Answers to Editor:

Thanks a lot for carefully revising the manuscript. It reads much better now! I find it a great exploration of driving factors of SOC storage although I still find some sections rather speculative.

For instance at the first view, I have found TSIS a potentially great variable tackling seasonality but at a closer look the observed range seems close to the detection limit and thus somewhat ambiguous. Well, this is part of the discussion and identifying or presenting new controlling factors may stimulate other researchers to test them in their data set with a greater data span.

Looking at Figure 3, the range of TSIS seems very small (1°C, >70% of the values ranging less than 0.5°C), almost being in the range of measurement uncertainty, especially because TSIS is derived from two measurements and the relationship primarily be driven by three sites with low TSIS. Consequently, I find your conclusions that TSIS is a key driver somewhat too strong.

As we answered in the previous letter, we partially agree with you when you say some results are speculative. However, as you mentioned, one of the aims of our study is stimulate other researchers to test them, not only in observational but also in manipulative experiments. As we commented in the previous answers, there is an important lack in amount and variety of experiments testing interactions between drivers of soil properties (Rillig et al., 2019).

Focusing on your comments on TSIS:

We really appreciate your comments about TSIS, we find then really acute. Being conscious of the limitations of our analysis, we just refer TSIS as a "key driver of SOC" in **our study** (L 494). In the section before, we already explained that "it is not possible to unequivocally establish the causal links between SOC drivers" (L 460). Finally, the manuscript concludes that "we provided valuable information for further studies dealing with SOC predictions at broad several scales, and laid out the basis to generate new testable hypotheses for future studies" (L 717). In our view, the kind of information that our study provides is clear enough.

You argued that TSIS was derived of two measurements, however, **TSIS is not derived from only two measurements, it is derived from two variables**. TSIS is the difference between the mean summer temperature and mean annual temperature. Attending to the documentation of Worldclim 2.0 (Fick and Hijmans, 2017), each one of these variables were obtained from the annual means of the corresponding months, using data from weather stations which **comprised a 30 year period** (1970–2000). Additionally, note that temperature variables from WorldClim 2.0 had a very high accuracy. All temperature variables had a global correlation coefficient (between estimated and observed values) of 0.99. **Therefore, if one temperature variable of WorldClim 2.0 increases, the actual value surely increases in a similar way.** Of course climatic models like WorldClim 2.0 have their limitations, but considering the years and the amount of weather stations they compile for the modelling, they are nowadays the best possible available source of climate information considering the sample size and extent of our study.

We would like to compare TSIS with the temperature seasonality index, which can be found in many papers using bioclimatic variables a predictors (i.e. see Rodríguez et al., 2015; Cano et al.. 2018 and the references therein). Temperature seasonality index is the standard deviation of the mean temperature of each of the 12 months. This is, it gives information of how far are the mean temperatures of the 12 months from the mean. What we do with TSIS is considering just the difference between the warmest months (that is, the summer months) and the mean. Note in the following maps that both indexes look similar, but they have their differences, since TSIS just represents summer variations instead of annual variations. **TSIS has more ecological sense for us, since summer is the period when the productivity peak of mountain grasslands occurs** (Gómez, 2008). In addition, when we used SOC stocks models including the two variables, TSIS and the temperature seasonality index, TSIS always compared favourably, suggesting higher sensitivity to ecological variables than the other seasonality index.

Interestingly, TSIS has provided good results in preliminary SOC modelling for our analysis and also in other works by the group, using other variables in the same (species richness, Rodríguez et al., 2018) or a different database (soil activity variables; Debouk et al., 2020).

