Climate Variability Due to Selection of Computational Platform

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Abstract

Climate models generally require that results between runs are bit-for-bit reproducible. This becomes impossible when switching the computational platform or compiler that the model is run on. An ensemble of the Geophysical Fluid Dynamics Laboratory (GFDL) Atmosphere Model 4.0 (AM4, Zhao et al. 2018a,b)) is created by perturbing the temperature at a random point on the order of 10-13 (in the rounding error of the system). Previous results show that three different compilers on the same computing platform results in a spread of the global mean temperature of 0.14 K (Robinson et al. 2018). The current ensembles are run on three different computing platforms with different processors: the main production computer of GFDL with Intel broadwell/haswell, one with Intel knights landing, and the other with Intel skylake. The ensemble means and standard deviations for global surface temperature are compared in order to see if the spread of rounding error in the model is platform dependent. The means are also compared to see if they lie within the spread of each modeling platform.

Atmosphere ensemble global mean and standard deviations do not depend on computing platform.

Ensemble spreads over a local region may be platform/compiler dependent.

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Introduction

Changes to climate model code must often comply with the requirement for answers to bitwise reproduce the answers generated by the model prior to modifying the code. The requirement for bitwise reproducibility may not be attainable if the model is built on a different computational platform, with a different compiler, and/or with different compiler optimizations. Therefore, we introduce an ensemble-based method to assess climate model reproducibility that allows for small variations in answers that may occur from differences in hardware or software, but that may not affect the resulting climate in a statistically meaningful way.

An ensemble of the Geophysical Fluid Dynamics Laboratory (GFDL) Atmosphere Model 4.0 (AM4, Zhao et al. 2018a,b)) is created by perturbing the temperature at a random point on the order of 10^{-13} (in the rounding error of the system). Previous results show that three different compilers on the same computing platform results in a spread of the global mean temperature of 0.14 K (Robinson et al. 2018). The current ensembles are run on three different computing platforms with different processors: the main production computer of GFDL with Intel Broadwell/Haswell, one Intel with Knights Landing, and the other with Intel Skylake. The ensemble means and standard deviations for global surface temperature are compared in order to see if the spread of rounding error in the model is platform dependent. The means are also compared to see if they lie within the spread of each modeling platform.

TABLE 1:
LIST OF ENSEMBLES AND THEIR PLATFORMS

Ensemble	Compiler	Processor	Number
Gaea	intel 16	B/H	300
AVX	intel 16	B/H	100
intel 18	intel 18	B/H	100
Cray	Cray	B/H	95
Theta	intel 16	KNL	118
Hera	intel 19	Skylake	47

TABLE 2:
2M TEMPERATURE ENSEMBLE
MEAN AND STANDARD DEVIATION

Ensemble	Mean (K)	Standard Deviation (K)
Gaea	287.2679	0.13027
AVX	287.2602	0.12333
intel 18	287.2661	0.13002
cce	287.2692	0.13155
Theta	287.2683	0.13086
Hera	287.2733	0.13246

