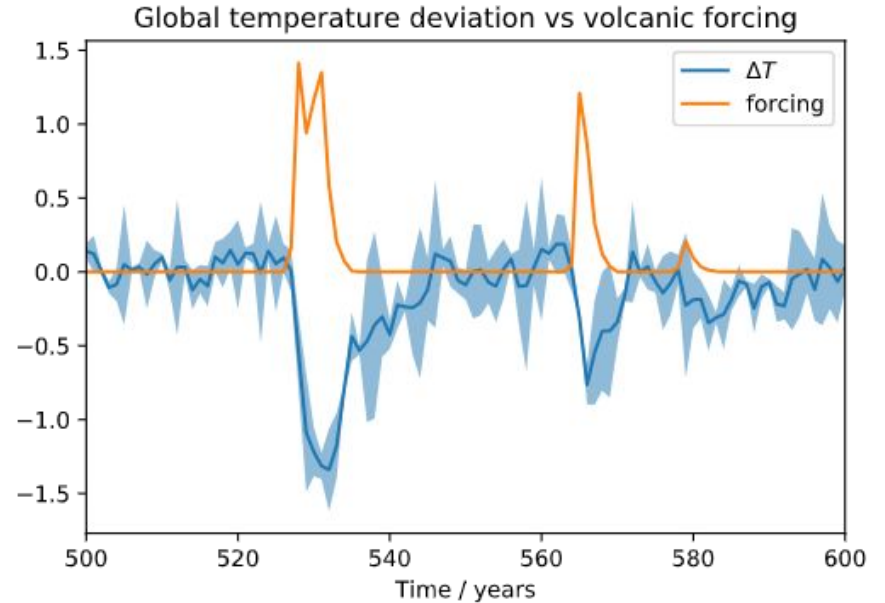
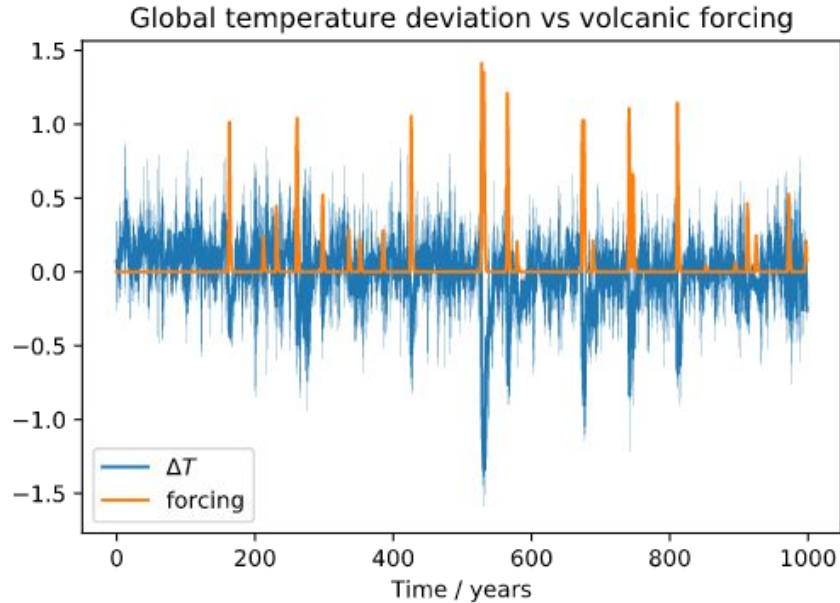


