Project information

Keywords

Growing season, soil frost/thawing, remote sensing, Big-data

Project title

SenSyF

Year

2016

Project leader

Eirim Lanes

Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)

69.55 N, 20.42Ø , 69.77N,19.45Ø, 78.20N, 15.95Ø , 78.06N, 13.70Ø

Participants

- **Eirik Malnes, Stein Rune Karlsen and Markus Eckerstorfer, Norut**
- **Hans Tømmervik, NINA**
- **Lennart Nilsen, UiT**

Flagship

Terrestrial

Funding Source

SenSyF was originally funded by the EU FP 7 project SenSyF (Sentinel Synergy Framework). This project ended in Dec 2015, but we applied for addtional funding from Fram to extend the activity and publish results.

Summary of Results

The Fram centre project SenSyF was initiated to exploit the developments made in the EU project SenSyF.. The satellites deliver frequent high resolution SAR and optical data worldwide, and Norut is responsible for two innovative EO based services for soil-frost monitoring and growing season monitoring. The Fram centre project has focused on validating the services developed by comparing results to in situ data sets and auxiliary remote sensing datasets. We have also focused on involving other Fram centre partners (NINA and UiT). The results are currently being published in international peer-reviewed journals.

The Fram centre project had four work-packages:

WP 1. BigData: Parallel cloud processing of Sentinel-1 and Sentinel-2

This work package had a small budget (27kkr) and was meant for utilizing the outcome of the cloud computing software developed in the EU project SenSyF for processing time series of Sentinel-1 and Sentinel-2 data. Due to limited support to the new sensors Sentinel-1 and -2 after the SenSyF project ended in December 2015, we quickly realized that the software could not be used effectively, and we hence continued to utilize the software already developed at Norut to prepair time-series of Sentinel-1 and Sentinel-2 data over the study regions. In the context of the Fram centre project this was totally adequate, but in the future there is a clear need for more effectively handling of the big data amounts delivered by the Copernicus satellites.

WP 2. Validation of soil-frost product

SAR based retrieval of soil-frost and snow information has a large potential at high latitudes due to problems in the winter season related to cloud cover and darkness that limits utilization of optical sensors. Within this framework several validation activities have been ongoing at Svalbard (Kapp Linne and Longyearbyen) and in main-land Norway (Nordnes). Availability of relevant in situ measurement stations in combination with long term satellite time series is crucial for understanding the radar signatures from soils.

We report on one activity at Kapp Linne where we have utilized a 10 year time series of Envisat ASAR and Radarsat-2 images with up to daily sampling rates. By studying the temporal variability of radar backscatter we were able to establish relationships between snow melting and sudden decrease in radar backscatter. We also established firm relations between maximum backscatter and maximum snow depth during winter time. Based on these results we were able to estimate at detailed spatial scale the number of thaw days at the location and assess correlations between active layer depts. This activity has been submitted as a paper (Eckerstorfer et al., 2016).

Figur 1:

: a) Development of number of days with thawed ground surface annually for all six studied landforms during the study period (2005-2013). Missing data values are due to gaps in the ground surface temperature field measurements. b) Active layer depths at all six study sites in the study period (2005-2013). The active layer depths are calculated from the ground temperature field measurements available in the NORPERM database (NORPERM, 2015). Missing data values are due to gaps in the ground temperature field measurements.

WP3. Validation of growth season, Sentinel-2

The last decade, several institutes and universities (UiT, Norut, NINA, Lund University) have established in-situ measurements of climate parameters like phenology, photosynthetically active radiation, spectral sensors, CO_2-flux and primary production in Adventdalen. In spring 2015, this project in cooperation with the RCN funded project SnowEco headed by UiT established 6 study sites in Adventdalen. At each site one rack was mounted and equipped with different sensors and cameras for environmental monitoring in the period May to September. All racks had an NDVI sensor, a digital color camera taking daily picture for measuring snowmelt and vegetation phenology, a sensor for combined measurement of soil temperature and moisture. In addition, two of the racks were equipped with hemispheric NDVI sensors for calibration purposes. We also mounted a sensor for calculating the Photochemical Reflectance Index (PRI), along with one hemispheric PRI sensor. PRI is a reflectance measurement developed by Gamon et al. (1992). PRI is used in studies of vegetation productivity and stress, since PRI is sensitive to changes in carotenoid pigments (e.g. xanthophyll pigments) in live foliage and these pigments are indicative of photosynthetic light use efficiency, or the rate of carbon dioxide uptake by foliage per unit energy absorbed. Since the PRI measures plant responses to stress, it can be used to assess general ecosystem health using satellite data or other forms of remote sensing like the in-situ network of near remote sensors we have established in Adventdalen (Anderson et al. 2016).

