



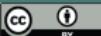
# Heat-Flow and Subsurface Temperature History in Eastern Senegal (West Africa)

Francis Luazeau<sup>1</sup> Frédérique Rolandone<sup>2</sup>

1 CNRS / Institut de Physique du Globe de Paris

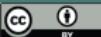
2 iSTeP, Université Pierre et Marie Curie



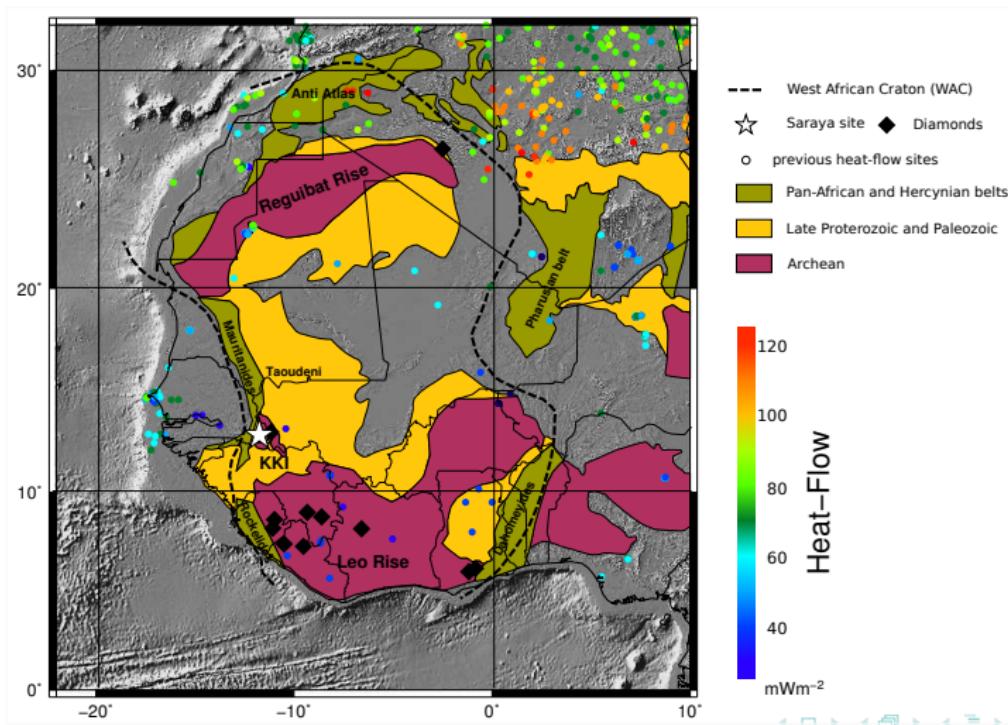


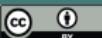
# Aim of the study

- Before measurements: understanding the thermal regime of the West African Craton;
- After measurements: understanding the temperature perturbations in the upper part of the boreholes
  - to what extent are the temperature perturbations related to climatic changes?
  - what are the causes of the local temperature variations in nearby boreholes? (site effects)
  - is the ground surface temperature history related to the African monsoon changes and the Sahel droughts? (regional effects)

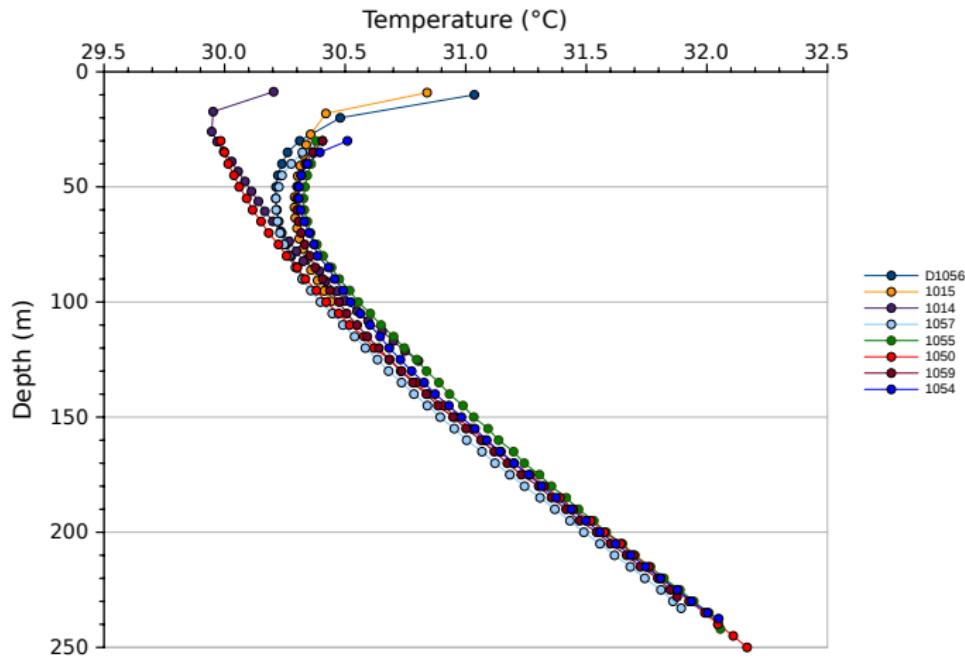


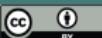
# Previous heat-flow measurements in West Africa



