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African girls pumping water in a village, photo: shutterstock.com

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Table of Contents

Climate change and other global crises viewed from space

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Abstract

Space technology is an indispensable part of modern-day existence. Earth Observation satellites are essential in detecting high impact natural phenomena on our planet's surface and atmosphere, in outer space, as well as human activity and influence. There are numerous international organizations operating satellite systems and Hungary plays a crucial role in this sector. This paper reviews the importance of the data provided by satellite systems and how they can be used, and ultimately argues for an expansion of their use.

The research below examines a number of practical sectors that are improved by the use of satellite-provided information. Low-orbit observation satellites carry out land monitoring which helps us understand and react to extensive territorial disasters (such as forest fires and droughts) and agricultural trends. Detecting clues left by human activities such as migration routes can help us improve our security by deploying forces and by providing help where it is necessary.

The paper also takes a look at what atmospheric monitoring can teach us about the human impact on climate change with statistics provided by observation satellites proving anthropomorphic impact. Beyond that, the paper also discusses solar and interstellar impacts on our lives, as well as possibilities in outer space.

Keywords: climate-change, space technology, low-orbit observation

Our home, planet Earth faces many worrying events in the present and just as the technology available for us advances day by day, our challenges become more and more complex. Climate change is one of the greatest issues modern man faces, so taking advantage of the current high-tech sector, and making use of space technology is something we cannot afford to neglect. Aside from the already existing services, which became part of our daily life, the opportunities presented by such a fruitful territory of science could help us ensure the safety of our countries and the future. In this article, I will introduce several projects, which already support us in the process of understanding the great changes in our surroundings. Only by integrating the best methods created by us can we achieve the betterment of our present and future.

When we first left the bubble of our atmosphere and stepped out of the protection of our planet, we caught a glimpse of the highly complicated system that we are part of. We just realized, how little we know of the "spaceship" we all live in, the one we call the biosphere. It contains adaptive feedback mechanisms of physical, chemical and biological processes; also, each of them is strictly necessary for the presence of life and our survival. A good example would be the Earth's electromagnetic shield, which as the name suggests, shields us from the deadly amount of solar radiation from the Sun. Though it is a necessary criterion for life to exist, it is not enough alone. The massive water reserves in the icecaps, the oceans' ecological effects, and the diverse vegetation itself cooperating through countless feedback mechanisms provide the perfect habitat for other lifeforms, and humans themselves. Space research and space activity might just be the best resource to follow up on several global phenomena, such as climate change, but also migration and many others. Nowadays our knowledge of global warming mostly relies on space technology through global observations made by satellites and other devices. These measurements taken by such types of equipment on the Earth's orbits are irreplaceable and they are the basis of any models created for worldwide changes.

One would think, that only the traditionally referred superpowers can afford to launch satellites since sometimes they are quite resource-consuming, but among the most important Earth Observation or EO sats many are sent by Asian, South American or even African countries. Hungary also contributed greatly to this network of global information collecting through the Sentinel satellite family, which is owned by the EU, but designed and operated by the European Space Agency (ESA) and a Hungarian company supplied its various elements.

So, for what reasons are we observing the planet? What can we see exactly? Marine, atmosphere and land monitoring, emergency management, natural disaster forecasting, security observations and climate observations are just some of the major possibilities in space technology and satellite programs. These services are in many international organisations' capabilities, just as the EU's satellite network, the Copernicus program.[1] Nine of the previously introduced Sentinel device family is in low Earth orbit as being part of the Copernicus network. As I mentioned previously, land monitoring is an important feature of this program that explains why it is necessary to invest in these areas of science. Precision

[1] European Space Agency.

