National Report to the XVIII Session of the Group of Experts for the Global Sea Level Observing System
Panama, March 2025

Global Sea Level Observing System

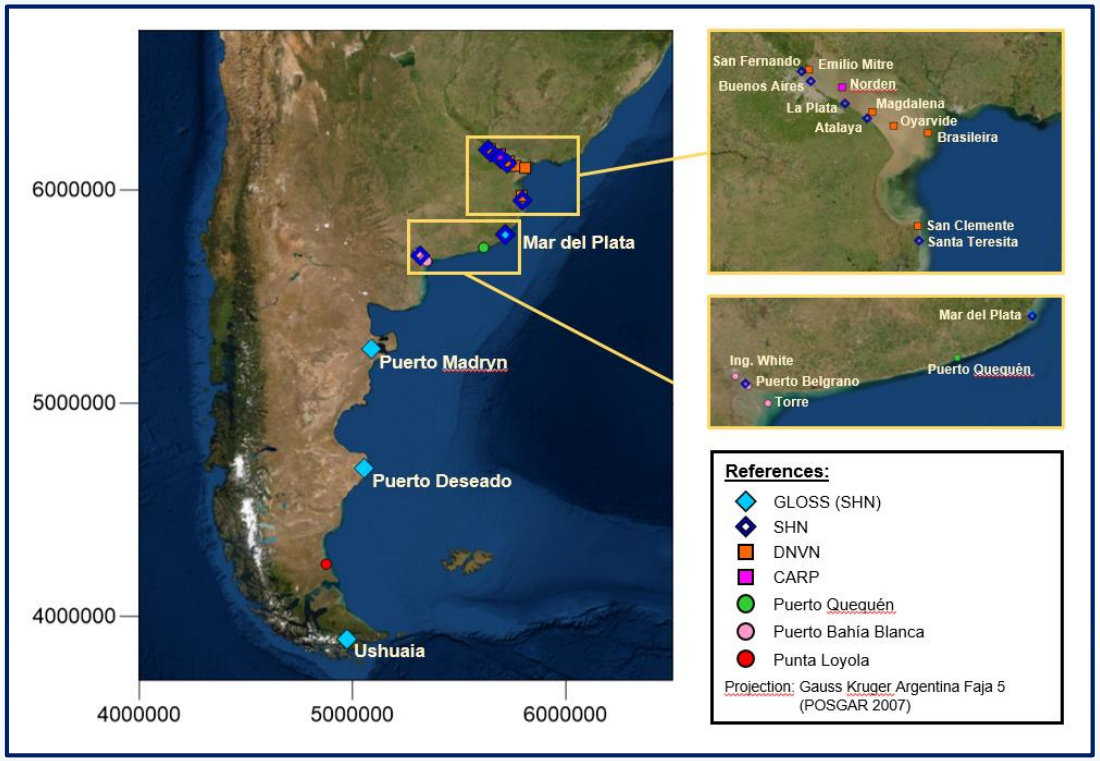
Current status of the Argentinian Sea Level Network

Fernando A. Oreiro

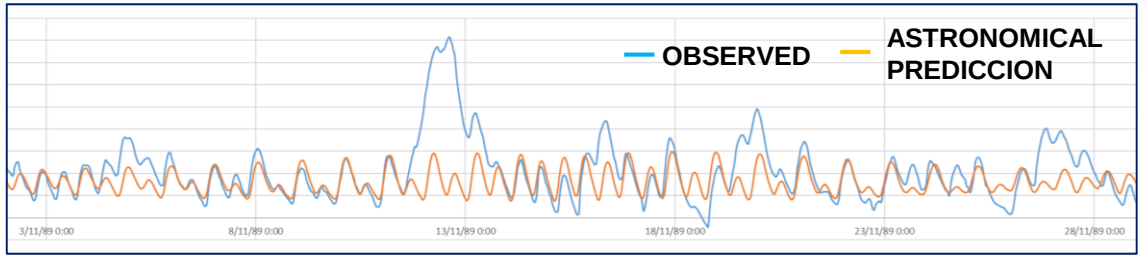
Servicio de Hidrografía Naval (SHN)
Ministerio de Defensa, República Argentina

Tide Gauge network in Argentina

The tide gauge network in Argentina is managed by the Naval Hydrographic Service (SHN) and includes the 4 tide gauges belonging to the GLOSS network, Mar del Plata, Puerto Madryn, Puerto Deseado and Ushuaia and the tide gauges located in San Fernando, Buenos Aires, La Plata, Atalaya, Santa Teresita and Puerto Belgrano.



Buenos Aires – Hourly Heights [m] – November 1989



In addition to the observations from these devices, the SHN processes observed water level heights from tide gauges installed and maintained by other national or binational organizations (Comisión Administradora del Río de la Plata -CARP-, Dirección Nacional de Vías Navegables -DNVN-), and by private ports (Puerto Quequén, Puerto Bahía Blanca, Puerto Punta Loyola).

These tide gauges are also used to identify in real time phenomena that may present a danger in terms of nautical safety, such as extreme storm surges events that occur frequently in the Río de la Plata. The observations of the tide gauges of the SHN and other agencies can be obtained through its website.

GLOSS station in Argentina

The Argentinian GLOSS tide gauges are jointly maintained with University of Hawaii Sea Level Center, and observations can be obtained through the IOC Sea Level Station Monitoring Facility website in near real time.

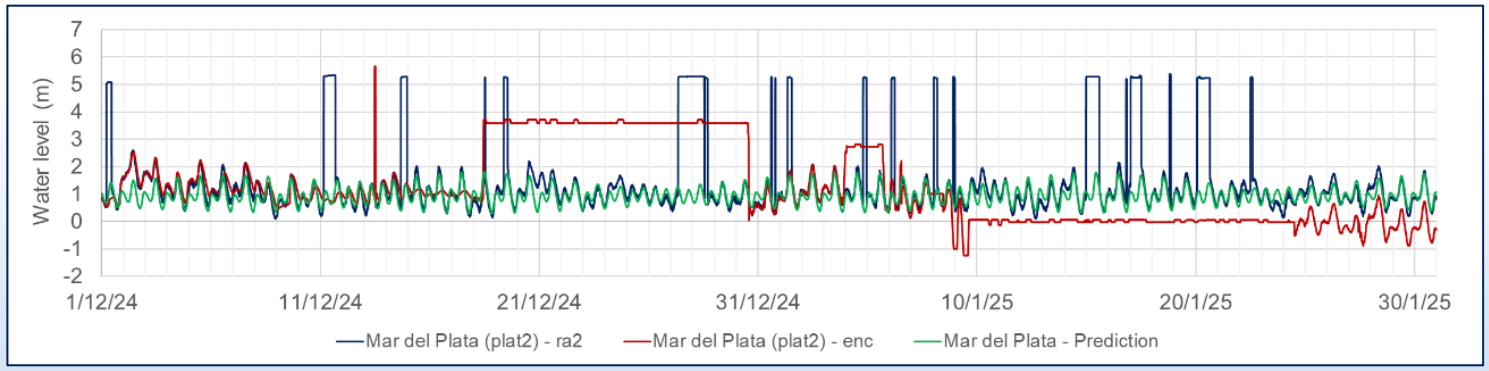
Since November 2022, the stations at Mar del Plata, Puerto Madryn, and Puerto Deseado have recorded observations with a data availability rate higher than 95% for at least one of the installed sensors.

