Tidal variability in the Hong Kong region

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SUPPLEMENTARY MATERIAL

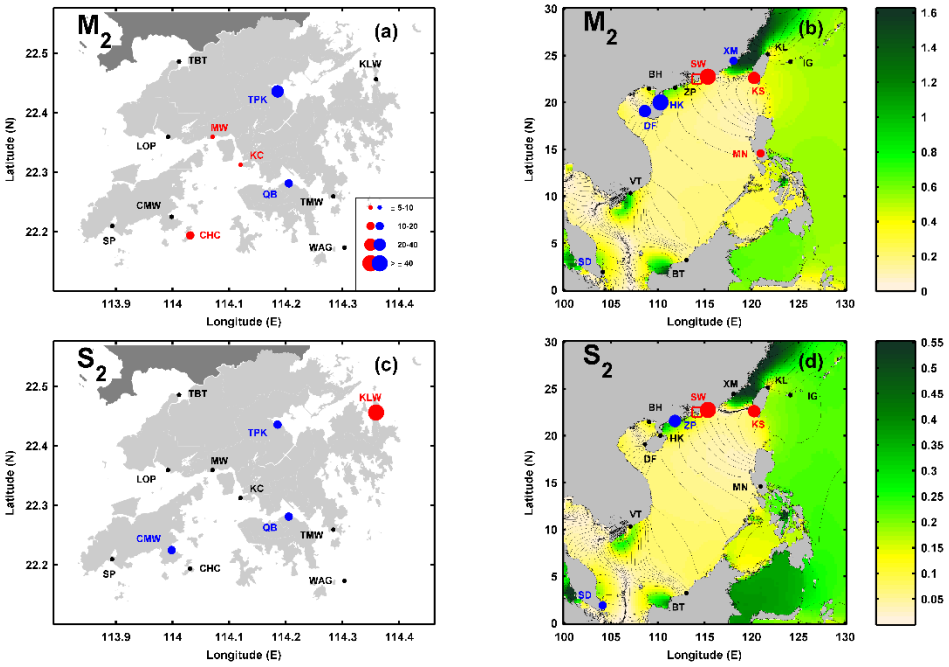

Figure S1 Semidiurnal tidal anomaly correlations (TACs) of detrended M_2 phase to detrended MSL in (a) Hong Kong, (b) the South China Sea, and of detrended S_2 phase to detrended MSL in (c) Hong Kong, and (d) the South China Sea. Red markers indicate positive TACs and blue indicates negative TACs, with the marker size showing the relative magnitude according to the legend. Black marks indicate insignificant TACs. Map backgrounds in (b) and (d) show mean tidal amplitudes over the period of 1993-2014 (color scale, meters) and phases (solid lines, 30° increment), taken from the ocean tidal model of TPXO7.2, (Egbert and Erofeeva, 2002, 2010).

