# A spatial emergent constraint on the sensitivity of soil carbon turnover to global warming

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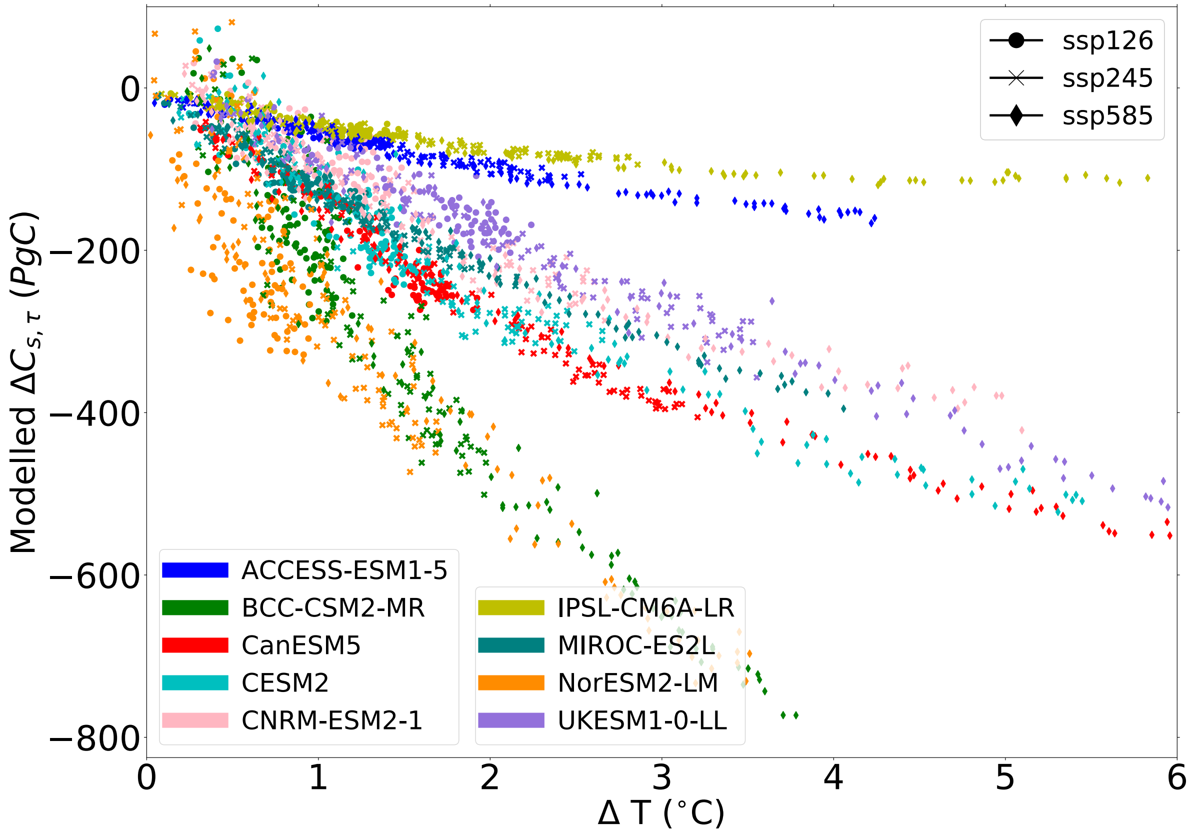
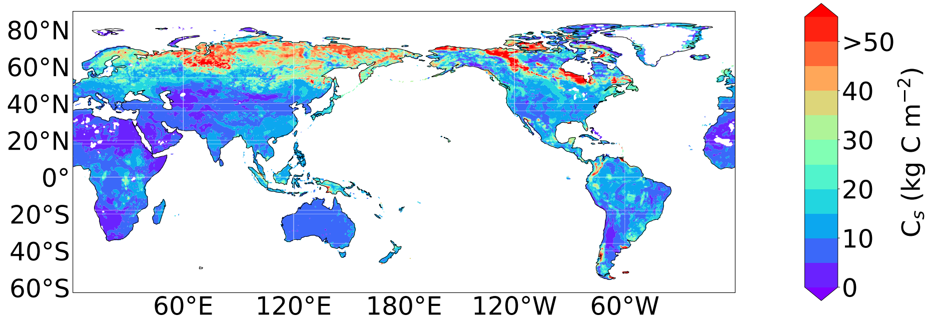
# Background – Importance of soil carbon turnover time