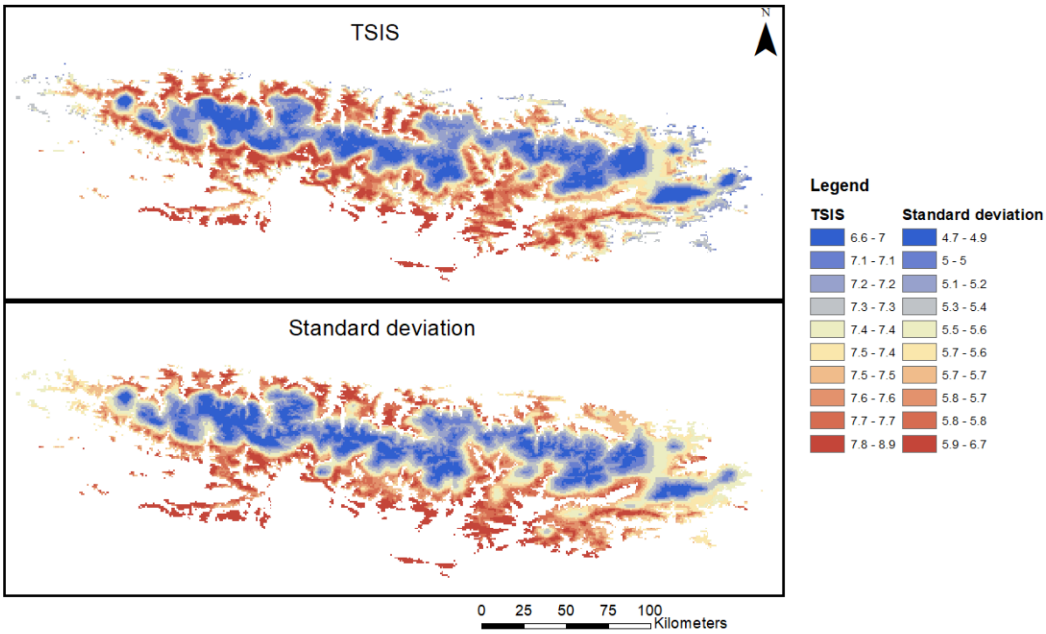

Figure: TSIS and standard deviation of the annual mean temperature (°C) according to WorldClim 2.0 in the Pyrenees (altitude > 1200 m).

Finally, we did a little exercise to determinate to what extent the relationship between TSIS and SOC stocks in our model is primarily driven by three sites with low TSIS, as you commented.

Firstly, we re-fit the geophysical model without the 3 sites with the lowest TSIS. Looking to the significance of the model terms (compare the table below with Table 2), although there was some variation in some estimates, **both the significance levels and the sing of the effects remained the same as in Table 2.**

Table: Results of the geophysical model for soil organic carbon excluding the 3 cases with the lowest TSIS values (R^2_{Adj} = 0.3). Compare with Table 3.

Model term	Estimate	SE	t-value	P-value	
Intercept	1.18	2.10	0.56	0.57	
Climate variables					
MAP	0.003	0.001	4.79	<0.001	***
TSIS	-0.35	0.26	-1.32	0.19	
Topography variables					
Slope	-0.38	0.12	-3.32	0.001	**
Exposed	-2.01	1.01	-1.99	0.049	*
Soil type variables					
Clay	0.11	0.03	4.24	< 0.001	***
Management variables					
Low intensity	-3.29	1.58	-2.09	0.04	*
Medium intensity	2.02	1.27	1.59	0.11	
Interactions					
MAPxClay	$9*10^{-5}$	$3*10^{-5}$	-4.37	<0.001	***
TSISxExposed	0.27	0.13	2.02	0.05	
TSISxLow intensity	0.43	0.21	2.07	0.046	*
TSISxMedium intensity	-0.27	0.17	-1.57	0.12	
TSIS:Slope	0.05	0.02	3.24	0.002	**

To illustrate this, we draw the plots of the TSISxMacrotopography and TSISxGrazing intensity effects, in the same way as we did in the manuscript (compare the plot below with Fig. 3). Although the effects are weaker**, we can appreciate the same effects.**

