SPACE RESEARCH IN SLOVAKIA

2016 - 2017

SLOVAK ACADEMY OF SCIENCES

COSPAR

SLOVAK NATIONAL COMMITTEE

APRIL 2018

ISBN 978-80-89656-23-3
EAN 9788089656233

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1. EXPERIMENTS FOR MEASUREMENTS IN SPACE

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1.1. ESS processor on board of ESA-ROSETTA spacecraft at comet 67P/Churyumov-Gerasimenko

The Rosetta mission was proposed and approved in early nineties of last century, the spacecraft design, construction and testing followed over a decade until its launch on 2 March 2004. After ten years and six billion kilometers of cruise flight over the Solar system, the spacecraft reached the comet 67P/Churyumov-Gerasimenko on 6 August 2014. On 12 November 2014, the lander module Philae performed the first landing on a comet in history.

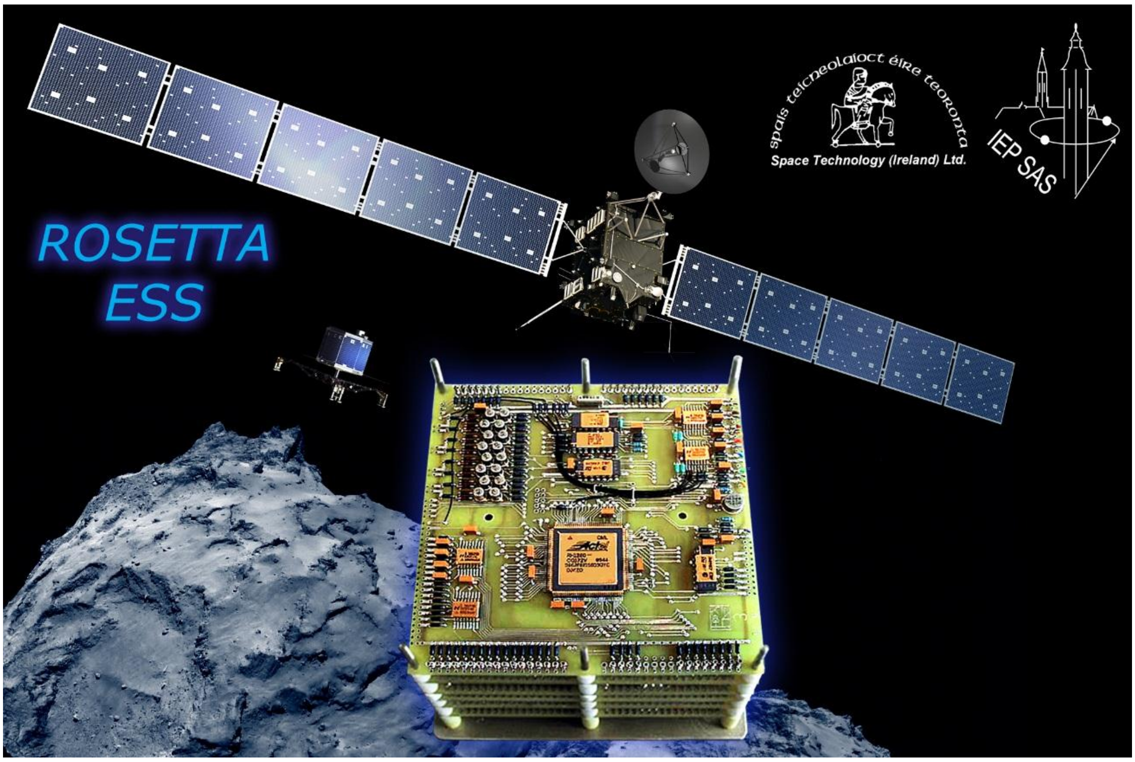


Figure 1.1. ROSETTA at comet 67P/Churyumov-Gerasimenko, the lander module Philae and the ESS processor unit.

The ESS processor unit (Electronic Support System) of the Rosetta spacecraft supported the lander module Philae separation from the main Rosetta orbiter and also provided bidirectional data communication between Philae and the Orbiter probe during the descent phase and also during Philae operations on the comet nucleus surface. Although Philae was hibernated after 57 hours due to unfavorable light condition, the ESS later provided another 9 successful "technical" connections with Philae when the comet was approaching its perihelion.

However, the attempts to restore the Philae science on the comet surface were not successful. The ESS processor operated flawlessly during whole mission and was only switched-off briefly before the end of the mission (the “Grand finale”) on 30 September 2016, when ESA directed the main probe to land on the comet surface. The design, performance and operation of the ESS processor unit during the Rosetta mission is described in [1], the mission overview, some results and the IEP participation are described in [2] and [3].

1.2. Experiment MEP-2 on board of Spektr-R (Radioastron)

Since its launch on high-apogee orbit on 18 July 2011, the programmable energetic particle spectrometer MEP-2, developed and constructed at the Department of Space Physics IEP-SAS is still operative. The MEP project is subject of cooperation with Democritus University of Thrace, Xanthi, Greece and Institute for Space Research (IKI-RAN). The instrument delivered valuable science data that are continuously archived and analyzed.

Figure 1.2. Energetic particle spectrometer MEP-2. The configuration on delivery and after installation on board of the space observatory Spektr-R (Radioastron).

The description and on-orbit operation of the PLAZMA-F suite is described in [4], the MEP-2 experiment is described in [5]. Amid significant results of the MEP-2 experiment, e.g., a new type of oscillations of energetic ions flux near the Earth’s bow shock was revealed [6]. This kind of particle flux variability could be ever observed due to high time resolution and wide energy range of MEP-2 spectrometer.

1.3. Experiment SERENA/PICAM for mission ESA-BepiColombo

IEP SAS contributes to ESA-BepiColombo mission to planet Mercury in the frame of scientific-technical cooperation with Space Technology Ireland (STIL) and Institute for Space Research of Austrian Academy of Sciences (IWF-ÖAW). The delivery involves the mechanical structures of the PICAM (Planetary Ion Camera) instrument that were manufactured in Slovakia (mechanical stress simulations and mechanical components manufacture on 5-axis centre of Q-Products, Bratislava, space-qualified processing and integration and testing at IEP-SAS, Košice).

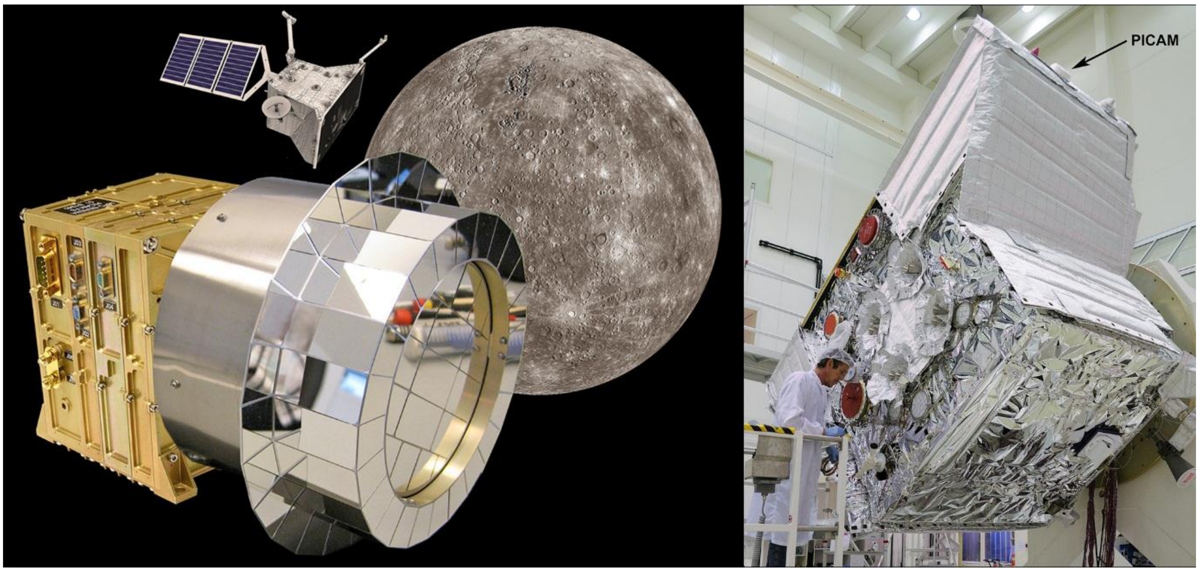


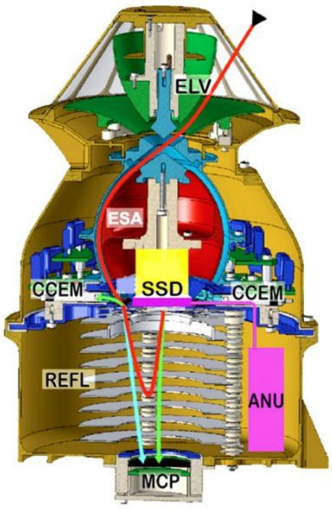
Figure 1.3. SERENA / PICAM and Mercury planetary orbiter (MPO) of BepiColombo mission.

PICAM is a part of a complex space science suite SERENA for particle detection at planet Mercury, the launch is scheduled for October 2018, the arrival to Mercury is scheduled in 2025. The detailed description of the PICAM device is provided in [7].

1.4. Experiment PEP/JDC for mission ESA-JUICE

Experiment PEP (Particle Environment Package) will provide comprehensive detection and analysis of the plasma and particle environment in the system of planet Jupiter and its Galilean moons Europa, Calisto and Ganymede. PEP will measure density and flux of positive and negative ions, electrons, exospheric neutral gas, thermal plasma and energetic neutral atoms in the energy range from <0.001 eV to >1 MeV with full angular coverage. The PEP suite includes six sensors (JDC, JEI, JoEE, NIM, JNA and JENI) that are under development at several EU and US institutions led by Swedish Institute for Space Physics (IRF, P.I. prof. S. Barabash). Based on invitation from IRF, the IEP-SAS contributes to development and construction of anti-coincidence particle detection system for

JDC sensor (Jovian plasma Dynamics and Composition) of the PEP suite. The anti-coincidence system will improve the plasma particles detection efficiency on the background of penetrating electron radiation from Jovian radiation belts. The system consists from silicon solid state detector (SSD) and dedicated processing electronic unit (ANU).



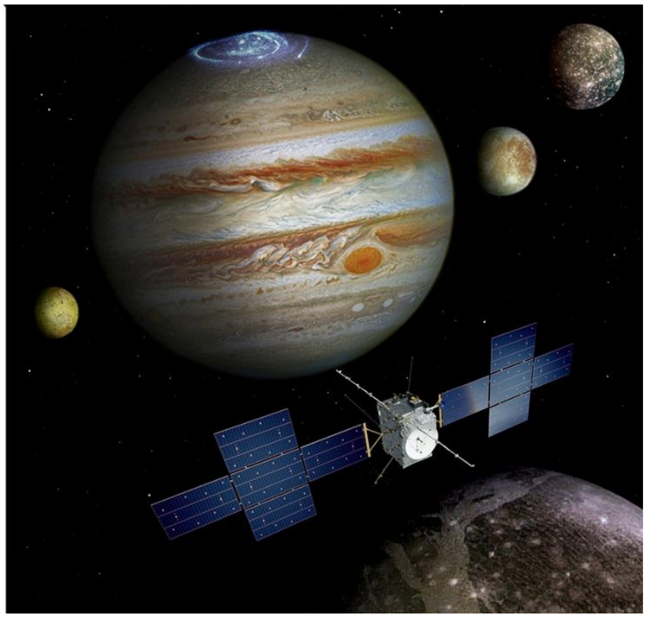


Figure 1.4. JDC sensor of the PEP science suite and JUICE spacecraft orbiting in the system of Jupiter and its Galilean moons.

The JUICE mission including the PEP science suite description is described in [8].

1.5. Experiment ASPECT-L for project LUNA-RESURS

The experiment ASPECT-L is currently under development at IEP-SAS in cooperation with Democritus University of Thrace, Xanthi, Greece and Institute for Space Research (IKI-RAN), Moscow, for lunar project LUNA-RESURS.

The Structural Thermal Model (STM) was already delivered to IKI-RAN, the engineering model of the instrument is currently in development at IEP-SAS and scheduled for delivery to IKI-RAN in May 2018.

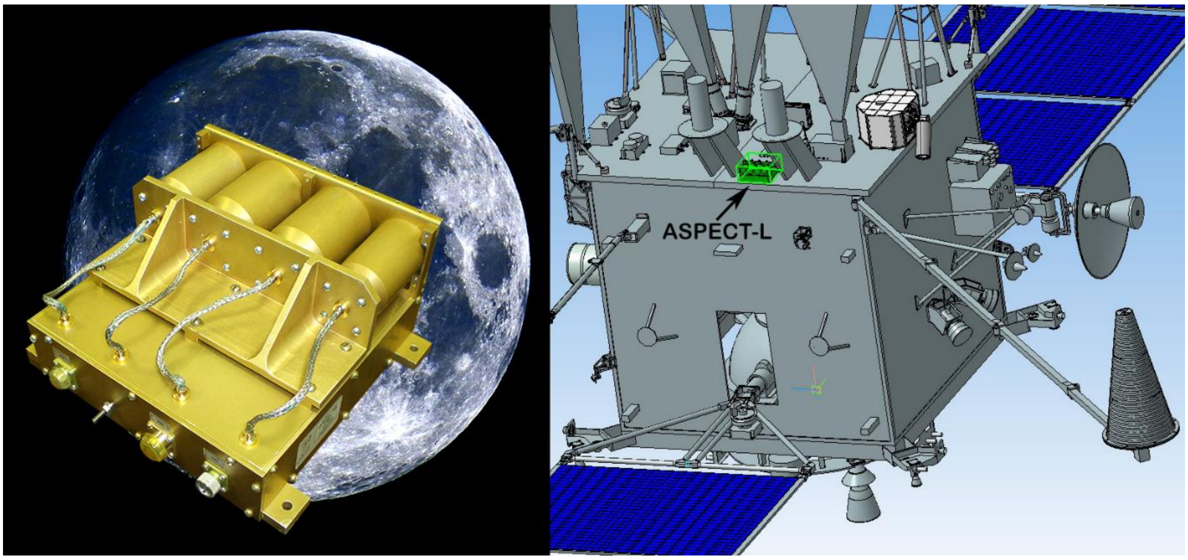


Figure 1.5. Energetic particle spectrometer ASPECT-L for LUNA-Resurs mission and its position onboard of the Orbiter spacecraft.

1.6. Experiment DOK-M for project RESONANCE

The experiment DOK-M is currently under development at IEP-SAS in cooperation with Democritus University of Thrace, Xanthi, Greece and Institute for Space Research (IKI-RAN), Moscow, for project RESONANCE.

RESONANCE is a magnetospheric space exploration mission conducted by IKI-RAN and dedicated for advanced study of the wave – particle interactions in the Earth's magnetosphere. Earth's magnetosphere, as natural resonator for many types of electromagnetic waves, is a place where electromagnetic waves efficiently interact with charged energetic particles via cyclotron resonance.

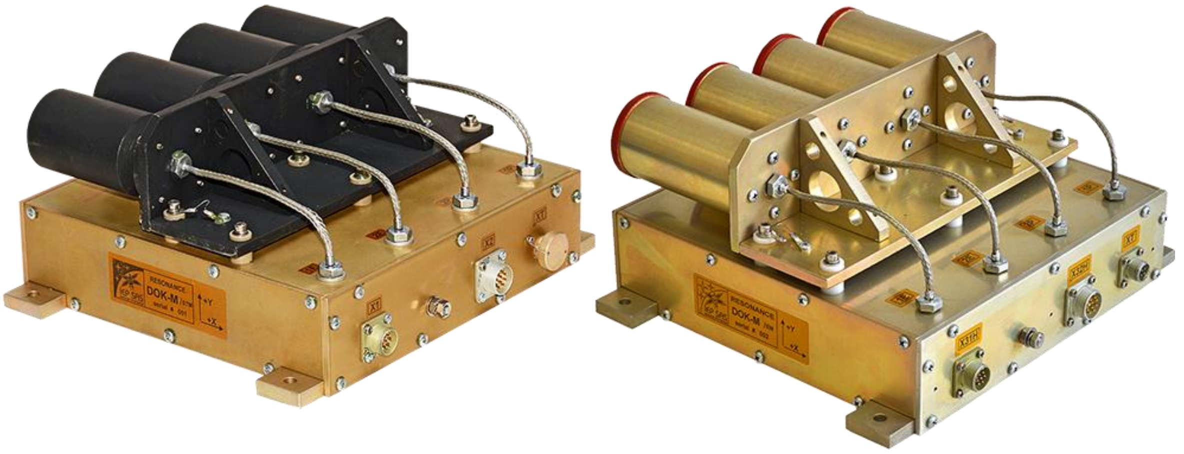


Figure 1.6. The structural thermal model DOK-M/STM and engineering model DOK-M/EM are undergoing testing at Space Research Institute, Moscow.

Two identical models of the DOK-M will be installed on board of two satellites of the RESONANCE project. The launch is presently scheduled for 2022.

1.7. Participation of Slovakia in the project JEM-EUSO

JEM-EUSO (Japanese Experiment Module – Extreme Universe Space Observatory) experiment will search for ultra-high energy cosmic rays (UHECR, with energy above 10^19 eV) by monitoring UV light produced in their interaction with atmosphere from International Space Station. Department of Space Physics IEP-SAS works in project frame mainly on UV background model at the Earth night side. IEP-SAS operate on pattern recognition methods for showers detection with Technical University in Kosice.

In UV background model we focus specifically to identification and quantification of in the upper atmosphere produced airglow light intensity variations. Analysis show main variations that should be searched in measurements of the precursors experiments EUSO-SPB and MINI-EUSO during the following year (2018). The outcome of the UV background model was the estimation of dynamic UV background maps for the Mini-EUSO experiment [9].

JEM-EUSO collaboration launch EUSO-SPB detector on NASA SPB balloon from New Zealand on April 24th and landed on the South Pacific Ocean on May 7th. Data analysis is in progress.

TA-EUSO experiment is installation of EUSO class detector close to Telescope Array in Utah. The results from preliminary analysis of TA-EUSO data were published in [10]. The implications for space-based UHECR observation from UV background light measurements by JEM-EUSO pathfinders were published in [11].

The activities of IEP SAS group were oriented also on preparing and building global network of UV detectors. The UV detector network is designed for long-term monitoring of the global dynamics of airglow radiation generation. In the course of the year 2017, we installed the measuring stations on the Lomnický štít in Slovakia, near Stockholm in Sweden, at Observatorio del Roque de Los Muchachos, La Palma in Spain, and at the Observatorio Astronomico Nacional de San Pedro Martir in Mexico.

The results from patter recognition of UHECR showers studies were published in [12].

1.8. The first Slovak satellite skCUBE

The first Slovak satellite skCUBE was successfully completed and launched into orbit on the 23rd June 2017. It suffered a problem in July 2017, which only prevents it from performing part of its experiments. To this date, it is still functional and ground stations all around Slovakia are collecting data from the satellite on a daily basis.

Figure 1.7. The first Slovak satellite skCUBE on orbit.

The skCUBE project is run by the Slovak Organisation for Space Activities (SOSA), in collaboration with the Slovak University of Technology in Bratislava, Technical University in Košice and the University of Žilina. During SOSA's research expedition in Svalbard (Norway) in 2017, a ground station for capturing satellite data was established there. The ground station was focused on receiving data from skCUBE. The station was successfully installed, however the cold and wind at the station caused the connections within the antenna to get damaged. Thus, after a few days of excellent performance, the antenna stopped working properly and only a small amount of data was received. The SOSA team plans on learning from this experience and perfecting the antenna systems, so that it will work better in the future. In an ideal case, an antenna and small ground station will be installed at the Czech Arctic Research station all year round sometime in the future.

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2. SPACE PHYSICS, GEOPHYSICS AND ASTRONOMY

R. Breier, I. Dorotovič, L. Kornoš, K. Kudela, J. Masarik, M. Revallo, J. Rybák, J. Šilha, J. Tóth

The Department of Space Physics, ***Institute of Experimental Physics, SAS, Košice*** (IEP) (http://space.saske.sk) in collaboration with the laboratories in abroad continued studies of the dynamics of low energy cosmic rays (CR) and of suprathermal cosmic particles, as well as high energy cosmic rays based on measurements in space and on the ground.

Papers/presentations related to very high energy CRs with significant contribution of coauthors in IEP SAS are mentioned in Chapter 1 in connection with JEM-EUSO project. Here just two additional papers are listed [1,2]. In those the coauthors within the complete collaboration list are included.

