KIAM RAS/ISON OPTICAL FACILITIES AND APPLICATIONS OF THEIR DATA

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ABSTRACT

The current status of the optical network of Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM RAS) and its partners within the International Scientific Optical Network (ISON) is outlined. We characterized our database of anthropogenic space objects orbiting the Earth and reported on the use of its continuously updated orbital data in 2019—2020, including a summary on close approach events in MEO and GEO, observed disintegrations and manoeuvres in GEO. Besides, we provided selected results of photometric studies of individual objects.

Keywords: ISON, optical observations, small-aperture telescopes, anthropogenic space objects, close approaches, manoeuvres, streak photometry.

1. INTRODUCTION

International Scientific Optical Network, or ISON, is an initiative of Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM RAS) stemmed from the need for observational data for scientific and applied research. International observing campaigns of ISON coordinated by KIAM RAS and focused mainly on resident space objects (RSOs) of the Earth, near-Earth objects and gamma-ray bursts optical afterglows. The observing campaigns involve small-aperture optical telescopes both of KIAM RAS and partner organizations signed with KIAM RAS corresponding agreements on scientific and technical cooperation. These partner organizations typically have access to data on objects which they observe and can apply for observing time of other telescopes within ISON for their research purposes. At the moment, ISON includes optical telescopes from 19 to 80 cm in diameter, generally having a wide field of view, at more than 20 sites (Fig. 2). Sites of optical networks that observing objects in GEO and HEO related to other Russian entities no longer included in ISON as previously [5]. Nevertheless, due to the favourable locations, ISON's telescopes can ensure full coverage of the geosynchronous region at present. For the processing of observational data, we use the Apex II software toolkit [4]. CHAOS or FORTE software [4] and, since recently, KDS software [2] are applied to control equipment of electro-optical systems.

2. KIAM RAS RESIDENT SPACE OBJECT DATABASE

A significant portion of time of telescopes involved in observing campaigns of ISON/KIAM RAS devoted to objects orbiting the Earth in GEO, HEO and MEO except for individual observations of objects in LEO for their photometric studies. In 2020, this provided regular data flow sufficient to detect again any of about 4 thousand of RSOs at any time. Combined with data that came from optical facilities of Roscosmos, this gave on average 10 thousand RSOs in total in the database of KIAM RAS in 2020 (Fig. 1). The number of objects in HEO has been growing at a faster rate than the number of objects in GEO due to the sequence of disintegrations in 2018 and 2019, and now comprises about 6 thousand. The GEO region is an area of particular interest where we tracked about 3 thousand objects in 2020. And only half a thousand objects in MEO were continuously tracked. Flat curves for the numbers of tracked objects resulted from a lack of significant disintegrations and changes in the telescope network (no commissioning of new sites most of the year, no serious equipment failures).

Orbital data are used for monitoring close approach events for all objects in the GEO protected zone and selected objects in MEO. Furthermore, we monitor deorbiting events of all GEO satellites and most manoeuvres in GEO, gather and promptly analyze observing data on fragments of break-ups, observe selected launches to GEO, HEO and MEO.

3. MONITORING OF EVENTS

Close approaches regularly predicted at evenly-spaced intervals of time using iterating over all pairs of objects in GEO and those crossing the GEO region. Distribution of 1172 actual close approaches less than 5 km and 1 km by longitude in 2020 shown in Fig. 3. Most (62 per cent)

Proc. 8th European Conference on Space Debris (virtual), Darmstadt, Germany, 20–23 April 2021, published by the ESA Space Debris Office
Ed. T. Flohrer, S. Lemmens & F. Schmitz, (http://conference.sdo.esoc.esa.int, May 2021)

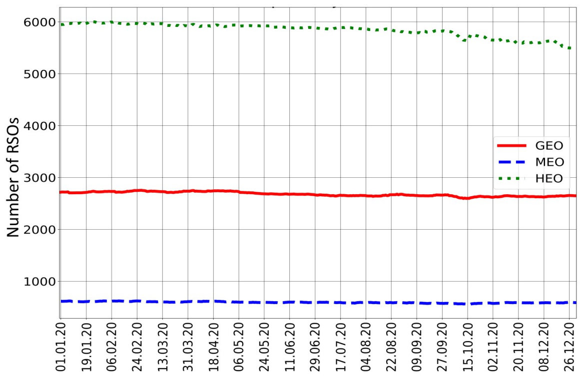

Figure 1. Variations in the numbers of objects having reliable orbital data in different orbits in the KIAM RAS database in 2020.

