Performance of the atmospheric correction of MERIS data over northern European waters

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ABSTRACT

The Northern European countries are particularly interested in monitoring water quality due to its source for fishery and tourism and due to the threats of accidental pollution. Water quality parameters derived from optical measurements require an excellent atmospheric correction, which is particularly difficult for northern European waters (North Atlantic, Bothnian Bight). The problems are manifold: between November and February the sun is very low and often exceeds a sun zenith angle of 65° where the plan-parallel assumption, which is used in most algorithms, reaches its limits. During the summer months, the sun glint limits the usage of a large portion of the MERIS swath. Clouds often cover large parts of the area. The air is known to be clear; reducing the problem of aerosol correction, however, very few measurements of aerosol properties of Northern Europe exists for validation. MERIS FR data are of great value for Norway because of the importance of the Fjords for fish farming and tourism. However, close to the shore, the environment effect is becoming very important because of the fragment shape of the coast.

An arbitrary point in mid-Norway is measured by one, and every third day by two MERIS overpasses per day, resulting in a total of 45 overflights during a cycle of 35 days. This situation is good compared with central Europe, but is more than balanced by the restrictions listed above. The performance of the atmospheric correction for MERIS is assessed by analysing RR and FR products of the Norwegian coast. The cloud screening, including the ice_haze flag for cloud borders, is found to be very severe leaving very little data for atmospheric correction. The aerosol optical depth and Angstrom coefficients are compared with Aeronet data. The results are not conclusive, but this could be due to the large distance to the closest Aeronet station in Norköping. The retrieved water leaving radiance reflectances of open ocean look excellent. But approaching the coast the reflectance in bands 1 and 2 tend to be overcorrected. In a distance of 1-5km off the coast the reflectances are starting to be flagged invalid and are partly getting negative, probably because of the environment effect. Recommendations for improving the atmospheric correction over such water types are formulated.

1 INTRODUCTION

Northern Europe waters are of great ecological and economical importance but also characterised by its vulnerability. The coastal areas of Scotland, Norway, Sweden, Denmark and Finland are nutrient rich and serve as fishing grounds and host many fish farms. The offshore areas, particularly in UK and Norwegian waters, are used for oil exploration, and heavily used shipping routes connect the major harbours of the area. European legislation regulates the marine exploitation and requests measures from its member states to protect and monitor the environment. Notably the Marine Strategy, the Water Framework Directive and Fauna Flora Habitat Directive impose concrete measures for monitoring and protection.

Marine applications are the primary mission objective of MERIS, and its spatial coverage, temporal resolution and its spectral features favour MERIS as an instrument to be used for these monitoring tasks. The Level 2 products which are generated operationally by ESA, and supporting initiatives such as the GMES project MERSEA or the GMES-GSE project MARCOAST provide suitable data products and related services. However, the standards products as well as most of the application that have been developed until now are globally applicable but are not ideal for Northern Europe water which are characterised by difficult environmental conditions, such as frequent cloud coverage or a low sun elevation during a large portion of the year.

2 EXPLOITABLE DATA

The orbit of ENVISAT has an inclination of 98.6° at a height of 784km. The MERIS sensor has a swath width of 1300km. Based on these figures, every point at the equator is passed every three days. Further north, the tracks converge, resulting in more frequent overpasses. An arbitrary point in mid Norway, at approximately 63°N, is observed daily, and every third day even two overpasses occur. This is a comfortable situation leading to 45 overpasses during a 35 day repeat cycle.
The number of useful images out of this set of images is limited due to various factors. Most importantly is the often prevailing cloudiness in high latitudes. Figure 1 presents a typical series of four images, taken on the 4th of the months April, May, June and July 2003. Parts of the North Sea and/or the Baltic Sea are always cloud free, but large areas of the image are cloud covered. Figure 2 shows a classification of the image of 4.4.2003 in the middle left image. White areas are clouds, and yellow areas are pixel characterised as ice or thick aerosol, so that they cannot be further processed. The second important limiting factor is sun geometry. During late autumn, winter and early spring the sun is too low for a good processing. The middle right image in Figure 2 shows in green the area where the sun azimuth is above 75°, which is set as the limit for the standard processing. During summer, the sun elevation is high so that the sun glint affects large portions of the image. The sun glint area is shown in purple colour in the middle left image of Figure 2. The pixels for which the atmospheric correction failed are indicated in red colour in the image. In summary, the black water pixels in the image are useful for further evaluation. These pixels are located north of Norway, at the South West coast of Norway, in the Oslo Fjord area and in a part of the Baltic Sea at the mid Swedish coast.

![Figure 1: MERIS L1b RGB of Northern Europe. Left to right: 04.04.03, 04.05.03, 04.06.03, 04.07.03.](image)

### 3 DATA ANALYSIS

Two of the areas, which have been identified as not masked in section 2, will be studied further: the area north of Norway and Finland (area 1) and the area on the south-west coast of Norway (area 2). The two areas are marked by white circles in the right image of Figure 2.

