A-3.6 Validation of satellite data such as ILAS and its application to middle atmospheric environmental studies

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Abstract It is indispensable to validate satellite observational data on atmospheric parameters, such as mixing ratio of minor species or temperature and pressure, in order to make better use of them for scientific studies. ILAS Version 5.20 data products of O_3, NO_2, and HNO_3 were validated using ozonesonde, balloon, aircraft, and other satellite data. Then, Arctic chemical ozone loss amount in 1996/1997 winter to spring was estimated using a trajectory analysis applied to the ILAS data. Year-to-year variation of descent rates of airmass inside the Antarctic polar vortex was estimated using the HALOE CH_4 data. Relationship between planetary wave activity and total ozone amount was also investigated. Global distribution and seasonal characteristics of gravity waves were investigated using the GPS/MET data.

Key Words satellite sensor, ILAS, minor species, polar vortex, gravity wave

1. Introduction

In order to investigate atmospheric phenomena using satellite sensor's data, it is indispensable to validate satellite observational data on atmospheric parameters, such as mixing ratio of minor species or temperature and pressure. For that purpose, data quality of minor species such as O_3, NO_2, and measured by the Improved Limb Atmospheric Spectrometer (ILAS) were validated using balloon and other satellite data. ILAS is a satellite sensor developed by the Environmental Agency of Japan, and was launched onboard the Advanced Earth Observing Satellite (ADEOS) in August 1996. ILAS made comprehensive measurement of minor species such as O_3, HNO_3, NO_2, N_2O, CH_4, H_2O, and aerosol extinction from November 1996 to June 1997 [*Sasano et al.*, 1999].

Next, several scientific analyses were executed using those satellite data. This include quantification of chemical ozone loss in the northern hemisphere high latitude region, analyses on year-to-year variation of descent rates of airmass inside the Antarctic polar vortex, relationship between planetary wave activity and total ozone amount, and global distribution and seasonal characteristics of gravity waves.

2. Validation of ILAS Version 5.20 O_3, NO_2, and HNO_3 Data

ILAS Version 5.20 O_3 data were validated using corresponding ozonesondes data and other satellites' data such as Version 19 HALOE, Version 6 SAGE II, and Version 6 POAM II. For comparison, all the data within 300 km in distance and 12 hours in time are selected with other satellite measurements, and within 500 km and 12 hours with ozonesondes measurements. Selected matching scenes were 202 with HALOE, 149 with SAGE II, and 120 with POAM II measurements, and 170 scenes with 13 northern hemisphere (NH) ozonesonde stations, and 40 scenes with 2 southern hemisphere (SH) ozonesonde stations. Comparisons were made in each 1 km geographical altitude bin. Figure 1 shows result of comparison with other satellites, while Figure 2 shows that with ozonesonde measurements. As a result, it can be said that ILAS data generally agreed with other measurements between 11 and 64 km. The absolute differences were within ±10% with a exception of 18% at 45-55 km in January 1997 in SH for comparison with HALOE and SAGE II, and a exception of 50% at <15 km in November 1996 in SH for comparison with HALOE and POAM II. In summary, it can be said that Version 5.20 ILAS O_3 data are improved form Version 3.10, and can be used for scientific purposes. Other study showed that ILAS Version 5.20 NO_2 and HNO_3 can also be used for scientific purposes.

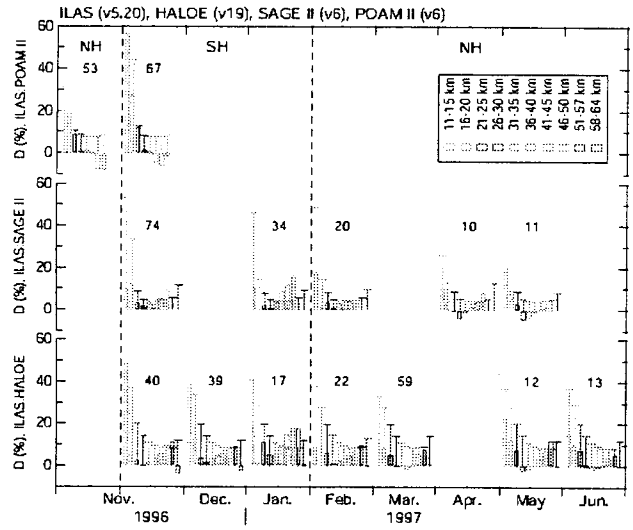

Figure 1. Comparisons between ILAS and HALOE, SAGE II, and POAM II O3 measurements. Average differences in 5 km or 7 km layers were shown.

