National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Unified Boundary Layer and Convection Parameterization: The EDMF Approach

João Teixeira, Kay Suselj and Marcin Kurowski

Jet Propulsion Laboratory, California institute of Technology, Pasadena

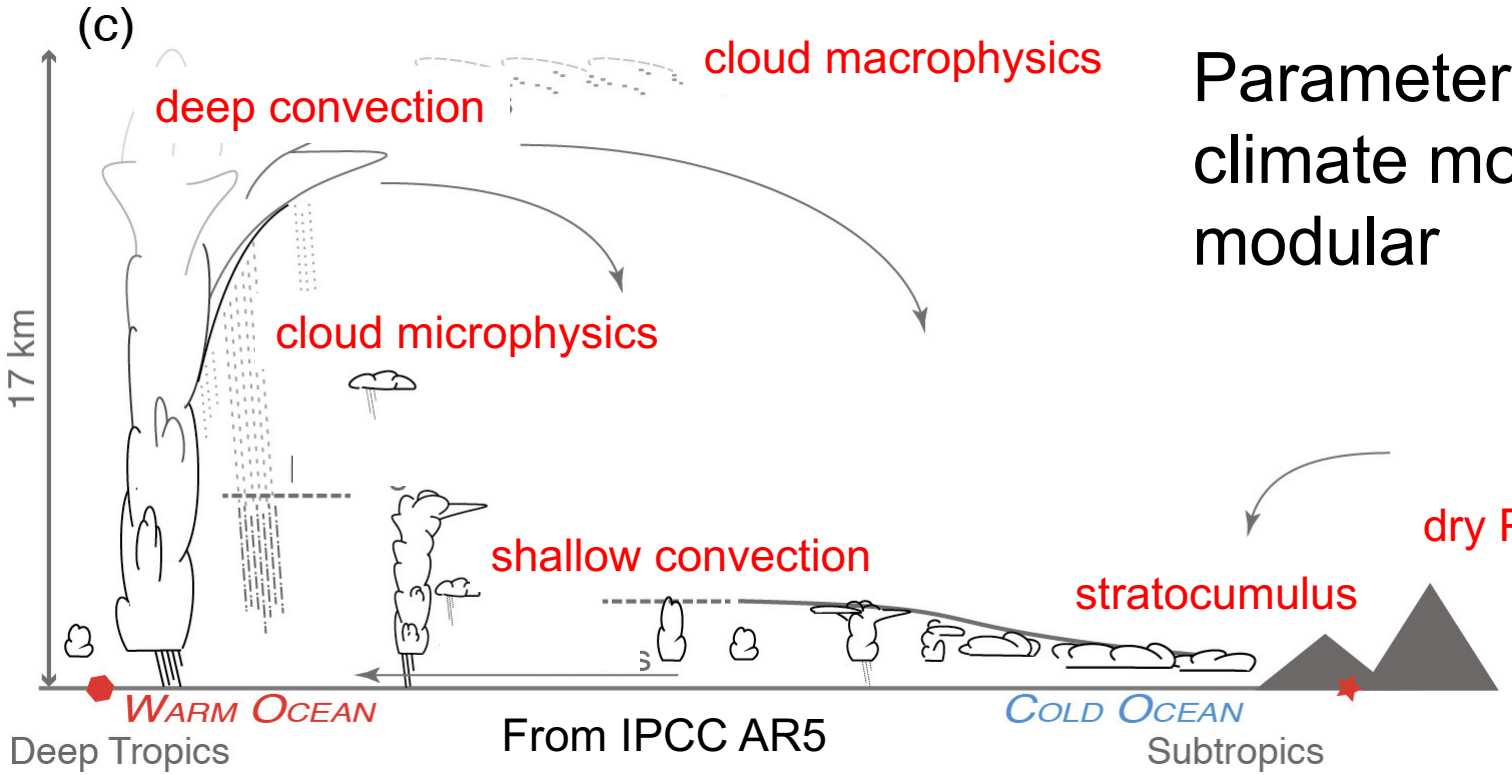
and

JIFRESSE, University of California Los Angeles

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

To solve cloud-climate feedback problem we need more realistic boundary layer and convection in models



