Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

Based on the city sub-domain scale model to study the meteorological environment of Xinjiekou district ,Nanjing

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Outline

- Study purpose
- The city sub-domain scale model (CSSM1.0)
- Model data
- Study area
- Model validation
- Sensitivity test
- Innovative point

Study purpose

- Due to high urbanization,the urban thermal environment problem will affect the comfort of human existence, and also affect the building energy consumption in different degrees.

Study purpose

- Due to the existence of urban buildings, urban ventilation capacity, temperature diffusion ability have been greatly affected.

Study purpose

- Our study can submit to the policy-maker and the planner for future amendments.

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The city sub-domain scale model

- The city sub-domain scale model (CSSM1.0) is a three-dimensional non-hydrostatic model with k-ε closure.

- In this model the distribution, azimuth and screening of short wave radiation by buildings and underlying surface type of urban are considered, the ground temperature is simulated using force-restored method.

- We use the model to study the meteorological problem in the urban sub-domain, it's horizontal scale is 1~2 km.

Control Equation

- Continuity equation : $$\frac{\partial U_i}{\partial x_i} = 0$$
- Momentum equation:

$$\frac{\partial U_i}{\partial t} + U_j \frac{\partial U_i}{\partial x_j} = -\frac{\partial}{\partial x_i}\left[\frac{\delta P}{\rho_0} + \frac{2}{3}k\right] + \frac{\partial}{\partial x_j}\left\{\nu_t\left[\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right]\right\} - \frac{\delta\rho}{\rho_0} g\delta_{3i}$$

- State equation: $$\frac{\delta\rho}{\rho_0} = -\frac{\delta T}{T_0}$$

- Kinetic energy equation: $$\frac{\partial k}{\partial t} + U_j \frac{\partial k}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\frac{\nu_t}{\sigma_k}\frac{\partial k}{\partial x_j}\right] + (S+G) - \varepsilon$$

- Thermal energy equation: $$\frac{\partial T}{\partial t} + U_j \frac{\partial T}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\frac{\nu_t}{\mathrm{Pr}_T}\frac{\partial T}{\partial x_j}\right]$$

Short wave radiation calculation

- The sun elevation angle formula which consider the slope aspect and gradient is:

$$\sin h = l\sin\delta + n\cos\delta\cos\omega + \sin\beta\sin\alpha\cos\delta\sin\omega$$

$$l = \sin\varphi\cos\alpha - \cos\varphi\sin\alpha\cos\beta$$

$$n = \cos\varphi\cos\alpha + \sin\varphi\sin\alpha c\cos\beta$$

- The formula of short wave radiation R_s is:

$$R_s = S_0(1-A)\left(\frac{a^2}{r^2}\right)p^m \sinh$$

- If the ground is covered by buildings, or buildings are obscured by itself, the solar radiation is taken as the 0.6 times of the short wave radiation that has not been sheltered from the ground.

- The formulas for slope aspect and gradient of building are:

$$\alpha = arctg\left[(\frac{\partial H}{\partial x})^2 + (\frac{\partial H}{\partial y})^2\right]^{1/2} \qquad \beta = \pi - arctg(\frac{\partial H}{\partial x} \Big/ \frac{\partial H}{\partial y})$$

- The sun azimuth of the moment is obtained according to the angle of the sun and the hour angle:

$$\cos h \sin B = \cos\delta \sin\omega$$

- The elevation of the grid lines of the horizontal and vertical coordinates to the calculated points are respectively h_i、h_j

$$h_i = \max\{arctg[(H_i - H)/L_i], 0\} \qquad h_j = \max\{arctg[(H_j - H)/L_j], 0\}$$

- The screen angle of the building $Z'(\varphi)$ is：

$$Z'(\varphi) = \max[\cdots, h_{i-1}, h_i, h_{i+1}, \cdots, h_{j-1}, h_j, h_{j+1}, \cdots, h_s(\varphi)]$$

Surface temperature calculation

- The model uses force-restored method to simulate the ground temperature.
- Heat balance equation is: $$C_g \frac{\partial T_g}{\partial t} = R_n - H_e - H_s - H_m$$

Net radiation is: $$R_n = R_s + I^{\uparrow} + I^{\downarrow}$$

Surface sensible flux is: $$H_s = \rho_s c_p c_H |v_a| (T_g - T_a)$$

Surface latent flux is: $$H_e = \eta \rho_s L c_H |v_a| (q_s(T_g) - q_a)$$

Soil heat flux: $$H_m = K_e C_g (T_g - T_{m)}$$

Disposal of the distribution of heat (temperature) on the surface of buildings

- In this model, the temperature on a building surface is obtained simply with the calculation of ground temperature using the force-restore method.
- According to the roof material, the roof is divided into three types: concrete, glass, ceramic tile. and the parameters are the same with concrete except the albedo of shortwave radiation.

The boundary condition of building

- In this model, the physical quantities located inside the building model grid points is taken as 0,such as U、V、W、k、ε

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Model data

Model data

- The percentage of surface use types (The order is: concrete, water, grass, trees, bare soil)

  Identify from the Baidu satellite map.
- Building height (m)

GARMIN GPSMAP 621sc

SOUTH total station NTS-342

- The percentage of roof materials (The order is: concrete, glass, ceramic tile, lawn, plastic)

  Field survey /IKONOS

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Study area

- The study area is about 2.7km^2

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Model validation

- Sounding data

  Site: playground of Jingluan district of NanJing No.3 Senior School

  Time: three days in the end of July (at typical weather of clear sky ,light wind in NanJing summer)

- wind direction ,wind speed, temperature data (in the same time with sounding)

  an anemometer and wind vane and an air temperature and humidity probe

- Every 3 hours sounding data can be used as initial field to simulate the meteorogical field of study area, and then compare the results with the synchronous wind direction ,wind speed data.

Site

1. 大铜银巷内（裸地）
2. 南京九中（南京市自动气象站）
3. 东铁管巷内停车场（商业区）
4. 明瓦廊附近街心公园（树木）
5. 户部街小区（高层小区）
6. 曹都巷小区（低层小区）
7. 秦淮河旁朝天宫广场（水体）
8. 白下路南京三中操场（草地）

★ 探空

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Sensitivity test

- Change the building below a certain height and the bare land into the lawn in certain area.
- Change all roof materials into lawn.
- Change the study area into business zone or uptown according to the mean height of buildings.

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Innovative point

- Added types of building roof material can make the simulation more close to the actual.

- we can understand the response of the meteorological field in the small scale to the city change because of more sensitivity tests.

Next work

- Arrange and process the obtained data into format required by the model.
- Research the model and use it .
- Find some problems during use and then optimize the model.
- Calculate the urban heat island intensities.

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Thank you