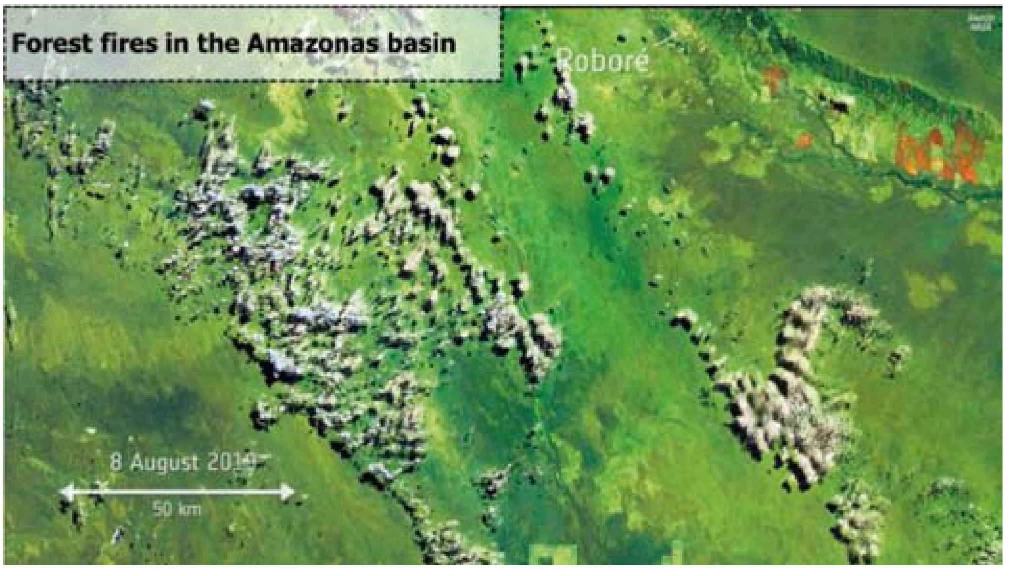
agriculture is a sector, which completely relies on the help of satellites, supporting farmers all around the world. With this method, we can easily measure the number of agricultural products, crops and even estimate their quality, all up from space. This could not have been possible a few decades ago, since these data cannot be acquired from the surface. Through the EU's LMS (land monitoring service) biophysical monitoring, mapping, spatial and urban planning, forest management and water management became accessible to many countries, as well as acquiring data regarding the acclimatization to climate change. Numerous models regarding the protection of national parks and important territories of vegetation rely on these LMS databases to present the changes in forests through the years.

The monitoring of droughts is an essential part of science centred on ecology. Not many people could argue about the importance of such research projects since water is of cardinal value, which cannot be replaced by any other substance on our planet. Droughts cause countless terrible problems around all the continents, from China and India to Africa, Australia and the Americas. The uncontrollable bushfires and disappearing ancient forests are now far from being simply frightening news on television even to the Hungarian people. As of 2021, Lake Velencei has started to lose a significant amount of water. As the problem escalates, more and more people will feel the consequences of it in their daily lives. With satellites, the extensive territorial disasters can be localised, so we can take proper actions to minimise the damage to our surroundings. A good example of this could be the forest fires in Siberia in 2018, which were recorded with synchronised monitoring from space by the Sentinel devices, but I could also mention the Amazonian forest fires recorded in 2019.[2]

Atmosphere monitoring services are another major project under the EO satellites. The most well-known area of use for these installations is the observation of CO_2 levels around the globe. With this technology, we can measure the amount of CO_2 emission above various industrial areas, and the consequences of forest fires can be easily seen as well. It is often used to create maps and models representing the most polluted areas. This also helps us in localizing the territories, which are in dire need of remodelling regarding the use of sustainable energy. The previously mentioned forest fires are not only a threat to the vegetation but also contribute to exponentially rising CO_2 levels. What we can see based on these recordings and models is that the northern hemisphere, where the proportion of land to water is more than in the southern hemisphere, tends to produce a greater amount of carbon dioxide, especially in the winter, when the flora cannot be used as a buffer as effectively. Regarding the state of the Arctic icecaps and other areas, like Siberia,

[2] NASA Earth Observatory 2020.

it explains the rapid decrease of frozen fresh water in the north. Meanwhile, in the southern hemisphere, the extensive and rich vegetation, like the Amazon rain forest can act as a regulator of this tendency. Although in 2019, when many forest fires took place in the South American continent, or regarding the 2020 Australian bushfires, the rise of the CO_2 concentration in the atmosphere was due to the burning flora.



