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## 2<sup>nd</sup> workshop “Preparations for Sentinel-2 in Europe: workshop summary”

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# 2<sup>nd</sup> workshop “Preparations for Sentinel-2 in Europe: workshop summary”

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# Contents

- Executive summary ..... 5
  - Context ..... 5
  - Workshop rationale and objectives ..... 5
  - Workshop salient findings ..... 5
- Summary of presentations and discussions ..... 6
  - What is the status of preparation for ColGS in the different countries? ..... 6
  - What are the services that the ColGS delivers? ..... 6
  - Observations and recommendations from the NMA’s ..... 7
  - What are common research topics? ..... 7
- Recommendations ..... 7
- Highlights from the presentations ..... 8
  - Sentinel-2: mission status, data access and outlook ..... 8
  - Sentinel-2: products, data quality and evolution ..... 9
  - From rapid development to operational processing: Sentinel data user's support provided by ESA's SNAP ..... 10
  - The French Theia Land data center products, based on Sentinel-2 data: cloud masks, atmospheric correction, snow cover and land cover maps at country scale ..... 11
  - Status of the Earth Observation Data Centre (EODC) services ..... 13
  - Status of preparations for the Sentinels in Sweden: validation and applications of data from Sentinel-2 ..... 14
  - Norwegian preparations for the National Ground Segment ..... 15
  - Fully automatic land cover map production ..... 16
- Outcome of the break-out sessions ..... 17
  - 1. National Mapping Agencies ..... 17
    - Quick background from persons present of organisation in their countries ..... 17
    - Ability to provide in-situ data when data licences provide a block? ..... 18
    - Opportunities in NMAs to develop visualisation tools of long S2 time series? ..... 18
    - Are there authoritative national databases that can be created/updated with Sentinel Images? ..... 19
    - Potential Research Tasks? ..... 19
  - 2. Collaborative Ground Segment ..... 20
    - Who has established ground segments? ..... 20

National basic requirements .....	21
3. Toolboxes and training .....	21
Do you use other tools to process Sentinel data (e.g. QGIS with Orfeo ToolBox (OTB), Python with osgeo, commercial tools)? Which and why?.....	21
Conclusions.....	22
4. Users/End Users Requirements.....	22
Have any of you used S2 data? Have you checked the quality with other data? .....	22
What did you see as the biggest obstacle to use S2 data? .....	22
Do you plan to use S1 and S2 in conjunction with each other? .....	22
Which application do you see have the highest potential? .....	23
Final remarks .....	23
5. Research and new algorithms .....	23
5.1 Summary of the break-out session :.....	23
What's new? .....	24
New studies regarding data availability .....	24
New methods for Big Data Handling .....	24
New hypotheses for complementarity.....	25
Temporal analysis strategy.....	25
Agenda.....	25
List of registered participants.....	27

# Executive summary

## Context

This was the second workshop on preparation for Sentinel-2 in Europe.

A technical committee on remote sensing in Norway started a study on the needs for preparations for acquisition and application of optical satellite data in 2012. One conclusion from this work was that we need a forum where the European countries can meet to discuss common challenges.

The target group for the workshop was national agencies responsible for serving the users with data from the Copernicus program. Specialists on key topics were invited as keynote speakers.

## Workshop rationale and objectives

The main objective is to initiate contact and collaboration among national agencies (or project groups) in Europe responsible for preparing or providing support and services to national users of satellite images, with special focus on Sentinel-2.

It is almost two years since the first workshop. Since then, Sentinel-1A, 1B, -2A and 3A are all operational and data are available from ESA's Science HUB. Some countries have already a Collaborative GS that serve national users or are in progress building a system. What are the experiences with handling big data and the user demands? What is required of the system to serve all types of use cases? What is the status of the Core GS and what are the plans for the European integrated GS for next years?

We will share experiences and knowledge gained in the preparations for Sentinel-1 and -2 in each country; identify common challenges and discuss possible solutions; identify fields of possible cooperation and R&D.

## Workshop salient findings

Sentinel-2 has been operational since 5 July 2016 and covers land surfaces between 56° S to 84° N. The revisit frequency is 10 days for Europe and 20 days in the rest of the world, but this will be 10 days globally when the EDRS service is ready. Sentinel-2B will be launched in March 2017 and both satellites will be operative from autumn 2017.

Orthorectified Level 1C based on the global terrain model PlanetDEM is available for download. The global reference image (GRI), used to improve the sensor model and thereby improve the geometric accuracy, will be validated in 2018. Several users request downloading of level 1B, a product level where no geometric correction are applied, but it will not be available for the near future. The absolute geometric accuracy and spectral geometric accuracy are higher than required. Multi-temporal geometric accuracy is still lower than required, but expected to meet the requirements when the GRI is completed in Q4 2017.

Systematic production of atmospheric corrected data, level 2A, is currently being prepared. An atmospheric correction pilot will take place in 2017 where several algorithms will be evaluated and compared: BC by Brockmann Consult, MAJA (MACCS and ATCOR joint algorithm) by CNES and DLR, SCAPE-M by GFZ Potsdam, and Sen2Cor by DLR/TPZ. A pre-operational production of level 2A based on Sen2Cor v. 2.2.3 will start in October 2016, followed by a feasibility study for operational

production. In a related study in the framework of CEOS, ESA and NASA are co-organizing a comparison of 14 algorithms: FLAASH (Spectral Sciences), SMACAA (South Dakota State University), Sen2Cor (DLR/TPZ), L8SR (NASA), GA-PABT (Geoscience Australia), ACOLITE (Royal Belgian Institute for Natural Sciences), GRASP (LOA), OPERA (VITO), BC (BC), LAC (ACRI), MACCS (CNES), ATCOR (DLR), Ind-prepro (Trier University), SCAPE-M (GFZ).

The Sentinel-2 archive at CoreGS will be restructured to a single tile format, so users can download single 100 x 100 km tiles. In addition, the file names will be made shorter to fix the problem with too long file paths on machines with Windows OS.

ESA SNAP is a modular tool developed for ESA to support ESAs Sentinel missions. It contains generic tools, instrument specific tools, and programming tools (API for Python). One neat feature is that it can work in native resolutions without the need to resample to a common resolution. Sen2Cor and Sen2Three can be imported to SNAP, and allows atmospheric correction and spatio-temporal composite for cloud free datasets.

