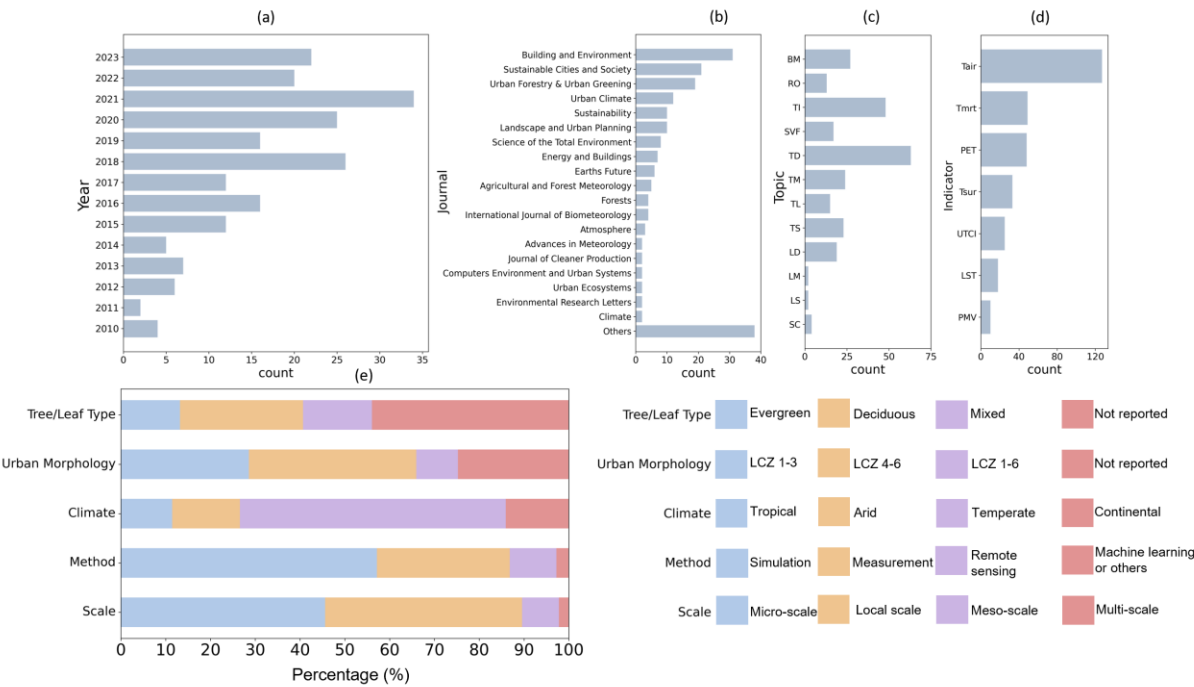


# Supplementary Information

## Supplementary Note 1. Characteristics of the analyzed literature

Our analysis is based on a thorough study of 182 scientific papers that investigate the effects of urban trees on urban heat mitigation and thermal comfort. **Supplementary Figure 1** illustrates the distribution of publication year, journal, topic, and climate indicators of the analyzed studies. It reveals a significant growth of awareness of the cooling benefits of urban trees with an increasing number of related publications in recent years. The number of articles has gradually increased since 2010, with 2021 reaching over six times the number of publications in 2010.



**Supplementary Figure 1.** Overview of the analyzed studies. The analyzed studies are classified by the (a) publication year, (b) publication journal, (c) topics describing the influencing factors of the trees' cooling effects and (d) quantitative climate indicator. (e) Percentage of studies classified by the tree/leaf retention type, urban morphology, methodology, spatial scale, and four main groups of Köppen climate classification of the study sites.

In **Supplementary Figure 1(c)**, we summarized the topics investigated in the analyzed literature that influence the trees' cooling effects. A large majority of studies focus on tree traits, including tree morphology (TM), tree species (TS), LAI and LAD (LD), leaf morphology (LM), leaf stomatal characteristics (LS), soil characteristics (SC), while studies also highlighted the importance of urban morphology, including building morphology (BM) and road orientation (RO), tree location and arrangement (TL), sky view factor (SVF), tree density (TD). The most investigated topic, tree density (TD), influences the sky view factor (SVF), which determines the amount of blockage on shortwave solar radiation<sup>1</sup>. To harness trees' cooling effects, an optimization of the parametric combination of the above factors with the consideration of local background climate is necessary.

## Supplementary Note 2. Research methodologies of the analyzed literature

Numerical simulation, full-scale and reduced-scale measurement, and remote sensing are the common, extensively applied methodologies for studying the thermal comfort of outdoor environments<sup>2</sup>. About 90% of the analyzed studies, focusing on street trees or trees adjacent to buildings, are carried out based on measurement and simulation methods. The choice of methodology depends on the research scales and available resources of the studies.

Studies on the local scale and micro-scale (up to 2 km) take up more than 80% of the studies. Micro-scale studies refer to a single street canyon or idealized standard street canyon investigations, while local scale studies investigate a neighborhood area with realistic urban morphology. At the micro- and local scale, the shading, evapotranspiration, and aerodynamic influences are investigated with high resolution, using field measurement, wind tunnel measurement, and urban microclimate simulations. On the micro-scale and local scale, Computational Fluid Dynamics (CFD) simulation is often used to predict complex outdoor wind and thermal environments under urban microclimate boundary conditions. More specifically, most of the simulation is coupled with heat-air-moisture (HAM) transfer model using software, including ENVI-met<sup>3,4</sup>, OpenFoam<sup>5,6</sup>, Anasys Fluent<sup>7</sup>, RayMan<sup>1,8</sup>, and SOLWEIG<sup>9,10</sup>. A few measurement studies are conducted on a reduced scale, in outdoor settings<sup>11</sup> and in the wind tunnel<sup>12</sup>. Urban trees are typically modeled as a porous medium with defined drag coefficients, thermal properties, and minimal stomatal resistance<sup>5,13</sup>. The CFD model can be solved in coupled subdomains, consisting of radiation, air, solid, and vegetation subdomains<sup>5</sup>. Radiation models, such as urban canopy models, are developed to simulate radiative heat exchange between trees and surrounding urban canopies<sup>14-17</sup>.

The meso-scale studies account for around 10% of the total analyzed studies, mostly using Mesoscale Meteorological Models (MMMs)<sup>18,19</sup> and remote sensing technologies<sup>20,21</sup>. Weather Research and Forecasting (WRF) and Consortium for Small-scale Modeling (COSMO) are meso-scale systems widely used in weather forecasting and urban climate research. They can be coupled with small-scale models to increase the resolution of the simulation<sup>2</sup>. Remote sensing and GIS-based assessment can be used to understand different tree types, land surface temperature (*LST*), humidity levels, etc. As satellite technology advances, the remote sensing technique is anticipated to become an increasingly helpful, non-invasive tool for collecting data.

