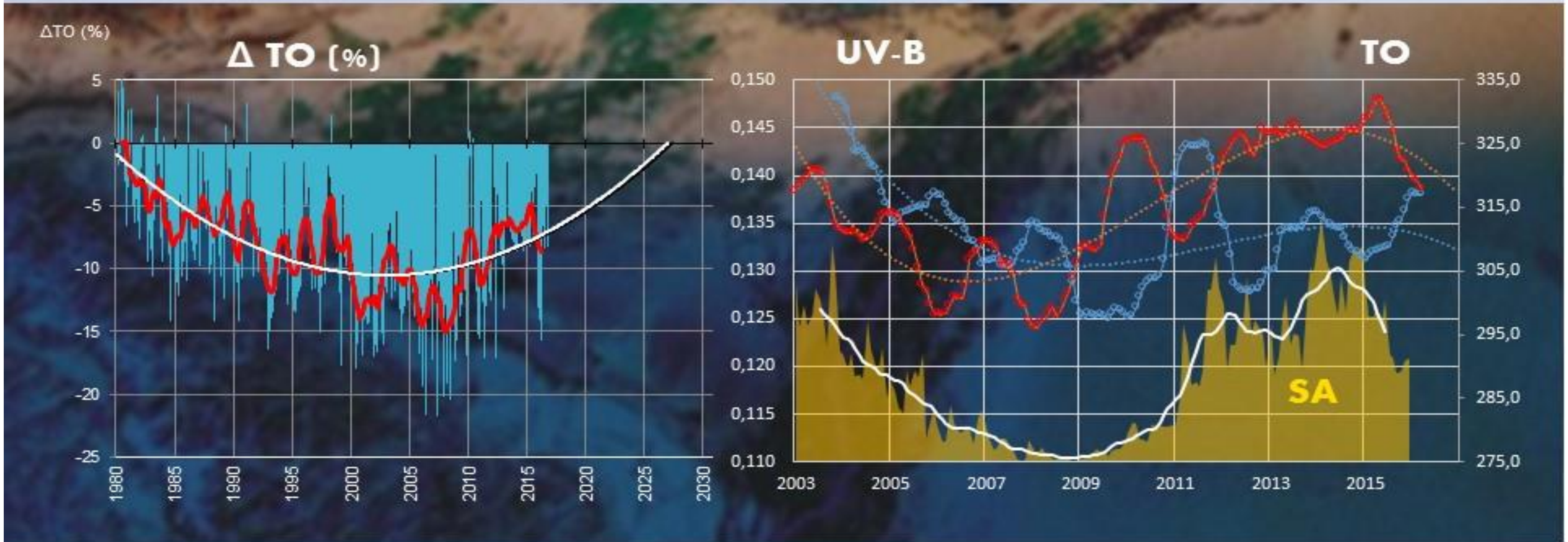
Kyrgyzstan

Variability of ozone layer and greenhouse gases in the atmosphere of the central part of the Eurasian continent

Orozaliev M.D., Toktomyshev S.J.



Variability of ozone layer and greenhouse gases in the atmosphere of the central part of the Eurasian continent

(Kyrgyzstan, Issyk-Kul station)

INTRODUCTION

Monitoring of the atmospheric ozone and main greenhouse gases in Central part of the Eurasian continent has been conducted for more than 35 years at Issyk-Kul Station, located on the coast of the mountainous lake Issyk-Kul (lat. 42.62; long.76.98 a.s.l.; 1640 m.). There were received a unique number for the duration of TO and researched narrow impurities of the atmosphere, which significantly complimented the measurement results of the monitoring network managed by the World Meteorological Organization (WMO).

The selection of the station location on the northern shore of Issyk-Kul Lake (42.60 N, 77.00 E, 1650 m.a.s.l., Kyrgyzstan) was due to:

- by-way location in the central mountainous part of the Eurasian continent, in contrainiction to the vast majority of stations in oceanic and coastal regions of the world (Fig. 1);

- deficiency of industrial enterprises - sources of significant anthropogenic researched atmospheric components;

- climatic conditions and, in particular, the large number of sunny days (≈200 days), which increases the efficiency use of the solar-spectroscopic absorption method.

The uniqueness of the station location is defined, due to the fact, that this by-way studied intracontinental region has powerful mountain ecosystems Middle and Central Asia (the Himalayas, Tien Shan, Pamir-Alai, the Tibetan Plateau) which have a significant impact on the high-altitude streams, which play a significant role in spatial-temporal distribution of the general content of ozone and other climate active narrow impurities in the atmosphere.

The scientific station Issyk-Kul registered in the databases of the world's centers on:

- ozone, 1994 (Issyk-Kul № 347- WOUDC, www.woudc.org), Toronto, Canada;

- greenhouse gases, 1995 (ISK 242 NOOWDCGG, www.ds.data.jma.go.jp), Tokyo, Japan;

- nitrogen dioxide, (NDACC - Issyk-Kul, www.ndsc.ncep.noaa.gov), USA;

The Issyk-Kul station has been included in the network of international stations, Global Atmosphere Watch (GAW) since 2004 (Fig. 1). The station is the exclusive in the whole territory of the former USSR and Russia, regularly working since 1980, according to the full program of GAW.

The station has been included in an International network of AERONET www.aeronet.gsfc.nasa.gov (NASA, USA) of the automatic monitoring of atmospheric aerosol properties since 2007.

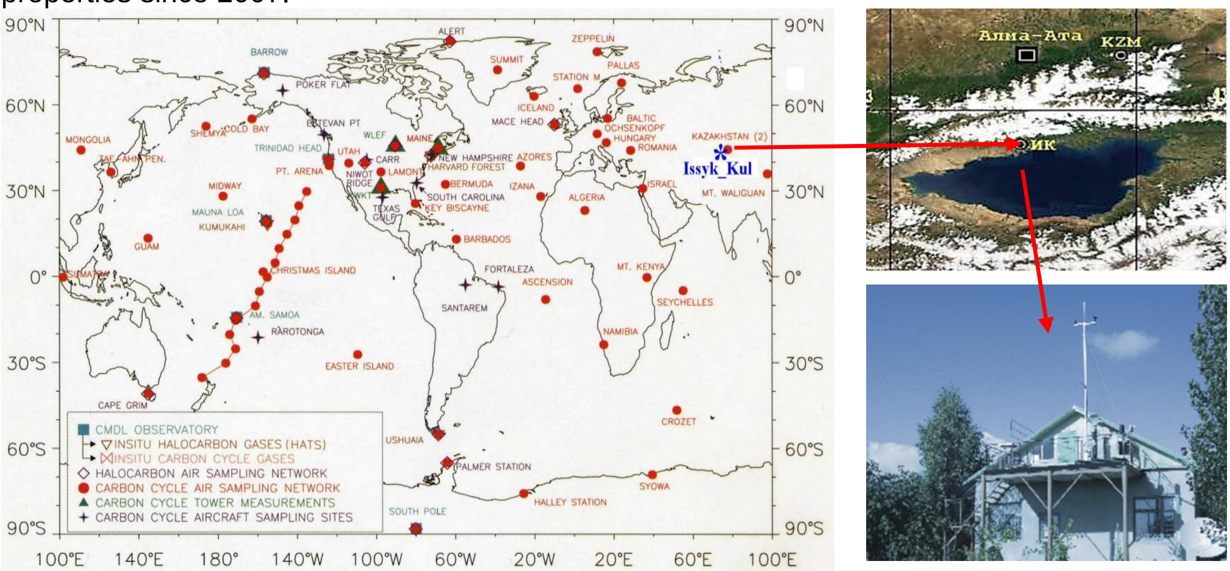


Figure 1. The location of Issyk-Kul Station relatively to other GAW monitoring stations

