On the study of a major ice pellet storm in the Toronto area in a climate change context

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Motivation

- Winter storms can impact power networks and transportation. In general, the most catastrophic consequences associated with precipitation occuring at temperatures near 0°C.
- Freezing rain (ZR) can lead to ice accumulation on the ground and serious damage to structures.
- Improving our understanding of their formation mechanisms and their interaction with the environment shall help to anticipate their occurrences in a future climate.

Objectives

To investigate the evolution of precipitation types during a winter storm when the temperature is near 0°C in both current and warmer climate scenarios.

- What are the horizontal and vertical distribution of precipitation types and accumulation ?
- How do the characteristics of the rain-snow transition will change ?

Experimental Design

Datasets :

- Used the 4-km WRF CONUS runs (Liu et al., 2016) in both historical (CTRL) and pseudo-global warming (PGW) context.
  - ⇒ PGW perturbations extracted from 19 CMIP5 GCMs using the RCP8.5 emission scenario and added to the re-analysis :

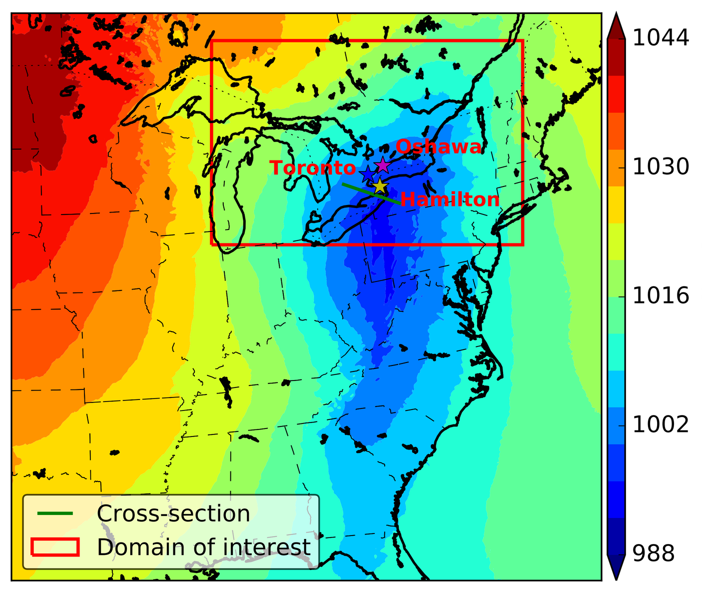
$$WRF_{in} = \text{ERA-Interim} + \Delta CMIP5_{RCP8.5}.$$

  - ⇒ Simulation results from December 2004 were used.
- Hourly precipitation data (Environment Canada) were used.

Methodology :

- Choose a case to study :
  - ⇒ Ice pellets (IP) storm on 22–24 december 2004 in the Toronto area.
  - ⇒ ~30 mm of IP were reported.
- Investigated precipitation types and their accumulation during the storm.
- Diagnosed ZR and IP to compare their occurrence in both CTRL and PGW context.

Sea level pressure (hPa)
1500 UTC 23 December 2004



This storm is associated with a low-pressure system formed in the Gulf of Mexico.

