Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

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Snow wetness estimation from MODIS images

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Why study snow from satellites?

- Indications on climate changes
- Hydro-electric power production
- Floods
- Avalanches
- Skiing conditions

Snow products made at NR

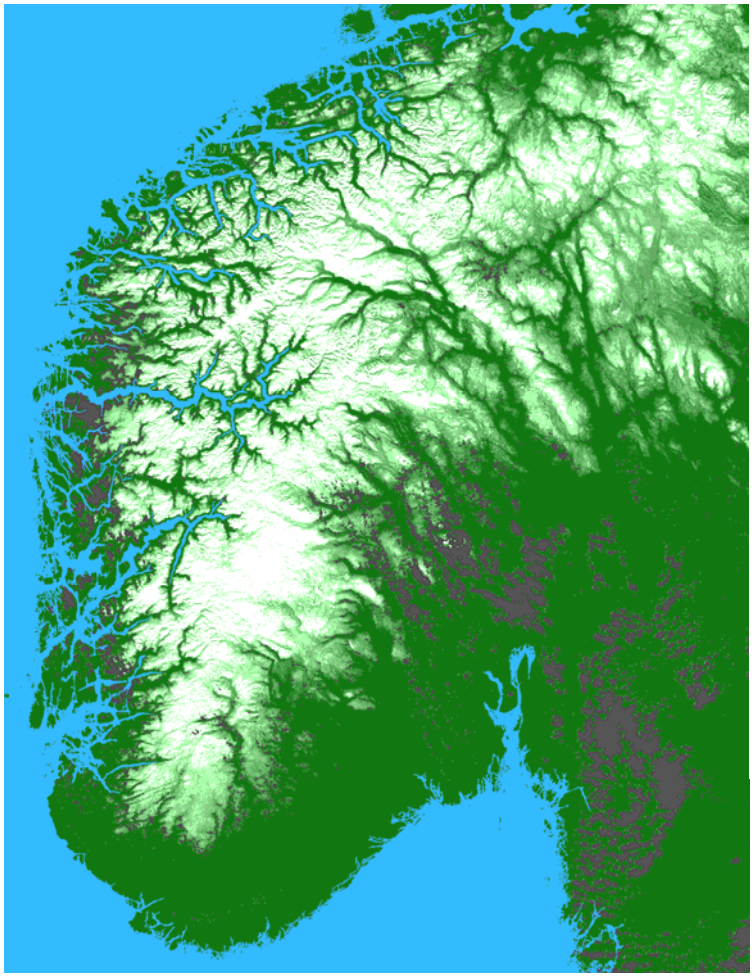
From MODIS images:

- Snow cover area (SCA)
- Snow surface temperature (STS)
- Snow grain size (SGS)
- Snow surface wetness (SSW)

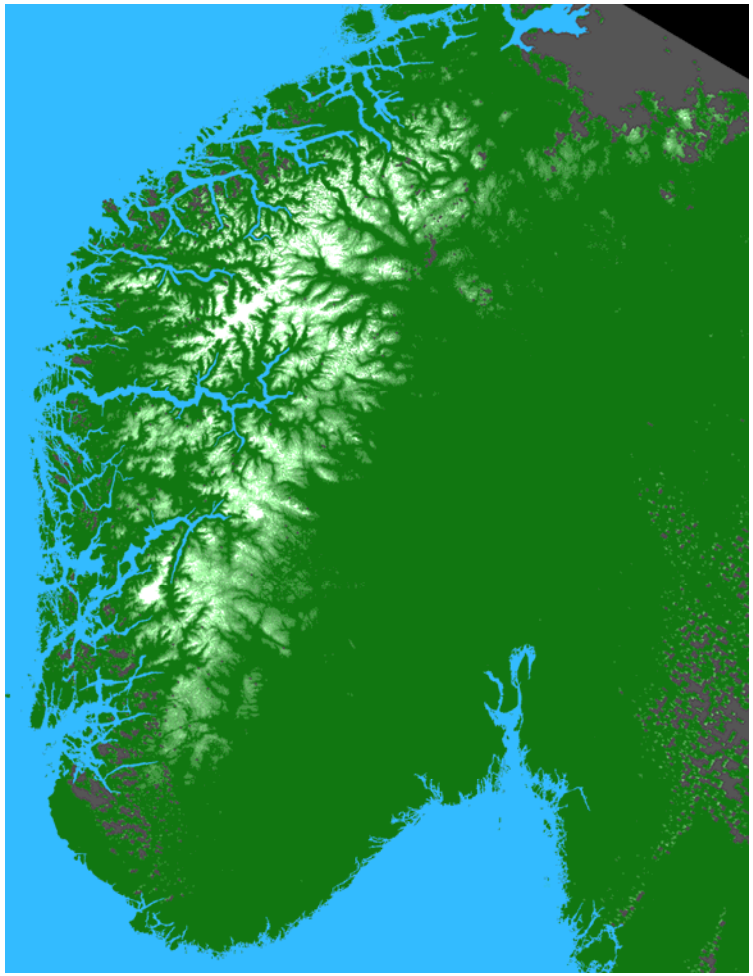
From MODIS and ASAR in combination (with NORUT):

