

## FIRST PART: ANSWERS TO REFEREE 2

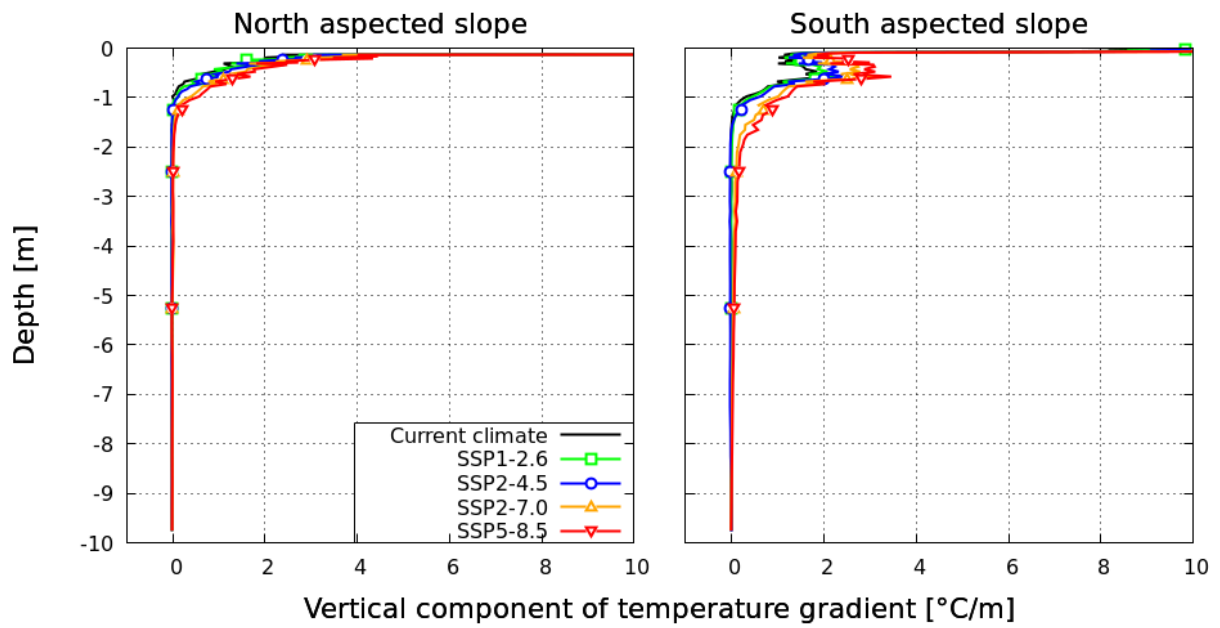


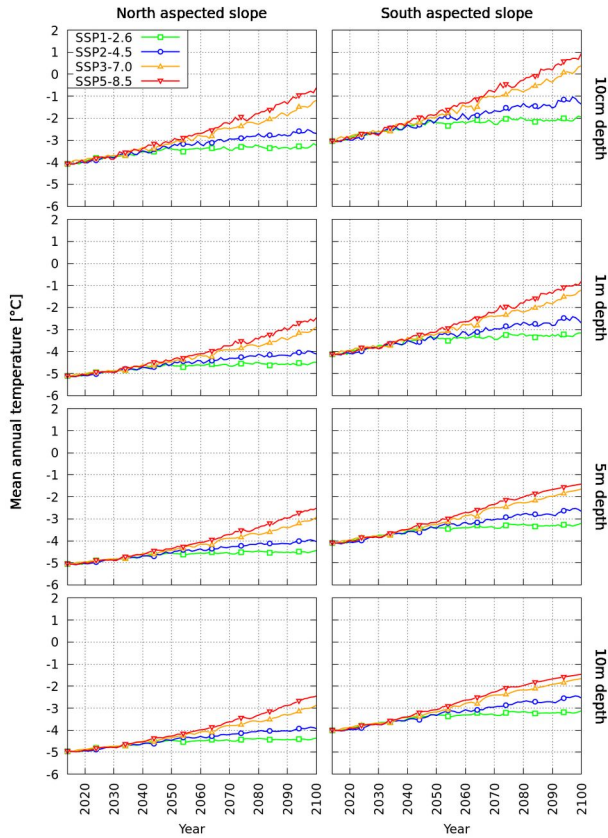
Figure R2.1: Vertical profiles of vertical temperature gradient in the middle of the North Aspected Slope (left) and in the middle of the South Aspected Slope (right), under current climate and in 2100 for four climate change scenarios.

## SECOND PART: SELF-MOTIVATED CORRECTION

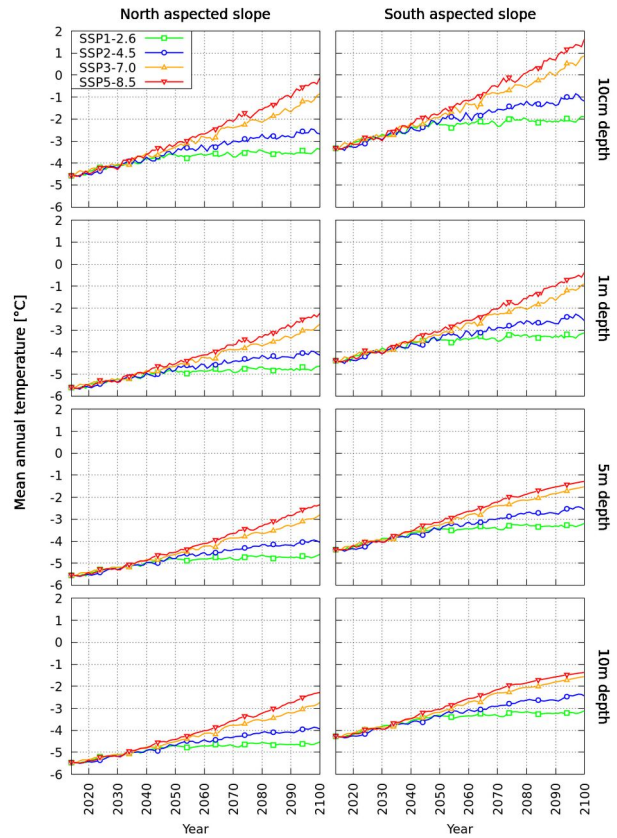
Comparison between ill-results and correct results:

Figure 6: Mean annual temperature evolution at 10cm, 1m, 5m and 10m under the surface for each scenario and slope considered.