Acknowledgments

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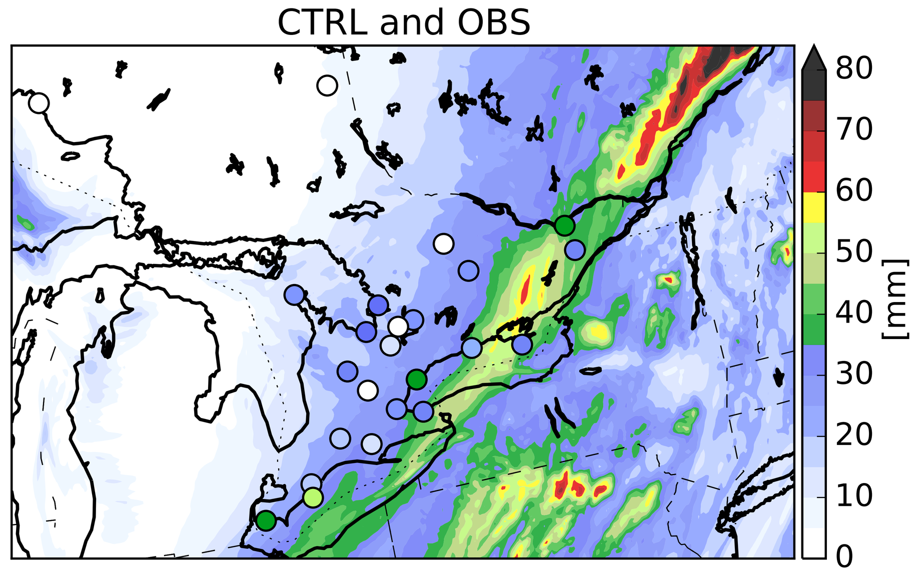
Surface precipitation types during the storm

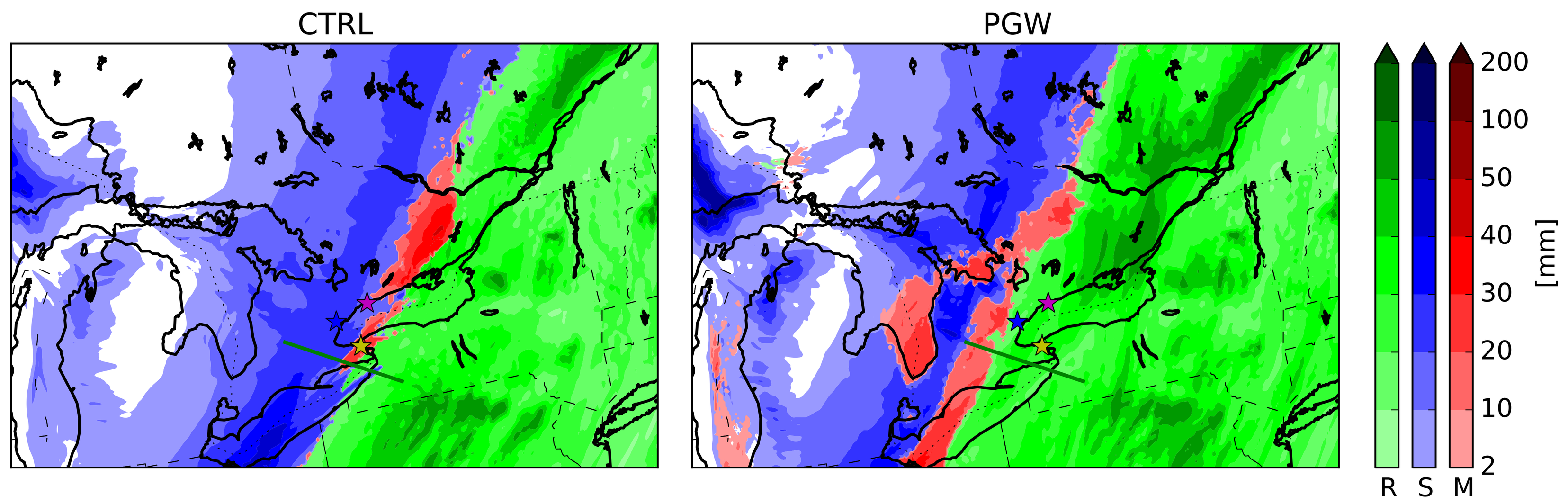
Total accumulated precipitation



- The simulated accumulated precipitation generally agrees with the observations.
- Highest amount of precipitation was located near the U.S.–Canada border.
- The model produced 30–35 mm of total accumulated precipitation whereas 35–40 mm were reported in the Toronto area.

Rain-snow transition and precipitation types

- Accumulated rain (R), snow (S) and mixed precipitation (M).