From IPCC AR5

Parameterizations in climate models are modular

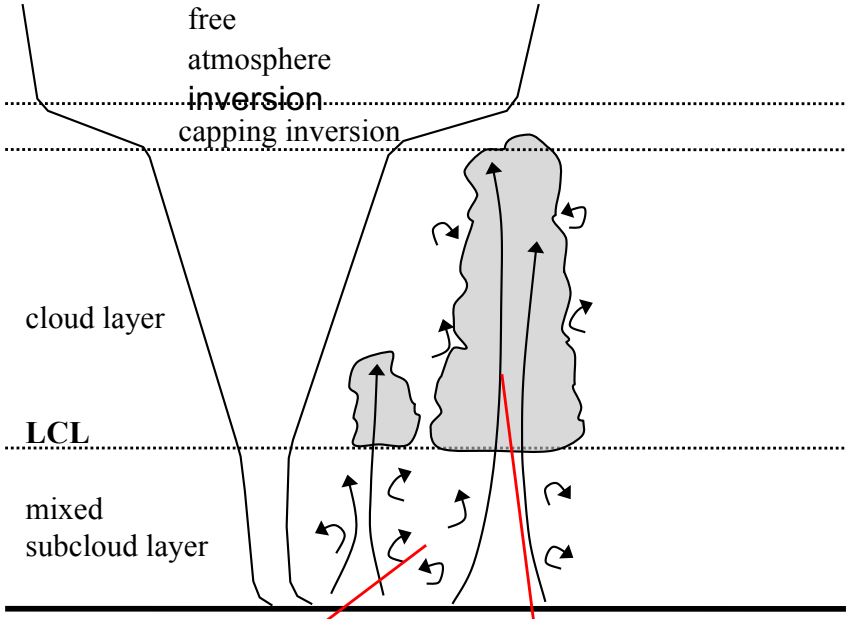
Artificial modularity leads to many problems: interfaces, transition

Key goal: Unified parameterization for boundary layer and convection

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Unified Parameterization: Eddy-Diffusivity/Mass-Flux (EDMF)



Small-scale
ED mixing

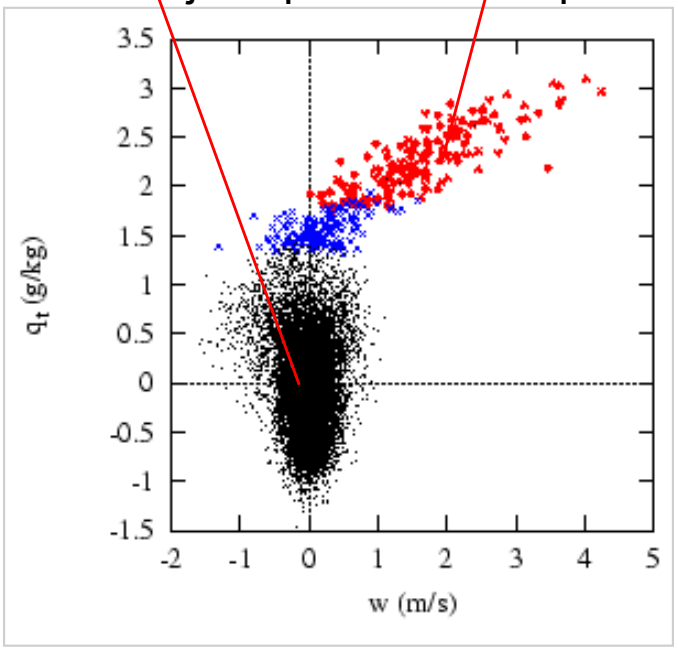
Large-scale
MF mixing

$$\overline{w'\varphi'} = -k\frac{\partial\bar{\varphi}}{\partial z} + M(\varphi_u - \bar{\varphi})$$