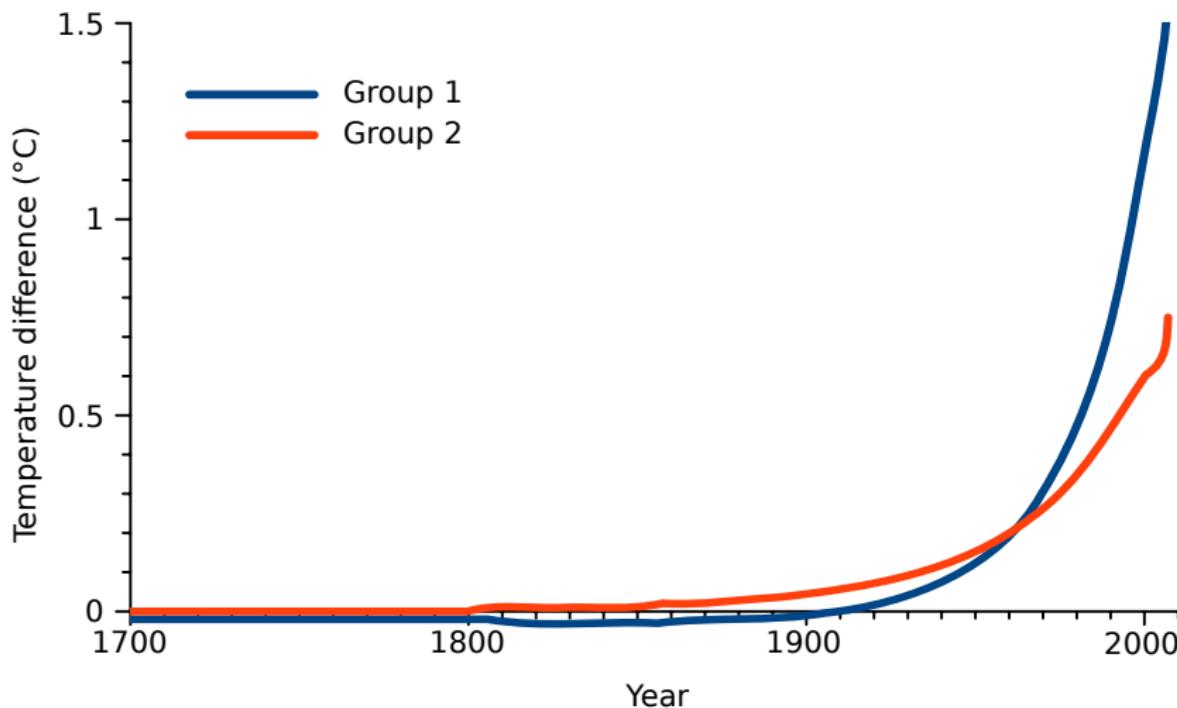


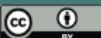
# Temperature profiles at the site of Saraya



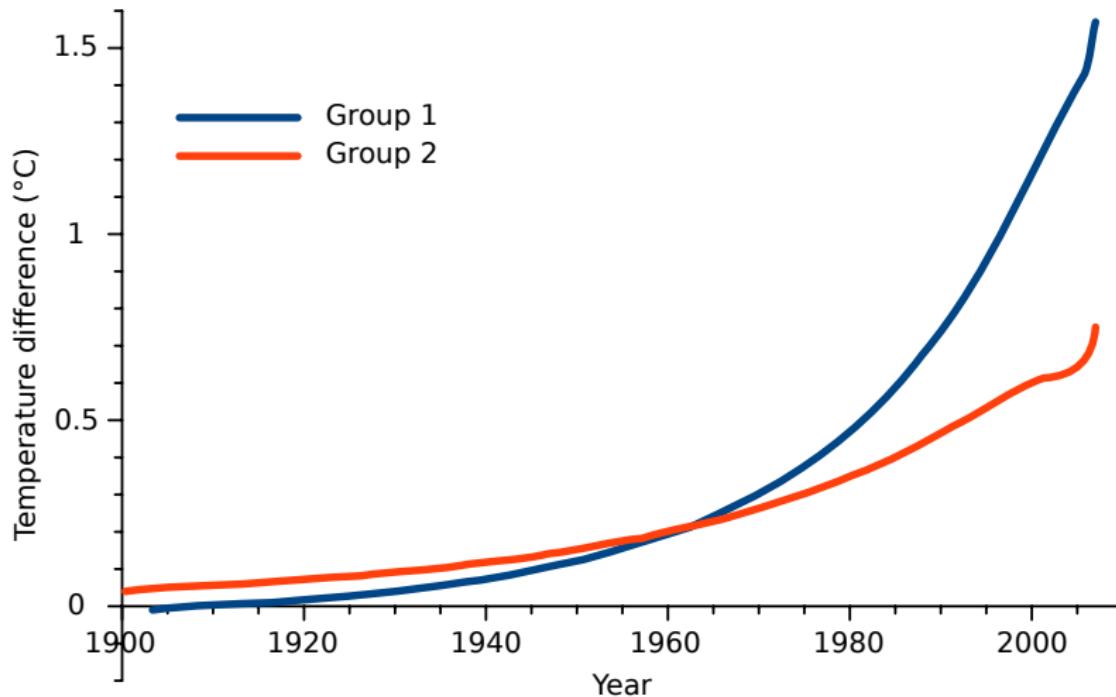


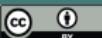
# GST inversion (Mareschal and Beltrami, 1992)



