AMIP NEWSLETTER

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An information summary and activities description for the Atmospheric Model Intercomparison Project (AMIP) of the Working Group on Numerical Experimentation (WGNE) in support of the World Climate Research Programme. Technical and computational support for AMIP is provided by the Environmental Sciences Division of the U.S. Department of Energy through the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory (LLNL), where this newsletter is edited by Peter Gleckler, Chairman, WGNE AMIP Panel, PCMDI, L-264, LLNL, P.O. Box 808, Livermore, CA, 94550, USA.

This edition of the AMIP newsletter is devoted to the documentation of the AMIP II Guidelines. Questions or comments concerning the Atmospheric Model Intercomparison Project should be sent by email (preferred) to amip@pcmdi.llnl.gov or addressed to: The AMIP Project Office, PCMDI, L-264, LLNL, P.O. Box 808, Livermore, CA, 94550, USA. Periodic project updates will be provided with future editions of the AMIP Newsletter. AMIP information is continuously updated at the WWW address http://www-pcmdi.llnl.gov/amip/amiphome.html

AMIP II Guidelines

Contents

1. Introduction

1.1 Background

In 1989 the need for systematic intercomparison and evaluation of atmospheric models was emphasized by the Joint Scientific Committee (JSC) of the World Climate Research Programme (WCRP). A project to address this need was established by the Working Group on Numerical Experimentation (WGNE), and officially endorsed by the JSC in 1990 as the Atmospheric Model Intercomparison Project (AMIP). 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 WGNE invited the PCMDI to serve the climate modeling community by implementing AMIP, and PCMDI has done so since 1990. Five years after its inception, the project reached a milestone: the analyses of the first AMIP simulations were presented at the First International AMIP Scientific Conference in May 1995. Prior to that conference, the PCMDI staff prepared a proposal for the continuation of the project. Although not without shortcomings, AMIP was regarded as a success by its participants, who, in response to PCMDI's proposal, overwhelmingly supported the concept of an AMIP II. Subsequently, many climate scientists have provided suggestions which have been incorporated into the AMIP II experimental guidelines. In late 1995, the WGNE chose to reconstitute and enlarge the AMIP Panel (Gleckler, 1996), whose first task was to assist PCMDI in the final design of AMIP II.

AMIP is an international effort to develop a community infrastructure for atmospheric modelers and diagnosticians. This is being accomplished by establishing a standardized experiment, with a diverse group of scientists performing extensive diagnoses. In support of this "benchmark" exercise, the project also serves to identify scientific, informational and cooperative standards that are acceptable to the community. The result is a more thorough and efficient evaluation of AGCM simulations, which is crucial for model development and improvement.

Return to Table of Contents

1.2 Motivation and mission

The impetus to continue AMIP stems from the strong support of the international community of climate modelers and diagnosticians. As the AMIP infrastructure has matured, the benefits of the project have continued to unfold. Since the inception of the project there has been a substantial increase in cooperation and collaboration among AGCM modeling and diagnostic groups. Many revealing diagnostics have been developed, leading to increasingly comprehensive model evaluation. The process of identifying systematic model errors has consequently been improved and accelerated.

Mission statement

AMIP II will assist community efforts to improve atmospheric general circulation models by establishing standards for model simulation, documentation, validation and diagnosis. This will be accomplished by the implementation of standardized experiments that facilitate improved comparison of simulations. Comprehensive documentation will serve to clarify experimental procedures to ensure that they are properly interpreted by the scientific community. The desired result is the continuing advancement of simulation diagnosis, which ultimately supports the improvement and development of models.

Return to Table of Contents

1.3 Project overview

AMIP II will maintain its focus on the support of a community standard control experiment, in cooperation with those analyzing the simulations. There will be a special effort to study the effect of intrinsic variability on climate model simulations, and AMIP II will also begin to support some numerical experimentation.

The minimum requirement for a modeling group's participation will be to carry out a standard AMIP II simulation (under the guidelines summarized below), and to submit standard model output to PCMDI in a timely manner. Contribution of multiple realizations will be optional for AMIP participants, as will participation in future AMIP-supported numerical experimentation.

In the years ahead, the AMIP control experiment is anticipated to evolve further. Model intercomparisons will take place at an increasingly fundamental level, as envisaged for Level 3 intercomparison defined by the WGNE (Gates, 1992).

The AMIP infrastructure will assist the development of other climate model comparisons such as the Coupled Model Intercomparison Project (CMIP), the Seasonal Prediction Model Intercomparison Project (SMIP), and the Paleoclimate Model Intercomparison Project (PMIP).

Return to Table of Contents

2. AMIP II Experimental Design

2.1 The AMIP II standard experiment

Development of a standardized control experiment presents a challenge, as the complexity and diversity of AGCMs in the community necessitates compromises in the experimental design. Thus the AMIP II experimental protocol is partitioned into *requirements* and *recommendations.* All participating modeling groups are expected to adhere to the experimental requirements. Treatment of the recommendations will be documented for each model (Section 5.3). Rationale for some of these specifications is discussed in Appendix B.

