Detection of Mesoscale Eddies in the eastern Caribbean Sea using sea water bio-optical properties

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ABSTRACT – Mesoscale eddies are large circulations currents in the ocean which can transport heat, salt and other properties of the ocean like kinetic energy. The principal objectives for this study is determine if mesoscale eddies can be detected in the eastern Caribbean Sea using bio-optical properties of the sea water. To determine the presence of mesoscale eddies in the eastern Caribbean Sea *in situ* data from drifters is used. The case study analyze corresponds to March 20 to 30, 2015 among the coordinates 16°N to 18°N and -67.5°W to -69°W. To detect chlorophyll concentration and identify circulation properties in mesoscale eddies data from MODIS is considered. SST from AVHRR was used to determine if this parameter is a good mesoscale eddy tracker. Some concentrations of chlorophyll_a was identified in the area of interest but any circulation was able to be confirmed.

KEYWORDS – mesoscale, eddy, chlorophyll_a, sea surface temperature

INTRODUCTION

The Meteorological Glossary of the American Meteorological Society defines *eddies* as the result of the turbulence of the oceanic circulation common throughout the World Ocean. Mesoscale eddies are large circulations currents in the ocean which can transport heat, salt and other properties of the ocean like kinetic energy. Mesoscale eddies can have diameters of hundreds of kilometers and their influence in the ocean can extend to depths of 1000 m or greater (Corredor et al, 2004). Their presence in the ocean can persist for periods of days to months.

As has been shown in the Caribbean, they can have anticyclonic or cyclonic circulation. This circulation can be detected due to the depressions or elevations formed as they spin. Oceanic cyclonic eddies have a shallow thermocline at the center and are therefore also known as cold-core eddies; anticyclonic eddies are associated with a depressed thermocline in the center and are also known as warm-core eddies.

In 2003 Corredor, et. lead The Caribbean Vorticity Experiment (CaVortEx I), here the authors characterize the physical, biogeochemical, and optical structure of the eddy and the Orinoco River Plume on biological productivity. The optical properties of the cyclonic eddy observed in MODIS reveals that, while the oceanic water of the eddy core exhibited low optical absorption and turbidity, near-surface waters of the surrounding river plume were not only more turbid, they exhibited sharply increased light absorption of the shorter wavelengths (blue and ultraviolet), a property characteristic of highly colored dissolved organic matter (CDOM) waters. More evidence of this work were published later in “Cyclonic Eddy Entrains Orinoco River Plume in Eastern Caribbean” in 2004.

To detect chlorophyll concentration and identify circulation properties in mesoscale eddies data from MODIS Aqua is used. The variety of wavelength and amount of bands designed for ocean color analysis make MODIS images a good source of information for this study. Once obtained, images will be processed with ENVI program and spectral bands combinations and other tools will be applied to complete the processing required.

The principal objectives for this study is determine if mesoscale eddies can be detected in the eastern Caribbean Sea using bio-optical properties of the sea water. For this we identify a significant event of mesoscale eddies in the eastern Caribbean Sea using *in situ* data from drifters and detect the presence of these systems using chlorophyll_a images from MODIS sensor and sea surface temperature (SST) images from AVHRR. Then we compare the results and conclude if the parameters and the sensors used are goods trackers of mesoscale eddies systems in the eastern Caribbean Sea

MATERIALS AND METHODS

In Situ data

To select the case study we identify a significant event of mesoscale eddies in the eastern Caribbean Sea using *in situ* data from drifters. The event corresponds to March 20 to 30, 2015. These data was retrieved from CariCOOS drifters equipment (Figure 1). These instruments use inexpensive GPS trackers to delineate the trajectory of a water parcel, which helps to understand ocean surface currents. This device have an antenna at the top which detect his position (GPS) in function of time, with this parameter the current velocity can be derived. Therefore, drifters are oceanographic devices that float on the surface water in a Langragian manner.