Forest fires in the Amazon basin, taken by a satellite, source: NASA

With the atmosphere monitoring services, we can measure the air quality in detail, regarding pollen concentrations and other components, which affect the local population's health. The source and the origin of these polluting elements are also part of the data that can be acquired. Lastly, the forecast services and warning systems rely greatly on these satellite network systems.

Observing land and water surfaces can add to security-oriented databases as well, supporting the border protection of countries. Masses of people traveling from Africa and the Middle East created migration-related issues in Europe that have only worsened since 2016. Satellites can detect the trends of illegal border crossings, not only by land but also by sea. Maritime surveillance is carried out in partnership with the European Maritime Safety Agency (EMSA), while border protection is possible with the cooperation of FRONTEX. The European Union also acquires the assistance of satellites when preparing for various external actions.

Not only can we monitor the migration routes and deploy appropriate forces to the affected areas, but also, based on these collected data, we can help people in life-threatening situations, especially when they are travelling by boats.

Aside from the Earth's Observational satellite networks, life without devices around the orbit is unimaginable nowadays. It is simple enough if we think about communication or navigational systems, coordinating the freight non-stop between all the continents. In addition, aside from air travelling companies and shipping services, during the major lockdowns and quarantines in the current pandemic, we all came to know the importance of telecommunication. The assistance that came from the satellite families helped us overcome the problems of social distancing and made education, along with most types of work possible through the internet.

Hence, the EU has focused on working on projects such as GOVSATCOM, GALILEO, ARTES and EGNOS investing a total budget of more than 14 billion euros. With the help of these funds, we are now able to connect people, places and economic sectors, better than before, all around the world.

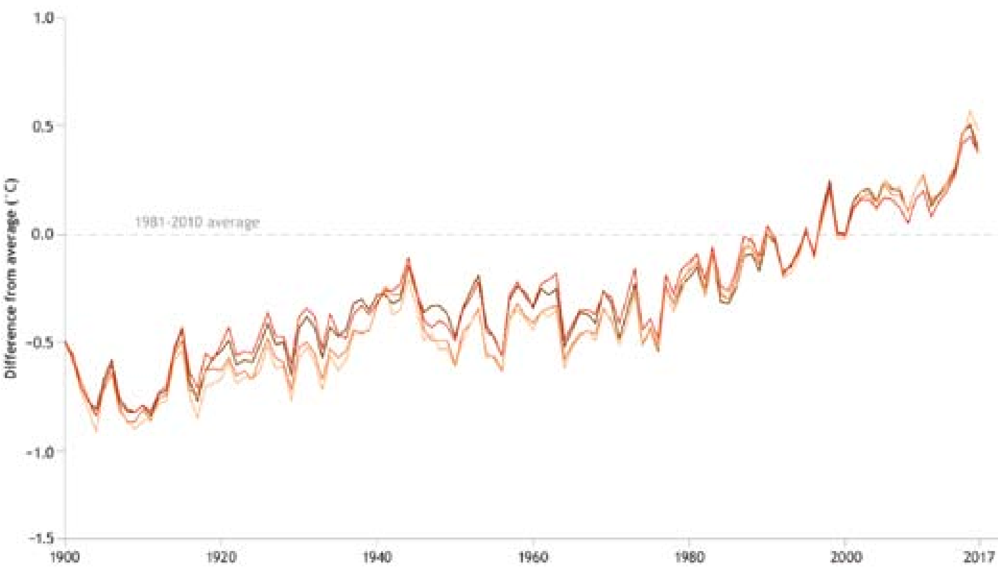
Aside from the ESA and EU programs, the Hungarian government also concentrates greatly on a national strategy regarding this high-tech sector. The most important areas of the Hungarian space strategy emphasise the significance of research and education since the future programmes are mostly based on today's efforts.[3] The achievements of these sectors can be later implemented in the Hungarian industry as well as the protection of borders, and the national security. Since the latter are highly associated with diplomacy, it is crucial to focus a sufficient amount of resources on space. Many investments already came to fruition in the field of agriculture, meteorology or communication, but we could also mention security and protection services.[4]

The governmental structure of the Hungarian space activity consists of three different levels. Each level represents authority in a hierarchical position. The entire area belongs to the Ministry of Foreign Affairs and Trade, which is represented by Minister Péter Szijjártó. Under his authority works the Ministerial Commissioner for Space Activity, and ESA Head of Delegation. Lastly, the department under that level of decision-making is the Department for Space Activity, currently led by a Head of the Department. Hungary was the first to remodel this sector, and place it under the Ministry of Foreign Affairs and Trade, to make international cooperation much easier. It helped in creating a lot of MOU (Memory of Understanding),

[3] Lechner Tudásközpont.
[4] Országos Meteorológiai Szolgálat.

