Spatial variability and optimal regional scale for intake fractions linked to a Canadian emission

Rima Manneh *rima.manneh@polymtl.ca*
Manuele Margni
Ralph Rosenbaum
Louise Deschênes




INTERNATIONAL CHAIR
IN LIFE CYCLE ASSESSMENT

A Research Unit of the CIRAIG™ Interuniversity Research Centre for the Life Cycle of Products, Processes and Services

CIRAIG - École Polytechnique de Montréal Chemical Engineering Department
P.O. Box 6079
Montreal, Qc
Canada, H3C 3A7

ÉCOLE POLYTECHNIQUE MONTRÉAL

Outline

- A reminder of the characterization factor
- Why spatial differentiation?
- Objective
- How to assess spatial variability?
- Results
- Conclusions and future work

A reminder of the characterization factor

$$S_i^{mn} = E_i \, F_i^{nm} \, M_i^{n}$$

Potential impact — Effect — Fate and exposure — Emitted mass

Characterization factor (CF)

With:

- i the substance
- n the emission compartment
- m the exposure pathway

(Hertwich et al., 2002)

Why spatial differentiation?

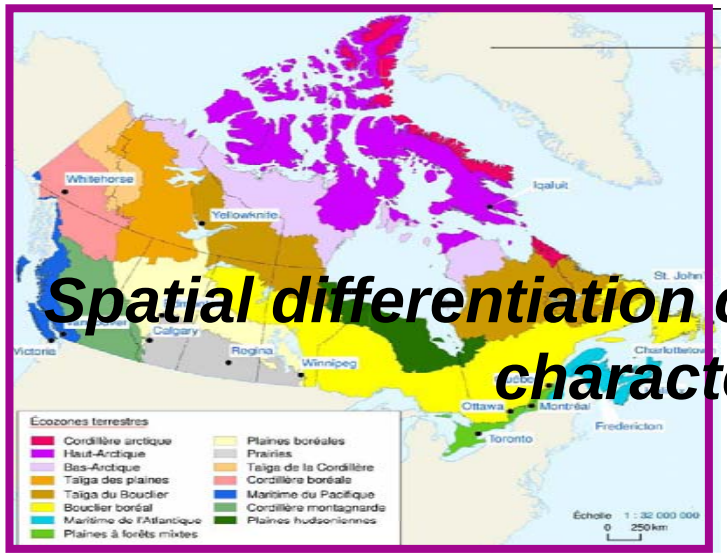
- Human toxicity impacts are considered local/regional
  - Fate and exposure parameters change with regions
  - Using a non-spatial model could result in additional uncertainties of 2 to 3 orders of magnitude (Pennington et al., 2005)

Importance of evaluating them within a specific regionalisation.

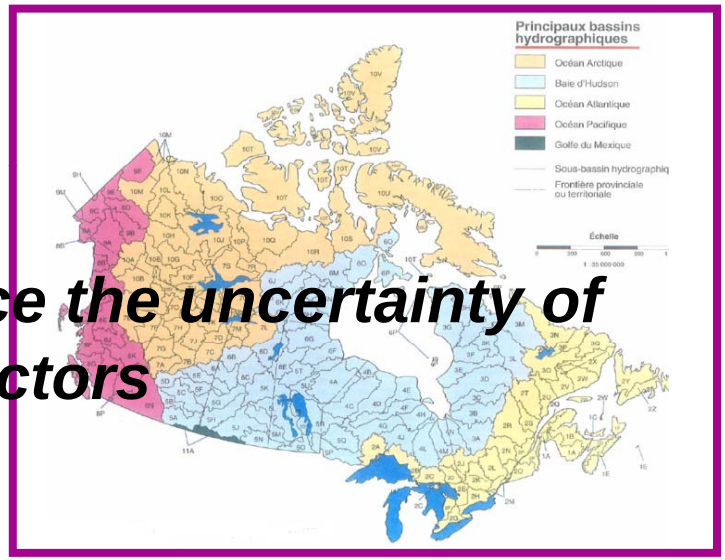
What is the level of spatial differentiation that is needed?

Why spatial differentiation?

LUCAS (Toffoletto et al., 2007) was developed from the necessity to have location-specific characterization factors