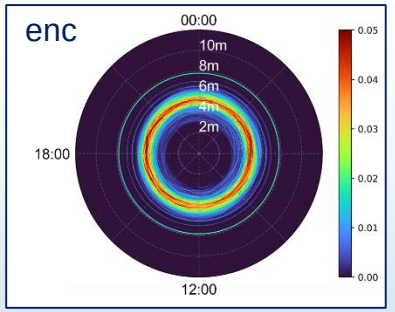
Station	Coordinates	PSMSL ID	GLOSS ID	UHSLC ID	Sensor (sampling rate)		
					1	2	3
Mar del Plata	38°.00015278 S 57°.53850556 W	819	192	729	R (1)	R (3)	F (5)
Puerto Madryn	42°.76265 S 65°.03068611 W	2305	191	731	P (1)	R (3)	R (3)
Puerto Deseado	47°.75357778 S 65°.91469444 W	185	190	286	P (1)	R (3)	F (5)
Ushuaia	54°.817 S 68°.217 W	1850	181	600	R (1)	R (5)	-

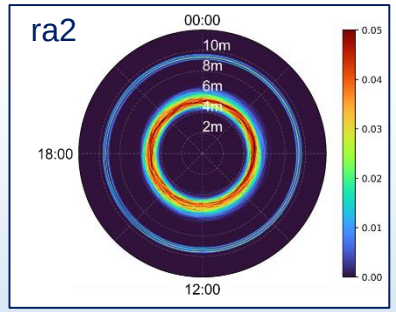
Type of gauges: R: Radar, P: Pressure, F: Floater

Mar del Plata

The rad sensor exhibited erratic behavior and was removed from publication in May 2024. The float sensor showed variations in the measurement reference and later began displaying frequent spikes and prolonged periods of constant values. The ra2 sensor has recorded data for more than 97% of the time with some spikes and outliers.





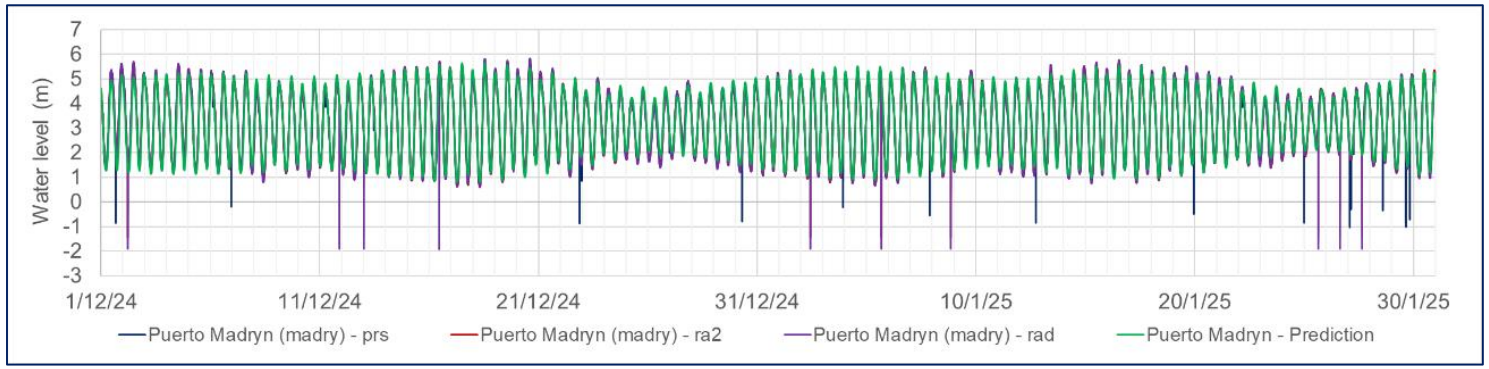


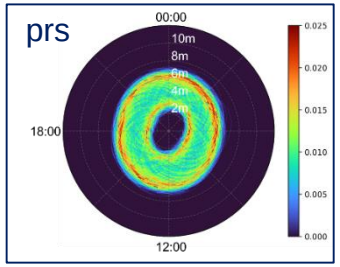
Global Sea Level Observing System

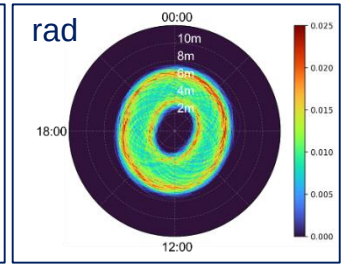
GLOSS station in Argentina

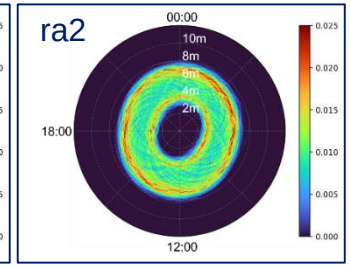
At Puerto Deseado, no data is available from the float sensor (enc), but the two additional sensors have recorded more than 99% of the observations. These sensors, along with the three sensors at Puerto Madryn, have provided continuous observations with few gaps and minimal outliers or spikes.

