Mesoscale Convective Mass Flux in Tropical Cyclones

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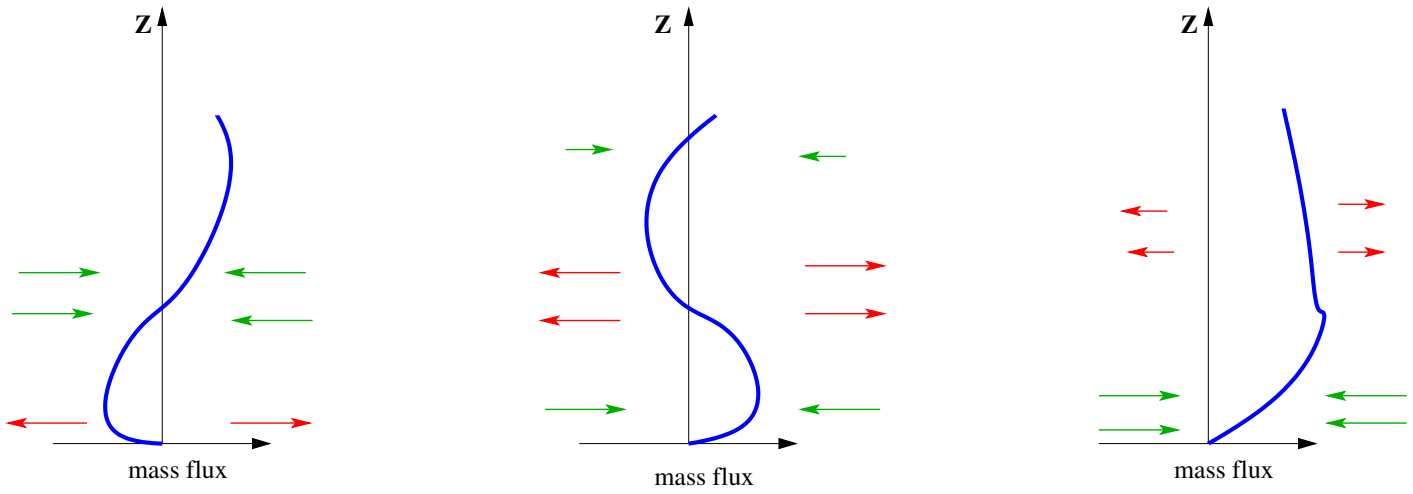
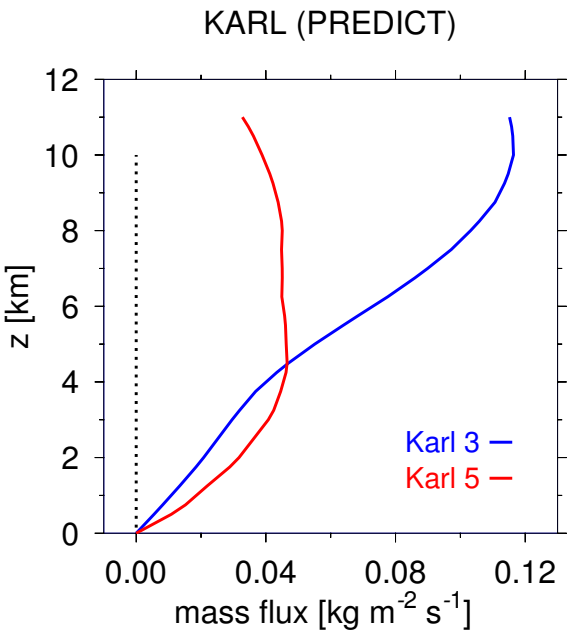
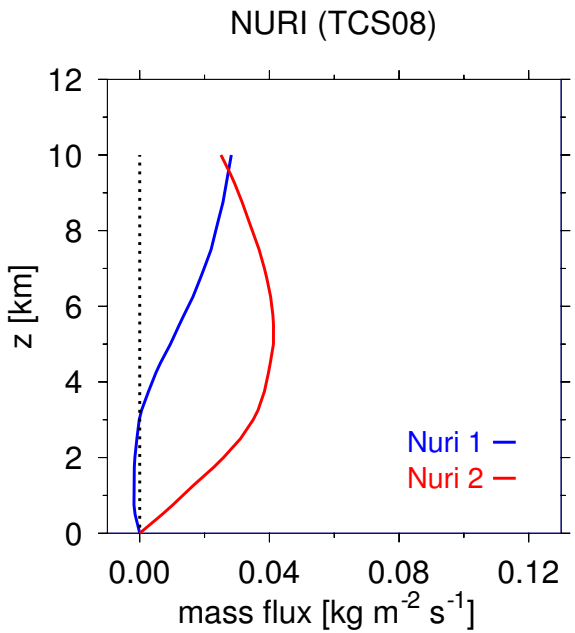
Mass flux profile and tropical storms