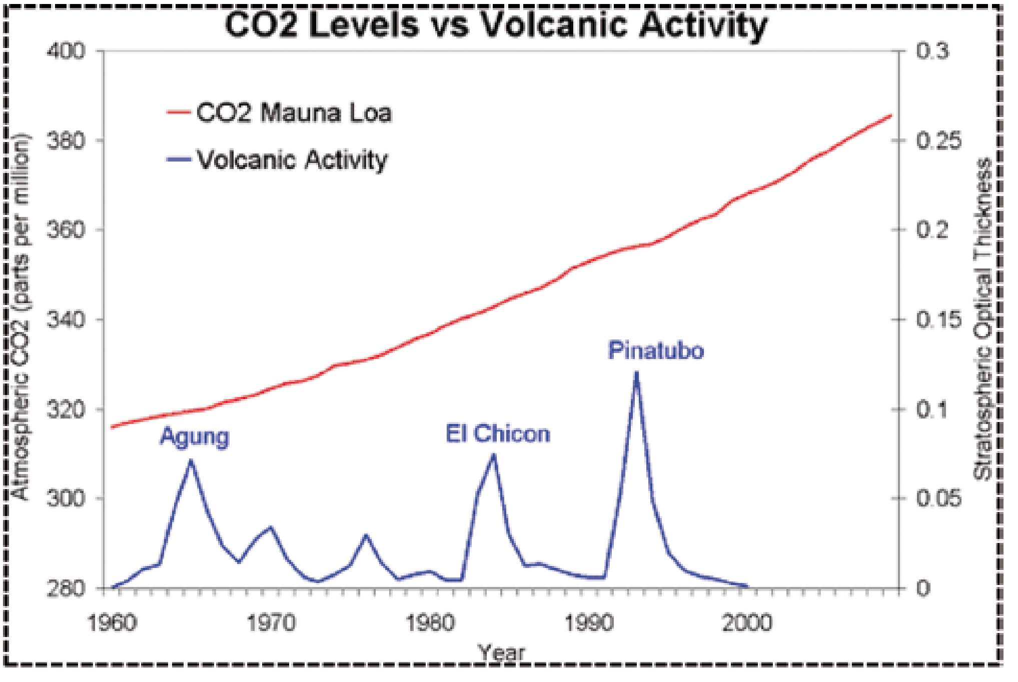
and agreements with different partners from Brazil to Finland, from Singapore to Israel. We could also organize successful negotiations with various actors of the civil sector as well, for example, the Virgin Galactic company from the United States of America. Other cooperation and contracts are underway with Axiom Space.

As mentioned previously, the space sector provides irreplaceable information along with terrestrial measurements regarding climate change. This creates a scientifically accurate basis as evidence of human responsibility in the current ecological problems. By measuring the average yearly temperature in Hungary, the continuous warming up of the country is indisputable. The yearly amount of tropical nights is also on the rise, which means a temperature above twenty degrees Celsius. This tendency can be seen everywhere, worldwide. The average temperature right now is around 0.8 degree Celsius warmer, than at the beginning of the 20th century. This change is in correlation with the rising levels of CO_2 in the atmosphere that show the same exponential tendency. It is said, that through the Earth's periodic changes, glacier and interglacial eras followed each other, with different levels of carbon dioxide concentration. So one could say that the current tendency is due to something unrelated to humankind, but by observing the rapidness of this warming, and the exponential growth of CO_2, we can clearly see, that this is not a natural phenomenon.