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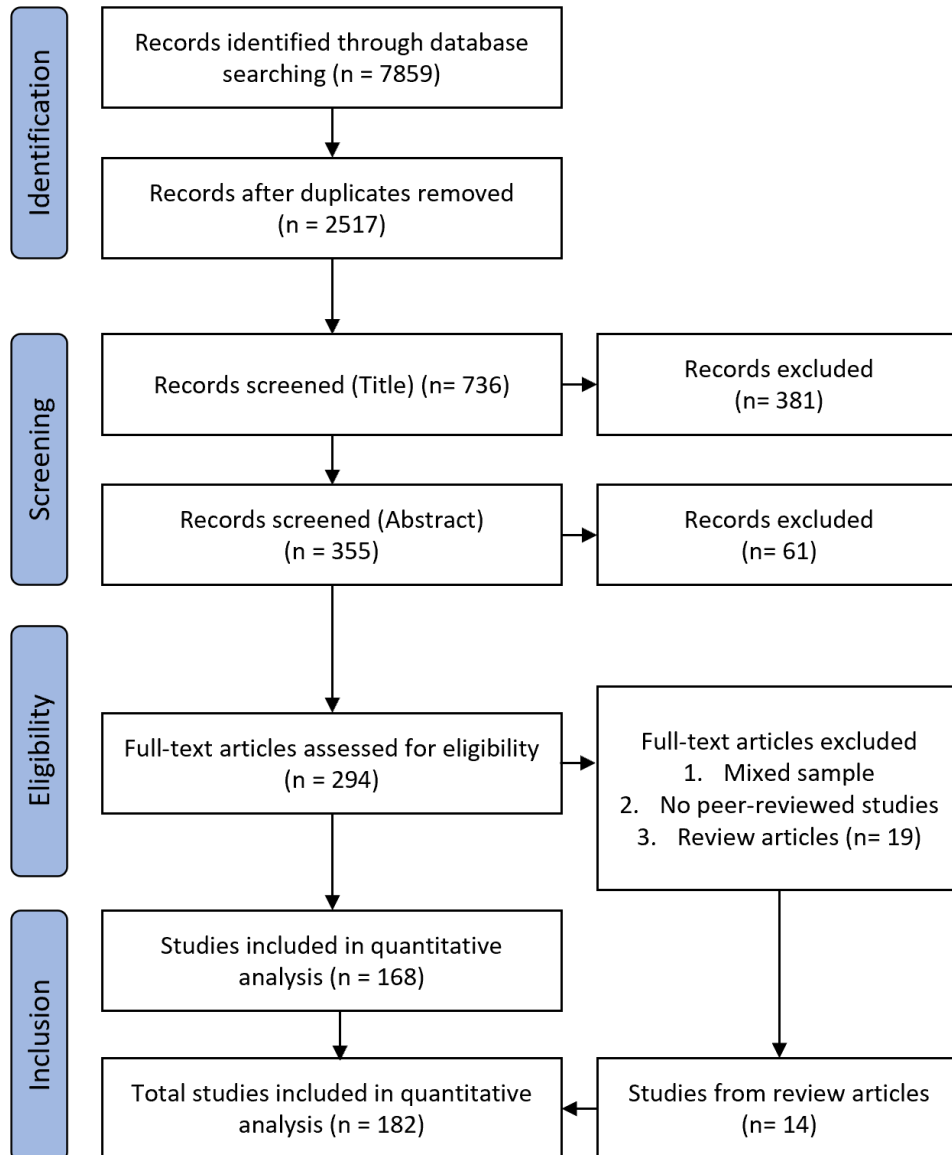
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density (TD), tree morphology (TM), tree location and arrangement (TL), tree specie (TS), LAI and LAD (LD), leaf morphology (LM), leaf stomatal characteristics (LS), soil characteristics (SC); (11) Quantitative climate indicators, including air temperature 2 m height ( $T_{air}$ ), surface temperature ( $T_{sur}$ ), mean radiant temperature ( $T_{mrt}$ ), Universal Thermal Climate Index ( $UTCI$ ), Physiological Equivalent Temperature ( $PET$ ), and Predicted Mean Vote ( $PMV$ ), land surface temperature ( $LST$ ) and others.



**Supplementary Figure 3.** Identification, screening, eligibility and inclusion process of papers.

## Supplementary Note 4. Classification of the analyzed literature

**Supplementary Table 1.** Köppen climate classification. The table shows the 17 climate types involved in the analyzed studies, explained by four main groups, names, and precipitation types. The table is presented for comprehending the definitions of climate zones<sup>22</sup>.

| Group       | Name | Full name                                                                  | Precipitation Type |
|-------------|------|----------------------------------------------------------------------------|--------------------|
| Tropical    | Af   | Tropical rainforest climate                                                | Fully humid        |
|             | Am   | Tropical monsoon climate                                                   | Monsoon            |
|             | Aw   | Tropical savanna, wet                                                      | Dry winter         |
| Arid        | BSk  | Cold semi-arid (steppe) climate                                            | Steppe             |
|             | BWh  | Hot deserts climate                                                        | Desert             |
|             | BWk  | Cold desert climate                                                        | Desert             |
| Temperate   | Cfa  | Humid subtropical climate                                                  | Without dry season |
|             | Cfb  | Temperate oceanic climate                                                  | Without dry season |
|             | Csa  | Hot-summer Mediterranean climate                                           | Dry summer         |
|             | Csb  | Warm-summer Mediterranean climate                                          | Dry summer         |
|             | Csc  | Cool-summer Mediterranean climate                                          | Dry summer         |
|             | Cwa  | Monsoon-influenced humid subtropical climate                               | Dry winter         |
|             | Cwb  | Subtropical highland climate or temperate oceanic climate with dry winters | Dry winter         |
|             | Dfa  | Hot-summer humid continental climate                                       | Without dry season |
| Continental | Dfb  | Warm-summer humid continental climate                                      | Without dry season |
|             | Dsb  | Mediterranean-influenced warm-summer humid continental climate             | Dry summer         |
|             | Dwa  | Monsoon-influenced hot-summer humid continental climate                    | Dry winter         |

**Supplementary Table 2.** Urban morphological characteristics. The case studies are classified into various LCZ types according to the reported sky view factor, aspect ratio, mean building height, and building surface fraction of the study cites.

