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AMIP: THE ATMOSPHERIC MODEL INTERCOMPARISON PROJECT

by

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ABSTRACT

The Atmospheric Model Intercomparison Project (AMIP) is an international effort to determine the systematic climate errors of atmospheric models under realistic conditions, and calls for the simulation of the climate of the decade 1979-1988 using the observed monthly-averaged distributions of sea-surface temperature and sea ice as boundary conditions. Organized by the Working Group on Numerical Experimentation (WGNE) as a contribution to the World Climate Research Programme, AMIP involves the international atmospheric modeling community in a major test and intercomparison of model performance; in addition to an agreed-to set of monthly-averaged output variables, each of the participating models will generate a daily history of state. These data will be stored and made available in standard format by the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory. Following completion of the computational phase of AMIP in 1993, emphasis will shift to a series of diagnostic subprojects, now being planned, for the detailed examination of model performance and the simulation of specific physical processes and phenomena. AMIP offers an unprecedented opportunity for the comprehensive evaluation and validation of current atmospheric models, and is expected to provide valuable information for model improvement.

1. Introduction

Intercomparison of the results from different atmospheric model integrations has been carried out since the beginning of large-scale atmospheric modeling in the 1950s, and is an important part of modeling research. Most such model intercomparisons have been made in connection with numerical weather prediction, in which short-term forecasts in selected cases are compared with one another and with observation. In particular, the Working Group on Numerical Experimentation (WGNE) has organized several such model tests since the early 1970s in support of the World Climate Research Programme (and of the earlier Global Atmospheric Research Programme). In the area of climate, however, fewer such tests have been carried out, due in part to the greater computational resources required and in part to the lack of a clear experimental strategy. Among the first juxtapositions of the results of atmospheric climate models was that given in the report of the U.S. GARP Committee's Panel on Climatic Variation (National Academy of Sciences, 1975) and in the subsequent compilation of the zonally-averaged monthly mean sea-level pressure and precipitation of then-current atmospheric climate models (Gates, 1975, 1987).

The recent intercomparisons of the performance of atmospheric models by the Intergovernmental Panel on Climate Change (IPCC) with climatological sea-surface temperatures (Gates et al., 1990, 1992) show that although there is continuing disagreement among current models (and between models and the corresponding observations), there has been an overall narrowing of the range of model results and a reduction in the models' systematic errors as a whole. A compilation of model systematic errors in the seasonal mean sea-level pressure, temperature, zonal wind and precipitation as simulated by 14 atmospheric models has also recently been completed under WGNE auspices (Boer et al., 1991, 1992). In this study it was found, for example, that a large-scale error common to all current atmospheric GCMs is colder than observed air in the lower troposphere in the tropics and in the upper troposphere in higher latitudes. A corresponding WGNE study of extended-range predictions with 8 atmospheric models shows a similar common error (Bourke et al., 1991).

2. AMIP background and purpose

The need for a systematic and comprehensive intercomparison of atmospheric climate models was emphasized by the Joint Scientific Committee (JSC) of the World Climate Research Programme (WCRP) early in 1989. A preliminary plan was developed at an ad hoc meeting of experts on modeling standards and intercomparison that took place in Boulder in August 1989. This plan was further developed by the WGNE at its meeting in Hamburg in September 1989, and officially became the Atmospheric Model Intercomparison Project (AMIP) upon the endorsement of the JSC in March 1990. During the same period the Program for Climate Model Diagnosis and Intercomparison (PCMDI) was established at the Lawrence Livermore National Laboratory (LLNL) by the Environmental Sciences Division of the U.S. Department of Energy for the purpose of increasing understanding of the differences among climate models. The support and implementation of AMIP quickly became a priority PCMDI activity. Since that time, substantial resources have been provided by the DOE for the support of AMIP, including the provision of computer time to participating modeling groups at the National Energy Research Supercomputer Center at LLNL. AMIP is also coordinated with the DOE Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) Program (Bader et al., 1992).

