ANALYSIS OF RELATIONSHIP BETWEEN METEOROLOGICAL CONDITIONS AND GROUND O_3 LEVELS IN SUMMER OVER THE CENTRAL KANTO AREA

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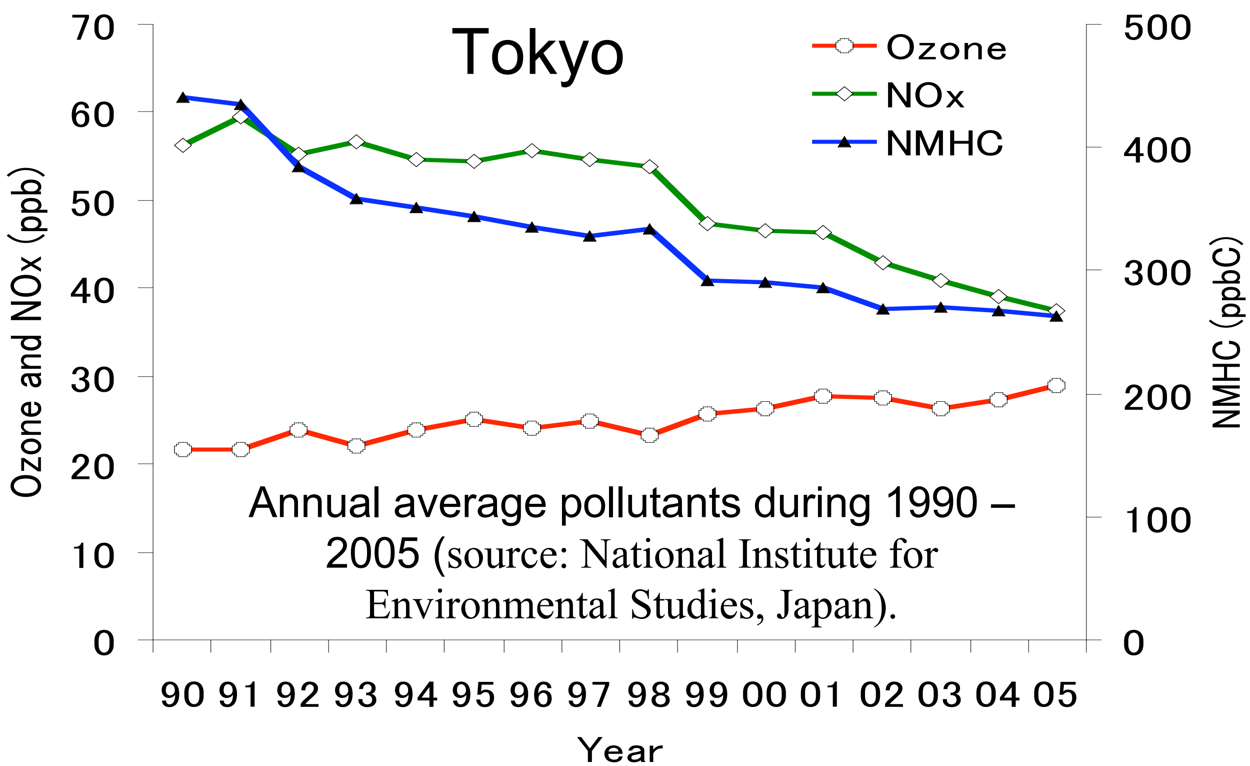
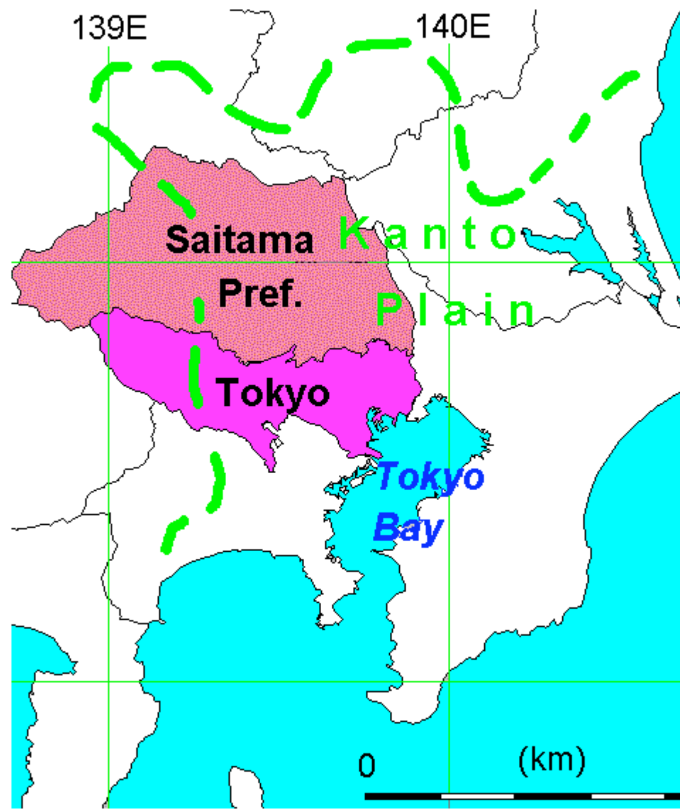
1. Background

- Both NO_X and NMHC have a decrease tendency. **However, O concentration has not been reduced**

- **About 10ppb/16 years in Tokyo**



Annual average pollutants during 1990 – 2005 (source: National Institute for Environmental Studies, Japan).