| Compact                   |                 |                |                |          |
|---------------------------|-----------------|----------------|----------------|----------|
|                           | LCZ 1: Highrise | LCZ 2: Midrise | LCZ 3: Lowrise | LCZ 1-3  |
| Sky view factor           | 0.2-0.4         | 0.3-0.6        | 0.2-0.6        | 0.2-0.6  |
| Canyon aspect ratio       | >2              | 0.75-2         | 0.75-1.5       | >0.75    |
| Mean building height      | >25 m           | 10-25 m        | 3-10 m         | NA       |
| Building surface fraction | 40-60 %         | 40-70 %        | 40-70 %        | 40-70 %  |
| Open                      |                 |                |                |          |
|                           | LCZ 4: Highrise | LCZ 5: Midrise | LCZ 6: Lowrise | LCZ 4-6  |
| Sky view factor           | 0.5-0.7         | 0.5-0.8        | 0.6-0.9        | 0.5-0.9  |
| Canyon aspect ratio       | 0.75-1.25       | 0.3-0.75       | 0.3-0.75       | 0.3-1.25 |
| Mean building height      | >25 m           | 10-25 m        | 3-10 m         | NA       |
| Building surface fraction | 20-40 %         | 20-40 %        | 20-40 %        | 20-40 %  |

**Supplementary Table 3.** Tree trait characteristics. Case studies are classified by the plant used.

|                     | Deciduous                         | Evergreen                                |
|---------------------|-----------------------------------|------------------------------------------|
| Leaf retention type | Leaf shedding                     | No shedding                              |
| Leaf shape          | Broad and flat                    | Needle-like or scale-like                |
| Leaf size           | Large, up to 30 cm in length      | Small and narrow                         |
| Leaf texture        | Thin and flexible                 | Thick and waxy coating                   |
| Crown shape         | Rounded and spreading             | Conical (conifer), columnar or irregular |
| Seasonal density    | Dramatic changes with the seasons | No visible seasonal change               |

|                             |                                                              |                                                                                                |
|-----------------------------|--------------------------------------------------------------|------------------------------------------------------------------------------------------------|
|                             | Example plants used in analyzed literature                   |                                                                                                |
| Broad and spreading crowns  | Oak (Quercus), Maple (Acer), Elm (Ulmus)                     |                                                                                                |
| Rounded crowns              | Apple (Malus), Cherry (Prunus), Linden (Tilia)               | Holly (Ilex), Magnolia (Magnolia grandiflora)                                                  |
| Columnar crowns             | Poplar (Populus), Lombardy Poplar (Populus nigra 'Italica')  | Italian Cypress (Cupressus sempervirens), Skyrocket Juniper (Juniperus scopulorum 'Skyrocket') |
| Vase-shaped crowns          | American Elm (Ulmus americana), Crepe Myrtle (Lagerstroemia) |                                                                                                |
| Conical or pyramidal crowns |                                                              | Spruce (Picea), Fir (Abies), Pine (Pinus)                                                      |
| Irregular or open crowns    |                                                              | Live Oak (Quercus virginiana), Eucalyptus (Eucalyptus spp.)                                    |

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## Supplementary Note 5. Literature in the meta-analysis

**Supplementary Table 4.** Detailed information of 182 literature in tropical climates regarding the author (year), method, scale, climate type, city or region, country, topic and quantitative climate indicator.

| Author <sup>ref</sup>               | Year | Method                     | Scale | Climate | City or Region | Country or Region | Topic      | $\Delta T_{air}$ ? Or Other Climate Indicators |
|-------------------------------------|------|----------------------------|-------|---------|----------------|-------------------|------------|------------------------------------------------|
| Zaki et al. <sup>23</sup>           | 2020 | Measurement                | Micro | Af      | Kuala Lumpur   | Malaysia          | RO, TI     | Yes                                            |
| Meili et al. <sup>24</sup>          | 2021 | Simulation                 | Local | Af      | Singapore      | Singapore         | TI         | Yes                                            |
| Meili et al. <sup>25</sup>          | 2021 | Simulation                 | Local | Af      | Singapore      | Singapore         | TI         | No, <i>UTCI</i>                                |
| Meili et al. <sup>26</sup>          | 2020 | Simulation                 | Local | Af      | Singapore      | Singapore         | TI         | Yes                                            |
| Wong and Jusuf <sup>27</sup>        | 2010 | Measurement                | Local | Af      | Singapore      | Singapore         | SVF        | Yes                                            |
| Shahidan et al. <sup>28</sup>       | 2010 | Measurement and Simulation | Micro | Af      | Serdang        | Malaysia          | TS         | No, thermal radiation filtration               |
| Wong and Jusuf <sup>29</sup>        | 2010 | Measurement                | Micro | Af      | Singapore      | Singapore         | TI         | Yes                                            |
| Shahidan et al. <sup>30</sup>       | 2012 | Measurement and Simulation | Local | Af      | Putrajaya      | Malaysia          | TI         | Yes                                            |
| Yang et al. <sup>31</sup>           | 2015 | Measurement and Simulation | Micro | Af      | Singapore      | Singapore         | RO, BM, TI | Yes                                            |
| Liu et al. <sup>32</sup>            | 2022 | Measurement and Simulation | Micro | Af      | Singapore      | Singapore         | TL, TM, TD | No, <i>PET</i>                                 |
| Herath et al. <sup>33</sup>         | 2018 | Simulation                 | Local | Af      | Colombo        | SriLanka          | TI         | Yes                                            |
| Saito et al. <sup>34</sup>          | 2017 | Simulation                 | Local | Af      | Malacca        | Malaysia          | TI         | No, <i>PET</i>                                 |
| Yang et al. <sup>35</sup>           | 2016 | Measurement and Simulation | Local | Am      | Tainan         | Taiwan            | TI         | Yes                                            |
| Vailshery et al. <sup>36</sup>      | 2013 | Measurement                | Local | Aw      | Bangalore      | India             | TI, TS, TM | Yes                                            |
| Morakinyo et al. <sup>37</sup>      | 2013 | Measurement                | Micro | Aw      | Akure          | Nigeria           | TI         | Yes                                            |
| Eente et al. <sup>38</sup>          | 2012 | Measurement                | Local | Aw      | Enugu          | Nigeria           | TS         | No, <i>UHI</i>                                 |
| Obi <sup>39</sup>                   | 2014 | Measurement                | Local | Aw      | Enugu          | Nigeria           | TS         | No, $T_{mrt}$                                  |
| Alabi and Christian <sup>40</sup>   | 2013 | Measurement                | Local | Aw      | Lokoja         | Nigeria           | TS         | Yes                                            |
| Morakinyo et al. <sup>41</sup>      | 2016 | Measurement and Simulation | Micro | Aw      | Akure          | Nigeria           | TI         | No, <i>PET</i>                                 |
| Jareemit and Srivanit <sup>1</sup>  | 2022 | Measurement                | Micro | Aw      | Pathum Thani   | Thailand          | SVF, TD    | Yes                                            |
| Srivanit and Jareemit <sup>42</sup> | 2020 | Simulation                 | Micro | Aw      | Bangkok        | Thailand          | BM, RO, TD | No, <i>PET</i>                                 |
| Abdulkarim et al. <sup>43</sup>     | 2020 | Measurement and Simulation | Local | Aw      | Bauchi         | Nigeria           | TD         | Yes                                            |

