THE SEVENTH International Exhibition and Scientific Congress
"GEO-Siberia - 2011"
27-29 April 2011, Novosibirsk, Russian Federation

International Cartographic Association Working Group
"Cartography on Early Warning and Crises Management"
International Society for Digital Earth (ISDE)
Siberian State Academy of Geodesy (SSGA)

INTERNATIONAL WORKSHOP ON

"EARLY WARNING AND CRISES/DISASTER AND EMERGENCY MANAGEMENT"

28-29 April 2011
Novosibirsk, Russian Federation

Proceedings

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The workshop confirmed growing interest in early warning and emergency/crisis management topics, stressed the importance of cooperation between international organizations in the area of geoinformation and cartography, as well as in the Digital Earth at a professional and academic level, and demonstrated practical applications and potential of maps, GIS, Web mapping and visualizations. Much attention was paid to geoinformation techniques which have already been proven that they could significantly facilitate emergency management. Analogue and digital maps, modern methods of mapping could have key role in analyzing situation, geocollaboration and making decisions on progressively higher level than before.

The proceedings are meant for professionals, emergency services, heads of departments and teaching stuff of universities, persons working for Ph.D. degree, postgraduates, masters and students, who are interested in problems of early warning and crises/emergency management, geoinformation and cartography, remote sensing and photogrammetry.

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Published by the decision of editorial advisory board of the academy.

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GREETING FROM PROF. DR. MILAN KONECNY, CHAIRMAN OF ICA WORKING GROUP CARTOGRAPHY IN EARLY WARNING (EW) AND CRISES MANAGEMENT (CM) (CEWaCM)

Dear Colleagues!

ICA Working Group Cartography in Early Warning (EW) and Crises Management (CM) (CEWaCM) was established to increase efforts linked with better and wider usage of cartographical, geoinformatics, remote sensing (incl. small satellites), navigation systems and other methods by integrative way. Recent large natural (tsunamis, earthquake such as in Japan) and anthropogenic disasters have clearly shown various shortcomings and failures in existing technologies and policies for efficient early warning and emergency response. One of the most important aspects is to have all necessary spatial and non-spatial data, information and knowledge integrated. They should be available in the forms of infrastructures and be able to use various types of infrastructures (SDI, critical infrastructures, ICT ones, etc.) in security-related systems. EW and emergency management requires different types of systems. The systems have to be user-centered and ensure that every person (professional or citizen) receives the information that will help him/her to avoid losses of life and damages of critical infrastructures.

In GeoSiberia trade fairs and conferences we are paying attention mainly to geoinformatic techniques which have already been proven that they could significantly facilitate emergency management. Analogue and digital maps, modern methods of ubiquitous, adaptive and context mapping could have key role in analyzing situation, geocollaboration and making decisions on progressively higher level than before, but not only. As we see on last catastrophic events (e.g. in Japan), people wants to be fully informed by true way to create own opinion to avoid needless panic and misunderstandings.

ICA WG created network of events over all World - Czech republic, Bulgaria, China, USA, South America – and one of the most important is event here, in Novosibirsk. ICA is using big knowledge, technological and social potentials which was discovered in and through the SSGA (especially Prof. Dmitry Lisitsky, Head of the Department of Cartography and Geoinformation) and great support from top management of SSGA (Prof. Dr. Alexander Karpik and Prof. Vladimir Seredovich). Our cooperation is good example of sharing of best knowledges and excellent example of the results of win-win strategies in the progressively developing areas of EW and Crises/Emergency management.

I would like to invite you to be part of the game which begins to look many times more important and relevant for solving of complicated situations than we thought in previous years.

Prof. Dr. **Milan KONECNY**
Chairman, ICA WG CEWaCM
President-Past, ICA

ABOUT ORGANIZERS

International Cartographic Association (ICA)
(www.icaci.org)

International Cartographic Association (ICA) is keeping a strong position in the development of cartographic science, methodology and methods of analysis, elaboration, handling, using, implementation and interpretation of spatial (geographic) and non-spatial (non-geographic) data.

ICA is the world authoritative body for cartography, the discipline dealing with the conception, production, dissemination and study of maps/

The ICA was founded on June 9, 1959, in Bern, Switzerland. The first General Assembly was held in Paris in 1961.

The activities of the ICA are important for promoting and advancing the theory and praxis of cartography. Throughout its 50-year history, ICA has brought together researchers, government mapping agencies, commercial cartographic publishers, software developers, educators, earth and environmental scientists, and those with a passion for maps.

The mission of the International Cartographic Association is to promote the discipline and profession of cartography in an international context.

The International Cartographic Association exists:

– To contribute to the understanding and solution of world-wide problems through the use of cartography in decision-making processes.

– To foster the international dissemination of environmental, economic, social and spatial information through mapping.

– To provide a global forum for discussion of the role and status of cartography.

– To facilitate the transfer of new cartographic technology and knowledge between nations, especially to the developing nations.

– To carry out or to promote multi-national cartographic research in order to solve scientific and applied problems.

– To enhance cartographic education in the broadest sense through publications, seminars and conferences.

– To promote the use of professional and technical standards in cartography.

The Association works with national and international governmental and commercial bodies and with other international scientific societies to achieve these aims.

ICA Working Group on Early Warning and Crisis Management

For a number of years the ICA has developed a focus on Early Warning and Crisis/Disaster/Risk Management. ICA Working Group on Early Warning and Crisis Management chair, immediate past-President Milan Konecny, first elaborated on the need for cartography and GIScience to be actively involved in this area at the Second International Conference on Early Warning (EWC II) in 2003.

At the 13th ICA General Assembly, held in conjunction with the La Coruna, conference, Professor Konecny proposed that the ICA should establish a Working Group on Early Warning and Crisis Management. He is current Chair of WG.

The aims of the Working Group

– Provide leadership in the development of concepts, ontologisation and standardization of early warning for hazard, risk and vulnerability mapping and cartographic modelling.

– Promote the cartographic use of remotely sensed and other geospatial data and various analysis techniques for early warning and crisis management by organizing conferences, seminar and workshops.

– Investigate psychological condition of end user given by their personal character and situation and psychological condition of rescued persons.

– Promote capacity building and quality mapping, and cartographic modelling including modern technology for early warning and crisis management through topic related publications.

– Participate and contribute to global initiatives in early warning and crisis management for instance through the maintenance of a website.

– Promote hazard, risk and vulnerability mapping for crisis management and communication.

– Develop mechanisms and networks for exchange of information among stakeholders on crisis management and early warning.

The start of 2008 saw the beginning of a number of seminars organized by or with direct contributions from the ICA Working Group: *The Early Warning and Disaster/Crises Management* Conference was held in Borovets, Bulgaria and a *Workshop on Cartography in Early Warning and Crises Management and Round Table* at AutoCarto 8, Shepherdstown, West Virginia, USA, which addressed natural anthropogenic disasters; current global, regional and local initiatives in early warning and crises management; paradigms of action; exchange of best practices for activities in the field; avoidance of shortcuts in crises situations; sharing and standardizing of data on material reserves and potential human provisions; the interconnection between current OGC/ISO activities and crises management.

The main activity of the Working Group in 2009 was conducting a Joint Symposium with the JBGIS Gi4DM - *Cartography and Geoinformatics for Early Warning and Emergency Management* - held in January 2009 in Prague, Czech Republic. The symposium topics were organized under the themes of: frameworks and tools; technologies and infrastructures; citizens in early warning and emergency management; e-government and e-governance; and cartographic and geoinformatic applications. At the Symposium a Round Table on Spatially Enabled EW and EM was held, lead by Professor Gottfried Konecny, Germany, and Professor Milan Konecny, Czech Republic.

Later that year Professor Konecny addressed the seminar on the *Potentials in Early Warning and Emergency Management* special session at the international **GeoSiberia** conference, held at the Siberian National Academy of Geodesy, Novosibirsk and leaded by Professor by Professor D. Lisitsky. The title of the paper was “Cartographic and Geoinformatics Potentials in Early Warning and Emergency Management”. Following the success of these sessions it was decided to include meetings of the WG as part of future GeoSiberia conferences.

A number of events were held in 2010. In April in Novosibirsk, Russia, a seminar on *Early Warning and Crises/Disaster Management* is under of leadership of Prof. M. Konecny and Prof. D. Lisitsky under auspicious of rector of SSGA Prof. A.P. Karpik. This was a joint event between the ICA, the International Society on Digital Earth - ISDE and SSGA, with the participation of colleagues from the ISPRS and FIG.

Another seminar was held in Nessebar, Bulgaria, June 2010 - *Digital Earth Summit and 3rd Conference on Cartography and GIS* - a seminar on *Early Warning and Disaster/Crises Management: European Concepts for Crises Management and Early Warning*; and Orlando, USA, November 2010 - a workshop at *Autocarto 2010*.

Coming seminar in Geo-Siberia 2011 will be held on April 28-29 with title: ***“Early Warning and Crises/Disaster and Emergency Management”*** under of leadership of Prof. M. Konecny and Prof. D. Lisitsky under auspicious of rector of SSGA Prof. A. P. Karpik and vice-rector Prof. V.A. Seredovich.

In summary, the International Cartographic Association began to be active in Early Warning and Crises Management in 2003. This followed with a number of activities that have now become part of the Working Group’s activities - seminars at Borovets and Nessebar in Bulgaria, seminars in Novosibirsk, Russia and at *AutoCarto* USA. The working Group continues to address the issues of Crises Management and Early Warning in collaboration with members of the JBGIS.

Prof. Dr. **Milan Konecny**
Chairman of ICA WG “Cartography on Early Warning and Crises Management”, Immediate Past President of ICA, Vice President of International Society for Digital Earth

INTERNATIONAL SOCIETY FOR DIGITAL EARTH (ISDE)

The **International Society for Digital Earth (ISDE)** was proposed together by the experts and scholars from more than 10 countries, such as China, Canada, USA, Japan, Russia and Czech Republic etc. Inaugurated in May 2006, the ISDE is a non-political, non-governmental and not-for-profit international organization initiated by the Chinese Academy of Sciences (CAS) with the collaboration of institutes and related scholars throughout the world. The ISDE secretariat is hosted by the Center for Earth Observation and Digital Earth (CEODE), Chinese Academy of Sciences. Prof. Lu Yongxiang, the vice chairman of the Standing Committee of the National People's Congress, and the President of CAS, serves as the founding president of the ISDE.

– **ISDE Aims**

The purpose of ISDE is to promote international cooperation of the Digital Earth vision, and enable Digital Earth technologies to play key roles in, *inter alia*, economic and socially-sustainable development, to promote information technology and to reduce digital gap.

International Society for Digital Earth will play key role in different aspects of using natural resources, optimizing environment, protecting cultural heritage, improving disaster mitigation ability , global change study, natural resource conservation and improvement of living standards.

– **ISDE Executive Committee Board**

The Executive Committee Board consists of 24 scientists from 17 countries and international organizations. In March 2011, a dozen of ISDE EC members and scientists in geospatial science fields had a meeting on discussing Digital Earth Vision towards 2020, will produce a new vision to guide the future development of Digital Earth in the world.

– **Series Symposia on Digital Earth**

The International Symposium on Digital Earth is held every odd year and the Digital Earth summit is convened every even year. From 1999 to 2009, six international symposia on digital earth and two digital earth summits have held in seven different countries on various continents. In August 2010, the 7th International Symposium on Digital Earth will be held in Perth, Australia.

– **International Journal of Digital Earth**

The International Society for Digital Earth (ISDE), in cooperation with Taylor & Francis Group launched its official journal *International Journal of Digital Earth (IJDE)* in March 2008. IJDE was a quarterly journal in the years of 2008 to 2010, and becomes a bimonthly journal in 2011.

IJDE has been indexed and abstracted in Science Citation Index Expanded and also other 6 international databases. In June 2010, IJDE got its first impact factor of 0.864 for the year 2009, becoming the first leading journal of Digital Earth in the world, and one of the high-level international journals in remote sensing category.

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IJDE Editorial Office:
E-mail: ijde@ceode.ac.cn,
Website: http://www.tandf.co.uk/journals/titles/17538947.asp

SIBERIAN STATE ACADEMY OF GEODESY (SSGA)

The Siberian State Academy of Geodesy (SSGA), the oldest in Siberia, was founded in 1933. Today it is the recognized leader in training specialists for geodesy, cartography, cadastre, environmental management, exploration of natural recourses, metrology and opto-electronics. There are four institutes in SSGA: Institute of Geodesy and Management, Institute of Cadastre and Geographic Information Systems, Institute of Remote Sensing and Natural Resources Management, Institute of Optics and Optical Technologies. The graduates of **SSGA** receive Bachelor’s (**B.Sc**) and Master’s Degrees (**M.Sc**., 2 years after B.Sc.) or qualification of Engineer’s/Specialist’s Diploma. The SSGA offers educational programs, focused on geoinformation management for sustainable development, each with specialization: digital photogrammetry, urban planning and land administration and GIS.

The Academy carries out a large volume of researches and the major fields of them are: surveying, geodetic maintenance for construction and operation of engineering structures, cartography, GIS technologies, digital and thematic map compilation, cadastre, photogrammetry and remote sensing, satellite geodesy, optics and spectrometry, uses of GPS for the purposes of applied geodesy and land cadastre, and environmental monitoring. The main tendency of research activity is to implement the advanced digital technologies, terrestrial 3D laser scanning, 3D modelling, GIS and GPS technologies. Besides, the academy took an active part in implementing GLONASS/GPS project owing to the reference station network with 19 permanent continuously operating GLONASS base stations had been established on the territory of Novosibirsk Region.

SSGA together with ITE Siberian Fair are the organizers of the international exhibition and scientific congress **“GEO-Siberia”, t**he first exhibition experience beyond the Urals representing also innovative developments oriented to Siberia subsurface use. Various companies exhibit their highly specialized equipment and there is nothing like it on the Siberian market. **“GEO-Siberia”** demonstrated the growing interest to this event not only in Russia but abroad too. It has gained a merited recognition among professionals of geo-industry and become an example of collaboration of professionals and scientists from the whole world.

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THE SEVENTH International Exhibition and Scientific Congress
"GEO-Siberia - 2011"
27-29 April 2011, Novosibirsk, Russian Federation

Organizers:

The international workshop on ***"Early Warning and Crises/Disaster and Emergency Management"*** is held for the second time within the Seventh international exhibition and scientific congress **"GEO-Siberia - 2011"**on **April 28-29** in Novosibirsk at "ITE Siberian Fair". The previous workshop has caused a great interest among professionals and proved their priorities for a society.

Organizers:

– International Cartographic Association Working Group "Cartography on Early Warning and Crises Management"
– International Society for Digital Earth (ISDE)
– Siberian State Academy of Geodesy (SSGA), Russian Federation

The keynote of forthcoming workshop is to define the role, values, state, challenges, and ways of using geoinformation, procedures and technologies, geosciences including geodesy, remote sensing, cartography, geophysics, and geomatics.

The international workshop intends to discuss the following issues:

- Geoinformation Technologies for Early Warning and Crisis and Emergency Management Including Geospatial Data Infrastructures for Civil Defense and Emergency Situations;
- Geoinformation Technologies for Activities of Civil Defense and Emergency Situations Subdivisions;
- Territory Monitoring Using Remote Sensing for Early Warning of Emergency Situations and On-line Information Acquisition in Crisis Situations;
- Satellite Monitoring and Laser Scanning for Real-time Crises Management;
- Using of Electronic Navigation Methods in Emergency Situations;
- 3D Modelling and Animated Mapping in Forecasting, Early Warning and Crisis Management;
- Application of Other Methods of Geosciences for Forecasting, Early Warning and Crisis Management;

ORGANIZING COMMITTEE

– Chairmen

Prof. Dr. **Milan Konecny**	Immediate Past President of International Cartographic Association (ICA), Chairman of ICA WG “Cartography on Early Warning and Crises Management”, Vice President of International Society for Digital Earth (ISDE), Czech Republic
Prof. Dr. **Dmitry V. Lisitsky**	Head, Department of Cartography and Geoinformation, Siberian State Academy of Geodesy (SSGA), Russian Federation

– Co-Chairmen

Vladimir N. Shumilov	Deputy Mayor of Novosibirsk, Head of Department for Emergencies and Mobilization Activities, Novosibirsk
Dr. **Irina N. Rotanova**	Deputy Director on Science, Head of Laboratory of Ecological-Geographical Mapping, Institute for Water and Environmental Problems, Siberian Branch of the Russian Academy of Sciences (IWEP SB RAS), Russian Federation

– Members

Prof. **Vladimir A. Seredovich**	Vice-Rector for Innovation Activities, Siberian State Academy of Geodesy (SSGA), Russian Federation
Prof. Dr. **Ammatzia Peled**	ISPRS Second Vice President, Israel
Dr. **Enkhtuvshin Baatar**	President, Mongolian Association of Geodesy, Photogrammetry and Cartography (MAG & C), Mongolia
Ivan A. Ryzhenkov	Deputy Assistant, FGU “Centre for Civil Defense, Emergency Situations and Fire Protection Measures for Novosibirsk Region”, Russian Federation
Em. Prof. Dr.**-Ing. Gottfried Konecny**	Leibniz University of Hannover, Honorary Professor of SSGA, Germany

Prof. Dr. **Valery I. Tatarenko**	Head, Department of Life Safety, Siberian State Academy of Geodesy (SSGA), Russian Federation
Prof. Dr. **Valery P. Pyatkin**	Head of Digital Image Processing Laboratory, Institute of Computational Mathematics and Mathematical Geophysics of SB RAS, Russian Federation
Prof. **Gethin Wyn Robert**s	Chair of FIG Commission 6, University of Nottingham Ningbo, China
Prof. Dr. **Vladimir Tikunov**	Laboratory of Integrated Mapping and Laboratory of Sustainable Development of Territories, Faculty of Geography, M. V. Lomonosov Moscow State University, Russian Federation
Dr. **Usny-Ekh. Sarangerel**	Executive Director, Mongolian Association of Geodesy, Photogrammetry and Cartography (MAG & C), President of the Foundation for support to GIS development of Mongolia
Prof. **Michael Govorov**, Ph.D	Vancouver Island University, Canada

- Secretary

Assoc. Prof. **Svetlana S. Dyshlyuk**, PhD	Department of Cartography and Geoinformation, Siberian State Academy of Geodesy (SSGA), Russian Federation

TECHNICAL PROGRAMME

Thursday, 28 April 2011	
Thursday 28 April 2011 12:30 – 13:00	**Registration of participants**
Thursday 28 April 2011 13:00 – 17:00 ITE Siberian Fair Hall 1	Session I

Chairs: Prof. Dr. **Milan Konecny**, Immediate Past President of International Cartographic Association (ICA), Vice President of International Society for Digital Earth (ISDE), Czech Republic
Prof. Dr. **Dmitry V. Lisitsky**, Head of the Department of Cartography and Geoinformation, SSGA, Novosibirsk

Co-chairs: **Vladimir N. Shumilov**, Deputy Mayor of Novosibirsk, Head of Department for Emergencies and Mobilization Activities, Novosibirsk
Dr. **Irina N. Rotanova** Deputy Director on Science, Head of Laboratory of Ecological-Geographical Mapping, Institute for Water and Environmental Problems, Siberian Branch of the Russian Academy of Sciences, Russian Federation

Secretaries: Assoc. Prof. **Svetlana S. Dyshlyuk**, PhD, Department of Cartography and Geoinformation, Siberian State Academy of Geodesy (SSGA), Russian Federation
Assoc. Prof. **Elena S. Utrobina**, PhD, Department of Cartography and Geoinformation, Siberian State Academy of Geodesy (SSGA), Russian Federation

Rapporteur:
Vladimir N. Shumilov (Deputy Mayor of Novosibirsk, Head of Department for Emergencies and Mobilization Activities, Novosibirsk):
Security Issues in Municipal Sphere

Prof. Dr. **Milan Konecny** (Immediate Past President of ICA, Vice President of ISDE, Czech Republic):
Geoinformatics and Cartographic Research Agenda in Early Warning and Crises Management

Prof. Dr. **Ammatzia Peled** (Second Vice President of ISPRS, Israel):
Remote Sensing Before, During and After Disaster

B. Enkhtuvshin (Mongolian Association of Geodesy, Photogrammetry and Cartography, Mongolia):
NEMA Early Warning System in Mongolia

Gethin Wyn Roberts (China), **Christopher John Brown, Oluropo Ogundipe** (UK):
Monitoring the Deflection of Bridges by GNSS

Sergey A. Miller (President, GIS Association, Russian Federation):
Problematic Issues on Creating Spatial Data Infrastructure in Russian Federation

Peter Baumann (Jacobs University Bremen, Germany):
Open Information Turnpikes and Just-in-Time Geoinformation for Rapid Response

Ryan Burley (LizardTech, USA):
MrSID Technology for Managing Large Raster and LiDAR Geospatial Datasets in Emergency Response Applications

LIU Liangming (School of Remote Sensing and Information Engineering, Wuhan University, China):
Drought Early Warning Based on Remote Sensing Technology

Valentin G, Tsukanov (Technokauf GmbH, Russian Federation), **Simon Baksh** (VP Product Development, Altus Positioning Systems):
State-of-the-Art Satellite Navigation Technologies for High Precision Off-Line Positioning

A.A. Buchnev, V.P. Pyatkin (Institute of Computational Mathematics and Mathematical Geophysics of SB RAS, Novosibirsk, Russian Federation):
Space Monitoring of Spatial Displacements of Natural Objects

S.N. Bagaev, V.A. Orlov (Institute of Laser Physics, SB RAS, Novosibirsk, Russian Federation):
Possibilities of Laser Methods for Seismic and Geodynamic Monitoring

Andrey I. Yashenko, A.B.Burtchev, A.A. Dorofeev (Engineering Centre GFK Ltd., Russian Federation):
The Implementation of Automated Deformation of the Monitoring During Restoration and Construction of Architectural Complexes “Moscow Kremlin and Red Square"

Oleg V. Evstafiev (Leading Manager, Engineering Centre GFK Ltd., Russian Federation):
The Importance and Tasks of Deformation Monitoring in the Bridges Structure Exploitation Safety

Bernd Hiller (Executive Manager, Engineering Centre GFK Ltd., Russian Federation):
Contribution of Innovative Surveying Technologies to Provide the Safety of Human Activities

S. Zaichenko, M. Potanin, G. Potapov (ScanEx RDC, Russian Federation):
Geo-Services of Operational Monitoring for Early Warning and Disaster Management

Em Prof. **Shunji Murai** (University of Tokyo, Japan):
How is Japan Managing the Disaster of This Magnitude?

M.V. Shchadrov (AshTech, Moscow, Russian Federation):
The Latest Satellite Solutions in Geodesy, Cartography and GIS

Friday, 29 April 2011		
Friday 29 April 2011 10:30 – 12:30 ITE Siberian Fair Hall 1	Session 2	
	Chairs:	Prof. Dr. **Milan Konecny**, Immediate Past President of International Cartographic Association (ICA), Vice President of International Society for Digital Earth (ISDE), Czech Republic Prof. Dr. **Dmitry V. Lisitsky**, Head of the Department of Cartography and Geoinformation, SSGA, Novosibirsk
	Co-chairs:	**Vladimir N. Shumilov**, Deputy Mayor of Novosibirsk, Head of Department for Emergencies and Mobilization Activities, Novosibirsk Dr. **Irina N. Rotanova** Deputy Director on Science, Head of Laboratory of Ecological-Geographical Mapping, Institute for Water and Environmental Problems, Siberian Branch of the Russian Academy of Sciences, Russian Federation
	Secretaries:	Assoc. Prof. **Svetlana S. Dyshlyuk**, PhD, Department of Cartography and Geoinformation, Siberian State Academy of Geodesy (SSGA), Russian Federation Assoc. Prof. **Elena S. Utrobina**, PhD, Department of Cartography and Geoinformation, Siberian State Academy of Geodesy (SSGA), Russian Federation

Rapporteur:
Em. Prof. **Gottfried Konecny** (Leibniz University of Hannover, Germany):
Meeting the World Hunger Problem

Carsten Haub, Sven Gilliams, Andreas Müterthies (EFTAS Fernerkundung Technologietransfer GmbH, Germany):
Global Monitoring for Food Security (GMFS): A GMES - Early Warning System for Food Security in Africa

Sascha Schneid (VMT GmbH, Bruchsal, Germany):
Intelligent Geo-Sensor-Networks as Foundation of Interdisciplinary Structural-Monitoring

Joël van Cranenbroeck (Leica Geosystems AG, Switzerland):
New Design for Hydro Power Plant Structural Geodetic Monitoring Network

V.A. Ponko (Institute for Water and Environmental Problems SB RAS, Siberian Research Institute of Farming, Russian Academy of

Agricultural Sciences, Russian Federation):
Emergency and Crisis Warning Based on Cosmo-Geoecological Methodology

Dr. **Yuri Raizman** (VisionMap Ltd. Company, Tel-Aviv, Israel):
Visionmap A3/A3-CIR in Disaster Management

V.N. Makeev, A.V. Soromotin, O.V. Gerter (Tyumen State University, Russian Federation):
Analysis of Scientific Organisations Activity in Solving Environmental Problems in Tyumen Region

V.M. Lazarev (Tomsk State University of Architecture and Building, Russian Federation):
Complex Geo-Monitoring System for Early Warning on Natural and Natural-Technologic Hazards' Activation within the Territory of Tomsk

A.N. Reznik, V.V. Novoseltsev (ORBIS, Russian Federation):
The Region's Geoportal as a Tool for On-line Visualization and Emergency Monitoring

L.K. Trubina, O.A. Belenko, D.V. Panov (Siberian State Academy of Geodesy, Russian Federation):
The use of Digital Images for Data Acquisition in Realistic Forest Fires Modelling

Alexey V. Dubrovsky (Siberian State Academy of Geodesy, Russian Federation):
Creation of Geoinformational Model of Probable Threats on the City Territory

E.E. Vasileva, A.V. Dubrovsky, A.I. Kalenitsky, E.L. Kim (Siberian State Academy of Geodesy, Russian Federation):
Application of GIS Analysis Opportunities for Modelling of Territory Floodings at River High Waters

Irina N. Rotanova, Olga P. Nikolaeva (Institute for Water and Environmental Problems SB RAS, Russian Federation):
GIS for Ecological-Recreational Safety of Population

P.M. Kikin (Siberian State Academy of Geodesy, Russian Federation):
Application of Tablet PC as GIS Client Platform for Emergency Management

Michael Govorov (Vancouver Island University, Malaspina, Canada), **Gennady Gienko** (University of Alaska Anchorage, USA):
Applied Spatial Statistics for Mapping Environmental Pollution

12:30 – 13:00 ITE Siberian Fair Hall 1	**Round-table**

HOW IS JAPAN MANAGING THE DISASTER OF THIS MAGNITUDE?

Shunji MURAI
Professor Emeritus, University of Tokyo, Japan

Introduction

I was given the title of this article by the Editor-in-chief of the magazine “Coordinates” but I dare to say that Japan is not yet managing the disaster but suffering from the hardships. Though all Japanese people are in mourning over the horror of this event, I feel it is my duty as an old scholar to report to the rest of the world on the worst earthquake and Tsunami in living memory to hit Japan. I hope that my report will be useful to prevent the similar misery for others.

What happened?

At 2:46pm on the 11th March 2011, the huge earthquake of M9.0 (firstly it was 8.8) occurred offshore of Sanriku (north east of Japan) with its epicenter covering a region 500km long (north-south) and 200km wide (east-west) in the Pacific Ocean (see Fig.1). Accordingly the damaged areas were also 500km long including a part of Hokkaido (the north island of Japan) in the north and Tokyo in the south. We have had many big earthquakes in the past, for example Kobe Great Earthquake in 1995, but the damaged area from this earthquake was limited in several 10s of km. I was in my house located in the west of Tokyo at the time of the earthquake. When I felt that it was dangerous to stay in my room I rushed out of my house together with my wife. The shaking continued for almost 3 minutes (normally most earthquakes only last about one minute even in the case of very big earthquakes) and many after-shocks followed. After the earthquake has settled I switched on TV because I had not realized that very serious damage had occurred in the Tohoku Area (north east of Japan) and that a Tsunami would be coming soon.

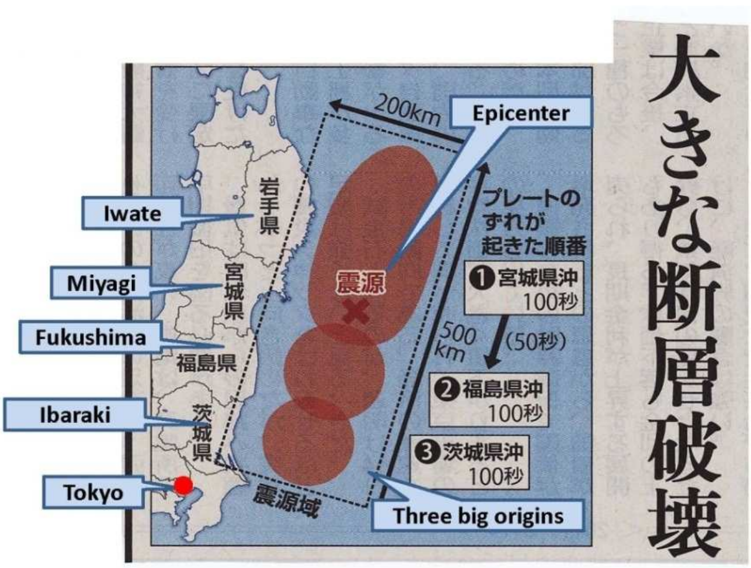

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Figure 1: Very Wide Area of Epicenter

The damages are as follows; 11,168 dead (so far confirmed), 16,407 missing (still increasing), 2,778 injured, 151,868 houses destroyed, 240,000 people evacuated, 2,200 roads damaged, 56 bridges collapsed, 6 fuel power stations destroyed, Tohoku Shinkansen (partially recovered) and Tohoku Highway (now recovered) but damaged (as of 29th March, 18 days after the earthquake). The main damage was caused by the Tsunami which swept away huge number of people, cars, houses, fishing boats, ports and harbors see (Fig.2a and 2b). A quick measurement of the height of Tsunami showed as follows; 23m at O-funato, 16m at Minami Sanriku, 15m at Onagawa, 14m at Fukushima nuclear power plant, 13m at Kuji port, 7~8m at Kamaishi, 5m at O-arai etc. The Tsunami hit small coastal towns 5km upstream along a river in the Sanriku Area, where the bay has a V shaped topography which exaggerates the height of Tsunami. Along the River Kitagami, the 5m Tsunami hit the mouth where it swept away all harbor facilities and boats, at the 4km point along the river a bridge collapsed, at the 6km mark riverside villages were flooded, at 14km along the river agriculture fields were inundated and at the 49 km mark the water level at the gauge station suddenly rose 10cm one hour after the earthquake. Even at Toda, 28km upstream on the River Arakawa, flowing into Tokyo Bay, the water level rose 1m 20cm after the earthquake. Such Tsunami propagation would normally be unexpected.

©Yu Tube

Figure 2a: Tsunami attacking Miyako City, Iwate Pref.

At 3pm, March 11, 2011 (The height: 10m)

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Figure 2b: A big boat flown on the roof of a building in Otuchi Town, Iwate Prefecture

The most serious accident was the destruction of the Fukushima Nuclear Power Plants at which the cooling system and electric and electronic facilities were severely damaged by the Tsunami (see Fig.3). It resulted in the extraordinary heating up of the nuclear reactors and protection vessels. Atomic radiation was spilled out polluting the air, water and soil as well as vegetables and milk. People within 20km radius had to move out of the residences and people within 20~30km had to stay inside their houses. The total number of people evacuated was a maximum of 450,000 as result of not only the earthquake and Tsunami but also the nuclear power plant accident. The survivors and evacuees have had to stay in congested houses without lighting, heating, water, food, blankets etc. in spite of sub-zero temperatures, until supporting materials arrived.

©Digital Globe

Figure 3: Accident of Fukushima Nuclear Power Plants with Hydrogen Gas Explosion

People in the metropolitan area of Tokyo were also panicking as all trains and subways were stopped making it impossible for several million people to go back home and very difficult to even move around. Within 30 minutes of the earthquake, all drinks and food were sold out in shops. From the next day, water, food, toilet papers etc. were also sold out at super markets, department stores, convenient stores and so on. Electricity failures also commenced as the electric power stations stopped operations leading to shortages of electricity. Tokyo Electric and Power Supply Company (TEPCO) had the capacity of 52 million KW before the earthquake which was reduced to 31 million KW after the disaster. Fukushima Nuclear Power plant was providing about 9 million KW. There were serious shortages of gasoline as oil refinery facilities were also damaged. Almost all gas stations and tanks were swept away in the coastal areas. This led to problems in transporting relief supplies to the damaged areas because of lack of gasoline. Even in Tokyo two weeks after the disaster, we have had to queue an hour for gasoline supplies which are limited to only 10 litres. In addition, almost all ports were damaged by the Tsunami, while roads and railways were unusable. Only defense helicopters were available to the rescue parties. Mobile phones and Internet at the sites were not available for many days, which made communications between safe and damaged areas, as well as among family and relatives difficult. Many survivors lost their mobile phones but even if they had their mobile phones, they could not use them because there were no electricity services.

Lessons from the past disasters in Japan

Japanese people are well educated on evacuation procedures in the case of earthquakes and Tsunami as so many terrible disasters have occurred in the past. Particularly the area of Sanriku was heavily damaged by the Great Tsunami in 1896 which killed almost 22,000 people including my great grandfather. Following this terrible lesson, many coastal towns constructed breakwaters to protect them against future Tsunamis. For example, Kamaishi City, Iwate Prefecture constructed huge breakwaters 2km long, 20m thick, 8m above sea level and 65m deep, which have been registered as the deepest breakwaters in the Guinness World Records (see Fig.4a and 4b). Taro fishing village, Miyako District, Iwate Prefecture constructed 10m high breakwaters against Tsunami, as the village was most seriously damaged by the 1896 and 1933 Tsunamis. But those breakwaters were completely destroyed by the Tsunami this time, which was 14m high, much higher than authorities had prepared for. Many people said that the Tsunami was higher than expected, but the Tsunami in 1896 was 38m high! We should have learnt the lessons that ‘hardware’ including very high breakwaters, cannot save people but we need to use ‘software’ including procedures for providing early warning and evacuation systems.

There was a small village in Aneyoshi District, Miyako City, Iwate Prefecture which was thoroughly damaged by the 1896 Tsunami and 1933 Tsunami with only 2 and 4 survivors respectively. An ancestor built a memorial stone on which an important lesson was written, “Don’t build any house below this point!” The stone is located 60m above sea level. The villagers followed this lesson and built their houses in the upper area. When the Tsunami came all villagers ran 800m up the slope and escaped to their houses built on the hill. The Tsunami stopped 50m in front of the hill and all villagers were saved.