Requirements

- *Simulation period: 00Z* 1 January 1979 through 00Z 1 March 1996.
- *Ocean surface boundary conditions:* use the AMIP II monthly mean sea surface temperatures and sea-ice (Fiorino, 1996). Explicit instructions are provided for the use of these data in AMIP II simulations (Taylor et al., 1996).
- *Model spin-up:*eliminate or minimize initial transients. Some technique must be used to ensure that the model is in "quasi-equilibrium" (e.g., a lack of perceptible trends in deep soil temperature and moisture) at the beginning of the AMIP II period. A recommended method is described in Taylor et al. (1996), and includes documentation of supplementary SSTs and sea-ice appropriate for the spin-up period.
- *Solar constant:* 1365 W m^{-2} (Hartmann, 1994)
- *Orbital parameters*: (Smith et al., 1995)

  - obliquity=23.441º

  - eccentricity = 0.016715

  - longitude of perihelion=102.7º
- *[CO_2]:*348 ppmv (AMIP II period average, derived from the 1995 IPCC).

Recommendations

- *Realistic calendar*(with 1980, 84, 88, 92, 96 leap years): define time of vernal equinox as March x, with x=20.41-0.0078(Y - 1987) + 0.25Y(modulo 4), where Y is the year and Y (modulo 4) the remainder after dividing Y by 4 (Smith et al., 1995). A time model of twelve 30-day months is strongly discouraged.
- *Ozone concentration:* use the Wang et al. (1995) latitude (zonal average)-pressure monthly climatology. Data, documentation and instructions are available from the AMIP homepage.
- *Land surface energy and hydrological balance:* do not prescribe the temperature of the deepest land surface level, nor a deep infinite reservoir of moisture.
- *Land-sea mask and topography*: use a land-sea mask (adopted to each model grid and available from PCMDI) based on the U.S. Navy 10' data set. High resolution state-of-the-art topography is also available from PCMDI, but no recommendation is made for topography smoothing.
- *Atmospheric mass & topography:* prescribe observed global average values for surface pressure (982.4 hPa) and topographic height (237.33 m). If proper specification of model topography requires a deviation from the observed mean, adjust the global mean surface pressure by 1 hPa per 8 m deviation (Trenberth and Guillemot, 1994).
- *Other greenhouse gases:* [CH_4] = 1650 ppbv and [N_2O]= 306 ppbv. Halocarbon concentrations

should yield ~0.24 W m^{-2} radiative forcing. Use of an "equivalent" [CO_2] is not recommended.

- *Aerosol concentration* (for those models that account for them): prescribe a background monthly climatology only.

Return to Table of Contents

Official AMIP II simulations

To qualify as an "official" AMIP II simulation, the following must be satisfied:

- adherence to experimental requirements
- fulfillment of documentation procedures (Section 5.3)
- contribution of AMIP II Standard Model Output (Section 4.1 and Tables 1-5 in Appendix A) to the AMIP archive in the appropriate data structure (Section 4.3), with satisfactory completion of all data quality control tests to be run at PCMDI.

To ensure that results are included in the next series of AMIP studies and presented at the 2nd International AMIP Conference, standard model output from AMIP II simulations should be submitted to PCMDI before the end of 1997. To demonstrate the results of model development and improvement, many groups may wish to submit revised-model AMIP II simulations (as in AMIP I) from time to time. PCMDI will process and distribute up to one revised model simulation per year for each participating modeling group.

Return to Table of Contents

2.2 Multiple realizations

To assess the statistical significance of some results, it is necessary to perform an ensemble of integrations that are identical except in their initial conditions. AMIP participants have expressed strong interest in the systematic study of this issue, and the AMIP Panel has chosen to coordinate an ensemble study in AMIP II. Multiple integrations require substantial computational resources, and it is therefore likely that only a few AMIP modeling groups will be able to contribute to the ensemble project. Modeling groups choosing to participate should run a minimum of 6 AMIP II simulations (Zwiers, 1996). To enable comparison of the weather-induced interannual variance with variance due to the boundary forcing, a 20-year run with the AMIP II SST and sea-ice *climatology* (Fiorino, 1996) is also recommended. Only a subset of the AMIP II Standard Model Output will be requested of ensembles (see Section 4.2).

Return to Table of Contents

2.3 Numerical experimentation

Many AMIP modeling groups have recommended that the project be expanded to include numerical experimentation, making use of the standard AMIP II simulations as control runs for comparison. In fact, most modeling groups have used their AMIP I simulations in this way, and this represents an important motivation for the AMIP "benchmark" exercise. However, some issues are sufficiently fundamental to justify a community-wide systematic model inter-comparison of carefully controlled sensitivity experiments.

While the AMIP Panel has approved the concept of numerical experimentation in AMIP II, it has concluded that further investigation is needed to determine which experiments justify the support of the AMIP infrastructure. PCMDI will establish an internet forum (available by regular mail if requested) to report experimentation proposals made by climate scientists. It is expected that most of the proposed sensitivity experiments will have already been performed with one or more models and these preliminary experiments will identify which issues warrant an organized comparison.

Experimentation will initially be limited to a few projects regarded by the AMIP Panel to have the most potential benefit to the modeling community. As the foundation for AMIP experimentation develops, sensitivity studies designed to address specific diagnostic interests will gradually be introduced. To benefit fully from the AMIP infrastructure, participants in the numerical experimentation projects will be expected to adhere to the AMIP guidelines for experimental documentation and data exchange standards. Scientists who wish to submit proposals should contact the AMIP Project Office. Proposals, and reactions to them, will be reviewed by the AMIP Panel within six months of their submission. As sensitivity experiments begin to be supported by AMIP, modeling groups will have the opportunity to participate in those that are of interest to them. Participation in AMIP experiments may range from several modeling groups to the entire AMIP community.

