4p.13 Observation of the total ozone columns using the IKFS-2 instrument aboard the Meteor-M N2 satellite in 2015-2020

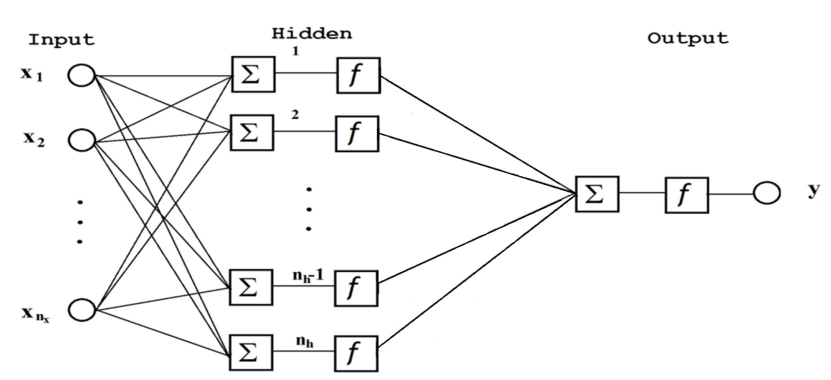
Alexander Polyakov, Yana Virolainen, Yury Timofeyev, Georgy Nerobelov.

Saint Petersburg State University **a.v.polyakov@spbu.ru**

Introduction A few years ago we have introduced a technique and some results of estimates of Total Ozone Columns (TOCs) using spectral measurements of IKFS-2 aboard Meteor M N2 satellite (see references: ITSC-XXI, articles). Now we improved the technique and extended a measurement period up to 6 years.

Instrument IKFS-2 is a Russian Fourier –interferometer on board satellite "Meteor M" No2. IKFS-2 measures radiances in 660-2000cm^{-1} spectral region with spectral resolution after apodization of 0.7cm^{-1}. Until November 2020, the swath width of IKFS-2 measurements was 1000 km until November 2020, and since 2020 December it was changed to 1500 km. We use all IKFS-2 measurement with swath width which equals 1000 km between March 2015 and November 2020.

TOC retrieval method



f – activation function
x_j – one of input parameters
$b_i^1, \omega_{i,j}^1, \omega_i^2, b^2$ - coefficients

$$TOC = f(b^2 + \sum_{i=1}^{N_h} \omega_i^2 f(b_i^1 + \sum_{j=1}^{N} \omega_{i,j}^1 x_j)$$

Artificial neural network - three-layer perceptron. Activation function is logistic. One outgoing parameter – TOC. 30 neurons in the hidden layer.

The input parameters are

a) spectral measurements of the IKFS-2 device: 25 Principal Components (PCs) of a whole spectrum, 50 PCs of the ozone band, and a satellite zenith angle;
b) The same as a) plus latitude and a day of year;

Training Training set was based on the OMI level 2 TOCs. Criterion for selection of datapairs: time mismatch less than 5 hours, distance less than 100 km. For every IKFS-2 pixel, the closest (in space and time simultaneously) OMI measurement was used.

$$(r/\Delta r)^2 + ((t_O - t_I)/\Delta t)^2 \to min$$

$$r < \Delta r \ and \ |t_O - t_I| < \Delta t, \quad \Delta r = 100km, \Delta t = 5 \ hours$$

Where r is a distance between two measurements, t_O and t_I are time of measurement for OMI and IKFS – 2, respectively.

Therefore, **16806989 pairs** of IKFS-2 spectra and OMI TOCs were selected. For the ANN training, only 3% (pseudorandom selection) of all data pairs were used. The error of the TOCs approximation using the ANN retrieval algorithm calculated for the whole (100%) data set totals:

a) 10.3 D.U.; b) 8.8 D.U.

TOCs comparison: IRFS-2 vs. ground-based measurements of WOUDC network

Table 1. Overview of ground-based stations and instruments used for validation of IKFS-2 TOC product.

