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Earth Observation – Space Technology

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1. Introduction

For monitoring of the Earth thousands of satellites have been sent into space on missions to collect data related different spheres of the Earth investigations and studies. Today, the ability to forecast weather, climate, and natural hazards, environmental monitoring and ecological issues depend critically on these satellite-based observations. Based on this data it is possible to gather satellite images frequently enough to create the model of the changing planet, improving the understanding of Earth's dynamic processes and helping society to manage limited resources and environmental challenges. Earth observations from space open and makes requirement to address scientific and societal challenges of the future.

Space technologies play the significant role in the sustainable development in national, regional and global level. Modern and advances of the Earth observation techniques are taking a great importance amongst existing traditional technologies. Radar remote sensing is one of the new Earth observation technologies with promising results and future. Interferometric SAR (InSAR) is a sophisticated radar remote sensing technique for combining synthetic aperture radar (SAR) complex images to form interferogram and utilizing its phase contribution to land topography, surface movement and target velocity. Presently considerable applications of InSAR technique are developed. It is an established technique for precise assessment of land surface movements and generating high quality digital elevation models (DEM) from spaceborne and airborne data. InSAR is able to produce DEM with the precision of a couple of ten meters whereas its movement map results have sub-centimeter precision. The technique has many applications in the context of Earth sciences such as in topographic mapping, environmental modeling, rainfall-runoff studies, landslide hazard zonation, and seismic source modeling.

Making observations of the land, sea and air from space allow scientists to develop and improve their models of the Earth. Space instruments provide continuous global measurements of the Earth for many years at a time. Currently this includes to consider following issues:

- Expertise in obtaining information on the surface and atmosphere using remote sensing methods;
- Expertise in modeling environmental phenomena;
- Expertise in and provision of facilities for generating archiving and distributing environmental data;
- Expertise in and facilities for characterizing spectral properties of environmental components;
- Expertise in and facilities for atmospheric research using radars;
- Expertise in the technology and practice of remote sensing at mm and sub-mm wavelengths;
- Carrying out a program of research in aspects of environmental science;
- Developing e-science applications in environmental research.

2. Earth observation systems

It is necessary to emphasize that one of the most important and controversial uses of satellites today is that of monitoring the Earth's environment. Many satellites study features on the ground, the behavior of the oceans, or the characteristics of the atmosphere. Satellites that observe the Earth to collect scientific data are usually referred to as “Earth observation satellites.” Sometimes the interpretation of their data has been controversial because the interpretation is difficult and people have used the data to call for substantial changes in human behavior.

One of the popular satellite for Earth observation the Envisat is an advanced polar-orbiting Earth-observation satellite that provides measurements of the atmosphere, ocean, land and ice. It was launched in March 2002 on an Ariane 5 rocket into an 800km polar orbit by the European Space Agency (ESA). Originally was planned for five years, the life of Envisat has been extended till 2013.

It is necessary to mention that the satellite also helps scientists access data for analyzing long-term climatic changes.

The recent advances and developments in information and communication technologies, education and health care, agriculture and agro-food processing, geo-strategic initiatives, infrastructure and energy and critical technologies and strategic industries have been realized in light of the space technologies. Earth observation techniques which apply optical and thermal spectra of the electromagnetic wavelengths have so far developed considerably. Although there is done a lot in this area beforehand, a long way is still ahead. The background of using microwaves for remote sensing goes far the decades ago while it was remaining in the experimental domain and exploratory status for years. It is only in the recent couple of decades that radar remote sensing techniques have been commercialized and used widely. Radar remote sensing is actually accounted for as a new earth observation technology with promising results and future. Its potentials and capacities by itself and being a strong complementary tool for optical and thermal remote sensing are undeniable currently.

i. Radar and SAR techniques for remote sensing

Obviously, the use of radar systems opens a wide opportunity to reduce an obstacles existing in the traditionally used technologies. For the time being it became very interesting and important explorations and examining a new radar technologies, their unique possibilities to comply the needs and answering the questions that the classic optical and thermal remote sensing techniques have been unable or difficult to tackle has grown the expectation that radar technologies can take place due to a more flexibility in bridging the gaps for sustainable development for which the optical and thermal remote sensing is an important tool while the latter techniques show shortage in some cases and areas.

Currently, radar remote sensing that is mainly developed on the Synthetic Aperture Radar (SAR) technique represents its values and potentials increasingly. Radar is a useful tool for land and planetary surface mapping. It is a good mean for obtaining a general idea of the geological setting of the area before proceeding for field work. Time, incidence angle, resolutions and coverage area all play important role at the outcome.

ii. InSAR techniques

SAR interferometry (InSAR), Differential InSAR (DInSAR), Persistent Scatterer (PSInSAR) is the a new achieved techniques in radar remote sensing systems. By using InSAR technique very precise digital elevation models (DEM) can be produced which privilege is high precision in comparison to the traditionally used methods. DEM refers to the process of demonstrating terrain elevation characteristics in 3-D space, but very often it specifically means the raster or regular grid of spot heights. DEM is the simplest form of digital representation of topography, while digital surface model (DSM) describes the visible surface of the Earth.

Considerable applications of InSAR have been developed leaving it an established technique for high-quality DEM generation from spaceborne and airborne data and that it has advantages over other methods for the large-area DEM generation. It is capable of producing DEMs with the precision of a couple of ten meters while its movement map results have sub-centimeter precision over time spans of days to years. Terrestrial use of InSAR for DEM generation was first reported in 1974. It is used for different means particularly in geo-hazards and disasters like earthquakes, volcanoes, landslides and land subsidence.

2.1 Earth observation satellites

The first satellite to be used for Earth observation purposes was Explorer VII, launched in October 1959. This satellite was equipped with an infrared sensor designed to measure the amount of heat reflected by the Earth. This measurement, referred to as the “radiation budget,” is a key to understanding global environmental trends, for it represents the difference between the amount of incoming energy from the sun and the outgoing thermal and reflected energy from the Earth. But it was not until the launch of the Earth Radiation Budget Satellite (ERBS) in 1984 by the National Aeronautics and Space Administration (NASA) that more authoritative readings of this important figure were obtained. Many Earth observation satellites like ERBS use specialized sensors that operate in non-visible wavelengths like the infrared, allowing them to gather data on many different types of atmospheric and ground phenomena.

