Comparison of precipation change estimates across the U.S. - Canadian border

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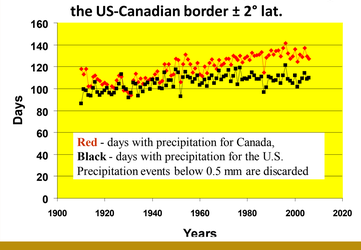
Rationale and Objectives

- There is a strong spatial and temporal inhomogeneity in precipitation information across the U.S. – Canadian border due to different observational practices and gauge designs.
- Furthermore, during the past 100 years there were instrumental (and methodological) change biases that introduce false trends, "jumps" and other non-meteorological "signals" in observational data.

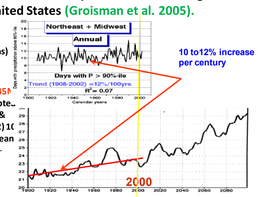
Annual number of days with precipitation along the US-Canadian border ± 2° lat.



During the past 50-100 years, there were reports of significant changes in heavy and very heavy precipitation frequency in several regions of Southern Canada and the northern United States (Easterling et al. 2000, Groisman et al. 2004, 2005).

Frequency of the upper 10% of rainy days over the northeastern quadrant of the contiguous United States (Groisman et al. 2005).

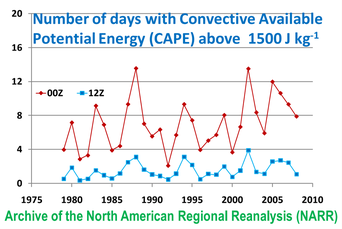
- Observations (Northeast and Midwest regions) for 1908-2002.
- ECHAM4 (35N-45N; 75W-85W; adapte... from Semenov & Bengtsson 2002) 10 year running mean values for 1900-2090.



Observations and GCM report the same scale of changes

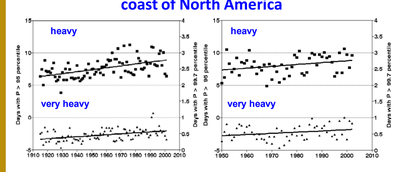
Northeastern United States. Summer

Number of days with Convective Available Potential Energy (CAPE) above 1500 J kg^{-1}



Archive of the North American Regional Reanalysis (NARR)

"Heavy" (upper 5%) and "very heavy" (upper 0.3%) daily precipitation events along the northwestern coast of North America

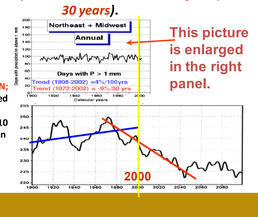


British Columbia south of 55° N Alaska south of 62° N

During the past several decades, there were reports of significant changes in precipitation frequency and duration of prolonged no-rain periods in the eastern regions of the United States and Southern Canada (Groisman et al. 2005, Groisman and Knight 2007, 2008).

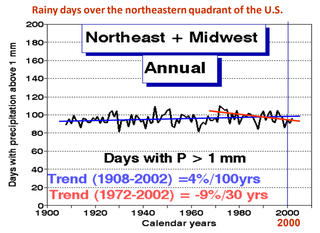
Frequency of rainy days over the northeastern quadrant of the contiguous United States (*both show a decrease during the past 30 years*).

- Observations (Northeast and Midwest regions) for 1908-2002.
- ECHAM4 (35N-45N; 75W-85W; adapted from Semenov & Bengtsson 2002) 10 year running mean values for 1900-2090.

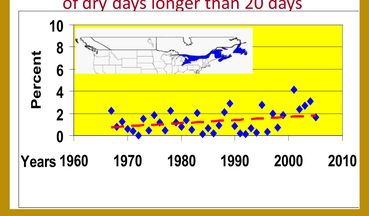


This picture is enlarged in the right panel.

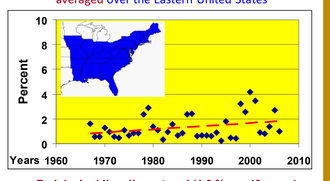
Rainy days over the northeastern quadrant of the U.S.



Southeastern Canada. Percent of strings of dry days longer than 20 days



Percent of the dry day episodes with 1-month or more length in the warm season during the past 40 years area-averaged over the Eastern United States



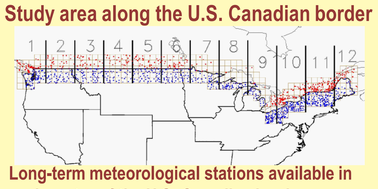
Red dashed line: linear trend (1.0 % per 40 years)

Objective of this study

- To separate climatic signals (if any) from the artifacts of the observation routines changes and
- To assess the changes in instrumentally homogenous characteristics of precipitation from both sides of the border during the period of instrumental observations using the time series at national networks and to secure the comparability of conclusions about these changes with focus on the changes in heavy and very heavy precipitation.

