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Using MODIS at met.no

Report from MODIS development project

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report

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Abstract

The quality and potential usefulness of several MODIS products is evaluated with focus on met.no's current and future need for satellite data in operational meteorology.

The quality of the data received is good, and it is our impression that data from the MODIS instrument represent a valuable source of information both for subjective use, and potentially also as input to objective routines. The level 2 channel product is seen as the most useful product at this point. Fast access to products, a reliable data flow, and separation of different level products into separate data files are the most important requirements that have to be met.

Keywords

MODIS, sea ice, cloud cover, snow cover

Disiplinary signature	Responsible signature

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1 Background

In cooperation with Kongsberg Spacetec AS (KSPT), the Norwegian Meteorological Institute (**met.no**) has evaluated the data from the MODIS instrument for use in operational meteorology. MODIS data is received at Kongsberg Satellite station (KSAT) in Tromsø, and a wide number of test products are put out daily on an ftp server.

The quality and potential usefulness of several MODIS products is evaluated with focus on **met.no**'s current and future need for satellite data. At this point we have focused on subjective exploitation of products from MODIS, and in particular visual monitoring of cloud systems and the ice conditions in the Arctic. However, it is the intention of **met.no** to also use MODIS data in more objective/automated ways, and the work in this project is done with this in mind.

Apart from assessing the quality and scientific potential the MODIS instrument offers, issues like regularity, technical solutions for data transfer, and time lag from reception to final product are also important to address in order to evaluate the usefulness of these data.

Chapter 2 is a description of the work done at **met.no** on the MODIS data within this project. Chapter 3 gives an evaluation of the available MODIS products, and their potential use at **met.no**. Chapter 4 specifies further the demands **met.no** has for operational use of MODIS data.

2 MODIS at met.no

The MODIS project started in August 2003. KSPT has been in charge of providing products from the MODIS sensor, as they are read down in Tromsø by KSAT. The first locally received MODIS data was presented to **met.no** in March 2004. Throughout the project period, data from maximum two daily passages of the Terra satellite have been available.

The MODIS products are available via ftp from KSAT to a local server at the Norwegian Meteorological Institute, where further processing is carried out, and products that can be presented to users at **met.no** are produced.

At **met.no** we have received products on a HDF5 file format defined by KSPT. This is the same format as known from the MEOS system for AVHRR data. The MODIS files contain both level 2 geo-located channel values, and level 3 value added products. Some of the files contain all 36 MODIS bands, while others have 4-7 channel bands plus some higher level products like snow cover maps and cloud masks.

Some adaptation of the current reading systems has been necessary in order to read the MODIS files and display them in DIANA (the analysis and visualisation tool at **met.no**) There has been some difficulties in retrieving the correct Brightness temperatures and albedo values due to uncertainty connected to the calibration coefficients available.

RGB combinations of channels have been made in order to learn more about the characteristics of the different spectral bands available. We have taken a special interest in the simultaneous presence of channel 6 (1.6 microns) and channel 20 (3.7 microns), as these channels are also present on the

AVHRR instrument, but never at the same time. It is known that these two wave bands are particularly sensitive to snow.

