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Comparison of Modelled Soil Moisture Drought of Two Land Surface Models

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Introduction

Drought early warning is of high importance in the context of prevention of damage to agricultural crops, and related effects on food security. Land surface models (LSMs) can be used to predict drought when combined with weather and climate forecasting systems. We explored the skill of two LSMs (JULES with different hydraulic configurations, CTESSEL and CHTESSEL) regarding the prediction of historical drought over Europe (Table 1).

Model name	Driving dataset	Time series	Hydraulic parameters	Pedotransfer functions	Soil map	Soil layer depths (mm)	Canopy exchange scheme	Veg. map
CHTESSEL	WFDEI (Weedon et al. 2014)	1979 to 2012	VG	(Wösten et al. 1999),	FAO/UNESCO Digital Soil Map of the World	L1: 70 L2: 210 L3: 720 L4: 1890	Jarvis	GLCC
CTESSEL							A-gs	
JULES			VG	VG params. from BC	combination of FAO, HWSO and IGBP soil data	L1: 100 L2: 250 L3: 650 L4: 2000	A-gs	MODIS
JULES			BC	(Cosby et al. 1984),				

Table 1: Model configurations, VG stands for van Genuchten, BC for Brooks and Corey

Methodology

Eight large domains in Europe were selected (UK:UK; FR: France; SP: Spain; NO: Nordic; DE: Germany; RU: Russia; EE: Eastern Europe; SE: Southern Europe, Fig.1).

Figure 1 Domains used for the model comparisons.

With the focus on plant droughts, two soil moisture drought indices were used: 1 – Plant water availability index, β (equation below; this is a model output for JULES and was derived for TESSEL); 2 – Soil Moisture Deficit Index (SMDI), a weekly indicator (Narasimhan & Srinivasan 2005).

$$\beta = \begin{cases} 0 & for\ \theta \le \theta_w \\ \dfrac{\theta - \theta_w}{\theta_c - \theta_w} & for\ \theta_w < \theta \le \theta_c \\ 1 & for\ \theta > \theta_c \end{cases}$$

Here θ, θ_c, and θ_w are the volumetric soil moisture content in the root zone, at the critical point and at the wilting point in m^3/m^3.

A water holding capacity (θ_c-θ_w) difference map between TESSEL and JULES models (Fig. 2) and its histogram (Fig. 3) are presented below. Here, we created a TESSEL-compatible 0.5 resolution, dominant soil map from JULES ancillary files to allow for comparison of the models.

