Using a super-parameterized version of WRF to study the ITCZ and convection parameterization

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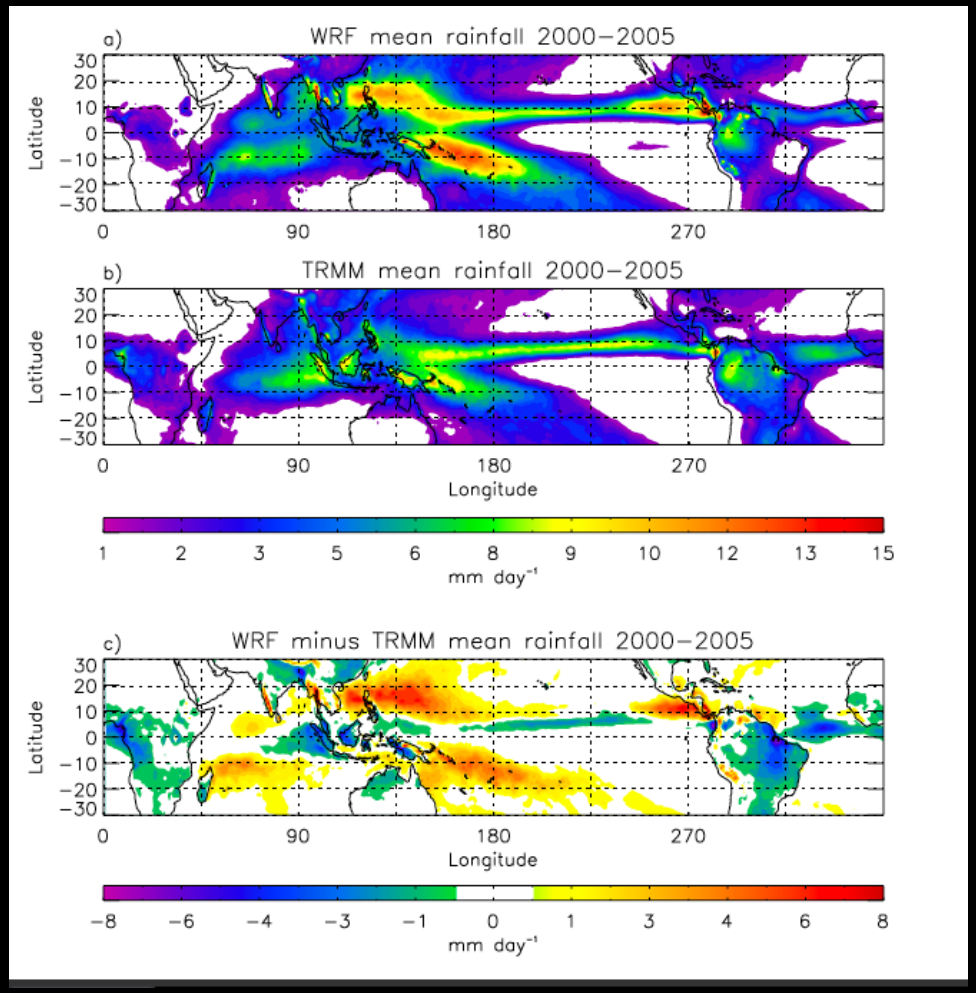
Motivation: WRF 36-km regional climate simulations exhibit significant tropical biases