of the close approaches occurred between active objects, relatively few (2 per cent) close approaches took place with objects having a high area-to-mass ratio, and a sizeable number (18 per cent) of approaches were with objects with no TLE data.

Conjunction analysis was conducted only for selected objects in MEO: in total, 12 close approaches less than 5 km were registered in 2020, only 2 of those were between two active objects. Large objects in near-circular orbits pose the biggest threat in MEO, unlike small space debris pieces, which were not involved in close approach events in MEO in 2020.

At least ten de-orbiting events were detected in GEO in 2020, of which two do not meet corresponding requirements: Intelsat 805 (see Fig. 4) and Venesat-1.

Resulting from the insertion of a payload to GEO in July 2020, the Russian Briz-M upper stage entered the orbit that is not in compliance with ISO. According to our optical observations and long-term orbit propagation, it does not put GNSS satellites in MEO in danger but will threaten the GEO protected zone twice a day for at least another 50 years.

Some observing facilities within ISON/KIAM RAS campaigns performed follow-ups of selected launches in 2020: 19 objects to GEO, 5 objects to MEO and 3 objects to HEO (see Tab. 1).

In 2019–2020, with the help of ballistic information provided by JSC Vimpel, we undertook three observing campaigns on identifying fragments of break-ups:

- 05:12 UTC 24/03/2019, the break-up of the Centaur upper stage (2009-047B) in HEO: orbital data obtained for 670 fragments.
- 20:06 UTC 06/04/2019, the break-up of the Centaur upper stage (2018-079B) in HEO: orbital data obtained for 607 fragments.

Table 1. List of observed payload insertions in 2020.

GEO Satellite	International Designator
TJS-5	2020-002A
GSAT-30	2020-005A
JCSAT-17	2020-013A
GEOCOMPSAT-2B	2020-013B
BEIDOU 3 G2	2020-017A
AEHF-6 (USA-298)	2020-022B
BEIDOU-3 G3	2020-040A
APSTAR 6D	2020-045A
EKSPRESS 80	2020-053A
EKSPRESS 130	2020-053B
BSAT-4B 2020-056A MEV-2	2020-056B
GALAXY 30	2020-056C
GAOFEN 13	2020-071A
TIANTONG-1 2	2020-082A
LUCAS (JDRS-1)	2020-089A
SXM-7	2020-096A
CMS-01	2020-099A
USA 311	2020-095A
MEO Satellite	**International Designator**
COSMOS 2454 (GLONASS-M)	2020-018A
NAVSTAR 79 (USA 304)	2020-041A
COSMOS 2547 (GLONASS-K)	2020-075A
NAVSTAR 80 (USA 309)	2020-078A
USA 310	2020-083A
HEO Satellite	**International Designator**
MERIDIAN 9	2020-015A
TDO-2 SPACECRAFT	2020-022A
COSMOS 2546	2020-031A

- 21:20 UTC 08/05/2020, the break-up of the Fregat upper stage (2011-037B) in LEO: 114 fragments observed, accurate and reliable orbital data were obtained only for 18 fragments (other lost or started to re-entry). Among the main causes of loss of the objects was that observing capacities were insufficient for large-scale observing campaigns of objects in LEO.

There are instances when objects show peculiar behaviour being in the area of monitoring. An example of such an object is USA 253 (2014-043A), which, after it had left the GEO protected region on 31st January of 2021, supposedly shown signs of activity on its light curve (Fig. 6) in line with [3]. Jumps of brightness consistent with the change of object's trajectory may probably be related to firing plumes released during short-term engine activations.