**Supplementary Table 5.** Detailed information of 182 literature in arid climates regarding the author (year), method, scale, climate type, city or region, country, topic and quantitative climate indicator.

| Author <sup>ref</sup>              | Year | Method      | Scale | Climate             | City or Region | Country or Region | Topic           | $\Delta T_{air}$ ? Or Other Climate Indicators |
|------------------------------------|------|-------------|-------|---------------------|----------------|-------------------|-----------------|------------------------------------------------|
| Darbani et al. <sup>44</sup>       | 2023 | Simulation  | Local | BSk                 | Mashhad        | Iran              | BM, RO, SVF, TD | Yes                                            |
| Darbani et al. <sup>45</sup>       | 2021 | Simulation  | Local | BSk                 | Mashhad        | Iran              | BM, RO, TD      | No, <i>PET</i>                                 |
| Sodoudi et al. <sup>46</sup>       | 2014 | Simulation  | Local | BSk                 | Tehran         | Iran              | TI              | Yes                                            |
| ArgHAVANI et al. <sup>18</sup>     | 2020 | Simulation  | Meso  | BSk                 | Tehran         | Iran              | TD              | Yes                                            |
| Abdi et al. <sup>47</sup>          | 2020 | Simulation  | Micro | BSk                 | Tabriz         | Iran              | TL              | No, <i>PMV</i>                                 |
| Teshnehdel et al. <sup>48</sup>    | 2020 | Simulation  | Local | BSk                 | Tabriz         | Iran              | TS, TD          | Yes                                            |
| Yang et al. <sup>49</sup>          | 2019 | Simulation  | Micro | BSk/Cw <sub>a</sub> | Xian           | China             | TD              | No, <i>PET</i>                                 |
| Yang et al. <sup>50</sup>          | 2018 | Simulation  | Micro | BSk/Cw <sub>a</sub> | Xian           | China             | TM, TL          | No, <i>PET</i>                                 |
| Zhang et al. <sup>51</sup>         | 2022 | Measurement | Local | BSk/Cw <sub>a</sub> | Xian           | China             | TS              | No, <i>UTCI</i>                                |
| Middel et al. <sup>52</sup>        | 2015 | Simulation  | Local | BWh                 | Phoenix        | USA               | TD              | Yes                                            |
| Aboelata <sup>53</sup>             | 2020 | Simulation  | Micro | BWh                 | Cairo          | Egypt             | RO, TD          | Yes                                            |
| Aboelata and Sodoudi <sup>54</sup> | 2020 | Simulation  | Local | BWh                 | Cairo          | Egypt             | BM, TD          | Yes                                            |

|                                    |      |                            |       |     |                  |           |            |               |
|------------------------------------|------|----------------------------|-------|-----|------------------|-----------|------------|---------------|
| Atwa et al. <sup>55</sup>          | 2020 | Simulation                 | Local | BWh | New Borg El Arab | Egypt     | TL         | Yes           |
| Fahmy and Abdelghany <sup>56</sup> | 2020 | Simulation                 | Local | BWh | New Cairo        | Egypt     | TI         | Yes           |
| Fahmy et al. <sup>57</sup>         | 2018 | Simulation                 | Local | BWh | New Cairo        | Egypt     | TS, TI     | Yes           |
| Salmon and Saleem <sup>58</sup>    | 2021 | Measurement and Simulation | Micro | BWh | Baghdad          | Iraq      | BM, TL     | Yes           |
| Zeeshan et al. <sup>59</sup>       | 2023 | Measurement and Simulation | Local | BWh | Karachi          | Pakistan  | BM, TI     | Yes           |
| Zhao et al. <sup>11</sup>          | 2018 | Measurement                | Micro | BWh | Tempe            | USA       | TD, TL     | No, $T_{sur}$ |
| Shata et al. <sup>8</sup>          | 2021 | Simulation                 | Micro | BWh | Giza             | Egypt     | SVF        | Yes           |
| Elbardisy et al. <sup>60</sup>     | 2021 | Simulation                 | Micro | BWh | Cairo            | Egypt     | TD         | Yes           |
| Meili et al. <sup>24</sup>         | 2021 | Simulation                 | Local | BWh | Phoenix          | USA       | TI         | Yes           |
| Fahmy et al. <sup>61</sup>         | 2010 | Simulation                 | Micro | BWh | Cairo            | Egypt     | TS, LD     | Yes           |
| Zeeshan et al. <sup>62</sup>       | 2022 | Simulation                 | Local | BWh | Keamari          | Pakistan  | TI         | Yes           |
| Zhao et al. <sup>63</sup>          | 2018 | Simulation                 | Local | BWh | Tempe            | USA       | TL         | Yes           |
| Wang et al. <sup>64</sup>          | 2018 | Simulation                 | Meso  | BWh | CA-AZ            | USA       | TI         | Yes           |
| Ma et al. <sup>65</sup>            | 2019 | Measurement                | Micro | BWk | Lhasa            | China     | RO, LD     | Yes           |
| Ruiz et al. <sup>66</sup>          | 2015 | Measurement                | Micro | BWk | Mendoza          | Argentina | BM, TD     | Yes           |
| Yahia and Johansson <sup>67</sup>  | 2014 | Simulation                 | Micro | BWk | Damascus         | Syria     | BM, RO, TI | No, $T_{sur}$ |
| Yahia and Johansson <sup>68</sup>  | 2013 | Simulation                 | Micro | BWk | Damascus         | Syria     | BM, RO, TI | No, $PET$     |

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107 **Supplementary Table 6.** Detailed information of 182 literature in Cfa temperate climates, regarding the author (year),  
108 method, scale, climate type, city or region, country, topic and quantitative climate indicator.

