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Impacts of microtopographic snow redistribution and lateral subsurface processes on hydrologic and thermal states in an Arctic polygonal ground ecosystem: a case study using ELM-3D v1.0

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In this work, the existing 1D physics formulations for subsurface hydrologic and thermal processes of ALMv0 are extended to included lateral processes. Numerical tests were performed to ensure that lateral coupling was implemented correctly for hydrologic and thermal processes. Sanity checks were preformed to ensure the 3D model solution is the same as in the 1D vertical model when the problem setup is horizontally homogeneous (Results not shown).

The thermal model is independent of gravity. Thus, additional tests were performed to ensure the numerical solution of the thermal model for propagation of heat is identical in a 1D column that is oriented horizontally and vertically. A test was performed to study the propagation of a heat perturbation that was applied on the left and top boundary of a spatially homogeneous 2D domain (Figure S 1). The difference of simulated temperature between the two cases was of the order of the tolerance of the numerical solver (Figure S 1c). An additional test was performed in which a sinusodially varying temperature perturbation was applied on the left and top boundary; and the difference in results was again within tolerance of numerical solver (Figure S 2). These tests ensured that lateral coupling was correctly implemented within the model.

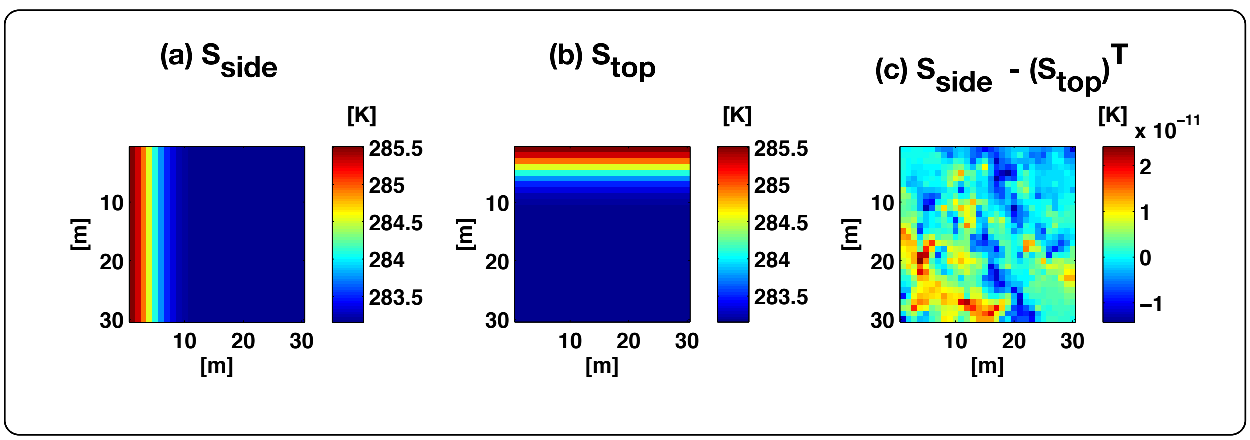

Figure S 1 Propagation of a spatially homogeneous temperature perturbation applied on the (a) left and (b) top boundary of a spatially homogeneous 2D transect at the end of 1-day. (c) The difference in evolved temperature between the two cases.