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Figure 4a: The Deepest Breakwater against Tsunami in Kamaishi Bay. Iwate Prefecture

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Figure 4b: Destructed Breakwater in Kamaishi Bay by Tsunami

In the case of the 1995 Kobe Earthquake, which killed more than 6,000 people the establishment of a GIS database was so important for recovery from the damage. Many local governments started a GIS database but everything including computers, databases, backups, even city and town halls/offices were swept away. Most people lost ID cards and passports which made it difficult to identify them by documentary evidence. In several towns, the official registration data bases were also lost as well as town offices.

Lessons from the disaster

First of all, I have to say that there is nothing absolutely safe. Though many Japanese doubted the safety of nuclear power plant, the Japanese government and industry convinced people to support the construction of nuclear power plants as they believed them to be absolutely safe. In spite of their aversion to nuclear matters, as the Japanese have been the only nation to experience atomic bombs, the majority of local people accepted the construction of nuclear power plants through a referendum. Electric power companies and consultants always said that power would be cheapest if produced by nuclear power stations. But now we Japanese realize that the cost has been tremendously high and in addition the accident is robbing them of their life and their use of land more than 250km wide (Tokyo is 250km away from the Fukushima Nuclear Power Plant and its drinking water is in danger of contamination from atomic radiation). We are learning how difficult, complicate and time consuming it is to control a nuclear plant after an accident.

Many local people have made mistakes and misjudgments though they were given lessons by their ancestors on how to evacuate from a Tsunami. But some people did not know enough about the behavior of Tsunamis. For example, Asahi City, Chiba Prefecture located on the sea coast was hit by the first Tsunami at 3:45pm, one hour after the earthquake when local people had succeeded in evacuating to a hill. After the Tsunami withdrew, some people went down to their houses or the coast, even some people tried to fill their cars with gasoline. But a second Tsunami came at 4:20pm, 35 minutes after the first Tsunami when these people were swept away and died. After the withdrawal of the second Tsunami, the survivors wanted to search for victims in the city area near the coast as they did not think that the Tsunami would return. Unfortunately a third Tsunami, an even higher one hit the coast at 5:26pm, an hour after the second Tsunami and killed the remaining people. One of the survivors said that there would no more Tsunami after the second one. The occurrence of Tsunamis and their repetitions were different from place to place. The earliest Tsunami was 15 minutes after the earthquake while most Tsunamis came 30 minutes after. But we Japanese did know that sometimes it takes a long time for Tsunamis to arrive. For example, the big 6m high Tsunami hit the Sanriku Area 22 hours after the Great Earthquake occurred in Chile in 1960, killing 142 people. NHK TV immediately announces whether we have to prepare for a Tsunami but not after every big earthquake. At this time many people evacuated second or third floors of concrete buildings. They would or should be safe, but the Tsunami came up to the fifth floor of some buildings for which the roof was the only safe place.

In Japan, all local governments must produce hazard risk maps which show places of refuge or shelter and roads leading to them. Some villagers followed these guide maps and successfully reached the refuge, but in other cases they were unsuccessful as the estimated height of the Tsunami was lower than the actual Tsunami. There was an interesting report in which Sumo Hama, Miyako District, Iwate Prefecture succeeded to evacuate 109 people out of 110 villagers onto a safe hill even though the village had no breakwater against the Tsunami. Those villagers used to rehearsal Tsunami evacuation procedures every year including communication among villagers and evacuation routing. At Funakoshi Primary School located in Yamada Town, Iwate Prefecture, the school itself was designated as a place of shelter as it is located 13m above the sea level. 176 school children were first evacuated to this school, but Mr. Shuzo Tashiro (55), a school helper judged the shelter was not high enough when he saw the Tsunami wave at the coast. He urged all children and teachers to escape up to a hill 40m higher. Then Tsunami came and swallowed the school. If he had not guided them to the higher hill, all people would have died.

There was another successful story in the city of O-arai, Ibaraki Prefecture which was hit by a 5m Tsunami. A young fire man 19 years old continued to shout in front of the disaster wireless microphone which warned people through 45 speakers; "Escape to a higher hill immediately!" even though the Tsunami came to his legs, he continued to shout after the Tsunami went away "stay there and don't move" for two and half hours. It resulted in all local people including an old lady of 91 years old being perfectly safe. The lesson was obvious that 'software', particularly communication systems could work much better than hardware such as super high breakwaters.

Who survived and who did not?

Besides the above mentioned stories, I would like to introduce several fortunate and unfortunate stories as follows.

– When an old lady, 60 years old was swallowed by the Tsunami and was bobbing up and down in water and trying to get to the surface, luckily a "Tatami", Japanese mat floated in front of her. She jumped onto the "Tatami" but she was in a whirl and vortex rotating at high speed. Again luckily a wooden house floated by so she jumped onto its roof. Finally she was rescued by a helicopter.

– A young mother with two children tried to escape to a place of refuge in her car, but she could not move because of a traffic jam. She decided to go back but she could not make U-turn, she went onto the opposite lane and accelerated in reverse gear. Finally she could escape from the Tsunami but many cars in front were washed away.

– Another young mother tried to evacuate to a refuge on a hill by car together with her mother and children. She listened to a voice of a policeman shouting "Tsunami is coming!" She decided to get out of the car and took her mother with her children to a hilly forest nearby. In only a few seconds, the Tsunami came and swept away her car together with other cars in front of her. Five days later she discovered her car turned over and crashed.

– The town mayor of Otsuchi Town, Iwate Prefecture organized a rescue party immediately after the earthquake with other staff outside of the town office. The deputy town mayor realized the Tsunami was coming and shouted to escape to the top of the fifth floor building of the town office. When the deputy town mayor reached the roof of the building, the town mayor was on his way but was swept away by the Tsunami. There was no more than 30 seconds difference between safety and death. Similarly in Onagawa Town, a gentleman ran up to the fifth floor (15m high) and safety but he said no one could believe that the Tsunami would come up to such height (see Fig. 5).

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Figure 5: Water Level of Tsunami (15m) in Onagawa Town up to the Roof of the Fifth Floor Building

– One journalist of Iwate Tohoku Newspaper tried to drive his car to collect information about the damage. He brought his personal computer from the second floor office into his car. His wife also helped him but she recognized the Tsunami coming soon. She shouted to her husband to escape to the second floor immediately, but it was too late for him though his wife could escape. She saw her husband's face in the wave of Tsunami.

– A woman escaped to the second floor of her house where the Tsunami came up almost to the ceiling. There was only a small space, say 20cm for her to breath. She grasped a curtain rail to prevent from being swept away for more than 30 minutes until the Tsunami went down. She was lucky to be rescued in the next morning but she had to spend a very cold night being wet in below zero degree temperatures.

– A grandmother aged 80 years old and a grandson aged 16 years old were rescued 9 days after the earthquake. Their house was swept away about 100 m from its original location in the direction towards the coast, Ishinomaki City, Miyagi Prefecture. The house collapsed but luckily the kitchen floated in the water and they were forced to stay inside the room for several days as neither she could move to escape. As the grandson could move about in the narrow kitchen, he found water, cakes and yogurt in the refrigerator which were given to his grandmother. Finally the grandson succeeded in escaping 9 days later and called out to be rescued and was discovered by rescue patrol. This would be a very rare case.

– At a hospital located in Rikuzen Takada City, Iwate Prefecture, Secretary General of the hospital tried to bring a satellite communication device placed on the ground floor up to the fifth floor. He handed it over to one of his staff and tried to climb up to the fifth floor, but it was too late. The staff could escape to the roof of the hospital with the satellite communication device and survived. The Tsunami came up to the fourth floor and killed all patients who stayed on the third and fourth floors, and even the fifth floor. The speed of Tsunami is said to be 800 km per hour in the ocean and 60km per hour at coast and on land. It was much faster than expected.

– Mr. Ohtomo, Wakabayashi District, Sendai City, Miyagi Prefecture had recognized long before the earthquake that it was not appropriate for Sendai City to designated a primary school as a shelter for a Tsunami and requested Sendai City in September 2010 to change the hazard risk map to another place. When Tsunami hit the district Mr. Ohtomo did not go to the school but a higher road where he looked down to see the school swallowed by the Tsunami at the level of the second floor. The road he selected was safe, which was on the border of the Tsunami safe area. 300 people could survive on the road, but many other people who followed the hazard risk map died at the school.

Prediction of earthquakes

No one has succeeded so far to predict earthquakes. It is one of the most difficult sciences and technologies in the world. Japanese seismic scientists and engineers have not yet succeeded either. I tried to make a prediction using GPS fixed stations located all over Japan, which are constructed by Geo-spatial Information Authority (GSI). Dr. Harumi and I have developed a method for prediction by checking whether the changes in dimensions of triangles between GPS Stations exceed a threshold. I have already submitted a paper on “Prediction of Earthquakes with GPS Data” to GIM, Coordinates and Journal of Digital Earth. Unfortunately Dr. Araki and I are retired persons who have no assistants or research funds. We could confirm that all earthquakes in the past showed early signals before they occurred but we could not predict exactly on which day the earthquake would occur. The longest period between detected changes and the occurrence of the earthquake was two months and shortest case was only one day. Sadly not many people showed interest in our research and the method has been neglected even though we succeeded to register the method as a Japanese patent in 2006.

Dr. Araki and I are not interested in business but contributions to help people. I hope someone can follow our method of the prediction in future.

Role of geo-spatial technologies for the disaster management

RS and GIS are useful for damage assessment to compare between situations before and after the earthquake and Tsunami. There are two remarkable issues on this occasion. One was that high resolution satellite images clearly showed the damage and accidents at the Fukushima Nuclear Power Plants. Air survey was not available because of the high level of atomic radiation in air, as well as the destruction of local airports. Satellite images showed the condition of the power station buildings destroyed by the hydrogen gas explosion, which was useful for recovery planning. Another issue was damage assessment by comparing images before and after the Earthquake and Tsunami. As the damaged area was so huge, helicopters were inadequate. High resolution satellite images and also SAR were very useful to realize the scale of the damage (see Fig.6). Pasco analyzed high resolution satellite images and reported that

70% of the damaged areas by Tsunami were still inundated on the 24th March, almost two weeks after the earthquake. Insurance companies in Japan announced that they will provide compensation for earthquake insurance by assessing high resolution satellite imagery or aerial photographs without the site investigation, as access to the damaged areas was difficult and hence buildings could not be located or assessed.

A GPS wave height recorder located a few kilometers from offshore showed mostly 6~7m high waves which would usually be doubled depending on the sea depth and topographic conditions on land. A GPS recorder cannot be an early warning system as the speed of Tsunami is 800km per hour in deep sea areas and reduces to 60~100 km per hour on the coast and land. This means that cities 10km across will be inundated by the Tsunami waves in only 10 minutes. UAV was very useful to photograph Fukushima Nuclear Power Plants for analyzing the damage in detail and planning the next action, as ordinary aerial surveys cannot be made due to high risk of atomic radiation, while high resolution satellite images were also useful in the early stages.

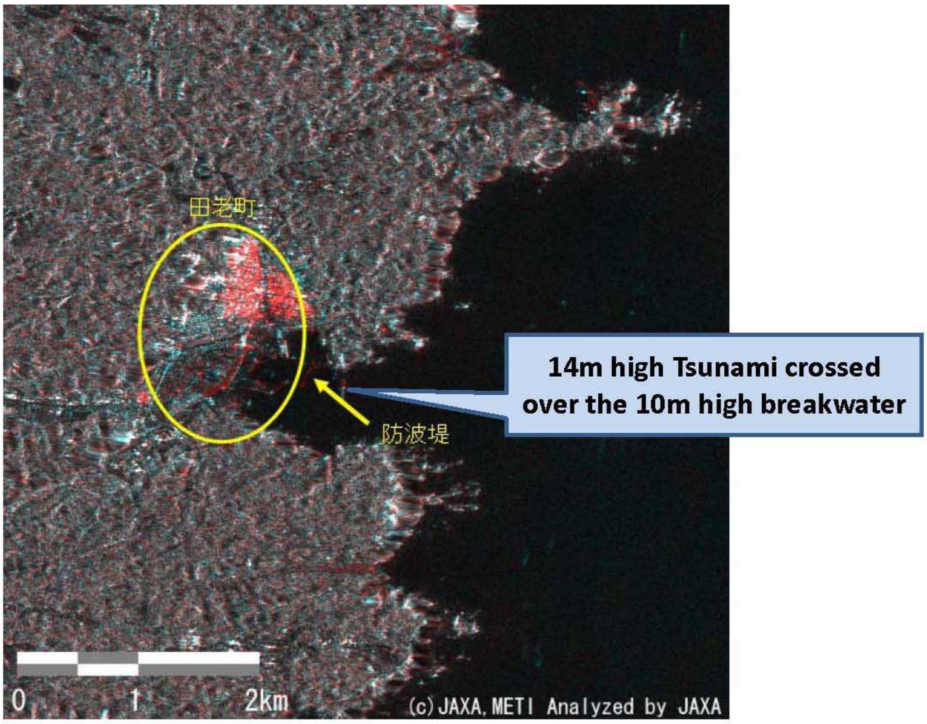

Figure 6: Damaged Areas (red) of Taro, Iwate Pref. Analyzed by JAXA with ALOS SAR

We thank Digital Globe, Google, JAXA, RESTEC and many other organizations for releasing satellite images for comparison purposes on the Internet. I also thank YouTube for publicizing video images of the Tsunami and other scenes. Many Japanese took videos and pictures of the damage of the earthquake and Tsunami using Japanese digital cameras and video cameras which would be very good references in future for establishing countermeasures on how to prevent, reduce or mitigate the effects of the disaster.

Concluding remarks

Although my family and my house in Tokyo are safe without any damage, I could not stand to watch the TV scenes as the real situation was too miserable. I sympathized with the affected people and those who lost their lives but as an old man living in Tokyo I cannot directly help those people except by donations. What I can do is to inform my friends and colleagues around the world about the real situation and stories. It could be somehow useful for our society to assist in saving human lives.

In conclusion, Japan committed a big mistake in listing nuclear power plants as a sustainable development which has proved to be not sustainable.

I would be pleased to know if you have become wiser by reading my article.

Finally I extend my condolences to those victims and their family who were lost as a result of the Tohoku Kanto Great Earthquake 311. I thank many friends from foreign countries and regions who have sent me kind words to encourage me as well as Japanese people.

MEETING THE WORLD HUNGER PROBLEM

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1. Introduction

The United Nations, and in particular its Agency FAO, the Food and Agricultural Organization has addressed the difficulties of sustainable development of the world due to the World Hunger Problem. The G8 countries have committed funding of 22B$ at the LrAquila Conference in 2010 to combat this global complex disaster. The Federal Republic of Germany has 3B$ in 3 years alone.

The reasons for this potential global disaster are manyfold and can be described as follows:

2. Urbanization

At present there are 6 B people in the world. There will be 9 B by 2060.

The highest rate of growth from 1B to 3B will be in Africa. E.g. Nigeria will grow to 300M people, and Lagos will grow 4 times by 2050.

Before 2010 the world rural population was more than 50% and the urban population was less than 50%. After 2010 the urban population will grow considerably higher, while the rural population will decline.

This trend cannot be reversed, but it may be possible to diminish the adverse effects.

3. Food

Between 2007 and 2010 the world will require 70% more food.

The 148 developing countries will need 97% more food, while the 63 developed countries only require 23% more food. In the period 1961 to 2007 the growth was 148% in the world, for the developing countries 255% and for the developed countries 63%. In that period this was possible by going to the limit in exploiting the available resources, which is not possible any more for the 2007 to 2050 period.

No planning for food security exists. The alternatives are migrations.

4. Fresh Water Resources

The limited availability of fresh water resources are an indicator. 70% of fresh water utilized is needed for agricultural production. 20% of the cultivated land for agriculture in the 219 countries of the world is irrigated. 40% of the agricultural production occurs in developing countries, 60% of which depends on irrigation.

Potential for further irrigation does not exist in Africa and Asia, but only in Latin America:

Irrigated area in M square km		area suitable for irrigation in M square km
S Asia	0.79	1.42
E & SE Asia	0.75	1.11
Latin America	0.19	0.78
NE & N Africa	0.28	0.43
Subsaharan Africa	0.05	0.39

There is a global demand for the increase of 10% of areas of irrigation.

5. Emissions

According to the U.S. Department of Energy Information the global CO2 emissions are continuously rising. This causes a rise of global temperature with more evaporation and more precipitation, except in the dry areas of the globe. The result is the melting of glacier ice and the rise if the sea level. At present 120M people are affected by this, but in 2050 there will be 1.2B people. If a global rise of temperature is to be limited to 2 degrees, this means, that the current agricultural production is to be lowered by 20% for 2030, by 40% for 2050 and by 50% for 2070.

At present global effects may be small, but local effects are large.

6. Energy

In the energy sector there is a need for an increase of 50% in the next 50 years. At present the oil price is the base price for food. Food needs to be transported to the market and properly stored costing energy.

The global energy need at present is for 500 EJ, 100 EJ is for transportation. Biomass fuel generates 50 EJ, 80% of which is in the developing countries.

7. Poverty problem

70% of the poor live in rural areas. The poor have too few resources to afford to buy food. Therefore investment in agriculture is required, so that the poor can be involved in the food production.

Food production has become an industry with partial automation in which the rural population does not share the wealth created by that industry. Its profit maximization often leads to monocultures with ill environmental effects.

The global market dictates raising of cattle by which the local resources of water and other crops are depleted. To diminish poverty the local population needs to be integrated into the process.

Microcredits for small farmers may be a solution to be offered by International economic cooperation, which serves as a key to strengthen the needed infrastructure and education.

8. International Aid to Rural Areas

The previous 18% of international donor aid to rural areas has in the last 2 decades diminished to 3 to 5%. Therefore the Millennium Goals cannot be reached. It is realized that the original level of support should be restored.

9. Needed Investments

In which areas are investments needed?

1) Infrastructure for roads, marketing paths, electrification, food safety: 18.5B$
2) Rural resources 9B$
3) Institutions (such as the cadastre) 6B$
4) Research and development 6.3B$
5) Safety networks 6B$
6) Food safety 7B$

The total need is for 50 to 60B$ of investments.

The funds foreseen by the **German Federal Ministry of Economic Cooperation** will amount to 1B$ per year for the next 3 years to support agriculture in rural areas.

850 M$ will go into bilateral projects
120M$ will go into multilateral programs (World Food Program)
30M$ will go into agricultural research

The problem is that rural development is cross-sectoral. 4 areas have been identified for needed cooperation:

1) Rural economy
2) Management of natural resources
3) Infrastructure
4) Political framework

Priorities must be defined in partnership with the receiver countries and in coordination with other donors.

The aim should be to develop small size farming.

The issues to be considered are:

1) Agriculture is a human activity requiring education and organizational setups. The optimal size of farms depends on the region.
2) The maintenance of biodiversity is important

3) Rural areas need to become more attractive

4) Governance is a burning issue. It requires a legal framework, political will and an administrative structure which guarantees secure land rights. This is of particular concern to the survey and geoinformatics professionals.

5) Gene technology can double agricultural production; however, further research is required

6) Sustainable fish cultures are mandatory. 75% of fishing grounds are overfished. Aquaculture is an alternative.

In these tasks the professional fields of geoinformatics are required in this multisectoral approach, which alone can lead to a sustainable solution of the problem.

Natural disasters are of major concern for a particular country or region.

However, the world hunger problem can become a worldwide disaster, if it is not tackled in a multisectoral integrated way.

10. Comments by a distinguished world economist:

Franz Radermacher was invited in July 2010 to address the goup of photogrammetrists, who celebrated the 100th Anniversary of the International Society for Photogrammetry and Remote Sensing. He is a founding member of the Club of Rome, who made the first impact in discussion the worldrs limited resources in the 1970rs. His contribution is summarized in the following comments compiled by the author of this paper. These comments are very much in line with the contents of this paper.

Radermacher acknowledged the contribution of ISPRS for international understanding and its reflection on the past, which is the key for the future. 100 years ago, the Austro-Hungarian Monarchy, as well as the Osmanian Empire had elements of a supranational structure, which failed, but from which we can learn in all modesty. There have been dwarfs on the shoulders of giants, as the Viennese economist Schumpeter expressed it. We can easily lose what scientists have brought about. It is the ability to cooperate, which can be the most powerful driver. Technology alone is not enough, it is only a chance, which can be used for the right purpose. Engineers in the past have been successful in solving problems, until a bigger problem came up. Examples for the boomerang effects and the following frustration were the invention of the “paperless office”, which created the biggest paper demand ever. Or, the idea that the Internet would stop travelling. Now we travel all the time, despite or because of it.

At the present time, when half the human population earns less than 2$ per day, there is not enough to eat. Nevertheless, cows, which are raised to feed us, consume more resources than humans. The production of bio-diesel is a similar issue. The adoption of a modesty principle would be appropriate. The main effort should be on human cooperation, not on self destructive competition. Competition should be regulated by law. 1000 years ago Europe lived in the dark ages, progress then went on in the Islamic world. Today, China is on the rise. Should the winner take it all? Or should also the loser gain?

The present global environmental problems have accelerated. Will we have a 2 degree higher global temperature? Will we cope with global reforestation, which calls for 5 million square km of new forest by 2040? At the Environmental Conference in Copenhagen there was a negative press with respect to China and India, and yet, these countries have a much lower CO2 emission per inhabitant, than the developed countries. We should cooperate and accept the modest offers, these countries make, and not dictate.

We know, that the financial sector needs regulations, as the free market alone cannot solve all problems, we need an ecological-social balance.

Adam Smith, the philosophical founder of capitalism worked under reasonable regulations, economy was a tool in this framework for him. The Club of Rome and the Global Ecoforum suggest, that we need science and we need cooperation. Greed in the brains does not bring happiness, but mutual understanding does.

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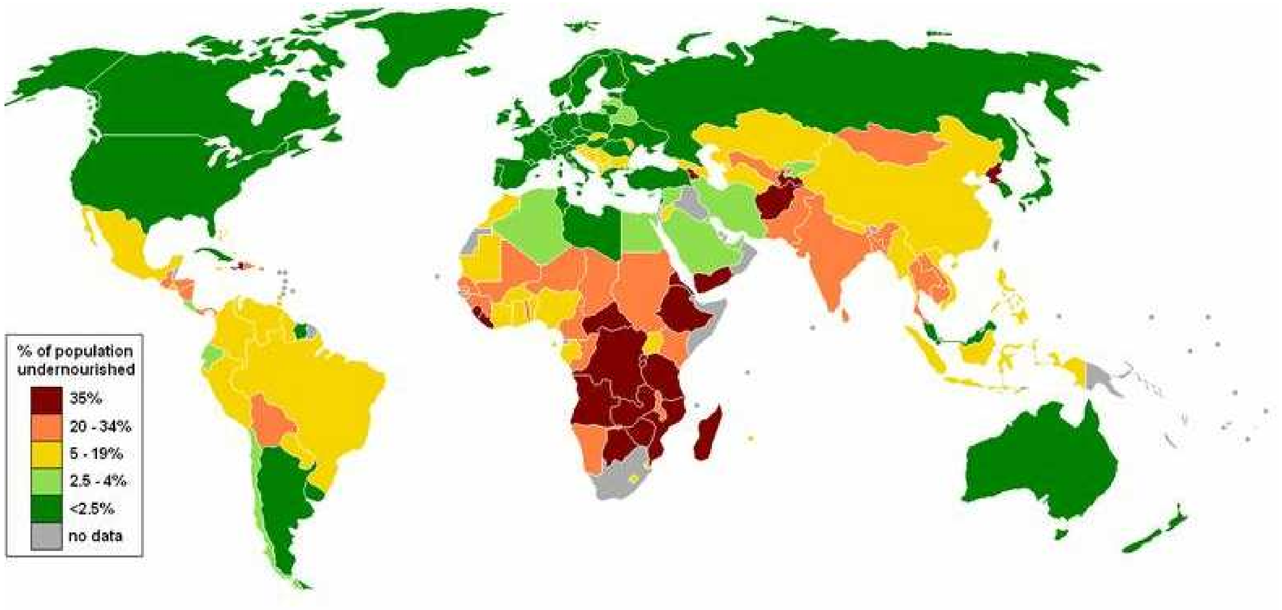

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GLOBAL MONITORING FOR FOOD SECURITY (GMFS): A GMES - EARLY WARNING SYSTEM FOR FOOD SECURITY IN AFRICA

Carsten HAUB, Sven GILLIAMS, Andreas MÜTERTHIES, Germany

This paper is an updated version of the publication by Haub et al. [5].

Key Words
GMFS, GMES, Food security, Early warning, Earth Observation, Crop Yield, fAPAR, VPI

Summary
The Global Monitoring for Food Security (GMFS) project aims to provide earth observation based services for, and encourage partnerships in, monitoring Food Security and related environmental processes. This is done, by concerting efforts to bring data and information providers together, in order to assist stakeholders, nations and international organizations to better implement their policies towards sustainable development.

GMFS is an ESA Earth Watch GMES Service Element (GSE) and is part of the ESA contribution to the EU/ESA Global Monitoring for Environment and Security (GMES) framework. Service lines and user network had been established and consolidated during the first two stages of the project, which ran from 2003 until 2009. The aim of the 3rd stage of GMFS, kicked off in June 2010, is the sustainable transfer and integration of ESA data and the GMFS service portfolio into operational contexts at the relevant African stakeholders networks.

1. INTRODUCTION

Currently more than 1 billion people on earth are affected by hunger and more than 30 countries are experiencing food emergencies [1]. Most of them are in Africa. Advanced Earth Observation technologies can certainly contribute to more effective mechanisms for identifying food crises and to define early reactions, but are at this stage rarely integrated into decision making processes. The main reasons for this were i) still limiting capacities and weak experts networks at the stakeholders levels, ii) lack of integrated processes to operationally generate the needed geo information at appropriate scales and iii) lacking long term availability and continuity of earth observation and satellite data.

Access to ESA satellite and Third Party Mission data to African stakeholders networks and the future availability of this type of data via the Sentinel missions, together with the recently approved data policy principles to ensure free-of-charge access to all Sentinel data is one important contribution to address these issues. The ESA GMES Service Element Global Monitoring for Food Security (GMFS) is another contribution to this.

GMFS aims to establish operational services for crop monitoring in support of Food Security Monitoring to serve policy makers and operational users, by ensuring sustainable integration and application of those solutions into a well nodded stakeholders network in Africa [2].

The GMFS framework is focusing on those aspects of food security monitoring where satellite derived technology brings added value. These include monitoring parameters reflecting crop condition, agricultural production and overall vegetation health [3]. Since 2003 the GMFS framework is aiming at establishing multi scale crop monitoring services by providing spatial information on variables in different spatial, temporal and thematic resolutions affecting Food Security [4]. Policy makers and operational users at the various administrative levels do need reliable and continuous information sources. Advanced crop information derived from Earth Observation data do contribute to their need to achieve transparency about the extent and distribution of agricultural production as essential information to assess food availability. Whereas the ultimate goal to identify food insecure areas and populations and to quantify their level of vulnerability with particular emphasis on food security, does need more than only innovative and robust processing chains. Assessing the information needs, being able to develop a technological solution and providing services is a first step. Ensuring know how transfer, following up the actual integration of the services into the day-to-day frameworks and being fully involved into the institutional networks is a second step, to really bring the solutions to the user institutions.

Coming from the current GMFS status (Chapter 2) this article will summarize the strategy how the service integration and know how transfer to the user community is being performed in GMFS3 (Chapter 3).

2. RECENT GMFS OUTCOMES

During the two previous stages of GMFS the value of Remote Sensing (RS) information from continental to local scale for crop monitoring and food security could be demonstrated.

Thanks to the multi scale GMFS portfolio (see tab.1) good working relations are established with the stakeholders network in Africa. These services provided the regional centres the necessary reliable access to early warning data sets and capacity building, to support their decision makers and the national early warning units. As an addition to the continuously production and provision of the Early Warning Services (EWS) GMFS established an extensive data cataloguing and dissemination infrastructure by means of GeoNetwork, internet, ftp transmission and the ESA Data Dissemination System (DDS).

At national level GMFS contributed to stakeholder frameworks with the introduction and the integration of the Agricultural Mapping Services (AM) into the common work flows. GMFS delivered demonstration cases and identified bottlenecks and weaknesses of RS for agricultural applications. In this respect GMFS also provided advanced training for ground truthing field work, GMFS- and satellite data handling and the integration of those products into the daily work of various government experts.

Table 1. GMFS II Service Portfolio between 2005 and 2008

Service	**Product Name**
Early Warning (EW)	FAST Evapotranspiration
	Vegetation Productivity Indicator (VPI)
	Fraction of Absorbed Photo synthetically Active radiation (fAPAR) / DMP
	Soil Water Index (SWI)
Agricultural Mapping (AM)	Cultivated Area (CA)
	Extent of Cultivation (EoC)
Crop Yield assessment	Crop Yield (CY)
Support to CFSAM	GMFS Support Kit for FAO/WFP CFSAM missions (SK)

Throughout the project user involvement and user contacts grew continuously. The GMFS partnership secured very good relations at regional level with the AGRHYMET centre in Niamey, RCMRD in Nairobi and the SADC-RRSU in Gaborone. At the national level very close working relations were established with Ministries and public authorities in Senegal, Ethiopia, Mozambique, Malawi, Sudan and Zimbabwe. These relations were strengthened by the fact that the GMFS partnership was opting to have local experts as national GMFS representatives to support the consortium with its user liaison and implementation of GMFS services.

With respect to the services provided in GMFS I and II a summary can be found in reference [6] In short it can be said that:

For the Early Warning services about 30 million km² were covered with indicators on a 10 daily basis, serving 8 regions of interest and 11 user organizations.

Agricultural mapping products were provided to 5 countries; Senegal, Ethiopia, Sudan, Malawi and Zimbabwe, addressing the needs of respective Ministries of Agriculture. Throughout the 6 years of GMFS operations, Malawi and Senegal were mapped 5 times and Ethiopia and Sudan were mapped twice. In other words 4.1 million km² were mapped at medium resolution and about 1 million km² was mapped with high resolution images.

Validation of these products was done based upon fieldwork. In collaboration with local experts and integrated in already existing national surveys, a total of nine fieldwork campaigns were executed.

Agro-meteorological departments in Senegal and Malawi were supported with yield estimates. These yield estimates were provided twice per year and covered the most important regions in the country.

For the support to the FAO /WFP CFSAM, inputs were provided for missions in Zimbabwe, Ethiopia, Sudan, Malawi, CILSS, Mauritania, Senegal, Gambia, Guinea – Bissau, Mali, Niger and Chad.

Over the past 6 years 30 training session were provided to a total of around 200 national, regional and international experts. Training sessions covered all aspects of GMFS:

- Field data collection
- Validation procedures
- Early Warning indicators
- High resolution SAR data and medium resolution optical data for agricultural mapping
- GMFS support to CFSAM methodology
- Agro-meteorological Yield forecasting
- ESA DDS

As a result of these achievements the consortium received clear request from several users to continue with the services after Stage 2.

3. TRANSITION TO GMFS3

For GMFS3 the service integration and know how transfer will be employed on:

- An organizational level to transfer the services to operational structures through the actual involvement of the users into the service network,
- A technological level through an ongoing evolution of the services and customization dedicated to the different user needs and,
- With a logistical focus aiming at establishing and strengthening data accessibility and dissemination by means of up to date technologies.

Whereas all developments will be a continuation of the recent outcomes, the consolidated Service Portfolio and the established Service Network [6] will specifically be customized to dedicated users needs (see Fig. 1).

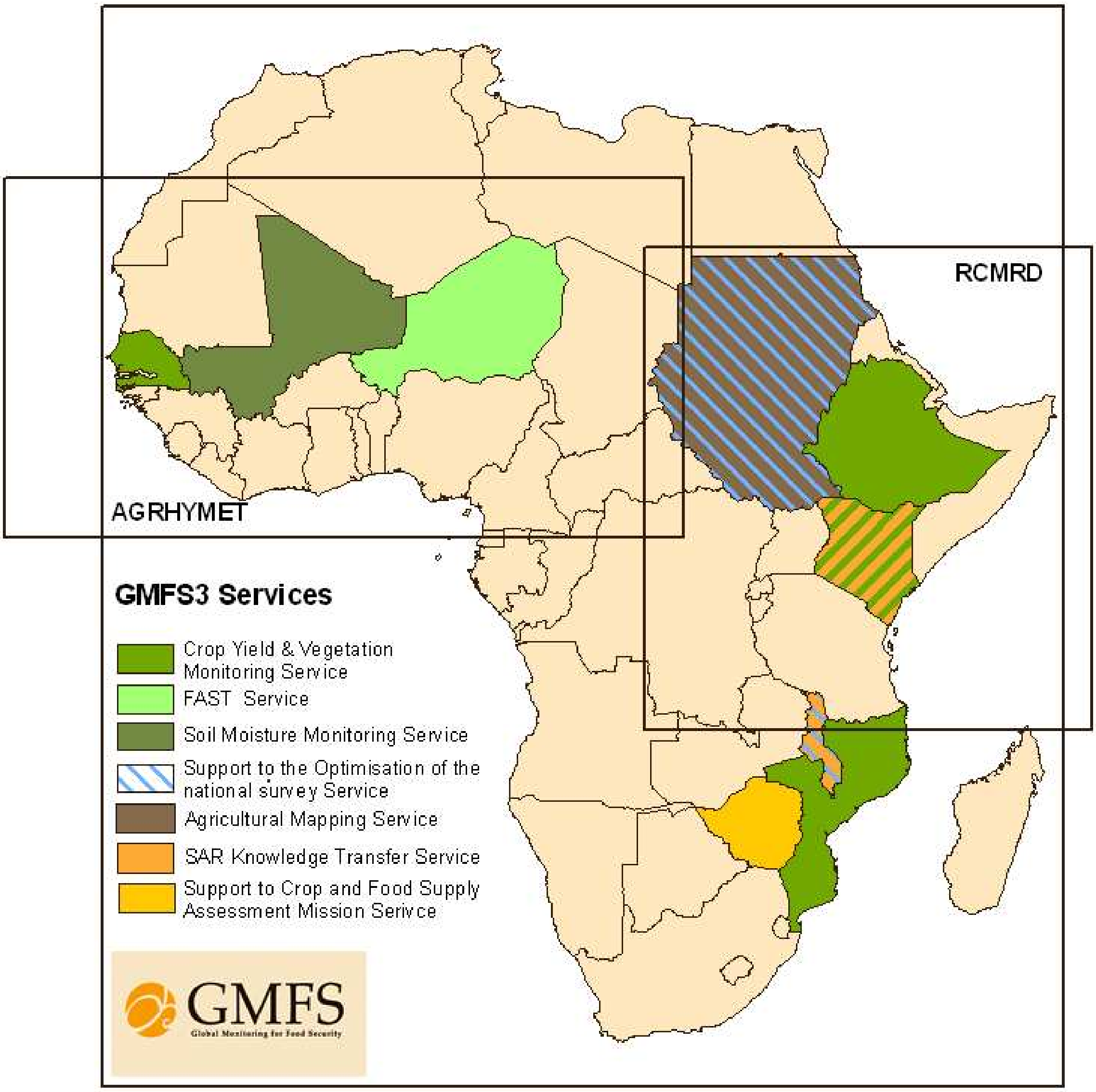

Figure 1. Overview of the GMFS activities by region and service

In this respect the particular emphasis of GMFS Stage 3 is to take the following measures:

3.1.Transfer services to operational structures

The GMFS partnership already initiated the organizational process of growing involvement into the African stakeholders' frameworks, established formal collaborations with the relevant legally mandated organizations in various countries at very high political levels and is going to strengthen these activities.

