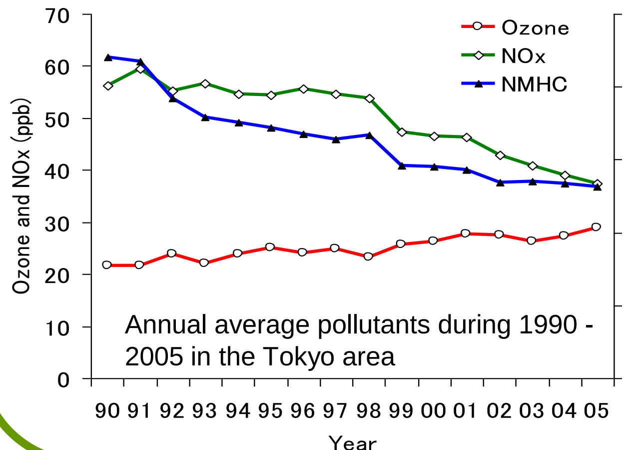
ANALYSIS OF INFLUENCE OF METEOROLOGICAL CONDITIONS ON SUMMER OZONE LEVELS OVER CENTRAL KANTO AREA

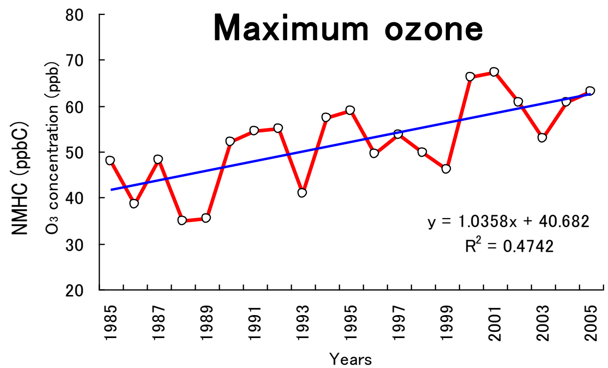
関東地方におけるオゾン濃度と気象条件の関連分析

Background

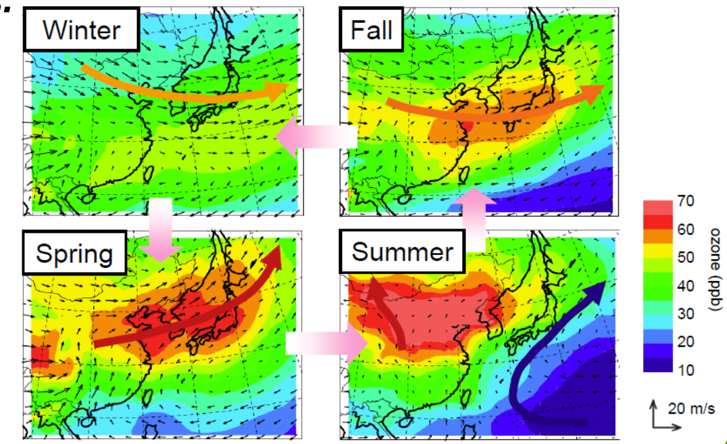
- Both NOx and NMHCs emission are decreasing, but ground O_3 concentration is increasing. It is believed that is due to increase of trans-boundary from East Asia, particularly in spring (Ohara, 2007).
- However, in summer, it is not clear yet how steady the increasing trend is.



Annual average pollutants during 1990 - 2005 in the Tokyo area



Long term changes in daily maximum O_3 concentrations in summer in Tokyo area



Seasonal variation of ozone (Ohara, 2007)

Investigate the factors that affect O_3 levels is very helpful for better understanding variations in ozone concentrations in summer

Objectives of research

- Apply multiple-scale numerical model for assessing environment issues
- Investigate the effect of meteorological conditions on O_3 levels in summer over the central Kanto area
- Analyze formation process of high O_3 levels in summer over the central Kanto area

Methodology

- Numerical simulation using the MM5/CMAQ modelling system
- Statistical analysis using a multiple regression analysis

