Estimating Societal Damages from Aviation Emissions in Canada

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October 2020

Outline

- Introduction
- Methodology
- Preliminary results
- Conclusion

OBJECTIVES

- Aviation emissions have been found to cause ~16 000 premature deaths (Koo et al.,2013)
- Development of national marginal benefit database for aircraft emissions
- Overcoming the limitation of estimating MBs
- Presenting backward/adjoint analysis to provide location-specific aviation-attributable marginal damages

Methodology

	Canada
Study Period	2 weeks in July and February 2014, each (plus 2 days for Forward and 1 day for Backward spin-up period)
Meteorology	ECMWF initialization / WRF v3.8.1
Emissions	SMOKEv4.5
Spatial Resolution	12km (480 x 200)
CTM	CMAQ v5.0 and its ADJOINT
IC/BC	Created by Hemispheric-Scale CMAQ
Epidemiological model	Crouse et al. (2012) and Burnett et al. (2014)
Adjoint cost function	Chronic $PM_{2.5}$ exposure mortality, and acute O_3 and NO_2 constructed from two-week simulations in each season.

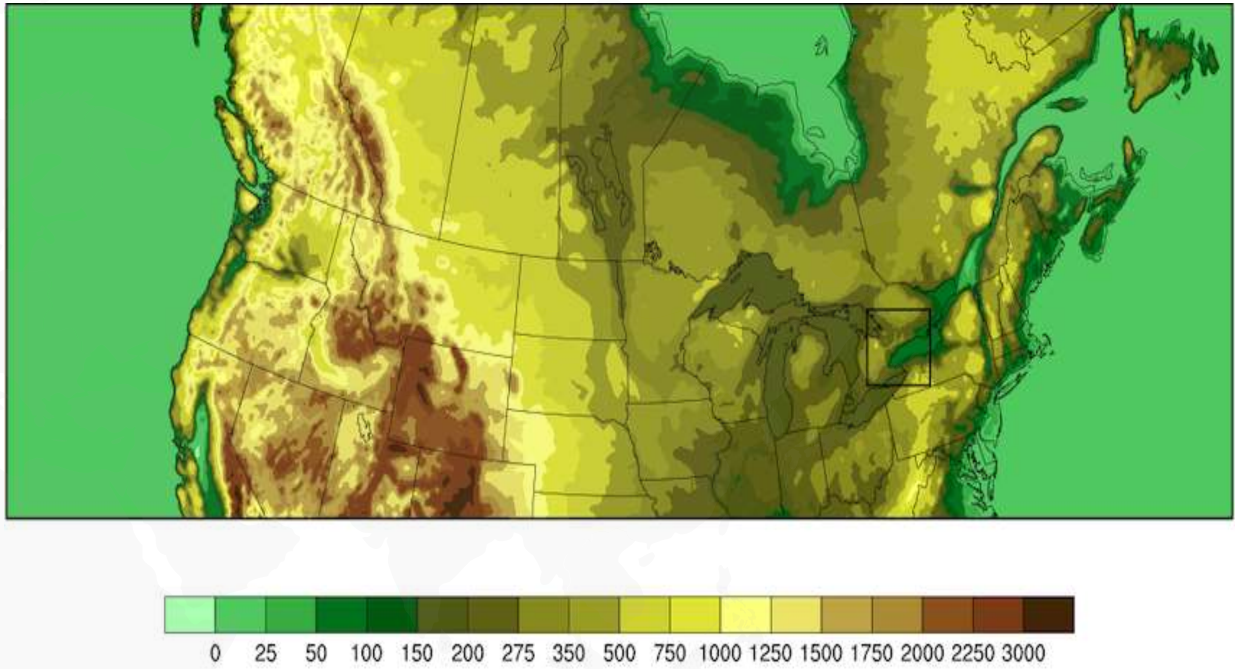
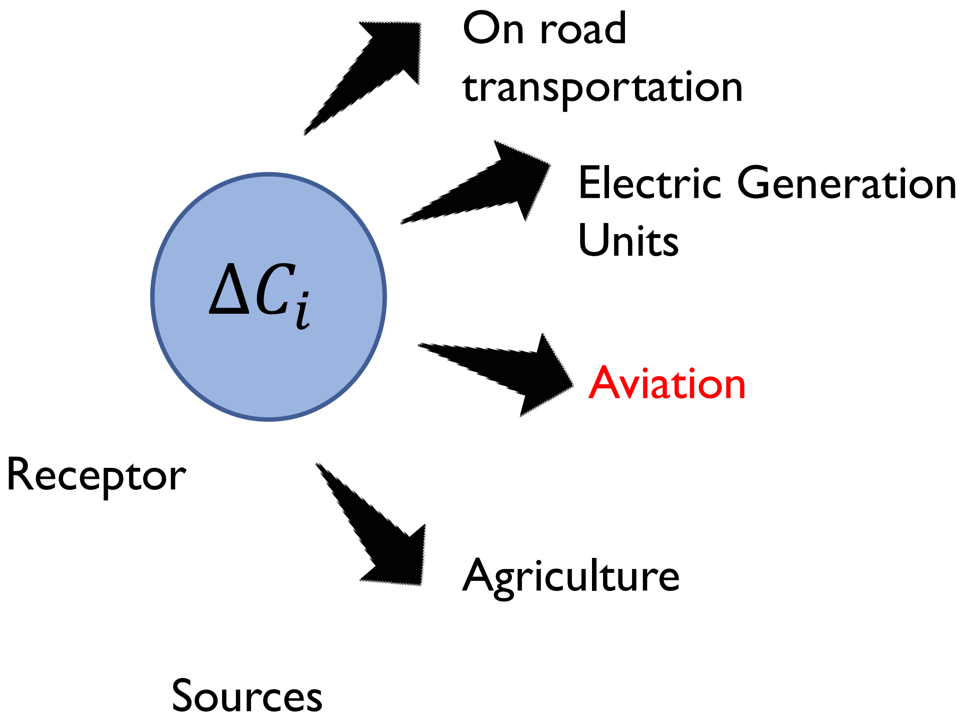


