Summary Report

Changes in Past Hydro-climatology and Projected Future Change – for the City of Whitehorse

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Summary Report

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Executive Summary

The North in general and Whitehorse (Yukon Territory) in particular are highly susceptible to climate change. Warming is taking place faster in this region than many others. Because of the potential for major disruptions to systems that humans rely on, it is important that planners are provided with information that they can use to initiate the development and implementation of relevant adaptation and mitigation measures.

The Pacific Climate Impacts Consortium (PCIC) participated in the City of Whitehorse Sustainability Charrette, October 22nd-25th 2007. For this event, PCIC conducted analysis and created graphics to demonstrate the influence of climate change and variability on air temperature, precipitation, and streamflow in the past for the Whitehorse region. Projections of future changes in these variables were presented as well as impacts such as, forest fire severity, growing degree days, and spruce bark beetle infestations.

PCIC Staff (Arelia Werner and Trevor Murdock) made presentations at the Charrette and participated in the planning process over the four days. They were on hand to interact with the Charrette participants and met one-on-one with municipal planners and engineers to discuss the implications of the climate change impacts presented. From this interaction a few key ideas for future work were identified. This brief report summarizes the findings for the historical changes in hydro-climatology for the Whitehorse region and projections for the future. Recommendations for future work will also be outlined.

In this report, the analysis that was prepared and presented at the workshop is summarized and synthesized. Whitehorse is situated in a location of large precipitation gradients, significant historical temperature trends, and influence of El Nino/Southern Oscillation, the Pacific Decadal Oscillation, and the Arctic Oscillation. Generally, historical and future changes to temperature are largest in the winter months but projections of precipitation and temperature imply complex changes to streamflow, with different changes in timing and amount depending on watershed location and type. Other important potential impacts include increased fire and forest pest risks, reduced heating demand, and increased agricultural potential. Recommendations for further work include incorporation of future climate projections when taking measures to reduce greenhouse gas emissions as well as directly in adaptation planning.

1. Hydro-climatology of the Region

Whitehorse is situated in a sub-arctic, transitional maritime-continental climate. It is shielded from storms arriving from the Pacific Ocean by the St. Elias/Wrangell/Coast Range Mountains to the south-west. Over these mountains there is a strong precipitation gradient with large volumes on the windward side (1,500 mm to greater than 2,500 mm) and drier conditions on the leeside (250 mm to 750 mm) (Figure 1b). Sub-zero winter time temperatures and low-mean annual temperatures (0^oC to -5^oC) are conducive to precipitation falling as snow (Figure 1a). The snow-dominated terrain of this area makes it susceptible to ice-albedo feedbacks, where reductions in snow cover on the ground can reveal darker surfaces that absorb more energy from the sun.

The Yukon River watershed, up-stream of Whitehorse, starts in BC and crosses the BC/Yukon border. Some of the highest mountains in North America are within this watershed. Glaciers, such as Llewellyn Glacier, are common and large snowpack accumulation has been measured at mid- to high-elevations in these mountains. The Yukon River watershed also has a large number of lakes including Atlin Lake, Tagish Lake, and Marsh Lake.

Hydrologically, the predominant streamflow types found in this region are snow-melt dominated and snow-melt/glacier-melt dominated. Streamflow in those rivers that are fed by glacier-melt tend to peak in June or July and those fed by snow-melt tend to peak in May. Both have low-flows in November to April. All other things being equal, catchments with glacier cover have larger and longer freshets that peaked later than snow-melt dominated catchments, as well as higher baseflow conditions (Fleming, 2005). The degree of glacier cover in a catchment is important in determining the magnitude of annual streamflow from that catchment. Snow-melt dominated and glacier-melt dominated rivers in this region have shown different responses to changes in climate in the past, with implications for how they will respond to changing climate in the future.

An additional streamflow type in the region has snow and glacier-melt, but is modified by lake effects. Those rivers which are fed by lakes, such as the Atlin and Yukon Rivers, peak in August and have low-flows during the November to May period when precipitation falls as snow and contributes to snow-pack without promoting streamflow. Furthermore, summer precipitation may contribute to July through September flows in some snow-melt dominated rivers, such as the M'Clintock River near Whitehorse.

2. Vulnerabilities and Opportunities

Shifts in temperature and precipitation could change stressors on the municipal infrastructure in Whitehorse in ways that are likely to have significant cost implications. For example, increases in temperature could reduce the energy needed for heating. The cost of maintenance and renewal of roads and airport landing strips is partially dependent on temperature and precipitation. In particular, abnormal freezing and thawing cycles could expedite deterioration of these surfaces. Open water bodies, such as the Schwatka Lake water supply, and sewage treatment ponds are at risk to changes in the intensity of precipitation. Increased precipitation intensities could amplify turbidity in water sources and could also lead to overflows of treatment ponds.

The City of Whitehorse is built on a flood-plain, which makes it susceptible to upstream hydro-climatic changes that could lead to increases in the likelihood of flood or drought. Hydro-electric power generated on the Yukon River is the primary source of power for the City. Changes in the seasonality of the streamflow in the Yukon River could lead to changes in the ability to generate power.

Another potential outcome of climate change is adjustment of land-cover via shifts in vegetation. Warming and increased precipitation could potentially boost the capacity for agriculture. Forest fire could become a growing concern, as fire severity increases and the fire season lengthens. Furthermore, future conditions may be more suitable for new species of plants and animals, including invasive species. Land-cover changes in turn impact hydrology.

3. Trends

Eleven of the 12 years between 1995 and 2006 rank among the 12 warmest years in the instrumental global surface air record since 1950 (Solomon et al., 2007). The rate of warming over the last 50 years (0.13°C $\pm$ 0.03°C per decade) (1956-2005) is almost twice that for the last 100 years (0.074°C $\pm$ 0.018°C per decade) (1906-2005) (Solomon et al., 2007). Warming has been shown to be greatest in the northern latitudes and the majority of this warming has taken place in winter and spring (Solomon et al., 2007).

Analyzing trends in temperature, precipitation, snow water equivalent, and streamflow for Whitehorse and its surrounding area gives some indication of how these variables are being affected locally. Although current trends may not continue into the future, trend analysis illustrates the changes taking place in this region and provides context for comparison of trends in this area relative to others. It is also important to note that the trends are influenced by modes of large-scale circulation phenomena, such as the Pacific Decadal Oscillation (PDO), which was in a warm phase from 1977 to 1998.

3.1. Temperature

An analysis of annual mean temperature revealed that increases in the vicinity of the City of Whitehorse ranged from 1.5°C to 2.5°C during the 1950 to 2003 period. These trends were statistically significant at the 95% confidence level and match values found by other studies (Environment Canada, 2005). Night-time low (minimum; Figure 2a) and day-time high (maximum; Figure 2b) temperatures had similar increases to the mean. Temperature trends just south of Whitehorse over the 1900-2004 period had the greatest increases in the winter season for day-time highs and night-time lows (Rodenhuis et al., 2007). Increases in day-time highs in this area were also large in spring, but temperatures decreased in fall and had little change in summer for the same period (Rodenhuis et al., 2007). Conversely, night-time lows in this area increased in all seasons with the greatest increases in winter and spring, moderate increases in summer, and minimal, non-significant increases in fall (Rodenhuis et al., 2007)

3.2. Precipitation

Precipitation increased up to 30% over most of the region during the 1950 to 2003 period (Figure 3). However, most of these trends were not statistically significant. To the east of Whitehorse, a decrease in precipitation was observed.

3.3. Streamflow

Trends in mean flow ($m^3 s^{-1}$) for each pentad (5-day mean) over 1950 to 2006 were analysed for Dezadeash River at Haines Junction, Atlin River at Atlin, Yukon River at Whitehorse, Marsh Lake near Whitehorse, Takhini River near Whitehorse, and Pelly River at Pelly Crossing (Figure 4). Results were standardized and plotted on the same figure to allow comparison between stations. The plot starts at October 1st and ends at September 30th.

