Spatial model of air surface temperature using Landsat 8 TIRS

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Abstract. Over the past decade, the global temperature rise has become a hazard in the world. The UN Intergovernmental Panel on Climate Change (IPCC) released Fifth Assessment Report that the end of this century will increase 1-2°C in global mean temperature. Malaysia and Indonesia, which observed more than 30 years had increased temperature by 1°C, and this result in line with (IPCC) released Fifth Assessment Report. The research objective to analysis spatial-temporal of air surface temperature model. The spatial model air surface temperature generated from Landsat 8 OLI/TIRS. The research has shown the spatial-temporal change 2013-2018 for air surface temperature. The critical result is trend 2013-2018 with maximum temperature >30°C with increased 1°C. Finally, this research concluded that a spatial model of air surface temperature using Landsat 8 in the tropical country could be a spatial model of Air Surface Temperature.

1. Introduction
The natural consequences of urban heat have been studied using many types of data, such as air temperature from automatic weather station data [1], Land Surface Temperature (LST) data from land satellite measurement [2] and generated models [3]. The study of urban heat also has been conducted in many places with rapid urban development, such as Seoul [1], Singapore [3], Tokyo [5], Wuhan [6] and Hong Kong [7], Jakarta [8] and Kuala Lumpur [9]. An urban heat study in Bandung, Semarang, and Surabaya [8] used remote sensing ([10]; [8]; and [11]). The other study reported that land cover types with the highest vegetation cover [12] were related to low temperatures ([13]; [14]; [2]; [15]; [4]; and [5]). The previous study concluded that areas with high surface temperature (>30°C) mostly observed in city centers (less vegetated), and lower temperatures found over vegetated areas (suburban) and water bodies [8].

In general, spatial modelling is an activity that creates a phenomenon because of interaction between components can be represented spatially [18]. According to [19], spatial modelling consists of a collection of processes data to produce information in the form of maps. [20], stating interpolation is the process of predicting a value at a point that is not a sample point based on the values of the surrounding points based on the sample. According to Tobler’s first law of geography in [21], the value of closer observation points will have a close value compared to the longer point values. The interpolation process is data that records a continuous phenomenon, or a single location affects other locations. Spatial modelling using the distance-based interpolation technique is Inverse Distance Weights, assuming that the correlation level and the similarity between the estimated point and the estimator data are proportional to the (flat) distance from the data point (sample) against the block to be estimated [22]. In the power value, IDW interpolation determines the influence of the more massive input points on the point – the point closer and the weight will be smaller by increasing the distance resulting in a smoother-looking surface [23]. In predicting the IDW method data based on the assumption that the value of the
data attribute that estimated at an unlisted point is a function distance from the average value of the point surrounding it [22].

Over the past decade, the global temperature rise has become a hazard in the world. The UN Intergovernmental Panel on Climate Change (IPCC) released Fifth Assessment Report that the end of this century will increase 1-2°C in global mean temperature. Malaysia and Indonesia, which observed more than 30 years had increased temperature by 1°C, and this result in line with (IPCC) released Fifth Assessment Report. The research objective to analysis spatial-temporal of air surface temperature model. The spatial model air surface temperature generated from Landsat 8 OLI/TIRS.

2. Methods
The data-gathering methods from satellite images ([24]; [3]; [15], [25] & [26]; [27]; [28], [8]), the research used Landsat 8 [29] to acquire land surface data and used satellite imaging thermal bands [30]. From LST to generate the AST. The Landsat data for the UM campus used path 127, row 058, and the data for the UI campus used path 122, row 064; these data acquired from 2013 to 2016 and IPB Campus 2016 – 2019 for validation the model. (Table 1).