ILL:



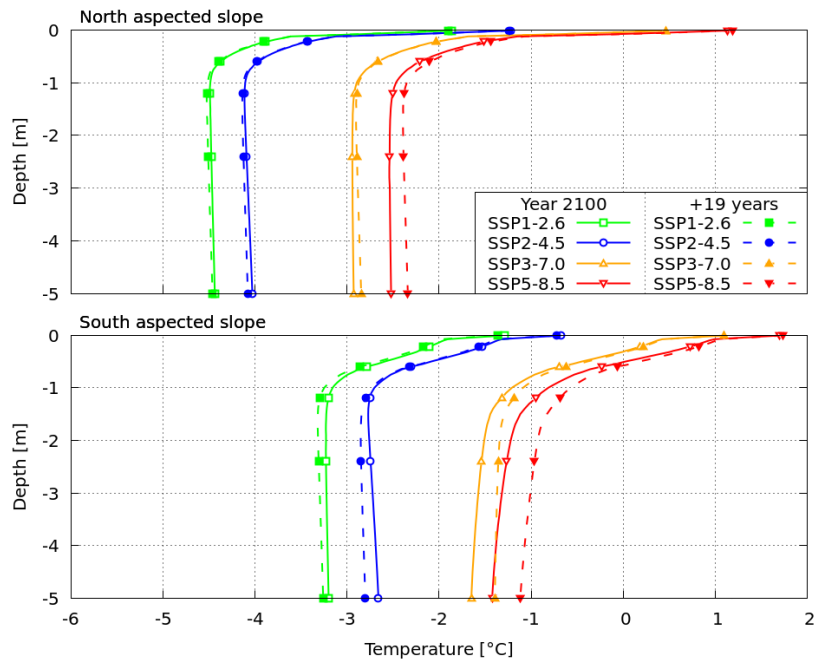
CORRECT:



- Left: Soil temperature evolutions with ill parameterization (with soil temperature amplitude limitation to the amplitude of monthly mean top soil temperature under current climate);
- Right: Soil temperature evolutions with correct parameterization (without soil temperature amplitude limitation).

Figure 7: Annual mean temperature profiles in 2100 and after 30 years of additional cycling of the climatic forcing of this last year.

ILL :



CORRECT :

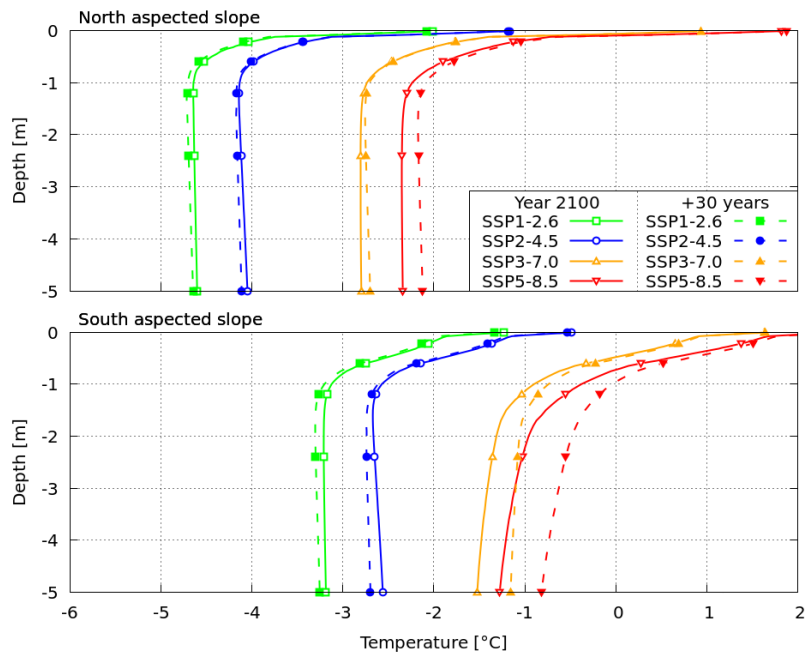
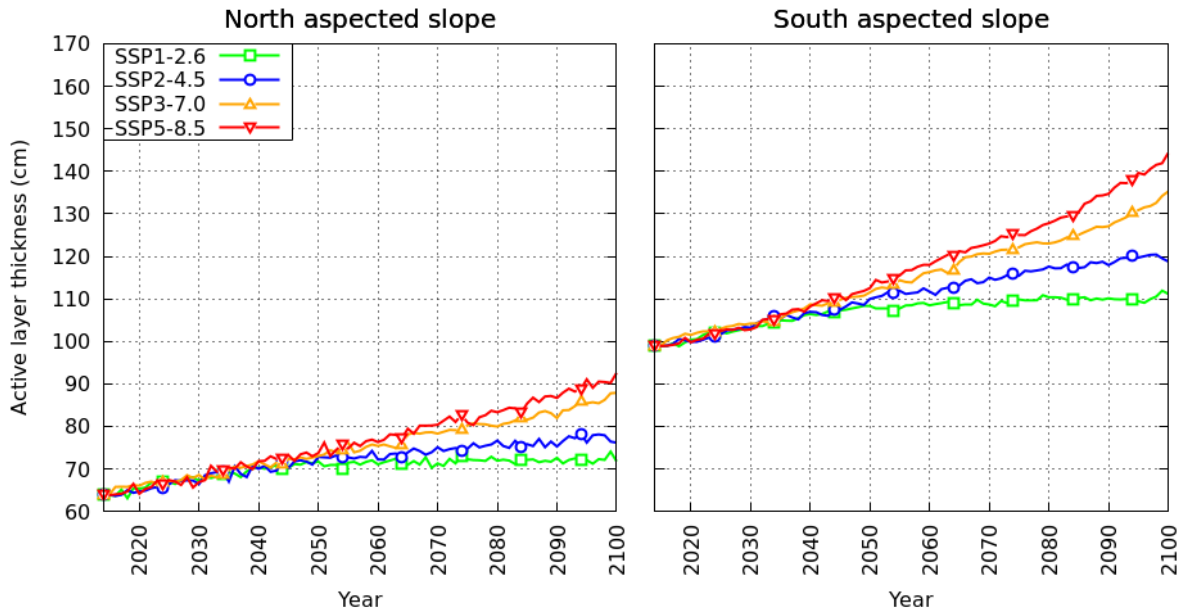


