Regional Climate Modeling in Urban Agglomerations of China

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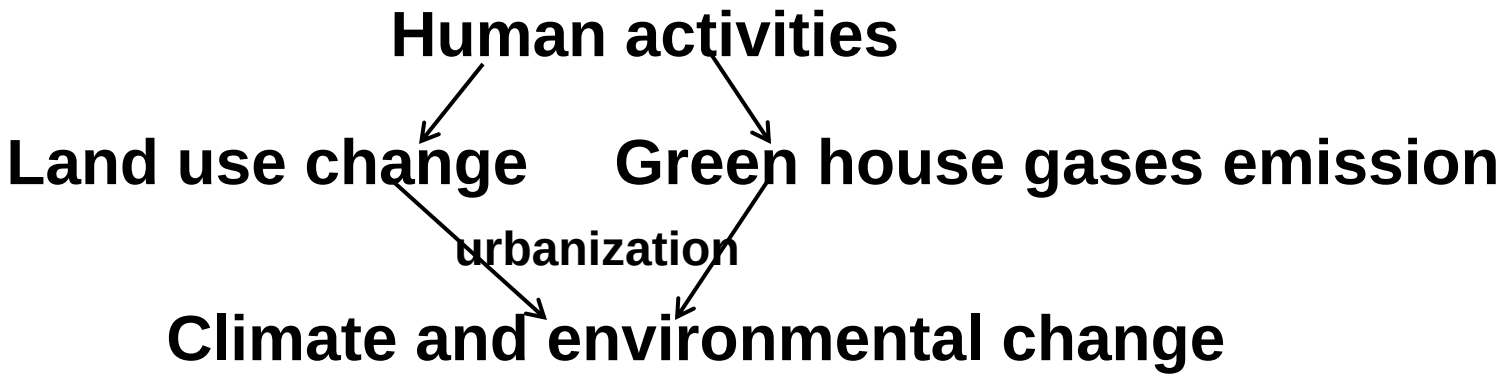
Part I The urbanization under the context of climate change

Part II Some facts for megacities of China

Part III Regional Climate Models (RCMs) application for the urban agglomerations of China

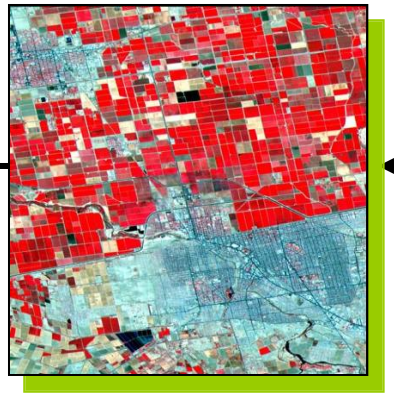
Part I The urbanization under the context of climate change



DYNAMIC GLOBAL LAND TRANSITIONS

LANDUSE ⟷ **LANDCOVER**

[Human control] [Biophysically controlled]


Human Systems ⟷ **HUMAN DECISION MAKING** ⟶ **Ecological Systems**

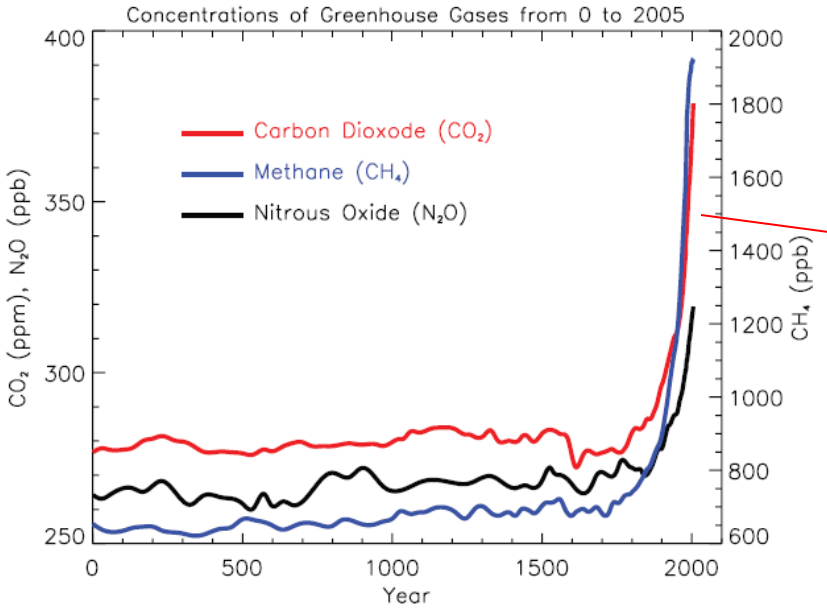
political/economic choices

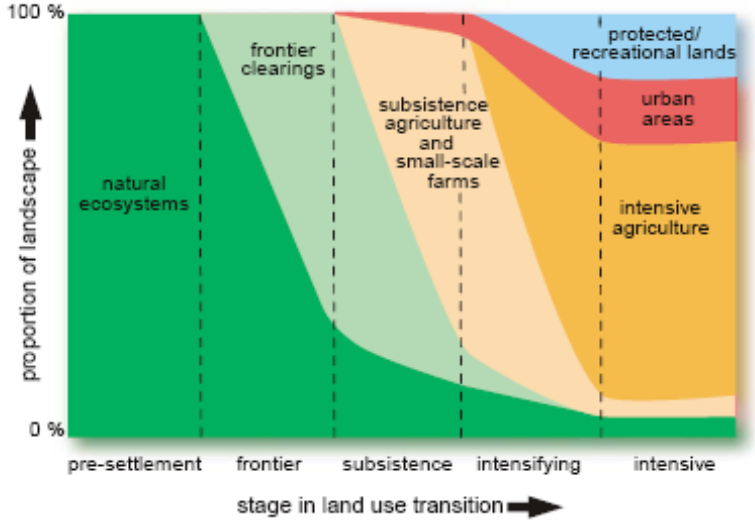
-Institutions
-Culture
-Technology
-Population
-Economic

-Biogeochemistry
-Genetic bank
-Water
-Air

Economic Problems	***Ecological Problems***	***Ecosystem goods & services***
-poverty	*-pollution*	*-clean air/water*
-unequal wealth	*-diseases*	*-waste recycling*
-war	*-food/fibre/fuel shortages*	*-food/fibre/fuel*
-globalization	*-overcrowding*	*-recreation*

How do Human Activities Contribute to Climate Change and How do They Compare with Natural Influences?





