

## KYRGYZSTAN

### 1. Introduction

For more than 35 years the monitoring of ozone, solar UV radiation, tropospheric aerosol and main greenhouse gases in the central part of Euro-Asian continent is made only at the "Issyk-Kul" station (42.6°N, 77°E, 1650 m a.s.l.).

During a long time the Kyrgyzstan carries out investigations on ozone and concerned problems in the Central Asian region in two directions mainly:

- a complex monitoring of ozone and main greenhouse gases;
- a monitoring of solar UV radiation, and of tropospheric aerosol.

The station is located in the mountains of the Northern Tien Shan, 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 an 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 began at the Kyrgyz National University in 1979. Different variants 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 different devices were made and the scientific station "Issyk-Kul" was created.

During the next years the monitoring of a content of a stratospheric nitrogen dioxide (N<sub>2</sub>O), an integrated content of carbon oxide (CO<sub>2</sub>), water vapor (H<sub>2</sub>O) in the atmosphere, and a spectral transparency of the atmosphere in a visible spectrum range of a solar radiation with an estimation of effective parameters of troposphere aerosol was organized at this station. 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 the data of measurements by the satellite device TOMS were 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 of erythemally weighted solar UV-B irradiance (UV-er) irradiance are regular measured since May 2003 with Model 501 UV-Biometer (Solar Light Co).

The measurements of surface ozone concentration in Issyk-Kul station started in August 2003 and 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 1. 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  $\pm 0.5\%$ . The same Figure 1 presents the smoothed total ozone values (curve 2) and linear trend line (3).

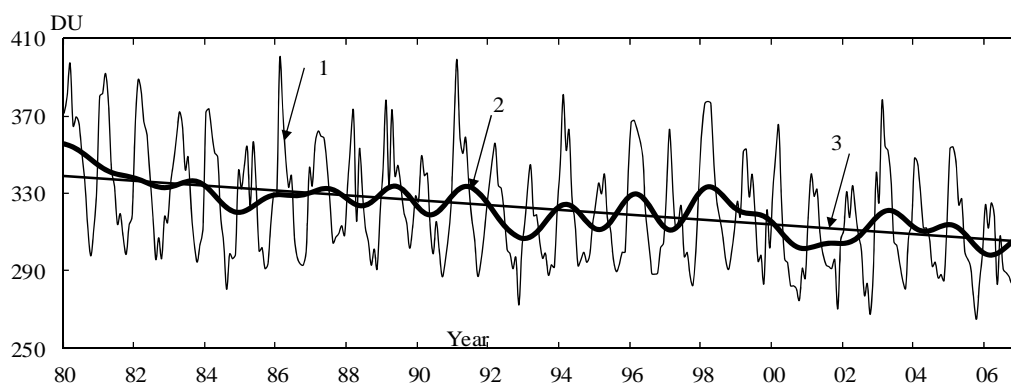


Fig.1. Seasonal (1), annual (2) variation total ozone and linear trend (3) at Issyk-Kul GAW station.

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 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 the 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 means annual ozone content in the atmosphere decreased to about 10.5% (34 DU) with an average rate  $-(0.39 \pm 0.03)\%$  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  $-(2.1 \pm 0.1)$  and  $-(4.5 \pm 0.1)\%$  a year, correspondingly. This is considered to be connected with the El Chichon and Pinatubo eruptions.