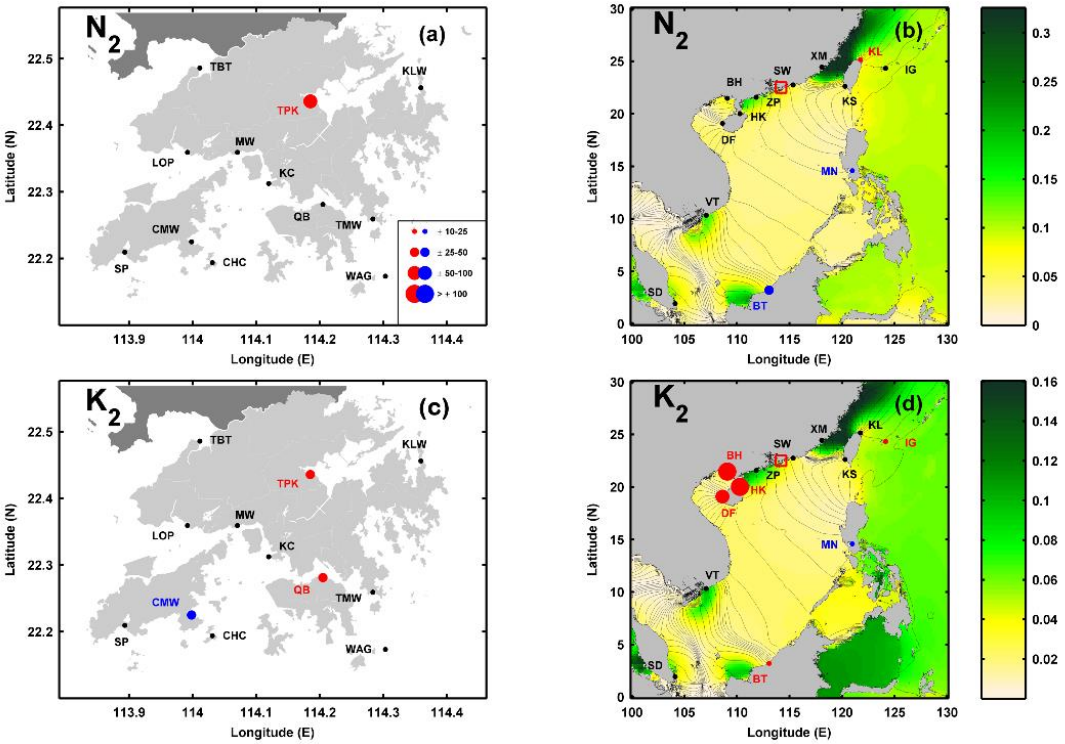

Figure S2 Semidiurnal tidal anomaly correlations (TACs) of detrended N_2 amplitude to detrended MSL in (a) Hong Kong, (b) the South China Sea, and of detrended K_2 amplitude to detrended MSL in (c) Hong Kong, and (d) the South China Sea. Red markers indicate positive TACs and blue indicates negative TACs, with the marker size showing the relative magnitude according to the legend. Black marks indicate insignificant TACs. Map backgrounds in (b) and (d) show mean tidal amplitudes over the period of 1993-2014 (color scale, meters) and phases (solid lines, 30° increment), taken from the ocean tidal model of TPXO7.2, (Egbert and Erofeeva, 2002, 2010).

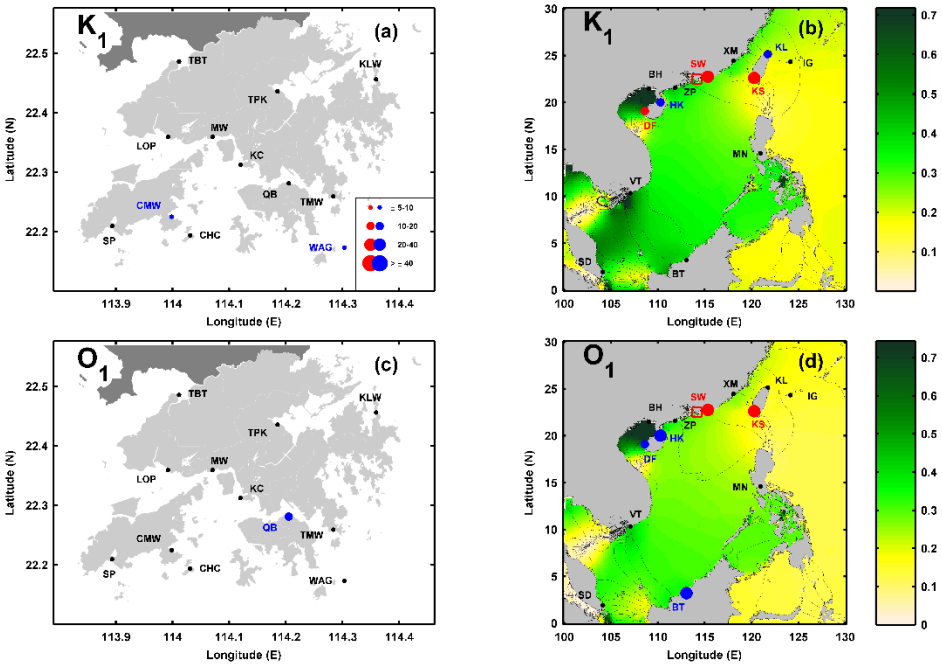

Figure S3 Diurnal tidal anomaly correlations (TACs) of detrended K_1 phase to detrended MSL in (a) Hong Kong, (b) the South China Sea, and of detrended O_1 phase to detrended MSL in (c) Hong Kong, and (d) the South China Sea. Red markers indicate positive TACs and blue indicates negative TACs, with the marker size showing the relative magnitude according to the legend. Black marks indicate insignificant TACs. Map backgrounds in (b) and (d) show mean tidal amplitudes over the period of 1993-2014 (color scale, meters) and phases (solid lines, 30° increment), taken from the ocean tidal model of TPXO7.2, (Egbert and Erofeeva, 2002, 2010).

