Masters Program in Geospatial Technologies

EXTRACTING TEMPORAL AND SPATIAL DISTRIBUTIONS INFORMATION ABOUT MARINE MUCILAGE PHENOMENON BASED ON MODIS SATELLITE IMAGES

A case study of the Tyrrhenian and the Adriatic Seas, 2010-2012

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Dissertation submitted in partial fulfilment of the requirements for the Degree of *Master of Science in Geospatial Technologies*

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A Case of Study for Italy Seas, 2010-2012

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February 2013

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to Prof. Mário Caetano, my research supervisor, for his patient guidance, valuable comment and useful critiques of this research work. My grateful thanks are also extended to Prof. Marco Painho my co-supervisor for his advice and assistance in keeping my progress on schedule and his support for us throughout the entire Geospatial Technologies Master's Program. I would like to also thank to Prof. Filiberto Pla for their co-supervision of this study.

I would also like to extend my thank to the following agency for their assistance with the collection of my data: NASA Land Processes Distributed Active Archive Center (LP DAAC), USGS/Earth Resources Observation, Regional Agency for Environmental Protection and Prevention of the Veneto (ARPAV) and of the Campania (ARPAC).

Special thanks goes to Prof. Dr. Marco Painho, Dr. Christoph Brox and all concerning person's for providing all the facilities and for executing this master program successfully. Equally I would also like to thank to all the staff member of ISEGI and IFGI.

I would like to thank all the people with whom I had the pleasure of sharing my hours of work and life in these last 18 months. In particular I would like to thank my friends and colleagues Stefan and Helder for their suggestions and good company during the thesis work and in the master. I would like to thank Lia that has proceeded to review the translation of my thesis work. I also like thanks my flatmates Silvio and Martina for their support and patience. I would like thanks Concetta and Marco that have been my family in Lisbon. I would like thank my friends Vanessa and Gunnar for making me feel at home in the middle of the westfalia. I would also like thank my collegue Riazzudin, Alberto, Roberto, Diego and Ardit for their friendship and availability during the rest of the master.

Lastly, I would like to thank my family and Alessandra, for all their love and trust, and for encouraging and supporting me in all my pursuits.

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ABSTRACT

A novel approach was used with data from the Moderate Resolution Imaging Spectroradiometer (MODIS) to detect Marine Mucilage in tow different marine areas of the Italy (Campanian Seas and North Adriatic Sea) from 2010 to 2012. The approach involves first deriving a Mucilage Index (MI) based on the medium-resolution (500 m) MODIS reflectance data correction of the ozone/gaseous absorption and Rayleigh scattering effects and then objectively determining the MI threshold value ($0.05<MI<0.45$) to separate the Marine Mucilage from other interference. The dynamic feature of time and space can be obtained for the two areas of study using extracted method. Variation of mucilage bloom in these areas is analyzed and discussed in different temporal scale. The mucilage bloom frequency index (MFI) is important criterion which can show the interannual and inter-monthly variation in the whole areas of Campanian Sea and North Adriatic Sea. Utilizing the MFI from 2010 to 2012, it found some phenomena that: thare is an increase of Mucilage formation in the last tree years in the Campanian seas, al contrario in veneto e' stata evidenziata una diminuzione. Month algae bloom variation of MFI reflect the existing similar cicling dynamics of formation for each year. Lower values there are in the months of June and September, while the peaks occur in the hottest and less rainy months of July and August. We can clearly see that there are three different stages: operation of low level, rising phase, and fall period. We noted that there is a stronge influence of sea temperature in Mucilage formation. Series of consistent MODIS MI data products provide baseline information to monitor Italian coast Mucilage Formation, one of the critical water quality indicators, especially in the summer on a weekly basis, as well as to evaluate its future water quality trends.

KEYWORDS

Remote Sensing

Oceanography

Marine Pollution

MODIS

Sea Surface Temperature

Mucilage Bloom

Mediterranean Sea

Italy

ACRONYMS

AVHRR Advanced Very High Resolution Radiometer

NASA National Aeronautics and space administration

SST Sea Surface Temperature

LP DAAC Land Processes Distributed Active Archive Center

MODIS Moderate Resolution Imaging Spectroradiometer sensor

MRT MODIS Reprojection Tool

QA Quality Assessment

QC Quality Control

RS Remote Sensing

USGS United States Geological Survey

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1. Introduction

Marine pollution is a serious global problem, especially in developing countries where excessive nutrients and other pollutants from rapidly growing agriculture, aquaculture, and industries are delivered to lakes, estuaries, and other coastal waters. As a result, coastal resources are under perceptible stress, with significant degradation in water quality, biodiversity, and fish abundance. In this condition most of seas areas are being affected increasingly and frequently by large scale phenomena of marine pollution (Cracknell et al., 2001).

One of the most discussed in the last two decades with regard to the Mediterranean Sea and in particular the Italian coast is the phenomenon of Marine Mucilage. These phenomena are characterized by rapid and excessive growth of amorphous aggregates of gelatinous material consist mostly by transparent exopolymeres particles (TEP) and organic matter (Aldredge, 1999).

The phenomenon of mucilage on the Italian coast is not at all new. The first reports about the presence of mucilaginous material on the Italian coasts date back to 1729 (Bianchi 1746) in the Adriatic Sea, one of the most severely affected area, and have taken place at various times from 800 to the present day. In the last decades this phenomenon shows itself more and more frequently, but with variable intensity, alternating periods of mass production with years of almost total absence (Giani et al, 2003).

Numerous studies in recent years have contributed to a better understanding of the causes responsible for the formation of massive aggregates gelatinous but have not yet clarified exhaustive, the mechanism of production. One of the most accredited hypotheses on the formation of marine mucilage is that algae populations especially planktonic diatom benthic or even in conditions of nutritional imbalance produce exudates (Myklestad 1997, Fogg 1990), for this to occur it is also necessary to occur some climatic conditions such as calm sea, stability along the water column and high water temperatures, in fact the appearance of mucilaginous material occurs above all in the summer months from June to September (Penna et al., 2003).

A part from Their intrinsic scientific interest, Their Importance lies in the fact that mucilage aggregate can have a negative impact not Also on the biocenosis of the seabed, but also on human productive activities related to tourism and fisheries (The European Union has compensated the Italian fishing for as many as 29 million euro for the fishing ban caused by mucilage in the Adriatic Sea in the summer of 2000 (Ecoharm 2003)), and although there are no reports of cases with negative consequences for human health, produced by contact with the mucilage (Funari & Ade, 1999), we cannot be completely ruled out, in polluted areas, health-related implications for bathing.

In this context, it appears really important to establish monitoring and forecasting tools, through which observe and investigate this type of large scale phenomenon. Over recent years the mucilage formation is monitored by some Environment Regional Agencies and Italian research institutes. However, this duty has been traditionally undertaken, through a series of 'in situ' monitoring programs with increasing frequency at the main algal bloom season. Under this perspective, Remote Sensing has the potential to provide greater spatial coverage, greater temporal coverage and additional environmental information (Fischer, 1985).

1.2. Research objectives

The overall objective of this Research based on MODIS remote sensing data is the study and monitoring of mucilage phenomenon in the Mediterranean Sea in particular with regard to the Italy coasts.

The main activities of the project will be focused on:

- Establishes method and technology to extraction the time and space distribution information of Mucilage Bloom.
- Based on extracted information and index, obtaining the dynamic feature of time and space in the Italian coasts from 2010 to 2012.
- Analyses and discusses variation of mucilage bloom in the Italy coasts during this time.

1.3. Study area

The study area includes all the Italian seas. As shown in figure 1 this area is located in the middle of the Mediterranean Bacin between latitudes 35 ° and 47 ° N, and Longitudes 5 ° and 20 ° E, in WGS84. The air study includes all the Italian seas. As shown in figure this area is located in the middle of the Mediterranean Bacine between latitudes 35 ° and 47 ° N, and Longitudes 5 ° and 20 ° E, in WGS84.

Each of these seas has different characteristics of depth, salinity, temperature, transparency, currents and tides. As for the rest of the Mediterranean, the surface temperature of the Italian seas is on average rather high. In the northern Tyrrhenian, the Sea of Sicily, Ionian and southern Adriatic it is about 13 º, in the Ligurian Sea about 12 º, in the southern Tyrrhenian about 14 º, but in the northern Adriatic, Because of the shallowness of the waters, it drops to 9 º. The Italian seas are also characterized by a high salinity, between 37.70 ‰ and 38.50 ‰, with lows of 32.70 ‰ due to insufficient riverine inputs of freshwater, moderate currents and a high transparency, except in areas subject to high fluvial or pollutants (Italian Air Force Meteorological Service).

Figure 1– Corsican Sea, 2-Sardinian Sea, 3-Strait of Sardinia, 4-Ligurian Sea, 5-N. Tyrrhenian Sea, 6-7 C. Tyrrhenian Sea (W,E), 8-9 S. Tyrrhenian Sea (W,E) 10 - Strait of Sicily, 11-5. Ionian Sea, 12-N. Ionian Sea, 13-S. Adriatic Sea, 14-C. Adriatic Sea, 15-N. Adriatic Sea.

2.1 Literature review

2.1. Marine mucilage

2.1.1. What they are and how they form

In marine areas with moderate or high primary production, the particulate organic carbon can represent up to 16–17% of the total organic carbon (Faganeli and Herndl, 1991; Giani et al., 1999). The particulate organic mainly appears as particles and aggregates, ranging from microns up to meters. In the Italian seas, in some years, amorphous aggregates of organic matter of up to several meters can form in the water column and frontal surface and subsurface (false bottom) organic layers, from hundreds of meters to several kilometres long, may develop. In the recent literature, the massive formation of these macro-aggregates is reported as the mucilage phenomenon (Precali et al. 2005). Several studies have contributed to a better understanding of the causes responsible for the formation of gelatinous aggregates in large areas of the northern Adriatic coasts to Slovenian-Croatian Italian ones, but have not yet clarified either exhaustive the formation mechanism. One of the most reliable hypotheses on the formation of mucilage consists in the fact that algae populations especially planktonic diatoms or benthic in conditions of nutritional imbalance produce polysaccharide exudates (Myklestad 1997, Fogg 1990). Evidence from both the field and laboratory analyses indicates that these transparent exopolymer particles, known as TEP, are a major component of diatom aggregates and facilitate the flocculation of diatom blooms (Alldredge et al., 1993). TEP are primary composed of sulphated polysaccharides, molecules known to be resistant to bacterial decomposition (Leppard 1995). Furthermore, the presence of TEP in diatom aggregates reduces the permeability of aggregates causing them to become neutrally buoyant and such as Cylindrotheca closterium, found abundantly in the Adriatic Sea, may produce particularly unique and copious quantities of TEP resistant to degradation (Chin et al., 1998). This material could accumulate as mucilaginous nuisance scums when environmental condition favours strong stratification of the water column, high diatom biomass, and the dominance of these species (Passow et al., 1995). The aggregates may have a very different size and morphology, and they have therefore been classified according to their structural form and their spatial arrangement along the water column (Stachowitsch et al., 1990; Precali et al., 1999). The different types (Figure 2) are briefly described in Table 1.

Value	Type of aggregates
1	Flocs: aggregates of small dimensions, from 0.5 mm to 1 cm
2	Macro-flocs: spherical or irregular aggregates, from 1–5 cm; generally whitish
3	Stringers: elongated aggregates, from 2–25 cm; few millimetres thick, typically in a shape of a comet; generally whitish
4	Ribbons: elongated aggregates, from 10 to 20 cm to over 1 m; few centimetres thick; generally from white to yellow
5	Cobweb: web-like aggregates formed from stringers, could reach few meters vertically and extend tens of meters horizontally; generally whitish
6	Clouds: huge aggregates, from 0.5 to 3–4 m, of lengthened shape with one "head" and one or more "tails"; generally yellow
7	False bottom: dense layer formed of stringers and macro-flocs; thick from few millimetres to tens of centimetres; usually positioned at the pycnocline
8	Blanket: layer of combined aggregates, covering uniformly cliffs and benthic organisms; from yellow to brown colour
9	Creamy surface layer: superficial layer of creamy consistency; formed from stringers or free flocs, up to 15 cm thick; float at or directly below surface
10	Gelatinous surface layer: a compact layer of spongy aspect, floating on the surface, mostly yellowish or brown; wide up to few hundred meters with long bands stretching tens of kilometres

Table 1- Description and images of the macro-aggregate types observed in the northern Adriatic Sea (Precali et al. 2005).

The aggregation forms consist of small flakes of lower dimensions to centimetre and filaments, slightly longer, are normal constituents of the particles of some seas such as the Adriatic-for example, and are indicated with the generic term *"marine snow"*.

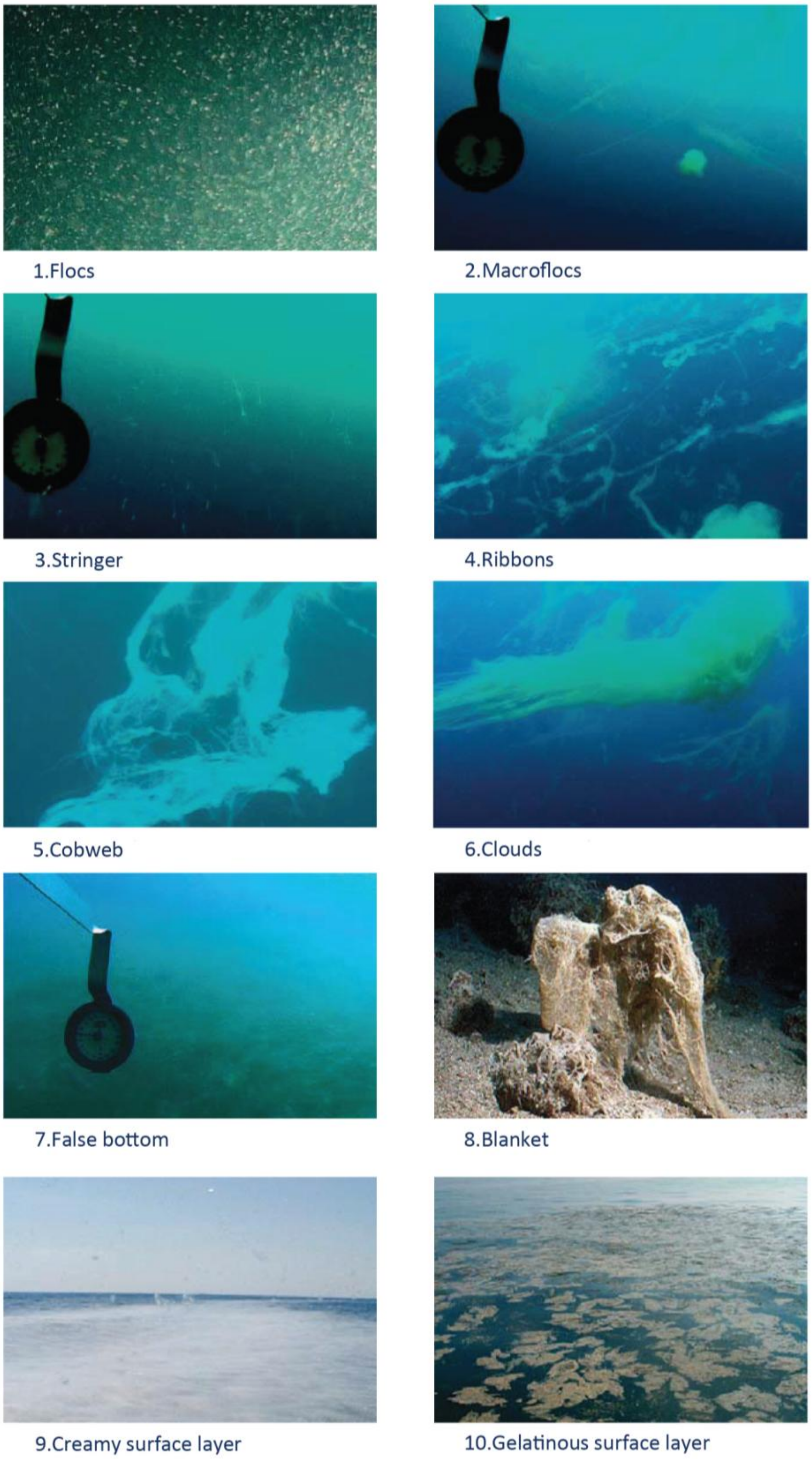


Figure 2 – Classification of different Mucilages aggregates (Precali et al. 2005).

2.1.2 Where and when form.

Aggregates, particularly large ones, tend to accumulate in the frontal areas of contact between the pelagic and coastal waters, or in correspondence of density gradients due to seasonal thermal stratification and the contributions of freshwater river (Giani et al, 2005).

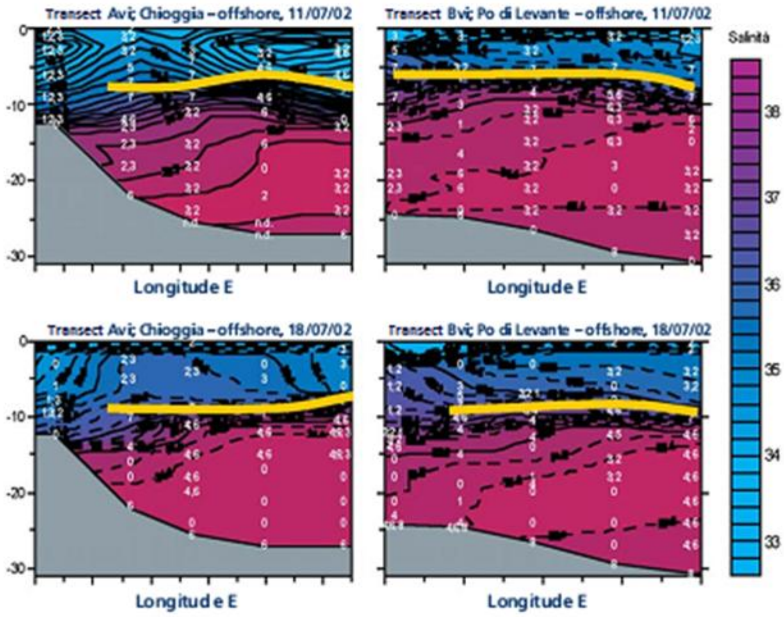


Figure 3- Formation of a false bottom at the picoclinio verified by observations with camera subacquea and ecoscandiglio (Giani et al, 2005).