Figure 1: Topographic map of the North American simulation domain

ADJOINT SENSITIVITY



The adjoint cost function (Pappin et al., 2016)

$$J = V_{SL} \sum_i M_{o,i} P_i (1 - e^{\beta \, \Delta C i})$$

where,
J= Marginal Benefit (MB)
β= epidemiological concentration factor
V_{SL} = value of statistical life
M_o = baseline non-accidental mortality rate
P = population

HEALTH IMPACT EVALUATION

$$\frac{\text{D\$}}{\text{DEmissions}} = \frac{\text{D\$}}{\text{DMortality}} \times \frac{\text{DMortality}}{\text{DConcentrations}} \times \frac{\text{DConcentrations}}{\text{DEmissions}}$$

Economics — Epidemiology — Air quality modeling

- Benefit Per Ton (BPT) Using Acute O_3 and NO_2 and chronic $PM_{2.5}$ in the Air Quality Benefit Assessment Tool (AQBAT v3.0) of Health Canada
- Baseline Mortality Rates (BMR) obtained from AQBAT v3.0
- Population data, age 25+ obtained from Statistics Canada 2010. Aggregated to our domain (12 km spatial resolution)

Table 1 BPT values of surface $PM_{2.5}$ and NO_X emissions at airports

Airports	Latitude	Longitude	BPT $PM_{2.5}$ ($1000/ton)	BPT NO_X ($/ton)
Toronto Pearson International Airport	43.6777	-79.6248	3820	4580
Vancouver International Airport	49.1967	-123.1815	390	830
Montreal-Trudeau International Airport	45.4657	-73.7455	3320	10140
Calgary International Airport	51.1215	-114.0076	1900	5140
Edmonton International Airport	53.3054	-113.5774	1410	5490
Ottawa Macdonald-Cartier International Airport	45.3192	-75.6692	2300	20140
Winnipeg James Armstrong Richardson International Airport	49.9098	-97.2365	1300	3880
Québec City Jean Lesage International Airport	44.8836	-63.5094	1250	23400
Billy Bishop Toronto City Airport	43.6285	-79.396	910	6820
Region of Waterloo International Airport	49.9569	-119.3787	1800	52740

