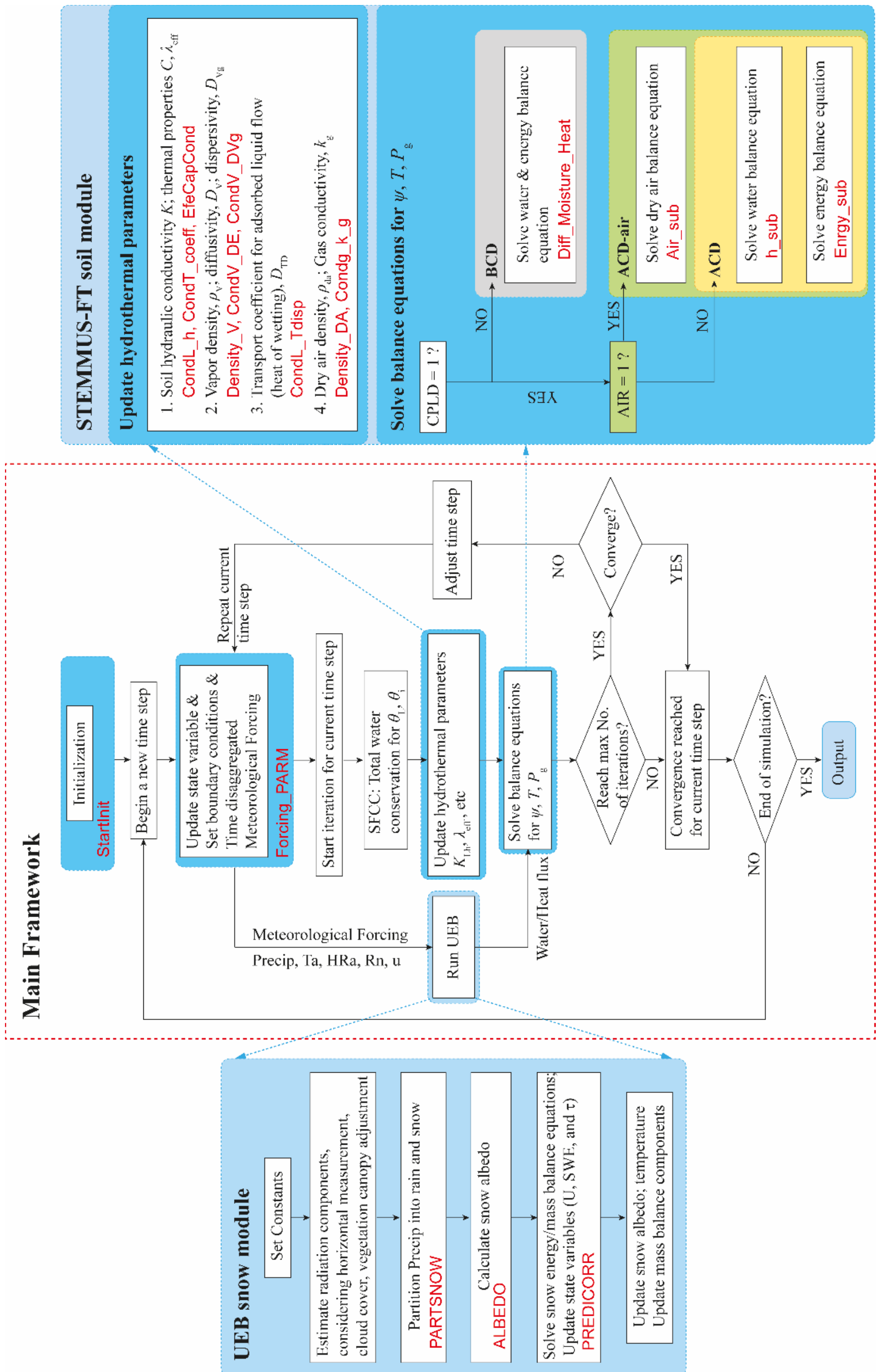

Figure 1. The overview of the coupled STEMMUS-FT and UEB model framework and model structure. SFCC is soil freezing characteristic curve; θ_L and θ_i are soil liquid water and ice content; K_{Lh} is soil hydraulic conductivity; λ_{eff} is thermal conductivity. ψ, T, P_g are the state variables for soil module STEMMUS-FT (matric potential, temperature, and air pressure, respectively). U, SWE, and τ are the state variables for snow module UEB (snow energy content, snow water equivalent, and snow age, respectively). UEB, Utah Energy Balance module. Precip, Ta, HRa, Rn, and u are the meteorological inputs (precipitation, air temperature, relative humidity, radiation, and wind speed). Model subroutines are in red fonts.

