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Sample Representativeness in Source Reconstruction

WOSMIP Remote II

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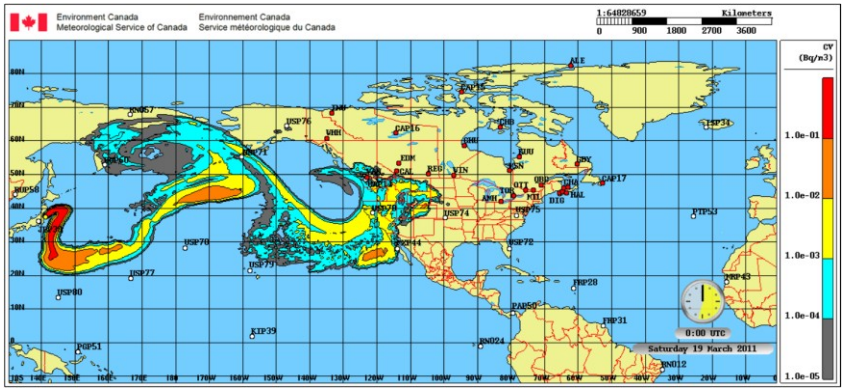
Introduction

- Source Reconstruction using Bayesian inference relies upon accurate estimates of uncertainty
  - Metrological uncertainty with spectroscopic measurement
    - Calibration, properties of peak signal, Radioactive Decay, etc.
  - Atmospheric transport and dispersion model (ATDM) uncertainty
    - Ensemble spread
    - See **On the model uncertainties in Bayesian source reconstruction…(**https://doi.org/10.5194/gmd-14-1237-2021)
  - What about statistical properties of the sampling process itself when used with ATDM?

Fukushima Revisited

- Radioactive plume was highly structured even after a few 1000 km transport
- ATDM suggested plume was relatively uniform in concentration
  - 1° x 1° models were used at the time
  - Even today with higher resolution ATDM results would look similar
- Fukushima showed evidence of sample inhomogeneity, but this was hot particle based.
  - Many other examples – parallel samplers where sample composition is completely different after analysis
  - Implications on source reconstruction algorithms not well understood



Adjacent aerosol analysers

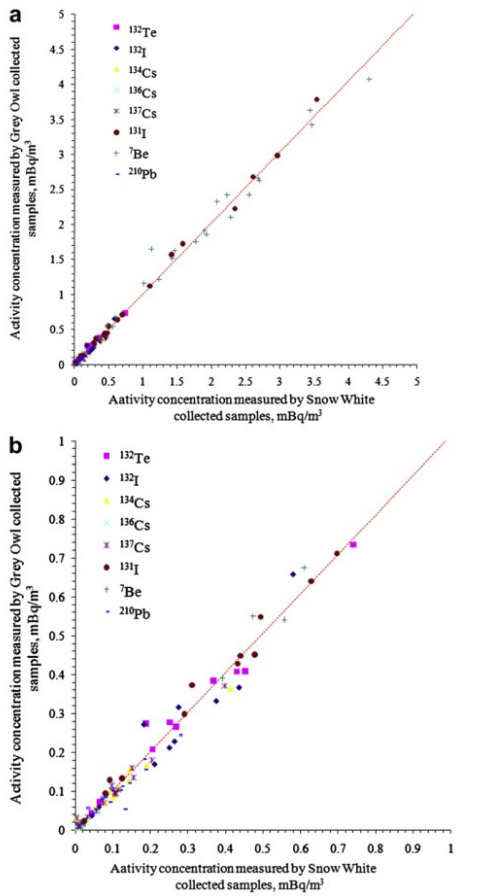
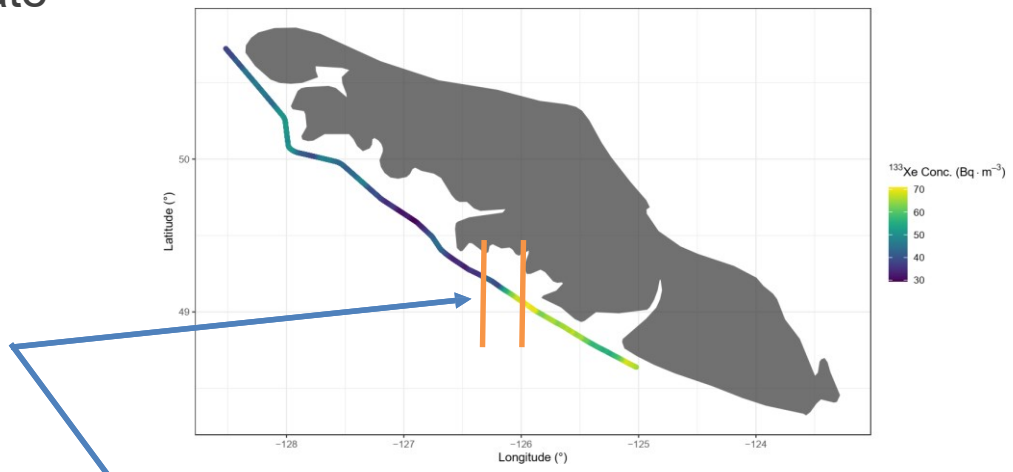


