B-51.1.4 Studies on the modeling of GHG balance and its influence at synoptic scale

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Abstract

The change of land-use/coverage, typically deforestation and the following change to agriculture or pasture field or plantation in South-east Asia, is suspected to change the greenhouse gas (GHG) emission from its traditional equilibrium stage. We developed estimation models for the influence to the atmosphere due to the disturbance at the GHG balance.

The prototype models are Chemical Transportation model for global scale, CTM, and Regional Transportation Model, RTM. These are developed at National Institute for Resources and Environment, MITI. It employs the analyzed meteorological data by European Centre for Middle Weather Forecasting. The target area for CTM is from 90E to 150W and between 30N and 30S, and RTM, from 90E to 160E and between 20S and 20S.

In order to investigate the feature of carbon dioxide, CO2, concentration is estimated by CTM using the source inventory data by Fung et al. During the first half of the year, the normalized difference of vegetation index, NDVI, of the forest in Borneo island is larger than 0.5 and the forest absorbs atmospheric CO2. In the last half year, NDVI is smaller and forest emits CO2. The calculated CO2 concentration in Borneo is low in the first half of year and high in last. This tendency could not be found at CO2 concentration observation at Bukit Sueharto, Kalimantan Timur. The model tuning is carried out by the high aerosol concentration caused by the large scale forest fire in 1997 El Nino. Aerosol distribution is calculated by RTM using the distribution of hot-spots observed/analyzed by ERS/ASTR. The calculation output consists with the satellite observation by NASA/TOMS. Forward and backward type trajectory models were developed to estimate the relationships between the sources and receptors.

Key Words land-use/cover change, CO2 concentration, chemical transportation model, regional transportation model, trajectory model

1. Introduction

land-use/cover features are changing due to the large scale deforestation in the tropical Asia. It is important for the prediction of the future CO2 concentration in the atmosphere to estimate the changes the emission/absorption of the green-house gases, especially carbon dioxide, CO2, due to the deforestation and the subsequent farmland or plantation. However, it is in controversy whether the tropical forest is a net sink for the atmospheric CO2. Considerably large portion of the tropical forest has already been logged. Additional area will be converted into agricultural field to meet with the increasing food demand. There needs to assess effects of land-use/cover change on the carbon dynamics in the tropical forest area.

2. Objectives of the research

The change of land-use/coverage, typically deforestation and the following change to agriculture or pasture field or plantation in South-east Asia, is suspected to change the greenhouse gas (GHG) emission from its traditional equilibrium stage. The objectives of this study is to develop estimation models for the influence to the atmosphere due to the disturbance at the GHG balance.

3. Materials and Methods

The prototype models are Chemical Transportation Model for global scale, CTM, 1) and Regional Transportation Model, RTM 2). These are developed at National Institute for Resources and Environment, MITI. It employs the analyzed meteorological data by European Centre for Middle Weather Forecasting, ECMWF. The model resolution is consistent to the meteorological data. The resolution of CTM is 2.5 degree in space and 12 hours in time and RTN 0.5 degree and 6 hours. The study area is set to Malesia and Melanesia, ie. from Malaysia peninsula to South Pacific islands. The target area for CTM is from 90E to 150W and between 30N and 30S, and RTM, from 90E to 160E and between 20S and 20S.

4. Results and Discussion

4.1 CTM

In order to investigate the feature of carbon dioxide, CO2, concentration is estimated by CTM using the source inventory data by Fung et al 3). This estimates the CO2 emission/absorption by air temperature and Normalized Difference Vegetation Index, NDVI, observed by NOAA/AVHRR. The seasonal change of the NDVI at Borneo island are shown in top of Figure 2 and the corresponding CO2 emission/absorption in bottom. During the first half of the year, it is rainy (not so clear) in Borneo island and NDVI of the forest is larger than 0.5 and the forest absorbs atmospheric CO2. In the last half year, NDVI is smaller and forest emits CO2. Figure 3 shows the source intensity distribution and the CO2 concentration distribution for spring time. Figure 4 shows the same as Figure 3 but for winter time. The calculated CO2 concentration in Borneo is low in the first half of year and high in last. This tendency could not be found at CO2 concentration observation at Bukit Sueharto, Kalimantan Timur 1998. This study should be continue to investigate that this is due to El Nino1997 or not.

