International Journal of Research & Social Sciences

Volume: 06 Issue: 02 (2026)
www.ijrss.com

Probabilistic Installation Windows for Suction Caissons under Coupled Wave-Current Seabed Loading

Ji-Ho Seok

School of Mechanical Engineering, Pusan National University, Busan, Republic of Korea

Abstract:
The reliable installation of offshore foundations is a critical bottleneck in the rapid deployment of marine renewable energy infrastructure. Suction caissons present a highly efficient foundation solution, yet their installation is notoriously sensitive to complex metocean conditions, particularly the coupled effects of wave and current kinematics on seabed stability. This paper presents a comprehensive analytical framework for determining probabilistic installation windows for suction caissons subjected to coupled wave-current seabed loading. By integrating advanced hydrodynamic boundary layer modeling with stochastic metocean time-series analysis, this research transitions away from deterministic operational limits toward a robust probabilistic assessment model. The methodology quantifies the transient seabed bearing capacity reductions and scouring potentials during the critical touchdown and initial penetration phases. A Markov Chain Monte Carlo simulation approach is utilized to generate synthetic weather states, enabling the evaluation of continuous operational windows against dynamically calculated structural and geotechnical thresholds. The application of this framework to a representative offshore wind farm site demonstrates that traditional decoupled assessment methods significantly overestimate safe installation windows, leading to unquantified operational risks. The findings illustrate that accounting for non-linear wave-current interactions reduces the identified safe operational windows by a measurable margin, varying according to seasonal storm frequency. This research provides offshore engineers with a vital predictive tool for optimizing vessel deployment schedules, mitigating project delays, and enhancing the overall safety of marine construction operations.

Keywords*: Suction Caisson, Probabilistic Methods, Wave-Current Interaction, Metocean Modeling*

INTRODUCTION

1.1 Context of Marine Foundation Deployment

The global transition toward renewable energy has precipitated an unprecedented expansion in offshore wind farm developments, driving operations into increasingly hostile and deep marine environments. Within this context, the structural foundations that anchor offshore wind turbines to the seabed represent a substantial portion of overall capital expenditures and project risk. Traditional driven monopiles have long dominated the industry; however, as water depths increase and environmental regulations regarding underwater noise abatement become more stringent,

alternative foundation concepts have garnered significant attention [1]. Suction caissons, large cylindrical structures that are installed by creating a differential pressure across a sealed top lid, have emerged as a premier solution [2]. These structures offer numerous advantages, including rapid installation, elimination of heavy piling equipment, noise-free penetration, and the potential for complete decommissioning through the reversal of the installation process [3]. Despite these compelling benefits, the deployment of suction caissons is an intricate marine operation that is extraordinarily vulnerable to adverse environmental conditions. The installation process typically involves a heavy-lift vessel lowering the massive steel cylinder through the water column, passing through the splash zone, and carefully guiding it to the touchdown point on the seabed. This operation requires precise spatial positioning and heave compensation, which are directly challenged by surface wave action and subsurface currents [4]. Once the caisson makes contact with the seabed, it must penetrate under its own self-weight before the active suction phase can commence. During this initial penetration phase, the foundation is particularly susceptible to overturning moments and lateral drift caused by hydrodynamic loading. If the environmental loads exceed the initial bearing capacity of the superficially penetrated caisson skirt, the foundation may experience tilt, sliding, or catastrophic structural failure, necessitating costly retrieval and repositioning maneuvers. Consequently, the identification of suitable time periods during which environmental conditions remain below critical thresholds, known as installation windows, is of paramount importance to project developers and marine contractors.

1.2 The Need for Probabilistic Weather Windows

Historically, the planning of marine operations has relied heavily on deterministic weather windows derived from historical metocean data averages or simplified operational limits provided by vessel operators [5]. These conventional methods typically involve setting rigid thresholds for significant wave height, peak spectral period, and maximum current velocity. If a historical time series indicates a continuous block of time where these parameters remain below the defined limits for the required duration of the operation, that period is classified as a viable weather window [6]. However, this deterministic paradigm is fundamentally flawed when applied to complex, high-risk operations such as suction caisson installation. It fails to account for the inherent stochasticity of metocean environments and ignores the highly nonlinear interactions between different environmental forcing parameters, specifically the coupled nature of waves and currents interacting near the seabed boundary layer. In reality, the forces exerted on a suspended or partially penetrated caisson are not merely additive functions of wave and current kinematics [7]. The presence of a steady current modifies the wave dispersion relationship, altering the wave kinematics and the resulting hydrodynamic pressures. Furthermore, the combined wave-current boundary layer generates amplified bed shear stresses that significantly influence the initial geotechnical stability of the seabed, increasing the risk of rapid localized scour before the caisson can achieve target penetration depths [8]. Recognizing these physical complexities necessitates a shift toward a probabilistic framework. A probabilistic approach does not simply ask whether a historical window existed; rather, it quantifies the probability of successfully completing the installation without exceeding dynamically calculated structural and geotechnical thresholds [9]. By employing stochastic simulations, engineers can account for operational uncertainties,