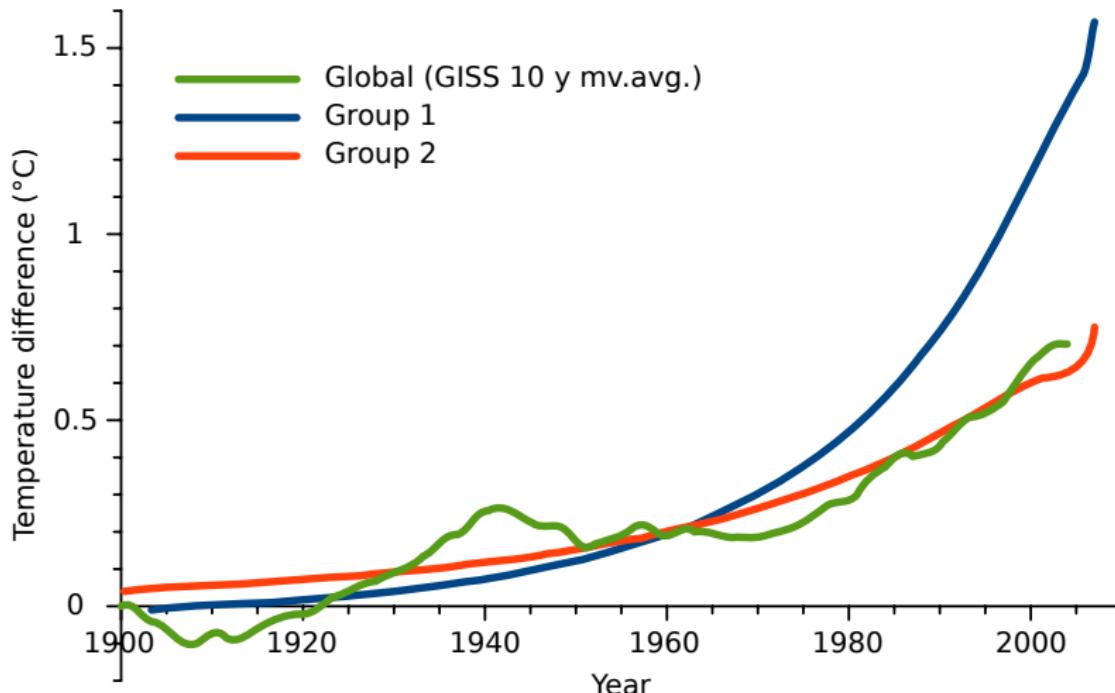


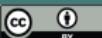
## Close-up during the period 1900-2010



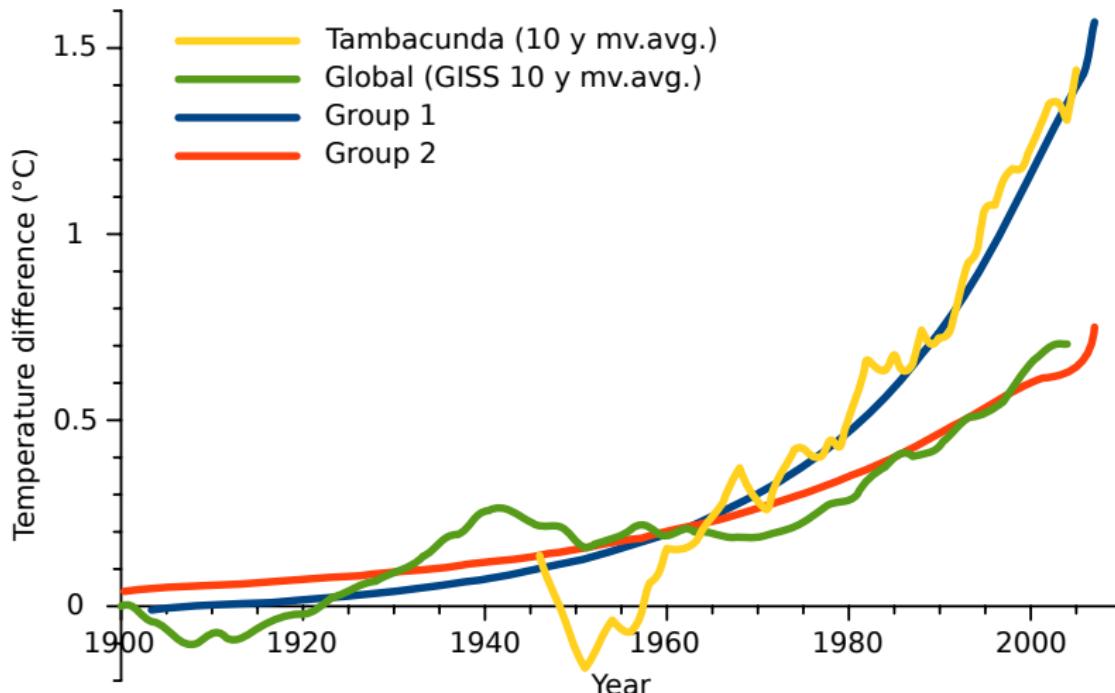


## Comparison with global air temperature record





## Comparison with nearby air temperature record



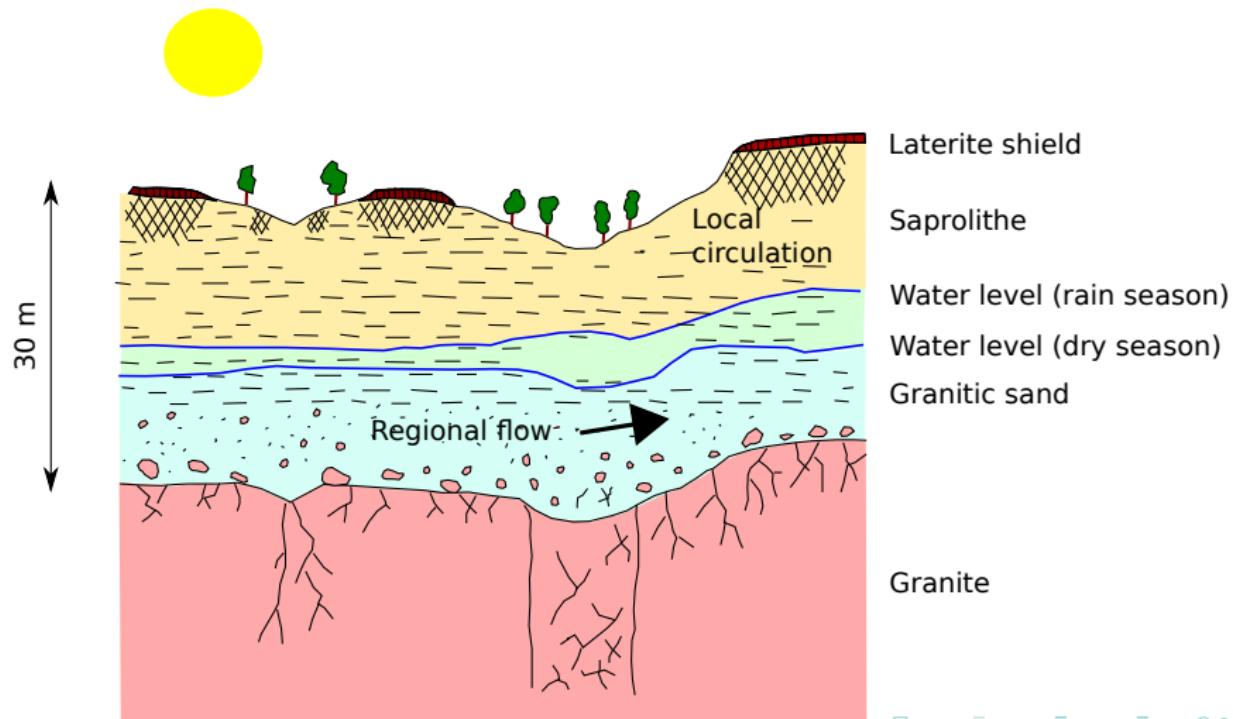


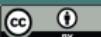
# The Saraya boreholes surface conditions





