Investigating the anthropogenic influence on the mesoscale over Kilimanjaro

Carolyne Pickler*, Thomas Mölg

Friedrich Alexander University Erlangen-Nürnberg

carolyne.pickler@fau.de

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Introduction

Anthropogenic influence has increased over time and been detected in all major components of the climate system.

High altitude mountains constitute highly sensitive regions

The anthropogenic influence is becoming...

More evident on global scales → Can show significant differences regionally → Becoming noticeable on some local scales

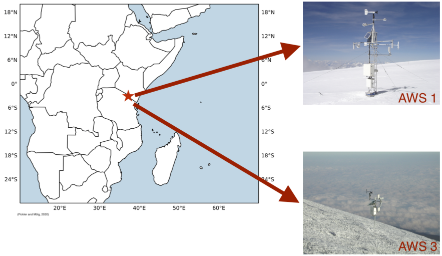
How are high altitude mountains influenced by anthropogenic forcing?

Where? Case Study - Kilimanjaro

- Address this question by studying Kilimanjaro and the glaciers on its summit

- Isolated peak at almost exactly 500 hPa

- allows for the examination of the large and local scale climate change dynamics and how they are linked by the mesoscale circulation over the mountain



How? Dynamical Downscaling!

Run the Weather and Research Forecasting Model (WRF) over East Africa for 1985-2015

- To evaluate anthropogenic forcing need to force the lateral boundaries of WRF with two distinct GCM simulations from CMIP5
  - Historical: includes natural and anthropogenic forcings
  - HistoricalNat: includes only natural forcings
- Difference between the two will allow for examination of anthropogenic influence

→ Force WRF with which GCM?

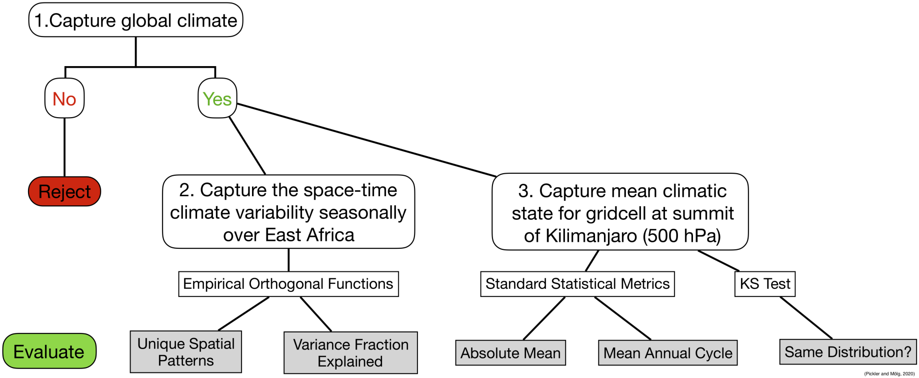
Model Selection

Firstly, evaluate GCM realizations...

- For the monthly means of atmospheric state variables (T, hus, U, V) at 200, 500, 850 hPa does the GCM realization...

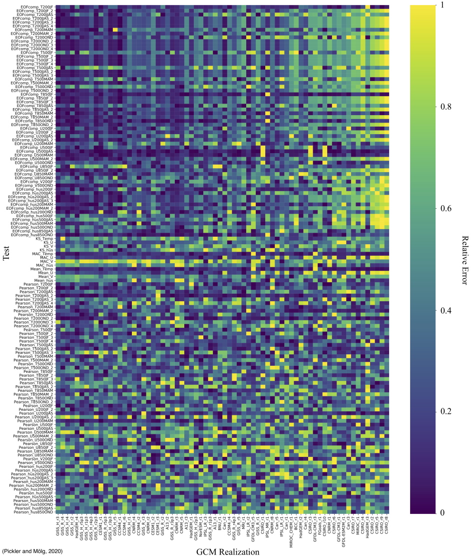
Model Selection

Secondly, evaluate retained GCM realizations...