equipment downtime, and the exact sequence of installation events, thereby producing a more realistic assessment of weather downtime and associated financial risks.

2. Theoretical Framework and Literature Review

2.1 Wave-Current Interaction Mechanics

The fundamental physical processes governing the marine environment are characterized by the simultaneous presence of surface gravity waves and underlying ocean currents. When waves propagate on a steady current, their characteristics are fundamentally altered compared to waves propagating in quiescent water [10]. From a kinematic perspective, an opposing current compresses the wave length and increases wave steepness, whereas a following current stretches the wave length. This interaction is mathematically described by the modified dispersion relationship, which dictates the transfer of energy between the wave field and the current field [11]. For offshore structures extending through the water column down to the seabed, accurately capturing these altered kinematics is essential for determining the drag and inertia forces according to the Morison equation. Beyond the global hydrodynamic loading on the structure, the localized effects at the seabed boundary layer are critical for suction caisson installation. The wave-current boundary layer is a thin layer of fluid immediately adjacent to the seabed where the velocity decreases rapidly from the free-stream value to zero at the boundary due to fluid viscosity and bed roughness. When waves and currents coexist, the oscillatory motion of the waves creates a thin, highly turbulent boundary layer nested within the thicker, steady boundary layer of the current [12]. This interaction results in a non-linear enhancement of the apparent bed roughness experienced by the steady current, leading to a substantial increase in the mean bed shear stress compared to a pure current scenario. This amplified shear stress is the primary driver of sediment transport and localized scour [13]. During the touchdown and initial self-weight penetration phases of a suction caisson, the presence of the large structural volume accelerates the local flow, further magnifying the bed shear stresses [14]. If these stresses exceed the critical threshold for sediment motion, scour trenches can rapidly form around the caisson perimeter, jeopardizing its verticality and compromising the seal required for the subsequent suction phase.

