

# ***Interactive comment on “Effect of Caribbean Water Incursion into the Gulf of Mexico derived from Absolute Dynamic Topography, Satellite Data, and Remotely – sensed Chlorophyll-*a*” by J. A. Delgado et al.***

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Received and published: 21 September 2019

We would like to thanks the reviewer for the positive criticism and recommendations. Below you find a point-by-point response to all comments.

QR2-There is a lack of discussion regarding previous studies, which referrer to the seasonal cycle of the LC, like Chang & Oey (2012, 2013), which expose a bimodal cycle obtained with model outputs; Hall & Leben (2016), which show an annual cycle with altimetry data; or Candela et al. (2019), which estimate the amplitude of the

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seasonal cycles of the transport at Yucatan Channel and at the Strait of Florida using mooring observations. Those works, among others, must be at least mention in the introduction and their findings should be discussed with what was found in this MS.

ANSWER: About the lack of discussion regarding previous studies which referer to the seasonal cycle we add in L98-105: “Loop current extension and anticyclonic eddy separation are the result of the momentum imbalance (Pichevin & Nof, 1997) and form the shape of future LCEs. Chang and Oey (2010) using a numerical model, proposed that the wind stress could be the primary forcing that releases LCE’s. In a second paper, supported by satellite observations, they proposed that the LC intrusion and the shedding of the LCE’s followed a biannual cycle (Chang and Oey, 2013). Recently, Candela et al (2019) analyzed four years of water current data and reported a seasonal cycle in the transport through the Yucatan channel with the annual cycle as the main harmonic peak in July and the semiannual peaks January and July”.

QR2-The conclusion regarding the decrease of Chl-a concentrations in the western Gulf of Mexico (GoM), where the authors state that there is a reduction due to a larger volume of waters coming from the Caribbean Sea toward the GoM, should be taken with caution and considers/discuss the limitations of the data series used for this conclusion. There are other sources that could contribute to a reduction in Chl-a in the western GoM. It is not obvious to me what the authors state with the footprint of the CW/LC path, in the Chl-a climatological patterns (Fig. 11).

ANSWER: We agree with the reviewer and we add in L441 to L446. “Our result and conclusions are based on SeaWifs and Aquamodis chlorophyll data, which in Type One water, correlate very well with chlorophyll measured with standard laboratory methods (Mati Kahru, personal communication). In our work we can only say that according to these satellite "products", we find a time-dependent diminution of the chlorophyll signal. This diminution has been widely observed by others in other waters (Behrenfeld et al., 2006, Polovina et al., 2008; Irwin and Oliver, 2009, Laffoley & Baxter., 2016)” About the state with the footprint of the CW/LC path, in the Chl-a climatological patterns

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(Fig. 11) we agree and we improve the line as follow: “During spring-summer, when the maximum CW penetration occurs, our data confirms that the footprint of the CWF water (delineated by the 40 cm isoline of ADT) is in general oligotrophic indicating that Caribbean water has indeed entered the GoM”.

QR2-The MS need to focused to highlight the relevant contributions.

ANSWER: The MS highlight the relevant contributions thanks to all the recommendations.

QR2-Additionally, statistical relevance of the seasonal cycle needs to be deeply discussed; it is necessary to specify how representative are the climatological averages (Fig. 1), obtained from the monthly averages of the individual years (using information from Fig. 4).

ANSWER: We improve section 3.1 but also we rewrote section 3.2 which includes discussions about seasonality.

QR2-Description of section 3.2 (lines 229 – 262 and lines 271 – 280) needs to be rewrite in order to guide the reader to the months of the year that the authors are talking about (maybe a Table will be useful); What is the main message given by all these numbers and description? Besides, there need to be an agreement between the months of the year with the LC extension/retraction throughout the MS.

ANSWER: All section 3.2 was rewritten and throughout the MS we are careful to connect the months of the year with the LC extension/retraction.

Specific comments QR2-The MS focus the discussion on the oligotrophic CW intruding the GoM owing to the Loop Current. Therefore, the description of the water masses that conform the GoM, must be introduced and supported by additional bibliography, aside from Nowlin & McLellan (1967), since the reference of Schmitz (2005) is not referred to water masses composition. Further Tanahara (2004), cannot be consulted.

