Modelling Present-Day and Future Caribbean Sea Level Changes
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The Caribbean Sea is connected to the North Atlantic Ocean and exchange transport values (in Sv, 1 Sv = 10^6 m^3/s) are fairly well known (Fig. 1). It plays an important role in the transport of mass, heat and salt in the Atlantic Ocean circulation system. The upper ocean circulation in the Caribbean Sea is characterized by a warm through flow known as the Caribbean Current. The path and intensity of this current are strongly modulated by the passage of large anticyclonic ocean eddies. These eddies penetrate the Caribbean Sea from the Atlantic and can be traced upstream to originate from the North Brazil Current retroflection area. As they have a clear dynamics related expression in the sea surface height, they may exert a large influence on regional sea level.

(a) 

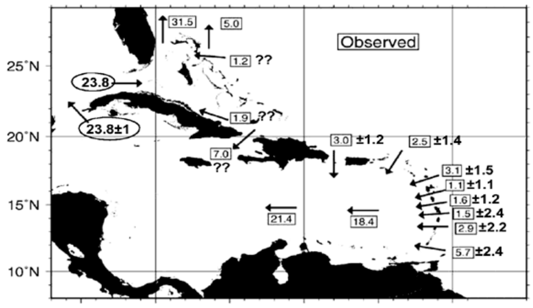
(b) 

Fig. 1. (a) Sketch of the geography of the Caribbean region. (b) Exchange transports of the Caribbean Sea with the North Atlantic Ocean.

Sea level is changing over the North Atlantic Ocean and in particular over the Caribbean Sea. The linear trend over the Caribbean Sea is estimated to be about 1.7 mm/yr over the period 1993-2010 with strong regional inhomogeneities (Torres and Tsimplis, 2013). Several processes were identified that could be responsible for the variations in sea level change in the Caribbean Sea (local wind changes, temperature and salinity changes, connections to El Niño/Southern Oscillation and vertical land movements) but no precise attribution of these changes has been made. As the flow conditions in the Caribbean Sea strongly depend on the inflow from the Atlantic Ocean, regional sea level changes are, however, expected to be strongly dependent on changes in the large-scale Atlantic flow, in particular changes in the North Brazil Current.

For the projection of the future regional sea level changes under the increase of greenhouse gases, currently Global Climate Models (GCMs) are used. In the IPCC-CMIP5 model simulations several Representative Concentration Pathways (RCPs) were used to study the effect of different radiative forcing scenarios on global climate and sea level. Under the RCP4.5 scenario, mean sea level increases (over the years 2000- 2100) along all coastlines is projected to range from 20 to 50 cm (peak at 40 cm) and under an RCP8.5 scenario from about 40 cm to 80 cm with a peak at 75 cm. However, for the projection of the future regional sea level changes in the Caribbean Sea, an adequate modelling of the regional changes in the North Atlantic Ocean circulation are crucial. These are not well captured by the GCMs as used in the CMIP5 because the ocean models do not have enough spatial resolution (typically 100 km is used). Once eddies are resolved in the ocean models, the connection between the North Brazil Current and the Caribbean Sea, and hence much more detail in regional sea level changes, can be captured.

What is also not considered in the CMIP5 simulations (Church et al., 2013) is the extreme scenario that the Atlantic Meridional Overturning Circulation (MOC) will undergo rapid changes in the near future because of its sensitivity to freshwater perturbations in the northern North Atlantic. Observational evidence from the RAPID mooring array indicates that the zonally averaged volume transport at 26°N has decreased over the last decade. The upper branch of the MOC passes through the North Brazil Current. The frequency and intensity of the North Brazil Current eddies varies with the variability of the MOC. Although MOC collapses have not been found in projections of the present-day GCMs, there are indications that these models fail to adequately represent the essential processes leading to such rapid changes (Weijer et al., 2012).

Substantial decreases in the MOC due to freshwater input from the Greenland Ice Sheet have been simulated in global high-resolution models. For example, in the POP model, the MOC decreases by about 15 Sv in 50 years due to a strong (0.5 Sv) freshwater perturbation. Over a period of 50 years also the North Brazil Current and consequently the circulation in the Caribbean Sea changes drastically (Fig. 2a) with substantial consequences for the annual mean sea level (Fig. 2b). This is not only due to changes in the mean path of the North Brazil Current, but also due to changes in eddy formation regions and the propagation corridors.

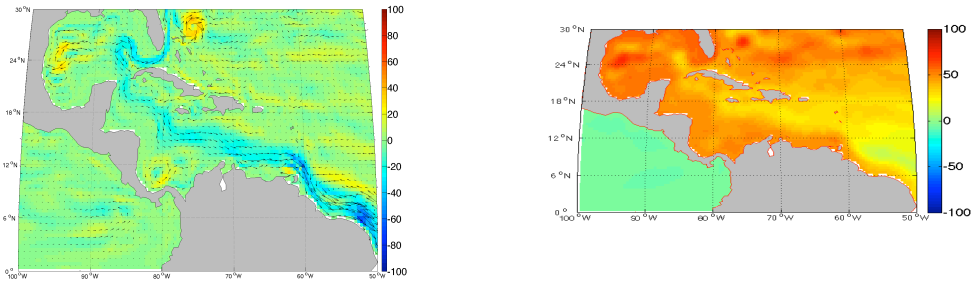


Fig. 2. Annual mean change (after 50 years) in (a) the horizontal velocity field (and speed in cm/s in colour) and in (b) dynamic sea level (cm) of the Caribbean Sea and adjacent regions due to a strong weakening of the MOC as computed in the POP model (Den Toom et al., 2014).

My presentation will address (past and possible future) connections between changes in the large-scale Atlantic Ocean circulation and sea level changes in the Caribbean Sea, with focus on the modelling requirements to determine: (i) how much of the Caribbean regional sea level changes over the past decades can be attributed to dynamic sea level changes caused by variations in the Atlantic large-scale flow, and (ii) whether future changes in ocean currents in the North Atlantic will have a major influence on the path and strength of the Caribbean Current (and the associated eddies) and hence on regional sea level and sea level extremes.

References:

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