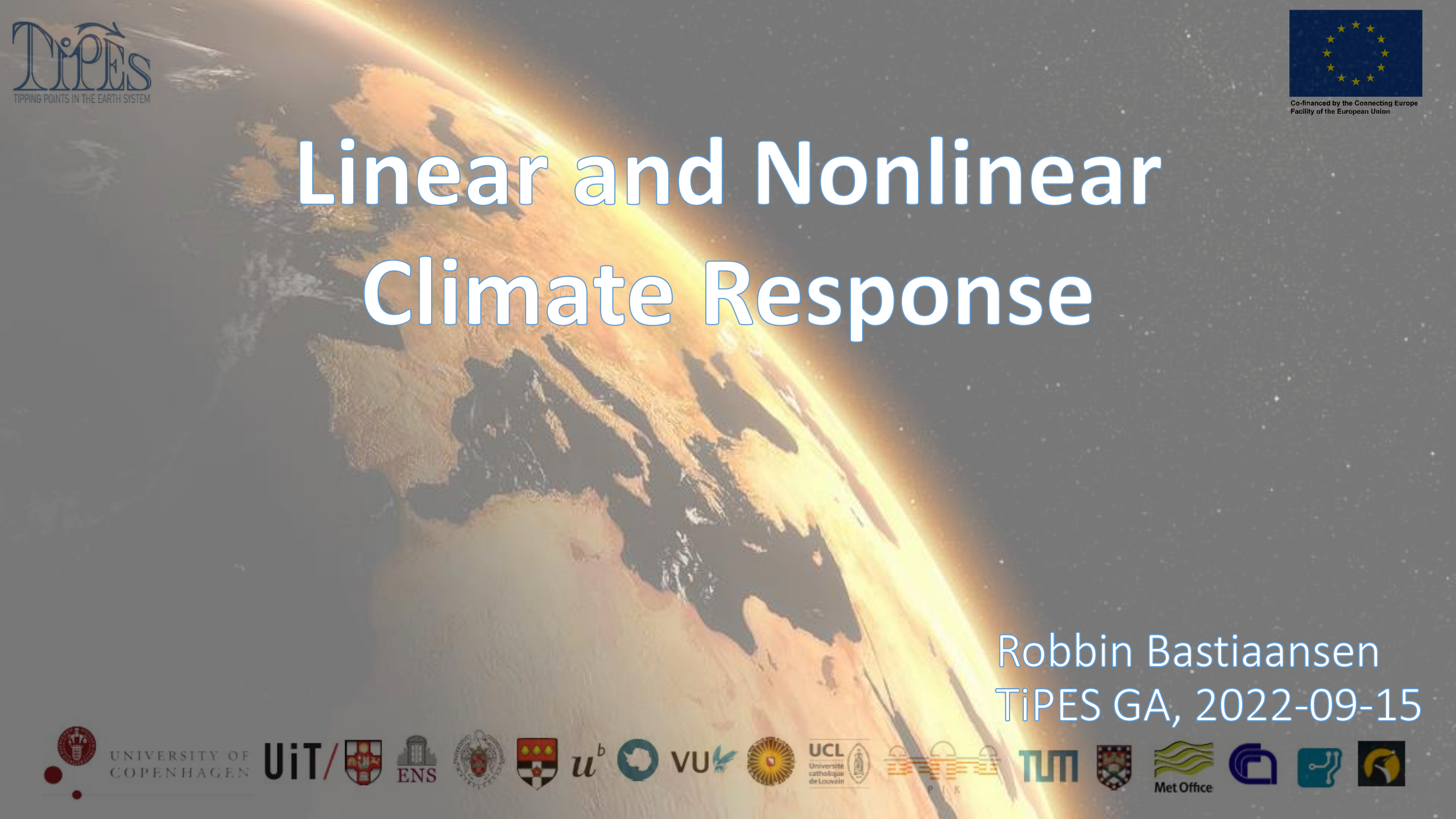


Linear and Nonlinear Climate Response

Robbin Bastiaansen

TiPES GA, 2022-09-15

Co-financed by the Connecting Europe Facility of the European Union

Climate Response

The change in observable due to climate forcing (e.g. CO2)

Equilibrium Climate Sensitivity (ECS)

change in equilibrium temperature
due to (instantaneous) doubling of CO2

Transient Climate Response (TCR)

change in temperature after 100 years
with 1% CO2 increase per year (until doubling)

Methodology

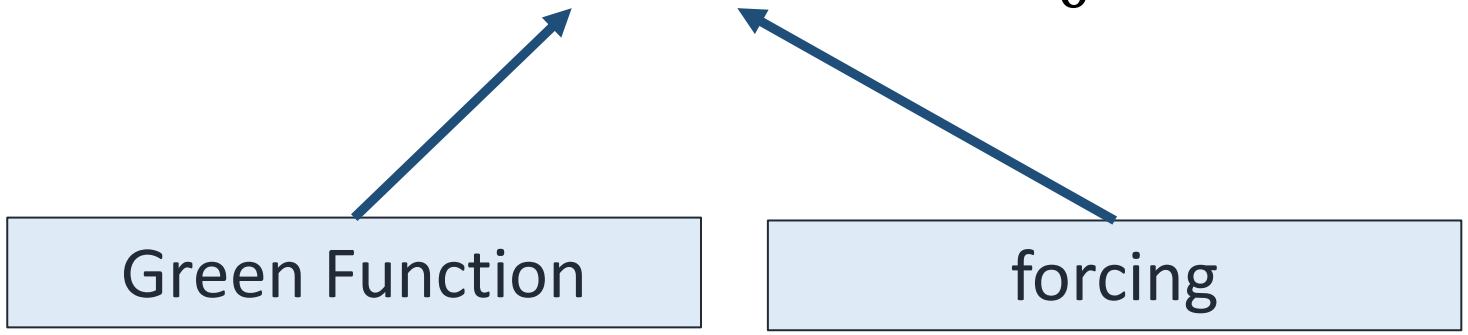
- DESIGN experimental protocol for GCM
- FIT resulting time series to simple model
- EXTRAPOLATION using simple model

Linear Response

$$\frac{dO}{dt} = \mathcal{L}\, O + g(t)$$

Evolution of temperature

$$\Delta T(t) = (G * g)(t) = \int_0^t G(s)\, g(t-s)\, ds$$



Approximation of Green Function:

$$G(t) = \sum_{m=1}^{M} \beta_m\, e^{-t/\tau_m}$$

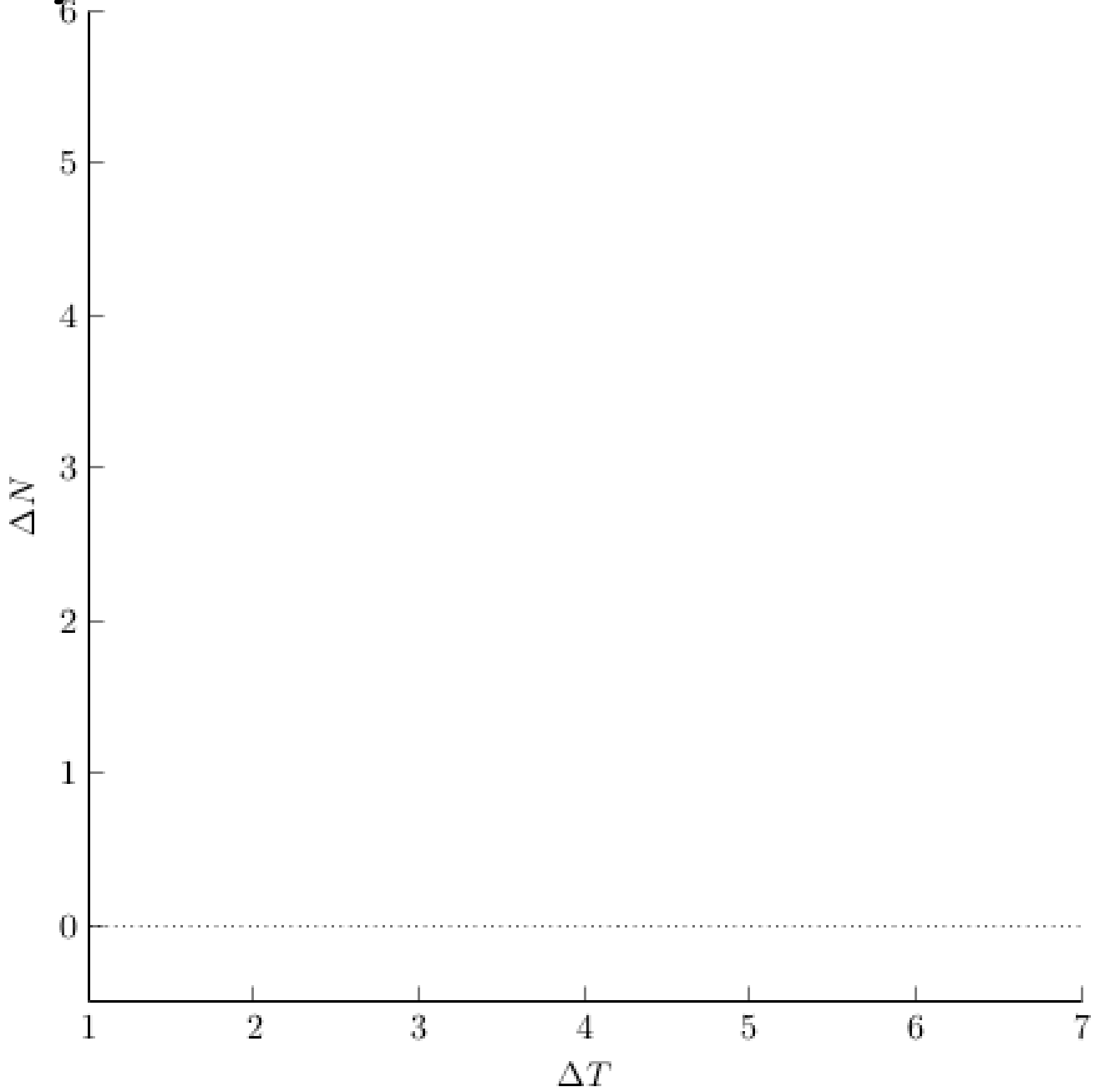
Gregory Method

Regress data to

$$\Delta N(t) = \boldsymbol{F} + \boldsymbol{\lambda}\, \Delta T(t)$$

Since $\Delta N_* = 0$ in equilibrium,
ECS estimation is

$$\Delta T_*^{est} = -\,\boldsymbol{\lambda}^{-1}\, \boldsymbol{F}$$



[Gregory et al, 2014]

