Optimizing Atmospheric Monitoring Networks Using Bayesian Methods and Genetic Algorithms for Multiple Objectives

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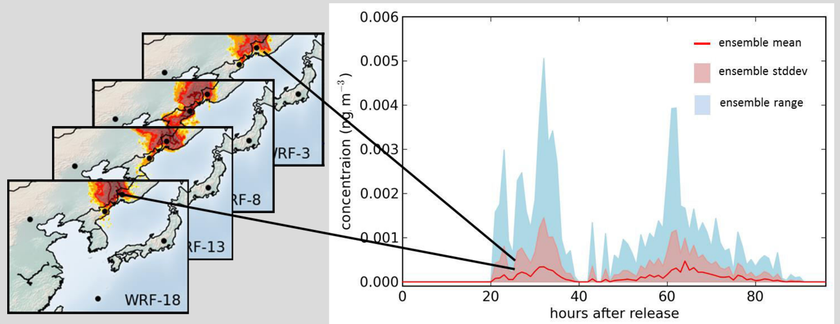
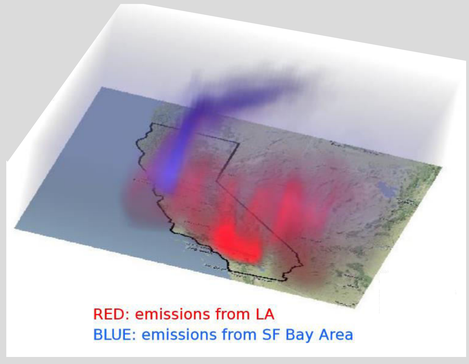
Optimizing the placement of sensors in an atmospheric measurement network could potentially help reduce monitoring uncertainty



Ensemble of weather and dispersion runs for a hypothetical radionuclide release

Bayesian inversion and genetic algorithms are used to design a monitoring network in California

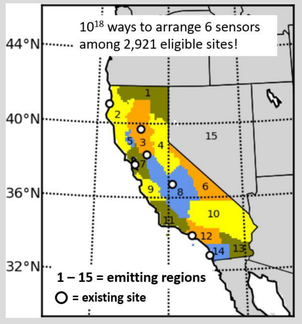


Network is needed to monitor emissions

Design goal: find best locations for 6 new sensors to minimize uncertainty and cost of monitoring emissions from 15 regions

Performance vs Cost Tradeoff

- Adding sensors to existing sites is inexpensive, but may not reduce uncertainty
- Placing sensors in new locations may reduce uncertainty, but is expensive.



Genetic Algorithm Loop

Choose locations for network

Bayesian Inversion Loop

For a given network

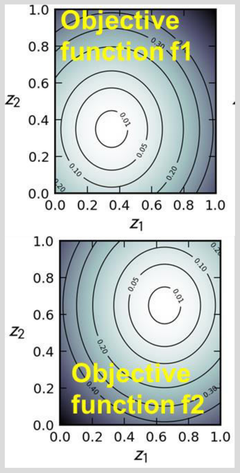
$$p(E|D) = \frac{p(D|E)\ p(E)}{p(D)}$$

PDF of emissions (E) using tracer data (D) from WRF

Minimize emissions uncertainty and network monitoring cost

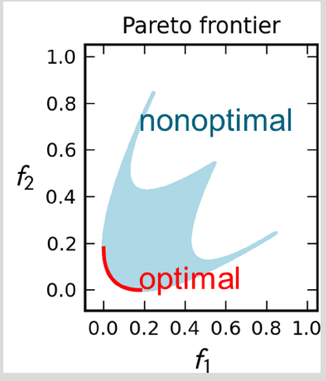
Networks designed to monitor atmospheric plumes need to consider many factors, such as interfering sources, sensor placement, cost and performance. Bayesian methods and Genetic Algorithms offer a way to optimize monitoring networks with multiple objectives, accounting for background interference. An example of a monitoring network that considers performance and cost is discussed. A multi-objective approach is used to optimize monitoring cost and sensor placement for a network of six sensors. The Pareto optimal set of networks illustrates the tradeoffs between monitoring cost and performance. The example demonstrates how such methods can help analyze the discrepancy between models and observations and thus provide an economic and scientific rationale to include additional sources, exclude certain sensors, or to explore specific sensors and their surrounding environment at higher fidelity.

