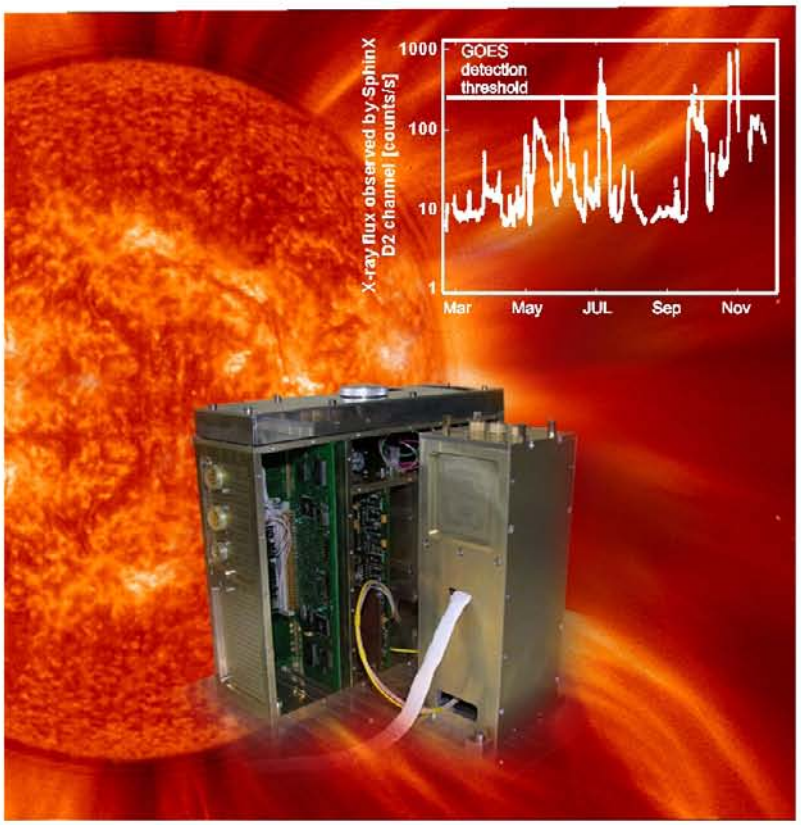
Space Research in Poland

Report to COSPAR 2010



Polish Academy of Sciences
Committee on Space Research

2010

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Report to COSPAR 2010

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Editor: Barbara Popielawska

Cover: SphinX instrument aboard the Coronas-Photon satellite and an example of a calibrated SphinX spectrum of solar X-ray radiation during deep minimum of solar activity (Sylwester *et al*., *EOS*, Vol. 91, No.8, 23 February 2010)

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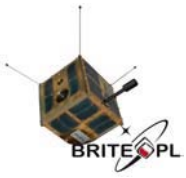
Foreword

This is the bi-annual report on Polish space activity to the international Committee on Space Research – COSPAR, prepared by the Committee on Space Research of the Polish Academy of Sciences. The responsible contributors to this Report are the chairpersons of the five Commissions of the Committee: Space Physics, Satellite Geodesy, Remote Sensing, Astronautics and Space Technology, Space Biology and Medicine. The report describes the progress during 2009-2010 in pure and applied space sciences in Poland.




HIFI LCU


SphinX

The historical milestone in Polish space activity was the decision of the Ministry of Science and Higher Education in December 2009 to grant the funds for the project "BRITE: First Polish Scientific Satellite". Poland became the third member of BRITE Consortium, joining the Canadian and Austrian scientific institutions in building the fleet of astronomical nanosatellites designed to observe the brightest stars of our galaxy. Other highlights are: the launch of the Herschel astronomical mission on May 14, 2009, with Polish involvement in HIFI instrument, and the launch of Russian Coronas-Photon satellite on January 30, 2009, with Polish SphinX instrument aboard. First results based on fascinating data from these space instruments have been already published. Another important step for Polish participation in space exploration it was signing the agreement with Space Research Institute of the Russian Academy of Sciences and the Lavochkin Association on Polish participation in the Phobos Sample Return mission. According to this agreement, the geological penetrator built in SRC, named Chomik (Eng. "hamster"), will measure the mechanical and thermal properties of Phobos surface and will scoop a little of Phobos ground to insert it into the capsule returning to the Earth.

During the two-year period, the fastest development in Polish space activity was due to participation in many R-D projects in space technologies, funded in the frame of ESA Plan for European Cooperating States (PECS) or supported by EU FP7 and EU Regional Development Funds. E.g., Space Research Center PAS has tripled its engineering staff, hiring many graduates with an aerospace degree from the Warsaw University of Technology.

During 2009-2010, the Ministry of Economy, consulted with potential space application users and experts from Polish space research community, elaborated the National Space Policy and the Plan of Actions in Space Activities. Cooperation with the European Space Agency, including full membership, is a priority for our government.

An important decision of 2009 was the final ratification of the EUMETSAT Convention. By the same, Poland became the new member state of this European organization in June 2009.

EUMETSAT

1. SPACE PHYSICS

Compiled by Jan Błęcki

Scientific research activity in the field of Space Physics was conducted in five thematic areas – Space Astronomy and Astrophysics, Solar Physics, Physics of the Heliosphere, Space Plasma Physics, and Planetary Science

SPACE ASTRONOMY AND ASTROPHYSICS

A. Zdziarski and R. Szczerba

Scientists and engineers from the Nicolaus Copernicus Astronomical Centre PAS and the Space Research Centre PAS were involved in building the INTEGRAL and Herschel space missions. Interpretation of data from INTEGRAL is still continued, and the Herschel Space Observatory is providing its first exciting results.

Scientific analysis of data from INTEGRAL in 2009-2010 covered studies of the following astronomical objects:

- Active galactic nuclei; in particular, elaboration of the second catalogue of active galactic nuclei observed by INTEGRAL. The catalogue shows that the grand unified theory of AGNs appears to hold, and that Seyfert galaxies of the type 1 and 2 are intrinsically the same but observed at different inclinations, resulting in different absorption.
- The bright Seyfert galaxy NGC 4151 has been studied in detail, using all the available observations by INTEGRAL and all simultaneous observations in lower-energy X-rays by other missions. We find the spectra are well fitted by thermal comptonization and Compton reflection. The electron temperature is a function of the flux level. We are able to distinguish between close and remote Compton reflector.
- The Cosmic X-ray Background and the Galactic Ridge X-ray emission have been studied using INTEGRAL observations. The spectra of both components have been measured, as well as the typical mass of white dwarfs contributing to the Ridge emission has been constrained to about 0.6 of the solar mass.
- Accreting pulsar in a binary system OAO 1657-415 - analysis of the eclipse light curve in the soft gamma-rays and the first "in situ" measurements of the density profile of the outer layers of the B supergiant companion; calculations of the new constraints on the orbit inclination of this binary system.

The Herschel observatory was launched on 14 May 2009. Space Research Centre PAS has been involved in the development of Heterodyne Instrument for Far-Infrared (HIFI) (*de Graauw et al*., 2010) and the software for the HIFI Instrument Control Centre. Owing to our involvement, we were granted observation time within the following four Guaranteed Time Key Projects (GTKP): atmospheres of planets and comets, molecular carriers in the interstellar medium (ISM), ISM in external

galaxies, and circumstellar envelopes of evolved stars. First results from Herschel were published in Astronomy and Astrophysics in July and October 2010 and covered all above listed GTKPs, including:

- Investigation of water vapor in different environments starting from our Solar system, protoplaneary disks, circumstellar envelopes, star forming regions and finishing on ISM in our and outer galaxies. The most intriguing result seems to be discovery of water vapor in carbon stars.
- Investigation of molecular inventory in ISM of Milky Way and other galaxies, in star forming regions and in circumstellar outflows.

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BRITE

A. Schwarzenberg-Czerny, T. Zawistowski

On December 16, 2009, the Minister of Science and Higher Education (MNiSW) signed the decision of grant funding (from the Fund for Polish Science and Technology) for the project: "BRITE: First Polish Scientific Satellite". The satellite, which is designed to observe the brightest stars in our Galaxy, will be the Polish contribution into the BRITE mission, developed by a consortium of Canadian, Austrian, and Polish institutes. According to the agreement with the Minister, two Polish satellites will be built, using the Canadian technology developed by UTIAS SFL (University of Toronto, Institute for Aerospace Studies, Space Flight Laboratory). The first one, named Lem (to commemorate Stanislaw Lem, popular Polish science fiction writer, philosopher, and satirist) is planned to be launched on the orbit of 800 km in 2012. The second one, named Heweliusz (to commemorate famous Polish astronomer Jan Heweliusz, 1611–1687), will be launched a year later. BRITE (BRIght-star Target Explorer) is a mission planned to make photometric observations of some of the brightest stars in the sky in order to examine these stars for variability. The observations will have a precision at least 10 times better than achievable using ground-based observations. Images of the sky will be taken by the wide field CCD cameras (24°) of a small aperture telescope to perform high-precision two-color photometry of the brightest stars in the sky ($\leq$ 4 m) continuously for up to several years. In the experiment, a few hundred stars of Milky Way will be observed. Polish scientists would like to investigate the mechanism of convection, the energy transport, which takes place in the hottest stars. This is an important process in the nature, known to physicists for over 100 years, but for stars it has not been mathematically described with enough precision until now. Observations

planned under the BRITE project can help to explain such phenomena. For technical description of BRITE satellites see page 70 of this Report.

PHYSICS OF THE SUN

J. Sylwester, B. Sylwester, S. Gburek, M. Siarkowski

CORONAS-F

The analysis of RESIK spectra was continued. RESIK was a unique Bragg soft X-ray spectrometer, in operation between 2001 and 2003 aboard the Russian *CORONAS-F* space observatory. It has measured hundreds of thousands of spectra in the range between 3.3 and 6.1 Å, emitted by active regions and flaring plasmas of temperature T > 3 MK. RESIK was the highest sensitivity solar Bragg crystal spectrometer ever flown. In the period 2008-2010, a final reduction of absolute spectra has been performed covering 20 flares and more than 3000 spectra of non-flaring active regions.

These Level_2 data, currently available for interested scientists online in the public domain (http://www.cbk.pan.wroc.pl/experiments/resik/resik_level2.php) constitute a basis for a number of dedicated studies concerning the properties of plasma responsible for the soft X-ray emission. First, it has been verified that the RESIK instrument is capable of measuring the true levels of X-ray continuum. By comparing the observed wavelength shape and its temperature dependences, it has been found that the contemporary theoretical approaches are sufficiently accurate (CHIANTI- http://www.chiantidatabase.org/) in representing the observed variability in the range 3.3 - 4.3 Å. It has also been found that by assuming the coronal composition the observed shape of the continuum is much better represented as in the case of the photospheric set of abundances. Realistic theory of the continuum formation processes (free-free and free-bound) allowed to study absolute (relative to hydrogen) abundances of elements contributing to the line spectrum in the range considered. This has been possible through the analysis of the line-to-continuum ratio temperature dependences. The analysis performed for the potassium, a low FIP element, revealed that its coronal flare abundance is above commonly assumed coronal value. As concerns the composition of non-flaring plasma, the study of 312 spectra taken when such conditions prevailed (more than 26 hours of spectral exposure) revealed that neither photospheric nor coronal abundances may account for the observed spectral shape and relative line intensities. A new set has been proposed, optimum for each class of the average low non-flaring activity. It has also been found that it is necessary to assume existence of very small (0.001) amount of hotter plasma (T ~10 MK) to be present in addition to overwhelming lower temperature component (T ~2-3 MK) in order to accommodate for the observed spectral shapes.

The intensities of silicon lines in the spectral range 5-6 Å, including the resonance and dielectronic satellite transitions were studied in order to better understand the plasma distribution functions. It has been found that neither

isothermal nor multithermal approaches are capable of providing appropriate description of the relative line intensities. On the contrary, the non-Maxwellian approach appeared as a viable scenario. The Si XIV, Si XIII, and Si XIId satellite lines observed with RESIK in the 5-6 Å range were used to determine the degree of deviation from Maxwellian, and the equivalent non-Maxwellian pseudo-temperature **τ**. The non-thermal analysis of RESIK spectra has shown that the largest deviations of the plasma electron distribution from Maxwellian appeared during the impulsive phase of the flare. The decay phase spectra had an almost isothermal character. Only about 20% of the observed spectra have been reduced to Level_2. RESIK data reduction and analysis is in progress.

CORONAS-Photon

On January 30, 2009, the launch of *CORONAS-Photon* Russian solar mission took place from Plesetsk Cosmodrome. Polish designed and built soft X-ray spectrophotometer SphinX (**S**olar **Ph**otometer **in X**-rays) has been included as a part of the TESIS instrument block, developed at the P.N. Lebedev Physical Institute (FIAN) Moscow (PI: Dr. Sergey Kuzin). SphinX, equipped with a set of PIN detectors has the unprecedented sensitivity (100 times better than *GOES* XEM sensors) and resolution in the energy range 1 – 15 keV. The instrument underwent detailed calibration at *XACT* facility in Palermo and *BESSY* synchrotron in Berlin. Thanks to this characteristics SphinX was able to take for the first time measurements of the solar X-ray fluence during the period of the lowest activity observed in 2009, when not a single active region was seen on the disc. These measurements revealed that a really quiet solar corona has a temperature 1.8 MK and emission measure 5 10^{47} cm^{-3}, contributing to the soft X-ray emission at the levels ~20 times below the detection threshold of *GOES* XEM detectors. Thanks to SphinX measurements, it has been possible to see for the first time the modulation of X-ray solar general flux due to presence of active regions and investigate in detail the microflaring activity of individual active regions. At present SphinX data are available as row telemetry files from the catalogue pages (http://156.17.94.1/sphinx_catalogue/SphinX_cat_main.html). Work is in progress (also funded from SOTERIA 7FP, http://soteria-space.eu/) on data reduction to Level_1 FITS format.

Hydrodynamic modeling

Thanks to installation of a new server at the SRC PAS Solar Physics Division at Wroclaw, it has been possible to re-activate the flare hydrodynamic code developed at PALERMO-Harvard. This adaptive mesh code (Betta, R., Peres, G., Reale, F., Serio, S.," An adaptive grid code for high resolution 1-D hydrodynamics of the solar and stellar transition region and corona", Astronomy and Astrophysics, Supplement series, Vol. 122, 585-592., 1997) will be used to simulate the response of plasma to various rate and time profiles of flare heating. In parallel, using a different hydrodynamic (NRL) code, simulations of plasma heating during the rise phases of the solar flares, have been continued

based on RHESSI observations of non-thermal electron energy spectra impeding on denser layers of the plasma.

Analysis of flaring kernels from TRACE observations

The *TRACE* EUV filters are supported on a dense nickel mesh which causes a characteristic diffraction pattern to be present in the telescope images. This diffraction pattern has been quantitatively modeled and included in *TRACE* point spread function (PSF) for EUV filters (see the software package: ***SolarSoft*** (http://www.lmsal.com/solarsoft/). Diffraction portion of the *TRACE* PSF has been subsequently used for determination of actual shape of the flare kernel and derivation of its physical parameters such as temperature and emission measure in the kernel from a single image and even in case the image is saturated. Results has been reported to COSPAR

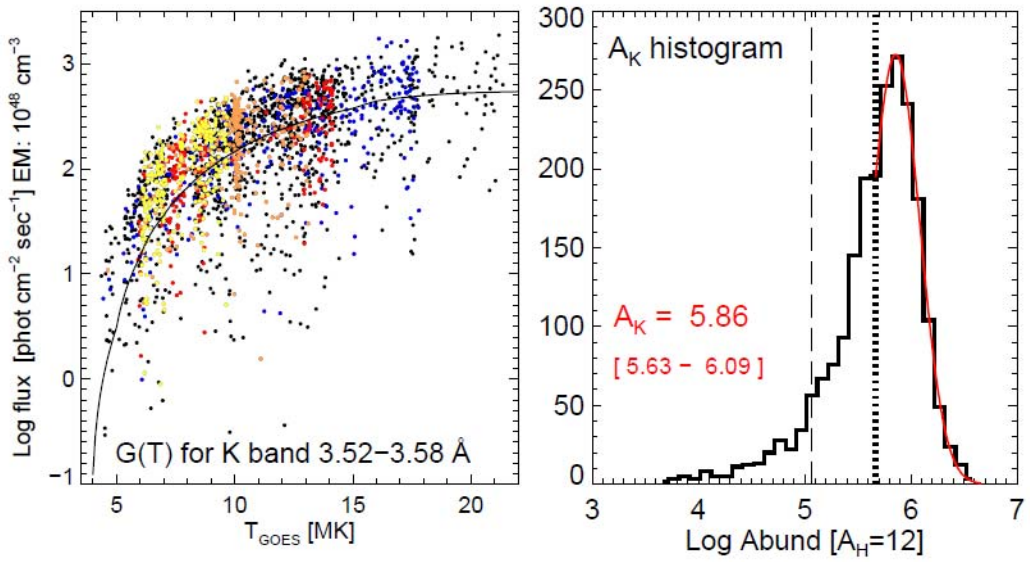

Figure 1. Left: flux of K XVIII *w* line (including unresolved dielectronic satellites) normalized to an emission measure 10^{48} cm^{-3} against T_{GOES}. Right: number distribution of estimates of the deduced K abundance (Log A_H=12). The peak of the distribution corresponds with half-width in the abundance range 5.63–6.09. The previous coronal (flare) abundance estimate of Doschek and the photospheric estimates of Lambert & Luck (1978) and Takeda *et al*. (1996) are denoted by the dotted and dashed vertical lines respectively.

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PHYSICS OF THE HELIOSPHERE

M. Bzowski, A.. Czechowski, R.. Ratkiewicz

The heliospheric research in Poland during the report period has been carried out in a broad international collaboration. Main topics included determination of the strength and direction of interstellar magnetic field in the Local Interstellar Cloud based on plasma observations from the Voyager spacecraft and MHD modeling, studies of hypothetical nano-dust particles in the solar wind based on observations from STEREO, and studies of the heliosheath thickness based on ENA observations from the HSTOF instrument on SOHO. Most effort, however, was put into the final preparations to the launch of the first dedicated heliospheric ENA space observatory IBEX, developed and operated in the United States under NASA contracts, and to the interpretation of first observations obtained from this mission.

The strength and orientation of magnetic field in the immediate Galactic neighborhood of the Sun escapes direct detection and thus has to be established indirectly based on proxies and appropriate modeling. The important discovery of the role of the local interstellar magnetic field (LIMF) in altering the shape and modifying the structure of the heliosphere was first demonstrated by R. Ratkiewicz at the COSPAR Symposium in 1996.

Crossing the termination shock by the Voyager spacecraft enabled an attempt to determine the parameters of LIMF from the MHD modeling that used as guidelines the following desiderate: 1. The heliospheric model should place the termination shock at the distances where the Voyager crossed it.