Analysis of long term continual measurements by neutron monitor (NM) at high altitude laboratory of IEP SAS Lomnický štít (LŠ, data in real time available at http://neutronmonitor.ta3.sk) along with other neutron monitors and with muon telescope data (including the new installation SEVAN at LŠ), yielded in (i) more detailed description of quasi-periodicities of CR time series [3,4]; (ii) finding the short time increases due to secondary CR at SEVAN detector system in connection to thunderstorm events in year 2016, especially during negative polarity of vertical component of electric field [5]; (iii) indicating the use of NM measurements at LŠ for estimate of the dose at airplane altitudes [6]; stressing relevance of simultaneous long term measurements of atmospheric and CR parameters at high mountain [7].

Papers [8,9] contribute to the analytical approach of the modulation of CR in the heliosphere and to the description of the CR transport within heliosphere.

Using earlier satellite measurements (i) the reconstruction of magnetic field structure in the solar flare region was analyzed for a strong flare with emission of high energy gamma rays [10]; (ii) the modulation of the suprathermal electron flux in the interaction wave – particles during the active plasma experiment was analyzed [11]; (ii) wavy structure of the energetic ion flux observed around the magnetospheric boundary mentioned in chapter 1, paper [6] has been revisited with the use of Interball data in paper [12]; (iii) redistribution of ring current during rather strong geomagnetic storm using the energetic neutral atom observations was analyzed in paper [13]. The method of estimate the high energy particle flux in the South Atlantic Anomaly region is described in [14].

An update of the review (http://www.physics.sk/aps/pubs/2009/aps-09-05/aps-09-05.pdf) with addition of new papers after 2009 and including the subject of dosimetric studies in space was published in [15]. Relations between CR Forbush decreases observed at LŠ in relation to coronal mass ejections and geomagnetic storms were analyzed in paper [16] not included in the biennal report for the period 2014-2015.

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The ***Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava*** was involved in the following eight directions of research as listed below.

A. Photometric observations and research of asteroids at Astronomical and Geophysical Observatory Modra, Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava

The photometric program of asteroid observations continued at Astronomical and Geophysical Observatory in Modra, Comenius University in Bratislava, some programs in collaboration with the Ondřejov Observatory, Czech Republic. In [1], we present lightcurves of 101 near Earth asteroids (NEAs) observed mostly between 2014 and 2017 as part of the EURONEAR photometric survey using 11 telescopes with diameters between 0.4 and 4.2 m located in Spain, Chile, Slovakia and Romania. As a main results, rapid oscillations (few minutes) and could fit fast tentative periods for 5 large newly suggested tumbling or binary candidates were evidenced. Using Mercator in simultaneous 3 bands MAIA imaging, for the first time, a clear variation in the color lightcurves of 10 NEAs [1] has been found.

Using all available disk-integrated optical data, a new convex shape model and rotational state of Phaethon [2] has been derived: a sidereal rotation period and ecliptic coordinates of the preferred pole orientation, Phaethon’s size, thermal inertia, geometric visible albedo, and there has been estimated the macroscopic surface roughness. We also find that the Sun illumination at the perihelion passage during the past several thousand years is not connected to a specific area on the surface, which implies non-preferential heating.

We collected and analyzed data on rotations and elongations of 46 secondaries of binary and triple systems among near-Earth, Mars-crossing and small main belt asteroids [3]. Of these, 24 systems were found or are strongly suspected to be synchronous and the other 22, generally on more distant and/or eccentric orbits, were found or are suggested to have asynchronous rotations. For 18 of the synchronous secondaries, we constrained their librational angles, finding that their long axes pointed to within 20° of the primary on most epochs. The asynchronous secondaries show relatively fast spins; their rotation periods are typically < 10 h. An intriguing observation is a paucity of chaotic secondary rotations; the secondary rotations are single-periodic with no signs of chaotic rotation and their periods are constant on timescales from weeks to years.

Pairs of asteroids, that mean, couples of single bodies on tightly similar heliocentric orbits, were recently postulated as a new category of objects in the solar system. They are believed to be close twins to binary and multiple systems. We searched for candidate very young asteroid pairs in the current catalog of asteroid orbits and selected the most promising case of the small asteroids (87887) 2000 SS286 and (415992) 2002 AT49. For them, we derived dynamical and rotational properties of asteroids (87887) 2000 SS286 and found out that they experienced a very close encounter, probably a formation event, some 7.4 ± 0.3 kyr ago [4].

B. Meteor observations and analyses by AMOS network

In 2016-2017 continued the monitoring of meteor activity above the Central Europe, Canary Islands and Atacama desert in Chile by All-sky Meteor Orbit System (AMOS), autonomous video observatory for detection of transient events on the sky. Hardware and software of AMOS have been developed and constructed at the Astronomical and Geophysical observatory of Comenius University in Modra.

We introduced and demonstrate the capability of the updated All-Sky Meteor Orbit System (AMOS) (called AMOS-Spec) [5] to measure the main element abundances of meteors. The AMOS-Spec program has been created with the intention of carrying out regular systematic spectroscopic observations. At the same time, the meteoroid trajectory and pre-atmospheric orbit are independently measured from data collected by the AMOS camera network. This, together with spectral information, allows us to find the link between the meteoroid and its parent body, from both dynamical and physical consideration. Here we report results for 35 selected cases.

The complex nature and origin of Taurid meteoroid stream was investigated [6] based on our observations of numerous multi-station meteor spectra observed during predicted outburst in November 2015 by our systems in Slovakia and Chile. It was shown that while the orbits of these bodies can be associated with several potentially hazardous near-Earth asteroids, the obtained spectral and structural properties point towards cometary origin with highly heterogeneous content. It was suggested that the determined enhanced material strengths may be caused by present carbonaceous inclusions. We have presented the most comprehensive spectral analysis of Taurids to date, and provided data on mineralogical densities and dynamic pressures of original meteoroids.

C. Development of Slovakian optical sensor for space debris objects cataloguing and research

The Department of astronomy which is part of the Faculty of Mathematics, Physics and Informatics of Comenius University in Bratislava, Slovakia (FMPI CU) won an ESA PECS Slovakia activity with a main goal to transform a 0.7-m Newton telescope (AGO70) dedicated to amateur astronomical observations to a professional optical system for regular support of the space debris tracking and research. The development started with the telescope installation at the FMPI's Astronomical and Geophysical Observatory in Modra, Slovakia (AGO) in September 2016. It was necessary to adapt the low-level telescope control to the needs of space debris tracking. For the image processing software we have chosen a modular design. It contains several individual elements performing tasks such as objects search on the frames, centroiding, astrometric reduction and tracklet building. The observation planning has been developed according to the AGO70 system's H/W limitations with focus on GEO, GTO and GNSS like orbits. The output products delivered by the system are astrometric positions in international formats (CCSDS TDM and MPC), light curves and relative color indices obtained by using Johnson-Cousins BVRI filters.

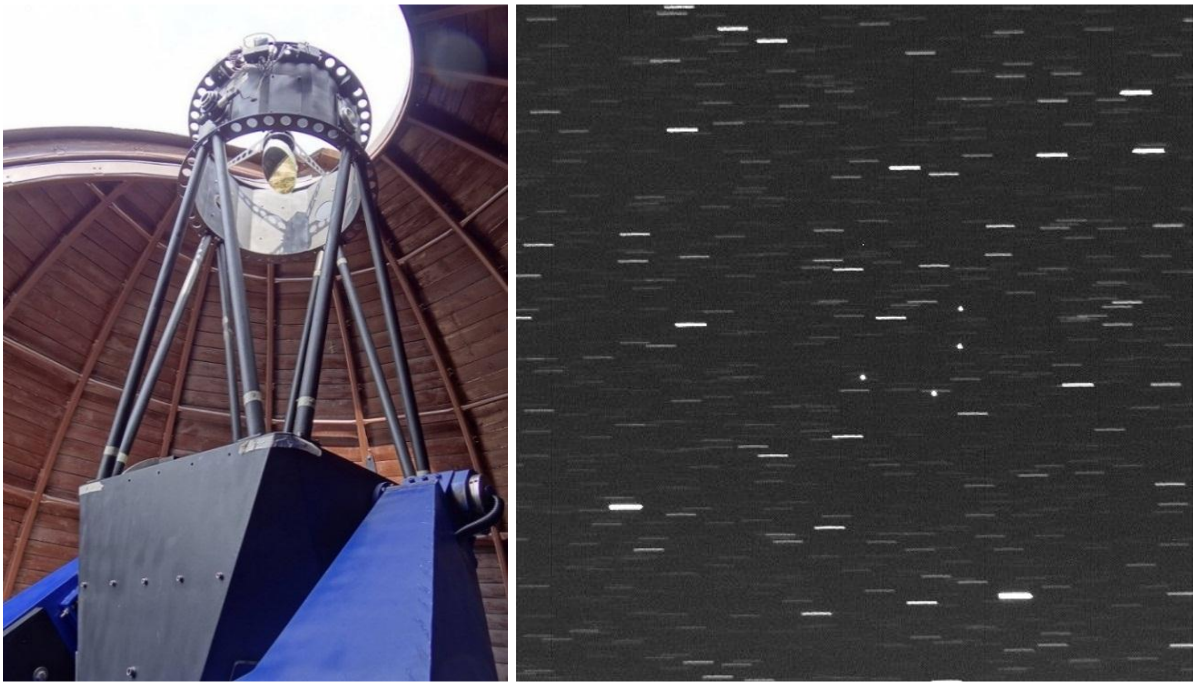

Figure 2.1. AGO70 telescope installed at the Astronomical and Geophysical Observatory in Modra, Slovakia (left) and light frame acquired with GEO tracking and I filter showing Astra GEO satellites (points). Used exposure was 5s. The size of field-of-view is 28.5' x 28.5'. North is facing upward.

Fully operational AGO70 system will support cataloguing efforts of Astronomical Institute of University of Bern (AIUB), which is maintaining its own internal space debris catalogue for research purposes. In case of contingencies during ESA satellite missions, e.g., when the spacecraft is not responsive a dedicated observation campaign can be performed with AGO70 to exam the integrity status of the affected spacecraft, to monitor its attitude motion state and to improve the object's orbital information.

D. Apparent rotation properties of space debris extracted from photometric measurements

Since 2007 the Astronomical Institute of the University of Bern (AIUB) performs photometric measurements of space debris objects [7]. To June 2016 almost 2000 light curves of more than 400 individual objects have been acquired and processed. These objects are situated in all orbital regions, from low Earth orbit (LEO), via global navigation systems orbits and high eccentricity orbit (HEO), to geosynchronous Earth orbit (GEO). For data acquisition, we used the 1-meter Zimmerwald Laser and Astrometry Telescope (ZIMLAT) at the Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald, Switzerland. We presented the AIUB's light curve database and the obtained rotation properties of 400 space debris objects as a function of object type and orbit.

E. Spin motion determination of the Envisat satellite through laser ranging measurements from a single pass measured by a single station

The Satellite Laser Ranging (SLR) technology is used to accurately determine the position of space objects equipped with so-called retro-reflectors or retro-reflector arrays (RRA). This type of measurement allows to measure the range to the spacecraft with high precision, which leads to determination of very accurate orbits for these targets. Non-active spacecraft, which are not attitude controlled any longer, tend to start to spin or tumble under influence of the external and internal torques and forces. In our work, we demonstrate how the SLR ranging technique from one sensor to a satellite equipped with a RRA can be used to precisely determine its spin motion during one passage [8]. We show our solutions of the spin motion determined for the non-active ESA satellite Envisat obtained from measurements acquired during years 2013–2015 by the Zimmerwald SLR station, Switzerland.

F. An optical survey for space debris on highly eccentric and inclined MEO orbits

Optical surveys for space debris in high-altitude orbits have been conducted since more than ten years. Originally these efforts concentrated mainly on the geostationary region (GEO). The ESA GEO surveys, e.g., resulted in the detection of a significant population of small-size debris and later in the discovery of high area-to-mass ratio objects in GEO-like orbits. Comparably less experience (both, in terms of practical observation and strategy definition) is available for eccentric orbits that (at least partly) are in the MEO region, in particular for the Molniya-type orbits. Optical observations were conducted in the framework of an ESA study using ESA's Space Debris Telescope (ESASDT) the 1-m Zeiss telescope located at the Optical Ground Station (OGS) at the Teide Observatory at Tenerife, Spain [9]. In total 30 uncorrelated faint objects were discovered Molniya regime. Some of these objects show a considerable brightness variation and have a high area-to-mass ratio as determined in the orbit estimation process.

G. Simulation of cosmogenic nuclides in meteorites

At the department of Nuclear physics and biophysics we studied cosmogenic nuclides in meteorites. Our approach was based mainly on simulations by Monte Carlo codes and comparison with experimental data produced in collaborating laboratories [10-12].

We studied noble gas data for 16 shergottites, 2 nakhlites (NWA 5790, NWA 10153), and 1 angrite (NWA 7812). Noble gas exposure ages of the shergottites fall in the 1-6Ma range found in previous studies. Three depleted olivine-phyric shergottites (Tissint, NWA 6162, NWA 7635) have exposure ages of similar to 1Ma, in agreement with published data for similar specimens. The exposure age of NWA 10153 (similar to 12.2Ma) falls in the range of 9-13Ma reported for other nakhlites. Our preferred age of similar to 7.3Ma for NWA 5790 is lower than this range, and it is possible that NWA 5790 represents a distinct ejection event. A Tissint glass sample contains Xe from the Martian atmosphere. Several samples show a remarkably low (Ne-21/Ne-22)(cos) ratio < 0.80, as previously observed in a many shergottites and in various other rare achondrites. This was explained by solar cosmic ray-produced Ne (SCR Ne) in addition to the commonly found galactic cosmic ray-produced Ne, implying very low preatmospheric shielding and ablation loss. We revisit this by comparing measured (Ne-21/Ne-22)(cos) ratios with predictions by cosmogenic nuclide production models. Indeed, several shergottites, acalpulcoites/lodranites, angrites (including NWA 7812), and the Brachina-like meteorite LEW 88763 likely contain SCR Ne, as previously postulated for many of them. The SCR contribution may influence the calculation of exposure ages. One likely reason that SCR nuclides are predominantly detected in meteorites from rare classes is because they usually are analyzed for cosmogenic nuclides even if they had a very small (preatmospheric) mass and hence low ablation loss.

The shape of meteorites is one of the major factors influencing the production of cosmogenic nuclides. Numerical simulations using the Los Alamos Code System (LCS) particle production and transport codes were done to investigate particle fluxes and production rates of cosmogenic nuclides Be-10, Al-26, and Co-60 in meteoroids of spherical, ellipsoidal, and cylindrical shapes. The calculations show that fluxes of nuclear active particles and also production rates of cosmogenic nuclides are sensitive to the shape of the irradiated parent body.

Low-level concentrations of primordial and cosmogenic radionuclides were determined in recently fallen chondrites and in meteorites from Mars and the Moon. The radionuclide measurements showed a wide range of concentrations of ^{22}Na, ^{26}Al, ^{46}Sc, ^{54}Mn and ^{57}Co. The absence of the neutron product (^{60}Co) in some of the meteorites indicates that their pre-atmospheric radius was small (on the other of 10 cm). This has also been confirmed by Monte Carlo simulations of the production rates of investigated cosmogenic radionuclides, and their comparison with experimental data. The cosmic-ray exposure ages of the investigated meteorites have been estimated to range from 1 to 5 million years. The agreement between the simulated and observed ^{26}Al activities indicates that the meteorites were mostly irradiated by a long-term average flux of galactic cosmic rays.

There are many opened questions related to the production of cosmogenic nuclides at early stages of Solar system development. Most of the short-lived radionuclides that were alive in the early solar system appear to have their origin in stellar nucleosynthetic processes. The possible production of some short-lived nuclides, e.g., ^{26}Al and ^{53}Mn, as the result of solar energetic particle bombardment of gas and/or dust during phases of the early Sun has been extensively studied. Some nuclei, however, such as ^{10}Be cannot be produced in stellar nucleosynthesis but are readily produced by spallation reactions from a wide variety of target materials. Other nuclides such as ^{36}Cl are produced in AGB stars but considering their lifetime ($T_{1/2} = 301 \pm 2$ kyrs) and the relatively low ^{36}Cl/^{35}Cl ratios of $(1.7\text{-}5.4)\times10^{-6}$ calculated for AGB envelopes, it is very difficult to propose a scenario with a stellar source for ^{36}Cl. This is readily seen considering the ^{36}Cl/^{35}Cl levels of 5×10^{-6} for Ningqiang and of 1.8×10^{-5} for Allende deduced from correlations between ^{36}S/^{32}S with ^{35}Cl/^{32}S in halogen rich phases. An origin for ^{36}Cl by intense local irradiation has been proposed. Considering the two nuclides that cannot have a stellar nucleosynthetic origin, ^{10}Be and ^{36}Cl, the latter is of special importance because there are two possible formation scenarios for ^{10}Be but so far there is not a clear and consistent formation scenario for ^{36}Cl.

H. Study of Schuman resonances.

Schumann resonances (SR) are resonant electromagnetic oscillations in extremely low frequency band (ELF, 3 Hz - 3 kHz), which arise in the Earth-ionosphere cavity due to lightning activity in planetary range. The time records in the ELF-band consist of background signals and ELF transients/Q-bursts superimposed on the background exceeding it by a factor of 5 - 10. The former are produced by the common worldwide thunderstorm activity (100 - 150 events per second), the latter origin from individual intense distant lightning discharges (100 - 120 powerful strokes per hour). A Q-burst is produced by a combination of direct and antipodal pulses and the decisive factor for its shape follows from the source-to-observer distance. Diurnal/seasonal variations of global thunderstorm activity can be deduced from spectral amplitudes of SR modes. Here we focus on diurnal/seasonal variations of the number of ELF-transients assuming that it is another way of lightning activity estimation. To search for transients, our own code was applied to the SR vertical electric component measured in October 2004 - October 2008 at the Astronomical and Geophysical Observatory of FMPI CU, Slovakia. Criteria for the identification of the burst are chosen on the basis of the transient amplitudes and their morphological features. Monthly mean daily variations in number of transients showed that African focus dominates at 14 - 16 h UT and it is more active in comparison with Asian source, which dominates at

5 - 8 h UT in dependence on winter or summer month. American source had surprisingly slight response. Meteorological observations in South America aiming to determine lightning hotspots on the Earth indicate that flash rate in this region is greatest during nocturnal 0 h - 3 h local standard time. This fact may be interpreted that Asian and South American sources contribute together in the same UT. Cumulative spectral amplitude of the first three SR modes compared with number of ELF-transients in monthly averaged diurnal variations quite successfully confirmed, that the number of transients could be a suitable criterion for the quantification of global lightning activity [11].

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In the **Earth Science Institute of the Slovak Academy of Sciences**, Bratislava and Hurbanovo, a number of issues concerning space weather were investigated and ground magnetic field measurements were performed. In particular, a computer method for modeling of geomagnetic K indices was developed and intense geomagnetic storms were studied using historical magnetic records.

New interactive computer method for producing geomagnetic K indices was developed in [3, 7]. The method is based on the traditional hand-scaling methodology that had been practised at Hurbanovo Geomagnetic Observatory till the end of 1997. The performance of the method was tested on the data of the Kakioka Magnetic Observatory. We have found that in some ranges of the K-index values our method might be a beneficial supplement to the computer-based methods approved and endorsed by IAGA. This result was achieved for both very low (K=0) and high (K≥5) levels of the geomagnetic activity. The method incorporated an interactive procedure of selecting quiet days by a human operator (observer). This introduces a certain amount of subjectivity, similarly as the traditional hand-scaling method. In [4, 6], the interactive computer method was tested utilising the data from the Hurbanovo and Budkov magnetic observatories. These data include both digital records of the geomagnetic field and hand-scaled K indices that had been derived by experienced observers. The authentic K indices from Hurbanovo cover the year 1997 and the same kind of data from Budkov covers the years 1994–1999. In addition to these data, hand-scaled K indices are used which were derived by the experienced observer from printed digital magnetograms for both of the observatories for the years 2000–2003. The results of this study indicate that for high values of K indices (the values being at least 5) the tested method follows the traditional hand-scaling better than the widely used computer methods FMI and AS. On the other hand, for the K indices less than 5 the tested method turns out to be the worst when compared with the FMI and AS methods. For very low geomagnetic activity (K-index values equal to 0) the performance of the tested method is comparable to the two computer methods.

In [1,2], a model to forecast one-hour lead geomagnetic Dst index known from earlier studies was revisited. The model was based on the method of artificial neural networks combined with an analytical approach. Attention was focused on medium and weak geomagnetic storms caused by coronal mass ejections (CMEs) and those caused by corotating interaction regions (CIRs). As the model input, the hourly solar wind parameters measured by the ACE satellite at the libration point L1 were used. The time series of the Dst index was obtained as the model output. The simulated Dst index series was compared with the corresponding observatory data. The resulting Dst index series were inspected and typical features of CME and CIR driven storms were isolated. The model reliability was assessed using the skill scores, namely the correlation coefficient CC and the prediction efficiency PE. The general observation was that in the case of medium and weak geomagnetic storms the model performance was worse than in the case of intense geomagnetic storms studied in our previous paper. Due to more complex Dst index record, the model response for CIR driven storms was worse than in the case of CME driven storms.