The most important early Earth observation satellites were members of the Nimbus series. NASA launched eight Nimbus satellites between 1964 and 1978, with only one failing to reach orbit. Although they started out as part of the weather satellite program, the Nimbus satellites were not weather satellites, but carried a number of instruments for measuring the temperature and humidity of the atmosphere. This was a major advance, for earlier weather satellites like Tiros (Television Infrared Observation Satellite) had only been capable of taking visible light photographs of clouds and could not provide the kinds of traditional weather measurements that meteorologists normally used. Eventually many of the instruments demonstrated on Nimbus, named “sounders,” were incorporated into later weather satellites. Atmospheric sounders are now common on many meteorological satellites, as well as on scientific satellites and even planetary space probes (Belew & Stuhlinger, 1973) , (Covault, 1991).

In July 1972, NASA launched the Earth Resources Technology Satellite (ERTS-1) into orbit. ERTS-1 used advanced instruments to view the Earth's surface in several infrared wavelengths. These sensors enabled scientists to assess vegetation growth, monitor the spread of cities, and make many other measurements of how the Earth's surface was changing. ERTS was so successful that it was followed by two more satellites named Landsat. By the early 1980s, with the launch of Landsat 4, the satellites became an “operational” system rather than an experimental one and their data was heavily used around the world by farmers, urban planners, geologists and environmentalists. Landsat and similar satellites are often referred to as “remote sensing satellites,” a term that is usually used to refer to satellites that focus on the ground rather than the oceans or atmosphere.

In the mid 1970s NASA also conducted numerous observation experiments aboard the Skylab space station. Skylab was equipped with handheld as well as fixed cameras using special film. It also had an array of other instruments. Data the crews obtained during their three visits to Skylab was used to refine the instruments on other satellites, such as Landsat. Skylab also demonstrated the value of other observations, such as tracking icebergs and the breakup of sea ice (Skylab, 1977) .

In 1978 NASA launched SeaSat, an ocean observation satellite with a synthetic aperture radar, or SAR. SAR works by taking several radar images from different positions and combining them to produce a more detailed single image. SeaSat's radar produced detailed images of the surface of the ocean, providing valuable data on waves and the interaction of the ocean's surface with the winds. Although SeaSat's mission ended prematurely due to a malfunction, it demonstrated the immense value of space-based SARs.

Approximately around the same time the United States was experimenting with SeaSat, the Soviet Union launched a similar series of satellites known as Okean. Later, during the late 1980s, the Soviet Union orbited several large radar satellites. These spacecraft, launched aboard Proton rockets, produced radar maps of the Earth's surface and were also used to measure waves on the oceans' surface. In 1991 the Soviet Union launched Almaz-1, which was another of this series of satellites but the first that the Soviet government openly acknowledged. Although they announced that this was a civilian Earth observation satellite and sought international customers, many experts speculated about the military uses of these satellites and their role in searching for objects such as submarines, which can create waves on the ocean surface when traveling at high speed at shallow depths. Because such data has military uses, SAR technology has always been sensitive. Although the Soviets attracted the attention of western military officials, they found no commercial customers for their satellite (SeaWifs projects).

During the 1980s, and 1990s NASA, along with German and Italian participants, conducted several Space Shuttle missions carrying a large SAR in the Shuttle's payload bay. This radar, called SIR (for Shuttle Imaging Radar) produced topographical maps of much of the Earth's surface. The radar equipment was modified several times to collect more accurate data during the latter missions. In February 2000, NASA flew another mission called SRTM, for Shuttle Radar Topography Mission (SRTM), with Italian and German participation. This time NASA used a modified version of the radar capable of obtaining much more precise altitude data. Three-dimensional electronic maps produced from the SRTM data are highly accurate and can be used in aviation to guide aircraft and missiles, even over rough terrain like mountain ranges. In 1991 and again in 1995, the European Space Agency launched the ERS-1 and ERS-2 (European Remote Sensing) satellites. Both were equipped with SARs and were highly successful **[1].**

In 1988 astronaut Dr. Sally Ride led a committee to evaluate America's future in space (Ride, 1987). One of her suggestions was that NASA focus more attention on environmental monitoring in response to increasing scientific discussion of global climate change, a program the agency called Mission to Planet Earth. As a result, NASA started the Earth Observing System (EOS). At the turn of the century, a number of EOS satellites were launched, most importantly Terra and Aqua, to be followed by Aqua's sister-satellite Aura. Terra, as its name implies, is focused upon monitoring the Earth's surface. It is equipped with instruments like MOPITT, the Measurements of Pollution in the Troposphere, and MISR, the Multi-Angle Imaging Spectroradiometer. Aqua has instruments such as microwave, infrared, and humidity sounders. These provide information on clouds, precipitation, snow, sea ice, and sea surface temperature.

In 1992, an Ariane 42P rocket launched a spacecraft named Topex/Poseidon. A joint French space agency (CNES-Centre National d'Etudes Spatiales) and NASA spacecraft, it was equipped with a radar altimeter to allow it to measure ocean topography, or surface features. Data gathered from Topex/Poseidon over years of operation have allowed scientists to accurately map ocean circulation, a key factor in understanding both global weather and climate change. In particular, Topex/Poseidon has been able to track the phenomenon known as El Nico, a warming of the ocean surface off the western coast of South America that occurs every four to twelve years. El Nico affects weather patterns in various parts of the world as well as fish and plankton populations. Another spacecraft, called SeaStar and carrying the Sea-viewing Wide Field-of-view Sensor, or SeaWiFs, was launched in 1997 to study biological organisms in the oceans such as algae and phytoplankton (microscopic marine plants).

In 2002, the European Space Agency launched a large environmental monitoring satellite named Envisat, aboard an Ariane 5 rocket. Envisat, the successor to ERS-1 and 2, is designed to take simultaneous readings of various atmospheric and terrestrial features and contribute to understanding of global change. The data from satellites like Envisat is used to develop complex computer models of how the Earth's environment works and how human activities, like burning down forests or operating automobiles, affects the environment.

For successful Earth observation issues sustainable development can be defined as maintaining a delicate balance between the human need to improve lifestyles and feeling of well-being on one hand, and preserving natural resources and ecosystems, on which we and future generations depend (Parviz, 2010).