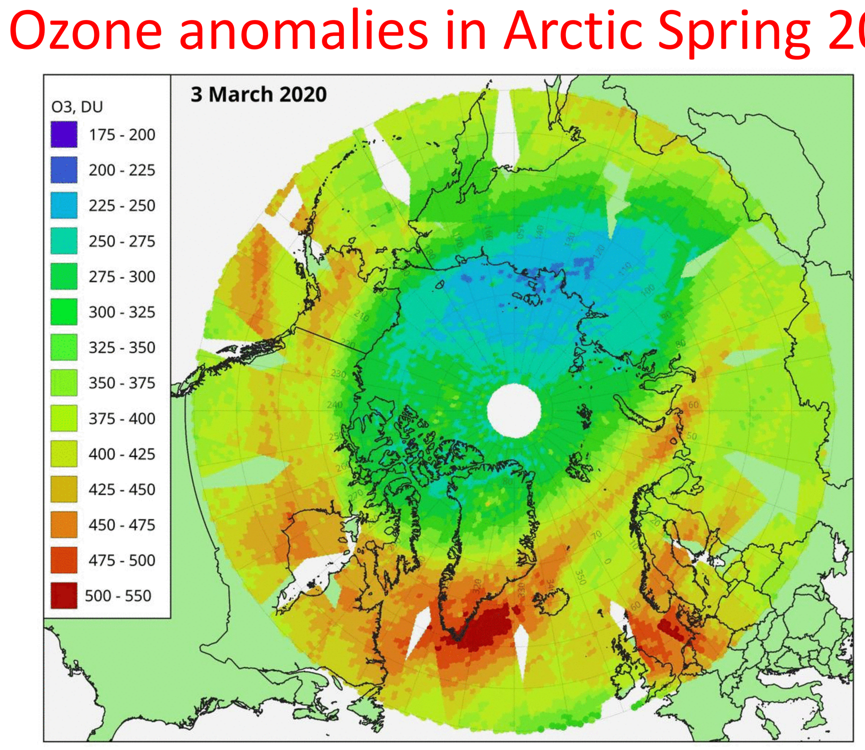
Station	Latitude	Longitude	Altitude	Instrument
Alert	82.45° N	62.51° W	220 m	Brewer #029 (MKIV)
Eureka	79.99° N	85.93° W	8.7 m	Brewer #223 (MKIII)
Resolute	74.70° N	94.97° W	68 m	Brewer #235 (MKIII)
Churchill	58.74° N	94.07° W	26 m	Brewer #239 (MKIII)
Obninsk	55.10° N	36.61° E	100 m	Brewer #044 (MKII)
Edmonton	53.55° N	114.11° W	752 m	Brewer #195 (MKIII)
Goose Bay	53.31° N	60.36° W	26 m	Brewer #018 (MKIII)
Lindenberg	52.21° N	14.12° E	127 m	Brewer #078 (MKIV)
De Bilt	52.10° N	5.18° E	24 m	Brewer #189 (MKIII)
Kyiv-Goloseyev	50.36° N	30.50° E	206 m	Dobson #040
Saturna Island	48.77° N	123.13° W	202 m	Brewer #012 (MKII)
Arosa	46.78° N	9.68° E	1840 m	Dobson #062
Aosta	45.74° N	7.36° E	570 m	Brewer #066 (MKIV)
Egbert	44.23° N	79.78° W	264.5 m	Brewer #145 (MKIII)
Lannemezan	44.13° N	0.37° E	590 m	Dobson #049
Toronto	43.78° N	79.47° W	202 m	Brewer #014 (MKII)
Kislovodsk	43.73° N	42.66° E	2070 m	Brewer #043 (MKII)
Thessaloniki	40.63° N	22.96° E	60 m	Brewer #005 (MKII)
Academy of Athens	37.99° N	23.78° E	180 m	Brewer #001 (MKIV)
El Arenosillo	37.10° N	6.73° W	41 m	Brewer #150 (MKIII)
University of Tehran	35.73° N	51.38° E	1419 m	Dobson #109
Mauna Loa	19.54° N	155.58° W	3397 m	Brewer #119 (MKIII)
Paramaribo	5.81° N	55.22° W	16 m	Brewer #159 (MKIII)
Natal	5.84° S	35.21° W	49 m	Dobson #093
Ciater / Bandung	6.90° S	107.4° E	728 m	Brewer #116 (MKIV) Brewer #092 (MKIV)
Cachoeira-Paulista	23.50° S	46.20° W	574 m	Dobson #114

Table 2. Mean, standard deviations and RMS of ground and IKFS-2 TOC differences depended on time and space mismatch.