Theia, the French national land thematic data center gives users access to data and advanced products based on several missions, incl. Sentinel-2: ortho-rectification, mosaics, atmospheric correction based on MACCS, cloud masks, and land cover classes. It serves currently French users. MACCS is not open source yet, and is better suited for distribution of processed products rather than the code itself. Sentinel-2 images covering an area of 5M km<sup>2</sup> will be processed to level 2A with MACCS.

EODC is an Austrian initiative and provides a platform for cooperation that offers a global archive and a cloud for super-computing of value-added products. Users can subscribe to the service. Currently value added products are for Sentinel-2 RGB composites, LAI, fAPAR, Albedo.

In Sweden and Norway work is under way to establish a national ground segment. Survey to map user needs has been carried out, and the functionality of the ground segment has been described. Some central requirements are: Subscription service, synthesis of images within a defined period, times series as data cubes, cloud/shadow masks, subpixel geometric accuracy, and Landsat 8 processed in the same manner as Sentinel-2.

## **Summary of presentations and discussions**

### **What is the status of preparation for ColGS in the different countries?**

The French ColGS is called PEPS (Sentinel Product Exploitation Platform) and is run by CNES. It contains a global copy of Sentinel acquisitions. Theia is a collaboration between 11 public partners and delivers value added products to national users based on several satellite missions and not only the Sentinels. In Sweden and Norway the ColGS are under establishment and are expected to be operational during 2017. In Austria, the ColGS consists of a national mirror ZAMG, which is a data hub relay. The EODC is a global sentinel archive and offers value added products.

### **What are the services that the ColGS delivers?**

The ColGS serves as archives of data over national territories and area of interest and some also plan to keep a global archive of sentinel data. As value added products the centers provides:

- archiving
- search and fast downloading
- simple products such as RGB composites
- orthorectification based on national DEM
- atmospheric correction based on Sen2Cor or MACCS
- cloud/shadow masks, temporal composites
- advanced products such as LAI, fAPAR, land cover classes
- multi-temporal datasets as data cubes
- subscription

### **Observations and recommendations from the NMA's**

No current use of satellite data in the NMA's among the participants. Their role regarding satellite data seems to be more coordinating or promoting. E.g. Norway (Digital Norway – NSDI), Germany (Technical coordination) or Switzerland (mandate to promote satellite data). Estonian NMA will host the mirror site for Copernicus. From some participants it was stated that the NMA's must change their thinking from “mapping” to “monitoring”.

Possible authoritative use: Change detection (“trend scouting”) to drive allocation of resources (E.g. New forest roads, clearings (forestry) etc.) Will require automated processes.

### **What are common research topics?**

Concerning applied research, the availability of Sentinel-2 image time series raises important methodological issues that could be explored as well as solutions for well-known remote sensing problems. The recommendations that can be suggested deal with the integration of Sentinel-2 images in existing methods, the need to develop new algorithms for temporal analysis, the exploration of different strategies to combine them with Sentinel-1 images, and the consideration of big data handling issues.

## **Recommendations**

The main objective with the workshop was to initiate contact and collaboration among European mapping agencies, institutes and companies involved in work to support national users of data from the fleet of Sentinel satellites, with special focus on Sentinel-2. There were 62 participants from 14 nations, represented by universities, research institutes, governmental and private industries gathered to discuss challenges and opportunities.

The Copernicus program is still in the very beginning. In the following years new applications will develop, and we will gain more experience both with the ColGS and the use of Sentinel-2 data.

A few recommendations:

- SRTM stops at 60 deg. N. ESA must provide Sentinel-2 data with the best possible DEM for all countries in Europe. For Nordic countries, the national DEMs are required. Can the Arctic DEM<sup>1</sup> available from 2018 replace the National DEMs or Planet DEM for ortho corrections?

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<sup>1</sup> ArcticDEM is a National Geospatial-Intelligence Agency (NGA)-National Science Foundation (NSF) public-private initiative to automatically produce a high-resolution, high quality, digital surface model (DSM) of the Arctic using optical stereo imagery.

- A possible research project within this field could be: How can the NMA's use Sentinel-2 data to improve or update basic topographic databases.
- It was a common interest among the participants to arrange a new workshop within two years (autumn 2018). Within this period more satellites are in service, national services are established and in use. New studies based on the new data are completed and new products are developed. Topics could be:
  - Functionalities of national services.
  - Access and processing of data including how to use toolboxes.
  - Use cases, new products and opportunities with regard to high and low level users.
- It is recommended to arrange conferences or workshops at national level to include the end user needs (potential of Copernicus data, possible products for end users, use cases).

## Highlights from the presentations

### Sentinel-2: mission status, data access and outlook

*Bianca Hoersch, European Space Agency (ESA)*



- Sentinel-2A has been fully operational from 5 July, 2016 and covers all land surfaces between 56° South latitude (Cape Horn in South America) and 84° North latitude (north of Greenland), including major islands (> 100 km<sup>2</sup>) and the whole Mediterranean Sea.
- Current revisit frequency in Europe, Africa and Greenland is 10 days and 20 days in the rest of the world, but that is expected to increase to 10 days globally when EDRS service/4<sup>th</sup> X-band stations are operative.
- On average data are ready in PDGS ±4-5 hours after sensing for transfer to data Hub, but once EDRS and/or 4<sup>th</sup> X-band station are available data the time will be within 200 minutes everywhere.
- Data volume has been a challenge: yearly volume is 1.4 PB for the L1C product with two satellites and 3 PB with both L1C and L2A products.
- S2B will be launched yearly 2017 (28 Feb – 8 Mar) and both satellites will reach full operational capacity in autumn 2017.
- L1B will not be available for download in the near future.
- Systematic global production of L2A is currently being prepared.

- All Sentinel data generated since October 2014 are currently available online on Open Access Data Hub (Scientific Data Hub).
- Archive will restructure to a single tile format, so users can download 100 km x 100 km tiles. Also the file names will be made shorter to fix the problem with too long filenames.
- Atmospheric correction pilot in Europe will take place in 2017 and the global reference image GRI will be validated in 2018.
- A large reprocessing campaign will take place from 2018 to reflect the new tile structure, improved geometry, shorter file names, and L2A product.