In general the seven dimensions including spiritual, human, social, cultural, political, economic and ecological can be considered for the sustainable development where the main components are economy, society and environment. Approaching sustainable development requires establishing a continuous balance between three latter components. An effectiveness of the space technology applications on the environmental, economical and social issues are quite apparent. The recent developments in information and communication technologies, education and health care, agriculture and agro-food processing, geo-strategic initiatives, infrastructure and energy, and critical technologies and strategic industries, construction, engineering and engineering management have been realized in light of the space technologies. Earth observation techniques are considered of great importance amongst these technologies. Earth observation techniques which apply optical and thermal spectra of the electromagnetic wavelengths have so far developed considerably. Although there is done a lot in this area beforehand, a long way is still ahead. The background of using microwaves for remote sensing goes far the decades ago while it was remaining in the experimental domain and exploratory status for years. It is only in the recent couple of decades that radar remote sensing techniques have been commercialized and used widely. Radar remote sensing is actually accounted for as a new earth observation technology with promising results and future. Its potentials and capacities by itself and being a strong complementary tool for optical and thermal remote sensing are undeniable currently.

2.2 Application of radar remote sensing and SAR techniques

As it was previously indicated InSAR is a sophisticated processing of radar data for combining synthetic aperture radar (SAR) single look complex (SLC) images to form interferogram and utilizing its phase contribution to generate DEM, surface deformation and movement maps and target velocity. The interferogram contains phase difference of two images to which the imaging geometry, topography, surface displacement, atmospheric change and noise are the contributing factors.

Satellite-based InSAR began in the 1980s using Seasat data, although the technique's potential was expanded in the 1990s with launch of ERS-1 (1991), JERS-1 (1992), Radarsat-1 and ERS-2 (1995). They provided the stable well-defined orbits and short baselines necessary for InSAR. The 11-day NASA STS-99 mission in February 2000 used two SAR antennas with 60-m separation to collect data for the Shuttle Radar Topography Mission (SRTM). As a successor to ERS, in 2002 ESA launched the Advanced SAR (ASAR) aboard Envisat. Majority of InSAR systems has utilized the C-band sensors, but recent missions like ALOS PALSAR and TerraSAR-X are using L- and X-band. ERS and Radarsat use the frequency of 5.375GHz for instance. Numerous InSAR processing packages are also used commonly. IMAGINE-InSAR, EarthView-InSAR, ROI-PAC, DORIS, SAR-e2, Gamma, SARscape, Pulsar, IDIOT and DIAPASON are common for interferometry and DEM generation.

It is obvious that digital elevation model (DEM) is important for surveying and other applications in engineering. Its accuracy is paramount; for some applications high accuracy does not matter but for some others it does. Numerous DEM generation techniques with different accuracies for various means are used. DEMs can be generated through different methods which are classified in three groups that are DEM generation by:

i. geodesic measurements,
ii. photogrammetry and
iii. remote sensing.

In DEM generation by geodesic measurements, the planimetric coordinates and height values of each point of the feature are summed point-by-point and using the acquired data the topographic maps are generated with contour lines. The 1:25000-scale topographic maps are common example. The method uses contour-grid transfer to turn the vector data from the maps into digital data. For DEM generation by photogrammetry, the photographs are taken from an aircraft or spacecraft and evaluated as stereo-pairs and consequently 3-D height information is obtained.

DEM generation by remote sensing can be made in some ways, including stereo-pairs, laser scanning (LIDAR) and InSAR. There are three types of InSAR technique that is single-pass, double-pass and three-pass. In double-pass InSAR, a single SAR instrument passes over the same area two times while through the differences between these observations, height can be extracted. In three-pass interferometry (or DInSAR) the obtained interferogram of a double-pass InSAR for the commonly tandem image pairs is subtracted from the third image with wider temporal baseline respective to the two other images. In single-pass InSAR, space-craft has two SAR instrument aboard which acquire data for same area from different view angles at the same time. With single-pass, third dimension can be extracted and the phase difference between the first and second radar imaging instruments give the height value of the point of interest with some mathematical method. SRTM used the single-pass interferometry technique in C- and X-band. Earth's height model generated by InSAR-SRTM with 90-m horizontal resolution is available while the DEM with 4-to-4.5-m relative accuracy is also available for restricted areas around the world.

InSAR ability to generate topographic and displacement maps in wide applications like earthquakes, mining, landslide, volcanoes has been proven. Although other facilities like GPS, total stations, laser altimeters are also used, comparison between InSAR and these tools reveals its reliability. Laser altimeters can generate high resolution DEM and low resolution displacement maps in contrary to InSAR with the spatial resolution of 25m. However, most laser altimeters record narrow swaths. Therefore, for constructing a DEM by laser altimeter, more overlapping images are required. Displacement map precision obtained by terrestrial surveying using GPS and total stations is similar or better than InSAR. GPS generally provides better estimation of horizontal displacement and with permanent benchmarks slow deformations is monitored for years without being concerned about surface de-correlation. The most important advantage of InSAR over GPS and total stations are wide continuous coverage with no need for fieldwork. Therefore, wide and continuous coverage, high precision, cost effectiveness and feasibility of recording data in all weather conditions are its main privileges. However, it is important that the InSAR displacement result is in the line-of-the-sight direction and to decompose this vector to parallel and normal components the terrestrial data or extra interferograms with different imaging geometry are required. It is shown that DEM generated by photogrammetric method is more accurate than the others. It has approximately 5.5m accuracy for open and 6.5m for forest areas. SRTM X-band DSM is 4m less accurate for open and 4.5m less accurate for forest areas.

Data availability and atmospheric effects limit using InSAR, however processing of its data is challenging. For each selected image pair, several processing steps have to be performed. One of the current challenges is to bring the techniques to a level where DEM generation can be performed on an operational basis. This is important not only for commercial exploitation of InSAR data, but also for many government and scientific applications. Multi pass interferometry is affected by the atmospheric effects. Spatial and temporal changes due to the 20% of relative humidity produce an error of 10cm in deformation. Moreover, for the image pairs with inappropriate baseline the error introduced to the topographic maps is almost 100m. In topographic mapping this error can be reduced by choosing interferometric pairs with relatively long baselines, while in the displacement case the solution is to average independent interferograms.

InSAR DEM advantages: Distinction between SAR imaging and the optical systems are more profound than the ability of SAR to operate in conditions that would cause optical instruments to fail. There are basic differences in the physical principles dominating the two approaches. Optical sensors record the intensity of radiation beamed from the sun and reflected from the features. The intensity of the detected light characterizes each element of the resulting image or pixel. SAR antenna illuminates its target with coherent radiation. Since the crests and troughs of the emitted electromagnetic wave follow a regular sinusoidal pattern, both the intensity and the phase of returned waves can be measured.

InSAR has some similarities to stereo-optical imaging in that two images of the common area, viewed from different angles, are appropriately combined to extract the topographic information. The main difference between interferometry and stereo imaging is the way to obtain topography from stereo-optical images. Distance information is inherent in SAR data that enables the automatic generation of topography through interferometry. In other words DEMs can be generated by SAR interferometry with greater automation and less errors than optical techniques. Moreover, using DInSAR surface deformations can be measured accurately.