The basic purpose of AMIP is to undertake the systematic intercomparison and validation of the performance of atmospheric GCMs on seasonal and interannual time scales under as realistic conditions as possible, and to support the in-depth diagnosis and interpretation of the model results. In particular, the simulation of the mean climate and the sequence of shorter-term climatic states, and the simulation of specific atmospheric processes and phenomena are of interest to both the climate and weather prediction communities. Such analyses and intercomparisons require that all models simulate the same time period under comparable experimental conditions, and that the same diagnostic measures of performance be calculated for all models. As simple as it sounds, the decision to undertake such a structured or standardized simulation is a major step forward in climate model intercomparison. In terms of the WGNE's definitions of model intercomparison shown in Fig. 1, AMIP is a level 2 intercomparison in which the models' climate is

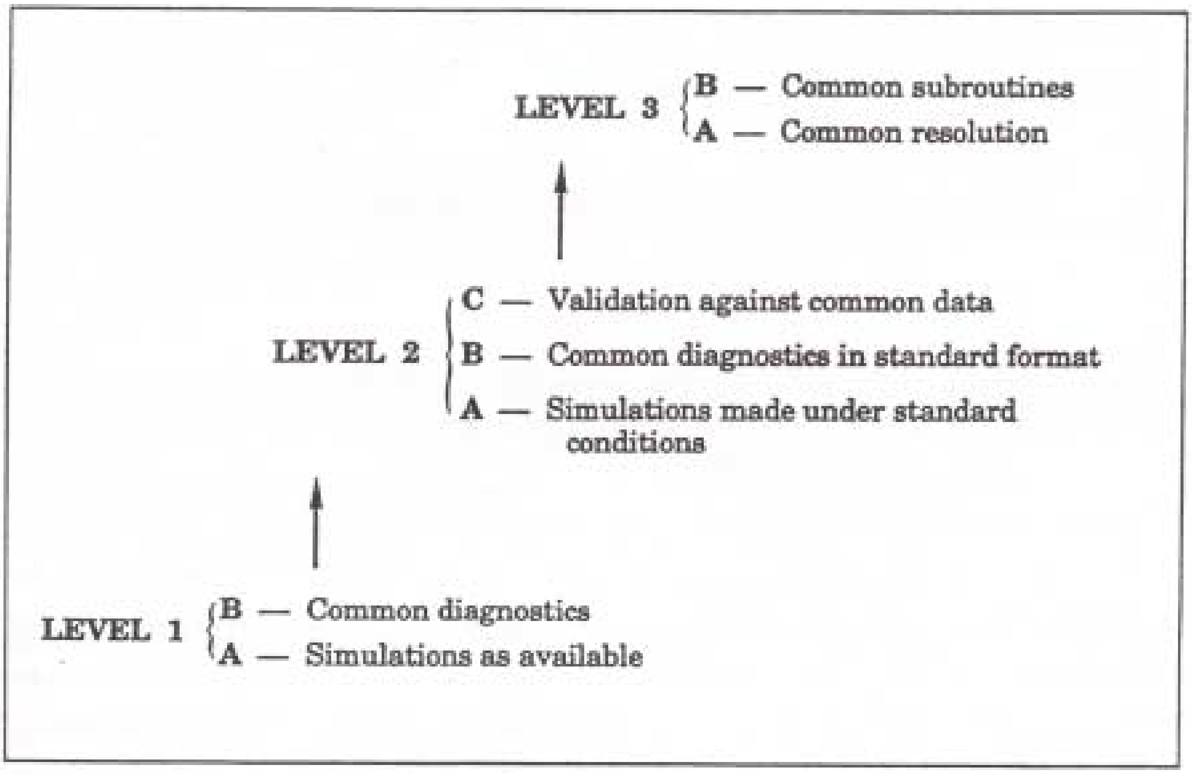

Fig. 1. Levels of model intercomparison as defined by the Working Group on Numerical Experimentation (WGNE). The attributes of lower intercomparison levels are assumed to be included in higher levels when appropriate.

specifically generated for the purpose of intercomparison, in contrast to model intercomparisons in which results are taken from uncoordinated and possibly disparate runs (i.e., level 1 intercomparisons). An earlier example of a level 2 diagnostic intercomparison is that of Cess et al. (1989), while the reports of Boer et al. (1991) and Neelin et al. (1992) are examples of level 1 model intercomparisons.