Description of a numerical model

Analysis area and configuration

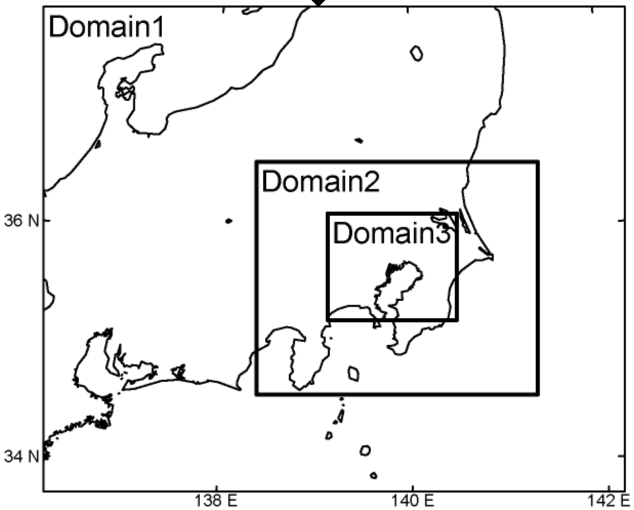


Table 1: Analysis size domains and grid resolution

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

MM5 model

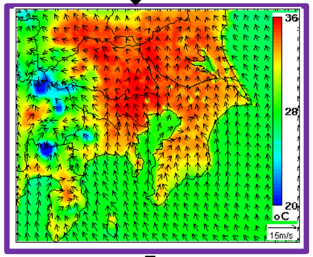
The Fifth-Generation NCAR / Penn State Mesoscale Model

Calculating

wind, temperature, pressure, etc.

FDDA

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

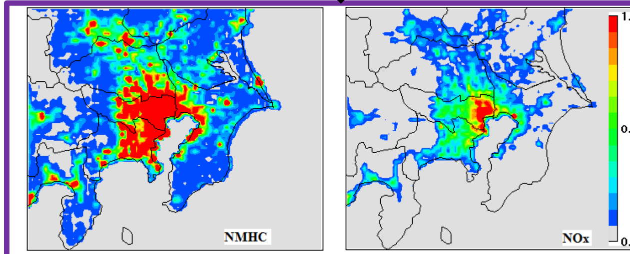


EMISSION DATA (2000)

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)

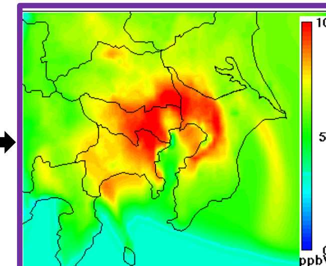
CMAQ model (EPA, USA)

