

# Response to second referee's comments on "Understanding Spatiotemporal Development of Human Settlement in Hurricane-prone Areas on U.S. Atlantic and Gulf Coasts using Nighttime Remote Sensing"

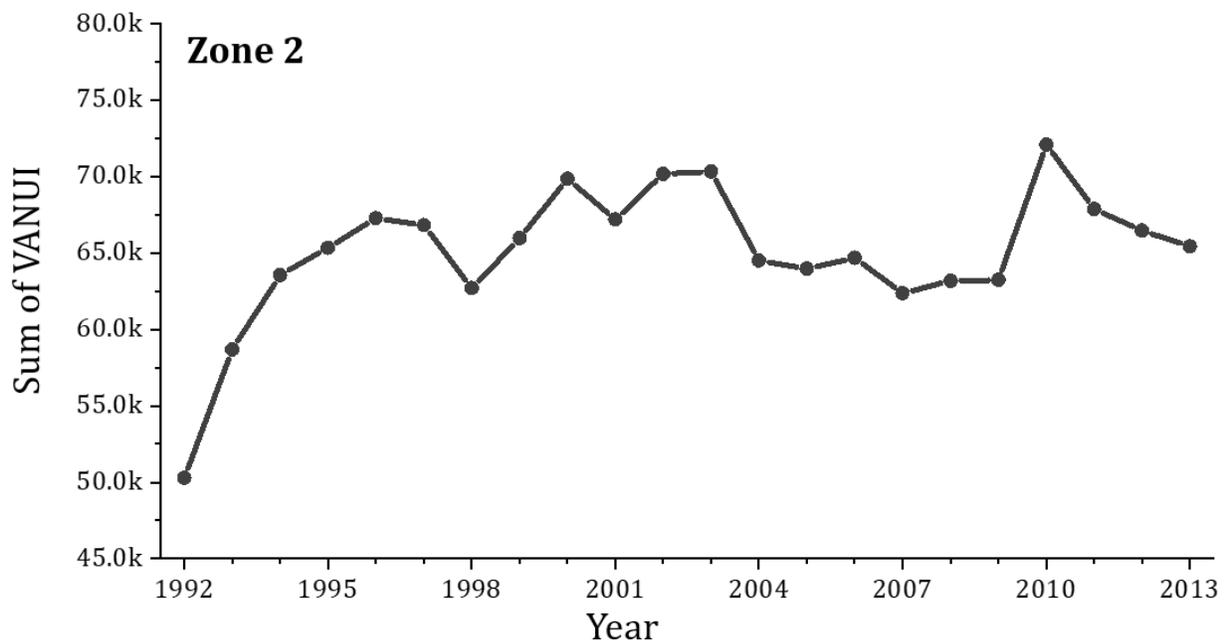
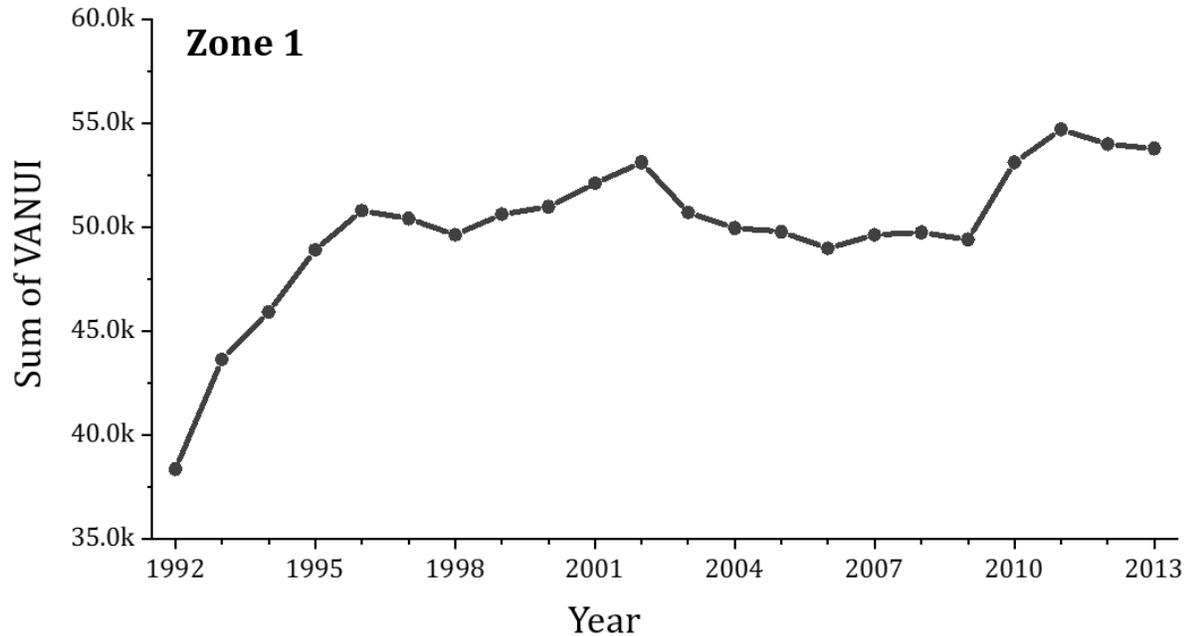
By Xiao Huang, Cuizhen Wang and Junyu Lu