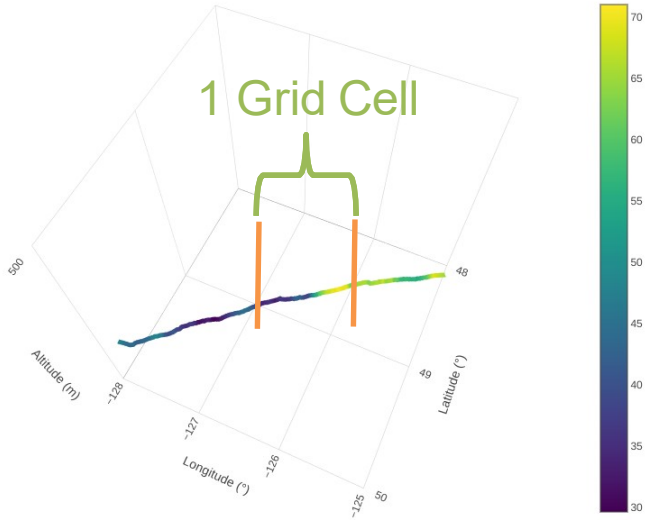
Fig. 4. Correlations between the Grey Owl and the Snow White monitored radionuclide activity concentration; (a) over the whole concentration range; (b) zoom for low concentrations.

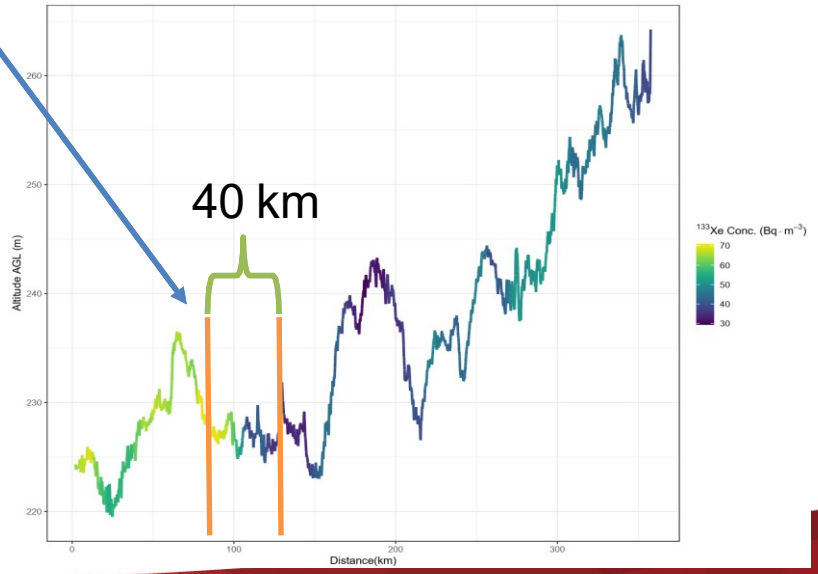
- 5 to 13% variation (see Gomez, Woods or Zhang papers on parallel samplers during Fukushima)
- Includes homogeneity when particle number density low (hot particles)
- Includes variability in rates of flow at different points in the plume sampling process when using non-mass flow controlled samplers