The Community Multi-scale Air Quality modeling

- transport
- chemistry
- depositions
- cloud, precipitation
- aerosols

Initial and boundary conditions

JCAP

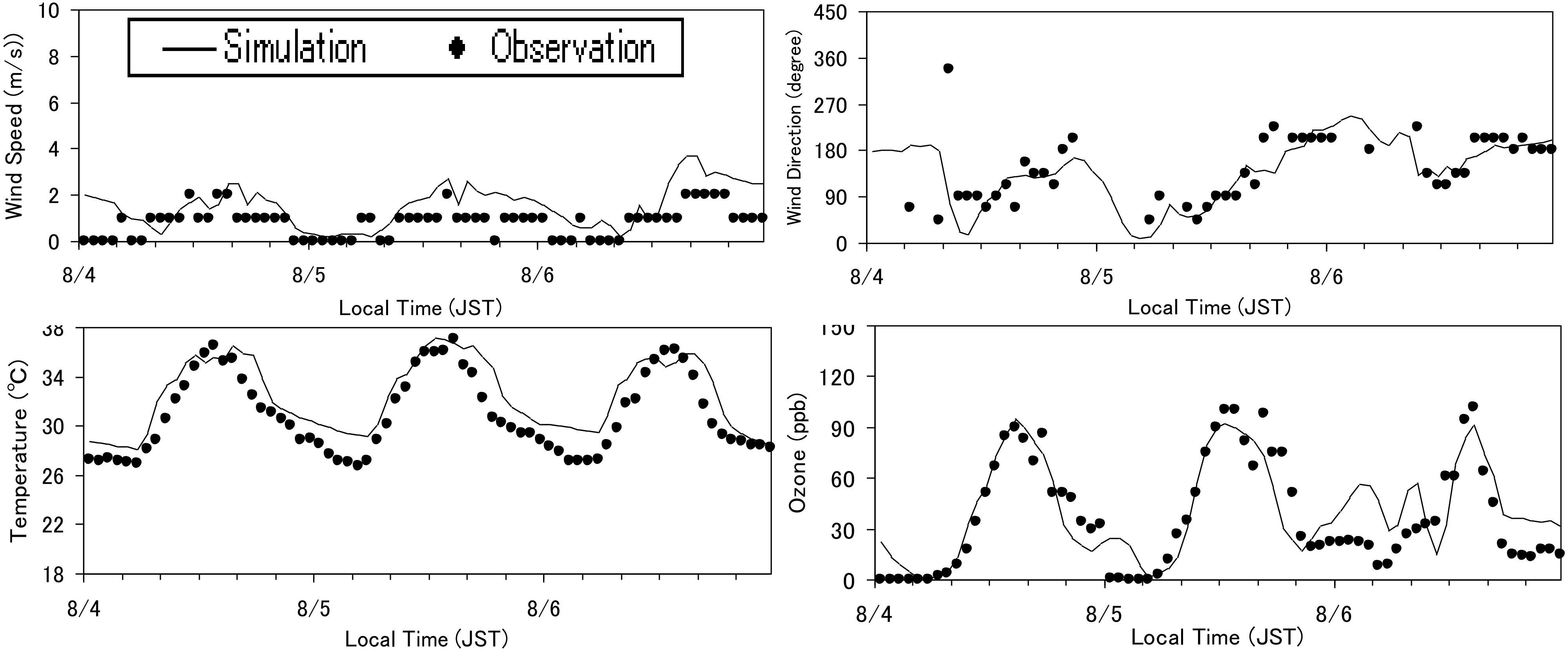


Air quality concentration O_3, NOx, CO..

Chemical/physical processes: MM5/CMAQ Default

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)										

Model evaluation (for Nerima, Tokyo)

