Using Climate models rather than ERA5 for wind resource assessment – a case study from Tanzania

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Introduction

Wind energy production is vital towards meeting climate goals, and relies on our understanding of meteorological conditions. However, across Africa the high-quality observational networks needed to estimate wind speeds, and therefore wind power potential are often lacking, especially in geographically complex areas. Because of this, reanalysis datasets are used as a proxy for the observed conditions, for inputs for a wind downscaling model, or as training data for an AI model. The ERA5 reanalysis is the most-used one of these, but verification over East Africa is lacking, despite it being known to fail for key features like the Turkana Jet. (Munday el al 2022)

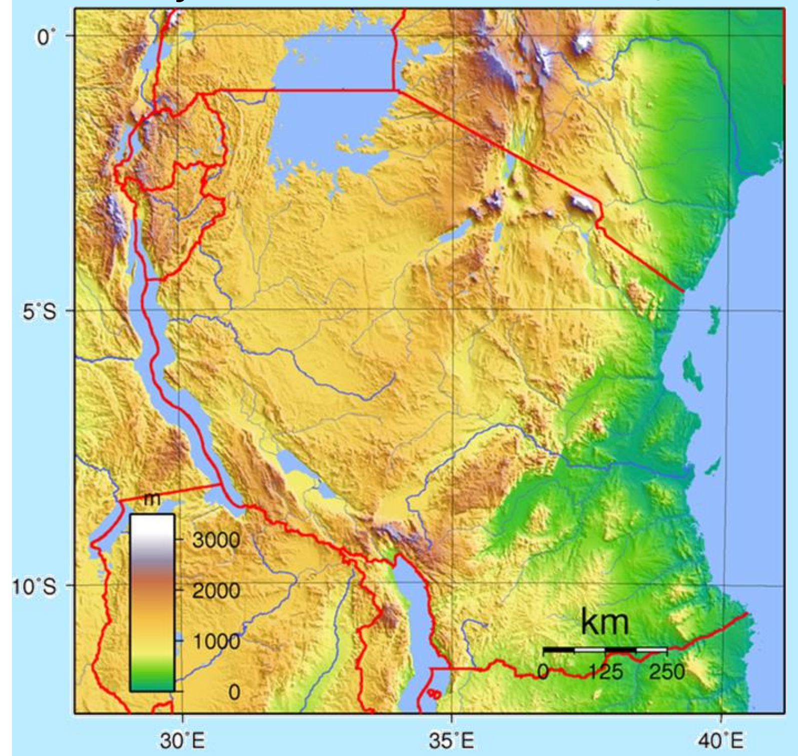


Figure 1: Topographic map of Tanzania

The FOCUS-AFRICA project has been working with TANESCO to develop wind power projections for Tanzania. TANESCO are the national energy company for Tanzania, who require wind speed data for the selection of proposed sites for wind power development. To achieve this, we will compare reanalysis data to current observations and then see if high-resolution climate models can better match these observations to model wind resources.

Observation sources

Measuring the wind of an area requires a high density of weather stations, that researchers can access. For this purpose, we used the ISD database of global weather stations collected by NOAA, often from regional airfields. These stations are not quality controlled or guaranteed to be regularly reporting, so we only used stations with at least 5 years' worth of reported non-zero measurements for wind from 2000. This left us with only 11 stations reporting. We supplemented this with 4 wind masts set up by TANESCO for wind resource monitoring in 4 sites across Tanzania, so we have 15 measurement sites in total, averaging 200km apart.

ERA5 compared to Observations

The performance of ERA5 against station observations has been evaluated over Europe, with records taken from the HadISD database. This allows us to compare Tanzanian station performance to European stations. Below is a Taylor diagram taken from Molina et al 2021 showing station performance against ERA5 in Europe (left) and the same diagram for our Tanzanian stations (Right). We can see that at both 1h and 24h meaning periods, ERA5 performs substantially worse for Tanzanian stations than for European ones, showing that ERA5 is not reliable for wind resource, so we look to climate models instead.

