KYRGYZSTAN

1. Introduction

For more than 30 years the monitoring of ozone, solar UV radiation, tropospheric aerosol and main greenhouse gases in central part of Eurasian continent has been made only at Issyk-Kul station (42.6°N, 77°E, 1650 m a.s.l.) located on the shore of Issyk-Kul Lake in the mountains of northern Tien-Shan. (Fig. 1)

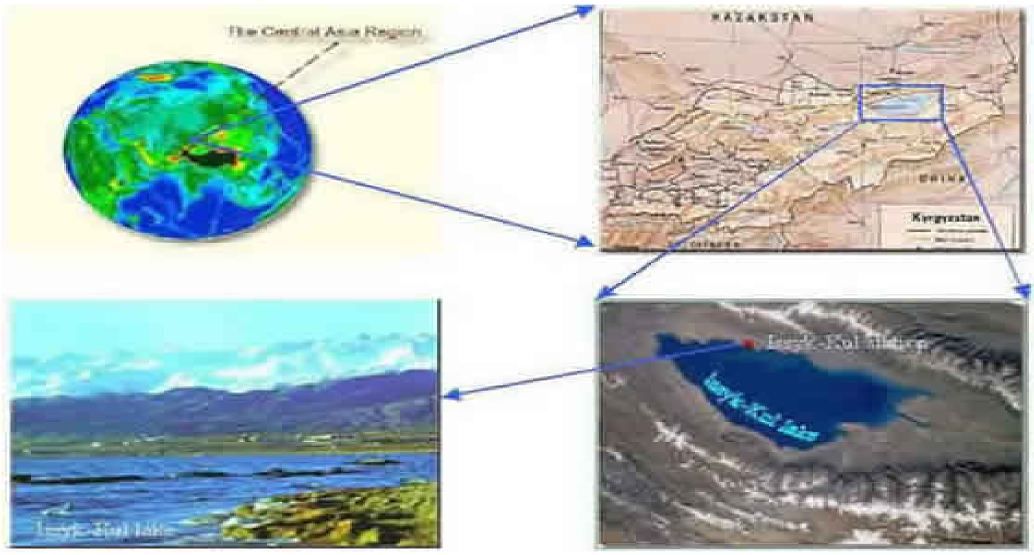

Fig.1. Locations of Issyk-Kul GAW station at Northern Tien Shan

The station is located in the mountains of Northern Tien Shan, it has very favorable conditions for investigations of the above-mentioned problems due to a high transparency of an atmosphere, a lot of sunny days in a year, and also because of absence of sources of anthropogenic pollution. It is unique in the central part of the Eurasian continent.

2. Monitoring

Investigations of atmospheric ozone in Kyrgyzstan had started at the Kyrgyz National University in 1979. Different versions of spectral multiwave methods of measurement of the total content of ozone (TO) and stratospheric nitrogen dioxide were developed. For realization of these methods the devices were made, and the scientific station Issyk-Kul was created.

For validation of ozone measurements in various years, a comparison of the measurements by the ozonometer at the station with measurements by the national etalon device of Russia (Dobson spectrophotometer #107) and with the data of measurements by the satellite device TOMS was carried out.

Since January 2000, a monitoring of intensity of solar UV radiation at the Earth's surface in 5 bands of a solar spectrum in width of 2 nm being centralized on wave lengths 305; 312; 320; 340 and 380 nm was carried out by the device MICROTOPS II. The device registers radiation of a solar disk plus scattered radiation within a solid angle of 2.5 degrees.

The global erythemally weighted solar UV-B irradiance (UV-er) is regularly measured since May 2003 with Model 501 UV-Biometer (Solar Light Co).

The measurements of the surface ozone concentration at Issyk-Kul station started in August 2003 carried out with the help of the UV ozone analyzer TEI 49C. The fence of air is carried out at height of 5 m above a surface of the ground.

3. Research

Mean monthly total ozone (TO) values in the atmosphere over the central part of Eurasia for 1980 - 2008 are given in Figure 2. These values are obtained by averaging mean measured daily TO (curve 1) values. A determination error for mean monthly total ozone TO is less than ± 0.5%. The same Figure 2 presents the smoothed total ozone values (curve 2) and linear trend (line 3).