| Path/Row | 2013       | 2014        | 2015       | 2016       | 2017-2018 |
|----------|------------|-------------|------------|------------|-----------|
| 127/058  | 22 April   | 4 February  | 7 & 23 Feb | 9 & 25 Jan |           |
|          | 27 July    | 8 & 24 March| 11 & 27 Mac| 26 Feb     |           |
| (UM)     | 12 Aug     | 25 April    | 12 April   | 13 & 29 Mac|           |
|          | 31 Oct     | 11 & 27 May | 30 May     | 14 April   |           |
|          | 16 Nov     | 12 & 28 June| 17 July    | 3 & 19 July|           |
|          | 15 & 31 Aug| 3 & 19 Sept | 29 Sept    |            |           |
| 122/064  | 22 June    | 22 April    | 30 July    | 23 Feb     |           |
| (UI)     | 8 July     | 9 & 25 June | 15 & 31 Aug| 27 April   |           |
|          | 25 Aug     | 12 Aug      | 2 & 18 Oct | 13 May     |           |
|          | 10 & 26 Sept| 13 & 29 Sept| 3 Nov      | 30 June    |           |
|          | 12 Oct     | 15 & 31 Oct | 5 Dec      | 16 July    | 1 Aug     |
|          |            |             |            |            | 19 July   |
|          |            |             |            |            | 22 July   |
| 122/064  |            |             |            |            |           |
| (IPB)    |            |             |            |            |           |

Tabular data processing begins with performing the average daily calculation of LST data that converted into AST values. The LST data is a numerical value every 16 days continuously. Each sample point has value; the value to be processed is the average value based on the time acquisition every month. From the result of LST at each sample point was made of AST spatial model with the interpolated technique. The Model is a representation of LST from remote sensing to modelling to AST. In modelling, where not all points in the observed space are measured, interpolation can be applied to interpret data from unmeasured territories.

The interpolation technique used is Inverse Distance Weights, directly implementing that something adjacent to each other will be more similar than the one that is far apart. In modelling, where not all points in the observed space are measured, interpolation can be applied to interpret data from unmeasured territories. A standard function of the weighted one is the inverse of the quadratic distance, and this equation used in the Inverse Distance Weighted method formulated in the following formula (1) and formula (2) [31]:
\[ u(x) = \sum_{i=0}^{N} \frac{w_i(x)u_i}{\sum_{j=0}^{N} w_j(x)} \]  \tag{1}

where is:
- \( U_i = U(x_i) \), for \( I = 0, 1, ..., N \)
- \( X \) = point you want to interpolate
- \( X_i \) = known Point
- \( d \) = x point distance to \( X_i \)
- \( N \) = number of dots
- \( p \) = power, number rill, positive

It is predicting the IDW method using data based on the assumption the value of the data attribute estimated at a point using a function of the distance the value from the average surrounding it.

3. Result and Discussion

Temporal of Land Surface Temperature (LST) on UM Campus from 2013 until 2016 explained in Table 2, with minimum temp is 21.8°C in November 2014 and maximum temp 39.8°C on March 2014. Figure 2 saw the LST in March 2014.

| Year | 2013 | 2014 | 2015 | 2016 |
|------|------|------|------|------|
| March | - | 39.8 | 29.8 | 36.3 |
| April | 31.2 | 29.7 | 29.4 | 30.9 |
| May | - | 23.4 | 24.2 | - |
| June | - | 35.1 | - | - |
| July | 24.8 | - | 22.8 | 34.8 |
| Aug | 23.0 | 23.4 | - | - |
| Sept | - | - | 28.1 | - |
| Oct | 31.3 | - | - | - |
| Nov | 24.9 | 21.8 | - | - |

Figure 2 explained land use cover in UM Campus in 2013/2014 dominants were vegetation with dense and open vegetated covered. Temporal of LST on UM Campus overlaid with land use cover explained in Table 3, with minimum temp is 30.0°C in 2013 on water bodies and maximum temp 39.0°C in 2014 on building covered. Based on land cover in June 2013 and March 2015, collecting data Air Surface Temperature (AST) on UM Campus explained in Table 4. The AST with high temp 34.8°C and 35.4°C on building covered, moreover the AST with min temp. 31.2°C and 30.4°C on water bodies.
Table 3. The LST based on Land Use Cover Types in UM Campus

| UM Campus LST Land use cover types | 2013 (°C) | 2014 (°C) | 2015 (°C) | 2016 (°C) |
|----------------------------------|-----------|-----------|-----------|-----------|
| Paved Open Space                 | 31.0      | 39.0      | 33.0      | 36.0      |
| Building Covered                  | 31.0      | 39.0      | 33.0      | 36.0      |
| Open Vegetation Covered          | 31.0      | 37.0      | 32.0      | 35.0      |
| Water Bodies                     | 30.0      | 36.0      | 31.0      | 35.0      |
| Dense Vegetation Covered         | 31.0      | 39.0      | 33.0      | 34.0      |