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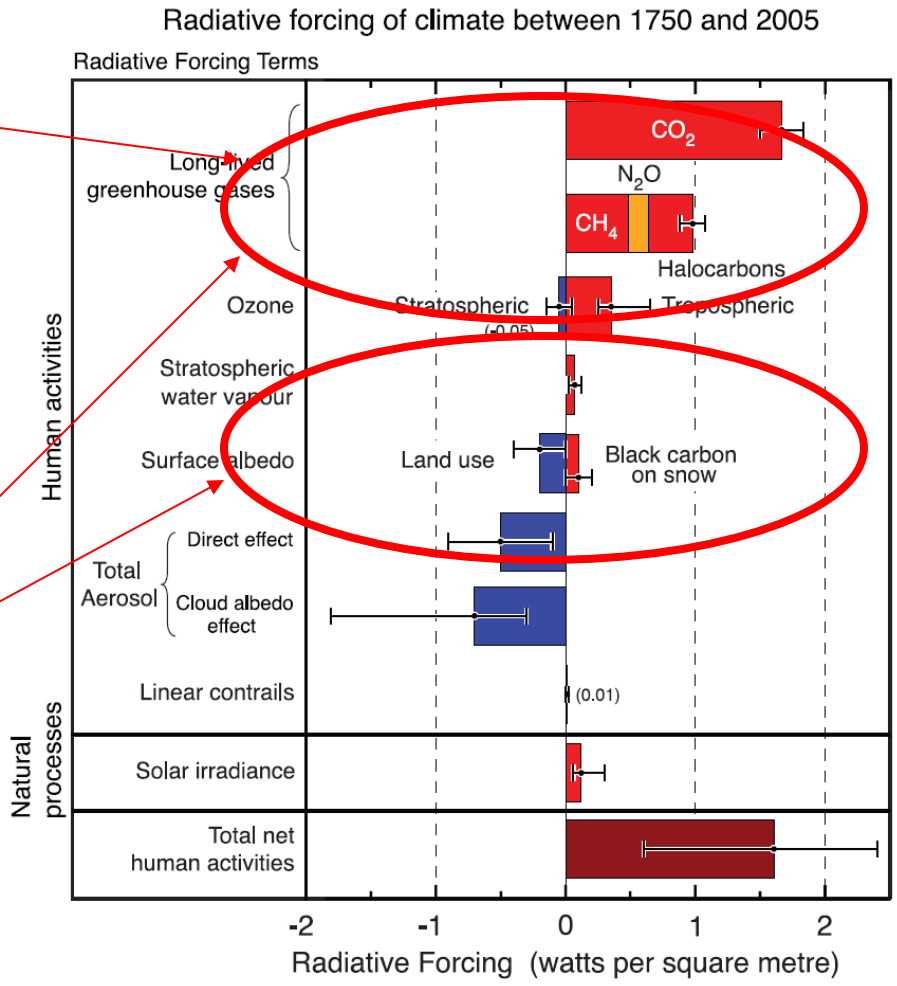
IPCC 2007



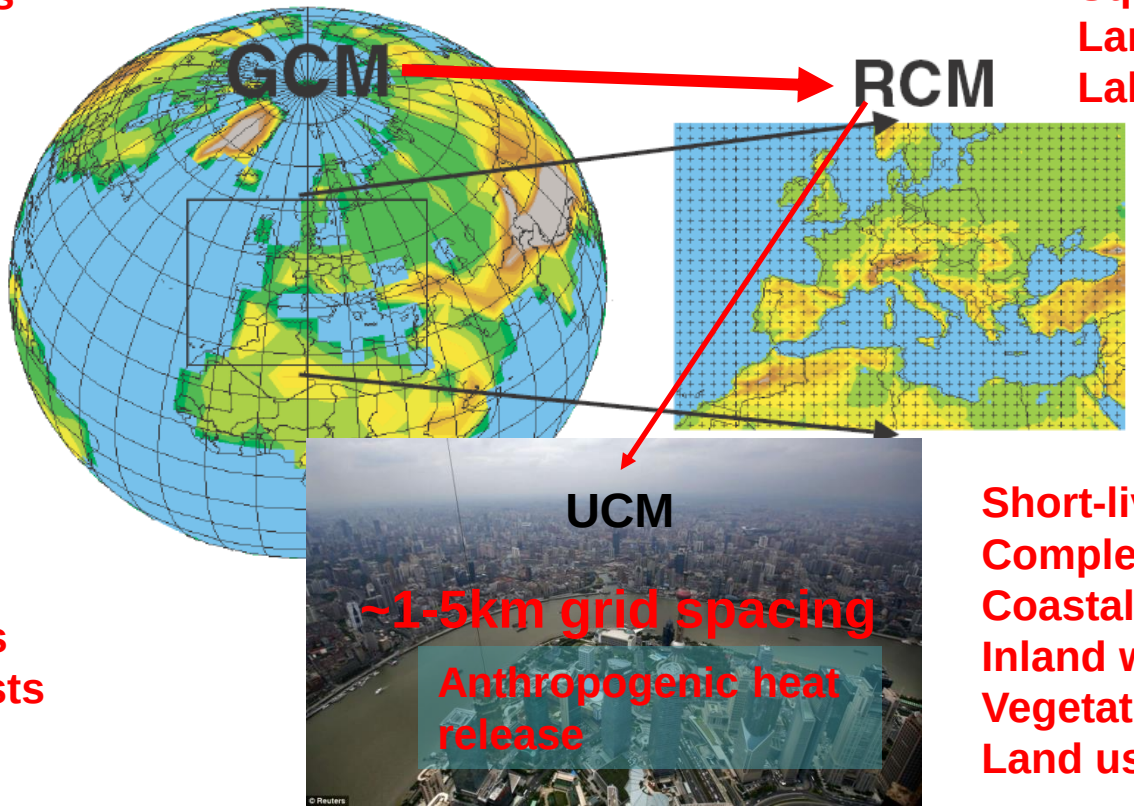
Foley et al. 2005

Downscaling – bridging the scale gap

General circulations
Jet streams
Major storm tracks
Monsoons
ENSO

Response
Forcing

Solar radiation
Greenhouse gases
Long-lived aerosols
Land/ocean contrasts
Large mountains



Local circulations
Low level jets
Squall lines
Land/sea breezes
Lake breezes

Response
Forcing

Short-lived aerosols
Complex topography
Coastal lines
Inland water
Vegetation distribution
Land use