## Sentinel-2: products, data quality and evolution

Ferran Gascon, ESA



- The absolute geometric accuracy of the S2 level 1C product is better than the requirement. The circular error is 9.2 m (95%) and the requirement is 12.5 m (95%).
- The spectral geometric accuracy between band pairs is better than the required 0.3 pixels for all band pairs.
- Multi-temporal geometric accuracy where tested on tiles without geometric refinement and the circular error was 1.12 pixels and higher than the required 0.3 pixels. When the global reference image (GRI) is used the accuracy is expected to comply with the requirement. GRI will be completed by Q4 2017
- The radiometric performances are tested and are all better than the requirements. The signal-to-noise ratio is well above the requirement for all bands and the absolute radiometric uncertainty is better than 5%.
- Bottom of atmosphere reflectance values calculated with sen2cor have been compared with ground reflectance measurements for bright and dark soils, crop land, and forest. The values are in agreement.
- Data quality report can be found at <https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/data-quality-report>
- L1C products geolocation is less accurate over mountainous areas due to the 90m resolution DEM used in the production. A pilot over Norway uses a 10m national DEM and generates a L1C product during the vegetation period 2016. The product will be evaluated by Norwegian users and the Quality Working Group (QWG).

- A pre-operational L2A production using sen2cor v. 2.2.3 (atmospheric correction) over Europe will start in October 2016 and will be followed by a feasibility study for operational production. L2A products will be made available from Open Access Data Hub after an evaluation period.
- A group of experts will evaluate the following algorithms for atmospheric correction:
  - BC by Brockmann Consult
  - MAJA (MACCS ATCOR Joint Algorithm) by CNES/DLR
  - SCAPE-M by GFZ Potsdam
  - Sen2Cor by DLR/TPZ

In a related study in the framework of CEOS, ESA and NASA are co-organizing a comparison of 14 algorithms:

- FLAASH (Spectral Sciences), SMACAA (South Dakota State University), Sen2Cor (DLR/TPZ), L8SR (NASA), GA-PABT (Geoscience Australia), ACOLITE (Royal Belgian Institute for Natural Sciences), GRASP (LOA), OPERA (VITO), BC (BC), LAC (ACRI), MACCS (CNES), ATCOR (DLR), Ind-prepro (Trier University), SCAPE-M (GFZ).

## From rapid development to operational processing: Sentinel data user's support provided by ESA's SNAP

*Carsten Brockmann, Brockmann consult, Germany*



- The enabling technology and sensing capacity increases exponentially.
- In early days in the 80-ties, volume was in order of Mbytes and we worked on mainframes with own programmed code (FORTRAN, C). Later commercial tools became more and more available through the 90-ties along with more and more open source tools. Today space agency provided tools with algorithms for sensor specific processing are available for the EO missions.
- ESA SNAP is a modular tool developed for ESA to support ESAs Sentinel missions. It contains generic tools, instrument specific tools, and programming tools (API for e.g. Python). At the bottom lies Java SE 8 platform and Python. On top of that is a layer with 3<sup>rd</sup> party libraries, such as GeoTools, NetCDF and NetBeans, next a layer with SNAP Engine and SNAP Desktop, and finally a layer with the sensor specific toolboxes, e.g. S1TBX, S2TBX, and S3TBX.

- One feature is the ability to work in native resolution, i.e. it can simultaneously work with 10m, 20m, and 60m data without the need to resample to a common resolution.
- The Python API allows using also numpy, scipy, pandas, etc. with SNAP.
- sen2cor and sen2three are modules that can be imported to SNAP. sen2cor performs atmospheric correction to L2A and sen2three performs a spatio temporal synthesis of L2A (or alternatively uncorrected top of atmosphere L1C images), retrieved by the Sentinel 2 Multi Spectral Instrument (MSI). sen2three is a level 3 product and results in cloud-free composites.
- sen2cor performs atmospheric-, terrain-, and cirrus corrections and delivers in addition aerosol optical thickness, water vapor, scene classification maps, and quality indicators for cloud and snow probabilities. The product format is equivalent to L1C
- SNAP has a rich list of radiometric indices that can be used.
- User support can be found at <http://step.esa.int/main/doc/tutorials/sentinel-2-toolbox-tutorials/>
- The majority of the SNAP functions are implemented as operators and they can be invoked either from the Desktop or the command line. Processing chains can be set up using a graph builder tool (gpt); the chains are configured in XML-files.
- SNAP is platform independent and can be set up in various environments, including virtual machines, web processing services, Apache Yarn/Hadoop (Calvalus).

## **The French Theia Land data center products, based on Sentinel-2 data: cloud masks, atmospheric correction, snow cover and land cover maps at country scale**

*Olivier Hagolle, CESBIO, France*



- PEPS (Sentinel Products Exploitation Platform) is the French collaborative ground segment and is operated by CNES. It contains a global copy of Sentinel acquisitions. In autumn 2016 three modes of processing are tested: 1) orthorectifying S1 datasets on demand (“pre-wired”); 2) all S1 datasets are orthorectified systematically; 3) users can select more freely how to process data in “a la carte” manner (uses Australian data cube and Jupyter console).
- Theia is the French national land data center and is a cooperation between 11 public partners. It gives the French users data access and advanced products from several missions (SPOT, PLEIADES, Landsat, and Sentinel-2): orthorectification, mosaics, atmospheric correction, cloud masks, land cover. Theia’s services are currently aimed at French users, but

Theia could also cover all of Europe if financed. The data policy is free and open; the only limits are set by data providers.

- First achievements of Theia are: 1) full yearly coverage by high resolution (<5 m) images; 2) access to Pleiades data bought by any public institution in France; 3) reprocessing of SPOT world heritage data to level 1C; 4) time series of SPOT data (Take5) from 2013 and 2015 taken every 5 days over 5 months; 5) Landsat data since 2009 over France and overseas territories processed to levels 1C and 2A.
- Theia uses its own processor MACCS for atmospheric correction of SPOT, Sentinel-2 and Landsat data. The algorithm is based on time series to detect cloud/shadow and to determine optical thickness and water vapor. MACCS has demonstrated good results and enhancements are on-going. Sentinel-2 images covering an area of 5M km<sup>2</sup> will be processed to level 2A with MACCS.
- MACCS is not open source yet and is better suited for distribution of processed products rather than the code itself. In contrast, sen2cor, which is based on ATCOR (not open source) and Python, uses single images and has a code better suited for distribution to the users. MACCS will be used in ESAs sen2agri system which will be ready in May 2017. DLR and CNES have agreed to join MACCS and ATCOR to create a joined algorithm MAJA (MACCS-ATCOR Joint Algorithm). I will be based on MACCS but use ATCOR's better methods for water vapor estimates, cirrus cloud correction and complement MACCS multi-temporal cloud detection.
- MAJA is proposed to ESA/EU for global production but there are other runners: sen2cor, Brockmann Consult, GFZ. Comparison exercise will start soon, but ESA is unlikely to start production before 2018.
- CESBIO has developed cloud free level 3A product which is a multi-temporal composite of L2A products. It needs both satellites S2A/B to be operational and will be implemented in Theia in 2017.
- Theia has organized several expertise centers where each center groups 1 to 8 laboratories. Each Theia partner can then support studies, implementation, and production carried out by the expertise centers.
- A snow cover monitoring tool has been developed. It is based on level 2A products plus a cloud mask. The software is open source and is based on the Orfeo Toolbox. Production over relevant tiles has begun and distribution is expected to start end 2016/beginning 2017.
- A method for fully automatic land cover map production has been developed and used on Landsat data to map all of France. The map has a nomenclature with 20 classes.