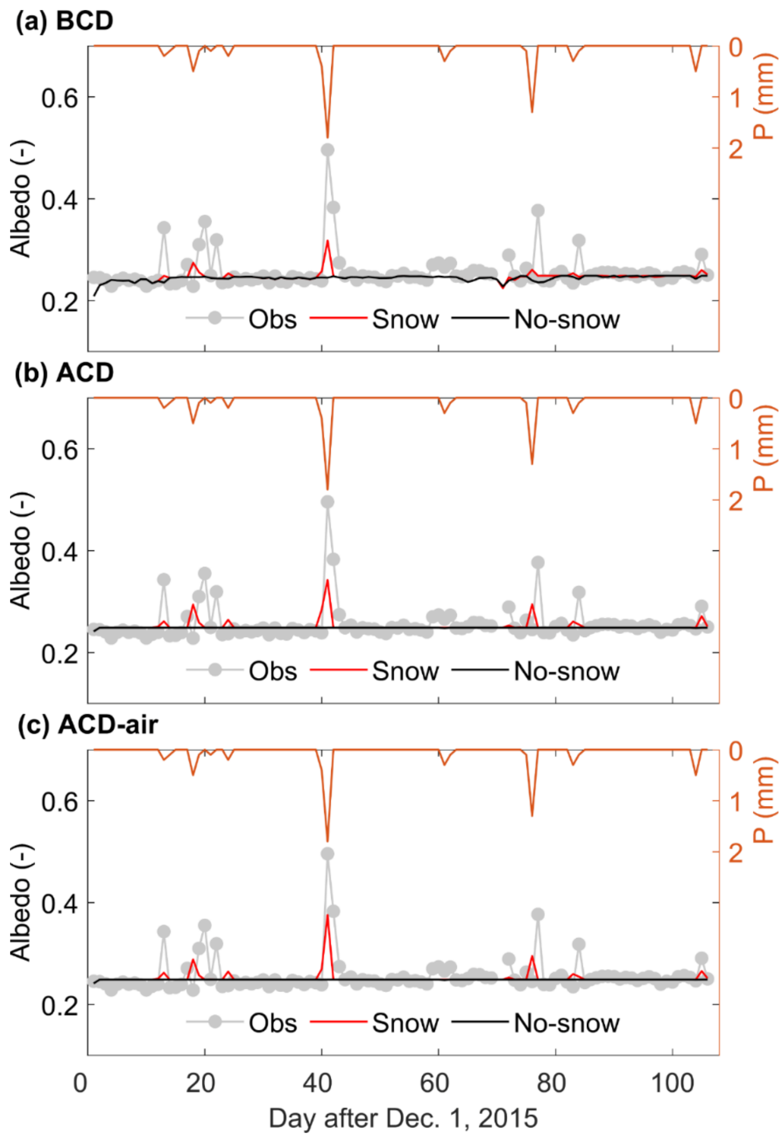

Figure 2. Time series of observed and model simulated daily average albedo using (a) BCD, (b) ACD, and (c) ACD-air soil model with/without consideration of snow module, with the precipitation.

