Recommendation from the CAM5.5 assessment panel

What follows is a brief summary of the assessment of a range of aspects concerning the inclusion of the Unified Convection scheme (UNICON) and Cloud-Layers Unified by Binormals (CLUBB) with Morrison-Gettelman version 2 microphysics (MG2) schemes in CAM5.5; the version of the CAM to be used in CESM CMIP6 experiments. The panel thanks the developers for performing simulations and providing all the requested supporting material. We encourage all Atmosphere Model Working Group (AMWG) members to view and assess this material, which can be found here

http://www.cesm.ucar.edu/working_groups/Atmosphere/development/cam6/cam5.5-process

The scientific validity and appropriateness of the two configurations were judged to have significant and sufficient merit. UNICON has a desirable unification of shallow and deep convection, precluding the need for separate and incompatible schemes. There are also significant benefits from the removal of legacy CAPE closures used in the Zhang-McFarlane (ZM) scheme. It also represents mesoscale features and feedbacks on to cloud base plume properties. CLUBB has a comprehensive and continuous treatment of turbulence and sub-grid probabilities of saturation (and hence cloudiness), and is able to represent through a set of high-order closures, dry and cloud-topped boundary layers, in addition to shallow convection and associated cloudiness. The assumed distributions of these higher order quantities are much more continuous than in the existing schemes in CAM5.3. Both schemes have demonstrated agreement with Cloud Resolving Models (CRMs) in single-column mode, that is superior to existing CAM5 representations, and they have the potential, through their inherent approximations, to be more applicable across varying vertical and horizontal grid scales than for CAM5.3 schemes.

The panel does express some concern that both schemes are very complicated. The number of parameters required for closure is substantial, complex and a significant increase from existing CAM configurations. Fundamentally, this makes the nature of each scheme's operating mechanisms and sensitivities very difficult to determine. Therefore, there is a need to further understand the multi-dimensional sensitivities within each scheme, both within the context of climate sensitivities and SCM comparisons. The panel recommends the developers investigate these sensitivities in depth, with a goal of simplifying their formulations.

High-level metrics indicate that the mean climate simulation is significantly improved with both CLUBB+MG2 and UNICON, largely beyond that of existing CAM5.3 simulations. Indications from the amounts of clouds, and their associated vertical distributions and radiative impacts (as inferred from COSP diagnostics) show the most improvement in the CLUBB+MG2 configurations, in particular for low clouds and short-wave cloud forcing distributions. UNICON however shows a reduction in cloud amount and further aggravation of the too few, too bright problem in CAM5.3. Precipitation distributions in CLUBB+MG2 demonstrate moderate reductions in double-ITCZ characteristics, but also exhibit worsening JJA precipitation in the Central Pacific and Indian Ocean. The excessive tropical humidity distributions in CAM5.3 are largely ameliorated in CLUBB+MG2 with only moderate improvements in UNICON.

Distributions of convective and large-scale precipitation categories are largely unchanged in UNICON, with high convective fractions. A higher and realistic large-scale fraction is apparent in CLUBB+MG2, but uncertainties remain in the quantification of like for like categories between the schemes.

In fully coupled simulations the two configurations do not in general outperform CESM-CAM5.3 simulations. To a certain extent this is to be expected, as the configurations have not been subjected to the extensive tuning of CESM-CAM5.3. Of note in these simulations is a smaller SST bias in UNICON than CLUBB+MG2 and stronger surface pressure biases in surface pressure at high southern latitudes in CLUBB+MG2. CLUBB+MG2 performs on the whole better for precipitation, but JJA South Asian amounts are excessive. Surface westward stresses in the Pacific, potentially a key indicator of ENSO variability, are too strong in CLUBB+MG2 compared to UNICON.

Sub-seasonal and higher frequency variability exhibits some areas of improvement in both configurations. The diurnal cycle of precipitation is improved in terms of having peak phase timing that occurs later during the day. The amplitude is somewhat different between the two configurations, being weaker than observed in CLUBB+MG2 and stronger than observed in UNICON. Madden-Julian Oscillation (MJO)-like variability is similarly improved in both configurations with a more accurate phase speed, but still too weak amplitude. Other equatorially trapped wave variability such as Kelvin waves are present in UNICON simulations, but have too strong amplitude and too slow a phase speed. A more significant concern is the almost complete absence of Kelvin waves in CLUBB+MG2 simulations.