Figure 2. The Land Cover on UM in 2013/2014

Before generated spatial model Air Surface Temperature (AST), the idea is Land Use Cover as fundament on reflection of the solar heat in earth surface. The land cover generated land surface temperature the effect on air surface temperature. Furthermore, the AST collected from land cover. Table 4 explained AST on land use cover in UM Campus in June 2013 and March 2015. The dominants high-temperature similar between land use cover types, except dense vegetated cover was the lowest temperature of AST.

Table 4. Air Surface Temperature in UM Campus

| AST at UM Campus Land use cover types | June, 2013 | March 2015 |
|-------------------------------------|------------|------------|
|                                     | Min (°C)   | Max (°C)   | Avg. (°C) |
|                                     | Min (°C)   | Max (°C)   | Avg. (°C) |
| Paved Open Space                    | 28.3       | 34.4       | 32.1       |
| Building Covered                    | 27.8       | 34.5       | 31.3       |
| Open Vegetated Covered              | 27.4       | 34.4       | 31.5       |
| Water Bodies                        | 27.8       | 33.9       | 31.4       |
| Dense Vegetated Covered             | 27.4       | 34.1       | 31.2       |

|                                     | Min (°C)   | Max (°C)   | Avg. (°C) |
|                                     | Min (°C)   | Max (°C)   | Avg. (°C) |
| Paved Open Space                    | 27.3       | 34.3       | 30.8       |
| Building Covered                    | 27.0       | 34.8       | 30.9       |
| Open Vegetated Covered              | 27.7       | 33.2       | 30.5       |
| Water Bodies                        | 27.7       | 35.2       | 31.5       |
| Dense Vegetated Covered             | 27.4       | 34.1       | 30.4       |

The research used comparative between AST and LST related land use cover types. Furthermore, to generated data spatial model of AST from LST create experiment of an algorithm in UM Campus. The Model AST (M-AST) UM = LST UM + Delta Average AST UM. Delta Avg. AST UM was generated from Delta 1 AST and Delta 2 AST. Delta generated from comparative LST and AST. The result of Delta Avg. AST on UM Campus saw in Table 5.
The result of The Model AST from LST on UM saw in Table 6. Based on Table 6, the result explained the AST every year generated from a model algorithm based on land use cover on UM Campus.

The Model AST from LST year 2015 on UM validated with AST in the year 2015. The result saw that comparative AST with Model AST is similar to the average difference was only 1.2. The rest of the result saw in Table 7. Figure 3 Spatial Model, using IDW, saw Model-AST on Um Campus.

Table 5. Delta of LST and AST year 2013 and 2015

| Land use cover types | 2013 LST (°C) | Delta 1 (°C) | 2015 LST (°C) | Delta 2 (°C) | Avg. Delta (°C) |
|----------------------|--------------|--------------|--------------|--------------|----------------|
| Paved Open Space     | 31.0         | 3.0          | 33.0         | 1.3          | 2.2            |
| Building Covered     | 31.0         | 3.5          | 33.0         | 1.8          | 2.7            |
| Open Vegetation Covered | 31.0       | 3.4          | 32.0         | 1.2          | 2.3            |
| Water Bodies         | 30.0         | 3.9          | 31.0         | 4.2          | 4.0            |
| Dense Vegetation Covered | 31.0      | 3.1          | 33.0         | 1.1          | 2.1            |

Table 6. Model AST using data LST year 2013 until 2016

| Land use cover types | 2013 LST (°C) | 2014 M-AST (°C) | 2015 LST (°C) | 2016 M-AST (°C) | Avg. Delta (°C) |
|----------------------|--------------|----------------|--------------|----------------|----------------|
| Paved Open Space     | 31.0         | 39.0           | 33.0         | 36.0           | 3.0            |
| Building Covered     | 31.0         | 39.0           | 33.0         | 36.0           | 3.0            |
| Open Vegetation Covered | 31.0       | 37.0           | 32.0         | 35.0           | 3.0            |
| Water Bodies         | 30.0         | 36.0           | 31.0         | 35.0           | 3.0            |
| Dense Vegetation Covered | 31.0      | 39.0           | 33.0         | 36.0           | 3.0            |