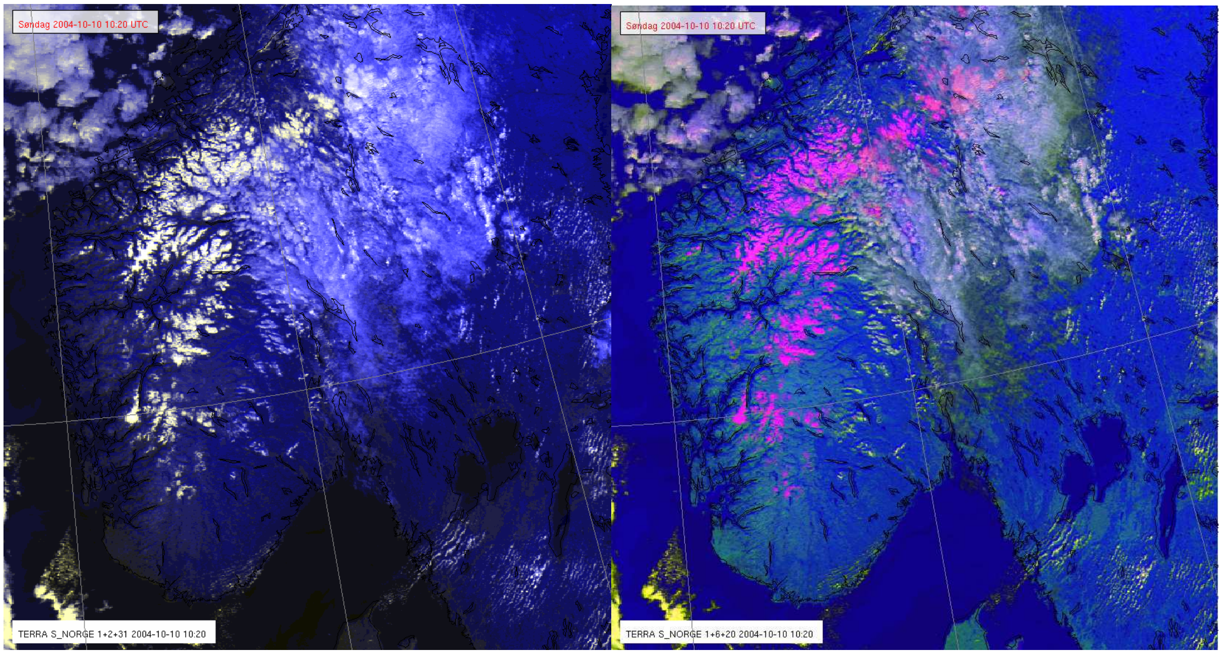

Figure 1: Examples of different channel combinations from the MODIS instrument. Left: RGB 1+2+31. This combination corresponds to the normal RGB for AVHRR (1+2+4). Right: RGB of 1+6+20. The visual ch. 6 and the Near-IR ch. 20 are known to be sensitive to snow.

Figure 1 gives an illustration of MODIS RGB's highlighting snow in the mountains in southern Norway, October 10 2004 at 10:20 UTC. Left is a combination of the two visual channels 1 and 2, and the thermal channel 31. Clouds are white/light blue, and the snow cover on the mountains is seen in yellow. Right is a combination of the two visual channels 1 and 6, and the Near-Infrared channel 20. In this combination of channels the snow is represented by a pink colour. By combining channels like this we learn how sensitive the channels are to different surface types, and this enables us to pick out the best suited channels depending on what feature we are looking for.

Part of the evaluation project has been to study the algorithms behind the different higher level products made available by KSPT. The algorithms are developed by the MODIS Science team.

Mapping of sea ice is the major concern for **met.no's** Ice Service in Tromsø. Today the ice products produced under the Ocean and Sea Ice SAF, AVHRR and QuikScat passages and occasional SAR images covering the Arctic region form the basis of the Sea Ice analysis. In addition, MODIS true colour jpg images are downloaded from the internet. As DIANA is becoming the primary analysis tool at the Ice Service, there is a clear potential for using locally processed MODIS products. Examples of MODIS products have been evaluated by the Ice Service as a part of this project.

3 Evaluation of the MODIS products provided by KSPT

3.1 Detection of clouds – the MODIS cloud mask

Satellite imagery is a powerful tool for monitoring the movement of cloud patterns, and for distinguishing between different cloud types. Forecasters on watch are used to looking at Meteosat and AVHRR imagery, usually presented as RGB colour composites. Clouds are also located automatically from AVHRR by the PPS cloud mask developed under the SAF. Having a reliable cloud mask is crucial if the data is to be used in an objective way, for instance as input in numerical models.

The MODIS cloud mask is based on threshold techniques known from other sensors like AVHRR, GOES and HIRS, where we find wave bands similar to MODIS. 17 visual and thermal spectral bands are used in 11 different threshold tests to separate cloudy from clear pixels (Ackerman et al, 2002). The mask indicates the likelihood for having clouds in each pixel, and also if the view is obscured by optically thick aerosols. The mask is presented on a horizontal resolution of one kilometre. It can be used both day and night.

The mask developed by the MODIS science team (MOD35_L2), has 48 different bitflags giving information on sun glint, type of clouds and other things relevant for the classification. The MODIS cloud mask as presented to met.no, contains the first 8 bits, giving information on cloudiness, underlying surface conditions and the sun elevation. As far as we can tell, it seems to work fine, and almost all cloudy pixels are identified without adding artificial clouds. For subjective use however, the duty forecaster would prefer to see a cloud type product rather than this rather coarse version.

