Development of New Types of Glacier Dynamics Maps

Manfred F. Buchroithner, Sebastian Walther, Klaus Habermann

TU Dresden
Institute for Cartography
Development of Three New Types of Glacier Dynamics Maps

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• Background
  – The Project OMEGA
  – Measurement of Glacier Movements using SAR

• Map Generation
  – Glacier Marginal Changes
  – Glacier Strain Rate
  – Glacier Velocity

• Conception and Generation of a True-3D Map
The Project OMEGA

• Development of an Operational Monitoring System for European Glacial Areas – Synthesis of Earth Observation Data of the Present, the Past and the Future

• Research project of the European Commission with participation of several institutes and companies

• Period: April 2001 – April 2004
• Funding: 3,24 M€
The Project OMEGA, ctd.

- Changes of the European glaciers induced by climatic changes
- Development of a European Monitoring System for the European glaciated areas
- Using of preferably versatile basic data sets
- Development of new evaluation methods
- Publishing of the results
- Sensitisation of the public
OMEGA Test Sites - Requirements

- Existing long-time glaciological and meteorological observations
- Reference points available
- Reachability
- Rating of the influence of climatic changes
SAR - Basics

SAR: Sending & receiving of microwaves
   - Tilted receiving geometry
   - Azimuth along track (synthetic aperture), range across track

InSAR: Elimination of sensor geometry effects and ambiguousness
   - One range of phase differences between $\pi$ and $-\pi$: “Fringe”

D-InSAR: 3 or 4 SAR Images $\rightarrow$ 2 Interferograms:
   - One consists only topographic fringes
   - One consists fringes with topographic changes
Gradient Approach InSAR – GINSAR

- Partial derivation of wrapped phase = partial derivation of unwrapped phase
- Subtraction of an interferogram from the transformed interferogram
- A. Sharov: “Topogram” – 3 channels: gradients in azimuth, range and total

- Subtraction of 2 topograms
- “Fluxogram” – 4 channels: differences in azimuth, range, total and direction of differential movement
Map Generation – Initial Situation

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Original Data</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copies</td>
<td>Topography</td>
<td>ESRI ArcInfo 8.1</td>
</tr>
<tr>
<td>Size</td>
<td>Topographic map</td>
<td>Erdas Imagine 8.4</td>
</tr>
<tr>
<td>Topic</td>
<td>Elevation contours</td>
<td>Macromedia Freehand 10</td>
</tr>
<tr>
<td>Purpose</td>
<td>DEM/DTM</td>
<td>Adobe Illustrator 9.0</td>
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<tr>
<td></td>
<td>Topic-related data</td>
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</tr>
<tr>
<td></td>
<td>Interferograms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Satellite images</td>
<td></td>
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</tbody>
</table>

Further sources:
- Colour tables
- World Wide Web
Map Design – Title and Content

“Svartisen Ice Caps (Norway) – Glacier Rheology”
“Hintereisferner (Austria) – Glacier Rheology”

<table>
<thead>
<tr>
<th>Title</th>
<th>Topic</th>
<th>Topography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glacier Marginal Changes</td>
<td>• 2\textsuperscript{nd} glacier stadium</td>
<td>• Coast line</td>
</tr>
<tr>
<td></td>
<td>• Areas of in- and decrease</td>
<td>• Glacier area</td>
</tr>
<tr>
<td>Glacier Strain Rate</td>
<td>• Rates of deformation</td>
<td>• Hydrography</td>
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<tr>
<td>Glacier Velocity</td>
<td>• Flow velocity</td>
<td>• Elevation contours</td>
</tr>
<tr>
<td>Original Interferogram</td>
<td>• Interferogram</td>
<td>• Spot heights</td>
</tr>
<tr>
<td>EROS Orthoimage Map</td>
<td>• EROS satellite image</td>
<td>• Lettering</td>
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</table>
## Map Design – Scale & Geodetic Parameters

<table>
<thead>
<tr>
<th></th>
<th>Svartisen Ice Caps</th>
<th>Hintereisferner</th>
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</thead>
<tbody>
<tr>
<td><strong>Base maps/scale</strong></td>
<td>Topografisk Hovedkartserie M711</td>
<td>Österreichische Karte 1 : 50.000 ÖK 50</td>
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<tr>
<td></td>
<td>1 : 50.000</td>
<td></td>
</tr>
<tr>
<td><strong>Geodetic parameters</strong></td>
<td>Ellipsoid WGS 84</td>
<td>Ellipsoid: Bessel</td>
</tr>
<tr>
<td></td>
<td>Projection: UTM</td>
<td>Projection: Gauss-Krueger</td>
</tr>
<tr>
<td></td>
<td>Grid: UTM</td>
<td>Grid: Austrian Bundesmeldenetz (BMN)</td>
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<tr>
<td><strong>Digital elevation data</strong></td>
<td>Raster data, resolution 25 m</td>
<td>Elevation contours</td>
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<tr>
<td><strong>Topics</strong></td>
<td>• Differential Interferogram</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Glacier Velocity</td>
<td></td>
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<tr>
<td></td>
<td>• Glacier Strain Rate</td>
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<td></td>
<td>• Glacier Marginal Changes</td>
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<tr>
<td><strong>Scale</strong></td>
<td>1 : 100.000</td>
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<tr>
<td></td>
<td>1 : 50.000</td>
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<tr>
<td><strong>Grid width</strong></td>
<td>5 km</td>
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<tr>
<td></td>
<td>2.5 km</td>
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<td><strong>Secondary maps</strong></td>
<td>• Eros Orthoimage Map</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Original Interferogram</td>
<td></td>
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<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>• Glacier Marginal Changes</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- **Ellipsoid:** Bessel
- **Projection:** Gauss-Krueger
- **Grid:** Austrian Bundesmeldenetz (BMN)
Map Design – Layout Svartisen Ice Caps