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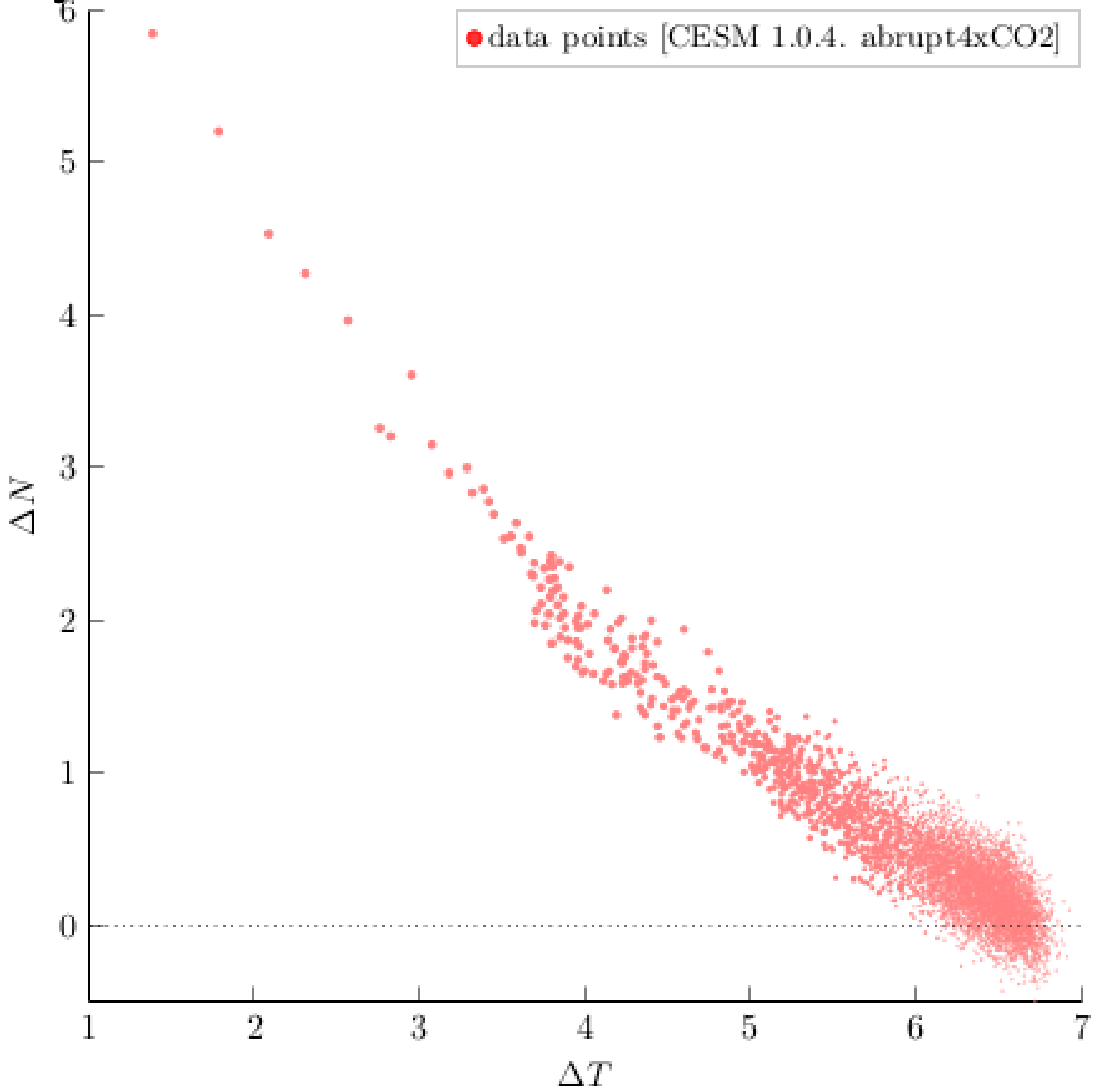

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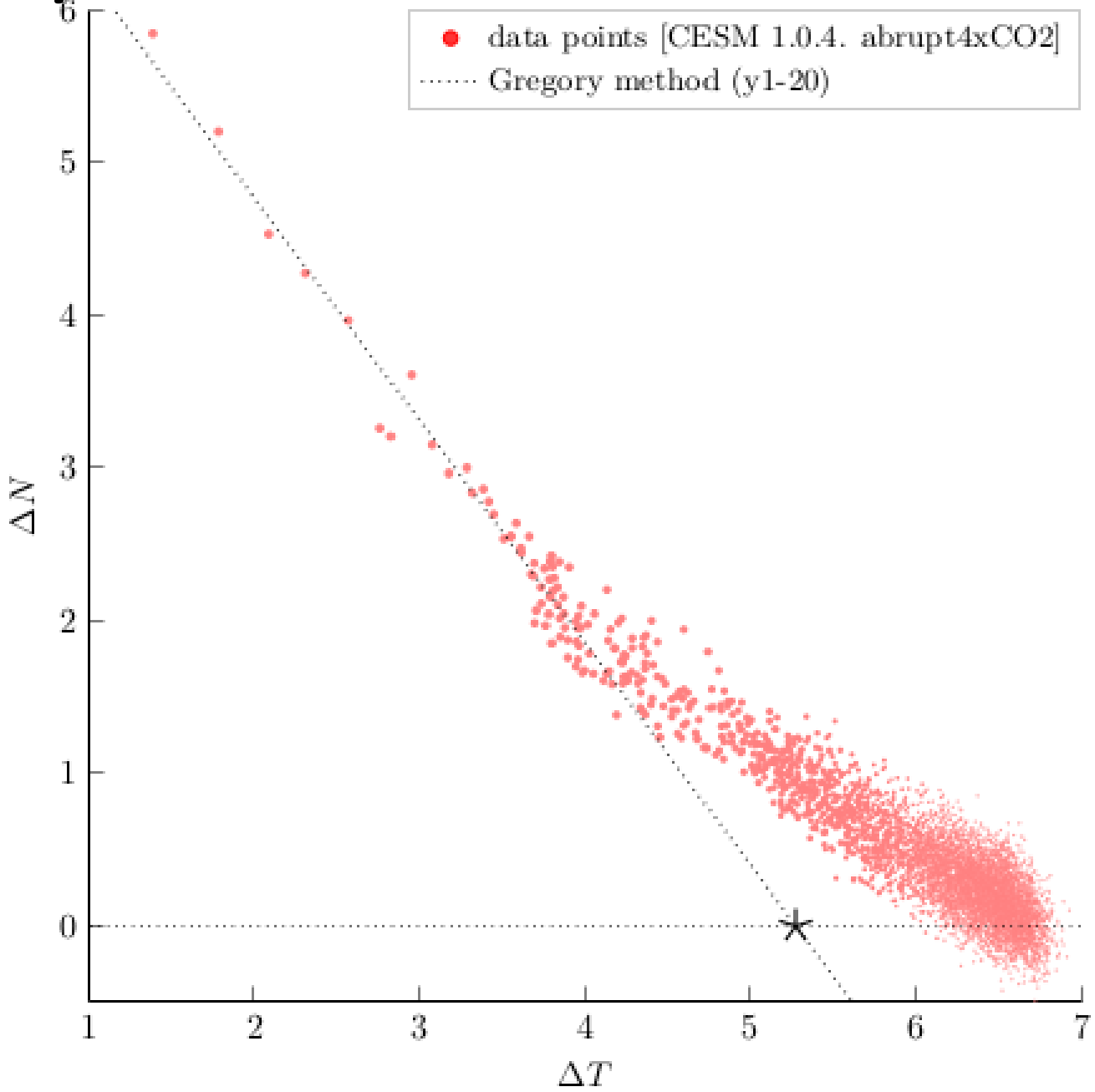

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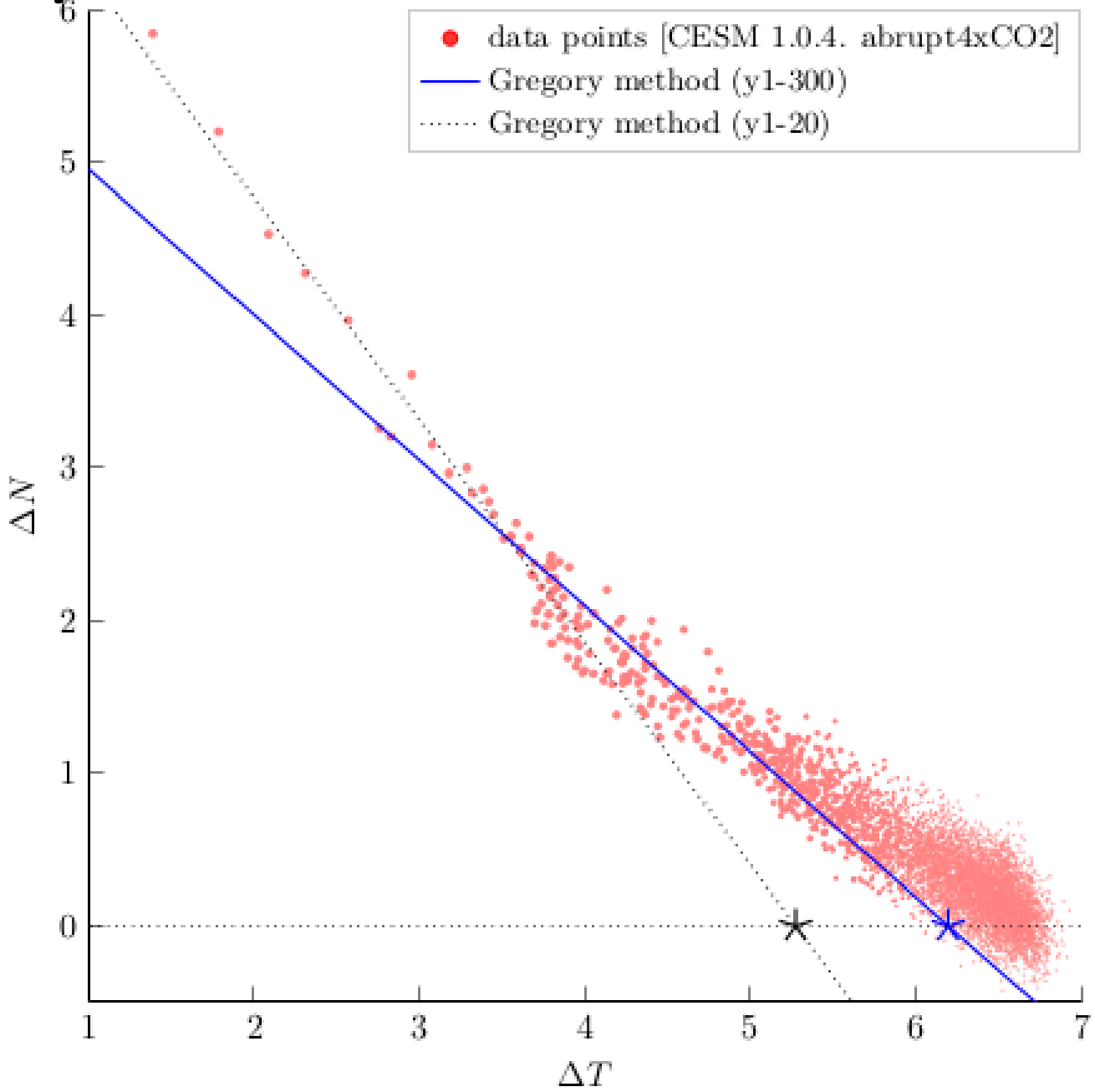