Spatial differentiation could reduce the uncertainty of characterization factors



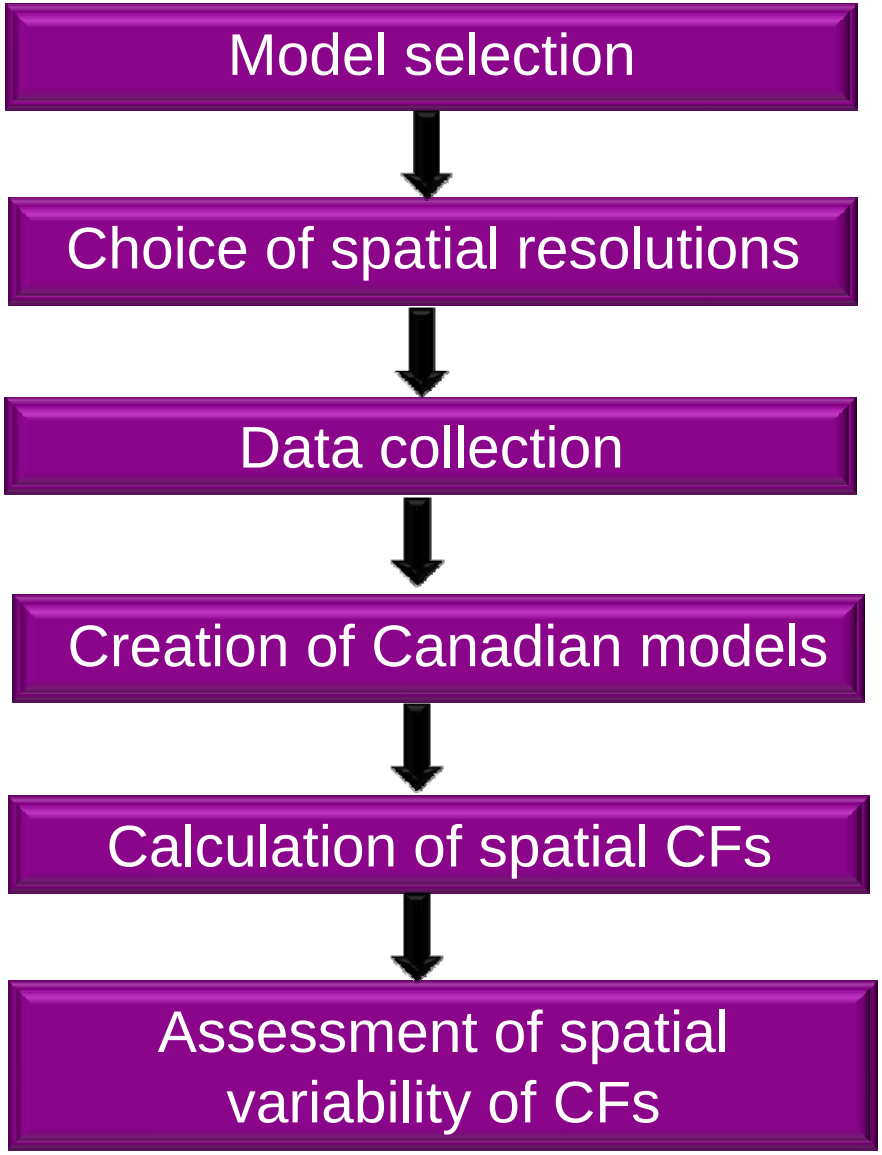
Statistics Canada, 2006

Natural Resources Canada, 2006

Objective

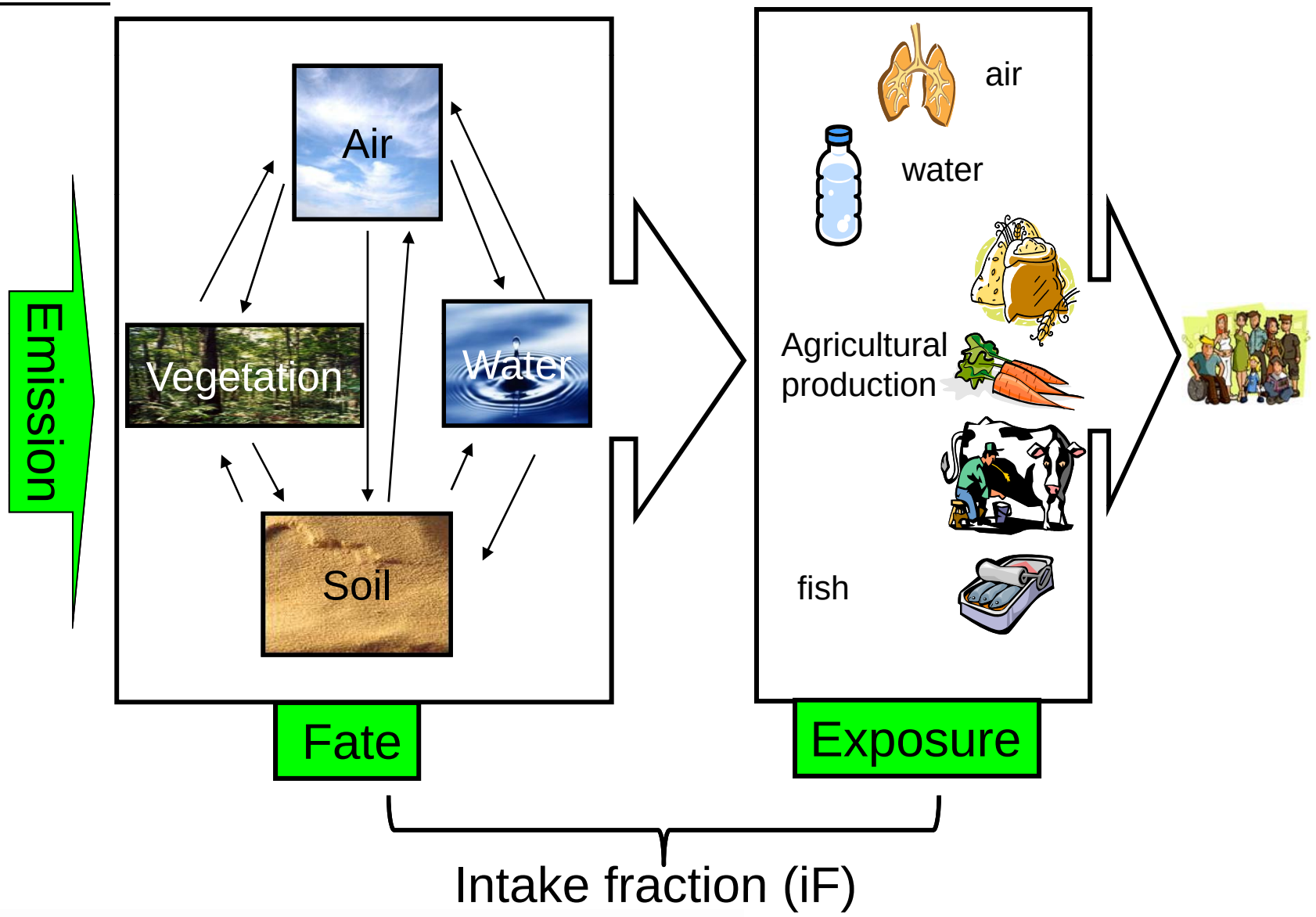
Determine the relevance of spatial differentiation and the optimal regional scale when assessing human health impacts in LCIA

How to assess spatial variability?