Different DEM generation methods of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) stereoscopy, ERS tandem InSAR, and SRTM-InSAR are used. Both the ERS-InSAR and SRTM DEMs are free of weather conditions, but ASTER DEM quality may be affected by cloud coverage in some local areas. InSAR has the potential of providing DEMs with 1-10cm accuracy, which can be improved to millimeter level by DInSAR. Its developments are rapid however it is our requirements that say which one is better for use.

2.2.1 Earth observation for river flood issues

Rivers of Azerbaijan can be divided into the three main groups regarding their water flow specifications:

1. Perennial rivers;
2. Seasonal rivers that flow only during the melting of snow in spring;
3. Episodic rivers that flow in episodes after a downpour of rain of flash flood.

These three groups differ from each other for the volume of underwater supply to their streams. Perennial rivers are fed by a constantly flowing baseflow (groundwater). Seasonal rivers are fed by an elevated water table during the rainy period, while episodic rivers are not at all dependent on base flow.

Like in all other countries, rivers have different feeding sources in Azerbaijan. Most rivers are fed by snow, rainfalls and ground waters. Snow is the predominant feeding source for the rivers of the Major Caucasus, while ground waters contribute the most to water supply of rivers in the Minor Caucasus. The Kur and Araz rivers pass Azerbaijan in their lower and middle courses.

The Kura river is the largest river of Azerbaijan. It stretches for 1,515 kilometers and covers an area of 188 thousand sq. km. The Kura originates from the Hel River in Turkey, passes through Azerbaijan and flows into the Caspian Sea in south-eastern part of the country. The Araz River covers an area of 86 thousand sq. km until its junction with the Kura River. It originates from the Bingol mountains in Turkey at the altitude of 3300 meters. On the whole, the Araz River forms Azerbaijan's border with Turkey and Iran. It passes through Azerbaijan in its lower 80 kilometers and joins the Kura River near Sabirabad. These two rivers belong to the group of rivers, flowing at full under the influence of snow and rainfalls in spring and rainfalls in autumn.

Weather produces the greatest impact on the river flow in Azerbaijan. Intensive rise in temperature causes melting of snow at heights of over 1500. The melting of snow further intensifies after heavy rainfalls of April and May. Snow melts more intensively in the high altitudes (over 2500-3000 meters) from early April through May until June. The melting process influences river flow even in summer time. Thus, melted snow water, absorbed by soil, emerges on the surface and raises water level in rivers. Low river basins (except for those of the Talysh region) are less influenced by the precipitation in spring and summer periods. Winter and autumn rainfalls account for the most part of precipitations in the Talysh region. Rivers are less full of water in summer in Azerbaijan. Heavy rainfalls that may from time to time occur in July and August, lead to floods, causing agricultural damages. Severe floods have been registered in the rivers of southwestern slopes of Major Caucasus Zengezur part. Rivers of the Major and Minor Caucasus mainly flow in hot seasons, while rivers of the Talysh regions flow in colder seasons of year. Rivers, flowing in hot seasons account for most part of all rivers (60-80%).

Such seasonal flows are difficult for industrial use. On the whole, rivers of the Azerbaijan Republic are divided into two groups, according to their water regime:

1. rivers of full-flowing regime;
2. rivers of flood regime.

Flood rivers are the Lenkoran rivers and episodic rivers of Gobustan. Other rivers are included into the first group of rivers.

Complex topography and other natural factors cause a non-standard flow across the country. The flow increases with altitudes and reaches its top at a certain height (2800, on the north-eastern slope of the Major Caucasus, 2000-2200-on its southern slope and 2200-2400 on the Minor Caucasus). The flow starts to decline from above the indicated height. Due to the orographic specifications of the Talysh mountains, the flow is inconsistent with the average height. It decreases with the increase of altitude in the Talysh mountains, while in Peshteser and Burovar mountains it rises with the altitude.

The full-flowing rivers of the Azerbaijan Republic mainly flow on the southern slope of the Minor Caucasus. The average flow of such rivers exceeds 45 l-cm. The flow falls to 5 l-cm till the Alazan-Ayrichay lowland. The flow module of rivers of the north-eastern slope of the Major Caucasus 18 l-cm. The increase of flow with the increase of altitude is relatively uniform in this part of the Major Caucasus. The intensive increase in the module of flow is registered on the area between the Yah mountain chains and the Major Caucasus mountains. (upper Qusar, Qudyal and other rivers.). The Average annual module of flow is from swings hesitates from 10 to 20 l-cm.

The flow of rivers, originating in the slopes of the Yah mountains, differs from that of the rivers, flowing from the Major Caucasus. The flow increases intensively and reaches from 6 to 18 l-cm at a height of 1000-2000 meters, due to high level of precipitation. The flow gradually decreases till the Caspian Sea shore down to 0.5 l-cm. the flow decreases beginning from the north-west of till south east of the seaside lowland and reaches zero level on the Apsheron peninsula. Compared with the Major Caucasus, the flow in the Minor Caucasus is more complicated, due to its orographic complexity and differing location of mountain chains. The highest flow has been registered in the rivers flowing from the slopes of Gamish and Qapidjic mountains (over 28 l-cm).

In the Karabakh plateau precipitation is absorbed by soil rocks, thus turning the region into the arid area, while in some places it bursts onto the surface thus increasing the water level in the rivers. That is typical of the upper Terter, Hekeri and other regions as under water provides 70-80% of water to them. The flow fluctuates from 0.8 to 22 l-cm in south east of the Minor Caucasus (rivers, originating in the Caucasus mountains) and from 0.5 to 10 l-cm in the Nakhchivan Autonomous Republic. The flow gradually decreases to the level even lower than 0.5 l-cm on the plains on the side of Araz. In the Talish region the flow increases in the direction from the north to south and from the west to east. The flow reaches its peak (over 25 l-cm) in Tengerud and Astara river basins in the central part of the region, while it reaches its minimum north of the Vilesh river, as well as in the Lenkeran and Vilesh rivers. Gobustan, Nakhchevan and Kura-Araz plains account for the lesser part of water system in Azerbaijan.