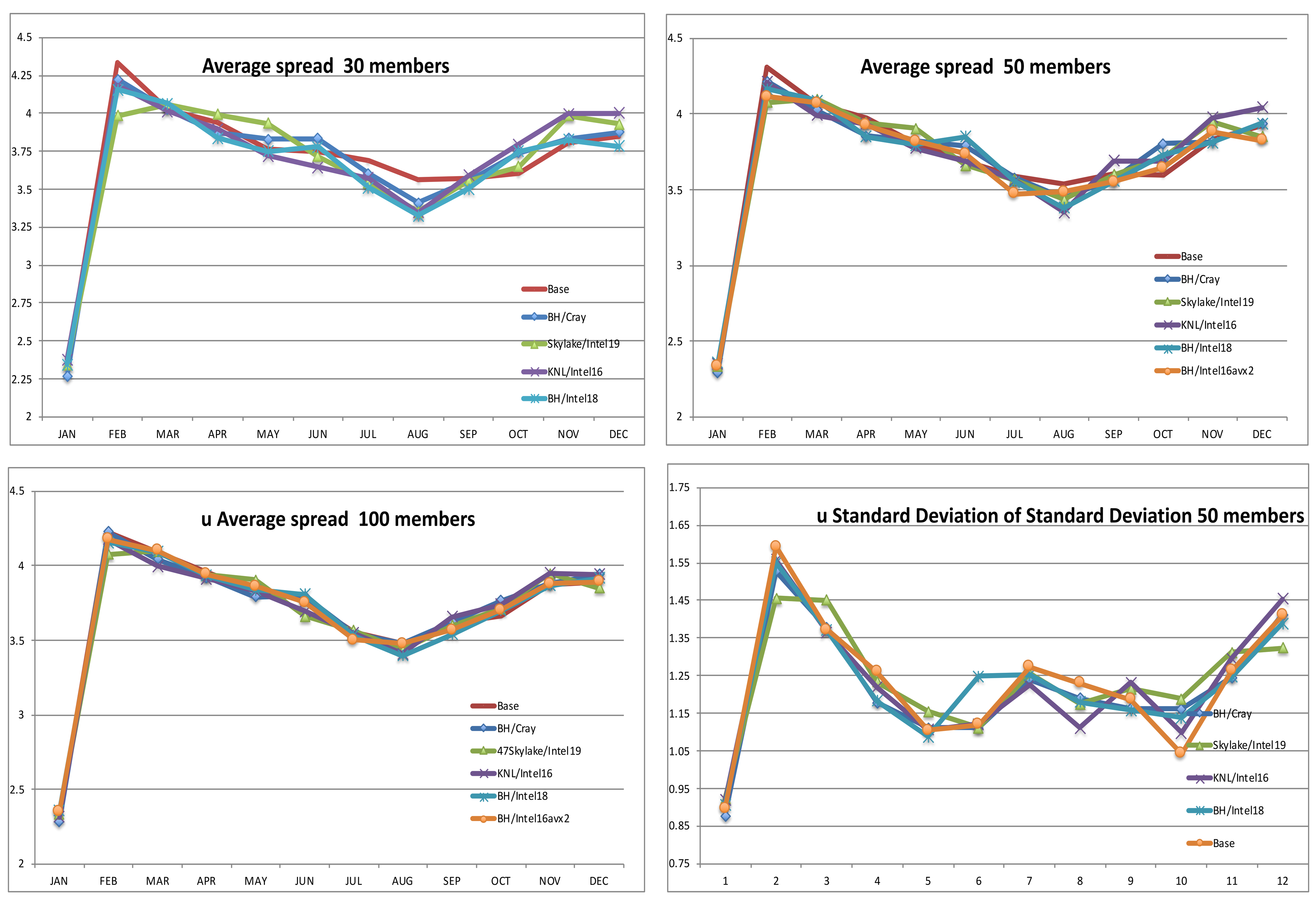

FIGURE 1: Global Mean of the point-by-point standard deviation of surface u-wind for 30, 50, and 100 ensemble members. The global standard deviations of the point-by-point standard deviations are on the bottom right-hand side panel. The global standard deviations follow the same trends and are closely related regardless of compiler or platform. However, the standard deviations of the standard deviations have the same general trend but are not as closely related the global standard deviation.

