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Interactive comment on "Local models reveal greater spatial variation than global grids in an urban mosaic: Hong Kong climate, vegetation, and topography rasters" *by* Brett Morgan and Benoit Guénard

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Dear Anonymous Referee 4,
Thank you very much for reviewing the manuscript and providing your feedback. Below we provide point to point responses (AC) to your comments (RC), as well as changes in the manuscript (CM). Page and line numbers refer to those in the submitted manuscript. We also provide a pdf supplement showing tracked changes, new citations, figures, and an appendix added to the original manuscript. This comment appears to have had some text encoding errors which we have left intact.

On behalf of the authors,
Brett Morgan

RC - Referee comment **AC** - Author comment **CM** - Change in the manuscript

RC4.01 The authors developed a very high-resolution (30m) gridded dataset of climate, NDVI, and topography for Hong Kong. The meteorological observations from weather stations are interpolated using thin plate spline model. The motivation for fine resolution dataset for Species Distribution Modeling (SDM) is clear and the final product of the study will be useful for SDM and other local applications, however, the manuscript lacks justification for the methodology used and meaningful evaluation of results. It seems to me that the construction of climate data at this high resolution is the novelty of the paper and the main finding (i.e. greater spatial variation in finer resolution data than the coarser) does not add anything new. The way method section is described is not clear; each variable is prepared separately and then they were used as inputs to the statistical model for the climatology interpolation? Why did the authors choose this method over others and how are the 6 predictors chosen? Also, the use of 'climate modeling' in the text is confusing as it usually refers to general circulation models or regional climate models, but the terminology is used for the spatial interpolation model. I recommend changing the title to something like "development of 30 m raster dataset of climate, vegetation, and topography for Hong Kong" and list specific comments below.
AC4.01 We agree that the main finding and novelty of this study is the higher resolution of the developed rasters. To reflect this focus and better represent the contents of the manuscript, we have modified the title as seen below. However, we believe that the findings of greater spatial variation in climate results is still a salient component of the study. Although this is a result that might be expected, it will have important consequences in projects that use this data, in particular for species distribution modelling for which changes in a few degrees can substantially modify final outcomes. Users should know that not only is the resolution different from products like WorldClim, but also that

the values are different. We also believe the increased variation indicates that global climate interpolation data exclude climate forcing factors that are relevant at smaller scales, which is an important result. We have made various changes and clarifications in the methods section, and provide a workflow schematic in Figure S1 to illustrate preparation of all of the rasters and variables. The thin plate spline methodology was used because of the availability of tools in the R environment to implement it, as well as its history of use in climate interpolation research, which we have now addressed in the manuscript. To select the six climate predictors, we searched the literature for what types of variables have been used in similar studies in the past, and then used those that we expected to have climatic effects at the geographic extent and scale of this study.

CM4.01 Title: New 30 m resolution Hong Kong climate, vegetation, and topography rasters indicate greater spatial variation than global grids within an urban mosaic
Page 5, Line 31: Independent variables were selected by searching the literature for similar studies, and choosing predictors we expected to have an influence on climate at this regional scale.

RC4.02 Gridded meteorological datasets have been generated using station observations and a variety of interpolation methods in the past. A flagship climate dataset may be the CRU climate data (New et al, 2002) which used thin plate spline technique, with functions of latitude, longitude, and elevation (and mean precipitation for precipitation coefficient of variation). The technique seems to be the standard in recently increasing number of global gridded climatological datasets with increasing spatial resolution (eg. WorldClim2, TerraClim). Additional spatial information that represent physical processes are required in order to resolve higher resolution. I understand a unique situation for Hong Kong for the small domain with dense station network, which may allow simplification compared to constructing global data, but it would be helpful to tie into existing gridded climatology data w.r.t. method of prediction. The paper may shed some lights on improving precipitation interpolation.

AC4.02 Thank you! We agree it is important to make clear that this methodology has

been used much in the past as well as recently in climate interpolation studies. We have added explanation in the methods to reflect this.