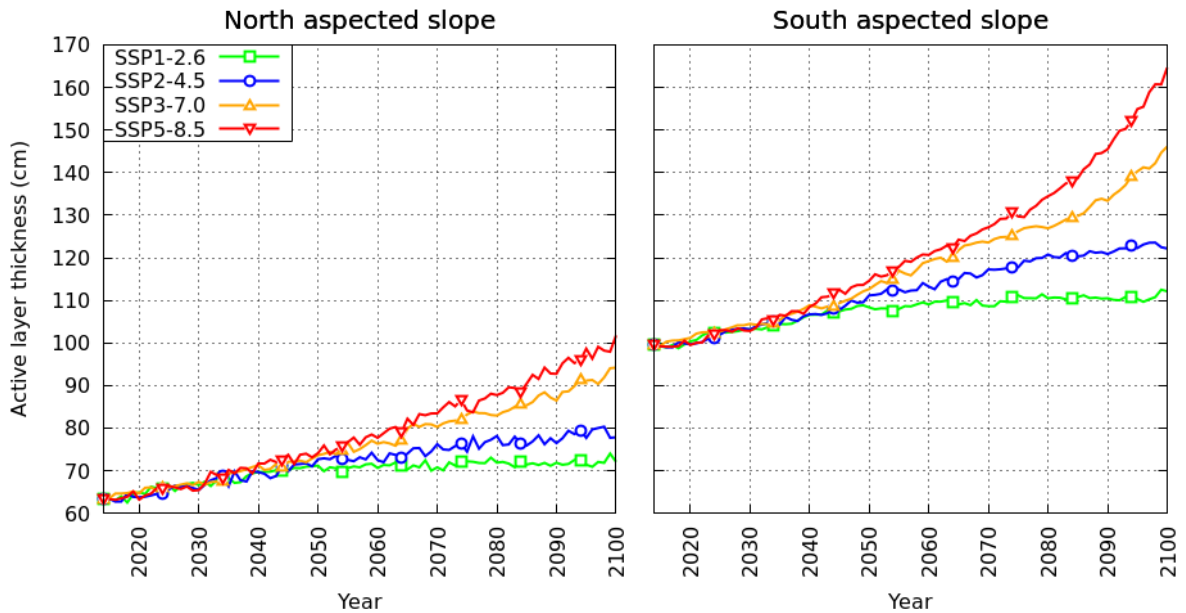
Figure 8: Active layer thickness temporal evolution on North (left) and South (right) aspect Slope of the Kulingdakan watershed obtained from permaFoam simulations under different SSP scenarios.

ILL:



- Above: Active layer thickness evolutions with ill parameterization (with soil temperature amplitude limitation to the amplitude of monthly mean top soil temperature under current climate);

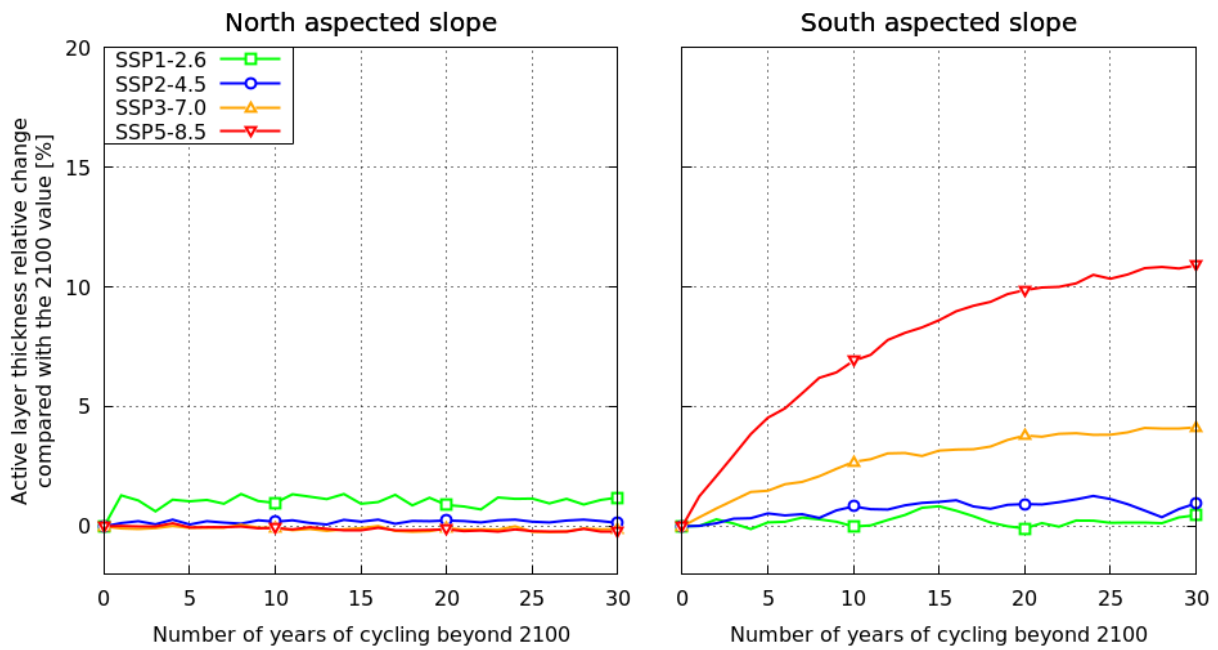
CORRECT:



- Above: Active layer thickness evolutions with correct parameterization (without soil temperature amplitude limitation).

Figure 9: Relative change in active layer thickness compared with the year 2100 over 30 years of spin-up of the 2100 climatic conditions.

ILL :



CORRECT :