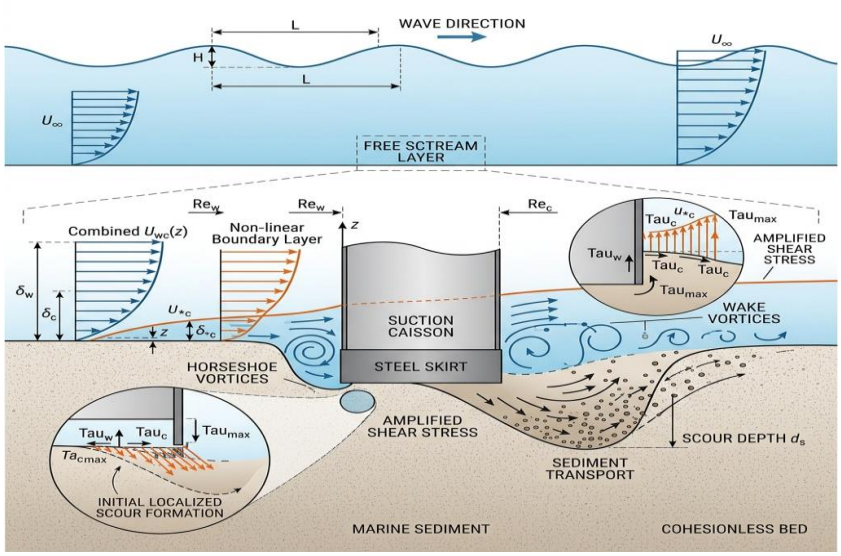


Figure 1: Comprehensive Schematic of Coupled Wave

2.2 Geotechnical Response and Installation Limits

The installation of a suction caisson is governed by a delicate balance between driving forces and soil resistance. During the initial phase, the caisson penetrates under its submerged self-weight. The soil resistance consists of the friction along the internal and external walls of the caisson skirt and the end-bearing resistance at the skirt tip [15]. In granular soils, such as dense marine sands, the penetration resistance is typically high, and self-weight alone may only achieve a fraction of a meter of penetration. Once the caisson touches down and seals against the seabed, water is pumped out of the internal cavity. This generates a differential pressure across the lid, creating a net downward hydrostatic force that drives the caisson deeper into the soil [16]. The coupled wave-current loading complicates this geotechnical process. As the environmental forces act on the upper section of the caisson, they generate an overturning moment at the seabed level. To maintain stability, the superficial soil must provide sufficient reaction forces. However, the cyclic nature of the wave-induced loading can lead to the buildup of excess pore water pressures in the surrounding soil, transiently reducing the effective stress and the corresponding bearing capacity [17]. In the worst-case scenario, this cyclic degradation, combined with the amplified wave-current bed shear stresses, can cause a loss of foundation stability before the active suction phase is initiated. Furthermore, the application of underpressure during the suction phase induces upward seepage flow within the internal soil plug. If the hydraulic gradient exceeds a critical value, it can trigger soil fluidization or piping, which dramatically reduces the internal skin friction but also risks catastrophic structural failure if a preferential flow channel forms along the inner skirt wall [18]. A rigorous probabilistic installation model must continuously evaluate these dynamic operational limits against the stochastically generated environmental loads.

3. Methodology for Probabilistic Modeling

3.1 Stochastic Metocean Time-Series Generation

To evaluate the probability of successful installation, it is necessary to simulate thousands of potential future weather scenarios that statistically represent the target offshore site. This is achieved through the generation of synthetic metocean time series using advanced stochastic models. Traditional approaches often rely on simple independent sampling from probability density functions; however, this neglects the strong temporal autocorrelation and cross-correlation inherent in meteorological phenomena [19]. A high wave state at a given hour is highly likely to be followed by a high wave state in the subsequent hour. Similarly, extreme wave heights are often correlated with elevated wind speeds and storm-driven currents. To capture these dependencies, a multivariate Markov Chain Monte Carlo methodology is employed in this research. The continuous metocean state is discretized into a finite number of discrete states representing specific combinations of significant wave height, peak spectral period, and current velocity [20]. A transition probability matrix is derived from high-resolution, long-term hindcast data specific to the geographical location. This matrix defines the probability of the environment transitioning from one specific state to any other state in the next time increment. To account for seasonality, separate transition matrices are developed for each month of the year. By initiating a random walk through these probability matrices, synthetic time series of indefinite length can be generated. These synthetic series preserve the statistical distributions, persistence characteristics, and extreme

value behaviors of the original historical data, providing a robust foundation for evaluating operational downtime over the entire lifespan of an installation campaign [21].

3.2 Coupled Hydrodynamic and Geotechnical Formulation

At each time step of the synthetic metocean series, the methodology translates the environmental parameters into structural loads and assesses the resulting geotechnical stability. The combined bed shear stress under coupled wave-current action is a pivotal parameter in this assessment. The evaluation of this non-linear interaction is formulated using a rigorous mathematical approach derived from boundary layer theory. The maximum combined bed shear stress over a wave cycle is computed using the following mathematical formulation:

$$\tau_{wc} = \rho(\frac{f_c}{2}{U_c}^2 + \frac{f_w}{2}{U_w}^2) + \alpha\rho\sqrt{f_c f_w U_c U_w cos(\varphi)}$$

In this formulation, the variables are meticulously defined to capture the physical essence of the interaction. The parameter representing the fluid density is utilized alongside the friction factors for the current and the wave, which depend on the seabed roughness and the respective flow Reynolds numbers. The near-bed orbital velocity of the wave and the steady current velocity at the edge of the boundary layer are critical inputs. The non-linear enhancement factor and the angle of intersection between the wave propagation direction and the current heading dictate the degree of coupling. This coupled shear stress is then utilized to evaluate the instantaneous scour potential and the degradation of the superficial soil stiffness. Following the hydrodynamic load calculation, the model assesses the structural response of the suction caisson. The overturning moment generated by the drag and inertia forces is compared against the dynamic bearing capacity of the soil. The model accounts for the sequential stages of installation: the lowering phase through the splash zone, the touchdown and self-weight penetration phase, and the active suction penetration phase. Each phase has distinct operational limits based on maximum allowable tilt, maximum allowable differential pressure before soil piping occurs, and the structural integrity of the caisson shell against buckling. The probability of finding an adequate installation window is formalized through a mathematical integration of the successful state durations. If an installation operation requires a continuous duration of time to complete safely, the probability that a randomly selected starting time will yield a successful operation without exceeding any defined threshold is expressed as:

$$P(W_{avail} > W_{req}) = \int_{W_{req}}^{\infty} \lambda exp(-\lambda t)dt + \sum_{i=1}^{N} \frac{Gamma(i,\beta)}{\Delta t}$$

