CHAPTER V

RESULTS DISCUSSION AND CONCLUSION

5.1 Results and Discussion

5.1.1 Seasonal Ozone Profile Patterns

Since the most of ozone is located in the stratosphere, changes in its abundance do not change location of the maximum in Umkehr curve. The shape of the curve and its maximum/minimum is related to the altitude of the ozone maximum. The monthly (or seasonal) changes in ozone in stratosphere and troposphere are caused by different processes: troposphere is largely affected by dynamically processes (planetary scale and synoptic scale dynamically processes such as Arctic/Antarctic oscillations, meteorological winds and local pollution), while stratospheric ozone is affected by chemistry processes (heating which depend on how much sun is available) as well as by Quasi Biennial Oscillation (QBO), Brewer-Dobson circulation, meridian transport (from low latitude to high latitude) and solar activity.

The measured ozone profiles show that most concentration is in the stratosphere at 10 to 50 kilometers above the earth's surface. The profiles can be illustrated with the curves in Figs.5.1 to 5.3.

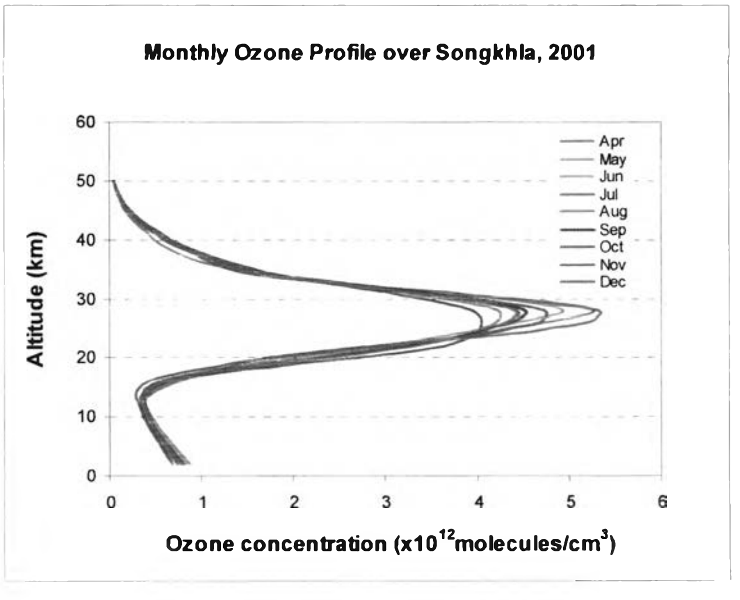

Fig 5.1 Monthly ozone profiles over Songkhla in 2001

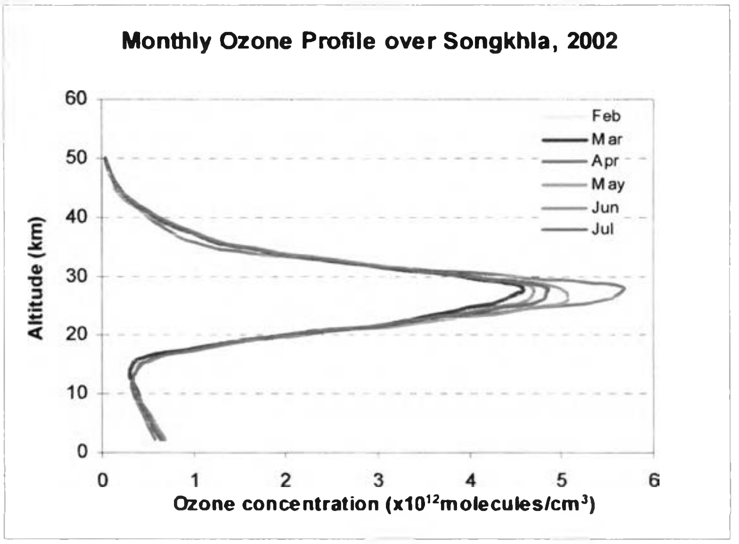

Fig 5.2 Monthly ozone profiles over Songkhla in 2002

