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Evaluation of soil water budget over the Iberian Peninsula using PRUDENCE regional climate simulations

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The various components of the soil water budget are evaluated over the Iberian Peninsula (IP) for both a control climate (1961-1990) period and future projection scenarios (2070-2100) using the regional climate models (RCMs) simulations conducted in the context the EU-funded PRUDENCE project (Prediction of Regional Scenarios and Uncertainties for Defining European Climate Change Risks and Effects; see http://prudence.dmi.dk/) (Christensen and Christensen, 2006).

The ten RCMs are shown with the name of their institutions (see Jacob et al. 2006 for details of the models) in the Table. The RCM simulations were conducted at a horizontal resolution of about 50 km. The lateral boundary conditions for all RCMs were provided by the global climate model (GCM) HadAM3H, in addition DMI and SMHI RCMs were also run with the GCM ECHAM4 lateral boundary conditions, and the lower (sea-surface) boundary conditions were taken from observations and HadCM3. A few RCMs have used a slightly different setup within PRUDENCE. The RCM CNRM is a global model with a stretched grid that does not require lateral boundary fields, and therefore only uses the SST as climate forcing. The RCM HC uses boundary conditions obtained with HadAM3P, which is a slightly modified version of the atmospheric GCM HadAM3H. All models have been run for a control period, 1961-1990, and a future scenario period, 2071-2100, following the A2 emission scenario from IPCC (Nakicenovic et al., 2000). Five RCMs were also run for 2071-2100 under the B2 emission scenario (see Table).

Table

	GCM					
	HadAM3H			ECHAM4		
RCM	Control	A2	B2	Control	A2	B2
DMI	X	X	X	X	X	X
ETH	X	X				
GKSS	X	X				
HC	X	X				
ICTP	X	X	X			
KNMI	X	X				
MPI	X	X				
SMHI	X	X	X	X	X	X
UCM	X	X	X			
CNRM	X	X	X			

SMHI(HadAM3H) = SMHI_H SMHI(ECHAM4) = SMHI_E
DMI(HadAM3H) = DMI_H DMI(ECHAM4) = DMI_E

CONTROL CLIMATE PERIOD (1961-1990)

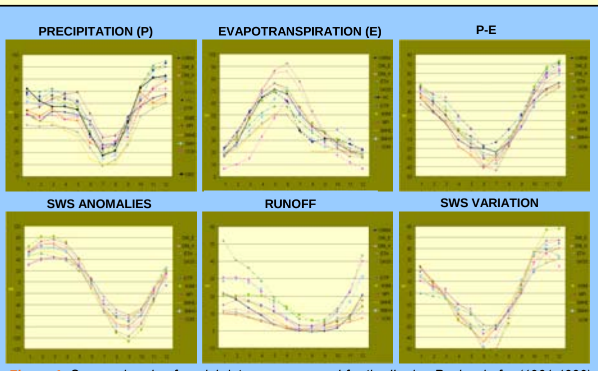

Figure 1. Seasonal cycle of model data area-averaged for the Iberian Peninsula for (1961-1990). (SWS anomalies are soil water storage differences respect to the annual mean value)

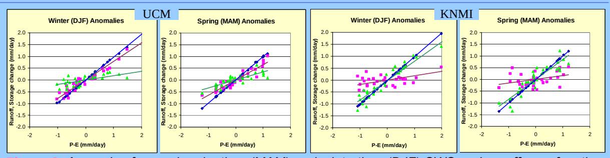

Figure 2. Anomaly of annual springtime (MAM) and wintertime (DJF) SWS and runoff as a function of the anomaly of P-E in Iberian Peninsula for model simulations from UCM and KNMI models for control period (1961-1990). Runoff anomalies: purple points and lines; SWS anomalies: green points and lines; summation of anomalies of runoff and SWS: blue points and lines.

