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Wind as driver of sub-annual sea level anomalies on South Brazil and Patagonian Shelf

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Motivation:

Sea level anomalies (SLA) on the shelf and at the coast are of particular interest, especially when it comes to higher temporal and spatial frequencies. Knowing the drivers of SLA is important to understand the ocean dynamics, make reliable projections for e.g. sea level extremes and possibly improve SLA products. Wind is known to impact ocean circulation and SLA on annual and seasonal scales on parts of the Patagonian and Brazil shelf (Saraceno et al. (2014), Ruiz Etcheverry et al. (2016)). Linking wind to SLA on sub-annual scales resolved by gridded SLA and wind speed (components) shows the capabilities and limits of the CMEMS gridded products and opens new possibilities for improvements.

The Data and Methods:

Data:

Daily SLA and wind speed (components) from 1993-2019 are taken from Copernicus Marine Environment Service (CMEMS, https://marine.copernicus.eu) from global gridded SSH and 6h-wind-fields in 0.25°x0.25° resolution. SLA are validated using daily averaged tide gauge SLA from GESLA3 (https://www.gesla.org), which are 40h-Loess filtered and corrected for Dynamic Atmosphere Correction (DAC, https://www.aviso.altimetry.fr/).

Methods:

Daily along-shore wind speed was estimated considering the coastline as line rotated by 39° to the geographic Merian. Coherence of daily SLA (DAC-corrected) and along-shore wind speed was estimated at each grid point over 27 years using hanning-window and 50%-overlap. Significance on 95% confidence level is reached at 0.32. EOF-analysis was used for decomposing the SLA signal on the shelf in order to identify modes of variability driven by wind.

SLA Validation:

	station name	time frame	$corr_{alt}$ (DAC)	$corr_{alt}$ (no DAC)
USH	Ushuaia	01/2015 - 12/2018	0.278	-0.008
MAR	Mar del Plata	01/2015 - 12/2018	0.667	0.508
PUE	Puerto Desado	01/2015 - 12/2018	0.568	0.376
UBA	Ubatuba	01/2015 - 07/2017	0.67	0.508
CAN	Cananaia	01/2015 - 10/2016	0.568	0.376

Table 1: Tide gauge stations (see Fig.1). Available time frame within study period, correlation with altimetry SLA, applying DAC on tide gauge SLA (DAC) and removing DAC from altimetry-based SLA (no DAC).

Correlation coefficients between daily, 40h-Loess-filtered tide gauge SLA and altimetry SLA are higher for DAC corrected data (DAC-correction applied on tide gauge data). All stations show a good agreement with altimetry SLA, with exception of the southernmost station Ushuaia.

