

## **Online Supplemental Material**

### **Comparisons of urban-related warming for Shenzhen and Guangzhou**

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**This file includes:  
Supplementary text and Figures S1–S4**

## **1. Data**

### **1.1 Reconstruction of annual urban gridded data**

The general trends of the urban surface expansion and their spatial patterns over China were determined based on the integrated data from population information, multiple-source satellite images, and National Land Cover Datasets obtained from the Chinese Data Sharing Infrastructure of Earth System Science (Jia et al. 2014). At the same time, the nighttime light datasets from the Defense Meteorological Satellite Program-Operational Linescan System, which could reflect socioeconomic activities for urbanization and population growth, were also considered. The datasets showing the closest results in describing urban area fractions and the evaluations were then chosen and combined to construct five urban fraction images over China (1980, 1990, 2000, 2010, and 2016; Jia et al. 2014; Hu et al. 2015) at the nested model resolutions of 30, 10, and 3.3 km, respectively, using 1-km urban surface data.

Fractional urban data for individual year from 1980 to 2016 were then reconstructed based on the five fractional images on each model grid cell. The increase in fractional urban areas was assumed to increase linearly during each time period (1980–1989, 1990–1999, 2000–2009, 2010–2016), for which the adoption of annual fractional urban areas could avoid unrealistic discontinuity-induced spurious values during long-term numerical integrations. The annual fractional urban data could offset the scarcity of satellite-based retrieved land use data in a certain degree. However, differences between the reconstructed data and the real urban surface distributions still existed, which might induced error between the simulated results

and observed values.

Annual land-use data for the coarse and nested domains, instead of the default land-use data in the WRF model, were obtained based on the reconstructed annual fractional urban area data and other land-use categories from the default land-use data. For the WRF model before version 3.6 (here version 3.4 are adopted), only one dominant land-use category was assigned to each grid cell during the numerical integrations according to the methods by Guo and Chen (1994).

## **1.2 Driving data**

The initial conditions and time-varying boundary conditions for the WRF model were provided by the National Centers for Environmental Prediction (NCEP) - the Department of Energy (DOE) Atmospheric Model Intercomparison Project (AMIP-II) reanalysis dataset during 1979 and 2016 (R-2, Kanamitsu et al. 2002). During the model integrations, the identical driving data, including sea surface temperatures and atmospheric data were used, and the forcing was only applied at the boundaries. The reanalysis data with a resolution of  $2.5^{\circ} \times 2.5^{\circ}$  were interpolated into the WRF model domain with the bilinear method and updated every six hours.

## **2. Experimental design**

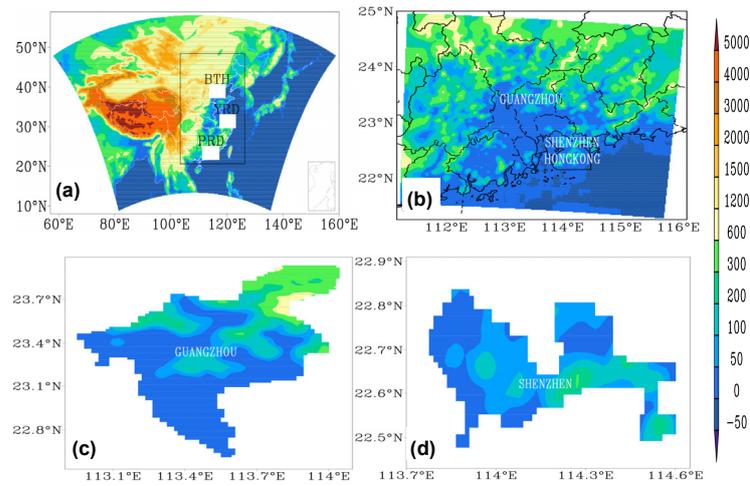
The central latitude and longitude of the simulated domain located at  $35^{\circ}\text{N}$  and  $108.5^{\circ}\text{E}$ , respectively, in which nested domains (30–10–3.3 km) and two-way feedback was adopted. The coarse horizontal mesh (30 km grid spacing) covered most part of East Asia and consisted of 259 longitudinal grid points and 199 latitudinal grid points, including a 15-grid-point buffer zone that was not used in the analysis. The

first nested domain (10 km-resolution) covered the majority of eastern China, including 222 and 312 grid points in the longitudinal and latitudinal directions, respectively. The second three nested domains (3.3 km-resolution) covered three city clusters (BTH: Beijing-Tianjin-Hebei; YRD: the Yangtze River Delta; PRD: the Pearl River Delta) within eastern China, including 150 and 120 grid points in the longitudinal and latitudinal directions, respectively. There were 51 levels in the vertical direction and the air pressure at the top of the model was 10 hPa.

