1. Improved Short-term Tidal Prediction for UKCMF: Summary

This guidance note describes an empirical method of tidal correction as a means of reducing the small inherent error in astronomical tidal predictions. Correction is made by applying a correction factor that reflects differences between observations and predictions for a few recent high water levels. To exclude the influence of diurnal inequality of high waters from the correction process, the adjustment is made using predictions and observations for alternate high waters, in accordance with the following correction algorithm:

$$HW_N = A_N + S_N + C_1\,[HW_{N-2} - S_{N-2} - A_{N-2}] + C_2\,[HW_{N-4} - S_{N-4} - A_{N-4}] + C_3\,[HW_{N-6} - S_{N-6} - A_{N-6}] + C_4$$

where HW_N is the observed high water level for tide number N, A_N is the astronomical prediction for the same tide and S_N is the storm surge component derived from the operational CS3x model for that tide. C_1, C_2, C_3 and C_4 are coefficients.

2. Derivation of the Correction Coefficients

The correction coefficients for each port are provided in Table 1. These were derived using multiple linear regression of the prediction error for HW_N against the prediction errors in preceding high waters, based upon tidal observations and predictions for 2006-2009 inclusive. However, for the relatively recent tide gauge installation at Avonmouth Portbury, the correction coefficients were derived from tidal observations and predictions for 2008-2009.

The ports of Bournemouth and Islay experience complex tides with more than 2 high waters per day and do not consistently exhibit diurnal inequality. Consequently, the derivation and implementation of the correction algorithm is not recommended for these ports; given their relatively small tidal range, the implementation of the correction method is unlikely to supply added benefit and coefficients are therefore not supplied for these locations.

3. Reduction in Prediction Error

The reduction in tidal prediction error obtained at each port using these correction coefficients has been estimated using the mean absolute error (MAE) and the root mean squared error (RMSE) of the predictions, together with the coefficient of determination (r^2) , which is defined as: $r^2 = 1 - var(err)/var(obs)$. These statistics are presented in Table 2.

4. Implementing the Empirical Tidal Corrections

This correction algorithm is relatively simple and can be implemented within NFFS or using MS Excel, using the following steps:

Step 1. At any given time, T, an improved predicted tide for the next high water, HW_N can be calculated by first calculating the prediction errors (V_1,V_2,V_3) in alternate preceding high waters (HW_{N-2}, HW_{N-4}, HW_{N-6}), where $N-2$ refers to the last high water but one (see Figure 1). The prediction errors can be calculated as follows:

$$V_1 = HW_{N-2} - S_{N-2} - A_{N-2}$$

$$V_2 = HW_{N\text{-}4} - S_{N\text{-}4} - A_{N\text{-}4}$$

$$V_3 = HW_{N\text{-}6} - S_{N\text{-}6} - A_{N\text{-}6}$$

Notation:	*HW*	Observed high water
	S	Surge at the time of observed high water, taken from the operational surge model CS3x
	A	Astronomical prediction of high water from tide table

Note that the correction method ignores differences in the arrival time of the predicted and observed HW. Thus, *A* and *HW* represent maxima in the predicted and observed water level time series, even though their respective timings may differ slightly.

