Quantifying the Impact of Precipitation Type Algorithm Selection on Projected Changes to Freezing Rain Events in an Ensemble of RCM Simulations

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Freezing rain events and their socioeconomic impacts are likely to change as the climate warms

January 2002 - Oklahoma

OK Mesonet/Chris Fiebrich

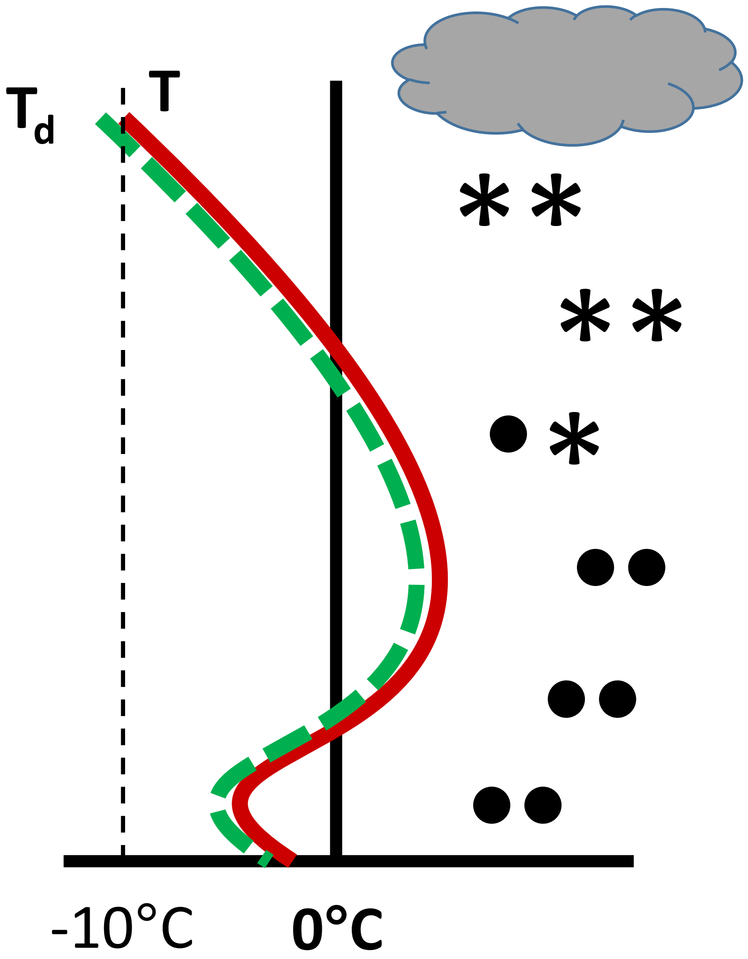
January 1998 - Québec

> $4 billion USD in damage

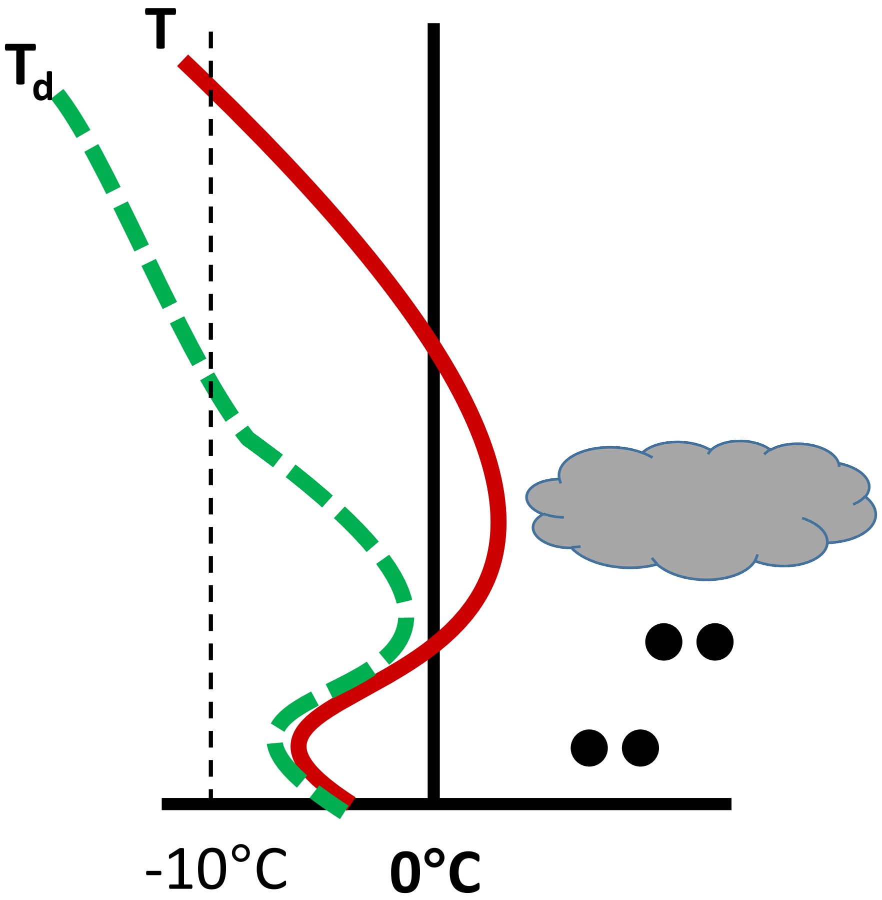
Hydro-Québec

Freezing precipitation (rain and drizzle) can form via one of two processes

Melting Process
(often freezing rain)