Over the 57 year period, streamflow increased at all rivers during October to May and decreased during April to September. Marsh Lake was an exception as it had a decrease in flow from late March to late June, and an increase in flow from June through to early March. This delayed response could have been caused by the attenuating affect of Marsh Lake, shifting the timing of these changes relative to those for streamflow.

The Yukon River showed a magnified effect due to the combined response of all the rivers and lakes that feed into it upstream of Whitehorse. The Yukon River Basin includes a substantial area at high elevation. Therefore, trends in precipitation and temperature at higher altitudes have a strong influence on this river.

Atlin River near Atlin was the only river to show increasing trends throughout the year. Increases over the summer period could be related to the relatively large percentage of glacier cover in the basin, which may have had increased melt over the summer months due to warmer summer temperatures (Fleming and Clarke, 2003). Additionally, some thickening of the glaciers in the North Coast mountain ranges occurred for altitudes between 2500 and 3000 m (Schiefer et al., 2007). Hence, more glacier volume may be available for melt over the summer.

Trends in snow water equivalent (SWE) indicate an increase in snow for the Atlin station during the 1961-1990 (80% to 100%, $p < 0.05$) and 1978-2007 (20% to 40%) periods (Rodenhuis et al., 2007). However, trends in SWE were not available for the full 1950-2006 period. This was one of the few stations in BC to have increases in SWE over this time. Increased snow pack could have lead to the increase in May-June streamflow in the Atlin River.

4. Variability

The El Niño/Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Arctic Oscillation (AO) were investigated for their influence on temperature, precipitation, and streamflow. These are large-scale phenomena often referred to as "teleconnections" because they correlate climate phenomena over large distances (Moore et al., 2007 in press). ENSO and PDO are related to changes in sea surface temperatures and atmospheric circulation patterns over the Pacific Ocean. The AO is associated with fluctuations in the strength of the stratospheric polar jet. The response of these variables during warm phases of these large-scale circulation phenomena can be used as temporal analogues for how climate and hydrology might respond to climate warming in the future, especially when the modes of these phenomena reinforce each (i.e. El Niño with warm-PDO).

Temperature, precipitation, streamflow timing and amount, and accumulation of snowpack are some of the variables that are affected by ENSO, PDO, and AO. Second order effects include changes to sediment transport, geomorphologic events such as land slides and flooding, and fluctuations in freshwater fish populations (Fleming et al., 2007). The past responses of these variables to climate variability can be used to forecast their behaviour in advance. For example, 6 day to 3 month outlooks can be found for the US at the National Weather Service Climate Prediction Center http://www.cpc.noaa.gov/.

Generally, ENSO effects are associated with anomalously warm (cool) sea water in the equatorial Pacific. The warm phase of ENSO is commonly referred to as El Niño, while the cool phase is called La Niña. During El Niño winter the jet stream in the mid-Pacific is more likely to split creating storm tracks at low and high latitudes (Shabbar et al., 1997). The positive (negative) PDO phase is observed when the sea surface temperatures (SSTs) in areas of the North Pacific Ocean are below (above) average, and the SSTs along the west coast of North America are above (below) average. Positive winter temperature anomalies occur throughout western Canada during positive PDO phases (Moore et al., 2007 in press). PDO is distinguished from ENSO by its long lasting phases, usually persisting for 20 to 30 years, while typical ENSO events persist for 6 to 18 months (Mantua et al., 1997). Cool PDO regimes prevailed from 1890-1924 and 1947-1976, while warm PDO regimes dominated from 1925-1946 and from 1977 through (at least) the mid-1990's (Hare and Mantua, 2000).

The AO is the dominant pattern of non-seasonal sea-level pressure (SLP) variations north of 20^{o}N, which are linked to the strength of the stratospheric polar jet (Moore et al., 2007 in press). A positive AO index value generally indicates negative and positive SLP anomalies in the Arctic and midlatitudes, respectively, and relatively strong 55°N (surface) westerlies (Thompson and Wallace, 1998). Conversely, a negative index value indicates the opposite pressure anomalies and weaker westerly flow (Thompson and Wallace, 1998). Negative AO phases are linked to the occurrence of extreme cold weather systems, such as Arctic outbreaks (Moore et al., 2007 in press).

4.1. Temperature and Precipitation

Positive AO events typically result in warmer temperatures during April to August and below average temperatures from September to December (Fleming et al., 2006). Temperatures are often colder between April and August during negative AO events, with the largest reduction versus normal taking place in June. Conversely, temperatures were warmer from October to March during negative AO events. Results were statistically significant ($p<0.10$) for all months but September (Fleming et al., 2006). Less precipitation occurred in July and August, and more occurred in December and January during positive AO events. Negative AO events are associated with more precipitation in May, July, and August and less in December and January than normal. The response during the remaining months is somewhat ambiguous and not statistically significant.

During warm PDO, temperatures can be 2°C to 4°C warmer than average (Figure 5b). Alternately, during the cool-PDO phase temperatures can be 2°C to 4°C cooler than average (Figure 5a). Because of the lack of gridded precipitation data for this area over the longer term (i.e. 100-years), the response of precipitation to PDO influences was not analyzed, and therefore not presented here. However, Rodenhuis et al. (2007) demonstrated that during the most recent warm-PDO phase precipitation and snowpack were greater than normal in the northwest portion of BC, the headwaters of the Yukon River.

ENSO responses were investigated by Environment Canada. Results show that winter and spring temperatures were warmer during El Niño years, by 0.7°C to 2.1°C and 1.6°C to 2.0°C respectively (MSC, 2003). Reductions in precipitation for winter and spring during El Niño were less than 0.1 mm/day (MSC, 2003). La Niña episodes, which commonly bring cooler than average temperatures, were near normal to slightly warmer during winter (0.0°C to 0.2°C) and warmer during spring (0.4°C to 0.9°C) than normal (MSC, 2003). This is likely because the strong warming trend in this area has led to La Niña years being warmer than average since the start of the 1990s (MSC, 2003). Changes in precipitation during La Niña in winter and spring were close to 0.0 mm/day (MSC, 2003). Effects of El Niño and La Niña on snow depth in millimetres was close to zero, except for March during El Niño events when snow depths decreased by 3 cm to 12 cm.

4.2. Streamflow

Response of streamflow to AO phases is dependent on the type of run-off regime. Significant differences were isolated to the spring and summer for both snow-melt dominated and snow/glacier-melt dominated basins (Fleming et al., 2006). Glaciated basins responded during positive AO with increased freshet flows from April through to June relative to negative AO. Furthermore, annual flows were greater during positive AO phases in glaciated basins. The consequences of the positive AO on snow-melt dominated basins were increased streamflow during April and decreased streamflow in August (Fleming et al., 2006). The spring freshet took place earlier during positive AO, which resulted in lower summer flows. Increased temperature from May through August may increase evapotranspiration leading to water loss in these months (Fleming et al., 2006).

During PDO-warm events Atlin River near Atlin had increased flows throughout the year when compared to PDO-cool events (Figure 6). This is likely because more precipitation falls as rain during PDO-warm, which increases winter streamflow, but decreases snowpack accumulation. Over the spring and summer months, increased temperatures melt the glaciers in the catchment creating streamflow. Conversely, in the PDO-cool phase streamflow is reduced throughout the year likely because a greater percentage of precipitation falls as snow. This snow accumulates as snowpack, and does not contribute to winter streamflow. In the flowing spring and summer, flows are reduced because of less glacier-melt occurring in the PDO-cool.

ENSO responses were not significant for many of the rivers analyzed. The Takhini River near Whitehorse responded in November with greater runoff during El Niño than La Niña (Figure 7). Atlin River near Atlin showed the strongest response. During El Niño (La Niña) run-off was greater (lesser) during fall and the start of winter (October through to January). This is likely because Atlin River in farther south where the influence of ENSO is stronger.