(Pickler and Mölg, 2020)

Model Selection



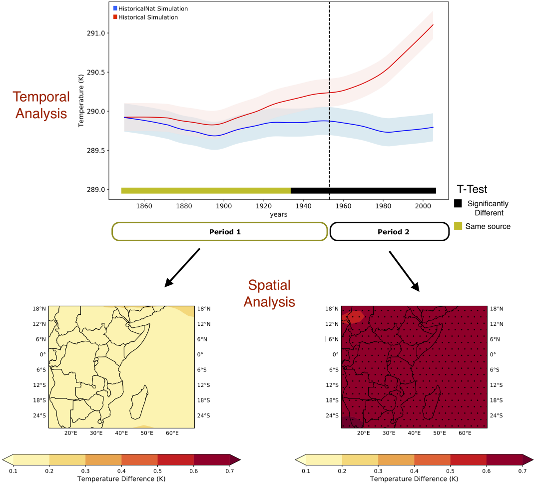
(Pickler and Mölg, 2020)

- GISS-E2-H r3i1p1 was the highest ranked realization
- No realization markedly performs best in all tests

Use top 5 GCMs to provide first estimate of anthropogenic forcing in East Africa

First Estimation of Anthropogenic Forcing

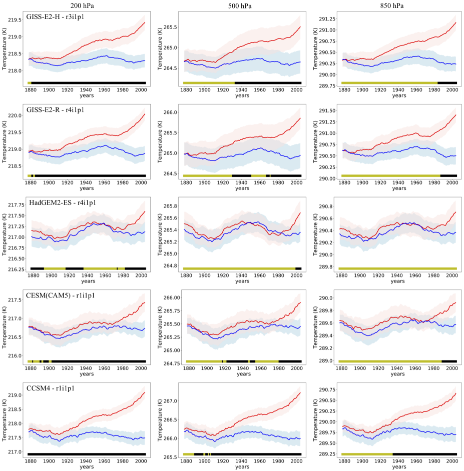
The atmospheric state variables at 200, 500, and 850 hPa from the top five ranked GCM realization from distinct GCMs are analyzed using...

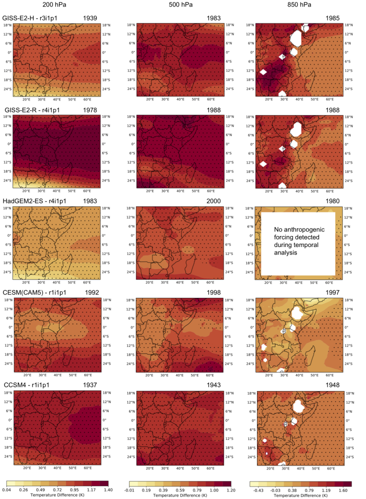


- Spatial analysis involves taking difference between historical and historicalNat for the time period determined by the temporal analysis
- Stippling indicates regions of significant difference between the two simulations

First Estimation of Anthropogenic Forcing

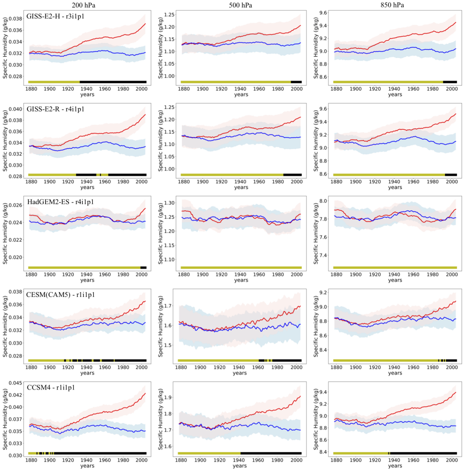
Temperature

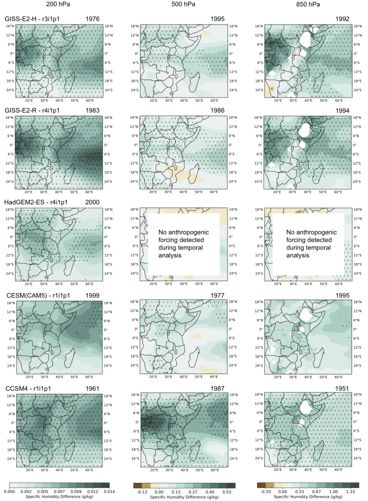




First Estimation of Anthropogenic Forcing

Specific Humidity





First Estimation of Anthropogenic Forcing

Overall...

