Modelling Equilibrium Soil Carbon using JULES

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September 2021

UK Centre for Ecology & Hydrology

SC Equilibrium

Why:

- Reduce/Eliminate model Spin-up
- Quick comparisons
- Operational info and forecasting

How:

- Use JULES as a base (Clark et al 2011)
- Equating Carbon input to Respiration
- Substitute in per Carbon Pool
- Gather relevant inputs for:
  - Litter fall (Based on leaf phenology)
    - LAI, VegCarbon, NPP
  - Soil Temperature Function
  - Soil Moisture Function
  - Vegetation coverage fraction
  - Constants
    - PFT parms
    - Respiration rates
    - Conversions

$$\frac{dC_s}{dt} = \Lambda_C - R_s, \qquad \textbf{Eq 1}$$

$$\Lambda_C = R_s. \qquad \textbf{Eq 2}$$

$$\frac{dC_{DPM}}{dt} = f_{DPM}\Lambda_C - R_{DPM}, \qquad \textbf{Eq 3}$$

$$\frac{dC_{RPM}}{dt} = (1 - f_{DPM})\Lambda_C - R_{RPM}, \qquad \textbf{Eq 4}$$

$$\frac{dC_{BIO}}{dt} = 0.46 \cdot \beta_R R_s - R_{BIO}, \qquad \textbf{Eq 5}$$

$$\frac{dC_{HUM}}{dt} = 0.54 \cdot \beta_R R_s - R_{HUM}. \qquad \textbf{Eq 6}$$

$$R_i = \kappa_i \cdot C_i \cdot \boldsymbol{F}(T_{soil}, SM, \nu), \qquad \textbf{Eq 7}$$

SC Pool Estimation

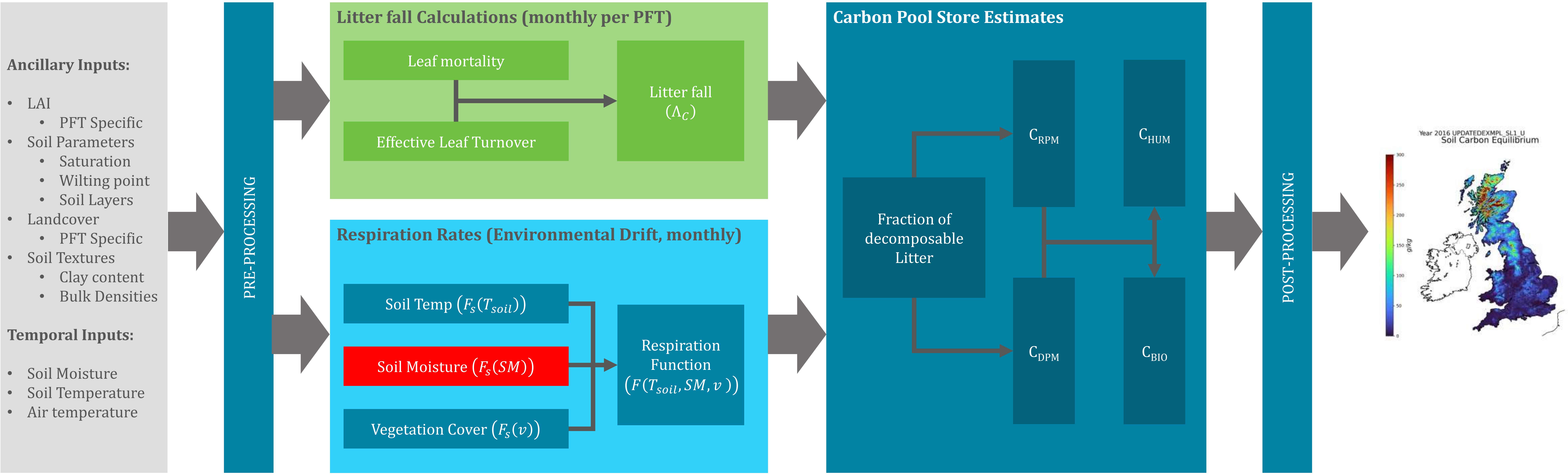
$$C_{DPM} = \frac{\sum_j f_{DPM_j} \Lambda_{C_j}}{\kappa_{DPM} \boldsymbol{F}(T_{soil}, SM, \nu)}, \quad \text{Eq 8}$$

$$C_{RPM} = \frac{\sum_j \left(1 - f_{DPM_j}\right) \Lambda_{C_j}}{\kappa_{RPM} \boldsymbol{F}(T_{soil}, SM, \nu)}, \quad \text{Eq 9}$$

$$C_{BIO} = \frac{0.46 \cdot \beta_R R_s}{\kappa_{BIO} \boldsymbol{F}(T_{soil}, SM, \nu)} = \frac{0.46}{\kappa_{BIO} \left({}^{1}/_{\beta_R} - 1\right)} [\kappa_{DPM} C_{DPM} + \kappa_{RPM} C_{RPM}], \quad \text{Eq 10}$$

$$C_{HUM} = \frac{0.54 \cdot \beta_R R_s}{\kappa_{HUM} \boldsymbol{F}(T_{soil}, SM, \nu)} = \frac{0.54}{\kappa_{HUM} \left({}^{1}/_{\beta_R} - 1\right)} [\kappa_{DPM} C_{DPM} + \kappa_{RPM} C_{RPM}]. \quad \text{Eq 11}$$

