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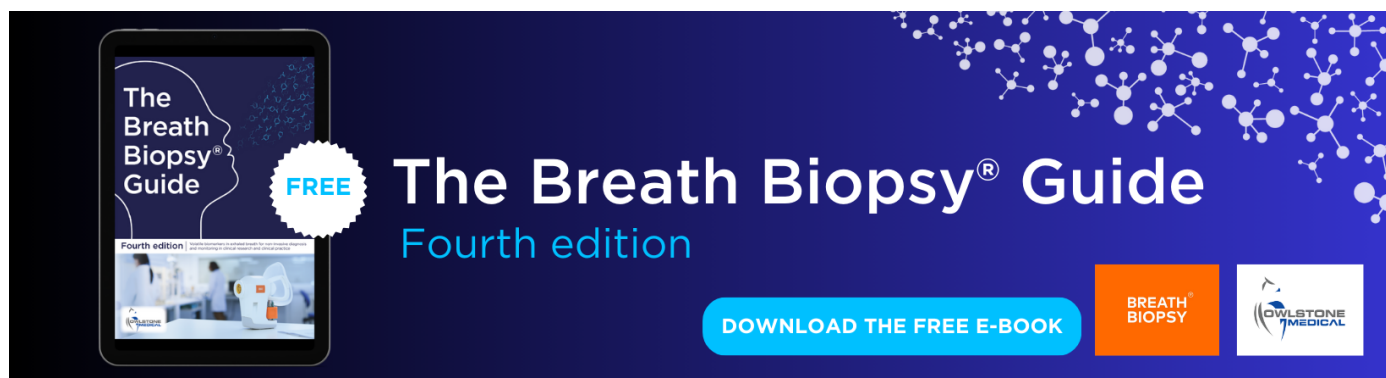
CMIP5 update of 'Inter-model variability and biases of the global water cycle in CMIP3 coupled climate models'

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ADDENDUM

CMIP5 update of ‘Inter-model variability and biases of the global water cycle in CMIP3 coupled climate models’

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Abstract

In this addendum we show results of the climate model consistency test performed with the control runs of all CMIP5 models. We calculate the closure of the atmospheric moisture budget. As already explained in the original article and confirmed again with CMIP5 models, a few outlier models can exhibit significant biases, and changes over time of these biases, that distort the multi-model means of water cycle components. These biases in the control runs of climate models can also be regarded as artificial, non-radiative forcings and should hence be taken in consideration in applications. We stress the need for ‘consistency tests’ in addition to ‘reality checks’ (comparisons with observations) of climate models for improving future climate change predictions.

Keywords: coupled climate models, water cycle, metrics

1. Introduction

Due to numerous requests from colleagues we recalculated the inter-model variability and biases of the global atmospheric water cycle previously performed for CMIP3 (Coupled Climate Model Intercomparison Phase 3) models for all newly archived CMIP5 models (see list in figure 1). In contrast to the original letter, we tested the several hundred yearlong *control runs* instead of the 20th and 21st century prediction scenarios. The control runs serve as baselines for many climate studies and are thus of particular interest. The test criterion is the physical consistency of the models, specifically the closure

of the atmospheric water budgets as formulated in (1), which is key to accurately predicting climate change and analyzing climate feedback processes. With this consistency test we could identify physical shortcomings of individual models and in specific time periods of individual runs and were able to objectively rank the quality of models with respect to the water cycle. Results are described below and shown in figures 1 and 2.

2. CMIP5 coupled climate models

Coupled climate models such as CMIP5 models are expected to balance the atmospheric water cycle. This means that the inter-annual variability of evaporation E minus precipitation P overlaps with the inter-annual variability of the annual change in global storage of moisture in the atmosphere W .



