From: Guinotte, John
To: Kevin Doherty
Subject: figs
Date: Tuesday, May 9, 2017 8:42:24 AM

Wolverine Report Figures FINAL DRAFT 5MAY2017.pdf

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

Wolverine Report – Figures

[NOTE: It is noted in the captions where figures are still to be replaced with revised versions due to requested revisions or captioning issues– 14 APR 2017]

Section 2: Project Overview (note: Section 1: No figures)

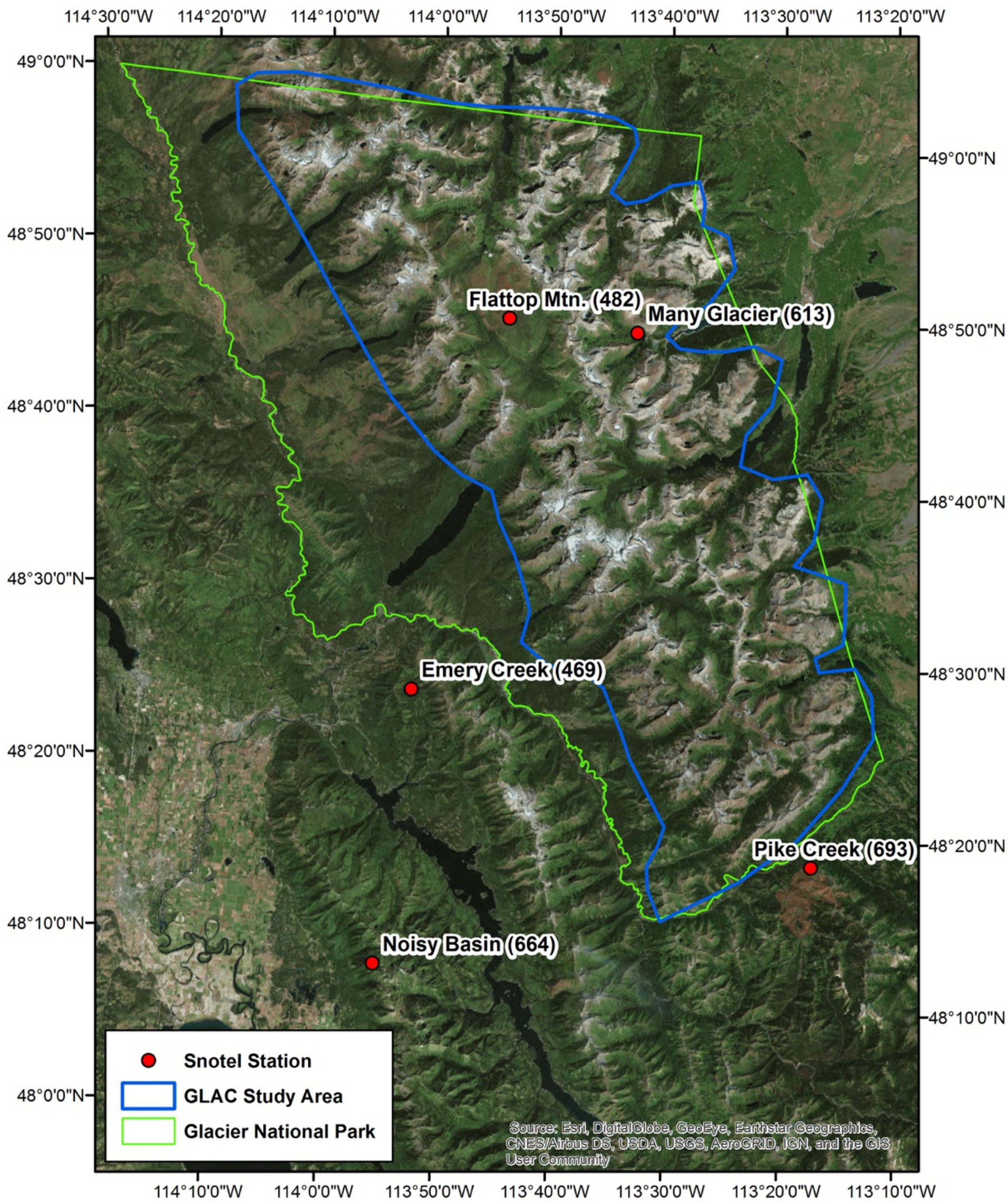

Figure 2-1: Glacier National Park (GLAC). The high-resolution study area domain (blue outline) consists of high-elevation areas within and in the vicinity of Rocky Mountain National Park (ROMO, bottom) including the northern Front Range and Never Summer mountain ranges.

SNOTEL stations indicated by red dots. Study areas were chosen to encompass areas with elevations from the ridgetops down to ~200m below treeline and do not follow National Park boundaries.

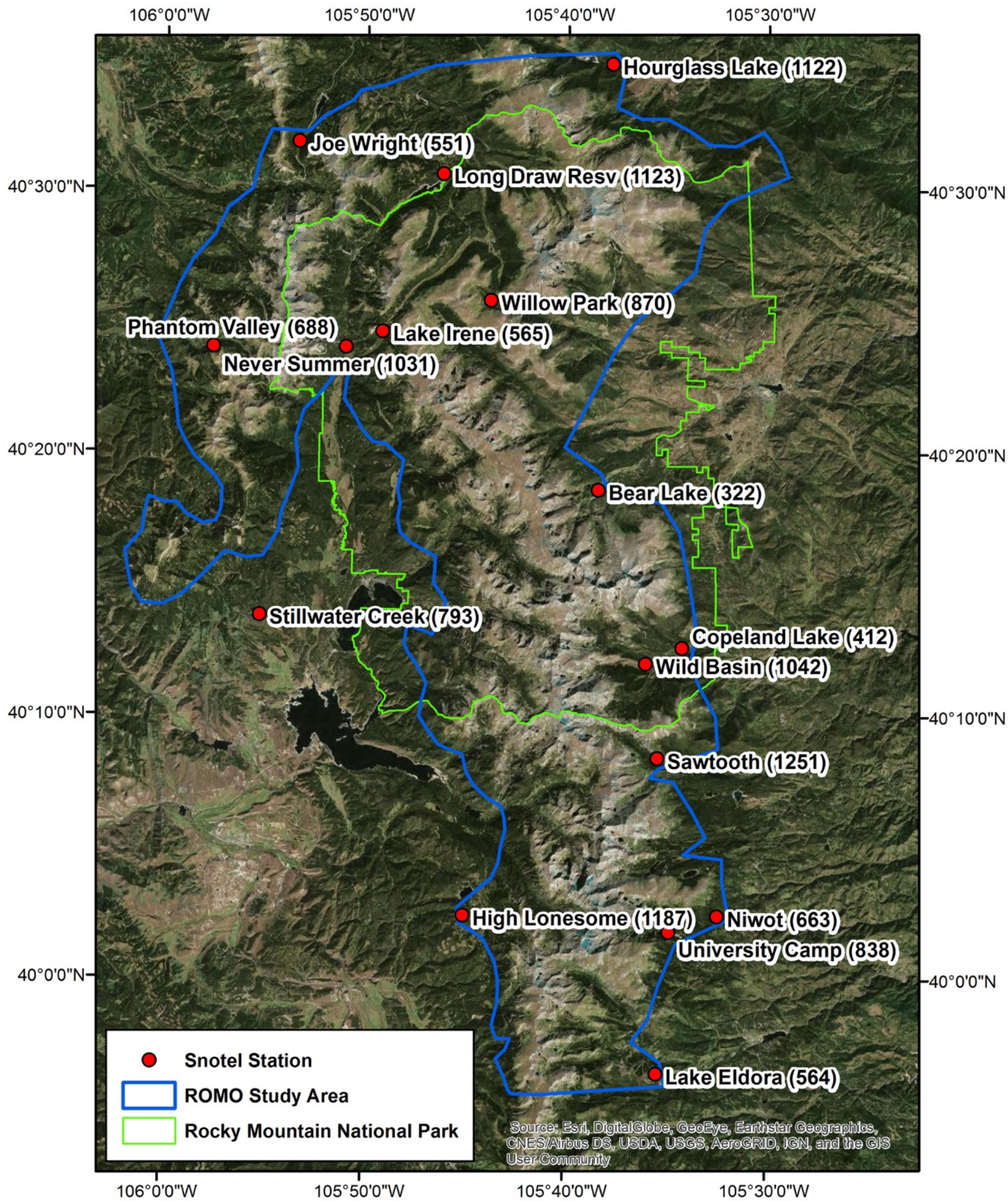

Figure 2-2 Rocky Mountain National Park (ROMO) Study Area. The high resolution domain (blue outline) consists of high-elevation areas within and in the vicinity of the Park including the northern Front Range and Never Summer mountain ranges. SNOTEL stations indicated by red

dots. Study areas were chosen to encompass areas with elevations from the ridgetops down to ~200m below treeline and do not follow National Park boundaries.

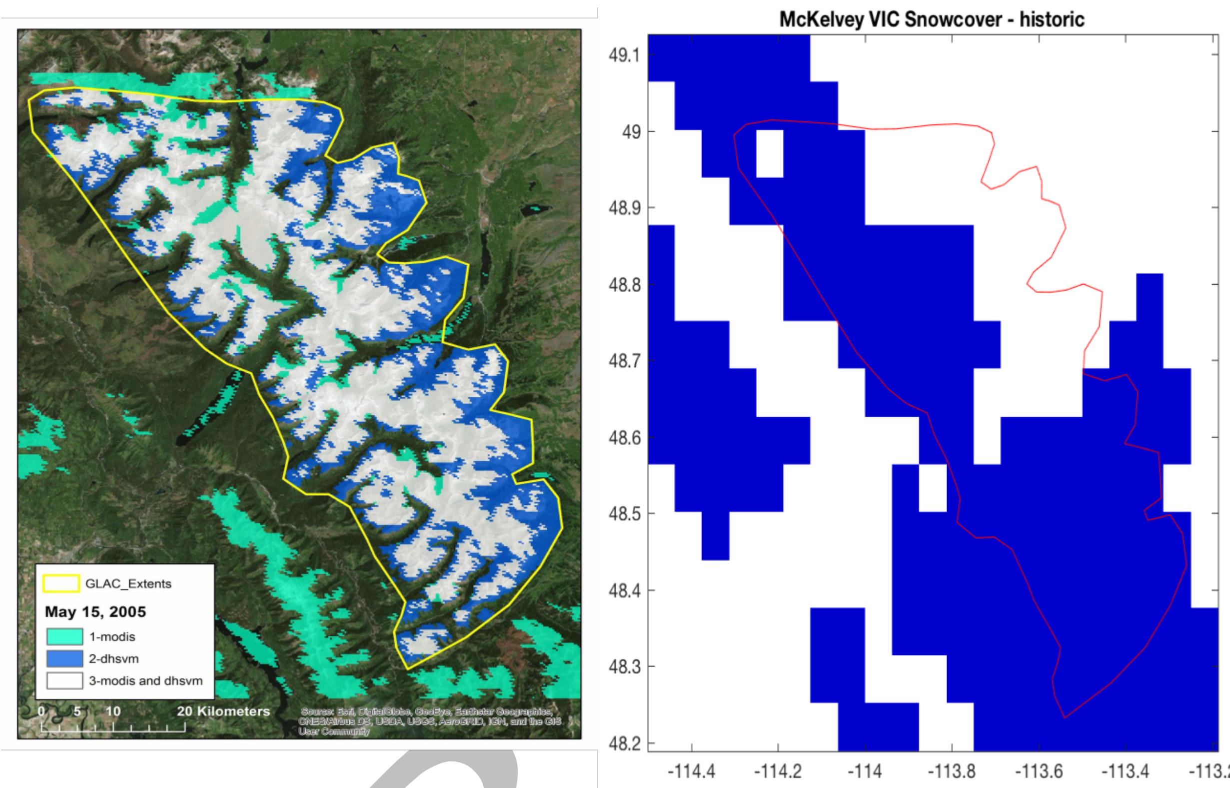

Figure 2-4: Visual comparison of resolution of our study (left) and the McKelvey study. Maps of the GLAC study area illustrate the differences in the resolution of the two studies. This report provides case studies of two high elevation areas analyzed on a UTM grid, 250m x250 m (0.0625 km^2). GLAC shown on the left as an example. The Copeland and McKelvey projects use data at 1/16 on a side (right). At 48°N latitude, Glacier National Park, the gridbox is slightly smaller than ~5km by 7 km (~37km^2). Grid boxes at Rocky Mountain National Park (southern extent at ~40°N), are ~5km by 7 km. Left image from John Guinotte.

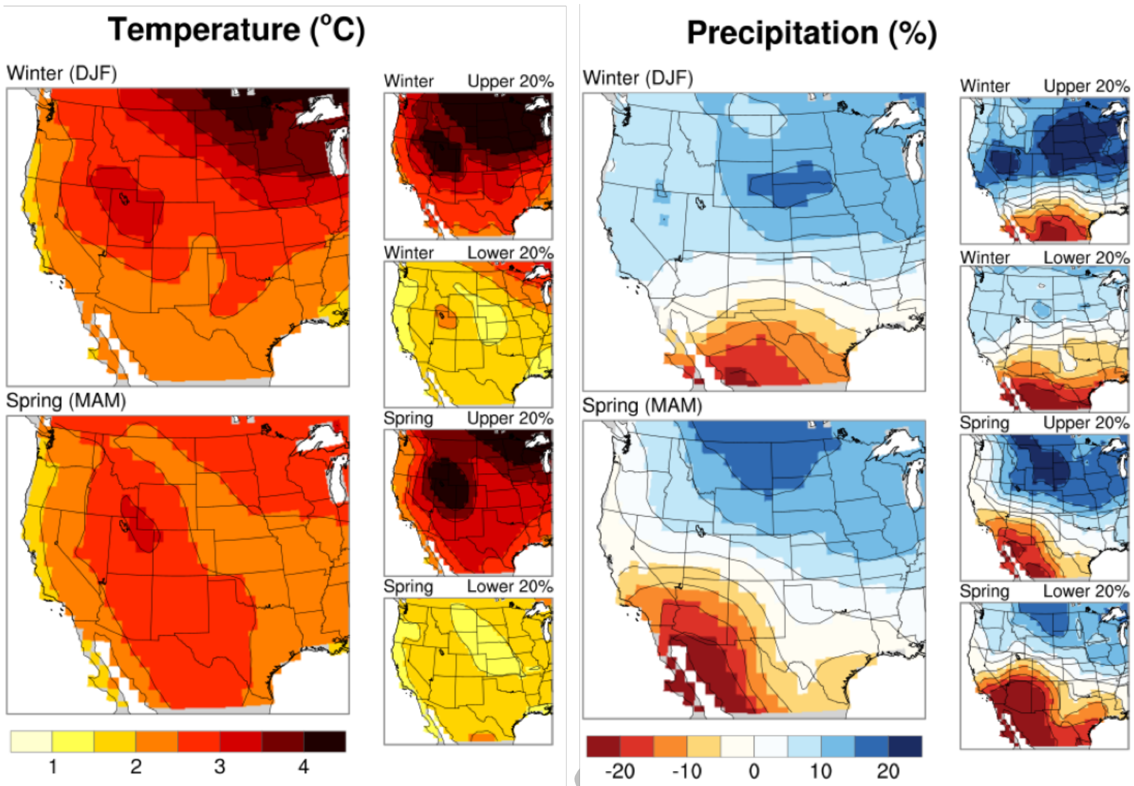

Figure 2-4: Projected changes in temperature (left) and precipitation (right) by 2050 over the western US for winter and spring from an ensemble of 34 global climate models under RCP 8.5 from CMIP5. The large maps show the mean of all models, and the small maps show mean changes from highest 20% and lowest 20% of the models based on statewide change in Colorado in temperature (left) or precipitation (right). All anomalies are calculated based on 2035-2064 relative 1971-2000. Adopted and modified from Lukas et al., 2014; (Data source: CMIP5 projections re-gridded to 1-degree grid, Reclamation 2013; http://gdo-dcp.ucllnl.org/).

Figures Section 3: Observed Climate and Variability

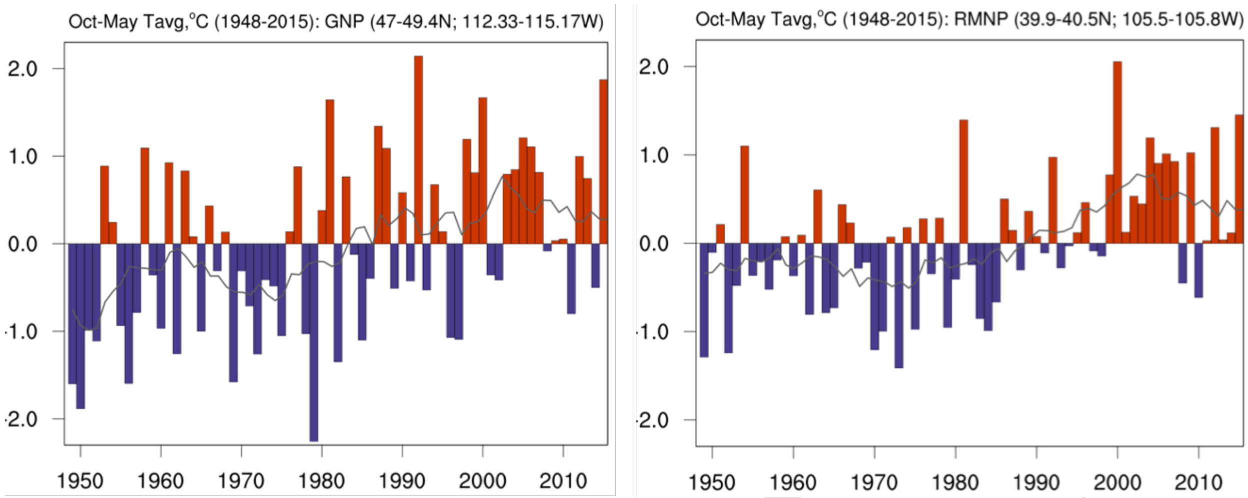

Figure 3-1. Historical trends in cold season (October-May) temperature for the Glacier National Park (GNP, left) and the Rocky Mountain National Park (RMNP, right). The plot shows anomalies in average October-May temperature between 1948-2015 based on the 800m-resolution gridded dataset from TopoWx for a rectangular grid surrounding the GNP (left, 47-49.4N; 112.33-115.17W) and RMNP (39.9-40.5N; 105.5-105.8W). Anomalies are relative to the 1971-2000 period. The grey curve shows a 10-year running mean trend. Linear regression (not shown) indicates about a 1.4 ^{o}C increase in temperature in GNP during this period, and about 1.2 ^{o}C increase in temperature in RMNP.

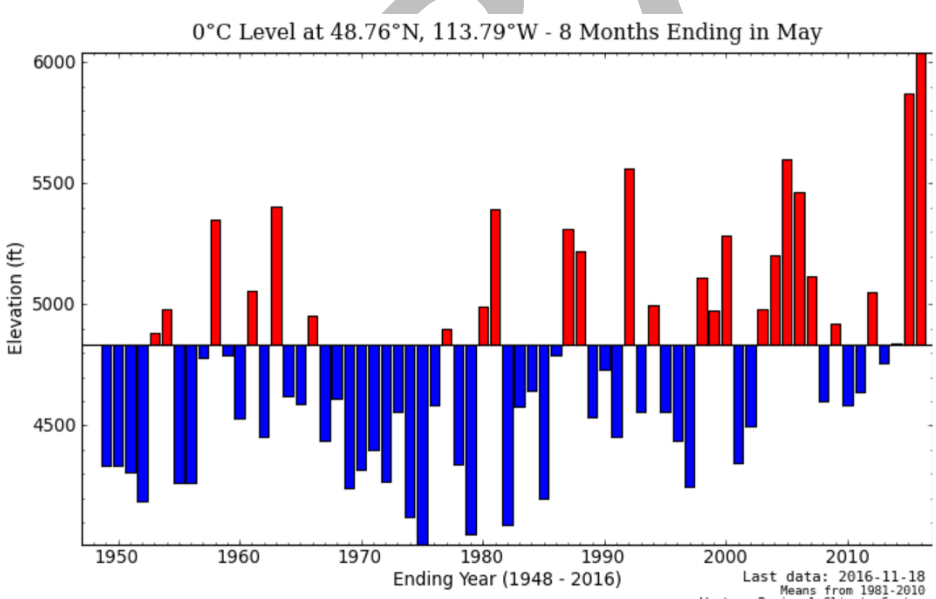

Figure 3-2. Historical trends in cold season (October-May) atmospheric freezing level for the Glacier National Park. Freezing level estimation shown in the plot are based on NCEP/NCAR Global Reanalysis 2.5^{o} x 2.5^{o} grid data provided by the North American Freezing Level Tracker (NAFLT, http://www.wrcc.dri.edu/cwd/products/). The plot shows average October-May

freezing level estimates for a broad atmospheric column in a gridbox centered over Glacier National Park (48.76N and 113.79W). Linear regression shows about 160 m (530 ft) increase in the freezing level. [Note: graphic downloaded from NAFLT provided in English units].

