Ground vegetation indexes (MGVI, MTCI, NDVI) and concentrations of sea chlorophyll and SPM remote sensed via ENVISAT MERIS sensor.

A Tuscany region study case.

S. Mori, P. F. Pellegrini, M. Tommasini
Dipartimento di Elettronica e Telecomunicazioni
Università di Firenze
Firenze, Italy
s.mori@labtele.det.unifi.it, pf.pellegrini@labtele.det.unifi.it, m.tommasini@labtele.det.unifi.it

***Abstract*— In this work problems are investigated which regard obtaining regional-scale ground quantities from the ENVISAT MERIS spectrometer. The MEdium Resolution Imaging Spectrometer sensor (MERIS) is a 15-band spectrometer on board the ENVIromental SATellite (ENVISAT) 1, launched by the European Space Agency (ESA). Interest in this instrument is due to the high ground resolution (approximately 290 m) and the great number of spectral bands which make it possible to observe many different environmental parameters. Two primary aspects are considered: a) exploration of the obtainable geophysical products, b) precise geolocation of retrieved pixels. For point a), maps of several vegetation indexes have been obtained, in particular from the MGVI, MTCI, NDVI and NDVI AVHRR comparable indices. Concentration maps of sea chlorophyll and SPM have also been obtained, the last using an original MERIS-AVHRR algorithm [8] (not discussed in this paper). For point b), starting with ESA positioning pixels, an original georeferencing procedure has been developed in order to increase navigation precision as necessary for regional and sub-regional problems. The results presented refer to acquisitions on 15.08.2002 and 19.08.2002, 10:00 UTC on the Tuscany region. MERIS Level 1B radiance data at high resolution has been used, furnished by ESA within the ENVISAT 168 Announcement of Opportunity (AO), as well as NOAA AVHRR sensor data, close in time (within 3 hours) to MERIS data retrieved at the Satellite Receiving Station of the University of Florence, Prato Campus (PIN). The four proposed vegetation index maps have been compared by evaluating their differences and similarities, whereas those for sea chlorophyll and suspended matter concentration have been compared with local data by using the measurement database of Agenzia Regionale Protezione Ambiente della Toscana (ARPAT).**

Keywords-MERIS; Vegetation Indices; Georeferencing

I. INTRODUCTION

The passive satellite sensors in orbit a few years ago with their resolution and spectral bands offered few possibilities for observing restricted geographical areas. These carry a significant practical interest, if one thinks of the possibility, for example, of monitoring toxic algal fronts near the coast, or the health status of wooded or agricultural areas, often characterized by a variety of species and limited extensions. The arrival of sensors like MERIS, spectrometer with a high ground resolution (approximately 290 m) and with a large number of spectral bands (15, programmable from Earth in width and central position) has opened possibilities that were once impossible.

Our intent in this research was to explore the possibilities offered by this sensor when observing regional (e.g. Tuscany) and sub-regional areas. This work primarily focuses on the results obtained from land observation, concretized in vegetation index maps. MERIS Level 1B Full Resolution data was used from acquisitions on August 15 and 19, 2002. The images presented below particularly refer to the August 15 study case.

II. VEGETATION INDEX MAPS FROM MERIS DATA

Terrestrial vegetation, regardless its seasonal, physiological, and species differences, tends to absorb green frequencies and to reflect red frequencies (Fig. 1). This characteristic behavior makes satellite vegetation observations possible using indices based on spectral band differences and ratios, such as the Meris Global Vegetation Index (MGVI), the Normalized Difference Vegetation Index (NDVI) and the Meris Terrestrial Chlorophyll Index (MTCI). These indices have been investigated on a regional scale (Tuscany area) on a basis of comparative analysis. The results have been presented on maps in Mercator projection.

The MGVI [3] Index aims at estimating the Fraction of Absorbed Photosinthetically Active Radiation (FAPAR), useful for evaluating the quantity of vegetation and the surface typology, with a bigger robustness in atmospheric effects and land radiative characteristics than the analogous NDVI index. Nevertheless the latter has a continuous history from AVHRR data. For this purpose an NDVI MERIS algorithm [4] with NDVI AVHRR compatibility has been considered (Fig. 2), so that the utmost MERIS precision could be used without losing AVHRR continuous history. In addition multisensor data analysis can include MERIS, AVHRR and SEVIRI/MSG [7].

With the support of ESA for MERIS Data and ARPAT for in situ sea measurements.

