

A High-Resolution Current Velocity Database from Observations in the Yucatan Channel

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Title

A High-Resolution Current Velocity Database from Observations in the Yucatan Channel

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Abstract

We present a high-resolution ocean current velocity database derived from moored observations in the Yucatan Channel, spanning September 2021 to August 2023. The dataset consists of daily velocity measurements from 12 moorings equipped with Acoustic Doppler Current Profilers and single-point current meters, providing one of the few publicly available, high-resolution moored velocity datasets for this region. A key feature of the product is the careful treatment of mooring motion using shape-preserving interpolation to align observations to fixed depths while maintaining minimal processing, making the dataset well suited for data assimilation applications. The dataset includes quality-controlled horizontal velocity components together with complementary uncertainty diagnostics that characterize instrumental noise and sensitivity to the vertical interpolation. Compared with previous efforts, these observations provide improved vertical resolution in the deep channel and a more refined characterization of near-bottom flows to support numerical model validation, data assimilation, and process studies of the Yucatan Current system.

Background & Summary

The Yucatan Channel is a key oceanographic gateway connecting the Caribbean Sea to the Gulf of Mexico. The flow through this channel is part of the western boundary current system of the North Atlantic and plays an important role in the Atlantic Meridional Overturning Circulation and in regional climate variability [1, 2]. Circulation in the channel is dominated by the energetic, surface-intensified Yucatan Current [3], which exhibits pronounced spatiotemporal variability, posing significant challenges for both observational and predictive efforts. Sustained, high-resolution *in situ* velocity measurements are therefore essential for advancing understanding of key processes, including current variability, deep water-mass exchanges, and eddy-mean flow interactions [4, 5, 6, 7, 8].

To address this need, the Canek Project was initiated in 1999 to monitor the volume transport and vertical structure of the flow through the Yucatan Channel using a mooring array instrumented with acoustic Doppler current profilers (**ADCP**) and single-point current meters [4] as well as a relatively small number of MicroCATs and other temperature sensors. Only velocity data are considered in this report. Over the past two decades, the Canek array has provided fundamental insights into the structure and variability of the Yucatan Current [4, 7, 8, 9, 10, 11], supporting ocean modelling and prediction efforts and advancing understanding of Gulf of Mexico circulation dynamics (see, for example, [12, 13, 14, 15]).

A distinctive feature of the Canek Project is its long-standing bilateral collaboration between Mexican and Cuban scientific institutions. Given the geographical and jurisdictional complexity of the Yucatan Channel, this partnership has been essential for sustaining observations throughout the channel and has enabled unprecedented long-term measurements in the region, enhancing our understanding of transport processes and current variability in the western Atlantic.

Here, we present a new, minimally processed, high-resolution velocity dataset from the Canek Project spanning September 2021–August 2023. Portions of these observations were previously incorporated into the objectively mapped Canek velocity fields of [16]. The present release is distinct from that mapped product because it provides individual mooring-resolved velocity profiles at fixed observational depths, with minimal spatial processing and separate diagnostics of instrumental and interpolation-related uncertainty. Shape-preserving interpolation is used only to correct vertical displacements induced by current drag on the mooring structures and to align the observations to fixed depth levels, making the product particularly well suited for quantitative analysis and data-assimilation applications.

By making this dataset publicly available, we aim to foster scientific collaboration, support data assimilation in numerical models, and provide a valuable resource for advancing our understanding of the ocean circulation at both regional and basin scales. This release represents a significant step toward expanding open-access oceanographic data in the region and underscores the central role of international cooperation in advancing ocean science. The dataset targets a broad user

base spanning physical oceanography and interdisciplinary studies, and is accompanied by uncertainty and correlation diagnostics that facilitate its use in data assimilation and other quantitative modeling applications.

Methods

Deployment, Design, and Instrumentation of the Mooring Array

The Canek mooring array (hereafter “Canek array”) consists of taut-cable moorings equipped with Acoustic Doppler Current Profilers (ADCPs) and single-point current meters. The array is deployed across a zonal transect of the Yucatan Channel, spanning the entrance to the Gulf of Mexico (**Fig. 1A**). The array includes a relatively small number of hydrographic instruments (MicroCATs and other temperature sensors) whose data are still being processed and are not part of the database reported here.

Campaign description

The Canek array was first deployed in 1999 for nearly two years [4]. Following deployments in the Mexican Caribbean and Campeche Bank during 2001–2009, observations in the Yucatan Channel resumed in 2010 and have continued since then. The data presented here are from the observational campaign that spans September 2021 to August 2023, beginning with a recovery and redeployment mission.

Moorings operations were conducted on board the multipurpose oceanographic research vessel *Justo Sierra* (IMO 8101367), owned and operated by the Universidad Nacional Autónoma de México.

During this mission, instruments from the previous deployment (September 2018–2021) were recovered to retrieve data, replace batteries, and perform routine maintenance, including compass calibration of the ADCPs. All calibrations were conducted onshore at the port of Puerto Morelos, Mexico (20.8417° N, 86.8780° W), following manufacturer guidelines. To avoid magnetic interference, instruments were positioned away from metallic structures and rotated through 360° at least twice. Calibration results were evaluated using the Teledyne-RDI WinADCP utility, and all instruments met the acceptance criteria (typical orientation errors <4°).

Description of the moorings and the instruments

The moorings are labeled YUC#, where # denotes the mooring number (from 1 to 10), starting from the western side of the section. Additional interior moorings, labeled YUCI#, were included to enhance vertical resolution in the deeper parts of the section relative to previous campaigns (see, for example, [16]).

100 A total of 59 instruments were deployed across the 14 moorings constituting the Canek array;
101 however, two very shallow moorings, YUC1 and YUC2 at 20 and 60 m depth, respectively, could not
102 be recovered (**Fig. 1B**). Each mooring was designed to obtain velocity measurements throughout
103 the water column with high vertical resolution.

104 The array contains seven types of velocity sensors, strategically distributed to optimize vertical
105 coverage across the section. Tall moorings (YUC6, YUC7, YUC8, YUC18, and YUC9) were equipped
106 with buoys carrying upward-looking RDI WorkHorse 300 kHz ADCPs (8 m bins, ~ 100 m effective
107 range) and downward-looking RDI LongRanger 75 kHz ADCPs (16 m bins, ~ 500 m effective range)
108 positioned at ~ 200 m depth. Together, these instruments sampled the upper ~ 700 m of the wa-
109 ter column. Below this depth, Aanderaa Recording Current Meters (RCMs) and SeaGuard current
110 meters were deployed to monitor the deep flow.

111 Interior moorings (YUC15, YUC16, YUC18, and YUC19) included an upward-looking LongRanger ADCP
112 sampling the upper ~ 600 m and a second LongRanger ADCP deployed below 700 m, supple-
113 mented by deeper current meters. Near the bottom, upward-looking RDI WorkHorse 600 kHz
114 ADCPs (8 m bins, ~ 60 m effective range) were installed to capture near-bottom currents.

115 For the first time in the Canek array, Nortek Signature 55 kHz ADCPs were deployed on three tall
116 moorings (YUC6, YUC7, and YUC9) at a nominal depth of ~ 800 m. These instruments were config-
117 ured with 20 m bins and a nominal profiling range of up to ~ 1000 m. Acoustic beam attenuation
118 in the deepest bins reduced the effective reliable profiling range to approximately 600 m, yielding
119 about 30 reliable bins.

120 To ensure redundancy, single-point current meters were co-located within the nominal sampling
121 ranges of the ADCPs. This configuration resulted in acoustic interference in overlapping bins,
122 which were identified and removed during processing (see **Supplementary Information, Text S1**
123 and **Fig. S1**). A complete summary of the instruments used is provided in **Table 1**.

Table 1: Summary of velocity instruments deployed in the Canek array during the 2021–2023 campaign.

