Please Stop and Smell the Tracers:
Predicting Tracer Concentration Behavior in Low-Order Models with Data Assimilation

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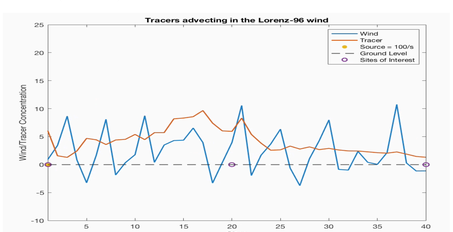
INTRODUCTION

Characterizing the source and behavior of airborne contaminants is an important problem in air-quality analysis and fighting air pollution. Identifying the location and strength of the source of a potentially harmful pollutant is often necessary to take appropriate actions for mitigation. At the very least, tracer releases from such sources need to be modeled to predict the damages they might cause. However, given the chaotic nature of atmospheric circulation, modeling airborne tracers with accuracy is a challenging task. To address this issue, a novel dynamical system is implemented to study the behavior of tracers by utilizing ensemble data assimilation.

METHODS

Our method coupled the low order **Lorenz-96** model with a **Semi-Lagrangian scheme** to advect model tracers on a circular array of sites (e.g., equally spaced sites along a latitude).

We then assimilated synthetic observations **(40 randomly distributed observations at each time step)** with our model predictions using the ensemble adjustment Kalman Filter **(EAKF)** inside the Data Assimilation Research Testbed **(DART)**. We were able to assimilate observations of Lorenz-96 state variables (wind) and tracer concentrations .