4.2 Trajectory Analysis

Forward and backward type trajectory models were developed to estimate the relationships between the sources and receptors.

Supposed starting points in forward trajectory model are set at Palembang and Jambi, Sumatra island and south Borneo island where forest fires occurred frequently in 1997 and 1998. The air-parcel starts at every 6 hours and the positions are calculated by interpolation of the surrounding wind data. Figure 5 shows the wind system and trajectory in early spring, 1992. In this period the air parcels are flown over Java sea by the weak north-west monsoon. After May, the wind system changes to south-east monsoon. Air parcels moves to Malaysia peninsula as shown in Figure 6. Then they turns to north-east along the InterTropical Covergence Zone, ITCZ, over the Malaysia peninsula and arrive Philippine island after 7 days. This situation continues up to November and returns to the first stage.

Backward trajectory model is used to investigate the origin and history of the air parcels at observation points. Figure 7 shows an example for early October, 1997. The starting points of backward are Tana Rata and Kuala Lumpur, Malaysia and Singapore. The starting altitude is 400hPa. The air parcels arrived these points come from over Borneo island by easterly winds. Ozone sounding at Tana Rata observed values which were influenced by the forest fire. This model gives powerful backup evidence for these phenomena.

4.3 RTM

Regional Transportation Model is applied in this area to adapt to the source inventory data set. The resolution is 1 degree, about 100km, in longitude and latitude at moment. The model tuning using GHG in this area is not suitable due to the shortage of the observation data. It is carried out by the high aerosol concentration caused by the large scale forest fire in 1997 El Nino. Figure 8 shows the distribution of the hot spots observed/analyzed by ERS/ASTR for October, 1997 4). Each hot spot is assumed to emits one unit of aerosol. Source intensity is the summation of the spots in 1 degree by 1 degree. Forest fire occurred mainly in the area of Palembang and Jambi, Sumatra island and south part of Borneo island. The hot spot data is summarised by month from August to December, 1997. Aerosol distribution is calculated by RTM using the distribution of hot-spots in October, when the forest fire was most frequent and the influence was extended to the neighbour countries. Figure 9a shows the calculated distribution of aerosol in surface layer at late October and Figure 9b for upper troposphere, 4km high. In the surface layer, the aerosol due to the forest fire flowed to Malaysia peninsula and south China sea driven by south-east wind over Java sea. Then turned to Philippine island by the westerly wind over south China sea. The aerosol in upper layer is carried toward west by easterlies. The features were more complicated by the locations of lifting from lower layer. The calculation output consists with the satellite observation by NASA/TOMS analyzed by Singapore Meteorological Service as shown in Figure 10.

5. Concluding remarks

Estimation models are developed for the change of GHG emission due to the land-use/coverage change. Global scale transportation model will be employed for the long life time material amd regional transportation model for short life time material. The physical relationships between the source and receptor is analyzed by the forward /backward trajectory model. These models are tuning to apply to field application. The large scale forest fire 1997-98 in Indonesia will support an opportunity to refine the model and analyze the atmospheric phenomena.

6. Reference

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2) Maeda T. et al., 1996: Development of long range transportation model of air pollutants in East Asia (in Japanese), Symposium on Environmental Technology.
3) Fung I. Et al, 1987: Application of advanced very high resolution radiometer vegetation index to study atmospheric-biosphere exchange of CO2, J.G.R. 92, 2999-3015
4) World Fire Atlas, 1999: http://shark1.esrin.esa.it/FIRE

Figure 1. Study area. Large area for global CTM and small for RTM.