Puerto Madryn

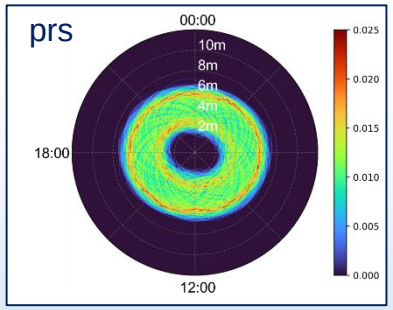


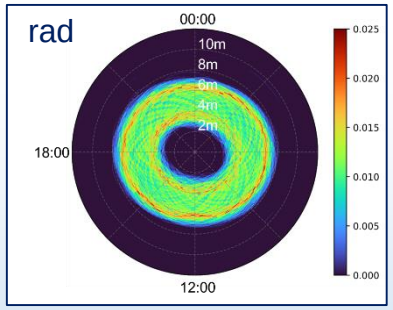


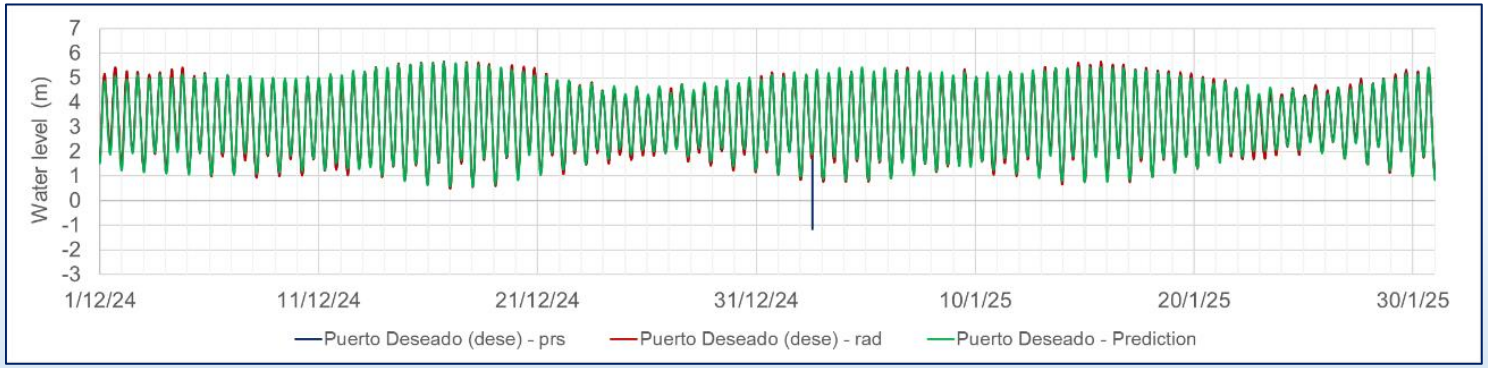




Puerto Deseado





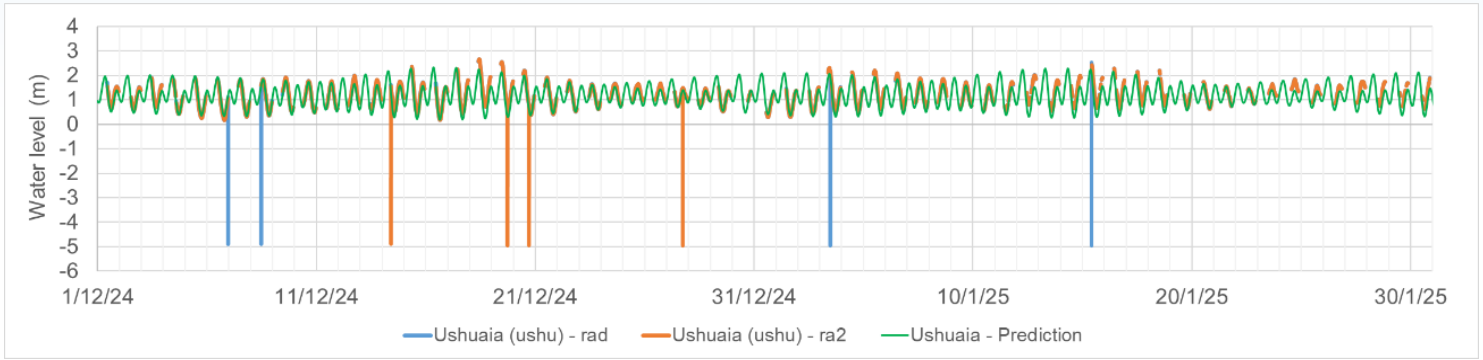


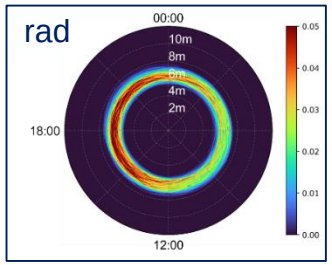
Global Sea Level Observing System

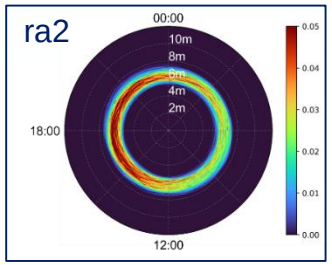
GLOSS station in Argentina

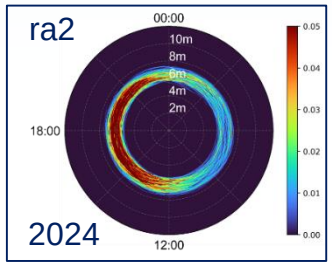
Ushuaia

The sensors at Ushuaia have experienced frequent outages since mid-2024, likely due to a battery issue. An inspection of the station was carried revealing infrastructure problems, which has led to an evaluation of the station's possible relocation.



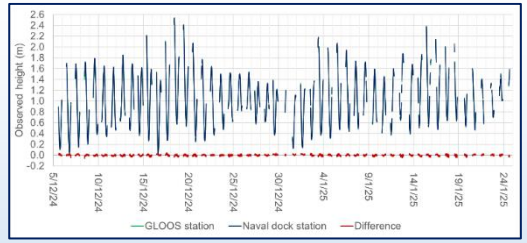






The SHN is currently in contact with personnel from the University of Hawaii Sea Level Center regarding the replacement of equipment at Mar del Plata and Ushuaia, as well as the selection of a potential new location.