## Status of the Earth Observation Data Centre (EODC) services

Christian Briese, EODC, Austria



- The Austrian collaborative ground segment consists of two parts: 1) the national mirror ZAMG, which is a data hub relay, and 2) EODC which is a global sentinel archive and a center for cloud computing, supercomputing and added-value products.
- EODC is a private/public partnership and founded in 2014. Its main goals are to: 1) offer big data storage and high performance computing (HPC); 2) provide data, processing chains, and added-value products; 3) virtual research, development, and operation environment. It is an Austrian initiative, but international partners are welcome.
- EODC is co-located at the Technical University of Vienna's super-computing center (Vienna Scientific Cluster). It has 2000 nodes with 32000 cores that produce more than 600 terraflops.
- EODC plans to evolve as a federation of data centers all directly connected to ESAs data hub.
- The users can trigger processing via a net browser interface and the jobs queues are scheduled and sent to several processing containers on the cloud; product delivery via e.g. WMS/WCS.
- EODC is currently being set up to host image store of S1 data with full coverage of Europe: monthly backscatter, composites, different polarizations, georeferenced.
- EODC provides on-demand processing of Sentinel-2 data to level 2A using sen2cor (v. 2.2.1). Value-added products delivered are RGB colour composites, Leaf Area Index, Albedo, fAPAR.
- Data access via dedicated API. An R package is currently being set up to allow easy access to data.
- EODC acts as a community facilitator and represents a new model for collaboration in earth observation through its aims to develop and operate shared resources, connect science with operations, and share know-how among different organizations.

## Status of preparations for the Sentinels in Sweden: validation and applications of data from Sentinel-2

Mats Rosengren, Metria, Sweden



- Current examples of uses of EO data from SPOT, Landsat, and IRS are: 1) yearly clear-cutting map; 2) national forest inventory map with timber volume predictions (based on kNN); 3) recurrent mapping of all natural reserves, national parks, Nature 2000 sites, and other protected areas. All applications are based on data from SACCESS, the Swedish national satellite data archive. SACCESS provides yearly coverages since 2005 and data are free and jointly funded by public and private institutes/companies.
- SACCESS provides one cloud-free composite yearly from the vegetation season. It contains historical data from all decades beginning with 70-ties. The data is used for land cover change monitoring and is free to download for residents in the Nordic Countries.
- SACCESS is temporary the Swedish mirror for Sentinel-2 data until the new national ground segment Swea is operative. All S2 data over Swedish AOI are downloaded and archived. All data are reformatted and reprojected into SWEREF99, the national spatial reference system.
- A set of different multi-band images with different band combination is produced and stored in either GeoTiff or BIL formats with simplified file names.
- In December 2014 a study for the Swedish National Space Board (SNSB) was started to map user needs and technical challenges. A review was made in January 2016 and an ITT was issued in March 2016, which was won by Spacemetric and a contract was issued in May 2016. Swea is planned to be operational in Q1/2017.
- Area of interest is the Swedish landmass plus the Baltic region (sea and drainage basin). The list of users include among others forest authorities, forest owners and industry, the board of agriculture, environment protection agency, environmental organizations and research community.
- A user need inventory shows that users demand subpixel absolute geometric accuracy enabling time-series analysis and integration with other geographical datasets (corrections for scene offsets and course global DEM is important); cloud/shadow mask; user friendly data formats including band subsets for easy use as visual backdrops.
- Swea will be built as a modular system with a mirror archive as the fundament and on top of that an increasing level of advanced products: 1) national standard products (L1C-SE, L2A-SE); 2) basic user defined products (subsets, wms, wcf views); 3) advanced user products

(change detections, time-series products); 4) recurrent monitoring services; and finally 5) user defined products/services.

- Some requirements on Swea are:
  - Users can subscribe on data streams for a specific area
  - Synthesis of images with pixels acquired the last 10 days
  - Time series as data cubes with data from several sensors
  - Cloud/shadow mask must be provided since automatic processes will depend on it
  - Subpixel accuracy necessary for time-series analysis to be useful
  - Landsat 8 to be handled the same way as Sentinel-2
- Three projects under development now are: a new land cover map, agricultural block database control and revision, and automatic clear-cut mapping.

## Norwegian preparations for the National Ground Segment

*Anja Strømme, Norwegian Space Centre (NSC), Norway*



- An early test for a CollGS was initiated with KSAT to provide easy access for Norwegian users of Sentinel-1 data.
- Some products established are 1) oil spill detection, 2) ship detection, 3) interferometric land-slide mapping.
- The Norwegian Space Centre has signed a down-link agreement with ESA and have established a NRT/QRT chain for S1 data.
- A technical team has investigated use cases, national needs, and technical issues for the land community and delivered two reports, in 2012 and 2014.
- By the end of October 2016 the national CollGS named Satellittdata.no will be opened. It will ensure easy access of data from Sentinel-1, -2, and -3 for Norwegian users. Data will be made ready with as short time delay as possible. Both basic and higher level products will be produced and made available in a user friendly format. That means data can be projected to a common national grid (i.e. S1 and S2 in same grid), users can freely select band combinations and area of interest, and system will support time-series and change detection. Several grids will be available, among others Euref89/UTM33. UTM33 fits most of Norway very well, except the most easterly parts in the north (Finnmark).
- At the start of the enhanced service focus is on: 1) Sentinel-1 QRT data; 2) orthorectified S1 data; 3) S2 level 1CN based on national 10 m DEM.

