APPLICATION OF NASA GIOVANNI TO COASTAL ZONE REMOTE SENSING RESEARCH

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ABSTRACT

The Goddard Earth Sciences Data and Information Services Center (GES DISC) Interactive Online Visualization ANd aNalysis Infrastructure (Giovanni) provides rapid access to, and enables effective utilization of, remotely-sensed data that are applicable to investigations of coastal environmental processes. Data sets in Giovanni include precipitation data from the Tropical Rainfall Measuring Mission (TRMM), particularly useful for coastal storm investigations; ocean color radiometery data from the Sea-viewing Wide Field-of-view Sensor (SeaWIFS) and Moderate Resolution Imaging Spectroradiometer (MODIS), useful for water quality evaluation, phytoplankton blooms, and terrestrial-marine interactions; and atmospheric data from MODIS and the Advanced Infrared Sounder (AIRS), providing the capability to characterize atmospheric variables. Giovanni provides a simple interface allowing discovery and analysis of environmental data sets with accompanying graphic visualizations. Examples of Giovanni investigations of the coastal zone include hurricane and storm impacts, hydrologically-induced phytoplankton blooms, chlorophyll trend analysis, and dust storm characterization. New and near-future capabilities of Giovanni will be described.

INTRODUCTION

The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) has created “Giovanni” (GES DISC Interactive Online Visualization ANd aNalysis Infrastructure) to facilitate rapid data exploration and basic data analyses using only a Web browser. Giovanni allows initial data examination and assessment without the need for specialty software packages or download of large data files in unfamiliar data formats.

Significant events in the coastal zone are highly dynamic, cover a range of spatial scales, and are frequently influenced by interactions of atmospheric, terrestrial and marine processes. Giovanni allows rapid and accurate characterization of remote-sensing observations for each of these data realms, allowing insight into the causes and effects of variability, unusual events, and trends in the coastal zone.

Ocean color radiometry data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Aqua satellite are featured in the Ocean Color Time- Series Project Giovanni interface (http://reason.gsfc.nasa.gov/Giovanni/). SeaWiFS data are available from September 1997, and the interface features monthly and 8-day Level 3 global data products, climatological anomaly analysis, and direct ordering of high-resolution daily swath data files. MODIS-Aqua data are available from July 2002 and features sea surface temperature (SST) data in addition to standard ocean color data products. Recent additions to the ocean color data sets in Giovanni are the Garver-Siegel-Maritorena (GSM) (1) merged chlorophyll, absorption coefficient of colored dissolved and detrital matter (a_{cdm}) and particulate backscatter coefficient (b_{bp}), and data output fields (including assimilated chlorophyll) from the NASA Ocean Biogeochemical Model (NOBM). The latter allows daily "under the clouds" data capability and model-based identification of major phytoplankton taxonomic groups.

Order capability from the Ocean Biology Processing Group (OBPG) data archive for high-resolution SeaWiFS and MODIS-Aqua daily data files is also available. Both Giovanni interfaces include image and ASCII text output. Ocean Color Giovanni includes the Multi-Dataset Intercomparison Interface, which allows multiple data product plots, scatter plots, and time correlation plots, for both SeaWiFS and MODIS-Aqua data.

Giovanni also includes data from the Tropical Rainfall Measuring Mission (TRMM), featuring 3-hour, daily, and monthly accumulated rainfall and rain rate. Although TRMM commenced observations in 1996, other precipitation data sets are available in Giovanni back to 1950. In addition to precipitation data, other data products from the TRMM Microwave Imager (TMI) are available. TRMM data allow important insight into precipitation events which may have major impacts on the coastal zone, such as sedimentation from floods; high-volume precipitation events due to tropical storms, cyclones, and hurricanes; and hazardous or noxious phytoplankton blooms induced by elevated nutrient concentrations in estuaries and nearshore zones due to increased flow from rivers and streams.

MODIS atmospheric data from the MODIS instruments on both the Terra and Aqua satellites are also provided for analysis in Giovanni. These data products include atmospheric aerosols (optical depth), smoke aerosols, and cloud coverage. Acker 2005 (2) used MODIS cloud data and SeaWiFS chlorophyll anomaly data to investigate the potential influence of cloud cover on the timing of the spring bloom in the eastern North Atlantic Ocean. MODIS aerosol optical depth data is highly useful to detect and observe the propagation of large desert dust storms which can influence open ocean and coastal marine processes a considerable distance from their origin.

Another Giovanni interface provides data from the Atmospheric Infrared Sounder (AIRS). AIRS data can provide additional meteorological variables to further characterize weather events impacting the coastal zone. Acker and Leptoukh 2007 (3) utilized AIRS and MODIS atmospheric data to create a four-dimensional characterization of a dust storm over the coast of Mauritania and Senegal.

METHODS

For this overview study, the Giovanni interfaces for ocean color data, MODIS atmospheric data, and TRMM precipitation data were utilized. Giovanni was used to produce area plots of several oceanic and atmospheric variables covering the Mediterranean Sea and for an event occurring on the Algerian coast. The time-series capability of Giovanni was also utilized for the Algerian coastal event. Data from a previous investigation of chlorophyll trends in various coastal regions, which utilized plotting and statistical analysis capabilities in Microsoft Excel, is also presented

The corner geographical coordinates for the Mediterranean Sea are 47.0°N and 30.0°N latitude, and 10.0°W and 38.0°E longitude. The corner geographical coordinates for the Algerian coastal event are 38.0° to 36.0°N latitude and 2.0° to 4.0°E longitude. For the chlorophyll trend analysis, regions in the North Sea, along the southern Mediterranean coast of France, and the northern Adriatic Sea are presented.

