OSDATUM Report

MANUAL FOR TIDAL DATA PROCESSING AND DATUM COMPUTATION: METHODOLOGY AND JUSTIFICATION

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CONTENTS

PREFACE

This report is intended to serve as a user's manual to the OSDATUM website. In addition to describing the input and output of all the data on the platform, the report gives an outline of the methods used.

Users who wish to receive updates of these programs and manual should send their names, needs, and recommendations to the author.

ACKNOWLEDGEMENTS

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1 USE OF VERTICAL DATUM AT OSES-ONWJ

The use of vertical datum in the OSES-ONWJ (Offshore Southeast Sumatra – Offshore Northwest Java) operational area is primarily intended to support offshore construction and infrastructure planning. Vertical datum serves as a crucial reference for determining accurate elevations and depths in marine environments. In offshore construction projects, such as the installation of oil and gas platforms or subsea pipelines, the correct use of a vertical datum ensures that structures are aligned properly with sea level references, minimizing the risk of errors related to depth miscalculations or environmental impacts.

One of the main applications of vertical datum is in hydrographic and geodetic surveys. These surveys rely on precise elevation data to map the seabed, which is essential for determining suitable locations for underwater construction. Vertical datum, such as Mean Sea Level (MSL), provides the standard baseline from which bathymetric data are reduced. Without a consistent datum, the interpretation of water depth or seafloor topography may lead to errors that affect the safety and efficiency of marine operations.

The OSDATUM website platform is designed to incorporate an integrated datum system, providing features such as a datum visualization to support decision-making in marine construction and operational planning.

2 TIDAL DATA PROCESSING AT OSES-ONWJ

2.1 Methodology Overview

The determination of tidal datum is a critical component in offshore vertical positioning, requiring precise and long-term tidal data. The following methodology outlines the steps undertaken to process tidal data for datum computation in the OSDATUM platform, emphasizing data accuracy, correction mechanisms, and scientific justifications.

According to the standards set by the National Oceanic and Atmospheric Administration (NOAA), a tidal datum should be computed from at least a 19-year tidal record, known as the National Tidal Datum Epoch (NTDE), to capture the full range of astronomical tidal cycles, including nodal variations (NOAA, 2000). To generate this long-term dataset, harmonic constants of tidal constituents extracted from the TPXO global tidal model is utilized, specifically TPXO Indian Ocean Atlas (1/12^{o} regional model).

TPXO is a global barotropic tidal model developed at the Oregon State University (Egbert & Erofeeva, 2002). This model is widely recognized in ocean modelling and research communities for its balance between global coverage and accuracy. The TPXO version used is the TPXO Indian Ocean Atlas (1/12^{o} resolution). This model utilizes 11 main harmonic constituents (M2, S2, N2, K2, K1, O1, P1, Q1, M4, MS4, and MN4).

Table 2.1 Main tidal constituent description

Tidal Constituents Type	Tidal Constituent	Origin	Period (hours)
Semidiurnal	M_2	Principal lunar	12,42
	S_2	Principal solar	12,00
	N_2	Lunar elliptical	12,66
	K_2	Lunar-solar declinational	11,97
Diurnal	K_1	Lunar-solar declinational	23,93
	O_1	Principal lunar	25,82
	P_1	Principal solar	24,07
	Q_1	Lunar elliptical	26,87
Shallow-water overtide	M_4	Nonliner interaction of M_2 with itself	6,21
Shallow-water compound tide	MS_4	Interaction between M_2 and S_2	6,10
	MN_4	Interaction between M_2 and N_2	6,27

Due to the absence of 19 years of field data at our project sites, OSES-ONWJ, tidal data are generated starting from 2006 to 2024 using UTide. The generated data is used as a base for the vertical datum calculation. However, to emphasize, field-observed tidal data remains the most reliable source. Therefore, 19-year generated outputs in other regions were corrected using reference field data. Figure 2.1 outlines the tidal data processing methodology.

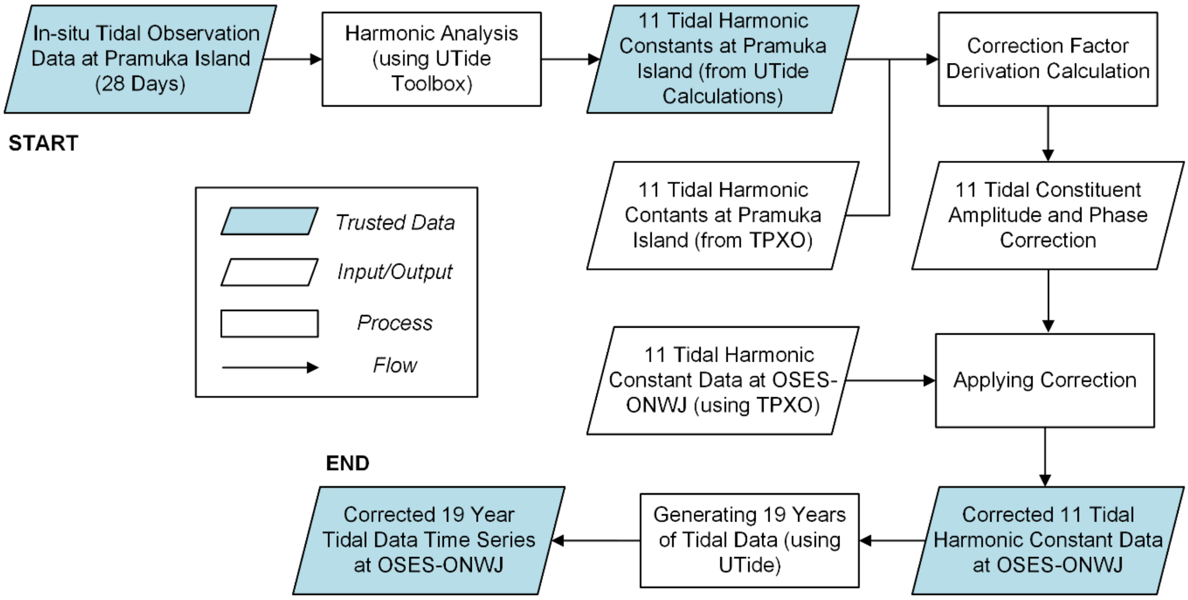


Figure 2.1 Tidal data processing methodology outline

2.2 Field Observation Tidal Data Processing

To correct the TPXO model predictions, a 28-day field tidal observation was conducted from May to June 2024 using the LUWES (Live Uninterrupted Water Elevation Sensor), a locally developed tide gauge system designed for high-frequency sea level monitoring. LUWES is equipped with a pressure sensor that records water level changes with a temporal resolution of one minute, suitable for capturing fine-scale tidal fluctuations. This 28-day observation period is consistent with established practices in tidal analysis, where a minimum of 15-day tidal data is required to resolve major diurnal (e.g., K1, O1) and semidiurnal (e.g., M2, S2) tidal constituents through short-term harmonic analysis (Byun & Hart, 2015).

The field data processing consisted of two major steps:

- Manual Data Cleaning: In this step, visual inspection and statistical checks were employed to identify and remove outliers, anomalous spikes, and discontinuities. Manual cleaning, although labour-intensive, ensures the fidelity of the resulting raw data.
- Temporal Averaging: The LUWES sensor records tidal height every minute. However, the TPXO model outputs are available at hourly intervals. To allow for consistent comparison and further harmonic analysis, the 1-minute field data was resampled to hourly intervals by averaging the sea levels for each hour.

These processing steps ensure that the field data is clean, consistent, and directly comparable with the TPXO model outputs, forming a reliable basis for subsequent tidal correction and calibration procedures.

2.3 Tidal Data Correction

To calibrate 28-day UTide model predictions, a two-step correction procedure was implemented, based on comparison with field-based observations. This approach ensures that long-term tidal predictions align closely with actual tidal behaviour measured on site.

- Harmonic Analysis Using UTide: As the initial step, a site-specific tidal prediction was generated at the LUWES sensor location using UTide, a harmonic analysis toolbox developed in MATLAB (Codiga, 2011). UTide performs least-squares tidal analysis and prediction by decomposing observed water levels into their tidal constituents. The LUWES 28-day tidal record was analyzed to extract 11 major tidal constituents, including M2, S2, N2, K2, K1, O1, P1, Q1, M4, MS4, and MN4; these constituents were chosen to align with the contituents extracted from TPXO. Matching constituent sets is essential to ensure consistency during comparative and correction stages.
- Validation of Harmonic Fit: The predicted tidal model generated by UTide was then statistically compared with the original LUWES observations. The Root Mean Square Error (RMSE) between the UTide output and the raw field data was calculated as 0.0559 meters, which indicates a high degree of fidelity. This low error value confirms that the UTide harmonic reconstruction effectively captures the observed tidal dynamics, justifying its use as a reliable proxy or “ground truth” for further comparison with TPXO model outputs.

Table 2.2 Tidal constituent amplitude and phase correction

Tidal	**UTide**		**TPXO**		**Calculation**		**Correction**	
Constituent	Amplitude	Phase	Amplitude	Phase	ΔA	ΔΦ	Amplitude	Phase
K1	0,261	14	0,2645	34,18	-0,0035	-20,18	0,261	14
O1	0,129	15	0,1374	22,3	-0,0084	-7,3	0,129	15
S2	0,0498	46,6	0,0363	92,88	0,0135	-46,28	0,0498	46,6
M2	0,0345	153	0,0209	194,01	0,0136	-41,01	0,0345	153
Q1	0,033	6,9	0,034	11,55	-0,001	-4,65	0,033	6,9
N2	0,0159	83	0,0057	92,8	0,0102	-9,8	0,0159	83
P1	0,0101	100	0,0751	30,05	-0,065	69,95	0,0101	100
MS4	0,00953	109	0,0014	202,82	0,00813	-93,82	0,00953	109
K2	0,00867	57,9	0,0087	48,99	-0,00003	8,91	0,00867	57,9
M4	0,00462	46,6	0,0011	130,36	0,00352	-83,76	0,00462	46,6
MN4	0,0012	79,3	0,0002	132,25	0,001	-52,95	0,0012	79,3

The second phase involved calibrating the TPXO data using the harmonically derived field reference (UTide prediction):

- Extraction of Model Data at Reference Point: TPXO model outputs for the same time period (May–June 2024) were extracted at the LUWES sensor coordinates. These data represent the uncorrected model prediction and serve as the baseline for identifying deviations from local tidal behaviour.
- Constituent-wise Comparison and Correction Factor Derivation: For each of the 11 tidal constituents, a comparison was conducted between TPXO-predicted amplitudes and phases and those derived from UTide analysis. This yielded two correction factors for each constituent:

$$\text{(Amplitude Correction) } \Delta A = A_{\text{UTide}} - A_{\text{TPXO}} \qquad ...(1)$$

$$\text{(Phase Correction) } \Delta\Phi = \Phi_{\text{UTide}} - \Phi_{\text{TPXO}} \qquad ...(2)$$

  These deltas quantify the local discrepancies in tidal constituents representation by the TPXO model, capturing both systematic underestimation or overestimation of wave heights and shifts in the timing of tidal events.
- Application of Correction Factors to Long-Term Data: The correction factors (ΔA and ΔΦ) were subsequently applied to harmonic constants at other geographic locations within the project domain (OSES-ONWJ). This step assumes spatial continuity in the nature of TPXO modelling errors across nearby coastal regions, an assumption constrained by the lack of spatially distributed in-situ data.

By aligning TPXO predictions with calibrated, field-informed corrections, this method significantly enhances the reliability of tidal data used for datum computation. It ensures that estimates are grounded in empirical observations, even in areas lacking direct measurements, thereby improving the integrity of long-term tidal analysis across the study region.

2.4 Predicted and Used Tidal Data

Using the corrected 11 tidal constituents—extracted from TPXO, 19-year modelled tidal data (2006–2024) was predicted for each selected geographic location using UTide. These geographic locations—included in Appendix 1 and Appendix 2—designated as centroids, represent the centers of grid cells that define the spatial boundaries for vertical datum computation. Each grid cell measures approximately 9,25 × 9,25 km, corresponding to the spatial resolution of the TPXO model (1/12°).

3 DATUM COMPUTATION AT OSES-ONWJ

The calculation of tidal datums within the OSDATUM platform is conducted using two primary data components: (1) a structure array of computed harmonic constituents derived from harmonic analysis, and (2) a continuous time series of predicted water levels from 2006 to 2024, interpolated at regular intervals. These datasets serve as the foundation for both constituent-based and peak-based tidal datum computations, as implemented using the Tide Peaks Toolbox in Matlab, developed by the University of Tasmania (Palmer et al., 2023).

For this project, five vertical datums are selected: Mean Sea Level (MSL), Highest Astronomical Tide (HAT), Lowest Astronomical Tide (LAT), Mean High Water Springs (MHWS), and Mean Low Water Springs (MLWS). These datums were chosen to align with those published by Indonesia's *Badan Informasi Geospasial* (BIG), facilitating the validation of results by enabling direct comparison with established national references.

An outline on the vertical datum calculation is illustrated in Figure 3.1.

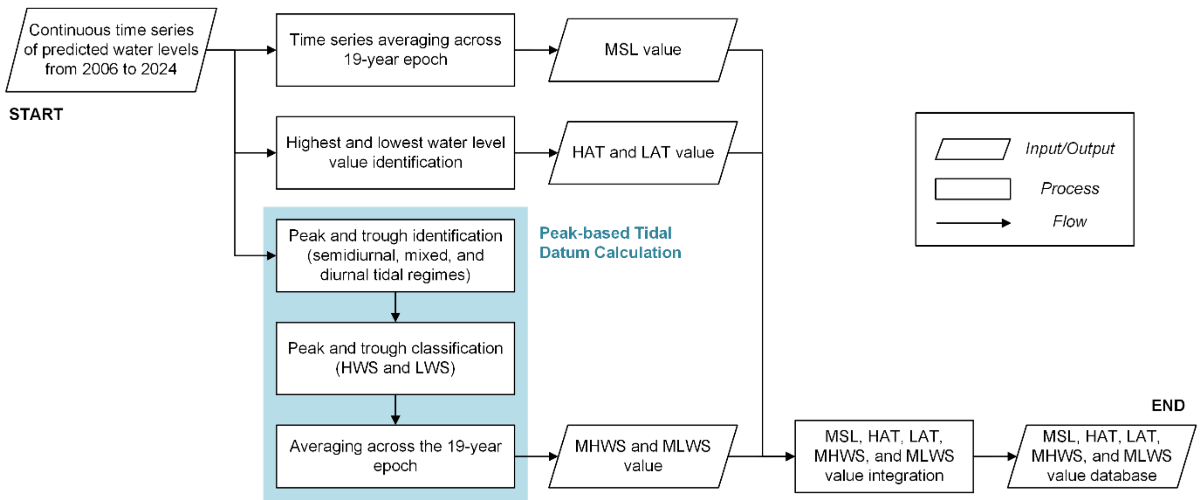


Figure 3.1 Vertical datum data processing methodology outline

The Tide Peaks Toolbox supports two methodological pathways for datum computation: constituent-based datums and peak-based tidal datum calculation. Constituent-based datums represent a proxy for the lunar and solar influences on water levels, peak-based datums represent the average heights of standard tidal cycles statistically. Each specific datum has its own calculation, as seen in

Table *3.1*.

Table 3.1 Used datum definition and calculation method

Tidal Datum	Definition	Calculation Method
MSL	Mean Sea Level	Averaging data [Z_0]
HAT	Highest Astronomical Tide	Identifying highest water level value
LAT	Lowest Astronomical Tide	Identifying lowest water level value
MHWS	Mean High Water Springs	Peak-based tidal datum calculation
MLWS	Mean Low Water Springs	Peak-based tidal datum calculation

The peak-based tidal datums are derived statistically from the predicted water level time series. The toolbox identifies all high and low water events (peaks and troughs) and classifies them by tidal cycle type (High Water Springs (HWS) and Higher High Water (HHW) peaks, and Lower Low Water (LLW) and Low Water Springs (LWS) troughs). Each datum is then calculated as the average height of its respective classified events over the selected time period. This method accounts for temporal variability and tidal asymmetry, offering a more empirical representation of tidal behavior.

The final output results in a robust set of tidal datums that serve as vertical references for hydrographic surveying, offshore construction, and sea-level monitoring across the OSES-ONWJ region.

4 TIDAL AND DATUM QUALITY

4.1 Tidal Prediction Testing Method

In the evaluation of tidal prediction data, calculations of Root Mean Square Error (RMSE) and the coefficient of determination were conducted. RMSE is a method used to measure the accuracy level of a prediction (Ruswanti, 2020). The closer the RMSE value is to zero, the more accurate the prediction results. Mathematically, RMSE is defined as follows, with “n” representing the number of data points.

$$\mathrm{RMSE}=\sqrt{\frac{\sum_{i=1}^{n}(\text{Observation data}-\text{Predicted data})^2}{n}} \qquad ...(3)$$

Meanwhile, the coefficient of determination indicates the extent to which the predicted data varies in relation to the observed data. It is used to evaluate how well the prediction results follow the observed data. Mathematically, the coefficient of determination is defined as follows, with “n” representing the number of data points.

$$R^2=\left(\frac{n(\sum xy)-(\sum x)(\sum y)}{\sqrt{n\sum x^2-(\sum x)^2}\times\sqrt{n\sum y^2-(\sum y)^2}}\right)^2 \qquad ...(4)$$

With, x as observation data and y as predicted data

4.2 Tidal Prediction Testing Results

The tidal prediction data will be compared with observational data from Pramuka Island. The observational data used consists of 28 days of measurements collected between May 5, 2024, and June 1, 2024. The tidal prediction assessment was conducted at the coordinates shown in Table 4.1.

