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Development of Bi-National Precipitation Anomalies in both the United States and Canada in the Great Lakes Basin

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Abstract

In 2016-2017, the Midwestern Regional Climate Center (MRCC) developed the merged Bi-National Precipitation Tool to allow for the best precipitation product from both Canada and the US to be used by the public in both countries. It was specifically developed to support the request of the International Joint Commission (IJC) and the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data to improve precipitation monitoring and science in the Great Lakes. This tool serves as an example of how the hindcast data can be distributed for advantageous use by experts in both Canada and the United States. As a result of this contract, the MRCC developed anomalies of the merged Canadian Precipitation Analysis (CaPA) and the U.S. Multisensor Precipitation Estimates (MPE) precipitation data based on averages of daily data from 2004-2018. These anomalies are readily-available to the public through the existing product interface at **(https://mrcc.illinois.edu/gismaps/naprecip.htm)**.

Introduction

The Great Lakes Adaptive Management (GLAM) Committee is directed by the International Joint Commission (IJC) to assess how the hydrological and climatological conditions may be changing in the Great Lakes and the St. Lawrence River Basin, and to identify the impacts that the changes will have on future lake levels and flows. Previously, to aid with this goal the MRCC had developed a daily precipitation dataset that used both the Canadian Precipitation Analysis (CaPA) and the U.S. Multisensor Precipitation Estimates (MPE) to create a "merged" dataset. This merged dataset combined the two national datasets around the Canada – United States border and across the Great Lakes to produce an average of the two. All three datasets were available through the internet via a mapped visualization at **(https://mrcc.illinois.edu/gismaps/naprecip.htm)** and for download from 2002-present at **(https://mrcc.illinois.edu/cliwatch/northAmerPcpn/getArchive.jsp)**.

While the three datasets could easily be compared, neither the datasets nor the existing visualization provided understanding of where values fit in the historical perspective. Through this effort, the MRCC provided contextualized historical precipitation data in the form of daily precipitation departures to aid in the creation of a baseline used in regional climate comparisons and future hydraulic models. Four major milestones were developed to fulfill this need.

1. Develop a historical mean daily precipitation grid for each day of the year based on the merged CaPA/MPE product. The mean daily grids are based on the 2004-2018 period of record.
2. The historical mean daily CaPA/MPE merged precipitation over the 2004-2018 period that serves to create the anomaly product by subtracting the historical mean product from the "observed" merged product.
3. The anomaly merged product is available at daily, monthly, and seasonal periods.
4. This anomaly product serves as a foundation for collaboration between the U.S. and Canadian governments on Great Lakes precipitation coordination. It also serves as a product within the joint Canada/United States Quarterly Great Lakes Newsletter for anomalies of precipitation in the Great Lakes. This product is now available to all, including representatives from industry, government, and academia.

Methods

The following describes the two datasets used as inputs for the merged product as well as how the merged product was produced. Subsequently, the development of the anomaly product and its availability are discussed.

Canadian Precipitation Analysis (CaPA)

The Regional Deterministic Precipitation Analysis (RDPA) configuration of the Canadian Precipitation Analysis (CaPA)[1] is a real-time gridded precipitation product provided by Environment and Climate Change Canada (ECCC). The grid has a resolution of approximately 10 km and the domain covers all of North America (Canada, USA and Mexico) (Fig. 1). It uses gauge data, radar reflectivity and GOES imagery to modify a trial field provided by the Global Environmental Multiscale (GEM) numerical weather prediction model[2] using a statistical interpolation technique. The product has been operational only since April 2011, but a hindcast that goes back to 2002 is available from ECCC[3]. The product is constantly being improved, with updates occurring once or twice per year.

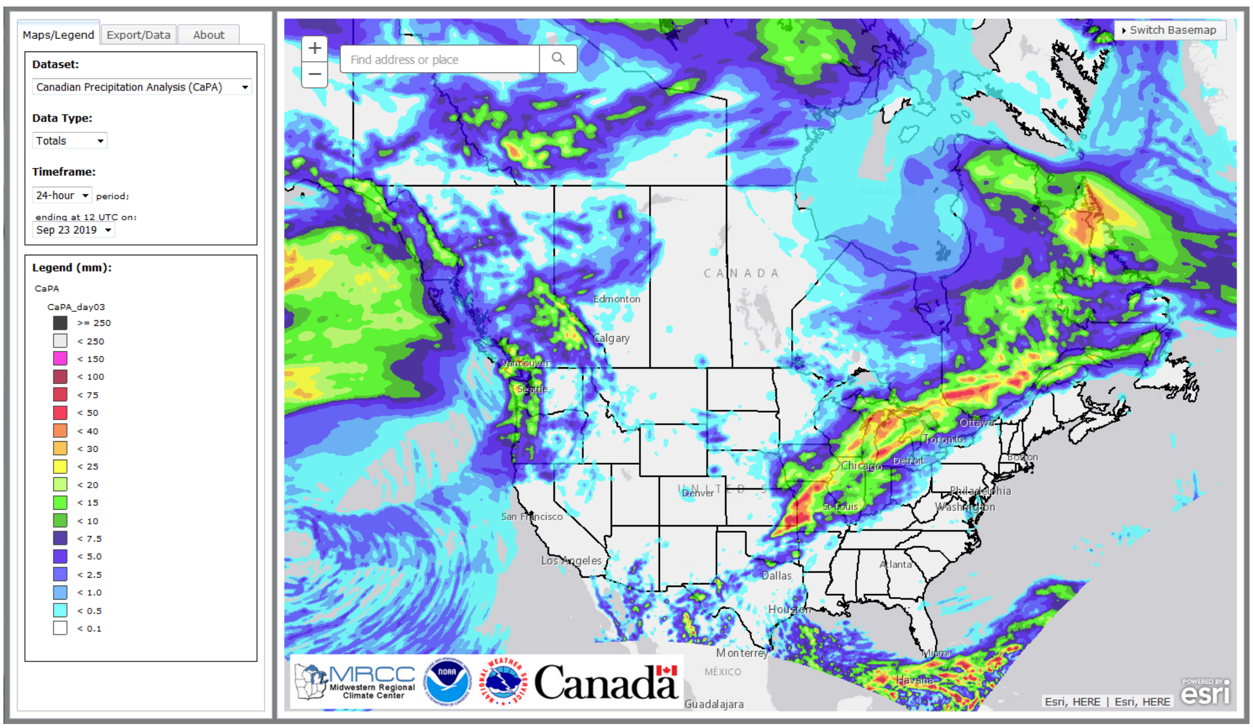

Fig. 1. CaPA derived grid - 10km cell size

Multi-sensor Precipitation Estimate (MPE)

Hydro-meteorologists at the National Weather Service's (NWS's) 13 River Forecast Centers (RFCs) utilize the Multi-sensor Precipitation Estimator (MPE) to produce rainfall estimates that cover the 48

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[1] RDPA – CaPA website (https://weather.gc.ca/grib/grib2_RDPA_ps10km_e.html)
[2] GEM Website (http://collaboration.cmc.ec.gc.ca/science/rpn/gef_html_public/index.html)
[3] Canadian Meteorological Centre (CMC) – CaPA Webpage (http://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/submenus/capa_e.html)

contiguous United States as well as portions of Canada and Mexico (Fig. 2). MPE uses radar precipitation estimates from NWS radars, as well as some U.S. Department of Defense radars. It also uses hourly rain gage data and satellite precipitation estimates. Other previously processed rainfall estimates can also be utilized, such as the National Severe Storms Labs (NSSL) Multi-Radar/Multi-Sensor (MRMS) data. These inputs are then manually analyzed at the RFCs to produce the day's best precipitation estimate on a 4 km grid on a 1-hour time step. Hourly estimates began to be produced in the mid-1990s, resulting in a 20+ year data set.

