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Performance Evaluation of IDSL for Tsunami Early Warning Systems at Bungus Port

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Abstract

Indonesia is highly vulnerable to near-field tsunamis due to its tectonic setting along active subduction zones. Rapid detection of sea-level anomalies is therefore critical for the effectiveness of Tsunami Early Warning Systems (TEWS). This study evaluates the performance of an Inexpensive Device for Sea Level (IDSL) installed at Bungus Port, West Sumatra, with particular emphasis on its suitability for real-time tsunami monitoring. The performance assessment includes sea-level measurement accuracy, data gaps, transmission latency, alert functionality, and webcam-based verification. IDSL observations show strong agreement with predicted tidal data from the Geospatial Information Agency (BIG), with a correlation coefficient of 0.98 and a root mean square error (RMSE) of 0.10 m. The average data transmission latency ranges between 3 and 10 seconds, indicating near-real-time capability suitable for early warning applications. Data gaps were generally short (3–5 minutes) and were primarily caused by communication disturbances. Webcam imagery also provided reliable visual validation, with more than 90% of the images classified as good quality. Overall, the results demonstrate that the IDSL system provides reliable, low-latency sea-level monitoring and represents a promising complementary instrument for strengthening Indonesia's TEWS, particularly in tsunami-prone coastal regions.

Keywords—*IDSL, Tsunami Early Warning System, sea level monitoring, latency, tsunami detection*

I. INTRODUCTION

Owing to its location at the convergence of the Eurasian, Indo-Australian, and Pacific tectonic plates, Indonesia is one of the most tsunami-prone countries in the world. Coastal regions facing active subduction zones, particularly along western Sumatra, are exposed to frequent seismic activity capable of generating destructive tsunamis (Sieh & Natawidjaja et al., 2000; Subarya et al., 2006). Historical events have shown that near-field tsunamis in this region can reach coastal communities within tens of minutes, leaving limited time for evacuation and emergency response. Effective early tsunami warning systems must rely not only on rapid earthquake detection but also on real-time sealevel observations to confirm tsunami generation and improve warning reliability (Lauterjung et al., 2017). The western coast of Sumatra, the southern coast of Java, Nusa Tenggara, northern Papua, Sulawesi, Maluku, and parts of eastern Kalimantan are vulnerable coastal regions in Indonesia (BMKG, 2012).

West Sumatra is one of the most susceptible Indonesian provinces to earthquake and tsunami hazards (Sandy, 2018). The offshore region is characterized by high seismicity associated with the Sunda Subduction System, where the Indo-Australian Plate converges beneath the Eurasian Plate (Yudichara et al., 2010). The distribution of earthquake epicenters shows increasing focal depths toward the east, reflecting the subducting slab's geometry (Natawidjaja et al., 2006). Geological evidence from coral microatolls further indicates that past megathrust earthquakes have generated significant vertical seafloor deformation, producing tsunamis that impacted the western coast of Sumatra and the Mentawai Islands (Natawidjaja & Triyoso, 2007). These characteristics highlight the importance of reliable coastal monitoring systems capable of detecting tsunami-associated rapid sea-level anomalies.

Despite significant technological progress, the exact timing of earthquakes and tsunami generation remains inherently unpredictable. Therefore, disaster risk reduction efforts primarily focus on minimizing potential impacts through effective monitoring and early warning mechanisms (Nanang, 2000; Baeda, 2010). Arrival times for nearfield tsunamis may be less than 30 minutes after the triggering earthquake, requiring extremely rapid dissemination of early warning information to support timely evacuation procedures (Husrin et al., 2013). In Indonesia, the Geospatial Information Agency (BIG) tide gauge network largely supports coastal sea-level monitoring. Although conventional tide gauges provide reliable long-term sea-level observations, their sampling intervals and transmission latency may limit their ability to detect rapid sea-level changes associated with near-field tsunamis. Furthermore, the spatial density of monitoring stations in several high-risk coastal regions remains limited.

