Uncertainty in ATD Modeling

Federal R&D Needs and Priorities for Atmospheric Transport and Diffusion Modeling

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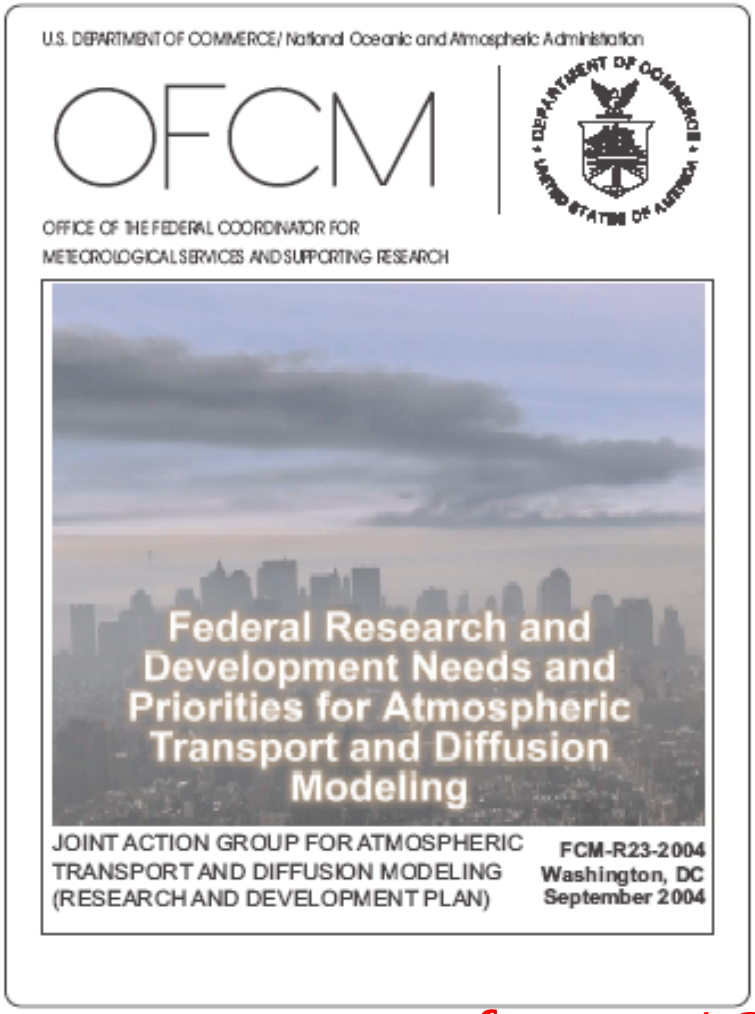
Walter D. Bach, Jr.
Cochair, OFCM Joint Action Group on Atmospheric Transport and Diffusion Research and Development Plan