3. AMIP experimental plan

The decade 1979-1988 was selected as the AMIP test period. This choice was a compromise between the desire to use as long a simulation period as possible in order to obtain representative results, and the increasing difficulties with observed global data sets as one proceeds to earlier years. This time period includes the FGGE observational year 1979 and the occurrence of the major ENSO event during 1982/3. Satellite observations also become increasingly available during this period. Realistic atmospheric forcing is sought by specifying the global distribution of the sea-surface temperature and sea ice in terms of the observed monthly averages on a 2° latitude-longitude grid, from which the appropriate spatial and temporal interpolations can be made for each model. A data set meeting these requirements was specifically constructed for AMIP by the NOAA Climate Analysis Center in cooperation with the Center for Ocean-Land-Atmosphere Interactions at the University of Maryland. An edited version of this AMIP SST and sea-ice data set is available from PCMDI, and has been distributed to AMIP participants. These data are illustrated for the month of September 1982 in Fig. 2. The sequence of 120 monthly mean observed SST and sea-ice distributions during 1979-1988 provides realistic forcing for (and constraint on) the atmosphere, and constitutes a "perfect" ocean for the purposes of AMIP.

Atmospheric GCMs represent the land surface character and its behavior in a wide variety of ways, including the possible interaction with vegetation. In order to keep the AMIP specifications as simple as possible, it was decided to make no common specification of the land surface. Thus, over land (as determined by each model's land-sea distribution) surface properties such as the albedo, emissivity, roughness, soil moisture and snow/ice cover, and the possible effects of surface vegetation, are left entirely up to each modeling group. (The validation and intercomparison of land surface parameterization schemes in atmospheric models is being