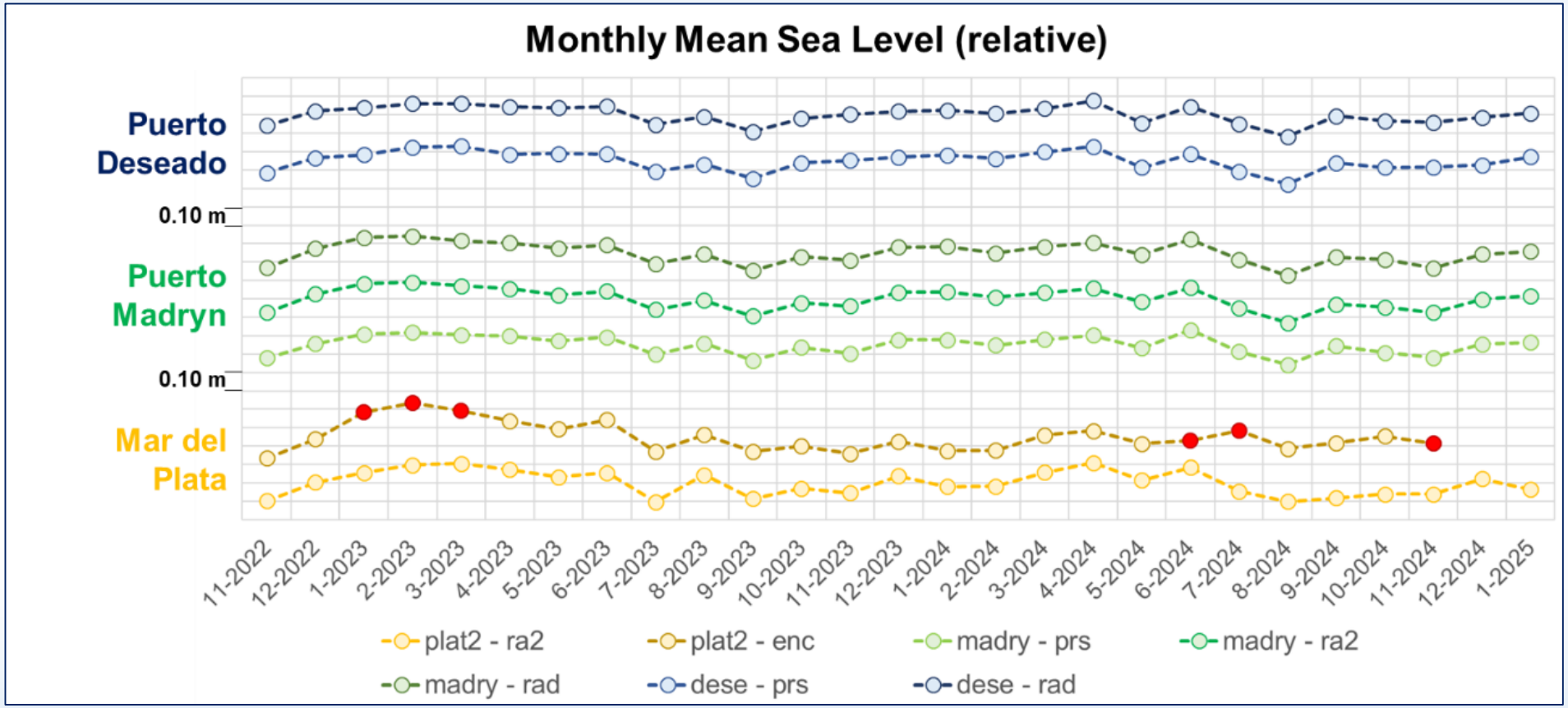
At the beginning of 2025, water level measurements were conducted at the naval dock in Ushuaia for sounding reduction purposes. The recorded heights were compared with the available observations from the GLOSS station, showing good agreement between both datasets (standard deviation of the differences < 0.013m), making this a potential site for the station's relocation.



Global Sea Level Observing System

GLOSS station in Argentina – Monthly Mean Sea Level

Comparison of the relative monthly mean sea levels of the GLOSS station sensors after applying spike and outlier filtering processing.



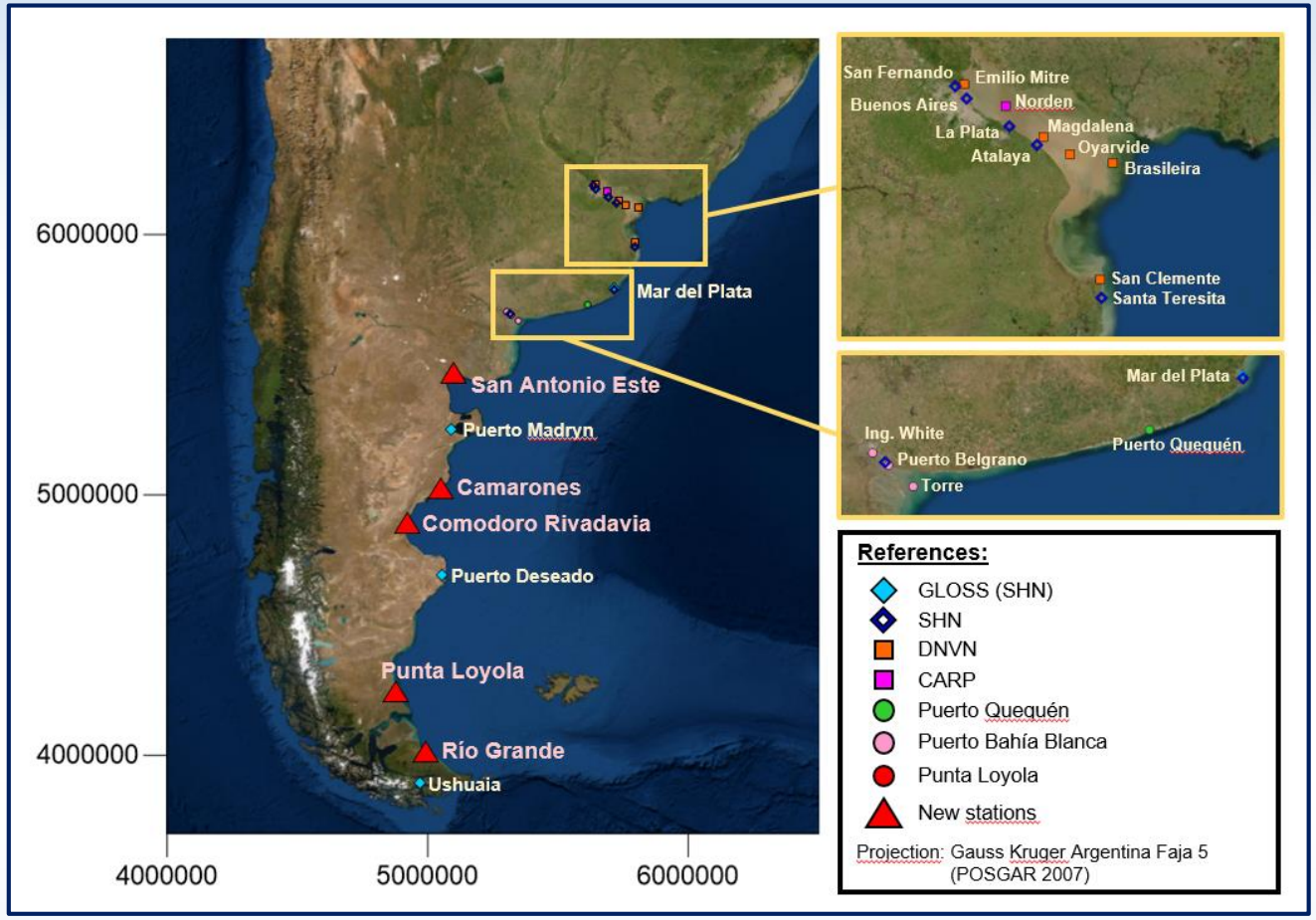
Global Sea Level Observing System

Possible locations for new sensors

In addition to the stations mentioned above, the SHN continues to work on upgrading and installing new sensors to measure water level. Currently, the verification and calibration of 5 radar sensors and 5 pressure sensors are being carried out at the Buenos Aires tide gauge station.