*"The paper is relatively clearly written and I enjoyed reading it. However, before I recommend publication of this work, several clarifications need to be done. In particular, I do have one major concern that may cause a major flaw in your research"*

**Our response:** Thanks for your encouragement and comments. All your concerns were addressed in this response letter. Please find our point-by-point response below.

*"To what extent the percentage of pixels with  $VANUI > 0$  is representative of an increased land development? If we look at the case of Philadelphia (Fig. 5b) the percentage does not significantly change from 1992 to 2013. What is changing here is the sum of VANUI values. Therefore, I strongly recommend to analyze the sum of VANUI to check for land development. If the sum of VANUI does not confirm your previous findings, then your analysis presents a major flaw and cannot be accepted for publication."*

**Our response:** Thanks for pointing out the issue. We totally understand your concern. In the second round of our internal revision, we purposely changed "VANUI sum" to "percentage of pixels with  $VANUI > 0$ ". Here are the seasons we'd like to present to you. Firstly,  $VANUI = (1 - vegetation) * light$ . We believe that  $VANUI > 0$  majorly represents lights in impervious surface area, not lights in vegetation area illuminated by cities ("1-vegetation index" solves the problem of light casted towards vegetation). For this reason, we believe that this yearly statistic illustrates the **expansion** of **newly** built area in different zones. Secondly, due to the saturation problem of DMSP (value capped at 63), we are worried that the sum of VANUI for **large-scale analysis** might suffer from some uncertainties (we did the sum of VANUI for different MSAs in CONUS, please see table 4). Thirdly, using the concept of " $VANUI > a$  certain threshold" to perform regional analysis has been proved efficient by many (Li et al., 2016; Lu et al., 2018). In this study specifically, we set the threshold to 0 in order to capture all the newly expanded human settlement. To answer your concern, we attached figures after calculating the "Sum of VANUI". Please see attached figures for the obvious increase of sum of VANUI in Zone 1 and Zone 2 during the 90s:



Finally, after the investigation of the regional statistics, we did a Mann-Kendal test to investigate the trend for each single pixel during the 22-year period. In the trend analysis, we extracted all the pixels that exhibit significant increasing trend and summarized in each according zone. This statistic provides a better spatial explicit result than simply summing up VANUI in each zone. Our presenting logic follows:

- 1) Firstly, establish a general trend by investigating regional statistic summarized yearly (Figure 6)

- 2) Secondly, investigate trend of every single pixel via Mann-Kendall test, extract pixels with a significant increasing trend, and then summarize in each zone (Table 3)

*“Why sum slope to represent the rapidness of human settlement growth? Each pixel (1 km<sup>2</sup>) can have a maximum slope value of 1/22=0.045. By summing slopes in a region, I assume that you can get an estimate of growth, but this is proportional to the considered area (namely, one of the four hurricane-prone zones), thus you cannot compare trends. To do this, you should consider the average slope.”*