36-km WRF

TRMM

Difference

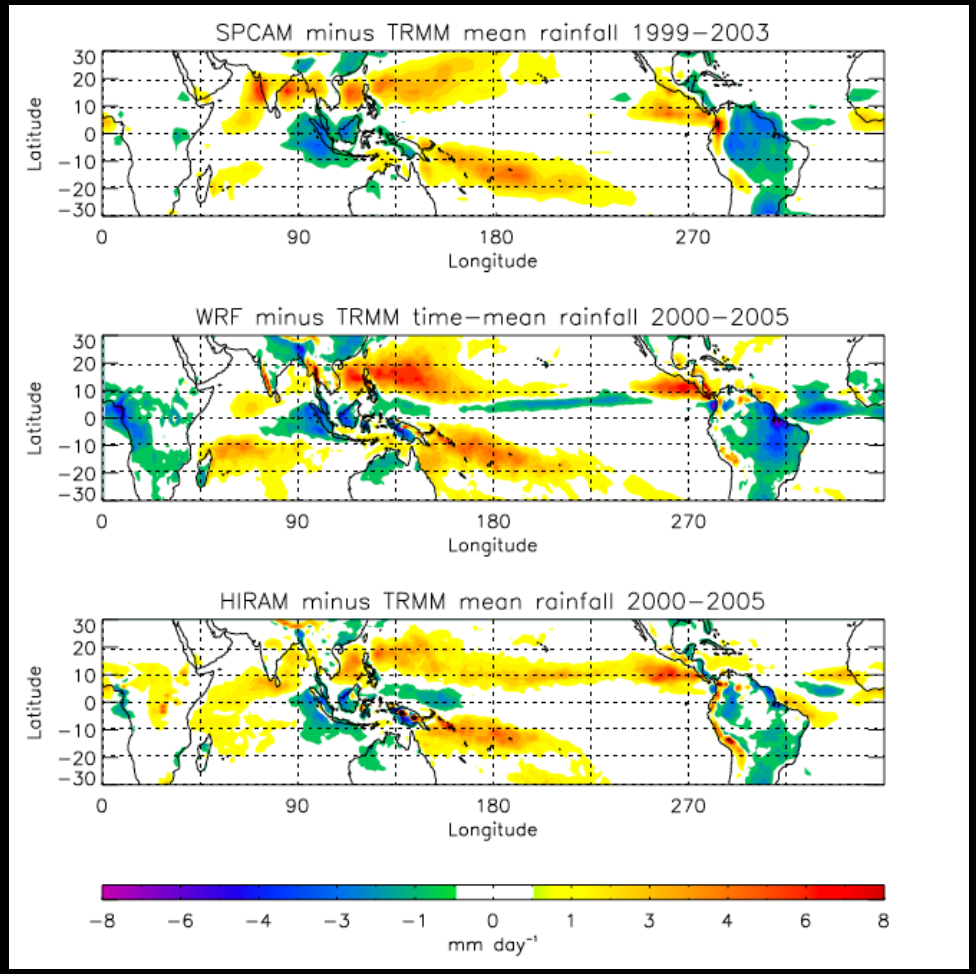


Similar biases are apparent in 2.8 deg. SP-CAM and GFDL's 50-km HiRAM

2.8 deg. SPCAM

36-km WRF

50-km HiRAM



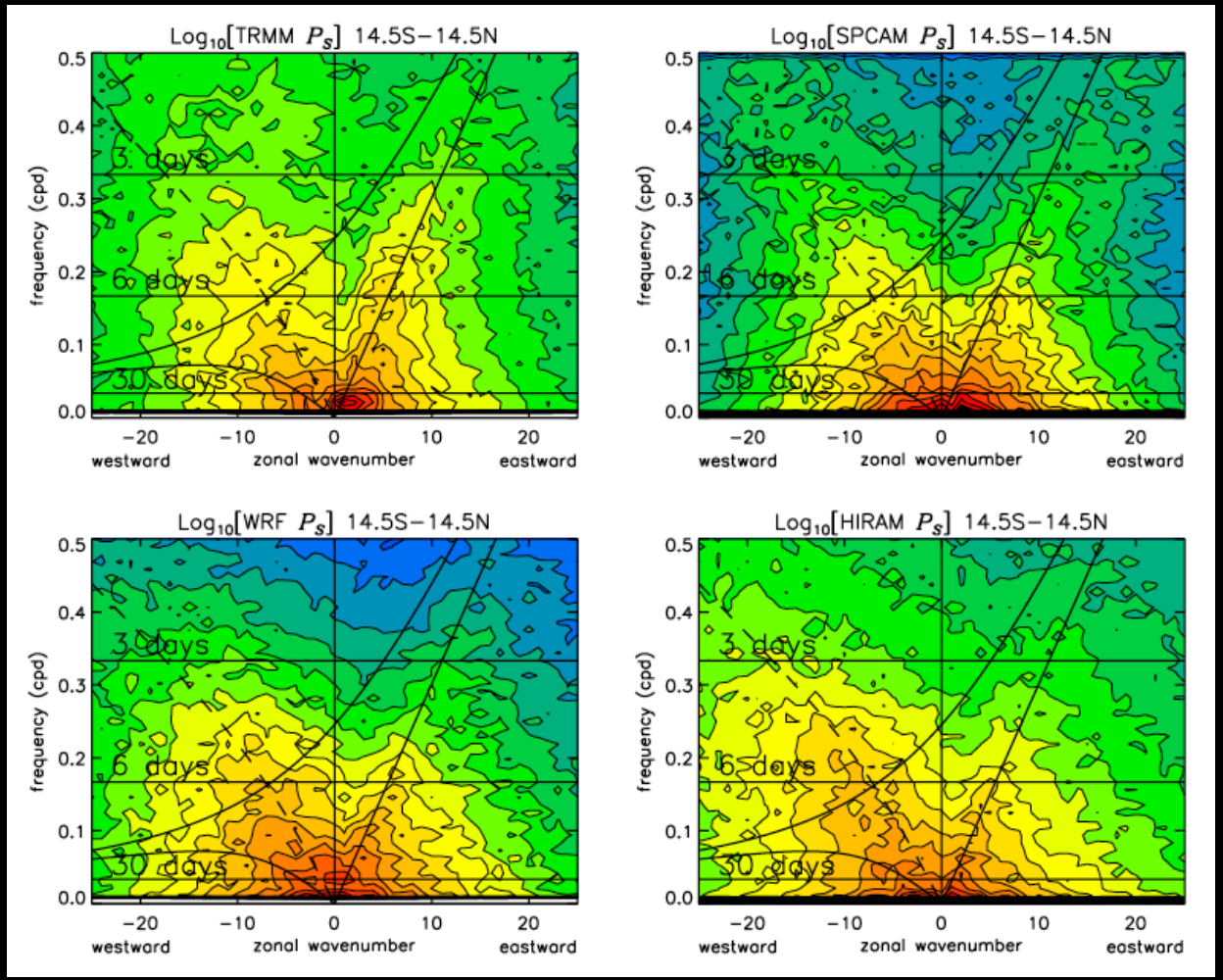
Biases in the time-mean are associated with biases in synoptic transients

TRMM

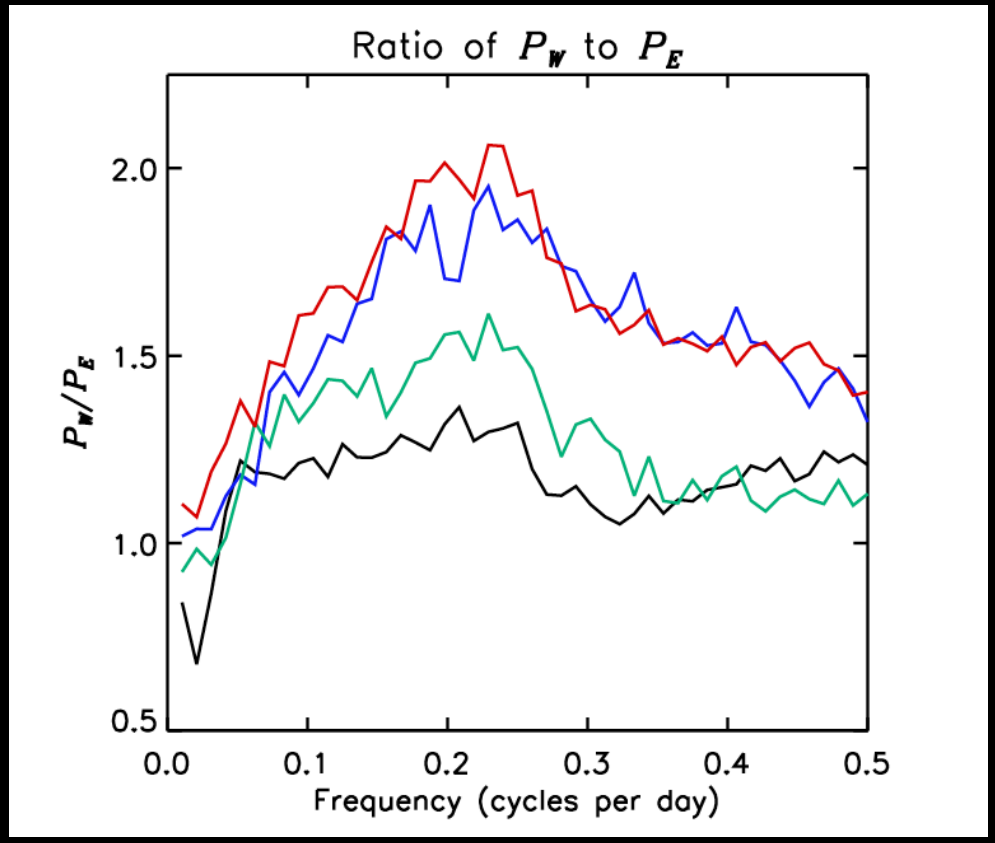
SPCAM

WRF

HIRAM



Ratio of westward- to eastward-moving variance (k =1-25)

