

ESTIMATING TEMPERATURE RESPONSE TO VOLCANIC ERUPTIONS

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INTRODUCTION

EQUILIBRIUM CLIMATE SENSITIVITY (ECS)

Simple energy balance model:

$$C \frac{d\Delta T}{dt} = -\frac{1}{s} \Delta T + f \quad (1)$$

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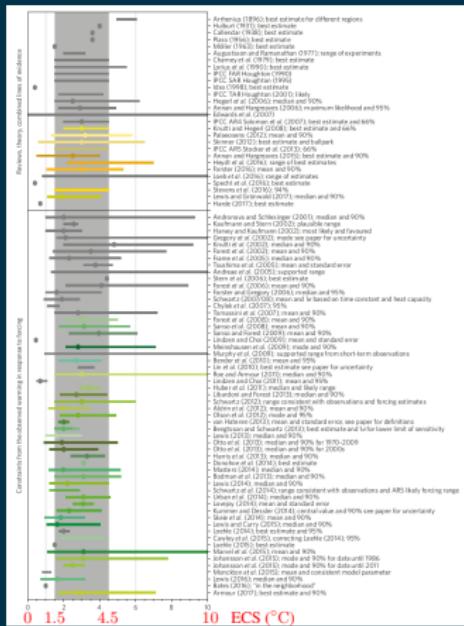
$$C \frac{d\Delta T}{dt} = -\frac{1}{s} \Delta T + f \quad (1)$$



$$\Delta T = s f_{2\times\text{CO}_2} \quad (2)$$

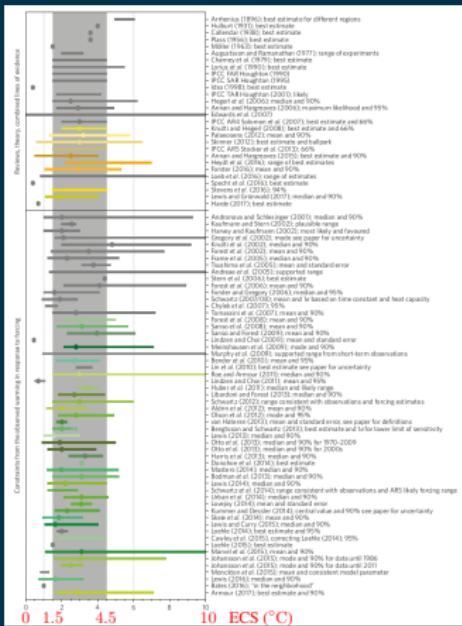
$\Delta T \sim$ Equilibrium climate sensitivity (ECS)

ESTIMATING ECS



[3] Knutti, Rugenstein, and Hegerl. "Beyond equilibrium climate sensitivity". 2017

ESTIMATING ECS



KEY POINTS

- Estimate global temperature response and climate sensitivity
- Volcanoes produce strong temperature fluctuations
- Non-parametric approach

METHOD

FILTERED POISSON PROCESS — EXAMPLES

The FPP model intermittent processes:

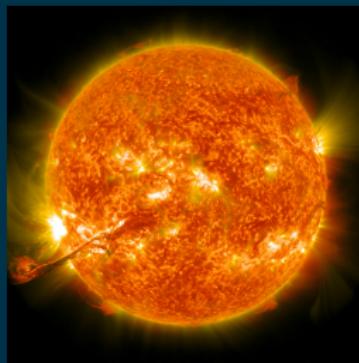
FILTERED POISSON PROCESS — EXAMPLES

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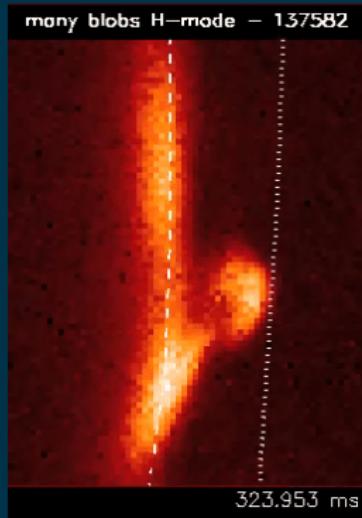
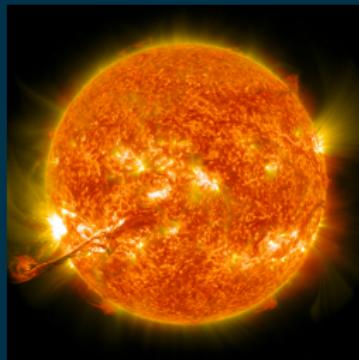
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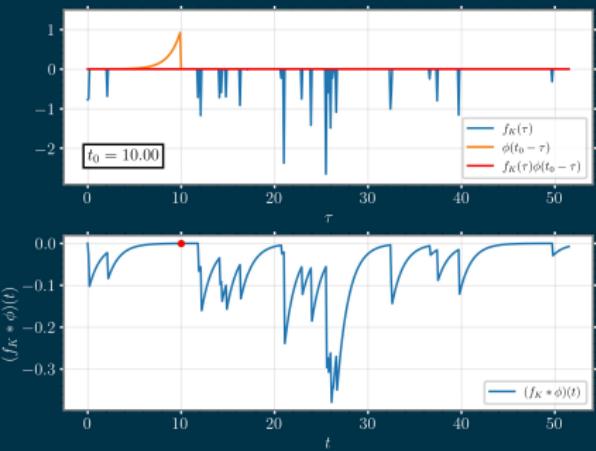


NSTX GPI Library (2010 data)

FILTERED POISSON PROCESS — DEFINITION

The underlying phenomenological model:

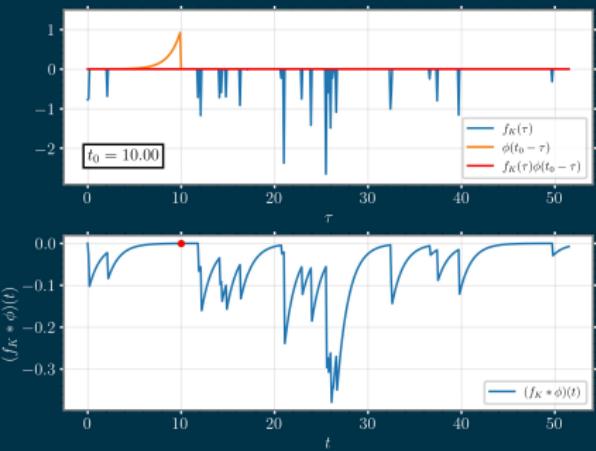
$$T_K(t) = \sum_{k=1}^K A_k \phi \left(\frac{t - t_k}{\tau_d} \right) \quad (3)$$