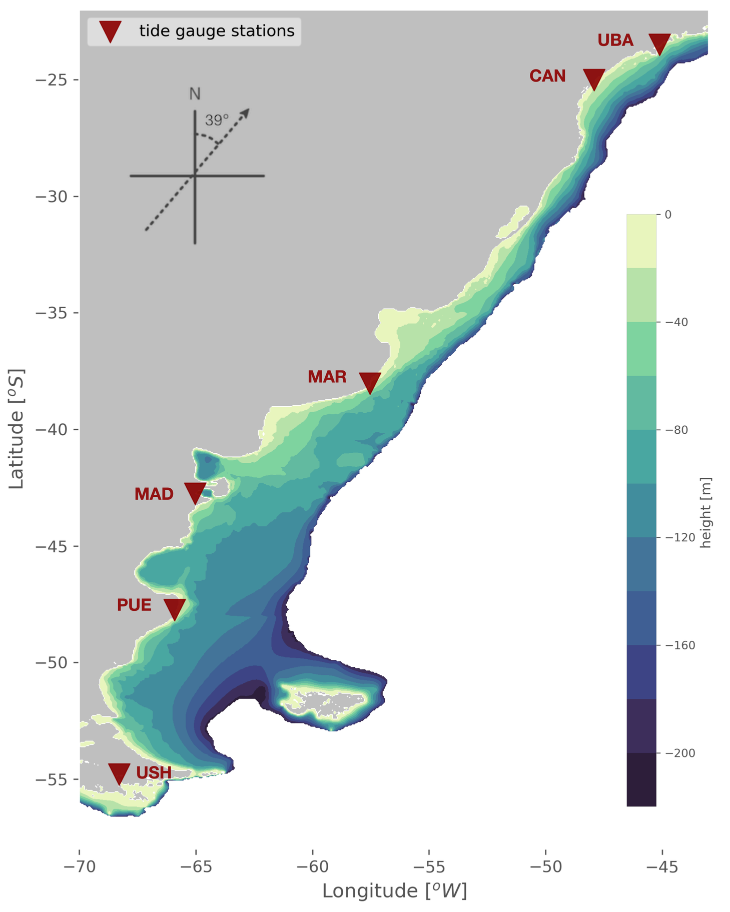

Figure 1: Study area of Southwestern Atlantic Shelf. Bathymetry on the shelf area in m from General Bathymetric Chart of the Ocean (GEBCO, 2003) combined with the bathymetry measurements from Servicio de Hidrografia Naval (SHN, Argentina) and tide gauge locations.

Wind variability and direction:

In the northern domain (>35°S), wind is directed from northwest and westward towards the coast. On the shelf wind variability increases south of 35°S, with highest variability in the winter months and at the southernmost end of the domain, connected to the Antarctic Circumpolar. In the south (<40°) strong westward winds are prevailing. For latitudes between 30-40°S, wind direction regionally changes between summer and winter on the shelf off the Rio de la Plata estuary and at the northern attached shelf.