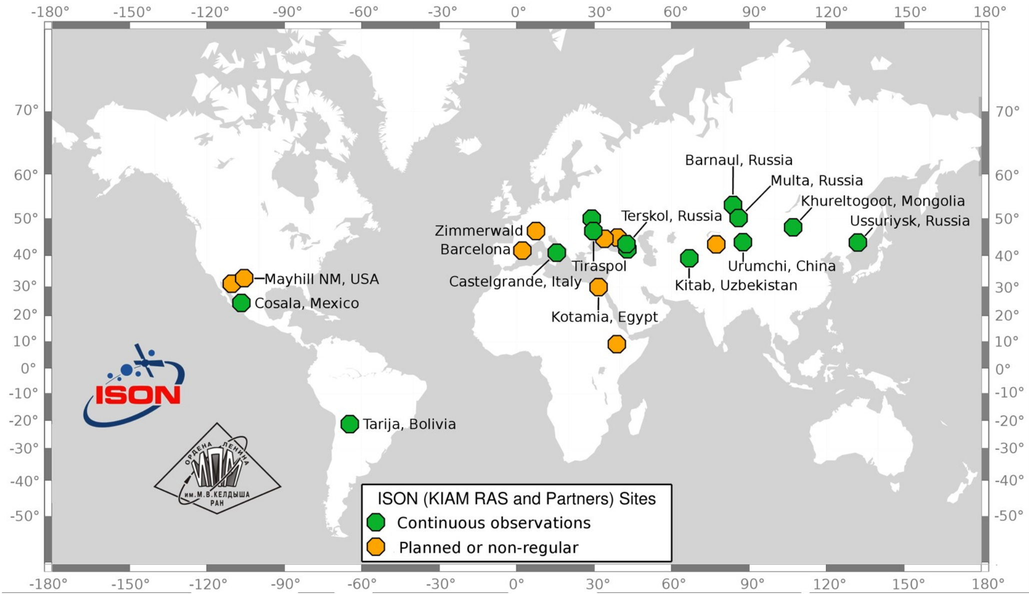

Figure 2. ISON/KIAM RAS network of optical telescopes.

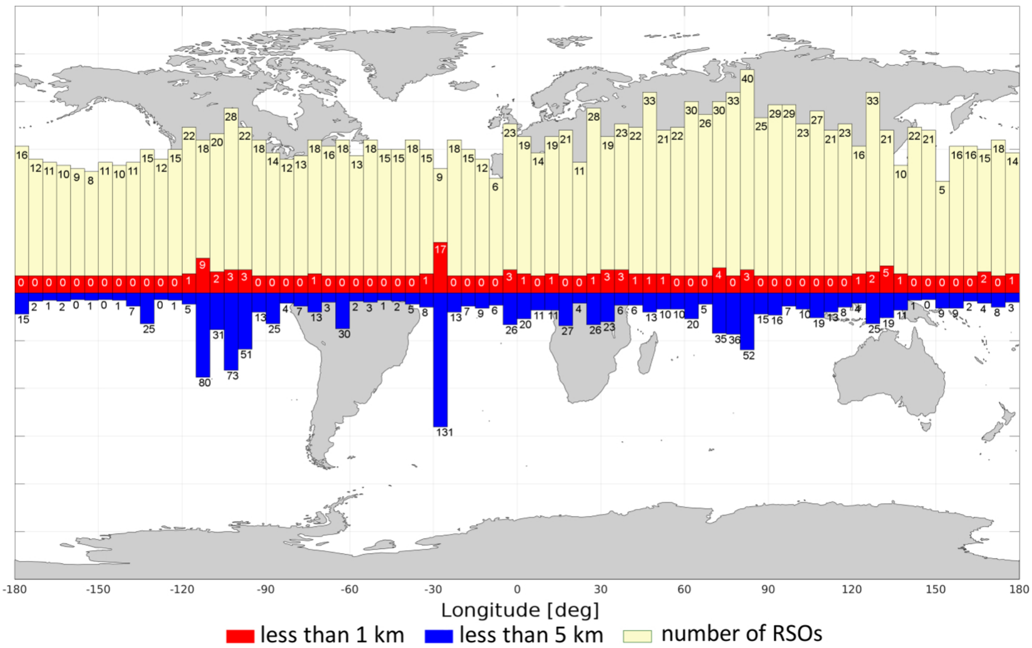

Figure 3. Distribution of close approaches in GEO by longitude in 2020 according to the KIAM RAS database. Light yellow columns contain numbers of RSOs, columns of close approaches less than 5 km coloured blue, and columns of close approaches less than 1 km coloured red.