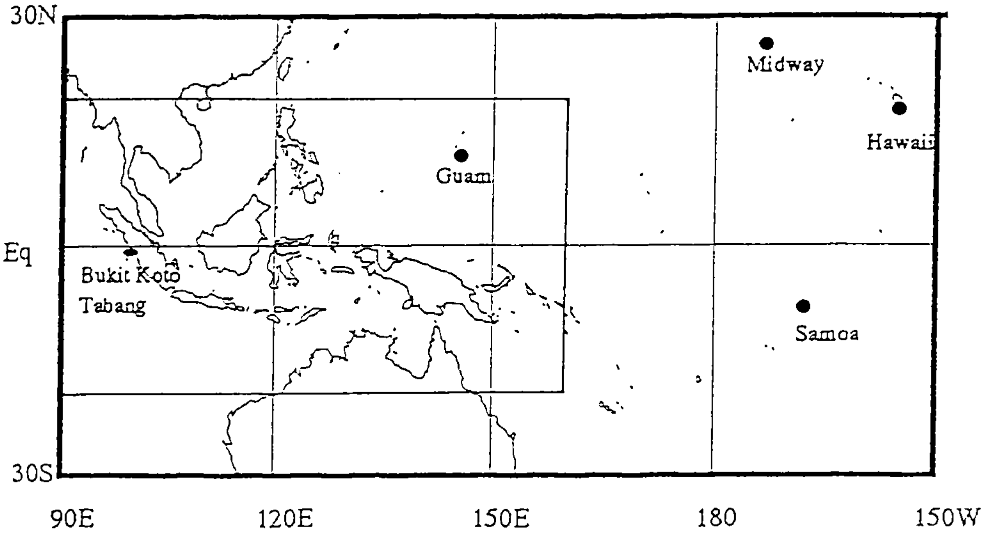

Figure 2. Seasonal change of NDVI over Borneo island along equator (top) and Corresponding CO2 flux from forest to atmosphere (bottom).

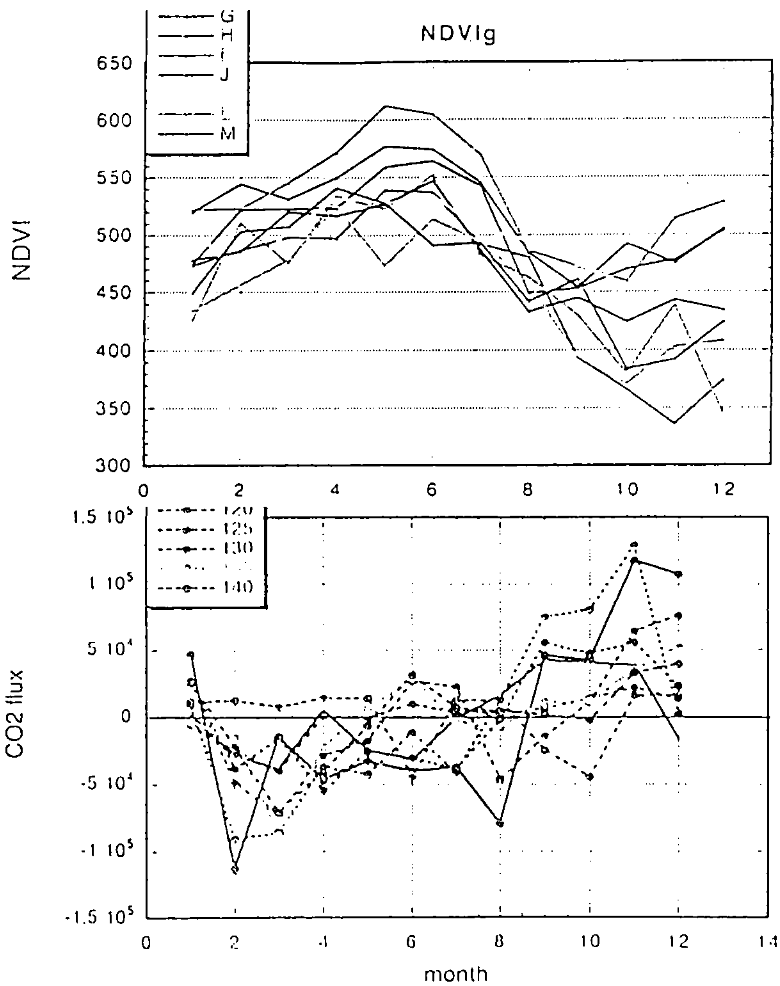

Figure 3. CO2 emission/absorption intensity distribution (top) for spring and Calculated CO2 concentration distribution in surface layer by CTM (bottom)