Instrument	Nominal / Effective Range (m)	Bin Size (m)	Typical Deployment Depth	Primary Purpose
Nortek Signature 55 kHz	~1000 / ~600	20	~800 m	High-resolution deep flow profiling
RDI LongRanger 75 kHz	500	16	Mid-water	Primary mid-water profiling
RDI WorkHorse 300 kHz	100	8	~200 m	Upper-layer currents
RDI WorkHorse 600 kHz	60	8	Bottom	Near-bottom currents
Aanderaa RCM11	Single-point	–	Deepwater	Deep flow monitoring
Aanderaa SeaGuard	Single-point	–	Deepwater	Deep flow monitoring
Nortek Aquadopp	Single-point	–	Mid and deepwater	Deep flow monitoring

124 *Time-series Length and Data Recovery*

125 Most instruments operated continuously, sampling every two hours for ~650 days and providing
 126 reliable velocity records. Only four instruments collected data for a shorter period, and just one
 127 for less than 200 days. The latter case corresponds to a downward-looking LR75 ADCP deployed
 128 on mooring YUC10 (not shown in **Fig. 1B** and excluded from subsequent analyses), which ceased
 129 operating after 15 days due to abrupt battery depletion. Relative to a target deployment period
 130 of approximately 650 days, the campaign achieved an overall data recovery rate of about 91%,
 131 accounting for both the number of instruments and their intended deployment duration.

132 Data Processing

133 *Velocity and Pressure Data Quality Control and Pre-processing*

134 After instrument recovery, standard quality control procedures were applied to the velocity and
135 pressure records. Invalid measurements from the uppermost $\sim 6\%$ of ADCP bins were discarded to
136 eliminate side-lobe contamination [17] and signal attenuation [18], using the manufacturer's pro-
137 cessing software. Additional bins were removed when acoustic interference occurred between
138 co-located instruments, particularly where single-point current meters overlapped with the sam-
139 pling range of long-range ADCPs. Following these corrections, a Gaussian filter with a 48-hour
140 standard deviation was applied to suppress tidal and supra-inertial variability, and the resulting
141 time series were subsampled to daily values.

142 Current-induced drag can cause substantial vertical displacements of moored instruments, mak-
143 ing high-quality pressure records essential for accurately resolving their instantaneous depth. Of
144 the 57 instruments successfully recovered, 45 were equipped with integrated piezoresistive pres-
145 sure sensors. Because pressure specifications differ among instrument models and measurement
146 ranges, we do not assign a single manufacturer-based uncertainty in dbar across the array; instead,
147 the magnitude of non-mooring pressure variability is evaluated empirically below.

148 To ensure data quality, all pressure time series were visually inspected, and two faulty records
149 were excluded due to sensor malfunction. In particular, the Aanderaa RCM current meters de-
150 ployed at YUC9 (1652 m) and YUC19 (1400 m) produced unrealistic pressure values, likely resulting
151 from biological fouling or electronic failure. These instruments are indicated by white circles in
152 **Fig. 2**.

153 After removing unreliable pressure records, we identified time series exhibiting long-term pres-
154 sure drift through visual inspection. This artifact was corrected by fitting and subtracting exponential-
155 linear functions proposed by [19] given by

$$a_1(1 - e^{a_2 t}) + a_3 t + a_4.$$

156

157 This analytical function represents the pressure drift itself. The de-drifting procedure introduces
158 an additional uncertainty of approximately 0.02 dbar, consistent with corrections applied to pres-
159 sure records spanning more than one year [19, 20, 21].

160 Only 9 of the 45 pressure time series exhibited long-term drift (marked with black circles in **Fig. 2**).
161 In the case of the YUC19 mooring, piecewise de-drifting was required (**Fig. S2c**), as the record
162 showed an abrupt increase in mean pressure of approximately 0.5 dbar around 12 July 2022. This
163 step change was consistently observed across all pressure sensors on YUC19, suggesting a slight
164 lateral displacement of the entire mooring, which is located in a region of strong topographic

165 gradients (**Fig. S2** in the **Supplementary Information**).

166 Finally, 10 of the 57 recovered instruments lacked integrated pressure sensors (marked by black
167 crosses in **Fig. 2**), while two additional instruments exhibited unrealistic pressure records (white
168 circles). For these 12 instruments, instantaneous vertical positions were estimated using pressure
169 measurements from surrounding instruments within the same mooring. Because instruments
170 without pressure sensors were typically deployed 100–200 m away from those equipped with
171 pressure recorders, this approach provides robust and accurate estimates of their vertical position,
172 as described below.

173 The procedure used to estimate pressure time series for instruments lacking integrated sensors
174 is summarized below (see also the schematic in **Fig. 3A**):

- 175 • At each time step, all available pressure measurements from a given mooring are collected.
176 For each instrument with a valid pressure sensor, the instantaneous pressure displacement
177 is defined as $\delta p_i(t) = p_i(t) - p_{n,i}$, where $p_i(t)$ is the observed pressure and $p_{n,i}$ is the nomi-
178 nal pressure. The nominal pressure is taken as the minimum pressure of the record, repre-
179 senting the instrument position under weak-current conditions. For instruments without a
180 valid pressure record, $p_{n,i}$ is estimated from the nominal pressures of surrounding pressure-
181 recording instruments and the known design distances between them.
- 182 • A fixed “anchor” boundary condition is imposed by prescribing zero pressure displacement
183 at the deepest instrument, whose variability due to current-induced mooring motion is neg-
184 ligible.
- 185 • The instantaneous pressure-displacement profile is reconstructed as a function of nominal
186 pressure, $\delta p(p_n)$, using a shape-preserving piecewise cubic Hermite interpolation (**PCHIP**)
187 scheme [22].
- 188 • The pressure displacement $\delta p_i(t)$ is then estimated at the nominal pressures of instruments
189 lacking valid pressure sensors.
- 190 • Finally, the instantaneous pressure of each such instrument is reconstructed as

$$p_i(t) = p_{n,i} + \delta p_i(t).$$

191 To illustrate this procedure, **Fig. 3A** shows a snapshot of the pressure-displacement profile on
192 day 300 for mooring YUC7. Instruments equipped with pressure sensors are indicated by black
193 squares, while instruments without pressure measurements are shown as red circles. The solid
194 line represents the interpolated pressure-displacement profile.

195 The accuracy of the pressure estimation was assessed using a leave-one-out cross-validation ap-
196 proach applied to moorings YUC5 through YUC19. In each test, pressure data from a given instru-
197 ment were withheld, while the remaining observations—together with the bottom anchor—were

198 used to estimate its displacement. Performance was quantified using the root-mean-squared er-
199 ror (**RMSE**) between observed and estimated pressures.

200 Representative examples are shown in the central panels of **Fig. 3**. Case 1 (**Fig. 3B**), at 731 dbar,
201 exhibits large vertical excursions, with an RMSE of 0.65 dbar. Case 2 (**Fig. 3C**), at 946 dbar, shows
202 excellent agreement (RMSE = 0.50 dbar), consistent with its location between closely spaced pres-
203 sure sensors. Case 3 (**Fig. 3D**), at 1518 dbar, yields the lowest RMSE (0.28 dbar), reflecting the
204 reduced vertical motion at depth.

205 Across all validation cases, RMSE values range from 0.2 to 13.7 dbar, with a mean of 1.7 dbar
206 (**Fig. 3E**), and are color-coded by distance to the nearest pressure observation. The gray-shaded
207 band marks the nominal-pressure range occupied by instruments lacking pressure sensors in prac-
208 tice (486–1892 dbar); within this range, the median distance to the nearest pressure observation
209 is $\Delta p_{\text{med}} = 142$ dbar. RMSE values within this practical range remain below 2 dbar. Although
210 two instruments are located more than 300 dbar from the nearest pressure sensor, these corre-
211 spond to moorings YUC16 and YUC19, where comparatively weak vertical motion suggests that
212 large estimation errors are unlikely.

213 The pressure coordinates were then converted to oceanic depth coordinates (z) in meters. This
214 conversion is not exact, as the observed total pressure variations may include three components:

- 215 • Pressure changes associated with vertical displacement of the instruments, which, as men-
216 tioned above, can range from 1 to more than 100 dbar.
- 217 • Dynamic pressure variations ($\frac{1}{2}\rho U^2$, where ρ is the water density, and U is a typical velocity
218 scale), which, even considering the strongest observed currents (e.g., $U = 2 \text{ m s}^{-1}$ and $\rho \approx$
219 1025 kg m^{-3}), would have a maximum contribution of approximately 0.2 dbar.
- 220 • Variations due to changes in hydrostatic pressure, which, considering sea level variations of
221 0.4–0.6 m observed from satellite altimetry in our study area (not shown), would result in
222 hydrostatic pressure changes of less than 1 dbar.

223 The RMS fluctuations of pressure anomalies measured by the deepest sensors, which experience
224 minimal vertical motion, are approximately 0.1 dbar. We use this value as an empirical indication
225 of background pressure variability at depth. It is small relative to the pressure changes associated
226 with the drag-induced mooring displacements considered here.

