



Twenty-five years of continuous temperature and salinity observations on the Uruguayan Atlantic coast

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Abstract: Long-term time-series are crucial for studying climate variability, climate change, and ecological processes. This study presents the first 25-year continuous record of temperature and salinity observations on the Uruguayan Atlantic coast (34.6°S, 54.1°W), covering the period from March 1, 1996, to February 28, 2021 (ongoing measurements). The mean annual temperature was 17.5 °C, with a seasonal amplitude of 10.2 °C, ranging from a monthly mean minimum of 12.4 °C in August to a monthly mean maximum of 22.6 °C in February. Mean annual salinity was 26.2 psu, also exhibiting seasonality, with an amplitude of 6.4 psu, a monthly minimum of 22.6 psu in June, and a monthly maximum of 29.0 psu in January. Temperature shows a significant positive trend of approximately 1°C over 25 years, consistent with satellite data. Additionally, a daily cycle with similar amplitude underscores the importance of comparing measurements taken at the same hour of the day to analyze daily coastal temperature variability. No significant trend was detected in salinity. Finally, we show a significant negative correlation of salinity in La Paloma with Río de la Plata runoff and along-shore winds. In particular, extremely low salinity events in La Paloma are associated with extremely high Río de la Plata runoff and predominance of southwesterly winds, often after an El Niño event. Climatologically, these conditions are optimal during May.

Key words: *in situ* measurements, coastal time-series, South America, climate variability.

Veinticinco años de observaciones continuas de temperatura y salinidad en la costa atlántica uruguaya. Resumen: Las series temporales de largo plazo son fundamentales para estudiar la variabilidad climática, el cambio climático y los procesos ecológicos. Este estudio presenta el primer registro continuo de 25 años de observaciones de temperatura y salinidad en la costa atlántica uruguaya (34.6°S, 54.1°O), cubriendo el período desde el 1 de marzo de 1996 hasta el 28 de febrero de 2021 (con mediciones en curso). La temperatura media anual fue de 17.5 °C, con una amplitud estacional de 10.2 °C, variando desde un mínimo mensual de 12.4 °C en agosto hasta un máximo mensual de 22.6 °C en febrero. La salinidad media anual fue de 26.2 psu, también con estacionalidad, con una amplitud de 6.4 psu, un mínimo mensual de 22.6 psu en junio y un máximo mensual de 29.0 psu en enero. La temperatura muestra una tendencia positiva significativa de aproximadamente 1 °C en 25 años, consistente con los datos satelitales.

Además, un ciclo diario con amplitud similar resalta la importancia de comparar mediciones tomadas a la misma hora del día para analizar la variabilidad diaria de la temperatura costera. No se detectó una tendencia significativa en la salinidad. Finalmente, mostramos una correlación negativa significativa entre la salinidad en La Paloma y el caudal del Río de la Plata, así como con los vientos paralelos a la costa. En particular, los eventos de salinidad extremadamente baja en La Paloma están asociados con caudales extremadamente altos del Río de la Plata y la predominancia de vientos del sudoeste, a menudo después de un evento de El Niño. Climatológicamente, estas condiciones son óptimas durante el mes de mayo.

Palabras clave: mediciones *in situ*, series de tiempo, La Paloma, Rocha, variabilidad climática.

Introduction

Long-term time-series are essential for studying climate variability, climate change, and ecological dynamics (Soreide *et al.* 2001; Merchant *et al.* 2019; Roughan *et al.* 2022). However, such extensive datasets have been historically scarce in the Southern Hemisphere, particularly in Uruguay (South America). While some freely available *in situ* records, such as those from the Scripps Pier in California, now exceed 100 years (Rasmussen *et al.* 2020), no continuous *in situ* measurements of more than 20 years are freely available in the Southwestern Atlantic. Although gaps can be partially filled using satellite-derived sea surface temperature (SST) or reanalysis data, these datasets still require validation with *in situ* observations. This need is even more pronounced in coastal waters, where temperature and salinity variability tend to be more pronounced (O'Carroll *et al.* 2019; Trinchin *et al.* 2021).

In particular, coastal salinity remains beyond the reach of satellite observations, which are limited to about 25 km offshore and typically provide a temporal resolution of one week (Bao *et al.* 2019). In regions influenced by freshwater input, salinity can be the primary factor shaping biological communities (Mianzan *et al.* 2001; Day *et al.* 2012). The Uruguayan Atlantic coast is part of the freshwater-influenced region of the Río de la Plata estuary (RdIP). Shelf circulation in this area is strongly seasonal, driven by the southward shift of the South Atlantic semi-permanent anticyclone in summer. This results in northward winds and shelf currents in winter and southward in summer (Möller *et al.* 2008; Strub *et al.* 2015). Interannual variability is closely linked to the El Niño Southern Oscillation (ENSO), with increased RdIP discharge during positive ENSO phases and reduced discharge during negative phases (Piola *et al.* 2005; Barreiro 2010, 2017).

The port of La Paloma is located on the Uruguayan Atlantic coast, approximately 100 km from the outer boundary of the RdIP estuary (Fig. 1). Despite this distance, waters from the RdIP - one of the largest estuarine systems in South America, draining the continent's second largest basin - can reach this area during extreme discharge events (Framiñan *et al.* 1999). Therefore, the objective of this study was to generate and analyze a 25-year quality-controlled time-series in the Uruguayan Atlantic coastal zone describing the seasonal cycle, the interannual variability and trend, and its correlation with RdIP discharges and extreme weather events.

Materials and methods

Temperature and salinity data collection: Twice a day, morning and afternoon, measurements were taken on the exposed side of La Paloma port (34°39'20.14"S - 54°08'28.17"W, Fig. 1) as part of an environmental monitoring program conducted by the National Direction of Aquatic Resources of Uruguay (DINARA). Water samples were collected using a sampling device with the sampler positioned among the shoreline rocks. This method allowed for taking a sample within a zone of higher circulation than on the beach shore and therefore being representative of a larger area. The samples were collected twice a day, with the morning sampling occurring between 09:00 and 09:30 and the afternoon sampling between 15:30 and 16:00. At each sampling time, a collector was lowered to a depth of 0.5 to 0.6 meters, approximately 2 meters away from the coastline, to extract water for salinity and temperature measurements. Monitoring began on 1 March 1996 and has continued to the present day. There were three instrument changes during the study period, each with overlapping measurement periods to ensure data continuity.

