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Hydrodynamic and hydrological processes within a variety of coral reef lagoons: Field observations during 6 cyclonic seasons in New Caledonia

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Abstract.
From 2014 to 2021, extensive monitoring of hydrodynamics was deployed within a variety of lagoons of New Caledonia during 6 tropical cyclone seasons. Globally, those coastal physical observations encompassed five different lagoons (four of which were never monitored before) and at least eight major atmospheric events ranging from tropical depression to category 4 cyclone. The main objectives were to characterize the processes at stake controlling hydrodynamics and hydrology of these lagoons (e.g ocean-lagoon exchanges, circulation, level dynamics, temperature and salinity variability) and capture their magnitude of change during extreme events. An additional objective was to build an adequate data set for assessment of high-resolution hydrodynamics models. Those field experiments took place within the PRESENCE project (PRESsures on coral Ecosystems of New CalEdonia) which aimed at building an efficient representation of the land-lagoon-ocean continuum of Grande Terre (main land) lagoons. Autonomous oceanographic instruments were moored at strategic locations to collect time-series of temperature, salinity, pressure, eulerian currents which characterize hydrodynamics at best. During field trips, whenever possible, lagrangian drifters releases and cross-shore hydrological profiles radials were additionally carried out. Surveys begun chronologically with SPHYNX campaign which lasted 15 months (December 2014 to February 2016) in the Hienghène-Touho lagoon followed with 5 months records in NOUMEA lagoon (December 2016 to April 2017). ELADE campaign in Poe lagoon encompassed 2 periods of measure (February to April 2018 and June to August 2018). In Koumac lagoon, CADHYAK survey was carried out between December 2019 until the end of May 2020 and finally, data have been recorded continuously for 9 months in Moindou lagoon (NEMO) (September 2020 to April 2021). In addition to characterize

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these lagoons, this data set stresses out some important features and processes, such as the presence of internal waves on reef slopes, wave-driven fluxes over reef barrier and exchanges through passes. It also contains the signatures of strong events materialized by surges, thermal drops inside lagoons or massive flash flood plumes dispersion. Raw data sets were processed, quality-controlled and validated, and processed files are publicly available in dedicated repositories on Seanoe in NetCDF format. Links (DOI) of individual data sets are provided herein.

1 Introduction

Home to a huge biodiversity, coral reefs support a large range of benefits and services for millions of humans (Hughes et al., 2017). It is among the most productive ecosystem on earth supplying seafood and coastal protection. Nevertheless, coral habitats and abundance are declining drastically due to their increased exposition to a range of climatic and local stressors (França et al., 2020). Specifically, during tropical cyclone seasons, threats due to strong atmospheric events are enhanced and mainly controlled through hydrodynamic processes. Those ecosystems may face thermal-stress (Lough et al., 2018) inducing disturbance in coral functioning (bleaching), mechanical damages caused by tropical storms or cyclones (Cheal et al., 2017) and flash floods altering water quality (Tan et al., 2012; Desclaux et al., 2018). Overall, hydrodynamic conditions play a central role by controlling distribution, growth and resilience of coral communities (Lenihan et al., 2015; Rogers et al., 2016; Shedrawi et al., 2017). Finally, geomorphological aspects (e.g. surface, mean depth, degree of openness) strongly influence circulation and thermodynamic major features such as water exchange rate, renewal time, mixing, heat budget (Umgiesser et al., 2014) so that lagoons may exhibit a wide range of responses to extreme events.

New Caledonia offers a high diversity of coral reefs complexes covering more than 4 500 km^2 (Andréfouët et al., 2009) counting a great variety of lagoons of contrasted sizes and shapes. Here, we refer to "lagoon" the water body located between the shore and the reef crest. In the past research works, knowledge on lagoon scale hydrodynamics (either from observations or modelling) were essentially limited on two lagoons located on the south-western side of the main land: the large south-west lagoon in front of the capital Nouméa (Douillet, 1998; Ouillon et al., 2010; Jouon et al., 2006) and the Ouano lagoon located a little further north (Sous et al., 2017; Chevalier et al., 2015). Furthermore, to our knowledge, none of observational strategies where specifically dedicated to observe the high-frequency signature of cyclonic events on hydrodynamics and hydrology of the Grande Terre lagoons.

In this context, the PRESENCE project (PRESsures on coral Ecosystems of New CalEdonia), sponsored by New Caledonia institutions (Government, North and South Province) has been launched to partially fill this gap. The aim was to provide a synoptic view of several lagoons functioning using field measurements, satellite observations and high-resolution hydrodynamic model and to characterize inter-lagoon heterogeneity. This project focused on physical processes occurring in coastal ecosystems and especially on the interactions and exchanges along the land-lagoon-ocean continuum. In this framework, field observations have been undertaken in a variety of unmonitored lagoons, with a focus on austral summer, i.e. cyclone season to identify mean circulation and forcings, as well as to highlight the scales of variability.

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Data presented in this paper are a contribution to the knowledge and understandings of the diversity of physical processes at stake in New Caledonia lagoons. It represents an essential database for improved realism of numerical modelling development and experiments. Five main surveys were conducted around Grande Terre lagoons in the 2014-2021 period, covering 6 consecutive cyclonic seasons. After a brief state-of-the-art of the lagoon hydrodynamics in New Caledonia lagoons in Section 2, study sites and observational strategies are then described in Section 3. Sensors types, processing and qualificating methods are detailed in Section 4. Finally, general outputs of observations acquired are illustrated in Section 5.

2 New Caledonia Lagoon's context

New Caledonia archipelago is located in the South-West Pacific Ocean between 19°S-23°S latitude and 163°E-167°E longitude. The mainland called the "Grande Terre" is an elongated mountainous island (approx. 400 km long and 50 km wide) oriented southeast-northwest. The Grande Terre is surrounded by the second world longest semi-continuous coral reef barrier in the world (1 744 km^2) after the Australian Great Barrier Reef, including deep channels that allow water exchanges with ocean. It thus delimits a wide range of lagoon seascapes covering globally 21 896 km^2 (Andréfouët et al., 2009). Since July 2008, four marine areas of the Grande Terre were listed as United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites, which had promoted monitoring, management, and conservation actions to maintain the integrity of those reef-lagoon ecosystems.

Grande Terre lagoons display a high diversity of geomorphologies and coral reef complexes (Andréfouët et al., 2009). While distances from shore to barrier reef range typically from 2 to 30 km, depth varies approximately between 1 to 50 m inside lagoons and drop rapidly to 600m over the oceanic slope of the barrier reef (Fuchs et al., 2013). Roughly, the western side of the mainland is characterized by shallower and narrower lagoons than the east side. Barrier reefs are partly drowned and sparser in the eastern side offering more openness to the Ocean. North-west and south-west lagoons are wider and deeper contrary to the central west area. Finally, a large lagoon named "Grand Lagon Nord" is extending 140 kilometers northward from the northern part of main land

2.1 Atmospheric forcings

New Caledonia's weather displays typical features of tropical climate in this region. Seasonality and inter-annual variability are mainly driven by the position of the South Pacific Convergence Zone (SPCZ) and the El Niño/Southern Oscillation (ENSO) respectively, although other timescales of modulation are induced by large-scale fluctuations such as Madden-Julian and Interdecadal Pacific oscillations (Dutheil et al., 2021). The south-east trade winds, which represent 70% of the yearly wind occurrence are prevalent all year long although slightly weaker and less constant during the cold season. Moreover, intensity of winds shows much more diurnal than seasonal variability (Caudmont and Maitrepierre, 2006). In phase with the seasonal migration of the SPCZ, rainfall is less abundant in austral winter than in summer with maximum precipitation observed around

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February-March (Payri et al., 2019). Due to the mountainous shape of the Grande Terre (the two highest peaks Panié and Humboldt over 1600m), orographic effects induce modulation of the SE trade winds regional regime and more precipitation on the windward eastern coast which eventually leads to higher freshwater flows to the lagoons (Lefèvre et al., 2010; Terry and Wotling, 2011).

The ENSO impacts precipitations dispersion over the whole Pacific Basin and leads to strong inter-annual variability of rainfall over New Caledonia. In its positive phase (El Niño), a decreasing occurrence of rainfall of 20-50% can be observed over New Caledonia while La Niña can bring up to 50 % more water (Nicet and Delcroix, 2000; Moron et al., 2016). Finally, during austral summer, tropical cyclones strike New Caledonia basin with an average occurrence of 1.5 per year bringing extreme winds and rainfall (Grenz et al., 2013). During La Niña events, tropical cyclones are more frequently observed between New Caledonia and Vanuatu (Dowdy et al., 2012).