3.1.1. Involvement of user organizations

By design, users are involved in GMFS Stage 3. The proposed activities build upon the partnerships established with key users during Stage 2 (Sudan, Malawi, Senegal, Zimbabwe, and Ethiopia). This ensures continuity in supporting those users and further paves the way for sustainability. With each of those users service level agreements have been established in the 2005-2008 time period.

The users are the driving force behind the implementation of proposed GMFS activities. Those will be the institutions to execute and use the GMFS services beyond this stage 3. The service network within Africa will be coordinated through two regional centres AGRHYMET and RCMRD for respectively West and East Africa. They are included as GMFS3 subcontractors of the GMFS partners. Thanks to their mandate the involvement of the regional centres will greatly facilitate the contacts at national level and assure know how dissemination at country level. The Regional Centres will be the key actors of the service sustainability ensuring a multiplier effect.

Table 2. National users in GMFS Stage 3 and actors at the international and regional level.

Institute	Country
International level	
Food and Agricultural Organization (FAO)	UN
EC Joint Research Centre – MARS-FOODSEC	EC
World Food Programme / Vulnerability Assessment Mapping Unit	UN
Regional Level	
AGRHYMET Centre, Niger	CILSS
RCMRD, Kenya	East Africa
National level	
Centre de Suivi Ecologique	Senegal
Ministry of Agriculture and Rural Development (MoARD)	Ethiopia
Federal Ministry of Agriculture (FMoA)	Sudan
FAO Emergency Unit	Zimbabwe
Instituto Nacional de Meteorologia-INAM	Mozambique
MINAG	Mozambique
Ministry of Agriculture, Irrigation and Food Security	Malawi
Laboratoire Sol - Eau – Plante/ soil – water – plant laboratory” (LaboSEP) of the Institut d'Economie Rurale (IER) in Mali	Mali

3.1.2. Scientific advisory group

A scientific advisory will critically review the scientific value of the provided services and provide recommendations on methodological improvements. Members that confirmed their interest are:

- Université Catholique de Louvain
- JRC
- FAO
- University of Bonn
- USGS
- User Board

One representative of all the GMFS users organisations will join the User board which will be connected with members of the GMFS Scientific advisory group to ensure collaboration and knowledge exchange between end users and the international experts.

3.2. Maintain services and benefits to users

The technological part of the transition to GMFS3 requires a revision of the given capacities and infrastructures of the user institutions on the one hand side and a revision of the appropriateness and usability of the services and products on the other hand side.

On basis of the lessons learned in former project stages and the very close embedding of the GMFS framework, future activities are aiming at strengthening the technology transfer by means of a systematic customization of the GMFS services to dedicated user requests at national scales (see Fig.2). These are linked up with complementary development initiatives in the different countries.

3.2.1. GMFS3 Services

All services that are part of GMFS3 are based upon a clear user request. This is the basis for collaboration and is also a primary condition in achieving service transfer to the user. Targeting specific user needs and helping users to better understand and use the GMFS3 products is a first step towards sustainability of the Services.

The following information services are planned:

- Crop Yield and Vegetation Monitoring Service (CVM)
- FAST Service (FAST)
- Soil Moisture Monitoring Service (SMM)
- Support to the optimization of national agricultural survey Service (ASO)
- Agricultural Mapping Service (AM)
- SAR knowledge transfer Service (SAR)
- Support to Crop and Food Supply Assessment Mission Service (CFSAM)

3.2.2. Service Evolution

Services will be continuously improved through dedicated R&D actions and through parallel R&D projects. In general the focus will be on service transfer to the users and as such users will benefit of these evolutions through dedicated training sessions. However there are also two dedicated service lines for R&D foreseen within GMFS3.

The dedicated R&D activities are foreseen for Malawi to ensure evolution of the services:

- Experimental crop acreage assessment
- Experimental crop specific and crop changes maps

These two work packages will tackle important outstanding issue of agricultural monitoring of selected agro ecological systems and will be performed in close collaboration with local expert (agricultural and remotes sensing) and the GMFS science team.

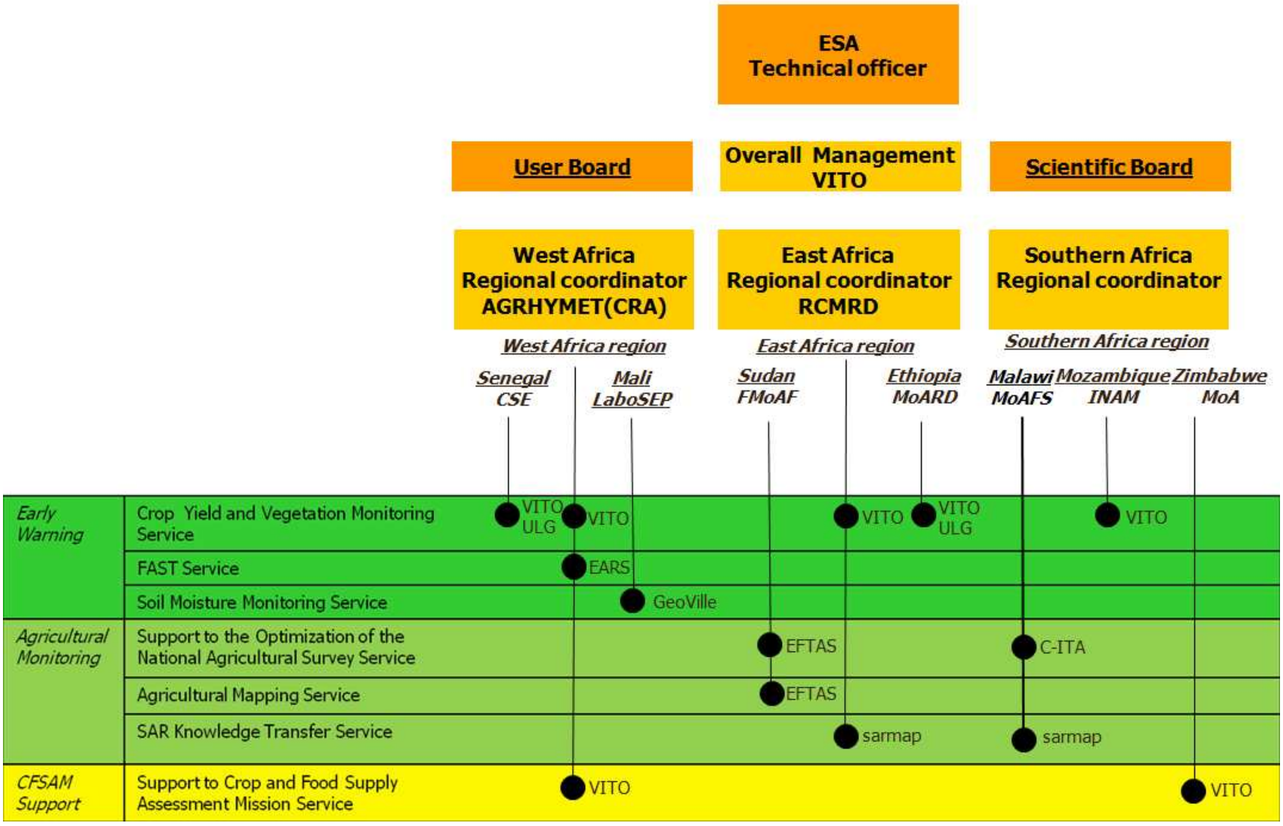

Figure 2. Overall schema of the GMFS project organization by Service, region, user and responsible GMFS partner.

3.2.3. Service Sustainability

The design of the project is such that all activities are geared towards the integration of these type of services into operational monitoring mechanisms.

In particular, the activities and actions foreseen are:

– Secure access to the users to Earth observation based products, through setting up operational multi-sensor processing chains and facilitating the distribution and usage through dedicated tools and dissemination mechanisms. As such ensuring a smooth transition to the upcoming sentinel mission.

– Capacity building and training in order to better understand and facilitate usage of the GMFS data and products

3.3.Set up access and data dissemination mechanisms

A logistical focus of GMFS3 is emphasizing the establishment and strengthening of operational reliable and easy to handle data accessibility and dissemination systems by means of up to date technologies. During GMFS Stage2, ESA DDS network, EUMETCAST (VGT4AFRCIA) and the UN GeoNetwork nodes in addition to standard means, such as ftp, web sites or e-mails, were used as data provision structures and access to GMFS products and satellite data archives such as the GMES framework as well as recent and future ESA missions.

This needs to be enhanced further into a more dense network of nodes in Africa, a wider spectrum of data and products and to future ESA satellite data and sensor missions.

Another important aspect is to arrange access to other data centres and providers. As various GMFS partners do maintain agreements with international EO data providers the GMFS framework should benefit from this relations.

4. OUTLOOK

For a successful continuation of the GMFS service chains beyond this stage 3 one basic requirement for operationability will be the insurance of financial continuity, which certainly will depend on the robustness of the processing technology, the reliability of data acquisitions, the accurateness of the products, the timeliness of the output information and the correct application of the outcomes.

In this respect the following aspects will indicate the success of the GMFS service integration and technology transfer:

– The range of implementation into users' operational structures

– Sufficient capacity and training aiming at understanding the provided services to facilitate the correct application of the services;

– Adequate participative customization of technologies to facilitate the data processing;

– Easy access and operational availability of the satellite data and geoinformation underlying the services.

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BIOGRAPHICAL NOTES

Dr. Andreas Müterthies

Dr. Andreas Müterthies has been working with Remote Sensing and GIS since 14 years. He received his PhD at the University of Münster (Germany) in 2002. Within his current activities as the head of the R&D division of EFTAS and as lecturer at the faculty of Geoscience at the University of Münster he is focussing on the development of new methodologies for the integration of Remote Sensing into environmental monitoring. He successfully managed several R&D- projects aiming at the development of feature extraction from airborne and satellite images in the context of environmental monitoring, nature protection and for navigation purposes. He is a member of the German society of Photogrammetry, Earth Observation and Geoinformation (DGPF e.V.) since 2002.

Recent publications (since 2008):

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Carsten Haub

Carsten Haub has been working professionally in remote sensing over the last 7 years. He is the head of the land use management division of EFTAS. He coordinated different remote sensing and GIS projects as e.g. several projects for Landuse mapping like LUCAS or CORINE Landcover. Moreover he is responsible for R&D-projects like GSE GMFS (GMES-Service Element Global Monitoring for Food Security).

Recent publications (since 2008):

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MRSID TECHNOLOGY FOR MANAGING LARGE RASTER AND LIDAR GEOSPATIAL DATASETS IN EMERGENCY RESPONSE APPLICATIONS

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Key words: LiDAR, Raster, Data, Compression, Emergency Response

SUMMARY

For over a decade, the MrSID® technology from LizardTech® has been the GIS industry's leading solution to the problem of storage and management of large geospatial datasets. Today, as the precision of sensors increases and as new data forms such as multispectral and LiDAR become more widely available, the need for advanced compression technology such as MrSID continues to grow.

In this white paper, LizardTech introduces you to the concept of compression, MrSID technology, and the features that the MrSID format brings to your applications and workflows.

I. The Need for Data Compression

Aerial and satellite imagery have been used by the geospatial community for decades. It is only in recent years, however, that such imagery has truly become critical, highly accurate, and ubiquitous: for this we can credit the Katrina disaster response efforts, worldwide counterterrorism initiatives, technical achievements in optics and signal processing, and browser-based mapping frameworks. Unfortunately, as rapid access to such data has become an imperative, organizations continue to struggle with storing, accessing, and exploiting the massive archives of high-resolution data that are so vital. National security agencies, web content providers, and your county government all have the same set of challenges.

Because digital image files are so large, maintaining imagery in its raw, uncompressed form requires immense physical storage resources, and accessing raw data requires high-bandwidth networks and large memory workstations. A typical alternative is to store imagery in compressed form, using file formats like JPEG. Although JPEG versions of the images may enable faster access to lower resolution image overviews, their quality is not suitable for analysis and exploitation work at high resolution. This often leads to the practice of storing multiple versions of each dataset, at different resolutions or compression ratios – one for browsing, one for analysis, and so on. The storage and maintenance problem gets worse, not better.

We know from working with customers such as the United States Geological Survey (USGS) and the National Geospatial-Intelligence Agency (NGA) that today's geospatial workflows regularly require support for files hundreds of gigabytes in size, storage of the imagery without significant quality loss, access to multiple resolutions or overviews quickly, efficient random access into the file to support arbitrary scene requests, and so on.

For over a decade, the patented MrSID® technology from LizardTech® has been the GIS industry's leading solution to these problems. Our applications such as GeoExpress® and Express Server® are used by thousands of people every day to encode and deliver imagery. And thousands more use MrSID files in hundreds of applications including ESRI ArcGIS, ERDAS Imagine, and Google Earth.

With the introduction of the MG4™ format, the latest version of the MrSID technology, LizardTech now offers compression for new kinds of datasets like multispectral images and LiDAR point clouds. In this white paper, we will introduce you to MrSID technology: what features it offers, where it can be applied, and how it works.

II. MrSID for Emergency Response Applications:

All emergency response activities require speed in providing responders with real-time imagery and data of the disaster zone or problem area. From Hurricane Katrina to California wildfires, from global anti-terrorism and homeland security activities to local municipal police and emergency response, MrSID is the preferred compression technology and file format for all types of emergency response, GIS, and dispatch applications due its small file size, fast performance, and the widely adopted support for the MrSID format across different GIS applications and platforms.

MrSID is supported in many applications including, but not limited to, ESRI, Intergraph, Trimble devices and applications, and others. In addition to 3rd party support LizardTech provides free access to the GeoViewer 4 application - a light weight viewer that can be locally installed on laptops and computers involved in the response efforts. What does this mean for emergency responders? Since users on the ground require information, data, and imagery in order to respond intelligently and quickly MrSID imagery is not only %5 (by default) smaller than TIFF and significantly smaller than other compression formats, it is also supported in the applications being used in the field to assist in the response efforts. MrSID is easier to manage, faster to distribute and work with, and supported in all major GIS applications.

Creating MrSID imagery and/or compressed LiDAR data is also fast. GeoExpress is used for creating any generation of MrSID (as well as JPEG2000 compressed imagery) and processes data at 6GB or more per hour. Many government agencies have archives of high resolution MrSID imagery online and ready should the data be required responding to a variety of emergencies and natural disasters. LiDAR Compressor quickly compresses LiDAR data. Express Server is used by several agencies for quickly serving massive amounts of high resolution MrSID imagery to a variety of different applications for many different projects simultaneously.

Due to the small filesize, the wide support of the MrSID file format throughout the market, and the speed inherent in the format, MrSID is the file format of choice for quickly delivering massive amounts of high resolution imagery to end users in the field for any activity, including emergency response.

III. MrSID Technology, in Detail

What is Compression?

Compression just means making data more compact so it occupies less space, but the word sometimes has negative connotations in our industry: often compressing imagery resulted in degraded data quality. You could have high fidelity or you could save disk space – but not both.

Consider a typical aerial image that is in 8-bit color and is 6,000 pixels wide by 6,000 pixels high. This means the raw data would consist of about 100 megabytes (MB) on disk: 36 million pixels (6,000 x 6,000), with each pixel requiring three bytes (three color bands of one byte each). A common workflow might, in fact, have dozens or even hundreds of such images arranged as tiles to make up a complete mosaic, but let’s just consider the one image.

When the pixels are stored in an uncompressed (raw) form like this, the image data is not compressed at all: the amount of disk space required is equal to the number of bytes needed to represent the pixels (plus some small amount for metadata such as the geospatial positions of the corner points). Geospatial file formats like GeoTIFF store data in this raw, or uncompressed, way: every single pixel is fully represented. Uncompressed formats have the advantage of representing each pixel’s data exactly as it was originally recorded, and so we say the image data is lossless. The obvious disadvantage, of course, is all the disk space you need.

Through the use of various algorithms, however, we can often represent the pixel data in a more efficient form. Intuitively, you can think of it this way: if the data consisted of a sequence of five identical values such as 123 123 123 123 123, you might instead be able to code it using a sort of shorthand notation like 123[5] in which you store the value only once but add a “repeat count” to it. Techniques like this yield data that is compressed – which means less disk space is needed – but the image data is still lossless.

If we push our compression algorithms further, we can find techniques which do not store the data for each pixel exactly but instead store only approximations of the data. Again intuitively, a high precision number like 3.1415, which requires five digits, might be stored as just the single-digit number 3, an 80% reduction in digit space (a 5:1 compression ratio). The JPEG file format, commonly used for small images on the web, uses this sort of lossy compression. The penalty for such lossy compression schemes is that you typically lose image quality: edges might not be as sharp, colors might seem flatter, small artifacts might be introduced. For some less demanding geospatial workflows, this might be acceptable.

In summary, then, we have a spectrum of three kinds of compression and data loss: uncompressed and lossless; compressed and lossless; and compressed and lossy. The naive techniques just described to achieve these kinds of compression will work, but by no means would provide high compression ratios, high image quality, and high performance. To do compression well in the real world, the algorithms need to be designed for specific kinds of data, such as geospatial imagery, and specific kinds of workflows.

MrSID Technology: Quality and Performance

The compression techniques used by MrSID technology provide both high quality imagery and high performance while still meeting our industry's challenging workflows.

Image Quality: MrSID technology's lossless compression yields compression ratios of 2:1 for typical imagery. This means you need only half the storage space and yet still retain your numerically identical, original data.

For further storage savings, MrSID technology's lossy compression can yield typical ratios of up to 20:1 while still offering a level of image quality that makes the data indistinguishable to the eye for most workflows. We refer to this style of compression as being visually lossless: there is still data loss, but with respect to what the image is being used for, the amount of loss is imperceptible.

Higher compression ratios are, of course, possible. Depending on how much image quality you need to retain, and depending on the type of your original imagery, ratios of 40:1 and beyond can be used.

Encoding Performance: Geospatial datasets can grow to consume terabytes of disk space. Sometimes the dataset is just one large file, but often it consists of hundreds of smaller tiles that, taken together, form a large mosaic. Either way, with many applications the amount of memory required to process and compress such large datasets is prohibitive, requiring the use of server-class hardware or requiring the end user to work with their imagery "piecemeal", only a subset of the tiles at a time.

MrSID technology is designed to address this problem. With full support for input and output file sizes larger than 2 GB and with support for 64-bit processors, there is virtually no limit to the size of the imagery that can be compressed.

Viewing Performance: Even at a ratio of 20:1, compression of a 20 TB dataset still results in an extremely large (1 TB) MrSID file. Users are often nervous about working with files of that size because many GIS applications will attempt to ingest the entire file, causing excessive and occasionally fatal demands on the CPU and memory. Two aspects of MrSID technology solve this problem.

First, the encoding technique we use creates multiple resolutions of the image within the generated MrSID file. This is similar in effect to the trick of creating image "pyramids", but the MrSID technique does not create extra files for all the pyramid levels nor incur the corresponding overhead in storage space. Instead, the resolution levels are inherent in the encoding scheme and fully contained within the single MrSID output file itself. These levels are scaled such that each level is one quarter of the previous level: for example, the full image at 1024x1024, then a quarter-scale image at 512x512, then a sixteenth-scale image at 256x256, and so on down to an "icon" or "thumbnail" of typically 32x32. Applications can be instructed to extract and process to only the level of detail required, without having to decode (and perhaps then manually down-sample) the entire full-resolution image.

In addition to enabling requests for only the resolution level desired, MrSID technology offers selective decompression, which allows applications to request and decode only the scene (geographic area) of interest from the file. Some other file formats and compression schemes, by contrast, require the whole image to be decoded even if only a small part is to be shown on the screen.

Introducing the MG4 Format: The prototype for MrSID technology was developed at Los Alamos National Laboratory in 1992. LizardTech's subsequent commercial version of the technology was called the MrSID Generation 2 (MG2) format and was introduced in 1998. The next version, the MrSID Generation 3(MG3) format, introduced in 2002, offered improved image quality and key features such as lossless encoding.

After a decade which saw the MrSID format become a de facto industry standard, LizardTech introduced the next generation of the MrSID family. In response to customer demand, we have extended the MrSID format to MrSID Generation 4 (MG4) to support multispectral imagery, enabling users to compress 4-band NAIP data, 8-band Landsat data or even 224-band AVIRIS data, losslessly or with our usual high-quality visually lossless compression. The MG4 format also adds support for alpha bands, enabling users with shapefiles defining the boundaries of their image data to perform more complex mosaicking operations than ever before.

Until now, MrSID technology has only supported raster data – pixels arranged in a very regular, 2D grid – but in the past few years, customers with very large, irregular, 3D elevation datasets have asked us for compression support. With the MG4 format, we have added support for LiDAR point clouds. With LiDAR data, users of the MrSID format get many of the same key features found in our raster compression technology, including lossless and visually lossless compression, and selective decoding.

MrSID technology is available in LizardTech's suite of applications and tools, ranging from full-featured encoding applications to image servers to lightweight viewers. In addition, through our integration partners, MrSID files are supported in hundreds of GIS applications. Whether you are using older MG2 files in your legacy applications, taking advantage of MG3's lossless files in your current workflows, or have a new need to efficiently encode multispectral raster or LiDAR point cloud datasets, MrSID compression technologies will support your needs.

IV. MrSID Technology for Imagery

In this section we describe in more detail some of the features and capabilities of the MrSID technology for raster image data.

Data Types and Formats

The MrSID technology is agnostic with respect to the input file format, as long as the input pixel data meets certain datatype requirements. This means that MrSID files can be generated from a variety of data sources including GeoTIFF, Imagine, and ECW.

The MrSID technology supports most data types used in geospatial raster imagery today: up to 16 bits per sample (signed or unsigned). Raster image data is almost always represented using unsigned integers. Digital elevation models and file formats like DTED, however, often use a signed integer representation, and so to support situations where our users want to compress these sorts of datasets, or perhaps use terrain models as base layers for their visualizations, MrSID supports signed integer data of up to 16 bits. The MrSID technology also supports 1-band grayscale, 3-band RGB, and 1- to 255-band multispectral or hyperspectral imagery.

Image Quality

As discussed above, MrSID technology offers excellent image quality for a given file size target.

- Numerically lossless: This level of compression typically yields a 2:1 compression ratio, for a 50% reduction in storage space. Lossless compression should be used when it is critical that all bits of the original image be preserved. This is the case for archival storage, as well as for uncommon workflows where no possible loss of precision is ever acceptable. You may also wish to use lossless compression when you are generating a “master” image from which other derivative images will be made, as through the MrSID optimization process described below.
- Visually lossless: This level of compression is typically 20:1 for RGB and 10:1 for grayscale imagery. This is the most common level of compression quality used, as it preserves the appearance of the imagery for most workflows, including use of your imagery as a background layer and for many forms of visual analysis and exploitation.
- Lossy: Beyond 20:1, image degradation and artifacts can appear, although often not too significantly until ratios of 40:1 or 50:1. Such lossy quality may be acceptable when the imagery is used only as a background layer for appearance or when the image quality is less important than the storage size or speed, such as for informal visual inspections.

Performance

When considering performance, we usually consider the cost of running some process, such as compression or decompression, in terms of memory usage, CPU usage, and I/O bandwidth. The MrSID technology is designed with these concerns in mind.

– Compression: When dealing with very large images, many image processing algorithms first partition the image into tiles and then process each tile independently. This allows the computation to proceed without slowing down due to excessive paging of memory to disk. However, especially in the case of compression algorithms, such tiling can introduce artifacts in the resulting image because the algorithms cannot efficiently process cross-tile regions. MrSID technology is specifically designed to process imagery whose size is larger than the amount of RAM available on the machine without resorting to tiling schemes and therefore without introducing any tiling artifacts.

– Decompression: When decompressing imagery, the most common use case is for viewing, which means extracting out scenes – only some subsets or regions of the image are needed at any one time. With the multiresolution support inherent in the MrSID format, the viewing application may first decide the resolution level needed to display the scene at some physical screen resolution and then extract only the resolution levels needed; this significantly improves disk I/O time and lowers the amount of imagery the CPU must process. Additionally, the viewer need only request those portions of the file that correspond to the region of interest; the entire image (at the given level) need not be processed, again saving I/O bandwidth and processing time.

When decompressing the entire image is required, the performance of the decompression step is roughly comparable to that of the earlier compression step: again, MrSID technology is designed to run within reasonable amounts of RAM, even for large datasets. If lossy compression was used, the decompression will be somewhat faster since there is correspondingly less data being read in and processed.

Metadata

Because MrSID is a geospatial data format, MrSID files also include geospatial referencing information such as the coordinate reference system (CRS), the geographic extents (corner points) of the image, and the pixel resolution. This metadata is an inherent part of the MrSID file format and is based on the well-known GeoTIFF tag scheme. When performing a reprojection operation or one of the optimization steps described above, the metadata is updated to reflect the properties of the derived image: when performing scale reduction, for example, the resolution metadata is updated accordingly. MrSID metadata also is used to record what operations may have been performed on your dataset. For example, you can determine if the file you have still corresponds to the lossless original data or if it has been modified in some way. This native geographic metadata support allows you use a third-party application to import your MrSID imagery for use as a base map with other georeferenced datasets you might have.

Multispectral Support

For many years, some types of geospatial data have included more than just the usual three color (RGB) bands. Only recently, however, have these kinds of multispectral datasets started to be widely available to GIS users. For example, in 2011, USDA's NAIP program plans to collect data for 15 states which will contain the red, green, and blue (RGB) bands plus a fourth infrared (IR) band. DigitalGlobe's recently launched WorldView 2 satellite records RGB plus five additional bands: a yellow band, two IR bands, and two "coastal" bands. Other remote sensing platforms are now collecting hyperspectral datasets, typically one hundred or more narrow bands. All these additional bands are chosen for their abilities to improve feature classification and extraction by providing more discriminating information in areas such as vegetation cover, shallow-water bathymetry, and man-made features.

To support these new, richer datasets, the MrSID technology can compress images with up to 255 bands. The same key features are still available: lossless and lossy encoding, multiple resolution levels, and selective decoding. As more data is being encoded and decoded, of course, more time will be required. The time required scales linearly, when normalized to the number of bands. That is, if it takes 1 minute to encode a 1-banded image, it will take 10 minutes to encode an 10-banded image of the same width and height.

The time required to decode imagery with varying numbers of bands scales similarly. However, many users of multispectral imagery only view one or perhaps three of the bands at a time, mapping the bands into the familiar grayscale or RGB space. In the same way that the MrSID algorithms will perform selective decompression for viewing only the scene of interest, they will also decode only the bands of interest.

Differences among the MG2, MG3, and MG4 Formats

As the MrSID technology has evolved over the years, the range of capabilities supported has evolved as well.

Specifically:

- MG2 does not support lossless compression
- MG2 does not support optimization
- MG2 does not support composite images
- Only MG2 supports 32-bit floating point data
- Only MG4 supports signed integer data
- Only MG4 supports alpha masking
- Only MG4 offers support for multispectral and hyperspectral imagery.

While some applications may only write newer versions of the MrSID format, all applications that read MrSID files will always continue to support all versions of the format. These considerations are important to keep in mind, since there are so many older MG2 and MG3 files kept in long-term archives.

V. MrSID Technology for LiDAR

After what seems like only a few years, LiDAR is now becoming a mainstream GIS technology. LiDAR data is already being used in a variety of areas, including utility corridor monitoring, construction of centimeter-accurate surface and elevation models, and vegetation or biomass measurement.

As with raster imagery, however, this data comes with a cost: file size. A typical day of LiDAR acquisition can result in a dataset hundreds of gigabytes in size and the amount of data collected will continue to grow as sensors improve in resolution and functionality. Large files mean storage hassles and hampered interactive workflows. But technologies like MrSID have been developed to address those problems for raster imagery – can the MrSID technology be used for LiDAR point clouds as well?

LiDAR data is fundamentally different from image data in three ways. First, and most obviously, we have a Z height component in LiDAR data. Second, we may also have a set of attributes associated with each point, such as intensity, classification label, or transmitted time of the laser pulse – more than just the pixel value (color) in images. And third, the LiDAR data do not lie on an implicit regular grid, as image data do: each LiDAR point must be stored explicitly, as we cannot infer position based on an implicit grid location.

Although the algorithms differ, the MrSID compression support for LiDAR gives still the same core features we find in the raster world.

Selective decompression – As the point cloud data is encoded, a spatial index is created which keeps track of where the compressed points are located in geographic space, regardless of where they may be located in the MrSID file. This means that the data for a desired region (bounding box) can be accessed and decoded without reading (or, worse, decoding) the whole file as may be the case with LAS files.

Multiple resolutions – Because the data is on an irregular grid, the multiresolution (pyramid) scheme described earlier for raster imagery is not as effective. Instead, the MrSID file is designed so that applications may request a certain density of points within the region of interest; as further requests are made, additional points may be retrieved. This allows an application to try to achieve a uniform point density across the entire dataset, rather than have an excess of points in some areas when the workflow does not require them.

Lossless and lossy compression – The data points are encoded using, again, techniques similar to the MrSID algorithms for raster compression, allowing for typical lossless compression ratios of 4:1. Lossy compression ratios of 10:1 or higher are typical. However, lossy compression is achieved only by removing some points from the dataset, unlike the approximation technique intuitively described above. (Consider that if the decimal value of a point position was “rounded”, then the point would actually move in space; this is a more significant issue for high-accuracy elevation workflows than for workflows using the intensity values of imagery.)

The time required to read the MG4 file is significantly slower for large scenes (over a third of the file, in this case) due to the computational overhead of the decompression algorithms. For smaller scenes, more realistic of many viewing and analysis workflows, the built-in spatial index inherent in the MG4 format dramatically speeds up the data access compared to LAS.

VI. LizardTech’s Products and Integrations

LizardTech was formed as a spin-off from Los Alamos National Laboratory to commercialize their MrSID compression technology. Since its first commercial release in 1998, the MrSID file format has become an industry standard. Today LizardTech offers a number of products that create, manage, and distribute MrSID imagery.

GeoExpress

The GeoExpress application is LizardTech’s flagship product for compressing imagery. It supports creation of MrSID files and includes tools for mosaicking, reprojecting, and color balancing imagery. The latest release, GeoExpress 8, adds support for the MG4 format. GeoExpress also fully supports JPEG 2000, an ISO standard technology similar to MrSID technology.

LiDAR Compressor

The LiDAR Compressor application is LizardTech’s first product to support LiDAR data with the new MG4 format. The software supports lossless compression up to 4:1 and offers both mosaicking and previewing. It supports reading both the LAS and ASCII point cloud file formats.

Express Server

The LizardTech Express Server system is the best solution for distributing MrSID imagery over the internet. A client connected to a website running the Express Server image server can download and view high-resolution imagery quickly using industry-standard protocols such as WMS. Client applications can include browser plug-ins for the desktop, applications on hand-held devices, or enterprise GIS applications.

The Express Server system can also be used in combination with ESRI’s ArcGIS Server and ArcGIS Image Server products to speed up image delivery. You can also publish Express Server catalogs as layers in ArcGIS Server and ArcGIS Image Server, or you can connect an ArcMap client directly to Express Server host so you can work with datasets hundreds of gigabytes in size right on your desktop.

GeoViewer and ExpressView

LizardTech offers two freely downloadable viewers for MrSID imagery.

GeoViewer is a standalone application for viewing raster imagery, vector overlays and LiDAR data. With GeoViewer you can combine, view and export visual layers from varied sources, such as local repositories, Express Server catalogs, and WMS servers.

The ExpressView Browser Plug-in enables you to view MrSID imagery in Internet Explorer or Firefox. Like GeoViewer, ExpressView enables you to save a portion of an image in a number of other image formats.

LizardTech MrSID Decode SDK

LizardTech offers an SDK to enable MrSID file format support in third-party applications. The SDK exposes C and C++ APIs that enables developers to open raster and LiDAR MrSID files, read the geospatial metadata, and extract scenes of arbitrary size and scale. The SDK is taken from the same code base LizardTech uses to build its own applications.

Our SDK may be downloaded and integrated into your application for free. Versions of the SDK are available for Windows, Linux, Solaris, and Macintosh.

Third Party Integration

Through our SDK program, hundreds of geospatial applications support the MrSID file format. ESRI's ArcMap, ERDAS' Imagine, and Google Earth all support importing MrSID imagery as fully georeferenced raster layers.

VII. Conclusion

LizardTech's MrSID technology is designed to be the most effective storage solution for geospatial imagery and elevation data on the market. We recognize that the quality of your data can be just as important as the cost of storing and accessing it, and we've developed the features of MrSID with that in mind:

- Data quality from lossless to visually lossless to lossy
- Compression ratios from 2:1 to 20:1 and beyond
- Multiple resolutions to obviate manually constructing and managing image pyramids
- Selective decompression for fast access to small scenes in big files
- Support for up to 255 spectral bands
- Support for irregular, 3D data sets like elevation data and point clouds

All these features are available in LizardTech's own suite of products and, through our partners, the MG2 and MG3 format is supported in all the other major GIS applications on the market today. Third-party adoption for the MG4 raster and LiDAR has already begun.

Every year, more airborne and satellite sensors are collecting more and more data, with new spectral bands and higher bit depths. Our software was developed to compress two-dimensional image data, and is now supporting three-dimensional elevation data. As we look to the future, we are starting to see some customer needs for compressing even more types of data such as sonar, SAR, and datasets with explicit time dimensions. LizardTech and our MrSID technology will continue to track the needs of our industry to make it easier to store, manage, and distribute geospatial data.

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GEO-SERVICES OF OPERATIONAL MONITORING FOR EARLY WARNING AND DISASTER MANAGEMENT

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Systems of monitoring based on space data are nowadays widely introduced into the operations of the Departments of Civil Defense and Emergencies. The variety of applied technology and data enable to conduct monitoring of different natural events and phenomena, which can sometimes be hazardous not only for human economic activities, but for live safety as well. Early detection of natural fires, of water pollutions with oil products or monitoring of river seasonal and flash floods – those are only a small part of tasks that ScanEx RDC endeavors to resolve applying modern web-technologies.