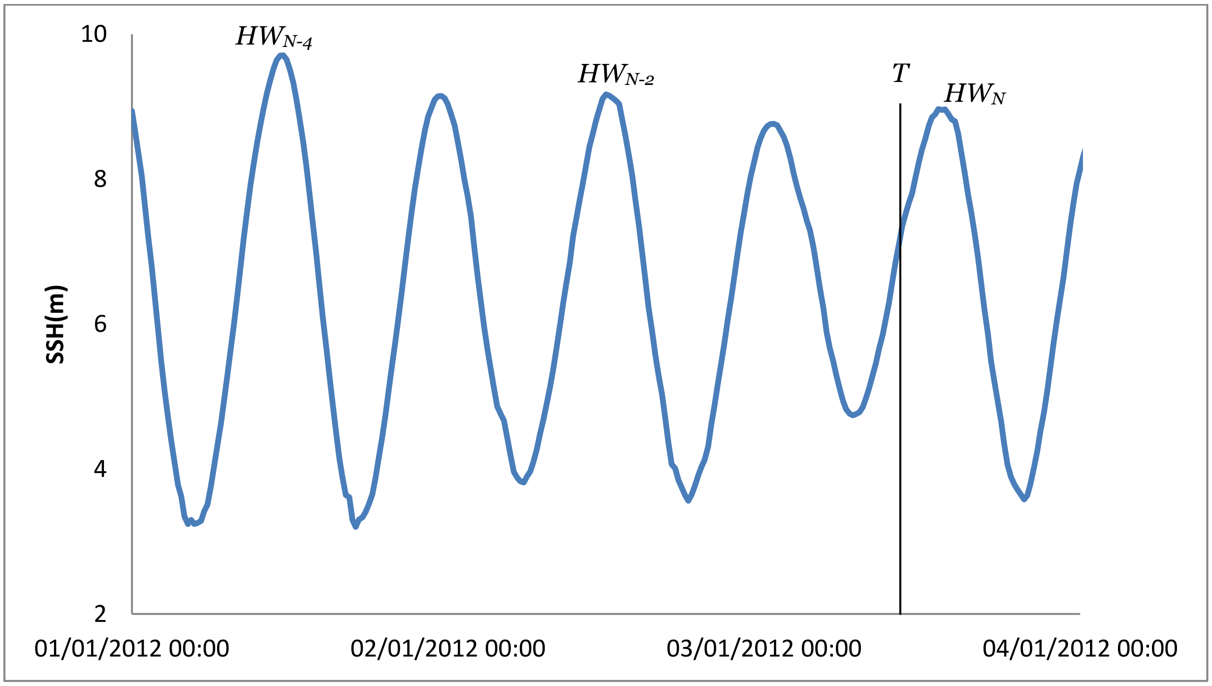

Figure 1

Step 2. The corrected tidal prediction for the next high water, HW_N, is a modification of the tide table value for the next high water, A_N. Naturally, the modelled surge for the next high water, S_N, should also be added during the normal operational procedure. In the following equation, C_1, C_2, C_3 and C_4 are the coefficients provided from the analysis and given in Table 1.

$$HW_N = A_N + (C_1 {*} V_1) + (C_2 {*} V_2) + (C_3 {*} V_3) + C_4 + S_N$$

Handling data gaps:

Where there are gaps in time series of HW observations, the correction algorithm can still be partially implemented if data exist for some preceding alternate high waters, although the resulting correction to the tidal predictions will be less effective, particularly where data are missing for the preceding high water but one ($HW_{N\text{-}2}$). Clearly, where observations are missing for the three preceding alternate high waters (i.e. $HW_{N\text{-}2\ldots N\text{-}6}$), the algorithm cannot be implemented and the user must revert to uncorrected astronomical tidal predictions (A_N).

Table 1. Tidal Correction Coefficients

	St Marys	Newlyn	Ilfracombe	Hinkley Point	Portbury	Avonmouth	Newport	Mumbles	Milford Haven	Fishguard	Barmouth	Holyhead
C1	0.6534	0.5757	0.5371	0.6323	0.7815	0.7104	0.6003	0.5161	0.5795	0.5226	0.4067	0.5045
C2	0.0850	0.1081	0.1010	-0.0026	-0.2466	-0.1848	-0.0057	0.1309	0.1042	0.2209	0.2023	0.1853
C3	0.0491	0.0779	0.0379	0.0263	0.1218	0.0783	-0.0062	0.0568	0.0532	0.1026	0.1110	0.1446
C4	0.0104	0.0212	0.0203	0.0173	0.0322	0.0381	0.0436	0.0049	0.0281	0.0043	-0.0002	0.0015
	Llandudno	Liverpool	Heysham	Port Erin	Workington	Bangor	Portpatrick	Portrush	Millport	Tobermory	Ullapool	Stornoway
C1	0.4177	0.4941	0.4944	0.5232	0.3980	0.5301	0.4442	0.5348	0.4376	0.4595	0.4799	0.5495
C2	0.1533	0.1125	0.1622	0.1517	0.2183	0.1447	0.1904	0.1458	0.1986	0.2249	0.2468	0.2273
C3	0.1072	0.0705	0.0876	0.0790	0.0918	0.0823	0.1404	0.1159	0.1171	0.1598	0.1470	0.1058
C4	0.0043	0.0222	0.0094	0.0090	-0.0088	-0.0021	0.0052	-0.0053	-0.0032	-0.0033	-0.0060	-0.0017
	Kinlochbervie	Lerwick	Wick	Aberdeen	Leith	North Shields	Whitby	Immingham	Cromer	Lowestoft	Harwich	Sheerness
C1	0.4894	0.4939	0.4732	0.3268	0.3698	0.3676	0.3298	0.3325	0.4144	0.3236	0.5575	0.5152
C2	0.2633	0.2151	0.2108	0.2861	0.1798	0.2512	0.2802	0.1842	0.1712	0.2218	0.1468	0.1396
C3	0.1203	0.1824	0.1602	0.1401	0.0798	0.1010	0.1529	0.1080	0.0715	0.1039	-0.0986	0.0436
C4	-0.0070	-0.0018	-0.0027	0.0049	0.0120	0.0152	0.0327	0.0238	0.0133	0.0076	0.0593	0.0281
	Dover	Newhaven	Portsmouth	Weymouth	Jersey	Plymouth						
C1	0.4195	0.4010	0.4025	0.5668	0.6226	0.6829						
C2	0.2154	0.2031	0.1910	0.1212	0.0310	-0.0011						
C3	0.0071	0.0443	0.0638	0.1405	0.0243	0.0713						
C4	0.0197	0.0109	0.0144	0.0023	0.0095	0.0105						

