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Satellittfjernmåling av snødekning og snøens egenskaper

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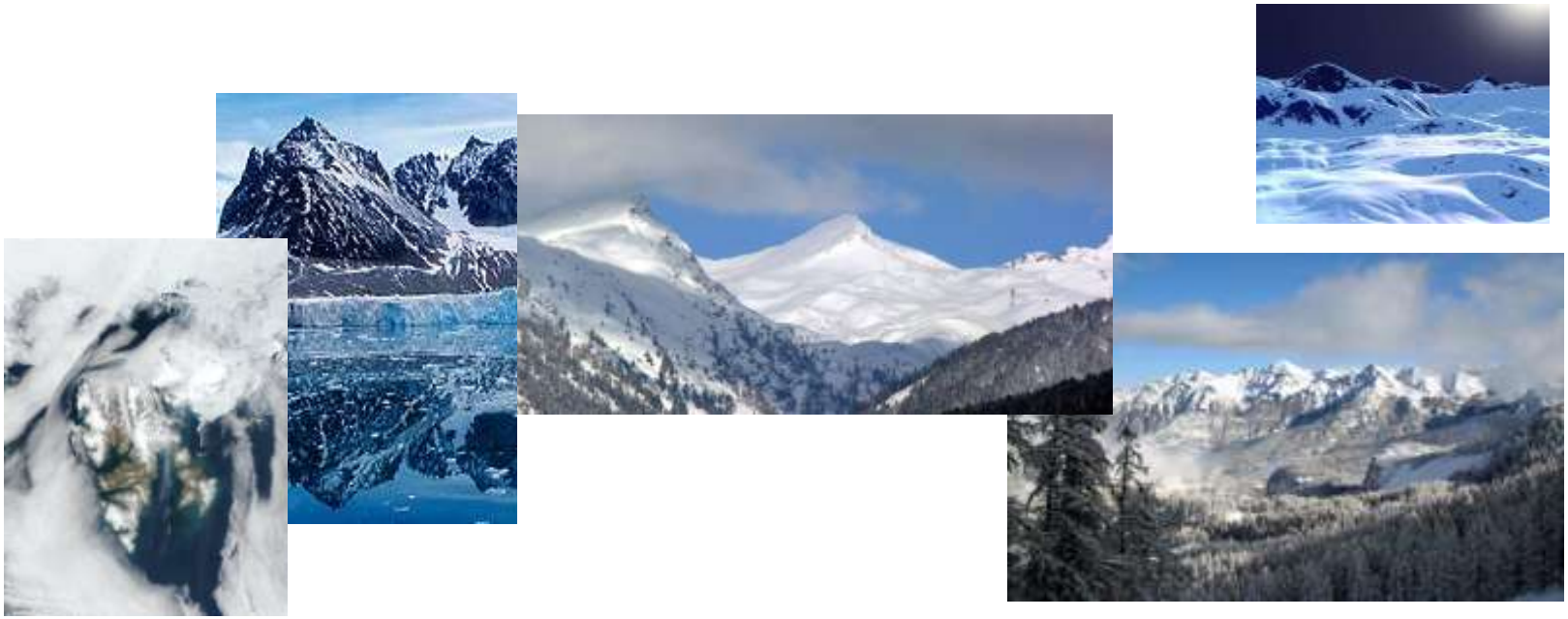
Norsk Regnesentral

Seminar om fjernmålingsbasert kartlegging og overvåking av reinbeiter og fjellvegetasjon, 2–4 april 2008, Skinnarbu, Rjukan

Outline

- Snow products
- Scandinavian Mountain Snow Monitoring Service
- The upcoming EuroCryoClim service



History

- Algorithm development and validation:
  - SnowTools (1996-1999)
  - EnviSnow (2002-2005)
  - SnowMan (2001-2004)
  - EuroClim (2001-2005)
- Service development:
  - EnviSnow (2002-2005)
  - EO-Hydro (2003-2007)
  - Polar View (2006-?)
  - SnowPower (2007-2008)

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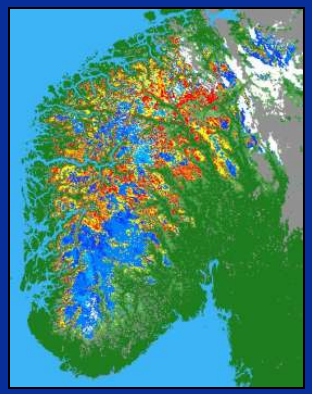
Snow products

Norwegian Computing Center

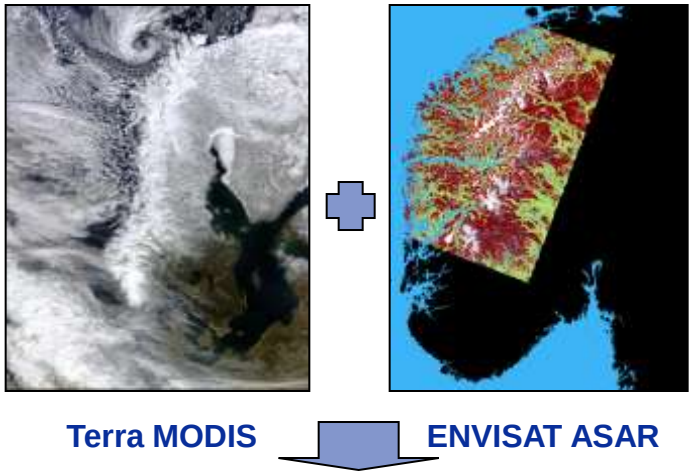


Snow products based on NR's algorithms

- Snow Cover Area
- Multi-sensor time-series Snow Cover Area
- Snow Surface Temperature
- Snow Surface Wetness
- Snow Distribution Pattern

Multi-sensor time-series snow cover

- **Objective**: New multi-sensor time-series algorithm combining optical and radar data
- **Product**: Statistically best estimate of the current day's snow cover area (fractional snow cover– FSC)

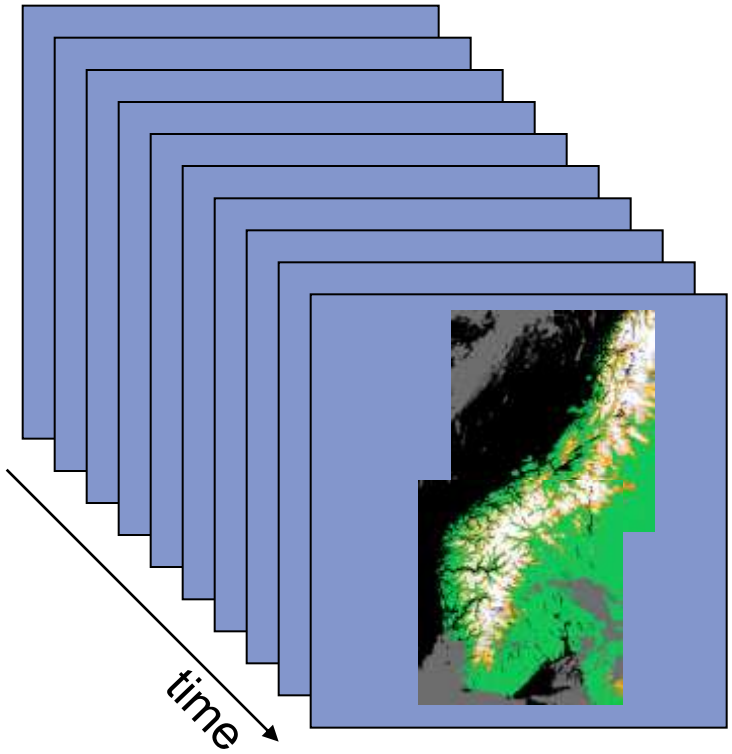


Terra MODIS ENVISAT ASAR

"Multi" snow cover product

Methodology

- Let each pixel in each optical and SAR image have a confidence value (based on sensor models)
- Let the confidence of a product decrease with time (e.g. linearly)
- Compute the most likely fractional SCA for each pixel based on the above



