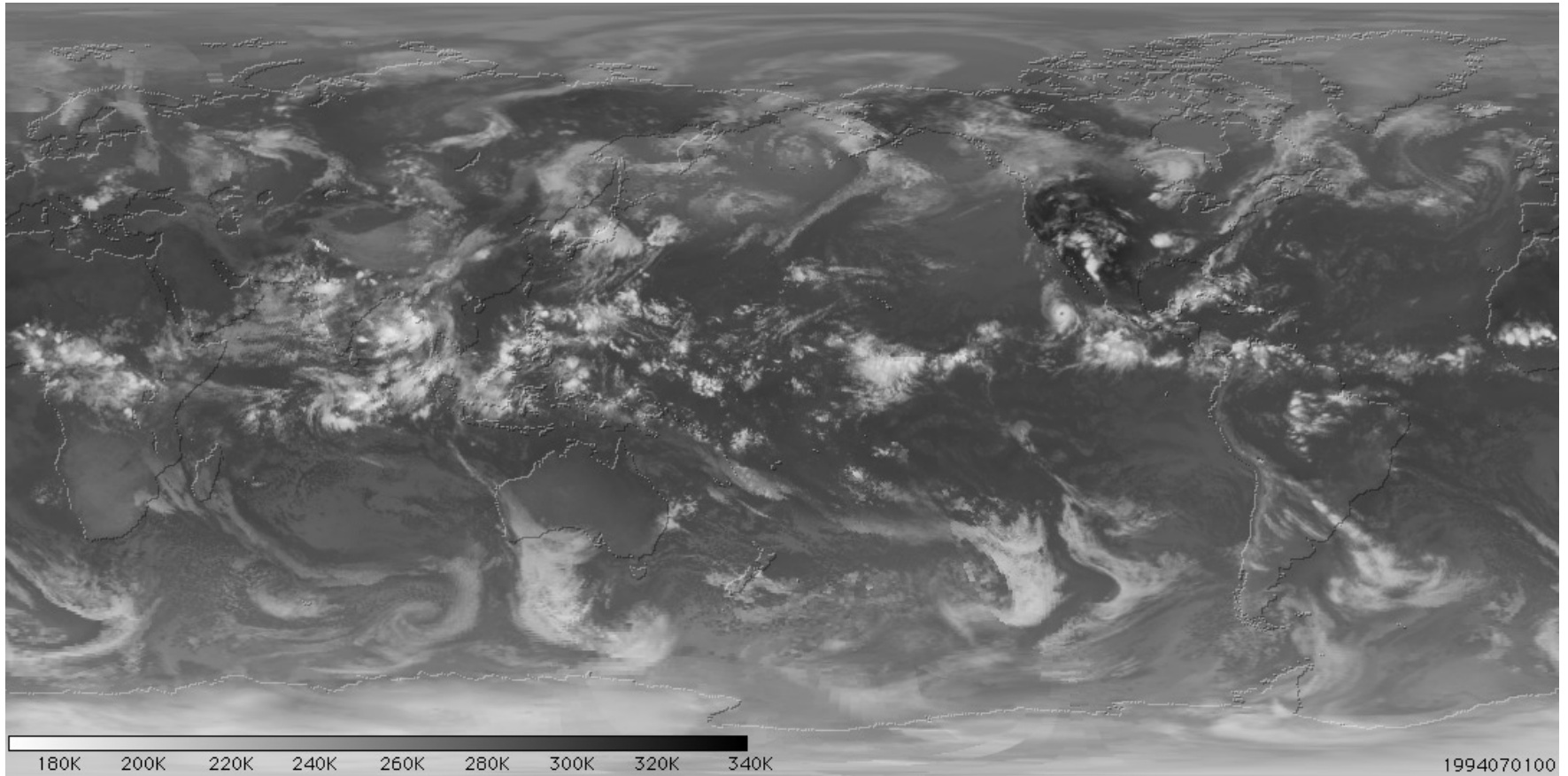# Convective organization at the largest scales: ITCZ, monsoonal precipitation zones and their link to the large-scale tropical circulation

Simona Bordoni

Environmental Science and Engineering

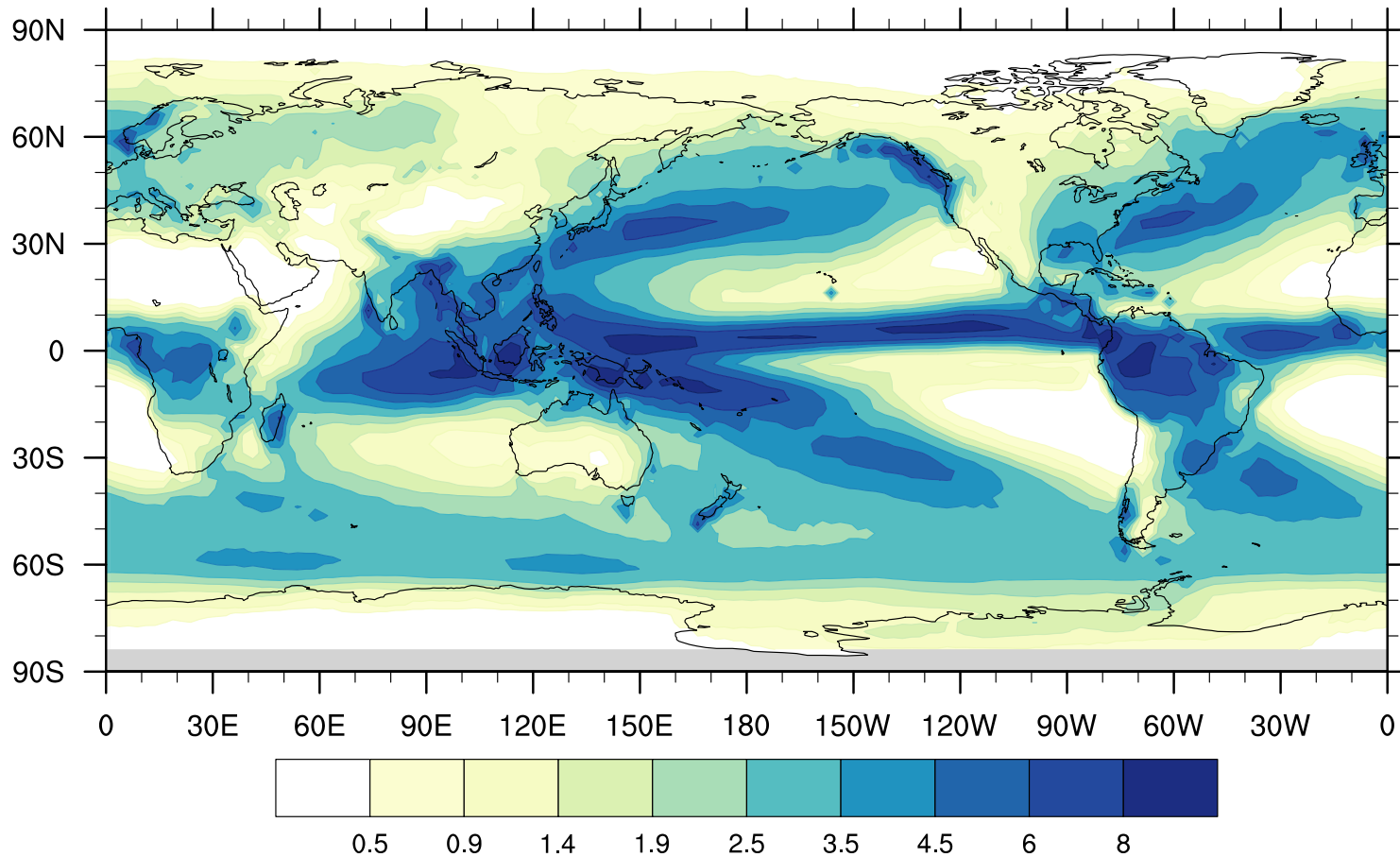California Institute of Technology

July 5 2019

Clouds seen from above

180K 200K 220K 240K 260K 280K 300K 320K 340K

1994070100

http://badc.nerc.ac.uk/data/claus/

Observed distribution of precipitation
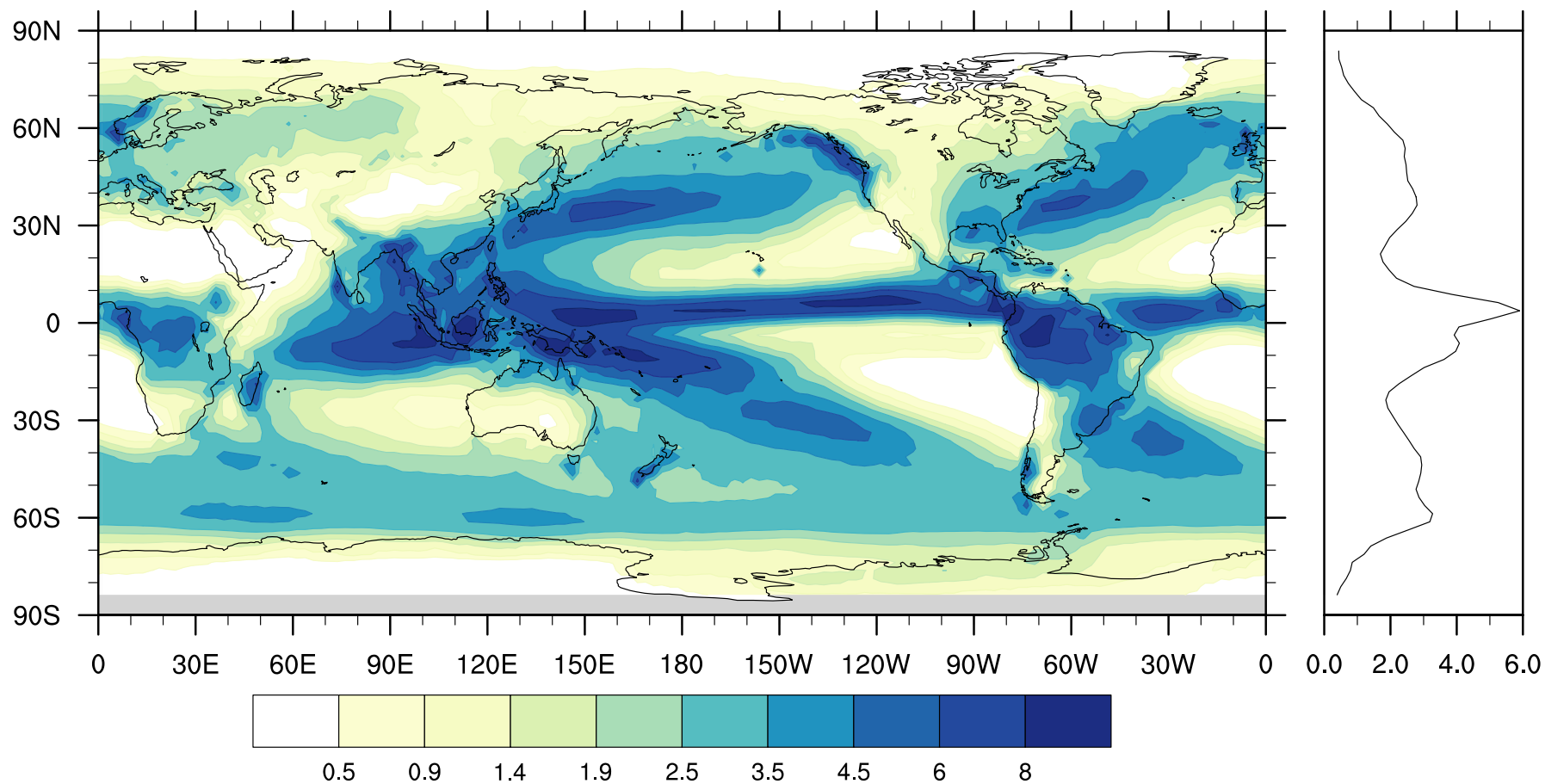