ANSWER: We introduce the description of the water masses that conform the GoM as

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follow in L74 to L79 (In addition, the reference Tanahara (2004) was deleted from the manuscript): “Based on a detailed analysis of the central and western GoM by Portela (2018), within the gulf there are seven water masses: remnants of the Caribbean Surface Water (CSWr: also referred to as CW), North Atlantic Subtropical Underwater (NASUW), Gulf Common Water (GCW), Tropical Atlantic Central Water (TACW), the nucleus of the (TACWn), Atlantic Intermediate Water (AAIW) and North Atlantic Depth Water (NADW)”

QR2-I do not understand why the Loop Current track is called Caribbean Water. Discernment must be used throughout the MS when the authors refer to the Caribbean Water and the Loop Current; CW could be used to name the water intrusion from the Caribbean with specific biological and physical characteristics (maybe when they talk about Chl-a characteristics) and the LC when you refer to dynamic characteristics, i.e. current that enters the Yucatan Channel, loops at the eastern GoM and through the Florida Strait.

ANSWER: We agree with the comment. Following the suggestions from the referee, we define the CW in L81-82: The CW enters the gulf via the LC with specific biological (i.e low Chl-a) and physical characteristics (warmer and salty waters).

QR2-Lines 66-67: I do not consider that the MS shows a detailed analysis of the Loop Current Eddies, maybe the approach could be focus to the analysis of the LC and the LCE path footprint.

ANSWER: We rewrite in L67-69. . .“Unlike previous studies, this work entails the analysis of the LC and the LCE path footprint, and of the dominant features of the surface circulation that transports Caribbean Water (CW) into the GoM”.

QR2-Line 77: Who is this acting as a primary forcing mechanism of the Loop Current? Yucatan Current? The term PFM is not clear and must be specified.

ANSWER: We deleted PFM and rewrote in L81: “The CW enters in the GoM via the

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QR2-Line 100: “which move CW”. . . . .where?

ANSWER: We add in Line “move CW into the GoM”

QR2-Lines 104-105: “In this work we reexamine the effect of . . .” Rephrase please.

ANSWER: We rephrase as (L120-124): “In this work, 25-years (1993-2017) of daily ADT data are used to investigate the variability of the transport of Caribbean surface water into the gulf and its effect on chlorophyll-a concentrations using monthly radiance data from 1998-201., We examined temporal changes, mean differences, and regional concentration tendencies.”

QR2-Line 121: “we considered eddies in any state of formation, detaching. . .”, then they are Loop Current Eddies (LCE), not only eddies.

ANSWER: We rephrase (L44) “In this work, we considered LCE’s in any stage of formation. . .”

QR2-Lines 146-154: The first three points of the paragraph referring to data description are repetitive with the first paragraph of section 2; the description of the datasets is disordered, since they are described in two different places. I suggest to add additional information, such as the years of the data that you are using at the beginning of the section, before methods description. The calculation description of the mesoscale instabilities, as well as the AR can be described in the methods section, where they have already been described (without paragraph mark).

ANSWER: We deleted the three points of the paragraph marks. These were incorporated in the first paragraph on section 2 because of repetition with lines..... We also added the years in which the data were collected at the beginning of the section (L128-137), as follow: “Three independent data sets were used to provide evidence of temporal variability in the extension of CW into the GoM. We used the ADT and surface velocity fields (geostrophy and Ekman) from the GEKCO (Geostrophic Ekman

Current Observatory, Sudre et al., 2013) product from 1993 - 2017 with a resolution of  $0.25^{\circ} \times 0.25^{\circ}$ , in conjunction with Chl-a ocean color data derived from the reprocessing R2014.0 product suite from Aqua MODIS (Moderate Resolution Imaging Spectroradiometer) and from SeaWiFS (Sea-Viewing Wide Field of view Sensor), using the OCx Algorithm with a spatial resolution of 9X9 km (<https://oceancolor.gsfc.nasa.gov/cgi/l3>). The 2003-2017 monthly Chl-a ocean color product was derived from Aqua MODIS and the 1998-2002 monthly Chl-a ocean color product was derived from SeaWiFS”.

