A simulation of climatic change induced by land use modification from 1976 to 2006 on summer over Tokyo metropolitan area, Japan

and winter

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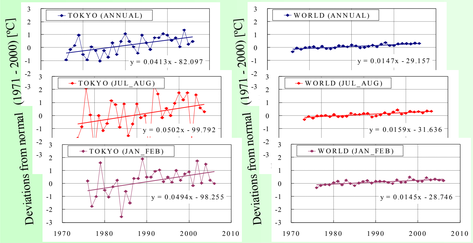
Introduction

Positive trend of surface air temperature during this 30 years is very clear at TOKYO observatory. Although yearly variations are large, the trend is much larger than world averaged data.

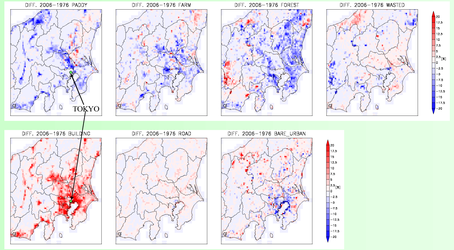


The differences between TOKYO and WORLD may include the effects of synoptic scale (east Asia scale) climate variability, local urbanization, etc.

Land use information on 1976 and 2006 shows growth of urban area fraction in the central part of Japan.

Original Data : Digital National Land Information of the Ministry of Land, Infrastructure, Transport and Tourism of Japan
http://nlftp.mlit.go.jp/ksj/index.html

Reduced vegetation area (paddy, farm, forest) were changed to urban area (building and road).



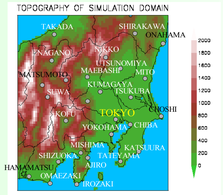
In order to figure out how much the land use modification affects to the meteorological factors (temperature, humidity, …), some numerical simulations were operated varying the lowest boundary conditions according to the land use information of 1976 and 2006.

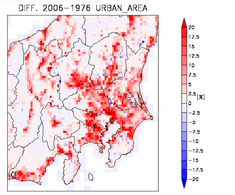
Experimental Design

Season: Summer (JA; July and August)
Winter (JF; January and February)

Domain: Central part of Japan, including Tokyo Metropolitan area

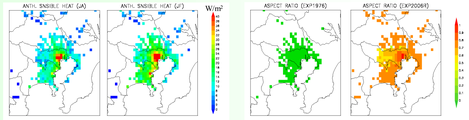
Atmospheric conditions:
Initial & Boundary : JMA Operational Mesoscale Analysis Dataset
Summer case : Start 01 Jul. 2006 – End 31 Aug. 2006
Winter case : Start 01 Jan. 2007 – End 28 Feb. 2007





EXP. NAME	Land Use Information	Anthropogenic heat release	Building aspect ratio Height : Width
EXP1976	1976	Not Considered	1 : 4
EXP2006HR	2006	Considered	3 : 4 *1

*1 Aspect ratio was determined from GIS dataset in Tokyo Metropolis



MODEL

NHM

Japan Meteorological Agency Non Hydrostatic Mesoscale Model

governing equations	Fully compressible non hydrostatic equations
Horizontal discretization	Grid point method
Treat of advection term	Forth order flux form , advection corrected
Map projection	Lambert conformal projection
Vertical grid series	z*-coordinate
Topography	GTOPO30
Sea-Land distributions	GLCC/Digital National Land Information
Cloud microphysics	Bulk scheme with ice phase predict qv, qc, qr, qi, qs, qg
Cumulus parameterization	Kain-Fritsch & Cloud microphysics
Turbulent closure	Improved Mellor-Yamada Level 3
Cloud radiation	Kitagawa (2000)
Clear sky radiation	Yabu, Murai and Kitagawa (2005)
Clouds in radiation processes	Partial condensation scheme
Surface flux	Beljaars and Holtslag (1991)
Solid water content	Force restore method
Surface parameters	Proportional distribution by land use area
Surface scheme	**SLAB(Beljaars and Holtslag, 1991) +SPUC* (only for urban grid)**

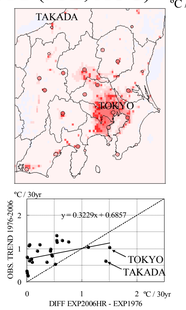
* Aoyagi, T. and N. Seino, 2011, JAMC, under review.

