



HMRSC-IX

9th International Symposium on High Mountain Remote Sensing Cartography

Graz and Hohe Tauern National Park, Austria
September 14-22, 2006

ABSTRACTS



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WELCOME

Dear Colleagues,

We would like to warmly welcome you to the 9th International Symposium on High Mountain Remote Sensing Cartography (HMRSC-IX) to be held in the beautiful City of Graz from September 14-15, 2006. Graz is the capital city of the Austrian Federal State of Styria. It is well-known for its Old Town which is an UNESCO World Cultural Heritage Site since 1999. In 2003 Graz was the Cultural Capital of Europe. The meeting place of the present symposium has been selected for the second time in Austria where this unique series of symposia started in 1990. Previous symposia on HMRSC were held at the following places:

HMRSC-I:	Schladming, Austria (1990)
HMRSC-II:	Beijing /Lhasa, China (1992)
HMRSC-III:	Mendoza, Argentina (1994)
HMRSC-IV:	Karlstad/Kiruna/Tromsø, Sweden/Norway (1996)
HMRSC-V:	Arcata, U.S.A.(1998)
HMRSC-VI:	Ethiopia, Tanzania, Kenya (2000)
HMRSC-VII:	Bishkek, Kyrgys Republic (2002)
HMRSC-VIII:	La Paz, Bolivia (2005)

The general topics of the bi-annual HMRSC symposia are:

- Application of remotely sensed image data (terrestrial, airborne, spaceborne) and other collateral data for information extraction in high mountain areas;
- cartographic representation of this data/information in maps (analog, digital, line maps, image maps, combined image-line maps, etc.) and within GIS-based environments;
- application-oriented analysis.

Emphasis is put on interdisciplinarity:

- Persons interested in: Geosciences (geography, geology, geomorphology, glaciology, etc.), cartography, photogrammetry, remote sensing, computer science, biology, tourism, regional planning, etc;
- provide a platform for young scientists (post-graduate students, PhD-students, post-docs, etc.);
- give a forum to decision makers (tourism agents, park managers, regional planners, environmental activists) to learn about HMRSC.

Each symposium is accompanied by a post-symposium field excursion with special focus on:

- Visit to an interesting high mountain region;
- discussion of application oriented projects carried out in this region;
- preparation of a field guide and handouts; explanations by experts, usage of image data and maps, in-situ studies;
- discussions, social contacts, sharing common interests, e.g. on high mountain scenery, meeting mountain people, experience of other cultures, etc.).

This abstract booklet provides you with condensed information on the forthcoming oral and poster presentations of this HMRSC-IX symposium.

On Thursday and Friday, September 14-15, 2006, experts from over 15 different countries will present their papers and posters on the various topics of high mountain remote sensing cartography. The preliminary program lists some 40 oral and another 30 poster presentations. The poster presentation on Friday afternoon will be followed by the closing ceremony where prizes for best posters and oral presentations given by young authors are awarded.

The social program includes a guided city tour and a reception by the Mayor of the City of Graz on Wednesday, September 13, 2006, and another reception by the Governor of the Federal State of Styria in a typical wine tavern of the wine-growing country of Southern Styria on the following day.

The post-symposium field excursion will last for seven days (September 16-22, 2006) and will bring the participants not only to the Schladming area where HMRSC-I took place in 1990, but also to other high mountain regions and scenic places of the Hohe Tauern National Park, Central Alps of Austria.

We wish you all a comfortable stay in Graz and a successful meeting.

Viktor Kaufmann and Wolfgang Sulzer
(Organizing Committee)

TABLE OF CONTENTS

(A) REMOTE SENSING (RS) TECHNIQUES

<i>A. BAUER, V. KAUFMANN, A. KELLERER-PIRKLBAUER, M. AVIAN, G. PAAR</i> TERRESTRIAL LASER SCANNING FOR GLACIER MONITORING: A COMPARISON TO STANDARD GEODETIC AND PHOTOGRAMMETRIC METHODS, AND DOCUMENTAION OF THE GLACIER RETREAT OF GOESSNITZKEES (SCHOBBER GROUP, AUSTRIA) BETWEEN 2000 AND 2005.....	10
<i>T. GEIST, J. STÖTTER</i> MAPPING AND MONITORING GLACIAL AND PERIGLACIAL PHENOMENA WITH AIRBORNE LASER SCANNING TECHNOLOGY.....	11
<i>L. GLEITSMANN, M. KAPPAS</i> PROBLEMS OF AN AERIAL APPLICATION OF CLOSE-RANGE-PHOTOGRAMMETRY METHODS TO COUNTER ADVERSE WEATHER CONDITION PROBLEMS OF SURVEY FLIGHTS IN MOUNTAINOUS TERRAIN.....	12
<i>A. GRUEN</i> HIGH ACCURACY 3D SATELLITE IMAGE DATA PROCESSING FOR MOUNTAINOUS REGIONS.....	14
<i>K. GUTJAHR, H. RAGGAM</i> GENERATION OF DIGITAL SURFACE MODELS FROM VERY HIGH RESOLUTION OPTICAL STEREO DATA IN ALPINE REGIONS.....	16
<i>M. HOLLAUS, W. WAGNER</i> OPERATIONAL USE OF AIRBORNE LASER SCANNING FOR FORESTRY APPLICATIONS IN COMPLEX MOUNTAINOUS TERRAIN.....	18
<i>K. LEGAT, J. SKALOUD, P. SCHÄR</i> DIRECT GEOREFERENCING IN ALPINE ENVIRONMENTS FROM A HELICOPTER.....	20
<i>A. L. MITCHELL, L. GE, H.-C. CHANG, L. HAZELL, T. MILNE</i> AIRBORNE LASER SCANNING AND RADAR INTERFEROMETRY FOR DIGITAL TOPORGRAPHIC MODELLING AND FLOOD RISK ASSESSMENT.....	21
<i>A. PROKOP</i> DETERMINATION OF SPATIAL SNOW DEPTH DISTRIBUTION ON SLOPES USING TERRESTRIAL LASER-SCANNER.....	22
<i>D. WUNDRAM, J. LÖFFLER</i> KITE AERIAL PHOTOGRAPHY IN HIGH MOUNTAIN ECOSYSTEM RESEARCH.....	23

B) MORPHOLOGICAL MAPPING

<i>G. BAX, M. SEARLE</i> 3D MULTISENSOR STUDY OF THE GEOLOGY AND GEOMORPHOLOGY OF QUOMOLANGMA FENG (MT. EVEREST), TIBETAN HIMALAYAS.....	26
--	----

<i>M. F. BUCHROITHNER, T. BOLCH, A. KUNERT</i> AN AUTOMATED METHOD TO OUTLINE THE ICE EXTENSION OF DEBRIS-COVERED GLACIERS BASED ON ASTER IMAGERY.....	27
--	----

<i>T. DREY, T. GLADE</i> MULTITEMPORAL OPTICAL SATELLITE DATA, DIGITAL ELEVATION MODELS AND SPATIAL DATA FOR THE MAPPING OF LANDSLIDES AND LANDSLIDE HAZARD ZONATION ON A REGIONAL SCALE.....	28
--	----

<i>K. GRANICA, M. HIRSCHMUGL, H. PROSKE, M. SCHARDT, A. WIMMER</i> THE DERIVATION OF INDICATORS FOR LANDSLIDE DETECTION USING VERY HIGH RESOLUTION SATELLITE IMAGERY.....	30
---	----

<i>L. MOSER, M. WURM</i> LANDSLIDE DETECTION WITH HIGH RESOLUTION SATELLITE IMAGERY IN KHUMBU HIMAL.....	31
--	----

<i>E. SAHLIN, N. F. GLASSER</i> GEOMORPHOLOGICAL MAPPING IN MID-WALES, UK, BASED ON REMOTELY SENSED DATA.....	32
---	----

C) MONITORING OF ENVIRONMENT

<i>J. AMLIEN, L. EIKVIL, H. KOREN, R. SOLBERG, L. AURDAL, R. HUSEBY, K. A. PULVER</i> SNOW AND VEGETATION IN THE SCANDINAVIAN MOUNTAINS.....	34
---	----

<i>İ. ATALAY, H. CUKUR, G. GUNDUZOGLU</i> LAND DEGRADATION BASED ON SPACE IMAGERY IN THE MOUNTAINOUS AREAS OF WESTERN ANATOLIA.....	35
---	----

<i>M. AVIAN, A. KELLERER-PIRKLBAUER, G. K. LIEB</i> THE RETREAT OF THE PASTERZE GLACIER (AUSTRIA) FROM 1996 TO 2005 – COMBINATION OF DIFFERENT DATA SETS FOR SPATIAL ANALYSIS.....	36
--	----

<i>M. AVIAN, A. KÄÄB</i> DIGITAL ASSESSMENT OF GLACIER CHANGES FROM REPEAT LANDSAT TM AND ETM+ SATELLITE DATA: A PILOT STUDY ACROSS THE BHUTANESE HIMALAYAS.....	37
--	----

<i>K. BAYR, D. K. HALL, S. DERRICK</i> THE RECESSION OF THE PASTERZE GLACIER, AUSTRIA, AS DETERMINED FROM MAPS, SATELLITE IMAGERY AND GROUND MEASUREMENTS FORM 1864 TO 2005.....	38
--	----

<i>J. DEUTSCHER</i> DIFFICULTIES IN MAPPING GEOMETRY CHANGES ON A HIGH ARCTIC GLACIER WITH STANDARD REMOTE SENSING SOFTWARE.....	39
<i>H. GALLAUN</i> ASSESSMENT OF CURRENT ONGOING LAND COVER CHANGES IN THE NIEDERE TAUERN RANGE ON STYRIA / AUSTRIA.....	40
<i>J. JAENICKE, K. SCHARRER, U. MÜNZER, Á. GUDMUNDSSON</i> MAPPING OF MASS BALANCE PARAMETERS ON MÝRDALSJÖKULL, ICELAND, BY OPTICAL AND RADAR REMOTE SENSING DATA.....	41
<i>K. KLEINOD, G. MENZ</i> RELATIONSHIP BETWEEN LANDFORM AND PHYTO-DIVERSITY IN THE TURTSMANN VALLEY, SWITZERLAND.....	42
<i>D. LEBER</i> QUALITATIVE HAZARD ASSESSMENT OF GLACIER LAKES IN THE HIMALAYAS BASED ON REMOTE SENSING TECHNIQUES.....	43
<i>S. LEGUIZAMÓN</i> ECOLOGY OF THE MOUNTAINOUS ENVIRONMENT AS A COMPLEX SYSTEM.....	45
<i>H. MACKAY, M. MASON</i> REGIONAL MAPPING OF REGIONE PIEMONTE USING AIRBORN INTERGEROMETRIC RADAR MAPPING.....	46
<i>T. NAGLER, H. ROTT</i> GLACIER MASS BALANCE AND RUNOFF MODELLING USING SATELLITE DATA.....	47
<i>M. NUTZ, U. SCHMITT, M. SCHARDT</i> HABITAT MONITORING IN ALPINE REGIONS BY MEANS OF QUICKBIRD DATA.....	48
<i>M.K. PRADHAN, D. WANGDA</i> LANDSLIDE MAPPING AND HAZARD ASSESSMENT.....	49
<i>H. TOPAN, G. BÜYÜKSALIH, D. MAKTAV</i> MAPPING POTENTIAL OF ORBVIEW-3 PANCHROMATIC IMAGE IN MOUNTAINOUS URBAN AREAS.....	50
<i>F. VILLA, S. SIRONI, M. DEAMICIS, F. ZUCCA, A. TAMBURINI</i> INTEGRATION OF DIFFERENT KIND OF REMOTE SENSING DATA AS A TOOL FOR QUANTITATIVE ANALYSIS OF GLACIER EVOLUTION.....	51

D) PERMAFROST STUDIES AND ROCK GLACIER MONITORING

<i>R. DELALOYE, C. LAMBIEL, R. LUGON, H. RAETZO, T. STROZZI</i> APPLICATION OF ERS INSAR FOR DETECTING SLOPE MOVEMENT IN A PERIGLACIAL MOUNTAIN ENVIRONMENT (WESTERN VALAIS ALPS, SWITZERLAND).....	54
<i>J. J. DE SANJOSÉ BLASCO, A. D. J. ATKINSON GORDO, N. A. DE PABLO, J. J. ZAMORANO OROZCO, D. PALACIOS ESTREMER, J. DE MATÍAS BEJARANO</i> CARTOGRAPHIC PRODUCTION (1997 – 2003) OF THE POPOCATÉPETL (MEXICO) AND THE VENTORILLO GLACIER FOR THE ANALYSIS OF HYDRO VOLCANIC RISKS.....	56
<i>H. HAUSMANN, K. KRAINER, E. BRÜCKL, W. MOSTLER</i> CREEP OF THREE ALPINE ROCK GLACIERS – OBSERVATION AND MODELLING (ÖTZTAL- AND STUBAI ALPS, AUSTRIA).....	58
<i>A. KELLERER-PIRKLBAUER, V. KAUFMANN</i> PARAGLACIAL TALUS INSTABILITY IN RECENT DEGLACIATED CIRQUES: SCHOBER GROUP, AUSTRIA.....	59
<i>R. LADSTÄDTER, V. KAUFMANN</i> MAPPING OF THE 3D SURFACE MOTION FIELD OF DOESEN ROCK GLACIER (ANKOGEL GROUP, AUSTRIA) AND ITS SPATIO-TEMPORAL CHANGE (1954 – 1998) BY MEANS OF DIGITAL PHOTOGRAMMETRY.....	61
<i>E. PERRUCHOUD, R. DELALOYE</i> SHORT-TERM CHANGES IN SURFACE VELOCITIES ON THE BECS-DE-BOSSON ROCK GLACIER (WESTERN SWISS ALPS).....	62

E) HIGH MOUNTAIN CARTOGRAPHY AND 3D RELIEF DEPICTION

<i>D. BLAZEJ, P. FINK, R. KOSTKA, W. SULZER</i> CERRO ACONCAGUA SAT-MAP.....	66
<i>G. BRANDSTÄTTER</i> ABOUT LIFE AND WORK OF A PATRIARCH OF AUSTRIAN ALPINE CARTOGRAPHY.....	67
<i>J. J. DE SANJOSÉ BLASCO, A. D. J. ATKINSON GORDO, F. S. FRANCH, A. GÓMEZ ORTIZ, J. DE MATÍAS BEJARANO</i> GEODESIC AND PHOTOGRAMMETRIC TECHNIQUES FOR THE CARTOGRAPHIC PRODUCTION AND THE OBSERVATION OF THE GEOMORPHIC DYNAMIC OF THE CORRAL DEL VELETA ACTIVE ROCK GLACIER (SIERRA NEVADA, ESPAÑA).....	68
<i>A. FLEMING, A. CZIFERSKY, A. FOX</i> AN ASSESSMENT OF ASTER ELEVATION DATA OVER GLACIATED TERRAIN ON POURQUOIS PAS ISLAND, ANTARCTIC PENINSULA.....	70

<i>M. GAMACHE</i> CONTINUOUS DATASETS FROM SATELLITE IMAGERY FOR LAND COVER MAPPING IN MOUNTAIN CARTOGRAPHY.....	71
--	----

<i>R. KOSTKA</i> SATELLITE IMAGE AND RELIEF REPRESENTATION A CONTRIBUTION TO THE THEORY OF MOUNTAIN CARTOGRAPHY.....	72
--	----

F) HYBRID SOLUTIONS OF GIS AND RS

<i>L. DRAGUT, T. BLASCHKE</i> CLUE-COMPLEX LANDSCAPE UNITS FOR ENVIRONMENTAL ASSESSMENT AND MODELLING.....	74
--	----

<i>J. GSPURNING, W. SULZER</i> THE DIVERSITY OF NATURE AND HOW TO MANAGE IT WITH GEOTECHNOLOGIES. EXPERIENCES IN SUSTAINABILITY GOT FROM FIELDWORK IN HOHENTAUERN.....	76
--	----

<i>M. KRIECHBAUM, E. HEINE, F. SUPPAN</i> ASSESSMENT OF HIGH ALTITUDE PASTURE DEGRADATION IN SOUTH TIBET SUPPORTED BY LAND COVER MAPS AND DIGITAL TERRAIN MODELS DERIVED FROM ASTER SATELLITE DATA.....	77
--	----

<i>J. E. NORTHEIMER, R. L. JONES, R. QUILLEN</i> USING A GEOGRAPHIC INFORMATION SYSTEM TO ANALYZE AND DISPLAY BREEDING BIRD HABITAT DATA UTILIZING IMAGE BASE MAPS FOR DECISION MAKING RELATED TO LAND MANAGEMENT.....	78
---	----

<i>M. POUDEL</i> INTEGRATED USE OF GIS AND REMOTE SENSING (A GEO-SCIENTIFIC APPROACH) IN SUPPORT OF AGRICULTURE DEVELOPEMENT AND PLANNING.....	80
--	----

G) METHODOLOGICAL IMPROVEMENTS CONCERNING HMRS

<i>F. INCERTI, F. DE NATALE, C. GAGLIANO</i> USE OF TOPOGRAPHIC FEATURES FOR THE GEOMETRIC CORRECTION OF LANDSAT TM IMAGES.....	84
---	----

<i>J. NIEMINEN, P. ZHOU, T. TOKOLA</i> FOREST CANOPY ESTIMATION USING K-NEAREST NEIGHBOUR ALGORITHM IN MOUNTAIN REGIONS OF NORTHERN SICHUAN.....	85
--	----

<i>O. RÖßLER, D. WUNDRAM, J. LÖFFLER</i> THE SURPLUS OF KITE AERIAL PHOTOGRAPHY (KAP) IN HIGH MOUNTAIN MICRO-SCALE CLIMATOLOGY.....	86
---	----