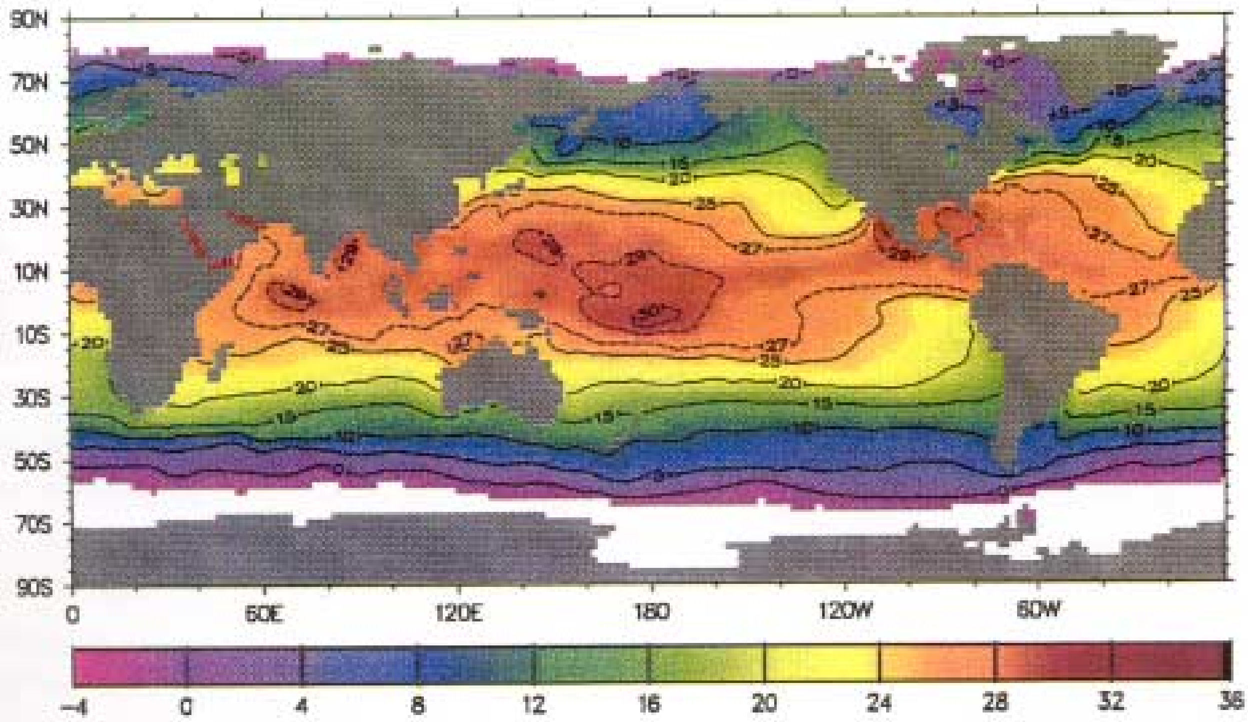

Fig. 2. An illustration (for September 1982) of the AMIP monthly-averaged sea-surface temperature (°C) and sea-ice distribution (white areas) as analyzed from climatological, satellite and in-situ observations on a 2 deg latitude x 2 deg longitude grid for the period 1979-1988.

undertaken by the joint WGNE/GEWEX project PILPS (Henderson-Sellers, 1992)). Neither has any attempt been made to use common surface elevation data or to specify the values of geophysical constants such as gravity and the orbital parameters, although standard values of the atmospheric CO_2 concentration (345 ppm) and solar constant (1365 Wm^{-2}) have been specified; these values are close to the averages observed during the AMIP period.

The initial conditions for the AMIP integrations beginning on 1 January 1979 were also not specified since these would presumably have no significant effect beyond the first month. The atmospheric forecast models in AMIP generally use an operational analysis for 1 January 1979 as initial AMIP conditions, while most of the atmospheric climate models use either climatological January conditions or the results of earlier model runs appropriate for January. In any case, the integrations are carried out over the 3653-day period 1 January 1979 to 31 December 1988, inclusive.

A common list of standard monthly-averaged output has been established as shown in Table 1. Set 1 consists of the monthly mean global geographical distributions of selected surface and vertically integrated variables (sea-level pressure, ground and surface air temperature, cloudiness, precipitable water, soil moisture and snow mass). In addition, the monthly means of selected components of the atmospheric heat and hydrologic budgets and the surface wind stress are accumulated at each physics time step in the models' integrations. Set 1 also includes the monthly mean cloud radiative forcing as found by subtracting the net outgoing radiation at the top of the atmosphere in the (artificial) case without clouds from that in the (normal) case with clouds. Set 2 of the AMIP standard output consists of the monthly mean global geographical distributions of selected three-dimensional variables (temperature, geopotential height, specific humidity, the zonal and meridional wind and the associated stream function and velocity potential) at the 850, 500 and 200 hPa levels. In addition, set 2 includes the geographical distributions of the monthly variance (defined as the variance about the monthly mean of the daily averages found from 6 hourly values) of all variables in the set, while set 1 includes the monthly variance of selected variables (sea-level pressure, ground and surface air temperature). Set 3 of the AMIP standard output consists of the monthly means of the zonally-averaged distributions of selected variables in the meridional-vertical plane (temperature, specific and relative humidity, cloudiness, zonal and meridional wind, and the mean meridional streamfunction).

Table 1. The monthly-averaged standard output data to be generated by the AMIP simulations for each month of 1979-1988.

<u>Set 1</u> <u>Global geographical distribution of surface, top-of-the-atmosphere and vertically integrated variables</u>

Sea-level pressure*
Temperature (ground)*
Surface air temperature*
Total cloudiness
Total precipitable water
Soil moisture
Snow mass
Precipitation†
Evaporation†
Eastward wind stress†
Northward wind stress†
Sensible heat flux†
Net surface short-wave flux†
Net surface long-wave flux†
Top-of-atmosphere net short-wave flux†
OLR†
Cloud radiative forcing