Rivers of Azerbaijan carry large quantity of sediment, the result of erosion in the river basins. The rivers in Azerbaijan are the most polluted rivers in the world. Their average annual pollution rate changes from 0.07 to 9 kg-1 cubic mete per region. It reaches its top on the north slope of Major Caucasus and minimum-on the Karabakh plateau. The surface erosion is intensive in the north slope of the Major Caucasus(100-6800 t/sq/km) , and it becomes weaker on the Karabakh plateau (5-10 t/sq.km). The surface erosion in the rivers of the Major Caucasus (0.53 mm) is by 13 higher from that of the Minor Caucasus (0.03 mm per year) and Talish mountains (0.04 mm per year).

The hydrological system of the Azerbaijan Republic contains 10.3 billion cubic meters of water reserves. These water reserves together with those, entering Azerbaijan from neighbor countries (20.6 billion cubic meters) make up 30.9 billion cubic meters. Each square meters of the country receives 90 thousand cubic meters of reserves, while the annual per capita volume of water reserves total 1270 cubic meters. The basin of the river Kura accounts from most part of the water reserves. The nonunifomal distribution of water reserves across the region and around the year hammers the utilization of these reserves and as a result of that the reserves are not able to meet constantly growing demands for fresh water. The situation requires the regulation of water flow. 60 water reservoirs of the country with the capacity of over 1 million cubic meters account for 21 billion cubic meters of water reserves. Most part of these reserves are used in different spheres (irrigation, water supply, industry, fishery, etc). The establishment of water reservoirs of the Middle Kura plays the important role to meeting demands for water. Currently, serious measures are undertaken to preserve pure water reserves and to prevent their polluting with communal and industrial wastes.

The Canals of the Azerbaijan Republic are the main source of irrigation. The canals used for the said purpose extend to 47058.8 kilometers., with canals, used by several farms, accounting for 8580.3 kilometers and those, used only by one farm-for 38478.5 kilometers. The amount of 11 billion cubic meters of water is used in irrigation each year. Irrigated area of Azerbaijan totals 1.4 million hectares.

3. Space technology in disaster monitoring, mitigation and preparedness

3.1 Natural disaster in global change

One of the main impacts of the global changes is the natural disaster. Natural disaster can be playing a significant indicator for the foregoing issue. Natural disaster is increasingly of global concern and its impact and actions in one region can have an impact on disaster in another and vice versa. This compounded by increasing vulnerabilities related to climate change, climate variability as well as other contributions like changing demographic, technological and socio-economic conditions, environmental degradations etc.

There is a highly need for international acknowledgement that efforts to reduce disaster risks which must be systematically integrated into policies, plans and programmes for comprehensive approach of global change and endorsed through bilateral, regional and international cooperation, including partnership.

The importance of promoting of natural disaster impacts reduce efforts on the international and regional levels as well as the national and local levels has been recognized in the past few years in a number valuable and significant multilateral frameworks and declarations.

The following main areas can be covers the challenges of objectives of the natural disaster as a key element of the global changes:

i. Governance – organizational, legal and policy framework;
ii. Natural disaster identification, assessment, monitoring and early warning;
iii. Knowledge management and education;
iv. Reducing underlying natural disaster factors;

Foregoing items can be discussed as a items for further developments. Given the close linkages between disaster risk factors and environmental and natural resource management issues, a huge potential exists for the exploitation of existing resources and established practices aiming at greater disaster reduction. The need for carefully drawn up forest, vegetation, soil, water and land management measures is increasingly recognized and such investigations are being effectively employed to learn the global change.

While countries valued the increased availability of advanced technologies, some were disappointed that their technical capabilities or data were insufficient to make more effective use of them. However, take advantage of space technology and its advance methodology applications for earth observation are being developed and will be executed through global and regional strategically partnerships. The United Nations Office for Outer Space Affairs and the action team of the Committee on the Peaceful Uses of Outer Space are proceeded to implement an integrated global system for the management of natural disaster. A global multilateral imitative, involving both developed and developing countries, including for the countries of the former Soviet Union and Southern European countries with the transit economy has developed a framework document for a 10-years plan to implement a Global Earth Observation Systems. One of the its objectives is the global observation of earth for the aim of global change, reduction of losses from natural disasters and improved understanding, assessment and prediction of weather and climate system variables.

The value of methodology and advanced technology for global change is widely recognized. Their use has increased as the tools have improved, costs have decreased and local access has increased. Methodology and techniques related to the remote sensing, geographical information systems, space-based observations, computer modeling and prediction and information and communication technologies have proved very useful, especially in earth observation systems, mapping, monitoring, territorial or local assessments and early warning activities in case of the natural disaster occurs.

The use of advance methodology and associated data sets in global observation suggests possibility for synergy and shared approaches with global change management. With decreasing costs, those tools have become much more readily available as routine capacities and more useful at local scales in many countries.

States and regional and international organizations should support and encourage the capacities of regional mechanisms and organizations to develop regional plans, policies and common practices, as appropriate, in support of networking coordination, exchange of information and experience, scientific monitoring of earth observation outcomes and institutional capacity development and to deal with natural disaster.

In view of the particular vulnerabilities and insufficient capacities of least developed countries to respond to and recover from natural disasters, support is needed by the least developed countries as a matter of priority, in executing substantive programmes and relevant institutional mechanism for the implementation of the framework of action, including through financial and technical assistance for and capacity building in natural disaster as an effective and sustainable means to prevent and respond to natural disaster.

There is a highly need of the establishing standards for the systematic collection and archiving of comprehensive national records pertaining to the many related aspects of earth observation. In the meantime evaluating country-wide assessments of earth observation and conducting natural disaster assessments, incorporating technical dimensions would be a significant contribution for this issue.

There is an important to assume that earth observation is a national and local priority with strong institutional bases for implementation. It has to be executed key activities within the national institutions and legislative framework as resources – assess existing human resource capacities, community participation – promote community participation through the adaptation of specific policies, the promotion of networking, strategic management of volunteer resources.

Global Earth observation is a voluntary partnership of governments and international organizations. It provides a framework within which these partners can develop new projects and coordinate their strategies, integrate research activities, share results for common interest and investments.

Remote sensing one of the key instrument of the Earth observation provides an important source of data for environmental monitoring and natural disaster mapping and in fact several satellites can service a map the terrain with one meter resolution.

Natural disaster monitoring with integration of space technology can be focused for following significant:

- indication of change throughout of Earth observation by means of natural disaster;
- reduce loss of life and property from natural disaster;
- satellite data evaluation with further understanding, assessing, predicting, mitigating and adapting to climate variability and change;
- effect of natural disaster factors on understanding of the human health

The use of remote sensing and development of GIS will increase the access of the developing world to global change data and harness global Earth observation efforts in support of global environmental challenges for natural disaster issues.