~200-km grid spacing

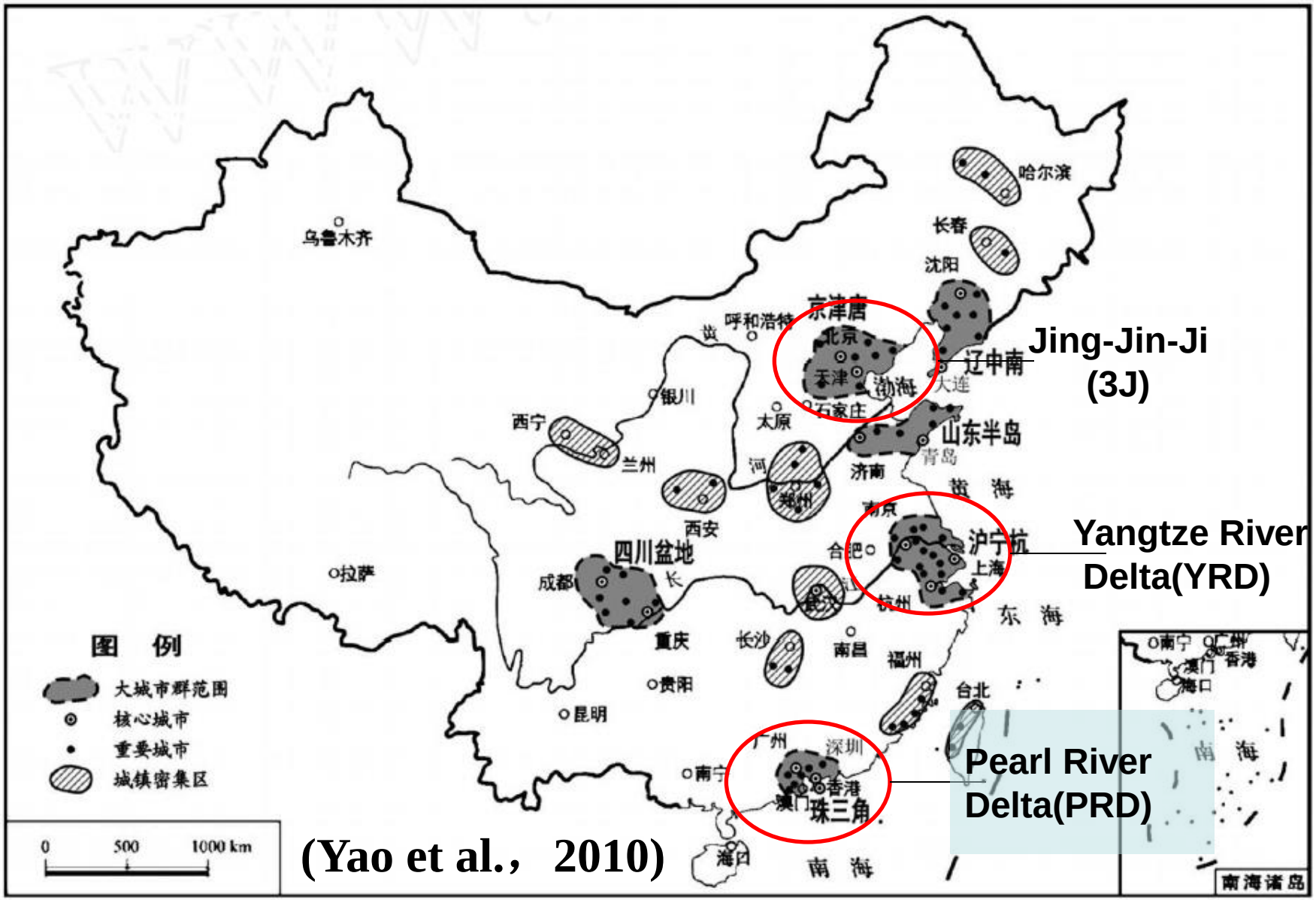
~20-km grid spacing

Revised from Giorgi 2006

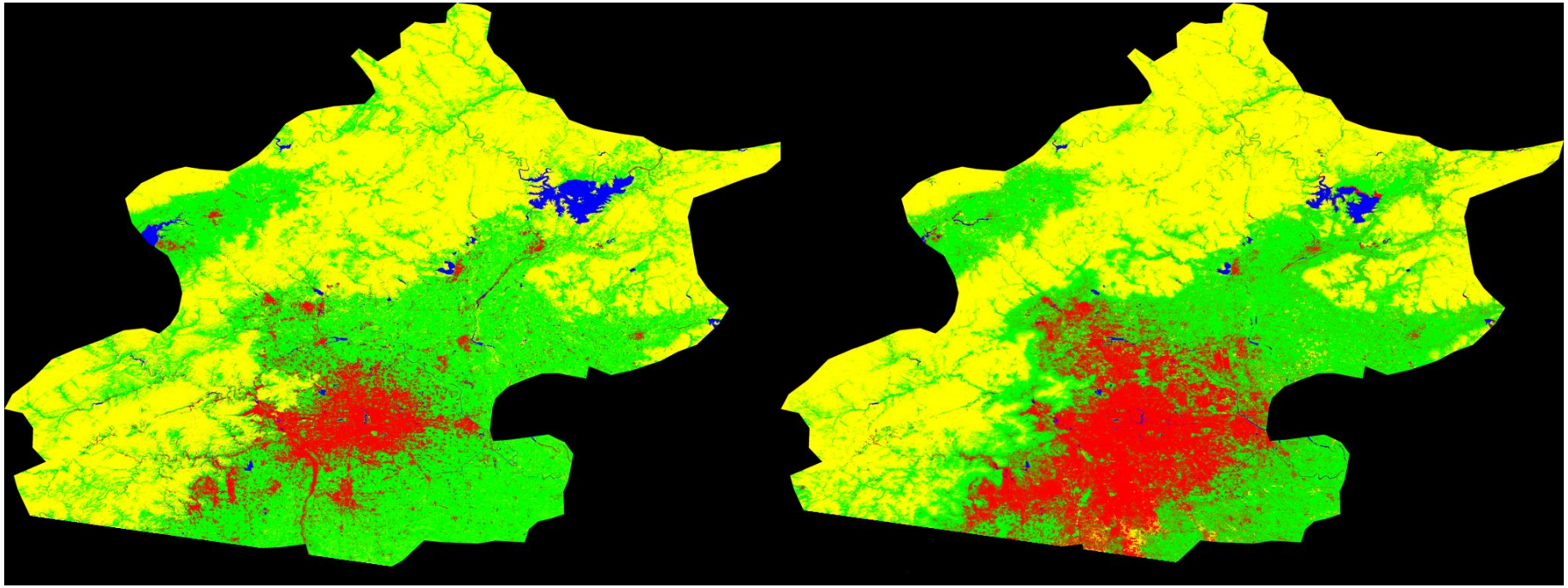
Part II Some facts for megacities of China