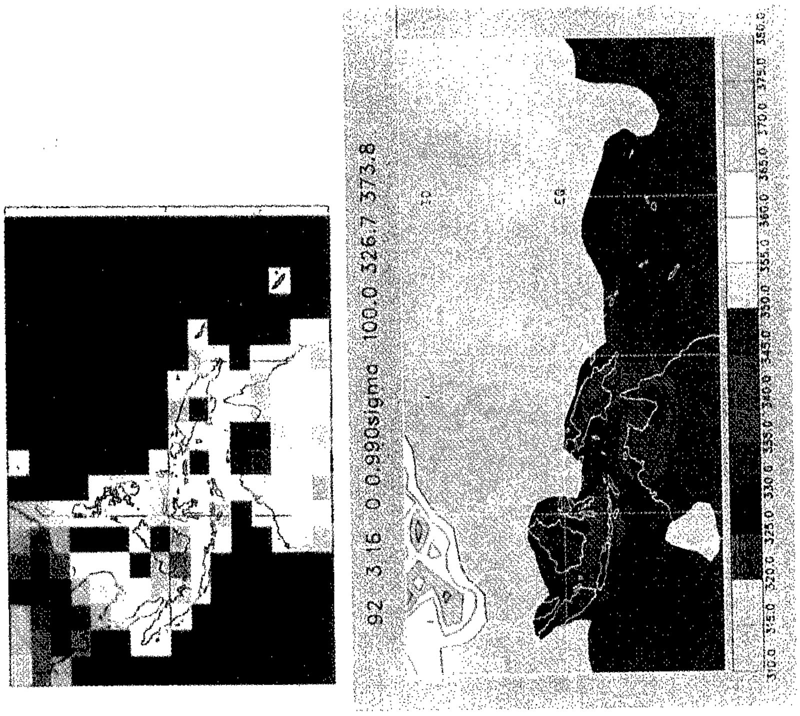

Figure 4. Same as Figure 3 but for winter.

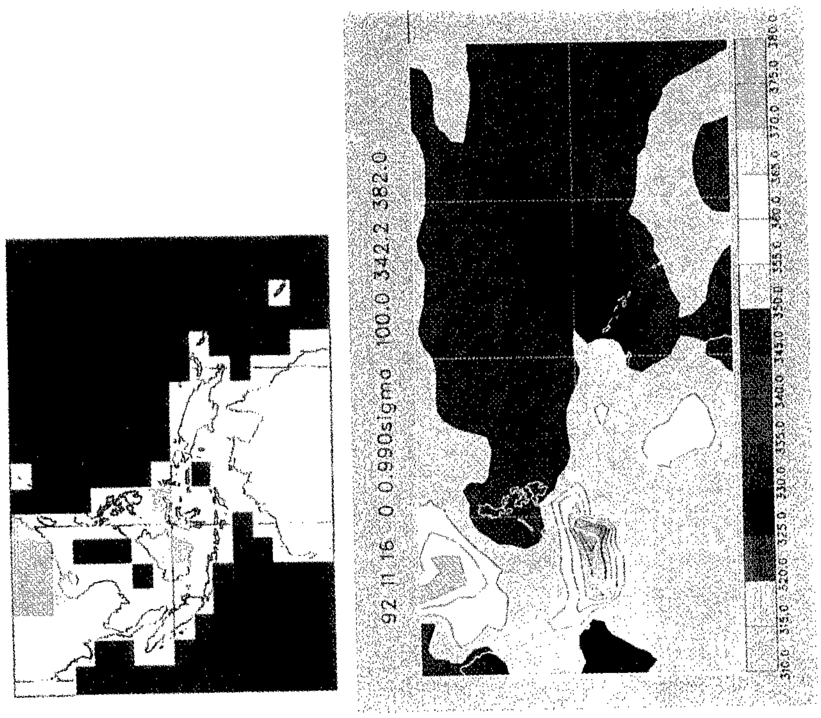

Figure 5. Wind system and the forward trajectory for February, 1992.

