



Aridity modulates the **apparent climate sensitivity** of climatological carbon cycle dynamics

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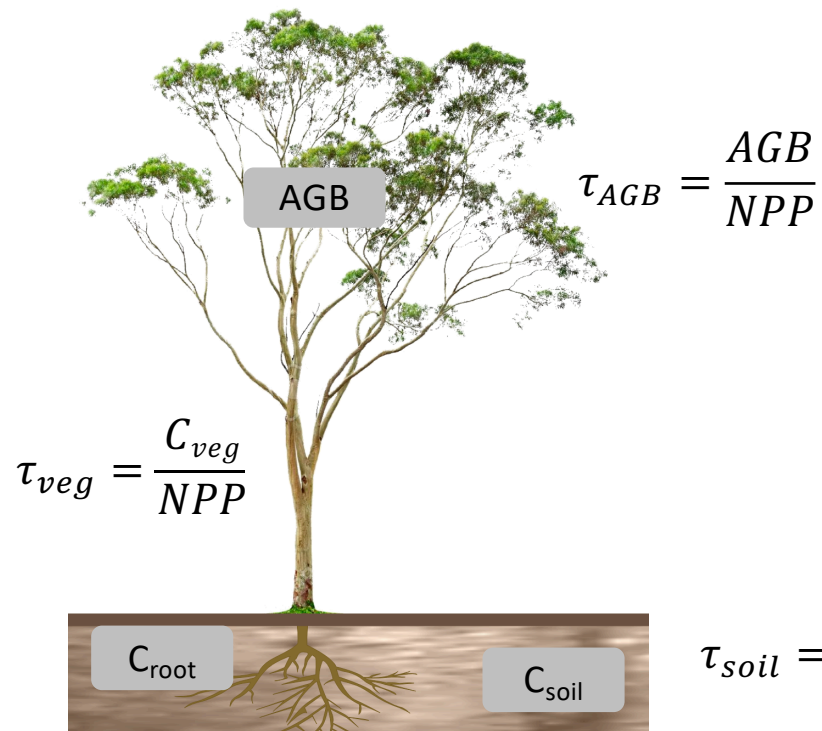


The Turnover Time (τ) and GPP

The time that a carbon atom stays in the land ecosystem

$$\frac{dC}{dt} = F_{in} - \frac{C}{\tau}$$

Steady State ($dC \rightarrow 0$) \rightarrow $\tau = \frac{C}{F_{out}} \approx \frac{C}{F_{in}}$



