Two stage inversion method for microplastics emission estimation

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Microplastics (MPs) and microfibers (MFs) data and atmospheric transport modeling

- measurements were collected weekly (wet) and monthly (dry) at 11 US national parks between 2017 and 2019

  - size classes: 5–10 µm, 10–25 µm, 25–50 µm, 50–100 µm, 100–250 µm, 250–500 µm (for Mps)

  - 236 wet and 103 dry samples were collected

  - see [Brahney et al., 2020] for more details

- source-receptor sensitivity is calculated for each sample using FLEXPART 10.4 backwards in time

  - Source-receptor matrix (SRM) is calculated for each spatial element of our domain

  - see [Evangeliou et al., 2022] for more details

$$y = M x$$

Estimate emission x
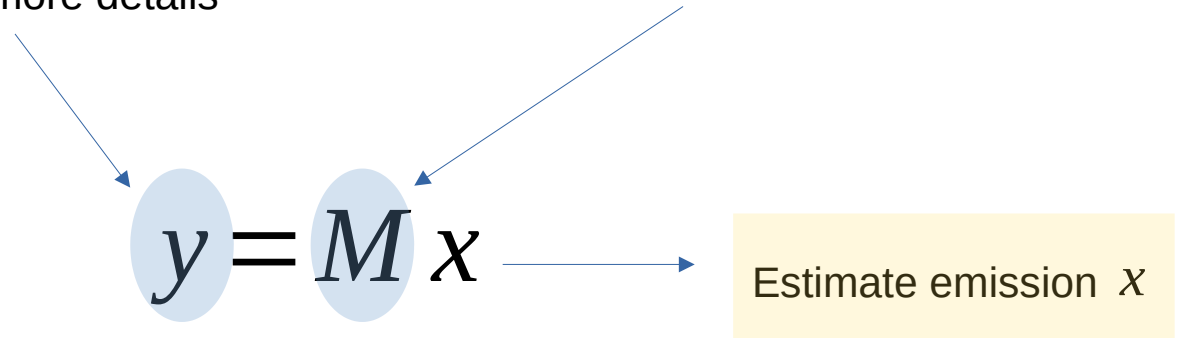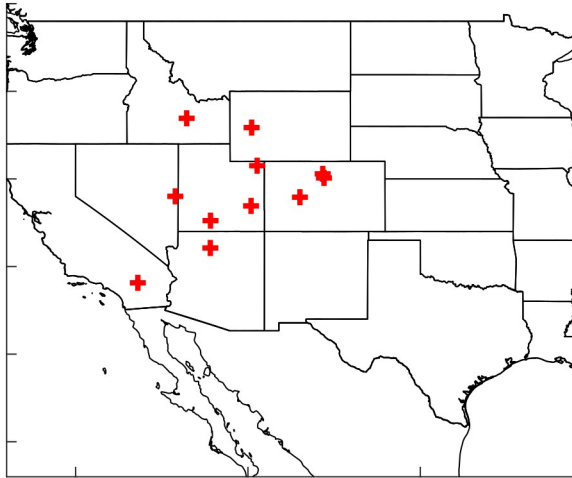
[Brahney, J., Hallerud, M., Heim, E., Hahnenberger, M., Sukumaran, S.: Plastic rain in protected areas of the United States, Science 368(6496), 2020]
[Evangeliou N., Tichý O., Eckhardt S., Groot Zwaaftink C., Brahney J. , Sources and fate of atmospheric microplastics revealed from inverse and dispersion modelling; from global emissions to deposition, Journal of Hazardous Materials, vol.432, 2022.]

