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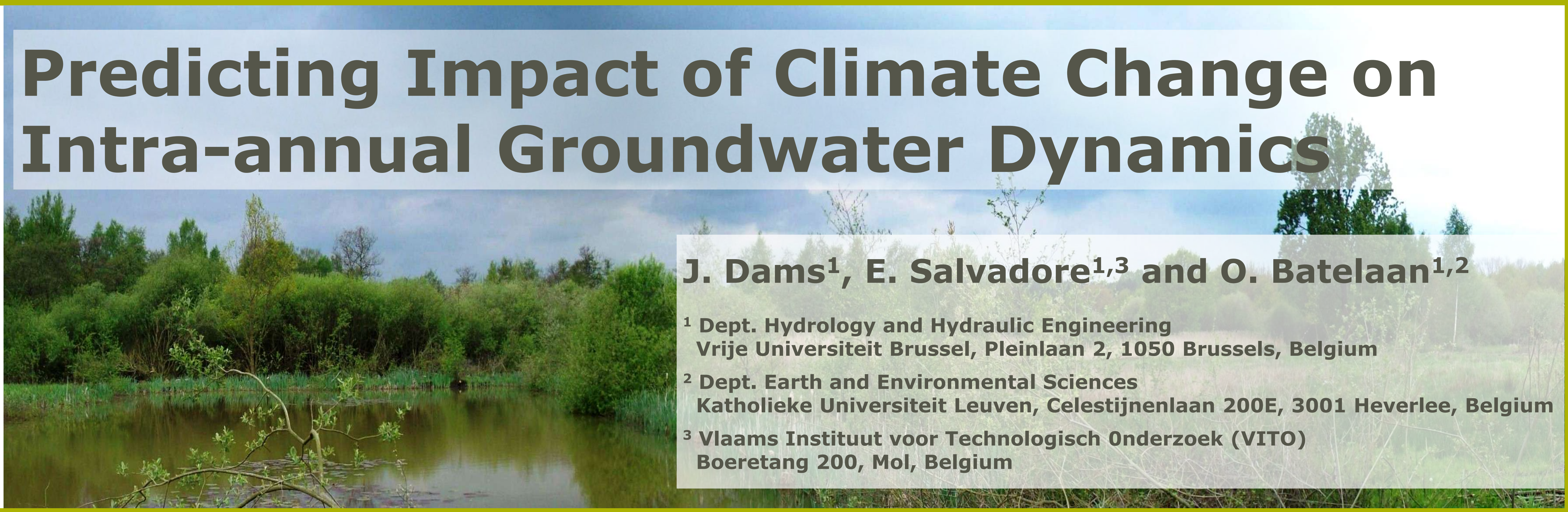

Predicting Impact of Climate Change on Intra-annual Groundwater Dynamics

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1. Objectives

There is growing evidence that climate is changing due to human emissions of greenhouse gases. **Freshwater resources**, such as groundwater, are **particularly vulnerable to climate changes**. Groundwater is a major source of drinking water and plays a vital role in maintaining the ecological value of many areas. Our objective is to **assess the impact of climate change scenarios on groundwater resources and fluxes**, including their intra-annual variability.

