Ocean Dynamics (2010) 60:1075–1084
DOI 10.1007/s10236-010-0308-0

# The influence of Gulf of Mexico Loop Current intrusion on the transport of the Florida Current

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Received: 13 September 2009 / Accepted: 24 May 2010 / Published online: 10 June 2010


**Abstract** Based on an empirical orthogonal function analysis of satellite altimeter data, guidance from numerical model results, and CANEK transport estimates, we propose an index, based on differences in satellite-measured sea surface height anomalies, for measuring the influence of Gulf of Mexico Loop Current intrusion on vertically integrated transport variability through the Yucatan Channel. We show that the new index is significantly correlated at low frequencies (cut-off 120 days) with the cable estimates of transport between Florida and the Bahamas. We argue that the physical basis for the correlation is the geometric connectivity between the Yucatan Channel and the Straits of Florida.

**Keywords** Florida Current · Loop Current · Yucatan Channel · Straits of Florida · Transport variation · Sea surface height anomaly

## 1 Introduction

The current system flowing through the Yucatan Channel and the Straits of Florida (see Fig. 1) forms part of the North Atlantic western boundary current system and is thought to carry not only part of the wind-driven return flow of the subtropical gyre but also the upper limb of the North Atlantic Meridional Overturning Circulation (Schmitz and Richardson 1991; Schmitz et al. 1992). Monitoring of the Florida Current between Florida and the Bahamas has been almost continuous since the early 1980s, beginning with the STACS program (Schott and Zantopp 1985), subsequently using submarine cables at 27°N (Fig. 1b; Larsen 1992; Baringer and Larsen 2001), and also as part of the RAPID/MOCHA array for monitoring the overturning circulation (Cunningham et al. 2007; Kanzow et al. 2007). Understanding the observed variability of the Florida Current is a topic of continuing interest. Niiler and Richardson (1973) first identified the seasonal cycle indicating a peak northward transport in the summer and a minimum in late autumn, at variance with expectations based on flat-bottomed Sverdrup theory. Anderson and Corry (1985) explained the discrepancy by noting that, on annual time scales, adjustment by baroclinic Rossby waves is too slow to compensate for the underlying variable bottom topography (see also Gill and Niiler 1973) and that the phase of the seasonal cycle can be explained using the topographic Sverdrup relation with an additional contribution from baroclinic coastal processes. This idea was exploited in the studies by Greatbatch and Goulding (1989), Fanning et al. (1994), and Greatbatch et al. (1995). In the latter, it is shown that a uniform-density, single-layer barotropic model with realistic bottom topography and driven by realistic, twice-daily wind forcing can capture the seasonal cycle in the cable transports, as monitored up to that time. Baringer and Larsen (2001) noted a change in the annual cycle after about 1990. It remains to be seen if this change can be accounted for by wind forcing. The model is rather less successful, however, at capturing the daily variability in the transport and is also missing an interesting component of variability with roughly 8-month time scale that is present in the cable data in some years (see, in particular, 1986 in Fig. 3 in Greatbatch et al. 1995 and also

Responsible Editor: John Wilkin

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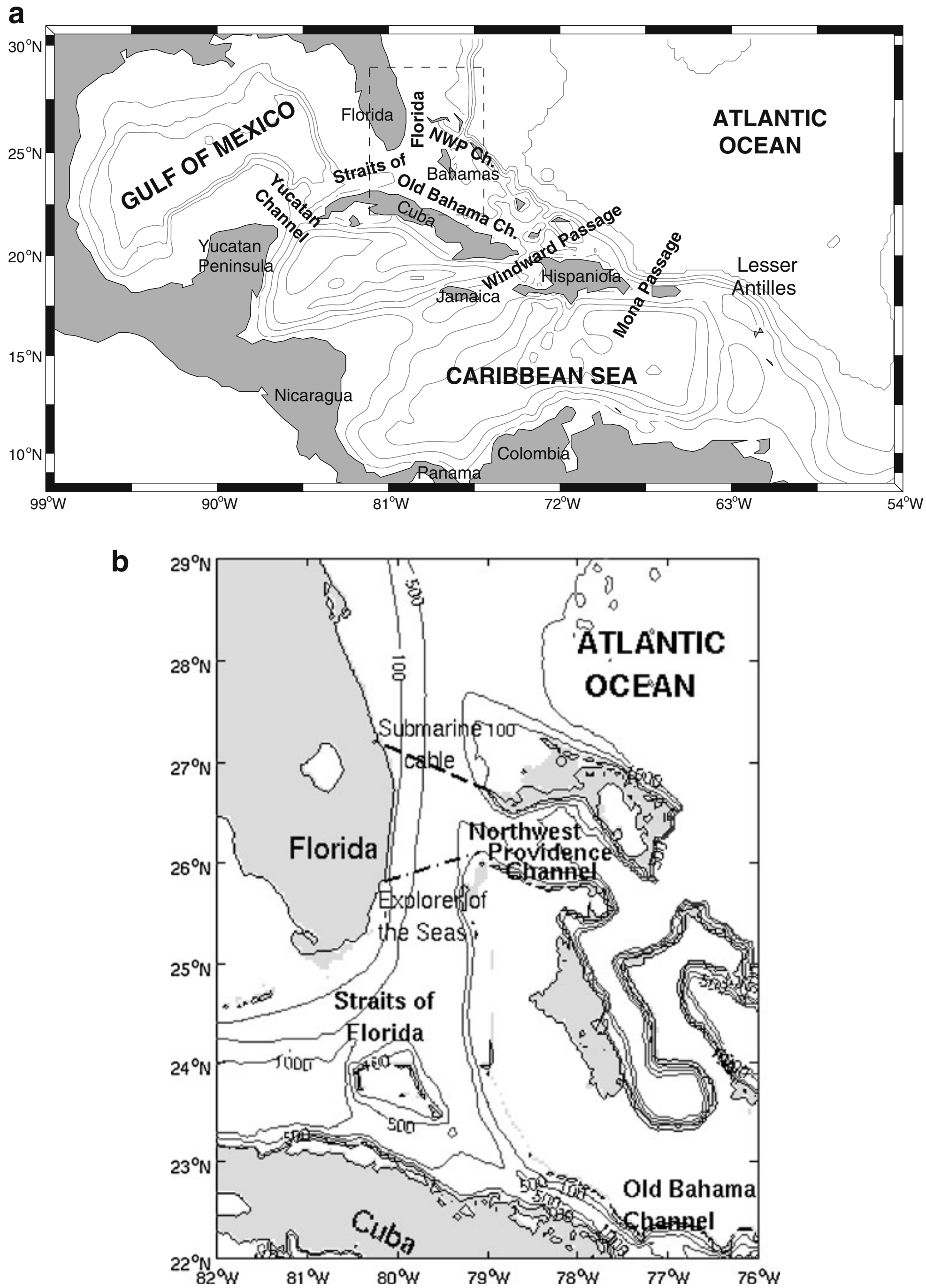