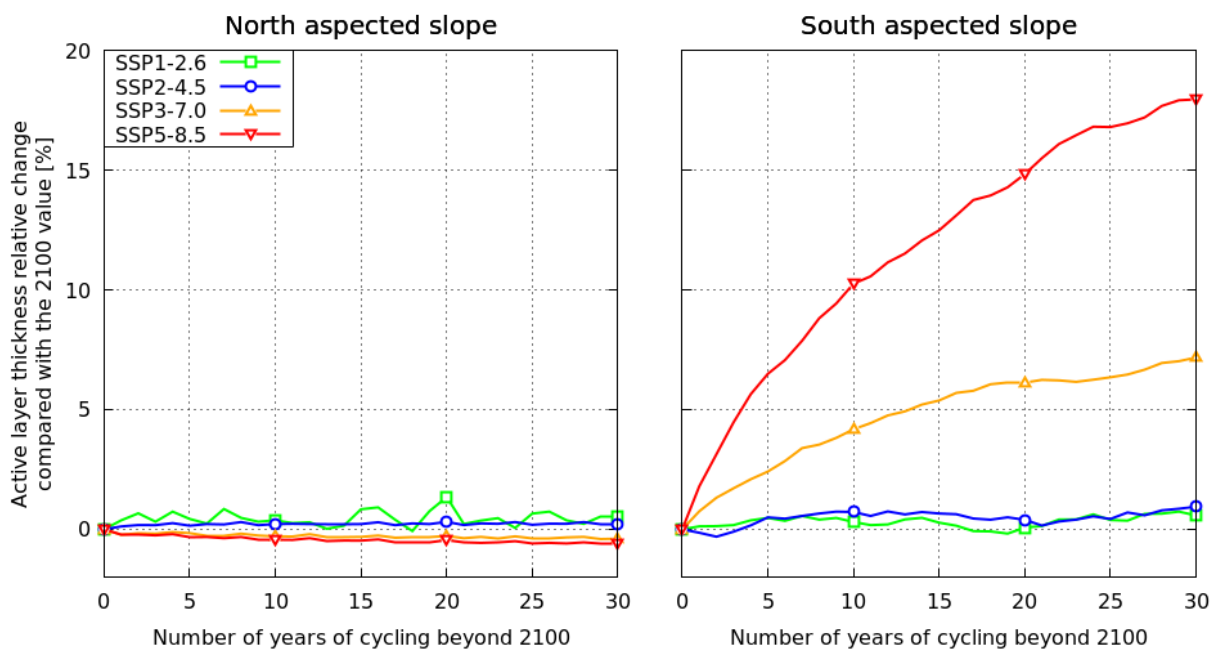
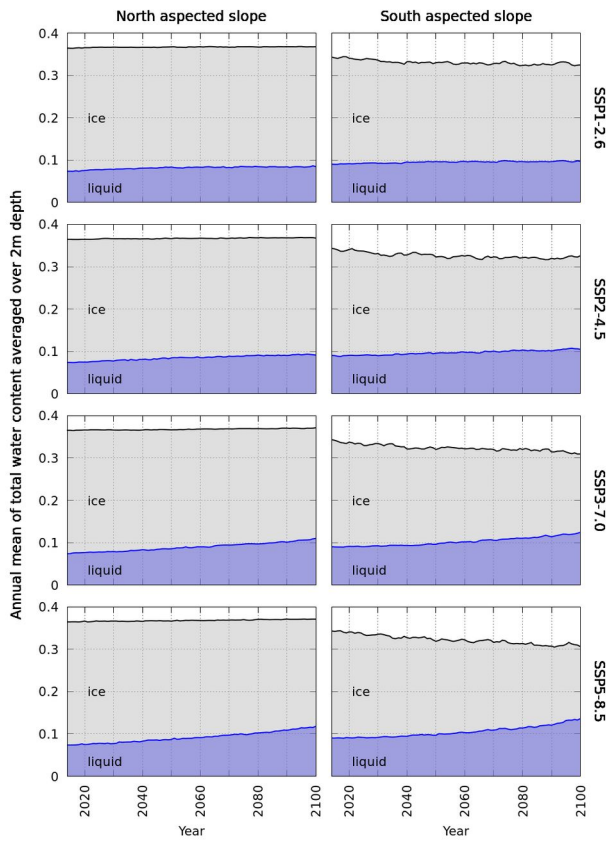
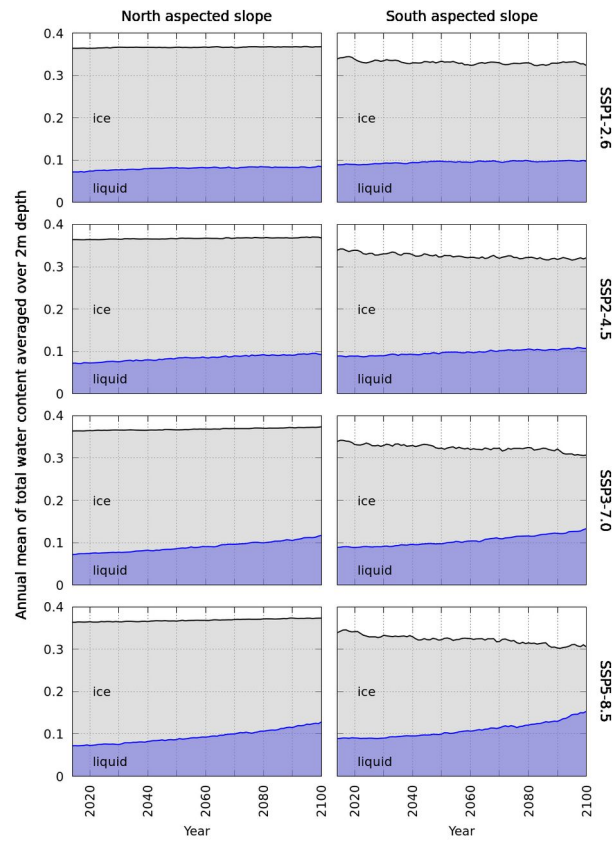


Figure 10: Annual mean of total water content [ $m^3$  of water /  $m^3$  of soil], liquid water content and ice content averaged over 2m depth in different climate projections.

ILL:



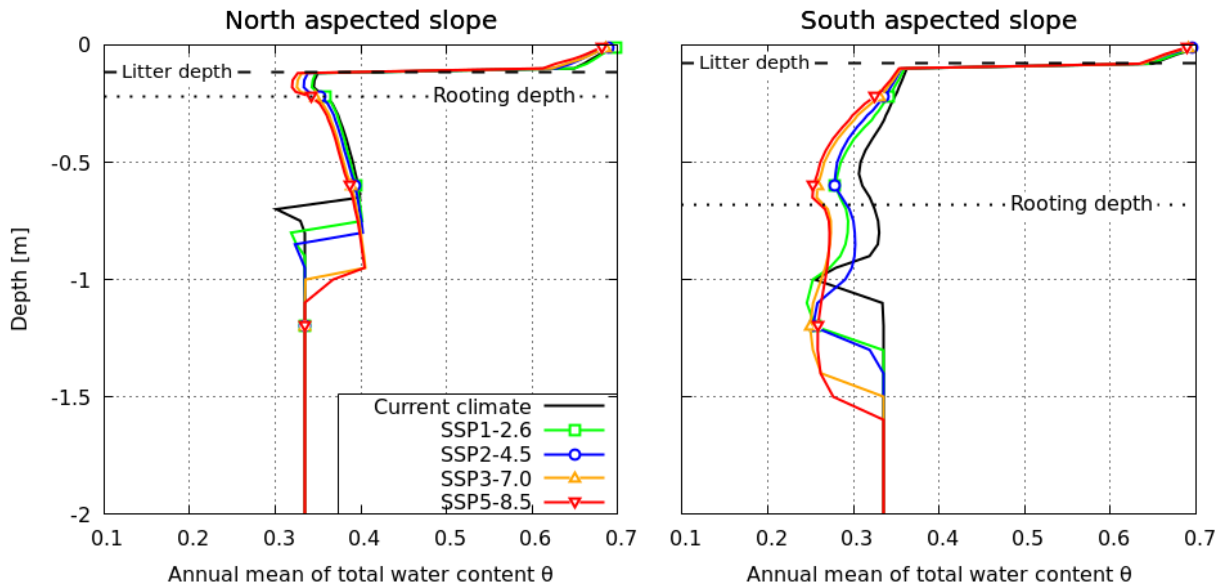
CORRECT:



- Left: Water and ice contents evolutions with ill parameterization (with soil temperature amplitude limitation to the amplitude of monthly mean top soil temperature under current climate);
- Right: Water and ice contents evolutions with correct parameterization (without soil temperature amplitude limitation).