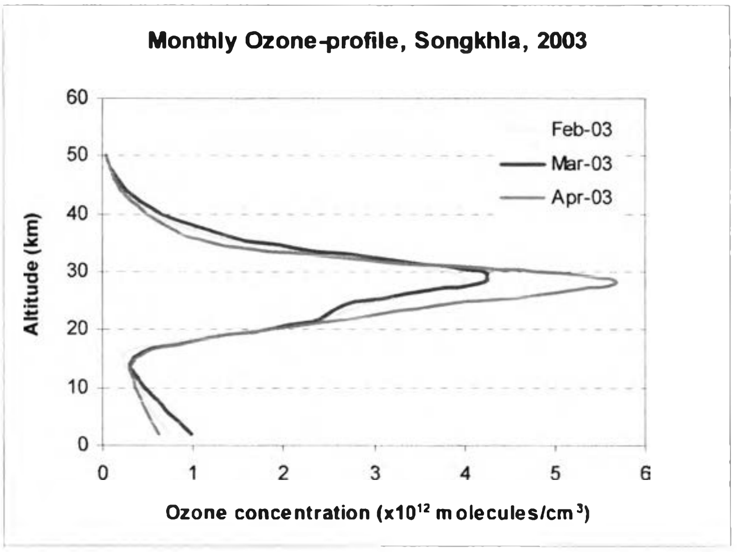

Fig 5.3 Monthly ozone profiles over Songkhla in 2003

The curves in the Figs.5.1 to 5.3 show seasonal variations of the ozone profiles retrieved from the Brewer measurements at Songkhla in 2001 to 2003. the higher concentrations is found in summer months (April to July). This is caused by the lower zenith angle and shorter path length of the sun ray (small μ-value). The lower concentrations are in October to December according to the higher zenith angle and longer path length (larger μ-values).

An ozone amount at each layer has no significant difference compared with of another station nearby although the total ozone is slightly related to latitude. The evaluation of the ozone profiles in this study was therefore considered to using Ozone

Sonde profiles from a station in Malaysia (Lat. 2.4° N; Long. 101.7° E) and SAGE II (scans at Lat. 8.9° N-15.8° N and Long. 133.5°-137.1° E). Figs.5.4 and 5.5 show ozone profile measured with the Brewer, SAGE II and Ozone Sonde.

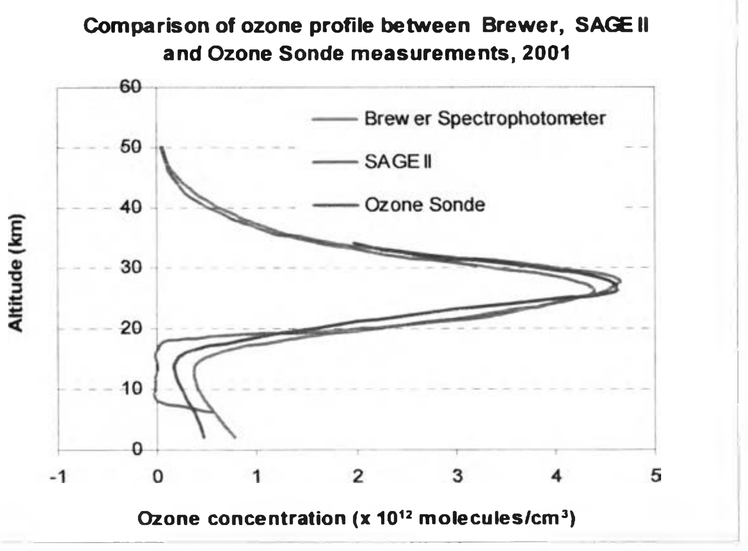

Fig 5.4 Comparison of ozone profile from Brewer Spectrophotometer, Ozone Sonde and SAGE II measurements in 2001

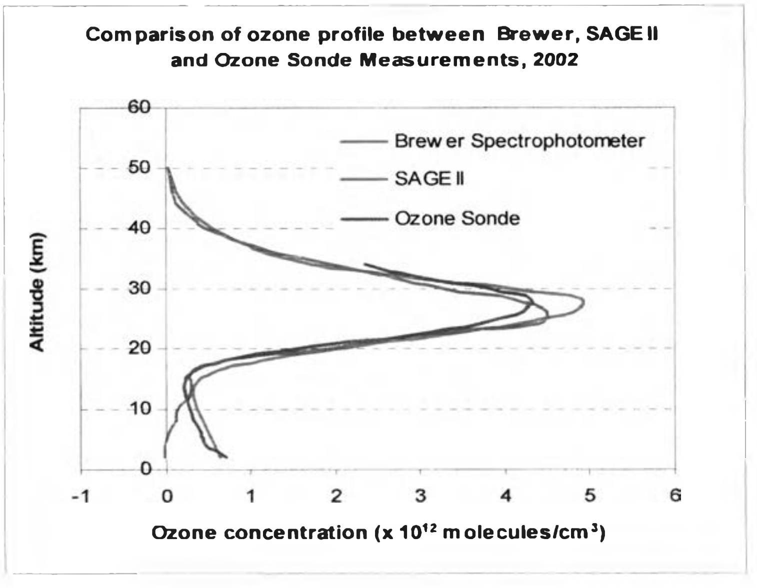

Fig 5.5 Comparison of ozone profile measured with Brewer Spectrophotometer, Ozone Sonde and SAGE II in 2002