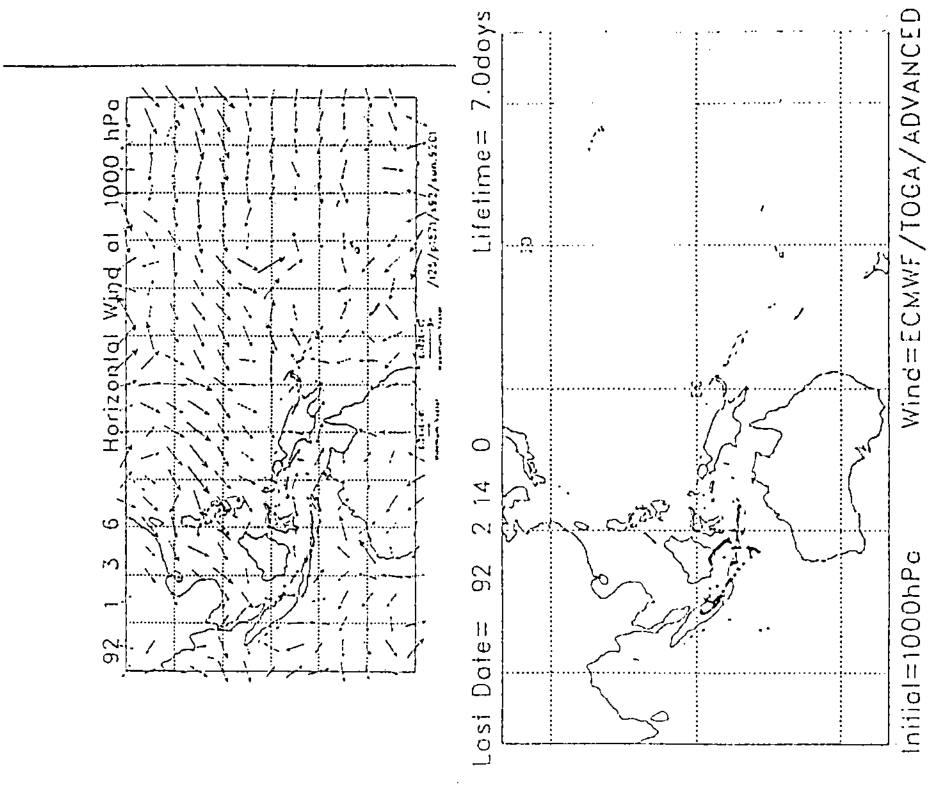

Figure 6. Same as Figure 5 but for October, 1997.

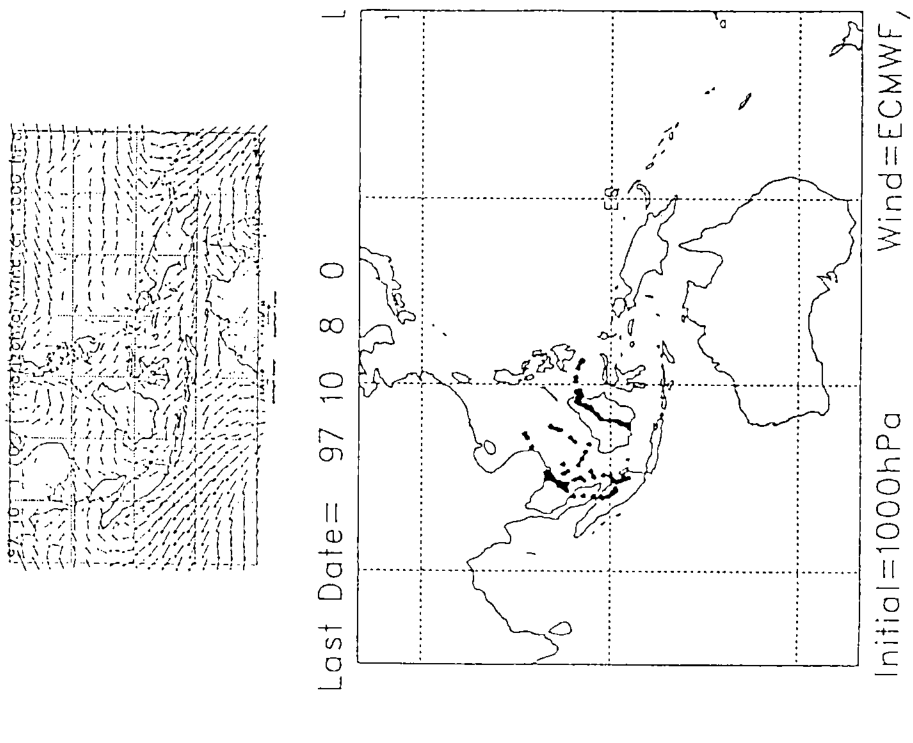

Figure 7. Same as Figure 5 but for backward and October, 1997.