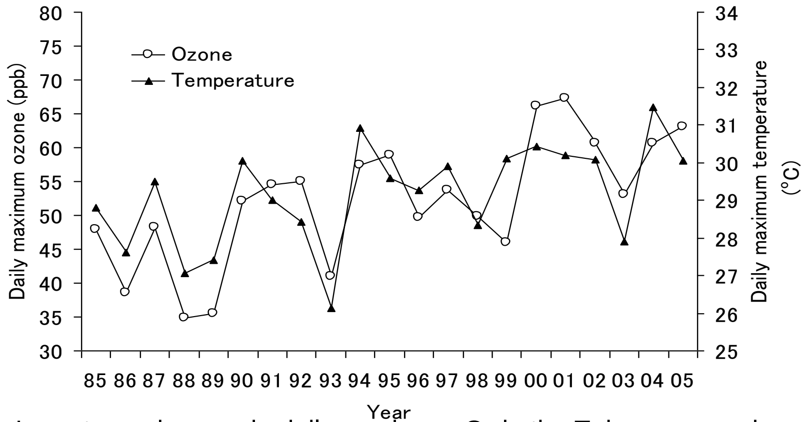


☐ Statistical measures

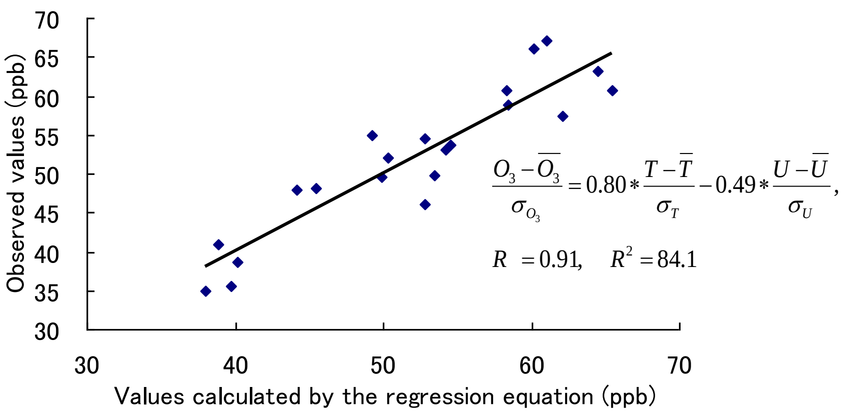
Variables	Mean Bias	Mean Error	Root Mean Squared Error	Correlation Coefficient
Wind speed ($m.s^{-1}$)	0.8	0.9	1.0	0.6
Wind direction (degree)	-6.0	35.6	56.2	0.6
Temperature (°C)	1.6	1.7	1.9	0.9
Ozone (ppb)	4.7	13.8	17.0	0.9

Investigating relationship between the meteorological conditions and O_3 levels in summer

◆The peak O_3 - meteorological conditions



Long-term changes in daily maximum O_3 in the Tokyo area and daily maximum temperatures at Nerima (Tokyo) in the summer



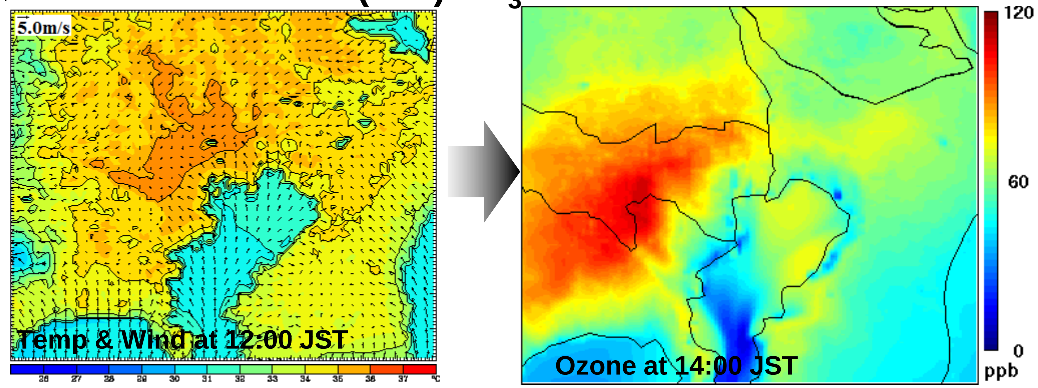
$$\frac{O_3-\overline{O_3}}{\sigma_{O_3}} = 0.80*\frac{T-\overline{T}}{\sigma_T} - 0.49*\frac{U-\overline{U}}{\sigma_U},$$

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

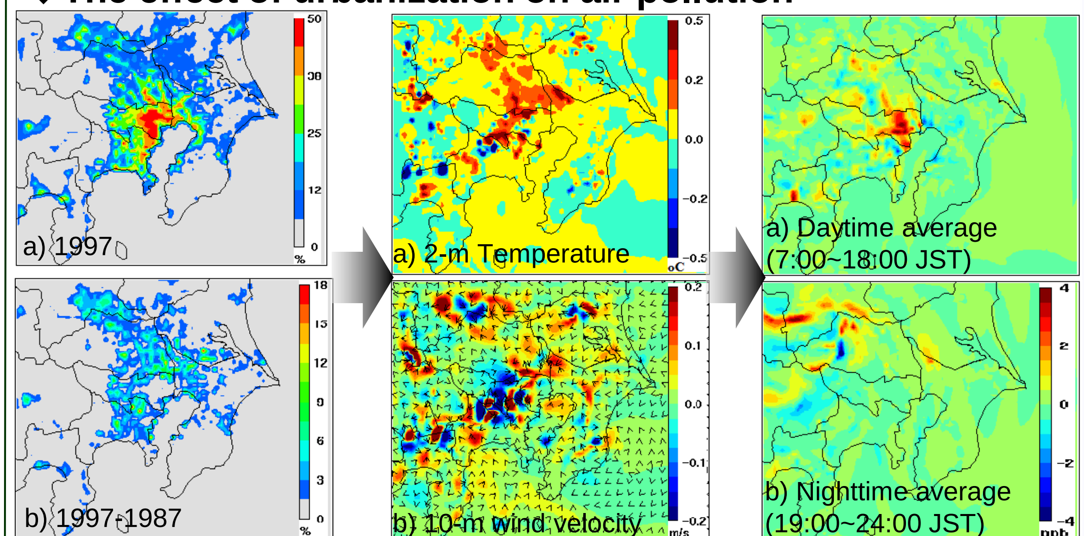
The observed seasonally averaged daily maximum O_3 for summer in the Tokyo area plotted against those predicted by the regression equation

