# Flexible, scalable, conservative spatial coupling infrastructure for climate models in E3SM

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## ABSTRACT

High fidelity modeling and simulation of climate systems involve computation of a consistent solution for the coupled atmosphere, ocean, land, river and ice component models. The Energy Exascale Earth System Model (E3SM) [1] is a coupled climate multiphysics infrastructure, which utilizes well known operator decomposition techniques to resolve spatiotemporal errors arising from nonlinear dependencies between the components. One of the fundamental causes of spatial errors propagated in such solvers is due to the inconsistent treatment of the nonlinear fields, and careful effort has been undertaken to ensure conservative remaps are generated to preserve solution accuracies during inter-model projection using different spatial grids. The communication of the field data between components and the cross-model partition mapping is also handled by the E3SM coupler, the Model Coupling Toolkit (MCT). In combination with preprocessing workflows to generate conservative remapping weights for scalar and flux fields, MCT handles the sparse matrix load at runtime through parallel I/O, and implements the application of the weight matrix onto solution vector to compute the field projections from a source to a target model. This two step computational workflow for each pair of coupled component models forms the foundation for the scalable spatial coupling in E3SM.

While such a simulation workflow provides clear separation of concerns, it presents several hurdles in terms of the scientific research productivity, since the offline remapping weights need to be generated for each grid resolution, thereby complicating cases with adaptive or moving meshes within models. To simplify this multistep workflow and to overcome the issues with adaptive meshes, we present a partition and mesh aware infrastructure based on the Mesh Oriented datABase (MOAB), to replace MCT within E3SM. Through interfaces to TempestRemap, the spatial remapping weights are then computed on the fly for model grid specifications, in parallel.

Unlike MCT, MOAB allows a complete description of the numerical grid used by submodels in E3SM, along with serialization of the discrete coupled solution fields, which are used in the online computation of mesh intersections, high-order interpolation and remapping weights through conservative schemes [2]. We present accuracy and scalability results from applying this flexible MOAB-TempestRemap workflow for coupled atmosphere-ocean-land E3SM problems. In addition to highlighting the performance of the new coupler, we will show improved remapping scalability on large-scale machines with parallel decompositions driven through task mapping with Zoltan. Additional coupler extensions to seamlessly handle point-to-point distributed coupling between models in comparison to the existing hub-and-spoke model will also be discussed.

## REFERENCES

[1] E3SM Project, DOE. Energy Exascale Earth System Model. Computer Software. https://github.com/E3SM-Project/E3SM.git. 23 Apr. 2018. Web.

[2] Mahadevan, V. S., et al, Improving climate model coupling through a complete mesh representation: a case study with E3SM (v1) and MOAB (v5.x), Geosci. Model Dev. Discuss., in review, 2018.