**Our response:** Thanks for pointing the Theil-Sen slope issue. We totally agree with your opinion. Further, we’d like to explain our idea of using Theil-Sen slope. Mann-Kendall test only identifies pixels with significant trend (increasing or decreasing). It doesn’t calculate the strength of the trend. After pixels are identified as having significant trend, Theil-Sen slope calculates how strong this trend is. By summing up all the Theil-Sen slopes in each zone, we can quantify the total increasing intensity in each zone. However, as you mentioned, this is proportional to the considered area. To solve this problem, we divided the summation of all the Theil-Sen slopes by the size of the zone. This is why (in Table 3) we added the column “Sum of Theil-Sen slope per 100,000 km<sup>2</sup>”. We are calculating the summation of Theil-Sen slope per unit in each zone.

*“To what extent sum of slopes in Table 3 are significant? I do have serious concerns related to the slope values reported in Table 3. If we assume that the maximum slope per pixel is 0.045 and in zone 1 there are 312,453 pixels (all starting from 0 in 1992 and reaching 1 in 2013), then ideally the maximum sum value would be 14,060. How is this value related to 9.02 (per 100,000 km<sup>2</sup>)? Please elaborate more on this, to prove the significance of slope values.”*

**Our response:** Please let us explain our methodology (Mann-Kendall + Theil-Sen slope) in this study. Mann-Kendall identifies pixels with significant trend, and Theil-Sen further calculates the slope of those pixels that **have been identified**. As you pointed out, Zone 1 has 312,453 pixels. However, pixels with significant increasing trend only occupy 4.22% (Table 3), meaning that we are only calculating the summation of Theil-Sen slope for around 13,185 pixels. Within those 13,185 pixels, only a small amount of pixels have increased from 0 (no urban at all) to 1 (fully urbanized). If, all the pixels in Zone 1 have max Theil-Sen slope (0.045), it should have a total of 593.3 (13,185 \* 0.045). However, the total Theil-Sen slope in Zone 1 is around 28, meaning that pixels increasing from 0 to 1 occupy only a small percentage, which makes sense as areas that transform from pure rural (0) to pure urban (1) are limited in a developed country like U.S. In our perspective, the significance in Table 3 is not about the absolute value of “sum of Theil-Sen slope”, but the comparison among different zones. After Mann-Kendall, as you may notice, the percentage of pixels with significant trend varies a lot in different zones (4.22% in Zone 1, nearly doubled from 2.34% in Zone 2). This statistic, however, only illustrates the coverage of significant pixels in different zones. It ignores the intensity of the increase. So we added the summation of Theil-

Sen slope in order to capture the “intensity” of this increase. As we expected, Zone 1 have not only the highest percentage of significant pixels but also the highest intensity of this increase. In our manuscript, we illustrated that “**The net increase zonal percentage represents the percentage of net increase area in each predefined hurricane-prone zone.....The sum of Theil-Sen slope, on the other hand, established the relationship between the hurricane proneness and the increase rate of settlement in each zone**”. We appreciate your concerns and we will better elaborate this part in our revision.

*“Detailed comments Page 5 L. 13: “resampled to the 1 km pixel size”. NTL are already at 1 km resolution.”*

**Our response:** DMSP NTL series has a resolution of 30 arc second, which transforms to around 1 km at the equator. However, the pixel size of raw DMSP data varies a lot, given different latitudes. In this study, we resampled both NTL and NDVI into 1 km grid using Lambert Azimuthal Equal-area projection.

*“Page 6 L. 20-21: categorization of hurricane-prone zones: what is the distribution of rho? You should consider (if not done yet) the frequency distribution of rho values to categorize zones.”*

**Our response:** Thanks for pointing out the categorization issue. We used Jenks optimization method (also called Jenks natural breaks classification method) to determine the arrangement of values into different class. The values in the sentence “**Zone 4 (0-0.2), Zone 3 (0.2-0.5), Zone 2 (0.5-0.7) and Zone 1 (0.7-1.0)**” are the rounded thresholds defined by Natural Jenks. We didn’t include this information in the manuscript because we believe it is trivial compared to the entire workflow. Spearman’s rho measures the strength of association between ranked variables. Since our density estimation is continuous, we believe Natural Jenks method is more valid in this case. We appreciate your understanding.