2.2 Oceanic forcings

The regional subsurface circulation around New Caledonia is characterized by two large ocean currents called the North Caledonian Jet (NCJ) and the South Caledonian Jet (SCJ). They both flow westward and are ramifications of the root South Equatorial Current (SEC) which bifurcate into NCJ and SCJ branch before reaching Loyalty Islands (Couvelard et al., 2008; Marchesiello et al., 2010). In the vicinity of the Grande Terre and Loyalty Islands, Gasparin et al. (2011) described a subpart of the NCJ called the East Caledonian Current (ECC) a boundary current located between 10 and 100 km from the east coast of New Caledonia and flowing north-westward. The alongshore transport around the mainland is mainly composed by two currents flowing southeastward, i.e. against the mean wind direction, in the subsurface layer: on the west the so-called Alis current, a very persistent feature and on the eastern side the more variable Vauban current located in the Loyalty Channel (Cravatte et al., 2015). Finally, in the south of the mainland arrives the STCC (Sub Tropical Counter Current), a subbranch of the original East Australian Current, which is flowing eastward from Australia.

Oceanic Sea Surface Temperature generally ranges from 23-24°C during winter to more than 28°C during the hot season (Payri et al., 2019). Furthermore, at the same latitudes, oceanic surface waters are cooler on the west side on the Grande Terre than on the east side. The mainland orientation aligned with the direction of the trade winds creates favorable conditions for generating wind-driven upwelling (on the west coast) and downwelling (on the east coast) (Marchesiello et al., 2010). Intense cooling events during summer season (October to march) were highlighted for the first time by Hénin and Cresswell, (2005) on the south-western outer reefs of NC. Sea surface temperature from satellite images observation associated with wind trade events allow to describe a cooling of surface temperature from 2-4 °C in this area. Few cooling events occur on the east coast especially during westerly and north-westerly winds (Hénin and Cresswell, 2005). Upwelling triggering processes and consequences have been thoroughly studied, either by the mean of modelling (Alory et al., 2006; Marchesiello et al., 2010; Fuchs et al., 2013) or using observations (Cravatte et al., 2015; Ganachaud et al., 2010; Neveux et al., 2010).

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Considering wave climate around New Caledonia, to our knowledge, only few fundamental work has been performed such as Ouillon et al., 2010 who described using litterature the seasonality around the SW lagoon. The highest swell generally comes from the south-south-east between March and May (mean monthly value range: 2.3-2.4m) and the lowest swell between October and January (around 1.9-2m). The yearly mean waves period around this south-western part of the Grande Terre ranges from 7.1s to 8.7s.

2.3 The ocean lagoon interface

Coral reef barriers provide an efficient protection against submersion, huge oceanic sea states and tsunamis, erosion and tropical cyclones (TC). This ocean-lagoon interface allows oceanic waters to penetrate lagoons through wave breaking, which can be particularly important for shallow lagoons circulation. Bonneton et al. (2007) developed an analytical model of the tidally wave-induced currents at the Aboré reef barrier in front of Nouméa (south-west of Grande Terre). The Ouano reef-lagoon system has also been the theatre of several field and numerical experiments. The wave transformation over the barrier reef has there been investigated by the means of observational and numerical data and revealed the presence of very low frequency wave patterns each side of the crest, as well as undular bore trains over the reef flat (Sous et al., 2019). The importance of the cross-reef fluxes (due to incident waves breaking and tide) on the barrier interface has also been highlighted for the circulation and water properties (Chevalier et al., 2015; Sous et al., 2017). Finally, Sous et al. (2020) studied more precisely the different terms in the momentum balance over the Ouano barrier reef and showed a regime shift between casual conditions and huge incident waves.

2.4 Lagoon dynamics

Tidal dynamics in the SW lagoon of NC was first studied by Douillet (1998) using observations and a 2D numerical model. While the influence of diurnal signal revealed to be weak, the south-west lagoon dynamics is driven mainly by semi-diurnal tides, especially the M2 and S2 components. Tidal levels range from 0.6m at neap tide to 1.4m at spring tide (Douillet, 1998). These cyclic dynamics of levels due to tidal forcing can be episodically modified by extreme events such as tropical cyclones. Numerical experiments have been designed by Jullien et al. (2017) to study the effect of atmospheric surge and wave-setup during TC Cook which hit NC in 2017 from the East coast. During this strong event, they revealed atmospheric surge around 0.5m and an anomaly due to wave-setup that can reach 0.25m depending on the lagoon's geomorphologies.

In the SW lagoon, tidally generated currents are mainly aligned along the lagoon axis (except near passages) and can reach 0.2 $m.s^{-1}$ for M2 and ~ 0.03 $m.s^{-1}$ for S2 (Douillet, 1998). Mean tidal currents are about 0.05-0.1 $m.s^{-1}$ in this lagoon and approx. 0.2-0.3 $m.s^{-1}$ in the passages (Ouillon et al., 2010). Observations using Acoustic Doppler Current Profilers in four different stations of Ouano lagoon showed a small vertical variability of currents (< 0.05 $m.s^{-1}$) and a high variability depending on the

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mooring site, up to 0.7 m.s^{-1} observed in a passage (Chevalier et al., 2015). Finally, fields observations and numerical modelling were used conjointly to characterize circulation patterns and residence times in both SW lagoon (Jouon et al., 2006) and Ouano lagoon (Sous et al., 2017)

The evolution and the spatial distribution of temperature, salinity and water turbidity within lagoons are deeply related to the seasonality and are amplified during ENSO episodes (Ouillon et al., 2005). During summer, bays and coastal areas record higher water temperature than lagoons while the contrary is true in winter. ENSO amplify this distribution with increasing temperature and saltier waters during El Niño due to low freshwater inputs and enhanced evaporation. Finally, the fate of plumes and their consequences on the SW lagoon were studied through biogeochemical and sedimentology points of view (Pinazo et al., 2004; Ouillon et al., 2004; Drouzy et al., 2019). These studies highlighted the gradient of suspended particulate matter, nutrients and chlorophyll-a displaying much higher values in the bays around Nouméa than in the lagoon.

Waves from ocean are strongly attenuated by reef barrier (wave breaking) but reef passages are interface areas where waves can enter into the lagoon. Nevertheless, in the SW lagoon, where trade winds can blow over a sufficient fetch distance to generate wind waves, Jouon et al. (2009) confirmed by observations that the sea state of this lagoon is clearly dominated by high-frequency wind waves. This was confirmed by Aucan et al. (2017) which undertook a yearly period of observations around two islets in the SW lagoon and detected three main modes: high frequency wind waves (period 3-8s), low frequency generated by incoming swell within the passages (period 8-25s) and infragravity waves (period 25-400s). Maximum significant wave height observed in the lagoon in these two studies peaks around 1m and 1.5m.

2.5 Past and on-going observational strategies

From the state of the art described above, one can see that field observations have mainly focused on the functioning of the SW lagoon (during CAMELIA unit research lifetime) and on the Ouano lagoon circulation and exchanges with dedicated cruises with the N/O Alis. To our knowledge, these past data sets are neither freely nor easily accessible. Nevertheless, another observation network called Reeftemps (Varillon et al., 2021) targets mainly temperature through a long-term acquisition network of coastal water to evaluate the effect of climate change on coral reefs ecosystems in Oceania (14 countries). Data sets are freely accessible on their web portal (*www.reeftemps.science*) and some of past field acquisition may be integrated. In New Caledonia, this network recently extended to other physical parameters (e.g salinity, pressure) but remains composed of stations distributed in and around the SW lagoon.

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3 Study sites and observational strategies

3.1 Global overview

Between December 2014 and April 2021, five distinctive lagoons have been instrumented around Grande Terre. The main goal of this observational strategy was to collect a robust data set enabling to improve hydrodynamics knowledge into a variety of unmonitored lagoons around the mainland during periods encompassing the cyclonic seasons (from December to May). At least 8 major meteorological events ranging from Tropical Depression (TD) to category 4 cyclone (see Fig. 1) were captured, as well as periods contrasted in terms of Southern Oscillation Index (SOI). Length of acquisition (from 2 to 15 months) and number of instruments moored for each campaign differed slightly depending on funds and availability of instruments. Due to the necessity of frequent maintenance (e.g. for fouling, batteries replacement and data retrieval), most of surveys were delimited in legs which lasted around 3 months (except when retrieval was not possible, e.g. cyclonic conditions or shut down due to the covid-19 pandemic situation).

Global sampling strategies have been thought to observe important features driving lagoon circulation and hydrology by mooring high-frequency instruments for monitoring currents, temperature, salinity, sea level (cf. Section 4) into chosen stations in the lagoon and the external reef slope. Most instruments were deployed by scuba-diving. For campaigns requiring maintenance field trips, cross-shore radials of CTD profiles were undertaken and lagrangian surface drifters were also deployed.

Main scientific objectives of these samplings were multiple as it aimed to, simultaneously, (i) characterize oceanic forcings of the lagoon (ii) quantify exchanges at lagoon-ocean interface (iii) capture hydrodynamic signatures of energetic events into the lagoon.

