PENNSTATE 1855

On Uncertainty in Atmospheric Transport And Dispersion (ATD) Models

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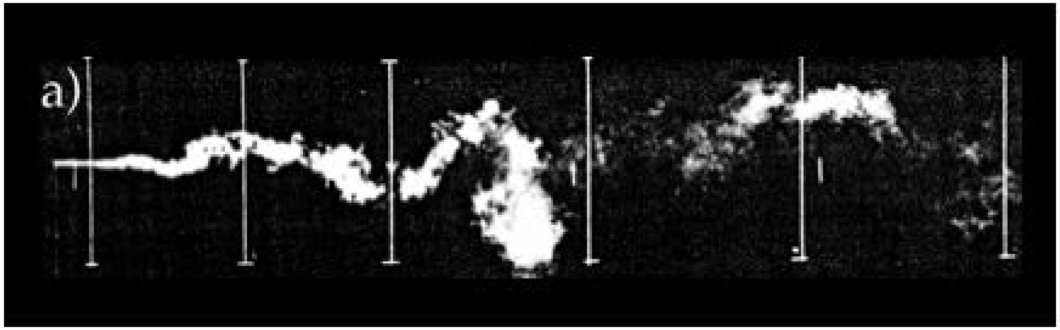
9th Annual George Mason University Conference on “Atmospheric Transport and Dispersion Modeling”
July 19, 2005

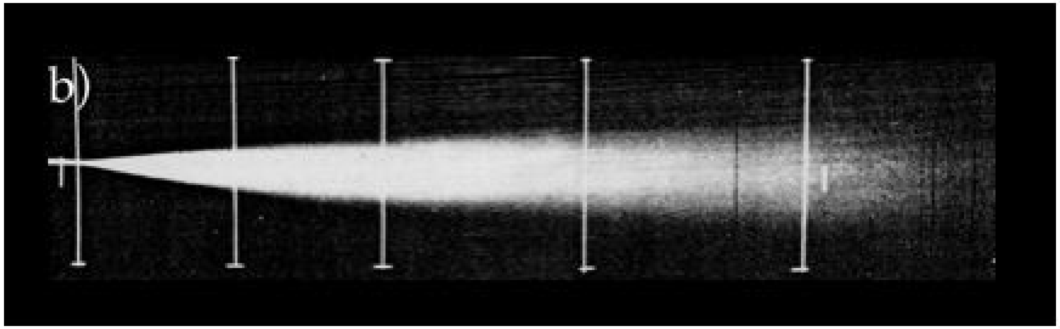
Two Main Categories of ATD Problems

- “Acute” (short-term, episodic) problems involve concentration excursions in both continuous and short-term releases.
- “Chronic” (long-term) problems involve ensemble-mean concentrations in continuous releases.

Two Categories of Effluent Plumes

- The instantaneous plume, a), is central to acute problems; it is the plume we see.
- The ensemble-mean plume, b), is central to chronic problems; it is a virtual plume.

