

A Framework for Evaluating Regional Air Quality Models

S.T. Rao
December 2010

Environ Fluid Mech
DOI 10.1007/s10652-009-9163-2

ORIGINAL ARTICLE

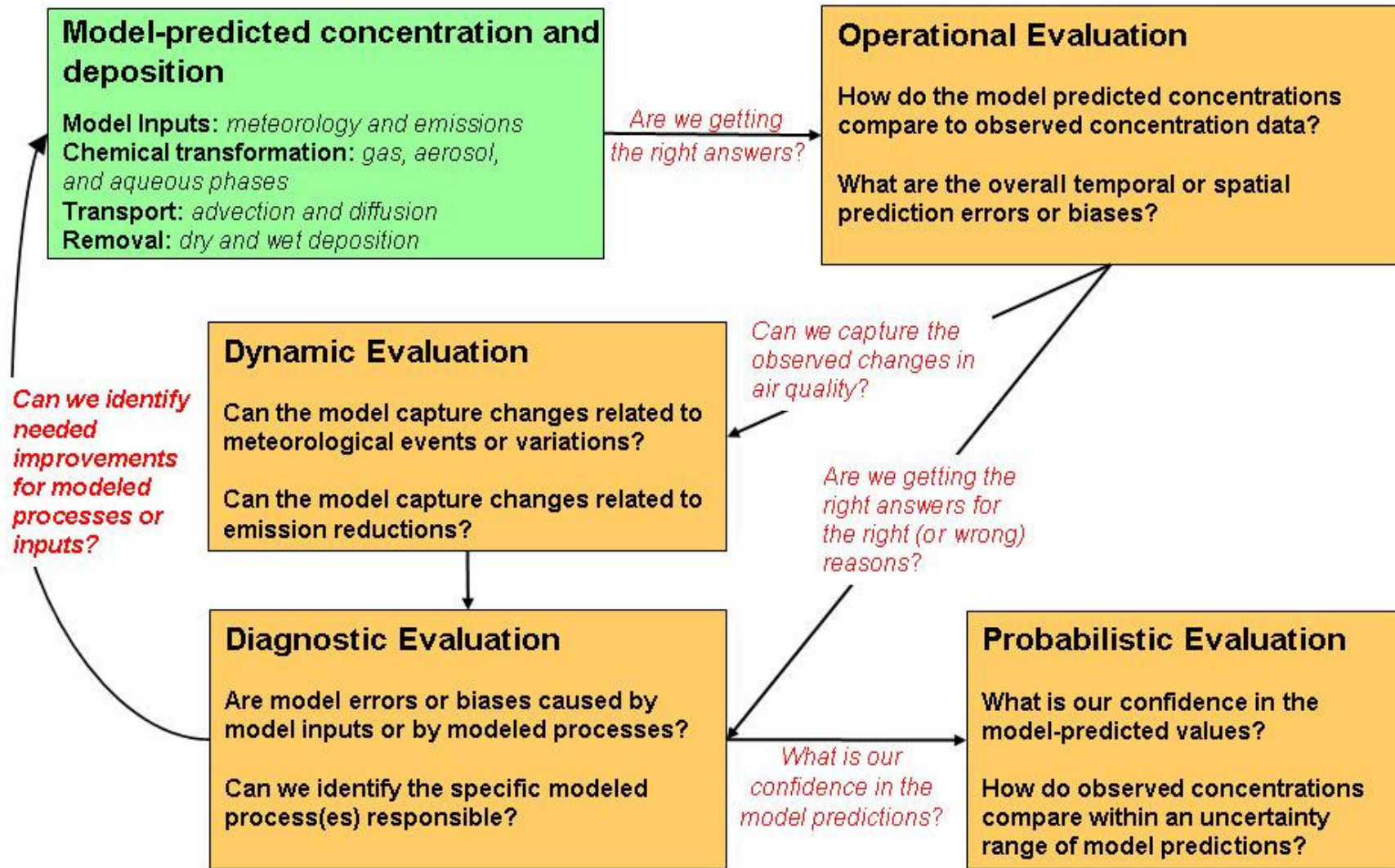
A framework for evaluating regional-scale numerical photochemical modeling systems

Robin Dennis · Tyler Fox · Montse Fuentes · Alice Gilliland ·
Steven Hanna · Christian Hogrefe · John Irwin · S. Trivikrama Rao ·
Richard Scheffe · Kenneth Schere · Douw Steyn · Akula Venkatram

Received: 21 August 2009 / Accepted: 16 December 2009
© The Author(s) 2010. This article is published with open access at Springerlink.com