The patterns of the ozone profile from all methods are consistent especially in the upper stratosphere levels except that in the lower stratosphere and troposphere below 10 km the ozone amounts obtained from the SAGE II is differed. However, all methods can be reliable information covered along the atmospheric layers because the profiles obtained from Brewer measurements can be a good relationship with the observations with the Ozone Sonde both in the troposphere and stratosphere especially at above 35 km when the balloon's Ozone Sonde is usually become burst. The maximum ozone concentrations are also presented at 26-28 km above the earth's surface. The ozone profiles retrieved from Umkehr measurements in this study was compared with the Ozone Sonde observed in Malaysia. The results of comparisons for 2001 and 2003 are shown in the Figs. 5.6 to 5.8.

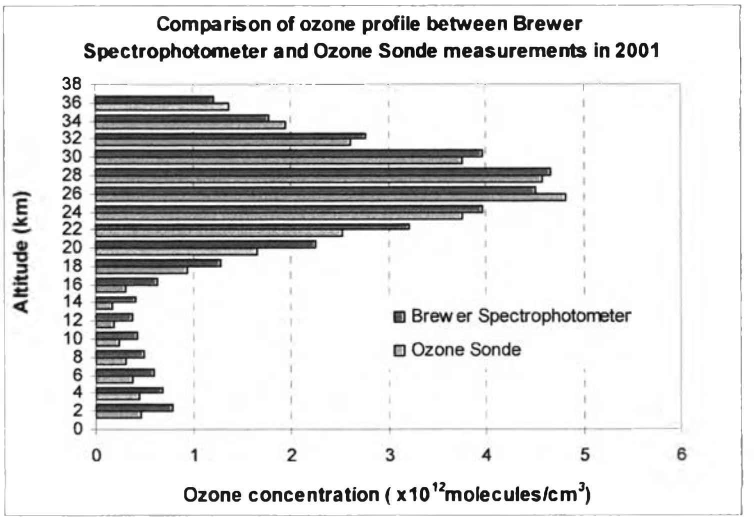

Fig 5.6 Comparison of ozone profile measured with Brewer Spectrophotometer and Ozone Sonde in 2001

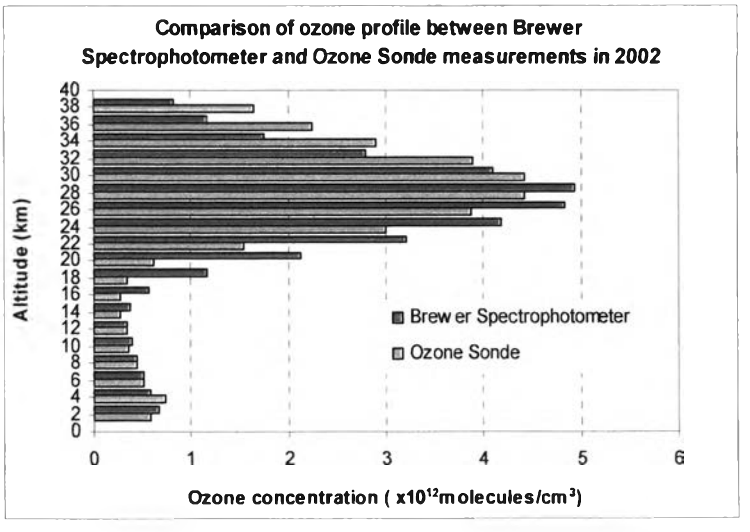

Fig 5.7 Comparison of ozone profile measured with Brewer Spectrophotometer and Ozone Sonde in 2002

