FSU Meteorological Seminar Series, Autumn 2022

Dr. Yair Cohen

Climate Modeling Alliance

California Institute of Technology

Combining physics and machine learning in the turbulence-convection parameterization of the CliMA climate model

The representation of turbulence and convection at the subgrid scale of climate models by various parameterization schemes is one of the largest sources of model uncertainty in long term climate predictions. The crux of these parameterization schemes is the formulation of closure functions for processes that cannot be observed or simulated in high resolution models. In this talk I will present a hybrid approach that combines a physics based parameterization scheme with physical and machine learning (ML) closures. Such a hybrid approach cannot be trained using backpropagation typical to neutral networks, as this requires partial derivatives of the physics+ML setup in parameter space. Instead we use a gradient free (ensemble) method to train physics+ML setup from high resolution LES data. The hybrid approach ensures conservation properties, allows for straightforward interpretability of its data driven components and reduces the degrees of freedom to allow us to train from spares data. The physical model is based on the extended Eddy Diffusivity/Mass Flux (EDMF) scheme, derived by a systematic coarse-graining of the equations of motion and includes subgrid scale memory and prognostic equations for first and second moments. The closures for this scheme combine physical arguments with nondimensional functional forms that can be learned from data using various ML architectures. Our parameterization, in a single column of a climate models, reproduces well the corresponding LES of the full spectrum of boundary layer and turbulent motions: from polar boundary layers (vertical scale of 300m), through the stratocumulus-topped boundary layer (vertical scale of 1km), shallow convection (vertical scale of 3km), and deep convection (vertical scale of 15km). Furthermore, using ML closures we show that a hybrid model is able to extrapolate by training on current climate simulations to a validation set from 4K climate warming scenario.

Time: Thursday, Sep. 29, 2022 @ 3:00 PM
Location: 1044 EOA
Host: Dr. Allison Wing