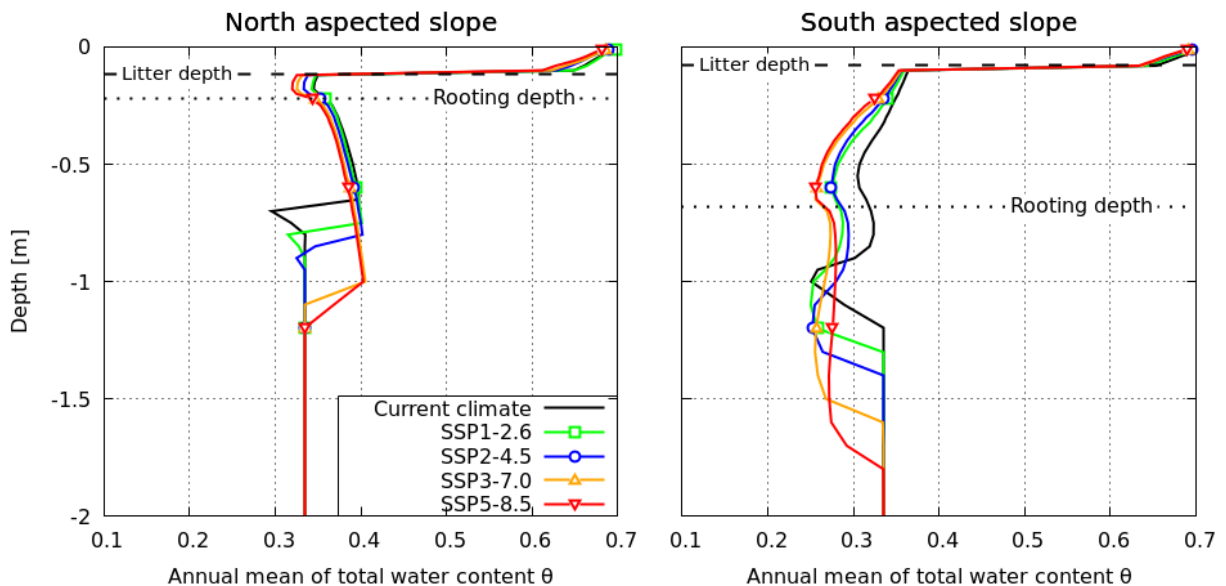
Figure 11: 2m-depth profiles of annual mean of total water content [ $m^3$  of water /  $m^3$  of soil] in 2100: projections compared to current state.

ILL:



- Above: 2m-depth profiles of annual mean of total water content [ $m^3$  of water /  $m^3$  of soil] in 2100: projections compared to current state – ill parameterization (with soil temperature amplitude limitation to the amplitude of monthly mean top soil temperature under current climate);

CORRECT:



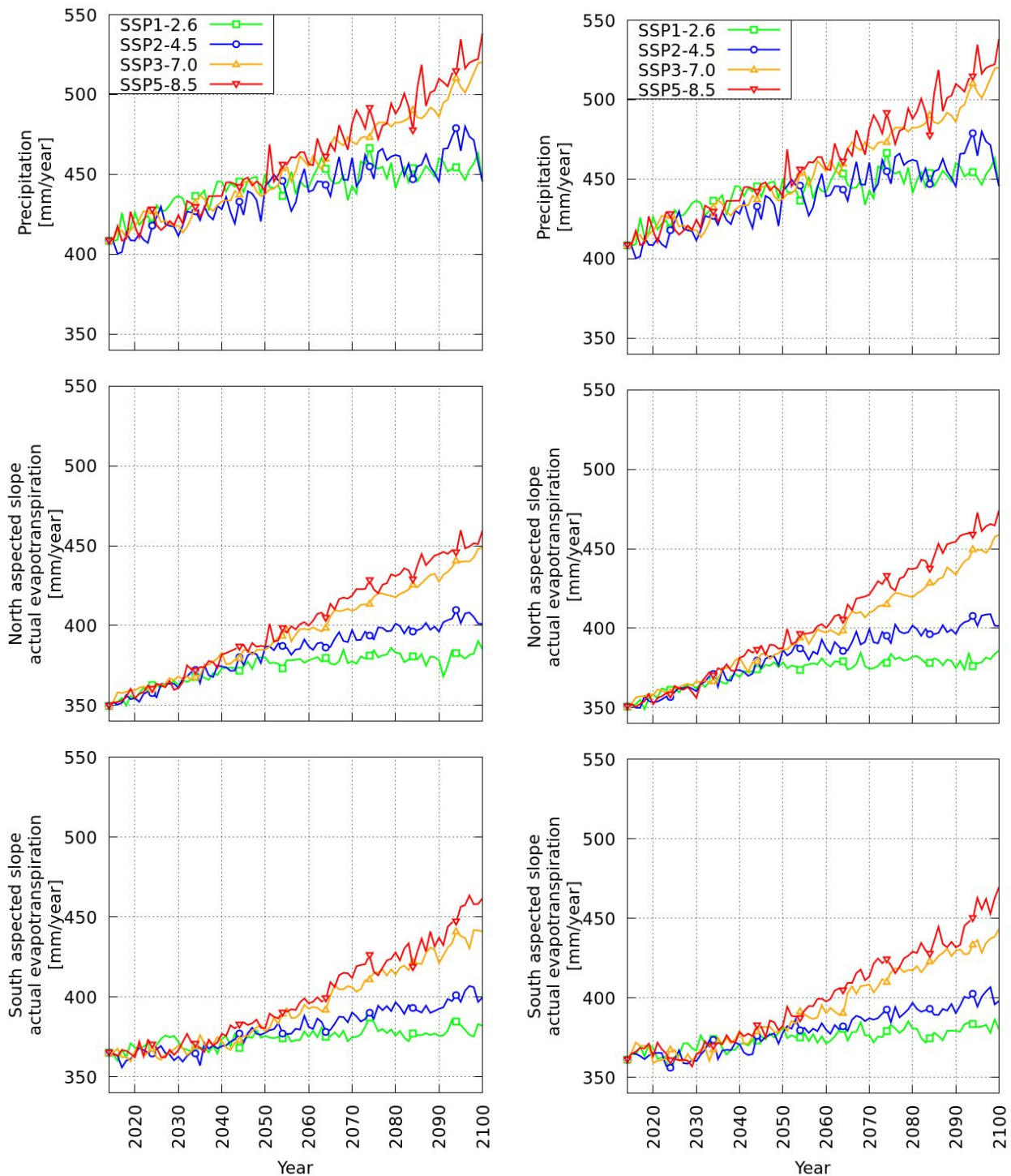
Above: 2m-depth profiles of annual mean of total water content [ $m^3$  of water /  $m^3$  of soil] in 2100: projections compared to current state – correct parameterization (without soil temperature amplitude limitation).