The ability to model potential flood inundation areas and map actual extent of inundation, timing, and intensity under different environmental conditions is central to understanding the dynamics between vegetation, soils, geomorphology, and land productivity in a floodplain. In many regions, the lack of hydrologic and spatial data, constrains the accurate delimitation of flood inundation zones. In spite of these factors, different techniques involving GIS and remote sensing could be used for rapid general zonations of areas susceptible to flooding to reduce costly monitoring infrastructure. This study showed the ability of a DEM-based surface and a wetness layer derived from a Landsat ETM image to identify potential areas to flood inundation in the Kura River Basin, Salyan districts of Azerbaijan. The analyses involved tests in relation to a map of flooded areas derived from soils and geomorphology maps. The statistical tests showed that there is a significant relationship between potential inundation areas derived from a DEM-based surface and satellite image-based dataset with potential inundation areas derived from existent cartographic information on soils and geomorphology. However, the relationships were weak. This analysis showed that the integration of ancillary geomorphologic and soils data, simple DEM-based surfaces, and satellite images maybe a useful first approach to characterize flood inundation areas.

3.2 Methods

The use and application of space technology in a huge case in particularly for the case of river flood reduction is a more suitable means due to the covering a large areas, high accuracy, availability of application in the unacceptability areas etc (Finkl,2000). Moreover, according to the created and developed database there is an advantage to be very sensitive to any available change occurred in the investigated sites.

The benefit analysis of disaster risk reduction involves a number of particular challenges, including:

- Little related information may be available on the frequency and intensity of the hazard event, particularly in a developing country context, implying uncertainty about the level of risk.
- Many of the benefits of any disaster risk reduction measures, whether undertaken in the context of a disaster risk reduction project or as part of another type of development project, are related to the direct and indirect losses that will not ensue should the related hazard event occur over the life of the project, rather than streams of positive benefits that will take place, as would be the case for other investments.

For carrying out of the goals undertaken within the framework of the project execution the following methods have been used:

- The use of ALOS space imagery to be created the land use / land cover basic map for the investigated area using urban, agriculture, garden, scrub, open area, river, stream, canal, road, railroad basic classes;

The use of Landsat ETM space imagery to be detected potential flood inundation areas within the Kura River watershed in the Salyan district of Azerbaijan using a tasseled cap transformation;

The derive 1 m Digital Elevation Model (DEM) from contour lines and elevation points of the investigated area to be generated a deterministic model of potential inundated areas for the region using the DEM and a convex-areas surface;

- The evaluate the sensitivity of each approach to be characterized the flood inundations through statistical tests involving comparison of flooding areas extracted from an inventory of soils and a geomorphology maps.

Investigated area description: The geographical area of interest is the Kura River basin in Saylan district of Azerbaijan (Figure 1). The area comprises approximately 24 km^2. The Kura watershed is one of Azerbaijan's most important agricultural production areas. During the last 10 years, it was affected by 5 excessive floods, causing a lot of damage to people and goods. The one of major source of Azerbaijan freshwater is the Kura River. The mean discharge of 1,144 m^3 sec-1 for the Kura River is the highest among the main rivers in the Azerbaijan, representing 39% of the total discharge from this lowland region. Mean precipitation in the Kura River drainage system is 885 mm year-1, which may range from less than 400 to more 1,800 mm during any one year.

3.3 Satellite data processing

ALOS imagery was acquired 10 June 2007 (Figure 2). The image was georeferenced to UTM zone 39 North, WGS84 using a first degree polynomial rectification algorithm with 30 ground control points (GCPs) extracted from a digitized topographic map at the scale of 1:100 000. The root mean square (RMS) error was equal to 0.5 pixel (5 m).

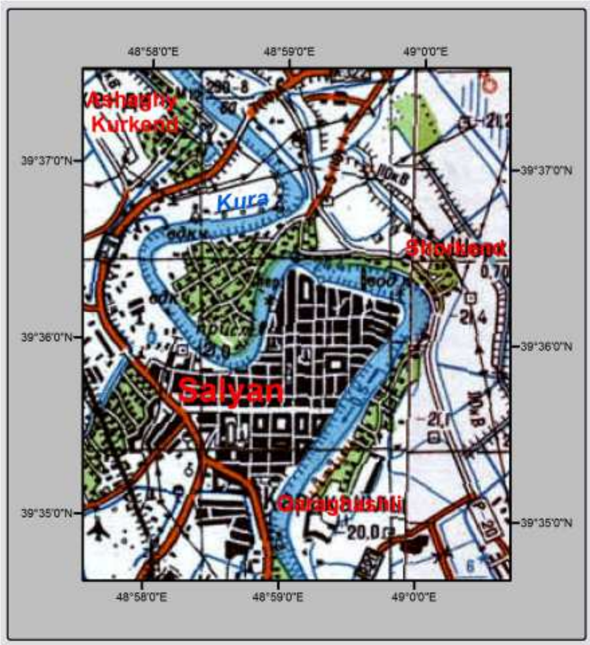


Fig. 1. 1:100 000 topographic map of the study area.

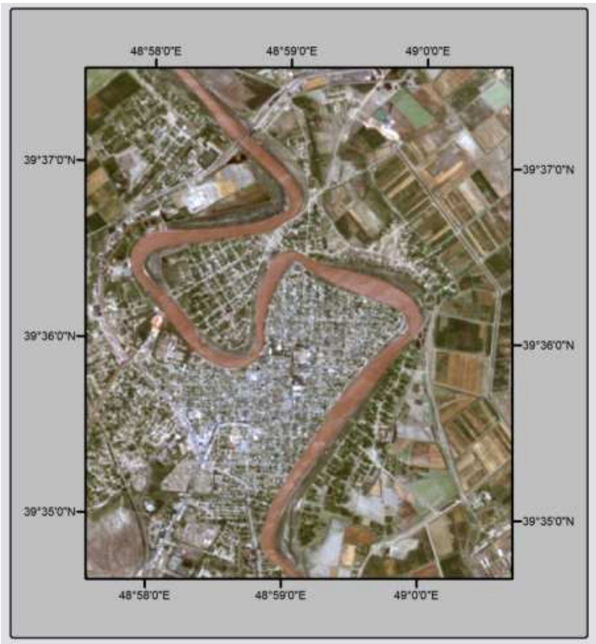


Fig. 2. ALOS imagery of the selected area.

Generation of a Digital Elevation Model: The digital elevation model (DEM) was generated from digitized contour lines and elevation points from topographic map (Figure 3). The digitized lines in shapefile format were converted to points in ArcGIS 9.2 using the "Feature to Point" transformation tools. The points were interpolated using the IDW – inverse distance weighting method.