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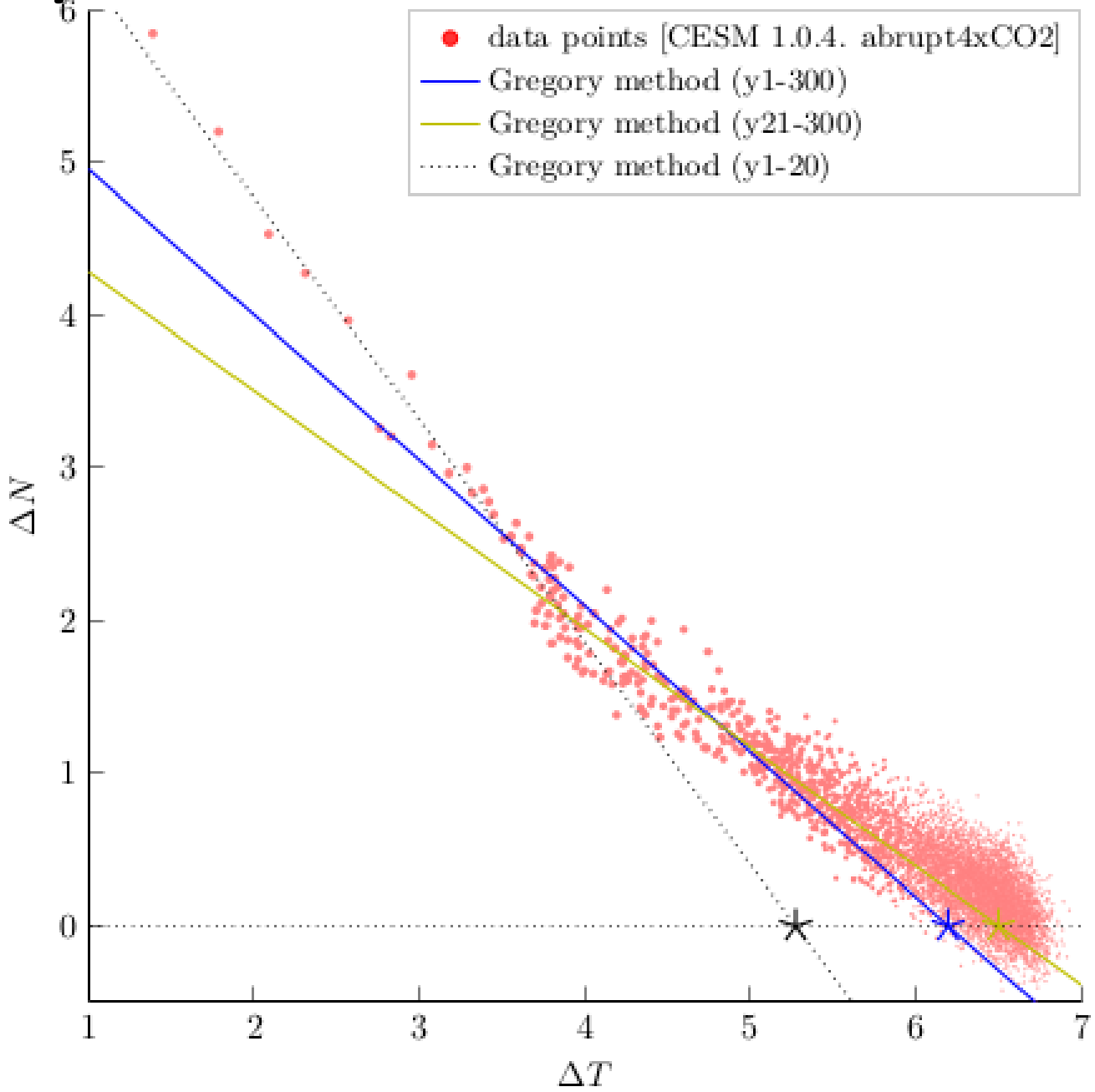

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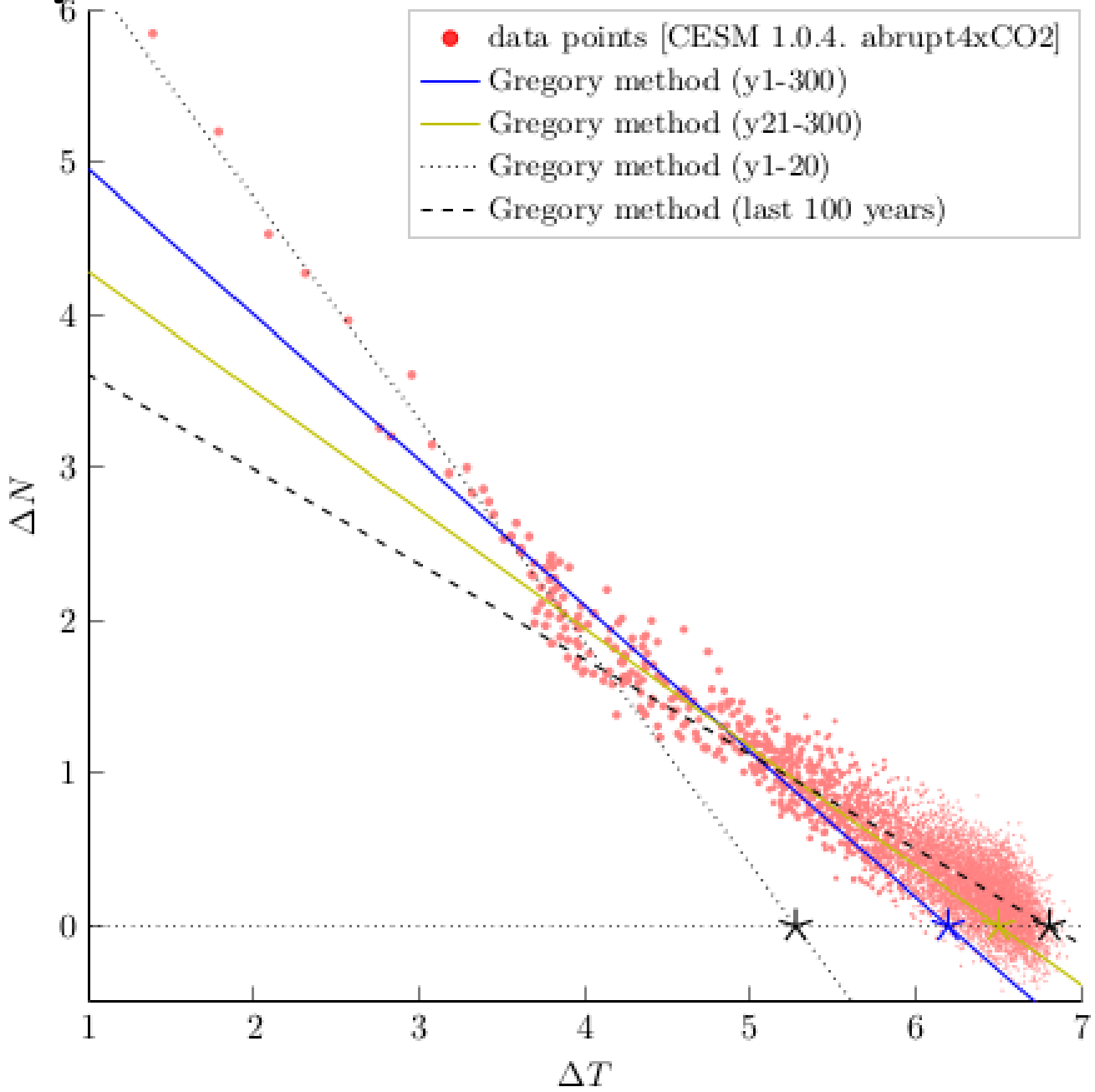


[Gregory et al, 2014]

New Multicomponent Linear Regression Method

Use additional observables!

Regress to:

$$\overrightarrow{\Delta Y} = \boldsymbol{A}\,\overrightarrow{\Delta X} + \overrightarrow{\boldsymbol{F}}$$

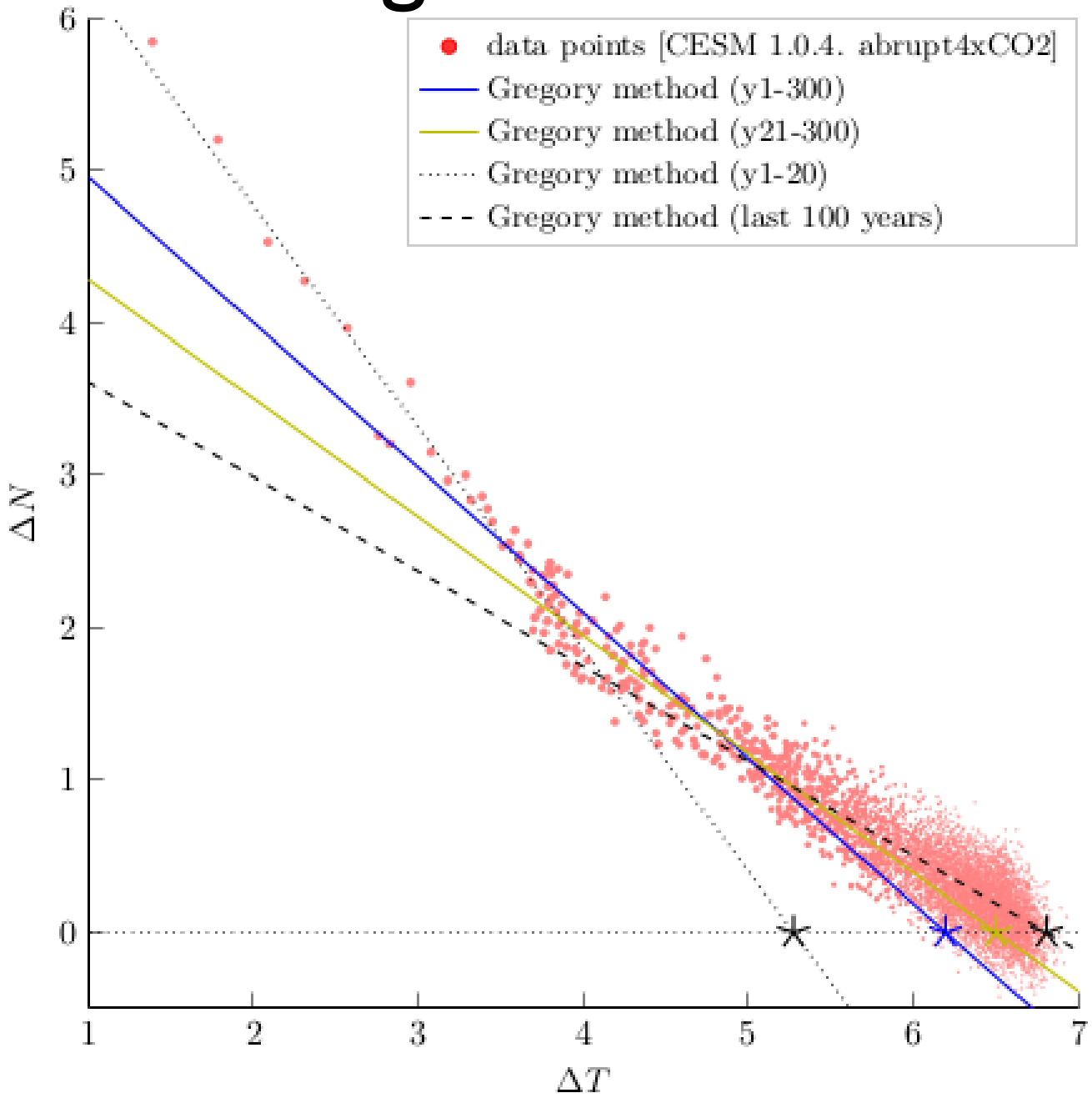
$\overrightarrow{\Delta Y}$: observables that **tend to 0** in equilibrium