- Satellittdata.no will store data globally for 4 to 6 weeks and data over Norwegian AOI permanently. Data will be stored in ESA's SAFE format to enable seamless integration of routines and scripts from other hubs.
- In cooperation with ESA, a project has been launched that will produce orthorectified images based on a national DEM with 10m resolution (level 1CN). This was initiated based on a recommendation from the technical reports from 2012 and 2014. The data will be made available at Satellittdata.no. A more careful study of the effects of using a more accurate DEM than the global PlanetDEM will be carried out and ESA will participate in this effort. Coordination with neighboring countries will be attempted to ensure continuity across borders and possibly include a Nordic DEM as part of PlanetDEM.
- Next steps are to evaluate atmospheric correction routines and cloud detection routines for Norwegian conditions and the effect of national DEM vs. PlanetDEM on level 2A products.
- NetCDF file format will be used by Satellittdata.no in addition to SAFE format to enable easy access to small areas and enhance search in terms of area, time and bands. Support for scripting is planned, tools for time-series analysis/change detection, and processing on demand. Some InSAR subsidence data products will be included (geohazards, rock slides, infrastructure).

## Fully automatic land cover map production

*Olivier Hagolle CESBIO, France presented Jordi Inglada's work*



- Up-to-date land cover maps are a crucial asset for many research works and operational services. It is therefore a need for frequent and regular updates. For high quality maps and short production times we need automatic, robust, and reliable methods. The method should be able to exploit all available relevant data (including reference data).
- Input data includes time series of Sentinel-2 data (plant phenology conveys information) and also Sentinel-1. The nomenclature includes 20 classes; the map has 20 m resolution, is yearly updated, and is delivered 3 months after the reference period.
- The kernel of the processing chain is a training phase where a part of the reference data is used as training data to teach classifiers how to identify the classes, this constitutes the supervised learning stage; and a supervised classification stage using the trained classifiers to produce a land cover classification; and finally a validation step based on the reference data not used for training.

- All available images are used regardless of cloud cover: 90% cloud cover means 10% of pixels are clear. Time series is used as a classification feature.
- A set of overlapping tiles, 100 km x 100 km in one spatial reference system, is used to split the mapping area (France) into manageable parts. All image data are resampled into this common grid and common virtual dates are used twice a month. Results show that this does not degrade the classification results very much.
- Several classifiers are trained and fusion of the classifiers gives more robust and homogeneous maps.
- Reference data are cleaned: e.g. Corine Land Cover maps are refined with topographic maps to e.g. separate urban areas into buildings, streets, parks, etc.
- Ongoing improvements comprise work to include Sentinel-1 time series.

## Outcome of the break-out sessions

The break-out session took place the second day and all participants could choose to take part in one of five groups:

1. National Mapping Agencies
2. Collaborative Ground Segment
3. Toolboxes and training
4. Users/End Users Requirements
5. Research and new algorithms

All groups got several questions they could choose to work on or they could freely define other questions relevant to the theme of the group.

### 1. National Mapping Agencies

#### Quick background from persons present of organisation in their countries

- Sweden NMA: responsible for Geospatial Data (via an established network of authorities working nationally). Sat. Data is also geo, but until now have no specific authority with responsibility for this data within the organisation. Swedish National Space Board recently designated lead (with support from NMA).
- Sweden Space Agency: ground segment responsibility (financed by multiple agencies including Met Office).
- Poland NMA: there is no use of Sat. Data within the NMA activities, but are interested in developing potential. There is no central authority responsible for this data.
- Estonia NMA: responsible for INSPIRE and major spatial data provider. Will also host the National Mirror site (via a commercial organisation) in order to support commercial applications.
- Switzerland: no use of Sat. Data in NMA operations mainly due to licence restrictions. Have a mandate to support Swiss clients in their use of Sat. Data (e.g. Swiss engineering company working on dams in Africa etc.). Scientific support from Zurich Uni. Mandate to also promote use of Sat. Data nationally. Swiss Space Office provided that mandate.

- Norway is not a member of EU, but a fully Participant country of the Copernicus Program. Required wide internal stakeholder engagement on the benefits - gained wide motivation. The Norwegian Space Centre under the Ministry of Trade and Industry is responsible for the implementation of the Copernicus Program in Norway, and hosts the Copernicus secretariate in Norway. Different actors have different roles in the implementation, and the NMA will be a crucial partner. Negotiations on a contract is under way on collaboration.
- 
- Norway (NMA): do not imagine being a core user of S2 data, but do have a coordinating role in NSDI and therefore will need a model to handle this big data element. Therefore a stakeholder and specification in services of Ground Segment services.
- Germany NMA: technical coordination point of land monitoring service of Copernicus with collaboration with Env. Agency. Undertaking research on VHR for statistical classification of land-use (want to use LUCUS/Nominstat classes – no other source for supplying data to EU). Also interested in using S1 and S2 for completing cloud free coverage. Want to provide web services for promotion of services.
- UK NMA: little interaction with Copernicus leads (policy: Defra [Min. for Environment] and facilitation: UK Space Agency)

### **Ability to provide in-situ data when data licences provide a block?**

A real problem is use of 'local' DEM that is appropriate for the country (and better resolution of ESA offering).

- Sweden: national public access contract to all geospatial data and therefore do not consider licence as such an issue
- UK: very complex public/private licence of data, but NMA choosing to ignore issue (assumption that it will be resolved!) and focusing on how to support the use of Sat. Data with in-situ technically.
- General discussion on the ultimate aim of open data to ease the supply of data between users. Dangers of substitution of alternative sources over what is offered by NMA (may also wider benefits – temporal frequency!).

### **Opportunities in NMAs to develop visualisation tools of long S2 time series?**

- Quality of data has improved significantly – however unrealistic demands placed on sector (in terms of resolution and 'cloud free' ability to get suitable coverage). Also 'thinking' has been dominated in terms of 'mapping' rather than thinking about appropriate use of technology: i.e. more focus on monitoring not mapping (i.e. snap-shot in time vs. complete coverage at defined scales/resolutions).
- Is the NMA responsible for these things or the agencies that are 'end-users'? Who provides the requirements and who provides the utilities? How to involve private partnerships? E.g. in Sweden commercial companies have 'large area' interests. Need to find ways to accommodate a wider range of end-users.