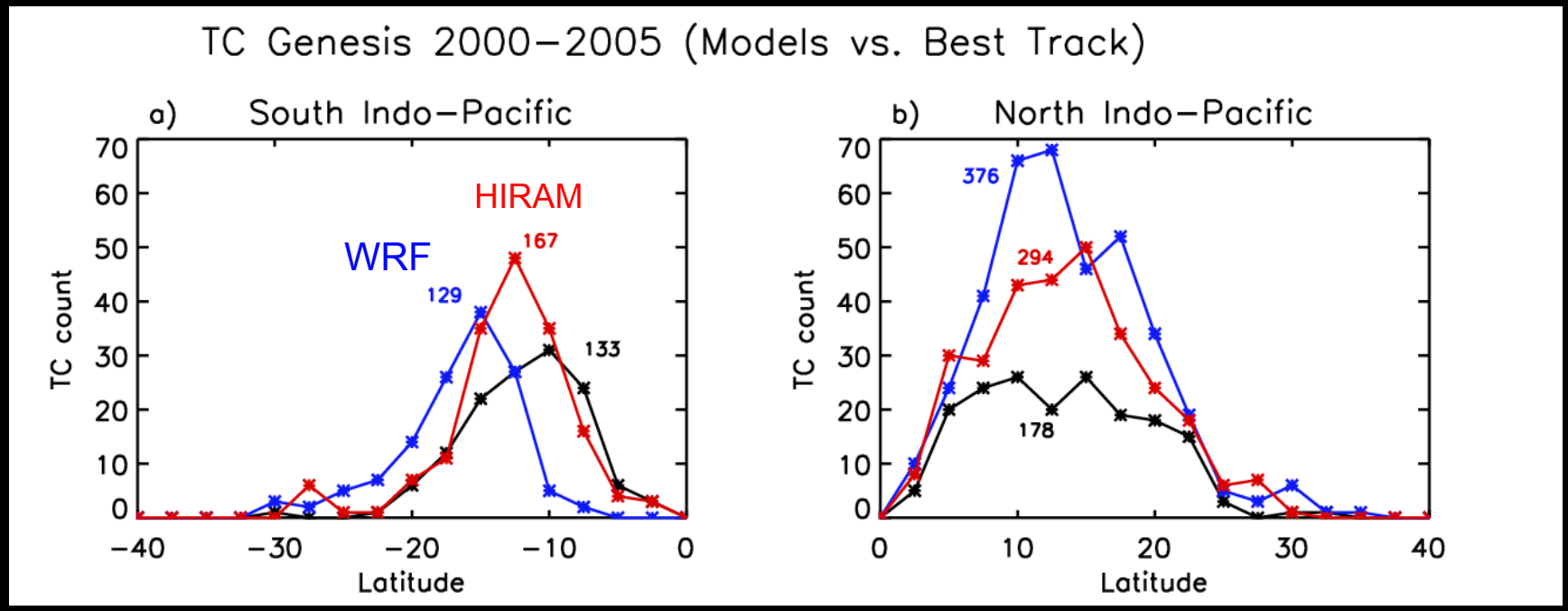


HIRAM

WRF

SPCAM

Large biases in TC genesis frequency also seen



WRF TC analysis by Asuka Suzuki (Georgia Tech)
HIRAM analysis by Ming Zhao (GFDL)

How are we to interpret these results?

On the one hand:

Too much time-mean off-equatorial rain

↓

Overly active Rossy-type wave disturbances

But its also plausible that:

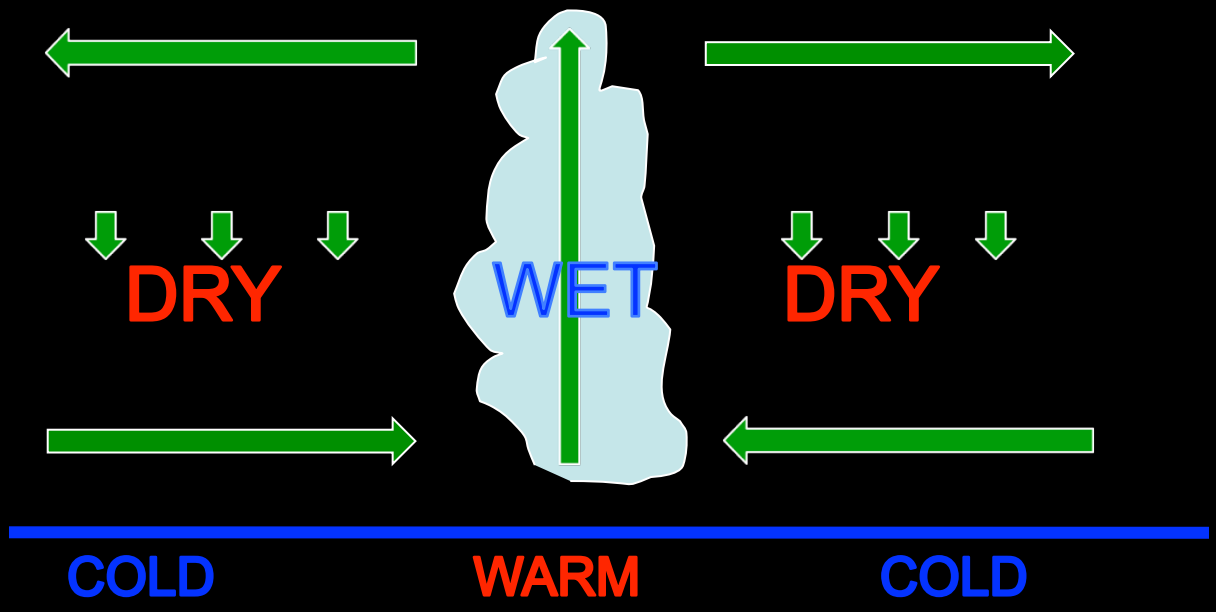
Overly active Rossby-type waves

↓

Enhance time-mean off-equatorial rain

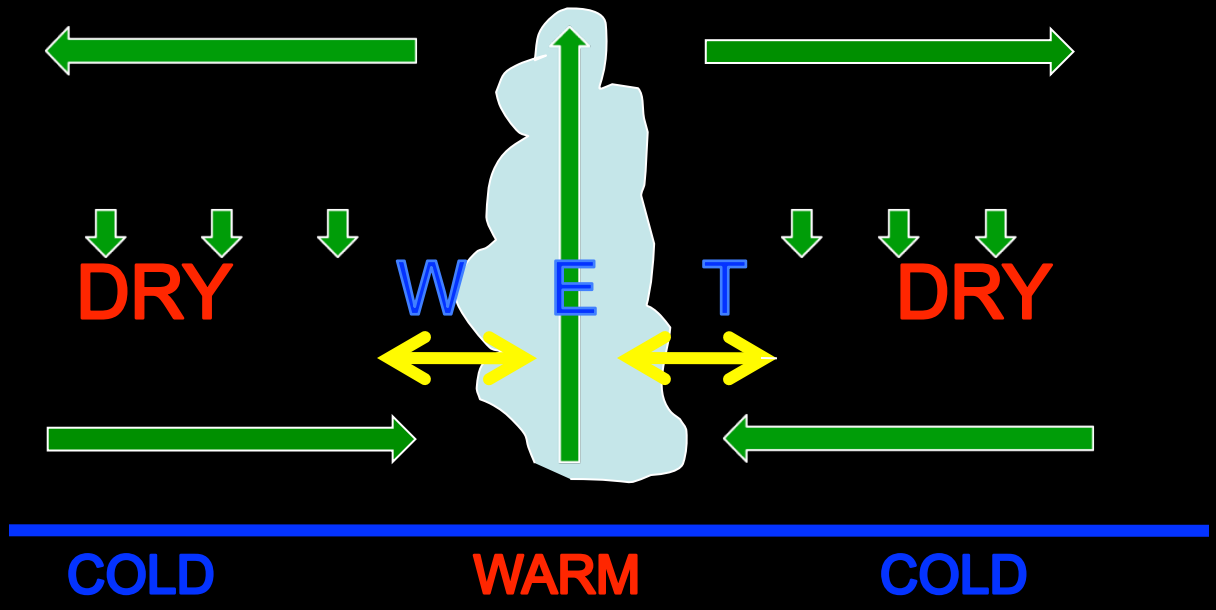
Rossby-wave feedback on the ITCZ?