Surface Air Temperature

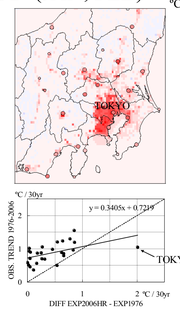
Shade: EXP2006HR - EXP1976
○ : Temperature trend during 30 years at meteorological observatories derived by least square method.
(removed global trend)
−0.477deg/30yr for JA, −0.435deg/30yr for JF

Significance of the trend (t -test)
10 % 50 % 80 % >90 %

JA (JUL, AUG)

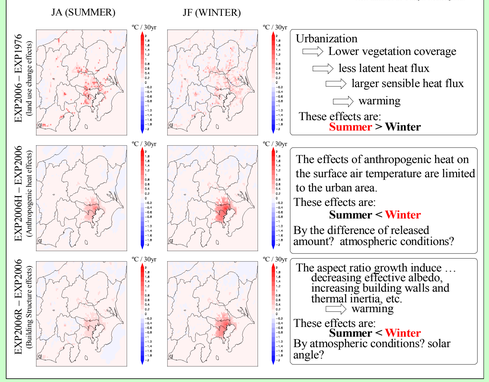


JF (JAN, FEB)



EXP. NAME	Land Use Information	Anthropogenic heat release	Building aspect ratio Height : Width
EXP1976	1976	Not Considered	1 : 4
EXP2006	2006	Not Considered	1 : 4
EXP2006H	2006	Considered	1 : 4
EXP2006R	2006	Not Considered	3 : 4 *1
EXP2006HR	2006	Considered	3 : 4 *1

*1 Aspect ratio was determined from GIS dataset in Tokyo Metropolis



Urbanization
⇨ Lower vegetation coverage
⇨ less latent heat flux
⇨ larger sensible heat flux
⇨ warming
These effects are:
Summer > Winter

The effects of anthropogenic heat on the surface air temperature are limited to the urban area.
These effects are:
Summer < Winter
By the difference of released amount? atmospheric conditions?

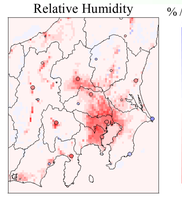
The aspect ratio growth induce …
decreasing effective albedo,
increasing building walls and thermal inertia, etc.
⇨ warming
These effects are:
Summer < Winter
By atmospheric conditions? solar angle?

Humidity

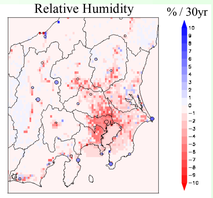
Shade: EXP2006HR - EXP1976
○ : Trends during 30 years at meteorological observatories derived by least square method.

Significance of the trend (t -test)
10 % 50 % 80 % >90 %

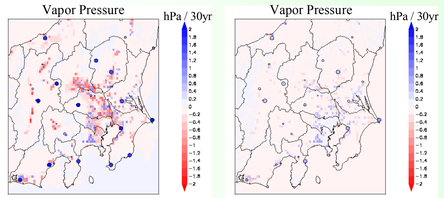
JA



JF



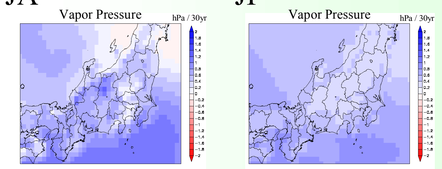
The sensitivity study showed that urbanization makes atmosphere dry. The effect is larger on summer than winter. Simulated spatial distribution of humidity change shows good agreement with observational trend on summer except for seaside. On winter, the reproduction of humidity change shall be improved in mountain area.



The simulated differences were mainly caused by urban area fraction changes, i.e. reduction of vegetation area.

The simulations generally show dry trend, though the observational trends show strong humid trend on summer case.
↳ Large scale humid trend > Local urbanization effects ?
Note: This study used only the atmospheric condition of 2006

Vapor pressure trend derived from NHRCM-20km results (downscaled from JRA-25 datasets)
NHRCM : Non Hydrostatic Regional Climate Model



Large scale climate variations show large humid trend. The observational humid trend is more affected by this large scale trend than the local urbanization.

Conclusions

* The land use change on this 30 years may make surface air temperature warmer.
* The main cause of temperature rise is the reduction of vegetation coverage. Less latent heat flux, more sensible heat flux. This factor affects effectively on summer.
* Anthropogenic heat seems to have large effect to the warmer temperature around the center of Tokyo. The effects of anthropogenic heat is limited to the released area. This effect is larger on winter.
* The structural change of buildings also have some effect to temperature rise. This effect is larger on winter.

* Observed trends and simulated differences of relative humidity both showed dry trend.
* On the other hand, the results of vapor pressure showed opposite tendency.
* This imply that large scale climate variation affects larger to surface vapor environment than local land use changes.

Comments

Please write down any comments …