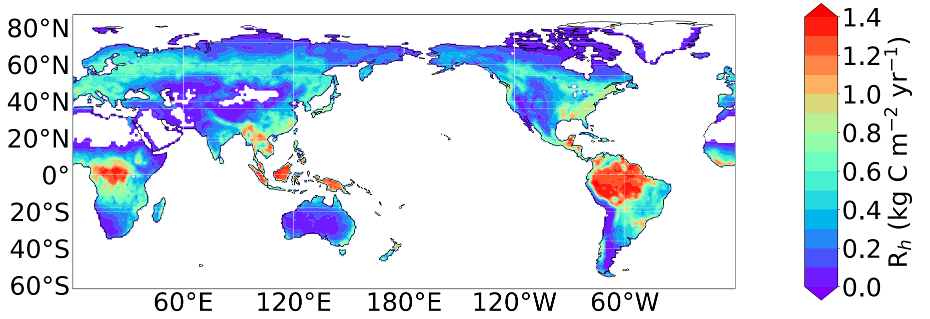
- Uncertainties in projected changes in soil carbon storage are key components of the uncertainties in the global carbon budgets for the Paris Agreement Targets.
- Uncertainty has remained across CMIP generations.
- Important as potential large positive feedback.

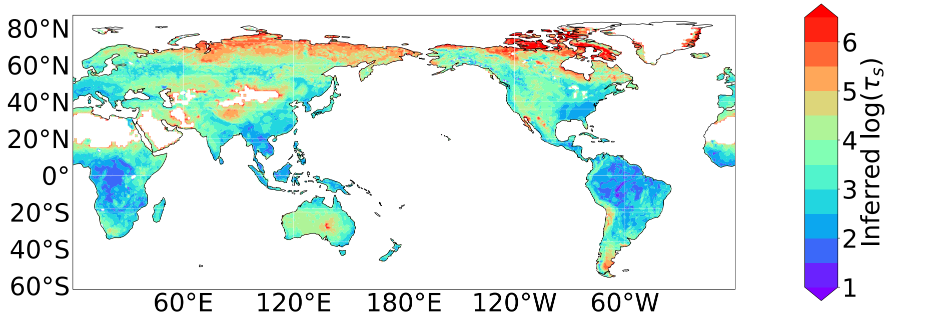
*Soil Carbon Turnover Time = Soil Carbon / heterotrophic respiration*