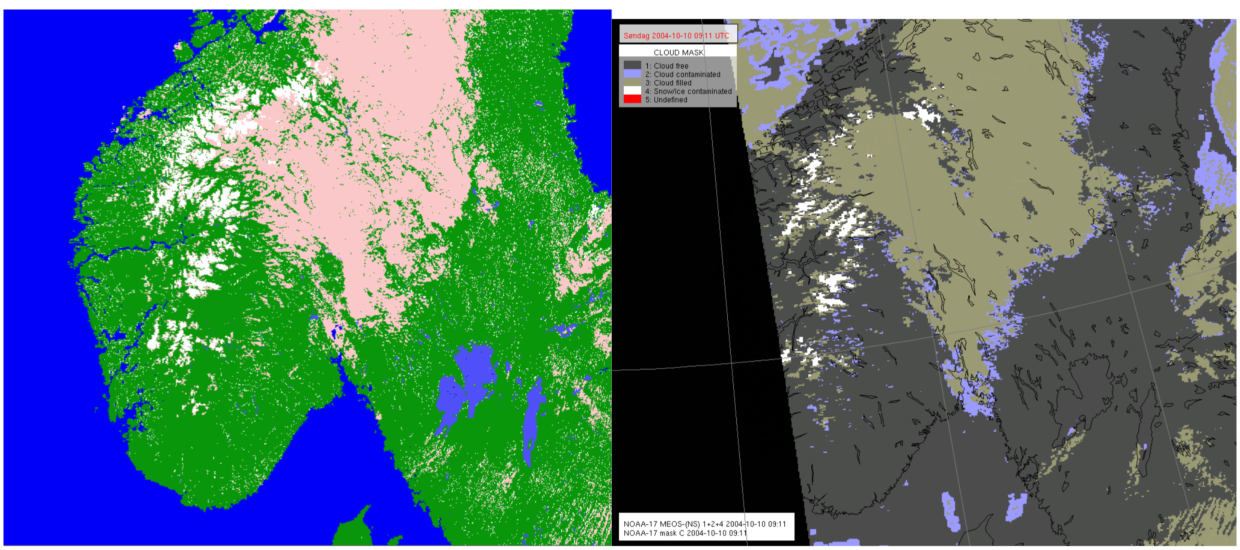

Figure 2: Comparing two cloud masks. Scenes from October 10 2004. Left: The MODIS cloud mask (overlying the MODIS Snow product) at 10:20 UTC. Right: The PPS cloud mask at 09:11 UTC. See text for details.

Figure 2 is a comparison between the MODIS cloud mask (overlying the MODIS Snow product) and the PPS cloud mask based on AVHRR. Clouds are pink in the MODIS product and grey/blue in the PPS product. As we can see the two masks agree nicely on the extent of the cloud cover, when we take into account the time gap of one hour between the two satellite passages.

There have been some problems reported on the cloud mask concerning the distinction between snow and cirrus clouds, leading to a slight over-estimation of the cloud cover.

3.2 Snow and ice cover – the MODIS snow product

Snow cover is an important parameter in Numerical Weather Prediction for initializing the lower boundary conditions of the models. Weekly snow cover analyses issued by the Ice Service are used at present to initialize the operational forecast models at met.no. This analysis is based on manual inspection of AVHRR imagery combined with SYNOP observations.

The MODIS snow cover product is based on several threshold tests using the visual channels 1, 2, 4 and 6 (Hall et al, 2001). The product is therefore only made in daytime. A land/sea mask is applied, and pixels over sea are not analyzed for snow. Clouds are masked using the MODIS cloud mask product (the full version, described above). Snow cover on land is the main parameter. The product classifies the image into 11 categories. The result is presented at a horizontal resolution of 500 meters at nadir.

Figure 3 shows the MODIS snow product (left), where snow is white, clouds are pink and bare land is green. Right is a simultaneous RGB scene combining channels 1,2 and 6. The snow in the mountains shows up as bright yellow in this combination of visual channels.

