Mapping of Snow Cover Extent over Mountainous Terrain in the Swiss National Park using Multi-temporal & Multi-angular CHRIS Imagery

Vittal Boggaram & Ray Merton

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The University of New South Wales
Sydney, AUSTRALIA
Hyperspectral Applications

Sensors
AstroVision
Hyperion, CHRIS/Proba, MSMISat.
AVIRIS, HyMap, CASI.
ASD.

Multi-angular
ESA CHRIS
Topographic normalisation
Coastal wave analysis
Goniometers

Multi-temporal
Hysteresis
Community succession
Near-shore topography

Vegetation
Biochemistry
Biogeochem
Stress
Lidar
Canopy geometry
Grapes/viticulture
Fire fuel load

Water
Bathymetry
Coral reefs
Phytoplankton fluorescence
Aquatic Ecosystems

Dr Ray Merton
Research Thrusts
2006 ESA CHRIS/Proba Papers


Dr Ray Merton

plus MSMISat.
Mapping of Snow Cover Extent over Mountainous Terrain in the Swiss National Park using Multi-temporal & Multi-angular CHRIS Imagery

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Study Area

- The SNP is located to the southeast of Switzerland and to the north of the Italian border. It is the largest naturally protected area in Switzerland and covers an area of approximately 172.4 km². The national park is located in the central Alps at elevations ranging from 1,400 m (Clemgia Gorge) to 3,174 m (Piz Pisoc) above sea level.
- The climate of the region is dry, harsh, with strong solar radiation and low humidity. The average annual precipitation is 950 mm and the average annual temperature is 0° C.
- SNP can be broadly divided into forest areas (28%), alpine and sub-alpine grassland (21%) and mountainous terrain (51%). The forest areas predominantly contain coniferous pine species like:
  - Mountain Pine (Pinus montana), Swiss Stone pine (Pinus cembra), European Larch (Larix decidua), Scots Pine (Pinus sylvestris) and Norway Spruce (Picea abies).
  - The dominant Mountain pine stands cover large areas of the mountainous terrain. The tree line in certain areas of the SNP is approximately 2,300 m a.s.l, which is comparatively higher than the average of 1,900 m a.s.l in Switzerland.
- A rational for selecting the study area was the relatively high tree line ranging from approximately 2,150 m to 2,250 m a.s.l and distinct permanent and seasonal snow covered areas. Satellite imagery of the area was acquired on a multi-temporal seasonal sequence to map the extent of the permanent and seasonal snow cover above the tree line on the mountain slopes.
## Multi-temporal

- 22 May 2005
- 28 May 2005
- 10 July 2005
- 2 Sept 2005
- 29 Nov 2005

### Table: CHRIS flight names and image details

<table>
<thead>
<tr>
<th>Flight name</th>
<th>Chronological order</th>
<th>FZA (°)</th>
<th>Observation azimuth angle (°) (HDF 4.1)</th>
<th>Observation elevation angle (°) (HDF 4.1)</th>
<th>Ascent track angle (°) (Geometric)</th>
<th>Along track angle (°) (Geometric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>42AC</td>
<td>1</td>
<td>+55</td>
<td>+51.15</td>
<td>177.01</td>
<td>3.70 (E)</td>
<td>51.11 (to S)</td>
</tr>
<tr>
<td>42AA</td>
<td>2</td>
<td>+36</td>
<td>+33.33</td>
<td>161.17</td>
<td>11.98 (E)</td>
<td>31.90 (to S)</td>
</tr>
<tr>
<td>42A9</td>
<td>3</td>
<td>0</td>
<td>+21.21</td>
<td>135.20</td>
<td>15.34 (E)</td>
<td>15.34 (to S)</td>
</tr>
<tr>
<td>42AB</td>
<td>4</td>
<td>-36</td>
<td>-37.76</td>
<td>36.02</td>
<td>24.48 (E)</td>
<td>32.07 (to N)</td>
</tr>
<tr>
<td>42AD</td>
<td>5</td>
<td>-55</td>
<td>-54.59</td>
<td>28.88</td>
<td>34.19 (E)</td>
<td>50.93 (to N)</td>
</tr>
</tbody>
</table>
Multi-angular Data
Curves Showing Snow Reflectance (%)

Grain Size:
- medium
- fine
- coarse

Wavelength (Micrometres)
Normalized Difference Snow Index (NDSI)

- The high albedo of snow and clouds in the visible region of the EMS makes it difficult to differentiate between the two (Hall, et al., 1998). The reduction in the reflectance of snow in the mid-IR region can be used in differentiating snow from cloud cover (Jensen, 2000). Cloud cover is predominant in the SNP images acquired during the summer month of July. Accurate estimation of snow cover in the July images was difficult as cloud & snow cover overlap. The multi-angular nature of the CHRIS images generates shadows in mountain terrain posing a greater challenge in estimating the snow cover area.