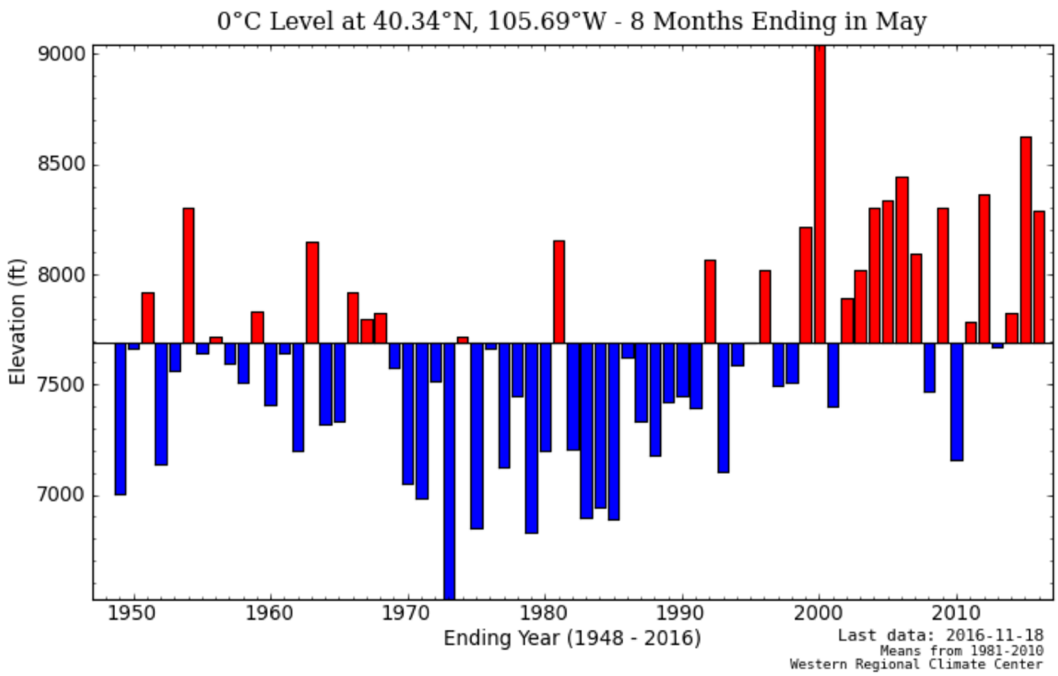

Fig 3-3. Historical trends in cold season (October-May) atmospheric freezing level for the Rocky Mountain National Park. Freezing level estimates shown in the plot are based on NCEP/NCAR Global Reanalysis 2.5° x 2.5° data provided by the North American Freezing Level Tracker http://www.wrcc.dri.edu/cwd/products/). The plot shows average October-May freezing level estimations for a broad atmospheric column in a gridbox centered over Rocky Mountain National Park (40.34N and 105.69W). Linear regression shows about 170 m (560 ft) increase in the freezing level. [Note: graphic downloaded from NAFLT provided in English units].

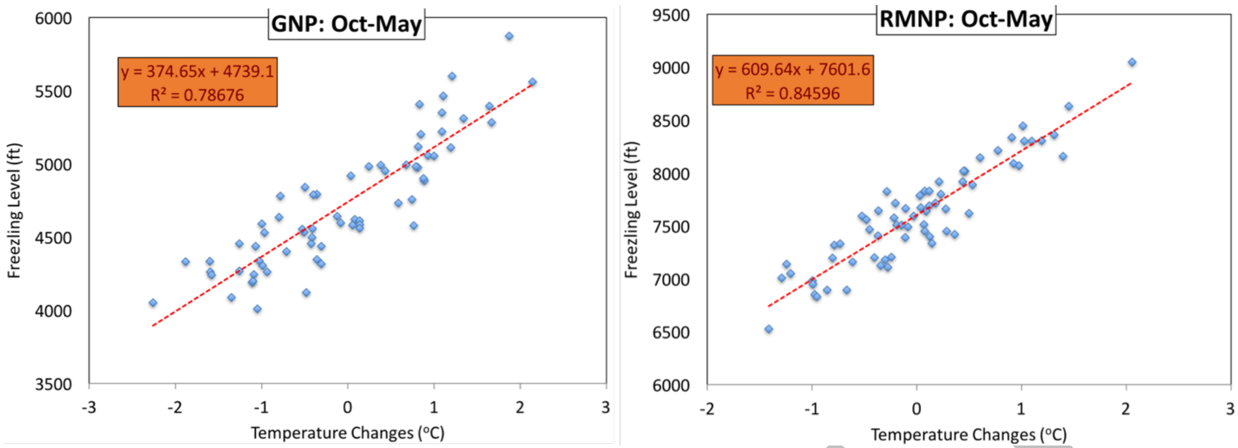

Fig 3-4. Relationship between temperature change and freezing level shifts for areas around (A) Glacier (GNP) and (B) Rocky Mountain (RMNP) National Parks. Note the difference in the y-axis due to the different elevations of the park. There is a strong relationship between freezing levels and temperature change for both regions in Oct-May with R^2 close to 0.8. For RMNP, there has been about a 180 m (600 ft) increase in the freezing level for 1°C increase in temperature, whereas for GNP, there is about a 115 m (375 ft) increase in the freezing level for 1°C increase in temperature.

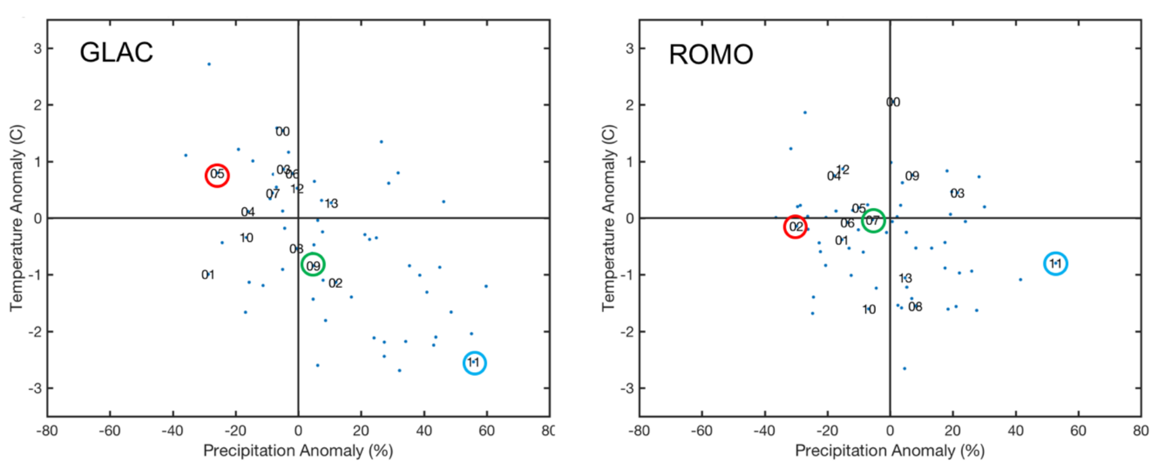

Figure 3-5. Cold Season (October – May) average temperature and precipitation departures from the 1981-2010 average for the GLAC and ROMO study areas. Circles show the representative case study years Warm/Dry (rec), Near Normal (green) and Cool/Wet (blue). Relatively warm/dry winters are in the upper left quadrant, cool/wet in the lower right quadrant. Individual years (00=2000, 01=2001, etc) are noted; unlabeled dots represent data from 1951-1999 to illustrate the broader climatological range. Data is from the Livneh (2014) dataset. Average is taken over a rectangular area in latitude and longitude surrounding the study areas GLAC (48N-49N,112W–114.5 W), and ROMO (39N – 41N, 105W-107W).

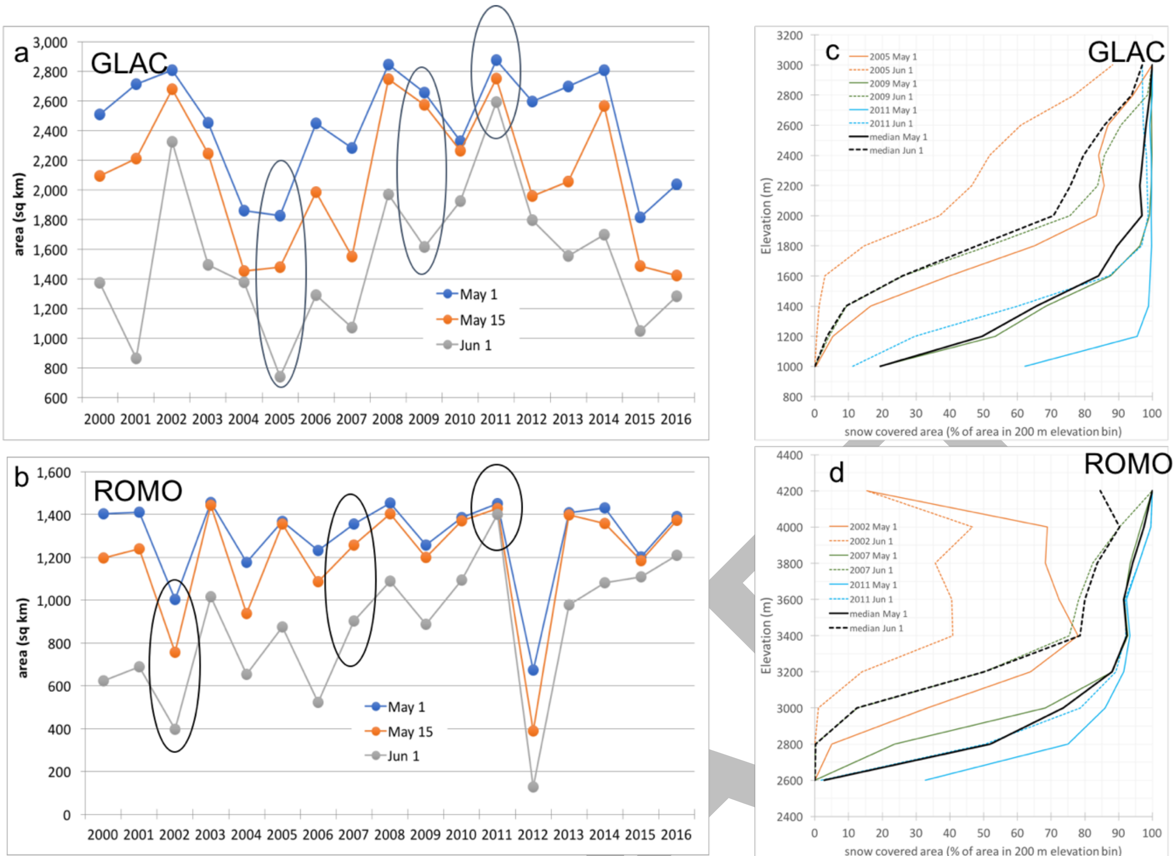

Figure 3-6. Snow covered area and elevation profile for the representative case study years. Panels a and b) Snow covered area (SCA) from MODIS as a function of year for May 1, May 15, and June 1. Dry, near normal, and wet representative years are circled. Panels c and d) SCA as a function of elevation for May 1 and June 1. Note that the “near normal” study years (green lines) are close to the median profile (black lines).

Section 4 MODIS Historical Snowcover Analysis – Figures

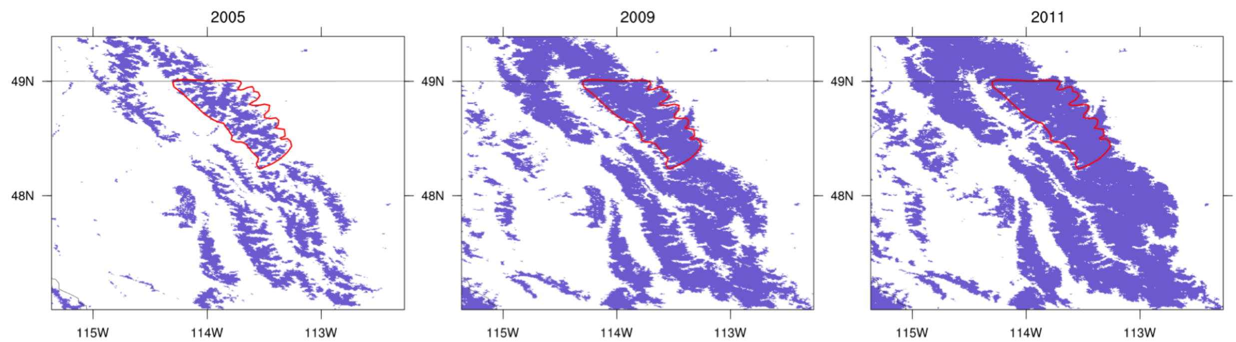

Figure 4-1. May 15 snow cover from MODIS for the GLAC study area (red outline) and vicinity. "Dry" year (2005, left), "near normal year" (2009, middle), and "wet" year (2011, right). Snow cover is defined as NDSI > 0.1, and includes fractional snow cover (see text for definitions).

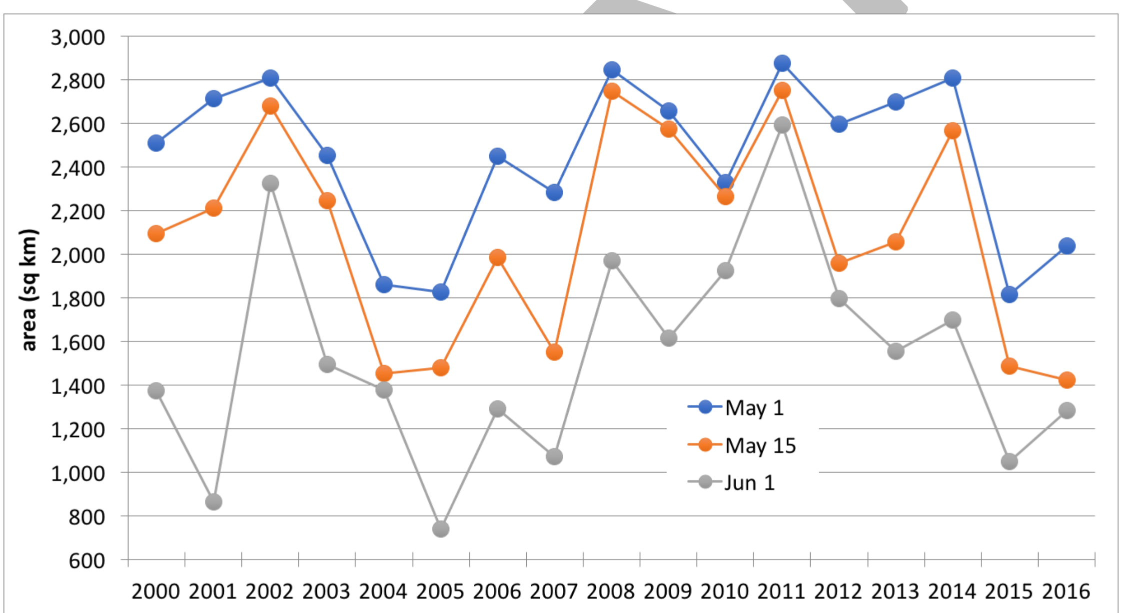

Figure 4-2: Total snow covered area (km^2) on May 1 (blue), May 15 (red), and June 1 (gray) by year from MODIS within the GLAC study area polygon. Snow cover is defined as NDSI > 0.1, and includes fractional snow cover (see text).

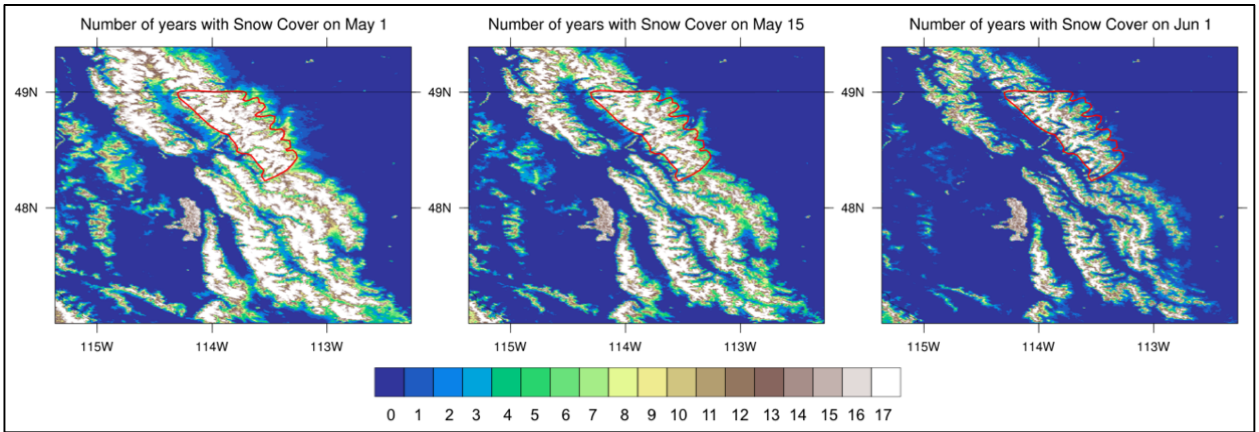

Figure 4-3: Number of Years (out of 17 total years, 2000-2016) with snow cover on May 1, May 15, and June 1 from MODIS for the GLAC study area (red outline) and vicinity. Snow cover is defined as NDSI > 0.1, and includes fractional snow cover.

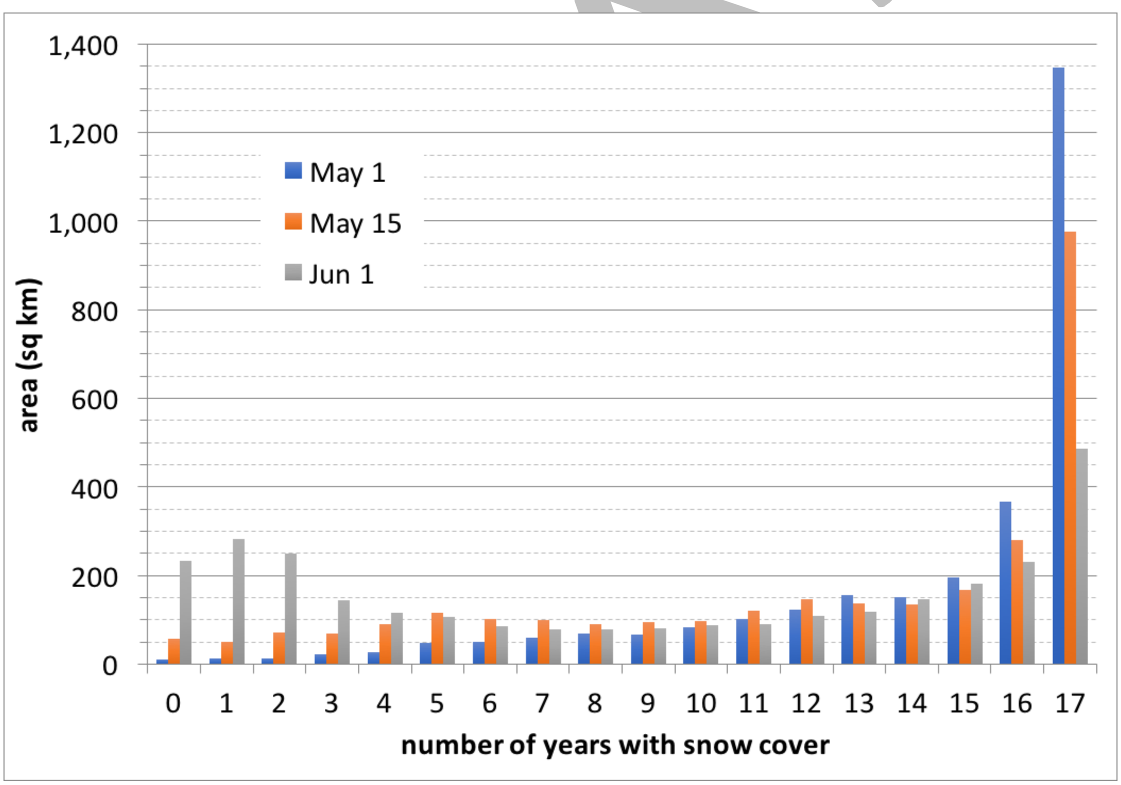

Figure 4-4: Snow covered area by number of years. Colored bars show the area within the GLAC study area polygon classified according to the number of years with snow cover (out of 17 total years) on May 1 (blue), May 15 (orange), and June 1 (grey). Snow cover data from MODIS.