The hypothesis of the formation of aggregates at of the sea floor (Castracane, 1873), recovery in recent times (Piccinetti, 1988, Bruno et al., 1993), has not been confirmed in many other studies; it shows that the aggregate formation occurs in pelagic environment (Giani et al., 1992). The aggregates of small dimensions, such as flocs and stringers, form especially after the phytoplankton seasonal blooms, later in winter, spring and also in autumn, on the contrary the pelagic large aggregates that form only late in the spring and in summer, when there are conditions of stratification and circulation that favour the accumulation of organic matter of planktonic origin. The pelagic mucilages are frequently formed in the

Adriatic Sea; on the contrary, in other Italian seas, such as the Tyrrhenian Sea, even if specific studies on this issue are limited, it has been reported as a phenomenon on basin scale. Some areas of the Adriatic, such as the Kvarner bay and the central area between the Po delta and Istria, appear to be favourable to the genesis and development of the aggregates (Precali et al., 2005). The phenomenon generally occurs, at first, along the Istrian and Dalmatian costs and, subsequently, along the Italian coasts, affecting sometimes the Central and South Adriatic.

One of the first observations concerning the outcrop of gelatinous masses on large surfaces, dates back to 1729 in the Adriatic Sea (Bianchi, 1746), but the first scientific description refers only to 1872. Similar phenomena were observed in the years 1880, 1891, 1903, 1905, 1920, 1949 (Figure), as documented by collecting reports of the time (Human Fonda et al., 1989). Then there are outcrops only in limited areas, such as in 1973, in the Kvarner (Zavodnik, 1977), in 1983, in the Gulf of Trieste and the Dalmatian island of Krk (Stachowitsch, 1984) along with an anoxic crisis in 1984, in various parts of the northern and southern Adriatic (Vilicic, 1991), in 1986, in the Kvarner (Herndl & Peduzzi, 1988) and in 1990, and in the Kvarner area near the coasts of Emilia Romagna (Andreoli et al., 1992). Studies in the last two decades show that this phenomenon shows itself more and more frequently, but with variable intensity, alternating periods of mass production with years of almost total absence (Giani et al, 2003).

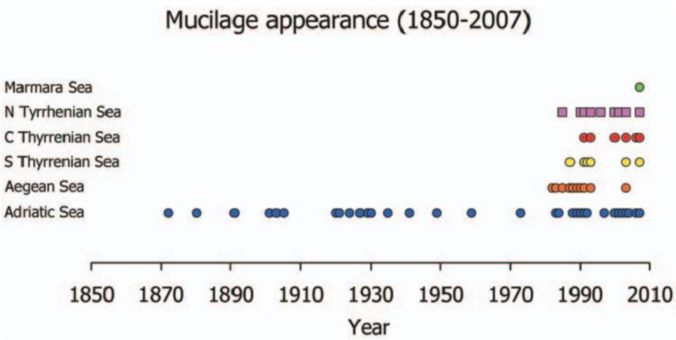


Figure 4 - The areas in the Mediterranean Sea where the mucilage has been documenteand the years of appearance. (R. Denovaro et al., 2009)

2.2. Meteo-climatic factors influence upon mucilage formation and dispersion.

The numerous studies conducted in recent years about the phenomenon of mucilage especially as regards the Adriatic Sea have allowed to determine some meteo-climatic variables of influence on the formation mechanisms of that phenomenon. In particular, it is observed the persistence of fields of high-pressure atmosphere, the low hydro-dynamism resulting in reduced water exchange, the lack of rainfall, and the average high temperatures on the bottom or on the surface of the sea, when added to "memory effect" hydrological conditions of the catchment areas of influence, are necessary conditions for the production of this phenomenon (Tommasino, 1989, 1996). The northern part of the basin is a very productive and ocean circulation plays an important role in the dispersion of organic matter and export to other basins. A slowing down and the establishment of recirculation increases the residence time of water favouring the accumulation of organic material suspended (Giani et al., 2003). The role of the winds and atmospheric turbulence are double, instead, which can facilitate the transport and dispersion of aggregates (Precali et al., 2005). The wind regime in the central Mediterranean and the Adriatic area has changed over the past decades showing a marked change in the mid-70s (Pirazzoli & Tomasin, 2003). The ecological effect of these changes has not been studied yet, however, it seems that the dinoflagellate, possibly responsible for the formation of mucilage, are particularly favoured by the absence of turbulence (Pistocchi et al., 2005). A limited turbulence can also promote the coagulation of transparent exopolymeric particles (Schuster & Herndl, 1995), the formation of larger particles (Stoderegger & Herndl, 1999) and also the emergence of aggregates as the case in 2004 because of the incorporation of air bubbles in the aggregates. It follows the conditions for which limited turbulence can promote aggregation processes, but when it exceeds a threshold value of intensity prevails the process of unbundling (Rinaldi et al., 1990). From the observation of the flow rates of the river basins of influence has been observed as the dispersion or the accumulation of such water also affects, in addition to the availability of nutrients vehicled, the stability of the water column due to density gradients that are created between the hot water and less salted surface waters and dense background, saltier and colder. Some studies demonstrate how some season’s rich mucilaginous phenomena have been characterized by a prior increase in stability of the water column (Degobbis et al., 2000). Finally, as regards temperature, spectral analysis of time series of temperature anomaly spring and the presence / absence of mucilage on meteorological data for northern Italy, in general, and some stations Adriatic, in particular, seems to indicate a correlation between the positive anomalies and events of mucilage, which occur common with frequencies of about 6 and 3 years. However, in evaluating these results must take into account the relative limitation of extension of the time series and the uncertainty in the definition of the events of mucilage. This definition includes all the events reported and should be considered that the grouping into clusters is less clear if we take into account only the events considered to be certain documented (Giani M, 2002). Trend anomaly of mean temperature of the air spring to the Po Valley area used for comparison with the episodes of mucilage occurred during the summer. Also shows the moving average of the weather variable calculated on 10 years. (Deserti M. et al, 2003).

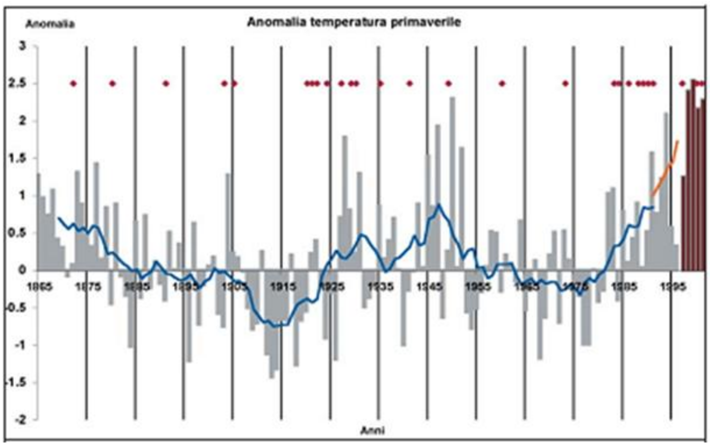


Figure 5- Trend anomaly of mean temperature of the air spring to the Po Valley area used for comparison with the episodes of mucilage occurred during the summer. Also shows the moving average of the weather variable calculated on 10 years. (Deserti M. et al, 2003).

For the last period of positive anomaly (i.e. increase with respect to the average), atmospheric temperature has also been verified an increase in sea surface temperatures of the Adriatic basin, while the deep have not changed or even show a slight decrease in the value of temperature. Therefore, the second half of the '80s, the northern Adriatic basin is characterized by a vertical temperature gradient more pronounced, which probably increased the stability conditions of the water column (Russo et al., 2003).

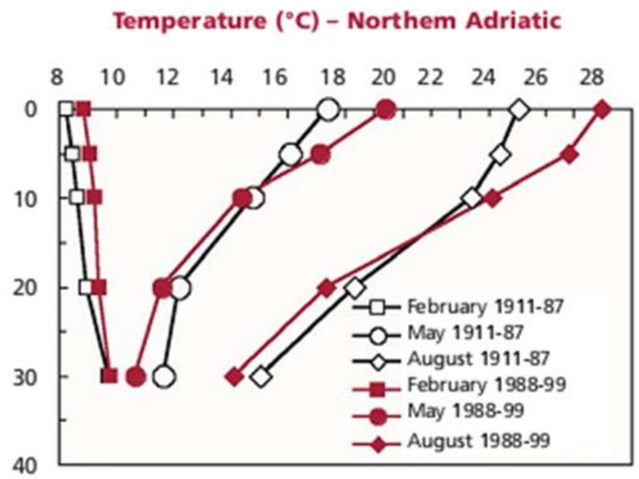


Figure 6- Comparison between the monthly mean temperature profiles (February, May, August) obtained using data prior to 1987 (black line) with those obtained using the data after this year (red line) (Russo et al., 2003).

An increase of the temperature gradient may lead to an increase of the density gradient favouring the accumulation and aggregation of organic substance in correspondence to the pycnocline. The hot water also causes dilation of the gas bubbles entrapped in the mucilage facilitating the outcrop during solar day irradiation (Russo et al., 2003). Climate change and the increase in water temperature produce significant effects on planktonic organisms (Edwards & Richardson, 2004; RicharDon & Schoeman, 2004) the impact of which on ecosystems Adriatic has yet to be fully verified. For example, in conditions of nitrate limitation, the aggregation of the cells of the diatom Skeletonema Costatum, isolated from waters north Adriatic in April 1993, was positively correlated with temperature (Thornton & Thacke, 1998). Another effect of temperature is to increase so exponential the benthic respiration facilitating the formation of hypoxia and anoxia, which may be aggravated by the sedimentation of organic material present in the mucilaginous aggregates (Herndl et al., 1989).

2.3. Remote sensing and mucilage detection

Satellite remote sensing provides rapid, synoptic, and repeated information on water state variables (physical and bio-geochemical) that avoids interpretive problems associated with under sampling. Indeed, over the last three decades, there have been significant advances in technology and algorithm development allowing satellite ocean colour measurements to be used for studying coastal ocean water quality. Most of these advancements have focused on turbidity, water clarity, or other bio-optical properties (Dekker, 1993; Hu et al., 2004; Chen et al., 2007, Lee et al., 2007). Some algorithms and case studies have been developed for algal blooms (D'Sa, 2003; Kutser et al., 2006), and long-term bloom patterns have also been established using multi-satellite data in some marginal seas (Kahru et al., 2007). However, the use of Earth observation data from satellites as a tool for monitoring mucilage blooms has to be regarded as experimental rather than operational. The first publication in the literature dating back to 1993 through the work of S. Tassan, which observe the phenomenon using the AVHRR sensor on board the satellite NOA, but only in cases of exceptional surface blooms as that of 9 July 1989. (Tassab 1993). The AVHRR images have in fact the limit of a low spatial resolution (1.1 km) not very suitable in identifying mucilaginous phenomena whose length is several kilometres but whose maximum width rarely exceed 200-300 meters (Vescovi et al., 2003). Thereafter, the interest generated by the increase in the mucilage phenomenon in the northern Adriatic area led to the establishment in 1999 of the cross-border project REQUISITE (Interreg IIIA) which saw the active regions of Emilia-Romagna, Marche, Abruzzo and Croatia. The project REQUISITE, foresaw the creation of a network for the collection and integration of information concerning the eutrophication and mucilage phenomenon of waters of the central and northern Adriatic, collected by environmental regional agencies and research institutes from Croatian and Italian (www.regione.emiliaromagna.it/pda/iiia_requisite_eng.htm). In this context, it is developed the work of the Remote Sensing laboratory of ARPA SMR in which a detection algorithm is implemented to identify the mucilage index through the use of MODIS Surface Reflectance product (Vescovi et al. 2003). The mucilage Index was used for the mapping of mucilage events occurred in the summer of 2004 (ARPA, 2005). However, to the best of my knowledge there are no more examples in literature on the application of mucilage index or implementations of new products for the automatic detection. Remain therefore limited information on the presence, extension and temporal evolution of mucilaginous phenomena about affected areas, with the exception of in situ observations made by the regional environmental protection agencies and news from the press agency.

2.4. The Mucilage Index.

The Mucilage Index from Mucilage phenomenon detection in The Nord Adriatic Sea defined by Vescovi et al. (2003) is descript by the follow equation:

$$M = (((B2 + B4)/2) - B3)/B6 \qquad (1)$$

B2 = Surface Reflectance Band 2 (841 - 876 nm)

B3 = Surface Reflectance Band 3 (459 - 479 nm)

B4 = Surface Reflectance Band 4 (545 - 565 nm)

B6 = Surface Reflectance Band 6 (1628 - 1652 nm)

The numerator of the formula enhances the decrease of reflectance typical of mucilaginous material in the channel 3 compared to the average values of the channels 2 and 4. The low reflectance in the band 3 (459-479 nμ) and the highest reflectance in band 4 (545-565 nμ) are confirmed by measurements in situ with radiometers made in previous studies (Berthon al. 2000)(Figure 7a). Furthermore, also the studies carried out by Tassan (1993) with sensor NOAAAVHRR confirm that in the near infrared wavelength, corresponding to the band 2 of the MODIS (841-876 nμ), the reflectance of this material is greater. The channel 6 in the formula is at the denominator because it usually has a very high value in case of the clouds and very low in case of mucilage. The formula, therefore, enhances the optical properties of the mucilage and discriminates the clouds, which could constitute the first element of confusion with the mucilage bodies as they also are very clear and sometimes filamentous case of stripes left by the aircraft (Vescovi et al., 2003).(Figure 7b)

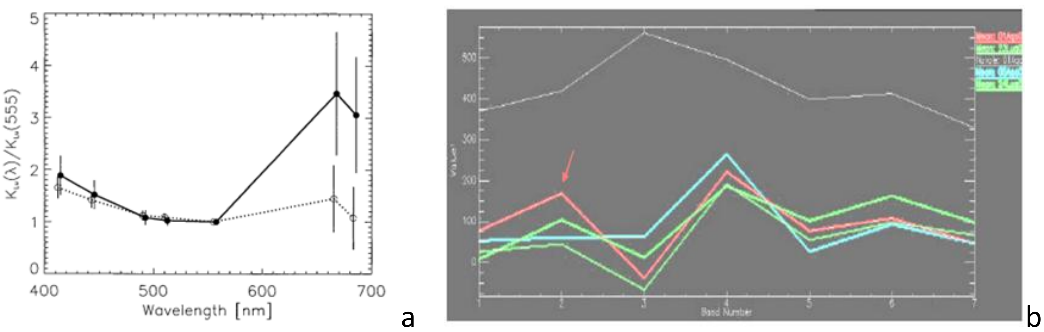


Figure 7– In the left: Average spectra of the diffuse attenuation coefficient for upwelling radiance, Kλu, normalized to the value at 555 nm, computed for 1m thick layers, for two different dataset (Berthon et al. 2000). In the right: MODIS spectral signature of the filaments observed in Adriatic Sea. In 23, 24 July, 1 and August 5, 2002. The values are lower than those of clouds on the sea August 1 (curve high) (Vescovi et al., 2003).

The algorithm was validated and calibrated for the North Adriatic through the use of in situ data collected with an underwater camera mounted on the ship's oceanographic structure DAPHNE (Vescovi et al., 2003).

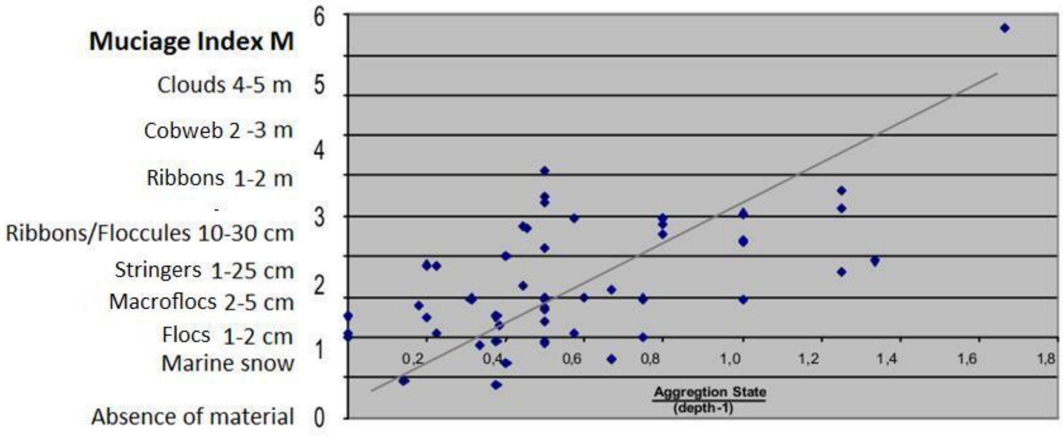


Figure 8 - Calibration curve of the satellite signal from data observed at sea (Vescovi et al., 2003).