<i>N. J. SCHNEEVOIGT, T. KELLENBERGER, L. SCHROTT, A. KÄÄB</i> OBJECT-ORIENTED CLASSIFICATION OF ALPINE LANDFORMS FROM ASTER SCENES (REINTAL, BAVARIAN ALPS).....	87
---	----

<i>M. SCHNEIDER, J.-C. OTTO</i> A NEW SEMI-AUTOMATIC TOOL FOR 3-DIMENSIONAL LANDFORM MAPPING.....	88
--	----

<i>B. SHRESTHA</i> MOUNTAIN ENVIRONMENT KNOWLEDGE HUB INITIATIVE IN THE HINDU KUSH- HIMALAYAN REGION.....	89
---	----

<i>R. WACK, H. STELZL</i> ASSESSMENT OF ALPINE PROTECTION FOREST PARAMETERS BASED ON LIDAR DATA AND SPOT V SATELLITE IMAGERY.....	90
---	----

<i>E. WEINKE, S. LANG</i> AUTOMATED BOUNDARY DELINEATION AND SPATIAL CHANGE ASSESSMENT OF ALPINE HABITATS.....	91
--	----

H) EDUCATION

<i>R. L. JONES, J. O. BRUMFIELD, J. NORTHEIMER</i> AN INTEGRATED DESIGN OF A GEOSPATIAL PROGRAM WITH AN INFORMATION TECHNOLOGY CORE.....	94
--	----

<i>J. LICHTENEGGER, P. BROGGER SORENSEN, M. FEA, J.-C. BIGOT</i> EARTH OBSERVATION EDUCATION IN THE HINDU KUSH – HIMALAYAN REGION, AN ESA INITIATIVE.....	95
---	----

<i>M.K. PRADHAN, D. WANGDA</i> MONITORING GLACIERS AND GLACIAL LAKES - CASE STUDY FOR EDUSPACE.....	96
--	----

<i>N. SPARWASSER, R. MEISNER, T. ANDRESEN, S. DECH</i> “MOUNTAINS FROM SPACE” – A BOOK BASED ON REMOTE SENSING DATA FOR SUPPORTING PUBLIC UNDERSTANDING OF SCIENCE.....	97
---	----

I) MISCELLANEOUS

<i>C. STEURER, M. ZEBISCH</i> ALPINE INSTITUTE FOR APPLIED REMOTE SENSING.....	100
---	-----

SYMPOSIUM PARTICIPANTS.....	101
-----------------------------	-----

A) REMOTE SENSING (RS) TECHNIQUES

TERRESTRIAL LASER SCANNING FOR GLACIER MONITORING: A COMPARISON
TO STANDARD GEODETIC AND PHOTOGRAMMETRIC METHODS, AND
DOCUMENTAION OF THE GLACIER RETREAT OF GOESSNITZKEES (SCHOBER
GROUP, AUSTRIA) BETWEEN 2000 AND 2005

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KEY WORDS: Glacier monitoring, Terrestrial laser scanning, Climate change,
Photogrammetric and geodetic methods, Goessnitzkees, Austria

The monitoring of glacier changes is an important task of environmental research. A number of different methods on a local, regional and global scale are available.

Terrestrial Laser Scanning (TLS) has developed to a new monitoring and surveying method during the past few years. Surveying an object is not restricted any more to the measurement of a limited number of object points as compared to traditional methods, such as geodetic survey using a total station and/or GPS, digital photogrammetry, and mechanical sensors. The geometric survey of terrain surfaces using TLS results in the acquisition of the whole surface in the form of point clouds with short repetition cycles. In contrast to spaceborne and airborne sensors, TLS can provide much more detailed high-resolution 3D data of surface structures, particularly in mountainous regions. TLS provides point clouds, sampled representations of 3D scenes, derived from range and angle measurements. TLS systems - applicable to geomorphometric mapping - include portable 3D profile measurement systems with a measurement range of up to 2 km. These are reflector-less, and thus require no targeting, which is of great importance for surveying non-accessible and/or hazardous regions.

After measuring selected regions-of-interest, pre-processing (to classify the measurement quality and reliability), geometric and radiometric compensation, and geo-coding, a dense digital surface model (DSM) is processed. Since the DSMs of (temporally) different surface measurements are geo-referenced, simple differences between DSMs reflect the changes in elevation. In consequence, we can derive a full description of change in volume and morphological shape or compute arbitrary profiles of the surface.

Since summer 2000 this method has been applied at Goessnitzkees, which is a small debris-covered glacier located in the Schober Group, Austria (12°45' E, 46°58' N; area c.0.75 km²). More than 60% of the glacier is covered by a prominent debris mantle. Five terrestrial laser scanning campaigns have been carried out during the last years focusing on the central part of the glacier including the glacier terminus (07-2000, 08-2000, 07-2001, 08-2001, 08-2004, 08-2005). These measurements allow the comparison of three different time scales (intermonthly, interannual, five years).

Additionally, 3D data is available from terrestrial digital photogrammetry (1997, 2003), and geodetically measured profile points (2000-2005). In this paper we focus on the comparison and distinctions to standard photogrammetric and geodetic methods going into detail of specific measurement system features and acquisition site properties.

MAPPING AND MONITORING GLACIAL AND PERIGLACIAL PHENOMENA WITH AIRBORNE LASER SCANNING TECHNOLOGY

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KEY WORDS: Airborne Laser Scanning, Digital Elevation Model, Glacier Monitoring, Change Detection, Periglacial

Airborne Laser Scanning allows for deriving high-quality topographic data. The most common products of the measurements are raster-type digital elevation models with horizontal and vertical accuracy in the sub-meter range. Between 2001 and 2005 a total of twelve airborne laser scanning data acquisition campaigns were carried out at Hintereisferner (Ötztal Alps, Austria), covering the same area of ca. 40 km² in each campaign, yielding a multi-temporal topographic data set of world wide significance for high mountain areas.

The high accuracy of the data allows for the mapping and monitoring of glacial and periglacial features and the reliable quantification of changes in area and volume. This contribution shows the main results of the data analysis so far, including

- checks of the data quality
- calculation, presentation and interpretation of surface elevation changes for the observed glaciers
- derivation of glacier flow velocity fields from multi temporal data analysis
- description and quantification of geomorphological processes in the periglacial environment

Ongoing research is outlined, e.g. the analysis of the laser intensity signal in order to classify different surface types (e.g. snow, firn or ice areas on the glacier surface), the automatic detection of crevasses, the derivation of surface roughness values or the use of the visualisation potential, e.g. for educational purposes. General remarks are made on the planning and organisation of further laser campaigns with emphasis on high mountain environments.

Overall the high potential of airborne laser scanning technology for a variety of mapping and monitoring tasks in high mountain environments is highlighted and discussed.

PROBLEMS OF AN AERIAL APPLICATION OF CLOSE-RANGE-PHOTOGRAMMETRY
METHODS TO COUNTER ADVERSE WEATHER CONDITION PROBLEMS OF
SURVEY FLIGHTS IN MOUNTAINOUS TERRAIN

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KEY WORDS: Convergent, multiple-image-photogrammetry, weather, "aerial survey",
Glaciers

Convergent-multiple-image photogrammetric analysis of digitised analogue oblique aerial photography using a hand-held survey camera from relatively low flying light aircraft reduces many of the traditional restrictions imposed by vertical aerial photography. This is true especially for the required weather conditions. Because the aircraft is not required to achieve a specific altitude as defined by scale, lens focal length, and ground coverage the methods work under adverse conditions. Instead, the aircraft needs to orbit the target area and can position for the best view angles. It can closely approach important targets to increase accuracy, depending on requirements. Slow aircraft speed and high shutter speeds are a key to successful application here. This method significantly reduces the weather requirements for the survey flight. The recent results clearly show the possibility of an aerial application of digital multiple-image-photogrammetry with automated surface measurements, which are based on matching algorithm and greyscale-differences in a search patch. With the use of a medium format camera for aerial surveys, the highest available scan quality with low image noise is necessary. Consumer product type scanners have proven unsatisfactory. The general reasoning for use of oblique imagery for detailed evaluations in high mountain terrain appears as a valid method, especially with the possible use despite adverse weather. Any airplane can be used since the camera is used without a mount, hand-held out of the open window. The remaining question is if the automated surface measurements can produce an accurate surface model over the full extent of the whole target area under these special conditions. Similar to stereoplotting, convergent-multiple-image photogrammetry Software is able to detect and recognise subtle features of natural surfaces between the Images. Small crosslike gaps in the maze of measurements are existing due to réseau-crosses of the camera, which happen to hit the same spot in the landscape in several images. This drawback can be countered by using a camera with less crosses, 9 or 36 would be possible too. With 121 crosses the effect is unavoidable, unfortunately the effect was not yet known when this survey camera was build. For many earth science studies in remote or un-surveyed areas this approach should open up new possibilities of making use of otherwise unattractive aerial surveys. The low cost and enhanced adverse weather ability should be significant enough to get access to data that would be not attainable otherwise. Adding positioning data from a differential global positioning receiver and mounting an inertial navigation system to the survey camera may eliminate the need for establishing ground control points in the target area in the near future. But with it the cost of the equipment would quadruple and field work with ground control may be a cheaper option. The aerial use of Convergent-Multi-Image-Photogrammetry can be a cheap and flexible option, but certainly only as long as the area which is to be surveyed is comparatively very small. As soon as a high number of image bundles is necessary the workload and the cost of the needed manual photogrammetry work outgrows its usefulness. -A smaller glacier, a volcano, a mountain or an open pit mine are suitable targets for the aerial use of convergent

photogrammetry, but with large acreage targets like counties, cities, states or whole mountain ranges other Remote Sensing methods are a more reasonable approach.

HIGH ACCURACY 3D SATELLITE IMAGE DATA PROCESSING FOR MOUNTAINOUS REGIONS

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KEY WORDS: Convergent, multiple-image-photogrammetry, weather, "aerial survey", Glaciers

With the advent of very high spatial resolution satellite images with stereo capabilities, as for instance SPOT-5, EROS, IKONOS, Quickbird, Orbview and similar ones to be expected for the near future, the potential for generating spatially-related 3D information from images and for mountainous regions has substantially increased. Methods for stereo- and multi-image processing rely heavily on photogrammetric concepts. Therefore techniques of digital photogrammetry, having proved themselves in close-range and aerial applications, can be transferred to the processing of satellite images. Experiences tell us that subpixel accuracy is realistically possible and indeed has been achieved in the past in many tests and projects. This opens new opportunities for innovative applications in mountainous areas, be it with respect to DSM generation, topographic and thematic mapping, glacier monitoring or the tracking of other dynamic processes over time and space.

This paper will report about our R&D efforts related to highres satellite image processing. We have developed a full suite of methods and the related software for the high accuracy processing of stereo- and multi-image satellite data. This software SAT-PP (Precision Processing of Satellite Images) includes modules like:

- User interface for image handling and image measurement in mono and stereo, in manual and semi-automated modes
- Sensor models adjusted to the particular sensor geometries
- Orientation of single stereo models and triangulation of larger units. Tie point measurement in manual, semi-automated and fully automated modes
- Derivation of quasi-epipolar images
- Automated generation of Digital Surface Models (DSM)
- Generation of orthoimages
- Mono-plotting functions
- Semi-automated extraction of objects

We will briefly report about the status of the software, the functionality and some new algorithmic approaches, particularly with respect to image matching for DSM generation. The functionality will be verified by results from various pilot projects, all related to mountainous areas. We will show results using IKONOS, Quickbird and SPOT-5 images and projects from Switzerland (Thun), Australia (Hobart), Bhutan (Thimpu), Bavaria (Chiemsee).

We put particular emphasis on the georeferencing, which can be done with sub-pixel accuracy the automatic generation of DSMs and the photorealistic 3D model generation.

We will also report about the establishment of a testfield in Switzerland and its use for the calibration and validation of JAXA's recently launched PRISM sensor on board of the ALOS satellite.

The many planned highres earthobservation satellite missions will even further enhance the applicability of these techniques, especially since it is to be expected that the costs for satellite images will then sharply decline.

GENERATION OF DIGITAL SURFACE MODELS FROM VERY HIGH RESOLUTION OPTICAL STEREO DATA IN ALPINE REGIONS

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As an alternative to laser scanning, stereo images with very high spatial resolution are getting more and more used for surface mapping applications, where high accuracy and level of detail is required. Image pairs acquired from spaceborne as well as airborne platforms promise height accuracy in the meter and sub-meter range leading to detailed digital surface models. In addition the preferred "in-track" acquisition scenario is realized which means that the images are taken during the same overflight, to get stereo image pairs in a short time interval as possible. Technically this is achieved either through forward/backward imaging of two instruments, like the present Spot 5 or the future PRISM instrument of the Japanese ALOS mission. Alternatively, highly agile imaging capabilities are realized for the EROS, the IKONOS or the QuickBird mission, where a single instrument is turned around during overflight in order cover a defined area twice during the same orbit. The short image acquisition intervals imply a high performance of image matching applied to such data as the image similarity is not degraded due to temporal changes in the scenes.

For an alpine area located in the Austrian Alps stereo image data were acquired from the Eros as well as the Ikonos sensor. An additional complexity of Eros is induced through an asynchronous imaging mode, where the sensor is bending backwards during the acquisition of an image. This high alpine area is covered by several glaciers and hence is subject to considerable topographic changes due to retreat of these glacier areas during the past. The update of surface topography is therefore a permanent geoscientific requirement for such areas.

This paper discusses the applicability of high resolution Eros and Ikonos stereo data to generate surface models for such alpine terrain. The processing steps to be completed and to be discussed are:

- Geometric modelling of the stereo data: this includes the utilization of given orbital and imaging parameters in case of the Eros data, and of rational polynomial coefficients in case of the Ikonos data. It is to be investigated whether reference and control data fulfil the precision requirements being inherent to these high resolution stereo images.
- Automatic matching of stereo images: the implications of high resolution stereo data onto the performance of this kernel procedure need to be investigated, thereby emphasising the problems being induced through the complex nature of alpine terrain.
- Generation of surface model: The matching results are converted to 3D information on ground as a basis for subsequent elevation raster model generation. Therefore, erroneous matching results need to be quantified, detected and eliminated with high confidence in an early processing stage.

As a key result of this investigation, high resolution surface models are extracted from both stereo data sets. The quality of these products is determined through a comparative analysis with existing reference data and in-situ measurements. Moreover, the stereo data will be orthorectified using the stereo-derived surface models. Superposition and comparison of such

products leads to further conclusion on the accuracy as well as level of detail of generated surface models.

OPERATIONAL USE OF AIRBORNE LASER SCANNING FOR FORESTRY APPLICATIONS IN COMPLEX MOUNTAINOUS TERRAIN

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KEY WORDS: Airborne laser scanning, forest inventory, mountainous forest, stem volume, canopy height

Today, one of the most promising techniques for the quantitative assessment of forest parameters is airborne laser scanning (ALS), also referred to as light detection and ranging (LIDAR). Airborne laser scanning is an active remote sensing technique where a laser emits short infrared pulses towards the Earth's surface and a photodiode measures the backscattered echo. When there are several objects within the travel path of the emitted laser pulse, multiple echoes are reflected. State-of-the-art laser scanner systems measure at least the round-trip time of the first- and last pulse, novel sensors are capable of recording the full waveform of the backscattered signal. As a result, ALS systems provide a 3D point cloud, where over vegetated terrain some of the points are caused by reflections in the vegetation canopy and some by reflections at the ground surface. For the retrieval of digital terrain models (DTM) from this 3D data it is therefore necessary to firstly classify the points into terrain and non-terrain points, a procedure commonly referred to as filtering. Then a DTM can be reconstructed from the terrain points by using an interpolation algorithm. The derivation of DTMs from ALS data can be done with a high degree of automatization and leads to high accuracies of the calculated terrain heights. Thus, ALS has revolutionized the way of how we obtain DTMs and therefore, for example in Austria, for large regions ALS data are already available and are planned to measure in the near future respectively. As ALS do not only provide terrain heights but also information about the horizontal and vertical distribution of forests, ALS data are now beginning to be used operationally in large-area forest inventories (FI) in Scandinavian countries. Its application in complex alpine terrain is lacking behind, at least partly due to the technological challenges of ALS operations and data processing in these mountainous environments.

Thus, the main objective of this presentation is to show the potential of ALS for an operational retrieval of forest parameters in a 128 km² large mountainous region in Vorarlberg, Austria. The complex mountainous landscape of the study area shows many different facets and is characterised by hilly to high alpine terrain, with altitudes rising from 800 m to 2,900 m. The ALS data were acquired in the framework of a commercial terrain mapping project and were measured during a winter- and a summer flight-campaign. The ALS data were processed with state-of-the-art methods to produce a digital terrain model, a digital surface model, and by subtraction of the previous two models a canopy height model. A comparison of the DTM with 22,000 ground control points shows that over non-forested terrain DTM errors increase from 10 cm for relatively flat terrain (local slope < 10°) to over 50 cm for local slopes greater than about 60°. However, the analyses have shown that errors of the terrain heights of several meters may occur over steep, dense forested terrain when only summer ALS data are available. The extraction of forest parameters from ALS data is commonly done with regression analyses. For such analyses reference data are required. For our analyses we use already existing field measured FI data as reference data. This FI data have the advantage of being readily available and do not lead to additional costs for extensive field works. Their disadvantage is that the

designs of such inventories are not optimised to use these data as reference data for remotely sensed data analyses. Therefore, a further objective of this presentation is to analyse and discuss the usability of such FI data as reference data for the estimation of stem volume and canopy heights.

In this presentation we validate the calculated canopy height model using the FI data as reference. For the estimation of stem volume we present a physically-based linear regression model which combines FI and ALS data. The developed plot-level based regression model uses canopy volumes from three predefined, fixed canopy height ranges as independent variables. The results show that this model leads to a coefficient of determination (R^2) of 0.87, the residuals derived from cross-validation range between 214 and 253 m³ha⁻¹ and have a standard deviation of 90 m³ha⁻¹. To demonstrate the practicability of this model we have calculated the stem volume for the whole study area. The comparison of the total stem volumes calculated from (1) the field measured FI data and (2) the ALS data has shown that they differ less than 1%. Finally, this presentation discusses the effects of the different laser scanner system parameters on the obtained forest parameters.