5. Future Projections of Climate Change and Uncertainty

Projections of temperature and precipitation are provided from the latest version of the Canadian Regional Climate Model (CRCM-4.1.1). This regional model has been dynamically downscaled from the Canadian Global Climate Model version 3 (CGCM3) 2050s projection following the A2 emissions scenario. The projected climate change with this model is 2.6°C warmer and 12% wetter than baseline (average for 1961-1990) on average for a region surrounding Whitehorse. These projections are on the warmer, wetter side of the range of projected changes in temperature and precipitation from an ensemble of models. From these ensembles, temperature was projected to be 2.2°C (1.5 °C to 3.0 °C) warmer and precipitation was projected to change by 4% (-2% to 11%) based on 117 GCM projections.

The resolution of this model is 45 km and projections are shown as differences from the 1961-1990 period because this period is commonly used when management strategies are formulated. The RCM has the advantage over the GCM because of its capability of showing relief related effects, such as how precipitation is deposited on the windward side of mountains and not on the leeside. Additionally, the RCM better represents the snow-albedo feedback. This feedback results in enhanced warming as snowpack diminishes. White surfaces, such as snow, have high albedo and as they are removed albedo is reduced. Thus, additional warming results that further melts available snow.

5.1. Temperature

Winter mean temperature is projected to increase by 3°C to 6°C for 2041-2070 compared with the 1961-1990 baseline based on projections from the GCM (Figure 8b) and RCM (Figure 8a). These are some of the largest projected increases in temperature for the Western North America. For example, they are above the average increase projected for BC of 2.6°C. Summer temperature increases are not as large, or as spatially variable as those for winter, with increases of only 2°C to 3°C (not shown).

5.2. Precipitation

Both winter and summer precipitation projections for 2041-2070 are greater than baseline (1961-1990), by 10% to 45% by the GCM (Figure 9b) and 25% to 45% by the RCM (Figure 9a). Increases are greater for the area north of Whitehorse than they are for the south where the headwaters of the Yukon River are located. Projections of the Snow Water Equivalent (SWE) for 2041-2070 suggest that SWE will increase by 5% to 50% of the baseline north of Whitehorse, but will remain the same or decrease by up to 75% south of Whitehorse in the region of the headwaters (Figure 10). Where precipitation increases are greater than the projected SWE enhancement there may be more rainfall.

Changes in the direction and magnitude of temperature are more certain than for precipitation. In the past, precipitation has had more variability than temperature see section 4.1 (Rodenhuis et al., 2007)).

5.3. Streamflow

Climate change projections made with the Canadian Regional Climate Model (CRCM) versions 3.6 and 3.7 were investigated for the Yukon River (Sushama et al., 2006). The CRCM was driven by the Canadian Global Climate Model (CGCM2) following the A2 emissions scenario and by National Centres for Environmental Prediction (NCEP) reanalysis data. For the majority of the year, streamflow modelled by the CRCM agreed with streamflow observed at the Yukon River at Kaltag (64°19N 159°43W). Flows were somewhat overestimated by the model during the June to October period, suggesting that snowpack was overestimated and evaporation was underestimated.

Projections are for an increase in streamflow during the September to May period versus the observed. This suggests that there will be an increase in the percentage of precipitation falling as rain (versus snow) over the winter season. Peak run-off during the spring freshet will occur earlier and magnitudes will be roughly on par with the average for 1961-1990 (Sushama et al., 2006).

The median number of days with low-flows below the 20^{th} percentile threshold is projected to decrease by roughly 50 days for all versions of the model (Sushama et al., 2006). Additionally, the number of 7-day low flows is projected to decrease and the magnitude of the low will be greater from 2000 to 5000 m^3 per second rather than below 2000 m^3 per second. The relative magnitude of 7-day low flows will increase from roughly 1.4 to 2.1 times that of the base case (Sushama et al., 2006). In the future, more high flows may occur in the August to October period and the number of high flows in May and June will likely be reduced.

5.4. Forestry

Fire-season length is projected to increase by 38 to more than 52 days with the Canadian Climate (CGCM2) model and more than 52 days with the Hadley (HADCM3) model (Kochtubajda et al., 2006). Thus, projections with the CGCM2 model were more modest than those with the HADCM3 model, which is possibly related to wetter conditions in the CGCM2 model as compared to the HADCM3 model.

Mean seasonal fire severity is projected to increase from 1.5 to 3 times as much in some places and could increase by up to 50 times by the CGCM2 model for $3 \times CO_2$ versus $1 \times CO_2$ (Kochtubajda et al., 2006). Changes were similar for the HADCM3 model, however, north of Whitehorse changes were not as severe as they were with the CGCM2 model, with increases in mean severity of only 0.75 to 1.5 times (Kochtubajda et al., 2006).

During warm years the spruce bark beetle may reproduce within one year rather than its normal two (Garbutt et al., 2006). Under warm, dry conditions trees can become water stressed and release a chemical signal that attracts the beetle. Furthermore, with limited water availability these trees are less able to fight off beetle attacks (Garbutt et al., 2006). Thus, warmer conditions could promote the expansion of this pest, particularly if accompanied by drier conditions.

5.5. Heating Degree Days

Heating degree days showed decreases of 4% to 19% for the majority of the years between 1983 and 2000 (MSC, 2003). Due to the warming trend in this area even La Niña years, which are normally cooler, are warmer than average since the start of the 1990s (MSC, 2003).

5.6. Growing Degree Days

Growing degree days ranged from 0 to 1000 for the 1961 to 1990 period in the Whitehorse area (Figure 11a). Projections are for growing degree days to increase to up to 1500 in the valley areas north of Whitehorse during the 2041-2070 period (Figure 11a). This range would be conducive to growing crops that previously could not have been grown in this area. For example, canola can mature within 1500 growing degree days (NDAWN, 2007).

6. Implications

The dry, snow-dominated, sub-arctic climate of Whitehorse makes it susceptible to climatic changes in the future. Ecosystems, infrastructure and management practices are adapted to the current climate and are not likely to be efficient outside of these narrow ranges. Hydro-electric power generation and susceptibility to flooding depend on the response of the watershed up stream where there are large elevation ranges, high variation in snowpack, and fluctuations in glacier volume.

Rates of warming in this region are more than twice the global average and annual precipitation has increased by up to 30%. The combined effect of changes to precipitation and temperature has been to modify the form of precipitation and to change the resulting streamflow patterns. Historical trends in river flows across the region are complex and appear to depend at least in part on the flow regime of a particular river. Overall, summer streamflows and annual river flow volumes in the region have generally increased in glacial rivers but decreased in snow-melt fed rivers, although there are important local and seasonal complications (see (Fleming and Clarke, 2003; Stahl and Moore, 2006) and Section 3.3 of this report). Shifts in the timing and magnitude of streamflow have implications for aquatic habitats, hydro-electric power generation, and flood control.

Regional temperature, precipitation, and streamflow patterns are related to modes of climate variability such as PDO, ENSO and the AO. Glaciated and snow-melt dominated basins differ in their response to AO. These influences could be taken into account when setting management strategies. Forecasting tools can be developed to better manage under warm versus cool phases of these events.

Temperatures are projected to increase by 3°C to 6°C and precipitation is projected to increase by 10% to 45% by the 2050s with an increasing proportion falling as rain. Changes in temperature of this magnitude will likely have an impact as they are above the historical range in variability for this region and hence will create conditions that have not occurred before. Ecosystems may shift, new plant species may migrate into this region and heating costs will likely be reduced.

Conditions created by warmer temperatures combined with more precipitation, are conducive to invasive plant and animal species. However, there will be greater potential to grow new crops and there may be an increase in the yield of those currently grown in the region. Warming and increased fuel load promote increases in the severity and length of the fire season.