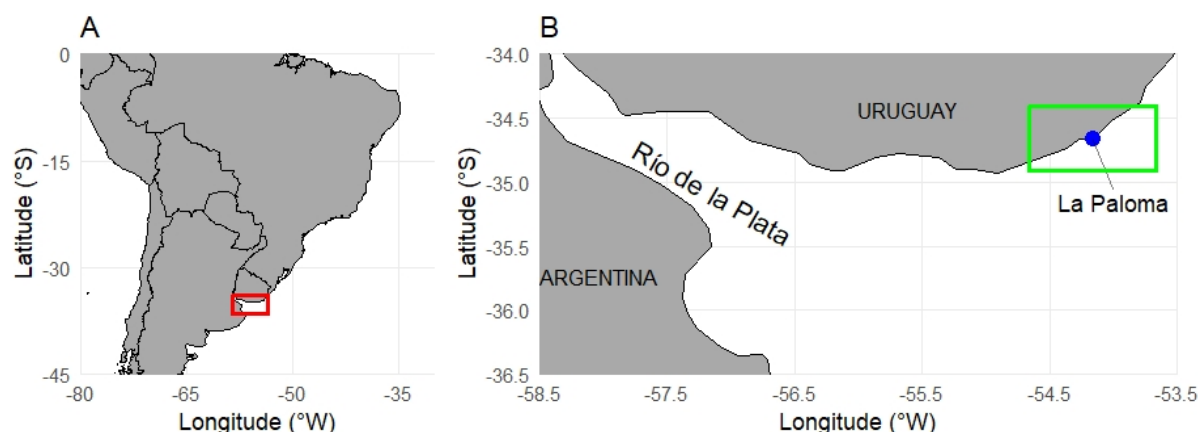


Figure 1. Study area in South America (A). Uruguayan coast (B). The blue point shows the position where the measurements were taken in La Paloma ($34^{\circ}39'20.14''$ S, $54^{\circ}08'28.17''$ W), and the green rectangle, defined by latitudes -34.91° S to -34.41° S and longitudes -54.66° W to -53.66° W, the averaged region used to create the wind time-series.

Sea surface temperature was measured using alcohol or mercury thermometers with an estimated error of $\pm 0.5^{\circ}\text{C}$. The method used for salinity measurements varied over the study period (Fig. 2A). From 1996 to 2008, salinity was measured using a refractometer (Cat $^{\circ}$ 2442 ATAGO Co., LTD). During the initial period (March 1996 - October 1998), calibration was performed monthly using solutions of known salinity and distilled water. However, from 1998 to 2008, calibration was only performed at zero using distilled water, which led to an overestimation of salinity measurements during this period. The ATAGO refractometer has a resolution of 0.5 ppt and an accuracy of $\pm 0.2\%$ (g/100g), making it suitable for field measurements but susceptible to systematic calibration errors. Between July 2008 and June 2015, salinity was measured using the YSI ECOSENSE EC 300^a, a portable conductivity, salinity, and temperature instrument. This device calculates salinity within a range of 0.0 to 70.0 ppt with a resolution of 0.1 ppt, providing improved precision over the previous method. A bias in the refractometer was detected when a new salinometer was installed. To resolve this issue, measurements were taken simultaneously with both instruments for three months after the salinometer was installed, allowing for cross-validation and correction of past discrepancies. For this study, a correction factor was applied to align the salinometer readings with the refractometer, and the salinity values for the earlier period were adjusted by subtracting the mean difference obtained during the overlap period (Fig. 2B). The overlap

between the two sensors allowed the calculation of a correction factor for the salinometer measurements, which showed a bias of 1.05 with a standard deviation of 1.36 from 1998 to January 2009. This correction formula (Salinometer reading = $0.9121 \times$ Refractometer reading - 0.2265) was applied to the analyzed time-series (Fig. 2C), ensuring consistency between the refractometer and salinometer data. During the four-month calibration period, given the demonstrated accuracy of the salinometer readings, these data were utilized for the time-series analysis. Finally, another YSI ECOSENSE EC 300^a was used from July 2015 to 2021 (Fig. 2A). Nowadays, the salinity sensor is calibrated every three months using standardized saline solutions of known conductivity to ensure measurement accuracy. Additionally, intercomparison with other salinity sensors is performed to validate the consistency and reliability of the data.

Data analysis: Weekly, monthly, and annual means of temperature and salinity were calculated to compute the climatology. Linear regression was performed on the annual mean to compute the trend, normality and homoscedasticity were checked using the Shapiro-Wilk and Breush-Pagan tests, respectively, and statistical significance was performed using the Student t-test (5%).

Weekly averages were calculated by first determining the daily mean (from morning and afternoon measurements) and then calculating the weekly mean from all the available measurements during that week. Histograms of temperature and salinity were generated for the whole time-series