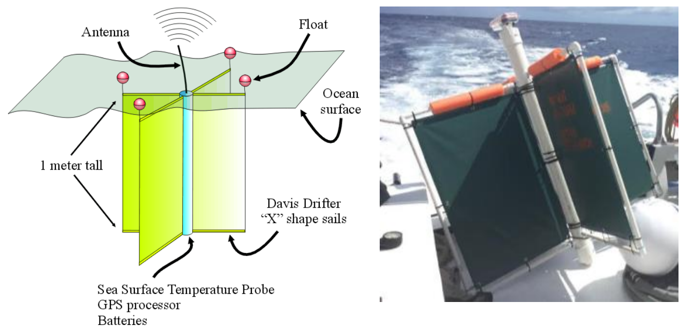

FIG. 1. CariCOOS drifter instrument used to collect *in situ* surface current data.

Images

The images selected to analyze the concentration of chlorophyll_a corresponds to the Moderate Resolution Imaging Spectroradiometer sensor (MODIS). This is a 36 bands multispectral sensor with 1km spatial resolution to ocean color images. The data was downloaded from the NASA’s Ocean Color Web available online and manipulated using SeaDAS image analysis program completing the following steps:

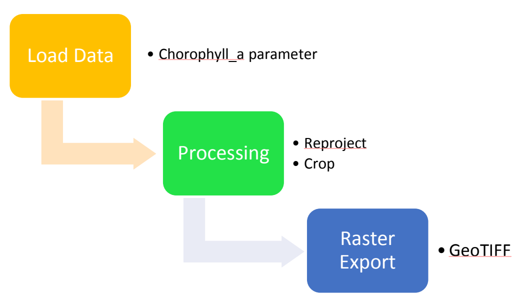

FIG. 2. Process completed in SeaDAS for MODIS chlor_a image.

The sea surface temperature images was obtain from the Advanced Very High Resolution Radiometer (AVHRR). This sensor have 5 bands and 1km spatial resolution. The images was downloaded from the NOAA Comprehensive Large Array-data Stewardship System (NOAA Class) data base. To analyze the SST from AVHRR the ENVI software was used.

Using ENVI 5.1 toolbox the AVHRR image was calibrated using as input the band 2. This band corresponds to the near infrared and was designed to determine land-water boundaries. The SST was calculated using the algorithm designed by ENVI in the raster management toolbox. Then a mask for land was created and applied to each image and finally georeferencing was applied. Using the MODIS chlor_a image a subset for the study area was generated.

In ENVI Classic the tool Quick Map was used to apply color table, add color ramp and save as JPEG format. The following is a resume of the steps completed:

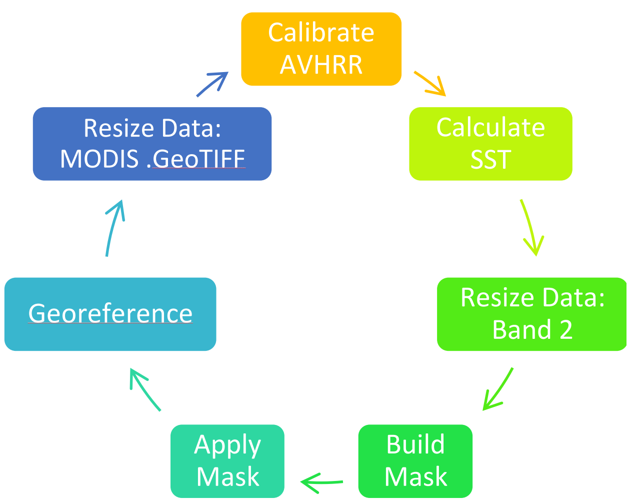

FIG. 3. Summary of the process completed in ENVI 5.1 for the SST AVHRR image.

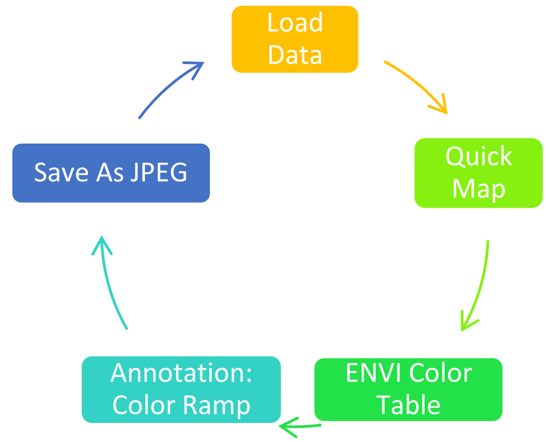

FIG. 4. Summary of the process completed in ENVI Classic for the SST AVHRR image.