Abstract This paper discusses the need for critically evaluating regional-scale (~200–2,000 km) three-dimensional numerical photochemical air quality modeling systems to establish a model's credibility in simulating the spatio-temporal features embedded in the observations. Because of limitations of currently used approaches for evaluating regional air quality models, a framework for model evaluation is introduced here for determining the suitability of a modeling system for a given application, distinguishing the performance between different models through confidence-testing of model results, guiding model development,

Model Evaluation Framework



Reference: Dennis et al. (2010) A framework for evaluating regional-scale numerical photochemical grid models, *Environmental Fluid Mechanics*, available at <http://www.springerlink.com/index/A65K45424U640247.pdf>

Model Evaluation Framework

Model-predicted concentration and deposition

Model inputs: meteorology and emissions
Chemical transformation: gas, aerosol, and aqueous phases
Transport: advection and diffusion
Removal: dry and wet deposition

Are we getting
the right answers?

Operational Evaluation

How do the model predicted concentrations compare to observed concentration data?

What are the overall temporal or spatial prediction errors or biases?

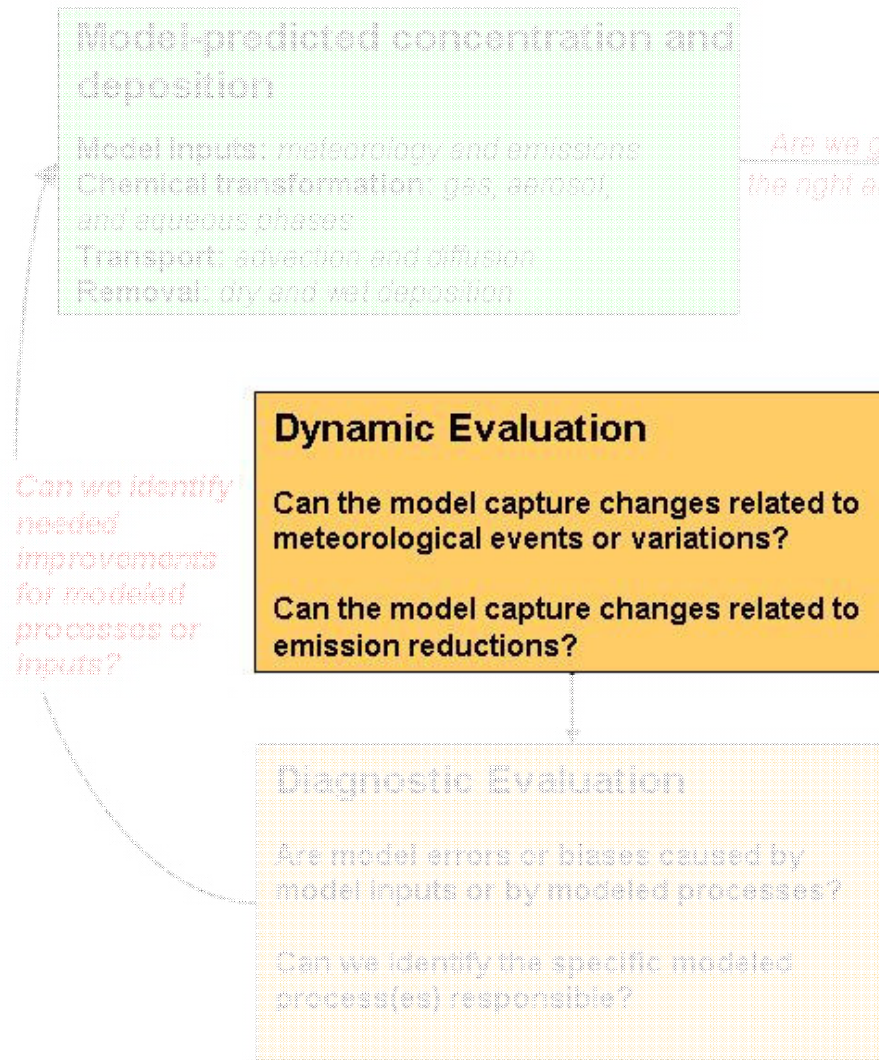
Examples of Operational Evaluation

Appel KW, Gilliland AB, Sarwar G, Gilliam RC (2007) Evaluation of the community multi-scale air quality (CMAQ) model version 4.5: sensitivities impacting model performance; part 1 ozone. *Atmos Environ* **41**:9603–9615.

Vautard R, Builtzes PHJ, Thunis P, Cuvelier C, Bedogni M, Bessagnet B, Honore C, Moussiopoulos N, Pirovano G, Schaap M, Stern R, Tarrason L, Wind P (2007) Evaluation and intercomparison of ozone and PM10 simulations by several chemistry transport models over four European cities within the CityDelta project. *Atmos Environ* **41**:173–188.