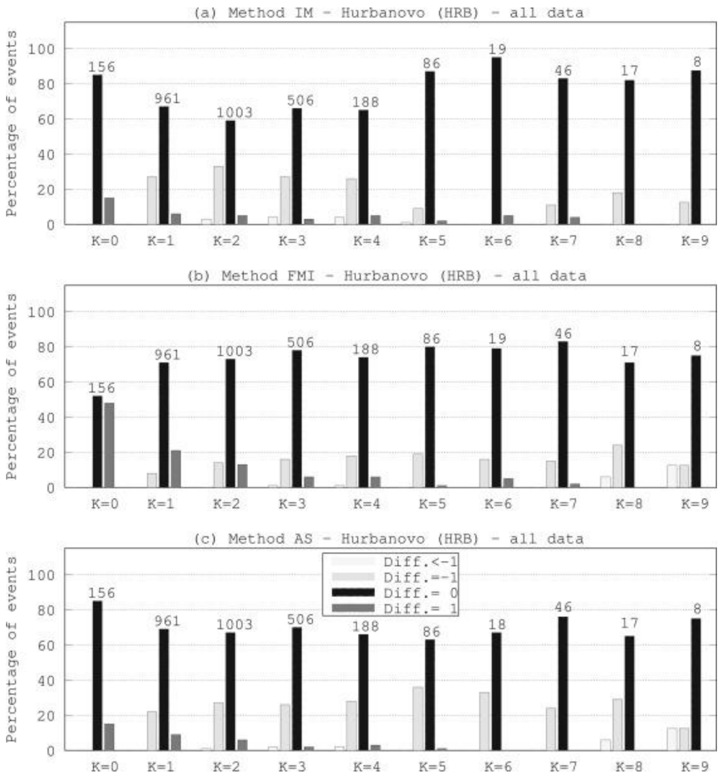

Figure 2.2. Differences between computer produced K indices and hand-scaled K indices for the Hurbanovo Geomagnetic Observatory (HRB). Here the computer methods are (a) IM, (b) FMI and (c) AS. The items are grouped according to the values of the hand-scaled K indices. The amounts of the differences are coded with a grey scale. The legend "Diff.<−1" means the difference that is equal to −2. There is only one exception from that; in one case the IM method provided K index 1 while the authentic index was 4. The numbers that are written above the columns give the total number of analysed events for the particular hand-scaled K indices.

The contribution of CMEs and CIRs to geomagnetic activity during the period 1996—2013 was assessed in [9, 11]. The period covers the 23rd solar cycle, the solar minimum between the 23rd and the 24th solar cycles as well as the ascending part of the current 24th solar cycle. Both CMEs and CIRs are capable of driving significant space weather effects on the Earth. The two principal questions are: (1) what is the contribution of CME and CIR type solar events to various levels of geomagnetic disturbances and how it varies during the solar cycle (2) how does the successive emergence of CME and CIR events influence the geomagnetic response. Sometimes it can be difficult to assign the response to a particular event properly, especially in the case of several successive events. We noticed that the CIRs appeared to play important role also in years when strongly geoeffective CMEs occurred. An interesting finding, which we have revealed on this subject, concerned the year 2009;

then the extremely low geomagnetic activity was probably caused by very slow solar wind from coronal holes along with the rare occurrences of CIRs.

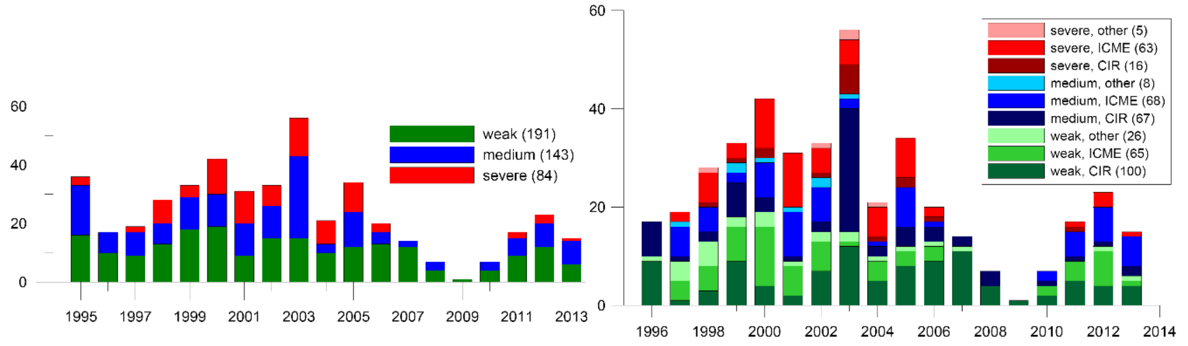

Figure 2.3. The distribution of the events of the enhanced geomagnetic activity in years 1996 – 2013 (left).The distribution of the events of the enhanced geomagnetic activity in years 1996 – 2013 with the indication of their causes (right). Total numbers across the entire period are given in parentheses.

In [10], the Dynamic Global Core Plasma Model (DGCPM) was studied. Ii is an empirical dynamical model of the plasmasphere which, despite its simple mathematical form, or perhaps because of its simple mathematical form, has enjoyed wide use in the space physics modeling community. In this paper we present some recent observations from the European quasi-Meridional Magnetometer Array (EMMA) and compare these with the DGCPM. The observations suggest more rapid daytime refilling and loss than what is described in the DGCPM. We then modify the DGCPM by changing the values of some of its parameters, leaving the functional form intact. The modified DGCPM agrees much better with the EMMA observations. The modification resulted in an order-of-magnitude faster daytime refilling and nighttime loss. These results are also consistent with previous observations of daytime refilling.

Records of the past geomagnetic field were studied in [8]. The records can be divided into two main categories. These are instrumental historical observations on the one hand, and field estimates based on the magnetization acquired by rocks, sediments and archaeological artefacts on the other hand. In this paper, a new database combining historical, archaeomagnetic and volcanic records is presented. HISTMAG is a relational database, implemented in MySQL, and can be accessed via a web-based interface (http://www.conrad-observatory.at/zamg/index.php/data-en/histmag-database). It combines available global historical data compilations covering the last 500 yr as well as archaeomagnetic and volcanic data collections from the last 50 000 yr. Furthermore, new historical and archaeomagnetic records, mainly from central Europe, have been acquired. In total, 190 427 records are currently available in the HISTMAG database, whereby the majority is related to historical declination measurements (155 525). The original database structure was complemented by new fields, which allow for a detailed description of the different data types. A user-comment function provides the possibility for a scientific discussion about individual records. Therefore, HISTMAG database supports thorough reliability and uncertainty assessments of the widely different data sets, which are an essential basis for geomagnetic field reconstructions. A database analysis revealed systematic offset for declination records derived from compass roses on historical geographical maps through comparison with other historical records, while maps created for mining activities represent a reliable source.

Historical magnetic records were also studied in the context of strong geomagnetic activity. They were proved to be useful for study of the most intense magnetic storms especially those of the Carrington type. In [12], the magnetic storm on March 8, 1918 is analysed, on the basis of a preserved analogue magnetogram that was recorded by observatory Ógyalla, present day Hurbanovo. It is inferred that much of the spectacular phenomena that were attributed to this storm, such as effects in telegraph lines, were likely caused by rapid changes of the geomagnetic field during two consecutive substorms. The storm sudden commencement that preceded the magnetic storm was probably also potent in this regard. This supports the recent findings that argue against the inevitable major role of the ring current in extreme magnetic disturbances at mid latitudes. Other Carrington-like events are studied in [13, 14].

Along with theoretical studies, magnetic ground or repeat station surveys are performed to determine the geomagnetic field spatial distribution. Hurbanovo Geomagnetic Observatory of the Earth Science Institute of the SAS performs continuous monitoring and registration of the geomagnetic field components. The one-minute mean values of all components of the geomagnetic field as well as the records acquired with the one-second sampling interval are available. K-indexes characterizing the geomagnetic activity in the middle latitudes are computed regularly. The data are published on the CD-ROMs prepared in the frame of INTERMAGNET. Information about the geomagnetic activity is also published on the web site of the observatory, www.geomag.sk. The level of the geomagnetic activity is reported to public media (TV), too.

The members of the Hurbanovo Geomagnetic Observatory staff regularly perform field measurements at the observation points of the national magnetic repeat station network, which is a part of the European repeat station network. The measurements are coordinated by the MagNetE Group. Measurements of the magnetic declination are performed regularly at selected Slovak airports.

The models of the distribution of the elements of the geomagnetic field must be updated regularly. For this purpose geomagnetic measurements have to be carried out repeatedly at geomagnetic observatories as well as at temporary observation points. In [5], results of the geomagnetic survey that was carried out in Slovakia in the year 2014 are presented. The measurements were performed at 12 observation points and they were reduced to the 2014.5 epoch. The secular variation between 2007.5 and 2014.5 was also calculated. The obtained values of the geomagnetic elements were used for calculating a 1st-degree polynomial model for the distribution of magnetic declination, inclination and total field. The comparison with the IGRF model showed that the polynomial model provided more accurate results for magnetic inclination and total field. For magnetic declination, on the contrary, the IGRF model produced slightly better results than the polynomial model.

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In the ***Slovak Central Observatory*** **(SCO)** in Hurbanovo (http://www.suh.sk), a number of activities related to space research were performed. We observed sunspots (the Wolf number data were submitted to the SILSO in Brussels, Belgium and to the SONNE Netz in Germany) and prominences (images are published at the website of the Observatory). We performed also spectrographic observations of the solar spectrum (variations of selected spectral lines during a solar activity cycle) using a horizontal solar telescope with spectrograph, we registered solar radio bursts using a solar radio spectrometer CALLISTO and impact of solar flares on the Earth's ionosphere using a SID monitor. We observed the total solar eclipse on August 21, 2017 with aim to investigate the structure of the white-light solar corona. The research activities comprise study of the:

- differential rotation of the solar corona, automatic detection and tracking of the sunspots and the coronal bright points,
- automatic detection of the chromospheric plages,
- asymmetry of the north and south hemispheric solar activity,
- temporal evolution of magnetic field and intensity properties of photospheric pores,
- oscillations of the cross-sectional area and the intensity of magnetic waveguides located in the lower solar atmosphere.

One researcher from the SCO is the national ISWI (International Space Weather Initiative, http://iswi-secretariat.org) coordinator for the Slovak Republic and since September 2014 he is also as a Scientific Discipline Representative of the SCOSTEP for the field of solar physics. He is member of the National Committee of both the SCOSTEP and the COSPAR.

We continued to publish at the website of the SCO data on the modified coronal index (MCI) and the modified homogeneous data set (MHDS) of coronal intensities based on satellite EUV measurements as a replacement of ground-based coronagraphic observations at Lomnický Štít. Both the MCI and the MHDS data sets can be used further for studies of the coronal solar activity and its cycle. These data are available at http://www.suh.sk/online-data/modifikovany-koronalny-index and http://www.suh.sk/online-data/modifikovany-homogenny-rad, respectively.

In the Computer Intelligence Group (CA3) of the CTS/UNINOVA (Caparica, Portugal) has been developed in previous years a software tool for automatic tracking of solar activity features (sunspots and coronal bright points - CBPs) using a hybrid algorithm combining PSO (Particle Swarm Optimization) and Snake algorithms for detecting and tracking of a feature, and determining the differential rotation of the Sun. In [1] we reported results of our tests with our evolutionary computation based algorithm for calculating solar differential rotation by automatic tracking of CBPs (Fig. 2.4).

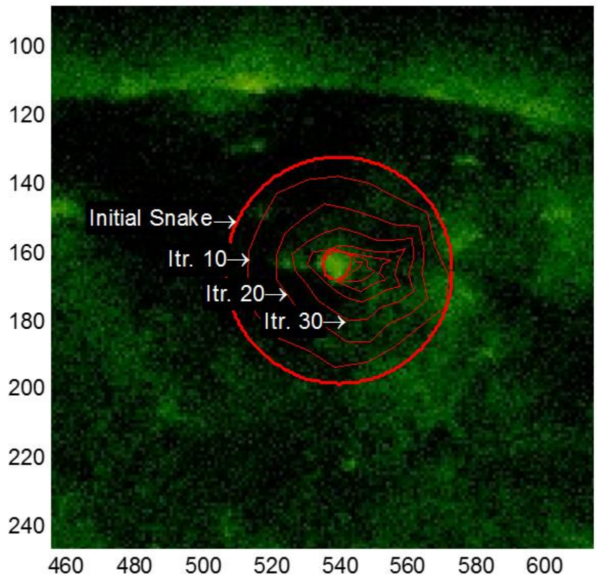

Figure 2.4. Detection process of a selected CBP (2010-10-5). Initial contour around the region of interest is evolved to precisely delineate the CBP boundaries. The outer contour is the initial snake and the inner contours are the transitional contours of every 10 iterations of the hybrid PSO-Snake detection algorithm. In the final stage contours converge and do not change much through iterations.

Collaboration with the research group of the Kyoto University (Japan) in the processing of solar images recorded in the Hida Obs. and the solar images by the instruments of the future SOLAR-C satellite is envisaged in [2]. In the period of January 1, 2016 – December 31, 2017 we developed new algorithms to detect and track solar activity features in the frame of a mobility project Slovakia – Portugal "Evolution of Solar Activity over a Solar Cycle – from Statistics to Physics". The research was performed in collaboration with the Observatório Geofísico e Astronómico da Universidade de Coimbra (OGAUC) and the CTS/UNINOVA-CA3 in Caparica (Portugal). The Slovak partner of the SCO in this project was the Astronomical Institute of the SAS in Tatranská Lomnica. In the frame of this project a new algorithm for automatic detection and tracking of CBPs based on the Gradient Path Labeling method was developed and we tested the algorithm on selected datasets of solar images recorded by the instruments AIA onboard the *Solar Dynamics Observatory* (SDO) satellite. The results were published in [3] (Fig. 2.5). Another segmentation algorithm for automatic detection of CBPs developed using SunPy and OpenCV in Python is described in [4] (Fig. 2.6). In the SCO we developed also an alternative software tool to estimate the solar rotational profile based on cross-correlation (CC) method. Rotational velocity was calculated for each day in 2016 from CC maxima of two consecutive SDO/AIA images with a cadence of 30 minutes taken through the 21.1 nm filter, in a window of 6° in heliographic longitude and 69° in heliographic latitude (241 x 2761 pxs). It was performed only in the rows where the CC maximum was higher than 0.5. The mean equatorial rotational velocity is 14.3°/day (Fig. 2.7).

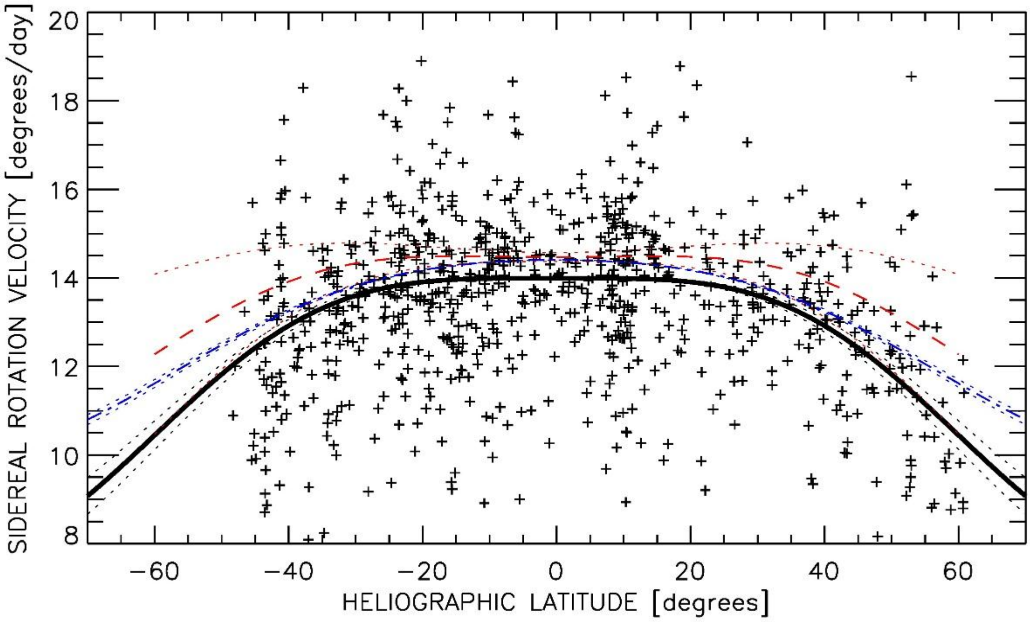

Figure 2.5. Individual measurements of rotational velocity in respect to latitude. Thick solid black line indicates the best fit to these values using the relation $\omega(b) = A + B \sin^2(b) + C \sin^4(b)$, where ω is the rotational velocity and the b is the latitude. Thin dotted black lines mark the fit uncertainty using the 1-sigma of the A, B, C parameters. The equatorial rotational velocity is 14°/day. Rotational profiles derived by other authors are showed for comparison.

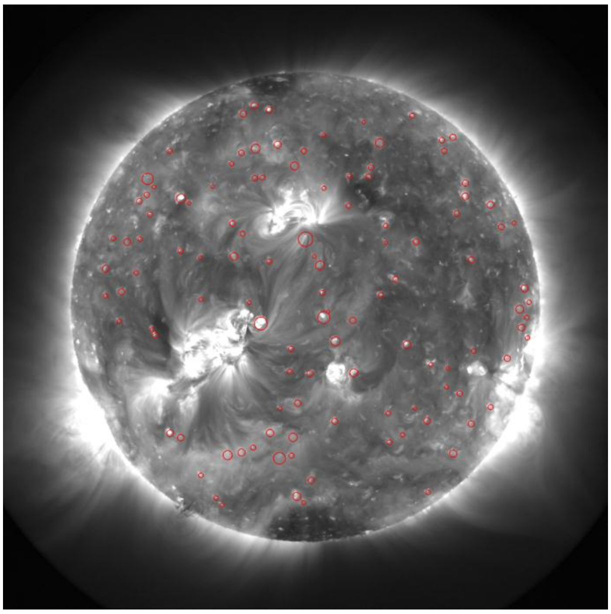

Figure 2.6. Illustrative result of the segmentation process using the Python tool for detection of CBPs in the 19.3 nm SDO/AIA image.

The Ca II K3 spectroheliograms registered in the Observatório Geofísico e Astronómico da Universidade de Coimbra – OGAUC (Portugal) were used to investigate the evolution of the chromospheric plages activity during the 24th solar cycle. Research team of the OGAUC created a special tool based on the segmentation by watershed method combined with other mathematic morphological operators to detect automatically and analyse the plages and/or other solar features. Several procedures are applied to achieve the automatic detection (top-hat trasnform, hole filling, tresholding, watershed operation, gradient operation which allows to obtain contours of plage regions). One of the great potentialities of using mathematical morphology is its power to deal with the geometry of complex and irregular shapes. More, north-south asymmetry of the solar activity can be studied using this tool. The results were published in [5] (Fig. 2.8).

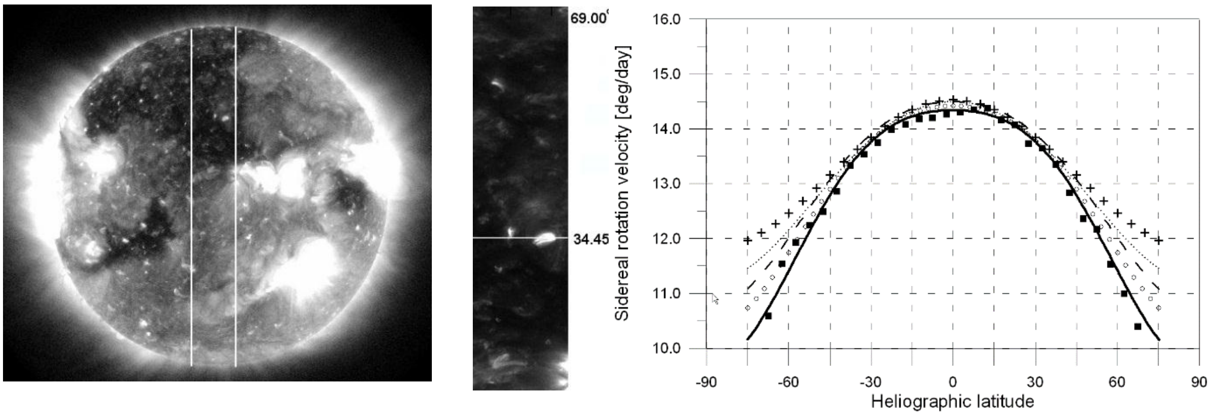

Figure 2.7. Solar corona on 30 August 2018 at 12:00:12.8 UT(left panel); region of interest along the central meridian (middle panel); rotational profile as derived using the CC method (right panel), where squares mark the mean values in 5° sectors and the solid line is the best fit of these values. Rotational profiles derived by other authors are showed for comparison.