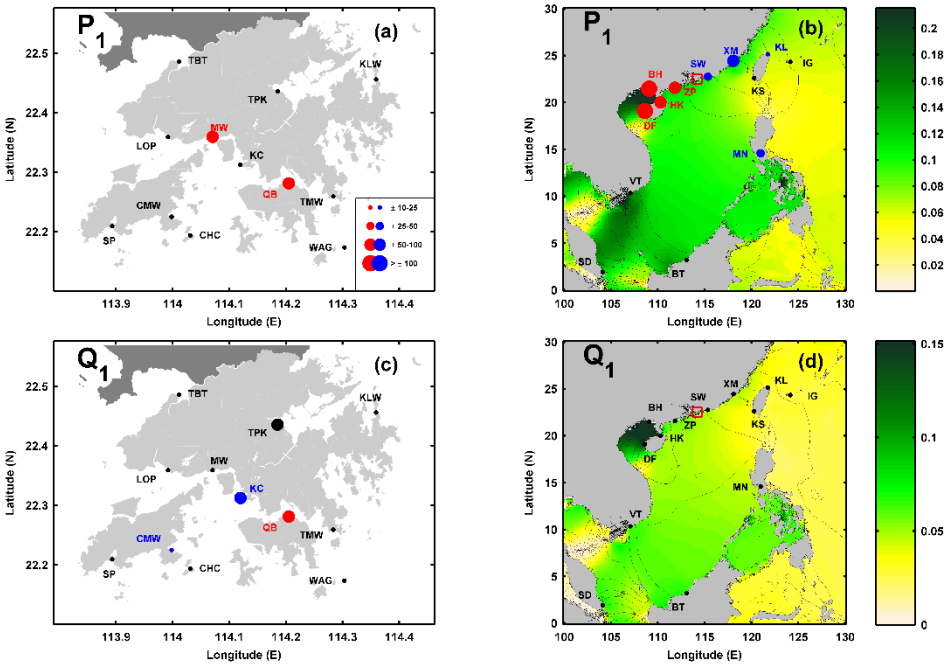

Figure S4 Diurnal tidal anomaly correlations (TACs) of detrended P_1 amplitude to detrended MSL in (a) Hong Kong, (b) the South China Sea, and of detrended Q_1 amplitude to detrended MSL in (c) Hong Kong, and (d) the South China Sea. Red markers indicate positive TACs and blue indicates negative TACs, with the marker size showing the relative magnitude according to the legend. Black marks indicate insignificant TACs. Map backgrounds in (b) and (d) show mean tidal amplitudes over the period of 1993-2014 (color scale, meters) and phases (solid lines, 30° increment), taken from the ocean tidal model of TPXO7.2, (Egbert and Erofeeva, 2002, 2010).