Return to Table of Contents

3. AMIP II Diagnostic Subprojects

3.1 Subproject structure

Analysis of AMIP II simulations will continue to be coordinated through a set of diagnostic subprojects, but with improvements and clarifications based on the experience of AMIP I. There will be no limit *a priori* to the number of subprojects the AMIP Panel will approve for AMIP II. However, the Panel will strive to ensure that all approved subprojects: 1) are of scientific merit, 2) have a high probability of being completed, and 3) are coordinated appropriately with one another and with the modeling community. Existing AMIP I diagnostic subprojects must be re-approved by the AMIP Panel to participate in AMIP II.

With the more comprehensive standard model output in AMIP II it will be possible to pursue a variety of new intercomparison studies. It is anticipated that diagnostic subprojects will continue to focus on evaluating simulations through in-depth analysis of processes, phenomena, regional characteristics, and by comparison with the best observations available.

AMIP II model output will initially be made available to approved diagnostic subprojects only, but two years after a simulation is entered into the AMIP archive, it will be placed in the public domain.

Return to Table of Contents

3.2 Subproject responsibilities

Participation in an AMIP II diagnostic subproject will ensure early access to model output, but will also entail certain obligations. AMIP is a community-based effort, and all participants must therefore accept certain responsibilities to ensure that the project is carried out in an efficient and equitable manner.

Diagnostic subproject leaders must agree to provide PCMDI with brief annual progress reports. These summaries should include a short analysis update (no more than a few pages and figures), and a listing of all AMIP-related conference and manuscript abstracts. The purpose of these summaries will be to keep all AMIP II participants informed of the projects' progress. PCMDI will organize these subproject summaries on the PCMDI web pages. Access to subproject progress summaries will be restricted to AMIP participants for a review period before they are made public. Diagnostic subproject leaders must also agree to keep modeling groups informed of model data usage. For example, before submitting an AMIP II study for peer-reviewed publication, the manuscript should be sent to each modeling group whose data were used in the analysis. Modeling group representatives should be given a reasonable period (at least one month) to provide comments.

While PCMDI will perform extensive quality control on all AMIP simulations, there is always the possibility that some suspicious data may be uncovered after the data has been distributed to the diagnostic subprojects. If a subproject discovers an error, it should be reported to PCMDI immediately so that it may be corrected.

The WGNE AMIP Panel reserves the right to revoke subproject privileges if the agreed-upon responsibilities are not fulfilled.

Return to Table of Contents

3.3 Collaboration protocol

In AMIP I, some difficulties were encountered because it was unclear what sort of cooperation was expected among participants. Based on these experiences, some guidelines have been developed for collaboration between diagnostic subprojects and modeling groups. These guidelines are (by necessity) compromises, but the aim is to provide an acceptable framework for all participants.

- *Equal treatment of all modeling groups:* Modeling groups participate in AMIP with the expectation that their simulations will be analyzed. In preparing manuscripts for journal publications, a subproject leader may choose to focus on only a few models that most clearly illustrate each point. When results for only a subset of models are shown, it is expected that the corresponding results would be sent to modeling groups whose results are not shown. At some level, however, results of all available models should be compared collectively (e.g., the results from all models shown on zonal mean plots or in a summary table).
- *Clarifying the implications of results:* There are two points that should be made clear in all AMIP studies. The first is the age or model version of each simulation. For simulations more than a few years old, it should be emphasized that the results may not be indicative of the current model version. The second point that should be expressed is a warning that the results of a specific subproject do not necessarily reflect the overall performance of the AGCMs. For example, attempts to rank the performance of AMIP I simulations have yielded very different results, depending on the aspect examined.
- *Authorship:* This issue is often a problem in large projects. Here we propose a compromise that reflects the sentiments of many subprojects leaders and modelers, namely that 1) no individual should receive co-authorship in an AMIP study without directly contributing to that study, and 2) the modeling groups deserve recognition for their participation in AMIP. The suggested

compromise is straightforward: For all reports and papers resulting from their analysis of AMIP simulations, subproject leaders should include in the authorship listing the phrase, "Participating AMIP II modeling groups." For example:

M. Brian[1], J. Smith[1], and Participating AMIP II modeling groups[2]

[1] University of John Doe

[2] List of all groups whose model output was used.

Modeling group representatives (not necessarily the official AMIP contact) will be given the opportunity to actively participate in diagnostic subprojects of interest.

When a modeling group representative acknowledges an interest to participate in a subproject, they should expect to provide sufficient assistance to earn explicit co-authorship. In the diagnostic subproject agreements, the leaders will agree to use their professional judgment to determine what constitutes a sufficient contribution to qualify for co-authorship. It is anticipated that individuals responsible for preparing models for AMIP-supported numerical sensitivity projects will have done sufficient work to justify co-authorship.

Return to Table of Contents

3.4 Call for proposals

The AMIP Panel is now accepting diagnostic Subproject proposals. The deadline for proposal submission is 1 April 1997. Late proposals will be reviewed, but may be disadvantaged in the final structuring of the diagnostic subprojects. Prospective project leaders should be aware that this is a multi-year project; AMIP II model output may not be available until early 1998.