- **Format**
  - 55 cm * 40 cm
  - landscape
- **Area** 370 km²
- **30 km N-S**
- **40 km W-E**
- **0.5 cm margins**
- **0.5 cm frame for coordinates**
- **Foldable to smaller than A4**
Map Design – Layout Hintereisferner

- **Format**
  - 55 cm * 40 cm
  - portrait
- **Area** 8 km²
- 8 km N-S
- 8 km W-E
- 0.5 cm margins
- 0.5 cm frame for coordinates
- Foldable to smaller than A4
Glacier Marginal Changes

- Areas of in- and decrease of glacier
- Comparison of two known stadia
  - 1st stadium: digitised from topographic map
  - 2nd stadium: classified from satellite images
- Generalisation
  - Area > 2500 m²
  - Area/Perimeter > 10 m
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Glacier Strain Rate
- Based on the fluxograms
- Strain rate in x- and y-direction
  - Green: y-direction
  - Red: x-direction
- IHS colour space:
  - Intensity: 0.3 – 0.6
  - Hue: 120 – 240
  - Saturation: 0.2 – 1.0
Glacier Velocity
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The Map Series
Proposal I: Useful Glacier Strain Rate Maps

Realised presentation: Without classification

- Continuous colour gradient
- Direction-dependent
- Indicative for crevasses
Proposal I: Useful Glacier Strain Rate Maps - I

Proposed classification with three classes of strain rate

- Value-dependent
- No perceptibility of direction of crevasses
- Highly generalised
Proposal I: Useful Glacier Strain Rate Maps - II

Proposed classification with five classes of strain rate
- Direction-dependent
- 5 classes
- Perceptibility of direction of crevasses
Proposal II: 3D-Visualisation – Intention & Realisation

• **Objective:** Visualisation of highly-complex phenomena in a user-friendly way suitable for fieldwork.

• **OMEGA:** Not only the changes in glacier coverage are of interest, also the alterations in thickness, and, hence, in the mass-household are important!
Principle of Lenticular Foil Technology

- **lenticular sheet**
- **f = focal length**
- **R = lens radius**
- **interlaced image**
Interlacing of Stereo-Mates

M: centre of the lens
r: lens radius
image-/focal plane
## Effects of lenticular displays

<table>
<thead>
<tr>
<th>2D Effects</th>
<th>3D Effects</th>
<th>Combined Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flip</td>
<td>True-3D</td>
<td>All combinations of 2D- and 3D Effects</td>
</tr>
<tr>
<td>Morphing</td>
<td></td>
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<tr>
<td>Zoom</td>
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<tr>
<td>Animation</td>
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</table>

Changed after MICRO LENS TECHNOLOGY 2005
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Workflow and Software

Modelling

Publishing

Display

MatLab/C++

Magic Interlacer
Flashband Generator

MatLab/C++
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3D-Modelling
Virtual Camera Disposition

convergent vs. parallel
... to sum it up:

True-3D hardcopies: a new subject in scientific cartography with a high potential for tourism and outdoor activities.

To be investigated in more detail: cognitive, syntactic and semantic aspects of cartographic models perceived in true-3D as well as geometric and material aspects of lens foils.
Acknowledgements

The initiative of the work presented, the input-data provision and the eager interest in our map design of Dr. Alexej Sharov, Institute of Digital Image Processing of Joanneum Research, Graz, Austria, is thankfully acknowledged. So are the valuable contributions, both in terms of brainwork and hands-on work, carried out by Sebastian Walther, Sven-Heico Etzold and Thomas Gruendemann, IfC, TU Dresden.
The presented types of new glacier dynamics maps allow to cartographically visualise areas which are potentially dangerous due to the occurrence of crevasses, even under a hiding cover of snow. In connection with the increasing winter outdoor-tourism in glaciated areas these types of maps may help to increase safety in alpine and polar regions.

For further questions please contact:
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USPs – Unique Selling Propositions

In contrast to anaglyphs, chromo-stereoscopy, active and passive polarisation:

- No glasses required
- No active or special illumination required
- Spontaneous stereoscopic perception
- Multi-user capability
- Multi-scene-displays
- Short animations possible
- Easily portable
- No energy (electric power) required
- Bendable (even foldable) displays