**Fig. 1** Major topography features in **a** the Intra-Americas Sea and **b** Straits of Florida and adjacent areas bounded by the *dashed lines* in (**a**). The *contour lines* show water depth with an interval of 1,000 m in (**a**) and water depth at 100, 500, and 1,000 m in (**b**). *Dashed line* and *dot-dashed line* in (**b**) show the approximate positions of the submarine cable and the "Explorer of the Seas" cruise track across the Straits of Florida

figure 4 in that paper for a comparison between 60-day low-pass filtered model output and the cable data). Variability at the longer, interannual to decadal time scales has received less attention, although Baringer and Larsen (2001) have pointed out an apparent link between the interannual variability of the North Atlantic Oscillation index and the cable transports. Recently, DiNezio et al. (2009) have found evidence that interannual to decadal time scale variability in the cable transports is linked to wind stress curl variability further east at the same latitude, suggesting that long Rossby wave propagation from the east plays a role in determining the Florida Current transport variability on these time scales.

As implied by the importance of the variable bottom topography, propagation of coastal trapped waves southwards along the North American continental slope play an important role in the studies of Anderson and Corry (1985) and Greatbatch et al. (1995). On the other hand, westward propagating Rossby waves are emphasized on the longer, interannual to decadal time scales considered by DiNezio et al. (2009). In the present study, we ask whether the transport of the Florida Current between Florida and the Bahamas is also influenced by variability upstream in the Gulf of Mexico. The geometry of the region (see Fig. 1) implies that variations in transport through the Yucatan Channel must pass either through the passageways northeast of Cuba (e.g., the Old Bahama Channel) or through the Straits of Florida between Florida and the Bahamas, suggesting the possibility of such a link. Unfortunately, we know much less about the transport variability through the Yucatan Channel than we do about the transport variability between Florida and the Bahamas. The only available long-term transport estimates in the Yucatan Channel are from the CANEK program (Ochoa et al. 2001; Sheinbaum et al. 2002) initiated in December 1996. CANEK used a combination of shipboard Acoustic Doppler Current Profiler (ADCP) measurements, hydrographic/velocity surveys using CTDs, lowered-ADCP measurements, and a current meter mooring array to monitor the transport. As noted by Lin et al. (2009), the correlation between the CANEK derived daily transports of the Yucatan Current and the cable voltage inferred transports of the Florida Current is only 0.15, suggesting that a large part of the Yucatan transport variability passes northeast of Cuba and not between Florida and the Bahamas at the latitude of the submarine cable. A similar conclusion was reached by Hamilton et al. (2005) based on a monitoring program for the Straits of Florida carried out between December 1990 and November 1991.

Nevertheless, a distinctive feature of the circulation in the Gulf of Mexico is the intrusion of the Loop Current (hereafter the LC), connecting the Yucatan Channel with the Straits of Florida, and the associated eddy shedding (see, for example, Hurlburt and Thompson 1980; Oey et al. 2005). The Loop Current can extend northward into the Gulf of Mexico, even as far as the Mississippi river delta and the Florida continental shelf (Huh et al. 1981; Wiseman and Dinnel 1988). Maul and Vukovich (1993) tried to find a consistent relationship between the monthly position of the LC and the monthly volume transport of Gulf of Mexico outflow, estimated from the sea level difference between Florida and Cuba, but were unsuccessful. However, a clear relation is found by Bunge et al. (2002) using CANEK observations between the LC extension area into the Gulf of Mexico and deep flows at the Yucatan Channel. Recently, Lin et al. (2009) have argued that the intrusion of the Loop Current into the Gulf of Mexico drives vertically integrated transport variations through the Yucatan Channel through the interaction between the density anomalies associated with the Loop Current intrusion and the underlying variable bottom topography (in particular, the pressure difference across the ridge linking Florida to Cuba). This finding led us to re-examine the link between the LC intrusion and the cable transport estimates. We find, for the first time, a statistically significant link at low frequencies (time scales longer than 120 days), suggesting that LC intrusion does indeed influence the cable-estimated transports of the Florida Current.