Interestingly, these increases in temperature are projected to increase the snow water equivalent or snowpack accumulation north of Whitehorse, but to decrease it to the south. This is possibly because, in the northern regions, temperatures are still cool enough to snow in spite of warming. Hence, the Yukon River, which is fed by upstream precipitation and streamflow, could be impacted by reductions in snowpack. However, projections from the RCM are based on the GCM projection that is one of the wettest and warmest of those available. Regional modelling based on a different GCM is likely to project a smaller increase or even a decrease in snowpack (e.g. ACIA).

Streamflow projections for the Yukon River are for more flow in winter and less in summer. This would be a continuation of the trends that we saw over the past 50 plus years for the Yukon River. These changes could possibly prove to be advantageous in producing hydro-electric power during the winter months when demand is greatest but streamflow is low (Yukon Electric, 2008). However, these changes could stress ecosystems that are adapted to wetter summer months.

7. Recommendations for Future Directions

This brief report is only a summary of trends and future projections. In order to use this information to inform development of adaptation strategies there are a few intermediate steps that need to be taken. The following recommendations are examples of ways to proceed:

- Make use of future climate projections when taking measures to reduce greenhouse gas emissions (e.g. consider future climate when undertaking green building, or considering alternative energy sources)(Castle et al., 1996).
- Identify trends on a seasonal basis to see which seasons have the most change.
- Investigate trends in precipitation intensity and exceedance of precipitation thresholds.
- Update rating curves for major rivers, streams, and waterways.
- Identify location, types, life span, and replacement costs of infrastructure (i.e. airports, bridges, energy, hospitals, buildings, railroad, roads, sewer, schools, telecommunications, etc.) in order to determine relevant time periods for future projections (Larsen et al., June 2007).
- Assess vulnerability of infrastructure to climate change and potential for adaptive measures. Develop cost structures to incorporate climate change in to planning for lifespan replacement estimates. Complete full socioeconomic investigation (Larsen et al., June 2007).
- Consider projections of precipitation and temperature for the Whitehorse region with an ensemble of global climate models to estimate a range of uncertainty for these projections.
- Implement pilot projects on adaptive measures which may require changes outside of current bylaws and regulations.
- Identify opportunities to take advantage of knowledge of current ENSO, PDO and AO cycles on year to year climate.

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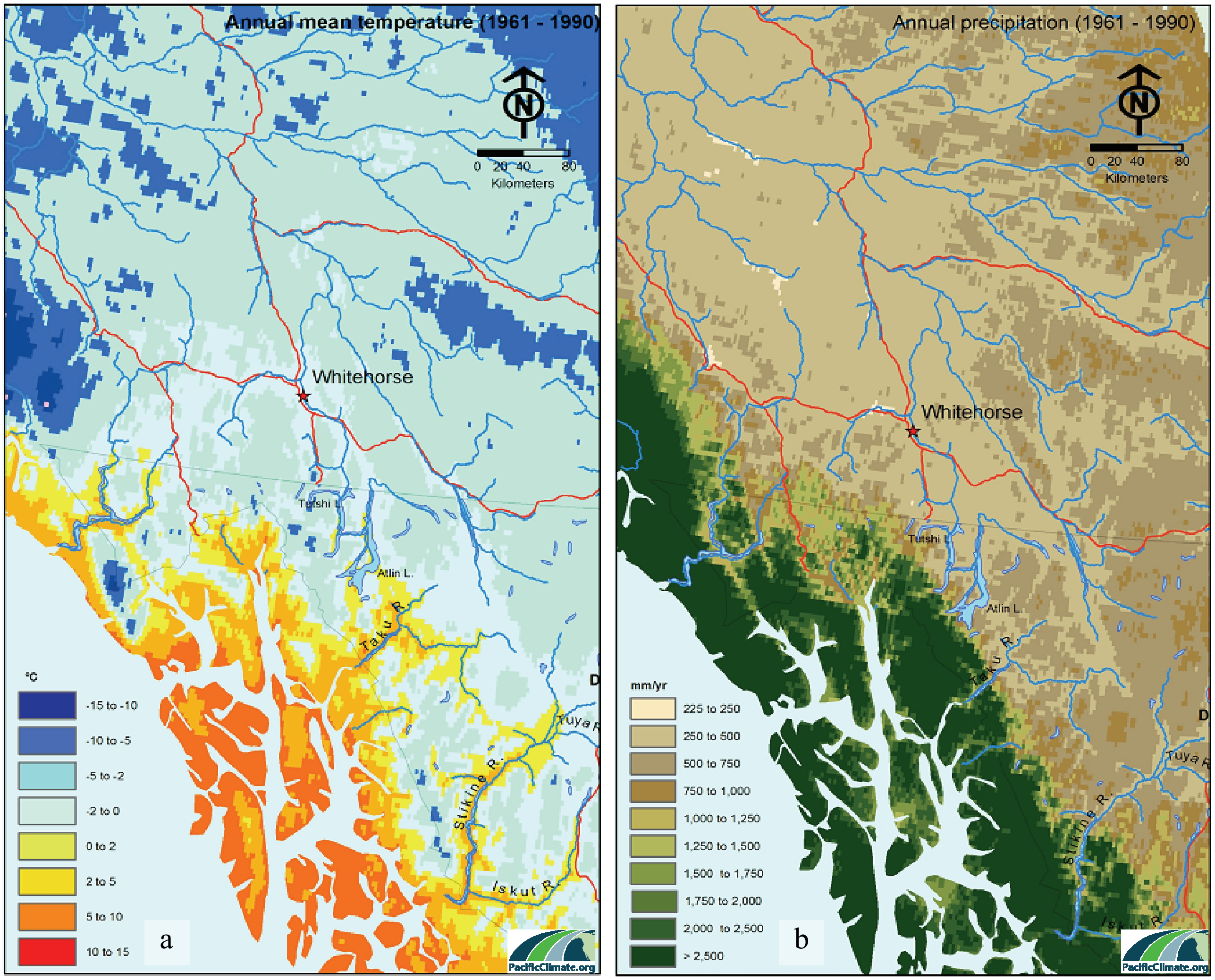
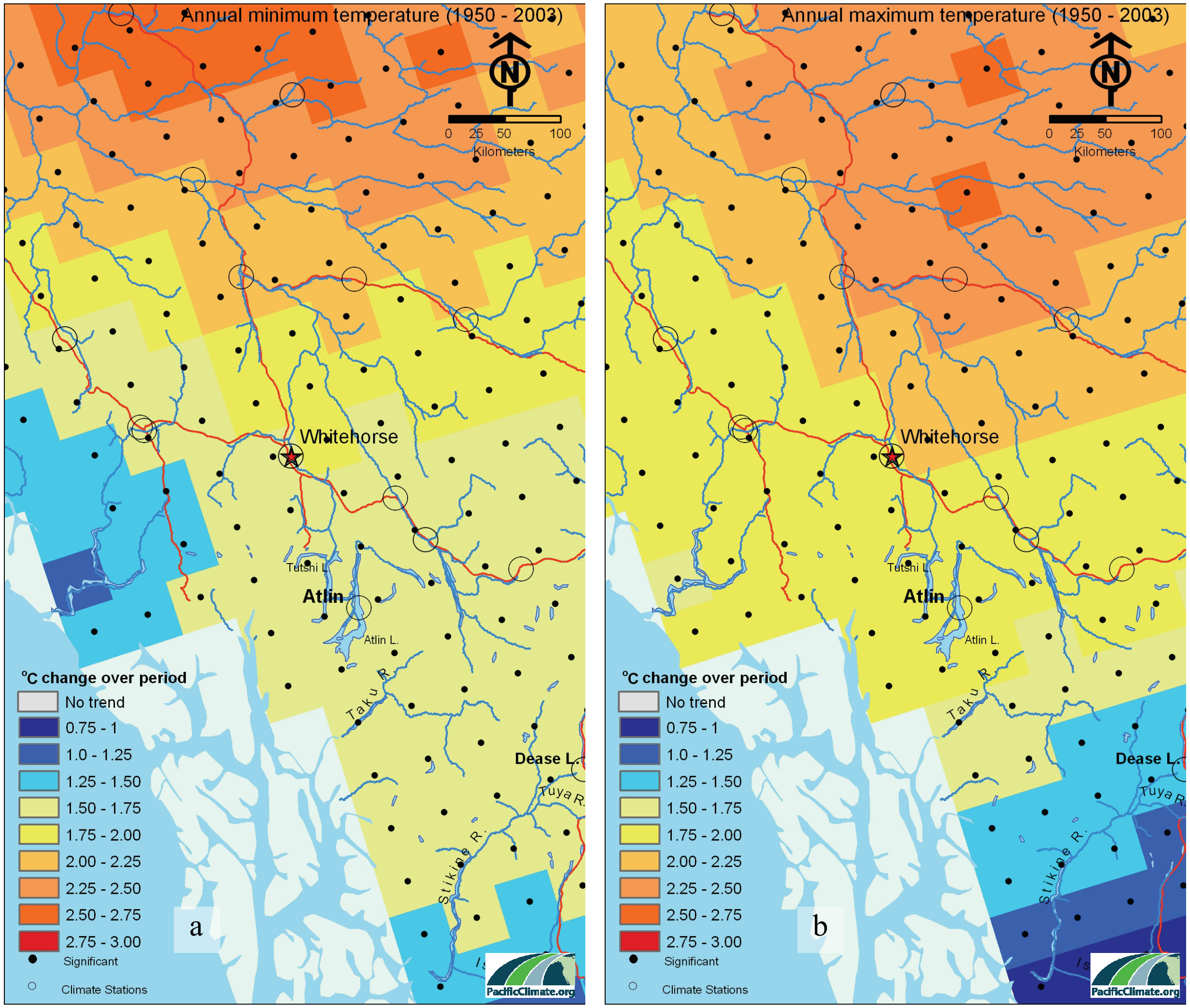