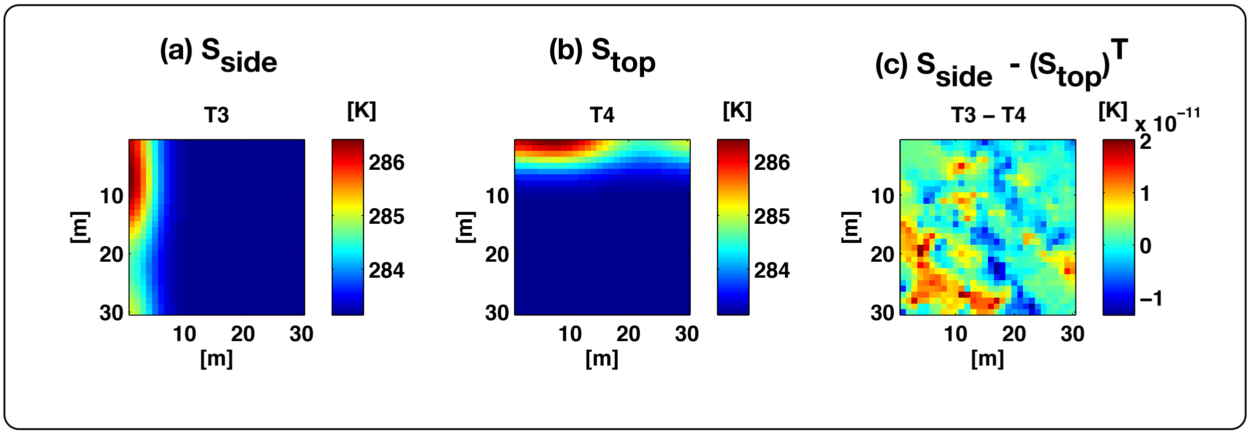

Figure S 2 Same as Figure S 1 except a sinusoidally varying spatial temperature perturbation was applied.