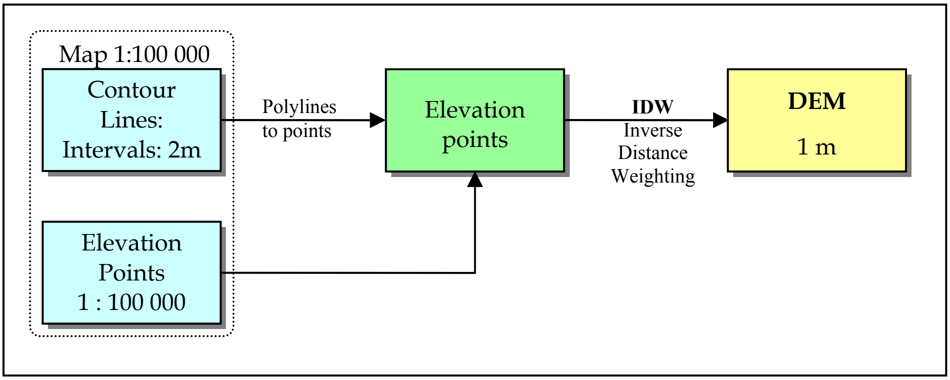


Fig. 3. The flowchart of Digital Elevation Model Generation procedure.

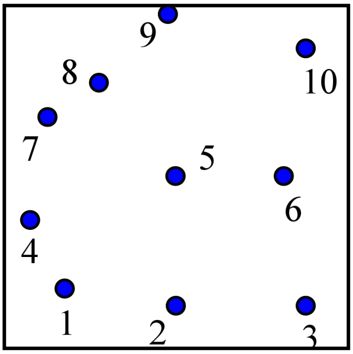
Inverse distance weighting method: Inverse distance weighting is a simple interpolation method, in which a neighborhood around the interpolated point is identified and a weighted average is taken of the observation values within this neighborhood. The weights are a decreasing function of distance. Generally, one can define the mathematical form of the weighting function and the size of the neighborhood expressed as a radius or a number of points.

The simplest weighting function (w) is the inverse power:

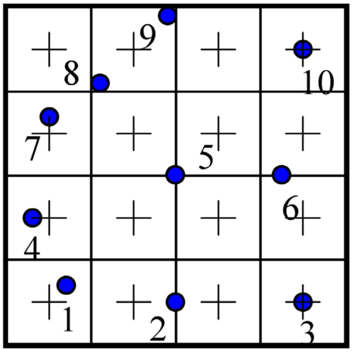
$$w(d) = \frac{1}{d^n}$$

with $n > 0$. The value of power can be specified depending upon data characteristics. The most common choice is $n = 2$.

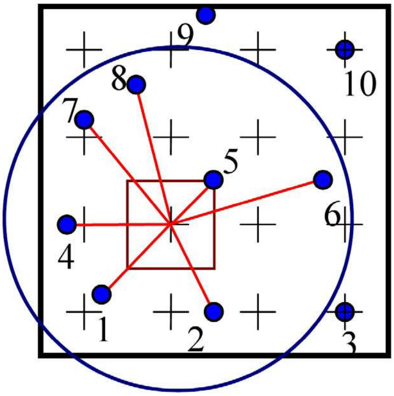
The neighborhood size determines how many points are included in the inverse distance weighting. The neighborhood size can be specified in terms of its radius, the number of points, or a combination of the two. If a radius is specified, the user also can specify an override in terms of a minimum and/or maximum number of points. Invoking the override option will expand or contract the circle as needed. If the user specifies the number of points, an override of a minimum and/or maximum radius can be included. It also is possible to specify an average radius based upon a specified number of points. Again, there is an override to expand or contract the neighborhood to include a minimum and/or maximum number of points. For example, given the following distribution of points with a known value Z:



and we want to interpolate a grid surface based on the spatial distribution of the points and their values,



then, using IDW we would assign a value to particular cell based on a number of neighbors and their distance to this cell,



$$D = \frac{\left(1/d_1^n\right)V_1 + \left(1/d_2^n\right)V_2 + \left(1/d_4^n\right)V_4 + \left(1/d_5^n\right)V_5 + \left(1/d_6^n\right)V_6 + \left(1/d_7^n\right)V_7 + \left(1/d_8^n\right)V_8}{\left(1/d_1^n\right) + \left(1/d_2^n\right) + \left(1/d_4^n\right) + \left(1/d_5^n\right) + \left(1/d_6^n\right) + \left(1/d_7^n\right) + \left(1/d_8^n\right)}$$

Which can be generalized as

$$D = \frac{\sum_{i=1}^{n} \left(1/d_i^n\right) V_i}{\sum_{i=1}^{n} \left(1/d_i^n\right)}$$

where D is the interpolated value, di is the distance from the cell to a point with a known value, and Vi is the value of a particular point.

In this study, IDW with a second order power was used to interpolate the elevation values because of the coarse detail of the original data and the general objectives of the research. IDW is a fast and simple interpolation method, which can be used when the values of points are spatially auto correlated, like in the case of elevation points. Other interpolation methods such as Kriging, could be used when higher accuracy is required.

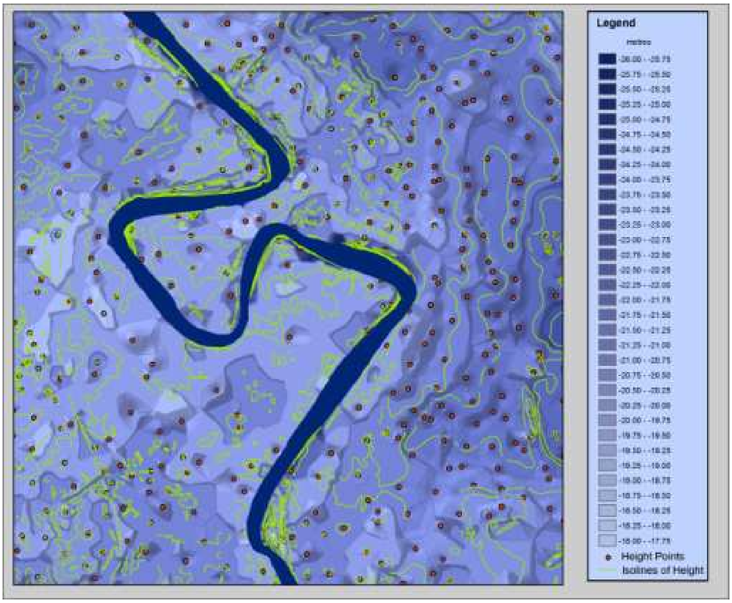


Fig. 4. Digital Elevation Model of the selected area with high points and isolines.