DIRECT GEOREFERENCING IN ALPINE ENVIRONMENTS FROM A HELICOPTER

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The paper describes the architecture of a handheld remote-sensing system developed at the Ecole Fédéral Polytechnique de Lausanne. This system involves a GPS/IMU navigation unit together with a digital camera and a laser scanner. The data flow inside the system is discussed, starting with the coordinated recording of the navigation- and remote-sensing data down to the generation of the final products. Examples of possible applications in alpine environments are given with consideration of practical problems during the data-recording process.

Another focus is a specifically developed coordinate-transformation procedure that allows obtaining the results of direct georeferencing directly in national coordinates without the need for ground-control points (GCPs). The strengths of this technique are discussed and its limits for applications in highly mountainous terrain are analyzed.

AIRBORNE LASER SCANNING AND RADAR INTERFEROMETRY FOR DIGITAL TOPOGRAPHIC MODELLING AND FLOOD RISK ASSESSMENT

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KEY WORDS: lidar, radar interferometry, topographic modelling, flood risk, vegetation

Digital terrain and surface models (DTM/DSM) derived from airborne laser scanning and radar interferometry can be used to provide 2D spatial information and 3D reconstruction of landscapes and objects (including buildings and vegetation). These data can subsequently be used to assess erosion risk, perform landslide and flood risk modelling, and simulate the effects of natural disaster events. For the purposes of flood risk assessment, flood intelligence in digital form is invaluable to those engaged in land management and disaster mitigation. High resolution DTMs are an important component of this intelligence, providing data on surface and feature heights, landform variation, flooding extents and, indirectly, flood behaviour. This study aims to provide these baseline height models and topographic products for a section of the Wollongong coastline (SE Australia) using a combination of Airborne Laser Scanner (ALS) and Interferometric Synthetic Aperture Radar (InSAR) data. DTMs and DSMs were derived using ground and non-ground lidar point data, and the height differences compared with those generated using ERS-1/2 tandem and JERS-1 data and also SRTM data. High resolution aerial photographs and ground survey data were available for 3D visualization and accuracy assessment. Typical height errors of between 0.1 – 0.5 m were achieved using the ALS data, with declining accuracy in steep terrain or that covered in dense forest, whilst only moderate accuracies were achieved using repeat-pass interferometry, given the high sensitivity to variation in terrain. The integration of the two led to localized improvements in topographic feature definition in the InSAR DTM. Additional products including slope and aspect maps, 3D perspective views and fly-through visualizations were generated and assisted in establishing flood risk in the area and in simulating the effects of flooding and landslide scenarios. Vegetation structure was also investigated using the SAR data and a community based classification using the DTM as input was obtained. The study resulted in the refinement of methods for height estimation over diverse terrain (including accuracy assessment), and establishment of consistent techniques for data integration and scaling up from fine (micro-scale) to moderate (macro-scale) spatial resolution.

DETERMINATION OF SPATIAL SNOW DEPTH DISTRIBUTION ON SLOPES USING TERRESTRIAL LASER-SCANNER

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The determination of the spatial snow depth distribution in potentially dangerous avalanchestarting zones is vitally important, both in terms of avalanche-prediction and dimensioning of permanent protection measures. Unfortunately, inaccessibility of the alpine terrain, as well as the acute danger of avalanches complicates snow depth measurements, for example when probes are used. Therefore, the possibility of measuring the snow pack using a terrestrial laser scanner was tested.

In use was the long-range laser profile measuring system Riegl LPM-i800HA. Without the use of a retroreflector, the scanner calculates the distance to the surface in question, based upon the time-of-flight measurement of a short laser pulse. Combination with a calibrated and oriented high resolution digital camera a hybrid sensor system was created. The measuring range is up to 800m, depending upon the weather-situation and the reflective condition of the snow pack. The wavelength is 0.9 μm (near infrared), the accuracy is typically within 30mm and the highest resolution is 1mm.

The objectives of the study are to prove under which meteorological conditions, state of the snow pack and technical circumstances the measurements have to take place to show accurate results. Additionally, the results are practically relevant by using the data generated by the scanner to check GIS-applications.

The results of the measurements taken at test sites in the Austrian Alps are presented and the changes in snow depth and snow mass caused by snow drift or melting are discussed.

KITE AERIAL PHOTOGRAPHY IN HIGH MOUNTAIN ECOSYSTEM RESEARCH

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KEY WORDS: Kite aerial photography, landscape ecology, digital elevation model, vegetation Patterns, high mountains

Within the discussion of global change mountains are of special interest, since these environments above the treeline are considered to be particularly sensitive to increasing temperatures and are accounted as ideal research objects concerning ecological responses.

To predict futures changes, understanding and modeling of actual ecosystem functioning on a spatial dimension is essential but requires supply of manifold spatial input data.

Existing remote sensing data would contribute a good starting point. But since most mountain environments are remote areas, the selection of available data is limited and obtainable official landform data are usually restricted to medium scales (25 m grid data, 1: 50,000 scale topographic maps with 20 m contour lines). The implementation of those data into modeling processes lead to inaccurate results; while state-of-the-art satellite data promise good results (e.g. concerning DEM extraction) but usually exceeds disposable budgets.

Kite aerial photography (KAP) has already been used in manifold environmental applications and within this study we used and proved this technique for a new application of high resolution mapping in mountain landscapes. Our experiences documented that KAP was well suited. Despite low costs, KAP ideally matches requirements for the use in severe mountain terrain. The entire equipment was transported in a backpack and the campaign could be aligned spontaneously to weather conditions. Furthermore, the flexibility of the system also enables repeated applications.

KAP limitations to a spatial extend of 1 – 10 ha were balanced by outstanding high resolution and our results matched spatial variability of mountain landscapes far better than other data, sensors and platforms.

B) MORPHOLOGICAL MAPPING

3D MULTISENSOR STUDY OF THE GEOLOGY AND GEOMORPHOLOGY OF QUOMOLANGMA FENG (MT. EVEREST), TIBETAN HIMALAYAS

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Based on a number of Digital Terrain Models (DTM) different aspects of the geology of Mount Everest will be visualized. We use terrain models based on ASTER satellite images, the "ETH" DTM (Prof. Dr. Armin Gruen, Institute of Geodesy and Photogrammetry, ETH Zurich), as well as SRTM-data and own digitized contours taken from maps (1 : 10 000) kindly provided by Dr. Brad Washburn (Boston museum of Science) in our study to create a 3D view over the study area. Differences in the DTMs will be discussed together with the way in which they merged to form our data base.

Ground truth of the geological information is given by the newly released geological map of the Everest region (Searle, 2003), and fieldwork carried out by both authors independently at different occasions. Satellite imagery used in this study was produced by the following space born high resolution sensors:

Landsat MSS, TM, ETM+, MOMS, ASTER, and HYPERION

Finally we draped geological maps and remote sensing imagery over the optimized DTM, which allowed an interactive evaluation and comparison of the different data sets. Results from supervised classifications of the imagery will be compared with different maps based on geological fieldwork. The interaction and dependence of geology and geomorphology of the Mt. Everest Massif will be discussed.

Reference:

Searle, M.P. 2003. Geological Map of the Mount Everest region, Nepal - South Tibet Himalaya. Scale 1:100,000. Dept. Earth sciences, Oxford University, UK.

AN AUTOMATED METHOD TO OUTLINE THE ICE EXTENSION OF DEBRIS-COVERED GLACIERS BASED ON ASTER IMAGERY

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KEY WORDS: debris glacier, ASTER Stereo Image, shape parameters, Mt. Everest Area

Recent glacier shrinkage results in an increasing coverage of the ice by debris. This, again, hampers the mapping of the actual ice snout by means of spaceborne imagery. On the other hand, satellite imagery would represent an ideal tool to develop an automated way of outlining the glacier ice extents. Using ASTER stereo images, a team of the TU Dresden Institute for Cartography undertook the task to solve this problem. Combining ASTER's thermal information with various shape parameters derived from stereo models, both the actual glacier beds and the marginal moraines along the active glacier, could be obtained. The results are quite promising. Field verification in the Mt. Everest Area in spring 2006 very well showed the proof of concept.

MULTITEMPORAL OPTICAL SATELLITE DATA, DIGITAL ELEVATION MODELS
AND SPATIAL DATA FOR THE MAPPING OF LANDSLIDES AND LANDSLIDE
HAZARD ZONATION ON A REGIONAL SCALE

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KEY WORDS: Optical satellite data, DEM, Landslide inventory, Hazard zonation,
Regional study

The presented concept shall demonstrate how multitemporal optical satellite data and multitemporal digital elevation models (DEM) in combination with derived spatial data can be used for landslide mapping and landslide hazard zonation on a regional scale. Beside the remote sensing images and their derivatives, field work will be used as a source of information; mainly for collecting of ground control points, sample and validation data.

So far, optical remote sensing data served only as a partial source of information in landslide hazard zonation, i.e. to map landslides by mainly visual interpretation or to assist in analysing the relationship between landslides and causative factors by extracting information related to geomorphology, topography, geology, land use and hydrology. This is the more remarkable as remote sensing data proved to be of value in the single domains, although, a systematic analysis about the use of satellite imagery is missing; this is especially valid for the mapping of landslides.

Therefore, emphasis is put on the evaluation of different remote sensing change detection techniques, i.e. Change Vector Analysis, Principal Component Analysis and Image Segmentation regarding their suitability to map landslides. The goal is to find a fast and objective method which is transferable to other areas. Besides landslide inventory maps also additional information related to landslides shall be extracted from remote sensing data, viz. geomorphology, topography, geology, land use and hydrology.

The obtained information, i.e. the landslide inventory maps of different landslide events, the DEMs and the derived spatial data can then be used for a combined analysis leading to a hazard zonation showing spatial and temporal probabilities.

As the mapping of landslides and also the extraction of most of the related spatial data requires information from digital elevation models only pre- and post-event remote sensing data offering stereo capabilities shall be used. The DEMs shall be generated with precise ground control points measured by a differential GPS in the field. Due to the high spectral resolution and the medium to high spatial resolution ASTER data is a good choice. But also data from other sensors like SPOT, IKONOS or even ALOS could be included and tested for their potential in landslide mapping and hazard zonation. The actual choice of data also depends on their availability for the study region.

It is envisaged to incorporate two study areas with different environmental conditions in order to be able to test the developed methods for their transferability. As a first field trip it is planned to investigate an area in Guatemala where hundreds of landslides have been triggered by torrential rains from hurricane Stan in October 2005. As a second study area Makawanpur district in Nepal has been chosen where several landslides occurred in 2003 and 2004.

Beside the briefly outlined concept at least first results of the field studies can also be presented.

By the predominant use of remote sensing data different benefits can be expected. Here, the independency of (outdated) maps and the possibility for regular updates of landslide zonation maps on a regional scale can be highlighted.

THE DERIVATION OF INDICATORS FOR LANDSLIDE DETECTION USING VERY HIGH RESOLUTION SATELLITE IMAGERY

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Currently existing very high resolution satellite remote sensing systems offer an opportunity to extract land surface information that until recently could only be derived from aerial photographs or by extensive field work. Within the EU funded project ASSIST (Alpine Safety, Security & Informational Services and Technologies) a test site has been defined in a high mountain terrain in the western part of Tyrol/Austria. This region is prone to many natural hazards, i.e. landslides, flooding and snow avalanches. For instance flooding caused heavy damage on the infrastructure and settlements in August 2005 disrupting the important Arlberg railway route for more than three months.

The focus in this investigation is the identification of parameters and/or indicators for natural hazards with special emphasis on landslides research. In order to fulfil these tasks QUICKBIRD data seem to be an adequate data source with its high spatial resolution of 60 cm in the panchromatic mode and an additional four multi spectral band range with 2.4m resolution. The derivation of detailed land use coverage can be performed on a catchment area basis due to the coverage of approximately 400km². A hybrid approach – supervised classification and visual interpretation - is foreseen for the classification of this kind of data with special emphasis on the development of automatic classification tools. The methodology has to integrate algorithmic background in the field of texture calculation and feature extraction. Expected results are the segregation of land cover classes especially important for landslides research and have hardly been derived from former medium resolution standard remote sensing images.

LANDSLIDE DETECTION WITH HIGH RESOLUTION SATELLITE IMAGERY IN KHUMBU HIMAL

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The area of the field study is located in the Himalaya region in the north-eastern part of Nepal in the so called Khumbu Himal or Sagarmatha National Park. Its height ranges from about 2600 to 8848m (Mt. Everest) and is thus part of the world's highest mountain area.

The sensitive high mountain environment is especially prone to be affected by hazards, which are threatening the surrounding area. Therefore the detection of dangers such as landslides, rockfalls or gully erosions reaches greater importance. As the remote location of the investigation area complicates terrestrial research, remote sensing states an outstanding method to survey these areas.

Various methods are to be tested to identify landslides in satellite imagery and to distinguish between them and other similar features such as debris-covered glaciers, moraines or river beds.

The used data are high resolution satellite imagery (IKONOS) and additional information from a digital elevation model, topographic maps, pre-existing GIS data, a Landsat landcover classification and material, which was gathered during the field work in Khumbu Himal.

GEOMORPHOLOGICAL MAPPING IN MID-WALES, UK, BASED ON REMOTELY SENSED DATA

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KEY WORDS: Southern Snowdonia, Central Cambrian Mountains, geomorphological mapping, palaeoglaciology, geoconservation.

Reconstructions of the last British-Irish Ice Sheet (BIIS) are often very simplistic and describe the ice mass as a configuration of several independent ice domes. Wales was repeatedly covered by a terrestrially based Welsh Ice Cap, in addition to the Irish Sea Glacier that encroached on the coast. The Ice Cap was semi-independent from the BIIS and had several dispersion centres in the upland areas of North and Mid-Wales. However, these reconstructions are not based on detailed geomorphological mapping.

This poster presents new detailed geomorphological maps of southern Snowdonia and the Central Cambrian Mountains, Wales, UK. The mapped landforms are used to make inferences about the Quaternary glacial history of the areas. Inferences are also made concerning ice thickness, ice flow directions, Quaternary glacier thermal regimes, and the impact of glacial erosion and deposition on the surrounding landscape. The geomorphological mapping will also be used as basis for geoconservation planning by the Countryside Council for Wales (CCW).

The geomorphological mapping is based on interpretation of colour aerial photographs (scale 1:10 000), winter Landsat TM satellite images, and field investigations of landform/sediment associations. The data has been coupled to a new digital elevation model (DEM), called NEXTMap Britain (horizontal resolution 5 m, vertical 1 m), which significantly enhance the ability to observe landforms, compared to the existing Ordnance Survey DEM (horizontal resolution 50 m).

The geomorphological maps (scale 1:10 000 – 1:25 000) shows spatial distribution of glacial, periglacial and postglacial features such as cirques, end moraines, striations, block fields, tors, meltwater channels, scree slopes and alluvial fans. Some of these landforms have not previously been identified, including glacially modified tors, rock drumlins and subglacial meltwater channels. The new findings will add detail and support large scale reconstructions, giving us clearer insight in the palaeoglaciology of Wales. The new geomorphological data will also contribute to the geodiversity knowledge of Wales.

C) MONITORING OF ENVIRONMENT

SNOW AND VEGETATION IN THE SCANDINAVIAN MOUNTAINS

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The monitoring of snow and vegetation in mountainous areas are motivated from needs within climatic monitoring, hydrology, nature protection / management and resource management. We present our long time activities within satellite image based snow monitoring in Scandinavia, as well as more recent work in the field of vegetation mapping and monitoring of mountainous vegetation in Norway. The products and services that are included in these activities are listed below.

From MODIS (MOD02) we retrieve a set of daily products that are related to the metamorphosis and the melting of the snow cover:

- SCA: snow covered area, represents the snow-percentage in each pixel, retrieved from 250m Modis data
- SGS: Snow Grain Size, an index retrieved from 1km Modis data
- STS: Snow Temperature at Surface is retrieved from 1km Modis data

Multi-temporal datasets are utilized for some snow products:

- SCA is improved by including recent results when the current image is covered by clouds
- SW (Snow Wetness) is estimated by using recent development of SGS and current STS

Multi-sensor data are utilized for some snow products:

- SCA is improved by including results from ASAR or other radar satellites when the current optical image is covered by clouds
- Snow distribution pattern: estimated on a weekly basis, using the MODIS SCA product and a snow distribution model based on high-resolution data, like Landsat or better.

Vegetation mapping and monitoring involves these activities:

- Composing a cloud-free dataset for a 'virtual season' by combining acquisitions from several years taking the into the account the natural variability between various years.
- Improving multi-temporal classification by applying a Hidden Markov Chain approach, which takes the phenology into account, defined as a set of phenological stages
- Mapping the feeding capacity of mountainous vegetation with respect to grazing domestic animals
- Monitoring long-term vegetation changes in the mountains.

LAND DEGRADATION BASED ON SPACE IMAGERY IN THE MOUNTAINOUS AREAS OF WESTERN ANATOLIA

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The horst-graben system is dominating topographical-geomorphological property of the western part of Anatolia. Mountains which are named Kaz M. (1776 m), Boz M. (2159 m), Honaz M. (2528 m) and Sandras M. (2295 m) extend in E-W direction and they fit horst, and grabens named Gediz, Big Meander and Small Meander are found between the horsts. In the mountainous areas land degradation processes have been continued. The slope, parent material and misuse of lands are responsible for the land degradation. The outcropped gneiss, mica schist and quartzite on the mountainous areas can be considered desertification areas due to the low cation exchange and/or low nutrient capacity. The dejection fan and thick colluvial deposits extending in the northern edges of Boz Mountains and in the southern edge of Aydın Mountains are deeply dissected by gullies.