Multi-objective genetic algorithms optimize design problems with competing objectives

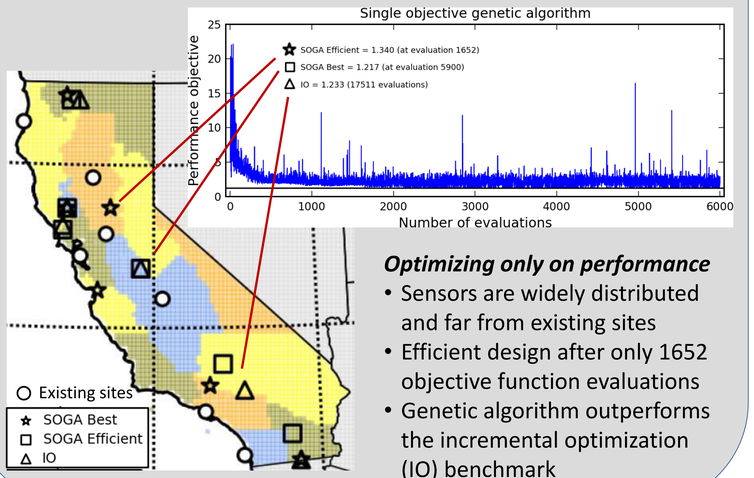


Simple example of two quadratic functions minimized at different locations in the design space.

The Pareto frontier represents the family of optimal solutions connected between individual objectives



Monitoring networks designed only to minimize emissions uncertainty using a single objective genetic algorithm (SOGA)

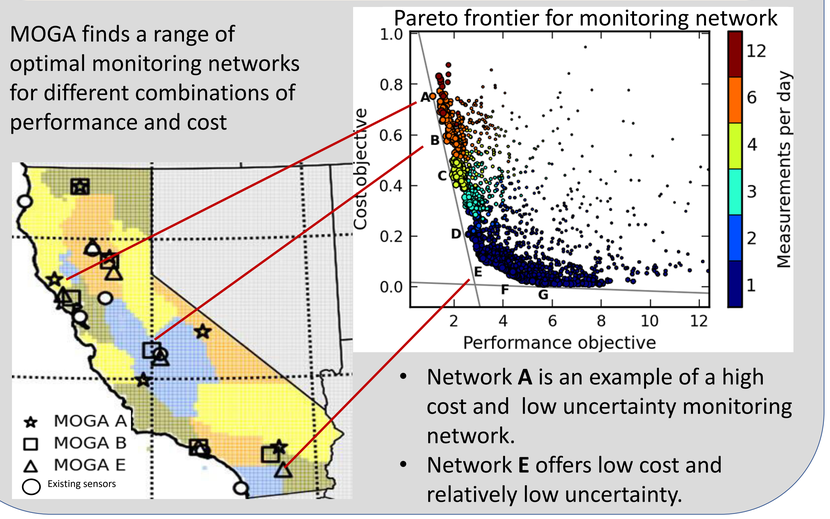


Optimizing only on performance

- Sensors are widely distributed and far from existing sites
- Efficient design after only 1652 objective function evaluations
- Genetic algorithm outperforms the incremental optimization (IO) benchmark

Monitoring networks designed to minimize emissions uncertainty and cost using a multi-objective genetic algorithm (MOGA)

MOGA finds a range of optimal monitoring networks for different combinations of performance and cost



- Network **A** is an example of a high cost and low uncertainty monitoring network.
- Network **E** offers low cost and relatively low uncertainty.

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