Table 7. Model AST Using Data LST Year 2015

| Land use cover types | LST 2015 (°C) | Avg. Delta (°C) | M-AST 2015 (°C) | AST 2015 (°C) | Validated Model-AST (°C) |
|----------------------|--------------|----------------|----------------|--------------|--------------------------|
| Paved Open Space     | 33.0         | 2.2            | 35.2           | 34.3          | 0.9                      |
| Building Covered     | 33.0         | 2.7            | 35.7           | 34.8          | 0.9                      |
| Open Vegetation Covered | 32.0       | 2.3            | 35.3           | 33.2          | 2.1                      |
| Water Bodies         | 31.0         | 4.0            | 34.0           | 35.2          | 1.2                      |
| Dense Vegetation Covered | 33.0      | 2.1            | 35.1           | 34.1          | 1.0                      |

Average 1.2
The other result of The Model AST from LST on UM, temporal trend of AST dynamic every year since 2013 average Model-AST is 33.46°C until 2018 is 37.90°C saw increased 4°C within four years. The increased every year, similar to the IPCC report, was 1°C per year. The result from UM Campus in Malaysia generated experiment in another place in the same tropical area. The Bogor University Campus was chosen to apply the Model AST from LST. Temporal of LST on BAU Campus from 2013 until 2018 explained in Table 10, with minimum temp is 23.9°C in July 2013 and maximum temp 34.8°C on July 2018. Figure 4 saw the LST in March 2014.

Table 8. The LST based on Landsat 8 TIR on BAU Campus.

| Year | Date   | Max (°C) | Min (°C) | Avg. (°C) |
|------|--------|----------|----------|-----------|
| 2013 | 8 July | 29.1     | 23.9     | 25.7      |
| 2014 | 11 Aug | 28.6     | 23.4     | 25.1      |
| 2015 | 30 July| 30.8     | 25.1     | 27.0      |
| 2016 | 1 Aug  | 29.9     | 24.4     | 26.3      |
| 2017 | 19 July| 29.5     | 24.4     | 26.0      |
| 2018 | 22 July| 34.8     | 27.8     | 30.0      |

Source: [32]

Figure 5 explained land use cover types in BAU Campus in 2018, dominants with vegetation with dense and open vegetated covered. These land cover types similar with UM Campus. Temporal of LST on BAU Campus overlaid with land use cover explained in Table 9, with minimum temp is 25.5°C in 2013 on water bodies and maximum temp 32.4°C in 2015 on paved open space. Based on land cover in April and June 2018, collecting data AST on BAU Campus explained in Table 4. The AST with high temp 35.0°C on paved open space, moreover the AST with min temp. 26.8°C on water bodies.

Table 9. The LST based on LUC Types in BAU Campus

| IPB Campus Land Cover Type  | 2013 (°C) | 2014 (°C) | 2015 (°C) | 2016 (°C) | 2017 (°C) | 2018 (°C) |
|---------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Paved Open Space          | 29.8      | 28.9      | **32.4**  | 27.0      | 27.4      | 28.1      |
| Building Covered           | 29.8      | 28.9      | 32.4      | 27.0      | 27.4      | 28.1      |
| Open Vegetation Covered   | 29.6      | 28.6      | 32.4      | 27.0      | 27.4      | 28.1      |
| Water Bodies               | 26.6      | 25.6      | 32.4      | 25.8      | 26.9      | 26.7      |
| Dense Vegetation Covered   | 29.8      | 28.9      | 32.4      | 27.0      | 27.4      | 28.1      |

Figure 5. The Land Cover on BAU Campus in 2018.

Table 10 explained AST on land use cover in BAU Campus in April and June 2018. The dominants lowest-temperature similar between land use cover types, except paved open space was the highest-temperature of AST on BAU Campus in 2018.
The result of The Model AST from LST on BAU Campus saw in Table 11. Table 11 explained the AST every year generated from modelling based on land use cover on BAU Campus.