Data and their problems

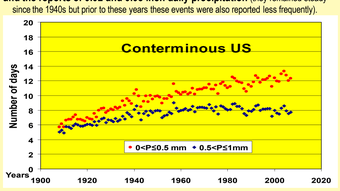
Study area along the U.S. Canadian border



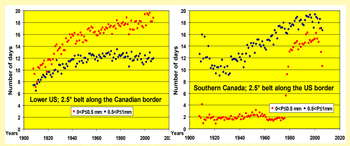
Long-term meteorological stations available in each sector of the U.S.-Canadian border area

	1	2	3	4	5	6	7	8	9	10	11	12	Total
Canada	65	35	31	32	36	39	9	4	24	85	94	41	495
USA	76	58	61	43	66	64	49	52	100	143	141	32	885

Changes in mean number of days with non-zero very light precipitation over the conterminous United States (Groisman and Knight 2008) illustrate the inhomogeneity of information stored in the U.S. digital archives regarding the 0.01 inch precipitation reports (their number steadily grows from 6 yr^{-1} to 13 yr^{-1}) and the reports of 0.02 and 0.03 inch daily precipitation (they remained steady since the 1940s but prior to these years these events were also reported less frequently).



Changes in mean number of days with non-zero very light precipitation along the 2.5-degree latitudinal belt along the US-Canadian border (Left: US Side; Right: Canadian Side).



In the northern U.S. along the Canadian border the inhomogeneity in counts of light precipitation events is even more pronounced (compared to nationwide) and in Canada the signal is completely contaminated.

Algorithm currently employed at NCDC to correct Canadian daily precipitation data in the absence of accurate information about the wind at each location.

- **For rainfall:** We critically re-assessed the results of Metcalfe et al. (1997) and introduced the following adjustment to each non-zero daily precipitation value: Prior to the date when we first spotted metric measurements at each station separately (usually around summer 1976 or somewhere in 1977): Adjusted Rainfall (mm) is equal to 1.02 x [measured rainfall + 0.3 mm] and after this date: Adjusted Rainfall (mm) is equal to 1.02 x [measured rainfall].
- **For snowfall:** We used parallel observations (snow ruler and snow gauge with a Nipher wind shield) to estimate climatological mean monthly transfer functions for each Canadian site. These transfer functions were used to homogenize the time series of snow ruler measurements to the readings of a snow gauge at each site (even if it never has been there). The constant (10/9) factor was applied to account for modest gauge snowfall undercatch.
- **Trace reports** were ignored in both rainfall and snowfall data due to instability of trace reporting around the Canadian network.
- Rationale for such set of corrections is provided by NCDC (1998) and Groisman et al. (2003, 2004).

Comparison of cold precipitation along the U.S. Canadian border in the North Dakota Sector. Average precipitation (January February, 6-year period) at 15 stations in northern North Dakota is compared with average precipitation at 21 stations in southern Saskatchewan and Manitoba (Peck, E.L., 2002; Final Contract Report to National Climatic Data Center)

Country	Type of observations	Long-term precipitation, mm	Ratio Canada/U.S.
USA	Observed	24.6	1.47
Canada	Observed	36.3	
USA	Bias-Corrected	31.8	1.03
Canada	Bias-Corrected	33.0	

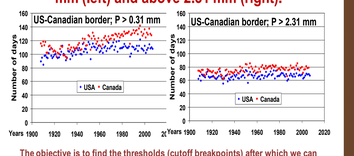
References:

- Groisman, P.Ya. and R.W. Knight, 2008: Prolonged dry episodes over the conterminous United States: New tendencies emerging during the last 40 years. *J. Climate*, 21, No. 9, 1850–1862.
- Groisman, P.Ya., B. Sun, R. S. Vose, J. H. Lawrimore, P. H. Whitfield, E. Førland, I. Hanssen-Bauer, M. C. Serreze, V. N. Razuvaev, and G. V. Alekseev, 2003a: Contemporary climate changes in high latitudes of the Northern Hemisphere: Daily time resolution. In: Proceedings of the 14th AMS Symposium on Global Change and Climate Variations, CD ROM with Proceedings of the Annual Meeting of the American Meteorological Society, Long Beach, California, 9-13 February, 2003, 10 pp.
- Groisman, P.Ya., E.G.Bogdanova, and B.M. Ilyin, 2004: Adjusted precipitation for the United States and Russia. CD ROM of presentations at the International Workshop on Climate Data Homogenization (Toronto, Canada, 19-21 April, 2004), Meteorological Service of Canada.
- Metcalfe, J.R., B. Routledge, and K. Devine, 1997: Rainfall measurement in Canada: Changing observational Methods and archive adjustment procedures. *J. Climate*, 10, 92-101.
- National Climatic Data Center (NCDC), 1998: Data Documentation For Archive TD-9816, Canadian Monthly Precipitation, November 18, 1998. 21 pp.