ED mixing

MF mixing

Bimodal joint pdf of w and qt

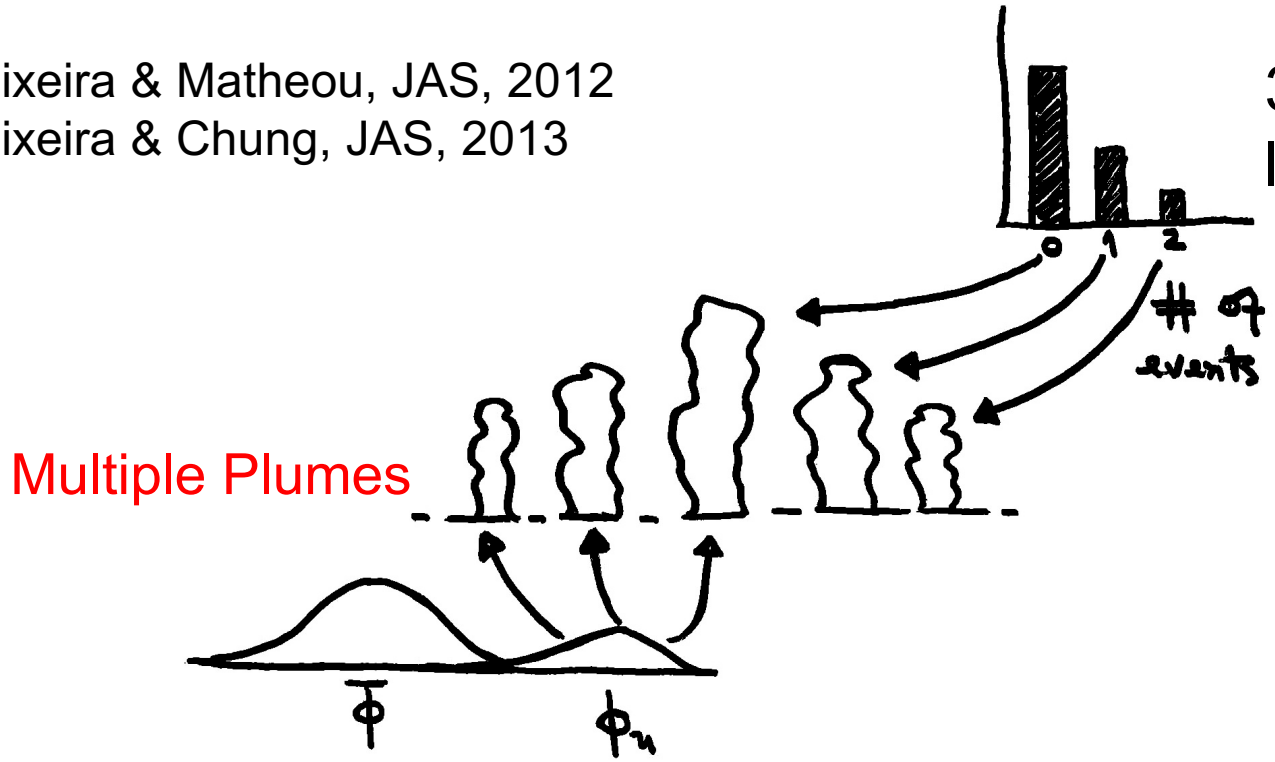


National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

EDMF and moist convection: multiple plumes and stochastic entrainment

Suselj, Teixeira & Matheou, JAS, 2012
Suselj, Teixeira & Chung, JAS, 2013



3) Stochastic lateral entrainment

Partly inspired by Romps & Kuang, JAS, 2010

1) Parameterization of surface layer PDF of thermodynamics
2) Monte Carlo sampling of PDF to produce multiple plumes