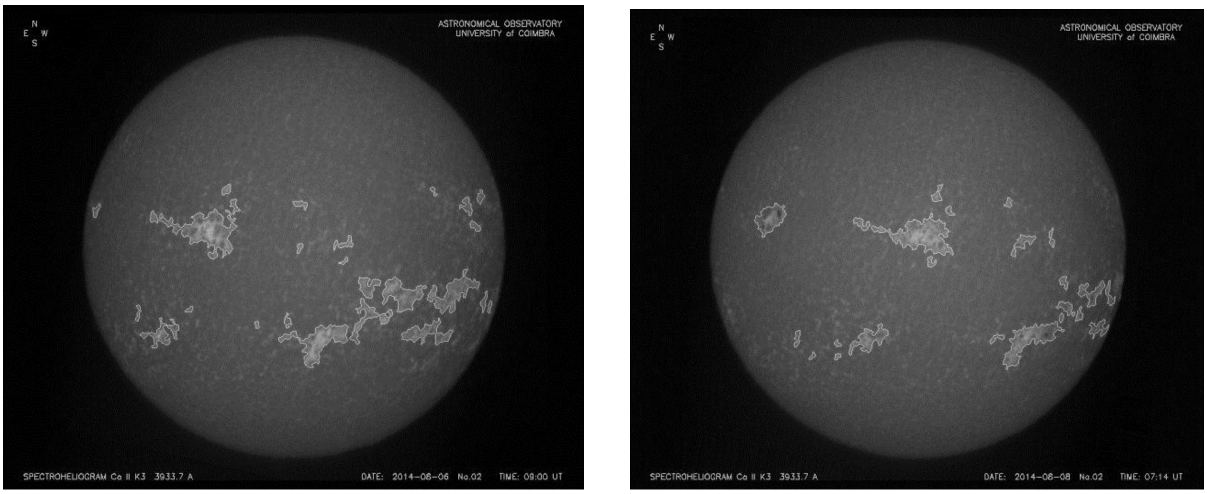

Figure 2.8. Results of automatic identification of chromospheric plages: original images acquired on 6 August 2014 (a) and on 8 August 2014 (b), respectively, with contours of identified plage regions superimposed to the original image.

We aimed in [6] to identify properties of the observed magneto-acoustic waves and study the background properties of magnetic structures within the lower solar atmosphere using two series of high-resolution intensity images with short cadence of two isolated magnetic pores captured by the Dutch Open Telescope

(DOT) and Rapid Oscillations in the Solar Atmosphere (ROSA) instruments, resp. Combining wavelet analysis and empirical mode decomposition (EMD), we searched for characteristic periods within the cross-sectional (i.e., area) and intensity time series. Several oscillations have been identified within these two magnetic pores. Their periods range from 3 to 20 minutes. Both the wavelet analysis and the EMD enable us to find the phase difference between the area and intensity oscillations. From these observed features, we conclude that these oscillations can be classified as slow MHD sausage waves.

We described in [7] conditions of pore formation in relation to the configuration and intensity of magnetic field, using observations of the SDO/HMI instrument. We analysed the temporal evolution of the area and brightness of the pores (time step 15 minutes), their statistics, and in parallel a time-sequence of the line-of-sight magnetic field intensity and its correlation with the area and brightness. Positions of the magnetic field maxima precede the visible positions of the pore in the direction of rotation for the positive polarity and lag behind it for the negative polarity.

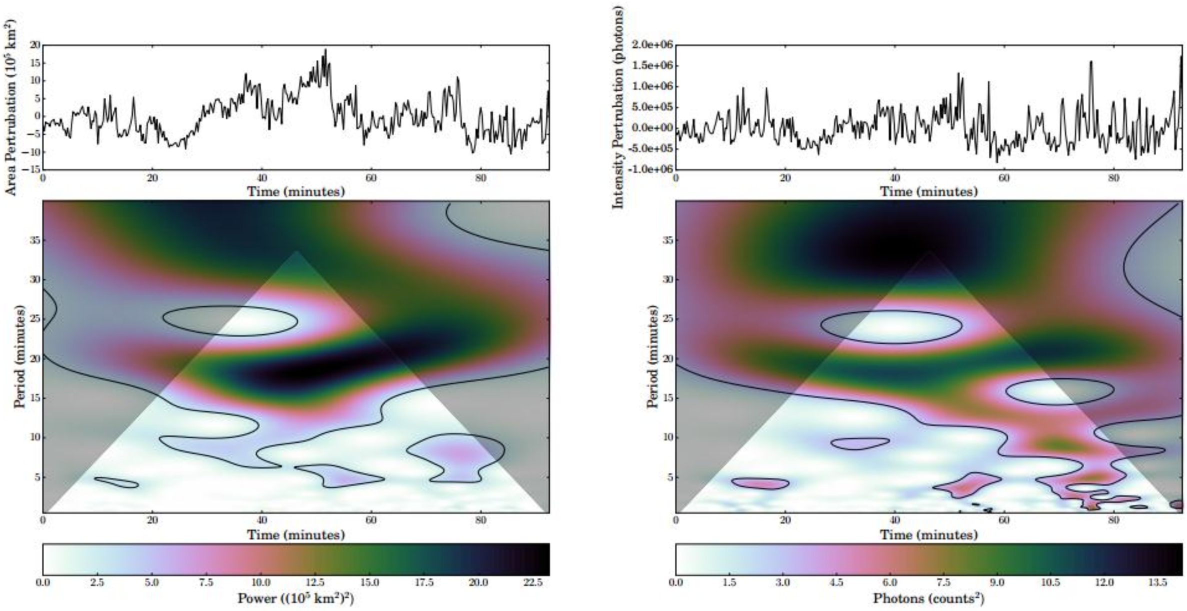

Figure 2.9. Evolution of the area of the pore (Upper panels). The corresponding wavelet power spectrum for a white noise background. The cone of influence is marked as the shaded region and the contour lines show the 95% confidence level (Lower panels).

The SCO organised in the year 2016 the 23rd National Solar Physics Meeting with participation from abroad. The goal of the Meeting was to present new results of solar physics and from the field of the space weather (Sun-Earth connections), to provide overview of present status in selected fields of solar physics and geophysics. A separate space was devoted to the presentation of research results of undergraduate and PhD students of university and academic departments and also to results of scientific and popularisation activities of Astronomical Observatories in the Slovak Republic and the Czech Republic. Invited talks, short contributions and posters covered the following fields: physical phenomena in the solar atmosphere, solar activity, total solar eclipses, space weather and geoactivity.

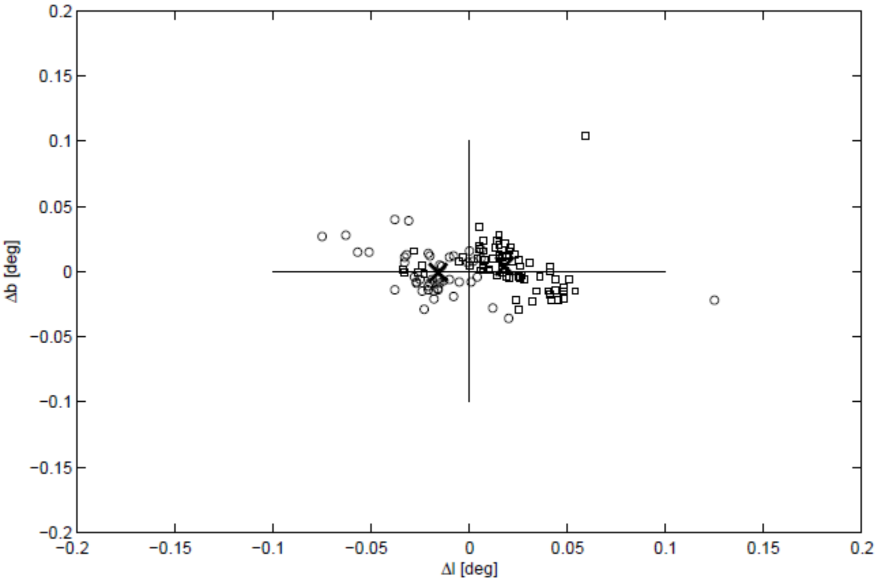

Figure 2.10. Differences between positions of intensity minima and magnetic maxima of pores in the (Δl, Δb) coordinates. The magnetic field maxima precede the pore positions for positive polarity (squares) and vice versa (circles). The cross at Δl = −0.02° indicates centroid position of the magnetic field maxima for negative polarities and the cross at Δl = 0.02° indicates centroid position of the magnetic field maxima for positive polarities.

One researcher from the SCO was co-editor of Proceedings of the Coimbra Solar Physics Meeting 2015 (CSPM-2015) "Ground-based Solar Observations in the Space Instrumentation Era", http://www.mat.uc.pt/~cspm2015/ published in the Astronomical Society of the Pacific Conference Series (Vol. 504) San Francisco in April 2016.

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The activities of *the Astronomical Institute of the Slovak Academy of Sciences (AISAS)*, Tatranská Lomnica (www.astro.sk), related to COSPAR, were devoted to research in stellar and solar physics using different satellite observations, mainly in the UV, XUV and X-ray spectral regions. Stellar data of the IUE, Kepler satellites, and the HST were used for research of various variable stars and start hosting exoplanets [1-5]. Data of the current SOHO mission, Hinode, SDO, STEREO, GOES, Fermi, IRIS, and RHESSI satellites were used for solar research mostly focused on solar prominences and flares. In common, these data were used with the simultaneously acquired data by the ground-based solar telescopes [6-14]. Hereby we present an example of the results obtained by the AISAS staff, information on an education activity of the AISAS, and information on the WAMIS proposal cooperation [15].

Researchers from AISAS analysed the observation of KIC8462852 obtained by the Kepler satellite [5]. These observations show mysterious eclipse like events. It was even proposed that they might have been caused by aliens. We explored the possibility that such eclipses are caused by the dust clouds associated with massive parent bodies orbiting the host star. We assumed a massive object and a simple model of the dust cloud surrounding the object. Then, we used the numerical integration to simulate the evolution of the cloud, its parent body, and resulting light-curves as they orbit and transit the star. We found that it is possible to reproduce the basic features in the light-curve of KIC 8462852 with four objects enshrouded in dust clouds (Fig. 2.11). With such physical models at hand, at present, there is no need to invoke alien mega-structures for an explanation of these light-curves.

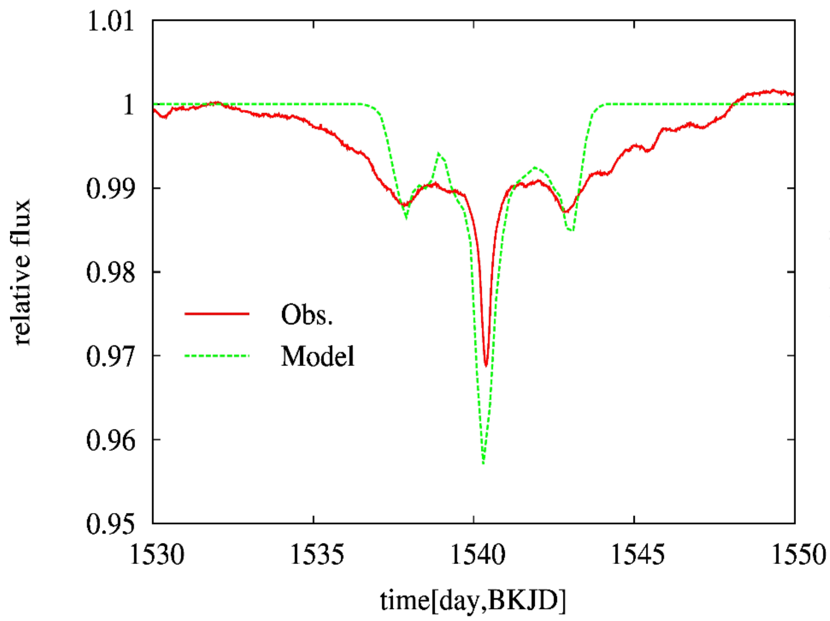

Figure 2.11. An example of a main eclipse event in the light-curve of KIC8462 observed with Kepler analyzed in this study [3] and comparison with the model. The fits may not be perfect but the main morphological features are represented.

Observations carried out with the space observatories, the Far Ultraviolet Spectroscopic Explorer (FUSE) and Hubble Space Telescope (HST), were used to model the spectral energy distribution of the symbiotic nova AG Pegasi [4]. In this way we demonstrated a high luminosity of the hot component of around 2200 solar units during the quiescent phase (Fig. 2.12). This implies that the hydrogen-rich material nuclearly burns at the surface of a low-mass white dwarf (WD) in AG Peg. This luminosity requires accretion rate of a few times 10^{-8} solar masses per year. To increase the luminosity of the burning WD by a factor of ~10, to values observed around the maximum of the new 2015 outburst, a transient increase of the accretion rate to ~3.10^{-7} solar masses per year is needed. This accretion rate, however, exceeds the stable-burning limit, which leads to blowing optically thick wind from the WD. As a result the enhanced wind is ionised by the hot WD's pseudophotosphere, and thus converts a fraction of its stellar radiation to the nebular emission. The corresponding increase of the nebular emission then causes a relevant brightening in the light curve which we indicate as the outburst.

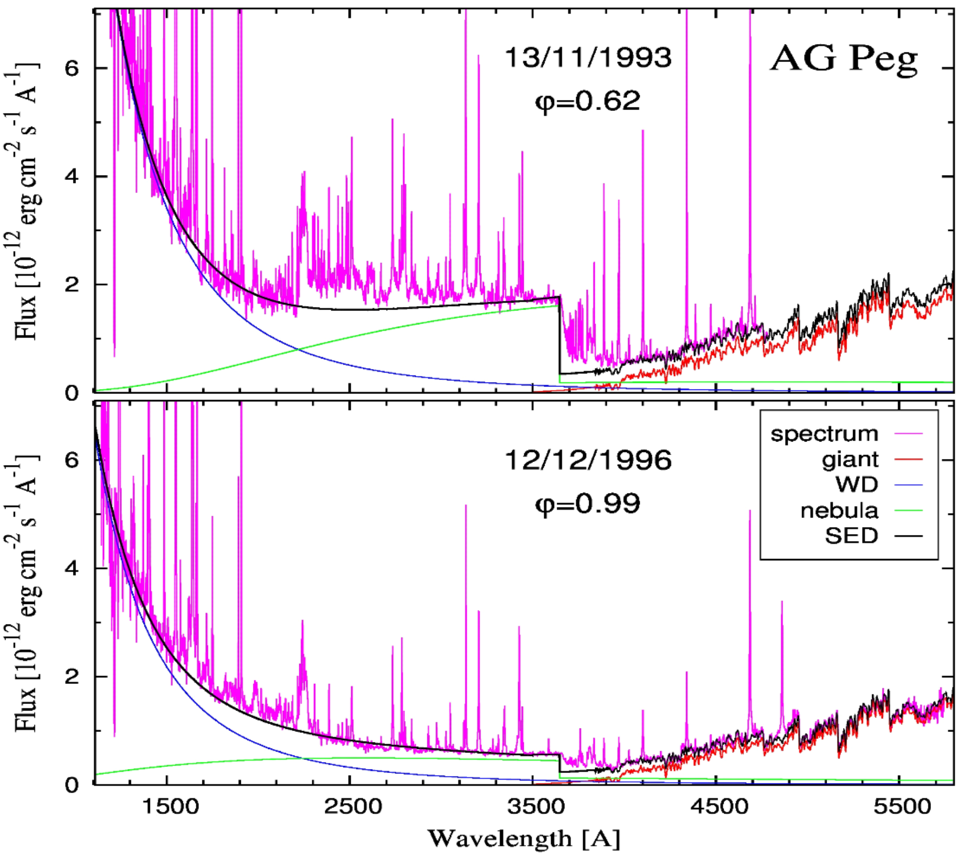

Figure 2.12. Ultraviolet/optical spectral energy distribution of AG~Peg during quiescent phase from two opposite orbital phases. Observations are represented by the HST spectra (magenta line). The model (black line) consists of the hydrogen nebular continuum (green line), the hot stellar source radiating at ~160 000 K (blue line) and the red giant spectrum (orange line). It corresponds to a high luminosity of the nuclearly-burning WD of around 2200 solar units.

The study by Koza et al. [12] has been focused on the analysis of a quiescent solar prominence observed in the spectral line He I 5876 Å D3 on 2 August 2014 by the solar telescope THEMIS, located at Observatorio de Teide (Tenerife, Canary Islands). This study employs a context imagery of this prominence obtained by the cosmic solar observatories SDO and STEREO B in the EUV spectral regions. Figure 3 shows the prominence in the spectral regions around 304 Å, 211 Å, and 195 Å and selected intensity levels corresponding to the ground-based observations in the Hα (red contour) and He I 5876 Å D3 (yellow contours) spectral lines. Combination of such data allows to derive more detailed results on the followed solar activity features. In the case of this study, since the separation angle of the STEREO B spacecraft with Earth is 162 degrees, the SECCHI/EUVI 304 Å and 195 Å images of the prominence in the bottom panels of Fig. 2.13 provide almost rear views of its dark central pillar and arcades stretching to the right, resembling its AIA 304 Å counterpart in the top left panel.

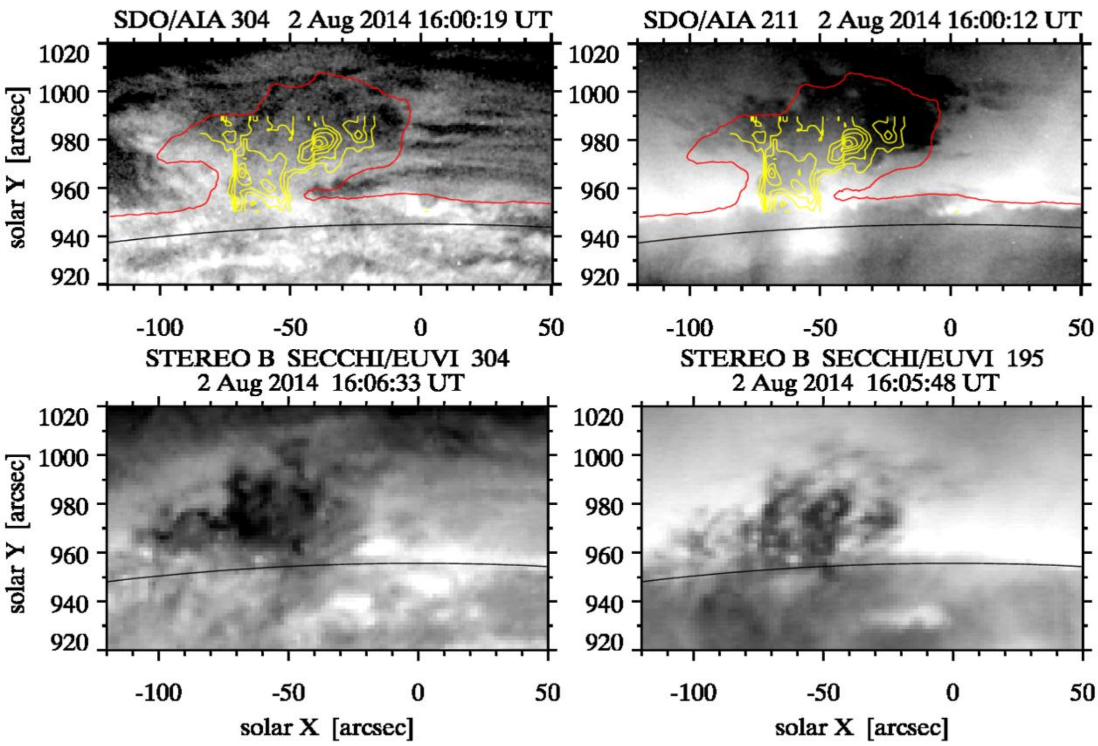

Figure 2.13. Top: The SDO/AIA images of the quiescent solar prominence, which occurred at the east solar limb on 2 August 2014, in the 304 Å (left) and 211 Å (right) passbands. The red and yellow contours mark the selected Hα and He I 5876 Å D3 intensity levels observed by ground-based instruments. The black arc indicates the east photospheric limb.
Bottom: STEREO B SECCHI/EUVI images of the prominence in the 304 Å (left) and 195 Å (right) passbands. Since the separation angle of the spacecraft with Earth was 162°, the black arc indicates the west photospheric limb from the spacecraft viewpoint.

The Astronomical Institute organised in the year 2017 the lecture course – Radiative Transfer in Solar and Stellar Atmospheres - given for the undergraduate and PhD students from Slovakia by prof. Petr Heinzel of the Astronomincal Institute of Czech Academy of Sciences (Ondřejov, Czech Republic) on May 29 - June 2, 2017 at AISAS at Tatranská Lomnica. This course of lectures was an intensive one-week course in the theory of radiative transfer in stellar atmospheres and related numerical methods. More details about the course of lectures can be found at the dedicated web page – *https://www.ta3.sk/~koza/school2017*.