To address these limitations, additional real-time monitoring technologies must complement the existing tsunami observation networks. The Inexpensive Device for Sea Level (IDSL), developed by the Joint Research Center of the European Commission, is designed to provide high-frequency sea-level measurements with automated anomaly detection and rapid data transmission (Annunziato et al., 2019). Its relatively low cost and autonomous operation enable deployment in remote or underserved coastal areas, supporting the development of denser monitoring networks. Since 2019, IDSL sensors have been installed at eight locations across West Sumatra and southern Java since 2019 (Husrin et al., 2022). However, despite their increasing deployment, comprehensive evaluations of IDSL operational performance under real-world coastal conditions remain limited.

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Therefore, this study aims to evaluate the operational performance of the IDSL instrument deployed at Bungus Port (IDSL 305), West Sumatra (Figure 1) and assess its suitability as a supporting component of Indonesia's tsunami early warning infrastructure. Through integrated webcam observations, the evaluation focuses on key operational parameters, including measurement accuracy, data transmission latency, data reliability, alert system behavior, and visual verification capability. The results of this study provide important insights into the potential role of low-cost realtime sea-level monitoring systems in strengthening early warning capabilities in Indonesia's tsunami-prone coastal regions.

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II. RESEARCH METHOD

The analysis focuses on the IDSL-305 station located at Bungus Port, Padang City, West Sumatra, Indonesia. Operational since August 1, 2020, the instrument facilitates continuous coastal monitoring by capturing highresolution sea-level data at precise 15-second intervals. These empirical datasets were systematically retrieved from the centralized IDSL monitoring server (https://webcritech.jrc.ec.europa.eu/TAD_server/Device/483) to conduct a detailed performance analysis covering the initial observation period from August 1 to August 31, 2020. The evaluation encompasses a multifaceted assessment protocol, which includes validating the accuracy of the sea-level measurements, analyzing data continuity through gap identification to determine operational reliability, assessing data transmission latency, verifying the responsiveness of the automated alert system, and evaluating the integrated webcam imagery for visual validation. The location of the IDSL-305 installation can be seen in Figure 1.

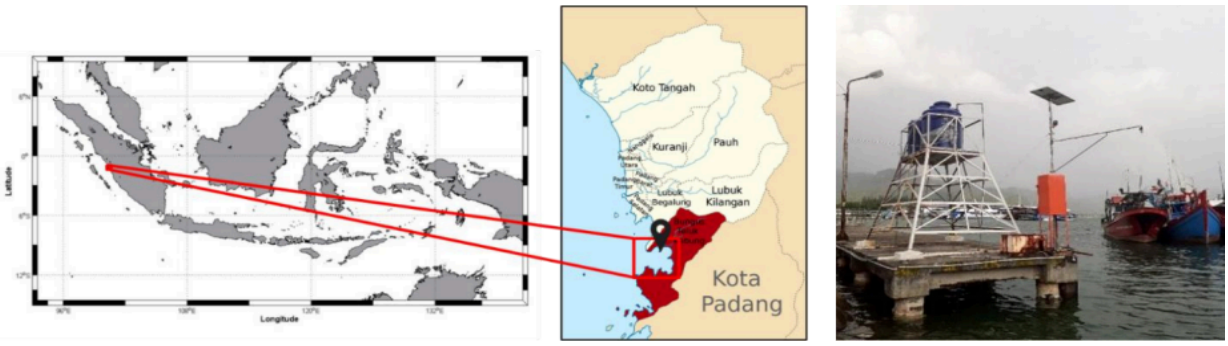

Figure 1 IDSL-305 installation location

To rigorously ascertain the observational accuracy of the IDSL-305 station, the recorded sea-level measurements were validated against authoritative tidal prediction data sourced from the Indonesian Geospatial Information Agency (Badan Informasi Geospasial, BIG). The statistical robustness of this validation was subsequently quantified utilizing established metrics, specifically the Correlation Coefficient (CC) to measure the strength of the linear relationship, the Root Mean Square Error (RMSE) to evaluate the standard deviation of the measurement errors, and the Mean Absolute Percentage Error (MAPE) to determine the overall measurement precision relative to the predicted models.
The statistical metrics were calculated using the following equations:

$$CC = \frac{\sum_{i=1}^{N}(x_i - x)(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i - x)^2 \sum_{i=1}^{N}(y_i - \bar{y})^2}} \quad (1)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(y_i - x_i)^2}{N}} \quad (2)$$

$$MAPE = \frac{1}{N}\sum_{i=1}^{N}\left|\frac{y_i - x_i}{y_i}\right| \times 100\% \quad (3)$$

Where:

n : the number of data

i : data order

X_i : model data

y_i : obsrvasi data

: mean ofmodel data

y : average observation data

III. RESULTS AND DISCUSSION

The analysis focuses on the IDSL-305 station located at Bungus Port, Padang City, West Sumatra, Indonesia. Operational since August 1, 2020, the instrument facilitates continuous coastal monitoring by capturing highresolution sea-level data at precise 15-second intervals. These empirical datasets were systematically retrieved from the centralized IDSL monitoring server (https://webcritech.jrc.ec.europa.eu/TAD_server/Device/483) to conduct a detailed performance analysis covering the initial observation period from August 1 to August 31, 2020. The evaluation encompasses a multifaceted assessment protocol, which includes validating the accuracy of the sea-level measurements, analyzing data continuity through gap identification to determine operational reliability, assessing data transmission latency, verifying the responsiveness of the automated alert system, and evaluating the integrated webcam imagery for visual validation. The location of the IDSL-305 installation can be seen in Figure 1.

A. Writing Format

The paper size must conform to A4 dimensions, i.e., 210 mm (8.27") in width and 297 mm (11.69") in height. The margin settings are as follows:

- Top = 20 mm
- Bottom = 20 mm
- Left = Right = 15 mm

Paragraphs must be well organized. All paragraphs must be justified, meaning aligned evenly on both the left and right margins.

B. Number of Pages

The maximum length of a paper submitted to the * Indonesian Journal of Coastal & Ocean Engineering* is 15 pages.

C. Document Fonts

The entire document must be written in Times New Roman. Other font types may be used if necessary for special purposes.

D. Title and Authors

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The title must be in Regular 20 pt font. Author names must be in Regular 11 pt font. Author affiliations must be in Italic 10 pt font. Email addresses must be in Regular 9 pt font.

The title and author names must be formatted in a single column and centered. Each word in the title must begin with a capital letter, except for short words such as “a,” “and,” “in,” “by,” “for,” “from,” “on,” “or,” and similar words.

Author names must not include job titles (e.g., Academic Advisor), academic degrees (e.g., Dr.), or membership in professional organizations (e.g., Senior Member HAKI).

An email address is mandatory for the corresponding author. The designation as corresponding author must be written after the email address.

E. Heading Sections

It is recommended that headings not exceed three levels. All text must use a 10 pt font. Each word in a heading title must begin with a capital letter, except for short words.

1. **Heading Level-1:** Level-1 headings must be in Small Caps, centered, and numbered using uppercase Roman numerals.
2. **Heading Level-2:** Level-2 headings must be italicized, left-aligned, and numbered using uppercase letters. For example, see the heading “E. Heading Sections” above.
3. **Heading Level-3:** Level-3 headings must be indented, italicized, and numbered using Arabic numerals followed by a closing parenthesis. Level-3 headings must end with a colon. The text continues on the same line as the heading.

F. Figures and Figure Captions

Figures must be centered. Large figures may span both columns. Any figure that spans more than one column in width must be placed either at the top or the bottom of the page. Figures must not have borders outside the image area.

