DEEP LEARNING LARGE SCALE AEROSOL-CLOUD INTERACTIONS FROM SATELLITE IMAGERY

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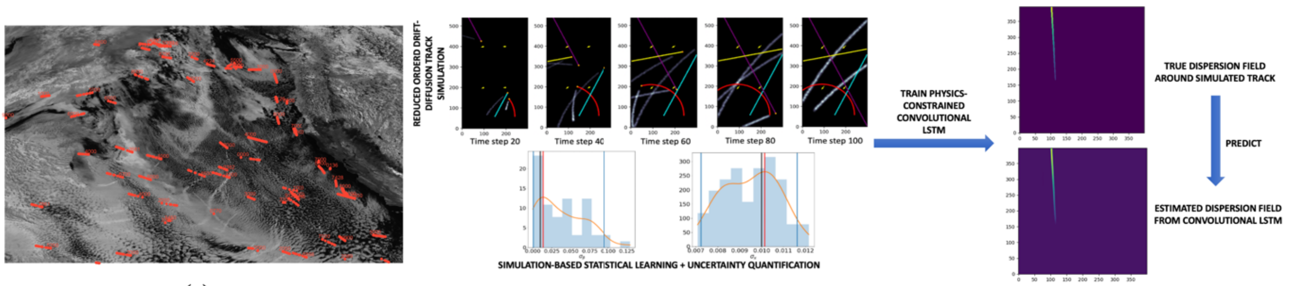
ABSTRACT

For decades, satellite imagery has been able to detect ship tracks, temporary cloud trails created via cloud seeding by the emitted aerosols of large ships traversing our oceans (see Figure 1a), a phenomenon that global climate models cannot directly reproduce. Ship tracks are of interest because they are satellite-observable **benchmark examples** of *aerosol-cloud interactions*, dynamic processes that constitute the largest uncertainty in climate forcing predictions. Specifically, ship tracks are visible evidence of the ability of large amounts of aerosols to perturb boundary layer clouds enough to alter the albedo of the atmosphere and contribute to indirect radiative forcing [1]. While most analyses of cloud changes come from unrealistic simulations under pristine conditions, satellite-observed tracks form in complex environments that are challenging to physically replicate. Further, satellite retrieval products do not provide a wholistic view of these changes, motivating reduced order representations in analyzing and predicting ship-track forcing observed from satellite.



(a)

(b)

Figure 1: Visible ship tracks (a) on April 12, 2019 on April 7, 2019 with 3 hours of ship movement (shown in red); resolution at (5000km × 3000km) taken off coast of California[1]. Novel statistical-learning algorithm capable of simulating true ship-tracks under a ROM with parameter uncertainty quantification vs an emulation based physics-constrained convolutional LSTM (b).

In this work, we first present a simulation based statistical-learning approach to emulating and learning underlying ship-track trajectories based upon a *reduced order* drift-diffusion model (ROM). Here, we construct a novel class of diffusion processes utilizing known wind fields to determine the drift of aerosols, and stochastically parameterize the unknown spatio-temporal diffusion field describing their diffusivity through the atmosphere. In doing so, we demonstrate probabilistic learning of diffusion fields via a novel Approximate Bayesian Computation - Sequential Monte Carlo (ABC-SMC) algorithm for data assimilation (see Figure 1b) [2]. Due to computational burden, we then describe a novel physics-constrained convolutional LSTM model that can be trained on the emulated data (Figure 1b). To show the effectiveness of our framework, we last compare estimated diffusion fields learned both statistically and via the convolutional LSTM on real satellite data.

REFERENCES

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