apparent turnover time τ

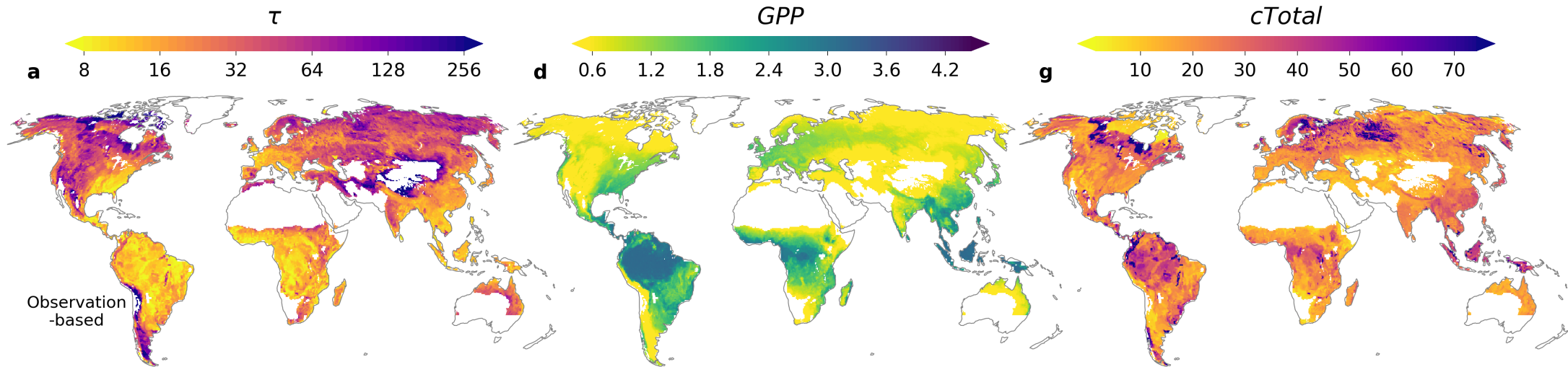
$$\tau_{eco} = \frac{C_{total}}{GPP}$$

$$\tau_{eco} = \frac{C_{total}}{R_{eco}}$$

❖ Climate sensitivities of τ and GPP shape the variations of $cTotal$



Observation based global patterns

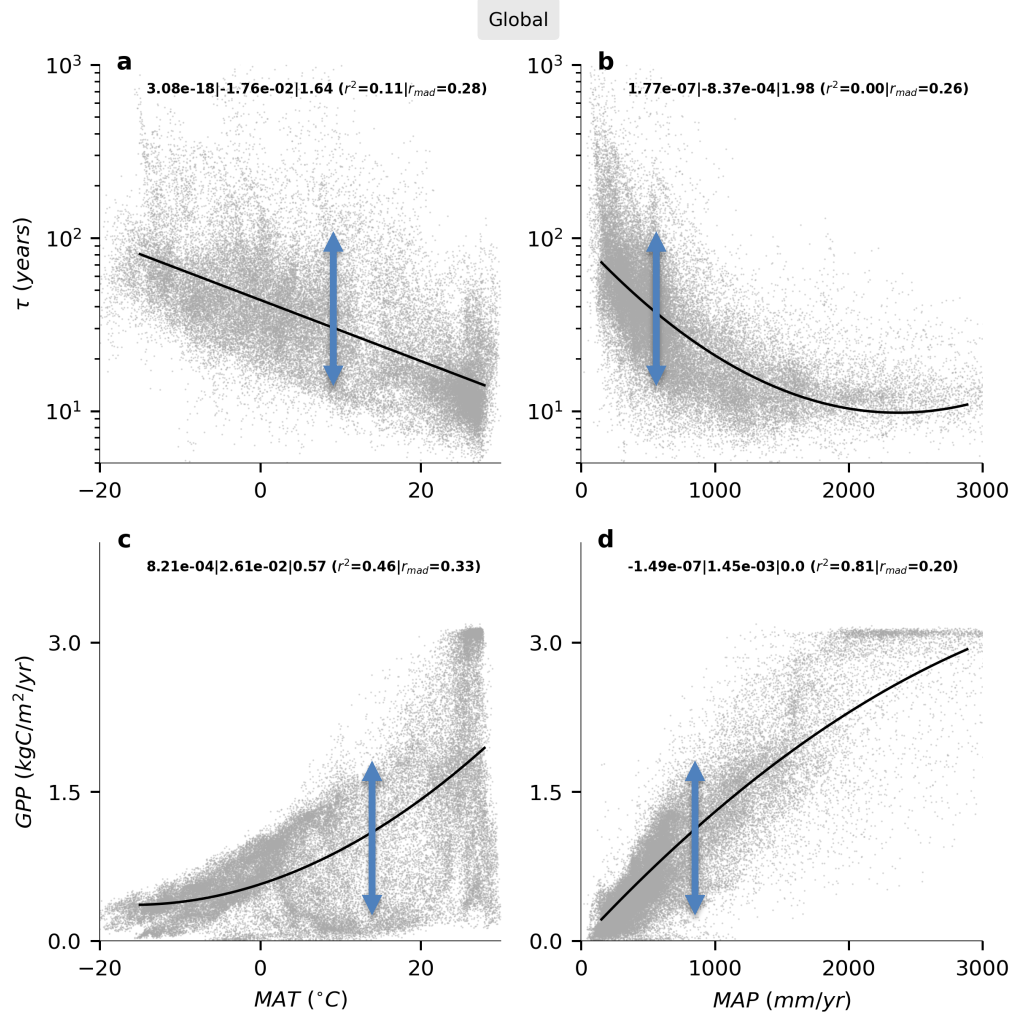


❖ Climatological mean GPP , $cTotal$, and τ have different spatial patterns

- Which aspect of climate, i.e., precipitation (potential moisture, MAP) and temperature (potential energy, MAT) drives the spatial variability?
- How do CRESCENDO models perform?



Large scale gradients (Obs-based)