Graphs may be presented in color. For colored graphs, ensure that the colors are sufficiently contrasted to distinguish one line from another. For black-and-white graphs, use different line styles (e.g., solid lines, dashed lines, dotted lines, etc.).

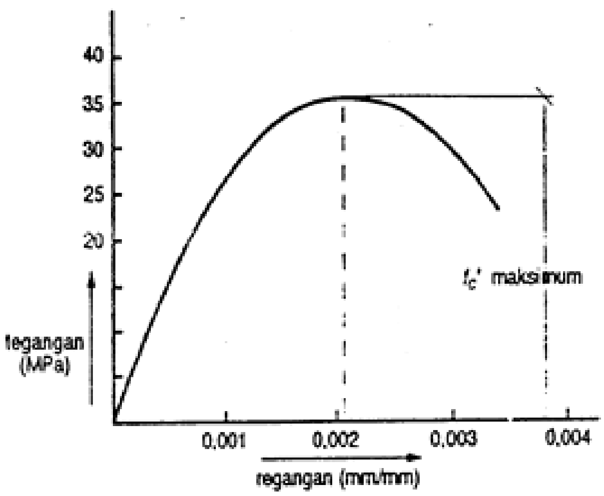

Figure 1. Example of a line graph using black and white. Note the writing of labels and units on the horizontal and vertical axes.

Label pada sumbu horisontal maupun vertikel sering kali dapat membingungkan. Oleh karena itu sedapat mungkin gunakan kata-kata, dan bukan hanya simbol. Berikan satuan di dalam tanda kurung, namun penulisan label jangan hanya berupa satuan tanpa keterangan secukupnya. Contoh penulisan label yang tepat adalah ”Tegangan (MPa)” atau ”Tegangan, σ_{max} (MPa)”. Contoh penulisan label yang keliru adalah ”σ_{max}” atau ”(MPa)”. Gunakan font yang konsisten dan seragam pada grafik. Font yang disarankan adalah Times New Roman (atau Times), Arial (atau Helvetica), Symbol dan Courier. Contoh grafik dapat dilihat pada Gambar 1.

Pastikan bahwa resolusi gambar cukup untuk mengungkapkan rincian penting pada gambar tersebut. Untuk gambar yang bersumber dari file JPG, pastikan mempunyai resolusi sebesar 300 dpi. Gambar 2 menunjukkan contoh sebuah gambar dengan resolusi rendah yang kurang sesuai ketentuan, sedangkan Gambar 3 menunjukkan contoh dari sebuah gambar dengan resolusi yang memadai.

Keterangan gambar diletakkan di bagian bawah gambar. Keterangan gambar menggunakan 8 - 11 pt Reguler font (ukuran font dapat disesuaikan) dan diberi nomor dengan menggunakan angka Arab. Keterangan gambar dalam satu baris (misalnya Gambar 2) diletakkan di tengah (*centered*), sedangkan keterangan gambar yang lebih dari satu baris harus dirata kiri (misalnya Gambar 1). Keterangan gambar dengan nomor gambar harus ditempatkan sesuai dengan poin-poin yang relevan, seperti ditunjukkan pada Gambar 1 – 3, kecuali jika gambar berukuran besar melebihi satu kolom.