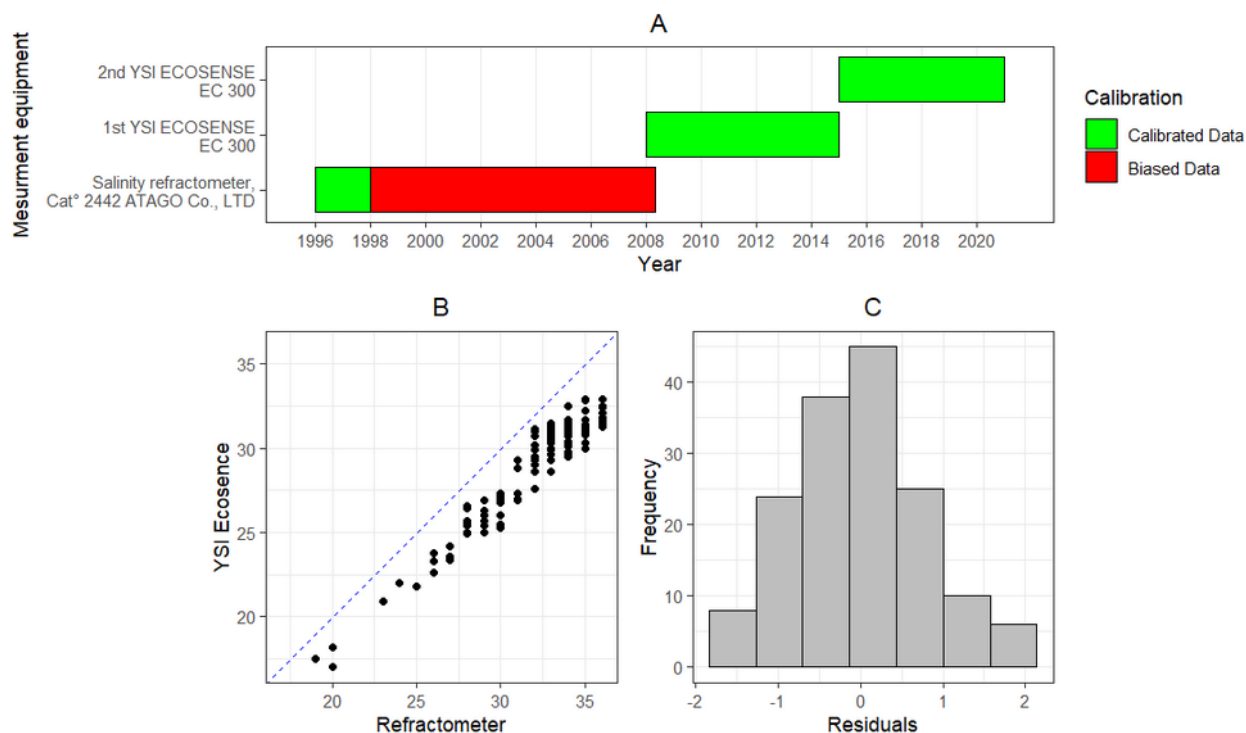


Figure 2. A) Equipment used to measure salinity from 1996 to 2021 in La Paloma, Rocha, Uruguay. B) Comparison between refractometer (Rm) and salinometer (Sm). C) Histogram of the difference in measurements between the refractometer and the salinometer.

(Appendix Fig. S1) as well as for each season (summer: DJF, autumn: MAM, winter: JJA, spring: SON).

To investigate the relationship between the temperature and salinity variations identified in this study and the weekly and monthly mean runoff of the RdIP, a Pearson's correlation analysis was performed. Daily runoff data for the RdIP were obtained from the Instituto Nacional del Agua (INA), Argentina (J. Borus, personal communication, March 2019). The total runoff of the RdIP was calculated by adding the runoff of its three main tributary corridors: Guazú, Palmas, and Uruguay.

To assess the influence of extreme events on salinity variations, daily wind data at 10 m height from the ERA5 reanalysis (Hersbach *et al.* 2020) were retrieved from the Copernicus Climate Data Store (2021). These data, covering the period from 1 March 1996 to 28 February 2021, were analyzed within the domain 30-39°S, 56-49°W, with a horizontal resolution of 0.25°.

A boxplot was employed to visualize the monthly data distribution and identify potential extreme values. Each boxplot represents the interquartile range (IQR) of the data, which is the range between the 25th percentile (Q1) and the 75th

percentile (Q3), marked by the lower and upper edges of the box, respectively. The line within the box indicates the median (50th percentile) of the data. Whiskers extend from the box to the largest and smallest values within 1.5 times the IQR from the lower and upper quartiles, respectively. Data points outside this range are considered extreme values and are represented as individual points beyond the whiskers. Extreme values are defined as values that fall below $Q1 - 1.5 \times IQR$ or above $Q3 + 1.5 \times IQR$. Also mean monthly values are represented. Note that the boxplots for temperature and salinity were constructed using all available measurements (about 4 per week) to keep all the available information in the plot, while for runoff and alongshore winds, weekly means of daily values were used to better visualize the amplitude of the seasonal cycle.

Results

Time-series analysis: The daily coverage of the period was 72.1 %. At least one measurement with weekly frequency was made in 99.2 % of the cases. The years with less coverage presented 58% of the data (1998 and 2006, also July 1998 being the month with the least coverage, Table S1). The mean duration of data gaps was 1.9 days for both temperature and salinity. The longest consecutive

period without measurements was 11 days for temperature and 15 days for salinity. The mean temperature during the morning across the entire time-series was 17.1 °C, which was 1.1 °C lower than the afternoon mean of 18.2 °C. This difference could be attributed to diurnal warming. The mean salinity of the morning for the entire time-series was 26.3 psu and 26.2 psu in the afternoon, with a difference of 0.1 psu, within the error of the instrument. Temperature time-series showed an annual cycle with a monthly mean minimum in July of 12.4 °C and a maximum of 22.6 °C in February (Figs. 3 and 4). The salinity time-series also showed an annual cycle with a monthly mean minimum in June of 22.6 psu and a maximum of 29.0 psu in January (Figs. 3 and 4). The historical minimum and maximum of the temperature time-series were 6.0 °C on the morning of 2013-07-25 and 28.5 °C in the afternoon of 2017-02-24, respectively. For salinity, the minimum was 5.0 psu in the afternoon of 1998-05-04 and 1998-05-06. The maximum was 33.5 on the morning of 2000-02-28, 2000-03-13, 2000-03-14, and 2000-04-15.

Weekly averaged values ranged from 9.2 °C to 26.8 °C and salinity from 7.1 to 32.4 psu (Fig. 3 A and B). The weekly salinity minimum occurred during the week of 2016-04-29 to 2016-05-05. The standard deviation (Sd) for weekly temperature was 3.9 °C and salinity 4.1. The linear regression fit for annual average temperature presented a statistically significant positive trend of 0.033 °C/yr. Salinity also showed a positive trend, although not statistically significant (Fig. 3 E and F).

On a monthly time scale, the climatology presented lower temperatures during July with similar values in August. Highest temperatures were present during February, though higher daily maximums persisted during the first days and weeks of March (Table S2, Fig. 4 A). Salinity presented a maximum during January followed by February, while June was the month with the lowest value of mean salinity, and the lowest daily records were registered in May (Fig. 4 B). Monthly mean values for runoff and along-shore winds are shown in Fig. 5. The highest mean runoff values occur in June, while May exhibits the largest weekly variability and largest upper interquartile values (Fig. 5A). Along-shore winds reach their highest mean value also in May and June, and their maximum variability occurs in September (Fig. 5B).

Based on the histogram of weekly temperature, we identified two opposite

distributions: one in winter (mean: 12.99 °C; sd: 1.55 °C) and another in summer (mean: 21.56 °C; sd: 1.70 °C), with a transitional pattern observed in autumn (mean: 19.65 °C; sd: 2.48 °C) and spring (mean: 15.71 °C; sd: 2.24 °C) (Fig. 6 A). While autumn temperatures were closer to those observed in summer, and spring temperatures more similar to winter, these patterns represent gradual transitions rather than exact matches. The overlap in temperature distributions between autumn and summer, and between spring and winter, suggests that the seasonal temperature shifts may not always follow a linear or strict pattern. Salinity also showed distinct seasonal differences, with lower values in winter (mean: 23.64 psu; sd: 4.27 psu) and higher values in summer (mean: 28.35 psu; sd: 2.67 psu), as can be appreciated in Fig. 6 B. The salinity distribution in autumn (mean: 25.39 psu; sd: 4.58 psu) resembled that of winter, while spring salinity (mean: 27.20 psu; sd: 3.09 psu) was more similar to summer (Fig. 6 B). Autumn presents an infrequent occurrence of extremely low values (Fig. 6 B). The influence of the Río de la Plata discharge: Monthly and weekly variations of runoff, especially extreme events of high runoff, decrease the monthly averages of salinity in La Paloma (Fig. 7A). For example, the minimum monthly average salinity recorded in the time-series (12.8 psu) occurred during the maximum runoff of the time-series (65800 m³s⁻¹) in June of 1998. The correlation between the salinity and RdlP discharge time-series was -0.39 ($p < 0.05$) and -0.31 ($p < 0.05$) for monthly and weekly resolution time-series, respectively (Fig. 7B). The highest lagged correlation (absolute value) with salinity was observed with the runoff of the previous 4 to 6 weeks ($r = -0.37$, Fig. 7C).