- Tropical cyclones - interaction between dynamics and thermodynamics.
- Mass flux profile - means of communication between thermodynamics and dynamics.



Mass flux profiles from observations





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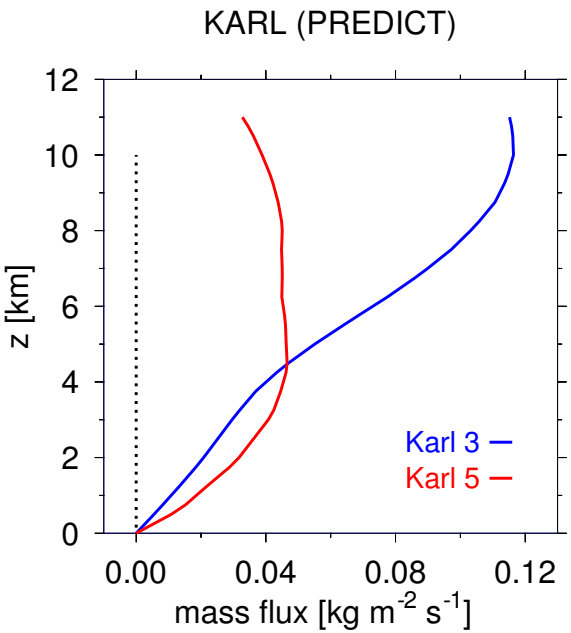
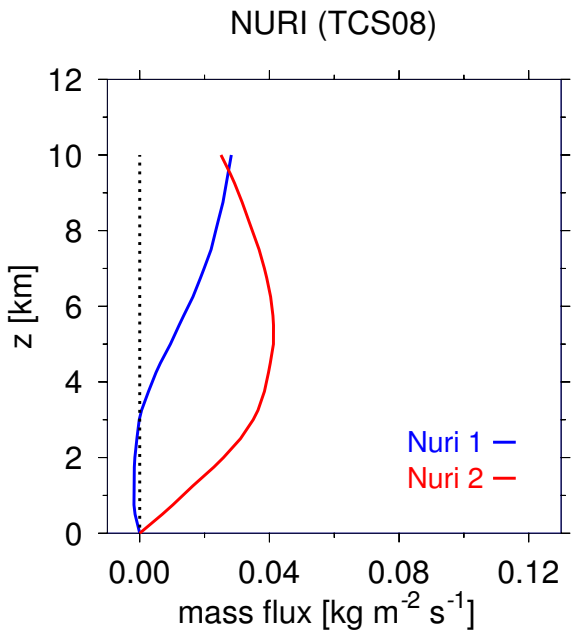
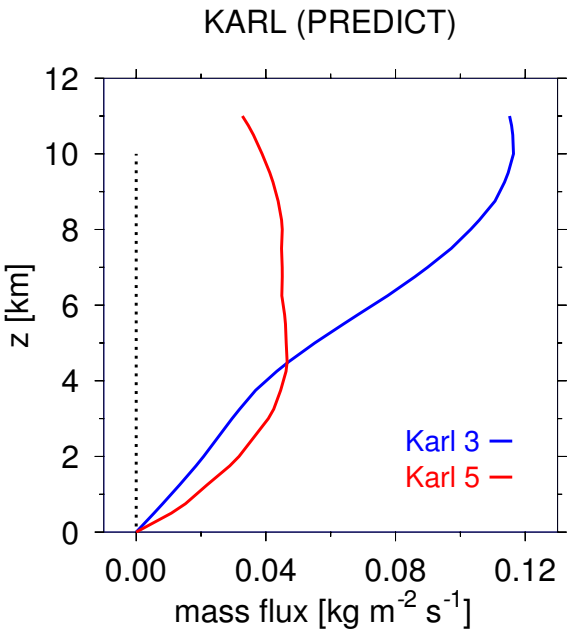