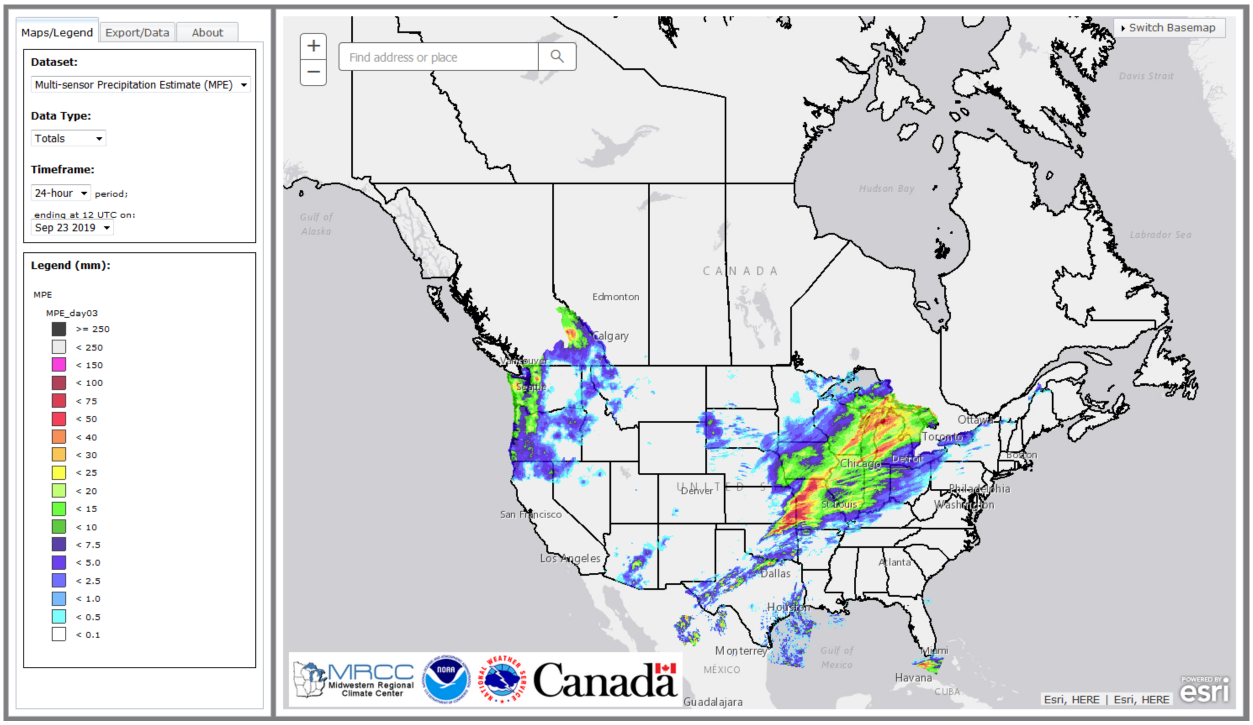

Fig.2. MPE derived grid - 4km cell size

Merged CaPA/MPE Dataset

The merged dataset is created daily by a Python script using ESRI ArcGIS software. The following process results in a combination of the CaPA and the MPE datasets. Outside of the contiguous 48 United States, the CaPA data are copied using the 'Extract by Mask' tool, without further processing (Fig. 4). Within the contiguous 48 states, the MPE data are resampled from their original 4-km cell size (Fig. 5) to a 10-km cell size (Fig. 6) using a bilinear resampling type, and then copied (Fig. 7). Additionally, a 10-km buffer polygon was created on either side of the boundary between Canada and the contiguous 48 United States. This polygon was extended to completely cover the Great Lakes as well. From both input datasets, point features intersecting this polygon are selected and appended into a single point feature class. An inverse distance weighted interpolation with a power setting of 0.5 and 10-point variable search radius is used to create a new raster dataset with a 10-kilometer cell size (Fig. 8). Finally, the interpolated raster data is mosaicked with the appropriate parts of the CaPA and resampled MPE data described above, using the 'mean' mosaic method (Fig. 9).