$\overrightarrow{\Delta X}$: observables that **get estimated** in equilibrium

Multivariate ECS estimation is

$$\overrightarrow{\Delta X}_*^{est} = -\boldsymbol{A}^{-1}\,\overrightarrow{\boldsymbol{F}}$$

[Bastiaansen et al, 2021]



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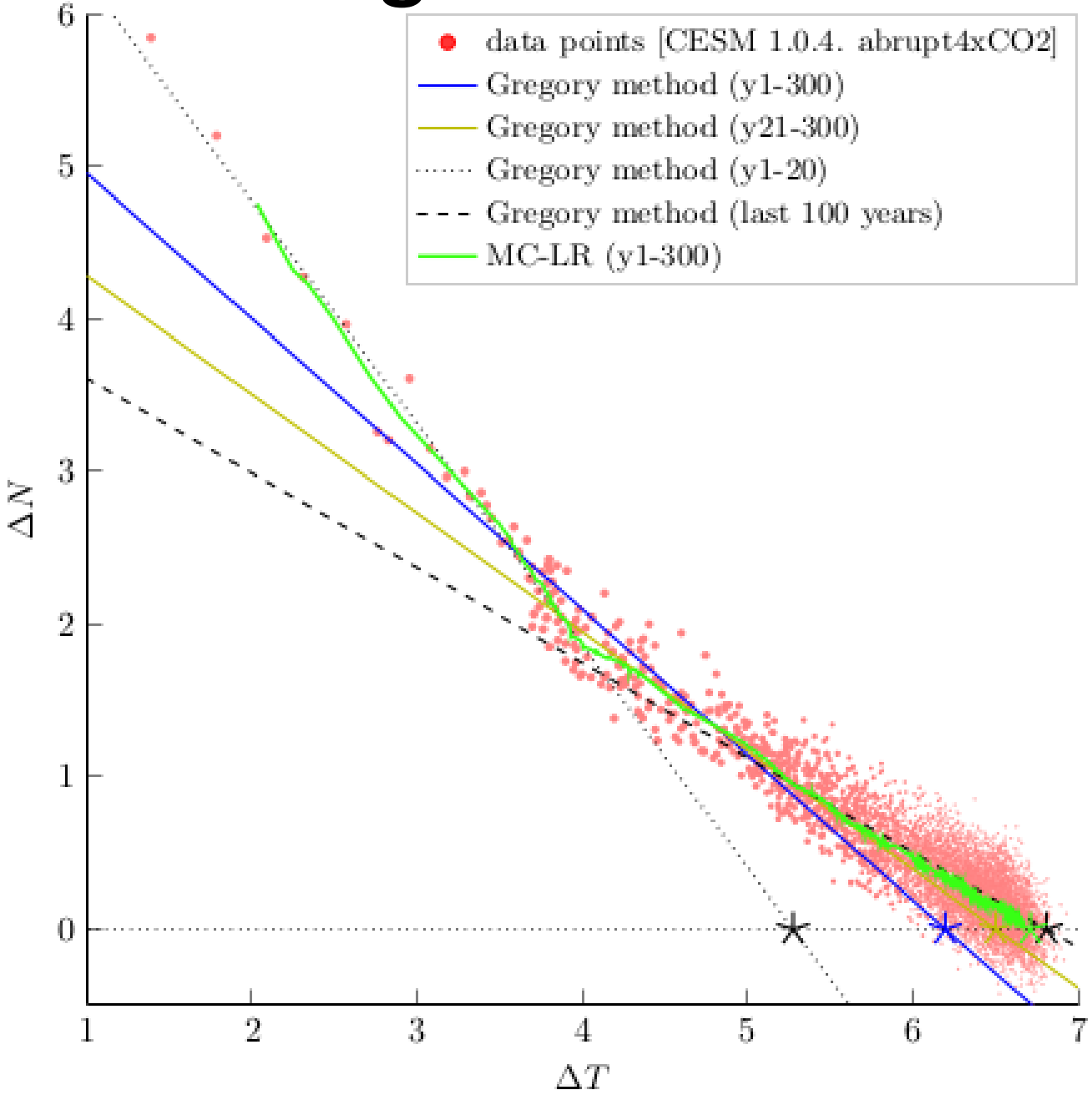
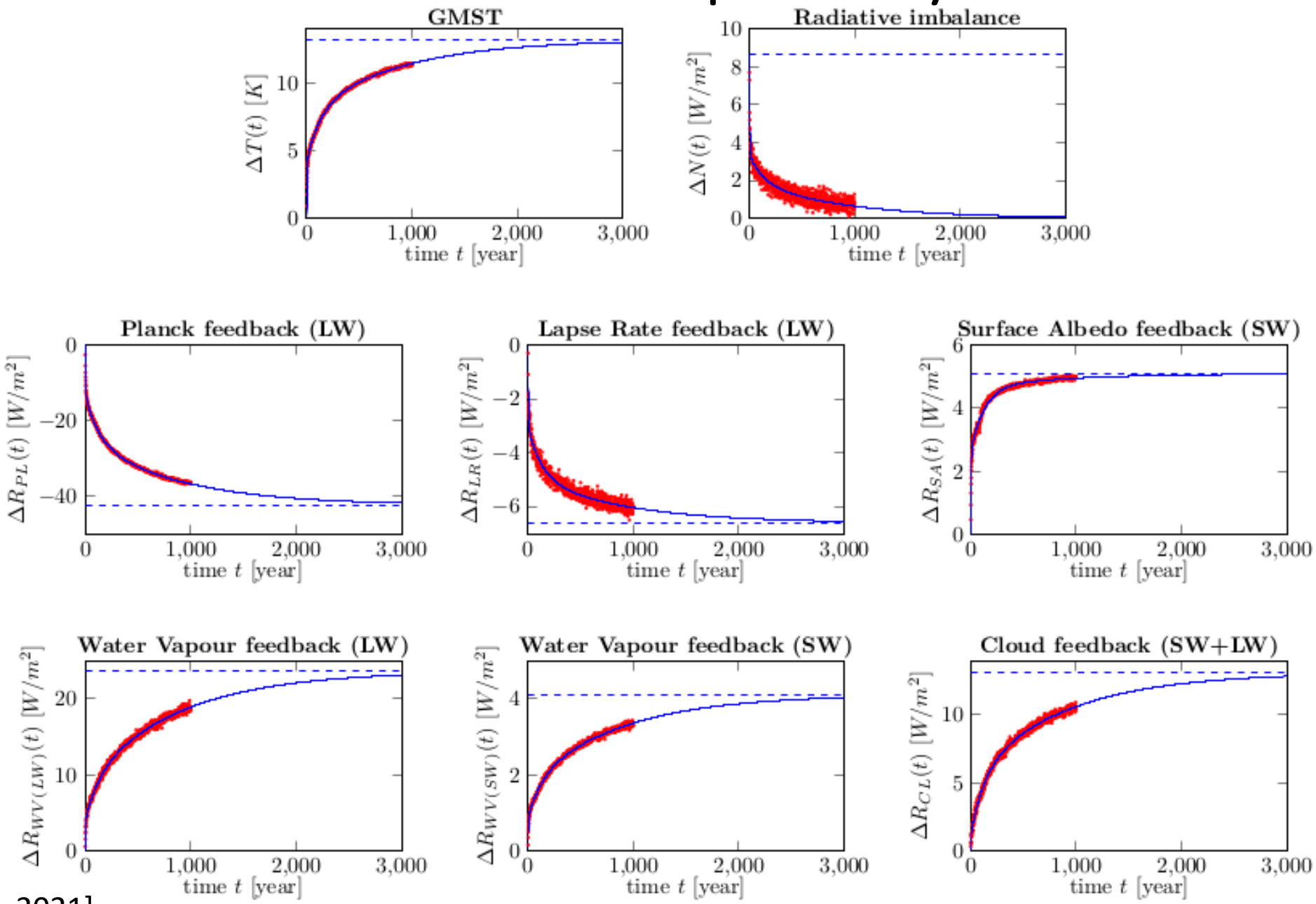


