Resolution dependence in the Zhang-McFarlane deep convection parameterization and impact of CAPE calculation

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Objective

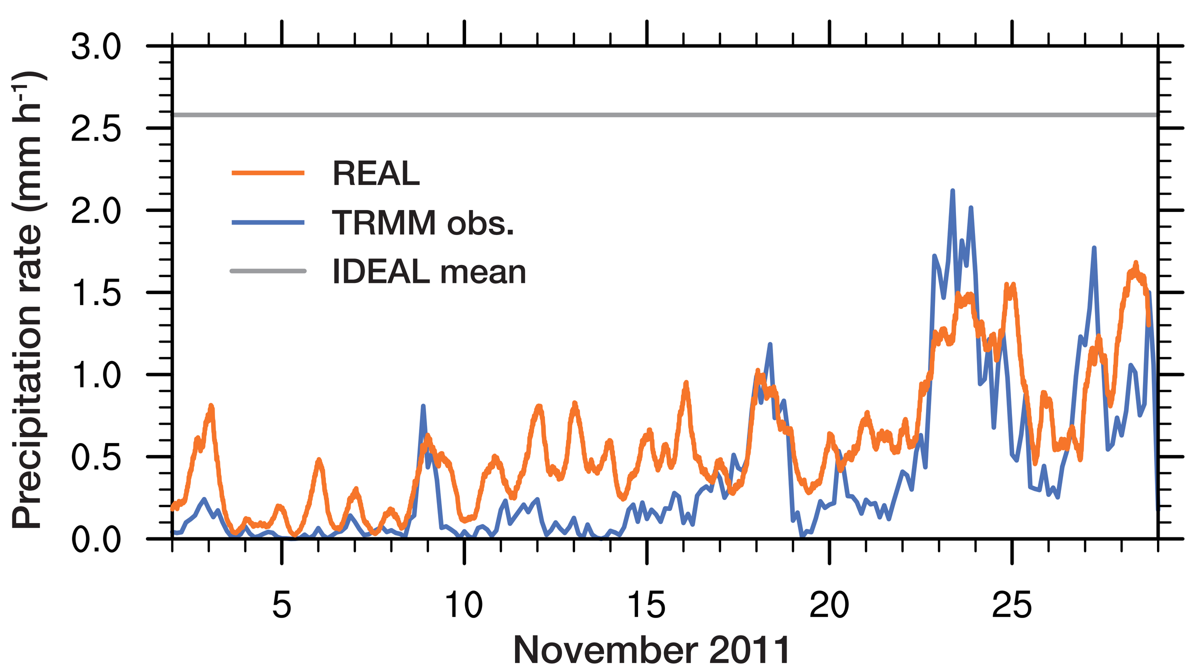
To better understand what drives the resolution dependence of quasi-equilibrium (QE) based convection parameterizations by analyzing the subgrid-scale vertical transport of moist static energy, $\overline{w'h'}$.