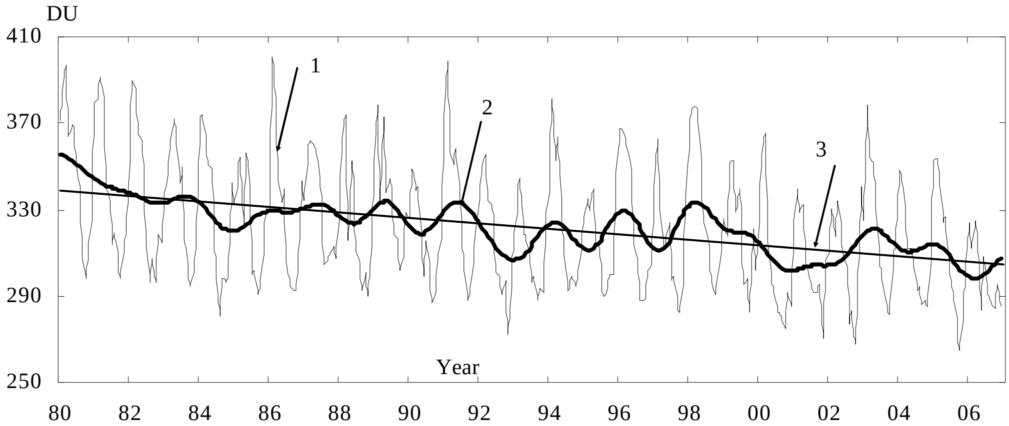

Fig. 2. Seasonal (1), annual (2) variation total ozone and linear trend (3) at Issyk-Kul GAW station.

The results of mean daily TO values obtained during ground-based measurements with the values of TO satellite measurements made by the TOMS installed on board of the NIMBUS-7 comparison. For the whole period of comparison the data of both measurements correlated with each other with the correlation coefficients r = 0.95. The value of r in separate years changes from 0.92 to 0.98.

As it was shown the results of long-term observations at Issyk-Kul station, the 20 - 30% amplitude of total ozone variations was relative to mean annual values of TO with oscillations from 60 DU (1987) to 110 DU (1980, 1986 and 1991). Maxima in TO seasonal variations are observed in February-April and minima in August-November. Here during the whole observation period the changes of maxima in March were 40% and changes of minima in October were only 6%. For Issyk-Kul mean for the observation period annual TO seasonal variation, with the account to a total ozone decrease in 1990 - 1998, is in good agreement with the mean seasonal variation of total ozone during a year 1973 - 1990 averaged for Central Asia (42 N). During the whole observation period at Issyk-Kul station mean annual ozone content in the atmosphere decreased to about 10.5% (34 DU) with an average rate -(0.39 ± 0.03)% in a year.

During the whole measurement period almost regular quasibiennial oscillations of smoothed TO values with an amplitude of 15 DU. were observed. In 1980 - 1983 and 1991 -1992 a disturbance of these oscillations regularity took place. In 1980 - 1983 and 1991 – 1992 TO decreases were maximal and the TO decrease rates were equal to -(2.1±0.1) and -(4.5±0.1)% per a year, correspondingly. This is considered to be connected with the El Chichon and Pinatubo eruptions.

In different time intervals the real trend of inter-annual ozone change may significantly differ from the linear trend for all period of observations. After a short period (1993-1998) of restoration of ozone layer with the mean rate 0.6% per year, further ozone layer depletion with the rate -1.5% per year took place during the following period.

It is seen from Figure 2, that during some time periods along with usual seasonal total ozone variations considerable "gaps" - negative anomalies of different duration (from several days to several months) - were observed at the station. Their appearance and, consequently, a possible increase of UV radiation fluxes deserve special attention. In their essence these anomalies are regional, local "micro holes" in ozone layer similar and equal in size to the anomalies observed

over Europe in 1980s.
The data of several ozonometric stations located in the Eurasian centre have shown that during the period of 1980 - 1995 the negative anomalies were observed at all stations. Almost simultaneously the anomalies were observed in the first half of the 1990s at the Issyk-Kul, Alma-Ata and Karaganda stations. The first two stations are distanced from each other by ~70 km, and the latter is almost 800 km away from them. In spring 1993 the ozone negative anomaly in this region was probably about 1000 km in length and southern boundary was registered in Dushanbe.