Table 4.1 Tidal station coordinates at Pulau Pramuka

Point	Tidal Station at Pramuka Island
Latitude	-5 ° 44’38,56701”
Longitude	106 ° 36’46,24227”

The results of the prediction for the period from May 5 to June 1, 2024, are presented in Figure 4.1, which displays a comparison between the observational data and the model prediction. Visually, the graph demonstrates that the model is capable of replicating the tidal patterns reasonably well, consistently following the rise and fall of sea level fluctuations.

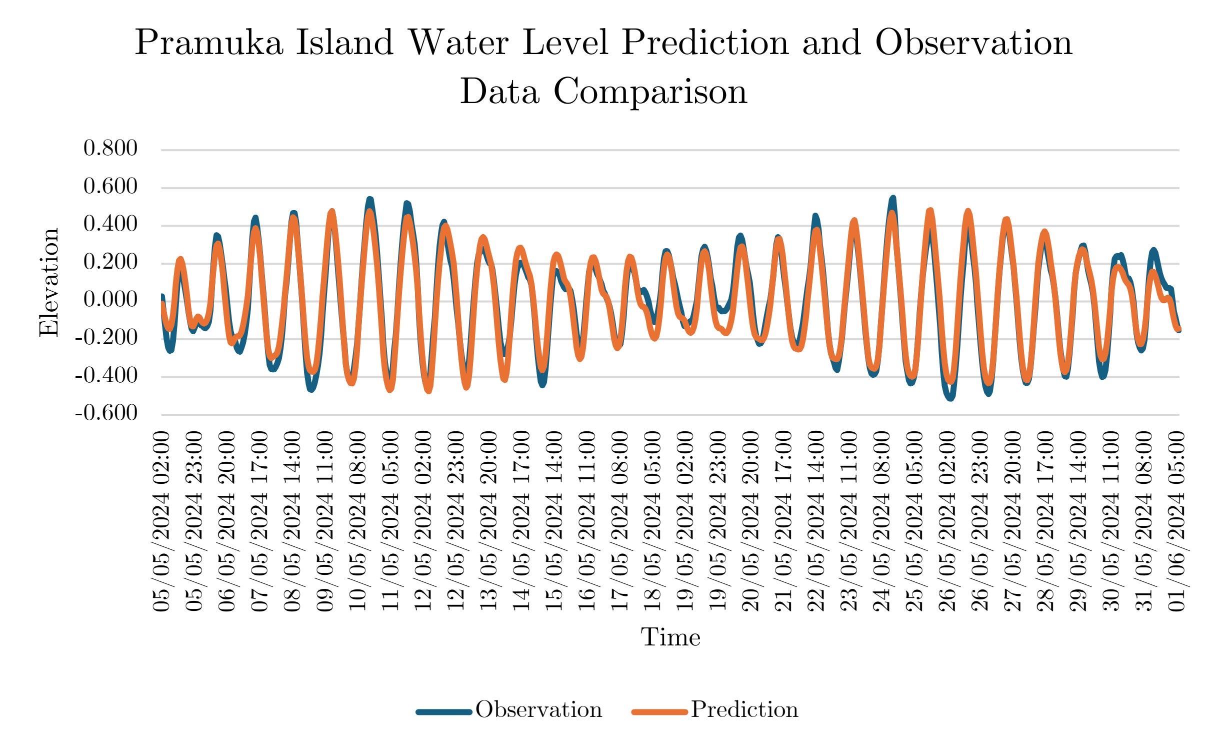


Figure 4.1 Pramuka Island water level prediction and observation data comparison

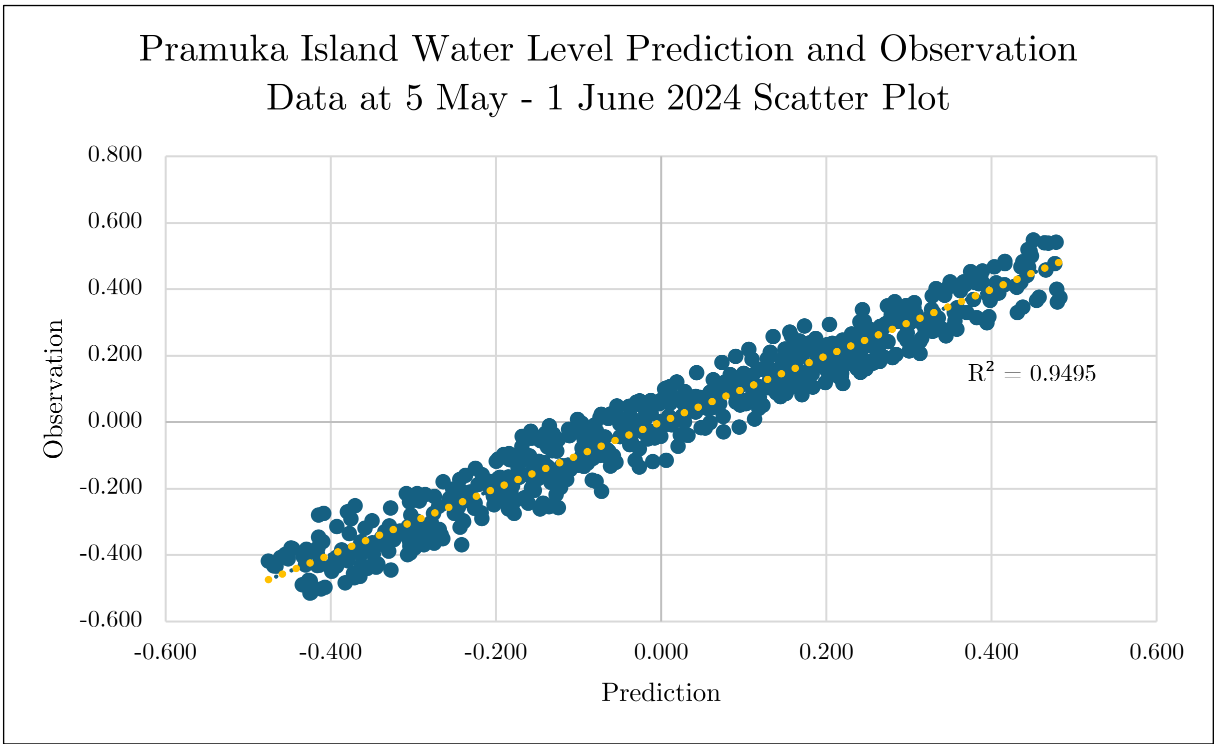


Figure 4.2 Pramuka Island water level prediction and observation data scatter plot

The RMSE value of 0.056 meters indicates a relatively low prediction error. Meanwhile, the R^2 value of 0.9495 suggests that 94.95% of the variation in the observational data is explained by the model prediction. These results indicate that the prediction performs well and is reliable in representing tidal dynamics during the observed period.

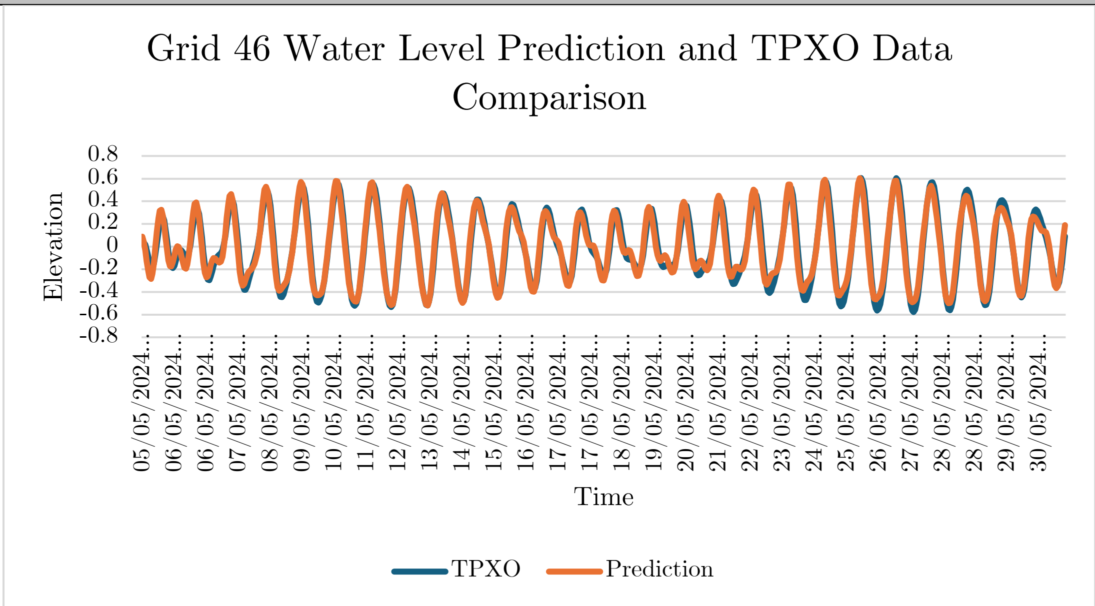
In predicting tides within the OSES-ONWJ region, a validation process was conducted to assess tidal patterns across different tidal regimes. The validation was performed by comparing the prediction results against the TPXO model as a reference. Testing was carried out at sampled locations with coordinates as listed in Table 4.2.

Table 4.2 Tidal prediction data results testing coordinates sample

ID	Distance from Pramuka Island Station (km)	Latitude	Longitude	Tidal Type
46	84.918	-5.003	106.412	Diurnal
138	97.065	-5.878	107.479	Mixed Diurnal Dominant
191	222.202	-6.206	108.566	Mixed Semidiurnal Dominant

Table 4.3 shows that the prediction results are able to follow the tidal patterns in each regime, with varying R-squared values. This variation indicates the degree of agreement between the predicted data and the TPXO model, which is influenced by the distance between the grid points and the Pramuka Island Tide Station. The farther a location is from the Pramuka Tide Station, the lower the prediction accuracy tends to be.

Table 4.3 Testing results in sampled coordinates

<table>
<tr><th>ID</th><th>Comparison Results</th></tr>
<tr><td>46</td><td>


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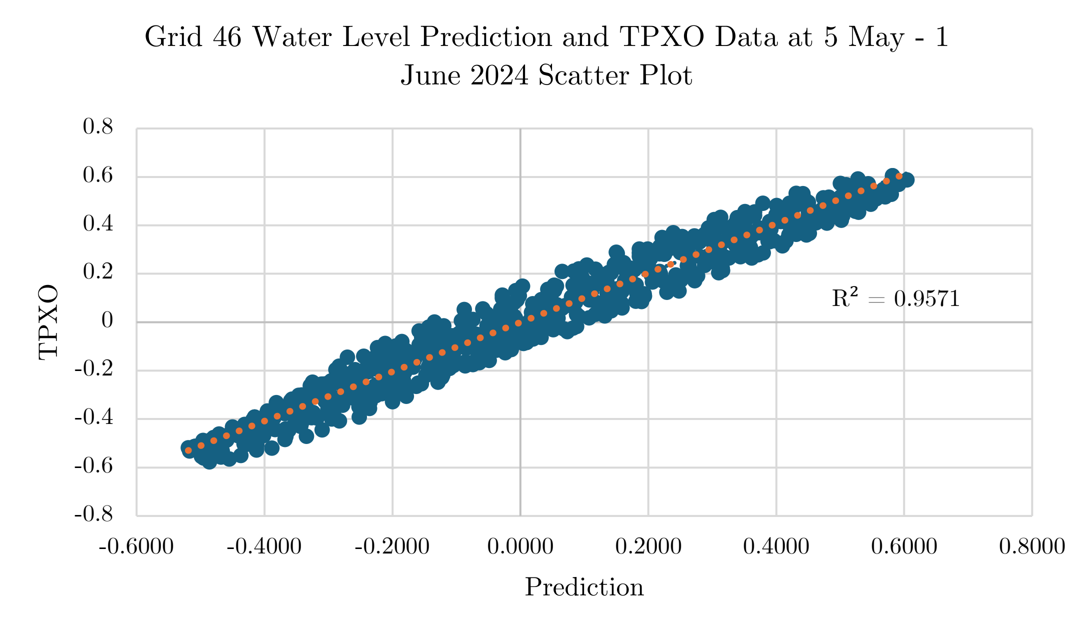
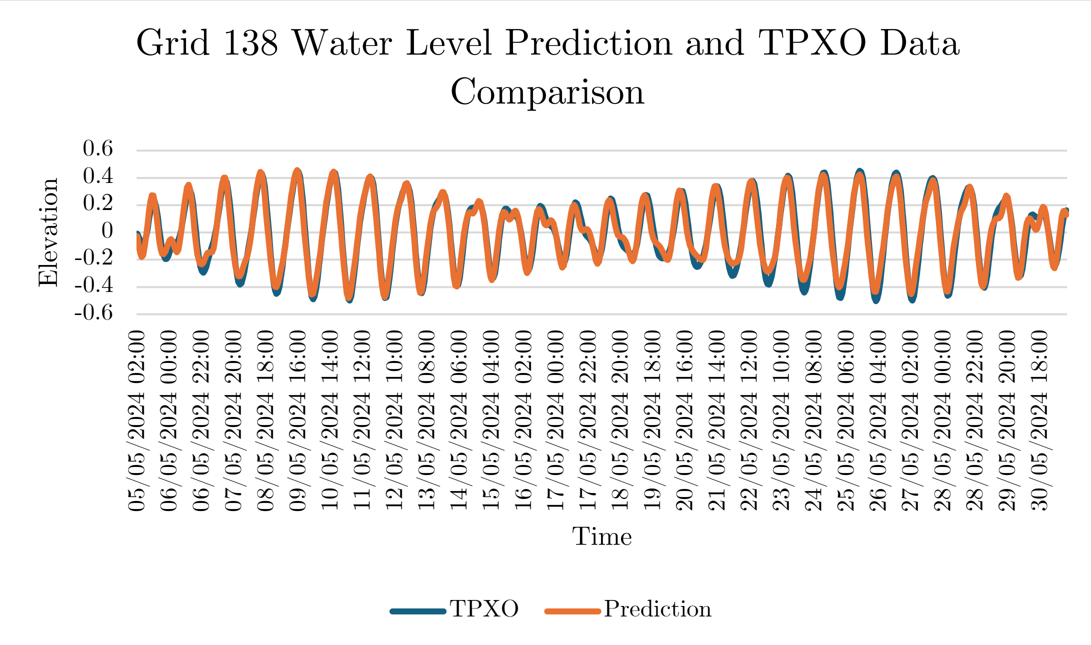

Grid 46 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
Prediction
$R^2 = 0.9571$
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.6000
-0.4000
-0.2000
0.0000
0.2000
0.4000
0.6000
0.8000

138


Grid 138 Water Level Prediction and TPXO Data Comparison
Elevation
Time
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
TPXO
Prediction