$MSCA_t(x,y) = USCA_i(x,y)$ for *i* which gives

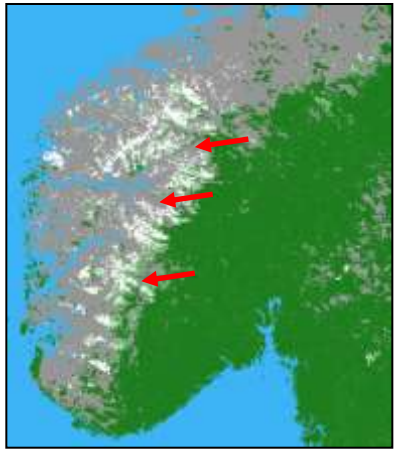
$\max(conf_{MSCA}(USCA_i(x,y))$ $i = t,...,t-n$

Some results

9 May 2004: MODIS only

9 May 2004: MODIS + ASAR. Improves coverage in south

18 May 2004: MODIS only. Optical data in west timed out. ASAR shows less snow in west



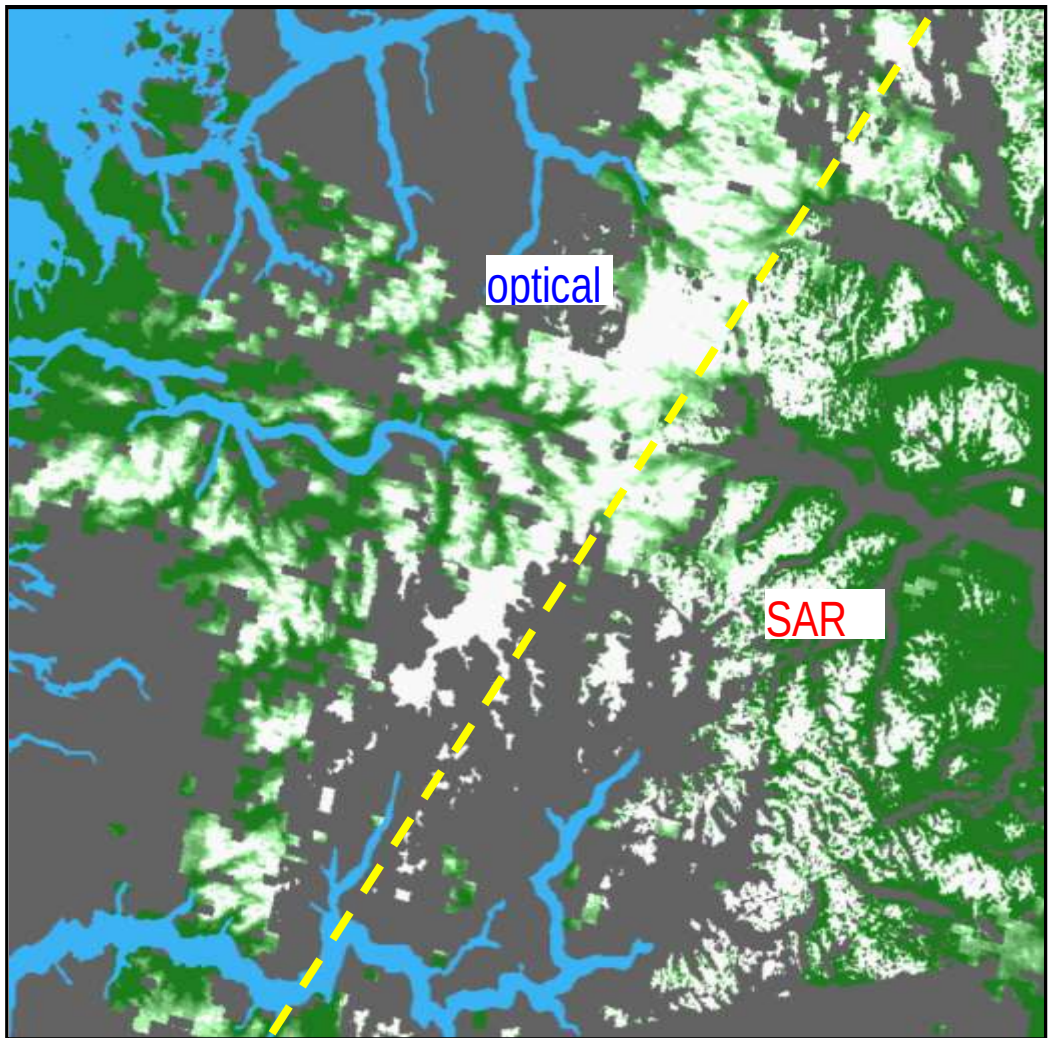
19 May 2004: MODIS only. More clouds due to timeout

19 May 2004: MODIS + ASAR. Coverage of eastern mountains

31 May 2004: MODIS + ASAR. After a clear period ASAR gave no additional changes

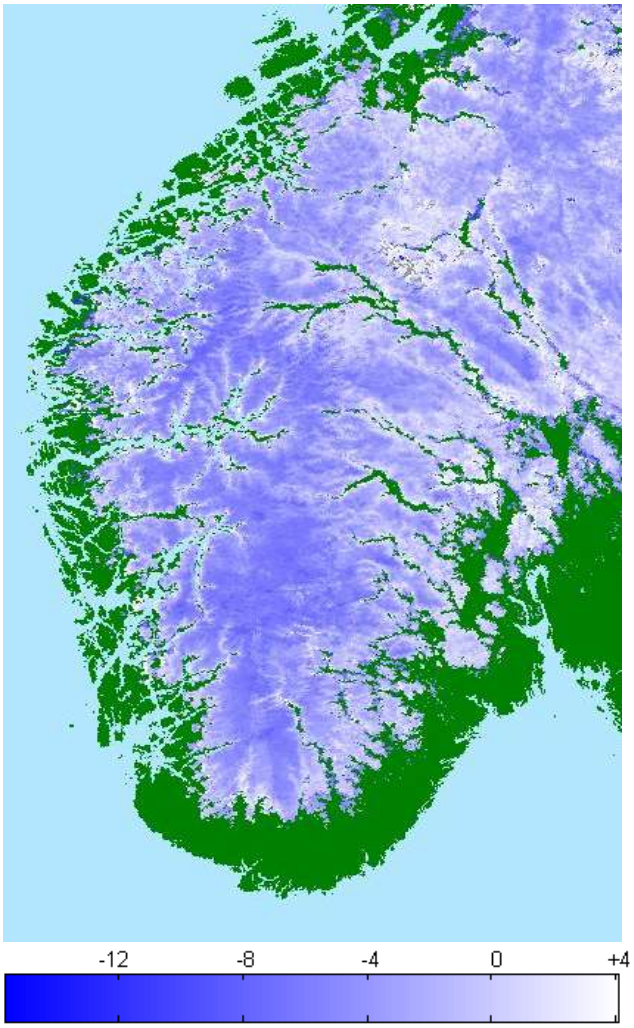
Example of sensor fusion problems

- Example using the fusion algorithm in Solberg et al. 2004 combining MODIS and ASAR
- Snow Cover Fraction (SCF) retrieved independently from optical and SAR sensors
- A time series of SCF maps are then fused pixel by pixel based on a set of confidence models
- Pixels resulting from the optical sensor show smooth transition from 100% to 0% SCF
- Pixels resulting from the SAR sensor show much more patchiness (a more binary look)
- Hard to obtain completely consistent results when doing sensor fusion at the geophysical level