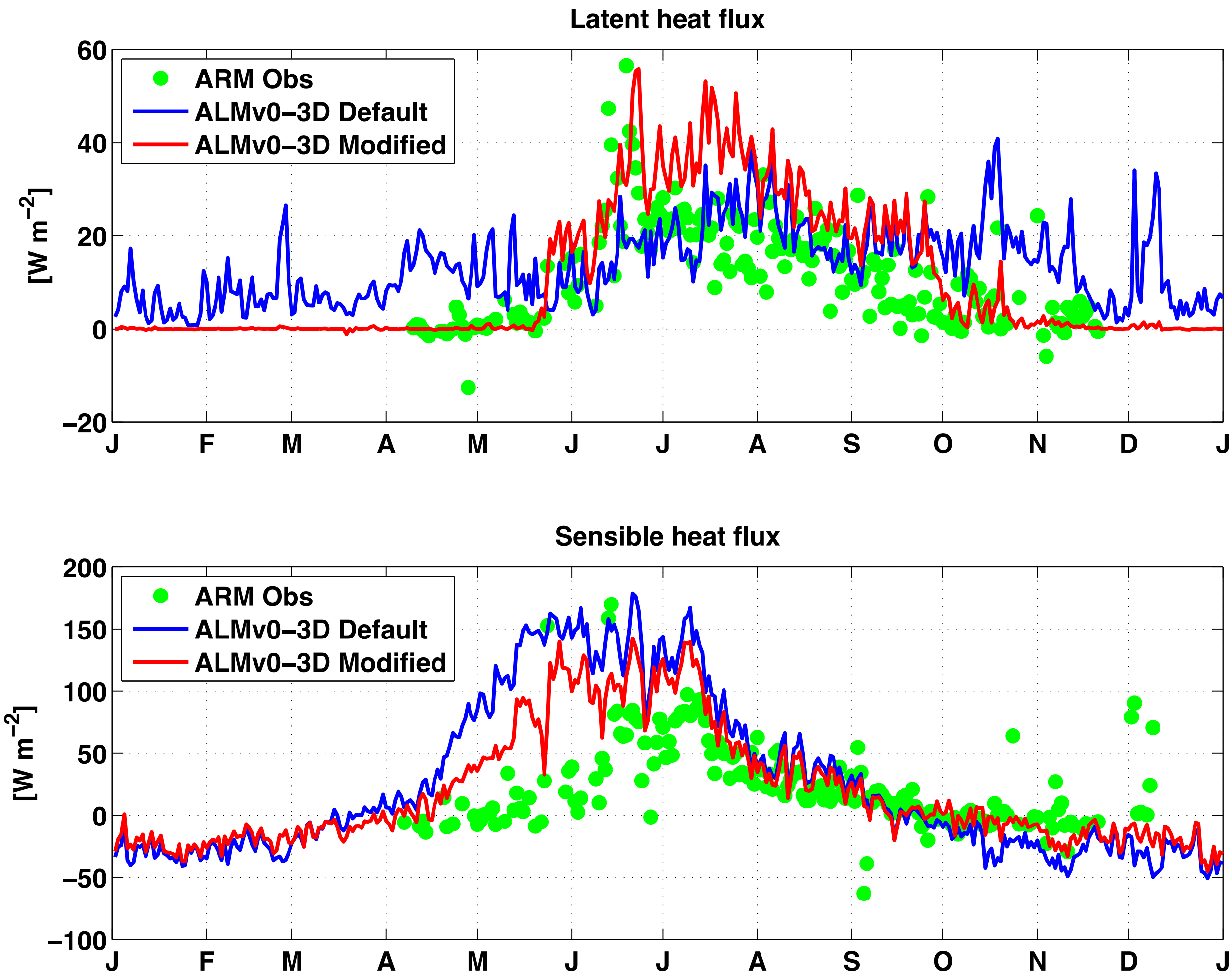

Figure S 3. Effect of modifying the sublimation flux calculation in ALM-3D on the predicted sensible and latent heat fluxes: (a) latent heat, (b) sensible heat.