- City expansion
- Climate change of agglomerations

The urban agglomerations of China

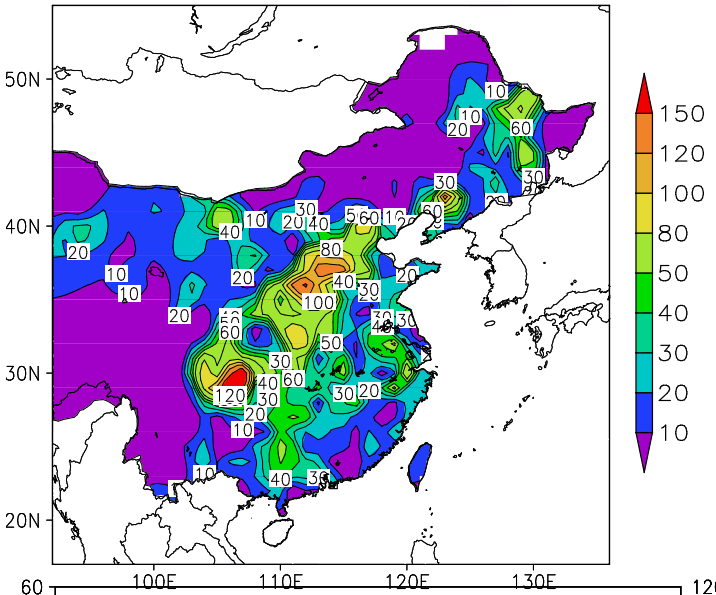


1995-2010, three times expansion for the city area of Beijing (red area)

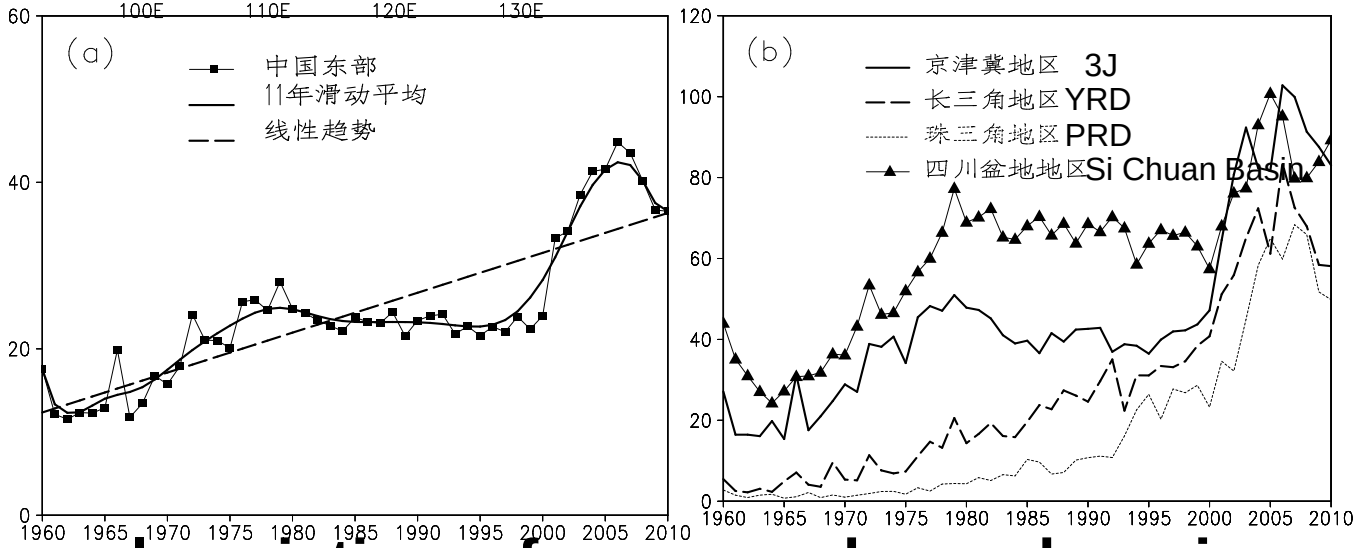


1995 2010

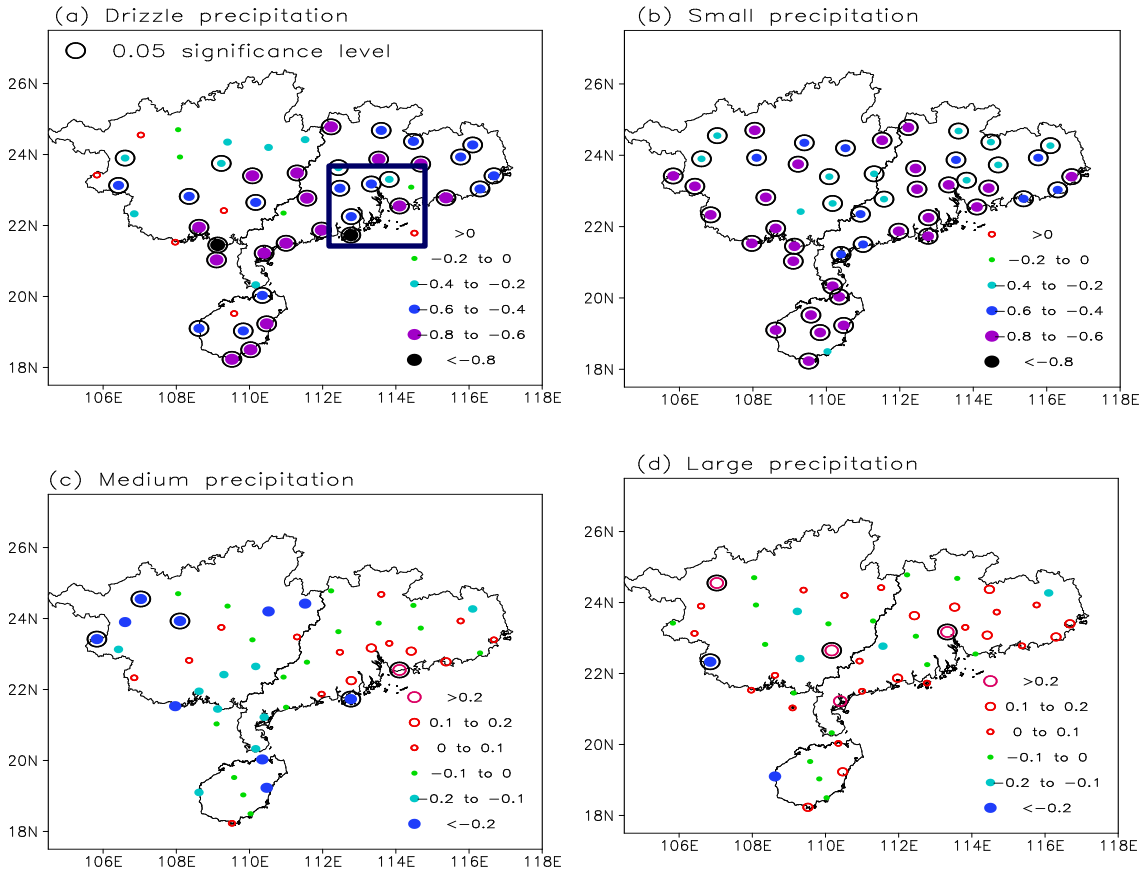
1973~2008，increased sixfold for city area of Beijing (National Development Report of China,2010)