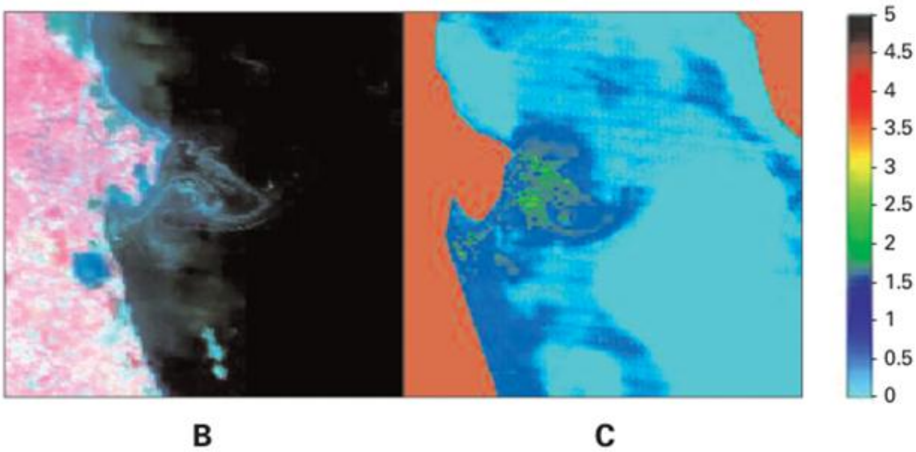


Figure 9- Mucilage Event of 7 July 2004, North Adriatic Sea (Vescovi et al., 2003)

3 . Data and methods

3.1. Satellite data

In this study we used satellite images from MODIS sensors. MODIS (Moderate Resolution Imaging Spectroradiometer) is a land, ocean, and lower atmosphere observing instrument. It is aboard the Terra (EOS AM) and Acqua (EOS PM) satellites that are part of NASA's Earth Observing System (EOS) established for long term observations of the Earth's biosphere. MODIS acquires images from every point on Earth at least once every 1 or 2 days. It covers the visible to the near infrared (0.4-1.4 um) spectrum with 36 spectrum channel and its scanning width is 2330 km, whose spatial resolution is 250m, 500m and 1000 m and the temporal resolution is twice a day. Science teams have developed a variety of standard data products which are distributed free of charge by the Land Processes Distributed Active Archive Centre. (NASA 2009).

Data products from MODIS and other instruments are processed at different levels. Level 0 data is raw data at the instrument's full resolution, it has been reconstructed. Level 1A data is also reconstructed unprocessed data at full resolution, it does however have ancillary information associated with it such as calibrations and georeferencing parameters but this information is not applied. Level 1B data is Level 1A data that has been processed to sensor units and is geometrically and radio-metrically corrected. Level 1B data is most often used by researchers to conduct their own calculations. Low-level data are corrected for atmospheric gases and aerosols, yielding a level-2 basis for several higher-order gridded level-2 and level-3 products. Level 3 data is at a high level of processing, variables are mapped on uniform space-time grid scales usually with some completeness and consistency. Level 4 data is usually the of a model or analysis that used lower level data and may have multiple measurements (EODIS 2009).

3.1.1. The Surface Reflectance products

The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmospheric scattering or absorption. In particular for this study we used MOD09GA product. The MOD09GA provides Bands 1-7 in a daily gridded L2G (Level 2) product in the Sinusoidal projection, including 500-meter reflectance values and 1 kilometre observation and geo-location statistics. The product also contains data sets describing cloud cover and data quality for each pixel (Table 2) (EODIS, 2009).

500 m	num_observations_500m	none	8-bit signed integer	-1	0 - 127	NA
	sur_refl_b01: 500m Surface Reflectance Band 1 (620-670 nm)	Reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
	sur_refl_b02: 500m Surface Reflectance Band 2 (841-876 nm)	Reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
	sur_refl_b03: 500m Surface Reflectance Band 3 (459-479 nm)	Reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
	sur_refl_b04: 500m Surface Reflectance Band 4 (545-565 nm)	Reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
	sur_refl_b05: 500m Surface Reflectance Band 5 (1230-1250 nm)	Reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
	sur_refl_b06: 500m Surface Reflectance Band 6 (1628-1652 nm)	Reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
	sur_refl_b07: 500m Surface Reflectance Band 7 (2105-2155 nm)	Reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
	QC_500m: 500m Reflectance Band Quality	Bit Field	32-bit unsigned integer	787410671	NA	NA
	Obs_cov_500m: Observation coverage	Percent	8-bit signed integer	-1	0 - 100	0.01
	iobs_res: Observation number	none	8-bit unsigned integer	255	0 - 254	NA
	q_scan: 250m scan value information	none	8-bit unsigned integer	255	0 - 255	NA

Table 2- Science Data sets for MODIS Terra Surface Reflectance Daily L2G 500m SIN Grid V005 (MOD09GA)

3.2. Field data

Many field sampling data have recorded and documented the events of Mucilage blooms in coastal waters around Italy, for the summer seasons of the years 2010, 2011 and 2012 (Table). They are collected from different regional environmental agency of Italy (ARPA), with not standardized mode. The majority of these is the result of chemical, physical and biological measurements. Fortunately, thanks to the work carried out by ARPA Campania (ARPAC) following the mucilaginous exceptional events occurred in the summer 2012 on the Campania coasts we have also a useful photographic documentation of the most important events, including geographic location, extension and state of aggregation (APPENDIX2)(www.arpacampania.it/balneazione/a_mucillagini2012_relazioni_sopralluoghi.asp). We subsequently used this data to calibrate and validate the product derived from satellite images. Another Dataset from ARPA Veneto (ARPAC), originated from video-observations of underwater marine monitoring stations it was also used to compared the different source (http://www.arpa.veneto.it/bollettini/htm/qualita_acque.asp?a).

3.3 Data acquisition and pre-processing

The Land Processes Distributed Active Archive Center (LP DAAC) stores a variety of MODIS land products in standard 10º x 10º tiles in Sinusoidal projection and HDF-EOS format (Figure 10).

To download and pre-processing the satellite images we used the MODIS Re-projection Tool on the Web. This software is designed by NASA‟s Land Processes Distributed Active Centre (LP DAAC) which is readily available on NASA website (https://lpdaac.usgs.gov/get_data/mrtweb). Through the use of MTRWeb we were able to spatial subsetting, band subsetting, re-projecting, resampling, and reformatting all the images before to downloading.

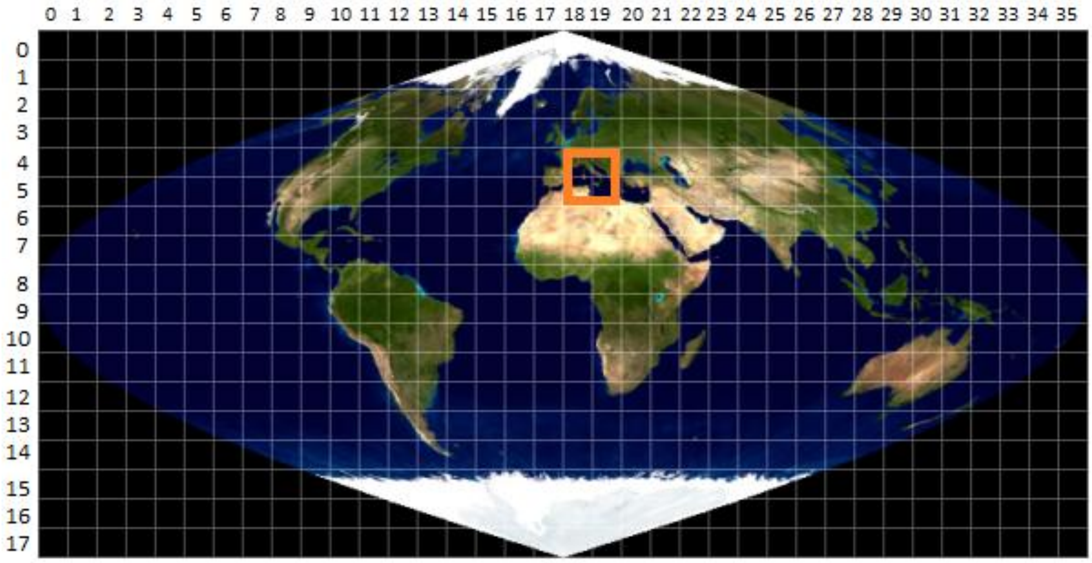


Figure 10- A global representation of standard MODIS land product tiles.

We downloaded daily images for the summer period (01 Jun - 31 September) of tree years (2010 - 2012). To avoid cloud-induced bias in the area coverage statistics, only when the study area contained at least 75% cloud-free data were those data extracted and analysed (APPENDIX 3). We selected for each day 6 layer used in the analysis, Band 1, Band 2, Band 3, Band 4, Band 6 and 500m Reflectance Band Quality.

To save time in data acquisition we setting in MTRWeb latitude and longitude to clip and download just the study area (see paragraph 1.3), contained in the tile 18:19 Vertical and 4:5 Horizontal (Figure 10). The images were reprojected in UTM ZONE 33, datum WGS84 based on nearest neighbor resampling method where the output file format was GEOTIFF.

3.3.1. Quality correction

All Modis products include quality assurance (QA) Informations. This information are produced by the MODIS Land Science Team (MODLAND) that is responsible for the MODIS land products in terms of their QA and validation. MODIS QA information provides vital clues regarding the usability and usefulness of the data products for any particular science application. At Pixel level QA provides information for each science parameter through the binary representation of bit combinations that characterizes particular quality attributes defined in MODIS LST Products Users Guideline (Wan 2009). For MOD09GA it was available the QC_500m Reflectance Band Quality product which the quality information is stored in 32 bit integer with a valid range of (0-4294966019) (Vermote et Al., 2002).

Based on the criteria defined in Table 3 a number of permutations and combinations were calculated in order to determine the pixel values in the QC image to be retrained as good quality pixels. Different combinations and permutations of bit flags compose an 32-bit binary number which has a decimal equivalent in QC image within (0-4294966019) range. For MOD09GA we have information about quality of each band, atmospheric correction and adjacent correction. In order to obtain a good quality for the Mucilage Index Product we decide to choose only pixel with the highest quality (0000) for the band used in the next analysis (band 2, band 3, band 4 e band 6)(APPENDIX 1). Pixels in the QC image with these values were assigned as “1” where the remaining pixels were assigned as “0”. The resultant image is a binary image which was used to retain only the good quality LST image pixels to further image analysis.

Bit No.	Parameter Name	Bit Comb.	QC_500m
0–1	MODLAND QA bits	00	corrected product produced at ideal quality all bands.
		01	corrected product produced at less than ideal quality some or all bands.
		10	corrected product not produced due to cloud effects all bands.
		11	corrected product not produced due to other reasons some or all bands may be fill value.
2–5	band 1 data quality four bit range	0000	highest quality.
		1000	dead detector; data interpolated in L1B.
		1001	solar zenith >= 86 degrees.
		1010	solar zenith >= 85 and < 86 degrees.
		1011	missing input.
		1100	internal constant used in place of climatological data for at least one atmospheric constant.
		1101	correction out of bounds pixel constrained to extreme allowable value.
		1110	L1B data faulty.
		1111	not processed due to deep ocean or clouds.
6–9	band 2 data quality four bit range		SAME AS BAND ABOVE
10–13	band 3 data quality four bit range		SAME AS BAND ABOVE
14–17	band 4 data quality four bit range		SAME AS BANDABOVE
18–21	band 5 data quality four bit range		SAME AS BANDABOVE
22–25	band 6 data quality four bit range		SAME AS BANDABOVE
26–29	band 7 data quality four bit range		SAME AS BANDABOVE
30	atmospheric correction performed	1	Yes
		0	No
31	adjacency correction performed	1	Yes
		0	No

Table 3- 500-meter QA Descriptions (32-bit)

3.4. The Mucilage Index application.

The processing carried out by us on MODIS data is based on the calculation of the Mucilage Index M, defined by Vescovi et al. (2003).

$$M = (((B2 + B4)/2) - B3)/B6$$

B2 = Surface Reflectance Band 2 (841 - 876 nm)
B3 = Surface Reflectance Band 3 (459 - 479 nm)
B4 = Surface Reflectance Band 4 (545 - 565 nm)
B6 = Surface Reflectance Band 6 (1628 - 1652 nm)

Were analysed MODIS images during the time interval June-September of the years 2010, 2011, 2012 and were drawn 296 scenes for a total of 270 cards produced.

	Processed Images		Not Processed
	Effective Monitoring Days	**Bad Quality Days**	**Cloudless Days**
June 2010	20	1	9
July 2010	24	6	1
August 2010	22	9	-
September 2010	13	3	14
June 2011	20	-	10
July 2011	22	2	7
August 2011	29	1	-
September 2011	21	1	8
June 2012	26	1	3
July 2012	27	1	3
August 2012	30	1	-
September 2012	16	-	14
Total	**270**	**26**	**69**

Note: Effective monitoring day means the days of completing activities of monitoring indicator normally. Cloudless days are the days without cloud cover within the whole Study area in a year (less 75%). Bad Quality Days are the days whit presence of large areas covered by errors that have not been masked by the pre-processing.

Table 4- The total days of the status of monitoring mucilage bloom using MODIS image in 2010, 2011 and 2012, in Italy seas.

Some dates are missing due to the presence of excessive errors detected in the data that have not been masked by the pre-processing (Table 4). We performed this check through visual analysis of the images processed by the algorithm and the correspondent True Band Composition (Band 3, Band 1, Band 4) and False Band Composition (Band 2, Band 1, Band 4). These last have been produced for each day of monitoring through Band Composite Tool in ArcGIS.

To automate the processes of analysis described so far we have built a Data processing Model through a Model Builder in ArcGIS (Figure 11). This allowed us to significantly reduce the Data processing times.

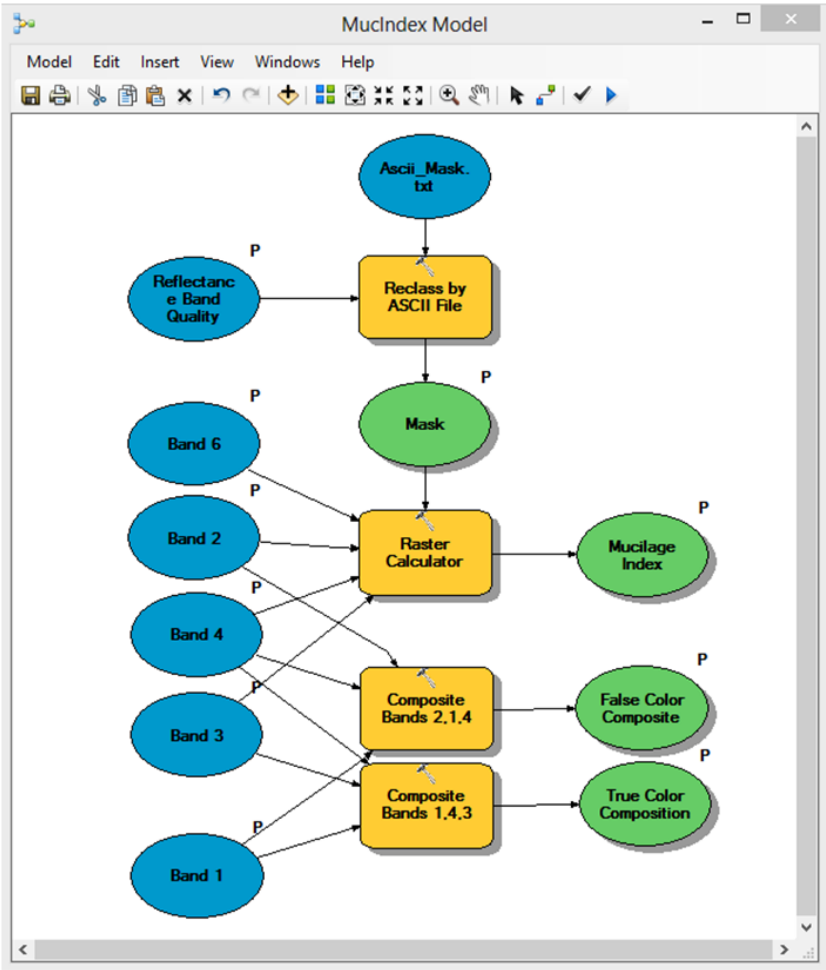


Figure 11– The workflow created with the ArcGIS Model Builder illustrates a graphical environment in which the different data sources used in this study (represented in dark blue circles) are connected to the operations previously descripted (represented in brown boxes) and chained through the outputs (new data represented in Green circles).

3.4. Mucilage Index threshold

The most critical task in distinguishing Mucilage Phenomenon from other waters disturbances (e.g. river sediments) was to determine the threshold value in the Mucilage Index imagery.

In a previous study the mucilage index has been calibrated with in situ data for the area of the Northern Adriatic Sea (see Paragraph 2.4). It was identified a range of values between 0 and 5 that corresponds to the occurrence of mucilage. The study also shows that values below 0.6 exhibited little interference from other substances in the sea (Vescovi et al., 2003). Therefore we decided to keep that value as limit threshold in the beginning stage of our analysis. Unfortunately, visual analysis of the preliminary results revealed that the afore mentioned threshold is not appropriate for the discrimination of mucilage from other interference phenomenon, in particular turbidity and river plume.

Furthermore, sampling values of mucilage index for the points corresponding to actual measurements in situ has been noted as the range of values obtained were for the 93% positive and below the threshold chosen (Figure 12 and 13).

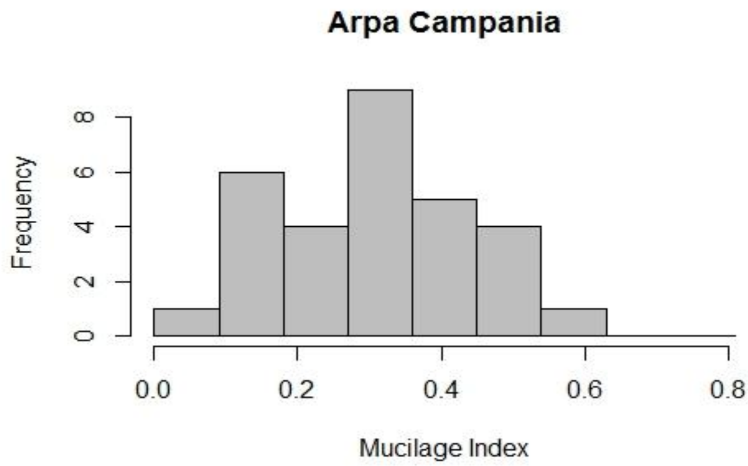


Figure 12– Histogram of validation result using ARPAC in situ dataset.