In order to determine and spreading of the land degradation areas landsat imagery photos containing seven bands are used. So the degraded lands are classified.

THE RETREAT OF THE PASTERZE GLACIER (AUSTRIA) FROM
1996 TO 2005 – COMBINATION OF DIFFERENT DATA SETS FOR
SPATIAL ANALYSIS

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The record of variations of Pasterze glacier represents one of the longest data series in the Alps, annual measurements started as early as 1878. The results clearly show that since then the glacier which belongs to the largest in the Alps never advanced due to the short duration of colder phases in this period. This paper focuses on the recent development of the near terminus area of the glacier tongue which is characterised not only by a pronounced retreat but also by an accelerated surface lowering combined with several areas of ice collapse. In terms of data acquisition annual terrestrial laser-scanning campaigns as well as DGPS measurements create spatial information with high temporal and geometric resolution in addition to “traditional” geodetic measurements of cross-sections. Comprehensive analysis of all data sets provides information about surface elevation and subsequently morphology changes on a new level of quality.

DIGITAL ASSESSMENT OF GLACIER CHANGES FROM REPEAT
LANDSAT TM AND ETM+ SATELLITE DATA:
A PILOT STUDY ACROSS THE BHUTANESE HIMALAYAS

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The Bhutanese Himalaya Range is one of the most unknown glaciated areas in the world in terms of comprehensive data sets available and knowledge about current environmental dynamics. The present pilot-study focuses on the feasibility of repeat medium resolution optical remote sensing data – Landsat TM and Landsat ETM+ - for glaciological applications in this region. A range of multispectral classification and change detection approaches are tested and evaluated. Dynamics of glacier fluctuations, and changes of para- and supraglacial lakes on the catchment level are crucial issues for assessing hydrological impacts of climate change and natural hazard potentials in the region studied. Recent retreat of glaciers in the Bhutanese Himalayas is believed to show a North-South gradient with higher rates at the southern, monsoon influenced areas than in the Northern Tibet plateau. Between 1990 and 2000 maximum glacier retreat rates of up to 650m, and enlargements of proglacial lakes of more than 20% are detected. Rock outcrops in smaller glaciers indicate a loss of thickness.

THE RECESSION OF THE PASTERZE GLACIER, AUSTRIA, AS DETERMINED FROM
MAPS, SATELLITE IMAGERY AND GROUND MEASUREMENTS FORM 1864 TO 2005

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KEY WORDS: Pasterze Glacier, IKONOS, Landsat, Global Positioning System, Geographic Information Systems

Many glaciers in Europe have been receding since 1928 or before. Research teams have kept track of glacier advances and recessions by measuring the movement and location of selected glacier termini for many years. A good record has been established from these activities of glaciers in Austria. Other researchers measure glacier terminus movements using satellite data, though there are known limitations. For example, it is difficult to distinguish between till of lateral and terminal moraines and the actual glacier ice because till can overlie the ice. Thus it is important to perform ground-truth measurements when possible. Old maps can be used as to determine the approximate location of glacier termini. Maps dating back to 1864 were used in this research. While the dates of such maps might not reflect the exact location of the terminus in that year, the old maps represent the only credible record that is available for these early years. Satellite imagery is available from 1972 on, from the Landsat series of satellites, and more recently, from other satellites as well. For this work, the terminus of the Pasterze Glacier of Austria is digitized from maps and the lines are transferred onto a recent map or satellite image to show the former location of the terminus with respect to the present-day terminus location. The terminus in the older maps is often not clearly seen because of the blending of the black contour and hachure lines with the other signatures on the map. In recent years ground-truthing in conjunction with global-positioning system (GPS) measurements, the use of a laptop computer in the field using the GIS program IDRISI, and the newly published digital maps of the Alpenvereinskarte made it possible to record the exact terminus position by walking along the terminus. Because of the recent rapid recessions of the glacier and the resulting breaking apart of the glacier ice, the steepness of the glacier at the terminus, and the discharging water in pools, as well as the running waters in front of the terminus, it is impossible to walk exactly along the edges of the terminus. Estimates of the recording line to the actual terminus were recorded. In this work, the authors demonstrate graphically the location of the Pasterze Glacier terminus from 1864 to 2005.

DIFFICULTIES IN MAPPING GEOMETRY CHANGES ON A HIGH ARCTIC GLACIER WITH STANDARD REMOTE SENSING SOFTWARE

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KEY WORDS: glacier monitoring, mapping, digital photogrammetry, geometry changes, Etonbreen, Svalbard, High Arctic

The glacier Etonbreen (79°35'-79°50' N and 21°35'-23°50' E) is an outlet glacier of the Austfonna ice cap on Northeastland, Svalbard. Historic aerial photographs suggest that Etonbreen has experienced an active surge in the mid 1930s. Recent studies indicate a growing of the ice cap in its central parts and an increase in slope on Etonbreen. These factors can be considered as possible indicators of a new surge event.

This paper focuses on mapping geometric changes that occurred on Etonbreen from 1970 to 1990. Aerial photographs from the Norwegian Polar Institute were used to photogrammetrically derive digital elevation models for the investigation area. By subtracting the DEMs information on surface deformations and surface height changes were obtained. Data processing was done with a standard software package. Due to a limited total number of GCPs in the investigation area, different acquisition dates and insufficient image overlap the accuracy of the DEMs was reduced considerably. This paper describes the difficulties encountered during the study and presents results both numerically and graphically. Finally, the geometric changes are discussed in a glaciological context.

ASSESSMENT OF CURRENT ONGOING LAND COVER CHANGES IN THE NIEDERE TAUERN RANGE ON STYRIA / AUSTRIA

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KEY WORDS: land cover change, monitoring, alpine area, natura 2000, management plan

The Niedere Tauern range in Styria / Austria is affected by large scale land cover changes which are mainly caused by extensivisation of agricultural land use. Appropriate information on these changes which are a main driver of the current and future development of the region was not available up to now. In commission of the Government of the Province of Styria, therefore, colour infrared (CIR) aerial images were acquired and land cover was interpreted for an area of 130.000 ha. For the definition of the interpretation key, special emphasis was put on categories that are associated with ongoing change processes (e.g. dwarf-shrub plant community with trees with crown-cover below 10%). For estimation of the velocity of the change processes, historical aerial images from the 1950's were compared with the actual CIR aerial images in selected test sites. Statistics on land cover change processes were derived separately for the montane, subalpine and alpine hight level. The results show the aerial extent and the type of current ongoing changes of land cover in the Niedere Tauern range. From the results it can be expected, that the cultural landscape of the Niedere Tauern will change as a whole in the next decades. Currently, the results are used by the Government of the Province of Styria as reference data sets, for setup of management plans for Natura 2000 sites within the Niedere Tauern area and as input for so-called "Waldfachpläne".

MAPPING OF MASS BALANCE PARAMETERS ON MÝRDALSJÖKULL, ICELAND, BY OPTICAL AND RADAR REMOTE SENSING DATA

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A series of satellite images of Mýrdalsjökull ice cap, south Iceland, was analysed in view of their value for mass balance investigations. A combination of optical satellite images from the Advanced Spaceborne Thermal and Reflection Radiometer (ASTER) with Synthetic Aperture Radar (SAR on ERS-2) and Advanced Synthetic Aperture Radar (ASAR, Envisat) data proved very useful.

The whole glacier margin of Mýrdalsjökull was delineated with several ASTER images from summer and winter 2004. With a time series of summer ASAR images it was possible to monitor the temporal and spatial development of the transient snow line (TSL) throughout the year 2004 as well as the firn line (FL) at the end of the balance year. Interannual mass balance fluctuations could be observed by comparing the late summer snow/firn lines mapped on three radar images from 1998, 1999, and 2004 respectively. It was found that winter SAR images are not useful for mass balance studies at Mýrdalsjökull because of frequent surface melt conditions even during winter time. A SAR image enhancement method was developed, which improves the contrast between glacier ice and wet snow/firn, allowing a better manual delineation of the snow or firn line.

By delineating the glacier margin of Mýrdalsjökull on ASTER images and combining it with a digital elevation model (DEM), a total glacier area of 586 km² for the year 2004 was determined. The observed interannual mass balance fluctuations follow the same trend as the annual mean air temperature, which shows a strong increase between 1999 and 2004. An accumulation area ratio (AAR) of less than 0.43 was determined for 2004 and indicates clear negative mass balance conditions. Mapping the annual evolution of the temporary snow line yields interesting information for mass balance studies and hydrologic research.

This study was made within the ESA project "Hazard Assessment and Prediction - Long term Observation of Icelandic Volcanoes and Glaciers Using Envisat-ASAR and Other Radar Data" (ID 142).

RELATIONSHIP BETWEEN LANDFORM AND PHYTO-DIVERSITY IN THE TURTSMANN VALLEY, SWITZERLAND

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KEY WORDS: landform, biodiversity, vegetation, HRSC, Swiss Alps

High mountain regions present hotspots of biodiversity. They exploit the third dimension over a relatively small area creating different topoclimatic conditions over short distances and therefore, generating high biodiversity.

For nature conservation an actual map of biodiversity within high mountains would be useful to identify areas with a particularly high biodiversity and which need a special protection. As area-wide mappings during field campaigns are very time-consuming and costly, observations with remote sensing could serve as a continuous source for extracting diversity information indirectly by means of spectral as well as topographic data. In the framework of the research training group remote sensing data comprise aerial, satellite as well as DEM data derived from remote sensing information.

The main focus of this study is to analyse the relation between phyto (plant)-diversity and landform at different scales using a DEM from very high resolution data (HRSC) and other remote sensing data of the Turtmann valley, Switzerland. Initially, the relation between geomorphometric parameters and phyto-diversity will be analysed and consequently a model will be developed to predict phyto-diversity from the remote sensing based parameters. In order to set up the model ambitious vegetation parameters were mapped during the field campaign 2005. The study areas were chosen randomly taken into consideration exposition, height, slope and curvature. They were gauged by a differential GPS and mapped using two scales: 2m x 2m and 10m x 10m. All vegetation plots were analysed and categorised into plant communities. Additionally, diversity indices (α -diversity) were calculated for each plot. In a second step, particularly geomorphometric parameters and landform elements, but also spectral and geometric parameters (e.g. texture) were derived from a digital elevation model and remote sensing data (e.g. HRSC) respectively. The parameters were linked to the vegetation pattern using linear correlations. Similar correlations were performed between vegetation mappings and the extracted parameters on a smaller scale. In this contribution the analysis of relationships between phyto-diversity and the parameters derived by remote sensing data will be presented.

QUALITATIVE HAZARD ASSESSMENT OF GLACIER LAKES IN THE HIMALAYAS BASED ON REMOTE SENSING TECHNIQUES

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The high-mountain areas of the Himalayan countries (Bhutan, India, Nepal) have been undergoing dramatic developments in the last decades: (1) intensified impact from rural and urban settlements in the deeply incised valleys with considerable change in land-use, and (2), threat from dramatically retreating glaciers. The present steady and fast glacier melting caused by global warming is responsible for glacial hazards like glacier ice falls, glacier surges, catastrophic debris flows and glacial lake outburst floods (GLOFs) affecting vulnerable settlements up to 200 km downstream the main valleys. Additionally other geo-hazards like landslides and rock falls are a major threat to the vulnerable infrastructure in the Himalayan watersheds.

In the last decades the public awareness of the problem of glacier hazards raised considerably due to catastrophic glacier lake outburst flood events in Nepal (Dig Tsho - 1985) and Bhutan (Luggye Tsho - 1994) devastating the downstream valleys, thereby killing numerous people and destroying vulnerable infrastructure. An inventory of glaciers and glacier lakes of the Indo-Nepal-Bhutan Himalaya based mainly on the interpretation of satellite imagery showed the dimension of the problem. In Nepal 2323 glacier lakes were identified, in Bhutan 2647 glacier lakes were located.

Most of the glacier lakes in the Himalayas were formed after the last glaciation, termed "Little Ice Age" (1550-1850). The receding glaciers left behind large pro-glacial lakes dammed by - in some cases - unstable natural dams (moraines). The actual rates of glacier retreat in Bhutan - as reconstructed from a time series analysis of topographic information and satellite imagery - can be more than 20 m per year. Different triggers like e.g. melting ice cores in the moraines, increasing lake water level and related hydrostatic pressure, groundwater undercurrents and erosion and sudden mass movements into the lakes can lead to a dam burst, discharging millions of cubic meters of water and debris mixture. These GLOFs are highly destructive in nature and lead to long-term environmental degradation and to a high socio-economic loss.

Investigation of glacier hazard risk, prevention, mitigation and remediation measures are difficult to perform due to the remoteness of the source areas. Nowadays satellite remote sensing, due to the wide variety of available sensor products, can play a major role supporting an integrated, interdisciplinary geo-hazard assessment procedure like shown within a co-operation between the Department of Environmental Geosciences of the University of Vienna and the Geological Survey of Bhutan, funded by the Austrian Development Co-Operation. This is especially due to the fact that for most of the high-alpine areas of the Himalayan countries accurate and up to date topographic maps or aerial images are not available.

High resolution IRS-1D satellite imagery in connection with a generated Digital Elevation Model served as a basis for field mapping operations and the extraction of geomorphologic information of the glaciers and glacier lakes. CORONA images, dating back to the early 1960ies, and other available multi-temporal imagery were used for time series analysis and change detection revealing the extent of glacier advance and retreat and the development of glacier lakes and other processes like mass movements. Multispectral LANDSAT-TM satellite data - due to the characteristic wavelength-dependent absorption/reflection features of

materials represented in the spectral response curves derived from the different channels/bands – were utilized for the differentiation of glaciers, snow, water bodies and moraine sediments. The integration of the results of satellite image interpretation with geological, geomorphological and hydrogeological mapping of the lake areas combined with an analysis of dam stability based on geotechnical parameters and information from engineering geophysical methods lead to the definition of hazard scenarios. Based on these hazard scenarios and on the integration of information on process dynamics of previous events, a dam breach and flood wave modeling was performed. This was the basis for the definition of hazard mitigation measures, like the widening of the outlet channels of dangerous lakes, the construction of retention dams or reflection dams, the implementation of hazard zonation maps, indicating the given risk for individuals and infrastructure at a defined location and the definition of the structure of a forewarning system.

ECOLOGY OF THE MOUNTAINOUS ENVIRONMENT AS A COMPLEX SYSTEM

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Modelling and analysis of ecosystems is a formidable and challenging task in every environment. But modelling the ecosystems in a mountainous environment is further difficult. The cause of this additional difficulty stems mainly in the presence and influence of the relief in the behaviour of any parameter we are trying to modelling.

On the other hand, since several years ago, the study of so called “complex systems” is becoming more and more important. The reason of these sort of systems is not a mere “wave” or “mode” but the change of the post-modern scientific attitude that deals with the explanation of the reality with a holistic and multidisciplinary approach since almost every is in some way interconnected.

Complex systems are mainly characterised for non-linearity, self-organisation and near-to-chaos dynamics. All these features are present in the mountainous environment and ecosystems. Therefore, the more appropriate computational tools used in the field of complex systems and still under development, such as, cellular automata, genetic algorithms, neural networks, etc. should be understood and used by modern scientists in the mountainous regions.

The main goal of this paper is to emphasize the importance of the study of complex systems and their particular tools to take them into account in the education of geographers, environmentalist, and also managers of the mountainous landscape.

REGIONAL MAPPING OF REGIONE PIEMONTE USING AIRBORN INTERGEROMETRIC RADAR MAPPING

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KEY WORDS: interferometric, radar, digital elevation model, topography

Intermap Technologies GmbH of Munich and Air Data S.r.l. of Padua recently completed airborne Interferometric Synthetic Aperture Radar (IFSAR) mapping of 5,600 square kilometres of Regione Piemonte in Italy. This landmark regional mapping program, sponsored by the Istituto Geografico Militare (IGM) Italiano, resulted in the most detailed and accurate digital mapping ever created for the mountainous alpine terrain and the head waters of the River Po Basin.

The IFSAR mapping provided two data sets; a digital elevation model (DEM) and an orthorectified radar image (ORI). These data sets will now be used for a wide range of applications, including flood mapping and modeling, landslip modeling, transportation and utility corridor modeling, 3-D scene visualization, topographic mapping, and many other applications. This presentation closely examines the data acquisition, data processing and applications of the data, particularly the high-resolution digital elevation model. Results of independent data validation and verification by the IGM, Italy's national mapping organization, will also be presented.

The Piemonte Project is the initial coverage in Intermap's NEXTMap Italia national mapping program of Italy. The NEXTMap Italia Project is part of the larger NEXTMap Europe Program that will result in the completion of a high-resolution homogenous digital elevation model of Western Europe by 2008.

GLACIER MASS BALANCE AND RUNOFF MODELLING USING SATELLITE DATA

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KEY WORDS: satellite images, glacier mass balance, runoff, modelling

Glaciers are important indicators of climate change and are crucial sources of fresh water in many parts of the world. However, in-situ mass balance studies require significant efforts and resources, and therefore are carried out only on a limited number of glaciers world-wide. Satellites can help to overcome this problem, providing regular repeat observations and global coverage. A wide range of sensors and satellites is available, which offer plenty of opportunities for snow and ice observations, but the use of this information for estimating glacier mass balance and runoff requires appropriate tools. We developed a tool for using satellite-derived information in synergy with meteorological observations to model glacier mass balance and runoff. Multispectral optical and synthetic aperture radar (SAR) satellite data are used to map the extent of glaciers, retrieve surface albedo, and monitor the temporal evolution of snow and ice areas. Surface motion of glaciers is derived from repeat pass SAR images by means of interferometric analysis. A conceptual, semi-distributed model is applied for calculating daily changes of glacier mass and runoff. For model input temperature and precipitation data from meteorological stations are extrapolated to DEM grids and integrated with satellite-based time series of snow and ice extent. The model was initially developed and tested for glaciers of the Eastern Alps, revealing good agreement between simulated and measured mass balance and runoff. For the EC project INTEGRAL the model was also applied to Scandinavian glaciers. The investigations demonstrate the feasibility to estimate mass balance and runoff of glaciers by combining time series of satellite data with meteorological observations.

