Review of ‘GeoDS (v.1.0) : a simple Geographical DownScaling model for long-term precipitation data over complex terrains’

Link to manuscript.

In general, I found the paper difficult to read and digest because of the way it’s written. It does provide a lot of technical details, but I get lost in them. Making use of unfamiliar acronyms and abbreviations doesn’t help. It’s funny, as the mathematical notation spells out their representation in the form of subscripts. Nevertheless, after having read the paper, I’m struggling to remember what it was all about and what were the important points. The paper also contains the odd graphics without reference nor caption. Perhaps it’s because of the way the paper was structured, but I also think the paper is not ready for submission because it still bears the character of being in the draft stage. I got half way through, and thought it would be a struggle to get through the rest. I suggest a major revision and then that the authors make sure that it’s really ready for the next revision.

Abstract

The abstract makes a number of undocumented statements and resembles more an introduction than an abstract. It has to be rewritten to provide an overview on what was done and what was achieved, and statements about the science should be moved to the introduction and should come with proper references.

The phrase “order of tens of kilometers” - the models have a minimum skillful scale (see e.g. DOI:10.2151/jmsj.2015-042) of around 8 grid-boxes, and the global climate models typically have a spatial resolution of ~100 km, so tens of kilometres is not right.

“For climate applications, it is notoriously difficult to generate high spatial resolution data over long timescales (typically millennial)” - not really with empirical-statistical downscaling calibrated on station data, for instance represented through principal component analysis (PCA) components, and then gridded over a limited region. But it’s too computationally costly with dynamical downscaling. See e.g. DOI:10.5194/hess-29-45-2025.

The statement “but they often exhibit important limitations when applied over long periods of time” is strange and warrants at least a reference. But I don’t see the limitations that the authors do, because empirical-statistical downscaling requires little computational resources and can be applied to millennia-long simulations.

The real test is to assess the skill in terms of predicting changes over time - spatial variations are not so hard and often encoded in the local in-situ measurements.

Introduction

The sentence "..., limitations regarding their spatial and temporal cover-age often lead to combining them with data derived from models" doesn't make sense.

The numerical models have a minimum skillful scale associated with their design which is larger than the model resolution, see e.g. doi:10.2151/jmsj.2015-042. The introduction could give a fuller account on downscaling and explain what downscaling is, as AI-based methods have lots to learn from empirical-statistical downscaling (ESD).

The sentence "Such limited-area models are supposedly able to spatially and temporally refine the global circulation signal by physically accounting for sub-grid processes and effects" may be a bit misleading - it's often desired that the regional climate models (RCMs) reproduce the global circulation signal provided by the global climate model (GCM), and are therefore often subject to spectral nudging to ensure physical consistency between the two. The RCMs provide an improved representation of the topography and do the calculations on a finer grid.

All models rely on the stationary assumption, e.g. the parameterisation schemes which upscale unresolved (e.g. cloud microphysics) to a greater volume. Hence the statement "SDS relies on a strong hypothesis of stationarity" gives a misrepresentation that this only is a caveat for ESD, which is far from the truth. The question of stationarity can be deal with by downscaling the parameters describing the shape of statistical distributions rather than day-by-day outcome and it is possible to use kriging with elevation as a covariate to get results for a whole area in addition to the sites where measurements have been made (e.g. DOI:10.5194/hess-29-45-2025).

The rain gauge data from different locations embed information about the effect of geographical factors such as slope and elevation as well as large-scale ambient conditions or teleconnection. It is therefore also possible to downscale a group of rain gauge records and subsequently use kriging to model the effect on topography, rather than trying to use topography-based models to try to predict the rainfall at different locations. It's also useful to keep in mind that statistical properties are more systematically dependent on geographical factors and vary more predictable in space than more random daily or monthly outcomes.

The use of many different variables at different levels from a climate model may provide a tight fit (over-fit?), but also places very strict demands that the model used for projection/prediction reproduces the internal structure between these so that the downscaling makes sense. The internal structure may change as a consequence of climate change/variability, and it's not obvious which variable or level should carry most weight if they diverge. This is the reason why 'downscaling weather' (predicting the state for each time step) may not be such a good idea for climate studies (but good for forecasting) and 'downscaling climate' (i.e. statistical parameters) based on univariate predictors may be a more robust method.

Methods

A focus is on orographic precipitation, but it's important to regard precipitation as a byproduct of a range of different meteorological phenomena: cyclones, cut-off lows, fronts, convection, atmospheric rivers as well as orographic forcing (some of them may overlap or be related). There is both warm and cold initiation of precipitation (ice crystals, cloud drops, snow and rain) depending on the situation. The description of meteorological situations should make use of references.
L159: typo "]-π, π]". Equation 1 is difficult to understand - what is h() and how does w factor in? Equation 2 makes me wonder if it has been AI-generated with such elaborate naming? Figure 2: show the prevailing wind as well as arrows?

Precipitation downscaling

One question is whether the GCMs reproduce the prevailing wind with realism. The GCMs' ability to reproduce the winds needs to be evaluated. The limitation of this type of downscaling is that it only reproduces orographic type precipitation.

Fig. 6 shows a surprisingly good match between downscaled and observed monthly precipitation. If the downscaled results only captures orographic precipitation, that is even more surprising, as I'd expect rain from thunder storms over theAlps from time to time.

I stopped here because I felt that the paper was not ready for submission.