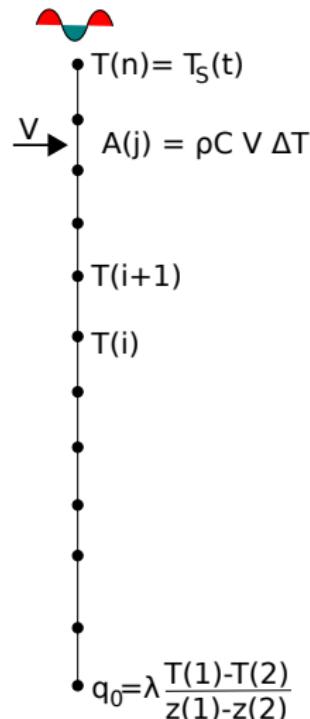
# Lateritisation of the Saraya granite (Ndiaye, 1994)



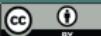


# 1D Finite Differences Model

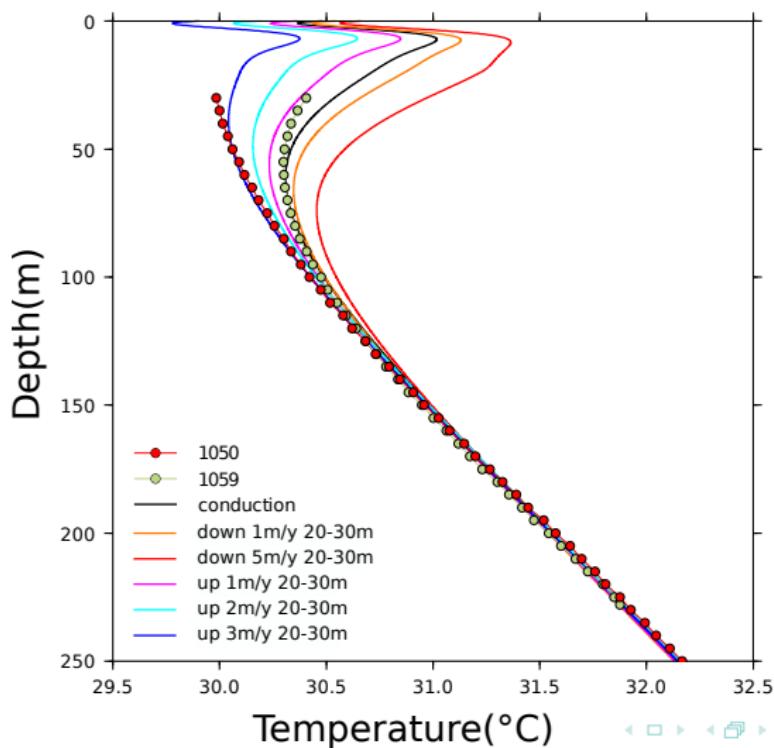
$$\rho_b c_b \frac{\partial T}{\partial t} = \frac{\partial}{\partial z} (\lambda_b \frac{\partial T}{\partial z}) + A + \rho_w c_w V_z \frac{\partial T}{\partial z}$$

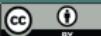


- 1D transient resolution of the heat equation
- Finite differences resolution ( $2500 \times 0.1$  m cells / time step = 0.0833 years)
- five parameters:  $V_z$  (20-30m),  $V_h$  (20-30m),  $\lambda$  (0-30m),  $q_0$  and  $T_S$  (including climatic fluctuations)
- Monte Carlo inversion

