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LETTER

On the key influence of remote climate variability from Tropical Cyclones, North and South Atlantic mid-latitude storms on the Senegalese coast (West Africa)

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E-mail: rafael.almar@ird.fr**Keywords:** sea level, coastal vulnerability, longshore sediment transport, North Atlantic oscillation, Southern Annular mode, Tropical Cyclone, wavesSupplementary material for this article is available [online](#)**Abstract**

The low-lying Senegalese sandy coast is extremely vulnerable to marine flooding and erosion. Using climate and wave reanalysis, we establish the remote connections between Atlantic climate modes and coastal wave variability in Senegal. We show that impacting swells come from the North Atlantic in boreal winter but also from the South and Tropical Atlantic in boreal summer. Near shore-normal tropical cyclones swells have a large impact on the sea level contribution at the coast but a limited influence on the longshore sediment transport. In contrast, boreal summer south swells have a large destabilizing coastal impact due to a reversal of the climatological southward sediment drift. They also induce large sea level anomalies on the southern Senegalese coast, the most exposed to flooding. This study emphasizes the importance of quantifying the influence of both the regional and remote climate variability on wave activity to better understand the drivers of coastal evolution and vulnerability.

1. Introduction

Due to the potentially dramatic societal impacts of coastal flooding and erosion on a worldwide increasing littoral population, there is an urgency to better establish the local and remote connections between climate variability and coastal dynamics (Nicholls and Cazenave 2010). Regional studies of coastal flooding exposure do not generally incorporate all the sea-level components of flooding levels, most notably waves (Menéndez and Woodworth 2010, Nicholls *et al* 2014). Yet, waves have recently been shown to contribute greatly to extreme sea level episodes (Rueda *et al* 2017, Serafin *et al* 2017, Vitousek *et al* 2017, Vousdoukas *et al* 2018), whether associated with a local windstorm or a remote storm (Hoeke *et al* 2013, Ford *et al* 2018). For instance, a temporarily increased sea level combined with an energetic wave event can lead to increased probabilities of flooding with potential catastrophic impacts on coastal structures (Almeida *et al* 2018). The wave setup corresponds to the rise in mean water level at the coast due to nearshore wave dissipation (Longuet-Higgins and Stewart 1962). As a general rule of thumb, wave setup on sandy beaches represents up to 20% of the offshore wave height (Bowen *et al* 1968). Changes in offshore waves can therefore modulate wave setup and affect water level at the coast at longer time scales (e. g. Melet *et al* 2018, Mentaschi *et al* 2018).

The West African coast (5°N–20°N, 17°W–9°E) is generally considered a storm-free environment. Nonetheless, the open coast is dominantly exposed to North Atlantic swells (Sadio *et al* 2017) and can also be under the influence of long travelling swell generated in the southern hemisphere as well as by tropical storms. Wave regime along the South coast of West Africa (i.e. the Gulf of Guinea) is mostly influenced by the extratropical South Atlantic Southern Annular Mode (SAM) and its own natural variability. The SAM strongly affects sea level variability (Melet *et al* 2016 2018) and the longshore sediment transport (Almar *et al* 2015), both of which drive significant coastal changes in this part of Africa (Anthony *et al* 2019). For example, Melet *et al*

(2016) reported a significant contribution of wave setup to coastal water level from individual event up to interannual time scales. The morpho-sedimentary evolution of the West African sandy coast is controlled by a strong longshore sediment drift resulting from oblique waves (Davies 1980, Anthony 1995, Laibi *et al* 2014). Given the magnitude of longshore sediment transport rates, small changes in alongshore gradients can result in massive local erosion or accretion. Such perturbations have been increasingly occurring over the last few decades due to recent human intervention, especially from the construction of river dams and coastal urbanization, but also due to changes in wave regime (Sadio *et al* 2017, Anthony *et al* 2019). While erosion is a global issue (Luijendijk *et al* 2018), the recent increase is exacerbated and rapidly becoming a major issue along Senegal (14° N– 16° N; 17.5° W– 16.5° W) and West Africa low lying sandy coasts (Ndour *et al* 2018).

In this paper, we bring together local and remote wave regimes and their coastal impacts in order to quantify the main causes of coastal vulnerability along the Senegalese coast. The paper will be structured as follows: in section 2, we present the datasets and methods designed to grasp the different sources of wave activity. Section 3 details the main results and in particular the impact of wave events from different origins on the Senegalese coast. The last two sections include a follow-up discussion and concluding remarks.