Model selection

IMPACT 2002



Fate/Exposure parameters for Canada

- **Demographic** (population, production…)
- **Meteorological** (precipitation, air advection…)
- **Geographic** (water areas…)
- **Hydrological** (water depth, water flow rates…)

References used for data collection

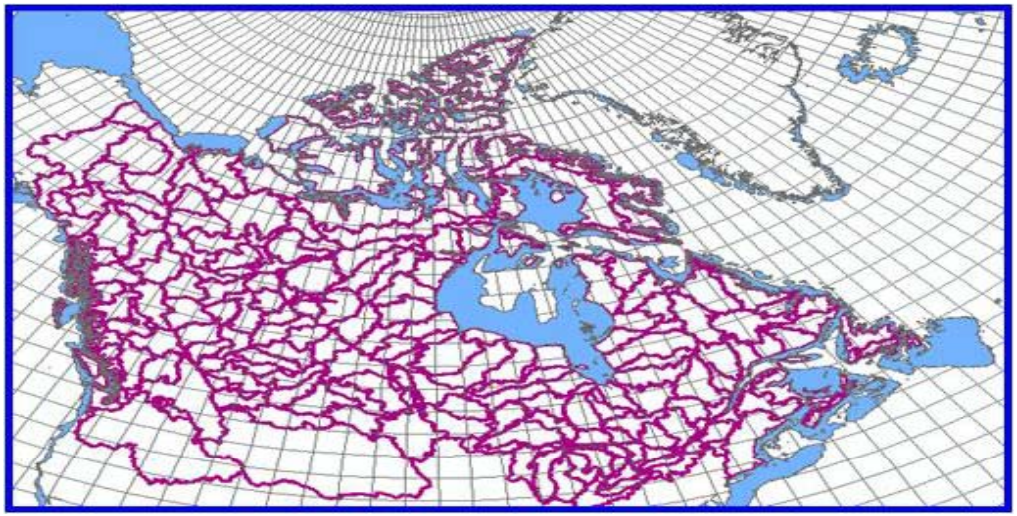
- Statistics Canada
- Environment Canada
- Natural Resources Canada
- Atlas Canada
- Agriculture Canada
- Hydrology of Canada
- FAO

Software used

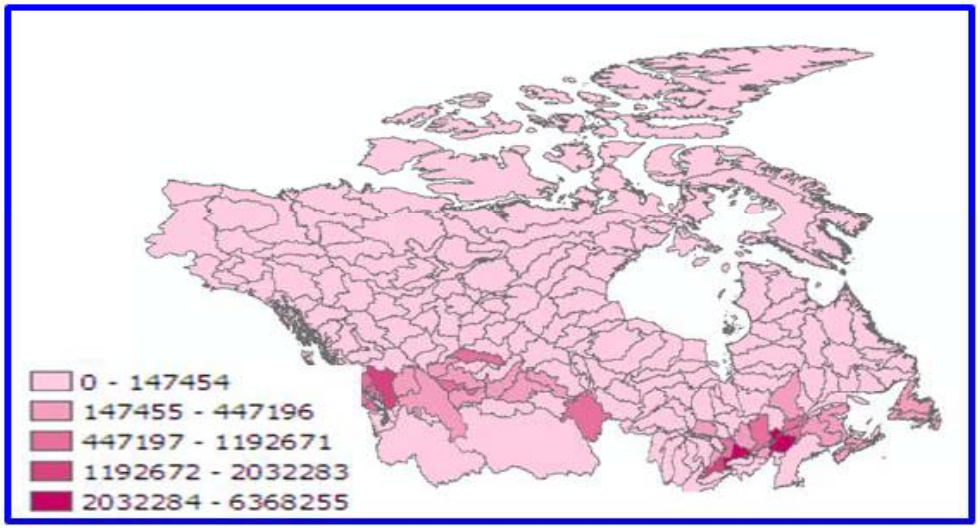
Geographic Information System (GIS)
ArcGIS

Fate and exposure parameters for Canada

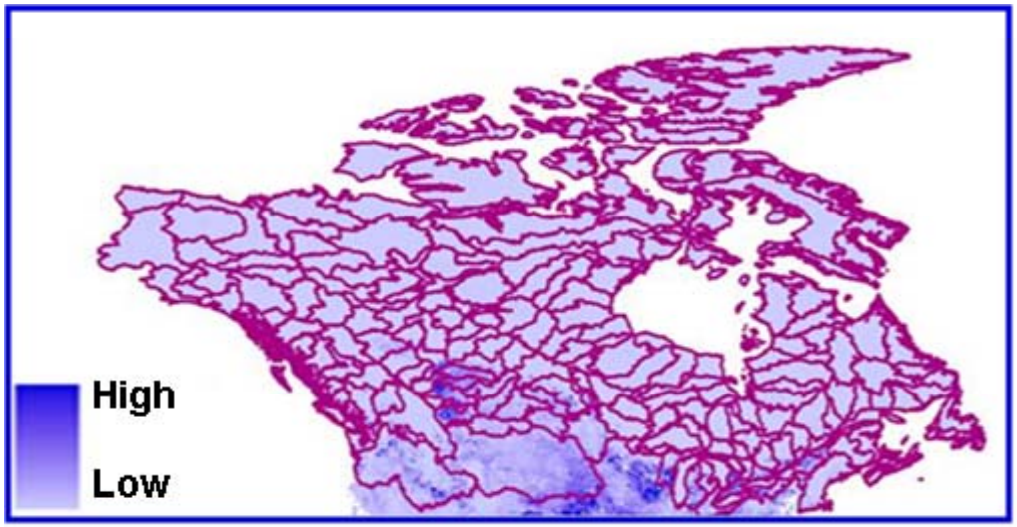
Direction of flow (Natural Resources Canada)