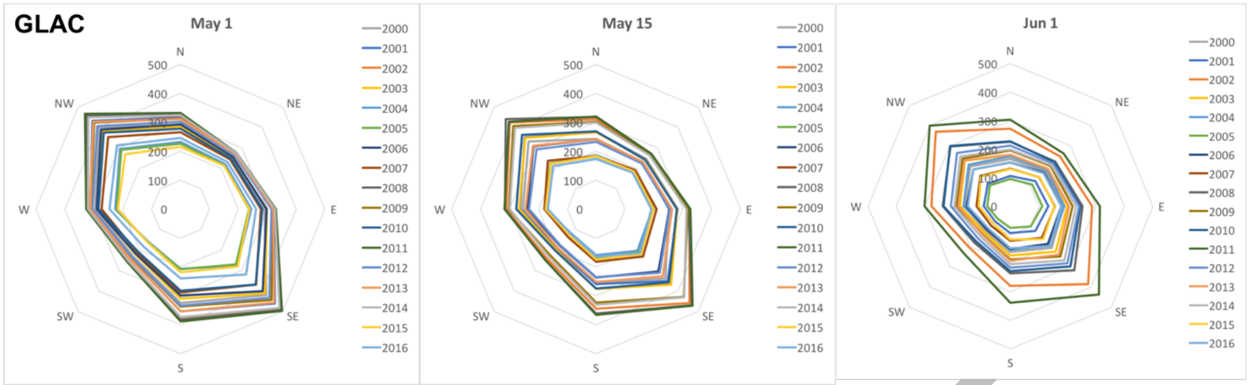

Figure 4-5: Total snow covered area (km^2) as a function of aspect for May 1, May 15, and June 1 for the GLAC study area. Data for each year is shown by a separate line. Aspect of the slope is determined from a digital elevation model and is binned into eight octants according to the compass direction. The shape of the curves is strongly determined by the total land area in each aspect bin. Concentric octagons (gray) denote the magnitude scale ranging from 0 to 500 km^2.

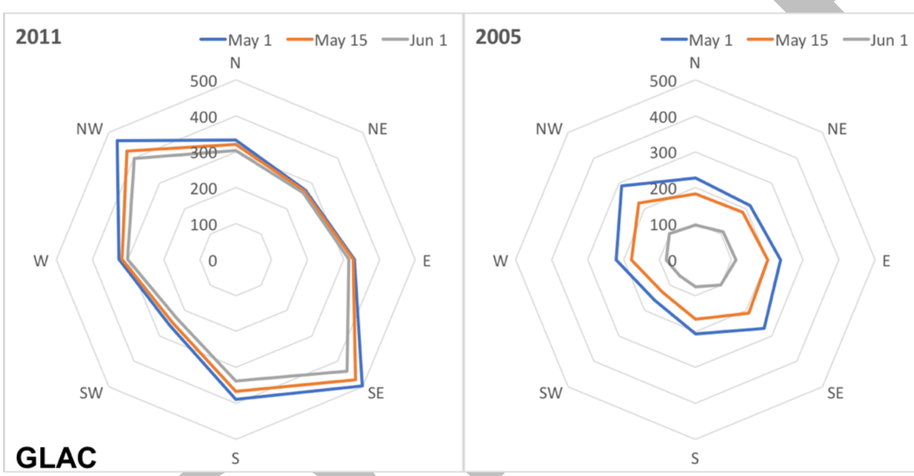

Figure 4-6: Total snow covered area (km^2) as a function of aspect for representative Wet (2011) and Dry (2005) years for the GLAC study area. For each year, the snowcovered area is shown for May 1 (blue), May 15 (red), and June 1 (thick gray) Concentric octagons (thin gray) denote the magnitude scale ranging from 0 to 500 km^2.

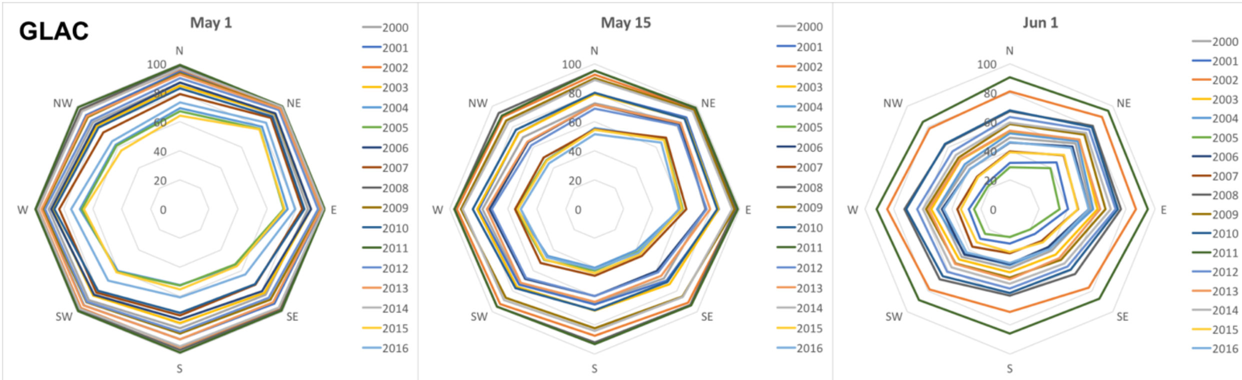

Figure 4-7: Snow covered area fraction (%) as a function of aspect for May 1, May 15, and June 1 for the GLAC study area. Each year is shown by a separate line. The total snow covered area has been expressed as a percentage of the total land area in each aspect bin. Aspect of the slope is determined from a digital elevation model and is binned into eight octants according to the compass direction. Concentric octagons (gray) denote the magnitude scale ranging from 0 to 100%.

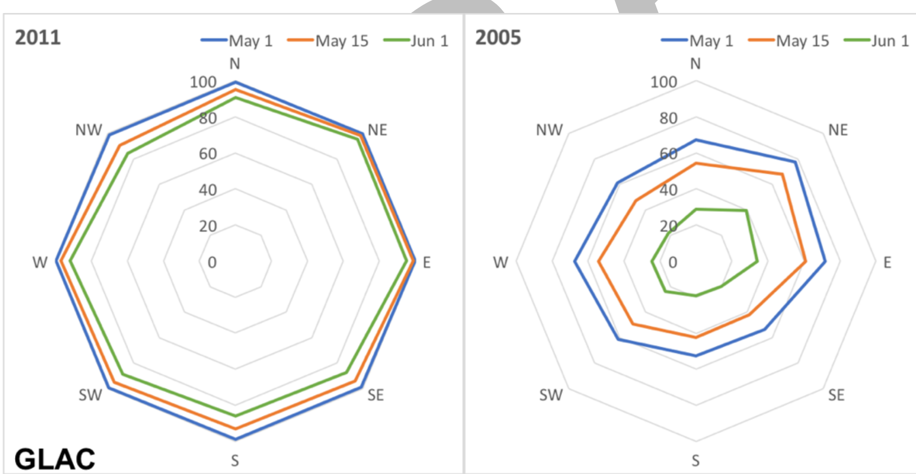

Figure 4-8: Snow covered area fraction (%) as a function of aspect for representative wet (2011) and dry (2005) years in the GLAC study area. May 1 (blue), May 15 (red), and June 1 (green) are shown for each year. The total snow covered area has been expressed as a percentage of the total land area in each aspect octant. Concentric octagons (gray) denote the magnitude scale ranging from 0 to 100%.

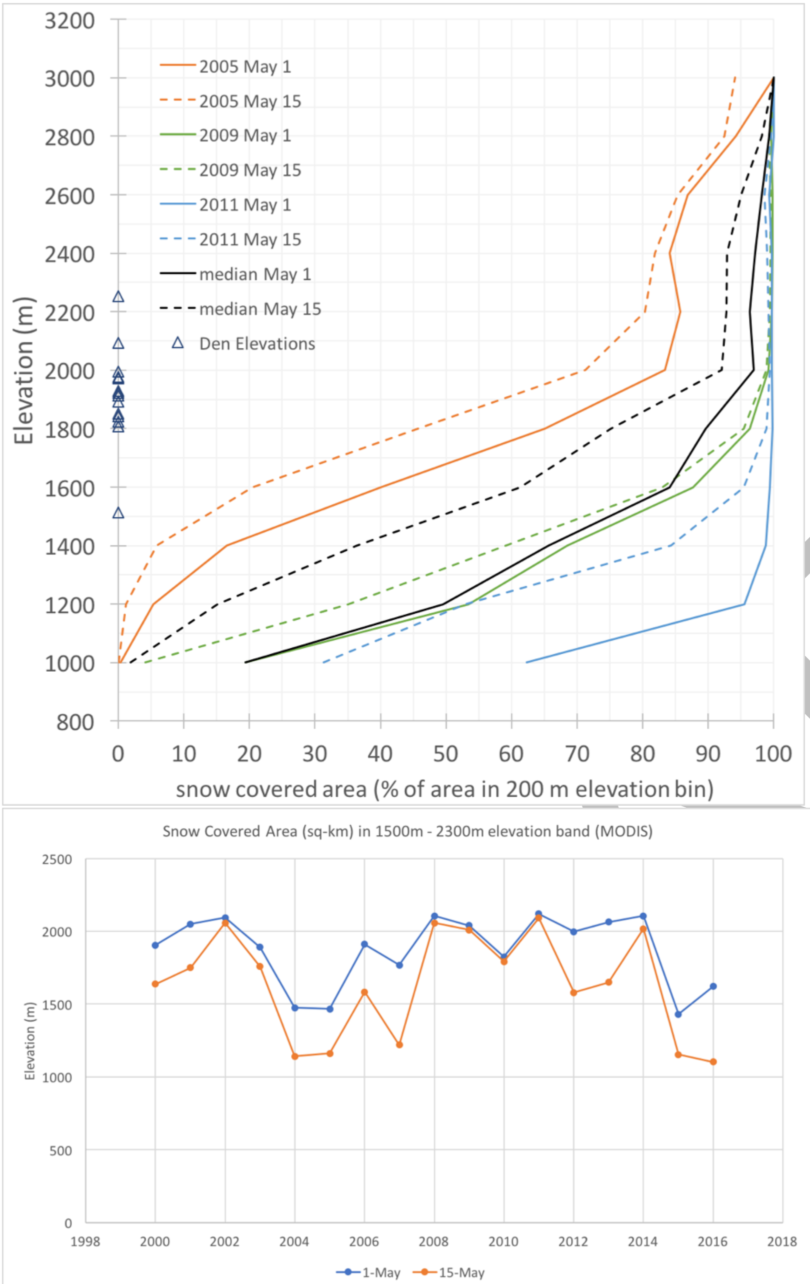

Figure 4-9: Analysis of Snow Cover versus elevation in the GLAC study area. Upper Panel: Snow covered area fraction as a function of elevation for the GLAC study area for representative wet (2011; blue lines), near normal (2009; green lines), and dry years (2005; red lines). MODIS pixels were classified into 200-meter elevation bands. Snow covered area is shown as the percentage of area within each elevation band with snow cover on May 1 and May 15. The median snowcover fraction for the given dates for the period 2000-2017 is shown in thick black lines. Elevations of wolverine dens in or near the study area are denoted by triangles. Lower Panel: Total snow covered area (km^2) in the 1500m and 2300 m elevation band that encompasses den elevations on May 1 (blue), May 15 (red) by year from MODIS

within the GLAC study area polygon. Snow cover is defined as NDSI > 0.1, and includes fractional snow cover (see text).

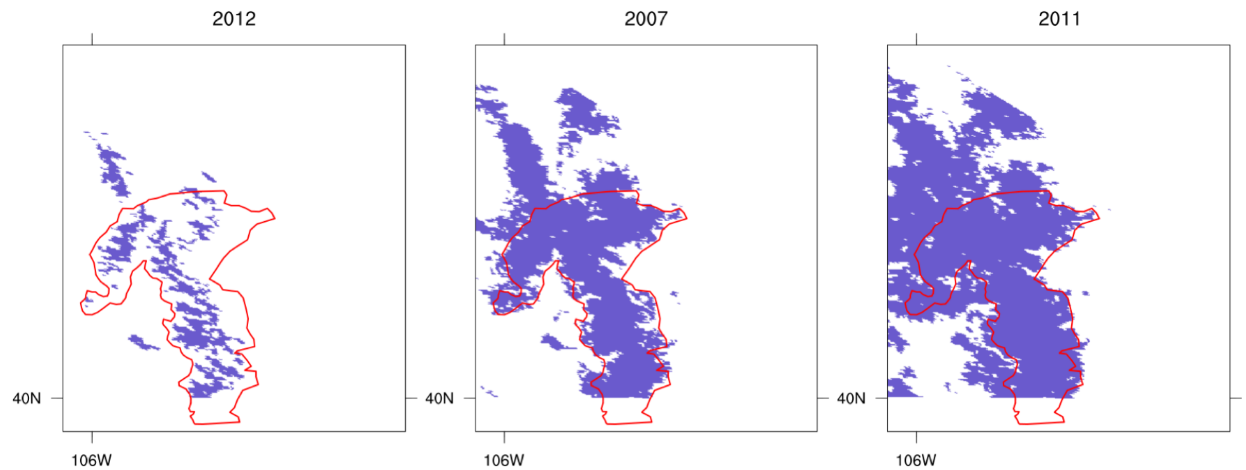

Figure 4-10: May 15 snow cover from MODIS for the GLAC study area (red outline) and vicinity. Represetative Dry (2012, left), Near Normal year (2007, right), and Wet years (right, 2011). Snow cover is defined as NDSI > 0.1, and includes fractional snow cover. The data were taken from a single MODIS tile which does not include the southernmost tip of the study area.

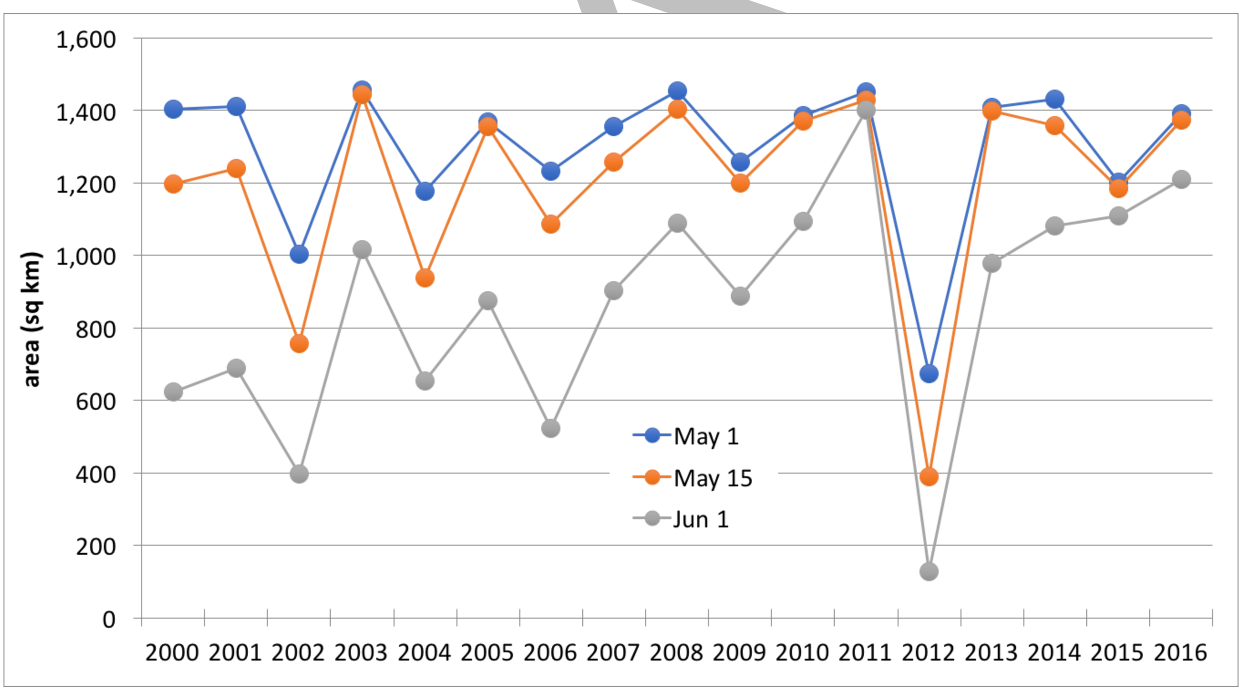

Figure 4-11: Total snow covered area (km^2) on May 1 (blue), May 15 (red), and June 1 (gray) by year from MODIS within the ROMO study area polygon. Snow cover is defined as NDSI > 0.1, and includes fractional snow cover (see text).

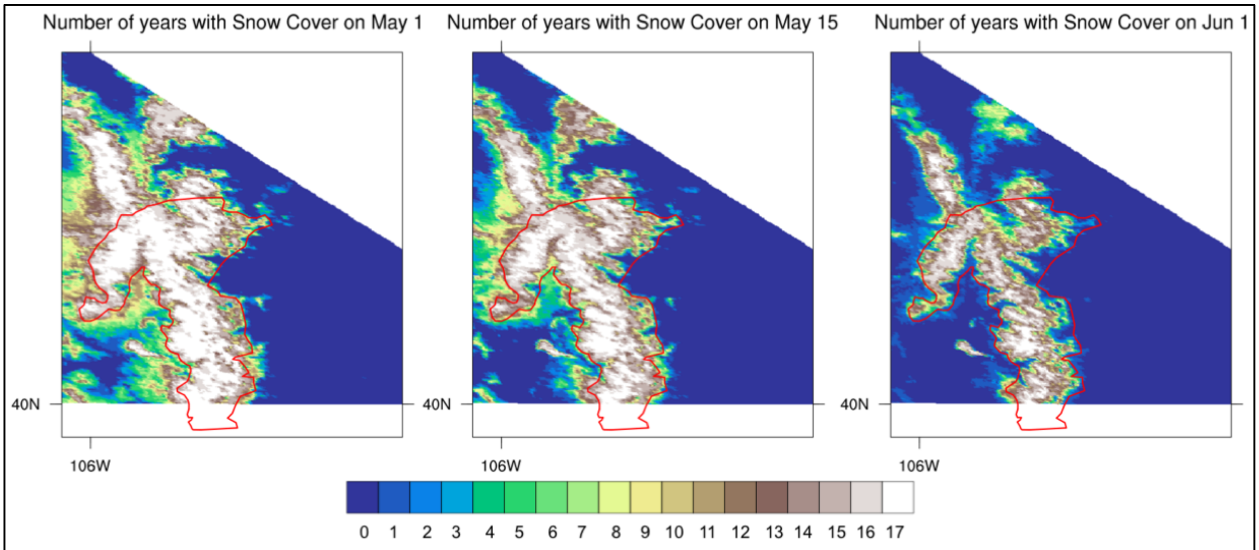

Figure 4-12: Number of Years (out of 2000-2016, 17 years total) with snow cover on May 1, May 15, and June 1 from MODIS for the ROMO study area (red outline) and vicinity. Snow cover is defined as NDSI > 0.1, and includes fractional snow cover. The data were taken from a single MODIS tile which does not include the southernmost tip of the study area.