Once the proposals have been evaluated by the AMIP Panel, prospective subproject leaders will be advised on how to formally proceed with the establishment (or continuation) of a subproject. This will involve elaboration of the proposal in the form of an agreement to adhere to the AMIP II subproject protocol. Proposals will be limited to one page and final subproject agreements to three pages. Instructions for the preparation of a subproject proposal may be accessed via http://www-pcmdi.llnl.gov/amip/DIAGSUBS/proposals.html or requested from the AMIP Project office.

Return to Table of Contents

4. AMIP II Standard Model Output

4.1 The AMIP II standard experiment

The AMIP standard model output has been substantially revised for AMIP II (see Appendix A). The monthly mean and high frequency output are more comprehensive than before, with nearly twice as many monthly mean fields in the AMIP II listing. It is expected that there will be no cosmetically altered output (e.g., spatial smoothing). For consistency with the reanalysis projects of NCEP/NCAR (Kalnay et al., 1996) and ECMWF (Gibson et al., 1994), monthly mean upper air variables are to be interpolated to the 17 WMO standard pressure levels in AMIP II, compared to the 1-3 levels in AMIP I. Several monthly mean variables are not well defined for some models (e.g., cloud ice). Because of the large data volume, the only high frequency output expected of all groups is listed in Table 3 of Appendix A. Table

6 is more than three times the data volume of Table 3 and is only expected from those groups with sufficient resources. For reference, the volume for one AMIP II T42L17 simulation (if in IEEE 32 bit) is 8.2 Gb for the variables expected from all groups (Tables 1-5), and an additional 22.4 Gb for the high frequency output optional (Table 6).

Many AMIP participants have provided valuable suggestions for the construction of the AMIP II standard model output, but practical considerations have resulted in some compromises based on: 1) the need for more fields to allow for more extensive analysis and intercomparison; 2) data management limitations; 3) availability of verification data; 4) special interest fields for GCM development; and 5) whether a field is well defined for most models. See Appendix B for a discussion of the decision-making process on the model output listing and temporal sampling for averages.

Return to Table of Contents

4.2 Multiple realizations

For practical reasons, the multiple realization intercomparison outlined in Section 2.2 will be limited to the analysis of low frequency model data, including Tables 1 and 2 of the AMIP II standard model output (Appendix A). Table 1 output will only be archived at 850, 500, 200 and 50 hPa.

4.3 Data transmission standards

For years, climate scientists have struggled with the lack of community standards for data formatting and structuring. While there are many popular data formats, varied data organization can seriously inhibit efficient communication and collaboration.

During the past five years, PCMDI has collected model and observational data from many institutions worldwide. The data have come in all forms, and have caused substantial challenges, a problem familiar to many in the field. Recognizing that no single format is going to be acceptable to the entire community in the near future, PCMDI has developed multi-format software enabling easy access to data in several popular formats (Section 5.2).

With the approval of the WGNE AMIP Panel and the encouragement of many collaborators, PCMDI has taken a further step to improve data communication in AMIP II. The Library for AMIP Data Transmission Standards (LATS, see Section 5.2) has been developed to establish data standards for AMIP II. All AMIP II data transferred to and from PCMDI will be required to be LATS-generated, which automatically conforms to several community standards.

The motivation for LATS, at least within the community of AMIP participants, is to create an environment where scientists will be able to read, analyze and display data much more efficiently. Compliance with the requirement will ensure that PCMDI can efficiently process AMIP II data, provide modeling groups with a "quick-look" intercomparison (Section 5.5), and distribute the output to the subprojects. Together with additional software developed by PCMDI (Section 5.2), this represents a significant effort to support accessibility and analysis of climate model and observational data. By conforming to accepted standards, LATS-generated data is accessible to a variety of popular analysis tools in addition to those supported by AMIP. It is hoped that LATS will inspire the climate community to pursue acceptance of data standards beyond the context of AMIP.

Return to Table of Contents

5. PCMDI Support

5.1 Coordination

PCMDI will continue to support AMIP and to serve as the project's central coordinating office, with the WGNE AMIP Panel providing scientific guidance. PCMDI will also work to coordinate and support (to the fullest extent possible) AMIP scientific workshops and conferences. All queries and comments concerning AMIP should be sent to the AMIP Project Office at PCMDI or by email at: **amip@pcmdi.llnl.gov**.

5.2 Supporting software

PCMDI has put considerable effort into developing software in support of AMIP. While individually each of these products has been popular in the AMIP community and beyond, collectively they are anticipated to provide the user with greatly increased capabilities in AMIP II. The four basic AMIP-supported products are:

- cdunif/EzGet: multi-data format read
- LATS: AMIP standard data-write library
- VCS: advanced visualization
- DDI: data format/structure manipulator

Each of these products is available from PCMDI at no charge, and will be supported by the PCMDI staff for all AMIP related applications. Together, these software provide easy access to data, with an assortment of analysis and graphical tools. Software and documentation may be requested from PCMDI.

