Meteorological conditions associated with the record rainfall and major flood of July 8, 2013 in Toronto, Ontario

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Introduction

- record rain fell on Toronto during July 8, 2013 and caused flash floods, electrical power outages, stranded cars on roads, and cancelled or delayed flights at two major airports
- about 1400 commuters were rescued from a stranded commuter train after railway tracks became flooded.
- for perspective, the monthly average rainfall for Toronto is 76 mm
- Toronto Pearson International airport, where official observations are recorded, recorded 126.0 mm
- some parts of Toronto received more than 90 mm in a few hours on the afternoon of July 8. -the previous record rainfall for a single day was 121.4. mm, on Oct. 15, 1954 (caused by Hurricane Hazel)
- what caused this unusual and record-breaking rainfall?
- examination of upper air patterns, surface pressure patterns, moisture, and precipitable water shows why the thunderstorms that developed moved very slowly and had anomalously large amounts of moisture available

This commuter train became stranded on flooded tracks. Credit: photos.thenews.com.pk, image courtesy of Bryant Isaacs

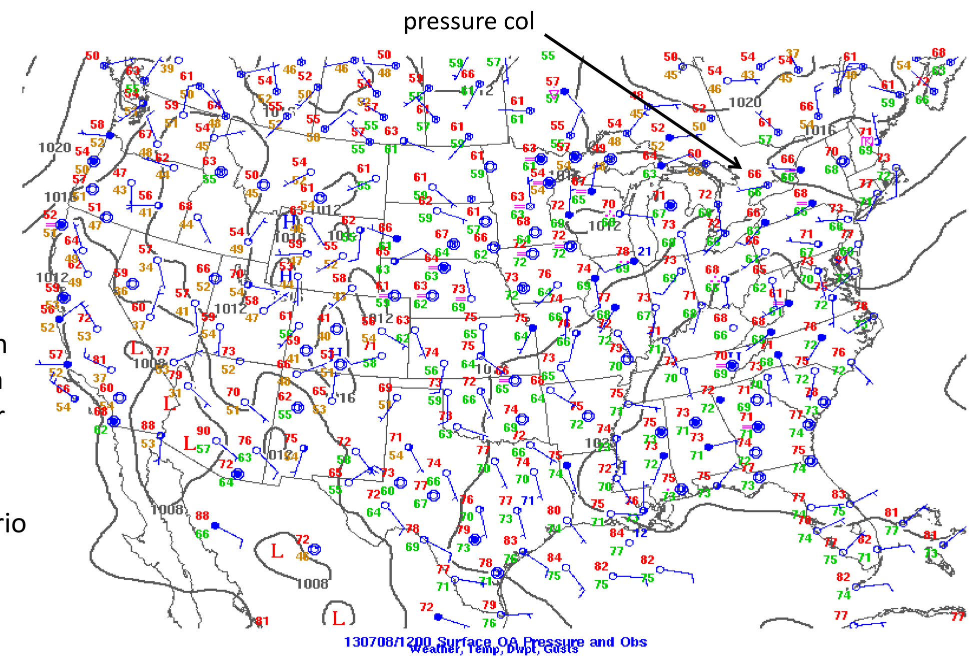
Flooded highways. Credit: Roger Petersen/City News

Synoptic situation, UTC 12:00

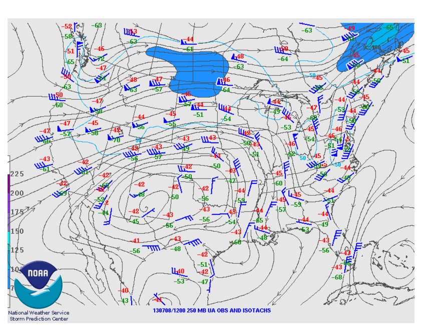
- 250 and 500 mb trough over southern Ontario and NE US, upper H over southern US with ridge building NE over Great Lakes, 700 and 850 mb ridge over Lake Huron (morning), 850 mb trough moving eastward over Lake Ontario, weak NW flow over southern Ontario, 850 mb temperatures near 16 C, sfc Td 20 C (Toronto)

- sfc col over southern Ontario between ridge over eastern US, ridge over NE Ontario and NW Quebec, trough over eastern Ontario and trough over Lake Huron and central Great Lakes, also analyzed as stationary frontal zone oriented W-E across southern Ontario (just north of Toronto)