In each case, the spatial region of interest and the time period of interest were selected, and the desired data products then specified. Giovanni was then employed to generate the visualizations or data output for these data products.

RESULTS

Examination of the Mediterranean Sea in March 2005 with Giovanni

The month of March 2005 was chosen because it is a period of change in the Northern Hemisphere. Giovanni was used to generate several different views of the Mediterranean Sea, indicating a variety of coastal zone phenomena. Figures 1 and 2 show the MODIS-Aqua chlorophyll concentrations and climatological chlorophyll anomaly for March 2005. Increased chlorophyll concentrations southeast of Italy, west of Corsica and Sardinia, and off the coast of Algeria and Tunisia are positive anomalies, and south of Spain strong positive anomalies are noted.

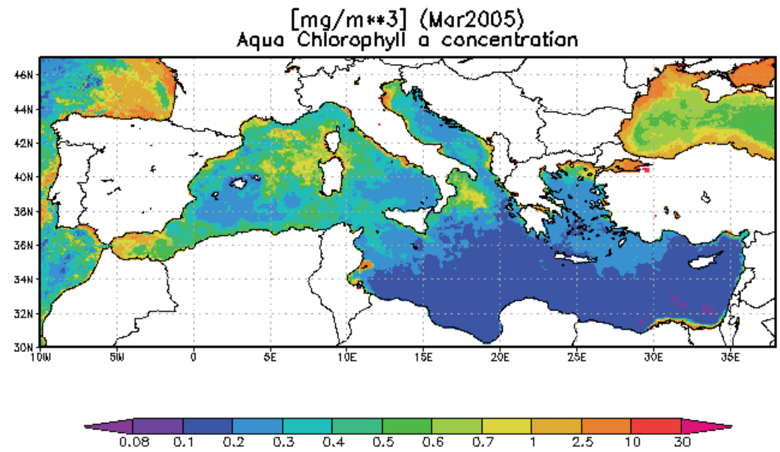

Figure 1: MODIS-Aqua chlorophyll a concentration area plot of the Mediterranean Sea for the month of March, 2005.

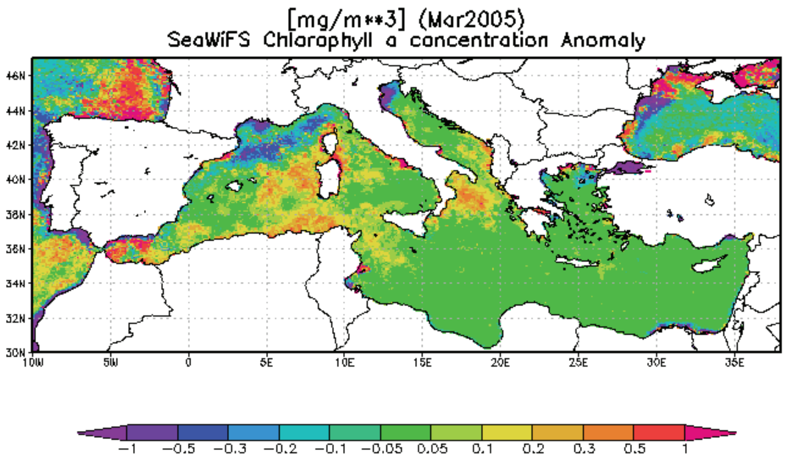

Figure 2: SeaWiFS climatological chlorophyll anomaly (base period September 1997-August 2006) of the Mediterranean Sea for the month of March, 2005.

Figure 3 is an area plot of MODIS-Aqua 11 μm (night) sea surface temperature for March 2005. Much cooler waters in the northern Black Sea are notable, compared to the warmer 12-18˚ C waters of the Mediterranean Sea.

This presentation also uses the newly-available GSM ocean optical products in Giovanni. Figures 4 and 5 show a_{cdm} and b_{bp} in the Mediterranean Sea for March 2005. The customized color scale option in Giovanni was utilized to enhance features of interest. Two significant areas of interest were noted; an area of increased a_{cdm} south of Spain, in the area with strong positive chlorophyll anomalies, which does not show a increased b_{bp} signal; and an area in the central northern Adriatic Sea, with elevated b_{bp} but no correspondingly elevated values of *chl a* or a_{cdm}. Close-up images of these areas are shown in Figures 6 and 7.

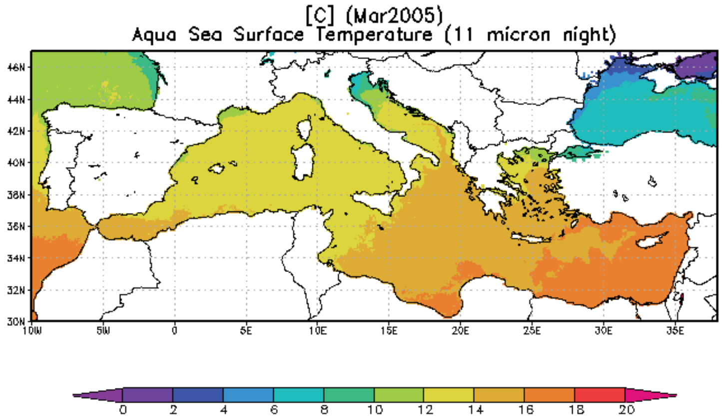

Figure 3: MODIS-Aqua 11 µm (night) sea surface temperature area plot of the Mediterranean Sea for March 2005.