- *cdunif/EzGet* enables the user to easily retrieve and manipulate all official AMIP data (see LATS description below). In addition, cdunif/EzGet can be used to read NetCDF, DRS, GrADS, GRIB (via GrADS), and HDF (in preparation) data. Users may access data by geographical region, spatially interpolate the data as it is being read, and control data retrieval with additional features.
- *LATS* (Library of AMIP Data Transmission Standards) is a user-friendly software library designed to prepare data in a standardized structure. LATS-generated data are readable by many popular analysis and graphical software (e.g., VCS, GrADS, all netCDF compatible tools, cdunif/EzGet, etc.). Users can choose to format their data in NetCDF (conforming to the COARDS convention, Mock et al., 1996) or in GRIB (a WMO standard, WMO, 1988). AMIP II data transmitted to and from PCMDI will be LATS-generated.
- *VCS*(Visualization and Computational System) is designed for the selection, manipulation and display of data. The user can access data in a variety of formats (all of those that are readable through cdunif/EzGet). VCS has a long list of features, including "point and click" specification of the desired data, multiple map projections, graphics methods (e.g., isoline, isofill, x-y and scatter plotting), scripting capabilities, advanced animation, and complete control over the appearance of a graphic display and text.
- *DDI*(Data Dimension Interface) provides an interactive interface allowing data transfer between files, formats and local or remote visualization systems. DDI enables the user to browse data files, randomly select variables, manipulate data dimensions, and rearrange them in new files for input into visualization systems.

Return to Table of Contents

5.3 Experiment documentation

In addition to supporting software, PCMDI will collect and provide information for each AMIP II simulation including:

- model characteristics
- simulation specifics
- model output description

This information will be required of all AMIP II simulations and made available via an extensive internet-accessible database, or may be requested from PCMDI. Model characteristics documentation is available for all AMIP I simulations (Phillips, 1994)

Instructions for the preparation of model documentation may be obtained from the AMIP Project Office or via the AMIP homepage.

5.4 Validation data

AMIP II validation data will be generated from a variety of sources. These data will be available in a form identical to the AMIP II model output (e.g., LATS-generated), thus ensuring that they will be accessible via the same data interfaces (e.g., VCS and GrADS). A WWW-based atlas of observational products will be available to aid quick-look evaluation of the models. The principal source of observational data will be the atmospheric reanalyses from NCEP/NCAR and ECMWF. AMIP II output variables not directly analyzed in reanalyses (e.g., water vapor) will also be available from other sources (e.g., SSM/I, Randel et al., 1996).

Return to Table of Contents

5.5 Computational support

PCMDI will continue to offer limited computational support to modeling groups with exceptionally restricted resources. This assistance is exclusively for running official AMIP II simulations. Participants who believe they might qualify for computer time should send requests and estimates of their needs to the AMIP Project Office.

5.6 Quick-look analysis

PCMDI is developing software to systematically analyze standard AMIP simulations. This library will be continuously updated to include advanced analyses and will ultimately be offered to participating modeling groups as part of the PCMDI diagnostics library. In support of AMIP II, PCMDI will provide all participating modeling groups with a quick-look summary of their simulation(s), including: up-to-date intercomparison with other AMIP II simulations, validation with state-of-the-art observations and reanalyses, and the results of selected diagnostics.

5.7 AMIP abstract archive

To assist AMIP participants and to keep the broader community informed of AMIP related-research, PCMDI has created an informational database consisting of all AMIP research abstracts and references. The archive will be continuously updated on the AMIP homepage

Return to Table of Contents

Appendix A

AMIP II STANDARD OUTPUT

This listing has been revised
Refer to the AMIP homepage for a current version

Table 1

Upper-air low frequency (monthly mean) output

* & 17 WMO standard pressure levels compatible with reanalysis products: 1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50,30, 20, 10 hPa (Variable units are MKS)

Variable	Units	Notes
Northward wind speed	m/s	2
Eastward wind speed	m/s	2
Vertical motion	Pa/s	2
Air temperature	K	2
Geopotential height	m	2
Specific humidity	kg/kg	2
Relative humidity	%	2
Pressure surface below ground	%	1, a
Temperature tendency due to total diabatic heating	K/s	1, b
Temperature tendency due to SW radiation	K/s	1
Temperature tendency due to LW radiation	K/s	1
Temperature tendency due to moist convective processes	K/s	1, c
Temperature tendency due to dry convective processes	K/s	1, d
Temperature tendency due to large scale precipitation	K/s	1, e

Total moisture tendency due to diabatic processes	(kg/kg)/s	1, f
Cloud fraction	%	5
Cloud amount (satellite view)	%	5, g
Cloud amount (surface view)	%	5, g
Cloud liquid water	kg/kg	1, h
Cloud ice	kg/kg	1, h
Extinction coefficient (cloud optical thickness/layer depth)	1/Pa	1, i
Cloud emittance (cloud emissivity/layer depth)	1/Pa	1, j
Eddy kinetic energy	m^2/s^2	2, k
Mean product of eastward and northward winds	m^2/s^2	3
Mean product of northward wind and specific humidity	m/s (kg/kg)	3
Mean product of northward wind and temperature	mK/s	3
Mean product of vertical motion and specific humidity	(Pa/s)(kg/kg)	3

* Comparison of AMIP II model output with reanalyses will be an important part of the project. For consistency with reanalysis products, the AMIP II monthly mean upper air data must be on the 17 WMO standard pressure levels that are included in both the NCEP/NCAR and ECMWF reanalyses. Modeling groups are requested to provide data on these levels to insure that they are interpolated in a manner consistent with their model. Data from models with fewer than 17 levels should also be provided on the 17 standard levels to minimize the possibility of the data being misrepresented. Exceptions will be made for models with a top level that is at a lower pressure than the highest reanalysis level (10 hPa), as the transformation to pressure coordinates should not involve extrapolation. Models with a top level corresponding to a pressure that is more than 10 hPa should only provide data on the pressure levels that are greater than 10 hPa.