From *Figure 1* , showing the monthly mean water budget components, follows:

Most models reproduce acceptably well the observed annual precipitation cycle (**OBS** in the figure) evaluated by Nieto and Rodríguez-Puebla (2006), although they tend to show an annual cycle range lower than the evaluated one: too high **precipitation** in summer and spring; too low in autumn and January.

The modeled RCM **evapotranspiration** shows strong divergence in spring and summer time. Higher summertime **precipitation** in some models is compensated by higher modeled evaporative loss, showing **P-E** lower divergence. In winter season, all RCMs have a similar evapotranspiration, except UCM that has a very low evapotranspiration from October to May.

The partitioning of the **net water flux into the soil (P-E)** into **soil water storage (SWS) change** and **runoff** is an important property of the hydrological system. The water put into runoff is lost and cannot be reevaporated locally, while the soil water content is a storage buffer available for later evaporation or runoff generation. **The behaviour** of models in terms of runoff estimation is quite different from that in terms of precipitation, indicating a strong soil control (via evapotranspiration or storage) on the runoff characteristics. In order to see the role of the soil hydrological memory in the hydrological partitioning process, the interannual variability of water budget terms must be considered. In *Figure 2* (following van den Hurk et al., 2005) the anomalies of annual springtime and wintertime **terrestrial water storage** and **runoff** as a function of the anomaly of **P-E** in Iberian Peninsula (IP) are shown for control simulations from KNMI and UCM models. In KNMI model anomalous water supplies are primarily buffered in the soil giving rise to a fairly small average annual cycle runoff. In summer the storage range has on average a large uptake capacity, and anomalies in P-E are rapidly absorbed in the soil. In wintertime, this buffer capacity is less and a there exists a stronger preference for discharge. However, the discharge response is still the smaller component in the partitioning of P-E anomalies. In UCM model, on the contrary, runoff is the principal destination of anomalous water supplies. Most models present a weak runoff seasonal cycle with maximum in winter. GKSS has a high runoff cycle range caused by high precipitation and saturated soil in winter. UCM and SMHI-H show too a high runoff range due to both a small storage capacity and a preference of runoff as principal destination of anomalous water supplies.

PROJECTIONS 2071-2100

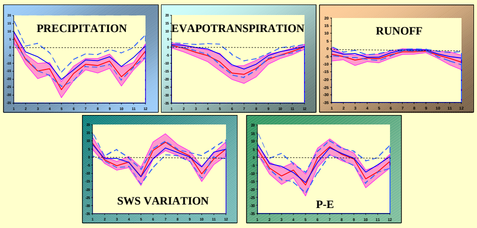

Figure 3. Mean differences in average annual cycle of water budget terms averaged for all RCMs over the Iberian Peninsula between both A2 (red heavy solid line) and B2 (blue solid line) projections and control simulations and their uncertainties (defined by strips with mean value ±σ; A2 red hatched; B2 bounded by dash blue lines)

From *Figure 3*, displaying the mean differences in average annual cycles between two scenarios and control over the IP, follows:

For **A2**: Less monthly mean **precipitation** except in January, particularly important in May, strengthening the annual cycle range. The little diminution in summer is due to the scarcity of precipitation in great areas of the IP in the control period inclusive. **Evapotranspiration** decreases most of months, mainly in summer caused by a strong reduction of SWS (not shown), decreasing the strength of its annual cycle. Intermodel differences in evapotranspiration are most pronounced in summer, when parameterized soil process control the water loss to the atmosphere. In summer the decrease of evaporation is larger than the decrease of precipitation (except for both UCM and GKSS). All models show a notable decrease of **P-E** in May, another one smaller in October, and most of them an increase in summer. **Runoff** decreases all the year around but, as expected, variation is very small in summer.

