Responses to Interactive comments on Manuscript HESS-2016-511

Title: Evaluation of various daily precipitation products for large-scale hydro-climatic applications over Canada

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The review comments are in regular bold typeface, while all responses are in italics and indented paragraphs.

Response to Reviews by MSc student

Paper Summary

This paper sought to evaluate the performance and reliability of daily gridded precipitation products for Canada – based on seasonality and eco/hydro-zones. The aim of defining specific climatic/hydrological regions and factoring in seasonality was to relay more usability and relatability with the results. The authors identified a need for such study as few had been done previously which looked at precipitation products for Canada – although they do make reference to a study being conducted previously for "North America".

7 datasets were assessed which fell under 1 of 5 types of precipitation products: station-based, station-based model-derived, Reanalysis-based multiple-source, GCM statistically downscaled and GCM-driven RCM dynamically downscaled. These products were compared against direct precipitation-gauge data from an adjusted and homogenized dataset covering Canada, with the authors acknowledging the scarcity of gauges and lack of quantification of the uncertainty associated with this benchmark dataset.

A Kolmogorov-Smirnov test was done to compare the probability distributions of the products and 4 performance measures were carried out: Percentage of Bias, Root-mean-square-error, Correlation coefficient and Standard Deviation. Ultimately, the results indicated a strong conclusion was not possible that would name one product superior to all others. Rather, 9 concluding points were presented which cover various regions, seasons and performance measures.

> *We thank the reviewer for reviewing our manuscript and providing a very nice summary of our work. We have now addressed all of the comments and presented our responses below, with deleted materials being crossed out by drawing a line through them and revised sentences being coloured in red.*

Main points:

1. **Overall this study does fall under the scope of HESS and has a meaningful aim in assessing the reliability of precipitation products as these same datasets are the ones which feed into hydrological models. This type of work appears to no have been carried out on such a large scale previously, but perhaps setting out to analyze and summarize 7 datasets, over 15 regions and for all seasons is too grand for a single paper. It is apparent that widespread results exist, as evidenced by the conclusions that the performance of the products depended on both season and eco-zone. An alternative approach to add greater clarity to a project of this size could be to re-structure the format of the paper to present the results based on the zones assessed, perhaps in a tabular format. This would also help users of this study to efficiently compare, contrast and determine the best dataset for their needs (which was an objective of this study). Although the results, discussion and conclusion sections are presented in a convoluted manner, the outcome is still thorough and definitive conclusions are presented. As well, the performance measure methodology is clearly presented and would be easy to reproduce.**

    We appreciate the value of the reviewer's suggestion on the format of the presentation of results. We agree that presenting the results based on ecozones in a tabular format would be very efficient to compare and contrast only when several datasets (e.g. three to four) over a few regions (e.g. up to five) are involved in the analysis (i.e. up to 20 numbers in a table). However, when more datasets and more regions are involved, such as in our case (six datasets over 15 ecozones), efficiency might be significantly reduced when going through a tabular table with 90 numbers. We have already thought about different ways to present and summarize our results (e.g. tabular table, Taylor diagram, line graph, box and whisker plot) and identified portrait diagram (Figures 5 and 6 in the original manuscript), which is widely used in climate models comparison studies (e.g. Pincus et al., 2008;Sillmann et al., 2013), is the most suitable way to show the results which can highly condense information in one diagram.

2. **The precipitation data section is incredibly unclear. It would first be beneficial to break the section into further components, for example data sources, limitations and treatment. Secondly, the authors have presented a lengthy description on how data was gathered, complied and corrected, although all of this work was carried out in previous research.**

    We agree that we have a lengthy data description section as it is also commented by Reviewers 1. The details in Sections 3.1 and 3.2 will be greatly reduced in the revised manuscript. In short, the spatial and temporal resolutions of each product, their compositions, and examples of their applications will be remained and other details will be deleted. The following shows the revised Sections 3.1 and 3.2:

3.1 Precipitation-gauge station data

Climate data collection is coordinated by the Federal government of Canada. Agriculture and Agri-Food Canada maintains a few stations nationally especially in ~~Alberta province~~ province of Alberta. Also, most hydro-power companies collect their own data. However, their data are not made available to the public but are sent to Environment and Climate Change Canada for archiving prior to release. In other words, the National Climate Data Archive of Environment Canada provide the basis for all the available climate data. Based on the National Climate Data Archive of Environment Canada, there are a total of 1499 precipitation-gauge stations (as in 2012) across Canada. However, due to the addition and subtraction of climate stations over the past few decades, the number of stations with available precipitation data for specified time intervals varies greatly. For instance, the numbers of precipitation-gauge stations that were active in any given years over the period of 1961 to 2003 ranged from 2000 to 3000 (see Hutchinson et al. (2009) Figs 1 and 2 for details). The issue with these data is they are subject to various errors, among which the errors due undercatch are quite significant in Canada (Mekis and Hogg, 1999). In order to account for various measurement issues, Mekis and Vincent (2011) provided adjusted daily rainfall and snowfall data for 464 stations over Canada that were based on the Adjusted Precipitation for Canada dataset (Mekis and Hogg, 1999). The data extend back to 1895 for a few long-term stations and run through 2014. For these data, daily rainfall gauge and snowfall ruler data were extracted from the National Climate Data Archive of Environment Canada and adjustments of rain and snow were done separately~~. Regarding each rain gauge type, corrections for wind undercatch, evaporation and wetting losses were performed based on field experiments at various locations~~ (Devine and Mekis, 2008)~~. For snowfall, a density correction based on coincident ruler and Nipher gauge observations was applied to all snow measurements~~ (Mekis and Brown, 2010). ~~Adjustments were also implemented to account for trace precipitations and accumulated amounts from multiple days were distributed over the affected days to minimize the impact on extreme values and preserve the monthly totals.~~ Observations from nearby stations were sometimes combined to create longer time series ~~and adjustments were done either based on overlapping observations or standardized ratios between test sites and their neighbours~~ (Vincent and Mekis, 2009). As a result of adjustments, total rainfall amounts were concluded to be 5 to 10 % higher in southern Canada and more than 20 % in the Canadian Arctic than the original observations. The effect of the adjustments on snowfall were larger and more variable throughout the country. Despite the lack of a measure of associated uncertainty, this adjusted precipitation-gauge station dataset has been recognized and widely used for different analyses (e.g. Nalley et al., 2012;Shook and Pomeroy, 2012;Wan et al., 2013). Therefore, this dataset was used in this study as the reference to represent the best available precipitation measurement and as the benchmark for all gridded precipitation product comparisons.