Standard (steady-state, axisymmertic) picture:



Rossby-wave feedback on the ITCZ?

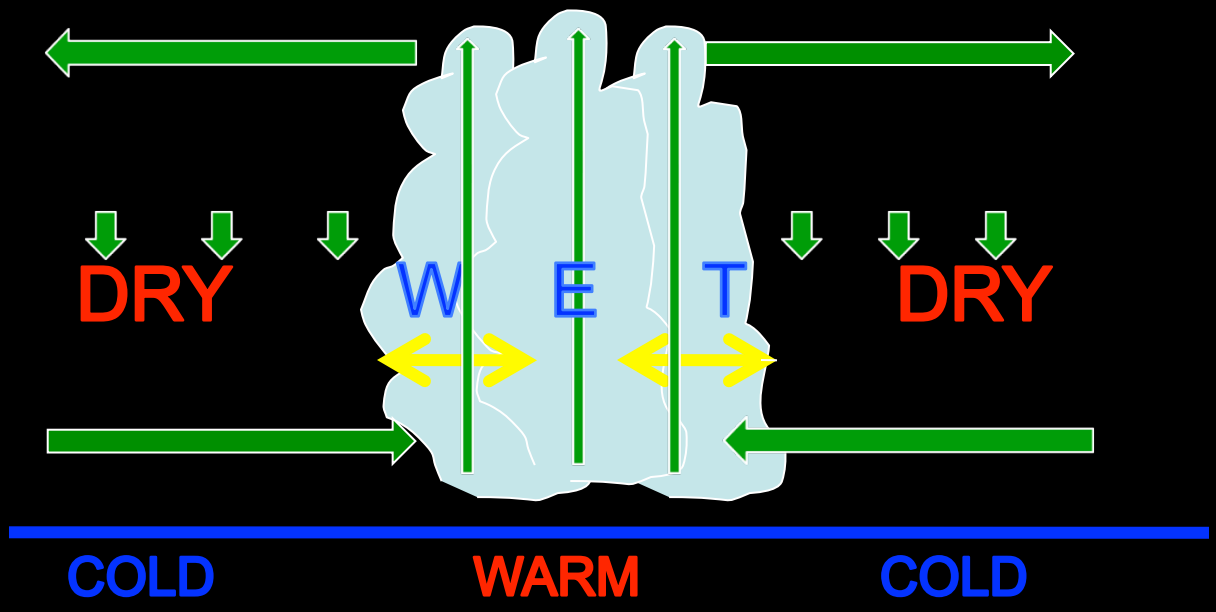
Revised picture with transient eddies*:



*Bellon and Sobel 2010

Rossby-wave feedback on the ITCZ?

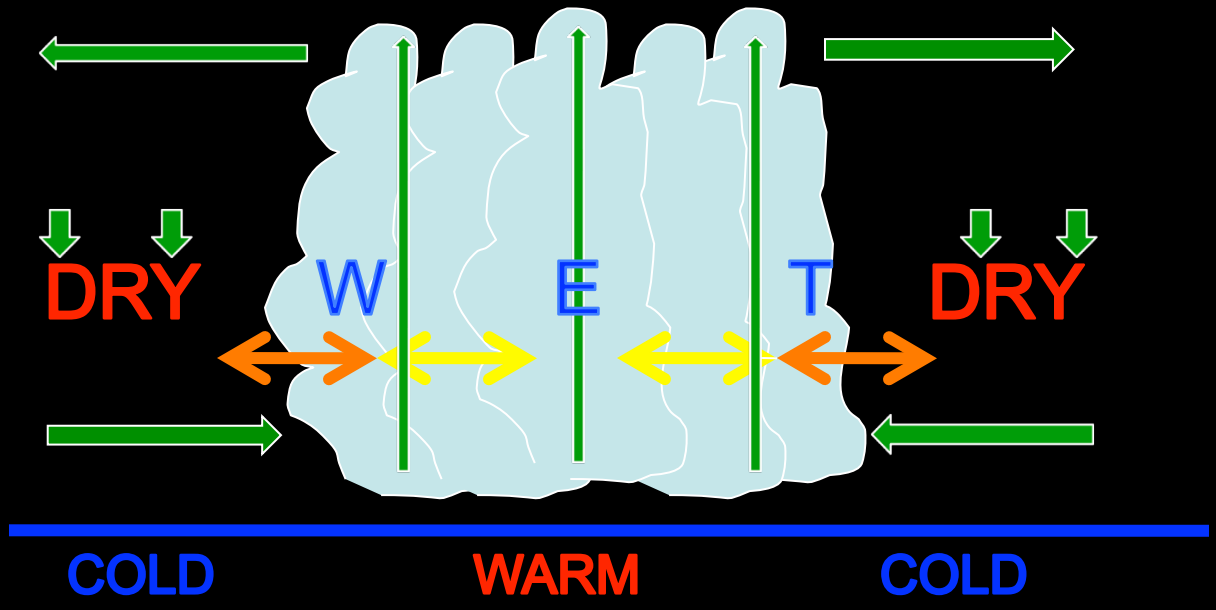
Revised picture with transient eddies*:



*Bellon and Sobel 2010

Rossby-wave feedback on the ITCZ?