*“L. 23-25: “Serving as the reference site in that study [Elvidge et al. 2009]”. Elvidge et al 2009 considered Sicily as the reference site to perform intercalibration, not Los Angeles and the City of San Diego, as you stated in your manuscript.”*

**Our response:** We sincerely apologize for the misuse of reference in our statement. Elvidge et al. (2009) did consider Sicily as reference site. In Hsu et al. (2015), they stated that “Los Angeles was taken as the reference for the Radiance Calibrated products for two reasons. First, Los Angeles has long been a mature metropolis and the light change is negligible. Second, being a metropolis, it can provide samples with high DN<sub>s</sub> from the city center, as well as low DN<sub>s</sub> from the suburban area”. We have revised this sentence as “**Serving as the reference site (Fig. 3a), the geographic area of metropolitan Los Angeles and City of San Diego, CA maintains high conformity of NTL values throughout the 22-year period (Kyba et al., 2017; Hsu et al., 2015), which satisfies the “pseudo invariant” rule for calibration site selection (Elvidge et al., 2009)**”

*“L. 30: Why do you calibrate DN values if you employ NDVI values? Zhang et al 2013 use original DN values. Please justify this.”*

**Our response:** In the study of Zhang et al. (2013), he proposed the calculation of VANUI but he did not focus on forming a time series. Since our NDVI were derived from two different satellites, we think it is valid to perform a calibration for two NDVI products as it is reported that NDVI for AVHRR and MODIS are different in a minor way (Gallo et al., 2004).

*“Page 7 L. 10: 30,000 samples – are 30,000 samples per year or 10,000 samples per year? Is this representative of the range of NDVI values within the study area? If I am correct, you examine 0.4% (if 30k in total) or 1.2% (if 30k per year) of pixel to intercalibrate NDVI values.”*

**Our response:** Sorry for the confusion this sentence might cause. It is 30,000 samples per year. We have modified the sentence as “30,000 samples were collected within four hurricane-prone zones in years 2003, 2004 and 2005, respectively”. In terms of the representativeness, we believe a total of 90,000 should be enough for a simple linear calibration. The result of  $R^2 = 0.934$  in the calibration of AVHRR and MODIS proves that the products of those two satellites are very similar. Many studies have compared and calibrated NDVI, but their sample sizes are mainly within thousands (Beck, et al., 2011) or tens of thousands (Gallo et al., 2004).

*“Eq. 5: “k-1” should be “k=1”. “j-k+1” should be “j=k+1””*

**Our response:** We appreciate your correction of our mistake. The mistakes in the function have been modified accordingly.

*“Page 8 Eq. 6: “p-1” should be “p=1””*

**Our response:** We appreciate your correction of our mistake. The mistake in the function has been modified accordingly.

*“L. 9: add the meaning of Z=0 in this sentence”*

**Our response:** Thank you for pointing out the missing explanation of  $Z = 0$ . We have revised the sentence as “The  $Z$  value in Eq.7 represents the monotonic tendency of a time series. A positive  $Z$  indicates an increasing trend while a negative  $Z$  indicates a decreasing one. A stable trend exists when the value of  $Z$  equals 0.”

*“L. 24: Fig 2a instead of Fig 1a”*

**Our response:** We apologize for mislabeling of our figure. “Fig. 1a” has been replaced by “Fig. 2a”

*“Page 9 L. 1-4: Hew Hampshire is missing. Please add it to the list.”*

**Our response:** We apologize for the missing New Hampshire in our list. This sentence has been revised as *“The study area contains all U.S. states covered in the hurricane-prone zones (Fig. 2c): Maine, Massachusetts, New Jersey, New York, North Carolina, **New Hampshire**, Pennsylvania, Rhode Island, Tennessee, Texas, Maryland, Alabama, Arkansas, Connecticut, Delaware, DC, Florida, Georgia, Kentucky, Louisiana, Mississippi, South Carolina, Vermont, Virginia and West Virginia.”*

*“Page 14 L. 13-15: “With increased land development, : : exposure.” You cannot state this without examining the sum of VANUI.”*

**Our response:** Please see our first response. We appreciate your understanding.

*“Page 15 Caption of Fig 6: what does “and the like” mean here?”*

**Our response:** We are sorry that the phrase “and the like” might cause confusion to our readers. The definition of “and the like” is more like the word “similarly”. We do not think this phrase is a good fit in the sentence. We replaced “and the like” to “and so on” in this revised manuscript.