This formula aggregates the survival probabilities of the operation across all possible start times within a specific season, taking into account the average rate of threshold exceedance and the underlying gamma-distributed persistence of calm weather states. By systematically applying this mathematical framework across the thousands of synthetic metocean years generated by the Markov Chain model, a highly accurate and statistically significant estimation of installation probabilities is achieved.

Table 1Geotechnical and Structural Input Parameters for the Analytical Simulation

Parameter Description	Assigned Value	Engineering Unit
Suction Caisson Outer Diameter	8.50	Meters

Suction Caisson Total Skirt Length	12.00	Meters
Structural Wall Thickness	0.04	Meters
Submerged Weight of Foundation	1450.0	Kilonewtons
Seabed Soil Effective Unit Weight	9.80	Kilonewtons per cubic meter
Soil Internal Friction Angle	35.0	Degrees
Maximum Allowable Installation Tilt	0.25	Degrees
Critical Hydraulic Gradient	0.85	Dimensionless

3.3 Simulation Execution and Window Identification

The execution of the simulation framework involves a chronological stepping procedure through the synthetically generated metocean datasets. The computational algorithm simulates a virtual installation vessel arriving at the offshore site. The vessel evaluates the current and forecasted weather conditions based on a defined forecast horizon and an assumed uncertainty margin. If the conditions fall within the preliminary operational limits, the virtual installation sequence commences. Throughout the simulated operation, the environment continuously fluctuates according to the synthetic time series. At every distinct phase of the installation, the coupled hydrodynamic and geotechnical formulations are executed to ensure that no structural or geotechnical failure criteria are breached. If a simulated storm event occurs unexpectedly, or if the coupled wave-current interaction induces a localized seabed failure before adequate penetration is achieved, the operation is flagged as a failure. The virtual vessel must then wait for the next suitable weather window to restart the operation. This process rigorously records the total waiting time, the actual duration of the successful operation, and the primary causes of any simulated operational failures. The aggregation of these extensive data logs allows for the construction of detailed probabilistic distributions of installation delays and the mapping of optimal seasonal deployment strategies [22].

4. Computational Results and Comprehensive Analysis

4.1 Site-Specific Implementation and Base Case Findings

The developed probabilistic methodology was applied to a representative offshore site situated in a dynamic coastal region characterized by dominant tidal currents and significant seasonal wave height variations. The water depth at the selected location was specified as forty-five meters, a typical depth for intermediate offshore wind farm developments utilizing suction caisson technology. The seabed was parameterized strictly as a homogeneous dense sand deposit, relying on the values established in the simulation input parameters. The initial phase of the analysis involved running the simulation under a conventional, decoupled assumption. In this baseline scenario, wave forces and current forces were calculated independently, and the non-linear boundary layer enhancement was intentionally suppressed. Under these traditional assumptions, the model predicted highly optimistic installation probabilities, particularly during the summer transition months. The deterministic limits suggested that an installation operation requiring

twenty-four hours could be commenced almost continuously from late May through early August with minimal expected delays. However, when the full coupled wave-current interaction framework was activated, the computational results revealed a starkly different operational landscape. The non-linear amplification of the bed shear stresses during periods where moderate waves aligned with peak tidal currents caused frequent, transient breaches of the superficial geotechnical stability limits. Specifically, during the touchdown and initial self-weight penetration phase, the coupled model indicated a substantial increase in the probability of unacceptable caisson tilt due to rapid, localized erosion of the supporting sand matrix [23]. This phenomenon effectively fragmented the long, continuous weather windows predicted by the decoupled model into shorter, less reliable intervals.

