Impact of Wind on the Spatio-Temporal Variation in Concentration of Suspended Solids in Tonle Sap Lake, Cambodia

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Empirical relationships between TSS and wind speed

Empirical relationships between wind and TSS was derived by using observed TSS, interpolated wind speed, and other environmental parameters (i.e. water depth, shear stress). The method of derivation was nonlinear regression analysis (eq 2.1 to 2.10) using the least squares method.

$$TSS = aW + b \tag{2.1}$$

$$TSS = aW^2 + bW + c \tag{2.2}$$

$$TSS = aW^3 + bW^2 + cW + d \tag{2.3}$$

$$TSS = a\frac{W}{D} + b \tag{2.4}$$

$$TSS = a\frac{W^2}{D} + b\frac{\mathrm{W}}{D} + c \tag{2.5}$$

$$TSS = a\frac{W^3}{D} + b\frac{W^2}{D} + c\frac{W}{D} + d \tag{2.6}$$

Appendix 2 - Empirical relationships between TSS and wind speed

$$TSS = a\tau_{wave} + b \tag{2.7}$$

$$TSS = ae^{bW} + c \tag{2.8}$$

$$TSS = ae^{b(W/D)} + c \tag{2.9}$$

$$TSS = ae^{b\tau_{wave}} + c \tag{2.10}$$

where TSS is total suspended solids concentration (*mg/L*), U is wind speed (*m/s*), D is water depth (*m*), τ_{wave} is shear stress (Pa), a, b, c, d are the calibrated parameters. Some of above relationships eq. 2.1, 2.3, and 2.7 had been explored previously (Hamilton and Mitchell, 1996), whereas, other equation is being investigated for the first time. eqs., 2.4, 2.5, and 2.6 were added specially to understand impact of water depth in TSS, as in general in TSL, TSS varied inversely with water depth (Siev et al., 2018).

In addition, in some cross section, TSS was as high as 650 mg/L (Siev et al., 2018), so it was also worthwhile to explore exponential relationships as in eqs. 2.8, 2.9, and 2.10.

Shear stress varies with depth, wave length, wave period, and was calculated as shown in eq. 2.11.

$$\tau_{wave} = H \times \frac{\rho \left\{\eta_0 \left(\frac{2\pi}{T}\right)^3\right\}^{0.5}}{2 \sinh \frac{2\pi h}{L}} \tag{2.11}$$

where τ is shear stress $(dyne/cm^2 = 0.1\,Pa)$, $\rho = 1.0(g/cm^3)$ is water density, $\eta_0 = 0.01(cm^2/s)$ is the kinematic viscosity of water, H is wave height (*cm*), T is wave period (*s*), D is water depth (*cm*), L is wave length (*cm*). In addition, wave length and wave period vary during dry and wet season (eq 2.12 – 2.15),

Appendix 2 - Empirical relationships between TSS and wind speed

1) Dry season;

$$T = \frac{2\pi W}{g} \times 2.82 \left(\frac{gH}{W^2}\right)^{0.57} \tag{2.12}$$

$$L = CT = \sqrt{gh} \times \frac{2\pi W}{g} \times 2.82 \left(\frac{gH}{W^2}\right)^{0.57} \tag{2.13}$$

2) Wet season;

$$T = \frac{2\pi W}{g} \times 2.88 \left(\frac{gH}{W^2}\right)^{0.64} \tag{2.14}$$

$$L = CT = \frac{2\pi W^2}{g} \times \left\{2.88 \left(\frac{gH}{W^2}\right)^{0.64}\right\}^2 \tag{2.15}$$

Parameters related to wave period and length were different in dry and wet season due to the relation from Bretschneider methods (Bretschneider and de Weille, 2018), and waves consider as long waves and as deep water waves at dry and wet season due to differences of water level.

Empirical relationships were derived and compared by R2 and RMSE at three conditions, i) whole area of TSL for combined wet and dry season (Table A2.1), ii) whole area of TSL for wet (Table A2.2.) and dry (Table A2.2) season, and iii) each cross section of TSL for dry season (Table A2.3 to 2.10).

Appendix 2 - Empirical relationships between TSS and wind speed

References

Bretschneider, F., & De Weille, J. R. (2018). Introduction to electrophysiological methods and instrumentation. Academic Press.

Hamilton, D. P., & Mitchell, S. F. (1996). An empirical model for sediment resuspension in shallow lakes. Hydrobiologia, 317(3), 209-220

Siev, S., Yang, H., Sok, T., Uk, S., Song, L., Kodikara, D., Oeurng, C., Hul, S., & Yoshimura, C., (2018). Sediment dynamics in a large shallow lake characterized by seasonal flood pulse in Southeast Asia. Science of the Total Environment, 631, pp.597-607.

Appendix 2 - Empirical relationships between TSS and wind speed

Table A2.1 Empirical relationship for the whole area of TSL (dry + wet season)

Regression Relationship	R^2	*RMSE*
$TSS = -0.97705W + 113.5862$	6.93E-06	139
$TSS = -185.998W^2 + 921.2936W - 1003.01$	0.0288	137
$TSS = -59.9944W^3 + 244.4455W^2 - 90.7807W - 222.719$	0.0342	136
$TSS = 28.61147\, W/D + 74.09183$	0.0542	135
$TSS = 0.028668\, W^2/D + 28.54154\, W/D + 74.09166$	0.0542	135
$TSS = -20.9059\, W^3/D + 102.8251\, W^2/D - 96.099\, W/D + 75.21281$	0.0546	111
$TSS = 11.58158\tau_{wave} + 97.42251$	0.00957	139
$TSS = 56.47475 \times exp(-0.01285W) + 56.47475$	4.99E-06	139
$TSS = 18895.06 \times exp(0.001501\, W/D) - 18821$	0.0540	135
$TSS = 1149.949 \times exp(0.009681\tau_{wave}) - 1052.28$	0.00946	138

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Table A2.2. Empirical relationship for the whole area of TSL in wet season

Regression Relationship	R^2	*RMSE*
$TSS = 0.357106W + 7.051045$	0.00735	2.01
$TSS = 1.686302W^2 - 8.16135W + 17.39081$	0.0211	1.99
$TSS = 0.800026W^3 - 3.90458W^2 + 4.502085W + 8.057258$	0.0235	1.99
$TSS = 1.239299\,W/D + 7.261585$	0.00818	2.01
$TSS = 0.785709\,W^2/D - 2.06481\,W/D + 7.951719$	0.0106	2.00
$TSS = 3.654301\,W^3/D - 17.7541\,W^2/D + 20.29054\,W/D + 8.074844$	0.0231	3.25
$TSS = -0.44856\tau_{wave} + 8.279326$	0.0255	1.99
$TSS = 3.555902 \times exp(0.083674W) + 3.557943$	0.00759	2.01
$TSS = 3.652916 \times exp(0.290726\,W/D) + 3.653002$	0.00827	2.01
$TSS = 5.389258 \times exp(-0.08969\tau_{wave}) + 2.90613$	0.0247	1.99

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Table A2.3. Empirical relationship for the whole area of TSL in dry season

Regression Relationship	R^2	*RMSE*
$TSS = -14.0558W + 195.657$	0.000888	145
$TSS = 459.2688W^2 - 2244.54W + 2860.55$	0.0572	141
$TSS = 131.4297W^3 - 553.303W^2 + 328.4071W + 706.7222$	0.0507	141
$TSS = -2.46552\, W/D + 165.6434$	0.000422	145
$TSS = 7.358683\, W^2/D - 20.4493\, W/D + 165.8009$	0.00152	145
$TSS = 139.3804\, W^3/D - 674.122\, W^2/D + 799.5387\, W/D + 163.61445$	0.0178	20.0
$TSS = -14.4267\tau + 177.7043$	0.0147	143
$TSS = 145.8207 \times exp(-0.93165W) + 145.8189$	0.00251	145
$TSS = 82.95514 \times exp(-0.03297\, W/D) + 82.95515$	0.000423	145
$TSS = 82.10698 \times exp(-0.02471\tau_{wave}) + 82.10698$	0.00328	144

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Table A2.4. Empirical relationship at CS1 (CS1-1 to CS1-4) in dry season

Regression Relationship	R^2	*RMSE*
$TSS = -46.0135W + 134.7192$	0.0785	25.2
$TSS = 402.5403W^2 - 2017.38W + 2508.103$	0.223	31.7
$TSS = 136.6375W^3 - 574.625W^2 + 293.4587W + 669.8042$	0.224	31.7
$TSS = 33.97792\,W/D - 24.6607$	0.354	43.6
$TSS = -12.8735\,W^2/D + 59.62325\,W/D - 18.528$	0.368	44.8
$TSS = -1974.71\,W^3/D + 9630.886\,W^2/D - 11388.2\,W/D - 137.125$	0.475	43.2
$TSS = 5.15549\tau_{wave} - 4.14939$	0.287	23.1
$TSS = 4.6 \times 10^8 \times exp(-18.918W) + 8.297129$	0.216	31.2
$TSS = 5.62 \times 10^{-5} \times exp(5.033471\,W/D) + 5.320411$	0.962	52.9
$TSS = 1.72644 \times 10^{-5} \times exp(1.112827136\tau_{wave}) - 1.31515$	0.919	21.7

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Table A2.5. Empirical relationship at CS2 (CS2-1 to CS2-5) in dry season

Regression Relationship	R^2	*RMSE*
$TSS = -272.105W + 855.1901$	0.514	227
$TSS = -3766.89W^2 + 19241.99W - 23466.7$	0.711	259
$TSS = -1117.53W^3 + 4790.455W^2 - 2305.33W - 5621.19$	-0.351	248
$TSS = 41.06283\,W/D + 149.1664$	0.0153	188
$TSS = -603.13\,W^2/D + 1062.512\,W/D + 550.0027$	0.683	256
$TSS = -143.598\,W^3/D + 145.9933\,W^2/D + 132.7386\,W/D + 540.4325$	0.686	256
$TSS = -121.097\tau_{wave} + 810.3705$	0.217	286
$TSS = 3352.857 \times exp(-0.10648W) - 2398.18$	0.512	226
$TSS = 3234.216 \times exp(0.012069\,W/D) - 3083.07$	0.0150	188
$TSS = 12893.49 \times exp(-0.00983\tau_{wave}) - 12070.3$	0.215	232

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Table A2.6. Empirical relationship at CS3 (CS3-1 to CS3-7)in dry season

Regression Relationship	*R^2*	*RMSE*
$TSS = -121.879W + 481.4072$	0.0731	154
$TSS = -1134.07W^2 + 5762.631W - 6987.83$	0.410	197
$TSS = -310.312W^3 + 1331.371W^2 - 702.725W - 1398.41$	0.416	198
$TSS = 0.9866\, W/D + 155.829$	1.59E-05	148
$TSS = -124.041\, W^2/D + 238.7834\, W/D + 248.2145$	0.0415	151
$TSS = -1232.43\, W^3/D + 6049.091\, W^2/D - 7417.12\, W/D + 367.9823$	0.412	182
$TSS = -50.7269\tau_{wave} + 417.0396$	0.0349	148
$TSS = 6180.155 \times exp(-0.02051W) - 5694.48$	0.0723	155
$TSS = 78.19084 \times exp(0.00683\, W/D) + 78.19084$	8.73E-06	148
$TSS = 3994.28 \times exp(-0.01319\tau_{wave}) - 3576.21$	0.0342	148

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Table A2.7. Empirical relationship at CS4 (CS4-1 to CS4-8) in dry season

Regression Relationship	R^2	*RMSE*
$TSS = 30.92737W + 39.57059$	0.00385	100
$TSS = 2159.245W^2 - 9941.79W + 11414.55$	0.573	158
$TSS = 723.0246W^3 - 2757.05W^2 + 1128.844W + 3156.17$	0.589	159
$TSS = 107.9979\, W/D + 7.040152$	0.150	111
$TSS = 154.978\, W^2/D + 179.944\, W/D - 47.4677$	0.224	116
$TSS = 2731.268\, W^3/D - 12498.2\, W^2/D + 14129.72\, W/D + 71.81387$	0.589	156
$TSS = -84.6489\tau_{wave} + 550.7531$	0.130	100
$TSS = 14.87521 \times exp(0.800383W) + 14.8778$	0.0113	101
$TSS = 14575.56 \times exp(0.007365\, W/D) - 14568.7$	0.150	111
$TSS = 5348.832 \times exp(-0.01717\tau_{wave}) - 4781.47$	0.171	100

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Table A2.8. Empirical relationship at CS5 (C5-1 to CS5-5) in dry season

Regression Relationship	R^2	*RMSE*
$TSS = 111.816W - 192.988$	0.524	78.4
$TSS = 48.94536W^2 - 121.537W + 76.67405$	0.541	78.8
$TSS = 9.587697W^3 - 12.086W^2 + 2.242239W - 2.7899$	0.543	78.9
$TSS = 17.2744\,W/D + 36.76444$	0.297	72.2
$TSS = 22.21485\,W^2/D - 36.4198\,W/D + 32.38688$	0.388	74.7
$TSS = 128.2505\,W^3/D - 617.43\,W^2/D + 750.7774\,W/D + 22.25363$	0.563	79.3
$TSS = -50.9826\tau_{wave} + 319.8818$	0.583	72.6
$TSS = 5.299968 \times exp(1.175741W) - 25.0721$	0.550	78.8
$TSS = 10559.67 \times exp(0.001617\,W/D) - 10522.8$	0.296	71.9
$TSS = 3702.322 \times exp(-0.01465\tau_{wave}) - 3375.7$	0.407	72.3

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Table A2.9. Empirical relationship at CS6 (CS6-1 to CS6-5) in dry season

Regression Relationship	R^2	*RMSE*
$TSS = 351.441W - 737.573$	0.519	135
$TSS = 1502.355W^2 - 6697.44W + 7406.003$	0.809	174
$TSS = 437.401W^3 - 1610.46W^2 + 636.1412W + 1689.499$	0.816	175
$TSS = 78.69073\, W/D - 15.8522$	0.549	139
$TSS = 235.9623\, W^2/D - 574.596\, W/D + 56.81924$	0.673	147
$TSS = 69.28737\, W^3/D - 122.834\, W^2/D - 109.525\, W/D + 50.75793$	0.668	147
$TSS = -162.842\tau_{wave} + 918.2791$	0.626	111
$TSS = 1.89 \times 10^{-5} \times exp(6.100683W) - 5.98787$	0.813	153
$TSS = 54236.85 \times exp(0.001442\, W/D) - 54252.8$	0.548	138
$TSS = 4207.832 \times exp(-0.04881\tau_{wave}) - 3194.11$	0.624	111

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Table A2.10. Empirical relationship at CS7 (C7-1 to CS7-4) in dry season

Regression Relationship	R^2	*RMSE*
$TSS = 157.8658W - 325.628$	0.546	88.4
$TSS = 568.3595W^2 - 2550.69W + 2842.035$	0.759	79.1
$TSS = 152.588W^3 - 564.856W^2 + 230.2635W + 590.1435$	0.543	78.9
$TSS = 60.20713\, W/D - 0.32355$	0.740	78.5
$TSS = 234.6982\, W^2/D - 606.142\, W/D + 49.99112$	0.869	82.1
$TSS = 84.2366\, W^3/D - 165.574\, W^2/D - 144.154\, W/D + 53.24668$	0.882	82.5
$TSS = -83.7729\tau_{wave} + 518.6047$	0.745	55.6
$TSS = 0.000421 \times exp(4.587612W) - 6.56971$	0.725	78.2
$TSS = 21469.47 \times exp(0.002782\, W/D) - 21469.6$	0.739	78.3
$TSS = 1675.825 \times exp(-0.400915\tau_{wave}) - 134.286$	0.774	51.2