Annual mean precipitation

Observed distribution of precipitation

Annual mean precipitation

Data source: GPCP

Observed distribution of precipitation

Annual mean precipitation
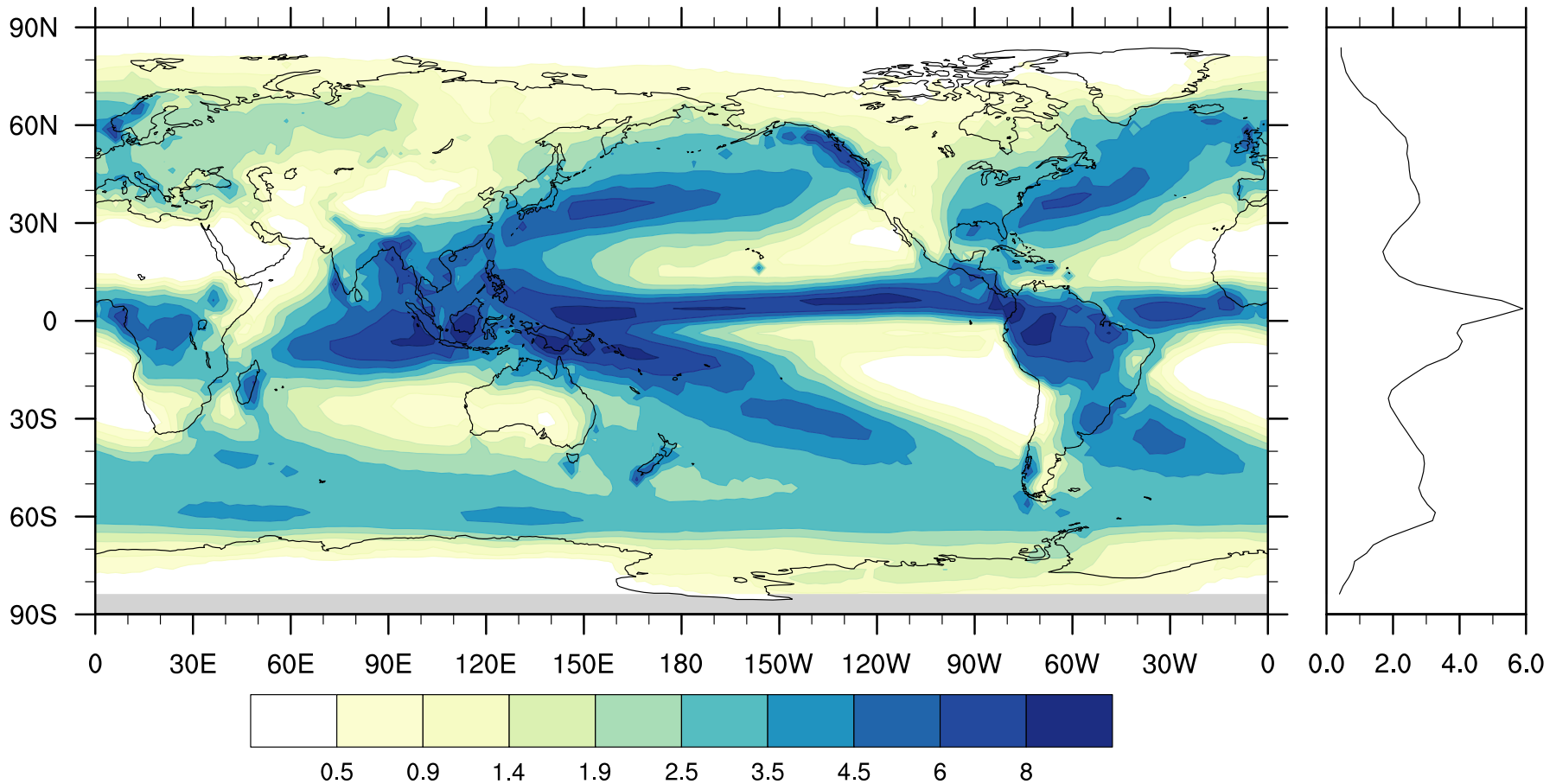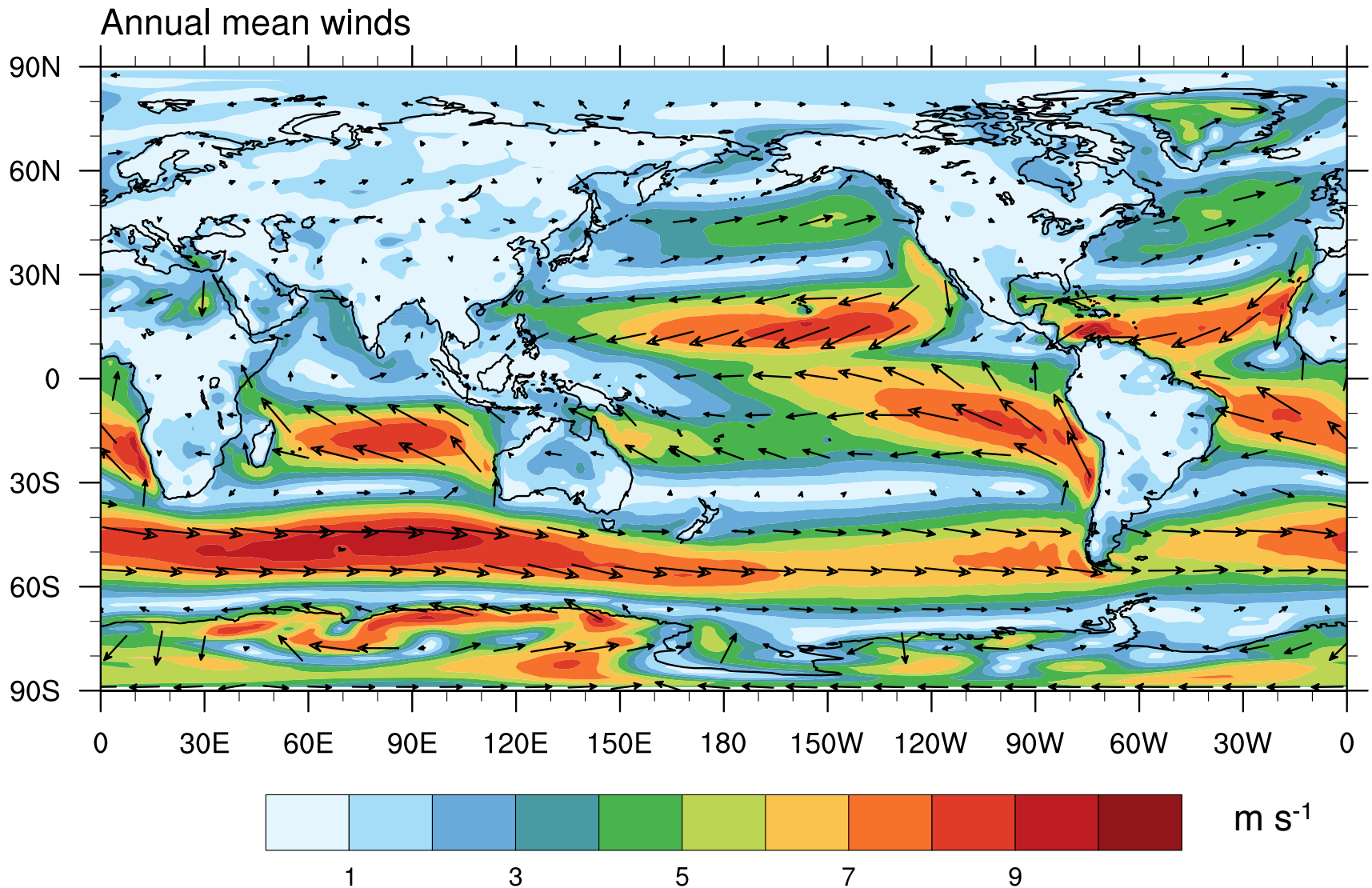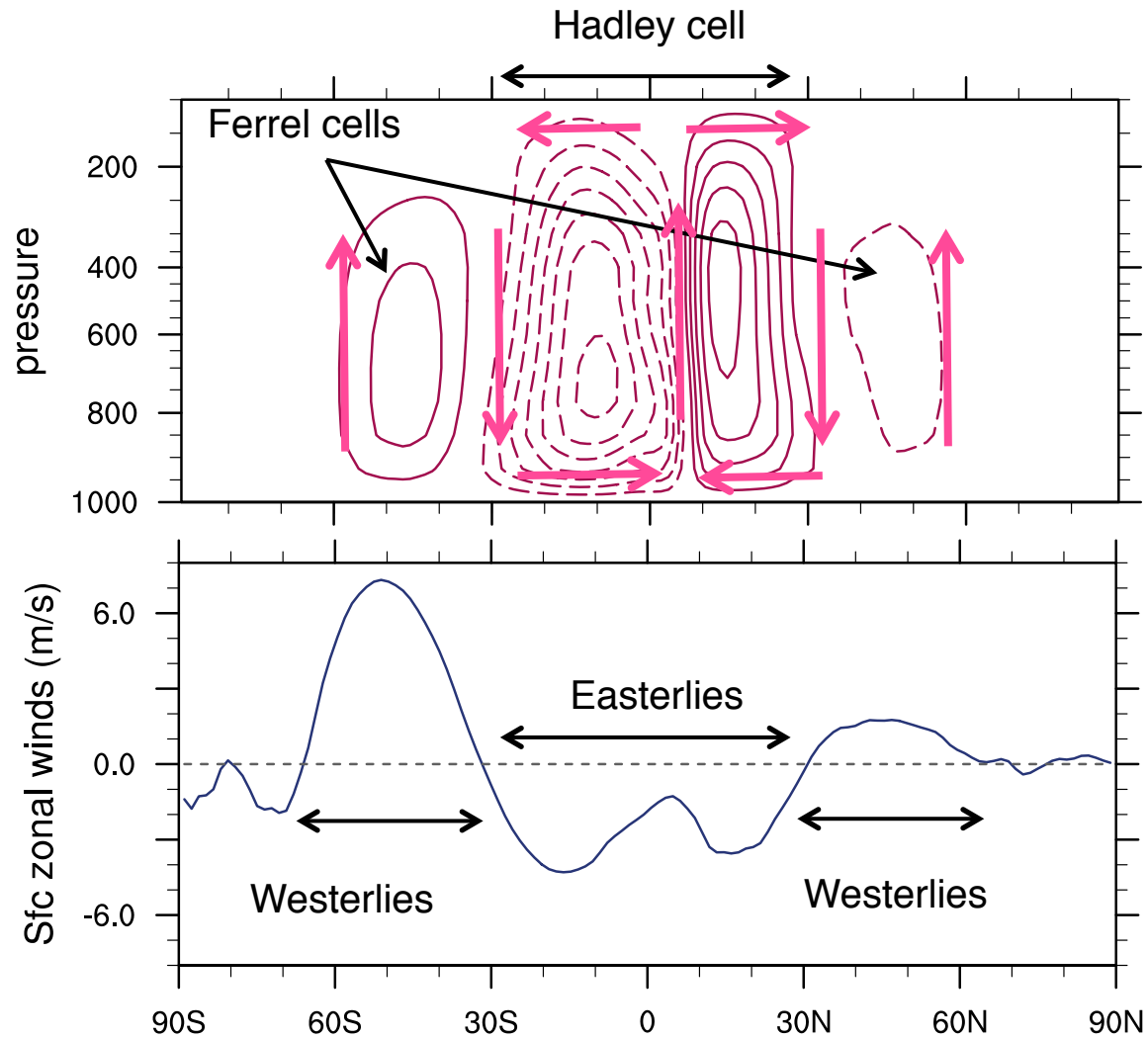
Why is the maximum precipitation (ITCZ) north of the equator?