Tabell 1: Summary table of locations, plant communities, instrument set-up and cameras mounted on the 10 racks in Adventdalen during the period May to September in 2016.

In 2016, 4 more sites were equipped with digital color camera and NDVI sensors and additional two hemispheric NDVI sensors. One more PRI-sensor and a hemispheric PRI was mounted. In addition to the mounted RGB camera (2015) up in the hills of Breinosa mountain, another RGB camera was positioned up in the mountain Lindholmhøgda, monitoring an area south of Isdammen in the lower part of Adventdalen in May 2016 (Figure 1).

Figur 2: Map shows distribution of the 10 racks and 2 landscape camera monitoring the Adventdalen area during growth season 2016. The inset show a typical set-up of rack with instruments in the field.

The Decagon NDVI- and PRI-sensors are mounted at 2 m height, programmable (every 4hrs) covering the wave lengths of 650 nm and

810 nm (NDVI) and of 532nm and 570nm (PRI), respectively. NDVI and PRI are calculated as the ratio between reflected and incident radiation, measured using down-looking and up-looking sensors, respectively. Depending on ambient sky conditions, one up-looking sensor may be able to provide reference values for multiple down-looking sensors (Figure 1).

Figur 3: Hemispherical or Directional Field of View of the NDVI/PRI-sensors. Source: Decagon.

We have published the results from the first year (2015) of monitoring of the growing season using data from the six racks within the area of the SnoEco project in Adventdalen below the Breinosa mountain (Anderson et al. 2016). We used both active and passive NDVI sensors and digital RGB cameras to monitor the greenness and NDVI of six different but common and widespread High Arctic vegetation types (Table 1). Of the three calculated greenness indices (2G_RBi, Channel G% and GRVI) derived from digital camera images, only GRVI $(G_{DN} - R_{DN})/(G_{DN} + R_{DN})$ showed significant correlations with NDVI in all vegetation types. Both NDVI and GRVI successfully recorded timings of the green-up and plant growth periods and senescence in all six plant communities. Some differences in phenology between communities occurred: the mid-season growing period reached a sharp peak in NDVI and GRVI values where graminoids were present (, but a prolonged period of higher values occurred with the other plant species/groups.

Figure 4 Ex

ample of an in-situ station in Adventdalen with Decagon NDVI- and PRI-sensors and a RGB-camera.

Unlike the other plant species/groups, *C. tetragona* experienced increased NDVI and GRVI values towards the end of the season. NDVIs measured with an active sensor (Trimble Greenseeker) at the same sites were strongly correlated ($r^2 > 0.70$) for the same plant species/groups. Thus, it is evident that GRVI measured with ordinary RGB-cameras and NDVI measured with active and passive sensors captured similar vegetation attributes of High Arctic plants. Hence, inexpensive digital RGB cameras may be used together with passive NDVI device to establish near remote sensing network for monitoring phenology and changing vegetation dynamics. Additionally, time series of already established RGB-cameras mounted in the field can be utilized, in order to compare them with climatic and remotely sensed time series back in time for both validation and assessments (Anderson et al. 2016).

Figur 4: NDVI and greenness index values from six different High Arctic plant communities throughout the growing season. Readings were taken between 5 June (day of year = 156) and 30 August (day of year = 242) 2015. NDVI was recorded using Decagon surface reflectance sensors (black circles) and a Trimble Greenseeker handheld sensor (open circles); the Green-Red Vegetation Index (GRVI) values (grey squares) were calculated from red and green channel data from RGB images. The rack within plant community 6 was relocated and renumbered 10 in 2016. Source: Anderson et al. 2016.

A processing chain for Sentinel-2 data has been developed. It includes automatic downloading and pre-processing of Level 1C product to different indices. For central parts of Svalbard Sentinel-2A data have almost daily coverage, only eight days are missing during the period 10 May to 20 September 2016.

Figur 5: Spectral properties during the snow free season of a tundra grass wetland in Adventdalen in 2016, based on the 13 bands in Sentinel-2A level 1c data. Such analyses are done in order to detect the best methods for mapping phenophases of different vegetation types, as well as in developing cloud detection algorithms.

Figur 6: ‘Raw’ Sentinel-2A, level 1C, NDVI data, and calibrated NDVI from Decagon device. Both the data are from station 6, a polar willow - grassland’.