An important issue is how the LC intrusion into the Gulf of Mexico is measured. Maul and Vukovich (1993) used the northern boundary of the LC estimated from satellite infra-red imagery. On the other hand, Bunge et al. (2002) used the extension area of the LC estimated from radiometer images and Ezer et al. (2003) defined an index in terms of area-averaged sea surface elevations over the LC region (89°W to 83°W, 21°N to 27°N) taken from their model. Here, we define a new index using satellite altimeter data (see Section 2). The choice of this index is based on an empirical orthogonal function (EOF) analysis of sea surface height anomalies from altimeter observations, guidance from the numerical model of Lin et al. (2009), and the CANEK transport estimates for the Yucatan Channel, as described in detail below. The index is not intended to be a comprehensive index for measuring Loop Current intrusion but rather only that aspect of Loop Current intrusion that is responsible for driving variations in vertically integrated transport through the Yucatan Channel.

## 2 Connection between Loop Current intrusion and transport variability through the Yucatan Channel

As shown in Lin et al. (2009), the density anomalies associated with the intrusion of the Loop Current into the Gulf of Mexico can drive significant variations in the vertically integrated transport through the Yucatan Channel. Lin et al. (2009) have shown that the key feature for driving the vertically integrated transport variations is the development of anomalies in the pressure difference on the sloping topography between the two sides of the ridge connecting Cuba and Florida. Fluctuations in this pressure difference drive vertically integrated transport variations between Cuba and Florida because of the topographic form drag effect, and these transport variations in turn lead to vertically integrated transport variations through the Yucatan Channel because of the geometry of the region. (See Fig. 1 and note that for there to be no net accumulation of water in the Gulf of Mexico, variations in vertically integrated transport between Cuba and Florida must be exactly compensated by variations in vertically integrated transport through the Yucatan Channel.) The density anomalies associated with Loop Current intrusion and the underlying pressure anomalies are themselves associated with anomalies in sea surface height, raising the possibility of using an index based on altimeter data as a means of measuring this component of Yucatan Channel vertically integrated transport variability. In order to derive such an index, we begin by revisiting the relationship between Loop Current intrusion and variations in vertically integrated transport through the Yucatan Channel in the model of Lin et al. (2009), while noting that other higher resolution models (e.g., the model used by Cherubin et al. 2005 and the 1/12° North Atlantic model used by Eden et al. 2007) exhibit very similar behavior.

The model domain used by Lin et al. (2009) covers the Intra-Americas Sea (see Fig. 1a) with a horizontal resolution in both latitude and longitude of 1/6°. The model is forced by six-hourly NCEP wind fields from 1996 to 2001. Readers are referred to Lin et al. (2009) for more details. The model was integrated for 6 years and the model results (3-day average) from year 2 to 6 are used for analysis. There are a total of 10 eddy shedding events during the 5-year period. The separation interval between shedding events varies between 5 and 8 months, which, while on the short side, nevertheless falls into the range of observed eddy separation intervals (e.g., Vukovich 1995; Sturges and Leben 2000). It should be noted, however, that it is not eddy shedding that is important for the model transport variations through the Yucatan Channel but rather the Loop Current intrusion itself and the interaction of the associated density anomalies with the underlying bottom topography (Lin et al. 2009). This is an important point because Loop Current intrusion does not always lead to the shedding of an eddy.

Figure 2a shows the time series of vertically integrated transport through the Yucatan Channel in the model (positive northward). Composites of sea surface height (SSH; Fig. 2b and d) and sea surface height anomaly from the model (Fig. 2c and e) are made at the times of the transport maxima and minima shown by the vertical bars in Fig. 2a (here anomaly means departure from the average over the whole analysis period and it should be noted that the composite plots are almost everywhere significantly different from zero at the 99% level). When the transport is at a minimum, the LC intrudes strongly into the Gulf (Fig. 2b and c), with a corresponding positive sea surface height anomaly centered at 25.0°N and 86.5°W, and a negative sea surface height anomaly centered at 23.5°N and 84.0°W off the northwest coast of Cuba. On the other hand, when the transport is a maximum, the LC is in its port-to-port configuration (Fig. 2d and e) and the pattern of sea surface height anomalies is reversed. In particular, at this time a negative sea surface height anomaly is found at 25.0°N, 86.5°W and there is now a positive sea surface height anomaly off the northwest coast of Cuba around 23.5°N, 84.0°W. It should be noted that when the sea surface height is anomalously high off the northwest coast of Cuba, there is a pool of anomalously warm water at the same location and, likewise, a pool of anomalously cold water at the same location when the sea surface height is anomalously low (see figure 12 in Lin et al. (2009)).

We now turn to the altimeter data and begin with the Merged Maps of Sea Level Anomalies (resolution 1/3°× 1/3°) from Le Traon et al. (1998). The time series at each grid location are low-pass filtered with a cut-off time scale of 120 days to focus on the low-frequency variability. An EOF analysis is then carried out on the low-pass filtered data for the region 92°W to 82°W, 22.5°N to 28°N where the sea surface height anomalies in the model output are found. The analysis period is from 14 October 1992 to 23 January 2008. The first two EOFs explain 29.3% and 19.7% of the variance, respectively, and so, together, explain almost 50% of the variance. The spatial pattern of both EOFs (Fig. 3a and b) is similar to the model anomaly pattern at the time of maximum transport through the Yucatan Channel (Fig. 2e), be it with some displacement in the centers of action. However, as we shall see in the next paragraph, it is the second EOF whose principal component (PC) times series, at least during the CANEK period, is linked to the vertically integrated transport variability through the Yucatan Channel. The first EOF (Fig. 3a), on the other hand, corresponds to the transition between transport maxima and minima and tends to vary in quadrature with the second mode. Indeed, the PC time series associated with the first two EOFs have a correlation of 0.6 (significant at the 99% level) with the first EOF lagging by 63 days (cf. Fig. 3c and d).