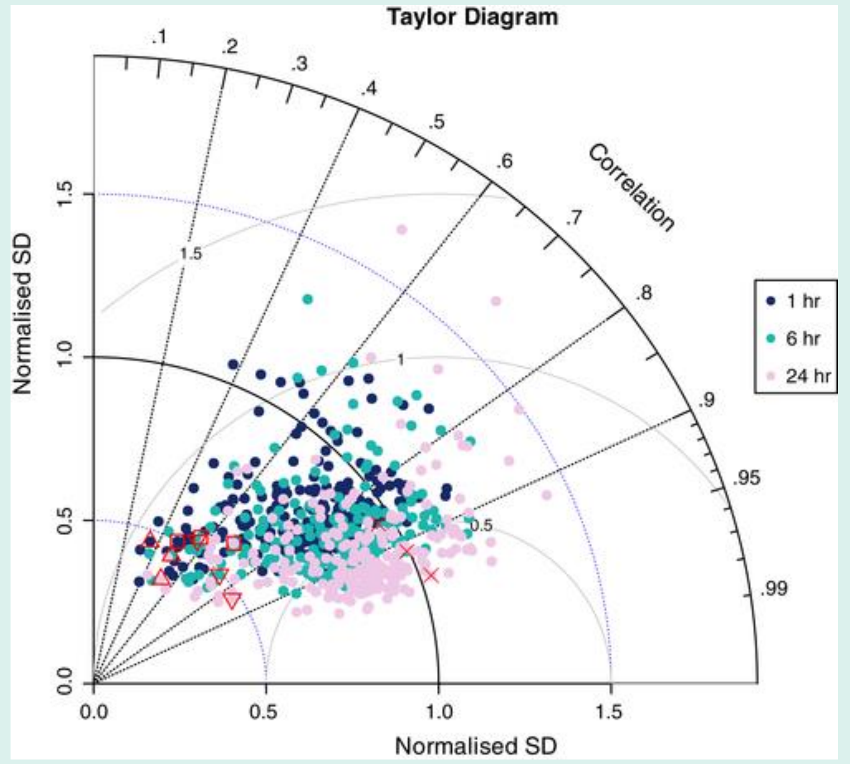


Figure 2: Taylor diagram of European HadISD stations against ERA5, taken from Molina et al 2021