The mean latitude in area 1 is 71°N. The sun zenith angle is 64°, which is at the lower limit for most of the standard MERIS Level 2 processing algorithms. The wind was blowing from west with a speed of 5-7m/s. At 7 m/s white caps start to occur, which might degrade the quality of the atmospheric correction. The air pressure was low with 995 hPa. The aerosol optical depth which was derived from MERIS is 0.14, which is a not very clear and possibly due to the low pressure weather system. The aerosol alpha is 0.16, which is a typical value for a maritime atmosphere. Unfortunately did none of the two Aeronet stations of the area (Svalbard and Andeness) report during April 2003. Area 2 is at 60°N. The sun zenith is at 58°, which provides much better illumination condition than in the northern area. However, the wind is blowing strong with 10m/s from northern direction. The white caps risks is high under these conditions. The air pressure is also higher with 1021 hPa. The derived aerosol optical thickness is
Figure 2: MERIS image of 04.04.2003. Left: RGB, middle-left: classification flags; middle right: low sun flag; right:aerosol optical thickness.

Figure 3: Water leaving reflectance spectra in the northern area 1 (blue) and the south western area 2 of the MERIS image of 4.4.2003.

Figure 4: MERIS FR image, 4.7.2003. Left: Chlorophyll concentration (algae2 algorithm), right: total suspended matter.
0.16 and the alpha is 0.27, which is a quite steep slope and an indication for coastal type aerosols. The water leaving reflectances (Figure 3) in both areas showed realistic spectra. Area 1 is a typical clear water spectrum, which high reflectance in the short wavelength and monotonously decreasing reflectance with wavelength. In area 2 higher concentration of phytoplankton is leading to higher absorption in the blue. This spectrum shows also nicely the fluorescence peak at 681nm, caused by living phytoplankton.

So far the analysis has been performed on reduced resolution data and the analysed pixel were taken within sufficient distance (> 20 km) from the coast. However, most important for the ecosystem, the fish farms and the tourist industry is the near coastal areas including the Fjords. A full resolution scene of the 4.7.2003 has been studied for this purpose. The atmospheric correction performed well for pixels off the coast, and Figure 4 shows the finally derived chlorophyll and total suspended matter concentrations. The black areas close to the coast are those areas where the atmospheric correction did not produce reliable values and the product (non-)confidence flag (PCD-1-13) was raised. A subset of the Fjord area is shown in Figure 5. The image presents the water leaving reflectance in band 2 (442nm), whereby the PCD-1-13 is not overlaid in order to study the behaviour of the atmospheric correction more detailed. When the land is approached closer than ~ 3km (1km), the green colour turns to blue, indicating that the derived reflectance became negative. 4 points have been selected along a transect from the open sea into a Fjord. In Figure 5 these points are indicated by a pin symbol. The spectra at these 4 points are shown the right part of Figure 5. This sequence shows that, starting from a “normal” spectra, an overcorrection of the blue bands takes place, which increases when the transects enters deeper into the Fjord. A possible explanation for this phenomenon is the so called environment effect. Photons scattered from near by vegetated land pixel, which are bright in the near infrared, cause an artificial increase of the signal in the near infrared, which is treated as increased aerosol optical depth by the atmospheric correction. Such an overestimation of the aerosol would lead to the observed overcorrection in the blue. Another possible explanation, which is optically very similar, would be pixel which are partly water and partly land, e.g. due to little islands or even rocks close below the surface. This needs further investigations.

4 NEW APPROACHES FOR ATMOSPHERIC CORRECTION

Two algorithms have been developed recently which provide an alternative atmospheric correction. The Case2R algorithm, developed by the GKSS research centre, and the FUB algorithm, developed by the Free University Berlin. The FUB algorithm is available as a plug-in for BEAM (www.brockmann-consult.de/beam) and the Case2R method will also be made available via this channel. First tests with the two methods indicate that they perform better in the critical regions close to the coast and also under moderate sun-glint conditions compared to the standard Level 2 algorithm. Further investigations and sensitivity studies are necessary.

5 SUMMARY AND RECOMMENDATIONS

Northern European waters are a challenge for the Level 2 processing of MERIS in general and the atmospheric correction in particular. The cloud coverage, glint and low sun limit the number of useful images significantly. The ecologically and economically most important areas close to the coast and in the Fjords are currently not correctly processed by the atmospheric correction of the standard Level 2 processing.

This indicates that optimised, dedicated algorithms are required. These should include a cloud screening algorithm which is aligned with the atmospheric correction algorithm, so that a maximum of water pixels is retained for
further processing. The atmospheric correction should work also for medium glint conditions and low sun elevation, and should take the environment effect into account. It should be studied if an un-mixing step should be applied in order to separate the water signal from land signal within a pixel. The aerosols prevailing in the area should be studied by in-situ measurements in order to base the atmospheric correction on a proper aerosol model.