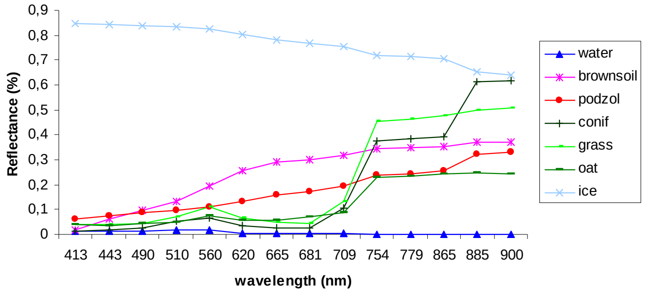

Figure 1. Spectral reflectance of some materials (ESA source). MERIS standard bands indicated (nm). Notice the behaviour of vegetation.

The MTCI index [5] (Fig. 3) aims at estimating the Red Edge Position (REP). This is the maximum slant point in the red and near-infrared region of the vegetal spectral reflectance (Fig. 1). It tends to move towards higher wavelengths when the chlorophyll concentration increases. It is useful for observing the chlorophyll contents, vegetation senescence, and stress for water and nutritional deficiencies, but it is less suitable for land classification [6]. Other methods are available for estimating REP but they are not efficient like MTCI when the chlorophyll concentration increases [5].

The cross correlation (1) values shown in Tab. 1 are the result of comparative evaluations among the values of the various indices of only land pixels in the defined region (Fig. 2). REP and MTCI result as being very correlated (>0.96), just as MGVI and NDVI (~0.9), the latter correlation not being so obvious . Furthermore, it has been observed how MGVI and NDVI actually have different informative contents than MTCI and REP (correlation ~0.7).

TABLE I. CORRELATION AMONG TUSCANY VEGETATION INDEX MAPS

	MGVI	MTCI	REP	NDVI	NDVI c. AVHRR
MGVI	-	0.745	0.729	0.897	0.9
MTCI	0.745	-	0.961	0.718	0.718
REP	0.729	0.961	-	0.708	0.698
NDVI	0.897	0.718	0.708	-	0.995
NDVI c. AVHRR	0.9	0.718	0.698	0.995	-

Cross correlation (1) in %. Only land pixel, see Fig. 2 for the considered geographic area.

$$corr(\underline{A},\underline{B}) = \frac{1/(m\cdot n)\cdot\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left[A_{i,j}-1/(m\cdot n)\cdot\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}A_{x,y}\right]\cdot\left[B_{i,j}-1/(m\cdot n)\cdot\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}B_{x,y}\right]^{*}}{\sqrt{\frac{1}{m\cdot n-1}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left[A_{i,j}-1/(m\cdot n)\cdot\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}A_{x,y}\right]^{2}}\cdot\sqrt{\frac{1}{m\cdot n-1}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left[B_{i,j}-1/(m\cdot n)\cdot\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}B_{x,y}\right]^{2}}} \quad (1)$$

The practical use of these index maps also depends on the geographical positioning accuracy of the observed pixels. In particular, sub-pixel precision is generally necessary when working in small and fragmented areas. Therefore, in order to obtain useful results in small zones of the region, two geolocation techniques have been researched, one of these being original.

III. MERIS DATA GEOLOCATION

A first geolocation technique for MERIS Level 1B data is suggested in [1] and consists of bilinear interpolation of the given coordinates for obtaining the latitude and longitude of every point of the scene. This is allowed by MERIS Level 1B data supplied by ESA, which includes the latitude and longitude (WGS84 datum) of a regular point grid of the captured scene. Nonetheless, as indicated in ESA studies [2], these data can be affected by an error that is not insignificant on a regional scale.