2. Approach, data and methods

2.1. Forcing of coastal vulnerability

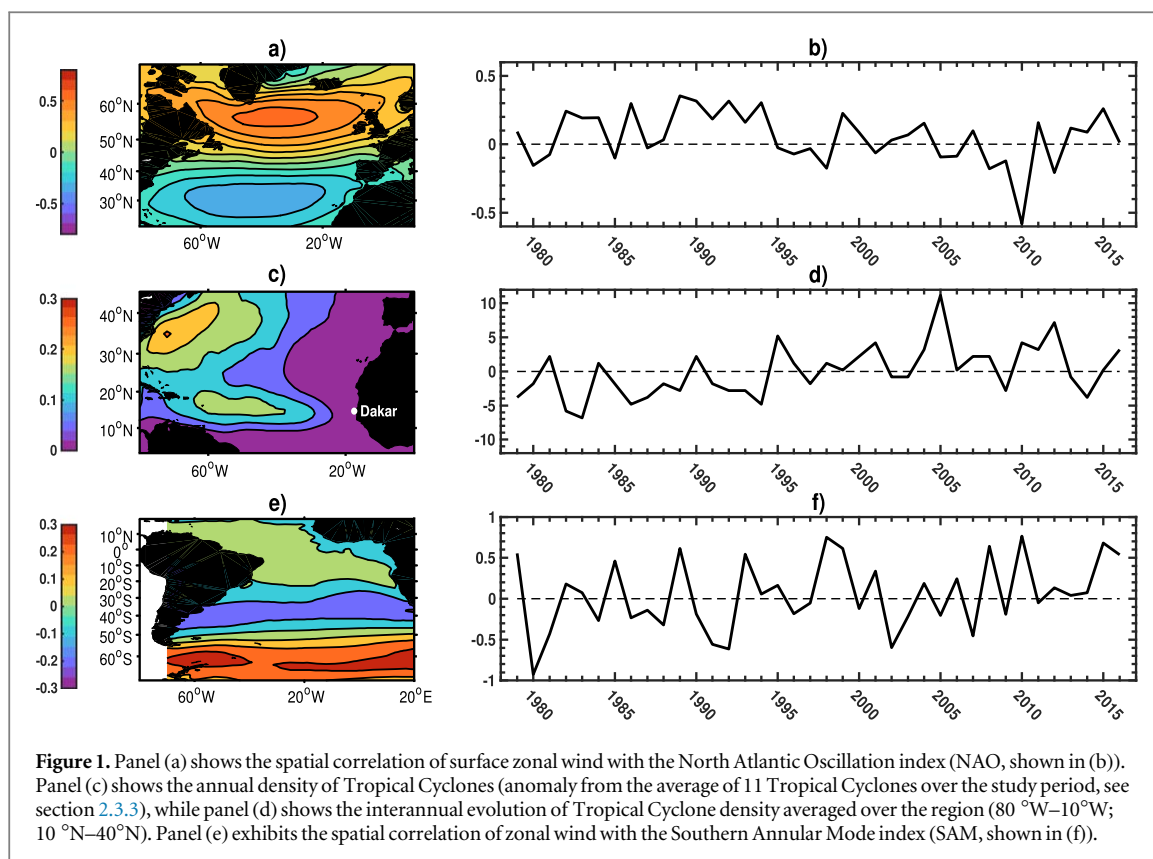
In this study, we focus on two major threats to littoral population, namely coastal erosion due to wave-induced sediment transport anomalies and flooding through extreme sea level episodes. The leading contributors differ depending on the time-scales and the region considered (Melet *et al* 2018); they include steric sea level anomalies, local oceanic circulation, atmospheric pressure, winds, tides and waves effect. Altimetry sea-level timeseries are extracted from the gridded daily maps produced by the SSALTO/DUACS (Pujol *et al* 2016). The wind and atmospheric corrections (named DAC), removed from the final altimetry product, were re-introduced in the dataset. The wave-induced contribution to the sea level at the coast, i.e. the wave setup, is computed from the classic parameterization proposed by Stockdon *et al* (2006) (see equation (1) in the supplementary material) and added to the altimetry component to compute the total sea level at the coast. As a way to quantify the coastal erosion potential, we estimate the bulk longshore sediment transport along the coast using the empirical formula proposed by Kaczmarek *et al* (2005), where the longshore sediment volume transport is computed within the surf zone in sandy environments (Almar *et al* 2015; see equations (2)–(4) in the supplementary material).

2.2. Wind and wave data

Atmospheric variables (surface winds, sea level pressure) and wave data (significant height H_s , peak period T_p and direction) are extracted from the European Centre for Medium-Range Weather Forecasts model (ERA-Interim) at a $0.5^{\circ} \times 0.5^{\circ}$ and 6-hr temporal resolution in the Atlantic Ocean between 1979 and 2016. The ERA-Interim reanalysis uses an ocean wind–wave model coupled to the atmosphere (Hasselmann *et al* 1988), which has been extensively validated (Sterl and Caires 2005, Caires *et al* 2006, Dee *et al* 2011). A word of caution must be mentioned here. Although ERA-interim reanalysis is widely used for both tropical cyclone and wave studies and the ‘satellite era period’ examined in this article is considered as the most reliable, the reader must keep in mind that this product still suffer numerous biases. Reanalysis and ERA-Interim in particular are known to underestimate the extremes (Hodges *et al* 2017). However, waves are less affected than winds by the relatively coarse resolution of ERA-Interim and the underestimation of extremes winds experienced during Tropical Cyclones because they are more controlled by the fetch and more long-lasting processes, in particular for distant location to the generation zone such as West Africa. This bearing in mind that extra-tropical meso-scale storm-induced waves in the South and North Atlantic are mostly well reproduced by ERA-Interim. We choose to extract Senegal’s daily wave characteristics at the closest model grid point off the coast of Dakar. Indeed, the populated capital of Senegal is located at the tip of the Cape Verde peninsula and therefore is under the influence of incoming waves from a wide range of direction (i.e. roughly from 180° (South) to 360° (North)) and likely to undergo various wave regimes. West Africa is maybe one of the less documented coastal zones around the world and long-term observations are highly needed. However, preliminary verifications of ERA-Interim performances in the Gulf of Guinea using long-lasting coastal sensors (Abessolo Ondoia *et al* 2017) give us confidence in the use of this product.