Salinity in La Paloma was also significantly and negatively correlated with along-shore winds, so when winds blow from NE, salinity increases, and when winds blow from SW, salinity decreases (Fig. 8A). In particular, extremely low salinity events in La Paloma, defined as those below the 5th percentile (16.0 psu), occurred during a combination of both high discharge, above the 95th percentile (41697 m³/s), and southwesterly winds, opposite to the predominant winds from the NE (Fig. 8C and D). In addition, high runoff events were not associated with any particular wind direction, as can be appreciated in the similarity of the wind rose associated with high runoff events and the climatology (Fig. 8 B and D).

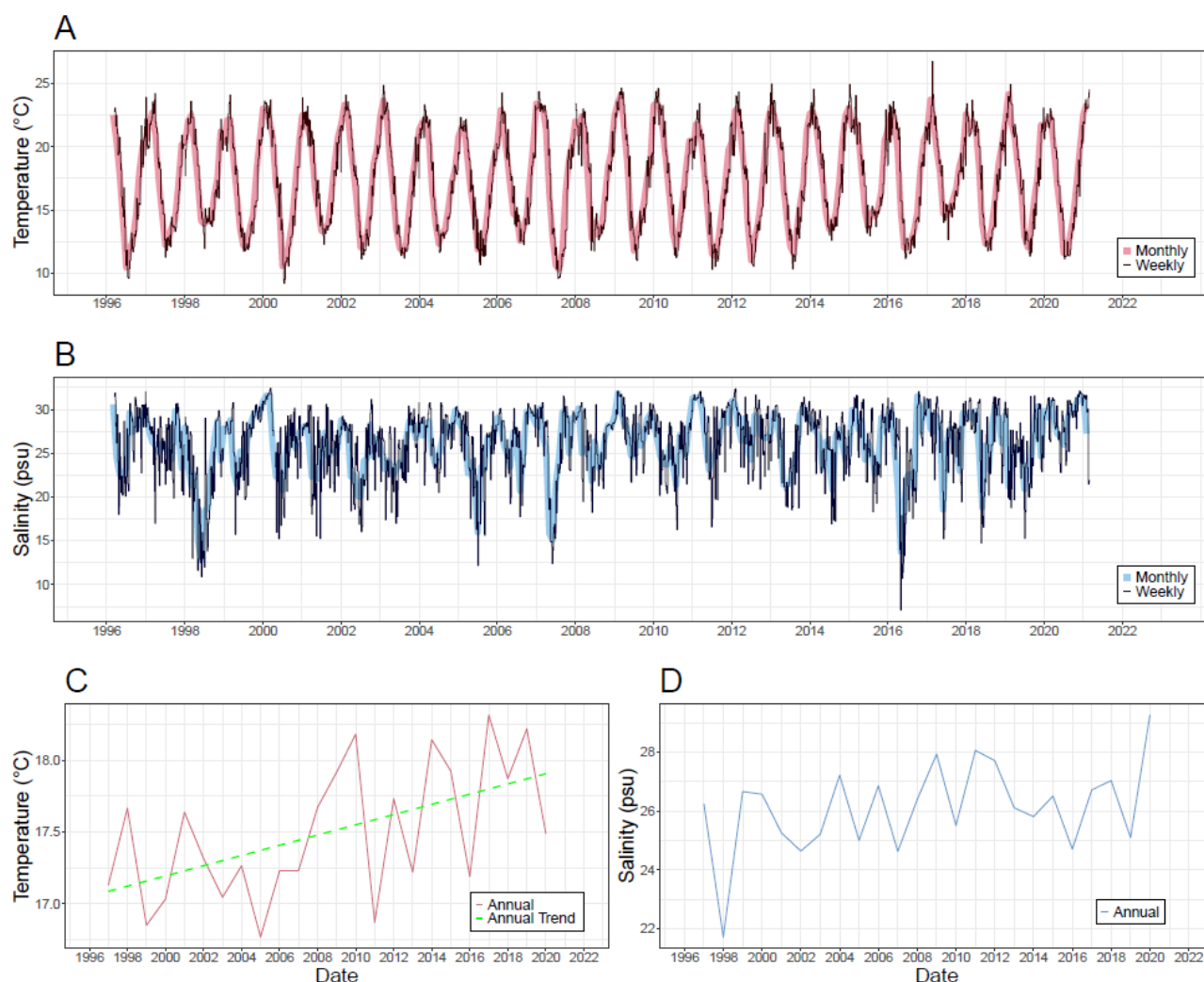


Fig. 3. Weekly and monthly (A and B) and annual (C and D) averages of measured temperature (red line, °C) and salinity (blue line, psu) during the period 1996 to 2021 in La Paloma, Rocha, Uruguay. A statistically significant trend for annual *in situ* temperature is shown in green with a slope of 0.033 °C/yr ($R^2 = 0.26$, p -value < 0.05) while salinity did not present a significant trend (p -value > 0.05). The annual means for 1996 and 2021 were discarded as those years were not complete.

Discussion

We have established the first quality-controlled *in situ* time-series of sea surface (0.5 to 0.6 meters) temperature and salinity on the Uruguayan Atlantic coast, spanning 25 years with daily and weekly resolution. Characterizing the seasonal cycle from these *in situ* observations is fundamental for a wide range of studies, including understanding environmental drivers.

The variability and marked seasonality revealed by this long-term record are crucial for deciphering the dynamics of the Uruguayan coastal ecosystem and provide a robust baseline for future analyses. Furthermore, our characterization of annual, monthly, and weekly variability and trends identified a significant increasing trend in temperature of approximately 1°C over 25 years.