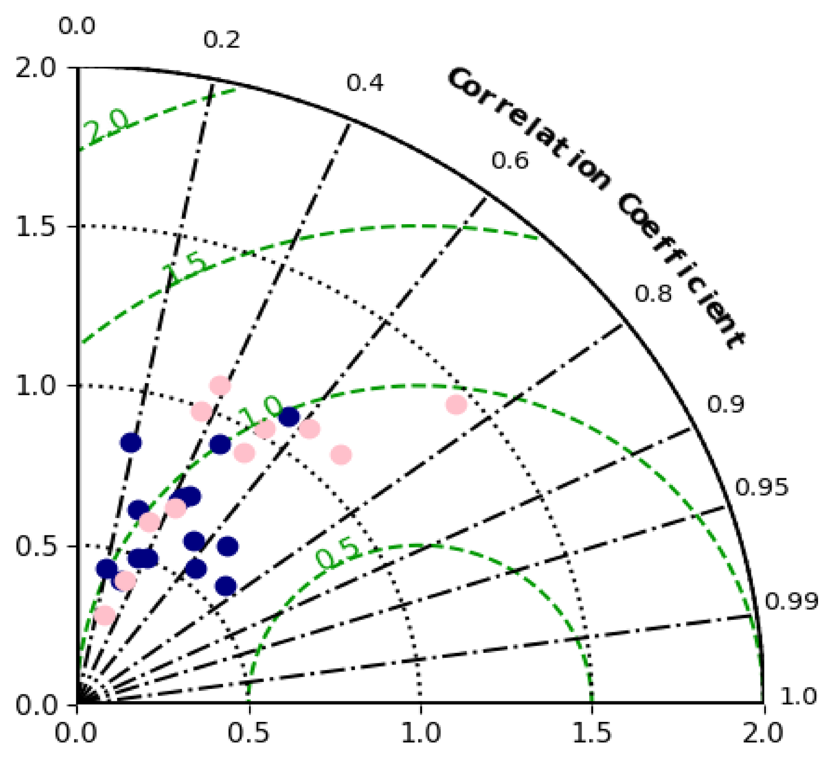


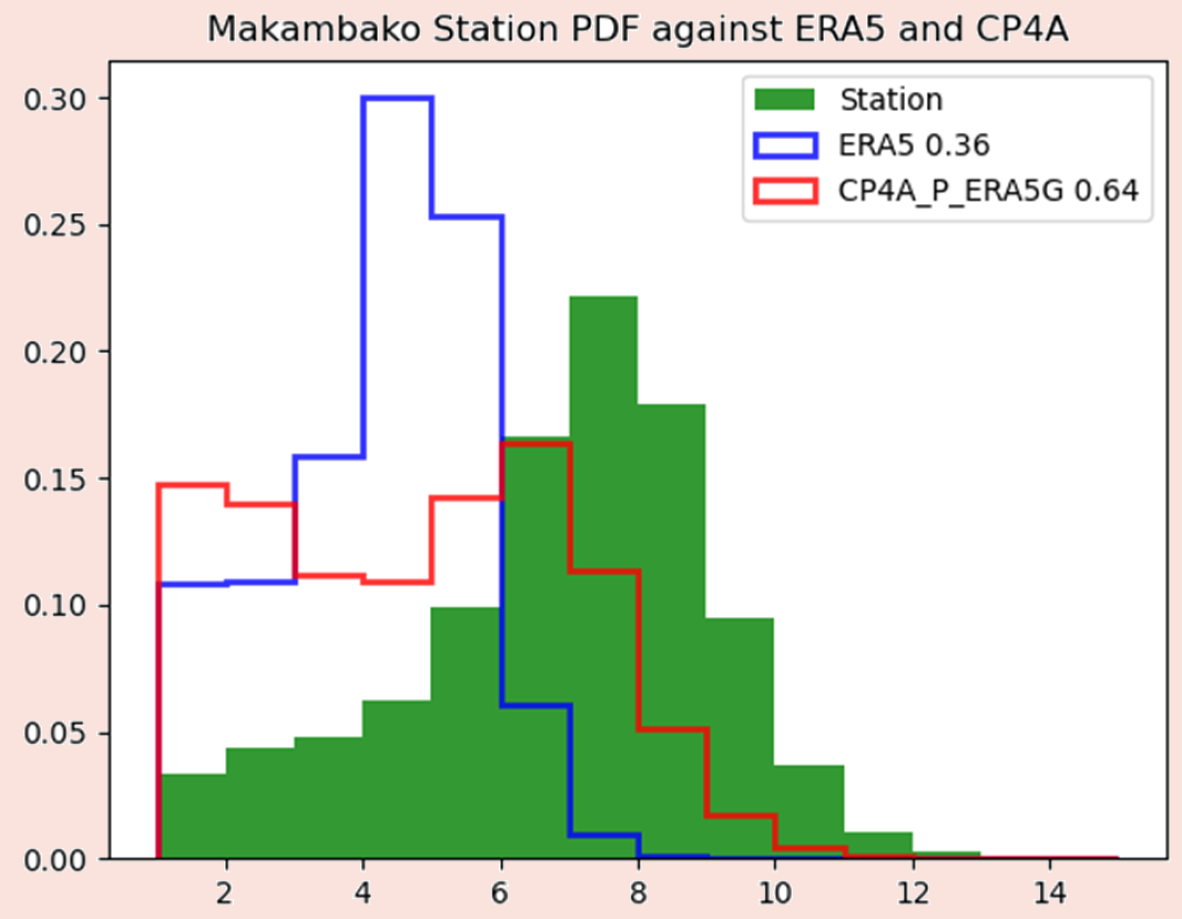
Figure 3: Taylor diagram on same axis of Tanzanian stations against ERA5, with hourly data in navy and daily data in pink, to match Figure 2