On the base station Issyk-Kul received a unique on duration (more than 35 years) and complexity a timing series database, on the base of which were researched features of changes in ozone, greenhouse gases, ultraviolet (UV-B) radiation and aerosol characteristics in the atmosphere over the Central mountainous part of Eurasian Continent. The results of the research showed, that for mountainous conditions, the influence effect of solar and geophysical processes on the variability of the researched impurities was more significant than that of the ocean and the plains.

The data from Issyk-Kul Station are also used for validation and comparative analysis of satellite measurements, for development and specifications of models on forecasting of the ozone layer dynamics, greenhouse gases content and regional climate.

Detailed description of measurement methods, complex of measurement devices used at the research station Issyk-Kul, processing procedure and input-output analysis of measurements as well as detailed reference list on this subject are given in works [1-17].

Due to the large volume of material presented in the article informative and most significant results are shown in graphs

1. MONITORING OF TOTAL OZONE

The ozone content measurements are performed with the spectrophotometer scanning installation (SPS).

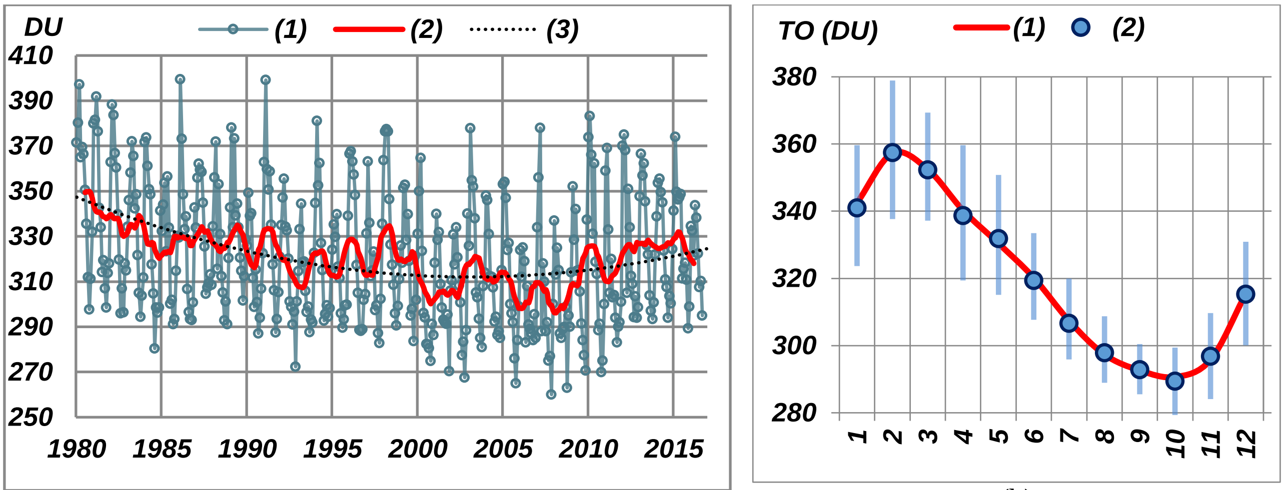
Results of TO monitoring, presented in Fig. 2, 3, 4, showed that TO changes is a complicated fluctuating process with distinct annual and quasi-biennial circularity.

Annually average TO numerical values for monitoring period (1980-2015) are presented in the Table1.

Table 1. Annually average TO values for monitoring period (1980-2015)

year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
TO,DU	349	340	338	334	329	323	330	332	324	335	316	333
year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TO,DU	315	310	323	315	325	315	332	320	305	306	307	320
year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
TO,DU	310	310	300	306	299	311	323	313	326	329	326	329

Fig. 3 shows, that ozone layer depletion and recovery occur at different rates (b): for 1980 - 1985, value of b = -0.4 DU/mon.; 1984 - 1990, b = 0.18 DU/mon.; 1989 - 1994, b = -0.26 DU /mon.; 1993 - 1998, b = 0.14 DU /mon.; 1997 - 2006, b = -0.16 DU/mon.; 2006 - 2015, b = 0.29 DU/mon. The amplitude of the oscillations of the rate of change of the TO (Fig. 4) varies within wide limits, and increase in magnitude of the amplitudes is observed at the beginning and its reduction at the end of the observation period (1980-2015) like the beating of amplitudes.



(a) (b)

Figure 2. Temporal variations of total ozone content according to data measured at Issyk-Kul station (ISK 347): (a). Variations of monthly average (1) and inter annual values of TO (2), parabolic trend (3); (b). Mean (1981-2013гг.) seasonal changes of TO (2) in comparison to model (curve 1), the correlation coefficient between (1) and (2) r=0.999.

Fig. 5 presents deviations of average monthly TO values (columns 1), expressed as a percentage to the average annual cycle of TO for year 1980. Curve "smooth" represents inter annual variations of the TO deviations, curve 3 is a polynomial trend of the second kind, showing the TO evolution during the monitoring and coming years. It shows that the impoverishment of ozone layer, according to parabolic trend, was 11% on average during 1980-2005, and in the last decade has been observed its recovery. According to the trend, the predictive recovery of the ozone layer to the level of 1980 over North Tien Shan is expected in 2025-2028, respectively.

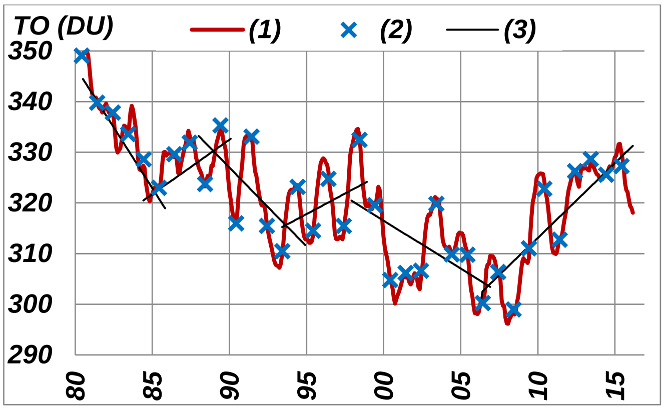


Figure 3. Variations of inter-annual (1) and average annual (2) TO values with linear trends (3).