➢ About 84.1% of the long-term variation of the averaged daily maximum ozone during 1985-2005 may be accounted for by changes in daily maximum temperature and averaged wind speed

◆ Urban heat island (UHI) - O_3 concentration



◆The effect of urbanization on air pollution



The areal percentage of urban land-use

Simulated results of case 1997 minus case 1987 at 12:00 JST.

Surface O_3 of case 1997 minus case 1987.

◆The results imply that:

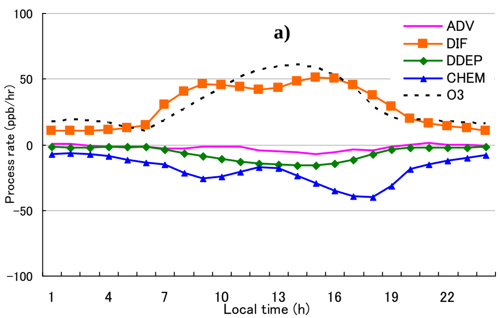
Process analysis of ozone formation under different weather conditions over the central Kanto Area

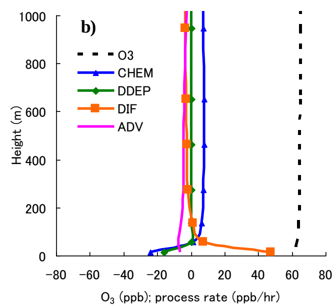
These physical and chemical processes which effect ion O_3 formation can be described in mass conservation equations as follows:

$$\frac{\partial C_i}{\partial t} = -\left[\frac{\partial}{\partial x}(uC_i)+\frac{\partial}{\partial y}(vC_i)+\frac{\partial}{\partial z}(wC_i)\right]_{ADV} + \left[\frac{\partial}{\partial x}\left(K_x\frac{\partial C_i}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial C_i}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z\frac{\partial C_i}{\partial z}\right)\right]_{DIF} + CHEM_i + \left(\frac{\partial C_i}{\partial t}\right)_{DDEP} + \left(\frac{\partial C_i}{\partial t}\right)_{WDEP} + \left(\frac{\partial C_i}{\partial t}\right)_{CLOUD} + \left(\frac{\partial C_i}{\partial t}\right)_{AEROSOLS} \quad (1)$$

Where: C is the concentration of ozone; u, v, and w are the component of the velocity vector; K is the eddy diffusivity; ADV is advection process; DIF is diffusion process; CHEM is the net rate of chemical production; DDEP, WDEP, CLOUD, and AEROSOLS are rate of change of concentrations due to dry deposition, wet deposition, cloud, and aerosol, respectively