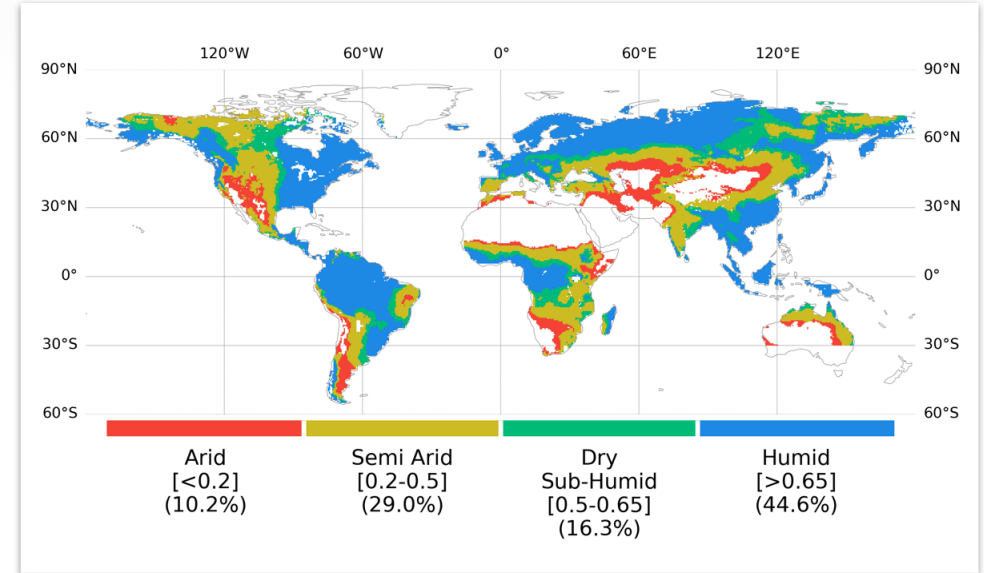
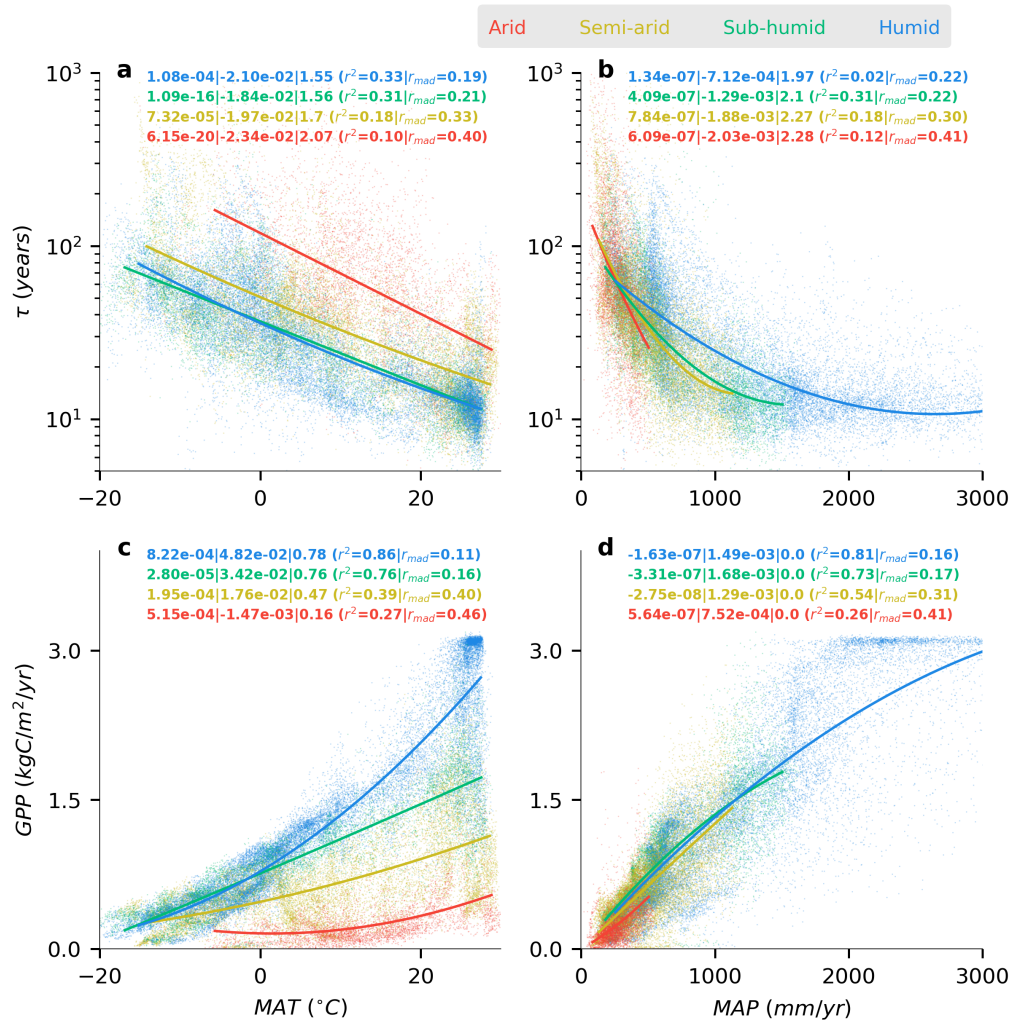


❖ τ and GPP covary with MAT and MAP (spatial/apparent sensitivity)

❖ large spatial heterogeneities



Large scale gradients (Obs-based)