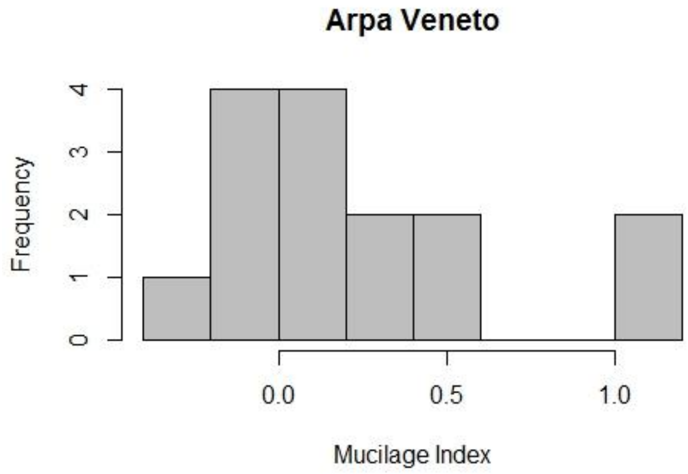


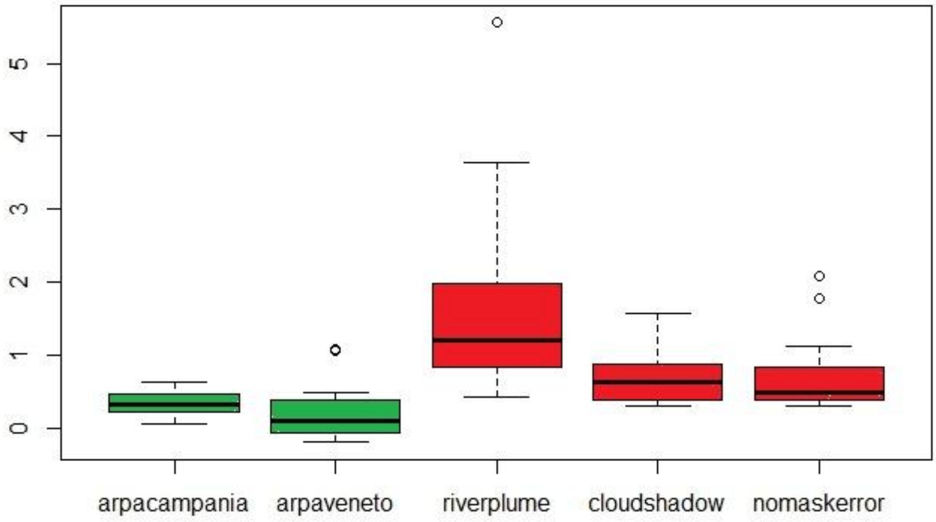
Figure 13– Histogram of validation result using ARPAV in situ dataset.

The differences between the mean values of mucilage index obtained from the two different datasets are due to the use of different sampling methods. The data collected by ARPA Campania being sampled directly on the sea surface are considered the most reliable ones.

In order to define the most appropriate limit threshold for the used algorithm and improve the accuracy of the final result we decided to compare the validation result from in situ data with the average value of MI obtained from the most common errors in the images (collected by visual analysis).

We particularly concentrated on errors caused by river plume (and turbidity), clouds, cloud shadows and other MODIS errors that were not masked during pre-processing (bow-tie effect, Sun-glint, etc..) but easily recognized by a visual analyse.

The results are represented by the use of box plots shown in figure 14




```
     arpacampania        arpaveneto            riverplume
Min.    :0.05183   Min.    :-0.20136   Min.    :0.4205
1st Qu.:0.21887   1st Qu.:-0.06115   1st Qu.:0.8348
Median :0.31146   Median : 0.09460   Median :1.2077
Mean    :0.33276   Mean    : 0.23600   Mean    :1.5704
3rd Qu.:0.45194   3rd Qu.: 0.38384   3rd Qu.:1.9666
Max.    :0.62053   Max.    : 1.08333   Max.    :5.5542
NA's    :45        NA's    :69

cloudshadow        nomaskerror
Min.    :0.3024   Min.    :0.3025
1st Qu.:0.3832   1st Qu.:0.3743
Median :0.6180   Median :0.4722
Mean    :0.6384   Mean    :0.6831
3rd Qu.:0.8774   3rd Qu.:0.8286
Max.    :1.5714   Max.    :2.0769
NA's    :11       NA's    :16
```

Figure 14– Box-plot of validation data and common errors using MI.

The values of the validation dataset exhibit a different range than those of the mentioned error sources: the upper limit of the upper quartile (75th percentile) of the validation datasets lies beyond the lower quartile (25th percentile) of the latter. A small interference can only be observed for clouds as well as the MODIS errors. Consequently, we decided to choose the minimum and Upper Quartile (3rd Qu in Figure 14) from ARPA Campania dataset (0.05<Mucilage Index< 0.45) as threshold for our MI.

Subsequently the maps of mucilage index were reclassified with values equal to 1 for the pixels that have values within our threshold and 0 for the remaining pixels. The results are daily maps of effective mucilage detection.

To automate the processes of analysis for the entire mucilage index database we built a data processing model through model builder in ArcGIS (Figure 15).

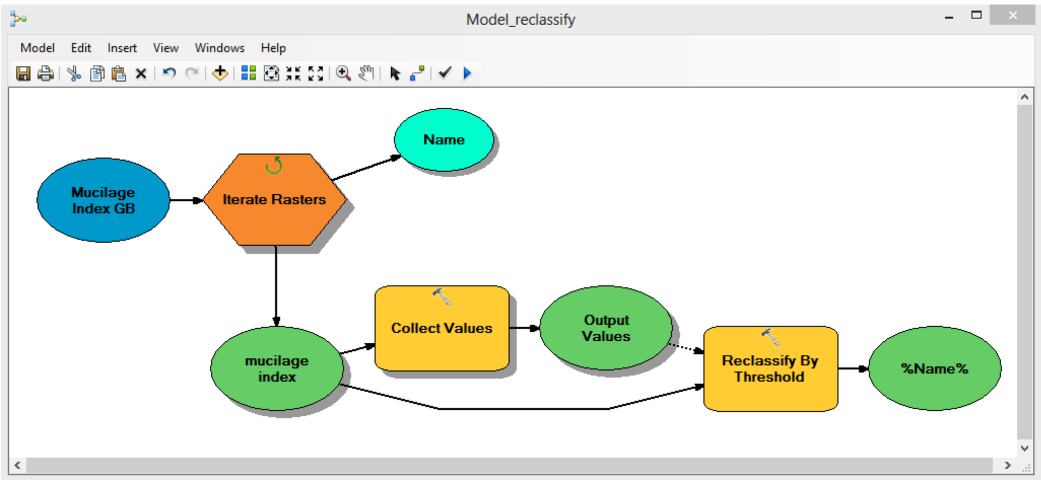


Figure 15– The workflow created with the ArcGIS Model Builder illustrates a graphical environment in which one entire dataset is processed through iteration of the same operation to produce the images of Mucilage detection.

3.5. Spatio-temporal analisis

In order to extract information on spatial and temporal phenomenon of mucilage to the area of study we applied a method used in previous studies for the analysis of spatio-temporal phenomena of eutrophication (Hu et al, 2010; Chunguang et al., 2012), which includes the use of the algal frequency index (AFI).

AFI is defined as the number of the algae bloom days against the number of effective monitoring days marked as T in a certain water area at certain time. Using MODIS data, the size of a certain water area is the 500m*500m, a size of a pixel, and a certain time usually is 365day in a year (Jin Y et al, 2009; Ma et al, 2010). The mathematical expression is as the follow:

$$AFI = t / T*100\% \qquad (2)$$

As the algae bloom study we used AFI to extract spatio-temporal distribution of Mucilage phenomenon.

In order to measure the inter-month variation, a certain time is often set to the days of a month in a year and certain water region is defined as the whole study area or a sub-region. This kind of AFI is called monthly mucilage bloom frequency index (MMFI).

In order to measure the annual variation, we also computed the index for the 3 summer seasons for the years 2010, 2011, 2012. This kind of AFI is called annual mucilage bloom frequency index (AMFI).

To better describe the spatial temporal dynamics of mucilage formation we decide to focus the analysis in two sub-region of the study area:

- The North Adriatic seas, between latitudes 44° 10' and 45°90', and Longitudes 12° and 14 ° E. In correspondence of Venetian coasts.
- The South-Central Tyrrhenian See between latitude 39° 90' and 41° 0', and Longitude 13° 50' and 15°70'. In correspondence of Campanian coasts.

-

These two areas show the maximum value of mucilage index in the preliminary step of analysis. Therefore are available for this areas in situ data for the period of study 2010-2012.

-

Figure 16- Selected areas for Spatio Temporal Analisis of Mucilage phenomenon in the summer of 2010, 2011 and 2012.

4. Results and discussion

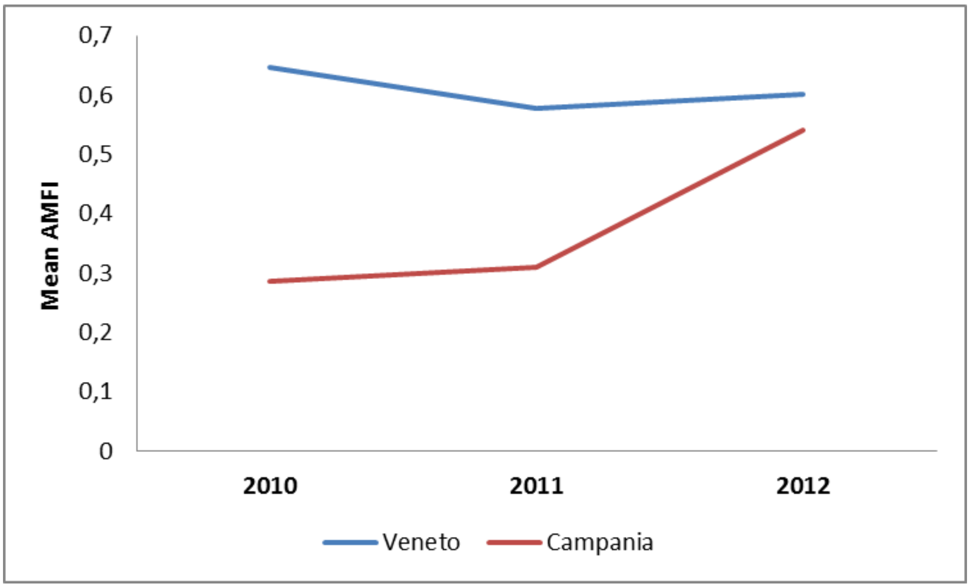
4.1 Spatial and temporal distribution of mucilage phenomenon

4.1.1 Annual Mucilage Frequency Index

Figures 18 e 19 show the spatial and temporal distribution of mucilage phenomenon (0.05<MI<0.45) in the Tyrrhenian Sea along coast of Campania as well as the North Adriatic Sea.

To avoid cloud-induced errors in the area coverage statistics, we only considered images that were at least 75% cloud-free in the desired coast segment for further analysis. Also, some images were excluded due to errors not masked during the process of quality assessment

Looking at the maps of Mucilage Annual Frequency Index along the Campania coast (Figure 4.2) it can be seen that the phenomenon primarily affects the areas in proximity to the coast. The intensity of the phenomenon increases progressively when approaching the bathing areas along the seaside reaching most significant frequencies of 20-25% in less than 1-2 km off the coastline. Highest MAFI values were recorded for the coastline that belongs to the provinces of Caserta and Naples. Major parts of the Campania coast register a considerable alternation of the phenomenon between 2010 and 2012, whereas in the course of the mentioned time an increment of extent is noticeable in the most affected areas as well as an expansion to less afflicted zones as the northern part of Salerno province and the islands of the province of Naples (Ischia, Procida, Capri). The Gulf of Naples present significant frequencies of more than 20% in all three reference years reaching a maximum extension in 2012. In this year the intensity of the phenomenon has almost doubled compared to the 2010 - 2011 observation periods, which can be seen in Figure 4.1. presenting the average values of AMFI for the two examined areas from 2010-2012. The growth of the phenomenon of mucilage within certain sections of the Campanian coast in recent years is confirmed by numerous reports from news agencies (www.ansa.it, www.ilmattino.it) and official bodies that are in charge of coast control. Particularly in 2012 the intensification of the mucilage phenomenon was due to the climatic conditions during summer season, which was characterized characterized by poor hydrodynamics of the water body and high surface temperatures (www.arpacampania.it / bathing/mucillagine).



NB: In this case the values of AMFI are expressed as average days of detection for pixels that fall in the considered study areas. The average values were normalized to the number of effective monitoring days per study year.

Figure 17– The Annual Mucilage Frequency Index from 2010 until 2012 in South-Central Tyrrhenian (Campania) and North Adriatic Sea (Veneto).

The Adriatic Sea records a reverse trend to that observed on Campania shore: The greatest value in terms of intensity as well as extension occurred in 2010 (Figure 4.2), while between 2011 and 2012 a significant attenuation can be perceived. ARPAV confirmed these observations by the use of subaqueous cameras that were spread across the Veneto seaside in order to record the phenomenon. Indeed, in 2010 the majority of the cameras registered an elevated intensity and persistency of mucilaginous aggregates (flocs and stringers) than in subsequent years, especially at monitoring stations that are about 3500 meters off the coast. A mucilage formation of “considerable dimension” was detected on August 10th 2010 about three miles off the coast of Albarella, in Venice Provence. Unlike along the Campania coast the mucilage phenomenon in the Adriatic Sea occurs as isolated areas also in the open see, whereas in Campania it tends to appear as adjacent areas close to the coast. Suchlike, a persistent mucilage formation with an extension of approximately 30 km^2 can be observed off the coast of Rovigo province at the estuary of the Po river. Numerous studies conducted in recent years identified this as one of the most affected areas (Sciarra, 2006; Vescovi et al., 2003; Precali et al., 2005).

Large aggregations of mucilage also occurred south of the lagoon of Venice and along the north coast of Emilia Romagna, areas of only modest size can be noticed in the Gulf of Trieste.

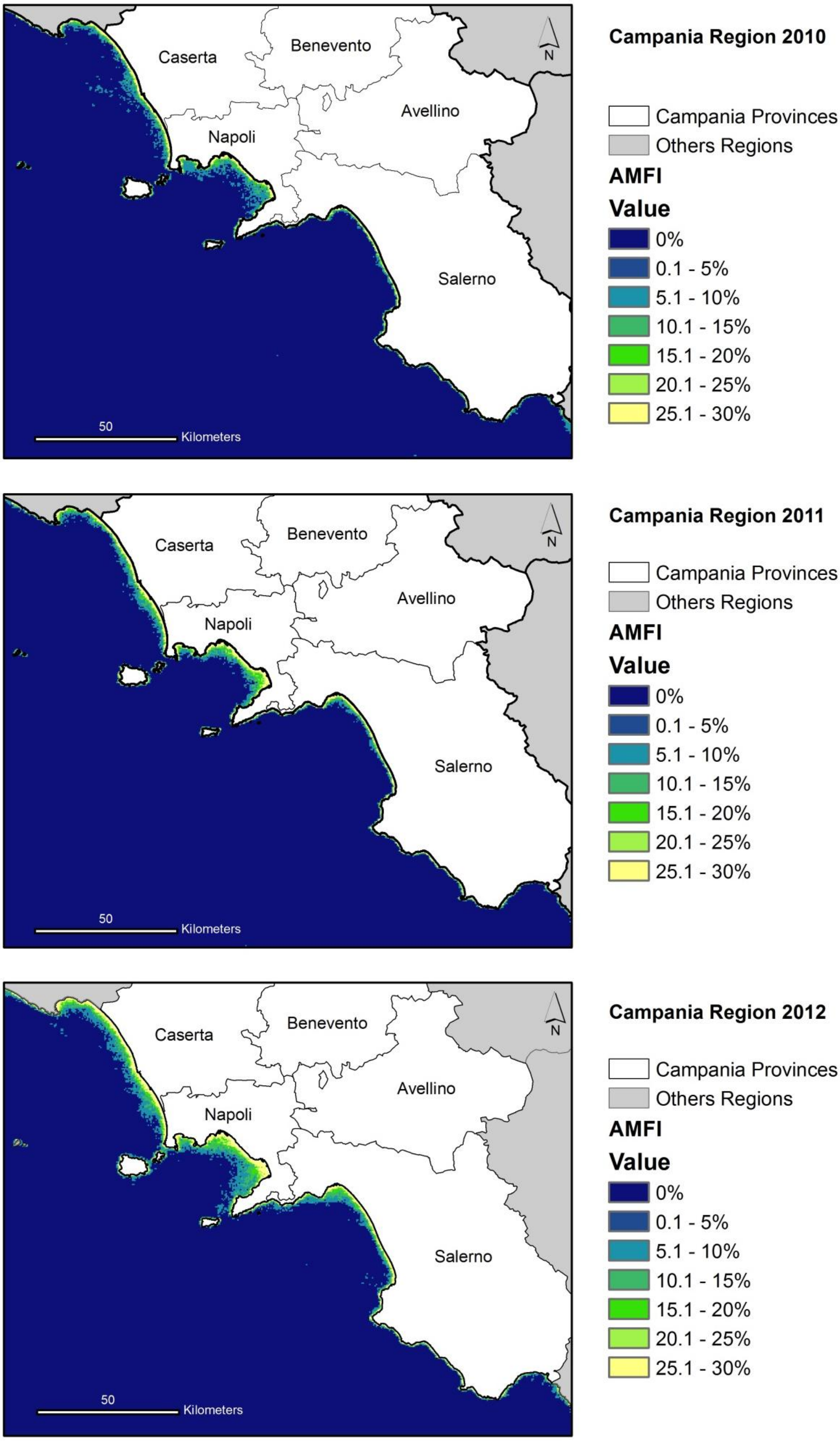


Figure 18- The spatial distribution patterns of the annual mucilage frequency index in Campanian sea