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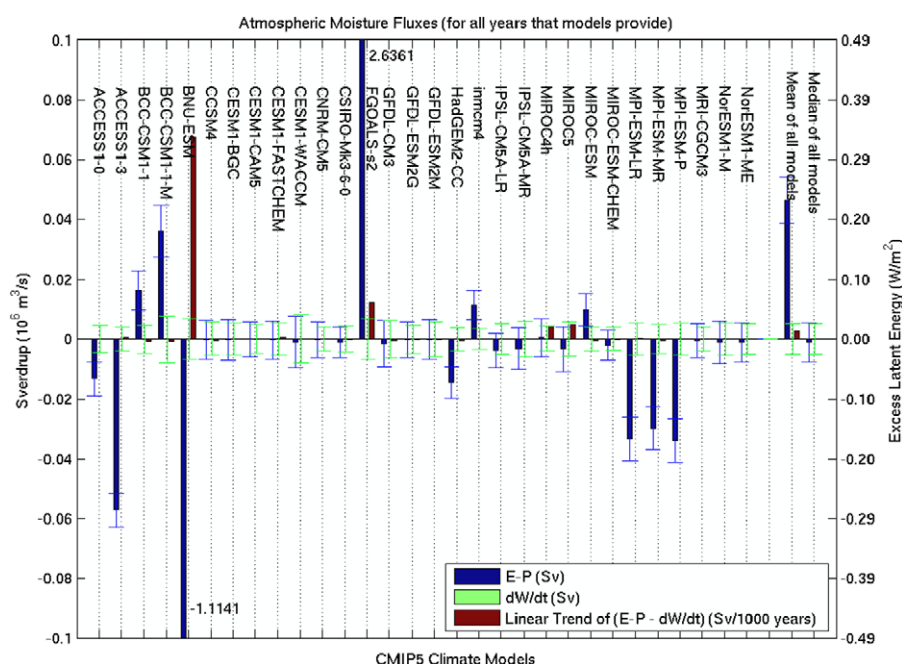


Figure 1. Water cycle consistency test of CMIP5 coupled climate models. Shown are global atmospheric moisture fluxes of evaporation minus precipitation ($E - P$) in blue and atmospheric moisture content change (dW/dt) in green according to equation (1). Long-term annual means are in columns and standard deviations in error bars. The mass flux in Sverdrup ($10^6 \text{ m}^3 \text{ s}^{-1}$) is on the left- and the excess latent energy in W m^{-2} on the right-hand side of the axis. The numbers on the two columns that are cut off represent the corresponding imbalances in Sverdrup of these models. The red bars show the drifts over time of the imbalances calculated as linear trends in Sverdrup per millennium (see also figure 2).