HABITAT MONITORING IN ALPINE REGIONS BY MEANS OF QUICKBIRD DATA

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Diverse organisations dealing with the protection of the Alps have strong interest in comprehensive, comparable, up to date and repeatable information on the land use/land cover. Whereas the Alpine Convention requires data at a scale of approx. 1:100.000, a national park management organisation needs very high resolution data.

The National Park Hohe Tauern, for example, up to now owns the result of one visual aerial photo interpretation. As time and cost effort for such an investigation is very high, the park management is strongly interested in a cheaper, quicker, and possibly more reliable method which can be repeated more often. The objective is the assessment of the feasibility of high resolution satellite data (in this case QuickBird) for habitat monitoring instead of or in combination with traditionally used orthophotographs. The main focus of the study is the validation of the interpretability of the different geometric resolutions. Additionally, other advantages or disadvantages of QuickBird data are discussed such as spectral, radiometric or temporal resolution, conditions of admission, the possibility of semi-automatic interpretation, archiving, acquisition, and costs. The investigation is based on the same, very detailed, HABITALP nomenclature as used for the existing aerial photo interpretation.

The assumption, that it would be possible to determine a majority of categories in a primary mapping, was verified. As a next step the potential for semi-automatic updating e.g. with respect to wind throw or avalanche damages will be investigated.

LANDSLIDE MAPPING AND HAZARD ASSESSMENT

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Landslide and slope instability are one of the inherent natural phenomena occurring in the mountainous regions around the world. It creates havoc on the people living there creating loss of lives and property. It is mostly associated with earthquake tremors, high intensity and prolonged rainfall over a region and the geological and geomorphological conditions of the ground. This problem is probably nowhere more severe than in the Himalayas.

In order to address the problem more vividly among the people of the region and the world a case study has been taken up for Eduspace's Himalaya from Space module. It deals with the use of satellite remote sensing data especially the MERIS and ASAR data from the satellites of European Space Agency (ESA) and the field knowledge.

The case study provides procedural steps for learning how the landslide mapping and change detection followed by hazard assessment is done using remote sensing data obtained from the space borne satellite data. It may not be possible to prevent landslide hazard. But based on knowledge of hazard, the disaster can be prevented in the vulnerable areas. LEOWorks software and the satellite data of an area in the southern foothill of Bhutan were utilized for mapping and analysis in computer environment.

Bhutan being situated in the totally mountainous Eastern Himalayas which has young and dynamically changing landscape the problem of landslide hazard is more wide spread and prevalent. Most landslides occur from natural causes in the southern foothill belt where the terrain are steep and the rocks underlying the soil cover are highly fractured allowing easy seepage of water. Here, the tropical monsoon climate favours faster weathering of rocks resulting in a greater magnitude of erosion activity, widespread slope instability and mass movements.

Not all slopes have same degree of landslide hazard. The land need to have certain characteristics which contribute to the risk of downhill mass movement of material. These characteristics include slope, active landslide, landuse, type of soil and rock, vicinity to drainage and human intervention areas such as road, settlement etc.

The case study provides exercise on landslide mapping and satellite interpretation for the high school students without using computer tools and with using computer and software tools.

MAPPING POTENTIAL OF ORBVIEW-3 PANCHROMATIC IMAGE IN MOUNTAINOUS URBAN AREAS

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KEY WORDS: OrbView-3, mapping, high resolution, information content, effective ground resolution, object identification

One of the important and recent trend of remote sensing is to generate large scale topographic maps. OrbView-3 is a new-generation and low-cost high resolution remote sensing satellite for this purpose. The available panchromatic image of OrbView-3 with 1 m GSD is used for generation of large scale topographic map of Zonguldak test field where is with very narrow and not regular streets, partially mountainous and surrounding rural areas. Unplanned areas with small buildings, steep and curved roads, sometimes hidden by trees make object identification more complicate. During the study, the GSD is the key value for object identification. Besides the object contrast, atmospheric condition, sun elevation and azimuth, spectral range and multispectral information are other parameters. Caused by the imaging geometry, the multispectral images taken with panchromatic band synchronously are not available, generation pan-sharpened images with GSD value of panchromatic and colour information of multispectral images is not possible. This is the main inadequate characteristic of OrbView-3.

INTEGRATION OF DIFFERENT KIND OF REMOTE SENSING DATA AS A TOOL FOR QUANTITATIVE ANALYSIS OF GLACIER EVOLUTION

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KEY WORDS: Glaciers, GIS, Geodatabase, Climate Change, Remote Sensing

Alpine glaciers dynamics may serve as an indicator of Climate Change. In the Alps glaciers are strongly related to environmental and economic factors, but also to touristic ones.

Since some years, a geodatabase containing data related to some test glaciers evolution since Little Ice Age to present day in the Western Italian Alps, is being developed by some of the Authors. The structure of this database is made with the idea to be easily updated with new surveys and with new sensors data when they' will be available.

In order to fulfil this request we're developing a true temporal GIS able to manage, visualize and analyse the high amount of 4D data.

This geodatabase will be used for different purposes: analysis of mass balance in relation to geographic parameters (aspect, slope, bedrock morphology, ice thickness), moraines mapping and analysis to support field reconstructions, mapping of different kind of features (seracs and crevasses i.e.) to support glacier dynamics analysis. Furthermore, it can be a useful base point for a web-mapping use of this data (environmental paths, geosites descriptions etc.).

Moreover a more integrated quantitative analysis can be carried out by the use of a geosensors network. A geosensor can be defined as a tool to acquire different kind of spatio-temporal data. GPS, total stations, digital cameras, laser scanners can be therefore defined as geosensors.

GIS will be able to integrate this network of several sensor data type, offering to the research an added value in terms of a common ground for the fusion of data and in a forecasting perspective.

**D) PERMAFROST STUDIES AND ROCK GLACIER
MONITORING**

APPLICATION OF ERS INSAR FOR DETECTING SLOPE MOVEMENT IN A PERI-GLACIAL MOUNTAIN ENVIRONMENT (WESTERN VALAIS ALPS, SWITZERLAND)

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KEY WORD: SAR interferometry, permafrost, slope instabilities, rock glacier

Available data on slope movements in mountain periglacial areas is to date only restricted to punctual sites. Regional overviews on landslide and permafrost creep (rock glacier) activity in such areas are often lacking. InSAR (space-borne synthetic aperture radar interferometry) appears to be a potential tool to fill in, at least partially, this gap. In addition to the ESA (European Space Agency) SLAM (Service for Landslide Monitoring) program, the Swiss Federal Office for the Environment (FOEN) intended to test the capability of the ERS (European Remote Sensing Satellites) InSAR technique for detecting and inventorying both location and magnitude of slope instabilities in a mountain periglacial environment, namely the western part of the Valais Alps. The reliability of the results was thus evaluated by comparison with existing and newly acquired field data such as rock glacier inventories, GPS measurements, air-borne photogrammetry, etc.

ERS-InSAR is sensitive to changes in surface topography in the satellite radar line of sight, which is inclined at 23° to the east or to the west. InSAR processing generates 2D “displacement” maps for cm to dm range displacements at cm to sub-cm accuracy. For this project, 34 interferograms (ERS-1/2 images; base line less than 100-150 m; wave length: 5.6 cm) available between 1995 and 2000 have been computed by Gamma Remote Sensing. Time lapse varies between 1 and 1085 days (only multiples of 35 days +/- 1 day, time necessary for the satellites to be approximately at the same position). Coherent results can be obtained between early summer and mid fall (the snow free period) and, for daily time lapse, also in winter when the snow surface still remains cold. They are moreover restricted to areas located above the tree line or sparsely vegetated. Due to the mountain topography (deep valleys, steep rock walls, etc.), many gaps occur in image covering. Steep rock walls do not provide reliable InSAR signals.

The major obstacle limiting the potential of InSAR is the presence of wet snow (fresh and/or old) which strongly disturbs the radar signal. To prevent any misinterpretation of SAR interferograms, estimating the snow conditions at SAR image dates is necessary in a previous step. A second significant limitation of the ERS-InSAR technique is that north and south slopes are not favorably illuminated by the ERS SAR, what decreases the capacity for detecting slope instabilities in such orientations.

The comparison of InSAR data with “terrestrial” data (air-borne photogrammetry and GPS survey) showed an encouraging and often excellent fitting of the results in both magnitude order and spatial pattern of slope motion. The combined use of interferograms with various time lags (1 day, 1-2 months, 1-3 years) appeared to be a useful step for obtaining a complete

overview of potential slope instabilities in a given area of interest. This systematic method permitted moreover to identify not only the location and spatial extent of instable zones but also the magnitude order of the 3D displacement velocities. It was also possible to define typical ERS-InSAR signature depending on the activity and/or type of different geomorphic landform. Indeed, more than 600 polygons were identified as ERS-InSAR-detected slope instabilities within the tested area. The inventory was not an exhaustive list of all the slope instabilities in the area, but an inventory of all areas showing any kind of signal on ERS-SAR interferograms, that can be interpreted as a possible slope movement. Both identification and delimitation of polygons was subjective and obviously might differ depending on user. It appeared that a good experience of the investigated terrain, particularly of possible slope movements, may improve the robustness of the InSAR interpretation.

The resulting inventory of ERS-InSAR-detected instabilities can be seen as a preliminary tool compiled at regional scale which can be useful for further investigations to be carried out (if required) at local scale. It appears to be an attractive perspective both for early natural hazard management and process understanding of slope movement in permafrost areas.

CARTOGRAPHIC PRODUCTION (1997 – 2003) OF THE POPOCATÉPETL (MEXICO) AND THE VENTORILLO GLACIER FOR THE ANALYSIS OF HYDRO VOLCANIC RISKS

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KEY WORDS: Popocatepetl volcano, Ventorillo glacier, cartography, photogrammetry, hydro volcanic risk

The Popocatepetl volcano (5452 m) is situated in the middle of the Transmexican Volcanic mountain range, at less than 80 km between the centre of Mexico City and the city of Puebla. This is elevated from 4000 m, forming a considerably regular cone of some 13 km in diameter at its base.

The cartographic projects realized on the Popocatepetl volcano (crater and Ventorillo glacier) has an objective of contributing to the methodology and the techniques necessary to perform an effective monitoring of the volcano and the possible risks of catastrophe provoked by lahars. The last active volcanic period began December 21, 1994, and is currently still active.

In the period 1997-2003, restorations with stereoplotter were made at a scale of 1/5000 (equidistance of 10 m) of the volcanic cone. For this, the flights made by SCT in November 1997, December 1998, June 1999, November 2000, March 2001, June 2002, December 2002 and February 2003 were used. In addition, cartography with a scale of 1/20000 was obtained of the area surrounding the volcano.

For the production and the cartography, we encountered some inconveniences:

- Aerial Photographs in which the problem exists of smoke emitted from the volcano in such away that it makes the restitution difficult in some areas.
- The summit of the volcano is located at 5540 m and in front of the glacier it is at 4900 m, which provokes different scales of flight for the same cartography. Also, each photogrammetric flight has different scales due to the changes in the altitude of the flight.
- Because of the inaccessibility of the zone, we could not have “control points”. The solution was to turn to existing cartography from 1982 with a scale of 1/10000, from which we obtained the reference points. Given that the same control points have always been used, the relative errors between the different restorations were reduced to 2 m of the absolute orientation.

The cartography was produced using both the “SD 2000” analytical stereoplotter.

With the obtaining of the different temporal cartography, both the evolution of the internal dome of the crater and the loss of volume of the Ventorillo glacier can be observed.

The projects realized in the Popocatepetl volcano (Mexico) are financed in the framework of the national project of investigation "Development of an integrated system for hydro-volcanic hazard prevention" – "LAHAR" (REN2003-06388), of the Ministry of Science and Technology of the Spanish Government.

CREEP OF THREE ALPINE ROCK GLACIERS – OBSERVATION AND MODELLING (ÖTZTAL- AND STUBAI ALPS, AUSTRIA)

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Our study concentrates on three active rock glaciers in the Eastern Alps, where displacements were observed by the comparison of aerial photographs and GPS (RTK) measurements. The structure of these rock glaciers was also explored by geophysical methods (GPR, refraction seismology and gravimetry). Additionally comprehensive geological, geomorphological, and hydrological studies were carried out. The three studied examples are Reichenkar (Stubai Alps), Ölgrube, and Kaiserberg (Ötztal Alps) rock glaciers. The source areas of these rock glaciers are situated at altitudes of 2700 to 2800 m a.s.l. The fronts of the tongues extend down to elevations of 2300 - 2600 m a.s.l. Their total areas vary between 0.22- 0.27 km², the maximum thickness measures 30 - 50 m.

At Reichenkar rock glacier GPS measurements on 37 markers were taken in an interval of one year from 1997 to 2005. A continuous acceleration of 1.8 - 3 m/a was observed at all markers. During summer 2002 a continuous GPS measurement (46 days) shows that the flow velocities (~6 mm/d) are independent from the strongly varying melt water flow and equal to the annual average. Ölgrube rock glacier also shows an increase in flow velocity from 2000 to 2005 (from 0.9 m/a to 1.5 m/a). In contrast to Reichenkar rock glacier the flow velocities of 166 surveying markers show lateral variations and decrease from the toe to the head. For a period of 57 days in summer 2003, daily mean flow rates were significantly higher compared to the daily mean flow rates computed from the yearly data. This indicates significantly less displacements during the winter period. Flow velocities generally increased from 2000 to 2004, but decreased in 2005, a similar pattern to Reichenkar rock glacier. At Kaiserberg rock glacier 112 surveying markers were observed in 2002, 2003, and 2004. The average flow velocities vary from 0.4 to 1 m/a on the western and central part of the rock glacier. The measurements do not show any significant increase in flow velocity.

Models of the internal structures of the rock glaciers were derived from integrated geophysical studies (thickness and density of the debris layer, thickness and debris-content of the frozen core). On the basis of these geophysical models and the rheology of ice the observed creep velocities were successfully modelled. During the last decades the thickness and inclination, and therefore the internal states of stress of the rock glaciers did not change significantly. Therefore, the increase in creep velocity is assumed to be a consequence of either higher internal deformation due to higher temperature, or of higher basal sliding due to higher pore water pressure. Support for the theory that higher internal deformation of the frozen core due to higher temperatures caused an increase of flow velocity comes from the observation that the P-wave velocities of the accelerating rock glaciers (Reichenkar, ~3300 m/s; Ölgrube, ~3600 m/s) are below the P-wave velocity of pure ice (3750 m/s), and the P-wave velocity of the steady rock glacier (Kaiserberg, ~3900 m/s) is above. P-wave velocity below the velocity of pure ice indicates reduction of the solid (frozen) contacts between ice and debris within the frozen core and formation of a water film along these contacts.

PARAGLACIAL TALUS INSTABILITY IN RECENT DEGLACIATED CIRQUES:
SCHOBER GROUP, AUSTRIA

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KEY WORDS: Small-scale lobated landforms, Glacier changes since the LIA, Paraglacial slope processes, Permafrost and buried glacier ice, Central Austrian Alps

The withdrawal of glacier ice commonly exposes a landscape that is susceptible to rapid morphological changes as well as to the formation of permafrost in topoclimatic suitable locations. In such a paraglacial environment (i.e. environment formed by nonglacial processes that are directly conditioned by glaciation and deglaciation), the spatial extent of ice-free areas causes destabilisation of rock faces and debris slopes above a glacier and consequently potential debris release. Thus, the input of debris on top of the retreating glacier and on ice-free areas at the foot slope increases. This paper presents observations on the paraglacial reworking of debris in two recently deglaciated and neighbouring cirques in the Schober group, Hohe Tauern range, Central Austrian Alps (N46°59' E12°47'). During the Little Ice Age advance (c.1850), both studied cirques - Hinteres Langtal cirque (HLc) and Kögele cirque (Kc) - have been covered by small glaciers and large perennial snow fields. Since then, these cryospheric landscape elements disappeared almost completely. The evolution of the extent of areas covered by glaciers and perennial snow has been reconstructed for the years 1834, c.1850, 1872/73, 1928/29, 1969, 1982, 1997 and 1998 by using morphological evidences (terminal and marginal moraines), historical maps, and aerial photographs. Today, only small areas of superficial glacier ice and perennial snow patches are found in radiation-sheltered locations. In both deglaciated areas, a number of vegetation-free small-scale lobated landforms (HLc: n=12, Kc: n=9) have evolved from the slope sediments during the last decades. Spatial distribution, geometry, analyses of clast samples, and possible genesis of the features is discussed. These landforms are only found on northern expositions (NW, N and NE) and are very active according to their fresh geomorphic appearance. Morphometric studies reveal heights of the frontal slope (1-6m), lengths (38-125m), widths (13-34m) and areas (700-3700m²). Clast analyses (shape, size, lithology) at selected lobes show a predominance of very angular to angular platy mica-schist. Average long-axis to short-axis ratio is between 1:0.23 and 1:0.31. Clasts have generally more elongated and slabby shapes typical for periglacial weathered products. Mean values of long-axis and short-axis are 25-45cm and 6-14cm, respectively. In close neighbourhood to the described lobated landforms, debris slopes show no signs of deformation due to a different lithology in the rock wall above (less-jointed mica-schist, gneiss, quartzite-lenses and amphibliote) producing coarser weathering products. The differences in slope material indicate that finer-grained material favours the formation of small-scale lobated landforms, whereas coarse-grained debris slopes show no sign of lobe formation but nourish blocky landforms (block slopes, rock glaciers) instead. It is assumed that ice occurs underneath the lobes at both studied cirques. In the more radiation sheltered locations (annual potential short-wave radiation/PSWR <1600 Wh/m²) remnants of buried glacier ice partly exist underneath the lobes closed to the surface; the unconsolidated material covering the ice acts as a thermal insulator. Such lobes can be considered as supraglacial features. In contrast, near-surface ice is absent at less radiation-sheltered lobes (annual PSWR >1600 Wh/m²). Due to

their altitudinal (lower limit c.2700 m. a.s.l.) and topographical position (NW, N, NE expositions) it is most likely that they are underlain by permafrost, thus, they are periglacial features. At such locations the question arises which processes cause the lobe formation, i.e. what is the correct term of the landform: (i) active layer processes, thus, stone-banked solifluction lobe, block stream or creeping scree slope or (ii) creeping permafrost, thus, a small rock glacier in its initial phase? It can be concluded that similar looking small-scale lobated landforms may form on slopes underlain by permafrost as well as on buried remnants of glacier ice.