Precipitation is tied to the atmospheric circulation

Annual mean winds
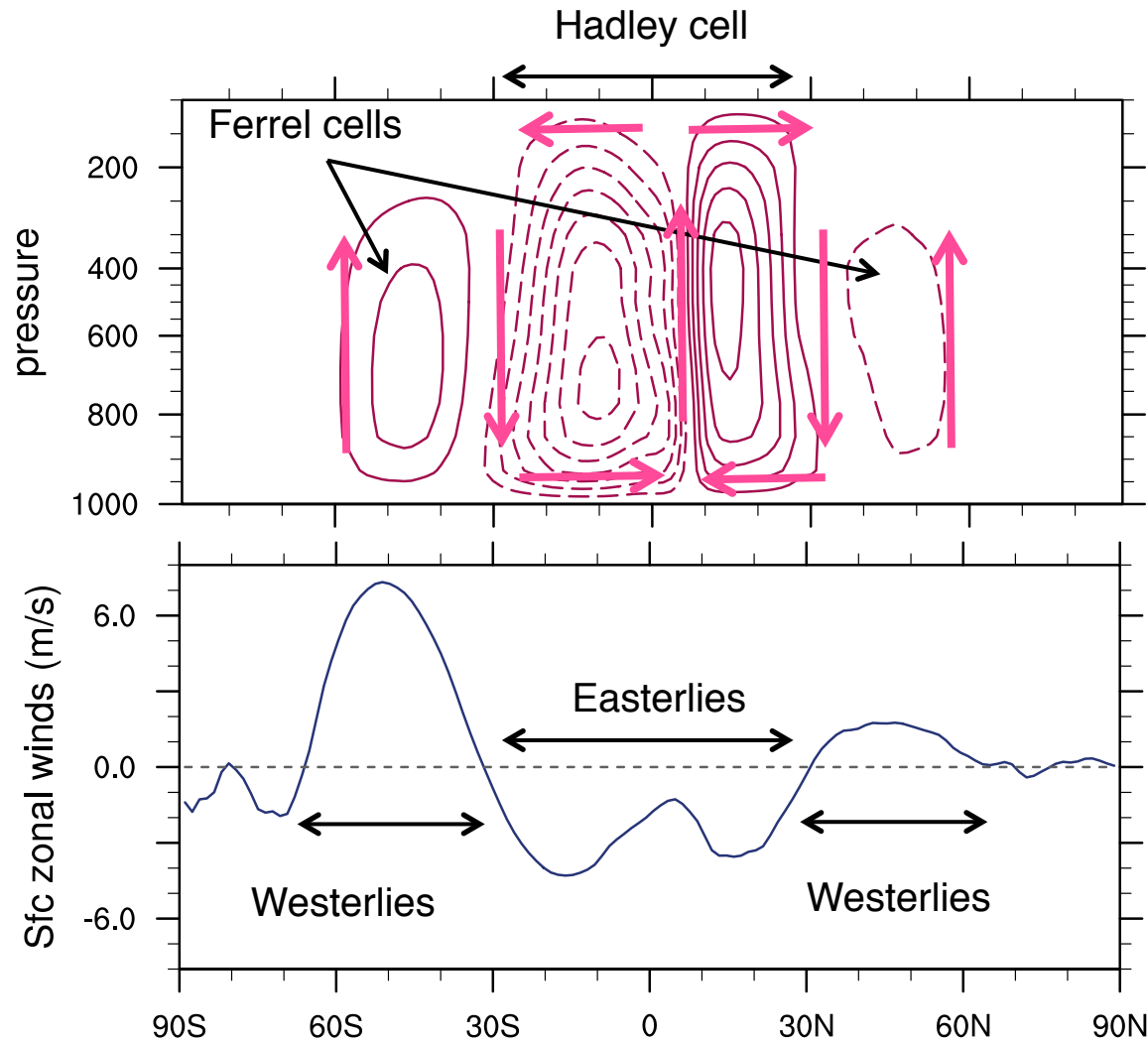

Data source: ERA40

Precipitation is tied to the atmospheric circulation

Data source: ERA40

Precipitation is tied to the atmospheric circulation

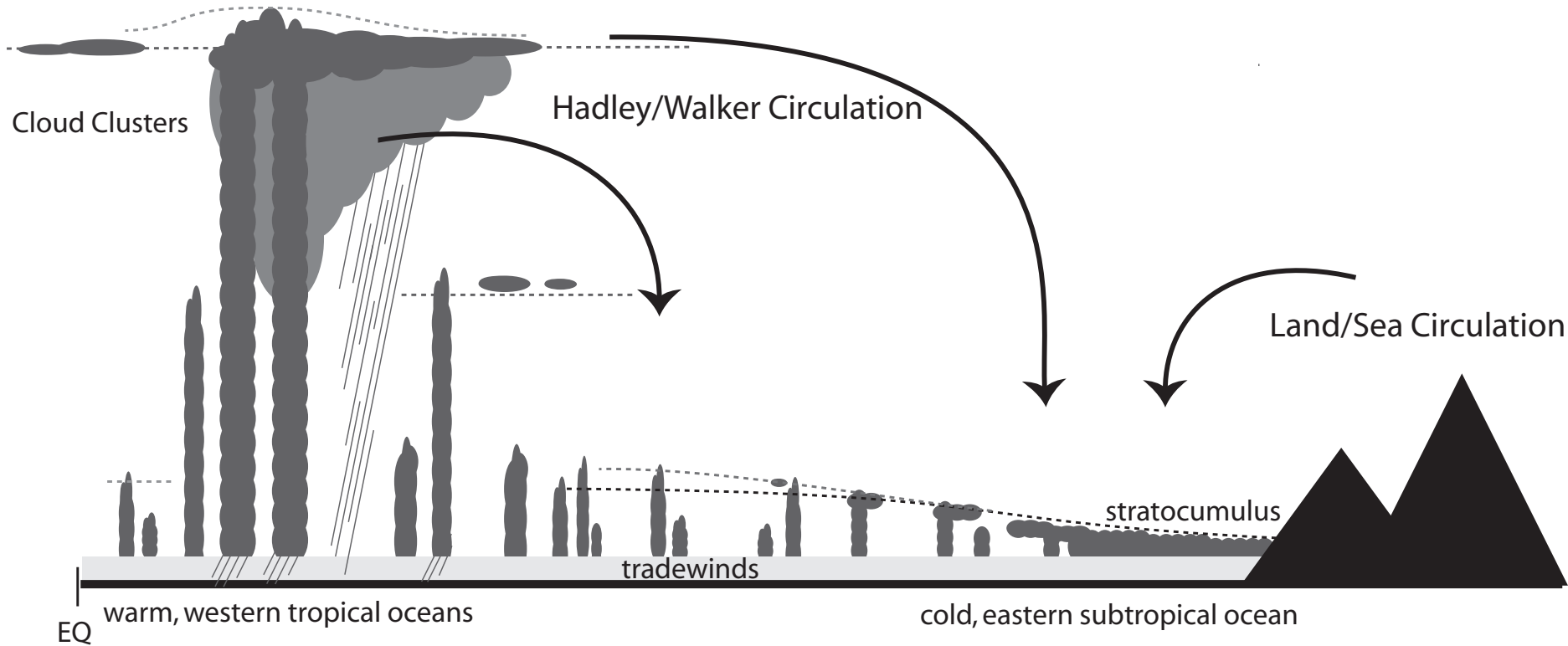Hadley cell

Ferrel cells

pressure

200
400
600
800
1000

90S 60S 30S 0 30N 60N 90N

Sfc zonal winds (m/s)

