Loop Current variability as trigger of coherent Gulf Stream transport anomalies

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Introduction

The Loop Current (LC) is a major source of variability in the Gulf of Mexico. On timescales of weeks to months the LC can expand well into the Gulf of Mexico until it sheds an eddy. The LC is thought to affect transports downstream of the Gulf of Mexico (e.g. Mildner et al. 2013). Here we provide an alternative view of the link between the LC and downstream transports using data from a high resolution ocean model (NEMO 1/12) and observations (geostrophic surface velocity from AVISO). Composite analysis is used to investigate links between transport anomalies in the Florida Straits and the large scale surface ocean circulation (**Figure 1**).

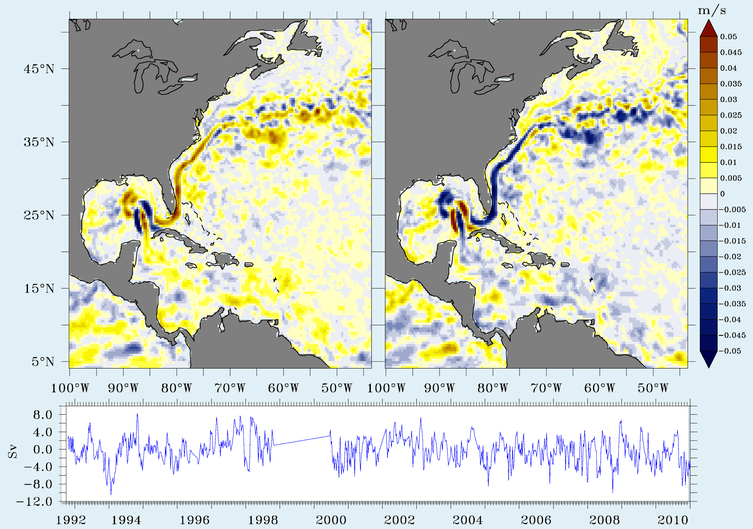

Figure 1: a) Composite of AVISO velocities coinciding with positive Florida Straits transport anomalies. b) as a) but for negative Florida Straits transport anomalies. c) Observed Florida Straits transport anomalies (Sv).

Gulf Stream pulses

Lagged composites between the Florida Straits transport and surface velocities reveal a precursor role for the Loop Current. This is illustrated in **Figure 2** for negative transport anomalies in the Florida Straits. Prior to the development of a negative transport anomaly in the Florida Straits there is a clear indication of a loop shaped positive surface velocity anomaly in the Gulf of Mexico. This is indicative of the Loop Current expanding into the Gulf of Mexico. From lags of about -40 to 30 days onwards a negative surface velocity anomaly starts to propagate from southeast Florida towards the Straits of Florida. Within a few few weeks the negative velocity anomalies extend along Forida up to Cape Hatteras and into the Gulf Stream extension. For positive lags (Florida Transport anomalies leading surface velocities) the negative velocity anomalies along the southern part of Florida start to fade (lag 14 days) whilst extending further into the Gulf Stream extension. The loop shaped positive velocity anomaly in the Gulf of Mexico gradually starts to fade and disappears after about 100 days.

The lagged composites in **Figure 2** suggest that negative transport anomalies through the Florida Straits coincide with a long Loop Current path into the Gulf of Mexico and vice versa. This is tested in the model and in the observations (**Figure 3**) and we indeed find that positive transport anomalies through the Florida Straits (> 1.5 Std. Dev.) coincide with a higher probability of short Loop Current path (even though long paths extending in the the Gulf do occur as well). For negative transport anomalies through the Florida Straits (<-1.5 Std. Dev) there is a clearly increased probability for long Loop Current paths which extend well into the Gulf of Mexico. Results are similar for both the model and the observations.