For (i), temperature and sea level were monitored on the ocean reef slopes to acquire high-frequency sea level time series (e.g. incident waves breaking on barrier reefs, surges) as well as thermal dynamics of importance such as upwellings or internal waves. (ii) was dedicated to quantify fluxes across the barrier reef as well as currents inside passes where it was pertinent and achievable. Finally, the monitoring strategy aimed at capturing functioning of lagoons during trade winds conditions (current, sea level dynamics, temperature and salinity) as well as the signatures of strong events inside the lagoon and at the land-lagoon and lagoon-ocean interfaces (surges, plume dispersal, intensification of ocean-lagoon exchanges…etc.).

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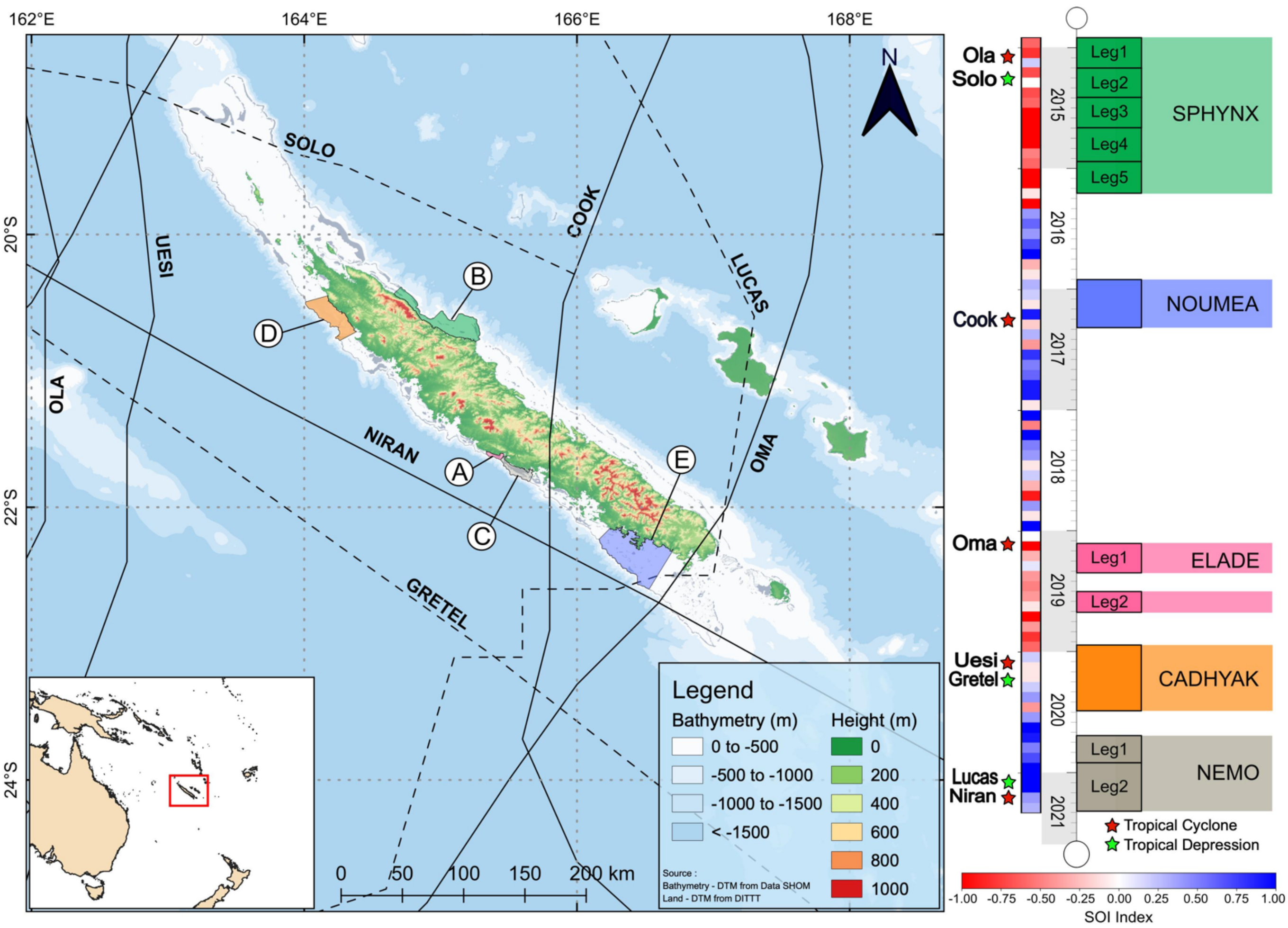

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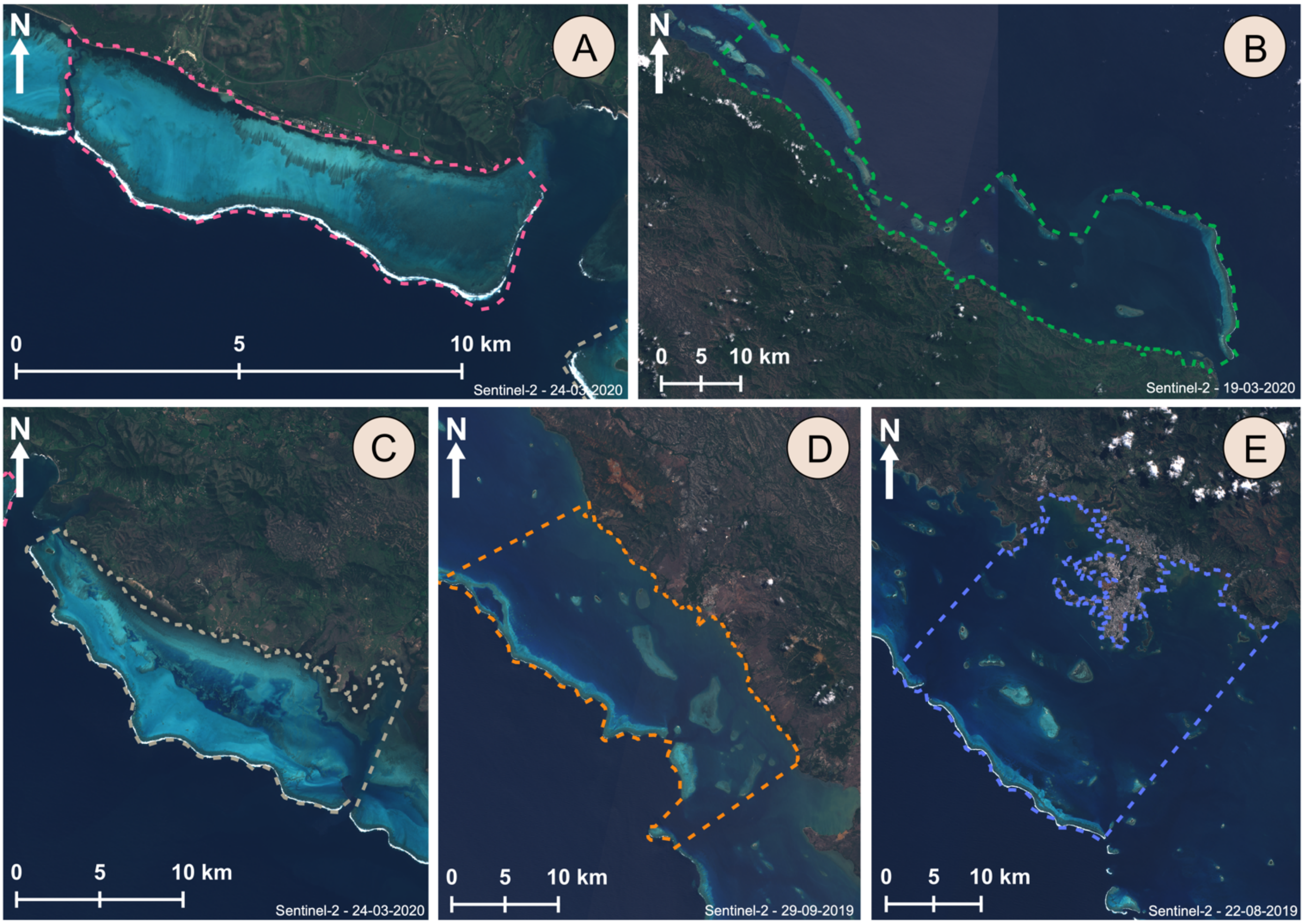

Figure 1: Top. Map of New Caledonia including the location of the five studied lagoons. Chronology of the observational strategy, SOI time-series (NOAA), date and trajectory of the 8 major atmospheric events. Names in uppercase refer to the names of field campaigns, some being composed of several field trips ("Leg"). Bottom: Geomorphologies of the lagoons from Sentinel-2 imagery from European Space Agency (ESA): (A) Poé lagoon (B) Hienghène-Touho lagoon (C) Moindou lagoon (D) Koumac lagoon (E) SW lagoon (Nouméa).