Projections of the Transient State-Dependency of Climate Feedbacks



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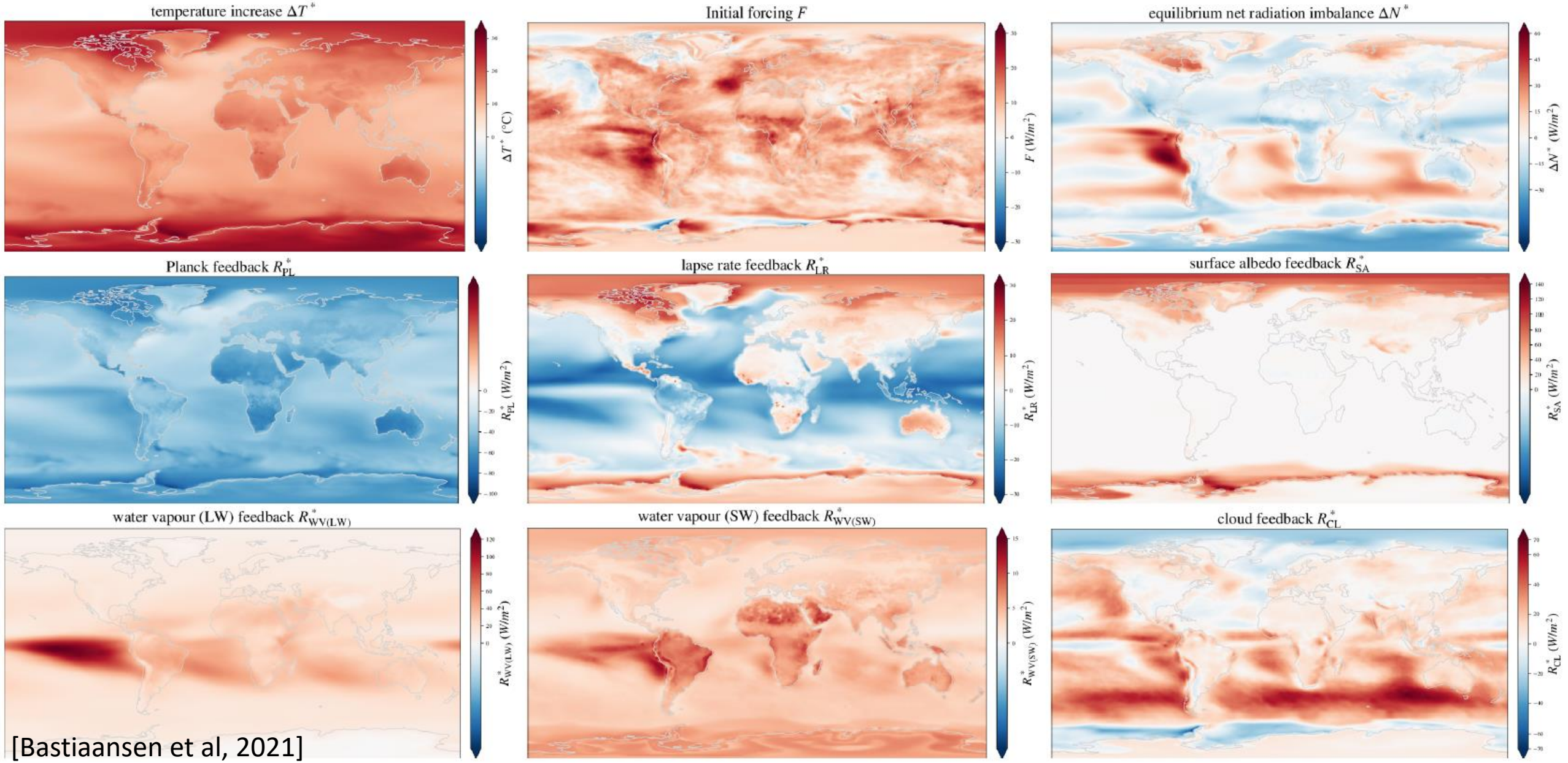
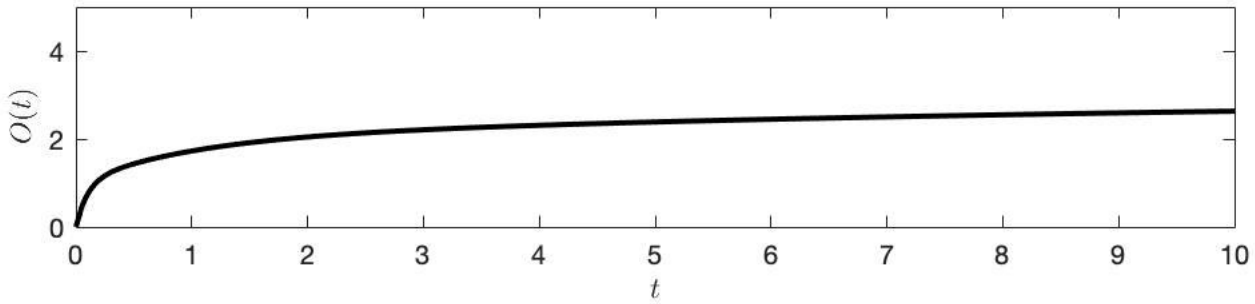
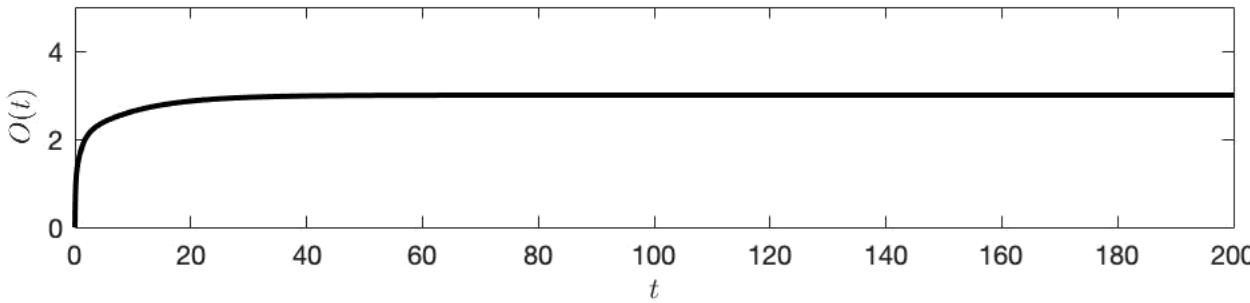
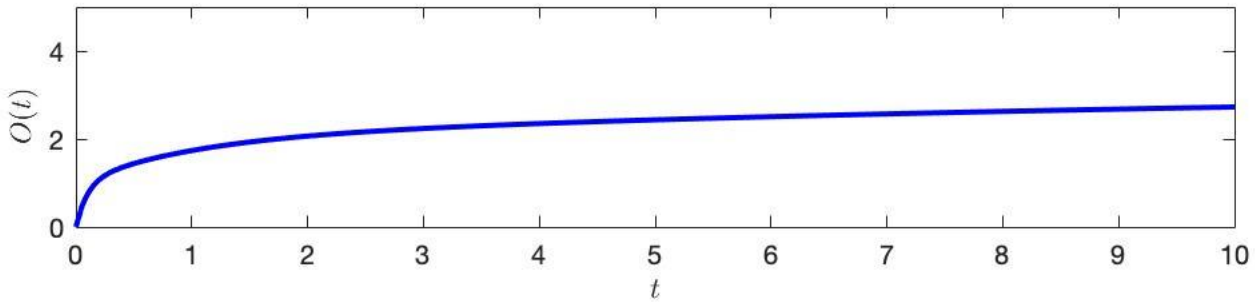


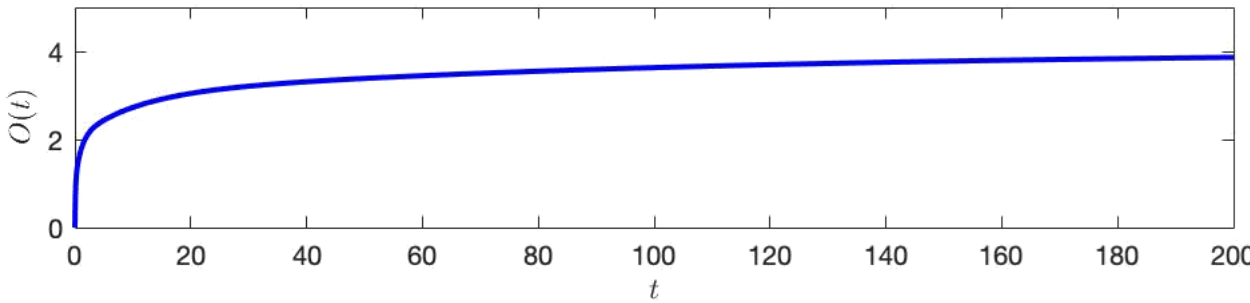
[Bastiaansen et al, 2021]