Appel KW, Bhave PV, Gilliland AB, Sarwar G, Roselle SJ (2008) Evaluation of the community multiscale air quality (CMAQ) model version 4.5: sensitivities impacting model performance; part II—particulate matter. *Atmos Environ* **42**:6057–6066.

Model Evaluation Framework



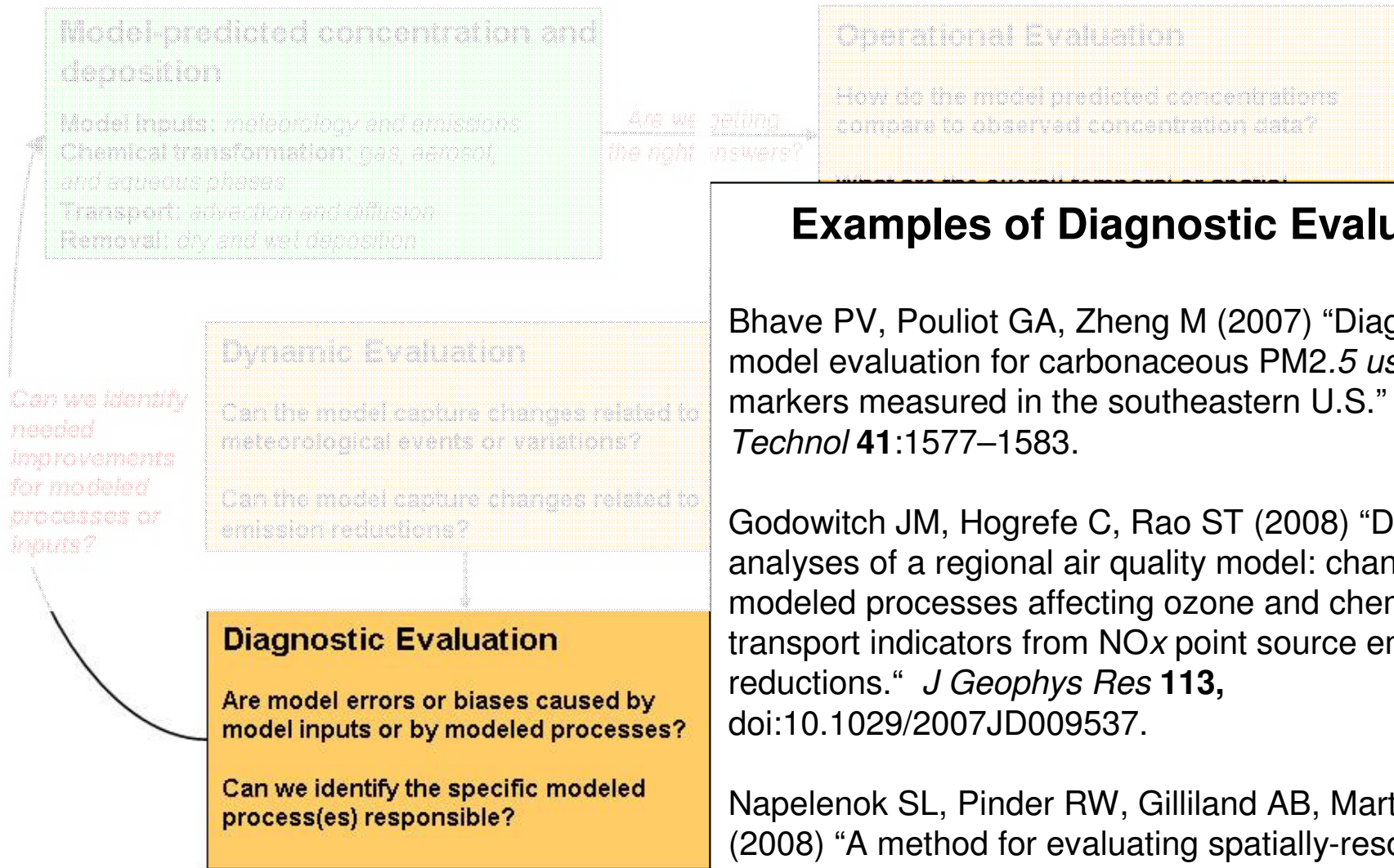
Examples of Dynamic Evaluation

Gilliland, A., C. Hogrefe, R. Pinder, J. Godowitch, K. Foley, S.T. Rao (2008) "Dynamic evaluation of regional air quality models: Assessing changes in O₃ stemming from changes in emissions and meteorology." *Atmospheric Environment* **42**:5110-5123.

Godowitch, J. M., G. A. Pouliot, et al. (2010). "Assessing multi-year changes in modeled and observed urban NO_x concentrations from a dynamic model evaluation perspective." *Atmospheric Environment* **44(24)**: 2894-2901.