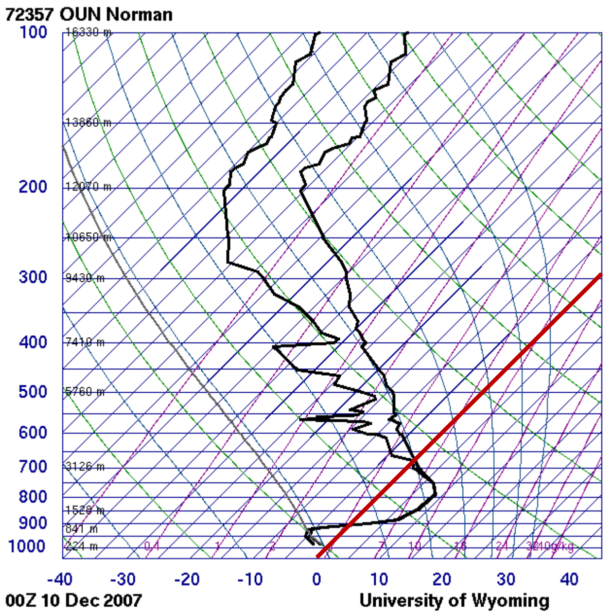


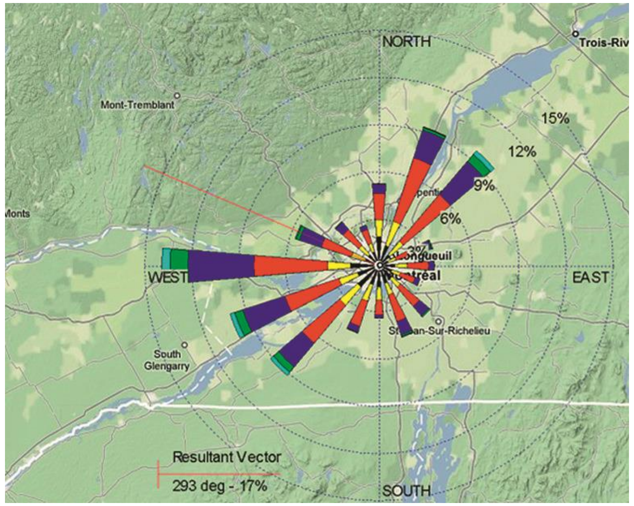
Supercooled warm rain process
(often freezing *drizzle*)



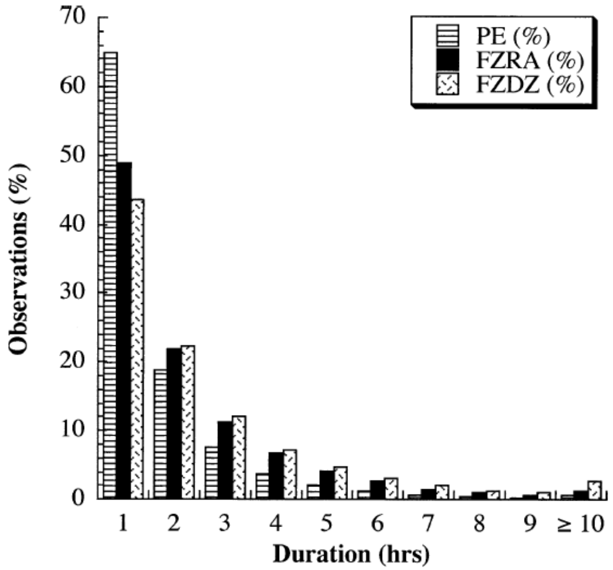
Representing freezing rain in weather and climate models remains a major challenge

- Sufficient **vertical resolution** required to represent shallow near-surface cold layers, shallow/sharp warm layers aloft
- Sufficient **horizontal resolution** necessary to reproduce terrain features
- Sufficiently **frequent output** required to simulate brief events
    - Most freezing rain events < 3 hours (Cortinas 2004, McCray et al. 2019)