Linear inverse problem and its solution

- inverse problem for one spatial domain element, size fraction, and dry/wet samples

$$y = M x$$
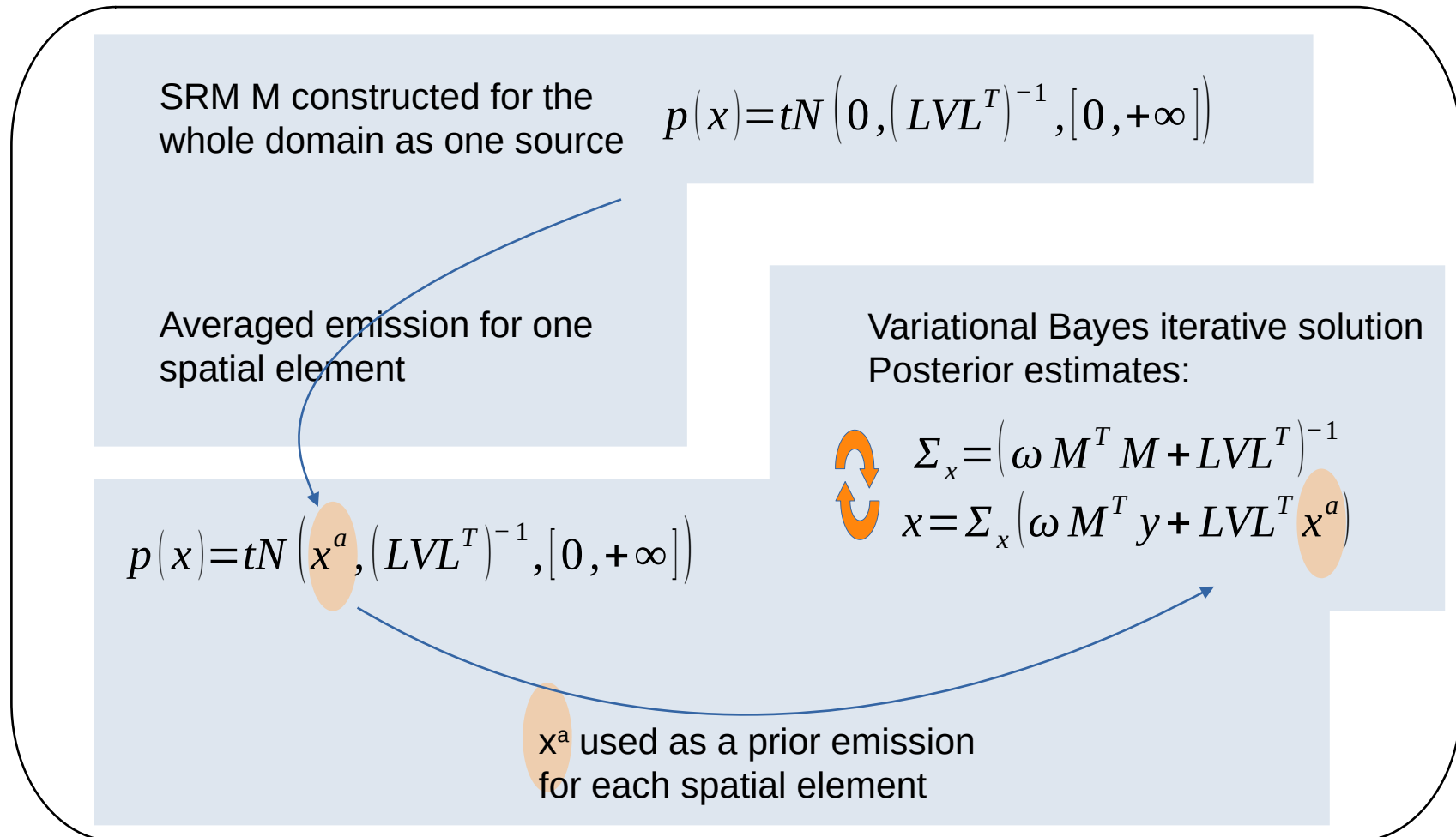
- to estimate emission vector x, we optimize the mismatch between measurements (vector y) and theoretical model output (SRM M)

- we follow variational Bayes methodology where all unknowns have assigned prior model

  - emission prior model:

$$p(x) = tN\left(x^a, \left(LVL^T\right)^{-1}, [0, +\infty]\right)$$

  - tN: truncated Gaussian distribution –> non-negative emission

  - x^a: prior emission vector (if available)

