Atmospheric Environment Vol. 24A, No. 8, pp. 2011–2018, 1990.
Printed in Great Britain.

0004–6981/90 $3.00+0.00
Pergamon Press plc

SEASONAL VARIATIONS OF ATMOSPHERIC TRAJECTORIES ARRIVING AT OSAKA IN THE KANSAI AREA

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(*First received* 15 *January* 1989 *and received for publication* 9 *February* 1990)

Abstract—Seasonal characteristics of back trajectories of long-range pollutants beyond 100 km from the ground are studied for the Kansai area of Japan from the climatological point of view. The wind fields in the domain being considered are first determined by a mass-consistent model and then trajectories of pollutants terminating the central urban area of Osaka are estimated using these wind fields. The result shows that routes of back trajectories are primarily determined by synoptic-scale pressure distributions and the topographic feature.

Key word index: Trajectories, mass consistent wind fields.

1. INTRODUCTION

Seasonal or annual characteristics of the transport of airborne materials in a scale of 10 km have been studied for a long time in the research area of air pollution. Recently, increasing attention has been paid to the long-range transport of air pollutants, or radioactive materials that are released from nuclear power plants. Further, as is well known, acid rain falls with water droplets contaminated by sulphur compounds that are released from distant sources in the atmosphere. It can cause serious environmental damage on woodlands in North America and Northern Europe. In Japan, it has been noticed that the long-range transport of air pollutants by sea breeze over the Kanto plain as well as by other local winds sometimes causes inland night-time high oxidant concentrations (e.g. Kimura, 1983; Kurita *et al.*, 1985, 1986; Ueda *et al.*, 1988).

In this paper, seasonal characteristics of back trajectories of airborne material beyond 100 km are investigated from the climatological point of view for the domain centered at the urban area of Osaka (Fig. 1). Surface back trajectories reaching the domain center are estimated for each month of January, April, July and October 1985. The wind fields used for estimating back trajectories are determined by the mass-consistent model developed by Sherman (1978) and with use of the surface wind data obtained by the AMeDAS (Automated Meteorological Data Acquisition System) of JMA (Japan Meteorological Agency). Further, the probability distributions of back trajectory in the research region are estimated.

2. METHOD OF CALCULATION

Figure 2 gives a three-dimensional perspective of the domain under consideration, viewed from the southwest. The central urban area of Osaka is located in the domain center. The horizontal domain sizes are 300 km in both directions and the domain is divided into a grid, with grid-spacing of 5 km. Thus the total number of grid points is 61 × 61 on each horizontal plane. The domain is divided into 12 levels to cover from the ocean surface to 2000 m in height. Vertically stretched coordinates are used with higher resolutions at low levels.

The first task in this study is to estimate the surface wind at each grid point in the model domain. The mass-consistent model proposed by Sherman (1978) is used for this task, since this model handles the wind over complex terrain reasonably well. The wind measured in the AMeDAS is used to construct an initial guess for the wind field. It is next adjusted to satisfy the following equation of mass continuity for an incompressible fluid:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad (1)$$

$$u=u^0+\frac{1}{2\alpha_1^2}\frac{\partial \lambda}{\partial x} \quad (2)$$

$$v=v^0+\frac{1}{2\alpha_1^2}\frac{\partial \lambda}{\partial y} \quad (3)$$

$$w=w^0+\frac{1}{2\alpha_2^2}\frac{\partial \lambda}{\partial z} \quad (4)$$

$$\frac{\partial^2 \lambda}{\partial x^2}+\frac{\partial^2 \lambda}{\partial y^2}+\left(\frac{\alpha_1}{\alpha_2}\right)^2\frac{\partial^2 \lambda}{\partial x^2}=-2\alpha_1^2\left(\frac{\partial u^0}{\partial x}+\frac{\partial u^0}{\partial y}+\frac{\partial w^0}{\partial z}\right) \quad (5)$$

where u^0, v^0 and w^0 are wind components of an initial guess field derived from the observed wind, α_1, α_2 are weighting factors on the relative amount of adjustment in the horizontal and vertical directions, respectively. Equation (5) is solved numerically for λ with the