A correlation of variations of mean monthly and mean annually total ozone (TO) content over the mountain regions of Central Asia for two observation periods 2009 and 2010 at the station 'Issyk-Kul " is given in Fig. 3. The horizontal lines indicate means for 12 months. As shown in Figure 3, for 2009, the TO content is 0.309 atm-cm, while for the later of the second period (2010) obtained a value equal to the TO content -0.326 atm cm and ozone in the atmosphere over Kyrgyzstan increased by approximately 3.3% in 2010 compared with 2009. From Fig. 3 is seen that the main characteristics of intra-annual variations of TO content preserved - a maximum of TO content occurs in spring, at least - in the autumn, with preservation of phase seasonal variation.

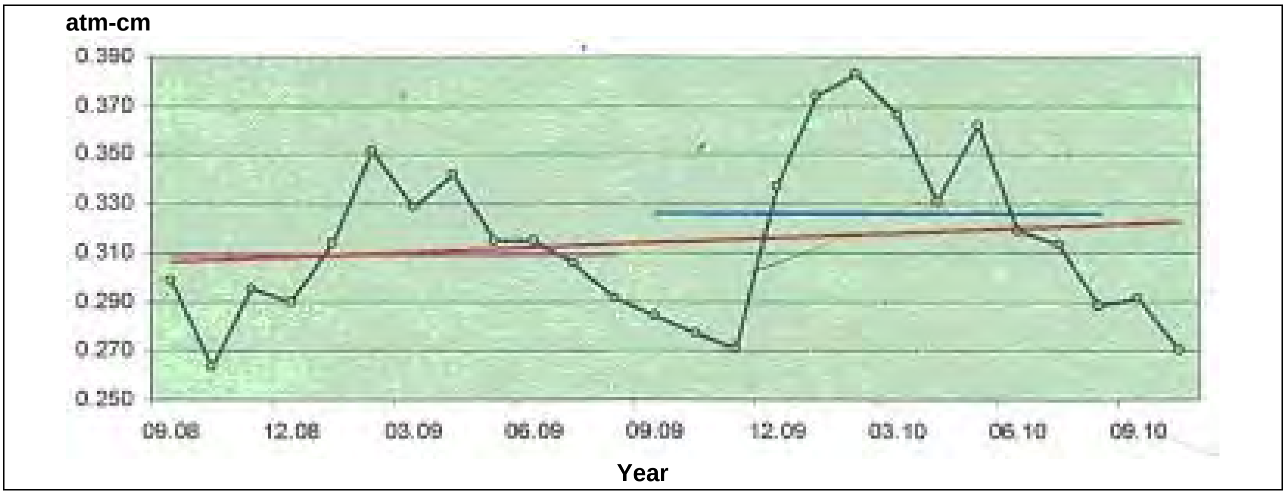

Fig. 3. Intra-annual fluctuations mean (points) monthly TO content and linear trend. Mean total ozone in the atmosphere above the station "Issyk-Kul " for 12-months (horizontal lines) in 2008 - 2010.

The variations of mean monthly intensities of the ozone surface in the Issyk Kul from May 2003 to 2008 are given in Fig. 4

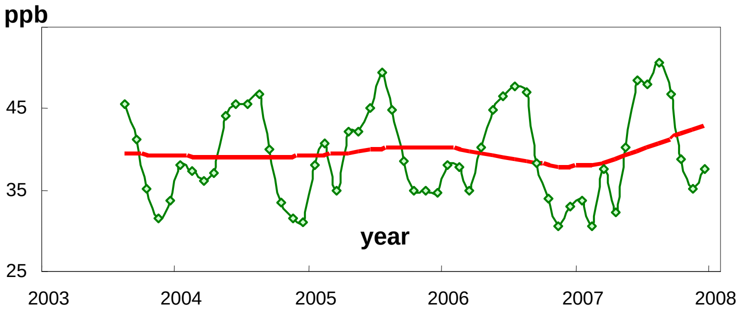

Fig. 4. The variations of mean monthly intensities of the ozone surface

The variations of mean monthly intensities of the ozone surface in Issyk Kul from 2009 to 2010 are given in Fig. 5.

From the figure 5 is seen, that in 2010 compared to 2009 mean annual concentration of COS increased from 39,1 ppb (in 2009) to 41.7 ppb (in 2010), i.e. to 6,4%.