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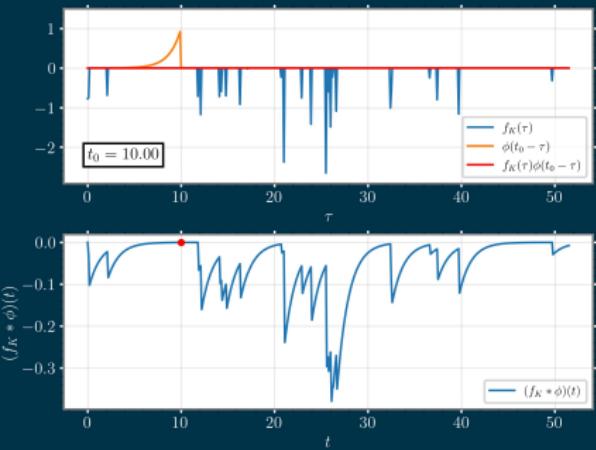
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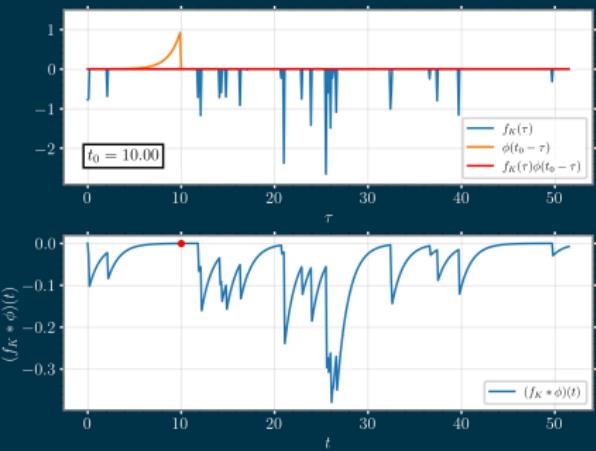
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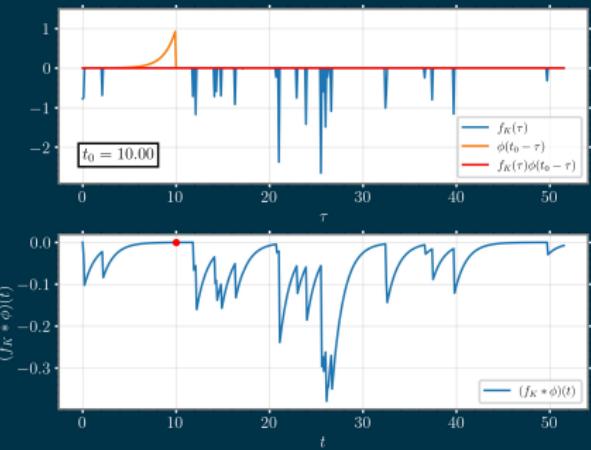
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RICHARDSON-LUCY DECONVOLUTION

An iterative process: [4]; [6]; [1]

$$\phi^{(n+1)} = \phi^{(n)} \frac{(T_K - \langle T_K \rangle) * \hat{f}_K + b}{\phi^{(n)} * f_K * \hat{f}_K + b} \quad (5)$$

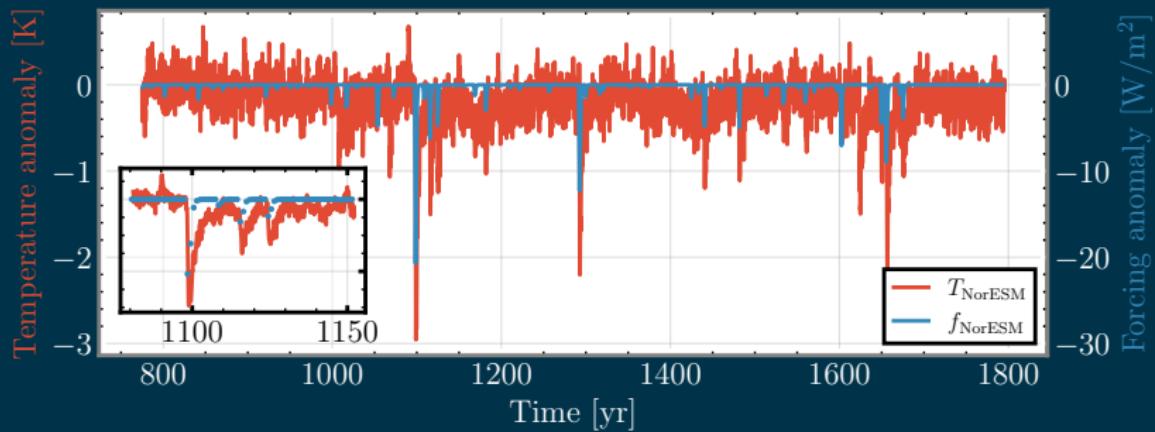
[4] Lucy. "An iterative technique for the rectification of observed distributions". 1974

[6] Richardson. "Bayesian-Based Iterative Method of Image Restoration*". 1972

[1] Benvenuto et al. "Nonnegative least-squares image deblurring: improved gradient projection approaches". 2009