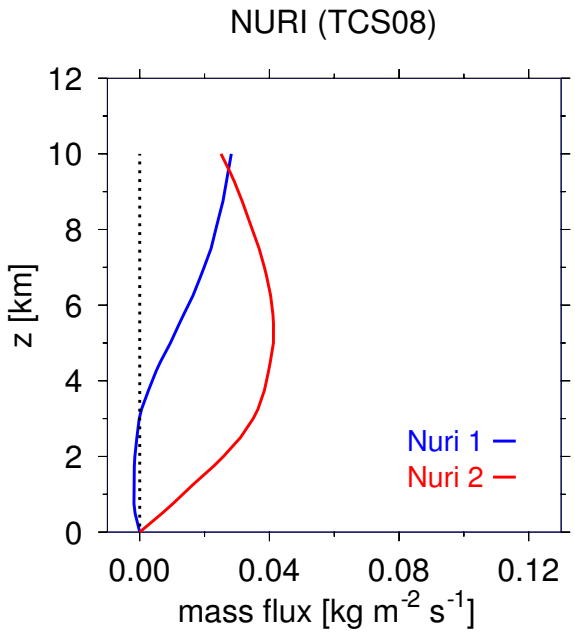


Tropospheric conditions for bottom-heavy mass flux profile?

Mass flux profiles from observations

Instability Index: $\Delta s^* = s^*_{1-3km} - s^*_{5-7km}$





$\Delta s^* = 26.2$ J/kg/K

$\Delta s^* = 16.4$ J/kg/K

$\Delta s^* = 17$ J/kg/K

$\Delta s^* = 11$ J/kg/K

Questions to address in a Numerical Model

"Controls" of the mass flux profile

- Effects of surface fluxes on mass flux profile.
- Effects of stability on mass flux profile.
  - Why more stable stratification is conducive to bottom-heavy mass flux profiles?
- Combined effect?

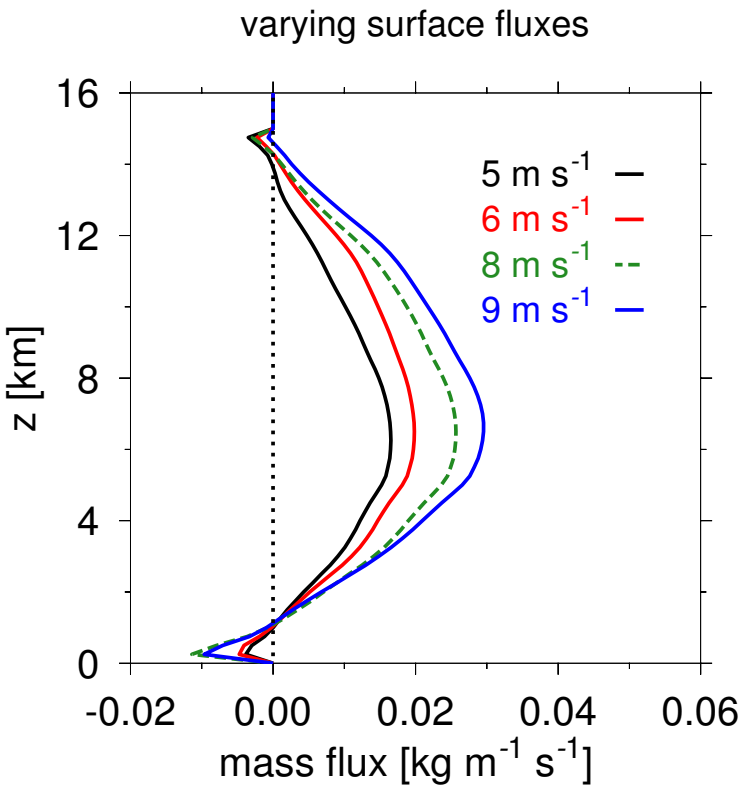
Cumulus Resolving Model (CRM)