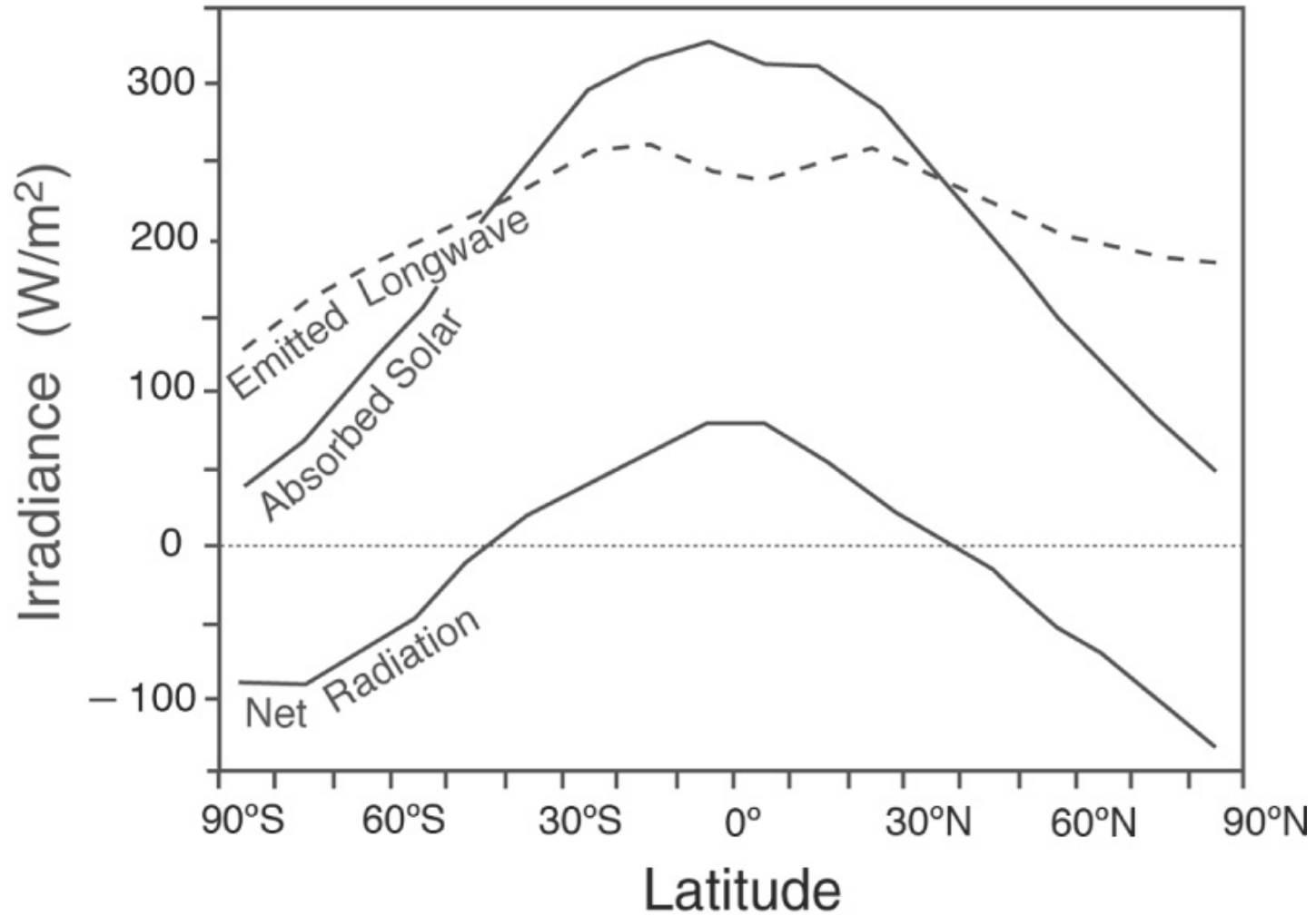6.0
0.0
-6.0

Easterlies

Westerlies

Westerlies

Maximum precipitation is co-located with ascending motion in the Hadley cells

Large-scale circulations and clouds

Cloud Clusters

Hadley/Walker Circulation

Land/Sea Circulation

stratocumulus

tradewinds

warm, western tropical oceans

cold, eastern subtropical ocean

EQ

Courtesy: Bjorn Stevens
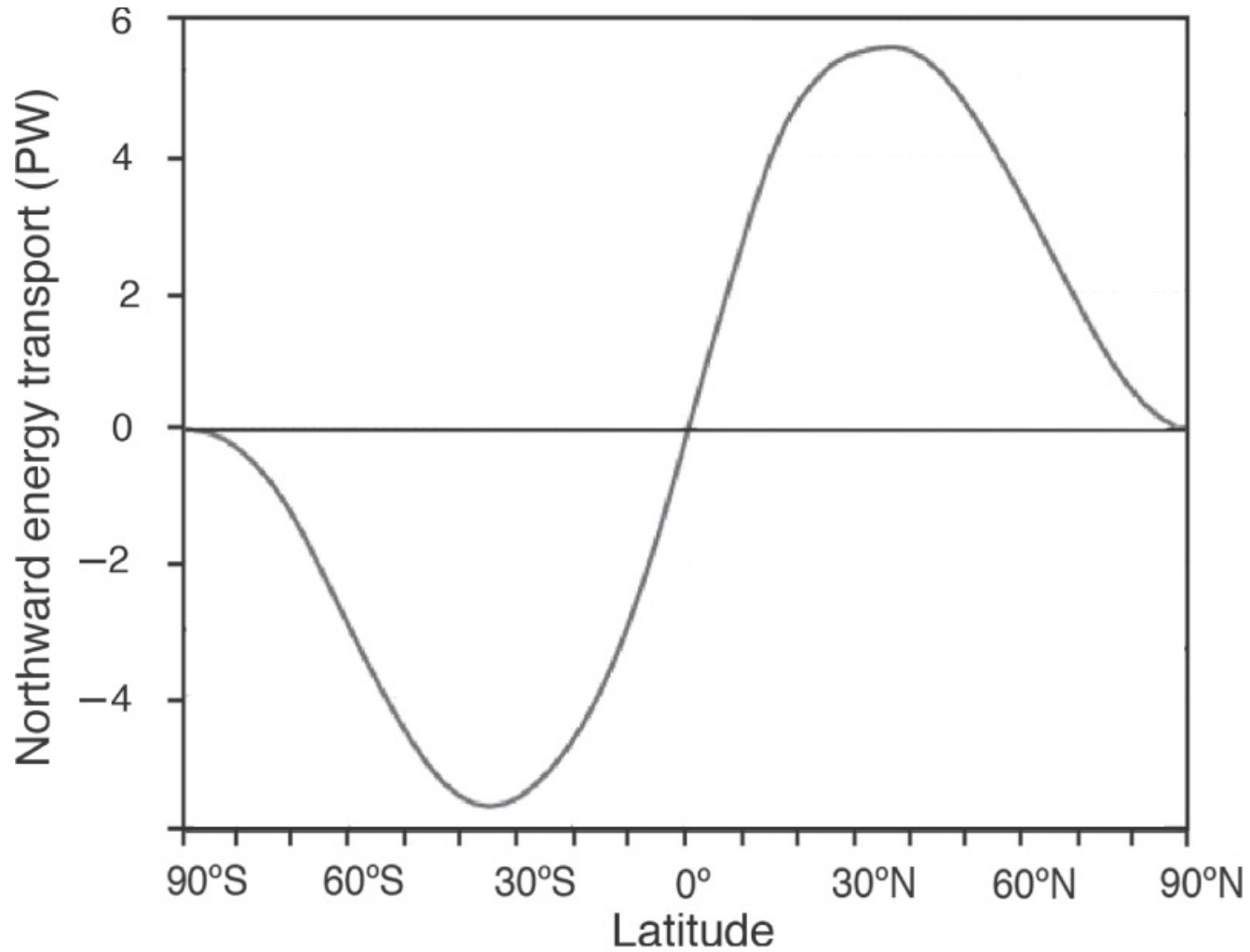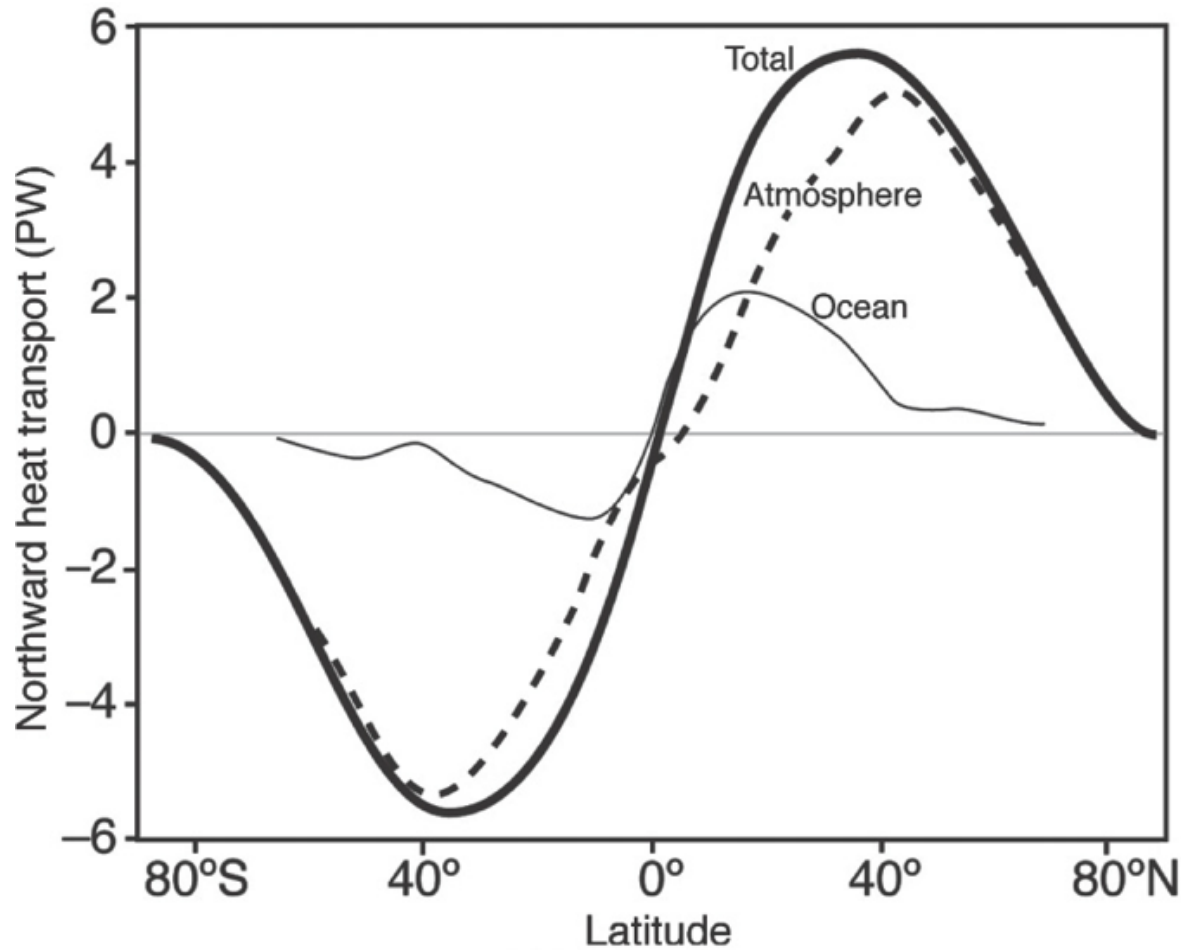
What drives the Hadley circulation

Implied poleward energy transport

Atmospheric and oceanic energy transport

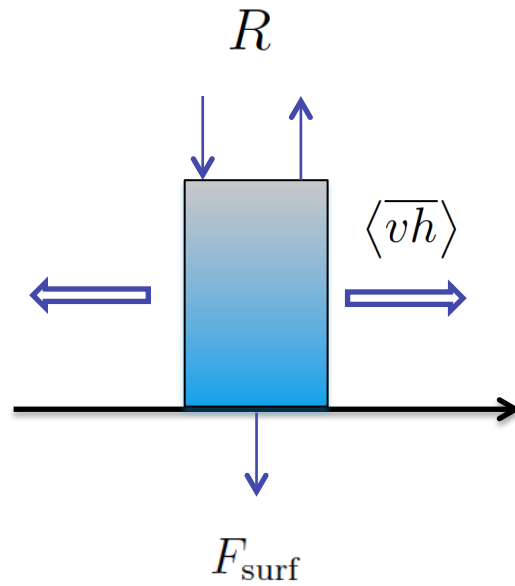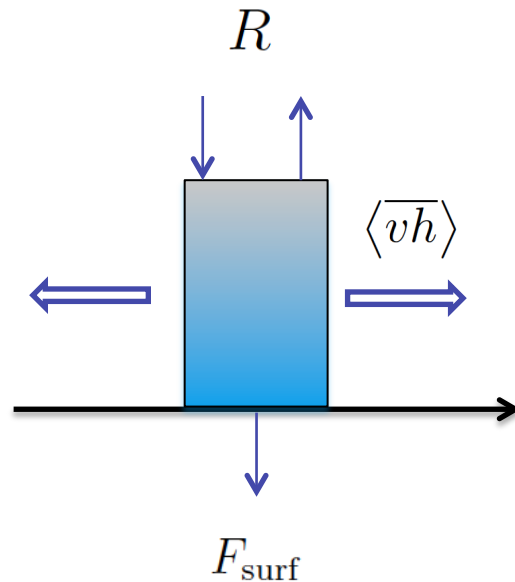(From Trenberth and Caron (2001).)