## **Are there authoritative national databases that can be created/updated with Sentinel Images?**

- Norway: to produce statistical data (2003 – 12) using S2 (vegetation change) with cadastral data. Is it possible to identify change, when development has started. Following the building construction activity (e.g. similar to German “Building Radar”).
- Sweden: not currently using S2/S1 data for this purpose but interested in developing databases to support these uses (to meet other agencies responsibilities/requirements): SACCESS database (to be transferred to National Space Board when CGS is set-up – and supported by contractors). Thus activity is moving to the ‘users’. Sweden has number of examples of long-time series:
  - Sweden e.g. long-term study – on forestry clear cuts and monitoring progress of notifications/clean-up/replanting (15 years). Data not used in Topo Map. (not NMA – national forest agency / environment agency)
  - Sweden: integration of all available sat data in a 10 year (every 3yr? In order to get cloud free [SPOT] cover) HR data cover. S2 will improve re-refresh rates.
  - Sweden: identification of older woodland (60 year archive – combined of aerial, SPOT, etc.). Not automated. Identifies ‘touched’ woodland and removes for ‘ancient tree layer’.
  - Note: global ancient forest research – with a visualisation tool (slider bar) to see change (illegal logging impacts etc.)
- Estonia – suffers illegal forestry, and does monitor (but from aerial imagery not sat. data)
- Switzerland: identified that if use of Sat. Data is to be used then automated processes are a must. However this required a mind-set change from ‘definitive’ mapping to probability mapping (100% certainty that a forest is there – not 95.5% that this is polygon is a forest). It is noted that a map is not ‘right’ (cartographic constraints, simplified representation, age) but it is deterministic – not process. Will require ‘training’.
- Benefit in ‘extrapolated’ values (from Sat. Data) between NMA change. Or use of Sat. Data to identify change (“trend scouting”) to drive allocation of resources (or to identify ‘no change’ areas – no change being easier to identify!)
- Norway: finances international ‘Redd+’ programme (rainforest monitoring) (US\$M! Also UK, Germany). What other support can CGS provide to international programmes?

## **Potential Research Tasks?**

Issue of promoting use of sentential data:

- Automation (requires geometric accuracy – use of appropriate DEMs). Note: SRTM stops at 60 deg. North. Requires appropriate data for ESA (Nordic Level Cooperation)
- Cloud cover (use of every cloud free pixel!) – data at right time of year (winter/leaf off vs. leaf on).
- Atmospheric correction (big changes addressed with haze, precise things such as leaf area/health/vegetation etc. needs greater work. Note that correction also removes ‘bright’ targets [roads/sand/etc.] and therefore are issues to resolve).

## 2. Collaborative Ground Segment

### Who has established ground segments?

Yes: Austria, Norway, Finland, Poland, France, Germany, Greece, and Sweden.

No: Estonia.

Task of the ground segments:

- Facilitate (open) data access and usage
- Access to all data levels (low to high) is important - interested users will want to check details
- Should be easy to harvest pixels, not images
- Transparency in data and algorithms
- Let users choose data sources
- Enable sharing of algorithms
- Find common workflows and tools
- Separate (local) “know-how” and IT/technical requirements
- Local know-how must be part of development
- Common European/continental solution makes sense (e.g., for a DEM) but availability of local solutions through national ground segments is needed – flexibility important

ESA/EU approach:

- File based
- Focused on the satellite data
- Own format - metadata difficult to read and extract
- Requires knowledge from the user side, few has competence to use it

Estonia

- “move processing to data”, ice monitoring application, crop field monitoring

France

- IT part separated from user part
- Peps is IT and is funded until 2017
- Additionally 4 data centers uses peps as source

Sweden

- Infrastructure
- Make data available in the form users want it

Norway

- NetCDF and SAFE formats
- Real-time data, from Sentinel-1,-2 and -3 from 2017 National DEM

Google Earth Engine

- Has a lot of data

- Useful for simple things to explore data
- Risk of change of permissions
- API not open-source
- Data quality check missing

Requirements are similar but solutions are different.

- Integration/combination with in-situ data is important (national/local knowledge)
- Global data
- How to bridge the gaps?
- Ongoing task, needs to follow up over time when things get established

### **National basic requirements**

- Coordination between groups with similar interests (e.g., DEM for Scandinavian countries)
- Need more “joint progress”
- Summary of potential collaboration is needed
- Copernicus data services - are countries waiting for this instead of creating national ground segments?
- For Norway, important with value-adding to Copernicus
- Possibility to reprocess data

### **3. Toolboxes and training**

#### **Do you use other tools to process Sentinel data (e.g. QGIS with Orfeo ToolBox (OTB), Python with osgeo, commercial tools)? Which and why?**

The members of the group (four people) are using GRASS, Python ecosystem (incl. osgeo, numpy, pandas, Jupyter), QGIS, ENVI, eCognition, SNAP, ArcGIS, sen2cor, and Fmask.

The reasons to use the particular tools are:

- GRASS is powerful (handle huge amount of data via cloud and high performance computing (HPC)) and has a time series module TGRASS.
- Python has rich 3rd party libraries (incl. snappy from SNAP), easy to program and to learn, many user groups and forums and therefore easy to get answers, supports all platforms, similar to R, very convenient programming interface with Jupyter.
- QGIS is easy to understand and is open source, easy to extend with 3rd party plug-ins or to write own plug-ins, possible to use other tools from within QGIS, good graphical user interface and cartographic output.
- ENVI is a commercial image processing tool with a rich set of tools.
- eCognition has a rich set of algorithms for object oriented analysis, esp. useful for high resolution data.
- SNAP gives easy access to ESA’s optical and SAR data and other EO data, has scientific work flows, is extendible, and has API for Python.
- sen2cor is a free tool (but not open source) to do atmospheric correction based on ATCOR, can be used from command line, maintains the state of the processing (smart).
- Fmask is fast and easy to use on Landsat and Sentinel-2 datasets.

## Conclusions

- Large set of tools in use (by even a small group of 4 people)
- Each tool has its strengths and weaknesses
- Each tool has its justification to be used
- Coordination among tools is important
- Overview of available tools would be useful together with documentation about strengths and weaknesses
- Interoperability among tools is important
- ESA to coordinate its various developments better (instrument toolboxes, tools developed in R&D projects)
- Tools should implement FULL compliance with standard: finding out that a certain dataset can't be read after 3 days of work is annoying
- Training is needed
- Open source tools are preferred
- Python is a powerful tool for Earth Observation
- Documentation should be written by people USING the tool, not developing it

## 4. Users/End Users Requirements

### Have any of you used S2 data? Have you checked the quality with other data?

Usage of Sentinel-2 products:

- Mosaic of the territory providing RGB and IRC composites.
- Forestry monitoring (Norway) – clear cutting and changes in the forest.
- Glaciers monitoring (Norway and Greenland)

Data quality:

- In general, data quality is considered good both in terms of radiometry and geometry.
- For some products geolocation issues identified (~30m).