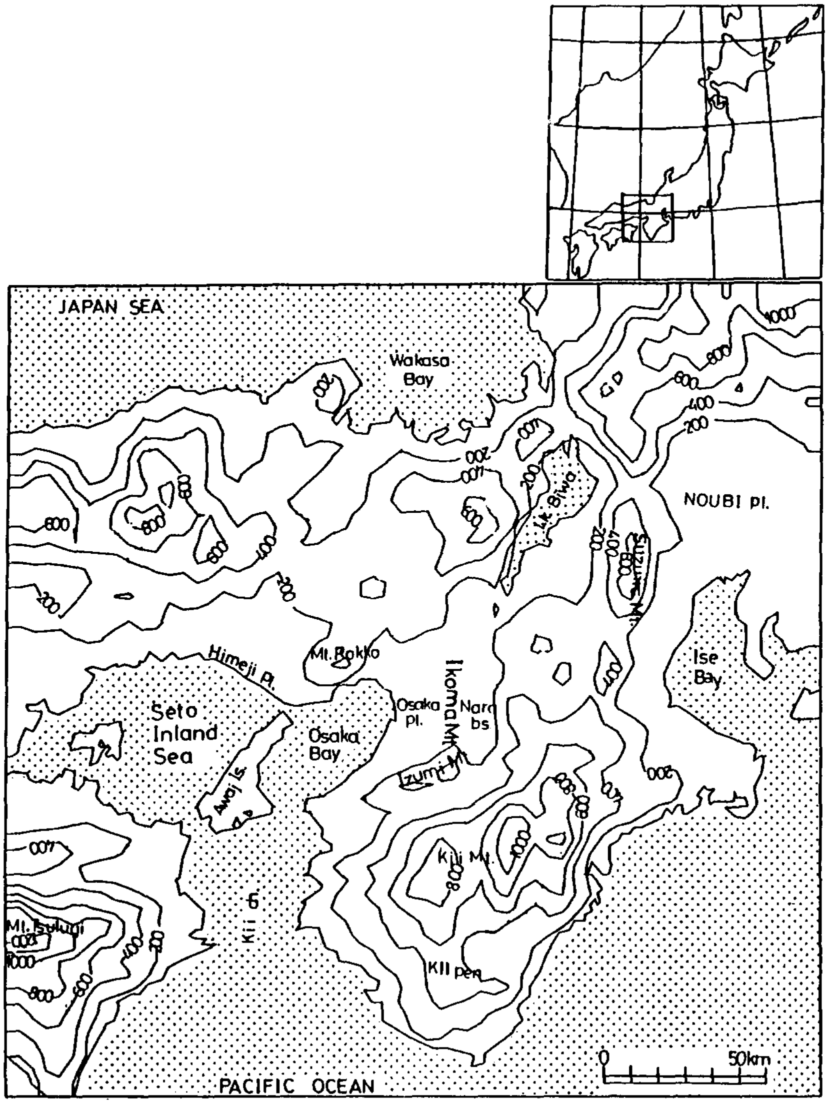

Fig. 1. Map of the research area with topography. Numbers indicate the altitude above sea level.

boundary conditions, using a successive overrelaxation method. Once λ is known throughout the model domain, the adjusted wind (u, v, w) is calculated by (2)–(4).

Sherman (1978) considered two types of boundary conditions: the normal derivative $\partial\lambda/\partial n = 0$ at solid surface and $\lambda = 0$ at open or through flow boundaries. Ishikawa (1983) investigated these boundary conditions in a two-dimensional case with a hypothetical triangle-shaped hill, with the conclusion that the boundary condition $\partial\lambda/\partial n = 0$ at all boundaries gives a more reasonable result. Therefore, Ishikawa's conditions is used in this study.

The horizontal interpolation of wind at 10 m height above the surface is performed by applying a weighting factor of $1/r^2$ at each grid points, where r is the horizontal distance from the grid point to the observation point. The AMeDAS surface wind is observed at every hour. On the other hand, only very little observed upper wind data are available. Consequently, the wind at upper levels is estimated from the surface wind with the aid of the atmospheric boundary layer theory and by making the following assumptions.

(i) The model atmosphere is divided into the three layers: the surface boundary layer (surface to 50 m height); the upper boundary layer (50 m to the free atmosphere) and free atmosphere (model top).

(ii) Wind profiles are prescribed for each layer. In the surface layer, the logarithmic law is assumed without change of wind direction. In the upper boundary layer, a power law profile is assumed with the wind direction varying linearly with height between the top of the surface layer and the free atmosphere (top of model).