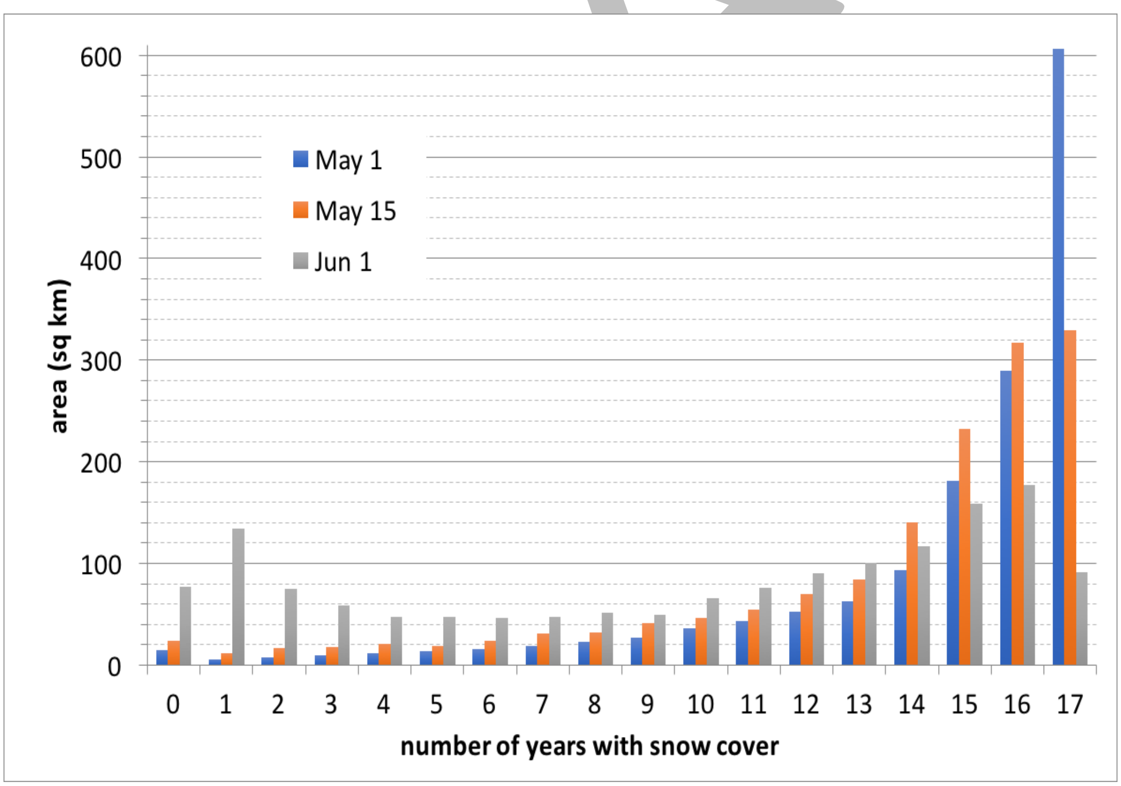

Figure 4-13: Area within the ROMO study area polygon classified according to the number of years with snow cover (out of 17 total, 2000-2016) on May 1, May 15, and June 1 from MODIS.

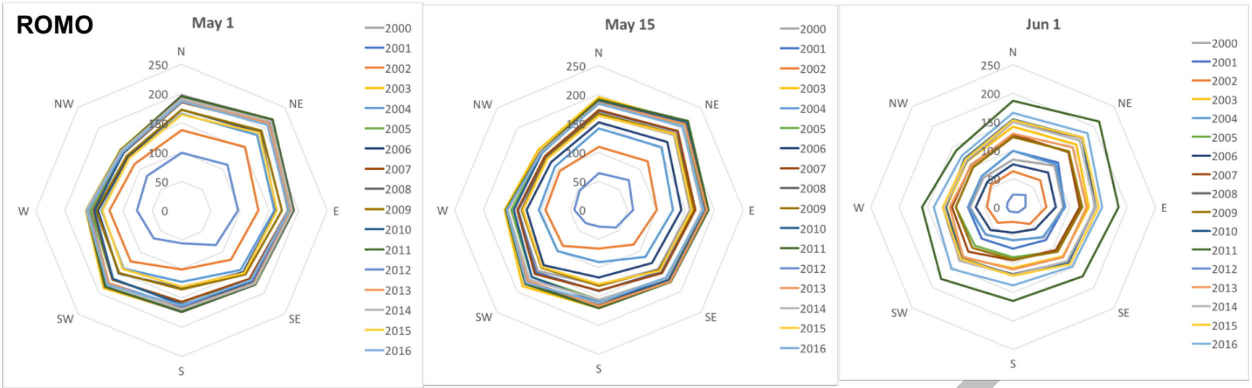

Figure 4-14: Total snow covered area (km^2) as a function of aspect for May 1, May 15, and June 1 for the ROMO study area. Data for each year is shown by a separate line. Aspect of the slope is determined from a digital elevation model and is binned into eight octants according to the compass direction. The shape of the curves is strongly determined by the total land area in each aspect bin. Concentric octagons (gray) denote the magnitude scale ranging from 0 to 500 km^2.

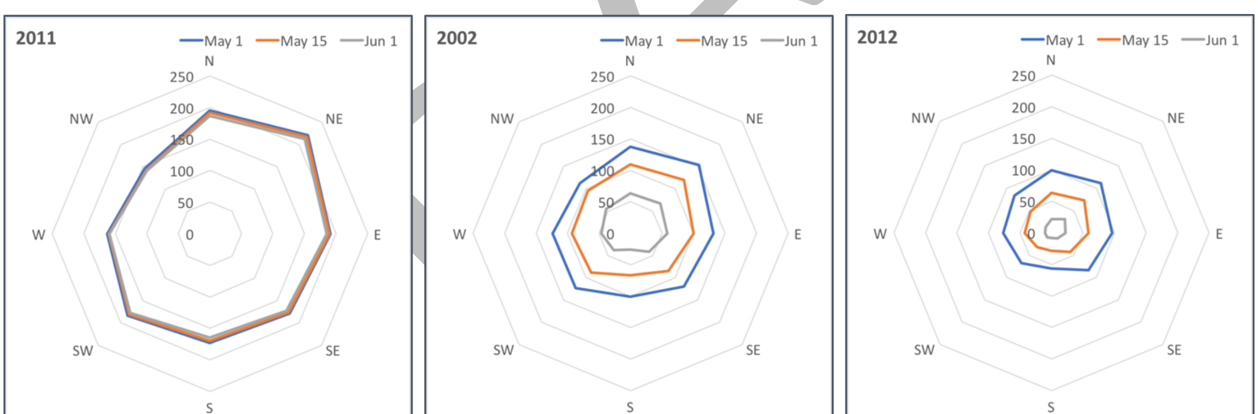

Figure 4-15: Total snow covered area (km^2) as a function of aspect for “wet” (2011) and “dry” (2002) representative years for the ROMO study area. For each year the snow covered area is shown for May 1 (blue), May 15 (red) , and June 1 (thick gray) Concentric octagons (thin gray) denote the magnitude scale ranging from 0 to 500 km^2. Note that while 2012 had the least snow cover in late Spring, 2002 was adopted as a representative dry year due to modeling considerations in Section 5. We show both dry years here which exhibit similar features.

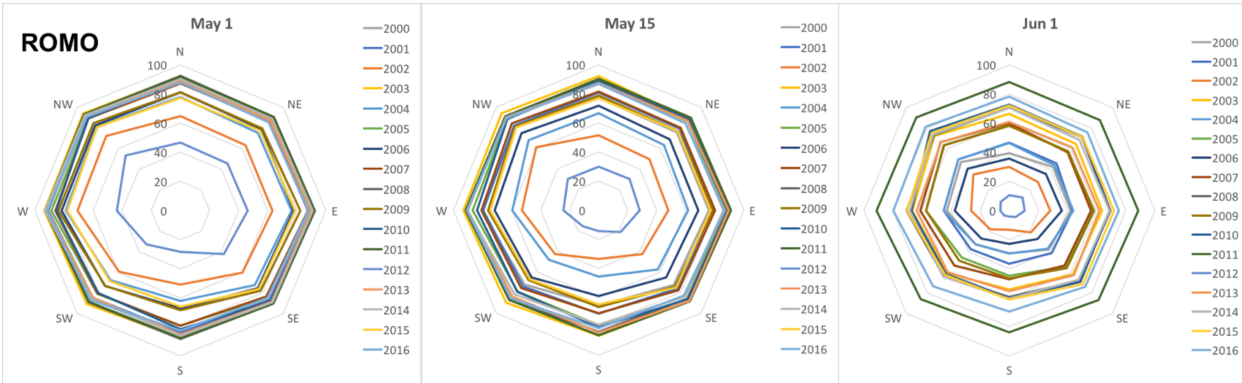

Figure 4-16: Snow covered area fraction (%) as a function of aspect for May 1, May 15, and June 1 for the ROMO study area. Each year is shown by a separate line. The total snow covered area has been expressed as a percentage of the total land area in each aspect bin. Aspect of the slope is determined from a digital elevation model and is binned into eight octants according to the compass direction. Concentric octagons (gray) denote the magnitude scale ranging from 0 to 100%.

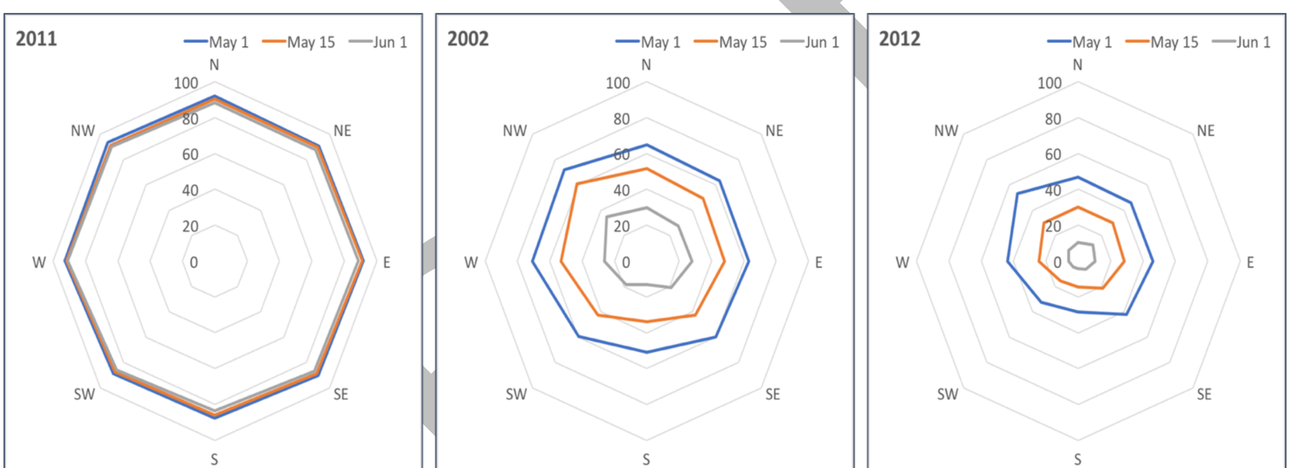

Figure 4-17: Snow covered area fraction (%) as a function of aspect for 2011 (“wet”) and 2002 (‘dry”) representative years in the ROMO study area. May 1 (blue), May 15 (red), and June 1 (green) are shown for each year. The total snow covered area has been normalized by the total land area in each aspect octant. Concentric octagons (gray) denote the magnitude scale ranging from 0 to 100%. Note that while 2012 had the least snow cover in late Spring, 2002 was adopted as a representative dry year due to modeling considerations in Section 5. We show both dry years here which exhibit similar dependence of fractional snow cover on aspect.

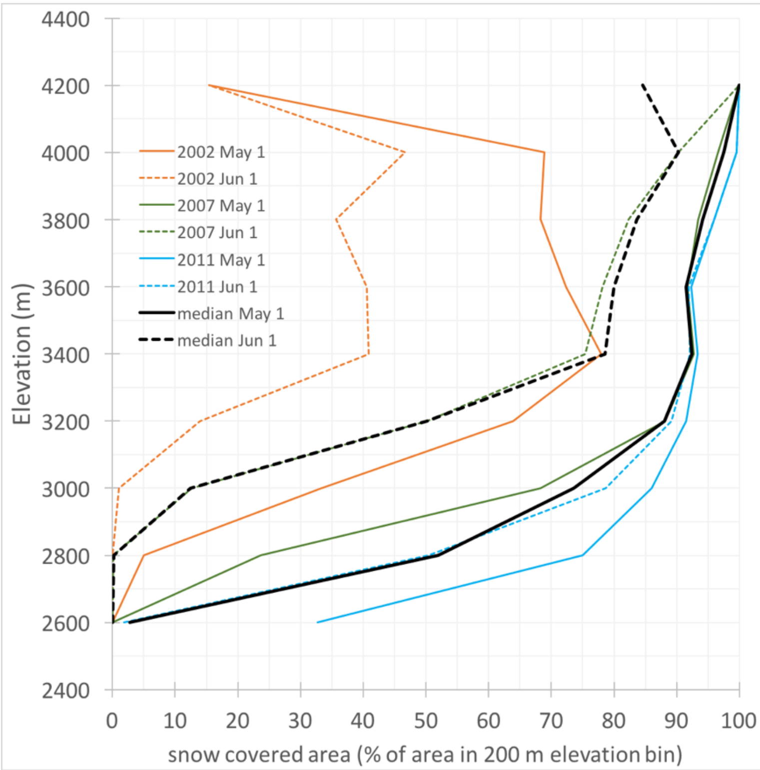

Figure 4-18: Snow covered area fraction as a function of elevation for the ROMO study area for representative wet (2011; blue lines), near normal (2007; green lines), and dry years (2002; red lines). MODIS pixels were classified into 200-meter elevation bands. Snow covered area is shown as the percentage of area within each elevation band with snow cover on May 1 and June 1. The median snow cover fraction for the given dates for the period 2000-2017 is shown in thick black lines. 2002 only is shown because it was ultimately used as a representative year in the scenarios analysis, not 2012. Note that 2012 also shows a decrease in snow covered area at the highest elevations.

Chapter 5 Figures: Future Snowpack Projections: DHSVM Modeling

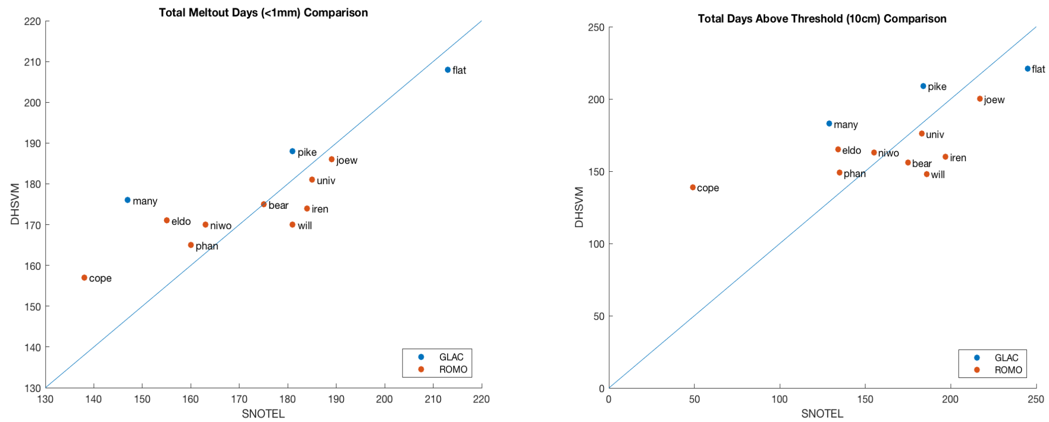

Figure 5-1: Validation of DHSVM Historical Simulation at SNOTEL sites in ROMO and GLAC. a) left panel: Simulated and observed meltout date (numerical day of year) defined as the first day in Spring when Snow Water Equivalent was less than 1mm. b) right panel: Simulated and observed snowpack duration defined as number of days with greater than 10cm of SWE. SNOTEL station abbreviation codes are provided in Table 5-1.

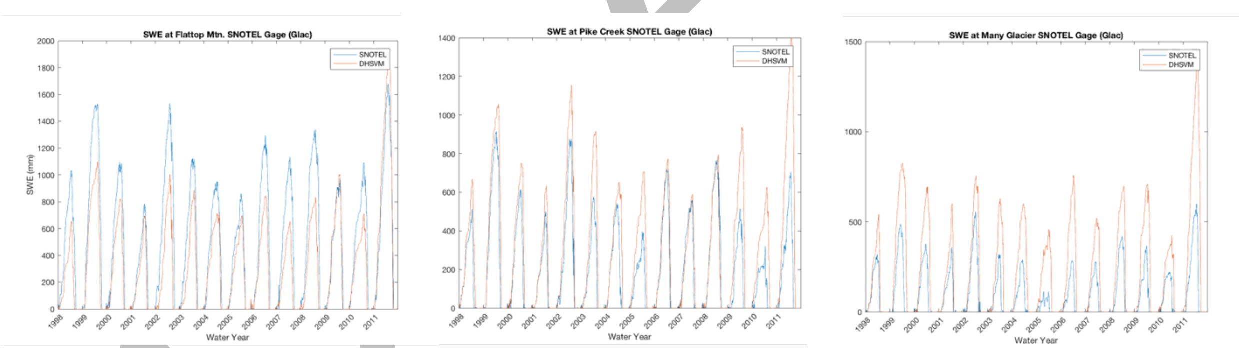

Figure 5-2 **Time series comparing observed (blue) and modeled (red) Snow Water Equivalent (mm) for the Glacier Study Area (GLAC) study area.** Flattop Mountain (left), Pike Creek (center), and Many Glacier (right) SNOTEL stations.

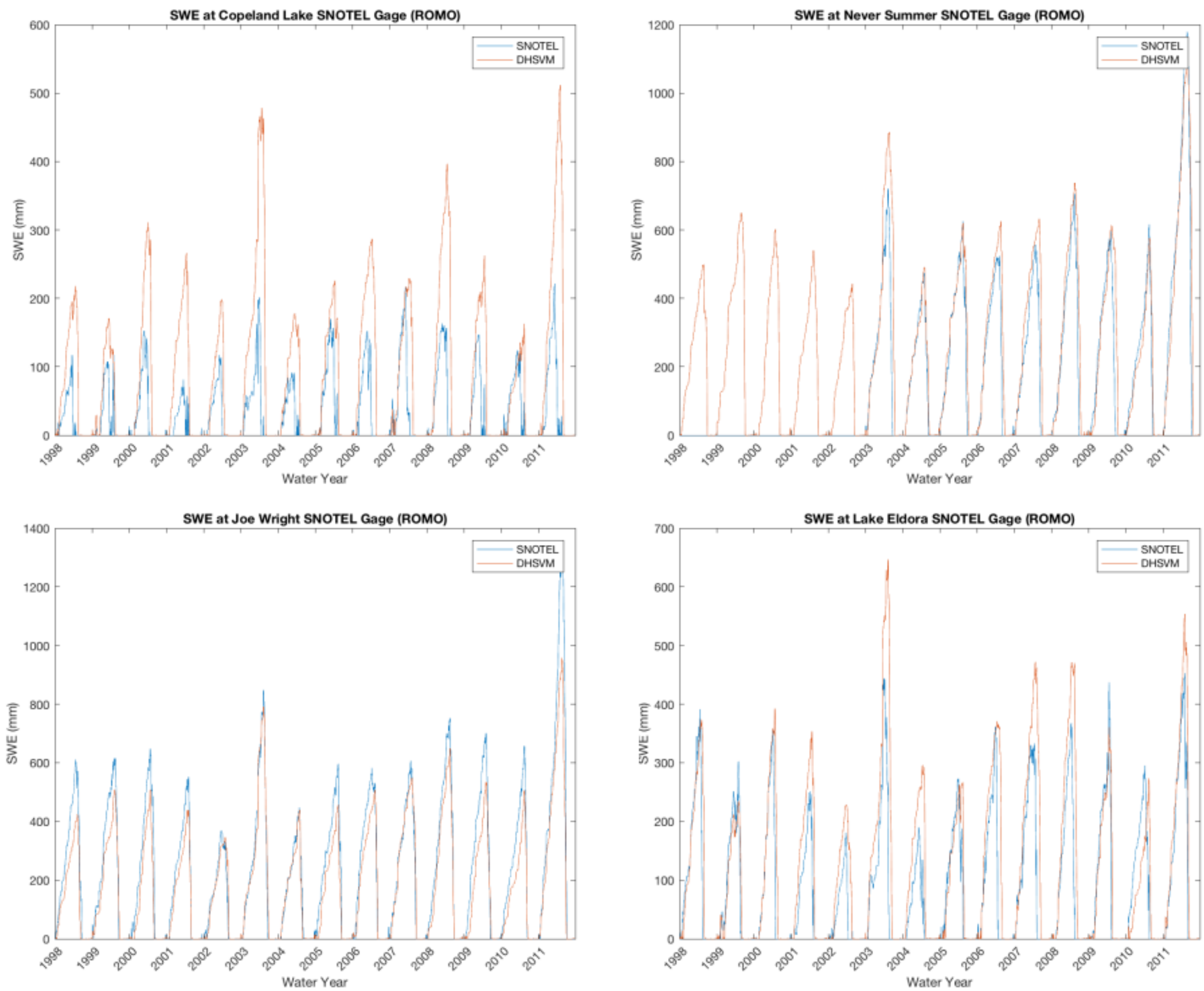

Figure 5-3. Timeseries comparing observed (blue) and modeled (red) Snow Water Equivalent (mm) for the Rocky Mountain National Park (ROMO) study area. Copeland Lake (upper left), Never Summer (upper right), Joe Wright (lower left), and Lake Eldora (lower right) SNOTEL stations.