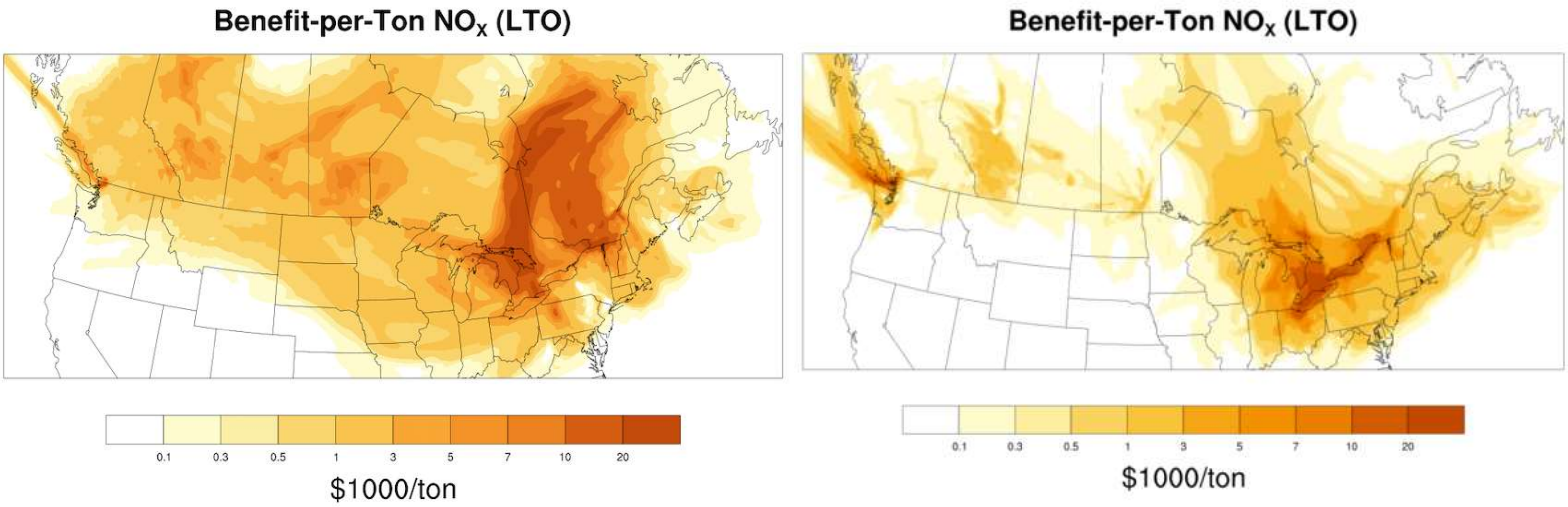


Figure 2 BPTs for NO_X emissions under 900 m altitude where landing/takeoff takes place
Left (Winter) and Right (Summer)