RESULTS AND DISCUSSION

The *in situ* data from drifters reveals the presence of a mesoscale anticyclone among the coordinates 16°N to 18°N and -67.5°W to -69°W between March 20 and March 30, 2015 (Figure 5). Having identifying this event, images for a period of 11 days was considered but only images for 3 of these 10 days was acceptable. The reasons are shown in table 1. The data analyzed corresponds to March 20, 21 and 26 of 2015 because in order to make good comparisons and detect mesoscale eddies, images must be for the same day. Also the spatial resolution in the sensors was considered, MODIS and AVHRR have 1km resolution.

Figure 6 correspond to the results obtained for March 20, 2015. Image A is the chlor_a concentration by MODIS, image B is the SST as measured by AVHRR, C is the MODIS image manipulated in ENVI and D is chlor_a and SST layer stacking. The black spots in image A, B and D corresponds to the land and cloud mask applied, in image C the mask applied is in white.

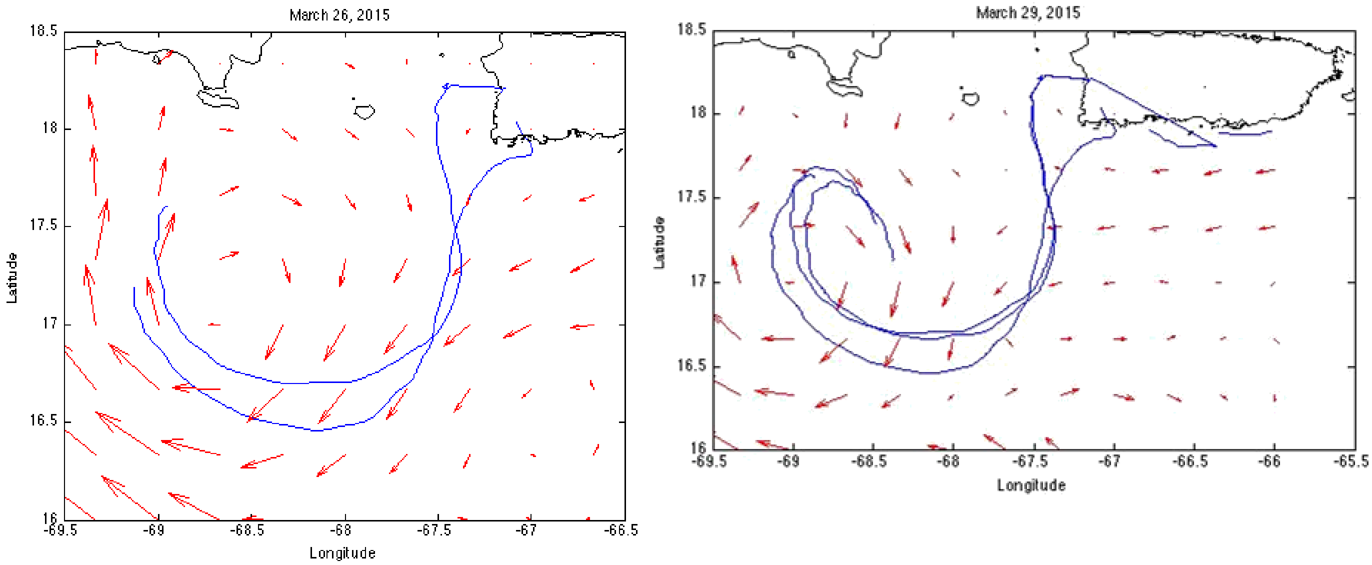

FIG. 5. Drifter data results for March 26, 2015 and March 29, 2015. The vectors in red color represents the surface current direction. Each blue line is a drifter released from the southwest coast of Puerto Rico.

TABLE 1. List of the reasons why the images were not considerate. In order to be considerate both images has to be "Ok".