2.3. Wave origins and their connection to climate modes

Dakar is potentially under the influence of three distinct wave regimes detailed below:



2.3.1. North Atlantic Oscillation (NAO)

The NAO is the main mode of climate variability at mid-latitudes in the North Atlantic (Hurrell 1995). Here, we use daily values of the North Atlantic Oscillation (NAO) index provided by the United States National Oceanic and Atmospheric Administration (NOAA). The NAO spatial pattern is presented in figure 1(a) by the correlation map between the yearly NAO index (figure 1(b)) and surface zonal winds. This pattern depicts the well-known meridional seesaw of atmospheric sea-level pressure around the storm-track in the North Atlantic. It is known that the interannual to decadal variability of winter wave's activity in the North Atlantic is strongly affected by the NAO (e.g., Bacon and Carter 1993, Dodet *et al* 2010, Izaguirre *et al* 2010, Martinez-Asensio *et al* 2016, Castelle *et al* 2018). Because the NAO dominantly affects storm waves in Western Europe, it was recently related to dramatic coastal flooding (Thorne, 2014) and erosion issues in this region (e.g., Castelle *et al* 2015, Suarez *et al* 2015, Masselink *et al* 2016). We expect similar dramatic effects occurring along the West African coastline.

2.3.2. Southern Annular mode (SAM)

We use daily values of the Southern Annular Mode (SAM) daily index from the British Antarctic Survey (BAS) (Marshall, 2003). Similarly, the SAM spatial pattern, shown in figure 1(e) by the correlation map between yearly values of the SAM index (figure 1(f)) and surface zonal winds exhibits an atmospheric sea-level seesaw around the South Atlantic storm track. Hemer *et al* (2010) observed that wave energy in the South Atlantic are negatively correlated with the SAM in austral winter (Bosselle *et al* 2012). In particular, negative SAM values are related to an increase in wave activity due to an increase in the atmospheric pressure gradient between the mid and high southern latitudes (figure 1(e)), which forces the storm track to remain south of 50 °S. A positive trend is currently observed in the yearly SAM index (figure 1(f)) with an intensification of the Southern Ocean storm activity (Marshall 2003, Sterl and Caires 2005), although this tendency is not as clear in the South Atlantic domain of the Southern Ocean. While Almar *et al* (2015) showed that swells travel from the South Atlantic to the Gulf of Guinea's South coast, it is still unclear to which extent these wave events may influence coastal wave energy along the Senegalese coast where they are mixed with dominant North swells in this region.

2.3.3. Tropical cyclones (TC)

The Atlantic is the third most active Tropical Cyclones basin, with a seasonal average of eleven named storms (i.e. tropical storm or higher strength) including six tropical cyclones and two major tropical cyclones (Category 3 and above). Atlantic tropical cyclones do not usually affect directly West Africa (e.g. no landfalls), since easterly

winds carry the storms away from land. Also, storms that move off the African coast are generally weak as they are still at the beginning of their genesis phase and haven't reached their maximum potential intensity. However, Atlantic Tropical Cyclones can develop just off the West African coast (Zipser and Gautier 1978, Sall and Sauvageot 2005, Zipser *et al* 2009) and generate frontal waves that might have potentially significant destabilizing impacts along this coastline.

The trajectories and intensities of Tropical Cyclones are extracted over the period of 1979–2016 from the best track archives provided by NOAA's Tropical Prediction Center. As a measure of Tropical Cyclone activity, we use a spatial density index. The storm density is the monthly number of storms with maximum sustained winds larger than 32 knots in a $5^\circ \times 5^\circ$ sliding box covering the entire Atlantic basin at a $1^\circ \times 1^\circ$ resolution (cf procedure described thoroughly in Boucharel *et al* 2016).

Figure 1(c) shows the Tropical Cyclone mean density pattern in the North Atlantic, which exhibits two main areas of high storm activity, one off the coast of Senegal that extends zonally across the basin and one along the US east coast. Figure 1(d) shows the annual time series of Tropical Cyclone density averaged over the main genesis region (80°W – 10°W ; 10°N – 40°N) during the Tropical Cyclone boreal season (April–November). There is a strong interannual variability over the period 1979–2016 superimposed onto a significant trend (i.e. which passes the Mann-Kendall test, significant at the 95% level) towards an increased number of Tropical Cyclones in this region (around 1.6 additional event per decade). This increase in storm density is consistent with Klotzbach (2006), and has been associated with a change in phase (i.e. from negative to positive) of the Atlantic Multidecadal mode (Gray *et al* 1997, Goldenberg *et al* 2001, Pielke *et al* 2005).