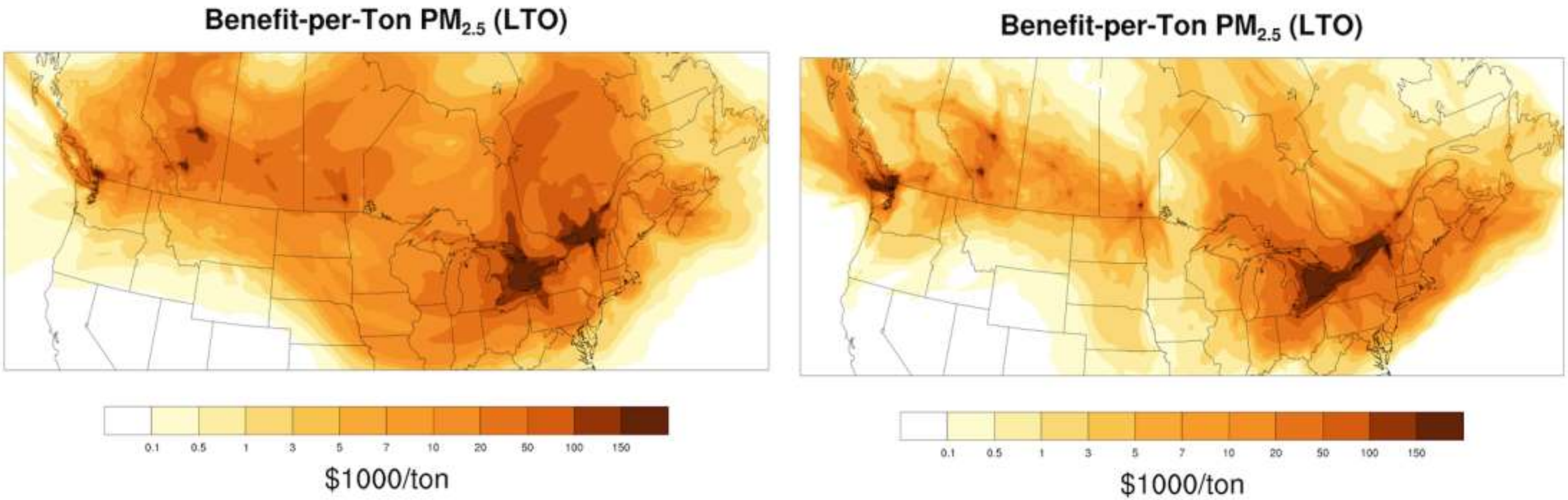
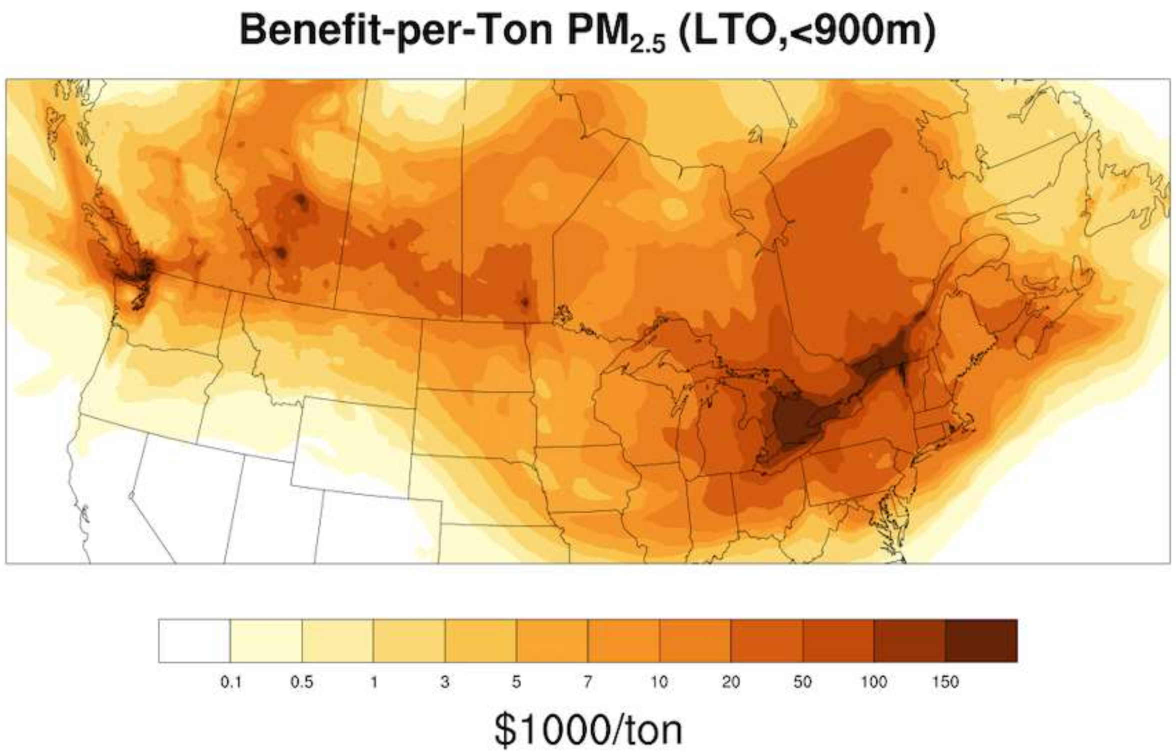


Figure 3 BPTs for $PM_{2.5}$ emissions under 900 m altitude where landing/takeoff takes place
Left (Winter) and Right (Summer)