Date	Julian Date	MODIS	AVHRR
March 20	079	Ok	Ok
March 21	080	Ok	Ok
March 22	081	Sunglint	Ok
March 23	082	Sunglint	Ok
March 24	083	Area	Sunglint
March 25	084	Sunglint	N/A
March 26	085	Ok	Ok
March 27	086	Sunglint	Area
March 28	087	Ok	Sunglint
March 29	088	Area	Clouds
March 30	089	Clouds	Sunglint

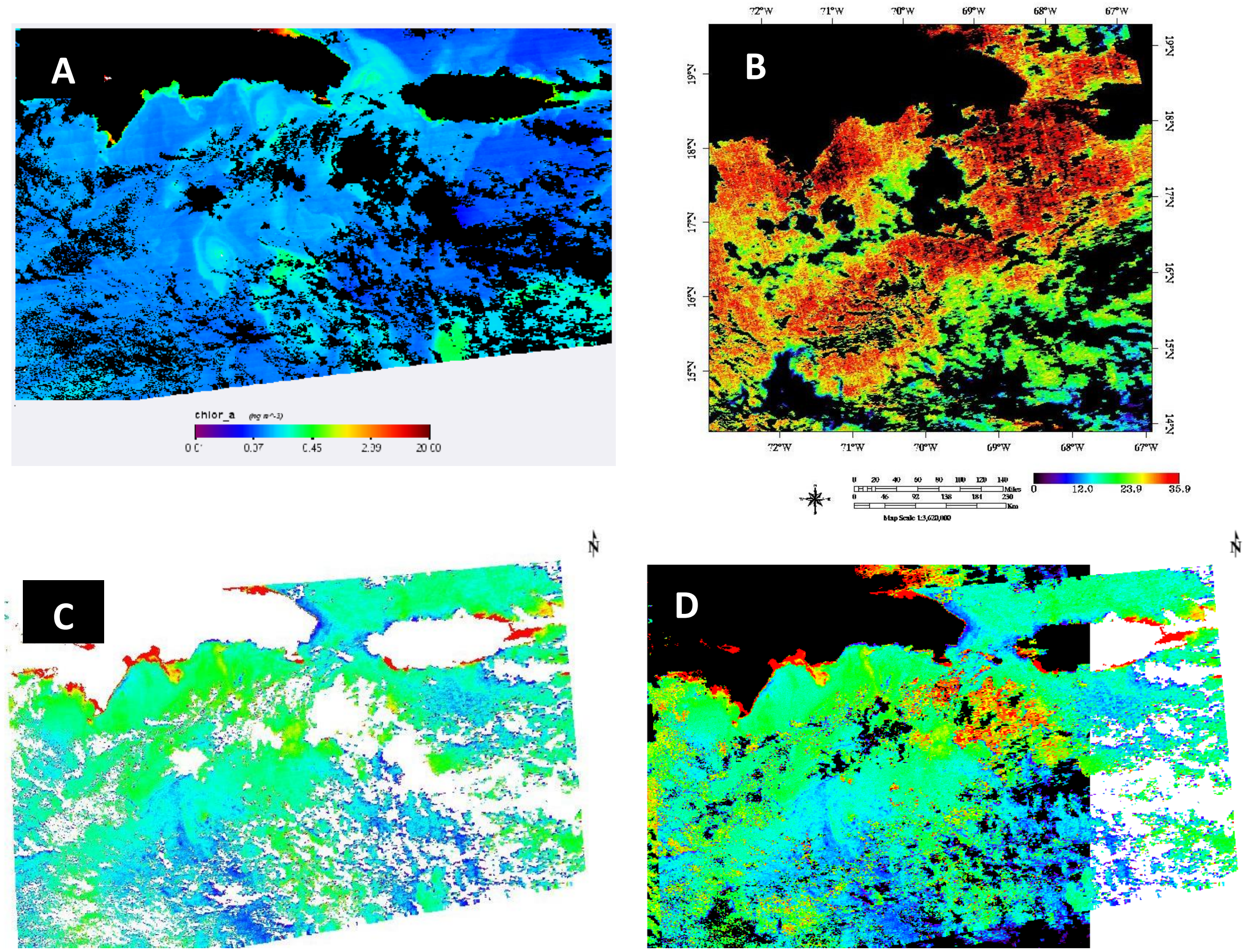

FIG. 6. Results for March 20, 2015. A is chlor_a as measured by MODIS, B is SST as measured by AVHRR, C is chlor_a band 8 to 16 spectral subset in ENVI and D is chlor_a spectral subset and SST layer stacking.