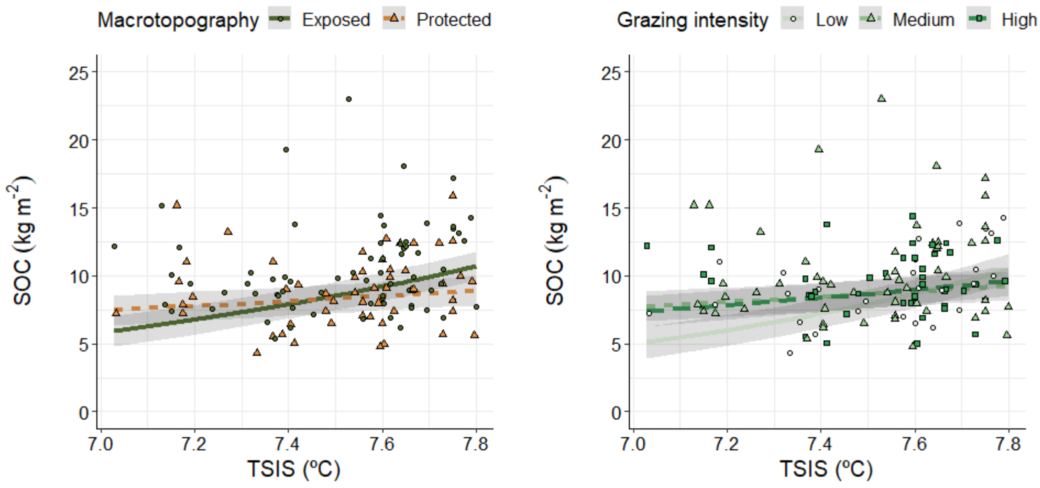

Figure: TSIS and macrotopography and TSIS and grazing intensity effects on SOC according to the model fitted excluding the 3 cases with the lowest TSIS values. Compare with Fig. 3.

Secondly, we refit the geophysical model using the function “lmrobust” in the “robustbase” R package. This function fits linear models with robust estimates (Yaffee, 2002). In a few words, models are built with conservative estimates that take less into account the cases which are the most extreme outliers.

Comparing the table below with Table 3, **we can appreciate that the sign and the significance of the geophysical model still the same if we use robust estimates instead of conventional ones.**

Table: Results of the geophysical model for soil organic carbon excluding the 3 cases with the lowest TSIS values (R^2_{Adj} = 0.38). Compare with Table 3.

Model term	Estimate	SE	t-value	P-value
Intercept	-0.19	1.84	-0.10	0.92
Climate variables				
MAP	0.003	0.001	4.48	0.00
TSIS	-0.14	0.23	-0.60	0.55
Topography variables				
Slope	-0.36	0.10	-3.67	0.00
Exposed	-3.10	0.96	-3.24	0.00
Soil type variables				
Clay	0.12	0.03	4.28	0.00
Management variables				
Low intensity	-5.18	1.22	-4.25	0.00
Medium intensity	2.21	1.20	1.83	0.07
Interactions				
MAPxClay	$9*10^{-5}$	$3*10^{-5}$	-4.44	0.00
TSISxExposed	0.41	0.13	3.25	0.00
TSISxLow intensity	0.68	0.16	4.17	0.00
TSISxMedium intensity	-0.29	0.16	-1.81	0.07
TSISxSlope	0.05	0.01	3.55	0.00

We think that these explanations support properly our interpretation of the results: TSIS was an important factor that drove SOC in interaction with other variables. The 3 lowest TSIS values provide valuable information to the model, but they are not necessary to get similar results in significance and sign. In other words, the relationship is not primarily driven by those three sites. Moreover, even with an apparently low range we get robust and significant effects for this variable.

To conclude: TSIS has a low range of variation, but ecological variables (including SOCS stocks in this study; plant species richness in Rodriguez et al. 2018; soil activity variables in Debouk et al.

2020) show high sensitivity within this range; we expect other authors to test this variable further, and our own group is considering testing TSIS further; TSIS performed favourably compared to similar seasonality indices previously used, showing higher sensitivity to ecological variables than those.

In a similar sense at

L. 554 ‘contrast with most other’ – this is not correct, the other studies have simply not included TSIS in their set of parameters – I would rather argue that your data suggest to include it in other studies which may also test it for stronger gradients than in this study.

We think this is a judicious suggestion, we changed the text as follows:

“While most of the previous studies addressing soil carbon not included any temperature seasonality variable as potential SOC predictor, usually focusing in mean temperature and precipitation as the most important climate drivers of SOC (Hobley et al., 2015; Manning et al., 2015; Wiesmeier et al., 2019), our models suggest that TSIS and other temperature seasonality indexes should be included in further studies, to provide more evidence of the extent of the effects of temperature seasonality on SOC stocks.” (L 544).

Please carefully check the use of upper and lower case throughout the whole manuscript (see examples below).

We checked the use of upper and lower case throughout the whole manuscript.

426 change 88.31% to 88%

Change done.

L. 427 change Clay to clay

Change done.

L. 435 Combined

Change done.

L. 436 add empty space before (Fig…)

Change done.

L. 439 Geophysical Model

Change done.

L. 503 the sentence reads incorrect, especially the last half.

We changed the phrase: "This increase in soil organic matter inputs during summer would overcome an eventual increase of soil organic matter decomposition caused by high temperatures (Sanderman et al., 2003)." (L 503)

L. 561 Cold Sites

Change done.

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