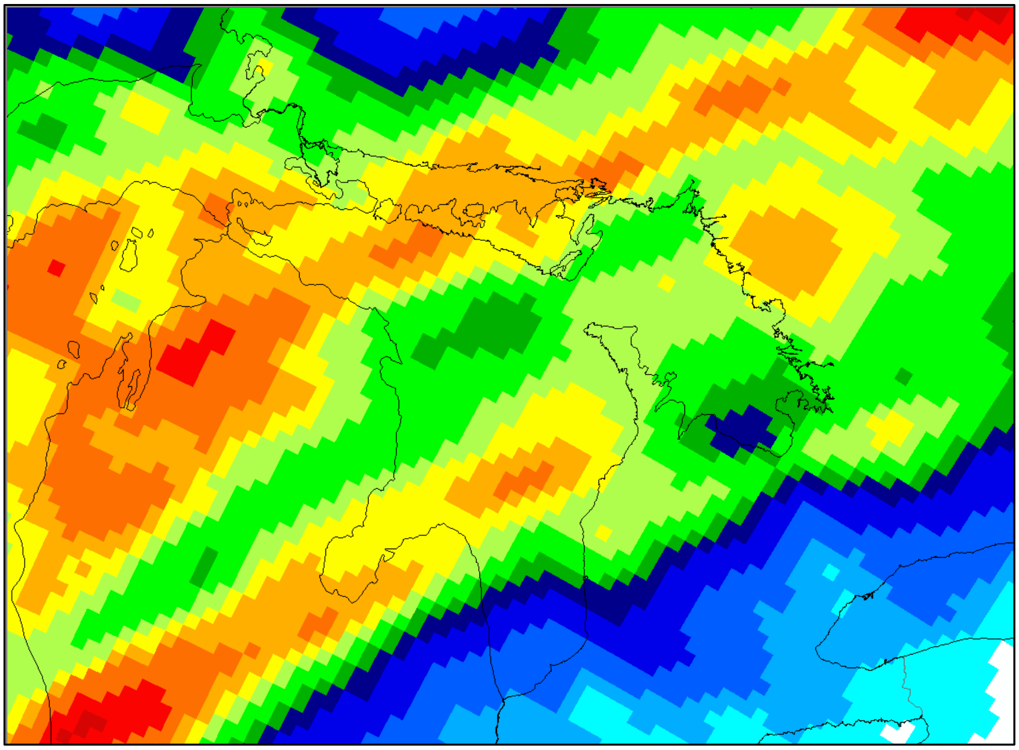

Fig. 3. CaPA derived raster - 10km cell size

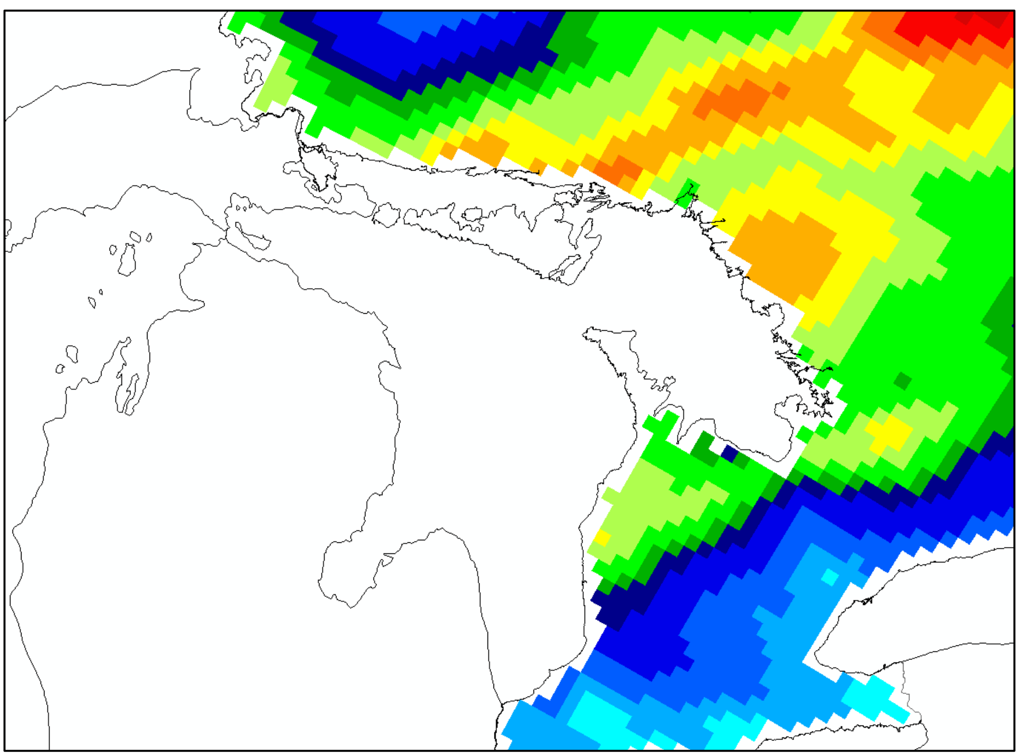

Fig. 4. CaPA derived raster - area extracted for Merged dataset

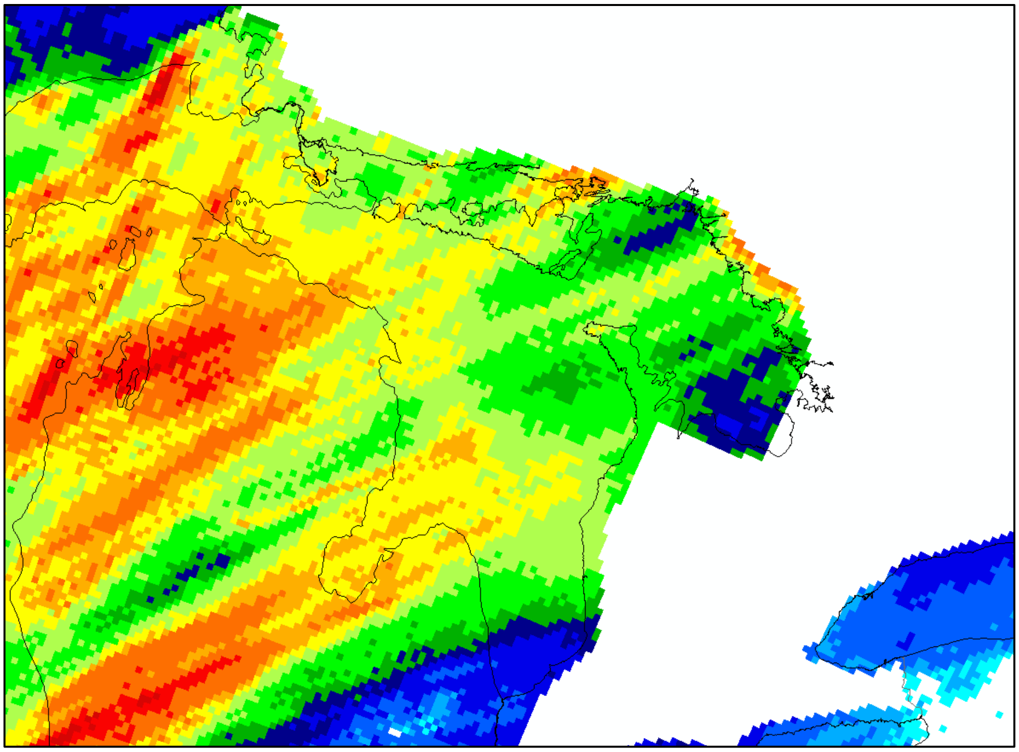

Fig. 5. MPE derived raster - 4km cell size

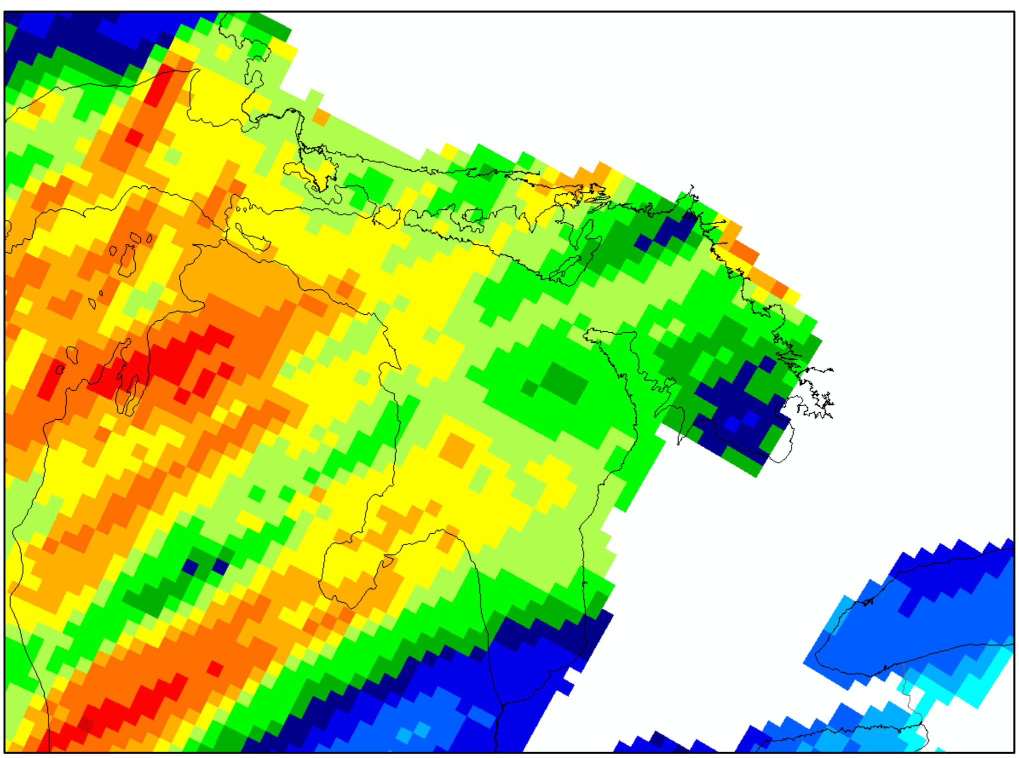

Fig. 6. MPE derived raster - resampled from 4km to 10km cell size

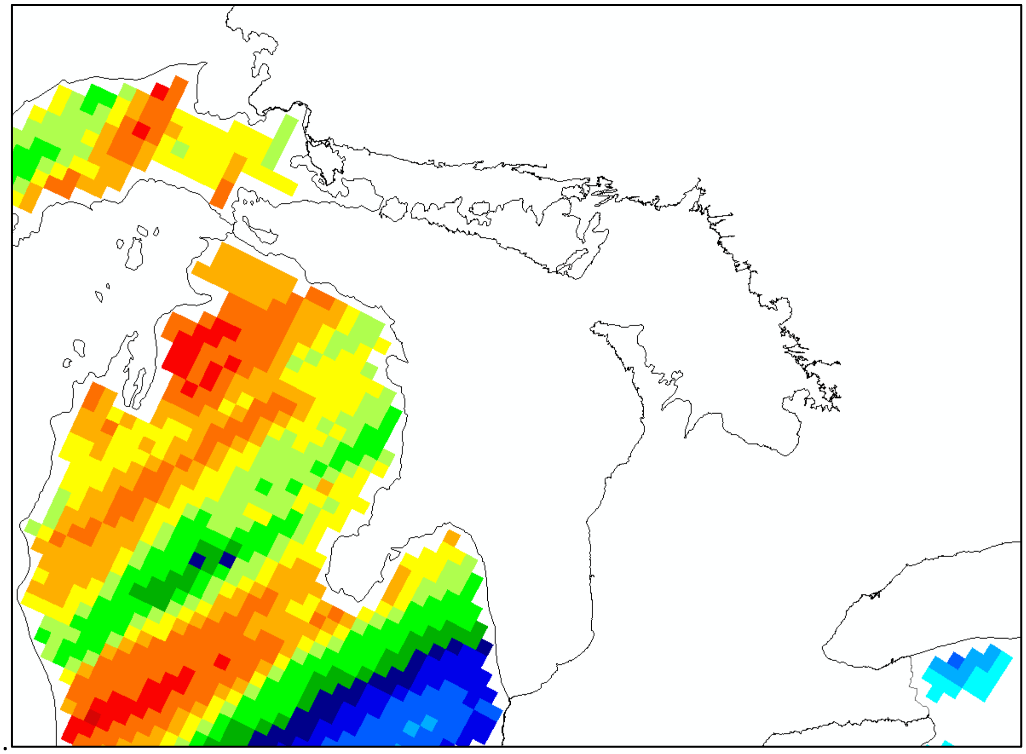

Fig. 7. MPE derived raster - area extracted for Merged dataset

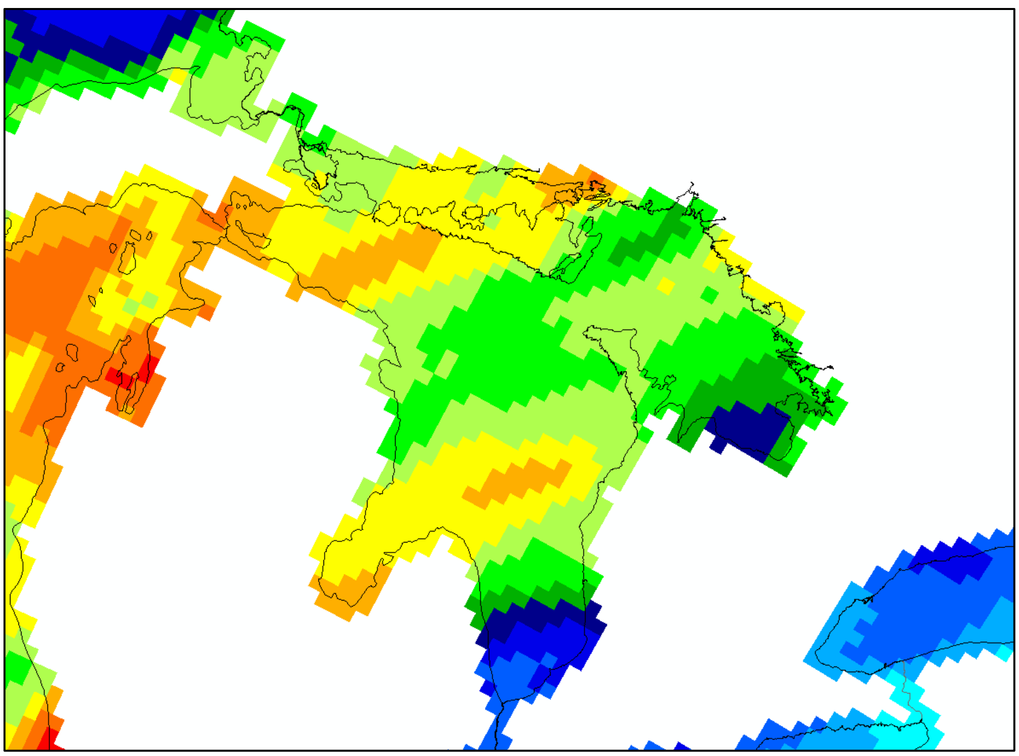

Fig. 8. Raster created from interpolation of CaPA and MPE points - 10km cell size

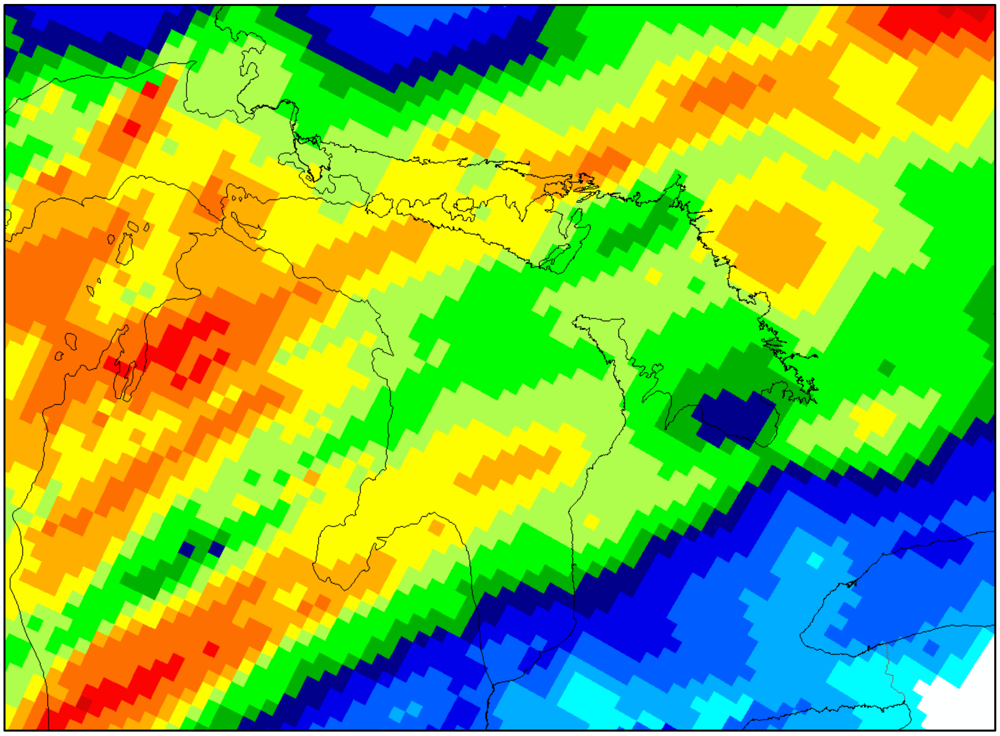