- NDSI is based on the NDVI concept used for mapping vegetation in remote sensing imagery (Hinkler, et al., 2000; Hall, et al., 1998). NDSI uses spectral band ratios to determine the relative band intensity to differentiate snow from cloud cover (Hinkler, et al., 2000; Hall, et al., 1998). The NDSI band ratio is advantageous in mapping the snow line in mountainous terrain. The spectral band ratio can enhance features by eliminating atmospheric effects and viewing geometry of the image (Gupta, 2005).

- The NDSI band ratio is generated by calculating the difference between the visible band (0.52µm - 0.59µm) and the near-IR band (1.55µm – 1.7µm) and dividing the result by the sum of the two bands (Gupta, 2005; Hall, et al., 1998). The algorithm is designed to detect snow in each pixel. The NDSI algorithm was modified for trial in this study as:

\[
\text{NDSI} = \frac{\text{CHRIS B3} - \text{CHRIS B18}}{\text{CHRIS B3} + \text{CHRIS B18}}
\]

- July images were processed using the NDSI spectral band ratio. The July NDSI images were not accurate in differentiating snow from cloud cover as the wavelength range (0.4μm to 1.05μm) of the CHRIS images pose limitations. Wavelength bands in the near and mid-IR regions (1.55μm – 1.7μm) of the EMS can generate better results. The NDSI images can be combined into a colour-ratio-composite (CRC) image, which helps in determining the approximate spectral shape for each pixel.
Normalized Difference Snow Index (NDSI)
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SAM image with features classed together. Cloud cover classed as snow.
SAM image with features classed together. Cloud cover classed as snow.

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Minimum Distance

(a) CHRIS–SNP–10JULY04–42A9–NDSI

→ Cloud Cover
→ Cloud Shadow
→ Snow Cover

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Minimum Distance

(e) CHRIS-SNP-10JULY04-42AD-NDSI

Cloud Cover

Cloud Shadow

Snow Cover

Cloud cover
Snow & Cloud cover
Cloud cover
Water & Rock
Cloud cover
Vegetation

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NDSI Minimum Distance

(a) CHRIS–SNP–10JULY04–42A9–NDWI

Cloud Cover

Cloud Shadow

Snow Cover

(a) CHRIS–SNP–10JULY04–42A9–NDWI–Min Dist

N

Cloud Cover
Snow
Vegetation
Water

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July 2004 - Snow Cover

November 2004 - Snow Cover
Classified Vector Images

(b) 10July04-42A9 Snow Cover

0°

N

SAM
Minimum Distance
Multi-Angular Mapping Techniques for the Enhancement of Steep Terrain Classification

Ray Merton

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The University of New South Wales
Sydney, AUSTRALIA
Table Mountain
-Cape Town, South Africa
CHRIS/Proba
Steep Terrain Normalisation

- $+36^\circ$ datasets for N slopes
- $-36^\circ$ datasets for S slopes
- Across track capability for E-W
- Across+along track options

e.g. 32% more pixels
Observation Zenith Angles

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Observation Zenith Angles

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Obs. Angles vs. Slope Elevation Angles

- Slopes 0 - 20°
- Slopes 21 - 50°
- Slopes 51 - 90°
- Cliff face
- ±36°
- ±55°
- 50°
- Elev. = 20°

...this also applies to across-track observations.
Observation Angles vs. Slope Angles

...this also applies to across-track observations.
Mountainous Terrain
Table Mountain, Cape Town

...analogous to multi-angular ROI’s
Mountainous Terrain
Cape Town, South Africa

Dr Ray Merton
CHRIS/Proba PI, Australia

Cable Car top station
33.957394S, 18.402964E

Devil’s Peak

Lion’s Head

Topographic normalisation technique, veget.
fire regrowth, multi-angular corrections.

☐ = Priority 1 research area
☐ = Priority 2 research area
☐ = Priority 3 research area
Table Mountain
-Cape Town, South Africa

Nadir [100%]

...perfect coverage...

New CHRIS image centre coord [63% of full scene]
33.957394S, 18.402964E

HRC image centre coord [37% of full scene]
33.942290S, 18.395176E

Devil's Peak

Lion's Head

Cable Car top station

Priority 1

Priority 2

Priority 3

CHRS TM_060203 (not acquired??)
Steep Terrain Normalisation Model

5 X-angular CHRIS Images

BRDF Modelling

5 Classification Images

5 ROI subset Classification Images

Single layer Composite Image

Aspect Polygons

DEM/TIN