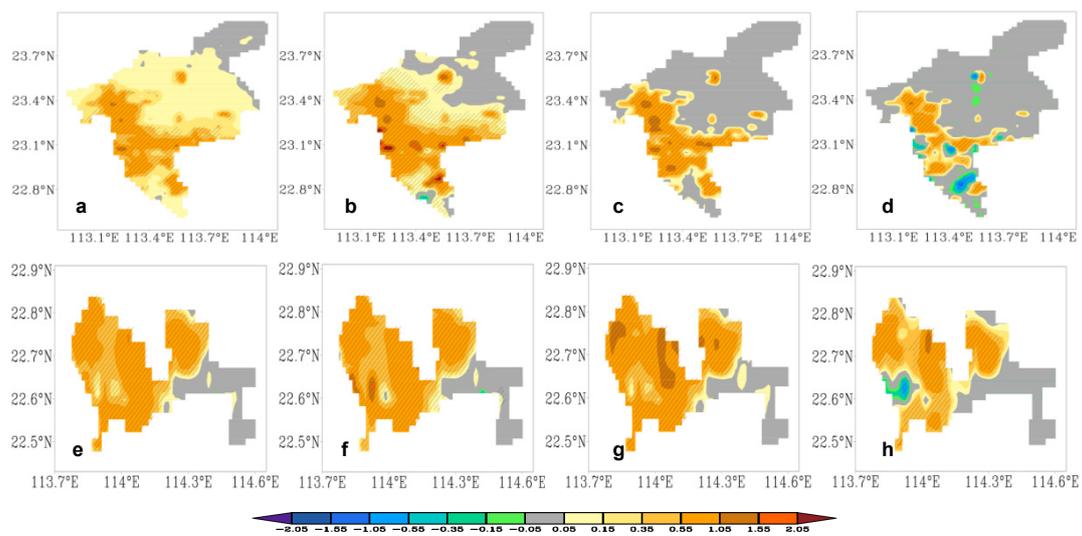
Two numerical experiments (1980–2016), which differed only in the land use data over China (including China, eastern China, and the three nested domains at different spatial resolution), were performed using the regional climate model WRF3.4. The International Geosphere Biosphere Programme (IGBP)-modified 20-category land-use categories were used in the model. The first experiment (EX1) was conducted using the fixed-in-time land-use data (urban data in 1980), whereas the second experiment (EX2) was performed based on annual land-use data (differed annual urban data) from 1980 to 2016. The numerical integrations consisted of a series of restarts for individual years starting from 1 July of the previous year, the first six months of which were used as 'spin-up' time and only integrated results for the present year were analyzed.

In order to include urban effects in computing energy and water exchanges between the land surface and atmosphere, the unified Noah land-surface model (including a four-layer soil model and urban canopy model with the default urban-related parameters, Chen et al. 2006), was adopted in the integrations. Other