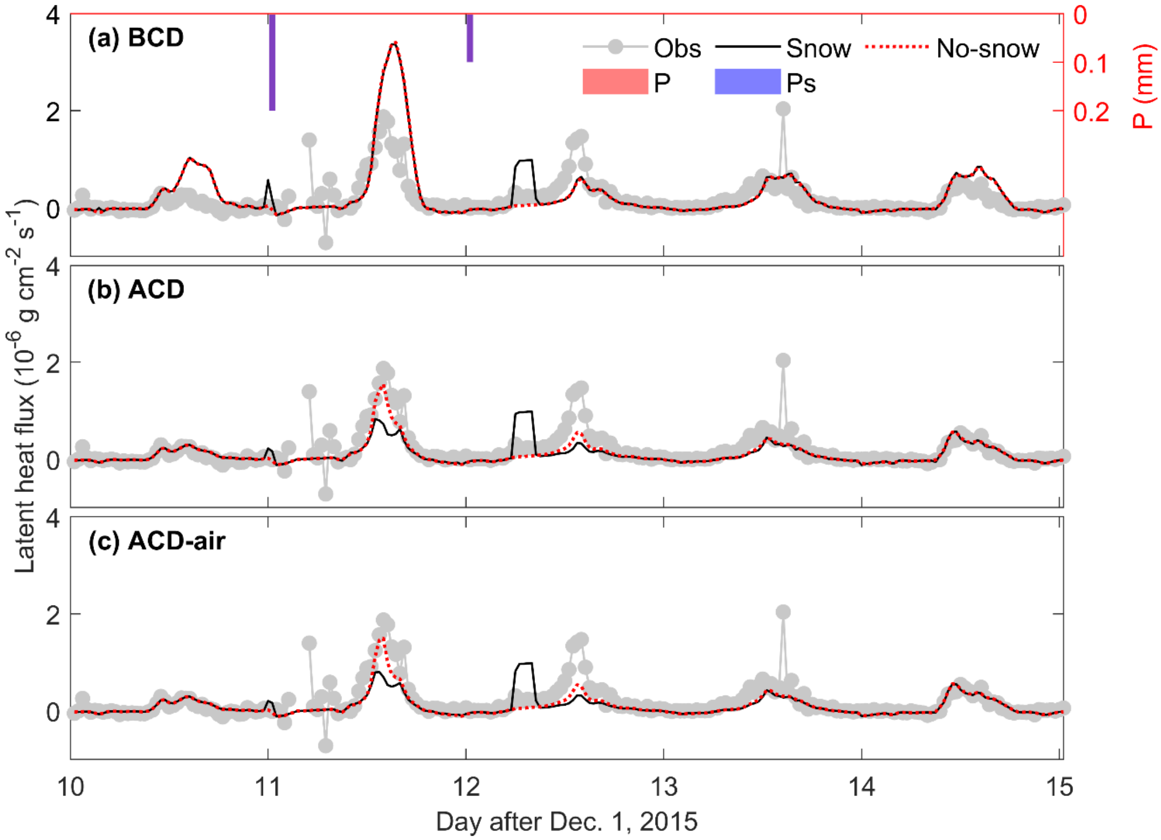

Figure 6. Observed and model simulated latent heat flux, using (a) BCD, (b) ACD, and (c) ACD-air soil model with/without snow module, of a typical five-day freezing period (from 10th to 14th Days after Dec. 1. 2015). P is the precipitation and Ps is the snowfall. All precipitation is in the form of snowfall.