Fig. 9. Final merge raster (mosaic of CaPA, MPE and interpolation rasters) - 10km cell size

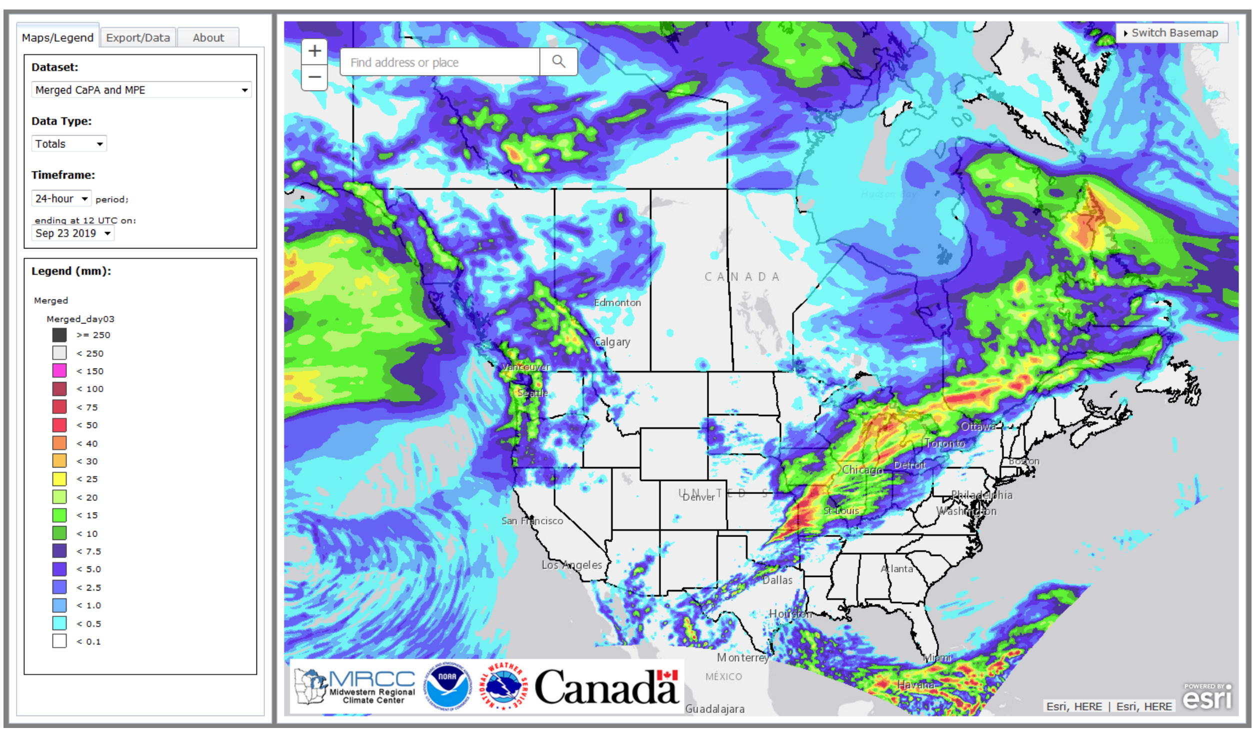

Fig. 10. Final merge grid (mosaic of CaPA, MPE and interpolation rasters) - 10km cell size

Historical mean daily precipitation grids

To calculate daily historical averages for each grid point for all three datasets, a 15-year average (2004-2018) was used. These years were chosen due to a shift in the MPE dataset's grid that occurred on May 11, 2004 (Fig. 11). Eliminating the 2002 and 2003 data from the mean meant that only a few months during 2004 needed to be recalculated to be on the same grid as the rest of the averaging period.