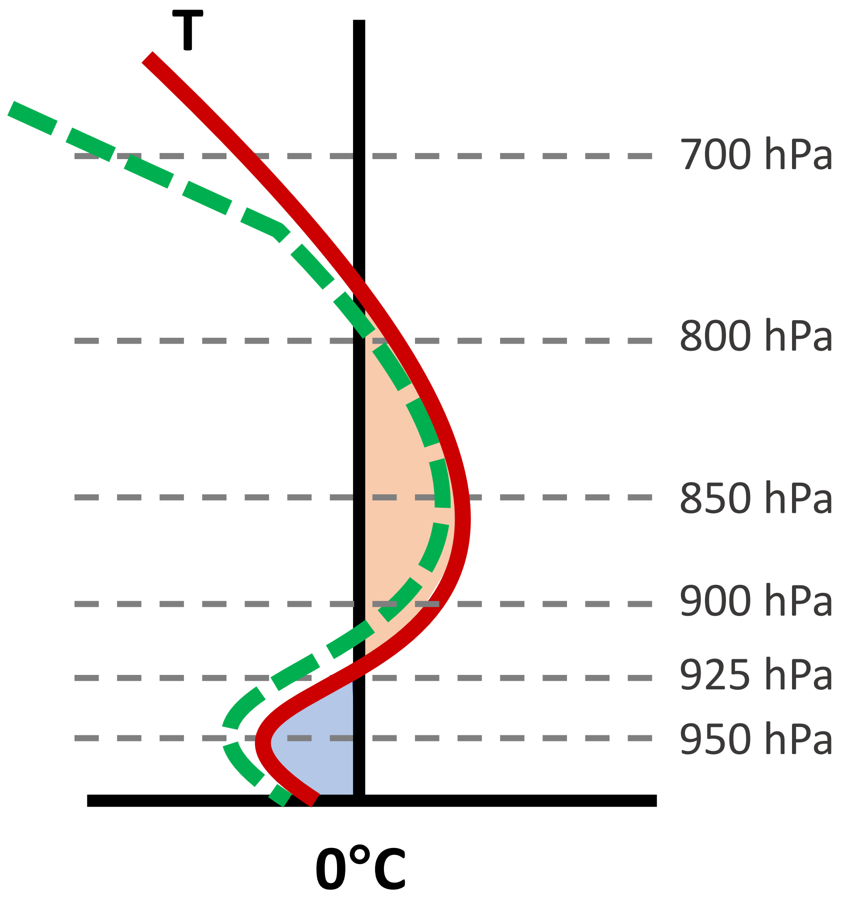
(Razy et al. 2012, Fig. 2)



(Cortinas et al. 2004, Fig. 11)

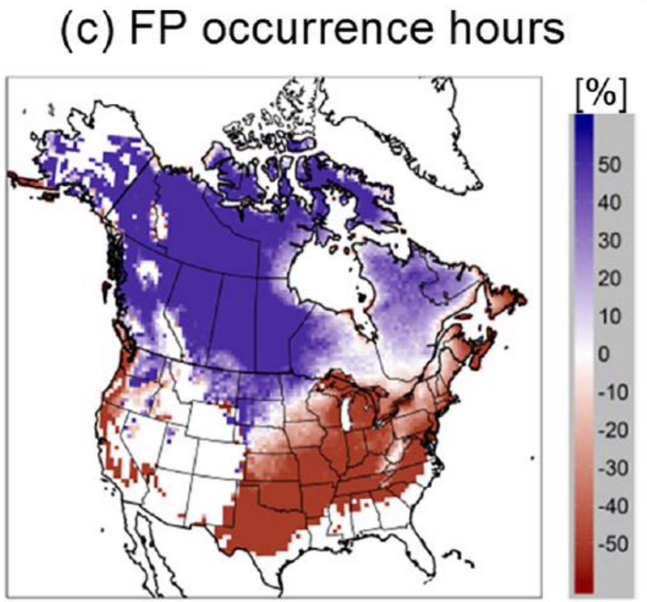
Freezing rain is often identified in model output using precipitation-type algorithms

- Vertical **temperature**, **humidity** profiles
  - Wet-/dry-bulb temperature
  - Relative humidity, dew-point depression
- Empirically derived **thresholds** for melting/refreezing (layer areas/depths)
- Freezing rain difficult to distinguish from **ice pellets**
- Algorithms have varying **biases**
  - Preference for ice pellets or freezing rain (Reeves et al. 2014)



Past studies on freezing rain in a warming climate have typically chosen one algorithm