The distribution of annually mean haze days during 1960-2010 over eastern China

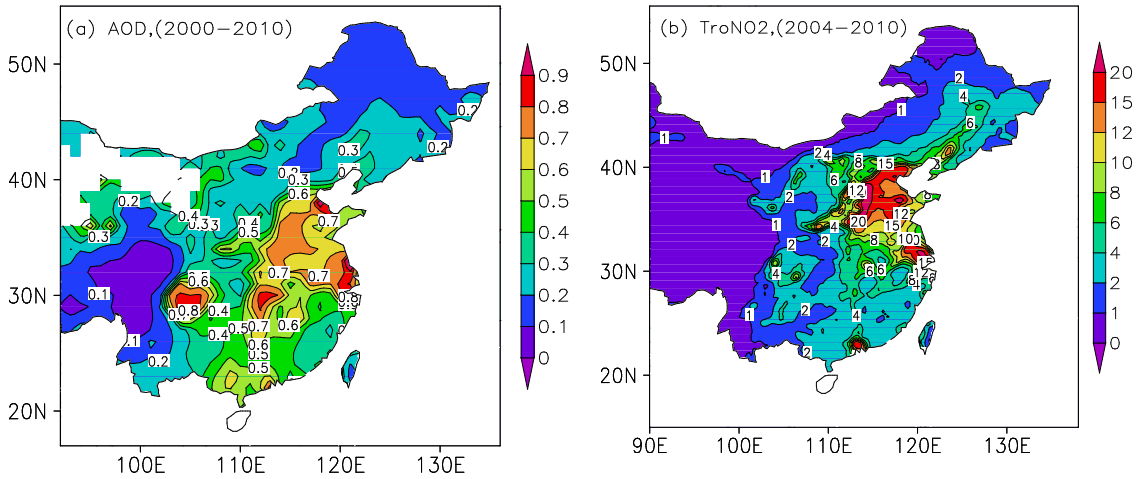


Annual variation of average haze days in eastern China (a) and four urban agglomerations (b) during 1960-2010. (Fu and Dan, 2014,paper under review)

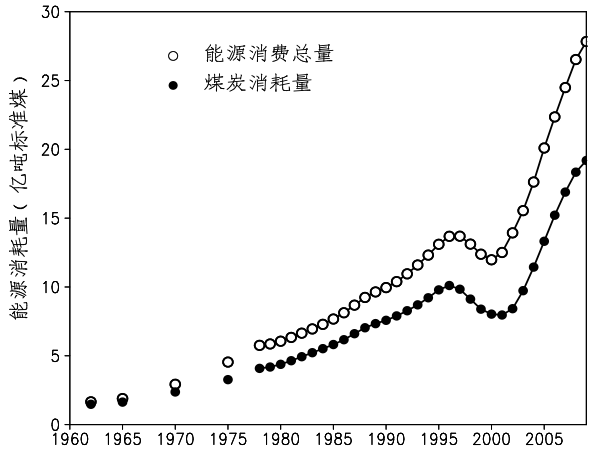


Fu and Dan,2014

Spatial distribution of trend coefficients from 1960 to 2010, Station trend indicators with open circle stands for passing 95% confidence level.



The spatial distribution of AOD (2000-2010) and $TroNO_2$ (2004-2010, units: 1015molec·cm-2) over eastern China.



Fu and Dan,2013&2013

The annual variation of energy consumption during 1960-2010 in China (units：0.1 billion standard coal)

Part III Regional Climate Models (RCMs) application for the urban agglomerations of China

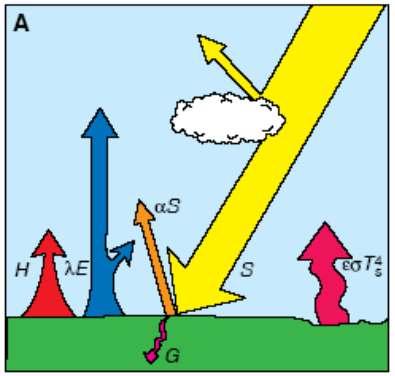
WRF model+Noah UCM

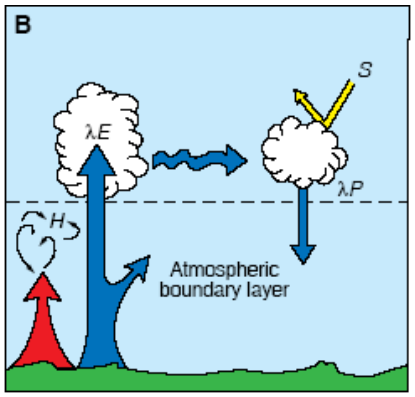
Sellers, P. J., Dickinson, R. E., Randall, D. A., et al. 1997. Modelling the exchanges of energy, water and carbon between the continents and the atmosphere. *Science*, 275, 502–509.

Anthropogenic heat release (AHR) — **city** — $Q_F=Q_M+Q_I+Q_V+Q_L$

$$R_n + Q_F = H + \lambda E + G$$

$$R_n = S(1-\alpha) + L_w - \varepsilon\sigma T_s^4 \qquad R_n = H + \lambda E + G$$