<u>Set 2</u> <u>Global distribution of 3-D variables</u>

Temperature at 200 hPa*
Temperature at 850hPa*
Geopotential height at 200 hPa*
Geopotential height at 500 hPa*
Geopotential height at 850 hPa*
Specific humidity at 200 hPa*
Specific humidity at 850 hPa*
Zonal wind at 200 hPa*
Zonal wind at 850 hPa*
Meridional wind at 200 hPa*
Meridional wind at 850 hPa*
Streamfunction at 200 hPa*
Streamfunction at 850hPa*
Velocity potential at 200 hPa*
Velocity potential at 850 hPa*

<u>Set 3</u> <u>Meridional-vertical distribution of zonal means</u>

Temperature
Specific humidity
Relative humidity
Cloudiness
Zonal wind
Meridional wind
Streamfunction of mean meridional circulation

* Includes variance of daily averages about monthly mean
† Accumulated value

In anticipation of the use of the AMIP results in a wide variety of diagnostic studies, some of which may require information not contained in the monthly averaged standard output sets, each participating modeling group is requested to generate a 6-hourly history-of-state consisting of the prognostic variables of the model, along with the 6-hourly sub-totals of those quantities accumulated for the standard output. For those models without a diurnal cycle, a once daily history is appropriate.

4. AMIP implementation and present status

As part of its commitment to the implementation of AMIP, the PCMDI with the support the Environmental Sciences Division of the U.S. Department of Energy is providing computer time to those atmospheric modeling groups wishing to run their models' AMIP simulation at LLNL, and is supporting the visit to Livermore of a representative of each group for that purpose. In order to manage effectively and to access the standard output and history-of-state data that are expected to be in archival storage at LLNL, the PCMDI has developed a data management system (known as the Data Retrieval and Storage system, DRS) for storing, retrieving and visualizing both model-generated and observational data. DRS is a file-oriented system of libraries and utilities that support a machine-independent data file format. These consist of the DRS Library, which is the programming interface to DRS, and the PCMDI Graphics package, which is a menu-driven, point-and-click utility that allows interactive data selection from DRS files and the creation and manipulation of graphic displays and animations. This software, as well as interactive utilities that support DRS file browsing and manipulation, are available to all AMIP participants as well as to other groups engaged in related studies.

In support of AMIP and the broader interests of the atmospheric modeling community, PCMDI is developing a computerized database of the properties of the models participating in AMIP, as a subset of a more comprehensive information system of the principal historical versions of atmospheric GCMs. PCMDI is also assembling an observational database for validation of the AMIP simulations and related diagnostic studies (see section 5).

In testimony to the widespread interest in model validation and intercomparison in both the forecasting and climate modeling communities, there are presently

29 atmospheric GCMs participating in AMIP. This includes models from all of the world's principal climate modeling groups as well as those from many operational weather forecasting centers. Some of the principal characteristics of the AMIP models are listed in Table 2. The horizontal resolution of the models being used for AMIP ranges from 2.5° latitude x 3.75° longitude to 8° latitude x 10° longitude among the ten finite-difference models represented, and from R15/T21 to R40/T42 among the nineteen participating spectral models, while the number of vertical levels (usually in σ or hybrid coordinates) ranges from 2 to 30. Although most models include a diurnal cycle, there are wide variations in the schemes used in models' parameterization of radiation, convection, clouds, frictional effects and soil properties. At the present time, the ten-year AMIP simulation has been completed by 14 of these GCMs, and it is anticipated that the results for all participating models will be available by the end of 1993 (although AMIP remains open to additional atmospheric modeling groups).

From the monthly-averaged standard output (see table 1), the PCMDI, in cooperation with the participating modeling groups, will undertake the preparation of a series of reports summarizing and intercomparing the models' results, together with an estimate of the models' systematic errors on the basis of the observational data bank being assembled for AMIP model validation (described below). While much important information on the model's individual and collective performance will be provided by these statistics, insight into the models' portrayal of specific physical mechanisms requires a deeper and more revealing diagnosis of the results.

5. AMIP diagnostic subprojects

To promote the advanced or sophisticated diagnosis of the AMIP results, a series of diagnostic subprojects is being undertaken by members of both the climate modeling and climate diagnostics communities. Following approval of a diagnostic subproject proposal by the WGNE AMIP Panel, the AMIP modeling groups are polled as to their willingness to release their model's data and/or their interest in being more actively involved by providing the required diagnostics and participating in the analysis.