Methodology

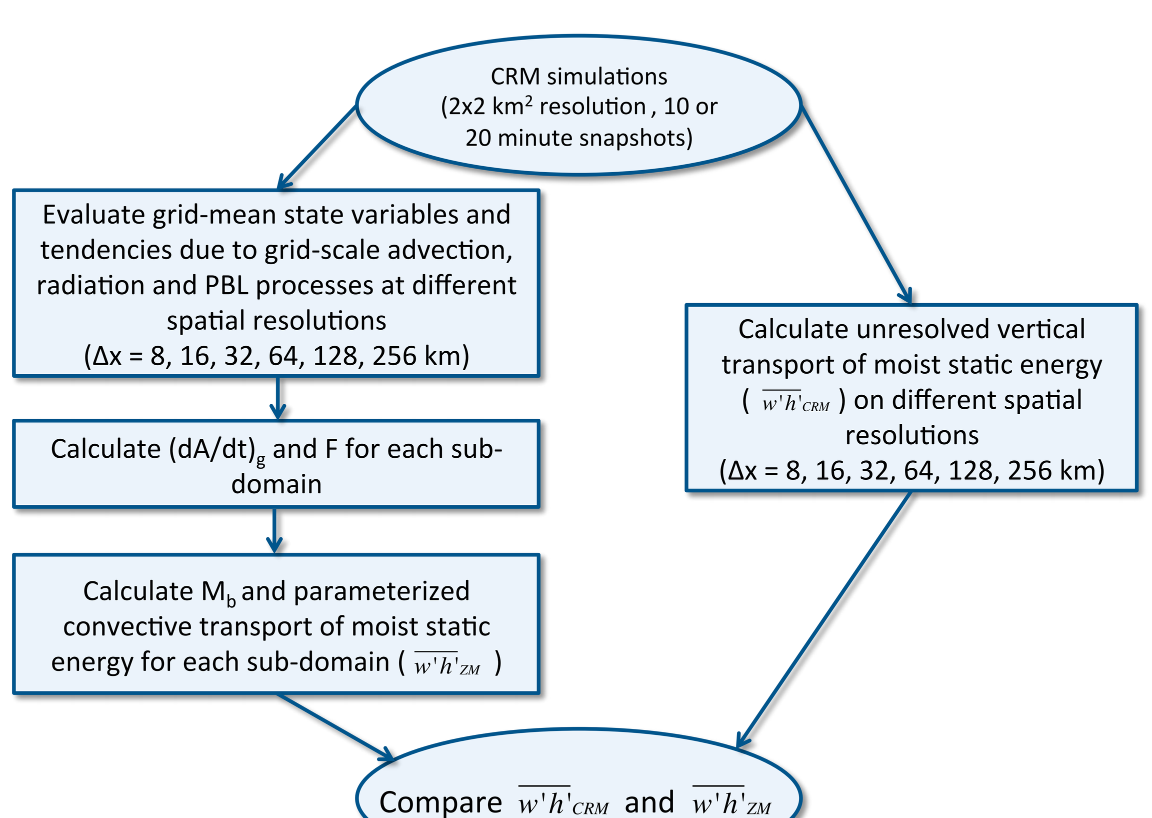
Use two CRM simulations to generate meteorological conditions to drive the Zhang-McFarlane convection parameterization (ZM) in an offline, diagnostic mode.

1) *Ideal case:* a radiative-convective equilibrium configuration using constant Q1 and Q2 forcing; the shear case from Arakawa and Wu (2013, JAS, doi:10.1175/jas-d-12-0330.1).

2) *Real case:* a 28-day realistic maritime tropical case with time-varying boundary conditions for the AMIE/DYNAMO period.