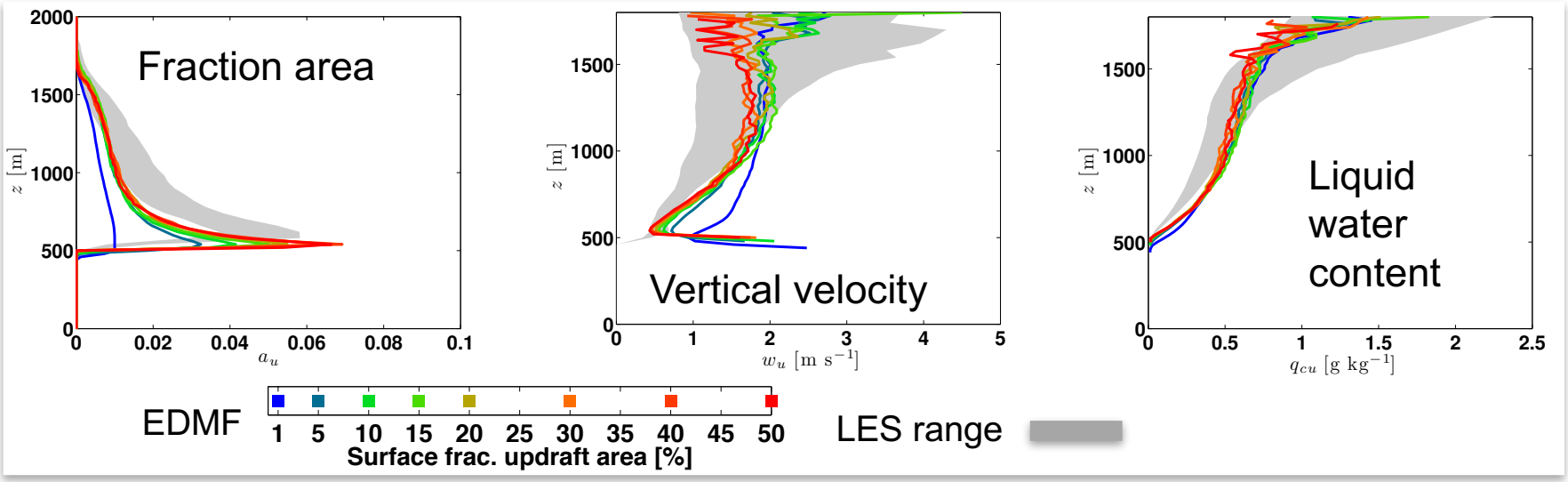
Provides estimates of updraft area and avoids need for cloud base closure