Identification of potential flood inundation areas: A convex surface was obtained with the formula:

Filled DEM – mean filled DEM

Where values < 0 where identified as convex zones (Figure 5). The mean DEM was calculated using standard GIS neighborhood operations. The areas selected as potential flooding areas where those that were convex and fall within an elevation range between -26 m and – 21 m, which is approximately the elevation range corresponding to the lower alluvial plain which is generally affected when severe flooding occurs.

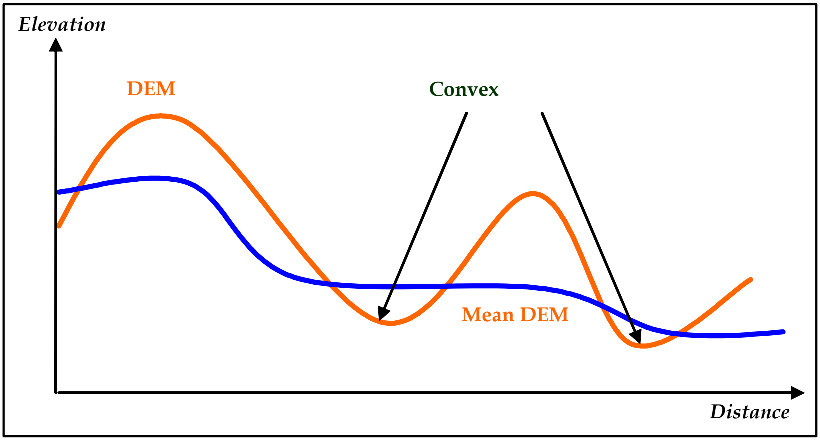


Fig. 5. Determination of convex areas based on the difference between the DEM and a mean DEM.

Potential flood inundation areas mapping: The study and identification of the potentially flood inundation areas in advance is a useful and important aspect of the natural disaster impact reduction.

For this reason the areas potentially flood inundation with a high probability of flooding has been developed and mapped. In this measurements and calculations the staring point has been undertaken as -26m.

The result reflects the potential flood inundation areas based on the height data supposed being as -22m. The result of data calculation and processing from DEM (Figure 4) has been demonstrated in a Figure 6. RF indicated zones reflect potentially flood inundation areas in case of the river level will be increased up to 4m.

This methodology can be successfully applied for potentially flood inundation areas after implementation of geodetic measurements related to the river level for acceptance of the high accuracy data.

Field trip measurements: The main aim of conducted field trips was identification of the inundation areas of the Kura river selected for investigation. One of the needs of this approach was defined due to the luck of the appropriate space data related to the seasonal date with a reach of flood impact of the area.

For the foregoing mentioned reason two field trips have been conducted for the selected area of investigation Salyan district of Azerbaijan. Those trips were implemented in summer season due to the heavy snow melting and autumn season due to the reach of raining when the river flood is more impacted among the all Kura river basin.

Field trips implementations have been scheduled and developed from the stage of the selection more sensitive areas of inundation in place. After those actions the counter of the river has been marked using the sticks installed among the river counter. Coordinates of the counters have been measured using GPS.

Fig. 6. Forecasting of the potentially flood inundation areas.

Based on those measurements all points of counters were installed on topographical map with further bounded of the space image.

The same actions have been applied for the seasons both summer and autumn. The results received from those measurements allow to compare the seasonal river level depends of the weather impacts. At the time it is the way to identify the expected inundation areas.

Based on those results as well as existed database for the river level change there is approach of study and identification of the dynamic change of the Kura river level. It is advantages of development of GIS technology which can be play a significant place on river flood problem solution especially valuable and extremely important instrument for local authority decision makers.

4. Conclusion

In this chapter have been reflected aspects of the use of space science and technology achievements in Earth observation systems. Furthermore it is described currently advances of space technology systems for Earth observation.

One of the main targets of this chapter is to develop of an advance tool for monitoring, data collection, data processing, review and report on progress and challenges in the implementation of disaster risk reduction and recovery actions undertaken at the national level. An advance tool has been undertaken of the use and application of modern achievements of space science and technology for the natural disaster events particularly the river flood.

Furthermore, the other target of project is to be undertaken to assist the local authorities to build up useful database in disaster risk reduction in particularly for the selected area with a more sensitively part of country in point of view the river flood in Azerbaijan. In the meantime the next issue was to demonstrate a contribution of the possibility and advantage of use of remote sensing methods and GIS technology based on space image data collection and data processing for application of similarity problem solving.

It was a highly desirable to create a favorable conditions and mechanisms to be able to develop the strengthened coordination and interaction for appropriate partners at the national level and facilitate explanation of the present status of the selected area and prioritization of strategic areas needed to be considered for purpose of natural disaster risk reduction.

Azerbaijan is the country of the Commonwealth of Independent States (CIS) with the transit economies. The Millennium Development with the eight Goals and Hyogo Framework Actions with three strategic goals and five priorities for actions have been related to the CIS countries.

The river flood is not a reason of damage impact of property and human life. The consequences are a huge as the eventually tracking with malaria, drinking water problem etc. The same problems with appropriate impact of scale occurs in case of Kura river when happens river flood. All this indicated accepts have to be undertaken for further successful management in order to be able to reduce the effect of natural disaster on river flood. An appropriate sufficient with high accuracy database has to be developed for local authorities for decision making.

The other very significant problem is the intended to be undertaken of diversion of the Kura river bed which plans to be started to construct in the upcoming period which will reduce of river flood impact for saving human life and properties.

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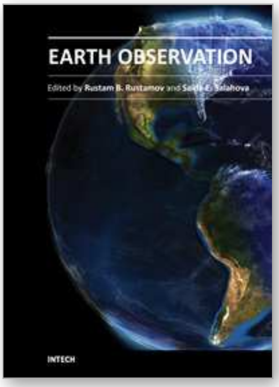

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Today, space technology is used as an excellent instrument for Earth observation applications. Data is collected using satellites and other available platforms for remote sensing. Remote sensing data collection detects a wide range of electromagnetic energy which is emitting, transmitting, or reflecting from the Earth's surface. Appropriate detection systems are needed to implement further data processing. Space technology has been found to be a successful application for studying climate change, as current and past data can be dynamically compared. This book presents different aspects of climate change and discusses space technology applications.

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