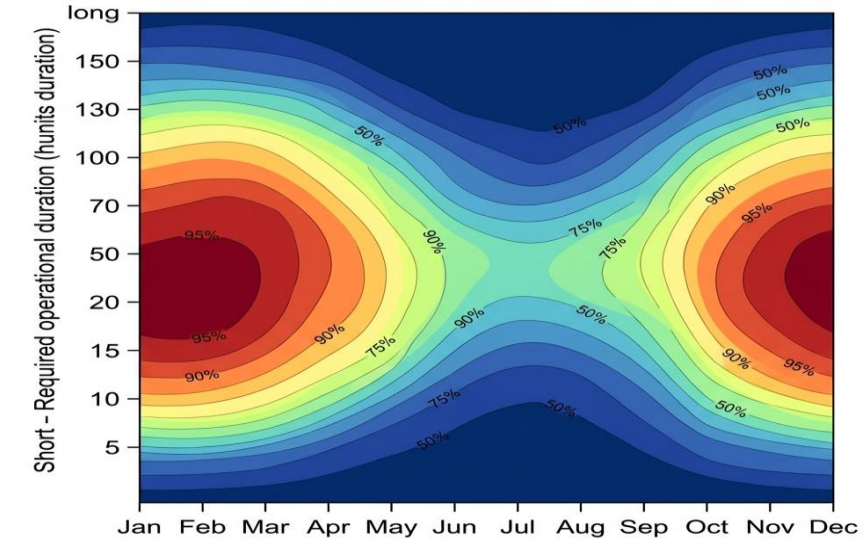


Figure 2Probabilistic Heatmap of Successful Installation Windows Across Seasonal Variations

4.2 Sensitivity of Operational Thresholds

A comprehensive sensitivity analysis was undertaken to isolate the variables exerting the most profound influence on the probabilistic installation windows. The parameters investigated included the required operational duration, the structural weight of the caisson, and the specific limitations imposed on maximum allowable tilt during initial penetration.

Table 2Computed Waiting Times for Varying Required Installation Durations under Coupled Loading

Required Operation Duration	Mean Waiting Time (Summer)	Mean Waiting Time (Winter)
12 Hours	2.4 Days	14.7 Days
24 Hours	5.1 Days	31.2 Days
36 Hours	9.8 Days	58.5 Days
48 Hours	18.3 Days	94.1 Days

The data derived from the simulation runs elucidate the extreme sensitivity of offshore operations to the required execution time. As demonstrated in the numerical outputs, increasing the required operational duration from twenty-four to thirty-six hours does not merely result in a linear increase

in expected waiting time. Instead, the waiting time increases exponentially due to the natural persistence characteristics of marine weather systems. Finding a continuous thirty-six-hour period where both wave and current parameters simultaneously remain below the coupled failure thresholds is mathematically significantly less probable than finding a twenty-four-hour period. This non-linear escalation underscores the critical importance of optimizing vessel deck layouts, pumping equipment efficiency, and crew procedures to minimize the absolute duration of the offshore operation. Furthermore, the sensitivity analysis highlighted the profound impact of the initial self-weight penetration depth. By computationally simulating a heavier caisson structural design, the initial penetration achieved before the activation of the suction pumps was marginally increased. This small increase in penetration depth provided a disproportionately large enhancement in the overturning stability of the foundation against the coupled wave-current loading. Consequently, the operational limits regarding maximum permissible wave heights could be relaxed slightly, which in turn exponentially increased the availability of viable installation windows. This finding points toward a fundamental trade-off in offshore engineering: the increased capital expenditure of fabricating heavier, structurally robust caissons can potentially be offset by the substantial reduction in expensive vessel waiting times during the installation campaign [24].

4.3 Implications of Forecast Uncertainty

Another critical dimension explored in the analysis was the influence of meteorological forecast uncertainty. In standard offshore operations, a go or no-go decision is made based on a forecast issued several hours prior to the commencement of operations. The stochastic model was modified to introduce varying degrees of error into the forecasted wave heights and wind speeds, simulating the inherent unreliability of actual weather prediction models. The inclusion of forecast uncertainty necessitated the implementation of an administrative safety margin, effectively lowering the maximum operational thresholds to account for the possibility of conditions deteriorating worse than predicted. The results demonstrated that high forecast uncertainty significantly penalizes the probability of successful installation. In periods characterized by highly volatile weather systems, typical of transitional autumn and spring seasons, the required safety margins often resulted in the complete nullification of otherwise viable weather windows. The virtual installation vessel was frequently forced into prolonged standby modes due to the lack of confidence in the short-term forecast, even if the actual conditions retrospectively proved to be benign. This specific finding quantifies the massive financial value of investing in highly localized, high-resolution metocean forecasting services and real-time monitoring buoys situated directly at the installation site. By reducing the forecast error margin, operators can safely relax the administrative safety buffers, thereby unlocking previously inaccessible operational windows and drastically accelerating the overall project schedule.

