Final report for the NOAA/CPO MAPP Project:
Towards improving convection parameterization and the MJO in next generation climate models

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Term of project: 2011-2015

Results and Accomplishments:

This project involved a collaborative effort among four different institutions, each aimed at improving the representation of convection in next-generation global climate models so that they better simulate the Madden-Julian Oscillation, an important predictable component of large-scale tropical variability that is often notably absent in such models. The models utilized were the: 1) GFDL HiRAM (PI Zhao), 2) NASA GEOS5 (PI Putman), 3) NCAR CAM5 (PI Bacmeister), and 4) a modified version of the NCAR WRF with a "superparameterization" (SP) for convective-system-scale processes, known as the SP-WRF (PI Tulich). The strategy involved running each of these models in "hindcast" mode starting from real-world initial conditions to simulate one or more observed MJO events for a period of several weeks or more. As detailed collectively in previous progress reports by the PIs, as well as in a recent MAPP-supported publication by Xiang et al. (2015), model modifications that led to improvements in MJO hindcasts were made at all centers except NCAR, which found than none of their modifications led to changes in MJO fidelity.

In the case of the SP-WRF, a number of important advances and discoveries were made that not only contributed directly to this project's goal of improving simulation of the MJO, but also lead to a follow-on project by the lead PI (supported by the NOAA CPO/ESS program) aimed at understanding the cause of the common double-ITCZ bias seen in almost all global weather and climate prediction models. To illustrate how both of these issues (MJO and ITCZ simulation) appear to be related in the SP-WRF, Fig. 1 and 2 shows results from a series of MJO hindcast simulations (encompassing an ensemble of 15 different events) that were performed using two different versions of the model: one with the model's standard bulk surface flux algorithm and one where essentially just a single "knob" of this scheme was adjusted, namely, that controlling the strength of parameterized wind-gustiness. As shown in Fig. 1d, turning the gustiness knob all the way down to "zero" results in seemingly complete loss of the observed signal, which is qualitatively well captured using the standard (strong-gustiness; MM95) formulation , as shown in Fig. 1b. The case of moderate gustiness (Fig. 1c) is somewhere between these two extremes.

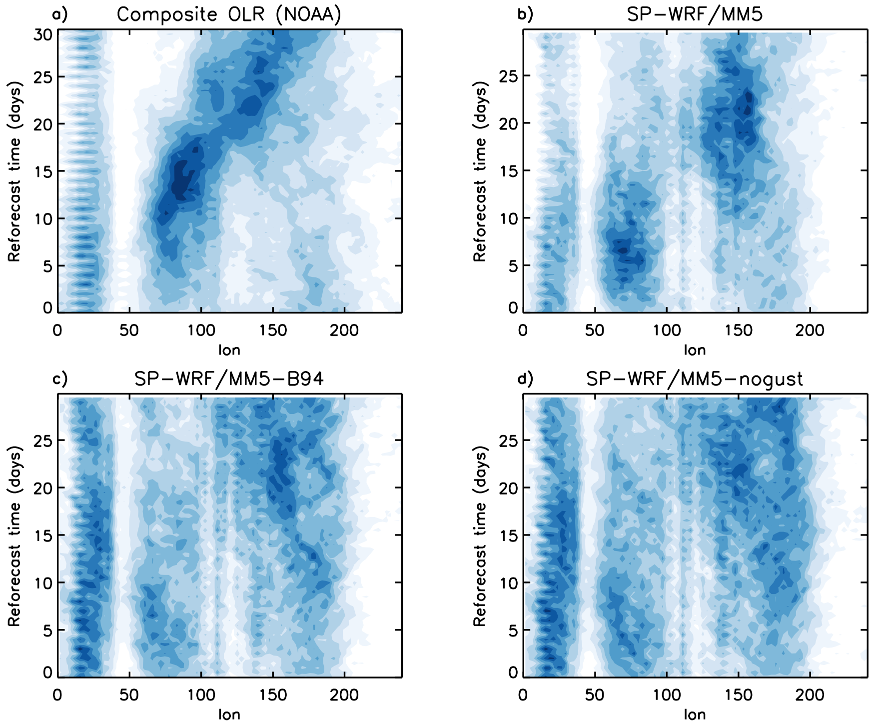

Fig. 1 Composite OLR evolution of 15 observed (a) vs reforecast (b-d) MJO events. The reforecasts were performed using the global SP-WRF model with the MM5 surface layer scheme under one of three different treatments of gustiness: b) the standard MM5 formulation, c) the B94 formulation (resulting in weaker gustiness), or d) no gustiness correction at all. The horizontal grid spacing of the global model is 2.8 deg, with each grid box containing a 2D CRM with 32 columns at 4-km grid spacing.