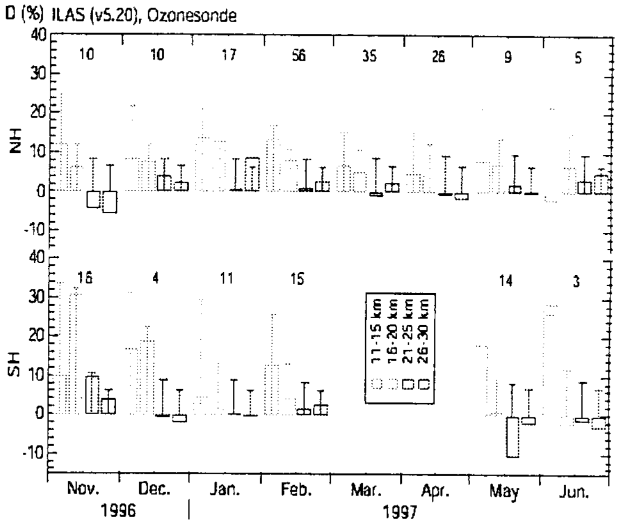

Figure 2. Comparisons between ILAS and ozonesonde measurements. Average differences in 5 km layer were shown.

3. Scientific Research Results

3.1 Quantification of chemical ozone loss in 1997 spring in NH high latitude region

Quantitative chemical ozone loss rates and amounts in the Arctic polar vortex for the spring of 1997 are analyzed based on ILAS Version 5.20 ozone profile data, using an extension of the Match technique [*von der Gathen et al.,* 1995; *Rex et al.*, 1998; 1999]. In this study, we calculated additional multiple trajectories and set very strict criteria to overcome the weakness of the satellite sensor data, lower vertical resolution, and larger sampling air mass volume, and to identify more accurately a double-sounded air mass. Figure 3 shows the result.

On average inside the vortex (north of about 70°N equivalent latitude), the local ozone loss rate was found to be 50-70 ppbv/day at the maximum during late February between the levels of 450 K and 500 K potential temperatures. The integrated ozone loss during February to March reached 1.9 ppmv (about 55%) at 450-490 K levels, and the column ozone loss between 400 K and 600 K during the two months was 94 DU. These values are larger in comparison with those estimated by the Match analysis using ozonesondes. The magnitude of the ozone loss increased gradually towards the vortex core, and the maximum ozone loss rate of 6.4±0.6 ppbv/sulit-hour at 80°N equivalent latitude was higher than near the vortex edge by a factor of 2. Temperature histories of double-sounded air parcels indicated that the extreme ozone loss in the innermost part of the vortex was observed when the air parcel experienced temperatures below T_{NAT} during the two soundings and had experienced temperatures slightly below T_{ice} in the 10 days prior to the first sounding. These facts suggest that the high ozone loss rate deep inside the vortex in the 1997 Arctic early spring correlates with the presence of Type Ia PSCs.

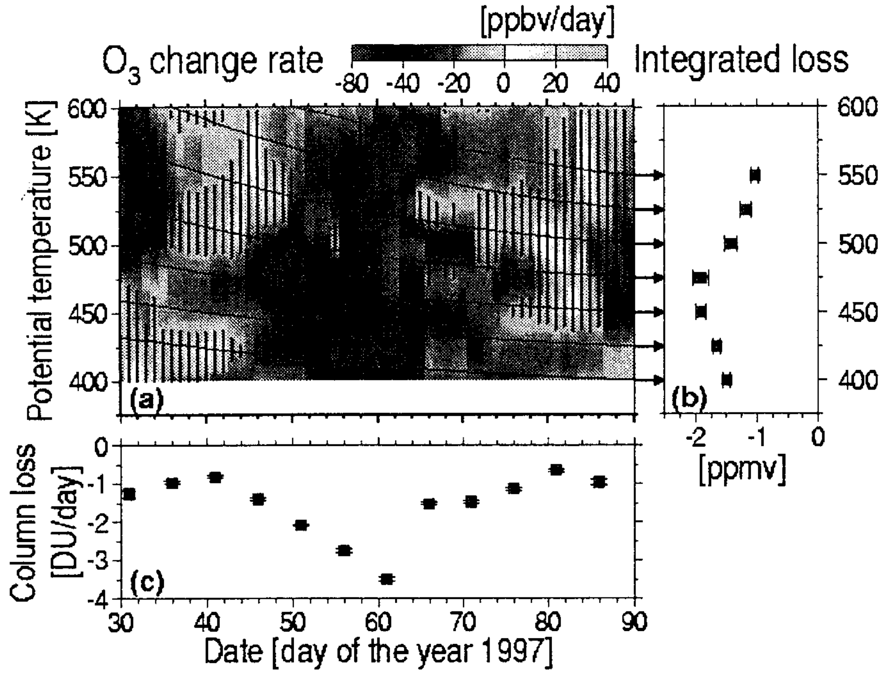

Figure 3. (a) Color-coded ozone change rates (in ppbv per day) as functions of potential temperature and date. Vertical bars indicate the region with statistical significance less than 99%. Smooth thin curves show potential temperature changes of air parcels (diabatic descent of air masses) [adopted from *Knudsen et al.*, 1998]. (b) Integrated ozone changes from January 30 (day 30) to March 31 (day 90) along each descent curve of the air mass. For the uppermost two levels, days 51-90 and days 37-90 are used for the integration, respectively. Error bars represent one sigma. (c) Ozone column change rates (in DU per day), which are obtained by integrating local ozone change rates (in number density per day) from 400 to 600 K. Plots are done every five days.