Program Manager, Environmental Sciences Division
U.S. Army Research Office

The Report



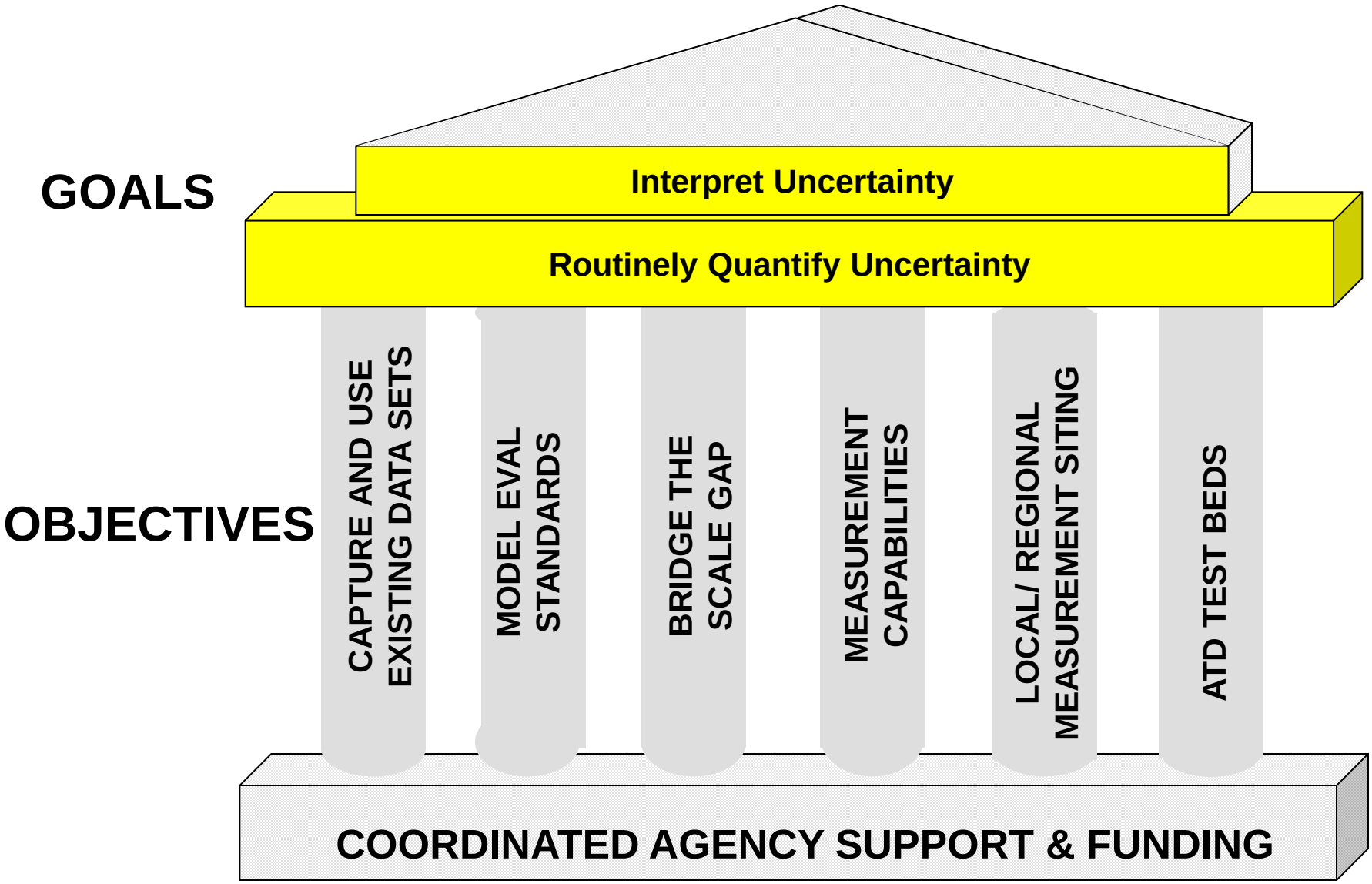
- **Purpose**
- **User's Needs from User's Perspective**
- **Model Capabilities to Meet User's Needs**
- **Modeling and Measurement Research Needs**
- **R&D Strategy to Meet User's Needs**
- **Recommendations**

www.ofcm.gov/r23/r23-2004/fcm-r23.htm

Perspectives

Decision Maker	Science / Provider
Safety of people is first	No prediction (model) is perfect
Need actionable information	Not enough data
Best, timely, consistent representation of hazard areas over time	Multiple users /decision makers
No time to evaluate	Evolution on multiple time and space scales
Add a margin of error	Acute and chronic exposure

An R&D Strategy to Meet User Needs



Tennekes' Challenges

No observation is complete without an appropriately sampled estimate of the variance of the properties observed.

No forecast is complete without a preceding estimate of forecast skill.

No model calculation is complete without a calculation of its variance

ATD Modeling Uncertainty

The total model uncertainty is measured by the variance in the ***predicted*** and the ***observed*** quantity over a large number of events that have similar properties (an ensemble).

Total Model Variance

Let $\mathbf{C}_o = \mathbf{C}_{oa} + \delta\mathbf{C}_o$ and $\mathbf{C}_p = \mathbf{C}_{pa} + \delta\mathbf{C}_p$

$$\overline{C}(\vec{x},t) = \lim_{n\to\infty} [\frac{1}{n}\sum_{r=1}^{n} C^{(r)}(\vec{x},t)]$$

$$\overline{(C_o - C_p)^2} = \overline{(\delta C_p)^2} + \overline{(\delta C_o)^2} + (\overline{d})^2 + \sigma_c^2$$

