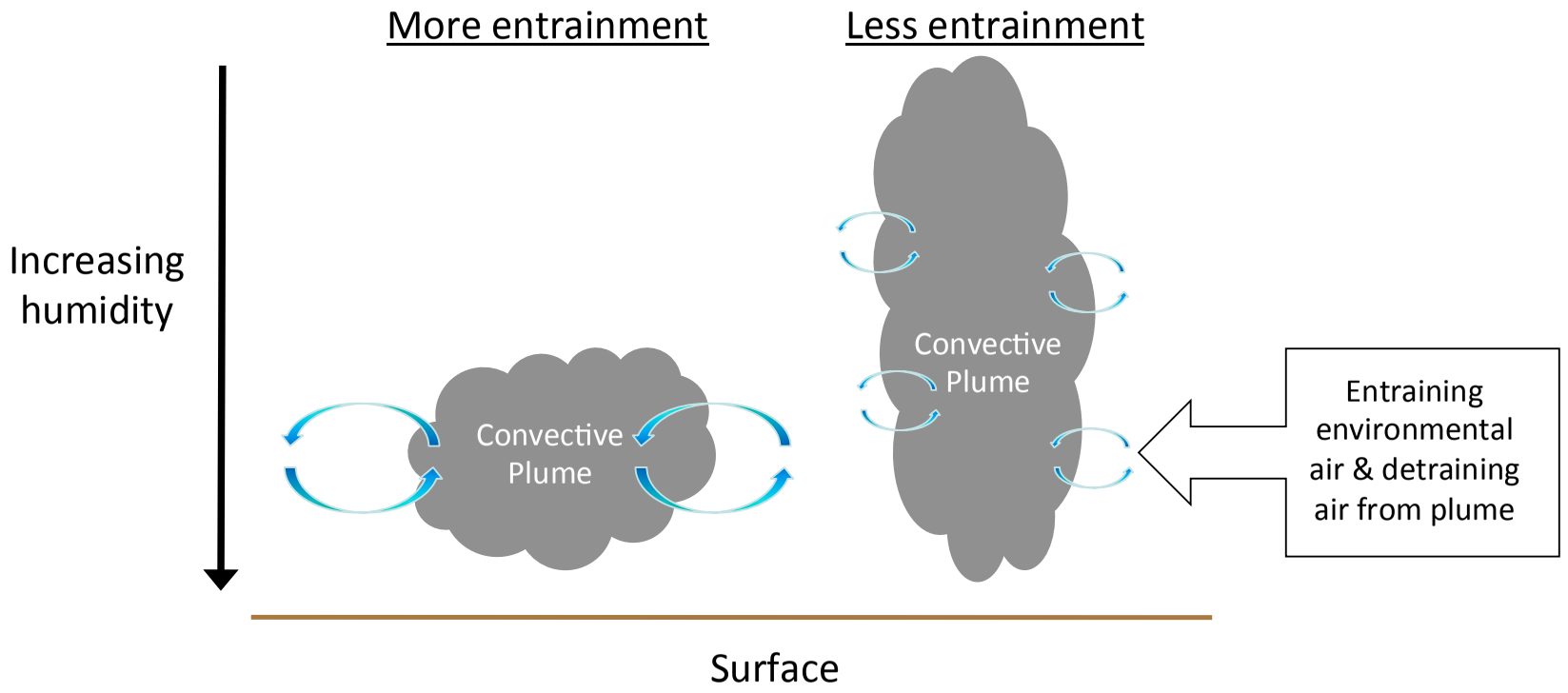
Increasing the entrainment rate

We expect that increasing the entrainment rate increases mixing of moist convective plumes with drier air aloft.



With increased entrainment we expect:
Suppressed convection, decreased precipitation, moistening of column.
Stronger effects in drier environments.

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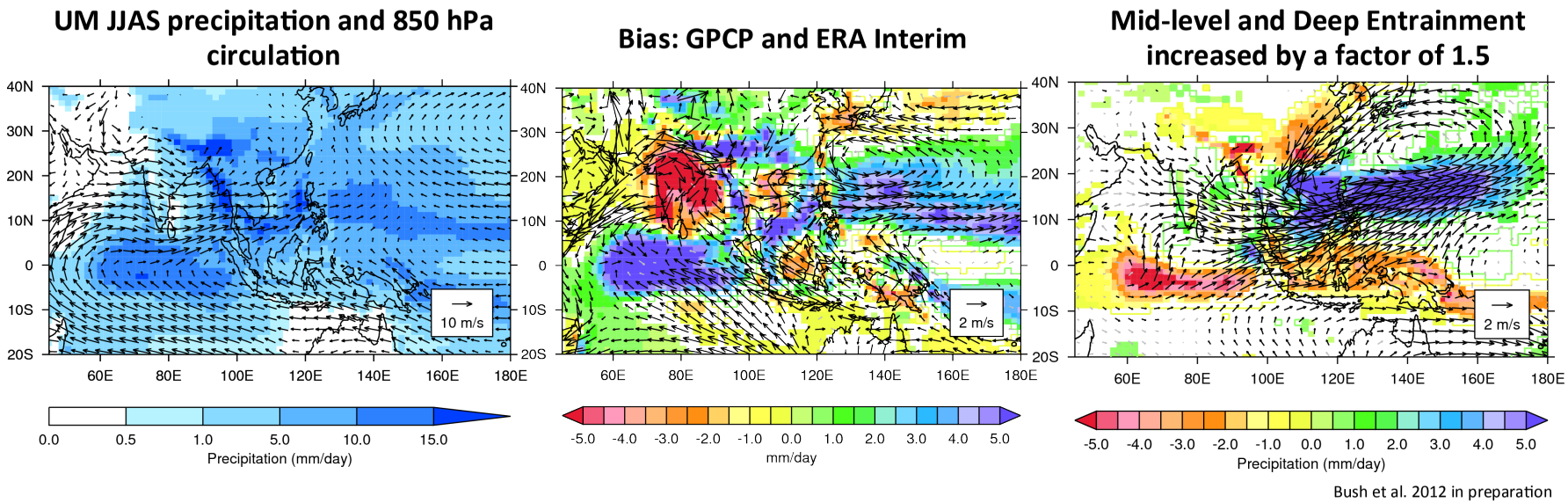
The effect of increased entrainment on tropical summer precipitation biases

