Three-Dimensional Distribution of Atmospheric Ozone

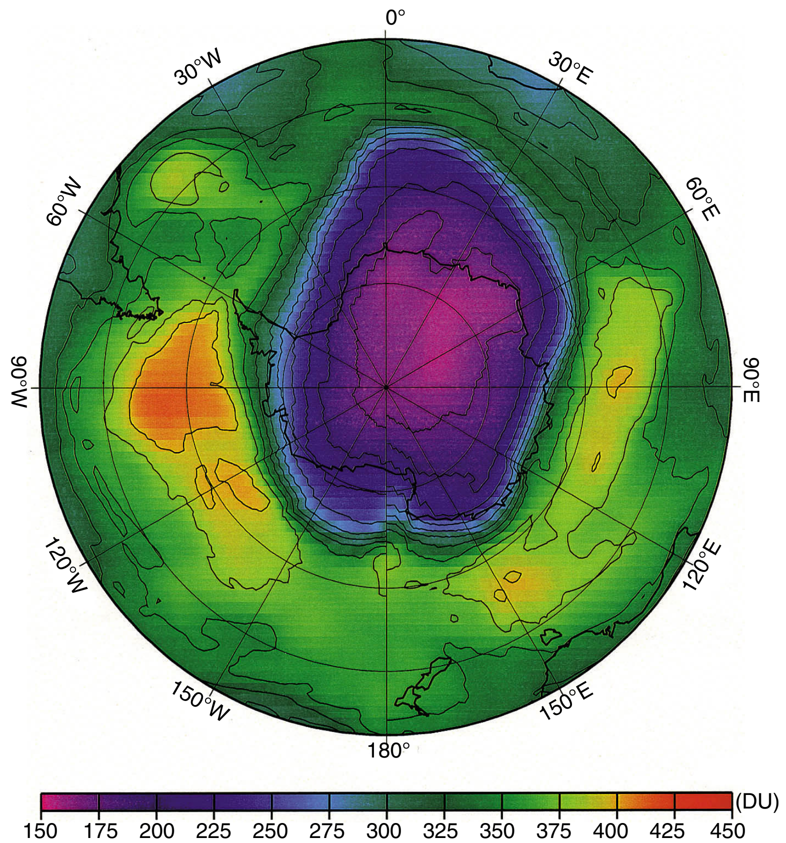

Fig.1*1 Total Ozone　　ADEOS TOMS

Total ozone map around the south pole (4 November 1996). The data was provided by ADEOS TOMS.