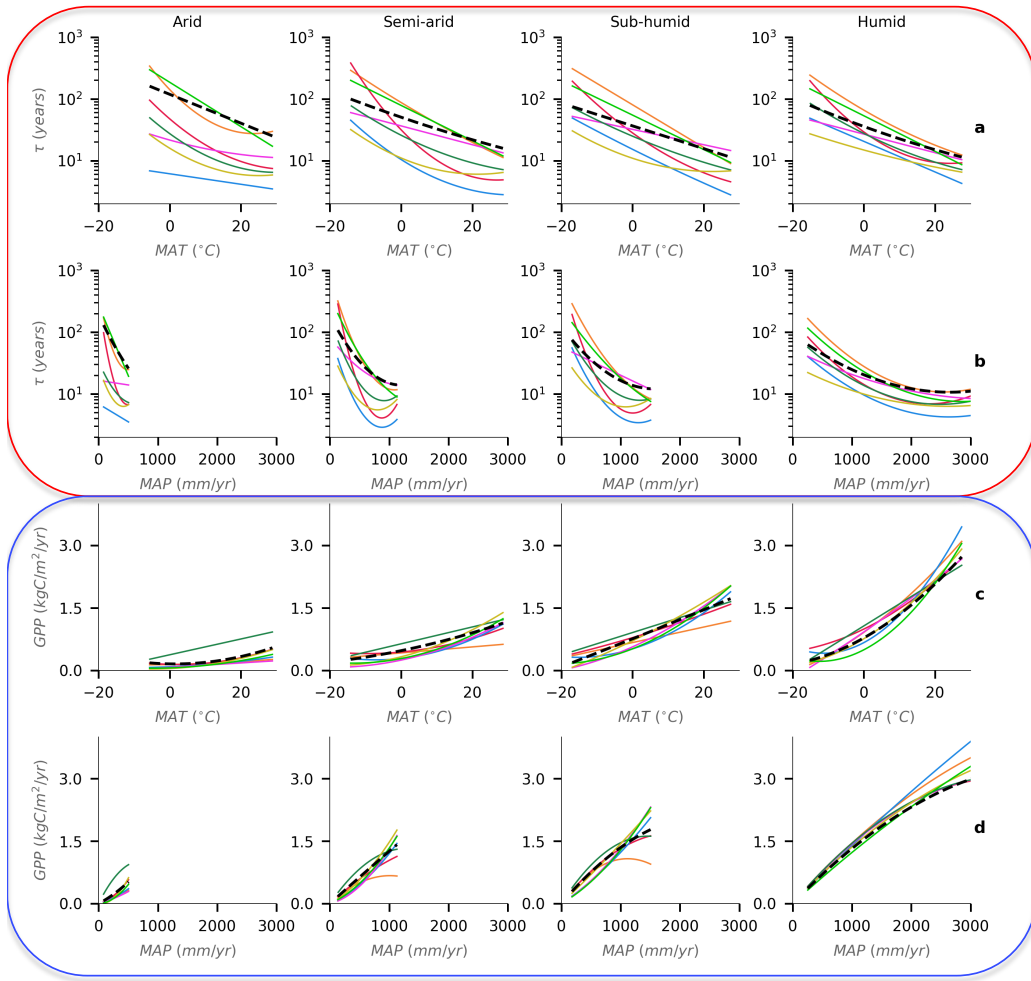


- ❖ τ -MAT has an offset when the climate is arid
- ❖ Relatively smaller difference of τ and GPP relationship with MAP in different climate



Large scale gradients (CRESCENDO Models, S3 simulation, 1990-2010)