### What did you see as the biggest obstacle to use S2 data?

- SNAP not easy enough for End Users (need GIS expertise).
- Preferred QGIS than SNAP for visualizing.
- Products filenames are too long.
- Difficult to industrialize.
- Need to re-project at the areas at the transition between UTM zones.
- Data quality flags are not always reliable (some times marked as failed while the product is still usable).
- To cope with product format changes with short advance notification.
- For End Users, the non-availability of prepared products specialized for the applications needed.

### Do you plan to use S1 and S2 in conjunction with each other?

- Currently users do not have concrete plans to fuse radar and optical.

- However, the recent availability of S1 and S2 will foster new applications taking advantage of both.
- For iceberg monitoring in conditions where S1 is not sufficient (e.g. over windy areas where the water backscatter is too high).

### **Which application do you see have the highest potential?**

- Land cover products for road and infrastructure planning having an updated product very often (as current available data is not always up to date).
- Combined use of S1 and S2 for land cover mapping in cloudy areas.
- Interest on using L3A products (in particular users working on very cloud areas and with snow).
- For road network monitoring (detection of road displacements/cracks), there is a potential of S1/S2 combined usage.
- Identification of green areas in cities and monitoring over time.
- Land cover maps produced on a yearly basis (with fewer classes).

### **Final remarks**

- We need innovative ways to really collect and understand end users needs as well as promote and offer capacities; we are too focused on professionals (to/from professionals); we need to transform user needs into technical and operational requirements, this is the only way to manage expectations.
- We need new indicators to identify the performances, satisfaction of end users, and the social return of products and services is paramount.

## **5. Research and new algorithms**

### **5.1 Summary of the break-out session :**

Concerning applied research, the availability of Sentinel-2 image time series raises important methodological issues that could be explored as well as solutions for well-known remote sensing problems. The recommendations that can be suggested deal with the integration of Sentinel-2 images in existing methods, the need to develop new algorithms for temporal analysis, the exploration of different strategies to combine them with Sentinel-1 images, and the consideration of big data handling issues.

- Without the need to develop new methods, the availability of Sentinel-2 data should improve results of existing land-cover mapping and monitoring methodologies. The integration of **spectral** (red-edge bands) and **temporal features** should be primarily explored. In particular, vegetation classification (discrimination between tree species, seasonal changes), and tracking issues (glaciers, ...) can benefit from this new kind of information.
- The availability at large-scale and at high spatial resolution of high temporal resolution time series (5 days) is a major new feature. The fact that data continuity is guaranteed up to 2030 should make it possible to develop **new methods for temporal analysis**. In the field of change detection and particularly high-frequency change detection, methods taking into account the **entire time series** (e.g., 1 year) , instead of image-image approaches, should be supported. The **robustness** of these methods to partial or **missing data** (due in particular to cloud coverage),

**time-shifting** of the time series or **heterogeneous** observations (Sentinel-1+Sentinel-2) is a crucial point to be tackled. Such long time series make it possible to use machine learning and clustering techniques over temporal profiles. In this context, methods that could be investigated are based on **learning of temporal signatures** of the objects, **learning of changes** or nomenclatures of changes, and the **complementarity** with unsupervised approaches for environments where changes are difficult to forecast (e.g., urban areas). In particular, change detection for National Mapping and Cadastral Agencies is important as the update of national geographic databases can be based or guided by the anomalies or changes that can be automatically detected.

- The **complementarity** with Sentinel-1 radar images should be investigated. Radar provides complementary information on land cover types. Moreover, its more regular temporal sampling is useful to fill in or to be combined with Sentinel-2 image time series (thanks to its weather condition independence). In this sense, it has been proposed that complementarity should more be tackled on the basis of the **interactive strategy to combine Sentinel-1 and Sentinel-2** than the standard fusion level and related methods. As a result, the different methodologies developed would depend on the applications.
- The growing size of the Sentinel archives is a great issue to be addressed. Big data handling - in addition to mining- is itself a research topic. Working within the framework of big data will ensure that the methods developed can further produce operational results. For instance, it should be taken into account the fact that these methods can be based **on distributed archives** and compatible with **distributed or hosted processing** techniques. Moreover, initiatives to rewrite existing remote sensing algorithms to make them parallelizable should be supported.

### What's new?

- HR spatial resolution
- temporal resolution
- S1 + S2
- long-time series
- systematic acquisition
- spectral resolution

### New studies regarding data availability

- spectral features
  - red-edge bands
- tracking
  - pair-wise vs. time series analysis
- temporal features
  - seasonal changes

### New methods for Big Data Handling

New methods for

- distributed processing
- hosted processing
- distributed archiving
- how to format data?

### New hypotheses for complementarity

- interactive use of S1 + S2
  - not about fusion level, more about interactive strategy
- depending on the application
  - example: snow mapping
- fill-in /combine time series

### Temporal analysis strategy

- Methods for learning
  - temporal signatures
  - changes/nomenclature of changes
  - complementarity with unsupervised approaches
- High temporal change detection
  - with entire time series
  - robust to
    - partial, missing data (S2)
    - offsets
    - amplitudes
    - heterogeneous

## Agenda

<b>Title</b>	<b>Preparations for the Sentinel-2 in Europe</b>
<b>Objective</b>	Initiate contact and collaboration among European mapping agencies, institutes and companies involved in work to support national users of data from the fleet of Sentinel satellites, with special focus on Sentinel-2.
<b>Goal</b>	It is almost two years since the first workshop. Since then, Sentinel-1A, 1B, -2A and 3A are all operational and data are available from ESA's Science HUB. Some countries have already a Collaborative GS that serve national users or are in progress building a system. What are the experiences with handling big data and the user demands? What is required of the system to serve all types of use cases? What is the status of the Core GS and what are the plans for the European integrated GS for next years? We will share experiences and knowledge gained in the preparations for Sentinel-1 and -2 in each country; identify common challenges and discuss possible solutions; identify fields of possible cooperation and R&D.
<b>Preparation</b>	How are the preparations for the Sentinels organized in your country and what is the current status for a Collaborative GS? How is the production