3.2 Gridded precipitation products

Seven precipitation datasets were assessed. Table 1 provides a concise summary of these datasets, including their full names, and original spatial and temporal resolutions for the versions used. These particular datasets were chosen based on the following criteria: (1) a complete coverage of Canada; (2) minimum of daily temporal and 0.5° (~50 km) spatial resolutions; (3) sufficient lengths of data (>30 years) for long-term study and cover recent years up to 2012; and (4) representation of a range of sources/methodologies (e.g. station based, remote sensing, model, blended products). Note that other commonly used datasets including the monthly Canadian Gridded temperature and precipitation (CANGRD) dataset (Zhang et al., 2000) and the coarser resolution Japan Meteorological Agency 55-year Reanalysis (JRA-55) (Onogi et al., 2007;Kobayashi et al., 2015) and the Modern-Era Retrospective Analysis for Research and Applications (MERRA) (Rienecker et al., 2011) products were excluded as they do not meet criteria # 2 above.

3.2.1 Station-based product – ANUSPLIN

With the application of the Australian National University Spline (ANUSPLIN) model (Hutchinson, 1995;Hutchinson, 2004), Hutchinson et al. (2009) developed a climate dataset of daily precipitation and daily minimum and maximum air temperature over Canada at a spatial resolution of 300 arc-second of latitude and longitude (0.0833° or ~10 km) for the period of 1961 to 2003, using observed stations (from 2000 to 3000 in any given years over the period) recorded in the National Canadian Climate Data Archives of Environment Canada. However, to retain a better spatial coverage, no adjustments were done on the archive station data before the generation of the product. The dataset was generated to model the complex spatial patterns by using tri-variate thin-plate smoothing splines method that incorporated spatially continuous functions of latitude, longitude, and elevation. Hopkinson et al. (2011) subsequently extended this original dataset to include the period of 1950 to 2011. This ANUSPLIN product for Canada (hereafter the ANUSPLIN) ~~has first been quality controlled with various flags indicating trace values, accumulated values over multiple days, and missing and estimated values. The accuracy of the product was then assessed by withholding from the analyses 50 stations broadly representing the southern half of Canada and by examining the error statistics for the withheld stations. The ANUSPLIN dataset~~ has further been updated to 2013 and has recently been used as the basis of 'observed' data for evaluating different climate datasets (e.g. Eum et al., 2012) and for assessing the effects of different climate products in hydrological applications (e.g. Eum et al., 2014;Bonsal et al., 2013;Shrestha et al., 2012a).

3.2.2 Station-based model-derived product – CaPA

Initiated in November 2003 through collaborations within the Meteorological Service of Canada, the Canadian Precipitation Analysis (CaPA) was developed to produce a dataset *of 6-hourly precipitation accumulation over North America in real-time at a spatial resolution of 15 km from 2002 onwards (Mahfouf et al., 2007). The dataset was generated based on an optimum interpolation technique (Daley, 1993), which required a background field and a specification of error statistics between the observations and the background field (e.g. Bhargava and Danard, 1994;Garand and Grassotti, 1995). For Canada, the short-term precipitation forecasts from the Canadian Meteorological Centre (CMC)'s regional model, the Global Environmental Multiscale (GEM) (Cote et al., 1998a;1998b), were used as the background field with the rain-gauge measurements from the observational network as the observations. ~~The analysis was created by simple kriging to interpolate the differences between the transformed data of GEM and stations, which was then re-transformed and applied back to GEM. The quality of rain-gauge stations was controlled by cross-checking with the neighbouring stations and by comparing with the radar-derived precipitation. The accuracy of the product was assessed by generating an analysis error that represented the amount of additional information gained from the multiple observations with regard to the background field.~~ CaPA has become operational at the CMC in April 2011, with updates to the statistical interpolation method (Lespinas et al., 2015), increase of spatial resolution to 10 km and the assimilation of Quantitative Precipitation Estimates from the Canadian Weather Radar Network as an additional source of observations (Fortin et al., 2015b). With its continuous improvement and different configurations, CaPA has been employed in Canada for various environmental prediction applications (e.g. Eum et al., 2014;Fortin et al., 2015a;Pietroniro et al., 2007;Carrera et al., 2015). However, the study period of these applications only extended back to 2002.*

3.2.3 Reanalysis-based multiple-source products – Princeton, WFDEI, and NARR

Princeton

The Terrestrial Hydrology Research Group at the Princeton University initially developed a dataset of 3-hourly near-surface meteorology with global coverage at a 1.0° spatial resolution (~120 km) from 1948 to 2000 for driving land surface models and other terrestrial systems (Sheffield et al., 2006). The global dataset at the Princeton University (called hereafter the "Princeton") was constructed based on the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis (2.0° and 6-hourly) (Kalnay et al., 1996;Kistler et al., 2001), combining with a suite of global observation-based data including the Climatic Research Unit (CRU) monthly climate variables (New et al., 2000, 1999), the Global Precipitation Climatology Project (GPCP) daily precipitation (Huffman et al., 2001), the Tropical Rainfall Measuring Mission (TRMM) 3-hourly precipitation (Huffman et al., 2002), and the NASA Langley Research Center monthly surface radiation budget (Gupta et al., 1999). ~~Regarding precipitation, the dataset has undergone several stages in terms of spatial downscaling with the use of GPCP data, temporal downscaling based on sampling~~

~~from TRMM data, and the sophistication of the correction methods (a correction to the wet-day statistics (Sheffield et al., 2004), and monthly bias corrections to match those of the CRU data (Adam and Lettenmaier, 2003)). The Princeton dataset has been evaluated against the Second Global Soil Wetness Project (GSWP-2) product (Zhao and Dirmeyer, 2003).~~ With the inclusion of new temperature and precipitation data (e.g. Willmott et al., 2001), Princeton has been updated and is currently available at 1.0° (plus 0.5° and 0.25°), 3-hourly (plus daily and monthly) resolution globally for 1948 to 2008. Experimental updates including a 1901-2012 version at 1.0° (plus 0.5°), 3-hourly (plus daily and monthly) resolution are also available. Studies employing Princeton to study different hydrological aspects have been carried out over different parts of Canada (e.g. Kang et al., 2014;Su et al., 2013;Wang et al., 2013;Wang et al., 2014).