Revised picture with transient eddies + deficiences in convection parameterization:



*Bellon and Sobel 2010

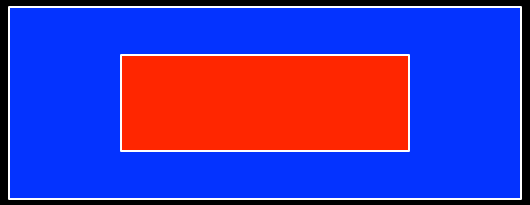
To study this issue further:

- Use the WRF model to conduct idealized simulations of the ITCZ in a tropical channel

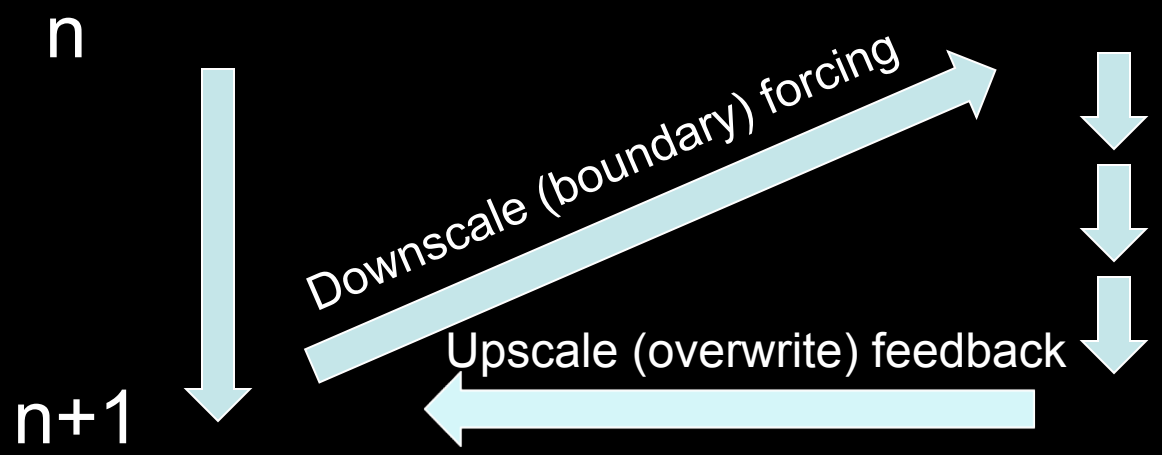
- Why WRF?
  - Non-hydrostatic full-physics so cloud-resolving is possible
  - Can be run regionally, affording computational savings
  - Variety of convective parameterization options are available, including now: super-parameterization (for me, at least)

Development of SP-WRF

- WRF already has nesting capabilities:

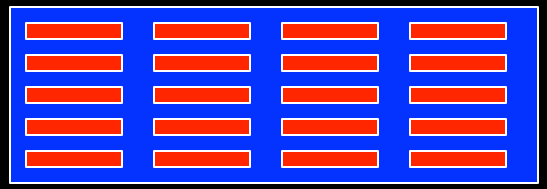


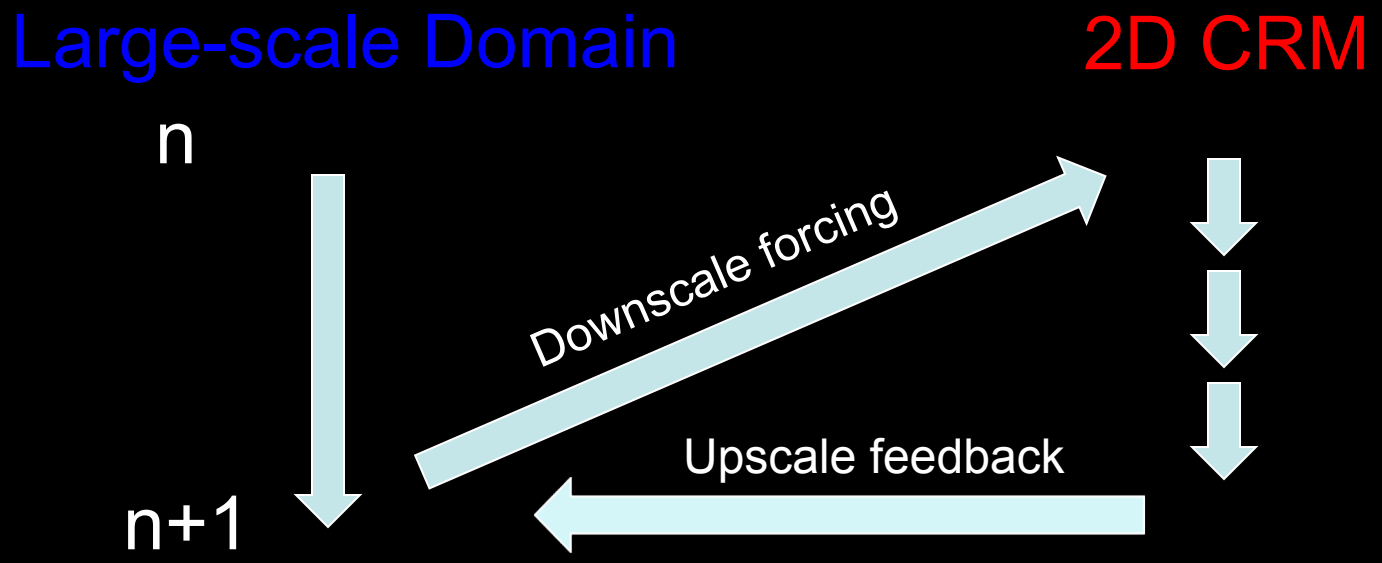
Coarse ("Parent") Domain Nest ("Child") Domain



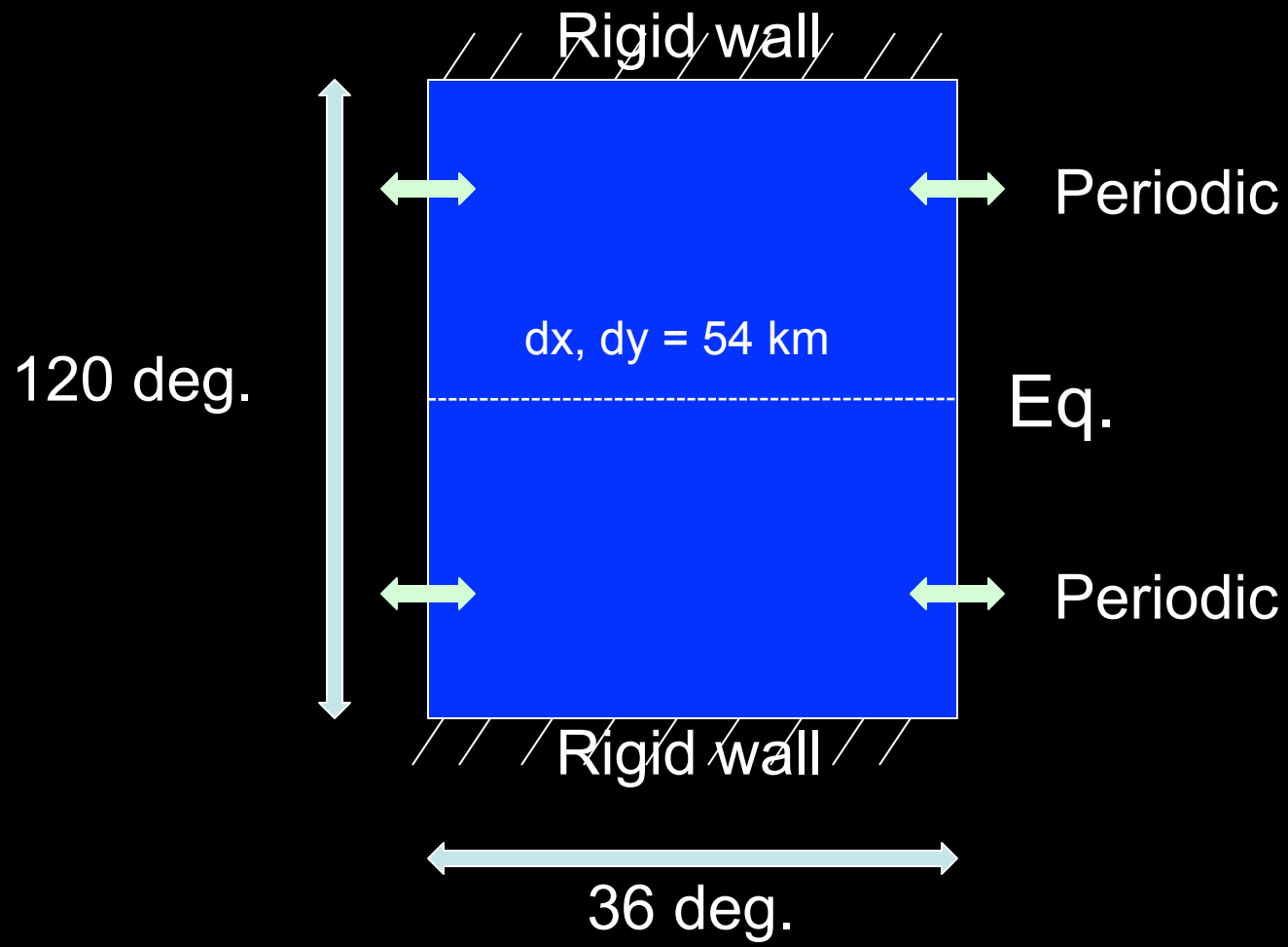
Development of SP-WRF (cont.)