Based on this prerequisite, Ratkiewicz & Grygorczuk (2008, 2010), and Ratkiewicz *et al*. (2008) proposed a constraint on the strength and direction of LIMF which placed it close to the so-called Hydrogen Deflection Plane, postulated by Lallement *et al*. in 2005 based on the deviation of the flow vector of neutral interstellar H, perturbed in the heliospheric interface, from the flow of neutral interstellar He, which is presumably unperturbed. Further measurements of the plasma flow and magnetic field in the inner heliosheath by Voyager 2 allowed to formulate another desiderate: 2. The solar wind flow obtained from the MHD simulation should follow the plasma flow measured by Voyager 2 in the inner heliosheath.

After the discovery of heliospheric ribbon by the first dedicated Energetic Neutral Atom spaceborne observatory IBEX[1] (McComas *et al*., 2009b), an interpretation of the ribbon as coming up due to the enhanced production of ENA in locations in space ordered by LIMF was proposed by the IBEX team (Schwadron *et al*., 2009b). Then, another desiderate was put forward: 3. The geometric location of the modeled LIMF perpendicular to the line of sight in the immediate neighborhood of the heliosphere should reproduce the shape of the ribbon as seen from Earth.

Based on these three criteria and 3D-MHD numerical simulations a team of researchers from SRC PAS (R. Ratkiewicz, J. Grygorczuk, M. Strumik) determined that a reasonable agreement of model results with measurements is obtained when the LIMF strength is between 3.3 and 4.5 μG and the LIMF vector points from the ecliptic coordinates close the center of ribbon (λ, β) = (221°, 39°) (work reported at the 9th Annual International Astrophysics Conference, Maui, Hawaii, March 14-19, 2010 in two presentations by J. Grygorczuk and R. Ratkiewicz). A team of researchers including J. Grygorczuk, A. Czechowski, R. Ratkiewicz, and M. Strumik using 3D-MHD simulations showed also the time evolution of the forms and shapes of the canonical heliospheric surfaces (termination shock, heliopause, and bow shock) resulting from such a magnetic field and measured variations in the solar wind (Grygorczuk *et al*., 2010).

From its launch in 1996 the instrument HSTOF on board SOHO was the only source of data about the energetic neutral atom fluxes (55-88 keV for hydrogen, 28-58 keV/n for helium) from the inner heliosheath. After Voyager 1 entering into the heliosheath it was possible to compare these ENA fluxes with the parent ion fluxes measured in situ (the LECP instruments on Voyagers have the energy range overlapping with HSTOF). This permitted the first estimation of the thickness of the forward heliosheath (the distance between the termination shock and the heliopause) which was done by the group including A. Czechowski SRC PAS, M. Hilchenbach from Max-Planck-Institut in Lindau and K.C. Hsieh and J. Kóta from University of Arizona in Tucson. Czechowski *et al*. (2008a,b) extended this study to the first attempt to image the forward heliosheath, by measuring the thickness of the

[1] IBEX is the latest in NASA's series of low-cost, rapidly developed Small Explorers space missions. Southwest Research Institute in San Antonio, TX, leads and developed the mission with a team of US and international partners. NASA's Goddard Space Flight Center in Greenbelt, Md., manages the Explorers Program for NASA's Science Mission Directorate in Washington DC.

heliosheath in three different directions (the nose and two flanks). These first studies were based on the HSTOF data together with the first post-shock measurements by Voyager 1. This work is now being continued by taking into account the ion spectra measured subsequently by Voyager 1 and 2 deeper in the heliosheath. Also, the new HSTOF data are included in the flank directions. To interpret the results for the flank sectors, it is necessary to understand the spatial distribution of the energetic ions in the heliosheath. A study of this problem was performed by A. Czechowski using the numerical model of the heliosphere developed by K. Scherer. The results were presented at a recent (2010) AIA conference on Maui; they suggest that the assumption of uniform ion distribution is incorrect and that it is likely to lead to the underestimation of the thickness of the heliosheath. An illustration of the results can be seen in Figures 1 and 2.

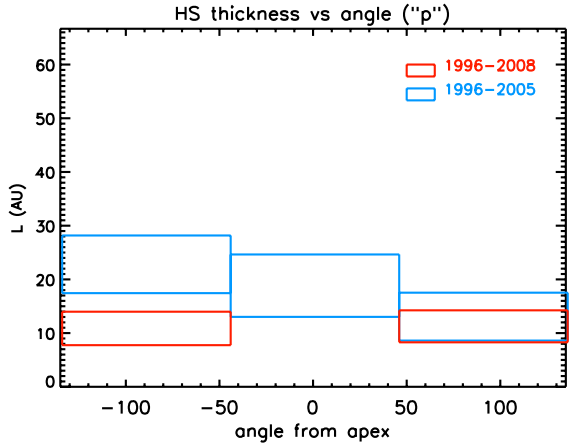

Figure 1: Estimated thickness of the heliosheath in three 90 deg wide ecliptic longitude sectors near the ecliptic: the "nose" sector ($\pm 45^{\circ}$ from the ISM inflow) and two flank sectors. The results including also the more recent HSTOF data for the flanks are shown in red. The heliosheath ion spectrum used for the estimation is the Voyager 1 $Z \geq 1$ spectrum up to year 2008 (see Krimigis *et al.*, *Science*, 2009). The results for the thickness L depend on the assumed neutral hydrogen density n_H in the heliosheath (here n_H=0.1 cm^{-1}) and the fraction of protons *fp* in the $Z \geq 1$ Voyager spectrum (here *fp*=1): the result for L scales as $L/[(n_H/0.1)*(fp/1.0)]$.

Polish participation in NASA IBEX mission, with M. Bzowski from SRC PAS is a Co-I, included both development of the mission itself and supporting it by modeling/theory research. The mission development & support included modeling and interpretation of the signal from the IBEX-Lo Star Sensor (M. Bzowski, M. Hlond) and development and interpretation of the theory of ENA propagation in the inner heliosphere and of their losses underway from their birth site to the detector (Bzowski 2008). It required development of a new model of the propagation and losses of neutral hydrogen in the heliospheric origin (published by Tarnopolski & Bzowski 2009), which apart from the IBEX mission was used by a Team fostered by the International Space Science Institute in Bern (ISSI), lead by E. Moebius,

including personnel from SRC PAS (M. Bzowski, supported by S. Tarnopolski), to determine the density of neutral interstellar hydrogen at the termination shock of the solar wind and in the Local Interstellar Cloud (Bzowski *et al*. 2008, 2009; Nakagawa *et al*. 2008, Pryor *et al*. 2008, and other papers by the Team, not co-authored by Polish researchers). After successful determination of parameters of the interstellar He in 2003 by an earlier ISSI Team, also lead by Moebius and including personnel from SRC PAS (M. Bzowski, D. Rucinski), the series of papers published in *Astronomy & Astrophysics* provided the missing link of parameters of the dominant species in the Local Interstellar Cloud. This result, together with the measurements of solar wind plasma at 1 AU and by Voyager spacecraft at the distant heliosphere, provided a reference for the interpretation of heliospheric ENA observations by IBEX.

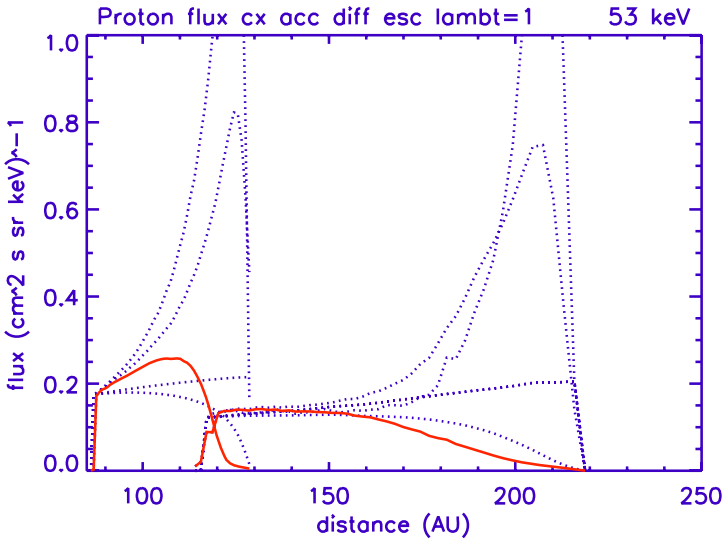

Figure 2: Calculated flux profiles of 53 keV protons in the heliosheath along two directions: the "nose" and the "crosswind" (the flank). The red curves show the final result including all transport processes considered in the model: the loss of ions to charge-exchange; the adiabatic acceleration; parallel diffusion; the escape across the heliopause by transverse diffusion. The dotted lines illustrate the results obtained neglecting some of these effects. The final result is clearly sensitive to the details of the model.

Other elements of IBEX preparation with participation of researchers from Poland included a study of detection possibilities of interstellar deuterium by IBEX (PhD awarded to S. Tarnopolski by SRC PAS, summarized in Tarnopolski & Bzowski (2008)). Another contribution it was the discovery of neutralization of the solar wind heavy ions by charge exchange with neutral interstellar gas in the inner heliosheath, the process that results in a flux of heavy-species ENA possible to detect at 1 AU (Grzedzielski *et al*. 2010a). Polish scientists were co-authors of publications in the "IBEX Book", a collection of papers reprinted from *Space Science Reviews* (McComas *et al*. 2009a, Frisch *et al*. 2009, Moebius *et al*., 2009a, Schwadron *et al*.,

2009a), where both scientific and technical aspects of the IBEX mission were detailed.

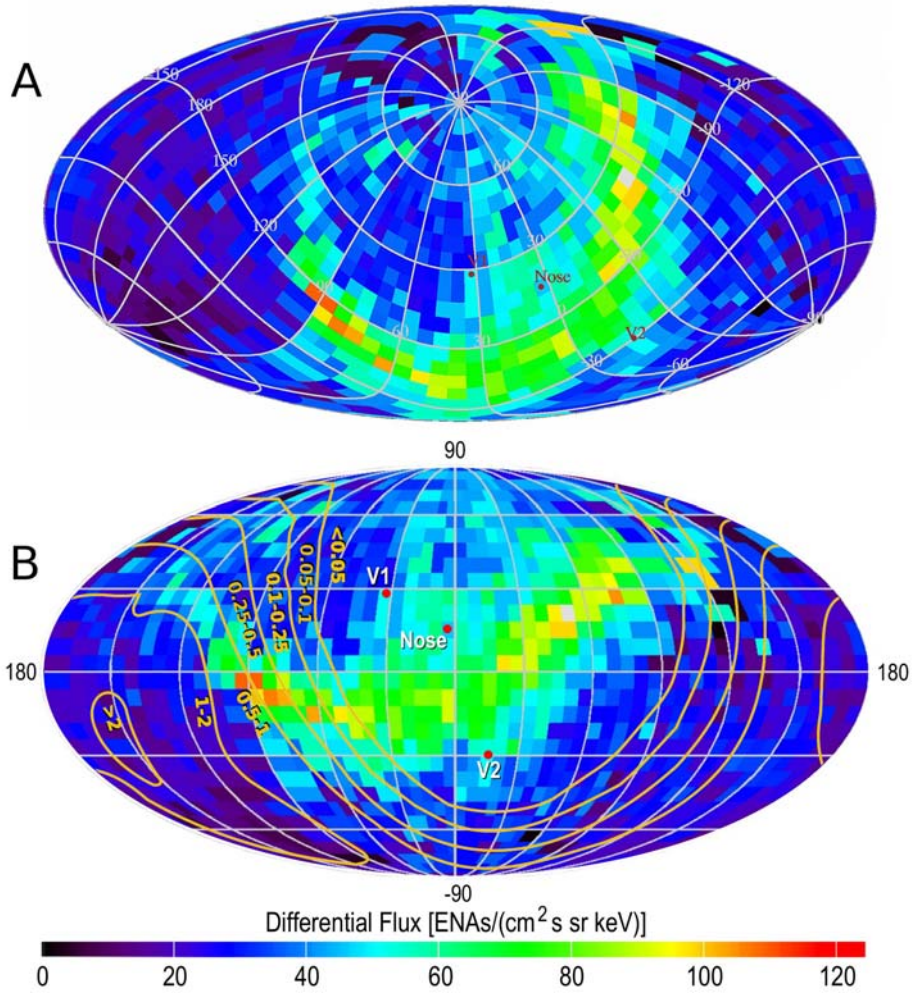

Figure 3. The almost-circular shape of the heliospheric ENA ribbon (upper panel) and its projection on equatorial coordinates (lower panel), with isocontours of the column densities of neutral gas in the solar neighborhood from Redfield & Linsky 2002, which suggests that the ribbon is located in the region of the sky pretty much devoid of neutral gas, as required by the hypothesis of extra-heliospheric origin of the ribbon proposed by Grzędzielski *et al*. (2010b).

IBEX was launched in October 2008. First results were published in a series of five papers in the *Science* journal, 3 of them coauthored by scientists from SRC PAS. The most notable discovery by IBEX was the heliospheric ribbon, an almost-circular area on sky of enhanced ENA emissions not predicted by earlier heliospheric models (Fig. 3). In the series of discovery papers, early attempts to explain the ribbon were reported by Schwadron *et al*. (2009b), who proposed 6 hypotheses involving mostly heliospheric processes and heliospheric and extraheliospheric magnetic field. As

mentioned above, based on some of them Grygorczuk *et al*. (2010) suggested the strength and direction of the local interstellar magnetic field. Since, however, none of the hypotheses was able to explain the details of the observations and not all aspects of the proposed models were sufficiently developed, *Grzedzielski et al*. [2010] proposed another, totally different hypothesis: ribbon comes up from a very nearby boundary between the local interstellar cloud in which the Sun is embedded and the hot tenuous Local Bubble cloud. Details of this hypothesis can be found in the caption to Fig. 4.

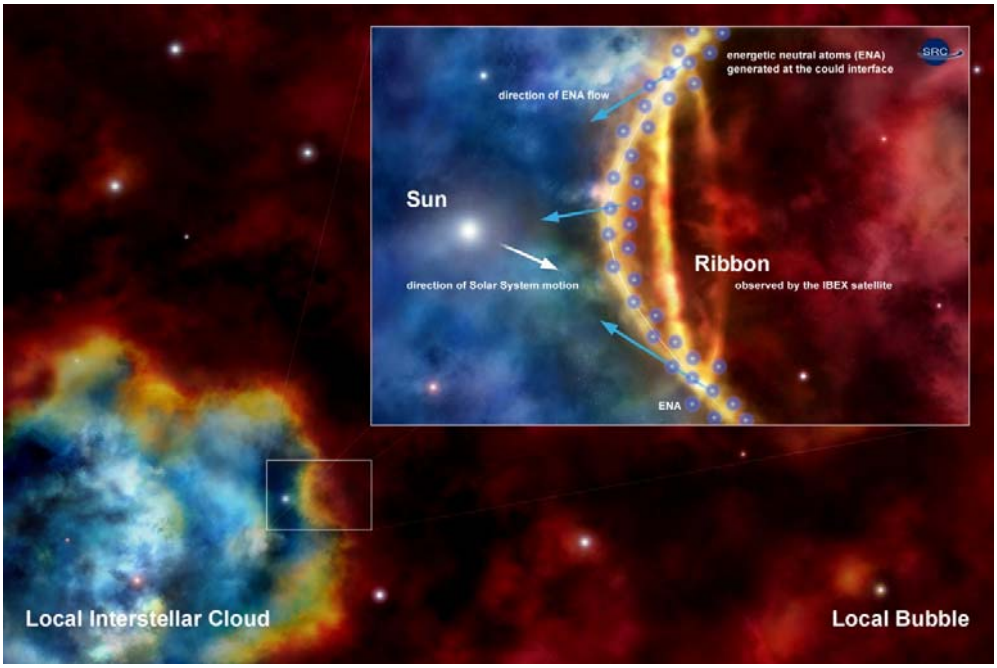

Figure 4. Schematic diagram illustrating the idea of heliospheric ribbon as a geometric effect coming up because the Sun happens to be located within ~1000 AU from the boundary between the Local Cloud of interstellar gas and the hot ($>10^6$ K), rarefied, fully ionized and turbulent Local Bubble cloud. The boundary should be planar or better slightly extruded towards the Sun. The cool (10^4 K) neutral gas penetrates the boundary between the LB and LIC plasma and starts to exchange charge with the energetic protons from the Local Bubble. Some of the hot protons from LB take away electrons from the cool atoms originating from the LIC without momentum change and, suddenly free from the confines of electromagnetic forces, run away at straight-line trajectories from their neutralization sites, some of them towards IBEX. Despite some ionization losses in the intervening slabs of interstellar gas, they are able to reach the detectors. The ribbon is a geometric effect: it is seen in the areas of sky where the lines of sight are longest in the LIC/LB boundary layer.

In still another IBEX effort, an international team lead by E. Moebius and including M. Bzowski, M.A. Kubiak, and M. Hlond from SRC PAS has been studying the neutral interstellar gas, measured in situ by IBEX Lo. In the discovery paper in Science (Moebius *et al*. 2009b) first direct detection of neutral interstellar

oxygen, neon, and hydrogen was reported, along with a strong signal from interstellar helium. A meticulous, detailed analysis of these observations is still going on.

The model proposed by Grzędzielski *et al*. (2010b) suggests that the ENA arriving directly from the LIC/LB boundary layer should be seen as the ribbon and the area inside the ribbon should be relatively empty, while some of the ENA that had originally run away from the LIC/LB boundary not directed towards the Sun might eventually be detected after a series of scattering and ionization/neutralization processes in the Local Cloud gas, forming an omnidirectional diffuse ENA background to the ENA signal of the genuine heliospheric origin.

Apart from the mainstream heliospheric research focused on establishing the heliospheric basics, a few other heliospheric topics of interest have been addressed:

The dust grains with size in the nanometer range are expected to be present in the circumsolar dust cloud. In distinction to the larger grains, the nano-grains dynamics is dominated by the electromagnetic forces. Detailed understanding of the nano-dust production and behavior in the inner solar system became important recently because of new observations. In particular, the voltage bursts detected on the STEREO spacecraft were attributed to the impacts of fast nano-dust grains.

In SRC PAS the dynamics of nano-dust is the topic of theoretical investigation by A. Czechowski, who works in cooperation with I. Mann, and also with N. Meyer-Vernet, who heads the WAVE experiment on board STEREO. The experimental results with a theoretical interpretation were published by Meyer-Vernet *et al*. (2009, 2010). It was found that the nano-dust grains produced in collisions between the larger grains in the circumsolar dust cloud can be accelerated to the velocity approaching that of the solar wind plasma by the interaction with the solar magnetic field and subsequently escape from the solar system (Czechowski & Mann 2010). These escaping grains may be responsible for the impacts observed by the STEREO spacecraft. However, the grains formed very close to the Sun (within about 0.15 AU) move in trapped non-Keplerian orbits characterized by low perihelium distance, leading to fast destruction of these grains by sublimation.