- Cheng et al. (2007, 2011)
  - Statistical downscaling of output from several GCMs (~2.5°-3.75°)
- Lambert and Hansen (2011)
  - One GCM (~2.8°)
  - One algorithm (Ramer et al. 1993) postprocessed on 20 pressure levels + surface, every 12 hours
- Matte et al. (2018)
  - One RCM (CRCM5) (0.11° over northeastern US/southern Quebec)
  - Five algorithms postprocessed on 56 vertical levels, every 300 s
- Jeong et al. (2019)
  - 50-member initial-condition ensemble (CanRCM) (0.44°)
  - One algorithm (Bourgouin 2000) postprocessed on 4 vertical levels (2 m, 500/850/1000 hPa) every 6 hours

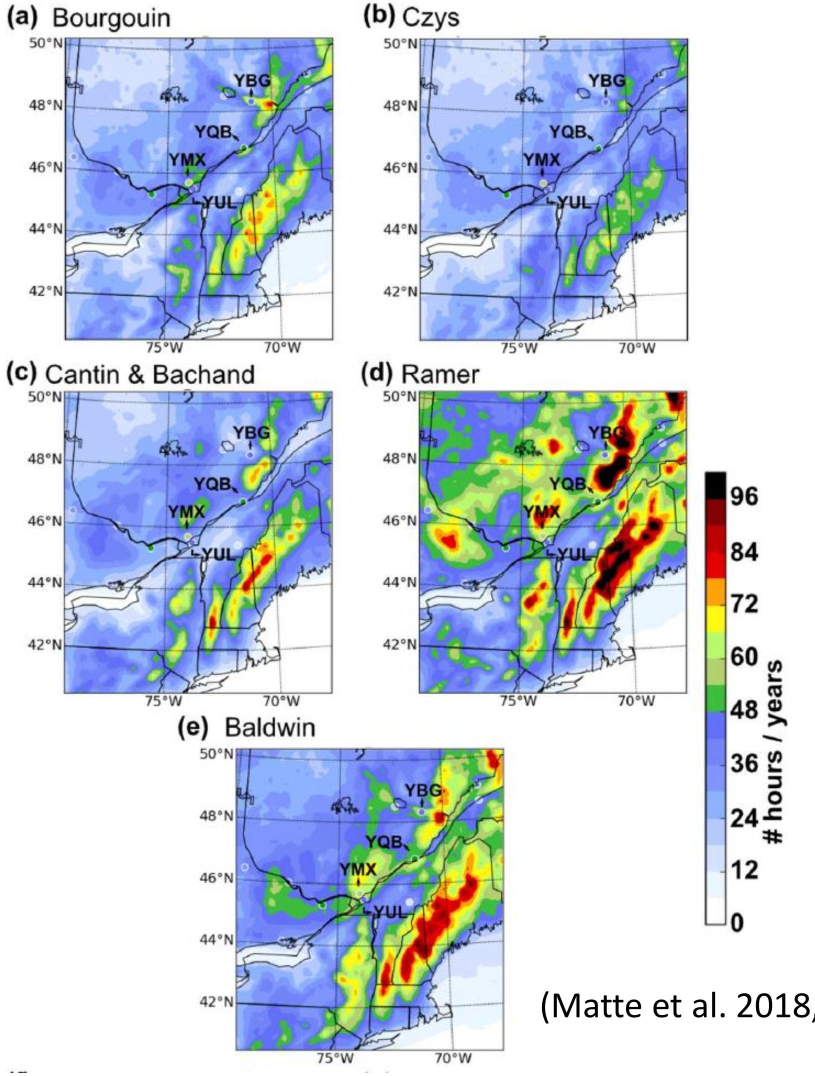


(Jeong et al. 2019, Fig. 7c)

Objective: Quantify uncertainty related to precipitation-type algorithm selection

- Only Matte et al. 2018 examined output using multiple algorithms
- Different algorithms have differing sensitivities based on variables used
- Changes in these variables may result in different projections of freezing rain
- **Question**: How do differences between algorithms impact projected changes to freezing rain events over North America?