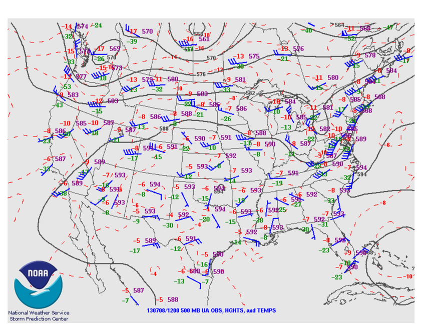
pressure col



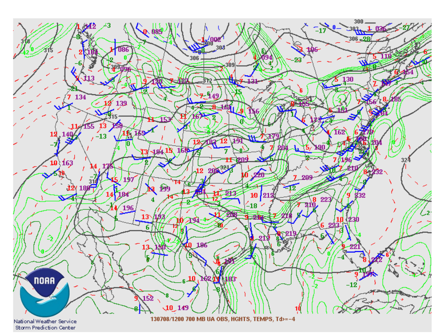
Surface analysis, July 08, 12Z. Credit: NOAA SPC



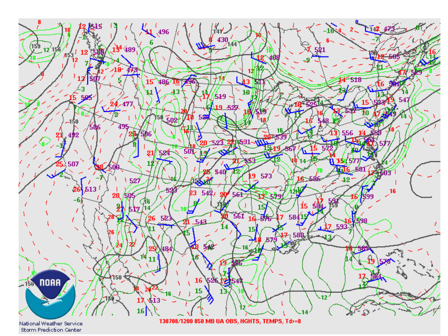
250 mb, July 08, 12Z. Credit: NOAA SPC



500 mb, July 08, 12Z. Credit: NOAA SPC



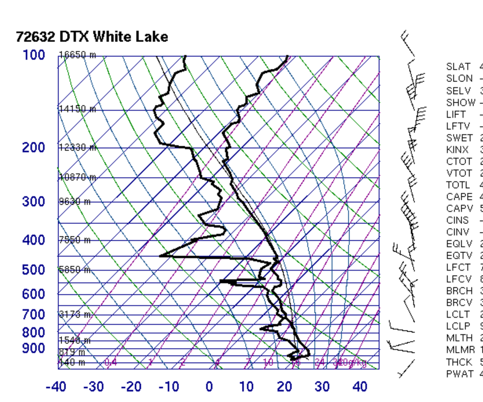
700 mb, July 08, 12Z. Credit: NOAA SPC



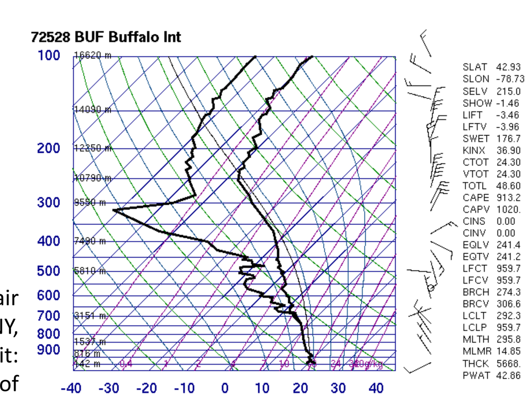
850 mb, July 08, 12Z. Credit: NOAA SPC

Thunderstorm environment

Lifted Index: BUF -3.5, DTX -2.7 (from 12Z soundings)
K Index: BUF 36.9, DTX 37.6
CAPE: BUF 913 J/kg, DTX 448 J/kg
CIN: BUF zero, DTX -75 J/kg
PW: BUF 1.7", DTX 1.7"
Showalter Index: BUF -1.46, DTX -1.83
Cross Totals Index: BUF 24.3, DTX 23.1
Vertical Totals Index: BUF 24.3, DTX 25.9
Total totals Index: BUF 48.6, DTX 49.0
SWEAT Index: BUF 177, DTX 206
General summary of indices: favourable for moderate thunderstorms to develop during the afternoon



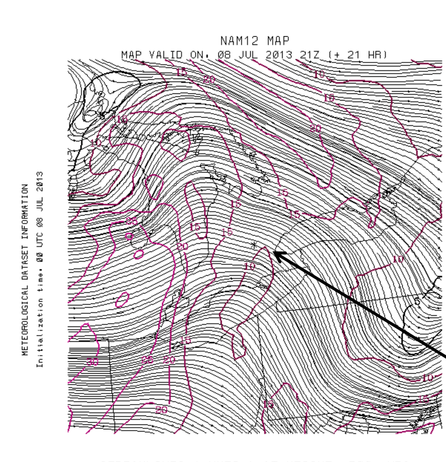
Left: Upper air sounding, Detroit MI, July 8, 12Z. Credit: University of Wyoming



Right: Upper air sounding, Buffalo, NY, July 8, 12Z. Credit: University of Wyoming