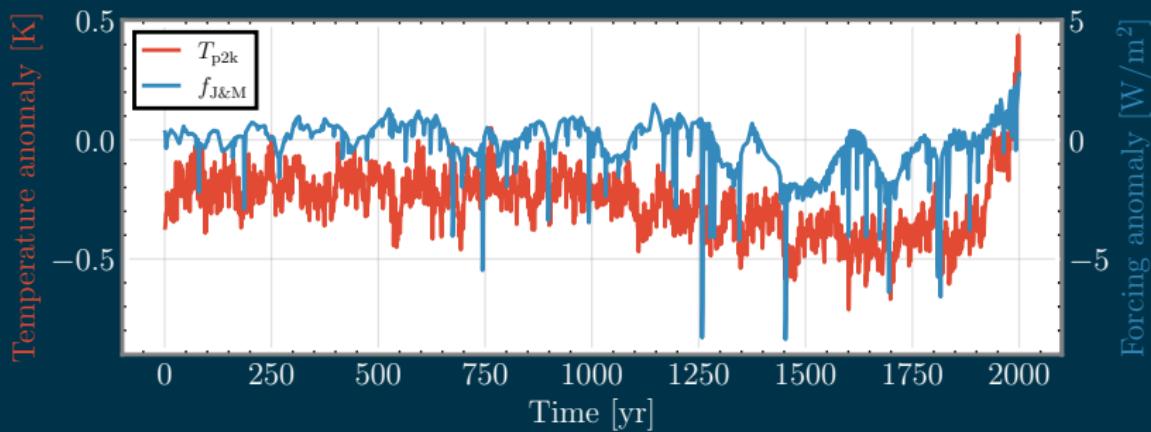
NORESM

1000 year long simulation run from the Norwegian Earth System Model (NorESM)



PROXY DATA

Forcing and temperature data from [2] and [5] of the last two millennia

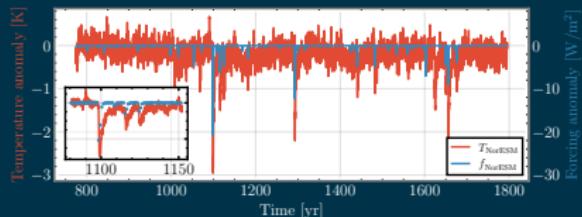


[2] Jones and Mann. "Climate over past millennia". 2004

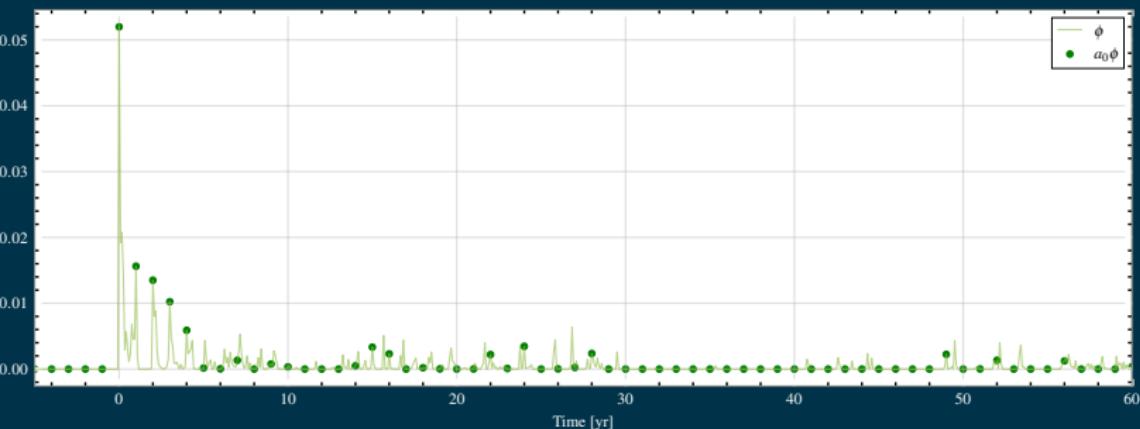
[5] PAGES 2k Consortium. et al. "Consistent multidecadal variability in global temperature reconstructions and simulations over the Common Era". 2019