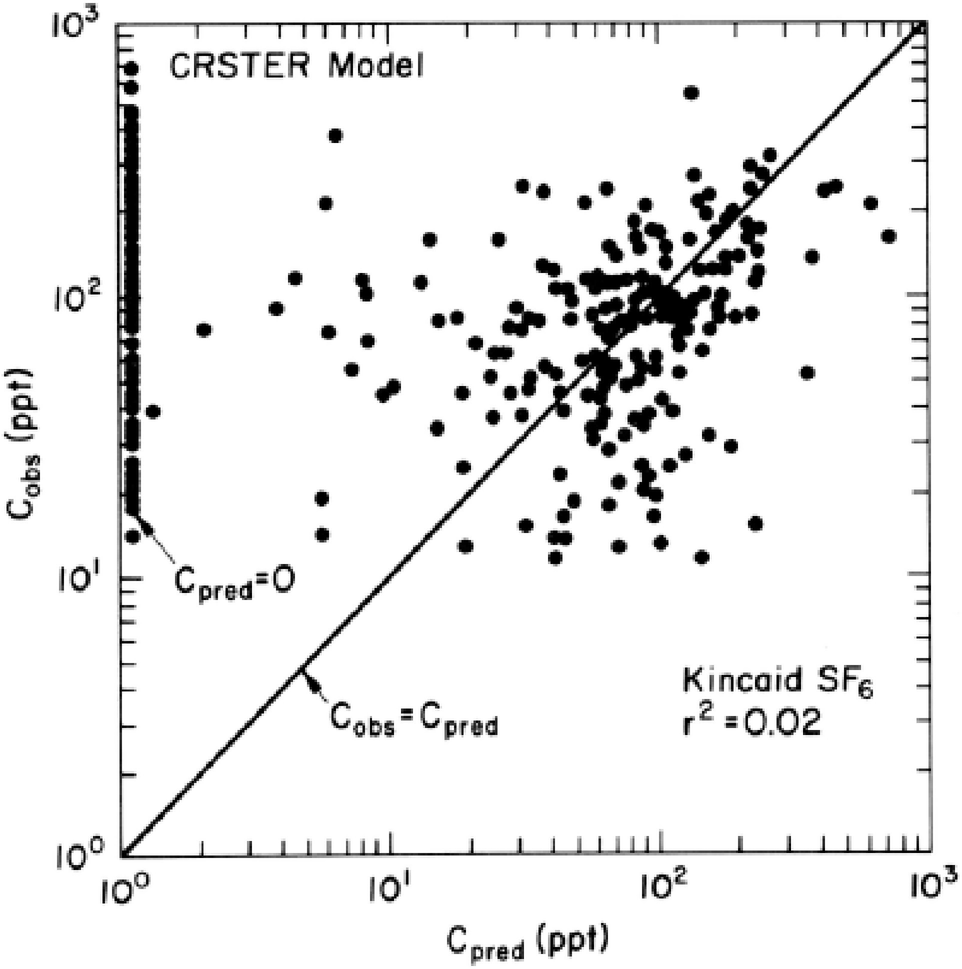




Categorizing ATD Models Is Not As Simple

- By framework: Eulerian, Lagrangian—but some use both (e.g., LES with Lagrangian subgrid model).
- By averaging type: ensemble, spatial—but some use both (e.g., mesoscale LES + SCIPUFF system).
- It seems that all types of models have been used on each type of problem.

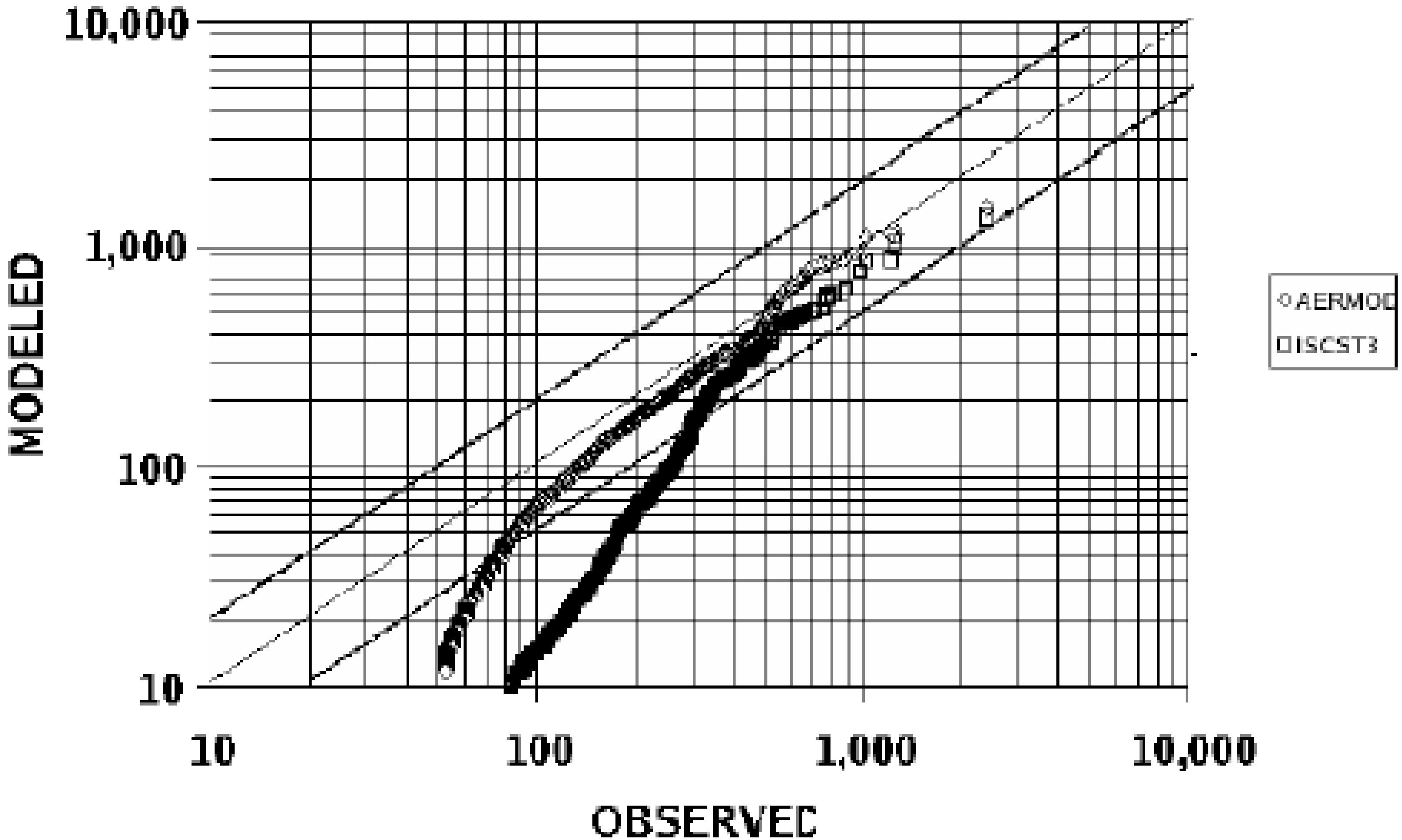
Typical Test Results for a Chronic Dispersion Model