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3.2 The five campaigns and study sites

Chronologically, the first and longest campaign is the so-called SPHYNX data set covering a total period of 15 months (5 Legs) into Hienghène-Touho lagoon from December 2014 to March 2016. This area is part of the North-East Coastal Region classified among UNESCO world heritage sites. The lagoon of interest is deep (average depth 29 m) and wide (maximum distance between coast and reef crest is around 19 km) separated from the ocean with a camelback shaped and discontinued reef barrier punctuated with large passages (See Fig. 1). A chain of 6 islets surrounded by large reef flats and scattered on the alongshore axis is present in the middle of the lagoon. SPHYNX data set is mainly characterized by a negative Southern Oscillation Index (SOI) and includes 2 major atmospheric events, the TC "Ola" causing cumulative rainfall around 50 to 100 mm in 48h on the east coast and the strong TD "Solo" generating 100 mm in 24h on the east (source Météo France Nouvelle Calédonie). In terms of human induced pressures, this lagoon might be qualified as "Pristine or natural area" as only 4800 inhabitants live in the surrounding tribes or villages (source ISEE, 2019) and no mining activities are found in the upstream watersheds.

NOUMEA survey was performed into the south-western lagoon of the main land over 3 months during 2016-2017 cyclonic season. The semi-opened lagoon has a funnel-shaped geomorphology and extends seaward with an averaged cross-shore distance between coastline and barrier reef of 17 km and a mean depth included between 15 and 20 m (Douillet, 1998). This lagoon undergoes several anthropic pressures due to the presence of the suburban area of Grand-Nouméa (180 000 inhabitants). The period of measure has recorded the huge TC "Cook" (category 4) inducing strong winds (130 km h^{-1}) and heavy rainfalls on the south-west region. Regarding to the SOI, it fluctuated between weak La Niña and El Niño phases.

The dedicated ELADE observations was devoted to Poé Lagoon and aimed at understanding hydrodynamics and nutrients pathways that triggered green algae stranding events in 2018 (Brisset et al., 2021). This UNESCO world heritage site is the main recreational area for the inhabitants of Nouméa, offering chill out areas and aquatic activities. In this area, the barrier reef complex lies directly in front of the shore, generating a shallow (< 4 m) lagoon of 25 km^2, encompassing sandy terraces, patch reefs, and fringing reefs. The so-called "lagoon" is separated from the ocean with a continuous barrier reef at approximately 2 km from shoreline, only segmented by a narrow pass called "Shark fault" with an average depth of 25 m (Amrari et al., 2021). The survey was performed along 2 separated legs in 2019, over austral summer and the cool season respectively. The legs are characterized by couple of months in El Niño phase and by the TC "Oma" which has impacted the mainland with strong winds (> 100 km h^{-1}) and huge sea states.

During CADHYAK survey, observations were carried out over 2019-2020 cyclonic season into Koumac lagoon which is located on the north-western coast of the mainland. This area denotes from the others sites due to extensive mining activities

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surrounding the region. The lagoon is characterized by a reef barrier established at a dozen of kilometers from coastline and an interval depth ranging between 0 to 20m. During sensor deployment, two extreme meteorological events have successively hit the Grande Terre, the strong TC "Uesi" generating heavy precipitations (3 days cumulated rainfall, 575.8 mm recorded at Koné station, source Météo France) and gust of winds upper than 100 km h^{-1} in Koumac. A month later, the TD "Gretel" followed the western coast and induced 150 mm of precipitation in 48 hours.

The last field experiment of the PRESENCE data set, called NEMO was conducted in Moindou's lagoon during 2020-2021 summer. Observations covered a period of 8 months separated in two legs. Observational strategy was thought to capture the main forcings and circulation features described above (see Fig. 2). As the Nouméa lagoon, Moindou lagoon has a funnel-shaped geomorphology, it becomes wider southward (2 km on the northern part until 7 km near Moindou passage). The lagoon is mainly shallow (< 6m) but includes some reticulated deeper "holes". The surrounding semi-continuous reef barrier includes two shallow passes on the reef crest. Nemo data set was recorded during a moderate La Niña event and two significant atmospheric events happened: the strong TD "Lucas" on February and the severe TC "Niran" on March causing extreme gust of winds (189 km h^{-1} at Nessadiou Météo France station).

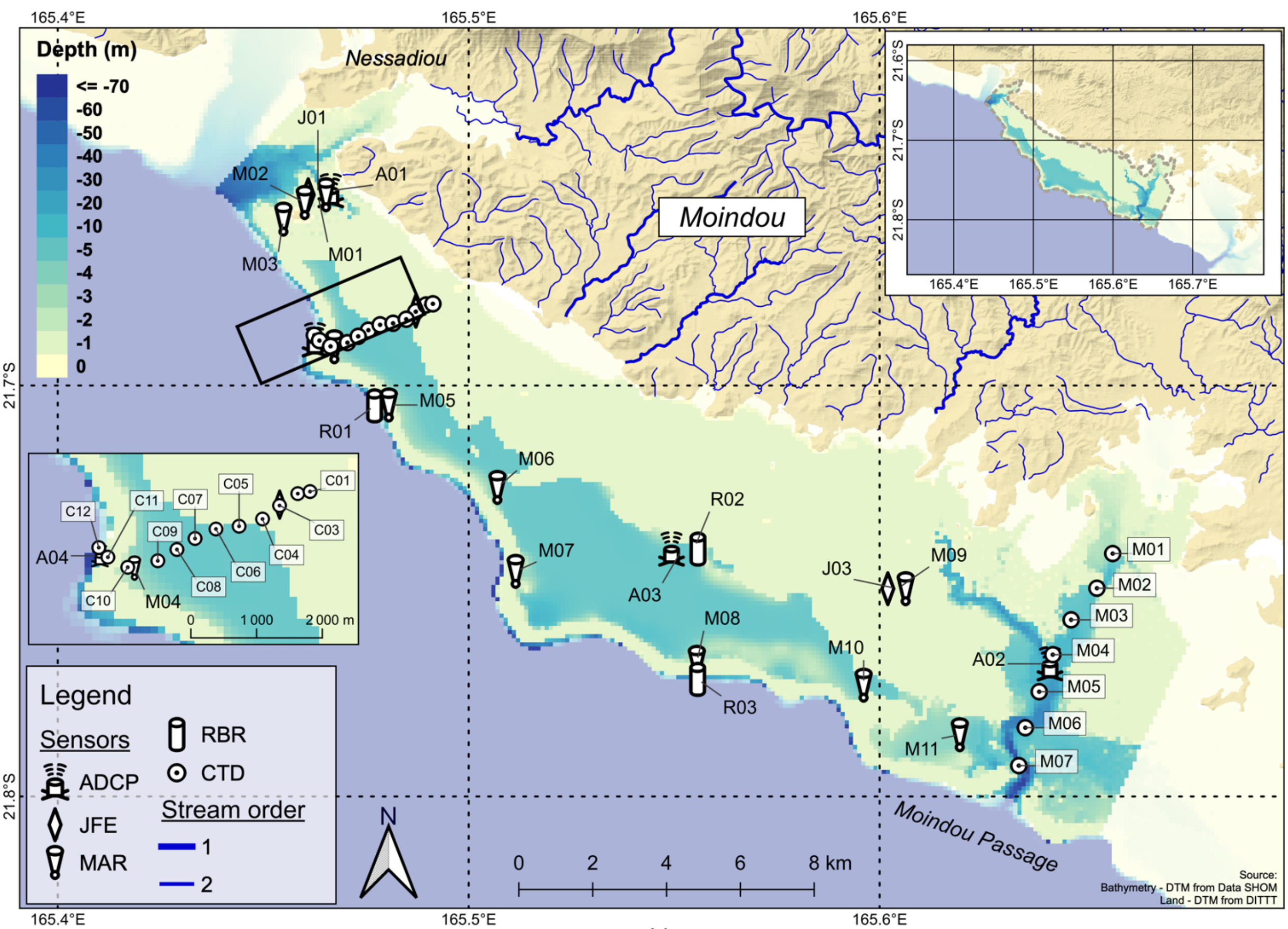

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Figure 2: Observational strategy deployed during NEMO field experiment. ADCP: Acoustic Doppler Current profiler; JFE: INFINITY-CTW; MAR: Marotte HS; RBR: RBR duo-T.D or RBR duet-T.D; CTD: Conductivity – Temperature – Depth.

3.3 Companion data sets

A few lagrangian drifters were also deployed during additional field experiments encompassing the 2019-2020 cyclonic season. They all concern the lagoon around the capital Nouméa. Some releases have been done in the Dumbéa bay during the SEARSE (Imprints of river and estuary waters) project (Lemonnier et al., 2020) which aimed to study the influence of flash flood plumes dispersal on microbial communities. Some other releases (which lasted from 2 to 3 days) where specifically dedicated to better calibrate numerical models during SAR (Search And Rescue) experiments.