RESULTS

RESPONSE FUNCTION FROM DECONVOLUTION



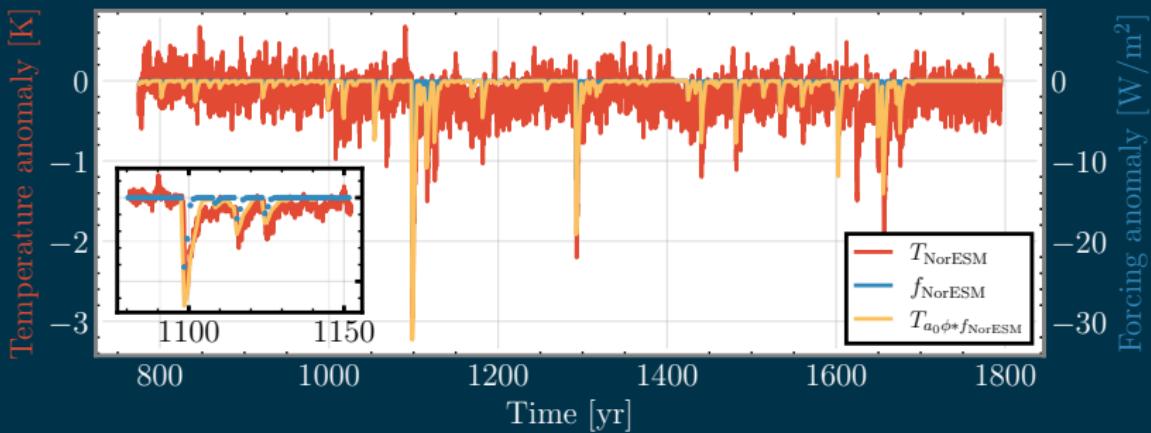
DECONVOLUTION



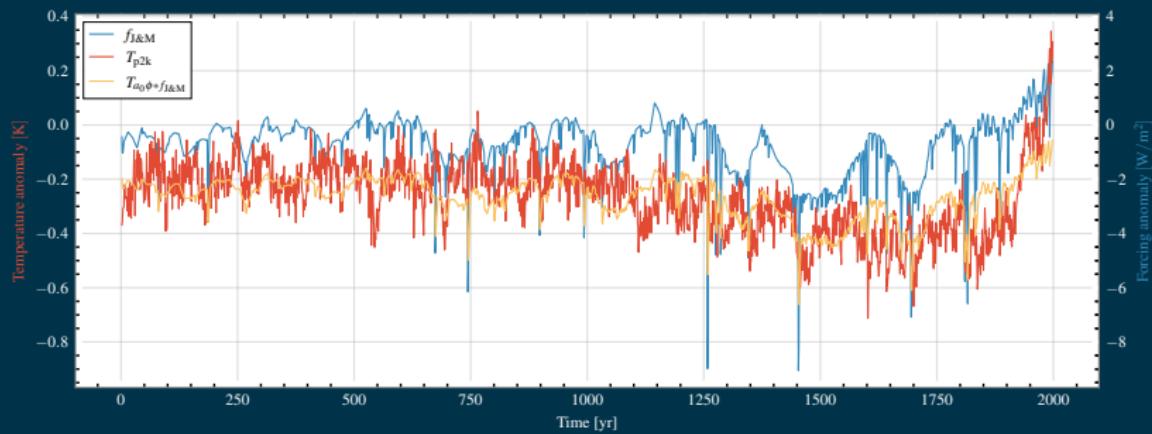
RESPONSE FUNCTION FROM DECONVOLUTION



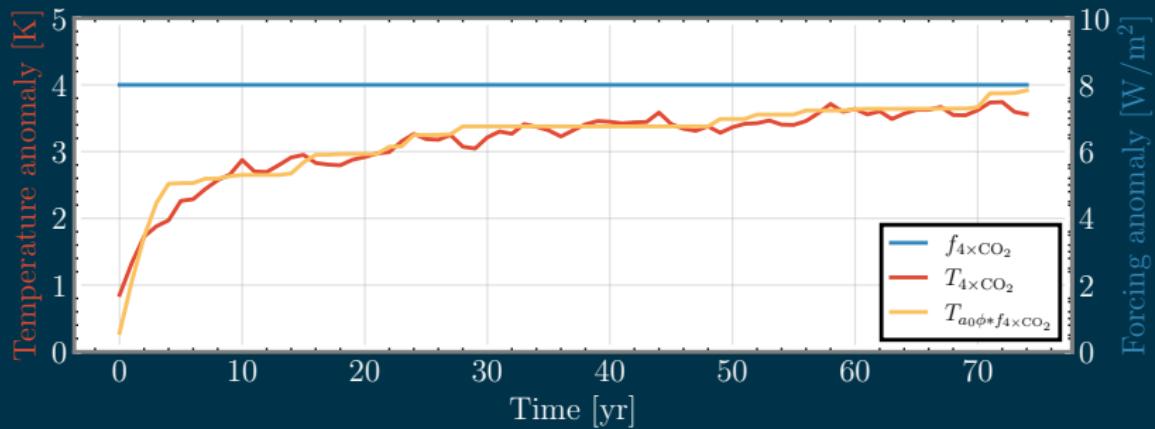
↓
CONVOLUTION



TEMPERATURE OF LAST TWO MILLENNIA



TEMPERATURE OF $4 \times \text{CO}_2$ EXPERIMENT



CONCLUSIONS

CONCLUDING REMARKS

- It is possible to obtain a response function from a non-parametric method

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- Historic temperature is reproduced from forcing data

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- Historic temperature is reproduced from forcing data
- Reproduces shape of $4 \times \text{CO}_2$ experiment → infer climate sensitivity

FUTURE WORK

- Analysis of the shape of the response function, for example using exponentials or power laws

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[.../figures/raw_historical_beam.pdf](#)

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REFERENCES I

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-  P. D. Jones and M. E. Mann. “Climate over past millennia”. In: *Reviews of Geophysics* 42.2 (2004), pp. 1–42. ISSN: 87551209. DOI: 10.1029/2003RG000143.
-  Reto Knutti, Maria A. A. Rugenstein, and Gabriele C. Hegerl. “Beyond equilibrium climate sensitivity”. In: *Nature Geoscience* 10.10 (Sept. 2017), pp. 727–736. DOI: 10.1038/ngeo3017. URL: <https://doi.org/10.1038%2Fngeo3017>.