2011 Aerial Survey (NRCan)

- Log scale appropriate to illustrate ATDM, but ground truth is different.
  - Do we have an uncertainty underestimation?
- High variation in ^{133}Xe concentration even over short distances







CTBT Sampling and Source Reconstruction

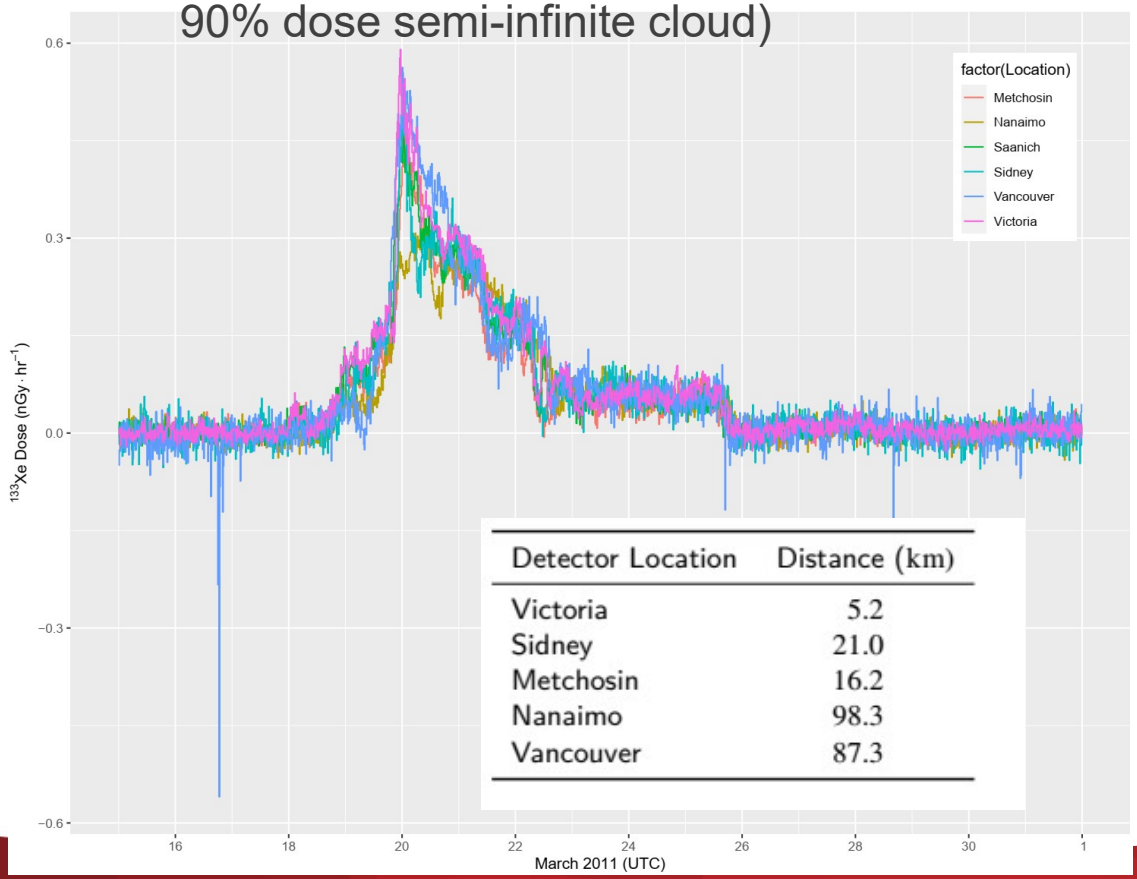
- Aerosol samplers collect ~20 000 m^3 per sample while noble gas samplers collect ~40-50 m^3 per sample
- Source reconstruction using ATDM uses models with horizontal resolution between 0.25° and 1° and the lowest vertical layer is often around 500 m AGL