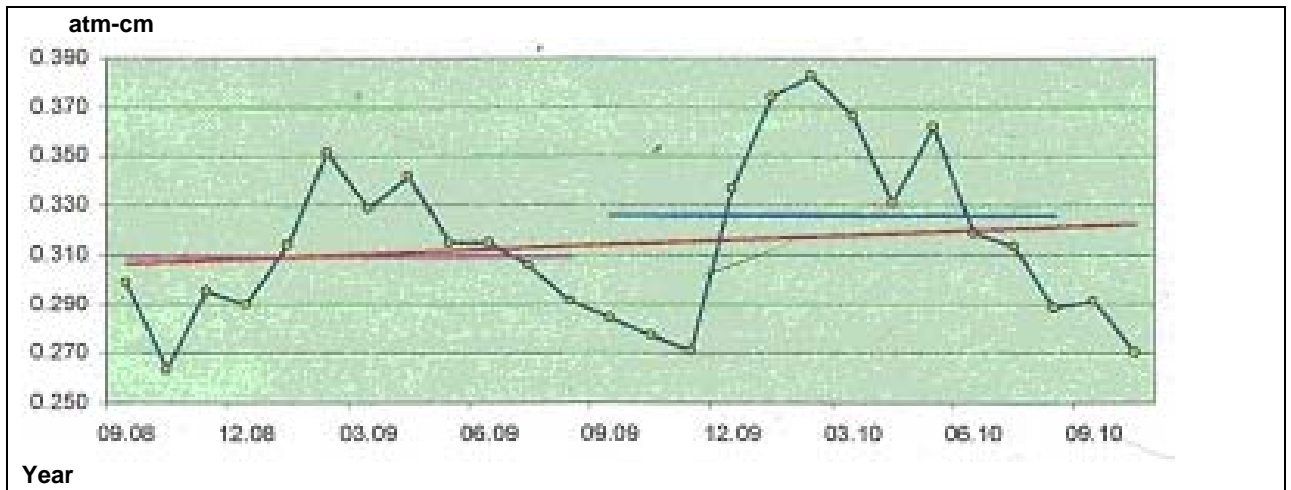
In different time intervals the real trend of inter-annual ozone change may significantly differ from the linear trend for all period of observations. After short period (1993-1998) of restoration of ozone layer with the mean rate of 0.6% per year, further ozone layer depletion with the rate of 1.5% 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 showed that during 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  $\sim 70$  km, and the latter is almost 800 km away from them. In the spring of 1993, the ozone negative anomaly in this region was about 1000 km in length and southern boundary was registered in Dushanbe.

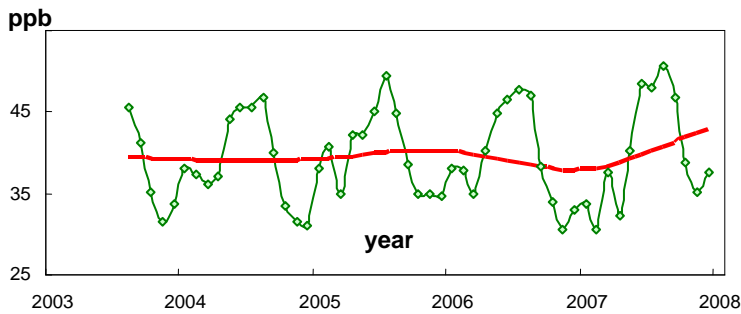
A correlation of variations of mean monthly and mean annually total ozone (TO) content over the mountainous regions of Central Asia for two observation periods of 2009 and 2010 at the 'Issyk-Kul' station is given in Fig. 2. The horizontal lines indicate means for 12 months. As it is shown in Figure 3, 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. 2 it 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.



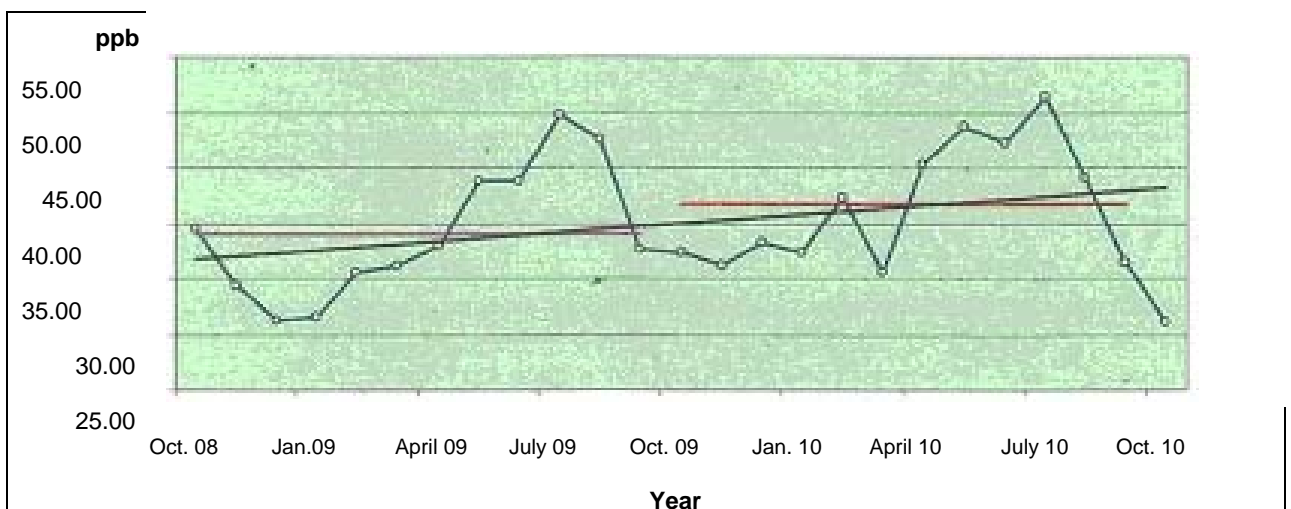
**Fig. 2.** Intra-annual fluctuations mean (points) monthly TO content and linear trend. Mean total ozone in the atmosphere above the “Issyk-Kul” station for 12-months (horizontal lines) in 2008 - 2010.

The variations of mean monthly intensities of the ozone surface in the Issyk-Kul from May 2003 to 2008 are given in Fig. 3



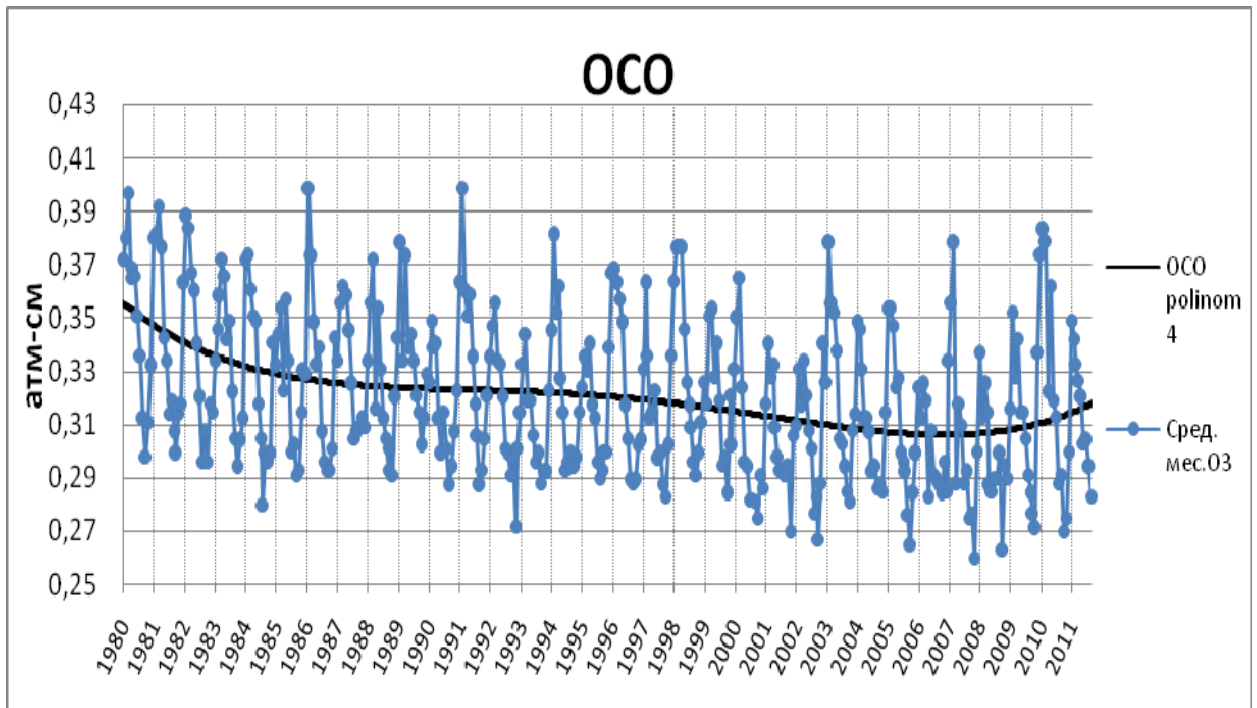
**Fig. 3.** The variations of mean monthly intensities of the ozone surface

The variations of mean monthly intensities of the ozone surface in the Issyk Kul from 2009 to 2010 are given in Fig 4. It 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. by 6,4%.