-  L. B. Lucy. “An iterative technique for the rectification of observed distributions”. In: *The Astronomical Journal* 79.6 (1974), p. 745. ISSN: 00046256. DOI: 10.1086/111605.

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W. H. Richardson. “Bayesian-Based Iterative Method of Image Restoration*”. In: *J. Opt. Soc. Am.* 62.1 (Jan. 1972), pp. 55–59. URL: <http://www.osapublishing.org/abstract.cfm?URI=josa-62-1-55>.

PREPARING NORESM DATA

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./figures/noresm_frc_dark.pdf
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PREPARING NORESM DATA

./figures/noresm_temp_dark.pdf

RE-SAMPLE RESPONSE FUNCTION

.../figures/noresm_raw_dark.pdf

DECONVOLUTION

TEMPERATURE OF LAST TWO MILLENNIA

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./figures/estimate_historic/best_fit_raw_temps_dar
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TEMPERATURE OF LAST TWO MILLENNIA

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./figures/estimate_historic/best_fit_raw_temps2_da
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TEMPERATURE OF LAST TWO MILLENNIA

./figures/estimate_historic/best_fit_raw_temps3_da

TEMPERATURE OF $4 \times \text{CO}_2$ EXPERIMENT

./figures/estimate_historic/temp_abrupt1_dark.pdf

TEMPERATURE OF $4 \times \text{CO}_2$ EXPERIMENT

./figures/estimate_historic/temp_abrupt2_dark.pdf

TEMPERATURE OF $4 \times \text{CO}_2$ EXPERIMENT

./figures/estimate_historic/temp_abrupt3_dark.pdf

POWER SPECTRA

./figures/estimate_historic/all_psd_dark.pdf