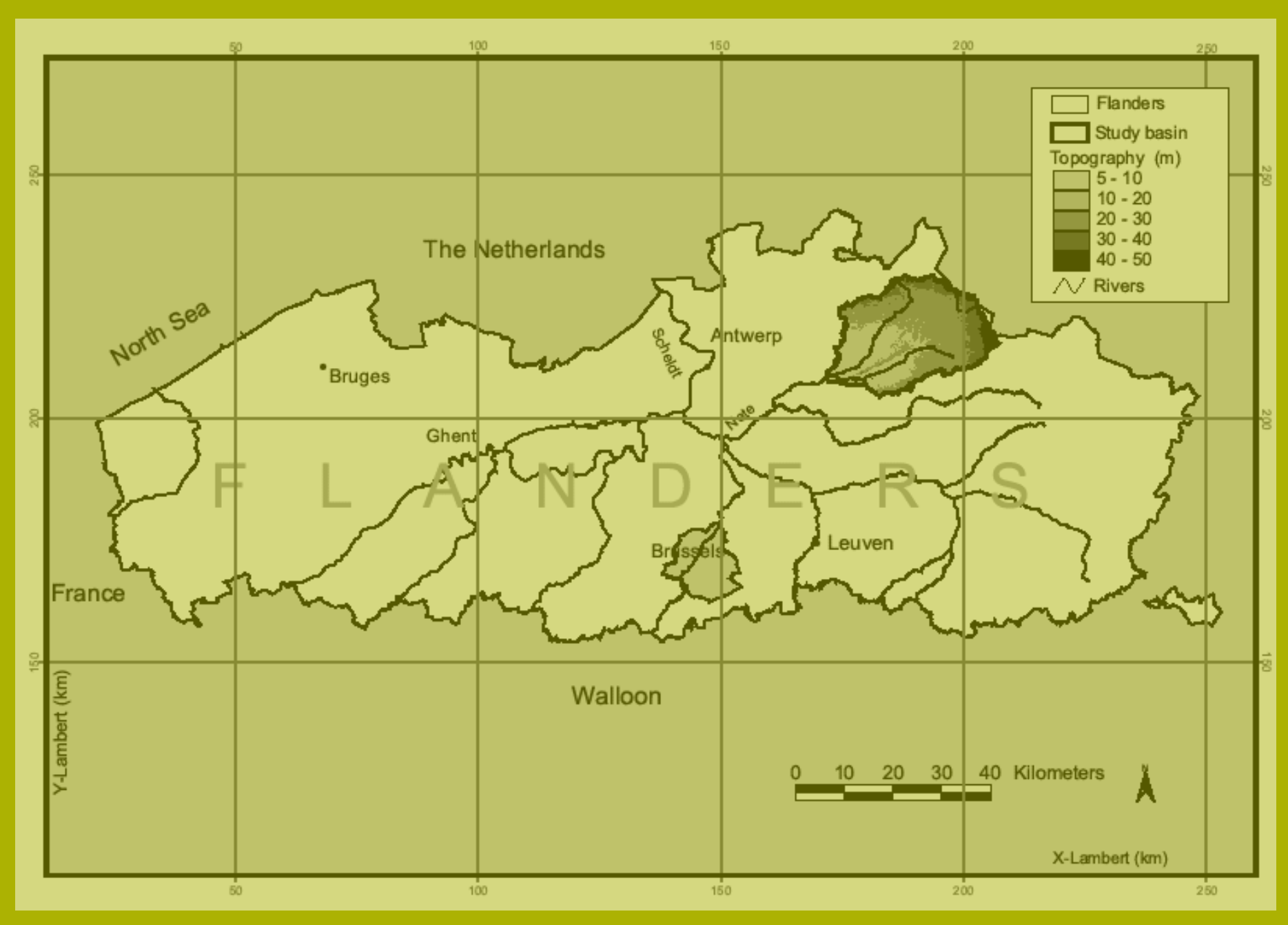

Fig. 1: Location of the study area: Kleine Nete basin – Belgium.