WFDEI

To simulate the terrestrial water cycle using different land surface models and general hydrological models, the European Union Water and Global Change (WATCH) Forcing Data (WFD) were created to provide datasets of sub-daily (3-hourly or 6-hourly) and daily meteorological data with global coverage at a 0.5° spatial resolution (~50 km) from 1901 to 2001 (Weedon et al., 2011). Similar to the composition of the Princeton dataset, the WFD were derived from the 40-year European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA-40) (1.0° and 3-hourly) (Uppala et al., 2005) and combined with the CRU monthly variables and the Global Precipitation Climatology Centre (GPCC) monthly data (Rudolf and Schneider, 2005;Schneider et al., 2008;Fuchs, 2009). ~~The generation of the WFD for 1958 to 2001, which was based on the ERA-40, followed the procedures developed by Ngo-Duc et al. (2005) and Sheffield et al. (2006) whereas the dataset for 1901 to 1957 was generated by using the reordered ERA-40 a year at a time. With respect to precipitation, the creation of the data (Weedon et al., 2010) involved spatially downscaling using the CRU data, sequential elevation correction, wet-day correction, monthly precipitation bias correction to match the GPCC data, and adjustment for gauge undercatch (Adam and Lettenmaier, 2003), however no corrections were made for orography effect (Adam et al., 2006). The same monthly bias corrections were also done using the CRU precipitation totals, resulting in two sets of precipitation data. The WFD were assessed by the FLUXNET data for selected years at seven sites (Araujo et al., 2002;Persson et al., 2000;Suni et al., 2003;Meyers and Hollinger, 2004;Grunwald and Bernhofer, 2007;Urbanski et al., 2007;Gockede et al., 2008).~~ The WATCH Forcing Data methodology applied to ERA-Interim (WFDEI) dataset has further been generated covering the period of 1979 to 2012 (Weedon et al., 2014). The WFDEI used the same methodology as the WFD, but based on the ERA-Interim (Dee et al., 2011) with higher spatial resolution (0.7°)~~, better data assimilation technique, updated monthly observation-based data, more extensive incorporation of observations, and correction of the most extreme cases of inappropriate precipitation phase~~. As for the WFD, the WFDEI *had two sets of rainfall and snowfall data generated by using either CRU or GPCC precipitation totals (hereafter the WFDEI [CRU] and WFDEI [GPCC] respectively). To date, specific studies using the WFDEI related to Canada has been limited to the studies of permafrost in the Arctic regions (e.g. Chadburn et al., 2015;Park et al., 2015;Park et al., 2016) but the WFDEI could be a potential source in other environmental applications in Canada.*

NARR

Concerning the spatial and temporal water availability in the atmosphere, the North American Regional Reanalysis (NARR) was developed to provide datasets of 3-hourly meteorological data for the North America domain at a spatial resolution of 32 km (~0.3°) covering the period of 1979 to 2003 as the retrospective system and is being continued in near real-time (currently up to 2015) as the Regional Climate Data Assimilation System (R-CDAS) (Mesinger et al., 2006). The components in generating NARR included the NCEP-DOE reanalysis (Kanamitsu et al., 2002), the NCEP regional Eta Model (Mesinger et al., 1988;Black, 1988) and ~~its Data Assimilation System, a recent version of~~ the Noah land-surface model (Mitchell et al., 2004;Ek et al., 2003), and the use of numerous additional data sources (see Mesinger et al., 2006 Table 2). ~~The use of NCEP-DOE reanalysis was a major improvement upon the earlier NCEP-NCAR reanalysis in both resolution and accuracy to provide lateral boundary conditions. Regarding precipitation assimilation scheme, the NARR adjusted the accumulated convective and grid-scale precipitation, assimilated the precipitation observations as latent heating profiles based on the differences between the modelled and observed precipitation (Lin et al., 1999), and disaggregated into hourly resolution using different sources over lands and oceans. For the period from 1979 to 2003 when NARR was run as the retrospective system, precipitation analyses over the continental United States (CONUS), Mexico, and Canada were derived solely from a gridded analysis of 24-hour rain-gauge measurements. For the period from 2004 onwards, NARR was generated in near-real time by the R-CDAS, which was identical to the retrospective NARR except for changes in input sources and their processing because of the real-time production constraints. One of the major differences was the use of radar-dominated precipitation analyses derived from the National Land Data Assimilation System (NLDAS) (Mitchell et al., 2004) over CONUS to disaggregate the 24-hour rain-gauge analysis to hourly precipitation whereas no assimilation was done over Canada due to the paucity of rain-gauge observations.~~ On the basis of hydrological modelling in Canada, Choi et al. (2009) found that NARR provided reliable climate inputs for northern Manitoba while Woo and Thorne (2006) concluded that NARR had a cold bias resulting in later snowmelt peaks in subarctic Canada. In addition, Eum et al. (2012) identified a structural break point in the NARR dataset over the Athabasca River basin.