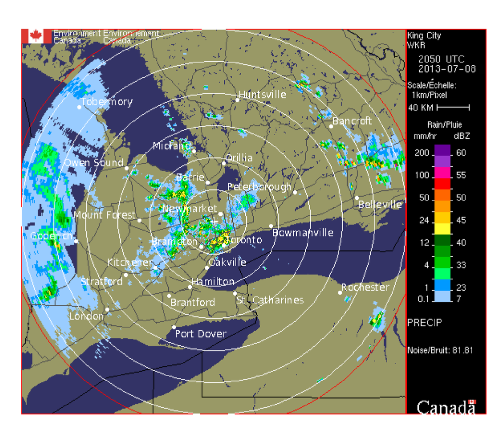
Afternoon situation:

- the col and stationary front was still over southern Ontario, just north of Toronto
- the pattern over southern Ontario was stagnant and no significant changes occurred by evening
- at Toronto Pearson International airport (CYYZ), MSLP was 1016.6 mb at UTC 12:00 and 1016.8 mb at UTC 23:00, and dewpoint was 20 +/- 1 C during the day
- winds were from SE during the early afternoon before strong thunderstorms developed by UTC 20:00 (EDT 16:00)
- thunderstorms or showers with heavy rain continued during the afternoon and evening
- advection at the 700 mb level was extremely weak, about 10-15 kn from NW to SE over Toronto

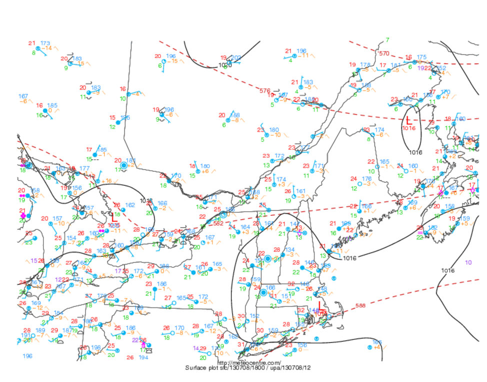


10 kn windspeed

Above: 700 mb streamlines and wind speeds, 21 UTC. Credit: NOAA ARL



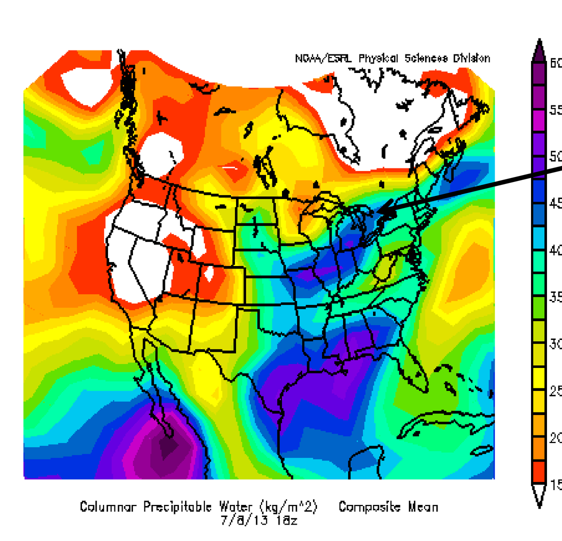
Above: radar, UTC 20:50. Credit: Environment Canada



Right: surface analysis, UTC 18, showing col and weak trough-stationary front over southern Ontario. Credit: www.meteocentre.com

Heavy rainfall causes

- thunderstorms that developed in the unstable airmass moved very slowly, but tapped into an anomalously large amount of precipitable water
- what caused the large amount of precipitable water to be present in the atmospheric column above the Toronto area?
- 500 mb level charts during the 10 days preceeding July 8 show a nearly stationary pattern dominated by a western ridge, trough over the Great Lakes, and ridge east of the Atlantic coast
- charts of precipitable water, as well as water vapour satellite imagery, during the same period show a northward flow of moisture near the Atlantic coast between the trough and eastern ridge
- the thickest column of water moved westward over the eastern Great Lakes region during July 6-8 and partly merged with another region of deep moisture that moved southward over the Great Lakes region (in northerly flow around the persistent trough near the Great Lakes region)