Figure 12: Precipitation and actual evapotranspiration evolution over the century

ILL:

CORRECT:

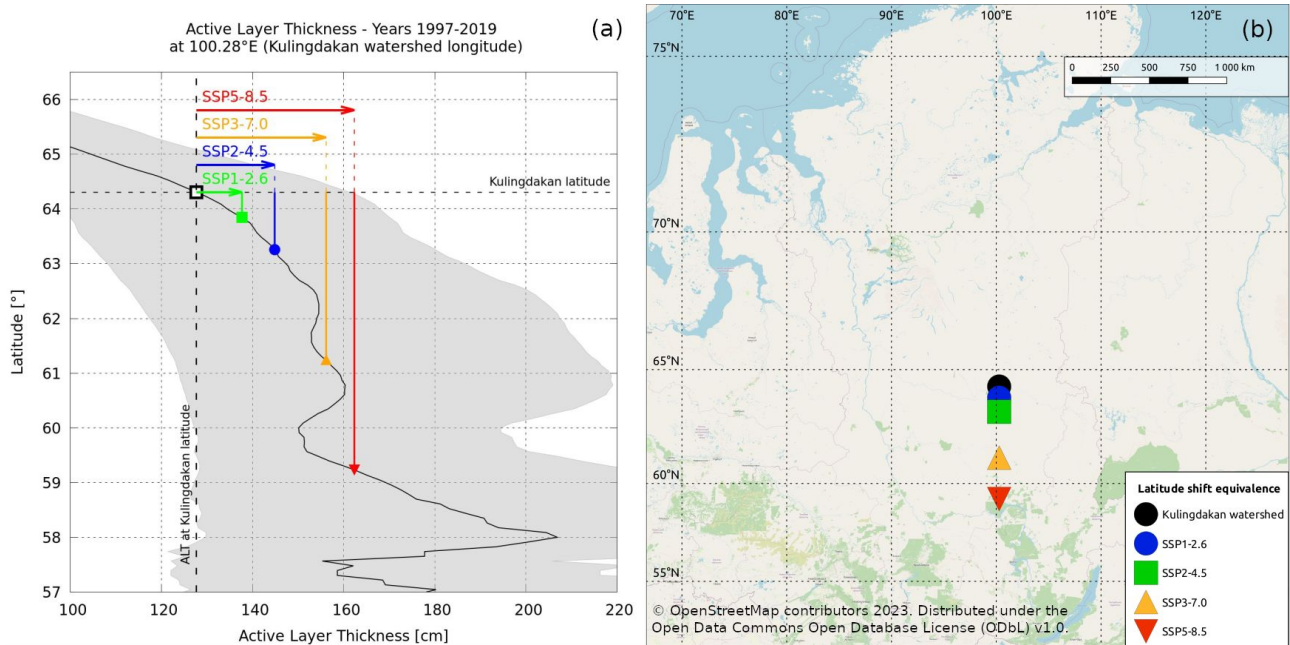


- Left: Actual Evapotranspiration evolutions with ill parameterization (with soil temperature amplitude limitation to the amplitude of monthly mean top soil temperature under current climate);
- Right: Actual Evapotranspiration evolutions with correct parameterization (without soil temperature amplitude limitation).



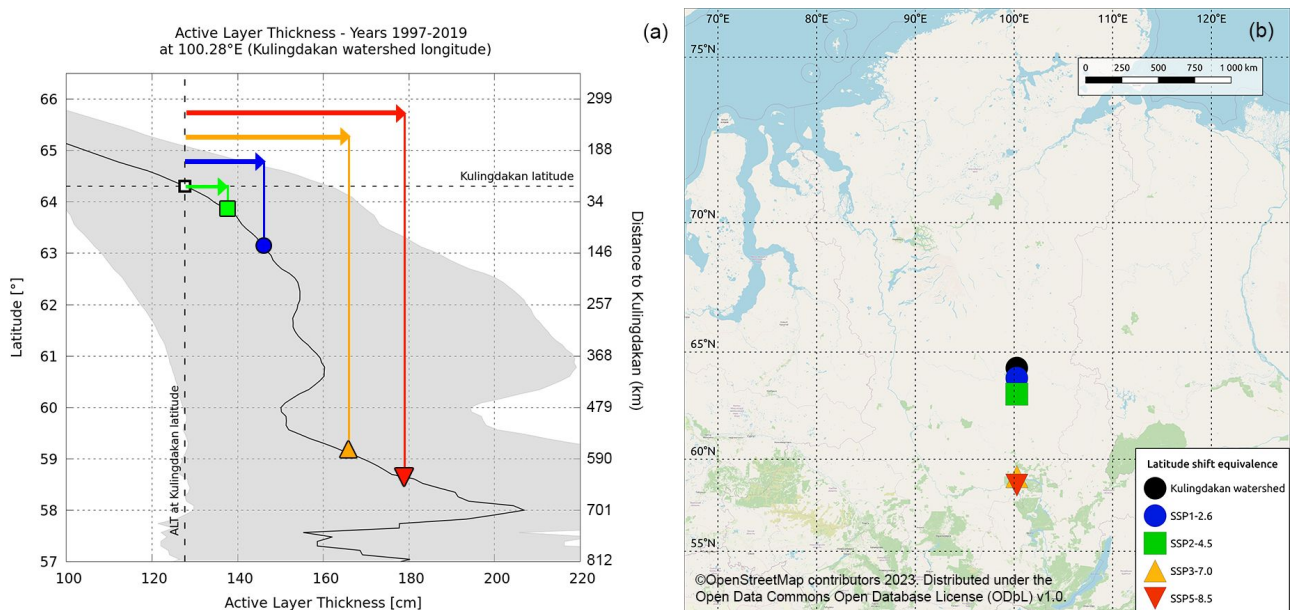
Figure 13: (a) Equivalence between simulated active layer thickening by 2100 under climate change (SAS and NAS average) and southward latitudinal shift in current climatic conditions (1997-2019). – latitudinal trend (black line - average over a 1°lat. × 1°long. polygon) and envelopes (in grey - min/max over year within the same polygon) extracted from Permafrost\_cci (Obu et al., 2021). (b) Representation of the latitudinal southward shift equivalent to each climate scenario's active layer thickening on the regional map.

ILL:



- Above: Equivalent ALT-Latitude shift based on Permafrost\_cci ALT data (Obu et al.,2021) - ill parameterization (with soil temperature amplitude limitation to the amplitude of monthly mean top soil temperature under current climate);

CORRECT:



- Above: Equivalent ALT-Latitude shift based on Permafrost\_cci ALT data (Obu et al.,2021) - correct parameterization (without soil temperature amplitude limitation).