Weak temperature gradient approximation (WTG)

- 2D (256 km, resolution 1 km)
- Non-rotational
- Interactive radiation scheme
- WTG - convenient way of parametrizing the convective environment.
  1) obtain a reference profile (RCE simulation)
  2) perturb the reference profile and run the model in WTG mode

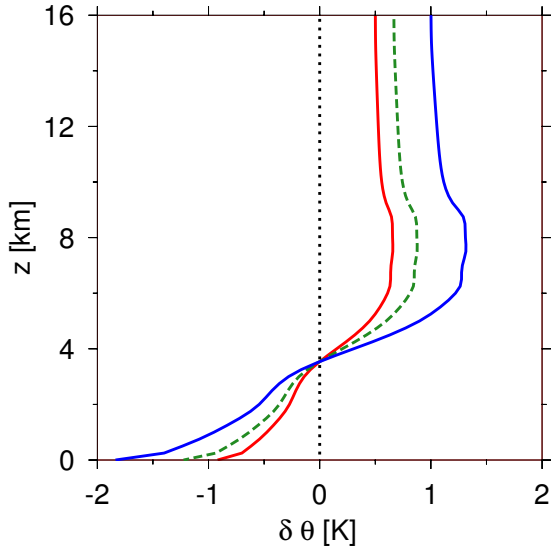
Convective mass flux in CRM

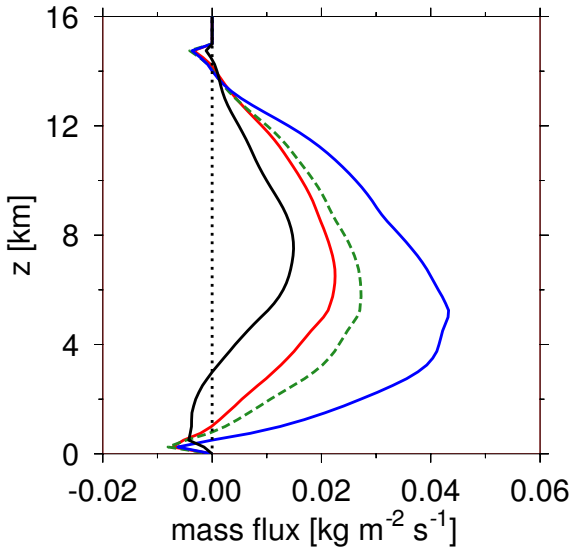
Effects of surface fluxes on mass flux profile