Air advection (Natural Resources Canada)



Population distribution (Natural Resources Canada)

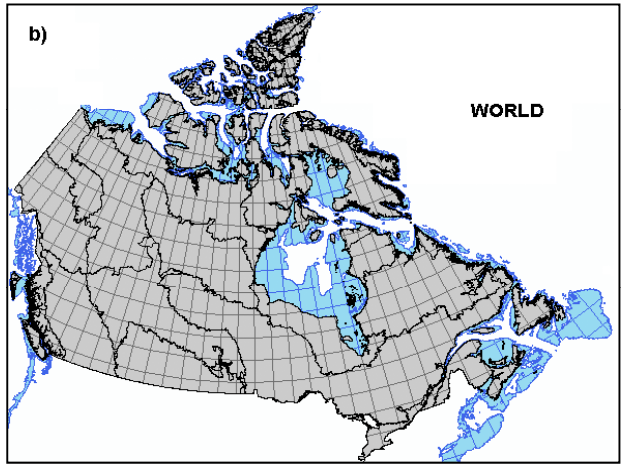


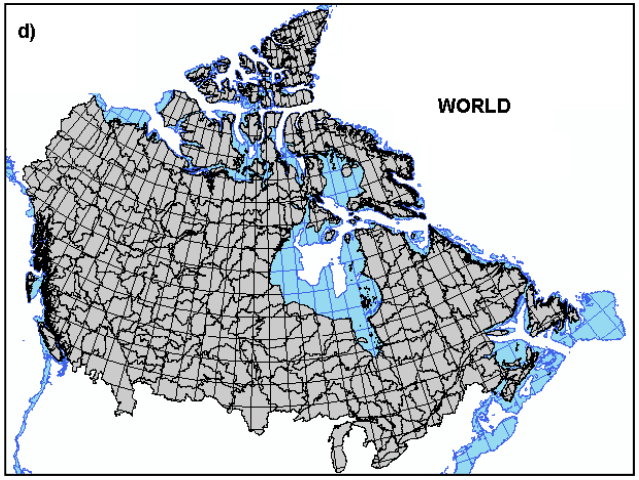
Animal production-Bovine (FAO)

Creation of Canadian models

1 non-spatial model

- 1 Canadian box,1 air zone and 1 oceanic zone
- 1 World box, 1 air zone and 1 oceanic zone

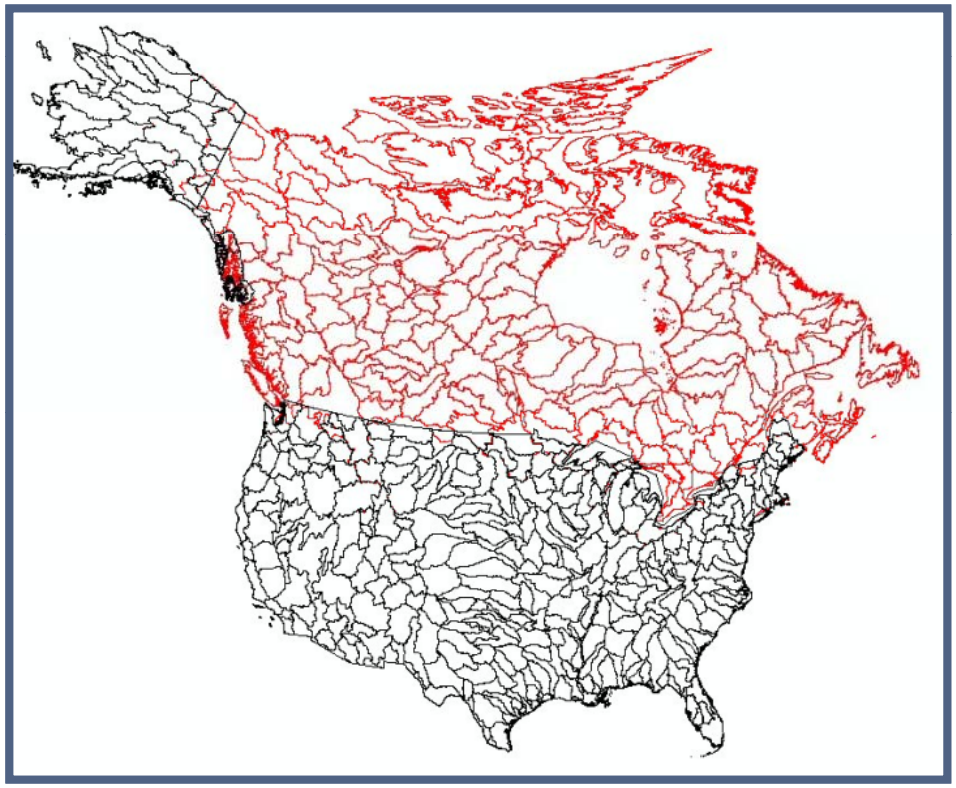




3 Spatial models

- 15 ecozones, 13 provinces, 172 sub-watersheds,
- 538 air regions and 4 oceanic zones
- 1 world box and 1 USA zone, with their respective air and oceanic zones