- Snow cover area (SCA)

SCA product

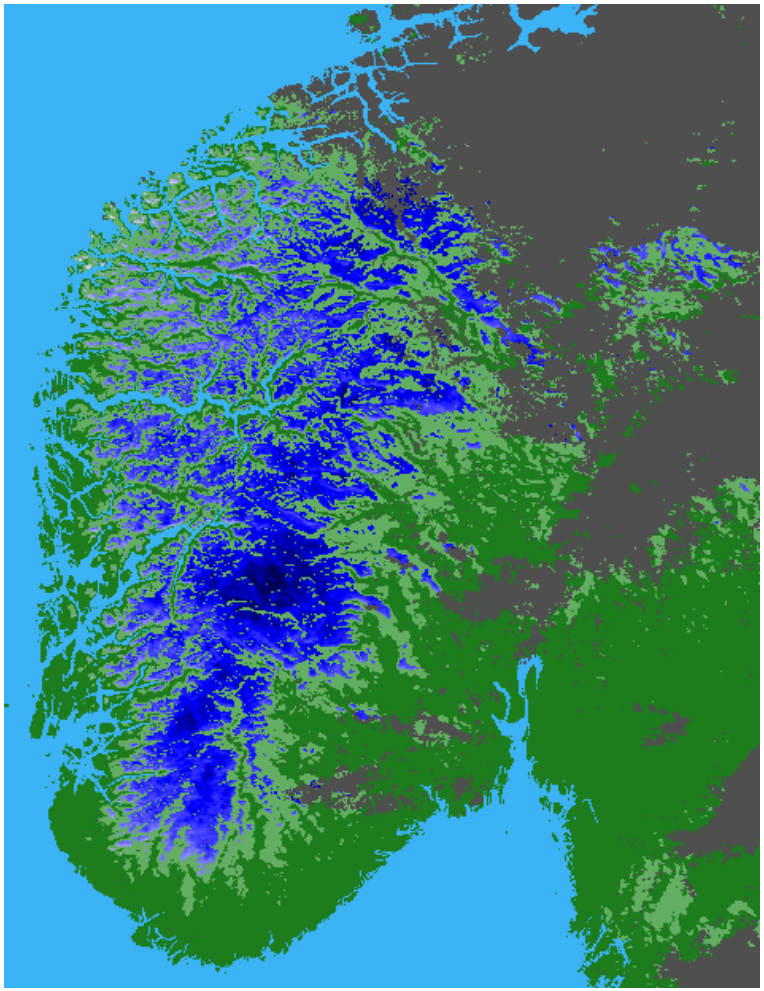


25 April 2005

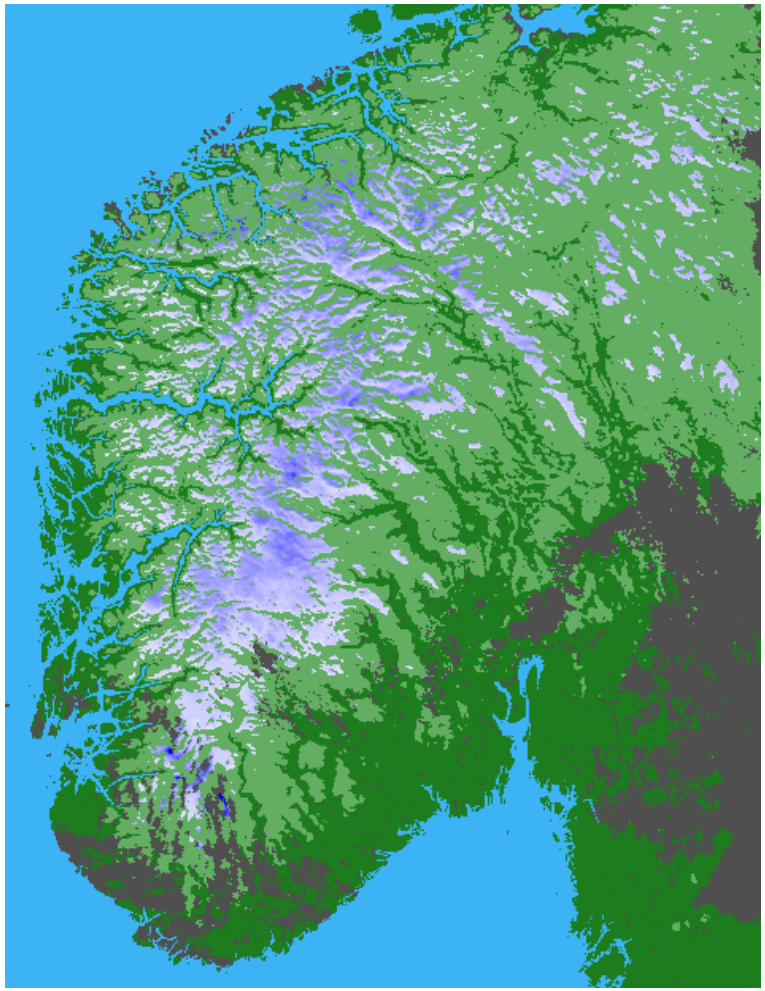


29 June 2005

STS product



25 February 2005



27 March 2005

The MODIS sensor

- Mounted on two satellites: Terra and Aqua
- At least one image per day from each of the satellites
- 36 channels covering wavelengths from 0.405 to 14.385 μm
- Nadir resolution:

  250 m for 2 channels

  500 m for 5 channels

  1 km for 29 channels

Why MODIS images?