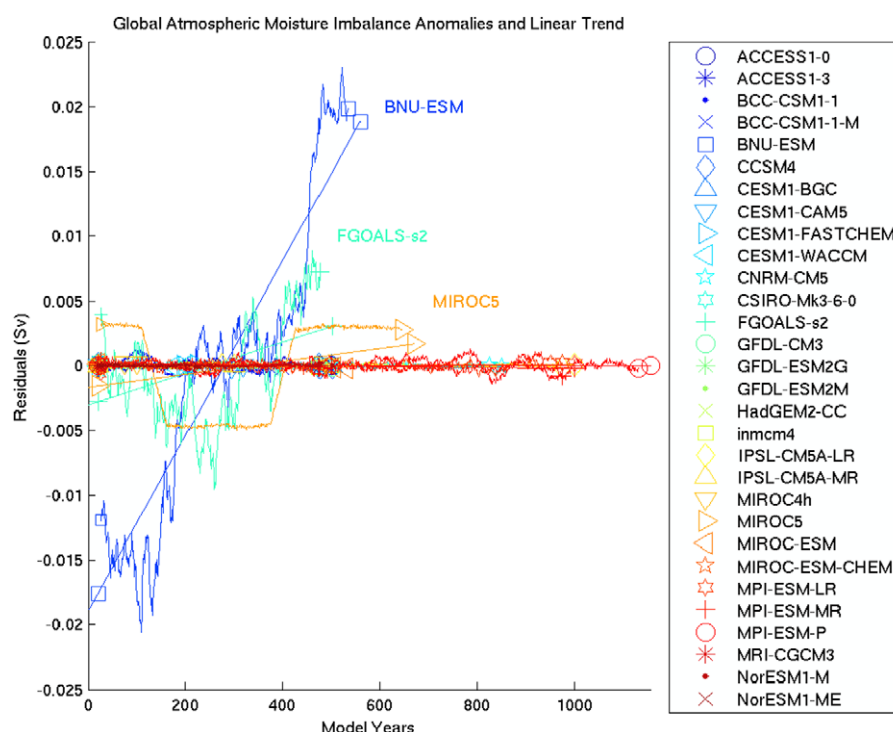


Figure 2. Residuals of the global atmospheric water cycle in CMIP5 coupled climate models. Shown are 50-year running means of the time series of global annual residuals calculated according to equation (1) for all 30 CMIP5 models. The average imbalances (from figure 1) of the atmospheric water cycle are removed. The linear trends of model runs that exhibit drifts are also shown. All data are given in Sverdrup, which corresponds to a mass flux of $10^6 \text{ m}^3 \text{ s}^{-1}$.

Equations (1) and (3) in Liepert and Previdi (2012) describe this balance: the global monthly integrals on the right side are summed up over the year and standard deviations and means are calculated (1). For the inter-annual standard deviations and means of the annual change in atmospheric moisture W (see the second bracket on the right-hand side of (1)), the difference between the global moisture content of one month a and the mean of the month in the previous year is calculated.

$$\text{Res}(y) \equiv \sum_{m=1}^{12} \langle E(y, m) - P(y, m) \rangle - \langle W(y, m = a) - W(y - 1, m = a) \rangle \quad \text{with } a \in [1, 12]. \quad (1)$$

Figure 1 summarizes the results in histogram format. The consistency test in figure 1 was performed with 100-year time periods and also the full control run time periods that cover between 500 and 1100 years. No regridding or other data adjustments were performed for the integration. For each model the long-term mean and inter-annual standard deviations of the moisture content changes are shown in green and the differences of evaporation and precipitation in blue. As expected and already concluded for CMIP3 models, the multi-model median of the water cycle is in balance whereas the multi-model mean indicates an erroneous and hence artificial source of moisture in the atmosphere of about 0.04 Sverdrup ($10^6 \text{ m}^3 \text{ s}^{-1}$) each year in the multi-model mean. This artificial moisture source corresponds to an artificial non-radiative forcing of about 0.2 W m^{-2} in the multi-model mean. Again as already shown in the CMIP3 analysis, a few outlier models are responsible for the distortion (see figure 1).

However, in contrast to 20th and 21st century transient runs of CMIP3 models, the control runs of CMIP5 coupled climate models generally do not drift over time as illustrated in the linear trend analysis (red bars) in figures 1 and in 2. Only in a few models are the imbalances in the control experiments changing over time. In BNU-ESM (Beijing Normal University-ESM) and FGOALS-s2 (Flexible Global Ocean–Atmosphere–Land System model, Spectral Version 2) the imbalance time series drift from an artificial ‘leak to a flooding’ (see figure 2). We were also able to identify inconsistencies in the MIROC5 (Model for Interdisciplinary Research on Climate) control run from year 140 to 400 (figure 2). The MIROC modeling team confirmed these inconsistencies and recommends removing these years from any analysis. Worth noting in figure 1 are the small artificial ‘leaks’ in all three Max-Planck Institute (MPI) earth system

models (MPI-ESM-P, MR, LR), which correspond to small but nontrivial, non-radiative forcings of about -0.15 W m^{-2} . The time series of the imbalances in MPI models show increasing oscillations over time (figure 2). A similarly small but persistent imbalance in the energy budget of MPI models have been observed by the modeling group (personal communication) and is worked on.

3. Conclusions

Overall, CMIP5 model performances are physically consistent in 18 out of 30 control runs in terms of their water cycle closures. A few models have significant biases that need to be addressed. And as emphasized before in Liepert and Previdi (2012), we stress the importance of using multi-model medians in contrast to the biased multi-model means, whenever the water cycle in climate models is concerned. This choice will prevent biased results due to inclusion of a few outlier models. Finally, we suggest that climate analysts test physical consistencies of the models before usage and assess possible implications of physical inconsistencies for their applications.

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References

- Liepert B G and Previdi M 2012 Inter-model variability and biases of the global water cycle in CMIP3 coupled climate models *Environ. Res. Lett.* **7** 014006