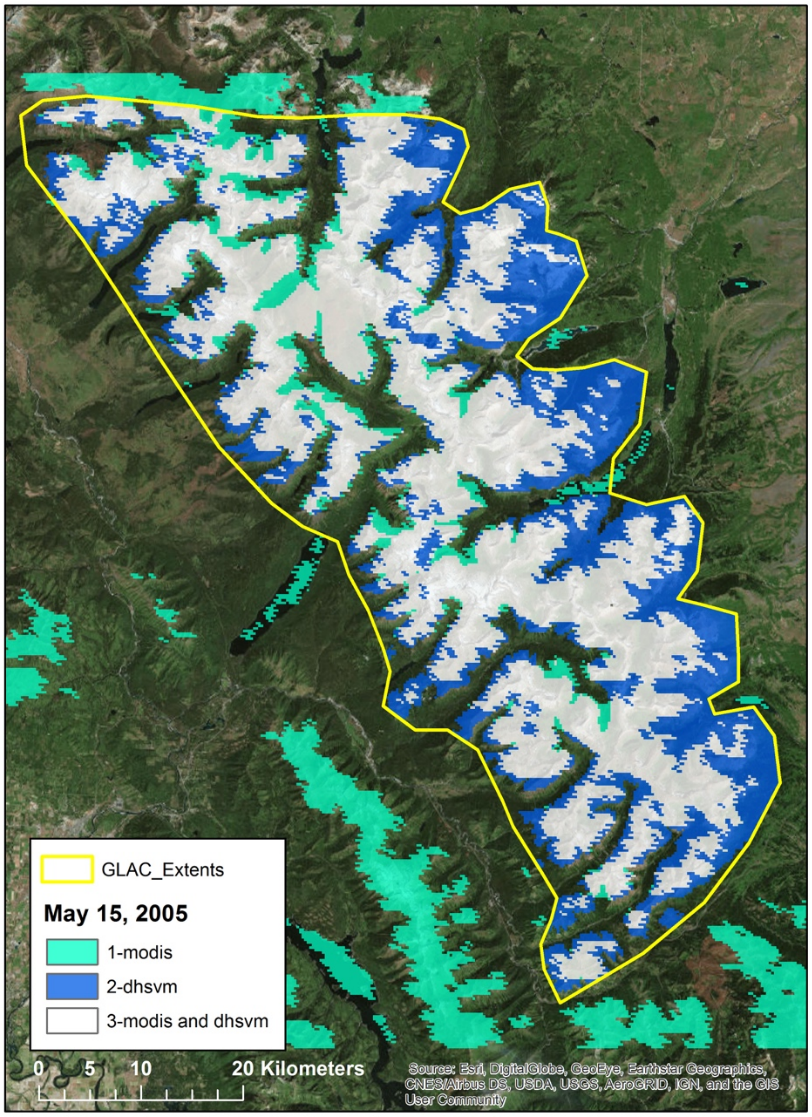

Figure 5-4. MODIS snow cover with DHSVM snow cover for May 15, 2005 for the GLAC study area (yellow outline). Spatial overlay of shows areas of agreement between DHSVM and MODIS snow cover (white), areas where only MODIS indicated snow cover (green), and areas where only DHSVM model indicated snow cover (blue). Graphic courtesy of John Guinotte, FWS.

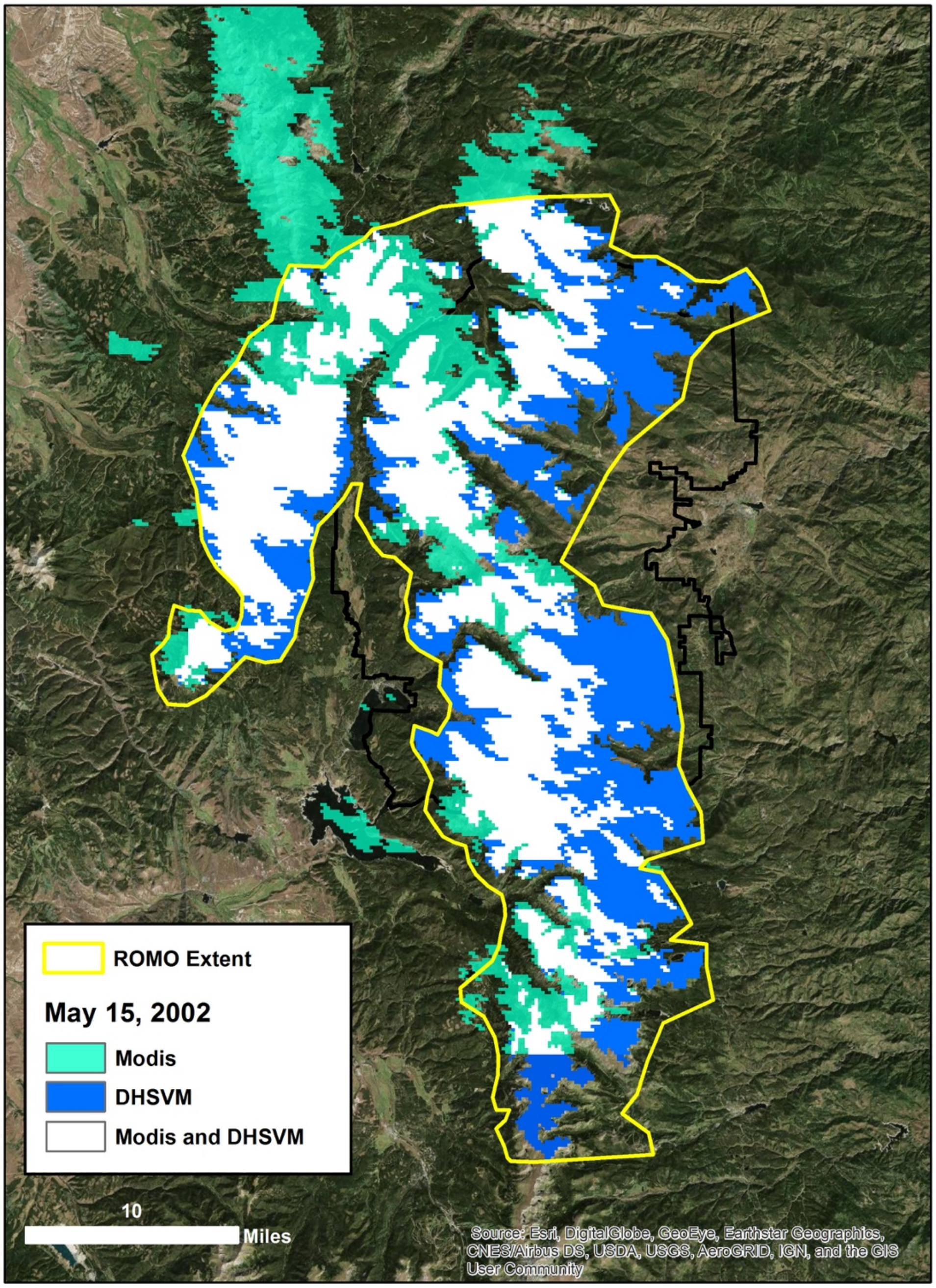

Figure 5-5. MODIS snow cover compared with DHSVM snow cover for May 15, 2002 for the ROMO study area (yellow outline). Spatial overlay of shows areas of agreement between DHSVM and MODIS snow cover (white), areas where only MODIS indicated snow cover (green), and areas where only DHSVM model indicated snow cover (blue). Graphic courtesy of John Guinotte, FWS.

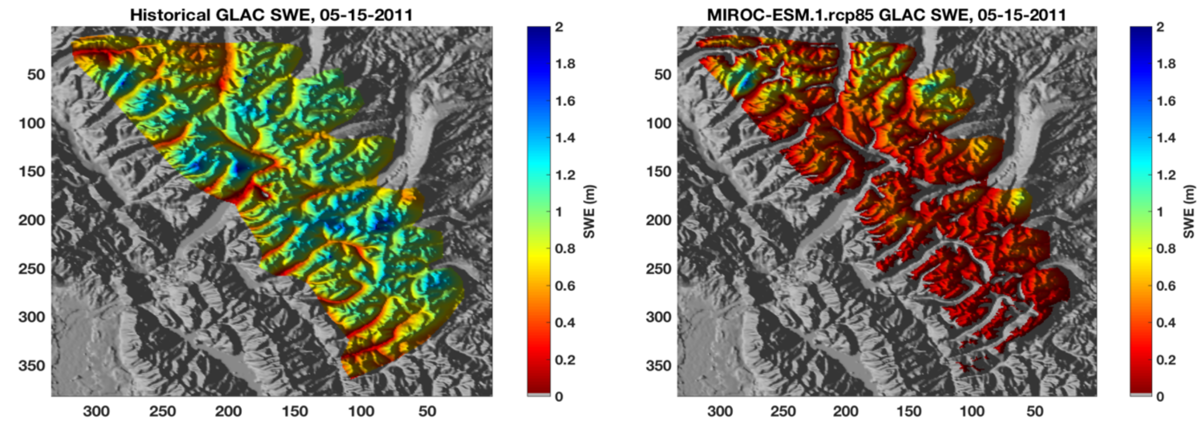

Figure 5-6: Example model output: May 15 SWE from a) left: historical simulation for 2011 and b) right, for the Hot/Wet future scenario (#3, miroc) applied for the period 2041-2070 derived from the MIROC climate model projections. The future scenario represents a year similar to 2011, that is, a relatively wet and cool year, but the temperature and precipitation adjusted to be consistent with the 2014-2070 projected climate from the MIROC climate model. Numbering on the axes indicates the regular grid of 250m x 250m gridcells on a Universal Transverse Mercator map projection – these grid numbers are not shown in subsequent figures. Simulation with the DHSVM model was only performed within the study area polygon.

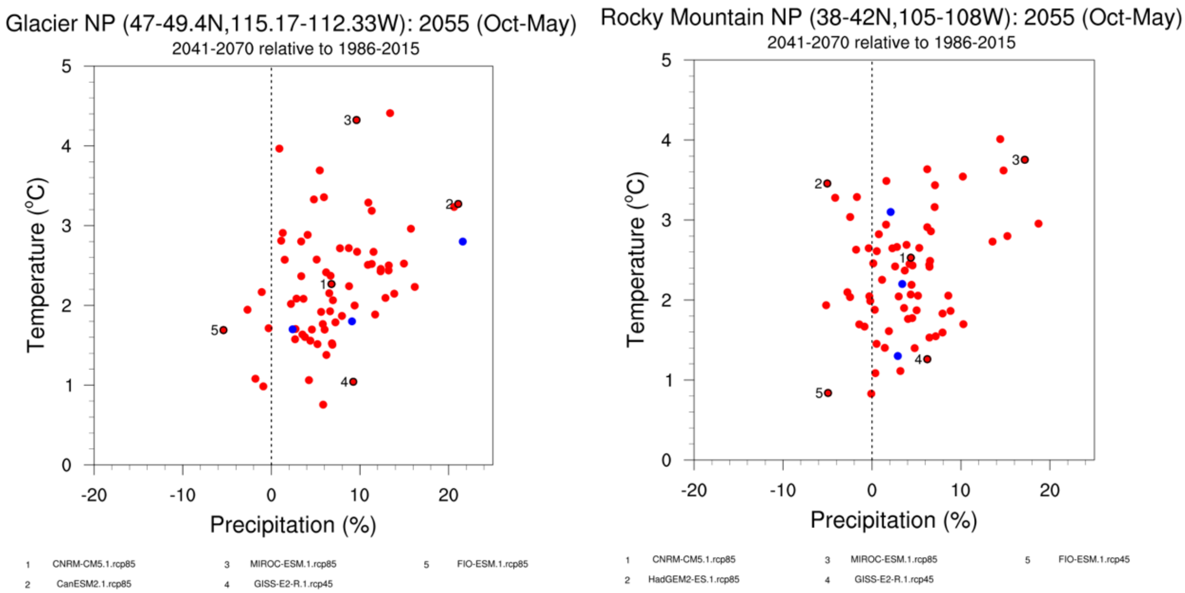

Fig 5-7: Projected Changes in Cold Season (October-May) Temperature and Precipitation by 2055. Left: GLAC Study Area, Right: ROMO study area. Filled red circles show changes in temperature and precipitation for a nominal 2055 climate, i.e. 2041-2070 period relative to 1986-2015, from 68 global climate model experiments --- 34 models each from RCP 4.5 and 8.5 emissions scenarios. Projections highlighted by the black circles are the five divergent climate scenarios selected for this region. Four of the same GCMs are used as future scenarios for both areas (#1, and 3-5); different GCMs are used for #2 in order to represent a range of futures. The models and futures are shown in Table 5-3. The filled blue circles show the three scenarios considered in the McKelvey et al. study for the 2030-2059 period.

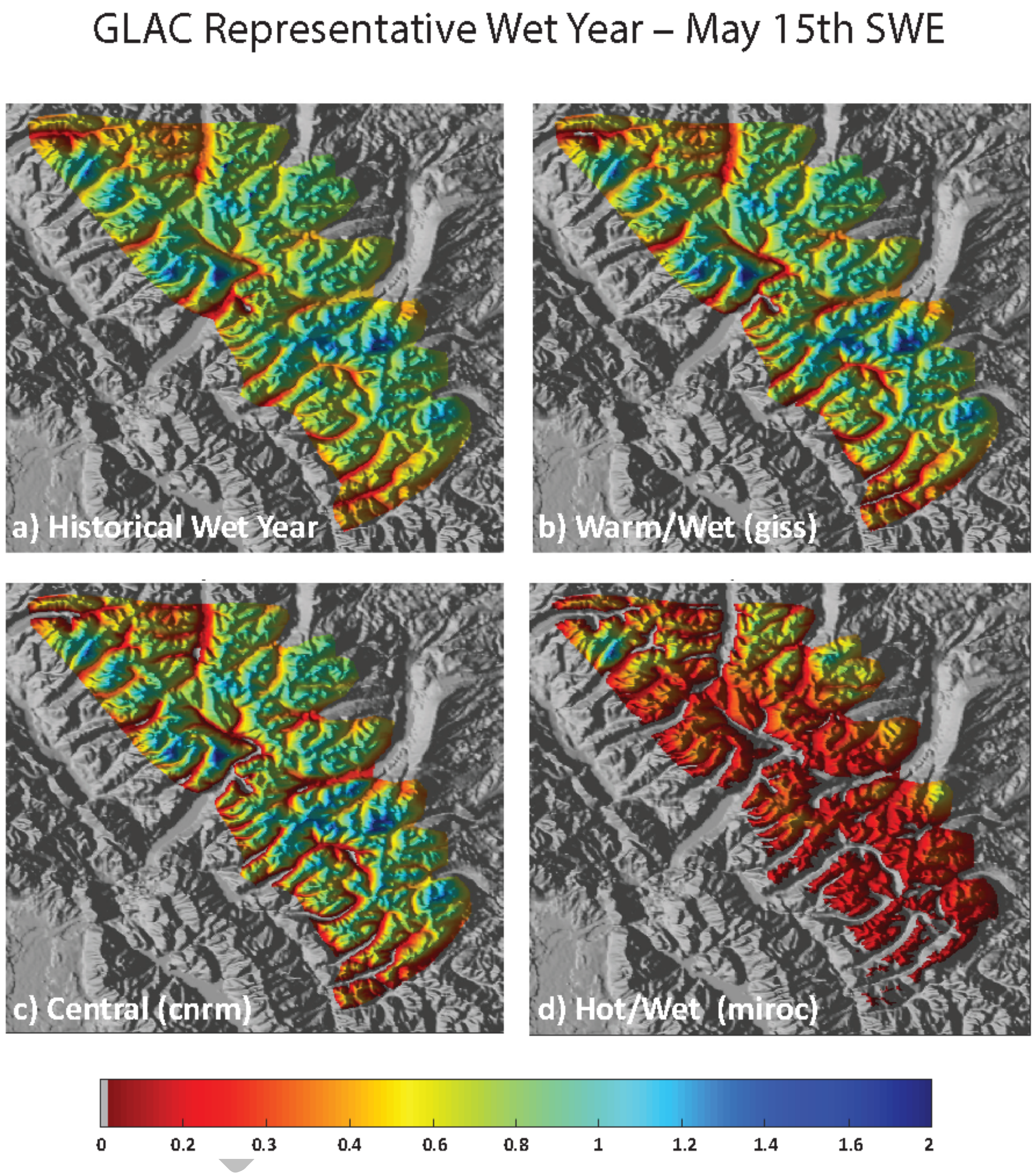

Figure 5-8: Historical and projected May 15th Snow Water Equivalent (meters) for a Representative Wet Year in GLAC. Historical simulation year 2011 (wet year, top left), and for three future scenarios applied to 2011: b) the warm/wet (giss) scenario results in the lowest change in SWE (top right), c) the central scenario (cnrm) results in a moderate change in SWE (bottom left), and the, d) hot/wet scenario (miroc) results in the greatest change in SWE (bottom right). Scenarios are listed in Table 5-3 and shown in Figure 5-7, maps for additional scenarios are provided in the Supplementary Material.

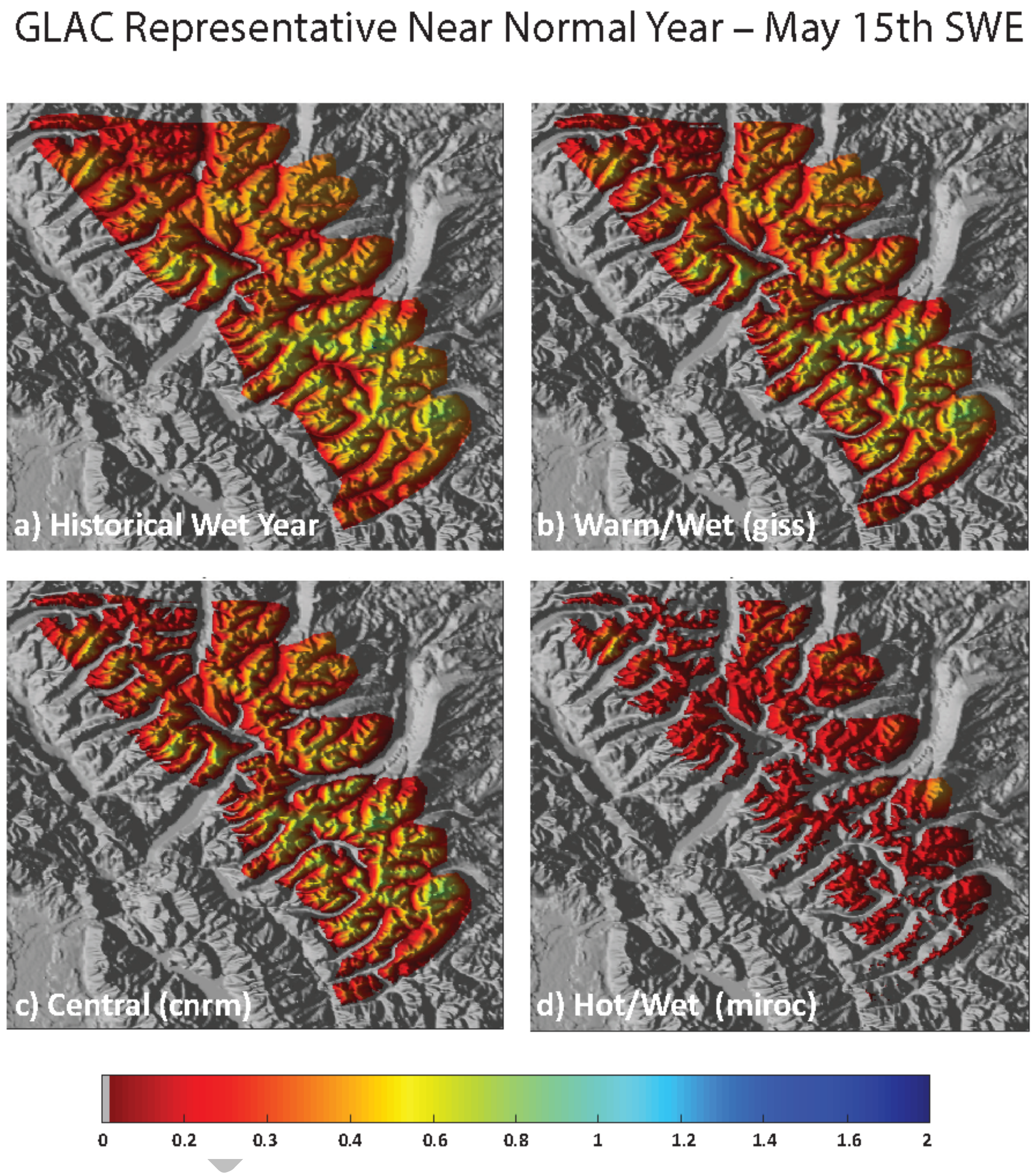

Figure 5-9: Historical and projected May 15th Snow Water Equivalent (meters) for a Representative Near Normal Year in GLAC. Historical simulation year 2009 (near normal year, top left), and for three future scenarios applied to 2009: b) the warm/wet (giss) scenario results in the least change in SWE (top right), c) the central scenario (cnrm) results in a moderate change in SWE (bottom left), and, d) the hot/wet model results in the greatest change in SWE (bottom right). Scenarios are listed in Table 5-3 and shown in Figure 5-7, maps for additional scenarios are provided in the Supplementary Material.