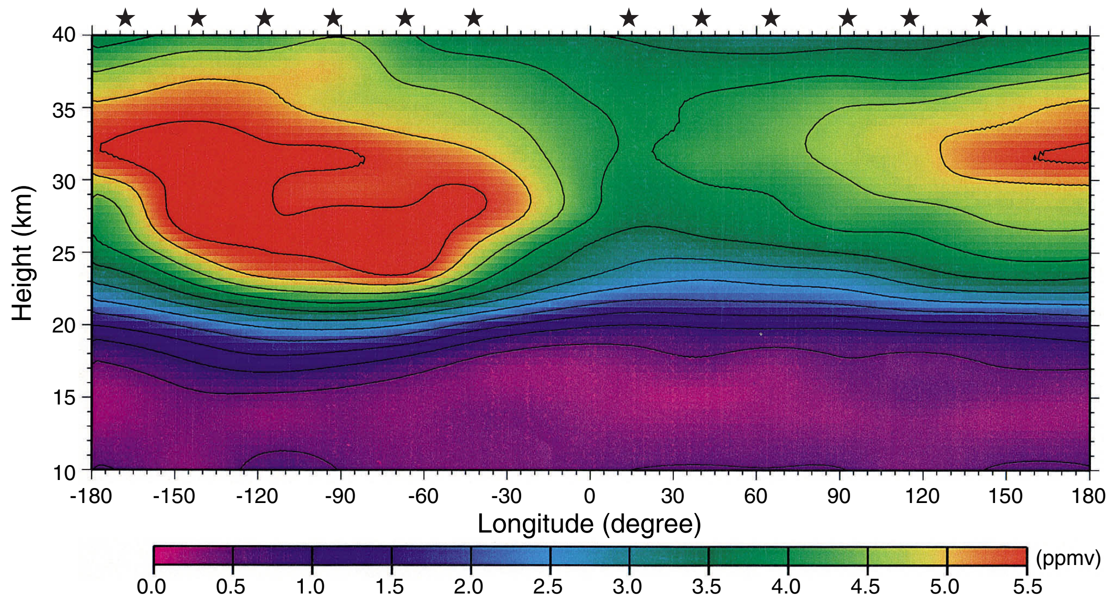

Fig.2*2 Ozone Mixing Ratio along 73.9°S - 74.2°S　　ILAS Version 3.10

Ozone distribution in an altitude-longitude cross-section along a 74°S latitude circle (4 November 1996). Stars give the footpoints of ILAS observations.

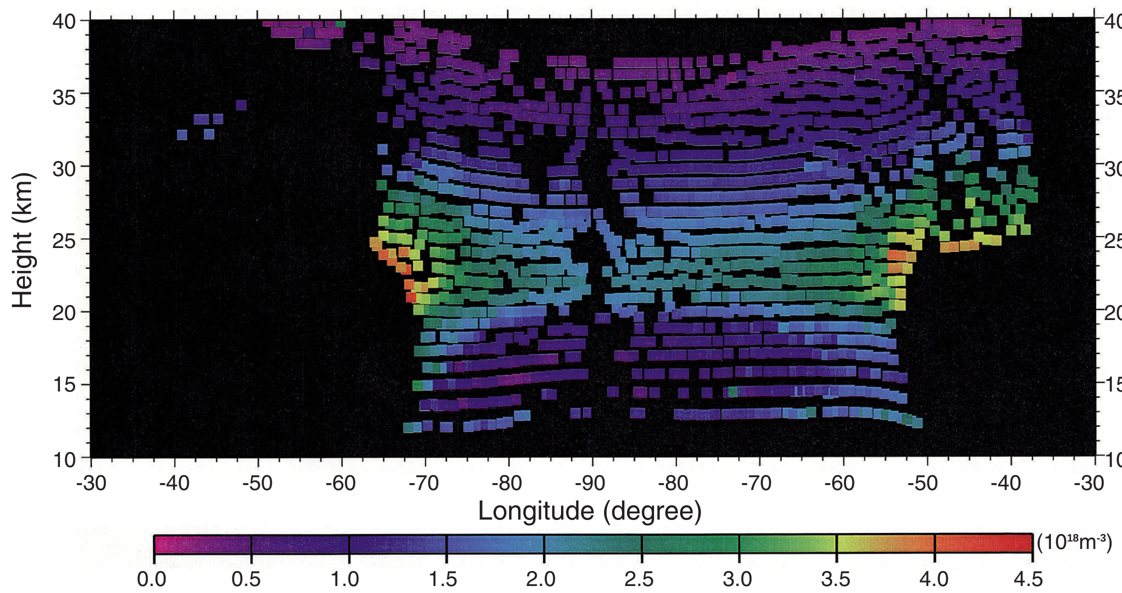

Fig.3*2 Ozone Number Density in the 0°- 180° longitude meridian in Southern Hemisphere　　ILAS Version 3.10

Ozone density distribution along a meridian (0E to 180E) in Southern Hemisphere (4 November 1996). The pattern was derived by a trajectory analysis using the UKMO assimilation data and the ILAS data inside the polar vortex obtained during the period of 30 October to 9 November 1996.

