MODELING TIDE'S INFLUENCE ON SEAWALL'S SURFACE TEMPERATURE IN TROPICAL REGIONS

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In tropical regions, intense solar radiation on seawall can lead to a high surface temperature, which far exceeds common marine species' tolerable limits. This is a primary reason for low biodiversity on Singapore's seawalls and therefore must be considered in eco-engineering practices. The intertidal zone of a seawall is periodically submerged and cooled by the tidal motion, and therefore can support a local ecosystem. The objective of this research is to establish a predictive model for surface temperature of seawall's intertidal zone and use this model to study how local biodiversity is affected by the occurrence of high temperature.

A PREDICTIVE MODEL

A theoretical model is developed based on the two dimensional heat conduction equation in the vertical plane perpendicular to shoreline. The model is mainly driven by the solar radiation, which is recorded by local weather station, and the method proposed by Hawlader (1984) is adopted to decompose solar radiation into beam and diffuse radiations. Some corrections for seawall's slope and facing angle are also applied to the solar radiation. Long wave radiation and convection due to seawater and air are also modeled as heat flux at the seawall surface. The tide information is obtained from the tide table supplied by Maritime and Port Authority of Singapore. Finite volume method is used to solve the governing equation. Tri-Diagonal Matrix Algorithm and Crank-Nicolson scheme are adopted in the numerical solution.

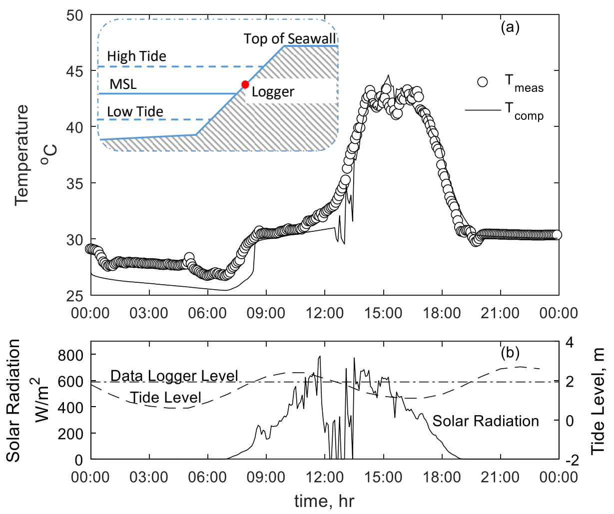

Fig. 1. (a) Temperature prediction for a typical day, and (b) Solar radiation & tide record

We first validate the model for predicting the daily temperature variation of seawall surface. To this end, temperature was measured with a data logger on a selected seawall surface at a level 0.34 m above MSL. As shown in Fig. 1(b), this logger was submerged during the high tide roughly from 9 AM to 12 AM, but was exposed about six hours in the afternoon. Therefore, the measured temperature follows the water temperature in the morning, but dramatically increases to approximately 43 °C in the afternoon, which is nicely predicted by the model for the surface element at the same elevation (Fig. 1a). The model is subsequently applied to the whole October of 2016. The model predicts at 5 min time interval, so the results are summarized to give the cumulative hours of high temperature, $t_c(T)$. As shown in Fig. 2(a), the model accurately predicts that $t_c(T)$ decreases with temperature, e.g., within this month, there is about 12 hours at 35.5 °C, which decreases to four hours at about 41.5 °C.

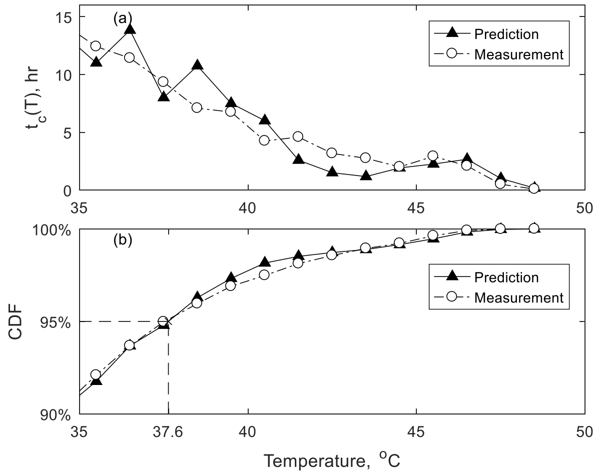

Fig. 2. (a) Monthly cumulative hours, and (b) Cumulative distribution function (CDF) of high temperature

MODEL APPLICATION

To illustrate the high temperature effect on local ecosystem, we treat high temperature as a random variable with certain occurrence probability, which can be obtained using Monte-Carlos simulations. Here, daily solar radiation data collected in the past years is used as surrogate solar radiation input. Tidal forecast can be obtained from local authority or model prediction. CDF of high temperature is therefore predicted for a given time scale, e.g., monthly. Based on the obtained CDF, statistic value such as 95% temperature (e.g. 37.6 °C in Fig. 2b) can be identified to represent the local high temperature. The vertical variation of $T_{95\%}$ can be determined for a seawall. The results will be linked with the 13-month biological survey by Loke and Todd (2016), which showed that species richness dramatically increases towards lower vertical levels. This demonstrates that the cooling effect of tide plays a key role. More results, including an ongoing field study, will be presented at the conference.

ACKNOWLEDGEMENT

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