In the years 2016-2017 AISAS has become involved in the proposal which has been submitted twice for consideration of an award by NASA (NASA H-TIDeS LCAS program). The proposal called "Waves and Magnetism in the Solar Atmosphere (WAMIS)" is led by Yuan-Kuen Ko (Naval Research Lab, Washington, USA) (PI), and its AISAS part by J. Rybak (Co-I). The team has received a negative agency decision due to NASA budget limitations although the proposal has been ranked high. The project is a long duration balloon based 20 cm aperture coronagraph designed to obtain continuous measurements of the strength and direction of coronal magnetic fields within a large field-of-view over at least weeks at the spatial and temporal resolutions required to address several outstanding problems in coronal physics [15]. The WAMIS investigation, comprising a balloon-borne infra-red coronagraph and polarimeter to observe Fe XIII forbidden transitions and the He I line, should enable breakthrough science and enhance the value of data collected by other observatories on the ground (e.g. ATST, FASR, SOLIS, COSMO) and in space (e.g. Hinode, STEREO, SDO, SOHO and IRIS), and will advance technology for a future orbital missions.

Besides of this, the AISAS staff was involved (or leading) in the last two years in several coordinated observing campaigns focused on observations of several aspects of the solar activity. The integral part of the campaigns were also measurements performed by the space-born instruments on different satellites, e.g. IRIS, EIS/Hinode. The measurements were coordinated with the ground-based instruments including the AISAS owned CoMP-S and SCD instruments at the Lomnický štít Observatory.

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3. LIFE SCIENCES

M. Musilová

Life sciences research in the space sector in Slovakia used to be performed primarily at the Institute of Experimental Endocrinology, Institute of Animal Biochemistry and Genetics, the Institute of Measurement Sciences, and in the Centre of Biosciences of the Slovak Academy of Sciences. The space-related research linked to life sciences in Slovakia is now primarily performed in the Slovak Organisation for Space Activities (SOSA) and at the Faculty of Electrical Engineering and Information Technology of the Slovak University of Technology in Bratislava (FEI STU), in collaboration with multiple Slovak and international partners.

The research performed at SOSA and FEI STU is wide-ranging, encompassing performing stratospheric research, simulating the conditions on the surface of Mars and the Moon, and studying the survival of life in extreme environments. The astrobiology aspect of the stratospheric research is focusing on studying the degradation of biological molecules when exposed to the harsh conditions in the stratosphere, such as DNA and cell membranes. SOSA has an ongoing collaboration with the German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt; DLR), which is interested in sending different types of biological molecules into the stratosphere using SOSA's stratospheric balloons.

In terms of simulating extraterrestrial environments, members of SOSA and FEI STU have performed multiple research projects focused on both the Moon and Mars. Recently, a simulation of lunar regolith materials was performed for astrobiology and planetary research, in collaboration with University College London (United Kingdom) and Curtin University (Australia). In 2017, a SOSA member was the Commander of a simulated mission to Mars at the Mars Desert Research Station (MDRS) in the USA. The astrobiology research performed there aimed to grow food in simulated Martian conditions. It also involved testing the applicability of food supplements, made by the Institute for Food Research (Slovakia), to astronauts and future Mars colonists. Astrobiology research was also performed with the Israeli Space Agency (ISA) and the Weizmann Institute of Science (Israel). This project focused on collecting extreme lifeforms, which survive in the Utah desert where MDRS is based, to then expose them to simulated Martian conditions and check their survival ability. SOSA was involved with the preparations and the operations of the AMADEE-18 Mars Analog Mission as well, run by the Austrian Space Forum, in partnership with the Oman National Steering Committee. Furthermore, a SOSA member was on the scientific committee of the European Mars Conference in 2017, which was run by the Austrian Space Forum, where they also presented research related to life on Mars.

Moreover, the life in extreme environments research has been performed by SOSA and FEI STU in Svalbard (Norway) in 2017. The project was based on a collaboration with the University of South Bohemia (Czech Republic) and the Faculty of Natural Sciences of the Comenius University in Bratislava (Slovakia). The ecosystems in Svalbard are a great analogue for similarly extreme environments, which exist elsewhere in the universe. Therefore, potential life in those extraterrestrial places could be similar to the lifeforms found in Svalbard. A team from SOSA studied two different environments in Svalbard, from an ecological, geological and microbiological perspective and their relevance to extraterrestrial conditions. The samples are currently being analysed in SOSA and FEI STU. Further biochemical and genetic analyses are planned, as well as experiments during which the extremophiles will be exposed to extraterrestrial conditions. Furthermore, these studies and samples will be provided to high school and university students in Slovakia for educational and outreach purposes. Students will be able to study the survival of these extremophiles in different simulated planetary conditions and use them for their bachelors, masters and PhD degree projects.

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4. MATERIALS RESEARCH IN SPACE

J. Lapin

Materials research in space at the ***Institute of Materials and Machine Mechanics of the Slovak Academy of Sciences*** (IMMS SAS) has been connected with the international project entitled "Gravity dependence of CET in peritectic TiAl alloys (acronym GRADECET)" in the framework of the ELIPS-4 programme of European Space Agency (ESA). The international consortium of the project consisted of seven partners: Access e.V. – project coordinator (Aachen, Germany), Ecole des Mines de Nancy (Institut Jean Lamour, SI2M, Nancy, France), Deutsches Zentrum für Luft- und Raumfahrt (Institut für Materialphysik im Weltraum, Köln, Germany), Trinity College Dublin, School of Engineering, Mechanical and Manufacturing Engineering (Dublin, Ireland), Wigner Reserch Centre for Physics, (Hungarian Academy of Sciences, Budapest, Hungary), Snecma Safran Group (Villaroche, France), and Institute of Materials and Machine Mechanics (Slovak Academy of Sciences, Bratislava, Slovak Republic). The participation of IMMM SAS in the project was financially supported by the Slovak Academy of Sciences (SAS) in the frame of international cooperation of SAS with ESA.

GRADECET project was exceptional concerning the studied TiAl alloys as well as experimental solidification conditions, which include Earth gravity in laboratory conditions, hypergravity in a large diameter centrifuge and microgravity during suborbital rocket flight. One possible event in casting of TiAl alloys is columnar to equiaxed transition (CET). The CET occurs during columnar growth when equiaxed grains begin to form, grow, and subsequently stop the columnar growth. The during solidification, the CET leads to a change of the grain structure within castings and hence to a change of their mechanical properties. For most TiAl castings, solidification with equiaxed grains is targeted, aiming to achieve isotropic properties throughout the cast component. Therefore, understanding the CET in microgravity, ground based gravity and hypergravity conditions was of a great importance from fundamental and industrial point of view to accelerate further development and industrial applications of these light weight high-temperature structural alloys.

The ground based experiments were carried out in Bridgman type apparatus designed at IMMS SAS. The new design of the apparatus allowed performing quench during solidification and CET experiments on cylindrical samples under controlled solidification conditions. The quench during solidification and CET experiments were conducted in dense high purity Y_2O_3 crucibles. The quenched during solidification experiments allowed to at preserve conditions in the mushy zone of the sample and estimate phase transformation temperatures, as shown in Fig. 4.1.a. The sample prepared by the power down technique showed clear CET, as seen in Fig. 4.1.b. In both types of the experiments, the primary solidification phase was identified to be dendritic β-phase with a clear cubic symmetry.

In order to study the effect of hypergravity conditions on CET, the directional solidification experiments were carried out in large diameter centrifuge (LDC) of ESA, as shown in Fig. 4.2. These experiments were performed in the furnaces designed for hypergravity conditions up 20 g, which were mounted into the capsules of LDC. The power down technique was applied to achieve CET under various gravity in the studied TiAl alloy.

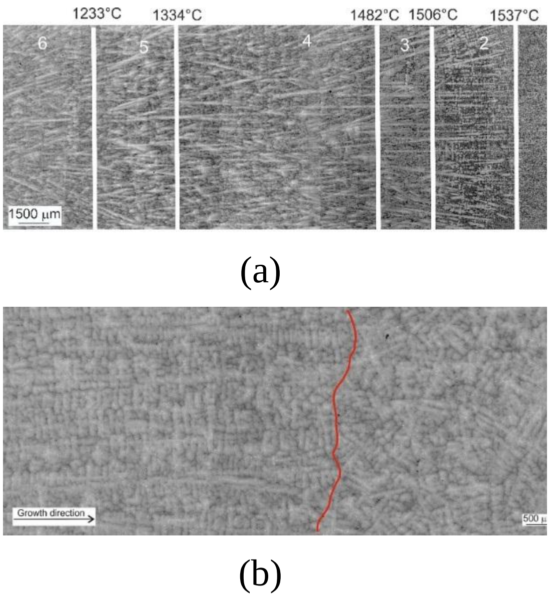


Figure 4.1. *TiAl alloy prepared by quench during solidification experiment with defined transformation temperatures (a) and power down technique with a clear CET at ground conditions (b).*

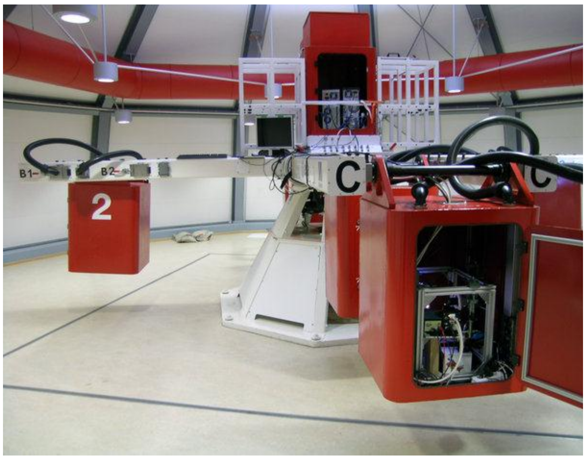


Figure 4.2. *Large diameter centrifuge (LDC) applied for CET experiments of TiAl alloy allowing the acquisition of measurement points in the range from 1 to 20 g.*

The international project GRADECET was completed by the launch of the MAXUS 9 rocket from Kiruna in Sweden followed by successful experiments carried on its board and the return of the experimental module with the samples back to Earth on April 7, 2017. Fig. 4.3 shows MAXUS 9 rocket with a scientific payload consisting of five modules including IMPRESS. The IMPRESS module consisted of four furnaces for power down solidification experiments, as shown in Fig. 4.4. During the suborbital rocket flight, the solidification experiments were performed with light titanium intermetallic alloys based on TiAl under microgravity conditions. The microgravity experiments focused on the columnar to equiaxed transition (CET) are unique and represent a significant breakthrough in the existing knowledge about the effect of gravity on the microstructure formation during the solidification of new lightweight intermetallic TiAl based alloys. These materials are used for the production of aircraft engine blades and the results of this project are very beneficial for the demanding validation process of the proposed casting technology for aircraft blade processing, which must ensure high quality, operation reliability and reproducibility of their mechanical properties.

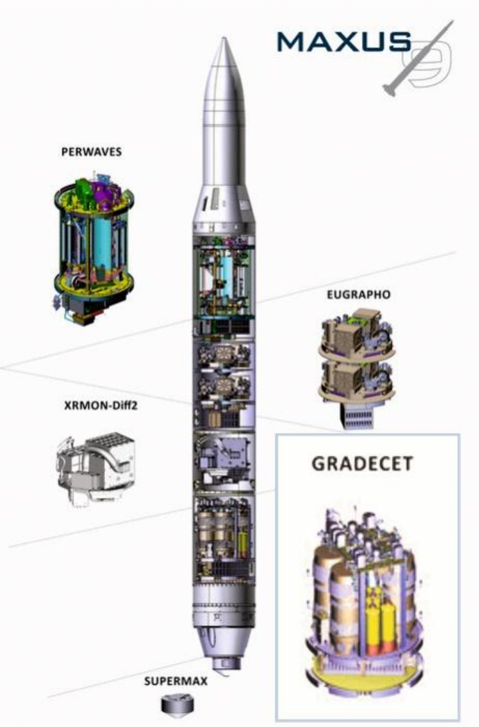


Figure 4.3. Five scientific reusable modules including IMPRESS carried by MAXUS 9. http://www.esa.int/spaceinimages/Images/2017/04/Maxus9_experiments

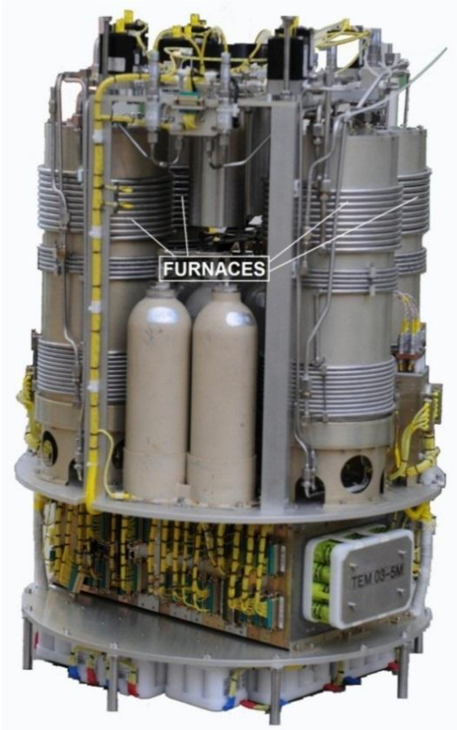


Figure 4.4. IMPRESS module consisting of four furnaces for directional solidification in microgravity conditions.

5. REMOTE SENSING

I. Barka, T. Bucha, J. Feranec, M. Kopecká, I. Kováčiková, J. Nováček, M. Rusnák, I. Sačkov, M. Sviček, D. Szatmári

Selected activities of four institutions are included in this report (2016-2017):

Institute of Geography, Slovak Academy of Sciences (IG SAS) in Bratislava

Project: ***Effect of impermeable soil cover on urban climate in the context of climate change*** (supported by the Slovak Research and Development Agency – APVV-15-0136)

Land cover of Bratislava for the years 1998, 2007, 2016 obtained by interpretation of satellite data (SPOT and Sentinel)

Three data layers about land cover/land use (LC/LU) for the years 2016, 2007 and 1998 and for the territory of Bratislava (its area of 229 km^2 coincides with the functional urban area (FUA) Bratislava as defined in the Urban Atlas Project). Out of the proposed 52 classes of the compiled nomenclature for the APVV-15-0136 Project there are 44 LC/LU classes (prevailingly urban landscape, see Fig. 5.1) within the FUA of Bratislava. The minimum area of polygons of the quoted classes is 1 ha with a minimum width 20 m. Their identification was based on the scope of soil sealing: in the span of less than 10% to 80% and more, height of the buildings and presence of grassy and tree vegetation identified by means of satellite images. This data will be used by the Slovak Hydrometeorological Institute, Bratislava (participating organisation in the project) as inputs into the MUKLIMO model (which makes possible simulation of heat characteristics of urban landscape) in 100 × 100 m raster including linear features. The compiled nomenclature is available in electronic version at the Institute of Geography SAS, Bratislava and at the Soil Science and Conservation Research Institute, National Agricultural and Food Centre, Bratislava *(Szatmári D., Kopecká M., Feranec J., Sviček M. 2017. Enlarged nomenclature Urban Atlas 2012. Bratislava, APVV-15-136).*

Figure 5.1. Example of land cover data visualization: part of Bratislava in 2016.

Analysis of Urban Green Spaces Based on Sentinel-2A data

Urban expansion and its ecological footprint increases globally at an unprecedented scale and consequently, the importance of urban greenery assessment grows. The diversity and quality of urban green spaces (UGS) and human well-being are tightly linked, and UGS provide a wide range of ecosystem services (e.g., urban heat mitigation, storm water infiltration, food security, physical recreation). In study Kopecká et al. (2018) an approach to UGS extraction from newly available Sentinel-2A satellite imagery is presented (Fig. 5.2).

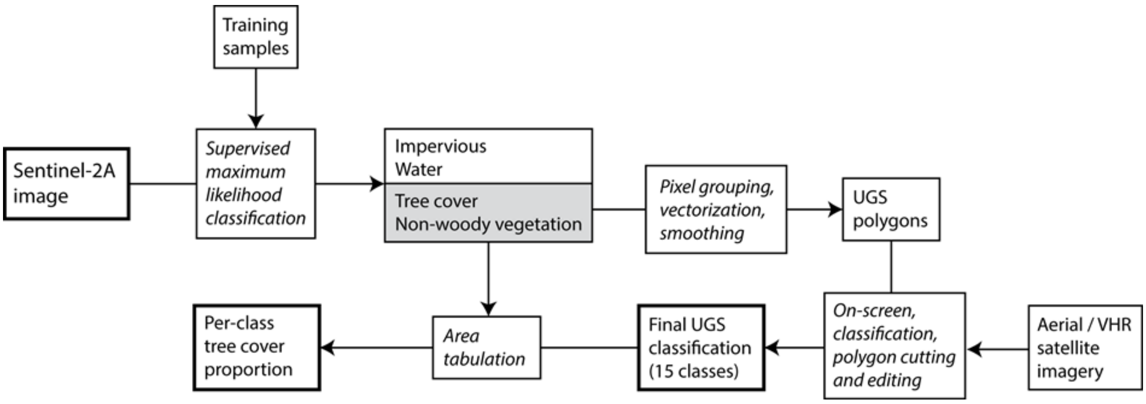


Figure 5.2. Scheme of the proposed methodology (Rosina, Kopecká 2016).