HIDA Remote Challenge 2020

Team Bayes

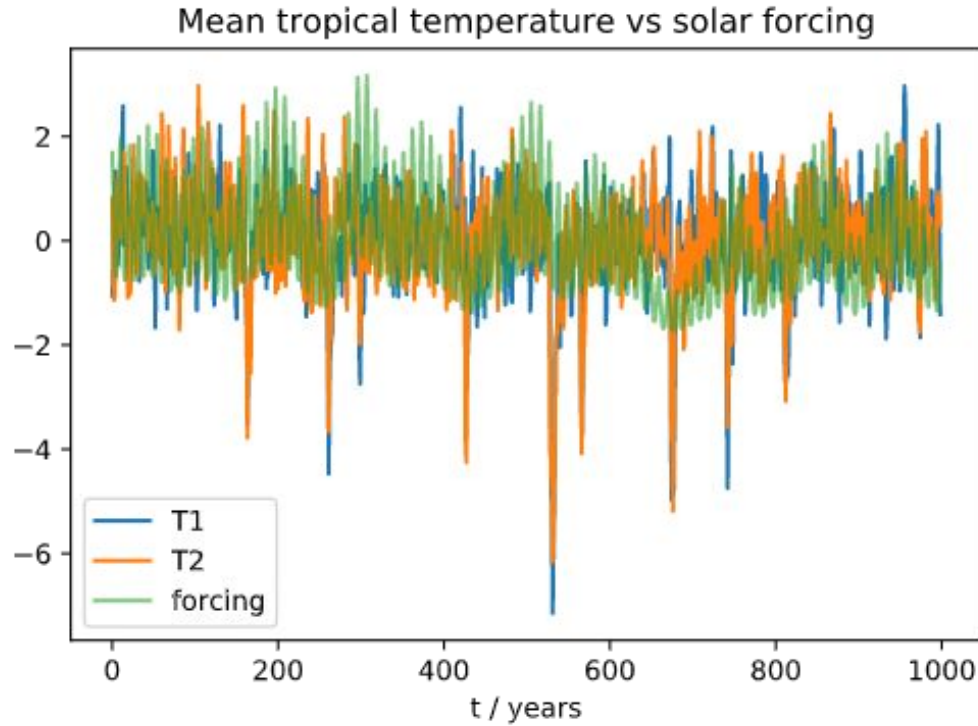


Volcanic forcing

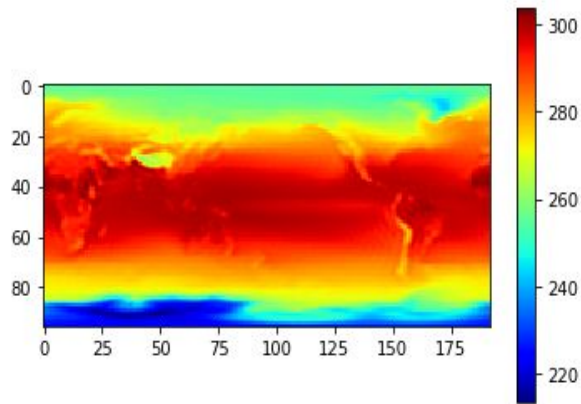


- High correlation
- Short time scale

Solar forcing



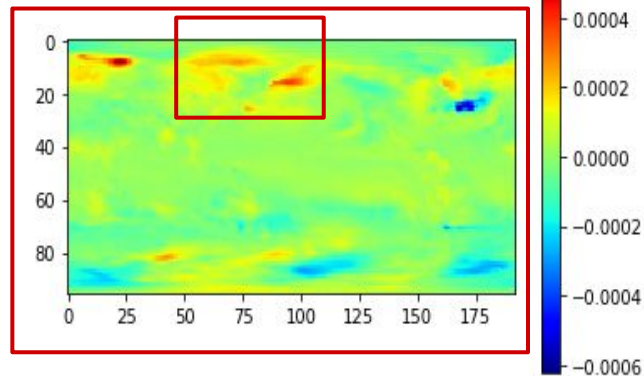
- Low correlation
- Long time scale



Renormalize data



regional effect (volcanic)



global effect (solar)

Why Bayes?

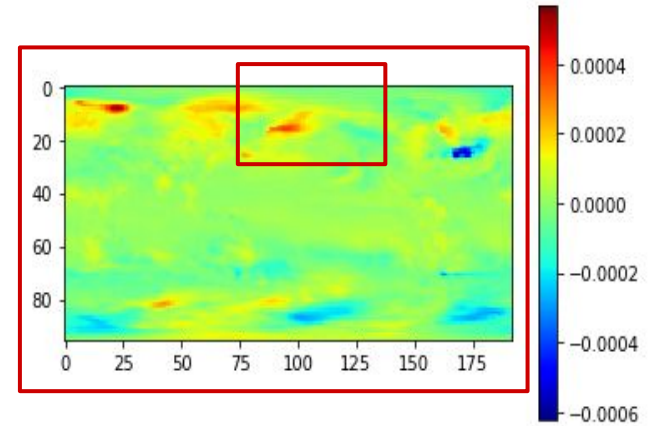
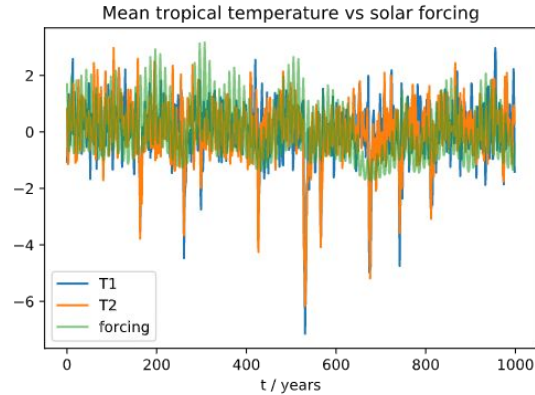
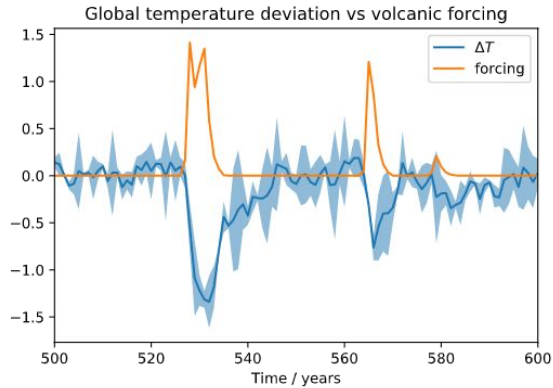
- 1) **LITTLE** data (just 2 observations)
- 2) Include a-priori-knowledge
 - a) forcing has chaotic but smooth effects
 - b) different effect scales
- 3) Quantify uncertainties (they are huge)
- 4) Quantify evidence for solar forcing (it is little)