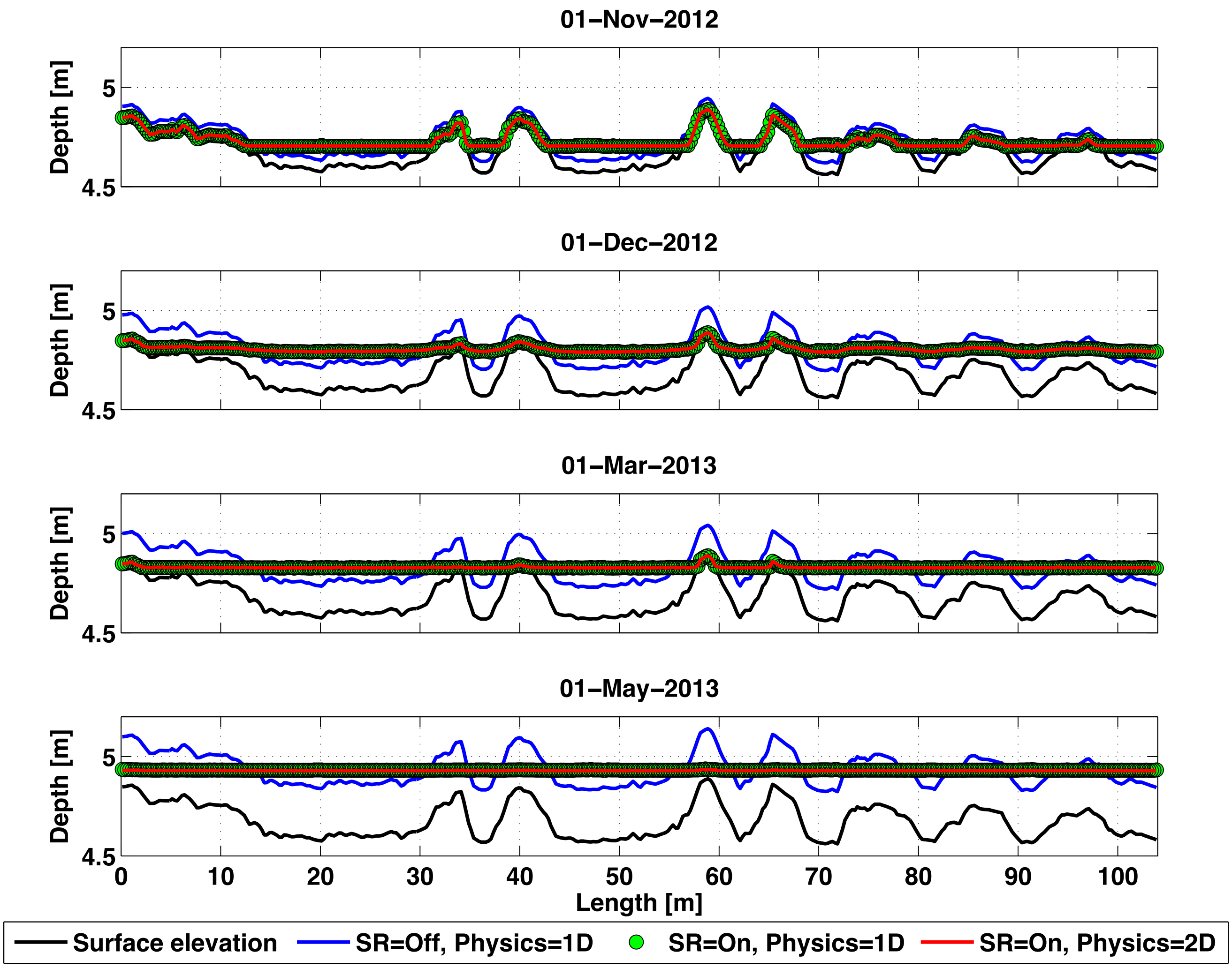

Figure S 4. Simulated snow depth across the transect on (a) 1st November 2012, (b) 1st December 2012, (c) 1st March 2013, and (d) 1st May 2013. Blue line shows model results for the case snow redistribution (SR) is turned off and 1D subsurface physics, green symbols are for model results with snow redistribution turned on and 1D subsurface physics, while red line corresponds to model results with snow redistribution turned on and 2D subsurface physics. Surface elevation of the transect is shown by the solid black line.