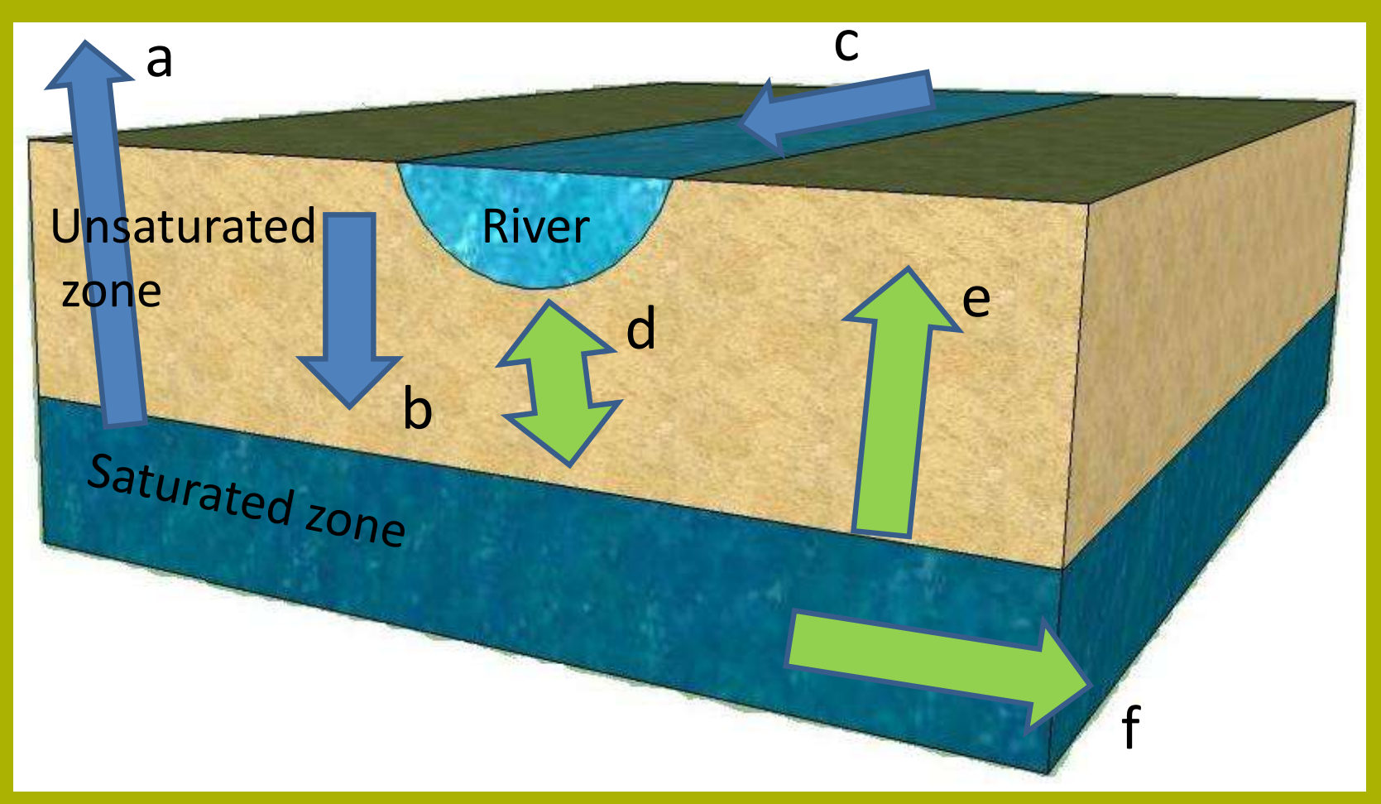

Fig. 2: Overview of the hydrological processes influencing the groundwater system: evapotranspiration from the groundwater reservoir (a), groundwater recharge (b), river head (c), river leakage/drainage (d), groundwater seepage (e) and groundwater flow (f). Flows shown in blue are calculated with the WetSpa model, flows shown in green are calculated with MODFLOW.

2. Methodology

To represent the uncertainty of climate change **twenty-eight scenarios were selected from the PRUDENCE database** (Christensen & Christensen, 2007). These scenarios combine several General and Regional Circulation Models and are based on the A2 and B2 SRES scenarios (Nakicenovic et al., 2000).

The impact of climate change on the groundwater system is calculated by applying a **coupled WetSpa – MODFLOW approach**. WetSpa (Liu et al., 2003), a physically based distributed hydrological model, estimates discharge and head for the main rivers in the basin and groundwater recharge for each 50 by 50 meter raster cell in the watershed. MODFLOW (Harbaugh and McDonald, 2000) simulates the effect of climate induced changes in river head and groundwater recharge on groundwater resources and fluxes. Figure 2 shows an overview of the involved processes.

3. PET and precipitation change

The average yearly **potential evapotranspiration** (PET) of 664 mm/year, measured during the reference period 1960-1991, is **predicted to increase with almost 30%** with a standard deviation between the 28 scenarios of 91 mm/year. The increase in PET occurs mainly between April and October (Fig. 3a).

From October to April the precipitation is expected to increase on average 50 mm while from May to September the precipitation drops about 100 mm. Annually, the precipitation will decrease from on average 821 to 771 mm/year with a standard deviation between the different scenarios of 35 mm.

4. Groundwater Recharge, Head and Flux

The yearly groundwater recharge pattern is shown in Figure 3c. The already low groundwater recharge during summer is expected to decrease even more in the future due to higher evapotranspiration and lower precipitation. On the other hand, during winter the increase in precipitation will cause more groundwater recharge. On average the **groundwater recharge is predicted to decrease about 40 mm during summer and increase about 20 mm during winter** resulting in an overall decrease from 278 to 258 mm/year with a standard deviation between the scenarios of 20 mm.

In early spring both average groundwater head and discharge are close to the values simulated for the reference period (Fig. 3d & 3e). **During summer** however, the climate scenarios predict a **faster and longer depletion of groundwater storage** and a stronger decrease of groundwater discharge. On the other hand, due to the increase in recharge, the raise in groundwater head and discharge during autumn is predicted to be more profound. By 2100 the annual average groundwater head declines about 7 cm. The **groundwater discharge** is than forecasted to **decrease with more then 10% in the August to December period**.

5. Conclusions and Recommendations

In conclusion, we proved that climate change scenarios predict a decrease in summer groundwater recharge causing lower groundwater resources and lower groundwater discharge fluxes especially during September and December. The increase in precipitation during winter causes groundwater head an flux to be only slightly less during April and May. The **lower availability of groundwater at the end of the summer** period could harm groundwater dependent terrestrial ecosystems. Wherever possible, **measures should be taken to prevent ecological loss** due to these low summer groundwater levels. As an adaptive measure for climate change **we recommend to increase summer recharge by reducing surface runoff**.