Obs-based CLM4.5 CLM5 JSBACH JULES LPJ-GUESS ORCHIDEE SURFEX

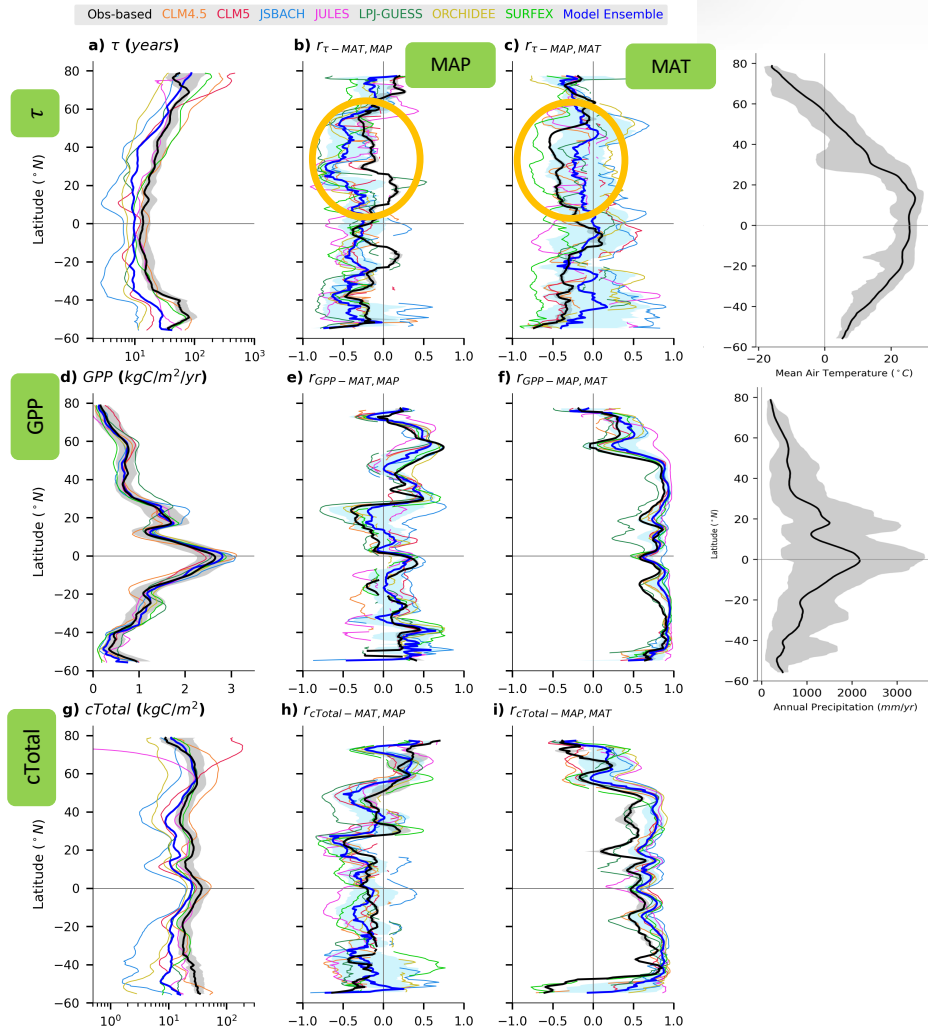


Model Name (LSM/ESM)	Institution	Native spatial resolution (° latitude x ° longitude)
CLM4.5/CMCC-ESM	Euro Mediterranean Centre on Climate Change (CMCC) Foundation	1°x1°
CLM5/NorESM	NORCE Norwegian Research Centre, Bergen, Norway	0.5°x0.5°
JSBACH/MPI-ESM	Max Planck Institute for Meteorology	~1.875°x1.875° (T63)
JULES/UKESM	Met Office Hadley Centre, UK NERC	~1.25°x1.875° (N96)