MAPPING OF THE 3D SURFACE MOTION FIELD OF DOESEN ROCK GLACIER
(ANKOGEL GROUP, AUSTRIA) AND ITS SPATIO-TEMPORAL CHANGE (1954 – 1998)
BY MEANS OF DIGITAL PHOTOGRAMMETRY

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KEY WORDS: Permafrost, rock glacier, long-term monitoring, flow velocity, digital photogrammetry, image matching, Doesen rock glacier, Hohe Tauern range, Austria.

Doesen rock glacier (46°59'N, 13°17'E, altitude range 2350-2650 m, width 150-300 m, length 1000 m) is located in the Ankogel group of the Hohe Tauern range in Austria. The rock glacier has been the subject of multi-disciplinary research work since 1994. For example, the kinematics of Doesen rock glacier has been studied by means of geodetic surveys and remote sensing techniques, i.e., photogrammetry and satellite-based differential SAR interferometry.

As far as photogrammetry is concerned, the 3D motion field of Doesen rock glacier was obtained from multi-temporal aerial photographs from various epochs between 1954 and 1998. This heterogeneous set of photographs was evaluated twice, (1) by means of visual tracking of prominent surface particles (boulders) in the 3D stereomodels and (2) by applying automatic image matching techniques. The latter method, however, was not successful from a practical point of view, since the photogrammetric scanner used for digitizing the aerial photographs introduced geometric errors in the scans which could not be eliminated during the evaluation process.

The present paper describes a second attempt to apply the same algorithms (ADVM software) to the newly digitized aerial photographs, this time using an UltraScan 5000 photogrammetric scanner of Vexcel Imaging Austria. We will briefly outline our approach of measuring 3D displacement vectors, and the practical work and the results obtained will be presented. A comparison of the results of the two photogrammetric evaluation processes, i.e., manual mapping and image matching, is also planned. The paper will conclude with a more precise re-interpretation of the 3D motion field of Doesen rock glacier and its spatio-temporal change.

SHORT-TERM CHANGES IN SURFACE VELOCITIES ON THE BECS-DE-BOSSON ROCK GLACIER (WESTERN SWISS ALPS)

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KEY WORDS: rock glacier dynamics, surface velocities, GPS, Swiss Alps

The observation of the short-term activity of the BeCS-de-Bosson rock glacier (BBrg) was initiated in 2001. Surface displacements have been surveyed by means of real time kinematics GPS (RTK/GPS). Significant changes in surface velocities have been recorded from year to year and also at a seasonal time-scale.

BBrg is an active rock glacier part of the PERMOS (Permafrost Monitoring Switzerland) program. Photogrammetry analysis of high resolution aerial pictures (1986-1999) revealed that the rooting zone of BBrg, which was covered by a glacier during the Little Ice Age and where permafrost is currently lacking, is not moving. The rock glacier comprises two lobes. Maximal superficial horizontal motion of the main lobe (L1) reached 1 m a-1, whereas its frontal section is not moving significantly. L2 is a rapidly moving smaller lobe where horizontal velocities decreased from about 1 m a-1 in the upward section to about 0.6 m a-1 on the front. Loose sediments in front of L2 are being strongly deformed by the rock glacier advance. A significant increase in velocities occurred between the period 1986-1991 and 1991-1999 (Kääb 2005).

Since 2001, GPS measurements have been carried out yearly in autumn. At first, 61 blocks have been surveyed on the front of the two lobes of BBrg. On L2, horizontal velocities, which were already about 50% greater in 2001-2003 than those observed by photogrammetry between 1986 and 1999, still increased of 10-15% between 2001-2003 and 2003-2004 before to drastically drop in 2004-2005 (5-13% slower than in 2001-2003, but still significantly faster than between 1986-1999 and even 1991-1999). The network was extended in 2004 to the whole rock glacier. It revealed annual horizontal velocities that were significantly faster in 2004-2005 (up to two times) than over the period 1986-1999 in most of the median and lower sections of BBrg, whereas they were much lower in the uppermost section of the moving area.

Since July 2004, GPS survey has been performed at monthly interval on L2 front. The measurement network was then extended gradually in October 2004 and in January 2005 (80 new points) to the whole moving area of the rock glacier. Large boulders were often chosen as marks in order to allow the survey to be performed during the winter season. In 2004, maximal velocities occurred during late summer and stayed high until January 2005 before suffering a strong decrease until April-May (50 to 80% of reduction). The horizontal movement increased then again rapidly in late May to reach values that remained high until at least December 2005 (last survey). Summer/autumn velocities were most often 10 to 40 % slower in 2005 than in 2004.

From the data available on BBrg at present and according to the delay and attenuation of surface-induced heat transfer with depth, a preliminary conceptual model of the vertical structure of the BBrg dynamics can be inferred. Three gradually superposed (deeper, intermediate and upper) zones can be distinguished reacting with different time lag to changes

in ground surface temperature. The deeper zone (at 15-30 m depth ?), where should be located the typical “shear zone” of the rock glacier, is sensitive to decadal changes in permafrost temperature. The trend to an increasing rock glacier activity since 1986-1991 may be consecutive, at least partially, to an increase in permafrost temperature in the deeper layer of the rock glacier. On BBrG however, the drop in velocities in late winter 2005 showed that only less than 50 % of the total horizontal surface motion is currently due to the deeper deformation. Deformation in the intermediate zone (5-15 m depth ?) reacts notably to interannual changes in mean annual ground surface temperature (MAGST) with a lag of about one year. Ground surface temperature measurements on BBrG thus show that both the maximal activity in 2003-2004 and the decrease in (summer) velocities in 2005 can be related with a one-year lag to the “MAGST heat wave” observed in 2002-2003 and the severe MAGST decrease in 2004 and early 2005, respectively. Finally, the significant variations in seasonal rock glacier activity, that occurred with a lag maximally restricted to a few months in winter have to be related to changes in deformation rate occurring in layers close to the surface (upper zone, above 10 m depth ?). On BBrG, the rapid increase in velocities in May-June 2005 appears to have been synchronous with the percolation of snowmelt water in the uppermost layers of the ground.

Reference:

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**E) HIGH MOUNTAIN CARTOGRAPHY AND 3D
RELIEF DEPICTION**

CERRO ACONCAGUA SAT-MAP

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KEY WORDS: cartography, high mountain, Aconcagua, image map

This paper/poster discusses the integration of various remote sensing based data (SRTM, LANDSAT and ASTER) for generating a topographic/tourist map (combine image line map) of Mt. Aconcagua (Argentina). Due to the lack of appropriate official topographic maps (1:50.000) Remote Sensing data are the only source which can provide adequate topographic and thematic information. The investigation area is located in the midst of the Central Andes in the Aconcagua Provincial Park (Argentina) with Mt. (Cerro) Aconcagua (6962m) is the highest mountain in South America and reaching out up to Argentinean-Chilean-Bolivian Border. The aim of the project is to provide a satellite based image map of the entire Aconcagua Mountain region in scale 1:100.000.

The hybrid workflow of the cartographic process, the methodology, advantages and disadvantages of High Mountain Environment Remote Sensing applications will be discussed and presented.

ABOUT LIFE AND WORK OF A PATRIARCH OF AUSTRIAN ALPINE CARTOGRAPHY

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KEY WORDS: Cartography, digital terrain model, mapping, topographic photogrammetry

The above mentioned patriarch is Leonhard Brandstätter, maybe the last important scientific representative of traditional alpine cartography. His life was dedicated to the idea of creating maps for practical use under the aspect of using exact data of terrestrial and airborne photogrammetry without neglecting any detail of evaluation, that means, without arbitrary generalization.

However, this rigorous principle imposes some difficulties, especially in the rocky areas of geologically young fold mountains because of steep slopes. The solution of the problem was the so-called „substitution of close contour lines“. Its meaning and the possibilities of representation will be explained in the paper. Besides of this feature, edges and slope-dependent hatchings and shadings are applied, in order to show the relief as clearly as possible. Hence, this way of cartographic mapping is a pure geometric method and could be automated up to a certain point, using a digital terrain model.

Our patriarch, after an eventful life, lives now in his home town in Carinthia and will have his 100th birthday this year. Therefore, the paper also is meant as a dedication to a remarkable journey through 100 years of life.

GEODESIC AND PHOTOGRAMMETRIC TECHNIQUES FOR THE CARTOGRAPHIC PRODUCTION AND THE OBSERVATION OF THE GEOMORPHIC DYNAMIC OF THE CORRAL DEL VELETA ACTIVE ROCK GLACIER (SIERRA NEVADA, ESPAÑA)

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KEY WORDS: Active rock glacier, geodesy, global positioning system, photogrammetry, Corral del Veleta, Sierra Nevada.

The southern most active rock glacier in Europe can be found in Sierra Nevada and the highest peaks in the Iberian Peninsula. The Corral del Veleta rock glacier can be found in the interior of the old cirque glacier that borders, with a northern orientation, The Veleta peak (3398 m asl). This rock glacier exhibits dimensional redundancies: 120 m longitude, 3700 m² of surface area, its front is situated at an altitude of 3090 m asl. The study of this rock glacier is especially interesting because of its meridional location in the European context (37° lat. N) and for its proven rapid morphodynamic response to the current environmental conditions (thermic and snow). The temperature of the surface of the ground in the summer months (July and August) can reach 27°C and the annual thermic amplitude 43°C.

At the present time, two main types of geomatic analysis are being carried out on the rock glacier: the production of detailed cartography and observation of the geomorphic dynamic (displacement, sinking). Since 1995, geomatic observations have been carried out; although with a constant and systematic character only since 2001 (five campaigns). In order to perform this analysis, geomatic techniques have been employed: terrestrial photogrammetries (land photogrammetric camera), classic geodesy (total station) and Global Positioning System (GPS-RTK).

1. Cartographic production of the rock glacier: The technique employed to obtain the detailed cartography was photogrammetries with which maps with the scale of 1/2000 and equidistance of the curves of 1 m have been generated. Neither the computer programmes of the analytic restorers nor the conventional digital restorers show problems when the photographs of the stereoscopic pair are “almost” parallel to each other and “almost” perpendicular to the stereoscopic base, this is what is known as the “normal case of photogrammetry”. This condition is difficult to obtain in high mountain field work, where the photographic shots (“Rollei metric 6006” photogrammetric camera) must be obtained manually from the Veleta peak, making the photographic shots both inclined and convergent.
2. Observation of the rock glacier dynamic: The classic geodesy and GPS were employed in the calculation of the glacier dynamic. Marks on large boulders and 35 rods located on the rock glacier are controlled (the displacement of each reference points is supportive of the rock glacier dynamic). The geodesy technique and GPS show similar results, with differences less than 3 cm in (X, Y, Z) of the reference points. When the use of GPS produces errors (PDOP), the point is re-measured using the “reoccupation” technique.

The future geomatic study of the Corral del Veleta rock glacier is focused on two lines of investigation:

1. Determination of the movement of the rock glacier in the winter period (existence of snow cover) and its dynamic in the summer period (snow cover is nonexistent and the environmental temperature is elevated).
2. Search for mathematical formula that relates the rock glacier dynamic to the climatic conditions (temperature, snow cover). But to do this, the availability of greater periods of field observation would be necessary.

AN ASSESSMENT OF ASTER ELEVATION DATA OVER GLACIATED TERRAIN ON POURQUOIS PAS ISLAND, ANTARCTIC PENINSULA

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The along-track stereo capability of ASTER satellite imagery provides a relatively efficient option for generating digital elevation models (DEM) compared to in situ and airborne techniques. This is an especially attractive technique for inaccessible glaciated regions of the Antarctic Peninsula. This poster presents the results of ongoing work by the British Antarctic Survey to determine the accuracy of elevation data from ASTER imagery for glaciated terrain in Antarctica. The work evaluates both the standard ASTER DEM product generated by the US EROS Data Centre and a DEM generated in-house using Leica software. The study area is Pourquoi Pas Island on the western Antarctic Peninsula, at approximately latitude 68° South, which contains a range of terrain types including both glaciated and steep mountainous terrain. Our control data consists of manually generated DEMs for the study area, based on a set of colour aerial photographs together with GPS measured camera frame centres and a set of highly accurate ground control points for geo-referencing. The errors in this data set can be regarded as significantly smaller than for the ASTER DEM and is therefore a suitable reference DEM. We measure the accuracy and effectiveness of the DEMs from ASTER data for a number of terrain types in the study area and assess their effectiveness for a number of applications such as topographic mapping, glaciology and geology.

CONTINUOUS DATASETS FROM SATELLITE IMAGERY FOR LAND COVER MAPPING IN MOUNTAIN CARTOGRAPHY

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The traditional depiction of land cover classification uses discrete, hard categories that are mutually exclusive. Remote sensing techniques exist to derive sub-pixel classification and continuous variables, these have proven to be fairly robust and accurate, yet few cartographic products or techniques have been developed to depict these more structurally complex datasets. Two maps of Gannett Peak, in Wyoming's Wind River Range (1:24,000 & 1:63,360) are used to illustrate new techniques and datasets and to propose that landscape characteristics can be used to guide land cover depiction and the choice of classifiers. A hybrid approach in which land cover elements with abrupt discontinuities such as hydrology and agriculture are depicted using traditional hard boundaries and soft transition and naturally occurring gradients such as altitudinal vegetation changes are depicted using continuous variables is illustrated. The use of a dasymmetric approach to soften a hard classification obtained from image segmentation is also illustrated and the limits and potential of object oriented classification is discussed.

SATELLITE IMAGE AND RELIEF REPRESENTATION

A CONTRIBUTION TO THE THEORY OF MOUNTAIN CARTOGRAPHY

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Problems of the Topic

Visualisation has to be visually conceivable (possibility for perception). In the field of mountain cartography this is not obvious in any case. Natural landcover, manmade objects, relief, names and possibly thematic facts have to be represented. The most important element in this assembling is the relief, for this feature distinguishes mountain cartography from other cartographic topics.

Relief Representation

This has a very long tradition. Nowadays the following elements are used:

- Equidistant contour lines as primary representation elements,
- Monochrome hill shading as secondary elements. In the last years further methods came to the fore such as
- Color (or greyscale) coded relief representation and
- True 3D-visualisation using lenticular technology.

For the representation of all elements in high mountain areas, the first two methods are used for large scale ground plan mapping in practice; the other methods are in the stage of research and development.

Interpretation of Map Examples

To verify this statement, four map examples from the Annapurna area in Nepal (1986, 1990/91, 1991 and 2005) are quoted and discussed. Concerning the totality of elements for high mountain features none of these maps is 100% satisfactory.

Vision of Solution

Two different possibilities using remote sensing data or derivatives from satellite images are recommended to enlarge the visual perception.

- The pictorial representation of the relief is the primary element. In this case the visualisation of image-elements combined with line-elements is easier to interpret.
- Dispersion of visual information

All elements for representation have to be stored only in layers of the digital intermediate product. Corresponding to the target only a selection of these layers should be visualised.

F) HYBRID SOLUTIONS OF GIS AND RS

CLUE-COMPLEX LANDSCAPE UNITS FOR ENVIRONMENTAL ASSESSMENT AND MODELLING

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Landscape composition and configuration are important factors influencing ecosystem function and habitat quality (Turner, 1989). Although terrain analysis is extensively used for practical purposes, it seems not to be too much addressed in Landscape Ecology even if topography is a key variable in a wide range of environmental processes (Bates et al., 1998). Topography shapes pattern indirectly through its influence on disturbance regimes and potential succession of the pathways, and directly, by creating permanent natural breaks in vegetation pattern.

The classic way to incorporate relief units into a model is to delineate them during field survey, or to interpret stereo aerial photographs. However, this approach is time consuming and a researcher often needs parallel skills to perform it.

During the last two decades, the DTM data availability has been continuously increasing, data accuracy has been improved, and many algorithms have been developed to derive new attributes from grid-format DTMs (Burrough et al., 2000). Increasingly GIS performances have made 3-D analysis operational even for large areas, but methodological approaches regarding comparable geomorphologic classification systems are still pending. Basically, these approaches rely on remote sensing techniques among which unsupervised methods (e. g. cluster analysis) have gained supremacy in landform elements or facets classification. Interesting results are provided by attempts to improve cluster analysis methods using generalization algorithms (Friedrich, 1996, Romstad, 2001) or to apply fuzzy logic to relief data (Irvin et al., 1997, de Bruin and Stein, 1998, Burrough et al., 2000, MacMillan et al., 2000). However, pixel-oriented approaches are limited in some aspects as Blaschke and Strobl (2001) pointed out.

A turning point in classification of geomorphologic elements is the concept of object-oriented image analysis, operational in the eCognition software. Several applications of this new concept to extract geomorphologic units were successfully developed (Strobl, 2001, Blaschke and Strobl, 2003, Blaschke and Dragut, 2003, Dragut and Blaschke, in press, Schneevoigt et al., in press).