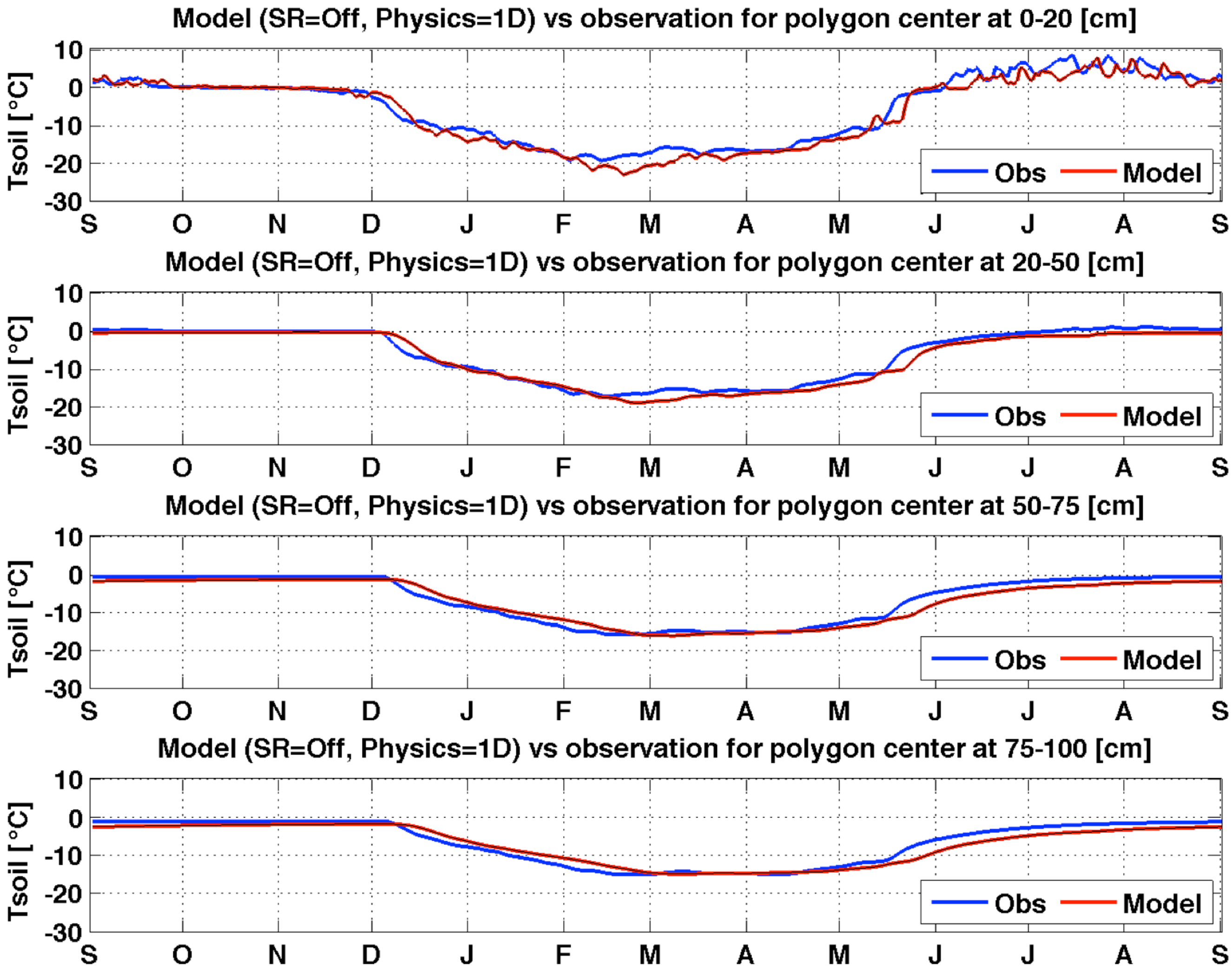

Figure S 5. Comparison of soil temperature observations and predictions in polygon center for September 2012 and September 2013 at various soil depths. Simulation was performed with no snow redistribution and 1D physics.

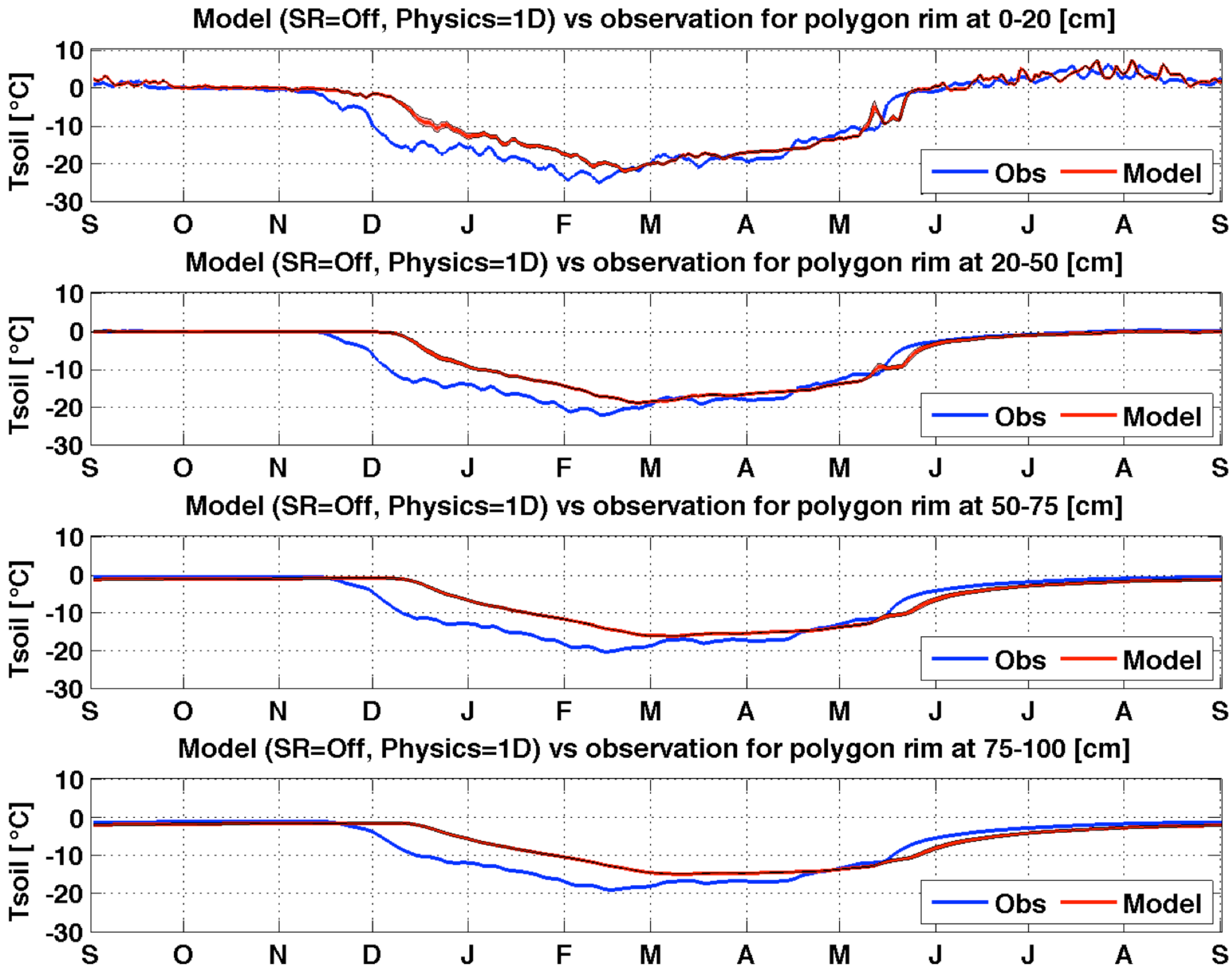

Figure S 6 Same as Figure S 5 except for soil temperature in polygon rim.