These sensors will be used to provide coverage of the Atlantic coast or, if necessary, to replace the sensors at GLOSS stations experiencing failures.

Possible locations for the new sensors are near the cities of San Antonio Este, Camarones, Comodoro Rivadavia, Punta Loyola, and Río Grande.



Global Sea Level Observing System

Latest research of SHN Tides Division

GNSS – Interferometric Reflectomatery

Water level measurement with a low-cost smartphone using GNSS-IR: an over 2-year study case in Buenos Aires, Argentina

Fernando Ariel Oreiro[1,2] · Mónica María Elisa Fiore[2]

Received: 11 December 2023 / Accepted: 18 July 2024 / Published online: 25 July 2024
© The Author(s), under exclusive licence to Springer Verlag GmbH Germany, part of Springer Nature 2024

Abstract
This work evaluates the capability of a low-cost smartphone to measure variations in water level caused by astronomical tide and storm surges along the coast of Buenos Aires, Argentina, over a period of 27 months, employing the GNSS-IR technique. To achieve this, the smartphone Signal to Noise Ratio-derived heights are contrasted with the heights acquired from a co-located tide gauge of the Argentine Naval Hydrographic Service. A novel methodology is applied to obtain the water levels from the smartphone observations by identifying density maximums in reflections calculated using the Lomb-Scargle periodogram. The density maximums are obtain using LOWESS regression, generating a water level series sampled every 5 min referenced to the Chart Datum. Water levels were calculated for 97.7% of the time, exhibiting a standard deviation of 0.047 m against tide gauge observations. Differences between the daily (monthly) mean levels of the analyzed series showed a standard deviation of 0.016 m (0.007 m), and the amplitude differences for the tidal harmonic constituents were smaller than 0.011 m. While the results found in this work show that these devices cannot compete with traditional tide gauges, they can complement them or be used independently to monitor water level changes in regions where installing and maintaining conventional tide gauges is challenging.

Keywords GNSS-IR · Low cost Smartphone · Tides and Storm Surge · Buenos Aires

Introduction
Measurements constitute a fundamental element within any research process. Particularly, measurements of water levels in rivers and seas are now essential for managing port operations and for studying a wide range of coastal processes that have a major impact on society. Any city located along the coast needs to know sea level variability to design adequate defenses (IOC 2016). Over the past decades, monitoring sea level has become a crucial indicator of global climate change (IPCC 2013; García-Soto et al. 2021; Pérez Gómez et al. 2022). In some locations, systematic observations of sea level have been conducted and recorded since the late 17th or early eighteenth century (Woppelmann and Pirazzoli 2006). In Argentina, the oldest sea level record dates back to 1905, and corresponds to the station in Buenos Aires.

Tide gauges have been the most commonly used equipment for measuring sea level. While sensors in direct contact with water often require more frequent maintenance, installing and maintaining any type of tide gauge is usually costly, especially for extensive networks covering vast coastlines, as is the case of the Argentinean coast, which spans over 5000 km.

For several years, the Global Navigation Satellite System Interferometric Reflectometry technique (GNSS-IR) has emerged as an alternative to obtain water height variations using GNSS measurements with geodetic antennas (Geremia-Nievinski et al. 2020). Anderson (2000) and Larson et al. (2017) determined water levels using this technique with an RMS of 0.12 m for various locations, comparing heights obtained with nearby tide gauge observations. Löfgren et al. (2014) showed that the RMS of differences between GNSS-IR and tide gauge observations varies based

Meteotsunamis

Estuarine, Coastal and Shelf Science

Meteotsunamis at the Río de la Plata estuary

Inel Perez[a], Walter Dragani[b,c,d,e,*], Fernando Oreiro[b,c], Mónica Fiore[b,c]

Pure Appl. Geophys. 181 (2024), 523–537
© 2024 The Author(s), under exclusive licence to Springer Nature Switzerland AG
https://doi.org/10.1007/s00024-023-03423-9

Pure and Applied Geophysics

December 8, 2022 Meteotsunami Along the Southeastern Coast of South America: A Case Study

Walter Dragani,[1,2,3,4] Inés Pérez,[4,5] Marcos Sanctino,[6] Fernando Oreiro,[1,2] Ruben Medina,[7,8] and Mónica Fiore[4,5]

Abstract On December 8th, 2022, a meteotsunami caused significant damage to the southern beaches of Mar del Plata city, Argentina, and the Montevideo Port in Uruguay. The event was observed over a wide area, from Puerto Belgrano in the south of Buenos Aires Province, Argentina, to La Paloma, Uruguay, including locations in the upper Río de la Plata estuary. The meteotsunami was driven by a relatively long perturbation of the surface atmospheric pressure caused by the movement of an elongated high pressure anomaly running parallel to a low pressure system associated with an atmospheric frontal zone. The atmospheric perturbation propagated faster than the meteotsunami between Mar del Plata and Montevideo, but both velocities may have been similar between Mar del Plata and Santa Teresita, where the maximum meteotsunami wave height of 0.92 m was recorded, likely due to the Proudman resonance mechanism. The propagation direction of the front from SW to NE partially explains the negligible response of the water level on the Argentinean Río de la Plata coast, where observation sites are close to the shore from where the forcing originates, as well as the almost identical starting time of the water level activity in the upper Río de la Plata and the outer sector of the estuary. This event was different from other past events in the study region, as there was no evidence of atmospheric gravity wave propagation. One significant limitation in understanding the observed atmosphere–ocean interaction in the study region is the nonexistence of high-frequency atmospheric pressure data.

Keywords: Meteorological tsunami, atmospheric cold front, atmospheric pressure disturbance, Río de la Plata estuary, Argentina, Uruguay.