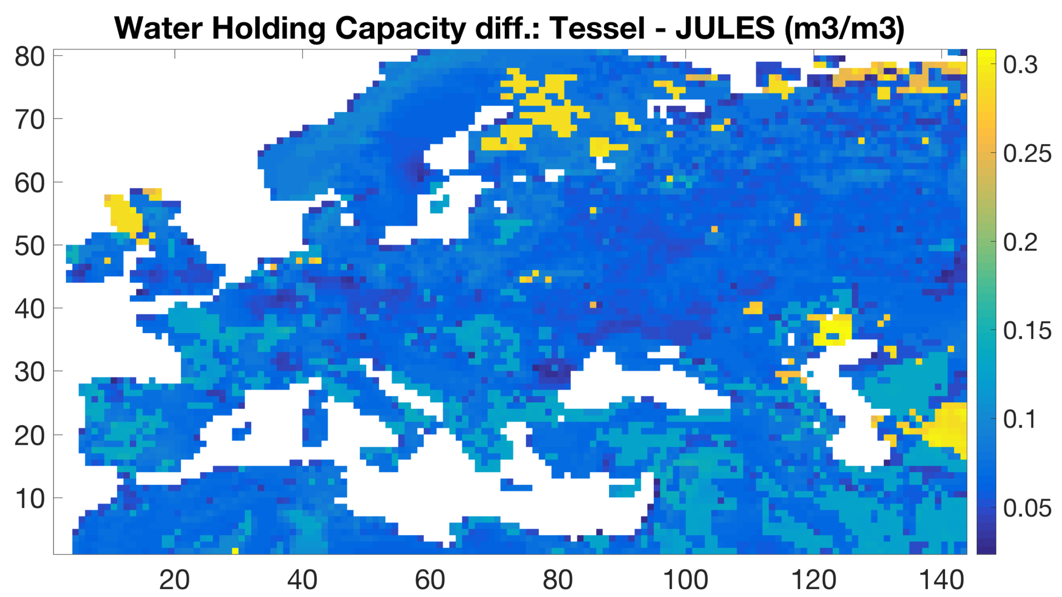

Figure 2. Water holding capacity difference map between TESSEL and JULES

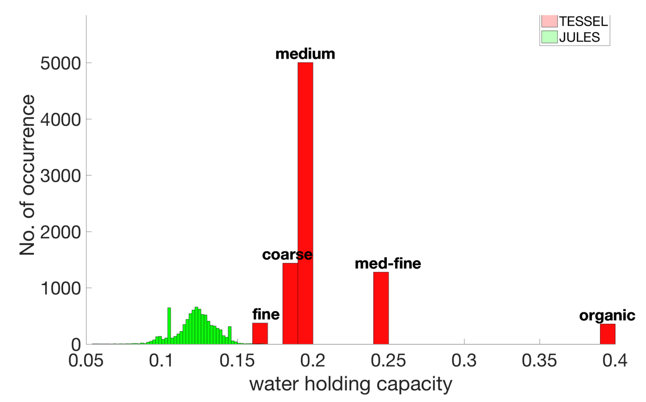

Figure 3. Histogram of water holding capacity of TESSEL and JULES

Results

Time-series plots of β (Fig. 4) and SMDI (Fig.5) for 2003 are presented, to compare the behaviour of models with regards to historical drought prediction.