Why Bayes?

- 1) **LITTLE** data (just 2 simulations)
 - a) big uncertainties

- 2) Include a-priori-knowledge
 - a) forcing has chaotic but smooth effects
 - b) different effect scales
 - c) model with Gaussian random fields

Solar and volcanic forcing

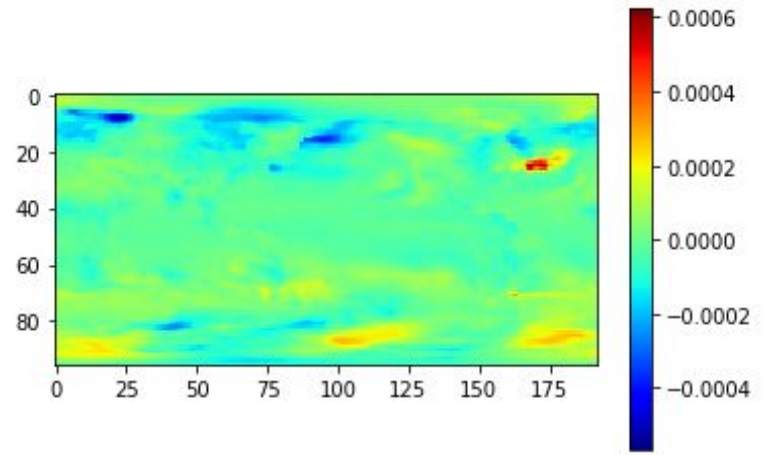
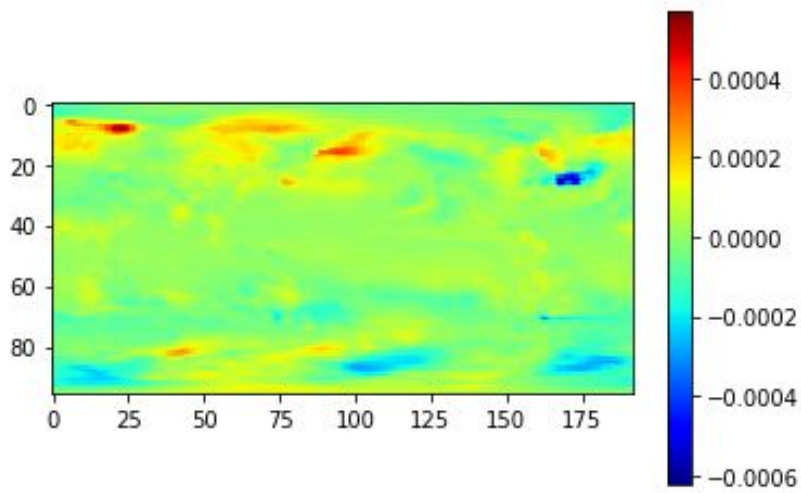