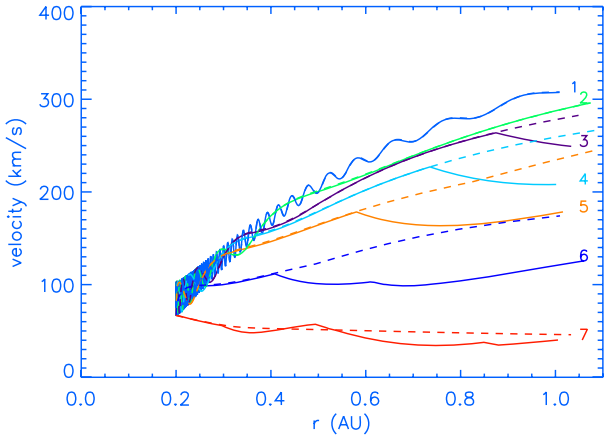

Figure.5: Grain velocity as a function of distance from the Sun for the nano-dust grains of different charge to mass ratios Q/m (equivalently, different sizes) produced at 0.2 AU from the Sun. The Q/m values are the following: Q/m = 10^{-4} e/mp (1); 10^{-5} e/mp (2); 7 10^{-6} e/mp (3); 5 10^{-6} e/mp (4); 3 10^{-6} e/mp (5); 10^{-6} e/mp (6); 10^{-7} e/mp (7). The solid lines show the results for the "focusing" magnetic field orientation, the dashed lines for "antifocusing" orientation. The "kinks" in the velocity curves occur at crossings of the current sheet.

The heliospheric current sheet (HCS) is a separating surface between the solar wind regions of opposite polarity of magnetic field. Despite numerous observations by spacecraft the global structure and the underlying physics of the heliospheric current sheet is badly understood. HCS is also very difficult to include in the numerical models of the heliosphere because of its thinness: it can be less than 10000 km across, much below the characteristic size of the heliosphere. However, HCS is likely to have an important role in the particle transport and in the physics of the outer heliosphere, where the magnetic field structure must somehow be rearranged to avoid unphysical singularities. SRC commenced a pioneering study of the structure HCS. A. Czechowski, M. Strumik and S. Grzedzielski, using the input from the time-dependent 3-D MHD model of the heliosphere by R. Ratkiewicz and J. Grygorczuk (and also from another model by K. Scherer) calculated the global structure of HCS and found new features resulting from the time-dependent structure of the flow, in particular the secondary folding. They also discussed the issues concerning the fate of HCS on approaching the heliopause, where the regions of opposite field orientation are pressed together by the slowing plasma flow.

Another pioneering investigation was based on the idea by S. Grzedzielski (in cooperation with A. Czechowski and M. Strumik), who proposed that the reconnection exhausts from the reconnection sites on the heliospheric current sheet can accelerate electrons. This process is efficient provided that the particle can interact with many reconnection exhausts. Such a situation is possible near the heliopause. This points to a possible connection with the 2-3 kHz heliospheric radio emissions, supposed to come from this region.

The Polish heliospheric research has been funded in Poland by five grants from the Ministry of Science and Higher Education and by the Space Research Centre PAS from the statutory research funding allocation, as well as by a number of national and international programs sponsoring international scientific cooperation.

During the report period, Polish researchers have been at the forefront of heliospheric research. They focused on the fundamental problems in heliospheric physics and provided answers or at least hypotheses to the pivotal questions on the physical state of the interstellar gas in front of the heliosphere, strength and direction of the interstellar magnetic field, and the thickness of the inner heliosheath. They proposed an explanation for the unexpected heliospheric ribbon, which they had helped to discover, participated in the discovery of the nano-dust particles picked up by the solar wind, and proposed a novel hypothesis on the structure of the heliospheric current sheet.

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PHYSICS OF THE MAGNETOSPHERE and IONOSPHERE

J. Błęcki, J. Hanasz and R.. Schreiber

Studies of the auroral kilometric radiation (AKR) are being continued. AKR is emitted from the extremely turbulent auroral magnetosphere of the Earth. Its study helps to understand dynamic processes taking place in this region. Pulsations of auroral kilometric radiation at Pc1 frequencies have been discovered from four Cluster spacecraft. Cases of AKR pulsations at frequencies 1 to 4 Hz, typical for Pc1 geomagnetic pulsations, were observed. 15 events were found in years 2001–2005, with 14 occurring in a recovery phase of a strong magnetic storm. In a studied event of 22 June 2003, the AKR pulses show positive frequency drifts, corresponding to the earthward motion of AKR sources along auroral magnetic field lines. The observed source velocities match calculated propagation of shear Alfvén waves within the auroral cavity. In our scenario a primary cause of the AKR Pc1 pulsations can be inertial Alfvén waves converted either from electromagnetic ion cyclotron waves generated in the equatorial magnetosphere, or from electromagnetic ion cyclotron waves generated in the auroral cavity. We suggest that the parallel electric field of the earthward propagating wave can periodically produce the 'shell' electron distribution, which could be the free energy source of the AKR pulse emission through the electron cyclotron maser instability.

Daily variations of AKR have been detected in STEREO/WAVES data. It has been found that the intensities of the AKR emitted from Northern and Southern sources are modulated with a period of 24 hours.

The occurrence frequency of AKR has been shown to be strongly dependent on the orientation of the rotating magnetic dipole of the Earth relative to the Sun. AKR is found to occur more often and emit in a broader frequency range when the axis of the terrestrial magnetic dipole in the given hemisphere is oriented toward the nightside. We suggest that the observed 24 h variations of AKR are connected with diurnal changes of the ambient plasma density in the auroral region.

The analysis of ELF emissions registered by CLUSTER and DEMETER satellites in the polar cusp and their role in particle acceleration has been studied. The strong emissions observed in the outer polar cusp associated with fluxes of energetic electrons (see Figure 1) can be generated by the so called fan instability, which plays significant role in the energy redistribution between different plasma particles populations. Similar effects were registered by DEMETER satellite at the ionospheric altitudes (Figure 2).

The French satellite DEMETER is devoted to study ionospheric response to Earthquakes. Many studies were performed to find these effects registered by these satellites. Some new results confirming the idea of correlation between Earthquakes and low frequency disturbances in the electromagnetic field and plasma parameters (density and temperature) have been found. Detailed analysis of data gathered over seismic areas prior to strong earthquakes indicates the presence of low-frequency turbulence in the ionospheric plasma even 5-6 days before the main shock.

Another subject of studies are electromagnetic phenomena accompanying Transient Luminous Events in the upper atmosphere. The new French satellite TARANIS to

study electromagnetic interactions between the upper atmosphere and near Earth space has been already accepted for realization. Planned launch is in 2015. SRC engineers will develop a DC/DC converter for the entire scientific payload of the mission.

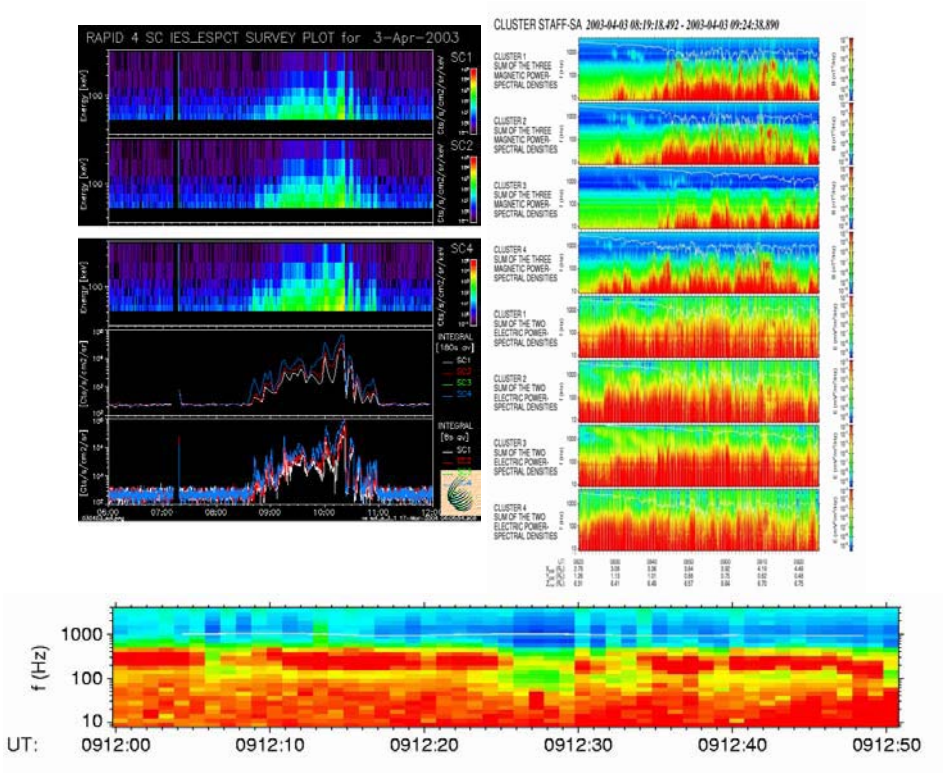

Figure 1. Registrations by CLUSTER satellites of energetic electrons (upper left panel) together with strong emissions (upper right panel) in the polar cusp. Lower panel shows the emissions at 1/3 f_{ce} which is likely associated with the fan instability (shown are 50 seconds of data only).

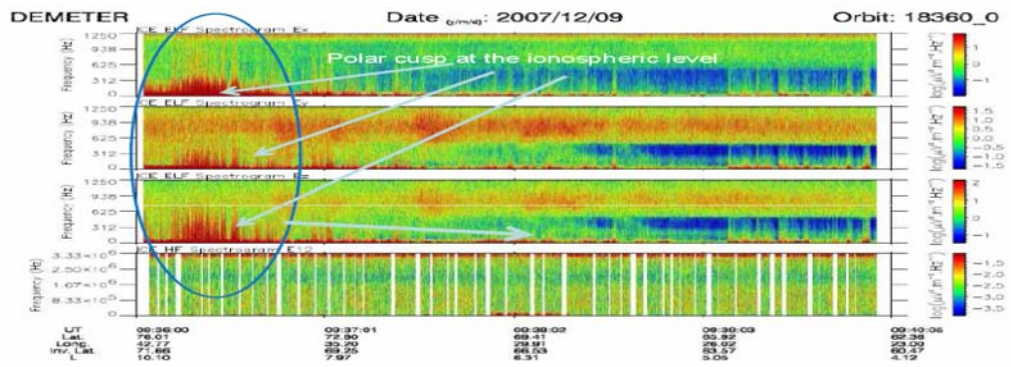

Figure 2. ELF emissions registered by DEMETER in the polar cusp at the altitude 650km.

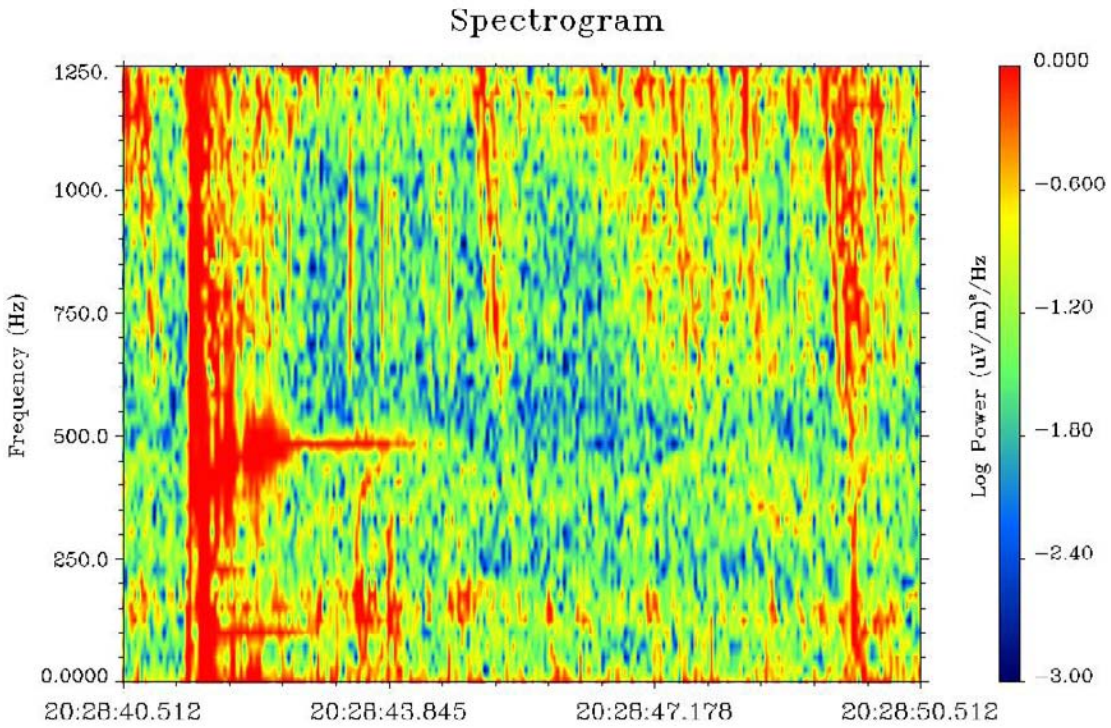

Figure 3. The spectrogram of the electric field variations in ELF frequency range registered by DEMETER satellite 2 days before the earthquake in L'Aquila (6 April 2009) over the area of epicenter.

Scientists from SRC participated in the development of the software for data processing and in the interpretation of DEMETER data registered during observation of sprites. The first satellite observations of the ELF/VLF emissions registered during the sprite event over the Polish territory has been analyzed using DEMETER data (see Figure 4).

Presently, SRC is developing several instruments for future ionospheric and magnetospheric missions. New hardware is being developed for the following projects: French microsatellite Taranis, Russian satellites RELEC, Resonance, RadioAstron, the International Space Station (ESA's ASIM experiment and Obstanovka on the Russian module), the ESA Cosmic Vision projects Cross-Scale (presently down-selected M-class mission) and Laplace (L-class mission to Europa and Jupiter system). Polish participation in FP7 projects SOTERIA (SOLar-TERrestrial Investigations and Archives) and ULISSE (USOCs knowLedge Integration and dissemination for Space Science and Exploration) will allow to make spaceborne data owned by SRC PAS (e.g., from SphinX) available online for all interested scientists.

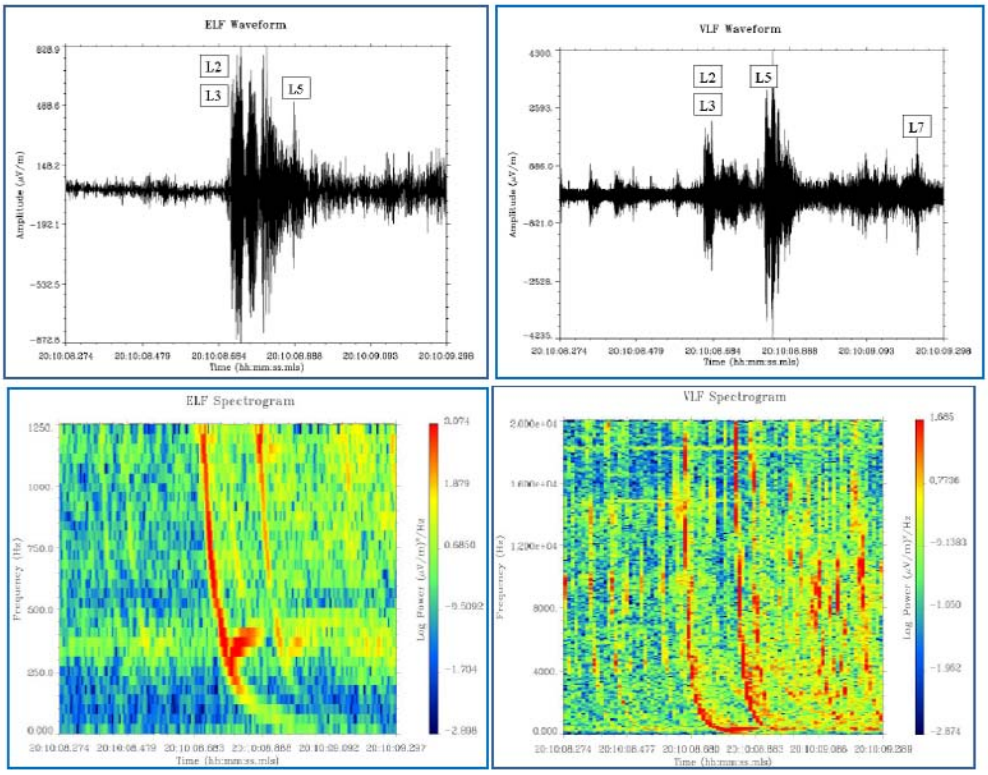

Figure 4. ELF/VLF data from the electric field experiment onboard the DEMETER satellite gathered during the time of sprite registration: (a) wave form of the VLF signal, horizontal axis —- time(UT), vertical axis —- value of the electric field in μV/m; (b) spectrogram of the signal shown in (a), horizontal axis —- time, vertical axis —- frequency; the intensity is color-coded according to the scale on the right; (c) wave form of the ELF signal; (d) spectrogram of the ELF signal shown in (c).

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PLANETARY SCIENCE

M. Banaszkiewicz, M. Błęcka, K. Seweryn

Planetary instruments build with Polish participation are installed on board of ESA Mars Express and Venus Express spacecraft. The goal of these instruments is to gain spectra of the infrared radiation originated from the atmosphere and surface of these planets. Polish scientists are involved also in numerical modeling of infrared spectra for different composition and physical conditions of the atmosphere and surface of Mars and Venus. Comparison with the experimental data showed good agreement with models and allowed to judge about physical conditions in the studied regions.

Another space mission carrying aboard the Polish experiment is Rosetta. Rosetta is in the cruise to the comet 67P/Churyumov-Gerasimenko. On the lander there is installed the penetrator MUPUS, built in SRC PAS to study the internal structure of comet's nucleus. Modeling of the infrared spectra of the comet's coma is also conducted in SRC and will be used for the interpretation of the data from French/Italian instrument VIRTIS when Rosetta approaches the comet.

Studies of planetary and cometary atmospheres using the data gathered by HIFI instrument on Herschel and the numerical modeling efforts are currently the main activity of Herschel Co-Investigators in SRC PAS (S. Szutowicz, M. Błęcka and M. Banaszkiewicz). For first publications see page 6 of this Report.

Figure 1. Assistant Monika Ciesielska of SRC PAS with the MUPUS penetrator model used in the Rosetta mission to comet 67P/Churyumov-Gerasimenko. In her left hand is a prototype container for the soil sample from Phobos, a moon of Mars.

A new development for the Polish planetology is the invitation by Russian partners to SRC PAS to participate in the Russian mission to Phobos. A unique geological penetrator CHOMIK (*Eng*. hamster) dedicated for the Russian Phobos Sample Return mission has been designed and manufactured at the Space Mechatronics and Robotics Laboratory of SRC PAS in Warsaw. One of the most important goals of the mission is to collect a soil sample from Mars' moon Phobos, and deliver it to Earth. The sample will be collected from the surface of the moon by the Polish penetrator and deposited in a container that is planned to land in 2014 in Kazakhstan, encased in the Russian re-entry capsule. Assuming everything goes according to the plan, in a few years we will be in possession of the first object acquired from a different planet's moon.

Works conducted at SRC PAS are aimed at participating in the space exploration program recently being elaborated by the European Union and the European Space Agency. Another such activity takes place in the frame of the International Lunar Network. SRC PAS has developed a device called KRET (*Eng*. mole), intended for geological study of the Moon.