The general circulation of the atmosphere exists to transport energy from regions with net energy gain to regions of net energy loss

The energy budget for a moist atmosphere
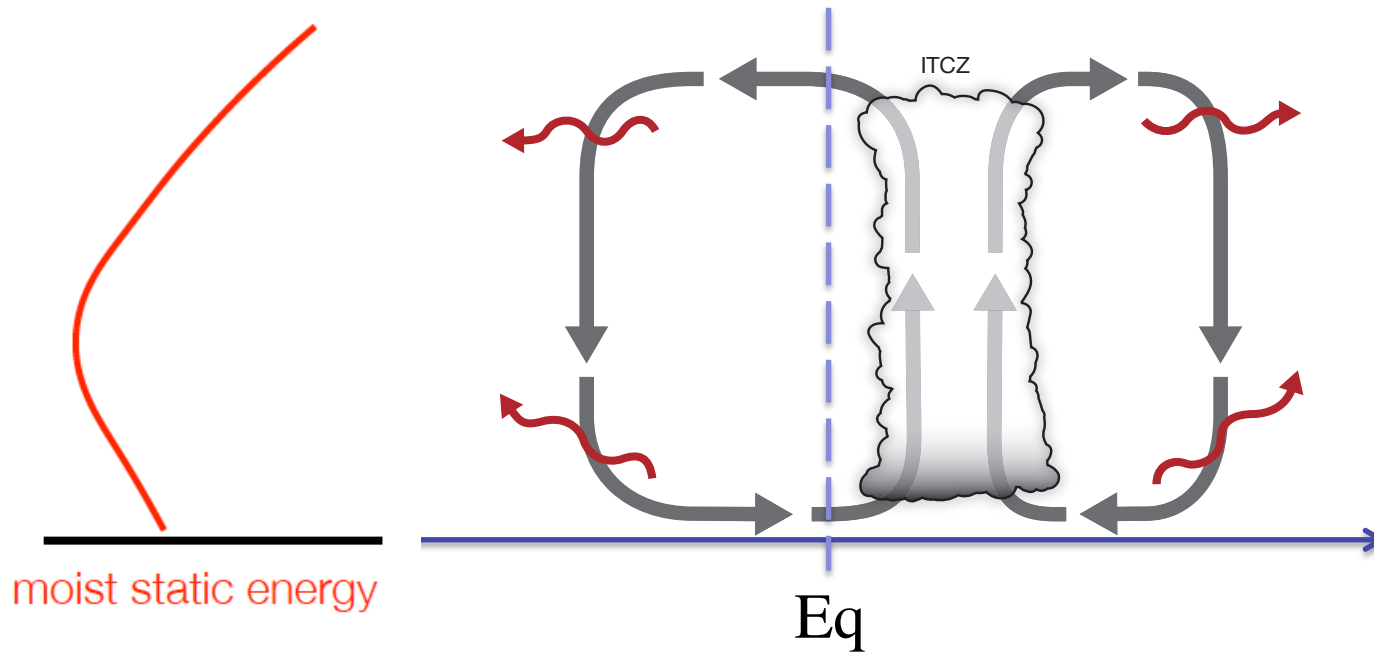
The energy budget for a moist atmosphere

$$\partial_y \left\langle \overline{vh} \right\rangle = R - F_{\mathrm{surf}} = F^{\mathrm{net}} \qquad\qquad h = C_p T + L_v q + gz$$

Relates the circulation to energy sources and sinks, without explicit consideration of latent heating

e.g., Neelin and Held (1987), Held (2001), Merlis, Eisenman, Bordoni and Schneider (2013 a,b,c)

Energetic constraint on Hadley cell

moist static energy

ITCZ

Eq

Adapted from Schneider et al. 2014

Because MSE is positively stratified, the Hadley cell usually transports energy in the direction of the upper-level flow

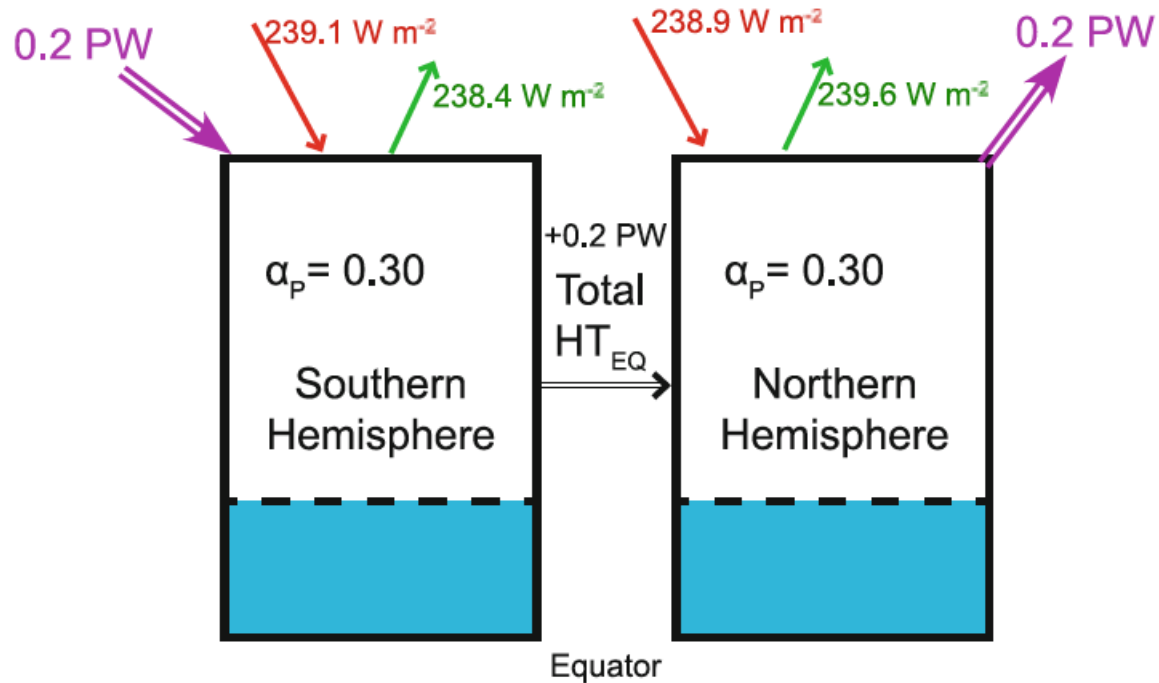# Energetic constraint on Hadley cell
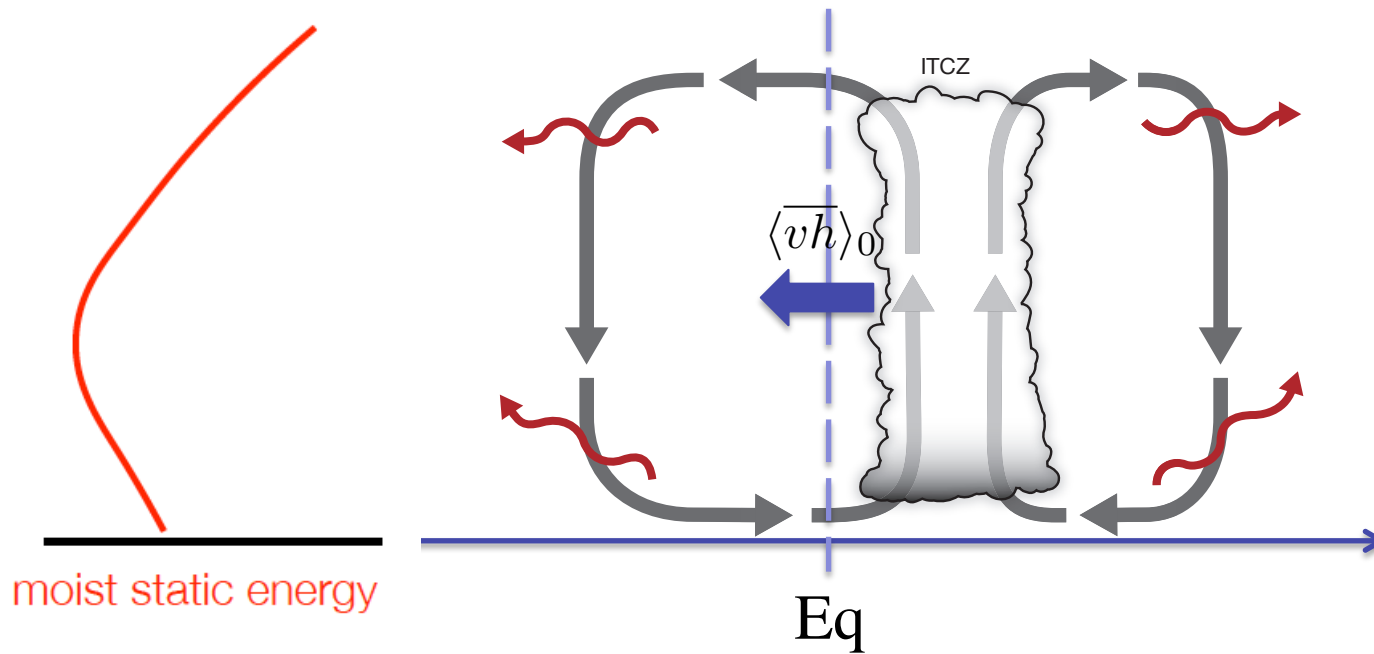
$\langle \overline{vh} \rangle_0$