Table 2. Selected characteristics of the atmospheric GCMs that are participating in AMIP

Group/Model	Horizontal Resolution §	Vertical Coord. and Levels	Diurnal Cycle	Radiation Scheme #
BMRC	R31	σ9	Yes	Lacis-Hansen, Fels-Schwarzkopf
CCC/GCMII	T32	Hybrid 10	Yes	Fouquart-Bonnel, Morcrette et al.
CNRM	T42	Hybrid 30	Yes	Geleyn-Hollingsworth
COLA	R40	σ18	Yes	Harshvardhan et al.
CSIRO/CSIRO9	R21	σ9	Yes	Fels-Schwarzkopf
CSU	4x5	Modified σ 17	Yes	Harshvardhan et al.
DNM	4x5	σ7	Yes	Manabe-Strickler, Lacis-Hansen, Feigelson
ECMWF/Cy36	T42	Hybrid 19	Yes	Morcrette
GFDL	R30	σ9	No	Lacis-Hansen, Rodgers-Walshaw
GFDL/DERF	T42	σ18	No	Fels-Schwarzkopf
GISS/Model II	8x10, 4x5	σ9	Yes	Lacis-Hansen
GLA/Version8	4x5	σ17	Yes	Lacis-Hansen, Harshvardhan-Corsetti
HMC	T21	σ15	No	Geleyn-Hollingsworth
IAP	4x5	Modified σ2	Yes	Cess et al., Katayama
JMA	T42	Hybrid 21	Yes	Lacis-Hansen, Sugi et al.
LANL	R15	σ20	Yes	Ramanathan et al.
LMD/M206	3.6x5.6	σ11	No	Fouquart-Bonnel, Morcrette
MGO/MGOHI	T30	σ14	No	Karol et al.
MPI/ECHAM3	T42	Hybrid 19	Yes	Hense et al., Rockel et al.
MRI	4x5	Hybrid 15	Yes	Lacis-Hansen, Shibata-Aoki
MSFC/CCM1	T42	σ12	No	Kiehl et al.
NCAR/CCM2	T42	Hybrid18	Yes	Briegleb, Kiehl et al., Slingo
NMC/MRF	T40	σ18	Yes	Lacis-Hansen, Fels-Schwarzkopf
NRL/NOGAPS	T42	Hybrid 18	Yes	Davies, Harshvardhan et al.
SUNYA/CCM1	R15	σ12	No	Kiehl et al., Wang et al.
UCLA	4x5	Modified σ17	Yes	Katayama, Harshvardhan et al.
UGAMP	T42	Hybrid 19	Yes	Morcrette
UILL	4x5	σ7	Yes	Oh-Schlesinger
UKMO/Unified	2.5x3.75	Hybrid 20	Yes	Slingo, Slingo-Wilderspin

§ R = rhomboidal spectral truncation; T = triangular spectral truncation; nxm = n deg latitude, m deg longitude
# Parameterization scheme references available on request