4 Instruments, methods, and deployments

A variety of physical oceanographic instruments were deployed during the PRESENCE project. They include moored loggers dedicated either to temperature, salinity, pressure, moored eulerian currents instruments (either punctual or profilers), drifters characterizing surface lagrangian circulation and Conductivity-Temperature-Depth (CTD) profilers capturing the vertical structuration of the water column. For instruments fixed on the seabed, moorings were adapted to the habitats and locations in terms of weight and size to ensure stability even during high energetic episodes. Supports were thus made up of different materials ranging from concrete blocks, brake drums, steel bars and were equipped with anodes to prevent electrolysis damages (see Fig. 3). To prevent biological fouling development on current loggers, Cayen pepper and grease have been spread on ADCP's beams and the logger was rolled up with electrical tape. All of the moored instruments were autonomous sensors including internal battery and memory.

4.1 Compact loggers: Temperature, Salinity and Pressure

Compact loggers were of three types measuring temperature, temperature and salinity or temperature and pressure. Each sensor was deployed into a drilled PVC cylinder to prevent from biofouling and ensure protection. For temperature, high-accuracy and fast-sampling recorders SEA-BIRD SBE56 (*https://www.seabird.com/sbe-56-temperature-sensor/product?id=54627897760*) were used. They were especially deployed during SPHYNX campaign, moored between 10 and 26 meters depending on station with raw sampling frequency of 30s.
INFINITY-CTW (from JFE Advantech Co., LTD) (*https://www.jfe-advantech.co.jp/eng/products/ocean-infinity.html*) were used to capture dynamics of temperature and salinity (Fig. 3.E). These instruments are designed for long-term observations as they include a biowiper which cleans periodically the conductivity cell and prevents drifts in measurements. They were typically deployed using bursts of 10 samples at 1Hz every 10 or 15 min. As one of the main objectives of these sensors was to capture plume dynamics, they were thus all moored in shallow water ranging from 2 to 5m.

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Finally, two models of RBR Ltd ® instruments (namely RBR Duo - T.D and RBR Duet - T.D) (*https://rbr-global.com/*) have been moored to collect temperature and pressure time series (Fig. 3.D). These loggers were generally set-up to sample at 1Hz intervals to provide high-frequency pressure data and offer the possibility to derive sea-state parameters. For sensors dedicated to incident waves on external slopes, the typical mooring depth was about 12 m. Few of them (those inside the lagoons) were nevertheless configured at lower frequency (10s) to allow long deployments and thus capture mainly tidal and surge signals.

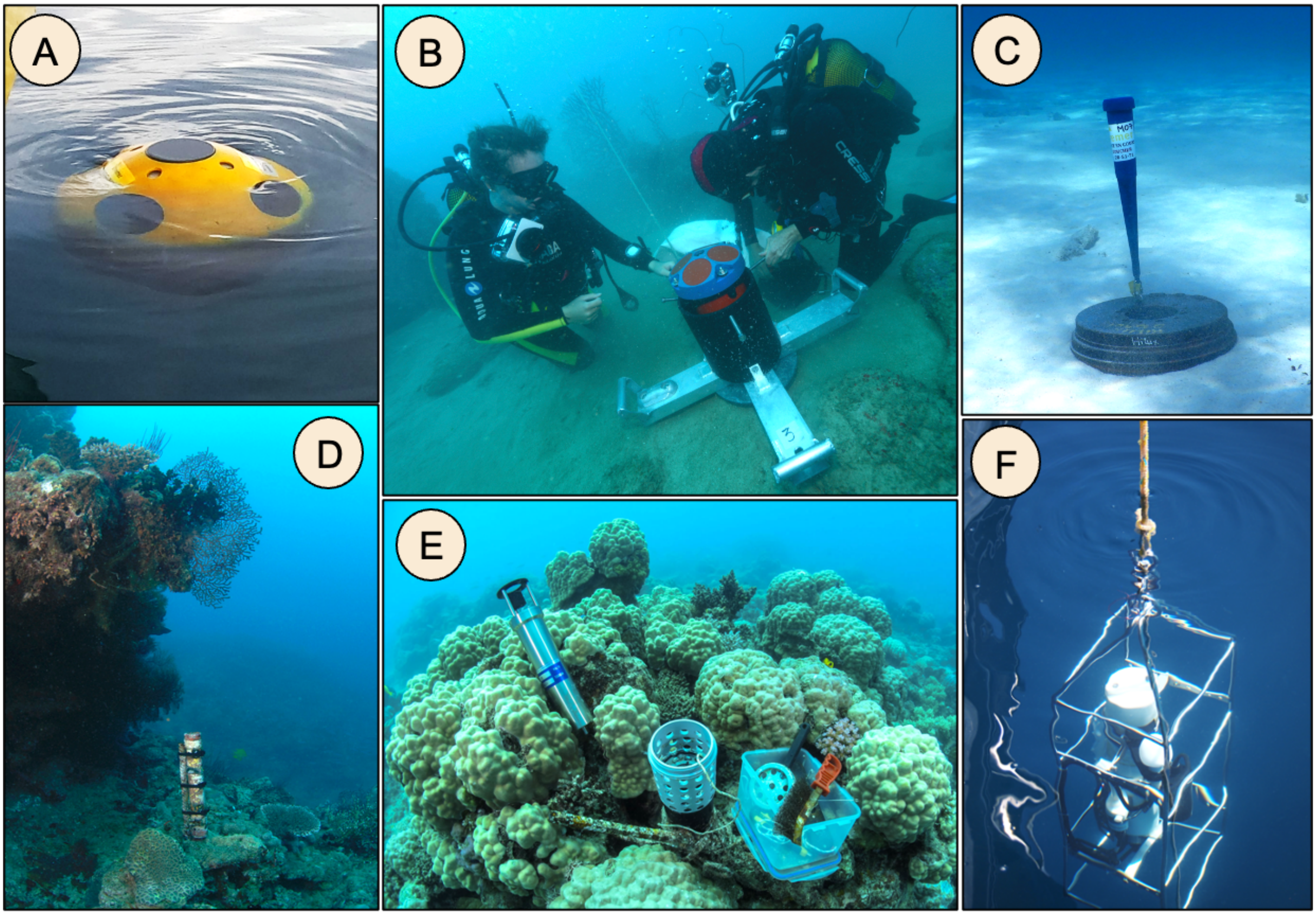

Figure 3: Photographs of deployed instruments for PRESENCE project. (A) Reef drifter (B) Acoustic Doppler Currents Profilers (C) Current meter Marotte HS (D) RBR duet T.D (E) Maintenance of a JFE Advantech logger (F) CTD SBE 19plus profiler. Credit photo: IFREMER LEAD-NC; US IMAGO.

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4.2 Eulerian and lagrangian current measurements

- Near-bottom currents observations: Marotte HS

Marotte HS are coastal drag-tilt current meters developed by the Marine Geophysics Laboratory (MGL) of James Cook University (Australia) (*https://www.marinegeophysics.com.au/current-meter/*) recording velocities (u,v) and temperature parameters (Fig. 3.C). The tilt sensor uses an accelerometer and a magnetometer to deduce current intensity and direction without knowledge about the orientation of the device. They internally record at 0.5 Hz and finally averaged to provide time series of near-bottom currents at 1 second frequency. These current meters were used in shallow water (from 2 to 5 m) to characterize fluxes generated by incident swells over the barrier reef or circulation in shallow areas inside lagoons.

- Acoustic Doppler Currents Profilers (ADCP)

Teledyne RD Instruments (TRD-I) ADCPs were deployed on several campaigns and were all moored on the seabed to collect time series of velocity profiles over the water column (Fig. 3.B), as well as pressure and bottom temperature variations. During Leg5 of SPHYNX campaign, four Workhorse Sentinel 300 KHz (former model of autonomous ADCPs from RDI) (*http://www.teledynemarine.com/workhorse-sentinel-adcp?ProductLineID=12*) were installed in the passes and on the external slope of Hienghène lagoon ranging from 29m to 32m. Typical sampling rates were set to burst every 10 min, with a cell size of 0.3m and 45 pings per ensemble (Fig. 3.B).
Two ADCP Sentinel V20 (1000 KHz) and V50 (500 KHz) (http://www.teledynemarine.com/sentinel-v-adcp?ProductLineID=12) were deployed during ELADE, CADHYAK and NEMO surveys, targeting mainly areas of high expected currents (e.g. passes). They were deployed between 13 and 30m depending on sites and aims.
For Sentinel V50 instrument, sampling rates were set to burst every 20 minutes with cells size equal to 0.5m and 180 pings per ensemble. For V20 instrument, the setup was 10 minutes burst with 1m cells size and 70 pings per ensemble.