The average surface temperature of the Earth from 1900 to 2017, source: NOAA

This correlation is already proven by scientific means, for example, the data recorded on Mauna Loa, on a Hawaiian base of the NOAA (National Oceanic and Atmospheric Administration) which works with atmospheric research alongside many others.[5] Overall, the graveness of this issue is clearly presented through the scientific community, and no argument can stand against it. Volcanic eruptions provide an insignificant amount of CO_2 compared to industrial areas. The strange and rapid rise in air pollution can also be traced back to the industrial revolution, since the major changes started mostly in the last century. This is something we can easily tell using ice samples, measuring and comparing the carbon-dioxide levels of old and newly formed ice. Another important field of research concentrates on the state of the Arctic ice because not only the quantity, but also the quality of this frozen territory matters greatly for the normal operation of the biosphere. Models show, that every year, the amount of "old ice", which had formed many years prior to the modern measurements, decreases as the warming climate speeds up the deterioration of the polar caps. This proportion of "old" and "new" ice diminishes gradually, which is problematic since newly formed ice is much less durable than the old one. Over the years, the newly frozen ice slowly replaces the unmelted old ice, which indicates the grave changes of the North Pole.

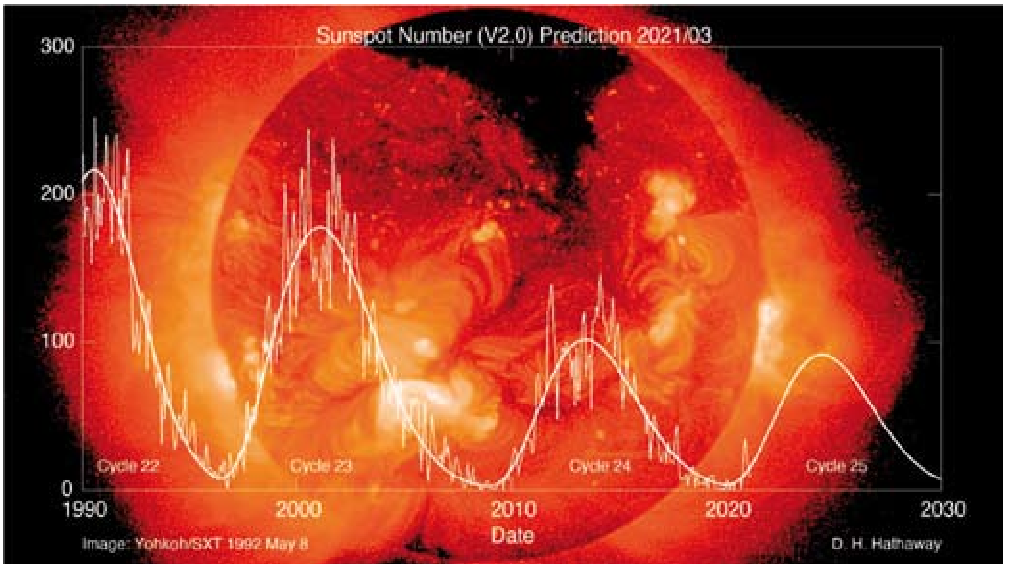


Based on the data of Mauna Loa, source: NOAA

[5] National Oceanic and Athmospheric Administration.

Another indicator of the industrial origin of the rising carbon dioxide level is that the different isotopes of carbon detected in the atmosphere, with different half-lives can show us that human activity produced them artificially.

Earth and the planet's surroundings are not the only focus of our space devices. The Solar System's most important component, the Sun also influences our daily life and future. Research concentrates on the cyclic functions of our star, observing sunspots and other variables. These studies also tried to find out whether there is a correlation between the Sun's activity and the global rise of temperature and carbon dioxide levels, but so far, it seems that the fluctuations in the Sun's activity are not relevant in this matter compared to human influence.