Green, yellow and red colors in image A represents chlor_a presence. As can see some circulations can be detected in the south region of Dominican Republic and trough the Mona Passage. Even though concentrations of chlor_a can be identified, determine the exact circulation it is not possible. The SST have a range of values between 0 and 35.9°C where the red color implies higher temperature. The mean value of temperature was near 24°C, the temperature expected in this region in this season. In images B, C and D any circulation or mesoscale eddy can be detected, the clouds presence prevents it.

The same parameters was analyzed for March 21, 2015 (figure 7). In this case the chlor_a concentration shows the Orinoco river plume and the concentrations identified in the previous chlor_a image persists. Again any mesoscale eddy circulation cannot be detected in images B, C and D.

For March 26, 2015 only the chlor_a and the SST are compare with the in situ drifter data. For the anticyclone mesoscale eddy considered this is supposed to be his peak, as can see in both images the presence of clouds in this exact point were the eddy is supposed to be, does not allow to saw it.

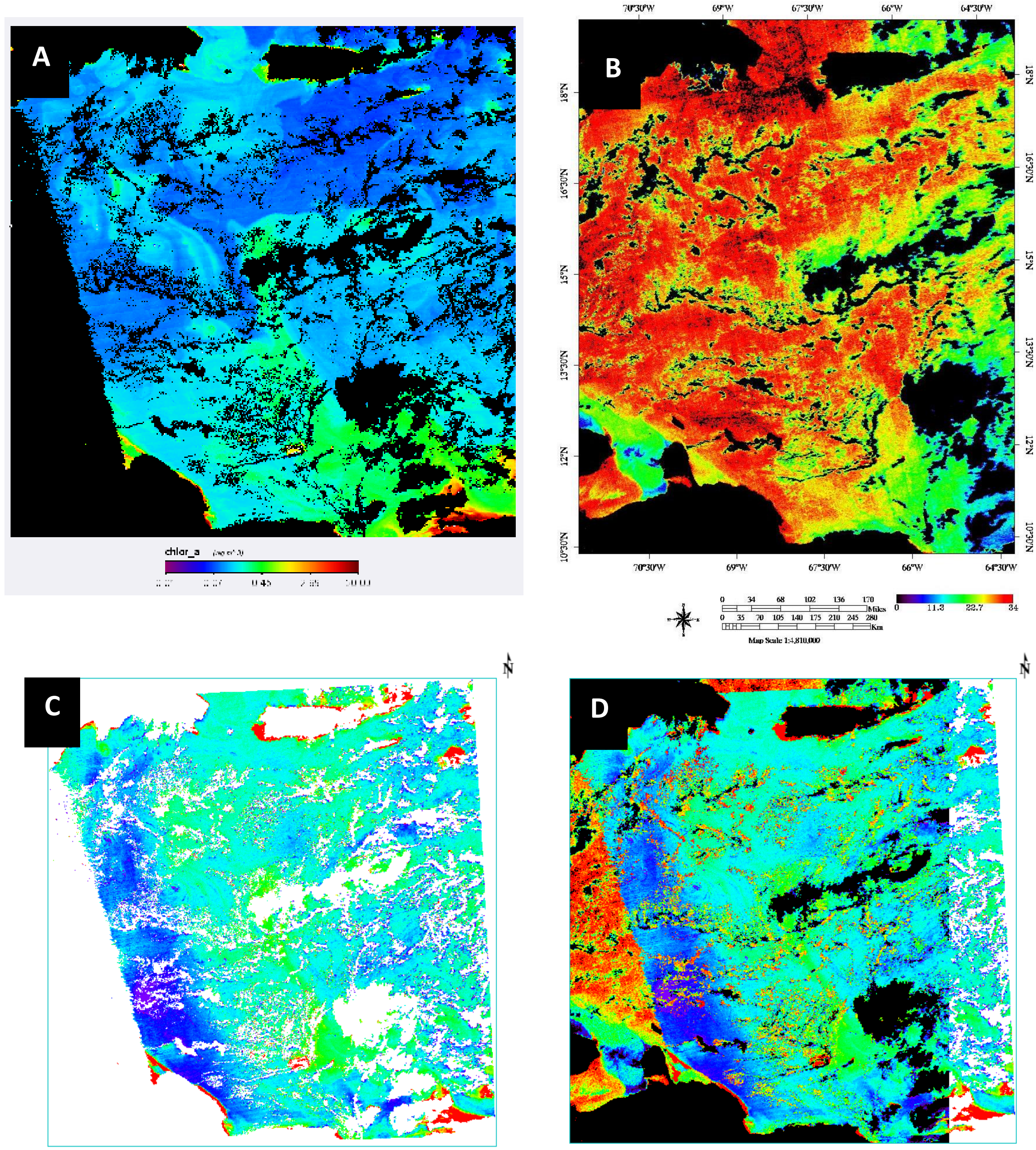

FIG. 7. Results for March 21, 2015. A is chlor_a as measured by MODIS, B is SST as measured by AVHRR, C is chlor_a band 8 to 16 spectral subset in ENVI and D is chlor_a spectral subset and SST layer stacking.