- Reef drifters: lagrangian surface current observations

Reef drifter constructed by PacificGyre® company (*https://www.pacificgyre.com/reef-drifter.aspx*) offered a Lagrangian view of the near-surface circulation (Fig. 3.A). These drogueless shallow water devices are tough holed spheres floating at the surface that send their GPS positions and the sea surface temperature every 10 minutes. Deployments were done during each campaign and, depending on the trajectories and the distance from coast, buoys were retrieved between 12 and 72 hours.

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4.3 Hydrological patterns: CTD profilers

Two versions of Sea-Bird SeaCAT profilers (SBE 19plus and SBE 19plus V2) (https://www.seabird.com/sbe-19plus-v2-seacat-profiler-ctd/product?id=60761421596) were used to describe the vertical and cross-shore patterns in temperature and salinity. Two auxiliary sensors also equipped our CTD profilers: the WET Labs ECO-FLNTU acquiring Fluorescence and Turbidity and the Biospherical/Licor for PAR acquisition. The SBE19plus (used for SPHYNX and NOUMEA campaigns) (Fig. 3.F) and the SBE19 plus V2 exploited during CADHYAK and NEMO surveys are both acquired data at 4Hz. All water column profiles were done manually from coastal boats on the water column (surface to bottom). For avoiding effects due to the drifting of the boat, only descent data were kept for final processing.

5 Processing and quality control

5.1 Global strategy of processing

Data processing and quality control were accomplished in a standardized way among each campaign so that the whole data set is congruent. Maintenance and recalibration of every instrument were realized by the manufacturers at the recommended frequency to ensure reliability and quality of values observed. For the whole data set, a specific nomenclature of files (either raw or processed) was implemented so that filenames contain the most important information about moorings: *Campaign-name_Station_Instrument-Model_Serial-number_Depth_Leg-Number.file-type.* Then, the global processing and quality control chain consisted systematically in applying the following steps:

1. Raw files were downloaded from instruments using dedicated manufacturer's softwares, renamed and saved on a secure network drive.
2. All data were carefully viewed using owner's softwares to check for bad data (e.g. out of water, outlier spikes) and find the exact date and time of first and last good observations.
3. Data were then exported in the most convenient formats (depending on the software) to be read with Python 3. These formats were mostly Ascii or Matlab files.
4. Python 3 was used to process data when required and stored them into NetCDF (Network Common Data Form) files. Metadata thus contain information on: beginning and end dates, positions, depth, instrument model and serial number, project, publisher, contacts, processing done…etc. During this step, data were also plotted and examined to ensure the quality of obtained time-series.
5. Converted NetCDF data were finally plotted using Ferret to perform a last visual check. Metadata were also displayed and checked using command line NetCDF tools.

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5.2 Specific processing steps

For each instrument types specific processing steps were conducted. For SBE56, raw data were averaged to provide final NetCDF time-series at 1 min. JFE data were averaged over the 10 samples of each burst, so that the final period is 10 or 15 min. For RBR data (pressure), no atmospherical correction was applied and signals were filtered (using linear theory reconstruction of wave parameters) giving final output files of two kinds. One file containing temperature & level dynamics at 1 min resolution and the second at 1 hour resolution offering computed wave parameters. ADCP data were filtered to avoid contamined surface cells within the NetCDF data. Final temporal resolution is thus the nominal resolution of the bursts. Marotte inclinometers data were averaged at 1 min sampling and orientation conventions was changed to be congruent with oceanographic currents convention. No specific treatment was applied to Pacific Gyre Reef Drifters so the nominal frequency (10 min) is given in the final data. Drifter's speed was also derived from the positions and included in the final data. For CTD casts, classic processing steps using SeatermV2 software were applied, in order: data conversion in cnv, low-pass filtering, align-CTD, derive and a bin averaging at 0.5.

The final data collection consists of 5 individual data sets, one for each sampled lagoon (see Section 7).

6 Overview of observations

Figure 4 highlights scientific objectives or processes evoked in section 3.1. Figure 4.A presents thermal variability over external reefs slopes for three campaigns (SPHYNX, CADHYAK, NEMO). Although this plot shows different years, it enables to stress out the inter-site variability in terms of processes from the oceanic side. During SPHYNX summer season, for example, cyclic pulses of fresh water stroke station C02 (SBE56 – depth 26 m) inducing thermal infra-daily variability. A thorough analysis (not shown here) showed that drops in temperature where around the M2 tidal waves frequency and that it was observable only in unusual wind conditions (either very few winds or North-West winds). Those facts lead us to consider seriously this area as an arrival point for internal waves, which might not appear in data when trade winds are present which induce downwelling favourable conditions. During NEMO survey, from 19th to 26th of January 2021, a significant decrease in temperature happened in R03 (RBR Duet – depth 9.7 m), reaching almost 5 degrees which was probably the signature of an intense upwelling event on the external slope of Moindou lagoon. Finally, the station R03 (RBR Duet – depth 11.7m) displays a temperature decrease during the passage of the Uesi cyclone that stroke during CADHYAK period. Ola and Lucas events did not seem to have significantly altered the oceanic temperature dynamics during SPHYNX and NEMO respectively.

Figure 4.B displays the salinity structuration of the Hienghène lagoon on cross-shore section T in December 2014, June 2015 and March 2016. T07 to T13 stations are more in the vicinity of the large passages on the North-West side of Hienghène lagoon and thus more influenced by oceanic waters. The two first plots reveal the difference in haline structuration between seasons with a coast-large gradient of approx. 0.2 PSU. At the end of the dry season (December 2014), coastal stations are saltier than

the "oceanic" ones, while it is exactly the opposite during after the wet season (June 2015). The March 2016 radial offers a view of the spatial and vertical extension of the river plumes during this campaign.

Fig. 4.C presents the trajectories of the buoys realized during SEARSE and SAR experiments in Nouméa lagoon. These drifter trajectories highlight the strong dependency of surface circulation to wind forcings in New Caledonian lagoons (e.g., February 2020 versus April 2020 SEARSE releases, February 2020 SEARSE release versus November 2019 green trajectory of SAR release). The cyan trajectory (SAR experiment) shows an interesting feature of the South-Western lagoon of New Caledonia which consists in an anti-cyclonic gyre in this portion of the lagoon (Ouillon et al., 2010).

Finally, Fig 4. D is centered on the Oma cyclone that hit New Caledonia early 2019. On the external slope of Poé lagoon (Fig 4.D.1), this event generated huge incident waves reaching a significant wave height of approx. 6m at the climax of the perturbation (RBR Duet – O2 station – depth 10.8m). These strong sea-states also induced an intense surge of 0.6 m inside the lagoon (RBR Duo – L13 station – depth 2.2m). Inclinometers located at the back of the reef crest (Marotte – Station L06 – depth 2m) recorded fluxes twice more intense as the normal conditions, reaching 0.5 $m.s^{-1}$. Finally, ADCP Sentinel V50 (Station P01 – depth 30m) also showed a significant increase over the whole water column during this event and the Shark fault circulation was not anymore linked to tidal cycle but only outgoing and flushing waters toward oceanic side (not show here).