Table 2 - continued

Cloud Scheme #	Prognostic Cloud Water	Convection Scheme*#	Horizontal Diffusion	Gravity-Wave Drag Scheme #	Number Soil Layers, for Temp./Moisture †
Slingo, Rikus	No	Kuo	2nd-order	Palmer et al.	2/1
McFarlane et al.	No	MCA	2nd-order	McFarlane	1/1
Geleyn et al., Tiedtke	No	Bougeault	6th-order	Clary	2/2
Slingo, Hou	No	Kuo	4th-order	Alpert et al.	2/3
Gordon-Hunt	No	MCA	2nd-order	Chouinard et al.	3/2
Randall et al.	No	A-S	2nd-order	No	1/1
Smagorinsky	No	Kuo	2nd-order	No	1/1
Slingo	No	Tiedtke	4th-order	Miller et al.	2/2
Wetherald-Manabe	No	MCA	4th-order	Hayashi	0/1
Gordon	No	MCA	4th-order	Pierrehumbert	3/1
Hansen et al.	No	Hansen	No	Hansen et al.	2/2
Slingo	No	A-S	No	No	2/3
Geleyn et al., Tiedtke	No	Kuo	4th-order	Pichugin	2/2
Zeng et al.	No	A-S	2nd-order	No	1/1
Saito-Baba	No	Kuo	4th-Order	Iwasaki et al.	4/3
Ramanathan et al.	No	MCA, A-S	2nd-order	No	5/2
Le Treut-Li	Yes	MCA, Kuo	4th-order	Boer et al.	1/1
Slingo	No	Kuo	2nd-order	McFarlane	3/2
Sundqvist	Yes	Tiedtke	2nd-order	Palmer et al.	5/1
Tokioka et al.	No	A-S	2nd-order	Palmer et al.	4/4
Kiehl et al.	No	MCA	4th-order	McFarlane	0/1
Slingo	No	Hack	4th-order	McFarlane	4/P
Slingo	No	Kuo	2nd-order	Alpert et al.	3/1
Slingo	No	A-S	4th-order	Palmer et al.	1/0
Kiehl et al.	No	MCA	4th-order	No	0/1
Suarez et al.	No	A-S	2nd-order	Palmer et al.	0/P
Slingo	No	Kuo	6th-order	Palmer et al.	2/2
Oh-Schlesinger	Yes	A-S	No	No	1/1
Smith et al.	Yes	Gregory	4th-order	Palmer et al.	4/1

* A-S = Arakawa-Schubert, MCA = moist convective adjustment

† An entry of zero (0) indicates there is no provision for soil heat/moisture storage; an entry of P indicates soil moisture is prescribed.

Footnote to Table 2.

Here BMRC = Bureau of Meteorology Research Centre, Melbourne; CCC = Canadian Climate Centre, Downsview; CNRM = Centre National de Recherches Météorologiques, Toulouse; COLA = Center for Ocean-Land-Atmosphere Interactions, University of Maryland, College Park; CSIRO = Commonwealth Scientific and Industrial Research Organisation, Mordialloc; CSU = Colorado State University, Ft. Collins; DNM = Department of Numerical Mathematics, Russian Academy of Sciences, Moscow; ECMWF = European Centre for Medium Range Weather Forecasts, Reading; GFDL = Geophysical Fluid Dynamics Laboratory, Princeton; GFDL/DERF = Geophysical Fluid Dynamics Laboratory, Dynamic Extended Range Forecasting, Princeton; GISS= Goddard Institute for Space Sciences, New York; GLA = Goddard Laboratory for Atmospheres, Greenbelt; HMC = Hydrometeorological Centre, Moscow; IAP = Institute of Atmospheric Physics, Beijing; JMA = Japan Meteorological Agency, Tokyo; LANL = Los Alamos National Laboratory, Los Alamos; LMD = Laboratoire de Météorologie Dynamique, Paris; MGO = Main Geophysical Observatory, St. Petersburg; MPI = Max Planck Institute for Meteorology, Hamburg; MRI = Meteorological Research Institute, Tsukuba; MSFC = Marshall Space Flight Center, Huntsville; NCAR = National Center for Atmospheric Research, Boulder; NMC = National Meteorological Center, Washington; NRL = Naval Research Laboratory, Monterey; SUNYA = State University of New York, Albany; UCLA = University of California, Los Angeles; UGAMP = UK Universities Global Atmospheric Modelling Project, Reading; UILL = University of Illinois, Urbana; UKMO = United Kingdom Meteorological Office, Bracknell.