- Increases in temperature and specific humidity as of 1990 were linked to anthropogenic forcing
- Magnitude of the increase in temperature and specific humidity increased from 850 to 200 hPa
- No clear tendencies for winds

Dynamical Downscaling

BNU-ESM r1i1p1 chosen to drive the lateral boundaries of WRF

Why? → Highest ranked realization with 6hrly resolution of the atmospheric state variables for the historical and historicalNat simulations

- Agrees with first estimate of anthropogenic forcing in East Africa

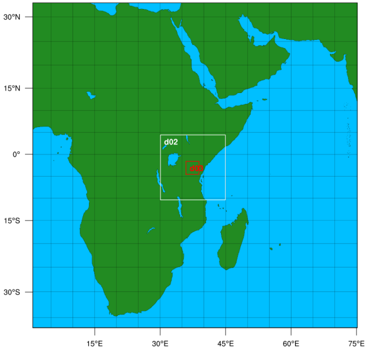
Why only one model?

- Very computationally expensive
- Sequence of day to day synoptic weather types varies between GCMs
  - Averaging over (ensemble) could lead to unrealistic atmospheric conditions and loss of information

Dynamical Downscaling

Run the Weather and Research Forecasting Model (WRF) over East Africa for 1985-2015

- Driven respectively by historical and historicalNat simulations of BNU-ESM r1i1p1
- Multiple grid nesting centered over Kilimanjaro
  - 50:10:2 km (domain grid spacing)
- Details concerning configuration, parametrization and physics can be found in Collier et al., 2018, 2019

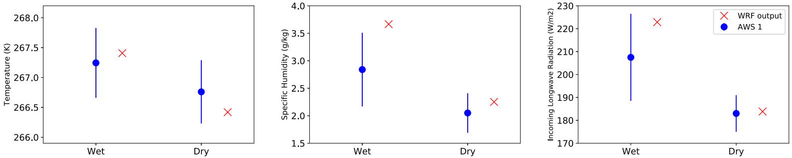


Preliminary Results

Ensure robustness of WRF simulations forced by historical simulation.

First quick check

- For 2005, compare output from WRF run forced by historical simulation with AWS 1
  - For wet (MAM,OND) and dry (JF, JJAS) seasons at summit of Kilimanjaro (gridcell)

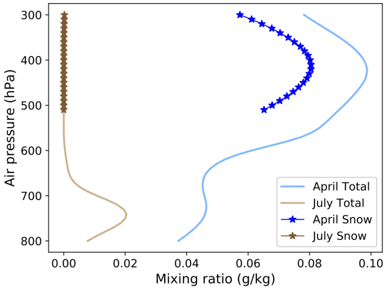


Preliminary Results

Second quick check

Robust vertical profiles of total condensate mixing ratio and snow mixing ratio from WRF run forced by historical simulation for domain 3 in 2005

- For the wettest month (April) and driest month (July)
- Atmospheric pressure level where snow mixing ratio commences coincides with the summit of Kilimanjaro (∼500 hPa)



Next Steps

- Run WRF simulations forced, respectively by historical and historicalNat simulations, for 1985-2005
- Comparing both WRF runs will how allow for the assessment of how anthropogenic forcing has...
  - Affected dynamical (e.g. flow regimes) and microphysical processes (e.g. cloud compostiton and stability) in the mesoscale over Kilimanjaro
  - Influenced all three WRF domains and how the anthropogenic forcing transfers between scales
- Use output from both simulations to drive a glacier mass balance model
  - Will illustrate how the glaciers on the summit of Kilimanjaro have been impacted

Lots to do!!

Acknowledgements and References

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