3.2 Estimation of interannual variability of the vertical descent rate in the Antarctic polar vortex

To investigate a descent rate in the Antarctic polar vortex, long-lived trace gas (CH_4) data from the HALOE onboard the UARS were analyzed from 1992 to 1997. By comparing the Antarctic fall (February and March) and spring (September and October) profile, middle stratospheric descent for each of the six winters were estimated. As a result, large year-to-year variations are seen (1.2-1.8 km month^{-1} at 0.6 ppmv) as shown in Figure 4, which consist of a biennial oscillation and a decreasing trend for the period analyzed. The descent rate was larger in the even years (1992, 1994, and 1996) than in the odd years (1993, 1995, and 1997). Dynamical fields for the 6 years were also analyzed using the UKMO assimilation data. The differences between the even and odd years are clear in the midwinter. In the even years the downward and poleward movement of the westerly jet occurs earlier. The thermal wind relation infers that this event is associated with the development of a “warm pool” around the Antarctic stratopause, resulting from adiabatic heating due to the downward motion of air. Planetary wave activity over the winter season is more vigorous in the even years than in the odd years, suggesting a close relationship between the mean flow and planetary wave.

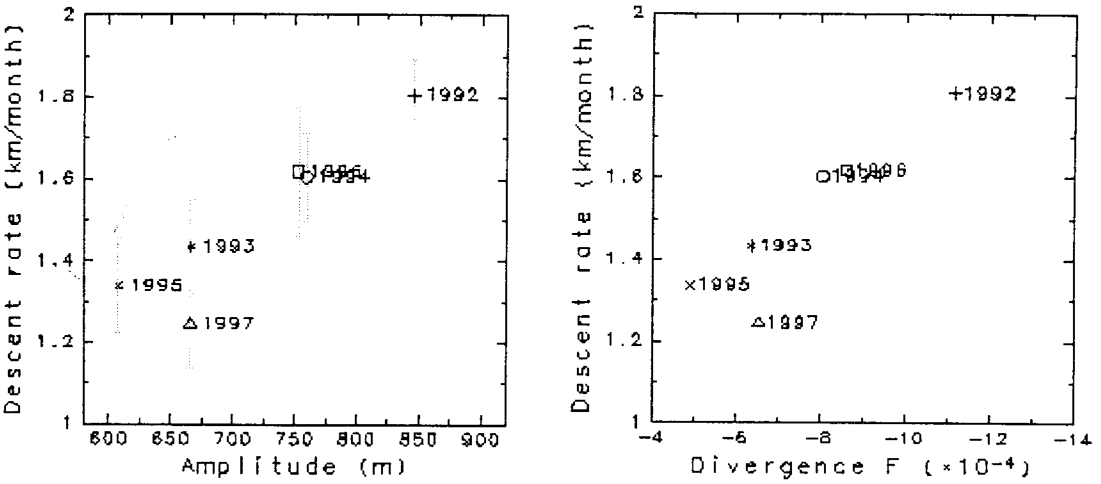

Figure 4. (Left) Relationship between Antarctic polar vortex descent rate at 0.6 ppmv methane and average amplitude of planetary wave (wave number 1) at 1 hPa, 60°S from February to October. Error bars correspond to 1σ standard deviation of descent rates. (Right) Same as (Left), but for E-P flux divergence.

4. Other Results

Using ILAS and other satellite data, the following researches have been made:

1) A study on relationship between NH winter lower stratospheric dynamic field and ozone amount

In order to investigate dynamical effect on ozone change in the NH, vertical component of the E-P flux (F_Z) was used as a index to see the wave activity propagating from the troposphere, and examined its relationship on ozone change. As a result, it was found that recent low ozone trend in NH high latitudes in March is caused by the delay of polar vortex breakup, and resulting positive radiative feedback between strength of polar vortex and low ozone amount.

2) A study on global seasonal distribution of gravity waves using GPS/MET temperature data

Gravity wave plays an important role in transporting momentum flux in middle atmosphere (stratosphere to lower thermosphere). However, global distribution of gravity waves has not yet investigated especially at the polar regions due to the lack of observations. Here, we used GPS/MET temperature data to investigate global distribution of gravity waves, and examined seasonal change by looking at the potential energy (PE) of the gravity wave. As a result, interesting peak of PE was found at upper stratosphere (30-45 km) in December in all latitude area. The cause of this peak was found to be an active cumulous convective activity in the equatorial region.

Reference

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