227 Given the above, we consider it reasonable to estimate the instruments' vertical position from
228 the reconstructed pressure records. After the pressure reconstruction is complete, instantaneous
229 pressure $p_i(t)$ is converted to oceanic depth $z_i(t)$ in meters using the TEOS-10 functions [23]. We
230 reserve the symbol p for pressure (dbar) and z for geometric depth (m) throughout the remainder
231 of the manuscript.

232 Mooring motion correction: Vertical interpolation of the velocity data

233 *Vertical motion characteristics*

234 As described above, the depth of the instruments fluctuates over time relative to their nominal
235 positions due to drag-induced mooring motion [24]. Because the circulation in the Yucatan Chan-
236 nel is dominated by a surface-intensified western boundary current, instruments deployed closer
237 to the surface experience systematically larger vertical displacements.

238 **Fig. 4A** summarizes mooring motion at each instrument location over the deployment period.
239 Circles denote nominal instrument depths, colors indicate the maximum pressure displacement
240 (dbar), and circle size represents the cumulative duration for which the corresponding TEOS-10-
241 converted vertical displacement exceeds 50 m.

242 In the western portion of the section, where time-mean Yucatan Current velocities are strongest
243 (**Fig. 4B**), the largest vertical excursions are observed. Moorings YUC6 and YUC7 experience max-
244 imum displacements of up to ~ 120 m, with episodes exceeding 50 m persisting for more than
245 120 days. At YUC5, however, where the upper buoy is located at approximately 500 m depth,
246 displacements are smaller despite the relatively strong currents. In contrast, moorings in the
247 eastern part of the channel exhibit substantially smaller displacements (< 30 m), consistent with
248 the weaker mean flow.

249 Moorings located near the center of the section (e.g., YUC8 and YUC18) also experience large max-
250 imum displacements, exceeding 90 m; however, these events are less persistent, typically lasting
251 40–80 days. Instruments on moorings YUC3 through YUC15 show comparatively small displace-
252 ments, either because they are deployed near the seabed (YUC3 and YUC4) or at intermediate
253 depths (~ 500 m), allowing continuous sampling of the Yucatan Current without significant data
254 loss.

255 *Vertical interpolation to fixed depths*

256 To produce a dataset suitable for quantitative analysis and data assimilation, velocities are mapped
257 to fixed depths defined as the mode observed depth of each instrument bin over its valid record.
258 These mode depths are used only as the target levels for the final velocity product. This choice
259 places each velocity record close to its most representative sampling depth, thereby reducing
260 the use of surrounding observations required to realign velocities to fixed depths. Velocity com-
261 ponents are interpolated independently at each time step using a shape-preserving monotonic
262 piecewise cubic Hermite interpolation (PCHIP) scheme.

263 The PCHIP approach is well suited to this application because the interpolant passes through the
264 observed values while local derivatives are constructed from neighboring observations in a shape-
265 preserving manner. In monotonic portions of a profile, the scheme preserves monotonicity and
266 avoids the overshoots that can arise with unconstrained cubic splines. This reduces the introduc-
267 tion of spurious extrema or oscillations between observations while keeping the inferred vertical
268 structure locally constrained by the data.

269 Interpolation is performed only within the range of available observations. Extrapolation above
270 the shallowest instrument is not permitted in order to avoid unphysical velocities during periods
271 of strong mooring motion. Near the bottom, the deepest instrument is assumed to remain at its
272 nominal position, as pressure variability in the bottom layer is negligible. If the deepest instru-
273 ment fails, no fixed-depth boundary condition is imposed, and the second-deepest instrument is
274 treated dynamically.

275 To maintain a minimally processed product, the PCHIP scheme is used exclusively to realign obser-
276 vations to their corresponding fixed depths. No new vertical levels are introduced, and values are
277 not interpolated beyond the observed depth range. Consequently, records are trimmed to the
278 active duration of each instrument. Apart from the Gaussian smoothing applied to remove tidal
279 and supra-inertial variability, no additional temporal or vertical filtering is applied.

280 During periods of strong vertical displacement, the shallowest portion of the velocity profile may
281 be intermittently lost, as extrapolation above the uppermost observation is not allowed (see
282 **Fig. 5A,B**). In these cases, observations from upper ADCP bins that fall between fixed depths are
283 excluded from the final profile. However, the downward displacement of the mooring simultane-
284 ously brings these observations closer to deeper instruments (e.g., single-point current meters),
285 increasing the local density of constraints and reducing interpolation uncertainty at depth.

286 **Uncertainty Assessment**

287 *Observation or Base Uncertainty*

288 We define the base uncertainty σ_b as an estimate of the instrument-observation error standard
289 deviation derived from the high-frequency noise floor of the velocity measurements, following
290 [16, 25]. For each velocity time series, the power spectral density (PSD) is estimated using Welch's
291 method with 50% overlap. The noise floor is defined as the median PSD over the highest quartile
292 of resolved frequencies, corresponding to the approximately flat high-frequency portion of the
293 spectrum. The archived processing code cited in the **Code Availability** section contains the exact
294 spectral implementation, including the input record used in the processing chain and the Welch
295 window and segment settings, so that the reported uncertainty fields can be reproduced without
296 inferring unspecified spectral parameters.

297 For ADCPs, the analysis is performed independently for each vertical bin to account for signal
298 attenuation with increasing distance from the transducer. The base uncertainty is calculated as
299 the square root of the integrated noise-floor PSD, yielding an estimate of the velocity-error stan-
300 dard deviation. When the resulting value falls below the manufacturer-specified velocity preci-
301 sion, a conservative lower bound of 0.5 cm s^{-1} is adopted. Across all instruments, the mean σ_b
302 is 0.84 cm s^{-1} , with maximum values reaching 4.22 cm s^{-1} . Single-point current meters gener-
303 ally exhibit higher estimated noise levels than ADCPs, particularly at greater depths where mean
304 velocities are weaker.

305 The noise-floor estimate is associated with each moving observation/bin before vertical realign-
306 ment. For the final fixed-depth product, σ_b is linearly interpolated in the vertical to the same
307 fixed target depths as the velocity observations. The archived base-uncertainty field is therefore
308 denoted $\sigma_b(z)$ and is reported as a single fixed-depth profile for each mooring rather than as a
309 time-varying uncertainty estimate.

310 *Interpolation Uncertainty*

311 To quantify sensitivity associated with the vertical realignment, we use a random-subsampling
312 ensemble that evaluates how the PCHIP-interpolated fields change with data availability and sam-
313 pling configuration. This diagnostic reflects the influence of instrument spacing, vertical data gaps,
314 and the combination of observations from different instruments; it does not quantify systematic
315 measurement bias.

316 For each mooring and time step, 80% of the available observations are sampled randomly without
317 replacement. PCHIP interpolation is applied to each subset, and the procedure is repeated 5,000
318 times independently for each velocity profile. At each fixed depth, the central 95% interval of the
319 resulting ensemble of interpolated values is calculated.

320 We define the interpolation-uncertainty metric $\sigma_i(z, t)$ as one half of the width of this central 95%

321 subsampling interval. The symbol σ_i is retained for consistency with the archived data product and
322 figures, but it should not be interpreted as a standard deviation or as a formal 95% confidence
323 interval. Instead, it is a time-dependent measure of interpolation sensitivity to the available verti-
324 cal sampling. Within the PCHIP scheme, locally inferred curvature is important: where curvature
325 is weakly constrained by adjacent observations, changes in the retained control points across sub-
326 samples can produce larger values of $\sigma_i(z, t)$.

327 Values of $\sigma_i(z, t)$ are generally small where dense ADCP sampling consistently brackets the fixed
328 target depths and become larger where the vertical coverage is sparse or heterogeneous. Elevated
329 values are systematically observed near transitions between instrument types (e.g., from ADCP
330 profiles to single-point current meters). These maxima indicate reduced robustness of the inferred
331 vertical structure under subsampling rather than enhanced flow variability.

332 The two reported diagnostics have different statistical meanings: $\sigma_b(z)$ is an estimated measurement-
333 error standard deviation, whereas $\sigma_i(z, t)$ is a central-95%-interval half-width from the subsam-
334 pling ensemble. In addition, they need not be statistically independent. We therefore do not
335 combine them in quadrature or report a single total uncertainty. They are supplied separately so
336 users can incorporate them under assumptions appropriate to their application.

337 The empirical horizontal and vertical correlation functions described below characterize the spa-
338 tial coherence of the observed velocity signal, not the spatial covariance of observation errors.
339 They are therefore used here to assess the resolving capability of the array and may inform application-
340 specific choices about representativeness or covariance length scales, but they should not be
341 inserted directly into an observation-error covariance matrix without additional assumptions or
342 error-model development.