- A lot of geophysical and meteorological parameters can be studied.
- Continous monitoring (NB! Without clouds)
- Simple and rapid ordering and downloading
- Free images

Snow wetness

- Snow wetness is defined as the percentage of free liquid water in the snow pack
- Not as applicable for runoff estimates as snow water equivalent or snow cover area
- Useful indicator for the prediction of snowmelt start and runoff

Estimation of SSW

We try to estimate if the snow in the surface is dry or wet. We do not estimate the exact percentage of free liquid in the snow pack.

The estimation of snow wetness is based on the knowledge of:

- Snow surface temperature (STS)
- Snow grain size (SGS)

Calculation of STS

Key's algorithm Key et al (1997)

correct for atmospheric attenuation utilizing path length

$T_s = a + b\,T_{11} + c\,(T_{11} - T_{12}) + d\,(T_{11} - T_{12}) / \cos(\Phi)$

MODIS channels:

31: 10.780 -11.280 µm

32: 11.770 -12.270 µm

Calculation of SGS

Fily et al. (1997) tried different ratios between Landsat thematic mapper channels:

$$R_{ij} = \frac{TM_i - TM_j}{TM_i + TM_j}$$

TM is the apparent reflectance or the ground reflectance for each channel.

Grain size index from Landsat ETM+ and MODIS

- Landsat R47

  channel 4: 0.775 – 0.900 μm

  channel 7: 2.09 – 2.35 μm

- MODIS R27

  channel 2: 0.841 – 0.876 μm

  channel 7: 2.105 – 2.155 μm

The ratio does not give the exact value of the grain size radius, but is used as an index of the size. A higher ratio means a larger size. It is easy to see if the grain size is increasing or decreasing.

Estimation of SSW

Using the snow surface temperature and the development of the grain size during the last days.

Without a new snowfall the grain size will increase

- slowly at low temperatures
- more rapidly at temperatures close to 0 °C
- very rapidly during melting and refreezing

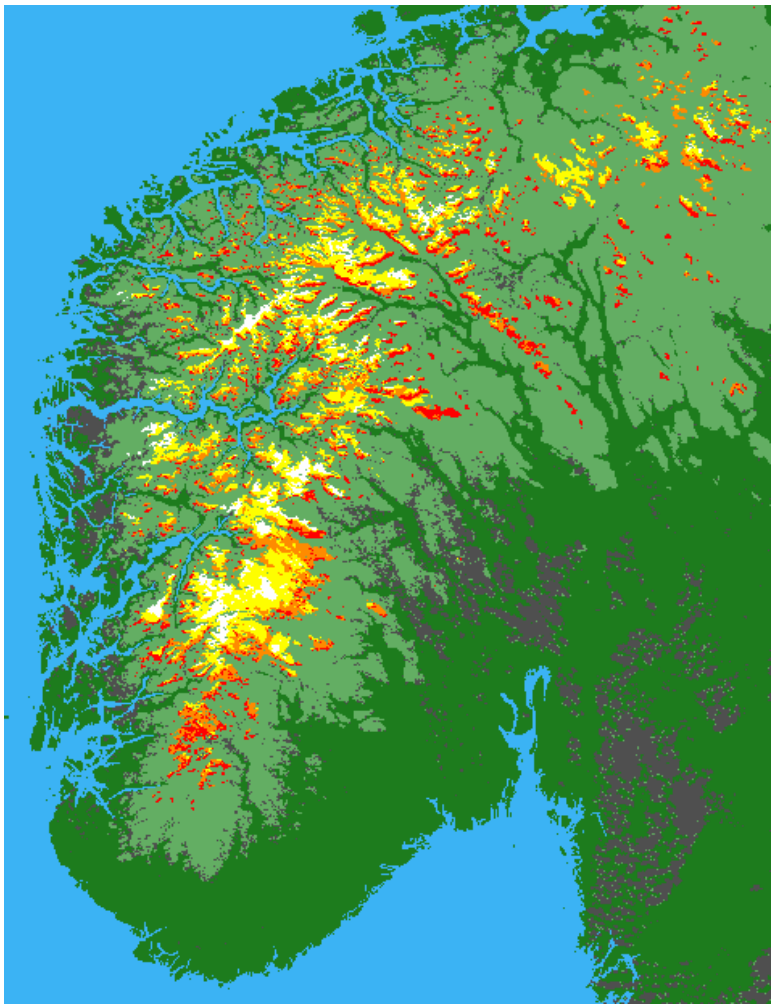
The grain size in the snow surface may decrease after new snowfall.