Stephanie Bush (JWCRP Research Scientist, Reading/UK Met Office),
Andrew Turner (Reading), Steve Woolnough (Reading), Gill Martin (Met Office)
Thanks to: Nick Klingaman (Reading) and Richard Levine (Met Office)

ICTP Workshop on Variability in the Western Tropical Pacific
November 13, 2012

Motivation



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- **Increasing the convective entrainment rate globally in the model decreases several long standing monsoon precipitation biases while increasing others:**
  - Improves rainfall biases over Western Equatorial Indian Ocean (WEIO) and steep continental orography
  - Slightly improves rainfall over India
  - Worsens rainfall biases over Western North Pacific (WNP) and Maritime Continent

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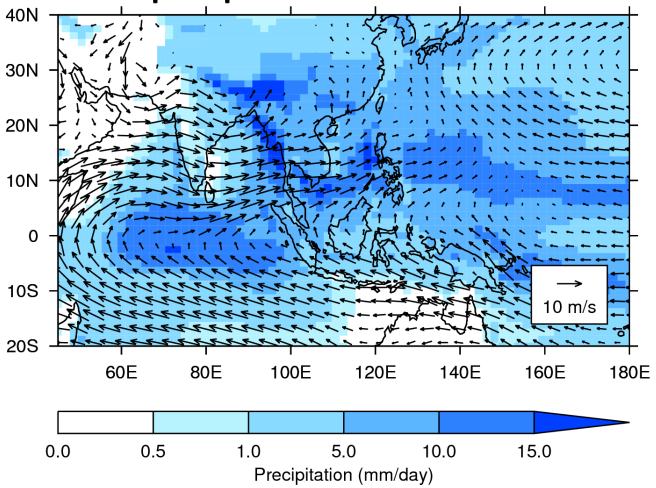
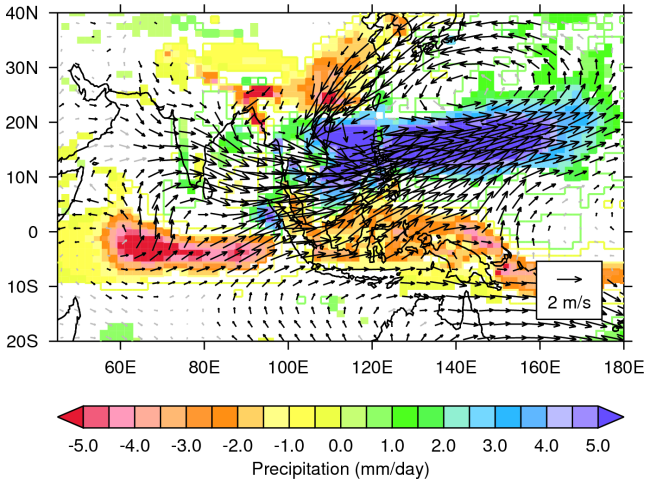
Response to increased entrainment

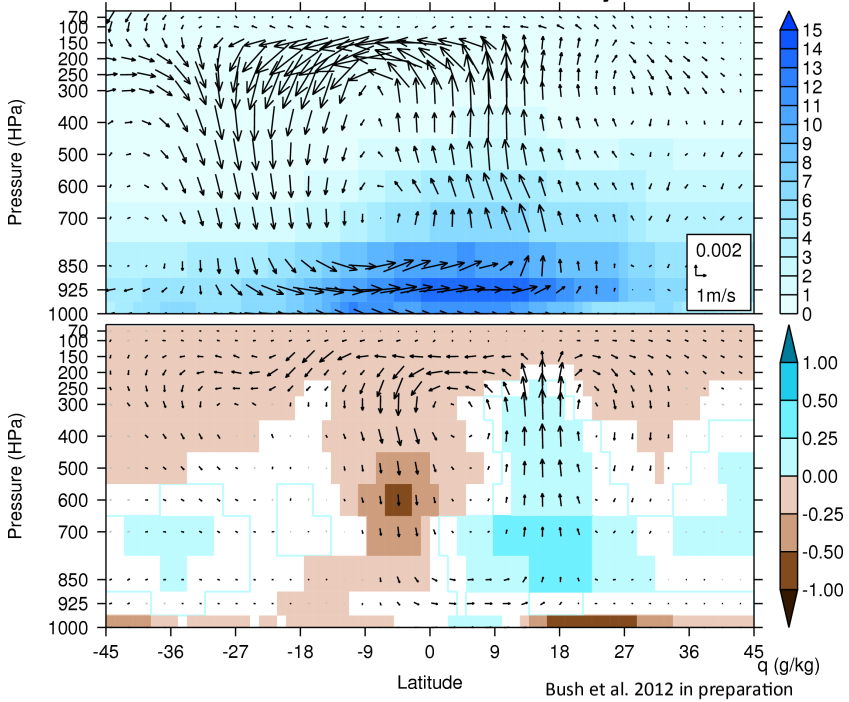
UM JJAS precipitation and 850 hPa circulation



Mid-level and Deep Entrainment increased by a factor of 1.5



Top: UM JJAS zonally averaged specific humidity and circulation
Bottom: Entrainment increased by a factor of 1.5



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Use experiments targeted at land, WEIO and WNP to:

Analyze the local response to entrainment change

Determine how modifying specific rainfall biases affects other rainfall biases

Inform efforts to reduce biases

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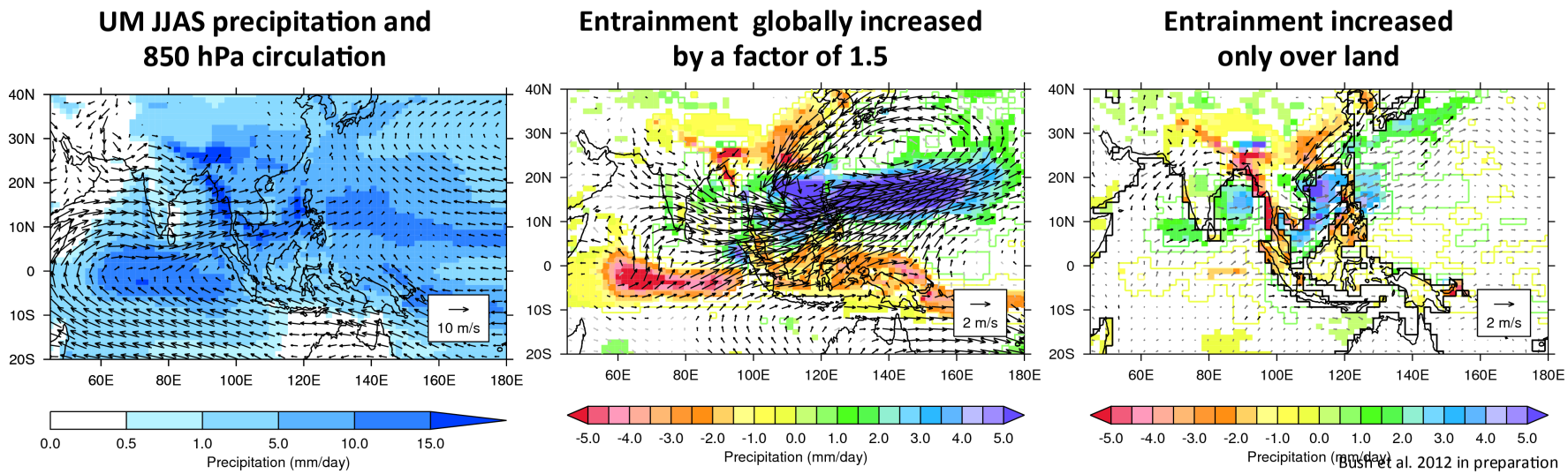
Land experiment



Increasing the entrainment rate by a factor of 1.5 over land points (including coasts):

Shifts intense precipitation over land to the Northern Indian Ocean and South China
Causes a mild increase over India where increased latent heating in the Bay of Bengal strengthens the Monsoon trough

Primarily improves existing biases

Northeasterlies driven over West China increase moisture flux into SCS and WNP

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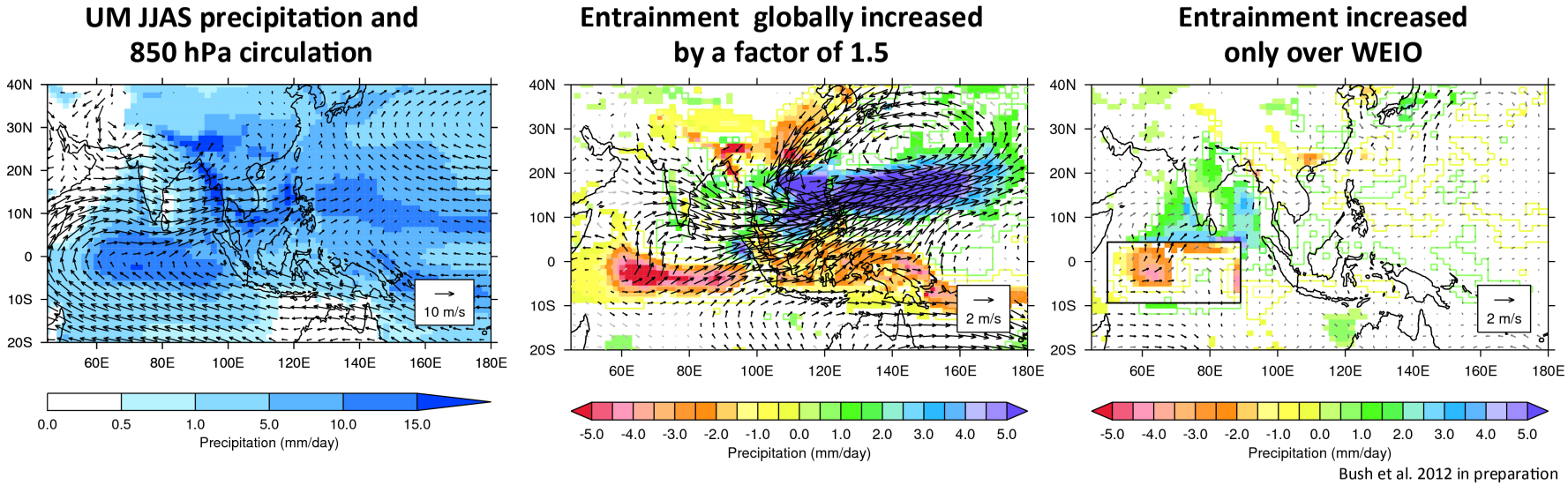
WEIO experiment



Increasing the entrainment rate by a factor of 1.5 in the western equatorial Indian Ocean (WEIO):

Locally decreases rainfall, improving WEIO rainfall bias

Decreased WEIO precipitation leads to more moisture in the Somali Jet and increased rainfall over India