Time mismatch Dt, hour	Distance D, km	N	TOC difference, D.U.			TOC difference, %:		
			mean	SD	RMSD	mean	SD	RMSD
Dt < 0.1	D < 35	9960	-2.4	10.9	11.1	-0.71	3.26	3.34
0.2	35	20326	-2.4	11.5	11.7	-0.71	3.44	3.51
0.5	35	50500	-2.4	12.3	12.5	-0.72	3.68	3.75
1	35	100293	-2.4	12.1	12.3	-0.72	3.61	3.68
1	70	400694	-2.4	12.8	13.0	-0.71	3.82	3.89
1	35 < D < 70	300401	-2.4	13.0	13.2	-0.71	3.89	3.95
1	70-125	3779278	-2.1	15.7	15.8	-0.63	4.70	4.74
1	125-250	14798182	-2.2	20.1	20.2	-0.67	6.00	6.04
0.1< Dt <.0.2	35	10366	-2.4	12.0	12.3	-0.72	3.60	3.67
0.2-0.5	35	30174	-2.4	12.8	13.0	-0.73	3.83	3.90
0.5-1	35	49793	-2.4	11.8	12.1	-0.72	3.54	3.62
1-2	35	97138	-2.4	11.5	11.8	-0.73	3.44	3.52
2-3	35	91733	-2.8	12.5	12.8	-0.83	3.72	3.81
3-5	35	171605	-3.2	13.4	13.8	-0.95	3.98	4.09
3-6	35	251490	-3.3	13.6	14.0	-0.99	4.04	4.16
6-12	35	388606	-3.4	16.7	17.1	-1.02	5.07	5.17
0.1	35-70	30020	-2.1	12.8	13.0	-0.63	3.85	3.90
12-24	35	924168	-2.2	20.7	20.8	-0.67	6.21	6.24

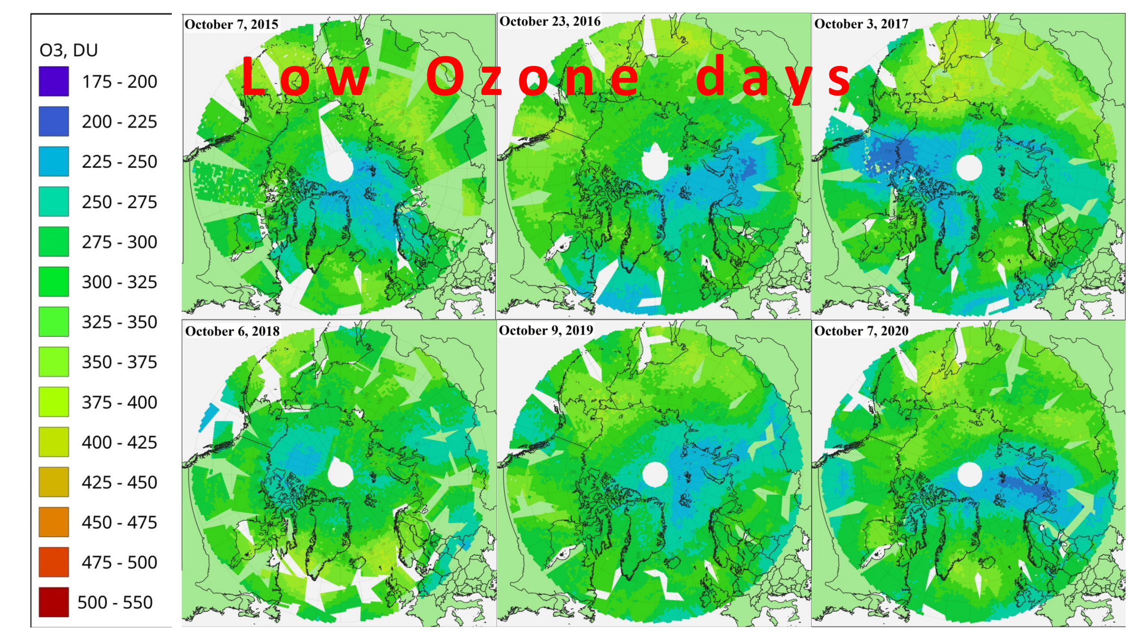
N – number of comparison, RMSD – root mean square of difference