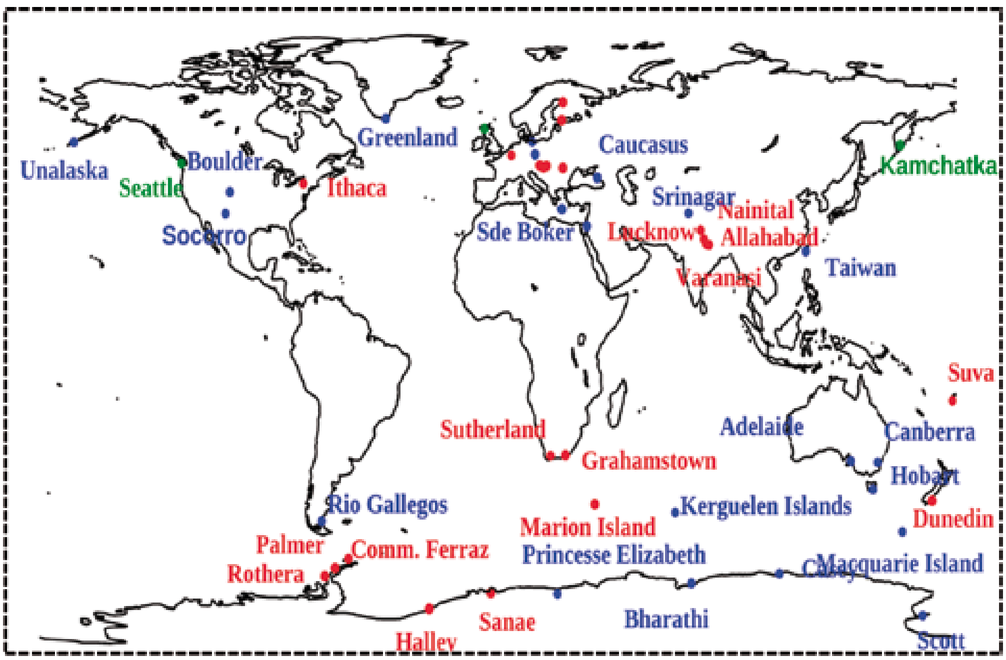
Periodicity of the detected and predicted sunspots from 1990 to 2030

What else can we see through the eyes of EO satellites? Observations about oceanic emissions and absorption are the key to understand the great system that we live in. As it is known, the sea provides a habitat to its own microscopic vegetation called phytoplankton. Billions and billions of unicellular and more complex forms of life from cyanobacteria to eukaryotes make up this crucial part of the ocean's wildlife. As we know, twenty-five percent of our CO_2 emission gets absorbed by the oceans because of the phytoplankton. Although they are not visible to the naked eye, we can measure their concentration through the EO sats.[6] They contain chlorophyll, which gives a green discoloration to the surface of the waters in high density. This indicator can be the base of the maps the satellites create using images from space.

[6] European Space Agency 2017.

The greener the area, the more phytoplankton there is. Using this method, we can gather important information regarding the distribution of sea vegetation, and from the models, it is clear, that the absorbing territories are located along coastlines and in shallow areas. Hence, the dominant emitting part of the oceans is in the centre of the water mass. While the most absorbent locations are where humans interfere with the marine ecology the most. The amount of chlorophyll that we detect can represent the density and size of the crucial phytoplankton populations, so their increase or decrease can also be detected along with the CO_2 emission and absorption just like the breathing of an organism.[7] This is yet another feature of the Earth Observation satellites.

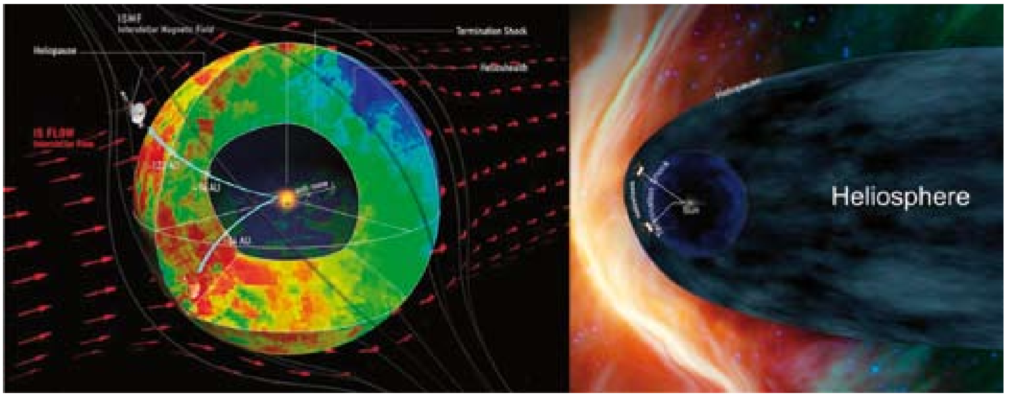
However, if we return to the planet's surface, we can find Hungary's participation in numerous earthbound projects as well. AVDANet, a network around the globe made by Hungary has stations on every continent, including the Antarctica.[8] The system is built and operated by the Eötvös Loránd University of Budapest (ELTE), and its main goal is to study electromagnetic occurrences in the atmosphere to create references to satellite databases. This research helps in expanding our knowledge regarding atmospheric processes in details that had not been available before.