This warming is consistent with findings from satellite observations in the region (Barros *et al.* 2005, Paesch *et al.* 2014, Martínez *et al.* 2017). Notably, the magnitude of this long-term temperature trend is similar to that of the daily cycle, emphasizing the importance of considering the time of day when comparing coastal measurements across extended periods. In contrast to temperature, no significant trend was detected in salinity.

Annual variations observed in temperature are conditioned by the seasonal variation in atmospheric temperature typical of temperate zones and the influence of climatic and oceanographic phenomena at a local scale, such as coastal upwelling or marine heatwaves (Manta *et al.* 2018, Trinchin *et al.* 2019). For instance, the maximum SST value registered in this time-series coincides with the dates of the

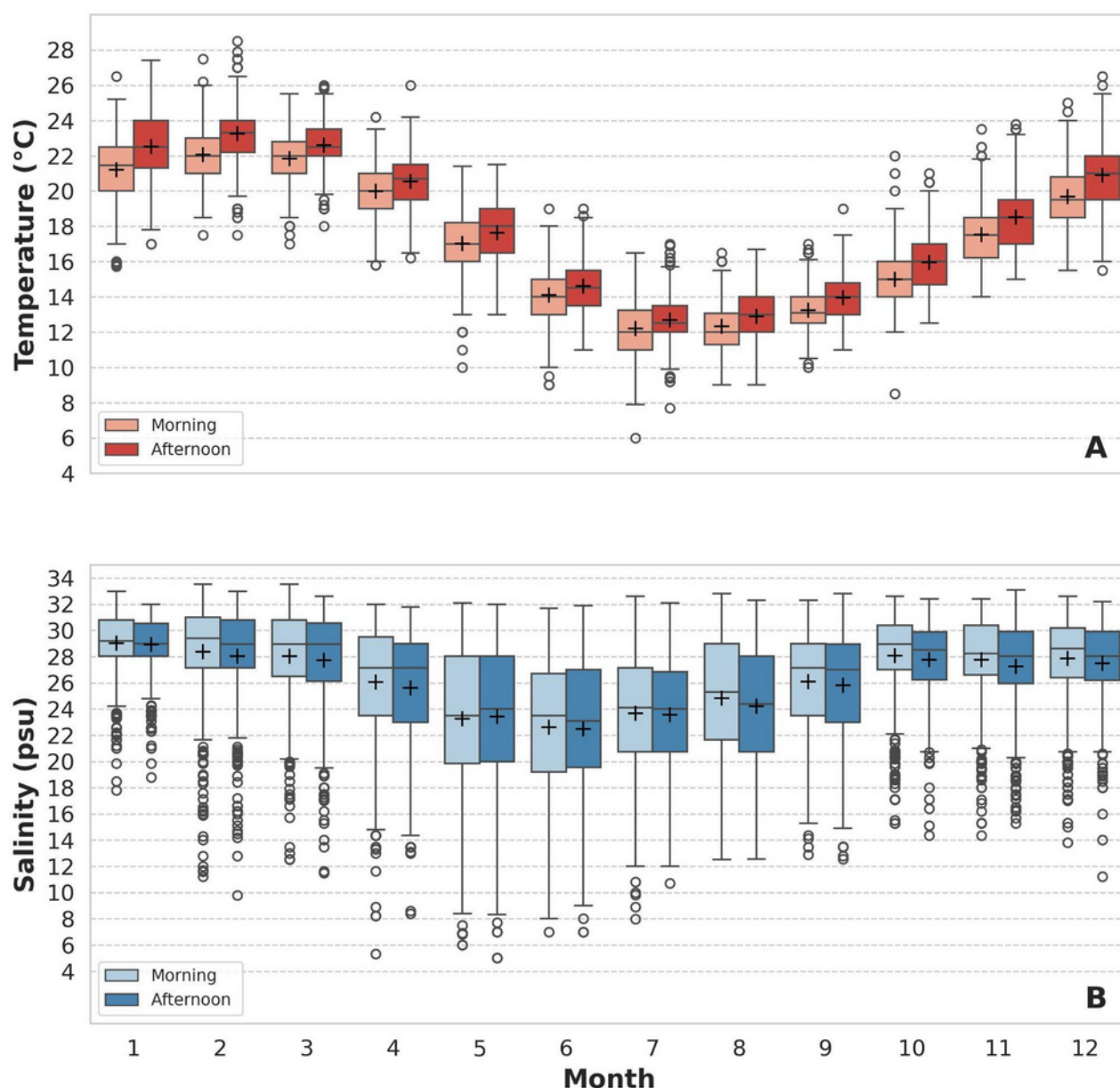


Fig. 4. Climatology using all measurements of: A) temperature (°C) and B) salinity (psu) between 1996 and 2021 in La Paloma, Rocha, Uruguay. Boxes represent the quartiles of the dataset while the whiskers extend to show the rest of the distribution, except for points determined to be extreme values (see methods for details). Mean monthly values are indicated with a plus sign (+).

maximum marine heatwave event that occurred in late February 2017 and was described by Manta *et al.* (2018) using satellite and in situ observations also in La Paloma. In addition, global-scale climate variability modes such as El Niño Southern Oscillation (ENSO) impact the study area which enhances these variations in different time scales (Barreiro *et al.* 2019; Franco *et al.* 2020). Uruguay is included in a region of the Southwestern Atlantic (SWA) where waters of subtropical and subantarctic shelf characteristics interact, influenced by waters of

tropical and subantarctic origin. The seasonal distribution of temperature on the Uruguayan shelf is influenced by the dominant water masses, with Tropical Water prevailing in autumn and colder Subantarctic Water dominating in spring (Ortega & Martínez, 2007). Changes recorded in wind patterns during the last decades over the SWA have led to a southward expansion of the semipermanent anticyclone of the South Atlantic and, consequently, the subtropical gyre, associated with increased surface heating in the region, ultimately generating a