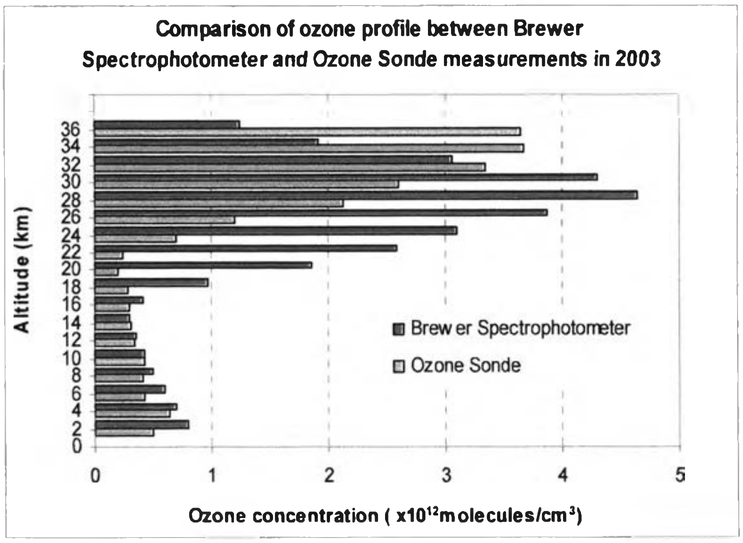

Fig 5.8 Comparison of ozone profile measured with Brewer Spectrophotometer and Ozone Sonde in 2003

Figs 5.6 to 5.8 show the Brewer Umkehr measurements give reliable information agreed with the Ozone Sonde in every altitude, although, this is not assumed for 2003 which the ozone data is available only a period of February to April. However, the ozone profiles at lower than 24 km above Songhla from the Brewer measurements are higher than the Ozone Sonde profiles throughout of the three years. This difference is due to Brewer Umkehr method is obtained from calculation but the Ozone Sonde is observed in the actual atmosphere which can be a consequence of chemical processes that of ozone molecules with NO exhausted into the atmosphere such as supersonic aircraft which transport in stratosphere. As we know that the NO causes to ozone reduction by this chemical reaction [17];

$$NO + O_3 \rightarrow NO_2 + O \quad (5.1)$$

$$NO_2 + O \rightarrow NO + O_2 \quad (5.2)$$

The result is

$$O_3 + O \rightarrow 2O_2 \quad (5.3)$$

In addition, the frequency of Ozone Sonde observation was taken at twice per month, therefore, the ozone amount from Brewer measurements could appear higher than of the Ozone Sonde in these layers.

The curves show physical behaviour of the ozone profiles which their maximum concentration are related to amount of total ozone and the height of maximum points is slightly different in each season. The seasonal changes of ozone in troposphere and stratosphere are caused by several processes such as the QBO, Brewer-Dobson circulation and solar activity that UV radiation cause directly an ozone production rate in the upper stratosphere. In tropical area like Thailand, the ozone has inter-annual variability which is dominated by the QBO, solar cycle and Brewer-Dobson circulation [5].

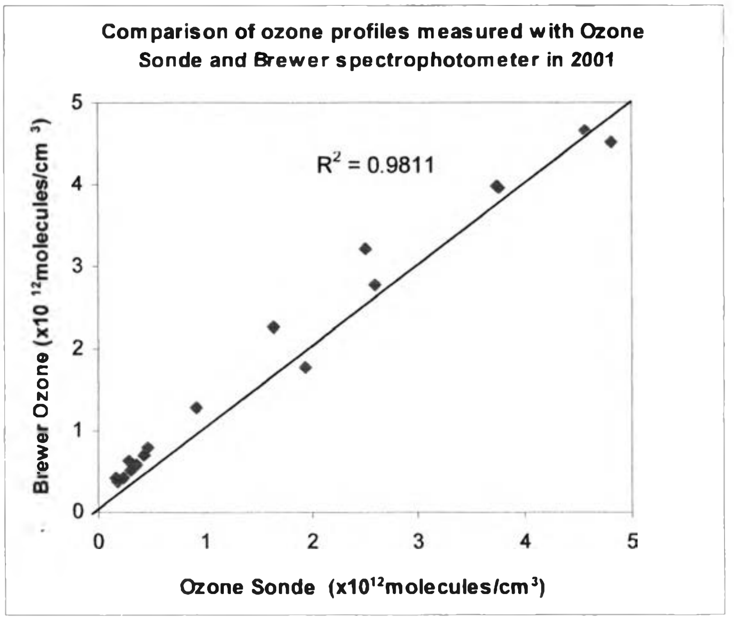

Fig 5.9 Comparison of ozone profiles measured with Ozone Sonde and Brewer spectrophotometer in 2001