The locations of stations of AVDANet, souce: ELTE

[7] Copenicus – Europe's Eyes on Earth.
[8] National Centers for Environmental Information.

Therefore, with the manufactured devices that we sent up to orbit over the decades and the surface equipment that we built, humanity developed an important and vulnerable network of technology. Studying space weather, which affects our planet and the newly created techno-sphere around it, is not concentrated only on our Sun and the Earth. The whole Solar System, and the way it interacts with the galaxy, and interstellar space is an important matter to investigate. Just as our planet has its own electromagnetic shield, that surrounds us like a bubble, the sun owns a much greater field of protection containing the whole Solar System. The heliosphere of our system protects us to a certain degree. Without these protective shields, life would be unimaginable on Earth. As we interact with our star, the Sun also interacts with the other parts of our galaxy, the Milky Way itself. Studying the structure of these forces can equip us with better insight into the dangers that affect us but remained unknown for centuries.



The structure of the heliosphere, source: NASA

The universe is not a "friendly" space. Even our relatively quiet star can cause tremendous harm to our ecosystem, and the technological infrastructure. The Sun's bursts have to be monitored to prevent unforeseen incidents. History's most known example of such an occurrence would be the Carrington event, which was due to a powerful solar flare, it was so strong, that the Aurora Borealis could be seen in Hawaii for days. The geomagnetic storm took place in September of 1859. Although, at that time humanity did not have the complicated electric systems of today, which could have been greatly damaged by this event, it was still recorded in history. We can only imagine the catastrophic consequences that we would have to face if a solar outburst of such scale reached Earth today. The chances of something like this happening are a terrifying one in eight.

Human impact is also a huge factor in changing the planet's surface. An interesting fact is that by satellites, we can clearly see the border between two countries, which was previously just a line drawn on a map. Here the reason is that different agricultural methods left Israel with a greener landscape compared to its neighbouring countries. The border between Egypt and Israel can be observed from space mainly because of the strategies regarding the preservation of vegetation and nature. This is one of the best examples of how we can create great changes with the correct regulations and laws. We should not forget the huge impact that we have on our surroundings, even if we tend to ignore it when we concentrate on the scale of the events around the globe. When it comes to long-term effects, everything can count.[9]

The border between Israel and Egypt

However, studying the global processes in their entirety and making sufficient models including each factor is a step that we must not skip. Only after the correct research, can we start to create adequate measures for the betterment of our current situation. At this point space technology is a necessary element. From communication and other services to climate research, space activity provides numerous opportunities, which are unavailable by any other known methods. As many countries have decided to invest in this territory, more than eighty of them have already sent satellites into space. In 2016, the value of the space market was estimated to be 339 billion US dollars. We still struggle to grasp the rapidness of this evolution in technology that will become a major aspect of the economy. Between 2024 and 2030, missions to

[9] Skeptical Science.

Mars are being planned, and the activity of many countries with the lunar projects in mind is increasing as well. Soon it will be revealed how the "value of space" will change our complete economical structure. It is enough if we think about mining in the Solar System, and transporting the raw material back to Earth. So far, there have been attempts to estimate the profit generated by asteroid belts, but what seems more likely in our near future is a project on our closest neighbour, the Moon.

All in all, life on Earth can only be preserved with a great amount of knowledge about the universe and our surroundings. For the sake of our ecology, expanding our boundaries in almost every aspect of our lives is necessary. Let us pursue the most advantageous route that humanity can take.

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