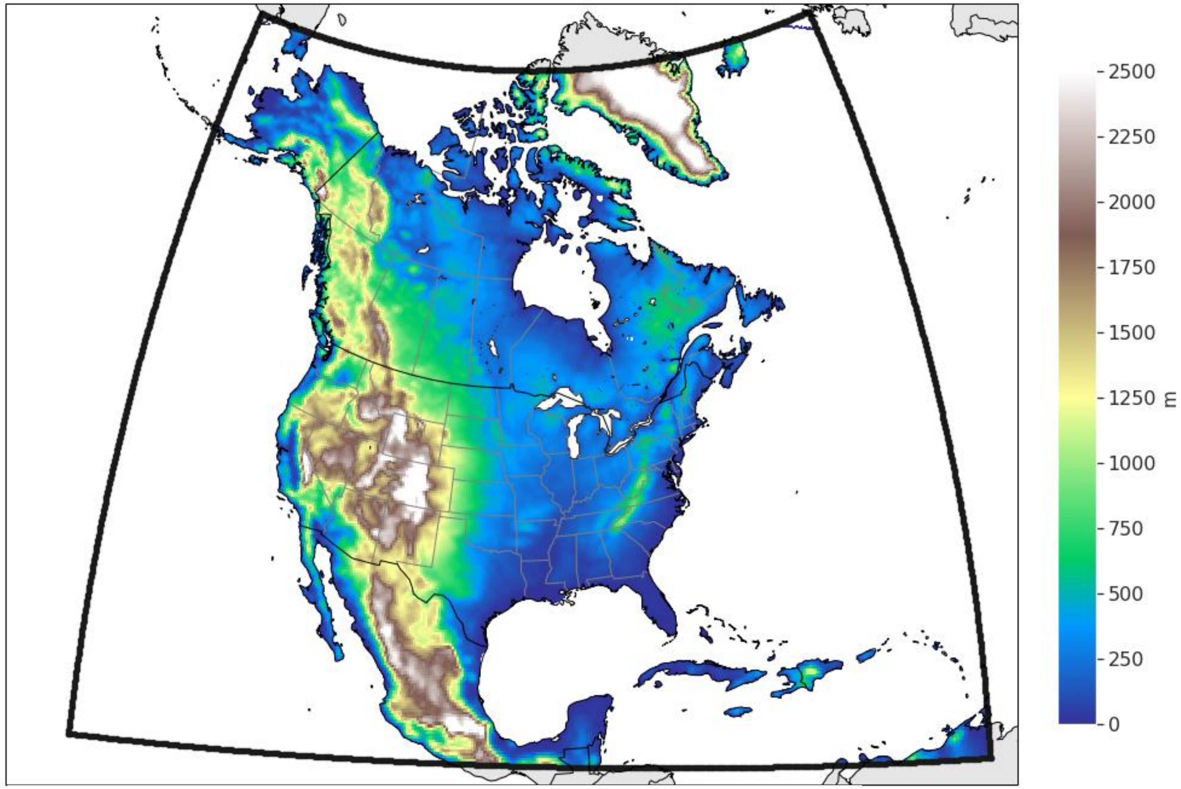
Mean annual hours freezing precipitation (1980-2009)



(Matte et al. 2018, Fig. 2)

Methods: fifth-generation Canadian Regional Climate Model (CRCM5) (0.22°)

- CRCM5 (Martynov et al. 2013, Šeparović et al. 2013) @0.22°, run at Ouranos
  - Developed at Centre ESCER (Étude et la Simulation du Climat à l'Échelle Régionale) - UQAM
  - Resolves key terrain features, freezing rain events over Quebec (Cholette et al. 2015, Bresson et al. 2017, St. Pierre et al. 2019)
- Several pilot GCM simulations available in NA-CORDEX
  - Here: **CanESM2**
- Two periods
  - 1980-2009
  - 2070-2099 (RCP 8.5)
- Four algorithms assessed on 3-hourly output when 3-h precip > 0.125 mm (1 mm day^{-1})
- 22 pressure levels + surface (2 m)



CRCM5 domain and surface orography

We diagnose freezing precipitation using four algorithms

Cantin and Bachand (1993) ("Partial thickness method")

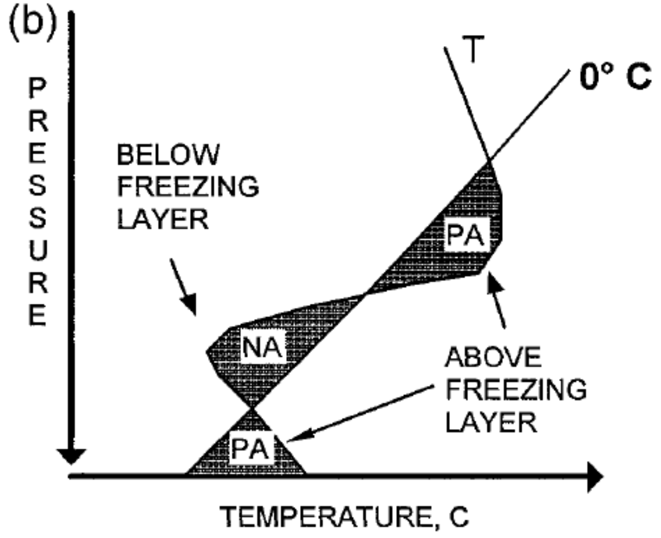
- No saturation/ice nucleation criteria
- Uses 850-700-hPa and 1000-850-hPa thicknesses
- Added surface temperature criteria (T ≤ 0°C)