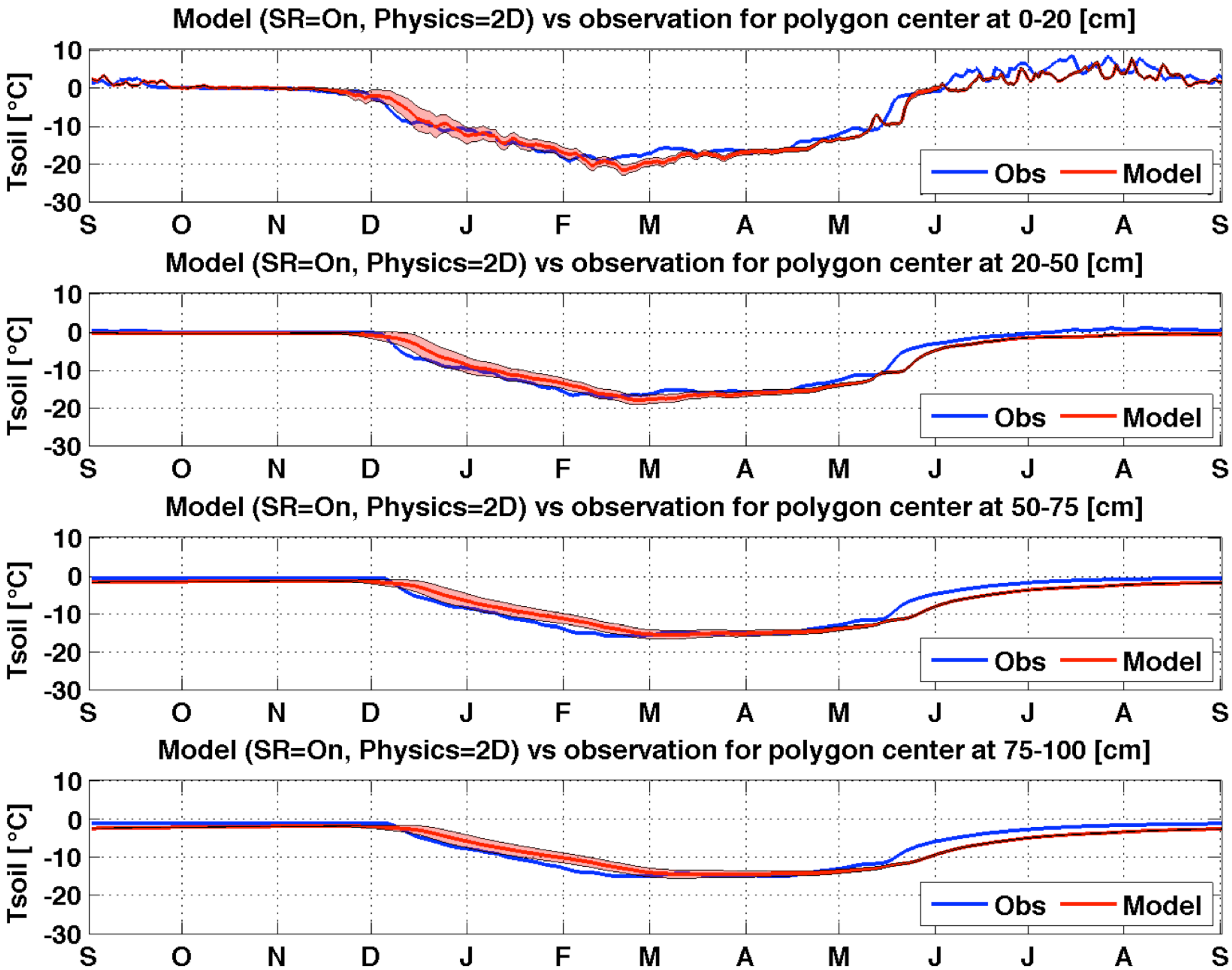

Figure S 7 Comparison of soil temperature observations and predictions, shown as solid lines, in polygon center for September 2012 and September 2013 at various soil depths. Simulation was performed with snow redistribution and 2D physics. The red band represents ±1 spatial standard deviation around the simulated mean soil temperature.