Estimation of SSW

The SSW product is presented as a map showing 4 different classes:

- Cold dry snow: STS < -2 °C
- Probably dry: -2 °C < STS < -0.5 °C
- Probably moist: -0.5 °C < STS < + 0.5 °C and SGS not increasing more than a given limit
- Most probably wet: -0.5 °C < STS < + 0.5 °C and SGS increasing more than limit or STS > +0.5 °C

SSW product



25 April 2005 10:45

Dry, cold snow

Dry snow

Moist snow

Wet snow

Partly snow cover

Bare land

Clouds

Sea

Limitations

- STS and SGS algorithms only apply for 100% snow cover

  - Low SGS index indicates bare land

  - STS > 0 °C indicates bare land, and probably wet snow, but the snow temperature could even be below 0 °C

- Clouds

  The SSW-product needs information about snow cover and clouds. NR has developed algorithms for snow cover percentage and clouds.

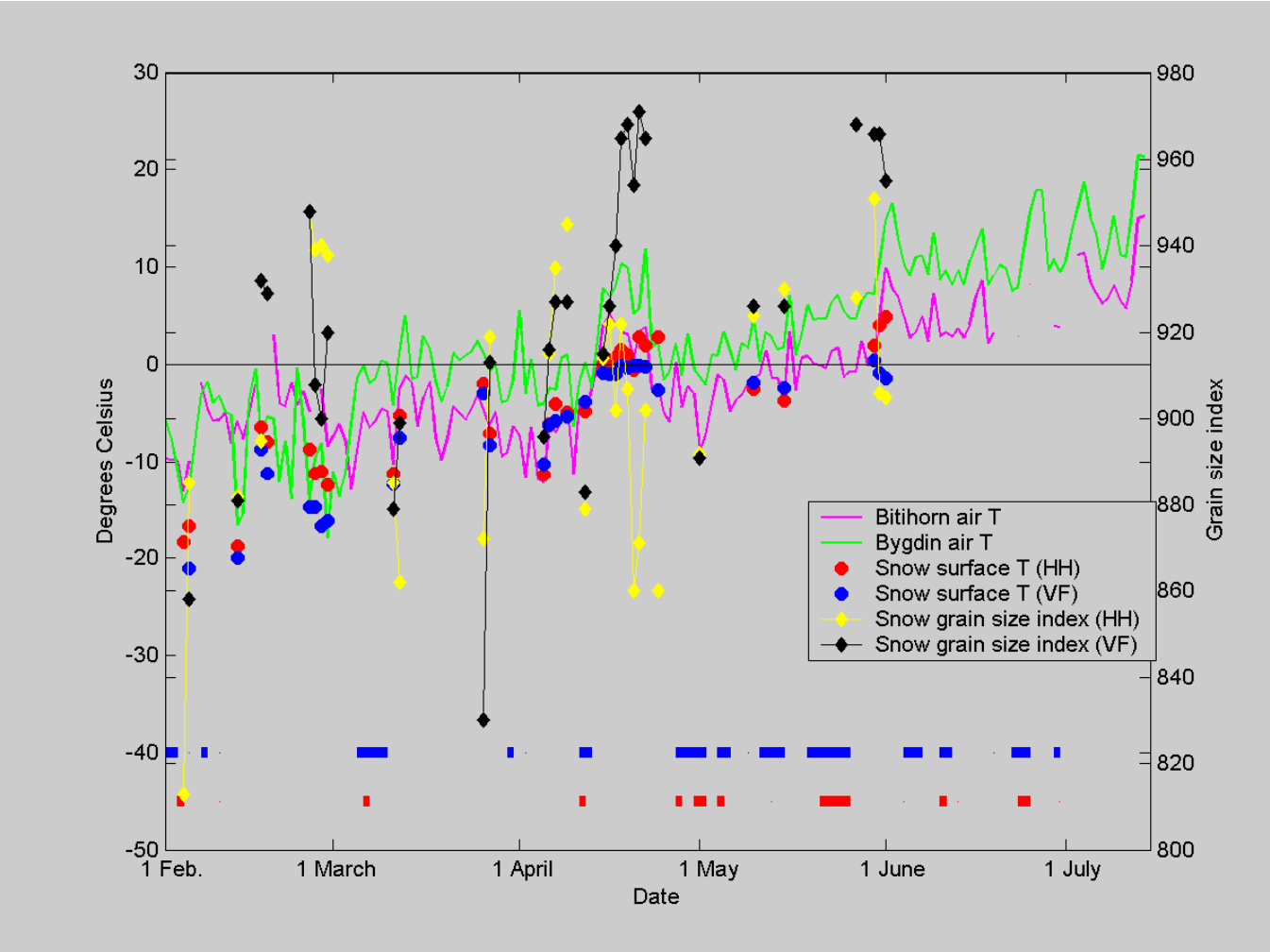
Calibration and validation

- Measuring snow parameters on ground at the time of satellite passages
- Measurements of all parameters during the complete winter and spring
- At many different sites
- Status: Lack of extensive ground truth measurements during the year