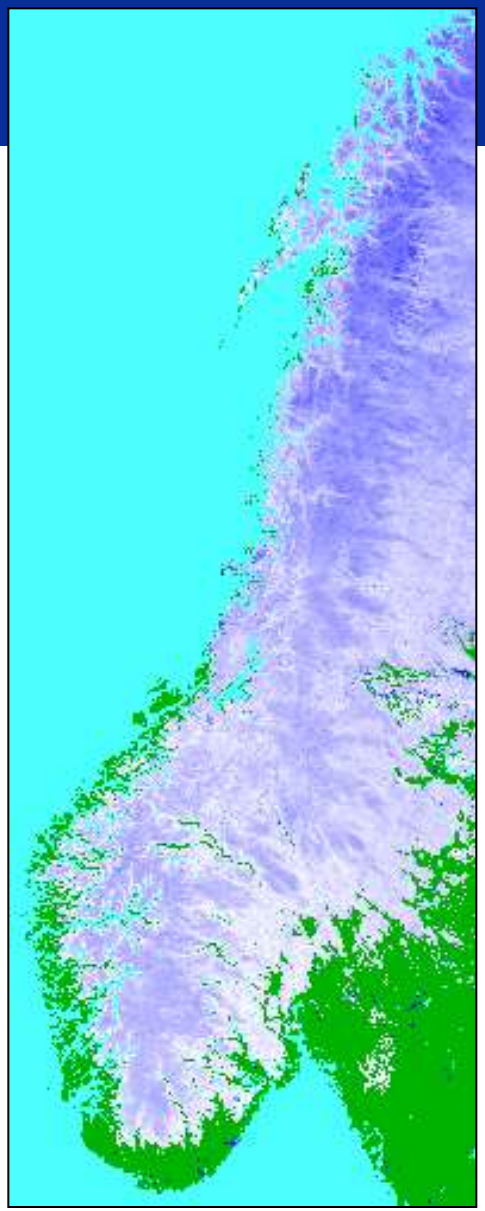
Snow Surface Temperature

- Experiments determined Key's algorithm (split window + view angle correction) to be overall best for snow monitoring
- The retrieval algorithm requires that the emissivity of the surface is known. Therefore, we restrict the use to snow-covered surfaces
- Atmospheric correction: Done by measuring the atmospheric effect at two wavelengths and then correcting according to atmospheric path length
- Can be applied on both NOAA AVHRR and Terra/Aqua MODIS



Results

- Comparison with field measurements shows excellent results
- At 0 C we found an accuracy of about 0.5 C in our test site
- STS maps limited to areas of 100% SCA



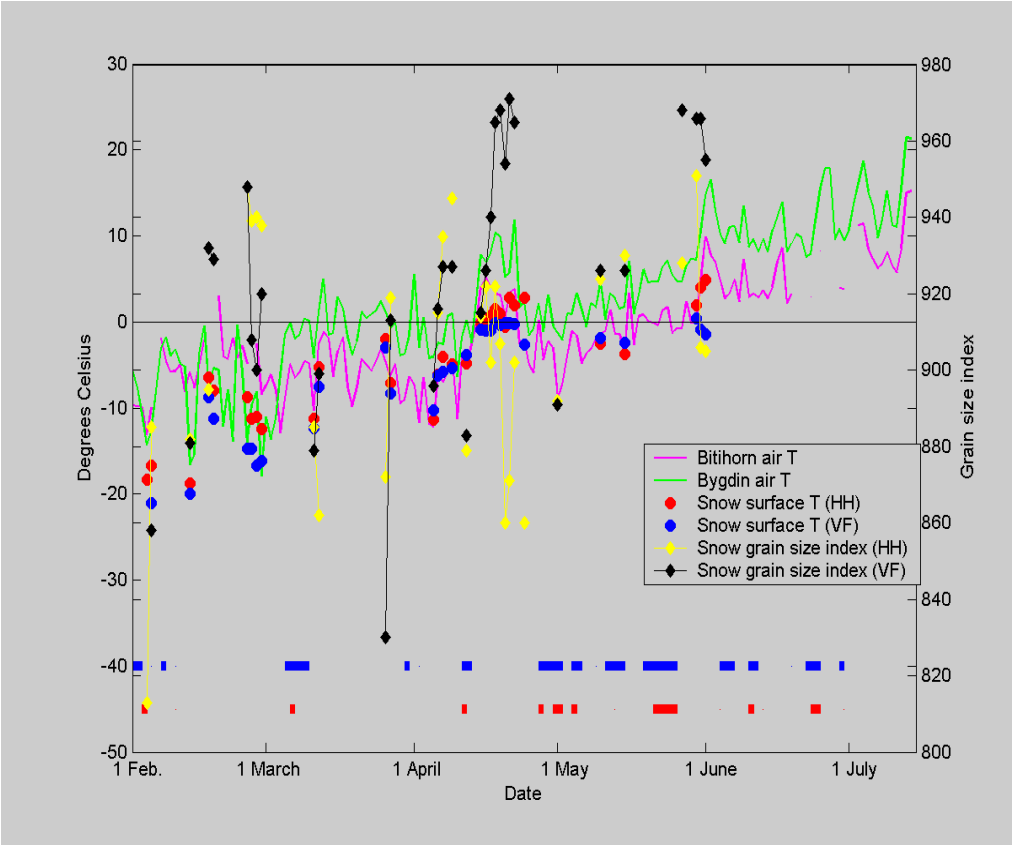
Snow Surface Wetness

Objective: Infer approximate snow wetness from the development of snow variables in a time series of optical images

Idea: Snow temperature close to 0°C combined with a rapid increase of the effective snow grain size is a strong indication of snowmelt start

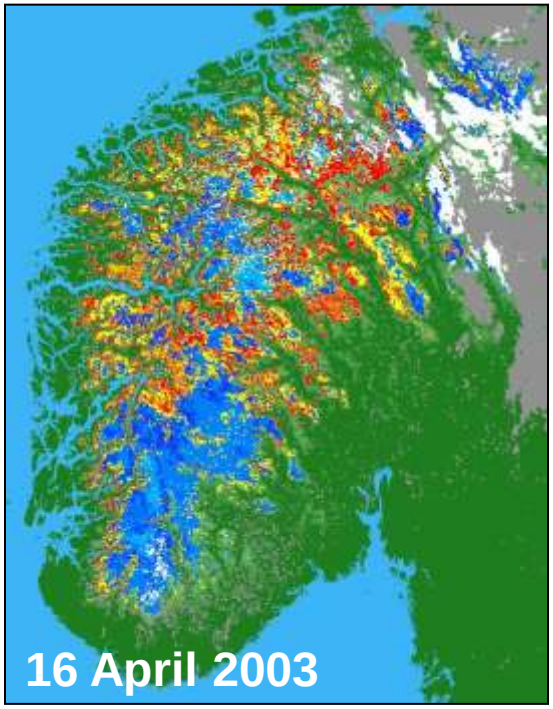
Approach: Combine snow temperature (STS), snow grain size (SGS) and snow cover (SCA)

