Table 1. Atmospheric Models

Model	Description	Critical Assumptions	Citations
ASTRAP Advanced Statistical Regional Air Pollution	Seasonal Lagrangian trajectory ensemble statistics, SO_2 to SO_4 conversion and NO_x to NO_3 conversion; air concentrations of SO_2, SO_4, NO_x, and total NO_3; S and N (NO_3 only) wet & dry deposition, precipitation pH, source-receptor matrix output	Linear SO_2 and NO_x conversion chemistry, pH by regression; 1980-1990 meteorology	Shannon 1981, 1999 Shannon & Sisterson 1992 Boyd et al. 1996 Huang 1996
RELAD Regional Lagrangian Acid Deposition	Lagrangian transport, atmospheric reactions; SB-RELMAP; Includes S & N chemistry, calculates effective acidity	3-layers within fixed depth mixed layer, 1st order conversion SO_2 to SO_4 and NO_x to NO_3; equilibrium NH_3 partitioning to aerosol	Cheng et al. 1995
MADE-50 Multi-layer Acid Deposition model for Europe (50 km grid)	SO_x and NO_x chemistry, SO_2, SO_4(a) HNO_3, NO_3(a) dry & wet deposition; 20 layers; source-receptor matrices for S and N	Hov et al. (1988) chemistry; constant V_d = 0.1 cm s^{-1} for all aerosols; prescribed oxidant and radical fields; 1996 LAM50 or 1997 PARLAM-PS meteorology	Barret et al. 1995 Berg & Jakobsen 1998 Jakobsen et al. 1995, 1997 http://projects.dnmi.no/~emep/eul/made.html
COMSTM Compre-hensive Sulfate Tracking Model	Evaluates contributions of SO_2 oxidation pathways to total atmospheric SO_4; gaseous and aqueous phase SO_2 oxidation to SO_4; wet & dry deposition of SO_2 and SO_4.	S-species only; prescribed OH, H_2O, O_3 fields; no NH_3 chemistry or aerosol; meteorological input from MM5 model; annual climatological composite of 30 5-day simulations	McHenry & Dennis 1994
Extended-RADM Regional Acid Deposition Model	Eulerian, gas-phase SO_x, NO_x, VOC, & oxidant chemistry, aqueous phase SO_2 oxidation, gas-particle partitioning of NH_3 and NH_4NO_3, clouds and scavenging, wet & dry deposition of S and N species, actinic flux; emissions preprocessor for plume height	Meteorological input from MM5 model; annual climatological composite of 30 5-day simulations; RADM 2.6 lumped VOC chemistry	Mathur and Dennis 2000 http://www.epa.gov/asmdnerl/racid.html
SUNY-RADM State University of New York's version of RADM	RADM 2.6 gas-phase SO_x, NO_x, VOC, & oxidant chemistry, aqueous phase SO_2 oxidation, clouds and scavenging, wet & dry deposition of S and N species including aerosols, actinic flux; emissions preprocessor for plume height; improved cloud and mixing algorithms	Meteorological input from MM5 model; annual climatological composite of 30 5-day simulations; RADM 2.6 lumped VOC chemistry; no NH_3 chemistry	Walcek & Hu 1993 Walcek 1994 Walcek & Tsai 1994

Conclusions

Any of the models listed in Table 1 could be used to generate the transfer matrix need for a reduced-form model of the emissions to deposition pathway. ASTRAP and RELAD are less desirable because their simplistic chemical mechanisms cannot handle the interactions among copollutants. The EMEP MADE-50 modeling system is presently set-up for simulating deposition over Europe. Transferring this modeling system to the USA would require development of new input databases or conversion of the model code to accept existing databases.

The most applicable models for simulating acid deposition over the eastern USA are based on the RADM2.6 model and its various supporting models for meteorology and emissions. Of the RADM versions listed above, the "extended RADM" is the only one that incorporates an explicit treatment of

NH_3 and NH_4 aerosol chemistry. However, the deposition of sulfate and nitrate aerosols is parameterized in both the COMSTM and SUNY-RADM models. An advantage of the SUNY-RADM version is the incorporation of improved cloud and vertical mixing algorithms that allow for the explicit treatment of both stratiform and cumuliform clouds. However, the biggest advantage of the SUNY-RADM version is that this modeling system has been successfully implemented at the NY-DEC.

All versions of RADM are episodic models that are designed to simulate relatively short episodes of 3 to 5 days. Thirty (30) cases representative of eastern USA deposition events in the1982 to 1985 period were selected during the National Acid Precipitation Assessment Program for simulation by RADM. The deposition results were then combined according to the climatological frequency of occurrence of similar events to obtain the long-term average deposition. The NY-DEC has obtained from the US-EPA the meteorological data for these 30 cases and can (has) run SUNY-RADM for various emissions scenarios to evaluate total sulfate deposition from precipitation.

The RADM models in Table 1 use an 80 km by 80 km grid covering the eastern USA for emissions and meteorology inputs and wet, dry and total S and N deposition output. From the emissions and deposition fields, a transfer matrix can be derived for specific areas of New York State to represent the emissions to deposition pathway in TMDL modeling.

New Citations in Table 1:

Barret K., Seland Ø., Mylona S., Foss A., Sandness H., Styve H. and L. Tarrason (1995) European transboundary acidifying air pollution. Ten years calculated fields and budgets to the end of the first Sulphur Protocol. EMEP/MSC-W Report 1/95. The Norwegian Meteorological Institute, Oslo, Norway.

Berge E. and H.A. Jakobsen (1998) A regional scale multi-layer model for the calculation of long term transport and deposition of air pollution in Europe. Submitted and accepted to Tellus.

Hov Ø., Eliassen A. and D. Simpson (1988) Calculation of the distribution of NOx compounds in Europe. In: *Tropospheric Ozone - Regional and Global Scale Interactions* (I.S.A Isaksen ed.). Reidel Publishers, Dordrecht, pp. 217-239.