Data Records

The complete velocity dataset is available through Zenodo at DOI: 10.5281/zenodo.20788450 [26], and consists of daily velocity records from the Canek mooring array deployed in the Yucatan Channel between September 2021 and August 2023. The release follows the Climate and Forecast (CF) metadata conventions (v1.10) and is distributed in NetCDF-4 format, ensuring self-describing and interoperable files suitable for direct use in oceanographic and climate applications.

Each file corresponds to one recovered mooring and contains daily time–depth profiles of the eastward and northward velocity components at fixed depths. The daily records are obtained by subsampling the quality-controlled, filtered two-hourly measurements described above. Each file also contains two complementary uncertainty diagnostics:

- **Base uncertainty** $\sigma_b(z)$: an estimate of the instrument-observation error standard deviation derived from the high-frequency velocity-noise floor and mapped to the fixed target depths. It is provided as one depth-dependent profile per mooring.
- **Interpolation-sensitivity metric** $\sigma_i(z, t)$: one half of the width of the central 95% interval obtained from the 5,000-member random-subsampling ensemble used to assess the vertical realignment. It varies with time and depth and is not a standard deviation.

The coordinate variables `time`, `depth`, `lat`, and `lon` are stored with the velocity fields and associated uncertainty diagnostics. Velocity variables reference their ancillary uncertainty fields through the CF `ancillary_variables` attribute. Global and variable-level metadata provide the mooring identifier, geographic position, deployment and recovery information, units, and descriptive attributes needed to interpret the files. The NetCDF files are self-describing; the exact variable names, dimensions, fill values, and CF attributes used in the released version are preserved in the archive and can be inspected directly in each file.

In total, 12 moorings were successfully recovered. Two additional moorings (YUC1 and YUC2) could not be recovered and are therefore excluded. The campaign achieved an overall data recovery rate of approximately 91%, and most recovered moorings provide continuous records exceeding 650 days. The archive contains 12 NetCDF-4 files, one for each recovered mooring.

For data-assimilation applications, $\sigma_b(z)$ provides an instrument-related error-scale estimate, whereas $\sigma_i(z, t)$ characterizes sensitivity of the fixed-depth interpolation to the available vertical sampling. Because these diagnostics have different statistical interpretations, they are provided separately. Likewise, the horizontal and vertical correlation functions reported in the Technical Validation section describe correlations of the observed velocity signal and should be treated as spatial-coherence diagnostics rather than direct estimates of observation-error covariance.

Portions of these observations were previously incorporated into the objectively mapped Canek

377 velocity fields described by Durante et al. [16]. The present release differs from that product
378 by providing the individual mooring-resolved velocity profiles at their fixed observational depths,
379 with minimal spatial processing and the separate uncertainty diagnostics described above.

Technical Validation

Internal Validation: Spatial Coherence Diagnostics

Following [25], we assess the resolving capability of the mooring array given the observational spacing by evaluating horizontal and vertical coherence scales and comparing them with the instrument spacing. When coherence scales exceed, or are comparable to, the spacing between instruments, neighboring measurements are expected to retain dynamically coherent variability. The correlations analyzed here are correlations of the observed velocity signal, not correlations of measurement or representation errors. They are therefore used as an internal consistency check on the sampling strategy and as descriptive spatial-coherence diagnostics. In data-assimilation applications, they may inform the choice of representativeness or covariance length scales, but additional assumptions are required before they can be interpreted as observation-error correlations (e.g., [27, 28]).

Previous analyses of Canek observations [3, 11, 16] indicate that the typical horizontal coherence scale for velocity along the Yucatan Channel is on the order of the first baroclinic radius of deformation ($\sim 30\text{--}80$ km), while vertical coherence scales range between 300–600 m.

To quantify the spatial correlation structure of the velocity field, we computed empirical correlations between speed time series as a function of separation distance in both the vertical and horizontal directions. Assuming stationary statistics, correlations were evaluated as a function of separation distance r , either vertically within individual moorings or horizontally between different moorings. The resulting empirical correlograms typically exhibit a rapid decay at small separations and, in some cases, a change of sign at larger distances, indicative of vertically or horizontally coherent structures with phase reversals. To represent these behaviors within a stationary parametric framework, we fit an oscillatory Matérn–cosine correlation model [29].

This formulation satisfies the mathematical requirements of a valid correlation function while providing greater flexibility than a Gaussian model through the inclusion of a smoothness parameter that allows the near-origin behavior to adapt to the observed correlation decay [30]. The cosine term permits the representation of empirical sign changes at larger separations without requiring these oscillations to be interpreted as evidence of strictly periodic dynamics. Rather, the objective is to obtain a statistically consistent parametric approximation of the empirical correlation function and a robust estimate of the associated integral decorrelation scales over the range of observed separations.

$$\rho(\mathbf{r}; \ell, \nu, \lambda) = \underbrace{\frac{2^{1-\nu}}{\Gamma(\nu)} \left(\frac{|\mathbf{r}|}{\ell}\right)^\nu K_\nu\left(\frac{|\mathbf{r}|}{\ell}\right)}_{\text{Matérn function}} \cos\left(\frac{2\pi\mathbf{r}}{\lambda}\right), \quad \rho(\mathbf{0}) = 1, \quad (1)$$

where ℓ is a decay (envelope) length scale, ν is a smoothness parameter, and λ is the oscillation

wavelength that controls the separation at which the correlation changes sign. Here, $\Gamma(\cdot)$ denotes the Gamma function and $K_\nu(\cdot)$ is the modified Bessel function of the second kind. Model parameters $\theta = (\ell, \nu, \lambda)$ are estimated via nonlinear least-squares fitting. Separate fits are performed for vertical and horizontal correlations (see **Fig. 6**).

Integral (Effective) Decorrelation Length Scale

For correlation functions that exhibit sign changes, a single decorrelation length based solely on the first zero crossing may not adequately describe the spatial extent of coherent variability. Following [31], an integral decorrelation (or coherence) length scale L_u is defined as

$$L_u = \int_0^\infty |\rho(r)| dr, \quad (2)$$

By taking the absolute value, this formulation allows positive and negative correlation lobes to contribute to the estimated coherence scale rather than canceling one another [32]. This is useful for empirical correlation functions that include sign changes, while avoiding the need to interpret each negative lobe as a distinct physical mode. The quantity L_u therefore provides an effective coherence scale that summarizes the spatial coherence represented by the fitted correlation function. It characterizes the observed velocity signal and is not interpreted here as an observation-error correlation length.

For horizontal correlations (**Fig. 6**, upper panels), velocity magnitudes between moorings were interpolated to common depths (100–600 m for the upper layer, 800–1400 m for the lower layer) at 100 m intervals. All possible correlation–distance pairs were computed (gray points), followed by bin averaging in 14 km intervals to estimate correlation decay with distance (black points and vertical bars).

In the upper layer (100–600 m), where the Yucatan Current core is typically located, correlations decrease rapidly with distance, dropping to approximately 0.65 at 20 km separation. Beyond 60 km, correlations become weakly negative and stabilize near -0.2 beyond 100 km. This behavior is consistent with lateral shifts or meandering of the upper Yucatan Current, which can produce alternating regions of positive and negative correlation across the section [11, 33, 34]. Similar correlation structures have been reported in other western boundary currents, such as the Gulf Stream and the Kuroshio, where current meandering influences lateral covariance patterns [33, 34]. As expected, the standard deviation of correlations increases with distance, reflecting greater variability and reduced sampling robustness at larger separations.

In contrast, the lower layer (800–1400 m) exhibits a more gradual decay. Correlations drop to approximately 0.5 at 20 km but remain weakly positive (~ 0.2) beyond 60 km. Compared with the upper layer, the deeper velocities are less directly affected by surface-intensified meandering and appear to be influenced by more persistent flow structures [11, 35]. Error bars are smaller in this layer, suggesting more stable correlation estimates.

For vertical correlations (**Fig. 6**, lower panels), time series from instruments within the same mooring were compared as a function of vertical separation using the final vertically interpolated data, with no additional treatment. This comparison provides a consistency check for spatially redundant measurements, particularly between ADCPs and current meters. Because of the higher vertical sampling density within individual moorings, the vertical correlograms are generally smoother than their horizontal counterparts.