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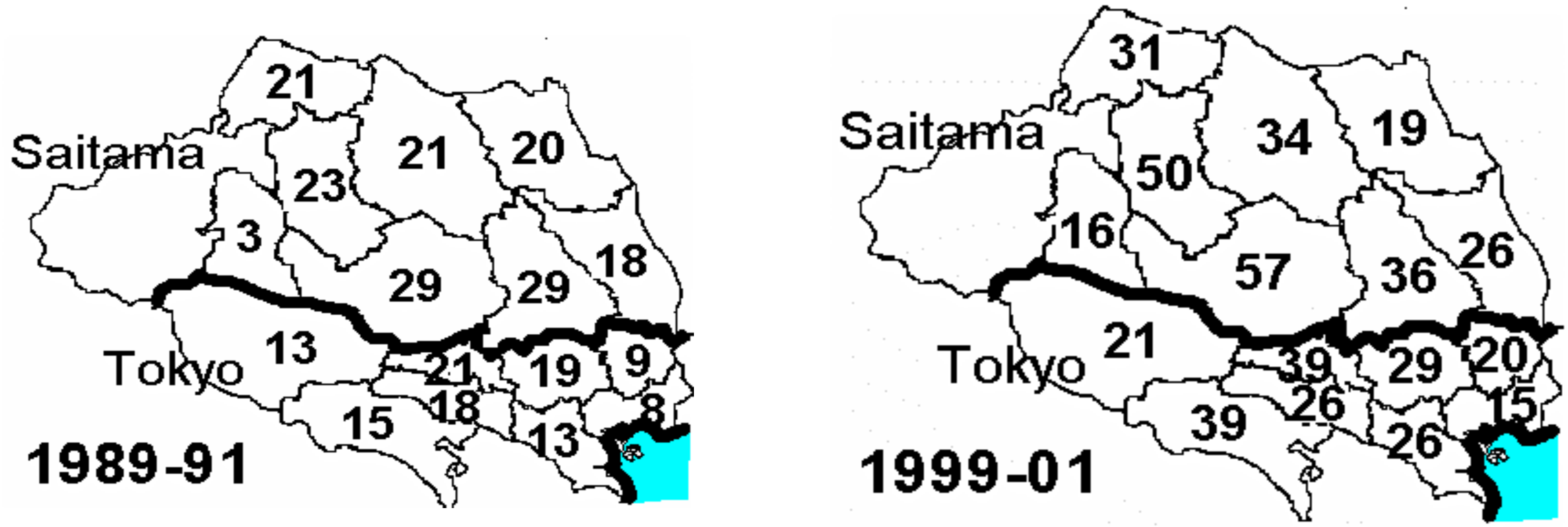
1. Background

Increase in number of high Ox days in summer

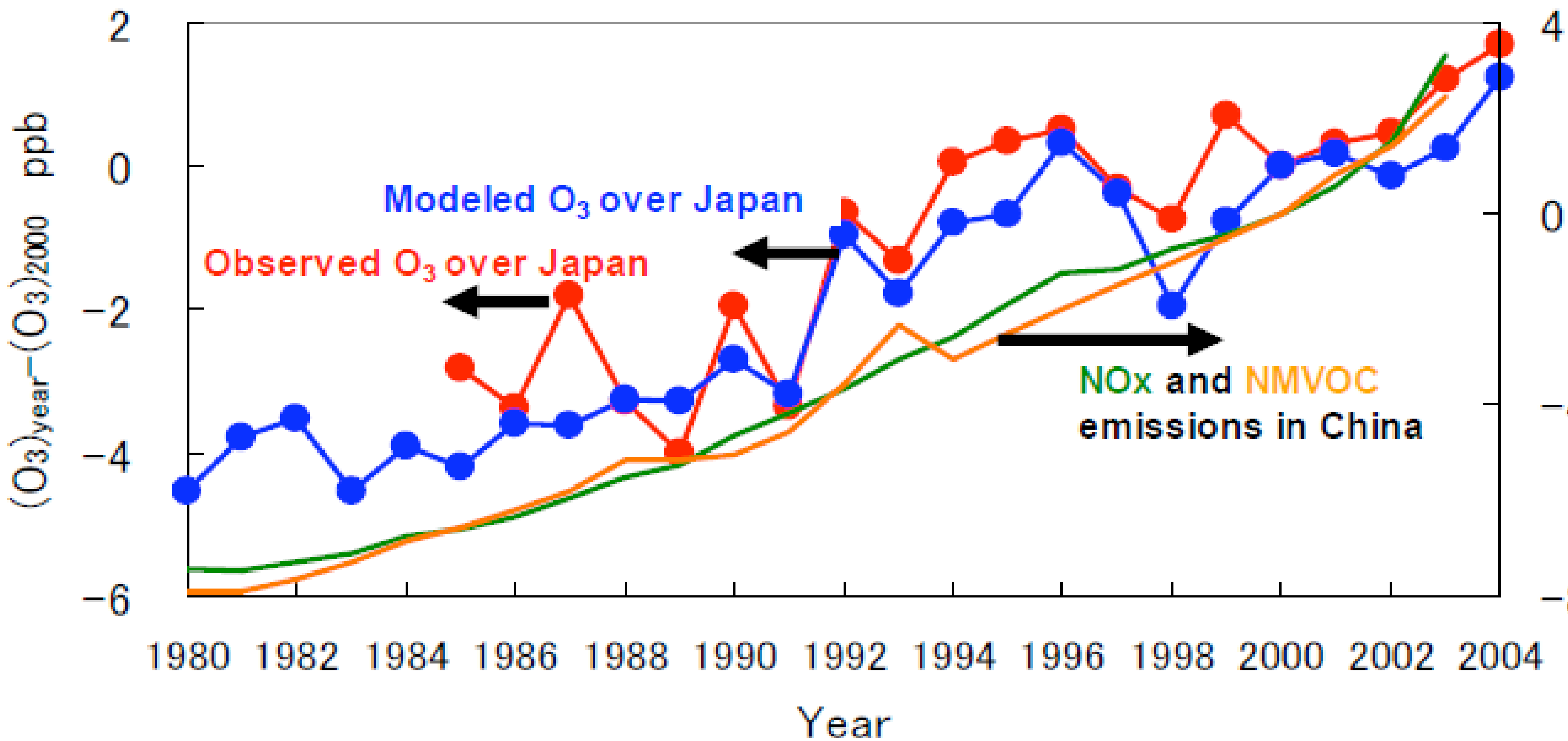


YoshiKado（2004）

*) High Ox day means its highest value in each sector exceeding 120 ppbV for two consecutive hours.

