1. Introduction

Land-atmospheric interactions are largely dictated by the aerodynamic and thermodynamic conditions at the lower boundary. In particular, the transport of heat and moisture underneath the Earth’s surface and the subsequent determination of the soil thermal field are critical in regulating the surface physical processes, such as the energy fluxes, using a single point measurement. The new approach is also capable of accurately reproducing results of some existing methods in the literature using a unified numerical framework.

2. A unified algorithm for reconstruction of soil thermal field

Conventional approach:

Subsurface thermal measurements usually consist of recording both soil temperature and heat flux data series at multiple depths.

Is it possible that a single measurement of either temperature or heat flux contains the signature of the entire soil thermal field?

By combining the Green’s function approach and Duhamel’s principle dealing with inhomogeneous boundary conditions, the problem is analytically tractable!

Subsurface thermal measurements usually consist of recording both soil temperature and heat flux data series at multiple depths.

The work was motivated by the concept that the evolution of soil temperatures and heat fluxes are inseparable physical processes in heat conduction.

Soil thermal field from flux plate measurement at 8 cm

Soil thermal field from thermometer measurement at 4 cm

3. Effect of soil water advection on the phase lag of soil temperature

From the idealized heat transfer model: evolutions of temperature and heat flux are most out-phase for impermeable surfaces, e.g. dry soils, engineered pavements, etc.

To extend the analytical result to realistic field measurements, two additional empirical coefficients, α and β were introduced to account for the environmental complexities and to relate W to LE.

Further hypothesize that phase evolutions of H and LE follow that of the surface temperature: urban areas will have a more dispersed distribution of peak heat fluxes and surface temperatures.

4. Hysteresis loop between the net radiation and ground heat flux

The phase lag concept can also be used to study the hysteresis loop between the net radiation and ground heat flux, assuming that temporal evolutions of net radiation and the surface temperature are similar.

Evolution of ground heat flux can be obtained by solving the 1D advection-diffusion equation with Dirichlet boundary condition.

With comparison to field measurements, this highly idealized conceptual model works strikingly well for predicting the hysteresis behavior between Rn and Go for different land cover types.

References: