A review of the MERIS sensor and its applications

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Introduction

MERIS, the Medium Resolution Imaging Spectrometer sensor, which is to be flown on ENVISAT-1, is one of the newest projects being completed by the European Space Agency (ESA). ENVISAT-1 is tentatively scheduled to be launched in July 2001 with a total of 11 sensors onboard including a SAR radar sensor (ESA, 2000). MERIS will be a multi-purpose sensor designed to gather data for a number of applications at regional to global scales (Dawson, 2000). The primary objective of MERIS will be to look at ocean colour, both in the open ocean and in coastal areas, and secondarily study atmospheric constituents associated with clouds, water vapour and aerosols and finally to look at land vegetation parameters (International, 2001). The oceanographic portion of the MERIS mission will consist of data collection focusing on photosynthetic potential (chlorophyll concentrations) and concentrations of yellow substance (Gelbstoff) and suspended mineral materials. The atmospheric applications will be used to study clouds, as well as to provide very accurate assessments of aerosols and atmospheric turbidity, which will aid in atmospheric corrections. The land portion of the mission will look at vegetation and the data may be used to help determine biomass and productivity (Rast, 1999, Moore, 1999 and Verstraete, 1999).

MERIS will be imaging the earth in the visible and near infrared (NIR) and will be able to gather a complete planetary data set in three days (Rast, 1999) (Figure 1). The data retrieved from MERIS will be usable in conjunction with other types of sensor data such as AVHRR (Advanced Very High Resolution Radiometer) and ASTR (Along-Track Scanning Radiometer) (Verstraete, 1999 and Doerffer, 1999).

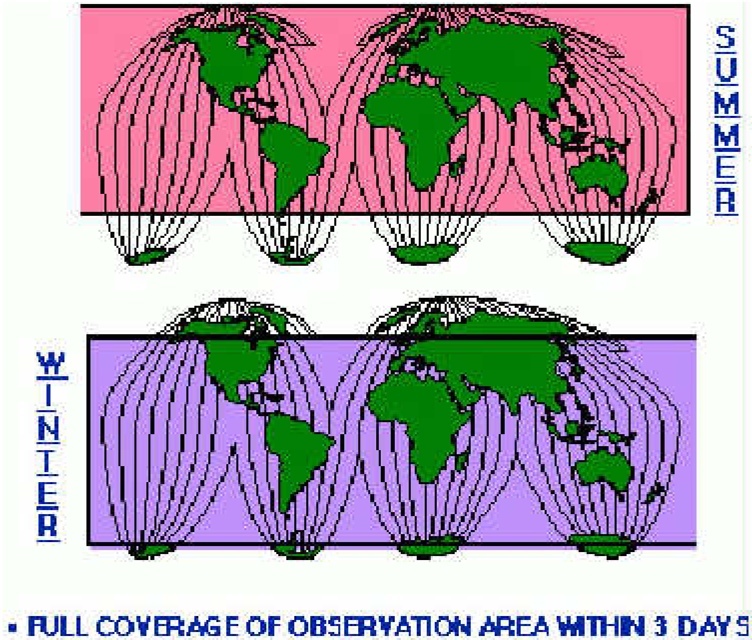

Figure 1. Extent of global coverage of MERIS sensor.

Sensor Characteristics

ENVISAT-1 will be in a sun-synchronous polar orbit at an altitude of 800 km. MERIS will only function when the solar zenith angle is less than 80^0, as it is a passive sensor (Verstraete, 1999). The field of view of MERIS will be 68.5^0 centred on nadir, which gives a swath width of 1150 km. This will allow for complete imaging of the earth in three days (Figure 2). MERIS will operate under two observation modes, Averaging mode and Direct and Averaging mode. The Averaging mode will collect reduced resolution (RR) data continuously (resolution of 1200 m), while the Direct and Averaging mode will collect both reduced resolution data and full resolution (FR) data (resolution of 300 m) (Rast, 1999). The collection of FR data will be done only during specific time intervals. The FR data will be available upon request and will only be collected for 20 minutes each orbit when the Direct and Averaging mode is being used, due to energy constraints on the platform (Verstraete, 1999). From this data, images will be available that are 1150 km by 1150 km for the RR data and 575 km by 575 km and 296 km by 296km for the FR data (Merheim-Kealy, 1999).