2. SATELLITE GEODESY

Compiled by Stanisław Schillak (with contribution of Mariusz Figurski, Jan Kryński, and Jerzy B. Rogowski)

Introduction

This part of the Polish National Report on Satellite Geodesy is the report of works on advanced space techniques performed in Poland in a period of a time from 2008 to 2010. The activity of the Polish institutions in the field of satellite geodesy and navigation are concentrated on the several main tasks:

- global and regional GPS and SLR measurements in the frame of International GNSS Service (IGS), International Laser Ranging Service (ILRS), International Earth Rotation and Reference Systems Service (IERS), European Reference Frame Permanent Network (EPN),
- Polish geodetic permanent network – ASG-EUPOS,
- modeling of ionosphere and troposphere,
- practical utilization of satellite methods in local geodesy,
- application of the Global Navigation Satellite System (GNSS) in overland, maritime and air navigation,
- time service for Galileo,
- GLONASS application in geodesy studies.

These activities were conducted mainly at the following research centers listed below:

- Institute of Geodesy and Geoinformatics, Wrocław University of Environmental and Life Sciences;
- Faculty of Mining, Geodesy and Environmental Engineering, University of Science and Technology – AGH in Cracow;
- Department of Planetary Geodesy, Space Research Centre, Polish Academy of Sciences (SRC PAS) in Warsaw;
- Institute of Geodesy, University of Warmia and Mazury in Olsztyn;
- Chair of Satellite Geodesy and Navigation, University of Warmia and Mazury in Olsztyn;
- Institute of Geodesy and Cartography in Warsaw;
- Institute of Geodesy and Geodetic Astronomy, Warsaw University of Technology (WUT);
- Naval Academy in Gdynia;
- Maritime University in Gdynia;
- Maritime University in Szczecin;
- Aircraft Academy in Dęblin;
- Centre of Applied Geomatics (CAG), Military University of Technology (MUT).

This Report was compiled from information reported in a period from 2008 to 2010 by the correspondents from Polish institutions dealing with different use of satellite navigation systems. The bibliography of the related works is given in the references.

Active GNSS Station Network in Poland

Permanent IGS and EUREF Permanent Network (EPN) GNSS stations operate in Poland since 1993. Recently 18 permanent GNSS stations, i.e. Biała Podlaska (BPDL), Borowa Góra (BOGO, BOGI), Borowiec (BOR1), Bydgoszcz (BYDG), Gorzów Wielkopolski (GWWL), Józefosław (JOZE, JOZ2), Kraków (KRAW, KRA1), Lamkówko (LAMA), Łódź (LODZ), Katowice (KATO), Redzikowo (REDZ), Suwałki (SWKI), Ustrzyki Dolne (USDL), Wrocław (WROC) and Żywiec (ZYWI) operate in Poland within the EUREF program (Fig. 1). The system for automatic determination of the deflection of the vertical using GPS and zenithal stars observations has been developed at AGH-University of Science and Technology in Kraków (Kudrys, 2009).

The stations BOGI, BOR1, JOZE, JOZ2, LAMA and WROC operate also within the IGS network (Table 1).

Figure 1. EPN/IGS permanent GNSS stations in Poland (2010)

Data processing at Local Analysis Centre at WUT

Warsaw University of Technology has been operating the WUT EPN Local Analysis Centre since 1996. The EPN subnetwork being analyzed by the WUT LAC which consists of 74 stations (December 2009) located mainly in Central Europe (Fig. 2). Four new stations were added to the network in 2009.

The WUT LAC contributes to EUREF with weekly and daily results based on IGS final products, and with rapid daily coordinate solution based on IGS rapid products. The development of software providing rapid daily solutions was

completed at WUT in December 2009, but official submission of the solutions to EPN started in January 2010.

The WUT LAC uses the Bernese v.5.0 GPS Software to analyze GPS observations. Data are processed according to EPN AC guidelines. All WUT products are available at the EPN Regional Data Centre at BKG (ftp://igs.bkg.bund.de/EUREF/products).

In 2010 WUT LAC has joined the EPN Re-processing project. In the Pilot Re-processing project the data of 55 stations from 2066 were re-processed and submitted to the BKG EPN Data Centre.

Figure 2. EPN stations providing data processed at WUT EUREF LAC (December 2009)

Data processing at Local Analysis Centre at MUT

The 17th Analysis Centre MUT LAC operates since December 2009 in the Centre of Applied Geomatics at the Faculty of Civil Engineering and Geodesy of the Military University of Technology. The first official solutions were performed for GPS week 1560. GNSS data from sub-network of 114 EPN permanent stations, distributed evenly in Europe (Fig. 3) are processed in the Centre (Figurski *et al*., 2009). Every week the solutions are delivered to the Regional Data Centre BKG, where together with the respective ones from other LACs they are used to produce final official weekly EPN solutions.

MUT participates in the EPN Reprocessing project which is another form of processing of the archive GNSS data using the newest strategies, products and models, gathered since the EPN establishment. The main purpose of this project is to obtain homogenous time series of sites' coordinates and to realize European Terrestrial Reference System (ETRS'89) using cumulative weekly solutions obtained with the highest possible accuracy. Results of the reprocessing (daily and weekly coordinates time series) give a comprehensive set of data for various geodetic, geodynamical and geophysical analysis.

Table 1. Permanent IGS GPS stations in Poland (2010).

4 char Station ID	Domes Number	**Location**/ Institution	**Receiver**/ Antenna	Started operating	**Meteo**/ Rec. device	Data transfer blocks	Additional observations
BOGI	12207M003	Borowa Gora Inst. of Geodesy and Cartography	Javad JPS Eurocard ASH700936C_M SNOW	06MAY2003	Yes LAB-EL Poland	24 h 1h	Ground water level Astrometry Gravity GPS/GLONASS
BOR 1	12205M002	Borowiec Space Research Centre, PAS	Rogue SNR-8000 Trimble NetRS AOAD/M_T	01JAN1994 08JUL2007	Yes Skye Instruments Ltd..	24 h 1h	SLR GPS/GLONASS Time Service
JOZE	12204M001	Jozefoslaw Inst. of Geodesy and Geod. Astr., WUT	Trimble 4000SSE TRM14532.00	03AUG1993	Yes LAB-EL Poland NAVI Ltd. Poland	24 h 1h	Ground water level Astrometry Gravity tidal GPS
JOZ2	12204M002	Jozefoslaw Inst. of Geodesy and Geod. Astr., WUT	Ashtech Z18 ASH701941.B SNOW	02JAN2002	Yes LAB-EL Poland NAVI Ltd. Poland	24 h 1h	Ground water level Astrometry Gravity tidal GPS/GLONASS
LAMA	12209M001	Lamkowko Inst. of Geodesy, UWM	Ashtech ZXII3 ASH700936F_C SNOW	01DEC1994	Yes LAB-EL Poland	24 h	Gravity GPS
WROC	12217M001	Wroclaw University of Environmental and Life Sciences	Ashtech Z18 ASH700936D_M	28NOV1996	Yes LAB-EL Poland	24 h 1h	Ground water level GPS/GLONASS

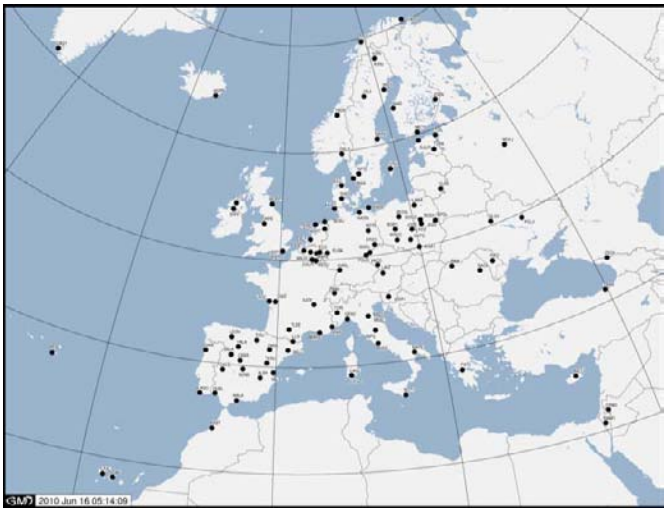

Figure 3. Subnetwork processed by MUT (www.epncb.oma.be)

The test reprocessing of the whole EPN was done simultaneously by two centers: Centre of Applied Geomatics/Military University of Technology (new orbits from the 'Potsdam-Dresden' IGS reprocessing were used) and the Royal Observatory of Belgium (where global IGS stations were taken into consideration). CAG performed calculations using FENIX cluster consisting of 16 dual processor HP servers, which enabled obtaining 210 GFLOP of computing power (processing daily

data from 200 stations lasts only 40 minutes). The results of the tests gave rise to a new strategy for official EPN reprocessing, which is under preparation at the moment (Kenyeres et. al., 2009).

As the majority of LACs uses Bernese software, CAG chose to perform tests using also another tool: GAMIT/GLOBK. These tests are being made in cooperation with Landmäteriet (Gävle, Sweden). The EPN network was divided into 7 sub-networks. 3 networks (138 sites, Fig. 3) are processed by CAG.

Activity within the EUREF-IP Project

The EPN stations at Borowa Góra (BOGI), Borowiec (BOR1), Józefosław (JOZ2, JOZ3), Kraków (KRAW), Lamkówko (LAM5), Warszawa (WARS) and Wrocław (WROC) take part in the EUREF-IP project (http://www.epncb.oma.be/_organisation/projects/euref_IP/index.php).
Three of them, i.e. BOGI, BOR1 and JOZ2 participated also in IGS IP project (Fig. 4). Since March 2005 Ntrip Broadcaster is installed at the AGH University of Science and Technology (gps1.geod.agh.edu.pl). The Ntrip Caster broadcasts RTCM and raw GNSS data from 17 sources, mainly from KRAW EPN permanent station in the framework of EUREF-IP project.

Figure 4. Polish stations participating in EUREF–IP project

Other EPN and IGS activities

GNSS for meteorology

The team of the Warsaw University of Technology continued the analysis of ZTD estimation results as well as IPW (Integrated Precipitable Water) time series derived from GPS solutions obtained at the WUT LAC as well as EPN combination (Kruczyk, 2009).

WUT LAC ZTD series monitoring is a proof of good tropospheric solution quality: decrease of differences between WUT LAC solutions and EPN combination after 2007 is shown in Figure 5.

Reliability of IPW values determined from GPS (WUT and other EPN LAC solutions and combination) was tested with three meteorological water vapour data sources: radiosoundings, sunphotometer (CIMEL, Central Geophysical Observatory PAS, Belsk) and numerical weather prediction model COSMO-LM (treated as meteorological database). CIMEL-318 sunphotometer data seems to be the most genuine source.

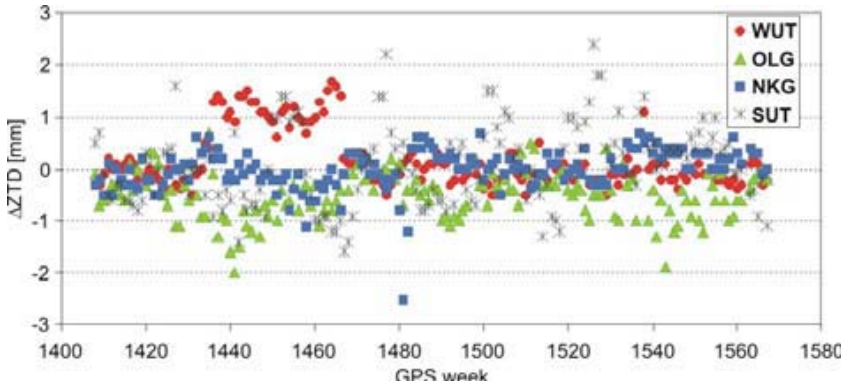

Figure 5. ZTD weekly mean absolute differences: EUR combined product – product of individual LAC for all EPN stations processed

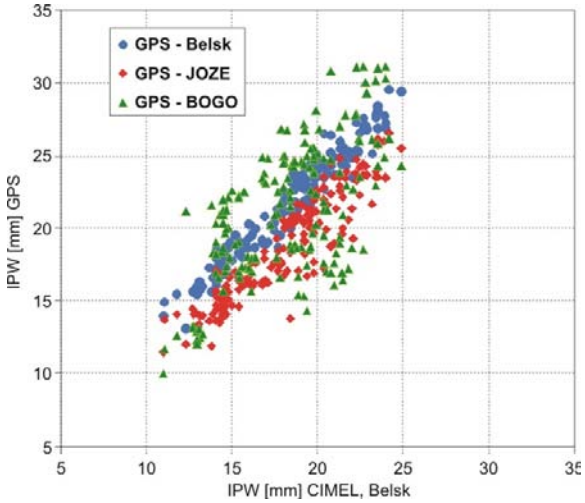

Figure 6. IPW from sunphotometer in Belsk and GPS data 'in situ', JOZE (33 km away) and BOGO (73 km away) in September 2009

Basing on the experience gained in precious investigations the GPS measurements were collocated with sunphotometer data (Kruczyk and Liwosz, 2009). GPS receiver Trimble 4000 SSE of WUT operates permanently since May 2009 at the Central Geophysical Observatory PAS in Belsk. Data was analysed with the similar strategy used to obtain EPN standard tropospheric solution but in a smaller network that consists of 27 stations only. Results from September 2007 show clearly decreasing data conformity with the increase of GPS receiver distance (Fig. 6).

In the Institute of Geodesy and Geoinformatics, Wrocław University of Environmental and Life Sciences, research in the field of GNSS meteorology initiated in 2005 was continued. The distribution of the wet refractivity was investigated with the use of 3D tomography – the technique to invert the integrals over the space into the distribution of the sensed compound. The solution to basic problems was found in the course of numerical simulations (Rohm and Bosy, 2009).

To assess the quality of the ground sensors data needed as reference when applying the tomography model on the real world situations, the special differential wavelet based method was developed. The results show that pressure measurements are highly inconsistent and just few stations comply with the accuracy standards needed in the GNSS tomography method. Regarding the temperature, the sensors perform better and the accuracy expectations are lower. The Coupled Ocean Atmospheric Mesoscale Predictions System (COAMPS) model outputs after interpolation (self developed algorithm) to the locations of meteorological sensors shows good agreement between pressure sensors and COAMPS model outputs in terms of pressure and temperature and fair agreement in the case of water vapour (Bosy *et al*., 2010).

Recent study concerns applying the model to the real world case, verification of the results of GNSS tomography model with the COAMPS outputs and inclusion of additional constraining scheme based on the flow analysis. The outputs of this analysis shows good accuracy and reliability of the tomography model itself but reveals the drawbacks in the model space formulation – the scanning rays which leave the model from the face are not trimmed accurately, which in turns produces numerical instabilities. Also, the flow analysis shows to have slight impact on the solution (Rohm and Bosy 2010). First attempts were performed to build the strategy and methodology to construct near real-time GNSS tomography model of the troposphere over the network of receivers (Rohm and Bosy 2010). It is meant to result in constructing real-time GNSS tomography model for the area of Poland.

Monitoring troposphere, ionosphere, and ionospheric models

The Geodynamic Research Laboratory (GRL) of the University of Warmia and Mazury in Olsztyn in collaboration with West Department of the Institute of Geomagnetism, Ionosphere and Radio-Wave Propagation of the Russian Academy of Sciences in Kaliningrad continues the analysis of long time series of GNSS data from EPN stations to study the Earth's ionosphere. In 2009, simultaneous GPS observations from about 150 stations of EPN have been used for studying dynamics of latitudinal profiles and structure of mid-latitude ionospheric trough (MIT) (Krankowski *et al*., 2009). The TEC maps over Europe were created with high spatial and temporal resolution. The diurnal, seasonal as well as storm-time dynamics of the latitudinal profiles and the trough-like structure during different geomagnetic conditions were also analyzed.

A methodology for GPS ultra rapid positioning that requires single minutes of dual frequency GPS observables for medium-length baseline processing was developed in GRL. It does not require ionospheric corrections and the ionospheric

delays are treated as pseudo-observations with certain a priori values and respective weights in the adjustment procedure. An a priori knowledge of a user's position is not needed. The proposed methodology may be applied in near real time processing. Numerical tests based on actual GNSS data show that the proposed methodology is suitable for rapid static positioning within 50-70 km from the closest reference network station and the centimeter-level precision in positioning is feasible when using just one minute of dual frequency GNSS data. It is believed that this approach is suitable for application in, e.g., ASG-EUPOS active geodetic network where a minimum of 15 minutes of dual frequency GPS data is currently required for static positioning with on-line automatic service (Grejner-Brzezinska *et al*., 2009; Cellmer *et al*., 2010).

The IGS VTEC maps of last ten years were analyzed as a reliable source of ionospheric information since (Hernandez-Pajares *et al*., 2009). Also near Earth space plasma monitoring under COST 29 was reported (Altadill *et al*., 2009)

Since January 2008, the IGS Ionosphere Combination Centre is located at GRL/UWM. Nowadays, the Ionosphere Working Group of IGS generates three types of ionospheric products: final, rapid and predicted, respectively. There are currently four IGS Associate Analysis Centres (IAACs) for the ionospheric products: CODE (Centre for Orbit Determination in Europe), University of Berne (Switzerland), ESA/ESOC (European Space Operations Centre of ESA, Darmstadt, Germany), JPL (Jet Propulsion Laboratory, Pasadena, U.S.A) and GAGE/UPC (Technical University of Catalonia, Barcelona, Spain). These centers provide ionosphere maps computed using different approaches. Their maps are uploaded to IGS Ionosphere Product Coordinator at GRL/UWM, which computes official IGS combined products. The IGS GIMs are provided in Ionosphere Exchange (IONEX) format with spatial resolution of 5.0 degrees in longitude and 2.5 degrees in latitude, and temporal resolution of 2 hours. Latency of the final and rapid GIMs is 10 days and 1 day, respectively. In November 2009, the IGS Iono WG started to generate predicted ionospheric products 1 and 2 days in advance (requested for ESA's SMOS mission). These new IGS products are currently based on predicted ionosphere maps prepared by UPC and ESA. During over 10 years of continuous IGS ionosphere operation, the techniques used by the IAACs and the strategies of combination have improved in such a way that the combined IGS GIMs are now significantly more accurate and robust. Future plans include, among others, increasing temporal resolution to 1 hour and studies on taking advantage of COSMIC occultation data.

Members of the Geodynamic Research Laboratory actively participated in the international scientific community actions, e.g., dr Andrzej Krankowski is a Chairman of the IGS Ionosphere Working Group and IGS Ionosphere Product Coordinator, dr Paweł Wielgosz is a Member-at-Large of the IAG Commission 4 Steering Committee.

The obtained results were published in highly regarded scientific journals indexed by ISI, i.e., Advances in Space Research, Journal of Geodesy, Annales of Geophysics, Journal of Surveying Engineering. In addition GRL members presented 26 papers during international scientific conferences, e.g.: General Assembly of the

EGU, Vienna, Austria, AGU Fall Meeting, San Francisco, USA, EUREF 2009 Symposium, Asia Oceania Geosciences Society General Meeting, International Association of Geomagnetism and Aeronomy Scientific Assembly, International Association of Geodesy Scientific Assembly, URSI/COSPAR International Reference Ionosphere Workshop, Beacon Satellite Symposium, IGS Workshop.