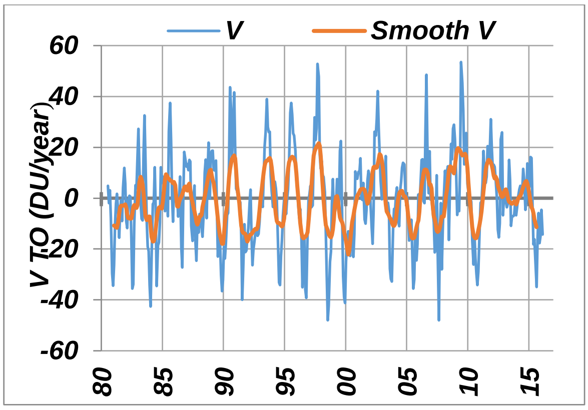


Figure 4. Fluctuation of TO change rate (V) and its smooth (smooth V) for 12 months.

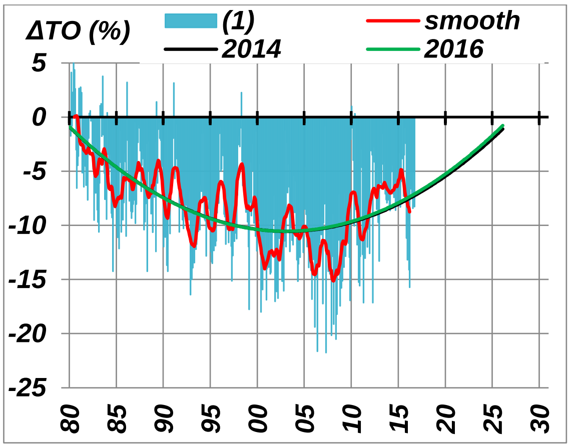


Figure 5.TO value deviations in % (1) relatively to TO values in 1980 and smooth (smooth) and parabolic trends (2014, 2016)

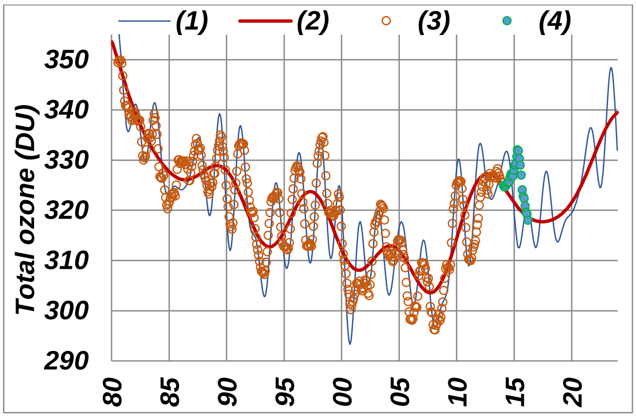


Figure 6. TO evolution: model based calculations with (1) and without (2) quasi-biennial contents in inter annual fluctuations of TO; experimental data for 1980-2013 (3) and for 2014-2016 (4)

Fig. 6 depicts comparison of inter annual changes of TO up to 2016 with model calculations of temporal variation of TO made in 2013 [6, 7]. According to estimated data in 2013 it was prognosticated, that observed recovery of the TO since 2008 should change to decrease in 2015 up to 2017-2018. Moreover, the scope of the oscillation amplitudes of the TO during the period (2014-2015) TO trend direction change was to decrease. Measured TO data in 2013-2016 (Fig. 2,3,4,5) proved prognosis about recession and decrease of amplitude excursion of fluctuations of TO. However, calculated and measured data differs with that fact that recession of quasi-biennial oscillation in TO takes place with delay, approximately, for 1 year. This delay is likely due to the fact that the beginning of 24th eleven years cycle of the solar activity occurred not in 2008 as previously predicted, but with a delay by one year in 2009.

To improve the model describing the observed experimental data and allowing prediction of TO changes for the coming years, more detailed study of solar and geophysical, astronomic and anthropogenic factors' impact on inter annual fluctuations of TO are required.

It needs to note, that in ozone layer recovery on regional and global scales, there is undisputed contribution of world community, successfully realizing programs documents, accepted by Montreal Protocol in 1987, which is a supporting document of Vienna Convention, UNEP.

1.1 Regional specific features and temporal evolution of the quasi-biennial oscillation in total ozone (TO) in the atmosphere

Fig. 7 presents averaged (smoothed) values of TO for three and twelve months, received after subtraction of the annual cycle (norm) and non-linear trend (correspondingly curves 3 and 12) [8]. In the same figure, in order to demonstrate the features of interrelation between quasi-biennial oscillation in TO and in equatorial zonal wind, the diagrams of temporal TO variations, zonal wind velocities (V QBO) at the level of 20 hPa (www.fu-berlin.de), as well as temporal variation of solar activity index (F 10.7 – radio waves length 10,7 cm) were presented (http://www.ngds.noaa.gov).

In order to make analysis of regional features of QBO TO, the data of Xianghe (XIA 208), Kunming (KUN 209), Arosa (ARO 35), Mauna Loa (MLO 31) and Brisbane (BBN 27) stations (http://www.woudc.org), which are located at different latitudes and longitudes [9], were processed using above mentioned method.

Fig. 8 presents the comparison of relative norms of TO, that were determined for the monitoring stations: ISK 347, MLO 31, ARO 35, XIA 208, KUN209, BBN 27.

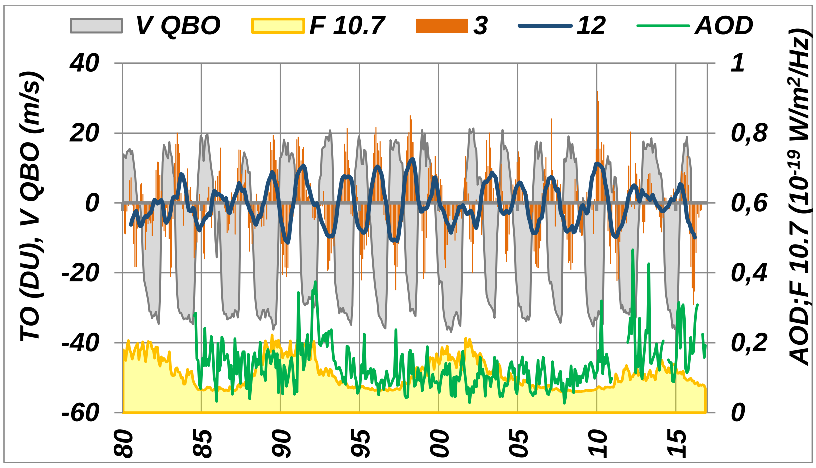


Figure 7.Comparison of quasi-biennial oscillation in TO (DU) (smoothed in three months - 3 and in twelve months - 12) with quasi-biennial oscillation in Equatorial Zonal Wind velocity (m/c) (V QBO) at the level of 20 hPa, with Solar Activity (Index F 10.7) and aerosol optical depth (AOD).