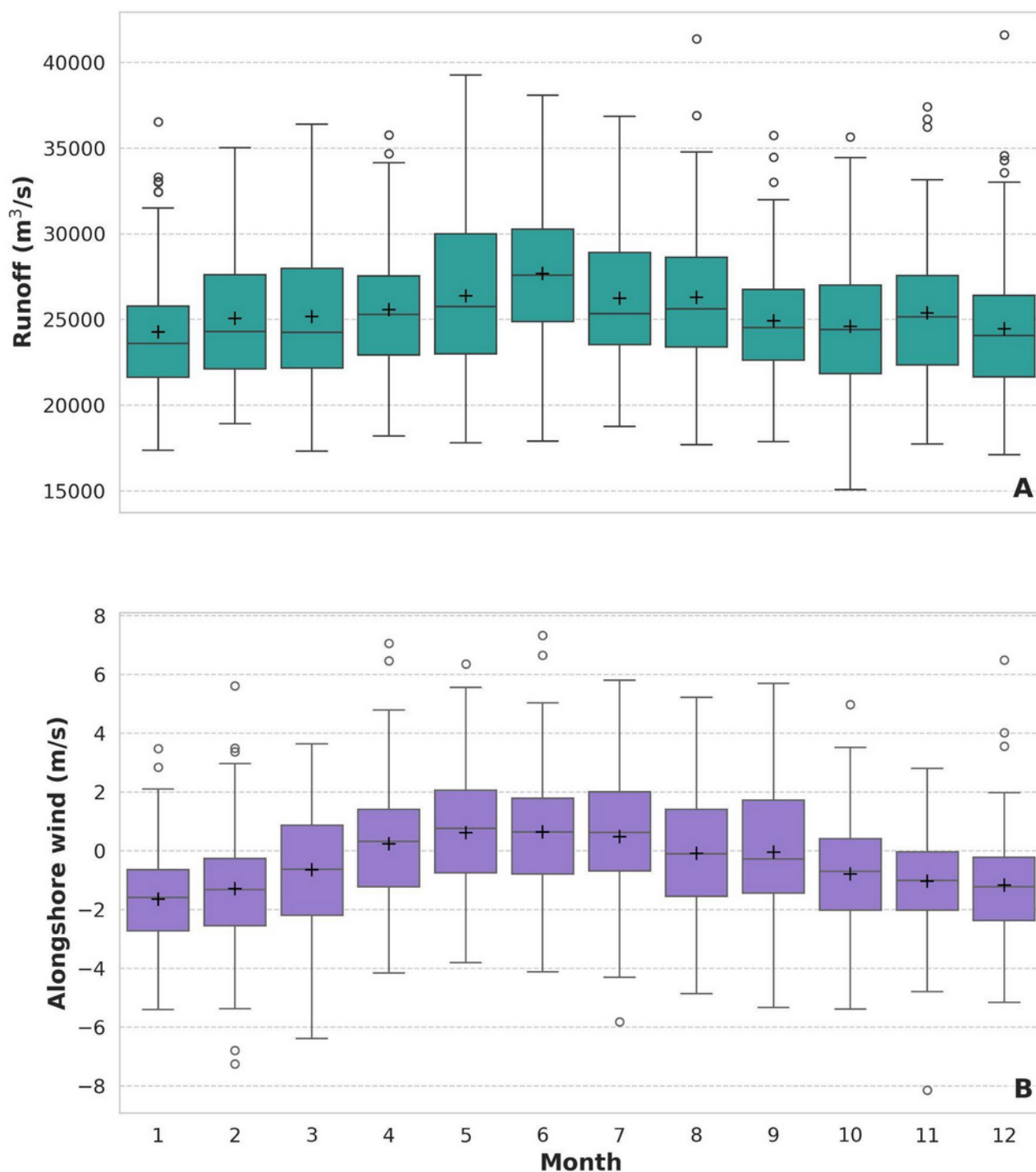


Figure 5. Weekly climatology of: A) runoff (m^3/s) and B) alongshore wind (m/s). Boxes represent the quartiles of the dataset while the whiskers extend to show the rest of the distribution, except for points that are determined to be extreme values (see methods for details). Mean monthly values are indicated with a plus sign (+).

positive trend in sea surface temperature (Goni *et al.* 2011; Lumpkin & Garzoli 2011; Franco *et al.* 2020; Li *et al.* 2022). It is possible that the trend of a 1°C increase in temperature obtained in this work could be associated with these changes in wind patterns. These changes in thermohaline properties have

consequences on the aquatic biota and consequently on the communities that depend on it, such as fisheries (e.g. Santana *et al.* 2015; Free *et al.* 2019; Gianelli *et al.* 2019, 2023; Silveira *et al.* 2022). Events of occurrence and mortality of tropical and subtropical origin species recorded in

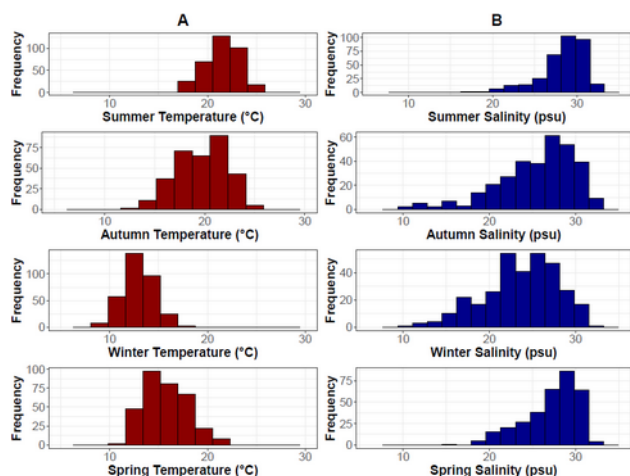


Figure 6. Seasonal distribution of temperature (°C) and salinity (psu) measured in La Paloma, Rocha, Uruguay, between 1996 and 2021. Panel A displays the frequency distribution of temperature in red for Summer, Autumn, Winter, and Spring. Panel B shows the frequency distribution of salinity in blue for Summer, Autumn, Winter, and Spring.

the region (e.g. Martínez *et al.* 2017; Pereyra *et al.* 2019; Laporta *et al.* 2021, 2022, 2024; Fabiano *et al.* 2021; Silveira *et al.* 2022) can also be an evidence of the changes, and the recording of *in situ*

temperature and salinity data are very useful to interpret them.

In the salinity measurements analyzed in this work, we show that this site is affected by extreme RdIP discharge events, often associated with positive ENSO events (Mechoso & Iribarren 1992; Pisciotto *et al.* 1994; Nagy *et al.* 2002; Barreiro 2010, 2017). This region is affected by the RdIP during extreme discharges and favorable wind conditions (Pérez *et al.* 2021; Kruk *et al.* 2019). We also showed that extremely low salinity is associated with extremely high RdIP runoff and southwesterly winds. When wind forces the RdIP plume northward (Piola *et al.* 2005, Guerrero *et al.* 2014, Matano *et al.* 2014), consequently, the potential for RdIP runoff to reach the coastal region of La Paloma becomes substantially greater. Climatologically, these conditions are more frequent during May.