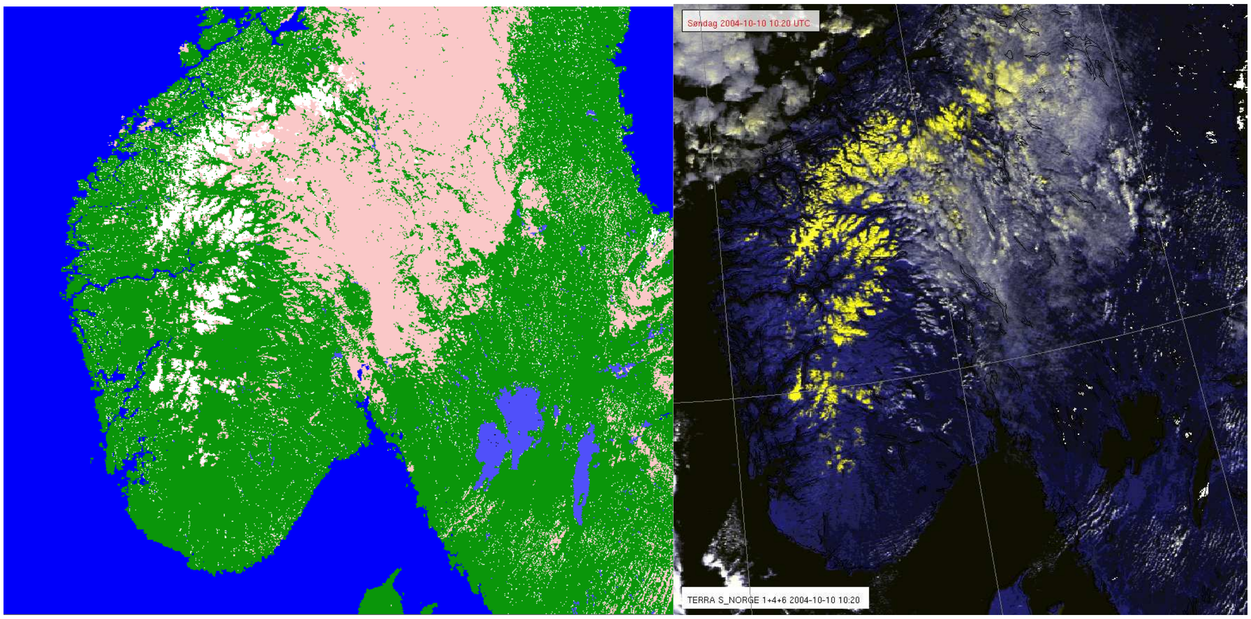

Figure 3: Detecting snow over southern Norway. Left: MODIS snow cover product. Right: MODIS RGB 1+2+6. MODIS scene from October 10 2004, at 10:20 UTC. See text for details.

The MODIS snow cover product seems to pick out snow with high accuracy. There is a small tendency of the MODIS algorithm to overestimate the snow cover, as can also be seen in figure 3. The scattered snowy pixels in the south-western part of Norway are not backed up by the RGB composite, close inspection of various channel combinations or SYNOP's in the area, and must therefore be regarded as false.

Correct mapping of snow is a major interest for **met.no**, both for climate studies and for providing quality initialisation of meteorological models. A quality snow cover product from satellite measurements is therefore very interesting. More work is required before we can say if this particular product can be used by **met.no**.

There is also a MODIS Sea Ice product (MOD29) available from the MODIS Science team (Hall et al, 2001). This is a 1 km resolution product using both thermal and visual MODIS channels. This product has not been part of the data delivery to **met.no** in this project, and is therefore not tested.

3.3 MODIS level 2 channel products

MODIS differs from AVHRR in that some of the channels provided have horizontal resolution up to 250m at nadir (compared to 1.5 km for AVHRR). This, combined with the wide number of wave bands available, makes the MODIS instrument an attractive supplement to the existing AVHRR instrument.

The geo-located level 2 product is very useful as a tool for presenting a fast overview of the current weather situation. The duty forecasters are used to RGB “images” from AVHRR / Meteosat, and the added coverage provided by MODIS is a good supplement to the existing satellite coverage. It is sufficient with a horizontal resolution of 1 km for the purpose of visual monitoring of synoptic systems.

The availability of more detailed data from satellites is especially interesting for **met.no’s** work in monitoring and mapping the sea ice extent in the Arctic. The Ice Service in Tromsø issues detailed ice maps for the Svalbard region every week, and this task will clearly benefit from exploiting more high resolution satellite data from this area. At this stage the MODIS passages over Svalbard will be inspected visually.

We have not yet tested the use of MODIS ice products operationally during a winter season, mainly due to delays in the data delivery at the beginning of the project. **met.no** would very much like to include high resolution MODIS products for use in ice monitoring in the Svalbard area for the upcoming winter season.

For this purpose it is necessary with at least two, and preferably several, daily passages covering Svalbard. At the moment it is not crucial that the products are available immediately after they are read down; we can afford to wait some hours before the products are presented to the Ice Service.