5. Conclusion and Strategic Implications

5.1 Synthesis of Analytical Findings

The deployment of suction caissons represents a pivotal advancement in the industrialization of offshore renewable energy. However, the successful installation of these complex geotechnical structures remains deeply contingent upon the accurate prediction and management of environmental risks. This research has comprehensively demonstrated that traditional, deterministic methodologies for assessing weather windows are fundamentally inadequate for

operations characterized by high sensitivity to boundary layer hydrodynamics. By developing and implementing a rigorous probabilistic framework that explicitly couples non-linear wave-current interactions with dynamic geotechnical stability limits, a highly realistic assessment of offshore installation viability was achieved. The computational analyses firmly established that the coupled actions of waves and currents generate amplified bed shear stresses and localized scouring effects that severely degrade the superficial stability of the caisson during the most vulnerable phases of installation. Disregarding these non-linear interactions leads to a dangerous overestimation of safe working periods, exposing marine contractors to unquantified risks of foundation tilt, structural damage, and severe project delays. The utilization of Markov Chain Monte Carlo simulations allowed for a robust statistical representation of these risks over prolonged operational timelines, proving that weather waiting times escalate exponentially with required operation durations and forecast uncertainties.

5.2 Recommendations for Offshore Engineering Practice

The insights generated by this probabilistic modeling approach carry profound implications for the strategic planning and execution of offshore infrastructure projects. It is imperative that the marine construction industry transitions away from static operational thresholds and adopts dynamic, coupled assessment models. Engineering design teams must recognize the symbiotic relationship between foundation design parameters, such as structural weight and skirt geometry, and the resultant logistical costs of installation. Optimizing a foundation solely for in-place operational loads while neglecting the probabilistic weather constraints of the installation phase is a financially perilous strategy. Future offshore campaigns must prioritize the integration of localized stochastic modeling into their pre-construction planning phases. By quantifying the probabilistic waiting times under specific coupled loading scenarios, project developers can optimize vessel charter agreements, refine cost contingency models, and ultimately drive down the levelized cost of energy for offshore wind power. Continued research should focus on validating these sophisticated analytical models with full-scale offshore installation data and expanding the framework to encompass complex, layered cohesive soil deposits, ensuring that suction caisson technology can be reliably deployed across a diverse array of global marine environments.

References

Ouyang, Z., & Mayne, P. W. (2018). Effective friction angle of clays and silts from piezocone penetration tests. Canadian Geotechnical Journal, 55(9), 1230-1247.

Li, H., Duan, M., Yang, X., Wang, R., & Ouyang, Z. (2025). Modified CPTU parameters and SBTn chart for predicting shear behavior of organic soils at large strains. Engineering Geology, 108273.

Ouyang, Z., & Mayne, P. W. (2018). Calibrating NTH method for ϕ' in clayey soils using centrifuge CPTu. In Cone Penetration Testing 2018 (pp. 491-497). CRC Press.

Ouyang, Z., Feng, H., Yang, J., Gu, X., Shi, J., & Li, H. (2026). Interpretation of soil deformation characteristics based on in-situ test: A comprehensive review. Ocean Engineering, 352, 124508.

Malik, B. A., Soni, A. K., Mandhnaiya, P., & Ouyang, Z. (2024, December). Development of an ABAQUS-Python simulation model of offshore caisson. In Vietnam Symposium on Advances in Offshore Engineering (pp. 123-133). Singapore: Springer Nature Singapore.

Li, Y. Z., Zhang, J. P., Chen, Z. Y., Wang, H. C., Zhang, K. X., Hu, S. S., ... & Dudley, M. (2026, September). Growth and Characterization of High-Quality Thick Epitaxial 4H-SiC Wafers for High Voltage Devices. In Defect and Diffusion Forum (Vol. 452, pp. 79-85). Trans Tech Publications Ltd.