2.4. Identification of swells origins

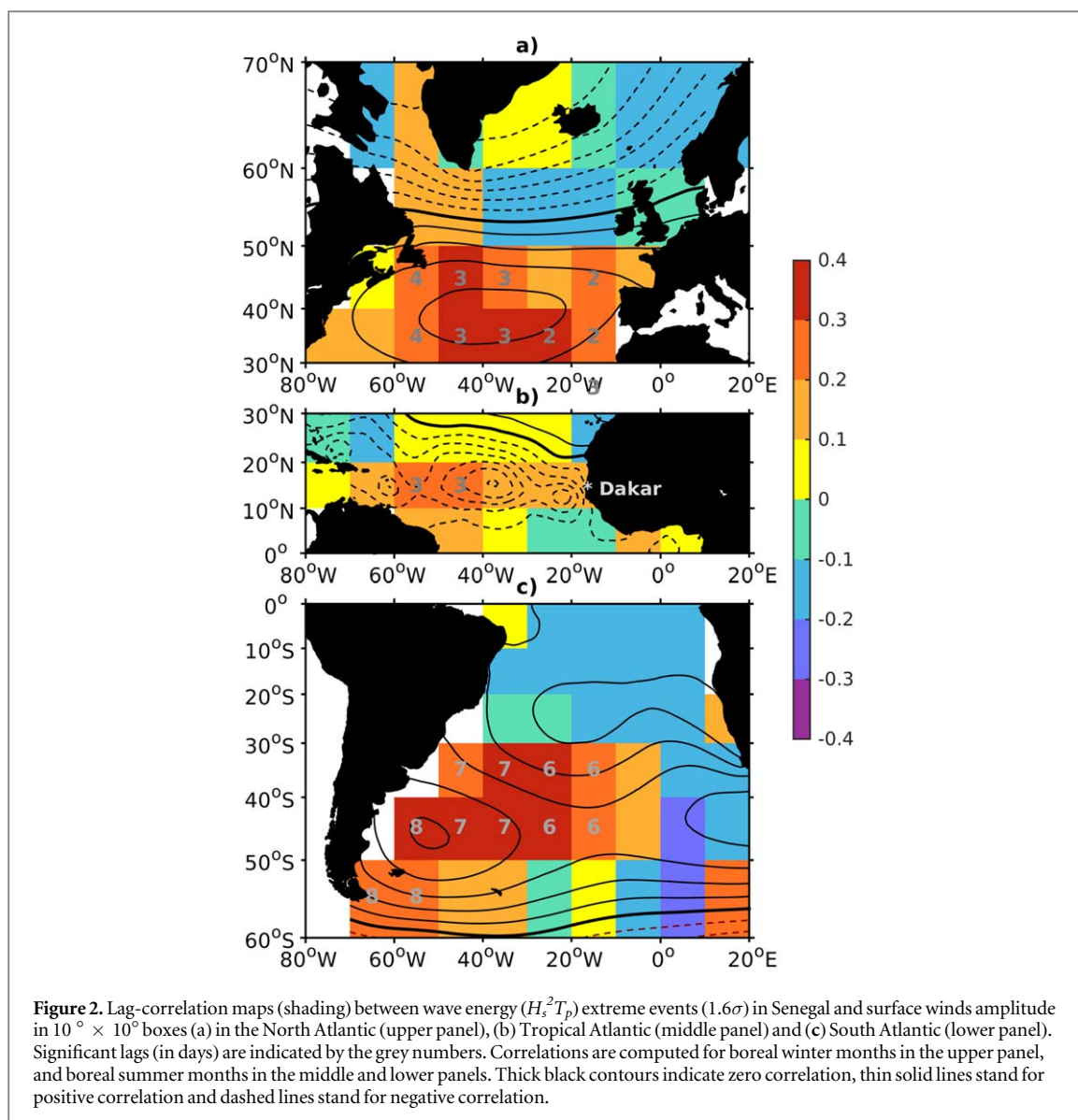
In this section, we describe the procedure that allows us attributing the origin (mid-latitude versus tropical) of significant wave episodes at Dakar. The difficulty here lies mostly in disentangling the provenance of summer/fall (i.e. Tropical Cyclone season) swells at Dakar characterized by a North-Northwest incoming direction since such wave events can originate either from a mid-latitude storm or a Tropical Cyclone. To identify which swell occurrences in Senegal have a tropical origin (i.e. are generated by Tropical Cyclone-induced winds),

(1) We first isolate the days when the waves characteristics fit the following criteria:

- Swell direction between 225° and 360° . Based on the pattern of Tropical Cyclone location (figure 1(c)), we set a lower limit of 225° (West South-West), as clearly waves at Dakar with a more southern origin cannot be generated by a North Atlantic Tropical Cyclone. Due to the West Africa coastline angle of inclination, swells with a Northeastern incidence cannot reach Dakar.
- Swell peak period $T_p > 12$ s. This criterion allows discarding local low-energy swells (i.e. wind waves) with little coastal impacts (Sadio *et al* 2017) and also optimizing the algorithm computation time. Results are however almost insensitive to the lower limit of the swell peak period (cf supplementary material).
- Interannual anomaly (relative to a monthly climatology) of wave energy (i.e. $H_s T_p^2$) above one standard deviation, calculated over the boreal Tropical Cyclone season only (May–November). We present results using different thresholds in the supplementary section.