	flow designed, from data input to user products? What is the main focus on application development in your country?
<b>Venue</b>	Premises of the Norwegian Space Centre, Oslo, Norway 6th floor, Drammensveien 165, 0277 Oslo ( <a href="http://www.romsenter.no/eng">http://www.romsenter.no/eng</a> ).
<b>Dates</b>	October 11 <sup>th</sup> and 12 <sup>th</sup> 2016
<b>Day 1 October 11<sup>th</sup></b>	
<b>11:30 – 12:30</b>	Registration and lunch
<b>12:30 – 12:40</b>	Welcome address.
<b>12:40 – 13:10</b>	Sentinel-2: mission status, data access and outlook. <i>Bianca Hoersch, European Space Agency (ESA)</i>
<b>13:10 – 13:40</b>	Sentinel-2: products, data quality and evolution. <i>Ferran Gascon, ESA</i>
<b>13:40 – 14:10</b>	From rapid development to operational processing: Sentinel data user's support provided by ESA's SNAP. <i>Carsten Brockmann, Brockmann consult, Germany</i>
<b>14:10 – 14:30</b>	Coffee break
<b>14:30 – 15:00</b>	The French Theia Land data center products, based on Sentinel-2 data: cloud masks, atmospheric correction, snow cover and land cover maps at country scale. <i>Olivier Hagolle, CESBIO, France</i>
<b>15:00 – 15:30</b>	Status of the Earth Observation Data Centre (EODC) services. <i>Christian Briese, EODC, Austria</i>
<b>15:30 – 16:00</b>	Status of preparations for the Sentinels in Sweden. Validation and applications of data from Sentinel-2. <i>Mats Rosengren, Metria, Sweden</i>
<b>16:00 – 16:30</b>	Norwegian preparations for the National Ground Segment. <i>Anja Strømme, Norwegian Space Centre (NSC), Norway</i>
<b>16:30 – 16:45</b>	Coffee break
<b>16:45 – 17:15</b>	Fully automatic land cover map production. <i>Olivier Hagolle CESBIO, France will present Jordi Inglada's work</i>
<b>17:15– 17:30</b>	Wrap up and practical information day 1 – Input to break out session from the audience
<b>20:00 –</b>	Get-together dinner (no host)
<b>Day 2, October 12<sup>th</sup></b>	
<b>08:45 – 09:00</b>	Coffee
<b>09:00 – 09:15</b>	Introduction day 2 Topics to be discussed in groups (decided after the meeting day 1 is finished)
<b>09:15 – 10:30</b>	Break out session
<b>10:30 – 10:45</b>	Coffee break
<b>10:45 – 11:45</b>	Presentation of outcome from the groups
<b>11:45 – 12:00</b>	Wrap up, conclusions and close of workshop
<b>12:00 – 13:00</b>	Lunch

## List of registered participants

Last_name	First_name	Company	Country
Aas	Christina	Science [&] Technology AS	Norway
Abelsen	Rune	FD	Norway
Andreassen	Liss	NVE	Norway
Andrzejewski	Adam	The Head Office of Geodesy and Cartography	Poland
Blumentrath	Stefan	NINA	Norway
Borg Pedersen	Åse Alexandra	Miljødirektoratet	Norway
Briese	Christian	EODC	Austria
Brockmann	Carsten	Brockmann Consult GmbH	Germany
Broge	Niels	SDFE	Denmark
Corbera	Jordi	Institute Cartographic and Geological of Catalonia	Spain
Dehls	John	Geological Survey of Norway	Norway
Drageset	Ola-Mattis	Norwegian Directorate of Public Roads	Norway
Drozdivskiy	Oleg	National University of Life and Environmental Sciences of Ukrainehas, Department of Geoinformatics and Aerospace Research of the Earth	Ukraine
Edgardh	Lars	Spacemetric AB	Sweden
Gascon	Ferran	ESA	Italy
Giordano	Sébastien	IGN	France
Gjertsen	Arnt Kristian	NIBIO	Norway
Groesz	Floris	Blom Geomatics	Norway
Grud	Kristoffer	SIOS	Norway
Hagolle	Olivier	CESBIO/CNES	France
Hansen	Morten Wergeland	Nansensenteret	Norway
Heisig	Holger	Swisstopo: Swiss Federal Institute for Topography	Switzerland
Helgesen Grud	Kristoffer	SIOS-KC	Norway
Hoersch	Bianca	ESA - European Space Agency	Italy
Holz	Kirsten	Statistics Norway	Norway
Home	Rollo	Ordnance Survey	UK
Jaccard	Pierre	Norwegian Institute for Water Research (NIVA)	Norway
Johansen	Bernt	Norut Tromsø	Norway
Jozefiak	Maria	Science [&] Technology AS	Norway
Kamper	john	SDFE	Denmark
Karlsen	Stein Rune	Norut - Northern Research Institute	Norway
Kjærstad	Lars	FD	Norway
Korosov	Anton	Nansen Environmental and Remote Sensing Center	Norway
Korsnes	Andreas	Norwegian Mapping Authority	Norway

Last_name	First_name	Company	Country
Kristiansen	Espen	Geodata	Norway
Kääb	Andreas	University of Oslo	Norway
Langkaas	Line	Norwegian Mapping Authority	Norway
Lonar Barth	Vigdis	Norwegian Space Centre	Norway
Mesner	Nika	Geodetic institute of Slovenia	Slovenia
Messerli	Alexandra	Norwegian Polar Institute	Norway
Moen	Stein	City of Oslo, Agency for planning and Building Services	Norway
Moholdt	Geir	Norsk Polarinstitutt	Norway
Moldestad	Dag Anders	Norwegian Space Centre	Norway
Nesje	Øystein	Klima- og miljødepartementet	Norway
Nordbeck	Ola	Norsk Romsenter	Norway
Nowell	Megan	NINA	Norway
Olovsson	Stigbjörn	Lantmäteriet	Sweden
Orthe	Nils Kristian	NVE	Norway
Puliti	Stefano	Norwegian University of Life Sciences	Norway
Ritchie	Jamie	Esri Europe	United Kingdom
Roolah	Viljo	Estonian Land Board	Estonia
Rosengren	Mats	Metria	Sweden
Sande	Øyvind	FD	Norway
Scheen	Anne-Elisabeth	Norwegian ministry of climate and environment	Norway
Skistad	Katrine Gunnberg	Norwegian Mapping authority	Norway
Soukup	Michael	Science [&] Technology AS	Norway
Strøm	Guro Dahle	Norwegian Space Centre	Norway
Strømme	Anja	Norsk Romsenter	Norway
Trollvik	Jon Arne	Norwegian Mapping Authority	Norway
Tømmervik	Hans	Norwegian Institute for Nature Research - NINA	Norway
Vain	Ants	Estonian Land Board	Estonia
Wiatr	Thomas	Federal Agency for Cartography and Geodesy (BKG)	Germany



The participants the second day of the workshop (some are missing). Photo: Arnt Kristian Gjertsen