Remote Sensing of the Cryosphere – an overview

Stefan Wunderle, Fabia Hüsler
Institute of Geography and Oeschger Center for Climate Change Research
University of Bern
Global Cryosphere

is undergoing dramatic changes

© Vladimir Ryabinin, WMO-WCRP; ESA-Globsnow workshop; Feb. 14, 2008
Cryosphere of Northern Hemisphere (January 2014)

> Permafrost (red)
> Glacier (yellow)
> Snow (white)
> Sea ice (blue)
GISS Surface Temperature Analysis (NASA)

December 2013 L-OTI(°C) Anomaly vs 1951–1980 0.60
Selection of sensor depends on:

- **Surface types of Cryosphere**
  - Snow extent
  - Snow water equivalent
  - Snow melt
  - Glacier extent
  - Glacier dynamic
  - Ice caps
  - Ice sheets
  - Permafrost

- **Climate, change detection or NRT**
Remote Sensing of Snow

Optical remote Sensing of the Cryosphere is an easy task because
— High reflectance of snow and ice in the solar spectra

<table>
<thead>
<tr>
<th>Wavelength (µm)</th>
<th>Reflectance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>1.3</td>
<td>100</td>
</tr>
<tr>
<td>1.8</td>
<td>0</td>
</tr>
<tr>
<td>2.3</td>
<td>0</td>
</tr>
</tbody>
</table>

AVIRIS-spectra, JPL
Reflectance depends on grain size and contamination

From Teruo Aoki, EARSeL WS 2005
Influence of grain size and thickness on spectral reflectance

> Snow layer (1m vs. 0.1m, 100 microns, no impurities) left
> Snow layer (1m vs. 0.1m, 1000 microns, no impurities) right

http://snow.engin.umich.edu/
Advanced Very High Resolution Radiometer
AVHRR on NOAA- and MetOp-satellites
Accuracy of snow extent (binary or fractional)

> Validation based on:
  — Station data (cm snow depth)
  — Model data
  — Satellite data with higher spatial resolution
Snow extent (binary or fractional)

- The spatial and temporal resolution varies as well as the accuracy
- Critical issues:
  - Cloud cover / sub-pixel clouds
  - Forest
  - Geocoding accuracy
  - Influence of topography
  - Calibration
  - Atmospheric effects
Detection of wet snow with C-band SAR (gamma remote sensing)

- Dry snow is highly transparent for this frequency
- Wet snow strongly reduces backscattering → wet snow vs. snow free
- Extrapolation of dry snow above the altitude of wet snow
MODIS – SSM/I snow product

Blended Snow Prototypes, Fall, 2003

Armstrong, R. et al. 2003: Poster presentation available at NSIDC
Snow coverage vs. snow water equivalent

> Significant difference between optical and coarse resolution microwave

**MODIS % Snow**  
**SSM/I SWE**  
**AMSR-E SWE**

*Tibetan Snow Cover, February 26 - March 5, 2003, left to right: percent area with MODIS snow, SWE derived from SSM/I and SWE derived from AMSR-E. Red box outlines area of patchy visible snow (MODIS) that is “smeared” by SSM/I but better resolved by AMSR-E’s improved spatial resolution.*

Armstrong, R. et al. 2003: Poster presentation available at NSIDC
Passive microwave (SSM/I, AMSR-E, etc.)
- Retrieval of Snow Water Equivalent (SWE)

Monthly average SWE estimate for, February 2013

ESA Globsnow SWE
Mean March SWE (~2000-2009)
Animation series: Klinaklini Glacier, Western Canadian Cryospheric Network, Landsat RGB
Remote Sensing of the Cryosphere – an overview
Remote Sensing of the Cryosphere – an overview

ESA, Kangerdlugssuaq ice stream
Landsat and SAR mosaic of Antarctica

> LIMA (Landsat Mosaic of Antarctica) filled with MODIS

RAMP (SAR Mosaic)
Ice velocity over the entire continent of Antarctica

Derived from ALOS PALSAR, ESA Envisat ASAR, Radarsat-2, ERS-1 and ERS-2 satellite radar interferometry overlaid on a MODIS mosaic of Antarctica. E.Rignot et al. 2011
Summary

- There are many products available to monitor the extent and behavior of the Cryosphere.
- Every product has its own advantage and limitation. Therefore, the user (climate, hydrology, hazards) needs a clear recommendation for the best product for their application.
- There is a need to include:
  — Probability for retrieval accuracy
  — Confidence interval for product accuracy
  — Error budget shall be included
- There is a need for an inter-comparison and careful validation of snow products for different scales (global – regional).
Outlook

> Future of snow and ice monitoring in Europe
  — ESA Glacier Climate Change Initiative (CCI) is ongoing (phase 2)
  — ESA Globsnow-2 project is terminated for June 2014
  — EU CryoLand will be finished in summer 2014

> After mid-2014 there will be no European project to continue with snow remote sensing beside Eumetsat H-SAF.
  — Time series of SE for climate research will depend on small research projects (regional – continental scale)
  — SE and SWE used for hydrological purpose (i.e. run-off forecast) can not be tailored for these applications. Interaction of user and data provider is needed.

> There is a strong need to continue snow monitoring in the frame of CCI Snow.