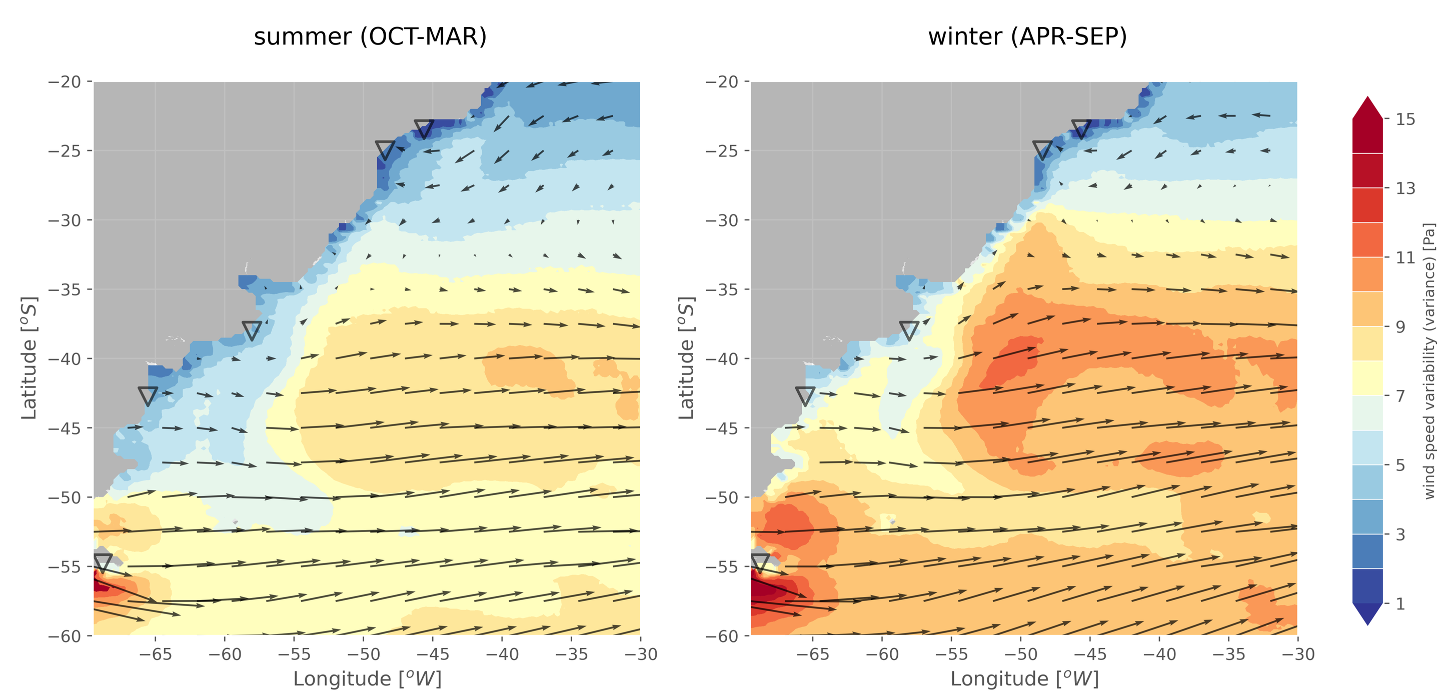

Figure 2: Wind speed variability (variance) and mean wind speed direction for summer (October- March and winter (April- September).

SLA and along-shore wind:

Coherence analysis:

The coherence of the SLA and along-shore wind speed component shows significant (>0.32) agreement over all periods (>20d) in parts of the study area (Fig. 3, north and south of Rio de la Plata estuary). The significant coherence in this area (shelf 25-43°S) could only be observed for the along-shore component of the wind below 110d.

Highest coherences on the shelf is reaches towards annual frequencies and periods higher than half a year. On higher frequencies, notable high coherence was obtained along the coast north and south of the mouth of the Rio de la Plata estuary with periods between 40-70d.