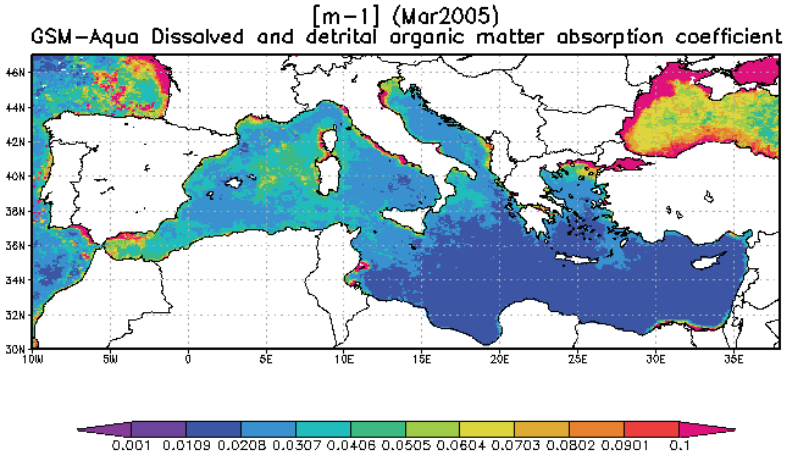

Figure 4: MODIS-Aqua a_{cdm} area plot of the Mediterranean Sea for the month of March 2005.

Initial interpretation of Figure 6 suggests that the elevated a_{cdm} values could be due to coastal upwelling of waters with increased chromophoric dissolved organic matter (*CDOM*), with the upwelling induced by the energetic water movement through the Straits of Gibraltar. Increased *CDOM* concentrations can cause erroneously high *chl a* retrievals. Initial interpretation of Figure 7 suggests that circulation in the northern Adriatic is transporting suspended sediments from the eastern coast of Italy (perhaps from Po River sediments) into the open waters of the Adriatic.

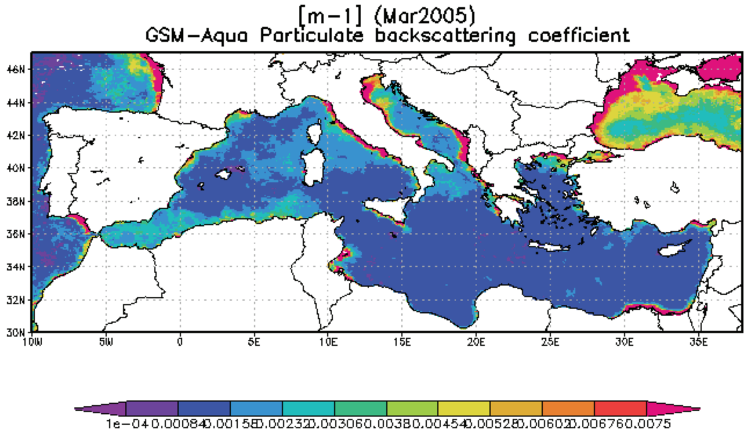

Figure 5: MODIS-Aqua b_{bp} area plot of the Mediterranean Sea for the month of March 2005.

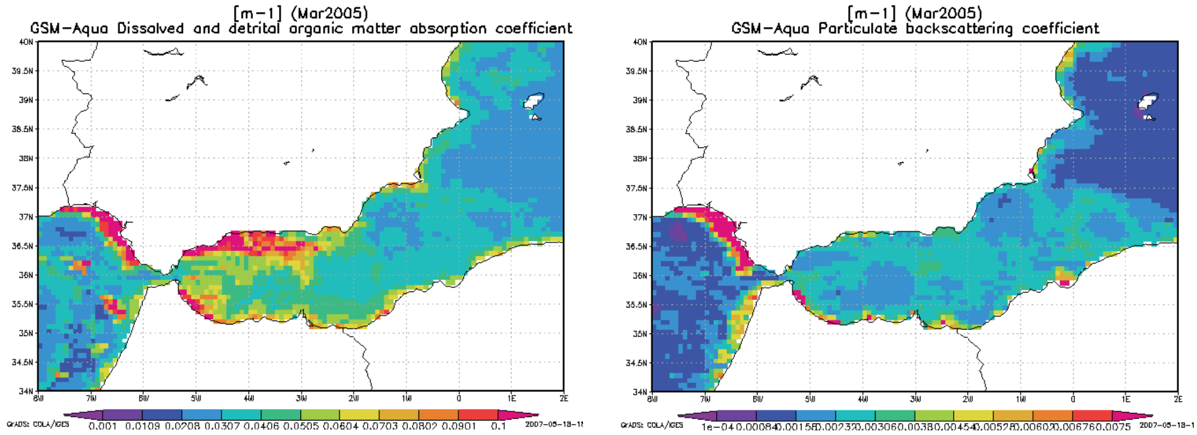

Figure 6: Area plots of a_{cdm} (left) and b_{bp} (right) for the coast of southern Spain and the Straits of Gibraltar (Alboran Sea) in March 2005. The elevated a_{cdm} feature, which does not have correspondingly elevated b_{bp}, also corresponds to strong monthly chlorophyll anomalies (Figure 2).