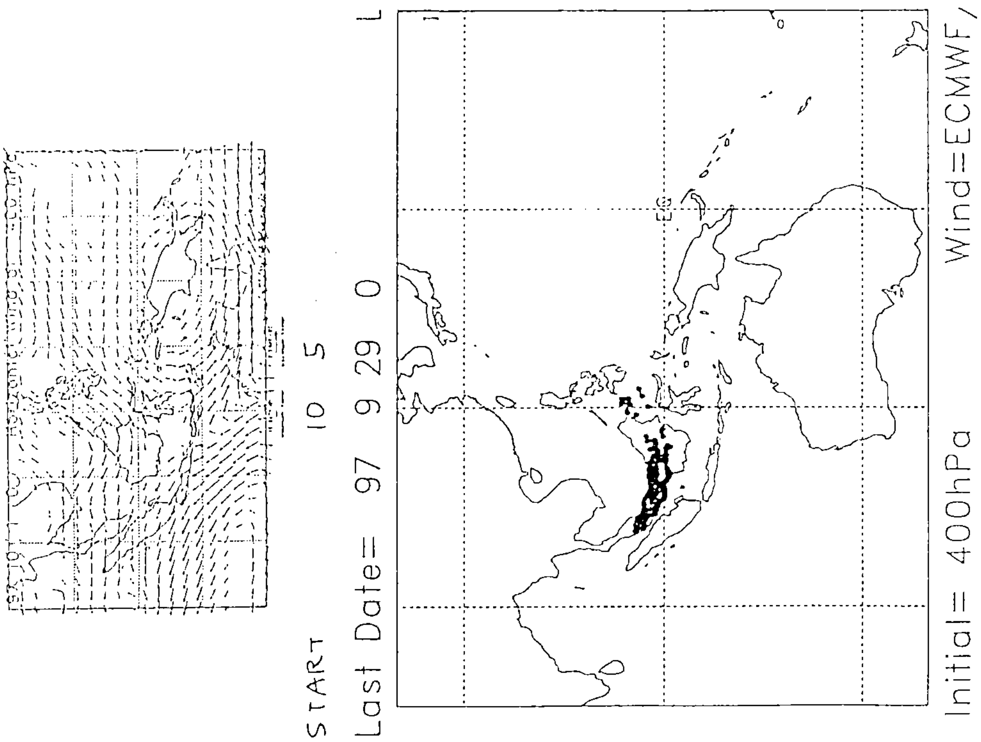

Figure 8. Forest fire hot spot in October,1997, in Indonesia.

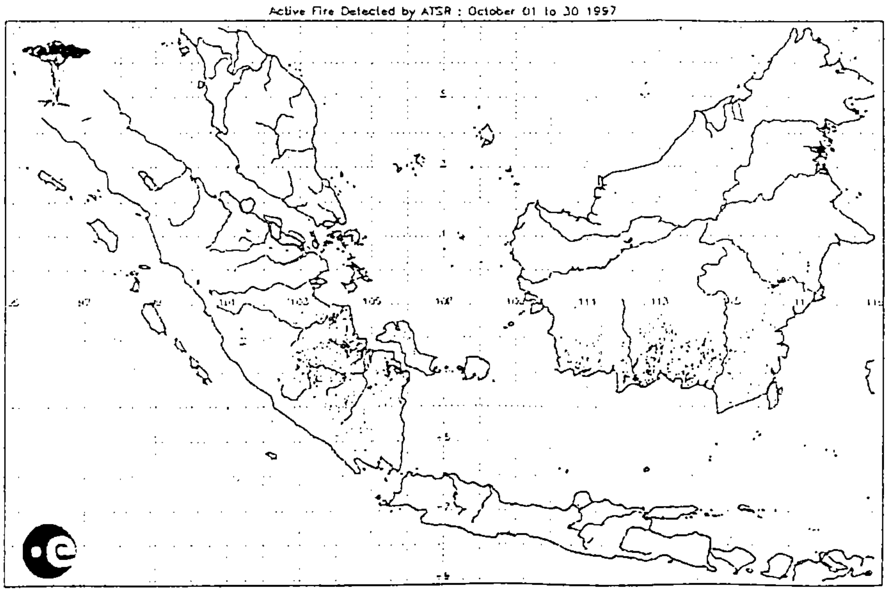

Figure 9a. Calculated aerosol distribution in surface layer for September 24, 1997.