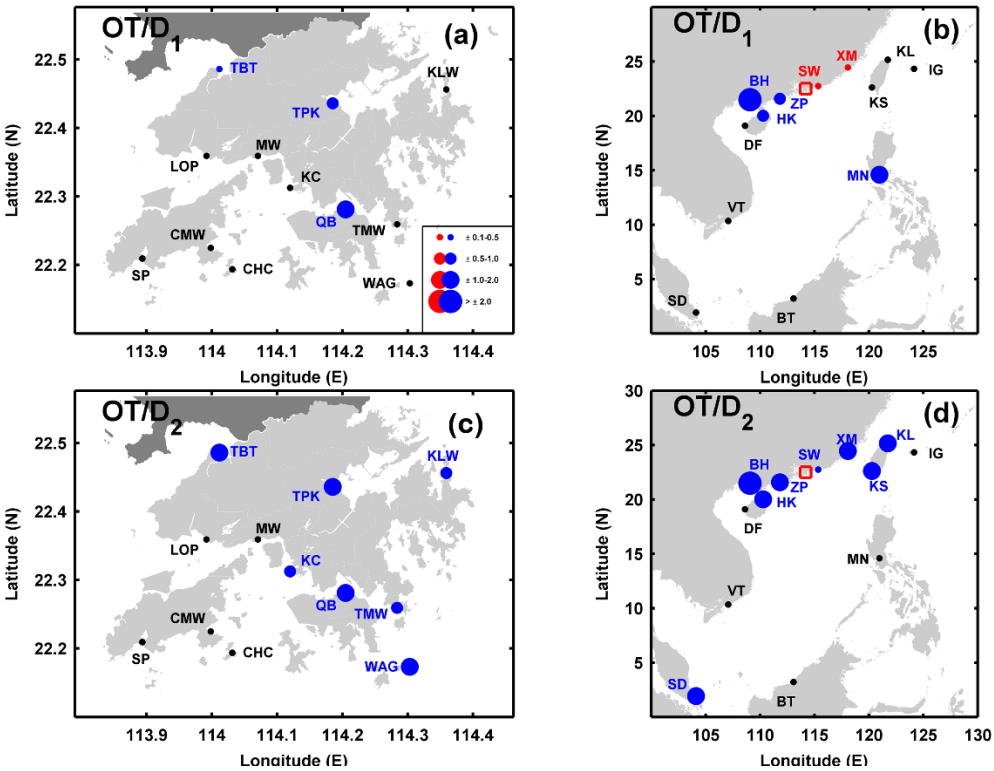

Figure S5 Results of the OT TACs for detrended D_1 to detrended in Hong Kong (a) and the SCS (b), and detrended D_2 to detrended OT in Hong Kong (c) and the SCS (d). Red markers indicate positive TACs, blue indicates negative TACs, with the marker size showing the relative magnitude according to the legend. Black marks indicate insignificant TACs.

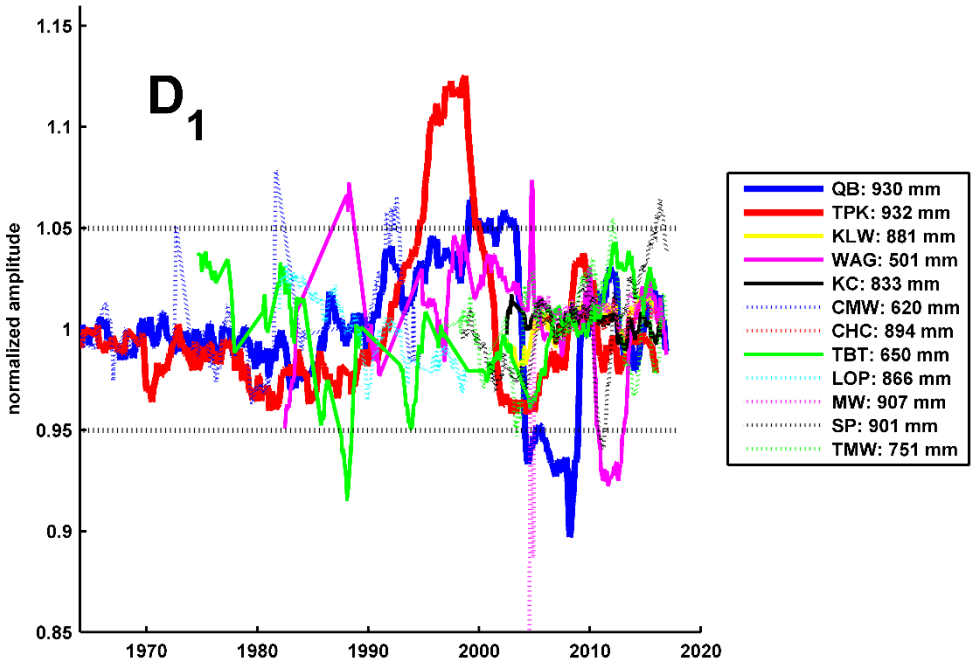

Figure S6 Time-series of detrended D_1 at all tide gauges in Hong Kong, plotted as a normalized amplitude to show relative variability, with mean values given in the legend. Each gauge is indicated by color according to the legend, with the QB (solid blue) and TPK (solid red) gauges shown as heavier lines. Horizontal dotted lines indicate the ±5% variational band relative to the mean amplitude.