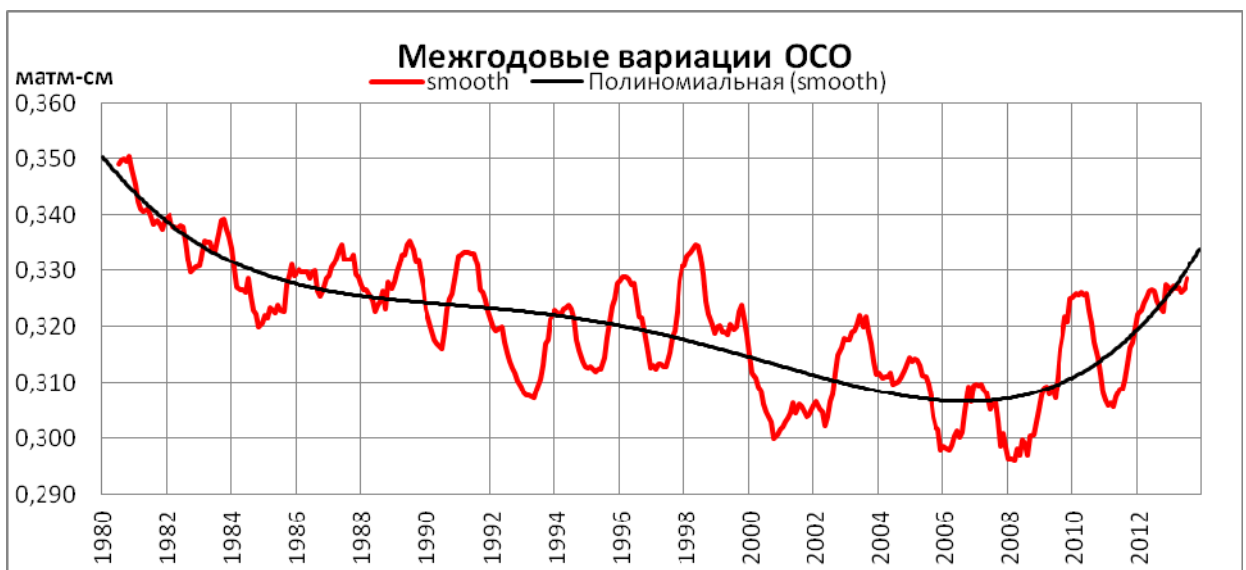
**Fig.4.** Intra-annual variation of mean monthly (points) and mean over 12 months (lines) of surface ozone concentrations in the area of the station of Issyk-Kul in 2008-2010.

Figure 5 shows, along with the measured values of TO, the trend in form of a polynomial of 4 degree, calculated by least squares method from measured data. In Figure 5 you can see that starting (at "Issyk-Kul" st.) from the year 2006, there has been a positive trend in ozone.



**Fig. 5.** TO 4<sup>th</sup> group polynomial trend

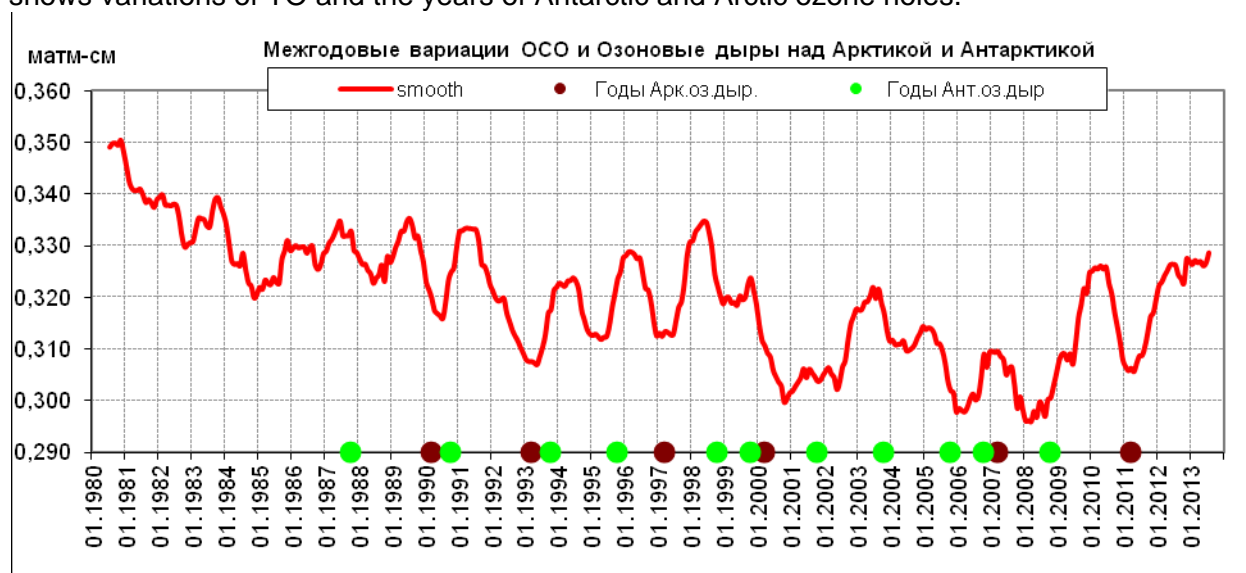
Figure 6 shows that, from 2006, there is a positive trend in the annual average (seasonal fluctuations are excluded) values of TO that is illustrated by a 4th order polynomial trend (solid line). In 2008, the TO had 299 u.d. value and in 2011 the average TO was 311 u.d., i.e. from 2008 to 2011 the annual average TO value increased for 13 u.d..