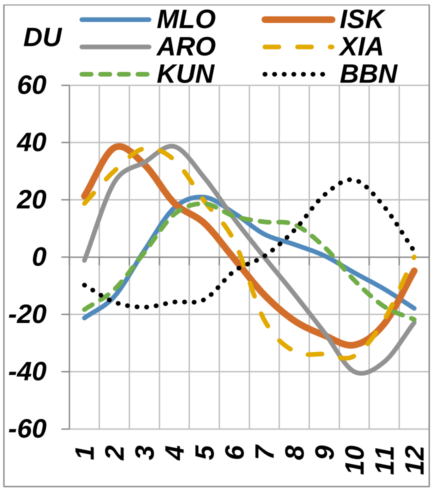


Figure 8. The relative norms of TO: ISK; MLO; ARO; XIA; KUN; BBN

Using Fourier and wavelet analysis of time series of TO and ZW have been identified parameters of significant harmonic QBO TO and QBO ZW components, as well as the period ratio, amplitude and phase of harmonics analyzed significant fluctuations.

Fig. 9 shows a good agreement between the experimental data ISK347 (2, 3 in Figure 9) to the mode

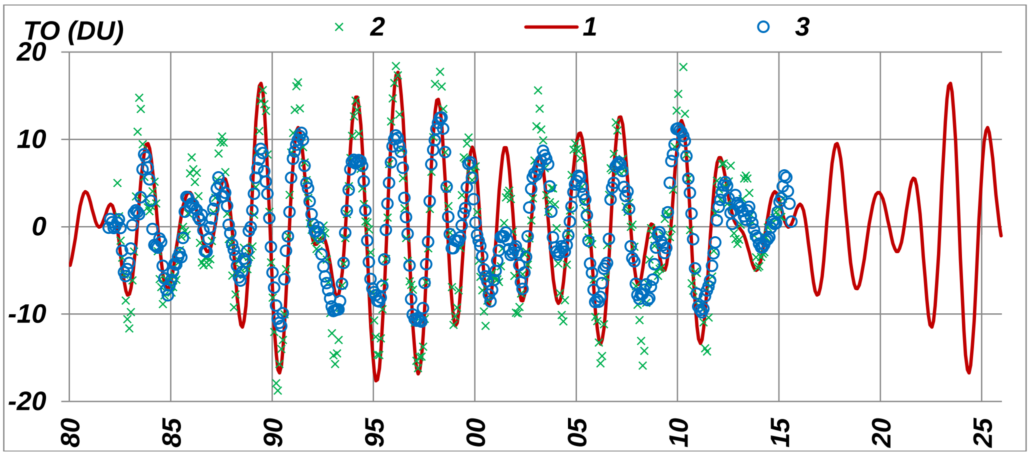


Figure 9. The comparison of model calculations (curve 1) with monitoring data of Issyk-Kul station (2 – smooth 6 month; 3- smooth 12 month).

Based on analysis of long-term (1980-2015) experimental data of Issyk-Kul station, in comparison with the data from other stations, there were defined specific features of quasi-biennial oscillation (QBO) in total ozone content over the North Tyan-Shan. It is established, that the regional specific feature and temporal evolution of QBO in total ozone, to a significant degree, are resulted by the synchronization of quasi-biennial and annual (seasonal) oscillations in TO. It was found, that experimentally observed QBO TO amplitude beats are based on superposition of harmonics of QBO TO, generated as a result of mutual-synchronization of quasi-biennial and annual (seasonal) oscillations in TO. Calculations revealed that the minimum in QBO TO amplitude excursion over North Tien-Shan was reached in 2015 and started new 34-years period in variations of ozone layer.

It is shown that the pattern of the relationship between TO and ZW is disrupted during the high values of the aerosol content in the atmosphere (volcanic activity), as well as during periods of change of magnetic polarity of the sun and its flare activity until r correlation coefficient sign is changed, the degree and duration of disturbances have regional features [6. 8]

1.2 Analysis of ground-based and satellite measurements of TO

Results of analysis of TO temporal variability in the region of mountainous zones of Middle Asia and Tibetian plateau obtained with traditional methods and the methods of spectral analysis, cross-wavelet and composite analyses are presented [15,17].

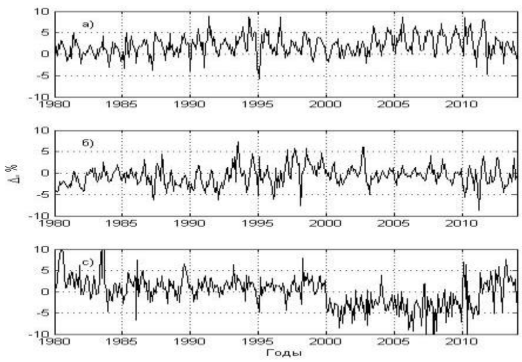


Figure 10. Relative deviation Δ (%) between ground-based and satellite (V86) measurement of TO 1980-2013. a) – Hianghe Station (No208), b) – Kunming Station (No 209), c) – Issyk-Kul Station (No 347).

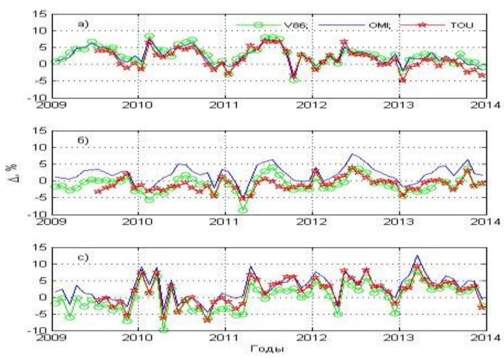


Figure 11. Relative deviation Δ (%) between ground-based and satellite (V86, OMI, TOU) measurement of TO 2009-2013. a) – Hianghe Station, b) – Kunming Station, c) – Issyk-Kul Station

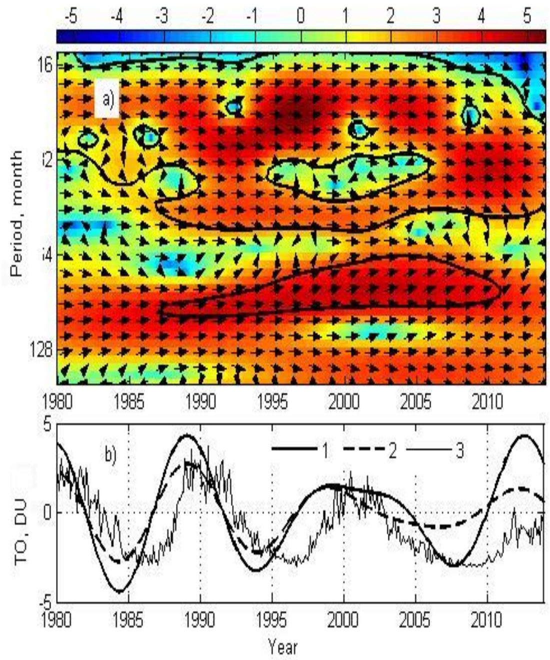


Figure 12. a) - Cross-correlation wavelet analysis of total ozone series based on ground-based and satellite data for the station 347, Issyk-Kul. Degree of correlation (color scale) is given in relative units. The thick black line marks the area with a confidence interval of 95%. Arrows show the relation between the phases of time series: the right - in phase, left - in the opposite, downward - G347 S347 variations ahead by 90 °, upwards - lagging by 90 °. b) - composite rows based on the ground (1) and satellite (2) data in 8-13 years and variations of solar activity (3).