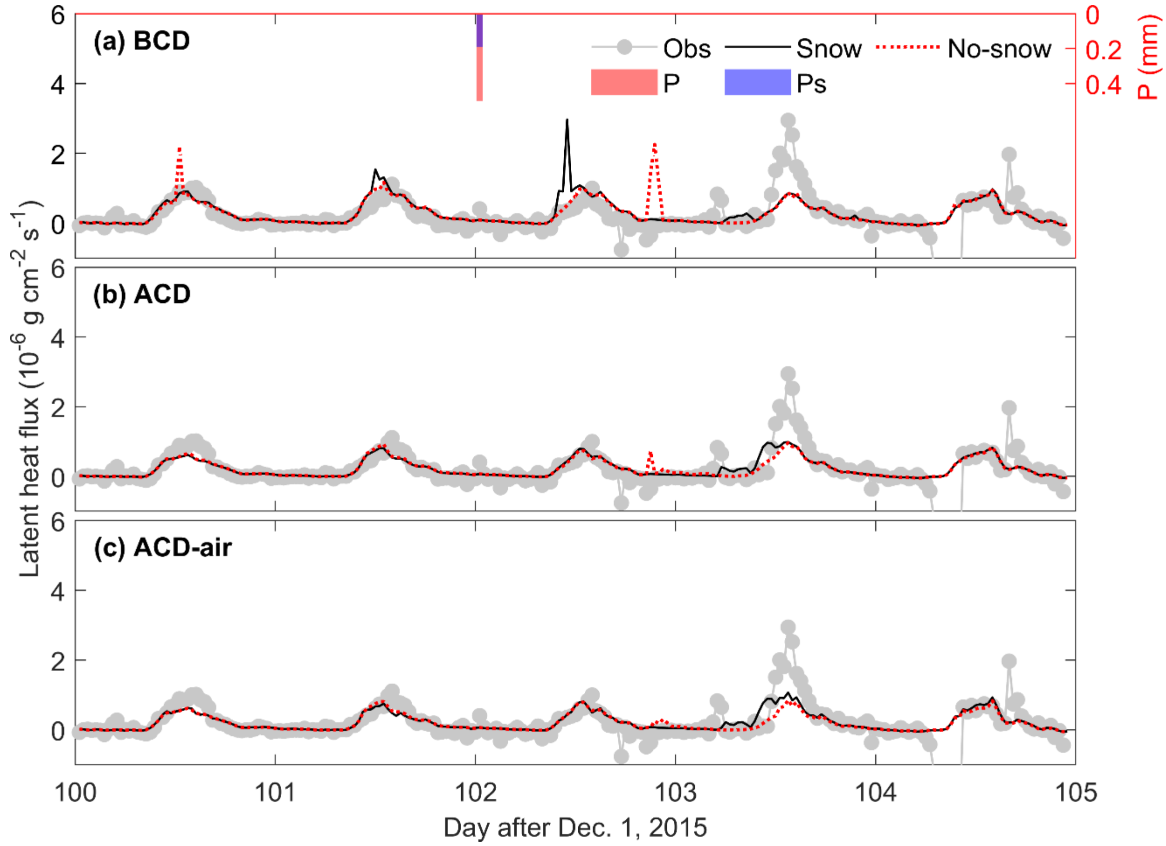

Figure 7. Observed and model simulated latent heat flux, using (a) BCD, (b) ACD, and (c) ACD-air soil model with/without snow module, of a typical five-day thawing period (from 100th to 104th Days after Dec. 1. 2015). P is the precipitation and Ps is the snowfall.