Another data set available to us is the daily estimates of transport through the Yucatan Channel made during the CANEK program (Ochoa et al. 2001; Sheinbaum et al. 2002). The data come from two time periods: 10 September 1999 to 15 June 2000 and 13 July 2000 to 31 May 2001. Since the gap between the two time periods is less than 1 month and we focus on low-frequency variations, we filled the gap with a linear interpolation and low-pass filtered the time series, as for the altimeter data, with a cut-off time scale of 120 days (see Fig. 3e and f). We then compare the PC time series for the first two EOFs calculated from the satellite data with the vertically integrated transport through the Yucatan Channel (positive northward) estimated during the CANEK program. For the second satellite-based EOF mode (Fig. 3d), going along with the sea surface height anomaly pattern shown in Fig. 3b, the principal component time series varies synchronously with the observed transport time series (Fig. 3d and f), consistent with what we noted earlier in the previous paragraph. The PC time series for the first satellite-based EOF mode also varies with the observed low-frequency transport variations through the Yucatan Channel, but lags the transport by about 50 days (Fig. 3c and e). The lag is consistent with the previous discussion in which the first EOF mode corresponds to the transition phase during which transport is either increasing or decreasing.

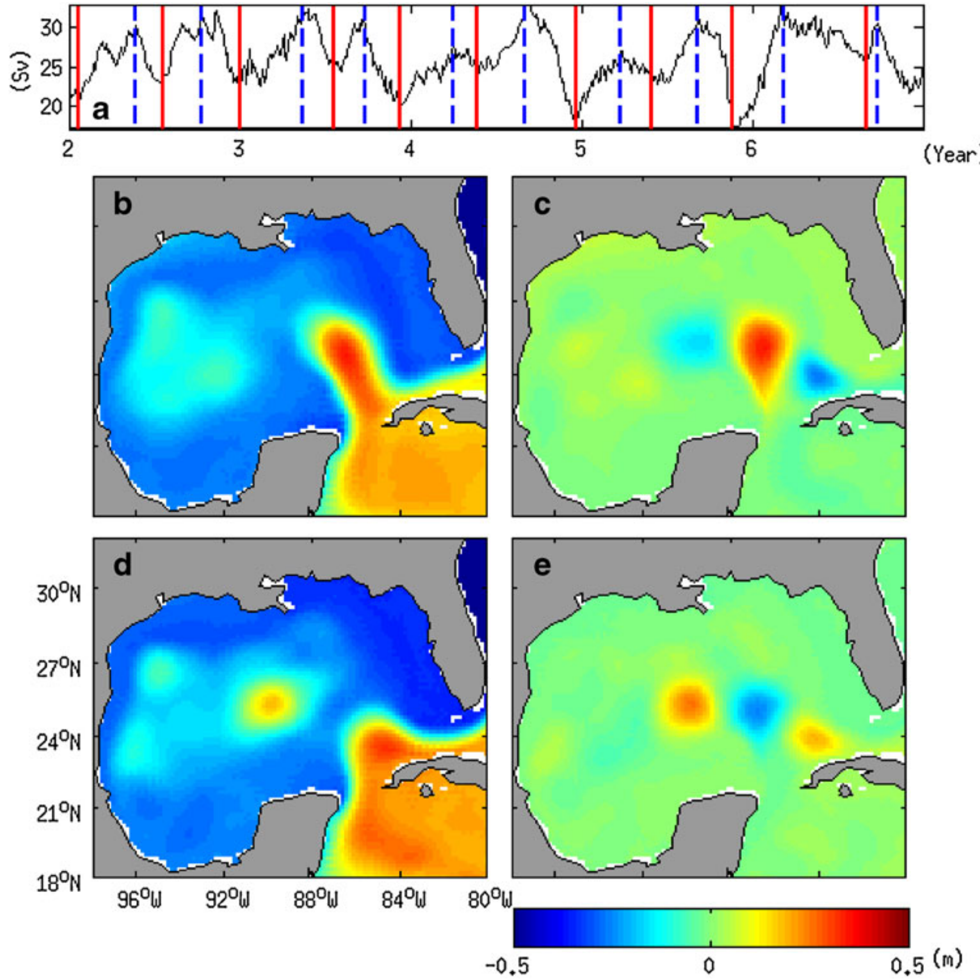


**Fig. 2** **a** Time series of the model-calculated transports (3-day average) of the Yucatan Current from year 2 to 6, positive northward. *Vertical dashed blue lines* and *solid red lines* mark the transport maxima and minima through the Yucatan Channel, respectively. **b**, **c** Composite plots of 3-day average sea surface height fields and associated anomalies calculated from model results corresponding to transport minima marked in (**a**). **d**, **e** Similar to (**b**) and (**c**) but for the results corresponding to transport maxima marked in (**a**)