ITCZ

moist static energy

Eq

Adapted from Schneider et al. 2014

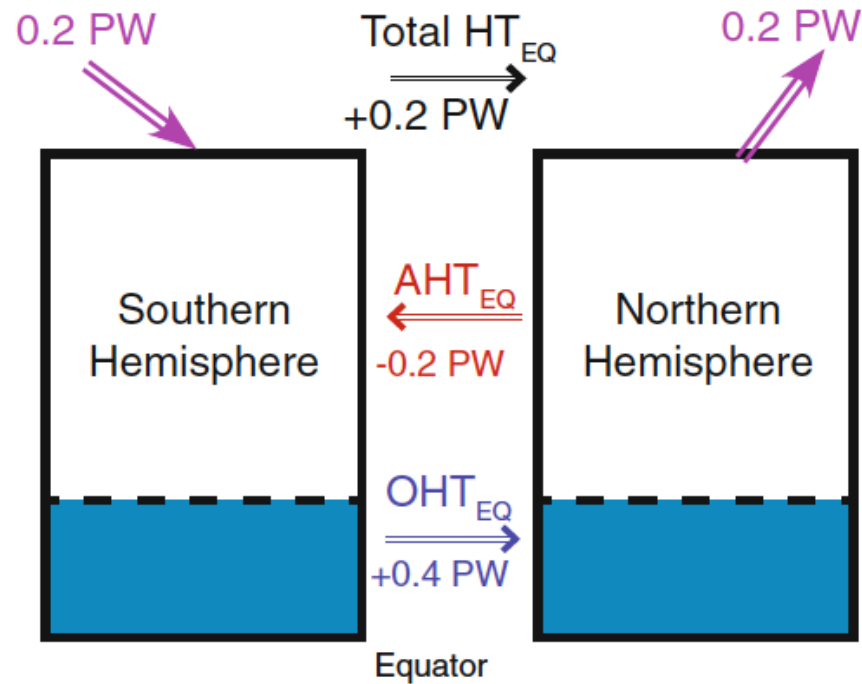ITCZ position is anti-correlated with the cross-equatorial energy transport $\langle \overline{vh} \rangle_0$

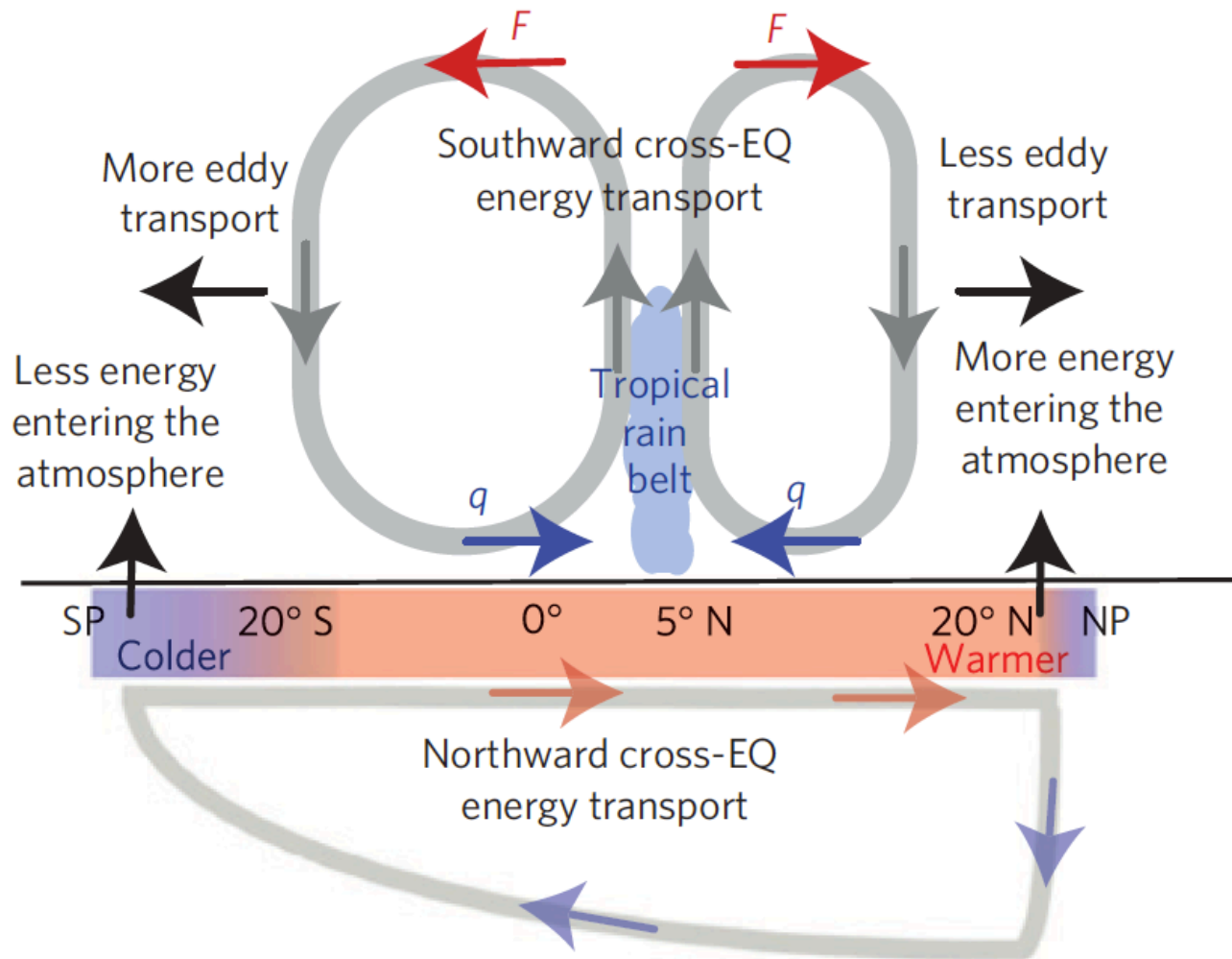e.g., Kang et al. 2008, Hwang and Frierson 2012, Donohoe et al. 2013, Bischoff and Schneider 2014

What drives hemispheric asymmetry?

Marshall et al. (2013)

Role of ocean heat transport

Mechanisms of northward shifted position of the ITCZ
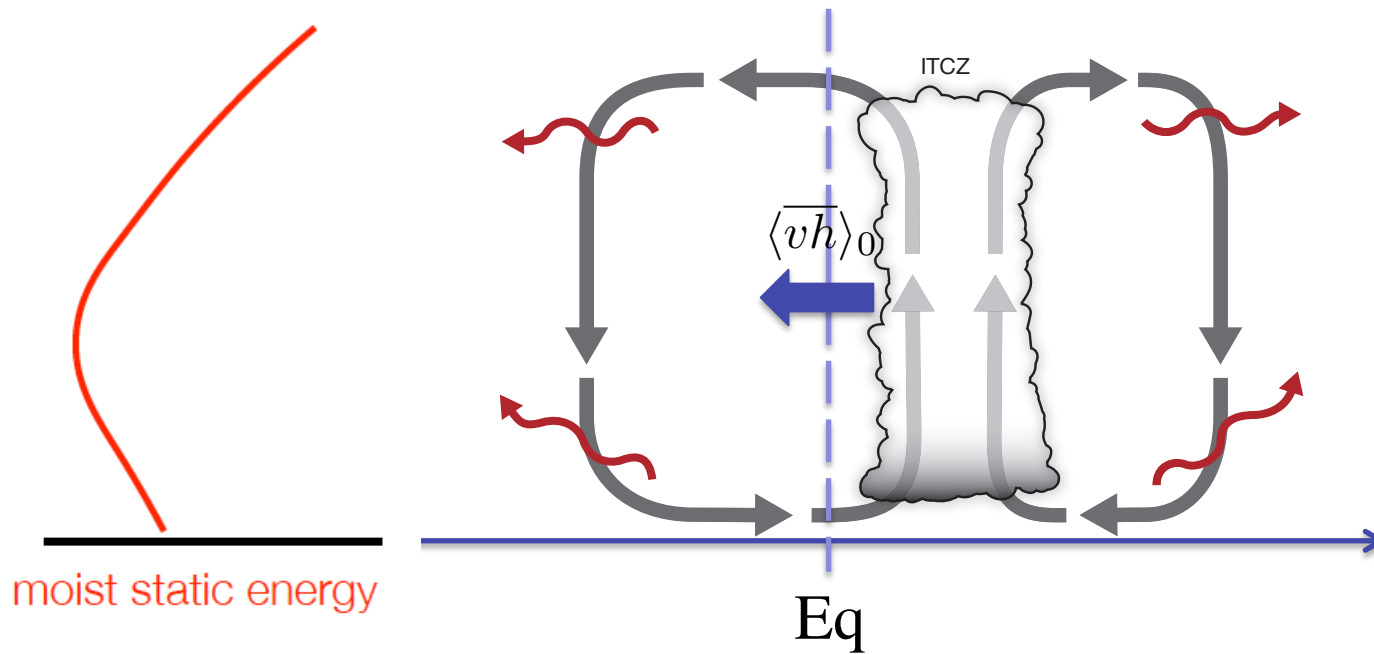
Frierson et al. (2013)