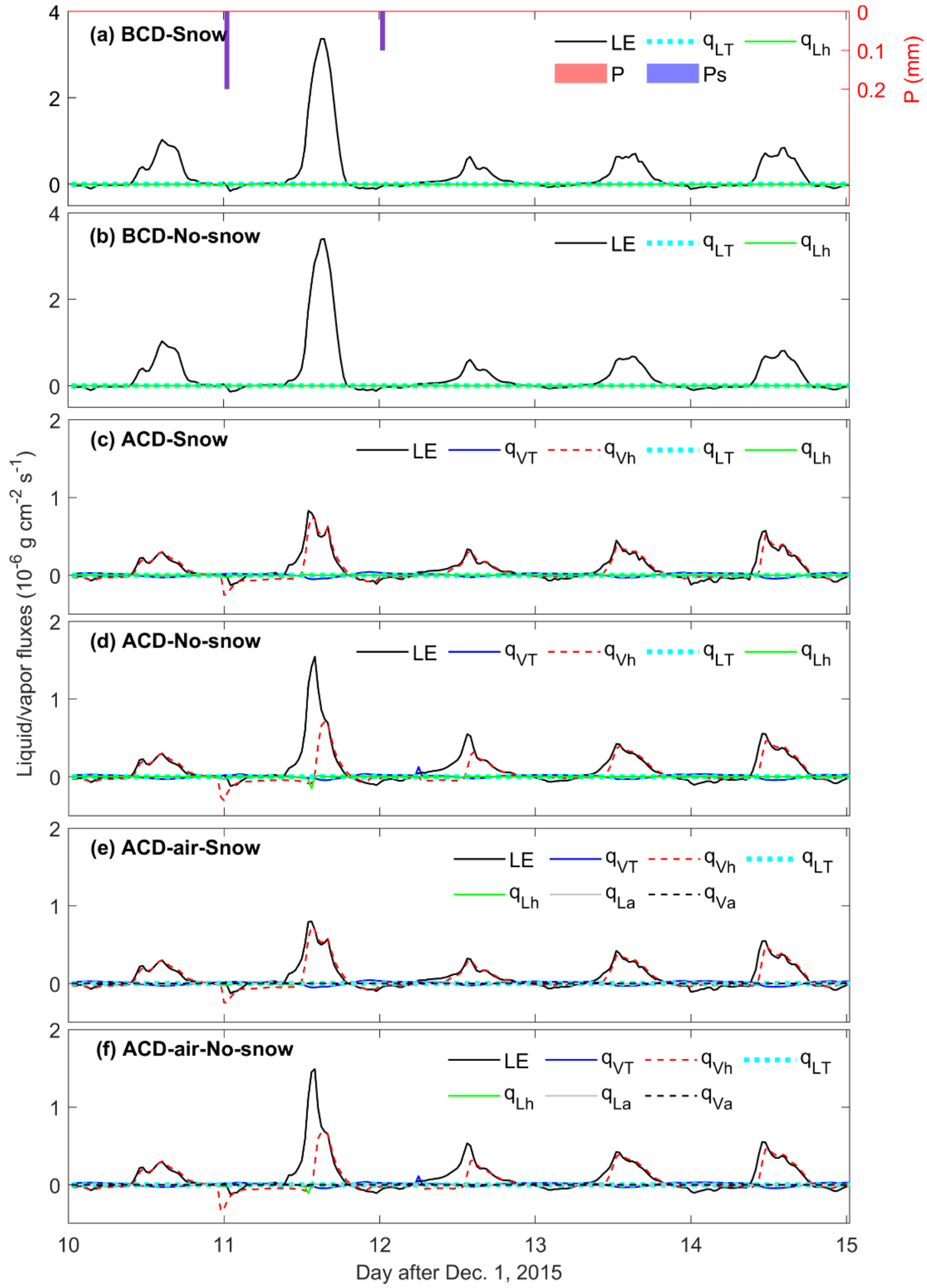

Figure 8. Model simulated latent heat flux and surface soil (0.1cm) thermal and isothermal liquid water and vapor fluxes (LE, q_{VT}, q_{Vh}, q_{LT}, q_{Lh}, q_{La}, q_{Va}), with and without snow module, of a typical five-day freezing period (from 10th to 14th Days after Dec. 1. 2015).a, c, and e are the surface soil thermal/isothermal liquid water and vapor fluxes simulated by BCD-Snow, ACD-Snow, and ACD-air-Snow model, respectively. b, d, and f are the surface soil thermal/isothermal liquid water and vapor fluxes simulated by BCD-No-Snow, ACD-No-Snow, and ACD-air-No-Snow model, respectively. LE is the latent heat flux, q_{VT}, q_{Vh} are the water vapor fluxes driven by temperature and matric potential gradients, q_{LT}, q_{Lh} are the liquid water fluxes driven by temperature and matric potential gradients, q_{La}, q_{Va} are the liquid and vapor water fluxes driven by air pressure gradients. Positive/negative values indicate upward/downward fluxes. Note that the surface LE fluxes without snow sublimation were presented. P is the precipitation and Ps is the snowfall. All precipitation is in the form of snowfall.