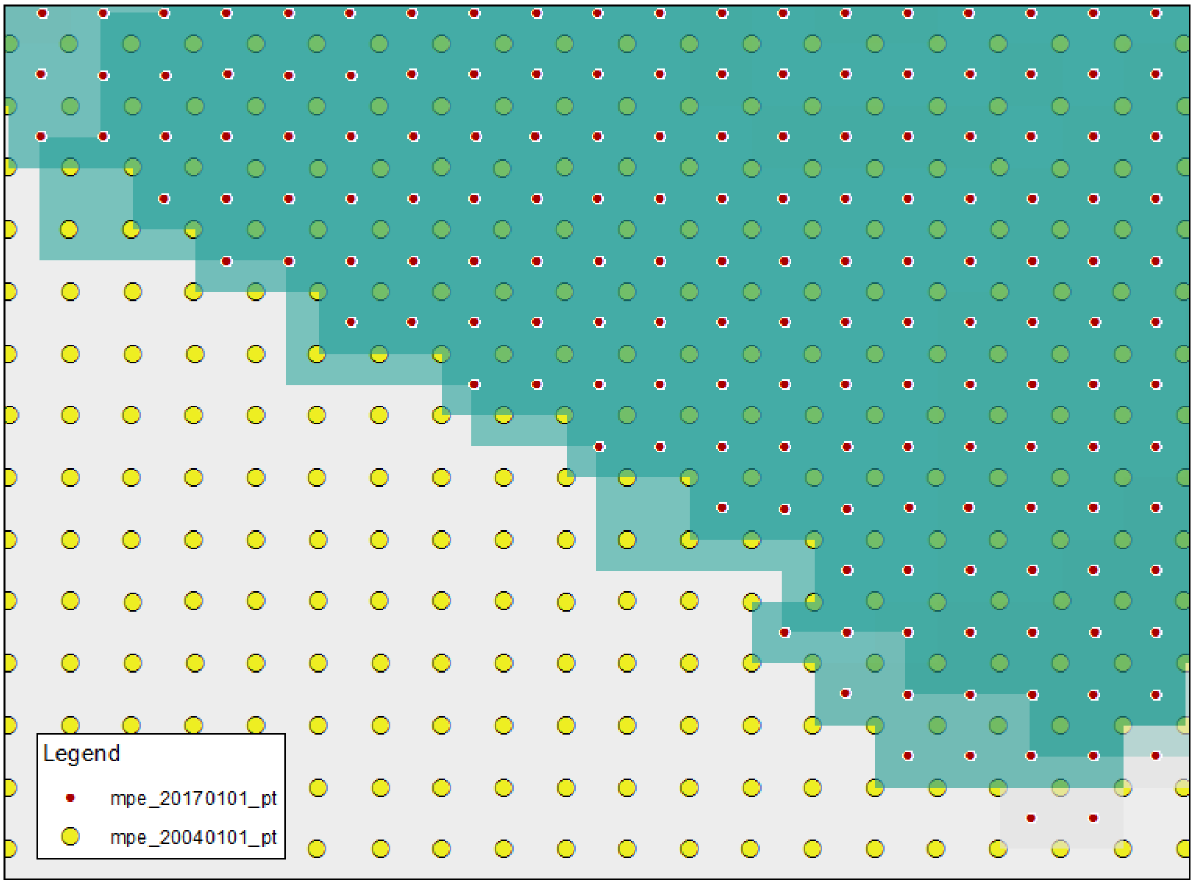

Fig. 11. The MPE grid on 1 January 2004 (yellow circles) vs. the grid on 1 January 2017 (red dots)

Once each precipitation dataset had a standard grid for the 2004-2018 period, averages were calculated for each day for the 15 years. Time series of these datasets revealed that the gridpoint averages were highly influenced by extreme events on a single day (Fig. 12). To decrease the day to day variability of the means, a moving window average was applied. Several different lengths of moving averages were tested including 15-, 21-, 31-, and 45-day periods. The 45-day filter was chosen because it smoothed the most variable peaks while also acceptably maintaining month-to-month and seasonal variability (Fig. 13).

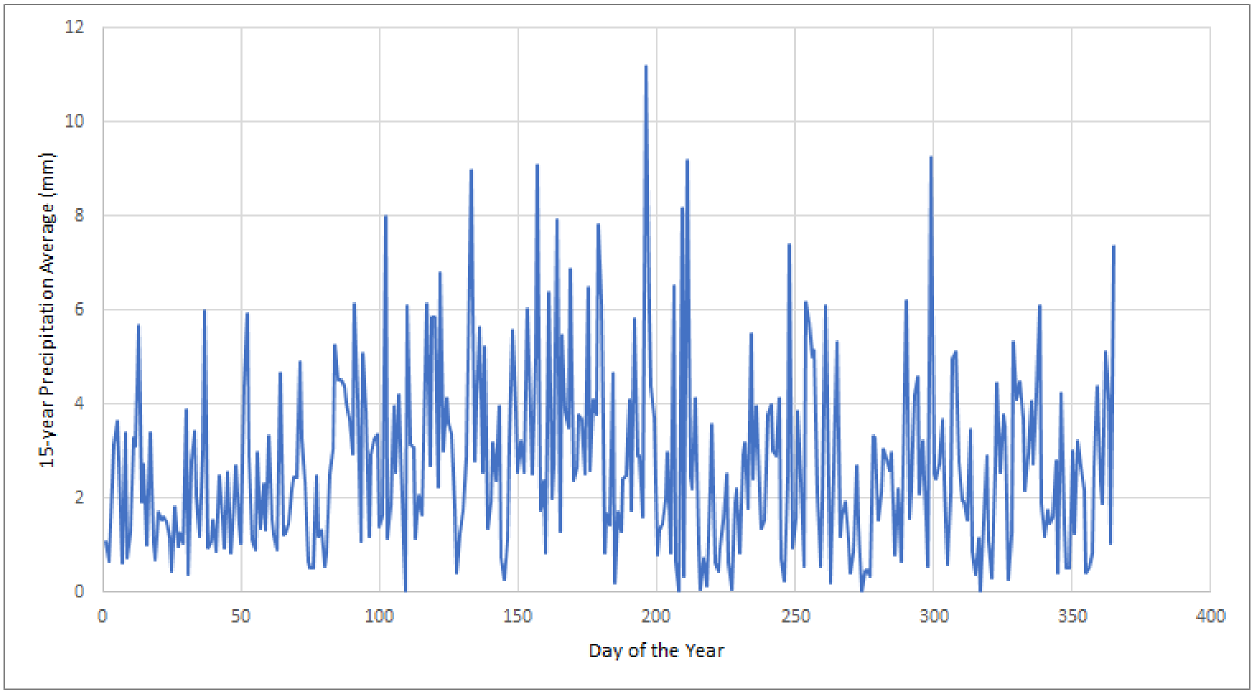

Fig. 12. The MPE 15-year averages for each day of the year for the 40.10, -88.65 coordinate prior to any smoothing being applied.