| Author <sup>ref</sup>               | Year | Method         | Scale | Climate | City or Region     | Country or Region | Topic              | $\Delta T_{air}$ ? Or Other Climate Indicators |
|-------------------------------------|------|----------------|-------|---------|--------------------|-------------------|--------------------|------------------------------------------------|
| Gao et al. <sup>69</sup>            | 2020 | Measurement    | Micro | Cfa     | Sydney             | Australia         | TI                 | Yes                                            |
| Chen et al. <sup>70</sup>           | 2021 | Measurement    | Micro | Cfa     | Guangzhou          | China             | BM, TD, TM, TS, LD | No, $PET$                                      |
| Chen et al. <sup>71</sup>           | 2021 | Measurement    | Micro | Cfa     | Guangzhou          | China             | BM, SVF, TD, TS    | No, $T_{air}$ 0.1m                             |
| Zheng et al. <sup>72</sup>          | 2018 | Measurement    | Micro | Cfa     | Guangzhou          | China             | TS                 | Yes                                            |
| Park et al. <sup>73</sup>           | 2012 | Measurement    | Micro | Cfa     | Saitama Prefecture | Japan             | TD, TL             | No, $T_{mrt}$                                  |
| Lin et al. <sup>74</sup>            | 2010 | Measurement    | Micro | Cfa     | Taipei             | Taiwan China      | SVF, TD            | No, $PET$                                      |
| Wang et al. <sup>75</sup>           | 2023 | Simulation     | Micro | Cfa     | Hangzhou           | China             | TD, TM             | Yes                                            |
| Feng et al. <sup>76</sup>           | 2021 | Simulation     | Micro | Cfa     | Nanjing            | China             | TL, LD             | No, $T_{sur}$                                  |
| Lin et al. <sup>77</sup>            | 2021 | Simulation     | Micro | Cfa     | Taipei             | Taiwan China      | RO, TD, LD         | Yes                                            |
| Zheng et al. <sup>78</sup>          | 2018 | Simulation     | Micro | Cfa     | Shantou            | China             | BM, RO, TM, LD     | Yes                                            |
| Zheng et al. <sup>79</sup>          | 2016 | Simulation     | Micro | Cfa     | Guangzhou          | China             | TS                 | Yes                                            |
| Cai et al. <sup>80</sup>            | 2022 | Measurement    | Local | Cfa     | Hangzhou           | China             | TD, TM, LD         | Yes                                            |
| Alonzo et al. <sup>81</sup>         | 2021 | Measurement    | Meso  | Cfa     | Washington DC      | USA               | TD                 | Yes                                            |
| Razzaghamanesh et al. <sup>82</sup> | 2021 | Measurement    | Local | Cfa     | New Jersey         | USA               | RO, TD, TM         | Yes                                            |
| Sabrin et al. <sup>83</sup>         | 2021 | Measurement    | Local | Cfa     | Philadelphia       | USA               | TI, TD             | No, $T_{mrt}$                                  |
| Yang et al. <sup>84</sup>           | 2015 | Measurement    | Local | Cfa     | Shanghai           | China             | BM, TD             | Yes                                            |
| Chiang et al. <sup>85</sup>         | 2023 | Others         | Local | Cfa     | Taichung City      | Taiwan China      | SVF                | No, $PET$                                      |
| Bartesaghi-Koc et al. <sup>86</sup> | 2022 | Remote Sensing | Local | Cfa     | Sydney             | Australia         | SVF, TD            | No, $LST$                                      |
| Chen et al. <sup>87</sup>           | 2022 | Remote Sensing | Local | Cfa     | Nanjing            | China             | BM, TD             | No, $LST$                                      |
| Xi et al. <sup>7</sup>              | 2022 | Simulation     | Local | Cfa     | Nanjing            | China             | TI                 | Yes                                            |
| Tan et al. <sup>88</sup>            | 2022 | Simulation     | Local | Cfa     | Chenzhou           | China             | TI                 | Yes                                            |
| Liao et al. <sup>89</sup>           | 2021 | Simulation     | Local | Cfa     | Changsha           | China             | TI                 | Yes                                            |
| Zhang et al. <sup>90</sup>          | 2018 | Simulation     | Local | Cfa     | Wuhan              | China             | TD, TM, TL, LD     | Yes                                            |
| Jiang et al. <sup>91</sup>          | 2018 | Simulation     | Local | Cfa     | Shanghai           | China             | TL                 | Yes                                            |
| Srivanit and Hokao <sup>92</sup>    | 2013 | Simulation     | Local | Cfa     | Saga               | Japan             | TD                 | Yes                                            |
| He et al. <sup>21</sup>             | 2021 | Remote Sensing | Meso  | Cfa     | Washington DC      | USA               | TD                 | No, $LST$                                      |

|                                |      |             |              |     |               |        |        |                 |
|--------------------------------|------|-------------|--------------|-----|---------------|--------|--------|-----------------|
| Loughner et al. <sup>19</sup>  | 2012 | Simulation  | Meso         | Cfa | Washington DC | USA    | BM, TI | Yes             |
| Johansson et al. <sup>93</sup> | 2013 | Simulation  | Micro & Meso | Cfa | Sao Paulo     | Brazil | BM, TI | Yes             |
| Li et al. <sup>94</sup>        | 2020 | Simulation  | Local        | Cfa | Guangzhou     | China  | TI     | Yes             |
| Rui et al. <sup>95</sup>       | 2018 | Simulation  | Local        | Cfa | Nanjing       | China  | TD, TL | Yes             |
| Rui et al. <sup>96</sup>       | 2019 | Simulation  | Local        | Cfa | Nanjing       | China  | TD, TL | Yes             |
| Shi et al. <sup>97</sup>       | 2020 | Simulation  | Local        | Cfa | Chongqing     | China  | TI     | Yes             |
| Kusaka et al. <sup>98</sup>    | 2022 | Measurement | Micro        | Cfa | Tsukuba       | Japan  | TI     | No, <i>UTCI</i> |

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110 **Supplementary Table 7.** Detailed information of 182 literature in Cfb temperate climate, regarding the author (year),  
111 method, scale, climate type, city or region, country, topic and quantitative climate indicator.

