What were the major goals of the project?

The research of University of Wisconsin --- Milwaukee (UWM) on this SciDAC Multiscale project occurred mainly in the context of four subprojects.

The goal of the first subproject was to improve the behavior of a configuration of ACME that uses our cloud parameterization ("CLUBB") to parameterize deep convection and uses a subcolumn sampler ("SILHS") to interface CLUBB and the microphysics. This subproject was carried out by an undergraduate at UWM, Eric Raut; the PI, V. Larson; and Wuyin Lin of BNL. Thayer-Calder et al. (2015) presents global simulations using CLUBB and SILHS to parameterize all cloud types, including deep convection. This paper is a milestone, because it shows that competitive results can be achieved with a unified parameterization (CLUBB) that treats all cloud types using a single equation set. In particular, the simulations exhibit an accurate cloud climatology and improved Kelvin waves. However, the use of CLUBB and SILHS doubles the model cost when the microphysics is sampled 8 times per grid column. To reduce this expense, we improved the sampling strategy. Namely, we placed more samples in the regions of evaporating rain, which turns out to be an important process in cumulus cases. In single-column simulations, this reduces the cost of the microphysical computations by a factor of 1.6 to 8, depending on the case. The results have been published in Raut and Larson (2016). In addition, Wuyin Lin has ported this CLUBB-SILHS configuration to a branch of ACME.

The goal of the second subproject was to analyze CLUBB's sensitivity to changes in parameter values. This subproject was a collaboration between UWM and PNNL. This question of parameter estimation of practical importance to ACME developers, because they wish to be able to tune ACME efficiently. In 2015, we published a paper (Guo et al. 2015) that used UQ methods to assess the sensitivity of global simulations to CLUBB's parameter values. The simulations use the Zhang-McFarlane scheme to parameterize deep convection. Guo et al. (2015) provides an overview of which parameters are most useful for tuning ACME v1.

In a third subproject, we compared CLUBB-SILHS as a deep convective scheme versus the Chikira and Zhang-McFarlane deep convective parameterizations. This was a collaboration with Bert Debusschere of Sandia and Don Lucas of LLNL. The intercomparison shows that, of the three parameterizations, CLUBB-SILHS is best at predicting surface precipitation in the eastern Pacific.

In a fourth subproject, UWM worked with two applied mathematicians at the QUEST Institute, Bert Debusschere and Dr. Kenny Chowdhary, and a researcher at PNNL, Sunny Lim. CLUBB currently works with SILHS to compute grid-box-average microphysical process rates. However, Sandia is developing an alternate averaging method that uses so-called deterministic quadrature. It converges rapidly and avoids the sampling noise that is inherent in Monte Carlo integration. In addition, it will provide an inexpensive alternative to SILHS when only a few physical processes, such as autoconversion, need to be averaged. A paper that presents non-interactive tests has been published (Chowdhary et al. 2015).

Project outcomes

Tests indicate that CLUBB-SILHS can successfully simulate deep convective cases. Storer et al. (2015) demonstrated that CLUBB-SILHS can simulate continental and maritime deep convective cases, using the same model configuration that works for shallow cloud cases. Thayer-Calder et al. (2015) showed that CLUBB-SILHS produces competitive global simulations when the deep convective scheme is shut off, and all clouds are parameterized using CLUBB-SILHS. We mention two reasons for this success. First, CLUBB-SILHS allows the accuracy and comprehensiveness of the MG microphysics to be applied to deep convection, where accurate microphysics matters most. Second, basic equations in CLUBB are prognostic, allowing deep convection to evolve naturally from shallow convection, rather than being tied directly to CAPE.

CLUBB-SILHS currently resides in a branch of the ACME repository that was merged fairly close to the head of the master branch as of late 2016. CLUBB-SILHS is interfaced with either the MG1 or MG2 microphysics.

Although many future improvements and extensions to CLUBB and SILHS can be envisioned, the overall goal of this proposal was met.

What opportunities for training and professional development has the project provided?

An undergraduate, Eric Raut, collaborated on some of the research. He learned about Monte Carlo sampling and has written a paper in the peer-reviewed literature (Raut and Larson 2016).

A graduate student, Rica Wedowski, helped to compare deterministic quadrature with analytic and Monte Carlo integration of microphysics over subgrid variability.

How have the results been disseminated to communities of interest?

The following papers, related to the project, were published:

2016: “A new subgrid-scale representation of hydrometeor fields using a multivariate PDF." B. M. Griffin and V. E. Larson, Geosci. Model Dev., 9, 2031–2053.

2016: “Parameterizing microphysical effects on variances and covariances of moisture and heat content using a multivariate probability density function: a study with CLUBB (tag MVCS)." B. M. Griffin and V. E. Larson, Geosci. Model Dev., 9, 4273–4295.

2016: “Vertical overlap of probability density functions of cloud and precipitation hydrometeors." Ovchinnikov, M., K.-S. S. Lim, V. E. Larson, M. Wong, K. Thayer-Calder, and S. J. Ghan (2016), J. Geophys. Res. Atmos., 121, doi:10.1002/2016JD025158.

2016: “Assessment of marine boundary layer cloud simulations in the CAM with CLUBB and updated microphysics scheme based on ARM observations from the Azores." Zheng, X., S. A. Klein, H.-Y. Ma, P. Bogenschutz, A. Gettelman, and V. E. Larson, J. Geophys. Res. Atmos., 121, 8472–8492.

2016: “A flexible importance sampling method for integrating subgrid processes." E. K. Raut and V. E. Larson, Geosci. Model Dev., 9, 413–429.

2015: “Parametric behaviors of CLUBB in simulations of low clouds in the Community Atmosphere Model (CAM)." , Z. Guo, M. Wang, Y. Qian, V. E. Larson, S. Ghan, M. Ovchinnikov, P. A. Bogenschutz, A. Gettelman, and T. Zhou. J. Adv. Model. Earth Syst., 7, 1005–1025.

2015: “Parameterizing deep convection using the assumed probability density function method." R. L. Storer, B. M. Griffin, J. Höft, J. K. Weber, E. Raut, V. E. Larson, M. Wang, and P. J. Rasch, Geosci. Model Dev., 8, 1–19.

2015: “A unified parameterization of clouds and turbulence using CLUBB and subcolumns in the Community Atmosphere Model." K. Thayer-Calder, A. Gettelman, C. Craig, S. Goldhaber, P. A. Bogenschutz, C.-C. Chen, H. Morrison, J. Höft, E. Raut, B. M. Griffin, J. K. Weber, V. E. Larson, M. C. Wyant, M. Wang, Z. Guo, and S. J. Ghan, Geosci. Model Dev., 8, 3801-3821.

2015: “Quadrature methods for the calculation of subgrid microphysics moments." K. Chowdhary, M. Salloum, B. Debusschere, and V. E. Larson, Mon. Wea. Rev., 143, 2955–2972.

2014: “A Sensitivity Analysis of Cloud Properties to CLUBB Parameters in the Single Column Community Atmosphere Model (SCAM5)." , Z. Guo, M. Wang, Y. Qian, V. E. Larson, S. Ghan, M. Ovchinnikov, P. A. Bogenschutz, C. Zhao, G. Lin, and T. Zhou. J. Adv. Model. Earth Syst., 6, 829–858.