(1) Then, for each swell event fitting the above characteristics, we evaluate if at least one Tropical Cyclone occurred in the entire North Atlantic domain up to 11 days before the wave episode happened at Dakar. 9–11 days correspond roughly to the travel time for a 12-seconds swell generated along the coast of Georgia (USA) to reach Senegal (i.e. approximately the largest possible distance between Dakar and a North Atlantic tropical cyclone, cf figure 1(c) and figure S1 is available online at stacks.iop.org/ERC/1/071001/mmedia). This propagation time is estimated using the deep-water approximation, i.e. $c \approx 1.56 T_p/2$. (c being the swell propagation speed, i.e. the group speed, and T_p the swell peak period).

(2) Finally, we assess if the storm's position, at any moment between the time of wave occurrence at Dakar up until 11 days before, can explain the actual wave characteristics along the Senegalese coast (i.e. direction and peak period). To do so, based on the direction and propagation speed (again estimated using the deep water approximation) of the swell impacting Dakar, we evaluate via a backtracking procedure if (or/and when) the storm's position (both in time and space) can generate such local waves characteristics. The remaining significant wave events (i.e. above the 1.6 standard deviation threshold) that do not have a tropical origin are simply separated by their direction of incidence, into a Southern ($<225^\circ$) and Northern ($>270^\circ$) origin. The

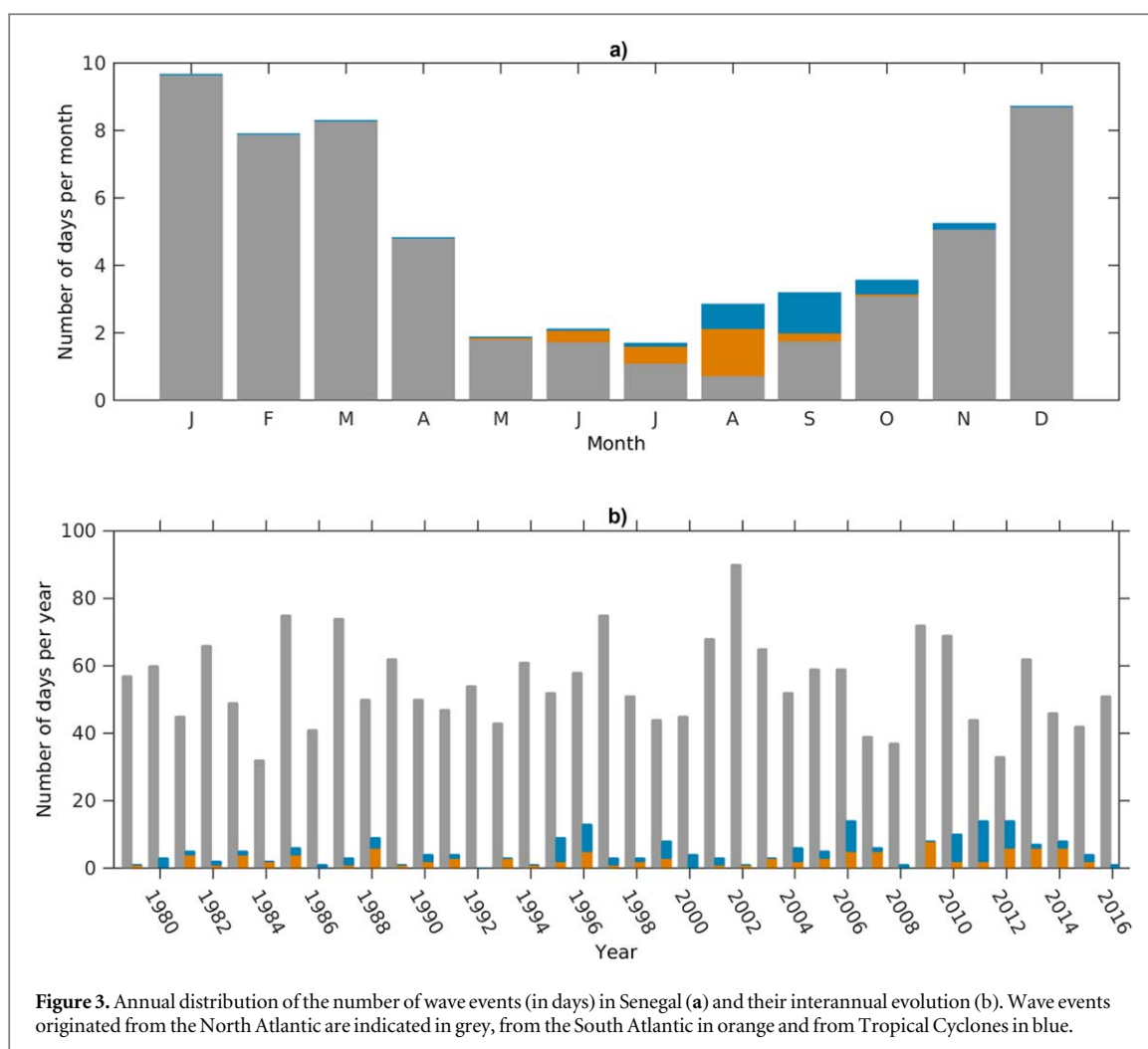


reader is invited to refer to the supplementary material for additional details and validations regarding this technique.