Interpretation and Implications

- The scatter is caused by (1) model errors and (2) measurement "errors" due to insufficient averaging time. In principle either can dominate.
- The predictions of a perfect chronic dispersion model would agree well with atmospheric dispersion data only if the averaging time were far larger than the standard one hour—which is impossible.
- Testing of chronic models is now done with Q − Q plots (in which predictions and observations are unpaired in space and time) rather than these scatter plots.

A Q-Q Plot for the Kincaid Power Plant



Modeling of Chronic Dispersion: Lessons Learned

- It is generally not possible to test dispersion models definitively in the atmosphere.
- The poor performance of the Gaussian-plume model in convective turbulence was discovered through LES and fluid modeling—and only then seen in specially designed atmospheric observations.
- Both LES and fluid modeling have compelling advantages over the atmosphere as testbeds for chronic dispersion models.

Key Features of "Acute" Dispersion Problems

- The *sensitive dependence of turbulent flow on initial conditions* implies that a numerical calculation of an evolving effluent field will diverge from the target field, however accurate the initialization, numerics, and physics, and however fine the resolution.
- A numerically predicted instantaneous plume is, at best, one member of an ensemble of possible plumes—and so it should be accompanied by a prediction of the statistics of the variability over the ensemble.

Key Features of "Acute" Dispersion Problems

- Initialization and data assimilation can help—but NWP experience (e.g., in hurricane forecasting) shows that good physics is still essential.
- The experience with testing chronic models suggests that (barring a breakthrough) it will not be possible to generate atmospheric data bases adequate for testing episodic models.

Key Features of "Acute" Dispersion Problems

- The experience in engineering fluid mechanics is that turbulent-flow models are not "predictive tools," but rather are to be used near their calibration conditions. Lumley called them "calibrated surrogates for turbulence."
- The experience in the convective-dispersion problem encourages the use of computational (e.g., LES) and fluid-modeling data bases in testing episodic models.

Toward Reliable Modeling of Regional Dispersion Episodes

- We need certified, fast models that predict both the expected outcome and the episode-to-episode variability.
- Certifying such models requires a large, high-quality data base on dispersion episodes—which does not exist. We cannot generate such a data base solely from atmospheric observations, but perhaps it could done by also using computations and fluid modeling.

A "Supermodel" For Episodic Dispersion?

- Can easily use $10^8 - 10^9$ grid points; e.g., $10^3 \times 10^3 \times 10^2$ in a 50 km × 50 km × 2.5 km domain. Subgrid-scale dispersion would have to be carefully treated.
- Using it, observations, and fluid modeling we could generate a "data base" on idealized regional dispersion episodes.
- This data base could be central in certifying the simpler, faster models used to predict episodic concentration statistics.
- Could this accomplish for the regional-scale episodic problem what LES has done for the chronic problem?

Questions

- It would seem essential to couple an episodic dispersion “supermodel” with weather-forecasting operations—but how and where in this model system should that coupling occur?
- Many of the components of this episodic modeling system probably exist but are scattered through our large, diverse community. Could we put them together?