Calibration and validation

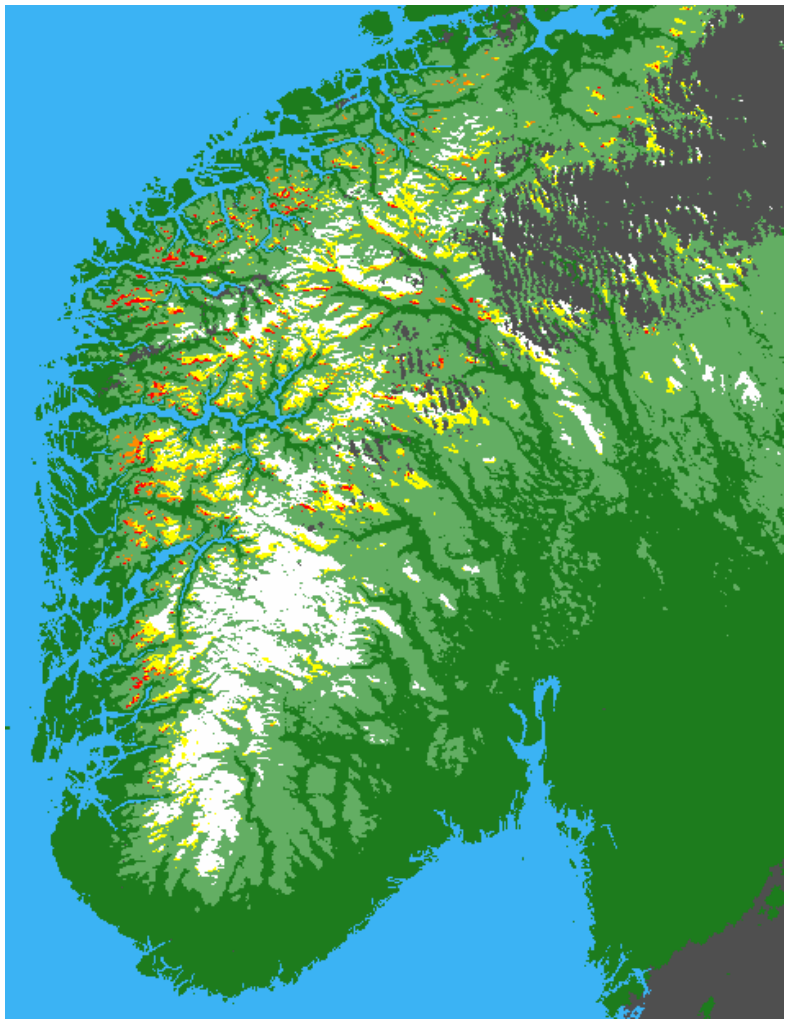
- Test area in Jotunheimen: Valdresflya, ~ 1350 m.a.s.l and Heimdalen 1000-1840 m.a.s.l.
- Yearly campaigns, measuring temperature of snow and air, snow grain sizes, snow reflectance, snow humidity
- Continuous monitoring of air temperature at nearby sites: Bygdin 1090 m.a.s.l. and Bitihorn 1609 m.a.s.l.
- Daily registrations of precipitation at Beito 754 m.a.s.l. 15 km to the south and Skåbu 890 m.a.s.l. 36 km north-east of the test area

STS and SGS vs air temperature and precipitation

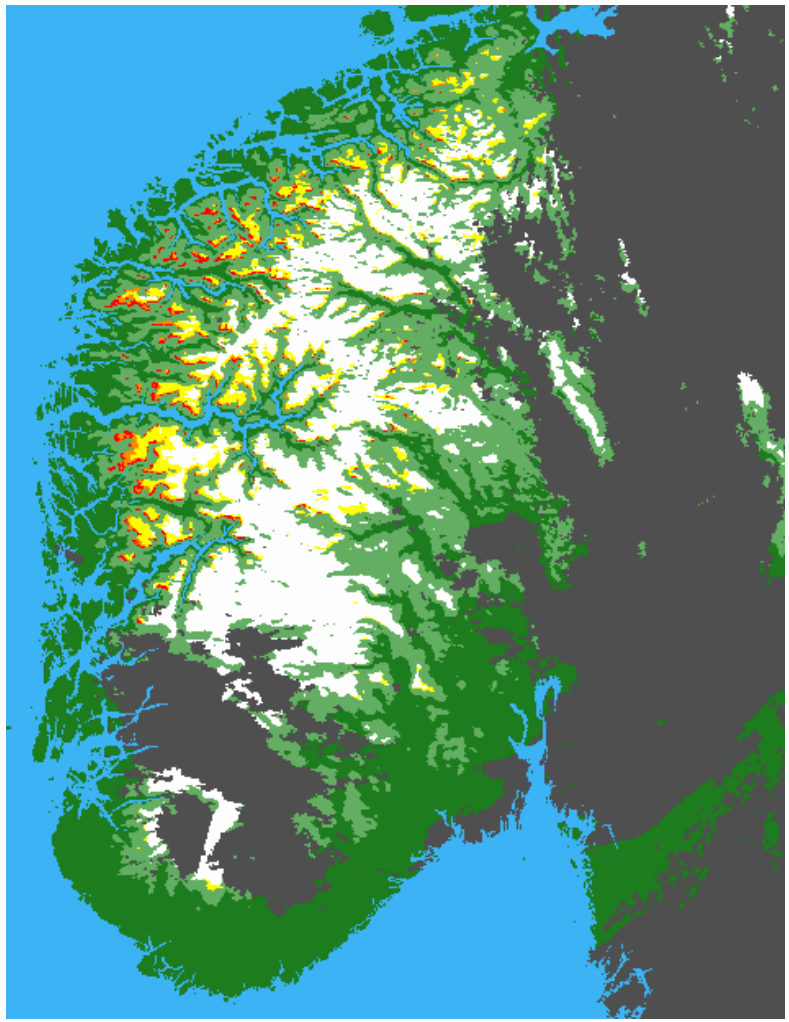


HH-Heimdalshø (1840 m), VF-Valdresflya (1380 m) Precipitation Beito (blue), Skåbu (red)