# Method – Temperature sensitivity of $\tau_s$

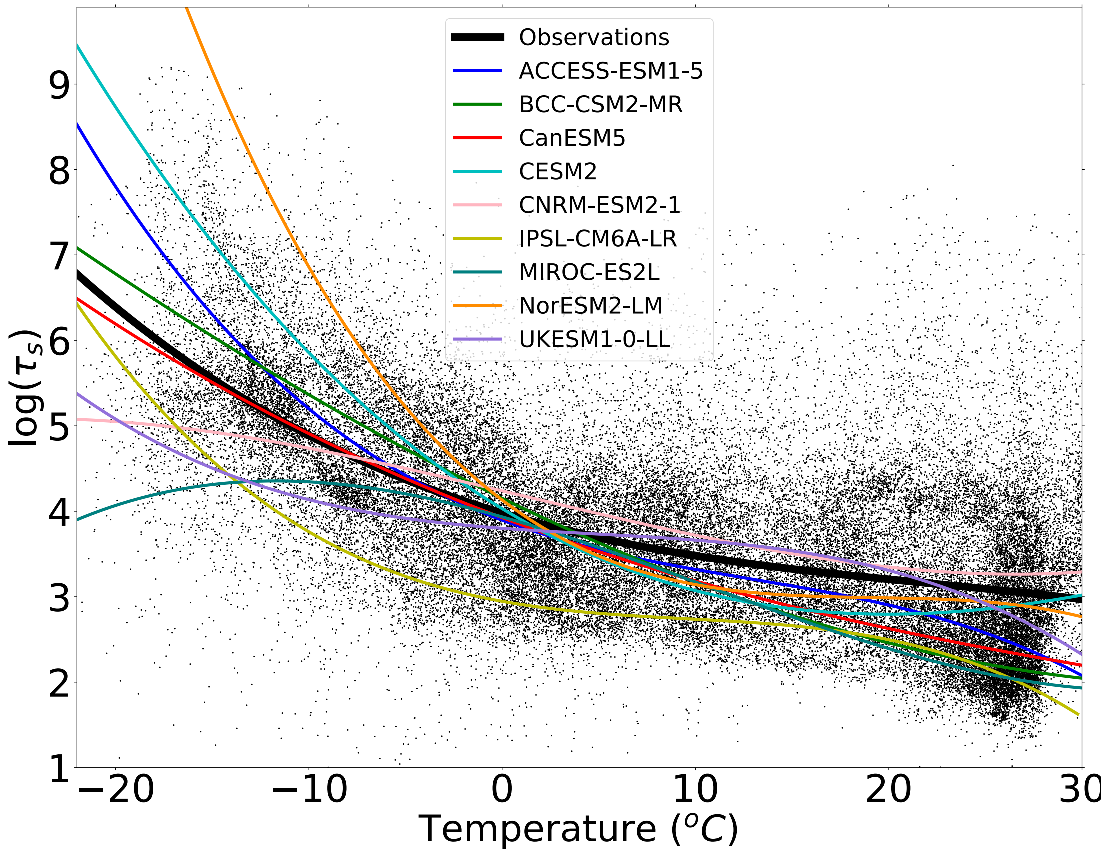



$$\tau_s = \frac{C_s}{R_h}$$

We use the spatial variation of soil carbon turnover, $\tau_s$, to estimate the sensitivity of $\tau_s$ to temperature.




*Soil carbon – Cs, Heterotrophic respiration – Rh, Soil carbon turnover time - $\tau_s$*

Harmonized world soil database (2012), The northern circumpolar soil carbon database: spatially distributed datasets of soil coverage and soil carbon storage in the northern permafrost regions (2013).
CARDAMOM 2001-2010 global carbon Model-Data Fusion (MDF) analysis, (2015).
The WFDEI meteorological forcing data set: WATCH Forcing Data methodology applied to ERA-Interim reanalysis data (2014).

# Method – testing principle

Change in Soil Carbon due to a change in Soil Carbon Turnover: $\Delta C_{s,\tau} = R_{h,0}\Delta\tau_s$

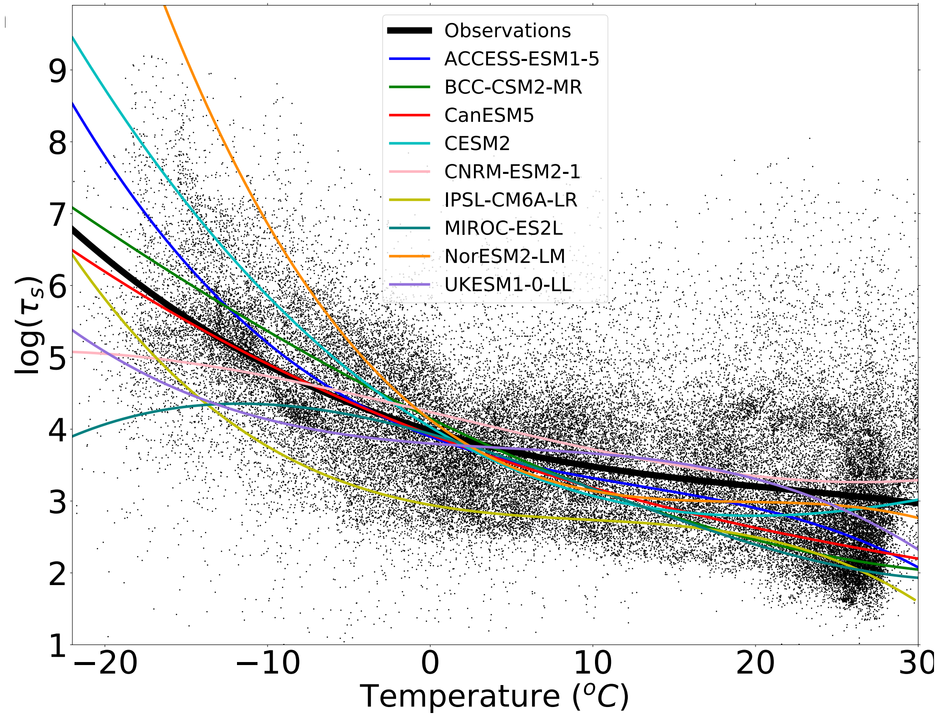
where, $\Delta\tau_s = \tau_s^{future} - \tau_s^{historical}$