Evaluation against Climate Models

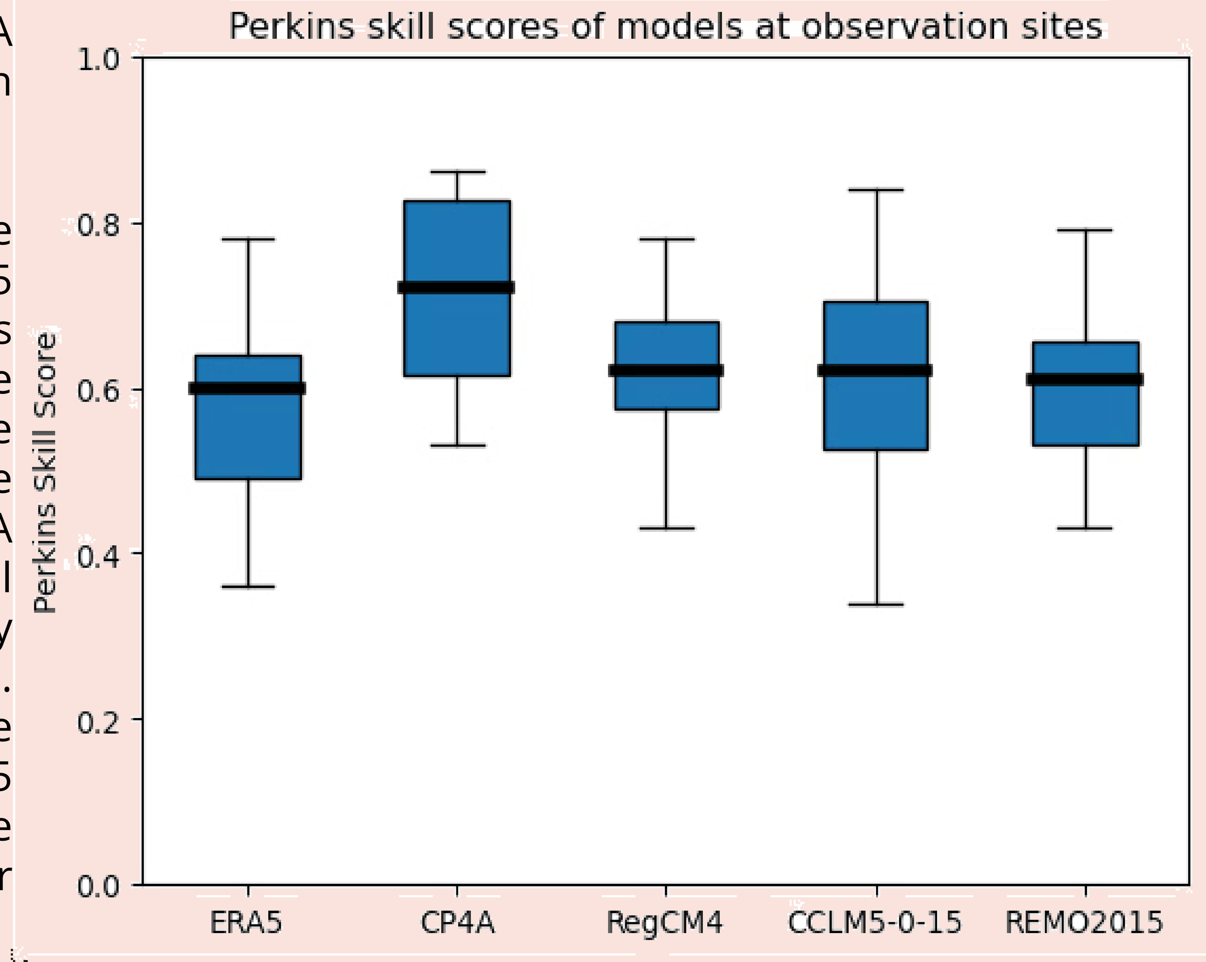
Global Climate models do not have the atmospheric resolution to match ERA5 (31km grid spacing), which required to be useful for wind resource assessment. Two sources of high-resolution climate models are the CORDEX-AFRICA experiment, and the IMPALA CP4A experiment. CORDEX-AFRICA provides 3 regional climate models at 25km grid spacing, each with 3 other global climate models providing the boundaries. CP4A provides a single 4km grid spacing model with a different global model providing its boundary conditions. As the output of surface wind in a model is mostly driven by the resolution of the land surface, through elevation and land use, it is hypothesized that they will provide a better match to the observed distribution than ERA5 does.

For comparing the models and ERA5 fairly, all the climate models are regridded to ERA5's grid, so any differences are due to model physics not better resolution of station surroundings. For the comparison, the Perkins Skill Score is used.