3.4 An example of increased details: Ice around Svalbard

We present an example of how MODIS can increase the precision of sea ice analyses. The situation is from 31. August 2004, from Edge Island in the Svalbard Archipelago; an area where **met.no** has operational responsibility of making ice charts of high resolution every week.

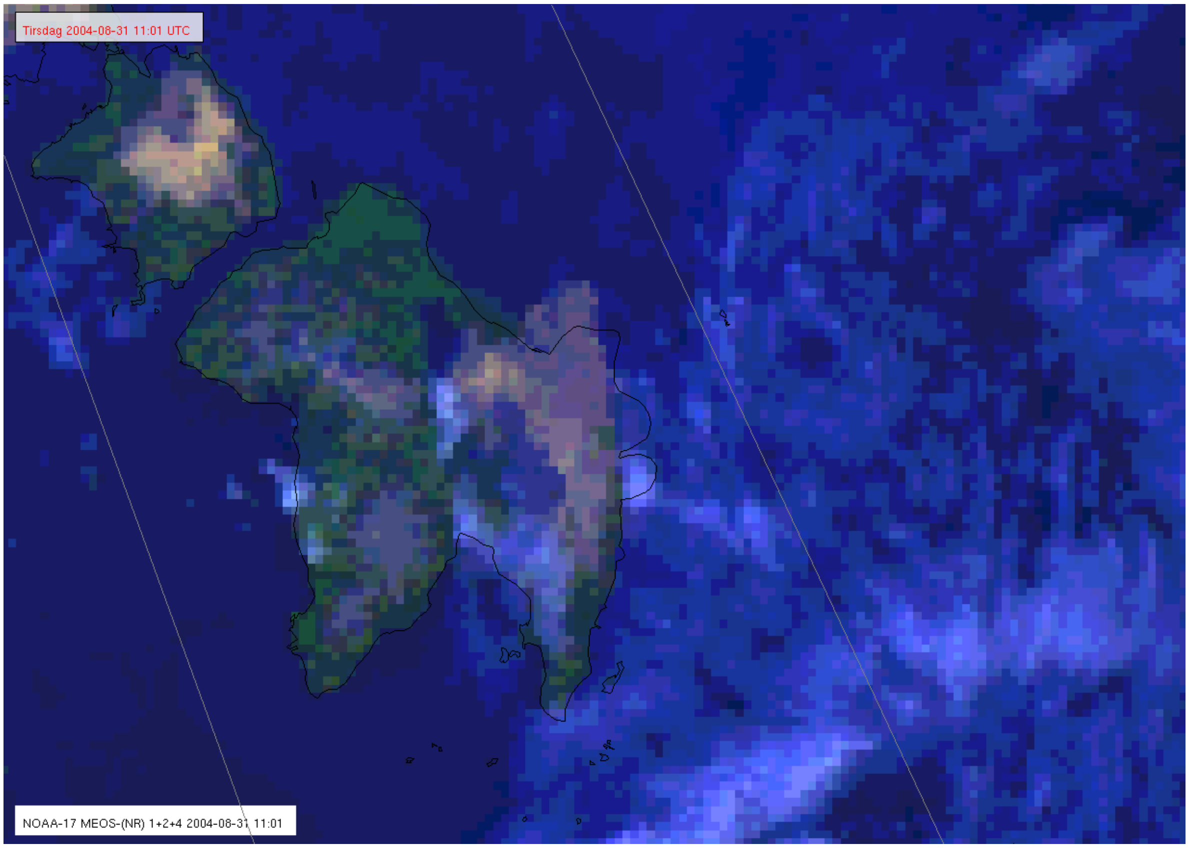

Figure 4: AVHRR scene over Edge Island, Svalbard, at 11:01 UTC, August 31. 2004. RGB composite using channels 1, 2 and 4. See text for details.

Figure 4 shows the scene as seen from the AVHRR instrument in RGB channel combination 1+2+4. The pixel size is 1.5 by 1.5 kilometres. This is the most detailed satellite information from optical sensors available to the Ice Service today. Ice is seen as yellow to red colours, sea is dark blue, clouds are light blue / white, and cloud free land is green.

Figure 5 shows the nearest MODIS-scene with an RGB channel combination (1+2+31) corresponding to that of figure 1. The pixel size is 1.0 by 1.0 km. It is already evident that more details are visible in this scene compared to fig.1. The edge of the glacier going out into the sea north of the Edge island is more defined than for the AVHRR scene (as for fig 1, ice is yellow in this RGB combination).