3. Results

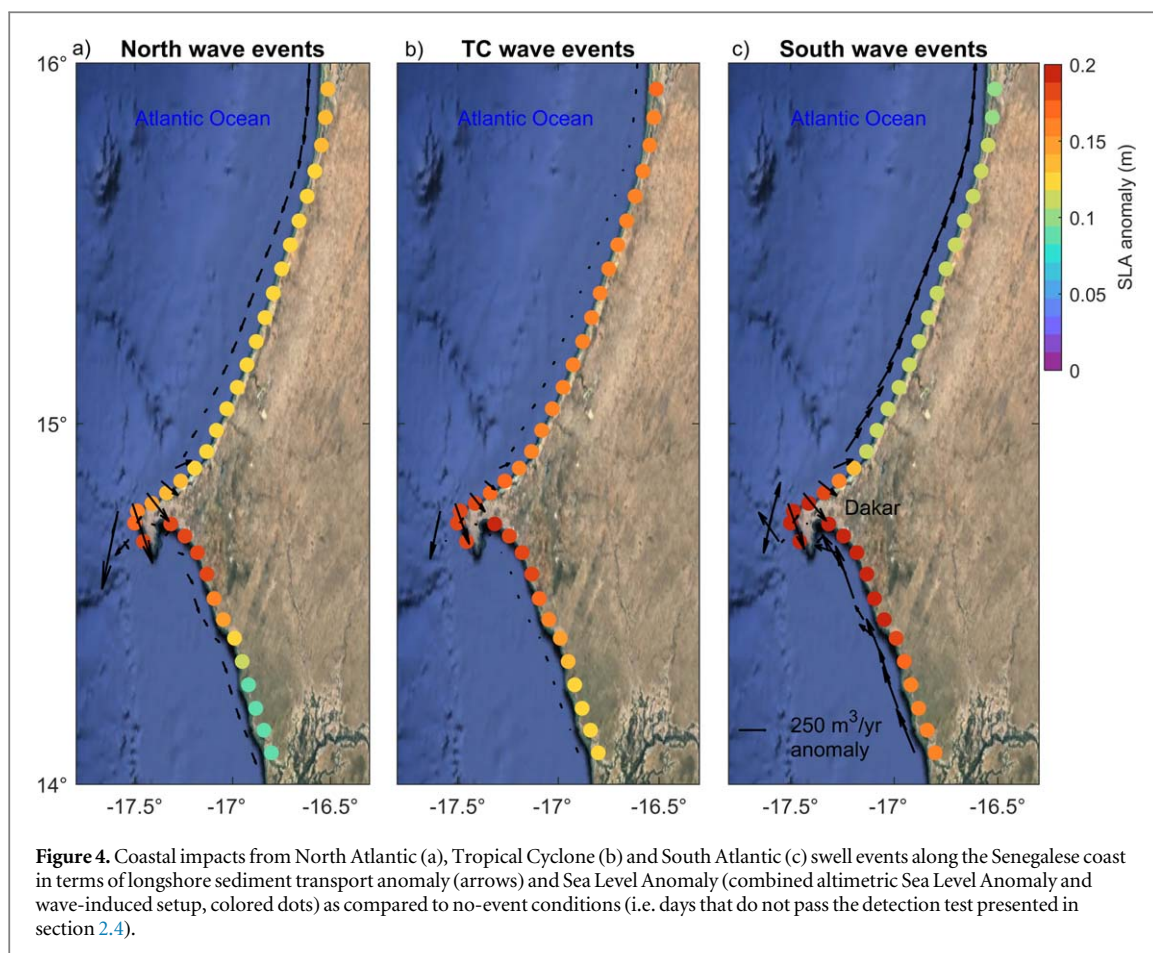
3.1. Origin and variability of waves in Senegal