3.2.4 GCM statistically downscaled products – PCIC

The Pacific Climate Impacts Consortium (PCIC), which is a regional climate service centre at the University of Victoria, British Columbia, has offered datasets of statistically downscaled daily precipitation and daily minimum and maximum air temperature under three different Representative Concentration Pathways (RCPs) scenarios (RCP 2.6, RCP 4.5, and RCP 8.5) (Meinshausen et al., 2011) over Canada at a spatial resolution of 300 arc-second (0.833° or ~10 km) for the historical and projected period of 1950 to 2100 (Pacific Climate Impacts Consortium; University of Victoria, Jan 2014). These downscaled datasets were a composite of 12 GCM projections from the Coupled Model Inter-comparison Project Phase 5 (CMIP5) (Taylor et al., 2012) and the ANUSPLIN dataset. The historical 1950 to 2005 period of the ANUSPLIN was used to drive the GCMs and the statistical properties and spatial patterns of the downscaled outputs tended to resemble those of the ANUSPLIN. ~~However, the timing of natural climate variability (e.g. El Niño-Southern Oscillation) in the observational record were not considered since GCMs were solved as a 'boundary value problem'.~~ Two different downscaling methods were used to downscale to a finer resolution. The first one was Bias Correction Spatial Disaggregation (BCSD) (Wood et al., 2004) following Maurer and Hidalgo (2008) and the second was Bias Correction Constructed Analogues (BCCA) with Quantile mapping reordering (BCCAQ) which was a post-processed version of BCCA (Maurer et al., 2010) . ~~In general, the most important distinction between the two methods was BCCAQ obtained spatial information from a linear combination of historical analogues for daily values and retained the daily sequencing of weather events from the coarse resolution, while BCSD only used monthly averages to reconstruct daily patterns by randomly resampling a historic month and scaling its daily values to match the monthly projected values.~~ The ensemble of the PCIC dataset has currently been used in studying the hydrological impacts of climate change on river basins mainly in British Columbia (e.g. Shrestha et al., 2011;Shrestha et al., 2012b;Schnorbus et al., 2014) and Alberta (e.g. Kienzle et al., 2012;Forbes et al., 2011) in Canada. In this study, only four GCMs with two respective statistically downscaling methods under RCP 4.5 and 8.5 were chosen for comparison (see Table 2 for details). The choice of selecting the four GCMs under RCP 4.5 and 8.5 only in the PCIC dataset was to match those GCMs available in the NA-CORDEX dataset (see next section for details).

3.2.5 GCM-driven RCM dynamically downscaled products – NA-CORDEX

Sponsored by the World Climate Research Programme (WCRP), the COordinated Regional climate Downscaling EXperiment (CORDEX) over North America domain (NA-CORDEX) was launched to provide dynamically downscaled datasets of 3-hourly or daily meteorological data over most of North America (below 80° N) at two spatial resolutions of 0.22° and 0.44° (or 25 and 50 km) under two different RCPs (RCP 4.5, and RCP 8.5) for the historical and projected period of 1950 to 2100 (Giorgi et al., 2009). ~~Within the NA-CORDEX framework, a matrix of six GCMs from the CMIP5 driving six different RCMs was selected to compare the performance of RCMs and characterize the uncertainties~~

~~*underlying regional climate change projections and thus provided climate scenarios for further impact and adaption studies.*~~ *On top of the knowledge and experience gained from the North American Regional Climate Change Assessment Program (NARCCAP) (Mearns et al., 2012), a matrix of six GCMs from the CMIP5 driving six different RCMs was selected to compare the performance of RCMs and characterize the uncertainties underlying regional climate change projections and thus provided climate scenarios for further impact and adaption studies.* ~~*the selection of GCM-RCM matrix of simulations, with higher spatial resolution and greater sampling of uncertainty, was based on model climate sensitivity and quality of boundary conditions. In addition, to determine the large variations in future climate due to internal variability of the GCMs on downscaled outputs, samples among multiple realizations of GCM simulations were used to drive the RCMs. The performance of participating RCMs in reproducing historical and projected climate was then assessed by comparing the ERA-Interim-driven RCM simulations.*~~ *Current studies using NA-CORDEX datasets were mainly focused on evaluating the model performance of different GCM-driven RCM simulations over North America (e.g. Lucas-Picher et al., 2013;Martynov et al., 2013;Separovic et al., 2013) but the NA-CORDEX dataset could also be a potential source in hydro-climatic studies in Canada. In this study, only two GCMs with three RCMs were chosen for comparison due to the availability of the NA-CORDEX dataset (see Table 3 for details).*

3. **What is lacking is a better description toward the end of the section to outline why exactly this reference dataset was selected despite it clearly having major deficiencies. Three studies are referenced with regards to this dataset being widely used yet no further information is presented. This reference dataset is an integral piece of the analysis, all of the datasets are being compared to it, therefore it is not enough to only state that it "has been recognized". It would make more sense to outline in detail why it is being used rather than how it came to be as that work has already been done.**

   We will further explain and justify the reasons of using Mekis and Vincent (2011) as our reference in the revised manuscript, which is shown as follows:

   > *Despite the lack of a measure of associated uncertainty, this adjusted precipitation-gauge station dataset has been recognized and widely used for different analyses (e.g. Nalley et al., 2012;Shook and Pomeroy, 2012;Wan et al., 2013). Since there are no readily reliable daily gridded precipitation data for Canada as viable alternatives,* ~~*Therefore,*~~ *this dataset was therefore used in this study as the reference to represent the best available precipitation measurement and as the benchmark for all gridded precipitation product comparisons.*

4. **This study was done for a large scale and included a number of variables. Textually the results are quite difficult to follow and there is an abundance of figures provided to illustrate these results, but they too are quite dense. A solution would be to either separate, enlarge or regroup the figures to add clarity and meaning to the results, and**

by doing so much of the text can be condensed to include key references to the figures without spelling out each result.