| Author <sup>ref</sup>                  | Year | Method                     | Scale | Climate | City or Region        | Country or Region    | Topic              | $\Delta T_{air}$ ? Or Other Climate Indicators |
|----------------------------------------|------|----------------------------|-------|---------|-----------------------|----------------------|--------------------|------------------------------------------------|
| Rahman et al. <sup>99</sup>            | 2020 | Measurement                | Micro | Cfb     | Munich                | Germany              | BM, RO, TD, TS     | Yes                                            |
| Masseti et al. <sup>100</sup>          | 2019 | Measurement                | Micro | Cfb     | Florence              | Italy                | LD                 | No, $T_{sur}$                                  |
| Rahman et al. <sup>101</sup>           | 2019 | Measurement                | Micro | Cfb     | Munich                | Germany              | TS                 | Yes                                            |
| Rahman et al. <sup>102</sup>           | 2018 | Measurement                | Micro | Cfb     | Munich                | Germany              | TS, SC             | Yes                                            |
| Rahman et al. <sup>103</sup>           | 2017 | Measurement                | Micro | Cfb     | Munich                | Germany              | TS, SC             | Yes                                            |
| Sanusi et al. <sup>104</sup>           | 2017 | Measurement                | Micro | Cfb     | Melbourne             | Australia            | TD, TS, LM         | Yes                                            |
| Rahman et al. <sup>105</sup>           | 2017 | Measurement                | Micro | Cfb     | Munich                | Germany              | TM, SC             | Yes                                            |
| Coutts et al. <sup>106</sup>           | 2016 | Measurement                | Micro | Cfb     | Melbourne             | Australia            | BM, TD             | Yes                                            |
| Konarska et al. <sup>107</sup>         | 2016 | Measurement                | Micro | Cfb     | Gothenburg            | Sweden               | BM, SVF, TD        | Yes                                            |
| Wang et al. <sup>108</sup>             | 2015 | Measurement and Simulation | Micro | Cfb     | Assen                 | Netherlands          | TI                 | Yes                                            |
| Lachapelle et al. <sup>109</sup>       | 2023 | Simulation                 | Micro | Cfb     | Vancouver             | Canada               | RO, TD, TL         | No, $T_{mrt}$                                  |
| Bochenek and Klemm <sup>110</sup>      | 2021 | Simulation                 | Micro | Cfb     | Lodz                  | Poland               | TD                 | Yes                                            |
| Azcarate et al. <sup>10</sup>          | 2021 | Simulation                 | Micro | Cfb     | Bilbao                | Spain                | SVF                | No, <i>PET</i>                                 |
| Wang et al. <sup>111</sup>             | 2021 | Simulation                 | Micro | Cfb     | Basel                 | Switzerland          | TI                 | Yes                                            |
| Meili et al. <sup>24</sup>             | 2021 | Simulation                 | Local | Cfb     | Melbourne             | Australia            | TI                 | Yes                                            |
| Bochenek and Klemm <sup>112</sup>      | 2020 | Simulation                 | Micro | Cfb     | Lodz                  | Poland               | TD                 | Yes                                            |
| Lee et al. <sup>113</sup>              | 2020 | Simulation                 | Micro | Cfb     | Freiburg              | Germany              | BM, TD, TM         | Yes                                            |
| Manickathan et al. <sup>5</sup>        | 2018 | Simulation                 | Micro | Cfb     | Validation in Varades | Validation in France | TD, TM, LD, LM, LS | Yes                                            |
| Napoli et al. <sup>114</sup>           | 2016 | Simulation                 | Micro | Cfb     | Florence              | Italy                | TM, TS, LD, SC     | No, $T_{sur}$                                  |
| Mballo et al. <sup>115</sup>           | 2021 | Measurement                | Micro | Cfb     | Angers                | France               | TI                 | Yes                                            |
| Quanz et al. <sup>116</sup>            | 2018 | Measurement                | Local | Cfb     | Berlin                | Germany              | RO, SVF, TD        | Yes                                            |
| Klein and Rozova <sup>117</sup>        | 2016 | Measurement                | Local | Cfb     | Nitra                 | Slovakia             | BM, TI             | Yes                                            |
| Sung <sup>118</sup>                    | 2013 | Remote Sensing             | Local | Cfb     | Woodlands Township    | USA                  | TI                 | No, <i>LST</i>                                 |
| Briegel et al. <sup>119</sup>          | 2023 | Simulation                 | Local | Cfb     | Freiburg              | Germany              | TI                 | No, $T_{mrt}$                                  |
| Balany et al. <sup>120</sup>           | 2022 | Simulation                 | Local | Cfb     | Melbourne             | Australia            | TI                 | Yes                                            |
| Aminipouri et al. <sup>9</sup>         | 2019 | Simulation                 | Local | Cfb     | Vancouver             | Canada               | TD                 | No, $T_{mrt}$                                  |
| Aminipouri et al. <sup>121</sup>       | 2019 | Simulation                 | Local | Cfb     | Vancouver             | Canada               | TD                 | No, $T_{mrt}$                                  |
| Morille and Musy <sup>122</sup>        | 2017 | Simulation                 | Local | Cfb     | Lyon                  | France               | TI                 | No, <i>UTCI</i>                                |
| Lee et al. <sup>123</sup>              | 2016 | Simulation                 | Local | Cfb     | Freiburg              | Germany              | TI                 | Yes                                            |
| Lindberg et al. <sup>124</sup>         | 2016 | Simulation                 | Local | Cfb     | Goteborg              | Sweden               | TD                 | No, $T_{mrt}$                                  |
| Ketterer and Matzarakis <sup>125</sup> | 2015 | Simulation                 | Local | Cfb     | Stuttgart             | Germany              | TI                 | No, <i>PET</i>                                 |
| Morabito et al. <sup>20</sup>          | 2021 | Remote Sensing             | Meso  | Cfb     | Italy                 | Italy                | TD                 | No, <i>LST</i>                                 |
| Wang et al. <sup>64</sup>              | 2018 | Simulation                 | Meso  | Cfb     | Florida               | USA                  | TI                 | Yes                                            |
| Wang et al. <sup>64</sup>              | 2018 | Simulation                 | Meso  | Cfb     | Texas Triangle        | USA                  | TI                 | Yes                                            |
| Skelhorn et al. <sup>126</sup>         | 2014 | Simulation                 | Local | Cfb     | Manchester            | UK                   | LD, TS             | Yes                                            |
| Duarte et al. <sup>127</sup>           | 2015 | Simulation                 | Local | Cfb     | Sao Paulo             | Brazil               | BM, TL             | Yes                                            |
| Lobaccaro and Acero <sup>128</sup>     | 2015 | Simulation                 | Local | Cfb     | Bilbao                | Spain                | BM, TI             | No, <i>PET</i>                                 |
| Zölch et al. <sup>129</sup>            | 2016 | Simulation                 | Micro | Cfb     | Munich                | Germany              | TI, TL, TM         | No, <i>PET</i>                                 |
| Milošević et al. <sup>130</sup>        | 2017 | Simulation                 | Micro | Cfb     | Novi Sad              | Serbia               | TL                 | No, <i>UTCI</i>                                |