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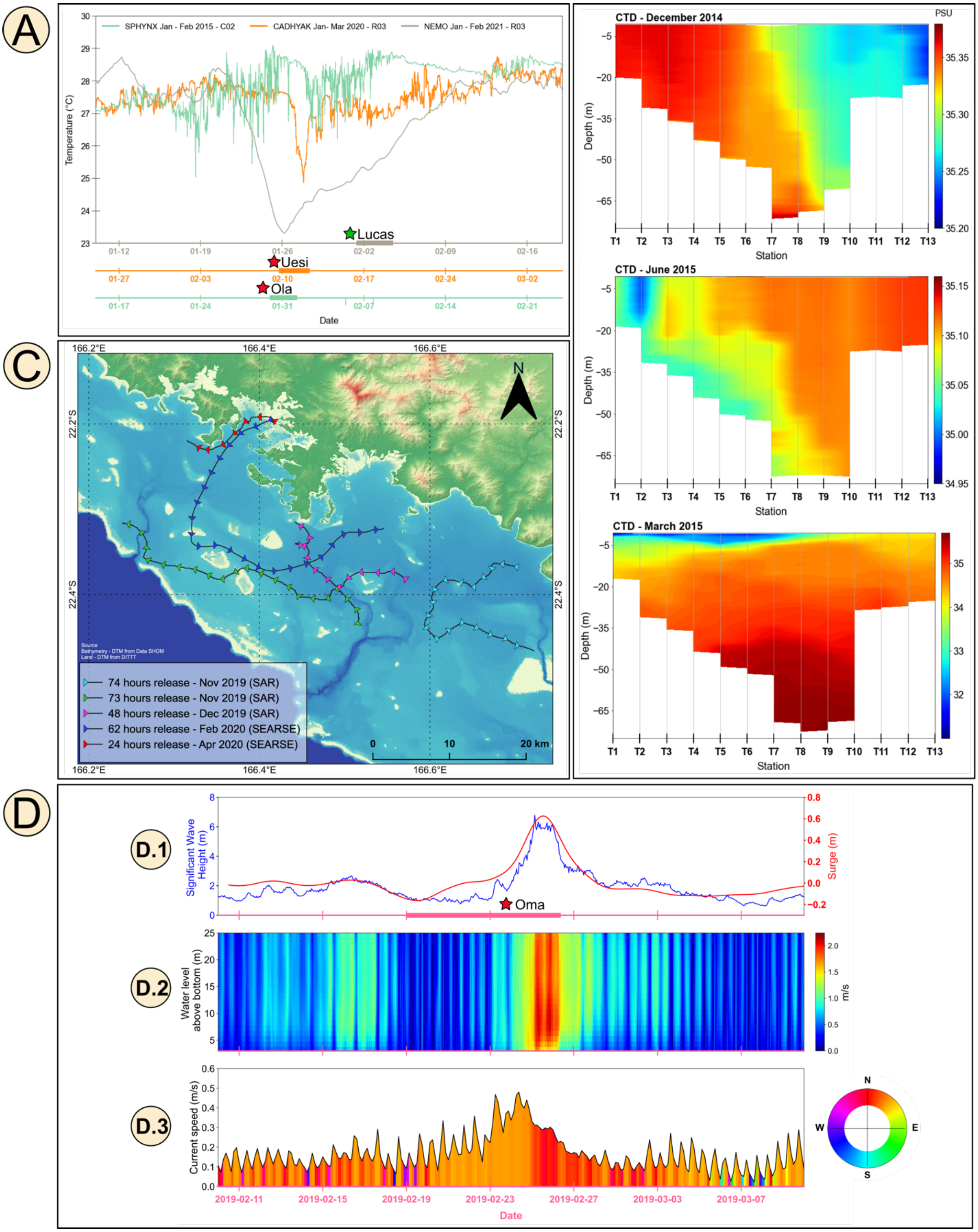

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Figure 4: Overview of some physical and hydrodynamical processes occurred over PRESENCE campaigns: (A) Presentation of temporal variation of temperature during SPHYNX, CADHYAK and NEMO surveys. (B) Cross-shore expansion and vertical stratification of salinity in Hienghène lagoon (SPHYNX survey). (C) Lagrangian circulation recorded with Reef Drifters in Nouméa area (SEARSE and SAR experiments). (D) Cross-reef and passage circulation in Poé lagoon (ELADE): (D.1) Significant Wave Height (Hsig) at O2 station and surge at L13 station; (D.2) Current speed over water column in the shark fault (P01 station); (D.3) Current speed measured inside lagoon at L06 station.

7 Data availability

All data sets presented herein are freely available on SEANOE in dedicated repositories in NetCDF format. DOI's for individual data sets are provided in Table 1. Survey reports are available in French on Archimer and present a global overview of the sampling region, the meteorological and oceanic conditions as well as raw representation of the observations acquired. Some of these are already being used for investigation of the dynamics conjointly with hydrodynamics models, and publications are in preparation.

Table 1: List of DOI and Reference associated for data sets and field reports.

Campaign	Data set		Archimer	
	DOI	Reference	DOI	Reference
SPHYNX	https://doi.org/10.17882/54005	Le Gendre et al., (2018)	https://doi.org/10.13155/56378	Le Gendre et al., (2018)
NOUMÉA	https://doi.org/10.17882/53974	Desclaux et al., (2017)	https://doi.org/10.13155/58315	Desclaux et al., (2018)
ELADE	https://doi.org/10.17882/76334	Le Gendre et al., (2020)	/	/
CADHYAK	https://doi.org/10.17882/79616	Bruyère et al., (2021)	http://dx.doi.org/10.13155/80615	Bruyère et al., (2021)
NEMO	https://doi.org/10.17882/81063	Bruyère et al., (2021)	https://doi.org/10.13155/87118	Bruyère et al., (2022)
SEARSE	https://doi.org/10.12770/fa99ffe5-83e5-483c-8065-90a79981140a	Soulard, (2019)	/	/
	https://doi.org/10.12770/dad19639-c901-4edb-85cd-1fd546aa4cdb	Soulard, (2020)		

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SAR	http://dx.doi.org/10.12770/96e4f2ef-e809-4005-b5df-529adc4e3306	Soulard et al., (2021)	/	/

9 Conclusion

The PRESENCE data set presented in this paper offers a remarkable and unique opportunity to investigate lagoon hydrodynamics both by being freely accessible and composed of observations on five different lagoons around New Caledonia Grande Terre during cyclonic seasons. Eight major atmospheric events have enameled our observations period (2014-2021) and sampling strategies deployed enabled to capture their signatures in various lagoons as well as on their external reef slopes (e.g incident swells). It represents a considerable contribution for the knowledge on lagoon dynamics around New Caledonia and will allow investigating easier and further on assessment of numerical model experiments or satellite derived parameters.

The spatial extent of all sampling strategies offers an interesting synoptic view of those distinct lagoons functioning and dynamics, in a way complements the existing Reeftemps network. Furthermore, even though the five lagoons were not sampled simultaneously, this data set is an important milestone about knowledge on processes at stake during cyclonic events.

Interesting features were also highlighted thanks to this long-term observational strategy, whether in terms of thermal dynamics (e.g. internal waves, upwelling) as well as surface circulation (e.g SW lagoon gyre, wind dependency drift), land-lagoon continuum variability through plumes dynamics or hydrologic structuration, quantification of ocean-lagoon exchanges over reef crests or through passes. Finally, the PRESENCE data set will provide a unique opportunity to go deeper into the apprehension of coastal vulnerability or impacts of Marine Heat Waves on coastal New Caledonian lagoons.

Author contributions:

RLG, TL, HLM and BS set up the PRESENCE project and raised funds. RLG and BS designed and conducted the experiments as principal investigators. All co-authors were implied in some of the field experiments. OB and RLG organized, processed, checked and archived the data sets. OB and RLG prepared the paper and designed the figures, with contributions from all co-authors.

Competing interest:

The authors declare that there are no competing interests associated with this study.

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Appendices

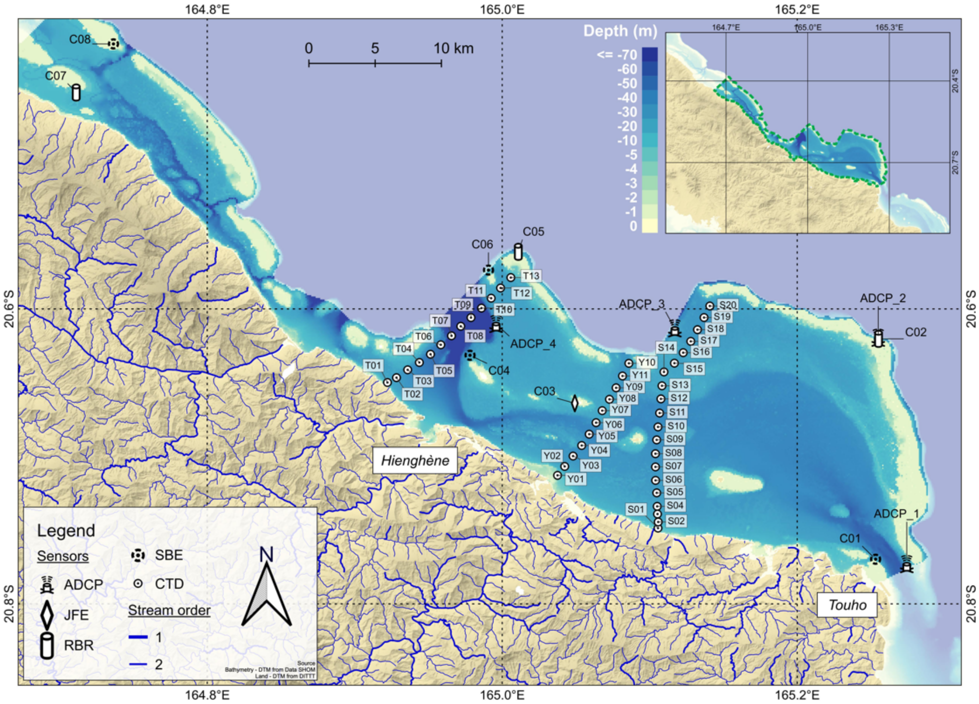

Fig. A1: Observational strategy deployed during SPHYNX field experiment. ADCP: Acoustic Doppler Current profiler; JFE: INFINITY-CTW; RBR: RBR duo-T.D or RBR duet-T.D; CTD: Conductivity – Temperature – Depth ; SBE: SBE 56.