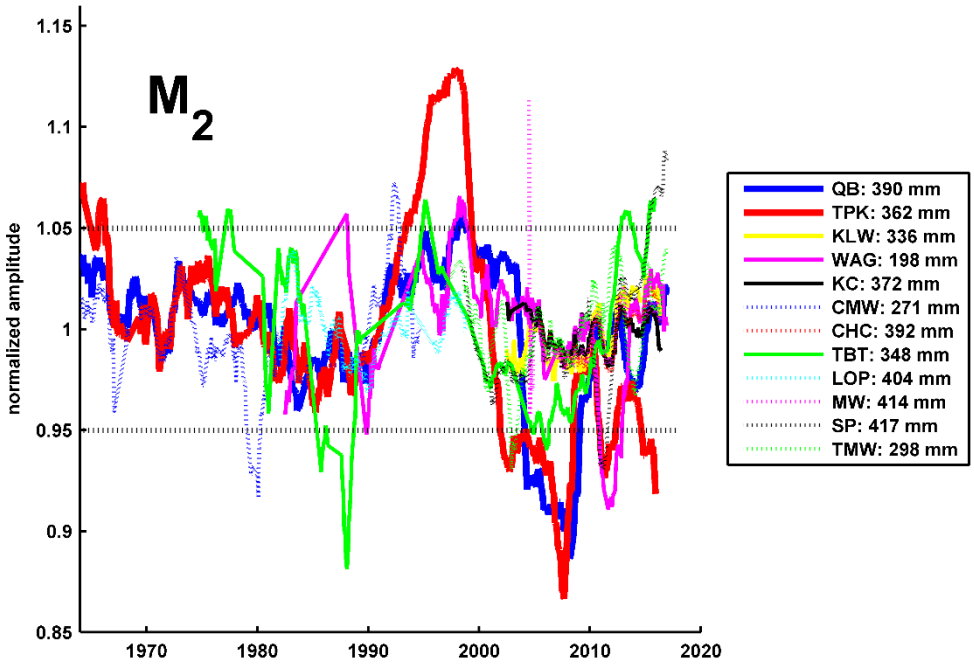

Figure S7 Time-series of detrended M_2 at all tide gauges in Hong Kong, plotted as a normalized amplitude to show relative variability, with mean values given in the legend. Each gauge is indicated by color according to the legend, with the QB (solid blue) and TPK (solid red) gauges shown as heavier lines. Horizontal dotted lines indicate the ±5% variational band relative to the mean amplitude.

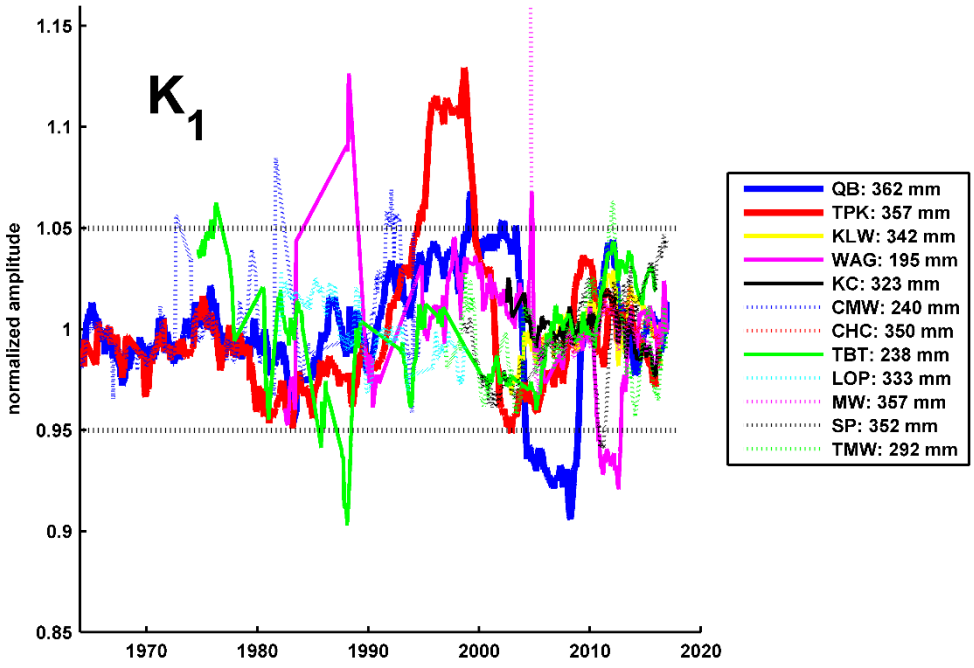

Figure S8 Time-series of detrended K_1 at all tide gauges in Hong Kong, plotted as a normalized amplitude to show relative variability, with mean values given in the legend. Each gauge is indicated by color according to the legend, with the QB (solid blue) and TPK (solid red) gauges shown as heavier lines. Horizontal dotted lines indicate the ±5% variational band relative to the mean amplitude.