What are reasons? The trans-boundary from other Asian countries, chemistry, meteorology …

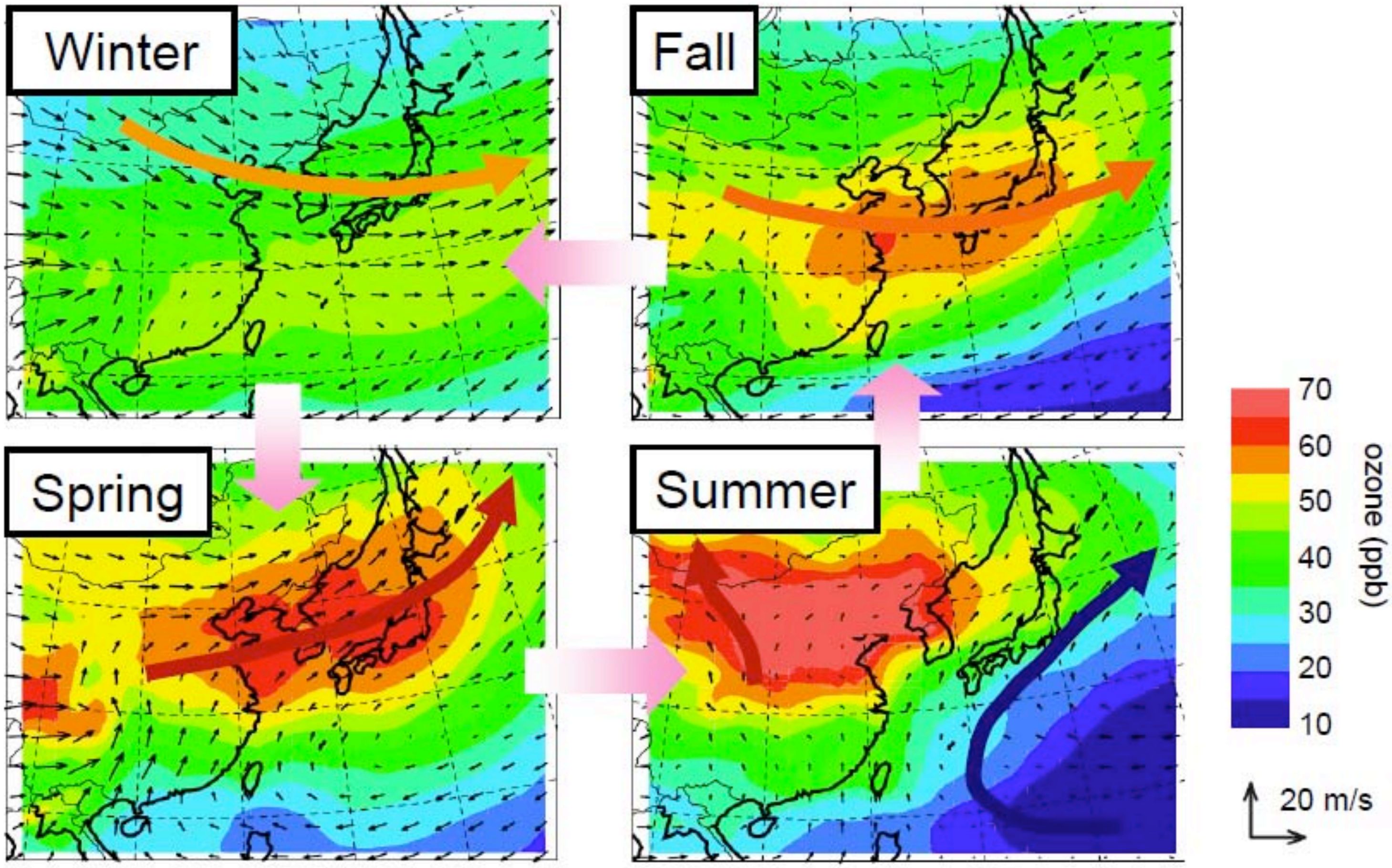
Relationship between O_3 concentration in Japan and emission of NOx and NMVOC from China (Ohara, 20(



There is a possibility of trans-boundary pollution.

1. Background

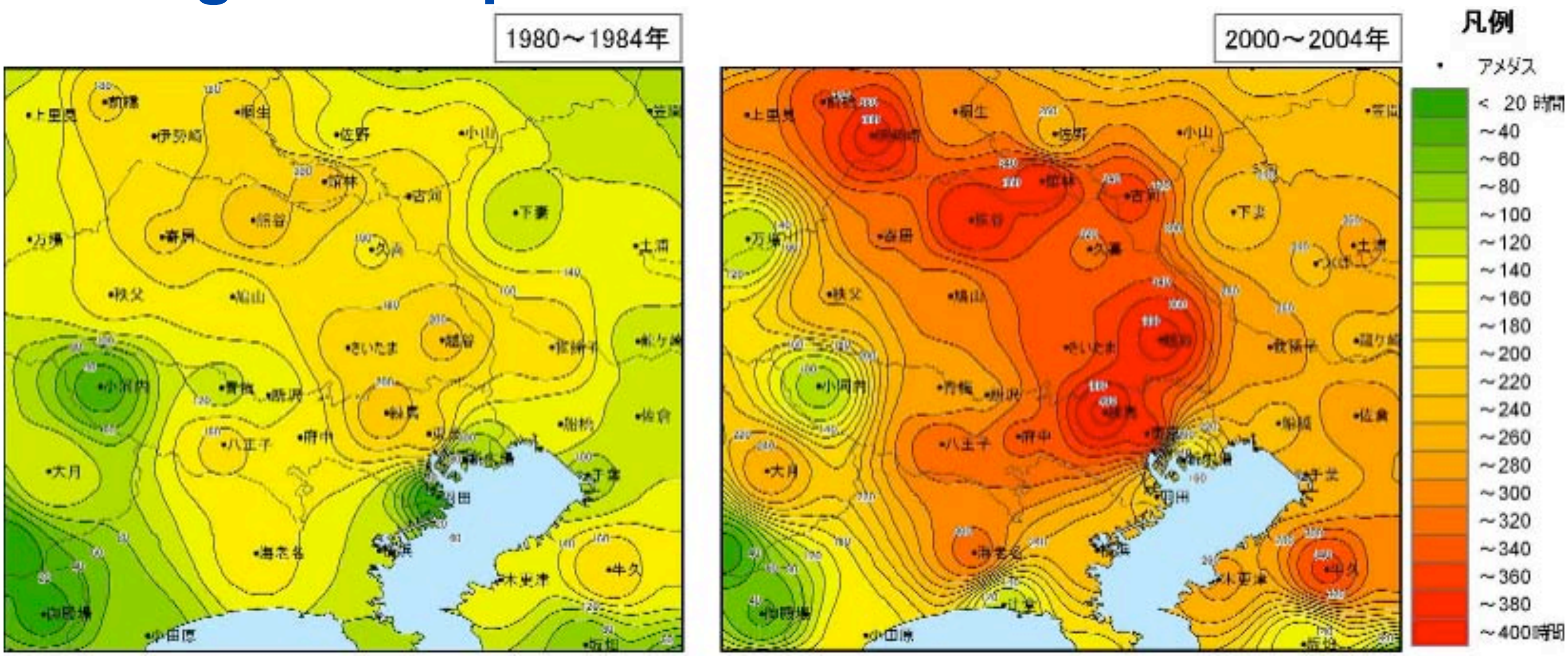
However, peak concentration of O_3 is observed in summer.



There is another reason except for trans-boundary pollution in summer.

1. Background

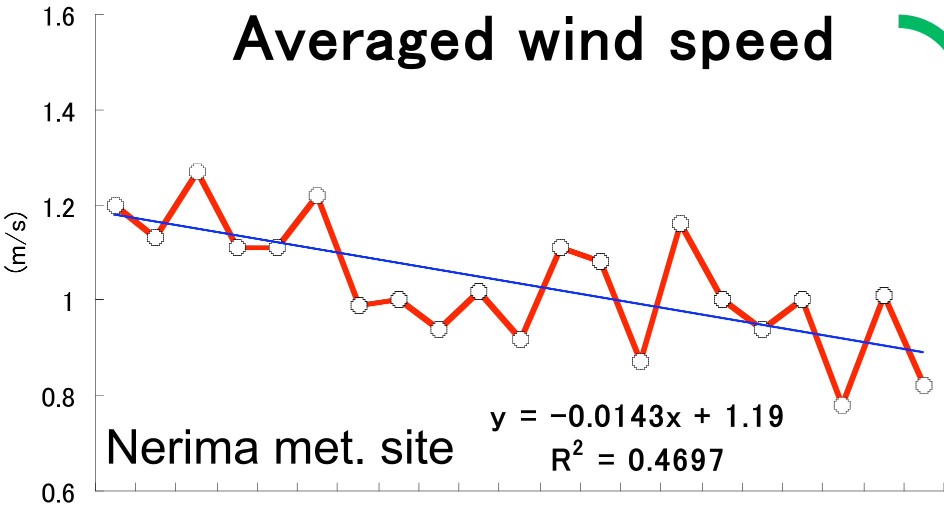
Global and urban warming has been recognized resulting from rapid urbanization

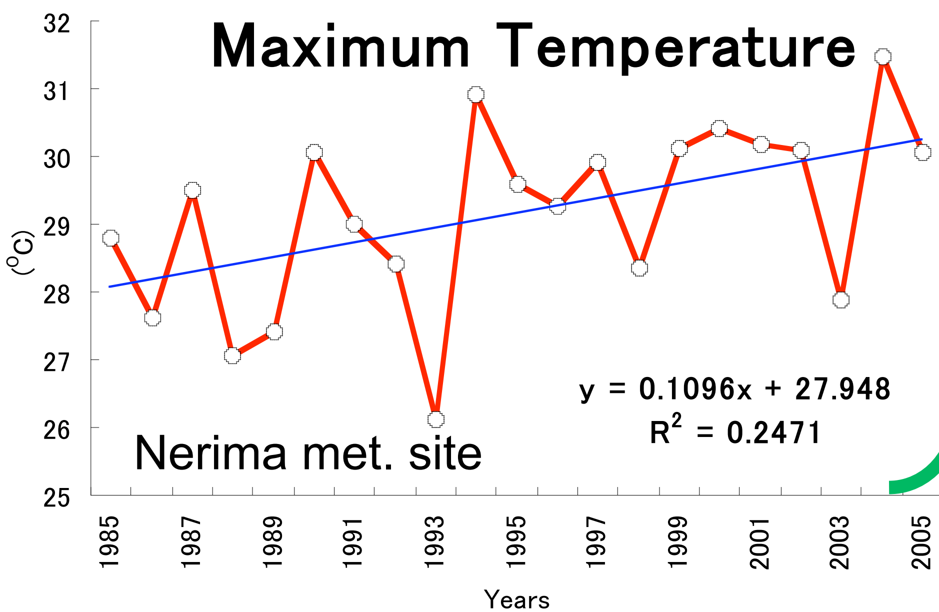


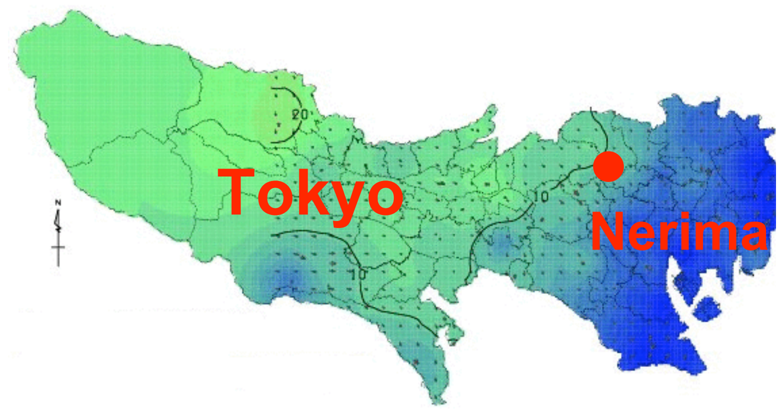
Total hours exceeding 30 deg C (Annual average for each 5 years). http://www2.kankyo.metro.tokyo.jp/heat/heat1.htm（2009.6）

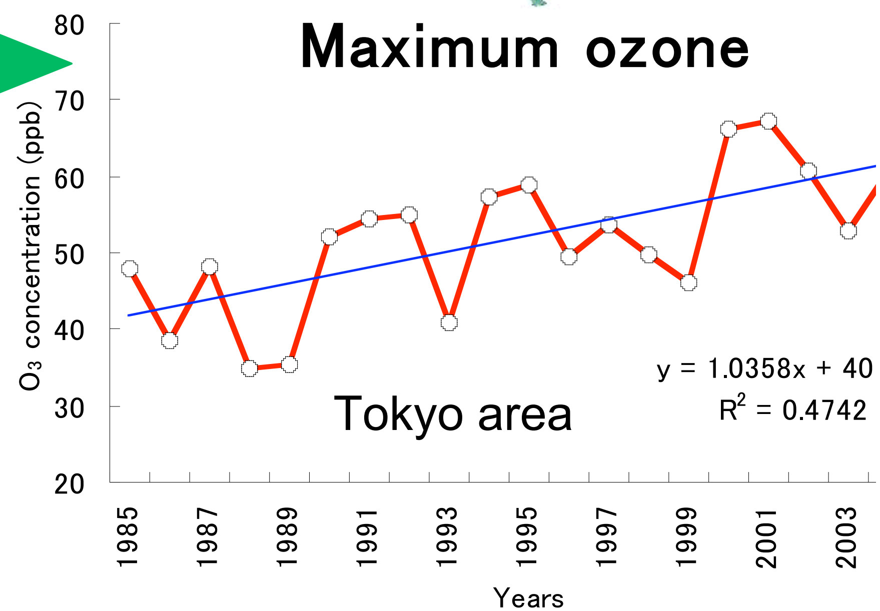
1. Background

Change in meteorological conditions









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2. Objectives

1. Analysis the variation of the peak O_3 and its possible relation with change in meteorological conditions based on measurements

2. Consider these relationships based on numerical simulation

3. Methods

- Statistical analysis (a multiple regression analysis)

$$y = a_0 + a_1 x_1 + \ldots + a_m x_m + \varepsilon$$

y: objective variable (ozone concentration)
xi: independent variables (meteorological variables)
ai: regression coefficients (estimated by least square procedure)

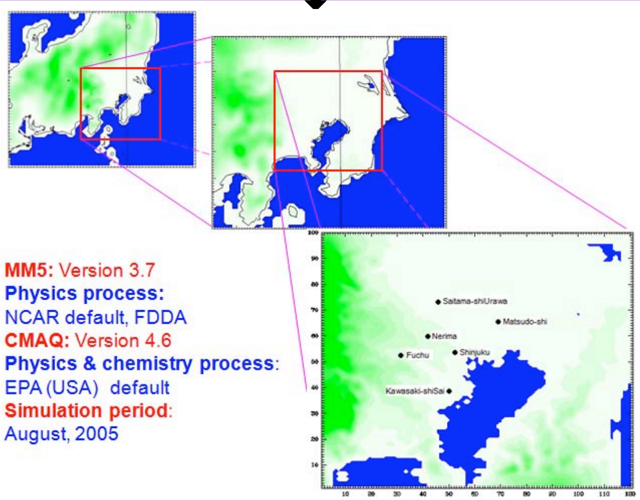
- Numerical simulation

MM5 model (The Fifth-Generation NCAR / Penn State Mesoscale Model)
Simulating meteorological variables; T, U, RH, P,…..

CMAQ model (The Community Multi-scale Air Quality modeling, EPA , USA)
Simulating aerosol and gas; O3, CO, NOx, NH3, SO2,…..

3. A multiple-scale numerical model

Analysis area and configuration



MM5: Version 3.7
Physics process:
NCAR default, FDDA
CMAQ: Version 4.6
Physics & chemistry process:
EPA (USA) default
Simulation period:
August, 2005

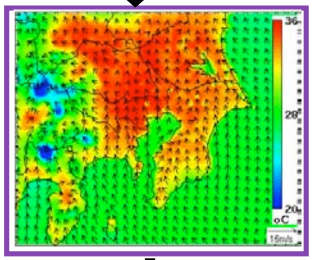
Table 1： Analysis size domains and grid resolution

	Size (X[km] x Y[km])	Grid number	resolution (km)
D1	450x540	51x61x23	9
D2	216x261	73x88x23	3
D3	99x120	100x121x23	1

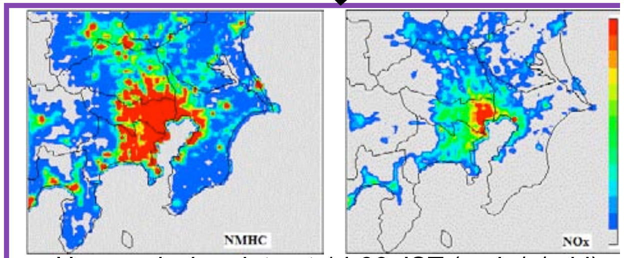
MM5 model
The Fifth-Generation NCAR / Penn State Mesoscale Model
Calculating
wind, temperature, pressure, etc.

FDDA

NCAR Met. Data:
T, U, P, RH,
SST, Topography
, Land Use, etc.



EMISSION DATA
Prepared by Central Research Institute of Electric Power Industry, Tokyo, Japan
Including
CO_2, NO_X, VOC, SO_2, NH_3, etc.



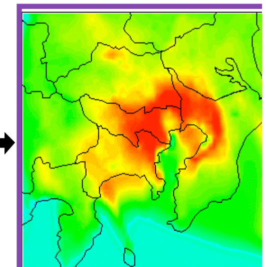
Hour emission data at 14:00 JST (mole/s/grid)

Solar radiation

Initial and boundary conditions

JCAP

CMAQ model
The Community Multi-scale Air Quality modeling
transport
chemistry
depositions
cloud, precipitation
aerosols



Air quality concentration simulation

Species		O3	NO	NO2	ALD	FORM	ETH	OLE	TOL	XYL	ISO	PAR
ICs		28	2.0	4.0	1.8	2.2	1.4	1.6	14.4	0.6	0.5	74.3
BCs	N	28	2.0	4.0	1.8	2.2	1.4	1.6	14.4	0.6	0.5	74.3
	E	25	2.0	4.0	1.8	2.2	1.4	1.6	14.4	0.6	0.5	74.3
	W	28	2.0	4.0	2.0	2.4	3.2	4.2	11.4	0.7	0.5	82.7
	S	Default (USA)										

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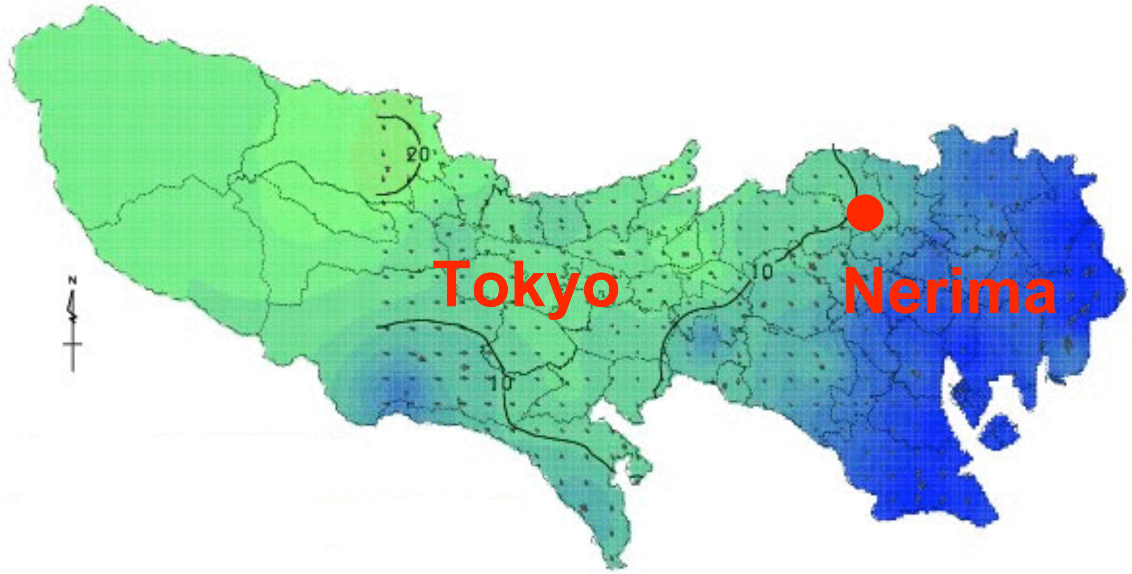
RESULTS

4.1 Long-term variation of the peak ozone: Observation analysis

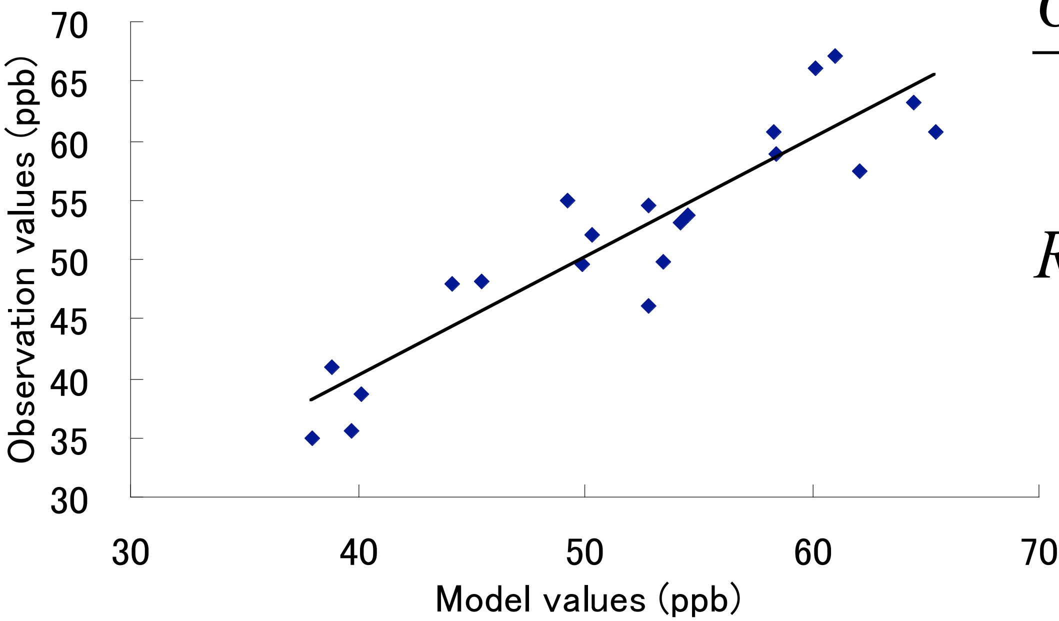
Analysis conditions

- Study periods：
  1985 ～ 2005
- Methods：
  Statistical analysis
- Data: Observation



Variables	Definition
Ozone (O_3)	- Seasonally averaged daily maximum value of environmental monitoring sites in Tokyo
Temperature (T)	- Seasonally averaged daily maximum temperature and averaged wind speed at Nerima meteorological site.
Wind speed (U)	

4.1 Long-term variation of the peak ozone: Observation analysis



$$\frac{O_3-\overline{O_3}}{\sigma_{O_3}} = 0.80*\frac{T-\overline{T}}{\sigma_T} - 0.49*\frac{U-\overline{U}}{\sigma_U}$$

$$R = 0.91, \quad R^2 = 84.1$$

R is the multiple correlation coefficient and,
R^2 is the fraction of the variance explained by the regression

- 84.1% of the variation of the peak O_3 may be accounted for by changes in temperature, and wind speed.

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4.1 Long-term variation of the peak ozone: Observation analysis

Trend of O_3 concentration in Tokyo area

	Periods	Observation	Model
Averaged daily maximum concentrations (ppb)	1980s	41.04	41.51
	1990s	51.77	52.25
	2000s	61.80	60.60
Difference between periods (ppb)	**1990s-1980s**	**10.73**	**10.74**
	2000s-1990s	**10.03**	**8.35**

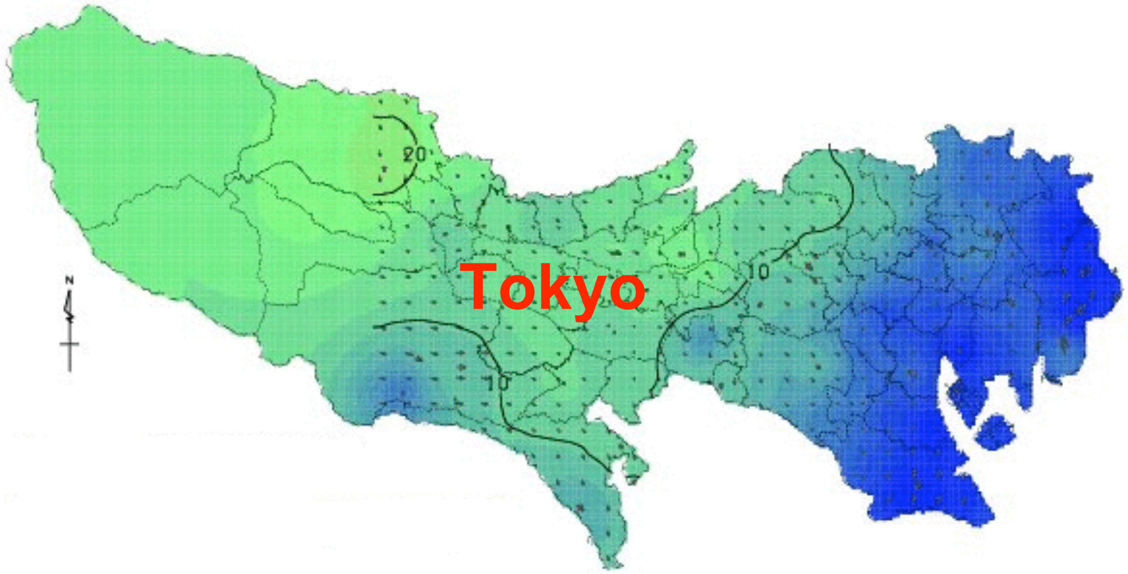
- Both Observation and Model show upward trend of the peak O_3 concentration

- This result suggests that changes in meteorological conditions contribute to increase the peak O_3 concentration

4.2 Short-term variation of the peak ozone: Observation analysis

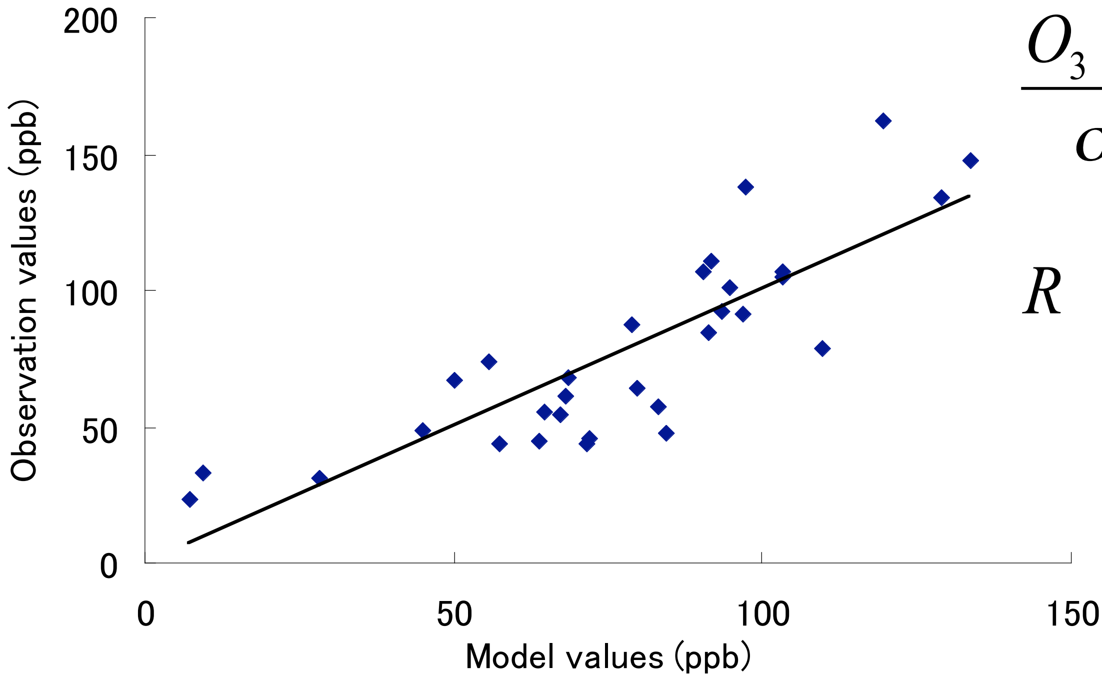
Analysis conditions

- Study periods : August, 2005
- Methods : Statistical analysis
- Data: Observation



Variables	Definition
Ozone (O_3)	- Averaged daily maximum O_3 of monitoring sites in Tokyo area
Temperature (T)	- Averaged daily maximum temperature, and averaged wind speed of monitoring sites in Tokyo area
Wind speed (U)	

4.2 Short-term variation of the peak ozone: Observation analysis



$$\frac{O_3-\overline{O_3}}{\sigma_{O_3}} = 0.57*\frac{T-\overline{T}}{\sigma_T} - 0.68*\frac{U\cdot}{\sigma}$$

$$R = 0.84, \quad R^2 = 70.3$$

- 70.3% of the short-term variation of the daily maximum ozone depend on temperature and wind speed

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4.3 Short-term variation of the peak ozone: Simulation analysis

Analysis conditions

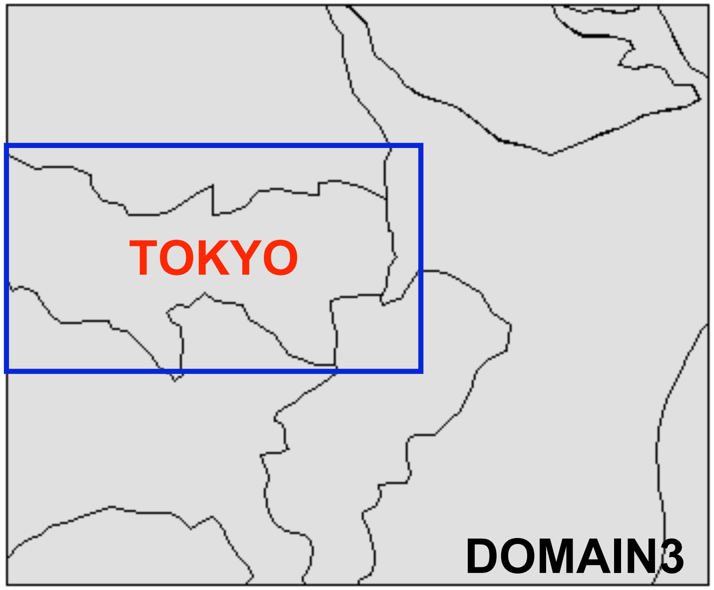
- Study periods :

  August, 2005

- Methods :