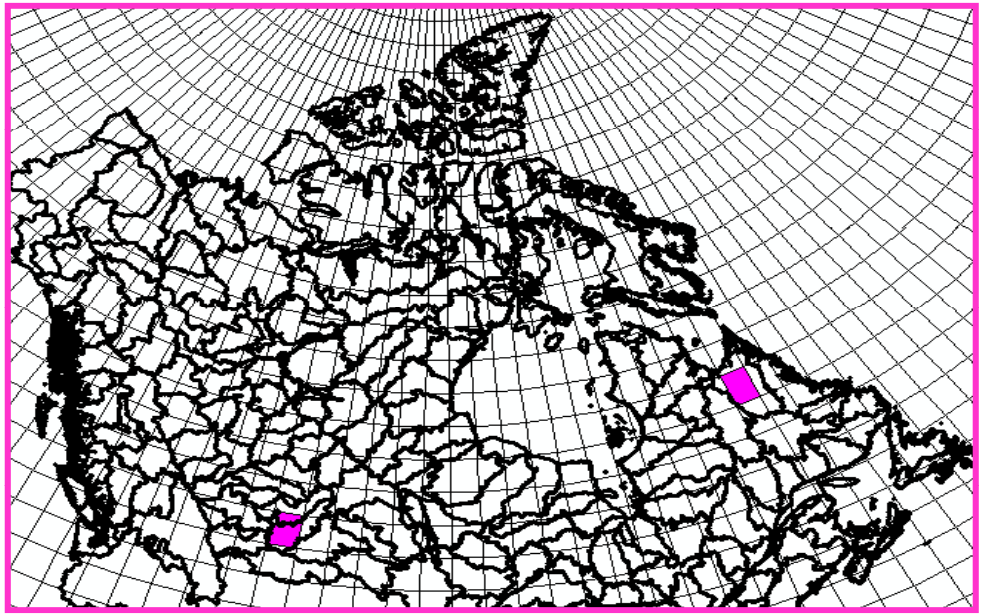
Creation of the North American model



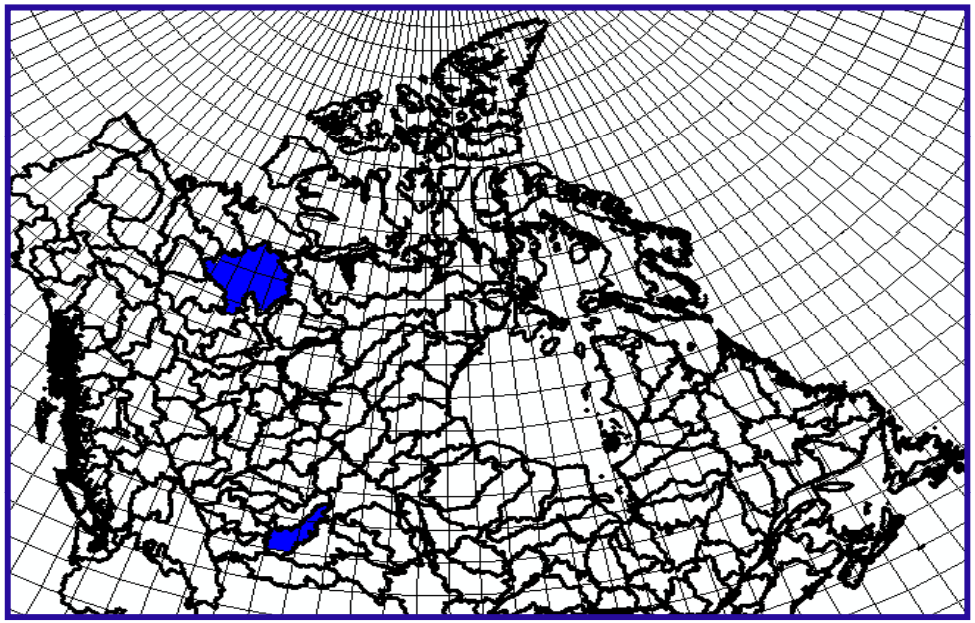
In collaboration with the University of California Berkeley and the University of Michigan

Humbert, S., Manneh, R., Shaked, S., Wannaz, C., Horvath, A., Deschênes, L., Jolliet, O., Margni, M. (2009). Asessing regional intake fractions in North America. The Science of the Total Environment, **407,** *4812-4820*

Calculation of spatial iFs



Develop iFs for air emissions into each of the 538 air regions, for each spatial resolution.

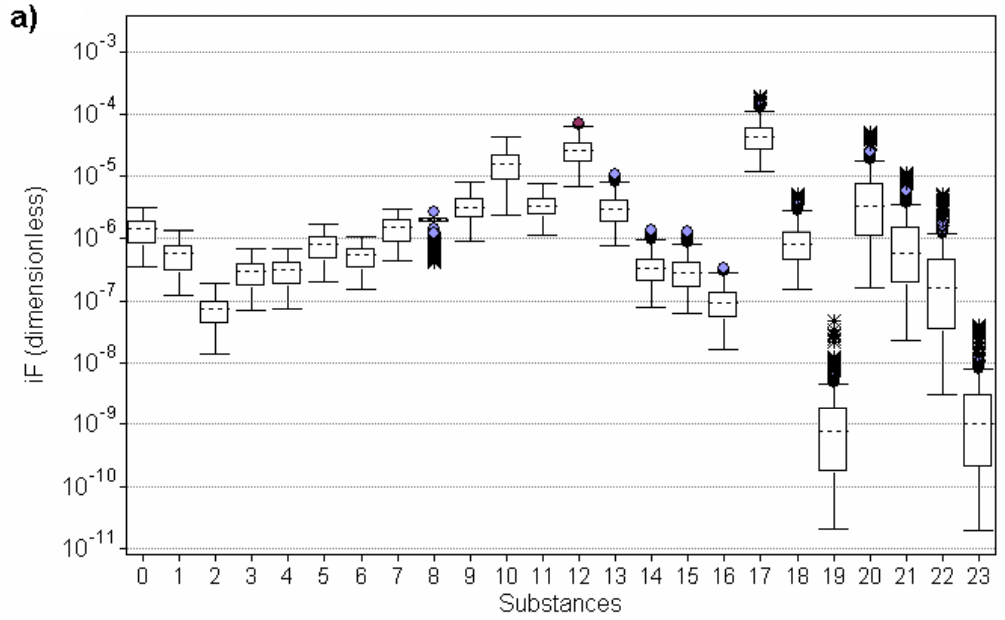


Develop iFs for water emissions into each of the sub-watersheds, ecozones and provinces/territories.