The Perkins Skill score measures the overlap of two probability density functions (PDF) and gives a score between 0 and 1. 1 is fully overlapped, 0 is no overlap whatsoever. Figure 4 (right) shows an example from a single station of how ERA5 and CP4A overlap with the station PDF,



Over the 15 stations, the median skill score for ERA5 was 0.6 (right). This is again lower than in Europe and the same performance as the CORDEX models. CP4A however has a median skill score of 0.72, noticeably higher than the reanalysis. Left shows a map the scores for CP4A and ERA5 at each station, and the difference is most clear for inland mountain regions



Conclusions

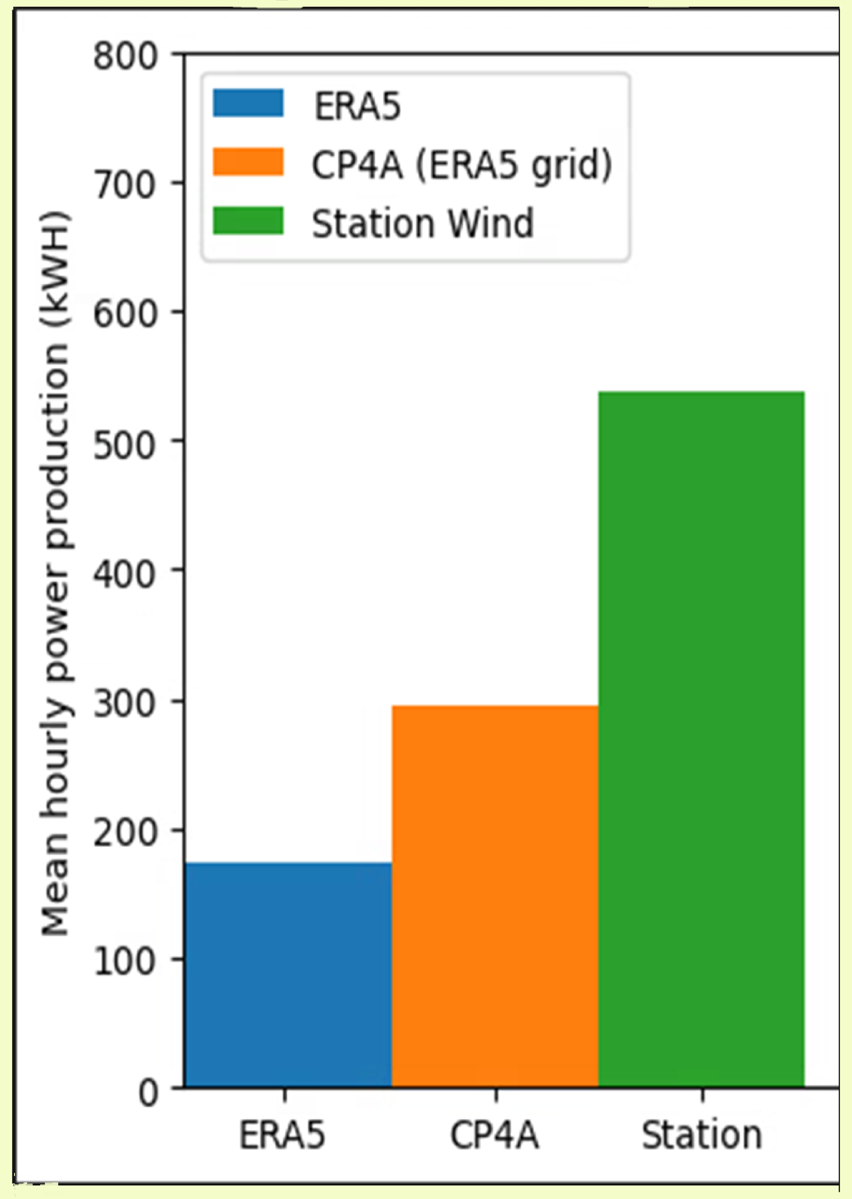
- **Compared to in situ observations, ERA5 performs significantly worse at simulating wind speeds in Tanzania than Europe.**
- **A Convection-permitting Climate Model (CP4A) gave a better representation of a site's wind speed distribution than ERA5 Reanalysis data, despite not being driven by the observed atmosphere.**
- **This is speculated to be caused by the coarse resolution of land orography, and limits in the parameterization of wind in reanalysis model.**
- **For estimating wind resource at a site in Tanzania, CP4A gave a 71% higher projected power output.**

Impact on wind power resource

To illustrate the difference between ERA5, CP4A and station observations for wind power, we estimated the power output from a wind turbine at 75m, using established wind power profiles. The turbine (Enercom E53/800) and hub height was chosen as it is the only operational type of turbine currently in Tanzania, so has demonstrated deployment capability.