|                                      |      |             |       |         |           |                |                |                        |
|--------------------------------------|------|-------------|-------|---------|-----------|----------------|----------------|------------------------|
| Speak et al. <sup>131</sup>          | 2022 | Measurement | Local | Cfb     | Florence  | Italy          | TL, TS, TM, TD | No, <i>UTCI</i>        |
| Jamei and Rajagopalan <sup>132</sup> | 2017 | Simulation  | Local | Cfb     | Melbourne | Australia      | TI             | No, <i>PET</i>         |
| Stratopoulos et al. <sup>133</sup>   | 2018 | Measurement | Micro | Cfb     | Munich    | Germany        | TS, LS         | No, transpiration rate |
| Speak et al. <sup>134</sup>          | 2020 | Measurement | Micro | Cfb     | Bolzano   | Italy          | TM, TS, LD     | No, $T_{sur}$          |
| Geletič et al. <sup>135</sup>        | 2022 | Simulation  | Local | Cfb     | Prague    | Czech Republic | TS             | No, <i>UTCI</i>        |
| Meili et al. <sup>24</sup>           | 2021 | Simulation  | Local | Dfb/Cfb | Zurich    | Switzerland    | TI             | Yes                    |
| Zhao et al. <sup>12</sup>            | 2023 | Measurement | Local | Dfb/Cfb | Zurich    | Switzerland    | BM, TD, TM     | Yes                    |

**Supplementary Table 8.** Detailed information of 182 literature in Csa, Csb, Csc, Cwa and Cwb temperate climate, regarding the author (year), method, scale, climate type, city or region, country, topic and quantitative climate indicator.

| Author <sup>ref</sup>                | Year | Method                     | Scale         | Climate | City or Region  | Country or Region | Topic           | $\Delta T_{air}$ ? Or Other Climate Indicators |
|--------------------------------------|------|----------------------------|---------------|---------|-----------------|-------------------|-----------------|------------------------------------------------|
| Shashua-Bar et al. <sup>136</sup>    | 2012 | Measurement                | Micro         | Csa     | Athens          | Greece            | BM, TD          | Yes                                            |
| Shashua-Bar et al. <sup>137</sup>    | 2010 | Measurement                | Micro         | Csa     | Athens          | Greece            | BM, TD, TS      | Yes                                            |
| Gulten et al. <sup>138</sup>         | 2016 | Simulation                 | Micro         | Csa     | Elazığ          | Turkey            | TI              | No, $T_{sur}$                                  |
| Thom et al. <sup>139</sup>           | 2016 | Simulation                 | Micro         | Csa     | Adelaide        | Australia         | TD              | No, $T_{mrt}$                                  |
| Salata et al. <sup>3</sup>           | 2015 | Simulation                 | Micro         | Csa     | Rome            | Italy             | TI              | Yes                                            |
| Gatto et al. <sup>140</sup>          | 2020 | Measurement and Simulation | Local         | Csa     | Lecce           | Italy             | TD, TS          | Yes                                            |
| Segura et al. <sup>141</sup>         | 2022 | Simulation                 | Local         | Csa     | Barcelona       | Spain             | SVF, TD         | Yes                                            |
| Bachir et al. <sup>142</sup>         | 2021 | Simulation                 | Local         | Csa     | Mostaganem      | Algeria           | SVF, TD         | Yes                                            |
| Duncan et al. <sup>143</sup>         | 2019 | Remote Sensing             | Meso          | Csa     | Perth           | Australia         | TI              | No, <i>LST</i>                                 |
| Altunkasa and Uslu <sup>144</sup>    | 2020 | Simulation                 | Local         | Csa     | Adana           | Turkey            | TI              | No, <i>PMV</i>                                 |
| Antoniadis et al. <sup>145</sup>     | 2018 | Simulation                 | Micro         | Csa     | Volos           | Greece            | TI              | Yes                                            |
| Salata et al. <sup>146</sup>         | 2017 | Simulation                 | Local         | Csa     | Rome            | Italy             | TI, TD          | No, <i>MOCI</i>                                |
| Detommaso et al. <sup>147</sup>      | 2021 | Simulation                 | Micro         | Csa     | Catania         | Italy             | TI              | Yes                                            |
| Makido et al. <sup>148</sup>         | 2019 | Simulation                 | Local         | Csb     | Portland        | USA               | BM, TI          | Yes                                            |
| Eckmann et al. <sup>149</sup>        | 2018 | Simulation                 | Micro         | Csb     | Portland Oregon | USA               | TI              | Yes                                            |
| Wang et al. <sup>64</sup>            | 2018 | Simulation                 | Meso          | Csc     | Cascadia        | USA               | TI              | Yes                                            |
| Zhang et al. <sup>150</sup>          | 2022 | Measurement                | Micro         | Cwa     | Zhumadian       | China             | TD, TM          | Yes                                            |
| Ouyang et al. <sup>151</sup>         | 2021 | Measurement                | Micro         | Cwa     | Hong Kong       | China             | TI              | Yes                                            |
| Cheung and Jim <sup>152</sup>        | 2018 | Measurement                | Micro         | Cwa     | Hong Kong       | China             | TI              | Yes                                            |
| Wang et al. <sup>153</sup>           | 2022 | Simulation                 | Micro         | Cwa     | Hong Kong       | China             | TM, TL, TS, LD  | Yes                                            |
| Jia and Wang <sup>154</sup>          | 2021 | Simulation                 | Micro         | Cwa     | Hong Kong       | China             | TI              | Yes                                            |
| Raman et al. <sup>155</sup>          | 2021 | Simulation                 | Local         | Cwa     | Patna           | India             | BM, TD          | No, $T_{mrt}$                                  |
| Ouyang et al. <sup>156</sup>         | 2020 | Simulation                 | Local         | Cwa     | Hong Kong       | China             | BM, TD          | Yes                                            |
| Tan et al. <sup>157</sup>            | 2017 | Simulation                 | Local         | Cwa     | Hong Kong       | China             | SVF             | Yes                                            |
| Tan et al. <sup>158</sup>            | 2016 | Simulation                 | Local         | Cwa     | Hong Kong       | China             | SVF             | Yes                                            |
| Morakinyo et al. <sup>159</sup>      | 2020 | Simulation                 | Micro & Local | Cwa     | Hong Kong       | China             | SVF, TD, TM, LD | Yes                                            |
| Morakinyo et al. <sup>160</sup>      | 2017 | Simulation                 | Micro & Local | Cwa     | Hong Kong       | China             | BM, TM, TS, LD  | No, <i>PET</i>                                 |
| Ma et al. <sup>161</sup>             | 2019 | Measurement and Simulation | Local         | Cwa     | Fo Shan         | China             | TI              | No, <i>PET</i>                                 |
| Ng et al. <sup>162</sup>             | 2012 | Simulation                 | Local         | Cwa     | Hong Kong       | China             | BM, TD          | Yes                                            |
| Yang et al. <sup>49</sup>            | 2019 | Simulation                 | Micro         | BSk/Cwa | Xian            | China             | TD              | No, <i>PET</i>                                 |
| Yang et al. <sup>50</sup>            | 2018 | Simulation                 | Micro         | BSk/Cwa | Xian            | China             | TM, TL          | No, <i>PET</i>                                 |
| Zhang et al. <sup>51</sup>           | 2022 | Measurement                | Local         | BSk/Cwa | Xian            | China             | TS              | No, <i>UTCI</i>                                |
| Ballinas and Barradas <sup>163</sup> | 2016 | Simulation                 | Local         | Cwb     | Mexico city     | Mexico            | TD              | Yes                                            |
| Wang et al. <sup>64</sup>            | 2018 | Simulation                 | Meso          | Cwb     | Northeast       | USA               | TI              | Yes                                            |