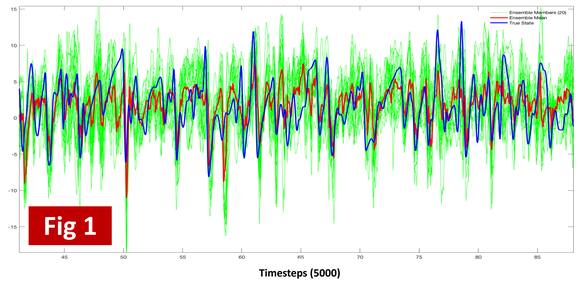


Fig 1

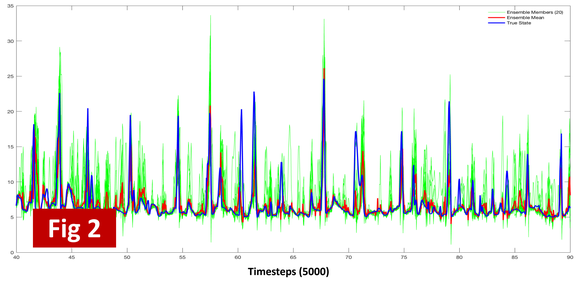


Fig 2

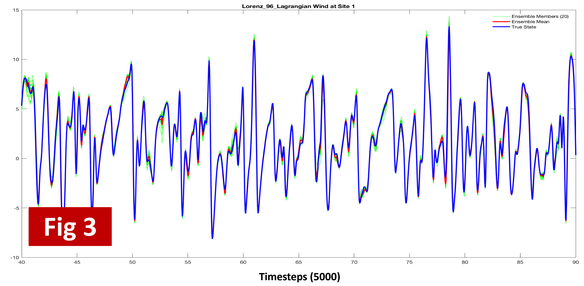


Fig 3

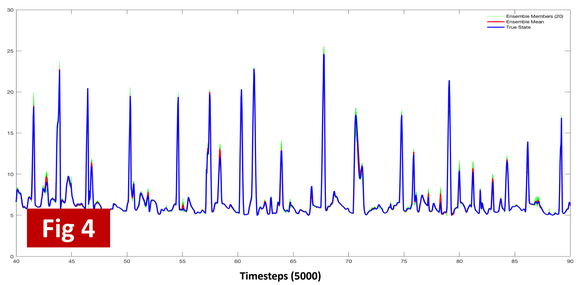


Fig 4

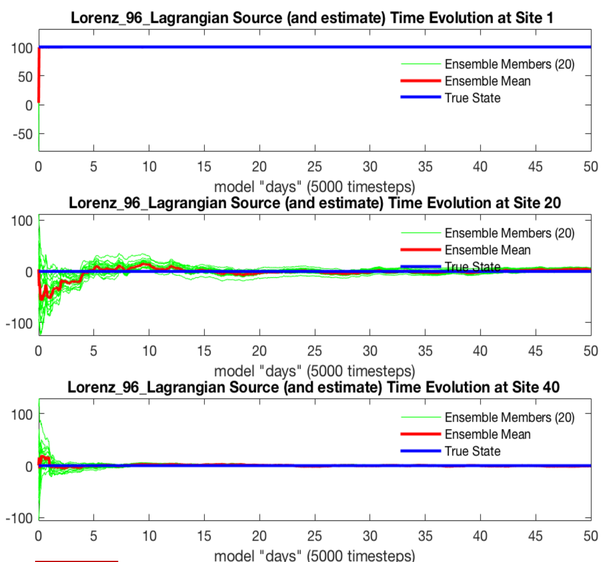


Fig 5

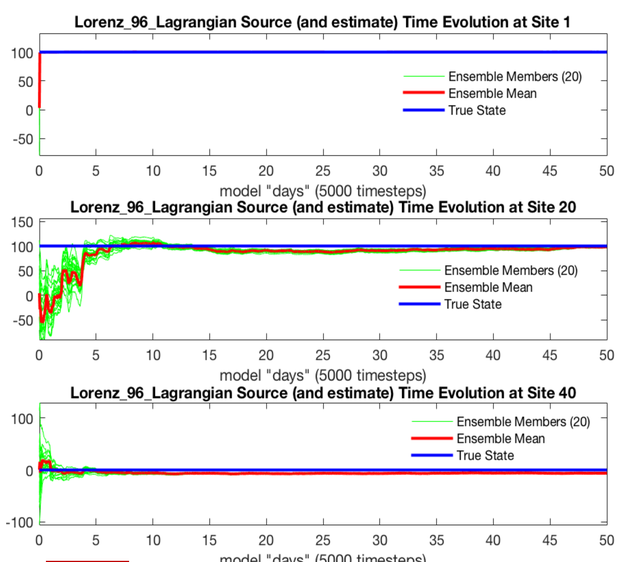


Fig 6

Fig 1: Wind Estimate after assimilating only tracer observations **Fig 2:** Tracer Estimate after assimilating only tracer observations **Fig 3:** Wind Estimate after assimilating both wind and tracer observations **Fig 4:** Tracer Estimate after assimilating both wind and tracer observations **Fig 5 and 6:** Tracer source characterization with assimilation. **In each figure, the blue line is the true state and the red line is the ensemble mean. The closer the red line is to the blue, the better the estimate. The green lines indicate evolution of individual ensemble members**

RESULTS

At every assimilation run, we assimilate 40 ensembles with 40 observations of wind and/or 40 observations of tracer concentrations. Simulated observations have a standard deviation on 0.02. While assimilating only wind observations improves tracer estimates, assimilating only tracer observations also improves wind estimates **(see Fig 1)**. Assimilating both tracer and wind observations improves the estimates for wind and tracer behavior at the sites **(see Fig 3 and Fig 4)**.

Moreover, assimilating both tracer and wind observations help us characterize the location and rate of our source(s). In **Fig 5,** our model estimates the correct location and strength of the source at Site 1 rapidly. In **Fig 6,** our model estimates the correct strength and location of two sources (at Site 1 and Site 2).

The error (RMSE) information from the different assimilation runs are summarized below:

Run Type	State Ensemble Mean Error	State Ensemble Mean Spread	Tracer Ensemble Mean Error	Tracer Ensemble Mean Spread
No Assimilation	23.1688	22.9384	7.9196	9.1916
Assimilate State Obs	1.7656	1.9191	1.043	1.1736
Assimilate Tracer Obs	22.8191	22.4523	3.7832	3.7914
Assimilate State and Tracer Obs	1.6284	1.7289	0.71986	0.7956

FUTURE STEPS

- Exploring source characterization capabilities with data assimilation in Lorenz 96 with lower quality observations
- Implementing tracer advection in higher level circulation models
- Exploring novel assimilation techniques designed specifically for tracers

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