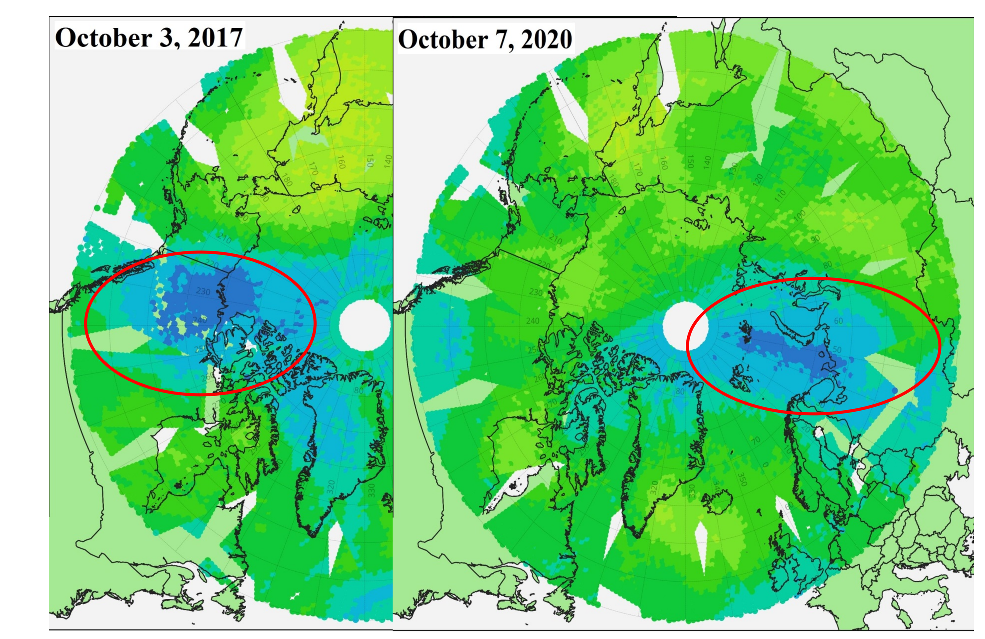
Ozone anomalies in Arctic Spring 2020



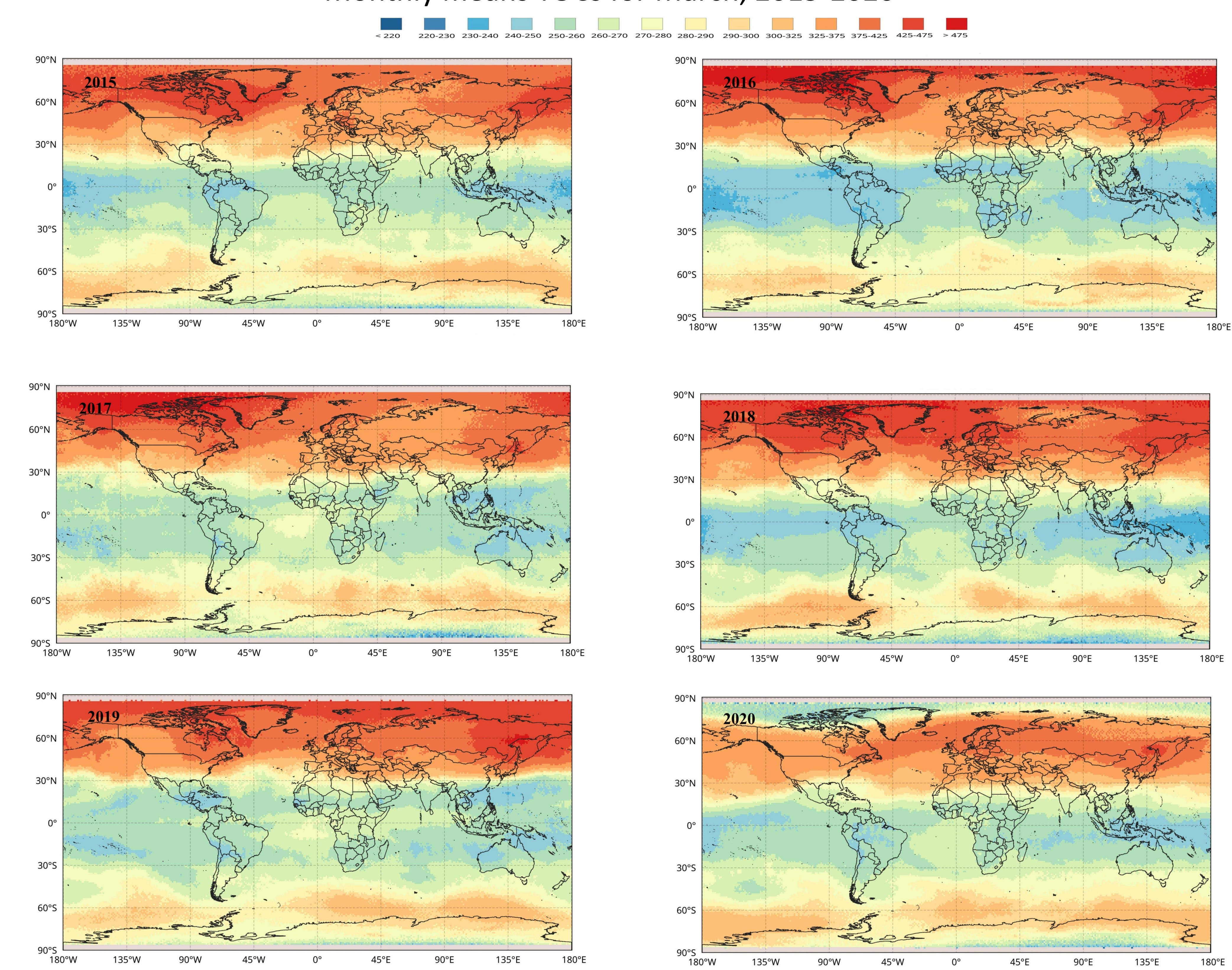
Slide show: https://www.dropbox.com/s/doopkzmjqpx35s2/IKFS-2_day-lat_O3_3-29_Mar_2020.gif?dl=0

Examples of the results





Monthly means TOCs for March, 2015-2020



References

ITSC-XXI 8p.05 Polyakov, Technique and results of retrieving the total ozone content using satellite IR measurements from «Meteor-M» No 2

Polyakov A.V., Timofeyev Y.M., Virolainen Y.A., Kozlov D.A. Atmospheric Ozone Monitoring with Russian Spectrometer IKFS-2 // Journal of Applied Spectroscopy, 86(4), 650-654. DOI 10.1007/s10812-019-00873-7

Timofeyev, Y.M., Uspensky A.B., et al Hyperspectral infrared atmospheric sounder IKFS-2 on "Meteor-M" No. 2 – Four years in orbit // J.Q.S.R.T. 238, 2019, 106579. https://doi.org/10.1016/j.jqsrt.2019.106579

Conclusions: We have shown that differences between TOCs retrieved from IKFS-2 spectral measurements and independent data: satellite (OMI) and ground-based (Dobson, Brewer, M-124), as a rule, are 3–5 %. The largest differences (up to 10 %) are observed over Antarctica in presence of the ozone hole in the southern polar latitudes. We demonstrated that IKFS-2 is able to monitor changes in total ozone content during periods of the appearance of ozone mini-holes (e.g., the Arctic Spring 2020)