  - LVL^T: flexible covariance structure

[Tichý, O., Šmídl, V., Hofman, R., and Stohl, A.: LS-APC v1.0: a tuning-free method for the linear inverse problem and its application to source-term determination, Geosci. Model Dev., 2016.]
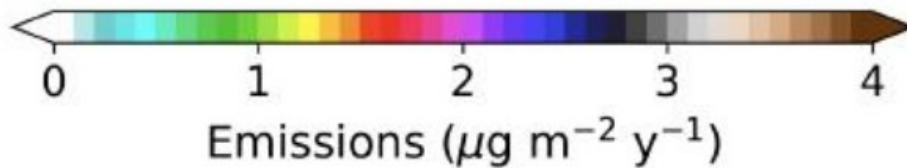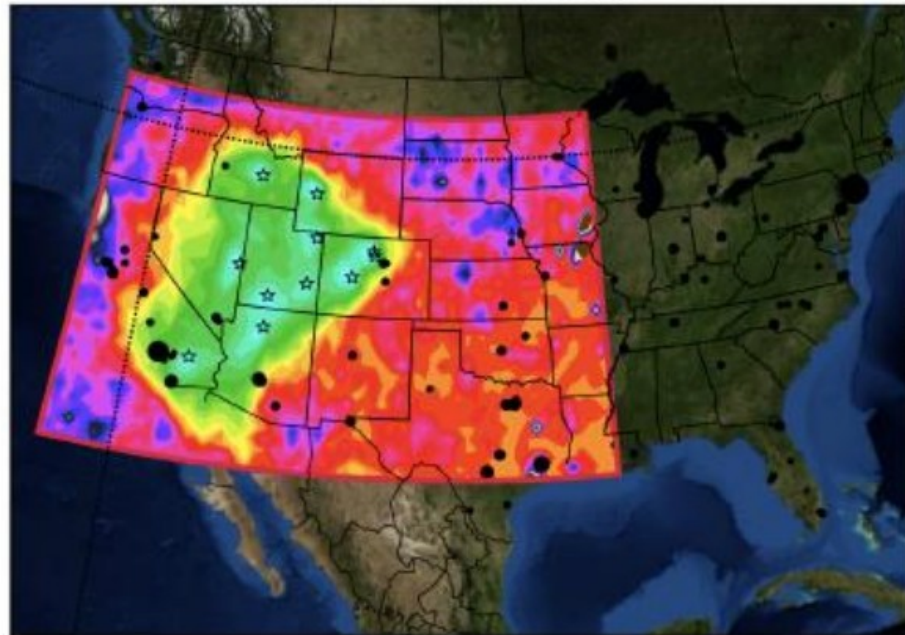
Inversion algorithm for spatial-temporal emission

- very unstable for many domain places → need for regularization of the inverse problem

  - we found the prior emission as the most crucial regularization term

SRM M constructed for the whole domain as one source

$$p(x) = tN\left(0, \left(LVL^T\right)^{-1}, [0, +\infty]\right)$$

Averaged emission for one spatial element

Variational Bayes iterative solution
Posterior estimates:

$$\Sigma_x = \left(\omega M^T M + LVL^T\right)^{-1}$$
$$x = \Sigma_x \left(\omega M^T y + LVL^T x^a\right)$$