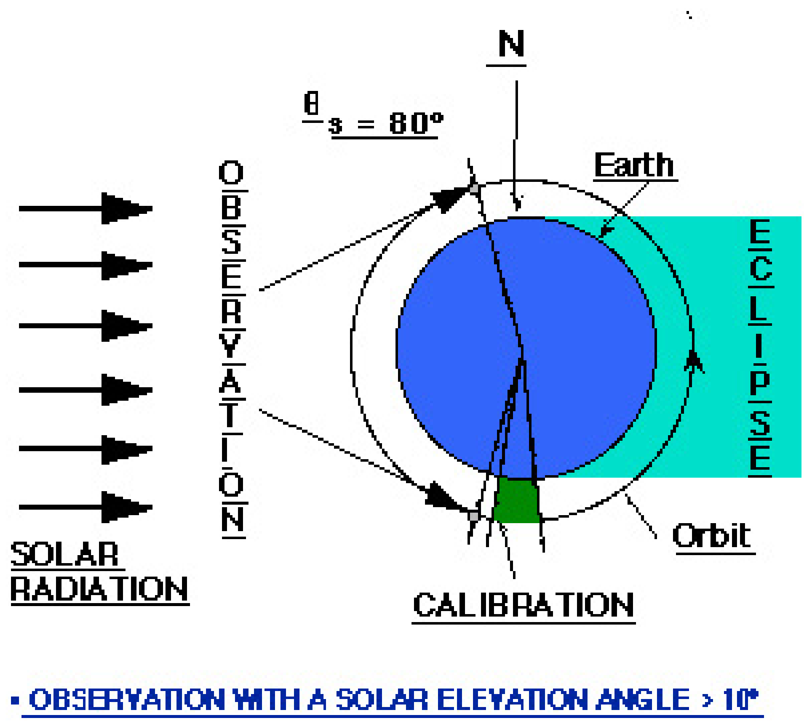

Figure 2. Periods of operation, inactivity and calibration for MERIS.

MERIS will be collecting data in 15 spectral bands ranging from 390 nm -1040 nm, nine of which will be in the visible spectrum (Doerffer, 1999) (Table 1). Bandwidths will be 10 nm on average over open-ocean, in both the visible and NIR portions of the spectrum. Each band is programmable to allow customization of bandwidths from a minimum of 1.25 nm to a maximum of 30 nm (Rast, 1999).

Table 1. MERIS spectral bands.

Band	Band centre (nm)	Bandwidth (nm)
1	412.5	10
2	442.5	10
3	490	10
4	510	10
5	560	10
6	620	10
7	665	10
8	681.25	7.5
9	705	10
10	753.75	7.5
11	760	2.5
12	775	15
13	865	20
14	890	10
15	900	10

The sensor itself only weighs 200 kg and is 1.8 m by 0.9 m by 1.0 m. It is designed to have a four-year lifespan, although it may continue to function after the projected period, as did the Coastal Zone Color Scanner (CZCS), which operated for eight years, but had a projected lifetime of one year (Bricaud, 1999).

Calibration of the CCD’s (charged coupled devices) on MERIS will be very crucial for maintaining the consistency of data collection. Two calibrations methods will be available. One will be done automatically every two weeks as MERIS crosses the South Pole region of its orbit and the other, done from the ground, will be performed any time the sensor’s parameters are altered (i.e. bandwidths re-programmed) (Rast, 1999 and Verstraete, 1999) (Figure 2).