External Validation with Satellite Altimetry

We use geostrophic velocity fields from the Copernicus Marine Service (CMEMS) multi-satellite Level-4 delayed-mode altimetry product [36]. This product provides daily gridded maps at $1/8^\circ$ horizontal resolution and combines observations from multiple satellite missions through optimal interpolation. Although distributed as daily fields, previous validation studies indicate that the effective temporal resolution of the product in the Caribbean Sea and Gulf of Mexico is approximately 18–26 days when compared with coastal tide-gauge observations [37]. Because the objective of the present analysis is to evaluate the ability of the mooring array to capture mesoscale current variability, the CMEMS geostrophic velocity fields provide an independent, basin-scale reference dataset for comparison.

To ensure a meaningful comparison, the mooring observations were smoothed with the 20-day Gaussian operator implemented in the archived technical-validation code, consistent with the effective temporal resolution of the CMEMS product. The comparison focuses on the lateral displacement of the Yucatan Current core using velocities at 100 m depth, corresponding to the shallowest observation level at mooring YUC3. In both datasets, core longitude is estimated as the average longitude of the two equal-speed positions that flank the longitudinal speed maximum. The identical core-tracking routine is applied to the CMEMS and Canek sections; the archived validation script provides the exact Gaussian-filter definition and the contour-selection, interpolation, and missing-data implementation used to reproduce the analysis. The comparison spans the 520-day operational period of YUC3, and the reported correlation is calculated using dates for which a core estimate is available in both datasets.

Fig. 7 presents Hovmöller diagrams of current speed from CMEMS altimetry (**Fig. 7A**) and the Canek array at 100 m depth (**Fig. 7B**), together with four instantaneous velocity maps (**Figs. 7C–F**) selected to illustrate contrasting flow regimes. Despite the fundamental difference between surface geostrophic velocities and direct subsurface current measurements, both datasets capture the lateral migration of the Yucatan Current core (yellow line), with a correlation of $r = 0.85$. This agreement provides independent support for the ability of the Canek array to resolve mesoscale displacements of the current. The snapshot panels illustrate a range of circulation states, from a weakly organized, westward-displaced current (**Fig. 7C**), through intermediate states (**Fig. 7D**), to a strongly concentrated northward jet (**Fig. 7E**). In all cases, the mooring-derived velocities (black arrows) are consistent with the CMEMS geostrophic velocity field (orange arrows), demonstrating that the array captures the principal spatial structure and temporal variability of the Yucatan Current across different dynamical regimes.

485 This agreement, derived from independent measurement systems, reflects the vertical coherence
486 of the Yucatan Current and further suggests the ability of the mooring array to monitor large-scale
487 Yucatan Current variability.

488 Usage Notes

489 The dataset is intended for studies of the Yucatan Current system, model validation, data assimila-
490 tion, and investigations of mesoscale to low-frequency variability in the northwestern Caribbean
491 Sea and Gulf of Mexico. Velocity records have been quality controlled, corrected for mooring
492 motion, filtered with a 48-hour Gaussian filter to suppress tidal and supra-inertial variability, and
493 subsampled to daily resolution.

494 To preserve the observational character of the measurements, no extrapolation was performed
495 above the shallowest available observation or beyond the range of valid measurements. Conse-
496 quently, intermittent gaps may occur near the surface during periods of strong mooring displace-
497 ment. Users interested in reconstructing complete velocity profiles should account for these gaps
498 using application-specific methods.

499 The dataset provides two complementary uncertainty diagnostics: the base uncertainty $\sigma_b(z)$, in-
500 terpreted as an estimated instrument-observation error standard deviation, and the interpolation-
501 sensitivity metric $\sigma_i(z, t)$, defined as the half-width of the central 95% random-subsampling inter-
502 val. These quantities have different statistical interpretations and may also be dependent, so they
503 should not be combined automatically in quadrature. Users should incorporate them according
504 to the assumptions and requirements of their particular application.

505 Because the product is optimized for low-frequency variability, applications requiring tidal, iner-
506 tial, or higher-frequency motions should use the original instrument records rather than the daily
507 processed dataset.

508 Data Availability

509 The complete velocity dataset is freely available through Zenodo at DOI: 10.5281/zenodo.20788450
510 [26].

511 The archive contains 12 NetCDF-4 files, one for each recovered mooring of the Canek array, to-
512 gether with CF-compliant metadata and uncertainty diagnostics.

Code Availability

The MATLAB processing and technical-validation scripts are available through Zenodo at DOI: 10.5281/zenodo.20789320 [38].

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Author Contributions

G.D. performed the data processing, uncertainty analysis, technical validation, figure preparation, and manuscript writing. J.S. designed and coordinated the Canek observing program and contributed to the interpretation of the results and manuscript preparation. M.T., D.N., E.P.-S., G.A., L.A.-O., P.P.-B., D.M., J.R.-O., and J.L.V.-F. participated in all, or subsets, of the following activities: field operations; instrument preparation, deployment, and recovery; and discussions regarding dataset organization, formatting, and processing procedures. The dataset reflects the collective efforts of all authors, together with those of many other members and contributors to the Canek

629 observing program and CICESE who are not listed here as authors. All authors reviewed and ap-
630 proved the final manuscript.

631 **Competing Interests**

632 The authors declare no competing interests.

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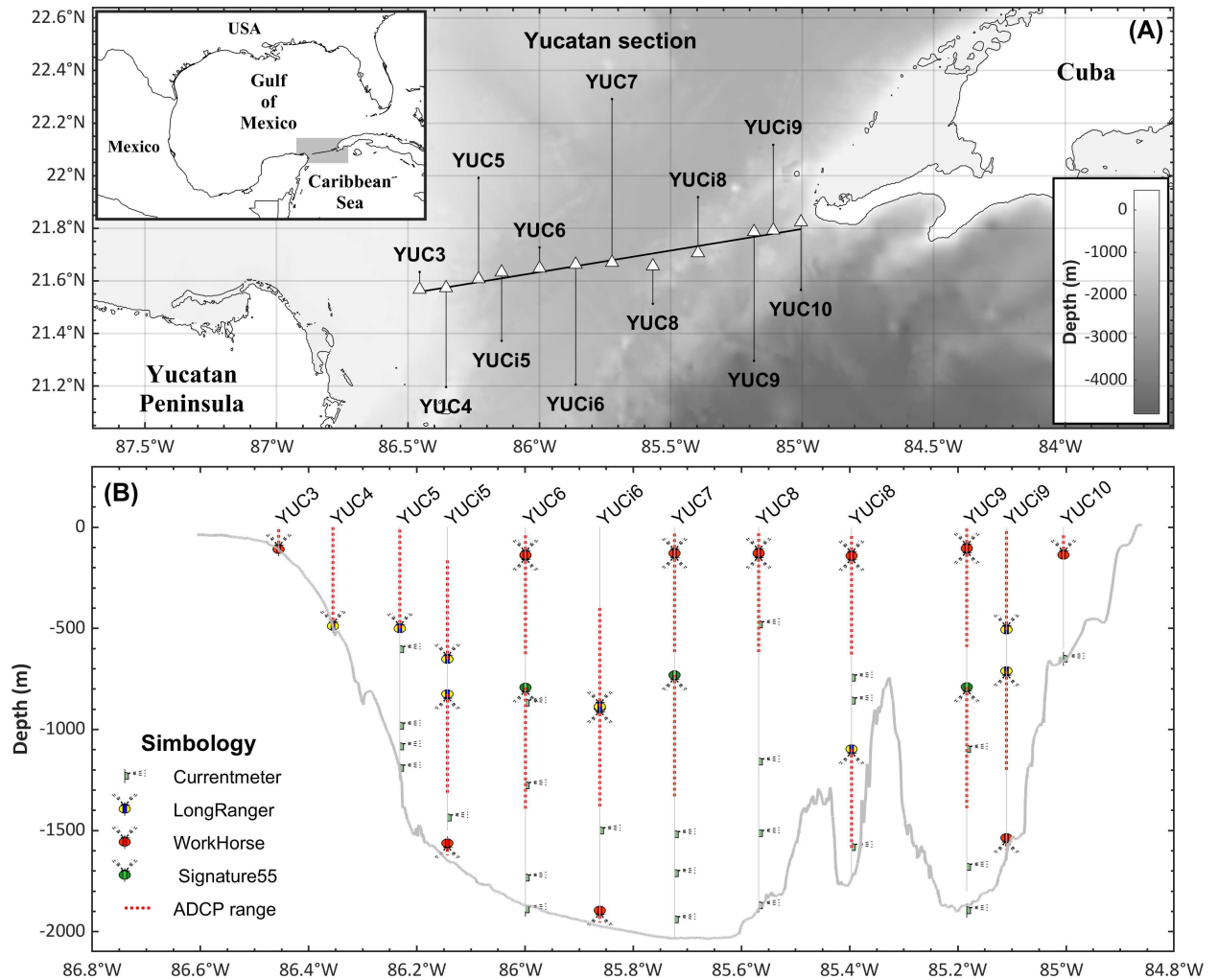