Ramer (1993)

- Saturated layer: RH > 80% (tunable parameter)
- Ice nucleation: wet-bulb temperature T_w <-6.6°C
- Calculates change in ice fraction as particles descend

Baldwin et al. (1994)

- Saturated layer: dew-point depression < 2, 4, 6°C
- Ice nucleation: wet-bulb temperature T_w <-4°C
- Compares several area calculations (e.g, area between -4°C and T_w)



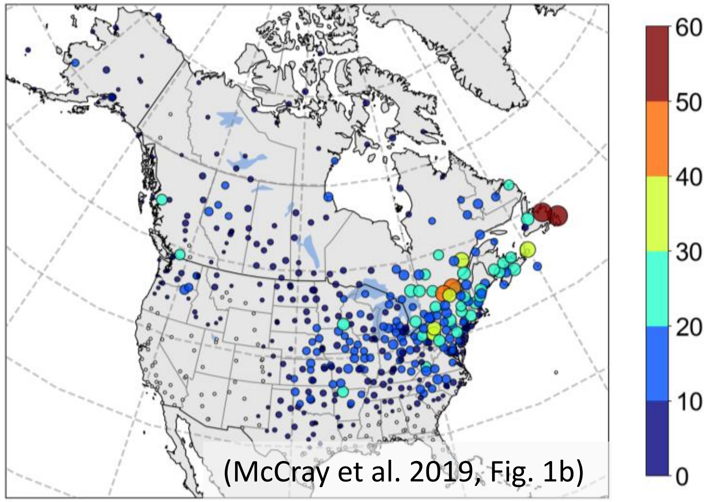
(Bourgouin 2000, Fig. 1b)

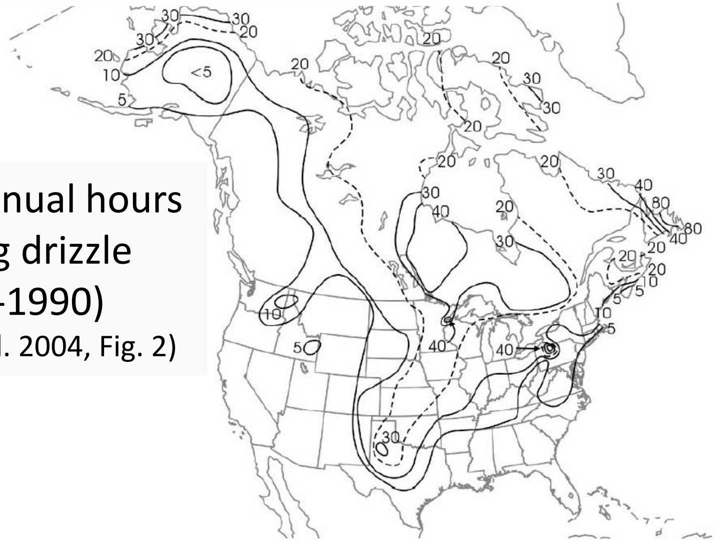
Bourgouin (2000)

- No saturation/ice nucleation criteria
- Calculates melting/refreezing energies (difference between dry-bulb temperature and 0°C)
- Precipitation type determined by relationship between the two