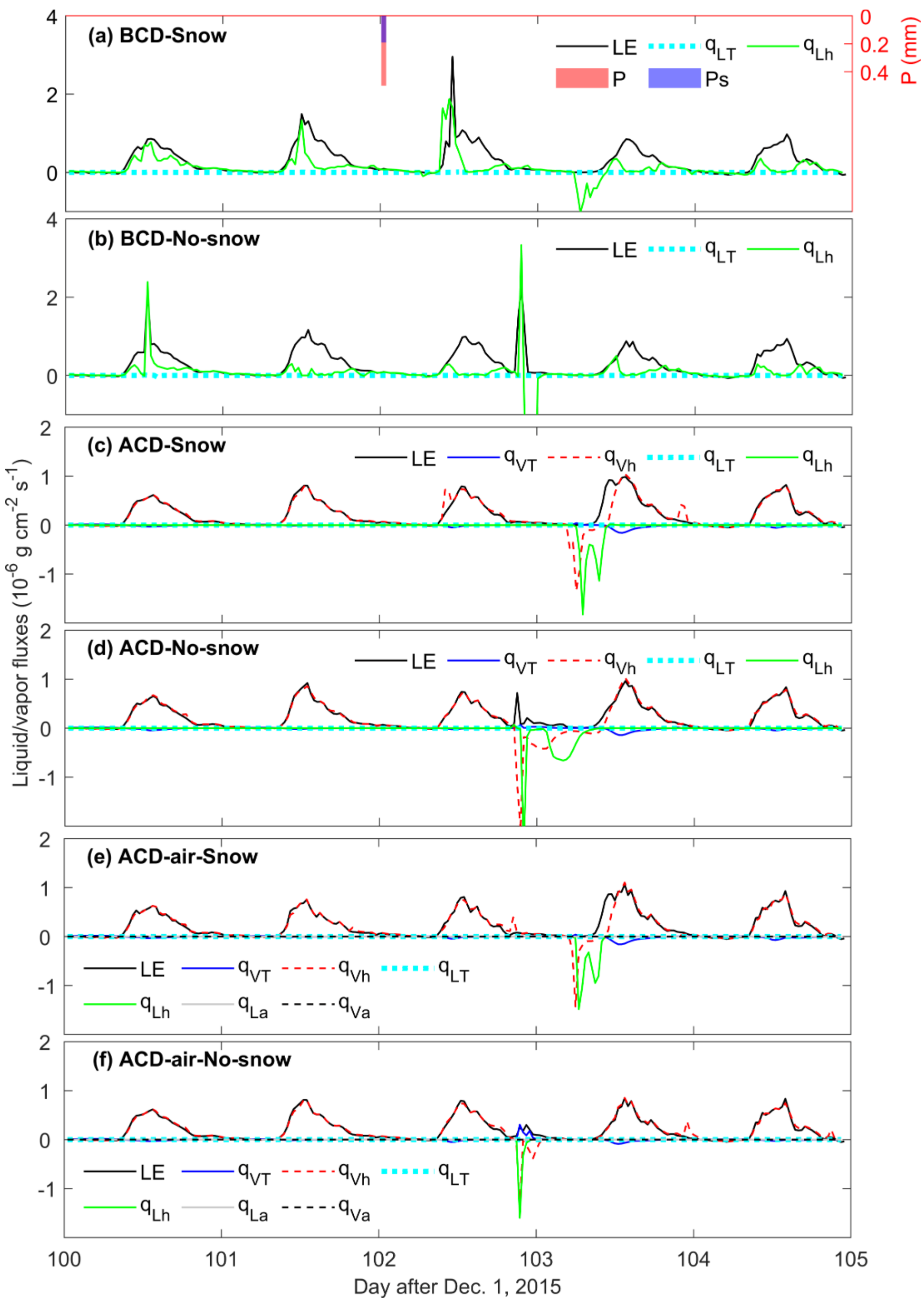

Figure 9. Model simulated latent heat flux and surface soil (0.1cm) thermal and isothermal liquid water and vapor fluxes (LE, q_{VT}, q_{Vh}, q_{LT}, q_{Lh}, q_{La}, q_{Va}) using BCD (a, b,), ACD (c, d,), and ACD-air (e, f) simulations with and without snow module, respectively, during the typical 5-day thawing periods (from 100th to 104th Days after Dec. 1. 2015). a, c, and e are the surface soil thermal/isothermal liquid water and vapor fluxes simulated by BCD-Snow, ACD-Snow, and ACD-air-Snow model, respectively. b, d, and f are the surface soil thermal/isothermal liquid water and vapor fluxes simulated by BCD-No-Snow, ACD-No-Snow, and ACD-air-No-Snow model, respectively. LE is the latent heat flux, q_{VT}, q_{Vh} are the water vapor fluxes driven by temperature and matric potential gradients, q_{LT}, q_{Lh} are the liquid water fluxes driven by temperature and matric potential gradients, q_{La}, q_{Va} are the liquid and vapor water fluxes driven by air pressure gradients. Positive/negative values indicate upward/downward fluxes. Note that the surface LE fluxes without snow sublimation were presented. P is the precipitation and Ps is the snowfall.