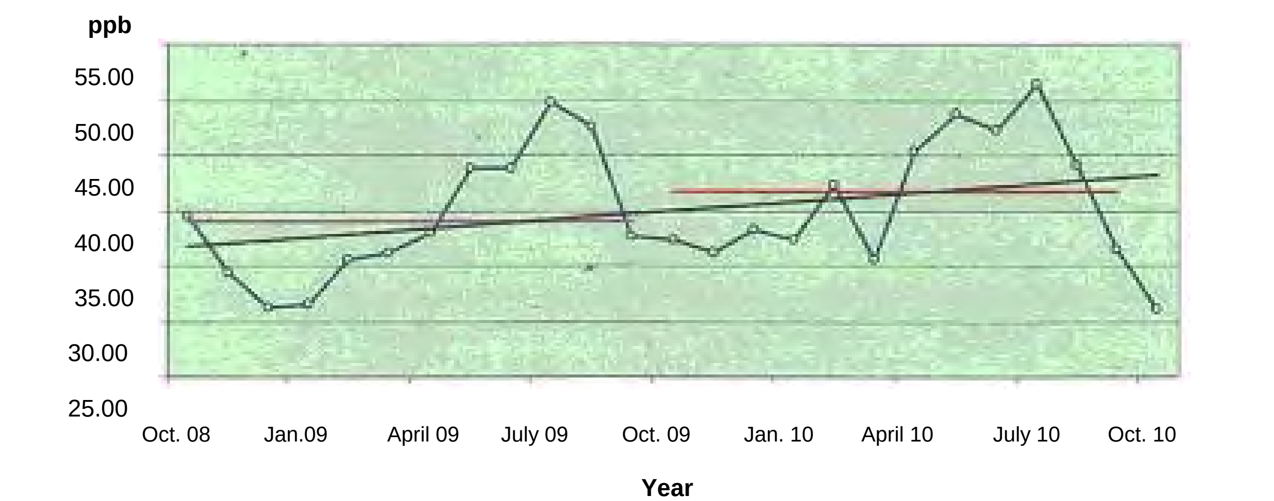

Fig.5. Intra-annual variation of mean monthly (points) and mean over 12 months (lines) of surface ozone concentrations in the area of the station Issyk-Kul in 2008-2010.

The variations of mean monthly intensities of erythemally weighted solar UV-B irradiance (UV-er) in ssyk Kul are given in Fig. 6.

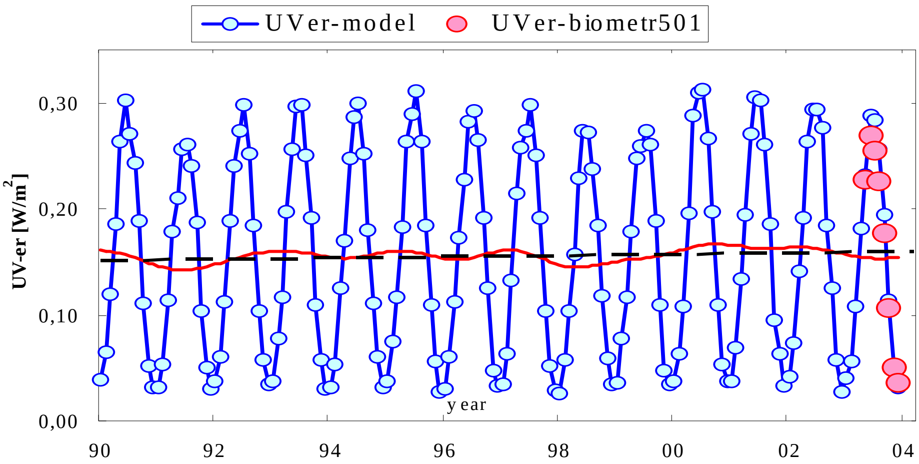

Fig. 6. Mean monthly total solar-weighted erythemal UV-radiation over the Issyk-Kul lake: model calculation (blue line); measured values (red dots); trend (dashed line).

