ESTIMATING TEMPERATURE RESPONSE TO VOLCANIC ERUPTIONS

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February 7, 2022

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INTRODUCTION

Equilibrium climate sensitivity (ECS)

Simple energy balance model:

$$C\frac{\mathrm{d}\Delta T}{\mathrm{d}t} = -\frac{1}{s}\Delta T + f \tag{1}$$

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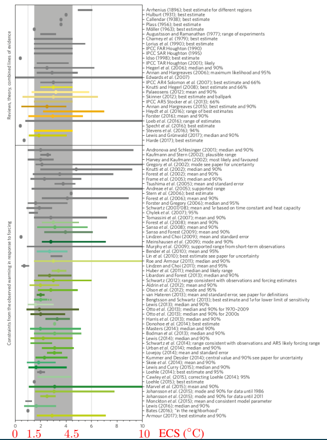
$$\downarrow$$

$$\Delta T = s f_{2\times\mathrm{CO}_2} \tag{2}$$

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

Estimating ECS



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

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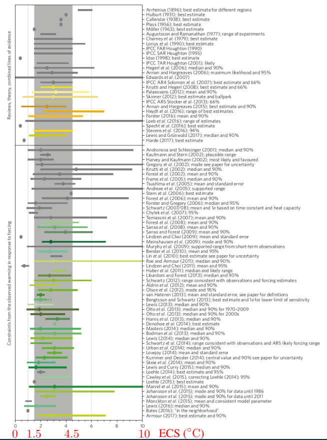
ESTIMATING ECS



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Key points

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

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METHOD

Filtered Poisson process — Examples

The FPP model intermittent processes:

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 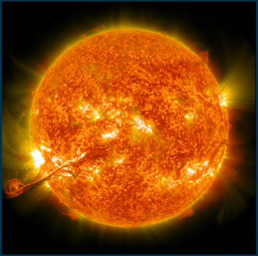

Filtered Poisson process — Examples

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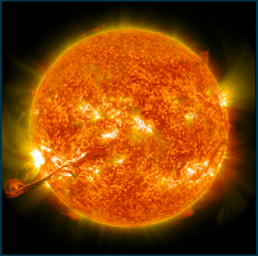

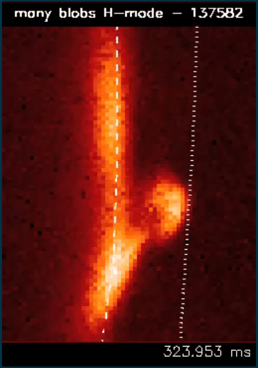

NSTX GPI Library (2010 data)

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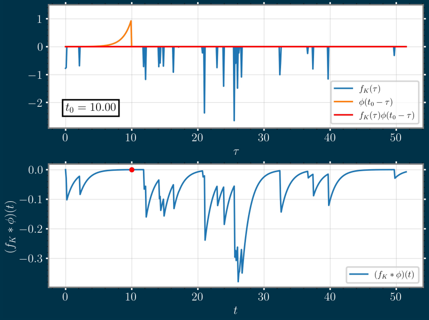
Filtered Poisson process — Definition

The underlying phenemenological model:

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



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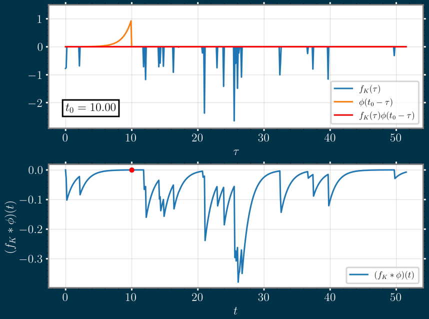

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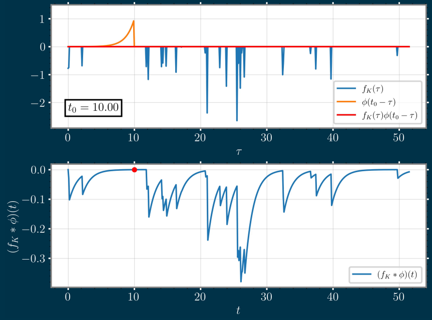

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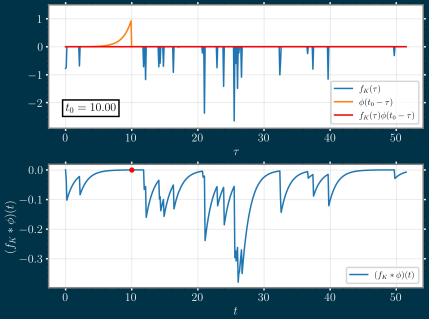

Filtered Poisson process — Definition

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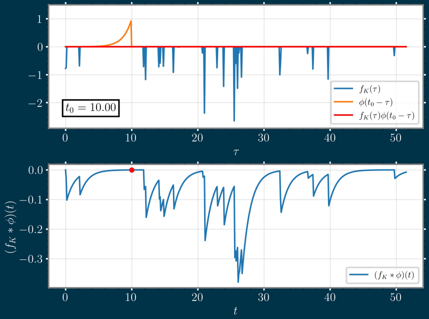
$$T_K(t) = \sum_{k=1}^{K} A_k \phi\left(\frac{t - t_k}{\tau_\mathrm{d}}\right) \quad (3)$$

$$\downarrow$$

$$T_K(t) = [\phi * f_K]\left(\frac{t}{\tau_\mathrm{d}}\right) \quad (4)$$



Filtered Poisson process — Definition

The underlying phenemenological model:

$$T_K(t) = [\phi * f_K]\left(\frac{t}{\tau_\mathrm{d}}\right) \qquad (4)$$

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RICHARDSON-LUCY DECONVOLUTION