Sensor Applications

Atmospheric correction

Atmospheric corrections will be done that should prove to be much more accurate than those done on CZCS data due to the fact that MERIS has three bands in the IR (bands 9, 12 and 13), dedicated to measuring atmospheric aerosol characteristics (Table 1) (Bricaud, 1999). The atmospheric correction over the ocean will allow the differentiation of Case II waters from Case I waters. Case I waters are waters which contain phytoplankton and its related materials only, and have close to zero water-leaving radiance in the NIR, while Case II waters contain phytoplanktons, as well as suspended mineral material and dissolved organic materials (Gelbstoff) and are usually found close to coast lines. The mineral components of Case II waters are problematic for atmospheric corrections because even at low concentrations (less than 2 g m^{-3}), considerable backscatter occurs, which effectively negates 'dark pixel' correction algorithms, where it is assumed that the water-leaving radiance is zero in the NIR.
A series of algorithms have been developed which will identify waters that are Case I waters, Case II waters dominated by Gelbstoff (Case II.y) and Case II waters dominated by suspended mineral material (Case II.S) (Figure 3). The data will be corrected for sun glint; land, ice and cloud interactions and then a determination will be made about the amount of water reflectance in the NIR. The final step assesses the types of aerosols in the atmosphere and amount of atmospheric turbidity. Essentially this will determine the atmospheric path radiance using single and multi-scattering algorithms. This system has been tested using available sensors set with the corresponding bands of MERIS, as well as using sea-truthing (Moore, 1999).