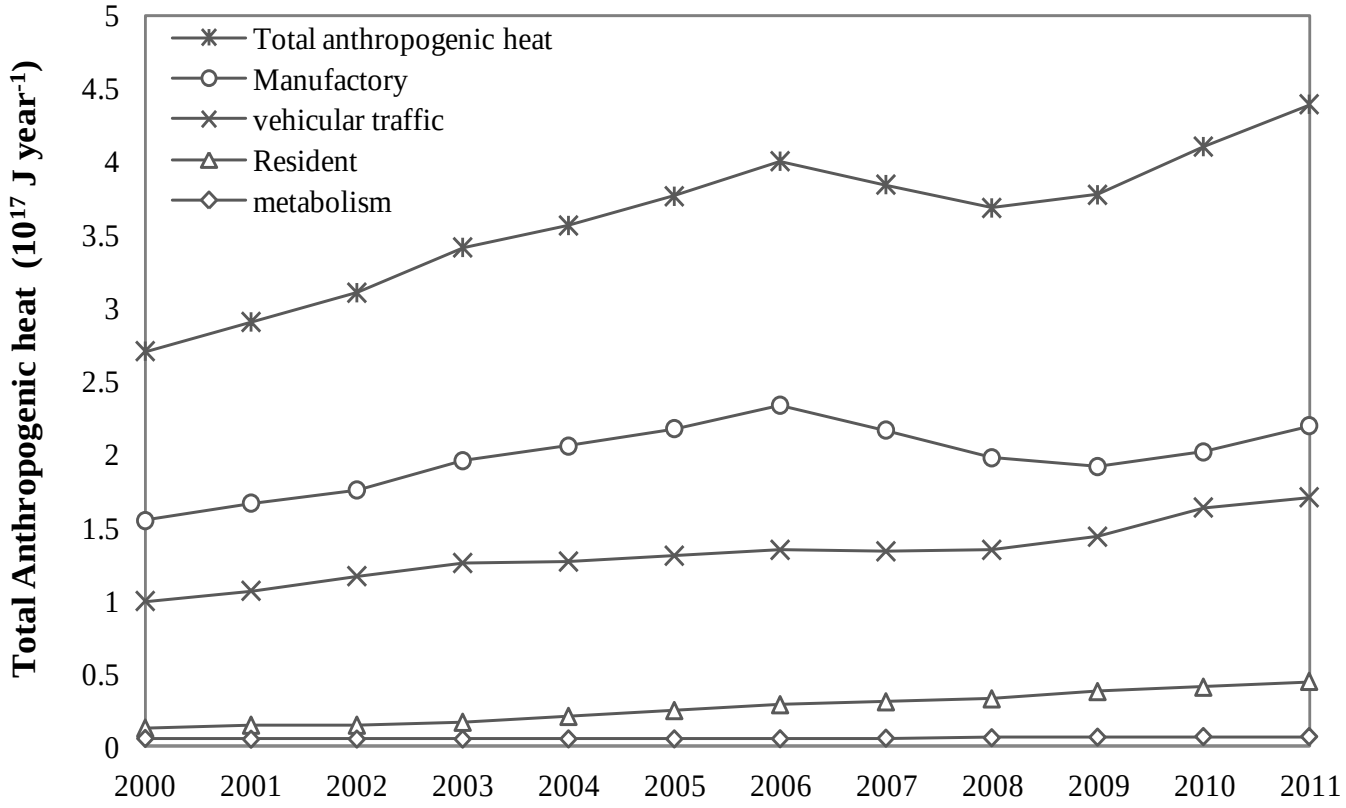




$$H = \frac{T_s - T_r}{r_a}\rho C_p$$

$$LE = \beta\left[\frac{e^*(T_s) - e_r}{r_s}\right]\frac{\rho C_p}{\gamma}$$

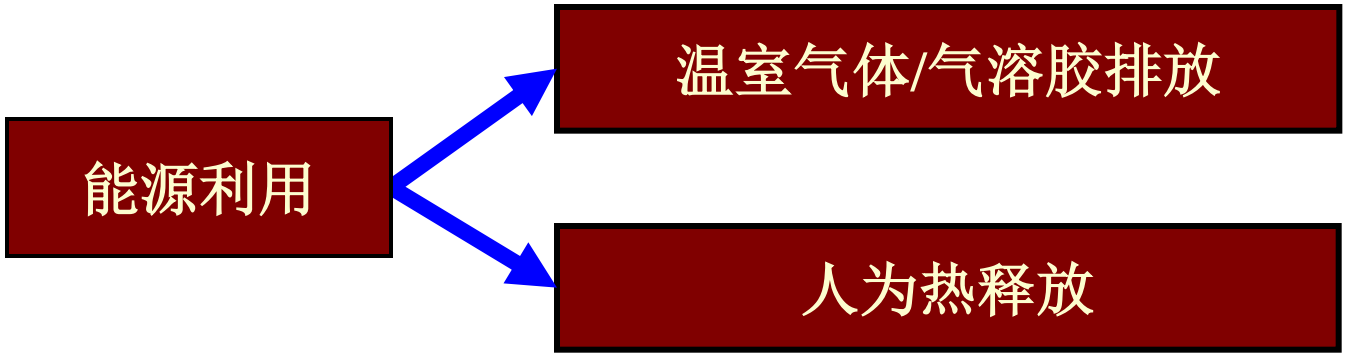
Interactions between the land surface and the atmosphere that have direct impacts on the physical climate system. (A) Surface radiation budget. (B) Effect of heat fluxes on the atmosphere.



2000年至2011年人类新陈代谢、工业、交通、生活排放的人为热以及人为热释放总量（单位：J）

Fig. Anthropogenic heat (J) from human metabolism 、manufactories、vehicular traffic、residents and total of them (J) from 2000 to 2011

Zhan and Dan, 2013



各大洲： 欧洲, 北美洲,亚洲: 0.15W/m^2

大洋洲, 非洲, 中南美洲: 0.05W/m^2

几个大城市: 中国香港 (2004), 28.8W/m2;

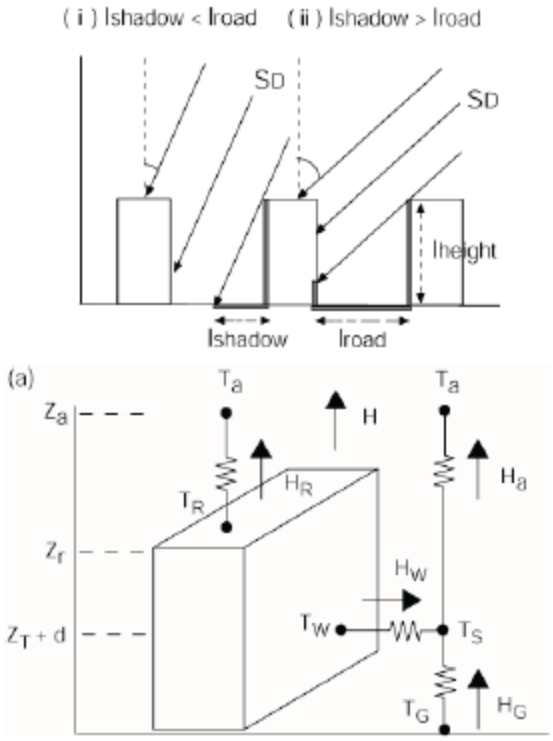
新加坡 (2004), 93.7W/m2(石广玉, 2007);

汉城 55 W/m2 (Lee, 2009);