The monitoring system – is the information service. How this information will be applied in practice and whether it will be useful in management and decision-making, depends on different factors, both technological and organizational. One of the approaches towards actual introduction of a monitoring system is the organization of the control system based on operational satellite data. We can say that the possibility of building a control system based on monitoring data is the indicator of the successful (efficient) monitoring service in general.

A monitoring service is something bigger than just a set of components, such as: data, data processing results, software for specialists and data display interface. A service is first of all is a system of bringing the information to end-users, as a rule requiring interpretation (decoding) and support from the specialists.

Main advantages of the web-service user:

- Access to information in a user-friendly (interactive) form;
- Use of a web-browser instead of a special software application;
- Multi-user access to monitoring data;
- Possibility to connect (using links, frames, API, etc.) with other user's web-resources (sites, portals, web-applications, etc.)

Different popular Web-GIS technologies are used to create geo-services: Google Maps API, OpenLayers, Mapserver, Geoserver, etc. It should be noted that different Web-GIS solutions have been rapidly developed lately and introduced into practice. ScanEx RDC, using its Kosmosnimki.ru project as a kick-off point, started to develop a proprietary Web-GIS GEoMixer engine since 2007 (http://geomixer.ru). Our experience in creation and support of geo-services of operational monitoring was illustrated in the presentation with working examples:

- Operational satellite-based monitoring of maritime oil pollutions (demo-version: http://ocean.kosmosnimki.ru);

– Monitoring of floods (in behalf of the Russian EMERCOM and on the website http://flooding.kosmosnimki.ru);
– Monitoring of fires (http://fires.kosmosnimki.ru).

GIS FOR ECOLOGICAL-RECREATIONAL SAFETY OF POPULATION

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Abstract

The assessment of a natural-resource potential of the territory and the provision of ecological-recreational safety gain the importance due to the rapid development of recreation and tourism industry in the Altai Krai. Targeted GISs are meant for providing the information support and spatial data processing based on the development of the unified information-cartographic environment for the ecological-recreational domain. The experience gained in the development of ecological-recreational GIS for Altai Krai has been presented.

Both recreation as health improvement and relaxation, and recreational activities as economical ones are closely connected with nature and nature management. The complex of notions about the ecosystems and their components, processes of functioning, properties, importance, consequences of changes due to the recreational influence are necessary for grounding the recreational activities. On the other hand, it is essential to be aware of ecological factors from the point of view of their influence on humans, i.e. ecological dangers and possibilities of deriving benefits for health. The development of recreational activities as business, which is directly connected with the location and construction of recreational facilities, cultural and health improving centers, infrastructure projects as well as with the influence of holidaymakers on the environment, stipulates the necessity to regulate the recreational impact on natural complexes, the decrease of the incipient risks, ecological-recreational safety maintenance. The most picturesque and appealing territories, and sites which are more suitable for recreation, which are often characterized as valuable and unique, are likely to be exposed to the impact of recreational activities.

It is generally understood that the recreational potential is a combination of natural, cultural and historical, and socioeconomical factors necessary for organizing recreational activities on a certain territory. The interdisciplinary study of recreational problems based on including a great amount of various data leads to the necessity of creating the informational systems in this sphere of human activity, and first of all, to the development of targeted geoinformation systems (GISs).

Preserving of natural environment as a recreational resource includes nature conservation and this is achieved mainly by means of a regular control of the territory condition and due to the well-coordinated actions of the parties concerned. The development of the recreational industry presupposes the use of the managerial approach, i.e. setting long-term objectives; assessing the range of recreational potential, forms and types of recreational activities; various patterns of assessing health improving environmental resources as well as the health improvement of the population along with the planning of the number of holidaymakers and tourists for any time horizon (both current and long-term). The above mentioned planning is based on the study of the demand for recreational service, the analysis of the influence of tourists on ecosystems, the development of nature-conservative measures based on ecological-recreational monitoring, etc.

The creation of GISs for providing information and spatial data processing, based on the development of the unified information and cartographic environment in the ecological-recreational domain, is getting more important due to the rapid development of the recreational and tourism industry in the Altai Krai. First of all, those systems are aimed at providing ecological-recreational safety, including the safety due to the assessment of the ecological and resource potential of the territory.

The above mentioned assessment of the natural resources is made according to the following factors: the ecological condition, environmental value, functional suitability, level of comfort, aesthetic properties, prerequisites of dangerous natural processes and phenomena.

The recreational activities are always carried out within range of natural complexes. This predetermines the use of the landscape analysis and the map of the landscape with an appropriate characteristic of the natural complexes for the ecological-recreational assessment of the territory. The map of the landscape serves as a pattern representing the geographically conditioned structure of the territory with the spatial distinctions and various recreational values. The differentiation of the assessed natural systems and the detail of the assessment depend on the purpose of the research. Alongside with the recreational nature management, the geosystems of the regional and medium-sized layout levels are also thoroughly analyzed. The maps of the landscape thoroughly reflect the regularities and the specific character of the regional nature conditions, and consequently allow taking into consideration a variety of recreational potentials in the ecological-recreational assessment of natural systems. For instance, in the Altai Krai for the territorial estimate units the natural complexes of various terrains are taken. A computer based version of the regional landscape map charted by IWEP SB RAS on a scale of 1: 500000 (IWEP SB RAS cartographic fund) serves as a cartographical base for ecological-recreational assessment. The database of landscape maps is represented by two types: graphical and thematic attributive.

The assessment of ecological condition of natural complexes includes the estimation of the degree of their anthropogenic transformation and the level of natural value. Electronic maps of the supply of land (on a scale of 1: 500000) and the Specially Protected Natural Areas are used as main cartographical materials.

The estimation of the degree of anthropogenic transformation of the Altai Krai natural complexes is based on figures which allow to range various land types according to the degree of the anthropogenic load on the basis of the land use types differentiation; to calculate in conventional units the index of anthropogenic transformation of natural systems and to range the natural complexes in accordance with the computed index. Consequently the map of the assessment of the Altai Krai natural complexes anthropogenic transformation was chartered. According to the map the natural complexes characterized by extremely low and low anthropogenic changes comprise only 0,2% and 14,8% of the territory correspondingly. This terrain group is represented by the territories which are mainly not cultivated and are considered to be nature reserves or territories of a limited use (such as protection forests, water protection zones, etc.). More than 85% of the Altai Krai is considerably changed: more than 40% of the territory is equally represented by areas with medium and high anthropogenic load. The territories of forest exploitation and the areas used as meadowlands belong to the areas with a medium anthropogenic load. A high anthropogenic load, and consequently the greatest anthropogenic changes, is typical of ploughed lands and human settlements. The present day situation contributes to the ecological imbalance as well as to the reduction of the recreational potential of the territory. Therefore it is of paramount importance to detect the territories which functions might solve simultaneously the problem of the environmental improvement and to provide socioeconomic development of the region including the sphere of recreational activities.

The main indicator of the territorial ecological-recreational well-being is the assessment of the ecological value of natural systems which is expressed by the index of the same name. The index correlates with the area and the categories of the Specially Protected Natural Areas (Protected Areas) located within the natural complex. For its calculation the following formula is used:

$$Ip = \sum(R * Si) / S,$$

where:

- Ip is the index of ecological value;
- R is the coefficient dependent on the categories of the Protected Areas;
- Si is the area of a certain category of the Protected Areas located within the natural complex;
- S is the total area of the natural complex.

The assessment of the ecological value of natural systems creates favorable conditions for the development of the territorial ecological-recreational base, detecting the ecological risk areas, long-term recreational development, working out of nature-conservative measures.

The calculation of the ecological value index of the Altai Krai natural complexes was performed with the help of the standard instruments ArcGIS 9.x. ESRI, Inc. According to the index value all the natural complexes were arranged into four groups: the areas of a low, medium, high and extremely high value. According to the results of this classification the ecological value map of the Altai Krai natural complexes was chartered. The spatial analysis indicates that the most part of the Altai Krai is occupied by the territories of a low value which are also characterized by a low index value. This is mainly connected with the fact that there is a sufficient lack of the Specially Protected Natural Areas: some of them either occupy only a small territory or are not represented at all.

For the assessment of the ecological-recreational resources the index of ecological capacity is used. Ecological capacity is the ability of the natural environment to withstand the load which is created by holidaymakers without significant transformation of natural complexes. Recreational capacity determines the norm of the territory use for recreational purposes and sets the period of time necessary for the restoration of the initial natural properties.

To assess the recreational capacity the database includes ranged indicators characterizing the main components of the natural complexes and reflecting the limiting factors for their use. Therefore, for assessing the recreational capacity of the Altai Krai the database includes the following ranged criteria indicating the recreational suitability of the components (see the table).

Table. Criteria for assessing the recreational capacity of natural complexes

Estimated figures	Degree of recreational capacity			
	the least suitable	slightly suitable	suitable	the most suitable
True relief altitude (m)	> 1500	1000–1500	500–1000	0–500
Horizontal division (km/square km)	> 2,5	2,5–1,2	1,2–0,8	< 0,8
Vertical division (km/square km)	> 600	600 - 800	300 - 600	< 300
Surface inclination (degrees)	> 12	6–12	3–6	0–3
Degree of climate comfort (points)	uncomfor-table	moderately uncomfortable	slightly comfortable	moderately comfort-table, comfortable
Stable snow cover time (days)	< 140	140–150	150–160	>160
Stream frequency (km/square km)	< 0,1	> 0,31	0,21–0,3	0,1–0,2
Percentage of lakes (%)	0–10; > 90	11–20	21–30	31–90
Saline composition (mg/l)	<400	400–600	600–2000	> 2000
Population density (%)	< 15; > 85	16–30	61–85	31–60
Diversity of useful plants(number of species)	≤ 2	3–4	5–6	≥ 7
Diversity of game animals(number of species)	≤ 4	5–8	9–12	≥ 13
Diversity of fish(number of species)	≤ 3	4–6	7–9	≥ 9
Number of Protected Areas	≤ 1	2	3	≥ 4
Number of cultural and historical places	≤ 1	2	3	≥ 4

For the assessment of the recreational load capacity the natural complexes are evaluated according to the stability to a certain type of influence. The assessment components are as following: surface inclination, hydrothermal coefficient, texture of soil, predominating vegetation, percentage of forest and the types of trees that constitute forests.

The results of ecological-recreational research are necessary for planning and organizing recreational nature management as well as for developing the system of nature-conservative measures. The imbalance between the ecological-recreational potential and load entails the recreational digression of the territory, the development of unfavorable natural processes and phenomena, and the ecological-recreational risks.

The development of the tourism industry stipulates the necessity of recreational load regulation. This is conditioned not only by the combination of favorable natural, sanitary-and-epidemiologic, medico geographical, ecological but also socioeconomic aspects within a given territory. The processes connected with the utilization of electrical energy, water and other natural resources, recycling, the development of building and transport infrastructure should also be worked out. GIS allows to solve problems connected not only with the creation of the ecological-geographical base and data processing in the problem domain of ecological-recreational safety but also to provide information in the sphere of management of recreational regional development.

THE USE OF DIGITAL IMAGES FOR DATA ACQUISITION IN REALISTIC FOREST FIRES MODELLING

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Abstract

Digital images have been used for cconducting pre-fire registrations and post-fire registrations of vegetation cover conditions and determination of dispersal characteristics of aerosol emissions. The results are given.

Forest fires are a powerful natural and anthropogenic factor which considerably affects forests state and functioning. The research of forest fires character is paid great attention to. Analysis of natural forest fires caused by the unknown sources and spreading spontaneously over the territory fails to reveal a number of factors determining the fire behaviour and the extent of its effect on the ecosystem. Local features of the woodlands resulting from the relief of underlying surface, the forest combustible materials, etc should be taken into account. The data on the specified ecosystem fire conditions may be obtained by the results of the experimental burning. Realistic fire modeling was carried out in the framework of ISTC Project 3695 “Gas and Aerosol Emissions from Forest Fires in Russia: Impacts on Chemical, Radiochemical and Optical Qualities of Atmosphere, Carbon Cycling, Radioecological Consequences, and Biocenosis Sustainability”.

The objective of this project is to obtain the quantitative data on rates, chemical and radiochemical compositions, and disperse characteristics of gas-and-aerosol emission of biomass burning products into the atmosphere, and biological and radio-ecological post-fire consequences caused by large-scale forest and forest-steppe fires in Russia.

Ecological effect of forest and forest-steppe fires on forest ecosystems is qualified and quantified during annual field studies on the territories subjected to the above “*in situ*” simulated fires, as well as spontaneous forest and forest-steppe fires, including regular (for several years period) post-fire monitoring of forest ecosystems and regular satellite data given on wildfires, about stability and reconstruction ecosystem after fire in wood of the Asian part of Russia.

The researchers of the Institute of Cytology and Genetics SB RAS, Siberian State Academy of Geodesy (SSGA, Novosibirsk) and the V.N. Sukachev ***Institute*** of Forest SB RAS (Krasnoyarsk) have performed series of nature-model fire experiments over the test fire areas of Krasnoyarsk region.

In the general complex of the works which are carried out at "fire" experiments at its different stages digital photography were used. For registration of a vegetative cover condition photographing was carried out before and after “a controllable burning out” site. For post-fire monitoring photography was carried out the next years after a burning out. For definition of disperse characteristics of the smoke aerosols collected on plates inertial impactors, the images of aerosol tests derived by digital microscope were used.

It is evident that use of the results of terrestrial stereo photogrammetric survey in different scales increases the efficiency of forest fires nature studies.

It is offered to use panoramic photography for the purposes of general photo mosaics supplementing a geo-botanical description of experimental forest sites, stereo-photogrammetric survey for detailed study and analysis of vegetative and ground covers, as well as use in 3D model formation.

General panoramic photo mosaics can capture the pre-fire and post-fire state of a forest plot to make general follow-up observations. The requirements for maximum visibility and details creating these mosaics makes it complicated for because of the often presence of dense forest vegetation. A special purpose technique for digital panoramic photography in these conditions is offered in this paper. The basic principle is to use digital panoramic photography from sample points to take two views of the forest plot from each sample point. Since these points can be registered by the use of pins to mark them, the same view can be retaken at different times after a fire. It is recommended that a series of overlapping images (e.g., 5 to 8) should be taken as the camera is sequentially moved along the horizon. To assure steadiness, the camera is set up and leveled horizontally on a tripod centered above the fixed registration pin. Panoramic photo mosaics can be created by Photoshop software (photo merge-based utility), where separate photos are composited into an integrated panoramic image. This is carried out by choosing identical objects or targets in consecutive photos to use in overlapping the adjacent images. Photographic parameters taken in advance minimize the mutual distortions of adjacent images. The example is shown in Fig. 1.

Today interactive 3D photo panoramas have a large range of possibilities. The feature of such photos panoramas is their visualization on the monitor in a 3D-interactive mode. For getting volume effect the photography should be carried out by a camera set on a tripod with a consecutive turn on 360°: at three positions of an optical axis – horizontal, at an angle 45° upwards and 45° downwards. Exposure processing consists in their combination by identical points and formation of the common image that is carried out in specialized program. Such photo panoramas provide the best overview and bigger volume of visual information than usual "flat". Besides, such magnification of chosen zones is easily realized providing full and detailed representation of wood vegetation condition. Virtually interactive photo panoramas increase the visual interpretation quality of vegetative cover changes. The example is shown in Fig. 2.

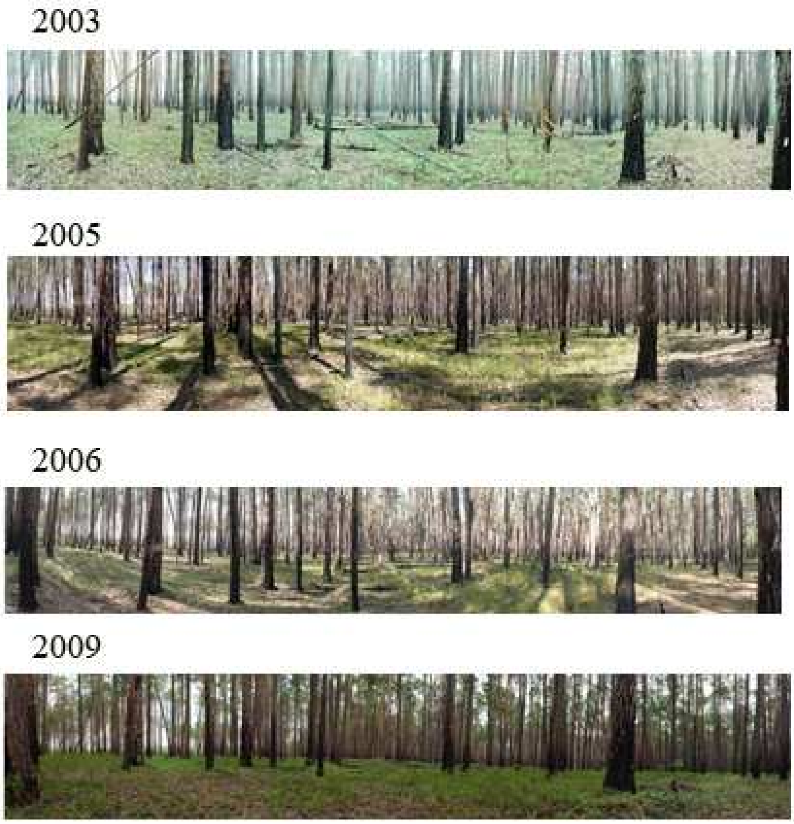


Figure 3. Panoramic views of experimental site showing: the site in 2003 prior to burning, and two (2005), three (2006) and six years later (2009)

Figure 2. Rotary panoramic views

Wildfires have a high impact on the understory vegetation and soil characteristics. To study the vegetation and ground cover changes, it is necessary to carry out close-range stereo photography from sample points using a “top view” camera position. For this purpose the camera has to be installed at a tripod by means of an especially custom-made bracket. It allows the camera to be moved when the first image is taken using a computed set value and to get stereo image pairs of the viewing area. In this case the angular elements of stereo-pair orientation are close to zero that considerably simplifies the further photogrammetric processing.

Stereo-pairs can be used for 3D models restoration showing the real state of vegetation on the site before making fire (Fig. 3). These stereo images are used in analyzing the vegetation dynamics. Such easy obtaining this image documentation allows their including into a common database for the fire experiments. To visualize 3D models, it is recommended to use of anaglyphic method when two superimposed images complementary colored (red and dark blue) are observed by means of glasses-optical filters having the same coloration.

Figure 3. An aerial stereo pair showing the ground fuel

Synchronous stereophotography was applied to registration of the movement of fire front during controllable burnings. In this case two cameras were placed on supports on the brink of a site so that all site got to an overlapping zone. Cameras work synchronization was provided by a control panel. For the purposes of scaling of the model formed on stereo-pairs the network of reference points is marked by metal cores on a site. With the same purpose it is possible to use points marked on stems of trees if those get to a site. Photography is made when the frequency of photography is set depending on wind velocity and rate of surface cover burning out. It is recommended to carry out the shooting in a manual mode that provides the minimal interval of photography - half of a second. The technique of coordinate definition of the fire front is based on joint processing of the stereo-pairs received during the different moments in software product PhotoModeler which allows making 3D-model construction by any quantity of pictures. The technique of registration of the fire front propagation was approved on a site in the size 6×10 meters. Stereophotography was carried out by cameras Pentax K200 with the indicated interval. During the experiment 30 stereo-pairs has been done. The images, illustrating the fire front moving during undertaking “fireman of the experience” are shown in Fig 4. The processing of all stereo-pairs has allowed getting fire behavior characteristics for the fixed moments of time both along a site and in a vertical direction (Fig 5). Thus, it is shown that the given technique allows defining the fire-propagation rate on a site both in horizontal and vertical directions.

Figure 4

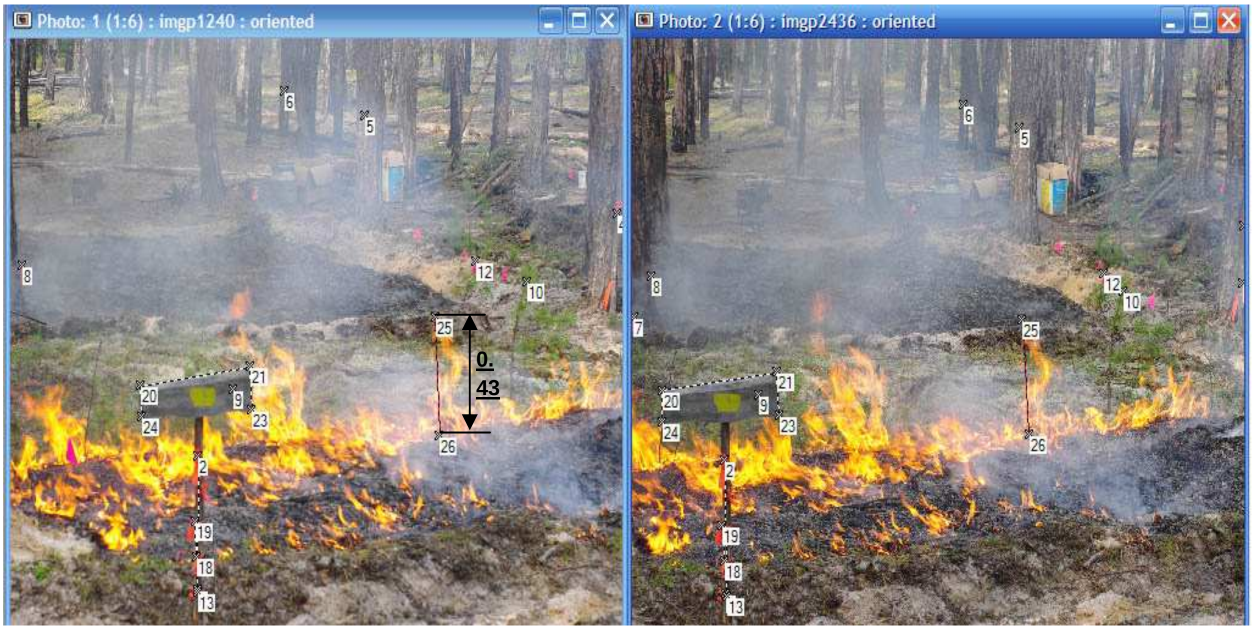


Figure 5. The processing of stereo images

Information on disperse characteristics of aerosol emissions selected during fire experiment on model plots is obtained in laboratory conditions. Particles of smoke aerosols were sampled from the plate inertial impactors.

Their images were received by a digital microscope Axioscop 2 plus. Lenses were used for micro photography with increasing $10^{\times}$ and $20^{\times}$.

The process of digital images processing included measurements of areas and perimeters of displayed particles with MapInfo software.

The further processing included the determination of equivalent diameters for each particle and the estimation of their distribution. The results are analyzed to perform variance estimate of aerosol particles (Fig. 6).

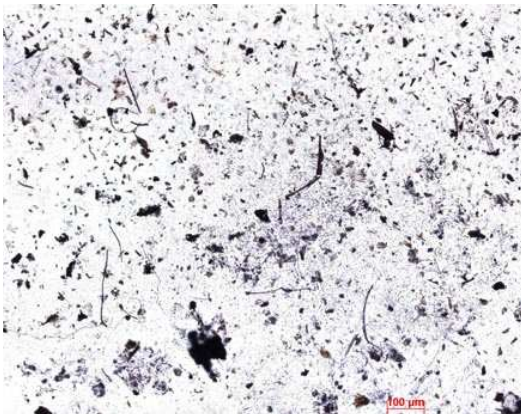
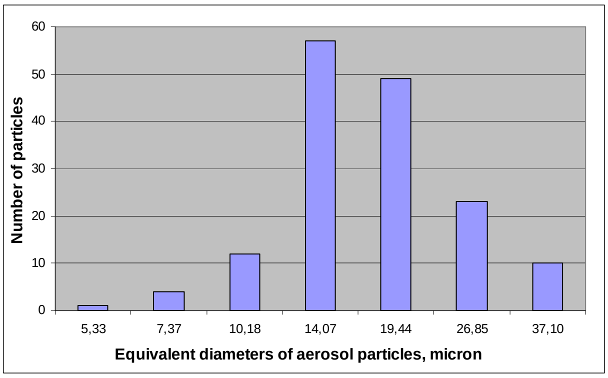
<table>
<tr><td colspan="2">17 July 2008 г. Spreading surface: Lichen, needles. Burning plots: plot #1;
6×10 m, Impactor #1. N (number of particles in an image) = 155</td></tr>
<tr><td>Images of aerosol samples</td><td>The results of sample analyzing</td></tr>
<tr><td>
</td><td>
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Figure 6. Data of aerosol samples selected during the expedition in Krasnoyarsk Region, July, 2008

The procedures developed have been tested on realistic modelled fire experiments. A multimedia database was created. It included the analysis results of 13 sites located in different silva zones of Krasnoyarsk Region obtained during four years. General photo mosaics for each site, stereo images of vegetative and ground covers, and digital elevation models were created and the characteristics of separate biocenosis components were determined.

The experience obtained has shown that digital terrestrial photography is an informative means for investigation of local forest plots. When modelling wildfire impacts, digital images are of great value as data to assess ground cover change caused by fire. Initial images can serve as a source to be used for updating long-term monitoring of a particular forest plot.

The work has been supported by the International Science and Technology Center (Project 3695).

COMPLEX GEO-MONITORING SYSTEM FOR EARLY WARNING ON NATURAL AND NATURAL-TECHNOLOGIC HAZARDS' ACTIVATION WITHIN THE TERRITORY OF TOMSK

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Abstract

The present material inquire into matters of present interest about solving an important scientific and technical problem of development and integrated use of geo-ecological geodetic and deformation monitoring methods within the territory of Tomsk with the use of the latest achievements in geodetic science and technology for early warning on natural and natural-technologic hazards' activation.

Urbanization explosion pose a number of global and local geo-ecological problem caused by wide spreading and activation of natural and natural-technologic hazards. Catastrophic processes lead to the decay of buildings and structures and pose a real threat to people's life. Therefore, one of major problems of the modern geo-ecology is survey of the geological environment's state and resistance in the urban lands, whereof study of natural and natural-technologic soil slips takes solely actual meaning. Under the circumstances for providing geo-ecological safety of life-sustaining activity of public and economic entities, for the purpose of engaging in town-planning, nature protection and other types of activity, in areas of natural and natural-technologic hazards' development forges the prevention of these hazards, in other words, early warning instead of rectification of their consequences.

Substantial improvement of urban lands' ecological state possible only, when complex solutions are being developed and implemented as a whole, it needs geological soil slips monitoring system's development not only at the municipal level, but also at the level of subject of the Russian Federation. In this context problem of system of geodetic support of geo-ecological monitoring development become more important for organization of continuous time-space control of natural-technological systems (NTS) and monitoring itself must be made more complex, it requires not only theoretical justification of different methods and technologies' combination inside of complex geo-monitoring, but also implementation of these methods and technologies. Use of results of NTS researches executed in urbanized lands through geodetic methodologies in practice allows implementing of complex program of NTS geo-ecological monitoring for early warning on dangerous processes activation. That solution is very important for cities geo-ecological safety, Tomsk city, for example, as its territory has 33 soil slip zones as City Coordinating Council in Ecology declared. The most dangerous areas are Solnechny district (soil slip flank) and Lagerny garden area on the Tom riverbank. Soil slip processes in the named areas damage city infrastructure as a result of buildings and constructions deformation and destruction. The situation required adoption of “On soil slip areas located in cities and villages of Tomsk Region” law applicable for Tomsk Region.

Therefore, for getting consistent results and problem solutions of NTS’s state and resistance estimation in complex, it is insufficient use only classical geodetic methodologies traditionally applied to soil slip observation, but, as it was given above, it is necessary to elaborate integral system of geodetic support of geo-ecological monitoring, which unify different measurement and modeling techniques. This situation requires development of theoretical and technological basis for merging of various geodetic, satellite, geophysical scoring and assessing methods with statistical modeling methods within geo-ecological monitoring complex program, which monitor sliding caused by technological NTS impact in the soil slip zones in time and space. This merge of different methods increase geo-monitoring efficiency and reliability of many times as results revealed with one method used could be proven with results of other methods.

Engineering constructions’ deformation process development in time and space allows using multiple nonlinear approximation method for exposure of deformation and analysis of its homogeneity under condition to minimize standard deviation between calculated deformation value and directly measured deformation value. Marking out constant and accidental components of vertical deformations for a whole construction, it is possible to research shifting of this construction as an organic whole and to identify marks with differential settlements, especially, that, which are the most dangerous for the continuity of construction, as operational integrity of examined engineering constructions generally depends not only on absolute settlement value, but also on settlement irregularity, in other words, on constructions’ deformation. Therefore for organization of engineering constructions’ standard exploitation is necessary to monitor settlements and deformations of construction foundation permanently, especially, it is important in the time of soil slip activation processes. Geodetic methodologies allow tracking natural-technogene processes in the “Engineering construction – geological environment” system. The results of geodetic measurements allows to identify surface shape of any construction, to analyze surface shape modification on basis of geodetic observations of engineering constructions’ settlements and deformations, also these results allows to predict the place of possible cracking and thereby to prevent emergency situations occurrence.

For providing geo-ecological safety of life-sustaining activity of Tomsk’ public the author devised the methodology, which consists of comprehensive approach to organization of the monitoring of soil slip processes and combines instrumental observations with usage of latest satellite-assisted technologies. Satellite-assisted technologies allows to build a computer model of random geodetic observations errors’ impact on modeling results for marking out real deformation value from measurement results and making management decision. It was researched that thermal deformation impact on deformable construction curtain walls’ crack opening in the time of soil slip process activation, it is allows to predict crack development, which depends not only on construction settlement, but also on environmental temperature variations.

Accuracy analysis of satellite-based measurements revealed that its accuracy generally depends on atmospheric errors. At the same time more accurate calculations of atmosphere impact on geodetic measurements with existent in present time spherically-symmetric atmosphere models are impossible to achieve, it caused a necessity of justification and development of new model of atmospheric triaxial ellipsoid. Accounting of the atmosphere asphericity in practice allows improving accuracy of satellite-based measurements.

Methodological background of geo-ecological problems (which are conditioned by soil slip processes development) solution reviewed in the present material involve analysis of standards for evaluation NTS' state, resistance of which is defined by dangerous NTS' state level and protection level, and survey of natural-technogene factors of dangerous processes development on urbanized lands, including also laws of dangerous soil slip processes' development within the territory of Tomsk, which were influenced not only by natural factors, but also by technogene.

The results of researches allowed developing and implementing complex system of geodetic support of geo-ecological monitoring at the municipal level in Tomsk city. This system is merging different observation methods and resources of not only classic geodesy, but also satellite-based, magnetometric and static modeling methods for NTS' state and resistance evaluation on the territory of town. Realization of main research results put into practice according to research program of the Tomsk City Engineering protection Coordinating Council with organization of soil slip process geo-monitoring. The results of research allowed generating recommendations on correction of general structure plan taking into account natural and natural-technologic hazards' development.

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MONITORING THE DEFLECTION OF BRIDGES BY GNSS

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Key words: Deformation measurement; Engineering survey

SUMMARY

Research into the use of GNSS to monitor the deflections of bridges has been ongoing at the Universities of Nottingham and Brunel for well over 12 years. The work initially focussed on large bridges such as the Humber and Forth suspension bridges, but then also included the London Millennium Bridge as well as a 174m long motorway viaduct.

The following paper brings the reader up to date with the work conducted more recently, including the monitoring of a cable stayed bridge in Korea, as well as two further large bridges in the UK.

1. INTRODUCTION

The following paper details the ongoing research in deflection monitoring and deformation monitoring of structures, notably bridges. The use of kinematic GPS is being used for this and the work has been ongoing for about a decade at the University of Nottingham in collaboration with Brunel University [Ashkenazi et al, 1996], [Ashkenazi et al, 1997], [Brown et al, 1999]. It is possible to measure 3D deformations of discrete points upon the bridge at rates of up to 100Hz using GPS alone. It is also possible to measure sub-centimetre precisions over the short baselines used for this work. Typically the baseline lengths from the reference to rover receivers are approximately 1km or so.

Initial trials were carried out on the Humber Bridge and since then a number of trials have been carried out on other bridges including the Wilford Suspension Bridge in Nottingham, the Millennium Bridge in London and more recently the Forth Road Bridge in Scotland. During the trials, survey grade dual frequency GPS receivers are used, however, more recently research has also been carried out investigating the use of single frequency survey grade receivers (code and carrier) [Roberts et al, 2004], [Cosser et al, 2003]. Further to this, trials have been carried out investigating the use of cheap hand held GPS receivers as it is now possible to output the carrier phase from these receivers [Cosser et al, 2004].

The work itself investigates the use of kinematic GPS as well as comparing this to the modelling of such structures. The overall aim is to be able to use a fixed number of GPS receivers located upon the bridge at pre-determined discrete locations and comparing the movements at these points with the FEM. Once agreement between the real data and the FEM established, then it is then possible to use the FEM to model how the remainder of the bridge moves based upon this real data.

More recently, surveys were carried out by the authors on the M5 motorway viaduct over the River Avon near Bristol. These results show that it is possible to detect the magnitude and frequencies of the movements of such a rigid structure using GNSS techniques.

In November 2009, data was gathered from 4 GPS receivers located on a cable stayed bridge near Pusan in Korea.

Future research will also include the monitoring of the M48 motorway, Severn Suspension Bridge.

2. CASE STUDY 1; THE WILFORD SUSPENSION BRIDGE

The Wilford Suspension Bridge is located approximately 4km from the University of Nottingham's Campus and is held by two sets of suspension cables restrained by two massive masonry anchorages. The bridge has a span of 68m in length and 3.65m in width. It consists of a steel deck covered by a floor of wooden slats. Underneath the deck there are three gas and one water pipe laid underneath the deck transferring the utilities across the River Trent. It is possible to obtain several centimetres of movement under normal loading and this has been used by the IESSG since 2000. There are no long suspension bridges in close proximity to Nottingham, therefore this bridge is ideal for carrying out preliminary trials before trying the techniques out on longer bridges. Various trials have been carried out on the bridge. Details about these trial and the results can be found in [Cosser *et al*, 2003].