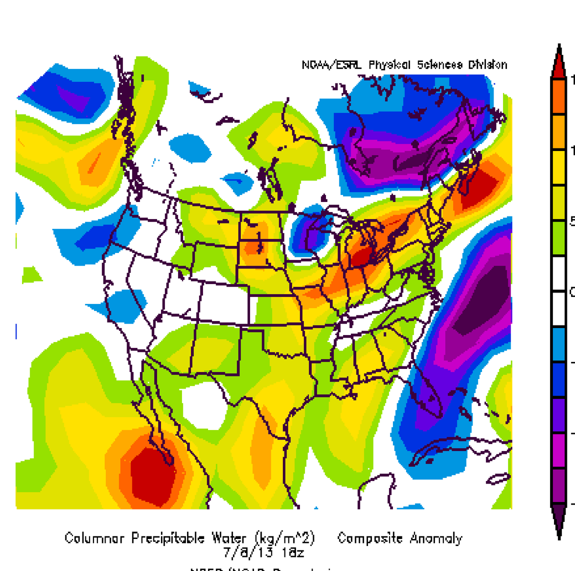


Toronto

Left: Column precipitable water, UTC 18:00 July 8, 2013 showing large PW over Toronto. Credit: NOAA ESRL

Significance of the blocking pattern to global climate change

- the pattern of the blocking ridge over the western Atlantic Ocean during early July 2013 appears identical to the expected results of Arctic amplification (Francis & Vavrus 2012)
- in Arctic amplification, longwave upper level ridges build further northward in response to warming Arctic temperatures
- the ridges, and Rossby waves in general, become more persistent and move eastward more slowly
- this blocking condition may occur more frequently in the future in the northern hemisphere and cause prolonged weather conditions associated with droughts, cold spells and heat waves, as well as flooding events



Left: Precipitable water anomaly, UTC 18:00. Credit: NOAA ESRL

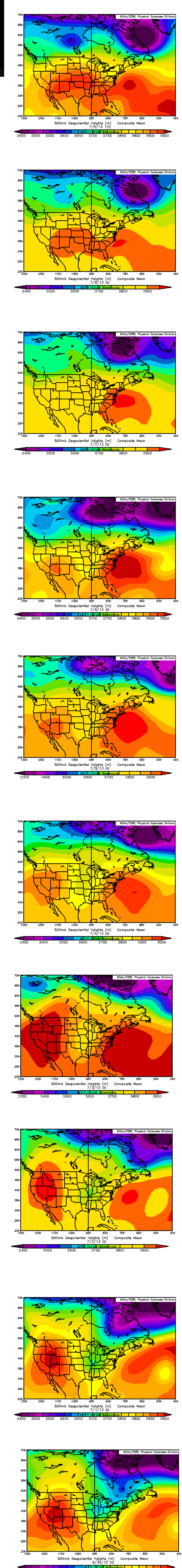
Summary

- the day was unstable and airmass thunderstorms developed during the afternoon
- steering flow at mid-levels was very weak and thunderstorms moved very slowly, enhancing training of storms
- the amount of precipitable water in the atmospheric column above Toronto was anomalously large and caused by a blocking pattern consisting of the Atlantic ridge and a trough over the Great Lakes region with resulting northward advection of moisture over the eastern US and eventually over southern Ontario
- this blocking pattern appears to fit the pattern of Arctic amplification associated with global climate change

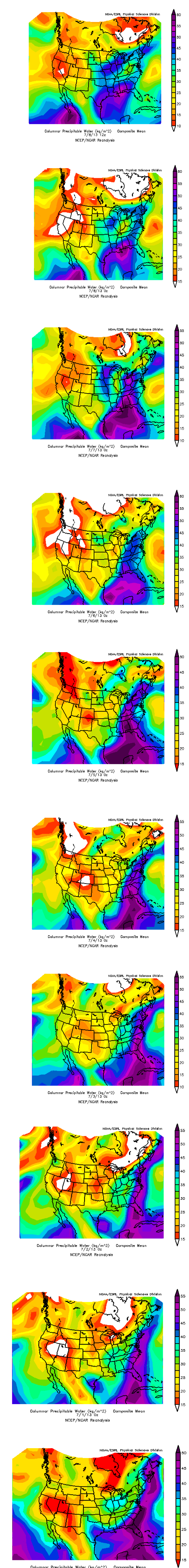
References

Environment Canada, online at weather.gc.ca
Francis, J. and Vavrus, S. 2012 "Evidence linking Arctic amplification to extreme weather in mid-latitudes", Geophys. Res. Lett., Vol. 39, L06801
NOAA ARL, online at http://ready.arl.noaa.gov/READYamet.php.
NOAA ESRL, online at http://www.esrl.noaa.gov/psd/data/composites/hour/
NOAA NCEP WPC, online at www.wpc.ncep.noaa.gov
NOAA SPC , online at www.spc.noaa.gov
University of Wyoming, online at www.uwyo.edu

500 mb GPH – previous 10 days (before July 8)



Column Precipitable Water – previous 10 days



July 8, 2013
July 7
July 6
July 5
July 4
July 3
July 2
July 1
June 30
June 29, 2013

GOES water vapour imagery – previous 10 days