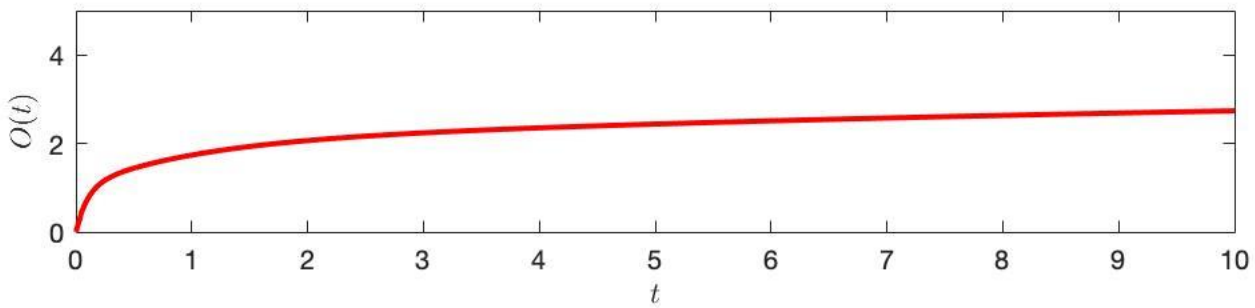
Pitfalls and problems

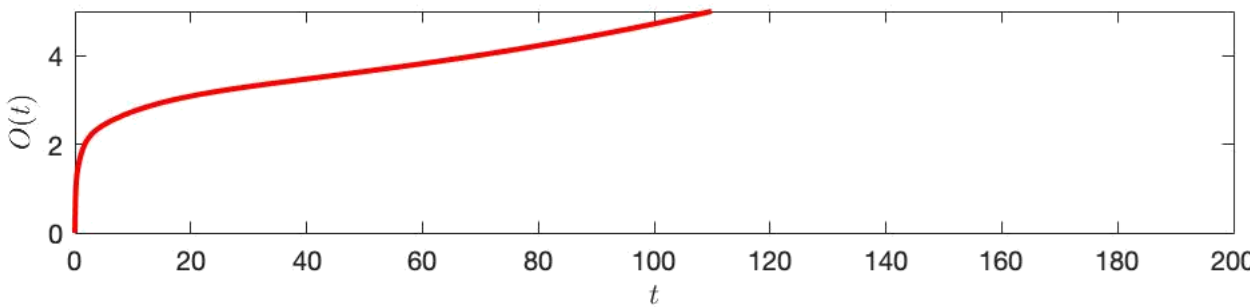






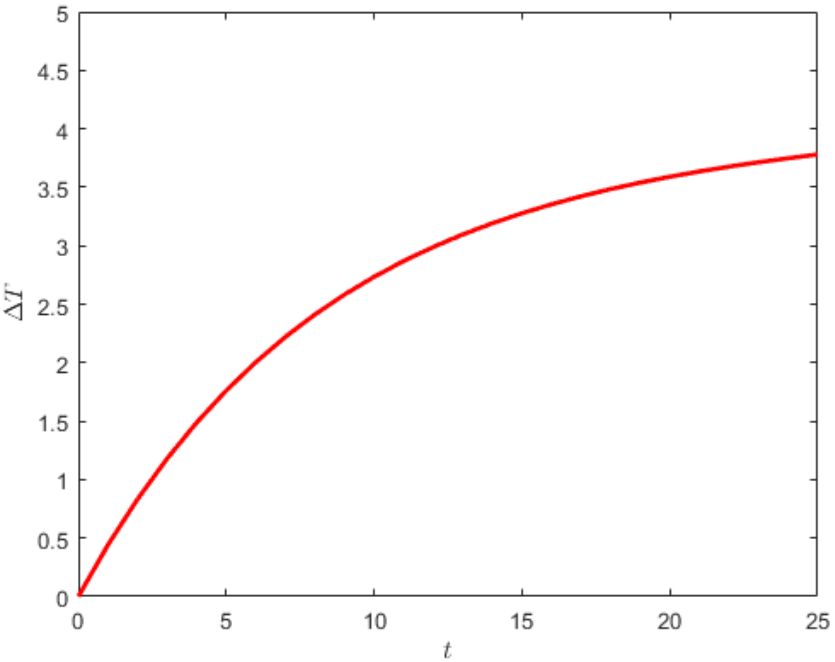


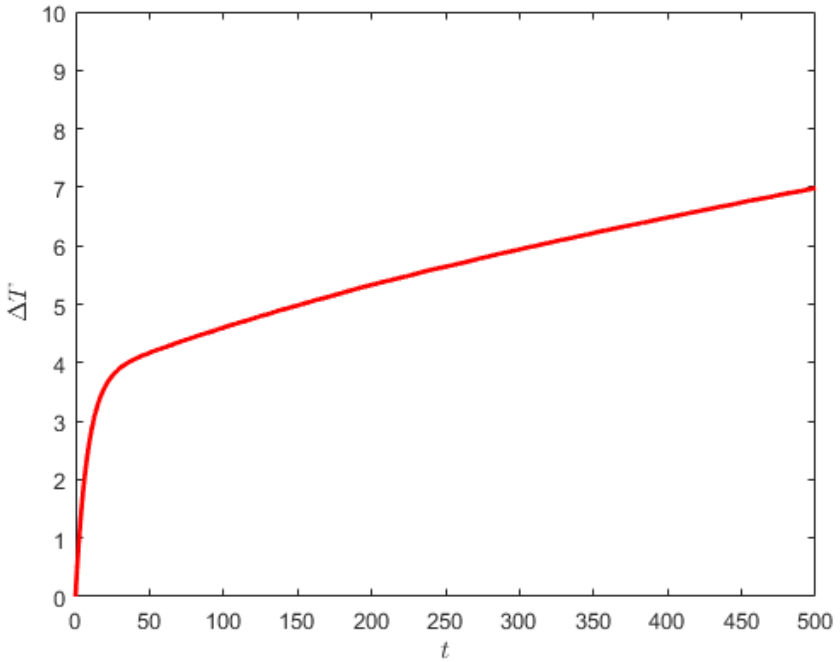


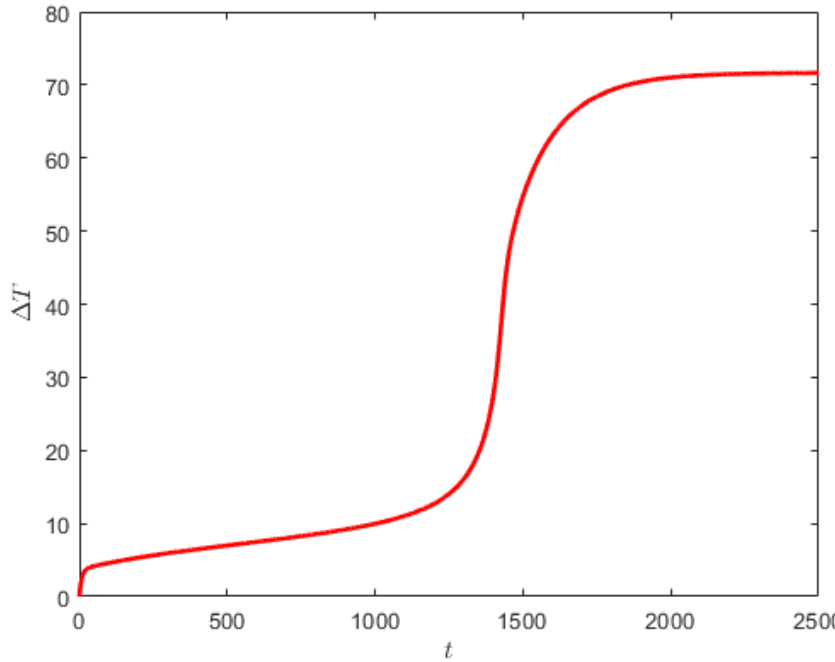


[Bastiaansen, Ashwin, Von der Heydt, 2022, *preprint*]

Nonlinear Response







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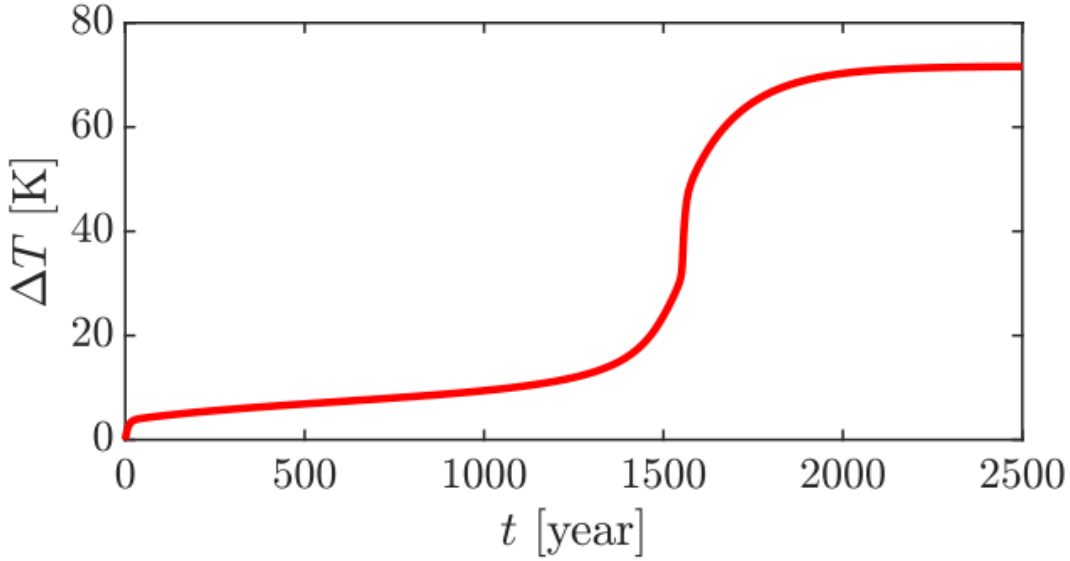