CM4.02 Page 5, Line 22: Here we use multiple linear regression to predict geographic climate patterns using weather station training points and raster covariates. This is followed by thin plate spline (TPS) interpolation (see Wahba, 1979) of the regression model residuals. TPS is a widely used approach in climate interpolation (e.g. New et al., 2002; Fick and Hijmans, 2017), which fits a curved surface to irregularly distributed points. This two-step interpolation (regression followed by TPS) was based on the approach of Meineri and Hylander (2017).

RC4.03 The stations should be indicated in the map of Hong Kong, Figure 1.

AC4.03 Adding the stations to Figure 1 would make it quite busy due to the density of stations in Hong Kong, so instead we plotted a new map as a supplemental figure showing the distribution of weather stations. It shows stations from which temperature or rainfall measurements are available. It is also used an opportunity to display elevation more clearly.

CM4.03 Added Figure S2.

RC4.04 Methods: I'm aware that R is a statistical package software. But what is the prediction model usedâĂ ÌĘŤËĞlinear regression? Section 3.2, page 5 line 30- page 6 line 17 describes two-step process, which seems to be the main model (as referred to "our model", "local model", "new model"). Either moving section 3.2 to the first section, or giving an overview of the model before subsections begin, and streamlining the reference to the model will help clarify. Does water proximity include inland water bodies such as river, pond, and wetland? Could NDVI be included as a predictorâĂ ÌĘŤËĞwouldn't it add more physical characteristics? Though annual mean or monthly climatology of NDVI, rather than instantaneous is suitable.

AC4.04 We have added an overview section as suggested (shown in CM4.02) that makes clear the modeling method is linear regression, with other relevant explanation. Water proximity does consider inland water bodies, most of which are artificial reser-

voirs. NDVI could be used as a predictor, but it is variable on a granular scale where neighboring pixels can have very different values. It is unlikely that climate variables would vary in this way, so we decided not to include NDVI as a predictor. Also, even if they are surrounded by vegetation, most weather stations are likely positioned on some type of structure that would bias local NDVI measurements.
CM4.04 Page 5, Line 5: Second, water proximity (including inland water bodies) was calculated as the percent surface land in the area surrounding a given pixel.

RC4.05 As NDVI data is the only remote sensing, physical variable that resolves 30-m, I think it's important to compile climatology. Authors admit that the index values vary seasonally (page 10, line 12), which seems to contradict with the statement earlier on the instantaneous NDVI being representative. With strong seasonality of rainfall pattern in Hong Kong from June to August, I'd expect NDVI would respond. Landsat data extends several decades, so I can't imagine there's not enough data to capture seasonal variation. If no data during monsoon season, dry and winter low and wet summer high would be useful.
AC4.05 We are unsure what is meant by "compile climatology," in relation to NDVI, and if our following response does not address this comment we would appreciate further explanation. We agree that discussion of the NDVI data may appear contradictory, and would like to emphasize that while the NDVI values may fluctuate, we expect that the overall geographic pattern of NDVI (highest in dense forests, lowest in urban centers) remains fairly consistent throughout the year. While precipitation is indeed strongly seasonal, the vegetation in Hong Kong is not seasonally deciduous, but evergreen, so changes in NDVI are unlikely to be drastic. Exceptions may include agricultural areas with rapid shifts associated with harvest cycles. The difficulty in acquiring suitable Landsat images for Hong Kong stems from several factors, as touched on within the manuscript. First, cloud cover is a hindrance, and overcast skies are especially common in the first half of the year. For the months of June-August, mean cloud cover (at the Hong Kong Airport weather station) can range from 65 to 80 percent. So

most Landsat images captured during this time are entirely obscured, and very few are cloud-free. Second, no Landsat image covers the entirety of Hong Kong: it is on the edge of the satellite path, and so generating a complete NDVI raster requires finding and merging two or more suitable images taken at a similar time of the year.
Upon checking Landsat 8 further, creating a dry season / winter NDVI layer would certainly be possible, but for calculating summer NDVI not enough cloud-free images are available. We will check Landsat 7, 5, and 4 databases as they are also available at 30 m resolution, but a concern with using older data that is that in comparisons some NDVI differences will be due to succession of vegetation and disturbance of lands due to continuous development over the years rather than seasonality.

