SOWER/Pacific the Shoyo-maru Pacific Ocean-Atmospheric Survey

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Introduction

The Soundings of Ozone and Water in the Equatorial Region (SOWER)/Pacific mission has been conducted on a campaign basis at San Cristobal, Galapagos and Christmas Island, Republic of Kiribati supplementing the on-going program in Watukosek, Indonesia (SPARC Newsletter No. 10 and 12). During September to October 1999, we were given the opportunity to join the ship cruise of Shoyo-maru, a research vessel of Fisheries Agency of Japan, investigating the fishery resources in the central and eastern tropical Pacific. This is a brief report on the scientific results from the atmospheric research group.

The scientific target of this cruise widely spreads from ocean and atmospheric sciences and from their dynamics and chemistry. In this report a general overview of the Shoyo-maru survey will be described.

The main fields of interest are as follows:

1 - Ozone distribution in the troposphere and stratosphere

2 - Atmosphere-ocean dynamical coupling associated with the tropical instability waves

3 - Marine boundary layer chemistry

We have made regular GPS radiosonde observations four times a day and ozone-sonde observations once a day. The geographical locations of the sonde release together with the ceiling altitude are displayed in Figure 1; you may see the cruise track from this figure. In addition, several types of on-board observations about such as surface ozone, radiation, air and water samples were made along this track.

Corresponding to this cruise, at the two SOWER bases, San Cristobal (the Galapagos Islands) and Christmas Island (see Figure 1), other SOWER team members also performed usual campaign observations.

The following is a description of each scientific field of the research.

Ozonesonde sounding

A VAISALA ozonesonde system (a Science Pump ECC ozonesonde connected with a VAISALA GPS radiosonde) was used for measuring the vertical distributions of ozone and meteorological parameters. Figure 2 summarises the results of ozonesonde observations in longitude-altitude panels. There are 14 successful soundings between 19 September and 3 October.

In the equatorial stratosphere the quasi-biennial oscillation (QBO) is one of the remarkable phenomena. During our cruise an altitude of 25km was nearly the boundary of westerly (lower) and easterly (upper) phases of QBO. As a source of momentum equatorial waves and gravity waves are supposed to play a central role in driving the QBO. However, studies of such waves are rather limited to the western Pacific region. Our soundings of meteorological variables over the central-eastern Pacific will contribute to the investigation of the global wave activities.

In the upper troposphere, above 12km, the average ozone concentration was about 60ppbv with a positive vertical gradient (the bottom panel of Figure 2). These characteristics are not common to those in Indonesia during the December-March period where the concentration is nearly constant at 25ppbv throughout the troposphere, but is consistent with the results in Brazil, over Atlantic Ocean, and in Congo (Fujiwara *et al.*, 1999b). This would be explained primarily by the longitudinal dependence of convective activity which transports ozone-deficit air mass in non-biomass-burning season and by that of ozone-rich air mass transport from the stratosphere.

Fujiwara *et al.* (1998) investigated a case of the upper tropospheric ozone enhancement by intensive observation with ozonesondes and radiosondes in Indonesia, and concluded that the equatorial Kelvin waves around the tropopause took part in the ozone transport from the tropical stratosphere. The Shoyo-maru 1999 result shows ozone variations near the tropopause probably related to the equatorial wave activity (the bottom panel of Figure 2). In relation to these variations, we observed about 5K change of the tropopause temperature.

In the troposphere the ozone concentration was about 40ppbv on average but had large variability especially in the vertical direction. As in Figure 2, we usually see layered structure in ozone and humidity profiles. Low (high) relative humidity corresponds to high (low) ozone concentration in several kilometre down to several-hundred-meter vertical scales. Because the ozone mixing ratio of more than 40ppbv could be interpreted as a mid-latitude origin or a biomass-burning origin (cf. Fujiwara *et al.*, 1999a; Fujiwara et al., 1999b), the tropical troposphere over the cruise should be viewed as the pile of atmospheric layers originated from either the inter-tropical convergence zone (wet and low ozone) or the mid-latitudes (dry and high ozone) (cf. Johnson *et al.*, 1999).

Atmosphere-ocean dynamical coupling

In the eastern tropical Pacific, from June to December, the strong SST front develops along about 2°N due to the equatorial upwelling. The SST front meanders meridionally with the typical zonal wavelength of 1000km and a period of 20-30 days. It propagates westward with the phase speed of about 0.4m/s. The meridional displacement of the SST front is about 5 degrees. Since Legeckis (1977) first discovered the wave from satellite infrared images, many studies have been done on this phenomenon to show that it is caused by the ocean dynamical instability (Philander, 1976; Cox, 1980). It is now called Tropical Instability Waves (TIWs).