LPJ-GUESS/EC-Earth	Department of Physical Geography and Ecosystem Science, Lund University	0.5°x0.5°
ORCHIDEE/IPSL-CM5	Institut Pierre Simon Laplace (IPSL), France	0.5°x0.5°
SURFEX/CNRM-CM5	CNRM, Météo-France/CNRS/Université Fédérale de Toulouse	1°x1°

- ❖ Each column is climate, each row is a relationship
- ❖ τ -Climate: Model spread decreases from arid (left) to humid (right)
- ❖ Most model tend to capture the GPP's relationships with climate (dashed lines closer to solid lines)



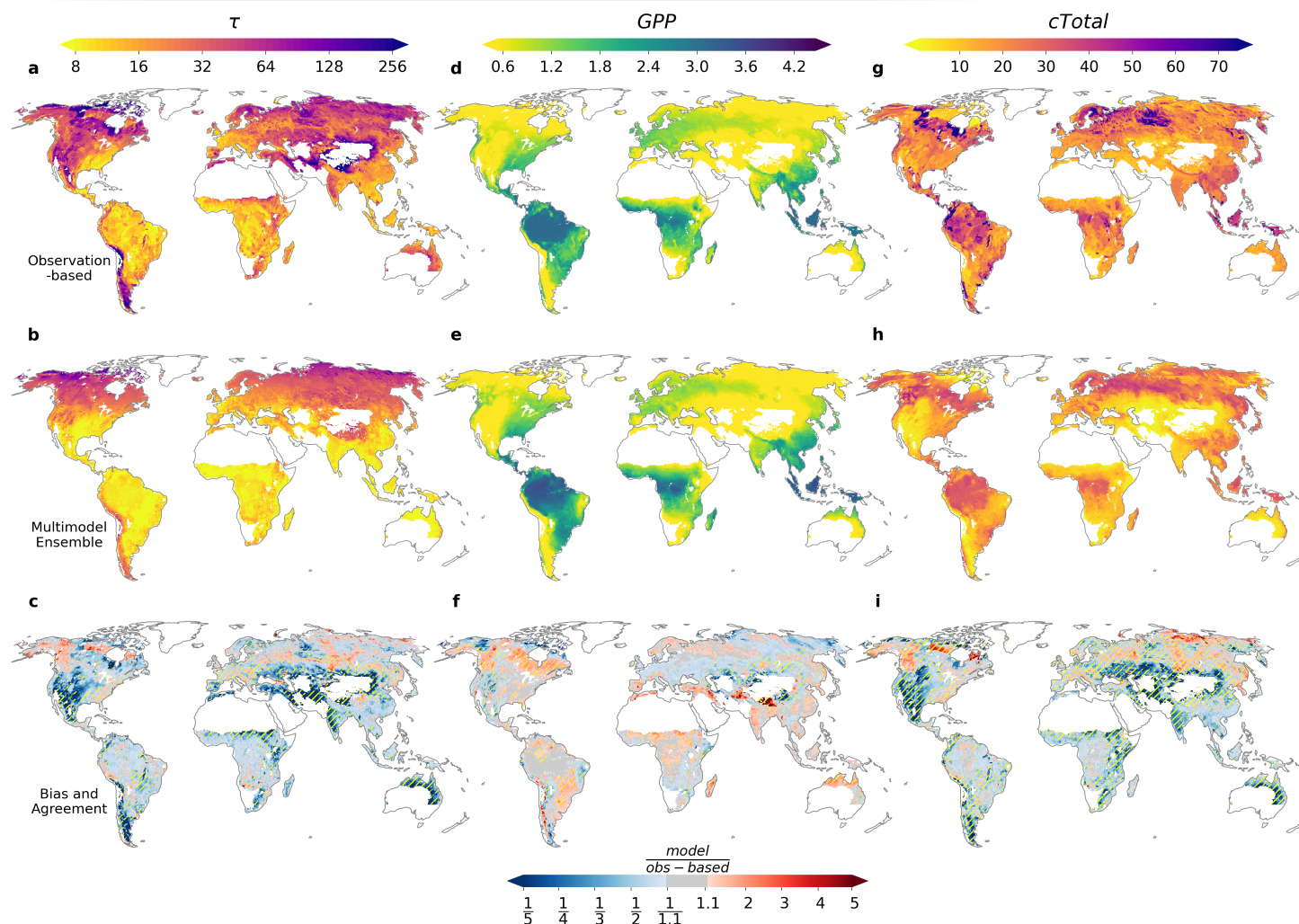
Zonal variations (local)