We can now construct an index for measuring the influence of the LC intrusion on Yucatan Channel vertically integrated transport variability. In particular, we take the difference between the sea surface height anomalies at locations B (23.5°N, 84.0°W) and A (25.0°N, 86.0°W) marked in Fig. 3b ($\Delta SSH = SSHA_B - SSHA_A$). Rather than using the product of Le Traon et al. (1998), the sea surface height anomalies at B and A are calculated directly from the altimeter data. In particular, sea surface height anomaly variations at location B are calculated based on the satellite track crossing the location B southward about every 10 days, and sea surface height anomaly variations at location A are calculated based on the satellite track crossing the location A southward about 3 days later. Satellite altimeter data from Topex/Poseidon between 1992 and 2002 and data from JASON between 2002 and 2009 are used (both time series agree closely during the roughly 1-year period of overlap). The resulting difference (B−A) is then low-pass filtered, as before, with a cut-off time scale of 120 days. The satellite-based index (ΔSSH) is consistent with the low-frequency (low-pass filtered with a cut-off time scale of 120 days) transport estimates at the Yucatan Channel from CANEK from September 1999 to May 2001 (Fig. 4). The correlation coefficient is 0.83. Unfortunately, given the shortness of the record from CANEK, the above comparison cannot conclusively demonstrate the existence of a link between Yucatan Channel transport variations and the Loop Current intrusion as measured by ΔSSH. Nevertheless, the above comparison is consistent with the existence of such a relationship and, as noted when discussing Fig. 2, we know that such a relationship exists in models. In fact, although not shown here, the index calculated from the 5-year model results of Lin et al. (2009) can be used as an index for the low-frequency transport variations through the Yucatan Channel in that model. It should be noted, however, that factors other than Loop Current intrusion (e.g., wind forcing and Caribbean eddies; see Oey et al. 2003) can influence the vertically integrated transport through the Yucatan Channel so we do not expect an exact correspondence between the transport variations and ΔSSH. What ΔSSH approximates is the contribution to the Yucatan Channel vertically integrated transport variability that is driven by the interaction between the density anomalies arising from the Loop Current intrusion and the underlying variable bottom topography.

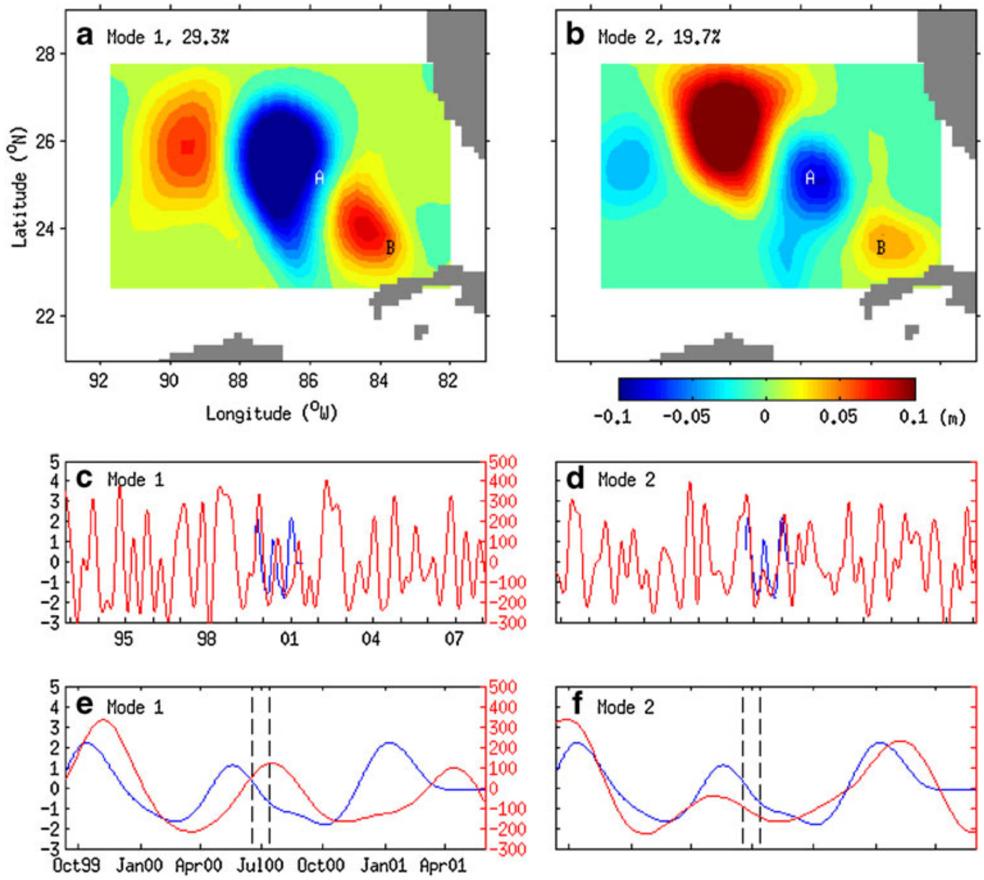


**Fig. 3** An empirical orthogonal function (EOF) analysis based on satellite altimeter data from 1992 to 2008 (low-pass filtered with a cut-off time scale of 120 days). Horizontal patterns of **a** the first EOF (29.3%) and **b** the second EOF (19.7%). Location A is at 25.0°N, 86.0°W and location B is at 23.5°N, 84.0°W. The corresponding principal component time series [*red lines*, units (non-dimensional) in *red*] for the first and second EOFs are shown in (**c**) and (**d**). *Blue lines* in (**c**) and (**d**) represent observed transport variations [low-pass filtered with a cut-off time scale of 120 days, in units of Sv (*left-hand axis*)] of the Yucatan Current from the CANEK program. (**e**) and (**f**) are the same time series from (**c**) and (**d**) but shown only for the CANEK period. Observations of the Yucatan Current were not made over the period of about 1 month marked by *vertical dashed lines* in (**e**) and (**f**)