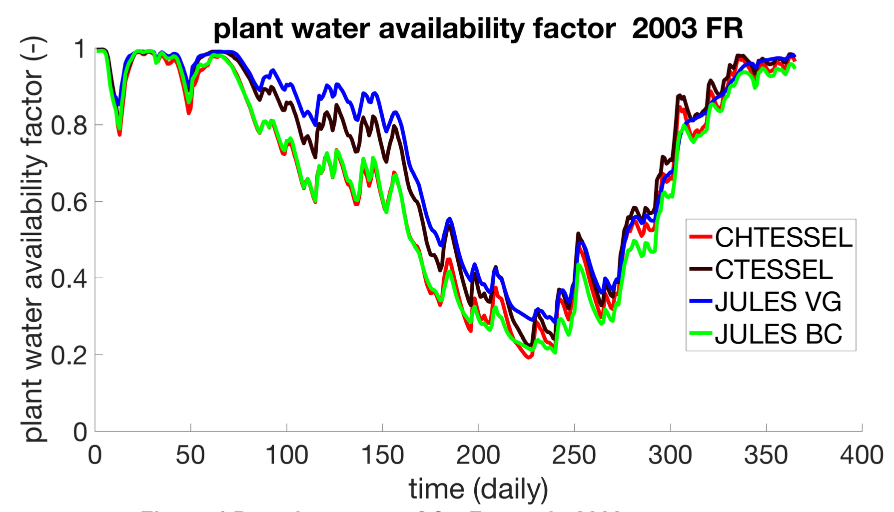

Figure 4.Domain-average β for France in 2003

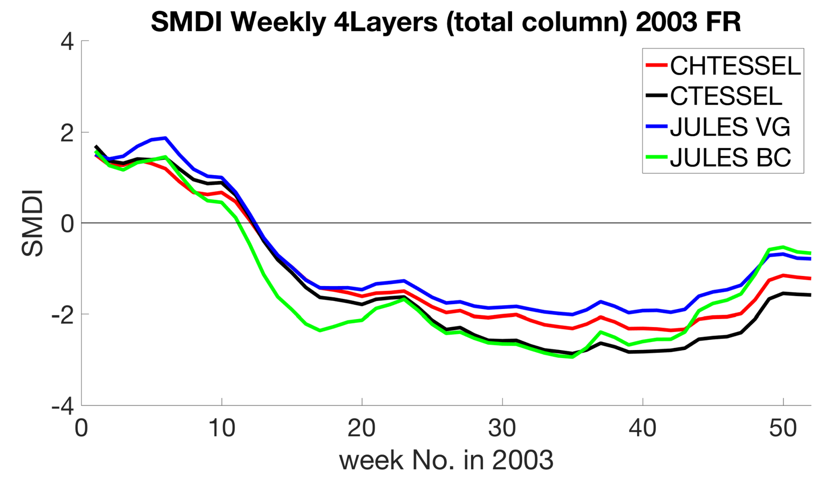

Figure 5. Domain-average SMDI in France for 2003

For each domain, the statistical significance of the difference between the models: CHTESSEL and CTESSEL; JULESVG and JULESBC; CHTESSEL and JULESVG, was investigated by using a Kolmogorov-Smirnov test at 0.05 significance level for different seasons. The results show the **P**roportion of **S**ignificant **D**ifferences (PSD = number of times the difference was significant / number of experiments; 1 denotes significant difference between modelled β values). The plots below show the PSD in June-July-August for β (Fig. 6) and SMDI (Fig. 7).

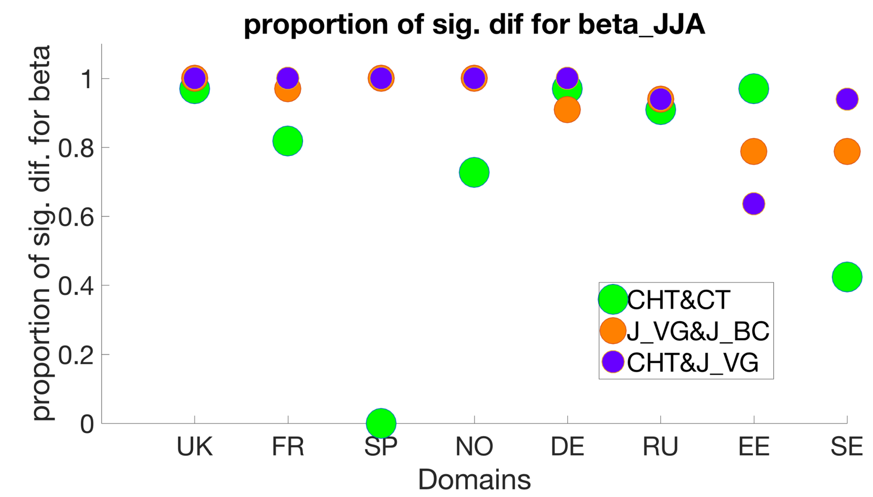

Figure 6. Proportion of significant difference between models for β in June-July-August for the 4 models of : CHTESSEL (CHT) and CTESSEL (CT); JULESVG (J_VG) and JULESBC (J_BC);

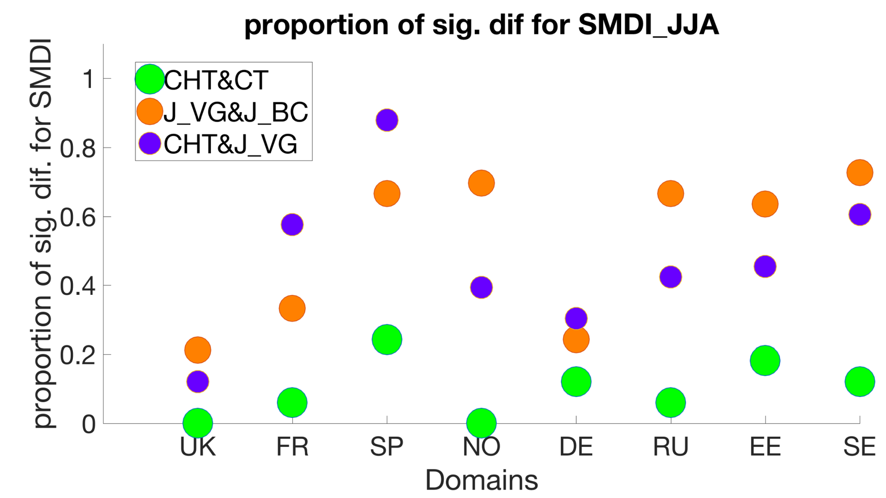

Figure 7. Proportion of significant difference for *SMDI* in June-July-August for the 4 models of : : CHTESSEL (CHT) and CTESSEL (CT); JULESVG (J_VG) and JULESBC (J_BC);

For verification purposes, the model predictions were compared to a satellite based agricultural vegetation index (Vegetation Health Index (VHI), Bachmair et al. 2018), that ranges from 0 (unhealthy) to 1 (healthy). It is based on MODIS NDVI and MODIS land surface temperature. The correlation coefficient (r) of β to VHI for a 0.5*0.5 degree grid cell in South Spain (Fig. 8) and Germany (Fig. 9) are presented for each model.