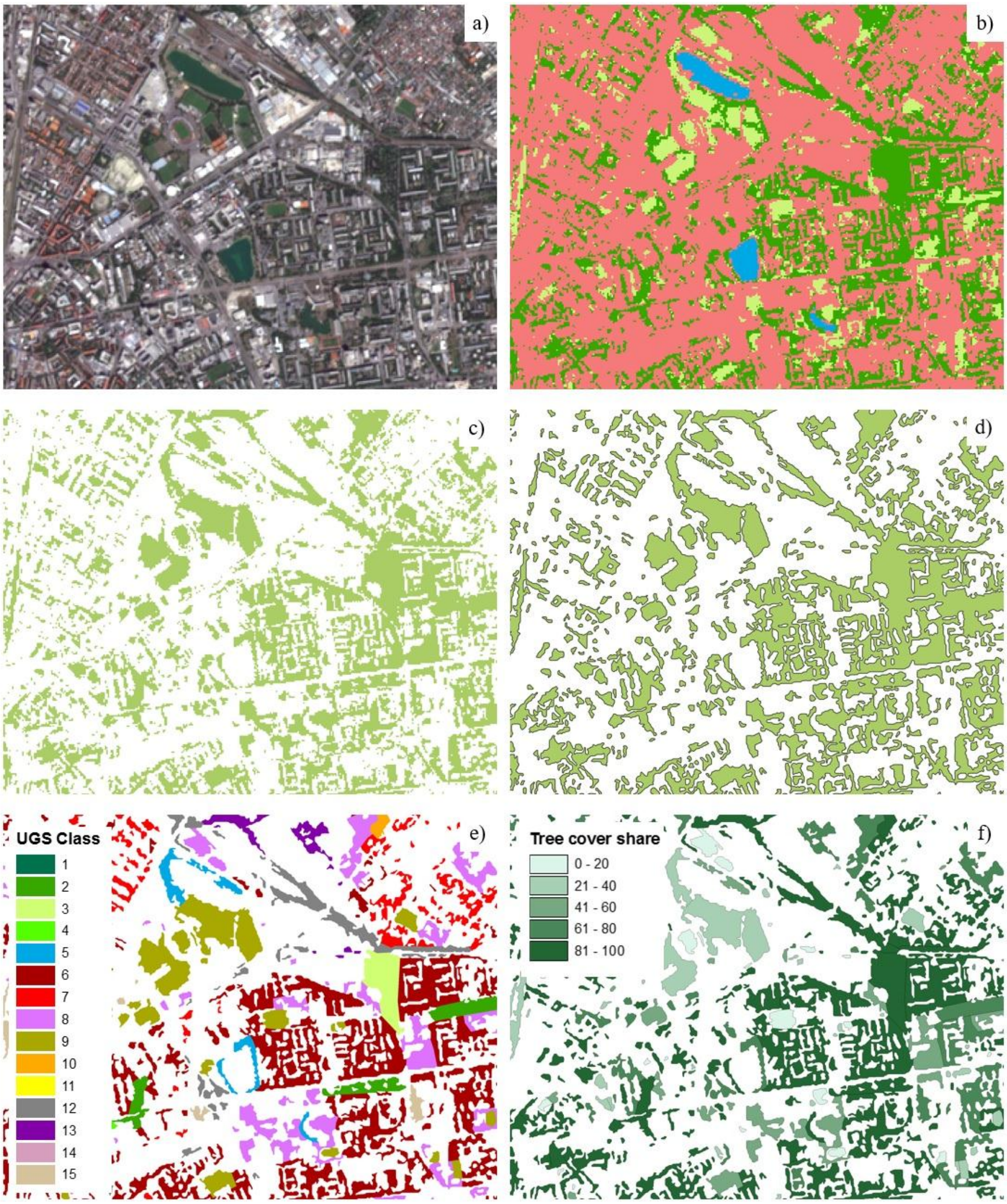
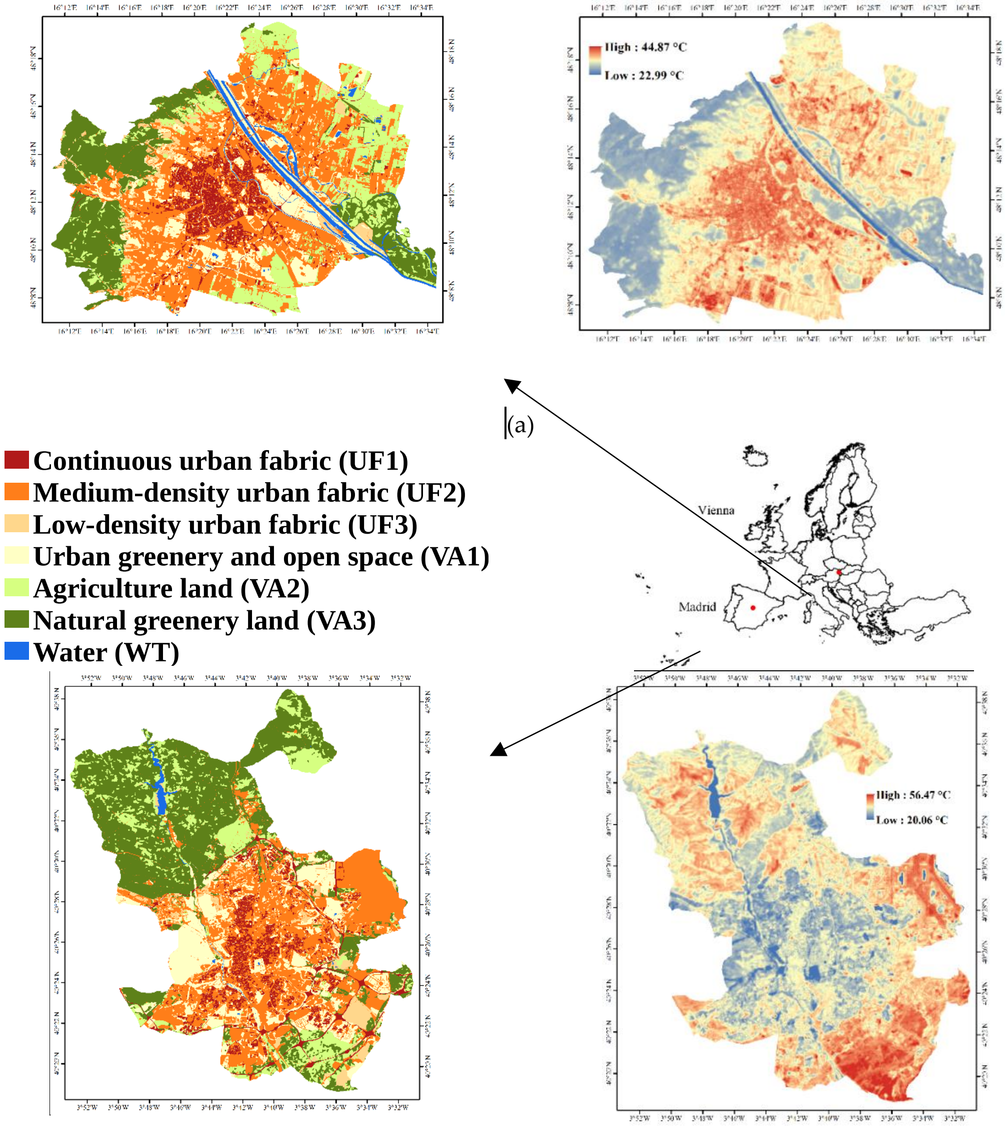


*Figure 5.3. Six processing steps of the UGS extraction and classification (an example from study area Bratislava). (**a**) A true colour composite produced from S2A data; (**b**) result of the maximum likelihood supervised automatic classification; (**c**) binary map of vegetation/non-vegetation land cover; (**d**) vectorised and visually enhanced polygons with the minimum mapping unit of 500 m^2 applied; (**e**) result of UGS visual interpretation and polygon editing; (**f**) tree cover share estimated using (**b**,**e**) on a per-polygon basis (Rosina, Kopecká, 2016).*

Supervised maximum likelihood classification was used to identify UGS polygons in three cities in Slovakia: Bratislava, Žilina and Trnava. The 100% cloud-free S2A scenes acquired in August 2015 (study area Bratislava) and in September 2016 (study areas Trnava and Žilina) were downloaded from Copernicus Sentinels Scientific Data Hub (https://scihub.copernicus.eu/dhus/). Based on their function and physiognomy, each UGS polygon was assigned to one of the fifteen classes, and each class was further described by the proportion of tree canopy and its ecosystem services. The results document that the substantial part of UGS is covered by the class *Urban greenery in family housing areas* (mainly including privately-owned gardens) with the class abundance between 17.7% and 42.2% of the total UGS area. The presented case studies showed the possibilities of semi-automatic extraction of UGS classes from Sentinel-2A data that may improve the transfer of scientific knowledge to local urban environmental monitoring and management (Fig. 5.3).

Responses of Urban Land Surface Temperature on Land Cover

The Institute of Geography SAS in co-operation with Remote Sensing and Digital Earth Institute, Chinese Academy of Sciences analysed the relationship between the land cover (LC) characteristics and the land surface temperature (LST) that is significant for surface urban heat island (SUHI) study and for sustainability research. For better understanding how the LST responds to LC, two urban areas, Vienna and Madrid, with different climatic conditions were selected and compared, using the thermal infrared (TIR) Band10 (10.30 – 11.30 μm, resolution of 90 m) of Landsat OLI-8 data and Urban Atlas data. To determine a suitable scale for analyzing the relationship between LC and LST, a correlation analysis at different sizes of spatial analytical scales was applied. To demonstrate the LC composition effects on LST, a regression analysis of the whole study area and in the specific circumstance was undertaken. The results show that: (1) In the summer, Vienna presents high temperature in the urban areas and low temperature in the surrounding rural areas, while Madrid displays the opposite appearance, being relatively cooler in the urban areas as compared to the rural areas, with the main different factors affecting elevated urban LST; (2) Suitable analytical scales are suggested in studying the LC–LST relationship between different LC characteristics in the two study areas; (3) Negative effects on the LST appear when the area of cooling sources, such as water or urban greenery, reaches 10% at a 990×990 m^2 scale in Vienna. Built-up area is the main factor affecting elevated urban LST where such areas cover the majority at a 990×990 m^2 scale in Madrid (Fig. 5.4). These findings provide a valuable view regarding how to balance the urban surface thermal environment through urban planning.



(b)

Figure 5.4. Land cover and land surface temperature maps from summer 2013 of (a) Vienna; (b) Madrid.

Application of UAV technologies

Development of the small Unmanned Aerial Vehicle (UAV) in the last 5 years has led to their massive utilisation in different scientific disciplines; providing a time-effective and low-cost facility for landscape mapping [1]. IG SAS used UAV for evaluation the suitability of photogrammetrically-derived DEM from UAV and the effect of vegetation on slope stability assessment [2]. The landslide in Svätý Anton village in Slovakia is the example used for these determinations. DEM computed by UAV photogrammetry was compared with terrain topography obtained by GPS survey. Although the landslide area contained the following classified objects; several trees (high vegetation), shrubs (medium vegetation), high grass (low vegetation exceeding 20 cm) and a building (the cellar); the slope deformation was continuously covered by several centimetre-high grass which could not be classified. Thus, vegetation remains are the principal problem of photogrammetrically-derived DEM, and this limits its viability for the topographic mapping which is so important in geomorphic studies (Fig. 5.5).

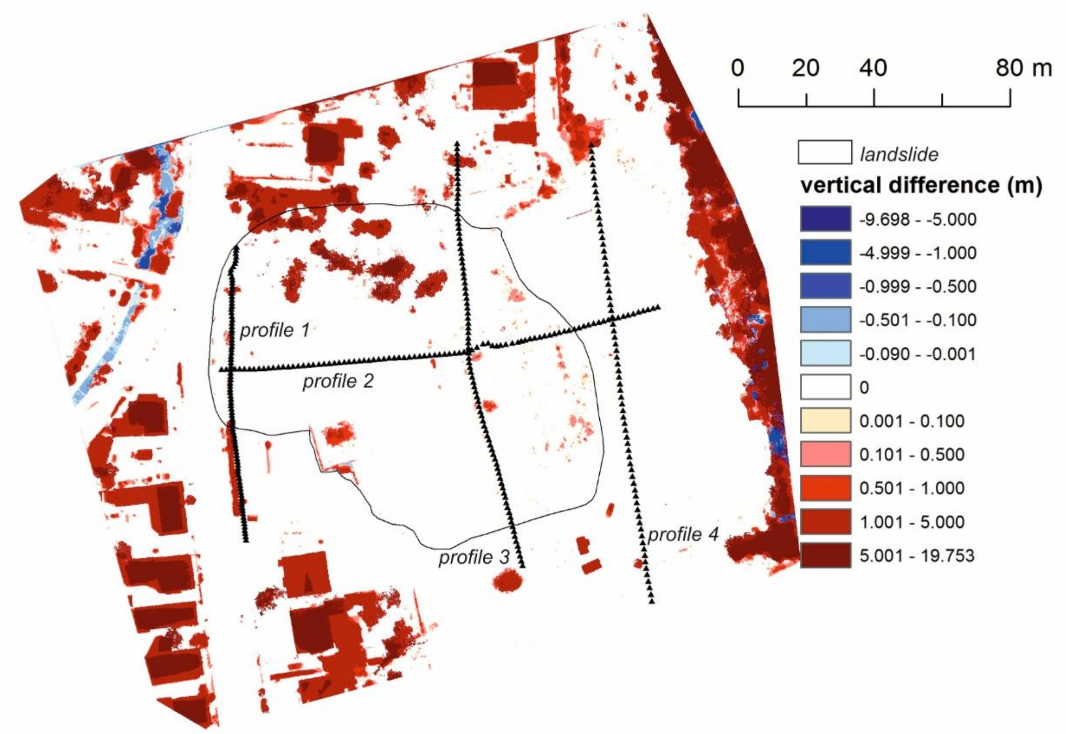


Figure 5.5. Vertical difference between classified (digital terrain model, DTM) and unclassified (digital surface model, DSM) digital models.

For high-resolution mapping of a river landscape by UAV technology a template was presented with the following five steps: (i) reconnaissance of the mapped site; (ii) pre-flight field work; (iii) flight mission; (iv) quality check and processing of aerial data; and (v) operations above the processed layers and landforms (objects) mapping (extraction) (Fig. 5.6). The small multirotor UAV (HiSystem Hexakopter XL) equipped with Sony NEX 6 camera with standard 16-50 mm lens provided image capture and workflow design applications. Images were processed by Agisoft PhotoScan software and georeferencing was ensured with 20 Ground Control Points (GCP) and 18 check points certifying accuracy assessment. Three imaging methods for 3D model creation of the study area were used: (i) nadir, (ii) oblique and (iii) horizontal. This minimized the geometric error and captured topography under the treetop cover and overhanging banks.

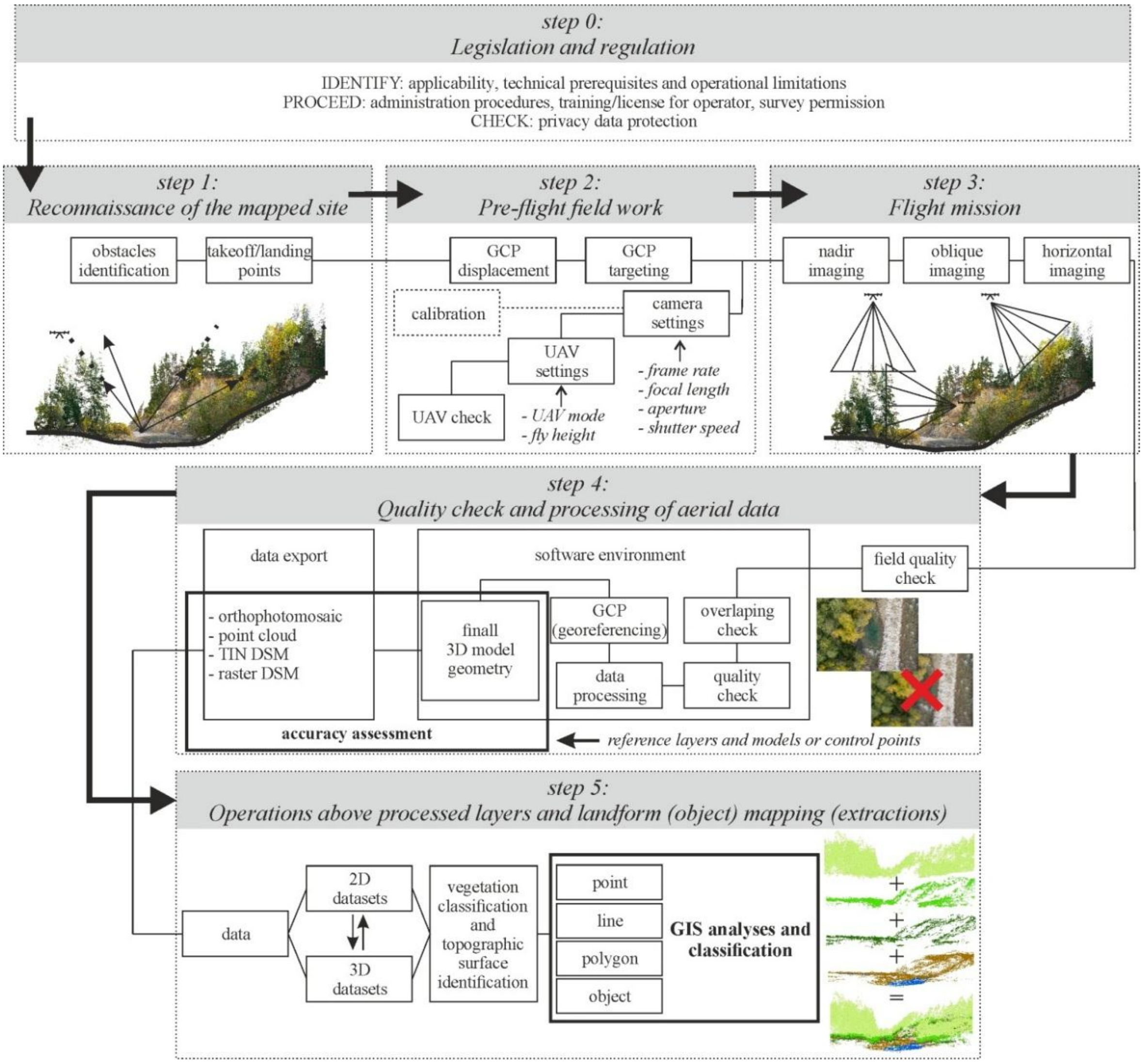


Figure 5.6. Scheme for mapping riverine landscape. Workflow consists of the following steps: (i) reconnaissance of the mapped site, (ii) pre-flight field work, (iii) flight mission, (iv) quality check and processing of aerial data, (v) operations above processed layers and landform (object) mapping (extractions). Prior to field mapping, it is necessary to check UAV regulations and permission for field mapping and flight missions (step zero).

The long-term co-operation of the Institute of Geography SAS in pan-European projects CORINE land cover (CLC) resulted in 2016 in the book publishing: *European landscape dynamics: CORINE land cover data* *(see reference remote sensing).*

The monograph presents methods of identification, analysis and assessment of land cover in Europe and its changes in the years 1990, 2000, 2006, and 2012 applying satellite images. Apart from that the book documents examples of solutions to environmental problems in Europe by means of CLC data (for instance, monitoring of urban sprawl, assessment of landscape fragmentation, mapping and assessment of ecosystems, and the like) along with estimation of their possible development in future.

Slovak Environmental Agency (SEA) in Banská Bystrica

Activities of the SEA were concentrated on the work involved with the ***Copernicus*** programme:

Copernicus programme is the European programme for Earth Observation. The Programme entered its full operational stage in the year 2014. The work on the EU level was concentrated on cooperation with the Copernicus Committee, Copernicus Security board, Copernicus User forum and Copernicus Ground segment task force and commenting on the EU level the technical and legislative documents regarding the Programme. Cooperation with the European Space Agency is limited due the fact that the Slovak Republic is not full member of ESA yet. Cooperation with the European Environment Agency (ESA) was concentrated on preparation of the next CORINE Land Cover (CLC) 2018 and High Resolution Layer (HRL) products as a part of the Copernicus Land observation service.

At the national level the Slovak national Copernicus working group continued its operation with the aim to coordinate Copernicus related activities on the national level and dissemination of information related to Copernicus programme. SEA distributes the Sentinel satellite images for the Slovak Republic on demand. User uptake and usage of the Copernicus data is relatively low in the Slovak Republic, mainly because of scarce experience with the processing and usage of remote sensing data. In the following years Slovakia plans to focus on user trainings in remote sensing and Programme information dissemination.

In the year 2017, preparation of the establishment of the Slovak node of the ESA Copernicus collaborative ground segment started with the preparation of the technical infrastructure in the Slovak governmental Cloud.

Pavol Jozef Šafárik University in Košice joined Copernicus academy network and is preparing courses and lectures regarding the Copernicus programme data usage and exploitation. Private company InSAR successfully joined the Copernicus Relays network. Two annual Hackathons were organised in Bratislava with successful use of the Copernicus data by the participants to develop application prototypes.

Copernicus supporting activities for the period 2017-2021:

SEA joined the activities in project Copernicus Local Land monitoring services under Framework Contract EEA/IDM/R0/16/009/Slovakia. The contract between SEA and EEA was signed on 8 June 2017. CLC2018 will be the fifth CLC inventory in Europe and has been planned so that the integrated European results will be available in late 2018 for the drafting of EEA SoER1 2020.

Project tasks undertaken by SEA:

- Verification of 2012 reference year local component products.
- Production of CLC for the 2018 reference year.
- Post-production verification of the HRL's for the 2015 reference year.
- Post-production verification of the HRL's for the 2018 reference year.
- Support and testing of future CLC+ (2nd generation CLC methodological improvements and developments), based on CLC2018 products.

National Agricultural and Food Centre – Soil Science and Conservation Research Institute (SSCRI) in Bratislava

Remote sensing oriented projects and activities 2016-2017

Remote sensing control of area-based subsidies in agriculture (2016-2017)

The subsidies play a key role in the agricultural sector and contribute to the prosperity of agricultural subjects. The subsidies to agricultural sector represent a major part of European budget and it is a reason why the control is emphasized.

The following figure (Fig. 5.7) displays the distribution of the control. The Slovak Administration has chosen six control sites in 2016 defined by 1002 km^2 ADAM, 365 km^2 BELO, 264 km^2 ERIK, 337 km^2 HUGO, 587 km^2 IGOR and 145 km^2 OLEG. For the 2017 campaign the Slovak Administration decided to have seven control sites defined by 133 km^2 DROP, 325 km^2 KUNA, 542 km^2 LAMA, 625 km^2 MLOK, 270 km^2 OVCA and 585 km^2 RYBA. They cover approximately 7.06% of applications in 2016 and 7.22% of applications in 2017.

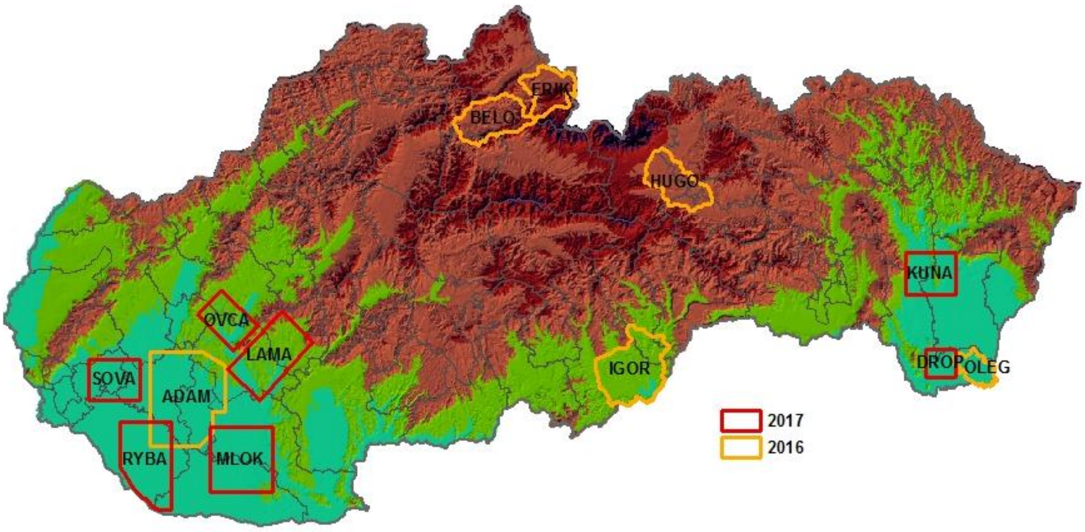


Figure 5.7. Localization of the controlled sites in campaigns 2016 and 2017.