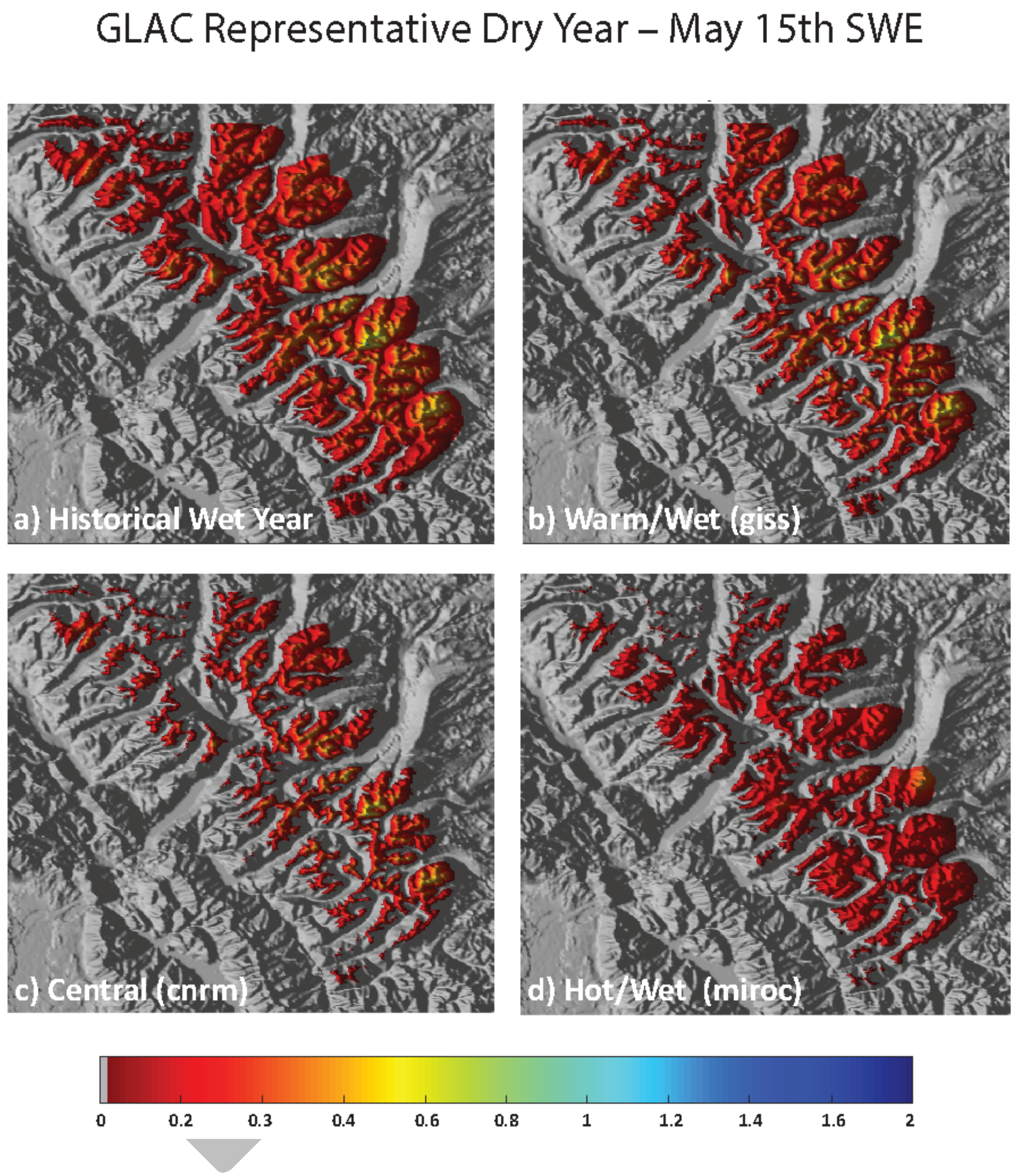

Figure 5-10: Historical and projected May 15th Snow Water Equivalent (meters) for a Representative Dry Year in GLAC. Historical simulation year 2005 (dry year, top left), and for three future scenarios applied to 2005: b) the warm/wet (giss) scenario results in the least change in SWE (top right), c) the central scenario (cnrm) results in a moderate change in SWE (bottom left), and, d) the hot/wet model results in the greatest change in SWE (bottom right). Scenarios are listed in Table 5-3 and shown in Figure 5-7, maps for additional scenarios are provided in the Supplementary Material.

I

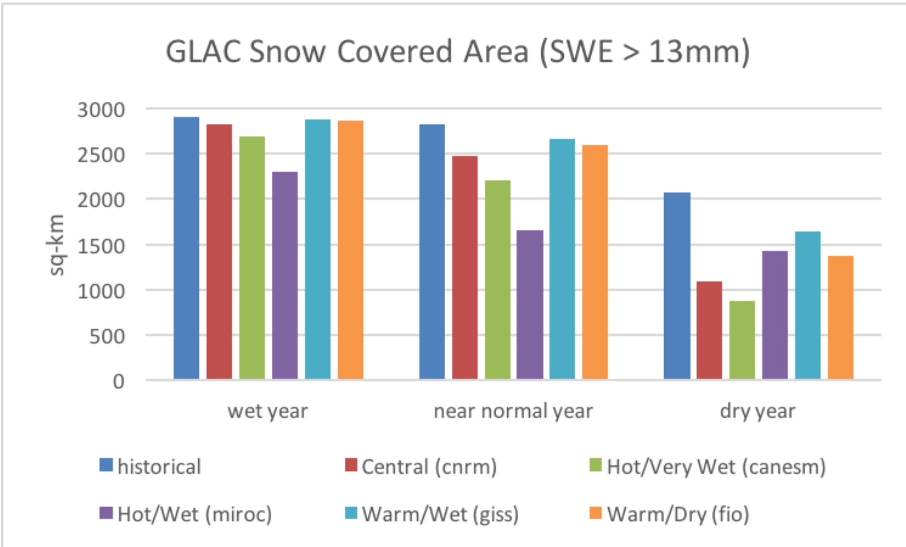

Figure 5-11: Snow Covered Area (km^2, 13mm SWE "light snow" threshold) for Dry, Near Normal, and Wet Case Study Years for GLAC. Historical and five future scenarios. May 1 (top), May 15 (middle), June 1 (bottom). Historical (blue), Central (red), Hot/Very Wet (green), Hot/Wet (purple), Warm/Wet (aqua), Warm/Dry (orange).

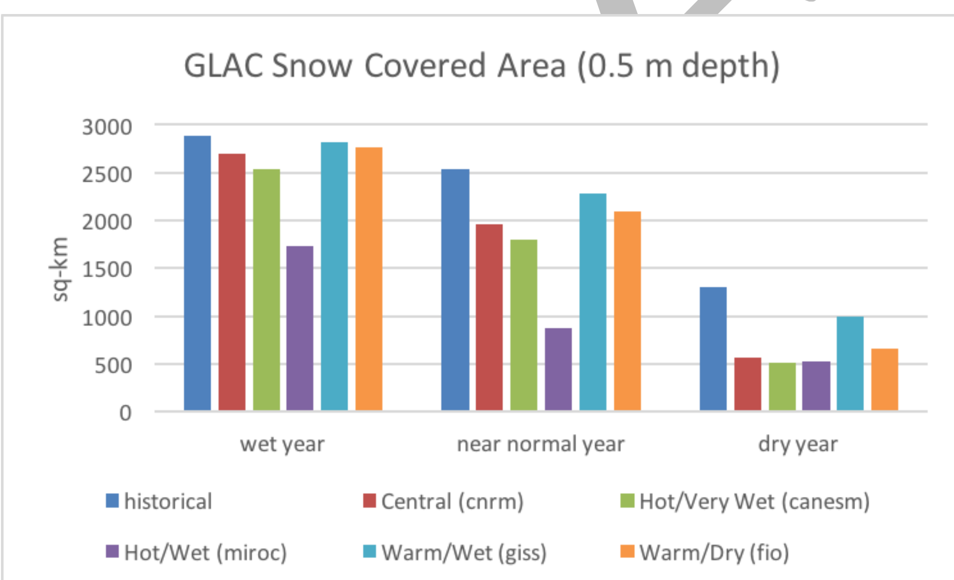

Figure 5-12: Snow Covered Area (km^2, 0.5 meter "significant" snow depth threshold) for Dry, Near Normal, and Wet Case Study Years for GLAC. Historical and five future scenarios. May 1 (top), May 15 (middle), June 1 (bottom). Historical (blue), Central (red), Hot/Very Wet (green), Hot/Wet (purple), Warm/Wet (aqua), Warm/Dry (orange).

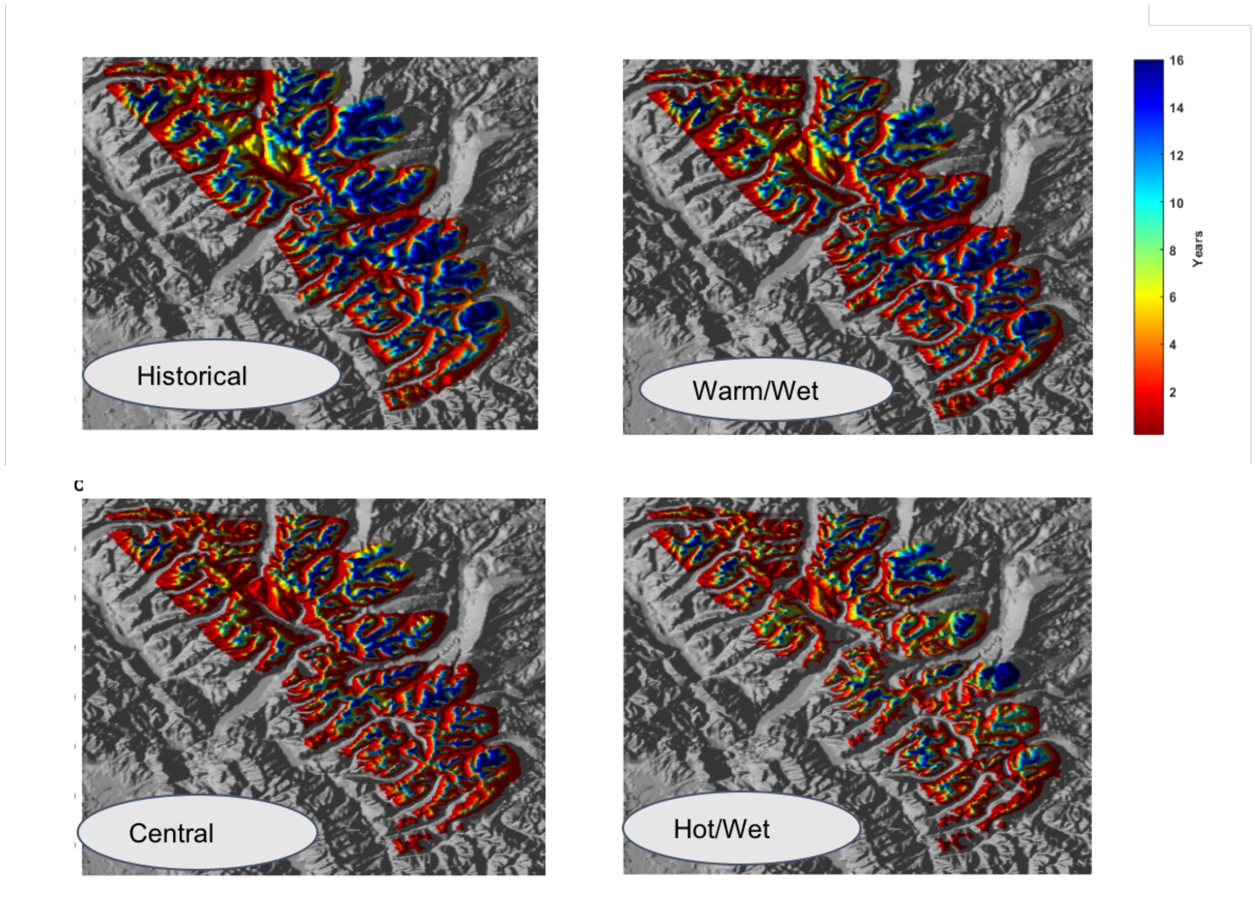

Figure 5-13: Number of years (out of 1998-2013) with Snow Depth > 0.5 m on May 15th. Historical simulation compared to the Warm/Wet (giss), Central(cnrm), and Hot/Wet(miroc) future scenarios. Scenarios are described in Table 5-3.

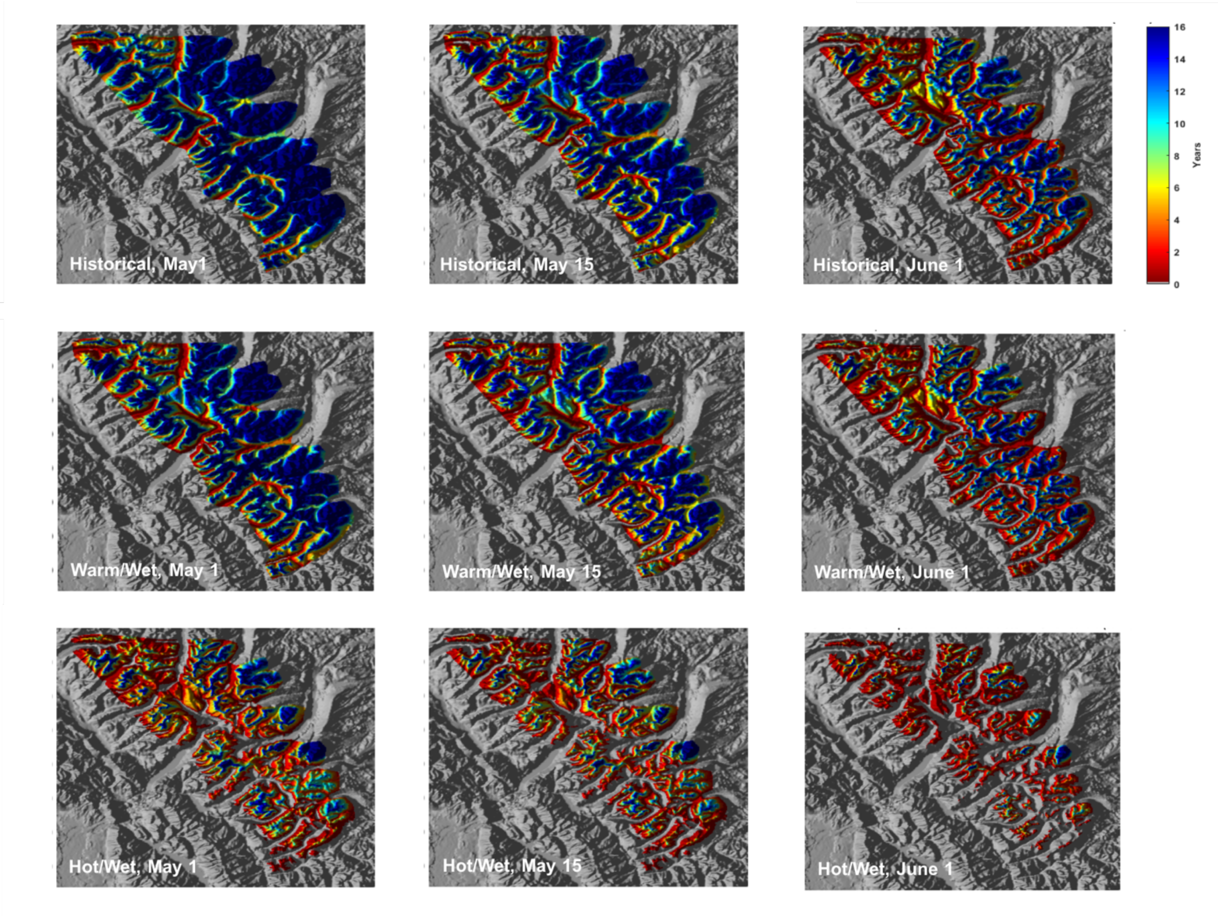

Figure 5-14: Number of years (out of 1998-2013) with Snow Depth > 0.5 m for historic and two future climate scenarios. The “number of years” indicates the yearly availability of deep snow at each model gridcell across all years in the DHSVM simulations, including wet, dry, and near normal years. Top Row: Historical Simulations on May 1st, May 15th and June 1st. Middle Row: Warm/Wet future scenario (GISS model, “Least Change”) at the same dates, Bottom Row: Hot/Wet future scenario (MIROC model, “Greatest Change”) at the same dates. The reduction in the number of years on May 1 for each future scenario can be compared to the historical simulation at a later calendar date, showing a < 2 week shift for the Warm/Wet scenario and a > 1 month shift for the Hot/Wet scenario. Scenarios are listed in Table 5-3.

ROMO Representative Wet Year – May 15th SWE

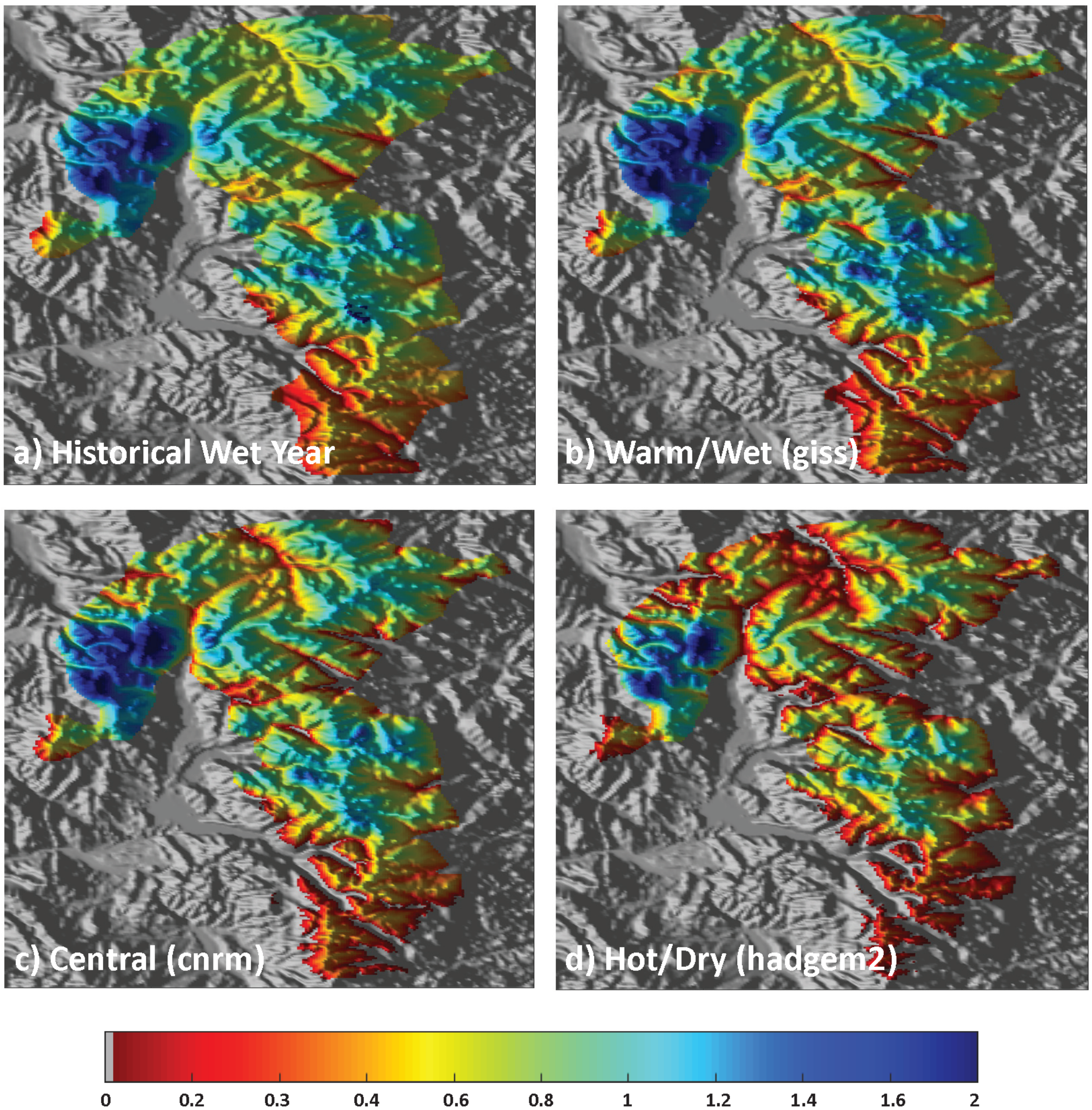

Figure 5-15. Historical and projected May 15th Snow Water Equivalent (meters) for a Representative Wet Year in ROMO. Historical simulation year 2011 (wet year, top left), and for three future scenarios applied to 2011: b) the warm/wet (giss) scenario results in the lowest change in SWE (top right), c) the central scenario (cnrm) results in a moderate change in SWE (bottom left), and, d) the hot/wet model results in the greatest change in SWE (bottom right). Note that while the representative wet year is the same in GLAC and ROMO, the representative near normal and dry years used are different, based on climatology (see section 3-3). Scenarios are listed in Table 5-3 and shown in Figure 5-7, maps for additional scenarios are provided in the Supplementary Material.