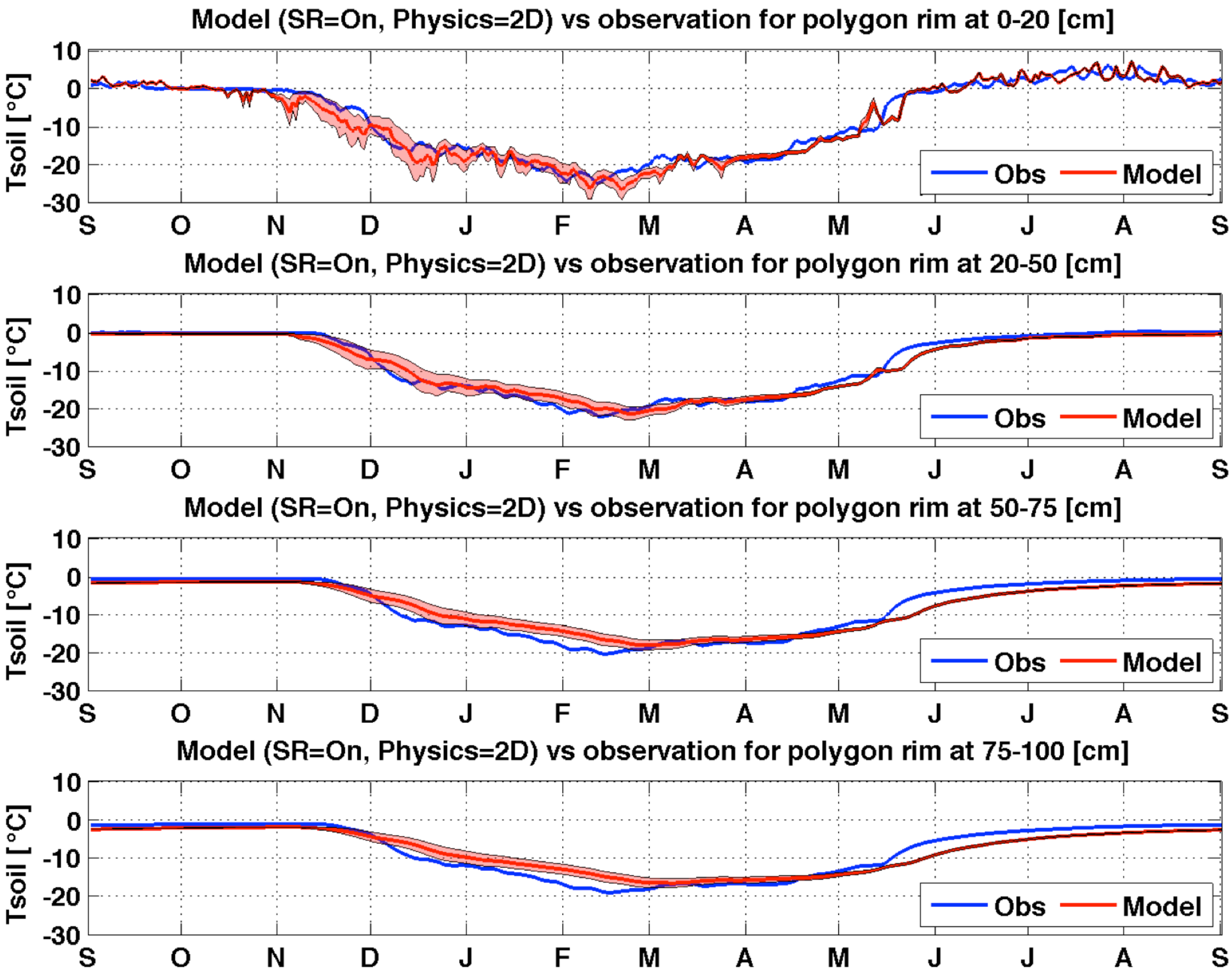

Figure S 8 Same as Figure S 7 except for soil temperature in polygon rims.