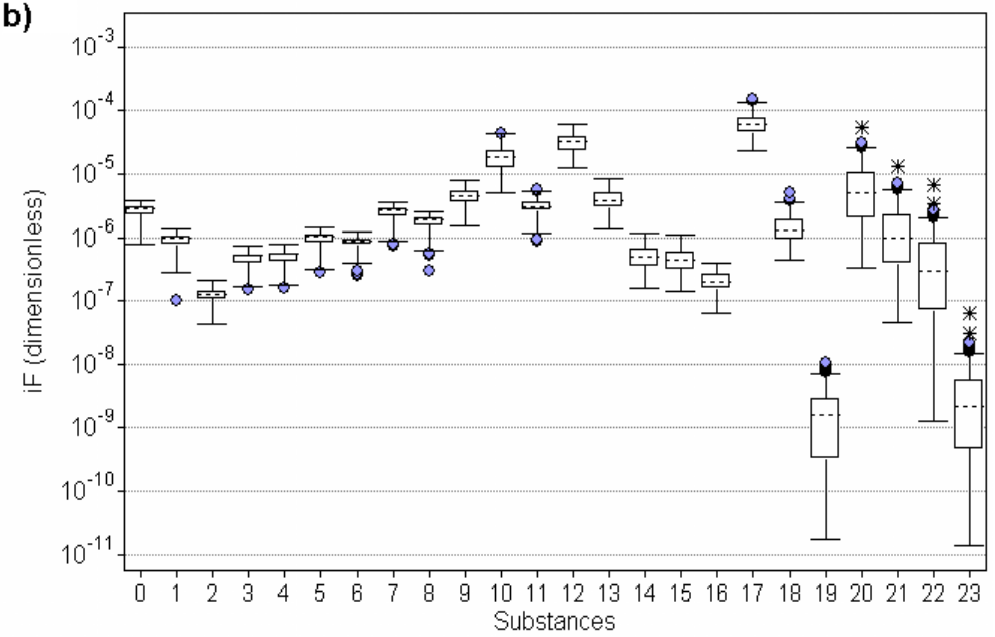
→ For each spatial resolution, what is the spatial variability of iFs as a function of emission location?

Spatial variability of iFs for the 3 resolutions (*Air emissions*)