Here these issues will be addressed by developing and testing a new methodology for the integration of landform elements within the landscape definition, using geographic information systems (GIS), remote sensing techniques, digital elevation models (DEM) and satellite imagery. The overall objective is to develop and test a methodology to integrate landform elements within the landscape definition, in order to better define and quantify its 'spatial context'. The resulting three-dimensional landscape units (or facets) will be tested and then used as basis in habitat modeling and assessment through landscape metrics applications. The methodology resulting from the proposed project has the potential to make landscape metrics applications more realistic by including landform elements in the definition of analyzed spatial units. Thus, the analysis of landscape spatial pattern and the ecological interpretation of landscape metrics should increase in accuracy, especially in topographically complex areas, in order to accomplish monitoring and management tasks in the context of NATURA2000 in Europe.

So far, a semi-automated classification system of landform elements based on object-oriented image analysis was developed. First, several data layers were produced from Digital Terrain

Models (DTM): elevation, profile curvature, plan curvature and slope gradient. Second, relatively homogenous objects are delineated at several levels through image segmentation technique. These object primitives are classified as landform elements using a relative classification model, built both on the surface shape and on the altitudinal position of objects. The classification has nine classes: peaks and toe slopes (defined by the altitudinal position or the degree of dominance), steep slopes and flat/gentle slopes (defined by slope gradients), shoulders and negative contacts (defined by profile curvatures), head slopes, side slopes and nose slopes (defined by plan curvatures). Classes are defined using flexible fuzzy membership functions. Results were visually analyzed by draping them over DTMs. Specific fuzzy classification options were used to obtain an assessment of output accuracy. Three implementations of the methodology were compared using (1) Romanian datasets, (2) Berchtesgaden National Park, Germany, and (3) Ozark Mountains, Arkansas, USA. The methodology has proven to be reproducible; readily adaptable for diverse landscapes and datasets, and useful in respect to providing additional information for geomorphological and landscape studies. A major advantage of this new methodology is its transferability, given that it uses only relative values and relative positions to neighboring objects. By using supplementary layers in the segmentation process, the method could be targeted to a great number of applications that need semi-distributed models (e.g. risk assessment).

THE DIVERSITY OF NATURE AND HOW TO MANAGE IT WITH
GEOTECHNOLOGIES. EXPERIENCES IN SUSTAINABILITY GOT FROM FIELDWORK
IN HOHENTAUERN

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Nowadays the measuring and valuing of the natural environment resides in the centre of interest of geographic researchers. In most of that cases the grade diversity (Biodiversity for the biotic or Geodiversity for the abiotic branch) can be used to quantify the value of the as-is state of the environment and to describe the relevant elements of the landscape's inventory. With other terms: The focus of sustainability and the goals of sustainable acting are seriously influenced by diversity of nature respectively their indicators.

Furthermore, dealing with diversity and sustainability in general has brought up a need for so called sustainable approaches as well as for an adequate (of course sustainable) set of toolboxes. This concept can be applied also in more detailed regional scales and particularly in high mountain environments where human and natural sphere typically are influenced by each other in a very intensive way.

Therefore, spatially referenced data material and the knowledge about how to work with it can be seen as fundamentals of diversity acquisition and management; according to this higher education in that field of research first of all has to provide an highly integrated introduction in GIS/RS/Mapping toolboxes and their application during intensive, methodically interlocked field campaigns. On these mandatory field trips the students have to elaborate special thematic packages of their choice, which might work as indicators for diversity and development of a region. In a vertical way of sight all characteristic elements of Geo- Technologies (acquisition, management, analysis and visualisation of spatially referenced data) have to be employed to perform the most important tasks of diversity research, actual state audit, change detection and conservation.

ASSESSMENT OF HIGH ALTITUDE PASTURE DEGRADATION IN SOUTH TIBET
SUPPORTED BY LAND COVER MAPS AND DIGITAL TERRAIN MODELS
DERIVED FROM ASTER SATELLITE DATA

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This paper will describe the experiences in the application of GIS and remote sensing for degradation assessment of pastures near the PekuTso lake (4500m).

The initial points for this study were reports about snow catastrophes and pasture degradation in Tibet. The causes of pastureland degradation are complex and varied, but land use changes among pastoral communities certainly play a crucial role. A case study was carried out in Porong (Nyalam County, Shigatse Prefecture) to assess the condition of pastures and to identify causes for its degradation, as well as to develop management strategies in a participatory way.

The first step is an inventory of the contemporary pasture vegetation according to dominating plants, pasture quality and pasture management. GPS had been used to geo-reference the vegetation data recorded during the field excursions of 2001 and 2004. Additionally a comparison of historical land use will be carried out according to documents from the region dating back to the 18th century, which record pasture boundaries, taxation rates and stocking rates, and contemporary boundaries and management practices.

The data were transferred to a geo information system (GIS) to visualize their location and their extension. But for most of the recorded vegetation zones no geo-information about their boundaries is available, because the different pastures are distributed over a wide area and are of difficult access. To delimitate the different areas and to analyse the spatial correlation between the different pasture areas collateral information is necessary.

ASTER satellite data were used to produce land cover maps as well as digital terrain models (DTM) of this remote, arid region.

The following topics will be discussed in detail:

- Methods of rapid assessment of pasture conditions used in the pilot project
- Constraints in the correlation of RS land cover classes and real land coverage due to the manifold limitations in gaining access to data for this region
- Difficulties in producing a usable DTM based on ASTER 1B data
- Possibilities for investigations on pasture vegetation and management by extrapolating the results achieved on a regional scale to larger areas.

USING A GEOGRAPHIC INFORMATION SYSTEM TO ANALYZE AND DISPLAY
BREEDING BIRD HABITAT DATA UTILIZING IMAGE BASE MAPS FOR
DECISION MAKING RELATED TO LAND MANAGEMENT

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The purpose of this study was to lay out a statistically valid sample grid and sample that grid to determine breeding bird occurrence, distribution, and habitat characteristics within Canaan Valley State Park, West Virginia. A graphical representation of the data was generated using a geographical information system (GIS) for identifying potential environmental impacts to these resources caused by factors such as land use specific to park events, new trail development, and habitat management.

A 250-meter grid was overlaid on a 7.5-minute USGS quadrangle using GIS. The centers of the grids were established as potential sampling points. The grid was oriented by selecting a random point on the map and rotating the grid a random number of degrees using the initial point as the axis. Sampling points were then selected systematically (every other point) using a random start. Points falling within highly developed or altered areas or open water were eliminated for sampling. Sampling points were not stratified by habitat, and those falling on divisions between two different habitat types were not rejected. A total of 162 individual points were selected for sampling within the boundaries of Canaan Valley State Park. All points were sampled once during June 2002 and again during June 2003.

UTM coordinates were generated for each sampling point. Sampling points were located in the field using a GPS receiver, topographic features, and plant community maps (aerial photographs). Sampling points were identified in the field using temporary markers during 2002.

Bird species and numbers present were recorded at each point using a fixed radius, independent double observer point count protocol. This protocol addresses the probability of detecting a bird when present.

Vegetation type and structure were recorded at each point within a 50-meter radius of each point. Dominant species were recorded for canopy, understory, and shrub layers. Cover density was estimated and scored as absent, sparse, moderate, or dense.

Analysis of the data allowed for the graphical representation of breeding bird occurrence, distribution, and habitat characteristics. Layered digital maps were created identifying such elements as vegetation density, vegetation type, and breeding bird richness and diversity.

Maps generated can be used by land resource managers to make decisions concerning potential environmental impacts on sensitive areas and breeding bird species. Impacts may result from special events, development within the park such as expansion of the golf course or ski slopes, and new trail development. Graphical representation allows the manager to view the actual area of possible environmental impact.

The geographic information system allows for the addition of future layers that contain information on other plant and animal communities within Canaan Valley State Park, West Virginia. This would broaden the knowledge base of the land manager, allowing more informed land management decisions.

INTEGRATED USE OF GIS AND REMOTE SENSING (A GEO-SCIENTIFIC APPROACH) IN SUPPORT OF AGRICULTURE DEVELOPEMENT AND PLANNING

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KEY WORDS: Geographic Information System (GIS), Remote Sensing (RS), Databases, Agriculture Planning and Food Security

Nepal due to its mountainous topography and located in Himalayan range, is blessed with a diversified agricultural potentialities, wide range of farming system varying from temperate to sub-tropical climate. About 83 percent of the total land is either covered by mountains or high mountains. Nepal's rural development is also largely focused on sustainable agriculture, which now demands appropriate product and sustainable management of land resources. The land is the most valued natural resource of Nepal which is either over exploited or under utilized due to poor and conflicting resource management. The ability of land to produce food is limited. The limited or low productivity is often blamed for poor resource management and planning. Comprehensive planning for agriculture is becoming increasingly important to ensure a sustainable future for agriculture, poverty alleviation through food security programme. The integrated use of GIS, RS and GPS is well recognized and powerful in accessing, evaluating, managing and monitoring of resources considering their spatial distribution. The use of GIS as a decision support tool has tremendous advantages especially for planner and decision makers for burning issues on food security as well as poverty alleviation in the developing countries like Nepal.

Despite the wide use of GIS and RS technology in various geo-scientific activities in today's world, its use in Nepal particularly in agriculture development and planning has been virtually limited and still not been fully harnessed. Among many potential users of this technology in our country Nepal, Ministry of Agriculture and Co-operatives is one of the principal users, having the responsibilities to carryout nation's agricultural related research and development activities.

Importance of integration of these data have been overwhelmingly felt with rapidly increasing pressure of population, which in turn creating excess stress in the environment and depletion of natural resources. An integrated approach of a strong database and GIS technology became effective tool for sustainable development of the country.

The widely used software in GIS environment (ArcInfo/ArcView, ArcGIS, Internet GIS, Image Processing Software ERDAS, ENVI etc) provides tremendous scope for creating GIS based database for planning purpose. ArcInfo has been used for the spatial data conversion by manually digitized topographical map sheets and then converting into transverse projection. Also, ArcView is an important management tool for land resource and agricultural planning.

The classification of land parcel into different spatial units based on climatic variability, soil properties, water availability and crop management practices etc would help in identifying the suitable pocket areas for crop production. Therefore, accurate inventory of current land use, biophysical resources, infrastructure networks, socio-economic situation etc are the pre-requisite for realistic planning.

The most significance applications of these tools in land resource management and agricultural planning are considered to be:

- Agro - ecological zoning
- Land suitability mapping involves identifying land use patterns and assessing LUT suitability and gives suitability in relative terms.
- Integrating time series data of agricultural statistics into map, which could be useful in planning
- Crop modeling, including soil/water requirement, assessing soil properties etc
- Building Agricultural Land Management Scenarios with GIS
- Agricultural monitoring and food security
- Estimation of Crop Area and Yield, crop conditions and early warning alerts with integration of GIS and RS
- Crop information including cropping pattern and crop calendar.
- Disaster monitoring and assessment of crop damage by disaster and other natural calamities.
- Environmental Impact Assessment

This paper is intended to conceptualize our organization mission/vision in integrated use and applicability of these tools (GIS and RS) in agriculture development planning with due emphasis on

- Agri-ecological zoning
- Land use planning
- Food security Strategy development

At the meantime, the efforts made so far in the promotion and advancement of GIS and RS in the field of agriculture specifically in mountain farming system will be explained. This paper also highlights the present status and strength of the Ministry in interpretation of available data (Remotely sensed data, Topo map, Analogue map, Aerial Photographs etc) and lab facilities for digitizing, scanning, and plotting as well as interpretation of aerial photographs, satellite images, and image processing for the preparation of user friendly maps.

**G) METHODOLOGICAL IMPROVEMENTS
CONCERNING HMRSC**

USE OF TOPOGRAPHIC FEATURES FOR THE GEOMETRIC CORRECTION OF LANDSAT TM IMAGES

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KEY WORDS: geometric accuracy, Landsat TM, topographic features

The analysis and interpretation of remote sensing imagery requires many corrections enabling the minimization of geometric and radiometric distortions generated by the acquisition system. The image corrections are a prerequisite in any multitemporal approach and they became fundamental in the mapping of land cover and change detection.

In particular geometric distortions are not only related to the sensor and imaging geometry but also to the topograph.

The main goal of this study is to consider the topography effects on the geometry of satellite images. In particular the proposed procedure allows for assessing the geometric accuracy obtained through different correction processes performed on the Landsat 5 TM data.

The topographic features extracted from a DEM were chosen to define different GCP selection criteria in a study area of northern Italy characterized by a complex orography.

For each test a set of 60 GCP's with different spatial distribution was selected on black & white ortho-photos in order to georeference and ortho-rectify a Landsat TM image and the accuracy of geometric corrections was checked.

The obtained results suggest the opportunity of performing additional tests and further investigation.

FOREST CANOPY ESTIMATION USING K-NEAREST NEIGHBOUR ALGORITHM IN MOUNTAIN REGIONS OF NORTHERN SICHUAN

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KEY WORDS: k-NN, forest canopy estimation, RUSLE, Upper Minjiang, Sichuan

The k-NN was used in the estimation of the forest canopy cover and land cover indices needed for erosion risk mapping in the Upper Minjiang Watershed region, Northern Sichuan China. The estimations are based on field sample plots, auxiliary GIS data and remote sensing information. The field study was conducted in the area over a three month period during the summer of 2004. The field measurements were used to define optimal parameters and reduce biasness of the k-NN technique and help in the estimation of canopy closure for Landsat TM7 image pixels. The parameters used in the calibration process include: number of nearest plots, elevation and digital elevation model derived parameters, and the use of stratified satellite imagery data based upon auxiliary data. The resulting canopy closure was used further in erosion risk assessment within the watershed. With the sampling intensity and geographic considerations (mountain ranges) included the geographical ranges (horizontal and vertical ranges) were found to be optimal with a search radius of 60 – 80 km. The differences in vertical distance were not significant for canopy closure, because number of nearest observations in vertical dimension were limited. The use of sampling data from outside this region increased the bias in the estimation. Output can be used for defining C-factor in regular RUSLE erosion risk mapping.

THE SURPLUS OF KITE AERIAL PHOTOGRAPHY (KAP) IN HIGH MOUNTAIN MICRO-SCALE CLIMATOLOGY

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KEY WORDS: Kite aerial photography (KAP), water balance, climatology, digital elevation model, Alps

Within the project “Water Balance as a Function of Landform and Land Cover in an Alpine Valley” (RTG 437, German Research Foundation) the water balance components and their relation to land form and land cover are studied at different spatial scales. Precipitation, soil moisture, and discharge are measured directly. Evapotranspiration is calculated using the Penman-Monteith equation. The latter requires micro-climatological measurements and detailed features of vegetation (LAI, resistance of stomata). Landform and vegetation are supposed to alter the micro-climatology to an extremely high degree. Since high mountains are characterised by their differentiated landform at all spatial scales, there is a high necessity for fine-scale elevation models and remote sensing data. The former is used to derive topographical features, the latter to derive features of vegetation structures. On the micro-scale we analysed the water balance of an alpine sub-catchment (0.4 km²) in the Lötschental, Switzerland. To obtain a submetrical elevation model and features of vegetation we used kite aerial photography (KAP) with a digital camera. An elevation model and vegetation classification is presented. Moreover, a comparison of KAP with other conventional methods like terrestrial photography and aerial photography is illustrated. Concluding, the surplus of KAP in high mountain micro-scale climatology is addressed.

OBJECT-ORIENTED CLASSIFICATION OF ALPINE LANDFORMS FROM ASTER SCENES (REINTAL, BAVARIAN ALPS)

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KEY WORDS: geomorphological landform detection, image segmentation, fuzzy logic, object-oriented classification

High mountain regions represent difficult terrain for detecting rock and sediment storage areas. By means of ASTER satellite scenes, a colour orthophoto and a digital elevation model (DEM), the geomorphological setting of the Reintal subcatchment (c. 17 km²) east of the Zugspitze is analysed using remote sensing methods. After extensive preprocessing, characteristic landform features are classified in a multiscale eCognition project comprising four levels. Its complex decision tree hierarchy largely finds on fuzzy membership functions and to a lesser extent on the hard nearest neighbour classifier. The final landform classification scores high in the assessments of both overall accuracy, kappa coefficient, user's and producer's accuracy. Fuzzy classification stability comes out lower, but best membership assignments score high, too. The results show that an identification of the present-day pattern of geomorphological process units, also with regard to their activity status and complexity, is largely possible by remote sensing. Besides, the approach provides a first insight into the otherwise inaccessible upper regions of the study area which could not be included in any previous survey.

A NEW SEMI-AUTOMATIC TOOL FOR 3-DIMENSIONAL LANDFORM MAPPING

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KEY WORDS: Geomorphologic mapping, Boundary detection, Interactive segmentation, 3d-Visualisation, HRSC-data

Landform mapping on digital air photos and digital elevation models (DEM) using geographical information systems (GIS) is commonly performed manually on plane two dimensional data. Several derivatives of the base data, such as slope-, aspect-, curvature maps and image classification, can be used to enhance the visual perception of the digital landscape and support the identification of landforms. However, the potential of high resolution DEM data as a resource for land surface characteristics is currently limited to the calculation of these derivatives neglecting the 3d perception capabilities of the human visual system. We introduce in this paper a new semi-automatic tool for 3-dimensional (3d) landform mapping. The tool is integrated into a real-time 3d visualisation engine, which allows interactive exploration of a virtual terrain based on air photo and high resolution DEM data. The user is enabled to perform the mapping directly in this 3d virtual terrain. In addition to the 3d visualisation capabilities, the tool assists the user at specifying geomorphologic objects quickly and accurately by using simple mouse gestures. To this end, digital image segmentation techniques are applied to the air photo and DEM. In contrast to other methods, that need tedious and time consuming manual segmentation, here the user input is minimized at no loss of accuracy. This tool allows for an efficient and accurate extraction of lines or polygons based on the image or DEM pixel information.