Although TIWs are oceanic waves, it may affect the atmosphere above through the strong influence on SST spatial pattern. We examined the relation between the surface wind and the SST perturbations using the satellite scatterometer data, showing that surface wind convergence has relation with the SST perturbation (Xie et al.,1998). Our additional numerical experiment using the AGCM (Xie et al.,1998) showed the result consistent with the satellite data analysis. This surface wind convergence may carry the vapour in the MBL to the upper layer, and hence affect the cloudiness over the TIWs.

Because the SST variation related to the TIWs is largest along 2°N, cruising latitude was chosen exactly on it. The vertical structure of the atmosphere was observed by radio sondes over TIWs. With our cruise from 140°W to 110°W, we crossed 2.5 wavelengths of this SST waves making sonde observations at the rates of 4 times a day in usual and 8 times a day in an intensive period with the cruising speed of about 6 m/sec.

From the sonde data, we can see that the influence of TIWs on the atmosphere appears mostly in temperature and relative humidity at the MBL top. It is related to the vertical displacement of an inverse layer; the existence of this layer is characteristic of the lower atmosphere in the eastern equatorial Pacific. We are analysing the results of the observation further.

Marine boundary layer chemistry

In the marine boundary layer (MBL), halogen atoms derived from biogenic halocarbons in the ocean as well as seasalt particles may be of considerable importance in controlling the ozone distribution (e.g., Dickerson *et al.*, 1999). Biomass burning has been suggested to be another controlling factor of the ozone-mixing ratio over the eastern equatorial Pacific (Schultz *et al.*, 1999).

To investigate the distributions of halocarbons in the equatorial Pacific, sea water samples were collected. Air samples were also collected to determine the concentration of non-methane hydrocarbons and their isotopic compositions which may be valuable tracers of continental airmass. Detailed studies are being conducted for better understanding of ozone and halogen chemistry in the MBL. Along the course of these studies, concentrations of surface ozone and NOx simultaneously measured on the ship will be used.

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APE-THESEO: Clouds, dehydration, and transport at the tropical tropopause

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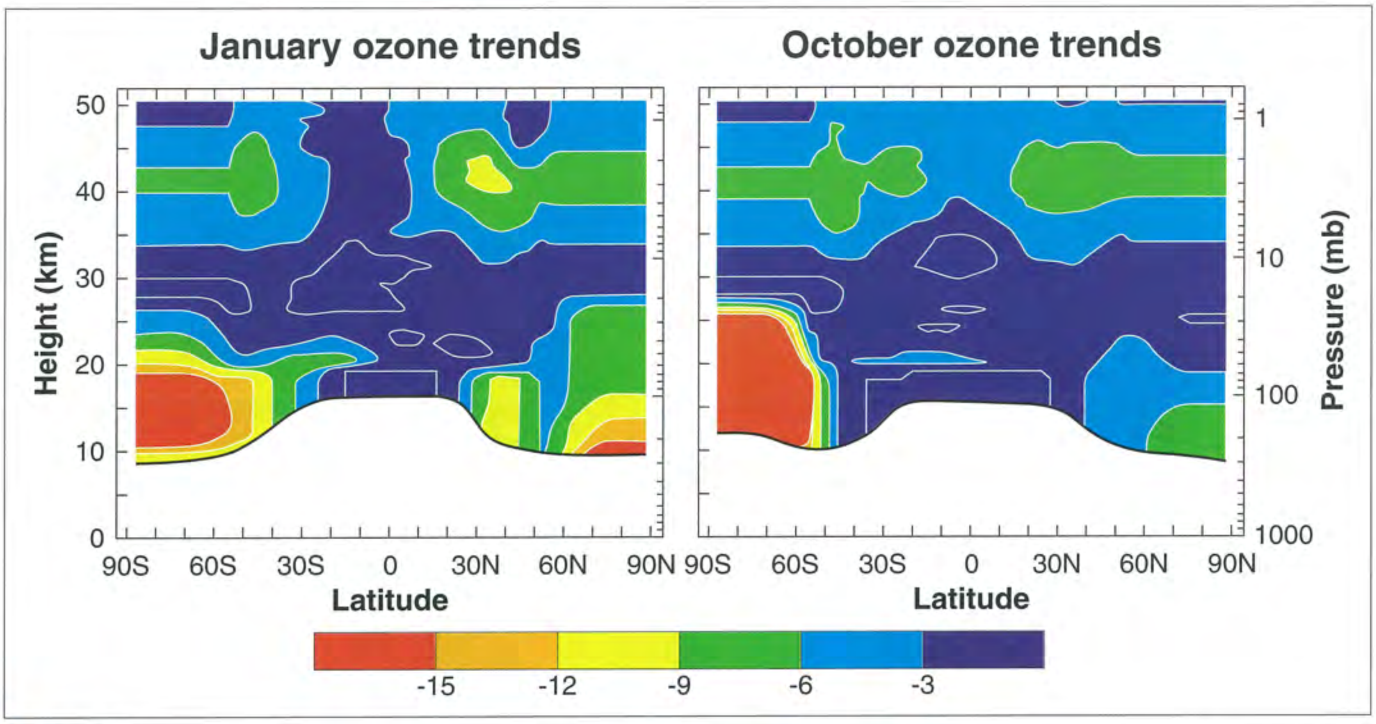
Introduction