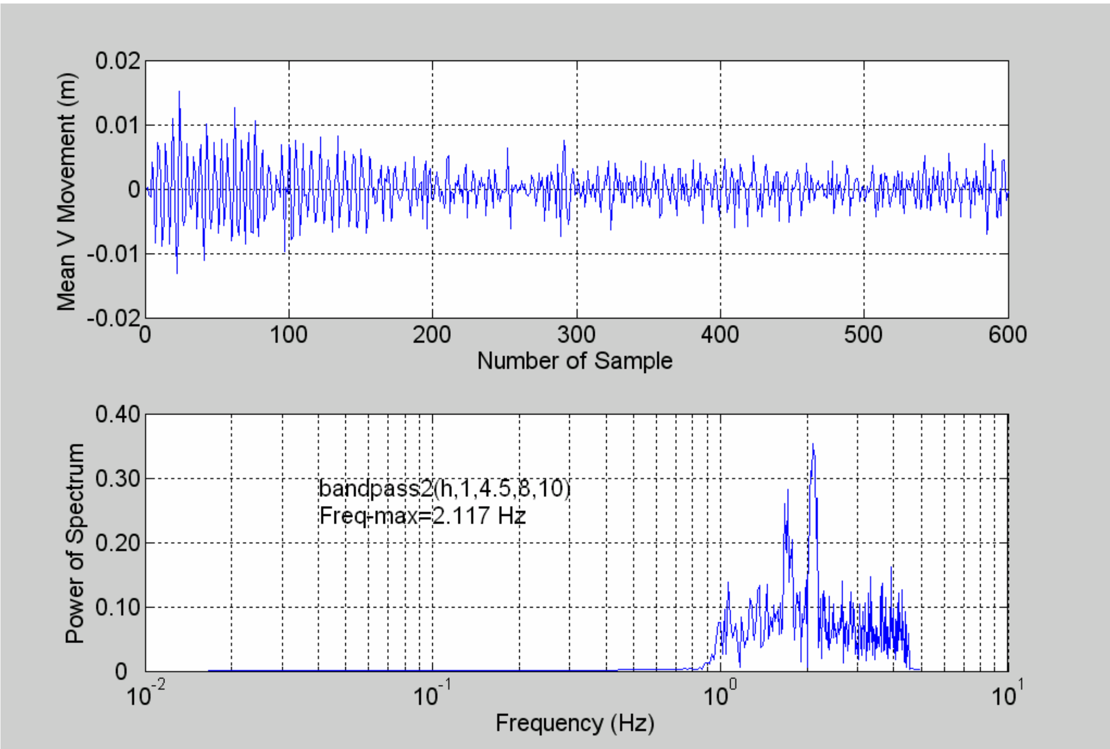


Figure 1. Illustrates that the fundamental frequency of the deflection is 2.117 Hz. This compares very favourably with the accelerometer results of 2.116Hz

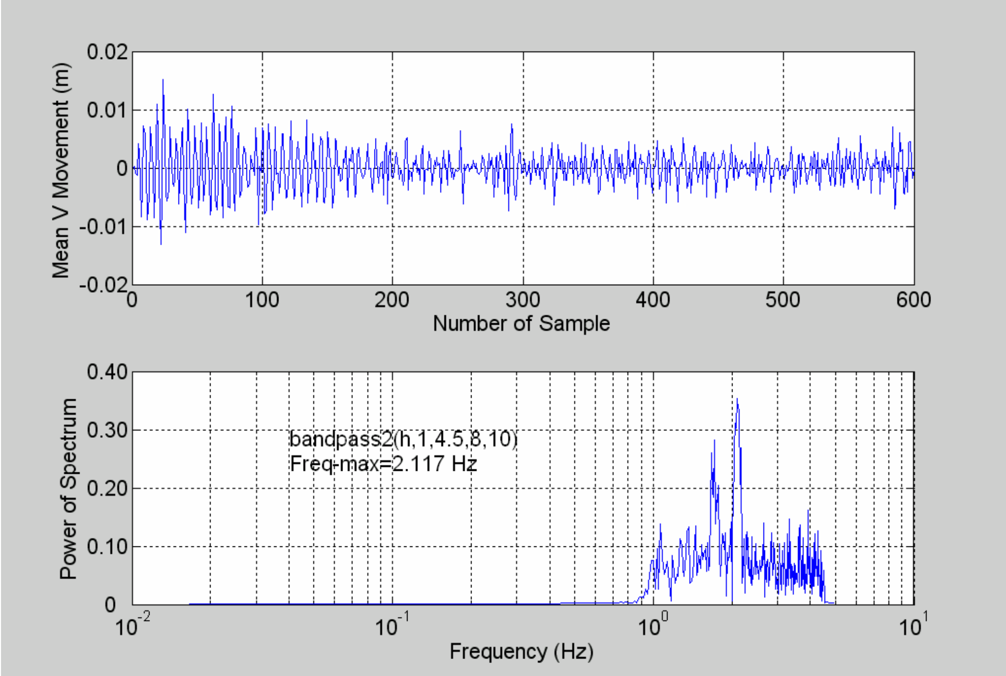


Figure 2. Fundamental Frequency extracted from the GPS time series for the Wilford Bridge

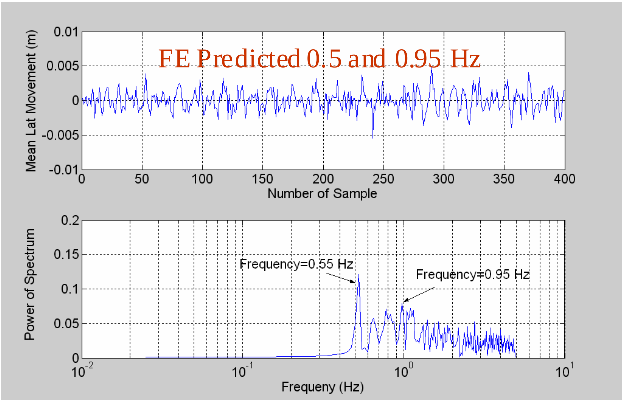
3. CASE STUDY 2; THE LONDON MILLENNIUM BRIDGE

The Millennium Bridge was designed by architect Sir Norman Foster, Sculptor Anthony Caro and Engineers Arup. The bridge was opened on the 10 June 2000, and closed on the 12 June 2000 following violent and un-predicted movements of the structure during a sponsored walk being carried out over it. The movement was rectified by placing dampers underneath the bridge. The bridge was closed for refurbishment and reopened on the 27 February 2002. The bridge has an overall length of 330m, width of 4m and lies at a height of 10.8 m above the River Thames at high tide. The bridge's piers are made of concrete and steel and the cables are 120mm lock coiled, with an aluminium decking. The construction cost for the bridge was approximately £18m and the modification costs were approximately £5m.

During its closure and before the refurbishment, the University of Nottingham and Brunel University were allowed to place GPS receivers upon the bridge to gather data to analyse the movement characteristics. Due to the fact that the University of Nottingham only had four Leica SR530 dual frequency GPS receivers at the time, the reference station and the GPS receiver at the midspan were constantly in place. The other two GPS receivers were shared between four other points on the bridge. These trials were carried out towards the end of November 2000.

Having processed the data an AF was used to mitigate the multipath, the results in Fig. 3 were found showing the lateral dynamics at the midspan. The prediction for the natural frequencies at this point were found to be 0.5 and 0.95 Hz and the actual frequencies obtained by the GPS were 0.55Hz and 0.95Hz.

Fig. 4 illustrates the lateral dynamics at the South Span. Again the prediction of the fundamental natural frequency is 0.77 Hz and the actual from GPS is 0.75Hz.



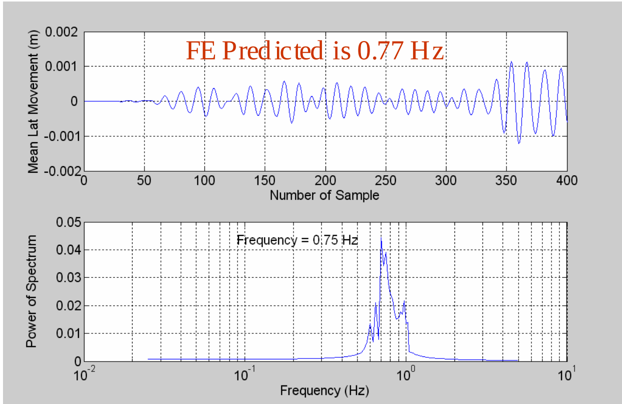


Figure 3 (left). Lateral Dynamics at mid span for the Millennium Bridge

Figure 4 (right). Lateral Dynamics at South Span of the Millennium Bridge

4. CASE STUDY 3; THE HUMBER BRIDGE

A whole series of trials have been carried out on the Humber Bridge. Fig. 5 illustrates the Humber Bridge with a midspan length of 1.4km, and an overall length of 2.22 km.

Extensive trials were carried out in March 2004, whereby 13 GPS receivers were used. Two receivers were located upon the Humber Bridge Control building, which is approximately at the same altitude as the bridge deck, one GPS receiver was placed at the estuary which is lower than the bridge and one receiver was placed at the top of the northern towers, which is approximately 155.5 m higher than the estuary.

Figure 5. The Humber Bridge showing a GPS receiver reference station in the foreground

Fig. 6 illustrates the height deflections of points 1 and 7. It is clear from here that the two receivers located at opposite sides of the same part of the bridge experience similar movements. However, under closer inspection it can be seen that the difference in height between these two points does vary, illustrating that there is a torsional movement.

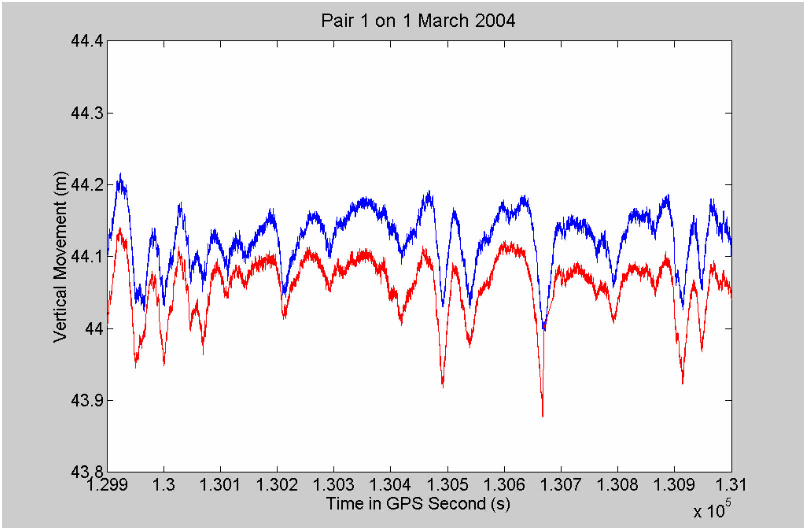
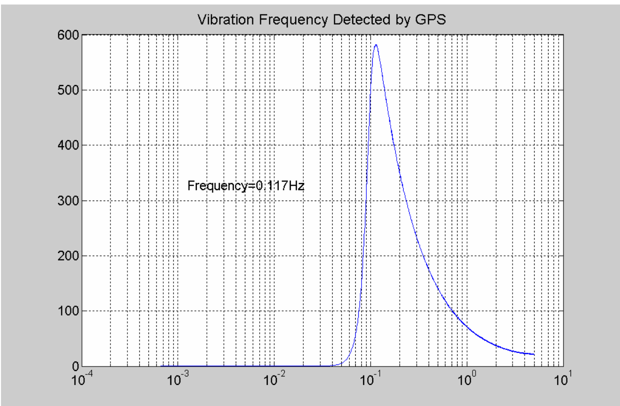


Figure 6. Height Deflections on the Humber Bridge.

Fig. 7 illustrates the results from carrying out a spectral analysis on the GPS results. It can be seen that the results of this are 0.117 Hz. The first vertical vibration frequency predicted by an FEM created by Brunel University is 0.116Hz.



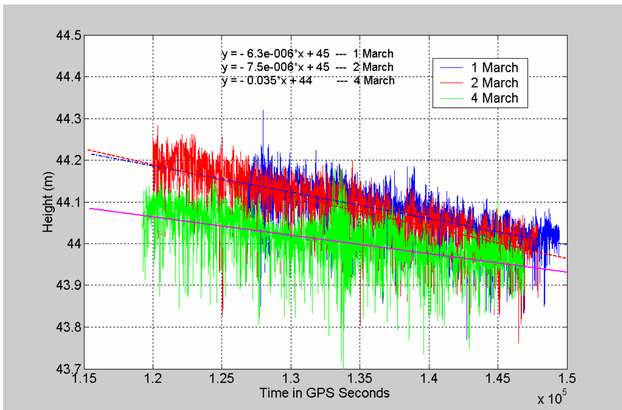


Figure 7 (left). Frequency analysis of the Humber Bridge data.

Figure 8 (right). Height deflections for the Humber Bridge.

Fig. 8 illustrates the height of a point on the bridge on 3 consecutive days. On the third day the temperature was warmer, and it can be seen that the overall height of the bridge deck is lower. On all days the height gradually drops over a period of hours. This is due to the heating effect causing the steel cables to expand.

5. CASE STUDY 4; THE FORTH ROAD BRIDGE

The data gathering trials were conducted over a nearly continuous 46 hour period from 11am on the 8 February 2005 to 9am on the 10 February 2005. For the whole period, 7 GPS receivers were located upon the bridge, as illustrated in Figure 9, and two reference GPS receivers were located on the viewing platform adjacent to the FETA building, Fig. 10. The GPS receivers gathered data at a rate of 10Hz. In addition, an Aplanix INS was located adjacent to point E [Hide *et al*, 2005]. The layout of the GPS antennas meant that a GPS antenna was located at each of the east side mid span, 1/4 span, 3/4 span and 3/8 span as well as the west side mid span and on top of the two southern towers. A selection of Leica SR530, SR510 and GX1230 surveying GPS receivers were used in conjunction with lightweight and choke ring GPS antennas.

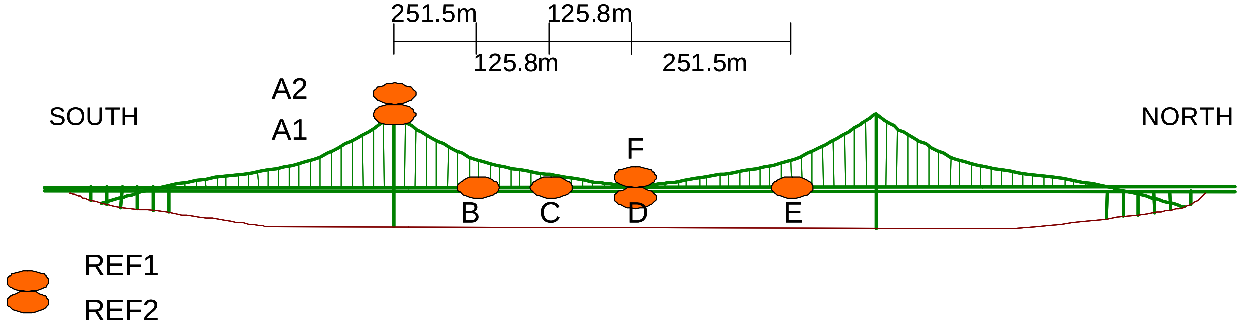


Figure 9. Schematic of the Forth road bridge, and GPS receivers.

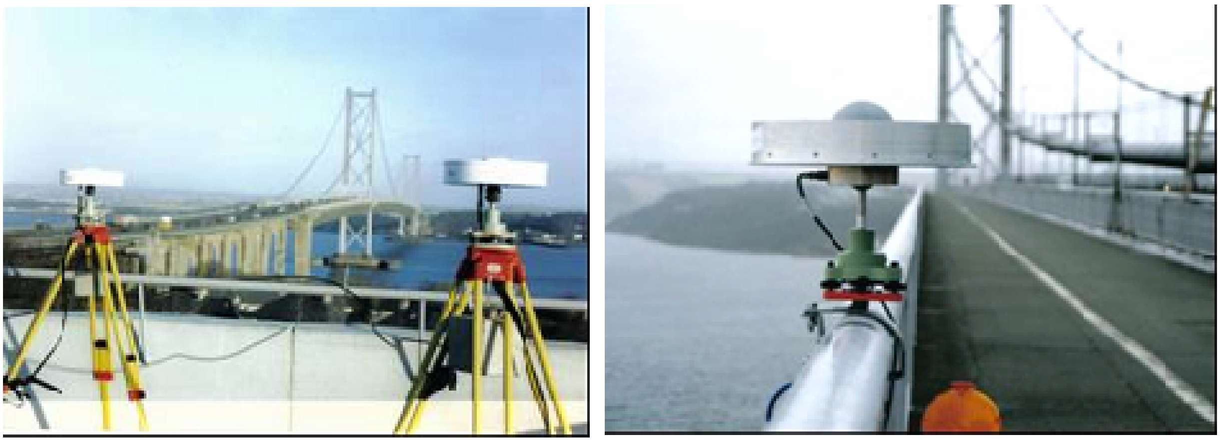


Figure 10. Two GPS reference receivers located adjacent to the Forth road bridge (left). A GPS choke ring antenna attached to the bridge (right).

During the second night, two 40 tonne lorries were hired by FETA, accurately weighed and used as a control loading of the bridge. These trials were carried out a couple of hours after the high winds experienced subsided slightly, and during these specific trials the bridge was closed off to other traffic. The trials were carried out in the early hours of the morning, when the traffic flow over was at a minimum, and only closed whilst the control lorries passed over the bridge ad re-opened whilst they turned around before subsequent crossings.

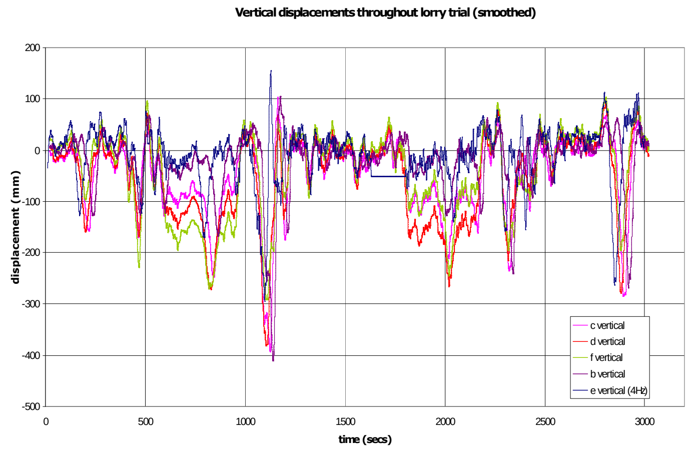


Figure 11. Height Deflections of the Bridge During the lorry trials

During these trials, the lorries travelled at 20 mph. Figure 11 illustrates the overall movements experienced by the bridge in the height component for the whole trials. The results show that the bridge deflected by up to 400mm due to the combined 80tonne loading.

Fig. 12 illustrates the final manoeuvre whereby the two lorries travelled from North to South whilst located side by side at 20mph. The graph also shows the physical location of the lorries at any time e.g. Midspan, North Tower etc.

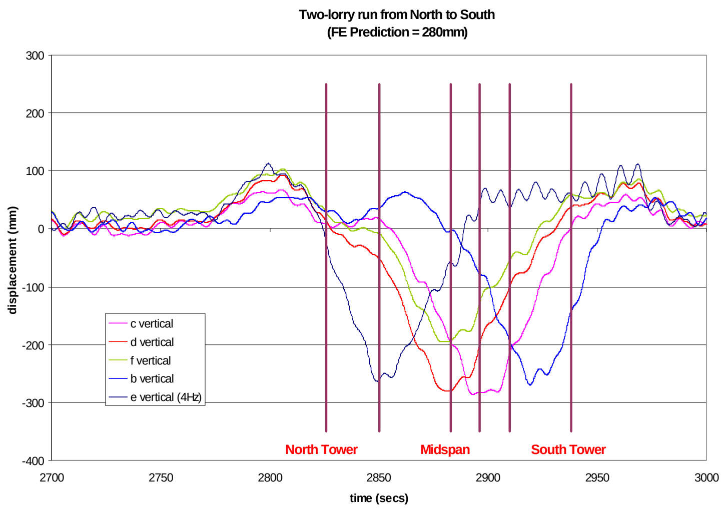


Figure 12. Height deflections during the two 40tonne lorries passing over the Bridge side by side.

Three main phenomena are evident in Fig. 12. Firstly the deflections are offset from each other. Secondly, the GPS receivers located at sites D and F, midspan, deflect by different magnitudes, even though they start off at the same height. This is due to the torsional movement of the bridge. The lorries, travelling on the left hand side of the carriageway from North to South, were in fact travelling on the East side of the bridge. Hence the eastern side (site D) deflects more than the Western side (site F). Thirdly, the reader should note that the bridge consists of three separate spans, each connected through a cable which passes over the top of the towers. As the lorries pass over the Northern side span, the load pushes this smaller span down, which in turn pulls the hanger cables down and the suspension cable which they are attached to. This then results in the suspension cable pulling up on the main span. This is evident in Fig. 12 at around 2,800s. The lorries pass into the main span, and their passage over the measured positions are shown in Fig. 12. As the lorries pass into the southerly side span, upward movement of the main span – described above – is observed.

6. CASE STUDY 5; THE AVONMOUTH CROSSING

The M5 motorway crosses the River Avon using a motorway viaduct, Fig. 13. Fig. 15 illustrates the vertical displacements of the four GPS receivers located on the structure. Again it is possible to see that GPS is indeed able to measure such movements.

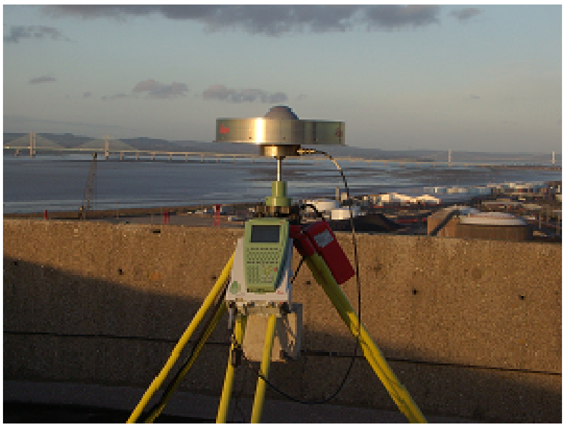



Figure 13 (left). A reference station with the viaduct in the background

Figure 14 (right) a second reference station with the two Severn crossings in the background

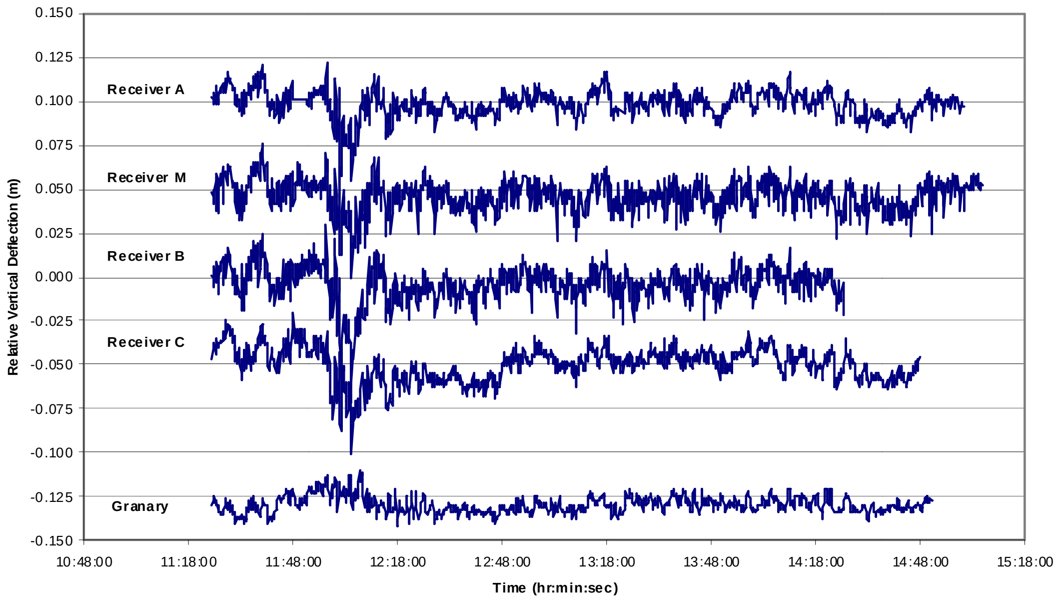


Figure 15. Vertical deflections of the viaduct during day 2

7. CURRENT WORK

In November 2009, the authors and colleagues from Korea gathered data from 4 GPS receivers located on a cable stayed bridge near Pusan. Fig. 16 illustrates the bridge with one of two reference GPS receivers in the foreground. The data from this research is currently under analysis and will be the focus of future papers.

Figure 16. One of the reference GPS receivers adjacent to the Pusan Bridge

Further to this, the authors are currently planning some new research actvities on the Severn M48 Suspension Bridge crossing. 72 hours of sata will be gathered from 10 GNSS receivers located on the bridge, relative to two reference stations. Again, the results from this research will be the focus of future resresearch papers.

8. CONCLUSIONS

The use of GNSS for bridge monitoring has been shown to be a valuable tool to monitor the movements, and the characteristics of the movements of bridges. Work by the authors will have covered 7 different bridges, of various sizes as well as various types.

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NEW DESIGN FOR HYDRO POWER PLANT STRUCTURAL GEODETIC MONITORING NETWORK

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Key words: Structural Health Analysis, GLONASS, GPS, Centralized Processing, RTK, Total Stations, Inclinometers, Least Squares Adjustment, Automatic Target Recognition, Geodetic Monitoring.

SUMMARY

The technical field of structural monitoring has made major progress in the recent years. New developments were driven by the need to keep engineering infrastructures in service beyond their expected lifetime due to limited funds for their replacement or because major modifications (like the change of turbines for increasing the power capacity) will have an impact. The environment can also change (seismic events) and hurt the infrastructure especially if the code of construction has been under evaluated.

Actually the term “Structural Health Monitoring” is more and more often used and refers to methods witch access the health status and safety of a structure and make estimation of its remaining lifetime.

However, structures can only be kept in service if they do not put the safety of the users at risk. Critical parts of a structure as well as global behaviour have to be monitored in continuous intervals with high precision.

The aim of deformation analysis has shifted and nowadays experts are not even looking if critical points of a structure have moved (and by the way due to thermal loads and the modification of water levels every structure such Hydro Power Plant is moving) but well is some patterns have significantly changed to be alerted and lead more investigations ...

With highest resolution and highest recording rate of today's instruments the small deformations caused by the daily temperature changes, water levels etc. can be observed.

The paper will review the performances of new geodetic sensors and analysis methods regarding the context of a solution that would address the today interests of the experts.

FACING NEW CHALLENGES

Engineering companies and contractors are facing challenges never experienced before. They are being charged with – and being held liable for – the health of the structures they create and maintain.

To surmount these challenges, engineers need to be able to measure structural movements to millimetre level accuracy. Accurate and timely information on the status of a structure is highly valuable to engineers. It enables them to compare the real-world behaviour of a structure against the design and theoretical models.

When empowered by such data, engineers can effectively and cost efficiently measure and maintain the health of vital infrastructure. The ability to detect and react to potential problems before they develop helps in the reduction of insurance costs and the prevention of catastrophic failures that may results in injury, death or significant financial loss.

A structural monitoring system will help reduce both the current and long term maintenance cost associated with structural movement and will reduces risks, as data analysis can be used to aid the understanding of current and future implications of structural movements. Safety and structural integrity concerns can be minimized. Potential problems can be detected and rectified before a critical situation develops.

FROM AUTOMATIC SURVEYING TO PRECISE CONTINUOUS MONITORING

Based on surveying sensors like GNSS receivers and Automatic Total Stations, Geodetic Monitoring solutions are integrating also wireless communication tools, acquisition software's, PC servers, accessories, power supply, solar panels, weather station, warning sensors, web interfaces and analysis to become complex systems.

And if the engineers today are considering often the surveying instrumentation just like "sensors" to be plugged and connected to even their real time analysis software's, they shouldn't forget that the key for succeeding in their monitoring projects is first to consider instrumentation and equipments that can deliver high accurate and reliable measurements 24 hours a days and 365 days a year through any communication media under any weather conditions and remotely controlled.

Sensors Fusion, Data Fusion

All modern automatic geodetic instruments can be combined in various systems where GNSS antennas collocated with 360° reflector are acting as "Active Control Points" for Automatic Total Stations networked.

If multiple total stations are able to make measurements to a common set of prisms, the measurements can be combined in a mathematically optimal way known as network adjustment.

By combining the measurements in a network adjustment it is possible to increase the precision of the solution and determine a common reference frame for all total stations even in the case that some of total stations cannot observe stable control points or are themselves unstable.

It has been proved also that the combination of a very precise inclinometer with a GNSS receiver can consist of a stand-alone basic monitoring station for high rise building monitoring and that the performances of a precise dual-axis inclinometer can fairly compete in the frequency domain with an accelerometer.

Recently the benefit of GNSS Network RTK corrections to provide unbiased positioning information from GPS and GNSS monitoring receivers has been demonstrated for several monitoring projects in Hong Kong and reported in several International Conferences such as ION (USA) and the FIG International World Congress in Sydney 2010.

But it’s not only concerning the Geodetic instrumentation and actually today there is a growing interest to collocate and correlate the information’s from the geotechnical sensors and with the geodetic sensors to develop an integrated deformation model. The GNSS receivers have the capacity to time synchronize all the other sensors by their PPS output.

AUTOMATIC NETWORK ADJUSTMENT AND DEFORMATION ANALYSIS

Continuous Geodetic Monitoring systems must also have the capacity to process in timely manner the huge amount of data gathered in a central computing centre to deliver in simple ways (graphically and with clear reports) the reliable warnings and alarms.

It’s therefore a must today to consider an automatic least squares network adjustment where the single epoch automatic deformation analysis is based on a rigorous statistical approach and can be used for designing a monitoring project to match the accuracy requirements.

The combination of measurements from multiple geodetic automatic instruments can be handled by a robust adjustment ensuring the highest precision and reliability. The detection of outliers is based on multi-level statistical hypothesis tests as well as the detection of unstable fixed points. It is essential for geodetic monitoring applications to have a complete system that can distinguish movement of the structure from problems in the reference frame and can identify which reference points are stable and which are not.

It is also of the prime importance for the engineers managing monitoring projects to have the tool to design the setup of the instruments in such a way that the ensemble will fit with the expected accuracy. Least Squares Adjustment can simulate the mathematical geometry to optimize the network accuracy and reliability.

HYDRO POWER PLANT STRUCTURAL GEODETIC MONITORING

The technical characteristics of facilities and contractor network design are to provide generally the accuracy of planned coordinates of monitoring points after processing by specialized software with errors (root-mean-square deviation – RMSD) not exceeding the values below:

- Horizontal: ±3mm (two times standard deviation).
- Vertical: ±5 mm (two times standard deviation).

The solution that the author suggests for achieving such requirements is a combined GNSS and TPS technology data fusion system processed by a strict Least Squares Adjustment model.

Such combination of GNSS and TPS technologies has already proven its efficiency in several projects (mining, building construction, ground surface monitoring etc.) but it was in 2005 that for the first time such system has been developed successfully for addressing the challenging accuracy specifications in the construction of the Burj Khalifa in Dubai (the tallest worldwide building).

The author named the concept “Active GNSS Control Points” where a Total Station is using as control points three to four GNSS antenna’s collocated with 360° reflector.

In the suggested new design for typical Hydropower Dams, all the GNSS Control Points antenna’s would be collocated with a 360° reflector that all Total Stations would be able to measure providing an unique combination of sensors.

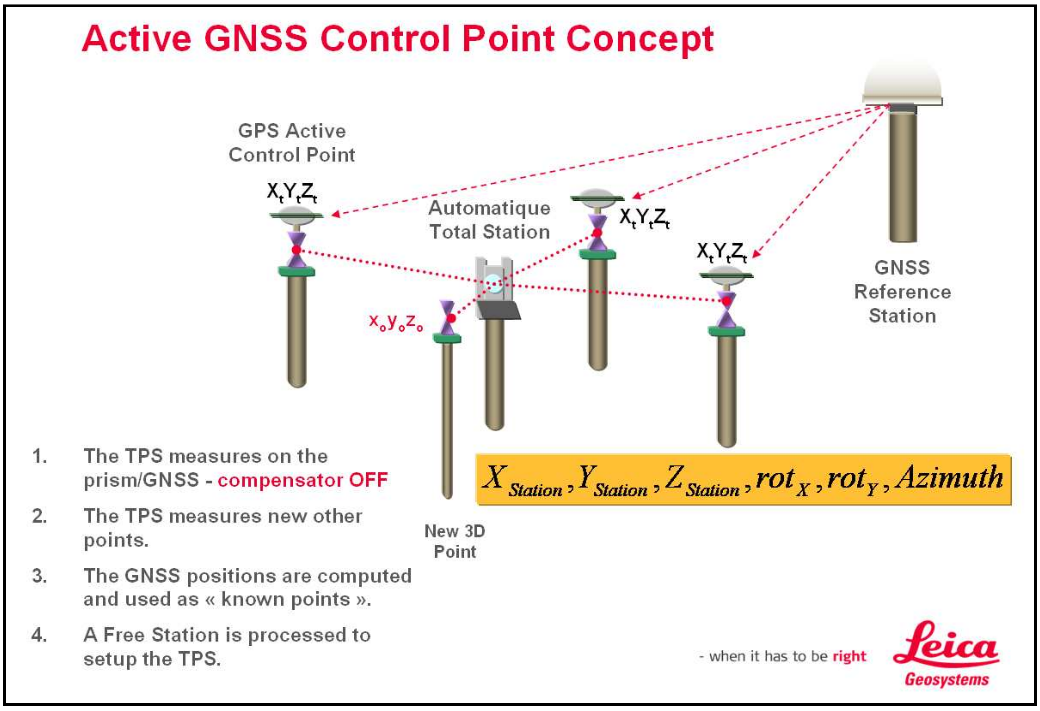


Fig 1. For the Burj Khalifa, the Total Station was even considered as not referenced to the gravity vertical and due to building motion and vibration, the compensator has been switched off. The processing was purely in a 3D frame. Total deflection of the tower was about 4 mm from the design.