Each diagnostic subproject is focussed on a particular phenomenological aspect of the simulations, on a particular physical or dynamical process, or on model performance in a particular region. So far, AMIP diagnostic subprojects have been established on the following topics (and principal organizers): Synoptic to intraseasonal variability in the tropics (J. Slingo and K. Sperber), interannual variability and potential predictability (F. Zwiers), extratropical intraseasonal variability and cyclone frequency (S. Lambert), clear-sky greenhouse sensitivity, water vapor distribution and cloud radiative forcing (J. Duvel and F. Cheruy), surface fluxes over the oceans (D. Randall, T. Jensen and P. Gleckler), monsoons (T. Palmer and M. Fennessy), hydrologic processes (W.K.M. Lau and M. Fiorino), polar phenomena and sea ice, (J. Walsh, H. Cattle, C. Mechoso and D. Bromwich), southern hemisphere circulation (B. McAvaney, I. Simmonds and I. James), and blocking (S. Tibaldi). Additional subprojects on soil moisture, cloudiness, diabatic heating, extreme events, land-surface effects, angular momentum, stratospheric processes and cloud radiative forcing are under consideration.

The PCMDI will assist the diagnostic subprojects in the acquisition of the required model data from the AMIP standard output and the model histories (which are expected to be available at LLNL in DRS format), and will provide computational assistance to the extent feasible. Proposals for additional AMIP diagnostic subprojects are welcome, and should be sent to the author as soon as possible.

6. Future plans

After completion of the computational phase of AMIP in 1993, attention will increasingly focus on the analysis and intercomparison of the results as discussed above. This diagnostic phase of AMIP is expected to continue for as long as necessary in order to exploit fully the unique AMIP dataset. An informal *AMIP Newsletter* is issued twice each year by PCMDI, in which summaries of the project's status and other information relevant to AMIP are given; *AMIP Newsletters* No. 1 (September 1991), No. 2 (February 1992), and No. 3 (October 1992) are available from PCMDI upon request. Depending upon progress, it is anticipated that an international AMIP scientific conference will be convened in 1994 or 1995.

The availability of observational data with which to validate the models' performance is essential to the success of AMIP. Although data from a wide variety of sources are currently available, they are generally not for the specific AMIP decade or in a format readily useful in model validation and diagnosis. To develop a model-oriented observational database in support of AMIP, the PCMDI is acquiring gridded global data sets for as many of the variables in the AMIP standard output and for as many months of the AMIP period as possible. These data include temperature, geopotential, wind and relative humidity from both ECMWF and NMC analyses, and the cloudiness, radiation and precipitation as generated by the WCRP International Satellite Cloud Climatology Project (ISCCP), the WCRP/NASA Earth Radiation Budget Experiment (ERBE), and the WCRP Global Precipitation Climatology Project (GPCP) observational programs, respectively. It is planned to store these data (and other relevant data that may become available) at PCMDI in uniformly-formatted DRS files for ease of access and use in connection with AMIP analyses. It is recognized that when a *reanalysis* of the period 1979-1988 is performed with an advanced data assimilation system (as currently under consideration by both the ECMWF and NMC), it will be possible to generate consistent observational estimates of the AMIP monthly-averaged standard output variables as well as a complete history. AMIP therefore provides an important justification for carrying out such a reanalysis in a timely fashion over the next few years (Bengtsson and Shukla, 1988).

In addition to its obvious and unprecedented value in the comprehensive validation of the current generation of atmospheric GCMs, the results of AMIP can serve as a reference for the systematic documentation of model improvements by the repetition of some or all of the AMIP simulation with new model versions, and may also provide a useful yardstick for sensitivity and predictability studies with atmospheric models. AMIP also compliments the intercomparison of ocean models being undertaken by the WCRP TOGA Numerical Experimentation Group (D. Anderson and T. Stockdale, personal communication), and may serve as a prototype for intercomparisons of coupled atmosphere-ocean GCMs. In the future it may be useful to extend the AMIP period beyond 1988 (and perhaps before 1979), and to repeat the AMIP integrations with improved boundary conditions as well as with improved models. Independent realizations of the AMIP integration with different initial conditions have already been recognized by several modeling groups as an important source of information on natural variability and climate predictability.

AMIP may be regarded as the first "electronic" model intercomparison, in the sense that its results and diagnoses (along with the corresponding observed data) will be electronically available for analysis and display. The greatest obstacle to achieving this goal lies in the development of efficient techniques for the storage, retrieval and visualization of extremely large databases. This is a major challenge to the computational sciences community on whose skills climate modeling studies increasingly depend.

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