The GNSS meteorology group at the Wrocław University of Environmental and Life Sciences, from the Institute of Geodesy and Geoinformatics has been studying the impact of the troposphere on the GNSS signal since 2007. First stage of the investigations concerns the usage of meteorological parameters from selected EUREF Permanent Network (EPN) stations to model the Zenith Tropospheric Delay (ZTD). The first results show the problem of accuracy deficiencies on some of tested meteorological EPN stations. To investigate actual accuracy of all meteorological stations mounted close to EPN sites the previously developed methodology (comparison with reference World Meteorological Organization WMO stations) with one year of observations was utilized (Bosy and Rohm, 2009). Results shows a number of stations with corrupted or miss functioning sensors, the stations administrators were informed about these issues. The next stage of the research was to use the ZTDs from GNSS observations to construct tomographic model of the troposphere, its most changeable part - water vapor. The investigations started from theoretical testing of the model, its optimal size, temporal and spatial resolution, scanning rays reconstruction techniques, effective numerical inversion. Findings in this area were published by Rohm and Bosy (2009). Since the model was well defined and tested against simulated values it was time to test it against real values. To obtain spatial and temporal behavior of the troposphere in the research area Coupled Ocean/Atmospheric Mesoscale Prediction System COAMPS model outputs were used. These results were validated and integrated with ground meteorological observations from the stations of approved accuracy. Afterwards meteorological parameters were interpolated to the center of voxels in tomographic model. The signal was ray traced and system inverted, results were very optimistic – the tomographic solution was squaring with COAMPS model outputs (Bosy *et al*., 2010). The following step was to validate the model with real GNSS observations in the most demanding terrain – mountains. Problems with numerical stability were resolved with air flow analysis, constraints scheme modification and special procedure for low elevation scanning rays (Rohm and Bosy, 2010). The most recent investigations were directed into Near Real Time application of the tomographic model. The description has been published by Bosy *et al.* (2010).

At Military University of Technology/Centre of Applied Geomatics Multistencil Fast Marching Method (MFMM) is being used for map of distances of ASG-EUPOS sites belonging to different areas of mezoscale model creation. Calculations are being performed in 1-hour intervals. Solutions are made using different resolution grid (39, 13, 4.3, 1.44 km) for ASG-EUPOS sites. These maps are being used for zenithal and slant delay determination. In case of ZTD, lengths of propagation path in vertical atmosphere columns above ASG-EUPOS sites are being determined. At present, prototype module for mezoscale slant delay values

determination basing on non-hydrostatic COAMPS model data is being used. Zenithal delays can be exploited directly as the parameters for methods of solutions (sites coordinates) determination (Bernese, GPSTools).

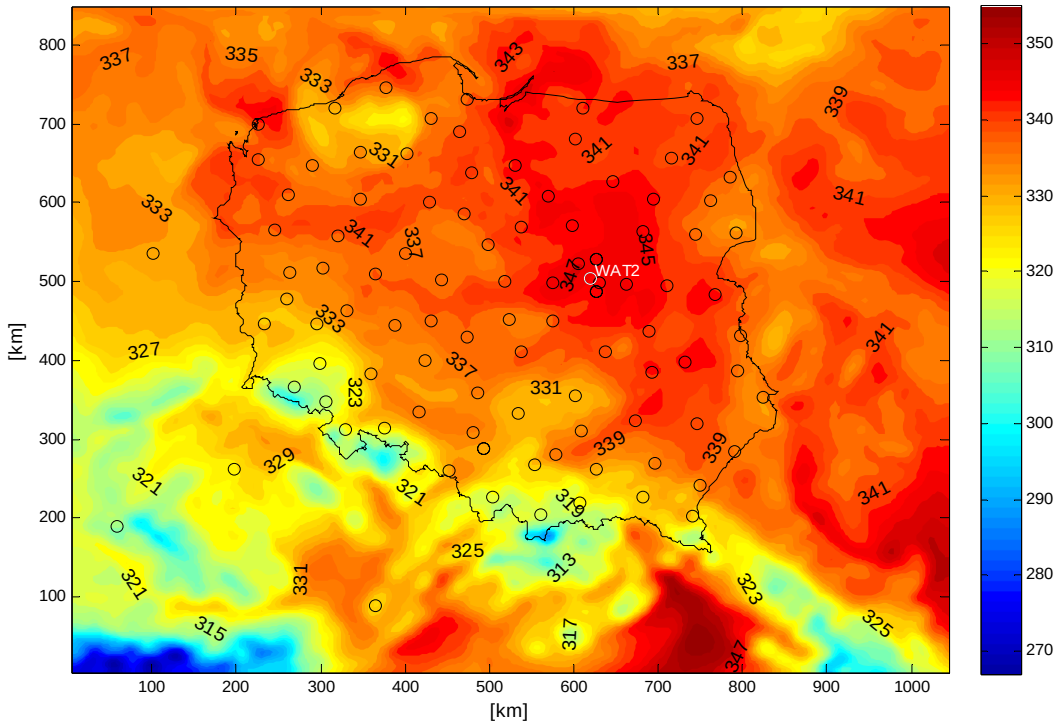

Figure 7. Horizontal cross section by WAT1 station, 2009.06.10.00.

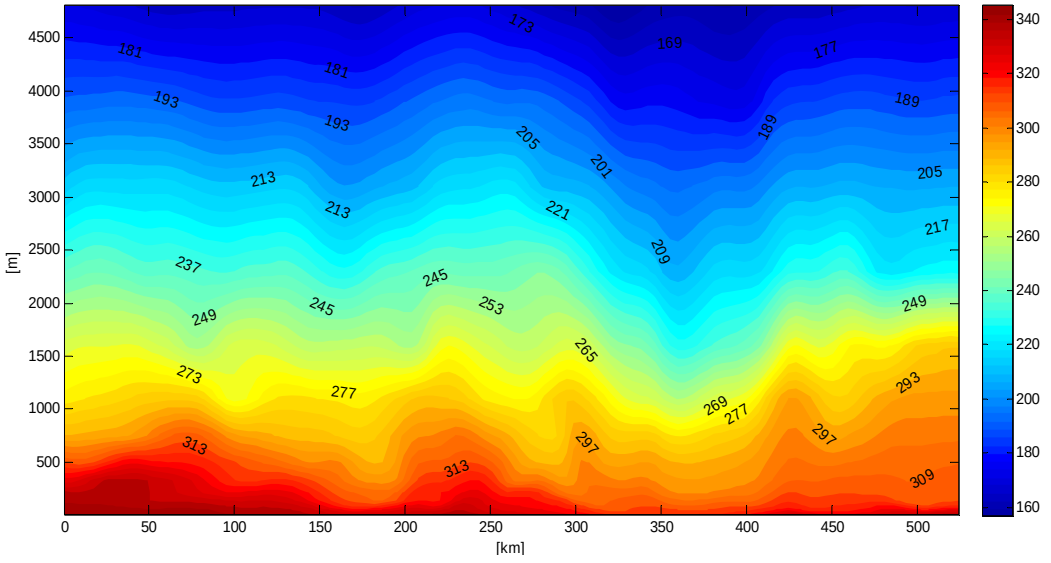

Figure 8. Vertical cross section by WAT1 station, 2009.06.10.00.

At Military University of Technology/Centre of Applied Geomatics higher ionospheric corrections are used for GNSS observations. First results showed that they affect the scale parameter of processed network. Obtained differences between coordinates from two solutions (one with higher ionospheric correction, second – without) showed some regular shift for northern and southern sites in North-component, but they were very small (less than repeatability). There are also some tests done with different mapping function available in GAMIT software. Zenith Total Delay is calculated from Niell Mapping Function (NIELL), Global Mapping Function (GMF) and Vienna Mapping Function 1 (VMF1).

Status of the ASG-EUPOS network

The ASG-EUPOS network, fully operating since 2008 (Krynski and Rogowski, 2009), is based on 98 reference stations located on the Polish territory and 22 foreign stations located in neighbouring countries (Fig. 9). In reference to 2008, locations of two reference stations have been changed: station KAMP, now called KAM1, and station SZEK, now called SZE2. Changes were made because of roof of building reconstruction. In 2009, 4 new foreign EUPOS reference stations located near German and Czech Republic border: 0139 and 0147 from SAPOS network and: CPAR, CSVI from CZEPOS network were included into the ASG-EUPOS system. CPAR is an EPN station. In 2009, additional 3 ASG-EUPOS stations were included in the EPN network: CFRM, CLIB and CPAR. Currently ASG-EUPOS network contains 19 EPN stations.

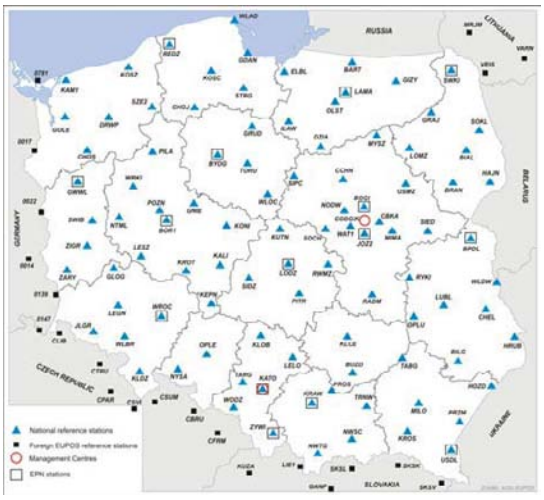

Figure 9. Reference stations of the ASG-EUPOS system

The permanent analysis of the stations coordinates performed by ASG-EUPOS management centre confirmed that stability of the reference stations is sufficient and deviation of coordinates has not exceeded 3.0 mm in horizontal and 5.0 mm in vertical component (http://www.asgeupos.pl).

The market of GNSS users in Poland was further growing in 2009. The number of registered users of the ASG-EUPOS services reached 5000 at the end of 2009. Among the real-time services the most popular one is definitely NAWGEO based on RTK and applied for high precision real-time surveys. The usage of that service has grown up from 98.7% in 2008 to 99.2 % in 2009 (Fig. 10), against KODGIS and NAWGIS services, which were used mainly for GIS applications. In case of offered post-processing services, POZGEO – offering an automated calculation of user RINEX files, has processed 16 201 files from total 20 403 requested, which gives a 79.4 % effectiveness rate.

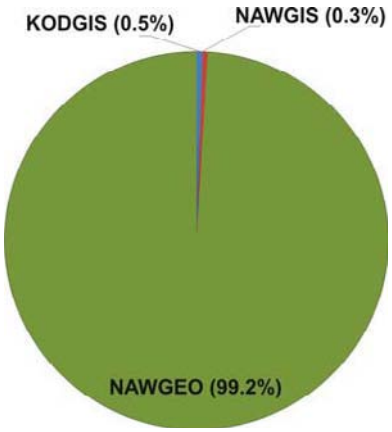

Figure 10. The percentage of real-time services usage of the ASG-EUPOS system in 2009

The system is being used mostly in areas where construction of roads and railways takes place and also in large municipalities. Approximate coordinates of users were the basis for creating a map of system usage in its operational period until December 2009 (Fig. 11).

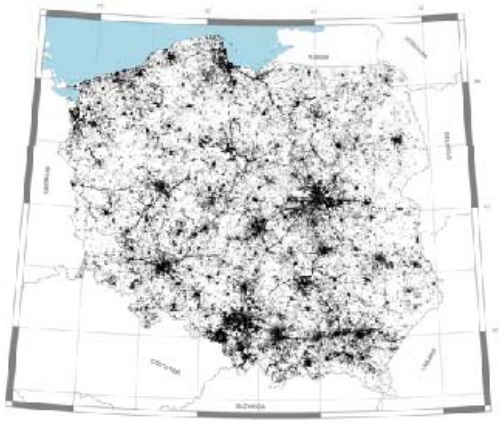

Figure 11. The map of the usage of real-time services of the ASG-EUPOS system from 2008.5 to the end of 2009

In April 2009 Faculty of Civil Engineering and Geodesy (Centre of Applied Geomatics) of Military University of Technology signed an agreement with The President of Head Office of Geodesy and Cartography (HOGC). The agreement concerns precise satellite positioning system of ASG-EUPOS network. HOGC will support MUT with no-charge access to data from reference stations since the beginning of the functioning of ASG-EUPOS. The main purpose of the first stage of

cooperation was the elaboration of archive data gathered on stations to establish the most reliable coordinates on these stations. The results were presented in an official report called "*The report concerning precise data elaborations from permanent ASG-EUPOS sites"*. The elaborations concerned the stations with the most reliable solutions. The Centre of Applied Geomatics also concentrates works on GLONASS observations based on satellite data.

Other GNSS Applications

Military University of Technology (MUT) uses satellite positioning system to investigate displacements and deformations of engineering constructions. This enables any geometric construction changes easy to detect (with up to 20 Hz and sub centimeter accuracy). Past, present and real-time laboratory tests prove that there is a high efficiency of such research. This method is a strong alternative for traditional methods of surveying (Figurski *et al*., 2008).

Activities in Galileo project

In 2009 new GESS+ (Galileo Experimental Sensor Station) station GWAR was installed in the Space Research Centre PAS, Warsaw. After few months of data quality tests, station was included as fully operational to the global network of monitoring GIOVE satellites starting from 16 December 2009 (Fig. 12).

Figure 12. GWAR GESS+ station of the global Galileo ground control network

PECS Project "EGNOS – EUPOS integration" is run in the Space Research Centre PAS in cooperation with Head Office of Geodesy and Cartography, Malopolska Voivodeship and commercial companies. Its objective is to improve the effectiveness and range of applications of the EGNOS system by achieving the full compatibility and integration with the ASG-EUPOS system. Due to the poor configuration of the RIMS stations in eastern part of Europe, the accuracy and

availability of corrections in Poland are degraded. The improvement of the EGNOS corrections, by including additional ASG-EUPOS reference stations located in the eastern part of Poland as complementary EGNOS monitoring stations is expected.

Time service for Galileo

The activity of the Time and Frequency Laboratory of the Astrogeodynamic Observatory of the Space Research Centre at Borowiec concentrated on time system for Galileo and development of technologies for time and frequency measurements. All these activities will support the Galileo program. The infrastructure of the Borowiec Time Service has recently been upgraded to two cesium frequency standards, two hydrogen masers, Galileo receiver and two-way method of time comparison. The time comparison with several time laboratories by two-way method (geostationary satellite) was on the level 200 picoseconds. The Borowiec Time Service participates in three GALILEO projects: “Precise Time Facility”, “Galileo Time Service Provider Prototype”, and “Harrison”.

New receivers, the TTS-4 (Fig. 13) observing GPS, GLONASS, and Galileo satellites were developed at the end of 2008 at the Astrogeodynamic Observatory at Borowiec. The receivers equipped with 116 channels carry on observations at GPS L1, GPS L2/L2C, GPS L5, Galileo E1/E5A, GLONASS L1/L2.

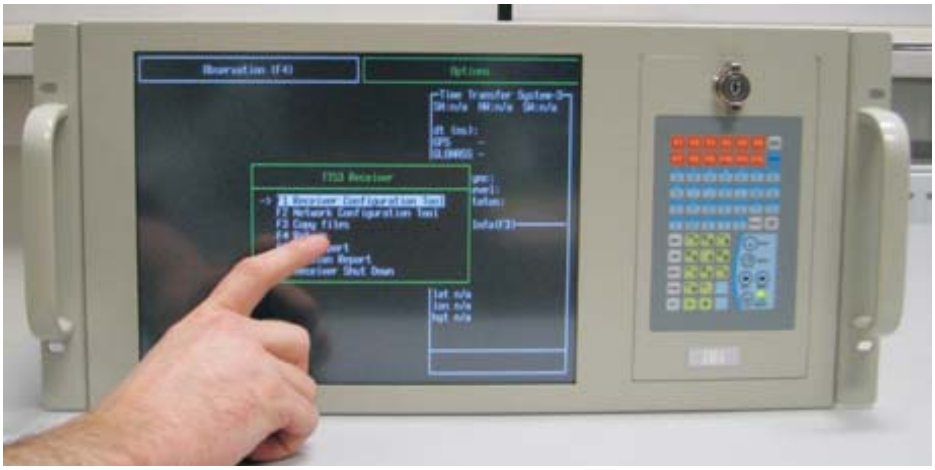

Fig. 13. New TTS-4 receiver with touch-control screen

Work on the Precise Time Facility (PTF) for Galileo at the Astrogeodynamic Observatory at Borowiec has passed from the design phase to realization. From March 2008 Borowiec Time Service started to write final version of the software package in ANSI C language.

The Borowiec Time Service staff organized and hosted representatives of the all main Time and Frequencies laboratories in the frame of the 17th meeting of the Consultative Committee for Time and Frequency (CCTF) Working Group on Two Way Satellite Time and Frequency Transfer (TWSTFT) held on October 20-21, 2009 in Poznań.

Activity in Satellite Laser Ranging

The Satellite Laser Ranging station in Astrogeodynamic Observatory of the Space Research Centre, Polish Academy of Sciences in Borowiec (ILRS 7811) (Fig. 14) collected, produced and delivered during 2008-2010 almost 250000 raw points to the scientific user community, tracking over 1000 successful passes of 27 satellites in the framework of the International Laser Ranging Service (ILRS) and EUROLAS Consortium. The data of the Borowiec SLR station supported research programs and was used for orbits calculations and determination of geodynamic parameters by many institutions and international organizations. In October 2009 the Borowiec SLR station participated in the Time Transfer by Laser Link (T2L2) international campaign.

Figure 14. Telescope of the satellite laser ranging system at Borowiec

Processing of the SLR observations was continued in Borowiec. GPS and SLR data (25 stations) were used for the determination of station positions and velocities for the same reference epochs in the period 1993.0-2009.0. The results show a good agreement of positions (several mm) and velocities (below 1 mm/year) for both satellite techniques for the most stations (Schillak and Lehmann, 2009). The determination of the SLR station positions and velocities from low satellites Starlette, Stella and Ajisai was continued. The results indicate that the data from low satellites such as Ajisai, Starlette and Stella can successfully be applied for the determination of the SLR station coordinates (Lejba and Schillak, 2009, 2010).

The Borowiec SLR staff organized and hosted the 16th International Workshop on Laser Ranging, held on October 13-17, 2008 in Poznań. Over 140 delegates from all the world attended the workshop, giving 125 oral and poster presentations. During the week, the participants and accompanying persons visited the Borowiec Astrogeodynamic Observatory.

Other activities

At the Space Research Centre of Polish Academy of Sciences it is being run a project "Core information models of main theoretical, methodological and observational segments of the GGOS - Global Geodetic Observing System". Within the project there are investigated links between specific components of the four pillars of the GGOS: the reference systems, the geometry and kinematics, the gravity field and the earth rotation, with respect to the theoretical, methodological, observational and organizational aspects, including also the investigators' points of view. The pictures on Fig. 15 and Fig. 16 present examples of the main models investigated (Pachelski *et al*., 2008, 2010).