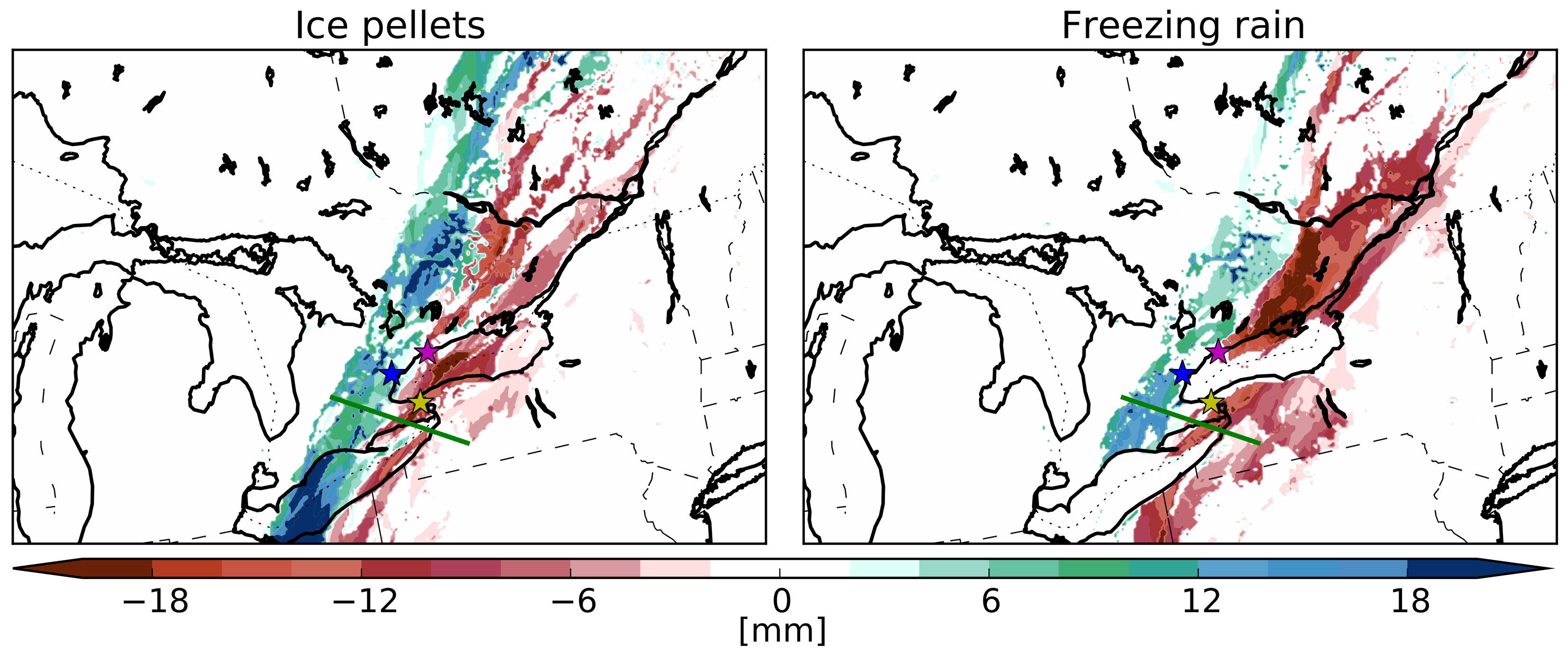


In a warmer climate :

- R-S transition shifted NW (about 100 km). For example, the precipitation type over the Toronto area changed from mainly S to R.
- Mixed precipitation covers a larger area.

