Multiple-scale simulations of the impact of PBL and shallow convection schemes on the initiation of convection over the tropical ocean

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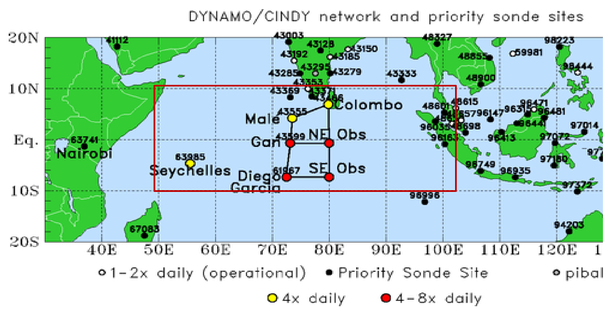
1. Abstract

The goal of this study is to identify weaknesses of current Planetary Boundary Layer (PBL), surface and convection schemes in capturing the initiation of convection and intra-seasonal variability of precipitation, and transfer our better understanding in those processes into improved parameterizations. By comparing the WRF simulation results with different spatial resolutions, PBL, surface layer and shallow convection schemes, we have identified the bias and weakness of each scheme and investigated the dependence of modeled PBL structure and initiation of convection over the tropical ocean, which provide insights for improving these parameterizations.

2. Model and Experiment

- Three PBL parameterizations: Yonsei University (YSU), Mellor-Yamada-Janjić (MYJ), and University of Washington (UW). The UW and MYJ scheme are TKE based while YSU is a non-local scheme. The UW PBL scheme is currently implemented in CAM5 as well.
- Two surface layer schemes: MM5 and Eta both based on Monin-Obukhov similarity theory.
- The KF-CuP convective parameterization has been modified to better account for shallow clouds (Berg et al. 2013).
- Free run vs. water vapor nudged simulations are used to quantify the component tendency and model bias.
- SST is prescribed in all simulations.
- Time period: November, 2011.

Model Domain

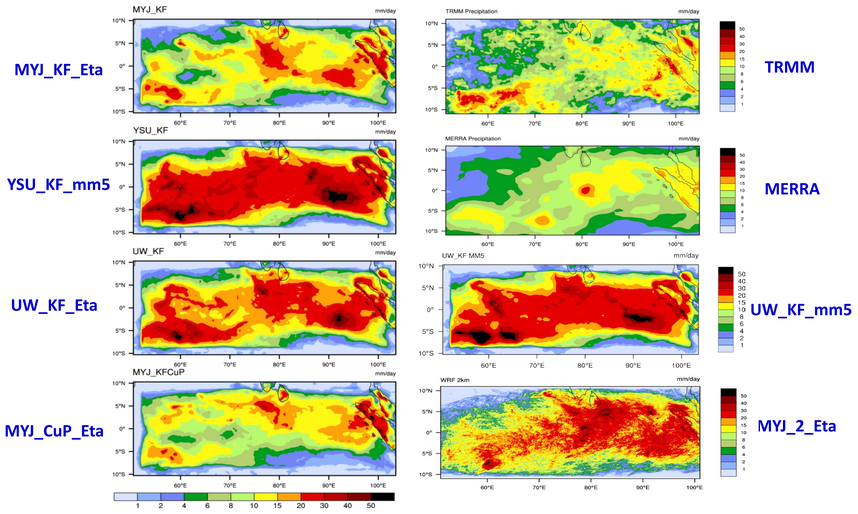


Experiments

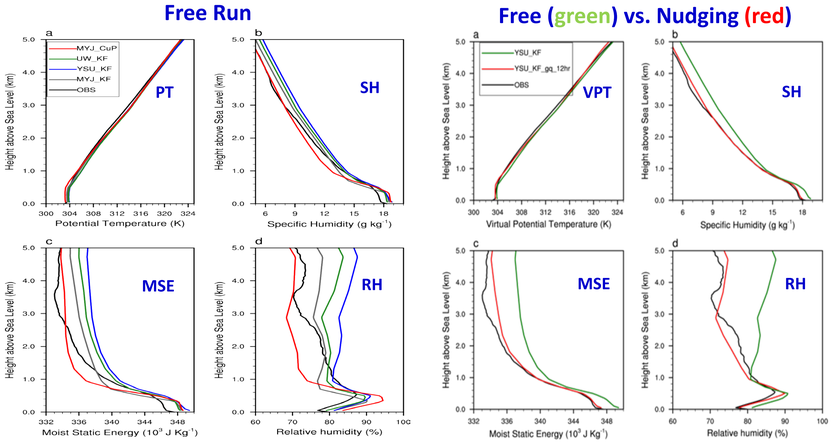
Experiment	Grid Spacing (km)	Convection Scheme	PBL Scheme	Surface Scheme	Nudging
YSU_KF_mm5	10 & 50	KF	YSU	mm5	Y & N
MYJ_KF_Eta	10 & 50		MYJ	Eta	Y & N
UW_KF_mm5	50		UW	mm5	Y & N
UW_KF_Eta	10 & 50			Eta	
MYJ_CuP_Eta	10 & 50	KF+CuP	MYJ	Eta	Y & N
MYJ_2_Eta	2	N/A	MYJ	Eta	N