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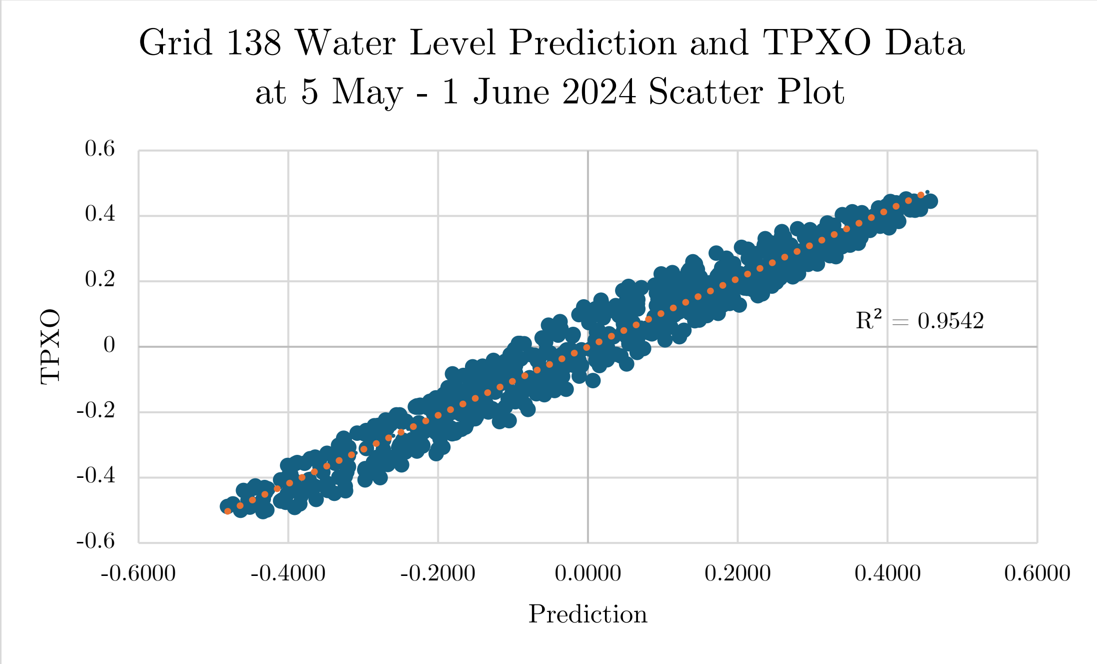
<tr><td></td><td>
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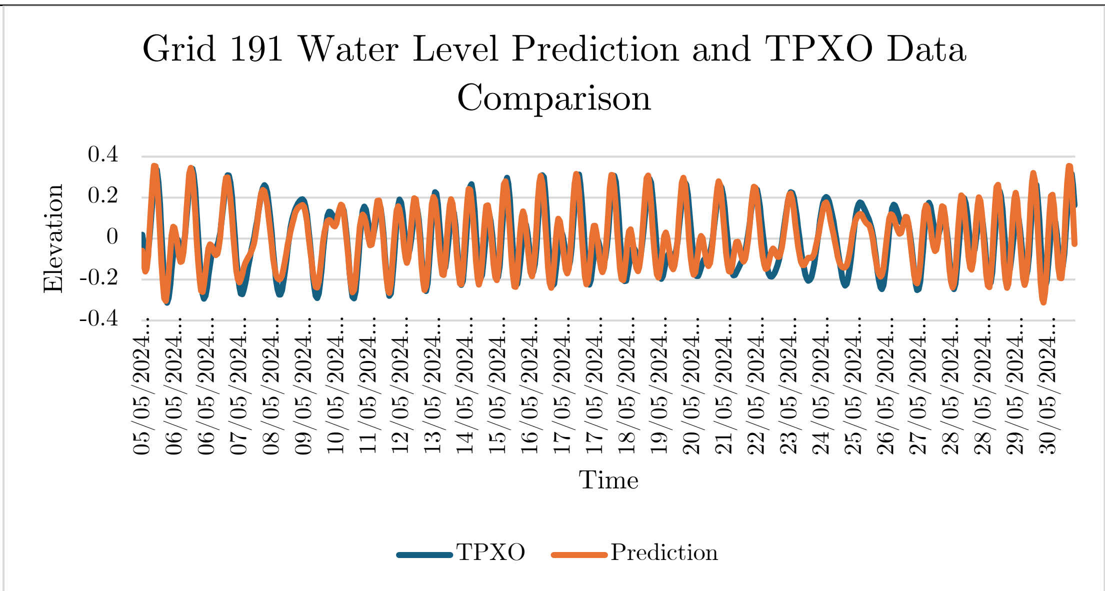
<tr><td>191</td><td>
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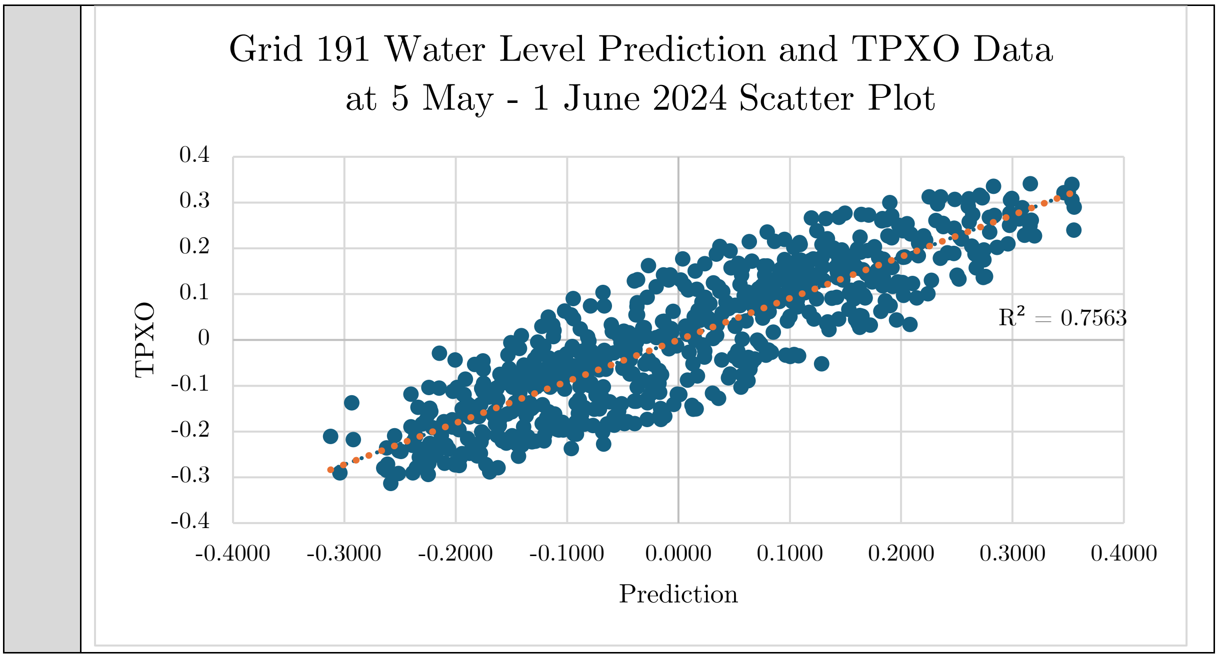

Similar tests were conducted at several other locations. The results show a general trend of decreasing prediction accuracy with increasing distance from the calibration site, i.e., Pramuka Island. The trend graph presented in Figure II.1 illustrates that for every one-kilometer increase in distance; the prediction accuracy decreases by approximately 0.001 in R-squared value. For detailed comparison at each sampled grid in Figure 4.3, see Appendix 3.

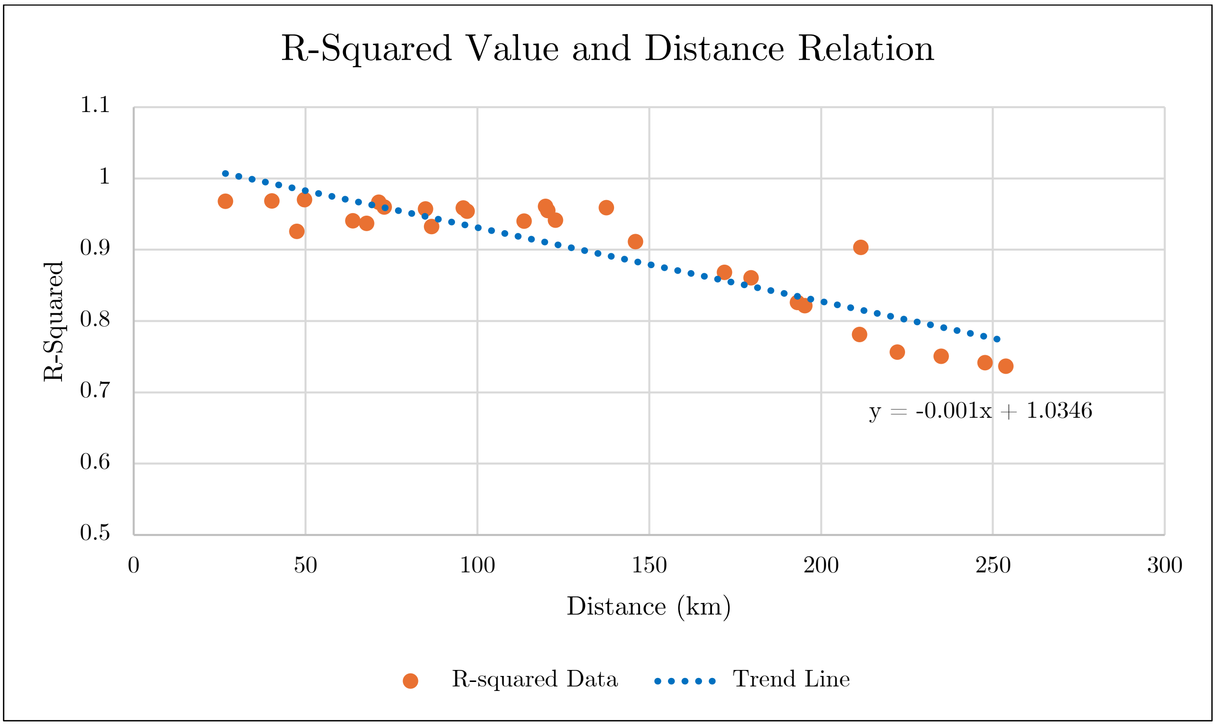

Figure 4.3 R-Squared value and distance relation

4.3 Vertical Datum Testing Method

The quality assessment of datum computation was carried out by comparing the predicted model results with the BIG datum model using Root Mean Square Error (RMSE). RMSE represents the magnitude of prediction error, where a smaller value (closer to 0) indicates higher prediction accuracy. A lower RMSE value signifies a more accurate prediction result (Zhang et al., 2017). Mathematically, RMSE is defined as follows, with "n" representing the number of data points.

$$\mathrm{RMSE}=\sqrt{\frac{\sum_{i=1}^{n}(\text{Predicted data}-\text{BIG data})^2}{n}} \quad ...(5)$$

4.4 Vertical Datum Testing Result

The BIG tide station used for calculating RMSE is the Sunda Kelapa station, with details provided in Table 4.4.

Table 4.4 Sunda Kepala tidal station description

Tide Station Description			
Station Code	SKLP	Station Name	Sunda Kelapa
Village/Sub-district	Penjaringan	City/Regency	Jakarta Utara
District	Penjaringan	Province	DKI Jakarta
Latitude	6° 7' 30,756" LS	Longitude	106° 48' 34,2"
Location Description	Located at PT Pelindo II, Sunda Kelapa Branch		
Ellipsoid Height (h)	19,225 meters		
Orthometric Height (H)	0,23319397 meters		

The Sunda Kelapa BIG station was selected because the available information can be used to compare the TPXO-based datum model with the BIG datum model. A conversion was performed from geodetic control point height relative to the tidal datum and orthometric height relative to the tidal datum. The calculation involved subtracting the geodetic control point height from the orthometric height, both referenced to the tidal datum.

$$\text{Datum}_{\text{konversi}} = \text{Tinggi orthometrik} - \text{Datum}_{\text{BIG}} \quad ...(6)$$

Subsequently, the datum at the predicted model location corresponding to Sunda Kelapa was calculated. A comparison between the predicted model datum and the BIG model datum is presented in the comparison table below:

The resulting RMSE is 0.1624 meters.

5 RECOMMENDATIONS

The accuracy of the vertical datum values displayed on the OSDATUM platform can still be improved through the incorporation of additional methodologies and supporting in-situ. At present, the primary limitation lies in the availability of high-quality field observations: only one trusted (a 28-day tidal observation at Pramuka Island) is available. Applying tidal correction based solely on the discrepancies identified at Pramuka Island may not adequately reflect the diverse tidal regimes present across the broader OSES-ONWJ region. Notably, the spatial separation between pramuka island and other offshore sites can introduce significant variations in tidal amplitude and phase, particularly in semi-enclosed or structurally complex marine environments.

To enhance the reliability and spatial resolution of tidal correction across the study area, the following recommendations are proposed:

1) Implement Spatial Interpolation When Sufficient Field Data is Available
If multiple high-quality in-situ datasets become available across different parts of the OSES-ONWJ region, spatial interpolation of the tidal properties (such as amplitude and phase) should be implemented. A promising approach is the use of multiple-order harmonic partial differential equations (PDEs), as demonstrated by Shi et al. (2013). This method solves a generalized PDE combining harmonic operators of different orders (e.g., Laplacian, biharmonic) on unstructured triangular meshes. It is particularly effective in regions with irregular coastlines and scattered tide stations, as it avoids discontinuities at data points and provides smoother and more accurate interpolation surfaces than traditional methods. This approach could significantly improve the accuracy of interpolated tidal constituents, especially when applied to offshore grids with sparse observations.
2) Request Access to BIG Tide Gauge Data
Several tide stations are operated by *Badan Informasi Geospasial* (BIG) across Indonesia, including locations closer to or within the OSES-ONWJ area. However, these datasets are not publicly accessible at this time. If project timelines allow, initiating formal communication with BIG to obtain access is highly recommended. The inclusion of more trusted field measurements from BIG would provide a more robust validation datasets and improve the spatial representativeness of vertical datum corrections.
3) Install Additional Tide Stations in Key Offshore Areas
Ultimately, the most effective way to enhance datum accuracy is to increase observational coverage. Given the heterogeneity of tidal dynamics in the OSES-ONWJ region, it is recommended to establish new permanent or temporary tide

stations in strategic offshore locations. These could be selected based on areas with the highest uncertainty in the interpolation or construction relevance. Data from these stations would serve both for direct correction and to improve the spatial interpolation model's performance.

4) Adding More Vertical Datum Types
   Currently, only five vertical datums are computed within the OSDATUM platform—MSL, HAT, LAT, MHWS, and MLWS. This selection is aligned with the vertical datums published by BIG, thereby enabling direct comparison and validation. The limited scope is intentional to ensure consistency and reliability during the validation phase. However, if additional verified datum references become available in the future, either through national datasets or new in-situ measurements, the platform can be extended to include other tidal datums (e.g., MHHW, MLLW, MHW, MLW, etc.) by incorporating corresponding computational modules.

In summary, improving the accuracy of tidal datum correction across the OSES-ONWJ area requires not only reliance on a single reference station but also the integration of spatially distributed observations and advanced interpolation techniques. The use of higher-order harmonic PDE interpolation, as proposed by Shi et al. (2013) offers a mathematically sound and computationally efficient framework to achieve this, especially when combined with expanded field observations.

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Appendix 1 OSES grid centroid coordinates

OSES_ID	Longitude	Latitude	OSES_ID	Longitude	Latitude
1	106,079	-5,004	48	106,413	-5,17
2	106,079	-5,087	49	106,413	-5,254
3	106,079	-5,171	50	106,413	-5,338
4	106,079	-5,255	51	106,413	-5,421
5	106,079	-5,338	52	106,414	-5,505
6	106,079	-5,422	53	106,495	-4,585
7	106,162	-4,753	54	106,495	-4,668
8	106,162	-4,836	55	106,495	-4,752
9	106,162	-4,92	56	106,495	-4,836
10	106,162	-5,004	57	106,496	-4,919
11	106,162	-5,087	58	106,496	-5,003
12	106,162	-5,171	59	106,496	-5,086
13	106,163	-5,255	60	106,496	-5,17
14	106,163	-5,338	61	106,496	-5,254
15	106,163	-5,422	62	106,497	-5,337
16	106,163	-5,505	63	106,578	-4,501
17	106,163	-5,589	64	106,578	-4,584
18	106,245	-4,669	65	106,578	-4,668
19	106,245	-4,752	66	106,579	-4,752
20	106,245	-4,836	67	106,579	-4,835
21	106,245	-4,92	68	106,579	-4,919
22	106,246	-5,003	69	106,579	-5,003
23	106,246	-5,087	70	106,579	-5,086
24	106,246	-5,171	71	106,58	-5,17
25	106,246	-5,254	72	106,58	-5,254
26	106,246	-5,338	73	106,58	-5,337
27	106,246	-5,422	74	106,661	-4,501
28	106,247	-5,505	75	106,662	-4,584
29	106,247	-5,589	76	106,662	-4,668
30	106,328	-4,669	77	106,662	-4,752
31	106,328	-4,752	78	106,662	-4,835
32	106,329	-4,836	79	106,662	-4,919
33	106,329	-4,92	80	106,663	-5,002
34	106,329	-5,003	81	106,663	-5,086
35	106,329	-5,087	82	106,745	-4,5
36	106,329	-5,171	83	106,745	-4,584
37	106,329	-5,254	84	106,745	-4,668
38	106,33	-5,338	85	106,745	-4,751
39	106,33	-5,421	86	106,746	-4,835
40	106,33	-5,505	87	106,746	-4,919
41	106,33	-5,589	88	106,746	-5,002
42	106,412	-4,668	89	106,828	-4,5
43	106,412	-4,752	90	106,828	-4,584
44	106,412	-4,836	91	106,829	-4,667
45	106,412	-4,919	92	106,829	-4,751
46	106,412	-5,003	93	106,829	-4,835
47	106,413	-5,087	94	106,829	-4,918

Appendix 2 ONWJ grid centroid coordinates

ONWJ_ID	Longitude	Latitude	ONWJ_ID	Longitude	Latitude	ONWJ_ID	Longitude	Latitude
95	106,811	-5,881	141	107,562	-5,711	187	108,482	-6,123
96	106,811	-5,964	142	107,562	-5,794	188	108,483	-6,207
97	106,894	-5,797	143	107,563	-5,878	189	108,483	-6,29
98	106,895	-5,88	144	107,563	-5,961	190	108,565	-6,123
99	106,895	-5,964	145	107,563	-6,045	191	108,566	-6,206
100	106,976	-5,378	146	107,645	-5,71	192	108,567	-6,29
101	106,977	-5,462	147	107,646	-5,794	193	108,567	-6,373
102	106,977	-5,546	148	107,646	-5,877	194	108,65	-6,289
103	106,977	-5,713	149	107,646	-5,961	195	108,651	-6,373
104	106,978	-5,796	150	107,647	-6,045	196	108,651	-6,456
105	107,06	-5,378	151	107,647	-6,128	197	108,652	-6,54
106	107,06	-5,462	152	107,729	-5,71	198	108,734	-6,372
107	107,06	-5,545	153	107,729	-5,793	199	108,735	-6,456
108	107,061	-5,713	154	107,729	-5,877	200	108,735	-6,539
109	107,061	-5,796	155	107,73	-5,961	201	108,818	-6,372
110	107,143	-5,378	156	107,73	-6,044	202	108,818	-6,455
111	107,144	-5,461	157	107,731	-6,128	203	106,812	-6,048
112	107,144	-5,545	158	107,813	-5,793	204	106,894	-6,044
113	107,144	-5,629	159	107,813	-5,877	205	107,063	-5,878
114	107,144	-5,712	160	107,813	-5,96	206	106,977	-5,879
115	107,145	-5,796	161	107,814	-6,044	207	107,153	-5,945
116	107,145	-5,88	162	107,814	-6,127	208	107,225	-5,943
117	107,227	-5,377	163	107,896	-5,793	209	107,316	-5,938
118	107,227	-5,461	164	107,896	-5,876	210	107,399	-5,959
119	107,227	-5,545	165	107,897	-5,96	211	107,423	-6,029
120	107,228	-5,628	166	107,897	-6,043	212	107,493	-6,115
121	107,228	-5,712	167	107,898	-6,127	213	107,565	-6,127
122	107,228	-5,796	168	107,98	-5,876	214	108,581	-6,54
123	107,229	-5,879	169	107,98	-5,959	215	108,571	-6,454
124	107,31	-5,377	170	107,981	-6,043	216	108,498	-6,435
125	107,31	-5,461	171	107,981	-6,126	217	108,409	-6,289
126	107,311	-5,544	172	108,063	-5,875	218	108,399	-6,207
127	107,311	-5,628	173	108,064	-5,959	219	108,422	-6,36
128	107,311	-5,712	174	108,064	-6,042	220	108,484	-6,374
129	107,312	-5,795	175	108,065	-6,126	221	108,316	-6,203
130	107,312	-5,879	176	108,065	-6,209	222	108,236	-6,199
131	107,394	-5,628	177	108,147	-5,875	223	108,144	-6,206
132	107,395	-5,711	178	108,147	-5,958	224	108,142	-6,279
133	107,395	-5,795	179	108,148	-6,042	225	108,07	-6,28
134	107,396	-5,878	180	108,148	-6,125	226	107,982	-6,21
135	107,478	-5,627	181	108,23	-5,874	227	108,002	-6,265
136	107,478	-5,711	182	108,231	-5,958	228	107,807	-6,178
137	107,479	-5,795	183	108,231	-6,041	229	107,728	-6,193
138	107,479	-5,878	184	108,232	-6,125	230	107,662	-6,191
139	107,479	-5,962	185	108,315	-6,124	231	107,916	-6,201
140	107,48	-6,045	186	108,399	-6,124			