116 **Supplementary Table 9.** Detailed information of 182 literature in continental climates, regarding the author (year),  
 117 method, scale, climate type, city or region, country, topic and quantitative climate indicator.

| Author <sup>ref</sup>             | Year | Method                     | Scale        | Climate | City or Region       | Country or Region | Topic          | $\Delta T_{air}$ ? Or Other Climate Indicators |
|-----------------------------------|------|----------------------------|--------------|---------|----------------------|-------------------|----------------|------------------------------------------------|
| Ziter et al. <sup>164</sup>       | 2019 | Measurement                | Local        | Dfa     | Madison              | USA               | TD             | Yes                                            |
| Park et al. <sup>165</sup>        | 2021 | Remote Sensing             | Local        | Dfa     | Columbus             | USA               | TD             | No, <i>LST</i>                                 |
| Berardi et al. <sup>166</sup>     | 2020 | Simulation                 | Micro & Meso | Dfa     | Greater Toronto Area | Canada            | TD             | Yes                                            |
| Wang et al. <sup>64</sup>         | 2018 | Simulation                 | Meso         | Dfa/Dfb | Great Lakes          | USA               | TI             | Yes                                            |
| Gillner et al. <sup>167</sup>     | 2015 | Measurement                | Micro        | Dfb     | Dresden              | Germany           | TS, LD, LS     | Yes                                            |
| Millward et al. <sup>168</sup>    | 2014 | Measurement                | Micro        | Dfb     | Toronto              | Canada            | TM, TL, TS, LD | No, $T_{sur}$                                  |
| De Luca <sup>6</sup>              | 2022 | Simulation                 | Micro        | Dfb     | Tallinn              | Estonia           | TD             | No, <i>UTCI</i>                                |
| Wang and Akbari <sup>169</sup>    | 2016 | Simulation                 | Local        | Dfb     | Montreal             | Canada            | TD, TM, TS, LD | Yes                                            |
| Meili et al. <sup>24</sup>        | 2021 | Simulation                 | Local        | Dfb/Cfb | Zurich               | Switzerland       | TI             | Yes                                            |
| Zhao et al. <sup>12</sup>         | 2023 | Measurement                | Local        | Dfb/Cfb | Zurich               | Switzerland       | BM, TD, TM     | Yes                                            |
| Wang et al. <sup>170</sup>        | 2016 | Simulation                 | Local        | Dfb     | Toronto              | Canada            | BM, TI         | Yes                                            |
| Yilmaz et al. <sup>171</sup>      | 2020 | Simulation                 | Micro        | Dsb     | Erzurum              | Turkey            | BM, TI         | Yes                                            |
| Du et al. <sup>172</sup>          | 2020 | Measurement                | Micro        | Dwa     | Harbin               | China             | TI             | Yes                                            |
| Jiao et al. <sup>173</sup>        | 2017 | Measurement                | Micro        | Dwa     | Beijing              | China             | TL, TS         | Yes                                            |
| Li et al. <sup>4</sup>            | 2020 | Simulation                 | Micro        | Dwa     | Harbin               | China             | SVF            | Yes                                            |
| Park et al. <sup>174</sup>        | 2019 | Simulation                 | Micro        | Dwa     | Seoul                | South Korea       | TI             | No, $T_{mrt}$                                  |
| Park et al. <sup>175</sup>        | 2019 | Simulation                 | Micro        | Dwa     | Seoul                | South Korea       | TM, TL         | No, $T_{mrt}$                                  |
| Hong and Lin <sup>176</sup>       | 2015 | Simulation                 | Micro        | Dwa     | Beijing              | China             | BM, TL         | No, <i>SET</i>                                 |
| Zhang et al. <sup>177</sup>       | 2023 | Simulation                 | Local        | Dwa     | Qingdao              | China             | TM, TS, LD     | No, <i>PET</i>                                 |
| Choi et al. <sup>178</sup>        | 2021 | Simulation                 | Local        | Dwa     | Seoul                | South Korea       | TD             | Yes                                            |
| Wu et al. <sup>179</sup>          | 2019 | Simulation                 | Local        | Dwa     | Beijing              | China             | BM, TD         | Yes                                            |
| Wang and Zacharias <sup>180</sup> | 2015 | Simulation                 | Local        | Dwa     | Beijing              | China             | TD, TM         | Yes                                            |
| Wu and Chen <sup>181</sup>        | 2017 | Measurement and Simulation | Local        | Dwa     | Beijing              | China             | TL             | Yes                                            |
| Ren et al. <sup>182</sup>         | 2021 | Measurement                | Local        | Dwa     | Changchun            | China             | TD             | Yes                                            |
| Park et al. <sup>183</sup>        | 2018 | Simulation                 | Micro        | Dwa     | Seoul                | South Korea       | BM, TI         | No, $T_{mrt}$                                  |
| Miao et al. <sup>184</sup>        | 2023 | Measurement                | Local        | Dwa     | Shenyang             | China             | TI             | Yes                                            |
| Yang et al. <sup>185</sup>        | 2022 | Remote Sensing             | Meso         | None    | None                 | None              | TI             | Yes                                            |
| Marando et al. <sup>186</sup>     | 2022 | Remote Sensing             | Meso         | None    | Europe               | Europe            | TI             | Yes                                            |
| Wang et al. <sup>187</sup>        | 2019 | Remote Sensing             | Meso         | None    | USA                  | USA               | TI             | No, <i>LST</i>                                 |

118

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