Part of the new design is based on the fact that Automatic Total Stations will also measure the directions Hz, Vz and the slope distances to the 360° reflector collocated with the GNSS antenna's of the Control Points such as illustrated here:

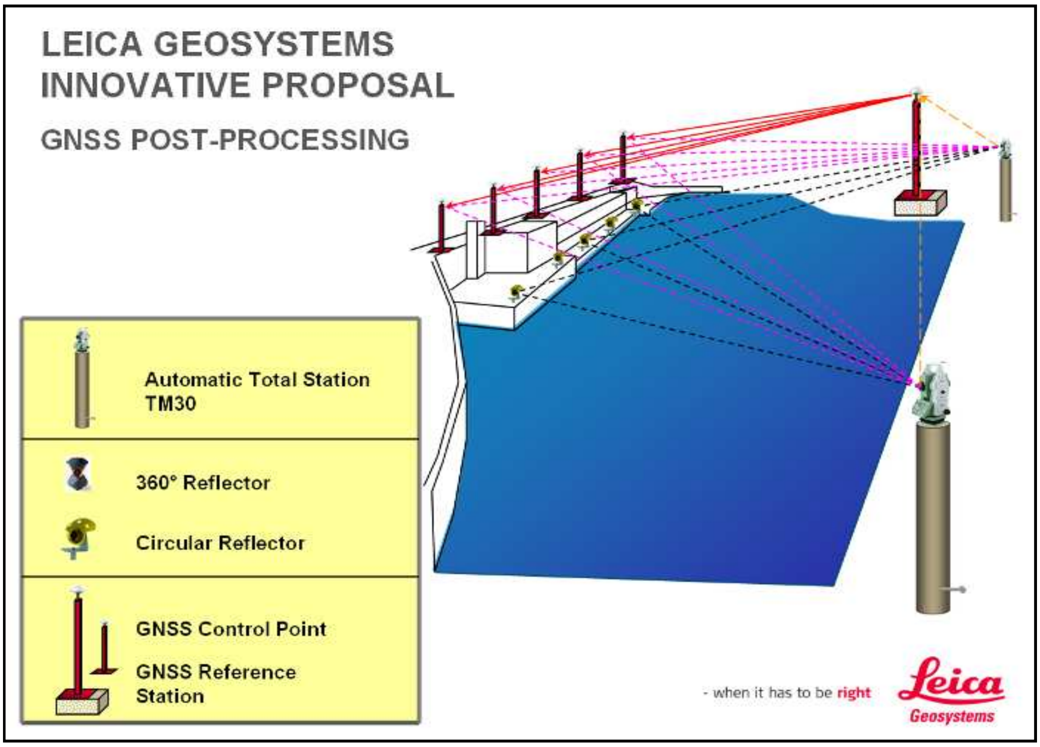


Fig 2: proposed new design

GNSS data can be processed in either real time (at rates up to 20 Hz) or in post processed mode. Real time processing enables movements to be detected very rapidly and on average has a one sigma accuracy of less than a centimetre for baselines up to 3km (Brown et al. 2006). The accuracy of real time processing is related to the geometry of the satellite constellation (the number, azimuth and elevation of the satellites that are tracked) at the time of measurement.

The GPS satellites travel with a speed of 4 km/s and orbit the earth approximately every 12 hours. Hence, the satellite geometry is constantly changing and there are times of the day when it is good and other times when it is poor, especially if the sky view is restricted. In times of poor satellite geometry it may not be possible to compute a high accuracy (ambiguity fixed) solution and the reliability of the solution (the probability that the ambiguities are resolved correctly) will be lower.

If high accuracy and reliability is critical, a better option is to collect data over a defined period (e.g. 10 minutes, 1 hour, and 24 hours) and post process. In post processing more data can be used to estimate the parameters (coordinates, ambiguities, error models) mitigating short term problems due to poor satellite geometry and resulting in a more reliable and accurate solution. Usually the result of post processing is a single high accuracy coordinate, essentially an average over the time period. Long data periods (e.g. one hour or more) also enable additional parameters to be estimated to account for atmospheric (troposphere) influences, which are strongly correlated with the station height, further improving the accuracy. As an additional step, a median can be computed from the post processing results over a longer time period in order to avoid any potential problems due to outliers.

Post processing combined with a median calculation is a very stable and accurate method for computing and updating reference coordinates using GNSS data. The downside of this approach is that if a sudden movement occurs, it will take some time for the system to react. The solution is then to compute multiple position estimates: a rapid estimate using real time data or a short post processing interval to detect sudden movements to provide alarms to the operator; and a slower estimate using a longer post processing interval to correct for the gradual movements of the pillars.

The standard mode of precise differential positioning is for one reference receiver to be located at a reference station whose coordinates are known, while the second receiver's coordinates are determined relative to this reference receiver. The use of carrier phase data in real-time, single baseline mode (one reference station and one rover or user receiver's coordinates to be determined in a relative sense) – also known as "single-base" mode – is now common place.

These systems are also referred to as RTK systems ("real-time-kinematic"), and make feasible the use of GPS/GNSS-RTK for many time-critical applications such as engineering surveying, GPS/GNSS-guided earthworks/excavations, machine control and structural monitoring applications.

Over the last decade and a half the use of GPS (and now GNSS) for structural monitoring, of dams, bridges, buildings and other civil structures, has grown considerably (see Ogaja et al., 2007, for a recent review), and nowadays the GNSS-RTK technique is widely used around the world. Such systems output continuous streams of coordinate results (or time series). The dynamics of the structure typically defines the nature of the coordinate analysis. For example, if a structure vibrates or deflects due to wind or surface loading the time series analysis is conducted in the frequency domain (see, e.g., Li et al., 2007), otherwise standard geodetic deformation monitoring techniques based on advanced network least squares analysis are used (Ogaja et al., 2007).

The interest of having at least two GNSS Reference Stations in a monitoring project is that both GNSS Reference Stations can also be checked each other in a relative mode to detect eventual movements that would be disastrous on the GNSS

Monitoring points. Last but not least a second GNSS Reference Station is also part of backing-up the system. This is clearly an "Integrity Control" solution.

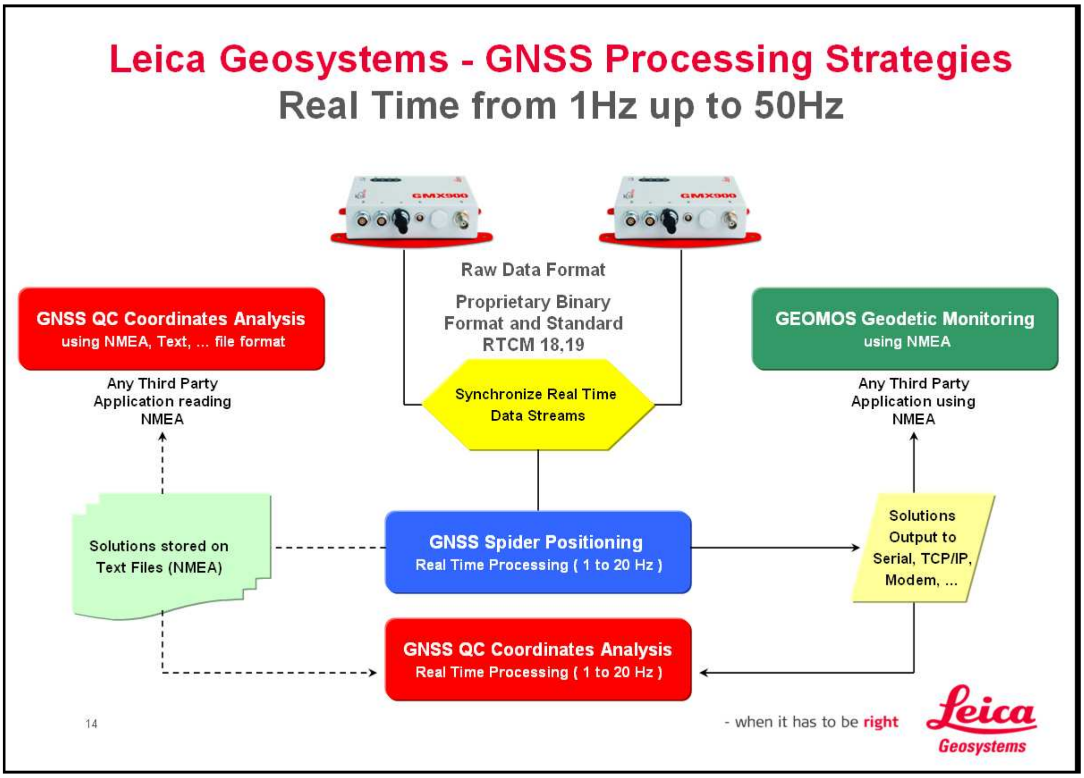


Fig 3. Leica GNSS Spider Positioning is centralized RTK processing "multi-baseline" software

The other significant advantage of having a "centralized" processing approach is that for the processing of the various baselines, the GNSS Reference Station can be selected freely and all combination of baselines can be considered.

Even more interesting is that the position between the GNSS Control Points or monitoring stations can also be processed. Each baseline can be processed in dual frequency (L1 and L2) mode but also in the single frequency mode (L1) and considering only GPS or GPS and GLONASS.

The resolution of the ambiguities has been also extended with a new "Quasi-Static" initialisation method where the variance of the GNSS monitoring station is considered for speeding up the initialisation time to fix.

But Leica GNSS Spider software can also process those multiple baselines in "near real time" mode and in the "post-processing" mode. The difference between those modes is only a matter of the session's timing.

As soon RINEX files are available from the GNSS sites – and also from any other source like from a FTP server (CORS regional networks for instance like IGS, EPN), the post-processing is engaged with some advanced parameters such as the choice of a Ionosphere model, a troposphere model, another cut-off angle, another frequency rate, and the choice between broadcast or precise orbits.

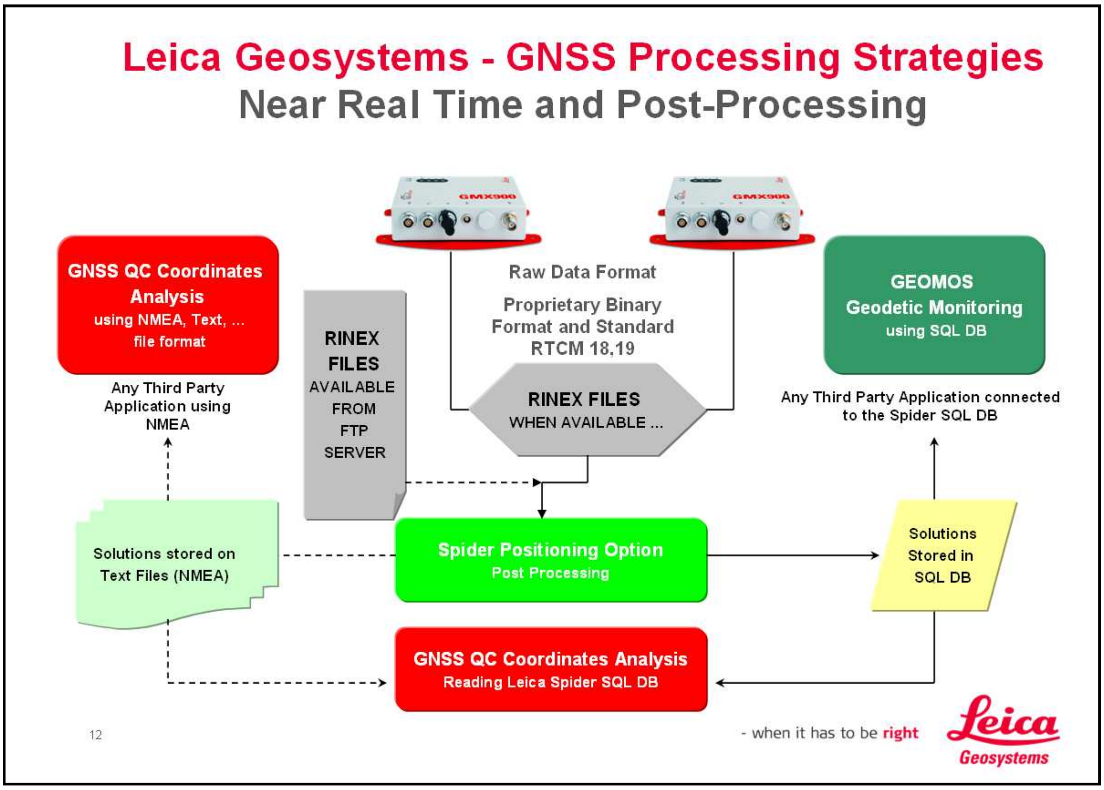


Fig 4. Leica GNSS Spider Positioning is centralized post-processing "multi-baseline" software

Different sessions can be processed in parallel such as a baseline between two GNSS receivers every 10 minutes, every hour, every 6 hours and a daily solution! This is simply to take the best possible solutions from the measurements without any compromise due to software capacity restrictions.

That led us to refine our proposal the following design where two GNSS Reference Stations is under consideration.

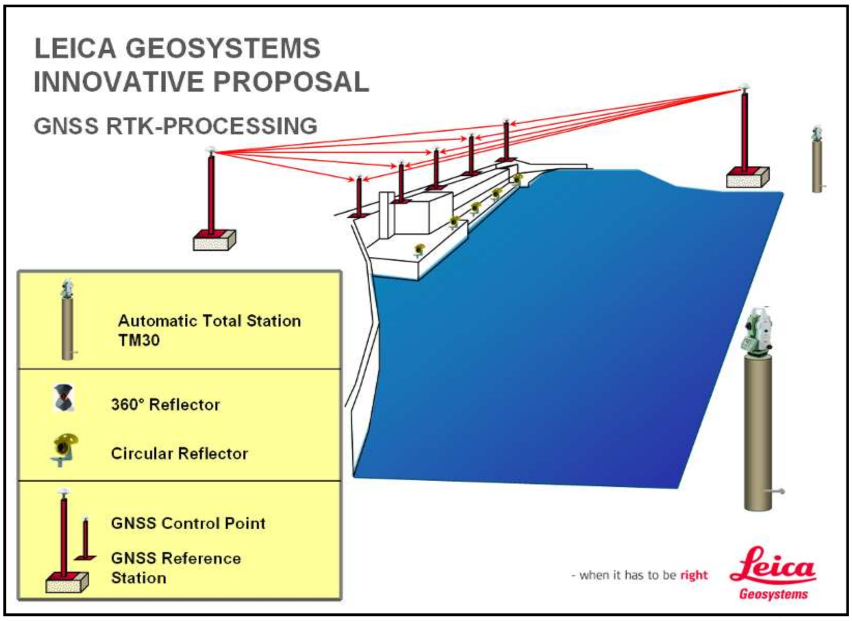


Fig 5. GNSS RTK-Processing design for UHE HPP site

Again, we would like to emphasize the fact that also the baselines between the different GNSS Control Points located on the dam's crest can be processed with different initialisation methods and using only GPS or GPS and GLONASS and by considering a L1 + L2 solution or just a L1 single frequency solution as it is also well known that the single frequency solution at short range can be more precise that a combination of both frequencies due to the higher noise of L2 measurements.

All those possibilities are clearly part of tuning the system to achieve an optimal highest accuracy.

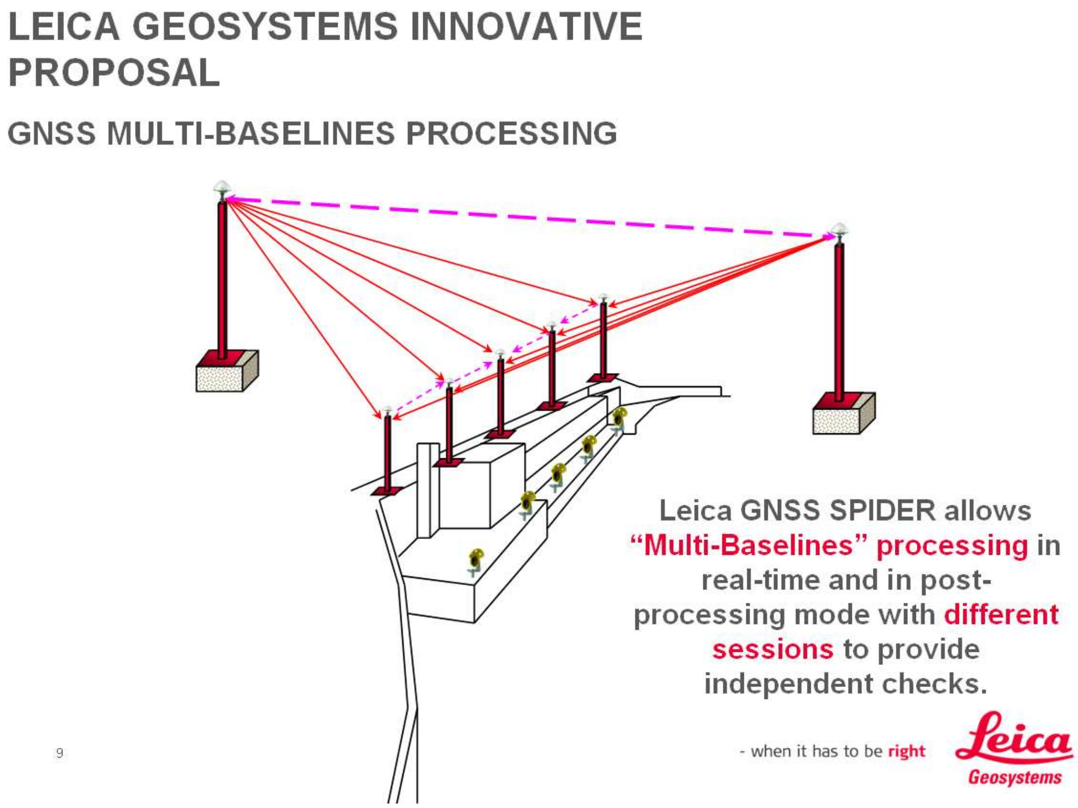


Fig 6: GNSS RTK-Processing design for UHE HPP site with multiple combination of baseline processing.

GNSS Post-Processing and Total Stations fusion design

If GNSS positioning technology allows various mode of processing such as "Real Time Kinematic" - requested in the tender specifications – only the "Post-Processing or "Near Real Time" mode is able to combine closely and at a compatible accuracy the measurements GNSS receivers with those obtained by the Total Stations an integrated rigorous Least-Squares Adjustment model.

The final design the author is suggesting is then the following:

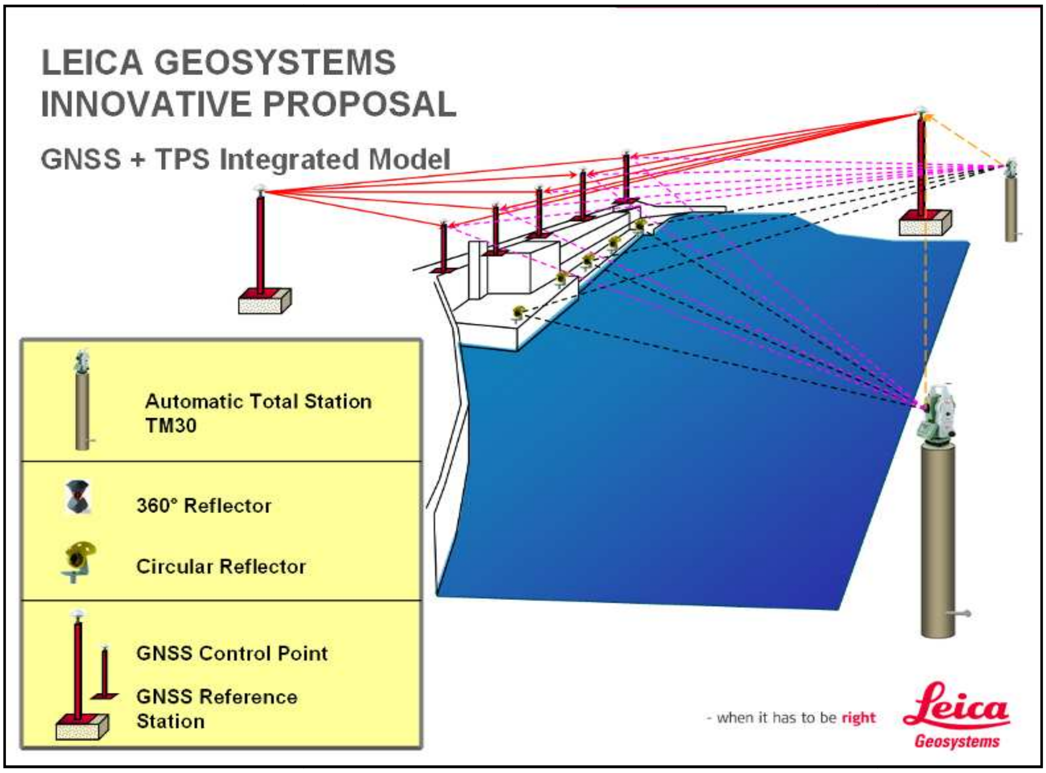


Fig 7. Author's final design proposal considering two GNSS Reference Stations surrounding the Hydropower Dam' sites to be integrated with the Total Stations measurements by using 360° reflectors collocated with the GNSS Antenna's Control Points into a global Least Squares Adjustment model

To summarize the author value proposition, there is a net advantage to consider more than only one GNSS Reference Station in that model.

– The computation of single baselines from the GNSS Reference Station to the GNSS Control Points cannot be controlled (no redundancy) independently and will depend entirely of the performances of that GNSS Reference Station. Simply said, there is no "back-up" no double check. Karl Friedrich Gauss favourite's sentence was *"Eine messung is keine messung!"* that could be translated by *"One measurement is not a measurement!"*

– One can argue that already in our design, the Total Station's measurements can control the performances of the GNSS processing (comparing the directions Hz, Vz and the slope distances Ds). But that will not bring enough contrast in the solution to clearly indentify possible "outliers" and much more important to discriminate if it is a movement induced by the deformation of the structure or simply by the noise level of the solution.

– The Total Station measurements will also be affected by the refraction caused by the water surface and the high humidity level. In our proposal we suggest to install meteo sensor outside the hut protecting the Total Station to mitigate some part of the refraction influence (using the well known Barrel and Sears model) but comparing the distance from the GNSS Receivers and the distance deduced from the solution obtained from the Total Station will allow the processing to "scale-up" the distance biased by the remaining un-modelled effects of the refraction.

– Therefore the following design will allow experts to study and derive the correct refraction model applicable in such very local case and tune the network processing accordingly the results.

– We cannot pretend that the areas where the Hydropower Dams are located will not be subject to deformation as well. There is a large interest today in the “reservoir induced earthquake”. In numerous parts of the world today, including some of the most highly developed countries, many dam designers and operators have tended to close their eyes to the engineering problems posed by reservoir-induced earthquakes. Virtually every careful study has concluded that there is indeed a cause-and-effect relationship between some earthquakes and some reservoirs, and two dams (Koyna, India, and Hsinfengkiang, China) have in fact come uncomfortably close to disastrous failure during such events. Furthermore, it is precisely in the regions of low natural seismicity where the major existing problems lie, because in areas of high seismicity dams are usually designed for substantial earthquake resistance anyway. For those reasons, the author is advocating to have one of the GNSS Reference Station as “Master” Reference Station to be part of a Regional Integrity monitoring program that would ideally be lead by the institution who has such positioning infrastructure under his responsibility.

The simulation studies that have been carried on that design have proven that the accuracy requested by the tender specifications will be achieved and even exceeded providing a good guarantee on the results.

We would like to stress once again that for “safety” driven projects, the results provided by a Deformation Permanent Monitoring System must be un-ambiguous and definitively not subject to contestation or justification by “force majeure” elements.

Unique Processing Workflow’s

All the data streams from the GNSS Receivers will be gathered in real time mode into for instance the Leica GNSS Spider software and share with different modules.

Leica GNSS Spider Site Server is managing the incoming data streams and will store and convert the data into the RINEX file format for archiving, transfer to the Integrity Monitoring processing centre and be used for GNSS Post-Processing sequences.

At an interval defined after the pre-run analysis of the network, all the data streams from the GNSS receivers will be converted into the standardized data exchange format RINEX.

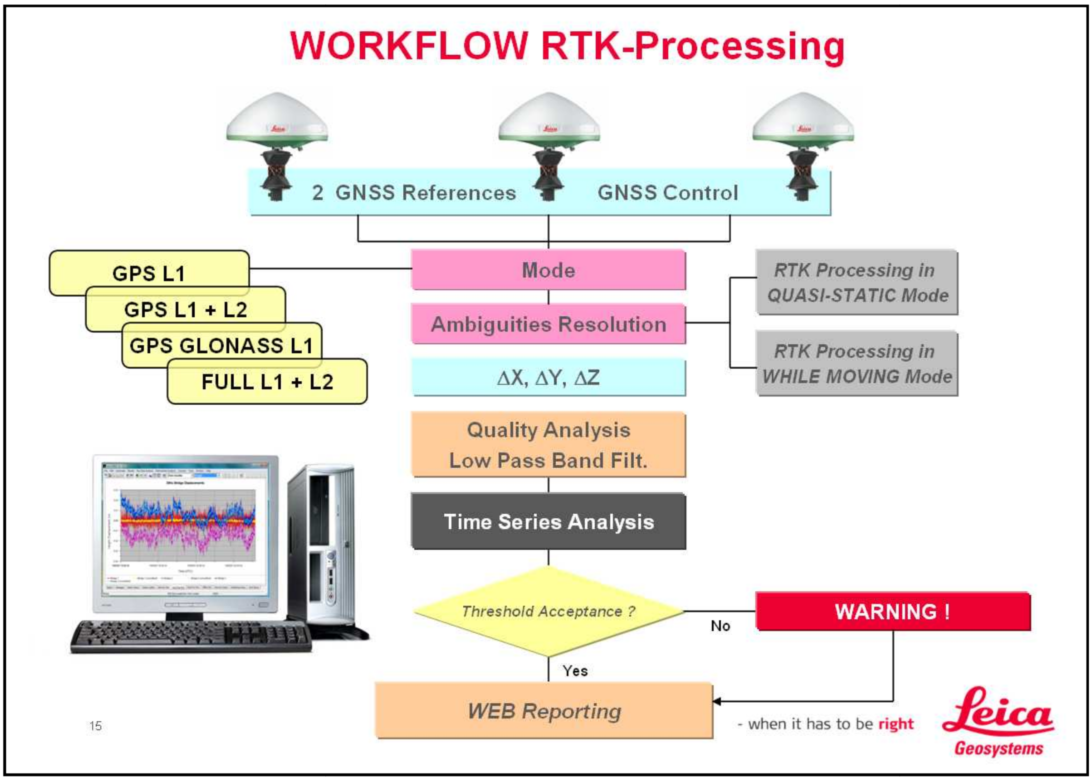


Fig 8. Workflow processing for GNSS RTK-Processing. The same baseline can be processed in parallel using different parameters

As soon those RINEX files will be produced (every 10 minutes, 1 hour, 6 hour, … daily), Spider Site server will automatically post-processed the various combinations of baselines defined and will write the results into the SQL database for being accessed by the monitoring software and combined automatically into a rigorous Least Squares Adjustment with the Automatic Total Stations measurements.

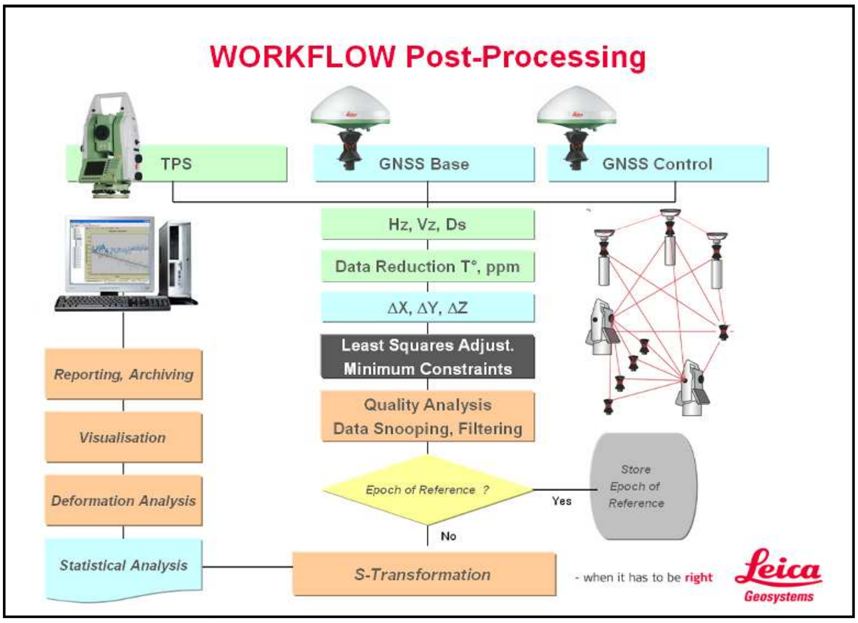
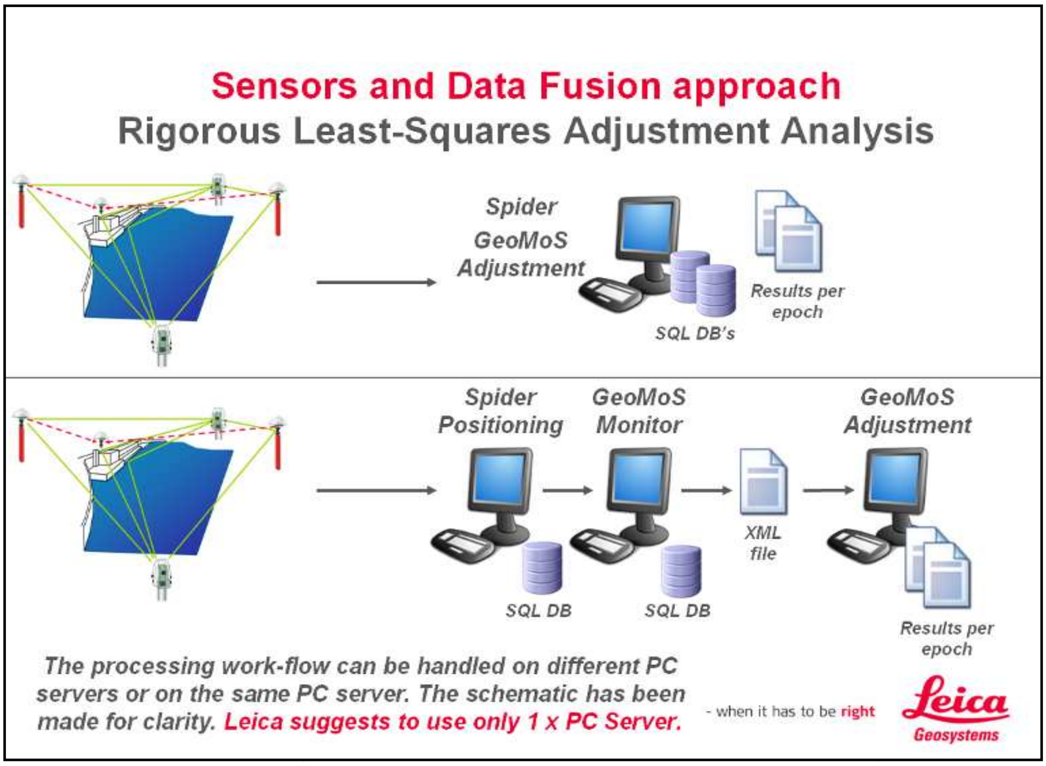


Fig 9. Workflow GNSS Post-Processing with integration of Total Station measurements into a global model of Adjustment

The software's are mainly driving the geodetic sensors such as GNSS receivers and Total Stations and processing after reduction, the observations separately to provide coordinates, while the automatic adjustment module is integrating all the observations into a global model.



New generation measurement devices such as automatic Total Station, Levelling instruments, GNSS receivers, laser scanners and the necessary equipment for data storage and transfer now allow the engineer to obtain and analyse data in a rapid way.

Satellite supported measurements especially with receivers for the Global Positioning System (GPS) or/and GLONASS, are now often used in survey engineering. However, there are situations when satellite related observations are not possible, for example in underground surveying or in places were high buildings or trees obstruct the signal to the receiver. In these cases it is necessary to complete or augment the satellite measurements with terrestrial observations.

Standard geodetic procedures are used for the analysis and except for the adjustment method and traverse; all methods are single point determinations. The computational strategy is devised in a linear and hierarchic way. New point coordinates depend on the manner and order of the computing steps.

Observations that do not fit the model are taken out for analysis, even if their quality is higher than those of the coordinate generating observations. Often errors can be detected late in the generation process. The detecting of these measurement errors (Gross errors, point identity mistakes) by testing each measurement is complicated and very time consuming.

Hand made adjustment calculations have been known about for over one hundred years. However it has not been possible to use these theories in practice because of a lack of technical resources. So until now standard methods had to be used. However, even when the first computers appeared limited data storage capabilities meant that it was necessary to develop simple programs for testing the hand made calculations.

Today we have the advantage of very powerful computers, which renders programs that do not compute automatically out of date. The capacity analysis programs should be comparable with the capacity of new age technical devices. Otherwise programs are left as the weakest limb in the chain of geodetic analysis, which can create obstacles in productivity.

In the functional model the principles of simultaneous and equal rank of all observation are used. I.e. all observations are used for coordinate determination independent of the way of calculation.

In the utilisation of GNSS observations the analysis software often does not consider terrestrial observations.

The programs determine coordinates by using an adjustment calculation in the geocentric coordinate system (World Geodetic System). After that they transform the geocentric coordinates into a praxis relevant system (Gauss-Krueger, Soldner e.g.). The actual terrestrial measurements are not considered.

These programs expect that an adjustment is undertaken before or after starting the calculation.

This attachment is contradictory to the principle of simultaneous and equal rank of all observations and is just a ‘solution in steps’. Finally the result depends on the path taken by both adjustment steps.

The automatic adjustment software module enables the joint analysis of terrestrial and GNSS observations, in an integrated three dimensional network adjustment, with the option to investigate fixed points simultaneously.

One point of criticism on the complex adjustment systems is the danger one has of loosing track. This could jeopardise the advantage of saving computing time in minor or average networks.

This system offers for the user a strategy to obtain results in a clear way for best interpretation. This advantage is achieved using the tool network analysis and the methods of pre analysis in terrestrial and GNSS analysis for an automatic calculation of coordinates and the detection and elimination of gross errors.

The Least Squares Adjustment is based on a three steps processing scheme that starts by considering all the control points as unknown. That’s what we call a “free network” adjustment where the processing is concentrated on the measurement without applying any constraint from fixed points like the one formed by the GNSS Reference Stations.

The eventual “outliers” detected in the measurement (those that are exceeding statistical thresholds determined by hypothesis test confidence levels and flagged by a global F-test and a individual T-test) will be de-weight and therefore their influences will not impact the processing of the coordinates.

The second step is the “weighted constraint” adjustment, where the fixed points will be characterized with a corresponding variance-covariance matrix (stochastical model) to constraint ad minima the coordinates and therefore validate the stability of the datum.

Finally the third step is the “full constraint” adjustment where all the fixed points will condition the observations to produce the last set of coordinates for the control points.

Along all those steps, a multiple hypothesis test is carry to analyse the adequation of the functional model (supposed to be linear while systematic errors such those induced by un-modelled effects of the refraction), the stochastical model (assuming the a priori variance factor and the covariance are reflecting the effective accuracy of the observations) and the observations.

The automatic deformation analysis is based on epoch-by-epoch scheme by considering the initial set of coordinates as the reference epoch.