Appendix 3 Tidal quality testing sample water level prediction and TPXO comparison

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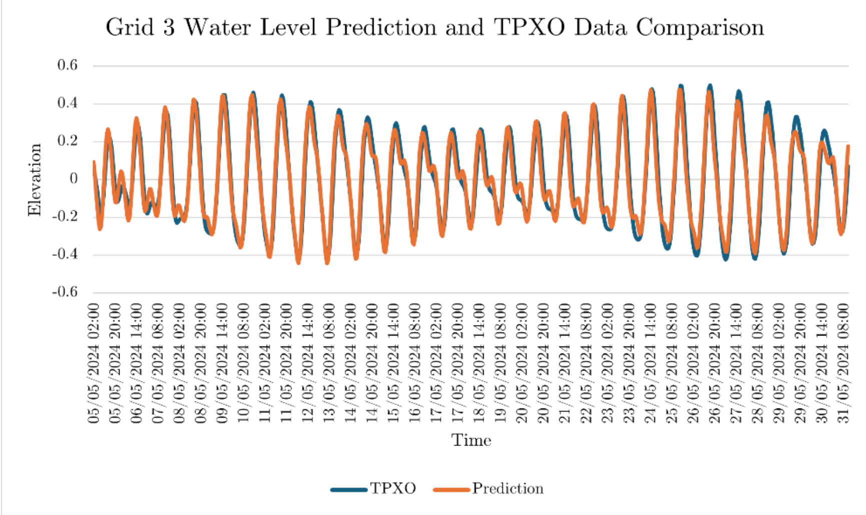
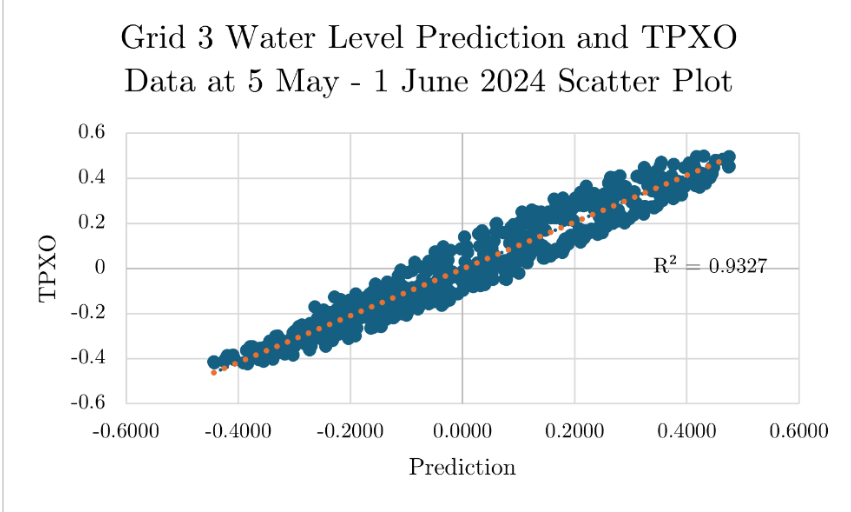
<tr><td>3</td><td>
</td><td>
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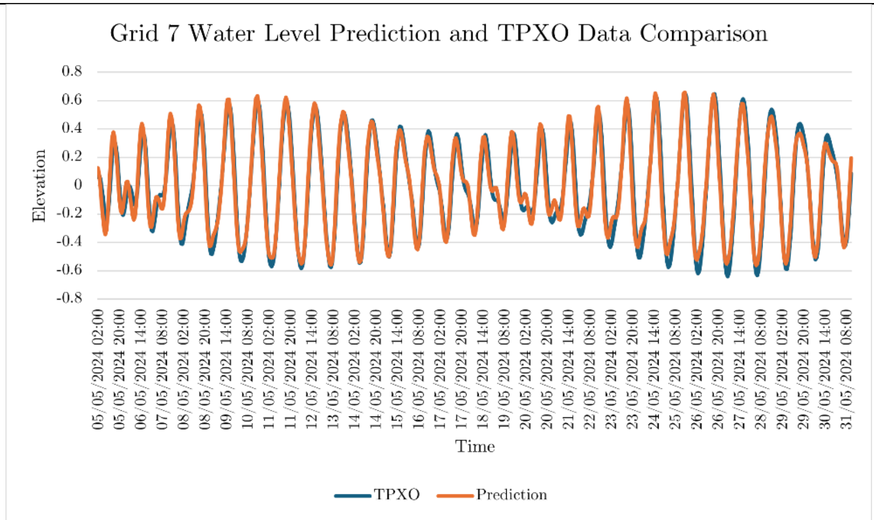
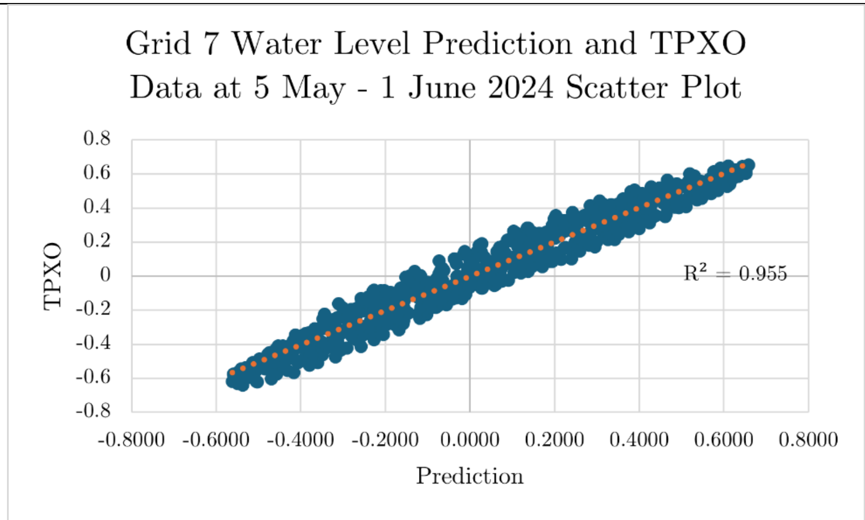
<tr><td>7</td><td>
</td><td>
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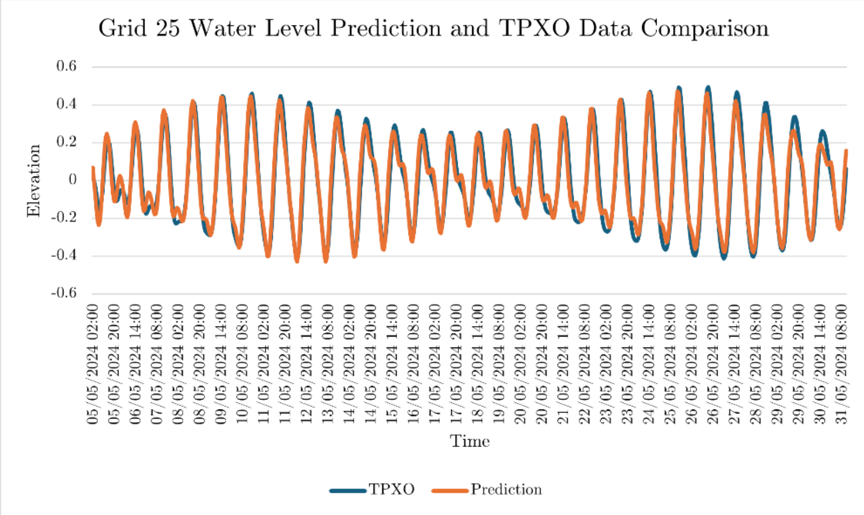
<td>
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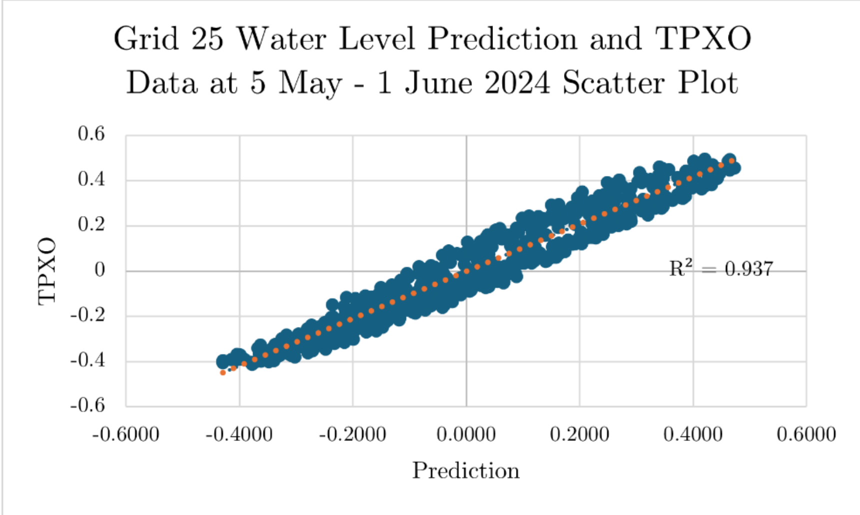
<td>
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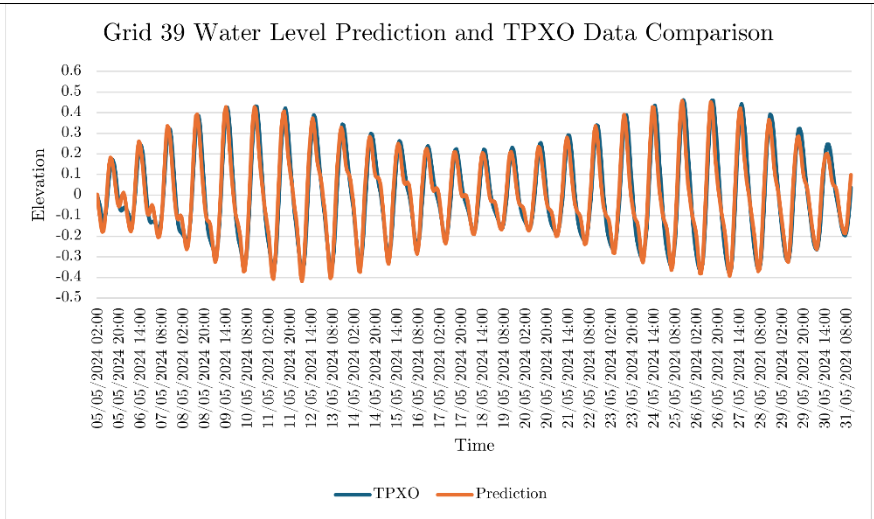
<td>
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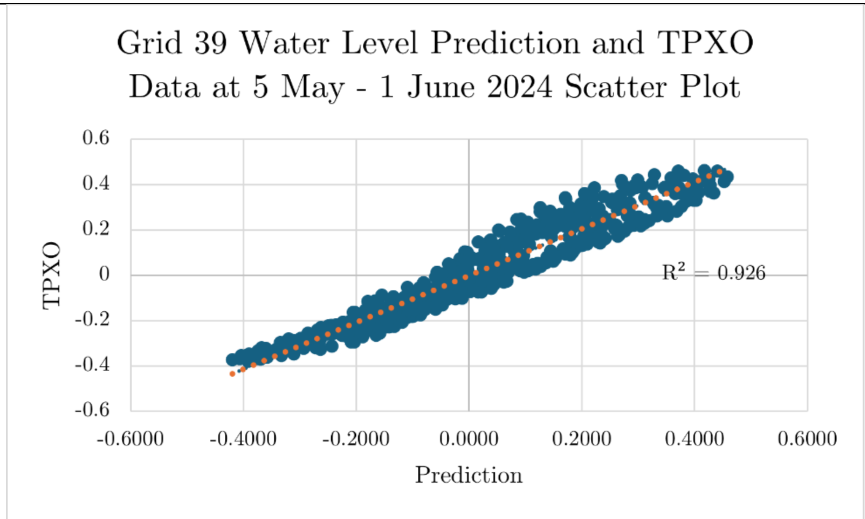
<td>
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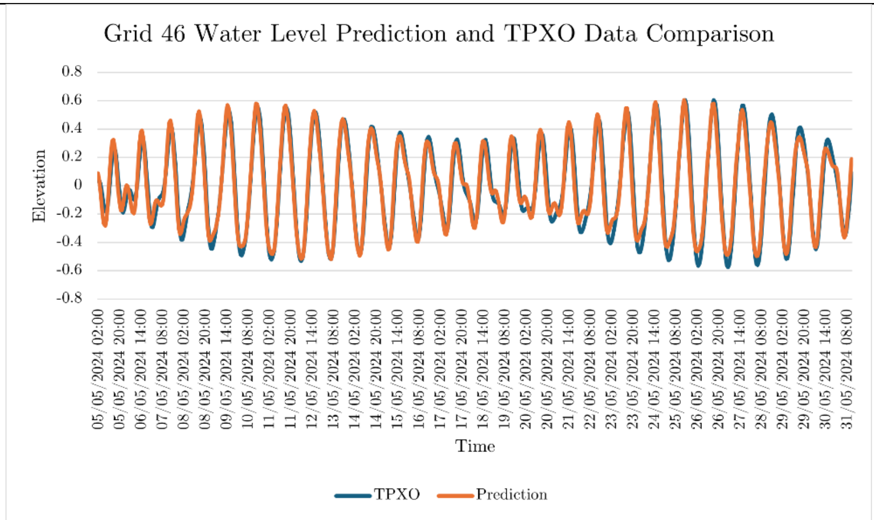
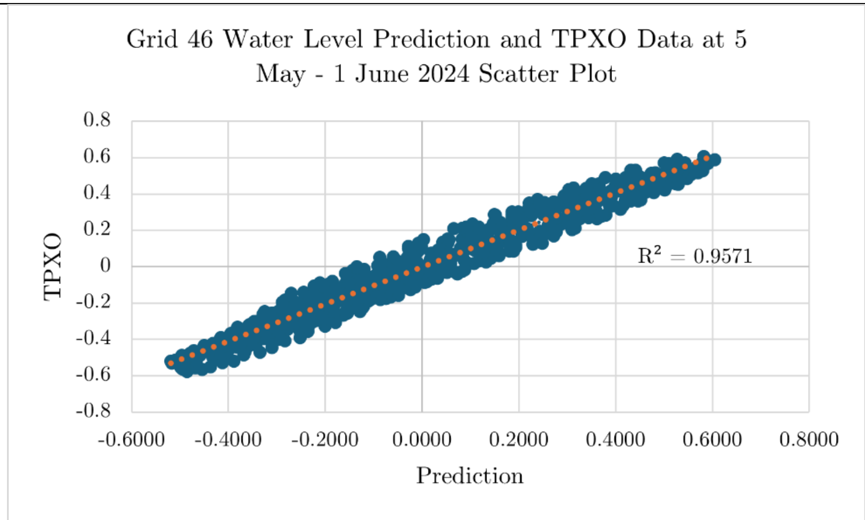
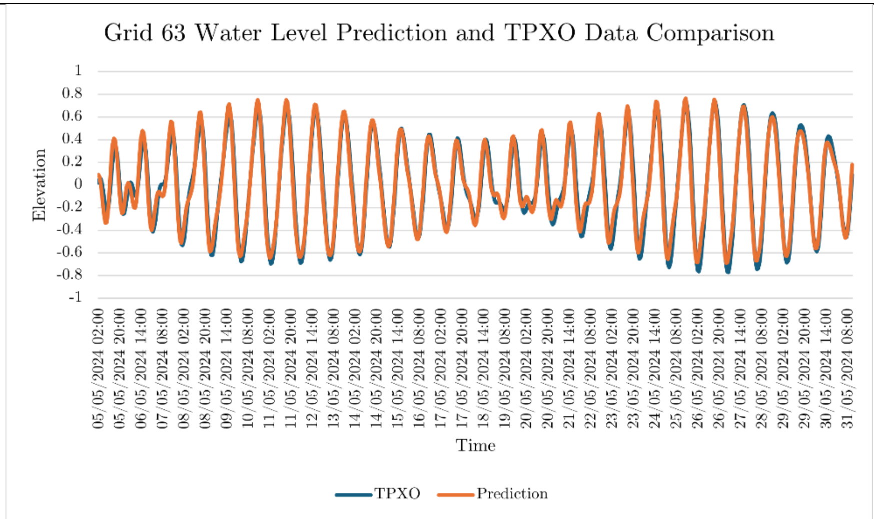
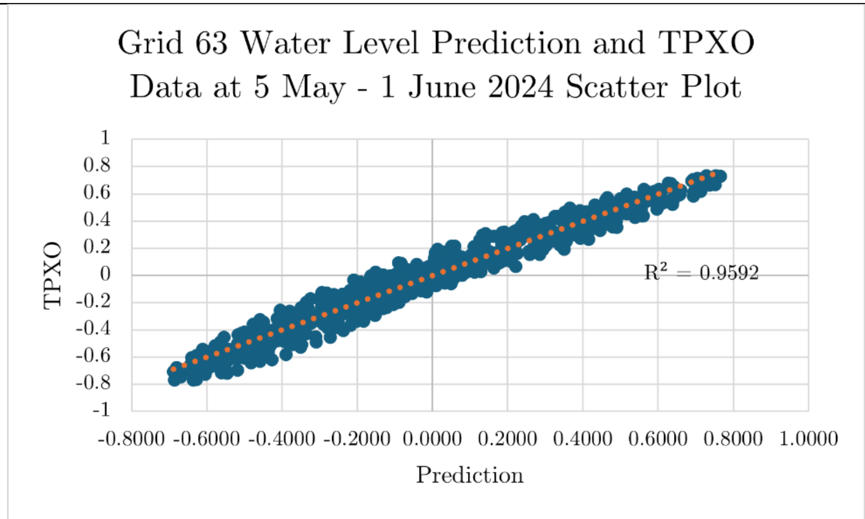
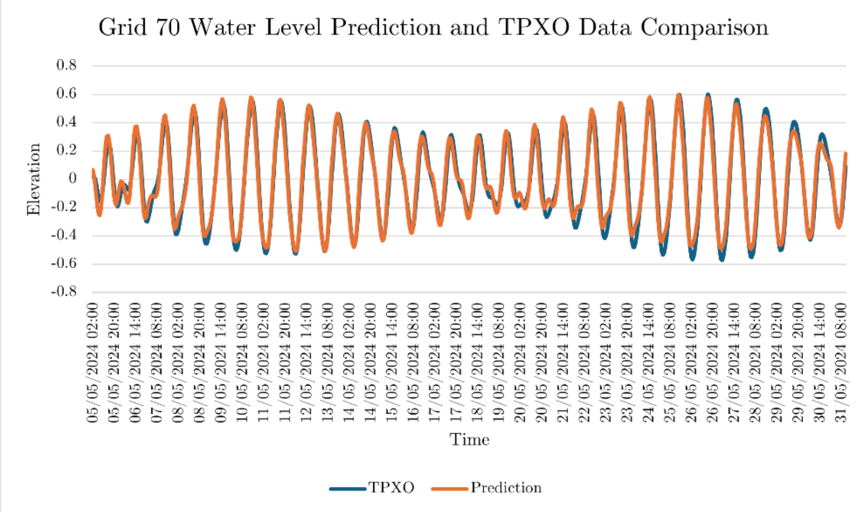
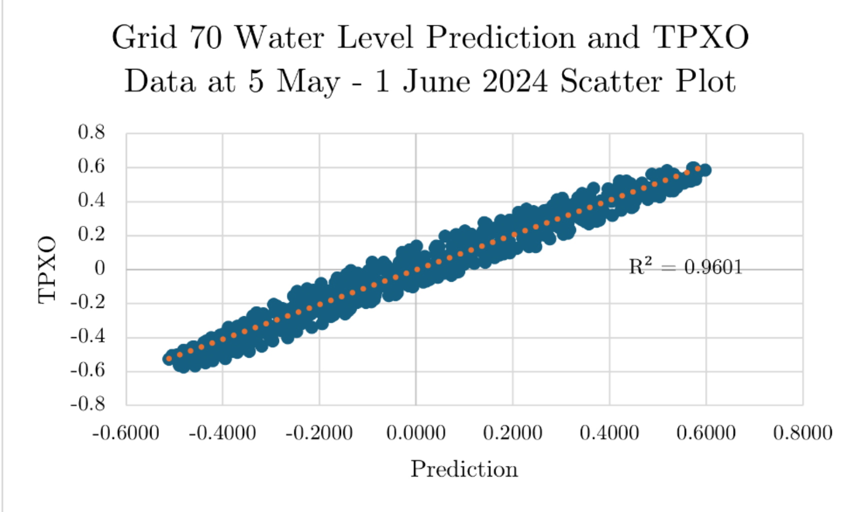
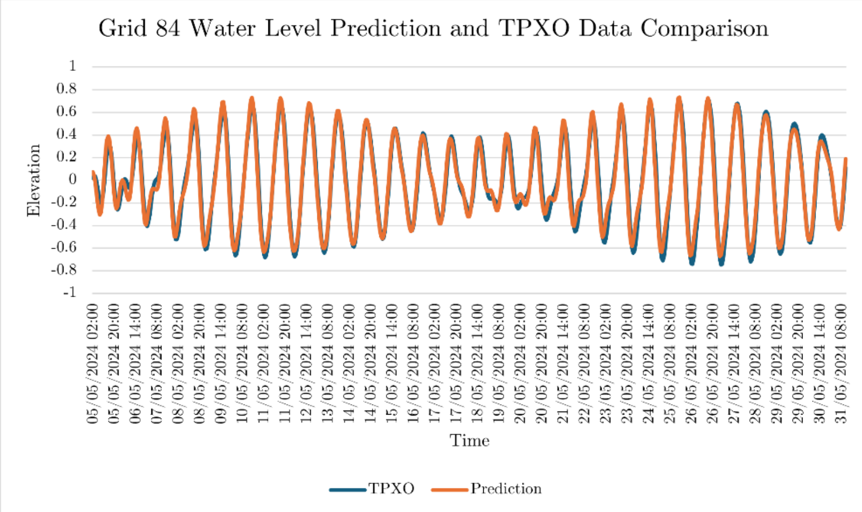
46	Grid 46 Water Level Prediction and TPXO Data Comparison Elevation Time TPXO Prediction	Grid 46 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot TPXO Prediction R^2 = 0.9571
63	Grid 63 Water Level Prediction and TPXO Data Comparison Elevation Time TPXO Prediction	Grid 63 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot TPXO Prediction R^2 = 0.9592