No change in the WNP

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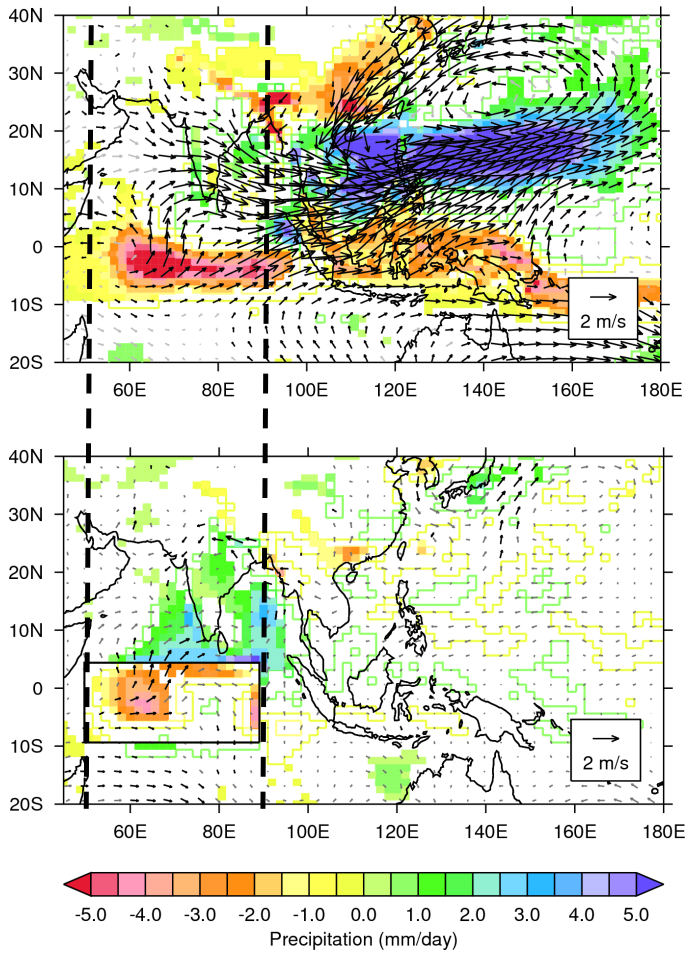
WEIO experiment

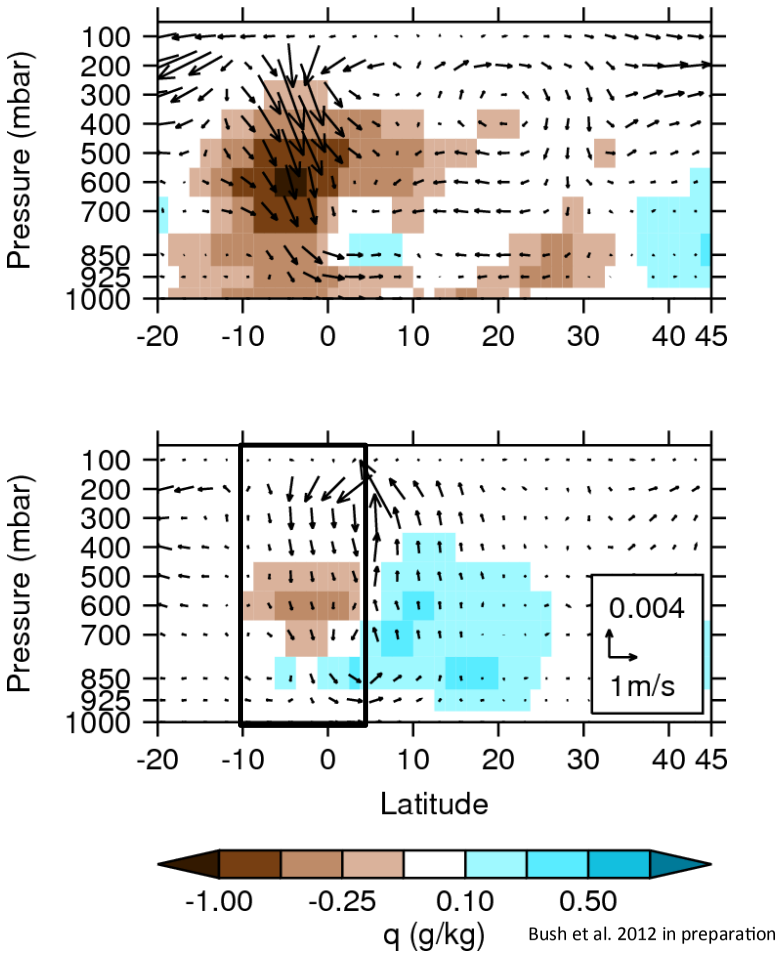
Entrainment globally increased by a factor of 1.5

Entrainment increased only over WEIO

JJAS precipitation and 850 hPa winds



JJAS zonally averaged specific humidity and meridianal winds



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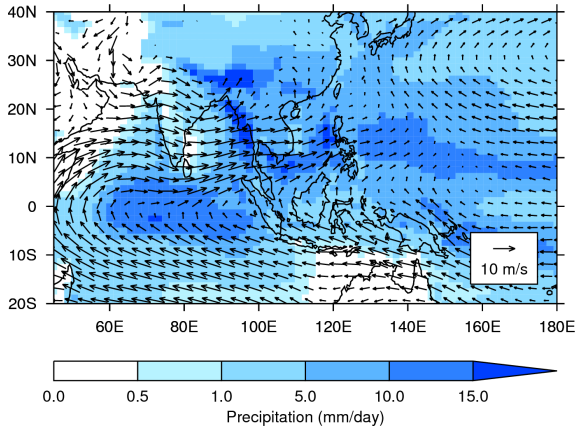
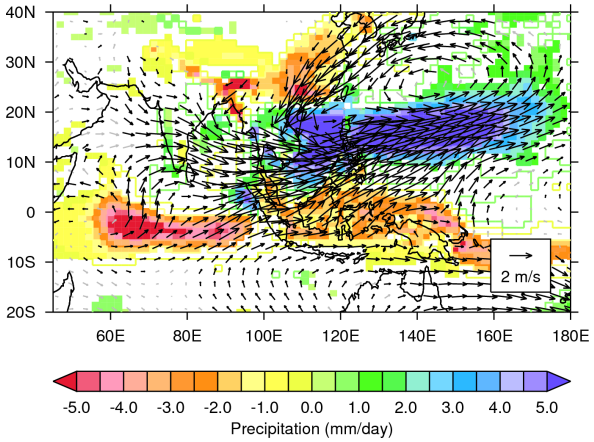
WNP experiment