For **B2**: The simulated changes are lower for B2 than for A2 scenario, although with some slight differences

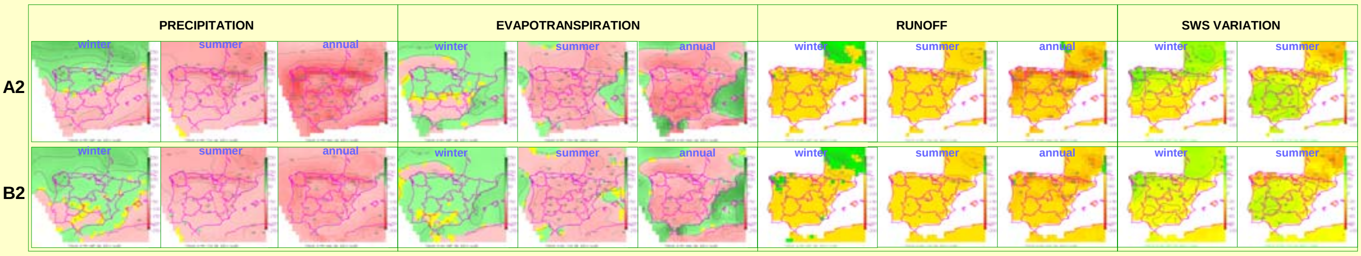

Figure 4. Mean differences of water budget terms (P, E, runoff and SWS variation) between A2 (top), B2 (down) projections and control simulations, averaged over all RCMs for winter, summer and annual mean

From *Figure 4*, where spatial changes of the water budget terms are represented, it can be highlighted:
For **A2**:

- Weakening of hydrological cycle over the IP with **decreasing annual means** for precipitation (~ 200 mm at north and ~ 100-150 mm at south), evaporation (~50 mm at north and ~100 mm at south) and runoff (~ 100-150 mm at north and less than 50 mm at south).
- Considering also *Figure 1*, the **amplitude of annual cycle** for: (i) precipitation increases at NW and decreases at south, (ii) evapotranspiration decreases everywhere, (iii) runoff slightly changes everywhere and (iv) soil water storage variation increases at north and northwest and decreases at center and at southwest.

For **B2**: Regional distributions are similar to the A2 scenario, but weakening of the hydrological cycle is smaller.

Although only two of the PRUDENCE RCMs (DMI and SMHI) have been driven by two different GCMs (Table), the influence of GCMs on its results can be inferred from *Figure 5*, where the variations of precipitation and runoff between A2 scenario and control are shown: GCMs have greater influence on precipitation, whereas soil parameterization, own for each RCM, has a primary influence on runoff.

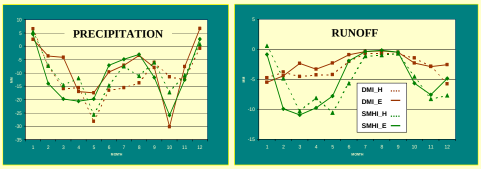

Figure 5. Differences in average precipitation and runoff over the Iberian Peninsula between A2 and control simulations for DMI (brown lines) and SMHI (green lines) models driven by two GCMs: HadAM3H (dash lines) and ECHAM4 (solid lines)

CONCLUSIONS

For control climate period (1961-1990): Most models reproduce acceptably well the observed annual cycle of precipitation. Strong divergence among modeled RCM evapotranspiration appears in spring and summer time. The partitioning of the net water flux into the soil over the soil water storage change and runoff depends on the surface parameterization of each RCM.

For 2071-2100 projections: All water budget terms (precipitation, evapotranspiration, runoff and soil water storage) averaged over all RCMs show a noticeable decrease, with notable differences between North-Atlantic and others regions of the Iberian Peninsula. The magnitudes of these changes of the hydrological cycle terms depends on:

a) The emission scenario followed, being stronger for A2 than for B2.

b) The GCM driver, showing greater influence over precipitation.

c) The surface parameterizations of each RCM, controlling mainly soil water storage change, runoff and summer evaporation; the convective parameterization, controlling precipitation in warm season.

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