SOOT DIAGNOSTICS THROUGH MULTI-ANGLE LIGHT SCATTERING: USING AN ARTIFICIAL NEURAL NETWORK

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The impact of aerosolized soot aggregates on human health and the environment depends on their morphology, which can be inferred through multiangle elastic-light scattering [1]. In the case of a polydisperse soot-laden aerosol, the light intensity scattered at an angle θ is related to the aggregate size distribution, $p(R_g)$, in terms of the radius of gyration, R_g, and the fractal parameters D_f and k_f by

$$b(\theta)=\int_0^\infty k\left(R_g,\theta,\mathbf{m}_\lambda,d_p,D_f,k_f\right)p\left(R_g\right)dR_g. \tag{1}$$

where $\mathbf{m}_\lambda$ is complex refractive index and d_p is the soot primary particle diameter. Inverting Eq. (1) is an ill-posed problem in the presence of measurement noise or model error, which can be quantified using Bayesian inference. While the model error is often neglected, the scattering kernel derived from Rayleigh-Debye-Gans Fractal-Aggregate (RDG-FA) theory has relative errors up to 15%, which are amplified by the inversion process into significant errors in the inferred variables [1]. More accurate calculations (e.g. generalized multisphere Mie, GMM) are too computationally-intensive for many applications. Talebi Moghaddam et al. [2] used principal component analysis (PCA) within the Bayesian framework to model this error without sacrificing the computational speed of RDG-FA. In this approach, GMM was used to find the exact light scattering kernels for a sample space of p pairs of fractal dimension and prefactor, and the model error is then approximated by

$$\delta k\approx\overline{\delta k}+\sum_{i=1}^{p}\beta_i u_i, \tag{2}$$

where $\overline{\delta k}$ is the mean of the RDG-FA error, u_i are principal component vectors, and β_i are unknown coefficients. The results showed that PCA could effectively capture the model error, although this increases the uncertainty in the inferred parameters due to the increased degrees-of-freedom associated with the β coefficients.

Another approach is to use a multi-layer artificial neural network (ANN) to invert Eq. (1). The ANN technique largely avoids the issue of model error by training from a set of accurate light scattering kernels. While this step is computationally-expensive, it only needs to be done once. This work compares Bayesian/PCA with the ANN approach for different numbers of unknown parameters and exact kernel samples. The results show that ANN provides more accurate estimates than Bayesian/PCA inference, particularly for k_f and D_f parameters. Moreover, increasing the number of training samples enhanced the accuracy of ANN noticeably, which was not the case for the Bayesian/PCA technique. Nonetheless, the Bayesian has the advantage of providing uncertainty bounds over the parameters of the interest.

REFERENCES

[1] F. J. T. Huber, et al., *J. Quant. Spectrosc. Radiat. Transf.*, vol. 184, pp. 27–39, 2016.

[2] S. Talebi Moghaddamet al., *J. Aerosol Sci.*, vol. 111, no. June, pp. 36–50, 2017.

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