- So to make an SP-WRF just change labels:

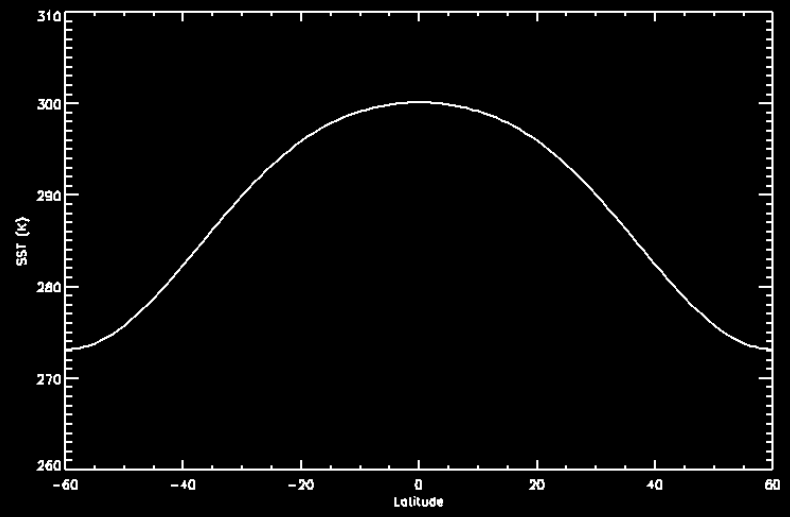




Experiment Setup



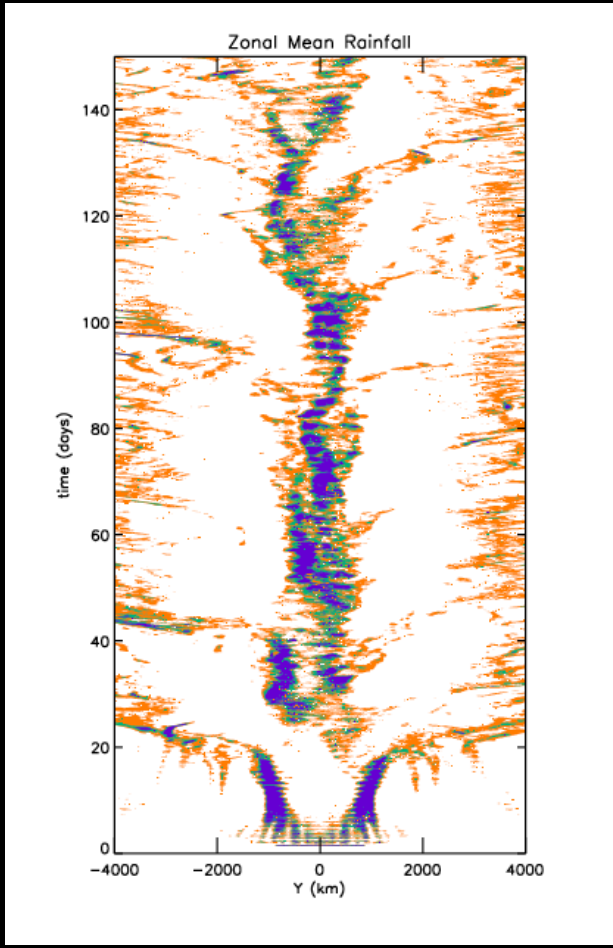
Experiment Setup (cont.)



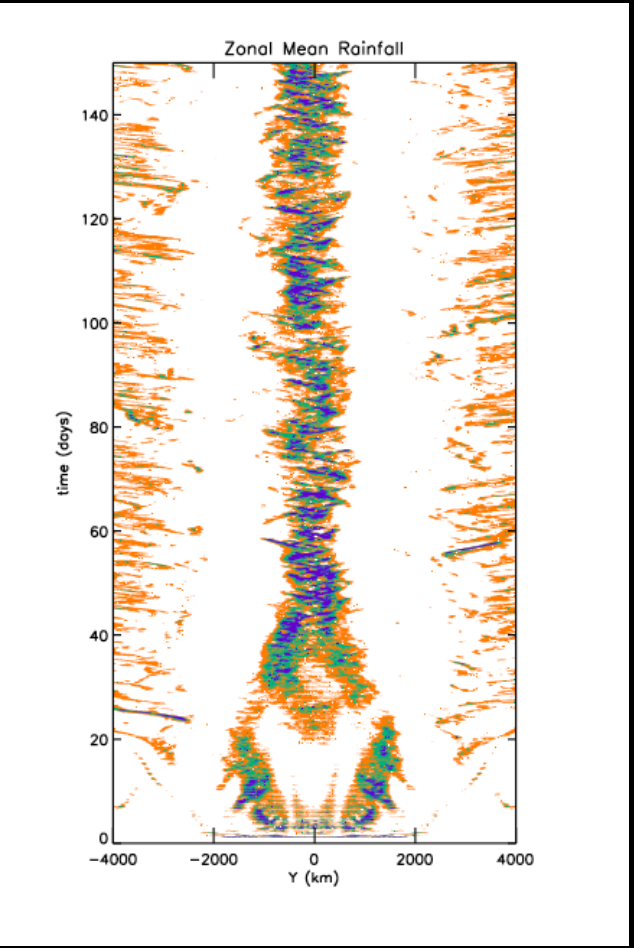
- “Observed” distribution of Neale and Hoskins (2001)
- 51 vertical levels with stretched grid up to 28 km (16 mb)
- Solar insolation is diurnally varying, perpetual equinox