ROMO Representative Near Normal Year – May 15th SWE

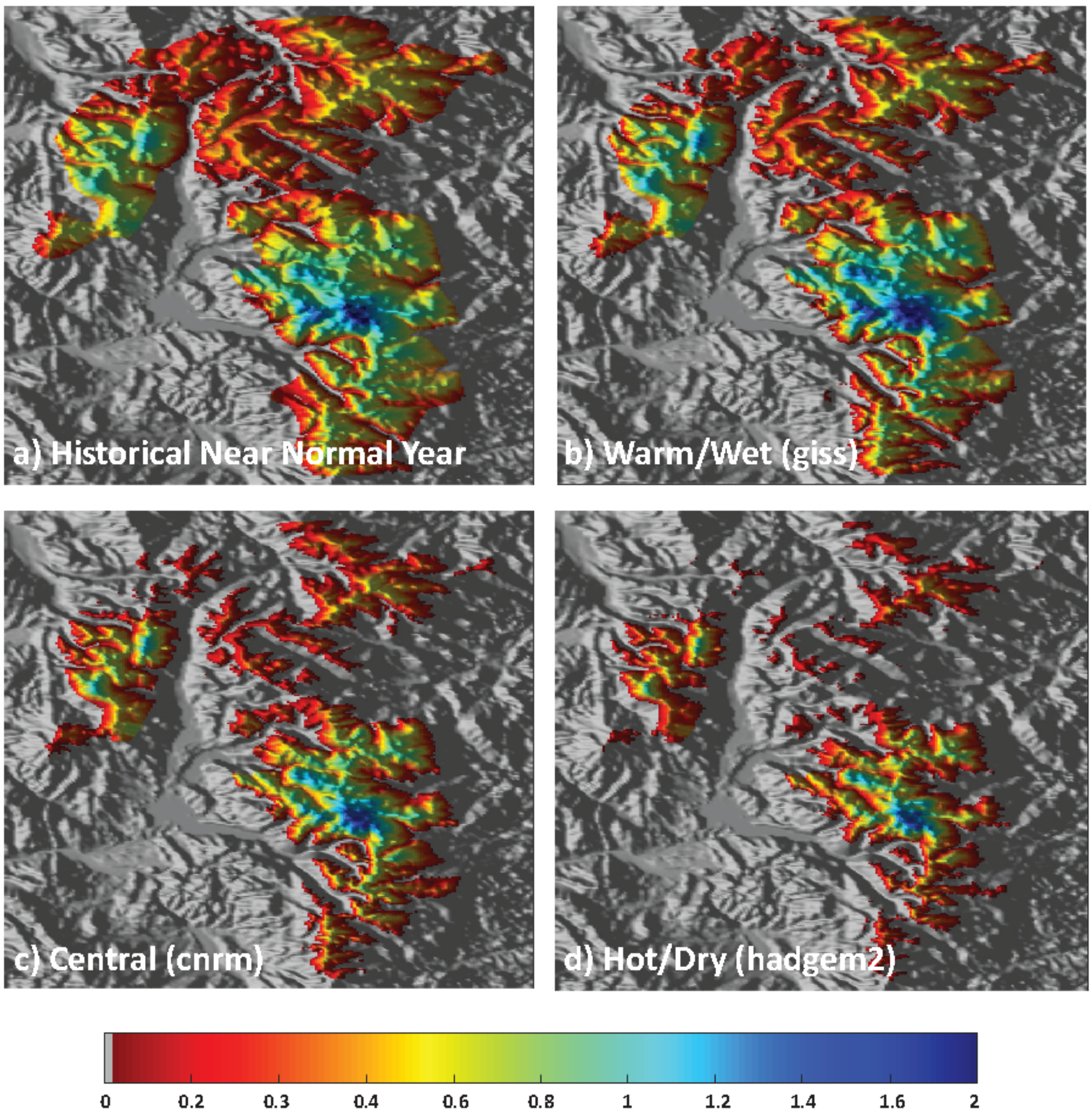

Figure 5-16. Historical and projected May 15th Snow Water Equivalent (meters) for a Representative Near Normal Year in ROMO. Historical simulation year 2007 (near normal year, top left), and for three future scenarios applied to 2007: b) the warm/wet (giss) scenario results in the least change in SWE (top right), c) the central scenario (cnrm) results in a moderate change in SWE (bottom left), and, d) the hot/wet model results in the greatest change in SWE (bottom right). Scenarios are listed in Table 5-3 and shown in Figure 5-7, maps for additional scenarios are provided in the Supplementary Material.

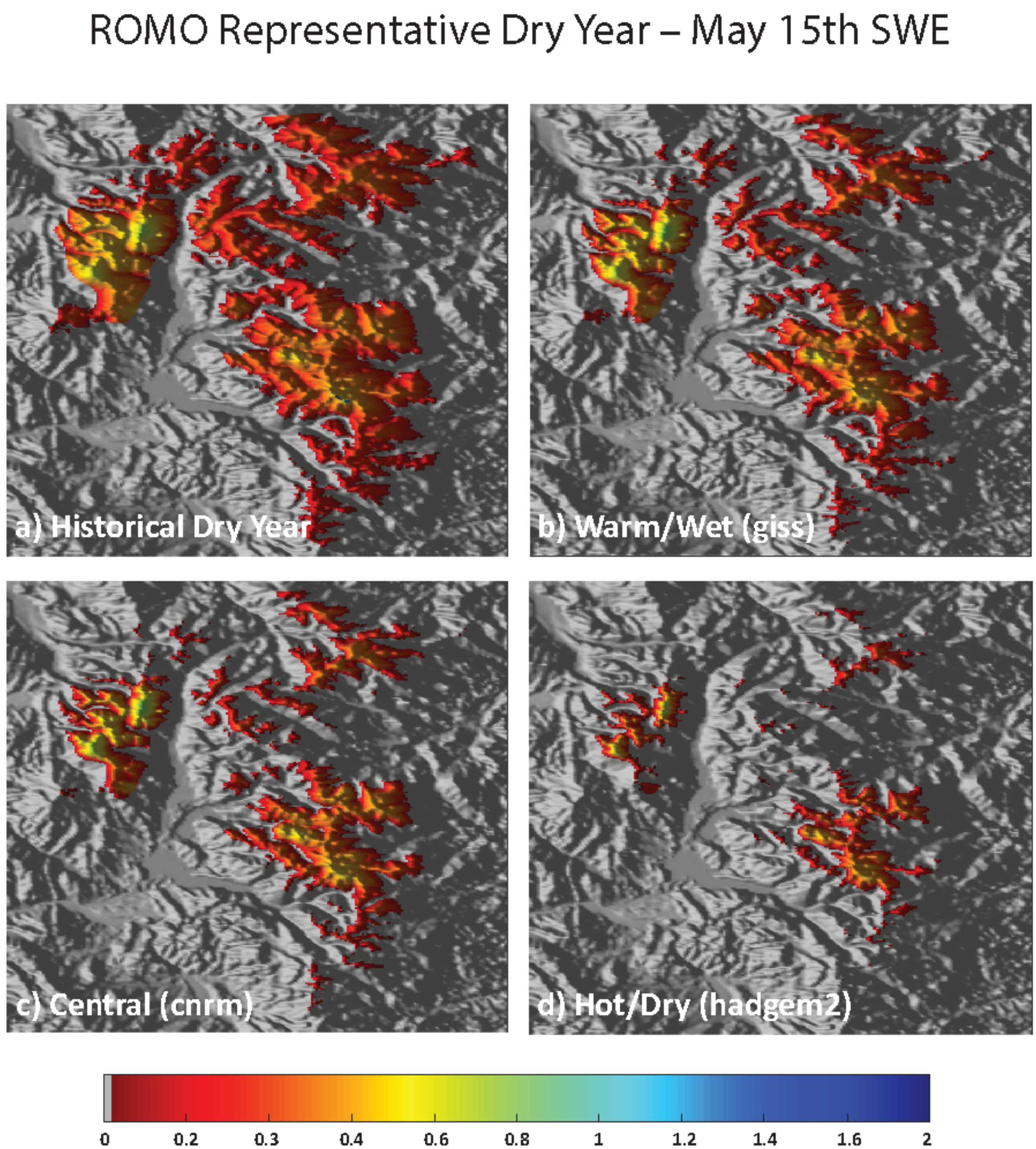

Figure 5-17. Historical and projected May 15th Snow Water Equivalent (meters) for a Representative Dry Year in ROMO. Historical simulation year 2002 (dry year, top left), and for three future scenarios applied to 2002: b) the warm/wet (giss) scenario results in the lowest change in SWE (top right), c) the central scenario (cnrm) results in a moderate change in SWE (bottom left), and, d) the hot/wet model results in the greatest change in SWE (bottom right). Scenarios are listed in Table 5-3 and shown in Figure 5-7, maps for additional scenarios are provided in the Supplementary Material.

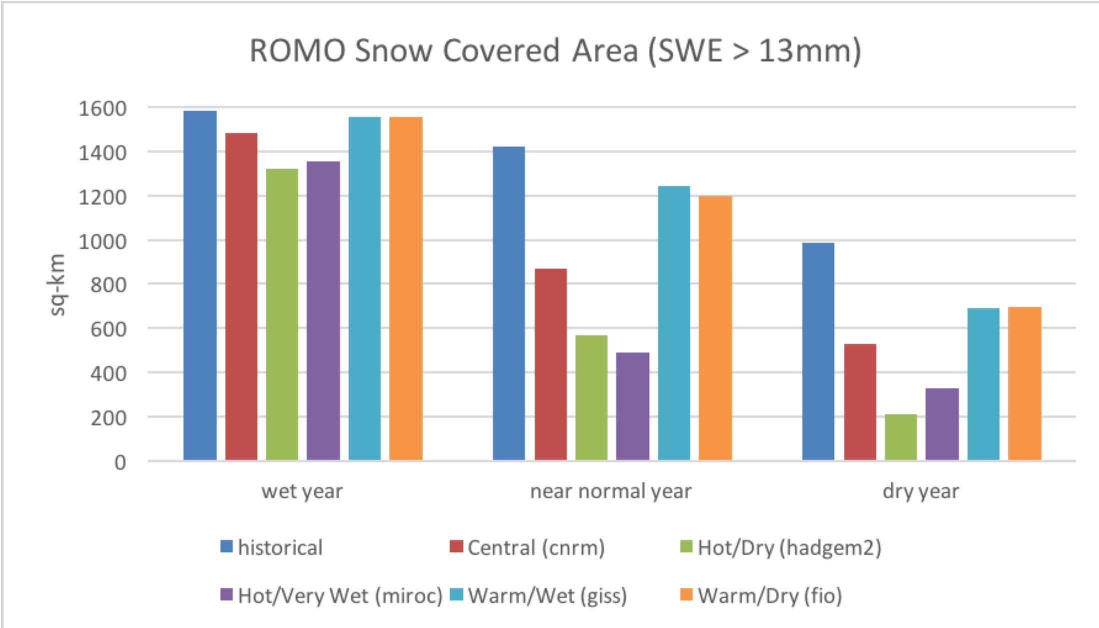

Figure 5-18: Snow Covered Area (km^2, 13mm SWE "light snow" threshold) for Dry, Near Normal, and Wet Case Study Years for ROMO. Historical and five future scenarios. May 1 (top), May 15 (middle), June 1 (bottom). Historical (blue), Central (red), Hot/Very Wet (green), Hot/Wet (purple), Warm/Wet (aqua), Warm/Dry (orange).

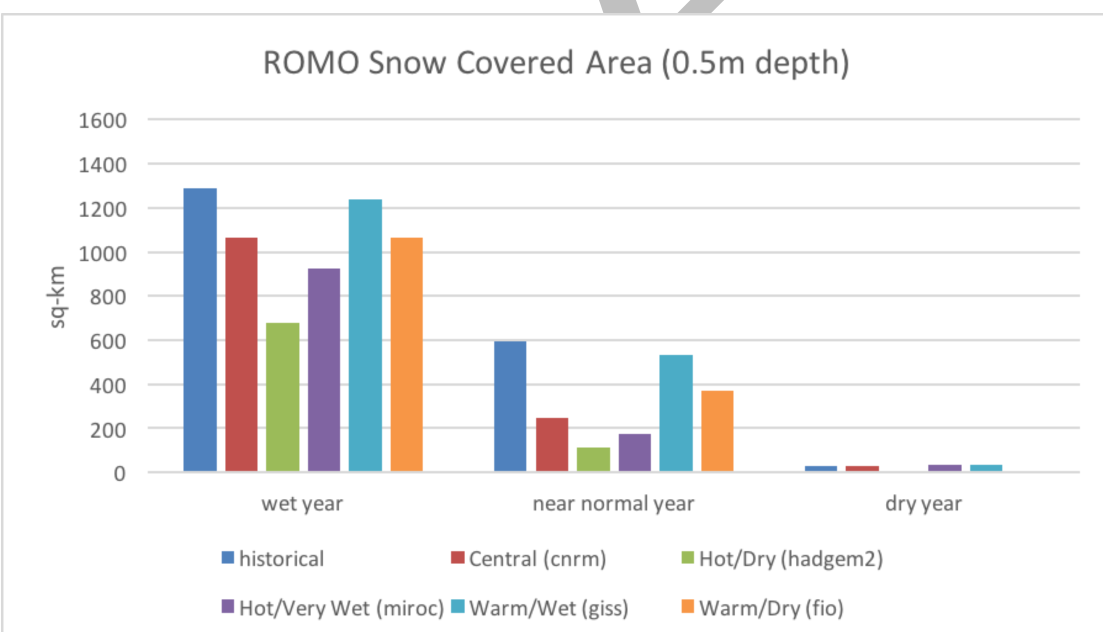

Figure 5-19: Snow Covered Area (km^2, 0.5 m "significant" snow depth threshold) for Dry, Near Normal, and Wet Case Study Years for ROMO. Historical and five future scenarios. May 1 (top), May 15 (middle), June 1 (bottom). Historical (blue), Central (red), Hot/Very Wet (green), Hot/Wet (purple), Warm/Wet (aqua), Warm/Dry (orange).

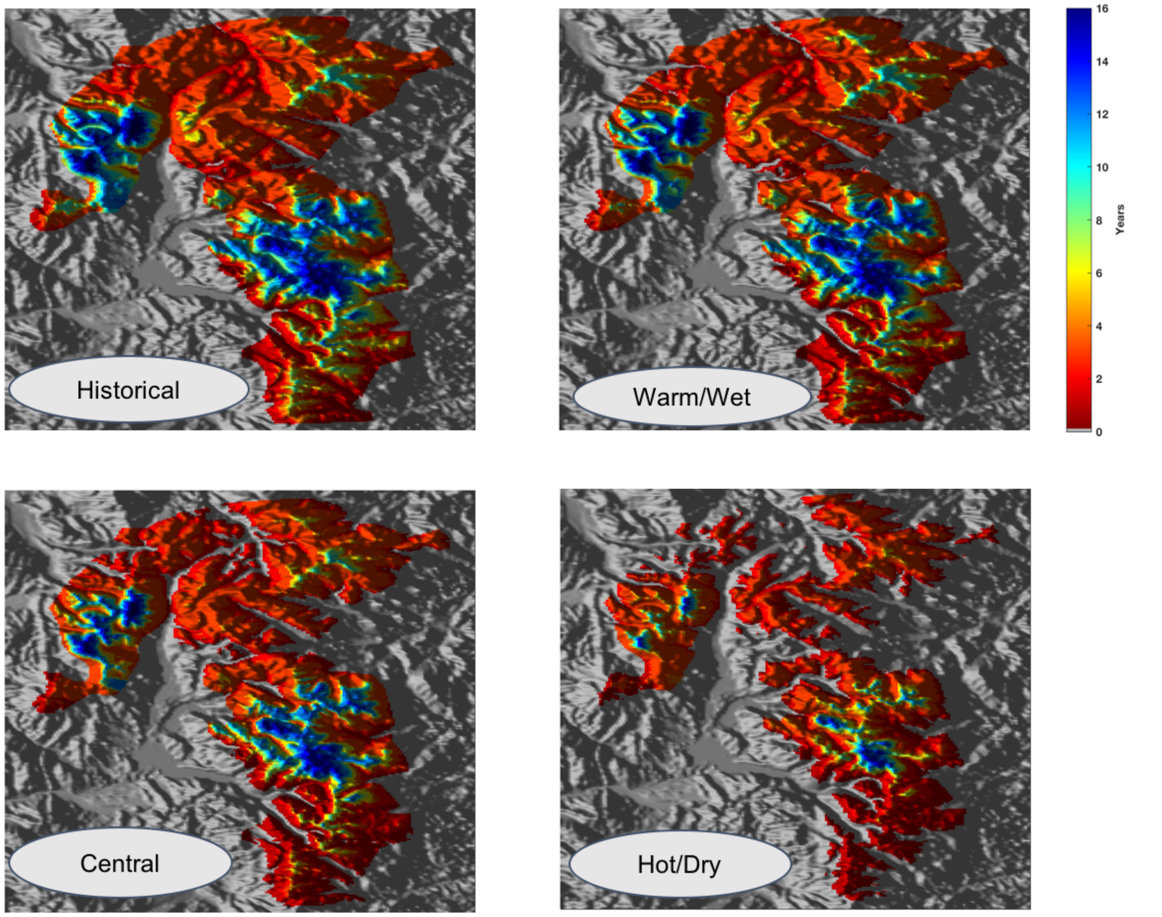

Figure 5-20 Number of years (out of 1998-2013) with Snow Depth > 0.5 m on May 15th for ROMO. Historical simulation compared to the Warm/Wet (giss), Central(cnrm), and Hot/Dry(hadgem2) future scenarios. Scenarios are described in Table 5-3. Note that scenarios were chosen independently for the two study areas.