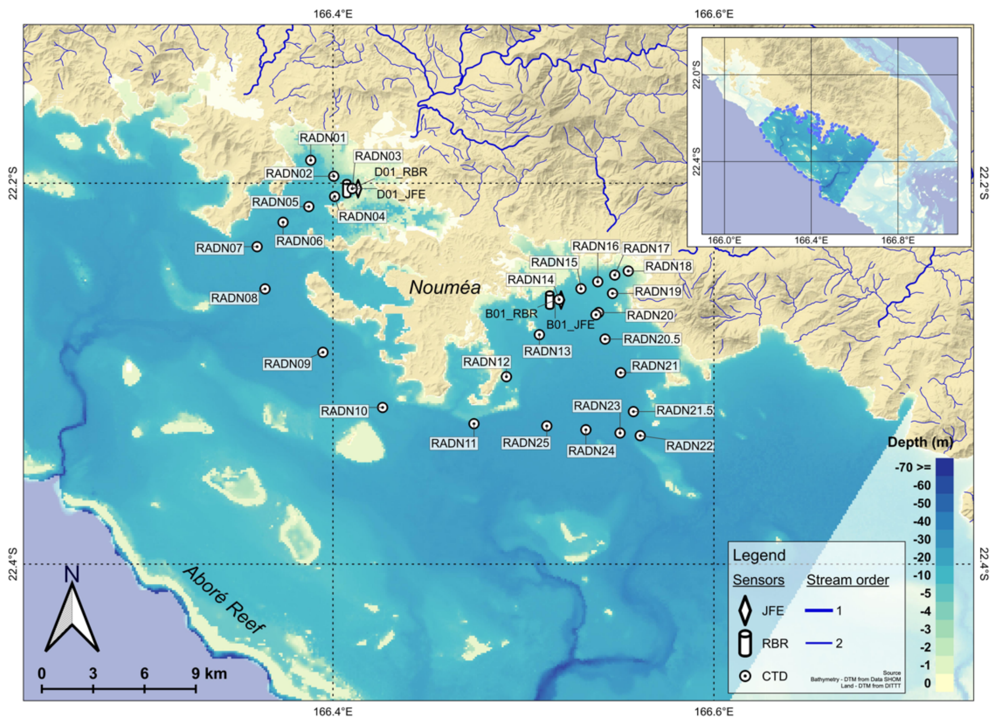

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Fig. B1: Observational strategy deployed during NOUMEA field experiment. JFE: INFINITY-CTW; RBR: RBR duo-T.D or RBR duet-T.D; CTD: Conductivity – Temperature – Depth.

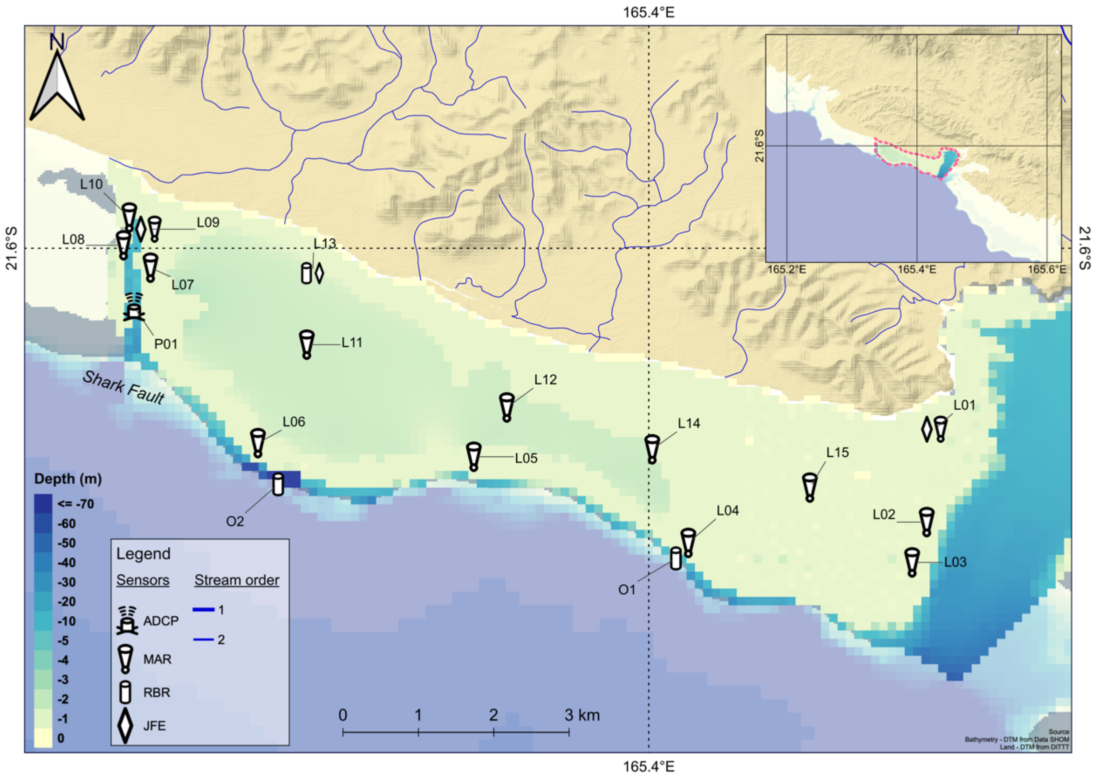

Fig. C1: Observational strategy deployed during ELADE field experiment. ADCP: Acoustic Doppler Current profiler; JFE: INFINITY-CTW; MAR: Marotte HS; RBR: RBR duo-T.D or RBR duet-T.D.

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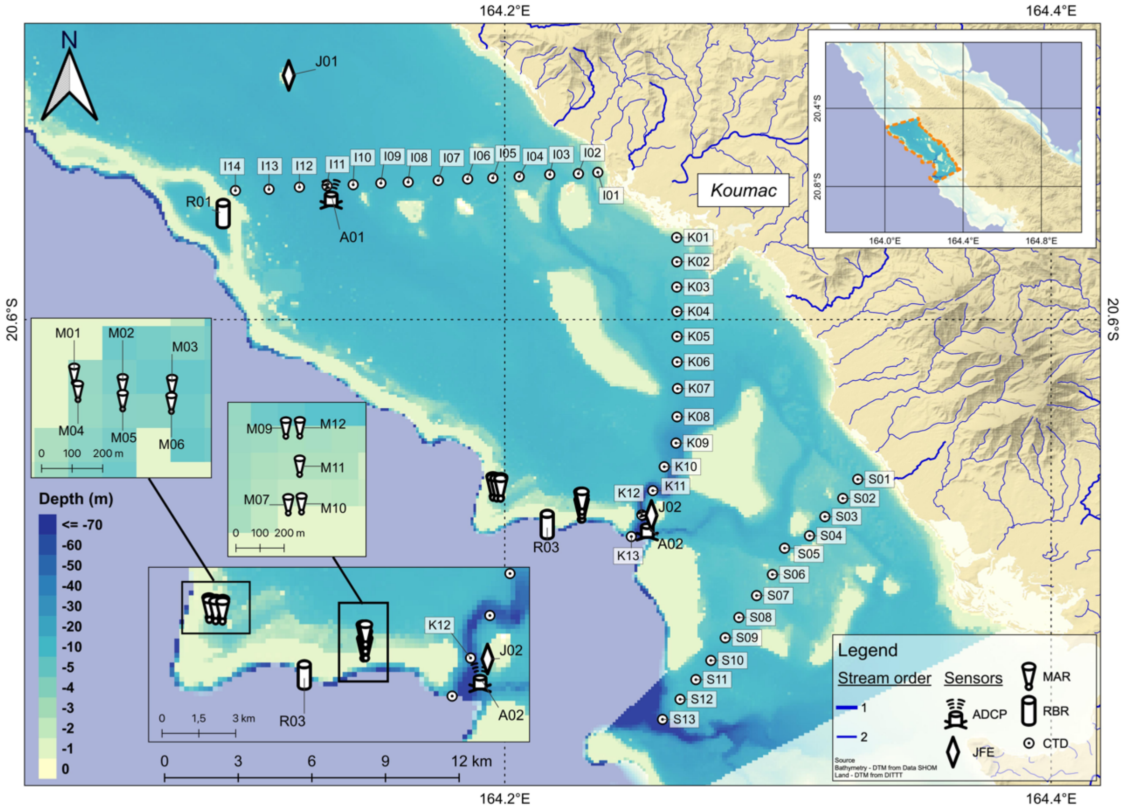

Fig. D1: Observational strategy deployed during CADHYAK field experiment. ADCP: Acoustic Doppler Current profiler; JFE: INFINITY-CTW; MAR: Marotte HS; RBR: RBR duo-T.D or RBR duet-T.D; CTD: Conductivity – Temperature – Depth.

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