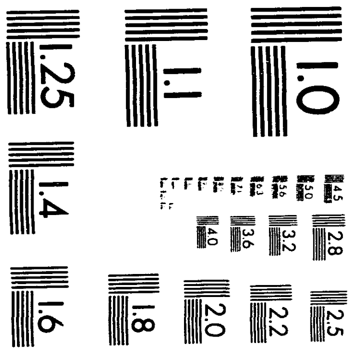
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THE VALIDATION OF OCEAN SURFACE HEAT FLUXES IN AMIP

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1. INTRODUCTION

Recent intercomparisons of Atmospheric General Circulation Models (AGCMs) constrained with sea-surface temperatures (Gates et al., 1990, 1992a) have shown that while there are substantial differences among various models (with each other and available observations), overall the differences between them have been decreasing. Some compilations of AGCM simulations (Boer et al., 1991, 1992) have demonstrated that a few systematic biases are common to all AGCMs. Still other intercomparisons have been informative regarding specific features of AGCM simulations (cf. Cess, 1990 and Randall, 1992) and have provided insight on how to improve AGCMs.

The need for a systematic and comprehensive intercomparison of AGCMs was recognized for some time by the World Climate Research Programme (WCRP). Such an experiment in now underway and has become known as the Atmospheric Model Intercomparison Project (AMIP).

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The primary goal of AMIP is to enable a systematic intercomparison and validation of state-of-the-art AGCMs by supporting in-depth diagnosis of and interpretation of the model results. Official AMIP simulations are 10 years long, using monthly mean Sea-Surface Temperatures (SSTs) and sea ice conditions which are representative of the 1979-1988 decade. Some model properties are also dictated by the design of AMIP such as the solar constant, the atmospheric CO_2 concentration, and the approximate horizontal resolution. For further details regarding the implementation goals of AMIP see Gates (1992b).

In this paper, some of the preliminary results of AMIP Subproject # 5 will be summarized. The focus will be on the intercomparison and validation of ocean surface heat fluxes of the AMIP simulations available thus far. We will take a cursory look at the simulated zonally averaged ocean surface net shortwave radiation, SW_{sfc}, and latent heat flux, LH, the two most dominant components of the surface energy balance. A more thorough discussion of all surface heat fluxes will be included in a paper planned for journal publication. All figures shown here will represent 120 month averages, which may be regarded as each model's simulated climatological annual mean.

The output of 12 (see Table 1) of the ~ 30 models which are being used in AMIP have been quality controlled and will be examined here. Because of the concise nature of this summary, little distinction will be made between the various models. For a summary of model characteristics and a complete description of AMIP, see Gates (1992b).

Table 1.

BMRC	GFDL
CCC	GLA
CSIRO	MPI
CSU	MRI
DNM	NMC
ECMWF	NRL

2. VALIDATION PROCEDURE

A variety of observationally-based ocean surface heat flux atlases have been created (Hsiung, 1986 and Oberhuber, 1988) over the years by utilizing parameterization formulae which are functions of commonly observed fields such at surface air temperature and surface wind speed. Unfortunately however, the uncertainties associated with these atlases are known to be large.

Other observationally-based methods of estimating surface heat fluxes include the use of satellite data or model analyses. Potential for satellites based estimates of SW_{sfc} are probably the most encouraging (cf. Darnell, 1992). However, systematic uncertainties associated with such methods have not yet been thoroughly studied, and thus we have chosen for now to focus our attention on the atlases which have been derived from bulk formulae.

A statistical perturbation analysis has been used to estimate the climatological uncertainties associated with each of the ocean surface heat fluxes in the Oberhuber (1988) atlas. The method attempts to account for random and systematic uncertainties due to observational errors, sampling deficiencies, and uncertainties associated with the parameterizations themselves. Essentially, the various uncertainties are determined by perturbing the parameterizations used by Oberhuber with the estimated uncertainties of observables and parameterization coefficients. These uncertainties represent a compilation of estimates made by numerous investigators (see Gleckler, 1993). Following simple sample theory, random (independent) uncertainties are reduced with increasing observations, whereas systematic uncertainties are not. Similarly, zonally averaged random uncertainties are reduced by the number of grid points along a zone.

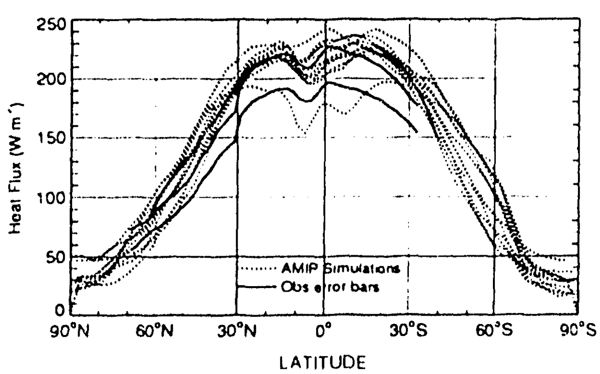
It is important to emphasize that the uncertainties which are shown as error bars in the following figures are approximate estimates. However, the analysis has demonstrated that the resulting surface heat uncertainty estimates are fairly robust, and has shed light on the relative importance various errors (Gleckler, 1993).