- At mid-latitudes the modelling domain at the receptor contains ~10^{12} m^3.
  - Samples are not statistically significant compared to ATDM volume
  - Evidence of high variability in sample collection

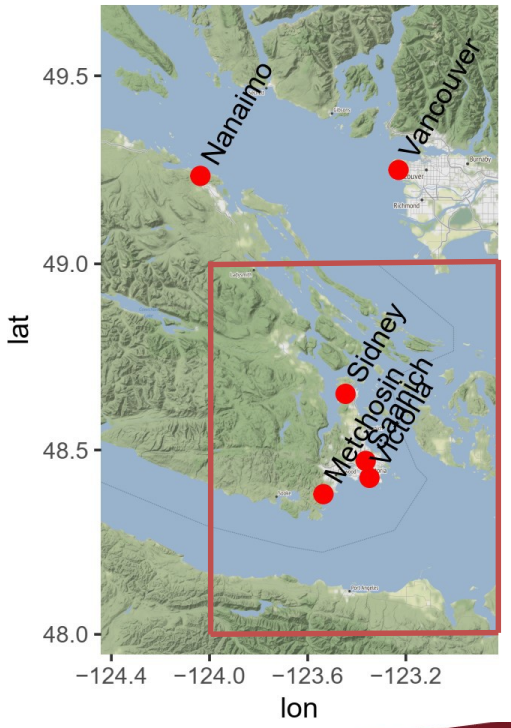
- What should the uncertainty due to the sampling process be?

Multiple Parallel Samples of Noble Gas Plume

- Can noble gas help to characterize?
  - 4 NaI stations in close proximity – but all 6 sites show nearly identical behaviour
  - 15 mins sampling integration
  - Much higher volumetric characterization of environment (400 m radius is over 90% dose semi-infinite cloud)

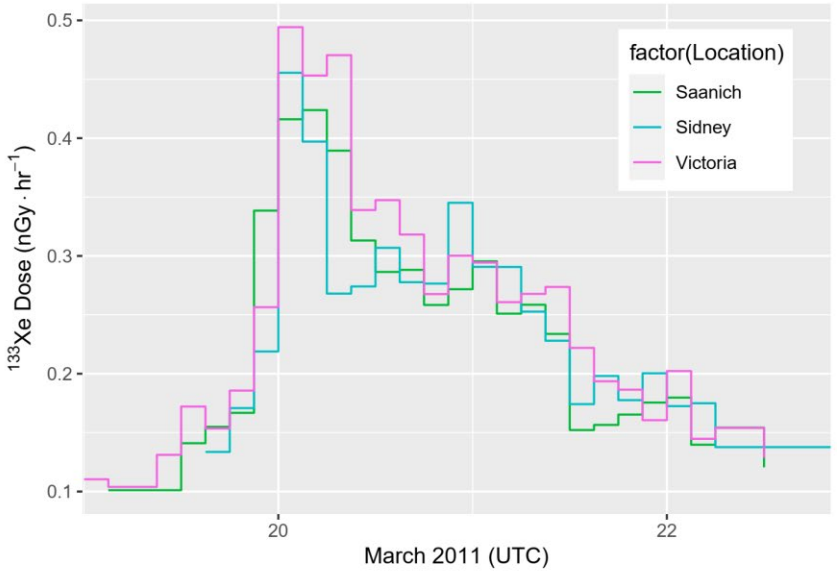


Detector Location	Distance (km)
Victoria	5.2
Sidney	21.0
Metchosin	16.2
Nanaimo	98.3
Vancouver	87.3