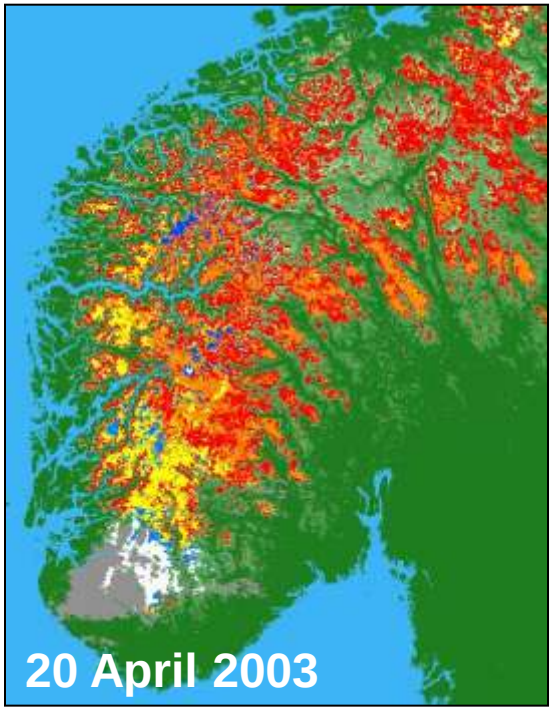
- **STS for today**
- **Recent time series of SGS**
- **SCA to mask out < 100% SCA areas**
- **Cloud mask**

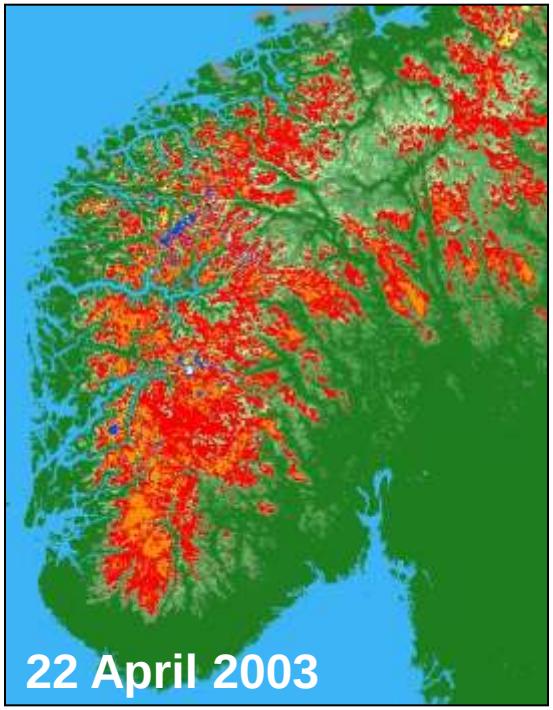


Field measured snow temperature, and satellite measured snow temperature and effective snow grain size for Heimdalen test site in 2003.
HH = Heimdalshø, VF = Valdresflya

Some results

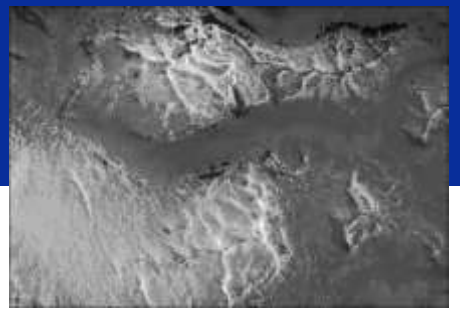




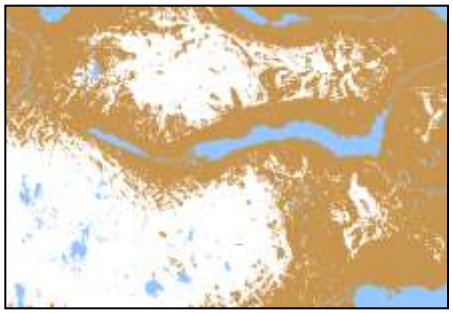


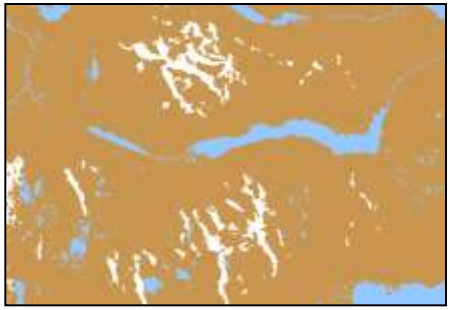
White - dry, cold snow: STS < -2°C.
Yellow/orange - moist: -0.5°C < STS +0.5°C.
& Unchanged SGS. & Increasing SGS
Light/dark blue - dry/moist: -2°C < STS and -0.5°C
Red - wet: +0.5°C < +1.0°C

Snow Distribution Pattern



- **Objective**: Frequent high-resolution estimate of the Snow Distribution Pattern (SDP) during the snowmelt season
- **Main ideas**:
  - Given the amount of snow, its location can be modelled
  - Combine MODIS and Landsat
- **Approach**:
  - Establish a high-resolution Snow Distribution Model for a local area (drainage area) from Landsat time series
  - For any given FSC value the corresponding Snow Distribution Pattern can be retrieved from the model (5%, 40%, 95% shown)
  - The FSC value for the local area retrieved from the SCA product
  - SDP estimated whenever a local FSC value have been observed
- **Evaluation:**
  - Some clouds (<50%) allowed
  - Problem: some years the SDP regime is different than the model
  - Product not yet integrated in current hydrological models





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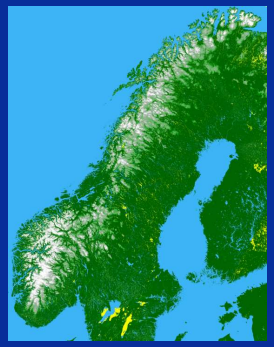
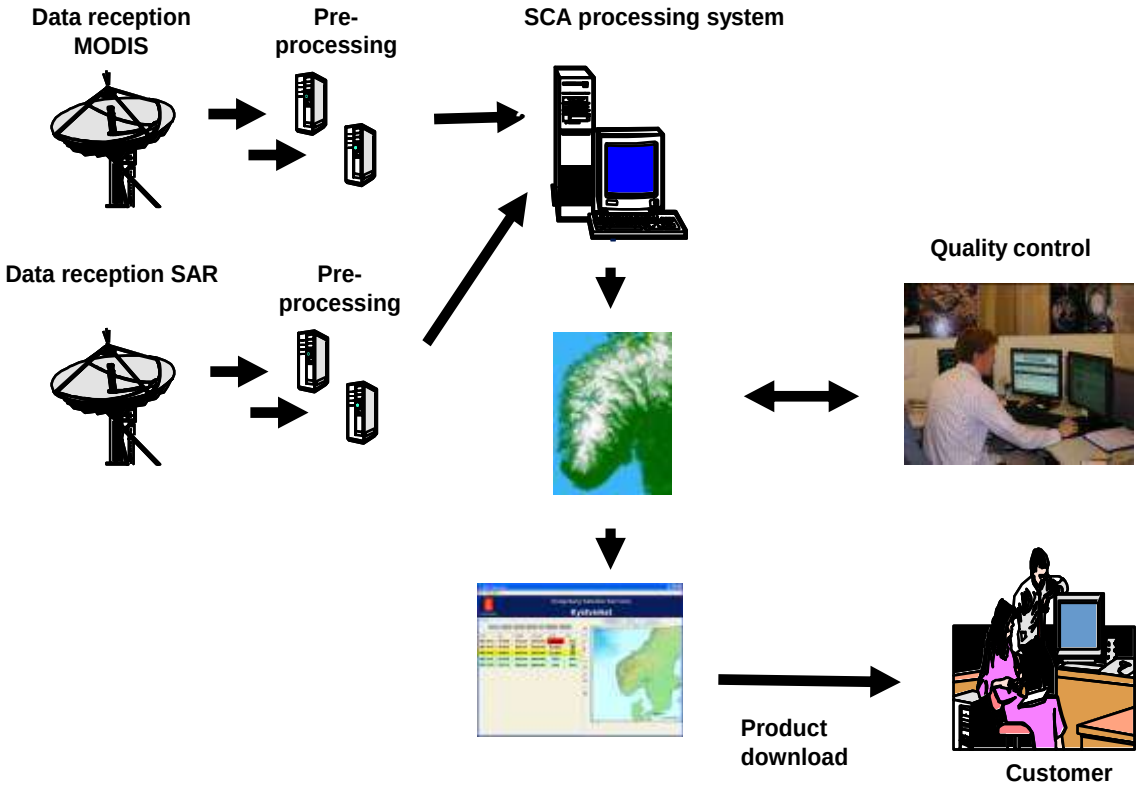
Scandinavian Mountain Snow Monitoring Service