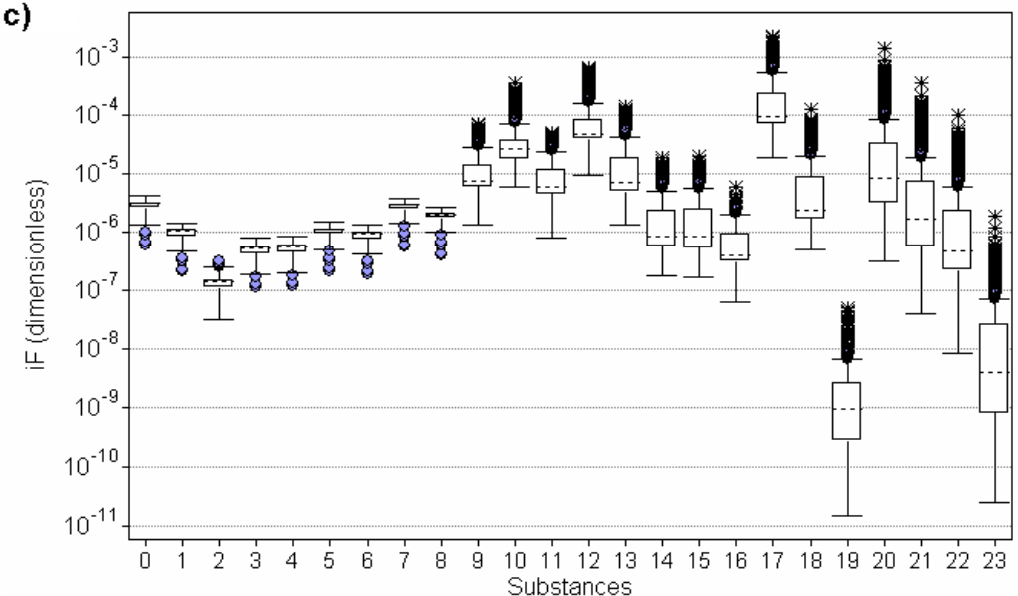
Ecozones



Provinces



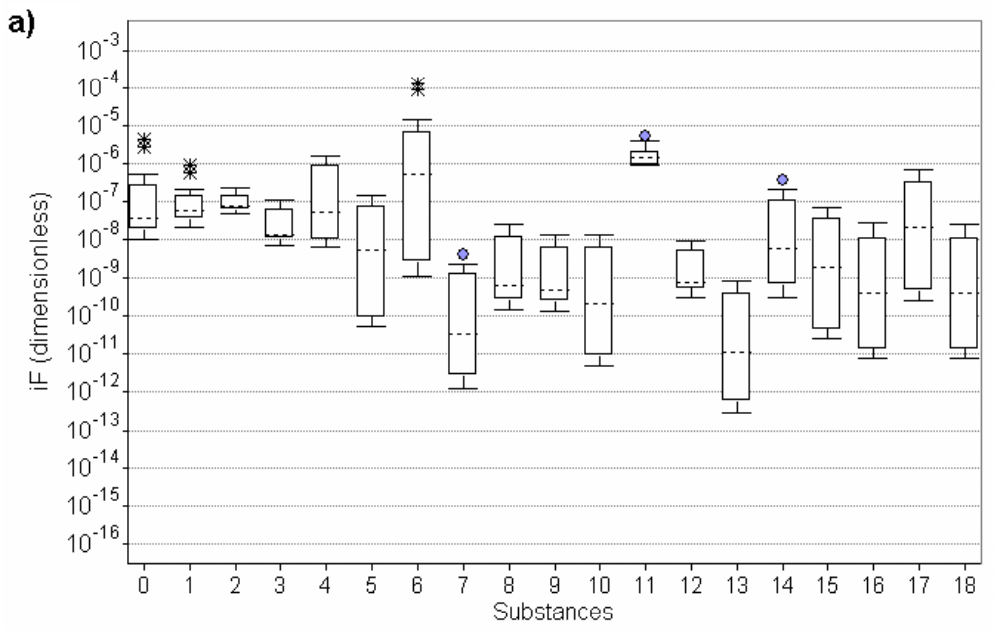
Sub-watersheds



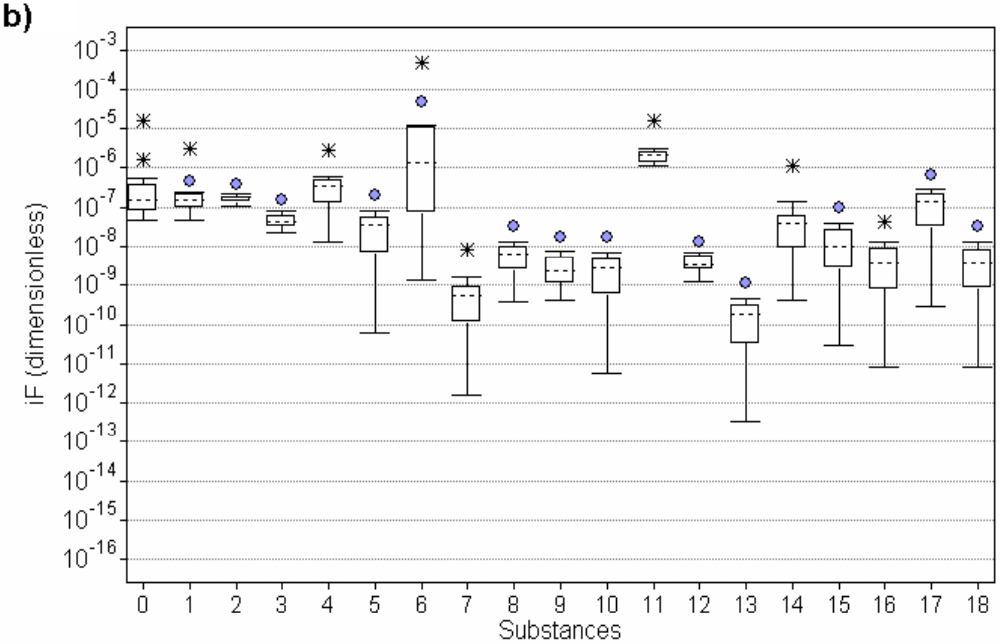
0 Carbon tetrachloride
1 1,2-Dichloroethane
2 Ethyl acetate
3 p-Dichlorobenzene
4 Tetrachloroethylene
5 1,1,2,2-Tetrachloroethane
6 Hexachlorocyclopentadiene
7 Hexachlorobutadiene
8 Hexachlorobenzene
9 Trifluralin
10 PCBS
11 gamma-Hexachlorocyclohexane
12 Benzene, hexabromo-
13 Heptachlor epoxide
14 Heptachlor
15 Anthracene
16 Methanol
17 2,3,7,8-TCDD
18 Dimethyl phthalate
19 1,3-Butadiene
20 Pronamide
21 Captan
22 N-Nitrosodiethylamine
23 Formaldehyde

Spatial variability of iFs for the 3 resolutions (*Water emissions*)