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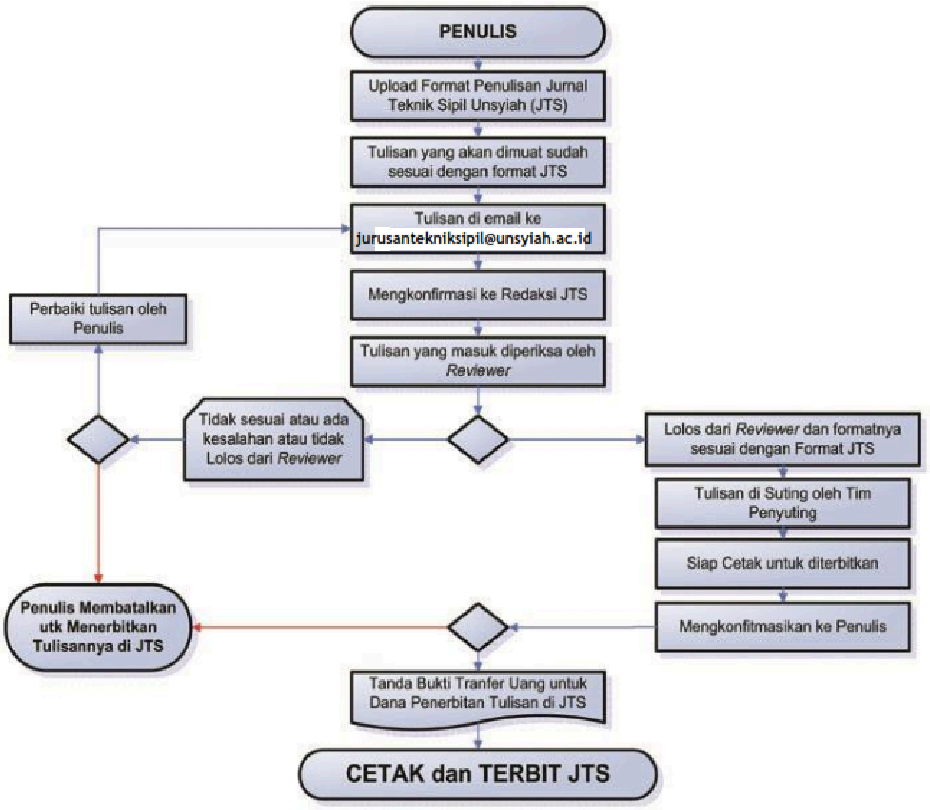

Figure 2. Example of an image with sufficient and clear resolution.

A. Tabel dan Keterangan Tabel

Tabel harus diletakkan di tengah (*centered*). Tabel yang besar bisa direntangkan di kedua kolom atau diputar menjadi vertikal. Setiap tabel atau gambar yang mencakup lebih dari 1 kolom lebar harus diposisikan baik di bagian atas atau di bagian bawah halaman.

Tabel dan judul tabel ditulis dengan font 8 - 11 pt Reguler (ukuran font dapat disesuaikan). Tabel diberi nomor menggunakan nomor angka huruf besar. Setiap awal kata dalam judul tabel menggunakan huruf besar kecuali untuk kata-kata pendek seperti yang tercantum pada Bagian III-D, dan ditulis menggunakan Small Caps. Keterangan angka tabel ditempatkan sebelum tabel terkait. Isi tabel ditulis rata tengah. Perhatikan bahwa pada tabel tidak terdapat garis vertikal. Contoh tabel dapat dilihat di Tabel 1.

Table 1. Example of a table of results of calculating wind stress factor values *(U_A)*

Tahun	**Waktu**	***WindSpd (m/s)***	**U10**	**(U) stabilitas**	**Lokasi (Uw)**	**Ua**
2014	0	1.96	1.96	2.16	4.32	1.83
2014	1	2.15	2.15	2.37	4.73	2.05
2014	2	1.46	1.46	1.60	3.20	1.27
2014	3	0.36	0.36	0.39	0.78	0.22

Tahun	Waktu	*WindSpd (m/s)*	U10	(U) stabilitas	Lokasi (Uw)	Ua
2014	4	0.87	0.87	0.96	1.92	0.67
2014	5	1.97	1.97	2.17	4.34	1.84
2014	6	3.22	3.22	3.54	7.08	3.36
2014	7	4.32	4.32	4.75	9.50	4.83
2014	8	4.75	4.75	5.22	10.45	5.42
2014	9	4.53	4.53	4.99	9.98	5.12
2014	10	3.28	3.28	3.60	7.21	3.44
2014	11	1.57	1.57	1.73	3.46	1.40
2014	12	0.62	0.62	0.68	1.36	0.44
2014	13	0.37	0.37	0.40	0.81	0.23
2014	14	0.54	0.54	0.59	1.18	0.37
2014	15	1.39	1.39	1.53	3.06	1.20
2014	16	2.38	2.38	2.62	5.24	2.32
2014	17	3.06	3.06	3.37	6.74	3.16
2014	18	3.46	3.46	3.81	7.62	3.68