3. VALIDATION AND INTERCOMPARISON

The simulated climatological annual mean SW_{sfc} for the models listed in Table 1 are shown in Fig. 1. Error bars resulting from the analysis outlined in Section 2 are also shown in Fig. 1. The error bars do not extend southward of 35°S because there is insufficient data in the observationally-based atlas. In the northern oceans the uncertainty in the climatological annual mean net $\langle SW_{sfc} \rangle$ is estimated to be ~ ± 10 W m^{-2}, and in the tropics it is ~ ± 17 W m^{-2}. Note regional random uncertainties can exceed their zonal averages by as much as 300%, because the zonal averages are greatly reduced by the averaging process.

Figure 1

Zonal Average Global Ocean Net SW_{sfc}
AMIP Simulations (120 month avg)



The differences between the 10-year average annual means shown in Fig. 1 are much larger than the year to year differences in the annual mean for a particular model. The shapes of the model curves in Fig. 1 are consistent, but in the tropics there is an obvious outlier in the tropical and sub-tropical latitudes. In general, the simulated $<SW_{sfc}>$ in the Northern Hemisphere mid-latitudes and sub-tropics are systematically greater than the estimated upper bound resulting from the observationally-based uncertainty analysis. In the tropics the models agree more closely with observations. It is conceivable that confidence in the quantification of these uncertainties will improve in the next few years as satellite based estimates are more thoroughly studies.

Figure 2 shows the climatological annual mean LH flux for the AMIP models examined thus far, along with the corresponding observationally-based error bars.

The LH of the various AMIP simulations are more consistent with the error bars than is the SW_{sfc}, but this in only because the LH uncertainties are so large. At all latitudes, the uncertainties in the LH are at least $\pm$ 25 W m^{-2}. Note however, that even with these very large error bars, there are regions (such as the tropics) where the simulated LH is consistently outside the uncertainty boundaries. Unfortunately, unlike prospects with the SW_{sfc}, there is little hope that the uncertainties in the global distribution of the LH will be substantially reduced in the near future.

Although the uncertainties in the net surface LW and the SH fluxes will not be discussed here, they have been used to estimate the uncertainties in the global ocean net surface heat flux, N_{sfc}. These are shown in Fig. 3 along with the N_{sfc} for the AMIP simulations. As anticipated from Fig. 1 and Fig 2, the uncertainties in N_{sfc} are very large.

At most latitudes, the simulated N_{sfc} is within the observationally-based error bars. One exception is the high northern oceans, which is likely to be due to the effects of sea ice. Of more interest here is that some of the models appear deficient in their tropical net surface heating. Interestingly, for many of the models, the N_{sfc} is greater at 50°S than it is in the tropics. Although this seems counterintuitive, we cannot refute the possibility of this oddity in nature because the uncertainties in the Southern Hemisphere are not well known.

Figure 2

Zonal Average Global Ocean LH Flux
AMIP Simulations (120 month avg)

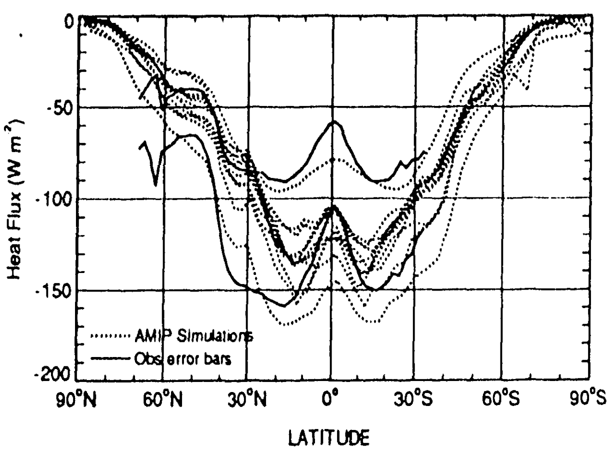
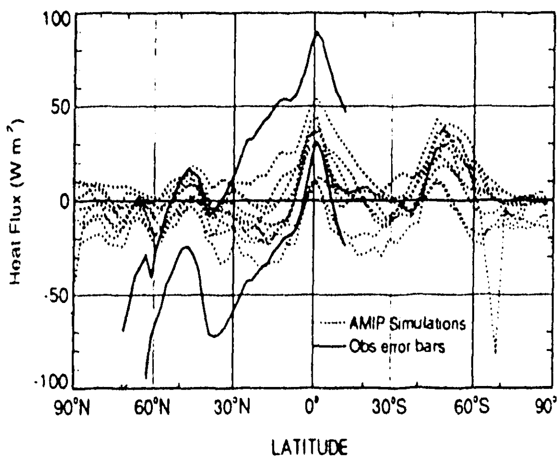


Figure 3

Zonal Average Global Ocean N_{sfc}
AMIP Simulations (120 month avg)



4. CONCLUSIONS

The results of this simplified examination of the AMIP simulations clarifies the deficiencies in our observational understanding of global surface heat fluxes and our ability to model them. However, although the uncertainties are very large and the differences among model are quite substantial, useful insight has been gained. A more in-depth examination (Gleckler, 1993) has clearly demonstrated the spatial distribution of the various uncertainties associated with the observational estimates, as well as their relative importance. A closer look at the various models has helped to understand the effects of other model properties (most notably clouds) on the surface energy budget. The results summarized in Fig. 3 have serious implications to the coupling of ocean and atmosphere GCMs. See paper P1.19 (entitled 'Interpreting the implied meridional oceanic heat transport in AMIP') of these proceedings for details.

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