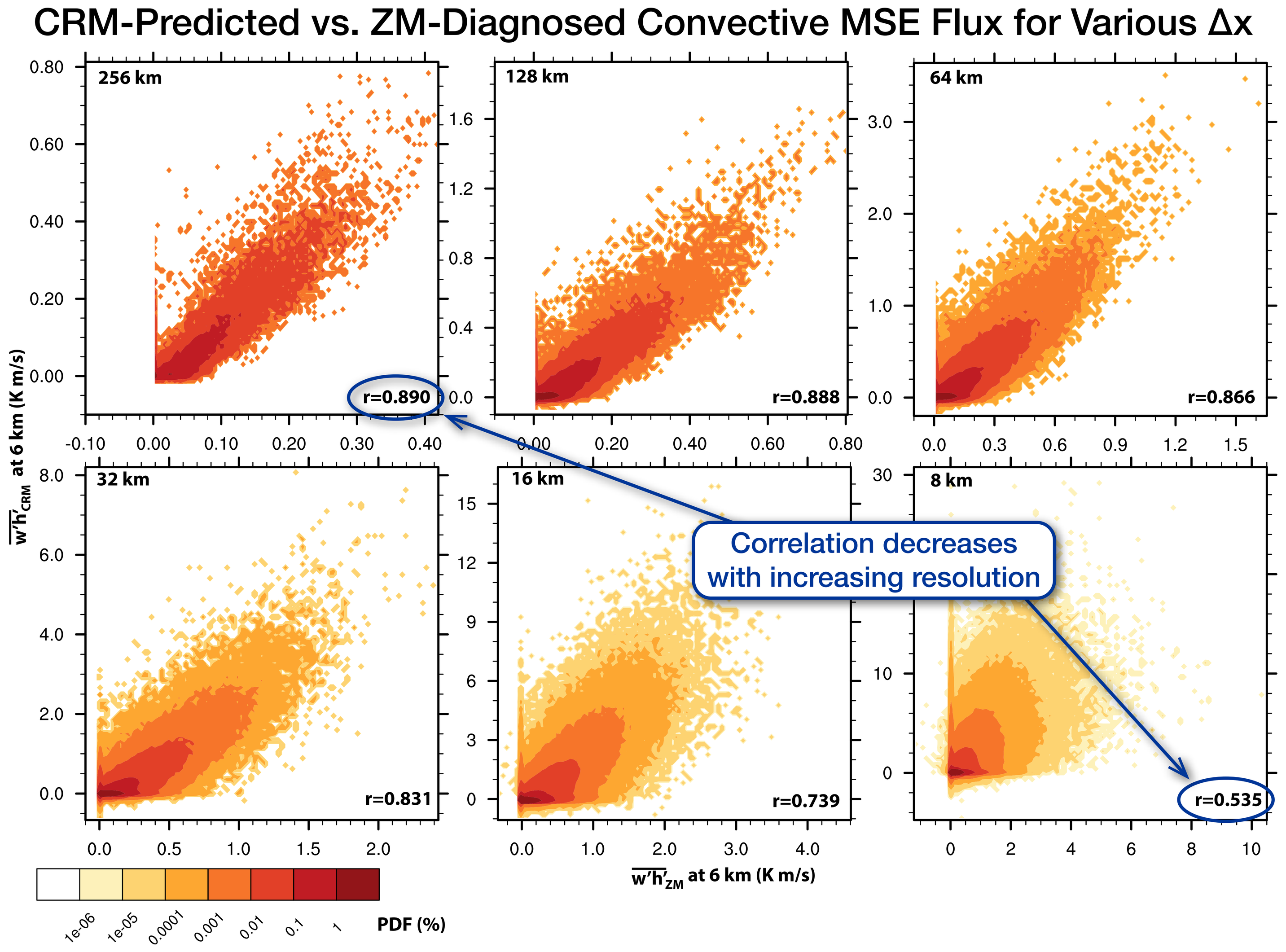


Average the 2-km CRM grid boxes to generate coarser grids ranging from 8×8 to 256×256 km², which are then used to drive ZM. The resulting diagnosed convective transport of moist static energy, $\overline{w'h'}_{ZM}$, is directly compared to the simulated equivalent from the CRMs, $\overline{w'h'}_{CRM}$.



Predictive capability of QE declines with increasing resolution

CRM-Predicted vs. ZM-Diagnosed Convective MSE Flux for Various Δx



Implications: parameterizing convection

QE-based closures need to consider scales large enough to encompase a range of cloud scales or else their predictive capabilities decline.

Local convective calculations that include non-local, larger scale information improve the ability to predict the overall convective state across a range of resolutions. This implies closures should be aware of regions larger than one column.

Details for scales smaller than the QE closure region could be treated stochastically.