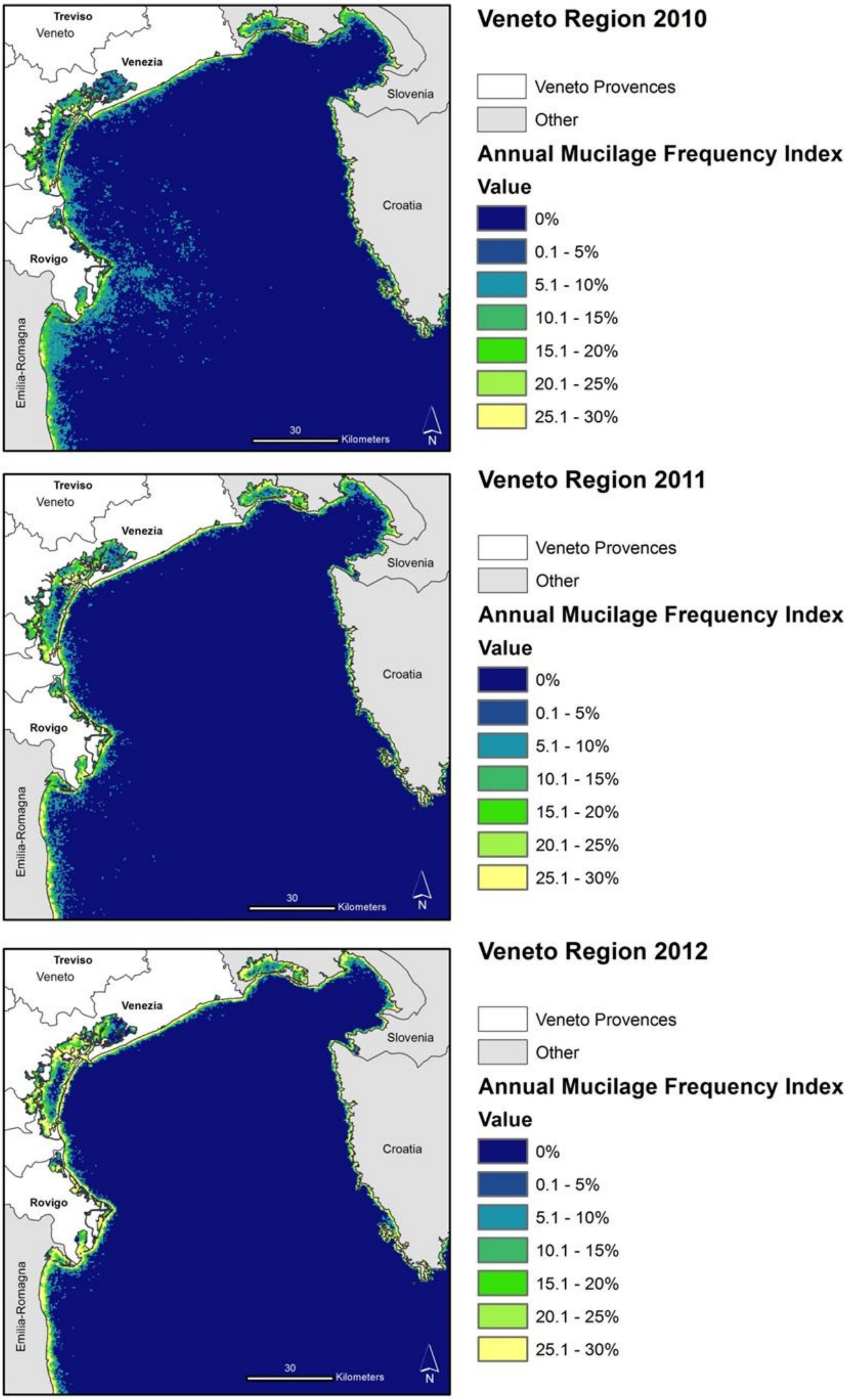


Figure 19–The spatial distribution patterns of the annual mucilage frequency index in North Adriatic

4.1.2 Mounthly Mucilage Frequancy Index.

It is necessary to discuss the overall progress of the phenomenon, booming in 2010-2012. The visible-infrared remote sensing is easily affected by clouds and rain, so the days of effective monitoring and days of flowering of mucilage monitoring was very different for each month in 2010, 2011 and 2012 (Table 4). In order to obtain the index comparable to reflect the intermonth variation, the mucilage bloom monthly frequency index (MMFI) was used as the reference standard (Figures 20 and 21). The analysis focuses on the summer months of June, July, August and September because in these months have the greatest concentrations of the phenomenon of Mucilage in the Italian seas (Penna et al., 2003).

The Map in Figure 20, 21, 22 and 23 graphs in 24 and 25 shows the monthly variation of mucilage bloom frequency about 2009, 2010 and 2011 for the Campanian Seas and North Adriatic Seas. We can see that the trend in the four months of monitoring is similar for the three years of sampling in the two selected areas.

Lower values there are in the months of June and September, while the peaks occur in the hottest and less rainy months of July and August. We can clearly see that there are three different stages: operation of low level, rising phase, and fall period. For each season the phenomenon has only a rising phase until reaching a peak of maximum production to then have a decay and sedimentation of the substance. So seasons that reaching the maximum production in July have lower values in August or the contrary.. Therefore, there are some obvious differences in the annual variation and intensity. Probably influenced by the different meteorological variables (Paragraph 2.2), but the result shows Also that this phenomenon is cyclically and continually present in the two sub-region.

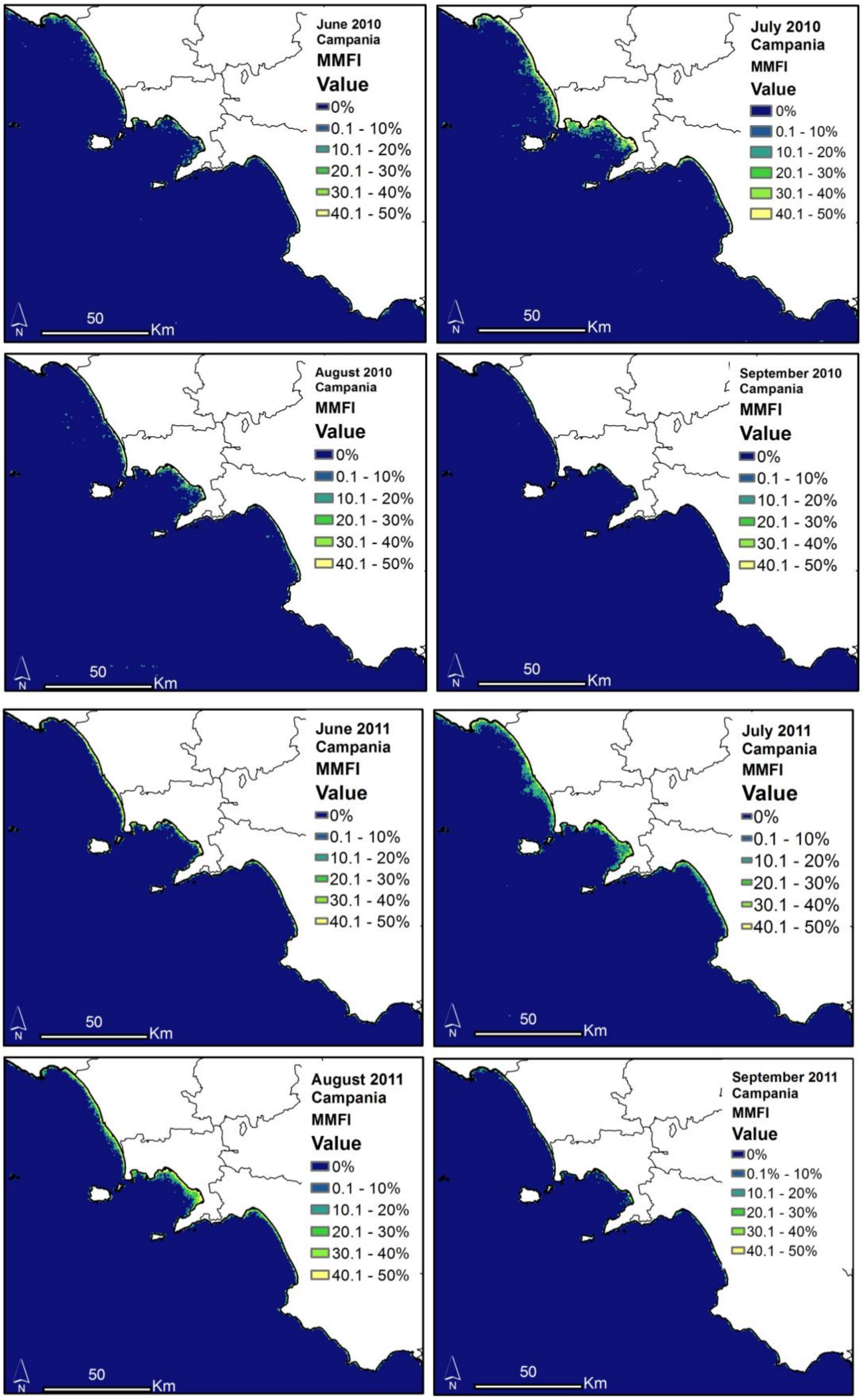


Figure 20–The spatial distribution patterns of the monthly mucilage frequency index in Campanian seas.

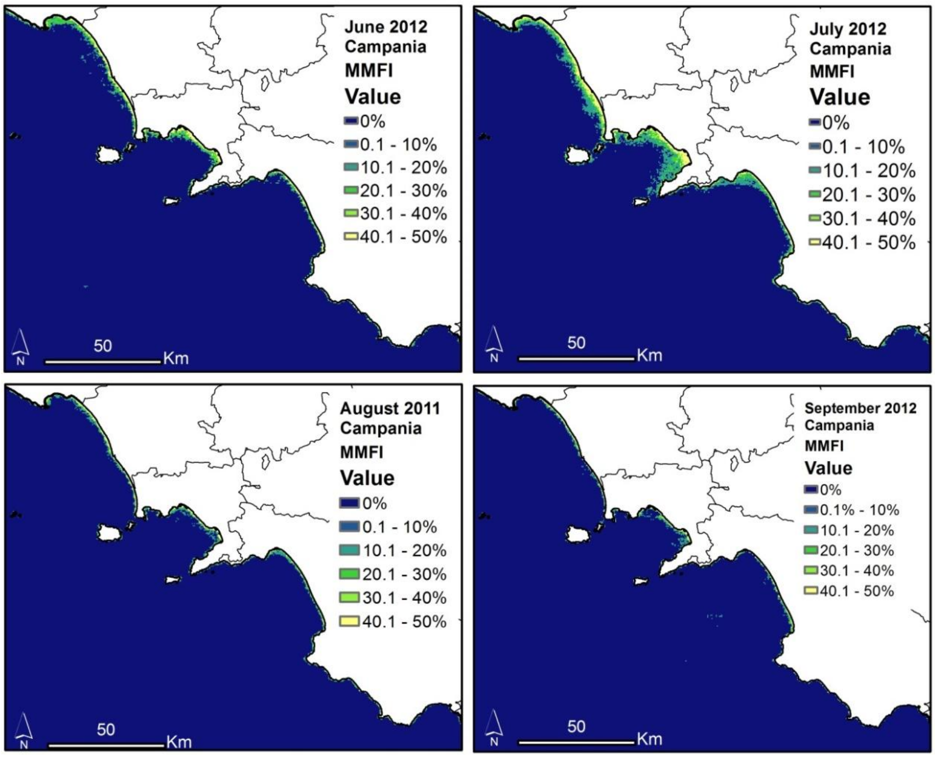


Figure 21–The spatial distribution patterns of the monthly mucilage frequency index in Campanian seas. 2012

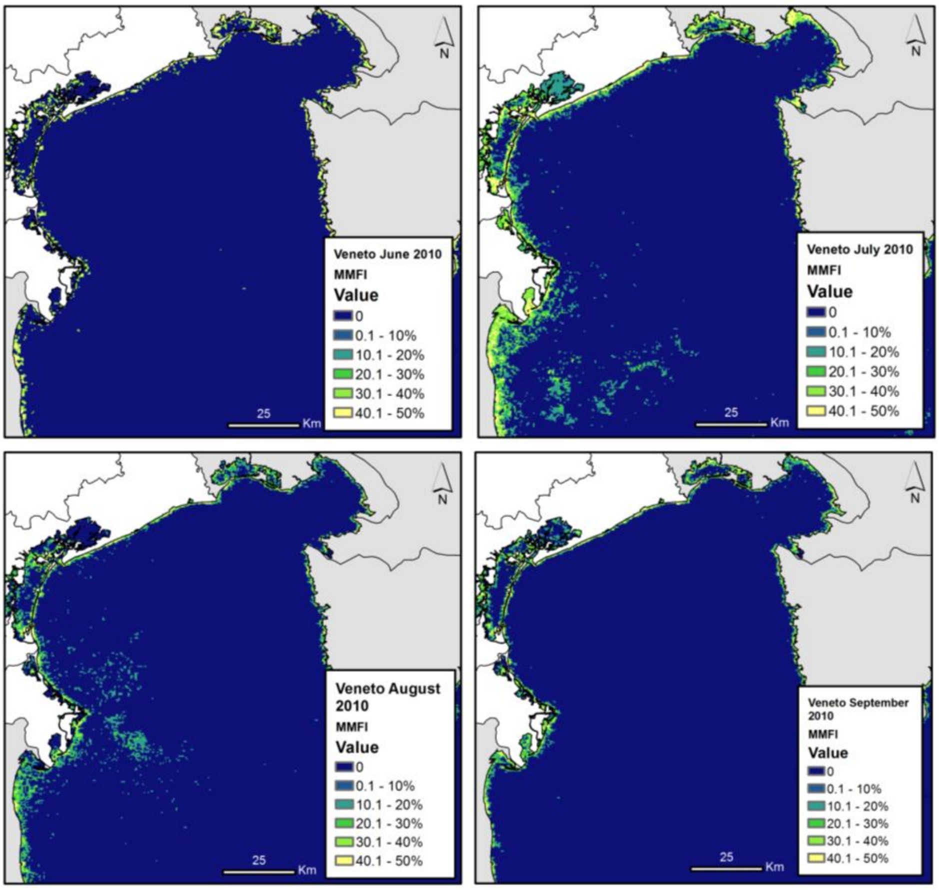


Figure 22–The spatial distribution patterns of the monthly mucilage frequency index in North Adriatic seas.

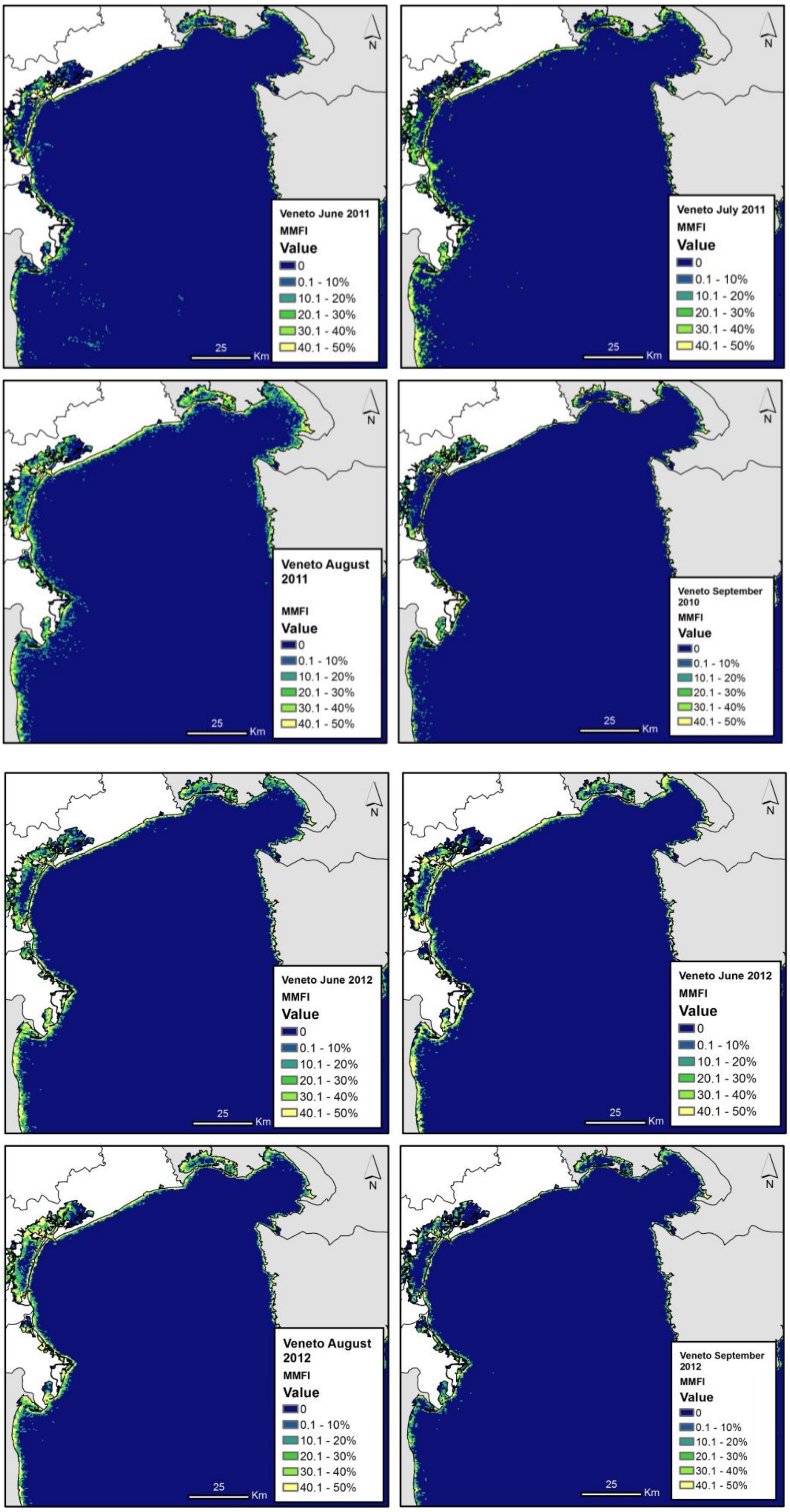
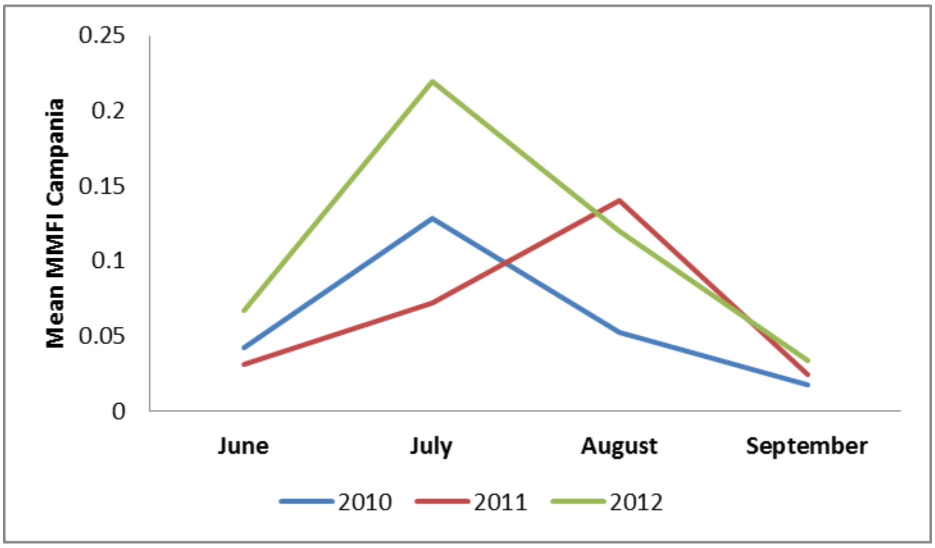