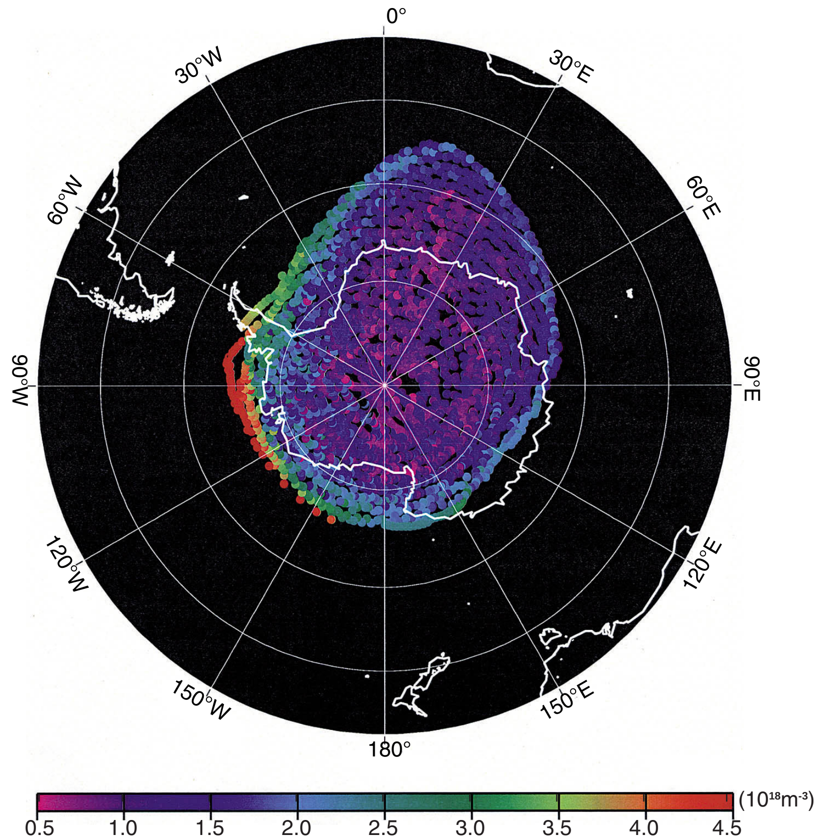

Fig.4*2 Ozone Number Density near 17.5 km in altitude　　ILAS Version 3.10

Ozone density distribution in a horizontal layer from 15km to 20km (4 November 1996). The pattern was derived by a trajectory analysis using the UKMO assimilation data and the ILAS data obtained during the period of 30 October to 9 November 1996.

*1 Produced by NIES using ADEOS TOMS data
*2 Produced by NIES using ADEOS ILAS data

Three-Dimensional Distribution of Atmospheric Ozone

In the upper air, there is an ozone-rich region called the stratospheric ozone or the ozone layer. The ozone layer is critical to life on Earth as it absorbs solar ultraviolet (UV) radiation of wavelengths less than 300 nanometers (nm). This shielding is not complete around a wavelength of 300 nm, and some solar UV can reach the Earth's surface. This solar UV which belongs to the B region of UV (UV-B) may adversely affect humans, crops and aquatic plankton. The amount of UV-B flux on the Earth's surface depends sensitively on the atmospheric ozone content as well as the solar elevation angle and clouds.

The solar UV energy absorbed by atmospheric ozone is converted to heat, providing an important atmospheric heat source. The general circulation is derived in the atmosphere because of the latitudinal difference of the heat source intensity. The variations in stratospheric ozone may influence medium-range weather variations and climatic variations near the Earth's surface. Stratospheric ozone depletion due to man-made CFCs (chlorofluorocarbons) became real when an ozone hole occurred in the Antarctic spring. A decreasing trend of ozone in the lower stratosphere has become evident in winter and spring seasons in middle and high latitudes of the northern hemisphere. It is ascribed to the ozone destruction by chlorine liberated from CFCs and bromine liberated from halon and methyl bromide. Although the production of ozone-destroying substances was phased out by the international treaty, it takes more than 10 years before the atmospheric chlorine and bromine content begins to decrease because of their long residence times in the atmosphere and because of their production in non-treaty countries. Moreover, the stratosphere will be cooled due to the increase of greenhouse gas concentrations, which will augment the ozone depletion due to chlorine and bromine. It is predicted that the decreasing tendency of stratospheric ozone will not terminate soon, and that the Antarctic ozone hole will not disappear until after the middle of the 21st century. Therefore, a sustaining watch on the stratospheric ozone variation is highly important.

The tropospheric ozone produces a greenhouse effect because it imprisons the Earth's thermal radiation. Ozone is produced in the troposphere through photo-chemical reactions among nitrogen oxides, carbon monoxide and hydrocarbons. The tropospheric concentrations of these species have increased due to human activities such as industrial combustion and biomass burning (wild fires, fuel wood burning, slash and burn practices, and so on) on the ground surface, and lightning and exhaust from aircraft engines in the upper air. The 1994 IPCC report states that the increasing ozone in the troposphere may impact global warming.

Atmospheric ozone is crucial in our living environment and in controlling the Earth's climate. In global change, it is essential to measure the temporal variation of three-dimensional distribution of atmospheric ozone accurately, to understand the mechanism of its variation, and to predict its variation.