(*Source :…………………..)*

Catatan : Jika Tabel tidak mencukupi / terpotong, tabel bisa diletakkan dihalaman tersendiri dalam satu kolom setelah daftar referensi.

A. Persamaan

Persamaan ditulis rata tengah. Gunakan *Microsoft Equation Editor* atau *MathType add-on*. Jangan *copy paste* persamaan dari file lain yang berbentuk pdf atau jpg. Penomoran persamaan ditulis rata kanan dengan angka arab di dalam tanda kurung. Contoh penulisan persamaan dapat dilihat di Persamaan (1) berikut ini.

$$\gamma = \frac{2\pi}{\lambda} \frac{n_2}{A} \quad (1)$$

Gunakan ukuran (*size*) berikut ini pada *Microsoft Equation Editor*:

- Full : 10 pt
- Subscript/Superscript : 5 pt
- Sub-subscript/superscript : 3 pt
- Symbol : 16 pt
- Sub-symbol : 10 pt

B. Nomor Halaman, Headers dan Footers

Nomor halaman, headers dan footers tidak dipakai.

C. Tautan dan Bookmark

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Semua tautan *hypertext* dan bagian *bookmark* akan dihapus. Jika paper perlu merujuk ke alamat email atau URL di artikel, maka alamat atau URL lengkap harus ditulis dengan font biasa.

D. Referensi

Setiap dokumen/pustaka yang disitasi di paper ini harus dituliskan di bagian ini. Jumlah pustaka yang disitasi minimal 15 buah, dengan 80% berupa acuan primer. Yang dimaksud dengan acuan primer adalah artikel jurnal, *book chapter*, paten, paper seminar/prosiding. Adapun yang dimaksud dengan acuan sekunder adalah buku teks dan *handbook*.

Judul pada bagian Referensi tidak boleh bernomor. Semua item referensi dalam 8 pt font. Silakan gunakan Italic Reguler dan gaya untuk membedakan berbagai bidang seperti ditunjukkan pada bagian Referensi.

IV CONCLUSION

The conclusion contains the main points of the article. It should not repeat what has been written in the abstract, but rather discuss the key findings, applications, and potential developments of the research conducted. This section should also indicate whether the research objectives have been achieved.

The conclusion should be written in descriptive paragraph form. Avoid using bulleted lists.

ACKNOWLEDGMENT

This section expresses appreciation to individuals or organizations who have provided assistance to the author. Acknowledgements to sponsors or financial support are also included in this section.

REFERENCE

The cited references are written using the Harvard referencing system, in which citations are listed in alphabetical order in the reference section. Meanwhile, in the body of the text, citations are written in parentheses. The content of the text includes the author's surname, year of publication, and page number if necessary. For example, in the body of the text it is written as (Kumar, Baliarsingh and Raju, 2010), then in the reference section it is written as:

Kumar, D. N., Baliarsingh, F., dan Raju, K., S., (2010). Extended Muskingum method for flood routing.

Boon, S., Johnston, B. and Webber, S., 2007. A phenomenographic study of English faculty's conceptions of information literacy. *Journal of Documentation*, [e-journal] 63(2), pp.204 - 228. http://dx.doi.org/10.1108/00220410710737187.

Wang, Z. Joseph H.W. Lee and Mengzhen Xu. 2012. Ecohydrolic and eco-sedimentation studies in China. *Jornal of Hydrolic Research* [e-Journal] 51(1), pp.55-62. doi:10.1080/00221686.2012.753554