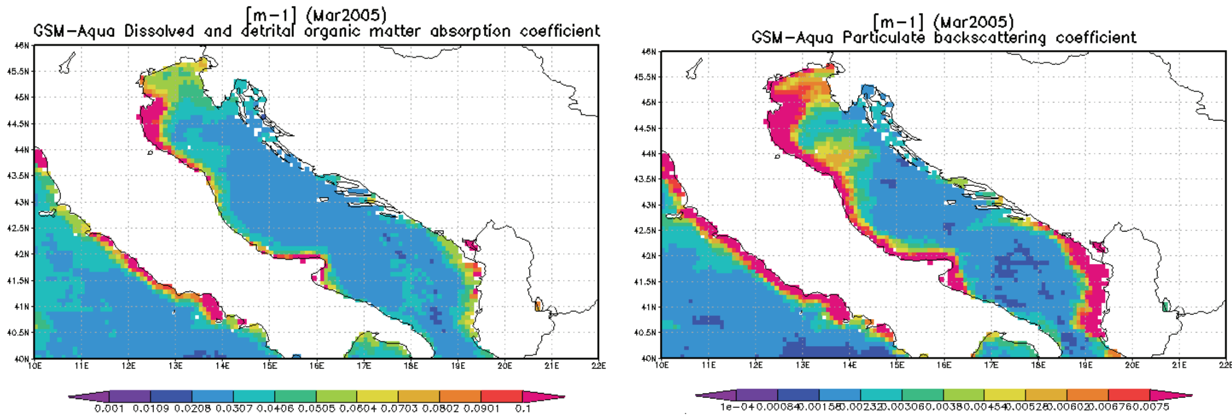

Figure 7: Area plots of a_{cdm} (left) and b_{bp} (right) for the Adriatic Sea in March 2005. In the northern Adriatic, an elevated b_{bp} feature lacking a correspondingly elevated a_{cdm} feature is seen emanating from the eastern coast of Italy into the open waters of the sea.

Giovanni was also used to characterize the atmospheric environment of the Mediterranean Sea during March 2005, primarily utilizing the aerosol optical depth at 865 or 869 nm (τ_{865}, τ_{869}) variable which is provided as an ocean color data product. The MOVAS (MODIS Online Visualization and Analysis System) Giovanni interface features MODIS atmospheric products, including aerosol optical depth at 0.55 µm, which could also be utilized for this purpose. At this time, however, it is not possible to generate climatological anomalies with the MOVAS interface (anomaly capability is being added to the Giovanni-3 system, in development).

Figures 8, 9, and 10 show the monthly MODIS-Aqua τ_{869} area plot for the Mediterranean Sea in March 2005, a SeaWiFS 8-day τ_{865} area plot for the period March 30-April 6, and a SeaWiFS climatological anomaly plot of τ_{865} for March 2005. The color scale was adjusted in Figure 10 to emphasize positive anomalies, which were actually small for this month, but which indicate the likely influence of dust from the deserts of northern Africa over the southeastern Mediterranean.

To complete this examination of the Mediterranean Sea environment, Figure 11 provides accumulated rainfall data from the Tropical Rainfall Measuring Mission for March 2005, and Figure 12 provides MODIS-Aqua cloud fraction percentage for March 2005.

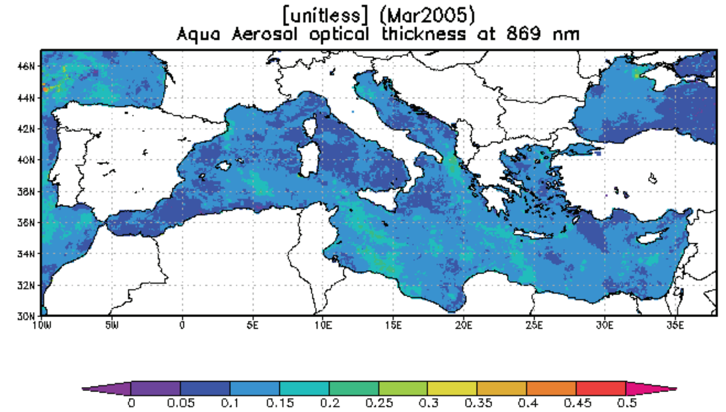

Figure 8: MODIS-Aqua τ_{869} area plot of the Mediterranean Sea for March 2005.

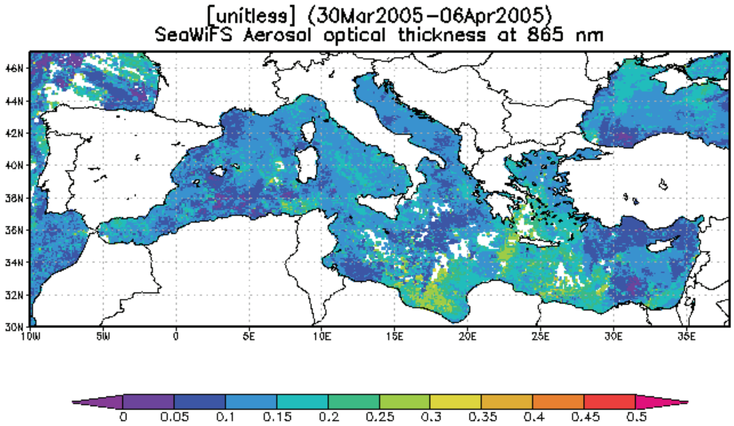

Figure 9: SeaWiFS τ_{865} area plot of the Mediterranean Sea for March 2005.

