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MODEL CAPABILITIES, 2-D

Charles H. Jackman
Laboratory for Atmospheres
Mail Code 916
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
Telephone: 301-286-8399; FAX: 301-286-3460

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2-D MODEL CAPABILITIES

Two-dimensional (2-D) atmospheric models provide results for altitude versus latitude as a function of time and are developed primarily for two reasons: 1) to help understand atmospheric occurrences; and 2) to give assessments / make predictions of future changes in the atmosphere. Historically, the formulation of transport in 2-D models has been a difficult problem. Most current 2-D models have a transport that is either 1) an Eulerian mean circulation with large stratospheric eddy diffusion or 2) a residual (also called diabatic or Lagrangian) mean circulation which typically is accompanied with small stratospheric eddy diffusion. Because of the assumption of zonal averaging, 2-D models are primarily useful in making predictions of atmospheric changes of time-scales longer than a season. Although decadel atmospheric changes may be reasonably well represented with a 2-D model, the year to year changes which result from interannual transport differences, stratospheric warmings, semi-annual oscillations, or quasi-biennial oscillations may not be well represented in the stratosphere and troposphere.

PREVIOUS 2-D MODEL VALIDATION

The photochemistry in 2-D models has been validated in a variety of ways. 2-D model photochemistry has been investigated using constrained model simulations along with satellite and balloon measurements of photochemically controlled species. For example, 1) the 40 km O_3 problem was investigated by fixing NO_2, ClO, H_2O, CH_4, HNO_3, and O_3 to measurements and then computing the O_3 loss and production; and 2) HO_x (OH, HO_2, H_2O_2) species were computed from measured NO_2, ClO, H_2O, CH_4, HNO_3, and O_3 and compared to other measurements of HO_x. Other ways of validating the photochemistry in 2-D models include 1) a comparison of a measured versus a computed CH_3CCl_3 lifetime, which can validate the gross model distribution of OH; and 2) a comparison of measured versus computed solar flux in which the model computation uses O_3 which is fixed to measurements.

The transport in 2-D models has been investigated using photochemically inactive radioactive species and relatively photochemically inactive long-lived source gases. Radioactive species simulated in 2-D models include ^{14}C, ^{90}Sr, ^{238}Pu, ^{7}Be, ^{10}Be, and ^{32}P, among others. An "ideal" radioactive tracer should have 1) a half-life greater than 100 years so that radioactive decay is not a significant loss over the duration of the model simulation (typically a few years); 2) no attachment of the tracer to stratospheric aerosols which could lead to some transport by gravitational settling which is difficult to model; 3) no rainout loss in the troposphere which could significantly alter the tracer distribution in the upper troposphere and lower stratosphere; and 4) only loss at the ground. Of the radioactive tracers listed above, ^{14}C is the only constituent to satisfy all the given conditions for an "ideal" radioactive tracer. Relatively photochemically inactive long-lived source gases whose losses are primarily through photolysis include N_2O, $CFCl_3$, CF_2Cl_2, and CCl_4. Other source gases which have been used to test 2-D transport include CH_4, CH_3Cl, and CH_3CCl_3.

Many minor constituents in the stratosphere such as NO_y, Cl_x, and O_3 are controlled by both photochemistry and transport, thus validation of model predictions of these species is much more difficult. Both profiles and columns of NO_y constituents have been used to test 2-D models. For example, there have been several constrained 2-D model computations. LIMS NO_2 and HNO_3 have been compared to model computed NO_2 and HNO_3 using a model constrained with measurements of N_2O, O_3, CH_4, and H_2O. Model simulated halogen-containing constituents (e.g., ClO, HCl, and HF) have been compared to measurements both in profile and column distributions.

Stratospheric model simulations are primarily of importance in the predictions of ozone distributions, both for the present-day and for the future. Ozone is affected photochemically by many constituents and also influenced by transport, thus a comparison of modeled distributions with measurements is often not very definitive. 2-D profile distributions of ozone, layers of ozone (10-1 mb, 100-10 mb, and 1000-100 mb), and total ozone (1000-0 mb) have all been compared to measurements. Since the prediction of total ozone is the most noticeable forecast of 2-D models, modeled total ozone is compared in great detail to observations. It is, however, possible to have a good simulation of total ozone as well as to have large differences between the simulated and measured 2-D ozone profile distributions.

Other tests for model validation include simulations of the atmospheric effects of solar proton events (SPEs) and simulations of HDO. There have been measured ozone decreases and NO increases as a result of SPEs, so model simulations of these constituents can be compared to observations. Such model predictions of SPE effects on the atmosphere require measured proton fluxes, which can then be used to predict NO_x and HO_x production and the associated ozone loss. About half of the H_2O in the stratosphere comes from tropospheric H_2O and about half from CH_4. Since D (deuterium) comes mostly from deuterated methane (CH_3D), a computation of HDO compared with observations can be a good check on a model simulation of H_2O.

FUTURE 2-D MODEL VALIDATION

A model-model photolysis rate intercomparison needs to be done with fixed O_3 and O_2. Any differences will be due to the radiative transfer procedures and not due to the photochemistry or transport. Other possible model-model intercomparisons include contrasting the partitioning of the constituents in the various families and comparing the transport fluxes of certain constituents at specific locations. Model-data intercomparisons should probably include a radioactive tracer such as ^{14}C, 2D distributions of NO_y, 2D distributions of ozone, total ozone, and the partitioning within the families of NO_y and Cl_y.

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