3. Results

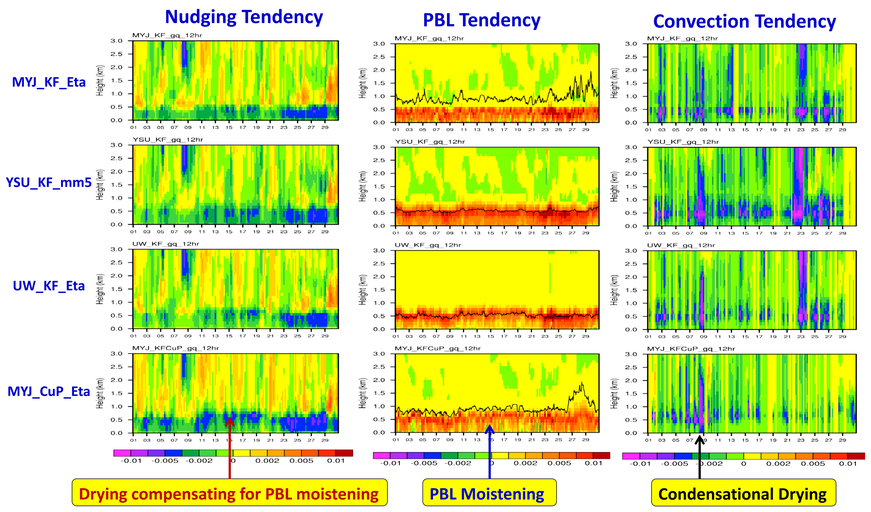
Precipitation (mm day^{-1})



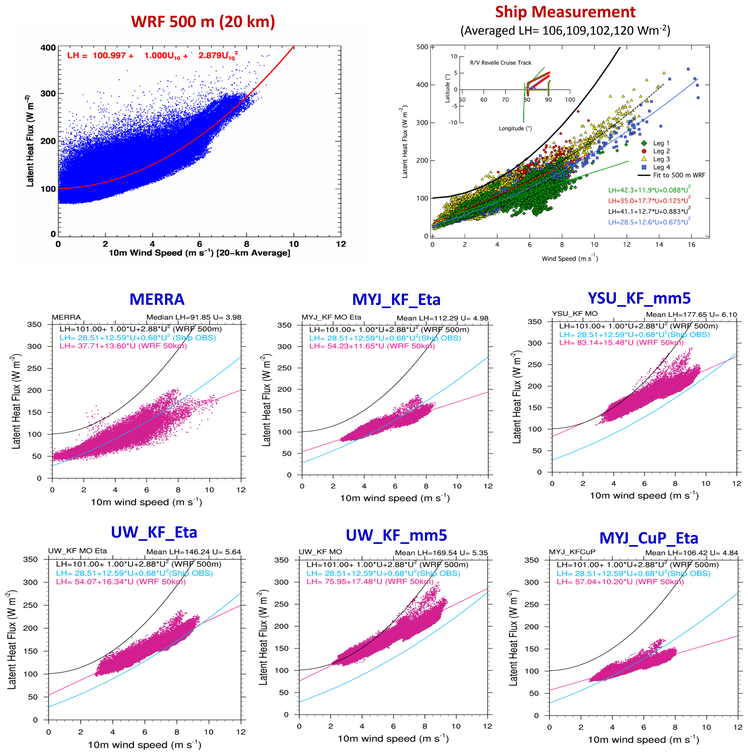
Vertical Profiles at Gan



Water vapor Nudged Simulation



Surface LH Flux vs. Wind Speed



4. Summary

- PBL and surface parameterizations have surprisingly large impacts on surface moisture flux, precipitation and convection initiation.
- All three tested PBL schemes tend to overpredict precipitation and moisture in PBL and free atmosphere, and consequently larger moist static energy.
- Updated shallow convection scheme KF-CuP tends to suppress the initiation and development of deep convection, consequently decreasing precipitation.
- Vertical transport of water vapor is too active in all PBL schemes and moisture nudging tends to suppress the initiation of convection and reduces the overpredicted precipitation.
- MM5 surface scheme, based on Monin-Obukhov similarity theory, predicts much larger upward moisture flux and consequently PBL moisture and precipitation than Eta surface scheme.
- Eta surface scheme predicts reasonable Latent Heat (LH) flux and LH-Wind Speed relationship, especially when coupled with MYJ scheme.
- When Eta surface scheme is applied, UW PBL scheme predicts larger surface wind speed and slope of LH vs. WP, thus larger LH than MYJ scheme. UW and YSU generally generate similar magnitudes of LH when the same MM5 surface scheme is applied in the simulations.
- Future work will include simulations using WRF with a complete CAM5 physics package.

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