Kongsberg Satellite Technology (KSAT)
Norut
Norwegian Computing Center (NR)



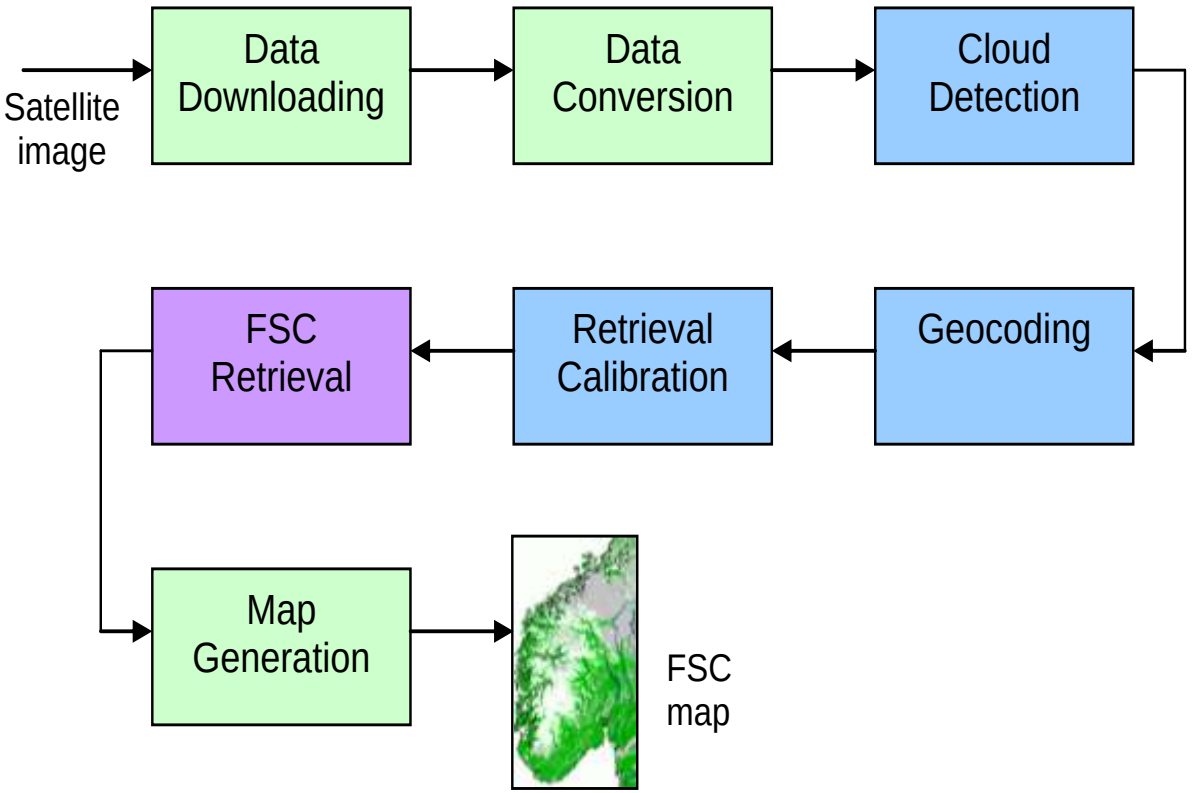
Processing chain

- Automated processing chain monitored by experienced operators
- Configuration of customer profiles according to wishes and requirements to the service
- Near-real time delivery to the customer's web page ready for download



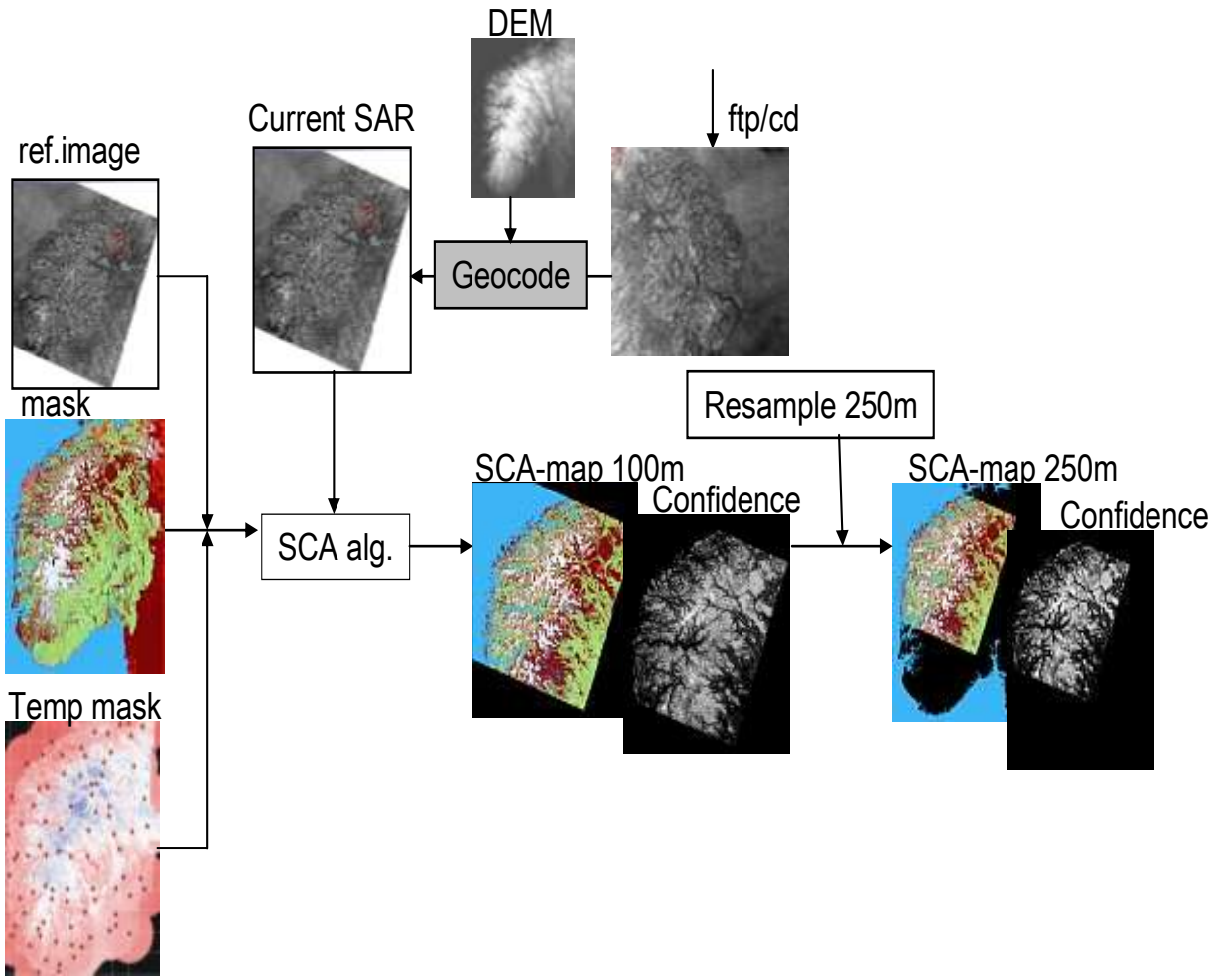
Optical production chain

- Fractional SCA based on a linear reflectance-to-SCA function (Solberg & Andersen, 1994)
- Per-scene calibration (predefined calibration areas)
- Some atmospheric correction implicitly included
- Cloud detection by an approach using K-means
- Based on MODIS (AVHRR or MERIS/AATSR optionally)