VOLCANIC

- High correlation
- Short time scale
- Regional effect

SOLAR

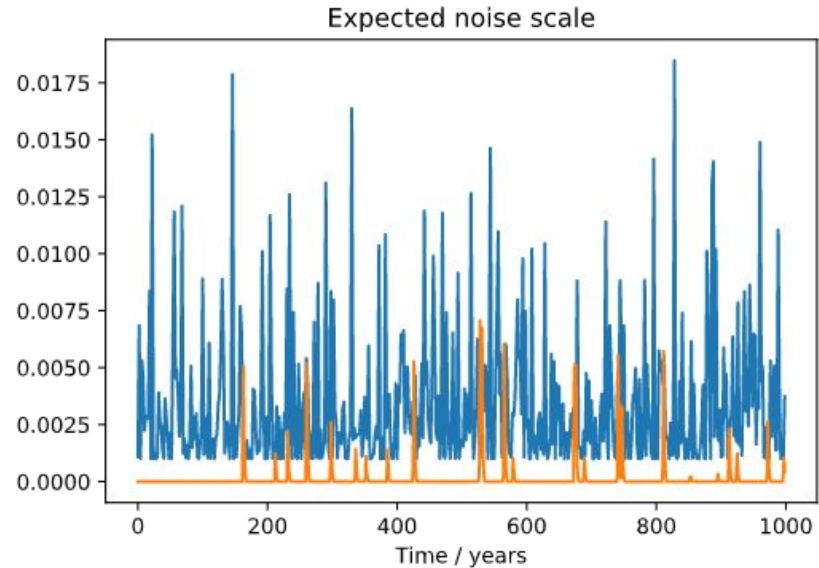
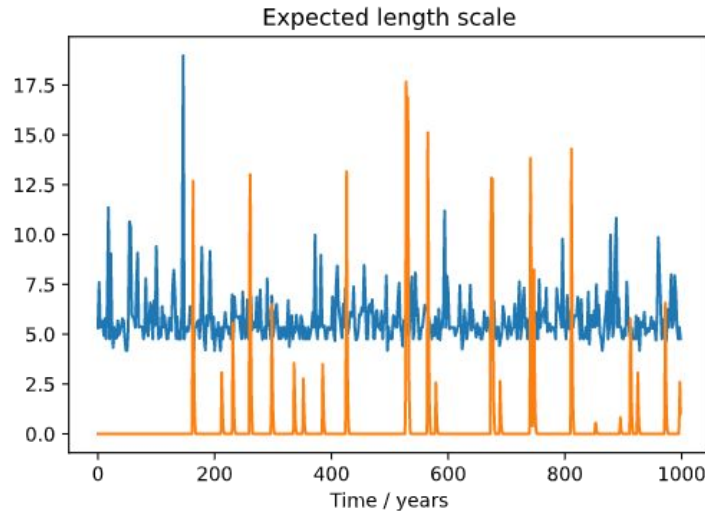
- Low correlation
- Long time scale
- Global effect



The Approach in a Nutshell

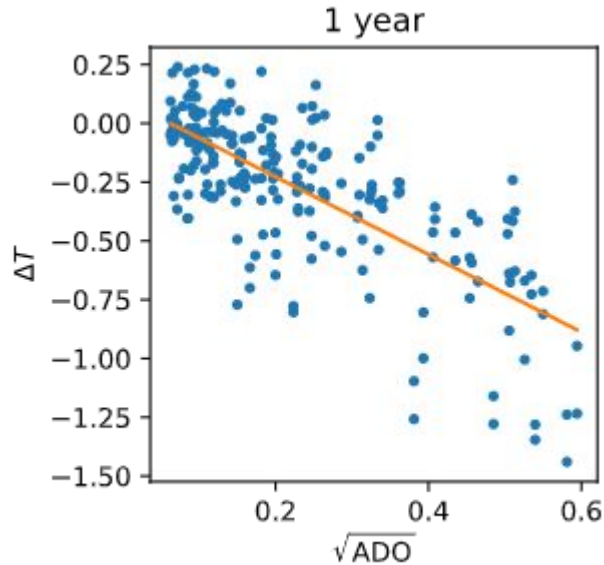
- 1) each simulation is a random field sample
- 2) find spatial correlation lengths
- 3) track spatial correlation lengths over time