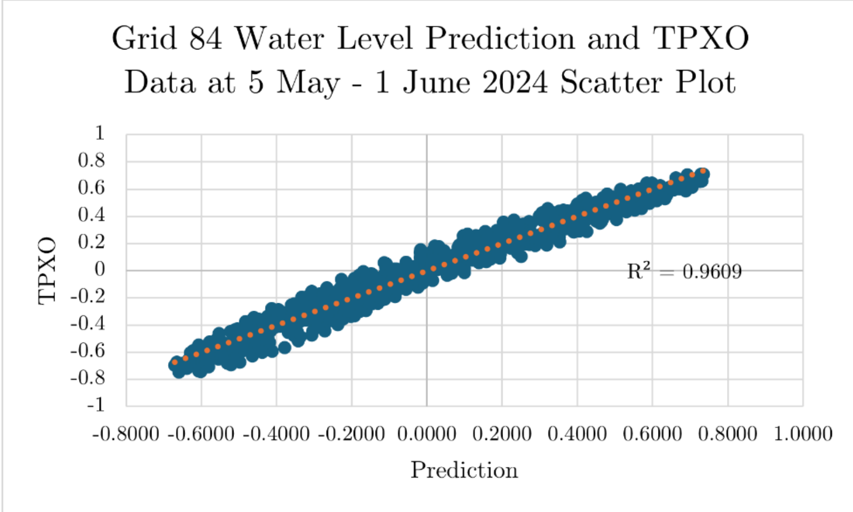
70


Grid 70 Water Level Prediction and TPXO Data Comparison
Elevation
Time
TPXO
Prediction

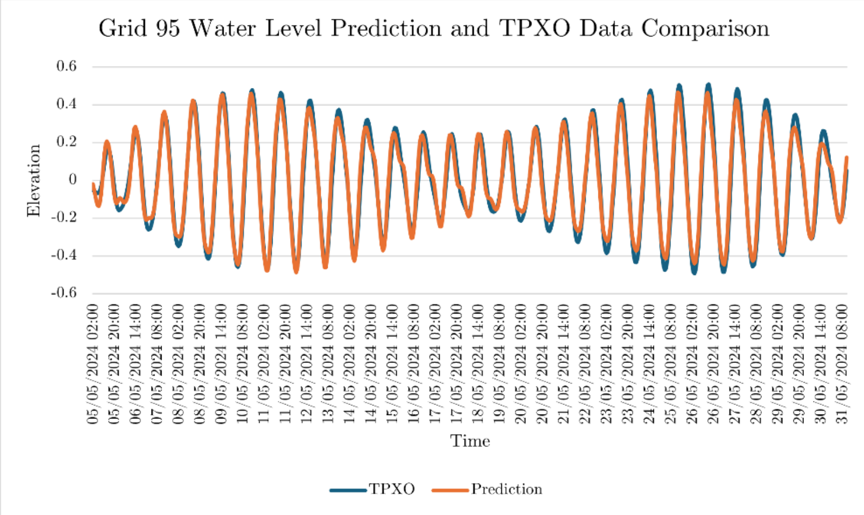

Grid 70 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
Prediction
R² = 0.9601

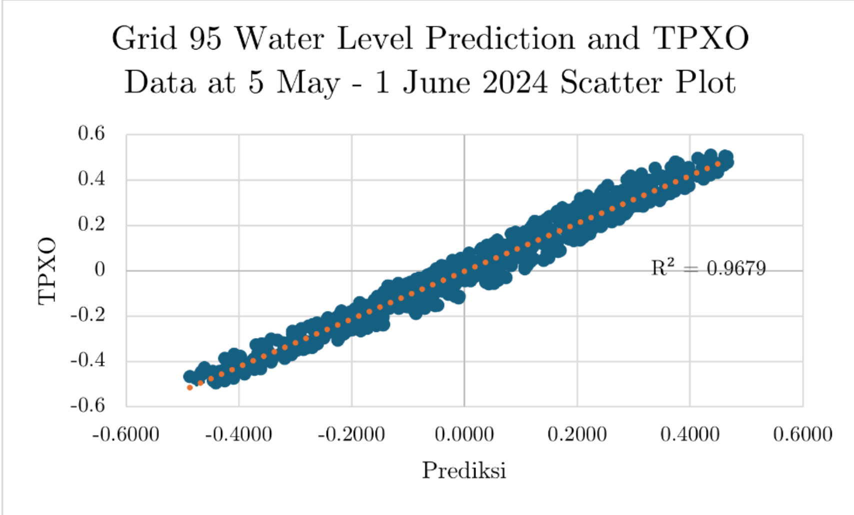
84


Grid 84 Water Level Prediction and TPXO Data Comparison
Elevation
Time
TPXO
Prediction

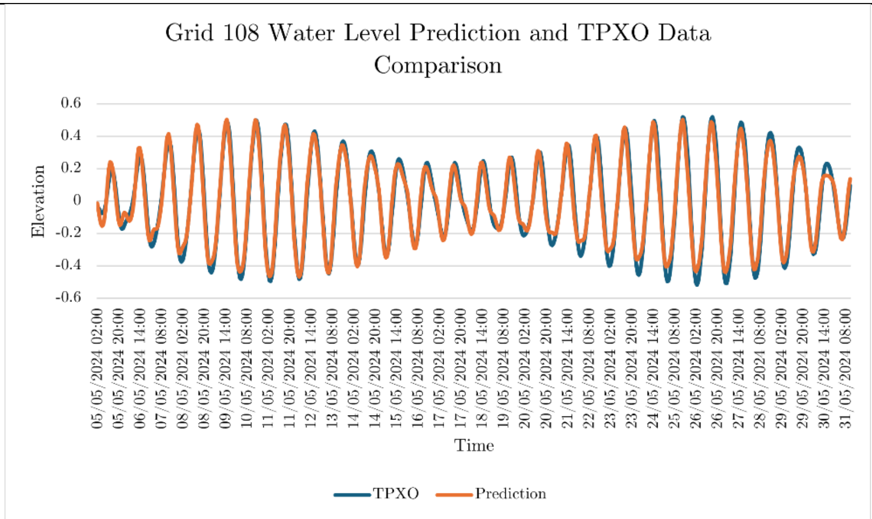

Grid 84 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
Prediction
R² = 0.9609

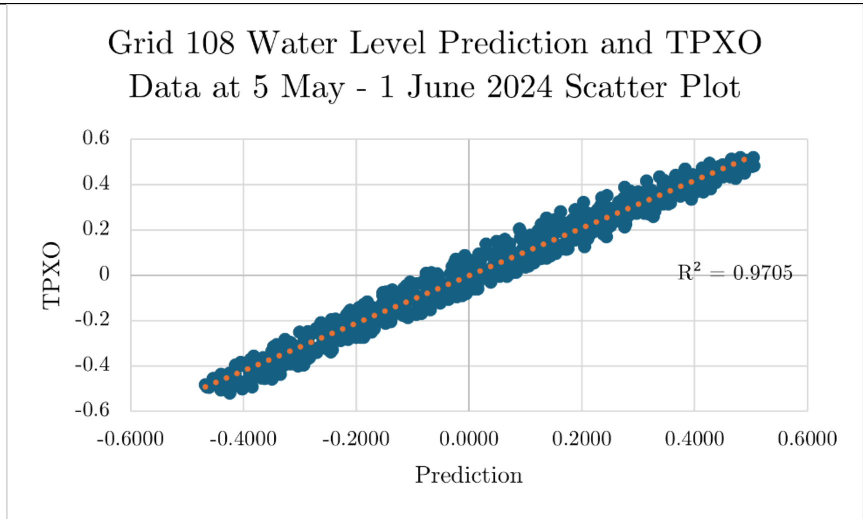
95


Grid 95 Water Level Prediction and TPXO Data Comparison
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Elevation
Time
TPXO
Prediction

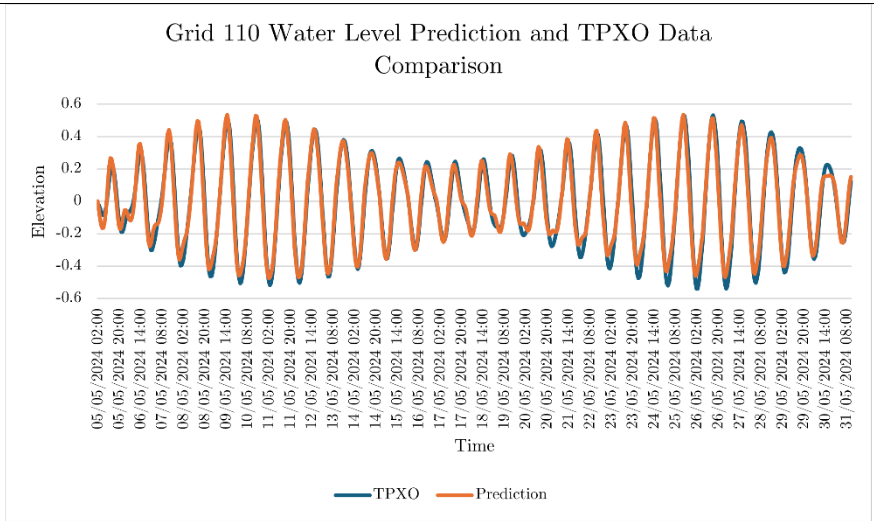

Grid 95 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
TPXO
R² = 0.9679
-0.6000
-0.4000
-0.2000
0.0000
0.2000
0.4000
0.6000
Prediksi

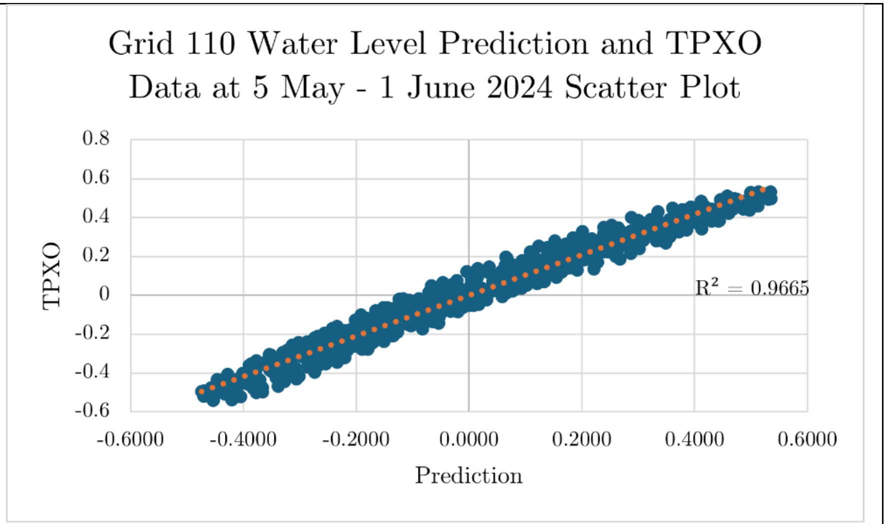
108


Grid 108 Water Level Prediction and TPXO Data Comparison
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Elevation
Time
TPXO
Prediction