Our explanation of these findings is that regions with active tropical convection tend to be the same regions where background wind speeds are relatively weak (especially at the equator and over the warm pool region), so that the strength of local wind gustiness (i.e., the amplitude of unresolved perturbations about the global-model-resolved winds) becomes important for controlling the amount of local evaporation that can feed and sustain convection. This argument holds for transient disturbances, such as the MJO, in addition to time-mean stationary phenomena, such as the ITCZ. Indeed, looking at Fig. 2b and c, we see that the time-mean pattern of rain differences between the MJO hindcasts with either the gustiness knob turned from its maximum to a more moderate value (Fig. 2b) or to zero (Fig. 2c) implies a systematic shift of time-mean rain from: a) on to off the equator and b) the warm pool to the east Pacific.

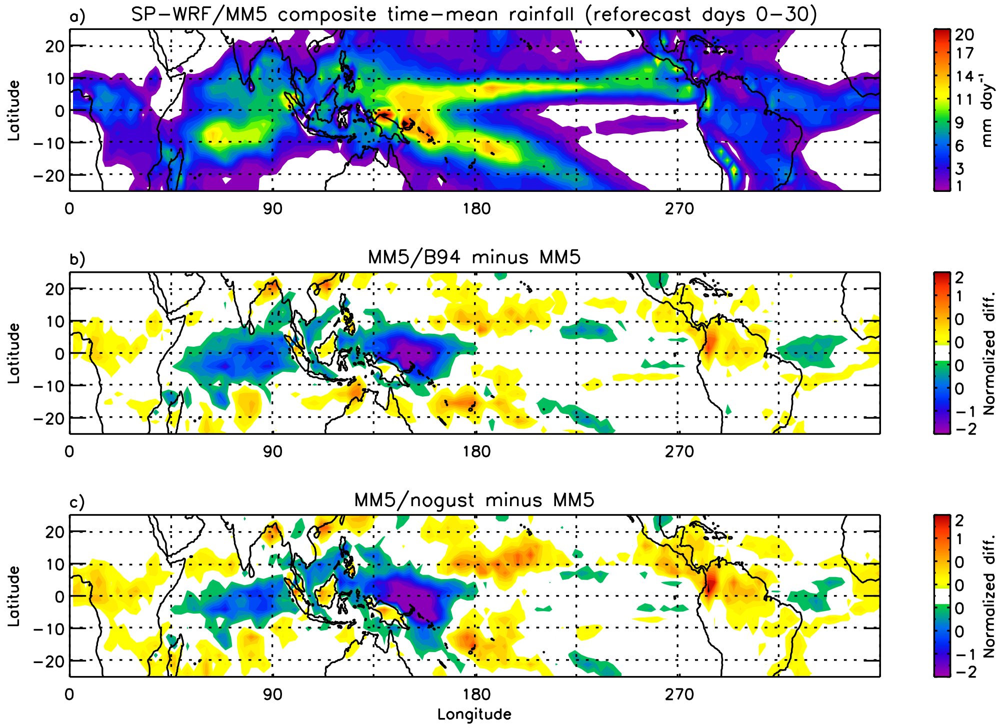

Fig. 2 Comparison of composite time-mean rainfall patterns for the set of 30-day MJO reforecasts in Fig. 1 under different treatments of surface gustiness. The top panel (a) shows the raw field from the standard run with the standard (strong; MM5) treatment of gustiness, while the bottom two panels show the relative changes for the runs with either moderate the B94 treatment (b) or no gustiness effects included (c).