The data of ground-based observation at stations located at Huanghe (№208), Kunming (№209) and Issyk-Kul (№347) along with the satellite data obtained at SBUV/SBUV2 (SBUV merged total and profile ozone data, Version 8.6) (ftp://toms.gsfc.nasa./ pub/sbuv/MERGED) during 1980-2013, OMI (Ozone Monitoring Instrument) (http://avdc.gsfc.nasa.gov) и TOU (Total

Ozone Unit) (http://satellite.cma.gov.cn) during 2009-2013 were used. A mean relative deviation from the data of SBUV/SBUV2 for the Kunming and Issyk-Kul for the period of 1980-2013 is less than 1%, for the Huanghe a typical excess of satellite data over the ground-based ones is registered at an average deviation of 2% (Fig. 10, 11).

The results of the Fourier analysis showed that the distribution of amplitudes and the periods of TO fluctuations within the range of over 14 months is similar for all the analyzed series. One of the reasons governing the general regularities of TO temporal variability in this region may be high mountainous systems of the Middle and Central Asia (Himalaya, Tien Shan, Pamir-Alai, Tibetan plateau) having a significant effect on the upper jets that, as it is known, determine in many cases both the TO spatial distribution and temporal variability. At the same time, according to the results of cross-wavelet and composite analyses, the phase relationships between the series may considerably differ, especially in the periods of 5-7 years. The phase of quasi-decennial oscillations for the Kunming station is close to the 11-year oscillations of the solar cycle, for the Huanghe and Issyk-Kul stations the TO variations go ahead the solar cycle (Fig. 12).

1.3 Monitoring of surface ultraviolet radiation (UV-B).

To monitor the total erythemal ultraviolet radiation in 2003 was purchased and installed an automatic UV 501modeli biometrics at the station "Issyk-Kul".

Fig. 13 shows the interannual variation in surface UV-B radiation (curve 2) and the CCA to order polynomial trend 3 (red and blue dashed line) and the average monthly value of solar activity index F10.7 (curve 3). Compare (Figure 13) interannual variations of UV-B (line 2) and TO (curve 1) and their rate of change (Figure 14) shows their high correlation [7, 9]

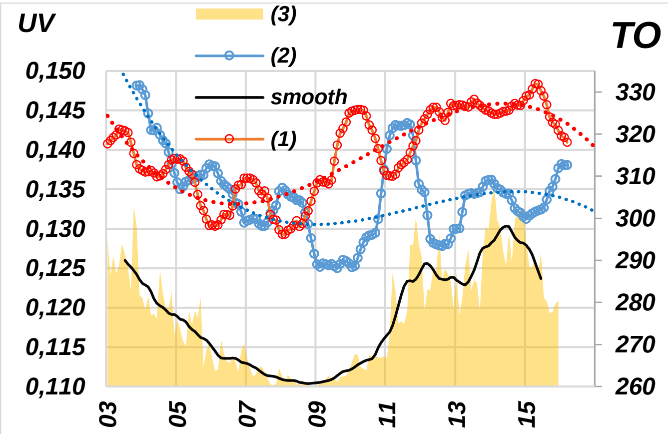


Figure 13. Inter annual variations of TO (1), surface UV-B radiation (2) with polynomial trends of 3rd order (dotted lines) and variations of monthly average solar activity index (F 10,7) values (3) and its smooth (smooth)

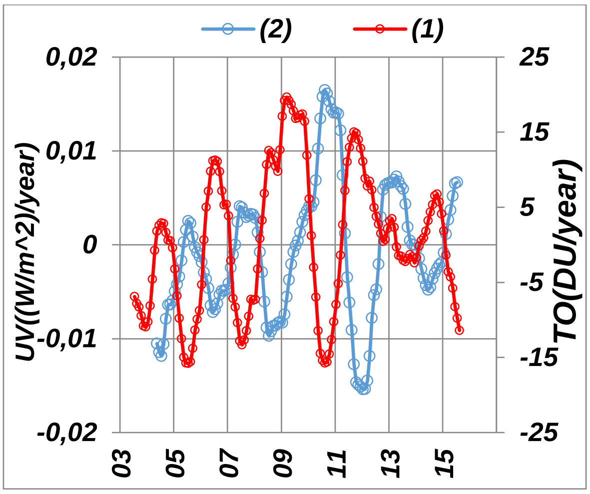


Figure 14. Inter annual variations of UV-B (2) and TO (1) changes rates

2. MONITORING OF VARIABILITY OF SMALL CONSTITUENTS IN THE ATMOSPHERE

2.1 Variability of total nitrogen dioxide (NO2).

For over 30 years (since 1983) measurements of NO2 total content are carried out at Issyk-Kul station, and the station in this part of the measurement is included to NDACC (www.ndsc.ncep.noaa.gov/sites/stat_reps/issykkul/). According to the continuous measurements, Issyk-Kul station is the longest in space in the former Soviet Union and the second longest for duration in the world.

The total NO2 content varies considerably throughout the day, especially during sunrise and sunset. NO_2 values dependence on time of a day is illustrated in Fig. 15.

Rapid and significant changes at sunrise and sunset, due to the rapid transformations between NO and NO2. Slower changes in NO2 content during the day and night are associated with slower photochemical processes involving N2O5 and NO3. Calculations using the three-dimensional transport and photochemical models of the atmosphere have shown that the values of NO2, corresponding to local noon time, exceed the value of the morning, but less than the value of the evening, appearing closest to half the sum of these two values (Figure 16).

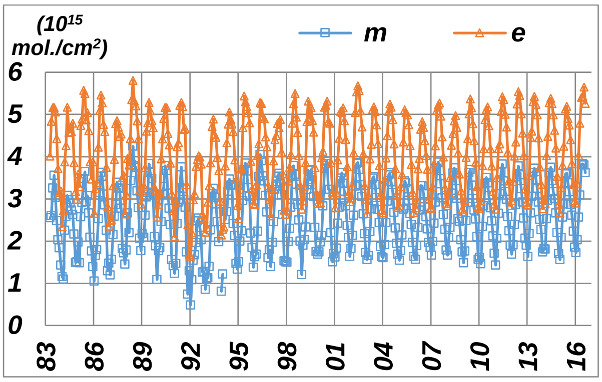


Figure 15. Variations of monthly average values of NO_2, obtained from morning (m) and evening (e) measurements

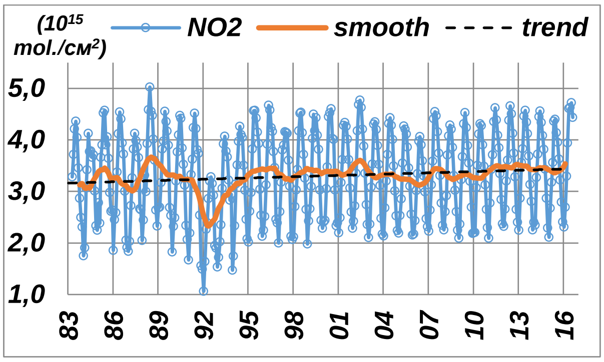


Figure 16. Time series of monthly average values of total NO_2, obtained from average daily data on NO2, it smooth (smooth) and linear trend (trend)

The growth rate (according to the linear trend), the total content of NO_2 in the atmospheric column for the observed period amounted to v = 8,8 * 1012 mol./cm2 or 0.28% per year. Total NO2 content for this period increased by 8.37%.