Model flow

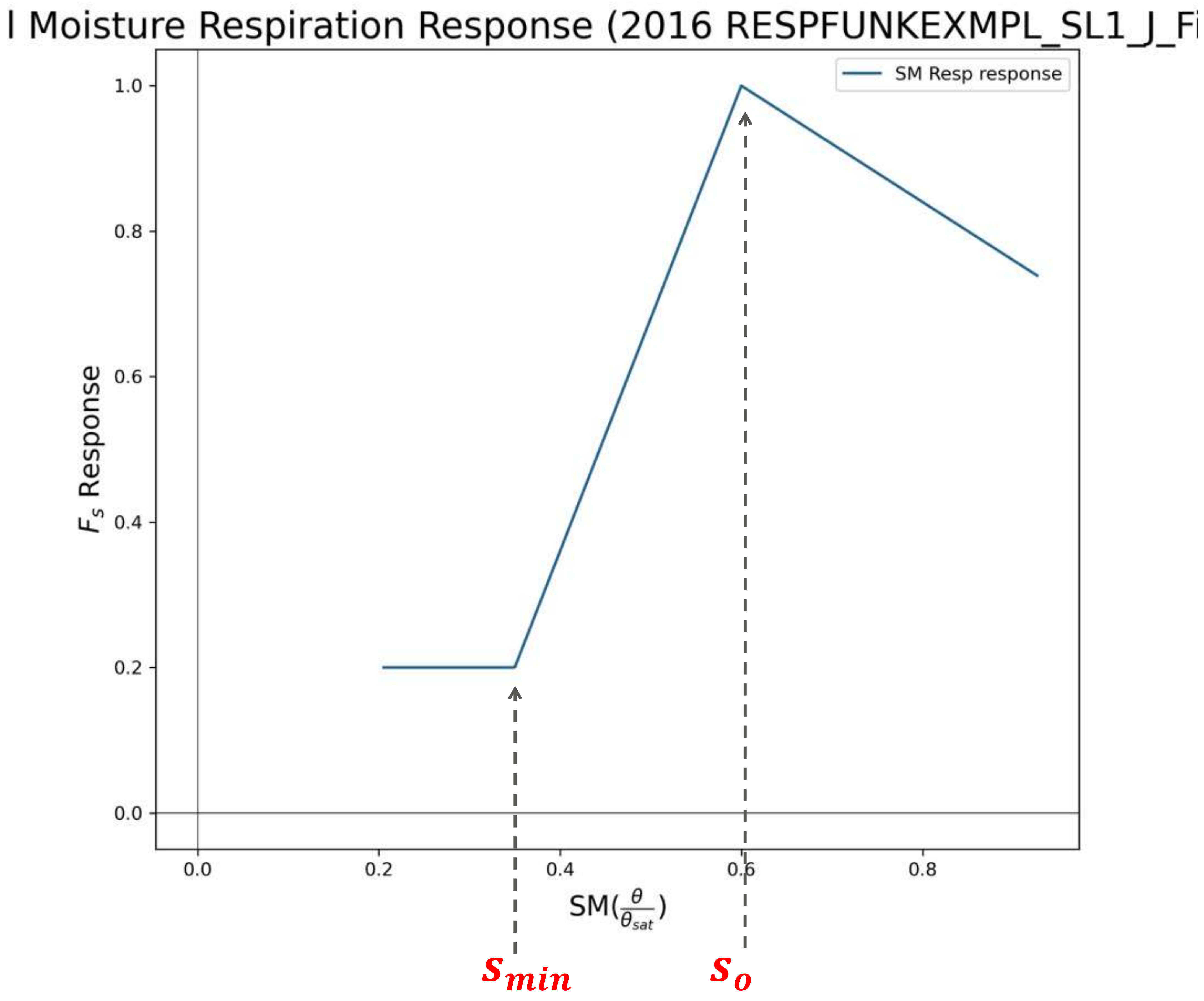


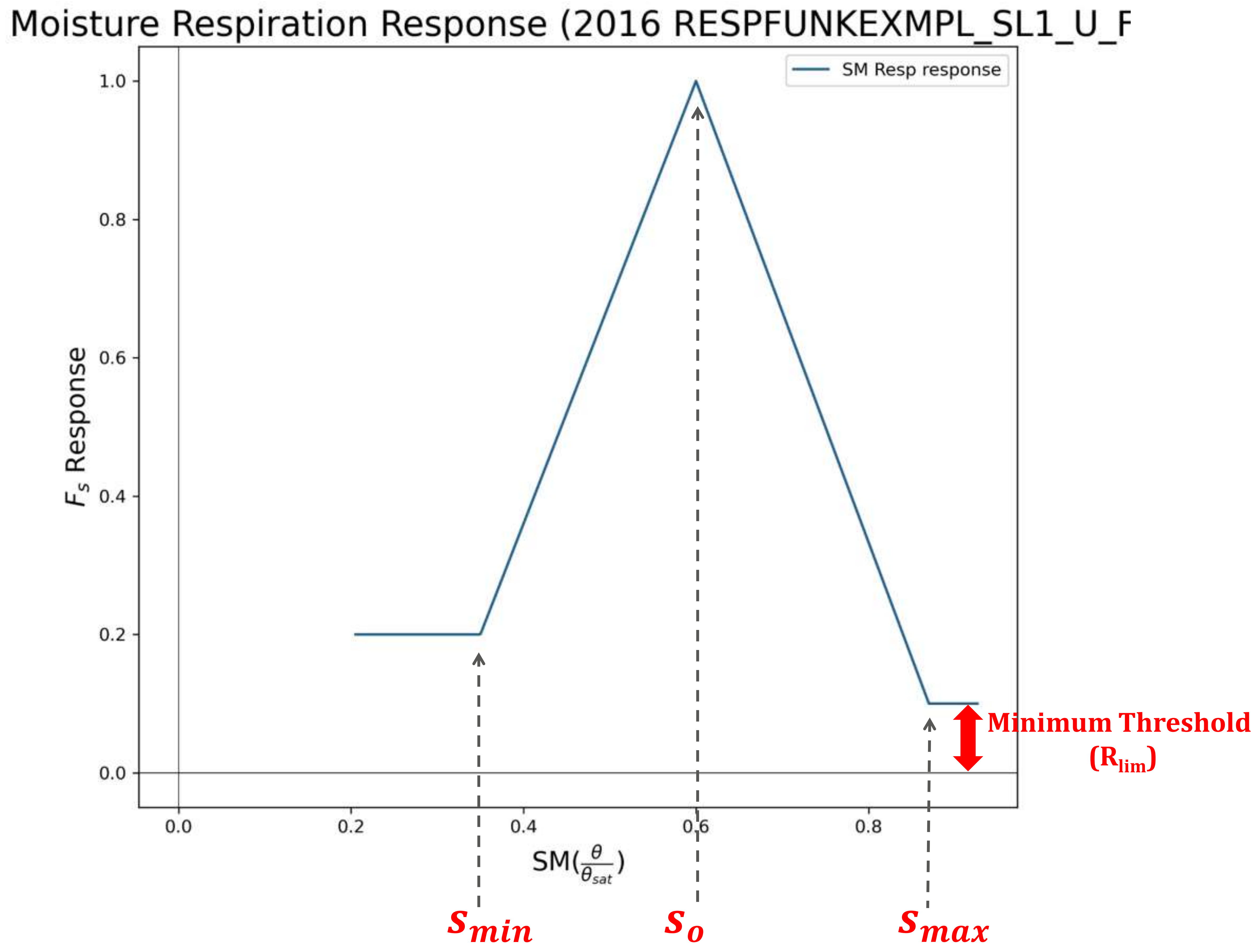
$$F_{s_J}(SM) = \begin{cases} 1 - 0.8(s - s_o)^{*1} & *\,1 \text{ for } s > s_o \\ 0.2 + 0.8\left(\dfrac{s - s_{min}}{s_o - s_{min}}\right)^{*2} & *\,2 \text{ for } s_{min} < s < s_o \\ 0.2^{*3} & *\,3 \text{ for } s \le s_{min} \end{cases} \qquad \textbf{Eq 12}$$

$$F_{s_M}(SM) = \begin{cases} R_{\lim}^{*4} & *\,4 \text{ for } s_{max} \le s \\ \dfrac{s_{max} - s}{s_{max} - s_o}^{*1} & *\,1 \text{ for } s_{max} > s > s_o \\ 0.2 + 0.8\left(\dfrac{s - s_{min}}{s_o - s_{min}}\right)^{*2} & *\,2 \text{ for } s_{min} < s < s_o \\ 0.2^{*3} & *\,3 \text{ for } s \le s_{min} \end{cases} \qquad \textbf{Eq 13}$$

SM Function Examples

$$s_o = \frac{0.5(1 + s_w)}{\theta_{sat}} \qquad s_{min} = \frac{s_w}{\theta_{sat}} \qquad s_{max} = 0.9\theta_{sat}$$