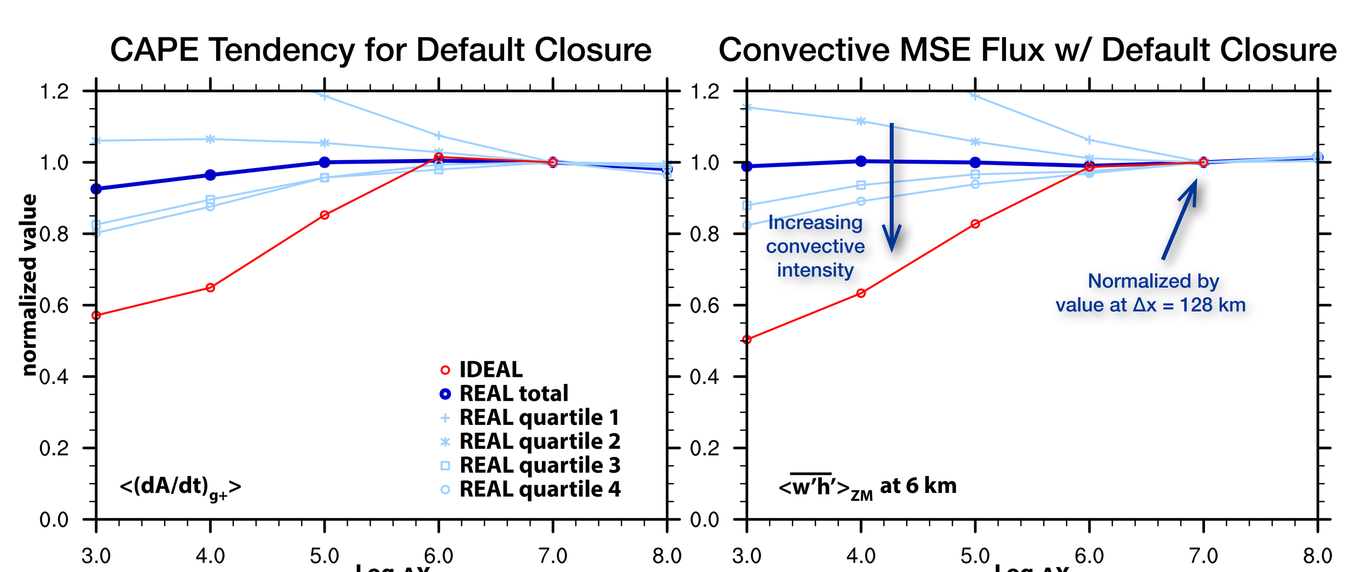
Xiao, H., W. I. Gustafson, S. M. Hagos, C.-M. Wu, and H. Wan, 2015: Resolution-dependent behavior of subgrid-scale vertical transport in the Zhang-McFarlane convection parameterization, *J. Adv. Model. Earth Sys.*, accepted.

Closure assumption impacts the resolution dependent behavior

The CRM is a proxy for realistic convective motions to compare against the diagnostic ZM calculated grid-scale values of CAPE tendency, $(dA/dt)_g$, and convective MSE flux. The ZM closure only uses positive CAPE tendencies to determine convective strength. A diagnostic equivalent connecting the CAPE tendency to the cloud base mass flux, M_b, is

$$M_bF = \left(\frac{dA}{dt}\right)_{g+} \equiv \max\left[\left(\frac{dA}{dt}\right)_g, 0\right]$$