Results

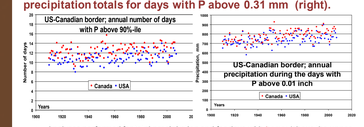
- Various cutoff breakpoints were used to eliminate a range of smaller values from the analyses of "days with precipitation". We discarded the day with precipitation below 0.01" (using cutoff value 0.31 mm), and compared the trends across the border. Then we incremented the cutoff value by another 0.01", etc. up to days with precipitation below 0.1" (or 2.6 mm) from both sides of the border and compared trends for the past century. We did not see problems with the U.S. trends (very soon they became invariant to the breakpoint selection). But, for southern Canada, in order to extract what appear to be reasonable trends (i.e., similar to those observed in a close southward proximity), it was found that only the value 2.31 mm (which eliminates 0.09" and lower daily precipitation events) is a safe value along the entire border.
- Further testing indicates that it is possible to use smaller cutoff points for days with precipitation, if we are intending to analyze the data only after 1978-1980 (the years when most of changes causing homogeneity problems last occurred in the Canadian observation practice).

Annual number of days across the US Canadian border (±2.5° lat.) with precipitation above 0.31 mm (left) and above 2.31 mm (right).



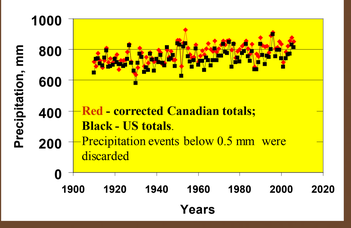
The objective is to find the thresholds (cutoff breakpoints) after which we can reliably analyze time series of "days with sizable precipitation" (i.e., days with precipitation above these thresholds) as well as precipitation totals.

Annual number of days across the US Canadian border (±2.5° lat.) with heavy precipitation (upper 10th percentile; left) and precipitation totals for days with P above 0.31 mm (right).



- Analyses performed for total precipitation and for days with heavy (above the upper 10th percentile) and very heavy (above the upper 1st percentile, not shown) precipitation show that the "breakpoint" problem is not acute and does not create changes between the slopes of trends across the U.S.-Canadian border. Separate analyses for entire Southern Canada (for area-averaging of seasonal totals as well as counts of heavy and very heavy precipitation over large regions) show no discernable effects of instrumental inhomogeneity on century-long time series of these characteristics.

Annual precipitation along the US-Canadian border ± 2.5° lat.



Linear trends [% (100 yr)$^{-1}$] for the 1910-2006 period of several precipitation (P) characteristics within the 2.5° latitudinal belts along the US-Canadian border.

Precipitation characteristic	Canada	USA
Total precipitation, P > 0.31 mm	16	10
Number of days with P above 90th percentile	12	13
Number of days with P above 2.31 mm	11	6

All trend estimates (a) are statistically significant at the 0.01 or higher levels and (b) their 95%-confidence intervals overlap.

Conclusions

- Only precipitation frequency trends over Canada are seriously affected by changes in instrumentation and observational practice. A cutoff (2.3 mm or possibly another slightly smaller) is sufficient to eliminate spurious trends in precipitation frequency in southern Canada along the U.S. Canadian border.
- Elimination of the lowest non-zero bin in the precipitation reports (0.254 mm) is sufficient to reliably assess precipitation frequency trends over the northern United States.
- For precipitation totals and for heavy precipitation characteristics, no homogeneity issues were found across the border between southern Canada and 48-lower US. Thus, after accounting for wind biases in these time series (that are different north- and southward of the border), the time series can be used for assessment of climatic changes over North American continent during the period of instrumental observations in absolute terms (e.g., in mm yr^{-1}) and are already compliant for analyses of these changes in relative terms (i.e., in % yr^{-1}; cf., *Table*).

Summary

- We assessed the changes in characteristics of precipitation within 2.5° latitude N/S of the USA – Canadian border during the past century using the long instrumentally homogeneous time series at national networks. Across the border, we compared the time series for total precipitation, seasonal counts of days with precipitation, and intense and extreme precipitation.
- Significant inhomogeneities were found on the lower end of the precipitation distribution in both countries and the thresholds after which we can reliably analyze time series of precipitation totals and "days with sizable precipitation" (i.e., days with precipitation above these thresholds) were estimated.
- Only a threshold of 2.3 mm is sufficient to eliminate spurious trends in precipitation frequency in southern Canada while the elimination of the lowest non-zero bin in the precipitation reports (0.254 mm) is sufficient to assess precipitation frequency trends over the northern USA after the 1940s.
- For heavy precipitation characteristics, no homogeneity issues were found. Here, increases of the annual number of days in the upper 10th percentile of the daily events vary from 12% (Canada) to 13% (USA) per century.