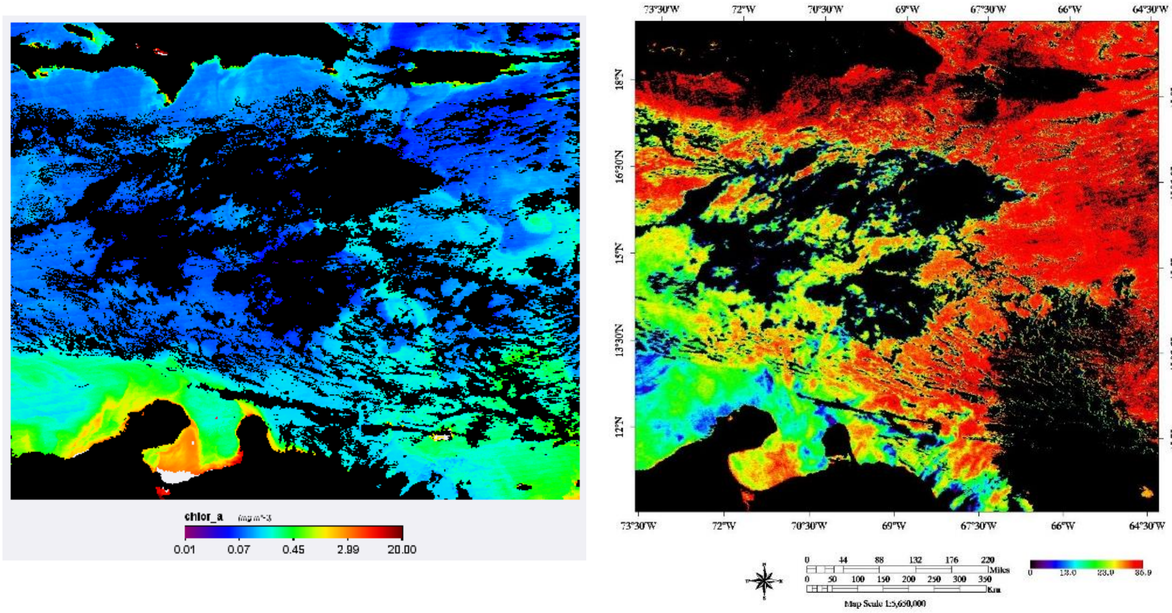

FIG. 8. Results for March 26, 2015. A is chlor_a as measured by MODIS and B is SST as measured by AVHRR.

CONCLUSIONS

The images analyzed from MODIS demonstrate be good indicators of the presence of chlor_a. Some concentrations was identified in the area of interest but any circulation was able to be confirmed.

It is known that anticyclonic mesoscale eddies are associated with a depressed thermocline in the center and are also known as warm-core eddies. By this circulation the thermocline is pushed downwards and the sea surface is slightly raised within the eddy as it propagates westward. Oppositely, cyclonic mesoscale eddies have a shallow thermocline at the center. This circulation raise the thermocline and nutrients move to the surface. Based on this, we should have seen a difference in the images of SST, but it was not. The SST was relatively constant in all the images analyzed.

In conclusion, circulations for mesoscale eddies cannot be identified in the SST images presented. For a better analysis more images needs to take in consideration. An average for all the products considered initially in table 1 would provide better results. Create enhancements with multiple images, consider others temperatures sensor or use other parameters, as altimetry or salinity, may be considered as future work.

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