In control procedure a set of high resolution (HR) multispectral images as SPOT 6 and SPOT 7 were used for precise identification of grown crop (Fig. 5.8). Two HR acquisition windows were used: HR-1 and HR+1.To control the cultivated area Very High Resolution (VHR) images from WorldView 2, 3 and 4 and GeoEye1 were used per each site (Fig. 5.9). Features which have to be excluded from the parcels like field path, straw stacks, midden, etc. are well recognisable on these images. As a complement to control vegetation development, the use of freely available Sentinel2 satellite images (resolution 10m/ pixel) was tested. The satellite images Sentinel2 are provided by ESA (European Space Agency).

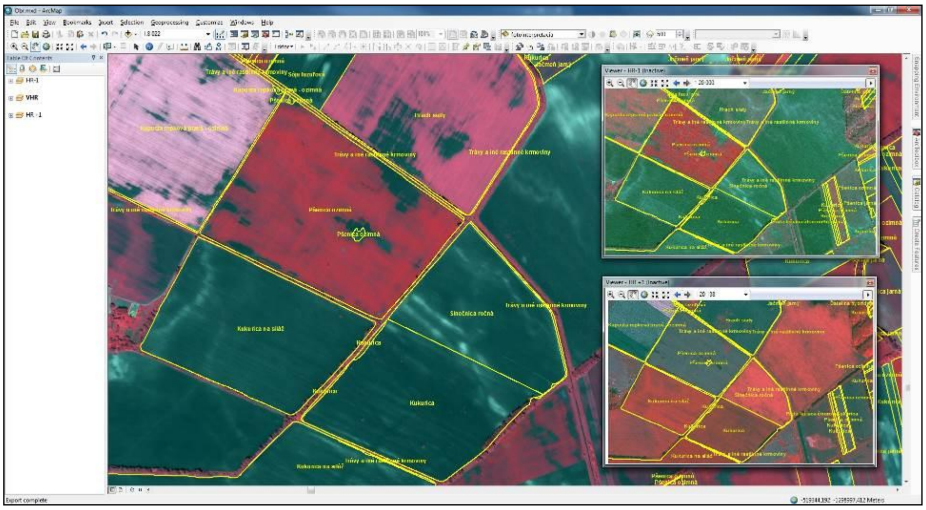


Figure 5.8. Example of land use check on HR images from different acquisition windows.

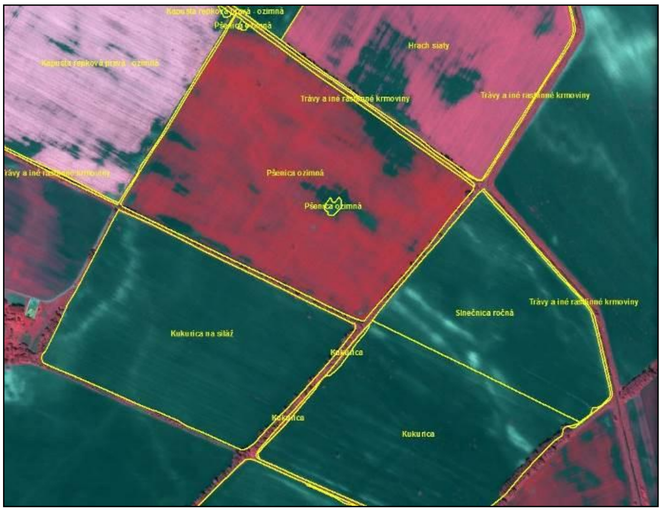


Figure 5.9. Example of boundary check on WorldView 2 image (VHR).

The CAPI has been adjusted to the annual conditions of regulations the subsidy schemes. Approximately *57 236* graphical annexes were printed and delivered to the farmers where they indicated the agricultural parcels they cultivate. Then the parcels together with vector data from IS GSAA were controlled on the basis of satellite images with high and very high resolution.

In the 2016 campaign the total number of applicants was *19,020*, the number of dossiers controlled with remote sensing was *1,342*. The total area controlled was *87,858.63* hectares with *2,931* reference parcels. There were *19,208* agricultural parcels to control (in 11 schemes), on average *14* parcels/farmer and *65.47* hectare/ dossier. According to the final diagnosis, which summarizes the diagnoses of the conformity and completeness tests at dossier level, 597 (44.49%) dossiers were accepted for Single area payment scheme, 5 (0.37%) for payment for agri-environment – climate action, 76 (5.74%) for area facing natural constraints, 560 (42.30%) for Complementary National Direct Payment scheme, no dossier for payments on organic farming, 34 (2.53%) for payment for agricultural practices beneficial for the climate and the environment, 1 (0.70%) for coupled direct payments for fruit with high labour inputs, 1 (0,70%) for coupled direct payments for fruit with very high labour inputs, 4 (0.30%) for coupled direct payments for vegetables with very high labour inputs and no dossier for coupled direct payments for tomatoes, vegetables with high labour inputs and hops and no dossier too for Special Areas of Conservation (Fig. 5.10).

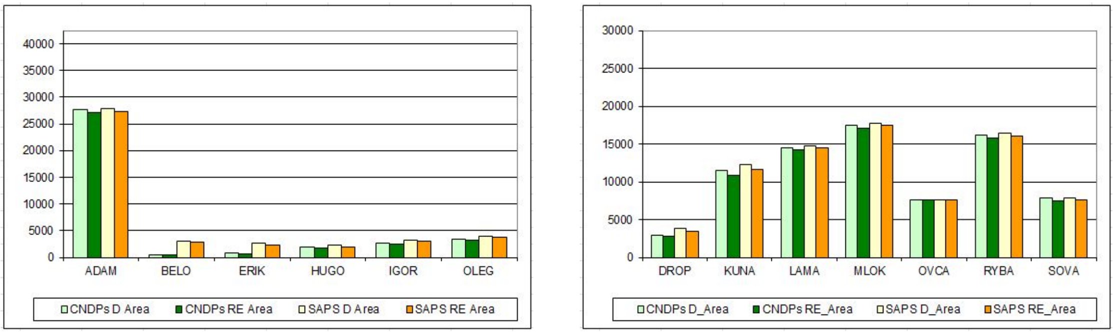


Figure 5.10. Declared and retained area (ha) for schemes CNDPs and SAPS per site.

In 2017 campaign the total number of applicants was *18,908*, the number of dossiers controlled with remote sensing was *1,366*. The total area controlled was *128,573.68* hectares with *3,632* reference parcels. There were *19,244* agricultural parcels to control (in 13 schemes), on average *13* parcels/farmer and *94.12* hectare/ dossier. According to the final diagnosis, which summarizes the diagnoses of the conformity and completeness tests at dossier level, 621 (45.46%) dossiers were accepted for Single area payment scheme, 1 (0.07%) for payment for agri-environment - climate action, 15 (1.09%) for area facing natural constraints, 610 (44.66%) for Complementary National Direct Payment scheme, no dossier for payments on organic farming, 52 (3.80%) for payment for agricultural practices beneficial to the climate and the environment, 1 (0.07%) for coupled direct payments for sugar beet, no dossier for coupled direct payments for fruit with high labour inputs, 6 (0.43%) for coupled direct payments for fruit with very high labour inputs, 2 (0.14%) for coupled direct payments for tomatoes, 1 (0.07%) for coupled direct payments for vegetables with high labour inputs, 3 (0.22%) for coupled direct payments for vegetables with very high labour inputs and no dossier for coupled direct payments for hops and no dossier either for Special Areas Of Conservation (Fig. 5.10).

Remote sensing within crop yield and crop production forecasting (2016-2017)

Monitoring of Crop Conditions and Crop Monitori*ng*

Regional monitoring of natural crop conditions aims to study the influence of weather (coupled with soil) on crop growth and crop development during current vegetation season. NDVI (Normalized Difference Vegetation Index) are derived from NOAA's AVHRR sensor. The NDVI Vegetation Index (Fig. 5.11), characterizes the total biomass state (volume and vitality), the higher the NDVI value, the more biomass is developed (characterized by a higher content of chlorophyll in plants and hence a more potent photosynthesis).

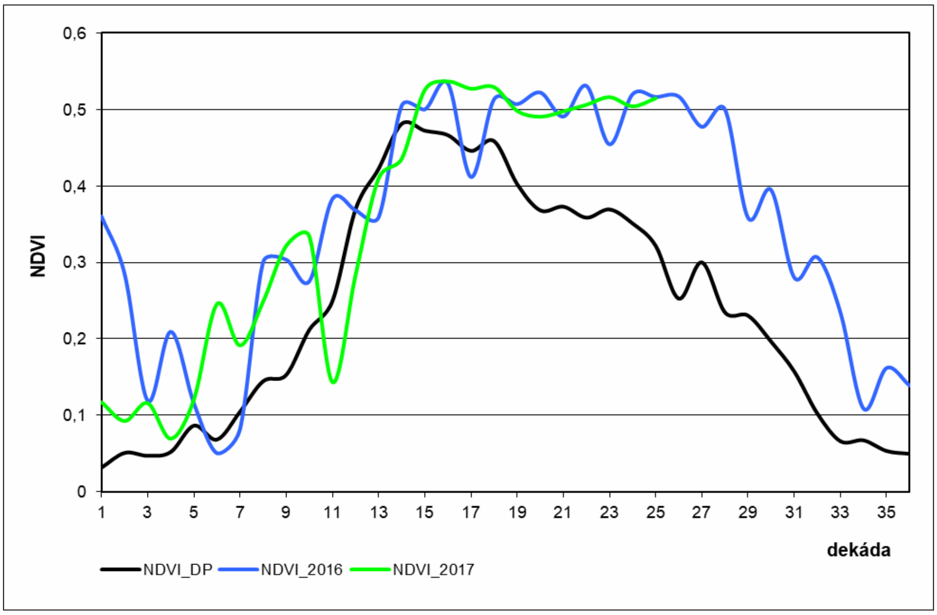


Figure 5.11. Comparison of NDVI development in 2016, 2017 and NDVI long term average.

Crop yield forecasting

The aim of the crop yield and crop production forecasting is to provide the most likely, scientific, and as precise as possible independent forecast for main agricultural crop yields for the Ministry of Agriculture and Rural Development of the Slovak Republic and for the public.

The National Crop Yield and Crop Production Forecasting System has been created on SSCRI and is based on three different principles which are applied to specify vegetation indexes as biomass development stage and biomass development:

- Remote Sensing method – method of interpretation of vegetation indicators (as NDVI or DMP – Dry matter development) from satellite images (mainly from low resolution satellite sensors such as NOAA AVHRR and SPOT Vegetation satellite system);
- Bio-physical modelling (WOFOST model) and simulation of vegetation indexes (mainly TWSO – Total Dry Weight of Storage Organs and TAGP – Total Above Ground Production). In WOFOST, weather and phenological data, soil hydro-physical data and crop physiological data are utilized as model key inputs;

- Integrated assessment method, which means the implementation of specific meteorological and vegetation indicators in the statistical analysis, assesses the impact of weather on the projected harvest. Integrated estimate summarizes a wider range of disparate indicators and indices that are currently used for the purposes of forecasting yields and consequently the production of crops.

The crop yield and crop production forecasting is carried out for main agricultural crops – winter wheat, spring barley, oil seed rape, grain maize, sugar beet, sunflower, and potatoes. The forecasts are reported six times per year – mid-May, June and July for “winter and spring crops” and in the end of July, August and September for “summer crops”. The forecast results are interpreted at national level as well as at NUTS3 and NUTS4 level. The example of crop yield forecasting in 2017 can be seen in the Fig. 5.12.

a b

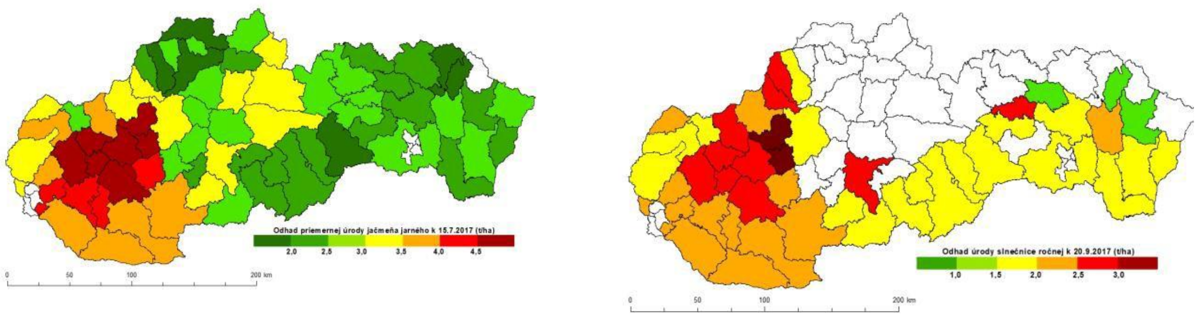


Figure 5.12. Example of crop yield forecasting by remote sensing in the second decade of July in 2017 for spring barley (a) and in the second decade of September for sunflower (b).

National Forest Centre Zvolen: Remote Sensing activities realised in 2016–2017 in Zvolen

Remote Sensing research activities of the National Forest Centre in Zvolen were aimed at four basic topics:

- Organization of SCERIN-4 and TAT2016
- Applications of airborne laser scanner technology in the forest management
- Satellite-based observation of forest decline.
- Biomass Mapping in Abandoned Agriculture Land using Novel Combination of Optical and Radar Remote Sensing Sensors

Organization of SCERIN-4 and TAT2016

SCERIN is an informal network of scientists and other professionals with scientific interests based in the region of South Eastern and Central Europe (Danube watershed and western Black Sea coast). This regional network is part of the GOFC-GOLD panel (Global Observation of Forest and Land Cover Dynamics) focused on observations, modelling, and analysis of terrestrial ecosystems to support sustainable development.

SCERIN-4 was held in Zvolen from 18 to 22 July 2016 with the following objectives:

- Forest change: disturbances, biomass production, forest LCLUC, driving forces
- Land cover change: climate change, agricultural land abandonment, urban expansion
- Validation/verification: for support of current and future satellite missions (e.g. NASA´s LDCM and HyspIRI, and ESA´s GMES program)

TAT (Trans-Atlantic Training) provides training activities for students and the early-career scientists in the area of Earth Observation, with an emphasis on remote sensing of land-cover changes and ecosystem dynamics. The purpose of TAT is to share and discuss advanced research methods and technologies from space during a series of meetings for scientists and students from both Europe and the USA.

TAT2016 was held in Zvolen from 23 to 27 July 2016 with focus on Multi-sensor Approaches in Monitoring Ecosystem Dynamics, such as Optical remote sensing, Synthetic Aperture Radar, and Airborne LiDAR.

Applications of airborne laser scanner technology in the forest management

Airborne laser scanning platform (ALS)

Remote sensing research activities related to the airborne laser scanning (ALS) over the years 2016-17 were solved based on projects "Innovative methods of close-to-nature forest management" (APVV-0439-12) and "Innovations in the forest inventories based on progressive technologies of remote sensing" (APVV-15-0393).

The goal of research projects was to develop and improve the algorithm usable in the frame of forest inventory and transportation survey based on ALS data. For all study areas situated in different ecosystems condition (from monoculture to natural forest) were taken aerial (multispectral images and point clouds) and ground data (field reference data contained the measured positions and dimensions of more than 18,000 trees).

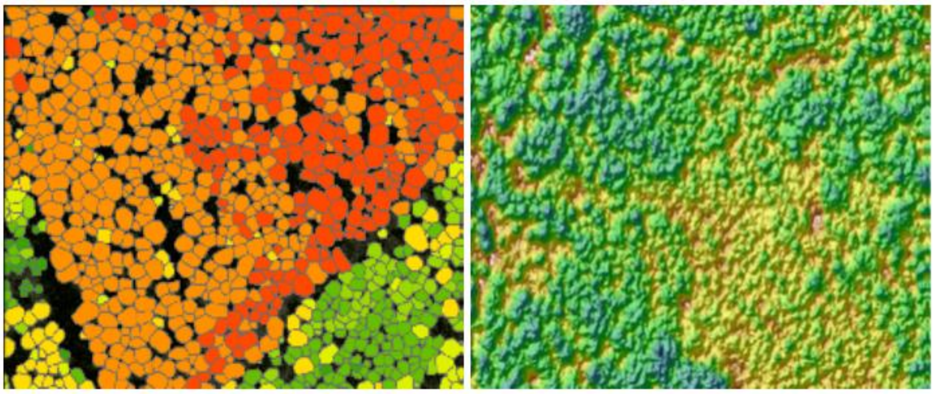


Figure 5.13. Results of reFLex algorithm for forest inventory based on ALS: tree detection approach (left); area-based approach (right).

Algorithm for forest inventory based on ALS

The proposal of algorithm is implemented in reFLex (remote Forest Land explorer, Fig. 5.13) software, which was developed by the National Forest Centre (Slovakia). The objective of such implementation is to develop an application, which is easy to use in the forestry practice (Sačkov et al., 2017a, 2017b).

The input file is a classified point cloud that contains ground and vegetation classes. The initial procedures are applied to transform the point cloud to a regular mesh and to reduce the number of points in the input file (Point cloud tiling; Height restriction). These operations produce a point cloud that is further used for an iterative search for treetops and tree crowns (Finding the local maxima; Geo-Dendrometric test; Delineation of tree crowns). Finally, the outputs of all procedures are exported to point and polygon vector files in the ESRI shp format.

Satellite-based observation of forest decline

The activities were focused on further development of the web service STALES *www.nlcsk.org/stales*. The English version is available since March 2015. The system is proposed to inform forest owners and forest state administration about the actual condition of forest stands and its changes. So far satellite images from all over Slovakia from 1990, 1996, 1998, 2000, 2003, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016 and 2017 were added.

The individual images were mosaicked into nationwide mosaic, from which we derived forest damage to each of those years. The services are based on Landsat satellite images in spatial resolution of 30 x 30 meters and Sentinel data in resolution 10 x 10 m in 2016. Mosaics are created from the composition of Landsat (Sentinel) bands in false colours, i.e. 4/5/3 - near-infrared, mid-infrared and red band.

Mapping applications are prepared so that the boundaries of forest districts are visible at the scale of 1:100 000 and the boundaries of forest compartments at the scale of 1:20 000 (Fig. 5.14). STALES has been gradually extended to reach into the current form when service consists of 4 map applications:

Map application 1 – visualisation of satellite scenes and forest health condition
Map application 2 – a comparison of satellite scenes from different time periods
Map application 3 – dynamic visualization of actual and historical satellite scenes
Map application 4 – dynamic visualization of forest health condition classifications

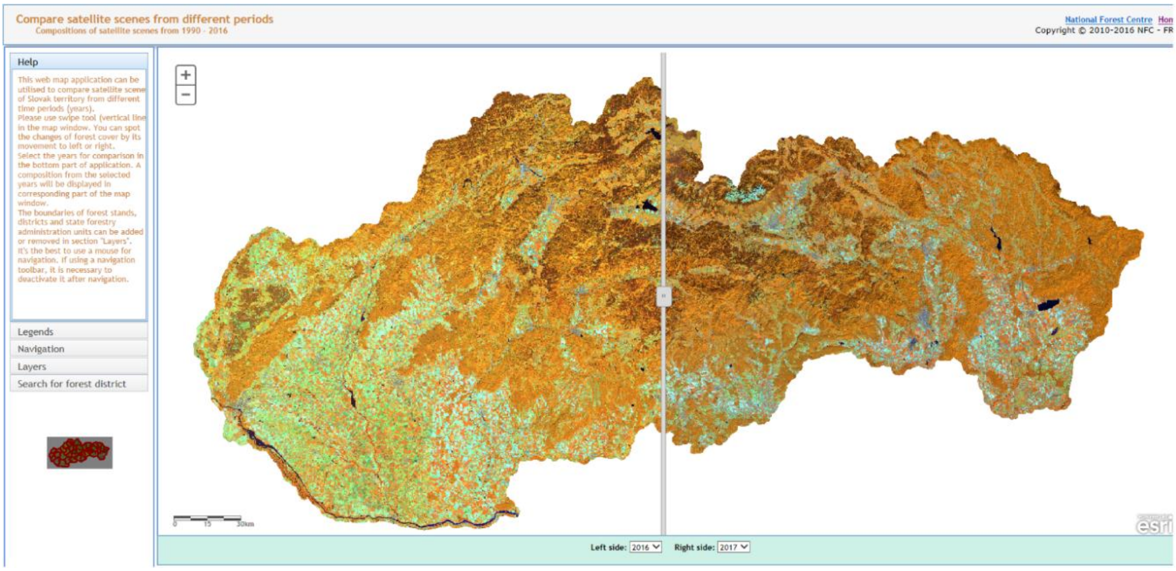


Figure 5.14. Web service http://www.nlcsk.org/stales/ – map application for comparison of satellite scenes from different time periods.