伦敦 135 W/m2（GLA 2007）

WRF/Noah LSM/Urban-Canopy Coupled Model

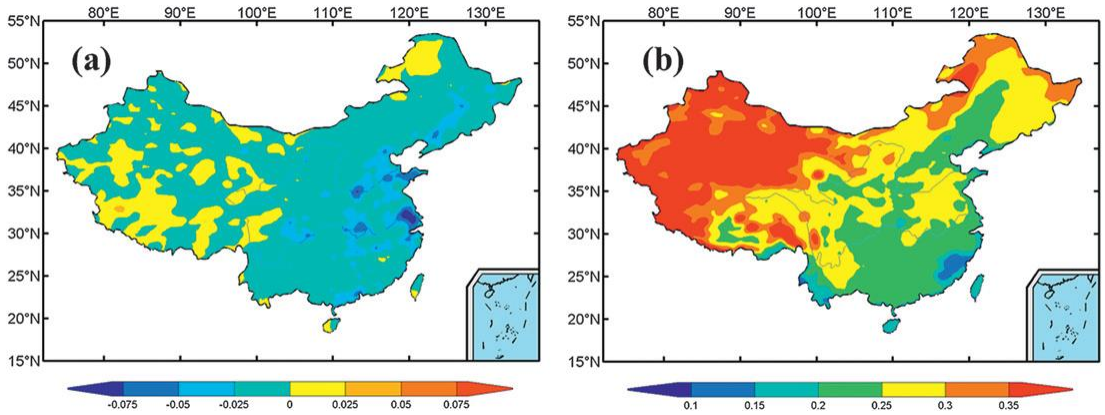
- Single layer urban-canopy model (UCM, Kusaka et al., 2004)
- Noah handle natural surfaces, UCM treats man-made surfaces
  - 2-D urban geometry (orientation, diurnal cycle of solar azimuth), symmetrical street canyons with infinite length
  - Shadowing from buildings and reflection of radiation
  - Multi-layer roof, wall and road models



The regional average temperature change (° C).

Scheme	Time period	China	Northeastern China	Northwestern China	Beijing–Tianjin–Hebei	Yangtze River delta	Southern China
S1-Ctr	Annual	0.13	0.14	0.04	0.10	0.84	0.43
	Summer	0.17	0.18	−0.05	−0.13	1.44	0.55
	Winter	0.09	0.09	0.06	0.16	0.30	0.34
S2-S1	Annual	0.15	0.18	0.12	0.36	0.89	0.40
	Summer	0.10	−0.05	0.21	0.35	0.66	0.19
	Winter	0.22	0.34	0.10	0.47	1.25	0.62
S2-Ctr	Annual	0.29	0.32	0.16	0.46	1.74	0.83
	Summer	0.27	0.13	0.16	0.22	2.10	0.74
	Winter	0.30	0.43	0.16	0.63	1.55	0.95

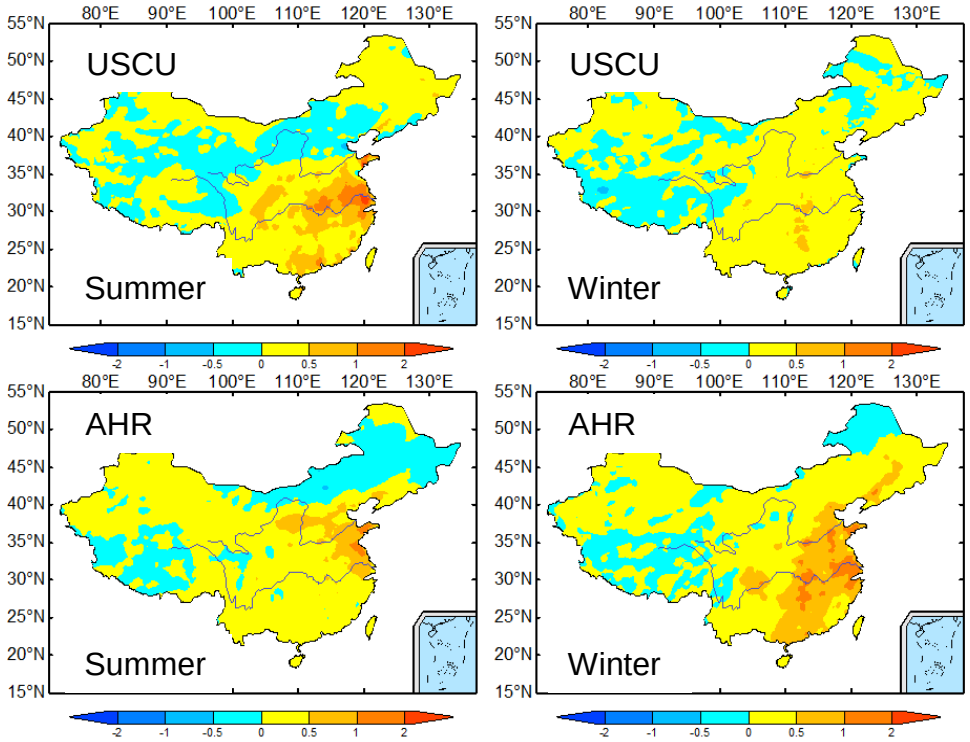
Ctrl: no urban; S1:urban, no AHR; S2:urban+AHR



Annual mean surface albedo of the control run and the differences between the control run and the sensitivity run: (a) S1-Ctr and (b) Ctr.

The simulation of regional climate effects of urbanization and anthropogenic heat release in China

Surface air temperature change caused by Underlying Surface Change due to Urbanization (USCU) and Anthropogenic Heat Release (AHR) (Unit: ℃)



The influence of AHR on temperature in winter is greater than that in summer, but the influence of USCU in summer is greater than that in winter.

Mechanism for effects of USCU and AHR across different season：Surface energy balance

$$R_N + Q_F = Q_H + Q_E + \Delta Q_S$$

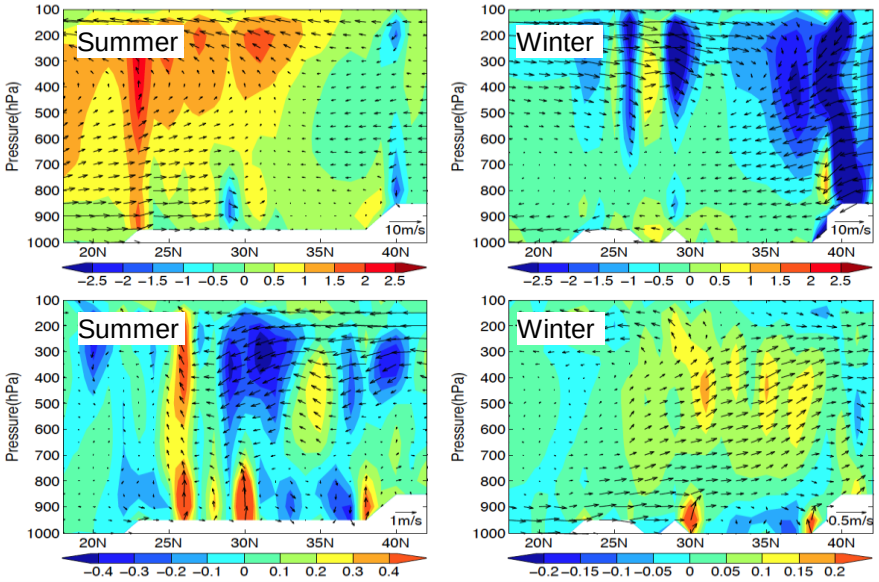
Urban surface albedo is decreased because solar short wave is multi-reflected and multi-absorbed by urban buildings.