**Fig. 6.** Anti-aliased (smooth) interannual variations of TO and 4th order polynomial trend (solid line)

It should also be noted, as can be seen from Figure 6, that during the observation period the speed of TO decrease (negative trend) in different intervals of time changed within wide limits. The four intervals should be pointed out: the first from 1980 to 1985, the second - 1989-1993, the third - 1998-2002 and the fourth - 2004-2006, where the decline was especially noticeable.

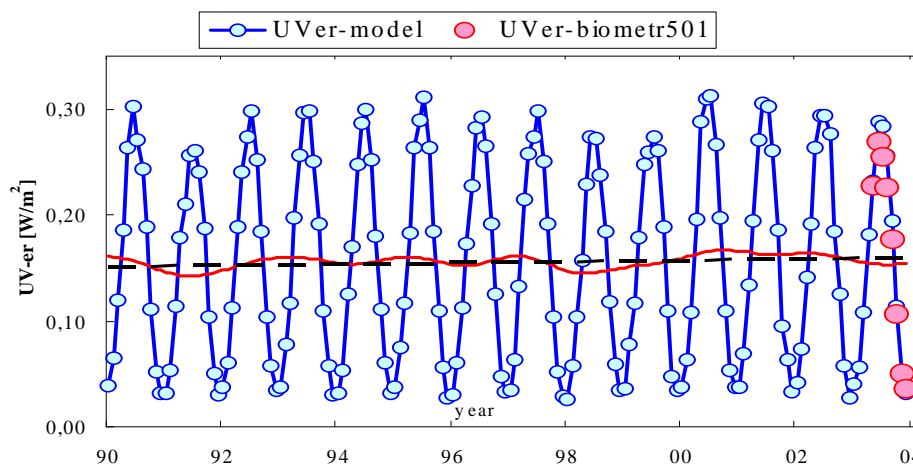
One of the causes of TO changes, together with anthropogenic ozone-depleting emissions, are emissions from volcanoes that contain fluorine-, sulfur-compounds which destroy the ozone layer getting to the stratosphere. Occurrence of ozone holes at the Poles affects the established circulation processes in the atmosphere, which ultimately leads to disruptions in quasibiennial fluctuations. Correlation of these processes is demonstrated in Figure 7, which shows variations of TO and the years of Antarctic and Arctic ozone holes.



**Fig. 7.** Interannual variations of TO and the years of ozone holes

The observed positive trend in the rate of change of TO from 2006-2008, is likely due to reduced emissions of ozone-depleting substances of human nature due to the operation of the Vienna Convention for the protection of the ozone layer and the Montreal Protocol on substances that deplete the ozone layer.

The variations of mean monthly intensities of erythemally weighted solar UV-B irradiance (UV-er) in the Issyk Kul are given in Fig. 8.



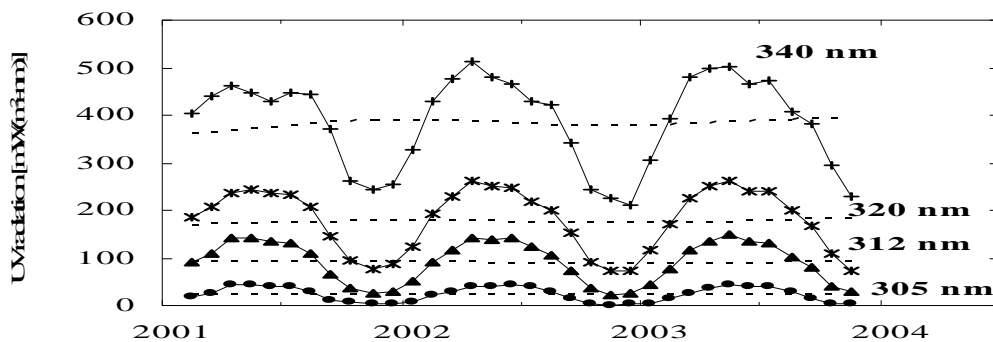
**Fig.8.** Mean monthly total solar-weighted erythemal UV-radiation over the Issyk-Kul lake: model calculation (blue line); measured values (red dots); trend (dashed line).