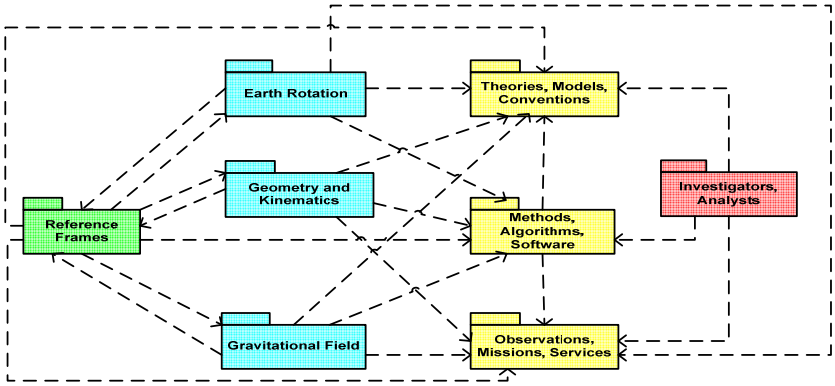

Figure 15. Main packages of GGOS

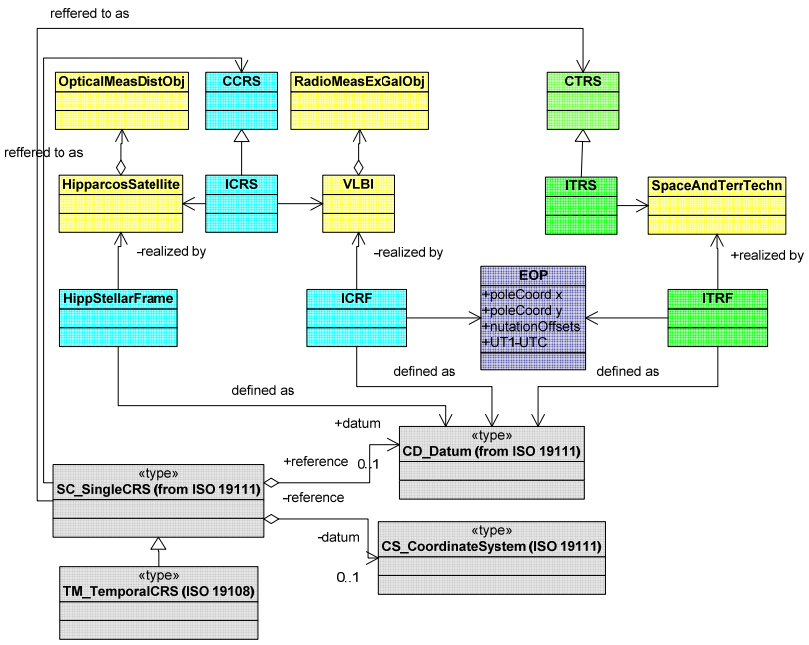

Figure 16. Reference systems and frames.

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3. REMOTE SENSING

Compiled by Jan Olędzki and Katarzyna Dąbrowska-Zielińska

Department of Geoinformatics and Remote Sensing (DGRS) at Warsaw University

DGRS is the only one academic unit in Poland that has rights to grant the Master of Science degree in remote sensing. Such MSc studies are organized within the field of geography, in the frame of geoinformatics specialization. Research conducted at the Department aims at the development of new methods of remote sensing and GIS analysis and their application in the study of changes in the geographical environment's structure.

During the period 2007-2010, DGRS granted the MSc degree to 35 graduate students. Post-graduate researchers have got two PhD degrees, granted for the following theses:

- "Diversity of *Pinus mugo Turra* as seen by remote sensing-based research" by Magdalena Zwijacz-Kozica
- "Application of hiperspectral remote sensing in studies and mapping of Alpine plants in the Tatra mountains" by Marcin Sobczak.

Dr Bogdan Zagajewski published in 2010 his Dr Habilitatus work on the application of neural networks and hiperspectral data in studies of plants in High Tatras. Studies were also carried on using the middle-resolution satellite data for environment monitoring. A monograph has been published on the geographic regions of Poland based on the Landsat images: J. Olędzki "Geographic Regions of Poland", published as the Volume 38 of the *Teledetekcja Środowiska* Monograph Series. Currently, another work is going on synoptic geomorphologic maps of Poland in 1:300 000 scale based on satellite images. Such a map has been already finished for the Podlasie and Mazowsze region. Other works are on using the microwave data in geographical studies and satellite images in studies of hazard of forest fire.

DGRS is involved in a wide international cooperation in the field of the remote sensing research, participating, e.g., in activities of the European Association of Remote Sensing Laboratories (EARSeL). Current joint project is following: "High-level training in hyperspectral imaging", project EU HYPER-I-NET MRTN-CT-2006-035927, 2007-2010.

Remote Sensing Department at the Institute of Geodesy and Cartography (IGiK)

Institute of Geodesy and Cartography, founded in 1945, is the research institution authorized to confer doctor's degree in the field of geodesy, cartography and remote sensing and conducts post-diploma studies. The main task of the Institute

is to do research in the field of geodesy and related disciplines for the needs of science, geodetic and cartographic service, public life, administration and state security. The Institute works for different ministries, governmental and self-governmental authorities, domestic and foreign scientific institutions and for geodetic/cartographic enterprises, regardless of their type of legal status. The Institute collaborates with many institutions in Poland and abroad.

In seventies the Institute of Geodesy and Cartography further extended its scientific tasks, dynamically developed scientific staff, co-ordinated scientific works in Poland to be profitable for practical works and for geodetic/cartographic administration. In 1976 the national remote sensing centre was established in the Institute. It is known as the **Remote Sensing and Spatial Information Centre – OPOLiS,** further The Remote Sensing and Spatial Information Department-OPOLiS, deals with applications of multisource and multilevel images (satellite and air-borne) for extracting information on objects, phenomena and processes on the Earth's surface. Information derived from remotely sensed data (optical and microwave) is mainly used for the needs of **agriculture, forestry, physical planning and environmental protection.** Numerous research and application-oriented works have been conducted by the Remote Sensing Department. Extensive experience of the Centre in remote sensing and GIS applications resulted in its recognising as the National Focal Point for undertaking joint international activities, related to Earth Observation programmes.

IGiK is currently carrying on the following research projects:

1. FP 7 Geoland-2 project

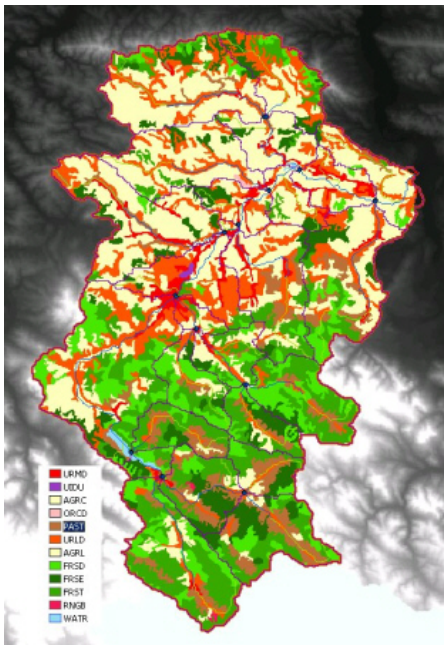
IGiK has undertaken work in the EU's GMES program, executing the tasks covered by the project Geoland2. Among them are the tasks relating to the use of satellite data in agro-meteo-organic models, drought and changes in agricultural land use across Europe. IGiK actively participates in development of three Geoland2 services: SATChMo, BioPar and Global Crop Monitoring. Within SATChMo module IGiK performs tasks concerning preparation of technology for land use and land use change mapping in Europe, applying high-resolution and medium-resolution satellite data. Operational methods of monitoring phenological trends and estimating crop acreages in Europe are also developed in this module with IGiK's contribution. Within Global Crop Monitoring module IGiK conducts works related to inter-comparison of various methods for estimating crop acreages and yields in global regional scale, which are based on multi-temporal remote sensing derived information. Within BioPar module IGiK is involved in the works aimed at development of methods of vegetation monitoring with the use of different indices derived from medium-resolution satellite images. Within Coordination Office of Geoland2 project IGiK performs tasks related to harmonization of validation approaches applied in various modules of the Project.

2. FP 7 project "Classification of European Biomass Potential for Bioenergy Using Terrestrial and Earth Observations — CEUBIOM "

The combined use of EO-derived data with in-situ measurements based on common agricultural and forestry survey practices can be a powerful tool for assessing biomass potential. The goal of CEUBIOM project is to develop a Platform and a self-sustained e-service that will directly assist and train professionals from the EO, agricultural and EO/biomass sectors about the new, common and harmonized applications of EO and a better understanding of each other requirements. Strategic objectives are following:

- Development a common methodology for gathering information on biomass potential using terrestrial and earth observations.
- Disseminating information, best practices and methodology on using earth observations in the assessment of biomass potential.
- Raise awareness for the use of EO on biomass potential of the scientific community and public.

3. ESA PECS project: "Application of remotely sensed data for transboundary water resource management"



Aim of the submitted project is to create system for monitoring quality of surface waters and associated ecosystems, which will use data acquired from remote sensing satellites. Such a system, characterizing quality of water resources within river catchments, should include information on pollution produced by agricultural areas. Taking into account spatial, large-area character of this information, related to agricultural land use type and productivity of arable land, it is indispensable to apply satellite images for characterizing these areas. Data delivered by new-generation satellites give possibilities to determine crop structure and biomass – elements needed for feeding models, which describe character and amounts of water pollution within river catchments.

Fig. 1. Land cover / land use map of Ropa catchment

The submitted project contributes to European policy concerning implementation of Water Framework Directive (WFD). In particular, it supports tasks aimed at construction of systems for monitoring quality of water resources on transboundary areas, defined within pan-European GMES Program (Global Monitoring for Environment and Security). The project is in 2010 in the middle of its lifetime. The catchment of Ropa River located in southeastern Poland has been

selected. All necessary materials indispensable for entering modeling phase through application of SWAT model for water quality assessment were collected. They include appropriate meteorological data, hydrological information on flow in the rivers within the study area, satellite images being the base for preparation of land cover map, soil maps, etc. These input materials were entered to the SWAT model and preliminary maps assessing water quality were produced. The results of Land Cover Mapping are presented in fig. 1. The model will be calibrated using 2010 data to refine methodology for delivering information on water quality within catchments.

4. ESA PECS Project: "Study and implement remote sensing techniques for the assessment of carbon balances for different biomasses and soil moistures within various ecosystems"

The objective of the Project is the assessment of the level of carbon balance with regard to land use, the amount of biomass, the soil moisture and meteorological conditions. The project will also assess the influence of the land use cover on carbon release and sequestration. Data gathered by various satellites have been used in this project. The thematic scope of the project makes an explicit reference to the current policy of the Ministry of Environment in Poland, expressed by biodiversity activities regarded to carbon balance and Climate Change. Change in carbon flow has been examined for the chosen areas used in the study. Since soil moisture influences the carbon balance, it is necessary to determine how much of the carbon is absorbed and how much is discharged. The following tasks have been carried out:

- Mapping of the land use with special attention to forest area changes, bio-energy plants and wetland areas,
- Measurements of the soil moisture in different vegetation areas by applying the L- band radiometer and TDR measurements in order to validate ASAR and PALSAR data,
- Measurements of variations of carbon fluxes for areas covered by various vegetation types.

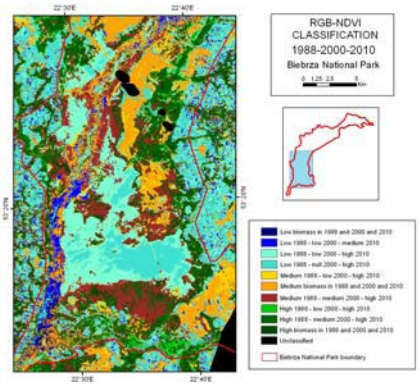


Fig1 Changes in Biomass Biebrza Wetlands

Fig 2 The set-up for measurement of CO_2 flux

5. ESA-PECS project - Detailed crop monitoring and mapping based on multi-frequency microwave images - Terra-SAR-X

The objectives of the project are following: the elaboration of the efficient method of crop discrimination using Terra SAR-X data and Terra - SAR with ENVISAT ASAR data of various polarization and angle; the development of new models that through inversion will give the canopy characteristics as various crop parameters, which will give possibilities to assess crop growth and yield estimation. Extensive field measurements of various crop-soil parameters and crop recognition will be carried out simultaneously with satellite overpasses for the verification of the model deliverables. Synergy of various wavelengths and polarization will be investigated in the context of crop and soil monitoring. The next approach will be to establish the relationship between the model parameters and soil-vegetation features providing the simulation of backscattering coefficient (using X and C multipolarization) and compare the model results with experimental data. For this approach the canopy cloud model of Atema and Ulaby will be applied. The inversion of the model against field measurements will allow estimating the canopy biophysical properties. It is obvious that during the season of crop growth the soil moisture varies and therefore the backscatter will be modeled for different soil moisture and different crop what will allow to interpret the backscatter value and understand its variability and distribution. Extending the canopy cloud model of Atema and Ulaby considered for the canopy as the single layer to one consisting more than one layer (as MIMICS) and combine optical and microwave data for soil moisture retrieval (under vegetated conditions) and replace the soil submodel with an IEM to better reflect the interaction between vegetation layer and soil surface. Methods of classification - supervised as well as unsupervised methods will be considered. Classification will be performed for signatures calculated for fields as a whole or segments of fields. Neural network classifier based on multi-layer perceptron will be used for classification of images. The eCognition method of object classification will be also applied. The test site is situated in the western part of Poland where since several years the measurement campaign has been carried out. The most common crops at the test site are cereals: wheat, rye, barley and triticale, which is a hybrid of wheat and rye. Rape, sugar beets, maize and alfalfa are also well represented. For the purpose of the project the Dual Polarization Stripmap product radiometrically enhanced will be used. Preferable acquisition starts the 1 of April until October; the elevation beam identification - STRIP 9 and STRIP 14, every 11 days with different dual polarization, VV/HH, HV/VV, respectively. Deliverables: classification maps, classification accuracy, results of modeling - various crop parameters. The funding is covered by national grant.

6. ESA ALOS ADEN AO Nr 3742 "Application of ALOS L band data for analysis of wetlands humidity and biomass assessment"

The objective of the project is aimed at using microwave satellite images in order to elaborate the efficient method for assessment of wetland humidity and its spatial and temporal changes with special emphasis for evaluation of biomass and its

transformation. The project will support the global wetlands inventory and the information about wetlands biophysical conditions. The area of Biebrza wetlands in Poland is one of the largest in Europe. It is considered as Ramsar site and according to Kyoto protocol plays important role as carbon sinks and exchange. The research will focus on developing and delivering the data on hydrological variation of the area and changes in biophysical parameters of vegetation. During the recent years the area experienced the changes due to drying effects caused by natural and human activities. That is why it is necessary to create the system which will include data on humidity and vegetation changes. These changes are relatively large due to the succession of new vegetation to the area where hydrological conditions have changed. The same team runs the AO-122 Project using ENVISAT ASAR and ENVISAT MERIS data for the same area. Also for the same area we are involved in the Project Cal/Val for SMOS. The opportunity to use microwave images acquired in L band jointly with C-band images from ENVISAT ASAR, ERS SAR will enhance the efficiency of vegetation and soil monitoring. For land use changes and vegetation monitoring we plan to elaborate the efficient method of vegetation mapping. Synergy of various wavelengths and polarization will be investigated in the context of vegetation including soil moisture monitoring. For the given project the following procedure will be established: a) delineation and mapping of the flood extend during the winter and spring season as important issue for water supply to the peat strata; b/ delineation and mapping of different vegetation classes; c/ distinguishing the changes in vegetation using current and archive data. It will be established the relationship between the model parameters and soil-vegetation features providing the simulation of backscattering coefficient (using L and C multipolarization) and compare the model results with experimental data. Selected ASAR modes with various polarizations and incidence angles and chosen PALSAR data will provide the information. Synergy of various wavelengths and polarization will be investigated in the context of vegetation including biophysical properties and soil moisture. It is obvious that during the season of vegetation growth the soil moisture varies and therefore the backscatter will be modeled for different soil moisture. It will allow interpreting the backscatter value and understand its variability and spatial distribution. Extensive field measurements of various vegetation-soil parameters and vegetation recognition including Absorbed Photosynthetic Active Radiation, LAI, wet and dry biomass, soil moisture will be carried out in the test site situated in the western part of Poland. The measurement campaigns will be performed simultaneously with satellites overpasses. Collected data will be used for verification of data, finding of the influences of biomass on backscatter and derivation of model parameters. Vegetation mapping will be performed using supervised as well as unsupervised methods of automatic classification. Classification will be performed for signatures calculated for fields as a whole or segments of fields. Neural network classifier will be used for classification of images. The eCognition method of object classification will be also applied. Ground truth data will be used for training the classifiers as well as for validation of the classification results. Resulting maps of vegetation will be used in the process of derivation of vegetation parameters.

7. ESA ALOS ADEN AO Nr 3677: "Analysis of soil moisture and vegetation parameters from multi-frequency microwave image"

The objective of the project is aimed at using microwave satellite images in order to:

- elaborate the efficient method of soil moisture assessment;
- develop inversion models supplying various vegetation parameters, which are important for the assessment of vegetation growth and crop yield prediction;
- elaborate the efficient method of vegetation mapping.

The opportunity to use microwave images acquired in L band jointly with C-band images from ENVISAT ASAR and ERS SAR and X band from TERRA SARX instruments will enhance the efficiency of vegetation and soil monitoring. Selected ASAR modes with various polarizations and incidence angles can provide data that are complementary to the planned PALSAR acquisitions. Synergy of various wavelengths and polarization will be investigated in the context of vegetation including crop and soil monitoring. The main aim is to establish the relationship between the model parameters and soil/vegetation features providing the simulation of backscattering coefficient (using L and C multipolarization) and compare the model results with experimental data. For this approach the canopy cloud model of Atema and Ulaby will be applied. The inversion of the model will allow estimating the canopy biophysical properties. It is obvious that during the season of vegetation growth the soil moisture varies and therefore the backscatter will be modeled for different soil moisture. It will allow interpreting the backscatter value and understanding its variability and spatial distribution. Extension of the canopy cloud model of Atema and Ulaby considered for the canopy as the single layer to the one consisting of more than one layer (as in MIMICS) is planned. We will combine optical and microwave data for soil moisture retrieval (under vegetated conditions) and replace the soil submodel with an IEM to better reflect the interaction between vegetation layer and soil surface. Extensive field measurements of various vegetation-soil parameters and crop recognition will be carried out in the test site situated in the western part of Poland. The measurement campaigns will be performed simultaneously with satellite overpasses. Collected data will be used for derivation of model parameters as well as for the verification of model deliverables. Vegetation mapping with a special focus on crops will be performed using supervised as well as unsupervised methods of automatic classification. Classification will be performed for signatures calculated for fields as a whole or segments of fields. Neural network classifier will be used for classification of images. The eCognition method of object classification will be also applied. Ground truth data will be used for training the classifiers as well as for validation of the classification results. Resulting maps of vegetation will be used in the process of derivation of vegetation parameters.