1. Introduction

Meteotsunamis are sea-level oscillations of meteorological origin that resemble tsunamis and have periods ranging from a few minutes up to a few hours (Rabinovich et al., 2009). These events occur regularly in various parts of the world ocean (Monserrat et al., 2006; Pattiaratchi & Wijeratne, 2015; Vilibić, et al. 2016; Rabinovich, 2020). In particular, meteotsunamis have been observed along the coast of the Buenos Aires Province (Fig. 1), with typical wave heights of approximately 0.30 m and spectral peaks ranging from 15 to 70 min (Perez et al., 2022, and references cited therein). Bulay (1955) was the first to suggest that these ocean waves could have an atmospheric origin in the coastal waters of Buenos Aires Province. Dragani et al. (2002) proposed that atmospheric gravity waves (AGWs) associated with frontal passages could be the forcing mechanism for meteotsunamis, which was later confirmed by Perez and Dragani (2017) through observations. Perez et al. (2021a) found that meteotsunamis are amplified when AGWs propagate along the coast. Subsequently, Perez and Dragani (2021) inferred the presence of meteotsunamis in the Río de la Plata (RDP) estuary,

Tide Models

Plataforma web para el cálculo de predicciones de marea astronómica: Implementación para el litoral marítimo bonaerense y su plataforma continental

Fernando A. Oreiro, Ing. Geodesta-Geofísico[1,2], Mónica M.E. Fiore, Lic. en Oceanografía[1,2]
[1]Universidad de Buenos Aires, Facultad de Ingeniería, Argentina. foreiro@fi.uba.ar, mfiore@gmail.com
[2]Servicio de Hidrografía Naval, Ministerio de Defensa, Argentina

Resumen— *Las mareas astronómica es un fenómeno que tiene influencia en complejos procesos físicos y dinámicos del océano, y en problemas prácticos tanto el acceso a puerto de los embarcaciones y la determinación de los ceros de las cartas náuticas. Los usuarios no especializados que requieren predicciones precisas de marea para la costa argentina sólo disponen de las 11 ubicaciones que publica el Servicio de Hidrografía Naval en sus Tablas de Mareas. En este trabajo se describe el funcionamiento de la plataforma web que permite obtener predicciones precisas de mareas astronómica para cualquier ubicación, ingresando únicamente la fecha y la coordenada geográfica de interés. La facilidad de acceso a las predicciones se logra a partir de la optimización del cálculo para consultas web, y de la modelización de este fenómeno a través de modelos empíricos o hidrodinámicos. Se desarrolla como ejemplo la región que comprende el litoral marítimo bonaerense y su plataforma continental adyacente, en donde las amplitudes y fases necesarias para el cálculo de las predicciones se obtienen del resultado de la implementación del modelo hidrodinámico 2DCIRC para la zona, de observaciones in-situ y de altimetría satelital.*

Keywords—predicciones de mareas astronómica, plataforma web, litoral marítimo bonaerense.

I. INTRODUCCIÓN

La marea astronómica modifica la altura de la superficie del océano en formas periódica, debido a que se genera una complementante por los movimientos relativos de la Luna y el Sol, respecto de la Tierra [1], [2], [3]. Tiene influencia en complejos procesos físicos y dinámicos que ocurren en el océano [4], [5], [6], [7], en la producción pesquera [8] y en el nivel de inundación cuando se combina con ondas de tormenta [9]. Desde el punto de vista de la navegación, es fundamental en la determinación de los ceros de las cartas náuticas [10], y en el acceso a puerto de las embarcaciones [11]. Las predicciones precisas de mareas astronómica son necesarias para estudios científicos y para aplicaciones prácticas en el medioambiente marino, como la planificación de construcciones costeras, la determinación de zonas inundables, el modelado de la dispersión de contaminantes y la estimación de energía mareomotriz.

Los usuarios no especializados que requieren predicciones precisas de mareas para la costa argentina sólo disponen de las 11 ubicaciones que publica el Servicio de Hidrografía Naval (SHN) en sus Tablas de Mareas [12]. La Fig. 1 muestra la ubicación de los puertos patria que se publican en las Tablas de Mareas, en donde se pueden identificar extensas regiones sin predicciones disponibles. Los usuarios que requieren información en estas regiones, deben obtenerla aplicando algún método de interpolación que no suele devolver resultados precisos.

Fig. 1 Ubicación de los puertos patria que se publican en las Tablas de Mareas.

Existen otros métodos para obtener predicciones de mareas astronómica que requieren que el usuario realice sus propios cálculos utilizando las amplitudes y fases de las ondas componentes, que pueden obtenerse de modelos globales o regionales de mareas. En los últimos años se desarrollaron modelos globales de los que se pueden obtener constantes armónicas para calcular predicciones de mareas astronómica, como el "Goddard Ocean Tide model" (GOT) [13], el OSU TPXO Tide Model (TPXO9) [14], el Finite Element Solution (FES2014b) producido por Noveltis, Legos y CLS, y distribuido por Aviso+ con apoyo de Cnes (https://www.aviso.altimetry.fr/) y el Empirical Ocean Tide model (EOT) [15]. Muchos de estos modelos se actualizan periódicamente para mejorar su performance, sin embargo, en las cercanías de las costas continúan siendo menos precisos que en el resto del océano debido a diferentes motivos, como su resolución, la incertidumbre en la batimetría y la línea de costa, la calidad y cantidad de datos de mareas asimilados o a una

Digital Object Identifier: (only for full papers, inserted by LACCEI)
ISSN, ISBN: (to be inserted by LACCEI)
DO NOT REMOVE

20th LACCEI International Multi-Conference for Engineering, Education, and Technology: "Leadership in Education and Innovation in Engineering in the Framework of Global Transformations: Integration and Alliances for Integral Development", Hybrid Event, Buenos Aires - ARGENTINA, July 17 - 21, 2023

Tidal influence in wetlands

Estuarine, Coastal and Shelf Science

Tidal connectivity modelling in wetlands associated with coastal lagoon of Punta Rasa natural reserve, Argentina

L. López[a,b], F. Oreiro[c,d], W. Dragani[b,c], J. Galliari[b,e], F. Cellone[b,f], E. Carol[b,g,*]

ARTICLE INFO

ABSTRACT

1. Introduction

Coastal lagoons are inland shallow water bodies separated from the ocean by a barrier and connected to the ocean by one or more tidal inlets which remain open at least intermittently (Quirós, 1994; Isla, 1995). The connection with the sea through one or multiple channels determines that tidal flow is an important component of the hydrological functioning of coastal lagoons. However, the geomorphological evolution of coastal lagoons tends to restrict connections with tidal flows (Duck and da Silva, 2012; Cáceres et al., 2016). Thus, as the connection with the ocean is lost, tidal inundation becomes less frequent and may even cease, with other contributions such as groundwater discharge becoming relevant (Morell et al., 2017). Consequently, there is a great hydrological variety of coastal lagoons that can receive inputs of freshwater and/or saltwater or be subjected to different tidal regimes and climatic conditions (Del Monte and Di Sipio, 2004; Perez Rozada et al., 2008; Kennish and Paerl, 2010; Basset et al., 2013; Nicholas et al., 2014; Meredith et al., 2022; Morel et al., 2022).