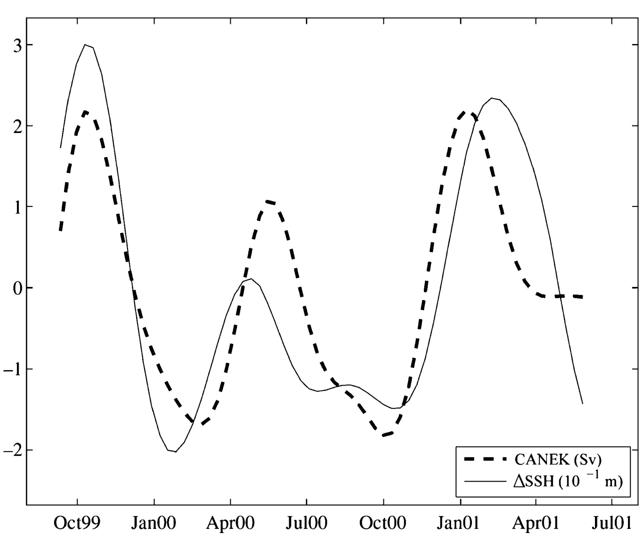


**Fig. 4** The index (ΔSSH, *solid line*) calculated from the sea surface height anomaly difference, location B minus location A, shown in Fig. 3b, based on the Topex/Poseidon sea surface height anomaly measurement (low-pass filtered with a cut-off time scale of 120 days). The *dashed line* represents transport anomaly estimates from CANEK (low-pass filtered with a cut-off time scale of 120 days) for the Yucatan Channel from September 1999 to May 2001, referenced to the long-term mean

## 3 The influence of Loop Current intrusion on the transport of the Florida Current

Based on 17 years of data, from 1992 to 2009, we can examine the relationship between the index, ΔSSH, defined above, and the transport of the Florida Current inferred from the Florida–Bahamas submarine cable at 27°N (Baringer and Larsen 2001). Synchronous cable data are used in the study (low-pass filtered with a cut-off time scale of 120 days, as for the altimeter data). The cable data are available for two periods, with the first period from 1992 to 1998 and the second period from 2000 to 2009.

Figure 5 shows the 17-year time series of the index (ΔSSH) and the low-pass filtered cable transport estimates. Visual inspection suggests a link between ΔSSH and the transport variations of the Florida Current, although the link is clearly not exact. The correlation coefficient between the detrended time series for the whole period is 0.45 (significantly different from zero at the 99% level). During the first period of data overlap (1992 to 1998) the correlation is 0.41 and during the second period of data overlap (2001–2009), 0.5. We believe the physical basis for the link is as follows. The index ΔSSH has been chosen in such a way as to capture the signature in sea surface height anomaly of that part of the Yucatan Channel transport

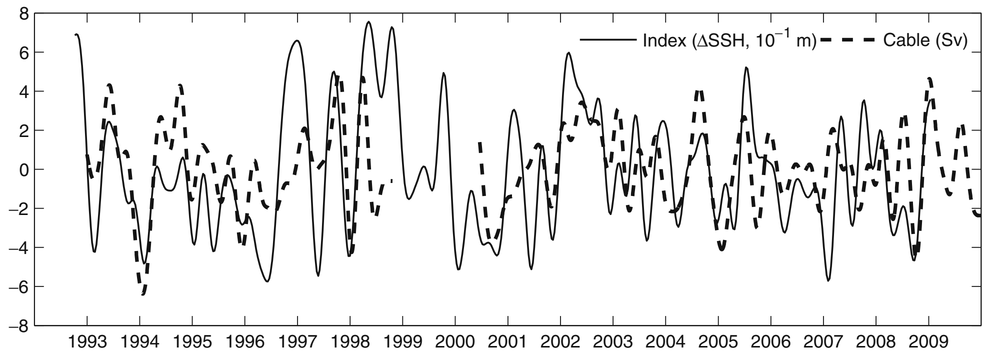


**Fig. 5** The sea surface height anomaly index, ΔSSH (*solid line*; units m), calculated for the period 1992 to 2009. *Dashed lines* (units Sv) are the cable-estimated transport anomalies for the Florida Current and referenced to the long-term mean. All time series are low-pass filtered with a cut-off time scale of 120 days

variability that is driven by the interaction between the density anomalies associated with Loop Current intrusion and the underlying variable bottom topography. Transport variability at the Yucatan Channel must, in turn, vary synchronously with the transport variability through the Straits of Florida between Cuba and Florida; otherwise, there will be an accumulation of water in the Gulf of Mexico (which is not observed). In turn, transport variability through the Straits of Florida between Cuba and Florida must be compensated either through the channels north of Cuba or through the Straits of Florida between Florida and the Bahamas. It is the part through the latter that we believe is being picked up by out correlation analysis.

We can also use the time series of the sea surface height anomaly at location B alone (see Fig. 3b) to provide an index for comparison with the cable data. The motivation for using location B alone, rather the difference in sea surface height anomaly between locations B and A, is that in the model of Lin et al. (2009) it is the fluctuations in density at the location B (see their figure 12) that are important for driving the associated vertically integrated transport anomalies through the Yucatan Channel. Figure 6a shows a comparison between the time series at location B and the difference B−A (i.e., ΔSSH) showing that, in fact, it is sea surface height anomaly at location B that dominates the difference B−A (the correlation is 0.86). Figure 6b compares the index time series calculated at location B alone and the cable data. The correlation over the whole time series is 0.37, and during the overlap periods 1992–1998 and 2001–2009 is 0.39 and 0.35, respectively. These correlations are lower than the corresponding correlations (0.45, 0.41, and 0.5, respectively) between the time series ΔSSH and the cable data found previously, suggesting that the full index, ΔSSH, is a better measure of Loop Current intrusion influence on vertically integrated transport variability between Florida and the Bahamas than the time series of sea surface height anomaly at location B alone.