Net radiation is bigger (smaller) in summer (winter), the proportion of AHR relative to net radiation is smaller (bigger) in summer (winter);

The magnitude of latent heat decrease and sensible heat increase is bigger (smaller) in summer (winter) caused by USCU.

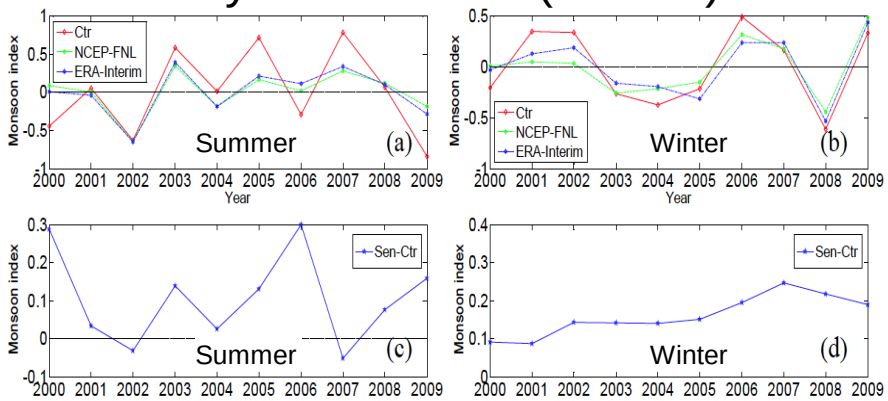
Feng Jinming，Wang Yongli, Ma Zhuguo, Liu Yonghe, 2012: Simulating the regional impacts of urbanization and anthropogenic heat release on climate across China, J. Clim. 25(20): 7187-7203. DOI: 10.1175/JCLI-D-11-00333.1.

Latitude-height cross section of vertical circulation and its change caused by urbanization along 115° E. Shading represents vertical velocity (Unit: cm/s) (Top: control run; Bottom: Change caused by urbanization)



Local upwelling airflow is strengthened by urbanization, especially in urban agglomerations. However, additional precipitation is not produced because of a decline of surface moisture in urban areas.

Interannual variation of East Asian monsoon index (Top) and its change caused by urbanization (Bottom)



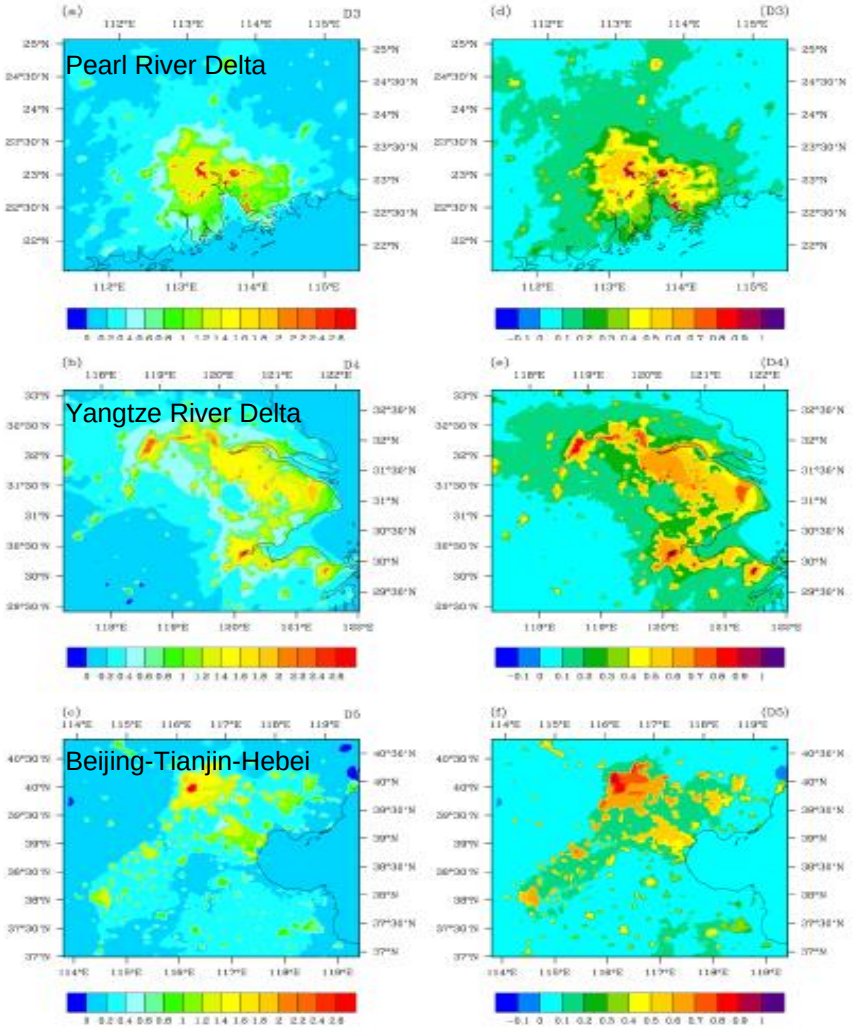
Monsoon index is defined as meridional wind over regional average (20-40° N, 105-125° E)

The summer monsoon is strengthened slightly and the winter monsoon is always weakened by large-scale urbanization.

Feng Jinming, Wang Yongli, Ma Zhuguo, 2013: Long-term simulation of large-scale urbanization effect on the East Asian monsoon, Climatic Change, DOI: 10.1007/s10584-013-0885-2.

Nested high-resolution simulation over three urban agglomerations

Spatial patterns of the change of annual surface air temperature (Left) and heat stress index (Right) due to urbanization



The heat stress index W= 0.567 T + 0.393e+ 3.94, where T is the temperature in ℃, and e is the vapor pressure in hPa.

Regional average surface air temperature of the three vast city agglomerations increased by 0.31℃, 0.44℃ and 0.28℃, respectively due to urbanization. Further, in the urban areas within these three domains, the temperature increase can reach about 1.10℃, 1.31℃ and 1.15℃.

Wang Jun, Feng Jinming, Z. Yan, Y. Hu, and G. Jia, 2012: Nested high-resolution modeling of the impact of urbanization on regional climate in three vast urban agglomerations in China, J. Geophys. Res., 117, D21103, doi: 10.1029/2012JD018226.


Thank you!