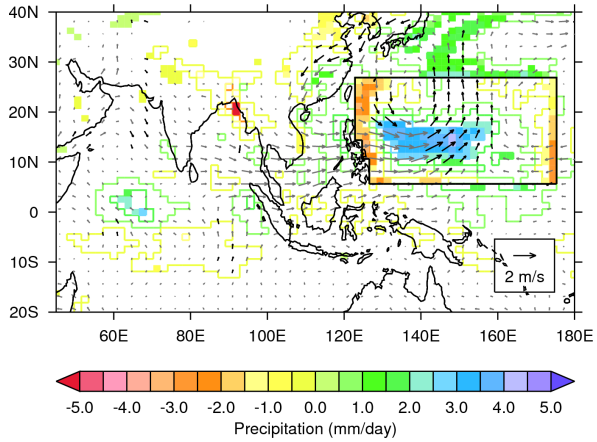
UM JJAS precipitation and 850 hPa circulation



Entrainment globally increased by a factor of 1.5



Entrainment increased only over WNP



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Changing the entrainment rate by a factor of 1.5 in the western north Pacific:

Locally increases precipitation, worsening WNP rainfall bias

Why does precipitation increase here, but not in the WEIO?

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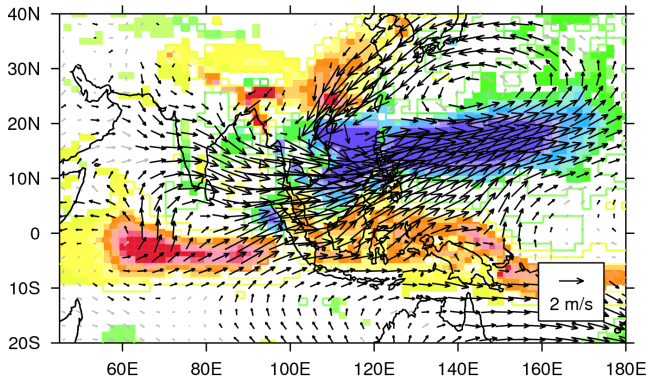
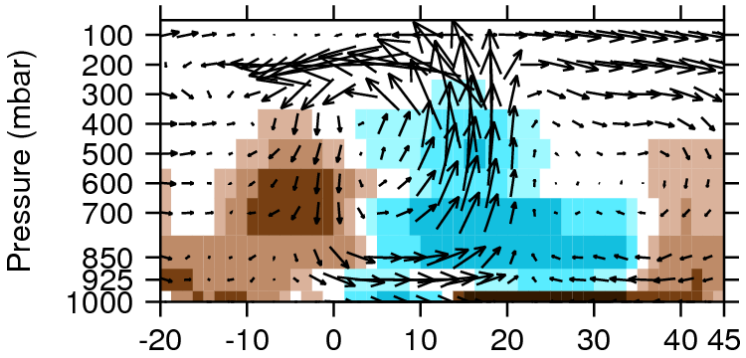
WNP experiment

JJAS precipitation and 850 hPa winds

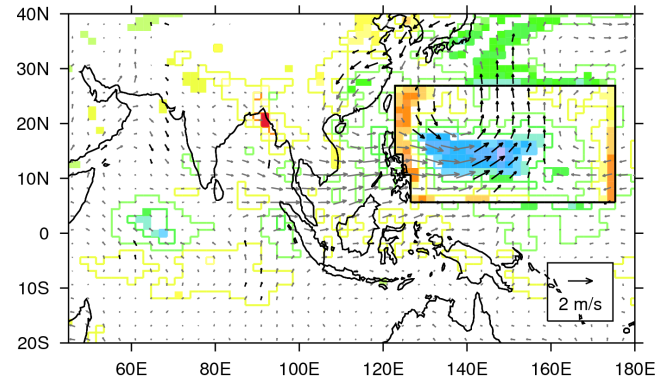
JJAS zonally averaged specific humidity and meridianal winds

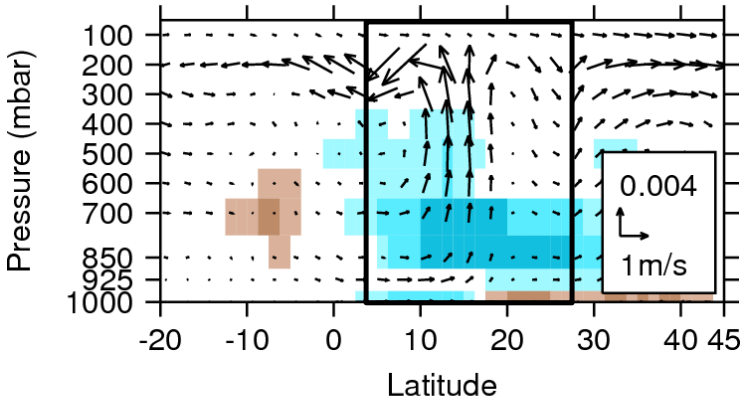
Entrainment globally increased by a factor of 1.5