Convective mass flux in CRM

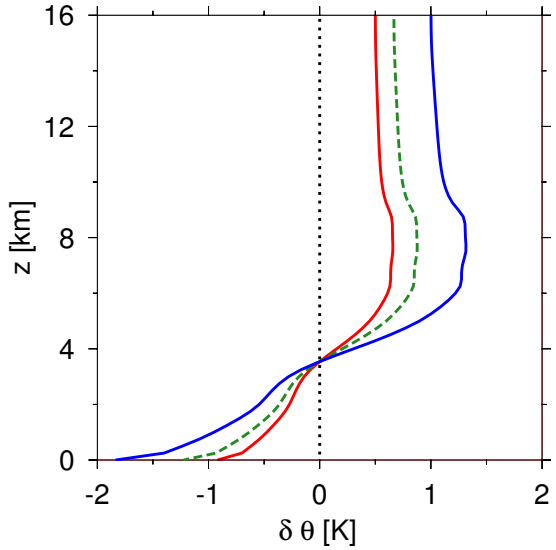
Effects of stability on mass flux profile

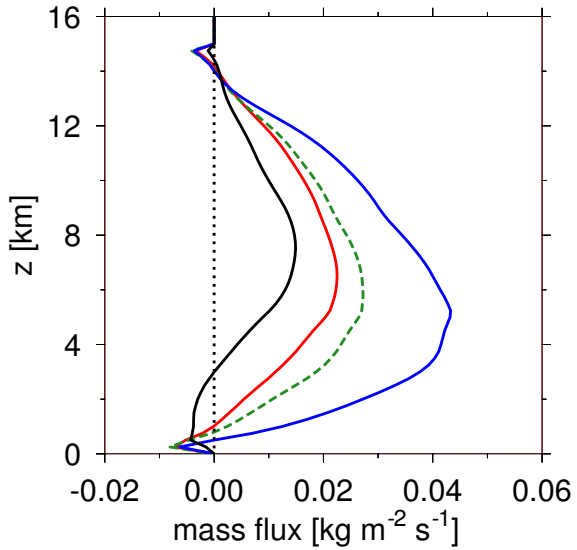


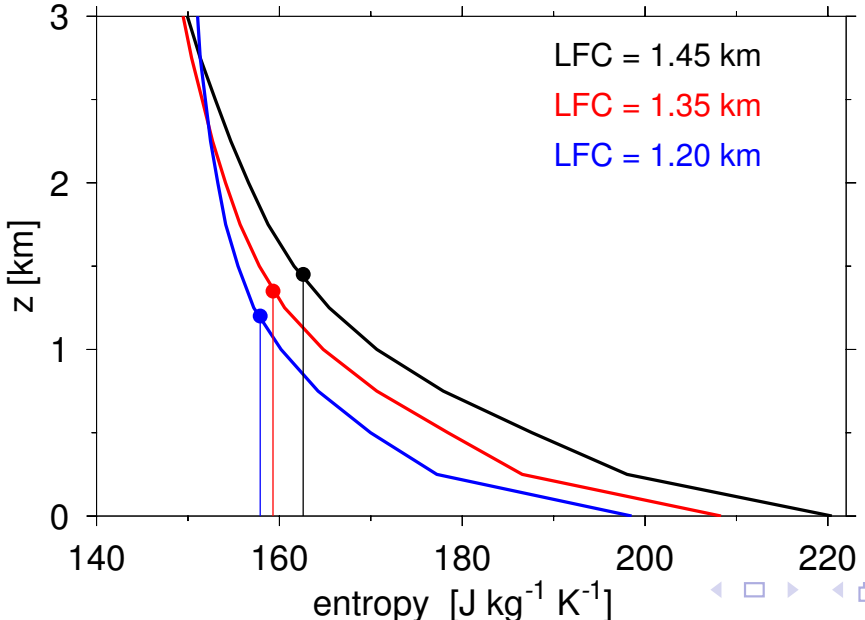


Convective mass flux in CRM

Effects of stability on mass flux profile







Convective mass flux in CRM

Diagnostic variables

Normalized vertical mass flux:

$$M(z) = \frac{(\rho w)(z)}{max[(\rho w)(z)]}$$

Mass flux index:

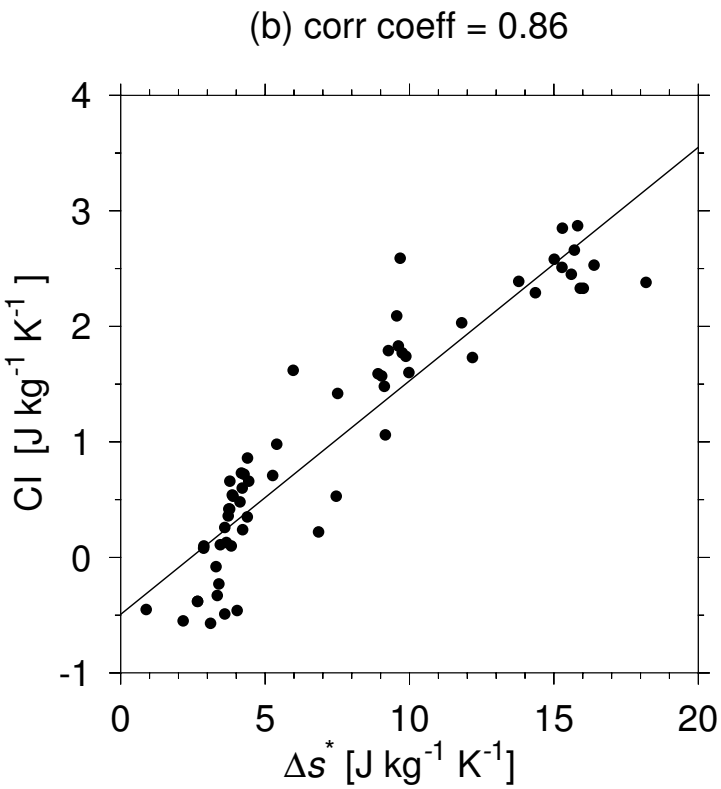
$$Mfi = M_{3-5km} - M_{7-9km}$$

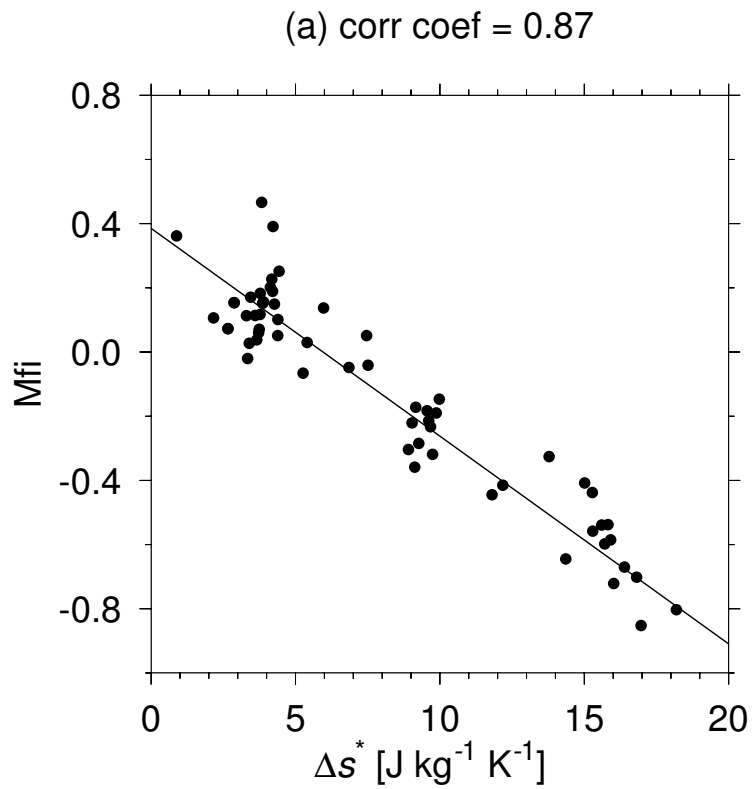
CIN index:

$$CI = (\theta_e^*)_{0.75-1km} - (\theta_e)_{0-0.75km}$$

Convective mass flux in CRM

Effects of stability on mass flux profile



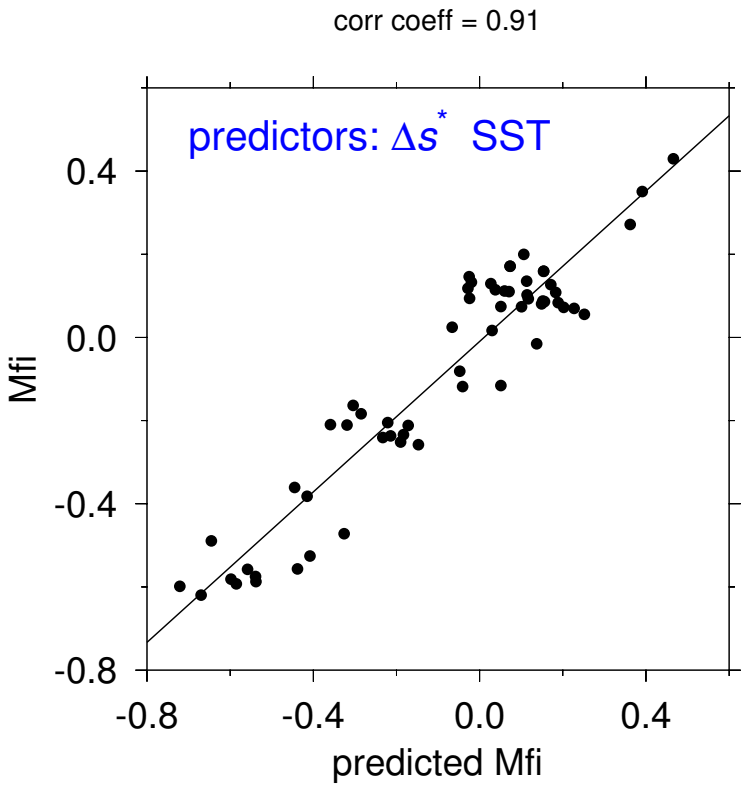


Reduced CIN in more stable stratification!

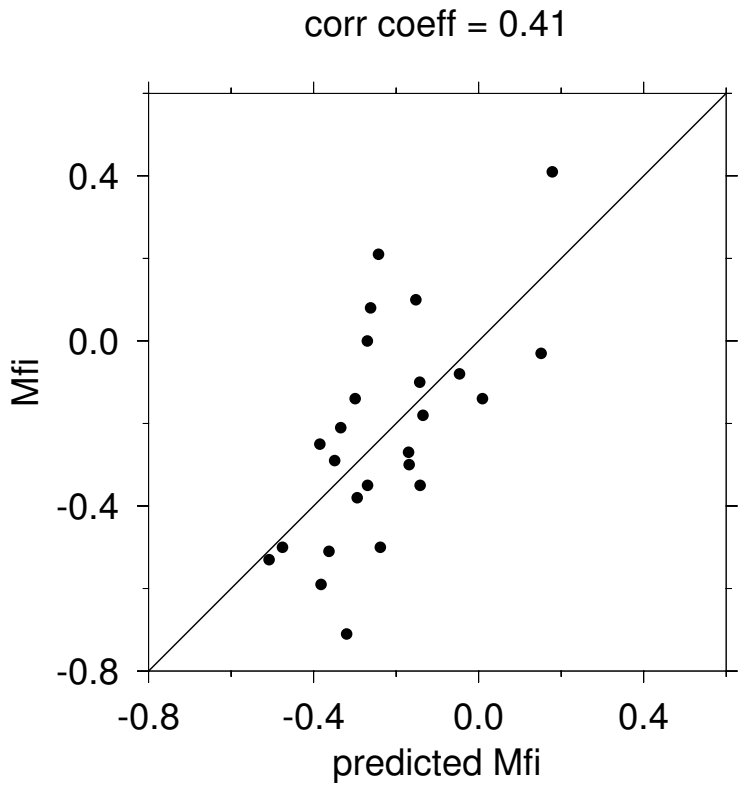
Convective mass flux in CRM & Observations