Results for conventional WRF first

Kain-Fritsch



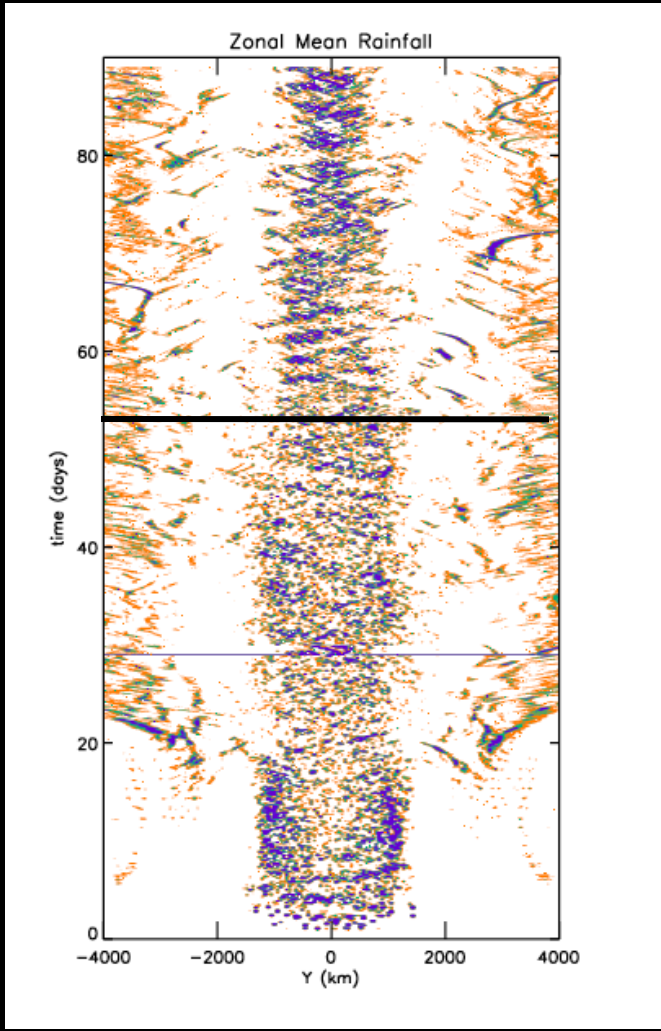
Betts-Miller-Janic



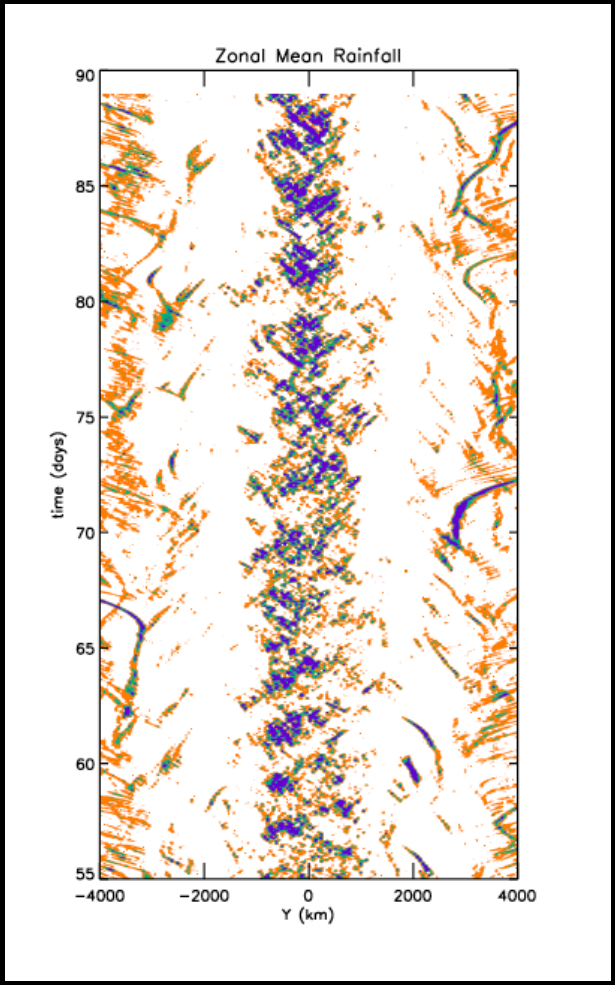
Results for SP-WRF

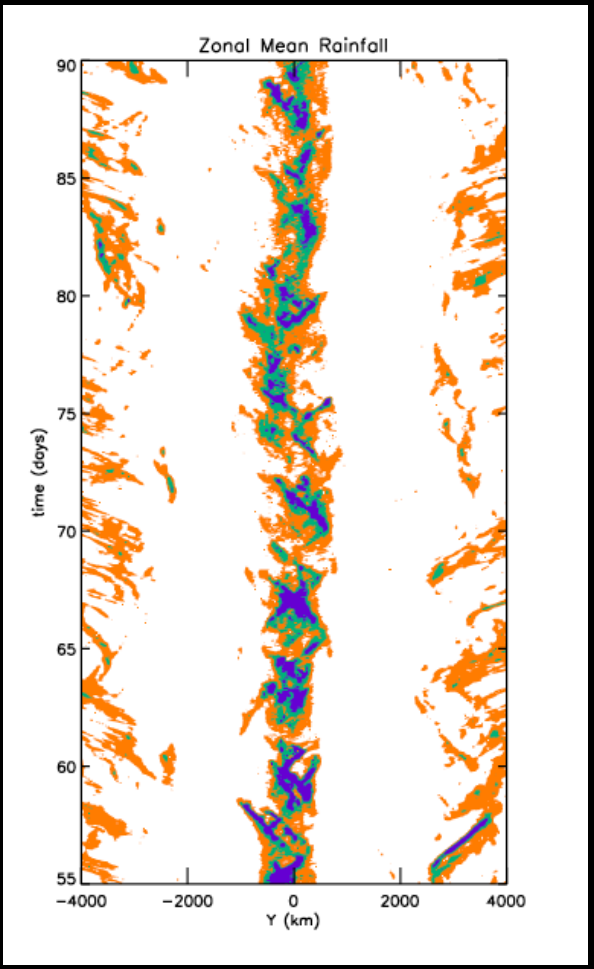
- 2D CRMs: 36-km wide; dx = 3 km
- Radiation applied on coarse-grained cloud fields
- No upscale momentum feedback
- Initialized on day 55 from a run with explicit convection on the 54-km grid
- Roughly 60 times more expensive than conventional WRF runs