Figure 1 - a) Annual Mean Temperature (1961-1990) climatology, b) Precipitation (1961-1990) climatology. Sources: PRISM data with Meteorological Service of Canada: Adjusted Historical Canadian Climate Data.



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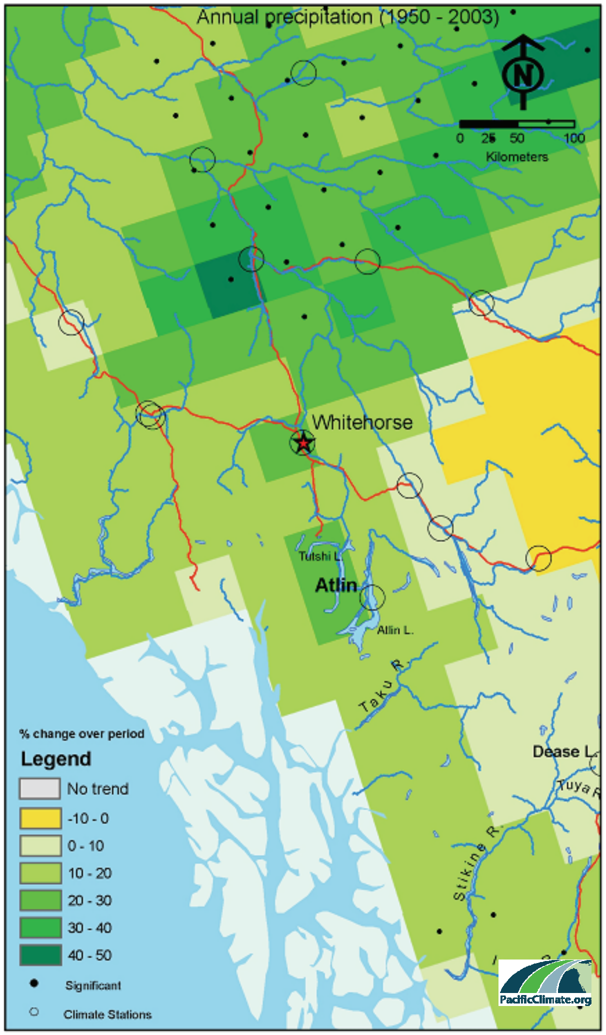

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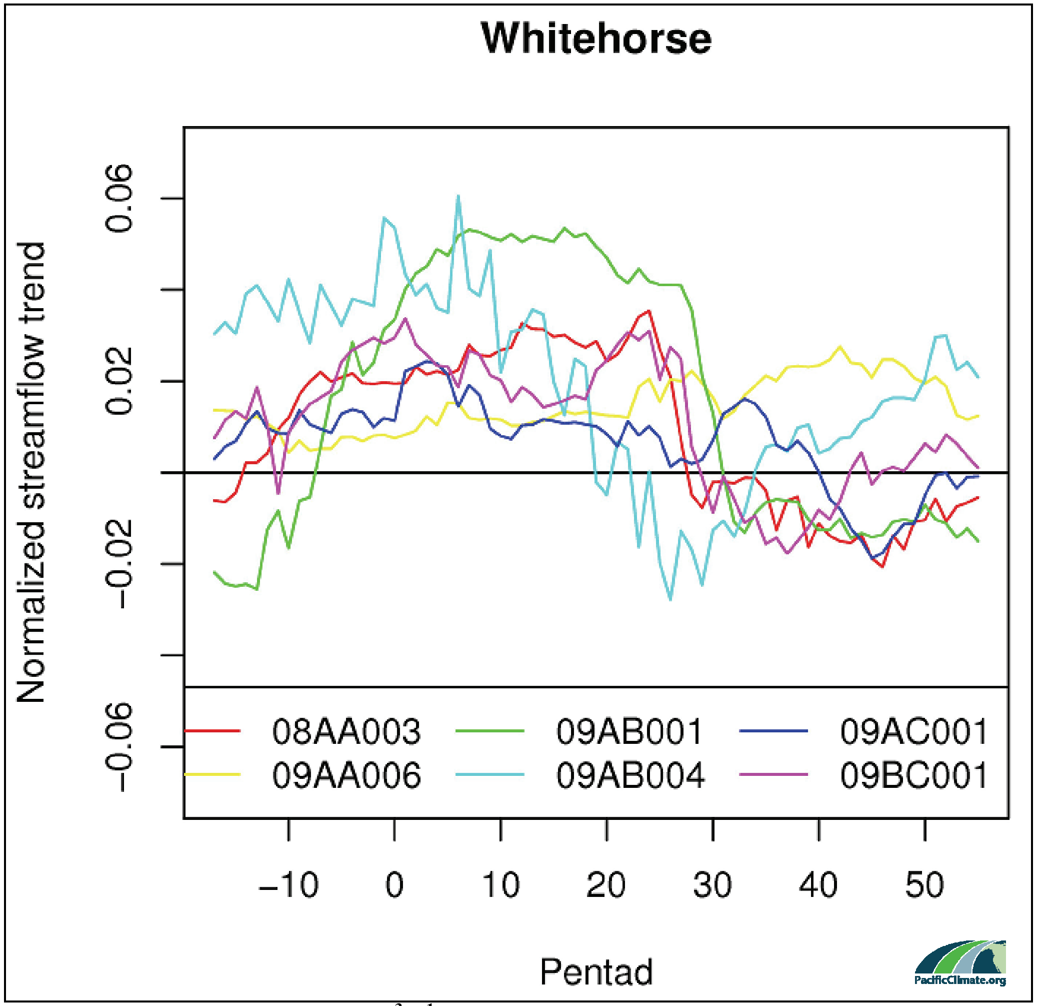