2.2 Variability of nitrous oxide (N2O).

As a result of nitrogen oxide N2O observations at the station Issyk-Kul are the lack of seasonal variation. During the observation period (2005-2015) N2O content increased by 3.54% in the atmosphere at a rate of 0.29% per year. It reported anomalously sharp increase in the content of the end of 2015. During the year, the content of N2O has increased by ~ 13%, i.e. about 5 times higher than the average N2O accumulation rate for the entire period 2005-2015. Increasing the content of nitrous oxide in the atmosphere represents a major threat from the point of view of climate change as well as the greenhouse effect of one molecule of N2O is about 300 times greater than the effect of a CO2 molecule. Furthermore, nitrous oxide is the main source of formation of nitrogen dioxide (NO2) in the stratosphere, which (NO2) is the main link in the catalytic cycle of stratospheric ozone.

2.3 Variability of water vapor (H2O).

The measurement results are integrated water vapor content in the atmospheric column at the station "Issyk-Kul" from January 1981 to September 2016 in the form of monthly mean (WM, g/cm2) values obtained by averaging the actually measured for the month average daily values of the water vapor content, presented at Fig. 17. It also shows the smoothed (averaged) curve 2 (smooth), obtained with the use of 12-month filter, which excludes seasonal variations H2O content. A positive linear trend was 0.18% per year.

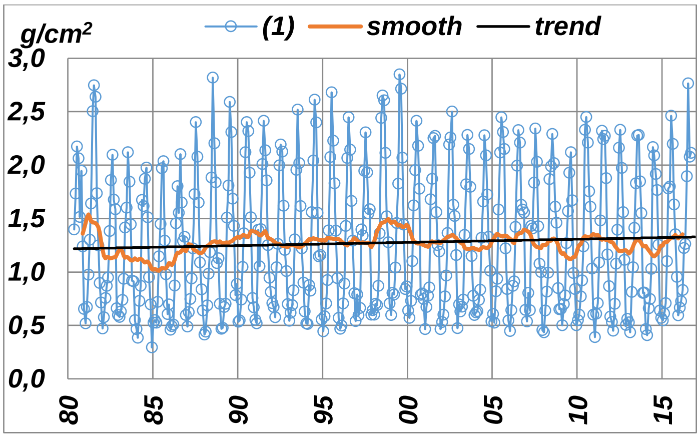


Figure 17. Variations of H2O: monthly average (1), inter annual (smooth), linear trend (trend)

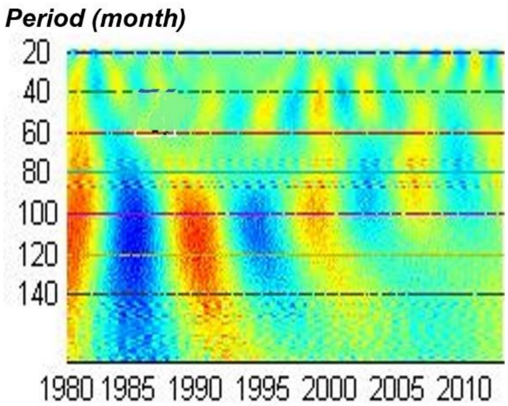


Figure 18. The results of wevelet analysis of time series of H2O (1980-2015).

From late of 2014 to 2016, the water vapor content has increased markedly. Most likely this is due to the El Niño phenomenon (2014-20150, which has a significant impact on the parameters of the atmosphere on a global scale.

2.4. Variability of carbon dioxide (CO2)

Fig. 19 represents a time series of monthly CO2 values, which demonstrates seasonal variation and the constant increase of CO2 in the atmosphere over the period 1980-2016 years. Since the end of 2013, there are abnormally high CO2 content in the atmosphere over the central part of Eurasia. This is most likely due to the volcanic activity of the Earth. Confirmation of this hypothesis are anomalously high values of Aerosol optical thickness (AOT) (Figure 21) and sulfur dioxide (of SO2) (Figure 23), which were received at the station "Issyk-Kul". These components of the atmosphere are products of volcanic eruptions. The growth rate (for linear trend) SO_2 concentration of the observed period amounted to v = 1.7 ppmv per year, or 0.49% per year. The total CO_2 concentration during this period increased by 16.3%.

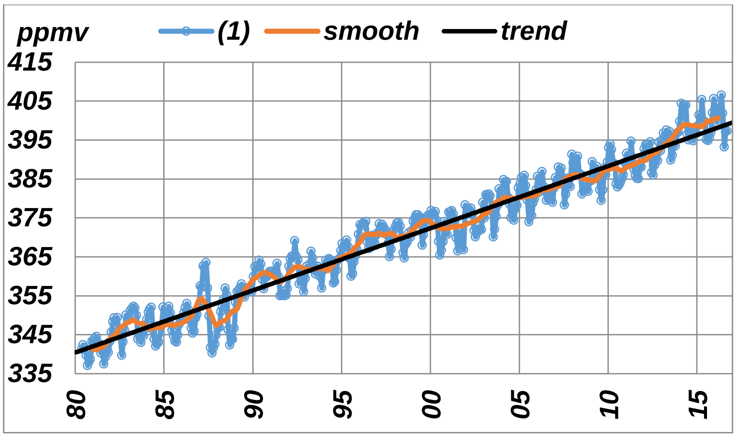


Figure 19. Variation of average monthly (1), inter annual (smooth) values of CO_2 and linear trend (trend).

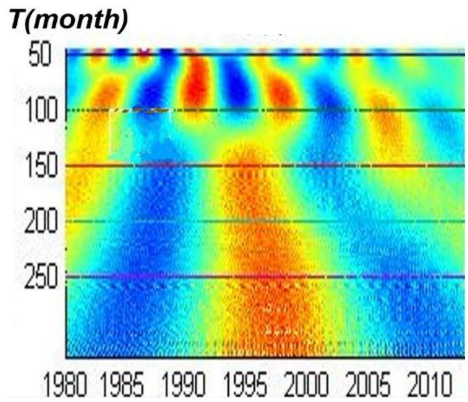


Figure 20. The results of wevelet analysis of time series of CO2 1980-2015 [3]

2.5 Variability of aerosol optical depth

From 1984 to 2009, the value of AOT (τa) was calculated from the measured value of the transparency of the atmosphere above the Issyk-Kul station.

At the station Issyk-Kul since August 2007 conducted the monitoring of the optical characteristics of aerosols modern automatic radiometer CIMEL model CE 318N-V8S5-M9, the results of which are published on the website [http://aeronet.gsfs.nasa.gov.] AERONET NASA.