Freezing precipitation anomaly (PGW-CTRL)

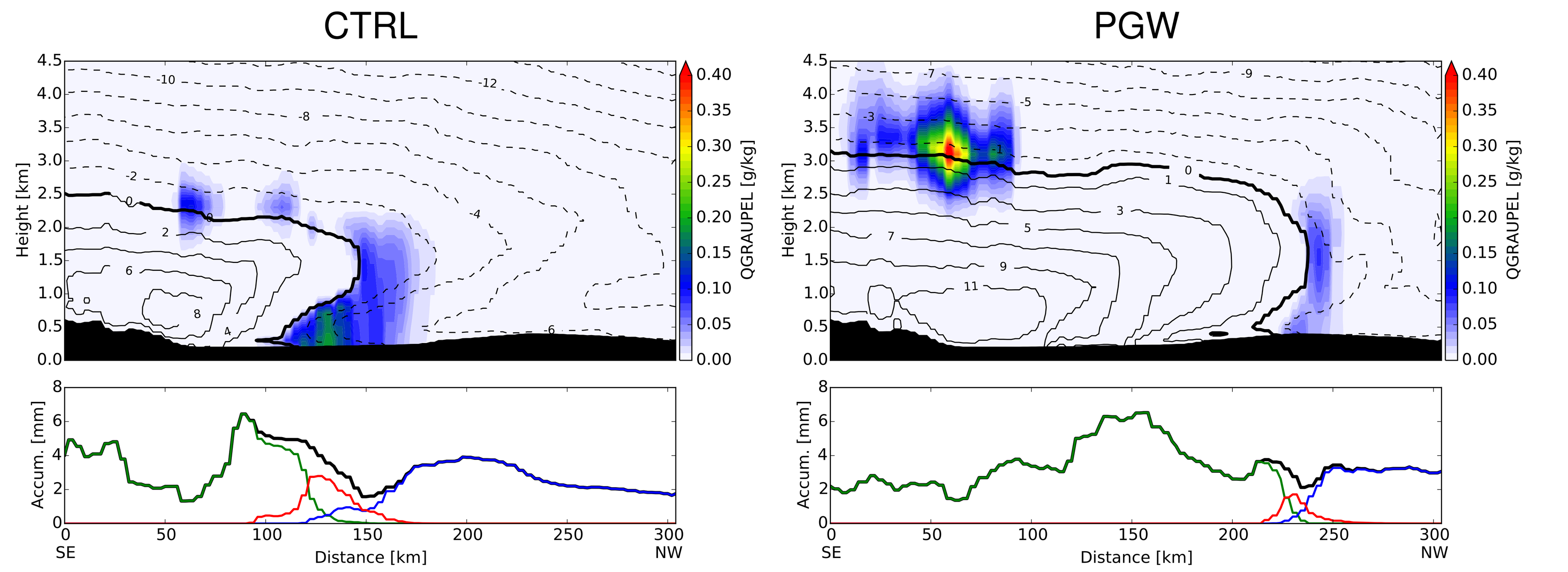
- Precipitation type diagnostic (Bourgouin, 2000)



- An increase in IP (~20 mm north of Lake Ontario and over Lake Eerie) and a decrease in ZR (~20 mm north of Lake Ontario)
- Lower level temperatures are generally higher in a warmer climate during this storm.
  - ⇒ If the increase of T is more important at the surface than at higher altitude, it can lead to a thinner melting layer.