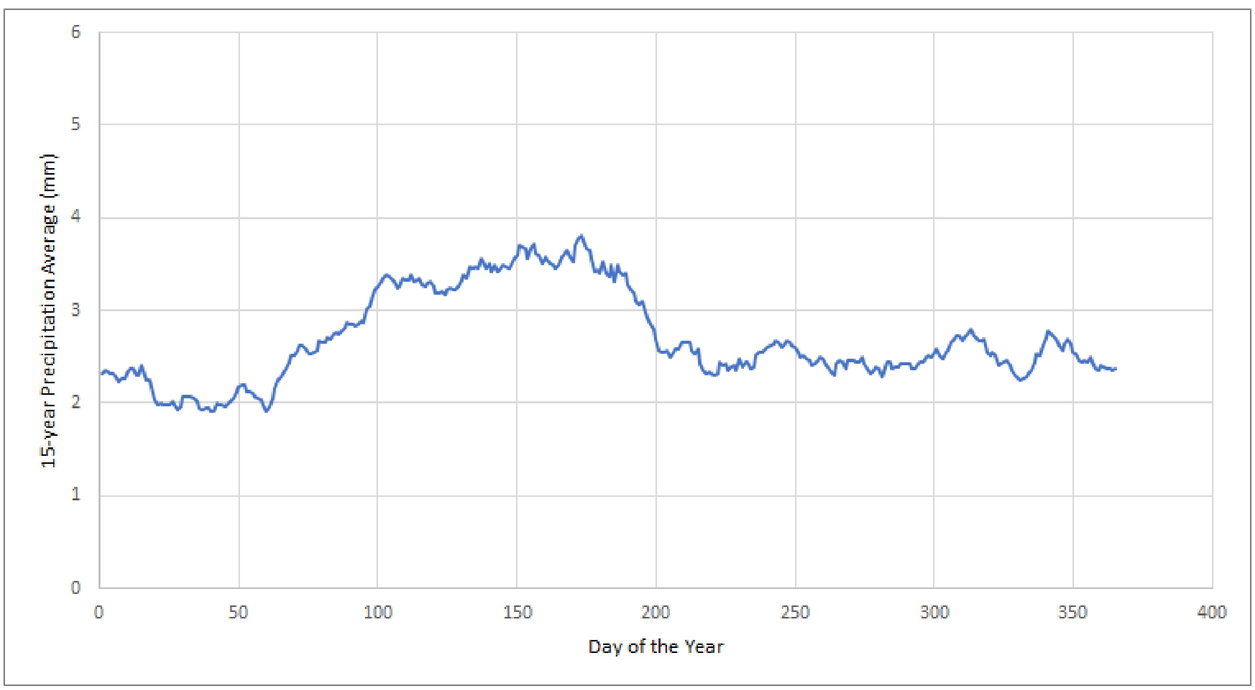

Fig. 13. The MPE 15-year averages for each day of the year for the 40.10, -88.65 coordinate after a 45-day moving window average was applied.

Daily anomaly precipitation grids

Once the 15-year, smoothed daily averages were calculated for CaPA, MPE, and the merged dataset, daily anomalies could then be calculated. This was done by subtracting the corresponding daily mean from each day's precipitation accumulation at each grid point. The departure calculations have been added to the process of creating the merged dataset daily. The previous day's departures are typically available around midnight Central time for the previous 12Z-12Z period.

Monthly and Seasonal anomaly precipitation grids

Beyond the daily precipitation values, the MRCC had previously calculated the current day's 30-, 60-, and 90-day accumulations for CaPA, MPE, and the merged dataset. The departures for these time periods are now also being calculated on a daily basis.

Anomaly grid availability

Anomaly grids are now available from two locations on the MRCC website. The web map (**https://mrcc.illinois.edu/gismaps/naprecip.htm**) has been updated to allow the user to select either the daily accumulations or departures for the last 30 days for any of the three datasets. The 30-, 60-, or 90-day accumulations or departures can also be viewed. Also from the web map, a user can directly download any of the mapped datasets in comma-separated value (CSV) format (Fig. 18).

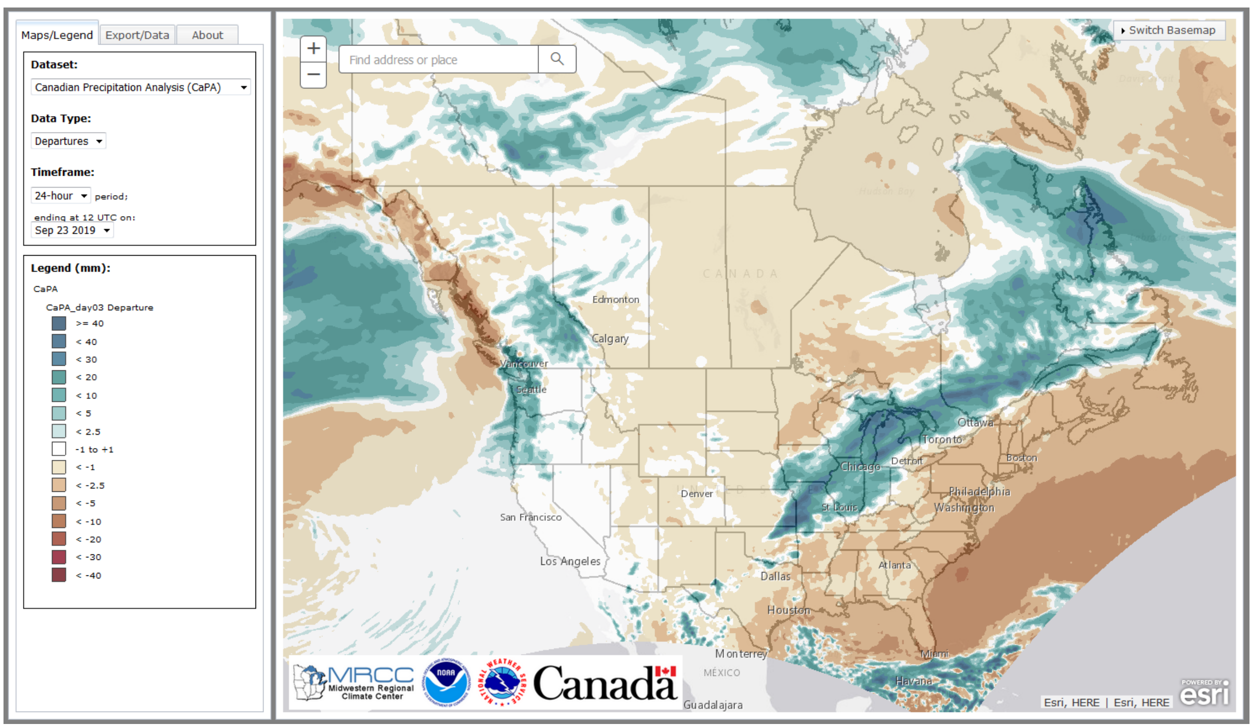

Fig. 14. CaPA derived anomaly grid (24-hour)