The calculation over the available ERA-Interim period (1979–2016) gives annual significant wave heights of $H_s = 1.5$ m and wave peak periods of $T_p = 9.2$ s (Sadio *et al* 2017). Figure 2 is a lag-correlation analysis between daily large-scale surface winds amplitude and wave energy in Senegal for different regions of the Atlantic basin. It shows that winter waves in Senegal are predominantly (correlation coefficient of 0.4) generated by mid-latitudes surface wind variability ($40\text{--}50^\circ\text{N}$) that takes around 3–4 days before reaching the Senegalese coast (figure 2(a)). This region of wind generation matches the NAO-related storm track location highlighted in figure 1(a). In addition, a significant negative correlation (-0.79 at interannual scale based on winter months' average, significant at the 95% level) between yearly waves energy in Senegal and NAO index (figure 1(b)) confirms that winter wave conditions in Senegal are mostly driven by NAO dynamics and enhanced by a southward displacement of the storm belt related to a negative NAO phase. Figure 2(c) displays a similar pattern highlighting that summer waves in Senegal originate dominantly from the South Atlantic mid-latitudes wind variability. There is a significant correlation located off Patagonia (0.35) at a 7–8 days lag, characterizing a larger distance of propagation as compared to the North Atlantic. Again, the region of swell generation that impacts Senegal in summer matches the SAM-related storm track location shown in figure 1(e) ($40^\circ\text{S}\text{--}50^\circ\text{S}$). The link between SAM and wave activity in Senegal along with the positive trend of the SAM index (figure 1(f)) are



indicative of a tendency towards larger waves from the South Atlantic impacting Senegal. Interestingly, we also observe a significant correlation between daily wave activity along the Senegalese coast and the tropical Atlantic surface wind variability in boreal summer (cf figure 2(b)). This region corresponds to one of the main Tropical Cyclone genesis region located off Western Africa (60°W – 40°W ; 10°N – 20°N), as shown also on figure 1(c). Such waves take approximately 3 days to reach Dakar (cf lags on the figure 2(b)).

We then quantify the respective contribution of these different swell regimes (Tropical Cyclones versus North/South Atlantic mid-latitudes; more details on these events in supplementary table 1) to both the seasonal and interannual variability of Senegal wave activity. Results are presented in figure 3 and clearly show that wave episodes in Senegal come predominantly from the North Atlantic, in particular during the boreal winter from November to June. However, figure 3(a) also highlights a change in swell origin in August when wave activity in Senegal mostly originates from the South Atlantic (increased storminess in the southern hemisphere in austral winter). Surprisingly, as noted already above, swells originating from Tropical Cyclone events are far from negligible especially in boreal summer. We identify on average ~ 3 days per year of significant swell at Dakar that have a tropical origin. Interestingly, not only Tropical Cyclones developing off the Senegalese coast, but also Tropical Cyclones along the North America East coast can generate swells that propagate across the basin (in 1 to 4 days depending on the swell dominant period) and affect the Senegalese coast. Such Tropical Cyclone-induced swells happen throughout the boreal Tropical Cyclone season (April–November) with a well-marked peak in September (54 days total or ~ 1.5 occurrences per year of waves generated by a Tropical Cyclone). The annual time series of swell days at Dakar originating from a Tropical Cyclone (figure 3(b), blue bars) exhibits a strong interannual and decadal modulation negatively correlated with the NAO index (-0.40 , significant at 95% level). Overall Tropical Cyclone have a similar occurrence frequency than South Atlantic swells, although shifted towards the boreal fall. While North Atlantic events show a large interannual variability they do not exhibit any significant trend, whereas Tropical Cyclones and South Atlantic events tend to display an increase (figure 3(b)) driven by the positive trends of Atlantic Tropical Cyclones and SAM (figures 1(d), (f)).



3.2. Coastal impacts

In this section, we assess the vulnerability of the Senegalese coast in relation with these different wave regimes, with a focus on their potential induced flooding and erosion. Most of the Senegalese sandy drift-aligned coast is marked by an overall southward longshore sediment transport ($\sim 700\,000\text{ m}^3\text{ yr}^{-1}$ at the North Coast, $\sim 300\,000\text{ m}^3\text{ yr}^{-1}$ at the South Coast; computed using the method described in section 2.1; more details in supplementary table 1) driven by the almost year-round dominant North Atlantic swells (cf previous section). This drives a significant and continuous erosion all along the coast of Senegal. However, some hotspots of erosion have been recently highlighted, such as the North Coast at the Senegal river mouth (Saint Louis sandspit and historical city, 16°N ; Sadio *et al* 2017, Ndour *et al* 2018), and the South Coast of Dakar (Petite côte and Mbour area, between 14.5° and 14.7°N ; Ngom *et al* 2018), which correspond to the area of interest of this study. Any change in regional longshore sediment transport pattern caused by strong swell events can affect and destabilize the coast in a different way (Anthony *et al* 1995). It is therefore likely that the various wave regimes identified previously will have contrasted impacts at the coast.

Figure 4 breaks down the sea level and longshore sediment transport anomalies for each of the wave regimes. We compute composites of these proxies of coastal vulnerability during their respective time of occurrence (i.e. events average). See section 2 and the supplementary material for more details on the estimation of these parameters. Figure 4(a) shows an enhanced southward longshore sediment transport caused by wintertime swells coming from the North Atlantic. They are also responsible for a strong positive sea level anomaly in the Dakar region and northern Senegalese coast. These energetic long period swells have the potential to refract more on the wide and shallow continental shelf and thus also impact the South Coast of Senegal. Interestingly, both Tropical Cyclones and South Atlantic swells have a strong signature in sea level and sediment transport (figures 4(b) and (c)). Although not as frequent, they occur in summer when the seasonal coastal water level is already high ($\sim 25\text{ cm}$ coastal sea level observed off Dakar from altimetry) due to local winds blowing onshore (toward the coast) (Capet *et al* 2017). Figure 4(b) shows that Tropical Cyclones are responsible for large water level events all along the coast in boreal summer. Tropical Cyclone waves have an almost shore-normal West-Northwest incidence (i.e. frontal), as compared to oblique extra-tropical waves, and thus promote large sea levels anomalies, potentially dramatic for coastal population (see supplementary equation 1) on both the North and South coasts, but a weak sediment transport anomaly (driven by oblique waves, see supplementary