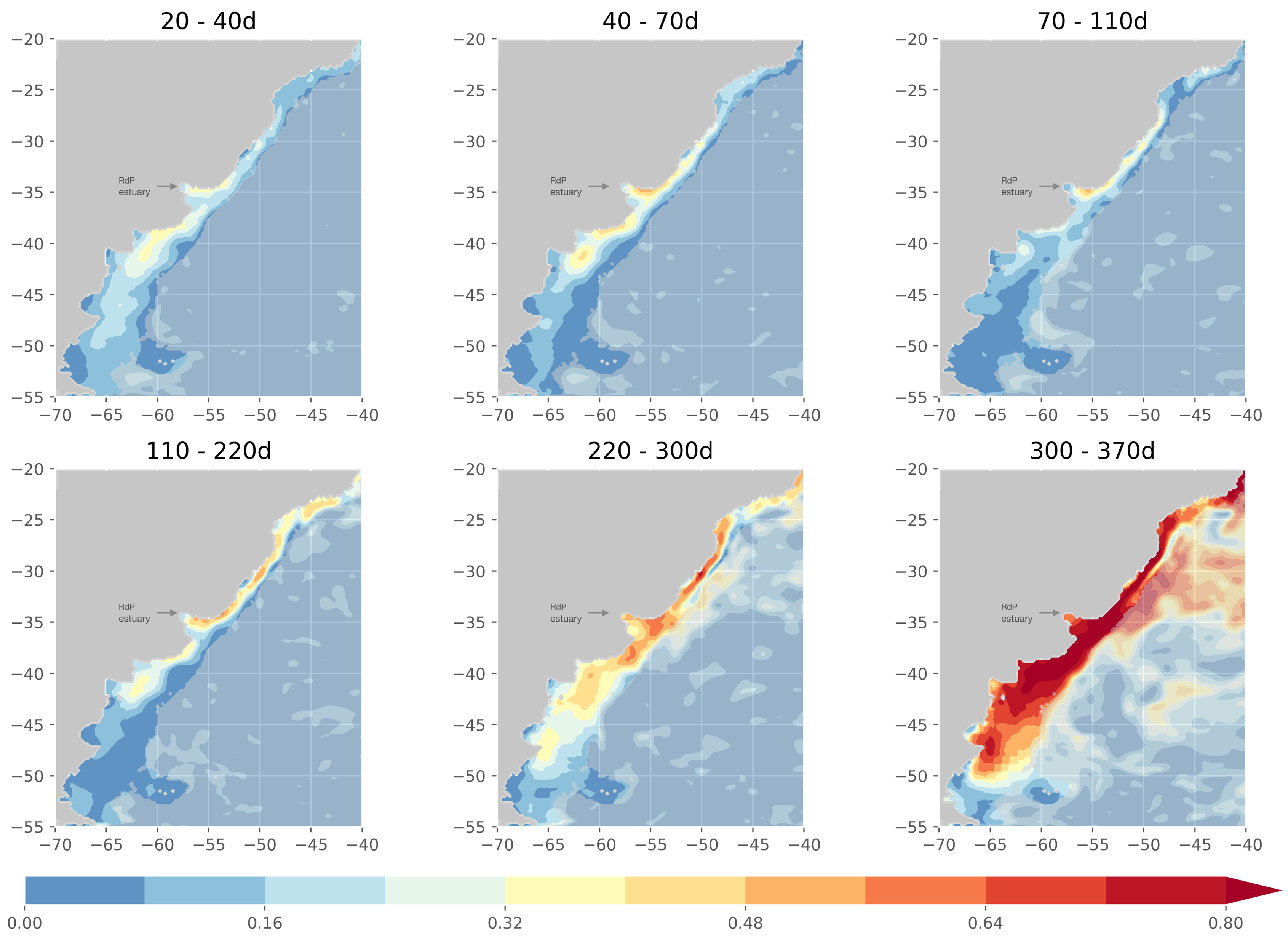

Figure 3: Mean coherence of daily SLA and along-shore wind speed (1993-2019) over selected frequency bands. Shelf region (above 200m-isobath) highlighted.

Coherence is below significance in the southern domain, where the wind and ocean dynamics shows different characteristic. Along the shelf break, coherence between wind and SLA might be prevented by geostrophic shelf current. Regions of large river mouths can be noticed as areas of decreased coherence compared to the surrounding, highlighting the local impact of e.g. river discharge having impact on SLA.

EOF-analysis:

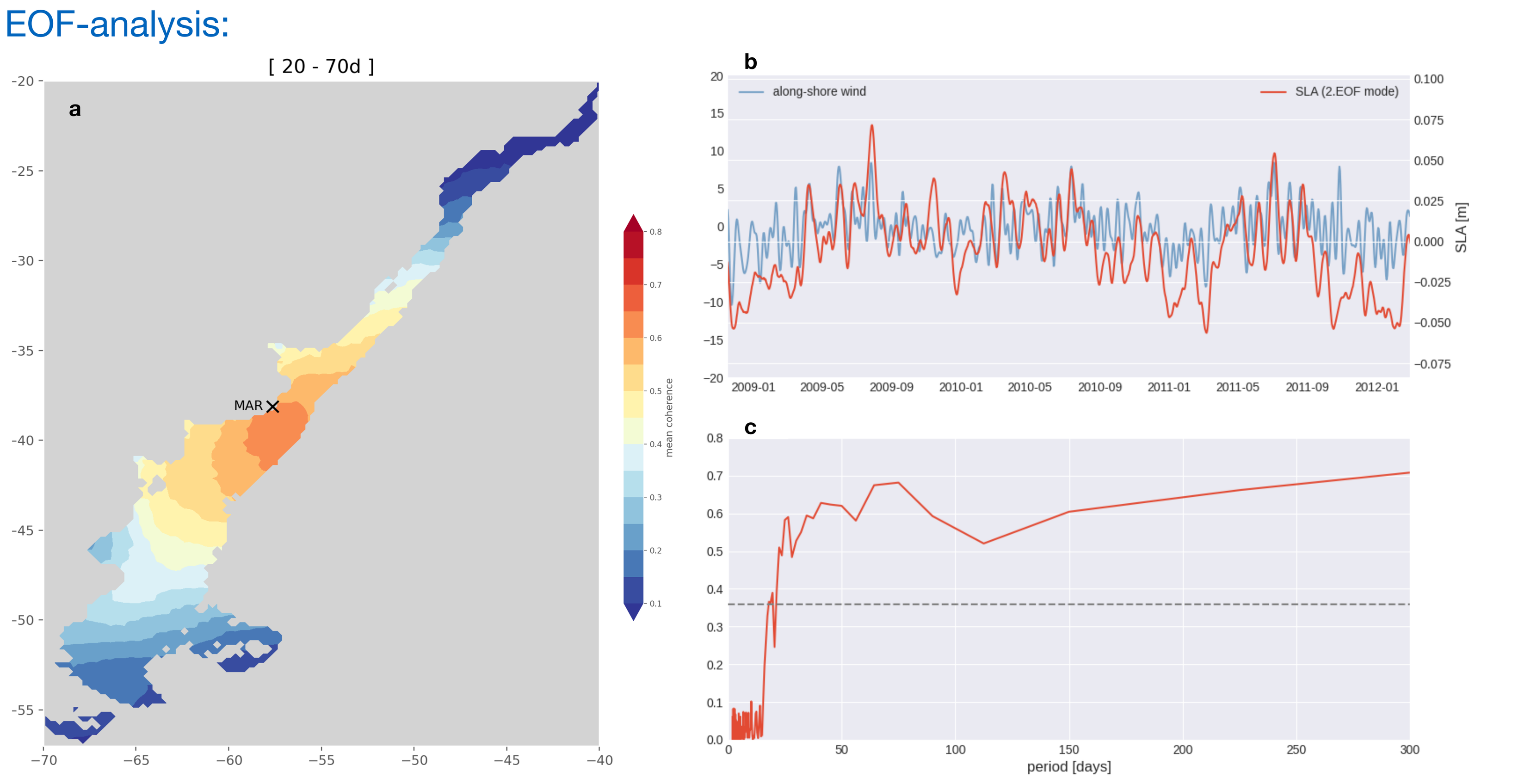

Figure 4: Left: (a) Mean coherence for periods 20-70d estimated for along-shore wind and SLA (2. EOF mode). Cross marks the tide gauge location of Mar de Plata (MAR, see Fig. 1). Right: SLA (2. EOF-mode) and along-shore wind at Mar del Plata (MAR, see Fig. 1). (b) Time series of 3 years out of the data from 2009-2012 out of the 27 year data record for along-shore wind (blue) and 2. EOF SLA (red). (c) Coherence of both time series from 1993-2019 shown for periods from 2-300 days. Dashed line sets the threshold of significant coherence.

The 2. EOF mode of SLA is explaining 10% of variability, the second highest proportion after 1. EOF describing the annual cycle mode. SLA reconstructed from the 2. EOF mode shows high agreement with the along-shore wind component at Mar del Plata and the shelf from 30-45°S (Fig. 4a, b). This agreement shows a peak on sub-annual scales for periods between 20-70d (Fig. 4c).

Outcome and Outlook:

Significant agreement of SLA and along-shore wind speed on the shelf is shown over all frequencies (>20d). For periods 20-70d wind is diver of significant portion (10%) of SLA-variability on the shelf, beside annually driven dynamics.

Blending high-frequency wind data to SLA data might bring improvement to existing products for higher-frequencies and fill gaps of low data density. The combination of wind data and SLA will be tested using a modulation of a new gridding approach where wind are considered as feature during the gridding (L3 to L4) of SLA on the basis of machine learning (Passaro, 2022).

References:

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