track spatial correlation length and noise over time



blue: expected parameter, orange: volcanic forcing

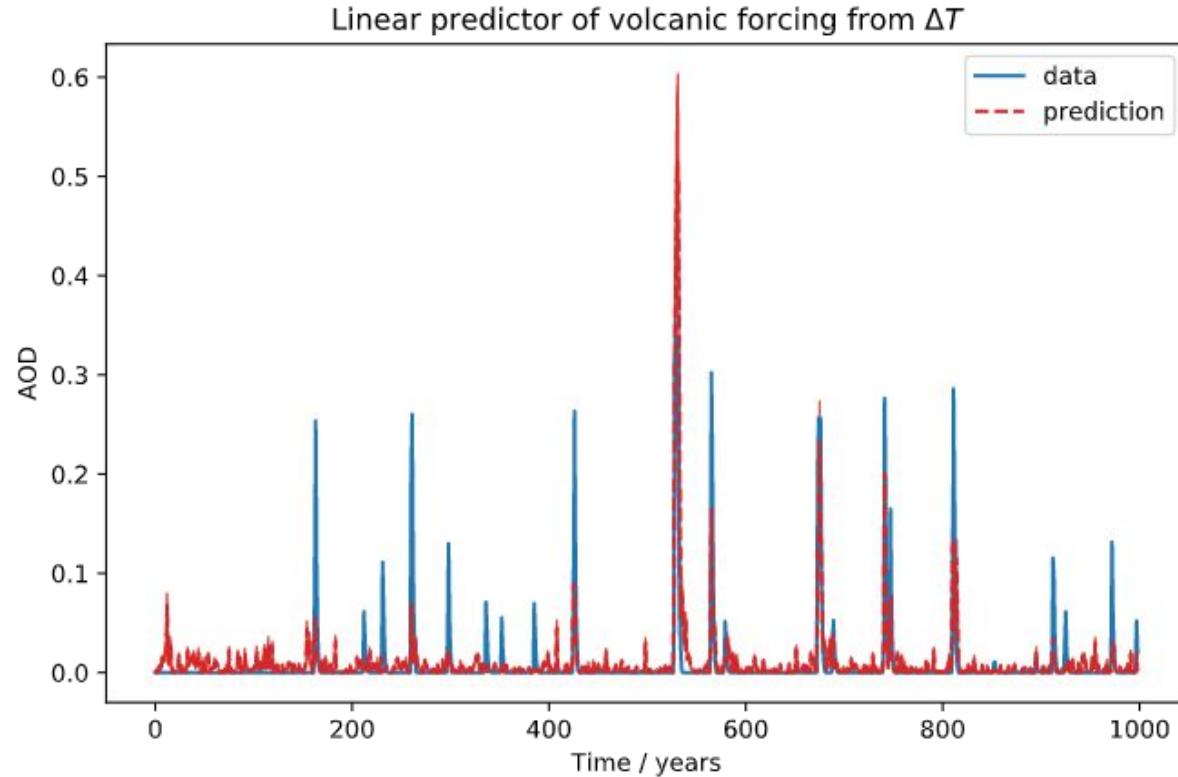
Fit of $\Delta T(t)$ in terms of $ADO(t-1)$



$$\Delta T(t) = -1.65\sqrt{ADO(t-1)}$$

Std. Err. in coefficient: 0.1

Can also reconstruct volcano data from ΔT



Q&A

a) Has there been volcanic forcing last year?

GP and fit work

b) Is solar forcing even detectable in data?

hard to impossible

c) How do length-scales and noise look over time?

-> spatial GP

d) Difference between tropical and polar regions?

can work with both

Conclusion

- Model heterogeneity with Gaussian random fields
- Bayes gives uncertainties and model comparison
- solution lies in the scales
- implementation not trivial (not enough time)

APPENDIX A

Exploratory Data Analysis

Motivation of Approach

Not BIG DATA, but LITTLE DATA (only 2 simulations!)

- Unsupervised (essentially)
- Temperature field:
 - “Somewhat random but somehow smooth”
 - Spatial and temporal correlations
 - Model as Gaussian Random Field

BAYESIAN PROBABILITY THEORY

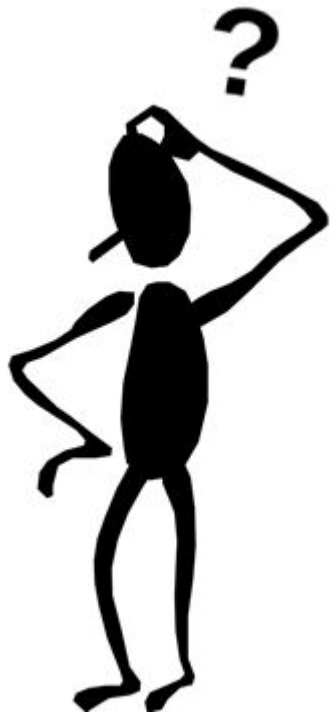
- “Little data theory”
- ONLY consistent and rigorous theory (mathematical proof)
- Quantifies uncertainties
- Includes a-priori-knowledge
 - smoothness, spatiotemporal correlations

The Approach in a Nutshell

1)

2)

3)



Each year is a Gaussian Process sample (2 samples per year)

• different magnitudes and spatiotemporal scales

• magnitudes not distinguishable

• scales very different

• for each year locally, i.e.