$$p(x) = tN\left(x^a, \left(LVL^T\right)^{-1}, [0, +\infty]\right)$$

x^a used as a prior emission for each spatial element

Results: microplastics and microfibers

[Evangeliou N., Tichý O., Eckhardt S., Groot Zwaaftink C., Brahney J. , Sources and fate of atmospheric microplastics revealed from inverse and dispersion modelling; from global emissions to deposition, Journal of Hazardous Materials, vol.432, 2022.]
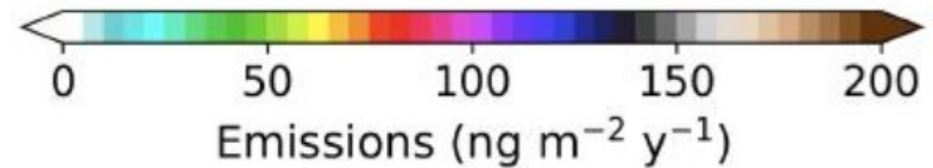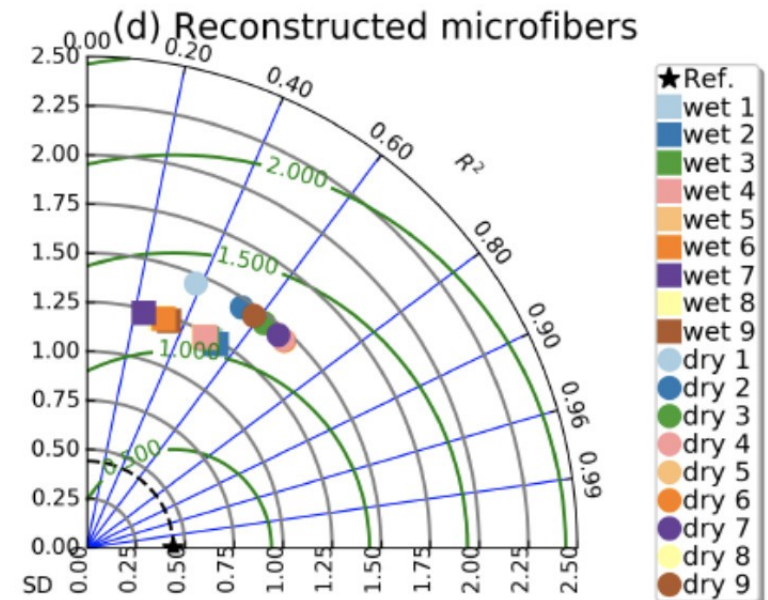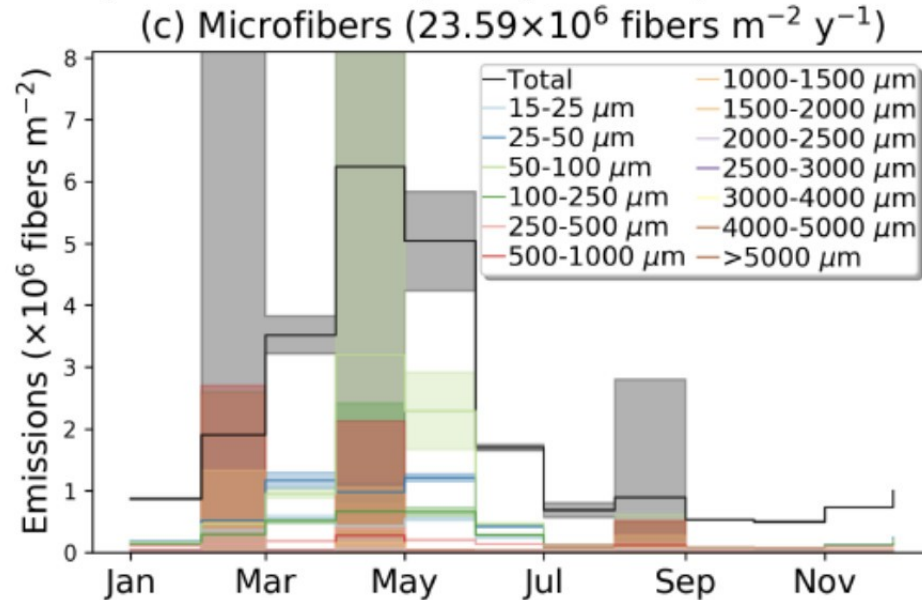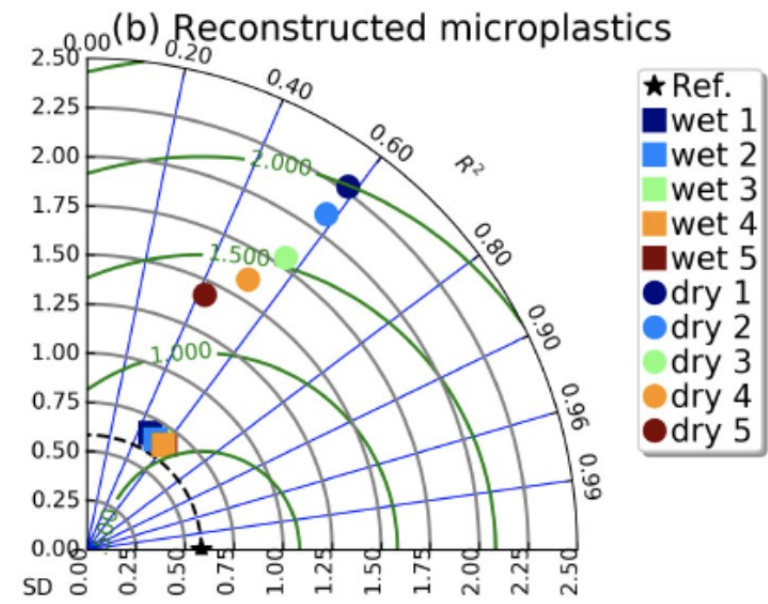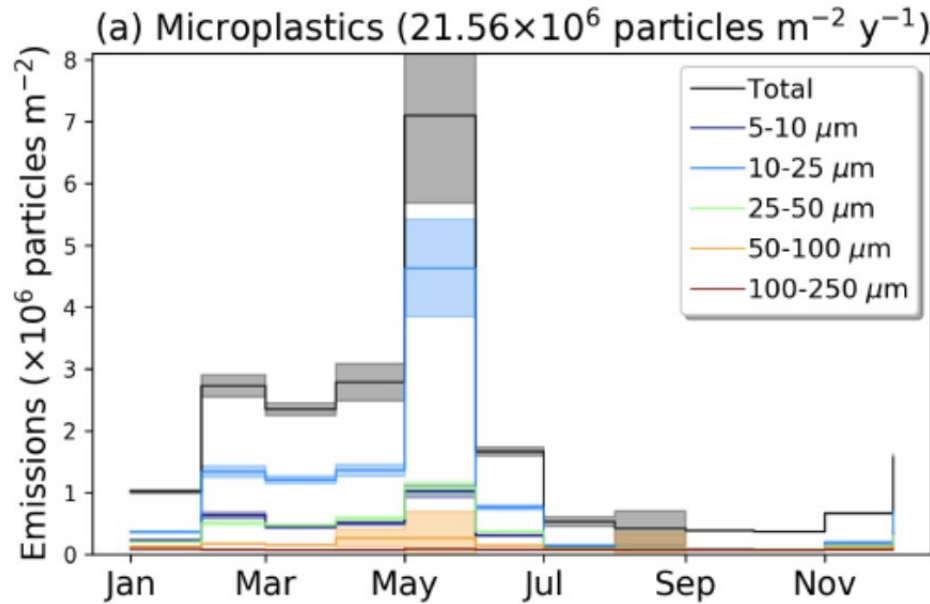
Results: microplastics and microfibers

(a) Microplastics (21.56×10^6 particles m^{-2} y^{-1})

(b) Reconstructed microplastics

(c) Microfibers (23.59×10^6 fibers m^{-2} y^{-1})

(d) Reconstructed microfibers

Conclusion remarks

- annual emissions in western USA (124–91 W, 29–47 N) were estimated to

  - 22 ± 10 million MPs m^{-2} y^{-1}

  - 24 ± 11 million MFs m^{-2} y^{-1}

  - validated using extrapolation to global domain

- current research directions:

  - x_a constructed based on known inventories (mineral dust, road dust, sea salt, and agriculture)

  - we can actually model correlations between particles size fractions

  - need for more measurements

Thank you for your attention!