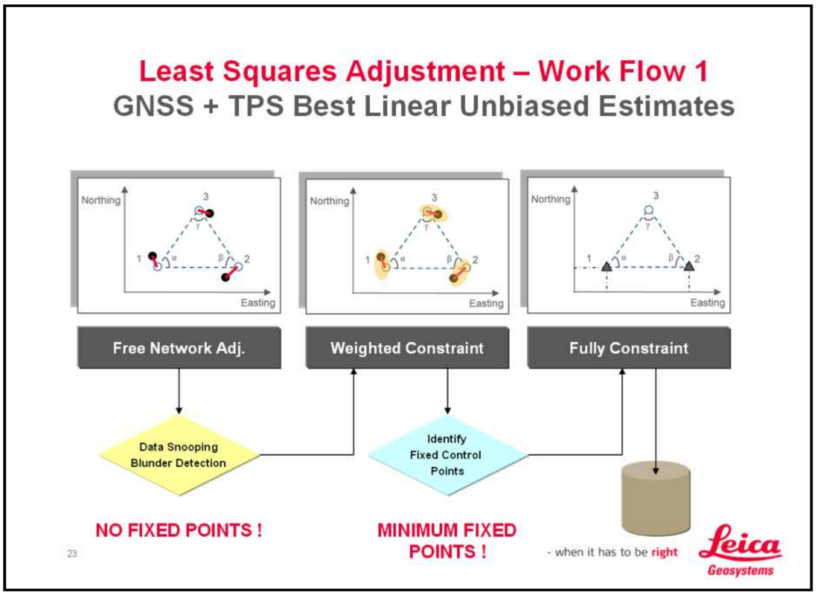


Fig 10. The automatic adjustment module is processing a rigorous Least Squares Adjustment in several steps to insure best linear unbiased estimators for all the control points

Each adjustment is producing a coordinates vector and its corresponding variance-covariance matrix with the a-posteriori variance factor that are first aligned using a similarity transformation type often named “S-Transformation” from which the residuals are analysed using hypothesis tests to check the “normality” of the corresponding distribution associated at each epoch.

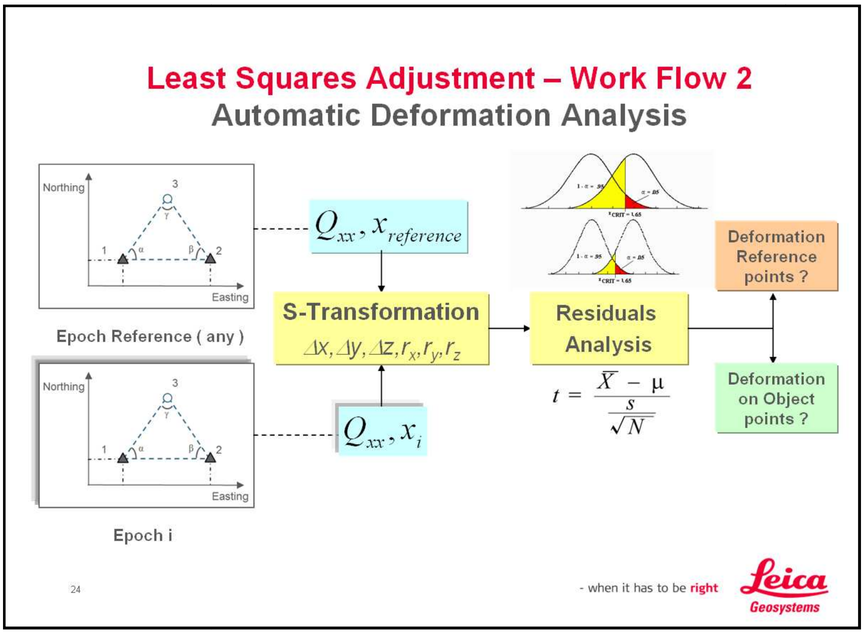


Fig 11. The automatic adjustment module is able to check if control points have moved as well as if fixed points (GNSS Reference Stations) are still stable

Feasibility Study of the New Proposed Design

We first examined the situation we could have with three GNSS Reference Stations, then we decreased to two GNSS Reference Stations and we examined at the end what would have been the performances with only one GNSS Reference Stations.

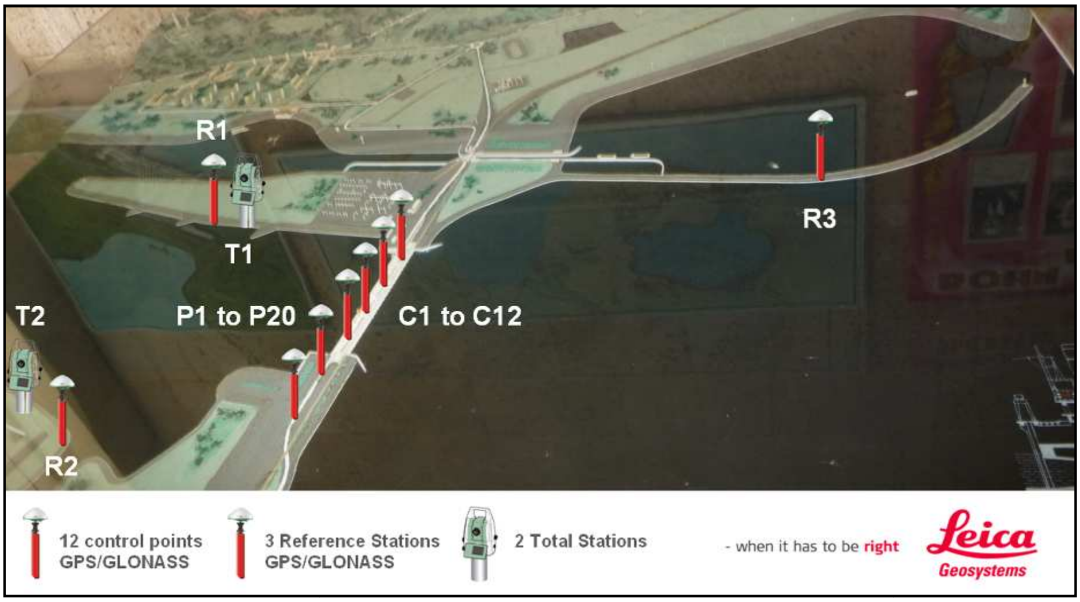


Fig 12. Design with three GNSS Reference Stations – Accuracy is meeting and exceeding the specifications

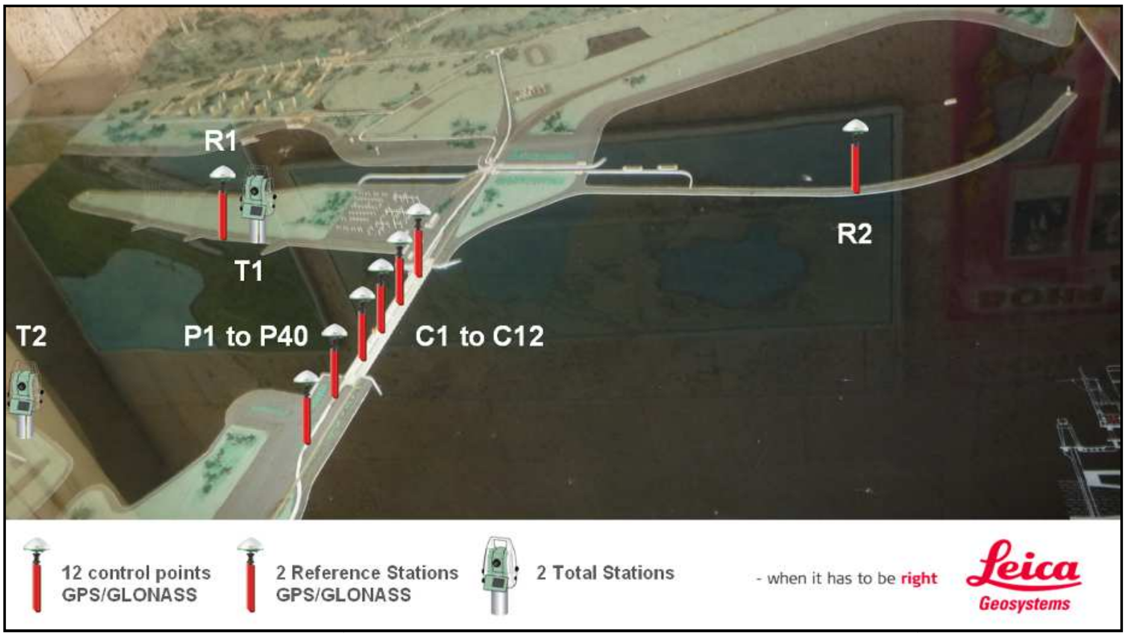
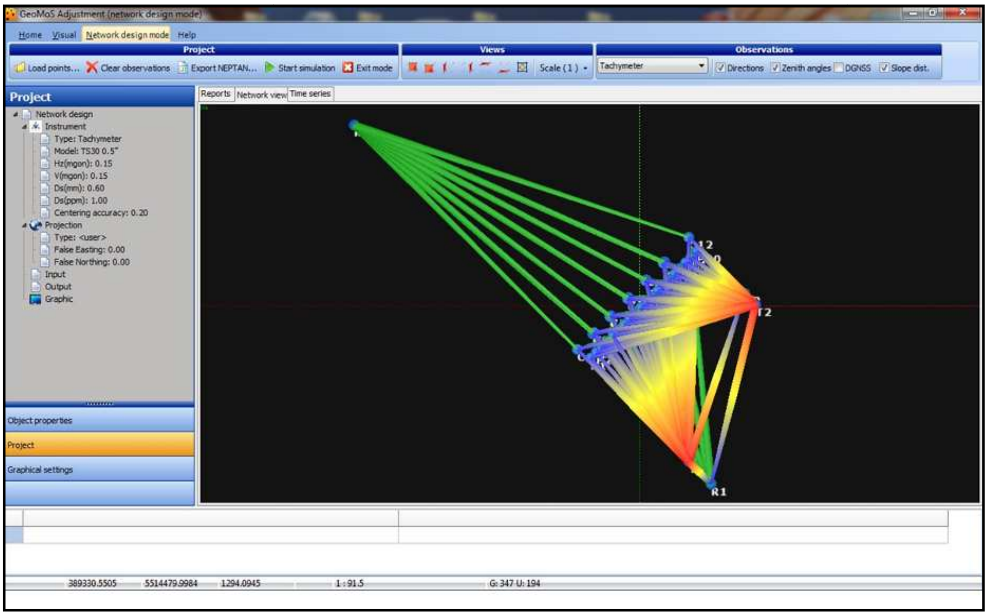


Fig 13. Design with two GNSS Reference Stations – Accuracy is meeting and exceeding the specifications. Difference with three GNSS Reference Stations is only about 0.2 mm!

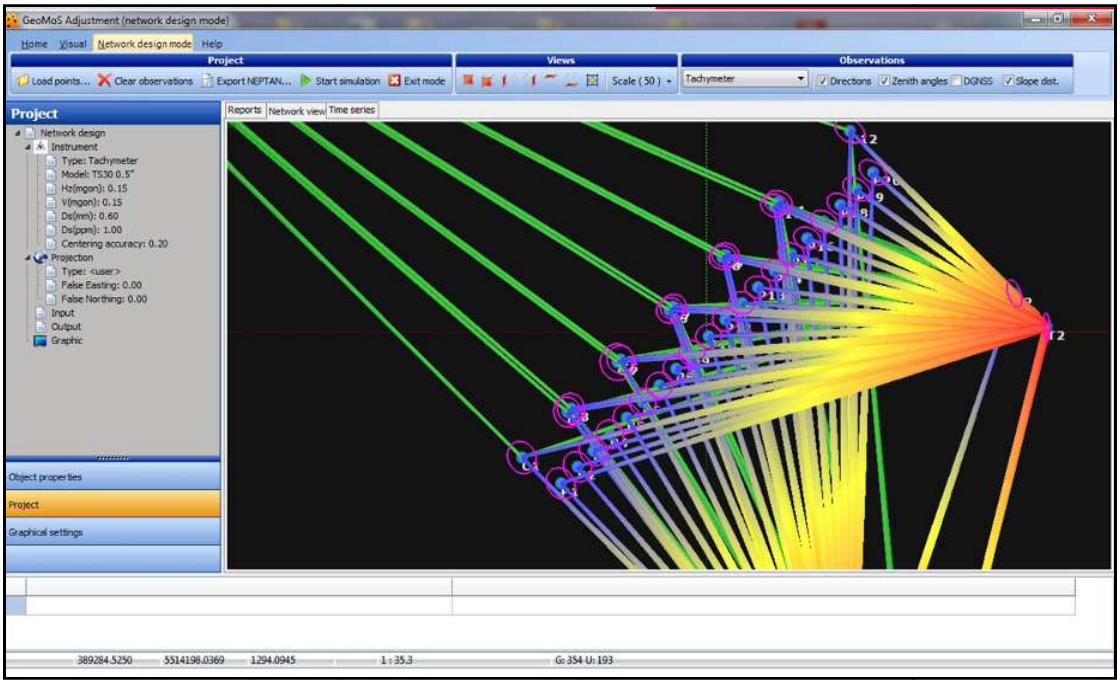
From this design, we have estimated the position of every sensor as well as the position of several circular reflectors. The level of all the points has been estimated from the graphics delivered with the initial specifications.

Having all the coordinates into a grid datum arbitrary defined we simulated all the observations that would be carried in the reality.

An adjustment software has the capacity to simulate a Least Squares Adjustment ignoring the real values of the observations but considering the associated stochastical model closed to the reality and based on the instrumentation and performances that could be achieved in real conditions.



In that simulation mode the size and direction of the error ellipsoids are indicators of how the design could impact on the final coordinates accuracy.



We can deduce from their numerical values that the results will be precise and homogeneous indicating that the proposed design based on three GNSS Reference Stations and the combination of GNSS Control Points collocated 360° reflector with the Total Stations meets and exceeds the accuracy requirements of the tender specifications.

The output of the simulation gave us also for each observation an estimate about the capacity each of them will have to detect a deformation of the related point.

The average standard deviation for the monitored object points in plane is about 1mm for the height 1.4 mm. This allows detecting movements – deformation in the engineering object better 2mm.The local redundancy is between 30 and 70 % and allows a reliable detection of deformations.

Finally the selected network geometry and defined instruments (GNSS and Total Station type) allows achieving a real reliable network for a long term monitoring.

In that table we have put for that given situational design the different values for the RMS xy and RMS z as performance criteria. The point C1 is compared with the point C2 (used as a reference and processed with 3 x GNSS + 2 x TPS).

So we can see that a network based on 2 x GNSS + 2 x TPS is offering theoretically the same performance level in term of point's accuracy than the 3 x GNSS + 2 x TPS.

	3 x GNSS + 2 x TPS								
Pt Id	Ellipse Or.	A	B	Mx	Mx	RMS XY	RMS Z	ΔRMS XY	ΔRMS Z
C1	207.4	0.9	0.8	0.8	0.9	1.2	1.8	**0.0**	**0.1**
C2	*217.4*	*0.8*	*0.8*	*0.8*	*0.8*	*1.1*	*1.7*		
	2 x GNSS + 2 x TPS								
Pt Id	Ellipse Or.	A	B	Mx	Mx	RMS XY	RMS Z	ΔRMS XY	ΔRMS Z
C1	207.9	0.9	0.8	0.8	0.9	1.2	1.8	**0.0**	**0.1**
C2	*217.8*	*0.8*	*0.8*	*0.8*	*0.8*	*1.2*	*1.8*		
	1 x GNSS + 1 x TPS								
Pt Id	Ellipse Or.	A	B	Mx	Mx	RMS XY	RMS Z	ΔRMS XY	ΔRMS Z
C1	250.0	1.1	1.0	1.1	1.1	1.5	2.4	**0.3**	**0.6**
C2	*218.2*	*0.9*	*0.8*	*0.8*	*0.9*	*1.2*	*1.8*		
	2 x GNSS								
Pt Id	Ellipse Or.	A	B	Mx	Mx	RMS XY	RMS Z	□ RMS XY	□ RMS Z
C1	200.0	2.2	2.2	2.2	2.2	3.2	7.1	**2.0**	**5.3**
C2	*218.3*	*0.9*	*0.8*	*0.8*	*0.9*	*1.2*	*1.8*		
	1 x GNSS								
Pt Id	Ellipse Or.	A	B	Mx	Mx	RMS XY	RMS Z	ΔRMS XY	ΔRMS Z
C1	200.0	3.2	3.2	3.2	3.2	4.5	10.0	**3.3**	**8.2**
C2	*218.3*	*0.9*	*0.8*	*0.8*	*0.9*	*1.2*	*1.8*		

In that table we have put for that given situational design the different values for the RMS xy and RMS z as performance criteria. The point C1 is compared with the point C2 (used as a reference and processed with 3 x GNSS + 2 x TPS).

So we can see that a network based on 2 x GNSS + 2 x TPS is offering theoretically the same performance level in term of point's accuracy than the 3 x GNSS + 2 x TPS.

Even in case of failure the situation 1 x GNSS + 1 x TPS is acceptable. At the end, the proposed instrument and software for a typical design guarantees to meet the specification in term of accuracy at 2 σ level.

In that new design proposal for a Deformation Permanent Monitoring System, the author has described the best possible way to engage the most advanced scalable and flexible geodetic monitoring solution for the various sites where again safety is the prime focus.

ACKNOWLEDGMENTS

The author would like to express his gratitude to the people who has adopted and supported Leica Geosystems geodetic monitoring solutions.

It is all the time and for every project a team work to find the best combination of instruments, processing software's to design the most appropriated solutions for standard, critical or challenging projects.

The author knows also that in geodetic monitoring there is simply no "traditional" project.

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INTELLIGENT GEO-SENSOR-NETWORKS AS FOUNDATION OF INTERDISCIPLINARY STRUCTURAL-MONITORING

Sascha SCHNEID, VMT GmbH, Bruchsal, Germany
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For more than 15 years now VMT GmbH from Bruchsal, Germany, offers software and hardware solutions for automatic gathering and processing of data derived during the process of in mechanically driven tunneling (Tunnel Boring, etc.).

Besides improvement of the successfully established automated TBM guidance systems in the light of increasing importance of modern information technology the focus of VMT's own developments extends towards customized information systems for recording, processing and evaluation of obtained data as well as monitoring of processes and objects within or outside the scope of tunneling.

As an approach to integrate all these tasks in one platform the new product line TUnIS (Tunnel and Underground Integrated Software Structure) in combination with the process data management system IRIS (Integrated Risk and Information System) is under development. Here VMT GmbH cooperates closely with ITC-Engineering who specializes on software solution for infrastructural construction projects.

This presentation concentrates on the subject of "Interdisciplinary Structural-Monitoring". Concepts as well as hardware and software solutions will be presented for the development of monitoring projects, the realization of intelligent geo-sensor networks and collection, processing, visualization, reporting and alarm management of geodetic measurements and geotechnical sensor data.

SPACE MONITORING OF SPATIAL DISPLACEMENTS OF NATURAL OBJECTS

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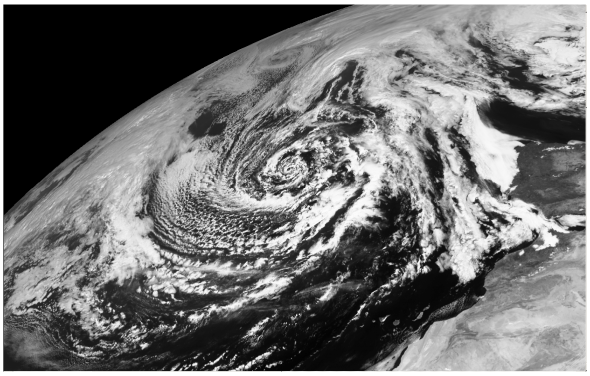
Abstract

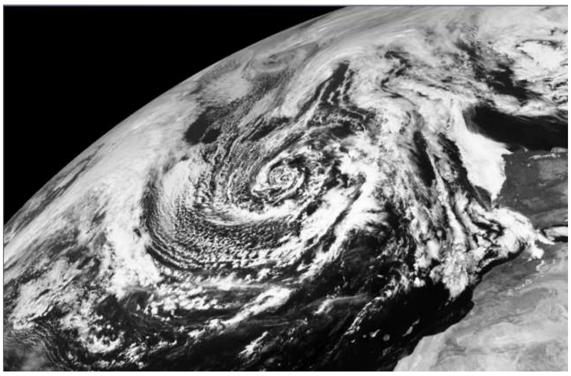
The technology of constructing vector fields of spatial displacements of the nature objects (ice fields, water bodies and clouds in the atmosphere) from a series of consecutive multispectral images obtained by space satellites is considered. The technology is based on searching for the maximum of the coefficient of mutual correlation between reference objects (targets) found in the current image in the series and their positions in the next image in the series.

The correlation-extreme analysis algorithms and technologies for space object displacement determining (ice fields, water bodies, clouds in atmosphere) from multispectral space images taken at different times are proposed and implemented. The results were obtained together with Scientific Research Center (SRC) "Planeta" in fulfilling of “Russian Federal Space Program 2006-2015”. The software as above was put into operative practice of the head center of satellite data acquisition and procession SRC “Planeta”. It is widely used in space monitoring of Earth Polar Regions (ice fields), Russian sector of the Black and the Azov seas (water bodies) and clouds in the atmosphere. The determination of object space displacements by satellite images occurring at different time is the method based on the search of maximums of mutual correlation coefficients between the objects of two neighbor images in a line of sequential images [1, 2]. A similar approach is considered as the method of objects recognition, known as “correlation comparison” [3]. However it’s impossible to speak about predefined dictionary of images because of random nature of objects on space images. This dictionary is being formed in analysis of image lines and it’s peculiar for each image. The building of the dictionary is based on the approaches mentioned in [4]. The elements of the dictionary, called reference objects, or just targets, form a square of original image of specified size. They are found in some neighborhood of nodes of square grid so that the maximal value of control parameter – dispersion or entropy is kept. If the achieved maximal value of control parameter exceeds the threshold, the corresponding part of the image is declared as a target. Otherwise the procedure of building of targets is directed to searching for square areas with maximal “variability”. In such areas an appropriate object might not be fully destroyed while moving to the next image in a line. Besides, there is less probability of accident correlation registration for parts of images with background distribution of image pixels. The next step to define space object displacement is the searching for positions of found targets on the next image. Displacement is defined for each found targets. The search of target position on the next image is carried out inside a square area of specified size. The center of the search area coincides with original target position. A new target position is a position, where the maximal value of mutual correlation coefficient is achieved. In scanning of the search area, the target is transformed by scaling and rotation. The selected positions can satisfy threshold conditions – minimal allowable value of correlation coefficient and minimal allowable shift. The process can be continued iteratively for the following images of the line: the areas with maximum correlation value are declared as targets; the targets got with the help of the procedure of the searching of targets as above, can be added to these area with maximal correlation, to get a new set of targets we should search their positions on the next image and etc.

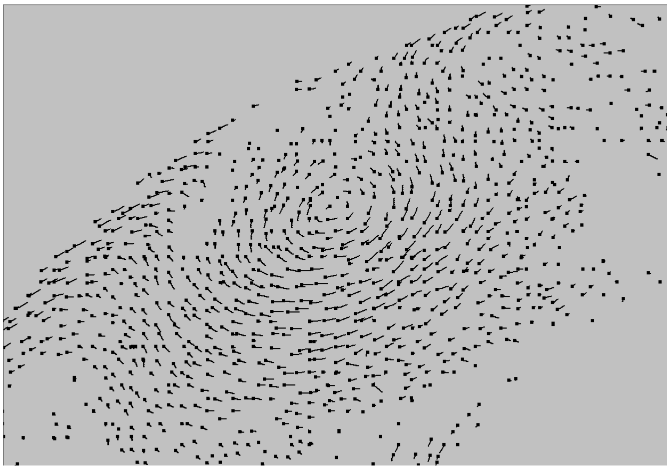
This procedure of building of fields of object displacement is used practically without changes to analyze clouds formations displacement on the base of a line of sequential images got from geostationary satellites. These images are obtained with comparatively small time interval (15 min for METEOSAT 8, METEOSAT 9 and 30 min for ELEKTRO-L in normal mode), that’s why we can expect high correlation between neighboring images. A single supplement – the editing of vector fields which means the deleting of clearly false vectors (it is because of clouds can have different directions of displacements at different altitudes). Fig.1. represents the fragment of the vector field of displacement of clouds in the atmosphere. You can see here the process of whirlwind moving. Vector field was built by five consecutive images in optical wavelengths. The first frame of a line of consecutive images (a), the last frame (b) and the corresponding vector field (c).



a).



b).



c)

Fig.1

However, for water bodies and ice fields the images of a line have a large time span – images of the Black and Azov seas are obtained twice a day (ascending and descending trajectory of the satellite TERRA), and images of ice fields are the result of merging (building of mosaics) of radar images obtained for a day period. That's why to avoid false correlations, it's necessary to tighten the requirements to targets building and correlation level. As the result, the number of vector displacement is not enough to build a vector field characterizing the dynamic of the process. Thereby, for these natural objects, the following addition to the technology of building of vector field displacement was suggested and implemented. On the base of the result targets positions Delaunay triangulation is build. This triangulation together with corresponding coordinates of new target positions on the next image defines the family of piecewise-affine transformations of a plane. A square grid of specified size is built on the original image. Affine transformation is applied to each grid node falling inside a convex shell of the position of targets. This transformation is defined by a triangle, having this node. Software technologies include the functions of obtaining of statistical characteristics of built vector fields – vector distribution according to directions (with specified discontinuity of the angle changing) and distribution of vector velocity. Correlation-extreme analysis of multispectral space images taken at different time was used to build the field of displacements of water bodies for monitoring of pollution transfer in the north-east part of the Black Sea. The result is represented in fig.2. Space pictures from satellite TERRA, scanner MODIS, channels: 0,620-0,670 μ (1); 0,545-0,565 μ (4) and 0,459-0,479 μ (3).

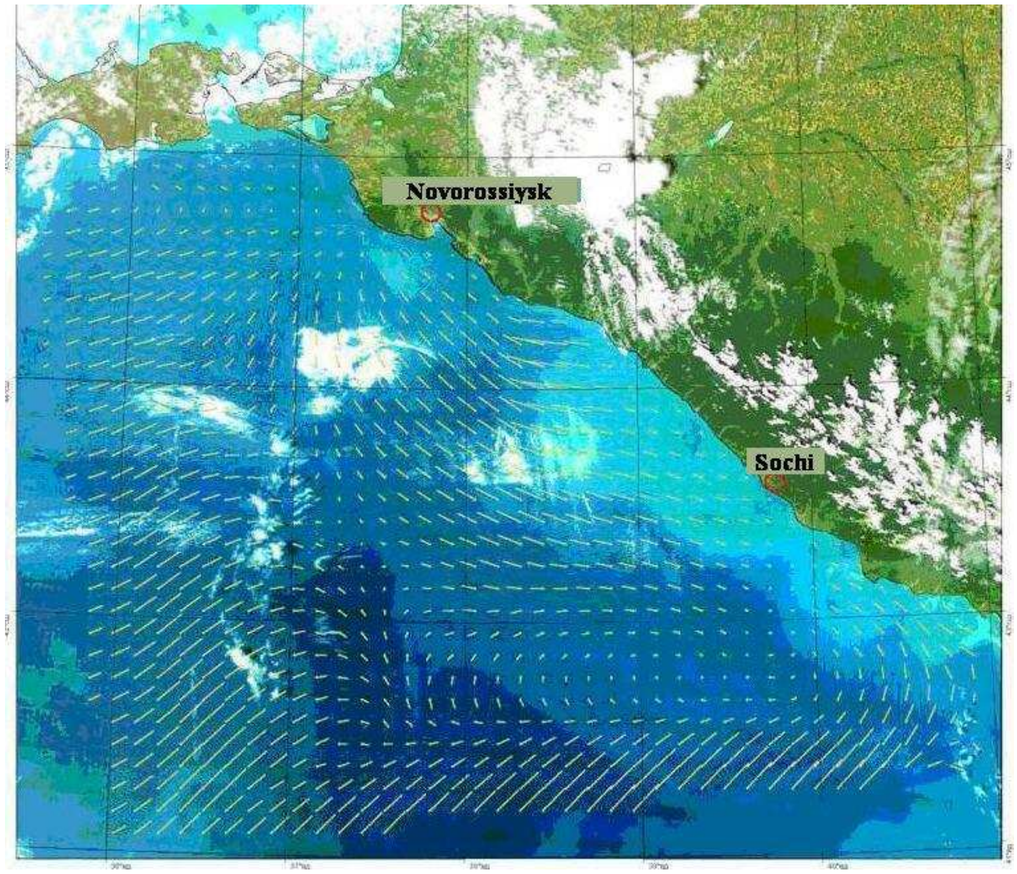
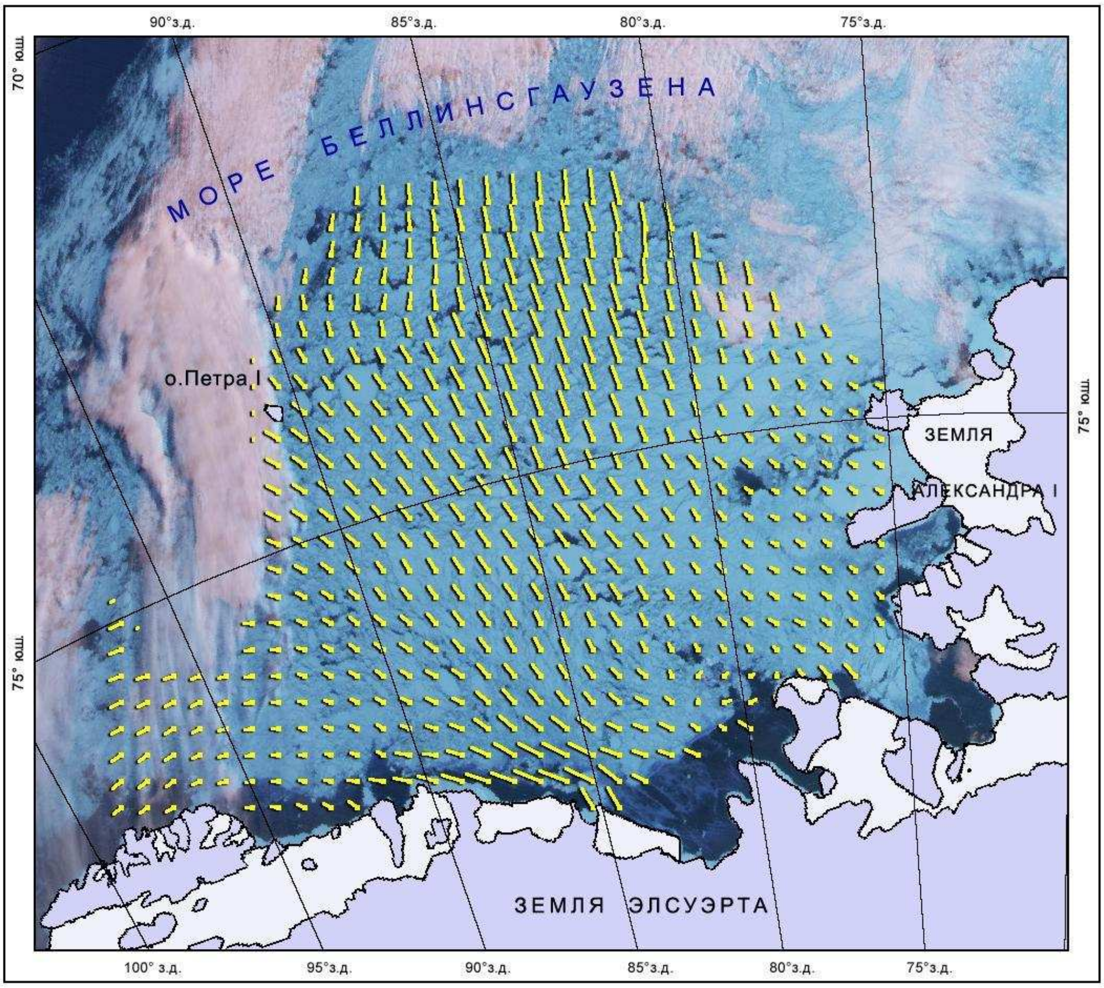


Fig. 2

In Fig. 3 the map of large-scale moving of ice in the Bellingshausen Sea is presented (a), combined with color synthesized image (satellite «Meteor-M» №1, scanner MSU-MP, 12.11.2009 г.), as well as diagrams of distribution of rate and directions of ice moving (b) from 10.11.09 (15:15) to 12.11.09 (16:00).



a)

б)

Fig. 3

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CREATION OF GEOINFORMATIONAL MODEL OF PROBABLE THREATS ON THE CITY TERRITORY

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Abstract

Complicated spatial structures and their relationship on the city territory are the sources of potential threats for the people life and health. Probability of emergency situations can be predicted beforehand. GIS-technologies make it possible to analyze probable techno-industrial, ecological and socio-economic risks. The results of the predictive GIS modeling may be used as an information basis for the decision making systems of civil defense and the ministry of emergency situations.

Difficult spatial structures and their relations, existing on a city territory, are sources of potential threats for the people life and health. Thus the most dangerous are the threats which development can be an incitement for occurrence of some emergency situations. [2].

It is evident that only the possibility of emergency situation can be expected in advance. Thus it's important to make the analysis of possible risk. In spite of the fact the concept "Risk" meets practically in all areas of social and economic activity of modern society, we will consider it in following aspects:

- Technical and industrial risk – risk of fire, damage on industrial objects or with the participation of different technical equipment;
- Ecological risk – risk of environmental disruption caused by people's industrial activity or by natural disaster;
- Social and economic– risk of deterioration of modern society's social and economic indicators as a result of natural and industrial threats.

"Risk" is inseparably linked with "Threats". The threat is a danger, connected with some facts or events, which cause the deterioration of modern society's social and economic situation, environmental disaster or trespass to people's life and health [2].

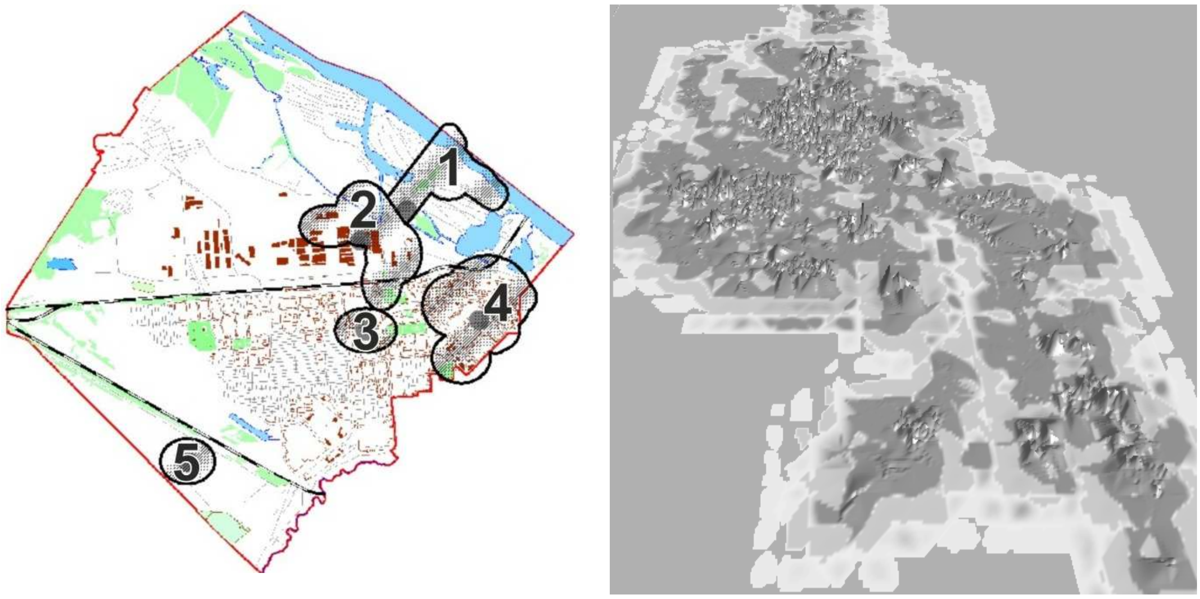
This research [1] gives us statistic analysis all possible threats on Novosibirsk city territory. The possibility of threats occurrence on the city territory can be defined under the classical Probability theory formula [3]: $P(A) = \frac{A}{N}$, where A – number of elementary situations, favorable for threat appearance; N – number of all possible elementary situations, at that each elementary situation A corresponds to number $P(A)$ – situation's possibility A, thus: $0 < P(A) \leq 1$.