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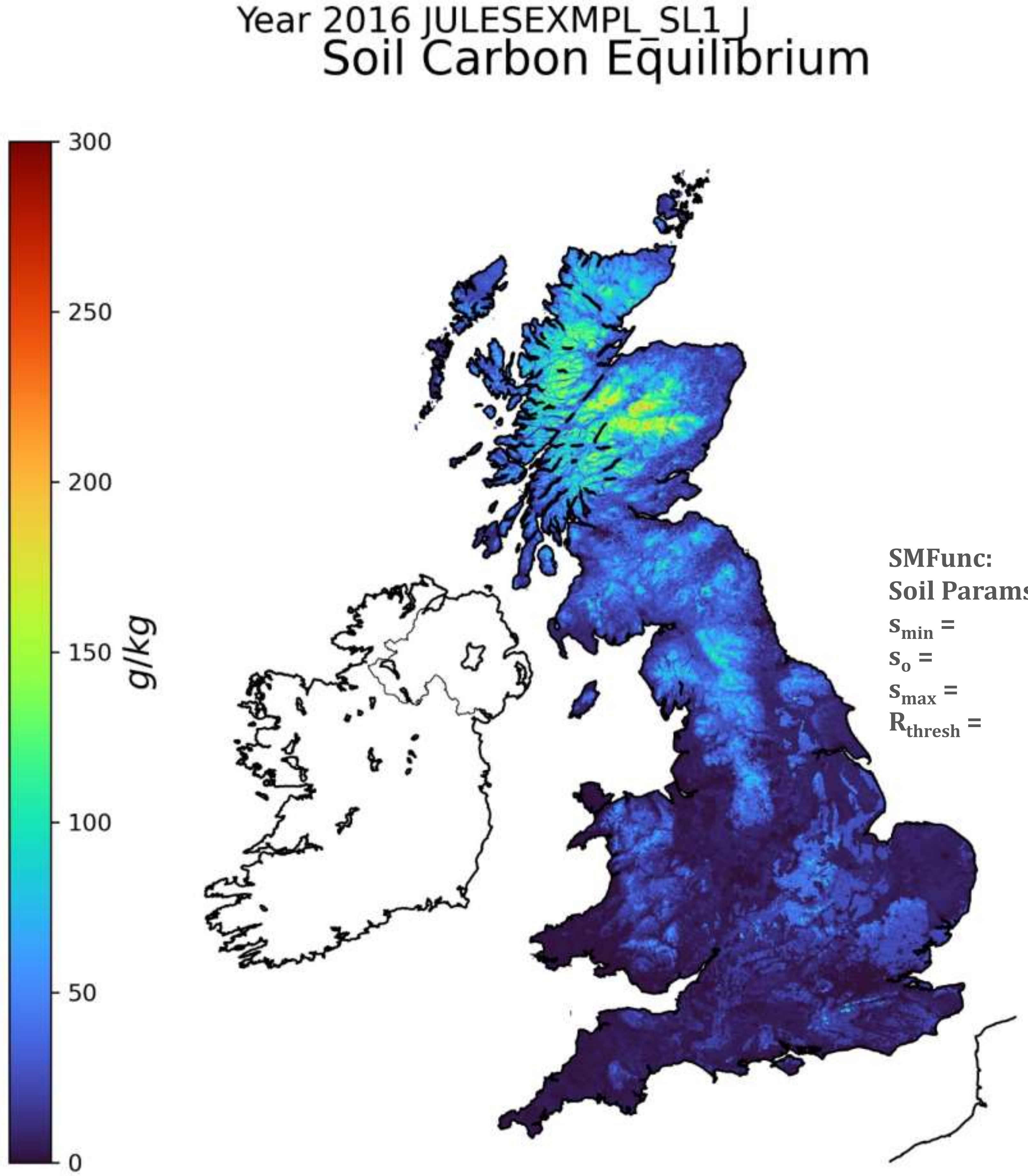
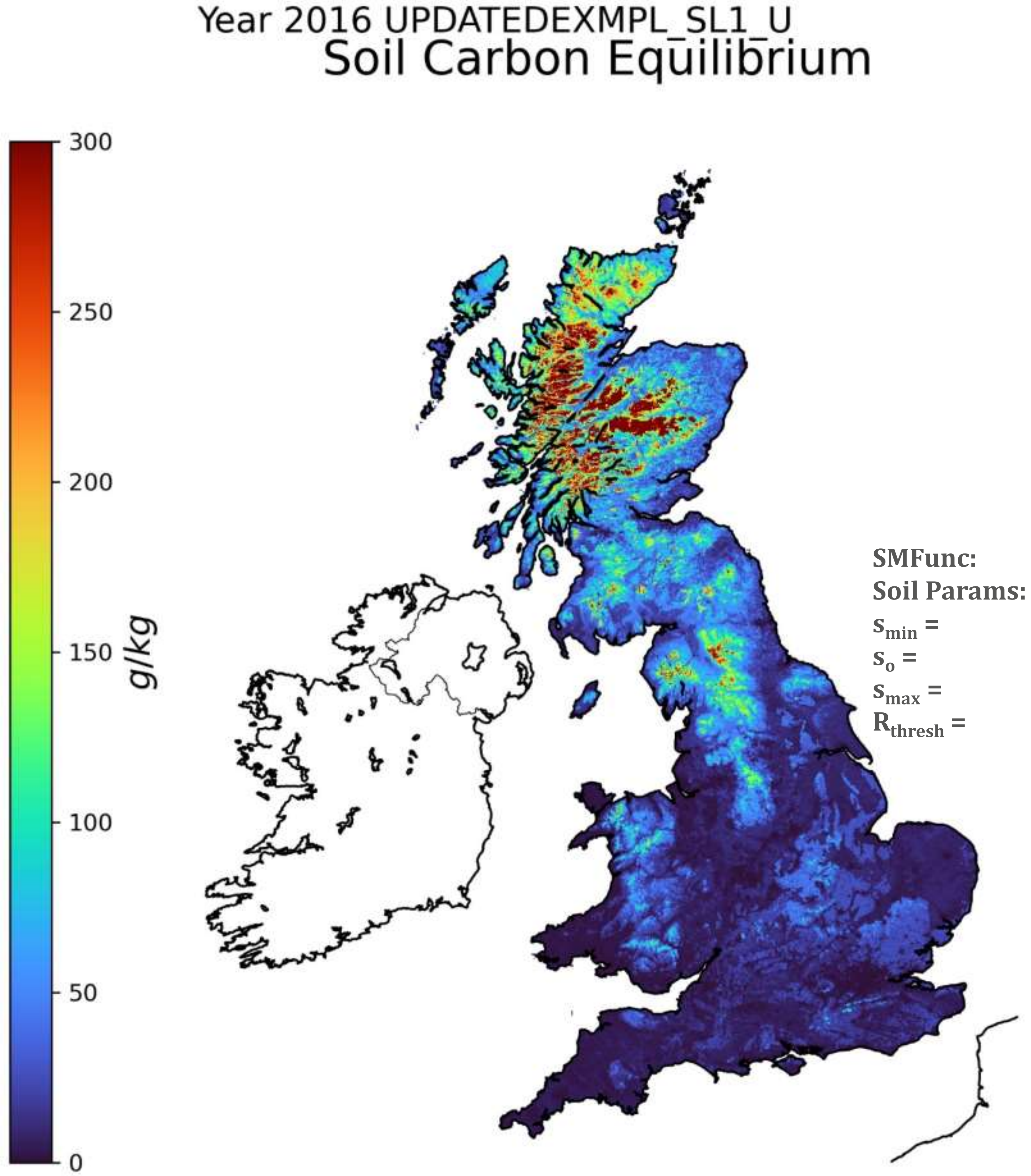
JULES and UPDATE