Located in the continent-ocean aquatic continuum, coastal lagoons are among the most productive environments and provide valuable ecosystem services such as contaminant and sediment attenuation, food production, nutrient cycling, breeding areas, and bird refuges (Odd-hedberg et al., 2013; Newton et al., 2014). Given their environmental significance, many of these coastal lagoons constitute natural reserve areas, such as the Punta Rasa Natural Reserve located in the transitional zone between the outer limit of the Río de la Plata estuary and the sea (Fig. 1). This reserve is part of the RAMSAR site Bahía Samborombón and comprises a system of small coastal lagoons formed during the

Ocean Loading (DinSAR)

OCEAN TIDE LOAD TREND ANALYSIS USING DINSAR ON VALDÉS PENINSULA

M. C. Mora [1,2,3,5*] y F. A. Oreiro [1,4,6]

[1] Ministerio de Defensa, Servicio de Hidrografía Naval, Departamento Oceanografía, CABA, Argentina.
[2] Universidad de Buenos Aires, Facultad de Ingeniería, Instituto de Geodesia y Geofísica Aplicadas, CABA, Argentina.
[3] Universidad de La Plata, Facultad de Ingeniería, Departamento de Agrimensura, Buenos Aires, Argentina.
[4] Universidad de Buenos Aires, Facultad de Ingeniería, Departamento de Agrimensura, CABA, Argentina.
[5] ORCID 0009-0005-1963-4147
[6] ORCID 0000-0003-3575-1106
*mariana.mora@defensa.gob.ar / mariana.c.mora@gmail.com

ABSTRACT

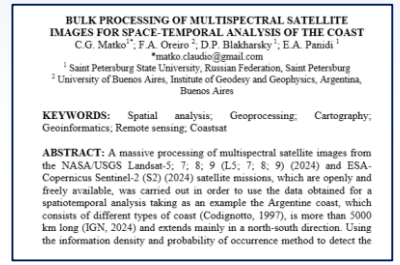
In this study, the DinSAR technique is applied to detect and analyze ground deformations caused by the elastic response of the crust to mass displacements driven by astronomical tides and storm surges in Valdés Peninsula, Chubut Province (42°-43° South; 64.5°-63.5° West).

Images from the European Space Agency's Sentinel-1 SLC constellation, acquired in descending passes with vertical polarization, were used. Based on tidal predictions for Nuevo Gulf (Puerto Madryn) and San José Gulf (F. San Román), 15 study dates were selected according to water height variability between the gulfs, resulting in 16 interferometric pairs.

By combining astronomical tide predictions in the gulfs, which have inversed tidal regimes, water height observations at Puerto Madryn, water height predictions from the global tide model FES2014b, and corrections from the DAC storm surge model, water height difference grids for the interferometric pairs were generated. A joint analysis of the observed differences was then conducted, classifying cases based on their amplitude, distribution, and corresponding relative ground deformation.

The results revealed a relationship between water height and detected deformations. When the water height difference decreased (loss of volume and thus reduced load), positive deformations (surface uplift) were observed; for increased water height differences (increased volume and load), negative deformations (surface subsidence) were detected. Cases with uniformly

Intertidal zone evolution using Landsat and Sentinel optical images



BULK PROCESSING OF MULTISPECTRAL SATELLITE IMAGES FOR SPACE-TEMPORAL ANALYSIS OF THE COAST

C.G. Matko[1*]; F.A. Oreiro [2]; D.P. Blakharsky [1]; E.A. Panidi [1]
*matko.claudio@gmail.com
[1] Saint Petersburg State University, Russian Federation, Saint Petersburg
[2] University of Buenos Aires, Institute of Geodesy and Geophysics, Argentina, Buenos Aires

KEYWORDS: Spatial analysis; Geoprocessing; Cartography; Geoinformatics; Remote sensing; Coastsat

ABSTRACT: A massive processing of multispectral satellite images from the NASA/USGS Landsat-5; 7; 8; 9 (L5; 7; 8; 9) (2024) and ESA-Copernicus Sentinel-2 (S2) (2024) satellite missions, which are openly and freely available, was carried out in order to use the data obtained for a spatiotemporal analysis taking as an example the Argentine coast, which consists of different types of coast (Codignotto, 1997), is more than 5000 km long (IGN, 2024) and extends mainly in a north-south direction. Using the information density and probability of occurrence method to detect the

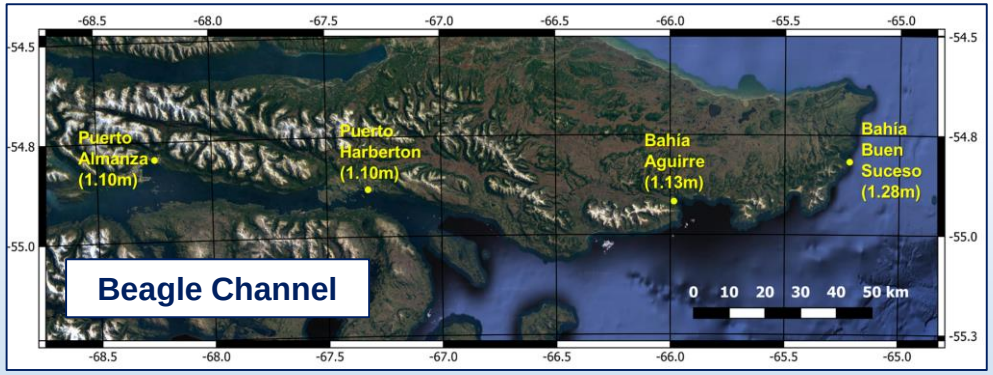
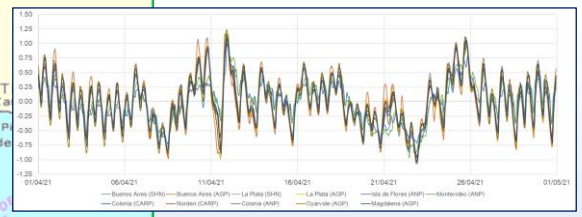