As proof of concept we mapped meso-scale geomorphologic landforms in the Turtmann valley, Switzerland, using both traditional 2d methods in a standard GIS (ArcMap, ESRI) and the new semi-automatic tool. The Turtmann valley is a high-alpine southern tributary of the river Rhone. Covering an area of around 110 km², the valley holds a complex set of geomorphic landforms typical for high mountain areas, with a particular high concentration of rockglaciers. A digital high resolution dataset (HRSC-A data, DEM, 1m, and multi-spectral air photos) served as a database for the 3d visualisation engine as well as the GIS mapping. To assess the applicability of our method, we compare efficiency, accuracy and mapping capabilities to those of existing methods.

MOUNTAIN ENVIRONMENT KNOWLEDGE HUB INITIATIVE IN THE HINDU KUSH-HIMALAYAN REGION

B. SHRESTHA

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KEY WORDS: Geographic Information, mountain environment, Mountain geographic information infrastructure, decision support system, MENRIS Portal, Mountain Geography Network

Improving the livelihoods of the mountain communities and environmental conservation in the Hindu Kush-Himalayan (HKH) region have been the twin agenda of the International Centre for Integrated Mountain Development (ICIMOD). ICIMOD is a multidisciplinary center for research and training on integrated mountain development and the chief commodity that the centre deals with is information and knowledge on mountain development. Availability, accessibility and affordability of geo-information at multiple scales and the capacity to use modern analytical and decision support system tools are becoming useful means to investigate key components of mountain ecosystem issues facing today. Realizing the potential of geographic information (GI) for integrated mountain development, ICIMOD through its Mountain Environment and Natural Resources Information Systems (MENRIS) programme, has been promoting the GI science, technology and applications for the mountain areas.

Earth observation from space (remote sensing) is a valuable technological tool that provides long-term, consistent measurements of key variables (geo-information) for studying the conditions and trends of different ecosystems. Mountain areas have received special attention due to remoteness and vastly varying bio-physical conditions. ICIMOD is one of the first and foremost regional institutions in the region addressing towards mountain geographic information infrastructure (Mountain-GII) at the local, national and regional level for sustainable decision making for integrated mountain development.

Through strategic partnerships with key regional/international agencies and together with national partners, MENRIS is making significant contributions towards capacity building; developing mountain thematic database and delivering useful mountain-specific applications and decision support systems. The information and knowledge products thus generated through these systems are useful to development practitioners and policy-makers for planning and decision making. MENRIS portal has been conceived and designed to create a common platform for effecting sharing and exchange of geo-information and knowledge resources accumulated by ICIMOD and its partners in a decentralized manner. Such a framework has proven to be a viable technological and institutional option for building mountain environment knowledge hub on key issues of concerns of mountain ecosystem such as: bio-diversity conservation, water resources management, trans-boundary air pollution, disaster management, landuse planning and many more – evolving a distributed mountain geographic information network in the region.

ASSESSMENT OF ALPINE PROTECTION FOREST PARAMETERS BASED ON LIDAR DATA AND SPOT V SATELLITE IMAGERY

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KEY WORDS: LIDAR, DTM, protection forest, forest parameters, SPOT 5

In summer 2003 the government of the autonomous province Bolzano decided, on suggestion of the departments of area planning, forestry and agriculture, to acquire laser scanner data of the entire area of the province for the generation of an accurate DTM. The project site covers an alpine environment of 7500 km² with heights varying between 230m and 3900m. To ensure a high quality of the laser DTM Joanneum Research/Institute of Digital Image Processing, responsible for the definition of the laser data capture parameters and the data processing, had to find cost effective laser data capture parameters as well as efficient methods for the verification of the delivered data, the handling of strip mismatches, GPS height offsets, atmospheric influences and the filtering of the laser data in an alpine environment.

Concerning the misalignment of neighbouring stripes a new approach, BIAS (best incidence angle to surface), was developed, which helped to improve the DTM quality and runs fully automatic. Together with a new modified filtering approach, hierarchic region growing, a software package was implemented which helped to generate accurate DTM's in a most efficient way.

Based on this data the assessment of protection forest parameters at stand wise level was investigated at a test site near Bolzano. The LIDAR data was used to extract parameters like vertical forest structure, average stand heights and timber volume. The required tree species information came from a classified SPOT V satellite image.

The resulting output – the protection forest parameters – were verified by 150 plots measured at the test site.

Finally, a 3D landscape model was generated in order to achieve an impressive and easy understandable visualization of the test area. As a database served a LIDAR DTM and DSM as well as vector information from a single tree detection based on LIDAR data. In addition a raster data classification from high resolution satellite data was used to provide information on the terrain coverage.

AUTOMATED BOUNDARY DELINEATION AND SPATIAL CHANGE ASSESSMENT OF ALPINE HABITATS

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KEY WORDS: habitat extraction, one-level representation, high resolution satellite imagery, HABITALP-Project, analyses of habitat geometry

1. Study area and scope of work

This paper presents a study on (1) automated habitat delineation using very high spatial resolution (VHSR) optical remote sensing data and (2) change assessment of spatially complex and temporally inconsistent habitat boundaries. The 16 sqkm sized study site represents a mountainous area, characterised by high bio- and habitat diversity and situated in the Berchtesgaden National Park (NPB), which lies in the Alpine region of South Eastern Germany. NPB participates in the Interreg IIIb project HABITALP (Alpine Habitat Diversity), one aim of which is to monitor habitat diversity and environmental changes on the basis of colour infrared (CIR) aerial photographs. Until now habitat delineation was accomplished in an intuitive way by experienced interpreters for large areas. However, driven by monitoring obligations in the framework of Natura 2000 as well as for reasons of time and economy, there is an increasing demand on updated image data in a high time rate. Parallel, the need for automated image analysis rises. The used approach of object-based image analysis (OBIA) resembles the human performance of interpretation with some limitations. First, the study investigates the potential of automated habitat boundary delineation via one-level representation (OLR), an objectbased segmentation strategy of VHSR remote sensing data. Second it uses the virtual-overlay-method to compare these habitat geometries with a visual interpretation and evaluates possible changes.

2. Methods

We used a pan-sharpened QuickBird scene from August 2006 (0.6 m spatial resolution) and a CIR airphoto mosaic from 2003 (0.5 m resolution). This imagery was pre-projected in UTM-33 (WGS-84) but with a low spatial accuracy. First the multispectral and the panchromatic bands were separately orthorectified using the rational polynomial orthorectification (RPC) model. Due to high relief the additional usage of ground control points has increased the geometrical correction. Pansharpening was performed according to LIU (2000). For image segmentation we used a region-based local mutual best fitting approach (Baatz & Schäpe, 2000) as being implemented in the software eCognition 4.0. The result is controllable by user-specific assessments of color and shape homogeneity and heterogeneity. Scenes of high spatial and spectral variability can be segmented using the one-level representation (OLR) strategy (Lang & Langanke, 2006). This means that through iterative segmentation one single target level is found, which reflects the appropriate scale domain for the delineation. Since the parameterisation is specific for certain habitat types, OLR can be repeated and passed onwards to a super level, which accommodates all representations. This process may lead to an iterative OLR-method. The produced geometries were compared with the existing visual interpretation using the virtual overlay method (Lang et al., in press) implemented in LIST (landscape

interpretation support tool), an extension for ArcView 3 GIS. This offers a way to prove spatial coincidence of two corresponding habitat geometries. A threshold value can be set to accept overlaps of corresponding, but not fully congruent delineations. By investigating the spatial relationships between boundaries of corresponding habitat delineations, the 'fate' of particular habitat can be determined.

3. Results and discussion

We could demonstrate that QuickBird data with enhanced spatial and radiometrical resolution are qualified for image segmentation of specific habitats. The OLR segmentation strategy turned out to be suitable for delineating alpine habitats at single representation levels. At these levels one or more habitats can be identified. A number of such target levels can be extracted from the whole scene via the iterative OLR-method and re-assembled on a super level. Alpine habitats with homogenous spectral behaviour (similar reflectance such as grasslands or regular texture, such as mixed forest) were successfully segmented and in many cases the results resembled the habitat geometries provided by an interpreter. In some cases the human interpreter mentally included one or more single features (like trees) in an otherwise homogenous habitat matrix (e.g. grassland), whereas the software segments the homogenous area as such. Other challenges are related to the fact that the algorithm adds the shadows of high trees to habitats which include these trees. In general, the two different systems, the visual human-perceptive system (interpreter) and the digital image analyses system (eCognition) provide geometries with non-congruent object outlines even when working in the same scale domain. Whereas the human interpreter works with a high degree of generalisation and subjectivity, eCognition strictly applies specific spectral and form parameter and would not generalize. Using LIST, these differences could be investigated and told apart from 'real' changes.

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H) EDUCATION

AN INTEGRATED DESIGN OF A GEOSPATIAL PROGRAM WITH AN INFORMATION TECHNOLOGY CORE

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This paper addresses the following issues. First, it addresses the problem of inadequately trained Geospatial technicians and professionals in computer science and information technology. Second, it addresses support systems that provide and promote Geospatial based economic development and expansion opportunities.

The traditional and non-traditional learner of Geospatial knowledge and training, that incorporates Geographic Information Systems (GIS), Global Positioning Systems (GPS), and Remote Systems (RS) with image based mapping, is offered with flexible opportunities to learn. This flexibility is represented by scalable education from the associate level through the doctorate level, with knowledge based upgrades with customized workshops and seminars through continuing education. The program has been designed to support economic development through support centers providing applied research and development as well as repositories of geospatial data needed by government, academic and private sector economic entities.

Broader impacts of this integrated cross discipline program include an expansion of geospatial knowledge and skills into the science curriculum of secondary schools, community and technical colleges, universities, private sector, and government, resulting in an increase in education and training of cross discipline geospatial, computer science, and information technicians and professionals.

Key to the success of the program has been articulation agreements which facilitate a seamless transition featuring multiple exit and re-entry points for students and professionals. While threads of associate, bachelor's, and master's level geospatial programs are extant among several campus departments at Marshall University, these threads continue to be woven into structured and flexible non traditional curricula providing students geospatial training beginning in the public high school and continuing education workshops leading to proficiency certificates, two-year transfer options, four-year, and advanced degrees in geospatial studies. It has been our intent to integrate existing and developing academic components into traditional structured and flexible non traditional organized education and training program at the high school, workforce training level, associate degree, bachelors', masters' and doctorate degree levels. The merit of this project lies in the adaptation of a geospatial curriculum to both traditional and non-traditional programs providing flexibility to regional urban and rural state, national, international students and professionals in terms of time, place, and pace of study.

EARTH OBSERVATION EDUCATION IN THE HINDU KUSH – HIMALAYAN REGION, AN ESA INITIATIVE

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KEY WORDS: Education, Earth Observation Applications, ESA, Eduspace, Himalaya

In the framework of the commitments for education made by the European Space Agency (ESA) at the UNISPACE II conferences and renewed at UNISPACE III, several initiatives have been realized and are now a corporate asset for ESA. Among those is Eduspace, a multilingual website for Earth observation in secondary schools. This website is now well established in the teaching community, with its nearly 2000 registered educational entities worldwide supposed to be used on a regular basis. ESA's prime objective is to provide teachers and students with a modern and stimulating teaching and learning tool.

ESA endeavours to further enhance this website and enrich it with additional pedagogical material linked to satellite image applications. Along this line, several new modules have been realized, among them "ENVISAT for Schools" and "Africa from Space" and the educational image processing software LEOworks.

With the latest module "Himalaya from Space", a new approach has been adopted for the production of educational material. In an Announcement of Opportunity addressed mainly to Universities and educational institutions in the Hindu Kush-Himalayan Region, proposals were requested for so-called Case Studies. These are pedagogically reworked results of investigations on the application of spaceborne remote sensing data to socially relevant topics. Case Studies shall present ideas how to apply Earth observation data in general and for specific problems and should demonstrate this in one particular case.

Preliminary results show interesting topics including recurrent floods in valleys and plains, glacial lake outbreaks, man-animal conflict in and around protected areas, habitat observations in National Parks, environmental impact of industrial exploitation, air-pollution over large cities in air-trapped situations and uncontrolled urban development. As a result all Case Studies are presented in a unified form, including an introduction, a background and a worksheet section. The latter is divided into a more simple approach to work on paper-prints, while a more enhanced section deals with digital image data, in some cases also incorporated in a GIS. Mostly ENVISAT data, but also some other high-resolution data are used.

Techniques proposed are kept simple and the presented material can be downloaded and is ready for use in the classroom. In the digital part, the available imagery is geocoded and software is available free for schools to work with. In both cases exhaustive questions at each learning step assure that the student can follow the sequence of the exercise.

The rationale behind the production of such Case Studies is to stimulate teachers and youngsters to become confident with the basics of remote sensing and eventually adopt a similar approach for a study in an area of their country, suffering e.g. from a similar problem.

MONITORING GLACIERS AND GLACIAL LAKES - CASE STUDY FOR EDUSPACE

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Global warming and climate change can be perceived by noticing the melting and receding glaciers which is more pronounced in the Himalayas. The rate of retreat of glaciers in Bhutan has been found to be 7.36 metres per year over last 30 years. The glacier lakes are filling up with more and more melted ice and in Bhutan alone, about 24 glacier lakes are poised to burst their banks leading to GLOF (Glacial lake outburst flood) events. Such an event has been experienced in Bhutan in the year 1994 due to burst of Luge Tsho in Lunana region. The impact of GLOF can be devastating in terms of damage to roads, bridges, hydropower plants, villages, agricultural land as well as loss of lives, property and infrastructure.

Since then lot of studies and mitigation measures have been taken in the area. A study carried out by International Centre for Integrated Mountain Development (ICIMOD) and Department of Geology and Mines, Bhutan (DGM) has identified 2674 glacial lakes among which 562 are associated with glaciers.

A case study on glaciers and glacial lakes has been chosen for Himalaya from Space module of Eduspace educational website covering the area where the 1994 GLOF event took place. Few larger size glacial lakes are existing in the study area. This educational case study shall help the students of higher secondary level to understand the problem of glacier retreat, melting process and GLOF event and teach them to monitor the glacier retreat and increase in size of glacial lakes.

The study uses the satellite remote sensing TM data from LANDSAT, and ASAR and MERIS data from ENVISAT of European Space Agency (ESA). Remote sensing software LEOWorks has been used in interpretation of satellite data and carry out change detection in the retreat of glaciers and increase in size of glacial lakes in the area. The exercises have been prepared with and without using computer and software.

The study area is inaccessible during most part of the year and aerial survey and monitoring would be highly expensive. So the satellite remote sensing would be most suitable technique of monitoring the glacial lake expansion.

“MOUNTAINS FROM SPACE” – A BOOK BASED ON REMOTE SENSING DATA FOR
SUPPORTING PUBLIC UNDERSTANDING OF SCIENCE

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KEY WORDS: Perspective view, Virtual Landscapes, Mountains from Space, Scientific Visualization, Public Understanding of Science (PUSH)

The cartographic depiction of high mountain areas has always been a challenge to generations of cartographers, surveyors and geographers. The resulting maps contain a wide range of information, which are difficult to understand for a non-expert community. Hence the fascination of high mountain areas was up to now mostly reserved to experts and climbers.

New techniques in Computer based visualization and especially the possibility to generate virtual landscapes allows a much more comprehensible and completely new perspective of mountain areas. The ease of access to high resolution digital elevation models and the vast availability of very detailed remote sensing data – like e.g. from IKONOS – complement these techniques. This combination of data and technology give the cartographer and geographer a comprehensive tool for generating high quality images of mountains.

Motivated by its work of the past years and recent developments in visualization the German Remote Sensing Centre initiated a new approach to unveil the beauty of high mountains all over the world. Together with scientists and some of the worlds most reputed mountaineers – among them Reinhold Messner, Sir Edmund Hillary and Stephan Venables – a concept for a book integrating different aspects of mountainous regions of the world was developed. Targeted at the broader non-expert public a wide range of remote sensing material and computer generated perspective views was gathered and compiled in a high quality book titled “Mountains from space”. The heart of the book is geographic content – illuminating history, geology, geomorphology, climatology and weather as well as many other phenomena concerning mountains.

The over 150 large format colour views of mountains from space show the audience a wide variety of digital, satellite based maps not shown in this context before.

In this paper the technology used for the generation of the maps will be discussed. This includes the state of the art in geo data visualization of digital elevation models in combination with satellite data. The global availability of data of mountain areas is key to the generation of perspective views especially of remote areas. Map content in combination with aspects like colouring and design are important issues when dealing with aspects of the public understanding of science – these aspects will also be addressed. Based on the data compiled for the book a range of computer animations was generated offering virtual tours of Mt. Everest and Denali. New data – like the high resolution SAR-data to be gathered with the launch of TerraSAR-X in mid 2006 – will offer new possibilities for the generation of virtual landscapes based on high resolution digital elevation models.

I) MISCELLANEOUS

ALPINE INSTITUTE FOR APPLIED REMOTE SENSING

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This poster presents the Alpine Institute for Applied Remote Sensing, which can be considered as youngest child of the European Academy in Bolzano (EURAC).

The institute is an initiative of the provincial government of South Tyrol and the EURAC and will presumably be initiated in 2007.

The main objective of the institute is scientific monitoring as well as investigations of the earth's surface and the atmosphere by means of aerial photographs and satellite images.

The mission of our institute is the development of remote sensing applications for the Alps and other mountainous areas addressing current environmental and security problems, i.e.:

- land use changes (withdrawal of agriculture, urban sprawl, reforestation)
- natural hazards (avalanches, mudflow, floods)
- retreat of glaciers and the rising snow line
- vegetation changes as a result of climate change
- air quality (particulate matter)

The development of those applications will be accomplished in cooperation with different research institutes as well as economic and administrative stakeholders, amongst others the authorities of South Tyrol. Thus, the results of remote sensing applications can directly be incorporated into regional planning, nature conservation, agriculture, forestry, civil defense and tourism planning.

By means of an own receiving station on the high mountain plateau Ritten (presumably finished in 2007) the institute will be able to receive and process satellite images in near-real time.

This offers an important time advantage for all applications with a need for most recent data like monitoring the consequences of natural hazards and risk management.

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