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

New multiple-plume EDMF: plumes start from PDF of surface properties

BOMEX: Comparison of EDMF moist updraft properties against LES results

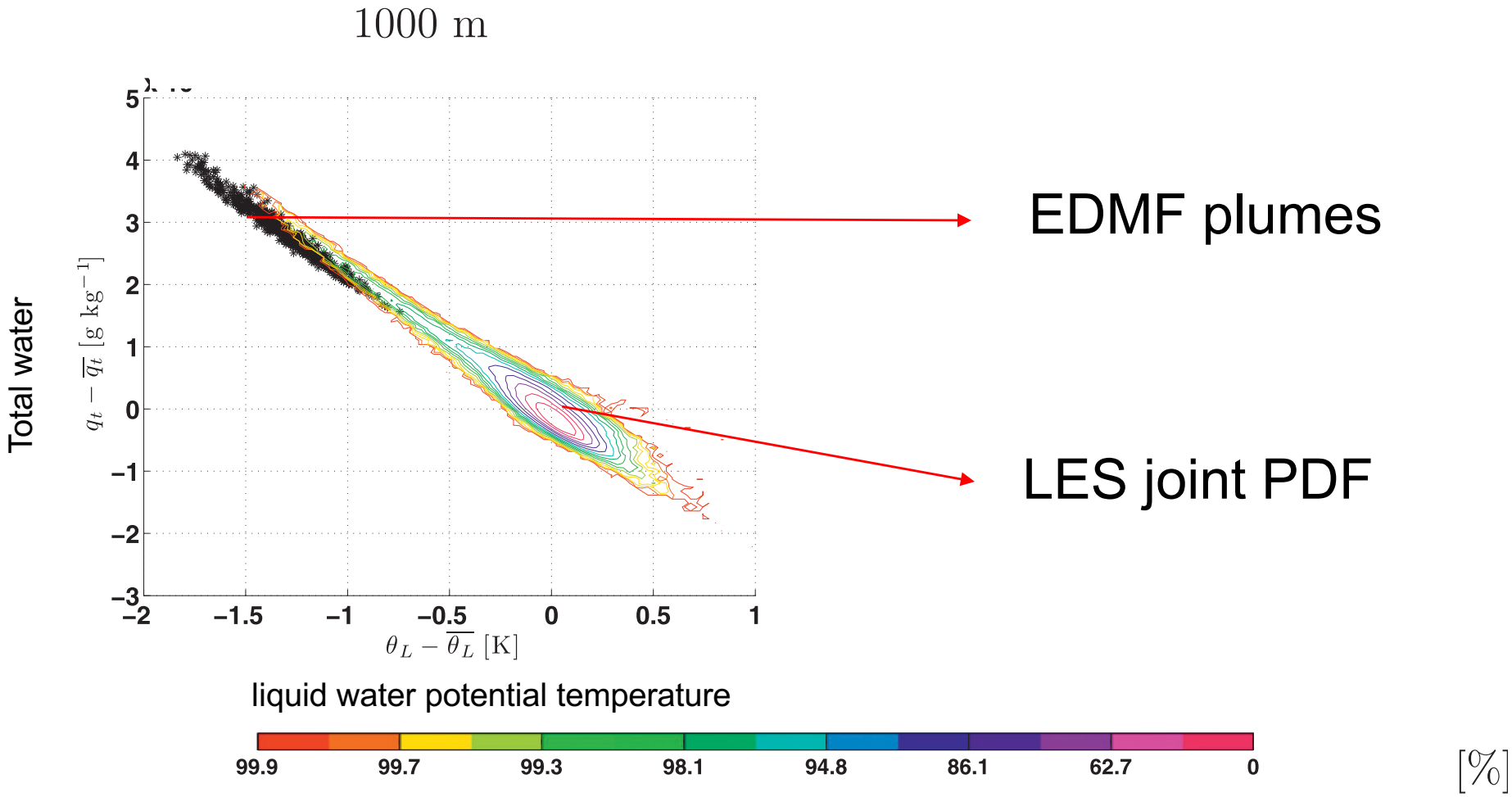


Low sensitivity of multiple-plume EDMF to surface updraft area

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

BOMEX: LES PDF vs EDMF plumes



EDMF plumes

LES joint PDF

EDMF multiple plumes represent skewed part of PDF

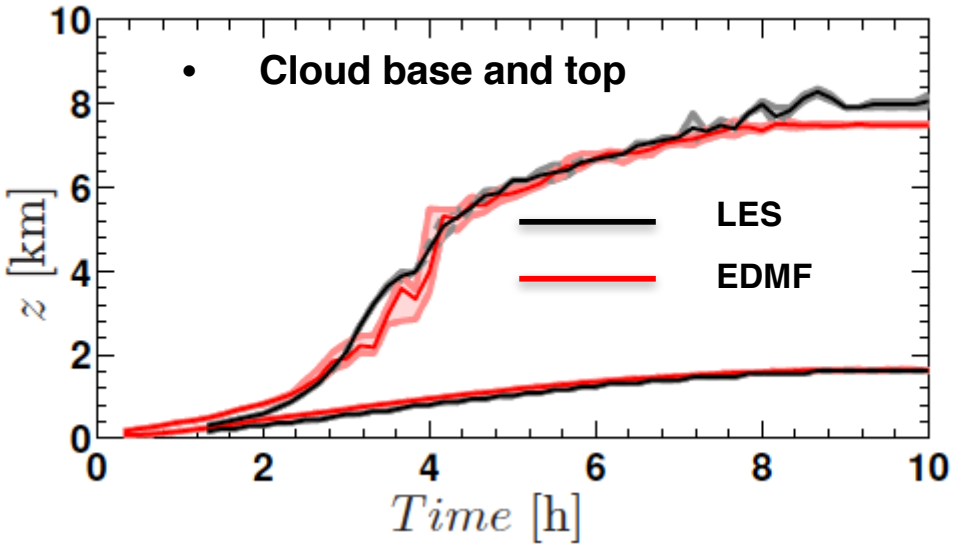
National Aeronautics and Space Administration