Preliminary results

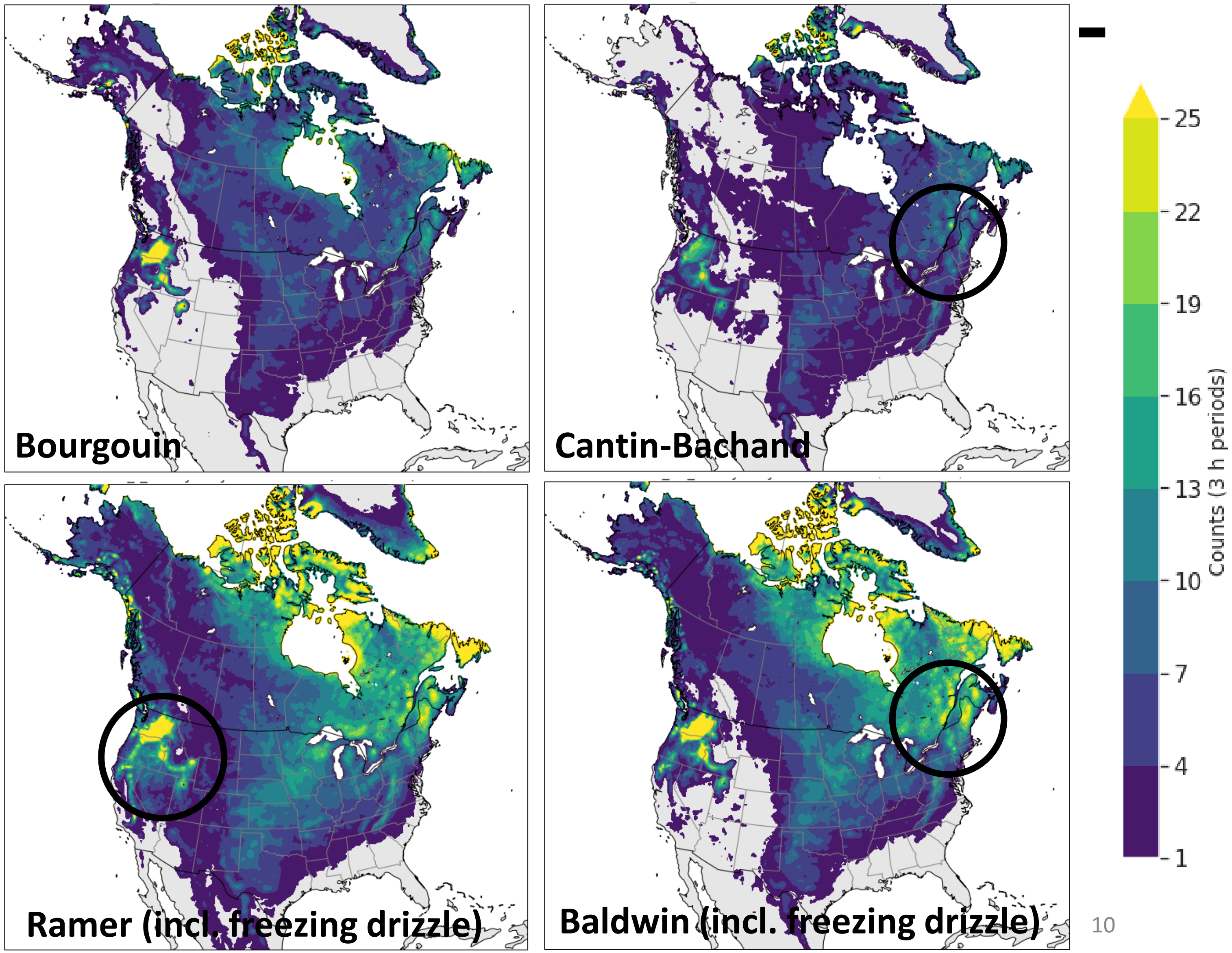
Median annual hours
Freezing rain (1979-2016)