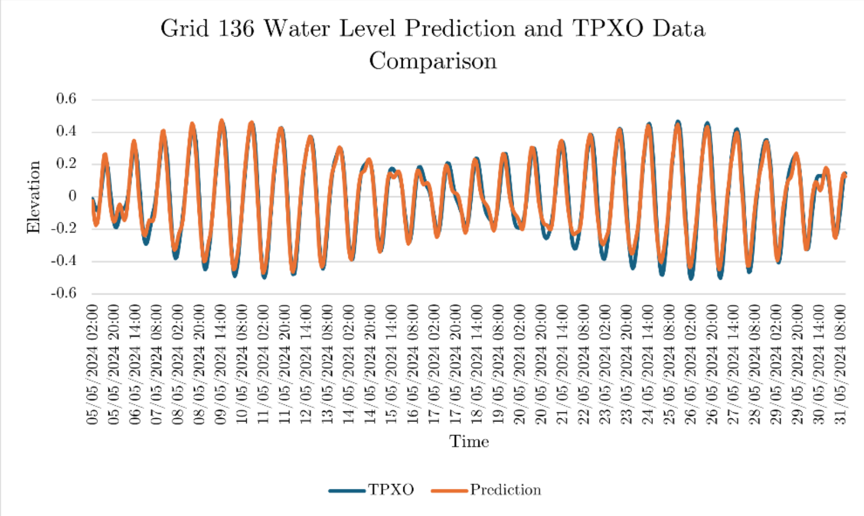

Grid 108 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
TPXO
R² = 0.9705
-0.6000
-0.4000
-0.2000
0.0000
0.2000
0.4000
0.6000
Prediction

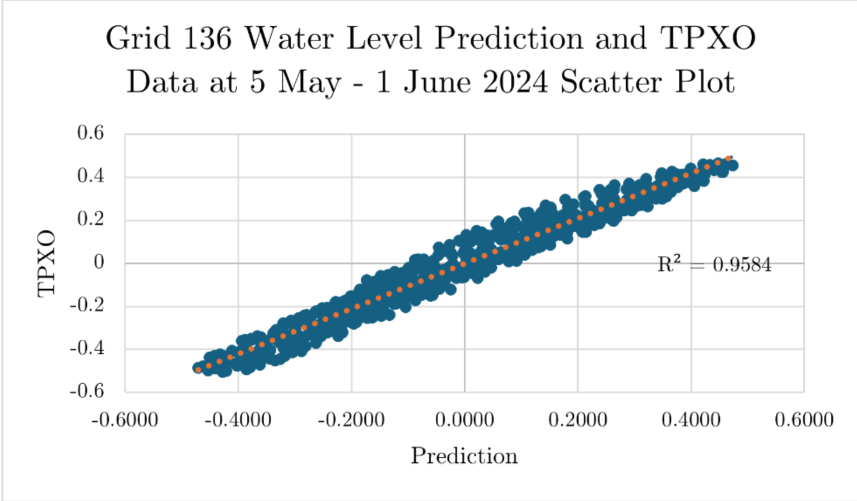
110


Grid 110 Water Level Prediction and TPXO Data Comparison
Elevation
Time
TPXO
Prediction


Grid 110 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
Prediction
R² = 0.9665

136


Grid 136 Water Level Prediction and TPXO Data Comparison
Elevation
Time
TPXO
Prediction


Grid 136 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
Prediction
R² = 0.9584

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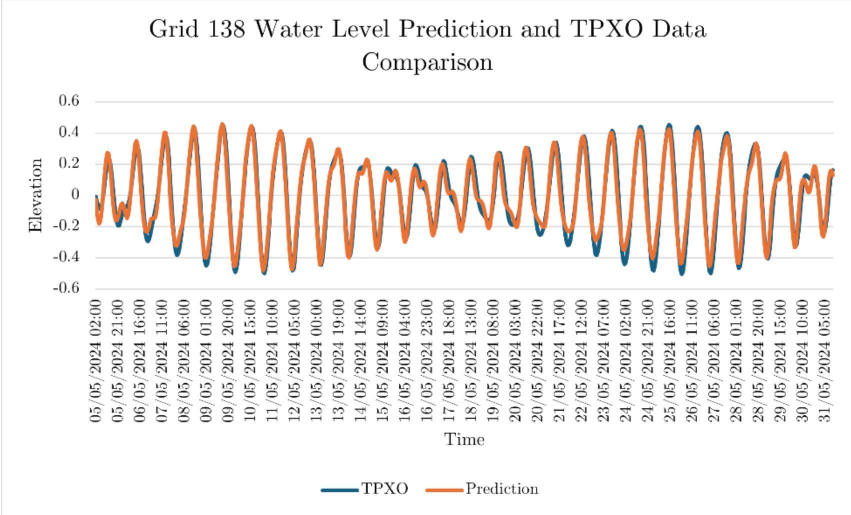
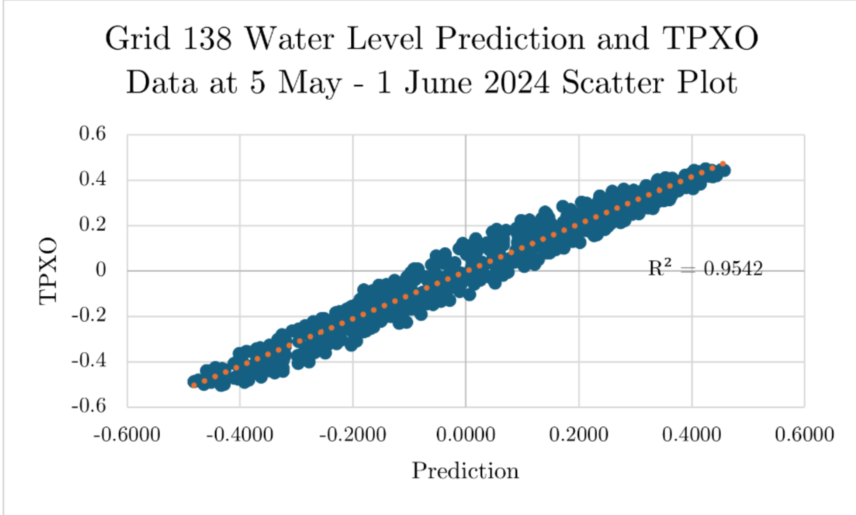
<tr><td>138</td><td>
</td><td>
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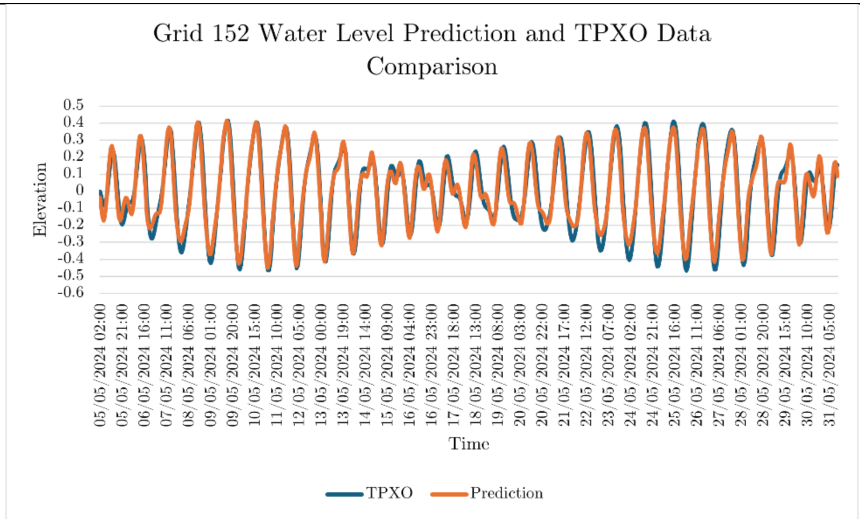
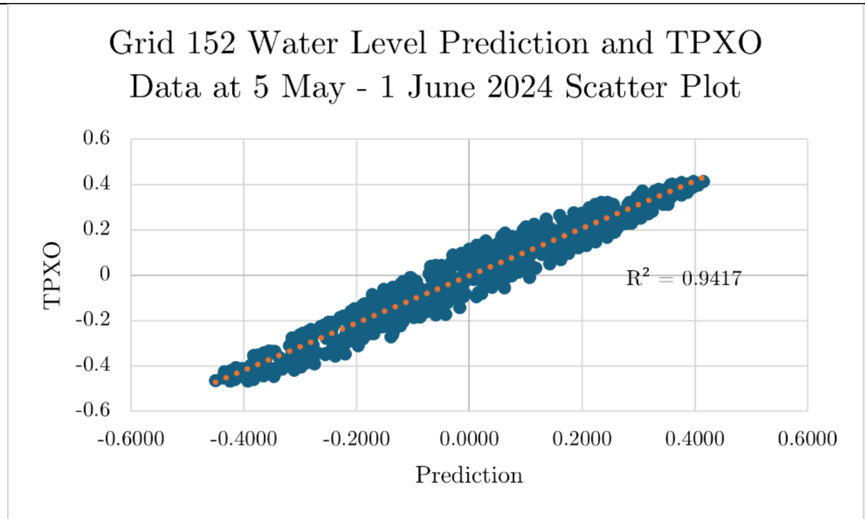
<tr><td>152</td><td>
</td><td>
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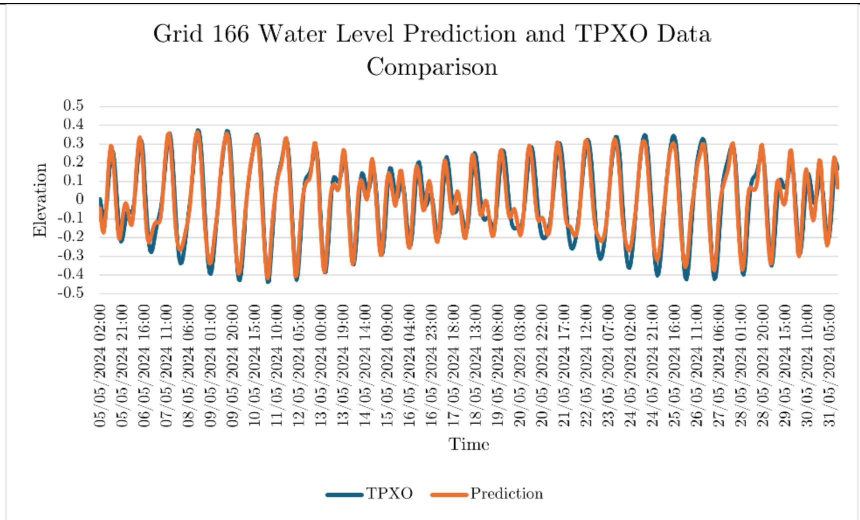
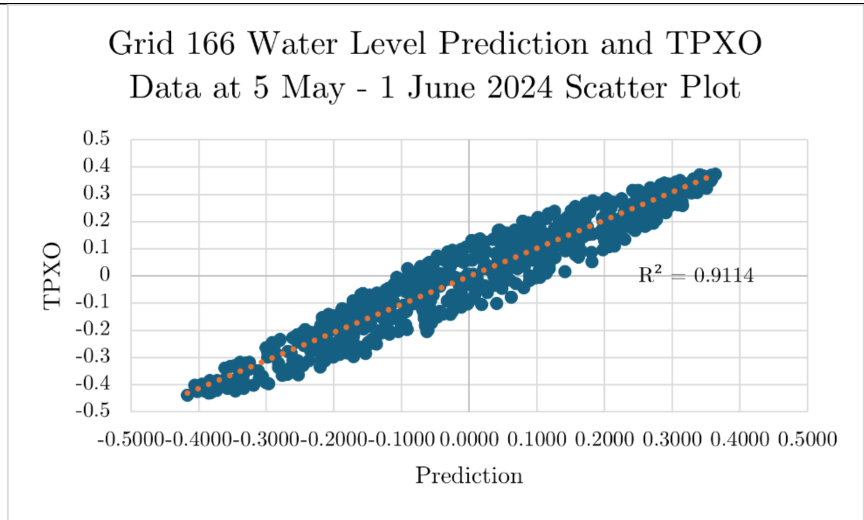
<tr><td>166</td><td>
</td><td>
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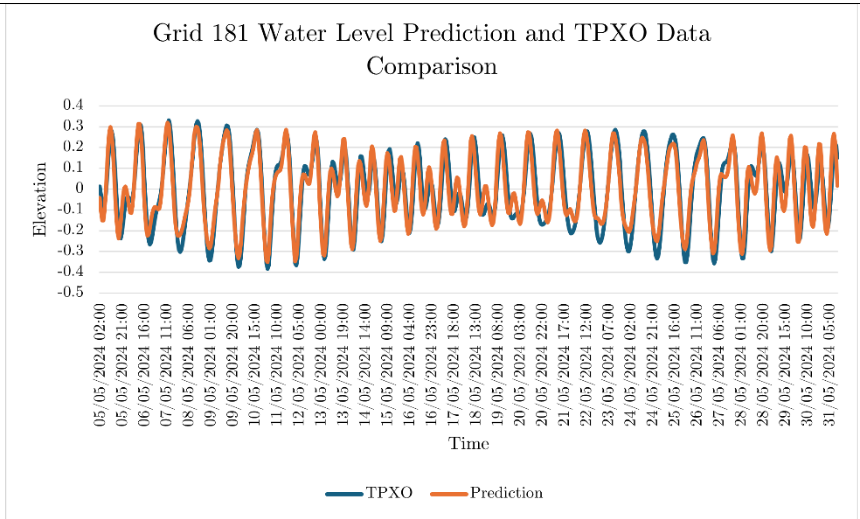
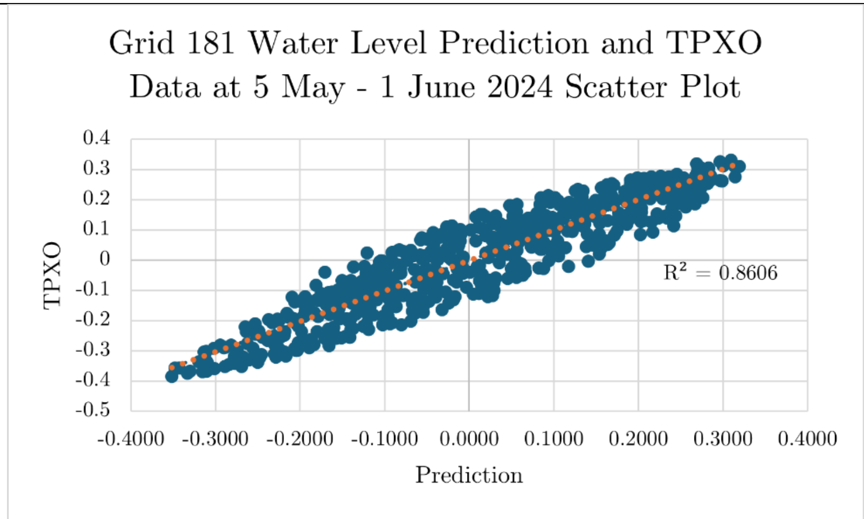
<tr><td>181</td><td>
</td><td>
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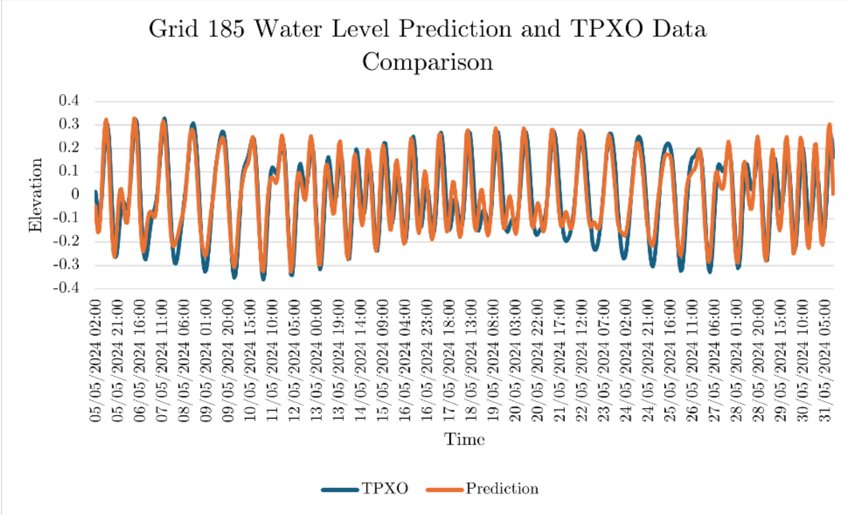
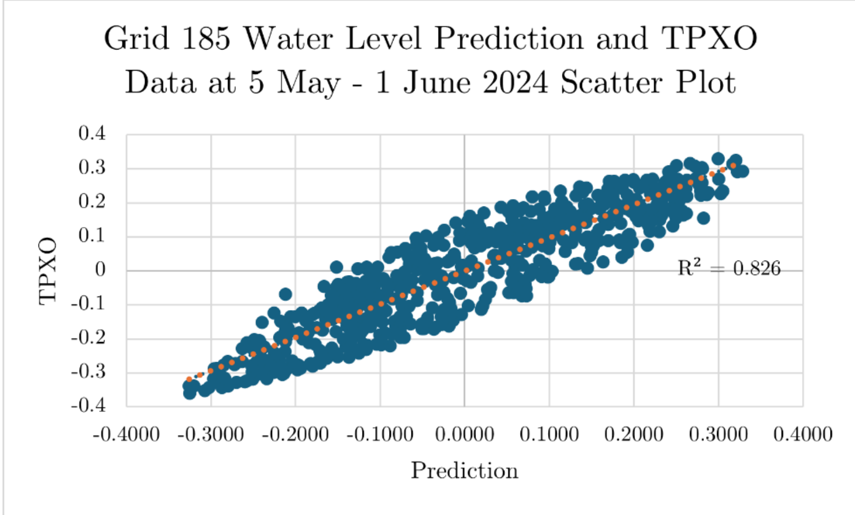
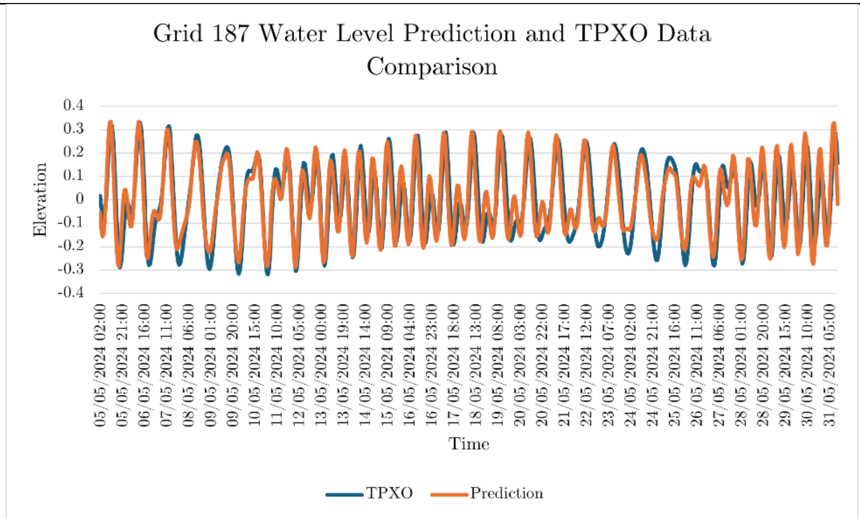
185