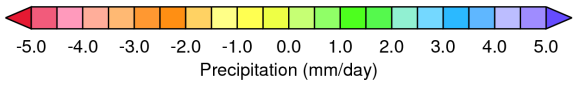


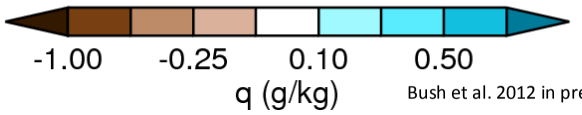


Entrainment increased only over WNP









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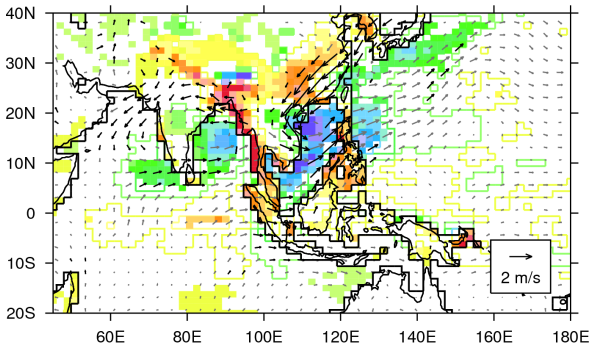
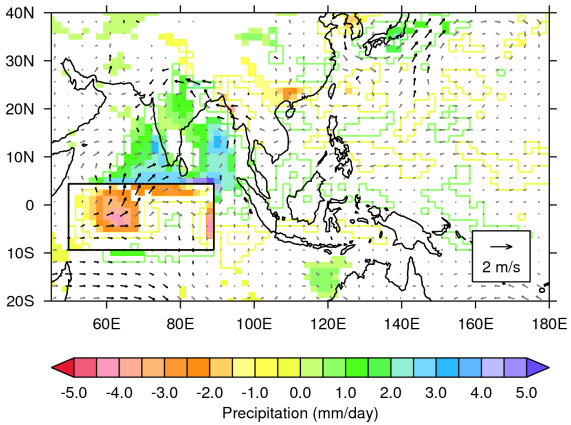
Targeted experiments

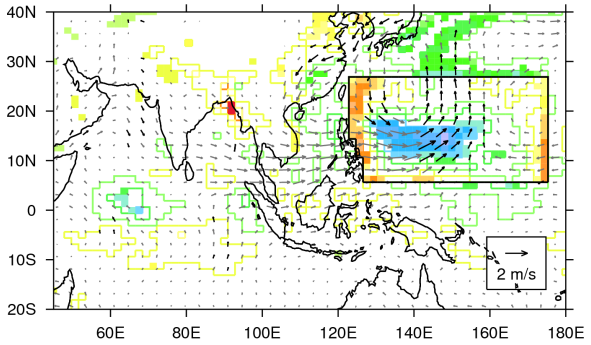
Entrainment increased only over land



Entrainment increased only over WEIO



Entrainment increased only over WNP



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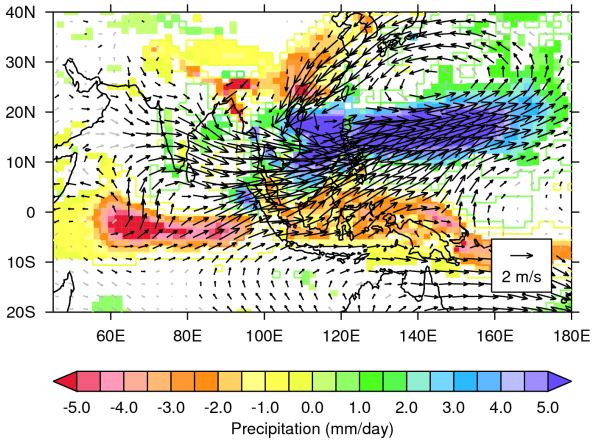
Entrainment globally increased by a factor of 1.5



The global response can be (mostly) understood as a linear combination of these effects. However, we still need to understand why these regions respond so differently to one another locally.

Decreased precipitation in the WEIO is not responsible for the enhanced precipitation in the WNP

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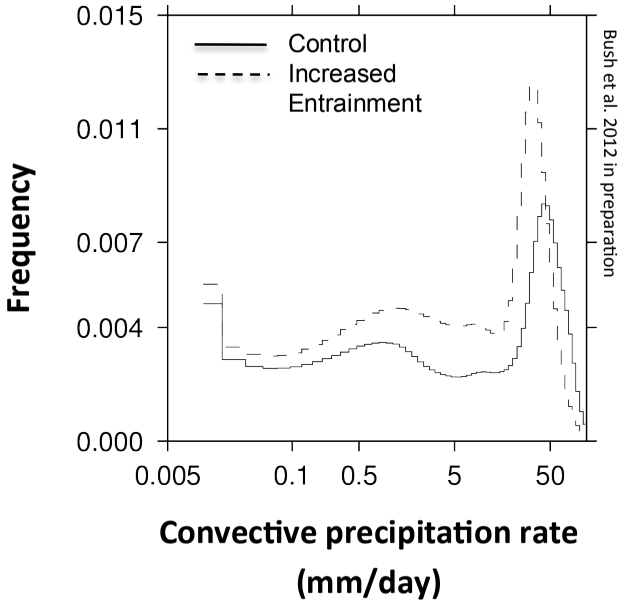
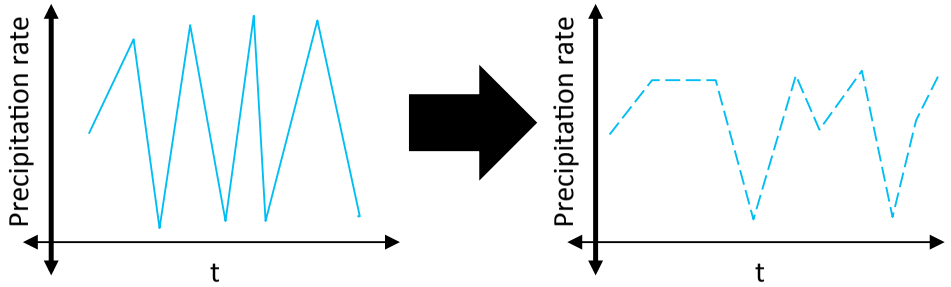
Time-step rainfall rates