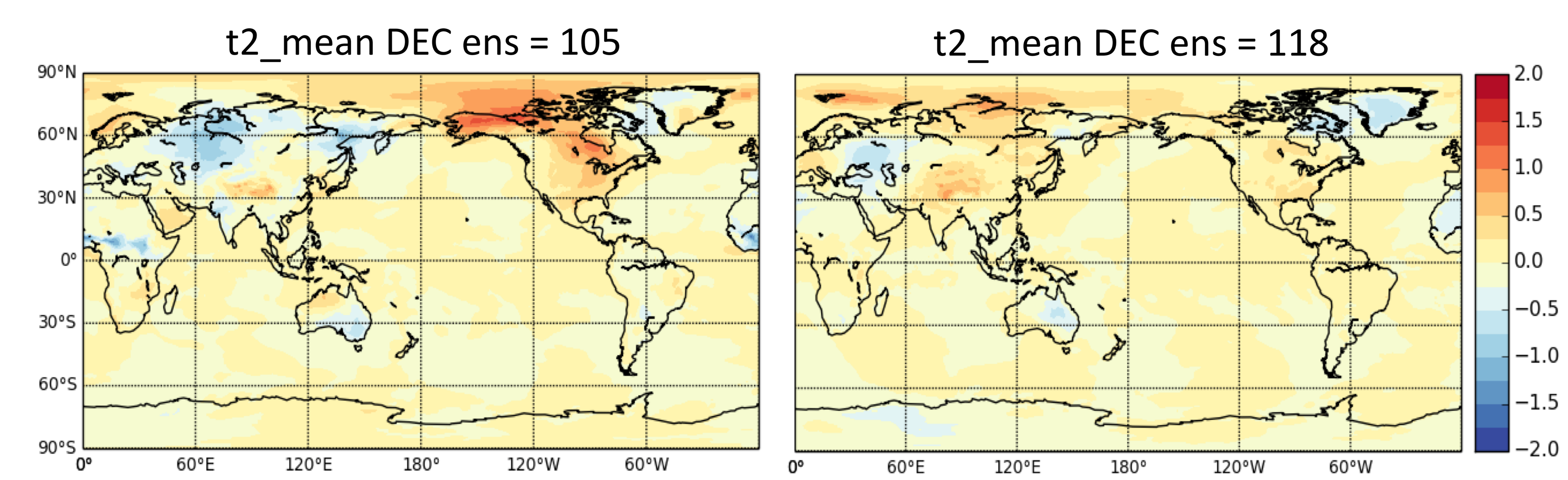

FIGURE 2: Differences in December 1979 mean 2m temperature between the Cray and Gaea ensembles (left panel), and between the Theta and Gaea ensembles (right panel). The mean Cray and Theta values lie within one standard deviation of the Gaea mean over most of the grid points, except for regions near the Northern Hemisphere marginal ice zone.

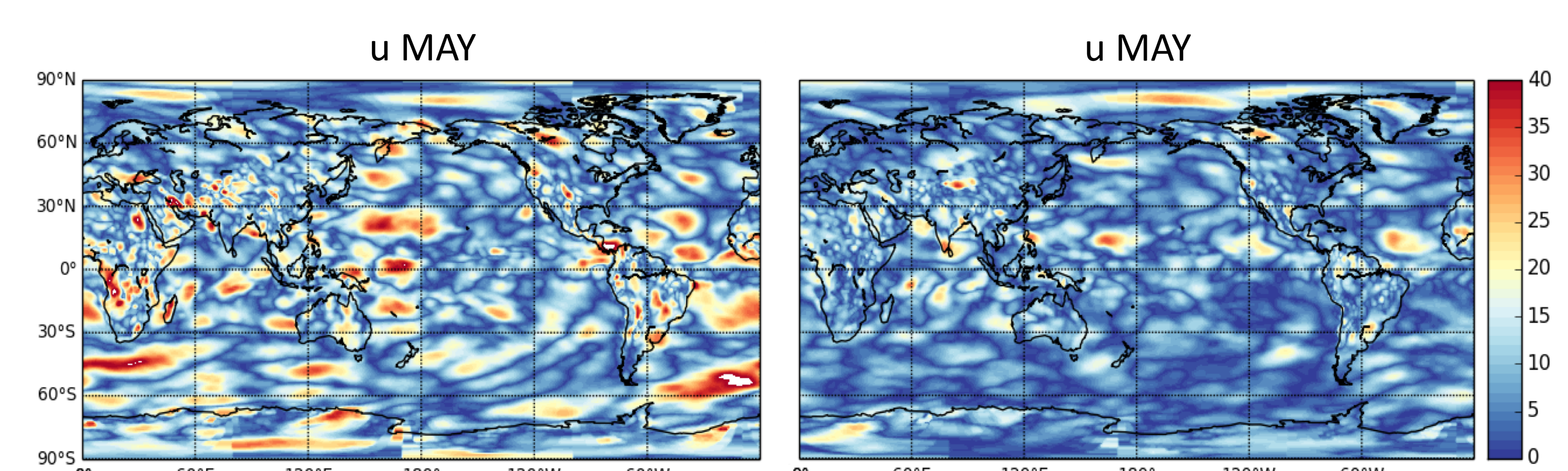

FIGURE 3: Percent difference of standard deviation of u-wind during the month of May between the Gaea and Hera ensembles (left panel), and between the Gaea and Theta ensembles (right panel). The May u-wind is more spatially variable in the Hera ensemble than the Gaea ensemble but varies similarly in the Theta and Gaea ensembles.

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