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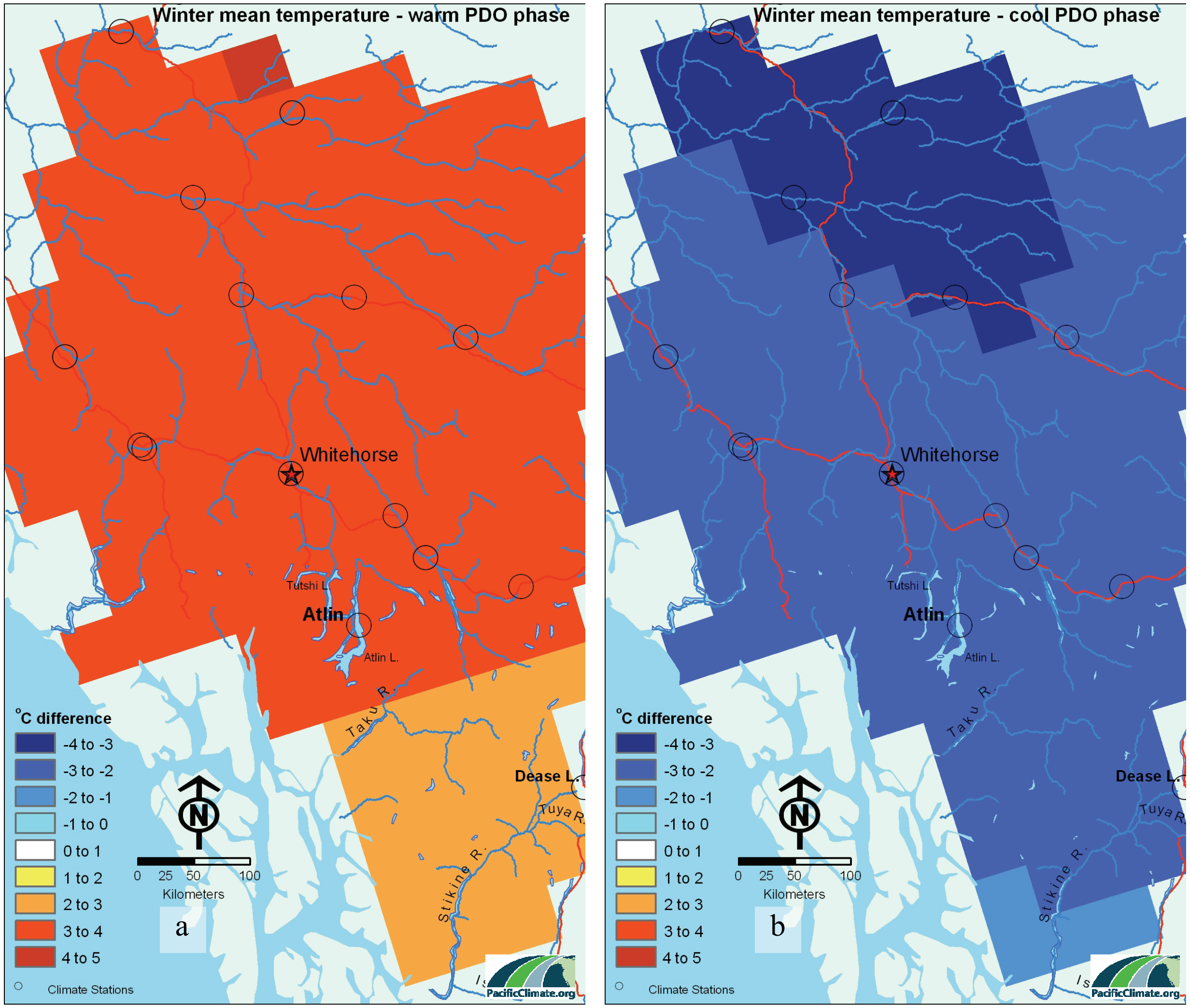

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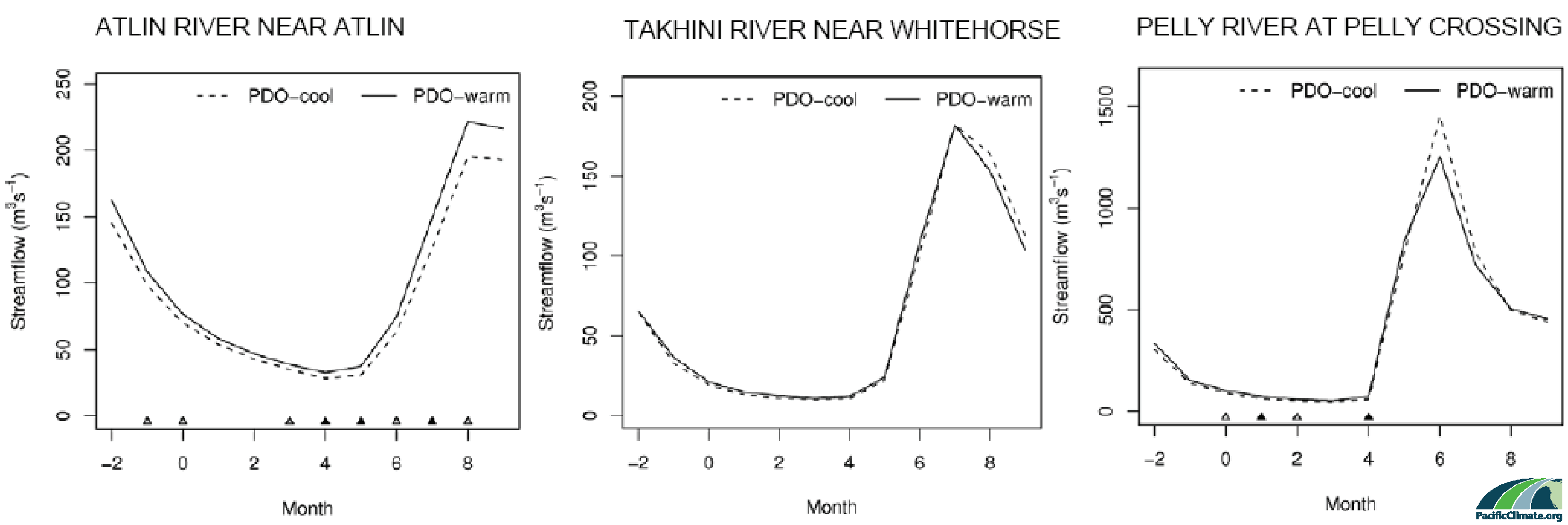