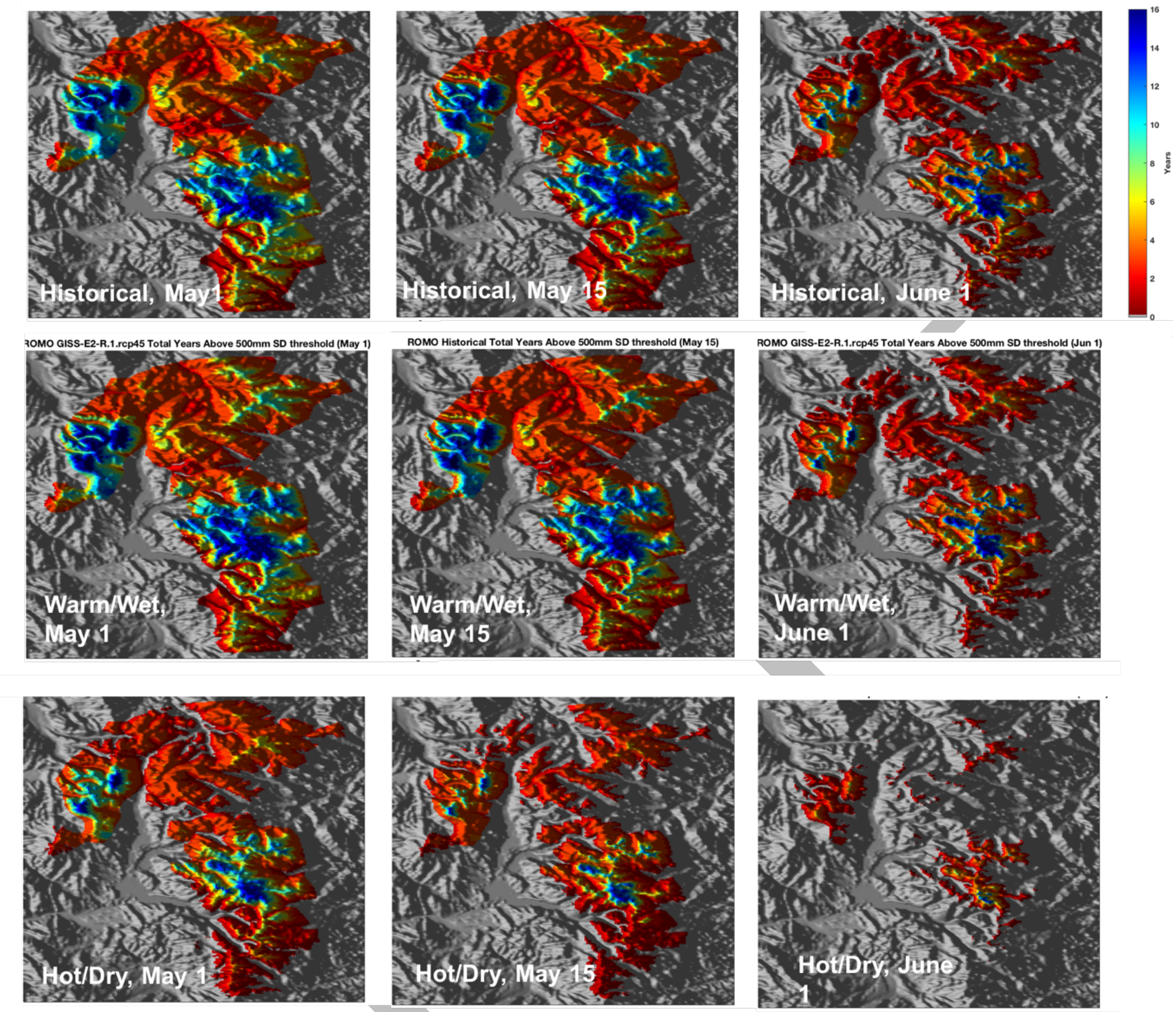

Figure 5-21: Number of years (out of 1998-2013) with Snow Depth > 0.5 m for historic and two future climate scenarios. The "number of years" indicates the yearly availability of deep snow at each model gridcell across all years in the DHSVM simulations, including wet, dry, and near normal years. Top Row: Historical Simulations on May 1st, May 15th and June 1st. Middle Row: Warm/Wet future scenario (GISS model, "Least Change") at the same dates, Bottom Row: Hot/Dry future scenario (Hadgem2 model, "Greatest Change") at the same dates. The reduction in the number of years on May 1 for each future scenario can be compared to the historical simulation at a later calendar date, showing little shift for the Warm/Wet scenario and a > 2 week shift for the Hot/Dry scenario. Scenarios are listed in Table 5-3.

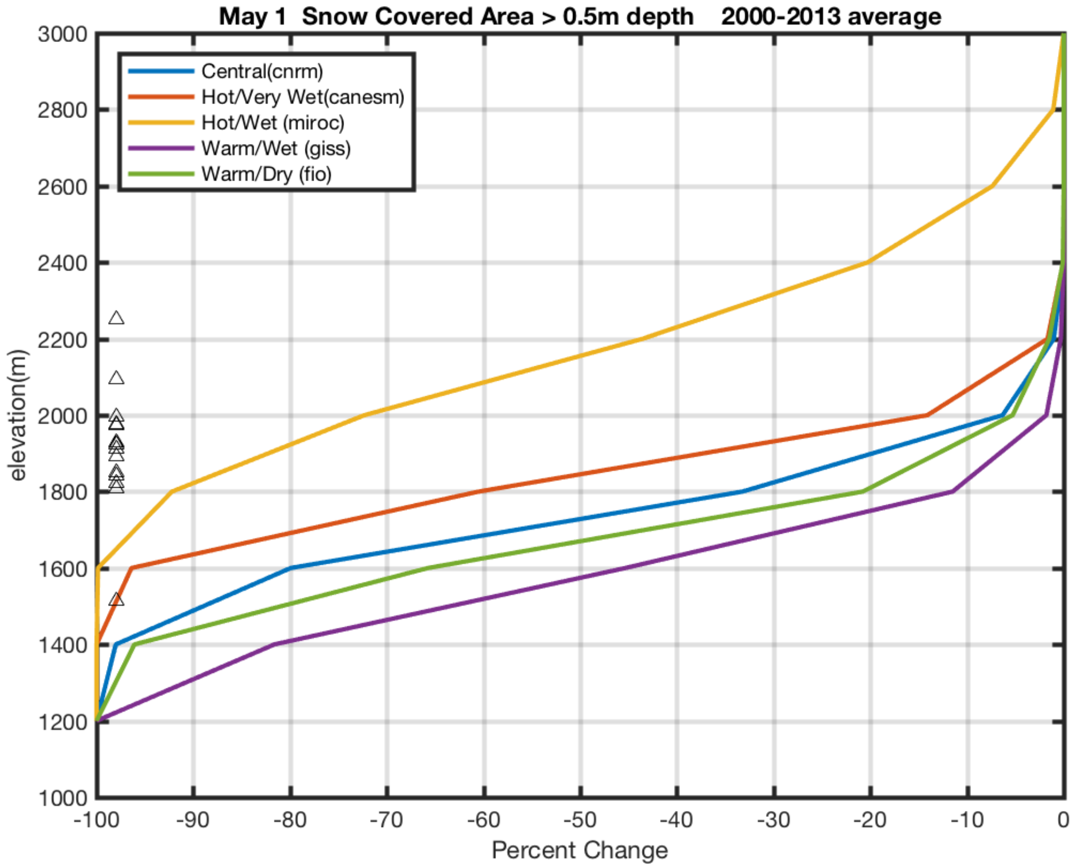

Figure 5-22: Average Snow Covered Area (km^2 with depth > 0.5 m) at elevation bands for GLAC for five future scenarios on May 1. Central (cnrm, red), Hot/Very Wet (canesm, green), Hot/Wet (miroc, purple), Warm/Wet (giss, aqua), Warm/Dry (fio, orange). Wolverine den site elevations are shown by black triangles.

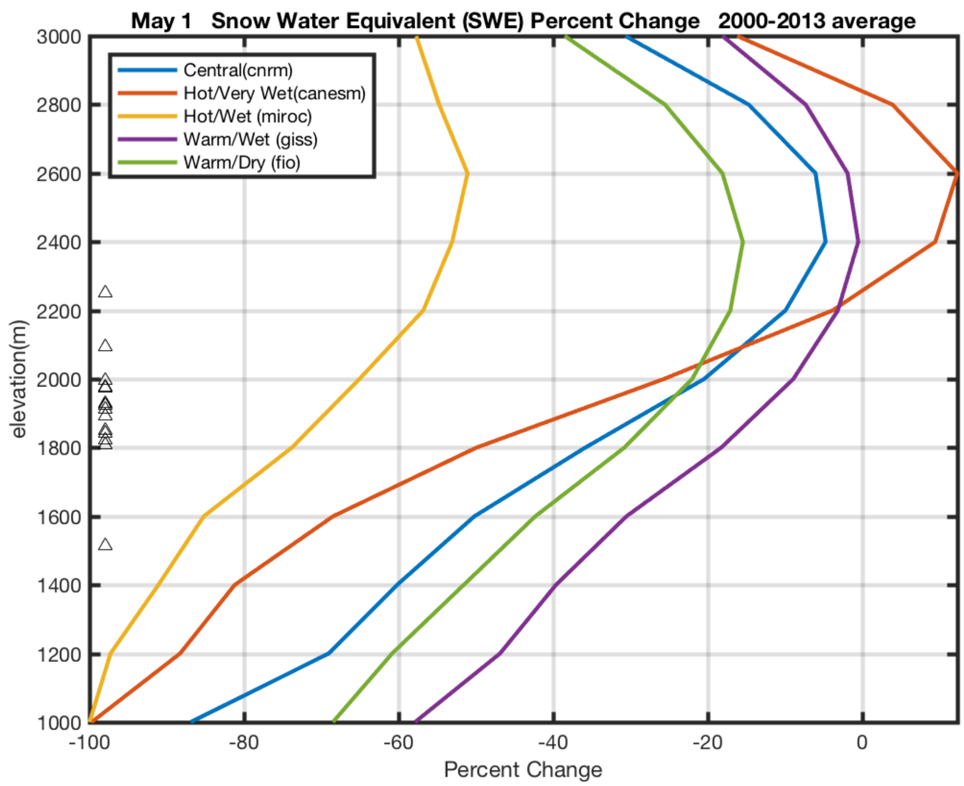

Figure 5-23: Average Snow Water Equivalent (SWE, percent change) at elevation bands for GLAC for five future scenarios on May 1. Central (cnrm, red), Hot/Very Wet (canesm, green), Hot/Wet (miroc, purple), Warm/Wet (giss, aqua), Warm/Dry (fio, orange). Known wolverine den site elevations are shown by black triangles. SWE is shown in addition to the snow covered area to emphasize that a Hot/Very Wet projection can have increased snowpack at high elevations despite the significantly warmer temperatures.

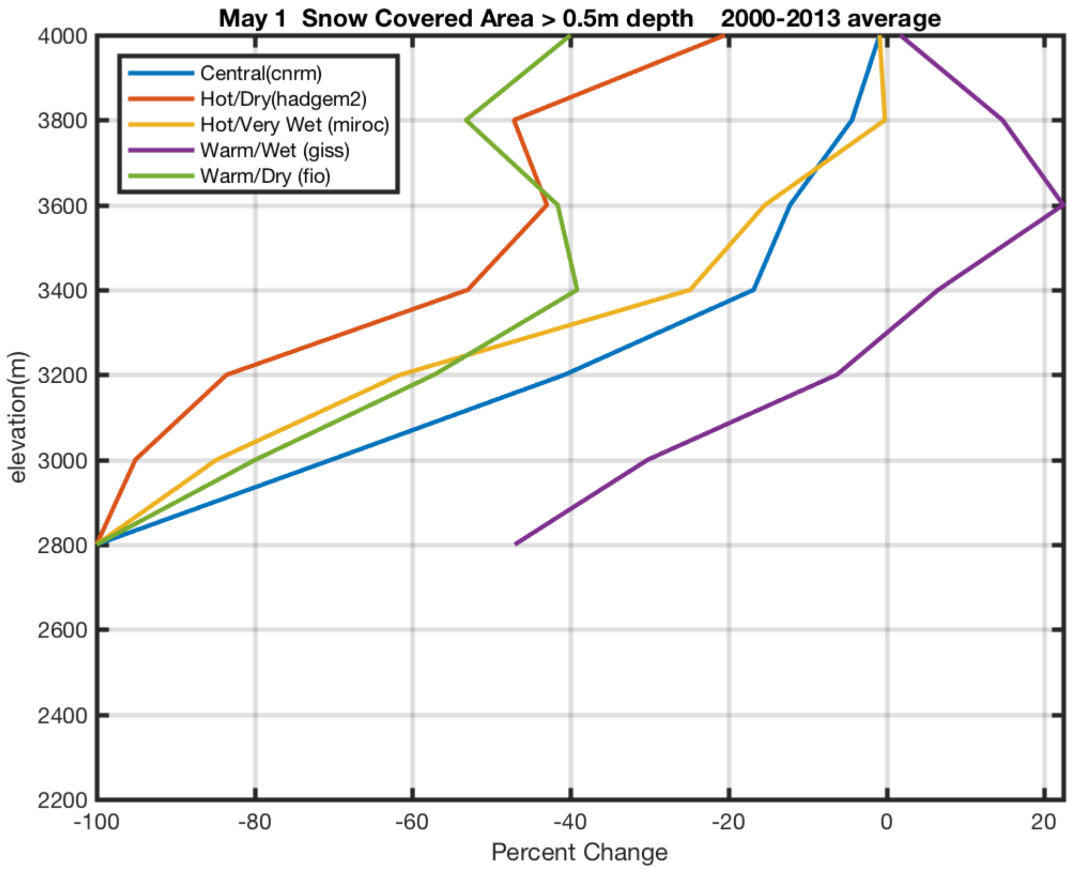

Figure 5-24: Average Snow Covered Area (depth > 0.5 m) percent change at elevation bands for ROMO for five future scenarios on May 1: Central (cnrm, red), Hot/Very Wet (hadgem, green), Hot/Wet (miroc, purple), Warm/Wet (giss, aqua), Warm/Dry (fio, orange). Note that the highest elevation band at ROMO tops out at 4000m, whereas the highest elevation band at GLAC tops out at 3000m.

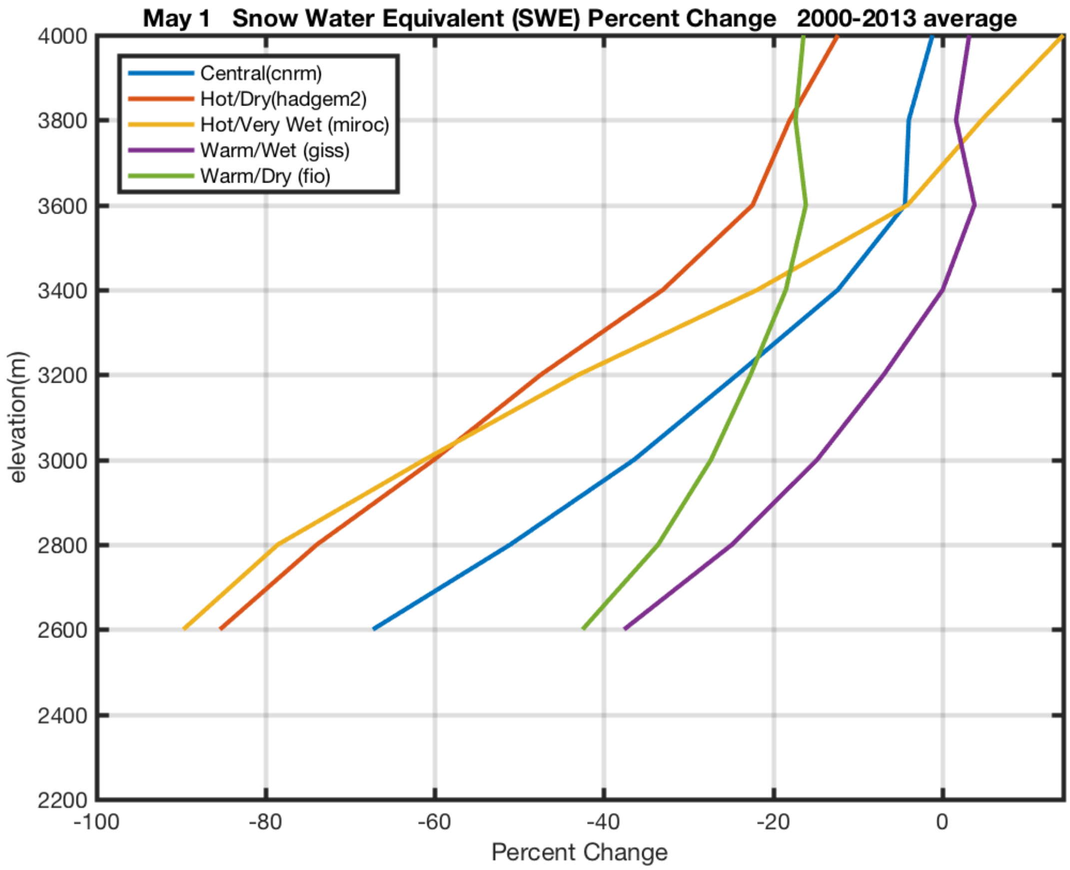

Figure 5-25: Average Snow Water Equivalent (SWE, percent change) at Elevation Bands for ROMO for five future scenarios on May 1. Central (cnrm, red), Hot/Very Wet (hadgem, green), Hot/Wet (miroc, purple), Warm/Wet (giss, aqua), Warm/Dry (fio, orange). Note that the highest elevation band at ROMO tops out at 4000m, whereas the highest elevation band at GLAC tops out at 3000m.

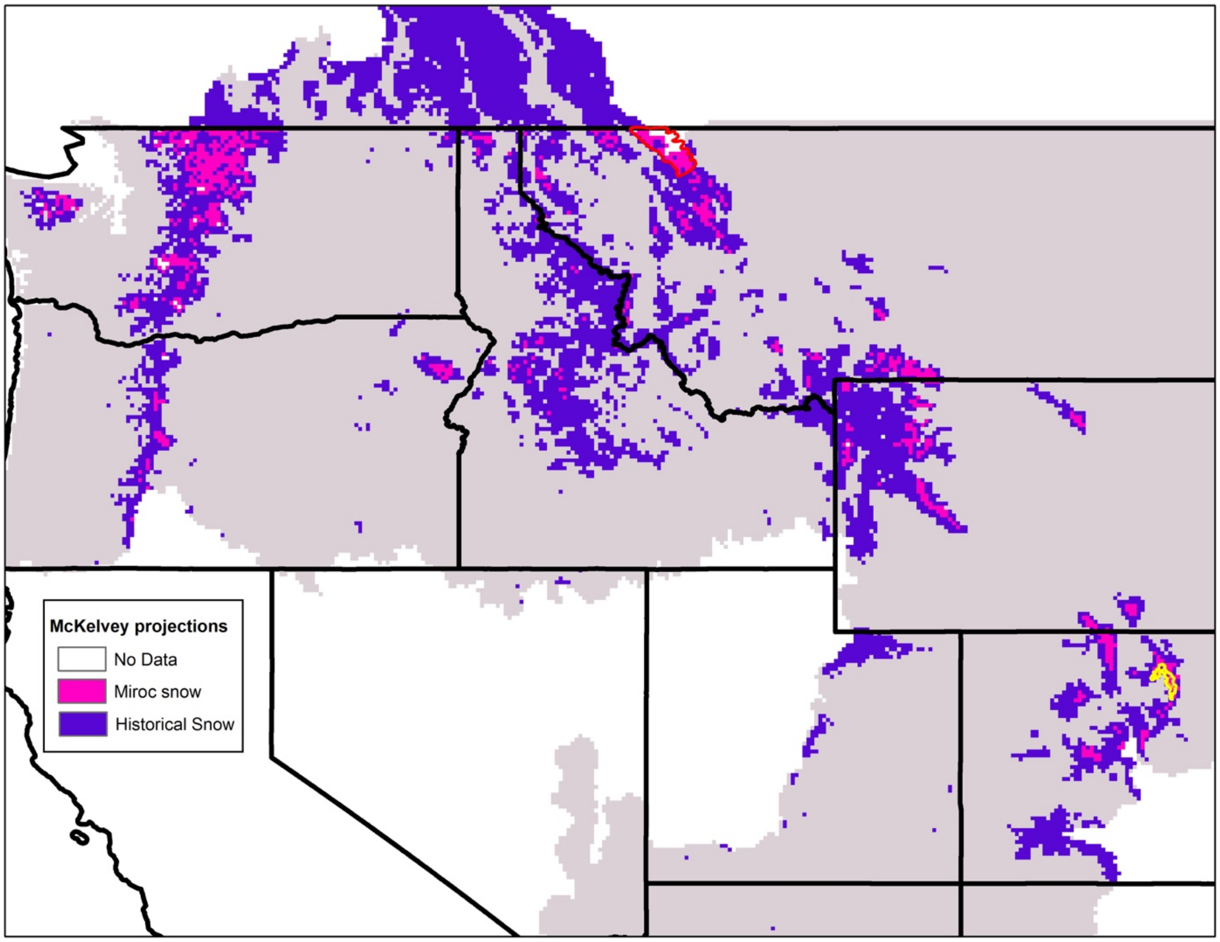

Figure 5-26: Simulated May 15 average snow cover inferred from 13cm snow depth on May 1 from McKelvey et al. (2011). Historical simulation and "MIROC 2080s" projection are shown. No projection data were included for Canada. Outlined areas are shown from the present study: GLAC (red), ROMO (yellow). Note that the domain simulated in McKelvey et al. (2011) did not include all of the GLAC study area. (Data were generously provided by Jeff Copeland. Graphic prepared by John Guinotte).