Figure 23 The spatial distribution patterns of the monthly mucilage frequency index in North Adriatic seas2012

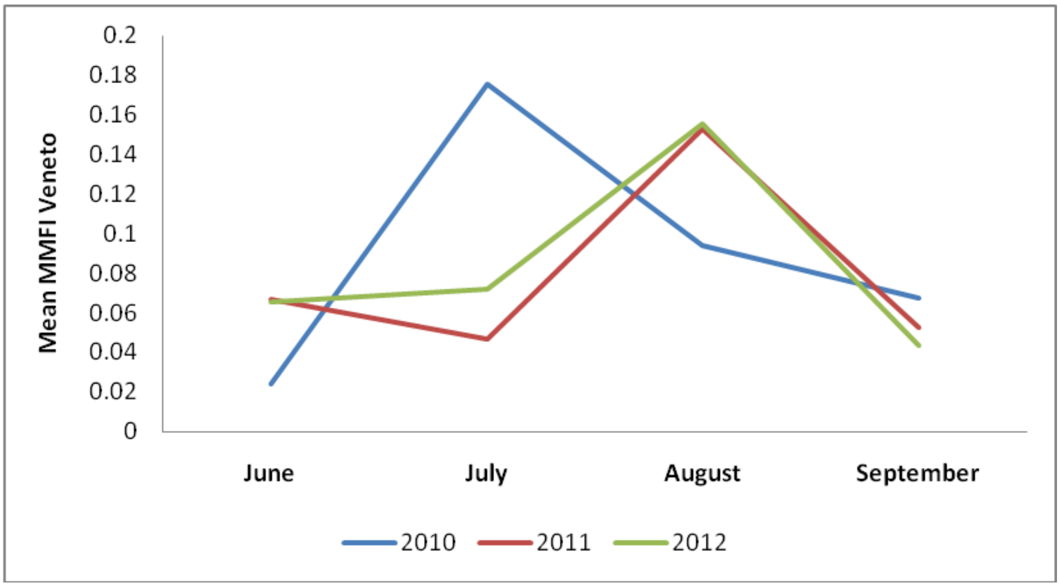
From the comparison between the two graphs for the monitored areas, we see that the peaks in the two regions are the same for the summers of 2010 (July) and 2011 (August), while in 2012 there is a peak in July in Campania and one in August for the Adriatic. This behaviour could be justified by a possible delay in reaching the maximum temperatures for the North Adriatic than the Tyrrhenian Sea in 2012. Other meteo-climatic factors like difference in hydrodynamics conditions or salinity can determine also this situation.

The more high monthly values were recorded in Campania in July of 2012. For this period it is reported by the press and official reports ARPAC several blooming of considerable size across the Campanian Coast (ARPAC, ilmattino.it). Interesting values also occurred for the month of July in the North Adriatic. In this period focus as the majority of the events documented within the last three years by ARPAV across the Veneto coast. This phenomenon continued in August as described by in situ measurements (ARPAV).



NB: In this case the values of AMFI are expressed as average days of detection for pixels that fall in the considered study areas. The average values were normalized to the number of effective monitoring days per study month.

Figure 24 - The monthly Mucilage Frequency Index in the summer season from 2010 until 2012 in South Tyrrhenian (Campania)



NB: In this case the values of AMFI are expressed as average days of detection for pixels that fall in the considered study areas. The average values were normalized to the number of effective monitoring days per study month.

Figure 25– The monthly Mucilage Frequency Index in the summer season from 2010 until 2012 in South Tyrrhenian (Campania)

4.1.3 Sea temperature influence on marine mucilage formation.

The study of monthly frequency of mucilage leads to the conclusion that there is some cyclicity in the mucilage phenomenon for the studied areas. The factors of influence on the mucilage formation are still under investigation, however some weather variables were already identified as possible elements of acceleration or deceleration in the dynamics of formation and degradation of that phenomenon (Paragraph 2.2).

For a first comparison, between monthly data of mucilage obtained and monthly surface temperatures (average and maximum) measured by local monitoring stations belonging to the network monitoring ISPRA (mareografico.it), has 'detected a clear similarity in their seasonal patterns. In particular with regard the achievement of the maximum peak of mucilage we could observe how this happens always in the same month when it reach the maximum peaks of temperature. (Figure 26)

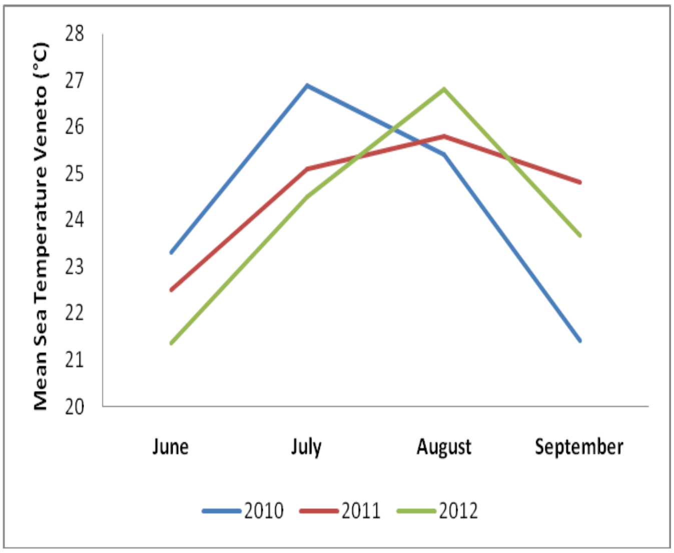


Figure 26 – Monthly mean of Sea Temperature in Veneto. The Value are collepted from ISPRA stations of Venice.

The scatter plot in Figure 27 show the correlation between the MMFI and the Monthly Mean of Sea Temperature. As it is shown by the graph there is a greater correlation between the highest values of 'index of mucilage and the temperatures of the sea .. The higher frequencies of the presence of mucilage are registered in the month with an average temperature between 25 and 27 degrees centigrade.

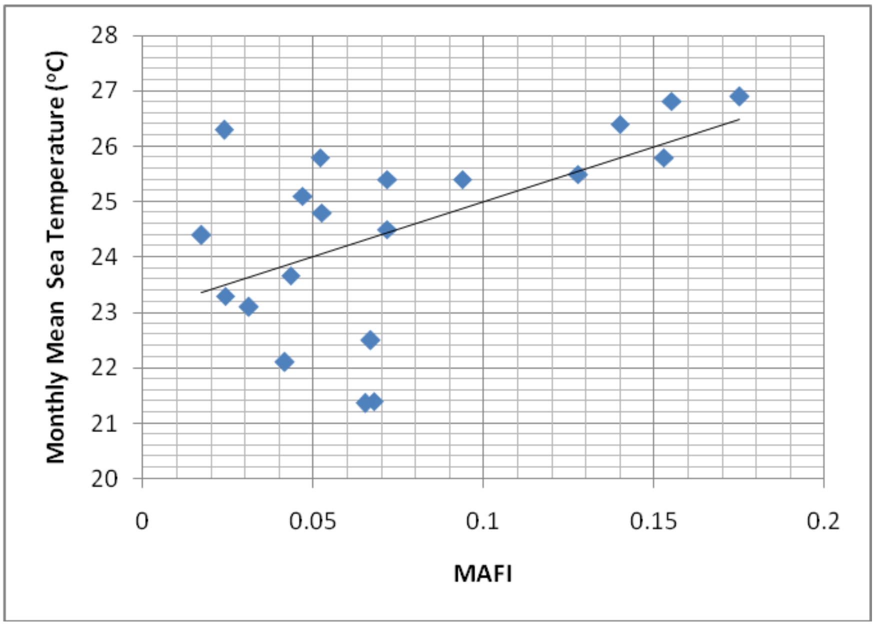


Figure 27- The Scatter plots in Figure showing the relationship between two variables of MAFI and Monthly mean sea temperature.

4.2 The 2012 bloom event in Campanian Sea.

To better understand the dynamics of the formation of mucilage, we chose to map the daily evolution of a single event of mucilage bloom.

The chosen event corresponds with the bloom of mucilage occurred on the Campanian coast in the summer of 2012, with a peak in July. As shown by the graphs in Figure 24 and 25 in July 2012 registering the highest value index of frequency of mucilage in the three years studied for the two sub-regions analyzed.

For the description of the event were chosen 12 dates, 10 of which correspond to the days on which have been documented mucilage aggregates by ARPAC (see Appendix 2).

The earliest presence of mucilage in Campanian seas was reported from ARPAC in 15 of June, an extensive bloom was found in Pollica in the south coast of Salerno province.

As you can see from Figure 28, sometimes the phenomenon is detected by algorithm across the Campanian coast, but with a moderate extension.

The phenomenon keeps these proportions throughout the month of June, appearing occasionally on small stretches of Campanian coast.

In the early days of July it begins to occur a first increase of the values of MI as shown in Figure 28. In the same days it is documented frequent formation of mucilaginous aggregates across the Campanian coast, especially in the islands of Ischia and Procida(stringers and macro-flocs) and on the southern stretch of the coast of the province of Salerno (Creamy surface layer) (Figure 28).

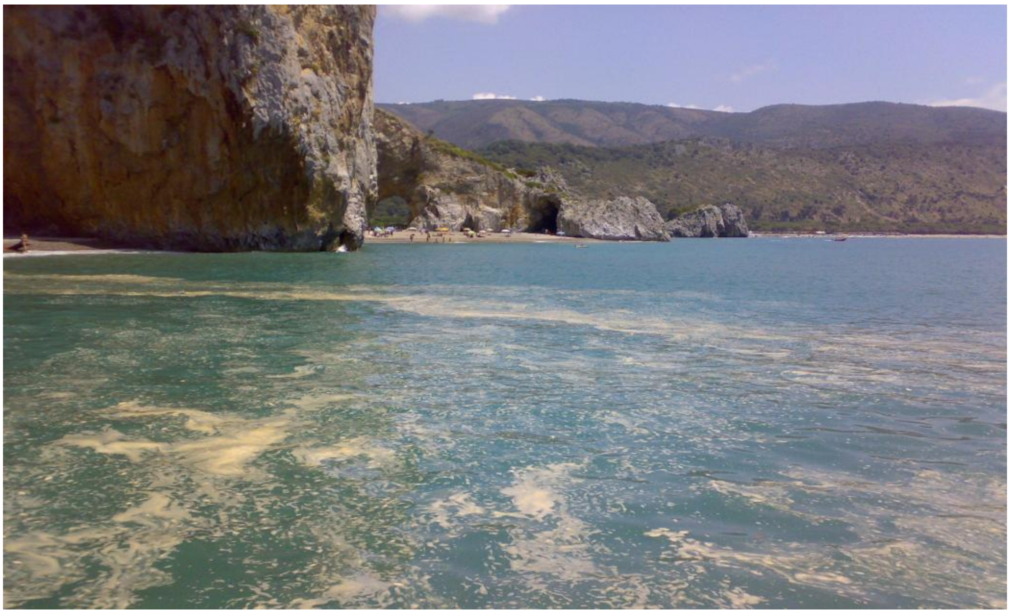


Figure 28- extensive mucilage bloom reported by ARPAC in July 03, 2012 (http://www.arpacampania.it/balneazione/a_mucillagini2012_relazioni_sopralluoghi.asp et) occurred in Centola (South of Salerno Province)

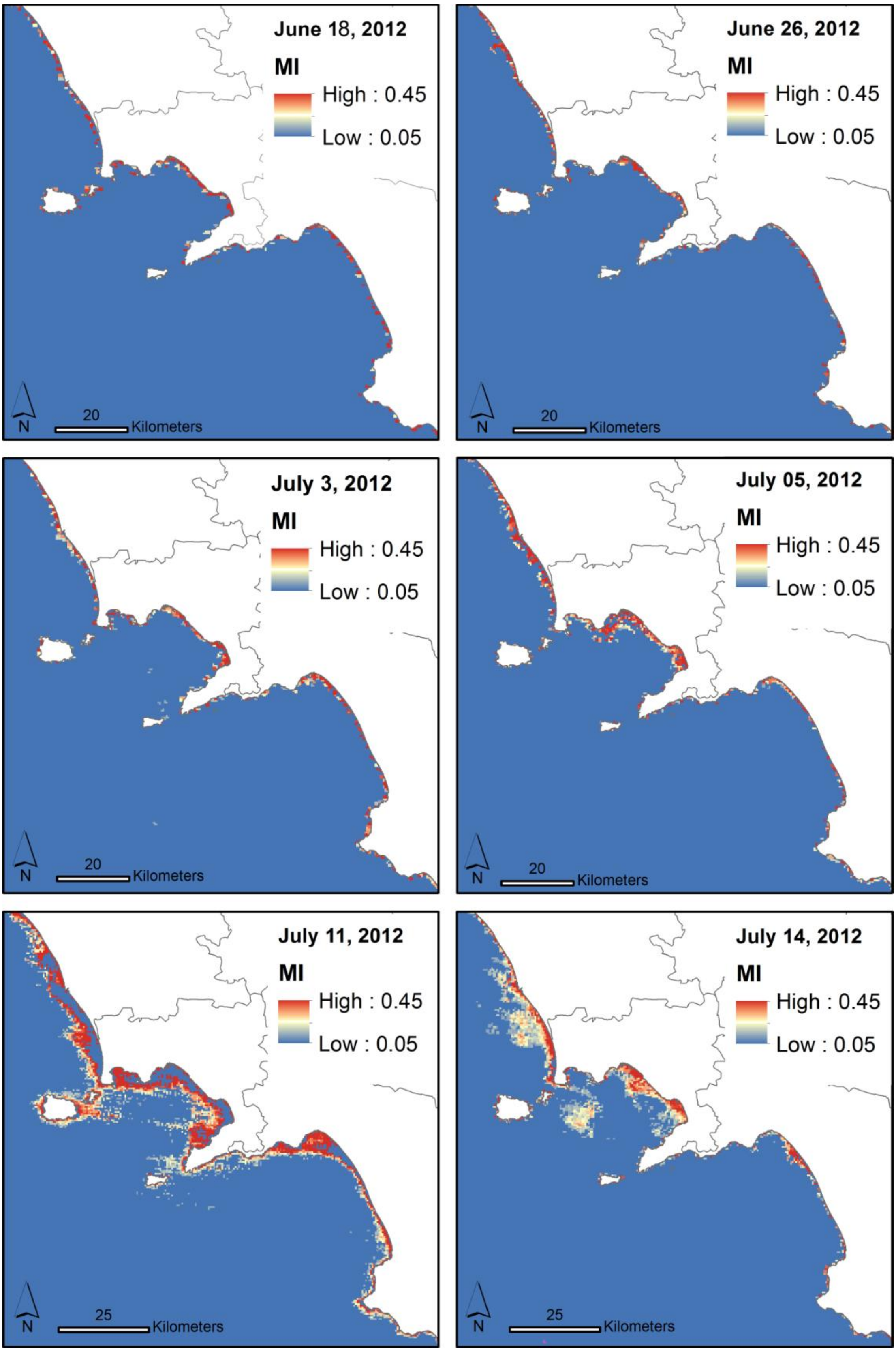


Figure 29- The sequence of figure describe a massive mucilage phenomeno in the summer of 2012 in Campanian seas by the use of Mcilage Index (MI). (Jun 15-Jul 14)