We agree that some of the figures are too dense as it is also commented by both Reviewers 1 and 2. However, we believe that Figures 1, 5 to 8 are clear enough to show the messages and therefore we will only enlarge the figures as much as possible in the revised manuscript. In response to comment 3 of Reviewer 1, we decide to limit the evaluation period to 2005 instead of 2012 for the climate model products. Accordingly, Figures 2, 3, and 4 in the original manuscript will be reproduced to reflect the change. In short, the evaluation for the climate model products from the period of 1979 to 2005 will be shown separately from that of station-based and reanalysis-based products. Thus, Figures 3 and 4 will only show the distributions of p-value of the K-S test for the station-based and reanalysis-based products and a new Figure 5 will be created to show the distributions of p-value of the K-S test for climate model products in the revised manuscript. The numbering of Figures 5 to 8 will also be changed accordingly. Note that all the figures in the supplementary materials will also be subject to the same changes as aforementioned but will not be shown here. The revised figures are shown as follows:

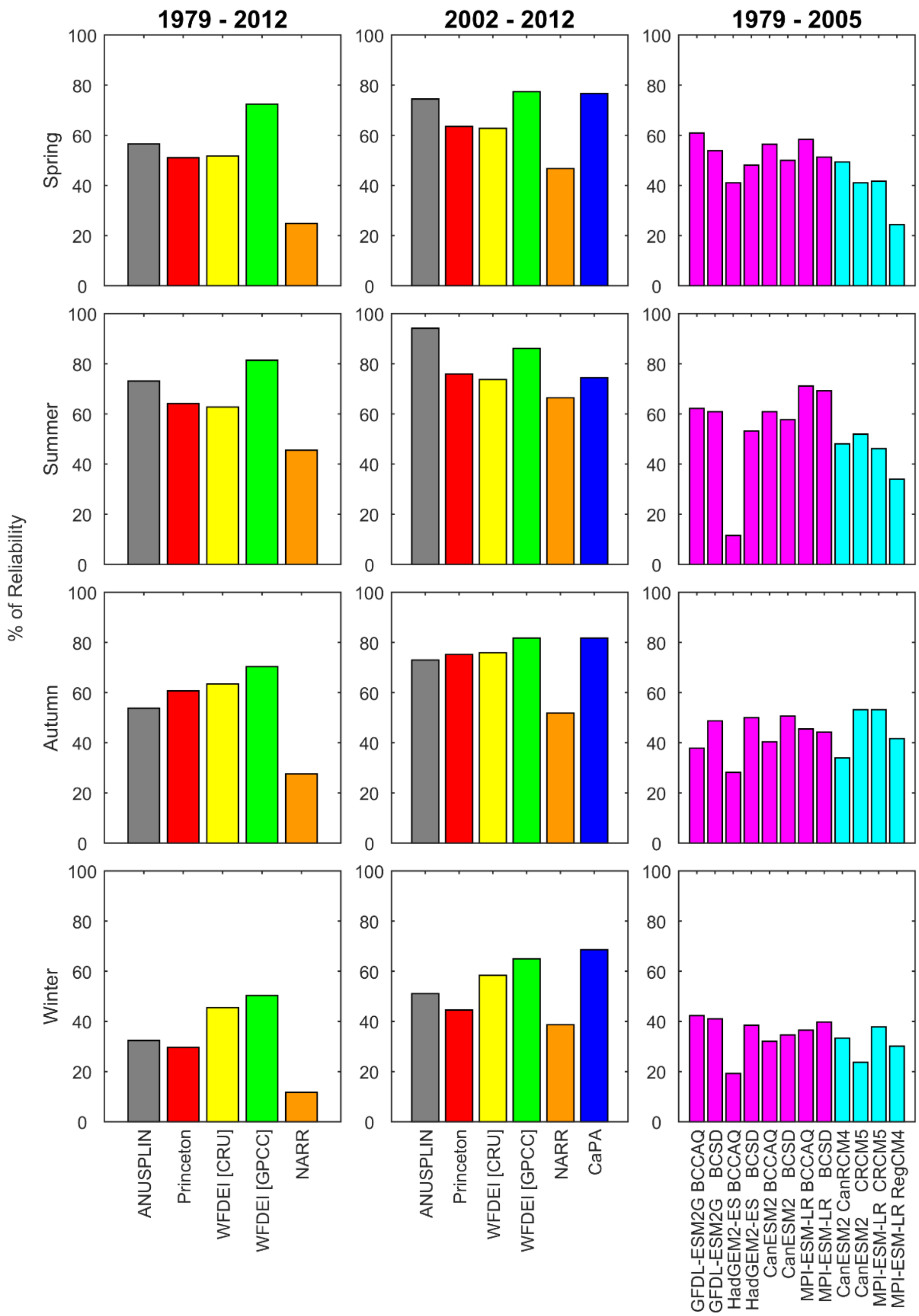

Figure 1. The percentage of reliability, calculated by the Eq. (1), of each precipitation dataset in four seasons for the period of 1979 to 2012 (left panel) and 2002 to 2012 (right panel) across Canada. The higher the percentage, the more reliable the precipitation dataset. Different colours represent different precipitation products, with magenta representing the whole PCIC datasets and cyan representing the whole NA-CORDEX datasets. The full names of the precipitation products are provided in Tables 1, 2, and 3.