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

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

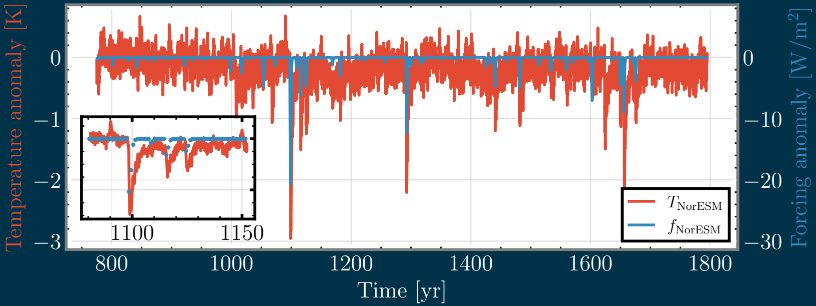
[4] Lucy. “An iterative technique for the rectification of observed distributions”. 1974

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

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

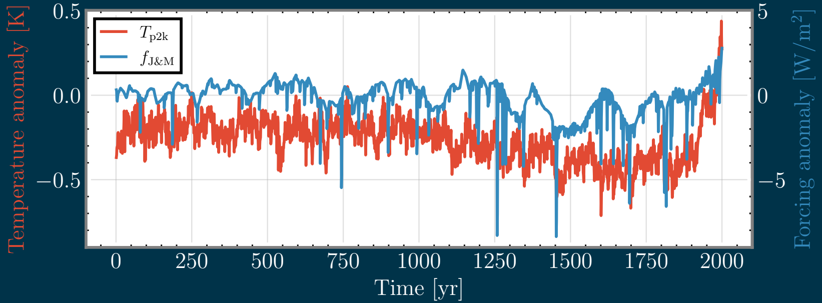
NorESM

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

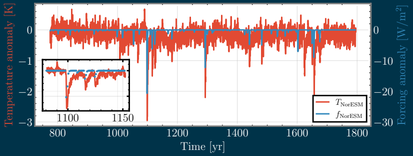


[2] Jones and Mann. "Climate over past millennia". 2004

[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

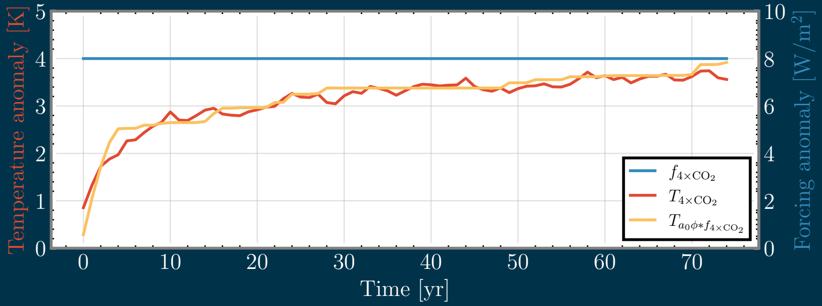
response_func_noresm1_choose_dark.pdf

CONVOLUTION

Temperature of last two millennia

estimate_historic/best_fit_raw_temp1_alone_dark.pdf

Temperature of $4 \times CO_2$ 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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Concluding remarks

- It is possible to obtain a response function from a non-parametric method
- Historic temperature is reproduced from forcing data
- Reproduces shape of $4 \times \mathrm{CO}_2$ experiment $\rightarrow$ infer climate sensitivity

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Future work

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

../figures/response_func_noresm1_choose_dark.pdf

Future work

- Analysis of the shape of the response function, for example using exponentials or power laws
- More exact study of the $4 \times CO_2$ experiment

../figures/estimate_historic/temp_abrupt1_alone_dar

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- More exact study of the $4 \times \mathrm{CO}_2$ experiment
- Effect of clustering of volcanoes

../figures/raw_historical_beam.pdf

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- More exact study of the $4 \times CO_2$ experiment
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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.
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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

../figures/noresm_frc_dark.pdf

Preparing NorESM data

../figures/noresm_temp_dark.pdf

Re-sample response function

../figures/noresm_raw_dark.pdf

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Re-sample response function

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RE-SAMPLE RESPONSE FUNCTION

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Re-sample response function

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Temperature of last two millennia

../figures/estimate_historic/best_fit_raw_temps_dar

Temperature of last two millennia

../figures/estimate_historic/best_fit_raw_temps2_da

Temperature of last two millennia

../figures/estimate_historic/best_fit_raw_temps3_da

Temperature of $4 \times CO_2$ experiment

../figures/estimate_historic/temp_abrupt1_dark.pdf

Temperature of $4 \times CO_2$ experiment

../figures/estimate_historic/temp_abrupt2_dark.pdf

Temperature of $4 \times CO_2$ experiment

../figures/estimate_historic/temp_abrupt3_dark.pdf

POWER SPECTRA

../figures/estimate_historic/all_psd_dark.pdf