Figure 6 is from the same MODIS passage, but with channels 1 and 2 only. These channels have horizontal resolution of 250 metres. The RGB combination 1+2+1 gives a clear separation between sea (dark blue) and ice (purple), and also between ice and land (green). The increased resolution reveals details along the ice edge that is not possible to see from the previous examples with coarser resolutions.

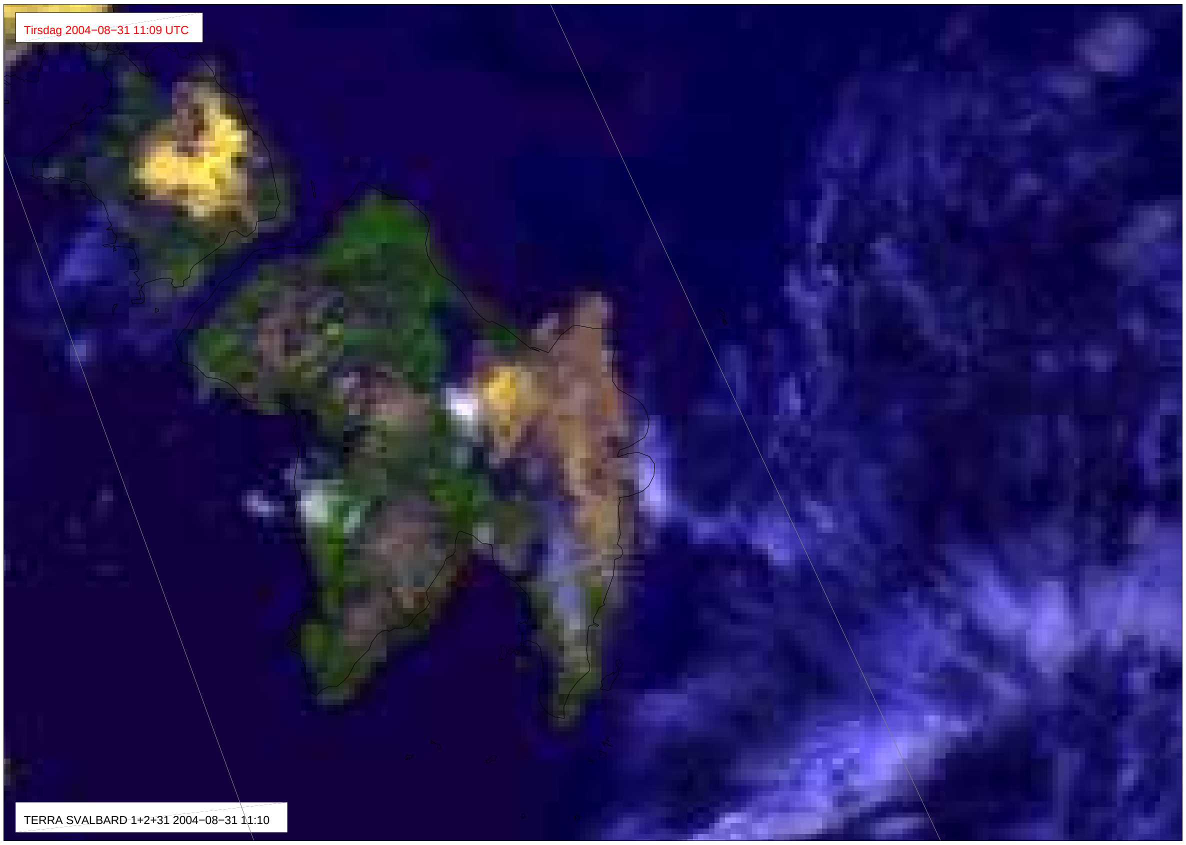

Figure 5. Scene from MODIS at 11:10UTC, August 31. 2004. RGB channel composite using channels 1,2 and 31.