The panel recognizes that the ENSO mode of variability was very well simulated in CESM-CAM5.3 and as such it would be a significant challenge for either configuration to retain it in its current form. That being said there are concerning degradations of ENSO characteristics with both configurations. UNICON inflates the amplitude of El Nino cycles resulting in an overly deterministic variation, a strong 3-year periodicity and excessive autocorrelation persistence. CLUBB+MG2 has a significant decrease in El Nino amplitude with no preferred periodicity between 2 and 10 years, and hence it has insufficient teleconnection strength. The panel cannot stress enough the importance of retaining, as near as possible, the correct simulation of ENSO as a vital requirement from the wider CESM. Therefore, both configurations need to apply significant planning and resources into tackling their individual deficiencies.

The final aspect of the configurations that the panel considered was the viability and long-term support of the schemes if they were to be included in the CAM. CLUBB+MG2 demonstrates many advantages from this perspective. The code base is used and developed across a broad range of researchers, is maintained as part of a developers repository and has been used in multiple applications and across other modeling centers. UNICON does not possess such a broad user base and has not been subject to the group code review rigor as with CLUBB+MG2. Given the somewhat unique nature of CESM being a community model the panel makes the strong recommendation that CLUBB+MG2 continues its broad user base, but more importantly that UNICON

developers allow a broader range of users to evaluate, use and develop the code. These actions would facilitate smoother and more seamless model development in the future, regardless of which direction CAM5.5 and its subsequent development takes.

After carefully evaluating all of the material available and drawing on their collective expertise the panel intends to make a two-stage recommendation. First, that the CAM5.4 configuration should continue to move forward, with appropriate coupled simulations, as the choice for CAM5.5 in the short term. Second, that the two model candidate configurations continue to move forward with development activities intended to address specific areas of concern (detailed below). Whichever candidate development has addressed these areas of concern most successfully, as deemed by the panel, will be recommended to combine with CAM5.4 to form CAM5.5. If neither candidate has satisfactorily addressed the areas of concern, as deemed by the panel, then CAM5.4 will become the contingency configuration for CAM5.5.

This recommendation is based predominantly on the insufficient quality of fully coupled simulations and on the desire to more comprehensively plan the evolution of CAM configurations for CAM5.5 and beyond. In making this recommendation the panel stresses that this is only to fulfill the remit that AMWG provide a low-resolution (1 degree) model for CAM5.5. The panel advises that the developers make their highest priority the improvement of ENSO and the fully coupled simulation. As well as working with AMWG the developers should work closely with other working groups with interest and expertise in ENSO simulation and the coupled system. At a minimum this should include interactions with the Ocean Model Working Group (OMWG) and the Climate Variability and Change Working Group (CVCWG) to determine relevant deficiencies and formulate solution approaches. The panel recommends setting a deadline of May 15, 2015 to respond to the recommended tasks. At that time, if the panel and the relevant working group co-chairs deem the simulation of ENSO to still be deficient then the panel recommends that CAM5.5 should adopt the CAM5.4 configuration.

A further strong recommendation by the panel is that the developers, in joint consultation, make explicit plans regarding how to scientifically and infrastructurally combine the two schemes for joint development beyond CAM5.5. The panel acknowledges that there are certain challenges to doing this, including reconciling the different representations of boundary layer turbulence and the consistent incorporation of deep convection, microphysics and macrophysics The developers should approach the joint effort with strong consideration of the fact that CESM is both developed and used as a community model. Its major strength lies in healthy collaboration, and as such the candidate codes should be made available to the development community following the February 2015 AMWG workshop. Plans for addressing and overcoming the challenges of future integrated model development should be provided to the panel by the May 15,s 2015 deadline. The panel recognizes that the deadlines for addressing the recommendations are short, but deficiencies in the coupled candidate simulations are just too great for either model to be delivered to the community at this time. However, since we believe that improvements to the coupled simulations are achievable over this time

frame then it did not make sense to definitively decide on a CAM5.4 fall-back choice until potential simulation improvements were explored.

Finally, the panel is happy to discuss their recommendations with the developers or other members of AMWG. The panel also expresses its gratitude to the leaders of the CESM community for involving them in this process. Once again we wish to stress that development should continue along all pathways for future assessment in CAM6, since the most optimal model configuration could be radically different from CAM5.5.

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