For the period of 1990 - 2003 values of total intensity of erythematous weighed UV-B radiation (295-315 nm) reaching the ground in area of Issyk-Kul lake are estimate using a three-layered model. In this model the measurements' results of ozone and aerosol optical depth in UV range were used. For the period June, 2003 - February, 2004 the calculated values of total intensity of UV-B radiation are compared to measurements results of UV-B radiation using the UV-Biometer 501.

The calculations have shown that at decreasing total ozone in the region of the Northern Tien Shan since 1990 to 2003 at a rate of (0.23 ±0.05)%/yr the intensity of the global solar UV-er irradiation increased with a rate of (0.38 ±0.07)%/yr.

When comparing the UV-er current mean monthly values with average long-term values, positive deviations of the UV-er were registered: (15-20)% in Feb.1993, April 1997, Feb. 1999, May 2000, Dec. 2000, Nov. 2001, January and March 2002. On some days in spring-summer positive anomalies reached (40-65)%. The increments in UV-er mentioned were observed when local ozone holes were located over the Northern Tien Shan.
The variations of mean monthly intensities of the direct solar UV radiation on the ground surface at local noon in the Issyk-Kul from January 2001 to December 2003 are given in Figure 7 for 4

wavelengths: 305, 312, 320 and 340 nm. Dotted lines are trends. A growth of total ozone for the past several years over the Northern Tien Shan with a rate of (2.5 ±0.14)%/yr is about 5 times higher than the rate of total ozone growth (observed in 1993-1997) caused by a decrease of the stratospheric aerosol burden induced by the Mt. Pinatubo eruption. This total ozone increase was accompanied by a decrease of the UV radiation intensity for λ = 305, 312, 320 and 340 nm on the Earth's surface with rates of 7.8; 4.6; 3.3 and 1.4%/yr, accordingly.

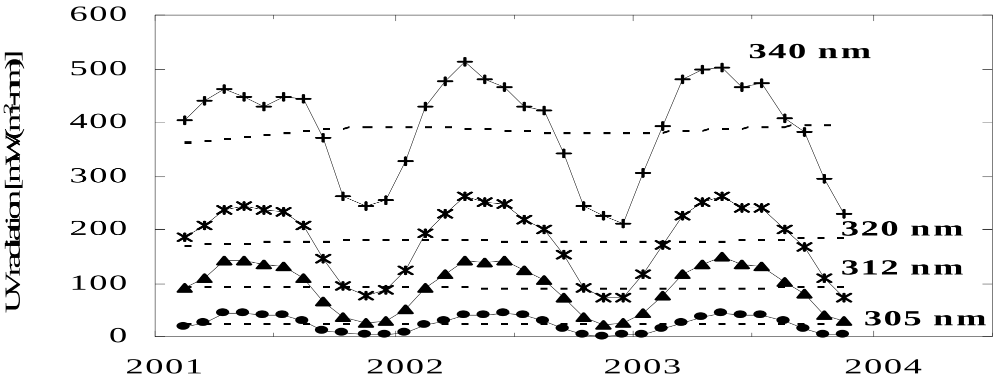

Fig. 7. Time series of the local noon direct solar UV radiation, from March 01 to December 03; dotted line represents trends - change in the data with the seasonal cycle removed.

The measurements have shown that in 2001-2003 the ozone changes is in a steady correlation with the intensity of the direct solar UV radiation (λ = 305 nm) only. Thus an increase UV-er irradiance over the Northern Tien Shan the last years occurred mainly due to the depletion of the ozone layer.

Fig. 8. shows a seasonal trend of variations of UV-B radiation and an increase of the mean annually UV-B radiation in 2010 by 2,4% compared with 2009 in Issyk-Kul.