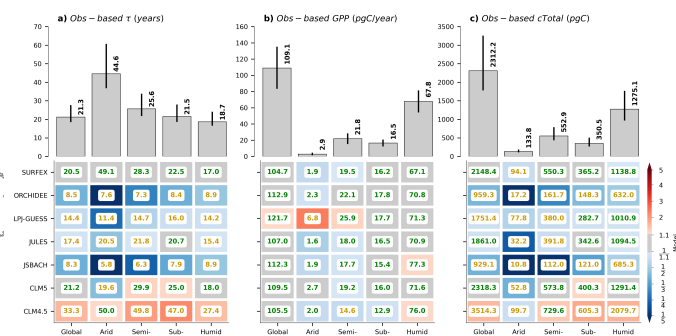
- ❖ Zonal means and partial correlations with climate
- ❖ Models have much stronger τ -MAT association, esp. in northern mid-latitudes
- ❖ GPP follows MAP, and most models get it correctly.
- ❖ cTotal is a mix of two, with a strong association with MAP.
 - Models have stronger association with precipitation



Grid-to-grid comparisons (Overall)

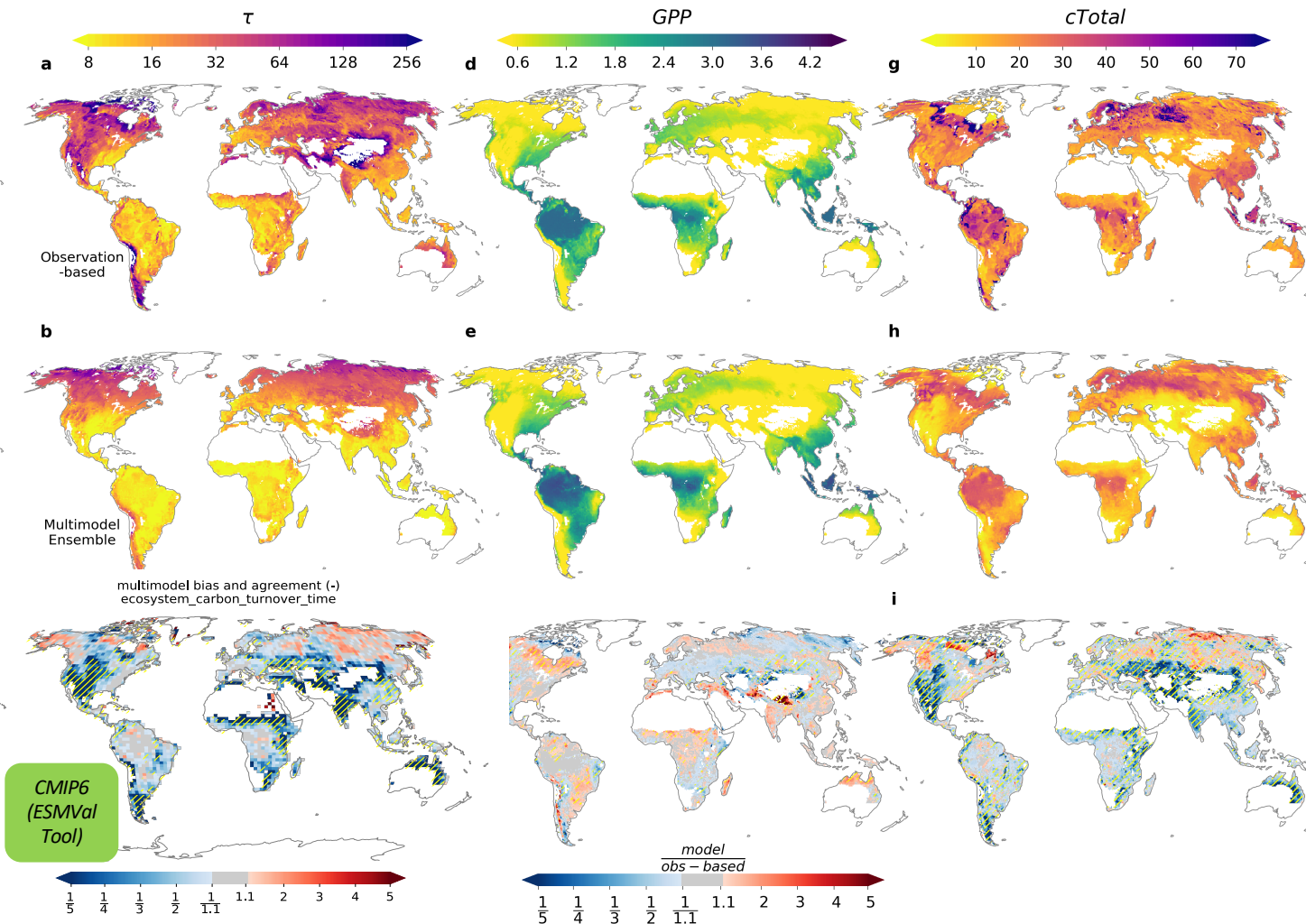


- ❖ Overall, the larger scale gradient are captured by the ensemble median of models
 - Still large biases in τ
- ❖ The model agreement has improved in the humid tropics, but remain poor in warm semi-arid regions

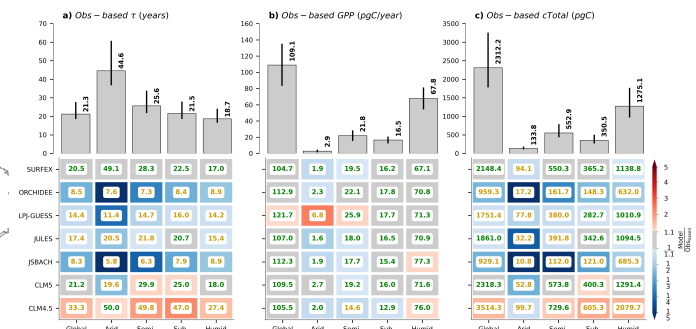




Grid-to-grid comparisons (Overall)