Influence of wind on salinity in La Paloma aligns with previous studies on the RdIP plume. Specifically, Piola *et al.* (2005) highlighted the control exerted by the alongshore component of wind stress on the seasonal variability of the plume, a factor that likely contributes to the salinity fluctuations observed at our coastal site. Furthermore, the observed association of decreased salinity with southwesterly winds, particularly

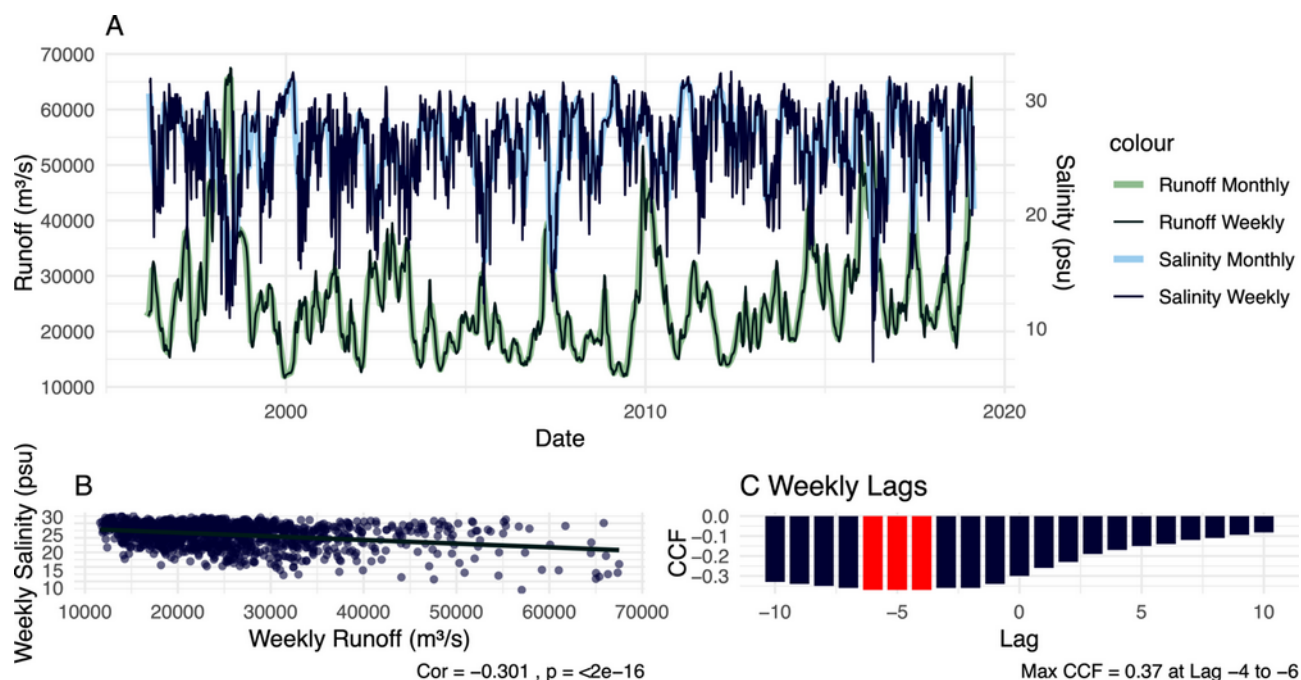


Figure 7. Relationship between salinity in La Paloma, Rocha, Uruguay, and runoff of Río de la Plata estuary from 1996 to 2021. A) Time series of average weekly (psu, dark blue line) and monthly salinity (psu, light blue line) and average weekly (m³/s, dark red line) and monthly runoff (m³/s, light red line). B) Scatterplot of weekly salinity versus weekly runoff, with a fitted linear regression; the correlation coefficient and p-value are provided. C) Cross-correlation function between weekly runoff and salinity, highlighting the lag with the maximum correlation.