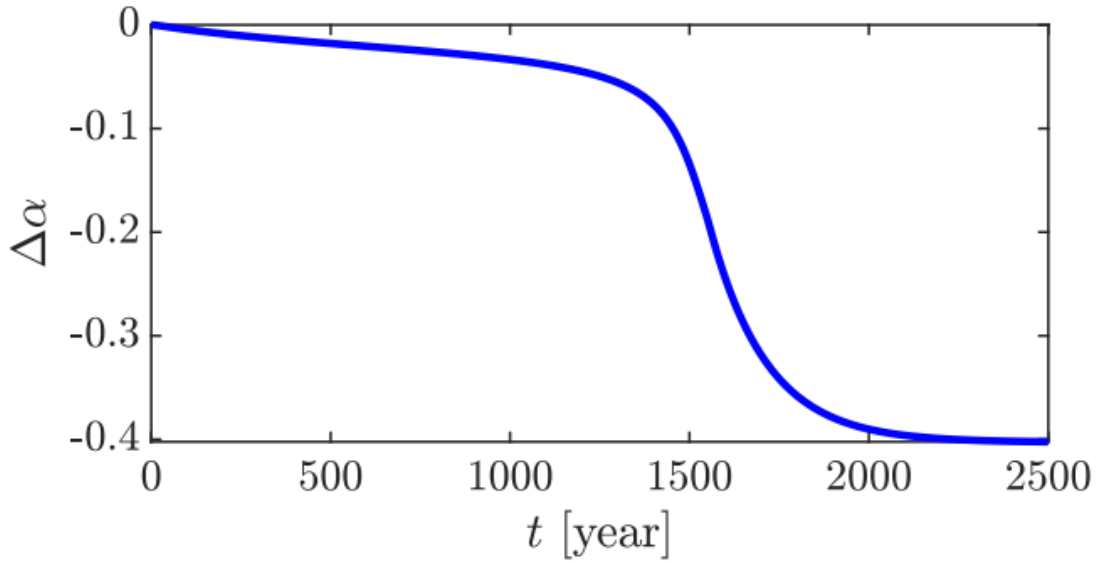

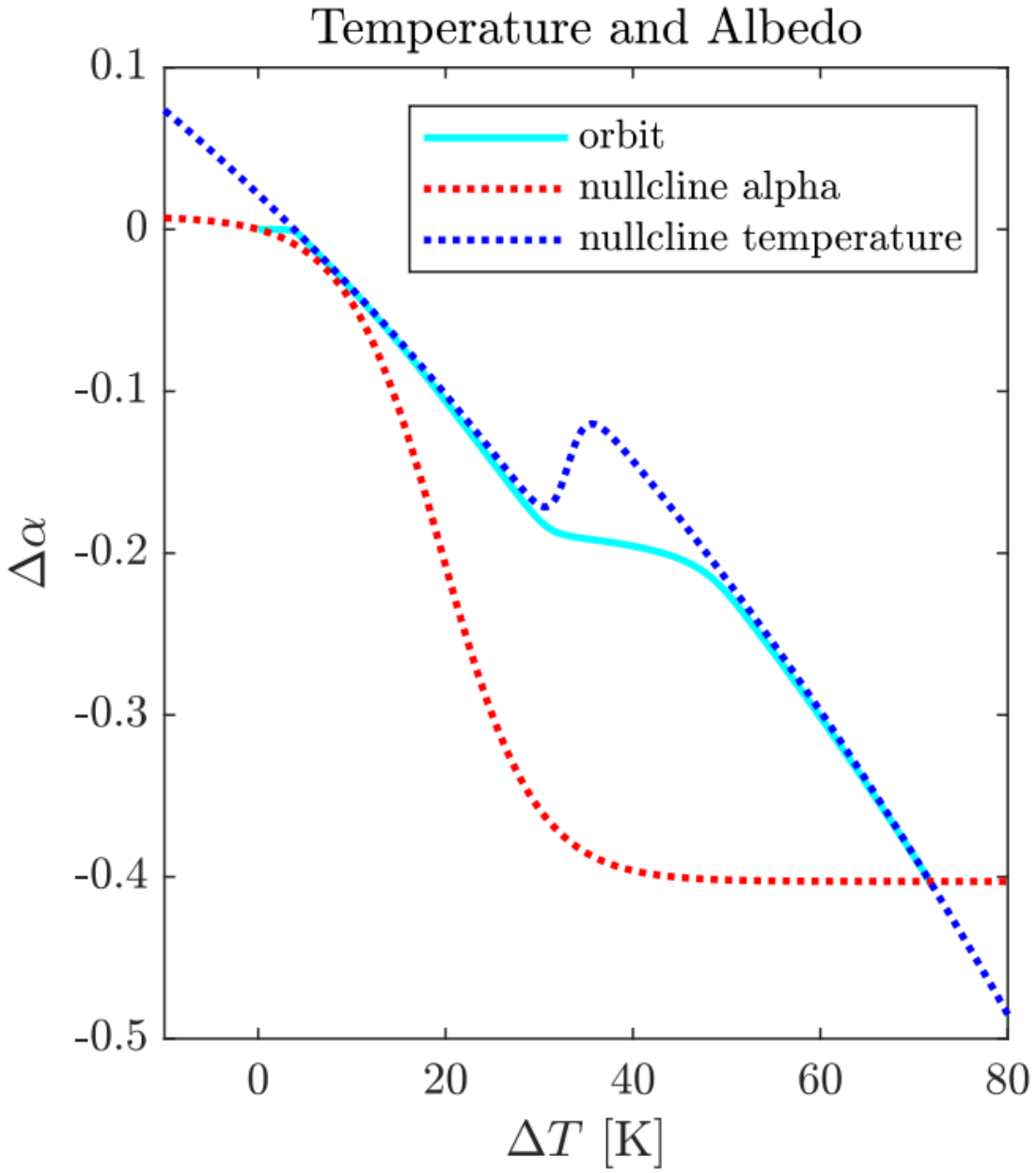

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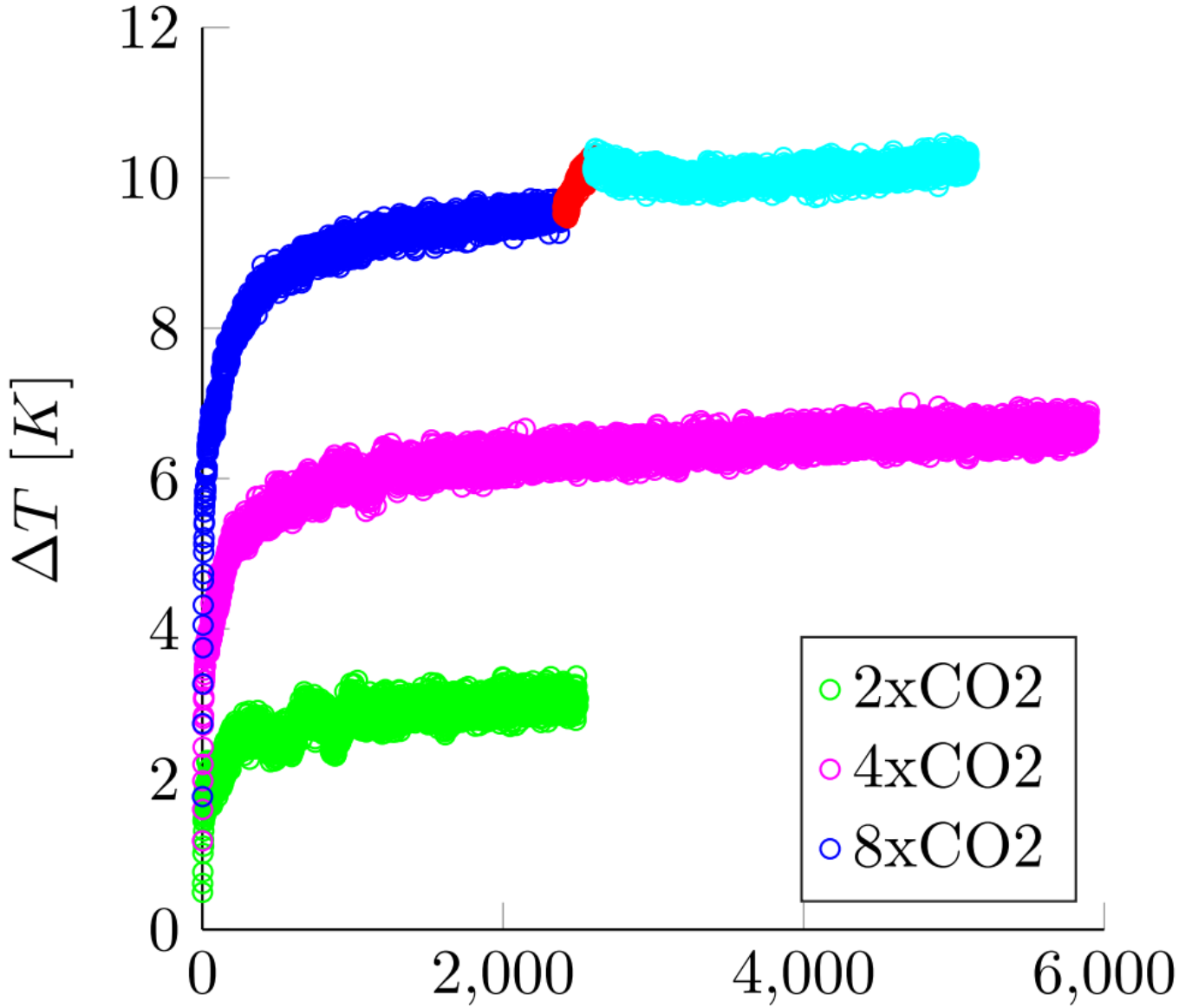
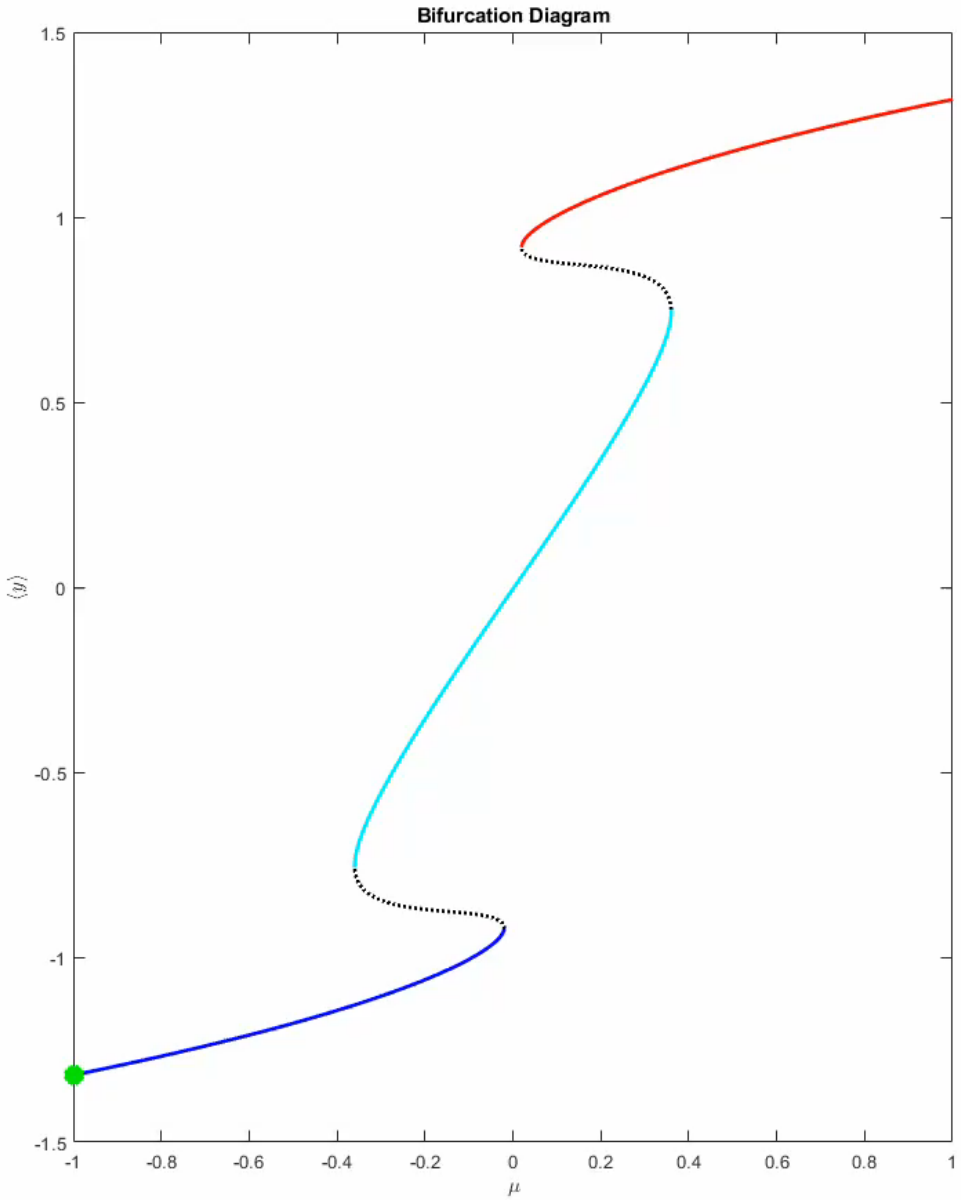
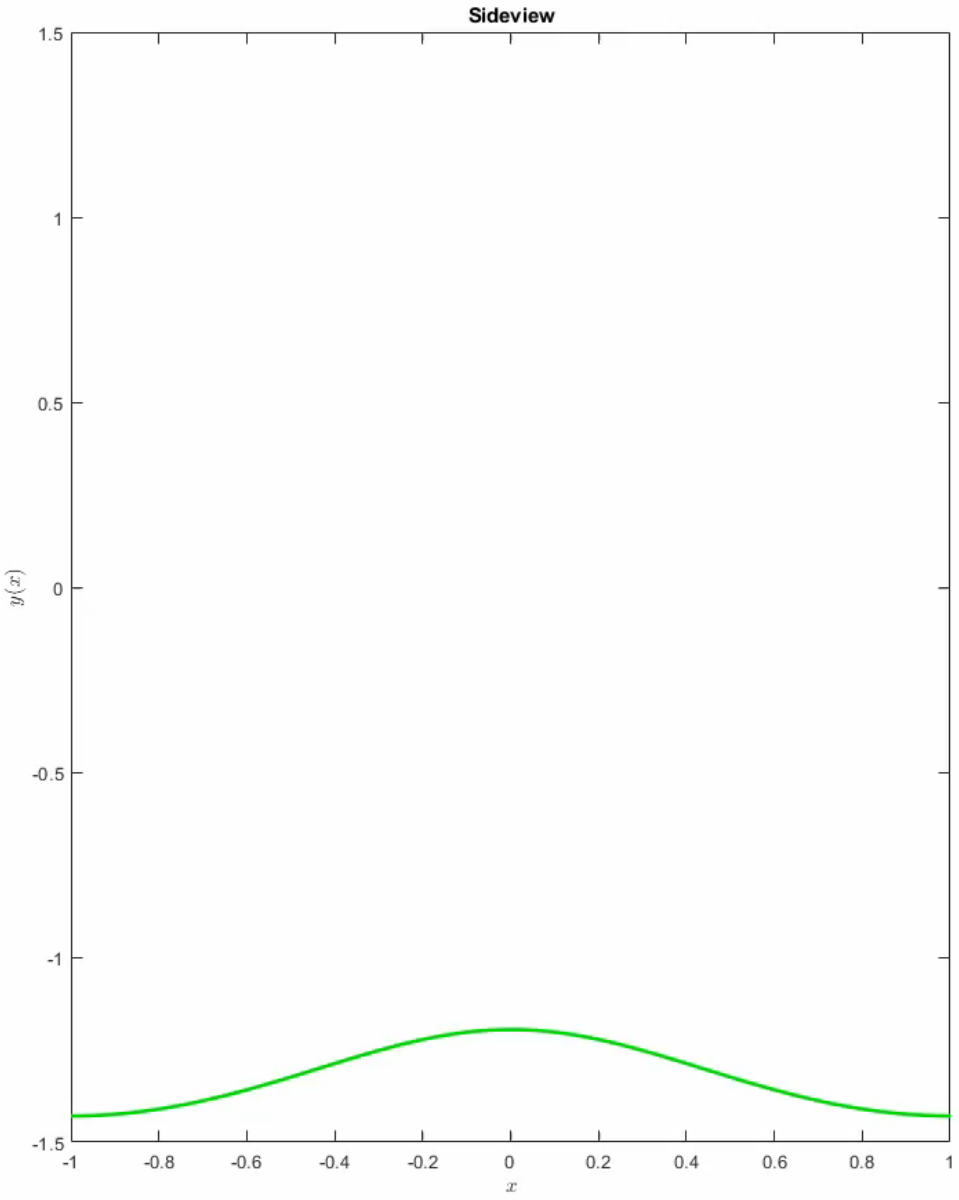