All possible threats are necessary to classify on following groups:

- Improbable $0 < P(A) \leq 0.2$;

– Few probable $0.2 < P(A) \le 0.4$;
– Probable $0.4 < P(A) \le 0.6$;
– Rather probable $0.6 < P(A) \le 0.8$;
– Highly probable $0.8 < P(A) \le 1$.

To refer the threat to a certain class by one of the basic criteria we use the statistical data about the frequency of happened emergency situations on considered territory for the certain time period. Besides, to calculate the threat possibility it is necessary to consider all around world statistics of emergency situations. In Fig. 1 a) is GIS analysis' result of technical and natural threats on Novosibirsk city territory.



a) б)

Figure 1. a) GIS model of probable technical and natural threats on city's district territory; б) spatial model of population's distribution on Novosibirsk city territory

During GIS analysis five potentially dangerous zones were identified, where high probability of emergency situations appearance is forecasted. In Fig. 1 a) 1 – "coastal", 2 – "industrial", 3- "academic", 4 –"central", 5- "warehouse" zones. Each zone is independent technogenic natural and territorial complex, which main properties are presented in Table.

During the creation of probable threats' GIS model on the city territory the population number is one of essential model's element. This element must be identified with high share of probability for each district. Daily population's migration is important to identify precisely population number in set point in set time. Population's fluctuation is also important to research models like: "day-night", "winter-summer", "Sunday-Monday" etc. On GIS analysis of the city territory the population's distribution model was created, using statistics data, areas, "interest points". The error is less than 5%. In Fig. 1 b) is spatial model of population's distribution on Novosibirsk city territory. The maximum level of rising is corresponding to the maximum crowd of people.

Table 1. Main properties of potentially dangerous zones

<table>
<tr><th>Zone number</th><th>Name/threat</th><th>Area (sq. km)</th><th>Industrial enterprises (pcs.)</th><th>Houses (pcs.)</th><th>Population (per.)</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">coastal</td><td>2,30</td><td>113</td><td>512</td><td>1340</td></tr>
<tr><td colspan="4">Crashes; threat of flooding</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">industrial</td><td>3,26</td><td>1011</td><td>19</td><td>2908</td></tr>
<tr><td colspan="4">Industry damage 3 – 5 danger classes; environmental disaster threat; terrorism threat; nature anomaly threat</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">academic</td><td>0,86</td><td>182</td><td>156</td><td>14531</td></tr>
<tr><td colspan="4">terrorism threat, epidemic threat, earthquake more than 5 points</td></tr>
<tr><td rowspan="2">4</td><td>central</td><td>4,05</td><td>660</td><td>538</td><td>68982</td></tr>
<tr><td></td><td colspan="4">terrorism threat; epidemic threat; crashes; threat of electromagnetic irradiation; earthquake more than 5 points</td></tr>
<tr><td rowspan="2">5</td><td>warehouse</td><td>0,79</td><td>185</td><td>23</td><td>554</td></tr>
<tr><td></td><td colspan="4">Industry damage 3 – 5 danger classes , environmental disaster threat; terrorism threat</td></tr>
<tr><td colspan="2">Total</td><td>11,26</td><td>2151</td><td>1248</td><td>88 315</td></tr>
</table>

The basic conclusions under geoinformation analysis of Novosibirsk city territory is:

– Works on the analysis and prevention of risks should be planned on the actual, authentic digital model (geoinformation space);

– Spatially-coordinated objects, processes and the phenomena together with statistical databases and results of territory monitoring should complete the automated knowledge base GIS model of probable threats;

– Created informational resource on threats distribution in studied territory should become popular and open the maintenance and possible consequences of threats.

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APPLIED SPATIAL STATISTICS FOR MAPPING ENVIRONMENTAL POLLUTION

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ABSTRACT

Modern GIS packages are well equipped with statistical and geostatistical tools which allow researchers to explore variety of environmental data in spatial context. This paper illustrates the use of several geostatistical methods to analyze associations and trends of spatially distributed data using different techniques, available in modern GIS packages. The paper uses concentration of fine particulates ($PM_{2.5}$) in Canadian cities as an example.

METHODOLOGY AND DATA

A common research task is the investigation of the spatial structures of natural or social phenomena using point observations and quantitative analysis. Modern GIS packages are well equipped with statistical tools, which allow researchers to explore their data in spatial context, employing variety of geostatistical tools and approaches. A typical spatial analysis of data, having spatial component, may be based on the following workflow. Exploratory spatial data analysis (ESDA) is used for initial data analysis, such as check for statistical distribution, linearity and presence (or absence) of a pattern (both in spatial and non-spatial domains). Based on results of ESDA and initial hypotheses, further exploration can be developed by testing data for auto-correlation, correlation, and building some regression model. Trend analysis, an essential part of data exploration, can supplement kriging and co-kriging techniques, designed for analysis of spatially distributed data. There is excessive literature describing various theoretical aspects of spatial statists and geostatistical analyses, some references are provided in the Reference section.

In this paper, we used environmental geospatial data from the national database service, maintained by the Environment Canada (www.ec.gc.ca). In this study statistical data reflecting air quality in Canada (best available data from 1997-2008) were used. This dataset includes geospatial data for air quality, greenhouse gas emissions and water quality indicators for different spatial units.

The primary dataset, which is used in this study, includes points with measurements of fine particulates ($PM_{2.5}$) by Canadian cities. $PM_{2.5}$ is key measure of air quality such as smog. The $PM_{2.5}$ indicator is based on the 24-hr daily average concentrations recorded at monitoring stations across Canada during the warm season (April 1 to September 30). According to the data description, 71% of fine particulates ($PM_{2.5}$) came from two sources: industry (35%) and home firewood burning (36%). To explore the factors behind observed spatial pattern of fine particulates across Canada cities, additional social-economical characteristics (or explanatory variables) at monitoring stations were prepared. Thus, the attributes of fine particulates dataset also include population and labor indicators. These social-economical data were derived from the 2006 Profile of Census Subdivisions (CSD) and Census Tract (CT) of Statistics Canadian (www.statcan.gc.ca). This set of socio-economical variables is used to explore distribution of $PM_{2.5}$ concentration across Canadian territories (see Fig.1).

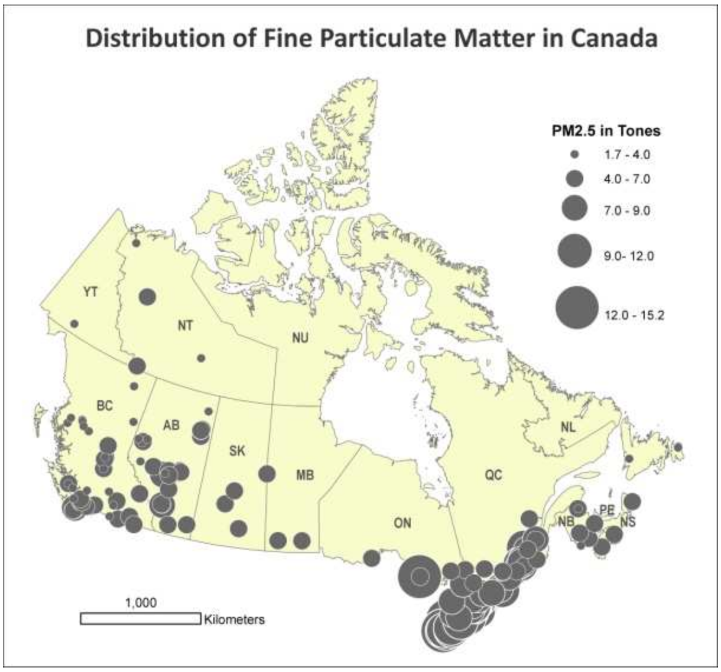

Fig.1. Distribution of Fine Particulate Matter ($PM_{2.5}$) emissions in tones in Canadian cities (data source: www.ec.gc.ca)

EXPLORATORY DATA ANALYSIS

Different statistical analyses techniques are based on certain hypotheses and assumptions, therefore, in order to get statistically correct results the source data should comply with particular requirements, including normality, linearity and spatial patterns.

For some methods of kriging, data should conform to the normal distribution. If the data does not exhibit a normal distribution, it may be necessary to transform the data to make it conform to a normal distribution before using certain interpolation techniques. According to analysis of the histogram and Normal QQPlot, distribution of $PM_{2.5}$ values does not satisfy criteria of normality. However, applied normalization in form of logarithmic transformation brings the dataset closer to the normal.

Often the first step in both correlation and regression analyses is to plot dependent and independent variables on a scatterplot graph. In this paper, we used linear regression methods. If the relationship between any of the explanatory variables and the dependent variable is nonlinear, the resultant regression model may perform poorly. In our case, the relationship between the most explanatory variables and the dependent variable is nonlinear.

Another issue of multiple regression analysis is multicollinearity. This leads to an overcounting type of bias and an unstable/unreliable regression model. Multicollinearity occurs if one or a combination of explanatory variables used in regression is redundant. This usually happen when independent variables are correlated, and therefore they are not independent from each other. Strongly correlated variables should not be used together in one regression model. According to analysis of scatter plots, some independent variables in our dataset exhibits strong positive relationship between each other.

We used spatial autocorrelation methods to identify patterns in $PM_{2.5}$ spatial measurements. Most GIS packages utilize autocorrelation methods such as Moran's *I*, *G*-Statistic, Cluster Anselin Local Moran's *I* (Anselin, 1995) or/and Hot Spot Local *G*-Statistic (Getis, 1992) analysis. All these methods consider both locations of a measurement point and variation of attribute's values at the locations. Spatial autocorrelation on the modeled variable indicates if the variable is spatially random, clustered, or dispersed. Results of spatial autocorrelation are useful in analysis of spatial regression.

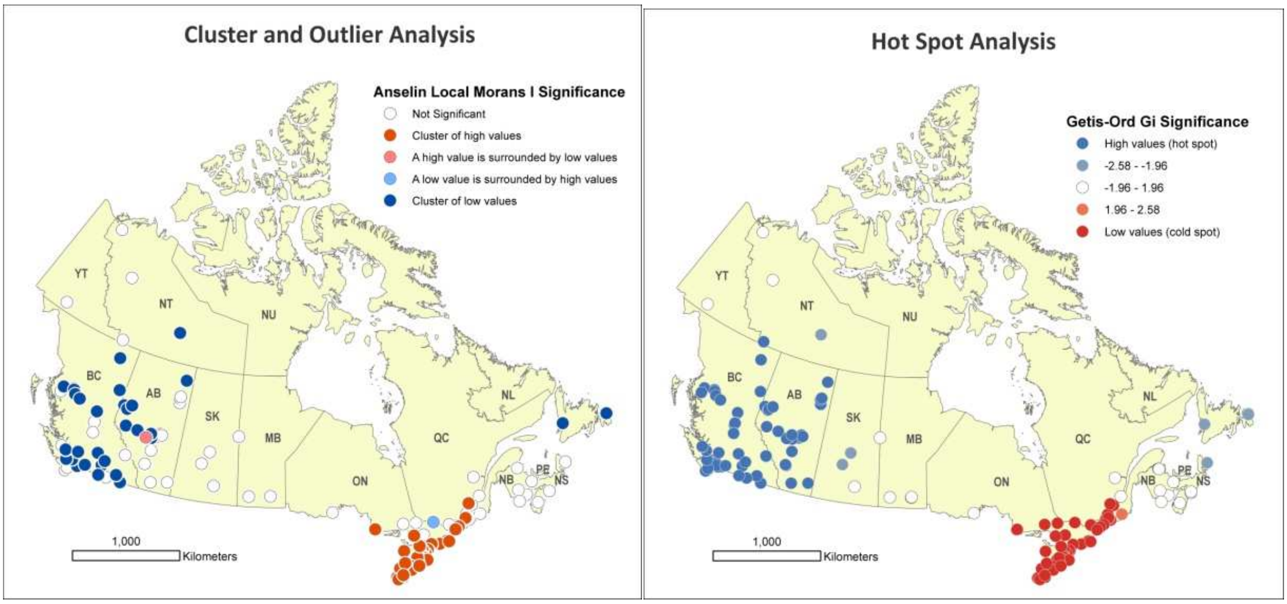

Fig.2. Cluster and outlier analysis (Anselin Local Moran's *I*) and Hot Spot Analysis (Getis-Ord Gi) of $PM_{2.5}$ observations.

The maps in Figure 2 show high level of clustering with high values of $PM_{2.5}$ in the south-eastern part of Canada and high level of clustering with low values of $PM_{2.5}$ in the two western provinces of Canada. Thus, spatial clustering of $PM_{2.5}$ observations should be taken into account in a regression and geostatistical models to avoid overcounting type of model bias.

REGRESSION ANALYSIS

Bivariate Linear Ordinary Least Squares Regression

Quantitative measure of correlation is used to confirm or reject relationship hypothesis by using correlation and regression analyses. Correlation analysis in our case study shows very weak association between the dependant $PM_{2.5}$ variable and independent variables for population and labor indicators. In addition, the residual values are highly clustered and not normally distributed.

Population and labor indicators, used in this study, were collected by Census Canada for polygonal units, Census Subdivisions (CSD) and Census Tract (CT), varying by area. At the same time, fine particulates ($PM_{2.5}$) were measured at monitoring stations (points). The measurements reflect condition of atmosphere in surrounding areas. To address this issue, population and labor variables were normalized by land area of respective observation polygonal units to be further used in regression analysis. Normalized density variables have certainly improved the model. We examined few variables, which significantly contribute into concentration of fine particulates.

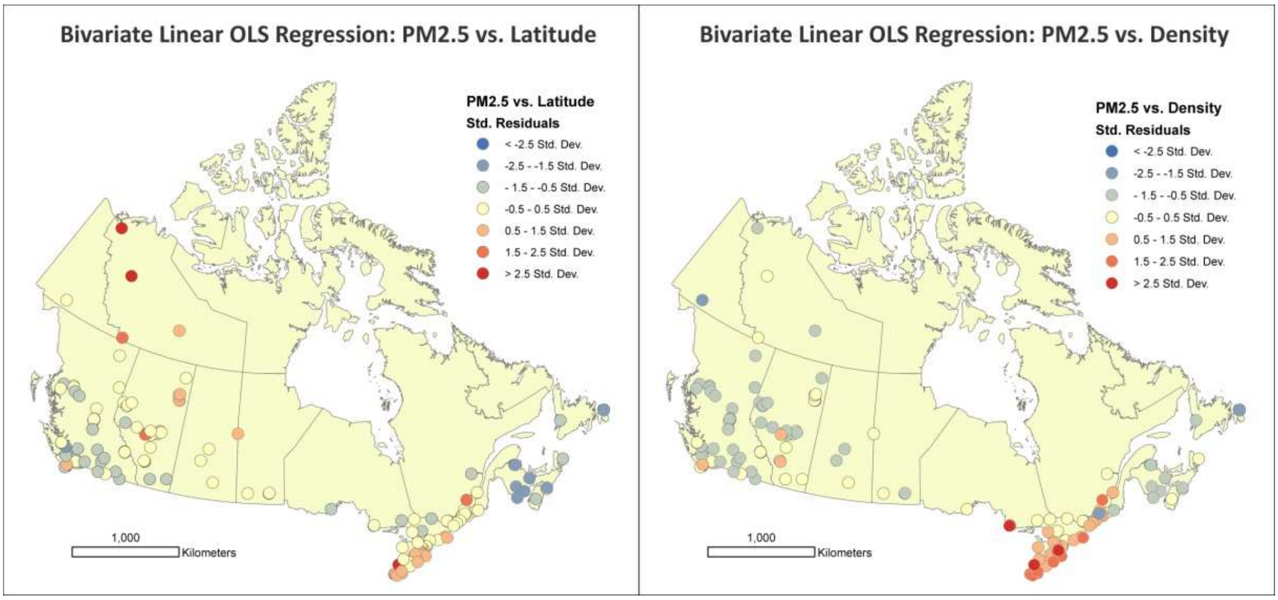

Fig.3. Bivariate linear ordinary least squares regression: a) $PM_{2.5}$ vs. Latitude ($PM_{2.5}$ = 23.7248-0.3581 x Latitude), correlation coefficient r = 0.693, goodness of fit S_E = 1.822; and b) $PM_{2.5}$ vs. Density of all occupations of industrial labor ($PM_{2.5}$ = 5.6278 + 0.0133 x IndLabDens), correlation coefficient r = 0.393, goodness of fit S_E = 2.326.

Multivariate Linear Ordinary Least Squares Regression (OLS)

In the next step, relationships between dependent variable and several explanatory variables were modeled by using multivariate regression analysis. We used several iterations to build the best multivariate regression model by including a different number and different variation of explanatory variables and comparing these multivariate regression models among each other by using RMSE criteria until we choose the best one.

We have chosen Latitude, Density of all occupations of labor (AllLabDen), and Density of all occupations of industrial labor (IndLabDens) as key explanatory variables for $PM_{2.5}$ multivariate regression model. This combination shows acceptable results with all correlation coefficient being statistically significant. Figure 4 illustrates results of the multivariate regression.

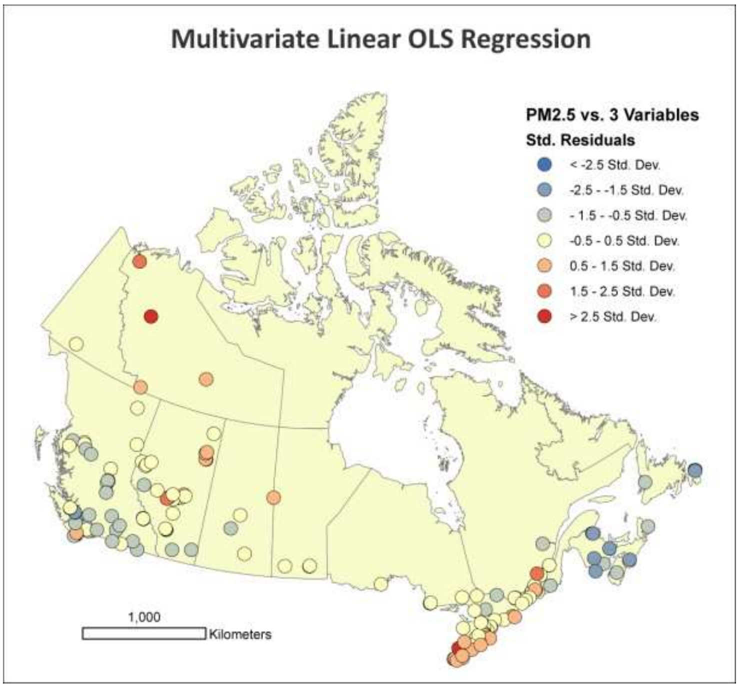

Fig.4. Multivariate linear ordinary least squares regression: $PM_{2.5} = 22.0715 - 0.3275 \text{x} Latitude + 0.0177 \text{x} IndLabDens - 0.0051 \text{x} AllLabDen$. $R^2 = 0.5157$, goodness of fit $S_E = 1.77$

The model has 52% of coefficient of multiple determination R^2; in other words, it explains 52% of $PM_{2.5}$ variations. Thus, the AllLabDen variable can somehow explain the home firewood burning component of fine particulates pollution. The IndLabDens variable can explain industry component of the fine particulates pollution. The model is still missing 48% of $PM_{2.5}$ variations, which can be result of non-linear relationship between the dependent variable and the independent variables; there are evidences of spatial correlation effect or clustering, and some important key variables are missing.

Local Geographically Weighted Regression

There is a possibility to improve model results by applying local Geographically Weighted Regression (GWR), which takes into account effect of spatial correlation (Fotheringham, 2002). The GWR local model with the key explanatory variables Latitude, AllLabDen and IndLabDens explains 52.2% of fine particulates ($PM_{2.5}$) values in the selected Canadian cites. The $PM_{2.5}$ residuals of the model are still highly correlated according the Moran’s *I* test. This indicates that the model is still not properly specified and some important key variables are missing, which can explain 48% of $PM_{2.5}$ residuals.

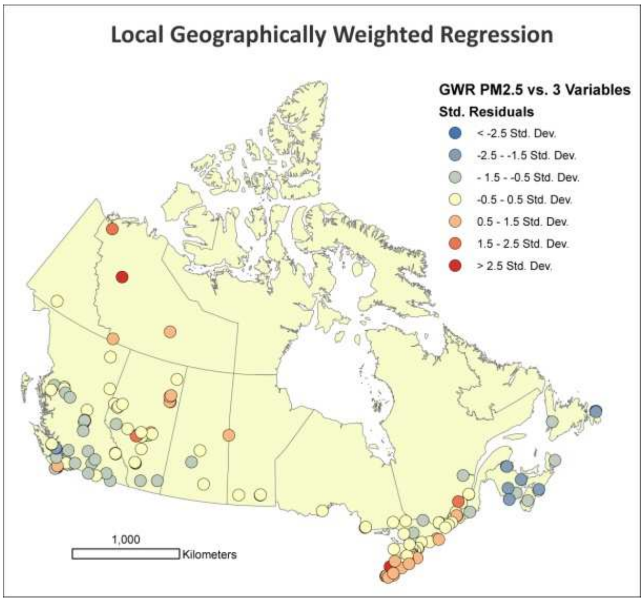

Fig.5. Local Geographically Weighted Regression: S_E = 1.7589; AICc = 716.4563; R^2 = 0.5224

Spatial interaction (spatial autocorrelation) can be explored using spatial econometrics technique (Anselin, 2001). Usually, autocorrelation creates an over-count type of bias for traditional (non-spatial) regression methods; however, this discussion is beyond the scope of this paper.

GEOSTATISTICS

If an experiment contains a quantitative independent variable, then shape of a function relating the levels of this quantitative independent variable to the dependent variable is often of interest. In this case study, we used several basic techniques to explore trends in $PM_{2.5}$ observations. Figure 6 illustrates trends in $PM_{2.5}$ observations as the results of applying polynomial models of the first, second and fourth orders.

The existing trend of $PM_{2.5}$ data shows the long-range variation of data values. The dominant direction of data changes is from north-west to south-east. It has approximately 140-degree azimuth (based on min RMSE value).

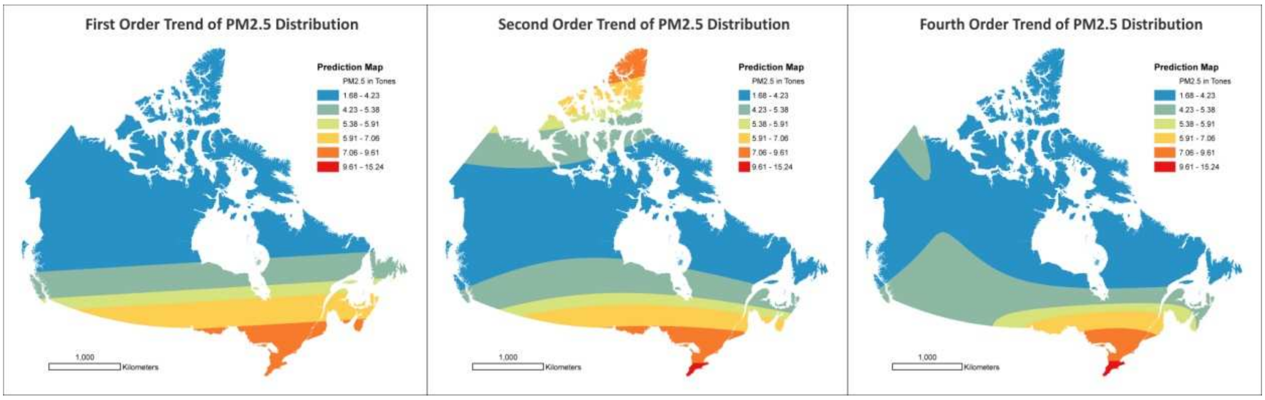

Fig.6. Trend analysis using polynomial models: a) first order, RMSE=1.6190; b) second order, RMSE=1.3295; and c) fourth order, RMSE=1.553

We used geostatistical approach (kriging) to predict values of $PM_{2.5}$ observations. Several geostatistical kriging methods were tested to get the best result based on RMSE of $PM_{2.5}$ values. We used Density of all occupations of industrial labor (IndLabDens) and Latitude as co-variables to model $PM_{2.5}$ values distribution.

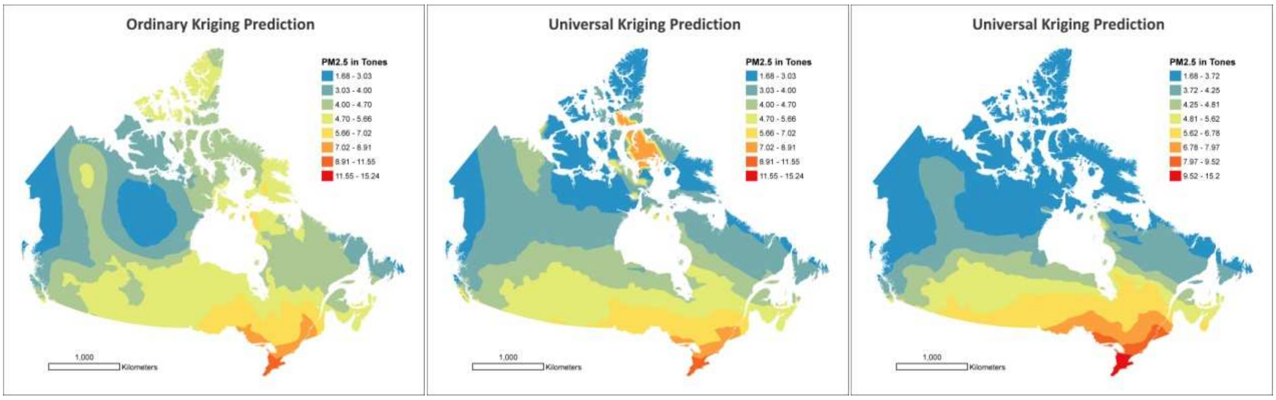

Fig.7. Predictions of $PM_{2.5}$ observation values based on kriging and co-kriging models: a) Ordinary Kriging, RMSE=1.2914; b) Universal Kriging, RMSE=1; c) Linear co-kriging with Latitude co-variable: RMSE=1.2851. All kriging methods are with 140 deg anisotropy and use normalized source data as a result of logarithmic transformation

Adding the trend to interpolation in kriging improves data prediction, especially using Conformal projection - the RMSE has slightly decreased from 1.2914 to 1.2768 for ordinary kriging and universal kriging respectively. Adding co-variables IndLabDens and Latitude to interpolation does not improve prediction (co-kriging yields RMSE=1.2851).

MODEL ANALYSIS AND DISCUSSION

Regression analysis and kriging optimal interpolation are used for prediction $PM_{2.5}$ values in known locations. According to results of our case study, kriging-based predictions give lower RMSE in situations when a regression model is not properly specified, i.e. when some important key variables are missing. Figure 8 illustrates best regression models (GWR and kriging) for $PM_{2.5}$ observations, based on analysis of available data. However, if the regression model is specified reasonable, regression and kriging may supplement each other and used for further validation of models.

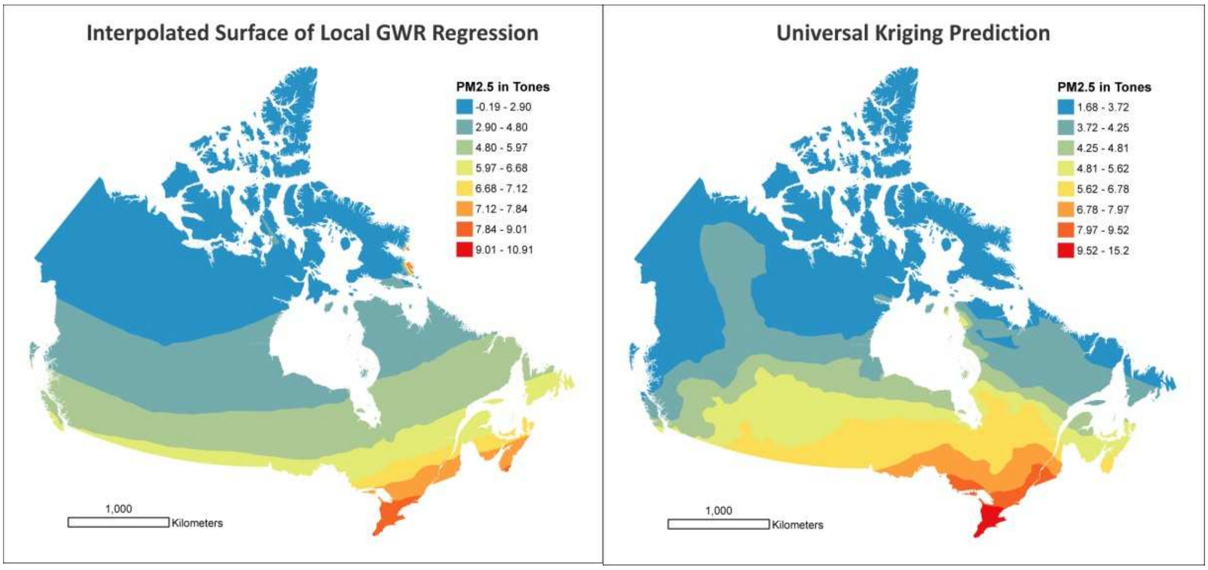

Fig.8. Interpolated surface of a) local GWR Regression, RMSE=1.738; and b) Universal co-kriging (Latitude as co-variable), RMSE=1.276

Combination of two methods can be beneficial in several situations. Regression and kriging modeling can be used for prediction at all locations where predictions are required. However, for regression analysis, values of the independent variables have to be available in predicted locations. Kriging modeling can be used to estimate the independent variables in predicted locations with the following use in regression. In addition, if one of independent variables of regression is a coordinate, this variable can be defined exactly in required prediction locations, and thus it can improve prediction based on the regression model. In addition to prediction, regression model can be used to examine and explore spatial relationships between dependent variable and independent (explanatory) variables. Key exploratory variables from regression modeling can be used as co-variables in co-kriging modeling. Moreover, it can be revealed even from the respective maps, that the results and natures of regression and global polynomial interpolations are very similar. Therefore, it can be an option to use the regression surface to obtain residuals for kriging modeling.

Explored geostatistical methods also shown high level of robustness to parameters of projections used to represent source dataset, with some excerption of global spatial autocorrelation (Moran's *I* index) and universal kriging.

CONCLUSION

Geostatistical mapping of environmental characteristics is a rapidly evolving area, which based on combined power of well developed methods of spatial statistics and geovisualization capabilities of modern GIS packages. Geostatistical mapping, partially based on classical statistics and mapping, has a number of unique methods, specifically designed to address spatiality of geographical data. While the real world provides very large range of applications for geostatistical mapping, some major steps of environmental spatial data analysis, described in this paper, are common and relevant to most studies.

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APPLICATION OF TABLET PC AS GIS CLIENT PLATFORM FOR EMERGENCY MANAGEMENT

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INTRODUCTION

Nowadays, information technologies have become an integral part of life of the majority of people. However, not all industrial objects on the post-Soviet territory are equipped with modern technological systems. A lot of engineering objects are still using old inefficient methods of manual control that reduces their development and financial efficiency. But what is worse, low level of control increases the risk of emergency situations and decreases response time. Sometimes it may cause very serious consequences.

GIS may be of help to industrial objects in emergency management. In this case, usage of GIS already supports many modern engineering systems. GIS is one of the most advanced branches of science, but has low temps of development. It always uses the most progressive information technologies. One of the latest developments in IT is different types of mobile computers, such as laptops, net books, tablet PCs, etc. Therefore, the most promising fields of GIS are portable monitoring systems, which uses tablet PC as a GIS platform. This article presents review of concept and advantages of using such GIS system for emergency management.

EFFECTS

There are several requirements for GIS in the field of engineering systems, which were identified according to the desires of different groups of users. One of them is centralized storage of data / distributed access. It means that the system should provide centralized storage and administration of large amounts of data and its protection. The access to information should be based on client-server technology in a local network, and through Internet for remote workstations.

This requirement is important for mobile GIS, because the information should be available for all company’s staff according to their access rights. Mobile GIS enables field workers to collect, store, update, manipulate, analyze and display geographic information.

During field works it will allow the use of digital maps on compact mobile computers, providing access to the corporate geographic information directly from the field. This allows organizations to add information in databases in real-time and to speed up analysis and worker's decision-making through the use of updated, more accurate spatial data. For example, a GIS will seek the necessary data, move to the found object or estimate the distance to the object or direction of its search. It’ll provide access to large amounts of information through the attribute window in which information can be visualized on mobile device's display and used to assist in the daily work related to the utilities' operation.

Thus, introduction of such a GIS on an enterprise will create a number of positive effects:

– Personnel reduction;
– Minimization of the risk of an accident due to continuous monitoring of the system;
– Minimization of the time needed to detect and prevent the accidents;
– Acceleration of the database updating.

STRUCTURE

Mobile GIS brings together a number of components: GIS, mobile devices, GPS, wireless communications, for access to GIS through Internet / Intranet. Such a GIS will be based on client-server architecture. Client GIS will be based on mobile devices, presented by the modern tablet PCs.

Server:

– GIS database;
– GIS;
– Process module.

Mobile device:

– Global Positioning System;
– Wireless access to the GIS server;
– Client GIS application or browser.

This GIS must support:

– Developed system of distributed authorized access to GIS map information;
– Input and editing of spatial data using a mouse, a pen or GPS;
– Protection against unauthorized copying raster data by the users
– Developed instrumental Internet \ Intranet system technology through which users can build their own relational tables of semantic data of cartographic objects;
– Means of maps publishing in the Internet with the ability to extract data objects;
– Standard vector and raster formats;
– Integration with GPS, including GPS navigation.

Due to the architecture of the system, we need to choose:

– A mobile device;
– Software;
– OS of mobile device;
– Way of data transmission.

Further researches will help selecting or developing necessary components for utilizing the client part of GIS.