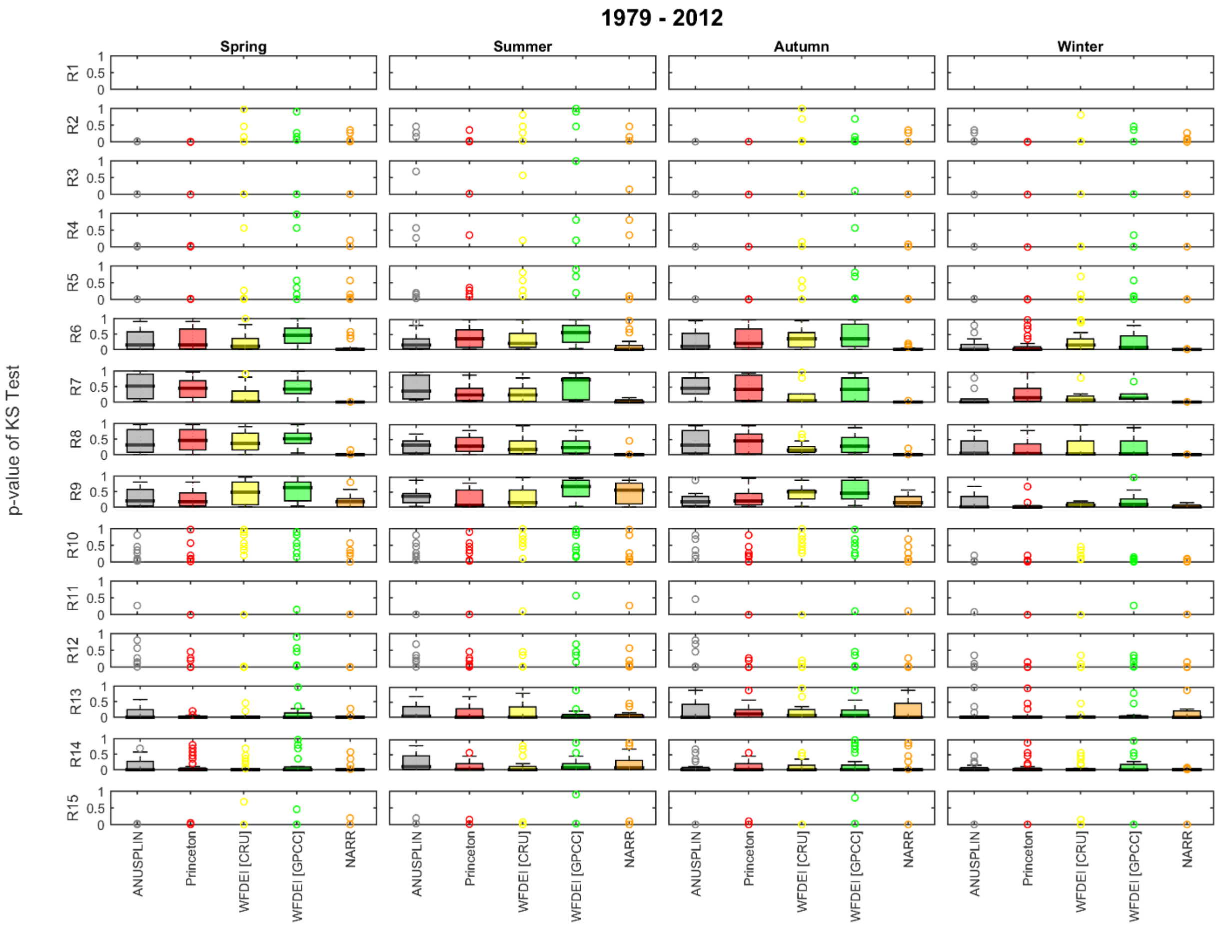

Figure 2. Distributions of p-value of the K-S test in the 15 ecozones in four seasons for the period of 1979 to 2012 (long-term comparison without CaPA). Note that the numbers of precipitation-gauge stations in each ecozone are different (see Table 4). Each hollow circle represents one p-value of the K-S test conducted at one precipitation-gauge station, with no stations in Region 1 (R1). The p-values of Regions 6 to 9, and 13 to 14 (R6-R9, and R13-R14), which have more than or equal to 10 stations, were shown in box-whisker plots with bottom, band (black thick line) and top of the box indicating the 25th, 50th (median), and 75th percentiles, respectively.