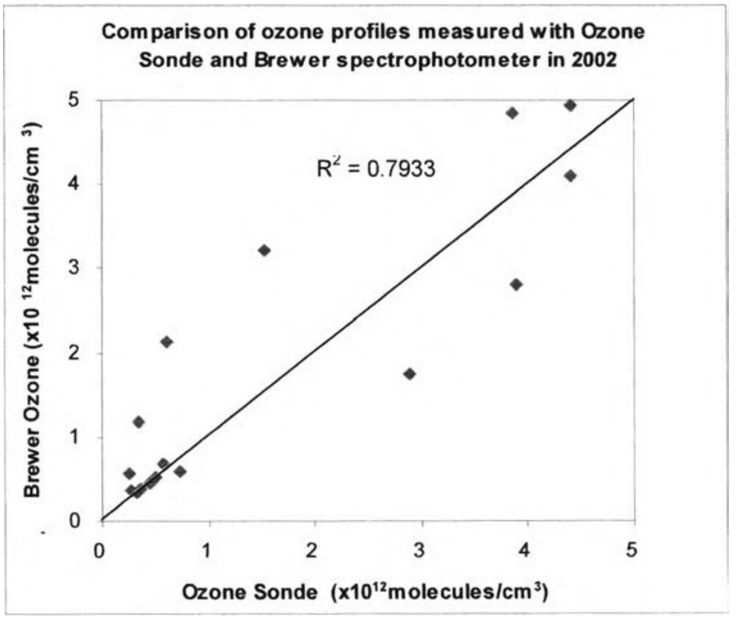

Fig 5.10 Comparison of ozone profiles measured with Ozone Sonde and Brewer spectrophotometer in 2002

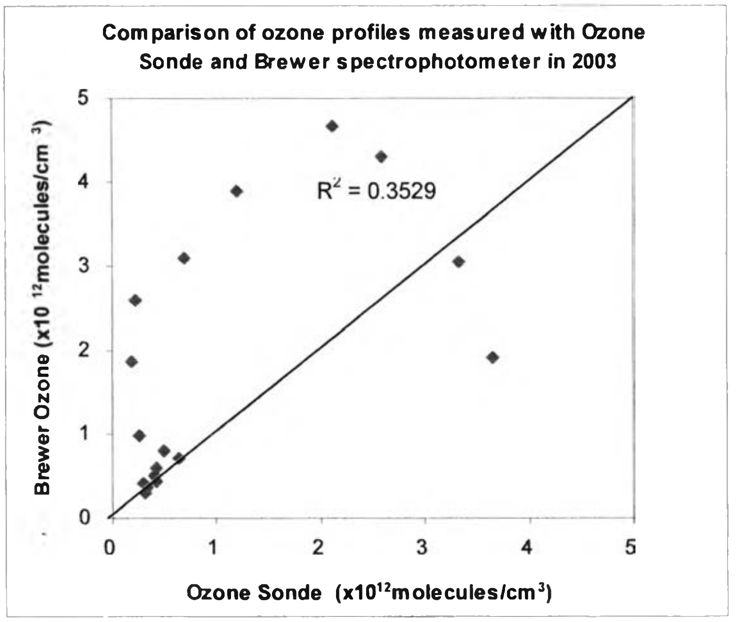

Fig 5.11 Comparison of ozone profiles measured with Ozone Sonde and Brewer spectrophotometer in 2003

The comparison of ozone profiles measured with Ozone Sonde and the Brewer Spectrophotometer measurement show consistency in using two methods which are presented in Fig.5.9 to Fig.5.11. They agree with square of correlation (R^2) in 2001 and 2002. In 2003, it should be remarked that the ozone profile data set is available only in February to April and not sufficient for analysis.

5.1.2 Annual average of vertical ozone distribution

The annual average values of ozone amount show small change at each layer (see Table 5.1) especially on upper layers where the atmosphere is thin rapidly with height. The amount of available oxygen for ozone creation drop offs quickly therefore less ozone is able to form even though the ultraviolet light available [17]. The highest value of ozone found in the middle layers where there is enough of the necessary ultraviolet light from the sun. This manner happens similarly in short term and long term trend, likely to total ozone. A comparison of trends derived from these data show in Fig.5.11 where the maximum concentration of ozone was in 2002.