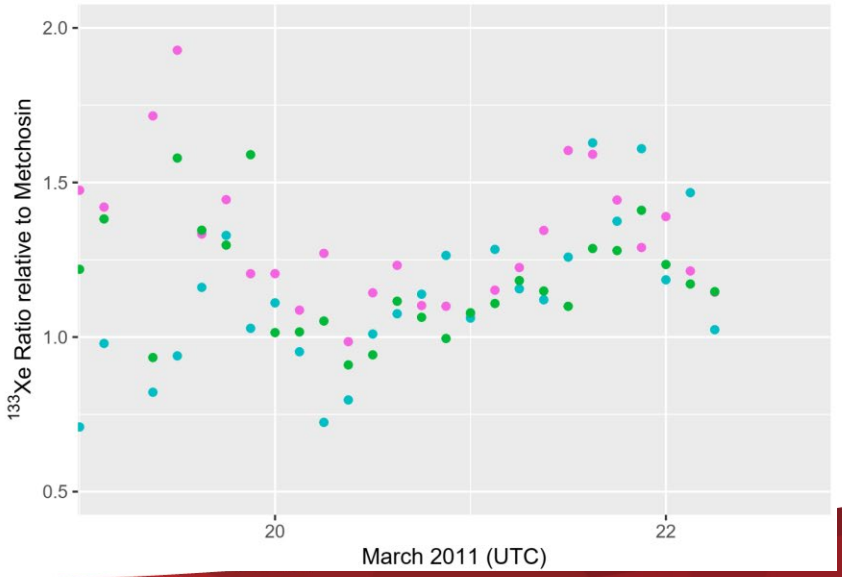
Discussion & Results

- Typical ATDM output has been every 3 hours
- Computed relative dose to Metchosin site for different integration times
- IQR then gives an non-parametric estimate of spread due to sampling process



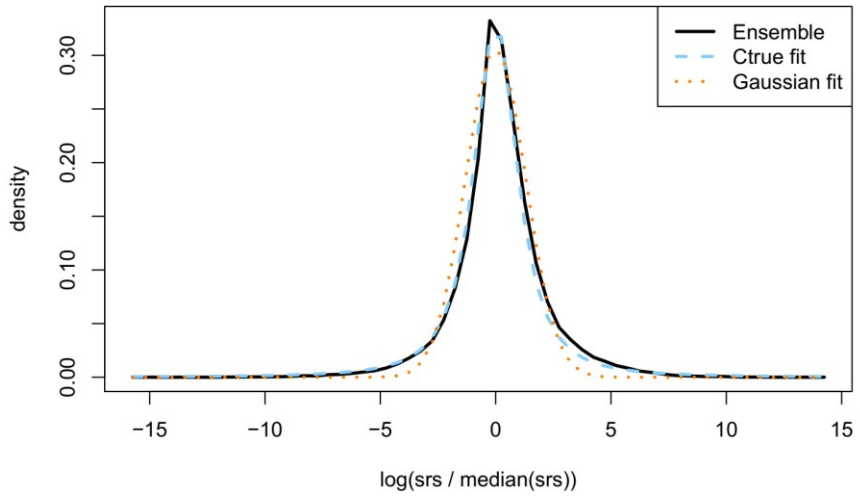
IQR of the observed dose (>0.1 nGy h^{-1}) relative to Metchosin for Several Integration Periods

	Integration Time			
Detector Location	15 min	3 h	6 h	12 h
Victoria	0.32	0.26	0.30	0.39
Sidney	0.35	0.25	0.18	0.14
Saanich	0.28	0.24	0.19	0.17
Mean	**0.32**	**0.25**	**0.22**	**0.23**



Discussion & Results

- Ensemble uncertainty was characterized in experiment by De Meutter (**On the model uncertainties in Bayesian source reconstruction…(**https://doi.org/10.5194/gmd-14-1237-2021)
  - SRS spread was within a factor of 20 (or the equivalent IQR was roughly a factor of 7)
- Sampling uncertainty is smaller, but warrants further examination
  - NaI measures much more air than sample collections
  - Many sample collectors are not mass-flow controlled
  - Shorter collection times (noble gas) will increase uncertainty



Conclusion

- Fukushima provided an opportunity to study broad scale aerosol behaviour with high temporal resolution NaI detectors in close proximity
- Uncertainty is probably underestimated for source reconstruction due to small sample volumes collected relative to ATDM grid box domain
- First estimates of additional uncertainty are on the order of 20-30%
  - Lack of mass flow control, collection interval duration all are important factors that can increase uncertainty to a level of consideration
- More characterization needed to better understand uncertainty

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