& If fields below ground are extrapolated, it is suggested that the method of Trenberth et al. (1993) be used.

Return to Table of Contents

Table 2

Single-level low frequency (monthly mean) output

Variable	Units	Notes
Ground temperature	K	2, l
Surface (2m) air temperature	K	2, m
Mean sea-level pressure	Pa	2, n
Surface pressure	Pa	2
Total precipitation rate	kg/(m^2s)	1
Snowfall rate (water equivalent)	kg/(m^2s)	1
Convective precipitation rate	kg/(m^2s)	1
Precipitable water	kg/m^2	1
Total soil frozen water content	kg/m^2	1
Surface soil water content (upper 0.1m)	kg/m^2	1, o
Total soil water content	kg/m^2	1
Surface runoff	kg/(m^2s)	1, o
Total runoff (including drainage)	kg/(m^2s)	1
Snow depth (water equivalent)	kg/m^2	1
Snow cover	%	5
Sea-ice concentration	%	5, p
Surface (10m) eastward wind	m/s	2, m
Surface (10m) northward wind	m/s	2, o
Surface specific humidity (2m)	kg/kg	2, m
Surface sensible heat flux (positive upward	W/m^2	1
Surface latent heat flux (positive upward)	W/m^2	1
Surface evaporation plus sublimation rate	kg/(m^2s)	1

Eastward surface wind stress (positive for eastward wind)	N/m^2	1
Northward surface wind stress (positive for northward wind)	N/m^2	1
Surface incident shortwave radiation	W/m^2	1
Surface reflected shortwave radiation	W/m^2	1
Surface downwelling longwave radiation	W/m^2	1
Surface upwelling longwave radiation	W/m^2	1
TOA incident shortwave radiation	W/m^2	1, q
TOA reflected shortwave radiation	W/m^2	1, q
Outgoing longwave radiation	W/m^2	1, q
Net radiation at model top	W/m^2	1, r
Surface incident clear-sky shortwave radiation (method II)	W/m^2	1, s
Surface reflected clear-sky shortwave radiation (method II)	W/m^2	1, s
Surface downwelling clear-sky longwave radiation (method II)	W/m^2	1, s
TOA clear-sky longwave radiation (method II)	W/m^2	1, s
TOA reflected clear-sky shortwave radiation (method I)	W/m^2	1, s
Daily maximum surface (2m) temperature	K	4, t
Daily minimum surface (2m temperature	K	4, t
Total cloud amount	%	5
Vertically integrated cloud water (liquid and solid phase)	kg/m^2	1
Vertically integrated cloud ice	kg/m^2	1

Return to Table of Contents

Table 3

High-frequency (6-hourly) output
(4 samples daily: 0, 6, 12, 18Z)

Variable	Units	Notes
Northward wind speed (850 and 200 hPa)	m/s	4
Eastward wind speed (850 and 200 hPa)	m/s	4
Outgoing longwave radiation	W/m^2	1
Total precipitation rate	$kg/(m^2s)$	1
Mean sea-level pressure	Pa	4

Return to Table of Contents

Table 4

Time Series of daily global averages (area-weighted)

Variable	Units	Notes
Net radiation at model top (positive downward	W/m^2	1, r
Net downward energy flux at surface	W/m^2	1
Total kinetic energy	J/m^2	1
Total relative angular momentum	kg/(ms)	1
Global average temperature	K	1
Global average surface pressure	Pa	1
Evaporation and sublimation	$kg/(m^2s)$	1
Total snow-covered area	%	5
Snow depth (water equivalent)	m	1
Average SST over open ocean	K	1

Return to Table of Contents

Table 5

Fixed geographical fields

Variable	Units	Notes
Model Topography	m	6, u
Land fraction (expressed as percent)	%	6, p
Glacier fraction (expressed as percent)	%	6, p
Surface soil moisture field capacity	kg/m^2	6
Surface soil moisture field capacity (upper 0.1 m)	kg/m^2	6
Ozone climatology (zonal average -pressure)	ppmv	7

Return to Table of Contents

Table 6. (optional)

Supplementary Output
High frequency (6-hourly)

Variable	Units	Notes
Air temperature (850 hPa)	K	4
Geopotential height (500 hPa)	m	4
Specific humidity (850, 500 hPa)	kg/kg	4
Surface (10m) eastward wind	m/s	4, m
Surface (10m) northward wind	m/s	4, m
Surface (2m) temperature	K	4, m
Surface specific humidity (2m)	kg/kg	4, m
Vertical motion (w) (500 hPa)	Pa/s	4
Northward wind speed (50 hPa)	m/s	4
Eastward wind speed (50 hPa)	m/s	4