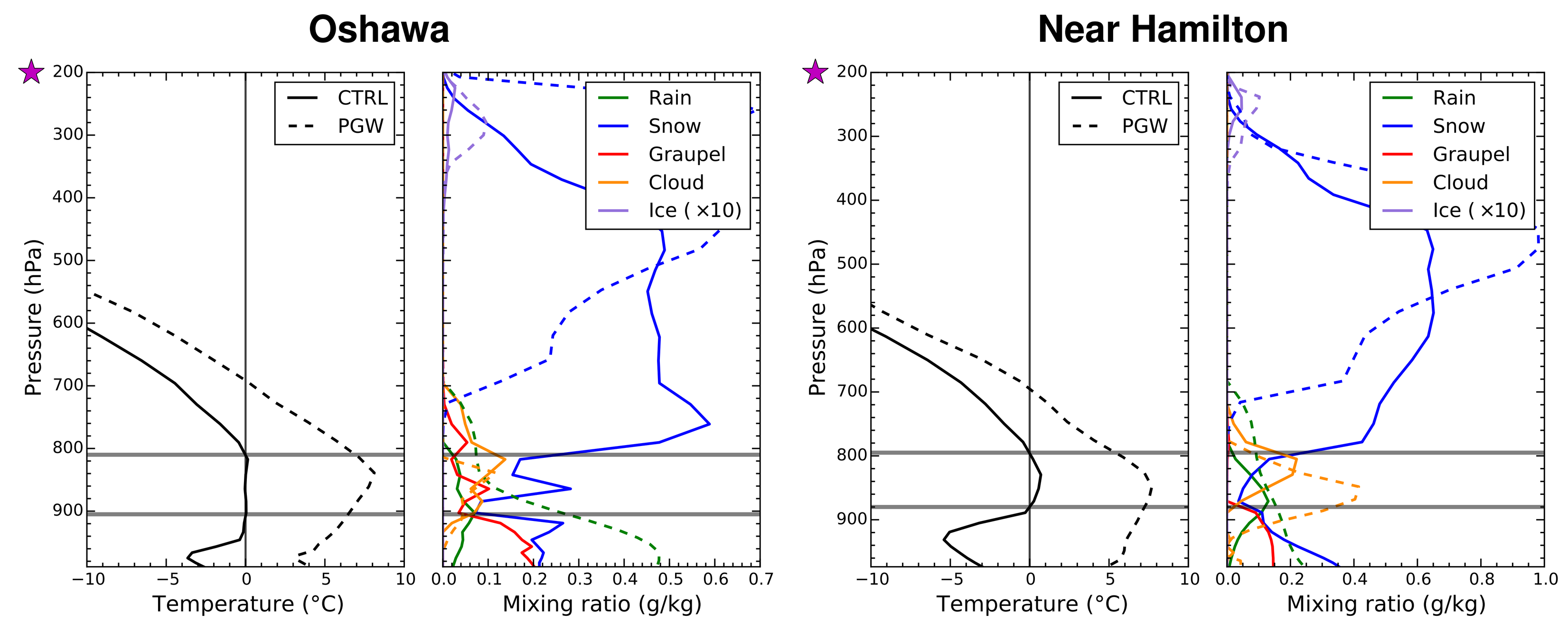
Precipitation type transition

- Cross-section of the warm front at 1500 UTC 23 December 2004.
  - ⇒ Note that IP could be approximated by Graupel (G).



- Warm front shifted towards NW in the PGW.
- The width of the mixed precipitation bounded by only rain and $T = 0°C$ aloft is ~30 km in CTRL as opposed to ~20 km in PGW.

Vertical evolution of temperature and precipitation types



- Oshawa :
  - ⇒ Thick 0°C layer allowing a mixture of S/R/G at the surface (CTRL).
- Hamilton :
  - ⇒ Melting layer aloft allowing a mixture of S/G (CTRL).
- All solid precipitation became rain in a warmer climate at both locations.
- Lower clouds and the ice mixing ratio is 2× higher in a warmer climate.

*T in °C		T_{sfc}	T_{max}	ΔT	Type (sfc)
Oshawa	CTRL	-2.6	0.2	7.9	S/R/G
	PGW	4.0	8.0		R
Hamilton	CTRL	-3.0	1.1	6.3	S/G
	PGW	4.9	7.4		R

T_{sfc}, T_{max} are the surface and maximum temperatures respectively as $\Delta T = T_{max}^{PGW} - T_{max}^{CTRL}$.

Conclusions

- Significant increase in temperature leading to mainly rain in the Toronto area in warmer climate scenario during thihs storm.
  - ⇒ Overall increase of IP accumulation and decrease of ZR in a warmer climate for this storm.
  - ⇒ R-S transition shifted northward by ~100 km and is narrower by ~10 km in the PGW experiment.