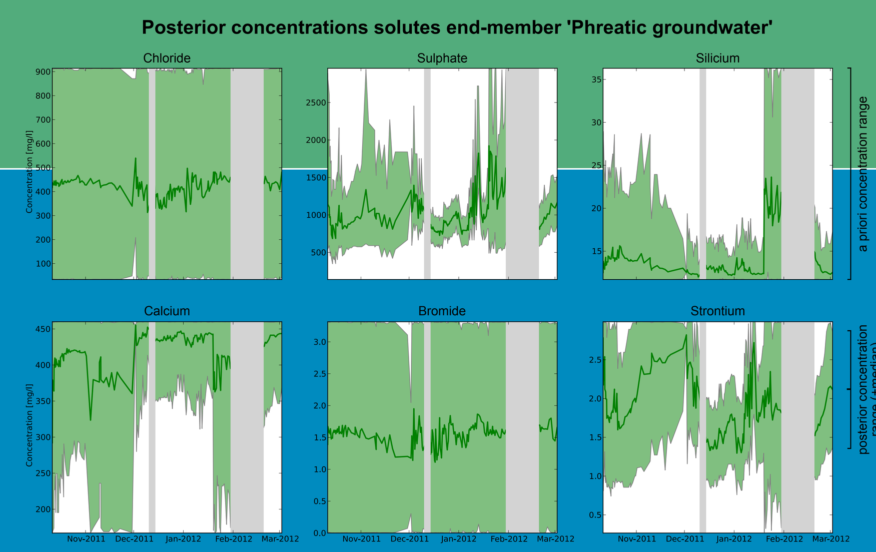

Figure 4: Posterior solute concentrations (min - median - max) of end-member 'Phreatic groundwater', scale of y-axis denotes prior concentration range

Conclusions

- Catchment response could be well identified using environmental tracers and end-member mixing
- Application of a Monte-Carlo framework quantified the associated uncertainty
- Investigating the behaviourial posterior end-member concentrations indicated temporal variations in solute concentrations
- The proposed method of end-member mixing allows for:
  - quantification of uncertainty
  - simultaneous evaluation of different conceptual models (not presented)
  - investigation of temporal patterns in end-member solute concentrations

References:
(1) Christophersen & Hooper, 1992, WRR
(2) Hooper, 2003, WRR
(3) Beven & Binley, 1992, HP
(4) De Louw et al., 2010, JoH
(5) Joerin et al., 2002, JoH

Knowledge for Climate

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