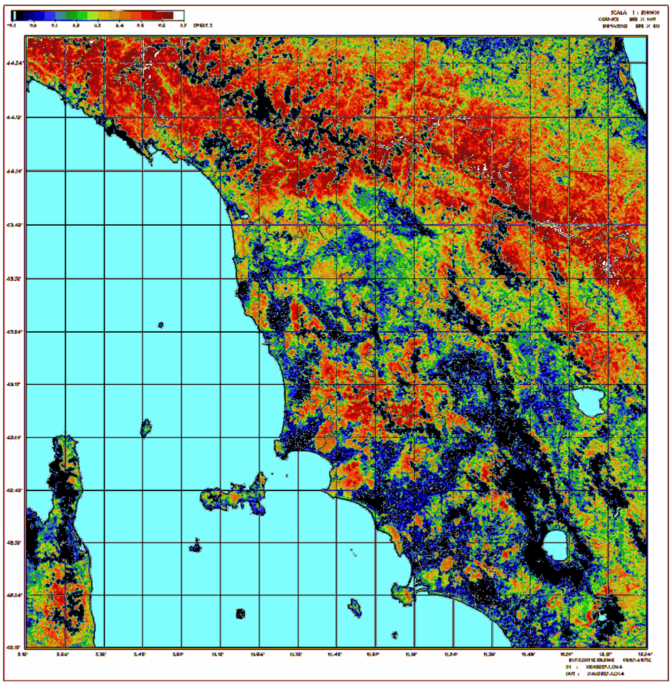

Figure 2. NDVI MERIS index map compatible with NDVI AVHRR.

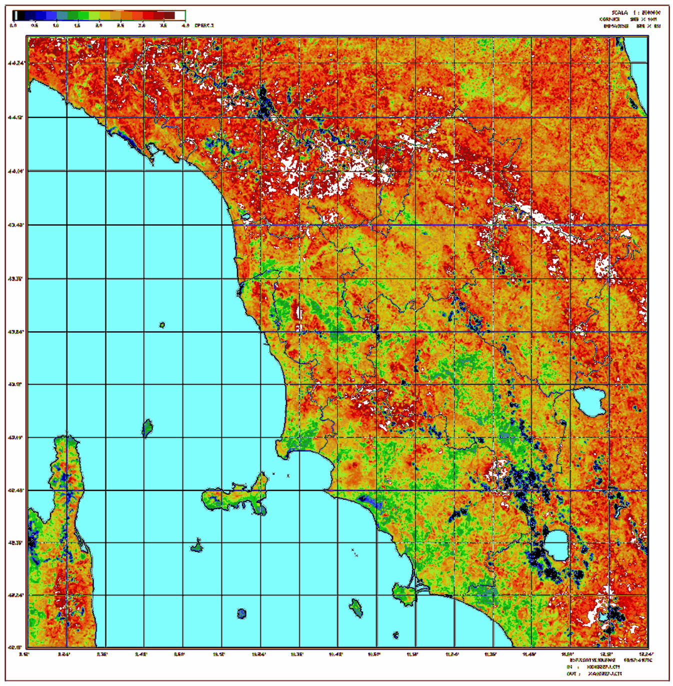

Figure 3. MTCI Index map.

A second and original technique has been implemented by considering the developed geolocation algorithms at the Department of Electronics and Telecommunications of the University of Florence (Telecommunications Laboratory). These algorithms are based on orbit reconstruction using a navigation model (SGP4), and on a sensor viewing model. Geocorrection is performed using two true points normally obtained in conspicuous points of the coastline. In this study such a technique has been applied to MERIS Level 1B data. The obtained results with the two methods have been compared towards the coastline.

A. Geolocation with ESA Level 1B data

An imprecision has been verified with this method on average expressed as a South-West shift from the actual coastlines. It has been also observed that this is slightly different in the two study cases considered. Nonetheless, a similar inaccuracy is significant only on a small scale (e.g. 1:500000) as shown in Fig. 4. In the August 15 case study, a coordinate shift of 391 m North-East has compensated on average for the shift.

B. Geolocation with orignal orbit reconstruction

The parameters utilized have been the orbital data of the passage (2 lines) which are available on the Web, the timecodes of the scan lines contained in the Level 1B data, and two accuracy points on maps, with which to carry out a manual geocorrection. This method has proved to be sensitive to the choice of accuracy points, nevertheless, it is resulted as being more flexible and precise in geolocating on a small scale, at least for the study cases examined (Fig. 5).

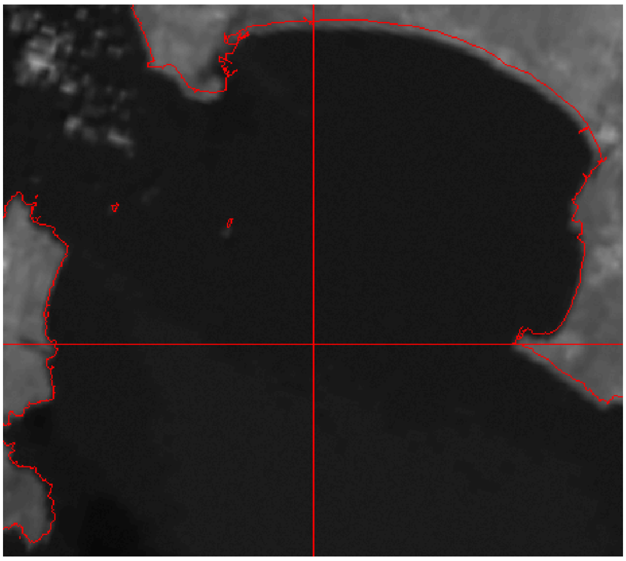

Figure 4. Geolocation with ESA Level 1B data, Gulf of Follonica.