Table 5.1 The annual average of vertical distribution of ozone at Songkhla

Altitude (km)	Molecules × $10^{12}/cm^3$		
	Ozone-profile 2001	Ozone-profile 2002	Ozone-profile 2003
50	0.1	0.1	0.1
48	0.1	0.1	0.1
46	0.2	0.1	0.2
44	0.3	0.2	0.3
42	0.4	0.4	0.4
40	0.6	0.6	0.6
38	0.9	0.8	0.8
36	1.2	1.2	1.2
34	1.8	1.8	1.9
32	2.8	2.8	3.1
30	4.0	4.1	4.3
28	4.7	4.9	4.7
26	4.5	4.8	3.9
24	4.0	4.2	3.1
22	3.2	3.2	2.6
20	2.3	2.1	1.9
18	1.3	1.2	1.0
16	0.6	0.6	0.4
14	0.4	0.4	0.3
12	0.4	0.3	0.4
10	0.4	0.4	0.4
8	0.5	0.4	0.5
6	0.6	0.5	0.6
4	0.7	0.6	0.7
2	0.8	0.7	0.8

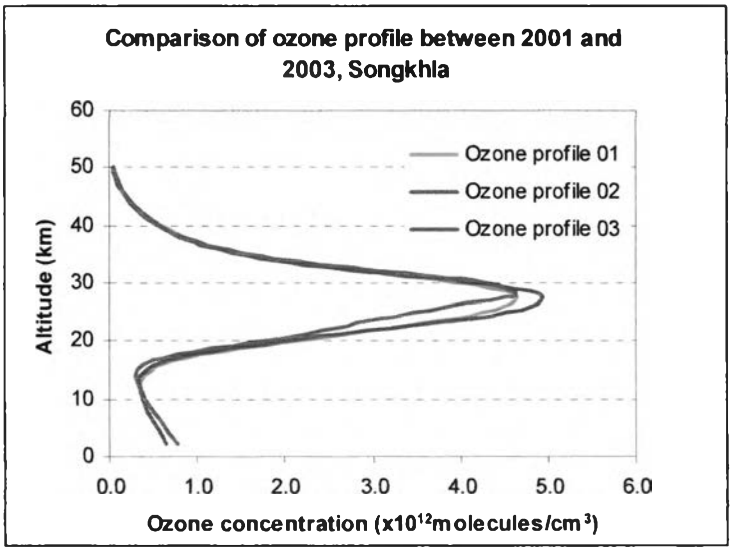

Fig 5.11 Comparison of Brewer ozone profile during 2001 to 2003

5.2 Conclusion

The atmospheric ozone profiles measured with a ground-based Brewer spectrophotometer in Songkhla using Umkehr technique is essential because there is no Ozone Sonde observation available. As well as the U
information at any height cover of the atmosphere 0 to 50 km which the Ozone Sonde usually reaching 35 km. and limitation of satellite such as SAGE II in the troposphere.

The maximum values of the ozone concentration in 2001 to 2003 are 4.70×10^{12} molecules/cm^3, 4.90×10^{12} molecules/cm^3 and 4.70×10^{12} molecules/cm^3 at 28 km. While the total ozone values in 2001 to 2003 are 3.68×10^{13} molecules/cm^3, 3.65×10^{13} molecules/cm^3 and 3.40×10^{13} molecules/cm^3 respectively.

It was found that the annual trend is declined since 2001 to 2003 which is according to the 11 years of solar cycle and the QBO events. For solar cycle, it usually effects to increasing total ozone by a few percent as shown in Fig.2.3. [2] While the QBO effects to decreasing within 3% change of total ozone as in Fig. 2.4 [2]. During 2000-2003, the total ozone values were appeared decreasing. Although the total ozone was also affected by the QBO in this period, it seems that the maximum of ozone concentration in 2001 and 2003 are equally. The solar cycle and the QBO were considered to balance the changing in this case. It should be remarked that the ozone profile data set in 2003 is available only in February to April and not sufficient for analysis.

The comparison of ozone profiles measured with the Ozone Sonde and Brewer Spectrophotometer had given square of correlation 0.9811 in 2001, 0.7933 in 2002 and 0.3529 in 2003. This results show that the Brewer umkehr method can be used for the Ozone Sonde especially at station in tropical area where the total ozone is not much changed. Additionally, the Umkehr method offers an inexpensive to study ozone profile and stratospheric ozone trend.