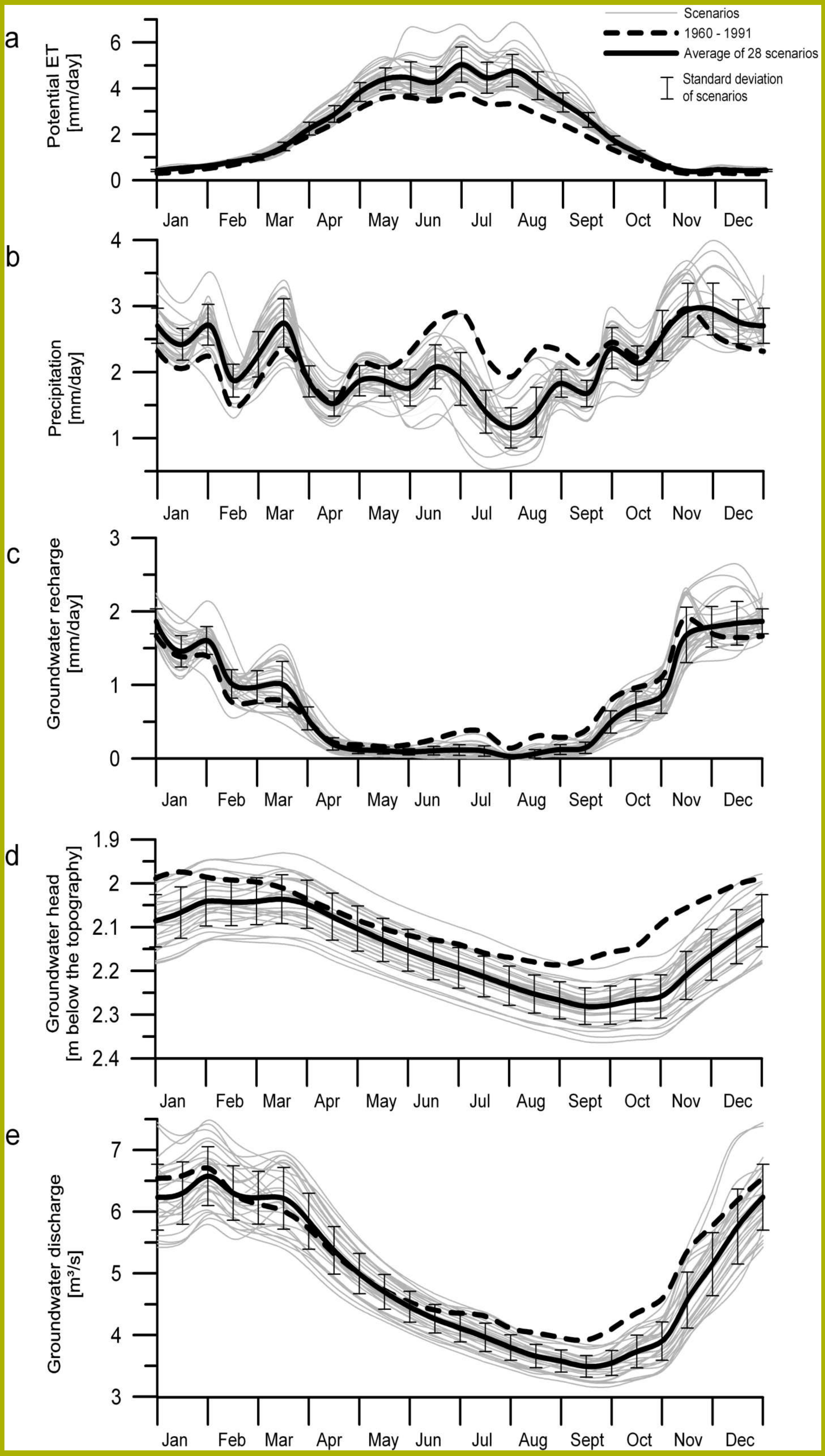

Fig. 3: Average intra-annual variability of PET (a), precipitation (b), groundwater recharge (c), groundwater head (d) and groundwater discharge (e) for the reference climate (1960-1991), the climate scenarios (2071-2100) and the average of the climate scenarios. One year is divided in 24 half monthly timesteps, for each timestep the average value of the 32 modeled years is presented. Error bars represent the standard deviaton between the climate change scenarios.

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