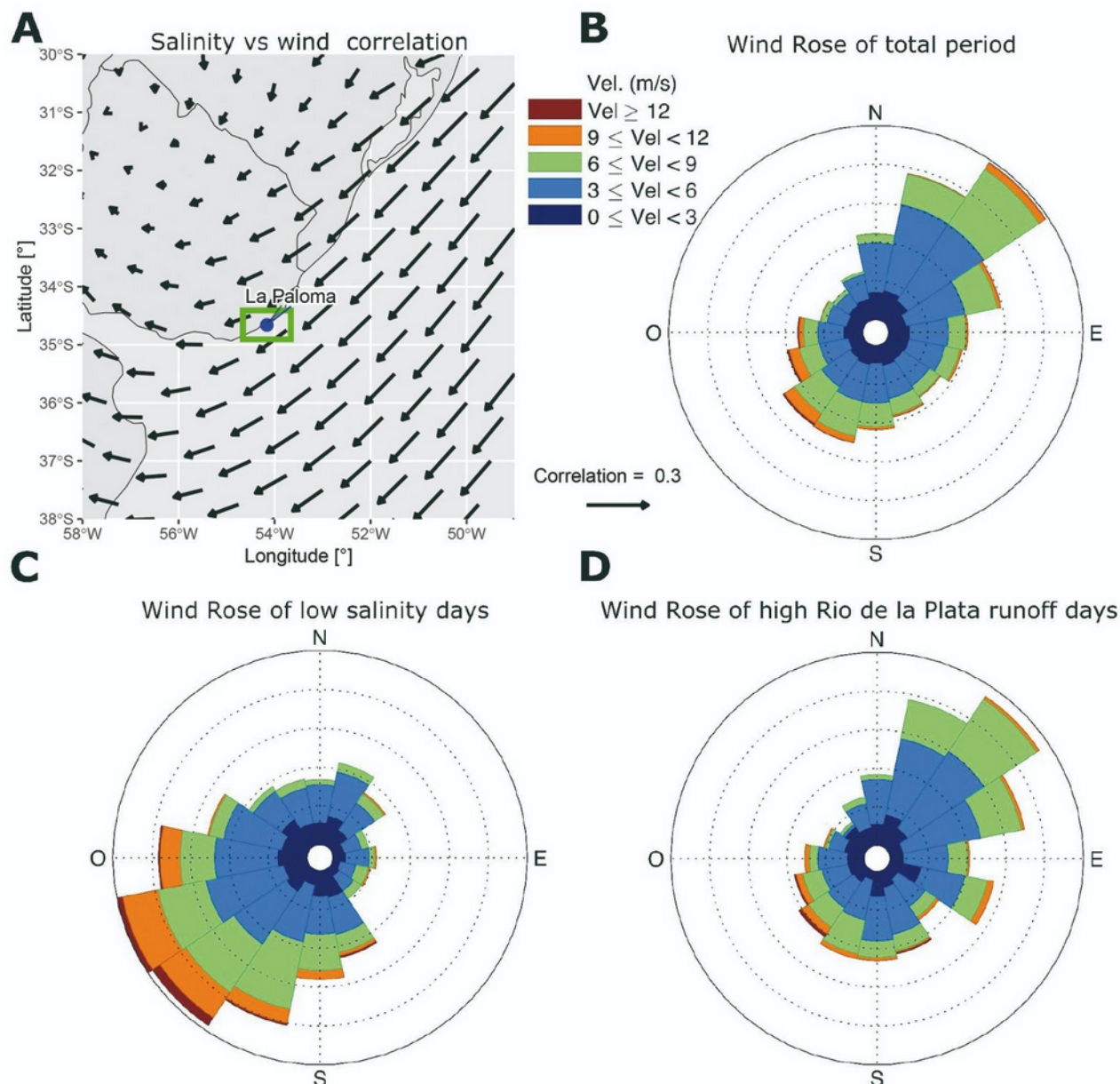


Figure 8. A) Salinity in La Paloma and wind correlation. The vector represents the direction of the combined zonal (u) and meridional (v) wind components in correlation with salinity at La Paloma. B) Wind rose for the spatially averaged wind within the green area for the 25 years of temperature and salinity sampling in La Paloma. C) Wind rose for the same area, but only for those days with salinity measurements below the 5th percentile in La Paloma. D) Wind rose for those days with Río de la Plata runoff above the 95th percentile.

during periods of high discharge, aligns with Pimenta *et al.* (2005), who illustrated the role of wind direction in plume distribution, with downwelling-favorable winds effectively advecting low-salinity waters coastward. While Matano *et al.* (2014) focused on cross-shelf exchanges, their findings also underscore the role of wind forcing in modulating the movement and distribution of the RdLP plume, thereby influencing coastal salinity regimes such as those observed at La Paloma.

Previous studies have shown the relevance of the effect of winds in the RdLP plume distribution (e.g., Piola *et al.* 2005; Trinchin *et al.* 2021). When the river plume reaches the Atlantic coast, it can have critical consequences for marine life. For example, there are recent records of biological contamination of the ocean coast by cyanobacterial algal blooms from reservoirs in the lower La Plata basin (e.g., Kruk *et al.* 2019, 2021). Changes in the salinity regime can also lead to the mortality of

species at the site that are not tolerant to low salinities (Riestra *et al.* 1998). Information from *in situ* monitoring of temperature and salinity together with other forcings modulators of river discharge (precipitation, winds, ENSO index) could help to explain and predict these events.

Finally, considering that the entire region of freshwater influence of the RdLP lacks long-term salinity and temperature measurements, the La Paloma time-series becomes extremely useful for this region, especially for biological and environmental studies. Therefore, maintaining this monitoring effort should be a priority for government agencies.

Ethical statement

The present investigation did not involve regulated animals and did not require approval by an Ethical Committee. DINARA has given the permits to use this dataset

Acknowledgment

Special thanks to Direction of Aquatic Resources of Uruguay (DINARA), Facultad de Ciencias- Universidad de la República Oriental del Uruguay (FCIEN-UDELAR), Comisión Técnica Mixta de Frente Marítimo (CTMFM), J. Borus (Instituto Nacional del Agua- INA Argentina), E. Delfino, O. Mora, A. Riet, G. de los Santos, C. de Mello, N. Alcantara y V. Apud. Also, we would like to thank the anonymous reviewers whose suggestions contributed to this article. On behalf of all the co-authors, we would specially like to thank Graciela Fabiano for her contributions to this article, and for her many years of work at INAPE-DINARA. We would also like to recognise her persistence in creating and maintaining ongoing salinity and temperature monitoring.

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Received: October 2024

Accepted: June 2025

Published: July 2025

Supplementary Material

Table S1. Monthly data coverage of the sampling in La Paloma (%). The last column and row show the yearly and monthly averages for columns and rows, respectively. Mean coverage for each month and year for the whole time-series is 72,06% as shown in the last cell.

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual mean
1996			45	73	74	73	71	68	67	77	73	58	68
1997	61	54	39	70	68	67	71	52	63	65	47	65	60
1998	55	54	48	57	65	70	39	61	63	71	50	65	58
1999	48	64	68	63	68	77	71	68	87	68	73	84	70
2000	65	69	71	47	68	73	58	71	77	81	73	71	69
2001	71	68	71	57	68	73	77	77	63	74	73	61	70
2002	65	46	48	73	81	53	74	71	77	74	77	68	67
2003	74	54	55	60	74	53	77	58	67	77	67	74	66
2004	68	62	74	60	52	70	65	61	47	81	80	87	67
2005	61	54	68	57	61	53	68	61	67	52	73	84	63
2006	61	46	65	53	55	57	65	48	57	71	67	55	58
2007	71	46	48	57	74	77	77	84	73	61	73	68	68
2008	81	69	65	53	52	53	74	65	70	81	73	71	67
2009	74	68	68	80	71	67	68	71	70	77	80	65	72
2010	84	93	87	50	77	83	81	81	83	90	97	97	84
2011	77	93	94	83	52	87	71	81	90	81	93	81	82
2012	94	59	97	90	84	93	81	84	73	87	90	94	85
2013	87	89	74	63	81	87	87	84	77	97	83	74	82
2014	81	71	94	77	90	100	90	87	80	97	60	84	84
2015	87	61	87	90	81	87	84	81	80	87	67	84	81
2016	84	79	71	70	84	63	71	84	67	74	83	94	77
2017	74	71	90	77	74	80	77	68	80	74	83	87	78
2018	87	82	81	83	87	77	77	81	77	68	87	77	80
2019	77	89	74	77	68	63	87	68	67	65	70	68	73
2020	77	69	90	87	61	67	65	61	70	68	70	74	72
2021	74	82											78
Time series total	74	68	71	68	71	72	73	71	72	76	75	75	72

Table S2. Monthly mean values of temperature and salinity at La Paloma in the morning and in the afternoon for the period 1996 to 2021.

Month	Temperature		Salinity	
	Morning	Afternoon	Morning	Afternoon
1	21,19	22,52	29,01	28,93
2	22,06	23,25	28,37	28,04
3	21,83	22,59	28,05	27,72
4	19,99	20,54	26,06	25,63
5	17,02	17,64	23,26	23,43
6	14,10	14,60	22,60	22,48
7	12,21	12,70	23,65	23,57
8	12,33	12,89	24,81	24,20
9	13,25	13,95	26,08	25,83
10	15,00	15,96	28,06	27,76
11	17,52	18,51	27,76	27,24
12	19,68	20,90	27,87	27,49

Figure S1. Weekly distribution of temperature in the morning (A) and in the afternoon (B), weekly distribution of salinity in the morning (C) and in the afternoon (D).