Fig. 1: Configuration of the Canek mooring array. **(A)** Regional map of the Yucatan Channel at the entrance to the Gulf of Mexico. Detailed bathymetry highlights the mooring positions (YUC3–YUC10 and interior moorings YUCi5–YUCi9); lighter shading indicates shallower depths. White triangles indicate historical mooring sites. **(B)** Cross-sectional view of the mooring array along the Yucatan Channel. Symbols denote instrument types: WorkHorse ADCPs (red circles, upper layer), LongRanger ADCPs (yellow circles, mid-depth, ~500 m range), Signature55 ADCPs (green circles, redundant ~600 m range), and current meters (black squares, deep flow). Red dotted lines show ADCP measurement ranges; gray line indicates bathymetry. YUC1 and YUC2 were deployed but not recovered.

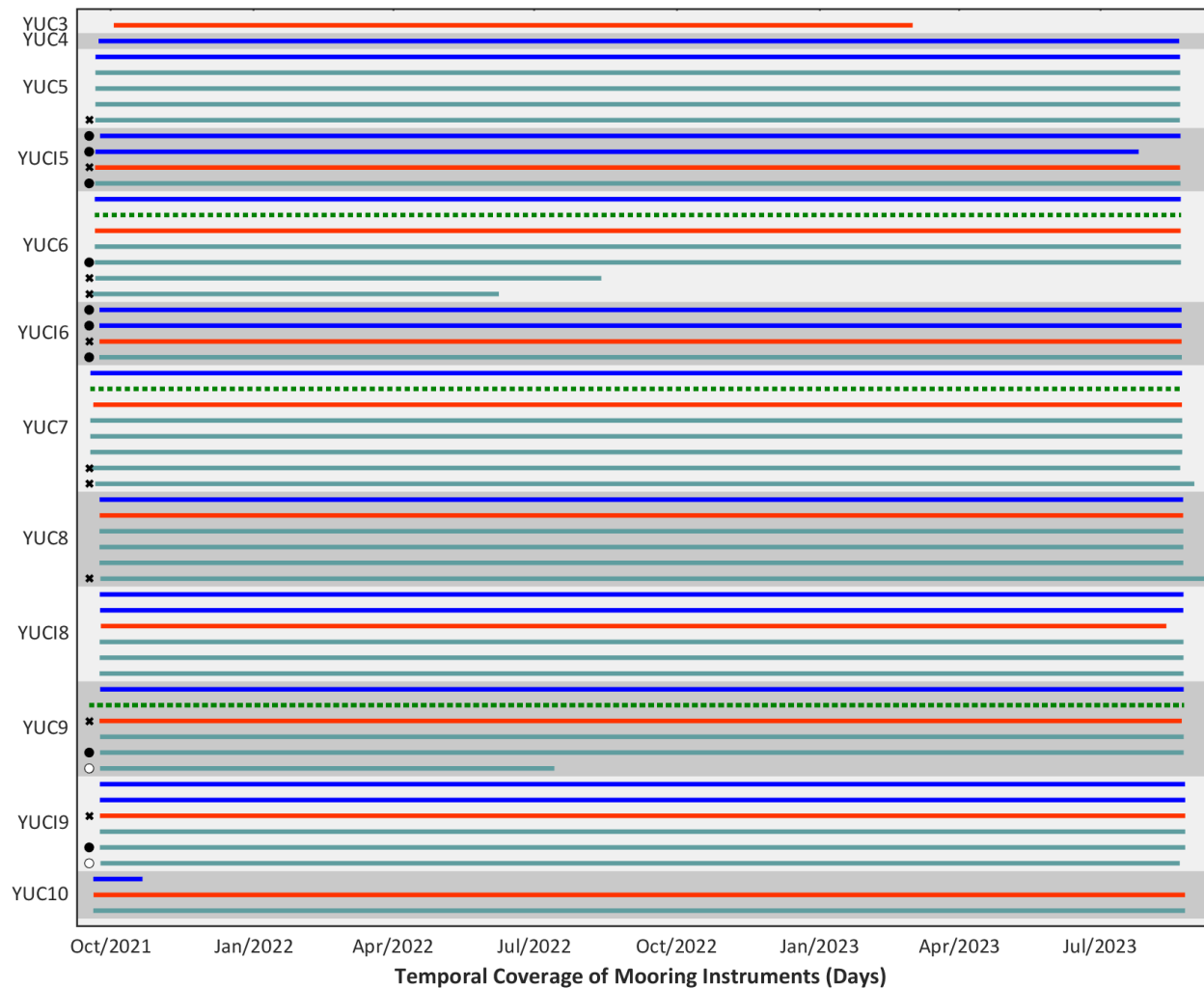


Fig. 2: Temporal coverage of velocity measurements from the Canek mooring array (2021–2023). Each horizontal line represents an individual instrument, with colors denoting instrument type: WorkHorse ADCP (red), LongRanger ADCP (blue), Signature55 ADCP (green dotted), and single-point current meters (teal). Within each mooring, the vertical ordering of lines corresponds to relative depth, with shallower instruments shown at the top. White circles indicate instruments with faulty pressure records due to sensor malfunction. Black circles mark pressure time series affected by long-term drift, which were corrected using de-drifting procedures. Black crosses denote instruments without integrated pressure sensors, whose vertical positions were estimated using co-located pressure records within the same mooring.

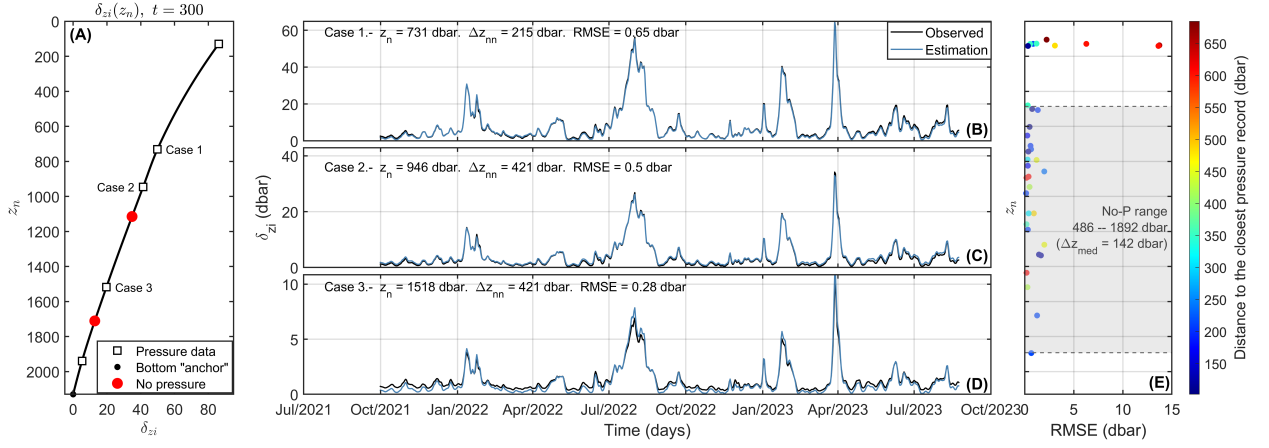


Fig. 3: Pressure estimation methodology and validation for instruments without pressure sensors. Left: Instantaneous pressure-displacement profile (δp) at day 300, showing instruments with pressure sensors (squares), bottom anchors (black circles), and instruments without pressure measurements (red circles). Center: Time-series comparison of observed (black) and estimated (blue) pressure displacements (δp) for three representative cases at different nominal pressures (p_n). Each panel includes the nominal pressure and the RMSE of the estimation. Right: Summary of pressure-estimation errors versus nominal pressure, with colors indicating the distance to the nearest pressure observation in dbar.