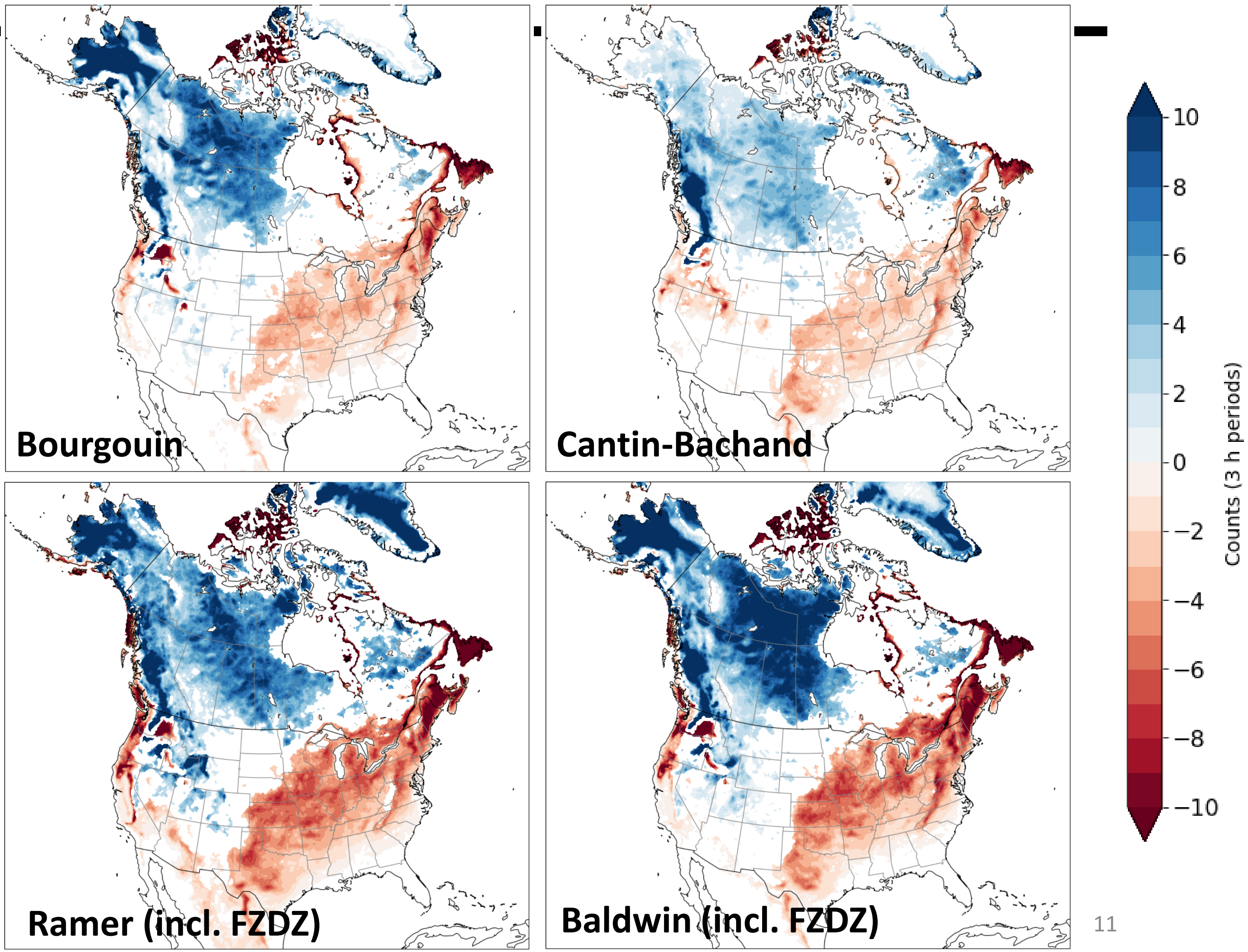


Median annual hours
Freezing drizzle
(1976-1990)
(Cortinas et al. 2004, Fig. 2)

Mean annual 3 h periods of freezing rain
1980-2009



Change (# of 3 h periods) (2070-2099 – 1980-2009)



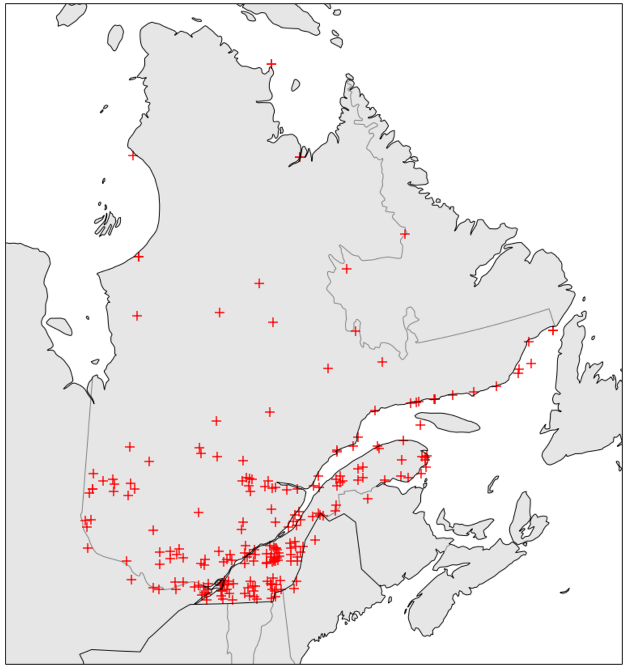
Summary

- CRCM5 at 0.22° generally **reproduces the current climatology of freezing rain** over North America
  - More detailed validation ongoing
- **General agreement** on changes between different algorithms, though some differences particularly at borders between increase/decreases
  - **Magnitude** of change sensitive to algorithm selection, though **relative changes** more similar
- Differences between algorithms related to **saturation and ice formation** (and therefore freezing drizzle formation) result in largest discrepancies between projections

Ongoing/future work

- **Validate climatology** of freezing rain in historical simulation (CRCM5 driven by ERA-Interim)
  - Comparison with climatological data from McCray et al. 2019
  - Comparison with Hydro-Québec ice accretion observations
- Examine changes to freezing rain **events**
- Expand analysis to additional simulations
  - Remaining CRCM5 Ouranos simulations
    - RCP 4.5, other pilot GCMs, mid-century period
  - Other CORDEX simulations (different RCMs)
  - Combine various sources of uncertainty to develop **complete picture of projected changes**

Hydro-Québec
ice measurement network



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Questions? Lightning talk: Friday, 15 January – 1:20 PM

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