Latitudinal shift compared to Kulingdakan Latitude (64.31°N)	ILL parametrization	CORRECT parametrization
SSP1-2.6	-0.46° / 51km	-0.45° / 50km
SSP2-4.5	-1.06° / 118km	-1.17° / 130km
SSP3-7.0	-3.10° / 345km	-5.20° / 578km
SSP5-8.5	-5.06° / 563km	-5.64° / 628km

*Supplementary material C: tables compiling the main variables change between present conditions and 2100 for the four climate scenarios considered in this paper (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5) for North Aspected Slope (Table C1) and South Aspected Slope (Table C2)*

<i>ILL:</i> Variables (NAS)	Annual value in present climate	Change from present values in projections to 2100			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Air temperature	-8.2°C	+1.6°C	+3.0°C	+5.6°C	+6.9°C
Yearly precipitations	408mm	+56mm / +14%	+49mm / +12%	+111mm / +27%	+115mm / +28%
Maximum snow water equivalent	108mm	+7mm / +6%	+13mm / +12%	+27mm / +25%	+29mm / +27%
Snow season extent	202days	-6days	-8days	-14days	-17days
Soil surface temperature	-3.3°C	+1.4°C	+2.3°C	+4.3°C	+5.2°C
Soil temperature (10cm depth)	-4.1°C	+0.9°C	+1.4°C	+2.9°C	+3.4°C
Soil temperature (1m depth)	-5.12°C	+0.6°C	+1.0°C	+2.2°C	+2.6°C
Soil temperature (5m depth)	-5.06°C	+0.6°C	+1.0°C	+2.2°C	+2.5°C
Soil temperature (10m depth)	-4.9°C	+0.6°C	+1.0°C	+2.0°C	+2.5°C
Active layer thickness	64cm	+7.8cm +12%	+11.9cm +19%	+23.9cm +37%	+28.2cm +44%
Total water content (averaged over root layer)	0.510	+1.7x10 <sup>-4</sup> +0.0%	-1.2x10 <sup>-2</sup> -2.3%	-1.7x10 <sup>-2</sup> -3.3%	-2.4x10 <sup>-2</sup> -4.7%
Liquid water content (averaged over root layer)	0.197	+1.2x10 <sup>-2</sup> +6.3%	+1.4x10 <sup>-2</sup> +7%	+2.8x10 <sup>-2</sup> +14.1%	+3.3x10 <sup>-2</sup> +16.5%
Ice water content (averaged over root layer)	0.313	-1.2x10 <sup>-3</sup> -3.9%	-2.6x10 <sup>-2</sup> -8.1%	-4.5x10 <sup>-2</sup> -14.3%	-5.6x10 <sup>-2</sup> -18%
Total water content (averaged over 0-2m)	0.365	+3.2x10 <sup>-3</sup> +0.9%	+3.0x10 <sup>-3</sup> +0.8%	+6.7x10 <sup>-3</sup> +1.8%	+6.3x10 <sup>-3</sup> +1.7%
Liquid water content (averaged over 0-2m)	0.074	+1.1x10 <sup>-2</sup> +14.7%	+1.8x10 <sup>-2</sup> +23.8%	+3.6x10 <sup>-2</sup> +49.3%	+4.4x10 <sup>-2</sup> +60.1%
Ice water content (averaged over 0-2m)	0.291	-7.7x10 <sup>-3</sup> -2.7%	-1.5x10 <sup>-2</sup> -5.0%	-3.0x10 <sup>-2</sup> -10.2%	-3.8x10 <sup>-2</sup> -13.1%
Actual evapotranspiration	350mm	+40mm / +11%	+52mm / +15%	+98mm / +28%	+100mm / +29%

*Table C1: main variables changes simulated for the four climate projections in 2100 for north aspected slope - ill parameterization (with soil temperature amplitude limitation to the amplitude of monthly mean top soil temperature under current climate);*

<i>CORRECT:</i>	Change from present values in projections to 2100				
<b>Variables (NAS)</b>	<b>Annual value in present climate</b>	<b>SSP1-2.6</b>	<b>SSP2-4.5</b>	<b>SSP3-7.0</b>	<b>SSP5-8.5</b>
Air temperature	-8.2°C	+1.6°C	+3.0°C	+5.6°C	+6.9°C
Yearly precipitations	408mm	+56mm / +14%	+49mm / +12%	+111mm / +27%	+115mm / +28%
Maximum snow water equivalent	108mm	+7mm / +6%	+13mm / +12%	+27mm / +25%	+29mm / +27%
Snow season extent	202days	-6days	-8days	-14days	-17days
Soil surface temperature	-3.3°C	+1.4°C	+2.3°C	+4.3°C	+5.2°C
Soil temperature (10cm depth)	-4.6°C	+1.2°C	+1.9°C	+3.7°C	+4.4°C
Soil temperature (1m depth)	-5.6°C	+1.0°C	+1.5°C	+2.9°C	+3.4°C
Soil temperature (5m depth)	-5.6°C	+1.0°C	+1.5°C	+2.8°C	+3.2°C
Soil temperature (10m depth)	-5.5°C	+0.9°C	+1.5°C	+2.7°C	+3.2°C
Active layer thickness	63cm	+8.8cm +14%	+14.5cm +23%	+30.9cm +49%	+38.5cm +61%
Total water content (averaged over root layer)	0.510	1.1x10 <sup>-4</sup> +0.0%	-1.2x10 <sup>-2</sup> -2.3%	-1.7x10 <sup>-2</sup> -3.4%	-2.4x10 <sup>-2</sup> -4.7%
Liquid water content (averaged over root layer)	0.198	1.2x10 <sup>-2</sup> +5.9%	1.3x10 <sup>-2</sup> +6.5%	2.7x10 <sup>-2</sup> +13.8%	3.2x10 <sup>-2</sup> +16.3%
Ice water content (averaged over root layer)	0.312	-1.2x10 <sup>-2</sup> -3.7%	-2.5x10 <sup>-2</sup> -7.9%	-4.4x10 <sup>-2</sup> -14.2%	-5.6x10 <sup>-2</sup> -18.0%
Total water content (averaged over 0-2m)	0.364	+3.5x10 <sup>-3</sup> +1.0%	+3.9x10 <sup>-3</sup> +1.1%	+9.4x10 <sup>-3</sup> +2.6%	+9.3x10 <sup>-3</sup> +2.6%
Liquid water content (averaged over 0-2m)	0.072	+1.2x10 <sup>-2</sup> +17.3%	+2.0x10 <sup>-2</sup> +28.4%	+4.5x10 <sup>-2</sup> +62.4%	+5.6x10 <sup>-2</sup> +77.8%
Ice water content (averaged over 0-2m)	0.292	-8.9x10 <sup>-03</sup> -3.1%	-1.7x10 <sup>-2</sup> -5.7%	-3.6x10 <sup>-2</sup> -12.2%	-4.7x10 <sup>-2</sup> -16.0%
Actual evapotranspiration	351mm	+35mm/+10%	+51mm/+14%	+108mm/+31%	+123mm/+35%