8. Analysis of range and effects caused by the flood wave in May and June 2010 in the Vistula and Odra River Valleys

In May and June 2010 a flood occurred in Poland, which was the result of intensive rain falls in the upper sections of the Vistula and Odra Rivers. Medium-resolution

TERRA-MODIS satellite images were used for analysis of the extent of the flood wave. Images taken on 6 June for the Vistula River Valley and on 9 June for the Odra River Valley were selected from a generally accessible database. The size of flooded areas was delineated using object-oriented classification methods in the eCognition software environment. Statistical analysis of classification results was performed at the municipality level, by comparing the classification with CORINE Land Cover 2006 Database. During the discussed flood, areas in 184 municipalities along the Vistula River and in 120 municipalities along the Odra River were flooded. The most extensive flooding occurred in Slonsk Municipality in the Odra River Valley, where 4055 hectares were flooded. In total, the Vistula waters flooded 4.01% of the area of municipalities located within the Vistula River Valley, and 3.29% of the area of Odra municipalities were flooded by the Odra River waters.

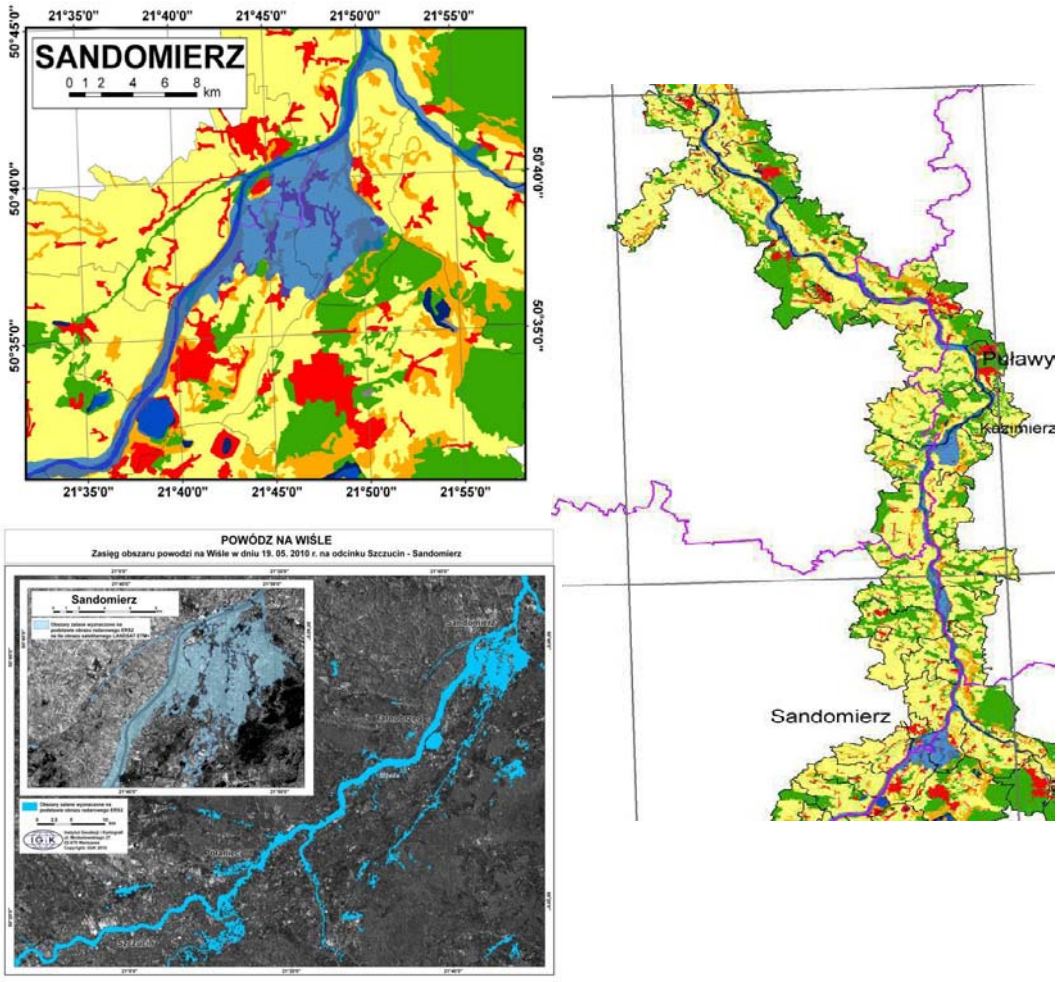


Fig 1.presents Flood in Vistula River Valley 15th May 2010 Szczucin - Sandomierz applying optical image (MODIS) and microwave ERS2. Both Maps were done at the same day of registration.

9. **ESA project No. 7847 "Application of microwave images for the area flooded in May and June 2010 in Poland."**

The objective of this project is to assess the area flooded in May and June in Poland. Data gathered by various satellites with radar sensor will be used at chosen test sites. These include microwave satellite images such as ALOS.PALSAR, ENVISAT.ASAR and ERS-2.SAR. Microwave satellite images will be used for mapping the extent of flooding. Optical satellite images such as ENVISAT.MERIS and ALOS.AVNIR-2/PRISM registered before and after flood will be used for mapping the type and area of land use classes which suffered from flooding. The maps of flood extension at chosen test sites will be the main deliverables of the project. In GIS the topographic maps and land use classes affected by flood will be included in the investigation. The damaged areas will be monitored after the flood runs off. The thematic scope of the project makes an explicit reference to the current policy of the Polish Government. Project is funded by national grant with support of GEOLAND-2 Land Use Changes.

10. **ESA-PECS Project: "Soil, Water and Energy Exchange/Research (SWEX/R) — Ground Based Monitoring of Soil, Water and Energy Exchange Conditions in Poland for Validation Purposes of the ESA mission SMOS" (led by SRC PAS)**

The consortium falls under coordination of the program GMES-Poland and feed hopes linked to program ESA PECS for Poland in the part dedicated to Earth observations. The consortium comprises several groups from different institutes working on soil, water and meteorological research on different scales. The Institute of Geodesy and Cartography (IGiK) uses satellite data interpretation on a regular basis for many years within a special scope on wetlands and forestry. Wetlands are target areas suitable for validation needs of SMOS. The proposed program is the attempt of finding a common subject of research. The water related observations from space are integrating means needed to keep a synergy between heterogeneous entities and prospective to bring a product usable in the country and beyond. Ground data from different providers usually suffer lack of consistency in precision, nonuniform space and temporal coverage, etc. Therefore their use becomes uncertain if temporal changes and spatial distribution are concerned. Methods on data fusion help a lot in managing different scales but cannot replace a space borne synchronous observations. SMOS fits the need and enables large scale research. The partners from SWEX see in that their good opportunity on stimulating local research practices extended on the country and region.

Institute of Meteorology and Water Management (IMWM)

Since 2009 Poland has been EUMETSAT Member State. As a result, the State Hydrological and Meteorological Service obtained full access to digital data and data processed from EUMETSAT meteorological satellites as well as those used by other operators. The Organization carries out also training courses. Since EUMETSAT

appreciates advanced digital data receiving and processing system and experienced IMGW research and technical staff, it offers organization of such courses in Poland. The IMGW representatives attend the seminars convened by EUMETSAT. IMGW participates in the implementation of many national and international research programs and projects such as HELCOM or COST projects.

Space Research Centre Polish Academy of Sciences

Space Research Centre PAS is very active in GMES (Global Monitoring for Environment and Security) thematic projects. In 2009 and 2010 SRC was involved in the following projects:

1. **LIMES** within FP6
2. **Geoland2**
3. **G-MOSAIC** } within FP7
4. **GEONetCaB**.

Year 2009 was the third year of **LIMES** (*Land and Sea Integrated Monitoring for European Security*) project implementation. The project is co-founded by the European Commission within the 6th Framework Programme as one of the projects that are related to the security domain of GMES program (Global Monitoring for Environment and Security). The main aim of that project was to do research and develop applications and services that intend to utilise the Earth Observations (EO) technology to increase the security in EU.

SRC, with partners from Thales and Walphot, has been responsible for final development of the Land Border Monitoring services. After data collection the final services has been created. The proposed services were presented and verified by users (Border Guards, FRONTEX Agency) during the final LIMES Land Border Monitoring Demonstration at the Thales premises in December 2009.

The developed services consist of cartographic products that are intended to support the work of authorities in the security domain by providing additional information necessary for their daily activities and in an emergency. During the work on services several different processing steps were applied. These include both remote sensing processes (orthorectification, classification of satellite optical and radar imagery) and spatial modelling and analysis.

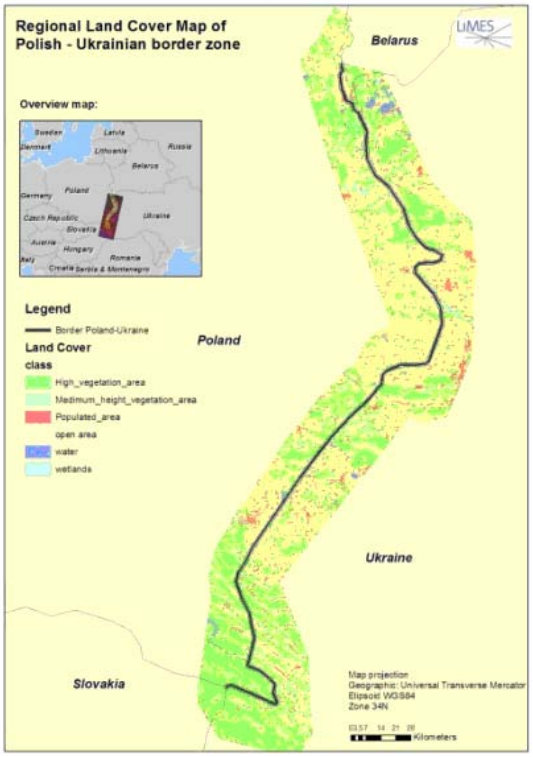
All products were developed for the test area of the Polish – Ukrainian border. The coverage of given product depends on its use and characteristics.
The Land Border Monitoring products are described below:

1. **Service 1: Cross- border geospatial information assessment**

PRODUCT 1: **Regional Land Cover Map**

The first product is a medium scale land cover/ land use map that is supposed to work at national / regional level. The map covers an area of approximately 20 km on each side of the Polish – Ukrainian border. CORINE Land Cover dataset was used on the Polish side. For the Ukrainian side of the border a similar product was created through classification of IRS-P6 satellite images (spatial resolution about 23m). The

accuracy of the final map is 85%. The Regional Land Cover map aims at assessing land cover in a harmonized way on both sides of the national border and provides the necessary input information for the Border Permeability Index.



Regional Land Cover Map

PRODUCT 2: **Detailed Land Cover/Land Use Map**

This product is a land cover / land use map in a fine scale based on classification of VHR optical data form IKONOS satellite with 1m resolution. It aims at providing detailed information of land cover in hot spot areas. Within the project the study area was located in Czarna region (Bieszczady Mountains) and covered an area of 100 km^2. This vector dataset is supposed to work at an operational level and to be used to update and enrich the existing cartographic data. It also allows the production of cartographic data by providing harmonized information for both sides of the border in the same scale and coordinate system.

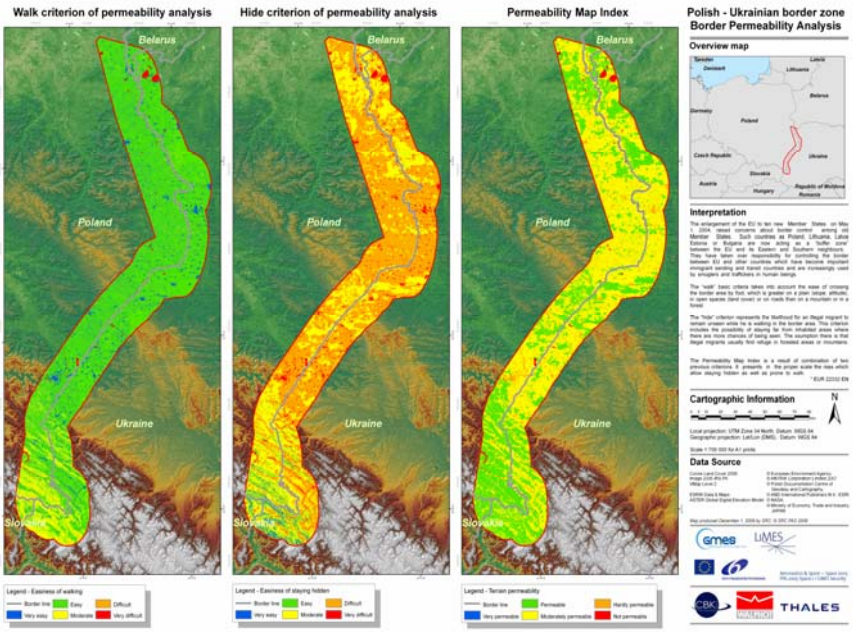
PRODUCT 3: **Detection of Land Cover Changes**

The last product of 1st service provides a tool for semi-automated detection of land cover changes. Based on the interpretation of a sequence of VHR radar imagery from TerraSAR-X sensor (0,7m), it allows the recognition of changes with the minimum area of 100 m^2. This product is going to improve the awareness of permanent and temporal changes in the border zones, like the appearance or disappearance of big buildings, groups of trees, temporal settlements or parts of the infrastructure.

2. Service 2: Border accessibility and permeability assessment

PRODUCT 1: **Border Permeability Index Map**

The Border Permeability Index Map is a cartographic product planned to be used at a strategic level and is developed on the basis of the previous analysis on the Permeability Index done in Join Research Centre (JRC). The map is created by spatial modelling of many input datasets as land cover maps, DEM, infrastructure network or weather condition information. It covers area of 20 km on each side of the Polish – Ukrainian border and analyses the easiness with which the border area can be crossed by illegal migrants on foot. This takes into account the easiness of walking in different terrain conditions and the possibility to remain unseen by other people while walking.



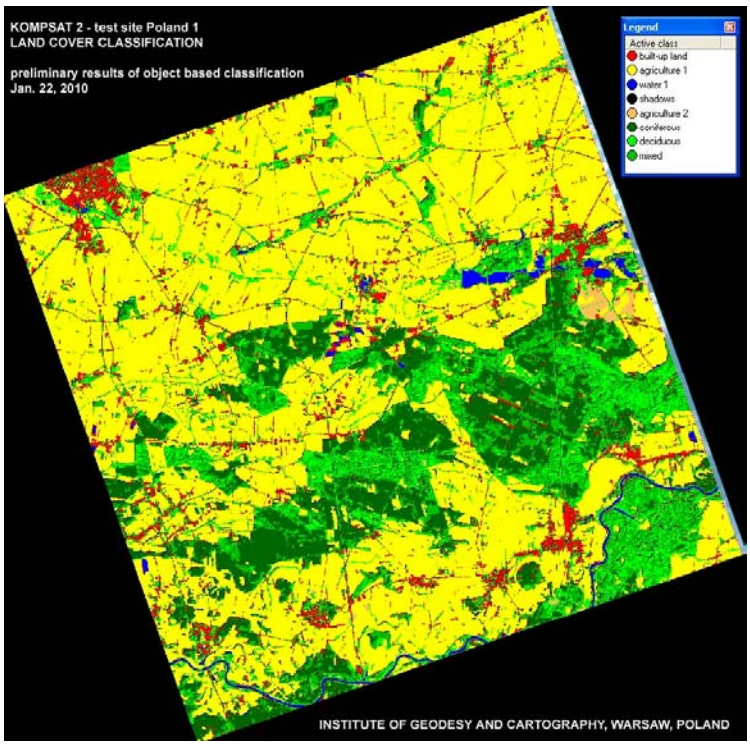
Border Permeability Analysis and Border Permeability Index Map

PRODUCT 2: **Accessibility Map**

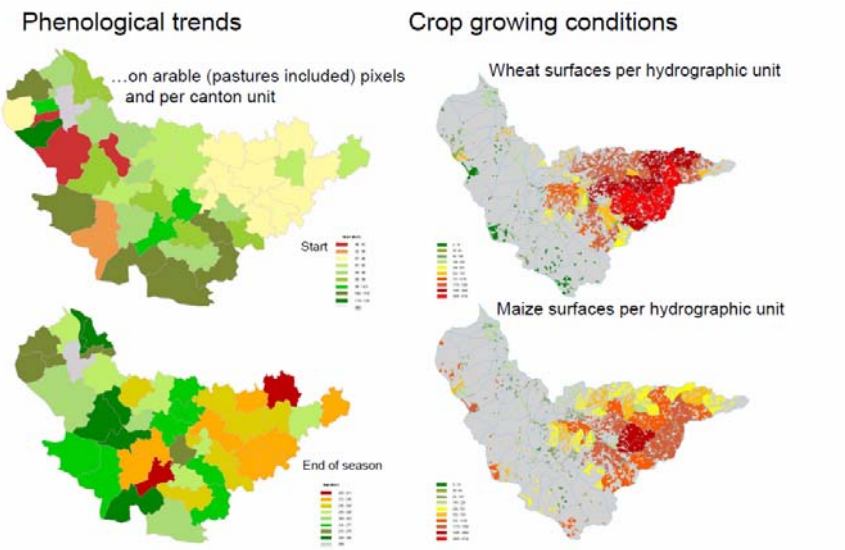
The Accessibility Map aims at analyses of terrain conditions for a walking person in order to estimate the distance that can be covered by that person in defined periods of time (minutes). The map covers the area of about 100 km^2 and is composed basing on VHR data that is 2nd product of 1st service - Detailed Land Cover/Land Use map. This product can serve as a source of information for planning the dispatch of troops in case of noticing of intruders in the border zones.

Space Research Centre plays important role in the **geoland2** project (co-funded by EC within the 7th FP). SRC coordinates one of the core mapping services, i.e. **SATChMo** (Seasonal & Annual Change Monitoring). SATChMo can be divided into four main groups of coherent products: Area Frame Sampling (AFS) Europe, AFS Africa, Vegetation Phenology (MR products) and Global Land Cover Change.

After more than one year of Geoland 2 project duration the final SATChMo products description and processing workflow have been developed. First processing steps were implemented.



Example of object-based classified imagery, IGiK®



Example of MR products, ITF®

In year 2009 two new projects funded by EC in the frame of the 7th FP have started. The first is called **G-MOSAIC** (GMES services for Management of Operations, Situation Awareness and Intelligence for regional Crises). Project aims at identifying and developing products, methodologies and pilot services for the provision of geo-spatial information in support of EU external relations policies and at contributing to define and demonstrate sustainability of GMES global security perspective. The project is led by Telespazio. SRC is involved in the work package **Routes and Borders** which objective is to monitor the migratory routes extending from politically unstable countries to third countries borders. To meet the requirement following services will be developed:

- Monitoring of (military) activities and border-crossing and related infrastructure along the borders
- Long range migration routes and temporary settlements along the routes.

The services methodology was defined and service specification was proposed. Extended Border Permeability Index was found as a basic product of the Routes and Borders work package. The EBP Index will include algorithms and processing chains already elaborated in the previous and ongoing projects (GMOSS, LIMES).
In 2009 several meetings with potential national end users of the services (Polish Ministry of Interior and Administration, Polish Ministry of Foreign Affairs, Polish Military Intelligence Service, National Defense University, General Staff of the Polish Armed Force) took place.