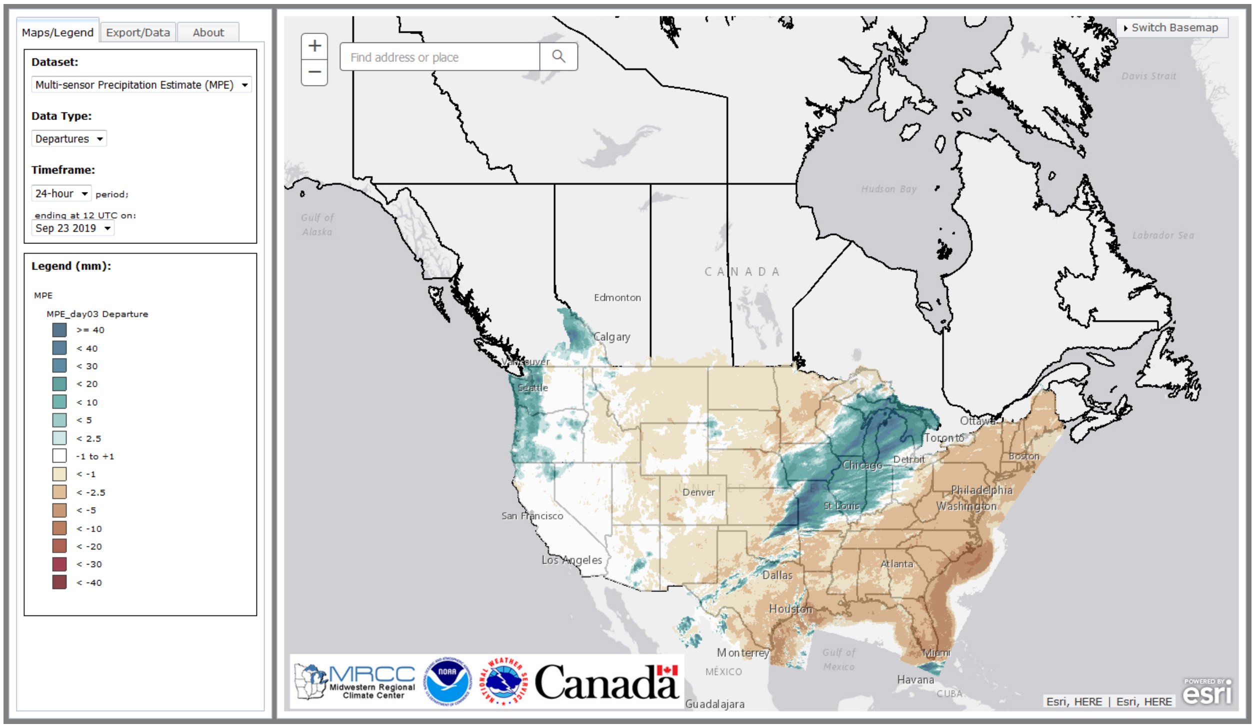

Fig. 15. MPE derived anomaly grid (24-hour)

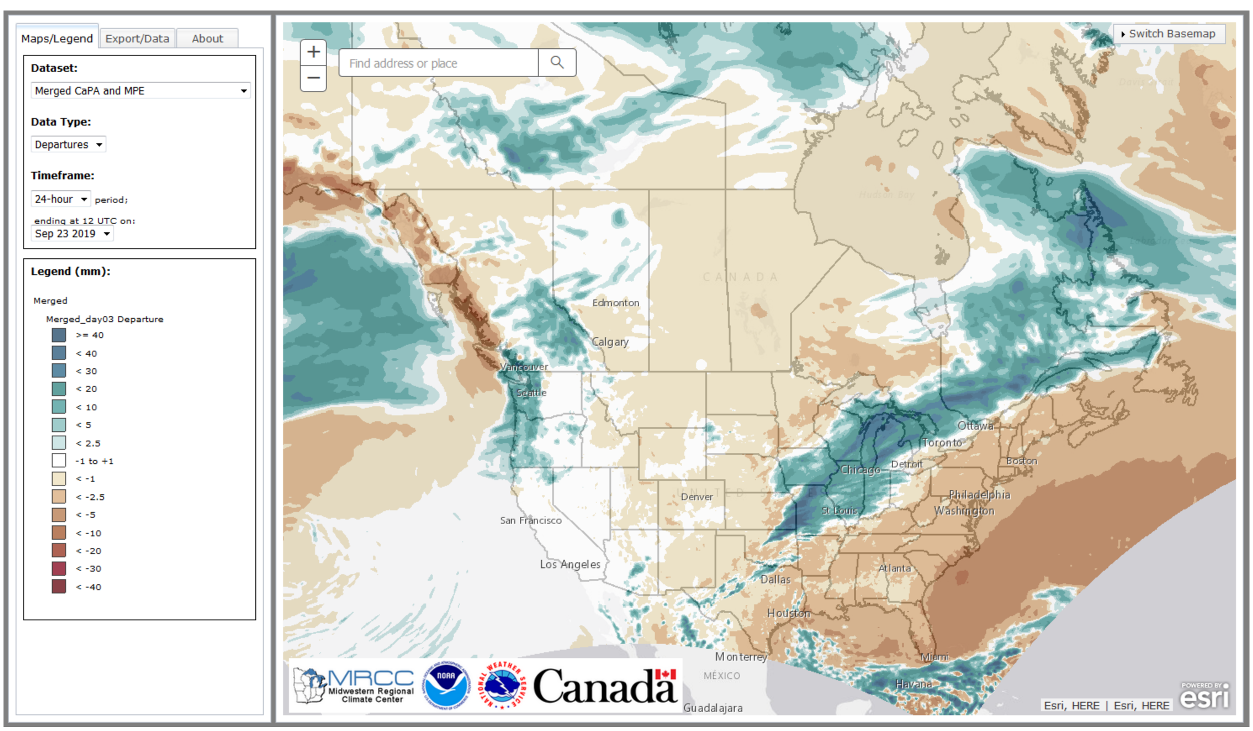

Fig. 16. Merged dataset derived anomaly grid (24-hour)

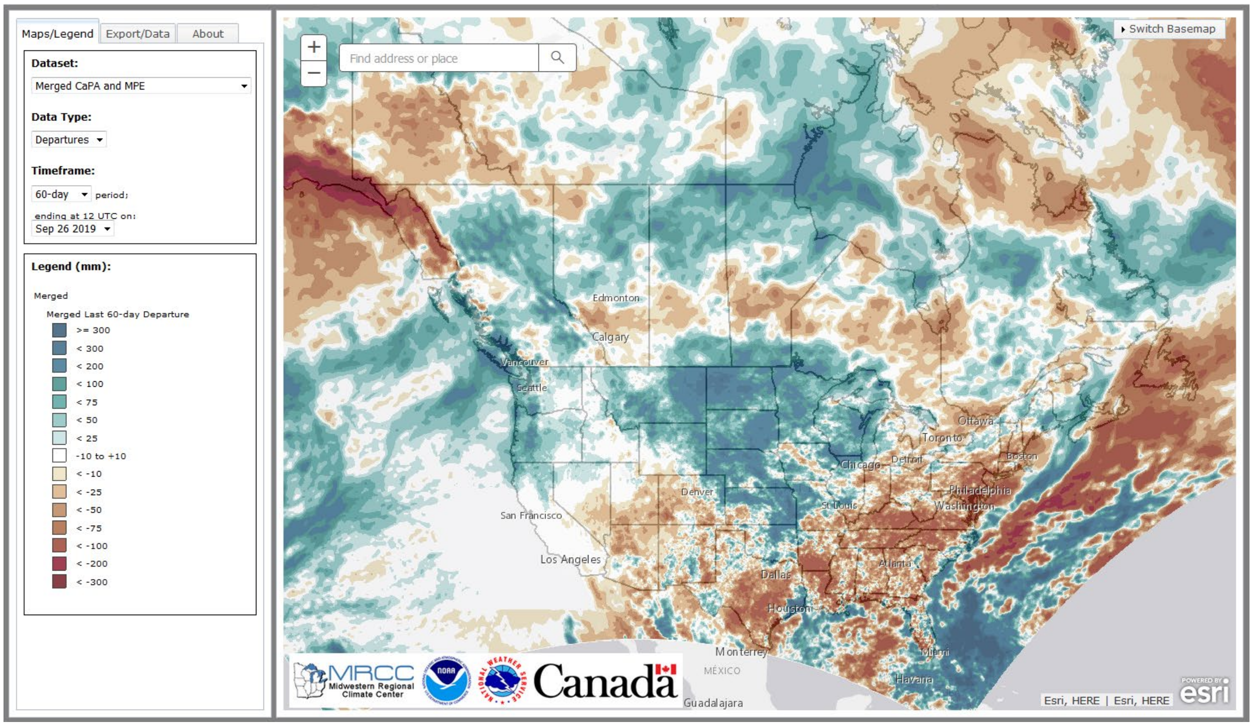

Fig. 17. Merged dataset derived anomaly grid (60-day)