Equation for Soil Carbon Turnover: $\tau_s = \dfrac{C_s}{R_h}$

We can define a polynomial relationship to represent the temperature sensitivity of $\tau_s$ for the models and observations.

We can calculate $\Delta C_{s,\tau}$ using:

1. Model output data
2. Derived $\tau_s$-temperature relationships




*Soil carbon – Cs, Heterotrophic respiration – Rh, Soil carbon turnover time - $\tau_s$*

# Method – testing principle

We can calculate $\Delta C_{s,\tau}$ using:

1. Model output data (**y-axis**)

$$\Delta C_{s,\tau} = R_{h,0} \Delta \tau_s$$

where, $\Delta\tau_s = \tau_s^{future} - \tau_s^{historical}$

$$\tau_s = \frac{C_s}{R_h}$$

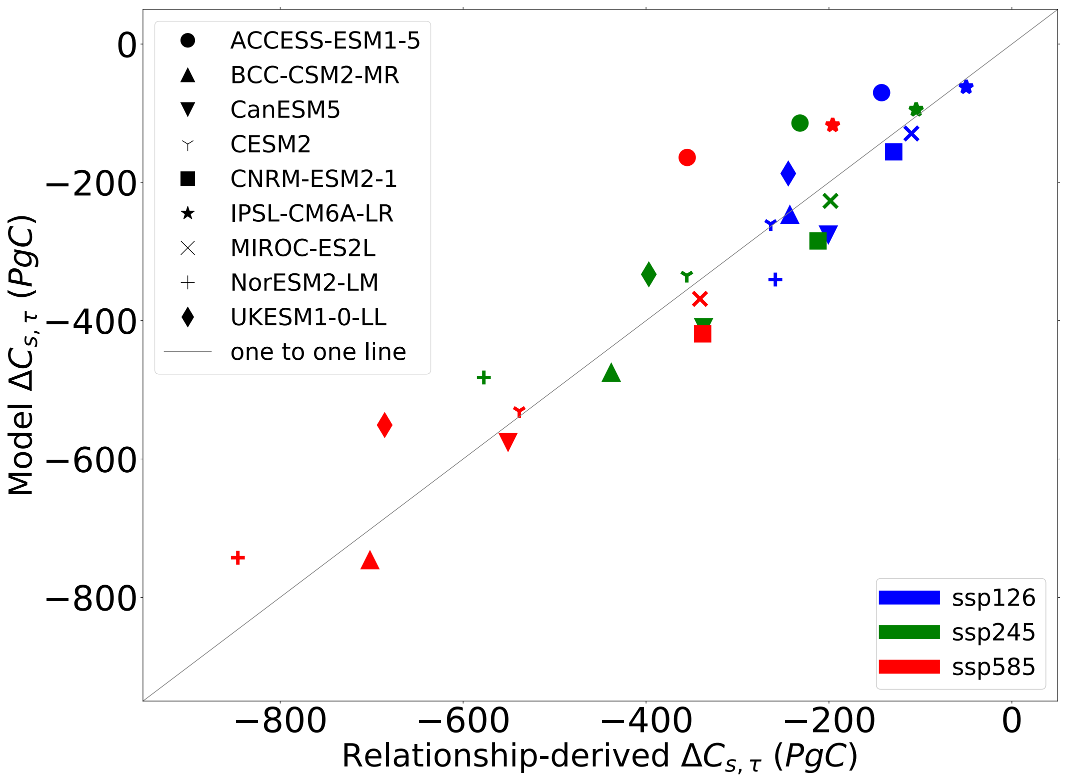
2. Derived $\tau_s$-temperature relationships (**x-axis**)