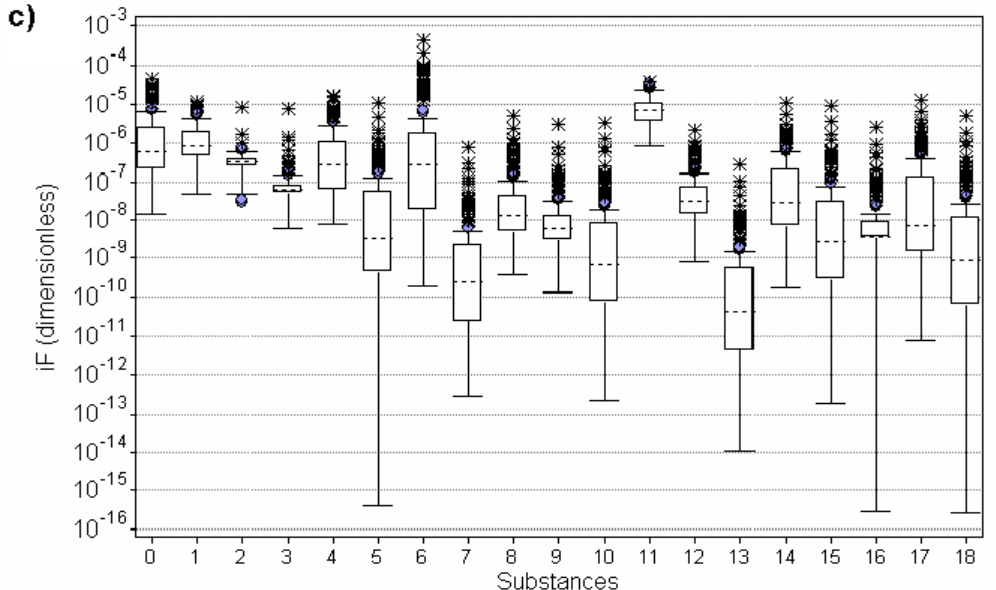
Ecozones



Provinces

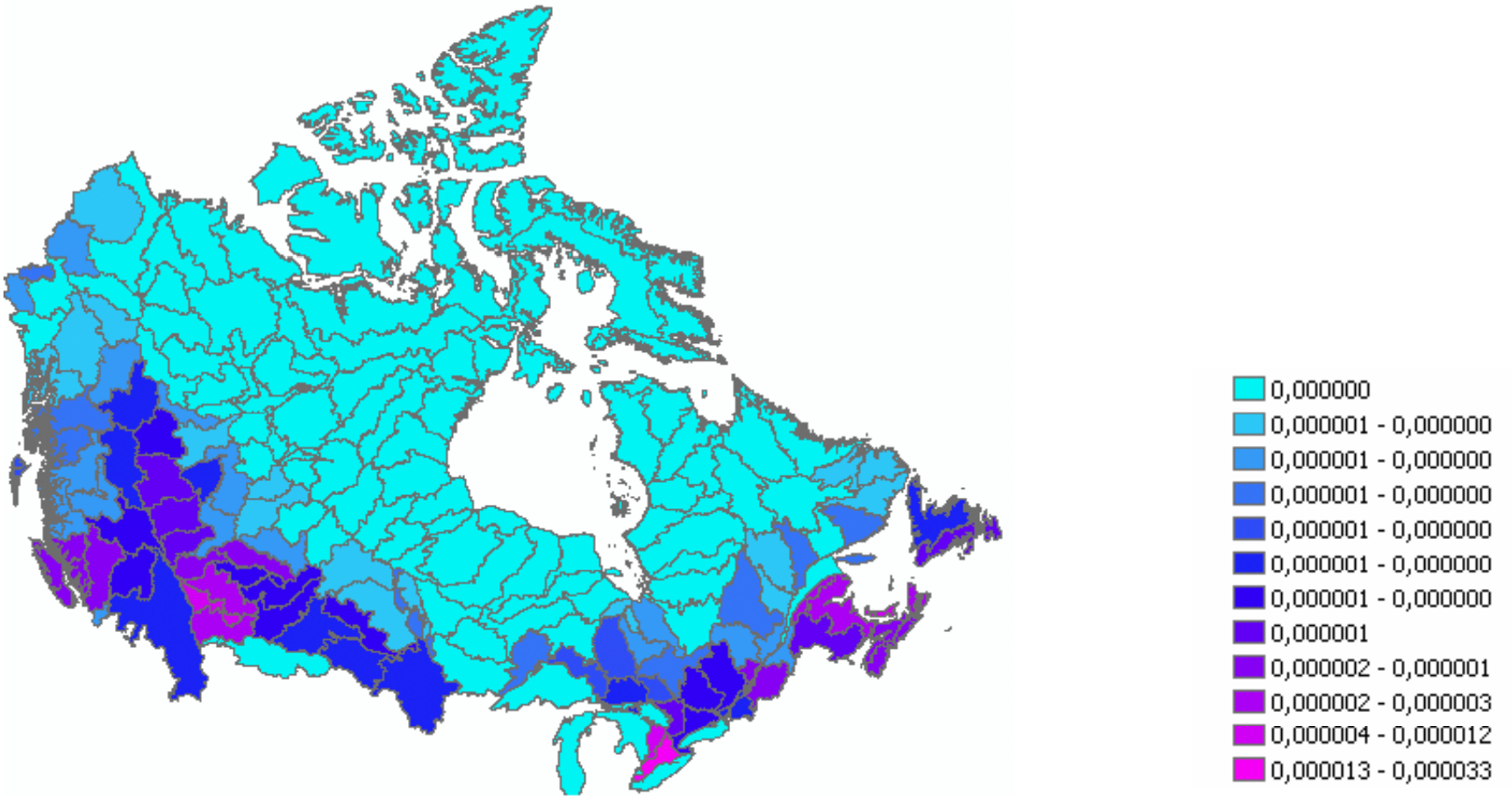


Sub-watersheds



0 Dicofol
1 Anthracène
2 1,1,2,2-Tetrachloroethane
3 1,2-Dichloroethane
4 1H-Isoindole-1,3(2H)-dione,
5 Acephate
6 Aldrin
7 Captan
8 Dimethyl phthalate
9 Ethyl acetate
10 Formaldehyde
11 gamma-Hexachlorocyclohexane
12 Methanol
13 N-Nitrosodiethylamine
14 Pronamide
15 Propoxur
16 Benomyl
17 Methomyl
18 Thioperoxydicarbonic diamide, tetramethyl-

Intensity of iFs as a function of emission location



Manneh, R., Margni, M., Deschênes, L. (2009). Spatial variability and optimal regional scale to assess intake fractions linked to a Canadian emission. Submitted to ES&T.

New regionalization!

Conclusions and future work

- Importance of spatial differentiation for human toxicity;
- Necessity to have a higher resolution scale when assessing human health impacts caused by pollutants emitted to water;
- Efforts should be focused on how to make results compliant with inventory data.

However, need to consider other types of uncertainty:

- Parameter uncertainty
- Temporal variability

Acknowledgements

/