Another data set available to use is the time series of transport estimates from the ship-of-opportunity platform "Explorer of the Seas" discussed by Beal et al. (2008) and available from 2002 onwards. These transport estimates are for the Florida Current at 26°N just to the south of the entrance to the Northwest Providence Channel (see Fig. 1b) and so are south of the location of the cable estimates but north of the Old Bahama Channel (the latter runs north of Cuba and in the model of Lin et al. (2009) is the main conduit for compensating transport variations at the Yucatan Channel). Figure 7a compares the index (ΔSSH) with the "Explorer of the Seas" transport estimates and also shows the cable data. A positive correlation between the index, ΔSSH, and the "Explorer of the Seas" time series (correlation 0.46 for detrended time series, significantly different from zero at the 99% level) can be seen from the beginning of 2003 onwards, although there are also times (e.g., earlier in 2002) when the two time series vary out of phase. The reasons for the out-of-phase behavior are not known at this time but, clearly, there is the suggestion that other influences, perhaps local to the Straits of Florida, are at work. The correlation between the index, ΔSSH, and the cable data over the same time period is slightly lower (0.41), as we might expect given the presence of the Northwest Providence Channel between the location of the "Explorer of the Seas" cruise track and the submarine cable (see Fig. 1b). Interestingly, sometimes out-of-phase behavior can be seen (e.g., around January 2006) between the "Explorer of the Seas" and the cable data, suggesting an influence from the Northwest Providence Channel.

Figure 7b compares the time series of sea surface height anomaly from location B alone, rather than ΔSSH, with the "Explorer of the Seas" data. The results are quite similar. The correlation between the two detrended time series from 2003 onwards (0.33) is actually lower than when using ΔSSH (0.46). However, the correlation between the sea surface height anomaly from location B and the cable data over the same time period is very close (0.35).

## 4 Summary and discussion

The current system flowing through the Yucatan Channel and Straits of Florida is important because it is the major feeder for the Gulf Stream which, in turn, carries the upper

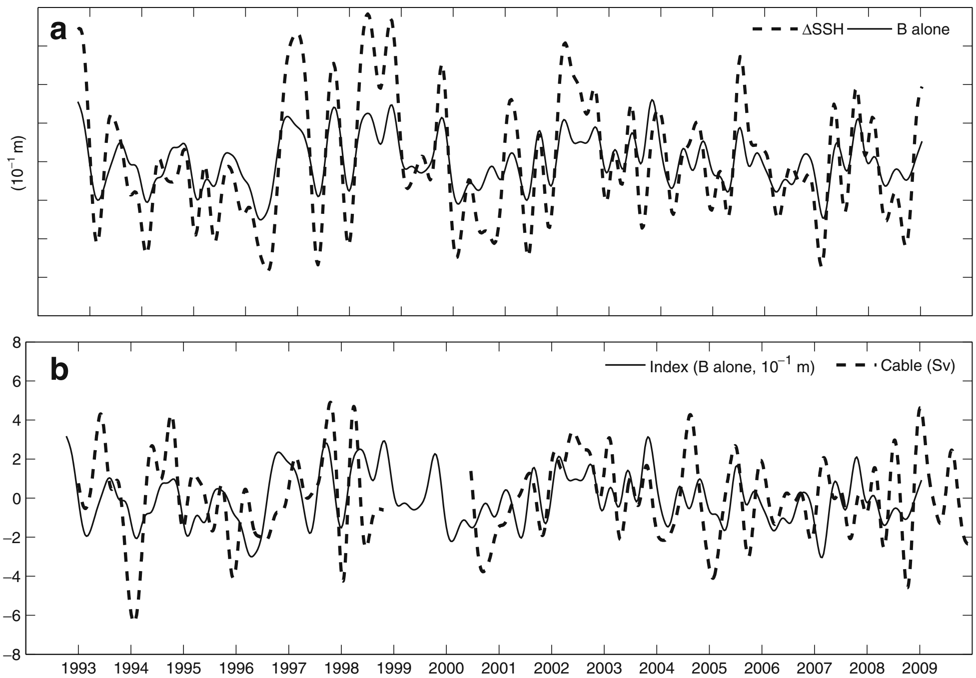


**Fig. 6** **a** Comparison between the time series of (1) the satellite-derived sea surface height anomalies at location B alone (*solid line*) and (2) the index ΔSSH that is the difference (B−A) in sea surface height anomalies between locations B and A in Fig. 3b (*dashed line*) for the period 1992 to 2009. **b** Comparison between the sea surface height anomalies at location B alone (*solid line*; units m) and the cable-estimated transport anomalies (*dashed lines*; units Sv) for the Florida Current during the same time period, referenced to the long-term mean. All time series are low-pass filtered with a cut-off time scale of 120 days

limb of the North Atlantic Meridional Overturning Circulation, important for climate (e.g., Cunningham et al. 2007). We began by noting that many studies have emphasized the likely importance of either the continental slope north of the Straits (e.g., Anderson and Corry 1985; Greatbatch et al. 1995) or westward propagation of long Rossby waves (DiNezio et al. 2009) for influencing the transport variations between Florida and the Bahamas, as estimated using submarine cables at 27°N (see Fig. 1; Larsen 1992; Baringer and Larsen 2001). Here, we have asked whether