Surface pressure	Pa	4
Total cloud cover	%	5
Eastward wind stress on surface (positive for eastward wind)	N/m^2	1
Northward wind stress on surface (positive for northward wind)	N/m^2	1
Precipitable water	kg/m^2	1
Surface sensible heat flux (positive upward)	W/m^2	1
Surface latent heat flux (positive upward	W/m^2	1
Total runoff (including drainage)	$kg/(m^2s)$	1
Total soil water content	kg/m^2	1
Snow depth (water equivalent)	kg/m^2	1
Surface incident shortwave radiation	W/m^2	1
Surface reflected shortwave radiation	W/m^2	1
Surface downwelling longwave radiation	W/m^2	1
Surface upwelling longwave radiation	W/m^2	1
TOA incident shortwave radiation	W/m^2	1
TOA reflected shortwave radiation	W/m^2	1
Potential vorticity 350, 380, 405K	1/(Pas)	4, v
Planetary boundary layer height	m	2, w

Return to Table of Contents

Notes for Tables 1-6

Recommended sampling

1 Accumulated averages computed to most accurately represent true simulation average.

2 Averages based on instantaneous samples at 0, 6, 12 and 18Z.

3	Mean products are the monthly means **{xy} = {x} * {y} + {x'y'}** where**{xy}** is the monthly mean of the product of 6-hour (0,6,12,18Z) instantaneous samples. If calculations are done in pressure coordinates they will be more consistent with reanalysis products.
4	Instantaneous values.
5	Accumulated time average of the fraction of the grid cell covered, expressed as percent.
6	Time independent, but two dimensional in space (longitude x latitude).
7	Monthly mean latitude-height (pressure) climatology.

Return to Table of Contents

Recommended calculations

a Fraction of time that a pressure surface is below ground: recommended method of calculation is outlined in Boer (1985).

b Total diabatic temperature tendency: temperature tendency due to radiation, shallow and deep convection, large scale precipitation, dry convective adjustment and vertical diffusion.

c Temperature tendency due to moist convection: for deep and shallow convection and including latent heat release, sub-gridscale vertical heat transport, and the tendencies due to the evaporation and phase change of falling precipitation.

d Temperature tendency due to dry convection: This should include the tendencies from dry convective adjustment only. Some models may not treat this explicitly.

e Temperature tendency due to large scale/stratiform precipitation: This should include the tendency associated with evaporation and phase change of falling precipitation.

f Moisture tendency: Include the total change in moisture due to diabatic processes. It should include shallow and deep convection, large scale precipitation, vertical diffusion, and the tendency due the evaporation of falling precipitation.

g Cloud amount (satellite/surface views): the fraction of sky covered by clouds as a function of altitude, after eliminating clouds obscured by intervening cloud layers.

h Cloud liquid water and ice: grid-cell average mixing ratios.

i Extinction coefficient: cloud optical thickness divided by pressure thickness of the layer.

j Cloud emittance: cloud emissivity divided by the pressure thickness of the layer.

k Eddy kinetic energy: is $\mathbf{1/2\ \{u'^2 + v'^2\}}$, where **{ }** represents the monthly average and u' and v' are temporal deviations of the winds from the monthly average.

l Ground temperature: this is the prescribed SST over ocean. Over land, the surface effective radiating temperature (as "seen" by the atmosphere) should be reported.

m Surface-air variables: calculations should be consistent with Hess et al. (1995).

n Mean sea-level pressure: use corrected ECMWF algorithm (Trenberth et al., 1993).

- o Land surface variables: for surface water content, integrate from surface down to 0.1 m of the soil. Surface runoff should include that portion of rainfall and snowmelt that does not infiltrate the soil.
- p Sea-ice concentration, land and glacier masks: those models that do not include fraction grid-cell coverage should report values as 0 (e.g., 0% sea-ice) or 100 (e.g., 100% sea-ice).
- q Top-of-atmosphere radiation fields: true "top-of-the-atmosphere" fluxes appropriate for comparison with satellite measurements (cf. model top calculations).
- r Model top calculations: should be based on the radiation calculations at the top of the dynamically active model (cf. top-of-atmosphere calculations).
- s Cloud-radiative forcing calculations: calculations consistent with Potter et al. (1992).
- t Maximum/minimum temperatures: monthly means of daily extremes, based on all timesteps.
- u Model topography: this should be the same as that which is used in the model. In AMIP I, some groups provided cosmetically altered topography.
- v Potential vorticity: recommended method of calculation is outlined in Hoskins et al. (1985).
- w Planetary boundary layer height: some suggestions are provided in Holtslag and Boville (1993), Beljaars et al. (1993), and Vogelezang and Holtslag (1996).

Return to Table of Contents

Appendix B
AMIP II DESIGN RATIONALE

An important objective of AMIP is to develop standard experimental protocols that evolve with the improvement of atmospheric models and technological advancements. The design of any community-wide effort is inherently difficult because of the lack of consensus. Conservative compromises have been made to preserve the goal of the project, i.e., to serve as a standard test of AGCMs. The reasoning behind some of the difficult decisions in the design of AMIP II is summarized below.

Experimental design

The AMIP II SSTs and sea-ice: In the original AMIP II proposal (Gates, 1995) the boundary conditions used in the NCEP/NCAR and ECMWF reanalyses were advocated for use in AMIP II. However, examination of the SSTs and sea-ice used in both reanalyses revealed a significant temporal discontinuity in the SSTs near the sea-ice margins as source data changed. This prompted construction of a corrected data set for use in AMIP II (Fiorino, 1996).