Chart Datum Unification

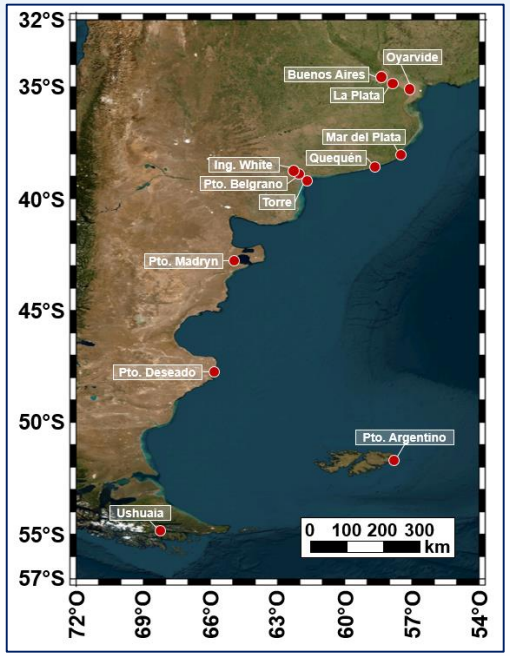


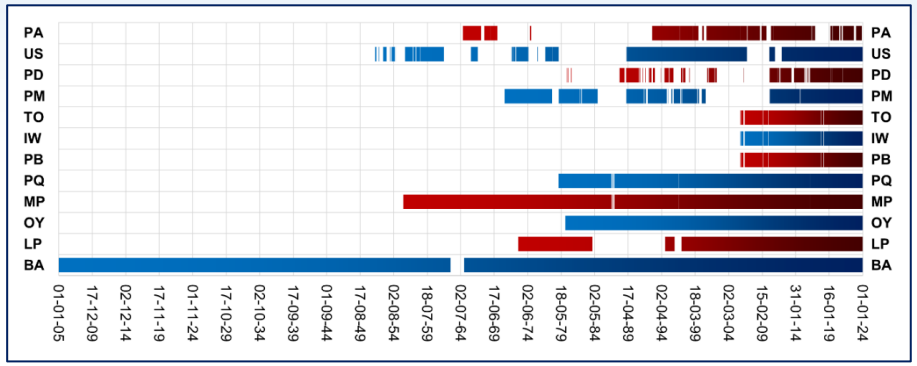
Global Sea Level Observing System

Latest research of SHN Tides Division

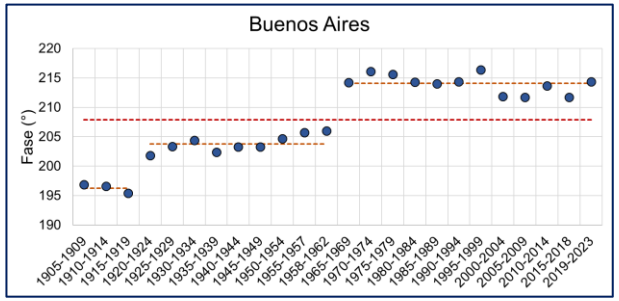
Mean Sea Level, Tides and Storm Surges in the Argentinian coast (currently being prepared for publication)

Available data

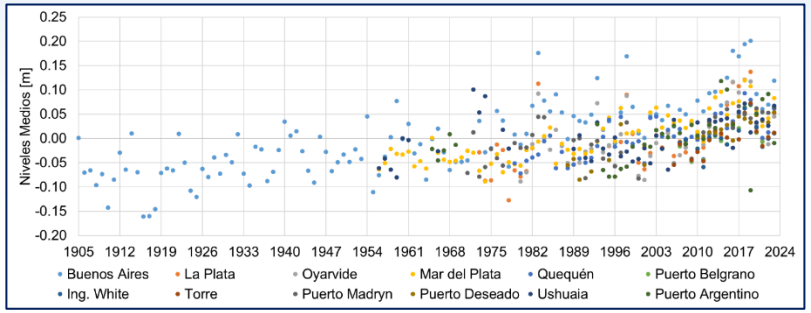


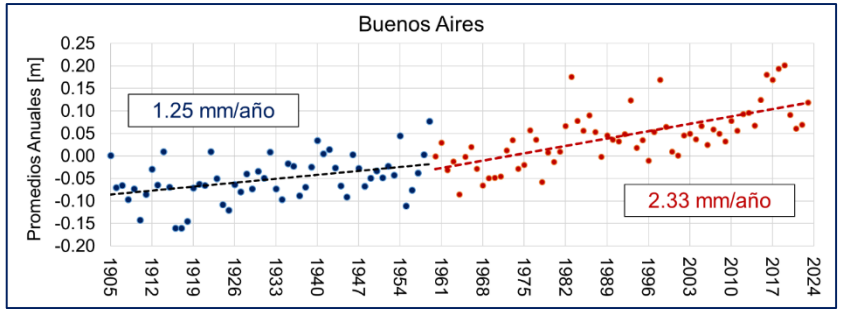


Tides

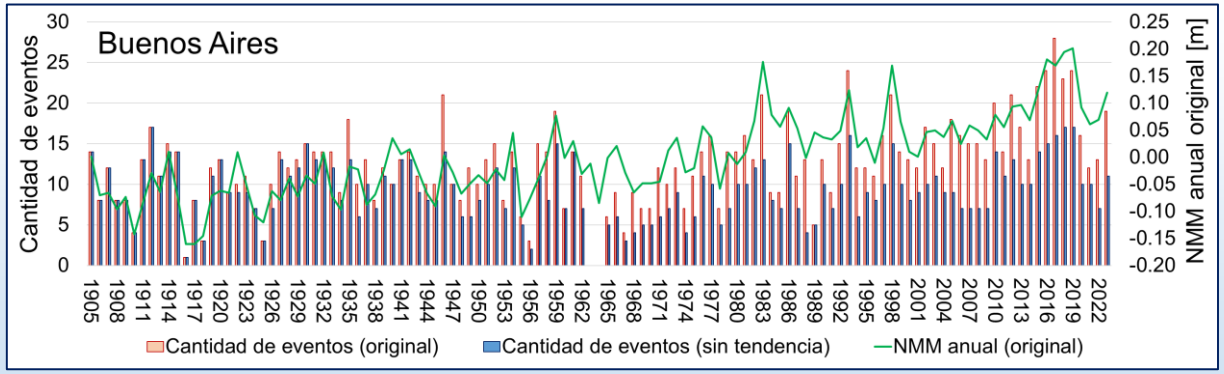


Mean Sea Level





Storm Surge



Servicio de Hidrografía Naval
Subsecretaría de Ambiente
Fundación Internacional y para Iberoamérica de Administración y Políticas Públicas.

Global Sea Level Observing System

Thank you for your attention

Fernando A. Oreiro
foreiro@hidro.gov.ar – foreiro@fi.uba.ar
Tides Division - Servicio de Hidrografía Naval, Argentina

Global Sea Level Observing System