$$\Delta C_{s,\tau} = R_{h,0} \Delta \tau_s$$

where,

$$\Delta\tau_s = polyfit(T^{future}) - polyfit(T^{historical})$$

We find that the spatial variation of $\tau_s$ enables us to estimate the change in soil carbon for each model.

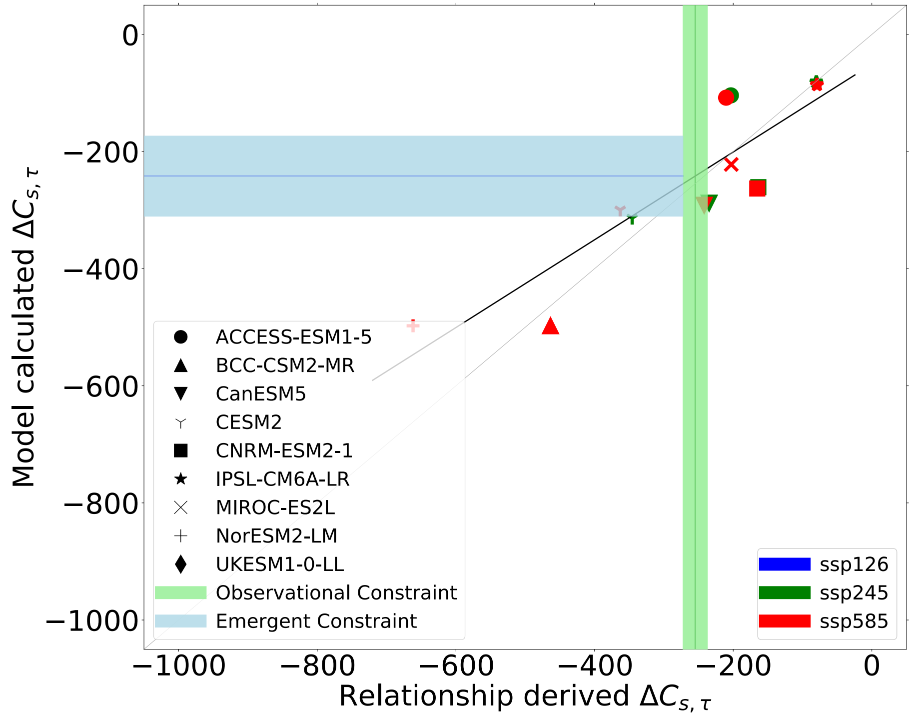


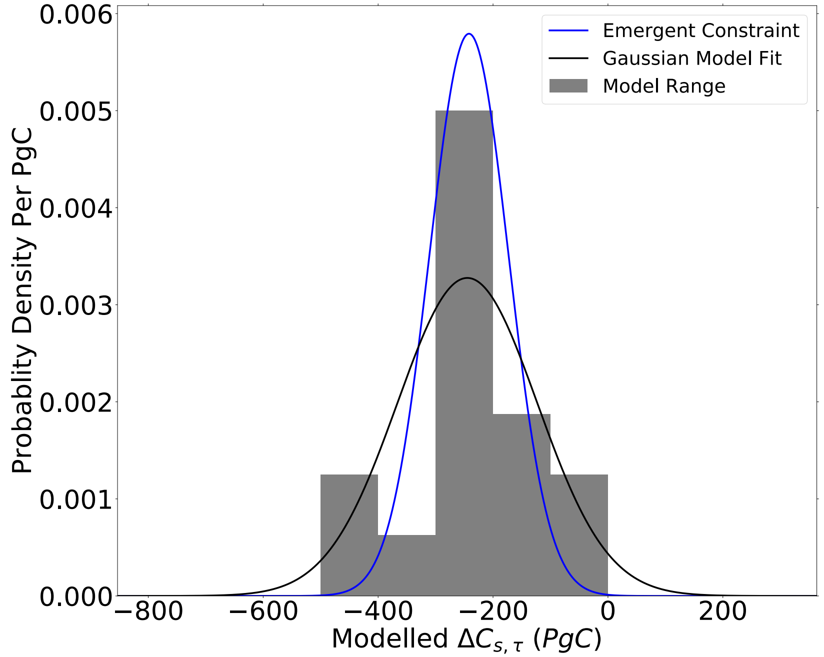
# Result – Spatial Emergent Constraint

We have showed our method holds, so can use the observational spatial temperature sensitivity of $\tau_s$ to predict $\Delta C_{s,\tau}$ (**x-axis**).

This allows us to obtain a spatial emergent constraint on the change of global soil carbon due to the temperature sensitivity of soil carbon turnover for the 2°C global mean warming on CMIP6 (**y-axis).**

Uncertainty in projections reduced from -245 ± 122 PgC to -242 ± 68 PgC.