Another concern was the temporal sampling of the SSTs and sea-ice. There are two reasons why it was decided that monthly mean SSTs and sea-ice should be used in AMIP II, rather than the weekly means used for some of the years in both the ECMWF and NCEP/NCAR reanalysis projects. First, satellite-based estimates of weekly means are not available prior to November 1981 and the sea ice became a daily analysis after 1991. Using the monthly mean data mitigates the potential conflicts between the quasi-independently analyzed SSTs and sea-ice. Second, the implications of forcing an AGCM with weekly SSTs and sea-ice are not clear. While the seasonal cycle is more realistic, some variability present in the weekly averages represents the effect of the observed weather, which may be inconsistent with the weather simulated by the AGCM. Experts are planning to develop consistent, higher frequency (weekly to daily) data sets. As these become available, some groups will likely be interested in evaluating the contribution of the higher frequency SST and sea-ice forcing. If there is sufficient interest, such experimentation could be supported by the AMIP infrastructure.

Recommended use of a realistic time model: It is clear from the point of view of climate statistics and the current state of AGCMs that the exact number of days in a given simulated month has little effect on model statistics. The recommended use of a realistic time model stems from a practical perspective. Differences in the AGCM time models in AMIP I caused a multitude of problems for both data managers and users. Improved software ameliorates this problem, but if this inconsistency persisted it would continue to greatly complicate the use of the data, particularly the high-frequency output.

The ozone recommendation: After discussing this issue with a number of modeling groups, it was evident that many would welcome a recommendation. Experts consulted by the AMIP Panel all agreed that it would be premature to constrain models with anything other than a monthly mean zonal average/height ozone climatology. Choosing a specific data set to recommend was difficult. An intercomparison of state-of-the art data sets (Boyle, 1996) revealed that all the products evaluated were equally credible, with varying strengths and weakness. These views were confirmed by the experts consulting with the AMIP panel. The final decision was based on the fact that the Wang et al. (1995) data set is the only one that has been published in the peer-reviewed literature, is already being used by many modeling groups, and represents a climatological average over most of the AMIP II period.

Surface energy and hydrological balance: This recommendation is less stringent than some would like. There is good reason to consider more serious restrictions, as many AMIP I simulations showed significant discrepancies in their surface schemes. However, this represents an area of continuing model development, determined by the interests and needs of each modeling group. It is not the aim of AMIP to dictate priorities of model development. Moreover, as a result of the problems revealed in AMIP I, many modeling groups have already improved their surface schemes.

Land/sea mask and topography: PCMDI has offered to provide land-sea masks on any grid requested because it was discovered in AMIP I that some models with the same resolution (e.g., 4x5 or T42) had substantial inconsistencies in critical regions (e.g., the Indian subcontinent).

Diagnostic subproject structure

The majority of AMIP I participants (both modelers and diagnosticians) were in favor of preserving the framework of focused projects established in AMIP I. Although not without complications, the organization of the AMIP I Diagnostic Subprojects was generally regarded as successful. It has operated at a "grass-roots" level, with diagnosticians working in small teams to pursue their special interests. AMIP II will be similar, but the AMIP Panel will process the subprojects according to their areas of study, and work to ensure that there is improved coordination.

Standard Model Output

Variable listing: The fields included in the AMIP II Standard Model Output were viewed to be the most important for the modeling and diagnostic communities. Many more variables were considered, but practical considerations (e.g., data volume and calculation difficulties) forced reductions to the list. In the coming years the advice of experts in other disciplines (e.g., hydrology) will be sought for diagnostics needed for impact studies. For the moment, however, it is believed that the current state of AGCMs and their application in AMIP II (e.g., relatively low resolution) does not justify further extension of the list of fields.

Temporal sampling: It has been recommended that the temporal sampling used to calculate the monthly averages be consistent with that of the reanalysis projects (especially Tables 3 and 6, the high frequency output). Monthly averages of state variables are based on four instantaneous samples per day, while physical tendencies are accumulated. The motivation for this recommendation is to address the concern of a sampling bias when model output is compared with reanalysis. It is only *recommended* for several reasons. First, preliminary studies suggest that the potential biases resulting from calculating monthly averages from four instantaneous samples per day (with respect to accumulation) are small compared to the model-to-model and model-to-reanalysis differences found in the AMIP I simulations. In cooperation with several modeling groups, PCMDI is currently quantifying this bias (averages based on samples versus accumulation) for the AMIP II Standard Output. Until this issue has been thoroughly investigated, only a recommendation can be justified because for some groups this sampling may cause an extreme data handling burden. A second reason for only recommending the sampling is that assimilation makes use of observations taken over a window of time (~$\pm$ 3 hr). Although the analysis system does account for the differing times of the observations, the result is not truly instantaneous. Moreover, the bias due is difficult to quantify. Despite these limitations, consistency between the reanalysis and model output is desirable. Modeling groups are encouraged to consider the advantages, keeping in mind that in the future this could become increasingly important (as systematic simulation errors are reduced, the sampling biases will be of more concern). It is expected that groups who do not follow these recommendations will provide output that represents the true model average (i.e., accumulate all fields). Coordinated efforts to study these and other issues (e.g., vertical interpolation) in AMIP II will help to determine what should be done in the future.

Return to Table of Contents

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Return to Table of Contents

Return to AMIP home page
Return to PCMDI home page

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