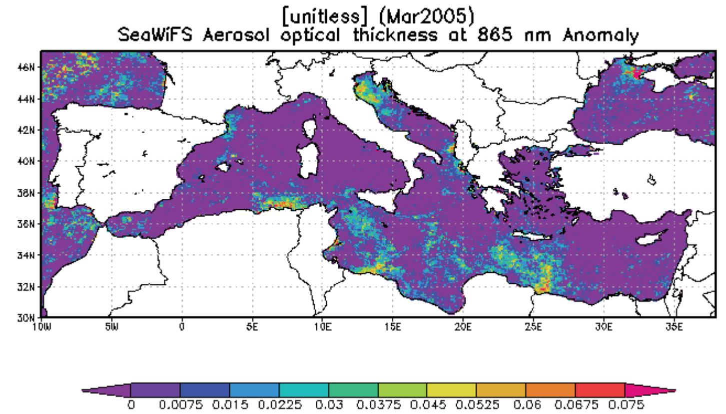

Figure 10: SeaWiFS τ_{865} positive monthly climatological anomaly area plot of the Mediterranean Sea for March 2005, showing the influence of desert dust aerosols in the central and eastern Mediterranean. Also note positive anomalies in the northern Adriatic Sea.

Examples of statistical time-series analysis utilizing Giovanni

Acker et al. 2006 (4) presented a compilation of twenty regional coastal areas which were examined with the Giovanni time-series function and SeaWiFS chlorophyll data. The ASCII text output for each of these regions was imported into a Microsoft Excel spreadsheet, which allowed the generation of time-series plot with linear fit slopes and calculation of the significance P-value. A P-value of .05 indicates trend significance at the 95% confidence level.

For this presentation, examples of three of the areas examined in Acker et al. 2006 are provided: the North Sea, the Mediterranean coast of France, and the northern Adriatic Sea. Figure 13 shows the locations of the areas examined (areas 17, 19, and 20, respectively). Figures 14-16 show the time-series analysis plots created with Microsoft Excel.

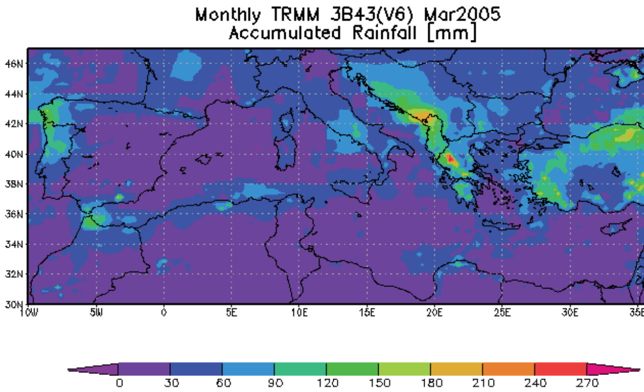

Figure 11: TRMM accumulated rainfall area plot of the Mediterranean Sea for March 2005.

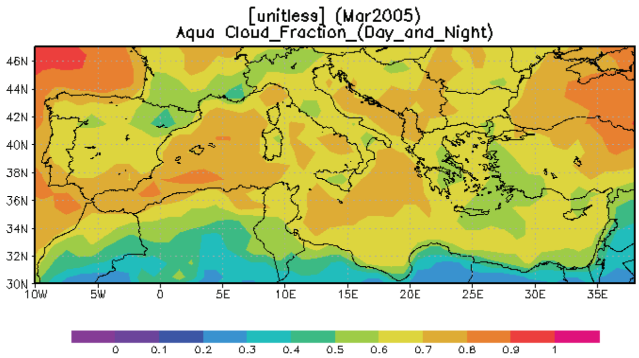

Figure 12: MODIS-Aqua cloud fraction area plot for the Mediterranean Sea for March 2005.

Of the three areas examined, the northern Adriatic was the only one exhibiting a statistically significant trend – in this case, an intriguing negative trend. The North Sea area had a noticeable trend that did not attain the 95% confidence level. The southern coast of France, while exhibiting strong and regular seasonality, did not exhibit a trend.

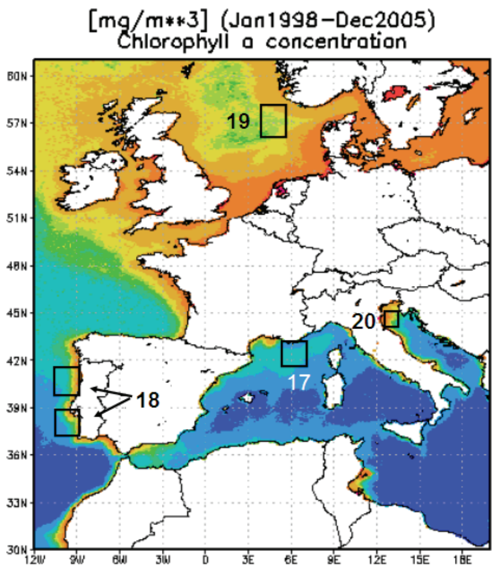

Figure 13: Areas for which time-series of chlorophyll concentration were analyzed in Acker et al. 2006. Time-series plots for areas 17, 19, and 20 are shown in Figures 14-16.