RC4.06 Precipitation results (4.2.2): I don't understand the last sentence. GCM outputs can be a predictor? If you mean using dynamical models, neither the GCMs nor even higher-resolution regional weather forecast model can't resolve micrometeorlogy at 30-m. Downscaling dynamical model climatology is a possibility but it will be a whole new paper and I'm not sure if it's attainable for 30m with limited information at hand.
AC4.06 Thank you, yes it makes sense that circulation models wouldn't be helpful without first downscaling them, and indeed that seems like it would be a substantial effort outside the scope of this study.
CM4.06 The sentence has been removed.

RC4.07 Climate variables discussion (4.2.4): Though direct validation is not possible, temperature and precipitation could be evaluated qualitatively. Worldclim2 is average for 1970-2000 but your climatology is for 1998-2017, so it's not apple-to-apple comparison. Did you adjust Worldclim data? Could that be the reason for huge discrepancy in precipitation? TerraClimate data set is coarser at âĹij 4km but coves 1958-2015 (https://www.nature.com/articles/sdata2017191), so you could get closer climatology of 1998-2015 for the comparison. I would first check if the climatology agrees at station locations, then map out the differences at 4 km. For temperature, you can downscale the 4 km data to 30 m via elevation correction using constant lapse rates of

-6.5âŮęC/km (Willmott and Matsuura, 1995; Maurer et al., 2002) since you have 30 m elevation data which can easily be aggregated up to 4km. The downscaled temperature should provide similar features as the modeled results and physical range of differences to expect. Also, effects of predictors other than elevation would be shown where they differ. Precipitation is difficult to evaluate or even to predict as indicated in the text. Does Hong Kong have radar data?
AC4.07 In our comparisons with WorldClim, the primary goal was to assess the geographic differences between the two datasets. So if in choosing a dataset for comparison, there is a tradeoff between higher resolution rasters (WorldClim 2) and a more congruent temporal window (TerraClim), we prefer to use the dataset with higher resolution. We did not adjust the WorldClim values. We did consider testing model predictions (both our models and WorldClim) against actual station values, but it seems there would be an issue of testing with data that was used to train one model but not the other. As for downscaling 4 km TerraClimate data down to 30 m based on elevation only, we are unsure that would allow for a valid comparison. Temperature lapse rates would likely vary by geographic region, as well as the temperature variable under consideration. The Hong Kong Observatory does record radar data (shown here https://bit.ly/2FyS4Rj), but it doesn't seem historical radar data are available for download.

RC4.08 Skin temperature from Landsat could be another data to evaluate the heterogeneity of the modeled temperature. Though skin temperature is not exactly the same as in-situ 2-m air temperature, it is an observation based, independent data.
AC4.08 Thank you for this interesting proposition. Is skin temperature the same as thermal infrared images (Landsat provides two thermal infrared bands, but only at 100 m resolution)? It seems this could be quite biased by many factors, like the ground cover, sun intensity at the moment the image was taken, etc. While we were able to put together NDVI, we are no remote sensing experts, and so would need some more guidance on how validation using Landsat data might be accomplished.

RC4.09 My understanding is that bilinear interpolation is for coarser to finer spatial interpolation and for aggregating from finer to coarser, arithmetic or area weighted average is appropriate. I'm wondering if using bilinear to aggregate from 30m to 1 km (Figure 7 etc.) results in different 1km if arithmetic averaging is used.
AC4.09 We are not familiar with using arithmetic or area weighted average interpolation, but our understanding is that bilinear interpolation is generally appropriate to use for resampling continuous rasters. We think the different methods would likely produce different results, but then the challenge would be to evaluate which is actually superior to the other in terms of accuracy.

RC4.10 Next step: It is important to note what's missing and limited for future enhancement, but you should also encourage people to use this dataset. Isn't the dataset ready to use in SDM to address the issues raised in the introduction section? 30 m is remarkably high resolution and the entire raster data contain valuable information for many modeling studies and local management applications.
AC4.10 Thank you! We have consolidated limitations into one section (4.4), and have tried to be more positive about the opportunities offered by the newly developed rasters in our discussion.

Please also note the supplement to this comment:
https://www.earth-syst-sci-data-discuss.net/essd-2018-132/essd-2018-132-AC4-supplement.pdf

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2018-132, 2018.