*“L. 6: I suggest to cite Fig 7 here”*

**Our response:** Thanks for your suggestion. We cited Fig 7 in the sentence you pointed out. The sentence has been modified as *“The Mann-Kendall trend test coupled with Theil-Sen slope estimator extracted the areas with significant change (increase or decrease) of human settlement in the 22-year period (Fig. 7)”*

*“Page 17 L. 1-3: how is this linked to the sum of slopes in table 3?”*

**Our response:** The Theil-Sen slope in our study case is relatively small (normalized VANUI value ranges from 0-1 and the time period investigated covers a 22-year period). The sentence you pointed out aims to explain value range of Theil-Sen slope in our study, providing an example of what Theil-Sen slope measures and how it measures.

*“Figure 7: You show in gray the urban area as derived from NLCD – does it show a yellow mann-kendall trend(i.e. insignificant)?”*

**Our response:** Our investigated time period starts from 1992 and this NLCD product shows the urban area in year 1992. Our idea is to provide a “base map”, showing the urban extent in the very first year. The red pixels in Fig 7 (b1) and (c1) show all the areas identified as “significant increasing” during the 22-year period (1992-2013). Yes, some urban areas in 1992 show significant increasing trend as their urbanization might further intensify (Theil-Sen slope statistics explore this intensification of urbanization).

*“Page 18 L. 12: “The three two years”: what does this mean?”*

**Our response:** We sincerely apologize for the typo here. The sentence has been revised as “**The last two years (2016-2017) have seen a consecutive above-average damaging Atlantic hurricane season.**”

*“Page 19 L. 15-17: You should tone down this sentence and verify if the sum of VANUI confirms your previous findings”*

**Our response:** In terms of “sum of VANUI” issue, please see our first response. In this paragraph, we specifically illustrated the results from Mann-Kendall coupled with Theil-Sen slope. Whether a pixel exhibits significance in trends (increasing or decreasing) during the investigated period of time totally depends on the Mann-Kendall test. After the test, we summarized the number of pixels in each zone and did a zonal ratio. “**Our result proves that 4.22% of the area in Zone 1 experienced significant increase in human settlement, followed by 2.34% in Zone 2, 2.08% in Zone 3 and 1.65% in Zone 4**”. This is the trend analysis result after we investigated the trend for every single pixel in our study area.

*“References: Could you please list them in alphabetical order?”*

**Our response:** Thanks for pointing out the issue. The references in the revised manuscript have been listed in alphabetical order.

## References used in this response:

1. Beck, H. E., McVicar, T. R., van Dijk, A. I., Schellekens, J., de Jeu, R. A., & Bruijnzeel, L. A. (2011). Global evaluation of four AVHRR–NDVI data sets: Intercomparison and assessment against Landsat imagery. *Remote Sensing of Environment*, 115(10), 2547-2563.
2. Gallo, K., Ji, L., Reed, B., Dwyer, J., & Eidenshink, J. (2004). Comparison of MODIS and AVHRR 16-day normalized difference vegetation index composite data. *Geophysical Research Letters*, 31(7).
3. Hsu, F. C., Baugh, K., Ghosh, T., Zhizhin, M., & Elvidge, C. (2015). DMSP-OLS radiance calibrated nighttime lights time series with intercalibration. *Remote Sensing*, 7(2), 1855-1876.
4. Li, Q., Lu, L., Weng, Q., Xie, Y., & Guo, H. (2016). Monitoring urban dynamics in the southeast USA using time-series DMSP/OLS nightlight imagery. *Remote Sensing*, 8(7), 578.
5. Lu, H., Zhang, M., Sun, W., & Li, W. (2018). Expansion Analysis of Yangtze River Delta Urban Agglomeration Using DMSP/OLS Nighttime Light Imagery for 1993 to 2012. *ISPRS International Journal of Geo-Information*, 7(2), 52.