APE-THESEO, the contribution of the Airborne Platform for Earth observation to the Third European Stratospheric Experiment on Ozone (THESEO), was performed from the island of Mahè in the Seychelles (4°S, 55° 30°E) in February and March 1999. The mission was the primary tropical component of the European Commission's THESEO programme, which aims to understand the processes affecting stratospheric ozone, particularly its decline over the middle latitudes in the last two decades. APE-THESEO contributes to THESEO by studying the way in which the composition of air changes as it moves from troposphere to stratosphere.

Two aircraft were used in APE-THESEO: the M-55 Geophysica high-altitude research aircraft and the DLR Falcon, which is an executive jet converted to research use. The mission's objectives and goals were to study the transport, chemistry, and cloud physics of the tropopause region (MacKenzie *et al.*, 1999). An important secondary objective was to provide top-of-troposphere measurements for INDOEX, the Indian Ocean Experiment, which focused on the direct and indirect aerosol effects on climate. In this article we describe general aspects of the tropopause region during the mission.

Stratospheric Aspects of Climate Forcing



▲ **Figure 2**

Global ozone trends for January (left) and October (right), shown in units of percent per decade, from Randel and Wu (1999). The local 95% statistical significance levels are trends on the order of 3-5% per decade.

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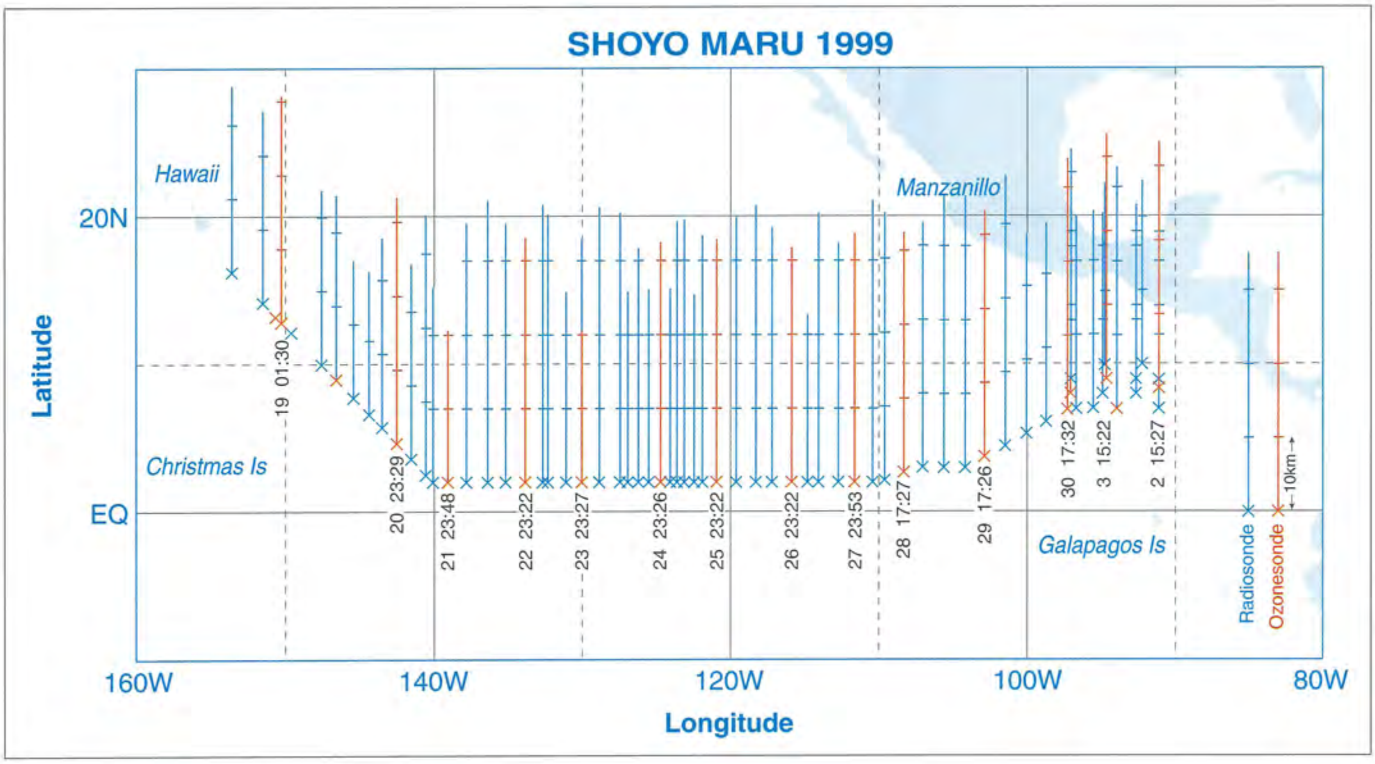