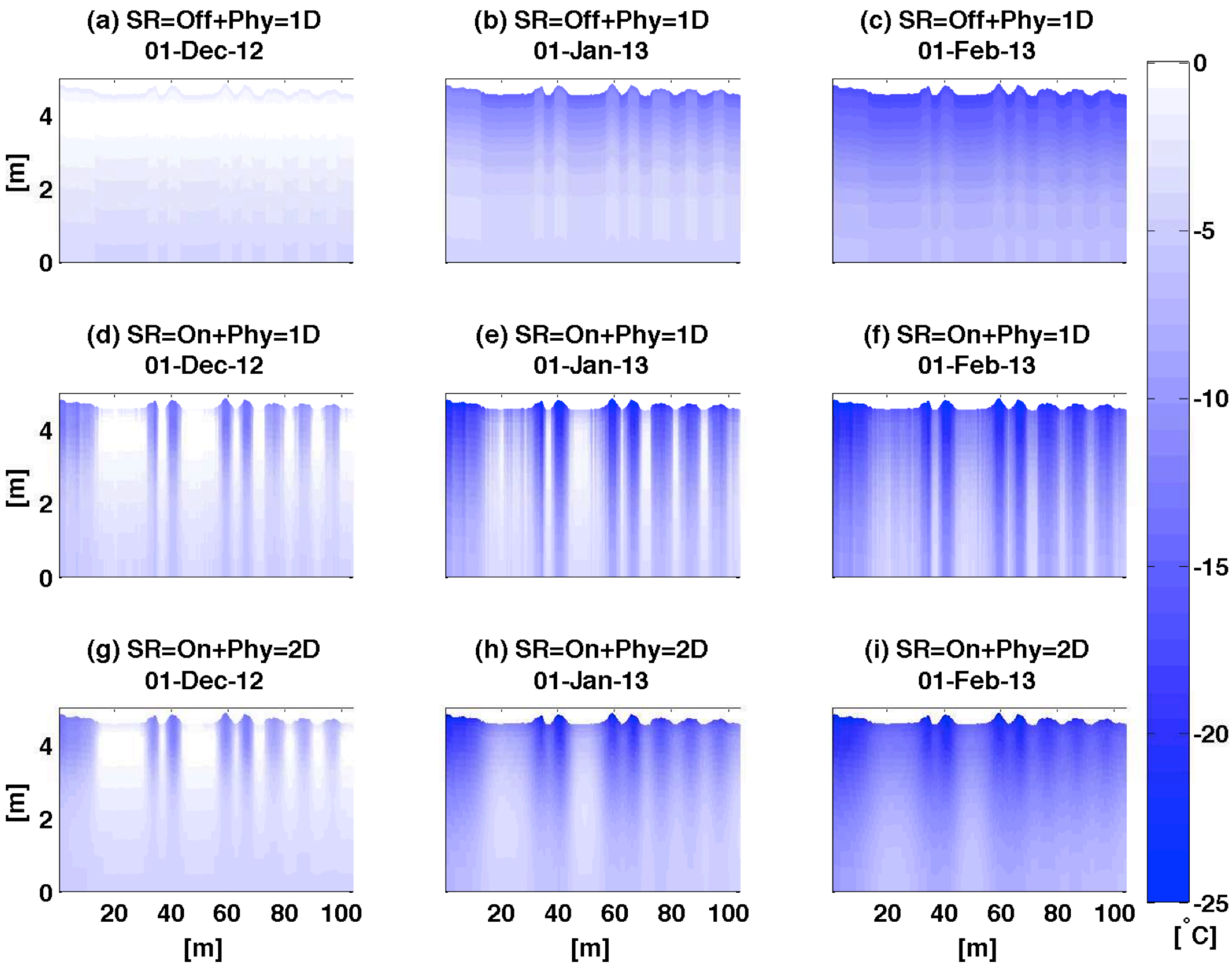

Figure S 9. Snapshot of simulated soil temperature profile across the transect on December 1, 2012, January 1, 2013, and February 1, 2013 for (a-c) no snow redistribution and 1D subsurface physics; (d-f) with snow redistribution and 1D subsurface physics; and (g-i) with snow redistribution and 2D subsurface physics.