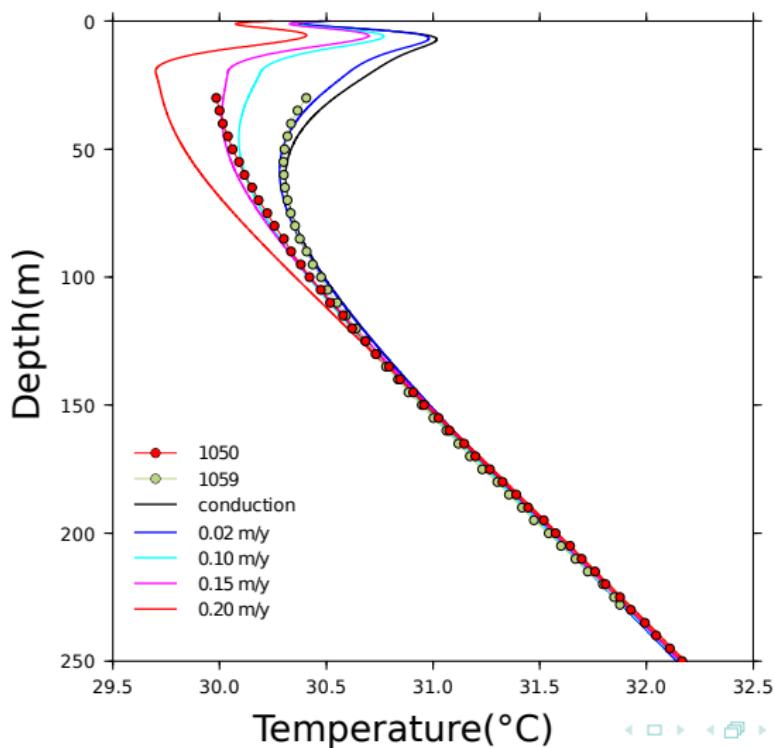


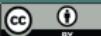
# Effect of vertical circulation



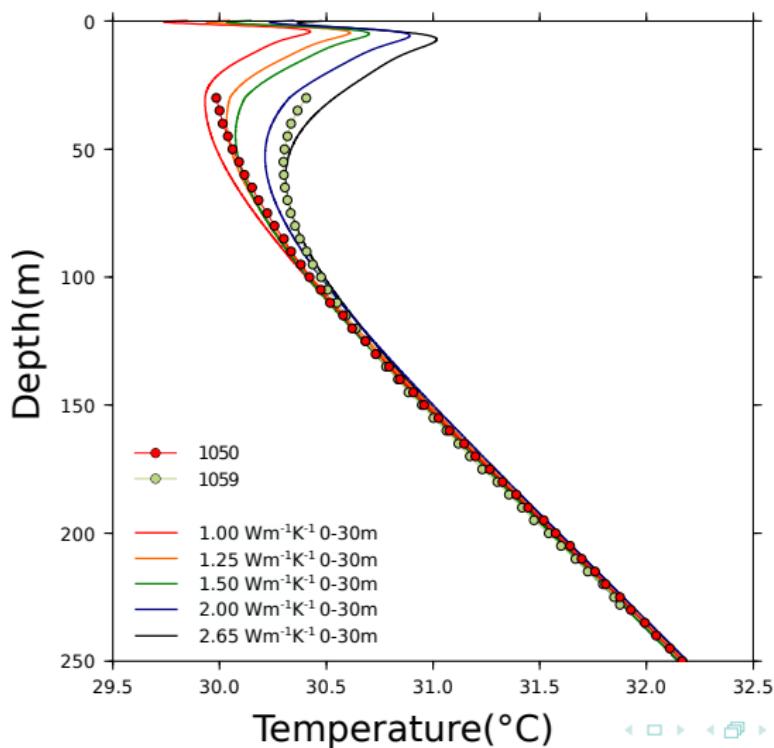


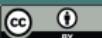
# Effect of horizontal circulation



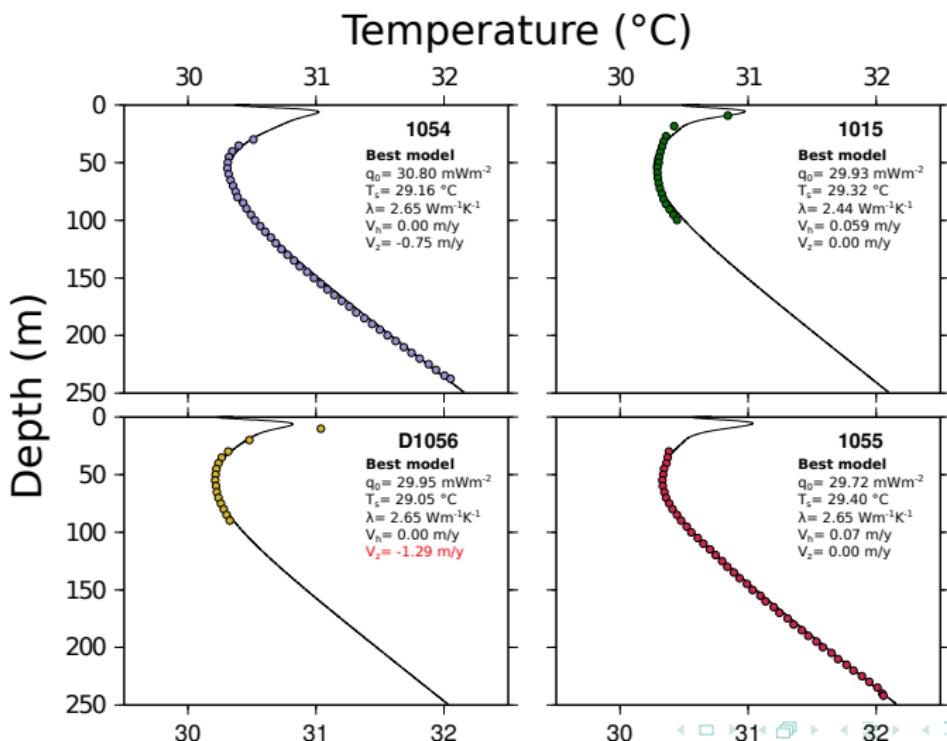


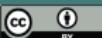
# Effect of thermal conductivity



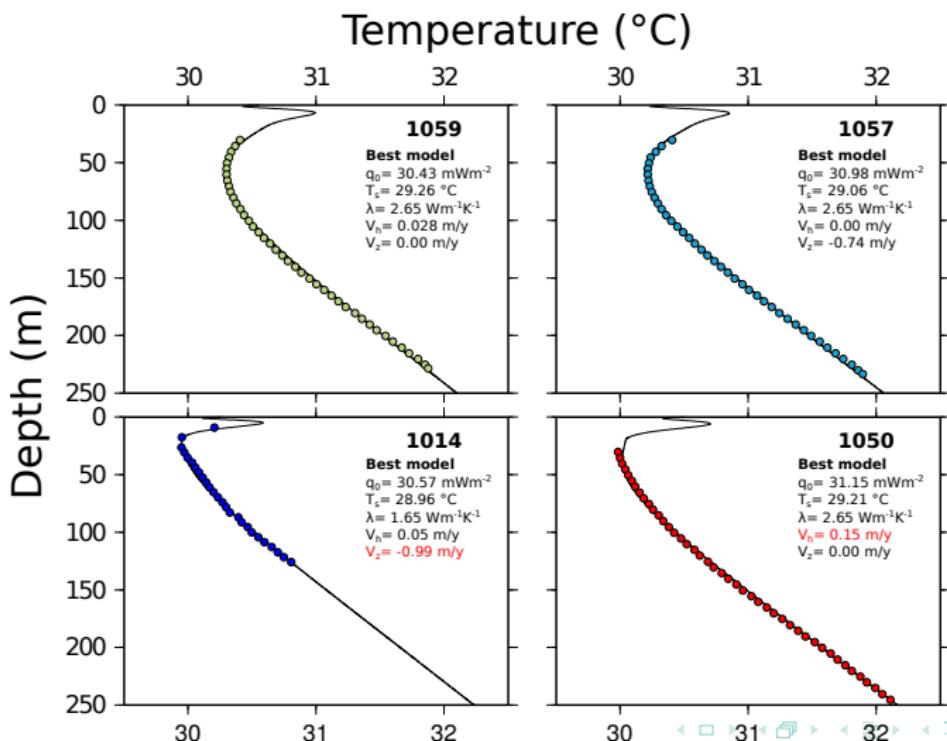


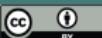
# Comparison of best models with observations