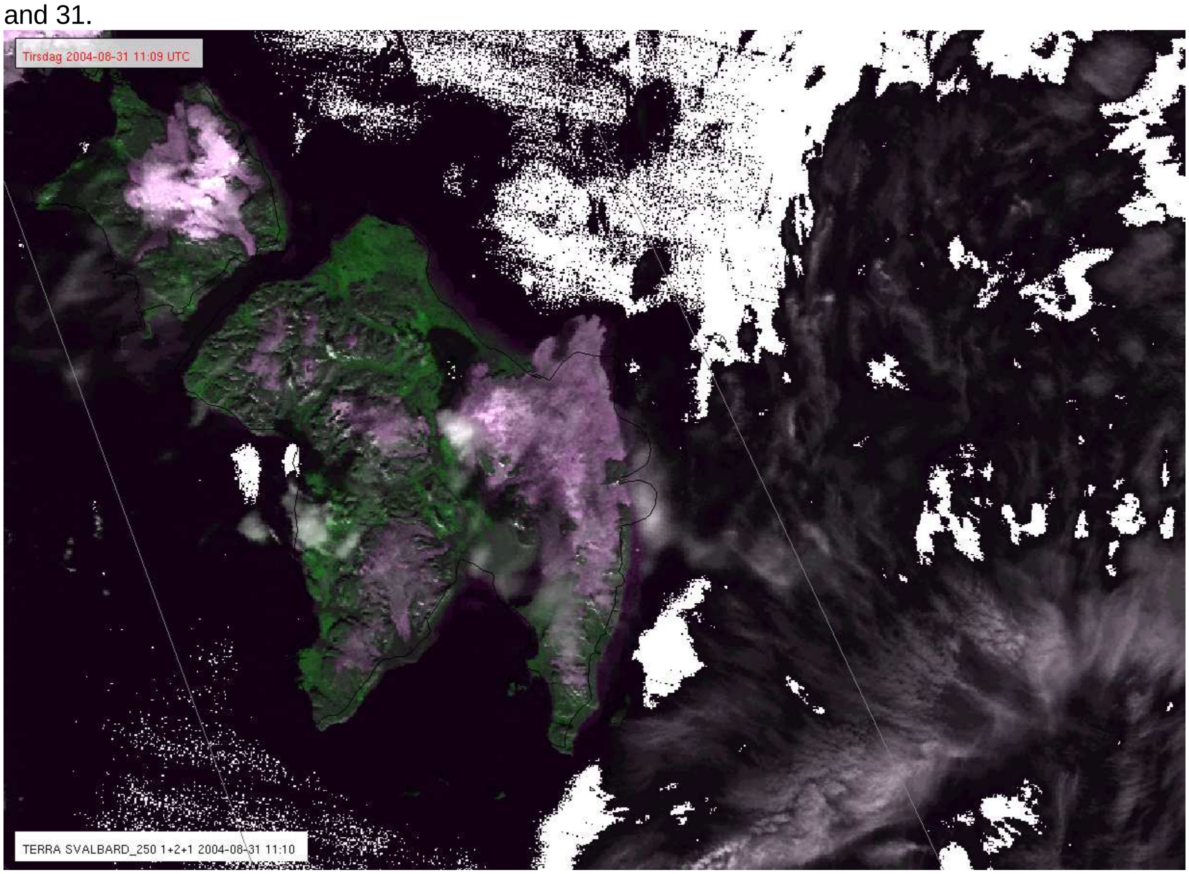

Figure 6. Same MODIS pass as figure 5. RGB channel composite using visual channels 1 and 2 at 250 meters horizontal resolution. Ice is purple in this RGB combination. The white fields are results of lack of data.

4 Future use of MODIS at met.no

4.1 Objective use of data

MODIS data also has a potential use in Numerical Weather Prediction (NWP). An important part of the products and services delivered by **met.no** originate from NWP products. **Met.no** receives NWP products from centres running global models, but also has its own production of NWP forecasts on shorter range and higher spatial resolution (at present with models down to 1 km horizontal resolution and time range up to 48 hrs). MODIS data can be used by forecasters to monitor the NWP forecasts, for instance to spot if phenomena not forecasted by the model appear. The most important aspect, however, would be to use MODIS data objectively to correct the initial state for the model forecasts in so called data assimilation.

There is a development at **met.no** towards running models at successively higher spatial resolution, and therefore the high resolution offered by MODIS becomes of increasing interest, particularly the cloud information and information on water vapour distribution from the MODIS water vapour channels. Several weather centres have experimented with assimilation of cloud and water vapour information in regional and local models. It seems clear that there is a capability for this type of information to significantly improve short-range weather forecasts.

It is also clear that at present there are limitations in the capability of present data assimilation methods to fully realize the potential of these data. This is however expected to change in the future, and the data assimilation methods will become more mature (more computer power, 4-dimensional as opposed to 3-dimensional variational schemes, better resolution in the models and better treatment of cloud and moisture information). We therefore conclude that it is of high interest for **met.no** to consider developments to be able to assimilate MODIS products delivered in near-real-time from KSAT in high-resolution NWP models.