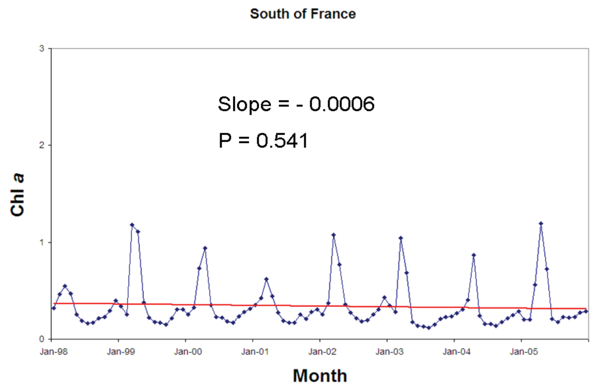

Figure 14: Giovanni and Microsoft Excel time-series analysis of SeaWiFS chlorophyll data for the southern coast of France, area 17.

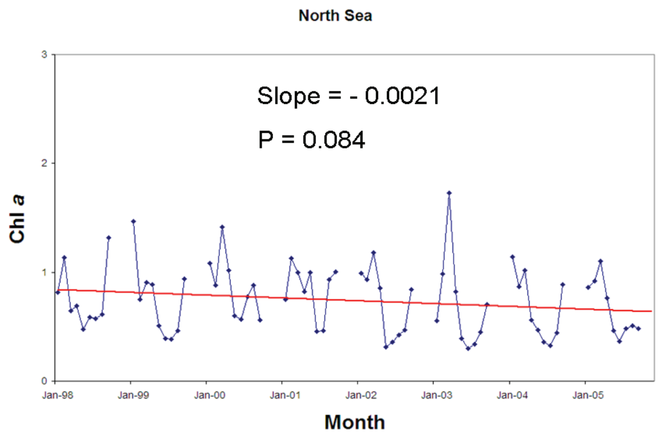

Figure 15: Giovanni and Microsoft Excel time-series analysis of SeaWiFS chlorophyll data for a region in the North Sea near the coast of Norway and the Skagerrak, area 19. Missing data is due to lack of coverage during winter months.

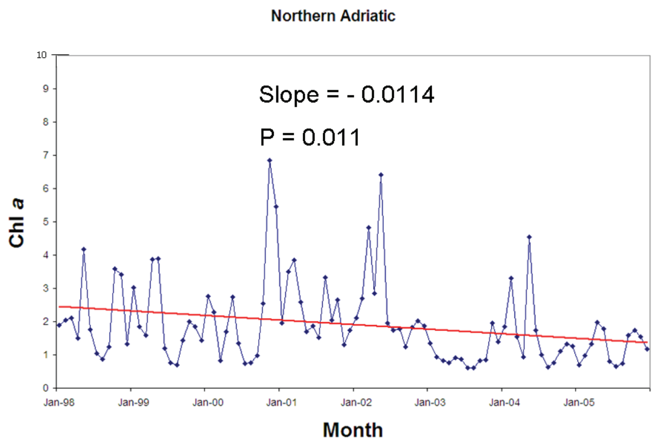

Figure 16: Giovanni and Microsoft Excel time-series analysis of SeaWiFS chlorophyll data for the northern Adriatic Sea, region 20.

Giovanni analysis of the "Bad Bloom Rising" event on the coast of Algeria, August 2003

In August 2003, members of the MODIS "Rapid Response" team at NASA Goddard Space Flight Center, who examine MODIS imagery for significant geophysical events, noticed an oceanic feature emanating from the coast of Algeria near the city of Algiers. These images were shown to members of the GES DISC and the Ocean Biology Processing Group (OBPG), which is responsible for SeaWiFS and MODIS-Aqua ocean color data processing. Examination of these figures and images preceding the event, and a perusal of international news reports, indicated that a significant area of storms had influenced the region just prior to the observation of the feature. This information led to the tentative identification of the feature as a runoff-induced phytoplankton bloom, likely stimulated by nutrients contained in storm runoff into the Bay of Algiers. Images of this event are shown in Figure 17. This event is described in the Web article "Bad Bloom Rising" (5), available in the Ocean Color *Science Focus*! section of the GES DISC Web site.