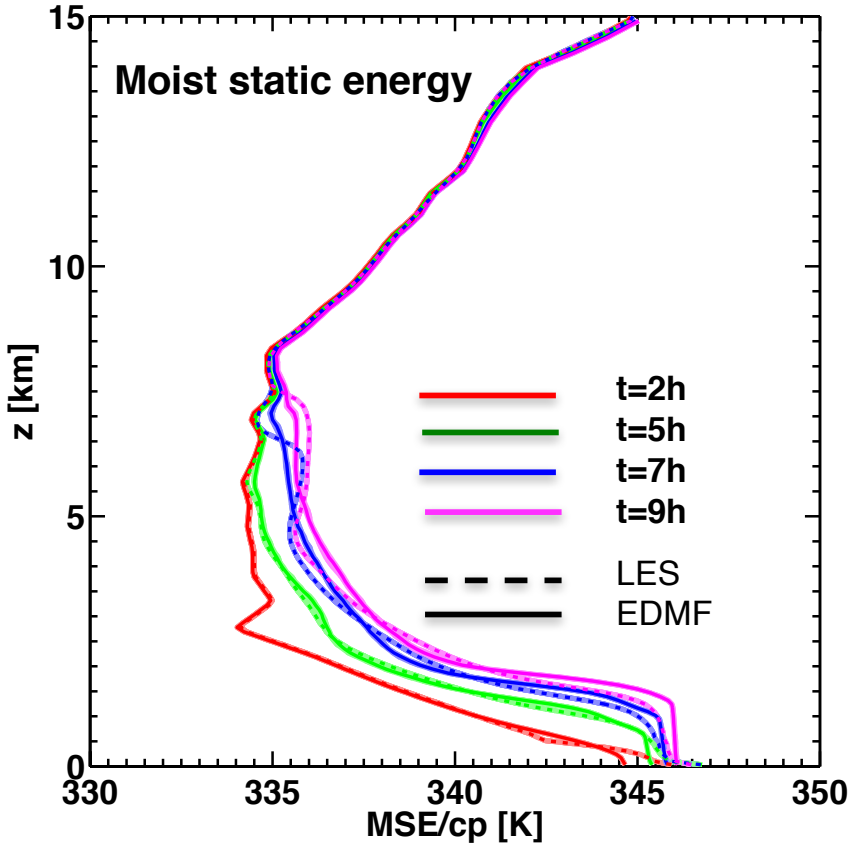
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Diurnal cycle of non-precipitating convection

Modified LBA case from Grabowski et al. (2006):

- Without microphysics, condensation with respect to liquid water
- EDMF validation against LES





EDMF plumes are realistic – microphysics still an open issue

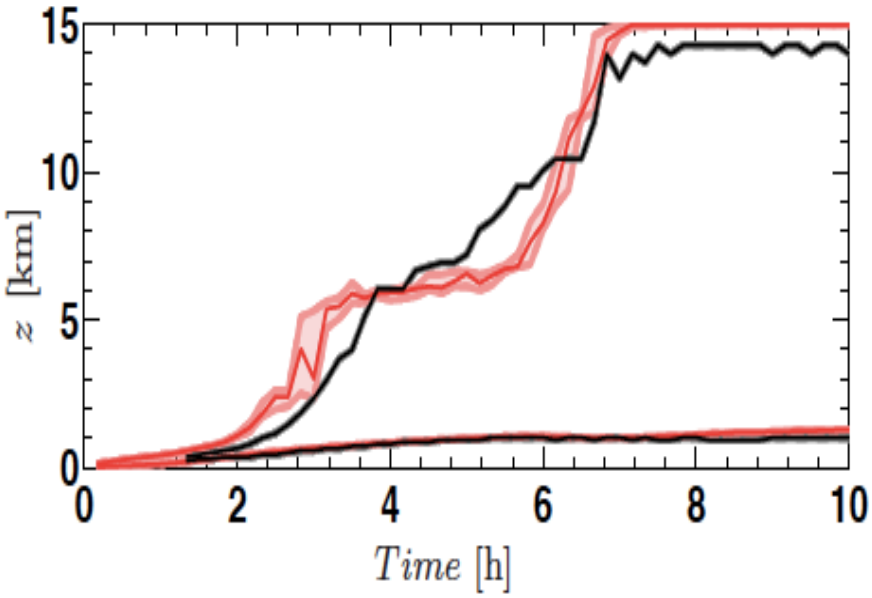
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