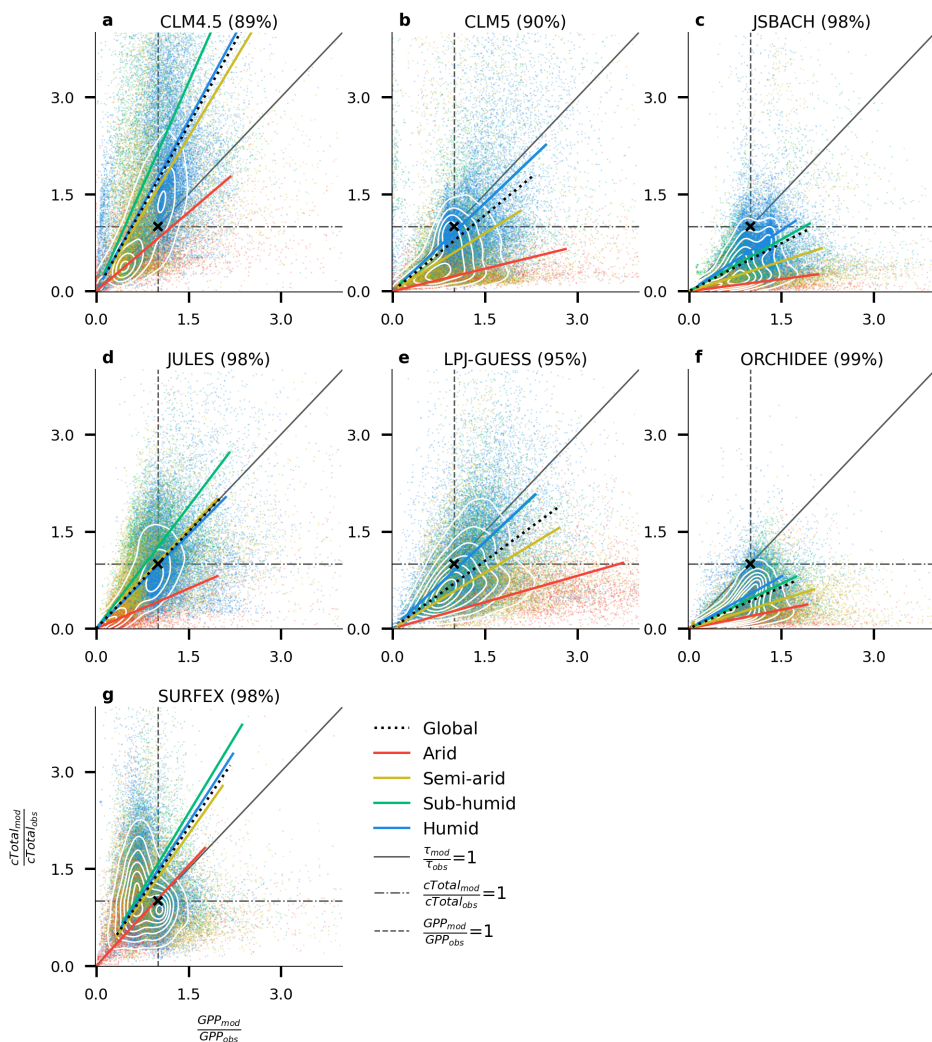


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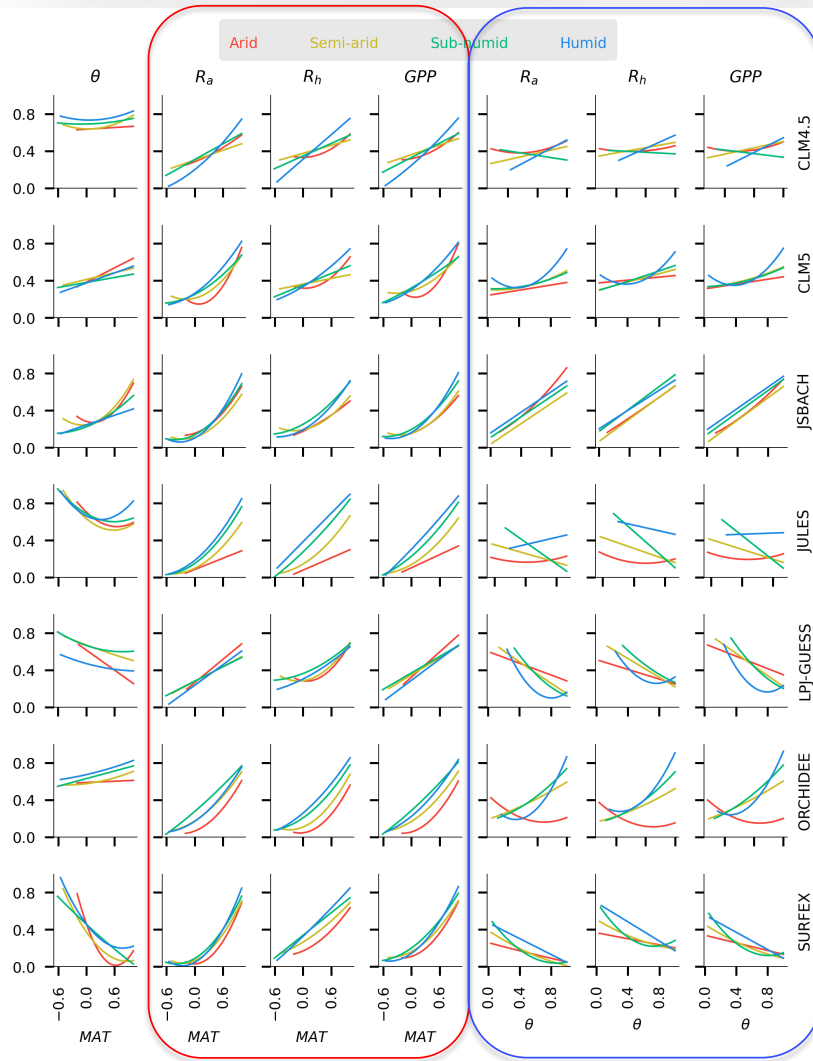
Diagnosing biases



- ❖ If τ is correct (along 1:1 line), the biases in GPP (X-axis) should translate to those in C stock (Y-axis)
- ❖ Most models have more grid cells with relatively lower biases in GPP than in stock (along vertical line)
- ❖ JULES and SURFEX have larger density of points where τ , GPP and stocks have low biases
- ❖ Some models have systematic biases in stock but not so much in GPP.



Understanding/differentiating model responses



- ❖ Model response curves for different climate
 - θ : soil moisture, MAT: temperature, R_a : autotrophic respiration, R_h : heterotrophic respiration, GPP: productivity
- ❖ The model with better performance of τ do not necessarily have a clear difference in responses
- ❖ Temperature responses consistent across models
- ❖ Diverging moisture response for different models, but consistent across variables



Summary & Challenges

- ❖ Aridity classes seem to separate/offset the τ with seemingly larger association with precipitation than anticipated/expected
- ❖ Models seem to perform much better for GPP than for τ
 - Benchmarking against observations has helped, presumably
- ❖ Modelled τ in humid and climate are better in CRESCENDO simulations, but seem to be biased in CMIP6
 - Too larger dependence on temperature in colder region, and no precipitation-limited checks in warmer semi-arid regions
- ❖ Difficult to pin-point processes
 - Temperature responses are more consistent than moisture responses
 - Within model behavior does not hold across models (contrary to emergent constraint philosophy for using spatial sensitivities)



Thank you very much!