SAR production chain

- **Wet snow algorithm**: (Nagler & Rott 2000) Wet snow when pixel backscatter cross section is less than 3 dB below the corresponding backscatter cross section of the reference image pixel
- **Dry snow algorithm**: Assumed if pixel is above the mean altitude for the wet snow. Checked against temperature map



Example product

Multi-sensor snow map

10 May 2006

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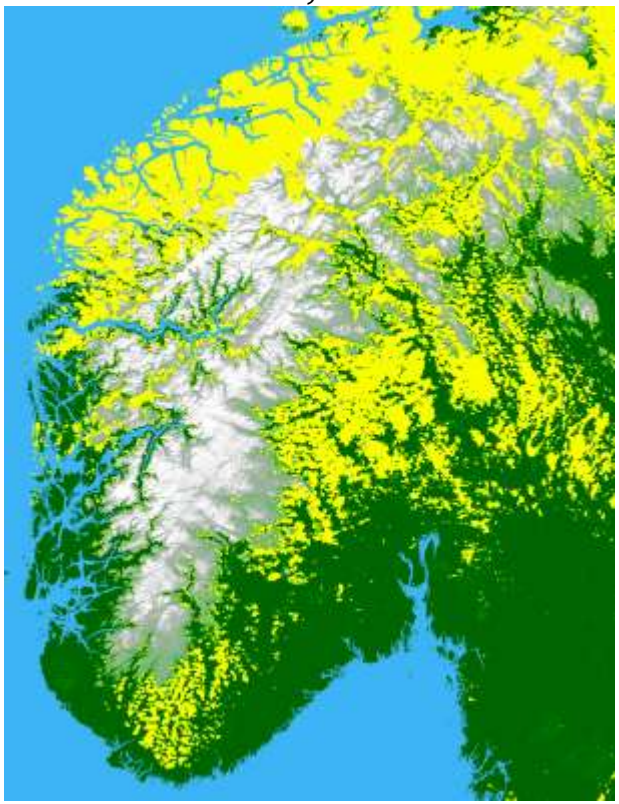
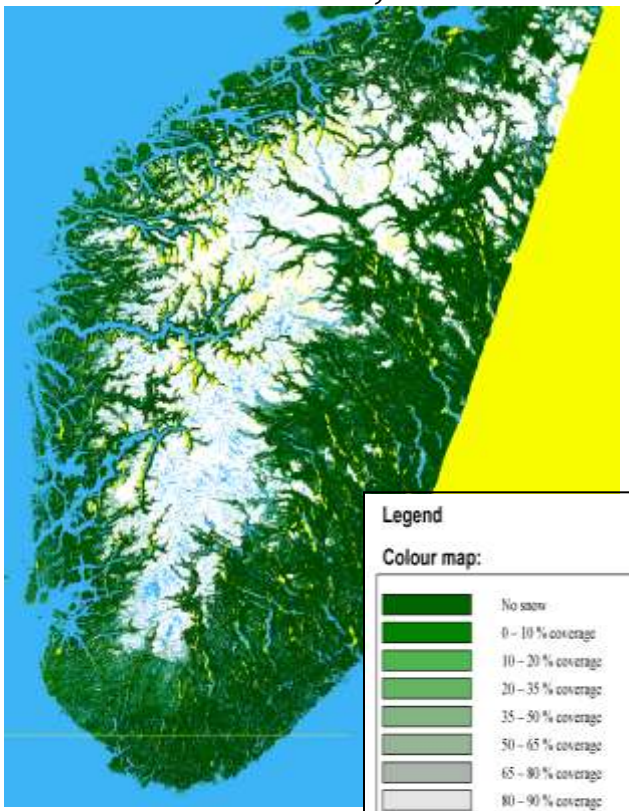
Example: South Norway, 13 May 2005

Terra MODIS, 10.35 UT

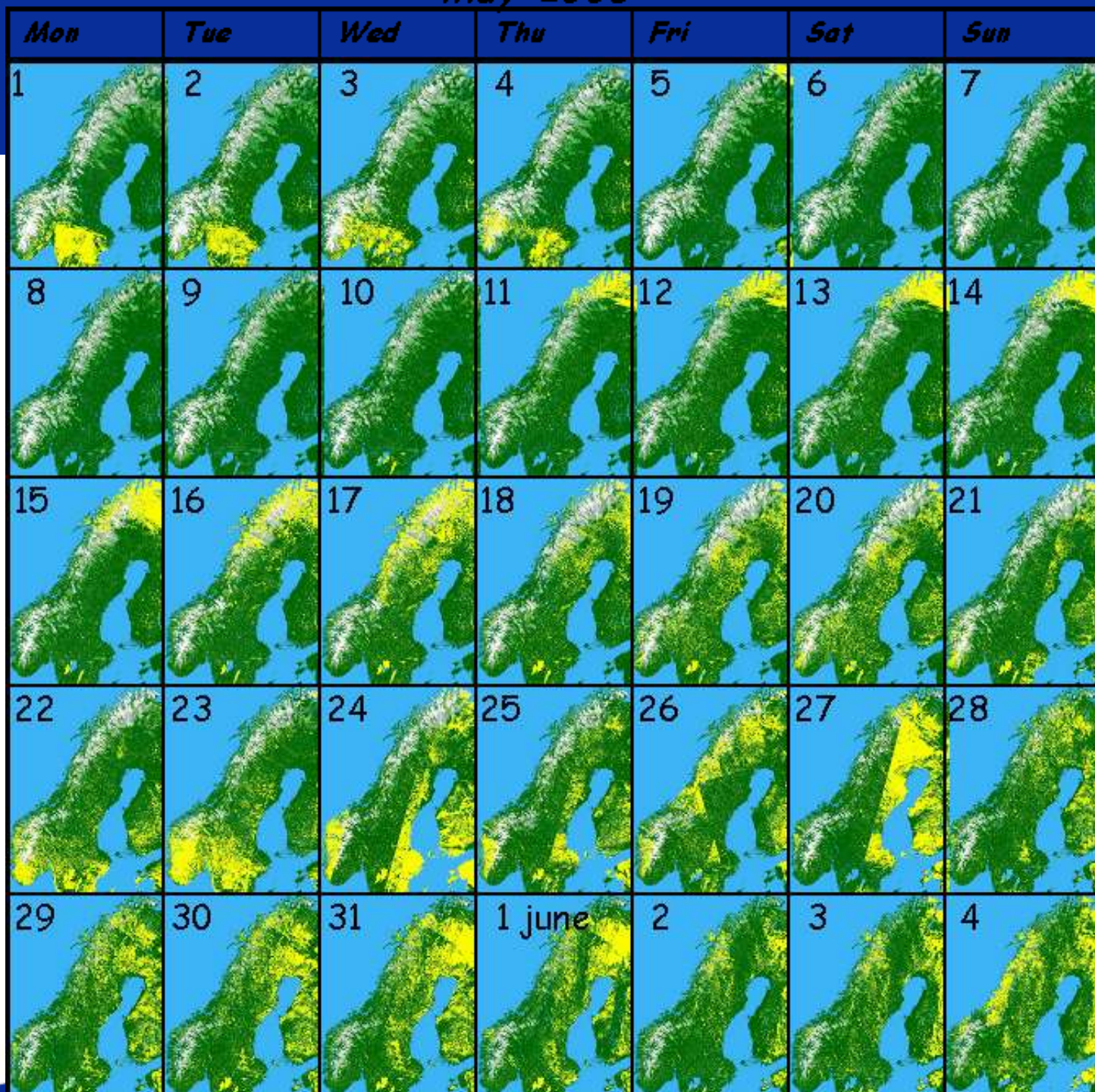


Envisat ASAR WS, 10:01 UT



Multi-sensor product

Snow maps in May 2006



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Operational service

- The service is operational in the snowmelt season April 1 – July 15
- Current pilot users (subscribing to snow maps):
  - Hydropower companies
  - Swedish met/hydrological office (SMHI)
  - Norwegian Institute for Nature Research (DN)
- The service is currently co-funded by Polar View and SnowPower projects