SSW product

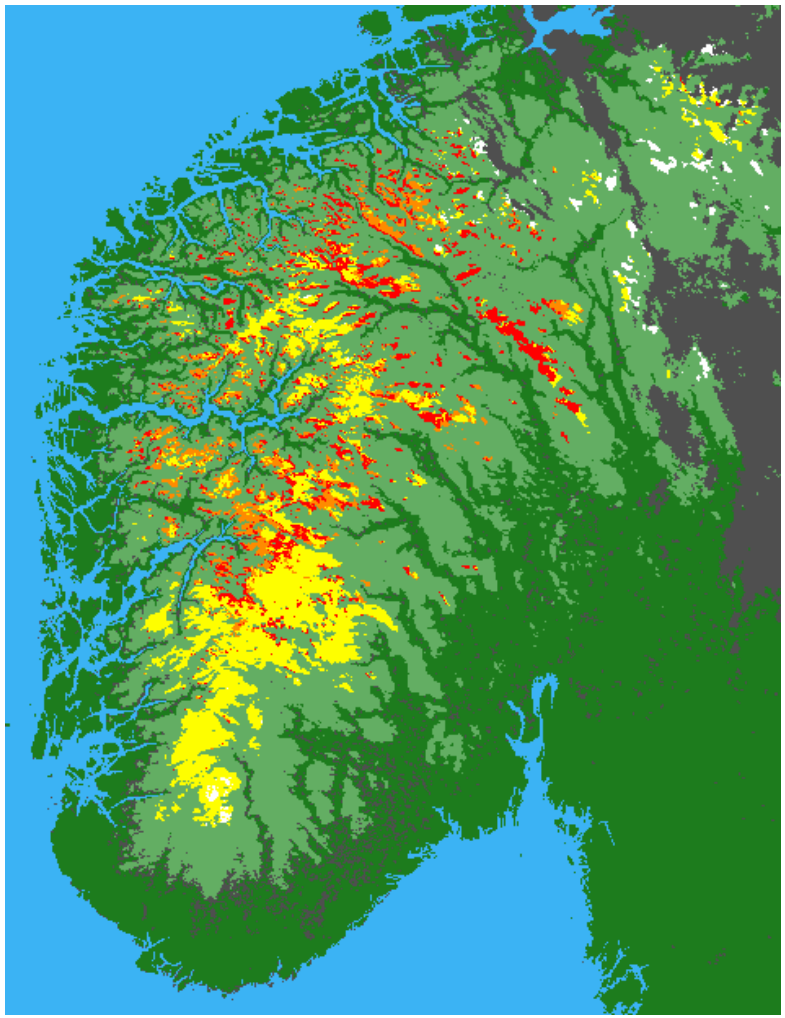


9 April 2003 11:05



10 April 2003 10:10

SSW product