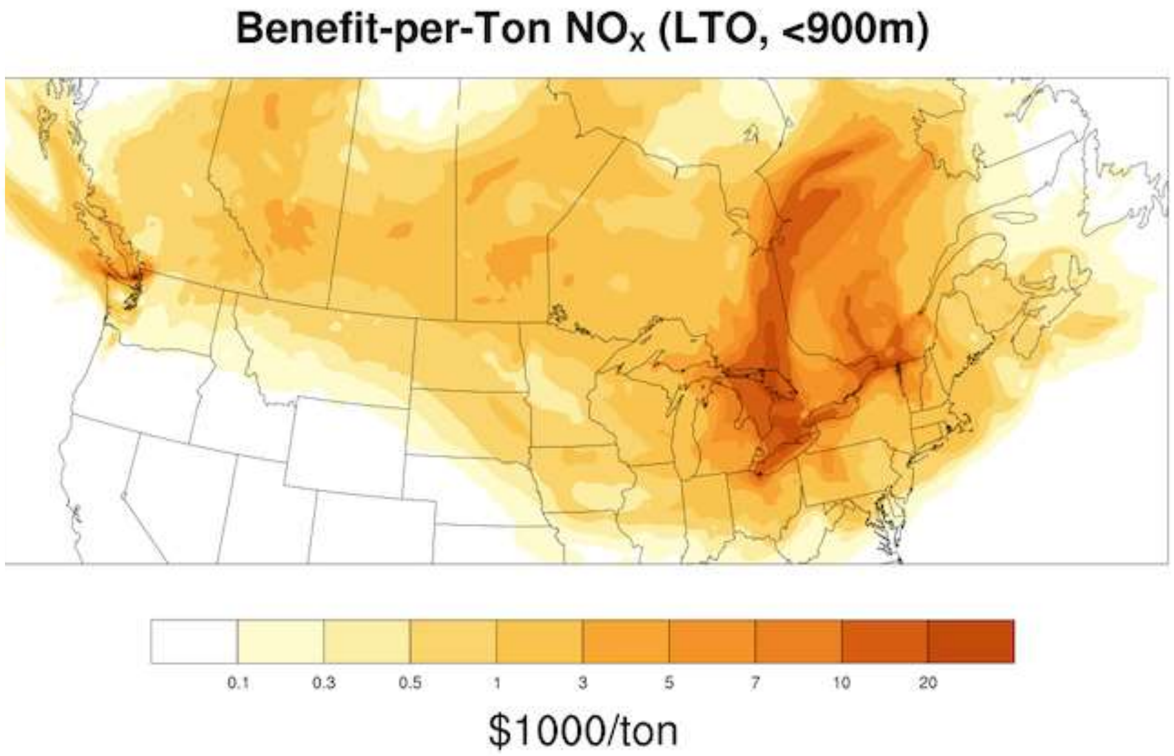


Figure 4 BPTs for $PM_{2.5}$ and NO_X emissions under 900 m altitude where landing/takeoff takes place