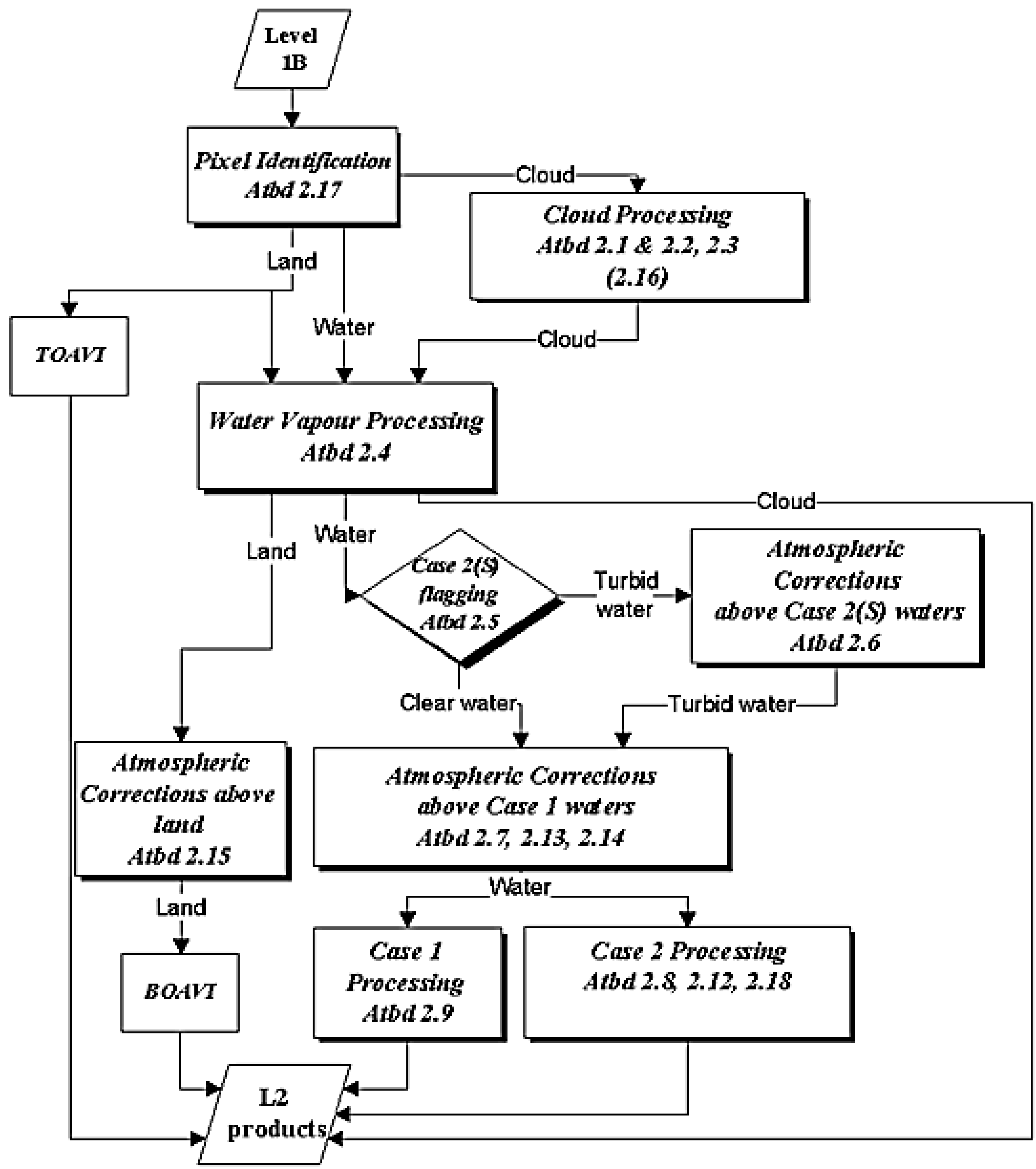

Figure 3. Flow chart of atmospheric correction procedures for MERIS

Land Applications

It is hoped that MERIS will be a valuable tool in increasing the effectiveness of photosynthesis measurements, as well as estimating the size of the terrestrial carbon sink, which may play a significant role in the global carbon cycle. Vegetation indices using two broad bands have been used regularly in the past and will now be implemented using narrow bands, resulting in more accurate information (Verstraete, 1999). The presence of three bands on the red edge will allow a more sophisticated algorithm series to calculate vegetation parameters more accurately, such as chlorophyll concentration, nutrient cycling and vegetation stress (Dawson, 2000).

Ocean Colour

The main application of MERIS will be to gather data to further the study of ocean colour, leading to determinations of phytoplankton distributions and estimates of oceanic primary productivity. The nine visible bands utilized on MERIS will allow for better data collection compared to the CZCS sensor, which had only four bands and the SeaWiFS sensor with six bands. The additional bands may increase the amount of information that can be derived from CASE II waters such as concentrations of suspended mineral materials, yellow substance and phytoplankton.

Phytoplanktons absorb mostly in the blue, with a maximum absorbance around 435 nm - 445 nm. The CZCS sensor detected in the same region and a band ratio was used to determine chlorophyll *a* concentrations. The same band ratio will be applied to the MERIS data, however, the higher radiometric accuracy will allow for higher accuracy of pigment identification. The band ratio that may be used is R_{443}/R_{560} because it spans the widest wavelength range and will therefore be the most sensitive to variations in algal pigment concentrations. It is hoped that the high spectral resolution of MERIS will allow for identification of individual groups of plankton, such as dinoflagellates, cryptophytes and coccolithophorides. This should be possible as it has been shown that differentiation between pigments (chlorophyll and phycoerythrin) can be done using SeaWiFS data. Each group of phytoplankton has a characteristic amount of different types of pigments. The determination of these pigments types and measurement of specific concentrations should lead to classification of individual groups in areas, which contain phytoplankton. MERIS will be one of the first sensors to be able to specifically detect chlorophyll *a* fluorescence at 681.25 nm. Measurement of *in vivo* fluorescence will be possible with band number eight in conjunction with bands seven and nine (Gower, 1999). This will allow for better estimations of phytoplankton concentrations. This measurement has been used for the past 20 years to describe the amount of pigment in the water, collected by airborne or *in situ* sensors (Gower, 1999). The technique uses a comparison between a 'baseline', which is determined by observing radiance measurements outside of the fluorescence peak (bands 7 and 9), and the fluorescence peak (band 8) (Rast, 1999). Fluorescence is a good measure of chlorophyll content in the water, even in Case II waters, because it is not affected by the presence of suspended mineral material or Gelbstoff. The limiting factors of this method are the absorbance of water, absorbance of atmospheric oxygen and the variation in fluorescence emission per unit of chlorophyll, which create noise (Gower, 1999). The accurate assessment of the amount of chlorophyll *a* in the water can be used to assess the primary productivity of the water-borne organisms (Rast, 1999).

Conclusions

The MERIS sensor will be a great asset to the remote sensing world. Not only will it continue the provision of information on ocean colour and phytoplankton concentrations, leading to conclusions about oceanic productivity and possible carbon storage, but it may also supply needed information on land vegetation biomass and productivity. The advanced algorithms used in conjunction with the MERIS data, in combination with the large number of spectral bands and high spectral resolution will allow for unsurpassed atmospheric corrections, making the data from MERIS extremely accurate. It will be a very exciting instrument to work with in the future.