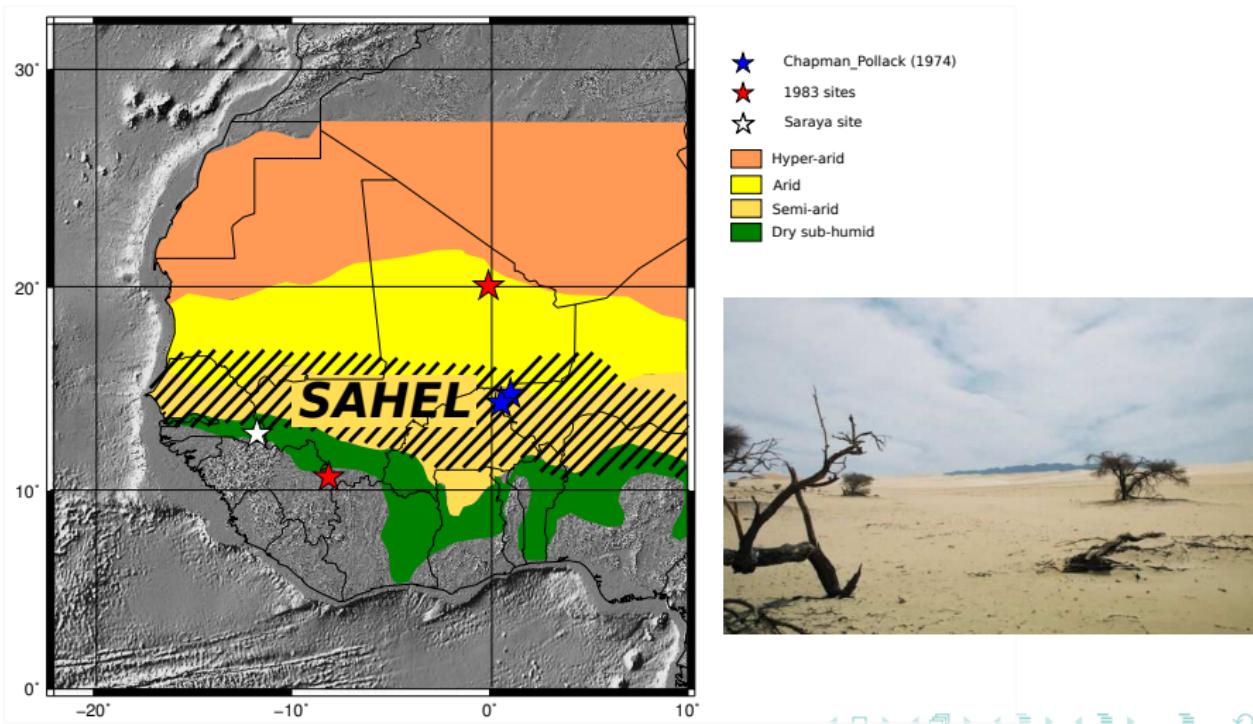


# Comparison of best models with observations

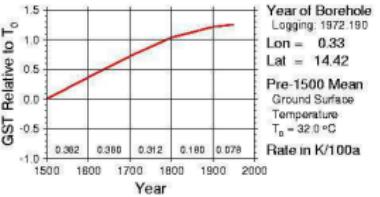
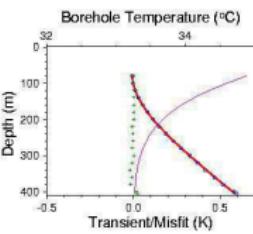
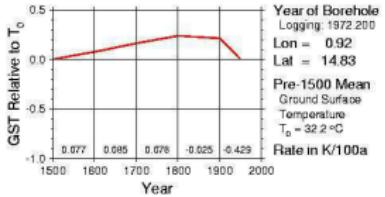
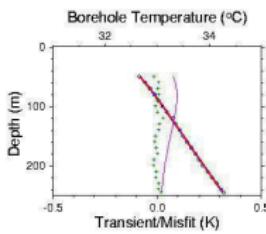




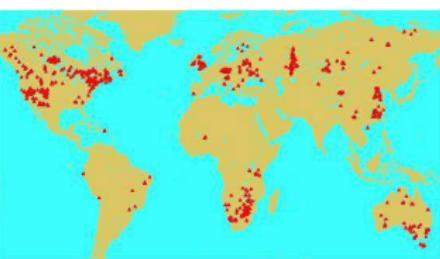
# The semi-arid transition and desertification of Sahel



# Borehole temperatures (Chapman and Pollack, 1974) and GST (Huang et al., 2000) from Niger

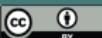


NOAA Paleoclimatology

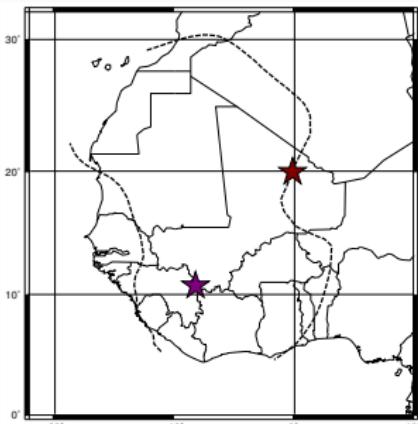
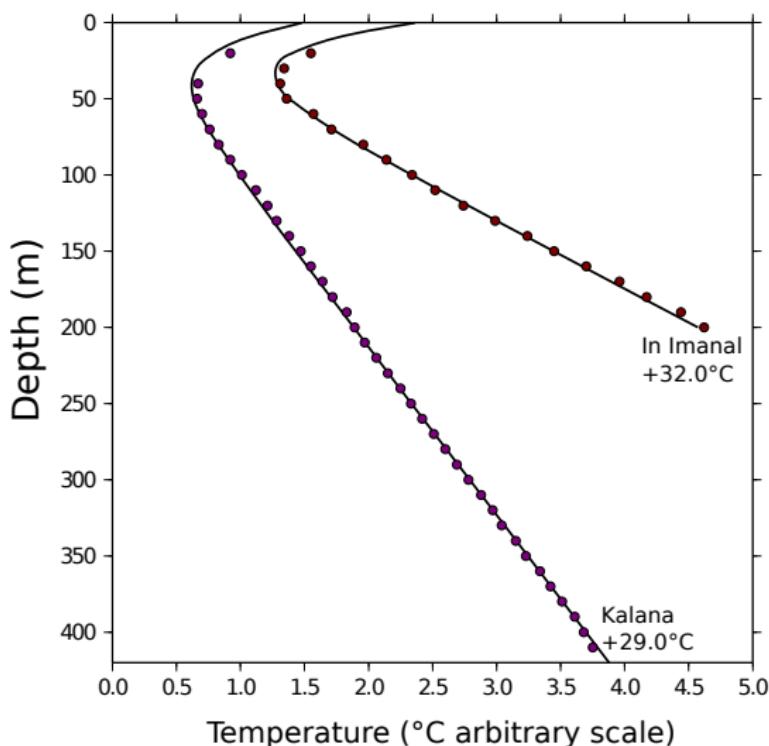


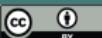
Please note that the climatic parameters presented in this database have been derived with a special focus on the century-long trends over the last five centuries (Huang et al., 1998, Geophys. Res. Lett., 23, 257-260). This standard data processing technique is not necessarily optimal for every individual site. However, it does provide a common basis for comparison of world-wide geothermal records and for the determination of regional and global trends.