Table S1 Phase TACs for M_2, S_2, K_1, and O_1. All values given are in units of degree change in the tidal phase for a 1-meter fluctuation in sea-level (deg m^{-1}). Statistically significant positive values are given in bold italic text.

Station	**M_2 TAC**	**S_2 TAC**	**K_1 TAC**	**O_1 TAC**
Quarry Bay (QB)	***-15 ± 2***	***-17 ± 5***	-4 ± 2	***-11 ± 1***
Tai Po Kau (TPK)	***-28 ± 6***	***-18 ± 3***	-6 ± 4	-13 ± 4
Tsim Bei Tusi (TBT)	+19 ± 13	+19 ± 17	+6 ± 5	+5 ± 4
Chi Ma Wan (CMW)	-5 ± 5	***-16 ± 2***	***-7 ± 4***	-3 ± 1
Cheung Chau (CHC)	***+13 ± 2***	+23 ± 15	+39 ± 36	+1 ± 13
Lok On Pai (LOP)	-2 ± 4	-15 ± 9	+1 ± 6	+3 ± 6
Ma Wan (MW)	***+9 ± 2***	+9 ± 8	+2 ± 13	-4 ± 5
Tai Miu Wan (TMW)	+4 ± 8	+2 ± 9	+1 ± 7	+2 ± 3
Shek Pik (SP)	-11 ± 6	-10 ± 12	-6 ± 6	+12 ± 2
Waglan Island (WAG)	-40 ± 30	+12 ± 2	***+6 ± 1***	+4 ± 3
Ko Lau Wan (KLW)	+7 ± 3	***+43 ± 22***	+10 ± 15	-3 ± 5
Kwai Chung (KC)	***+8 ± 2***	+45 ± 20	+29 ± 52	-9 ± 23
Dongfang (DF)	***-23 ± 6***	-15 ± 13	***+16 ± 3***	***-12 ± 2***
Beihei (BH)	+ 10 ± 6	+25 ± 23	+1 ± 5	-10 ± 3
Haikou (HK)	***-67 ± 21***	-6 ± 7	***-13 ± 2***	***-20 ± 3***
Zhapo (ZP)	-5 ± 4	***-22 ± 2***	+6 ± 7	-2 ± 7
Shanwei (SW)	***+58 ± 11***	***+86 ± 26***	***+31 ± 11***	***+28 ± 1***
Xiamen (XM)	***-12 ± 2***	-7 ± 1	-2 ± 3	-1 ± 3
Keelung (KL)	+8 ± 7	-3 ± 19	***-10 ± 2***	-3 ± 3
Kaohsiung (KS)	***+34 ± 9***	***+39 ± 14***	***+22 ± 4***	***+22 ± 6***
Manila, PHL (MN)	***+13 ± 3***	+1 ± 5	+2 ± 5	-6 ± 5
Vung Tau, VTM (VT)	-27 ± 22	-3 ± 18	-2 ± 3	-34 ± 22
Sedili, MLY (SD)	-8 ± 1	***-14 ± 4***	-9 ± 4	+8 ± 3
Bintulu, MLY (BT)	-3 ± 5	-7 ± 11	+8 ± 5	***-27 ± 4***
Ishigaki, JPN (IG)	-2 ± 4	-8 ± 9	-2 ± 3	-3 ± 3

Table S2 Amplitude TACs for N_2, K_2, P_1, and Q_1. All values given are in units of milimeter change in the tidal amplitude for a 1-meter fluctuation in sea-level (mm m^{-1}). Statistically significant positive values are given in bold italic text.