Increasing the entrainment rate decreases deep convective time-step rainfall intensity;
It rains on more time-steps at lower rates

<u>Increase in frequency of time-steps where convection scheme creates precipitation:</u>

WEIO: 10%

WNP: 30%

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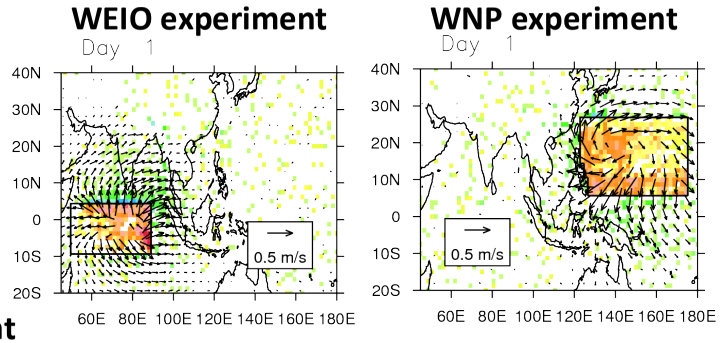
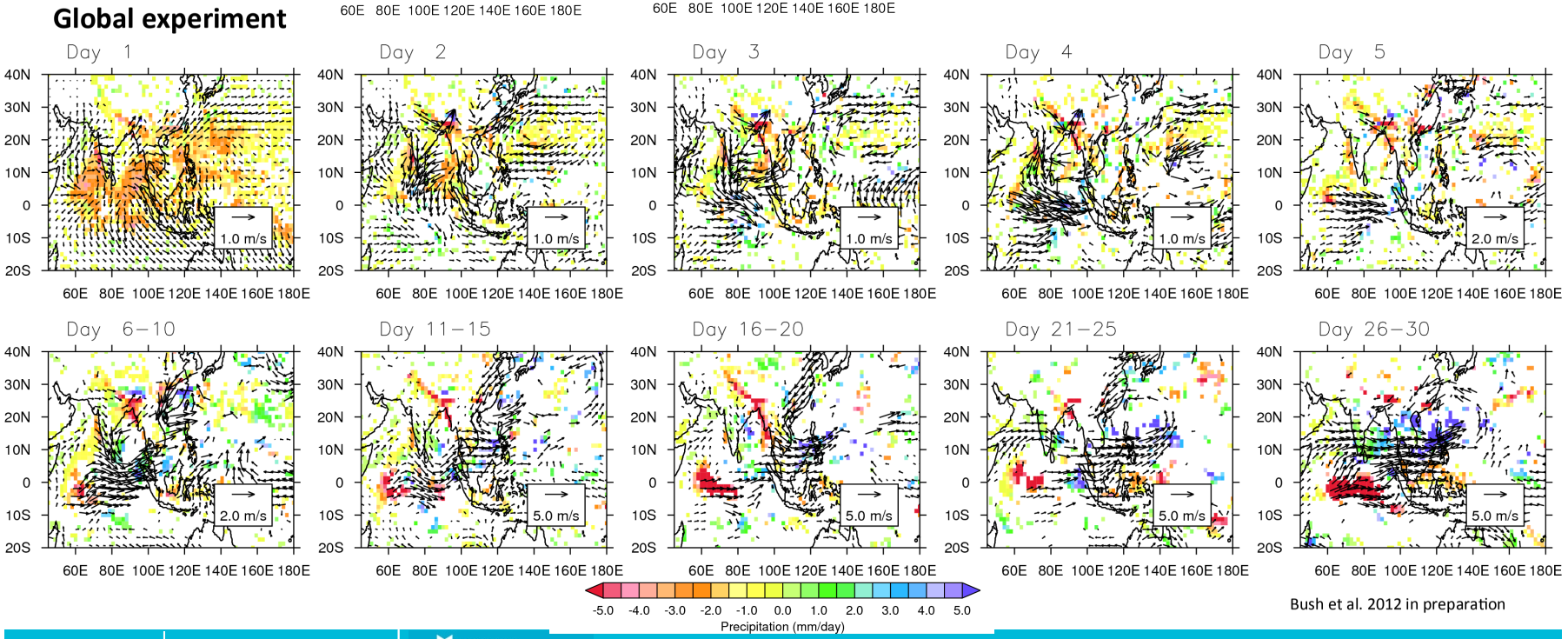
University of Reading

Local spin-up experiments

Increased entrainment imposed on July 1: after monsoon circulation established



Initial response:
Decreased precipitation
Gill circulation response to decreased latent heating
(Gill 1980)