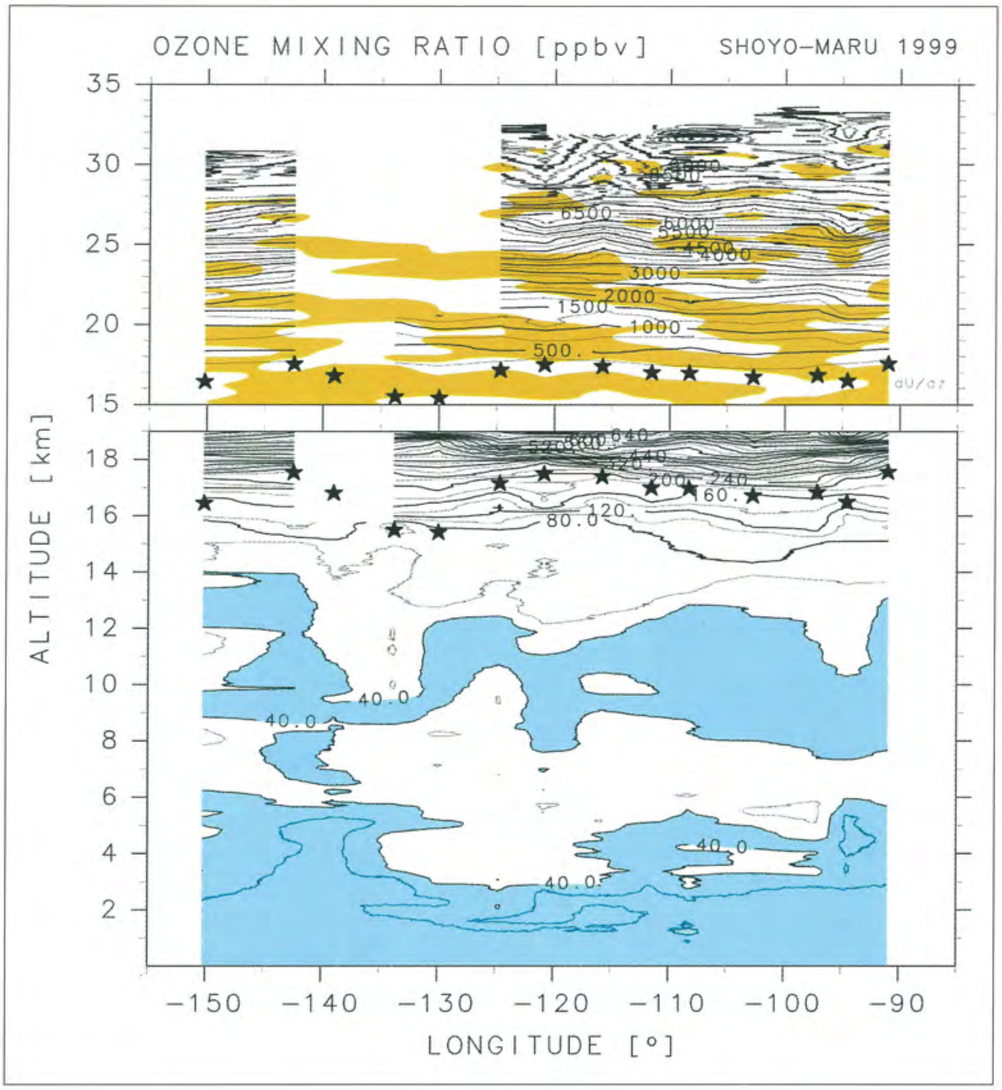

Figure 2
Longitude-altitude distributions of ozone mixing ratio between 15km and 35km (top) and between surface and 19km (bottom) obtained from the SHOYO MARU 1999 cruise. The contour intervals are 250ppbv for the top panel and 20ppbv for the bottom panel. The tropopause positions defined by the temperature minimum for each sounding are indicated by stars in both panels. The coloured regions in the top panel correspond to those of positive vertical gradient of zonal wind, and those in the bottom panel correspond to those of less than 40ppbv.

Figure 3
Preparation of a GPS-radiosonde launch which has been conducted within a U-shaped windscreen made of strong vinyl sheet in the backside of the observation deck of the Shoyo-maru.

Figure 1
Observation points of GPS radiosondes and ozonesondes with ceiling altitude indicated by blue bars (radiosonde) and red bars (ozonesonde).