Station	**N_2 TAC**	**K_2 TAC**	**P_1 TAC**	**Q_1 TAC**
Quarry Bay (QB)	+33 ± 10	***+35 ± 14***	***+71 ± 10***	***+50 ± 11***
Tai Po Kau (TPK)	***+85 ± 12***	***+35 ± 14***	+19 ± 16	+18 ± 6
Tsim Bei Tusi (TBT)	+23 ± 21	-2 ± 14	-9 ± 6	-8 ± 12
Chi Ma Wan (CMW)	-7 ± 5	***-25 ± 6***	-4 ± 6	***-18 ± 4***
Cheung Chau (CHC)	-22 ± 35	-12 ± 44	-26 ± 32	-33 ± 30
Lok On Pai (LOP)	-13 ± 24	-5 ± 18	+9 ± 12	-3 ± 21
Ma Wan (MW)	+22 ± 17	+3 ± 18	***+65 ± 9***	-15 ± 32
Tai Miu Wan (TMW)	+4 ± 13	+12 ± 8	+8 ± 4	-14 ± 12
Shek Pik (SP)	+4 ± 11	+17 ± 10	+12 ± 20	+18 ± 17
Waglan Island (WAG)	+5 ± 5	-6 ± 3	+2 ± 6	-2 ± 6
Ko Lau Wan (KLW)	+29 ± 29	+8 ± 14	-7 ± 26	-26 ± 14
Kwai Chung (KC)	-10 ± 29	-16 ± 36	-33 ± 50	***-60 ± 14***
Dongfang (DF)	-16 ± 22	***+67 ± 19***	***+120 ± 42***	+31 ± 28
Beihei (BH)	-15 ± 50	***+175 ± 56***	***+153 ± 33***	+111 ± 51
Haikou (HK)	+10 ± 25	***+152 ± 76***	***+70 ± 33***	-40 ± 37
Zhapo (ZP)	-12 ± 35	-3 ± 40	***+50 ± 15***	-2 ± 34
Shanwei (SW)	-46 ± 16	-1 ± 12	***-47 ± 10***	-13 ± 13
Xiamen (XM)	-15 ± 21	-22 ± 22	***-55 ± 20***	-13 ± 5
Keelung (KL)	***+17 ± 9***	-18 ± 4	***-19 ± 7***	+12 ± 11
Kaohsiung (KS)	+9 ± 14	-2 ± 12	-16 ± 10	+5 ± 13
Manila, PHL (MN)	***-22 ± 7***	***-23 ± 6***	***-33 ± 13***	-7 ± 10
Vung Tau, VTM (VT)	+44 ± 9	+3 ± 23	+3 ± 18	-38 ± 13
Sedili, MLY (SD)	-7 ± 18	-15 ± 7	-4 ± 13	+201 ± 76
Bintulu, MLY (BT)	***-31 ± 3***	***+18 ± 2***	+1 ± 22	+370 ± 64
Ishigaki, JPN (IG)	+13 ± 17	***+16 ± 4***	-9 ± 8	+10 ± 10

Table S3 The D_1 and D_2 OT TACs, given in unitless ratios (i.e., mm mm^{-1}). Statistically significant positive values are given in bold italic text.

Station	**OT/D_1**	**OT/D_2**
Quarry Bay (QB)	***-1.88 ± 0.43***	***-1.76 ± 0.61***
Tai Po Kau (TPK)	***-0.88 ± 0.07***	***-1.00 ± 0.05***
Tsim Bei Tusi (TBT)	***-0.47 ± 0.11***	***-1.12 ± 0.09***
Chi Ma Wan (CMW)	-0.17 ± 0.47	-0.13 ± 0.29
Cheung Chau (CHC)	-0.25 ± 0.76	-0.17 ± 0.66
Lok On Pai (LOP)	-0.11 ± 0.27	-0.42 ± 0.47
Ma Wan (MW)	-0.28 ± 0.60	-0.07 ± 0.86
Kwai Chung (KC)	-0.21 ± 0.63	***-0.74 ± 0.16***
Ko Lau Wan (KLW)	-0.07 ± 0.38	***-0.49 ± 0.29***
Tai Miu Wan (TMW)	-0.59 ± 0.40	***-0.50 ± 0.07***
Waglan Island (WAG)	-0.71 ± 0.66	***-1.73 ± 0.11***
Shek Pik (SP)	-0.36 ± 0.41	-0.42 ± 0.72
Dongfang (DF)	-5.06 ± 2.39	+1.02 ± 1.21
Beihei (BH)	***-2.88 ± 0.10***	***-2.33 ± 0.05***
Haikou (HK)	***-0.67 ± 0.03***	***-1.10 ± 0.04***
Zhapo (ZP)	***-0.59 ± 0.04***	***-1.39 ± 0.63***
Shanwei (SW)	***+0.22 ± 0.07***	***-0.23 ± 0.06***
Xiamen (XM)	***+0.27 ± 0.03***	***-1.21 ± 0.21***
Keelung (KL)	+0.36 ± 0.62	***-1.42 ± 0.31***
Kaohsiung (KS)	-0.31 ± 0.42	***-1.07 ± 0.37***
Manila, PHL (MN)	***-1.92 ± 0.70***	-0.04 ± 0.47
Vung Tau, VTM (VT)	-0.07 ± 0.29	+0.50 ± 0.33
Sedili, MLY (SD)	-0.39 ± 1.03	***-1.71 ± 0.03***
Bintulu, MLY (BT)	+1.72 ± 0.65	-0.15 ± 0.26
Ishigaki, JPN (IG)	-0.44 ± 0.32	+0.60 ± 0.48