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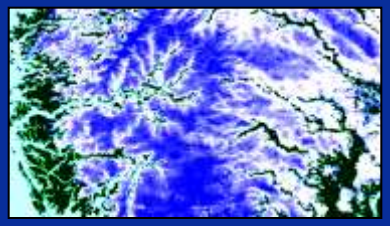
The upcoming EuroCryoClim service

Norwegian Computing Center

Norwegian Meteorological Institute

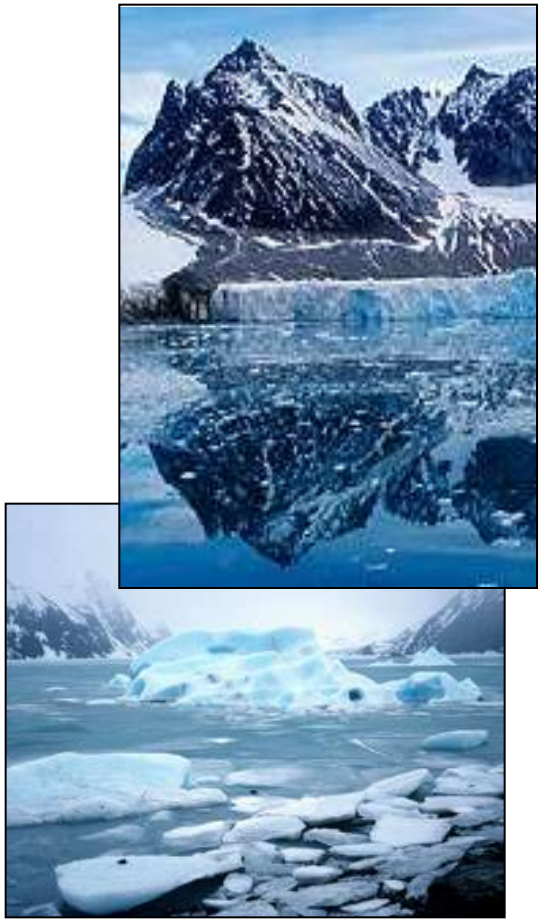
Norwegian Water Resources and Energy Directorate

Norwegian Polar Institute



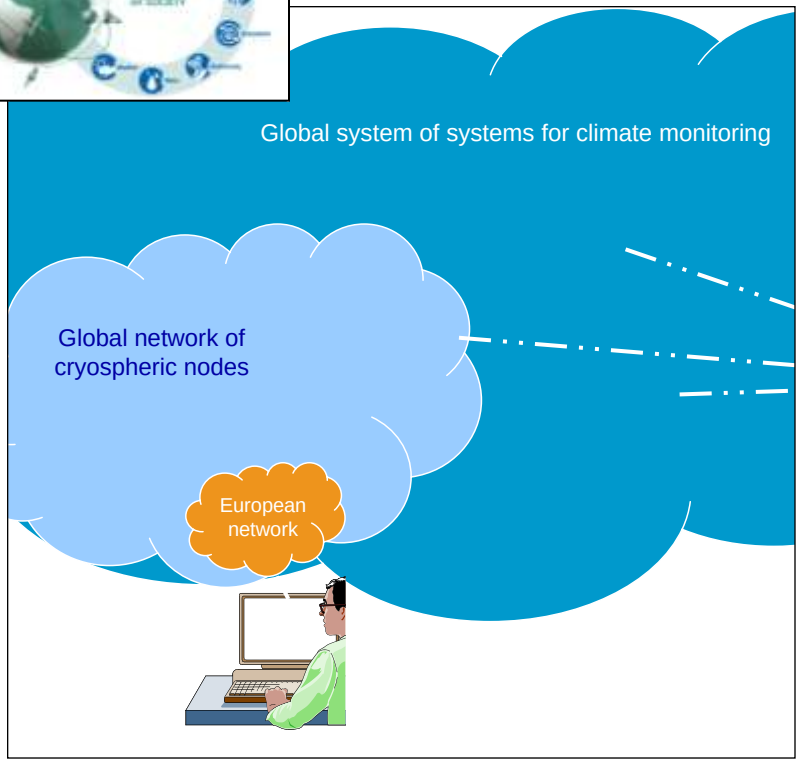
The EuroCryoClim vision

- **Goal**: Develop a service for cryospheric climate monitoring as a (national) contribution to GEOSS following GCOS monitoring principles and GMES and GEOSS recommendations and standards
- **Monitoring of**:
  - Sea ice (global)
  - Seasonal snow (global)
  - Glaciers (Norway)
- **Access**: Web service for searching, browsing and ordering
- **Costs**: Free of charge for non-commercial use
- **Production**: Produced by mandated operational organisations (met.no, NVE, NPI) by a set of automated nodes in a network
- **Funding**: To be secured by the ministries behind these organisations