WP4. Merged Sentinel-1 and Sentinel-2 data in multi-temporal analyses of the seasonal dynamics

In this workpackage we report activities related to remote sensing of seasonal snow covers. A paper on using MODIS to study the snow season variability in northern Scandinavia was published in 2016 (Malnes et al., 2016). This single sensor approach can be significantly improved when using SAR sensors to update the snow cover in periods when cloud cover or polar nights are a problem. We have e.g. used Landsat-8 and Sentinel-1 to assess the accuracy in wet snow cover detection, and we obtain very satisfactory results (Fig below). Methodology for fusing radar and optical measurements of snow cover has been implemented and tested.

Figur 7: Comparison of Landsat-8 (upper left) and Sentinel-1 (upper right) snow cover map for Folgefonna region. Image (lower left) snows difference map (red: S1 and LS8 detects snow, blue S1 and LS8 detect snow free, green/yellow: S1 and LS8 disagrees). The total probability of correct detection is 91%,

Master and PhD-students involved in the project

None

Published Results/Planned Publications

Anderson, H.B., Nilsen, L., Tømmervik, H., Karlsen, S.R., Nagai, S., Cooper, E.J. 2016. Using Ordinary Digital Cameras in Place of Near-Infrared Sensors to Derive Vegetation Indices for Phenology Studies of High Arctic Vegetation. *Remote Sensing*, 8, 847, doi:10.3390/rs8100847.

Eckerstorfer, M., Malnes, E. Christiansen, H.H., Periglacial lowland landscape scale snow dynamics and ground surface freeze-thaw cycles from C-band SAR data from Kapp Linné, Svalbard, Submitted to *Geomorphology*, August 2016.

Karlsen, S.R., L. Stendardi, K.A. Høgda, Johansen, B. 2016. Multiscale mapping of the seasonal dynamics of the High Arctic archipelago of Svalbard. Abstract in Living Planet Symposium 2016, Prague, Czech Republic from 9-13 May 2016.

Karlsen S.R., Nilsen, L., Tømmervik, H., Johansen, B. 2016. Processing a clear-sky time-series of Sentinel-2A data of central parts of Svalbard to monitor seasonal changes in vegetation. Abstract for the *1st Sentinel-2 Validation Team Meeting*, 28-29 November 2016, ESRIN, Frascati, Rome.

Malnes, E., Karlsen, S., Johansen, B., Bjerke, J., and Tømmervik, H. Snow season variability in a boreal-Arctic transition area monitored by MODIS data , *Environmental Research Letters.* ERL-102658, Accepted Oct 2016.

Stendardi, L., Karlsen, S.R. 2016. Monitoring of plant productivity in relation to climate on Svalbard. Norut Report 07/2016. 14 pp.

Park, T., Ganguly, S., Tømmervik, H., Euskirchen, E.S., Høgda, K.A., Karlsen, S.R., Brovkin, V., Nemani, R.R., Myneni, R. B. 2016. Changes in growing season duration and productivity of northern vegetation inferred from long-term remote sensing data. *Environmental Research Letters*, 11 (2016) 084001. doi:10.1088/1748-9326/11/8/084001.

Tømmervik H., Karlsen S.R., Vickers H., Høgda K.A., Zagajewski B. 2016. Changes in growing season productivity of Northern vegetation inferred from long-term remote sensing data. Abstract in: *Impact of climate change and pollution on vegetation distribution and condition in the temperate, boreal, alpine and polar zones. Warsaw*, 26-27.10.2016.

Vickers, H., Høgda, K.A., Solbø, S., Karlsen, S.R., Tømmervik, H., Aanes, R., Hansen, B. B. 2016. Changes in greening in the High Arctic - insights from a 30-year AVHRR max NDVI dataset for Svalbard. *Environmental Research Letters*, 11 (2016) 105004. doi:10.1088/1748-9326/11/10/105004.

Interdisciplinary Cooperation

Collaboration between remote sensing experts, geophysisists, and ecologists

Budget in accordance to results

Yes

Could results from the project be subject for any commercial utilization

No

Conclusions

The Fram centre project SenSyF have successfully achieved the main objectives in the project by

1) **Exploiting the results and processing software for massive amounts of EU data obtained through the EU project SenSyF to validate the developed services and publishing the results in scientific journals**

2) **We have involved NINA and UiT in the EU project through valuable user contributions, scientific collaboration/publishing, and collaboration on in situ sampling of mutual interest.**