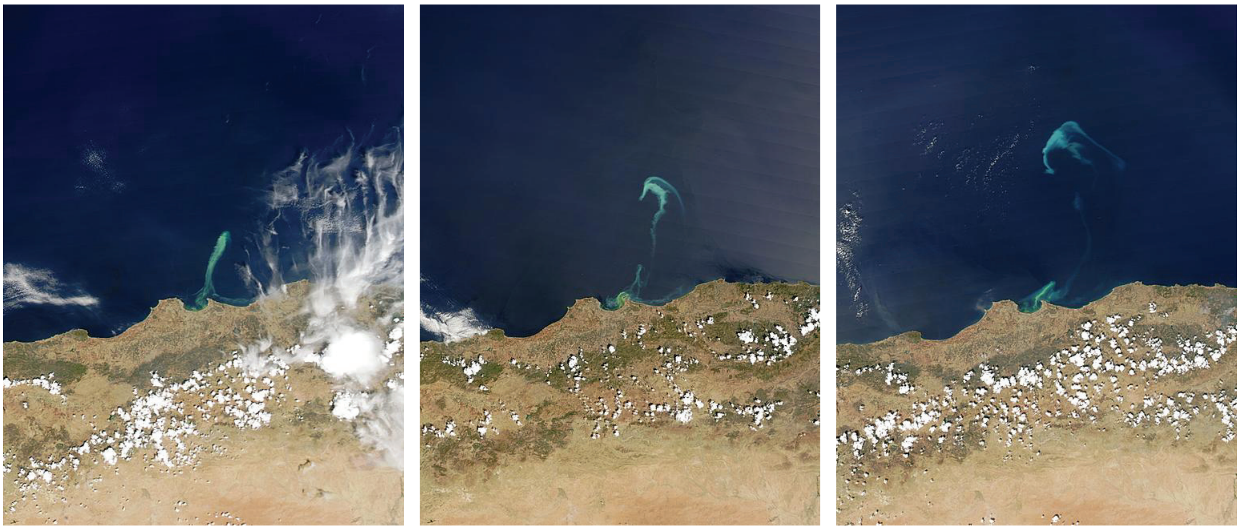

Figure 17: MODIS true-color images of a short-lived bloom off the coast of Algeria, emanating from the Bay of Algiers following a storm event. The images are from August 11 (left), August 12 (center), and August 13 (right).

For this presentation, Giovanni was utilized to provide additional quantitative details of this event. Daily precipitation data from the Tropical Rainfall Measuring Mission was examined to determine the quantity of rainfall which generated the feature. Figure 18 shows an area plot of accumulated rainfall for August 7-10, and Figure 19 displays a time-series of accumulated rainfall for the period June-September 2003. Note that because accumulated rainfall is averaged over the entire selected region, the time-series values are much less than the point data shown in the area plot. The time-series demonstrates that the August rainfall event was the first noteworthy rainfall for this region that summer, which is not an unexpected observation in this desert region. The highest rainfall values, occurring just to the east of the Bay of Algiers, are 24-27 mm.

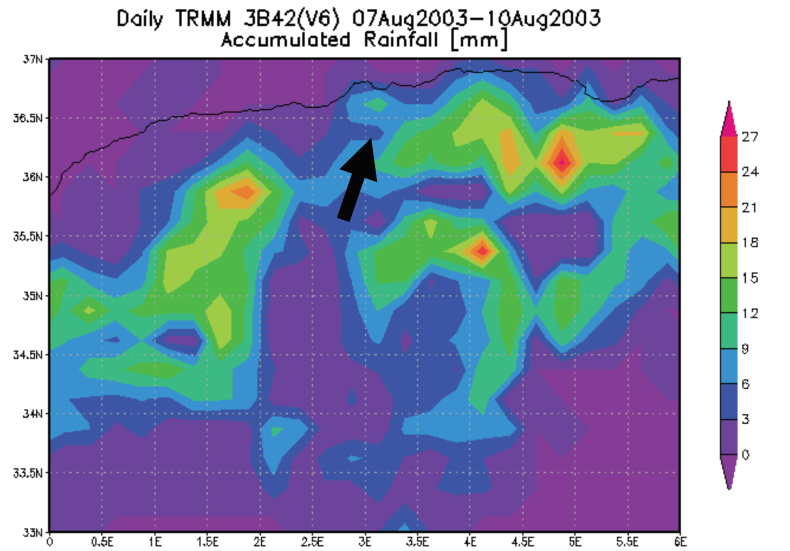

Figure 18: Area plot of accumulated rainfall from TRMM data, August 7-10, 2003, in northern Algeria. The arrow indicates the location of the Bay of Algiers.

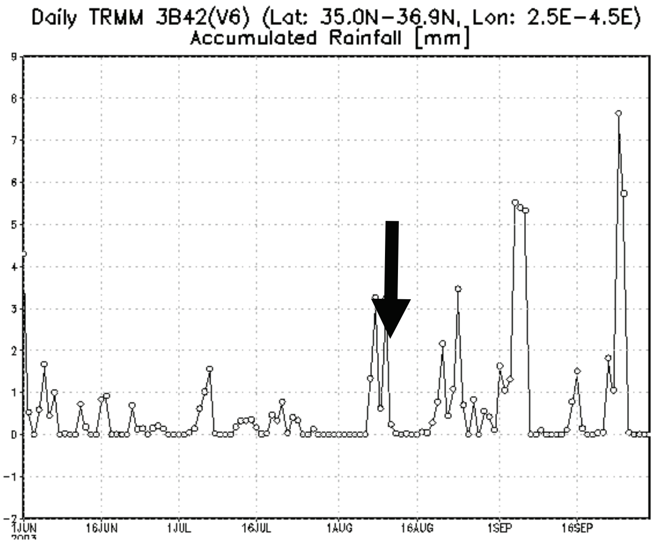

Figure 19: Accumulated rainfall time-series for June –September 2003 in northern Algeria. The arrow indicates the rainfall event which generated the short-lived bloom.