• draw rectangle over region

• estimate correlation parameters

• plot correlation parameters over time

• small scale correlations indicate volcanic forcing

• large scale correlations indicate solar forcing

Comparison:

Evidence for volcanic/solar forcing?

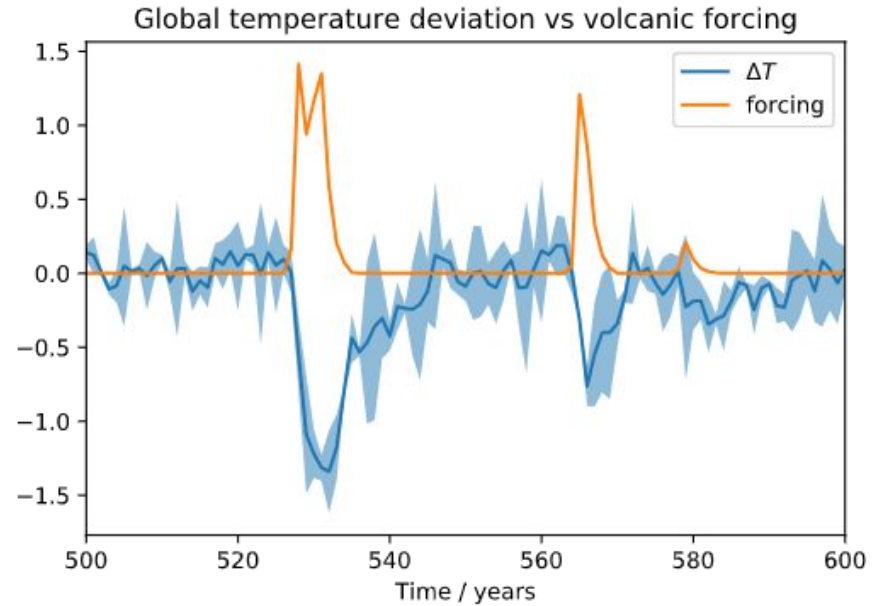
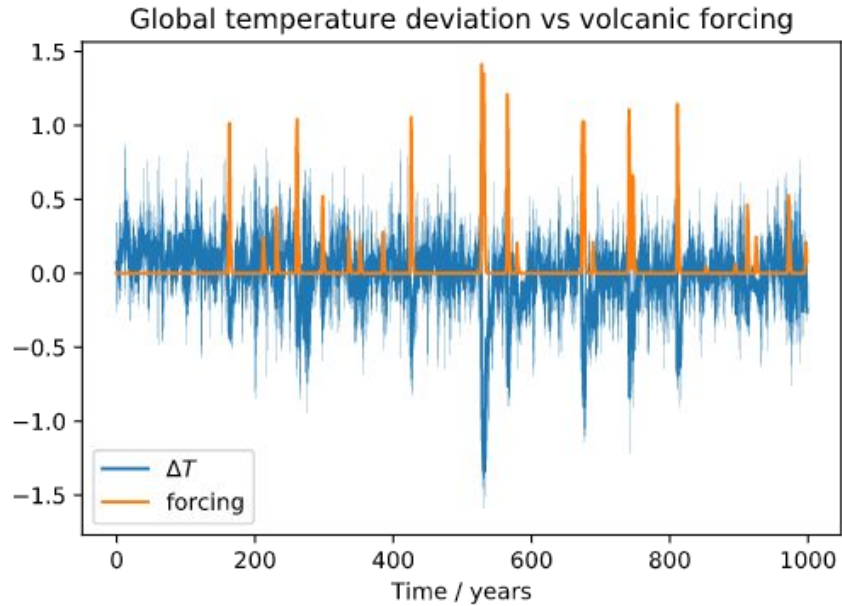
=

Evidence for small/large-scale correlations?

Problem 1

Can you find out **which periods** were **dominated by climate forcing** without knowing the exact dates of volcanic events or low solar activity? We know the solution to this question because we can match our simulations with time series data for changes in solar activity and volcanic outbreaks at the time, but we would like to be able to tell **just from the model**.