Grid 185 Water Level Prediction and TPXO Data Comparison
Elevation
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
05/05/2024 02:00
05/05/2024 21:00
06/05/2024 16:00
07/05/2024 11:00
08/05/2024 06:00
09/05/2024 01:00
09/05/2024 20:00
10/05/2024 15:00
11/05/2024 10:00
12/05/2024 05:00
13/05/2024 00:00
13/05/2024 19:00
14/05/2024 14:00
15/05/2024 09:00
16/05/2024 04:00
16/05/2024 23:00
17/05/2024 18:00
18/05/2024 13:00
19/05/2024 08:00
20/05/2024 03:00
20/05/2024 22:00
21/05/2024 17:00
22/05/2024 12:00
23/05/2024 07:00
24/05/2024 02:00
24/05/2024 21:00
25/05/2024 16:00
26/05/2024 11:00
27/05/2024 06:00
28/05/2024 01:00
28/05/2024 20:00
29/05/2024 15:00
30/05/2024 10:00
31/05/2024 05:00
Time
TPXO
Prediction


Grid 185 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
R² = 0.826
-0.4000
-0.3000
-0.2000
-0.1000
0.0000
0.1000
0.2000
0.3000
0.4000
Prediction

187


Grid 187 Water Level Prediction and TPXO Data Comparison
Elevation
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
05/05/2024 02:00
05/05/2024 21:00
06/05/2024 16:00
07/05/2024 11:00
08/05/2024 06:00
09/05/2024 01:00
09/05/2024 20:00
10/05/2024 15:00
11/05/2024 10:00
12/05/2024 05:00
13/05/2024 00:00
13/05/2024 19:00
14/05/2024 14:00
15/05/2024 09:00
16/05/2024 04:00
16/05/2024 23:00
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18/05/2024 13:00
19/05/2024 08:00
20/05/2024 03:00
20/05/2024 22:00
21/05/2024 17:00
22/05/2024 12:00
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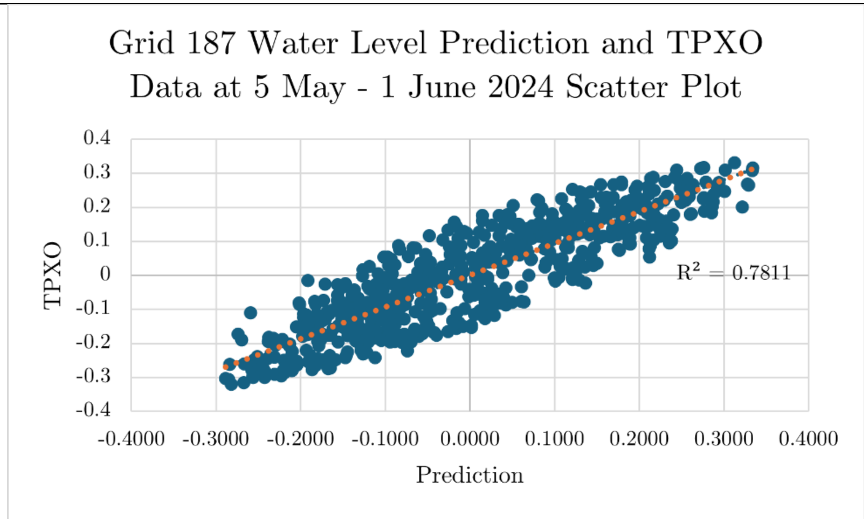
25/05/2024 16:00
26/05/2024 11:00
27/05/2024 06:00
28/05/2024 01:00
28/05/2024 20:00
29/05/2024 15:00
30/05/2024 10:00
31/05/2024 05:00
Time
TPXO
Prediction


Grid 187 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
R² = 0.7811
-0.4000
-0.3000
-0.2000
-0.1000
0.0000
0.1000
0.2000
0.3000
0.4000
Prediction

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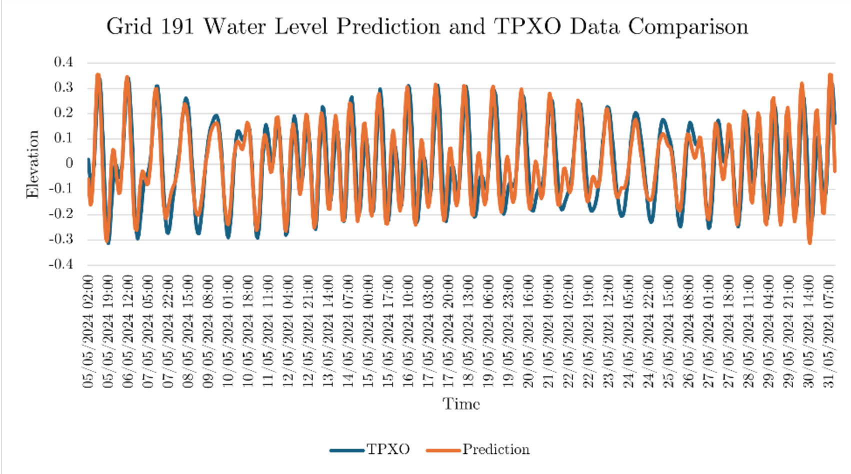
<td>
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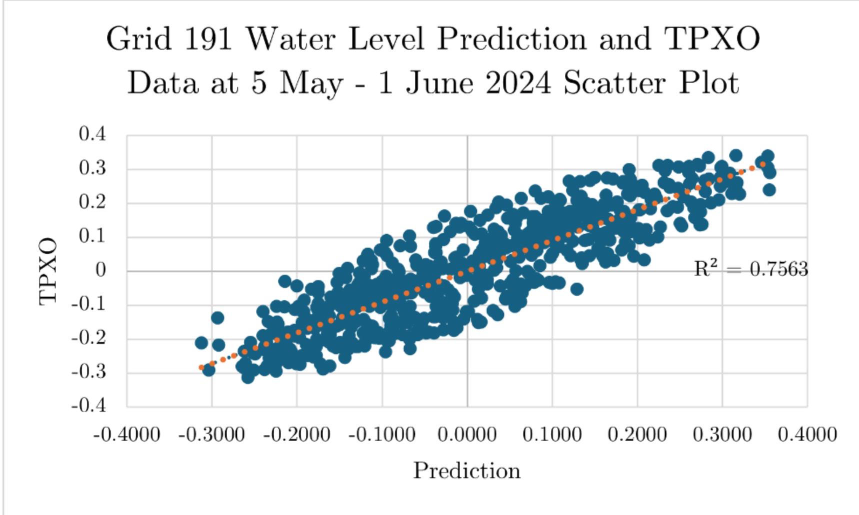
<td>
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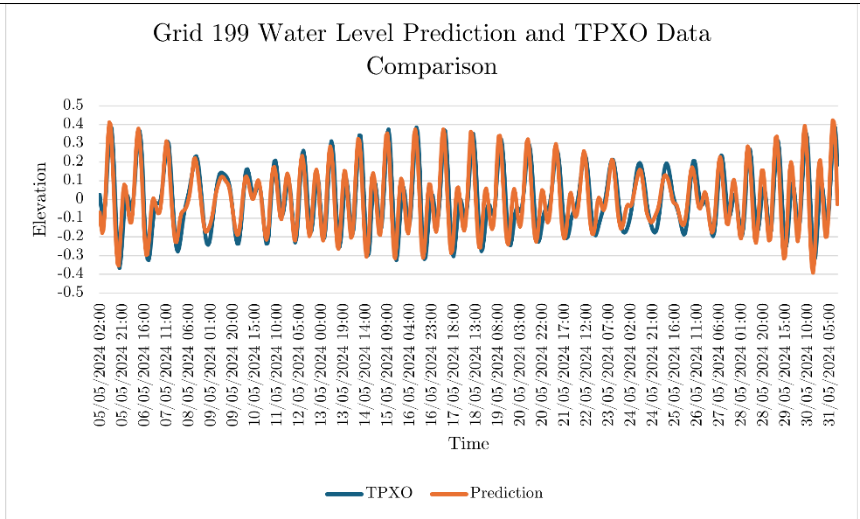
<td>
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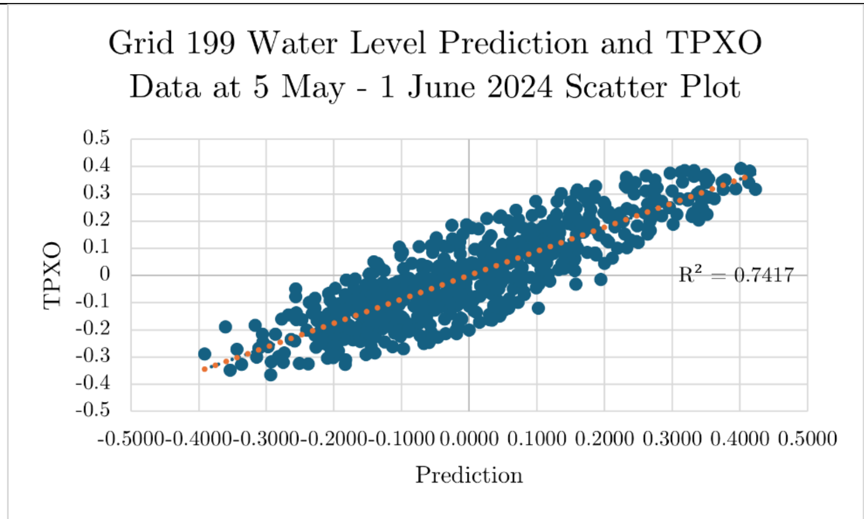
<td>
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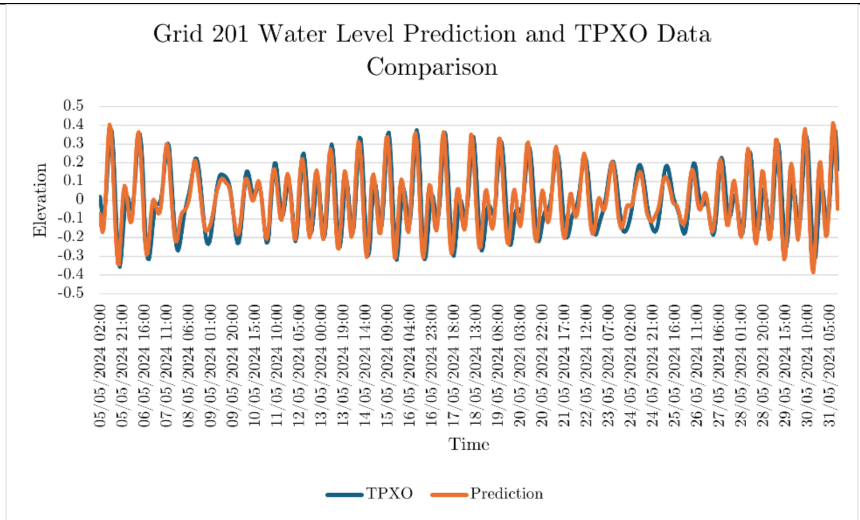
<td>
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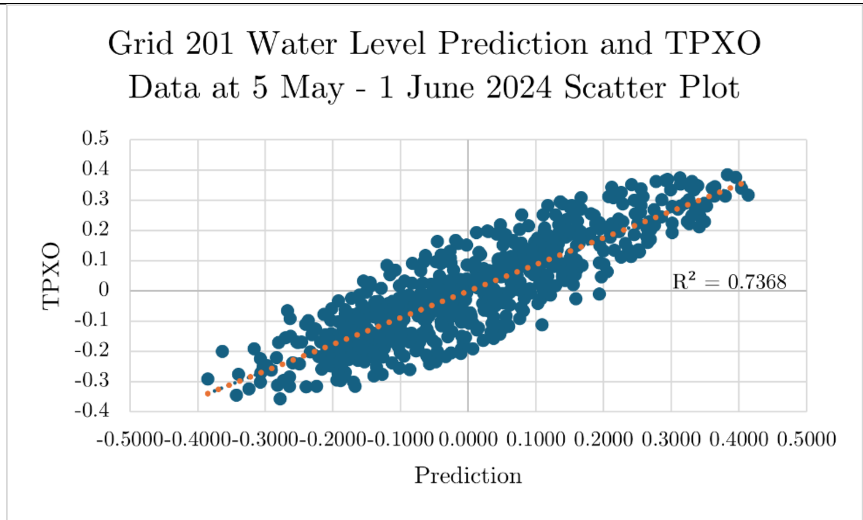
<td>
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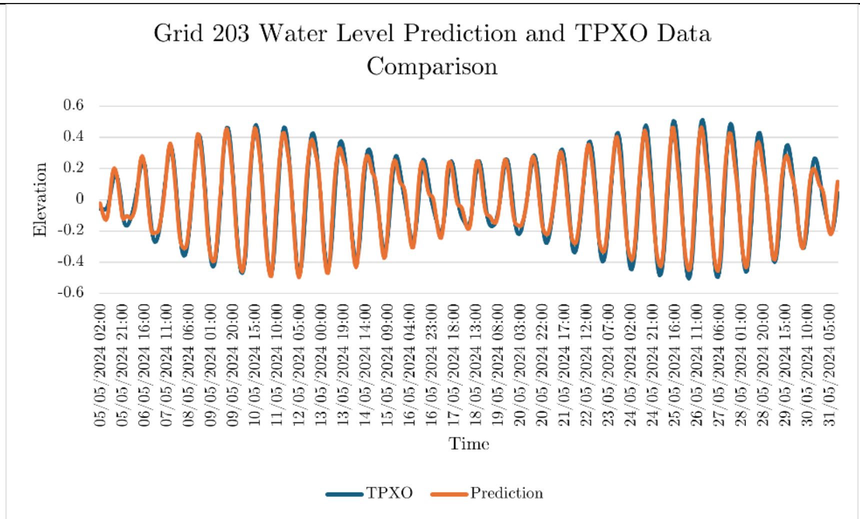
<td>
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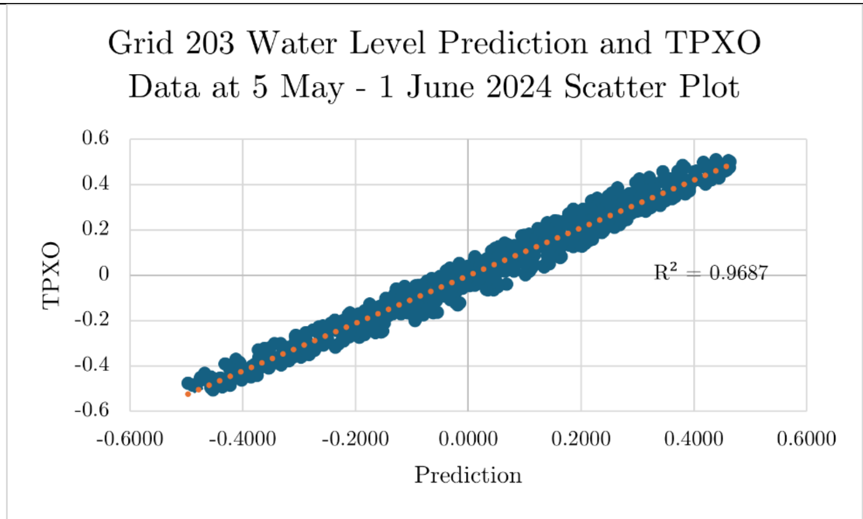
<td>
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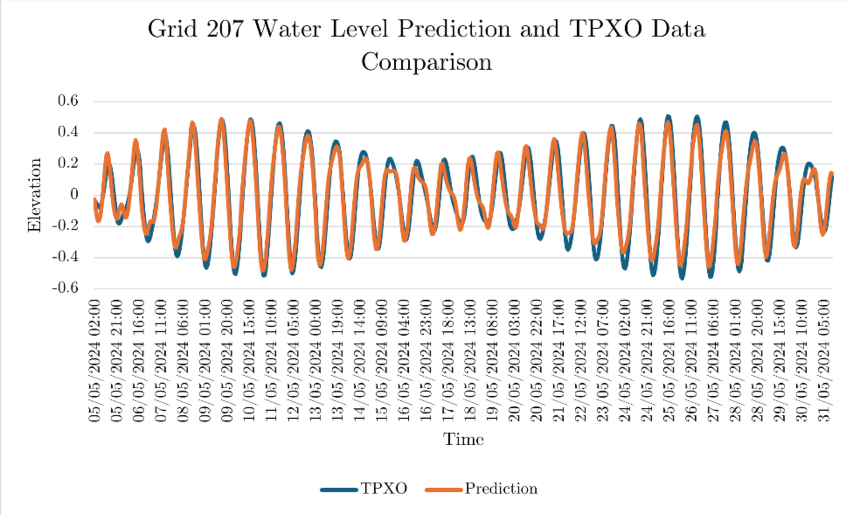
<td>
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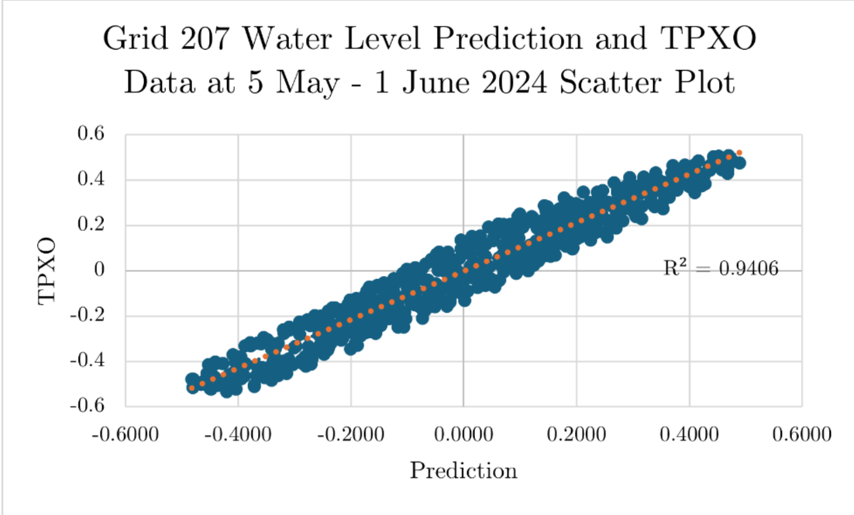
<td>
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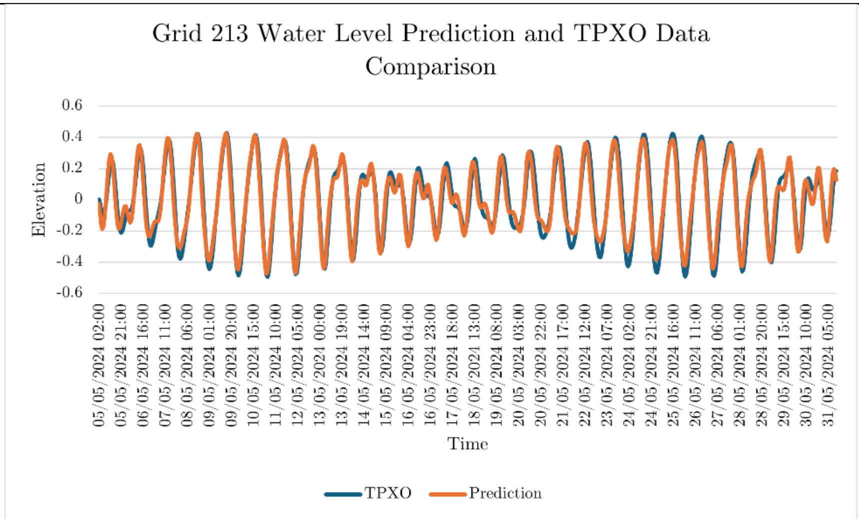
<td>
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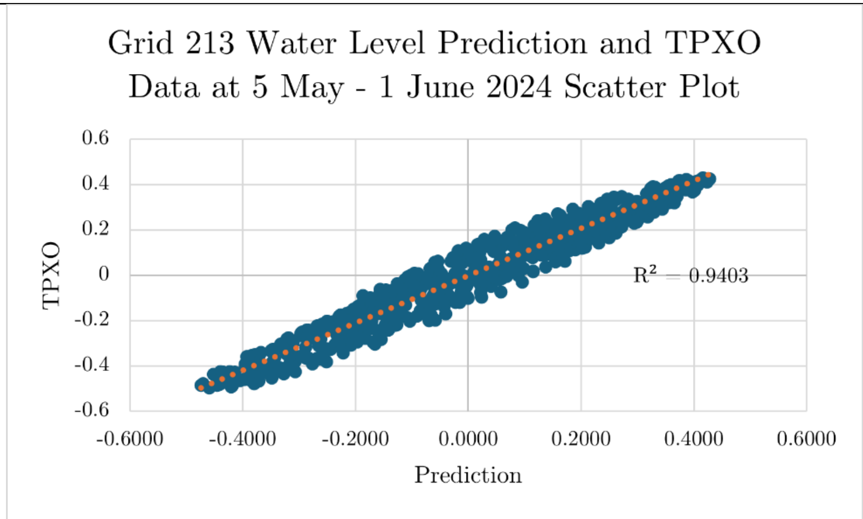
<td>
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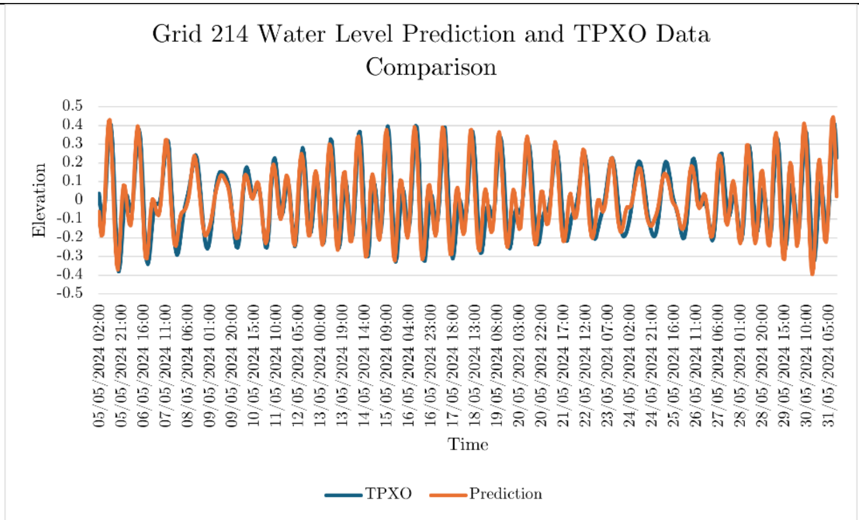
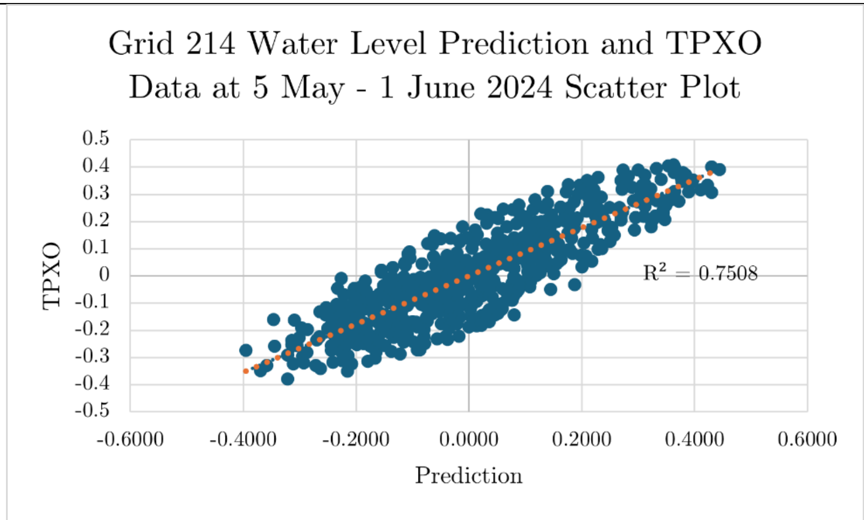
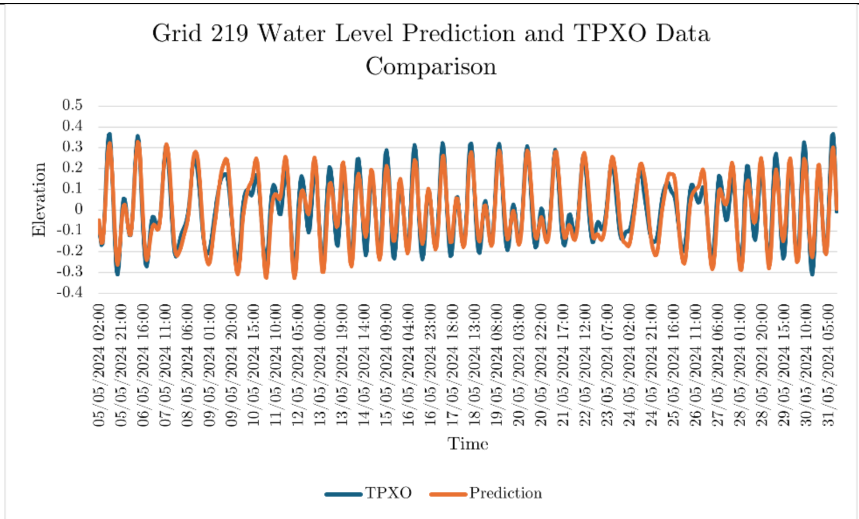
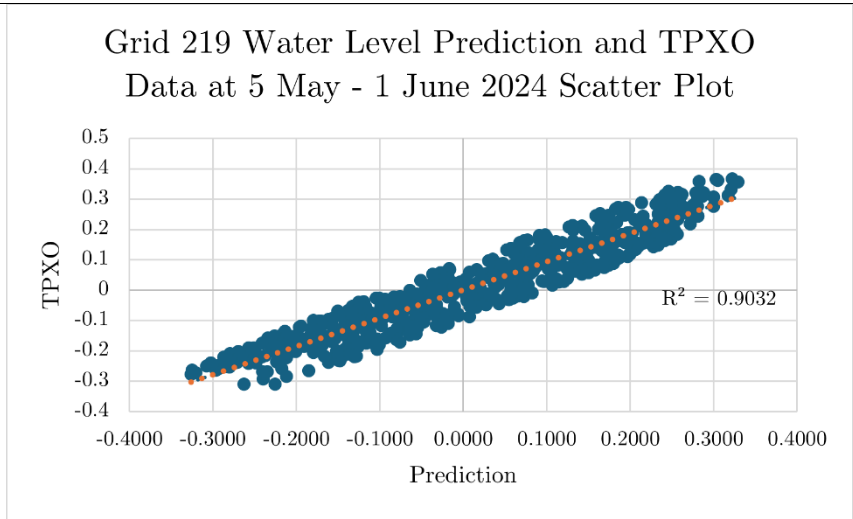