For the period of 1990 – 2003, the values of total intensity of erythematos weighted UV-B radiation (295-315 nm) reaching the ground in the area of Issyk-Kul lake, were estimated 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 of June, 2003 - February, 2004 the calculated values of total intensity of UV-B radiation were 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  $(0.23 \pm 0.05)\%/yr$  the intensity of the global solar UV-er irradiation increased with a rate of  $(0.38 \pm 0.07)\%/yr$ .

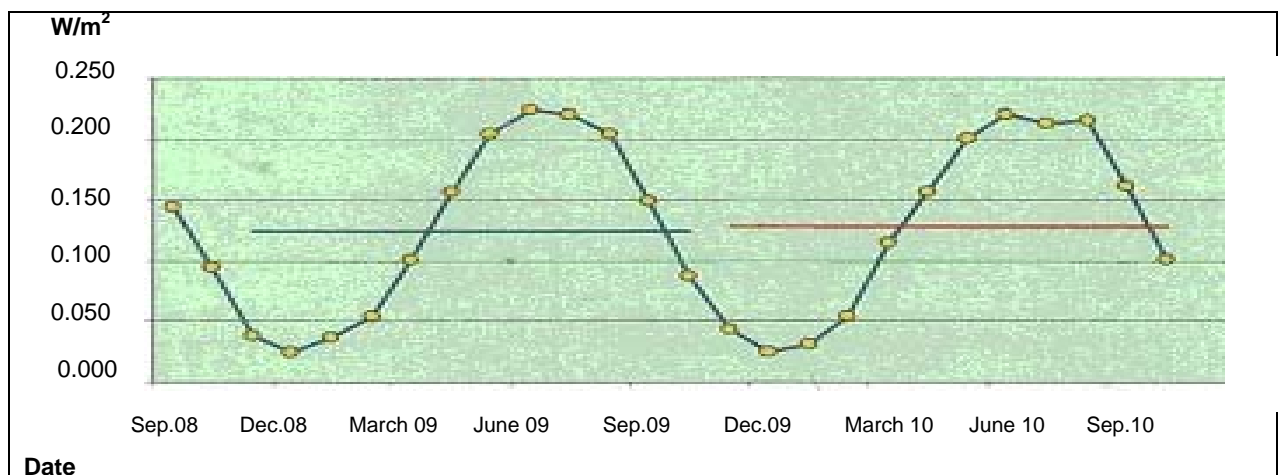
When comparing the UV-er current mean monthly values with average long-term values, positive deviations of the UV-er were registered: (15-20) % in Feb.1993, April 1997, Feb. 1999, May 2000, Dec. 2000, Nov. 2001, January and March 2002. On some days in spring-summer positive anomalies reached (40-65) %. The increments in mentioned UV-er 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 9 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  $(2.5 \pm 0.14)\%/yr$  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  $\lambda = 305, 312, 320$  and 340 nm on the Earth's surface with rates of 7.8; 4.6; 3.3 and 1.4%/yr, accordingly.



**Fig. 9.** 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 are in a steady correlation with the intensity of the direct solar UV radiation ( $\lambda = 305$  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.

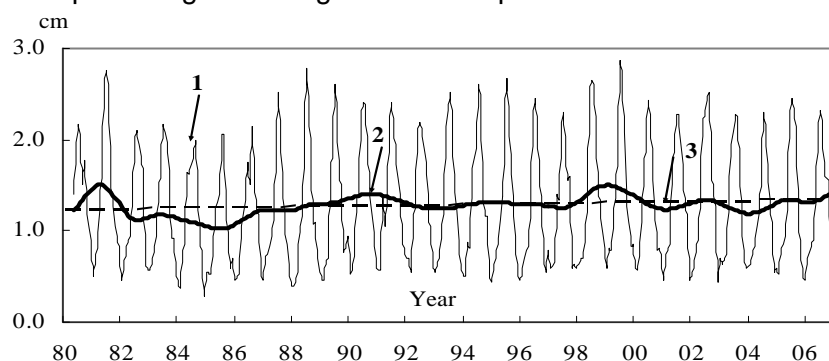
Fig. 10 shows a seasonal trend of variations of UV-B radiation and an increase of the mean annually UV-B radiation in 2010 by 2,4% compared with 2009 in the Issyk-Kul.