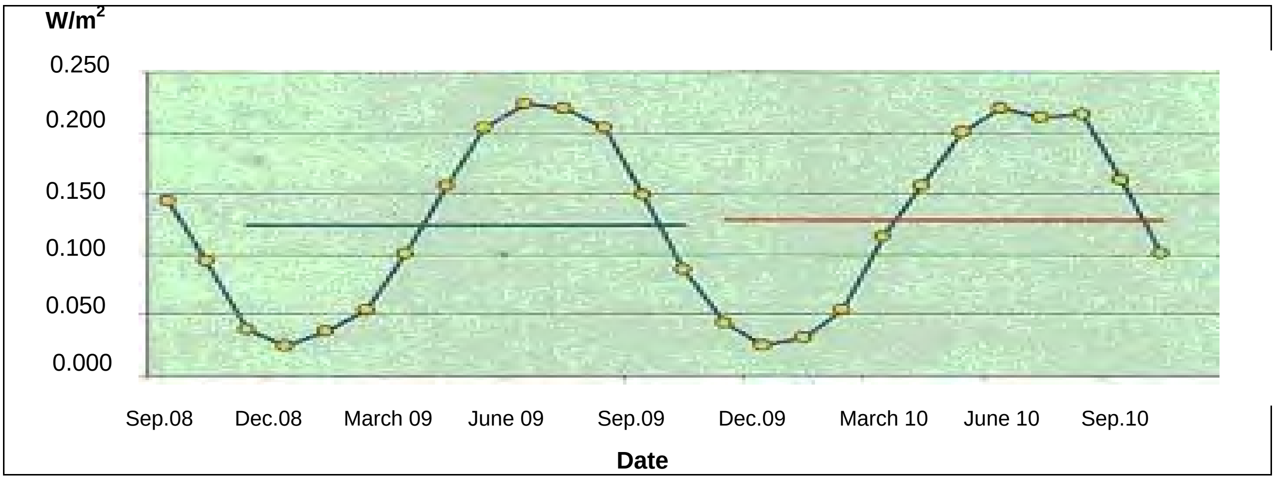

Fig. 8. Intra-annual fluctuations in the local noon (points) the intensity of solar UV-B radiation in the area of the Issyk-Kul Lake in 2008 and 2010.

Mean monthly values of water vapor total content in the atmospheric column of the Eurasia central part are given in Figure 9 for the period of 1980 – 2006.

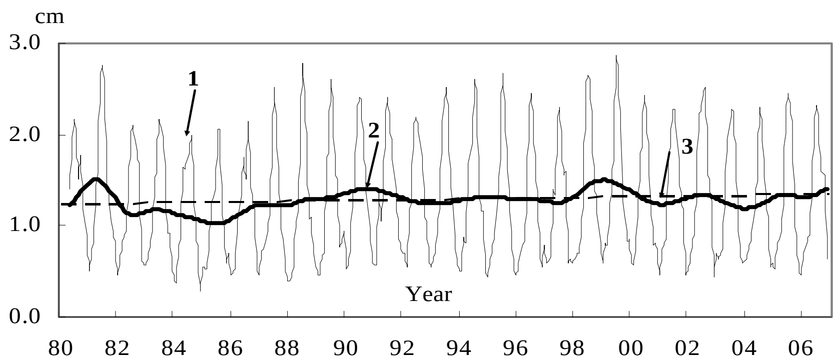

Fig. 9. Seasonal (1), annual (2) variation of water vapor and linear trend (3) at Issyk-Kul GAW station.

A total amplitude of seasonal variations of W from winter to summer at Issyk-Kul station has changed within wide ranges from 1.53 g·cm^{-2} in 1985 to 2.39 g·cm^{-2} in 1988 (Figure 9). The mean amplitude for the whole observation period was (1.91±0.23) g·cm^{-2}.

The mean monthly of the stratospheric nitrogen dioxide (NO_2) slant column content from April 1983 to December 2010 is presented on Figure 10. The NO_2 seasonal variations have 35-45% amplitudes.

Between 1983 and 2010, the total content of NO_2 vertical column (Y * 10^{15} mol/cm^2, hereinafter referred to as a convenience factor of 10^{15}, as a rule, falls) was measured during sunrise and sunset: 5121 morning and 5076 evening observing sessions, each of which consisted of approximately 170-200 individual measurements. The results are shown in Fig. 10.