Li, X., Wang, P., Li, G., & Zhang, Y. (2023). Design of a novel self-test-on-chip interface ASIC for capacitive accelerometers. IEEE Transactions on Circuits and Systems I: Regular Papers, 70(7), 2834-2843.

Xiong, S., Chen, T., Rupendra, A., Clement, C., Gasparri, E., & Lucchi, E. (2026). Embodied Carbon of Progressive Timber Integration in a 47-Storey Tropical High-Rise: A Singapore Public Housing Case Study. Building and Environment, 114910.

Yu, A., Huang, Y., Li, S., Wang, Z., & Xia, L. (2023). All fiber optic current sensor based on phase-shift fiber loop ringdown structure. Optics Letters, 48(11), 2925-2928.

Zhang, S., & Yan, W. (2025). In-trainNet: A Two-Step Data-Driven Framework for Enhancing Railway In-Train Forces Monitoring. Advanced Engineering Informatics, 65, 103352.

Luan, S., Wang, P., Zhang, L., He, Y., Huang, X., Jian, G.,... & Fu, Z. (2023). Atmospherically hydrothermal assisted solid-state reaction synthesis of ultrafine BaTiO3 powder with high tetragonality. Journal of Electroceramics, 50 (4), 97-111.

Wang, Y., Lou, M., Liang, W., & Zhang, C. (2023). Numerical and experimental investigation on tensile fatigue performance of reinforced thermoplastic pipes. Ocean Engineering, 287, 115814.

Zhao, R., Tang, J., Zeng, W., Guo, Y., & Zhao, X. (2025). Towards human-like questioning: Knowledge base question generation with bias-corrected reinforcement learning from human feedback. Information Processing & Management, 62(3), 104044.

Zhao, R., Tang, J., Zeng, W., Chen, Z., & Zhao, X. (2024, October). Zero-shot knowledge graph question generation via multi-agent llms and small models synthesis. In Proceedings of the 33rd ACM International Conference on Information and Knowledge Management (pp. 3341-3351).

Yao, Y., Shu, F., Li, Z., Cheng, X., & Wu, L. (2023). Secure transmission scheme based on joint radar and communication in mobile vehicular networks. IEEE transactions on intelligent transportation systems, 24 (9), 10027-10037.

Li, Q., Ye, Q., Zhang, N., Zhang, W., & Hu, F. (2025). Digital-twin-enabled industrial IoT: Vision, framework, and future directions. IEEE Wireless Communications, 32(6), 173-181.

Wang, S., Zhang, X., Wang, P., & Li, X. (2026). Design of Magnetic Sensor Array-Based PUFs for IoT Security. IEEE Transactions on Instrumentation and Measurement, 75, 1-9.

Liang, R., Xu, S., Xie, C., Chen, J., Ren, F., Yang, S., & Yabe, T. (2026). Abstain Mask Retain Core: Time Series Prediction by Adaptive Masking Loss with Representation Consistency. Advances in Neural Information Processing Systems, 38, 99445-99471.

Hu, H., Yang, Y., Zhao, Q., & Zhang, C. (2022, June). On the role of discount factor in offline reinforcement learning. In International conference on machine learning (pp. 9072-9098). PMLR.

Sha, L., Wang, Y., Meng, P., Deng, Y., Chen, T., Zhang, X., ... & Xu, Q. (2025). Pharmacological inhibition of PSPH reduces serine levels and epileptic seizures. Nature Chemical Biology, 21(11), 1742-1753.

Ghosh, R., Jia, X., Yin, L., Lin, C., Jin, Z., & Kumar, V. (2022, November). Clustering augmented self-supervised learning: an application to land cover mapping. In Proceedings of the 30th International Conference on Advances in Geographic Information Systems (pp. 1-10).

Liao, Q., Chen, Y., He, S., Wang, R., Xu, W., & Chu, W. (2025). Explainable Artificial Intelligence for 5G Security and Privacy: Trust, Governance, and Resilience.

Yin, Li, et al. "Targeted NAD+ Delivery for intimal Hyperplasia and Re-endothelialization: a novel anti-restenotic therapy approach." bioRxiv (2024): 2024-02.

Cai, Y., Li, H., Zang, S., Liu, K., Pu, Z., Li, H., ... & Yan, Y. (2026). Theoretical Chemistry Facilitated Understanding of Supramolecular Chirality Regulation by Metal Ions. ACS Materials Letters, 8(2), 621-627.