**Fig. 10.** 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.

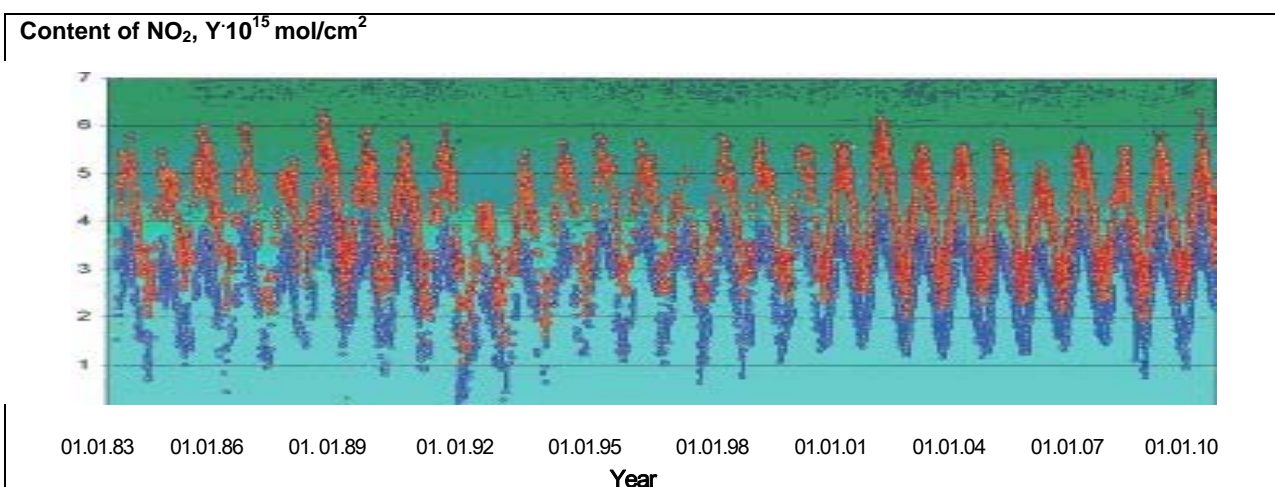


**Fig. 11.** Seasonal (1), annual (2) variation of water vapor and linear trend (3) at Issyk-Kul GAW station.

A total amplitude of seasonal variations of  $W$  from winter to summer at Issyk-Kul station has changed within wide ranges from  $1.53 \text{ g}\cdot\text{cm}^{-2}$  in 1985 to  $2.39 \text{ g}\cdot\text{cm}^{-2}$  in 1988 (Figure 11). The mean amplitude for the whole observation period was  $(1.91 \pm 0.23) \text{ g}\cdot\text{cm}^{-2}$ .

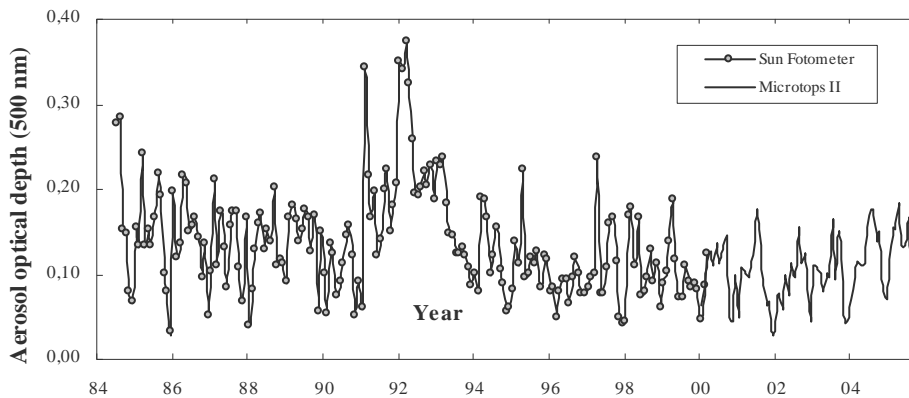
The mean monthly of the stratospheric nitrogen dioxide ( $\text{NO}_2$ ) slant column content from April 1983 to December 2010 are presented on Figure 12. The  $\text{NO}_2$  seasonal variations have 35-45% amplitudes.