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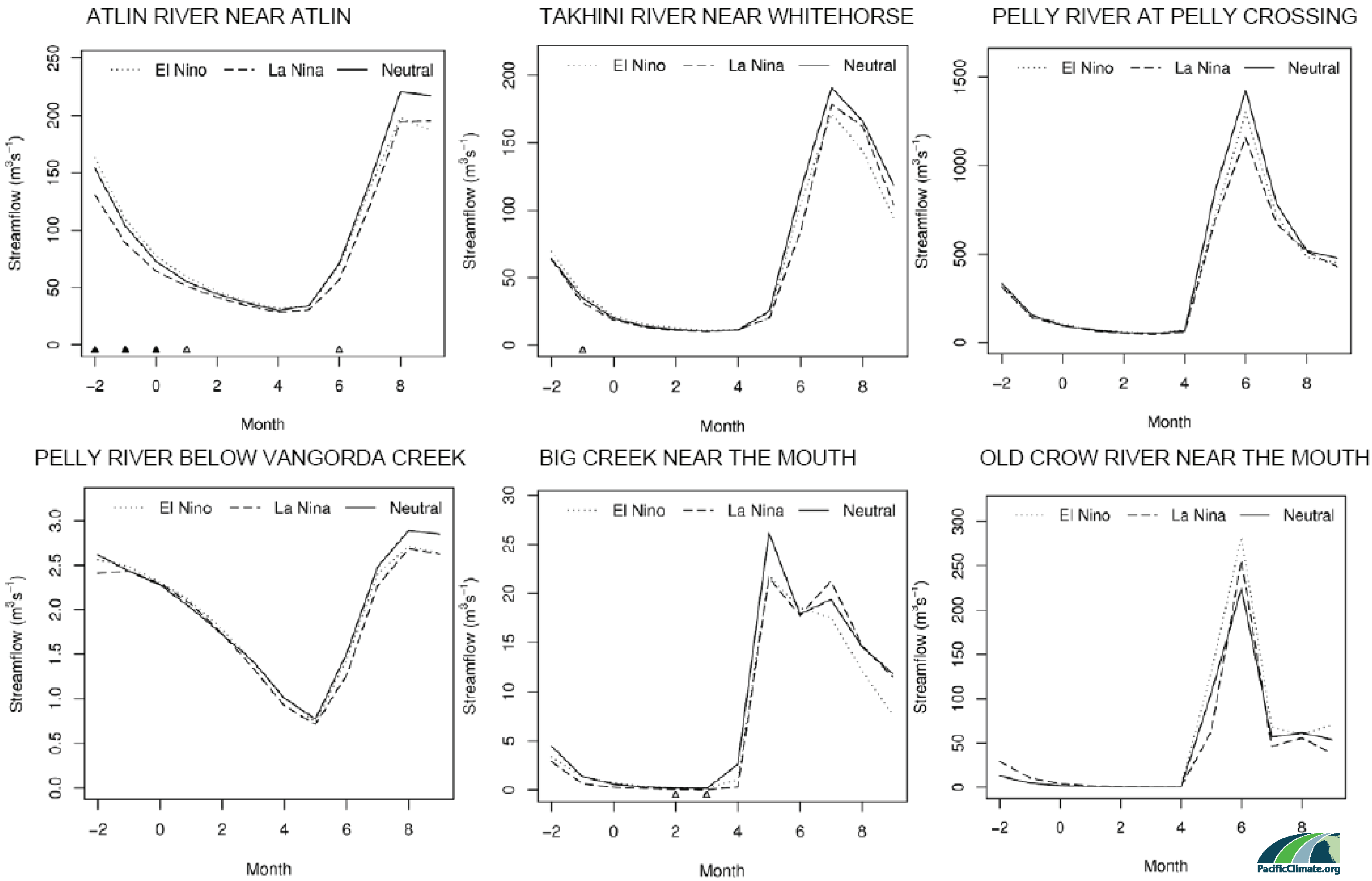

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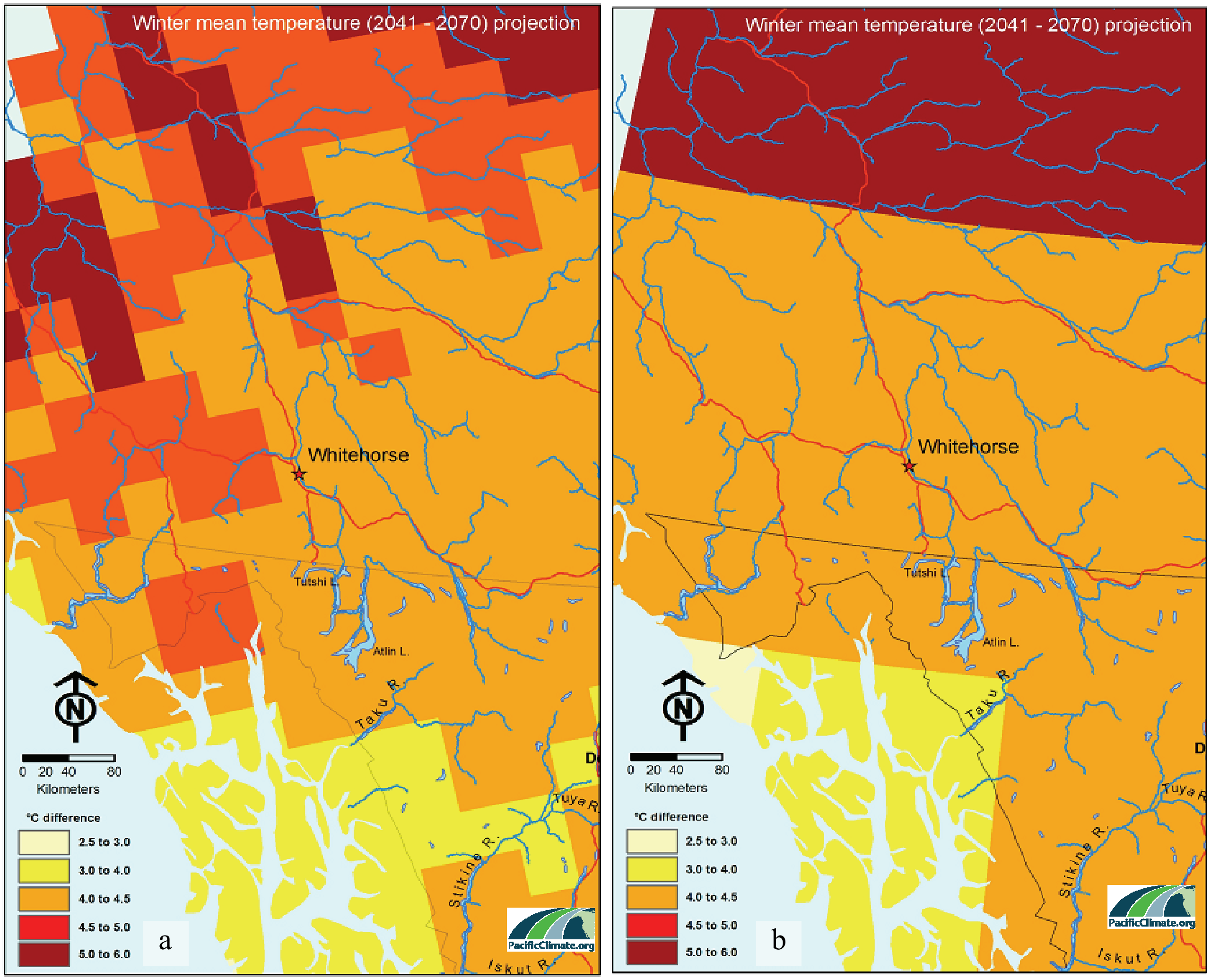