equations (2)–(3)). South swell events have a similar impact on the South coast and also drive a significant longshore sediment transport reversal (i.e. northward anomalies) along the whole coast (figure 4(c)). This tends to provoke destabilizing effects on sediment systems leading to increased coastal erosion.

4. Discussion

Our results show the link between modes of climate variability and strong wave events in Senegal originating from the North, Tropical and South Atlantic, for the present climate. Nonetheless, it would be crucial for local population and coastal management services to evaluate such connections in the context of global warming. In this section we provide a brief review of the future evolution of the climate modes related to the Senegalese wave regimes, which, we hope, can serve as a basis for such upcoming studies.

In the Atlantic, climate modelers (Yin, 2005, Bengtsson *et al* 2006, Semedo *et al* 2013) tend to reach the consensus that an overall warming world will lead to a poleward shift in extratropical storm tracks (especially in the Southern Hemisphere), with no overall intensification but considerable regional changes (Mizuta, 2012, Zappa *et al* 2013). Yet still an ongoing matter of debate, an increased intensity of tropical storms has been reported by various studies (e.g. Nicholls *et al* 2007, Sterl *et al* 2009, Hemer *et al* 2012, Vitousek *et al* 2017). Although no straightforward relationships between the NAO and Tropical Cyclone activity have been established in the Atlantic, McCloskey *et al* (2013) showed that a negative NAO phase promotes a weaker Bermuda subtropical high pressure system that leads to atmospheric conditions more favorable for storms tracking through the western tropical Atlantic and the Caribbean. Such storms are unlikely to generate swells that affect the Senegalese coast. Conversely, during positive NAO years, Tropical Cyclones tend to track Northward (along the U.S. East coast) over the extratropical Atlantic waters and therefore are more likely to produce swells reaching the coast of Senegal. Large uncertainties remain in the climate change projections of Tropical Cyclone activity, depending on the characteristic being considered (Camargo 2013, Woodruff *et al* 2013, Walsh *et al* 2016). Clearly, it is nearly impossible to tell if the trend in Tropical Cyclone activity observed over the last ~40 years in the Atlantic basin will continue, increase or even change sign, in particular in the context of the low-frequency internal variability and a potential reversal of the Atlantic multidecadal mode.

As wave coastal impacts depend on wave characteristics in the open ocean, they are also expected to be affected by modes of climate variability and thus undergo significant changes under future climate scenarios (Hemer *et al* 2010, Semedo *et al* 2011, Young *et al* 2011, Hemer *et al* 2013, Wang *et al* 2014). In addition to an expected increase in storminess and flooding impact (Vitousek *et al* 2017), more common Tropical Cyclones and South Atlantic events have the potential to change considerably the equilibrium state of the Senegal sandy coast and by extension probably the entire West African coast with a likely destabilization of the coastal alignment (Anthony *et al* 1995; Harley *et al* 2015).

5. Summary and conclusions

The low-lying Senegalese sandy coast is particularly vulnerable to marine flooding and erosion (Sadio *et al* 2017, Ndour *et al* 2018, Ngom *et al* 2018). In particular, swells have the potential to propagate wind variability over large distances. Using wind and wave reanalysis products, we established the local and remote links between modes of climate variability and local coastal wave activity in Senegal. In this region, wave forcing is complex, with waves coming from the North Atlantic in boreal winter, and the South and Tropical Atlantic in boreal summer. Waves reflect the contrasting wind climate and regional modes, summarized as no interannual tendency in the NAO, increased SAM, and Tropical Cyclone activity. Episodic Tropical Cyclone swells have an unexpectedly large impact on sea level at the coast but limited influence on the longshore sediment transport due to their almost shore-normal incidence. South swells have a large destabilizing potential on the coastal morphology due to a reversal of the southward climatological drift. They also induce large anomalies of sea level on the southern coast, the most exposed to flooding. This study stresses out the importance of quantifying the influence of large-scale climate modes on coastal waves to better understand changes in coastal vulnerability, namely erosion and flooding.

Furthermore, this study emphasizes the significant yet largely underrated effect of remote climate variability on wave activity in Senegal. In particular, Tropical Cyclones, which do not have a direct impact (e.g. landfalls, surface winds) on this coastline, are shown to strongly influence the Senegalese coastal dynamics. This should bring awareness to this research community in considering not only local but also remote origins of extreme coastal events. The methodology of this paper can therefore be applied to various tropical coastlines that are under the influence of diverse swell sources (e.g. Gulf of Mexico, Pacific and Tropical Atlantic Islands).

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