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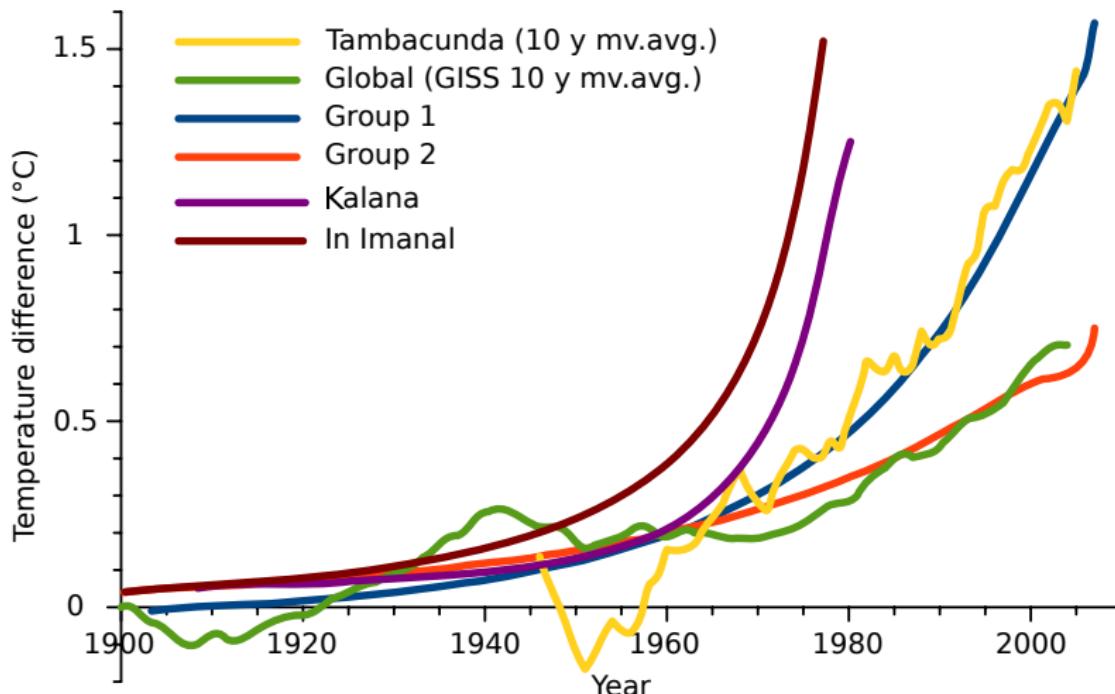


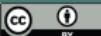
# Borehole data from Mali (Brigaud et al., 1985)



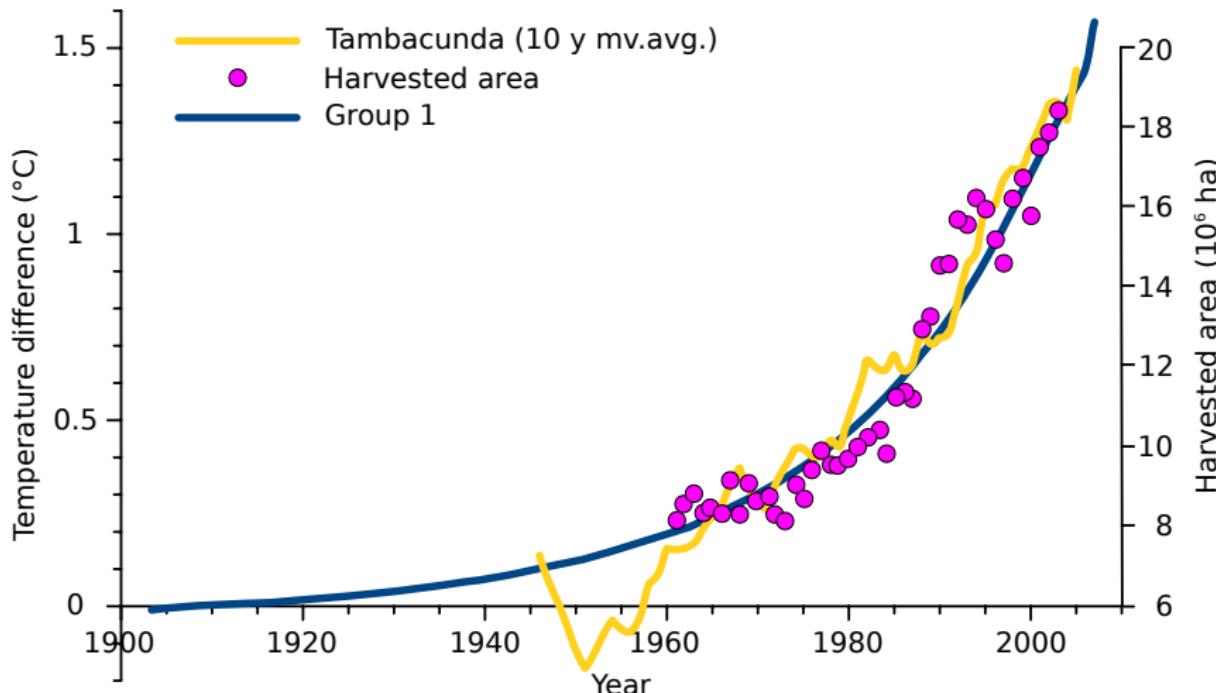


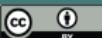
# GST from Mali (this study)