4.2 Data format

At present, **met.no** receives MODIS products on the HDF5 format defined by Kongsberg Spacetec. This is a familiar file format, well known from earlier deliverances of AVHRR data from the MEOS system. **met.no** has routines for reading such files and transforming to formats used by the analysis tool DIANA, which the duty forecasters use.

The MODIS test files delivered by KSPT contains both level 2 geo-located channel/band values and level 3 value added products. For future operational use of MODIS data at **met.no**, we need to receive the level 2 channel values and the level 3 value added products (like snow cover and cloud mask) in two separate files.

There are two main reasons for this;

1. It makes the local post processing at **met.no** less complicated
2. **met.no** can not afford to wait for the level 2 channel products while the level 3 products are being made. This is very important if the products are to be used for short time forecasting at **met.no**; either by visual inspection, or as input to high resolution models.

4.3 Operational Requirements

4.3.1 Time lag

The requirements of met.no
For all visual exploitation of satellite data in meteorology, it is important that the time between receiving the satellite signal and presenting a final product to the forecaster is as short as possible. For Nowcasting purposes, products must be available no later than 30 minutes from reception, in order to be of any use to the duty forecaster.
For objective use of satellite data we also need to have the data quickly after it has been read down. If the data is going into high resolution forecast models, time is of extra importance, as the cut-off time for such model runs is very short (around 2 hours), and is likely to become shorter in the near future.
For ice and snow detection fast data delivery is of less importance. **Met.no** issues ice and snow products once a day, and we can afford to wait for several hours for the latest ice and snow products from MODIS.

Experience from the MODIS project
This requirement of fast product deliveries is not met by the present production system at KSPT, where it takes from one to three hours from the satellite passage to the final product is ready at the ftp server. One way to speed things up could be to split up the delivery into several files containing MODIS products of different levels (see discussion under section 4.2 Data format). In any case, this is a problem that needs to be solved.

4.3.2 Regularity

The requirements of met.no
The main use of the MODIS data at **met.no** will be by the operational forecaster for Nowcasting purposes. It is essential that products are available on a regular basis, and it is also important that the forecaster has access to all passages, as weather conditions change rapidly. Due to short deadlines on making the forecasts, experience shows that the meteorologist is not interested in products that are not present on a regular basis. In order for MODIS to become a part of the daily routine, we have to make sure that the products are there every day.
For objective use of the data, it is equally important that data expected by the model are present when the model starts.

Experience from the MODIS project
Unfortunately there have been a number of stops in the data reception in Tromsø during the project period, leading to missing data over periods of days and sometimes weeks.
From an operational point of view this is very unfortunate. As mentioned before; the potential users at **met.no** are mainly forecasters on watch, and they are depending on a reliable set of satellite products and are not going to use MODIS at all if the products are missing frequently.
Towards the end of the project period **met.no** has received notifications before the data flow has been cut. This is a step in the right direction, but it doesn’t change the fact that we need a stable and reliable data supply in order to use the data operationally.

4.3.3 Geometry

For **met.no** to be able to use MODIS in objective routines, information of geometry must be included in the data delivery. The observation geometry (satellite and sun zenith and azimuth angles) is essential for performing atmospheric and anisotropy corrections. This has been communicated to KSPT several times, and from late September 2004, subtrack information and observation angles has been included in the MODIS data files.

Due to the limited resources in this project, and the lack of the necessary geometry information in the earlier products from KSPT, the use of MODIS in objective routines has not yet been tested at **met.no**.

5 Conclusion and future work

MODIS data has been examined and assessed for use in the operational services at met.no. The quality of the data received is good, and it is our impression that data from the MODIS instrument represent a valuable source of information both for subjective use, and potentially also as input to objective routines.

The operational requirements of met.no have not been met by the current production setup at KSPT. The time used between read-down and final product is too long, and there have been numerous stops in the data reception during the project period.

Of the products evaluated in this project, the one with most immediate use for met.no is the level 2 channel product. This may be a valuable addition to the satellite information already available to **met.no**. Fast access to the level 2 channel products, a reliable data flow, and different level products split up onto separate data files are demands that have to be met.

For use in ice detection it would be useful to have a winter season of MODIS passages over the Svalbard region. It would also be of interest to further examine the potential of the MODIS Sea Ice product.

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