In addition to the treatment of gustiness, two other factors found to affect MJO performance in the SP-WRF were firstly, the choice of horizontal resolution and secondly, the choice of cloud microphysics scheme. Comparing Fig. 3 to Fig. 1, for example, we see that decreasing the horizontal grid spacing of the outer (global) model from around 2.8 x

2.8 deg. to 1.4x1.4 deg. leads to substantial improvements in the model's ability to capture the disturbance's slow eastward migration, especially over the Maritime Continent region where the simulated convective signal in the low-resolution run appears to almost completely dropout. Meanwhile, Fig. 3 also shows how adopting the simpler single-moment scheme of Tao et al. (2003) leads to more modest improvements in both the

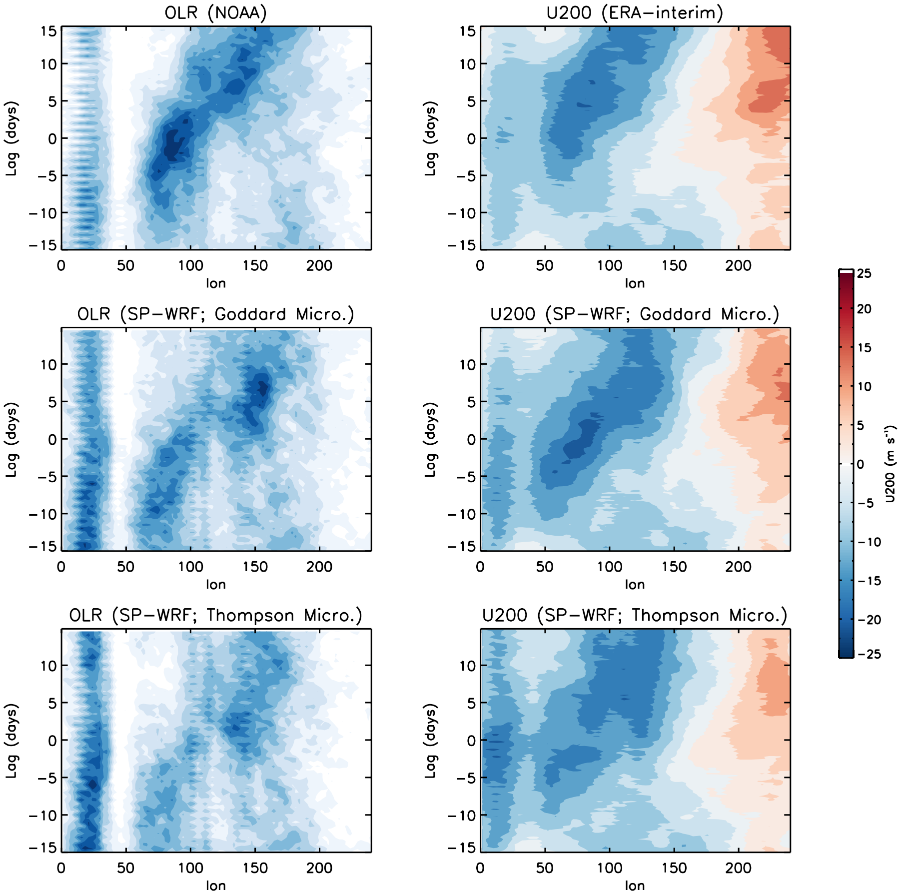

Fig. 3 Similar to Fig. 1 but for a global model grid spacing of around 1.4x1.4 deg. using one of two different cloud microphysics schemes: middle panels) the Goddard single-moment scheme of Tao et al. (2003) or bottom panels) the NCAR double-moment scheme of Thomspon et al. (2008). Left panels compare observed vs simulated OLR, while right panels compare observed vs simulated 200-mb zonal winds.

amplitude and coherence of the simulated disturbance. This last result serves to illustrate one of the main strengths of the SP-WRF in comparison to other SP models in the literature, namely, the ability to efficiently and affordably address how the choice of different smallscale physics schemes affects the performance of a global model with explicit convection, at a fraction of the cost of actually running a global CRM. The SP-WRF can therefore be considered as a steppingstone towards global convection-permitting weather and climate models of the future.

One possible argument against this last statement, and against the SP approach in general, is that such models do not generally include the effects of convective momentum transport (CMT), essentially owing to their reliance on a 2D CRM. To address this concern and to assess the impacts of including the effects on CMT on MJO simulation, this project developed and implemented a novel CMT parameterization that is general enough to be applied in any existing SP model. Interestingly, including this scheme was found to have only a minimal impact on simulations of the MJO; the main effect was to slightly weaken the kinematic signals of the disturbance, via "cumulus friction" (results not shown). All of these various findings concerning MJO hindcast sensitivity in SP-WRF will be published in a manuscript that is currently in preparation and whose stage has now been set by a recent publication (made possible through this award) describing the proposed CMT algorithm and its impacts on idealized and real-world SP-WRF simulations of weather and seasonal climate (Tulich 2015).

Publications citing support from this award

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