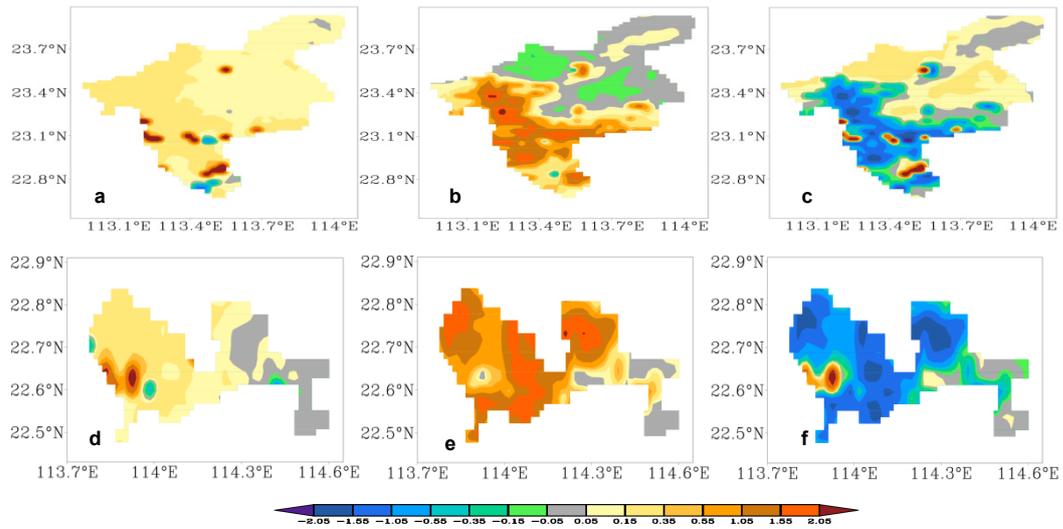
physical parameterization schemes adopted in the integrations included the WRF single-moment six class graupel microphysics scheme, the Community Atmosphere Model shortwave and longwave radiation schemes, the Yonsei University boundary-layer scheme, and the Grell 3D ensemble cumulus scheme (for 30 km and 10 km-resolution integrations only).



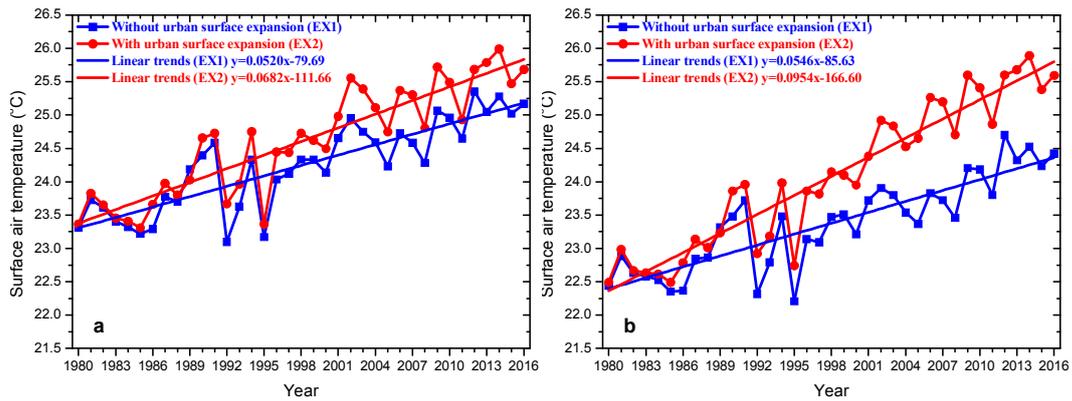
**Figure S1.** (a) Model domain and terrain elevation (units: m) with nested domains (BTH: Beijing-Tianjin-Hebei; YRD: Yangtze River Delta; PRD: Pearl River Delta). (b) Terrain elevation in PRD (units: m), including Guangzhou city. (c) Terrain elevation over Guangzhou (units: m). (d) Terrain elevation over Shenzhen (units: m).



**Figure S2.** Spatial distributions of seasonal urban-related warming for 37-yr averages in (a–d) Guangzhou and (e–h) Shenzhen between 1980 and 2016: (a, e) spring; (b, f) summer; (c, g) autumn; and (d, h) winter; the shaded areas passed the 90% confidence-level *t* test, units: °C.



**Figure S3.** Changes in JJA averaged values of the (a, d) SAT maximum ( $T_{max}$ ), (b, e) SAT minimum ( $T_{min}$ ), and (c, f) diurnal temperature range (DTR) for 37-yr averages in (a, b, c) Guangzhou and (d, e, f) Shenzhen between 1980 and 2016.



**Figure S4.** Time series of annual averages in surface air temperature and the trends for EX1 and EX2 for (a) U2U and (b) N2U.

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