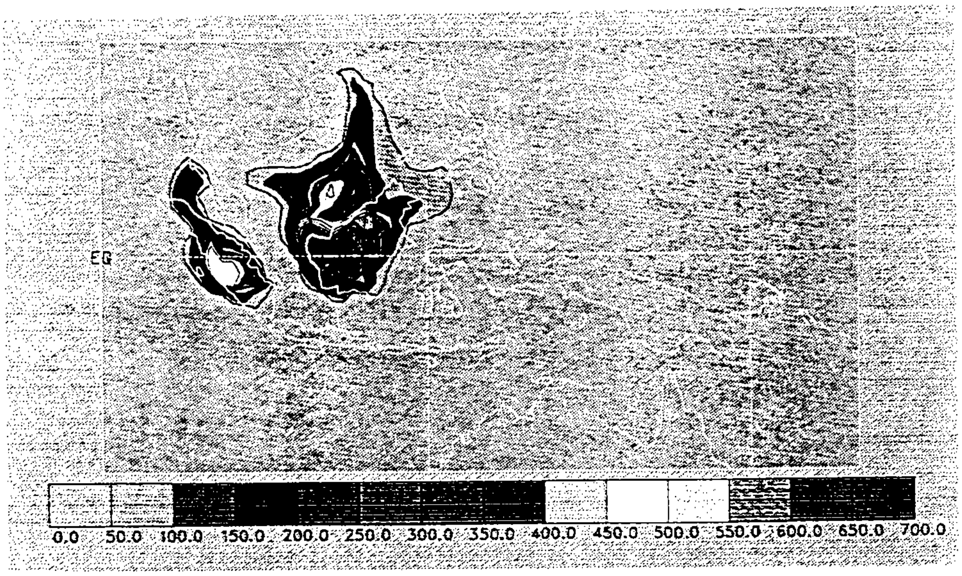

Figure 9b. Same as Figure 9a but for 4 km upper layer.

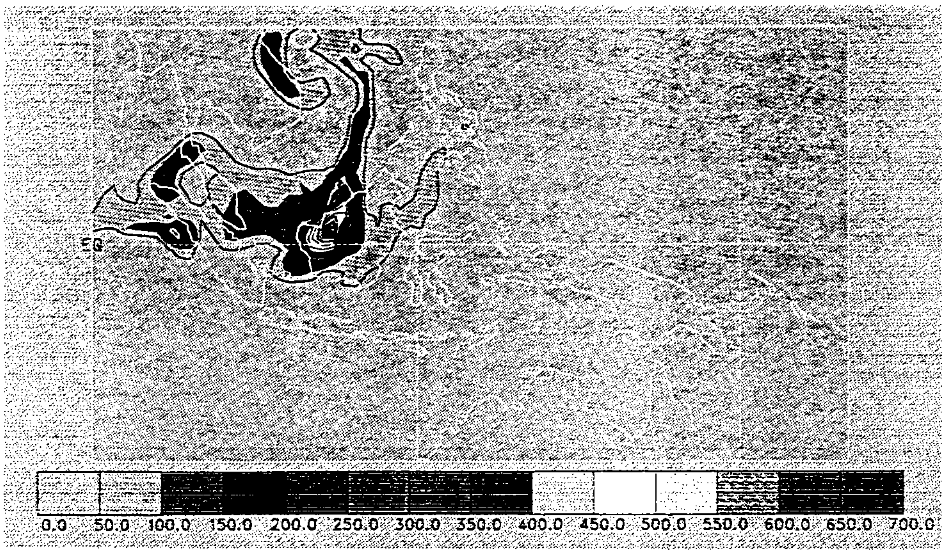

Figure 10. Aerosol distribution observed by NASA/TOMS and analyzed by Meteorological Service Singapore for September 24, 1997.