National Aeronautics and Space Administration

Development and validation of new unified parameterizations for cloud and boundary layer dynamics

Principal Investigator: Joao Teixeira (329)
Tapio Schneider (Caltech, 329), Yair Cohen (Caltech), Anna Jaruga (329, Caltech)
Program: Strategic Initiative (R&TD)

Motivation:

Boundary layer clouds and precipitation are major sources of uncertainty in numerical models of climate.

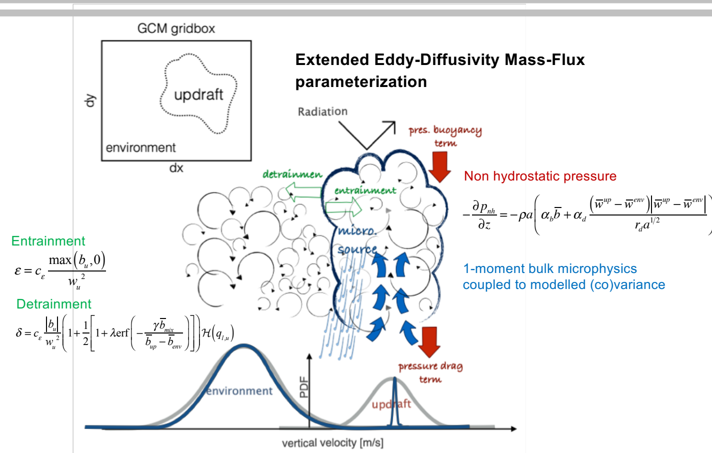
Project Objective:

Develop unified parameterization for cloud and boundary layer dynamics that is
- Suitable for boundary layer turbulence, shallow convection, deep convection
- Scale aware and has memory
- Validated with high resolution model and observational data

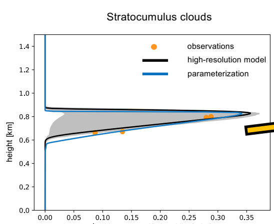
FY 18/19 Results:

The developed parameterization is based on an extended version of the Eddy-Diffusivity Mass-Flux (EDMF) approach. It decomposes the gridbox of a climate model into a turbulent environment and coherent updraft(s). The distribution of heat and moisture in the environment is assumed to be Gaussian with the second moment resolved by the parameterization. In the updrafts only the mean values are modelled. Several closures emerge from this coarse graining:

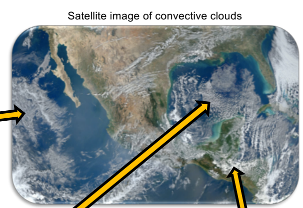
- Non hydrostatic pressure is written in terms of buoyancy and drag effects.
- Entrainment is derived from a balance of terms in the vertical momentum equations.
- Detrainment is given as a logistic function of a mixture buoyancy (representing evaporation).
- Mixing length is given as a balance in the turbulent kinetic equations.



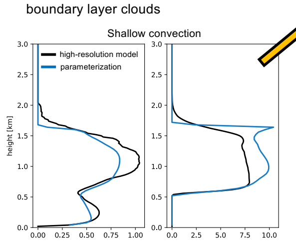
The EDMF parameterization is very successful in simulating various cloud regimes from stratocumulus to shallow and deep convective clouds. It compares well with high resolution Large Eddy Simulations (LES):



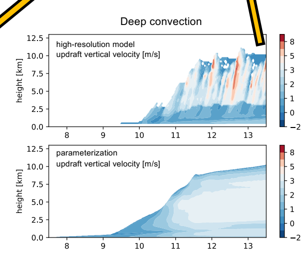
- The performance of the mixing length allows an accurate simulation of liquid water in boundary layer clouds



Jan 4th 2012 NASA/NOAA/GSFC/Suomi NPP/VIIRS/Norman Kuring

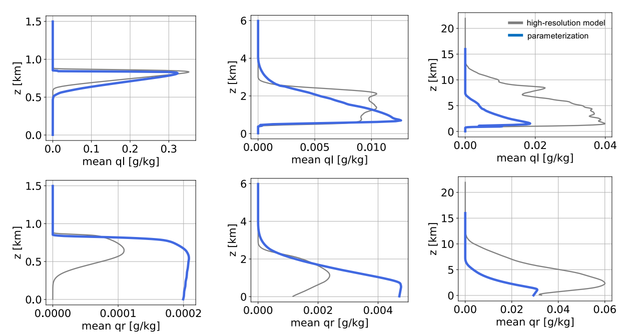


- The entrainment and detrainment closures preforms well as seen in the values of vertical vertical velocities and liquid water in shallow convection.



- The combination of pressure and entrainment closure is able to capture the diurnal cycle of deep convection

The EDMF parameterization of convection and turbulence is coupled to a 1-moment warm-rain microphysics scheme. The microphysics scheme takes advantage of the predicted (co)variance of heat and moisture in the environment by numerically integrating the microphysics source terms over the environmental distribution. The source terms in the updrafts are calculated based on the mean properties. The precipitation equations are time-dependent. The scheme keeps track of the precipitation created in the updrafts and the environment.
Below are the preliminary results of precipitation from the three different cloud types. The plots show the 1-hour average profiles of cloud liquid water and rain water specific humidity.



Stratocumulus cloud drizzle — Shallow convection precipitation — Deep convection precipitation

Benefits to NASA and JPL (or significance of results):

Broadens JPL capabilities in areas of strength:
- Modeling of clouds and convection, including high-resolution LES
- Use of satellite data (CloudSat, CALIPSO, AIRS) in the development and validation of parameterizations

Improves predictive capabilities for numerical weather prediction and climate models

Will help in the planning and design of future JPL Earth science missions focused on clouds and convection

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Publications: Zhihong Tan, Collen Kaul, Kyle Pressel, Yair Cohen, Tapio Schneider, and Joao Teixeira, 2018: "An extended eddy-diffusivity mass-flux scheme for unified representation of subgrid-scale turbulence and convection." *J. Adv. Mod. Earth Sys.*, **10**, 770-800.

+ 3 publications in preparation: On the automated learning of dynamical parameters for EDMF, On the integration of microphysics into EDMF, On the evaluation of the EDMF parameterization with space-based measurements

PI/Task Mgr. Contact Information: Joao Teixeira, (818) 354-2762, Joao.Teixeira@jpl.nasa.gov

Poster No. RPC-051