SMFunc: JULES Current
Soil Params: CHESS
s_{min} = grid
s_o = grid
s_{max} = N/A
R_{thresh} = N/A



SMFunc: UPDATED
Soil Params: CHESS
s_{min} = grid
s_o = grid
s_{max} = grid$(0.9\theta/\theta_{sat})$
R_{thresh} = 0.15

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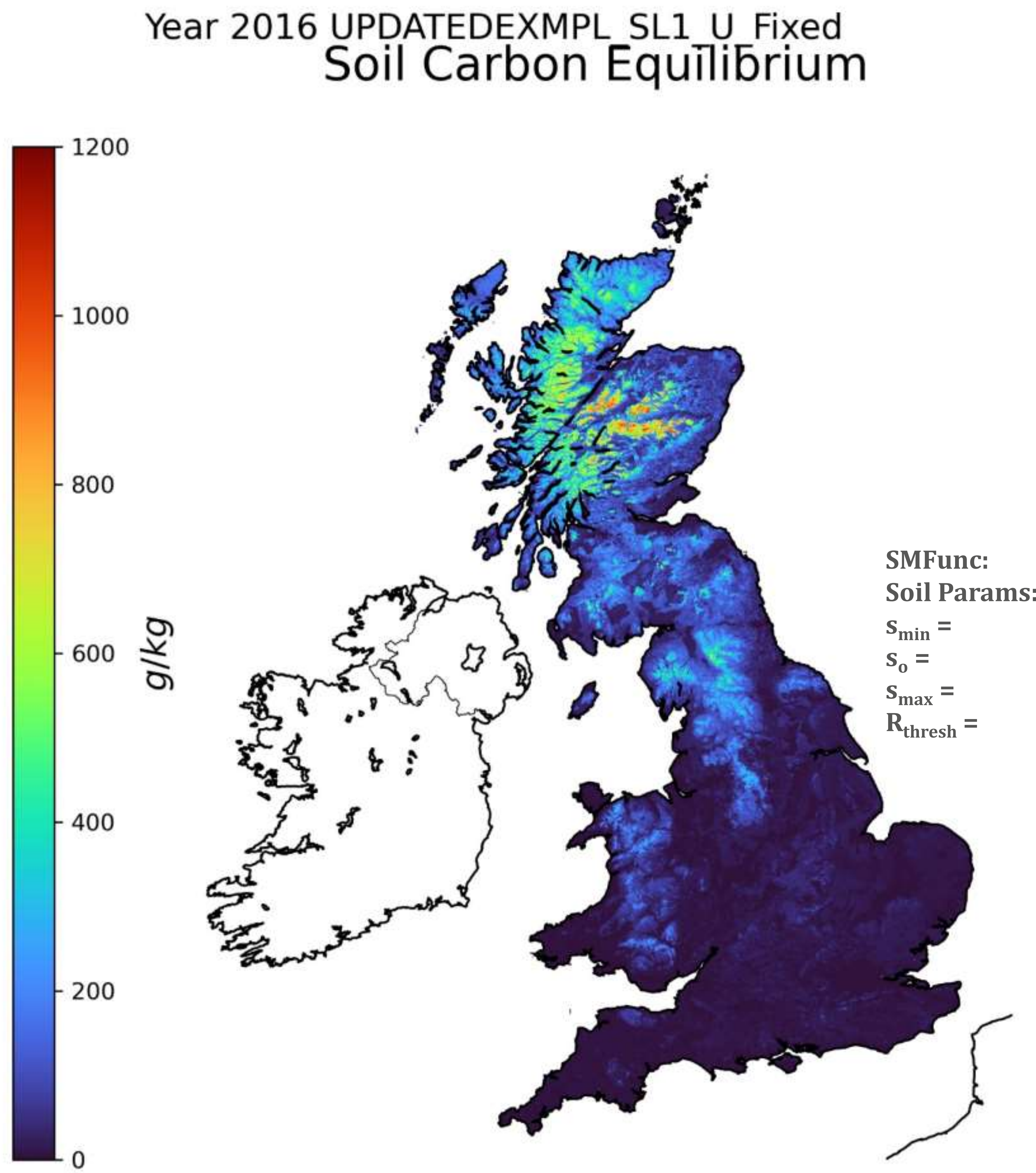
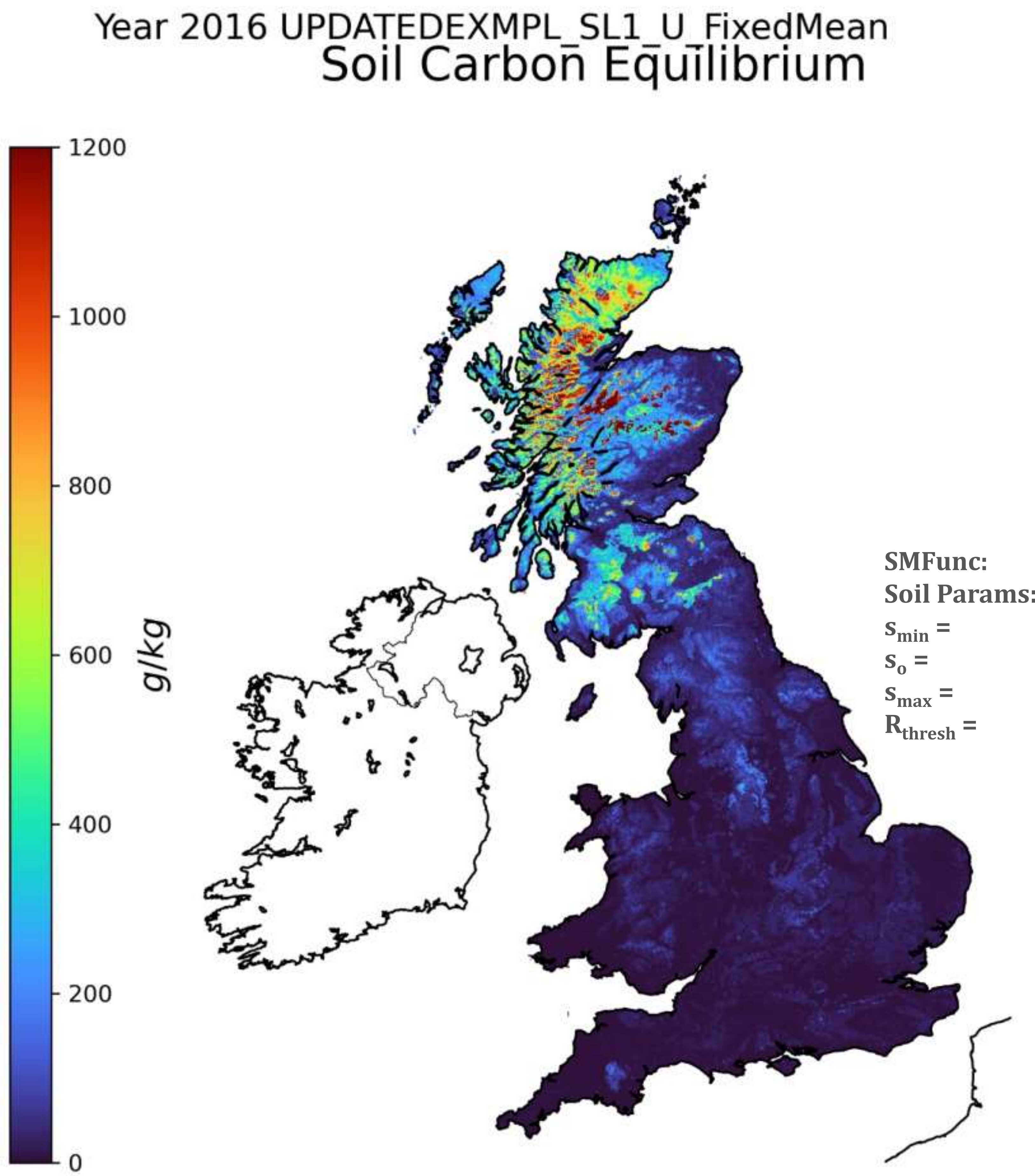
SM Function Tuning