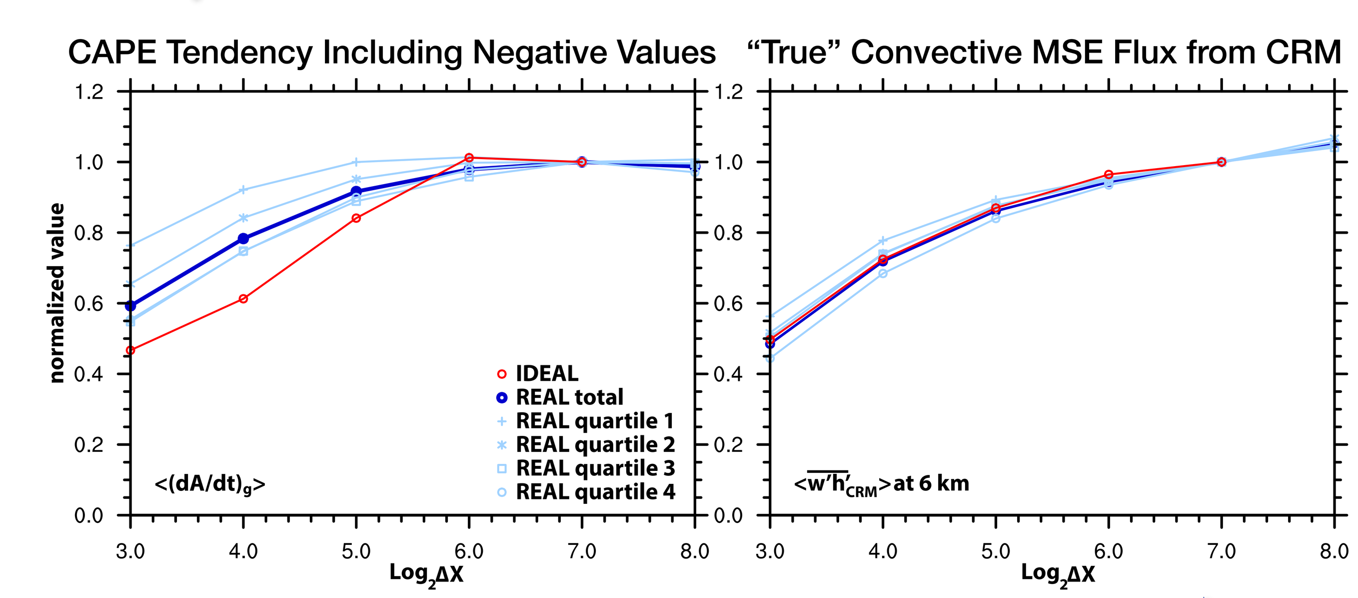
Resolution dependence of grid-scale CAPE tendency depends on convective intensity (quartiles in plots).



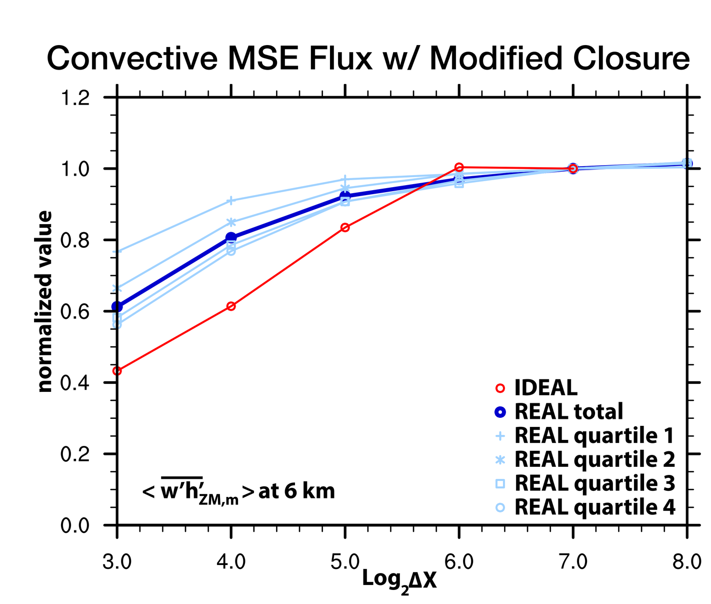
This directly leads to the resolution-dependent and convective-intensity-dependent convective MSE flux.

Reality sometimes has negative CAPE tendencies in the presence of convection, which alters the overall resolution dependence.

Including negative CAPE tendencies in the ensemble results in similar resolution dependence across convective intensities.



The resulting behavior mimics the CRM resolution dependence across convective intensities.



Resolution dependence can be improved by modifying the closure to average over an area where QE holds, *i.e.*, where negative CAPE tendencies cannot dominate the ensemble.

$$M_bF = \left(\frac{dA}{dt}\right)_{gm+} \equiv \max\left[\overline{\left(\frac{dA}{dt}\right)_g}, 0\right]$$

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