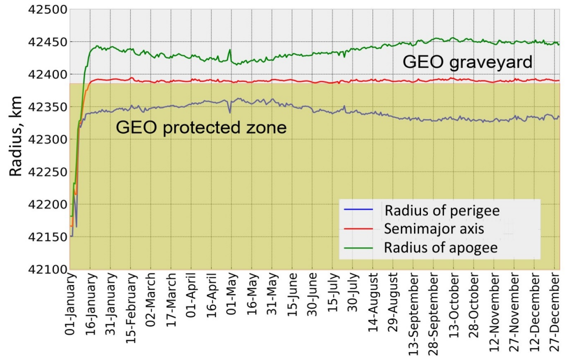

Figure 4. Inappropriate de-orbiting of INTELSAT 805 (1998-037A) in 2020.

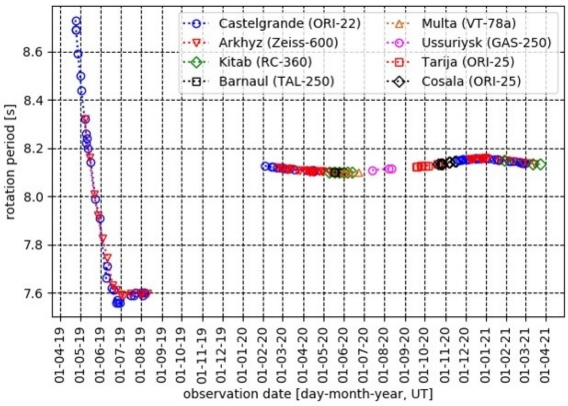

Figure 5. Variations in the period of rotation of Intelsat 29E (2016-004A) obtained from optical observations of eight telescopes from 19 to 60 cm in diameter.

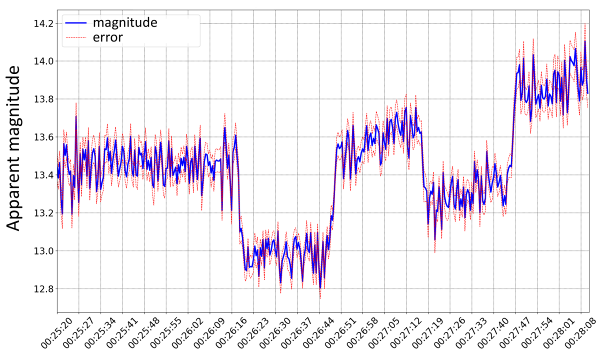

Figure 6. Light curve of the USA 253 (2014-043A) satellite for the selected timespan on 19th March of 2021 shown on the chart. Apparent magnitude means unfiltered magnitude uncorrected for range change detected using KAF-9000 CCD sensor. On the horizontal line is UTC.

4. PHOTOMETRY SUMMARY

ISON/KIAM RAS observing campaigns began to encompass objects in all types of orbits, including LEO, for their photometric studies in 2019. To date, light curves for more than 250 satellites have been derived using both tracking and observations with a stationary telescope. For processing observations of rounded shape objects, we used Apex II [4], and for streak like objects, the AstroImageJ software toolkit [1] was applied. The observing campaign of the Intelsat 29E defunct satellite in GEO is ongoing now. Intermediate results on change of its rotational period presented in Fig. 5.

ACKNOWLEDGMENTS

We wish to express gratitude and appreciation to the team of the Arkhyz observing site of Research and Production Corporation Precision Systems and Instruments for the significant contribution to studies listed in Section 4.

We would like to express our very great appreciation to JSC Vimpel and personally Dr. Z. N. Khutorovsky for comprehensive assistance in the analysis of the behaviour of resident space objects.

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