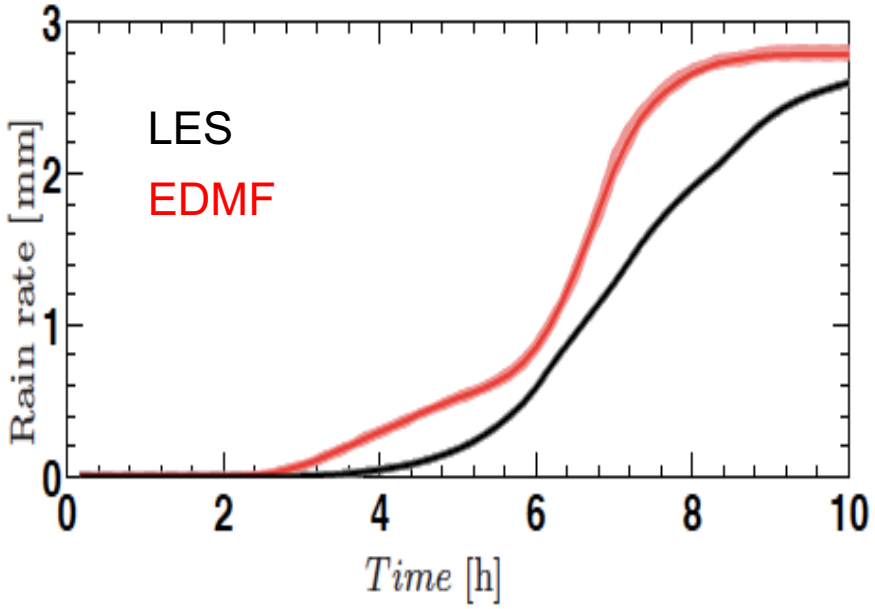
Diurnal cycle of precipitating convection over land - LBA

New fully unified (PBL + shallow + deep convection) EDMF evaluated for the LBA diurnal cycle of precipitating convection

Cloud base and top



Cumulative surface precipitation



Realistic transition with EDMF from shallow to deep convection

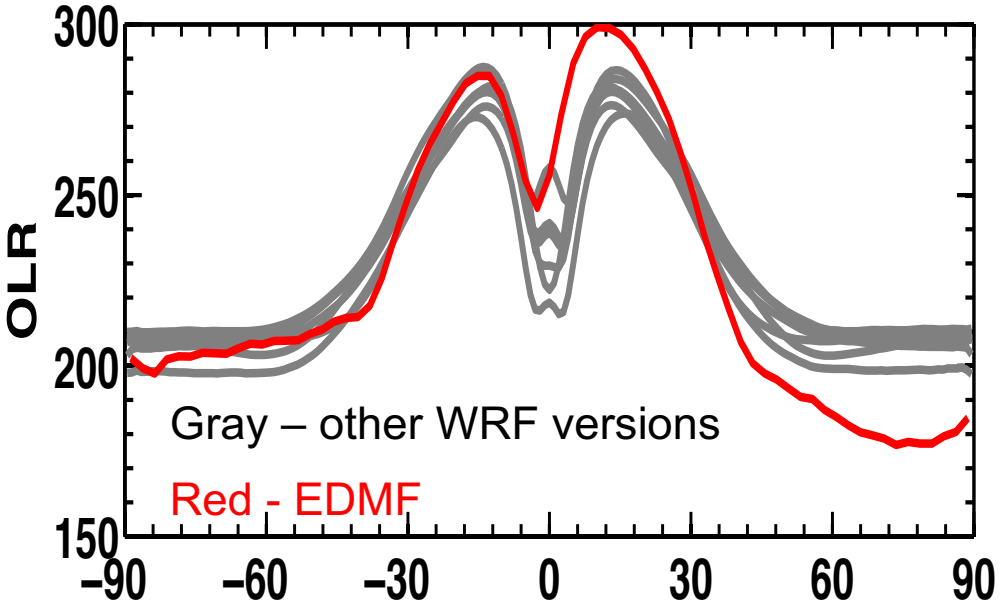
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