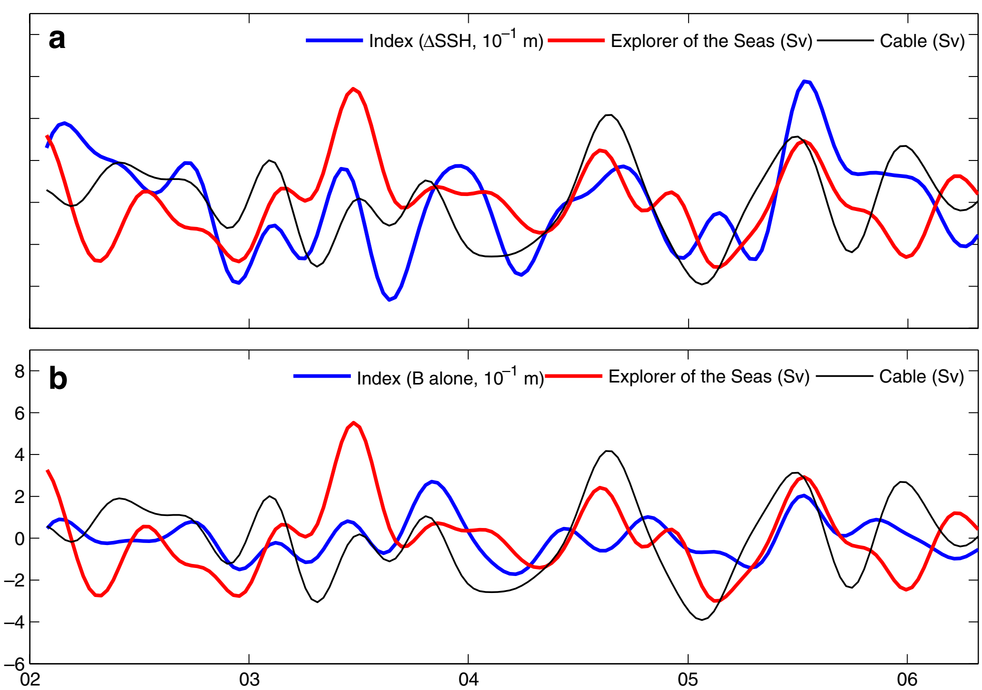


**Fig. 7** **a** Comparison between the index, ΔSSH (*blue line*; units m), and the estimates of the vertically integrated transport from the "Explorer of the Seas" data set for the period 2002 to 2006 (*red line*; units Sv), and referenced to the mean over the whole data set. The *black line* shows the cable-estimated transport anomalies in Sv for the Florida Current, referenced to the long-term mean. **b** Similar comparison but using the sea surface height anomalies at location B alone (*blue line*). All time series are low-pass filtered with a cut-off time scale of 120 days

the cable transport estimates are affected by influences from upstream in the Gulf of Mexico and, in particular, the time-varying intrusion of the Loop Current into the Gulf of Mexico. We have introduced an index based on the difference in sea surface height anomalies between two locations in the southeastern Gulf of Mexico; one is centered at 25.0°N, 86.0°W and the other at 23.5°N, 84.0°W off the northwest coast of Cuba. These locations were chosen based on an EOF analysis of satellite altimeter data following guidance from a numerical model and comparison with the CANEK estimates of vertically integrated transport through the Yucatan Channel (although it should be noted that there are only 2 years of data from CANEK). The new index can be interpreted as a proxy for that part of the vertically integrated transport variations through the Yucatan Channel that are driven by the interaction between the density anomalies arising from the Loop Current intrusion and the underlying variable bottom topography, as discussed by Lin et al. (2009). Given the geometric connectivity between the Yucatan Channel and the location of the submarine cable between Florida and the Bahamas, it is possible that intrusion-induced fluctuations in vertically integrated transport through the Yucatan Channel also have a signature in the cable-estimated transports of the Florida Current. We have presented evidence of such a link, in particular between the low-pass filtered sea surface height anomaly index (cut-off 120 days) based on satellite altimeter data and the low-pass filtered cable estimates of the vertically integrated transport variations between Florida and the Bahamas (see Fig. 5). The correlation between the two detrended, low-pass time series is 0.45 and is statistically significant at the 99% level, the first time such a relationship has been shown.

The physical basis for a connection between Loop Current intrusion and the transport through the Yucatan Channel is discussed in Lin et al. (2009), where it is shown that the transport is affected by the interaction between the density anomalies associated with Loop Current intrusion and the variable bottom topography between Florida and Cuba and, in particular, the associated pressure difference across the ridge connecting Cuba and Florida. For there to be no net accumulation of water in the Gulf of Mexico, the transport into the Gulf through the Yucatan Channel must be exactly balanced by the transport out through the Straits of Florida between the Florida and Cuba. However, not all the transport exiting the Gulf between Florida and Cuba has to pass between Florida and the Bahamas because of leakage through the Old Bahama and Northwest Providence Channels (Maul and Vukovich 1993; Hamilton et al. 2005). It seems likely that significant transport variability does indeed take place through the channels north of Cuba. Only much more detailed field studies, such as presented by Hamilton et al. (2005), will be able to sort out exactly how the transport variations between the connecting channels are linked.

**Acknowledgments** The authors wish to thank Julio Sheinbaum for providing the observations taken during the CANEK program and Lisa Beal for providing the transport estimates from the “Explorer of the Seas” data set. Comments from two reviewers led to improvements in the manuscript and are acknowledged. This work has been funded by the NSERC/MARTEC/EC Industrial Research Chair awarded to RJG and JS as well as support to RJG from IFM-GEOMAR.

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