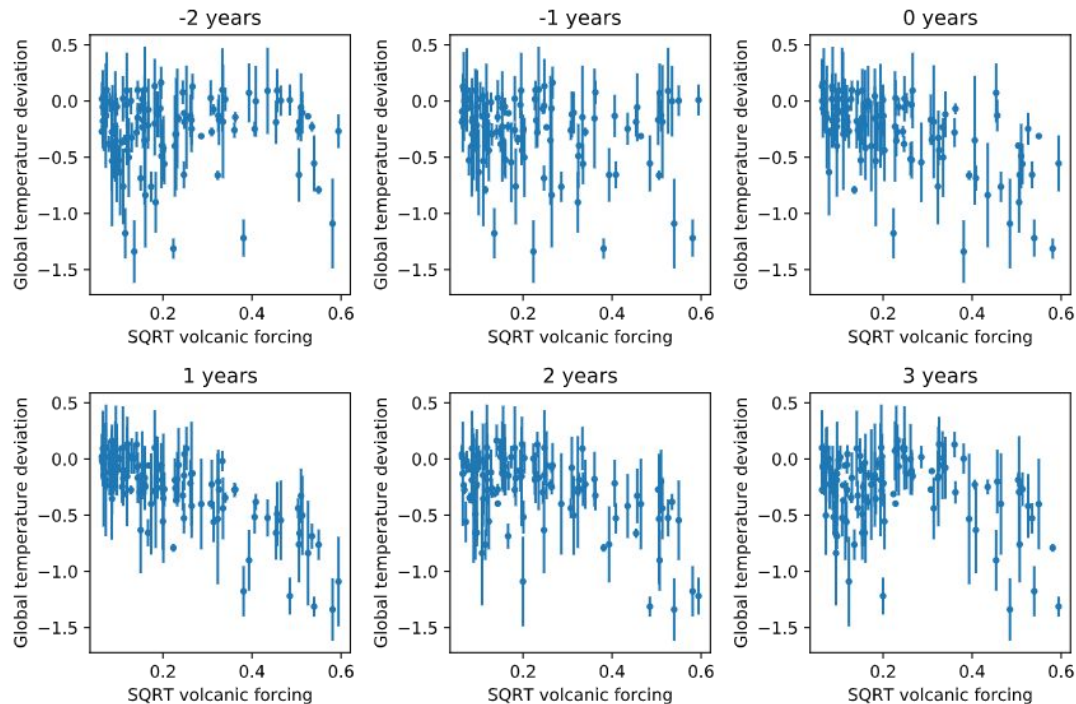
Effect of volcanic forcing



Lagged temperature response

Global temperature deviation

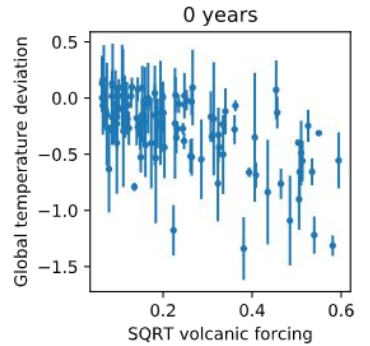
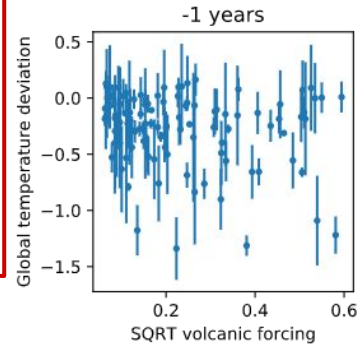
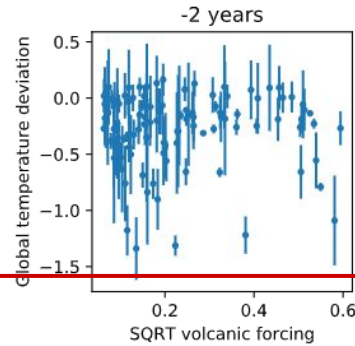
X years after volcanic forcing



Lagged temperature response

Global temperature deviation

X years after volcanic forcing

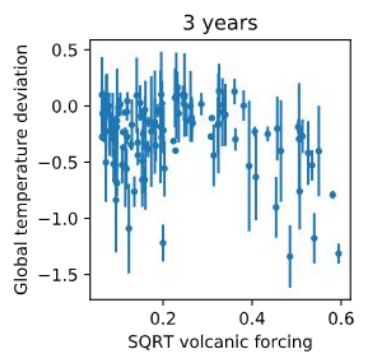
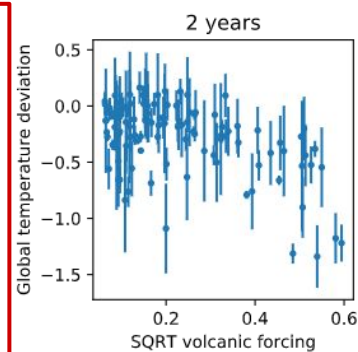
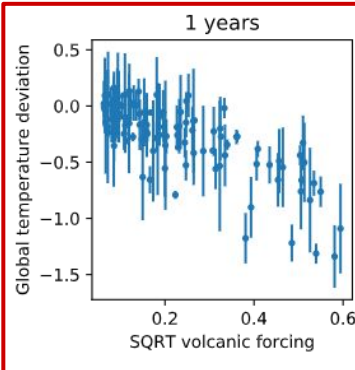