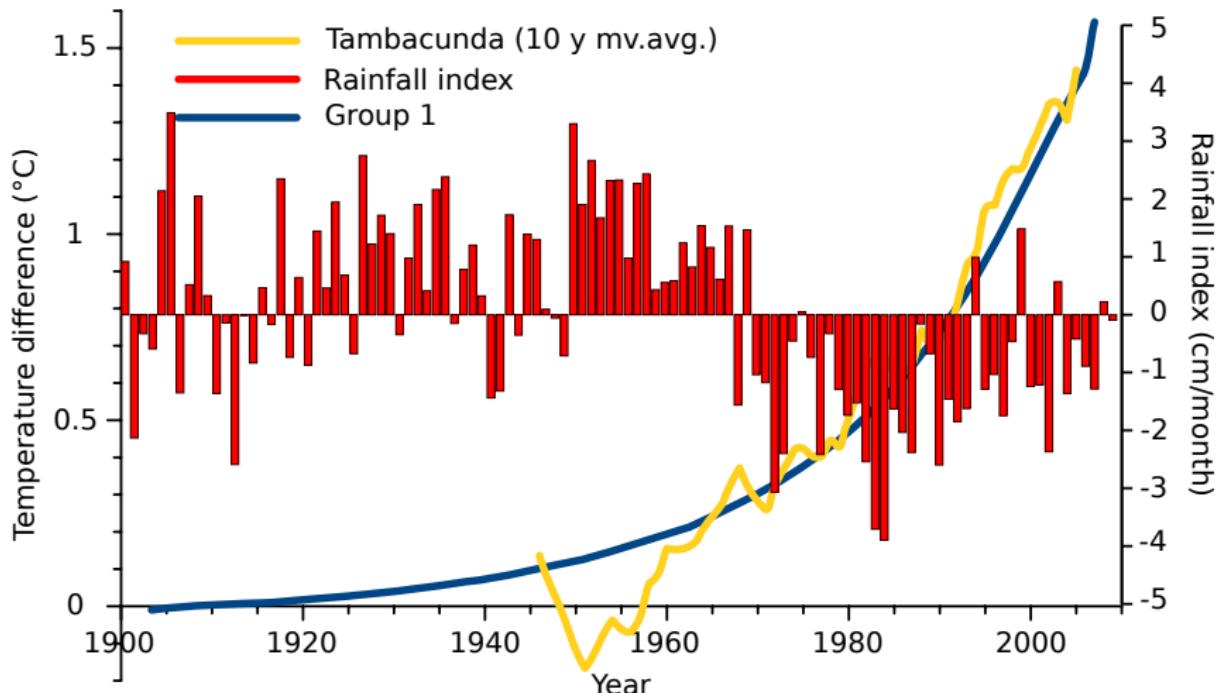


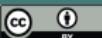
# Human influence? (Data from United Nations Environmental Programme)



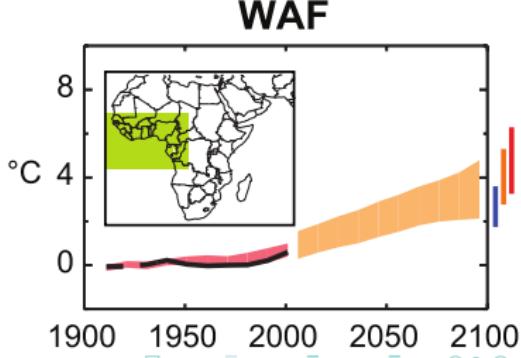
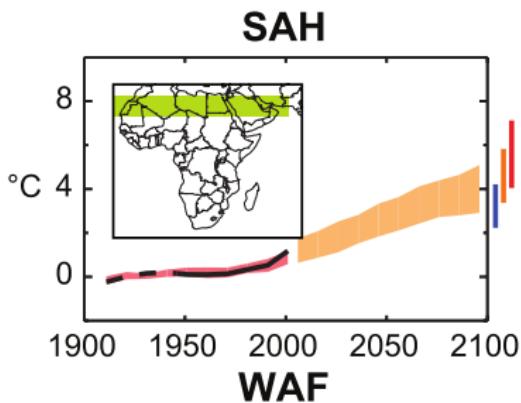
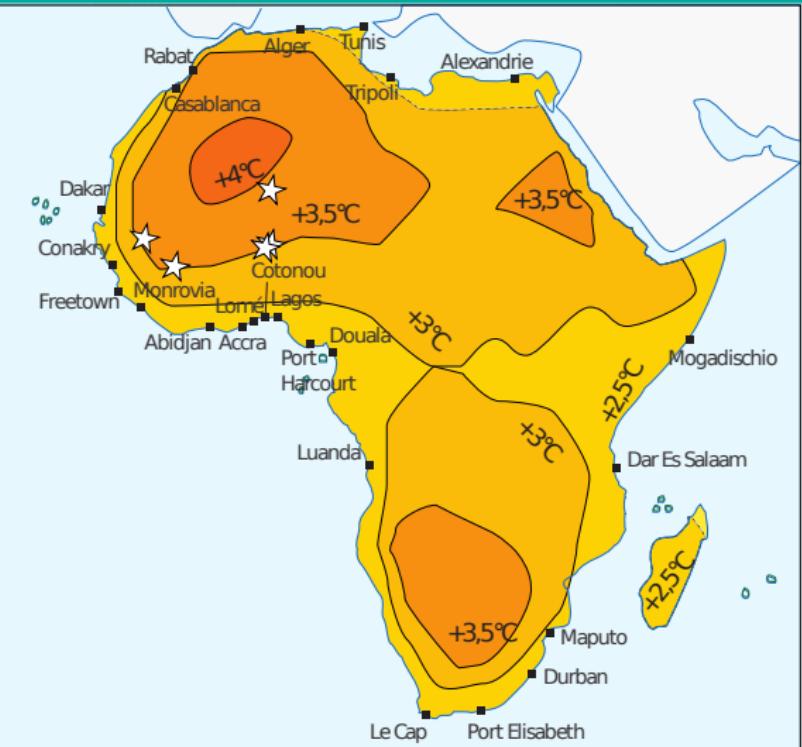


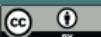
# Rainfall changes? (Rainfall data from <http://jisao.washington.edu/data/sahel/>)





# Temperature change in 2080-2099 (IPCC, 2007)



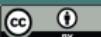


# Conclusions

- The boreholes record a recent surface temperature increase since mid-twentieth century, but nothing important before
- This increase is also recorded by nearby meteorological stations (Tambacounda, Kedougou)
- The ground surface temperature history is locally perturbed because of the alteration zone (upper 30 meters)
- The temperature increase is correlated to the increase of cropping and herding in the Sahel and to the decrease of rainfall
- But similar temperature changes are also inferred from the arid zone of the Adrar in northern Mali, which is not (or less) affected by these changes



Thanks for your  
attention!



# References

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