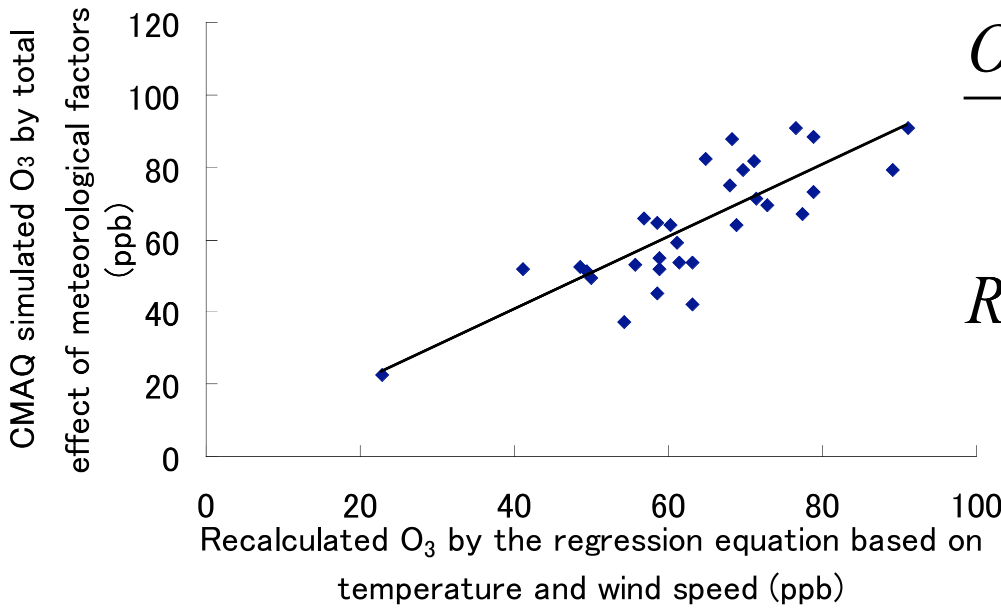
  Statistical analysis and MM5/CMAQ

- Data: MM5/CMAQ simulation



Variables	Definition
Ozone (O_3)	- Averaged daily maximum O_3 of grid points in Tokyo area
Temperature (T)	- Averaged daily maximum temperature, and averaged wind speed of grid points in Tokyo area
Wind speed (U)	

4.3 Short-term variation of the peak ozone: Simulation analysis



$$\frac{O_3-\overline{O_3}}{\sigma_{O_3}} = 0.45*\frac{T-\overline{T}}{\sigma_T} - 0.66*\frac{U \cdot}{\sigma}$$

$$R = 0.81, \quad R^2 = 66.0$$

- 66.0% of the short-term variation of the daily maximum ozone depend on temperature and wind speed

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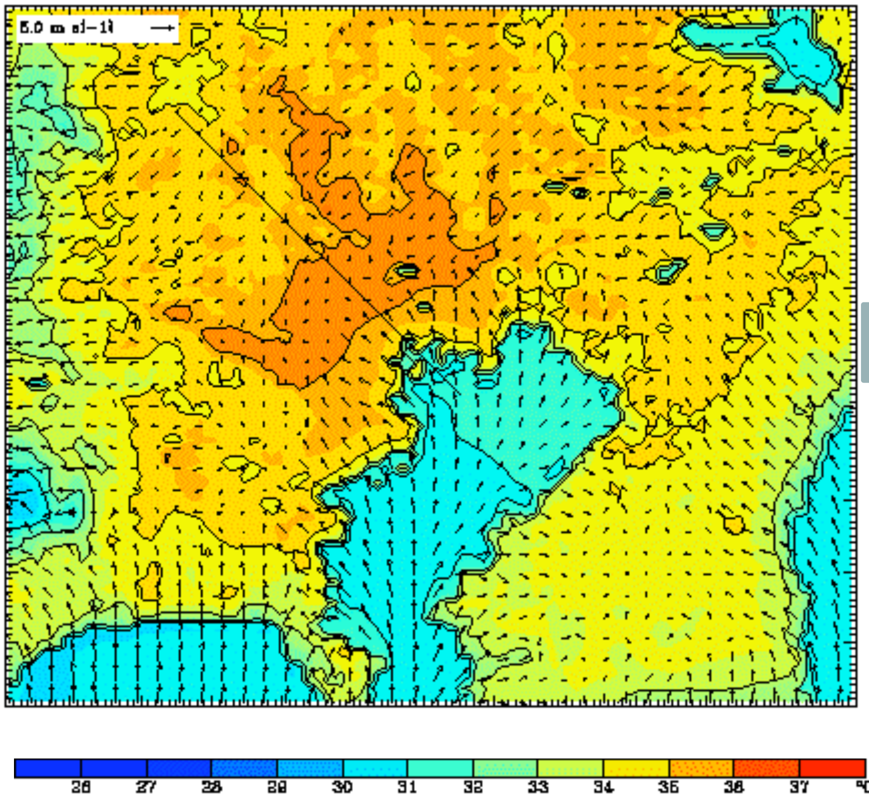
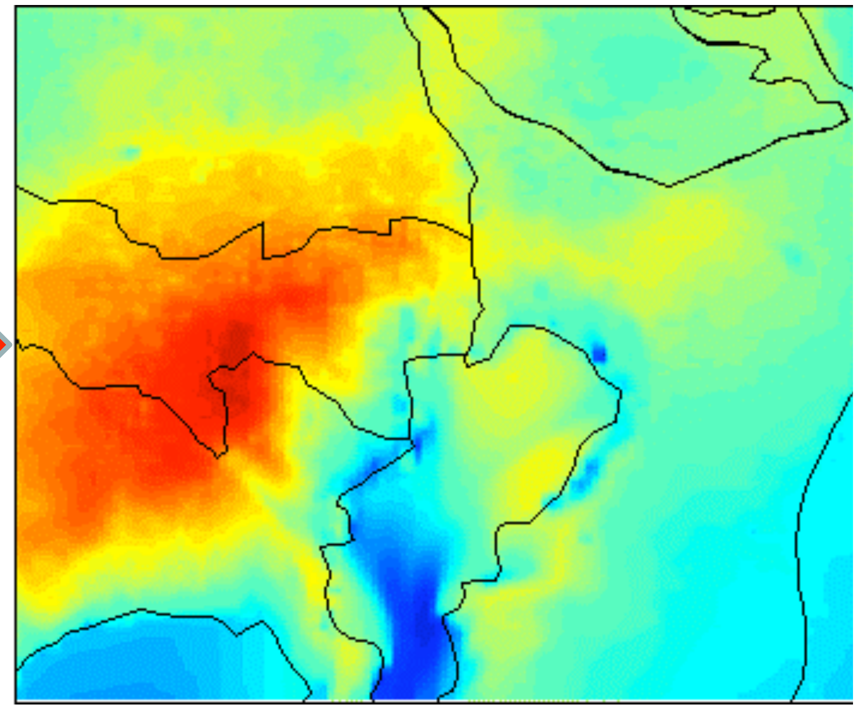
4.4 Ozone levels – Urban Heat Island: Simulation analysis

- UHI ~ high temperature, weak wind >> more photochemica production and more O_3 accumulation >> more O_3



Temp & Wind



Ozone

14:00 JST, August 4th

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5. Conclusions

- There is a close relationship between meteorological conditions and the peak O_3 in summer over the central Kanto area

- Up to 84.1% of the long-term variation of the peak O_3 may be accounted for by changes in T and U, while that is about 70.3% in the short-term variation

- UHI has strong effect on O_3 levels.

- **Changes in meteorological conditions may contribute to the rising O_3 levels over the central Kanto area!**

Thank you
for your attention!