ADEOS carried three instruments, TOMS, IMG and ILAS, to measure atmospheric ozone. TOMS produced a worldwide map of total ozone (*1) in a day. IMG measured the stratospheric and tropospheric ozone separately and globally in the daytime and at night. ILAS measured the vertical distribution of stratospheric ozone in both northern and southern high latitudes where the ozone depletion was most significant. Since ILAS measured other species related to ozone destruction reactions, its data are very useful in understanding the detailed mechanism of the ozone depletion.

Figure 1 is the southern hemispheric distribution of total ozone on 4 November 1996 as constructed from the TOMS data. It shows the ozone hole that constitutes the low values of total ozone over the Antarctic continent. The ozone hole on this day is elliptic in shape, elongating to the 0 degree longitude. There is a region of large values of total ozone surrounding the ozone hole. Figure 2 is constructed from the ILAS data on the same day, exhibiting the height distribution of ozone mixing ratio (*2) along a longitudinal circle at a latitude of 74 degrees South. It is interesting to see that in the region of 0 to 60 degrees East that is closer to the center of the ozone hole, the ozone mixing ratio is lower at altitudes above 20 kilometers.

The three-dimensional distribution of atmospheric ozone can be constructed based upon a model incorporating the global meteorological analysis data and the chemical reaction scheme, and by using the ozone data from the instruments aboard ADEOS, ground-based observations on total ozone, and ozonesondes on vertical profiles (This model is called a chemical transport model). The data on three-dimensional distribution of atmospheric ozone will be used as input data for the numerical weather forecast model for medium range and for the global climate model, to improve the accuracy of these numerical models.

*1 Total ozone: Ozone density integrated with height from the Earth's surface to the top of the atmosphere. The unit is Dobson Unit (DU), and 1DU = 2.687 X 10^{23} molecules/m^2

*2 Ozone mixing ratio: Ratio of volume density of ozone to the whole atmosphere at a certain altitude. The unit is parts per million by volume (ppmv).

Three-Dimensional Structures of Ozone Layer Observed by ILAS

The Improved Limb Atmospheric Spectrometer (ILAS) measured atmospheric constituents when it was looking at the Sun at sunrise and sunset as seen from the satellite while rotating around the Earth in a polar orbit. ILAS detected the sunlight as a function of wavelength to measure the transmittance spectrum, giving vertical profiles of ozone and other gases concentrations. As the satellite circled the Earth 14 times a day, ILAS could make 14 measurements over high latitude regions in both northern and southern hemispheres. Positions of the measurements made in a day were located along almost the same latitude band and separated from each other by about 25 degrees. Figure 2 shows an ozone mixing ratio distribution in an altitude-longitude cross section, which is a composite of 12 profiles of ozone from the measurements made on November 4, 1996 along the 74°S latitudinal circle.

The TOMS instrument on board ADEOS provided a view of total (column) ozone distribution around the south pole (Fig. 1). The ozone hole seen on the same day as in Fig. 2 was elongated and shifted a little toward 30°E. Since the ILAS measurements positions were along a 74°S latitude circle, ILAS looked at the ozone profiles inside the polar vortex on this day.

ILAS, in principle, provided one altitude-longitude cross-section data a day as shown in Fig. 2. A three-dimensional pattern of ozone distribution on a certain day can be reconstructed with a technique called "trajectory analysis" when combining meteorological data and ILAS-derived ozone data obtained for a period of several days. Figures 3 and 4 display an example of such analyses. The ILAS data inside a polar vortex for 11 days (from October 30 to November 9), with an appropriate interpolation, was used to generate a one-day, three-dimensional distribution pattern for November 4, 1996.

Figure 3 shows an ozone density distribution in a vertical cross-section along a meridian plane which contains longitude 0° and 180°. The left end of this image corresponds to longitude 180° and latitude 30°S, central part, i.e. 90° in the image corresponds to the South pole, and the right end of this image corresponds to longitude 0° and latitude 30°S. Figure 4 depicts a horizontal ozone density distribution of a layer from 15 km to 20 km altitude inside the polar vortex (*1). It is considered that ozone loss is the largest in this layer.

*1 Polar vortex: In the winter season for each hemisphere, a large vortex appears around the pole. This vortex is called a polar vortex.