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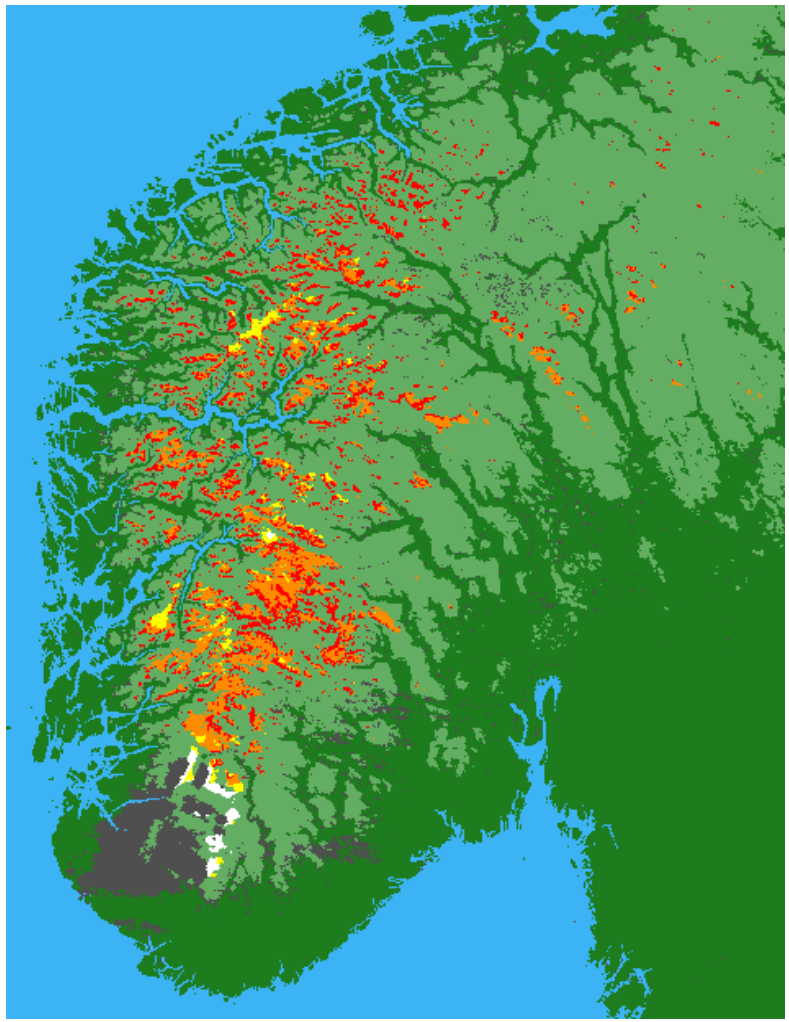
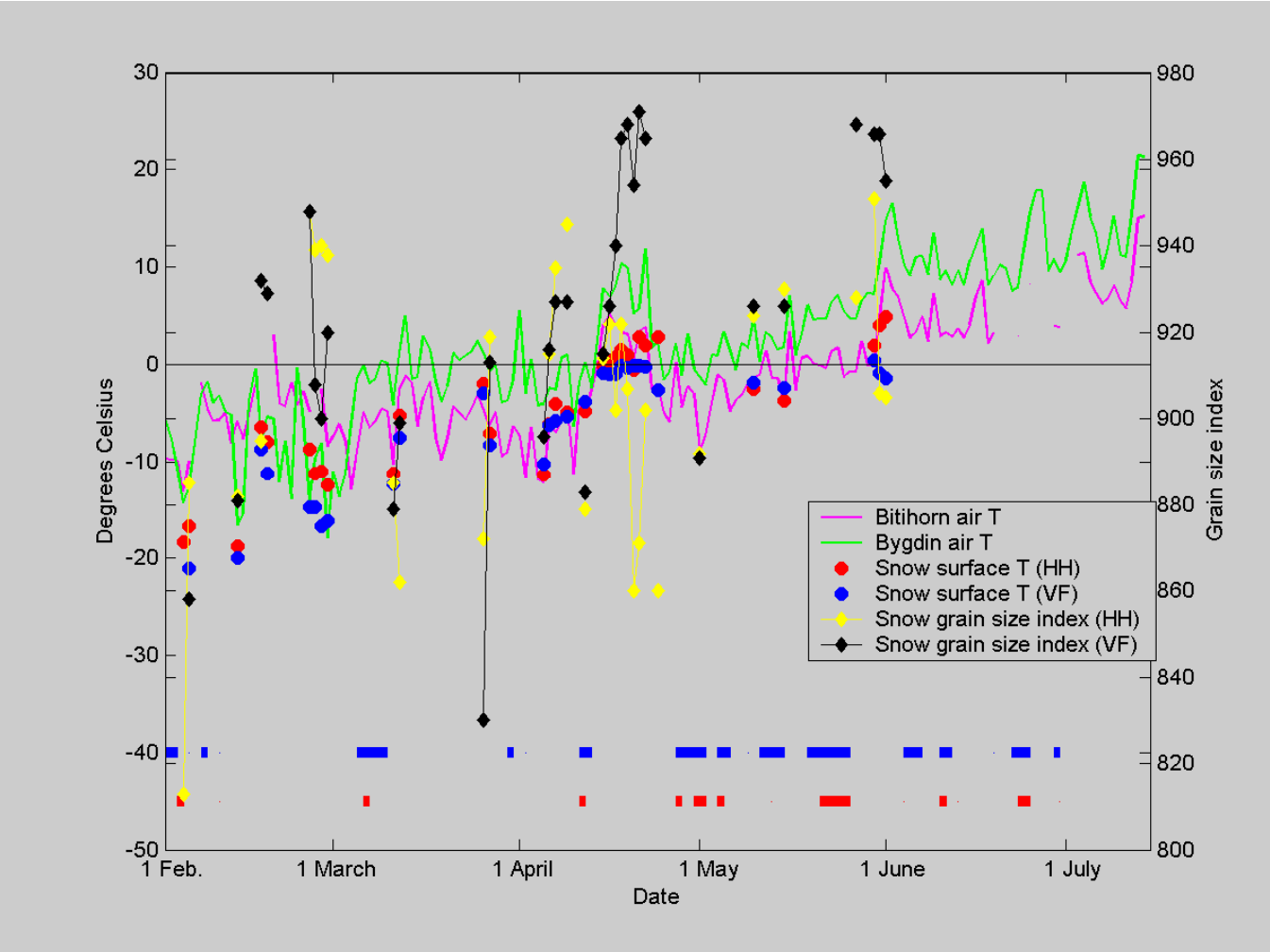