IV. CONCLUSIONS

Four MERIS vegetation indices (MGVI, NDVI, NDVI compatible with AVHRR and MTCI) have been studied, highlighting how they can help in monitoring the health status of the land vegetation and in classifying the territory, with the concrete possibility of using the MERIS large land accuracy without losing comparability with the past AVHRR NDVI. Work has to be done to verifying different indices integration, multisensor analysis and ground match. Regarding land accuracy, the importance of geolocation has been underlined; for this purpose the suggested ESA method [1] has been compared with an original one which proves to be more precise in the two study cases considered.

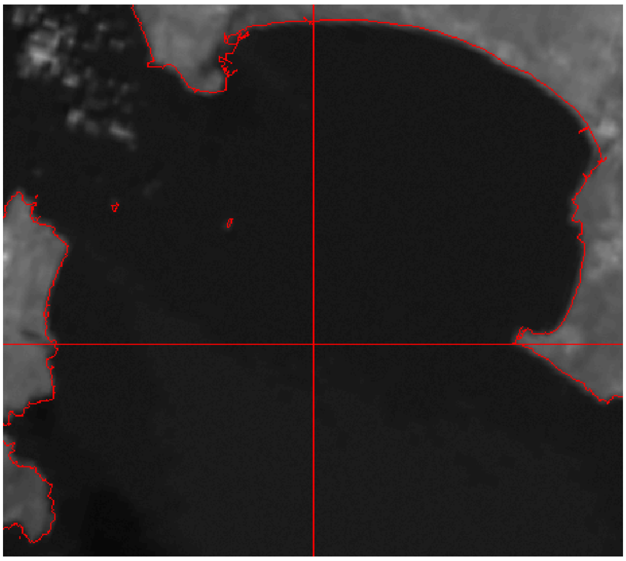

Figure 5. Geolocation with original orbit reconstruction, Gulf of Follonica.

ACKNOWLEDGMENT

The authors would like to thank Ms. Michelle Johnson for her very useful collaboration in the organization of the paper and its text.

REFERENCES

[1] MERIS, “MERIS Product Handbook,” ENVISAT-ESA, issue 1.2, September 2004.

[2] Goryl P., Saunier S., “MERIS absolute geolocation status,” ESA ESRIN e GAEL Consultant, Issue 1, Revision 0, 19.08.2004.

[3] Gobron N., Aussedat O., Pinty B. , Taberner M., Verstraete M., “Medium Resolution Imaging Spectrometer (MERIS) - Level 2 Land Surface Products Algorithm Theoretical Basis Documentt,”, Revision 3.0, JRC Publication No. EUR 21387 EN, November 25, 2004.

[4] Gunther K. P., Maier S. W.,”AVHRR compatible vegetation index derived from MERIS data”, Proc. of the 2004 Envisat & ERS Sympoium, Salzburg, Austria, 6-10 September 2004.

[5] Dash J., Curran P. J.,”MTCI: The MERIS Terrestrial Chlorophyll Index”, Proc. MERIS User Workshop, Frascati, Italy, November 2003.

[6] Klein D., Menz G., “Vegetation assessment in East Africa using MGVI and Red Edge Position from ENVISAT MERIS data”, proc. MERIS and (A)ATSR User Workshop, Frascati, September 2005.

[7] Poli G., “Monitoraggio di parametri fisici sul suolo da sensori satellitari passivi. Aspetti della qualità e dell’interscambio di dati per applicazioni sul territorio della Regione Sicilia”, Dottorato in Metodi e Tecnologie per il Monitoraggio Ambientale – XIX Ciclo, novembre 2006.

[8] Tommasini M., Mori S., Poli G., Pellegrini P. F., “Suspended Particulate Mattere (SPM) on a Regional Scale (Tuscan Archipelago) from AVHRR and MERIS Data,” ”, proc. MERIS and (A)ATSR User Workshop, Frascati, September 2005.