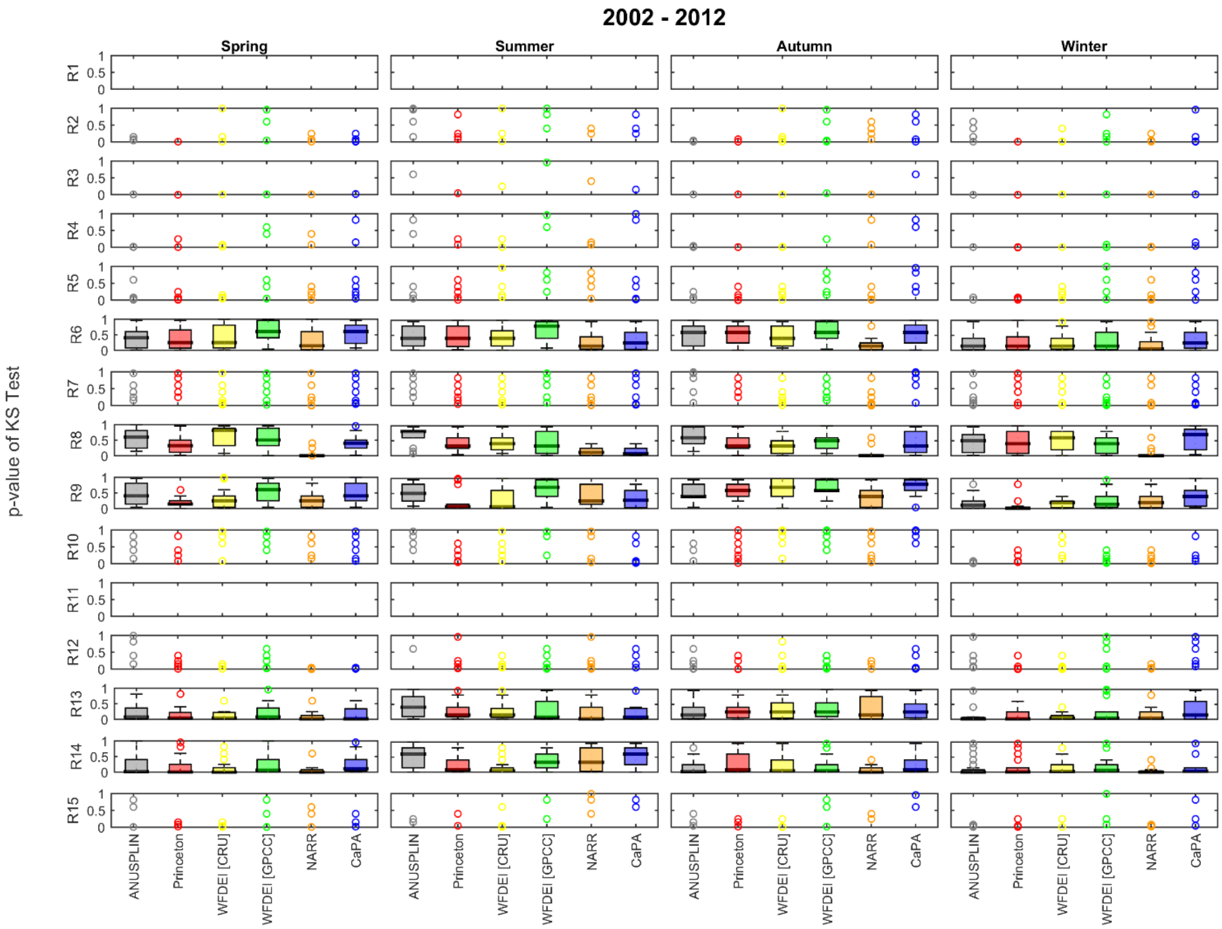

Figure 3. Distributions of p-value of the K-S test in the 15 ecozones in four seasons for the period of 2002 to 2012 (short-term comparison with the inclusion of CaPA). Note that the numbers of precipitation-gauge stations in each ecozone are different (see Table 4). Each hollow circle represents one p-value of the K-S test conducted at one precipitation-gauge station. The percentage of missing values in precipitation-gauge station in Region 11 (R11) exceeded 10% and thus no K-S test was conducted. The p-values of Regions 6, 8 to 9, and 13 to 14 (R6, R8-R9, and R13-R14), which have more than or equal to 10 stations, were shown in box-whisker plots with bottom, band (black thick line) and top of the box indicating the 25th, 50th (median), and 75th percentiles, respectively.

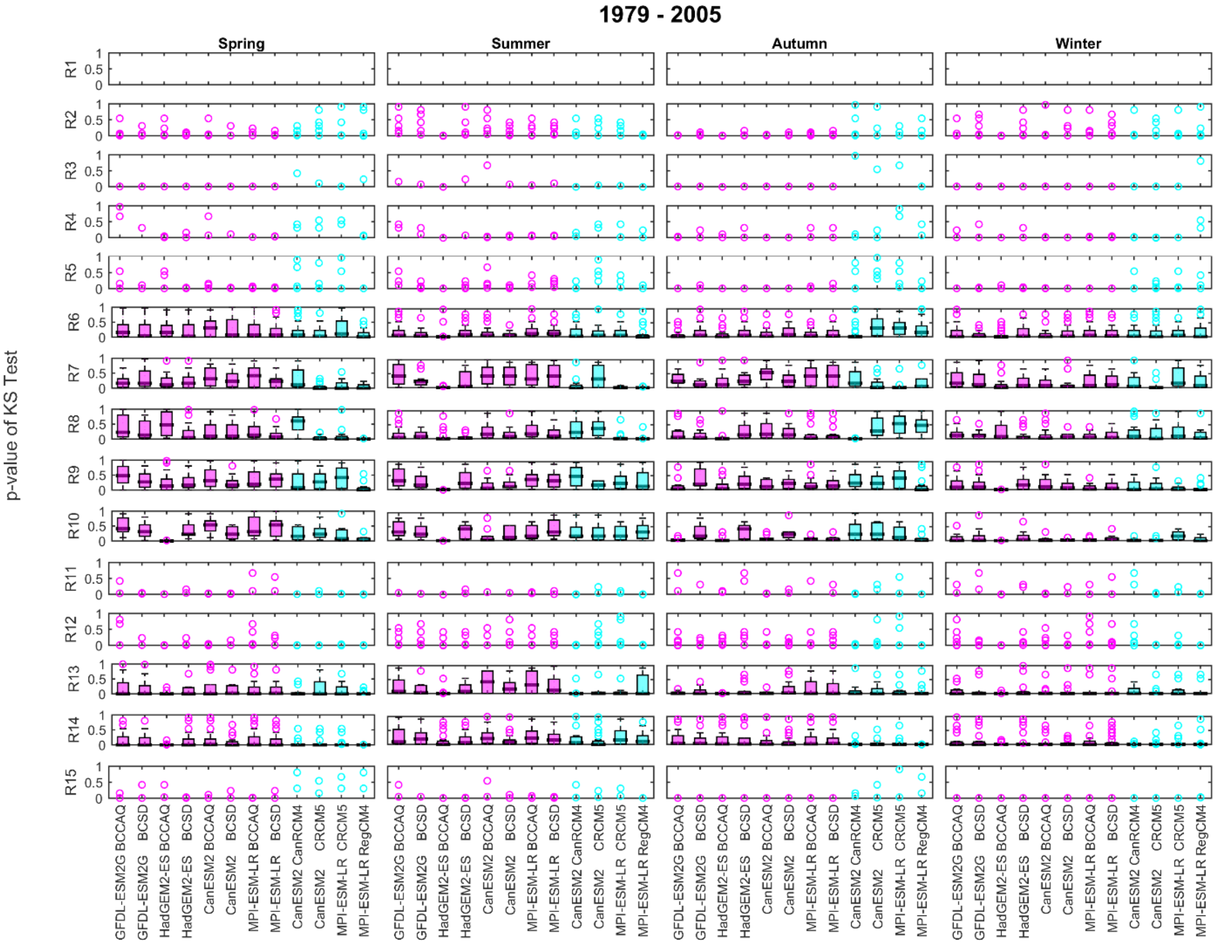

Figure 4. Distributions of p-value of the K-S test in the 15 ecozones in four seasons for the period of 1979 to 2005 (long-term comparison of PCIC and NA-CORDEX). Note that the numbers of precipitation-gauge stations in each ecozone are different (see Table 4). Each hollow circle represents one p-value of the K-S test conducted at one precipitation-gauge station, with no stations in Region 1 (R1). The p-values of Regions 6 to 9, and 13 to 14 (R6-R9, and R13-R14), which have more than or equal to 10 stations, were shown in box-whisker plots with bottom, band (black thick line) and top of the box indicating the 25th, 50th (median), and 75th percentiles, respectively.

Minor Points.