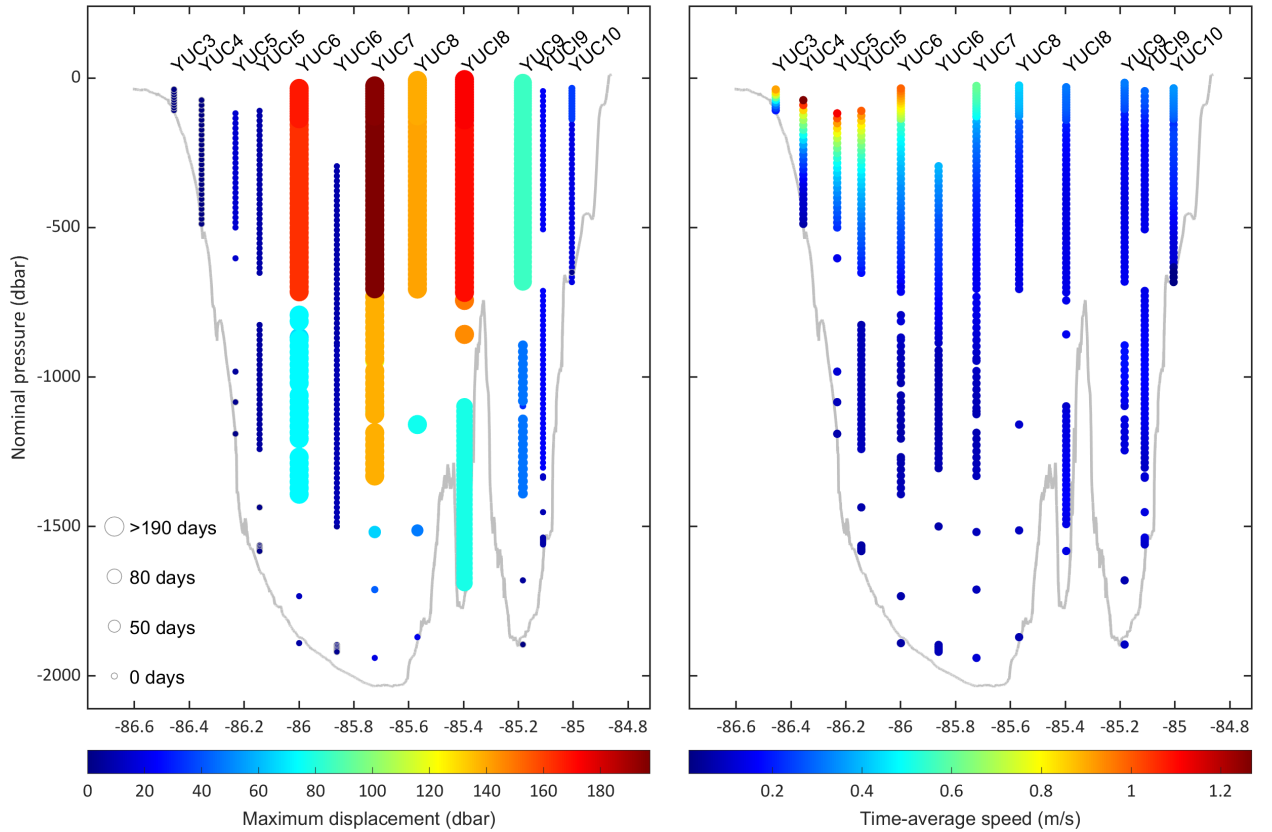


Fig. 4: Spatial patterns of mooring motion and velocity in the Yucatan Channel array. (A) Maximum pressure displacement of instruments (colors, dbar), with circle size indicating the cumulative duration of TEOS-10-converted vertical displacements exceeding 50 m. (B) Time-averaged current speed ($m s^{-1}$). Note the correspondence between strong mean flows and large mooring displacements in the western portion of the section, particularly at moorings YUC6 and YUC7.

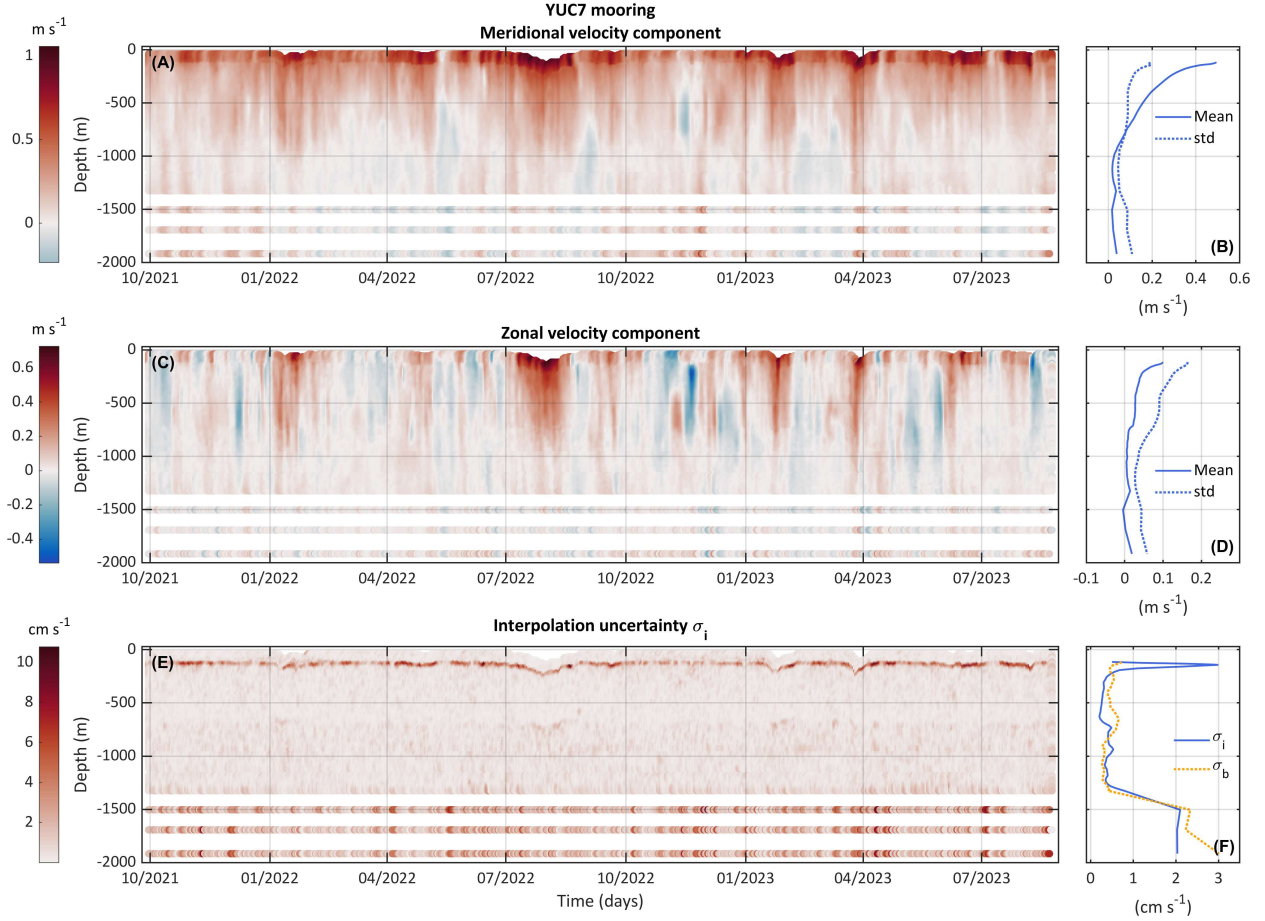


Fig. 5: Example time–depth evolution of velocity and associated interpolation uncertainty at mooring YUC7. (A) Meridional velocity component as a function of time and depth; (B) corresponding time-mean profile (solid line) and standard deviation (dashed line). (C) Same as (A), but for the zonal velocity component; (D) corresponding time-mean profile and standard deviation. (E) Interpolation-sensitivity metric $\sigma_i(z, t)$, defined as the half-width of the central 95% interval from the random-subsampling ensemble. (F) Time-mean profiles of σ_i (solid line) and base uncertainty σ_b (dashed line). The two curves are shown on the same velocity scale but have different statistical interpretations: σ_b is an estimated standard deviation, whereas σ_i is a central-95%-interval half-width. Periods of strong vertical mooring displacement result in the loss of the shallowest fixed-depth levels, as extrapolation beyond the uppermost observation is not permitted, leading to intermittent gaps near the surface. Enhanced σ_i is observed at depths corresponding to sparse vertical sampling and transitions between instrument types, reflecting reduced robustness of the inferred vertical structure rather than increased flow variability.