*Table C1: main variables changes simulated for the four climate projections in 2100 for north aspected slope - correct parameterization (without soil temperature amplitude limitation).*

<i>ILL:</i> Variables (SAS)	Annual value in present climate	Change from present values in projections to 2100			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Air temperature	-8.2°C	+1.6°C	+3.0°C	+5.6°C	+6.9°C
Yearly precipitations	408mm	+56mm/+14%	+49mm / +12%	+111mm / +27%	+115mm / +28%
Maximum snow water equivalent	108mm	+7mm / +6%	+13mm / +12%	+27mm / +25%	+29mm / +27%
Snow season extent	202days	-6days	-8days	-14days	-17days
Soil surface temperature	-2.6°C	+1.5°C	+2.3°C	+4.4°C	+5.2°C
Soil temperature (10cm depth)	-3.1°C	+1.1°C	+1.7°C	+3.4°C	+4.0°C
Soil temperature (1m depth)	-4.15°C	+1.0°C	+1.5°C	+2.9°C	+3.3°C
Soil temperature (5m depth)	-4.11°C	+0.9°C	+1.5°C	+2.4°C	+2.7°C
Soil temperature (10m depth)	-4.0°C	+0.9°C	+1.5°C	+2.3°C	+2.5°C
Active layer thickness	99cm	+13cm +13%	+20.0cm +20%	+36.3cm +37%	+45.2cm +46%
Total water content (averaged over root layer)	0.375	-1.6x10 <sup>-2</sup> -4.3%	-2.1x10 <sup>-2</sup> -5.6%	-3.2x10 <sup>-2</sup> -8.5%	-3.7x10 <sup>-2</sup> -9.7%
Liquid water content (averaged over root layer)	0.153	+1.1x10 <sup>-3</sup> +0.7%	+3.5x10 <sup>-3</sup> +2.3%	+1.2x10 <sup>-2</sup> +8.0%	+1.5x10 <sup>-2</sup> +9.8%
Ice water content (averaged over root layer)	0.222	-1.7x10 <sup>-2</sup> -7.7%	-2.4x10 <sup>-2</sup> -11.0%	-4.4x10 <sup>-2</sup> -19.9%	-5.1x10 <sup>-2</sup> -23.1%
Total water content (averaged over 0-2m)	0.343	-1.8x10 <sup>-2</sup> -5.4%	-1.7x10 <sup>-2</sup> -5.0%	-3.4x10 <sup>-2</sup> -9.8%	-3.7x10 <sup>-2</sup> -10.8%
Liquid water content (averaged over 0-2m)	0.090	+6.6x10 <sup>-3</sup> +7.3%	+1.5x10 <sup>-2</sup> +16.2%	+3.4x10 <sup>-2</sup> +37.7%	+4.6x10 <sup>-2</sup> +50.7%
Ice water content (averaged over 0-2m)	0.253	-2.5x10 <sup>-2</sup> -9.9%	-3.2x10 <sup>-2</sup> -12.6%	-6.8x10 <sup>-2</sup> -26.8%	-8.3x10 <sup>-2</sup> -32.7%
Actual evapotranspiration	364mm	+18mm/+5%	+34mm/+9%	+76mm/+21%	+94mm/+26%

*Table C2: main variables changes simulated for the four climate projections in 2100 for south aspected slope - ill parameterization (with soil temperature amplitude limitation to the amplitude of monthly mean top soil temperature under current climate);*

<i>CORRECT:</i> Variables (SAS)	Annual value in present climate	Change from present values in projections to 2100			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Air temperature	-8.2°C	+1.6°C	+3.0°C	+5.6°C	+6.9°C
Yearly precipitations	408mm	+56mm/+14%	+49mm / +12%	+111mm / +27%	+115mm / +28%
Maximum snow water equivalent	108mm	+7mm / +6%	+13mm / +12%	+27mm / +25%	+29mm / +27%
Snow season extent	202days	-6days	-8days	-14days	-17days
Soil surface temperature	-2.6°C	+1.5°C	+2.3°C	+4.4°C	+5.2°C
Soil temperature (10cm depth)	-3.3°C	+1.4°C	+2.1°C	+4.2°C	+5.0°C
Soil temperature (1m depth)	-4.4°C	+1.3°C	+1.8°C	+3.5°C	+4.0°C
Soil temperature (5m depth)	-4.4°C	+1.2°C	+1.8°C	+2.9°C	+3.1°C
Soil temperature (10m depth)	-4.3°C	+1.2°C	+1.8°C	+2.7°C	+2.9°C
Active layer thickness	100cm	+12.5cm +13%	+22.6cm +23%	+46.5cm +47%	+65.1cm +65%
Total water content (averaged over root layer)	0.375	-1.8x10 <sup>-2</sup> -4.9%	-2.2x10 <sup>-2</sup> -6.0%	-3.2x10 <sup>-2</sup> -8.6%	-3.5x10 <sup>-2</sup> -9.4%
Liquid water content (averaged over root layer)	0.152	+7.6x10 <sup>-4</sup> +0.5%	+3.9x10 <sup>-3</sup> +2.5%	+1.2x10 <sup>-2</sup> +8.2%	+1.6x10 <sup>-2</sup> +10.3%
Ice water content (averaged over root layer)	0.223	-1.9x10 <sup>-2</sup> -8.5%	-2.6x10 <sup>-2</sup> -11.8%	-4.5x10 <sup>-2</sup> -20.1%	-5.1x10 <sup>-2</sup> -22.9%
Total water content (averaged over 0-2m)	0.339	-1.6x10 <sup>-2</sup> -4.6%	-1.8x10 <sup>-2</sup> -5.4%	-3.2x10 <sup>-2</sup> -9.5%	-3.4x10 <sup>-2</sup> -9.9%
Liquid water content (averaged over 0-2m)	0.089	+8.2x10 <sup>-3</sup> +9.2%	+1.8x10 <sup>-2</sup> +20.4%	+4.4x10 <sup>-2</sup> +49.8%	+6.4x10 <sup>-2</sup> +72.4%
Ice water content (averaged over 0-2m)	0.250	-2.4x10 <sup>-2</sup> -9.6%	-3.6x10 <sup>-2</sup> -14.5%	-7.7x10 <sup>-2</sup> -30.6%	-9.8x10 <sup>-2</sup> -39.1%
Actual evapotranspiration	361mm	+19mm/+5%	+37mm/+10%	+82mm/+23%	+108mm/+30%

*Table C2: main variables changes simulated for the four climate projections in 2100 for south aspected slope - correct parameterization (without soil temperature amplitude limitation).*