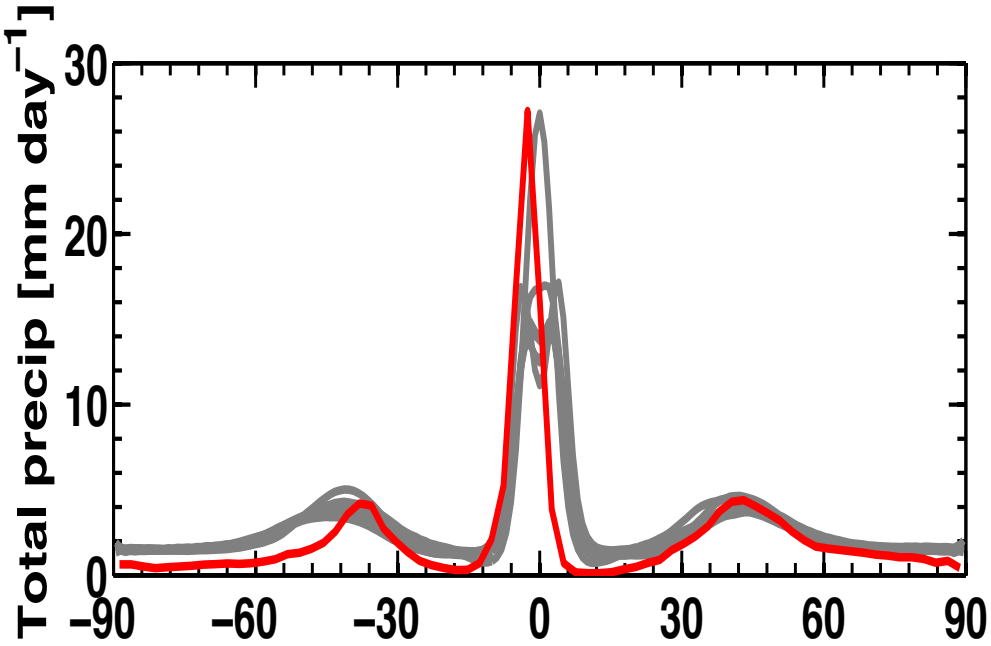
Fully Unified EDMF (PBL, shallow, deep convection): Aquaplanet Simulations

New fully unified EDMF implemented in global WRF aquaplanet
Single parameterization representing PBL and moist convection

OLR



total precipitation



Similar EDMF climate when compared with other WRF versions

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

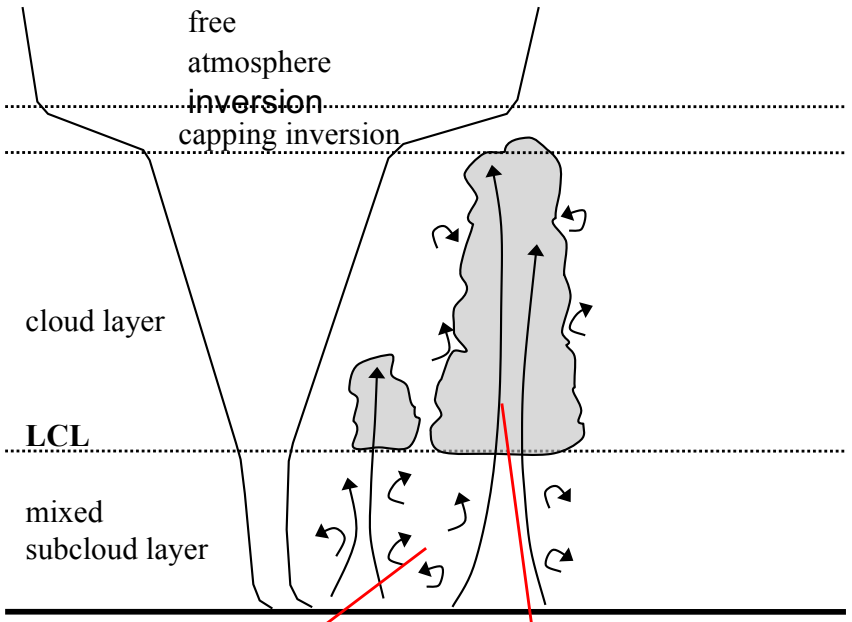
Summary

- EDMF combines ED and MF to represent in a unified way turbulence and convection in atmospheric models
- EDMF addresses key questions: counter-gradient flux, top entrainment, skewness of vertical transport in cumulus
- New EDMF version using surface PDF to generate multiple plumes represents well shallow and deep convection
- EDMF implemented into models: ECMWF, NAVGEM, NCEP
- Unified parameterization of turbulence and convection in atmospheric models: We are getting close

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Mass-Flux Model for Plumes/Updrafts



Small-scale
ED mixing

Large-scale
MF mixing

1) Integrating over plume area
2) Assuming steady-state
3) Neglecting some sources/sinks

$$\frac{\partial \phi_u}{\partial z} = -\varepsilon(\phi_u - \bar{\phi}) \text{ for } \phi \in \{\theta_l, q_t\}$$

$$M = \sigma_u w_u$$

$$\frac{1}{2}\frac{\partial w_u^2}{\partial z} = -b\varepsilon w_u^2 + a\frac{g}{\theta_0}\left(\theta_{v,u} - \overline{\theta_v}\right)$$

σ_u is updraft/plume area fraction and is fixed for each plume in our approach