Between 1983 and 2010, the total content of  $\text{NO}_2$  vertical column ( $Y \cdot 10^{15} \text{ mol}/\text{cm}^2$ , 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. 13.



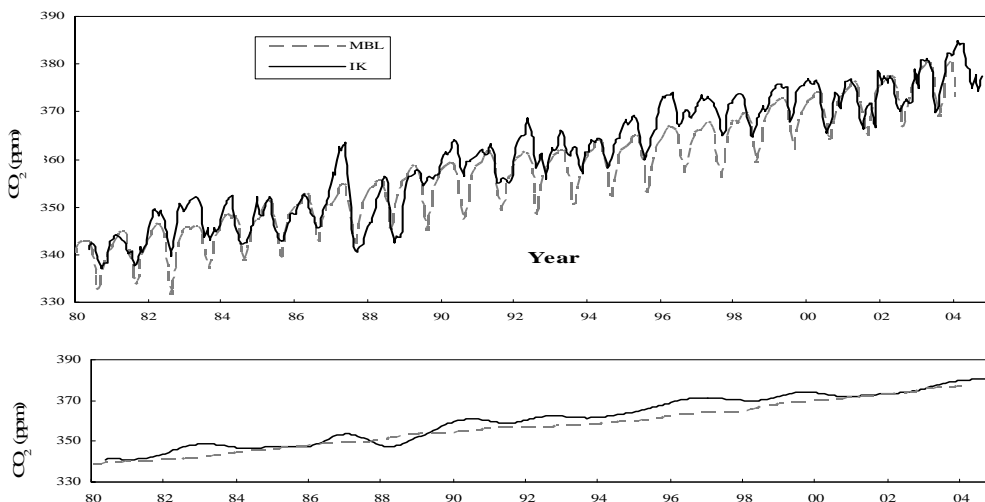
**Fig.12** A total of the nitrogen dioxide ( $\text{NO}_2$ ) in 1983-2010.

The results of measurements of  $\text{CO}_2$  and troposphere aerosol at Issyk-Kul station are presented in Fig.13 and 14.



**Fig. 13.** Temporal variations of monthly mean CO<sub>2</sub> column averaged mixing ratio over Northern Tien Shan (IK), zonally averaged marine boundary layer CO<sub>2</sub> mixing ratio (MBL) (upper panel). The long-term trends are represented in lower panel.

**Fig. 14.** 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 on 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](http://www.empa.ch/gaw/gawsis)).

#### 5. Future plans

In account of the COP Decision VIII/2, item 4. and Recommendations of the 8th meeting of the Ozone Research Managers, the priority at the above mentioned stations in Kyrgyzstan for the nearest future will be given to investigations of interaction between ozone and climate, between



stratospheric aerosol and climate, and influence of sulfuric acid stratospheric aerosol on ozone. To implement these tasks, it is necessary to carry out the following:

- to continue monitoring of ozone, NO<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>O, UV-er on the ground surface, and surface ozone at the station of Issyk Kul.
- to establish the devices for measurement of other greenhouse gases (CH<sub>4</sub>, N<sub>2</sub>O), tracer gases (SO<sub>2</sub>, CO), total and scattered solar UV radiation at the Earth's surface.

## **6. 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 and technical support from General Trust Fund for Financing Activities on Research and Systematic Observations Relevant to the Vienna Convention and other international organizations.

For validation of ozone measurements in different years, a last 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 in 1991.

Kyrgyzstan kindly requests to render assistance and financial support for calibration of scientific equipment on "Issyk-Kul" scientific research station. According to scientific standards, calibration of spectrophotometers must be conducted every five years, but because of lack of funds, Kyrgyz scientists were not able to implement it.

It is important to note that scientific research station "Issyk-Kul" for measurements of the ozone and green-house gases is the only station located at the great area - between Ural mountains chain and Pacific Ocean. The target technical and financial support of "Issyk-Kul" station will allow to continue scientific research of stratospheric ozone and green-house gases over Central Asian region, as well as to contribute to the global program of researches of the ozone layer.