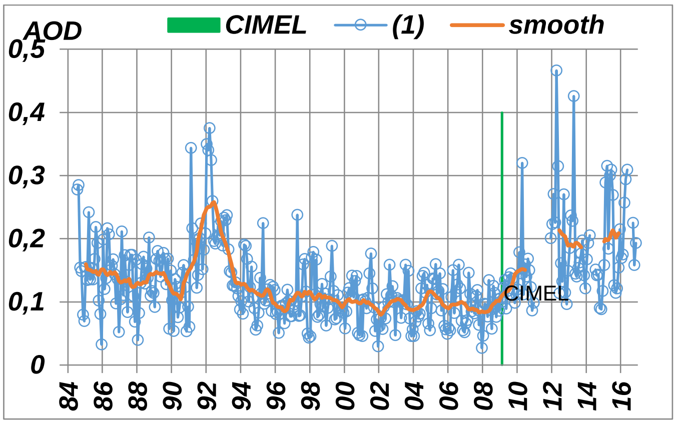


Figure 21. Variations of monthly average (1) and inter annual (smooth) values of AOD for 1984-2016

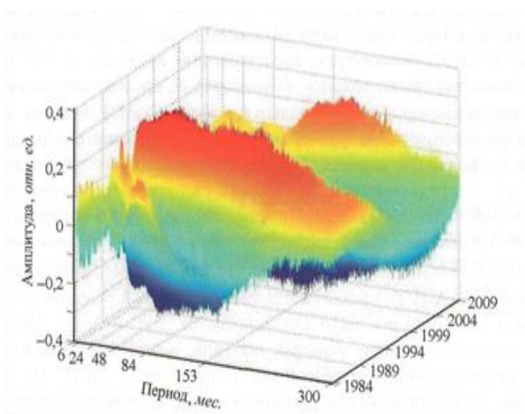


Figure 22. The results of wavelet transform of aerosol optical depth [12]

Fig. 21 shows the monthly variation (1) and interannual (smooth) AOD values for the period 1984-2016. Green dividing line (CIMEL) shows the border (2009), from which the AOD data starts only with the radiometer CIMEL. The lack of data in 2011, 2014 and 2016 is due to the passage of CIMEL Calibration Center Goddard Space Flight Center, NASA. One of the main reasons for an abnormally highly AOD values in the intervals from 1991-1993 and for 2010-2016. It is a high volcanic and seismic activity of the Earth.

2.6 Variability of sulfur dioxide (SO2).

The results of the measurement of sulfur dioxide at the station Issyk-Kul in the period from 2000 to September 2016 are shown in Fig. 23. SO2 variability is dominated by seasonal changes, minimum SO2 content is observed in July and August, the maximum - in February (Fig. 24). It should be noted that in recent years (2013, 2014, 2015) according to the "Issyk-Kul" station, in the atmosphere of the Northern Tien Shan observed abnormally high content of SO2. For example, in 2013 the average annual value of SO2, approximately 1.7 times (66%) exceeded the long-term average (2000-2011gg.) SO2 value for the entire period of observation, in 2014 - 1.6 times (58%), and in 2015 - 1.9 times (85.5%). One of the most likely causes of such anomalies to change the SO2 is volcanic and seismic activity of the Earth observed since 2010. This increase in SO2 in the atmosphere poses a threat in terms of the formation of sulfuric acid aerosols and acid rain, have a negative impact on the environment of the region.

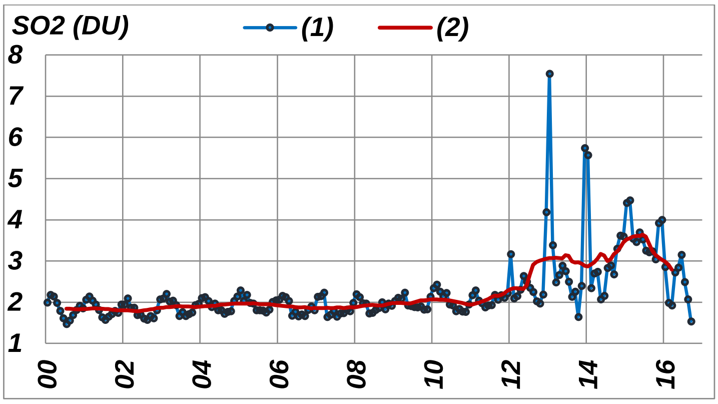


Figure 23. Monthly average values (1), inter annual (2) and linear trend (3) of SO2, according to data of Issyk-Kul Station.

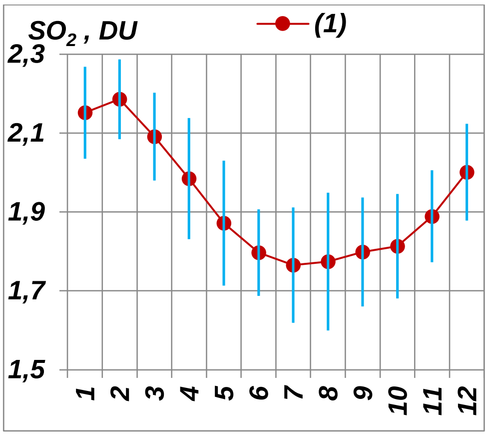


Figure 24. Mean for 2000-2011 seasonal rate of SO2 (1)

2.7 Variability if carbon monoxide (CO)

CO measurement results at the station Issyk-Kul in 2004 - 2016 years confirm the well-known facts of the presence of seasonal variations and the negative trend of CO. The highs and lows of seasonal variations often fall respectively in February and September, and in some years the extremes are shifted by one - two months. Over the entire period of observation (from 08 / 2004-09 / 2016) CO decreased by 27%. Linear trend indicator was -2.25% per year. The average annual value for the entire period of observation well (102,76 ± 8,36) ppb.

2.8 Variability of methane (CH4).

Based on the results of observations of CH4 at the station Issyk-Kul for the period 2004-2016 it can be noted the lack of seasonal variation, but there are more long-period fluctuations. During the entire observation period (2004-2016 years) was observed increase in CH4 content in the atmosphere at a rate of 5.13% from 0.43% a year.

3. DISSEMINATION OF RESULTS

3.1 Data reporting

The monitoring results (TO, H2O, CO2, CH4, NO2, aerosols and UV-B, etc.), received at the station «Issyk-Kul» are used:

- to expand the measurement results database world centers: Ozone (Issyk-Kul № 347-WOUDC, www.woudc.org); Greenhouse Gas (ISK 242 NOO WDCGG, www.ds.data.jma.go.jp); Nitrogen dioxide (NDACC - Issyk-Kul, www.ndsc.ncep.noaa.gov) Aerosol (NASA, Aeronet - Issyk-Kul, www.aeronet.gsfc.nasa.gov); for the development and adjustment of models forecast the state of the ozone layer and climate change;

- for comparative analysis and validation of satellite measurements [4, 5, 15, 17, etc.];

- for the development and adoption of international organizations (UNEP, WMO and others.) and government agencies (Kyrgyzstan, Russia, China and others) strategic plans and programs for the protection of the ozone layer and reduce the rate of climate change, as well as to address regional environmental and economic problems associated with abnormal changes in climatically active impurities in the atmosphere

4. IMPLEMENTATION OF THE RECOMMENDATIONS OF THE 9th OZONE RESEARCH MANAGERS MEETING

As a result of years of research in previous years created a database containing content measurements in the atmosphere of its trace gases (O3, CO2, NO2, H2O, CH4, CO, N2O, SO2, etc.) and related meteorological parameters. Analysis of the results obtained earlier revealed variability characteristics study of atmospheric gases, including variations in their content and long-term trends. These characteristics change with time under the influence of time-varying natural and anthropogenic factors, therefore, further experimental studies are needed to build predictive models refined temporal variability of the gas composition of the atmosphere.