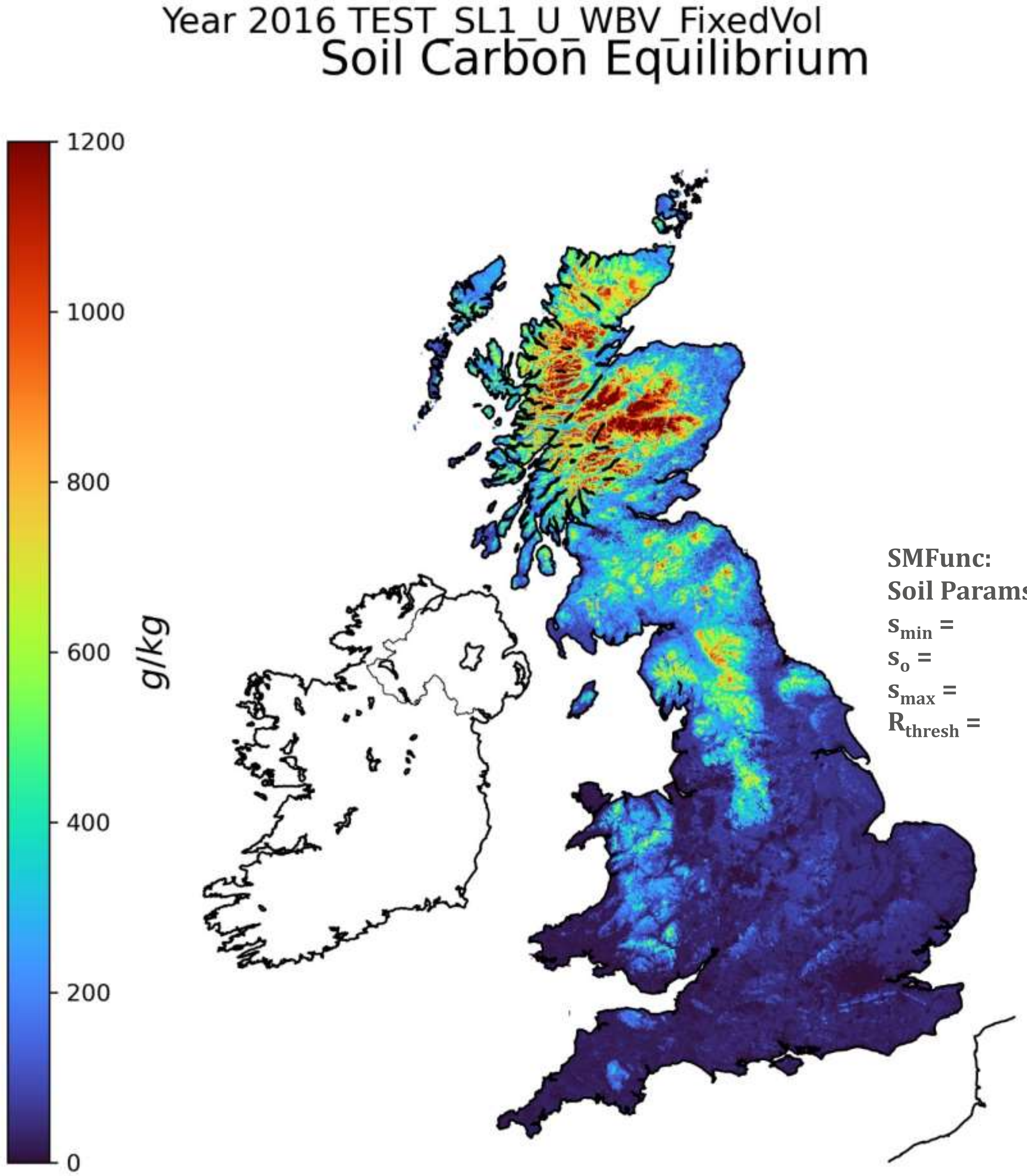


SMFunc:	UPDATED(Fixed)
Soil Params:	CHESS
s_{min} =	$0.2(\theta/\theta_{sat})$
s_{o} =	$0.4(\theta/\theta_{sat})$
s_{max} =	$0.9(\theta/\theta_{sat})$
R_{thresh} =	0.15