### Table 10. Air Surface Temperature in BAU Campus

| Code | Land use cover types | April 2018 | June, 2018 |
|------|----------------------|------------|------------|
|      | LST (°C)             | Max (°C)   | Avg. (°C)  | Min (°C)   |
|      | M-AST (°C)           | Max (°C)   | Avg. (°C)  | Min (°C)   |
|      | LST (°C)             | Max (°C)   | Avg. (°C)  | Min (°C)   |
|      | LST (°C)             | Max (°C)   | Avg. (°C)  | Min (°C)   |
| 1    | Paved Open Space     | 28.3       | 30.8       | 29.9       | 35.0       | 31.9     |
| 2    | Building Covered     | 27.8       | 30.2       | 27.8       | 31.7       | 29.5     |
| 3    | Open Vegetated Covered | 27.5       | 29.4       | 29.2       | 31.0       | 30.4     |
| 4    | Water Bodies         | 27.3       | 29.7       | 27.8       | 30.2       | 29.4     |
| 5    | Dense Vegetated Covered | 26.8       | 28.5       | 27.7       | 30.3       | 29.0     |

The Model AST from LST year 2018 on BAU Campus validate with AST in the year 2018. The result saw that comparative AST with Model AST is similar to the average difference was only 1.1. This result of validating model was smallest than validated the original model on UM Campus year 2015. The rest of the result saw in Table 12. Figure 6 saw the Spatial Model of Model-AST on BAU Campus.

### Table 11. Model AST using data LST year 2013 until 2018

| Code | LST (°C) | M-AST LUCT (°C) | LST (°C) | M-AST LUCT (°C) | LST (°C) | M-AST LUCT (°C) | LST (°C) | M-AST LUCT (°C) | LST (°C) | M-AST LUCT (°C) |
|------|----------|----------------|----------|----------------|----------|----------------|----------|----------------|----------|----------------|
| 1    | 29.8     | 32.0           | 28.9     | 32.1           | 32.4     | 34.6           | 27.0     | 29.2           | 27.4     | 29.6           |
| 2    | 29.8     | 32.5           | 28.9     | 32.6           | 32.4     | 35.1           | 27.0     | 29.7           | 27.4     | 30.1           |
| 3    | 29.6     | 31.9           | 28.6     | 30.9           | 32.4     | 34.7           | 27.0     | 29.3           | 27.4     | 29.7           |
| 4    | 26.6     | 30.0           | 25.6     | 29.0           | 32.4     | 36.4           | 25.8     | 29.8           | 26.9     | 30.9           |
| 5    | 29.8     | 31.9           | 28.9     | 32.0           | 32.4     | 34.5           | 27.0     | 29.1           | 27.4     | 29.5           |

The Model AST from LST year 2018 on BAU Campus validate with AST in the year 2018. The result saw that comparative AST with Model AST is similar to the average difference was only 1.1. This result of validating model was smallest than validated the original model on UM Campus year 2015. The rest of the result saw in Table 12. Figure 6 saw the Spatial Model of Model-AST on BAU Campus.

### Table 12. Model AST using data LST year 2018 on BAU Campus

| BAU Campus | M-AST LUCT-18 (°C) | Avg-AST LUCT-18 (°C) | Validate |
|------------|--------------------|----------------------|----------|
| Paved Open Space | 30.3               | 31.9                | 1.6      |
| Building Covered    | 30.8               | 29.5                | 1.3      |
| Open Vegetation Covered | 30.4               | 30.4                | 0.0      |
| Water Bodies               | 30.7               | 29.4                | 1.3      |
| Dense Vegetation Covered | 30.1               | 29.0                | 1.1      |
| Average                  |                    |                     | 1.1      |

![Figure 6. Model Spatial of AST using Landsat 8 TIRS on BAU Campus.](image)
4. Conclusion
The critical result is trend 2013-2018 with maximum temperature >30°C and with increased 1°C per year. Finally, this research concluded that a spatial model of air surface temperature using Landsat 8 in the tropical country success generated and applied with difference 1.0 between Model-AST and AST in UM university and BAU Campuses.

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