Table S4 Correlations of water level components with the North Point/Quarry Bay (QB) tide gauge, showing S_2, O_1, K_2, P_1, Q_1, and MSL. Two numbers are given in each column, representing the correlations in the "historical" era (pre-1997), and the "modern" era (post-1997). Non-existent data is indicated by "~". An average value is also calculated at the local (Hong Kong) and regional (South China Sea) scale for each era. Data records that cover both time periods will indicate the better correlated era by bold text.

Station	**S_2**	**O_1**	**K_2**	**P_1**	**Q_1**	**MSL**
TPK	**0.65**/0.39	**0.69**/0.16	**0.37**/0.34	**0.33**/0.18	0.63/0.60	0.50/**0.53**
TBT	0.34/**0.35**	**0.30**/0.07	0.19/**0.78**	0.10/**0.35**	**0.66**/0.66	-0.12/**0.37**
CMW/CHC	**0.44**/0.10	**0.67**/-0.09	0.39/**0.50**	0.22/**0.47**	**0.68**/0.44	**0.53**/0.50
LOP/MW	**0.36**/0.09	**0.54**/0.06	**0.71**/0.54	**0.69**/0.41	**0.75**/0.38	**0.64**/0.15
TMW	~/0.45	~/0.18	~/0.26	~/-0.09	~/0.31	~/0.73
SP	~/0.19	~/0.16	~/0.50	~/0.07	~/0.63	~/0.66
WAG	~/0.14	~/0.12	~/-0.10	~/0.06	~/0.60	~/0.76
KC	~/-0.03	~/-0.01	~/0.45	~/0.13	~/0.60	~/0.27
KLW	~/-0.09	~/-0.14	~/0.37	~/0.51	~/0.51	~/0.60
HK Ave.	**0.44**/0.18	**0.50**/0.06	0.40/**0.41**	**0.33**/0.23	**0.68**/0.53	0.39/**0.51**
DF	0.40/~	0.46/~	0.01/~	0.30/~	0.61/~	0.63/~
BH	0.40/~	0.42/~	0.13/~	0.30/~	0.62/~	0.36/~
HK	0.47/~	0.44/~	0.42/~	0.37/~	0.55/~	0.66/~
ZP	0.10/~	0.50/~	0.45/~	0.52/~	0.72/~	0.70/~
SW	0.32/~	0.19/~	0.56/~	0.28/~	0.59/~	0.65/~
XM	-0.41/~	0.39/~	0.03/~	0.25/~	0.49/~	0.57/~
KL	~/0.08	~/-0.18	~/0.24	~/0.27	~/0.15	~/0.36
KS	~/-0.14	~/0.32	~/-0.11	~/0.40	~/0.15	~/0.40
MN	~/-0.14	~/-0.44	~/-0.17	~/-0.08	~/0.26	~/0.21
VT	~/0.18	~/0.07	~/0.25	~/0.48	~/0.41	~/0.51
SD	~/0.49	~/0.48	~/0.32	~/-0.39	~/0.51	~/0.53
BT	~/0.28	~/0.60	~/0.41	~/0.26	~/0.61	~/0.79
IG	**-0.22**/0.07	0.11/**0.32**	**0.10**/-0.01	**0.11**/-0.20	**0.29**/0.08	**0.50**/0.01
SCS Ave.	**0.15**/0.12	**0.36**/0.03	**0.26**/0.133	**0.30**/0.11	**0.55**/0.31	**0.58**/0.40