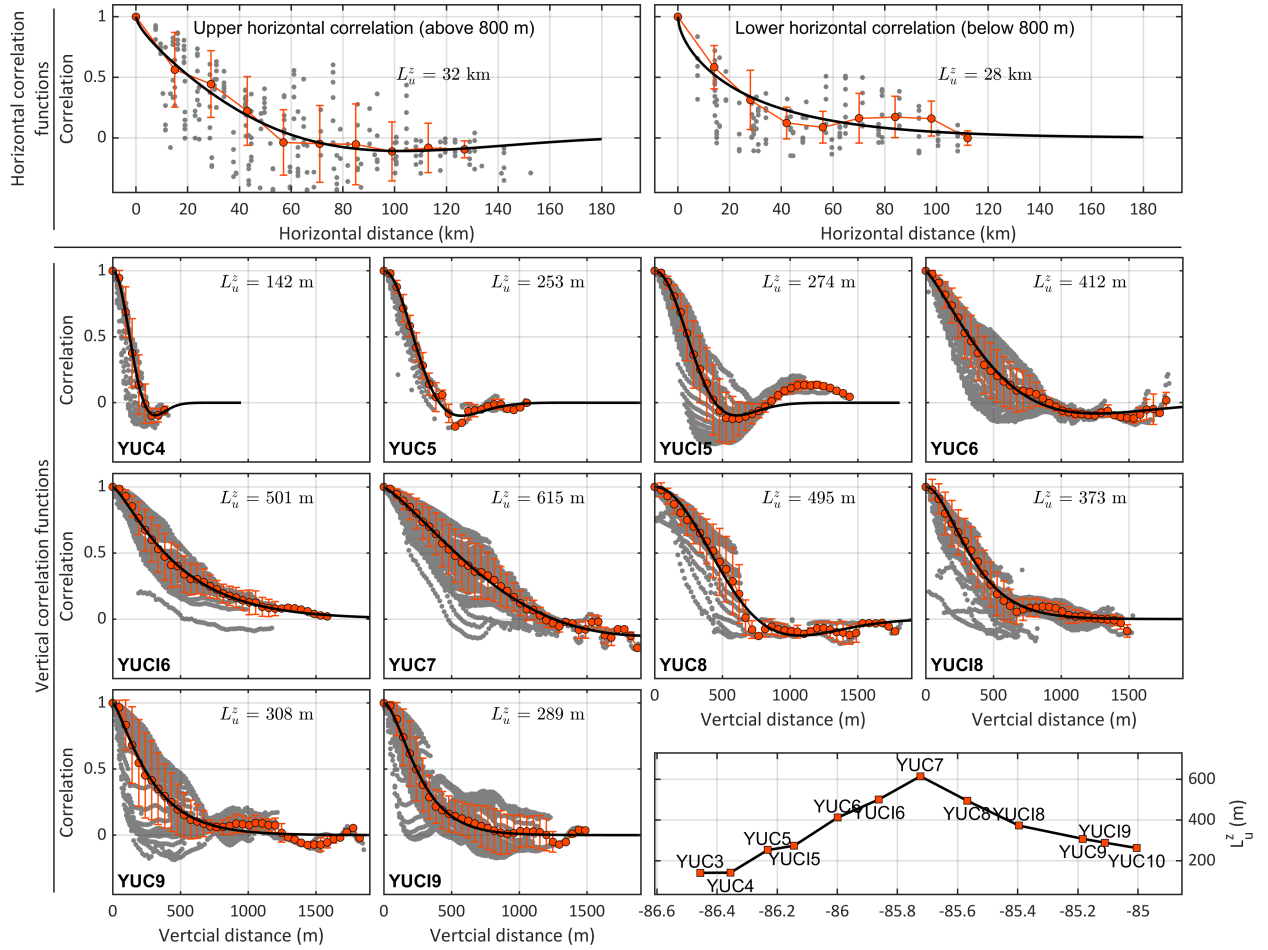


Fig. 6: Horizontal and vertical velocity correlations in the Canek array. Upper panels show horizontal correlations in the upper and lower Yucatan section. Lower panels show the estimated vertical correlation functions for each mooring. Gray dots indicate empirical correlations as a function of separation distance. Orange circles and vertical bars represent binned means and standard deviations of the empirical correlations. Black lines are the fitted Matérn-cosine functions described by Eq. (1).

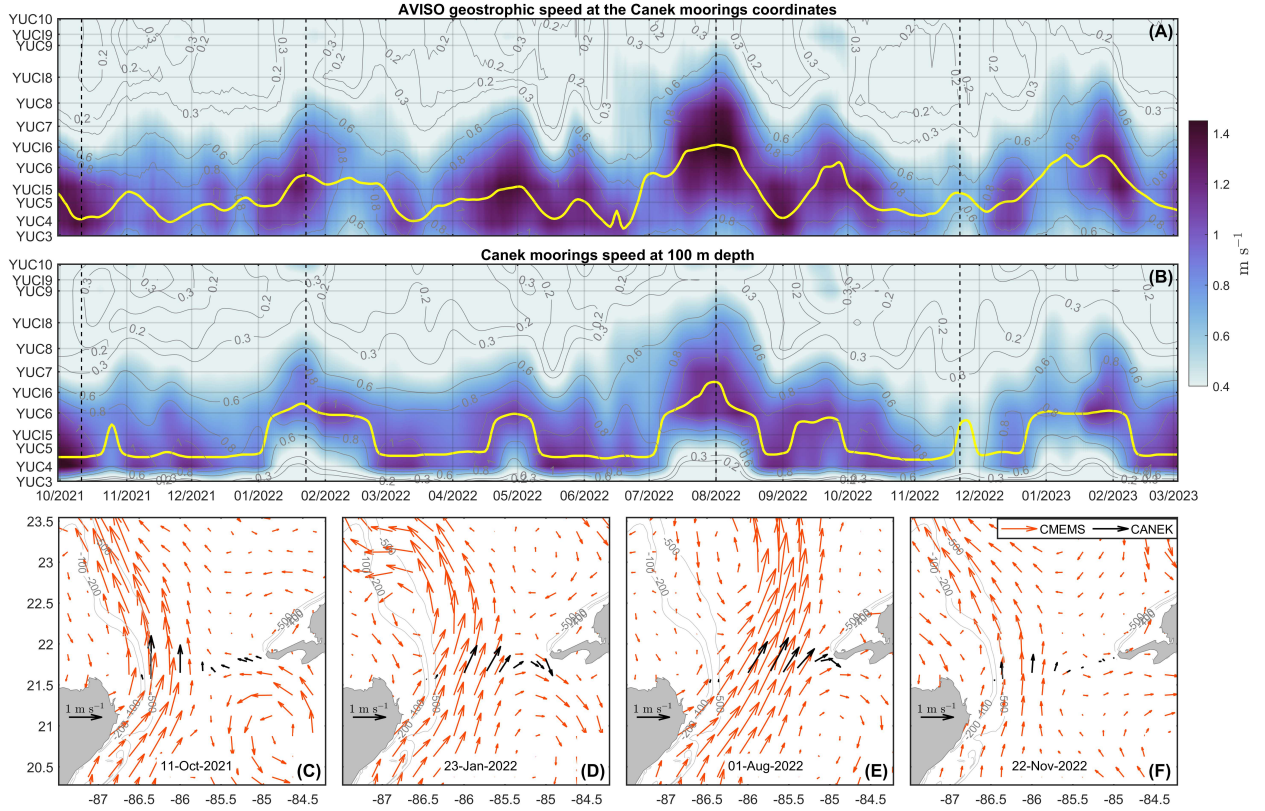


Fig. 7: Comparison of Yucatan Current variability from satellite altimetry and mooring observations. **(A)** Hovmöller diagram of CMEMS geostrophic speed interpolated to the mooring longitudes. **(B)** Same as (A), but for Canek mooring speed at 100 m depth, smoothed with the same 20-day Gaussian operator used in the technical-validation analysis. Gray contours are overlaid in both panels at 0.2, 0.3, 0.6, 0.8, and 1.0 m s⁻¹. The yellow line tracks the estimated Yucatan Current core position. Dashed vertical lines mark the four snapshots shown in panels (C)–(F). **(C)–(F)** Instantaneous velocity maps for selected dates illustrating contrasting current regimes, showing CMEMS geostrophic velocities (orange arrows) and Canek mooring velocities at 100 m depth (black arrows). Bathymetric contours at 100, 200, and 500 m are shown in gray.

Supplementary Files

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