The differentiation of natural and anthropogenic contributions to climate variability active impurities in the atmosphere is an urgent task that requires careful experimental studies based on modern, high-precision measuring equipment.

Unfortunately, in recent years, poor technical condition of obsolete equipment for 36 years to "Issyk-Kul" station poses significant difficulties in ensuring continuity of observations. Measuring instruments often comes from a working condition and it takes a long time to repair it due to the termination of the issue and the lack of spare parts. Such breaks in the observations significantly reduce the value and reliability of the data series of experimental studies at the patterns of change in the content of the measured pollutants in the atmosphere.

5. FUTURE PLANS

In connection with the above, there is an urgent need for a modernized station of the "Issyk-Kul OMD (Ozone Monitoring Development)», equipped with modern high-precision measuring equipment complex, which will generate a bank of high-quality experimental data, the value of which will increase with the increase of the observation period.

6. NEEDS AND RECOMMENDATIONS

Required equipment for modernization of the station:

Equipment that needs to be modernized:

- Brewer Spectrophotometer (latest modification) for monitoring of the TO;
- new Spectrometric Facility MP-32 manufactured by NGO “Typhoon” that allows to conduct the monitoring of greenhouse gases (H2O, CO2, CH4, CO, N2O) as in the depth of the atmosphere (at daily hours), as well as in air samples (at any time);
- device for measuring the concentration of ground-level ozone (GLO), TEI-49C;
- measuring device (latest modification) for an automatic control of intensity of the UV-B radiation reaching the Earth's surface;
- automatic photometer CIMEL for monitoring of the optical characteristics of aerosols;

For the modernization of the station in the Kyrgyz Republic prepared a new building to accommodate the instrumentation with a land about 0.5 hectares, and there are staff with many years of experience in monitoring and experimental studies of the variability of total ozone, greenhouse gases, ultraviolet radiation, aerosols and air pollutants.

REFERENCES

[1] Akimenko R.M., Arefiev V.N., Visheratin K.N., Upanak L.B., Orozaliev M.D., Sinyakov V.P., Sorokina L.I.,2015 // Main trends of the variability of greenhouse gases based on measurements at stations Obninsk and Issyk-Kul. Works of Russian research Institute of Hydrometeorological Information — World data center, 2015, Vol. 180.

[2] Arefiev V.N., Kamenogradskiy H.E., Semenov V.K. and Sinyakov V.P., 1995 // Ozone and nitrogen dioxide in the atmosphere over the North Tien-Shan. // Izvestiya Atmospheric and Oceanic Physics, 1, pp. 20-25.

[3] Arefiev V.N., Visheratin K.N., Sizov N.I., Orozaliev M.D., Sinyakov V.P., Sorokina L.I., 2016 //

Background concentration of carbon dioxide in the depth of the atmosphere over the North Tien Shan (monitoring station Issyk-Kul). // Meteorology and Hydrology, 2016.

[4] *Ionov D.V., Timofeyev Y.M., Sinyakov V.P., Semenov V.K., Goutail F., Pommereau J.-P., Bucsela E. J., Celarier E.A. and Kroon M., 2016 // Ground-based validation of EOS-Aura OMI NO2 vertical column data in the midlatitude mountain ranges of Tien Shan (Kyrgyzstan) and Alps (France), J. Geophys. Res., 113, D15S08, doi:10.1029/2 007JD008659, 2008.*

[5] *Ionov D.V., V.P. Sinyakov, V.K. Semenov. Validation of GOME (ERS-2) NO2 vertical column data with ground-based measurements at Issyk-Kul (Kyrgyzstan). //Advances in Space Research, 37, 2006, pp. 2254–2260*

[6] *Orozaliev M. D., Abdyldaev A. S., 2017 // «Regional specific features and temporal evolution of the quasi-biennial oscillation of total ozone (TO) in the atmosphere»//IOP Science, UK, 2017*

[7] *Orozaliev M. D., Abdyldaev A.S., Climatic response of surface air temperature on the variability of the ozone layer over the Central part of the Eurasian continent, KSUCTA Bulletin, No. 3 , 2014, pp. 60-69*

[8] *Orozaliev M.D., Abdyldaev A.S. / Quasi-biennial oscillation of total ozone in the atmospehere of Central Part of Eurasia// Proceedings of the International Symposium on Earth Observation for One Belt and One Road (EOBAR), Beijing, China, 2016, pp 35-43*

[9] *Orozaliev M.D., Toktomyshev S.J., Sinyakov V.P., Abdyldaev A.C. «Temporal variations of content of ozone, greenhouse gases in the atmosphere and climate variability in central mountainous part of Eurasia//» Proceedings of works the Second International Symposium on Earth Observation for Arid and Semi-Arid Environments (ISEO 2014) pp 217-229*

[10] *Semenov, V. K., A. Smirnov , V. N. Arefiev, 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*

[11] *Semyonov V.K. Sinyakov V.P. et al., Atmospheric CO2 monthly mean concentrations, Issyk Kul, WMO World Data Center for Greenhouse Gases DATA REPORT, WDCGG No. 29, , pp. 8, 62, 70. March 2005*

[12] *Sizov N I , Akimenko R M, Arefiev V N, Kashin F V, Orozaliev M D, Sinyakov V Pand Sorokina L I 2015 Aerosol optical depth veriability of the atmosphere over the North Tien-Shan Meteorology and hydrology № 3 pp 51 – 57*

[13] *Toktomyshev S J and Orozaliev M D 2011 The ozone holes over Central Asia(Bishkek, Kyrgyzstan) p 316*

[14] *Toktomyshev S J, Semenov V K, Amanaliev M K, Orozaliev M D and Sinyakov V P 2009 Regional monitoring of atmospheric ozone (Bishkek, Kyrgyzstan,L L Color) p 316*

[15] *Visheratin K N, Nerushev A F, Orozaliev M D, Xiangdong Z, Shumen S and Li L 2017 Temporal variability of total ozone in the Asian region inferred from ground-based and satellite measurement data Space Study of the Earth №1 pp 1-11.*

[16] *Visheratin K. N., Aref'ev V. N., Kashin F.V., Sinyakov V. P., Sorokina L. I. / Flask sample and total column greenhouse gas measurements at Obninsk and Issyk-Kul stations. // WMO Global Atmosphere Watch, Report No. 213. July 2014. C. 144 - 148.*

[17] *Visheratin K.N., Nerushev A.F., Orozaliev M.D., Zheng Xiangdong. Variability of total ozone in the Asian region inferred from ground-based and satellite data. Collection of abstracts. St. Petersburg: SPSU, 2015, (ISARD-2015), pp 246-247.*