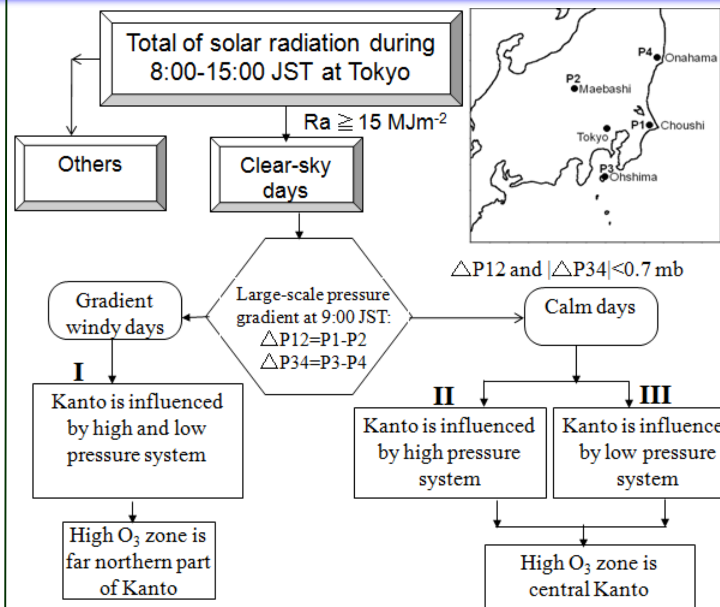
◆ ***Using MM5/CMAQ model , authors quantify the contribution of the different physical and chemical processes to high O_3 levels***

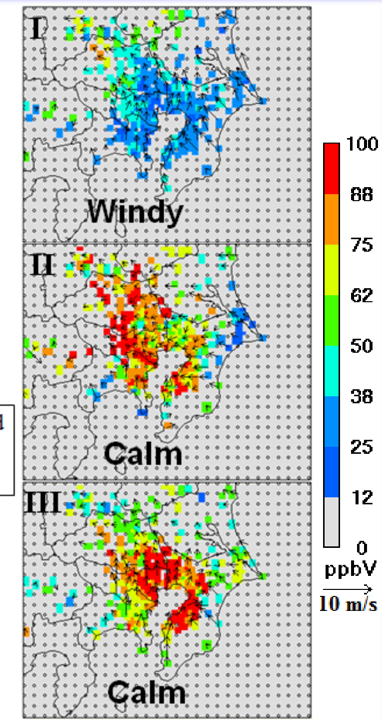




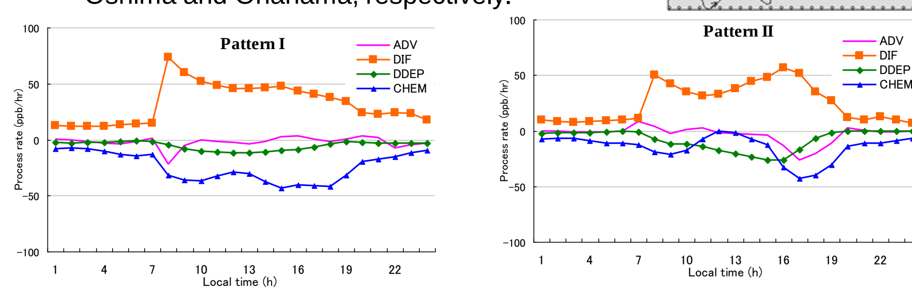
Diurnal variations of ozone concentrations and rate of change in O_3 concentration due to different processes for Nerima, Tokyo in August, 2005: (a) within the first vertical layer of the model; and (b) within the lower atmosphere at 14:00 JST.

◆ ***Comparison of various weather patterns in August 2005:*** High O_3 levels are controlled by three main weather patterns as shown in left side figure. Patterns I and II are regular summertime pressure patterns with a frequency of occurrence of 26% and 16%, respectively. Compared with Patterns I and II, Pattern III is an irregular pressure pattern in summer, and the number of occurrence is small. The contribution of the different components to O_3 with various weather patterns are shown in bottom figure.





Flow chart of weather pattern classification; P1, P2, P3, and P4 are sea level pressures at Choshi, Maebashi, Oshima and Onahama, respectively.



Diurnal variation of the rate of change in ground-level ozone concentrations due to the different processes for the two weather patterns at Nerima, Tokyo.

➢ it can be suggested that the significant decrease in ozone removal due to the chemical and advection processes under conditions of higher stagnation (Pattern II and III) is the most important reason for the enhanced levels of ozone in the central region of Tokyo.