Combined effect (stability + surface fluxes)

CRM

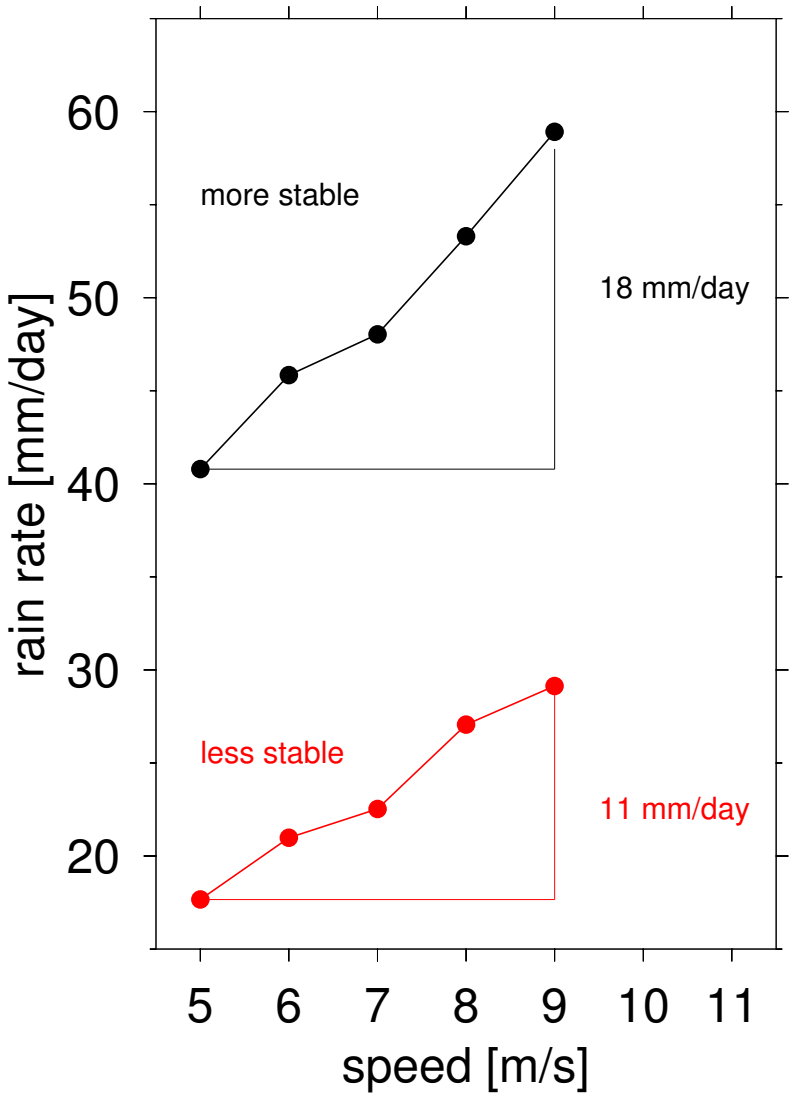


TCS08 and PREDICT



Convective mass flux in CRM

Combined effect (stability + surface fluxes)



Summary

- The shape of the MFP is largely determined by the thermodynamic stratification.
- Increased surface fluxes - more mass flux at high elevations.
- Increased stability - a lot more mass flux at lower elevations
  - less CIN, lower LFC -> parcels start accelerating at lower altitudes.
- Disturbances transitioning over warmer waters are likely to spin-up faster if they exhibit bottom-heavy MFP.

Simulating observed MFP

Nuri 1 and Nuri 2