At Makambako TANESCO has set up wind masts to record the wind at 10m and 45m. From this, an estimate of the exponent for the wind profile power law was taken and used to predict the wind at 75m. This was used with the turbine power profile to estimate annual power production from ERA5, CP4A regridded to ERA5 resolution, and station measurements

The results show that using the CP4A climate model gave a 71% higher estimated annual energy production (296 kWh vs 173 kWh) than ERA5. Both models underpredict compared to the site measurements, but this is expected when comparing a grid cell to a single point



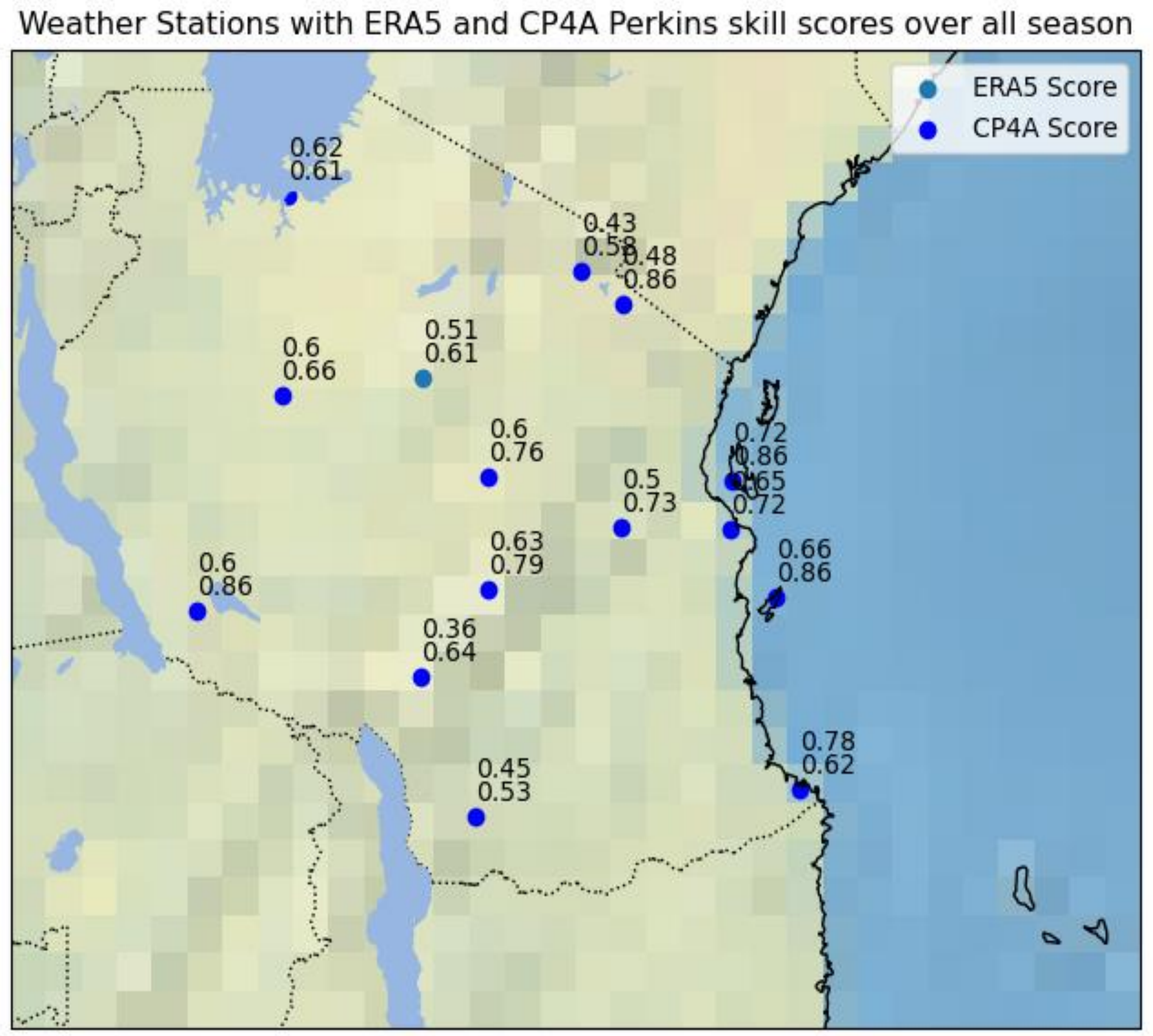


Figure 4: Map of Tanzania with observation stations marked, with Perkins skill scores of ERA5 (top) and CP4A regridded to ERA (bottom) added as annotations

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