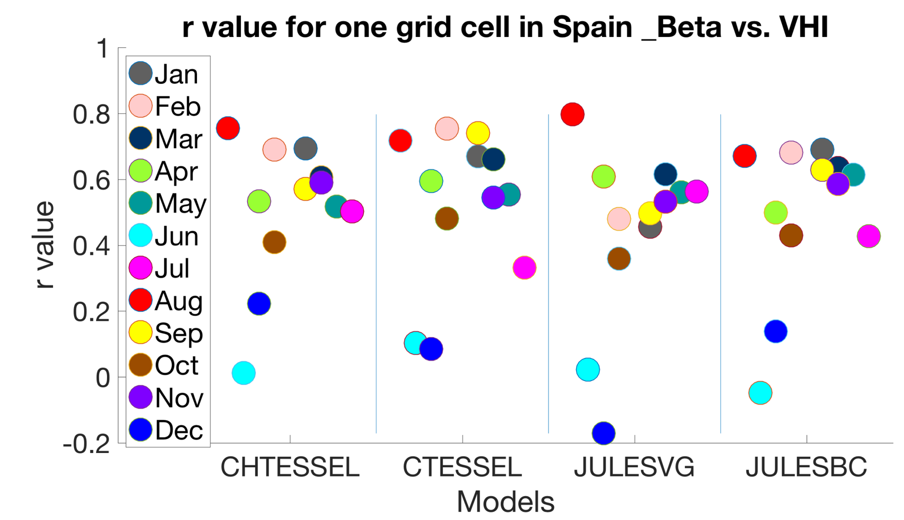

Figure 8. Correlation coefficient, r, for one grid cell in south Spain

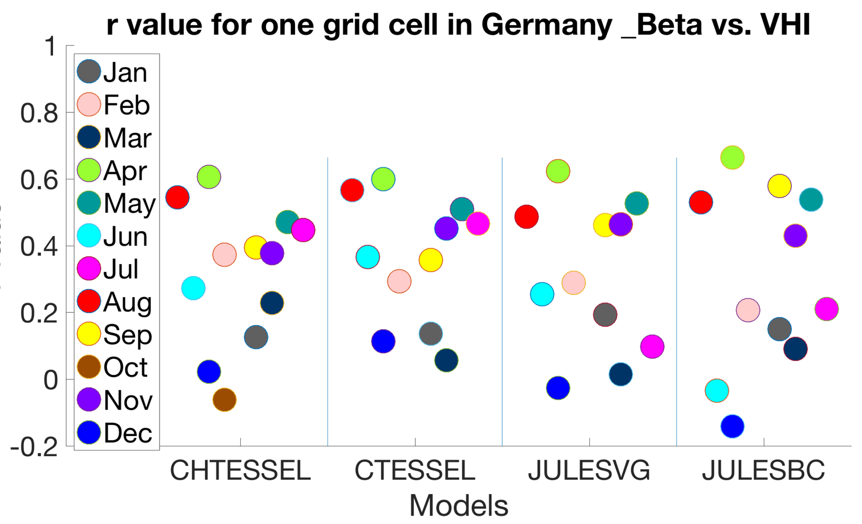

Figure 9. Correlation coefficient, r, for one grid cell in Germany

Discussion

The main difference between CHTESSEL and CTESSEL is in their canopy exchange scheme (Table 1), their soil hydraulic scheme (VG) is identical. Therefore, with regards to soil moisture availability (that depends largely on θ_c and θ_w) they have very similar courses (Fig 6: SP, also SE and NO and FR to some extent). JULESVG and JULESBC are identical but differ in their hydraulic parameters (Table1), which appears enough to create significant difference between the models outputs (Fig. 6). The lower PSD for SMDI (Fig. 7) is caused by the fact that SMDI is calculated weekly and concerns an anomaly, compared to β. The correlation between models and observations is more dependent on the season and domain, rather than the model type (Figs. 8&9).

Conclusion

It was found soil hydraulic parameter model choice and related parameters, are primarily responsible for the difference in behaviour of the two models and their configurations during drought. The remaining difference between the models can be explained by the soil maps, phenology and treatment of the effect of water stress on canopy exchange.

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