Grid 214 Water Level Prediction and TPXO Data Comparison
Elevation
Time
TPXO
Prediction


Grid 214 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
Prediction
R² = 0.7508

219


Grid 219 Water Level Prediction and TPXO Data Comparison
Elevation
Time
TPXO
Prediction


Grid 219 Water Level Prediction and TPXO Data at 5 May - 1 June 2024 Scatter Plot
TPXO
Prediction
R² = 0.9032

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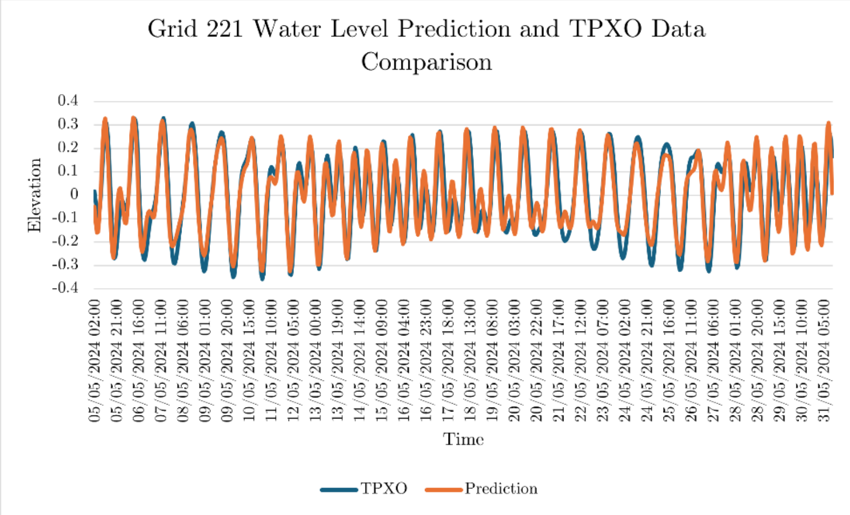

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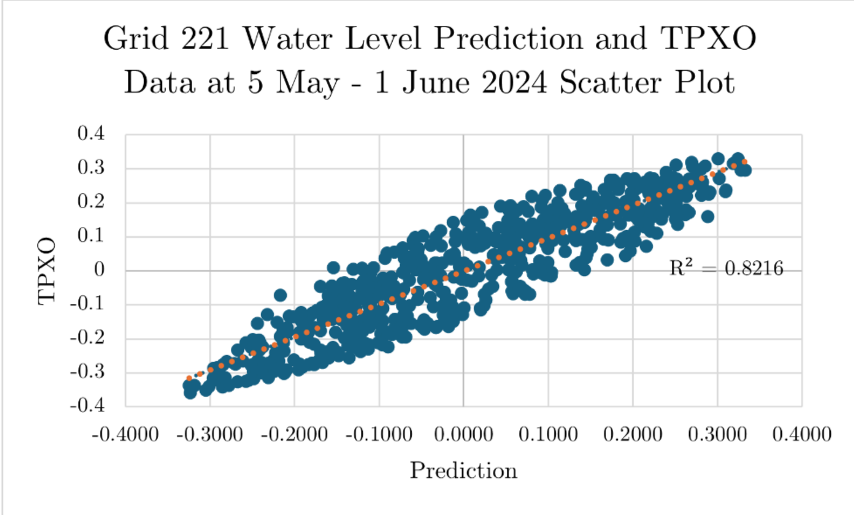

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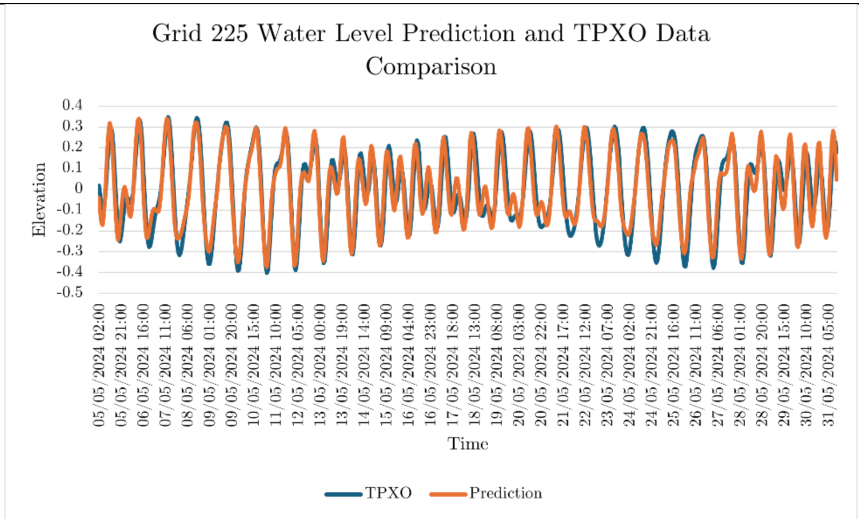

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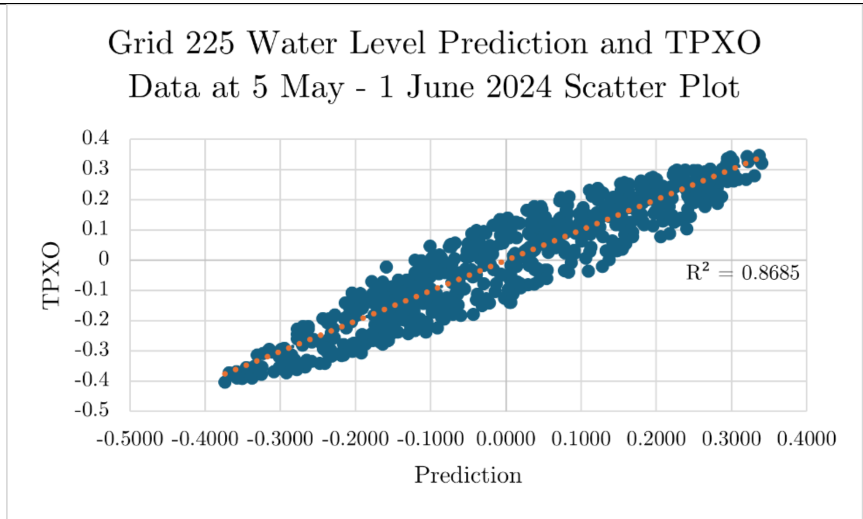

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