Table 2. Mean absolute error (MAE), root mean squared error (RMSE) and coefficient of determination (r2) of the astronomical predictions before (in black) and after (in blue) the correction algorithm was applied. Units of MAE and RMSE are metres.

	St Marys	Newlyn	Ilfracombe	Hinkley Point	Portbury	Avonmouth	Newport	Mumbles	Milford Haven	Fishguard	Barmouth	Holyhead
MAE	0.0594	0.0909	0.0814	0.1150	0.1425	0.1437	0.1583	0.0679	0.1092	0.0589	0.0647	0.0561
	0.0257	0.0285	0.0450	0.0788	0.0884	0.0894	0.0971	0.0490	0.0335	0.0322	0.0489	0.0346
RMS	0.0719	0.1030	0.0987	0.1412	0.1811	0.1780	0.1926	0.0847	0.1222	0.0737	0.0832	0.0712
	0.0341	0.0372	0.0587	0.1028	0.1150	0.1161	0.1289	0.0642	0.0434	0.0425	0.0655	0.0458
r^2	0.9892	0.9864	0.9923	0.9865	0.9834	0.9857	0.9821	0.9895	0.9915	0.9806	0.9763	0.9757
	0.9953	0.9932	0.9953	0.9919	0.9909	0.9914	0.9884	0.9938	0.9955	0.9925	0.9853	0.9897

	Llandudno	Liverpool	Heysham	Port Erin	Workington	Bangor	Portpatrick	Portrush	Millport	Tobermory	Ullapool	Stornoway
MAE	0.0646	0.0840	0.0733	0.0594	0.0676	0.0476	0.0622	0.0540	0.0645	0.0587	0.0736	0.0601
	0.0485	0.0447	0.0475	0.0344	0.0497	0.0340	0.0393	0.0336	0.0464	0.0355	0.0370	0.0309
RMS	0.0815	0.1000	0.0914	0.0723	0.0901	0.0630	0.0765	0.0706	0.0833	0.0769	0.0959	0.0753
	0.0655	0.0576	0.0628	0.0450	0.0675	0.0454	0.0527	0.0449	0.0615	0.0472	0.0482	0.0401
r^2	0.9852	0.9904	0.9900	0.9784	0.9855	0.9285	0.9355	0.9264	0.8945	0.9725	0.9694	0.9733
	0.9902	0.9940	0.9944	0.9886	0.9908	0.9620	0.9665	0.9658	0.9410	0.9887	0.9896	0.9921

	Kinlochbervie	Lerwick	Wick	Aberdeen	Leith	North Shields	Whitby	Immingham	Cromer	Lowestoft	Harwich	Sheerness
MAE	0.0740	0.0528	0.0531	0.0501	0.0635	0.0706	0.1414	0.0877	0.0647	0.0530	0.1533	0.1047
	0.0342	0.0277	0.0323	0.0342	0.0481	0.0407	0.0420	0.0607	0.0453	0.0418	0.0528	0.0535
RMS	0.0940	0.0671	0.0678	0.0621	0.0806	0.0871	0.1579	0.1155	0.0835	0.0690	0.1738	0.1294
	0.0445	0.0353	0.0419	0.0449	0.0626	0.0539	0.0557	0.0830	0.0608	0.0554	0.0693	0.0698
r^2	0.9699	0.8920	0.9521	0.9715	0.9731	0.9730	0.9709	0.9701	0.9696	0.8687	0.9050	0.9484
	0.9898	0.9680	0.9806	0.9834	0.9805	0.9831	0.9833	0.9778	0.9792	0.9059	0.9408	0.9695

	Dover	Newhaven	Portsmouth	Weymouth	Jersey	Plymouth
MAE	0.0774	0.0595	0.0638	0.0560	0.0753	0.0589
	0.0483	0.0416	0.0415	0.0323	0.0492	0.0314
RMS	0.0956	0.0747	0.0793	0.0698	0.0938	0.0730
	0.0646	0.0560	0.0554	0.0434	0.0673	0.0408
r^2	0.9758	0.9858	0.9591	0.9486	0.9936	0.9796
	0.9835	0.9902	0.9721	0.9794	0.9963	0.9902