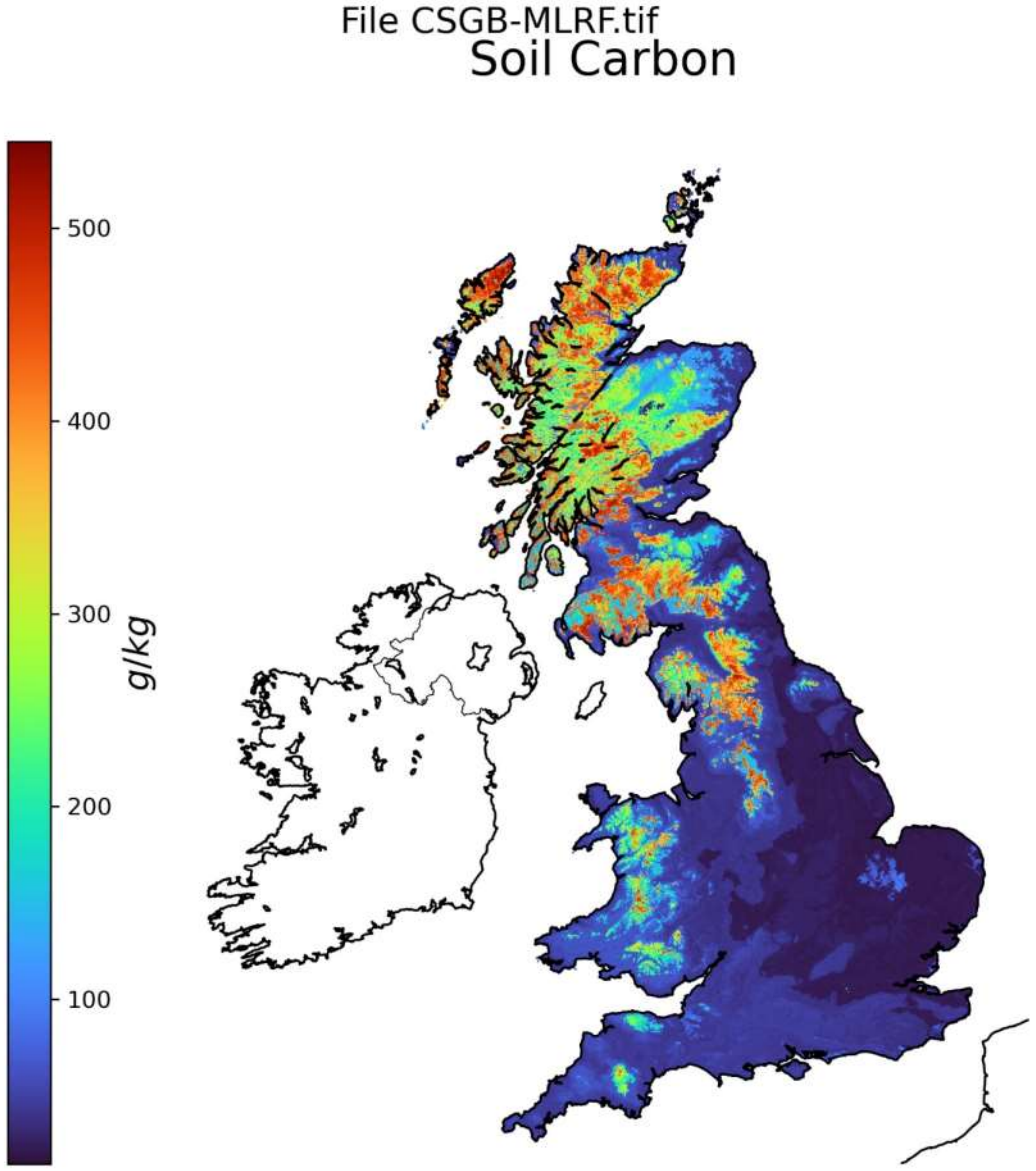


SMFunc:	UPDATED(Means)
Soil Params:	CHESS
s_{min} =	$0.58(M)(\theta/\theta_{sat})$
s_{o} =	$0.67(M)(\theta/\theta_{sat})$
s_{max} =	$MSat/Sat(\theta/\theta_{sat})$
R_{thresh} =	0.15

Independent of Saturation



SMFunc:	UPDATED(Volume)
Soil Params:	CHESS
s_{min} =	$0.10(\theta_{vol})$
s_o =	$0.13(\theta_{vol})$
s_{max} =	$0.15(\theta_{vol})$
R_{thresh} =	0.10



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Closing

Further work:

- Help needed to better constrain the SM Function(?)
  - Other Parameters/Processes that need to be taken into account.
  - Dependence on sat or volume, is s_{opt} necessarily 1?
  - Alterations needed to the function shape (Normal distributions perhaps).
- Validation and further testing
  - Known SC maps
  - Spun up JULES runs
- Comparisons between other SM products

Thank you

Any questions?

Reference and thanks

D. B. Clark, L. M. Mercado, S. Sitch, C. D. Jones, N. Gedney, M. J. Best, M. Pryor, G. G. Rooney, R. L. H. Essery, E. Blyth, O. Boucher, R. J. Harding, C. Huntingford, and P. M. Cox (2011). “The Joint UK Land Environment Simulator (JULES), model description – Part 2: Carbon fluxes and vegetation dynamics”. Geosci. Model Dev., 4, 701–722

Jenkinson, D., S. Andrew, J. Lynch, M. Goss and P. Tinker (1990). "The turnover of organic carbon and nitrogen in soil [and discussion]." Philosophical Transactions of the Royal Society B: Biological Sciences **329**(1255): 361-368

Thanks to Jack Cosby for the SOC maps and Eddy Comyn-Platt for the initial framwork.