QR2-For the comments “The calculation description of the mesoscale instabilities, as well as the AR can be described in the methods section, where they have already been described (without paragraph mark).

ANSWER: We removed the paragraph mark.

QR2-Line 164: Is repetitive with line 110.

ANSWER: We removed the line.

QR2-Line 192: The contours from the ADT are not determined by the influence of the CW, please rephrase.

ANSWER: We rephrase (L195-196) “In this work, we used the ADT to track both the LC and the LCE’s formed by the influence of the CW”.

QR2-Please define which months of the year are described for each season (I guess winter (Jan, Feb, Mar), spring (Apr, May, Jun), etc.?).

ANSWER: We define the months of the year described for each season as follows in L204 to 207: “Fig. 1 shows that mostly in November to April, the CW retracts to its most southeasterly location. In contrast, in May to October, CW penetration moves towards the northwest. In fact, the extension begins in May and reaches maximum penetration in August, showing an annual pattern”.

QR2-It is not clear to me, at least from Fig. 1, that the LC extension is retracted in au-

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turn and extended in spring (lines 200-203), or the fact that the maximum penetration occurs in September, instead of August (see also your statement in line 232). I think it could be useful for the authors to discuss their results with previous work referring about the seasonality of the LC (see comment above).

ANSWER: We decided to remove seasons and instead refer to months for more accurate reference (See lines 204-207). This will be discuss as follow (See L207-211): Fig. 1 shows that (predominately) from November to April, the CW retracts to its most southeasterly location. In contrast, from May to October, CW penetration moves towards the northwest. In fact, this extension begins in May and reaches maximum penetration in August, resulting in an annual pattern. This movement is similar to that observed by Chang and Oey (2013). They found that in summer, the maximum LC intrusion was forced by the trade winds. Their and our observations are also consistent with the work of Candela et al (2019) who reported that water transport through the Yucatan Channel into the GoM in July was at a maximum.

QR2-Line 241 and Fig.3: Please specified if the ADT was spatially averaged.

ANSWER: In Lines 237 to 239 we added: The monthly intrusions of the CW were tracked by taking as a reference the northernmost latitudes (hereafter CWF) and westernmost longitudes of the 40 cm ADT isoline representing 1993-2017 monthly average values of the ADT (not spatially averaged).

QR2-The steric signal included in the ADT data must be discussed, considering the high-energy observed in the annual period (see Hall & Leben, 2016).

ANSWER: Lines 246 to 249 we wrote: In this work, the ADT signal also includes the seasonal steric effect, and the spectral analysis reveals a high-energy peak in the annual frequency. Base on Hall and Leben (2016) a steric signal appears as an annual sine wave with 5.8 cm amplitude, the details of which are described below.

QR2-Section 3.2 (Fig. 4): Why the STD contour of 15 cm was chosen as a reference

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for the regions of maximum variability?

ANSWER: In Lines 273 to 275 we add “The STD contour of 15 cm was selected considering that this value was three times greater than the annual steric signal reported by Hall and Leben (2016)”.

QR2-Lines 278-280: How this cycle of the monthly ratios compares with the results of Chang & Oey (2012, 2013)?

ANSWER: In Lines 281 to 283 we compare the results as follow: Chang and Oey (2012, 2013) proposed that the LC intrusion and the shedding of the LCE present a biannual cycle. The biannual cycle can also be related to the annual lowest and highest ratio values.

QR2-It makes not sense to me the discussion of the monthly averages of the wind stress, shown in Fig. 6 and described in section 3.4, it is not relevant for the main objective of this section, further this discussion do not reinforce the main idea exposed here; I suggest to delete this part or move this description elsewhere in the MS.

ANSWER: We agreed with the reviewer and we removed the section and Figure 6 about wind stress.

QR2-Lines 300-301: Please be more specific; Do you mean an upwelling? Is so where? Please use references.

ANSWER: The lines 300 to 301 were part of section 3.4 (Was removed).

QR2-The whole paragraph of section 3.5 is not linked with the rest of the MS, if you want to keep it, at least it go deeper in the implications and discussion of these calculations.