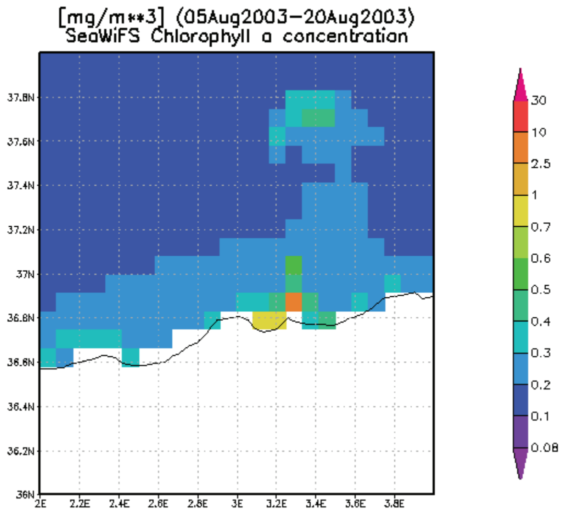

Figure 20: SeaWiFS chlorophyll concentration data averaged over the period August 5-20, 2003 utilizing two consecutive 8-day SeaWiFS data files in Giovanni.

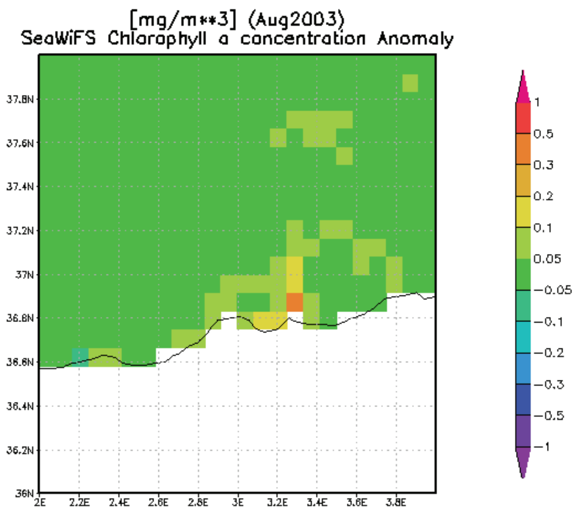

Figure 21: SeaWiFS monthly chlorophyll concentration anomaly for August 2003 near the coast of Algeria, showing the detection of the bloom event as a positive chlorophyll anomaly.

SeaWiFS chlorophyll and climatological chlorophyll anomaly data were examined to determine how well this event was captured in the 9km resolution data utilized by Giovanni. An area plot of chlorophyll concentrations averaged over the two 8-day intervals which included the event dates was created from SeaWiFS 8-day data files (Figure 20). The monthly climatological chlorophyll anomaly function clearly shows this event as a positive anomaly, even though the anomalies are calculated for the entire month. Because the Mediterranean Sea adjacent to the coast of Algeria is hightly oligotrophic, this small and short-lived event generated chlorophyll concentrations so much higher than normal that it is detectable in the monthly climatological chlorophyll anomaly area plots (Figure 21).

CONCLUSIONS

One of the concerns of Giovanni users interested in coastal zone applications is the 9 km resolution of the ocean color data sets featured in Giovanni. Although small-scale coastal phenomena will not be observable with these data sets, Giovanni provides excellent regional coverage into which higher-resolution data can be incorporated contextually. The examination of the Mediterranean Sea given in this presentation indicates how readily (and rapidly) ocean color data and other data types can be used to characterize a regional oceanic environment.

The unprecedented length of the SeaWiFS chlorophyll concentration data set now allows Giovanni to produce time-series analyses accompanied by relevant statistical variables. We believe that this capability should be exploited by coastal zone researchers, local and regional governments, and agencies concerned with coastal zone issues to establish a remotely-sensed ocean optical "baseline" for their region of interest and to relate it to other monitoring and measurement efforts.

Our analysis of the "Bad Bloom Rising" event indicates that short-lived phenomena occurring on moderate spatial scales can be analyzed with the current Giovanni system. Future development of Giovanni may allow the utilization of higher-resolution data products "custom-made" for Giovanni, and enable multi-dataset intercomparison capability with several different data sets from NASA remote-sensing missions.

ACKNOWLEDGEMENTS

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REFERENCES

1. Maritorena S & D A Siegel, 2005. Consistent Merging of Satellite Ocean Color Data Sets Using a Bio-Optical Model. Remote Sensing of Environment, 94(4): 429-440.
2. Acker J G, S Shen, G Leptoukh, S Berrick, H Rui, Z Liu & T Zhu, 2005. Spatial and Temporal Coherence of SeaWiFS Chlorophyll Concentration Anomalies in the North Atlantic Bloom (1998-2005) Examined with Giovanni. Eos, Trans. AGU, 87(36), Ocean Sci. Meet. Suppl., Abstract OS45N-03.
3. Acker J G & G Leptoukh, 2007. Online Analysis Enhances Use of NASA Earth Science Data. Eos, Trans. AGU, 88(2), pages 14 and 17.
4. Acker J, W Gregg, G Leptoukh, S Kempler, G Feldman, C McClain, W Esaias & S Shen, 2006. Use of Giovanni with Ocean Color Time-Series Project Data for Trend Detection in the Coastal Zone. In: Proc. Ocean Optics XVIII, October 9-13, 2006, Montreal, Canada.
5. "Bad Bloom Rising", Goddard Earth Sciences Data and Information Services Center, http://daac.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/bad_bloom.shtml