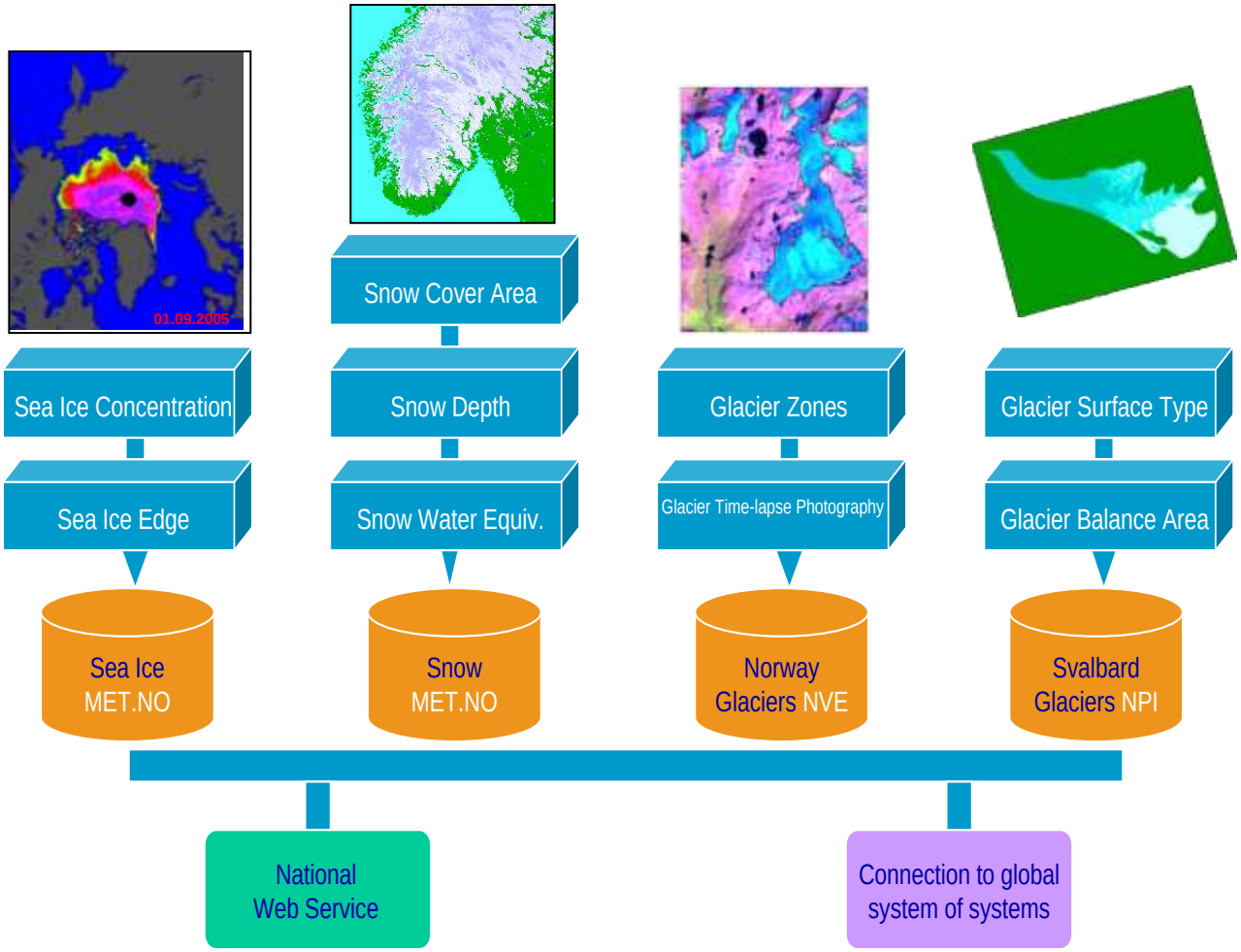


Partners behind the initiative

- Project partners:
  - Norwegian Computing Center (Rune Solberg)
  - Norwegian Meteorological Institute (Lars-Anders Breivik)
  - Norwegian Water Resources and Energy Directorate (Rune Engeset)
  - Norwegian Polar Institute (Stein Tronstad)
- Funded and supported by:
  - Norwegian Space Centre (Per Erik Skrøvseth)
  - European Space Agency (ESTEC + Pierre-Philippe Mathieu/ESRIN)

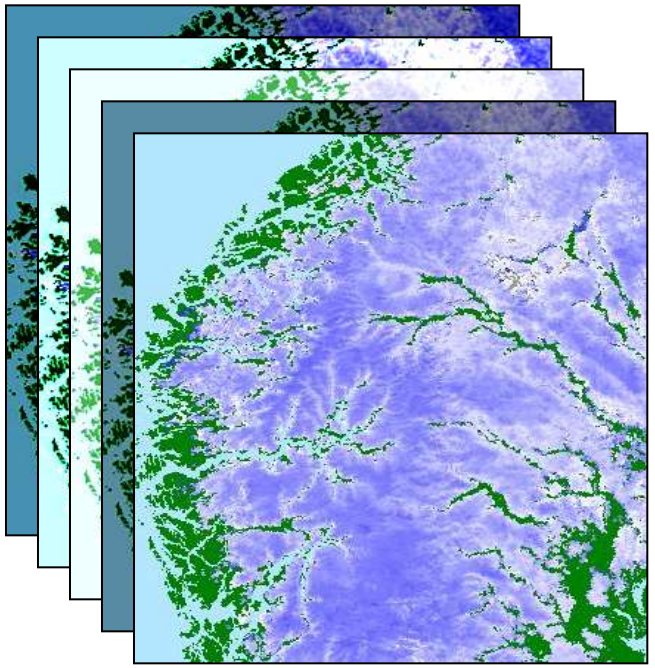


The initial network



Climate product ideas – baseline products

- The baseline products are envisioned to be maps of an aggregated geophysical variable
- Potential aggregation periods:
  - Week
  - Month
  - Season
  - Year
- Potential information layers:
  - Mean (top layer in the figure)
  - Minimum
  - Maximum
  - Standard deviation
  - Number of observations
  - Confidence
- Metadata coming with the product



Tentative product list

ECV	Name	Coverage	Frequency	Res.	Time span	Prov.
	Sea Ice					
O.1	SIC - Sea Ice Concentration	Bipolar	Daily	10 km	1978-present	Met.no
O.1	SIE - Sea Ice Edge	Bipolar	Daily	10 km	1987-present	Met.no
	Snow					
T.3	SCA - Snow Covered Area (PMR)	Global	Daily	10 km	1987-present	Met.no
T.3	SCA - Snow Covered Area (optical)	Regional	Daily	1 km	TBD	Met.no
T.3	SCA - Snow Covered Area (multi-sensor)	Regional	Daily	1 km	TBD	Met.no
T.3	SWE - Snow Water Equivalent (PMR)	Regional	Daily	10 km	1987-present	Met.no
T.3	SD - Snow Depth (PMR)	Regional	Daily	10 km	1987-present	Met.no
	Glacier – Norway					
T.2.1	GAO - Glacier Area Outline	Norway	1-5 years	30 m	1910-present	NVE
	GSL - Glacier Snow Line	Norway	1-5 years	30 m	1910-present	NVE
	GFL - Glacier Firn Line	Norway	1-5 years	30 m	1910-present	NVE
	GLO - Glacier-dammed Lake Outline	Norway	1-5 years	30 m	1910-present	NVE
T.2.1	GTP - Glacier Time-lapse Photo	Norway	Annual	N/A	1910-present	NVE
	Glacier – Svalbard					
T.2.1	GST - Glacier Surface Type	Svalbard	Annual	30 m	1992-present	NPI
T.2.2	GBA - Glacier Balance Area	Svalbard	Annual	30 m	1992-present	NPI

Climate product ideas – climate change indicator products

- Users might need higher-level products easily showing and quantifying climate change
- Some potential climate change indicators:
  - Change of area at minimum sea ice coverage
  - Change of the length of the snow season
  - Trends in the position of glacier fronts

Snow products

ECV	Name	Coverage	Frequency	Res.	Time span	Prov.
T.3	SCA - Snow Covered Area (PMR)	Global	Daily	10 km	1987-present	Met.no
T.3	SCA - Snow Covered Area (optical)	Regional	Daily	1 km	TBD	Met.no
T.3	SCA - Snow Covered Area (multi-sensor)	Regional	Daily	1 km	TBD	Met.no
T.3	SWE - Snow Water Equivalent (PMR)	Regional	Daily	10 km	1987-present	Met.no
T.3	SD - Snow Depth (PMR)	Regional	Daily	10 km	1987-present	Met.no

- The plan is to start with PMR (SSM/I / [SSMR]), then proceed with optical (AVHRR) followed by a multi-sensor product merging the two previous
- Options are to develop SWE and SD products based PMR
- Will be based on sea-ice experience and past projects that have developed retrieval algorithms for snow variables from PMR (like SnowTools) and optical (like EuroClim)
- Products will be available successively through the project period (about 4 years)

Summary

- Regional snow products developed for mountain regions:
  - Fractional Snow Cover (250 m)
  - Snow Surface Temperature (1 km)
  - Snow Surface Wetness (1 km)
  - Snow Distribution Pattern (30 m)
- Global snow monitoring to be developed in EuroCryoClim:
  - Snow Cover Area (10 km)
  - Multi-sensor SCA (1 km)
  - Snow Depth (10 km)
  - Snow Water Equivalent (10 km)
- More information:
  - rune.solberg@nr.no
  - http://earthobs.nr.no