ANSWER: We also removed those lines because we are agree with the reviewer.

QR2-Statement of line 327-329: The difference between the mean life of the LCEs (6.8 vs 11.7) needs to be discussed with previous studies.

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ANSWER: We complemented as follow in lines 313-316: “These observations also agree with the results of Lindo-Atichati et al. (2013), confirming that, on average, the LC northward intrusion starts to increase in 2002. These authors also report an increase in number/year of LC rings over the same period that also coincided with a significant increase in sea height residuals ( $2.78 \pm 0.26$  cm/decade from 1993–2009).”

QR2-Lines 378-379: How these three periods were chosen? Why not using the same two periods of the ADT? Please explain.

ANSWER: We decided to separate and evaluate the extreme period pattern from the transitional data.

QR2-Table 1 (lines 386-399), please specify what means the bold numbers in Table 1 and show the difference between Early and Contemporary periods at each row. Using the differences obtained here discuss the significance of the Chl-a averages between these two periods.

ANSWER: The bold numbers represent the average CHI-a concentrations. We add the meaning for bold numbers in table 1 as follow: “Table 1. Bold numbers denote average Chl-a concentrations (mg m<sup>-3</sup>). . . . .” We also include the differences between Early and Contemporary periods at each row. For discussion see section 3.5.

QR2-Second point mark of the conclusions (line 515). I do not see that in Fig. 10, or in Fig. 11.

ANSWER: We agree with the reviewer and we deleted.

Technical corrections:

QR2-Please avoid the double space throughout the manuscript (i.e., lines 58, 60, 144, 263, 267, 269, etc.).

ANSWER: Done. Spacing was corrected.

QR2-Caribbean water is mentioned for the first time in the MS in line 68 as the acronym

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CW and in the line 75 as Caribbean Water. The acronyms must be defined for the first time as they are mentioned in the text and then they should be used throughout the MS as an acronym (the same for Loop Current as LC, which is even lowercase in line 99).

ANSWER: The acronyms were defined in the Introduction and used through the MS.

QR2-Line 119: Specify the years used for the 25 years climatologies.

ANSWER: this issue was corrected, it was written (1993 to 2017).

QR2-Line 140: 'island' instead of Island.

ANSWER: This error was corrected.

QR2-Line 216 and 230: CWF instead of Caribbean water front, it is already defined in line 125.

ANSWER: Corrected.

QR2-Lines 294-295: Please specify that this is a supposition.

ANSWER: We calculate the area and this is not a supposition.

QR2-Line 314: Please use the accurate terms. ANSWER: The section 3.5 as was mentioned before it was removed.

QR2-Line 324: 'extended to the west' . . .in summer and autumn?

ANSWER: Done.

QR2-Line 337: Avoid the use of acronyms in the title sections (especially if it has not been previously defined).

ANSWER: Corrected.

QR2-Line 360: Use CW.

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ANSWER: Done.

QR2-Line 402: Add (see also Fig. 11).

ANSWER: Added.

QR2-Lines 413-415: Rephrase.

ANSWER: Done (See L371-373) as follow: This is also evident in the LC core, where Chl-a concentrations also decreased with time and signals the entrance to the gulf of more water oligotrophic during the middle and contemporary epochs”.

QR2-Line 432: Check the point marks.

ANSWER: Done.

QR2-Lines 446-450: Rephrase the way you mention the M-K work please.

ANSWER: We do not understand this request.

QR2-Please avoid the use of ‘we’, instead use something like ‘in this work. . .’

ANSWER: Because this is optional we prefer to use “We.

QR2-Line 470: R means correlation?

ANSWER: Correlation Coefficient (R)

QR2-Line 480: Change ‘begs’ for a more appropriate word (needs, requires, etc.).

ANSWER: it was changed for “requires”

QR2-Lines 508 and 509: Please change the term ‘lifespan’.

ANSWER: time life

QR2-Line 513: Please rephrase the first point of the conclusions.

ANSWER: it was done as follow: The intrusion of the CW by LC-LCEs extends further

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into the western GoM than was previously known.

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Interactive comment on Ocean Sci. Discuss., <https://doi.org/10.5194/os-2019-58>, 2019.

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