Results for SP-WRF



SP vs. Betts-Miller-Janic



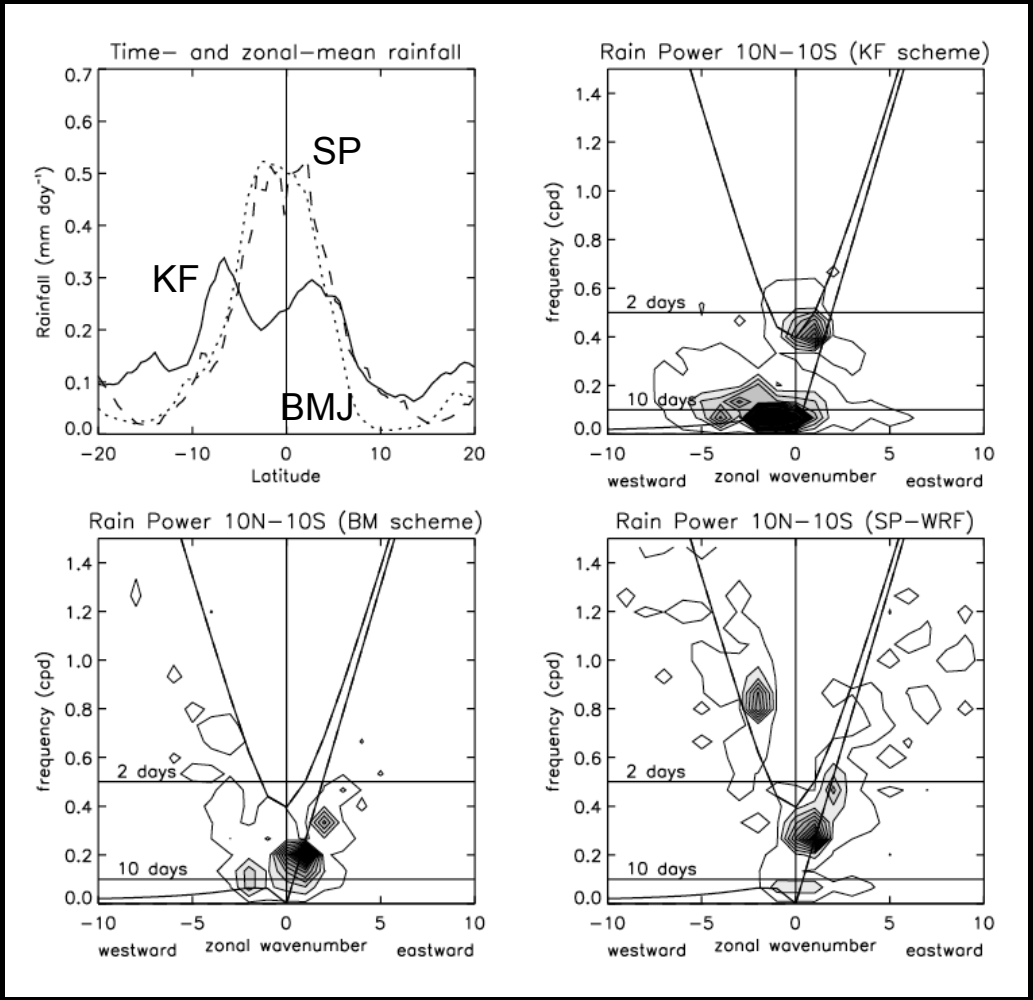


Comparison of time-mean rain and wavenumber-frequency spectra

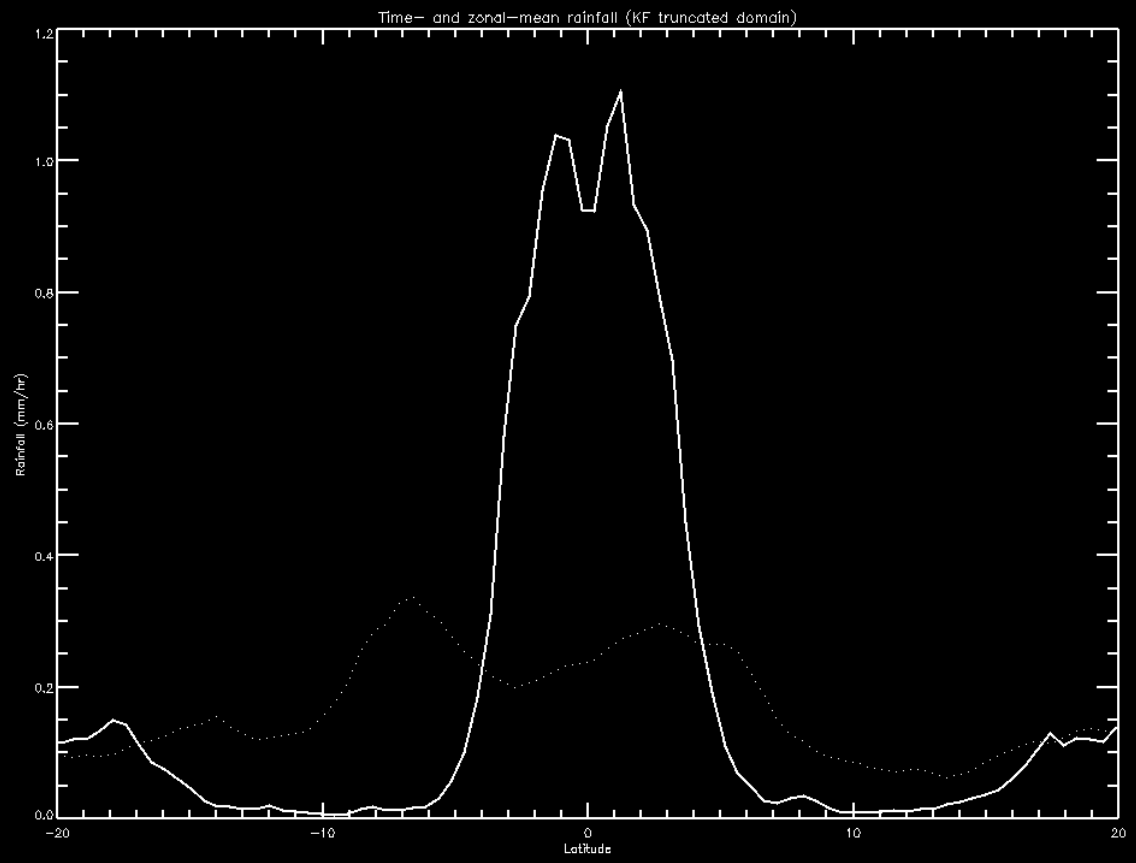
KF

BMJ

SP



Reducing the zonal extent of the domain causes narrowing of the ITCZ under the KF scheme



Moral of the story

- It appears that deficiencies in the simulation of convection-wave coupling → deficiencies in the mean climate
- This is taking the SP-WRF as “truth”, but really cloud-resolving model simulations are needed as benchmarks (beyond my computational budget)

Proposal for convection parameterization development and testing

- A dynamics-based test case for assessing the strength of coupling between parameterized convection and rotational vs. divergent circulation anomalies

- Basic idea: perform short-term (regional) weather forecasts of obs. tropical wave disturbances
  - Does the model tend to “spin up” the easterly wave relative to observations?
  - If so, what aspect of the parameterization causes this spinup?
  - Does increasing resolution help or make the problem worse? If so, why?