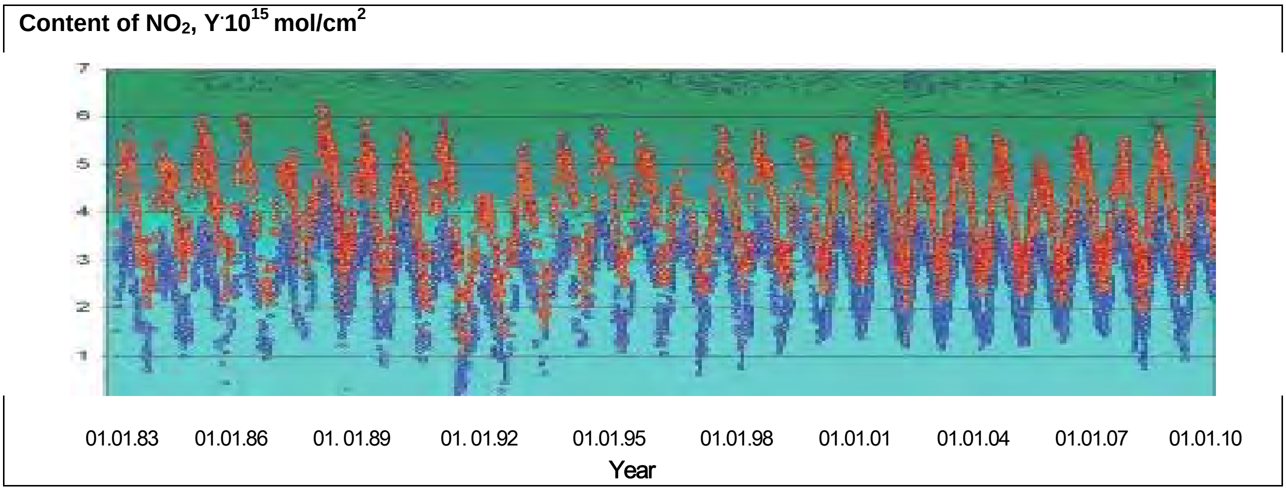

Fig. 10. A total of the nitrogen dioxide (NO_2) in 1983-2010.

The results of measurements of CO_2 and troposphere aerosol at Issyk-Kul station are presented in Fig.11 and 12.

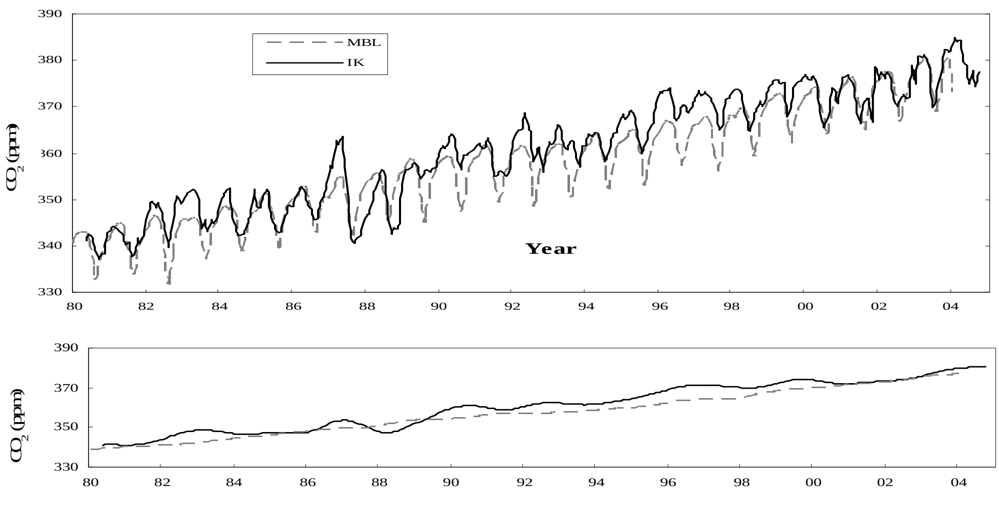

Fig. 11. Temporal variations of monthly mean CO_2 column averaged mixing ratio over Northern Tien Shan (IK), zonally averaged marine boundary layer CO_2 mixing ratio (MBL) (upper panel). The long-term trends represent in lower panel.

