Effect of bottom-water temperature with fluid flow on the sub-bottom temperature profile

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In a thermal conduction model with uniform physical properties and time-dependent surface temperature, which is appropriate for the bottom of lakes or shallow sea, the sub-bottom temperature is affected by the surface temperature variation. In this model, the analytical solution has been obtained by solving the one-dimensional thermal diffusion equation with a boundary condition of series of sinusoidal oscillation at the surface. The amplitude decays exponentially and the phase shifts lineally with depth. However, the assumption that the surface temperature variation propagates conductively may not be satisfied in areas with fluid discharge or recharge, such as hydrothermal sites and deep-sea biological community sites. In this presentation, I present an analytical situation obtained for the one-dimensional energy-conservation equation with constant fluid flow and the surface boundary condition of sinusoidal oscillation. The analytical solution resembles the solution for the conduction model except that the amplitude decay and the phase shift depend on the rate and direction of the fluid flow. In a downflow regime, the amplitude of temperature variation decreases with depth less than that in the conduction model, while it decreases more rapidly in an upflow regime. In both regimes, a longer-period component penetrates deeper than a shorter period one. Thermal diffusivity of the sediment material propagates also affects the temperature variation. The dependence on these parameters will be discussed using examples for specific cases.