In the end of 2009 the GEONetCaB project has started. The GEONetCAB acronym stands for **GEO Network for Capacity Building.** The project activities are closely related to the GEO (Group on Earth Observation) work. The purpose of GEO-Net-CaB project is to create the conditions for the improvement and increase of the GEO capacity building activities and framework, with special emphasis on developing countries, new EU member states (and EU neighbouring states) and climate monitoring and will serve the bigger goal of improved effectiveness and efficiency of GEO capacity building for application in the GEO societal benefit areas. Coinciding with this purpose, successful brokerage with (potential) clients for earth observation products and services will be facilitated. SRC is responsible for providing the information about current situation in Poland, bottlenecks, opportunities in the EO context.

Remote Sensing Club of the Polish Geographical Society

It gathers about 40 members involved in remote sensing research and development activity. Within statutory activity of the Remote Sensing Club, four new volumes of “Remote Sensing of the Environment” (“Teledetekcja Środowiska”, in Polish) were issued in 2007-2010, with 34 scientific articles. Three conferences were organized, in Warsaw in 2008 and 2010, and in Cracow in 2009, each with 160 participants.

Activities related to record flood in Poland in 2009

Another activity of remote sensing research groups in Poland, with IGiK, SRC PAS, Warsaw University, IMGW, and other entities involved, was the live support of local and national authorities in managing the flooding crisis in Poland in summer 2010. Mid May 2010, a succession of rainy and windy fronts caused flooding in southern Poland, the most affected regions being Silesian, Subcarpathian (Podkarpackie), Opole (Opolskie), Świętokrzyskie and the area of Kraków. On the 20th of May, 6 deaths were reported with approximately 3 500 persons being evacuated along the Wisla River, in particular in Kraków and Sandomierz. The floods led to the closure of schools, bridges and, e.g., the Auschwitz-Birkenau site. Numerous roads and railroads were under water, 2 dams, dikes and bridges broke, power cuts affected several zones, including part of Kraków and surroundings cities. European SAFER (Services and Applications for Emergency Response) was triggered by the National headquarter of the State Fire Service. SAFER products were produced by SERTIT (http://sertit.u-strasbg.fr). Polish GMES community organized itself spontaneously, analysed satellite maps 24 h per day and cooperated with the Crisis Management Centres, delivering needed information. There were two waves of flooding, and critical situation in Poland prolonged for more than one month covering nearly all Polish territory. SAFER has proven to be a crucial tool in this crisis management.

4. ASTRONAUTICS AND SPACE TECHNOLOGIES

Compiled by Piotr Orleański

SPACE ENGINEERING ACTIVITIES IN POLAND

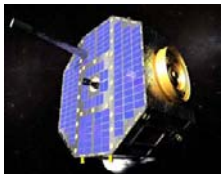
The activities were focused on international scientific satellite projects. Most of them were ESA missions. The projects are in different phases — a few of them have been already launched and still are delivering the scientific data from space, a few wait for the launch, the others are in phases B or C/D.

The data from INTEGRAL (ESA, Gamma Ray Laboratory), Mars Express (ESA, Mars Orbiter) and Demeter (CNES, Earth Orbiter for plasma investigations) satellites is still collected and used for scientific activities.

International Rosetta Mission is a Cornerstone Mission in ESA Science Program; its destination is short-period comet 67P/ Churyumov-Gerasimenko. Rosetta was launched on 2 March 2004 by an Ariane-5G rocket from Kourou, French Guiana. The Space Research Centre of the PAS was responsible for mechanical and electronic engineering and manufacturing of the MUPUS penetrator (including thermal sensors and densitometer), the MUPUS main electronics, and flight software. The journey to the comet lasts 10 years: the polish instruments waits for the last phase of the mission when MUPUS penetrator will be landed on the nucleus of the comet in November 2014.

The Coronas was the Russian program for studying the solar physics and solar-terrestrial relation using a series of satellites that provides for three solar-oriented spacecrafts to be placed on the near-Earth orbit. The CORONAS-Photon, third spacecraft of this series, was successfully launched on 30 January 2009 from Plesetsk Cosmodrome. The satellite carried aboard the Polish X-ray spectrophotometer SphinX. SphinX has been developed entirely in Wroclaw Solar Physics Division of SRC PAS and was the most sensitive instrument in orbit taking measurements of the solar X-ray flux and spectra in the energy range above 1 keV. The scientific results were collected up to December 2009 when the all scientific instruments on the satellite were turned off due to the problems with power supply.

In the frame of India/ESA Chandrayaan-1 Project to the Moon the IR spectrometer SIR-2 has been designed and manufactured in MPS/Lindau, University of Bergen and Space Research Centre of PAS. SIR-2 used a linear InGaAs photodiode array (900 to 2550 nm). SRC was responsible for delivery of 10W Power Supply Unit (PSU), the Programmable Current Source for IR detector cooler and the House-keeping System. The maintenance of the Flight Model of PSU Unit has been performed during the whole year of 2008. Chandrayaan-1 was successfully launched on 22 October 2008 from the Satish Dhawan Space Center in Sriharikota, India, using ISRO's four-stage PSLV launch rocket. After almost 300 days of successful operations on the Moon orbit the mission has been lost in August 2009.



IBEX (Interstellar Boundary Exploration) is a NASA Small Explorer satellite mission to study the interactions of the solar wind colliding with the inflowing interstellar matter. IBEX is the first spacecraft to image and map dynamic processes taking place in the outer Solar System in the region known as the heliospheric interface. The IBEX mission was successfully launched from the Kwajalein Atoll in the Pacific Ocean on October 19th, 2008. After some time necessary for the final stabilization of the orbit (high inclination, highly elliptic type, with the apogee of 50 Earth radii) and the commissioning phase operations, the first scientific data were delivered to the ISOC (IBEX Science Operation Center) in the middle of January, 2009. In the frame of the cooperation between the Space Research Centre group and the IBEX project scientific team, two packages of the simulation programs were developed and delivered to ISOC center. The first (engineering) software packet from SRC is designed to simulate the Star Sensor output signal during the IBEX mission and to predict the experiment conditions. The second (scientific) software packet is designed to calculate the transmission function of the energetic neutral atoms (hydrogen and oxygen), i.e. to determine their energy change and survival probability within the heliospheric environment between the termination shock and the IBEX detectors.

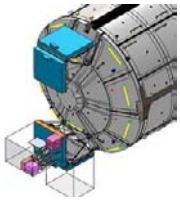
ESA Herschel space observatory will give astronomers their best view yet of the universe at far-infrared and sub-millimeter wavelengths, bridging the gap in the spectrum between what can be observed from ground and earlier space missions of this kind. Herschel was launched on 14 May 2009 on an Ariane-5 rocket. In less than six months, Herschel has reached its operational orbit around a point in space known as the second Lagrangian point (L2), situated at 1.5 million kilometers away from the Earth and started the observation campaign. Space Research Centre is involved in the HIFI experiment onboard Herschel satellite. SRC developed LCU – the control unit for Local Oscillator subsystem in HIFI instrument was switched on and worked up to 3 August, when the failure occurred due to the combination of few subsequent events. As it was reported at

the end of investigations the most probable sequence of failure started from SEU effect in RAM and finally resulted in broken diode inside one of DCDC converters in LCU Main Unit. After almost half of year of investigations the LCU Unit (and whole HIFI Instrument) has been finally repaired and switched on for normal scientific operations in January 2010.
The Flight Models of two instruments for Russian missions have been delivered for final integration on the satellites.

The Mexican-Russian nano-satellite project UNAMSATMAI is dedicated to monitoring the ionospheric plasma response to the seismic activity and to monitoring the electromagnetic near Earth environment. The group from Space Research Centre PAS developed and constructed the DC/DC module and designed the ultra light antennas and deployment units.

On board the ISS, in the Russian segment will be placed the new experiment called „Obstanovka" (the name means „Environment"). One of the instruments is the radio antenna (RFA), dedicated to measure natural and man-made electromagnetic emissions in the frequency range 100 kHz up to 15 MHz. The RFA is developed jointly by the Space Research Centre of the Polish Academy of Sciences (SRC PAS), Warsaw, Poland, and the Swedish Institute of Space Physics (IRF), Uppsala, Sweden. A few projects are actually in B (or early C/D) phases.

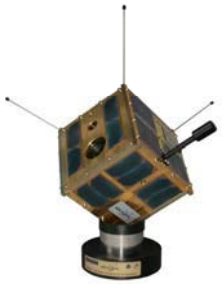
BepiColombo is Europe's first mission to Mercury. It consists of two orbiters, one for planetary investigation and one for magnetospheric studies. They will reach Mercury in 2019 after a six-year journey towards the inner Solar System to make the most extensive and detailed study of the planet ever performed. The 'Mercury Planetary Orbiter' (MPO), under ESA responsibility, will study the surface and the internal composition of the planet at different wavelengths and with different techniques. The Mercury Magnetospheric Orbiter (MMO), under the responsibility of the Japan Aerospace Exploration Agency (ISAS/JAXA), will study the magnetosphere, the region of space around the planet that is dominated by its magnetic field. Space Research Centre is involved in the MPO-MERTIS experiment and is responsible for the part of the spectrometer – Pointing Unit (acronym MPOI). MPOI consists of electro-optical system of rotated mirror and IR calibration sources plus the VHDL code located in MERTIS main FPGA chip and used for autonomous MPOI operations. MPOI development is supported by ESA PECS Program.



The Atmosphere-Space Interactions Monitor (ASIM) onboard ISS is proposed for the study of high-altitude optical emission from the stratosphere and mesosphere related to thunderstorms. One of the two main ASIM instruments is Miniature-X and Gamma-ray Sensor (MXGS) designed by the University of Bergen and University of Valencia in cooperation with SRC PAS in Warsaw.

SRC is responsible for the design and manufacture of the Power Supply Unit and its autonomous (FPGA based) Housekeeping System. ASIM PSU development is supported by ESA PECS Program.

TARANIS is a low-altitude CNES micro-satellite mission that will provide a set of unprecedented and complementary measurements on the physics of TLEs (Transient Luminous Events) and TGFs (Terrestrial Gamma ray Flashes). SRC participates in the scientific program of the mission and designs the MEXIC Power Unit (MPU) - the supply block dedicated for the whole TARANIS Payload.



BRITE-PL Project is the real milestone in Polish space activities. The two BRITE satellites will be the first scientific satellites to be fully assembled and tested in Poland, in SRC PAS. BRITE is a new project proposed by the University of Toronto, University of Vienna and University of Graz. Consortium plans to launch on the LEO the constellation of micro-satellites (20x20x20cm, 7kg). Satellites are dedicated for long-term observations of oscillations of bright stars. In 2009 Poland (CAC PAS and SRC PAS) has been invited to the consortium, two BRITE satellites have been proposed to be delivered by Poland in collaboration with SFL (Space Flight Laboratory of the University of Toronto, Institute for Aerospace Studies). The activities in 2009 focused on the preparation of the proposal to Ministry of Science and High Education. The decision for support of the project with three years grant has been made by the Ministry in December 2009.

During 2009-2010, groups of students from two Universities of Technology continued their activities in satellite manufacturing: in Warsaw the PW-SAT small satellite (CubSat Program) is under development; the Wroclaw groups are significantly involved in development of the communications subsystems for ESA ESMO and ESEO student satellites. In 2010, Polish students from Warsaw University of Technology took also part in the BEXUS - Balloon-borne Experiments for University Students. It is an annual stratospheric research balloon program of ESA. Polish students designed and manufactured part of the SCOPE 2.0 (Stabilized Camera Observation Platform Experiment) — the video camera stabilization and control system.

The two new laboratories have been organized in SRC PAS for development of space hardware. Laboratory of Mechatronics and Robotics focuses on the different aspects of space mechanics: thermal and structure analysis, space robotics, precision space mechanisms (plus their control) and penetration of planetary surface (moles). Laboratory of Space Applications of FPGA Circuits, organized on 200 square meters of ESD Protected Area under FOCUS Program of Foundation for Polish Science, focuses mostly on different applications of FPGA in space: reprogrammable

(hardware and software) processing units, CCD controllers, adaptive DCDC Converters.

In the Institute of Aviation (www.ilot.edu. pl) in Warsaw, the New Technologies Centre (NTC) carries out research and development projects in the area of aeronautics and space technology, which include theoretical works, design & analysis, and lab research. Recently, SRC PAS and Institute of Aviation have signed a Letter of Intent to establish a partnership to organize a joint Research Center of Space Technologies in preparation for future Poland's full membership in the European Space Agency. This long awaited breakthrough will certainly boost the development of the space industrial sector in Poland.

In 2010, new law regulations, about public finances and about Polish Academy of Sciences entered into force allowing for the partnership of private and public institutions in scientific results commercialization. Using this possibility a new firm in the space sector emerged in Poland, AstriPL. Astri Polska is a Warsaw-based enterprise being a subsidiary of the Astrium and the Space Research Centre PAS. Its mission is to develop space applications and technologies in co-operation with major Polish space stakeholders including public and private space-specialized organizations. Under contracts of European organizations including European Space Agency, AstriPL runs space technology and applications projects and serves as an information and collaboration facilitation platform for national space related scientific and industrial partner institutions. AstriPL's specialization includes electronics, optoelectronics, GNSS and Earth Observation applications, robotics, space surveillance and others. One of the main goals of AstriPL is to assist remote sensing and satcom SMEs in development of novel applications. Currently the company is involved in organizing demonstrations of new technologies in real environments, mainly in the security & crisis management sector. The company is strongly focused on enhancing its expertise in technical R&D areas. Since its foundation in mid-2010, the company has been involved in several FP7 projects.

5. SPACE BIOLOGY AND MEDICINE

Józef Kaźmierczak and Ewa Szuszkiewicz

A consortium named Centre for Advanced Studies in Astrobiology and Related Topics CASA* has been signed by five Polish scientific institutions: Space Research Center PAS, Nicolaus Copernicus Astronomical Center PAS, Nicolaus Copernicus University in Toruń, University of Szczecin, and Institute of Paleobiology PAS. CASA* works as an umbrella for scientific activities in the field of astrobiology. The structure of CASA* is that of a consortium that can act as an entity with legal identity. The legal identity is that of the University of Szczecin. The coordinator of CASA*, Prof. Ewa Szuszkiewicz, has the full authorization from the rector of the University of Szczecin to act independently and to conduct all activities necessary to the development of CASA* and of its research provided they are non-profit and in agreement with the statutes of the associated Institutes.

The highly interdisciplinary character of astrobiological studies requires a joint effort of scientists working in the different fields, having their expertise in applying a variety of different methodologies: observing, making experiments, interpreting data, constructing theoretical models and implementing advanced computational techniques.

The centre CASA* conducts, coordinates and promotes interdisciplinary scientific research and relevant technology development concerned with origin, distribution and evolution of life in the Universe.

The integrated research project under the common name "Through the cosmic dust to DNA" covers a whole range of topics which are of high relevance to astrobiology. Among others they are search for planets outside the solar system; origin, structure and evolution of planetary systems; effects of ionizing radiation on organic and inorganic molecules; mutagenic properties of ionizing radiation; search for life in extreme environments; creation of necessary conditions for appearance of life in the context of evolution of the early Universe; and carbonate and siliceous minerals and sediments as carriers of traces of extant and past microbial life.

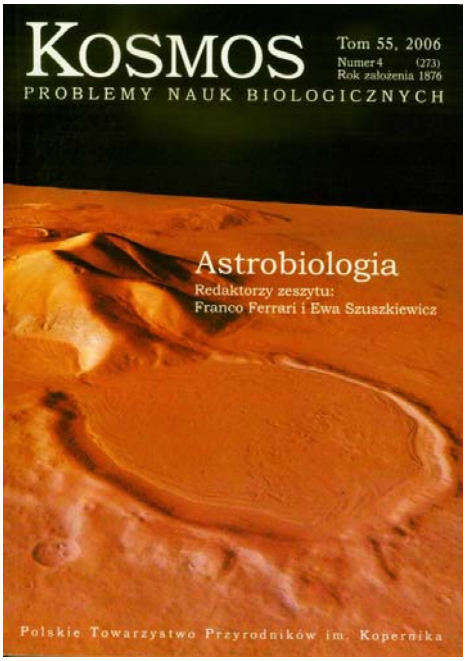
Scientific interest related to astrobiology of the groups composing CASA* are following:

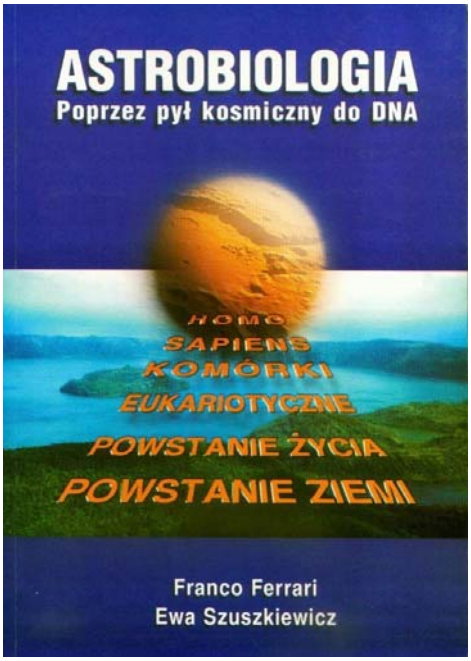
- astronomy (E. Szuszkiewicz, J. Krełowski, M. Różyczka) - planet formation, astrophysics, astrochemistry;
- physics (F. Ferrari) - protein evolution and effects of the cosmic radiation on living organisms and their evolution;
- medicine, genetics (J. Lubiński, B. Górski) - applications to space explorations, effects of cosmic rays on humans;
- paleobiology (J. Kaźmierczak, B. Kremer) - carbonate and siliceous minerals and sediments as carriers of traces of extant and past microbial life;
- microbiology (W. Deptuła) – extremofiles;
- space physics (M. Błęcka) – planetary atmospheres;

Prof. A. Wolszczan (astronomy, exoplanets) is one of the founding members of CASA. Another affiliate is prof. J. Tarasiuk, a biochemist working in the subject of the development of new medicines.

CASA* is a member of the European Astrobiology Network Association EANA. CASA members take part in the expert group working on the scientific program of ESA ExoMars mission named GEOMICROPAL; they also participate in the tests of scientific instrumentation Mars Analytical Microimager (MAM) devoted to search for life on Mars.

Education is an important ctivity of CASA*. Workshops on Astrobiology are organized for Polish university students (see Figure 1), with lectures on astronomy, astrophysics, planetology and paleobiology, delivered by Polish professors distinguished in their fields. At the Szczecin University, students have had possibility to listen to the European Astrobiology lectures within the 2nd Astrobiology Course ABCnet.





CASA also edited and issued two review Volumes about astrobiology in Polish language: "Astrobiologia: Poprzez pył kosmiczny do DNA", published by Szczecin University (2006), and "Astrobiologia", in *Kosmos (Problemy Nauk Biologicznych)*, Vol. 55, No. 4, 2006.

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