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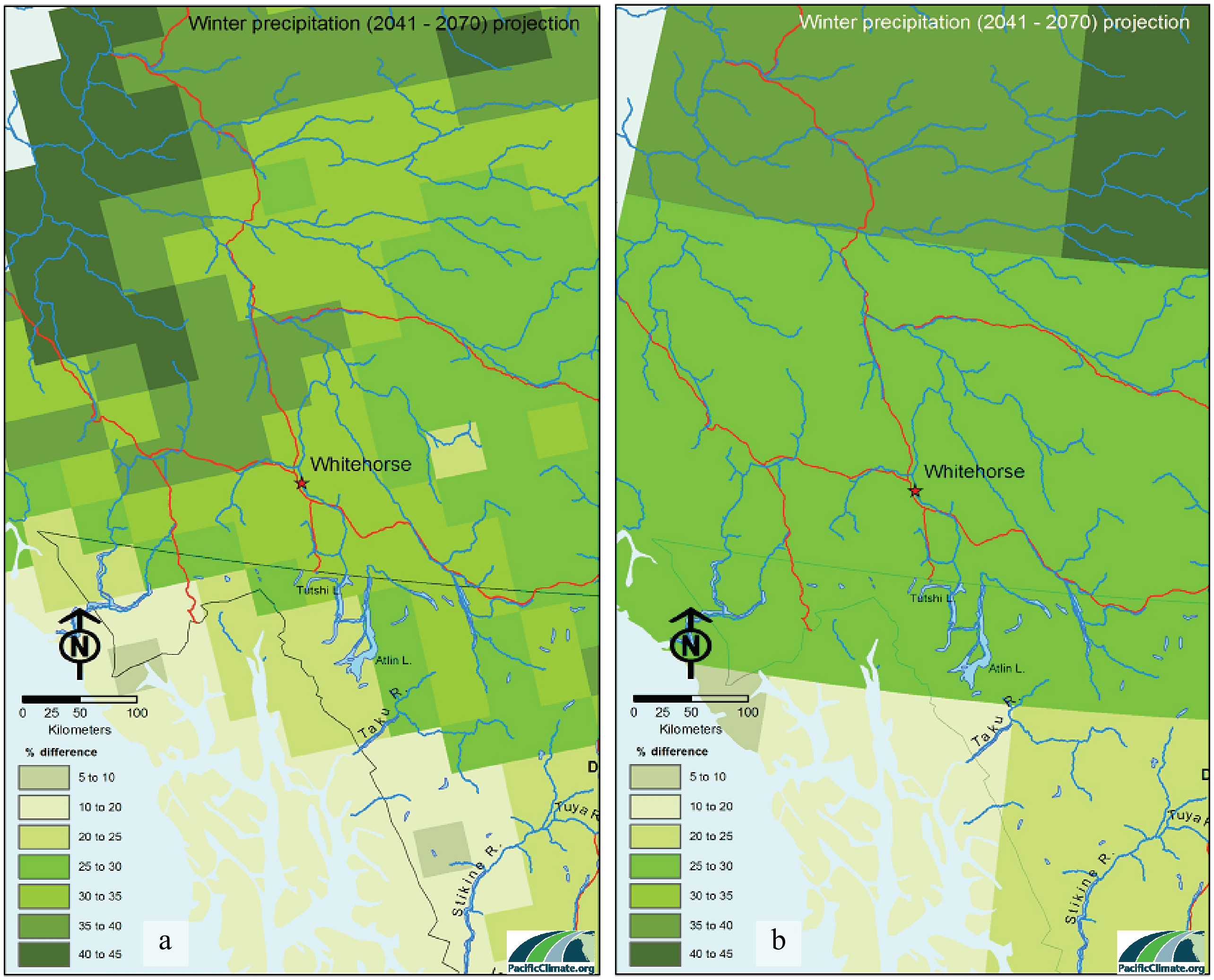

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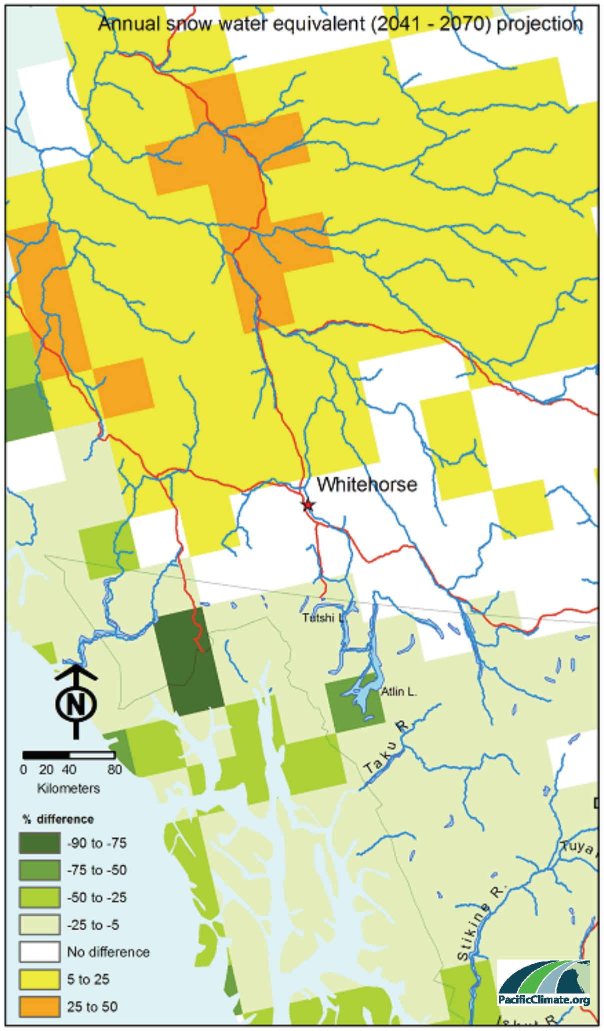

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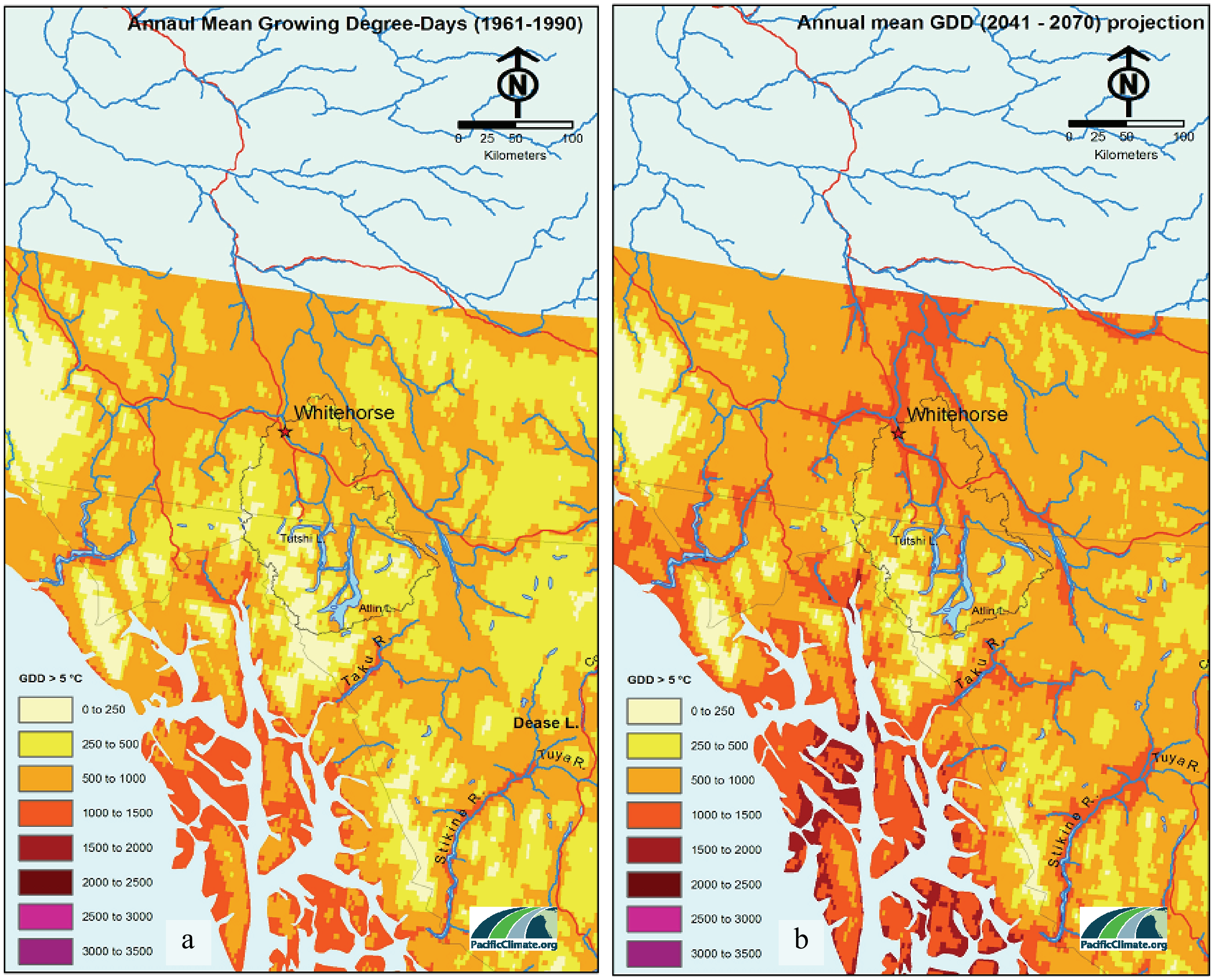

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