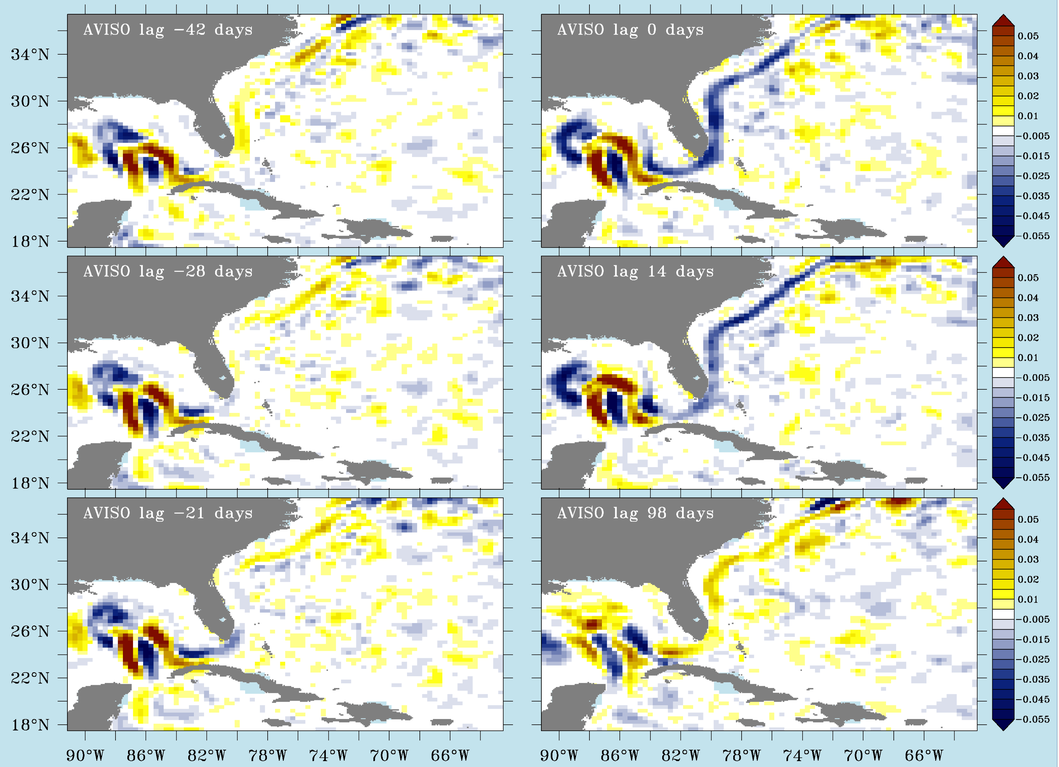

Figure 2: a) Lagged composites of AVISO velocities (in cm/s) preceding (negative lag) and following (positive lags) negative transport anomalies in the Florida Straits.

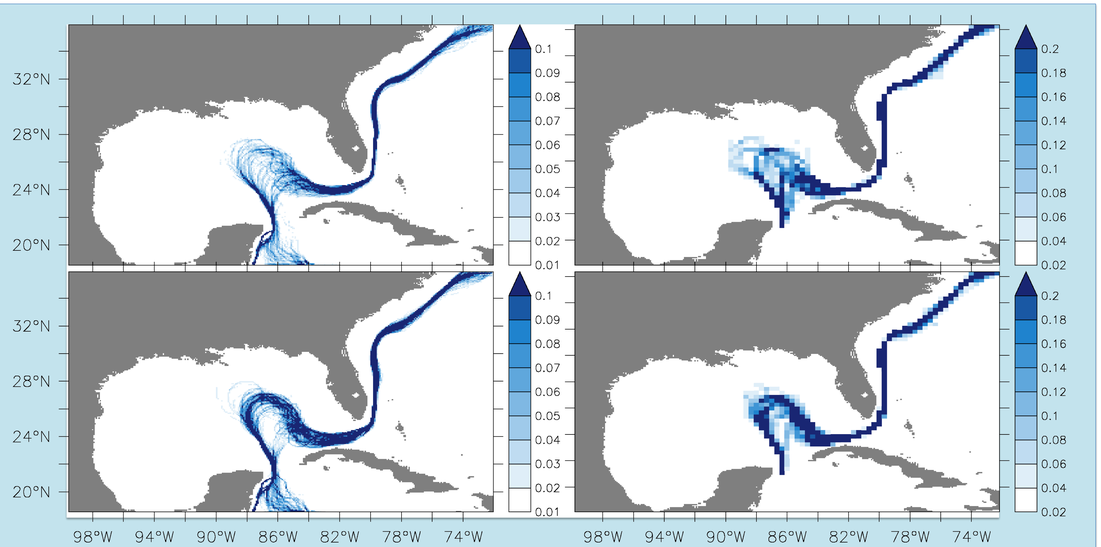

Figure 3: Gulf Stream path distributions for high (transport anomalies > 1.5 Std. Dev.) and low (transport anomalies < 1.5 Std. Dev.). Distributions are shown for AVISO and NEMO 1/12 degree).

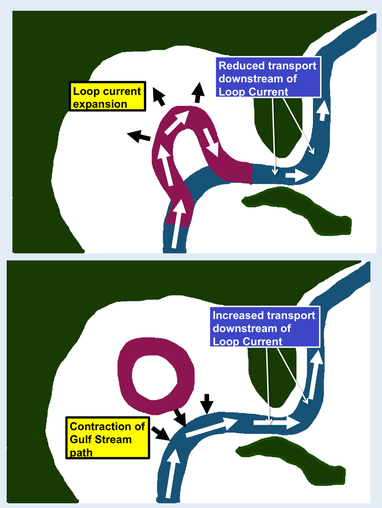

Figure 4: Schematic illustrating simple continuity argument linking LC and downstream transports.

A simple continuity argument

The link between the Loop current and the Florida Straits transport can be explained using a simple model based on continuity:

$$T_{FS} = T_{Yu} - A(t)\frac{\partial L}{\partial t},$$

where T_{yu} and T_{Fs} are the flow into (Yucatan Channel) and out of (Florida Straits) the Gulf of Mexico. *A(t)* is the Gulf Stream cross section and *L* is the Gulf Stream length between Yucatan and the Florida Straits.
If we assume T_{yu} to be constant at 30 Sv and that *A(t)* is temporally constant with a Gulf Stream width of 50 km and a depth of 500 m T_{FS} depends directly on changes of the length *L*. As the Loop Current expands, the flow the downstream flow is reduced. When the Loop Current length contracts (e.g. after the shedding of a Loop Current eddy) the downstream flow increases (**Figure 4**). Assuming a few months for the Loop Current length to increase/decrease by a few hundred km leads to transport changes of several Sv through the Florida Straits

References:

Hirschi et al., Loop Current variability as trigger of coherent Gulf Stream transport anomalies (in prep).
Mildner et al. (2013). Revisiting the relationship between Loop Current rings and Florida Current transport variability. Journal of Geophysical Research: Oceans 118 (12), 6648-6657