Biomass Mapping in Abandoned Agriculture Land using Novel Combination of Optical and Radar Remote Sensing Sensors (ATBIOMAP)

The common project proposal of the National Forest Centre and the Institute of Geography of the Slovak Academy of Science was submitted in the framework of the 2nd call under the Plan for European Cooperating States (PECS) in **Slovakia**. Abandonment of agricultural landscape is an all-European problem. The abandonment of cultural agricultural landscape has been obvious during recent almost 30 years in Slovakia as well. It is a phenomenon perceived in this country as a new social and landscape-ecological problem. It is also a large-scale issue as the unused area amounts to approximately 420-450 thousand ha representing 17.5%-18.6% of total 2,423,478 ha farmland in the country.

In spite of the mentioned large scale of this phenomenon, the theme of mapping the abandoned agricultural land (AAL), biomass quantification and its management has not been comprehensively addressed so far in Slovakia. The aim of the project is to develop and test the advanced Earth Observation methods by combining optical and radar data from Sentinel sensors for:

- Mapping of succession stages (herbaceous, scrub and tree formations) on abandoned agricultural land
- Quantification of wood stock and increments on abandoned agricultural land and proposal of a system of permanent inventorying of wood biomass within these areas.

Based on on-going negotiation process between ESA and NFC it is expected, that the project will start in April 2018.

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6. SPACE METEOROLOGY 2016-2017

Ján Kaňák, Ľuboslav Okon, Ladislav Méri, Marian Jurašek

6.1 Stereoscopic imagery based on Meteosat satellites

Studies on scientific and application potential of unique stereoscopic satellite imagery based on single High Resolution Visible (HRV) channel and/or HRV-based RGB color composites were done in last two year at Slovak Hydrometeorological Institute (SHMI). These studies demonstrate technical capabilities how to create and visualize 3D imagery for various applications. We provide examples of multiple cloud top layers, slopes of cloud top surface layers, interactions of different vertical cloud layers, and observations of various storm-top features. We proposed possible quantitative analyses of stereo-pair image data including calculations of mutual parallax shifts of cloud edges, overshooting tops with derivation of absolute cloud top height and its comparison to other relevant methods like NWCSAF cloud top height, and shadow-length based technique for cloud top estimation.

First stereoscopic experiments with Meteosat satellites appeared already in 2007, using first generation of Meteosat satellites at their Indian Ocean Data Coverage (IODC) positions at 63, 67.5 and 57.5 deg. E, during short periods of their parallel operations. After the second generation Meteosat 8 satellite movement to 9.5E longitude position in April 2008, new stereoscopic experiments were possible coupling rapid scan HRV images of this satellite with similar images from Meteosat 9 at 0 degree position. Due to small parallax angle and imperfect timing of scan processes by both satellites, stereoscopic effect was no significant and covered only region in between 0 and 9.5 degrees of longitudes.

In summer 2016 Meteosat 8 drifted to its new geostationary position at 41.5E for continuation of IODC services. From October 4, 2016 new unique satellite constellation of Meteosat 10 at 0 degree and Meteosat 8 is available for stereoscopic observations with extremely significant 3D effect over large areas defined by 0 and 41.5E longitudes and works within wide latitudes interval, from Northern Europe down to South Indian Ocean, including equatorial regions of Africa.

In case of first generation of Meteosat satellites the Earth surface spherical shape can be only observed. Atmosphere layer is too thin against pixel resolution for measurable parallax shifts of clouds. Example is showed in Fig. 6.1 (for proper view anaglyph glasses  are recommended).

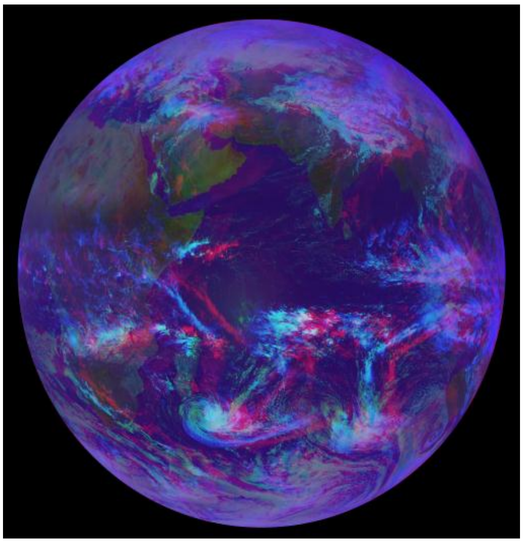

Figure 6.1. Meteosat 7, 57°E 1.3.2007 09:00 UTC (red image for left eye)+ Meteosat 5, 63°E 1.3.2007 09:00 UTC (cyan image for right eye).

In case of HRV images from second generation of Meteosat satellites the most important step is to re-project images from geo-sat view into some plane map projection common for image data from both satellites, as is it shown in Fig. 6.2.

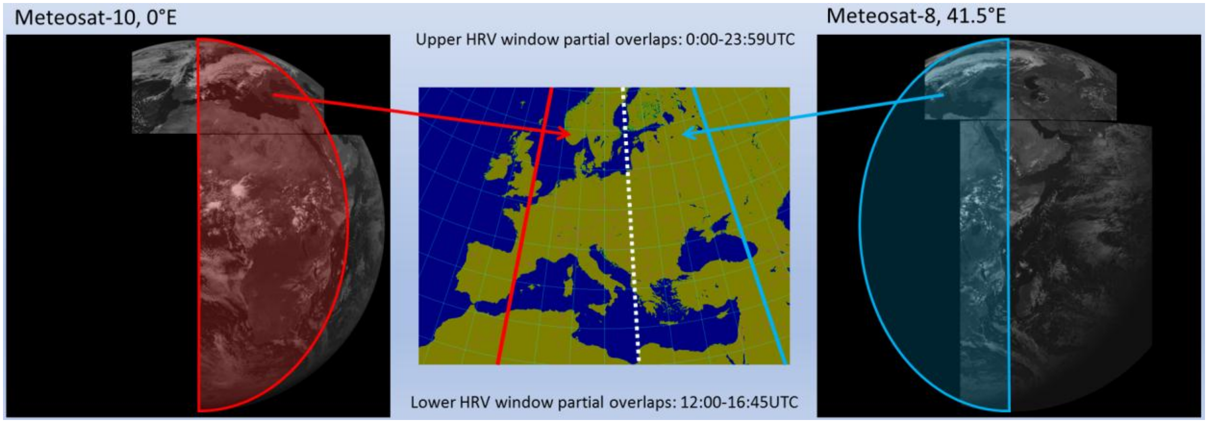

Figure 6.2. Projection of image data from left (red) and right (cyan) satellites into common map.

Stereoscopic data were used at SHMI for studies of cloud top height estimations. Methods to detect mutual parallax shifts of clouds were developed and used to calculate exact positions of clouds in 3-D coordinate system. Finally value of vertical coordinate as real cloud top over the Earth surface could be compared with other cloud top height methods, based on physical approach of radiative transfer in the atmosphere. Well known software package named NWCSAF was used to generate Cloud Type and Cloud Top Height products, examples of which are showed in Fig. 6.3.

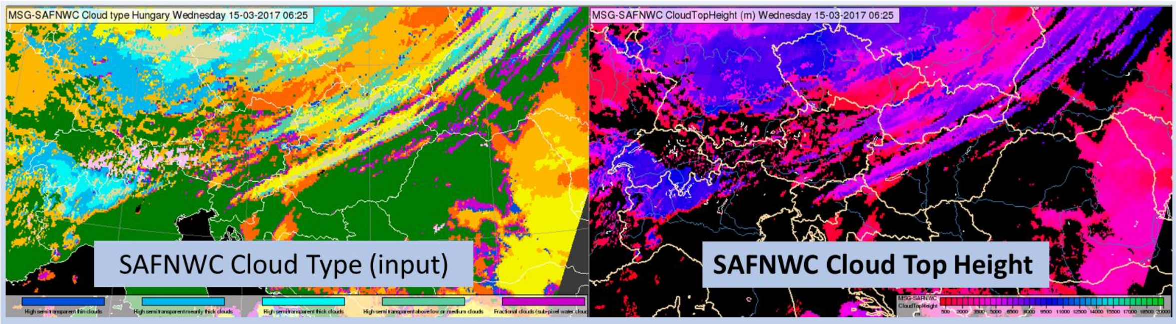

Figure 6.3. Example of NWCSAF Cloud Type and Cloud Top Height product.

On the base of these comparisons we created the database of CTH values for number of MSG timeslots from several selected days: 15 and 18 March 2017, 5 April, 24 May and 6 June 2017. Prepared database contains 3477 single points, distribution of which is shown in Fig. 6.4.

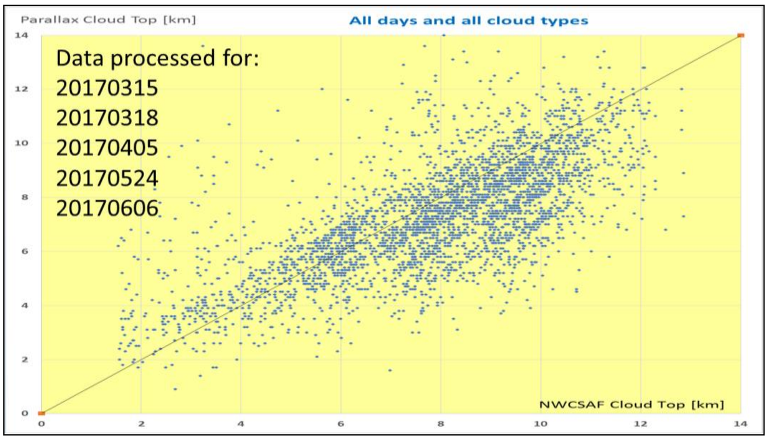

Figure 6.4. Database of coupled Cloud Top Height values (horizontal axes) estimated with NWCSAF CTH method and dual satellite observations of cloud parallax shifts (vertical axes).

Using the database we calculated several statistical parameters to estimate relative precision of 3D parallax method against NWC SAF CTH method. Results of correlation and bias together with number of cases for different cloud type categories are shown in Table 6.1.

Cloud type	Cloud index	Number of cases	Bias [km]	Correlation [%]
All clouds	ALL	3477	-0.60	0.70
Very low clouds	5	32	2.00	0.31
Low clouds	6	300	0.93	0.49
Mid level clouds	7	531	0.27	0.58
High opaque clouds	8	990	-0.62	0.56
Very high opaque clouds	9	154	-0.78	0.39
High semitransparent thin clouds	11	207	-1.16	0.47
High semitransparent meanly thick clouds	12	389	-1.34	0.53
High semitransparent thick clouds	13	565	-1.38	0.48
High semitransparent above low or medium clouds	14	309	-0.94	0.50

Table 6.1. NWCSAF and dual-parallax CTH statistical comparison

As prerequisites for the work described above we developed at SHMI in 2017 special software tool for manual measurements of cloud parallax shifts and this tool was integrated inside operational satellite visualisation system, see Fig. 6.5.

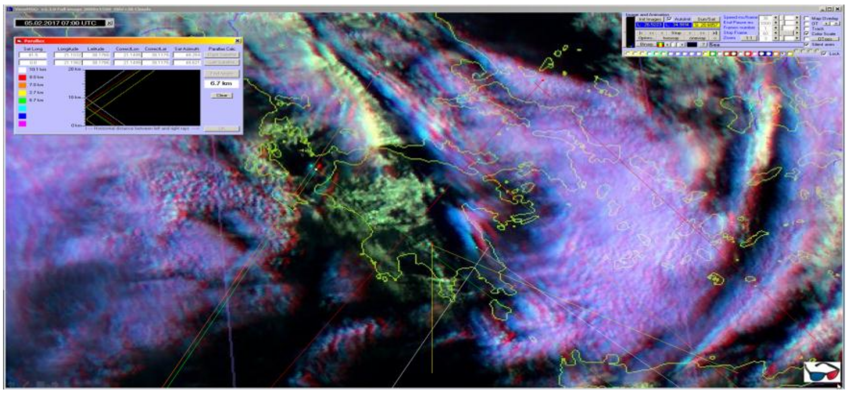

Figure 6.5. ViewMSG tool with implemented semi-automatic dual-parallax CTH method.

Another approach required by users is based on fully-automated methods of parallax detection. One of possibility bringing into account is to use pre-existing software packages. AMV (Atmospheric Motion Vectors) software package was tested at SHMI and selected as possible candidate for future operational method of 3D satellite data evaluation. Example of result is shown in Fig. 6.6.

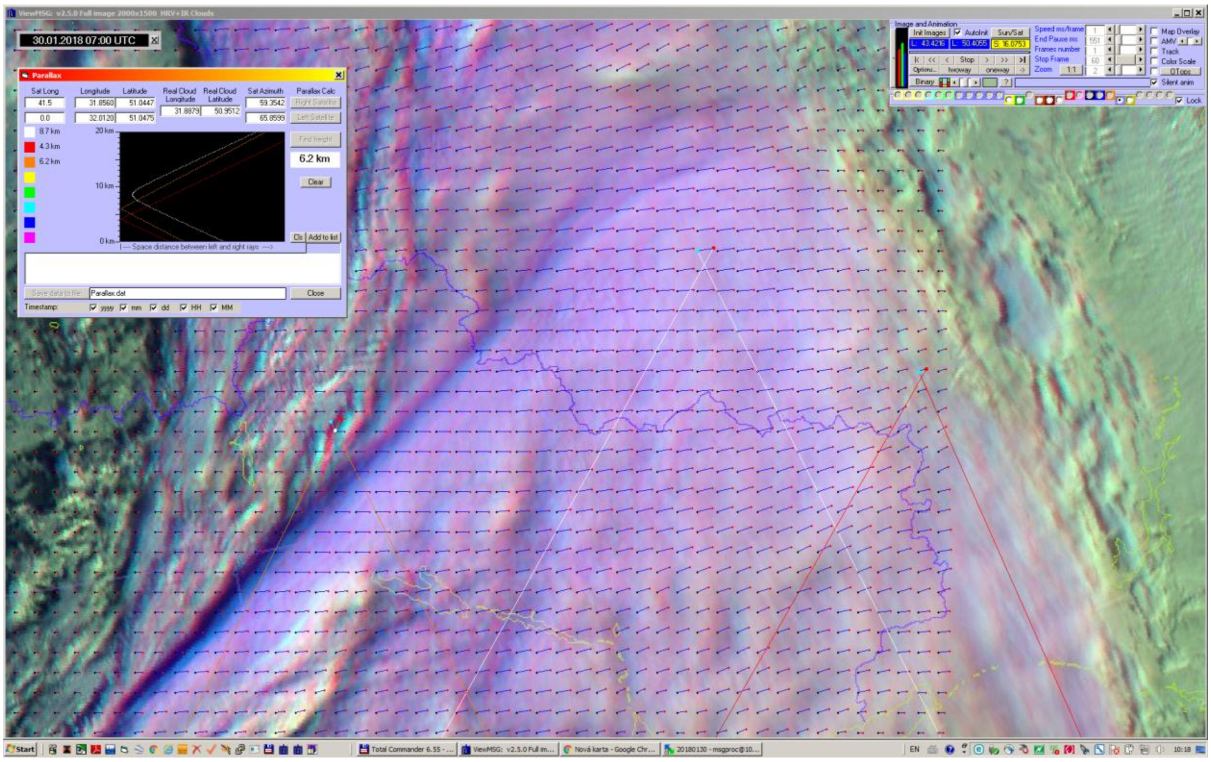

Figure 6.6. MSG-10 & 8 Anaglyph of frontal clouds over east Europe overlaid with dual satellite parallax shifts as blue lines calculated using AMV Algorithm. The line length is equivalent to cloud parallax.

6.2 Project H-SAF of EUMETSAT, Phase CDOP3 – SHMI validation activities

Within the H-SAF project precipitation products validation continued by means of ground based weather radars. This implicates the needs of radar data quality control before using these data for validation. We continued worked systematically on "Common Radar Rainfall Rate Estimation and Quality Control Procedure. SHMÚ continued also in standard validation of HSAF operational products and hydrological validation.

For more information about H-SAF project of EUMETAT and role of SHMI see official H-SAF web page: http://hsaf.meteoam.it/all-partners.php

6.3 Project MTGUP! - Users preparation for Meteosat Third Generation satellites

Slovakia is EUMETSAT member state from 2006. From this membership some advantages are coming, mainly access to EUMETSAT non-essential data and products for official duty activities, access to third party data, membership to EUMETSAT delegate bodies and EUMETSAT Council.

With the aim to help all member states and their users to be well prepared for change from current to new generation of Meteosat satellite, EUMETSAT established project Users preparation for Meteosat Third Generation. SHMI reflected to this offer and delegated participant to the first MTGUP! workshop, which help in Darmstadt in November 2017. Slovakia and SHMI specialists are aware of big opportunities which will bring MTG satellites: Enhanced imaging functionalities, new instruments for lightning monitoring from space and for vertical temperature and humidity soundings.

As first step in preparation for new satellite data at SHMI we upgraded our reception hardware, which is based on three Ayecka SR1 DVB-S2 digital satellite receivers and powerful computers. This hardware is now prepared to receive increased amount of data and is tested by third party data (data from geostationary satellite Himawari operated by Japan JAXA and GOES-16 operated by USA NASA agences).

SHMI experts already prepared test software package for processing of new data formats and EUMETSAT will provide in near future other test data from lightning instruments and synthetic data for atmospheric sounding from geostationary orbit.

Example from processing of high volume third party data is shown in Fig. 6.7.

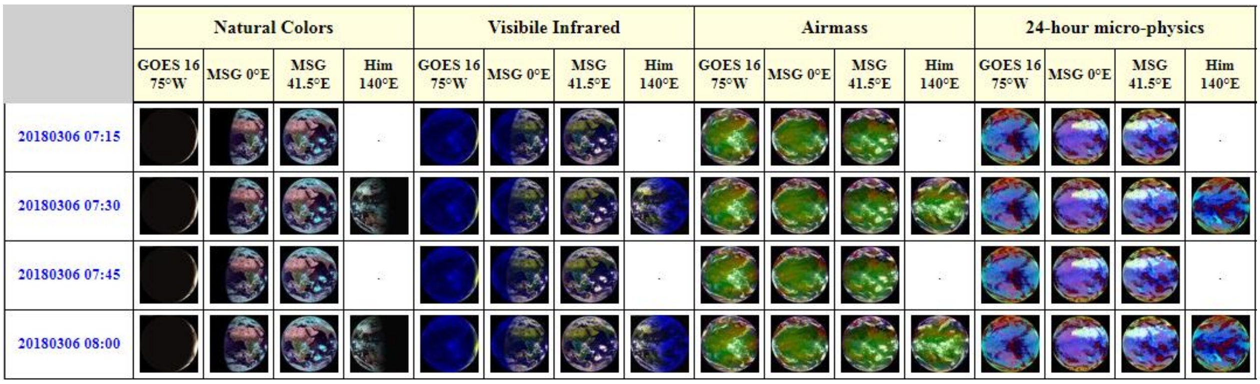

Figure 6.7. Full Earth disk RGB products from geostationary satellites GOES-16, Meteosat-11, Meteosat-8 and HIMAWARI generated operationally at SHMI. Time interval is 15 minutes (30 minutes for Himawari). Meteosat Third Generation satellite planned for launch in 2021 will provide 10-minutes, 5 or 2.5-minutes scan.

6.4 Participation to the project "SPACE FOR EDUCATION, EDUCATION FOR SPACE" in 2017

In April 2017 SHMI provided lecture "Basics of Earth atmosphere, land and sea surface observation techniques" for students of Slovak University of Technology in Bratislava. Lecture was done in cooperation of Faculty of Electrical Engineering and Information Technology (FEI STU) and ESA (European Space Agency).

Main topics of this lecture were:

Meteorological & environmental satellites:
– Geostationary and polar orbiting satellites
– EUMETSAT and ESA cooperation

Spectral bands for atmosphere, land and ocean surface observations:
– Physical characteristics
– Instruments and remote sensing methods

Satellite data and products:
– Acquisition, algorithms, processing, products generation

Image and video examples of
– Atmosphere, land, ocean surface, sea-ice observations

Complete lecture is available in pdf format:
http://www.ujfi.fei.stuba.sk/esa/slidy_prezentacie/basics_of_Earth_observation_techniques_mk_4.pdf

Students were informed about current and future meteorological satellite instruments, data and products which are used for weather analyses and forecasts, for estimation of cloud physical properties, atmospheric radiative transfer and its connection to numerical weather prediction models (NWP).

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Space Research in Slovakia 2016 – 2017
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Printed by CopyCenter Košice, April 2018
ISBN 978-80-89656-23-3