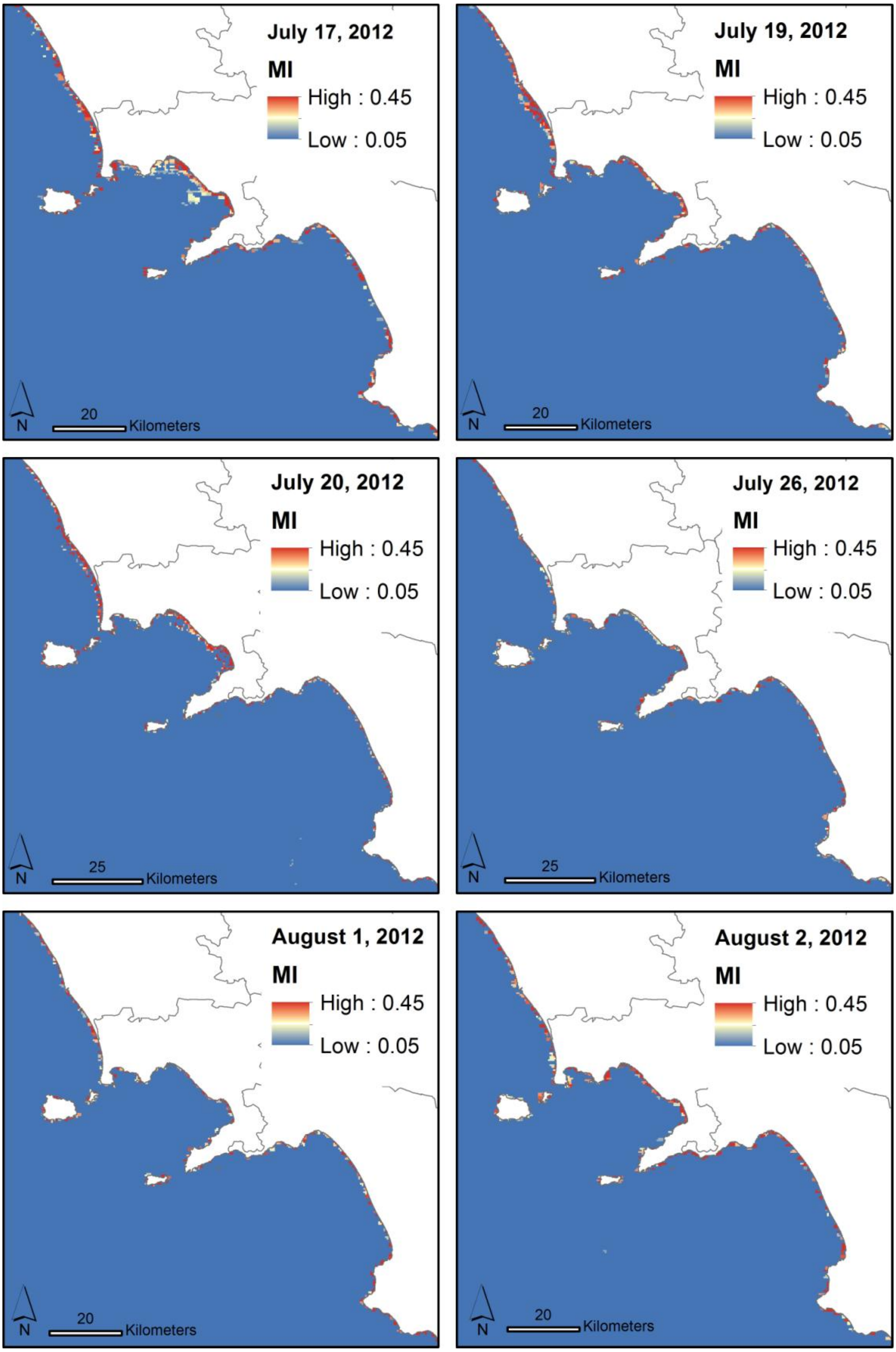


Figure 30- The sequence of figure describe a massive mucilage phenomeno in the summer of 2012 in Campanian seas by the use of Mcilage Index (MI). (Jul 17 – Aug 2)

The maximum value of MI,, which is corresponding to the peak value of the mucilaginous phenomenon likely, was obtained in the mucilage Index product of July 11. As we can see in Figure 29, the phenomenon seems to affect large areas of the whole stretch of coast monitored, in particular as regards the Gulf of Naples and the Gulf of Salerno. Particularly high values are also noted on the coast of the province of Salerno and the islands of Ischia and Procida.

In this case it detects a remarkable correspondence with the data, on-site, made by ARPA as a result of numerous reports by directors and tour operators on the day indicated and in the following days.

In particular, measurements are taken at different points in the bay of Naples (Naples, Pozzuoli, Bacoli and Monte di Procida) where it is recorded the presence of mucus surface of small dimensions and the presence of mucous aggregates floating in spread formations , in some cases as in the Bay of Trentaremi (Figure 31).

Figure 31 - extensive mucilage bloom reported by ARPAC in July 11, 2012 (http://www.arpacampania.it/balneazione/a_mucillagini2012_relazioni_sopralluoghi.asp et) occurred in Trentaremi bay (Golf of Naples)

From July 11 there is a slow and progressive attenuation of the phenomenon in terms of scope and in terms of intensity, these data are matched in official sources (ARPAC).

The performance of the mucilage phenomenon, described above, is exemplified in an even more clear from the graph in Figure 32, which describes the changing value in terms of sea surface affected, in the days monitored. As we can see the phenomenon follows a similar trend to the one described following the study of the monthly variation. Clearly we can see even more in detail That there are three different stages: an operation of low level, that occur before 18th and after 26; a rising phase, that occur since june 26 to July 11, where the mucilage phenomenon reaches its maximum extention peak, estimated at 30 Km of area covered; finally a fall period, that began in July 11 and end on July 26.

It is necessary to specify that this' area may present minor phenomena like marine snow, but also more extensive and obvious superficially phenomena like Creamy surface layer.

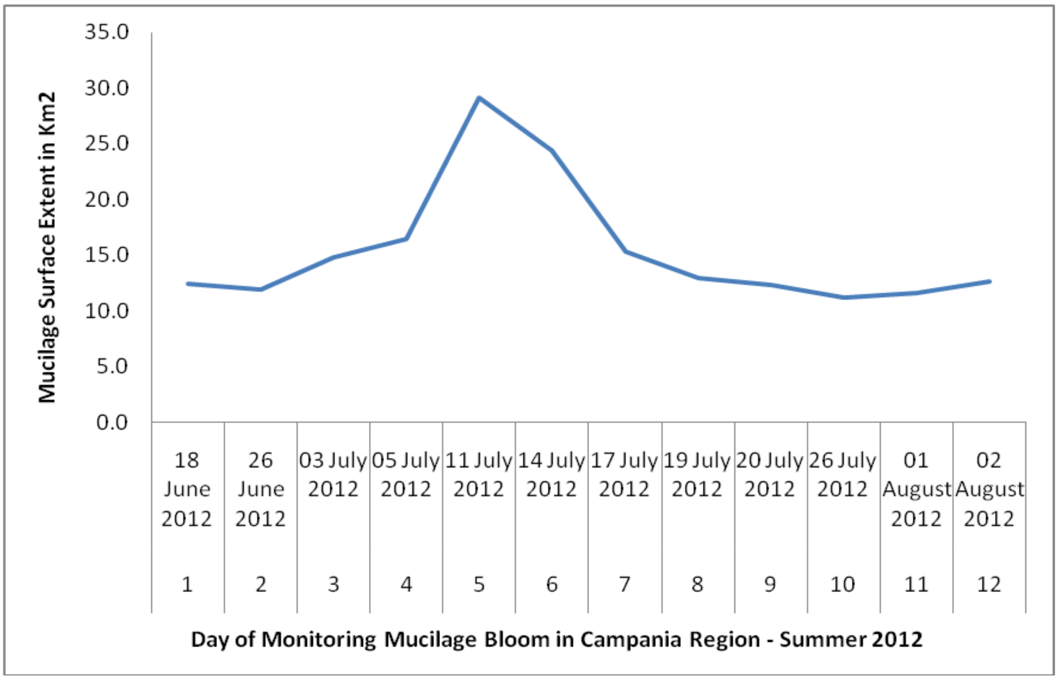


Figure 32- Extent (in Km2) of Mucilage phenomenon in Campanian Region during summer 2012.

5. Conclusion

Several major findings can be summarized from this work. The MI approach, originally designed to identify Mucilage Bloom in the North Adriatic Seas environment, can be applied to study this kind of phenomenon in other Italian seas.

Such blooms are otherwise hard to quantify in a consistent manner due to inherent limitations in field techniques and due to imperfect algorithms in remote-sensing techniques (e.g., interference from the atmosphere, suspended sediments, river plume). Therefore the choice of new limits of threshold allowed us to improve the results of the algorithm by lowering the interferences due to disturbing elements of the final product.

On the basis of MODIS imagery MI, we were able to identify to investigate two of the areas most affected by the phenomenon of mucilage on the Italian coast in recent years. The long-term spatial / temporal distributions of mucilage blooms in Campania and North Adriatic sea have been addressed in detail.

Utilizing the AMFI and MAFI from 2010 to 2012 and MI for 2012 in Campanian Coasts, we were able to observe annual periodical changing rules of marine mucilage. This cycle includes three stages, That Is operation of low level, rising phase and fall period. The pick occurring or in the July month or in August.

We observe that this maximum value occur every time for our study in the month with the maximum mean monthly sea temperature.

Finally, Because of the continuity from MODIS data as well as from other existing and planned satellite missions, the results can be used as baseline data to evaluate the marine mucilage status in the future.

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www.regione.emilia-romagna.it/pda/iiia_requisite_eng.htm

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http://www.ilmattino.it/napoli/provincia/golfo_di_napoli_invaso_da_mucillagine_bagnanti_in_fuga_situazione_indecente/notizie/208544.shtml

http://corrieredelmezzogiorno.corriere.it/napoli/notizie/cronaca/2012/13-luglio-2012/-pozzuoli-isole-golfo-emergenza-liquami-mucillagine-2011001086090.shtml

APPENDICES

APPENDIX 1: In the first column are all the Digital Number chosen as admissible quality. In the second column are the correspondent binary Number.

Digital Number	Binary Number
	Atm. Correction QA Band 6 QA Band 4 QA Band 3 QA Band 2 Summary Quality
1073741824	00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
1073741877	00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 00 01
1075576832	00 01 00 00 00 00 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
1075576835	00 01 00 00 00 00 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1075576885	00 01 00 00 00 00 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 00 01
1075576887	00 01 00 00 00 00 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1076625411	00 01 00 00 00 00 00 00 00 00 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1076625463	00 01 00 00 00 00 00 00 00 00 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1077149697	00 01 00 00 00 00 00 00 00 00 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01
1077149749	00 01 00 00 00 00 00 00 00 00 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 00 01
1077411843	00 01 00 00 00 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1077411895	00 01 00 00 00 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1811939331	00 01 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1811939383	00 01 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1813774339	00 01 01 00 01 01 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1813774391	00 01 01 00 01 01 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1814822915	00 01 01 00 01 01 00 00 00 00 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1814822967	00 01 01 00 01 01 00 00 00 00 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1815347203	00 01 01 00 01 01 00 00 00 00 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1815347255	00 01 01 00 01 01 00 00 00 00 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1815609347	00 01 01 00 01 01 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1815609399	00 01 01 00 01 01 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1946157057	00 01 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01
1946157109	00 01 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 00 01
1947992065	00 01 01 01 00 01 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01
1947992067	00 01 01 01 00 01 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1947992117	00 01 01 01 00 01 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 00 01
1947992119	00 01 01 01 00 01 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1949040643	00 01 01 01 00 01 00 00 00 00 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1949040695	00 01 01 01 00 01 00 00 00 00 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
1949564929	00 01 01 01 00 01 00 00 00 00 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01
1949564981	00 01 01 01 00 01 00 00 00 00 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 00 01
1949827075	00 01 01 01 00 01 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
1949827127	00 01 01 01 00 01 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
2013265923	00 01 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
2013265975	00 01 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
2015100931	00 01 01 01 01 00 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
2015100983	00 01 01 01 01 00 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
2016149507	00 01 01 01 01 00 00 00 00 00 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
2016149559	00 01 01 01 01 00 00 00 00 00 01 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
2016673795	00 01 01 01 01 00 00 00 00 00 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
2016673847	00 01 01 01 01 00 00 00 00 00 01 01 00 01 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01
2016935939	00 01 01 01 01 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01
2016935991	00 01 01 01 01 00 00 00 00 00 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 01 01 01

APPENDIX 2- Dataset of in situ data from ARPAC.

ARPAC								
Data	**MOD09GA**	**Cod Station**	**Località**		**Est**	**Nord**	**MI**	**Classification**
5 Luglio 2012	2012187	IT015063061008	Procida	Spiaggia del Cimitero	416,421.80	4,512,673.89	0.620531	Filaments
5 Luglio 2012	2012187	IT015063037002	Ischia	Spiaggia San Pietro	410,920.91	4,510,806.78	0.295259	Filaments
5 Luglio 2012	2012187	IT015063037004	Ischia	Castello Aragonese	411,963.54	4,509,724.06	0.141745	Filaments
5 Luglio 2012	2012187	IT015063019002	Casamicciolaterme	Perrone	408407.642	4511505.351	0.217687	Filaments
5 Luglio 2012	2012187	IT015063038002	LACCO AMENO	S. Restituta	411,963.54	4,509,724.06	0.141745	Filaments
9 Luglio 2012	2012191	IT015063019002	Casamicciolaterme	Perrone	408407.642	4511505.351	0.310659	Ribbons
9 Luglio 2012	2012191	IT015063038002	LACCO AMENO	S. Restituta	411,963.54	4,509,724.06	0.486369	Ribbons
9 Luglio 2012	2012191	IT015063031004	Forio	Citara	403,443.91	4,508,451.84	0.292308	Filaments
9 Luglio 2012	2012191	IT015063031005	Forio	Scogli Innamorati	403,321.55	4,509,733.07	0.051829	Ribbons
9 Luglio 2012	2012191	IT015063078002	SERRARA FONTANA	S. Angelo	406,454.43	4,505,692.37	0.311456	Macroflocs
10 Luglio 2012	2012192	-	Procida	Spiaggia Chialolella	415,512.30	4,511,996.41	0.110979	Ribbons
11 Luglio 2012	2012193	rete Ostreopsis OS11	Napoli	Trentaremi	431,336.09	4,516,473.03	0.489755	Creamy surface layer
11 Luglio 2012	2012193	-	Napoli	Tra Pozzuoli e Nisida	434,497.20	4,518,624.93	0.403731	Macroflocs
11 Luglio 2012	2012193		Pozzuoli	Circa 2 km dalla costa de	424,292.74	4,518,583.86	0.400484	Macroflocs
11 Luglio 2012	2012193	Tra punta pennata e procida			420,494.30	4,514,477.44	0.152862	Macroflocs
11 Luglio 2012	2012193	n il Comune di Bacoli (presso Miliscola) ed il porto di Marina di Monte			420,104.19	4,514,908.62	0.351019	Macroflocs
16 Luglio 2012	2012198	IT015007003	Barano	Marina dei Maronti	407,407.00	4,506,230.89	0.311207	Ribbons
16 Luglio 2012	2012198	IT015031003	Forio	Punta dell'imperatore	403,439.26	4,508,914.80	0.326342	Creamy surface layer
19 Luglio 2012	2012201	Ostreopsis OS17	Sorrento	Marina Grande	447,870.75	4,498,272.41	0.440433	Creamy surface layer
20 Luglio 2012	2012202	-	Procida	Canale di procida	418,672.02	4,513,577.78	0.438031	Cobweb
20 Luglio 2012	2012202	-	Forio	Punta dell'imperatore	403,500.95	4,508,079.62	0.260345	Flocs
20 Luglio 2012	2012202	IT015063037002	Ischia	Spiaggia San Pietro	410,920.91	4,510,806.78	0.429204	Creamy surface layer
18 Giugno 2012	2012170	-	Pollica	località Agnone	499,743.54	4,452,273.83	0.069502	Creamy surface layer
3 Luglio 2012	2012185	IT65039007	Centola	Foce Mingardo	527,172.37	4,431,418.54	0.630833	Creamy surface layer
4 Luglio 2012	2012185	IT015065066003	Maiori	-	498,942.50	4,452,238.87	0.324025	Creamy surface layer
11 Luglio 2012	2012193	-	Salerno Battipaglia	La Picciola	486,734.61	4,496,913.02	0.480505	Creamy surface layer
19 Luglio 2012	2012201	IT65031006	Castellabate	Molo sottoflutto Porto S	494,557.58	4,457,554.09	0.317529	Creamy surface layer
1 Agosto 2012	2012214	IT65039007	Camarota	Cala Bianca	532,966.70	4,428,506.47	0.359439	Creamy surface layer
2 Agosto 2012	2012215	IT015065157005	Vietri sul Mare	La Crestarella	477,246.10	4,502,078.66	0.416079	Creamy surface layer
6 Agosto 2012	2012219	IT 65025008	Capaccio	Foce acqua dei Ranci	500,272.55	4,470,508.88	0.284553	Creamy surface layer
7 Agosto 2112	2012220	IT65021001	Camerota	Foce Mingardo	527,172.37	4,431,418.54	0.388535	Creamy surface layer

APPENDIX 3 – MODIS Surface reflectance L2G 500 m used in the study and summary quality description.