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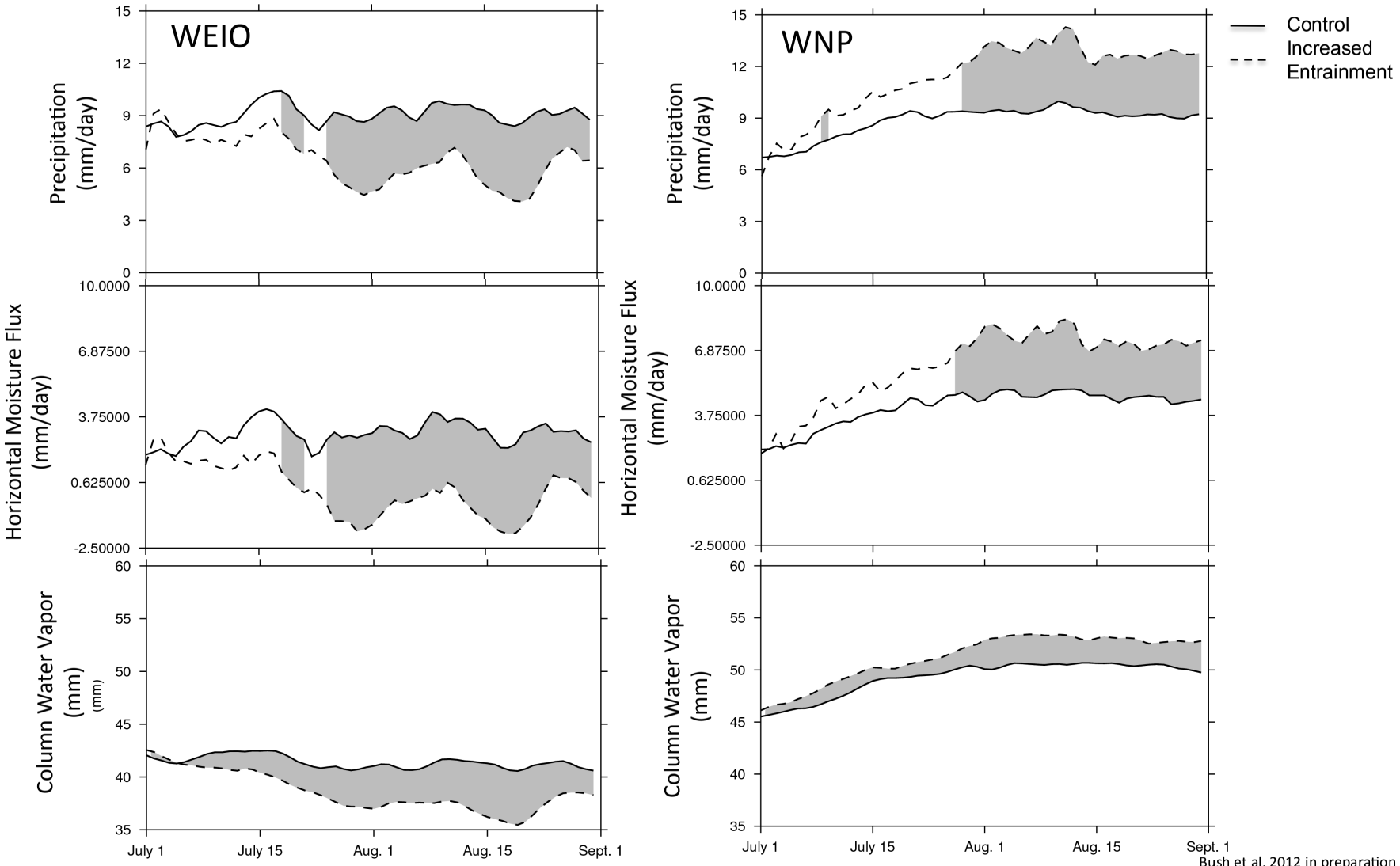
Spin-Up Time series



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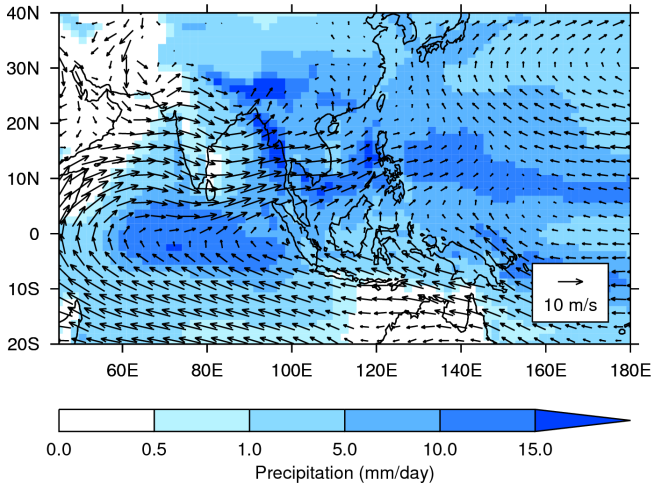
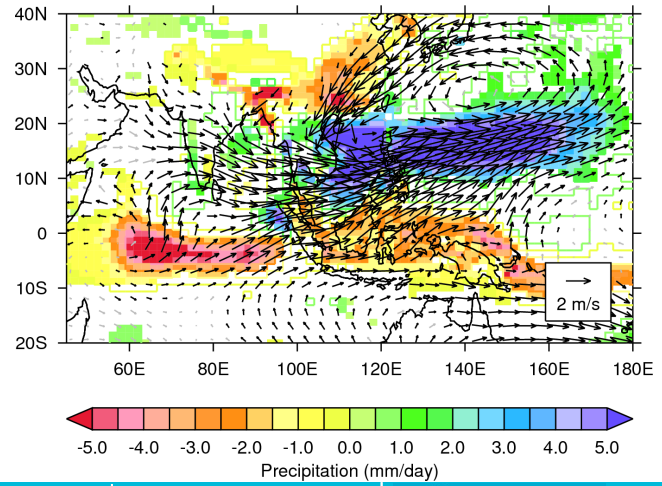
Conclusions

UM JJAS precipitation and 850 hPa circulation



Mid level & deep entrainment increased by a factor of 1.5



Increasing the convective entrainment rate has a large effect on the monsoon mean state

Global response is consistent with local response, but feedbacks strengthen local response

Can have a very different effect in similar regions.

Why do the WEIO and WNP respond differently?
Possibilities:
Difference in seasonal cycle
Difference in moisture content
Difference in moisture available to advect into a region
Equatorial vs. off equatorial dynamical response

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