20 April 2003 10:45

STS and SGS vs air temperature and precipitation



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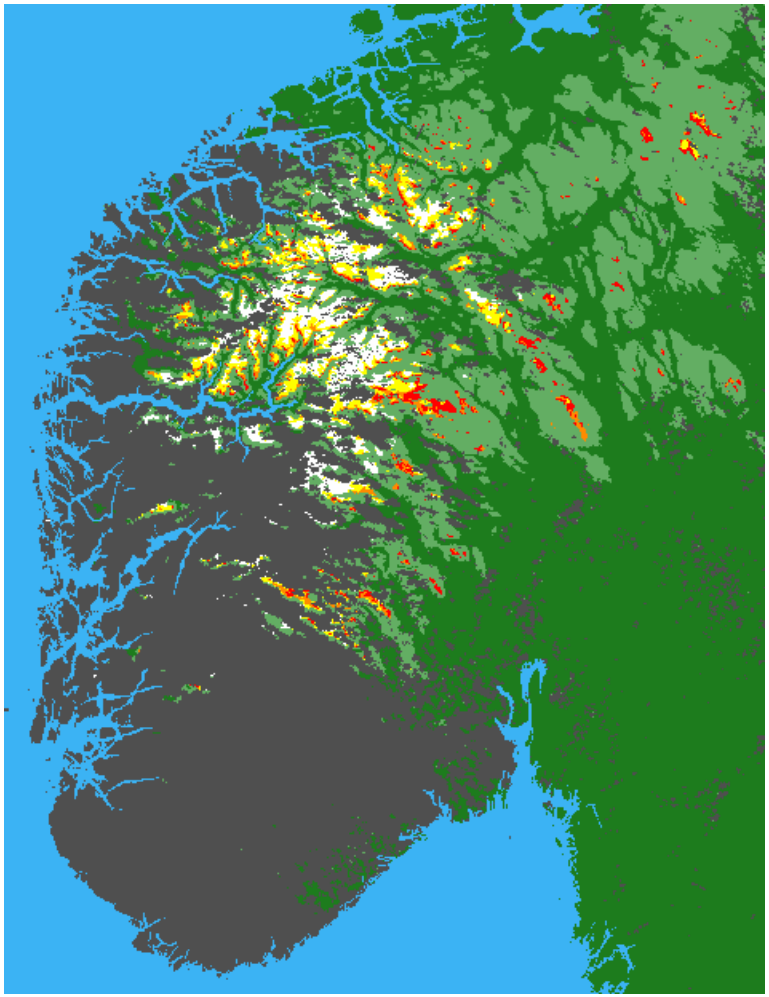
SSW product



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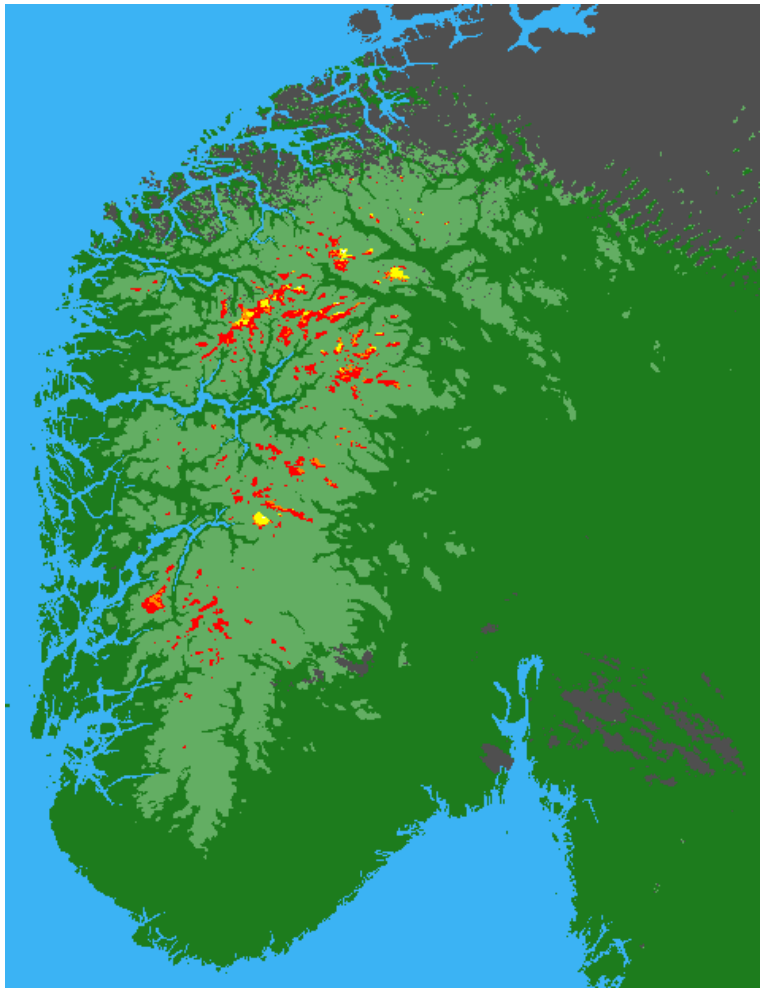

31 May 2003 10:40

Conclusion

- Snow wetness can be estimated from MODIS images
- The time of start of snow melting can be found
- SSW combined with the development of the SCA, can give indications of the progress of snow melting
- NB! The continuous monitoring may be obscured by clouds
- MODIS and SAR images in combination will improve the results. NR and NORUT are working together with multi sensor products