Pierce, T., C. Hogrefe, et al. (2010). "Dynamic evaluation of a regional air quality model: Assessing the emissions-induced weekly ozone cycle." *Atmospheric Environment* **44(29)**: 3583-3596.

Model Evaluation Framework



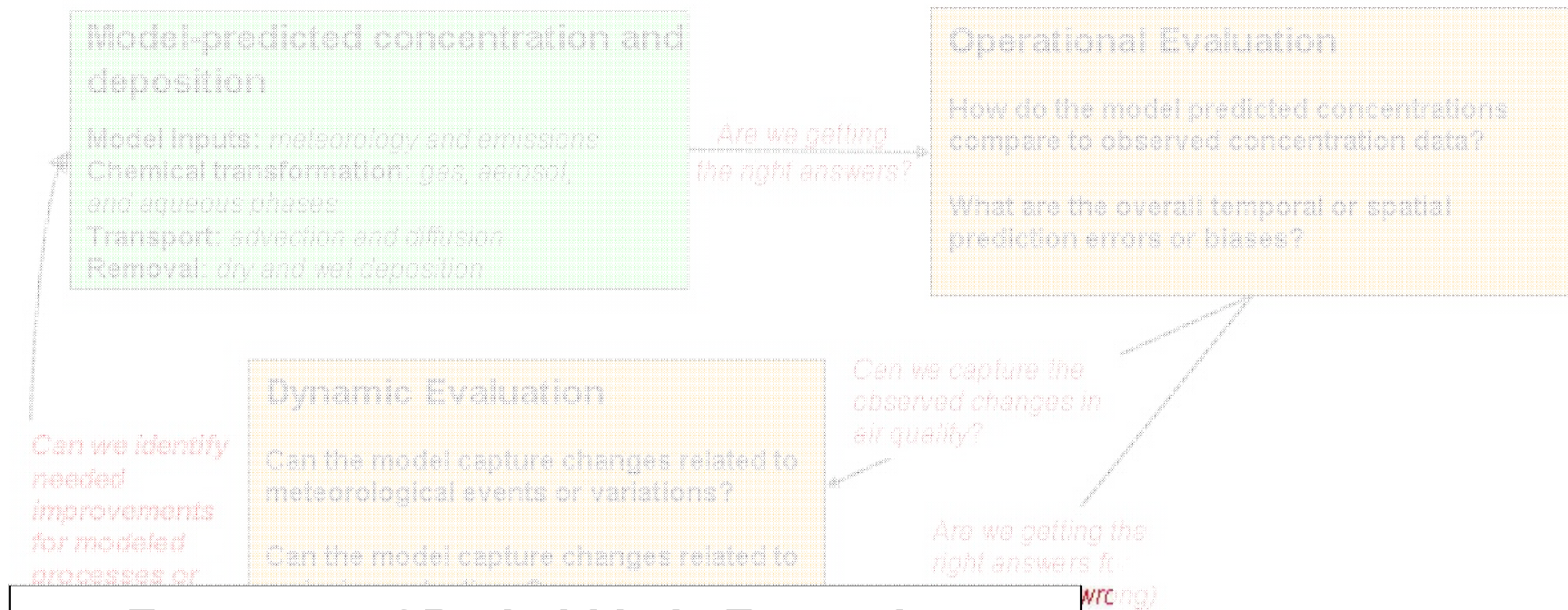
Examples of Diagnostic Evaluation

Bhave PV, Pouliot GA, Zheng M (2007) "Diagnostic model evaluation for carbonaceous PM_{2.5} using organic markers measured in the southeastern U.S." *Environ Sci Technol* **41**:1577–1583.

Godowitch JM, Hogrefe C, Rao ST (2008) "Diagnostic analyses of a regional air quality model: changes in modeled processes affecting ozone and chemical-transport indicators from NO_x point source emission reductions." *J Geophys Res* **113**, doi:10.1029/2007JD009537.

Napelenok SL, Pinder RW, Gilliland AB, Martin RV (2008) "A method for evaluating spatially-resolved NO_x emissions using Kalman filter inversion, direct sensitivities, and space-based NO₂ observations." *Atmos Chem Phys* **8**:6469–6499.

Model Evaluation Framework



Examples of Probabilistic Evaluation

Hogrefe C, Rao ST (2001) "Demonstrating attainment of the air quality standards: integration of observations and model predictions into the probabilistic framework." *J Air Waste Manag Assoc* **51**:1060–1072.

Pinder RW, Gilliam RC, Appel KW, Napelenok SL, Gilliland AB (2009) "Efficient probabilistic estimates of surface ozone concentration using an ensemble of model configurations and direct sensitivity calculations." *Environ Sci Technol* **43**:2388–2393.

Probabilistic Evaluation

What is our confidence in the model-predicted values?

How do observed concentrations compare within an uncertainty range of model predictions?