5. **Title: the word various does not add any meaning. It can be removed or the count of precipitation products can be used in its place.**

   We agree that the word various does not add much meaning in the tile and we decide to remove the word in the revised manuscript. Also, in response to comment 2 of Reviewer 1, we will change the title from "Evaluation" to "Inter-comparison" to better reflect our aim of the study. The title in the revised manuscript will become:

   > *Inter-comparison of daily precipitation products for large-scale hydro-climatic applications over Canada*

6. **Abstract: should list the precipitation products under review, as well, mentions a "systematic analysis framework" but the paper does not read as though any framework has been developed.**

   We fully understand that it is essential to list the precipitation products under review in the abstract. However, given the numbers of precipitation products we analyzed and the length of the full names of the products, listing the products in the abstract takes so much room which then limit the messages we can deliver from our study. Therefore, we prefer saving the space for telling the main findings of our study which are more important to the readers and decide not to add the list of the products in the revised abstract. We will delete "systematic analysis framework" and reduce the length of the abstract when responding to comment 1 of Reviewer 2, which is shown as follows:

   > *A number of global and regional gridded climate products based on multiple data sources and models are available that can potentially provide ~~better and~~ more reliable estimates of precipitation for climate and hydrological studies. However, research into the reliability of these products for various regions has been limited and in many cases non-existent. This study identifies several gridded precipitation products and ~~over Canada and develops a systematic analysis framework to assess the characteristics of errors associated with the different datasets, using the best available adjusted precipitation gauge data as a benchmark over the period 1979 to 2012. The framework~~ quantifies the spatial and temporal variability of the errors over 15 terrestrial ecozones in Canada for different seasons over the period 1979 to 2012 at 0.5° and daily spatiotemporal resolution ~~at the daily time scale~~. Results showed that most of the products were relatively skillful in central Canada. However, they tended to overestimate precipitation amounts on the west coast and underestimate on the east and especially in northern Canada (above 60° N). ~~but tended to underestimate precipitation amounts on the east coast and overestimate on the west~~. The global product by WATCH Forcing Data ERA-Interim (WFDEI) augmented by Global Precipitation Climatology Centre (GPCC) data (WFDEI [GPCC]) performed best with respect to different metrics. The Canadian Precipitation Analysis (CaPA) product of Meteorological Service of Canada,*

performed comparably with WFDEI [GPCC], however it only provides data from 2002. All the products performed best in summer, followed by autumn, spring, and winter in order of decreasing quality. ~~Due to the sparse observational network, northern Canada (above 60° N) was most difficult to assess with the majority of products tending to significantly underestimate total precipitation.~~ Results from this study can be used as a guidance for potential users regarding the performance of different precipitation products for a range of geographical regions and time periods.

7. **Structure and Content: needs reworking.**

- **P15:L28: references Section 2.1 which does not exist. Should reference section 3.1 instead.**

  Thank you for spotting out this mistake. We will correct the referencing to Section 3.1 in the revised manuscript, which is shown as follows:

  > *To identify the most consistent gridded dataset corresponding to different seasons and regions across Canada, comparisons of each gridded product with direct precipitation-gauge station data from the Canadian adjusted and homogenized precipitation datasets of Mekis and Vincent (2011) (see Sect. ~~2.1~~3.1) were carried out.*

- **Study area includes a discussion of data collection.**

  We are unsure what the reviewer means by "a discussion of data collection" and we believe that we have discussed the overview of data availability in Canadian situation in the second paragraph of Section 2 [P7:L9-30] and we have also provided the data descriptions in Section 3 in the original manuscript. Also, we believe that it is better to separately describe the study area and data collection given the amount of datasets being analyzed which otherwise it will be too long for one section.

- **Introduction should be presented on its own. "Precipitation measurements and their limitations" and "Objectives and Scope" should not be in the introduction.**

  Thank you for your suggestion. We think that having the subheadings in the introduction helps the readers to better understand and to faster grasp the ideas of the paragraphs. Therefore, we decide to keep the subheadings in the revised manuscript.

- **Most of section 3.2 can be removed and inserted as a summary table as it completely references the outcome of prior studies.**

  The details in Section 3.1 and 3.2 will be greatly reduced in the revised manuscript and the changes are shown in the response to comment 2. We do have a summary table (Table 1) in the original manuscript to provide an overview of the datasets being compared.

8. **Language: an edit should be conducted to check for grammar and sentence structure. Examples:**

The results point on P28:15 contains 3 sets of parentheses in a single sentence.

We will delete one set of parentheses in the revised manuscript, which is shown as follows:

In northern Canada (above 60° N), the different products tended to moderately (ranging from -0.6 % to -40.3 %) ~~(~~and in cases significantly (up to -60.3 % in Taiga Cordillera)~~)~~ underestimate total precipitation, while reproducing the timing of daily precipitation rather well. It should be noted that this assessment was based on only a limited number of precipitation-gauges in the north.

The sentence on P7:L20 ends with "along the southern Canada".

We will change the sentence in the revised manuscript, which is shown as follows:

The Meteorological Service of Canada has implemented a network of 31 radars (radar coverage at full range of 256 km) along ~~the~~ southern Canada (see Fortin et al. (2015b) Fig. 1 for spatial distribution).

P8:L4 refers to the province of Alberta as Alberta province.

We will change "Alberta province" to "province of Alberta" in the revised manuscript, which is shown as follows:

Climate data collection is coordinated by the Federal government of Canada. Agriculture and Agri-Food Canada maintains a few stations nationally especially in ~~Alberta province~~ province of Alberta.

9. **References: ample amount of references but this is appropriate given the amount of datasets being analysed. Though several references appear dated, for example the Radar Reflectivity and Surface Rainfall paper likely had several further advances on the topic since 1987.**

We agree that the Austin (1987) reference is a bit outdated and there are further advances in addressing the errors in rain-rate reflectivity by the radar. We will update and replace Austin (1987) reference in the revised manuscript by Villarini and Krajewski (2010), which is shown as follows:

Villarini, G., and Krajewski, W. F.: Review of the Different Sources of Uncertainty in Single Polarization Radar-Based Estimates of Rainfall, Surv Geophys, 31, 107-129, 10.1007/s10712-009-9079-x, 2010.

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