June 2010				
Data	Modis	Preprocessing	Quality	Description
1 June 2010	2010152	ok	ok	
2 June 2010	2010153	-	-	Cloud cover >75%
3 June 2010	2010154	-	-	Cloud cover >75%
4 June 2010	2010155	-	-	Cloud cover >75%
5 June 2010	2010156	ok	ok	
6 June 2010	2010157	ok	ok	
7 June 2010	2010158	ok	ok	
8 June 2010	2010159	ok	ok	
9 June 2010	2010160	ok	ok	
10 June 2010	2010161	ok	ok	
11 June 2010	2010162	ok	-	Error not masked
12 June 2010	2010163	-	-	Cloud cover >75%
13 June 2010	2010164	ok	ok	
14 June 2010	2010165	ok	ok	
15 June 2010	2010166	-	-	Cloud cover >75%
16 June 2010	2010167	ok	ok	
17 June 2010	2010168	ok	ok	
18 June 2010	2010169	ok	ok	
19 June 2010	2010170	-	-	Cloud cover >75%
20 June 2010	2010171	-	-	Cloud cover >75%
21 June 2010	2010172	-	-	Cloud cover >75%
22 June 2010	2010173	-	-	Cloud cover >75%
23 June 2010	2010174	ok	ok	
24 June 2010	2010175	ok	ok	
25 June 2010	2010176	ok	ok	
26 June 2010	2010177	ok	ok	
27 June 2010	2010178	ok	ok	
28 June 2010	2010179	ok	ok	
29 June 2010	2010180	ok	ok	
30 June 2010	2010181	ok	ok	

July 2010				
Data	Modis	Preprocessing	Quality	Description
1 July 2010	2010182	ok	-	Error not masked
2 July 2010	2010183	ok	ok	
3 July 2010	2010184	ok	ok	
4 July 2010	2010185	ok	ok	
5 July 2010	2010186	ok	ok	
6 July 2010	2010187	ok	-	Error not masked
7 July 2010	2010188	ok	ok	
8 July 2010	2010189	ok	-	Error not masked
9 July 2010	2010190	ok	ok	
10 July 2010	2010191	ok	ok	
11 July 2010	2010192	ok	ok	
12 July 2010	2010193	ok	ok	
13 July 2010	2010194	ok	ok	
14 July 2010	2010195	ok	ok	
15 July 2010	2010196	ok	ok	
16 July 2010	2010197	ok	ok	
17 July 2010	2010198	ok	ok	
18 July 2010	2010199	ok	-	Error not masked
19 July 2010	2010200	ok	ok	
20 July 2010	2010201	ok	-	Error not masked
21 July 2010	2010202	ok	ok	
22 July 2010	2010203	ok	-	Error not masked
23 July 2010	2010204	ok	ok	
24 July 2010	2010205	ok	ok	
25 July 2010	2010206	ok	ok	
26 July 2010	2010207	ok	ok	
27 July 2010	2010208	-	-	Cloud cover >75%
28 July 2010	2010209	ok	ok	
29 July 2010	2010210	ok	ok	
30 July 2010	2010211	ok	ok	
31 July 2010	2010212	ok	ok	

August 2010				
Data	Modis	Preprocessing	Quality	Description
1 August 2010	2010213	ok	ok	
2 August 2010	2010214	ok	ok	
3 August 2010	2010215	ok	ok	
4 August 2010	2010216	ok	ok	
5 August 2010	2010217	ok	ok	
6 August 2010	2010218	ok	ok	
7 August 2010	2010219	ok	-	Error not masked
8 August 2010	2010220	ok	ok	Error not masked
9 August 2010	2010221	ok	ok	Error not masked
10 August 2010	2010222	ok	ok	
11 August 2010	2010223	ok	-	Error not masked
12 August 2010	2010224	ok	ok	
13 August 2010	2010225	ok	ok	
14 August 2010	2010226	ok	ok	
15 August 2010	2010227	ok	ok	
16 August 2010	2010228	ok	ok	
17 August 2010	2010229	ok	ok	
18 August 2010	2010230	ok		
19 August 2010	2010231	ok	ok	
20 August 2010	2010232	ok	-	Error not masked
21 August 2010	2010233	ok	-	Error not masked
22 August 2010	2010234	ok	ok	
23 August 2010	2010235	ok	-	Error not masked
24 August 2010	2010236	ok	ok	
25 August 2010	2010237	ok	ok	
26 August 2010	2010238	ok	ok	
27 August 2010	2010239	ok	ok	
28 August 2010	2010240	ok	ok	
29 August 2010	2010241	ok	-	Error not masked
30 August 2010	2010242	ok	-	Error not masked
31 August 2010	2010243	ok	ok	

September 2010				
Data	Modis	Preprocessing	Quality	Description
1 September 2010	2010244	-	-	Cloud cover >75%
2 September 2010	2010245	ok	ok	
3 September 2010	2010246	-	-	Cloud cover >75%
4 September 2010	2010247	ok	-	Error not masked
5 September 2010	2010248	ok	ok	
6 September 2010	2010249	-	-	Cloud cover >75%
7 September 2010	2010250	-	-	Cloud cover >75%
8 September 2010	2010251	-	-	Cloud cover >75%
9 September 2010	2010252	ok	-	Error not masked
10 September 2010	2010253	-	-	Cloud cover >75%
11 September 2010	2010254	ok	ok	
12 September 2010	2010255	ok	ok	
13 September 2010	2010256	ok	ok	
14 September 2010	2010257	ok	ok	
15 September 2010	2010258	ok	-	Error not masked
16 September 2010	2010259	ok	ok	
17 September 2010	2010260	-	-	Cloud cover >75%
18 September 2010	2010261	-	-	Cloud cover >75%
19 September 2010	2010262	-	-	Cloud cover >75%
20 September 2010	2010263	ok	ok	
21 September 2010	2010264	ok	ok	
22 September 2010	2010265	-	-	Cloud cover >75%
23 September 2010	2010266	ok	ok	
24 September 2010	2010267	-	-	Cloud cover >75%
25 September 2010	2010268	-	-	Cloud cover >75%
26 September 2010	2010269	ok	ok	
27 September 2010	2010270	-	-	Cloud cover >75%
28 September 2010	2010271	-	-	Cloud cover >75%
29 September 2010	2010272	ok	ok	
30 September 2010	2010273	ok	ok	

June 2011				
Data	**Modis**	**Preprocessing**	**Quality**	**Description**
1 June 2011	2011152	-	-	Cloud cover >75%
2 June 2011	2011153	-	-	Cloud cover >75%
3 June 2011	2011154	ok	ok	
4 June 2011	2011155	ok	ok	
5 June 2011	2011156	-	-	Cloud cover >75%
6 June 2011	2011157	-	-	Cloud cover >75%
7 June 2011	2011158	-	-	Cloud cover >75%
8 June 2011	2011159	-	-	Cloud cover >75%
9 June 2011	2011160	ok	ok	
10 June 2011	2011161	ok	ok	
11 June 2011	2011162	-	-	Cloud cover >75%
12 June 2011	2011163	ok	ok	
13 June 2011	2011164	-	-	Cloud cover >75%
14 June 2011	2011165	-	-	Cloud cover >75%
15 June 2011	2011166	ok	ok	
16 June 2011	2011167	ok	ok	
17 June 2011	2011168	ok	ok	
18 June 2011	2011169	ok	ok	
19 June 2011	2011170	ok	ok	
20 June 2011	2011171	ok	ok	
21 June 2011	2011172	ok	ok	
22 June 2011	2011173	ok	ok	
23 June 2011	2011174	ok	ok	
24 June 2011	2011175	ok	ok	
25 June 2011	2011176	ok	ok	
26 June 2011	2011177	ok	ok	
27 June 2011	2011178	ok	ok	
28 June 2011	2011179	ok	ok	
29 June 2011	2011180	ok	ok	
30 June 2011	2011181	-	-	Cloud cover >75%

July 2011				
Data	**Modis**	**Preprocessing**	**Quality**	**Description**
1 July 2011	2011182	ok	ok	
2 July 2011	2011183	-	-	Cloud cover >75%
3 July 2011	2011184	ok	ok	
4 July 2011	2011185	ok	ok	
5 July 2011	2011186	-	-	Cloud cover >75%
6 July 2011	2011187	ok	ok	
7 July 2011	2011188	ok	ok	
8 July 2011	2011189	ok	ok	
9 July 2011	2011190	ok	ok	
10 July 2011	2011191	ok	ok	
11 July 2011	2011192	ok	ok	
12 July 2011	2011193	ok	ok	
13 July 2011	2011194	ok	ok	
14 July 2011	2011195	ok	ok	
15 July 2011	2011196	ok	ok	
16 July 2011	2011197	ok	ok	
17 July 2011	2011198	ok	ok	
18 July 2011	2012199	ok	ok	
19 July 2011	2011200	ok	ok	
20 July 2011	2011201	ok	ok	
21 July 2011	2011202	ok	ok	
22 July 2011	2011203	ok	ok	
23 July 2011	2011204	-	-	Cloud cover >75%
24 July 2011	2011205	-	-	Cloud cover >75%
25 July 2011	2011206	-	-	Cloud cover >75%
26 July 2011	2011207	ok	ok	
27 July 2011	2011208	-	-	Cloud cover >75%
28 July 2011	2011209	ok	-	Error not masked
29 July 2011	2011210	ok	ok	
30 July 2011	2011211	ok	-	Error not masked
31 July 2011	2011212	-	-	Cloud cover >75%

August 2011				
Data	**Modis**	**Preprocessing**	**Quality**	**Description**
1 August 2011	2011113	ok	ok	
2 August 2011	2011214	ok	ok	
3 August 2011	2011215	ok	ok	
4 August 2011	2011216	ok	ok	
5 August 2011	2011217	ok	ok	
6 August 2011	2011218	ok	ok	
7 August 2011	2011219	ok	ok	
8 August 2011	2011220	ok	ok	
9 August 2011	2011221	ok	ok	
10 August 2011	2011222	ok	ok	
11 August 2011	2011223	ok	ok	
12 August 2011	2011224	ok	ok	
13 August 2011	2011225	ok	ok	
14 August 2011	2011226	ok	ok	
15 August 2011	2011227	ok	ok	
16 August 2011	2011228	ok	ok	
17 August 2011	2011229	ok	ok	
18 August 2011	2011230	ok	ok	
19 August 2011	2011231	ok	ok	
20 August 2011	2011232	ok	ok	
21 August 2011	2011233	ok	ok	
22 August 2011	2011234	ok	ok	
23 August 2011	2011235	ok	ok	
24 August 2011	2011236	ok	ok	
25 August 2011	2011237	ok	ok	
26 August 2011	2011238	ok	ok	
27 August 2011	2011239	ok	ok	
28 August 2011	2011240	ok	ok	
29 August 2011	2011241	ok	-	Error not masked
30 August 2011	2011242	ok	ok	
31 August 2011	2011243	ok	ok	

September 2011				
Data	**Modis**	**Preprocessing**	**Quality**	**Description**
1 September 2011	2011244	-	-	Cloud cover >75%
2 September 2011	2011245	-	-	Cloud cover >75%
3 September 2011	2011246	-	-	Cloud cover >75%
4 September 2011	2011247	ok	-	Error not masked
5 September 2011	2011248	ok	ok	
6 September 2011	2011249	ok	ok	
7 September 2011	2011250	ok	ok	
8 September 2011	2011251	-	-	Cloud cover >75%
9 September 2011	2011252	ok	ok	
10 September 2011	2011253	ok	ok	
11 September 2011	2011254	ok	ok	
12 September 2011	2011255	ok	ok	
13 September 2011	2011256	ok	x	
14 September 2011	2011257	ok	ok	
15 September 2011	2011258	ok	ok	
16 September 2011	2011259	ok	ok	
17 September 2011	2011260	ok	ok	
18 September 2011	2011261	ok	ok	
19 September 2011	2011262	-	-	Cloud cover >75%
20 September 2011	2011263	-	-	Cloud cover >75%
21 September 2011	2011264	-	-	Cloud cover >75%
22 September 2011	2011265	-	-	Cloud cover >75%
23 September 2011	2011266	ok	ok	
24 September 2011	2011267	ok	ok	
25 September 2011	2011268	ok	**ok**	
26 September 2011	2011269	ok	ok	
27 September 2011	2011270	ok	ok	
28 September 2011	2011271	ok	ok	
29 September 2011	2011272	ok	ok	
30 September 2011	2011273	ok	ok	

June 2012				
Data	Modis	Preprocessing	Quality	Description
1 June 2012	2012153	-	-	Cloud cover >75%
2 June 2012	2012154	ok	ok	
3 June 2012	2012155	ok	ok	
4 June 2012	2012156	-	-	Cloud cover >75%
5 June 2012	2012157	ok	ok	
6 June 2012	2012158	ok	ok	
7 June 2012	2012159	ok	-	Error not masked
8 June 2012	2012160	ok	ok	
9 June 2012	2012161	-	-	Clood cover >75%
10 June 2012	2012162	ok	ok	
11 June 2012	2012163	ok	ok	
12 June 2012	2012164	ok	ok	
13 June 2012	2012165	ok	ok	
14 June 2012	2012166	ok	ok	
15 June 2012	2012167	ok	ok	
16 June 2012	2012168	ok	ok	
17 June 2012	2012169	ok	ok	
18 June 2012	2012170	ok	ok	
19 June 2012	2012171	ok	ok	
20 June 2012	2012172	ok	ok	
21 June 2012	2012173	ok	ok	
22 June 2012	2012174	ok	ok	
23 June 2012	2012175	ok	ok	
24 June 2012	2012176	ok	ok	
25 June 2012	2012177	ok	ok	
26 June 2012	2012178	ok	ok	
27 June 2012	2012179	ok	ok	
28 June 2012	2012180	ok	ok	
29 June 2012	2012181	ok	ok	
30 June 2012	2012182	ok	ok	

July 2012				
Data	Modis	Preprocessing	Quality	Description
1 July 2012	2012183	ok	-	Error not masked
2 July 2012	2012184	ok	ok	
3 July 2012	2012185	ok	ok	
4 July 2012	2012186	ok	ok	
5 July 2012	2012187	ok	ok	
6 July 2012	2012188	ok	ok	
7 July 2012	2012189	ok	ok	
8 July 2012	2012190	ok	ok	
9 July 2012	2012191	ok	ok	
10 July 2012	2012192	ok	ok	
11 July 2012	2012193	ok	ok	
12 July 2012	2012194	ok	ok	
13 July 2012	2012195	ok	ok	
14 July 2012	2012196	ok	ok	
15 July 2012	2012197	ok	ok	
16 July 2012	2012198	ok	ok	
17 July 2012	2012199	ok	ok	
18 July 2012	2012200	ok	ok	
19 July 2012	2012201	ok	ok	
20 July 2012	2012202	ok	ok	
21 July 2012	2012203	ok	ok	
22 July 2012	2012204	-	-	Cloud cover >75%
23 July 2012	2012205	-	-	Cloud cover >75%
24 July 2012	2012206	-	-	Cloud cover >75%
25 July 2012	2012207	ok	ok	
26 July 2012	2012208	ok	ok	
27 July 2012	2012209	ok	ok	
28 July 2012	2012210	ok	ok	
29 July 2012	2012211	ok	ok	
30 July 2012	2012212	ok	ok	
31 July 2012	2012213	ok	ok	

August 2012				
Data	Modis	Preprocessing	Quality	Description
1 August 2012	2012214	ok	ok	
2 August 2012	2012215	ok	ok	
3 August 2012	2012216	ok	ok	
4 August 2012	2012217	ok	ok	
5 August 2012	2012218	ok	ok	
6 August 2012	2012219	ok	-	Error not masked
7 August 2012	2012220	ok	ok	
8 August 2012	2012221	ok	ok	
9 August 2012	2012222	ok	ok	
10 August 2012	2012223	ok	ok	
11 August 2012	2012224	ok		
12 August 2012	2012225	ok	ok	
13 August 2012	2012226	ok	ok	
14 August 2012	2012227	ok	ok	
15 August 2012	2012228	ok		
16 August 2012	2012229	ok		
17 August 2012	2012230	ok	ok	
18 August 2012	2012231	ok		
19 August 2012	2012232	ok		
20 August 2012	2012233	ok	ok	
21 August 2012	2012234	ok	ok	
22 August 2012	2012235	ok	ok	
23 August 2012	2012236	ok		
24 August 2012	2012237	ok		
25 August 2012	2012238	ok	ok	
26 August 2012	2012239	ok		
27 August 2012	2012240	ok		
28 August 2012	2012241	ok	ok	
29 August 2012	2012242	ok	ok	
30 August 2012	2012243	ok	ok	
31 August 2012	2012244	ok		

September 2012				
Data	Modis	Preprocessing	Quality	Description
1 September 2012	2012245	-	-	Cloud cover >75%
2 September 2012	2012246	-	-	Cloud cover >75%
3 September 2012	2012247	-	-	Cloud cover >75%
4 September 2012	2012248	-	-	Cloud cover >75%
5 September 2012	2012249	-	-	Cloud cover >75%
6 September 2012	2012250	ok	ok	
7 September 2012	2012251	ok	ok	
8 September 2012	2012252	ok		
9 September 2012	2012253	ok	ok	
10 September 2012	2012254	ok	ok	
11 September 2012	2012255	ok	ok	
12 September 2012	2012256	ok		
13 September 2012	2012257	-	-	Cloud cover >75%
14 September 2012	2012258	-	-	Cloud cover >75%
15 September 2012	2012259	ok	ok	
16 September 2012	2012260	ok	ok	
17 September 2012	2012261	ok	ok	
18 September 2012	2012262	ok	ok	
19 September 2012	2012263	-	-	Cloud cover >75%
20 September 2012	2012264	ok	ok	
21 September 2012	2012265	ok	ok	
22 September 2012	2012266	ok	ok	
23 September 2012	2012267	ok	ok	
24 September 2012	2012268	ok		
25 September 2012	2012269	-	-	Cloud cover >75%
26 September 2012	2012270	-	-	Cloud cover >75%
27 September 2012	2012271	-	-	Cloud cover >75%
28 September 2012	2012272	-	-	Cloud cover >75%
29 September 2012	2012273	-	-	Cloud cover >75%
30 September 2012	2012274	-	-	Cloud cover >75%