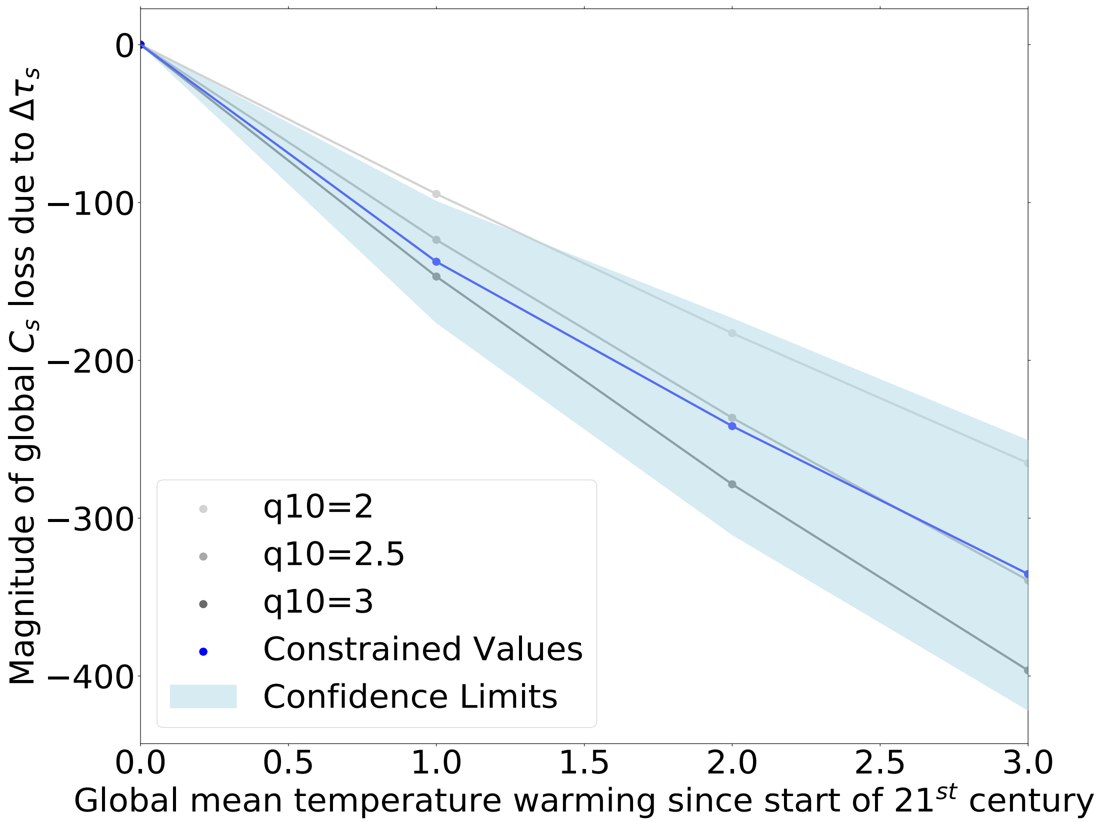
# Result – effective q10 sensitivity

By obtaining an emergent constraint on $\Delta C_{s,\tau}$ for differing levels of global mean warming, we can infer an effective q10 sensitivity on heterotrophic respiration.

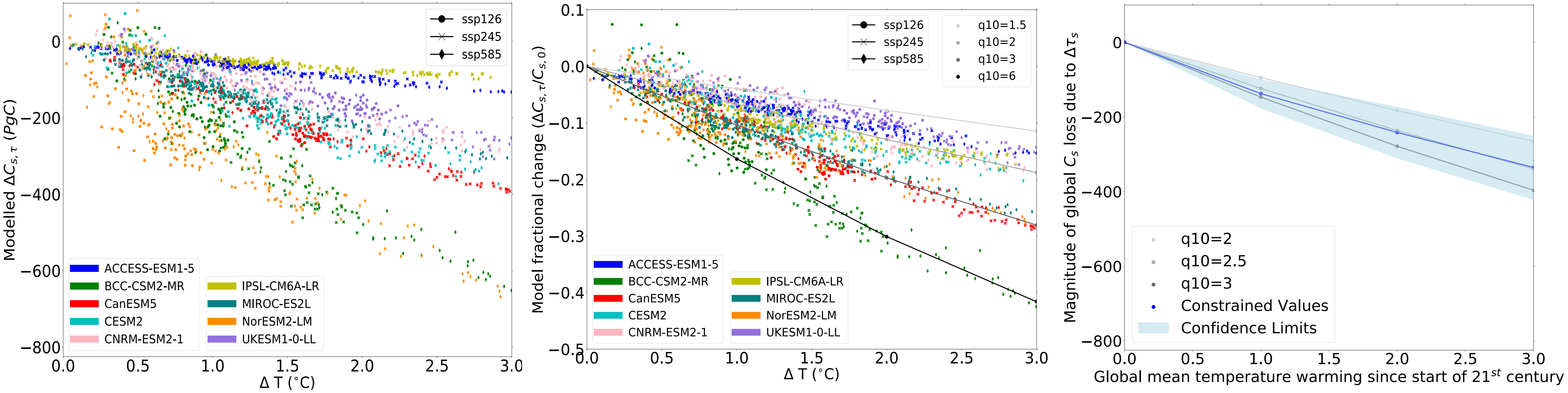
Our emergent constraint predicts an effective q10 sensitivity of approximately 2.5.

This inferred q10 sensitivity is dependent on the initial observational carbon stocks.

$$\Delta C_{s,\tau} = C_{s,0}[\exp((-0.1*\log q10)\Delta T)-1]$$



# Result – effective q10 sensitivity




We can compare our constrained effective q10 range to the original CMIP6 model spread.

# References


- Observational soil carbon:
  *Harmonized world soil database (2012), The northern circumpolar soil carbon database: spatially distributed datasets of soil coverage and soil carbon storage in the northern permafrost regions (2013).*
- Observational heterotrophic respiration:
  *CARDAMOM 2001-2010 global carbon Model-Data Fusion (MDF) analysis, (2015).*
- Observational temperature:
  *The WFDEI meteorological forcing data set: WATCH Forcing Data methodology applied to ERA-Interim reanalysis data (2014).*

- Method:
  *An observation-based constraint on permafrost loss as a function of global warming, Chadburn et al. (2017)*
  *Higher climatological temperature sensitivity of soil carbon in cold than warm climates, Koven et al. (2017)*