[Bastiaansen, Ashwin, Von der Heydt, 2022, *preprint*]

(Data from CESM1.0.4 runs in LongRunMIP)

Spatial Nonlinear Response





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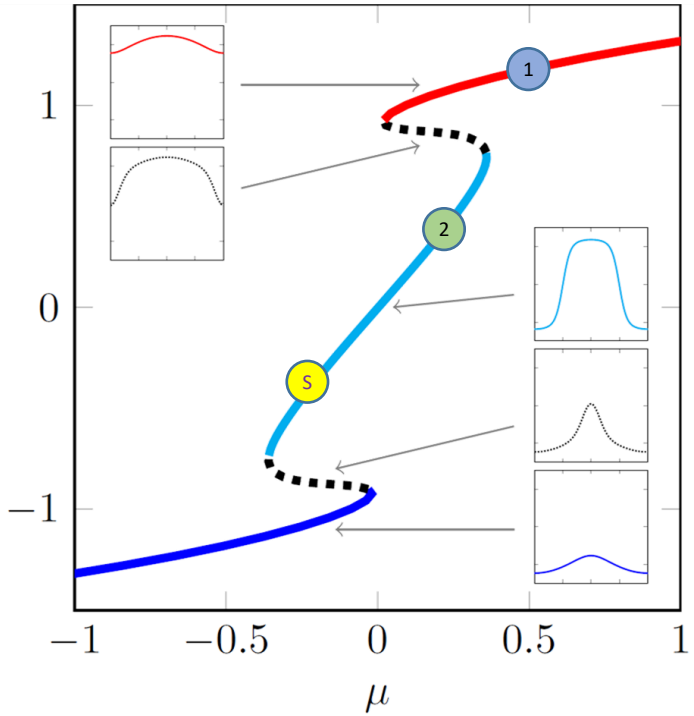
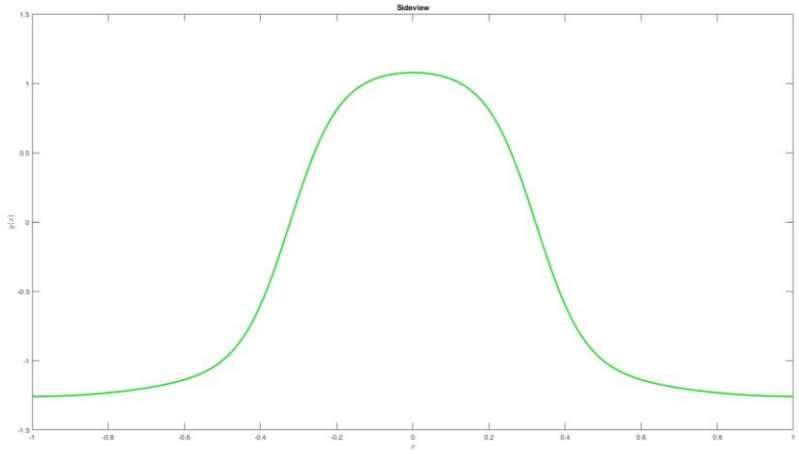
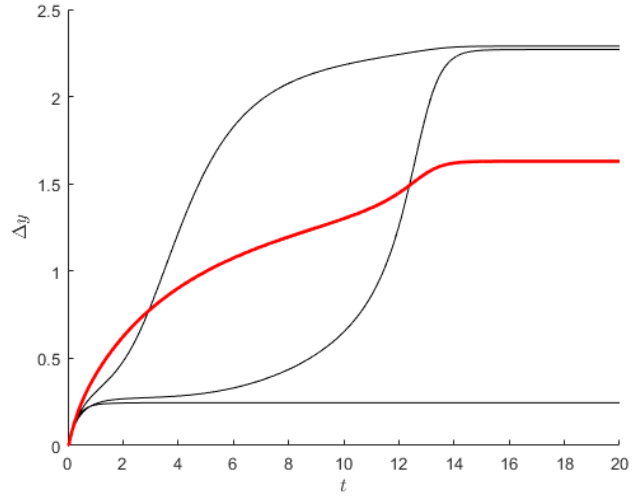
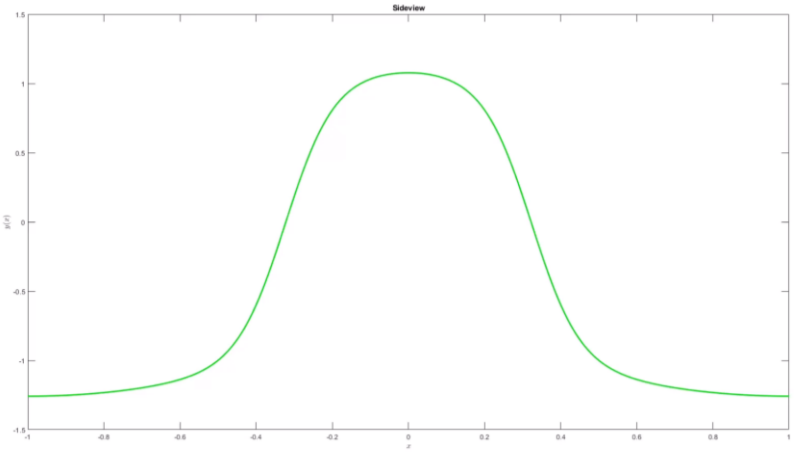


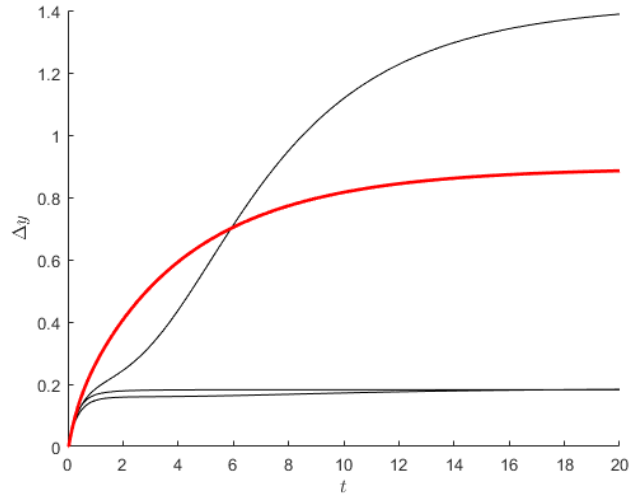
Tipping Point crossed





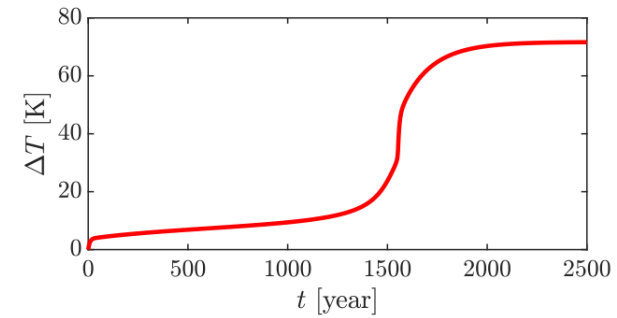
NO Tipping Point crossed

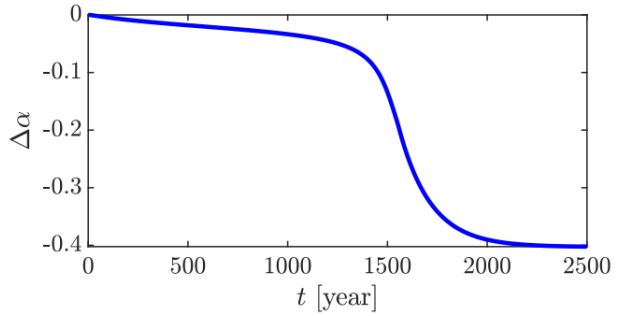


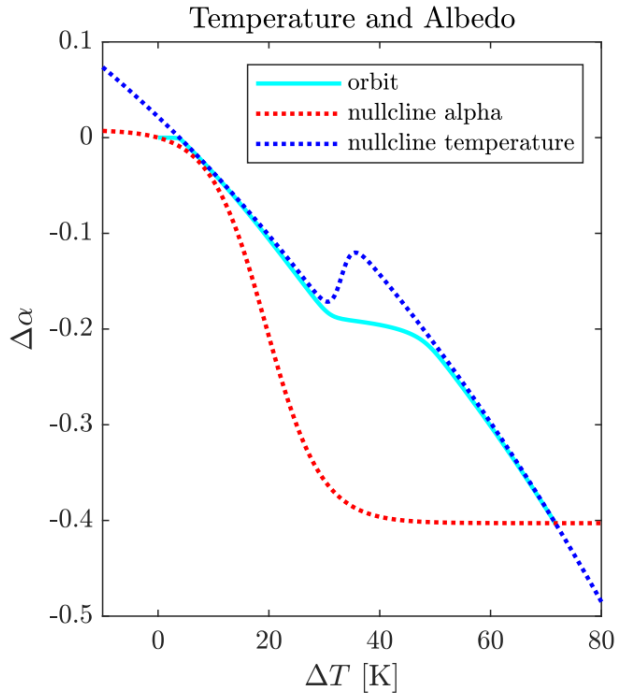


Conclusion

TIME SCALES !







Papers:

- R. Bastiaansen, H.A. Dijkstra & A.S. Von der Heydt (2020) Multivariate estimations of equilibrium climate sensitivity from short transient warming simulations. *Geophysical Research Letters, 48(1), e2020GL091090*
- R. Bastiaansen, H.A. Dijkstra & A.S. Von der Heydt (2021) Projections of the transient state-dependency of climate feedbacks. *Geophysical Research Letters, 48(20), e2021GL094670*
- R. Bastiaansen, H.A. Dijkstra & A.S. Von der Heydt (2022) Fragmented tipping in a spatially heterogeneous world. *Environmental Research Letters, 17, 045006*
- R. Bastiaansen, P. Ashwin & A.S. Von der Heydt (2022) Climate response and sensitivity: timescales and late tipping points. *Preprint available on arXiv*