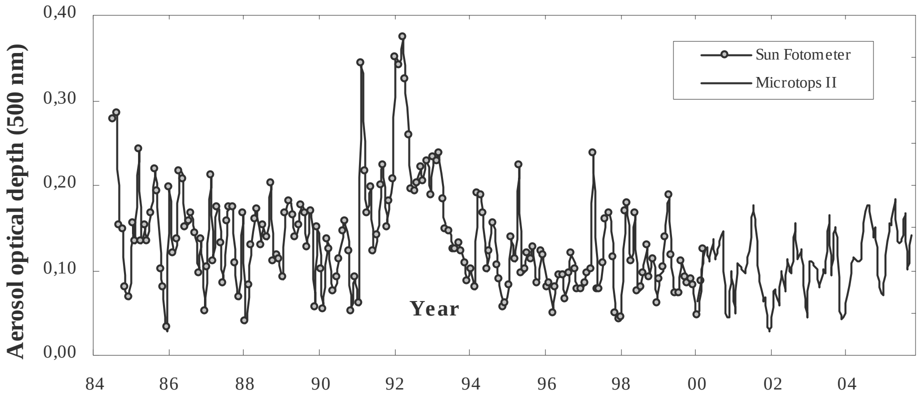

Fig. 12. Mean monthly values of aerosol optical depth at the wavelength 500 nm measured by two devices at Issyk-Kul station.

4. Applications

The results of measurements of ozone obtained at Issyk-Kul station are transferred regularly to the World Data Centers: in Ozone (Toronto, Canada #347-WOUDC), in Greenhouse Gases (Tokyo, Japan ISK242N00-WDCGG), in aerosol (USA) and on NDSC network of stations (www.empa.ch/gaw/gawsis).

5. Publications

The basic results of investigations are being published in national and international journals and proceedings:

1. Toktomushev S. J., and V.K. Semenov, Ozone holes above Central Asia, Central Asian and Himalayan Studies, v. 2, No 3-4, 111-121, 1993.
2. Semenov V. K., V.P. Sinyakov, S. J.Toctomushev, V.N. Arefyev, Ultra-violet radiation and a transparency of an atmosphfere in a resort zone of mountain lake Issyk-Kul. The Second international conference. Kislovodsk, on October, 8-14, Moscov, 67-69, (in Russian) 2000.
3. Semenov V.K., Sinyakov V.P.,Toktomushev S.J., Solar ultra-violet radiation and an environment of mountain region of the Central Asia / Studying of mountains and a life in mountains. Scientific reports of the International conference (on September, 8-9, Bishkek, 2000), with 195-200, (in Russian), 2000.
4. Toktomushev S.J., Semenov V.K., Ozone hole and climate of the mountain region Central Asia., Istanbul.– 213 p., (in Russian) 2001.
5. Semenov, V. K., A. Smirnov, V. N. Aref'ev, V. P. Sinyakov, L. I. Sorokina, and N. I. Ignatova, Aerosol optical depth over the mountainous region in central Asia (Issyk Kul Lake, Kyrgyzstan), Geophys. Res. Lett., 32, L05807, doi:10.1029/ 2004GL021746. 2005.
6. Ionov D.V., V.P. Sinyakov, V.K. Semenov, Validation of GOME (ERS-2) NO_2 vertical column data with ground-based measurements at Issyk Kul (Kyrgyzstan). Advances in Space Research, 37, 2254–2260, 2006.
7. Semenov V. K., Sinyakov V. P., Toktomushev S. J., Sorokina L. I., Ignatova N. I. Results of Experimental Studies of the Parameters of the Earth's Atmosphere in of the Issyk-Kul GAW Station / Edited by V. K. Semenov. – Bishkek, 58 p. 2007.
8. Webb A. and M. Stevenm , Measurementsof Solar UV-B Radiation in the English Midlands Arch, Met. Geoph. Biocl. Ser.
9. Ionov D.V., V.P. Sinyakov, Y. M. Timofeyev, V.K. Semenov, F. Goutail, J. P. Pomereau, E. J. Bucsela, E. A. Celarier and M. Kroon, Ground-based validation of EOS-Aura OMI NO_2 vertical column data in the midlatitude mountain ranges of Tien-Shan (Kyrgyzstan) and Alps (France), J. Geophys. Res., 113, D15S08, doi: 1029/2007JD008659, 2008.

6. Future plans

In according with recommendations of the seventh meeting of the Ozone Research Managers (7 ORM), the priority at the above mentioned stations in Kyrgyzstan for the nearest future will be given to investigations of interaction between ozone and climate, ozone layer and UV radiation, stratospheric aerosol and climate.

7. Need of support

For solution of above mentioned tasks, improvement and expansion of the base monitoring of ozone and stratospheric aerosol in the Central Asian region, Kyrgyzstan as a developing country needs a financial support from international organizations.