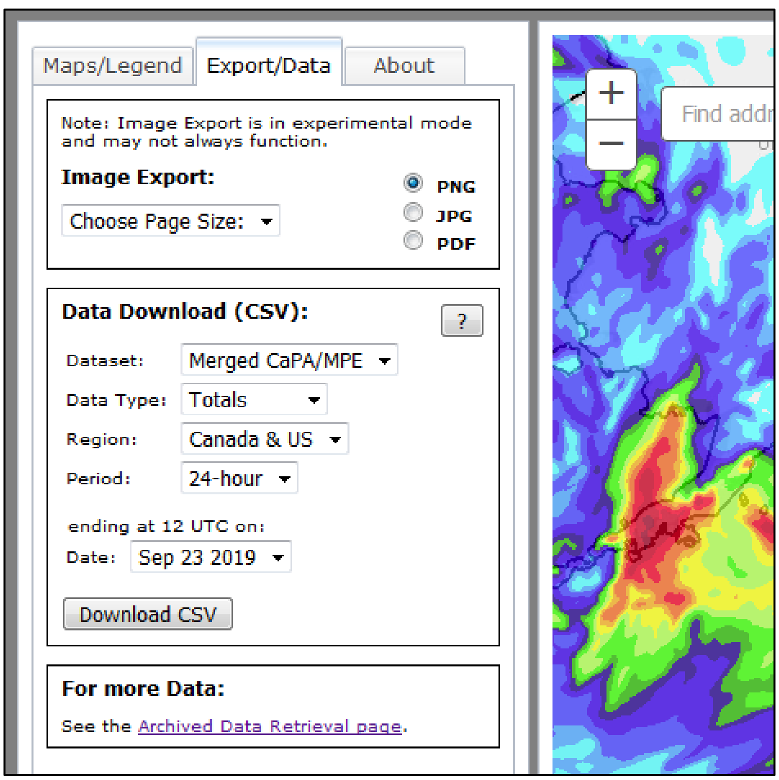

Fig. 18. Export/Data tab in web map, for downloading data

Also, all data from the 2002-present time period are accessible via the archive download (**https://mrcc.illinois.edu/cliwatch/northAmerPcpn/getArchive.jsp**) (Fig. 19)**.** Users can select between daily accumulations or departures for any dates between 2002 and the present from this page. The daily accumulations are available in either CSV or netCDF formats. The daily departures are currently only available as CSV, but the netCDF option may be added at a later time. Once users submit their request, the files are compressed in a .tar.gz format file, and a link to download this file will be sent to the user's provided email.

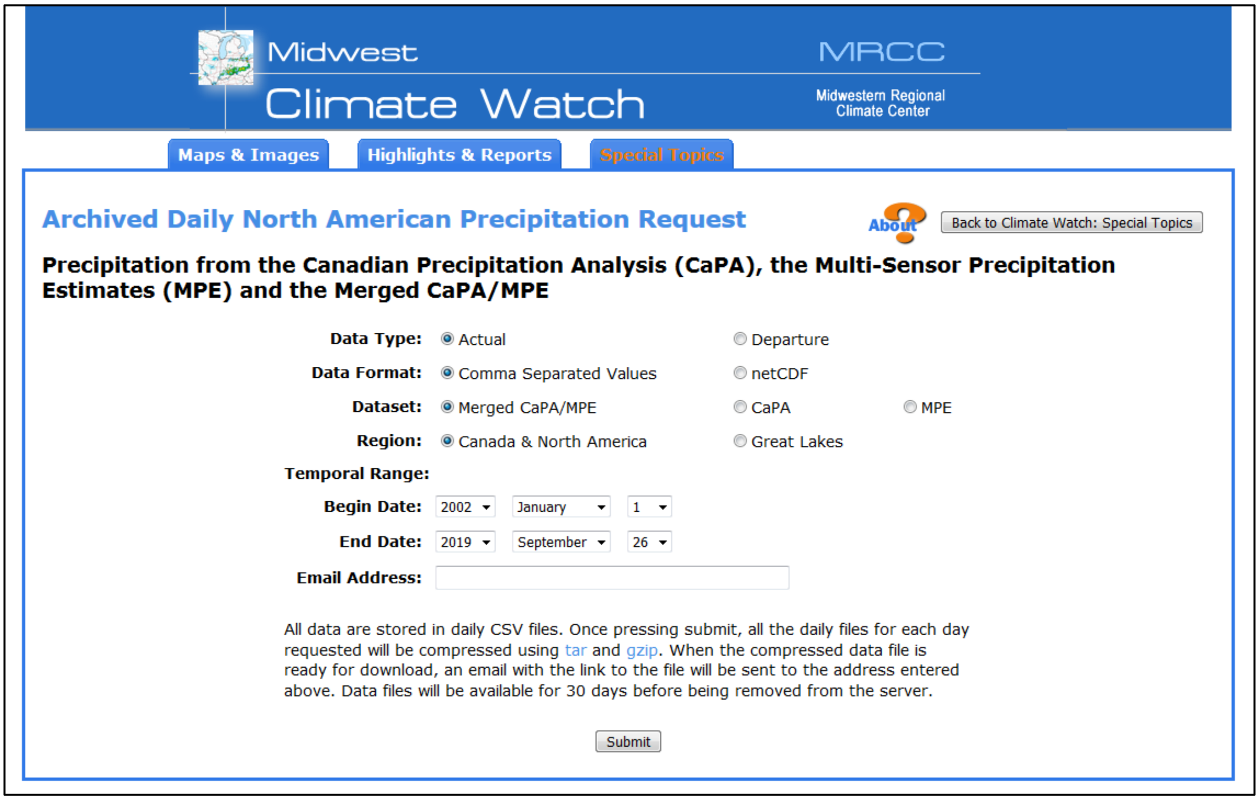

Fig. 19. Archive Download Webpage

Finally, users can also create maps and data files for any time period, via the MRCC's cli-MATE tool, Bi-National Precipitation Maps -Specific Period tool available (Fig. 20). Cli-MATE is the MRCC's customizable web tool application website that is free with user registration (**https://mrcc.illinois.edu/CLIMATE**). Users select the time period they wish to map, which dataset to map, whether to show the entire Canada and US region or just the Great Lakes and whether to show city labels. Links to the created map and a CSV file of the data used will be emailed to the user's provided email address.

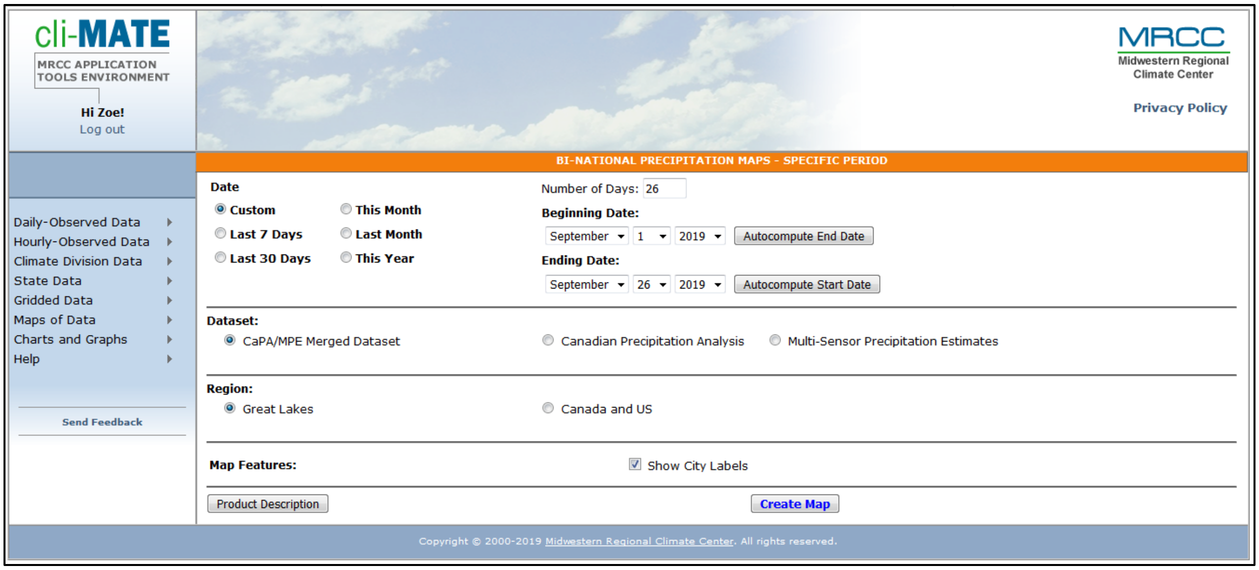

Fig. 20. Bi-National Precipitation Maps - Specific Period tool available in cli-MATE.

Conclusions

As a result of this effort, the MRCC developed anomalies of the merged Canadian Precipitation Analysis (CaPA) and Multisensor Precipitation Estimates (MPE) precipitation data from 2004-2018 and made them readily-available to the public through the existing product interface.

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