Conclusion:

Need only to look at lag of

1 year

(supported by statistical time-series analysis)



Questions

a) Has there been volcanic forcing last year ?

Has there been volcanic forcing (ADO) last year?

1. Fit relation between $\text{ADO}(t-1)$ and $\Delta T(t)$
2. Fit coarse behaviour of $\Delta T(t)$ over longer time-scales
3. Bayesian model comparison if 2. *alone* is enough or 1.+2. are needed

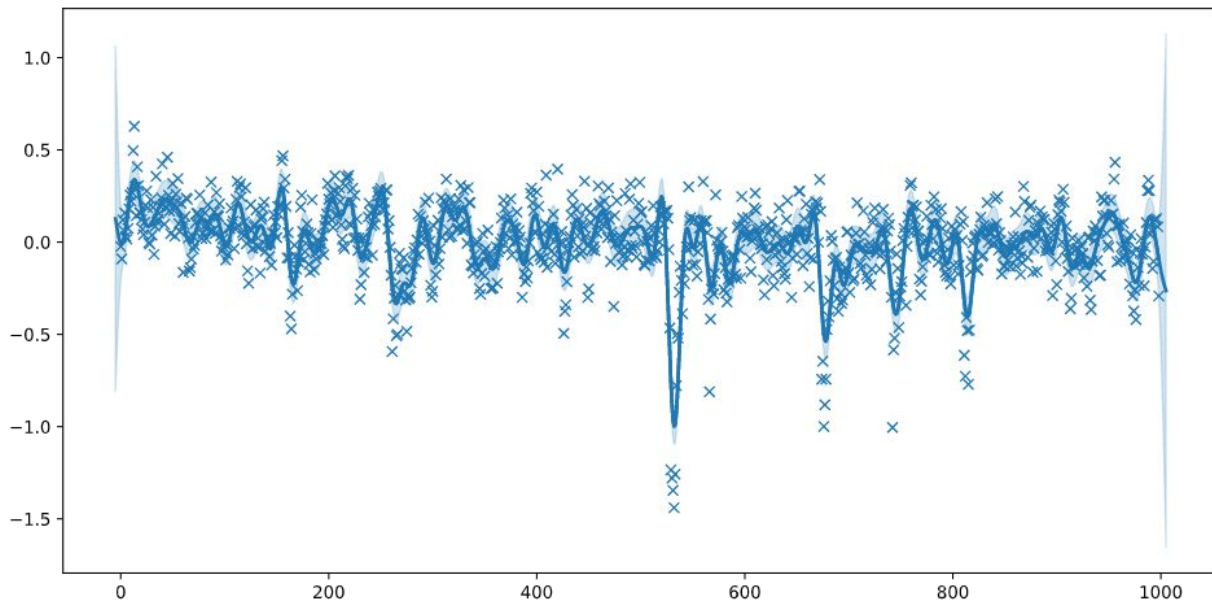
Has there been volcanic forcing (ADO) last year?

1. **Fit relation between $\text{ADO}(t-1)$ and $\Delta T(t)$ (it looks linear in square-root)**
2. Fit coarse behaviour of $\Delta T(t)$ over longer time-scales
3. Bayesian model comparison if 2. *alone* is enough or 1.+2. are needed

Tropical vs Polar data

Fit behaviour of $\Delta T(t)$ over **several** time-scales

Gaussian process regression with two time-scales yields good fit, but may be too much. With single-timescale we get about the same likelihood and that fit:



Problem 2

Can you tell how the **spatial patterns change** for periods with **strong volcanic activity**? In other words do all regions in the two simulations show the same temperature decline or maybe even increase?

Please consider that we see **greater impact** of factors other than volcanos and solar activity in so called **extratropical** regions, the closer we move towards the poles, north of 30°N and south of 30°S. It would also be interesting to **test** whether **tropical regions** show a **more coherent temperature response** pattern in R1 and R2 simulations compared to extratropical regions.

Questions

a) How do length-scales and noise look over time?