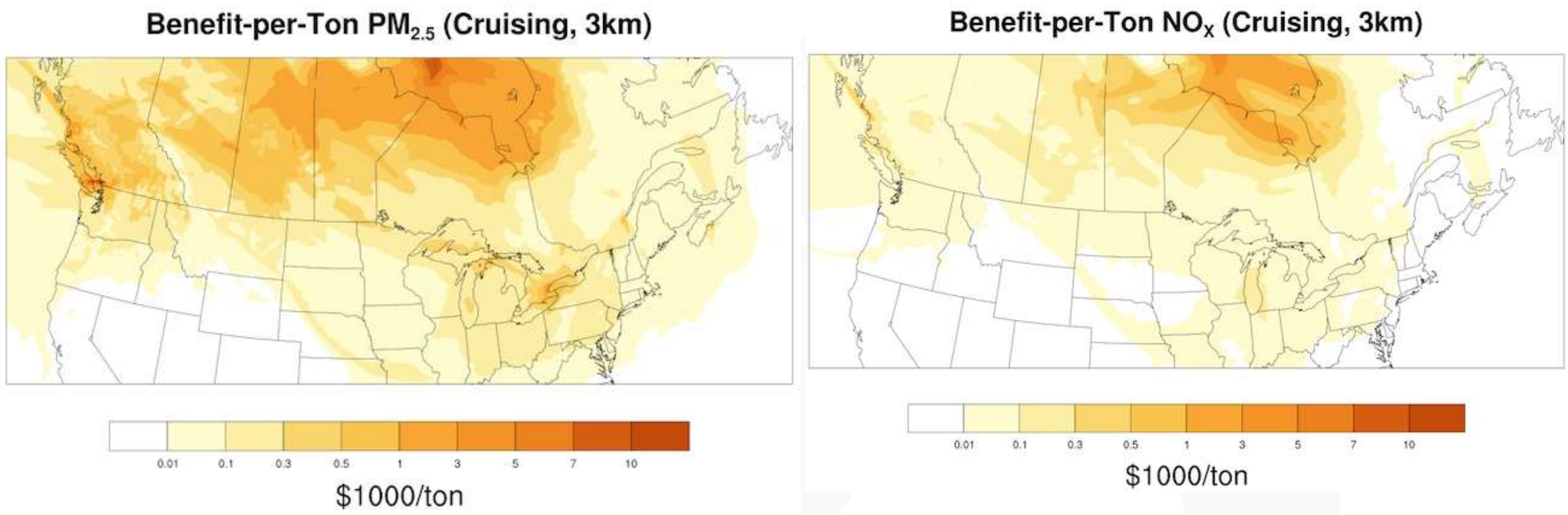


Figure 5 BPTs for $PM_{2.5}$ and NO_X emissions at 3 km altitude that is one of the aircraft cruising altitude

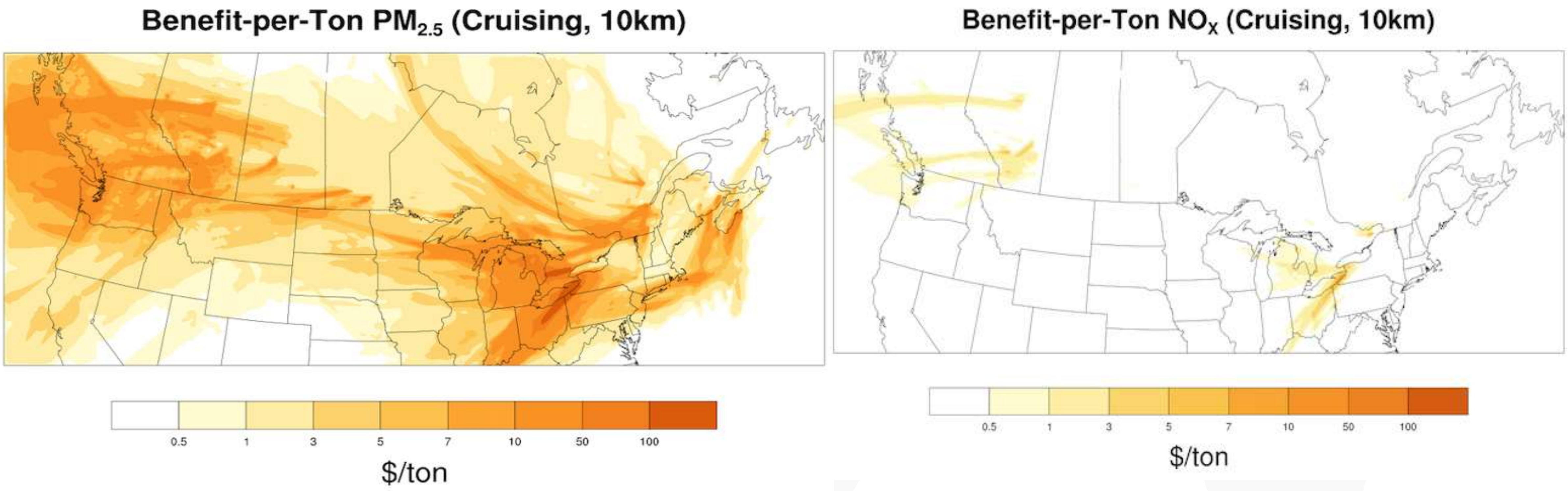


Figure 6 BPTs for $PM_{2.5}$ and NO_X emissions at 10 km altitude that is a common aircraft cruising altitude

Conclusion

- The largest estimated BPT of reducing $PM_{2.5}$ comes from Toronto Pearson International Airport
- Aviation associated health benefits can be as high as $1,370,000 per ton of reduction of $PM_{2.5}$ and $53,000 per ton of reduction of NO_x emissions due to LTO activities.
- Estimated marginal benefit of reducing one ton of $PM_{2.5}$ emissions is $260 while $8 per ton of reduction of NO_x emissions that contributes to surface $PM_{2.5}$ generated at common aircraft cruising altitude.
- The largest health benefit estimates are attributed to landing/takeoff that contributes to a quarter of the benefits.

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ACKNOWLEDGEMENTS

- Funding from Clean Transportation System – Research and Development Program, Transport Canada
- Computational resources from Compute Canada

THANK YOU.