Total model variance

Error variance of input data

Error variance of observations

Square of model bias

Stochastic uncertainty

$$\overline{d} = \overline{C_{oa}} - \overline{C_{pa}},$$

$$\sigma_c^2 = \overline{(C^{(r)} - \overline{C})^2}$$

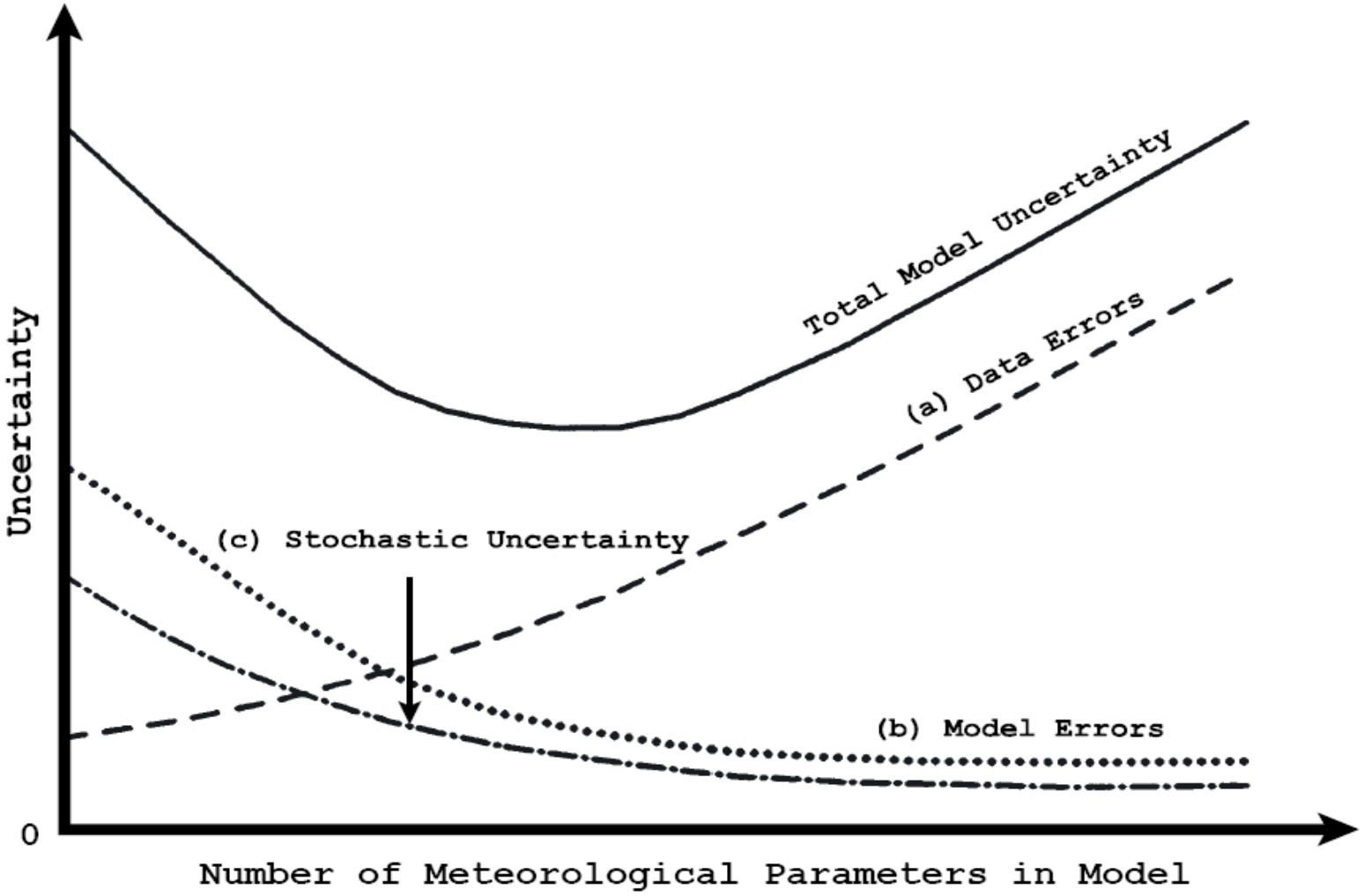
Contributions to Model Uncertainty

Internal: Numerical approximations, modeling errors, and treatment of dynamical processes

External: Data errors in execution and evaluation, model parameterizations, and initial & boundary conditions

Stochastic: Natural variability of the atmosphere (turbulence)

A Familiar Chart



Why Emphasize Uncertainty?

- Critical to making intelligent life / death decisions
- Ubiquitous
- Poorly characterized in modeling efforts
- Measure of the robustness of the modeling / observing system.
- Reducing uncertainty requires knowledge of current uncertainty
- Believability of our products

What to Do?

Capture and Use Existing Data Sets

- Basis of present ATD knowledge
- Accessible

Establish Test Beds

- All-weather conditions (24/7 operation)
- Daily test and evaluations
- Feedback among operational modeling and users

Develop Measurement Technologies

- Meteorological variables – T, h, winds, turbulence
- Tracer materials – cheap, harmless, remote, in situ

Conduct controlled experiments

- Physical modeling – flow channels, wind tunnels, convection tanks
- Computational modeling – DNS, CFD, LES

Implementation Actions

Develop robust techniques to assess probabilities of occurrence of exceeding significant thresholds

Adapt and verify measurement capabilities at or below scales of model predictions

Test, verify, and verify model improvements

Establish a shared data system to test and evaluate uncertainty quantification techniques

Quantify and reduce uncertainty in predictions

Implementation Actions

Develop applicable analysis techniques to display uncertainty in non-linear regimes

Use uncertainty analyses to guide improvement in ATD models

Develop and implement processes for uncertainty displays in data – sparse environments

Questions?

Comments?