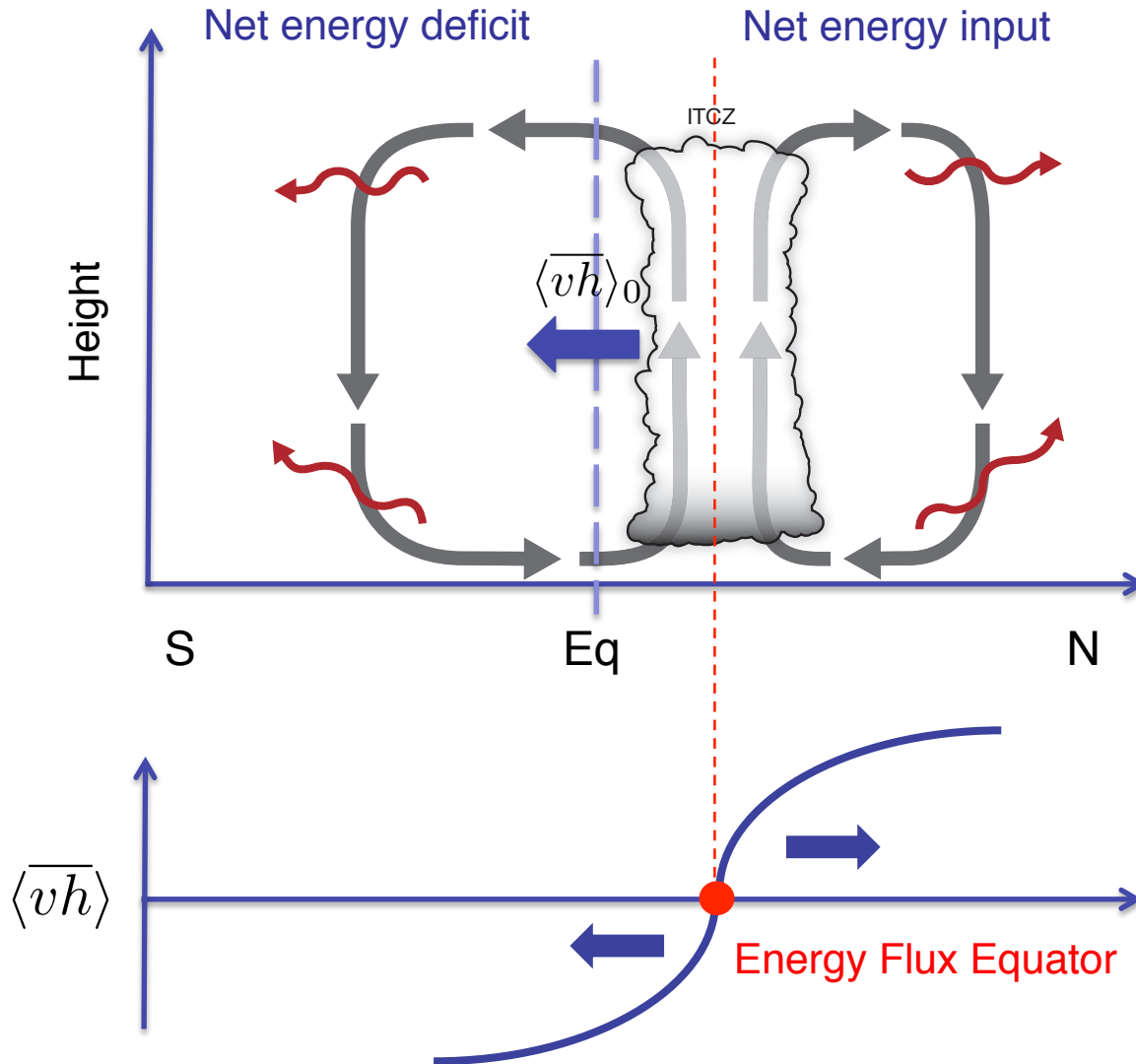# Energetic constraint on Hadley cell

moist static energy

$\langle \overline{vh} \rangle_0$

ITCZ

Eq
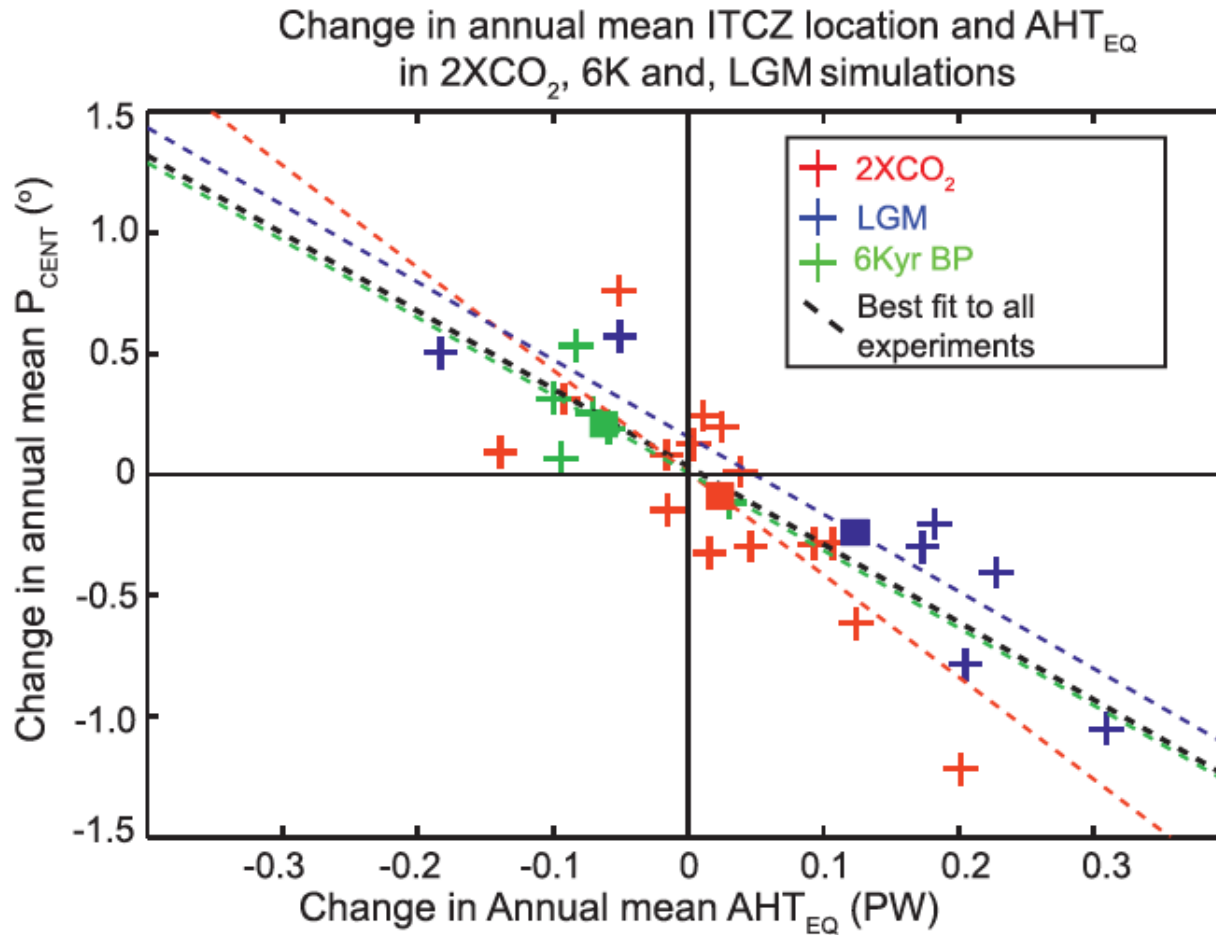
Adapted from Schneider et al. 2014

ITCZ position is anti-correlated with the cross-equatorial energy transport $\langle \overline{vh} \rangle_0$

e.g., Kang et al. 2008, Hwang and Frierson 2012, Donohoe et al. 2013, Bischoff and Schneider 2014

ITCZ and EFE

e.g., Kang et al. 2008, Hwang and Frierson 2012, Donohoe et al. 2013, Bischoff and Schneider 2014

ITCZ and cross-equatorial energy transport

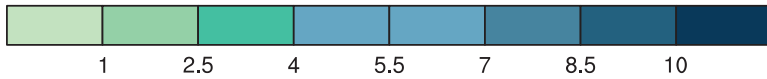Change in annual mean ITCZ location and AHT_{EQ} in $2XCO_2$, 6K and, LGM simulations
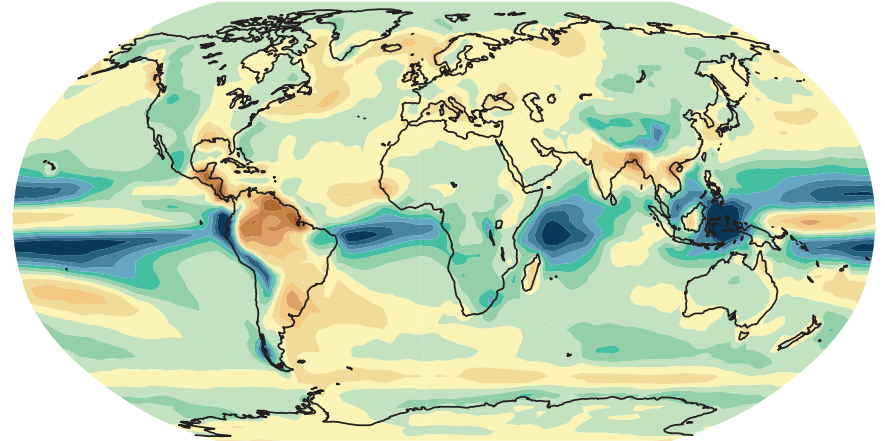
Tropical rainbelts in climate models

(a) Multi Model Mean Precipitation
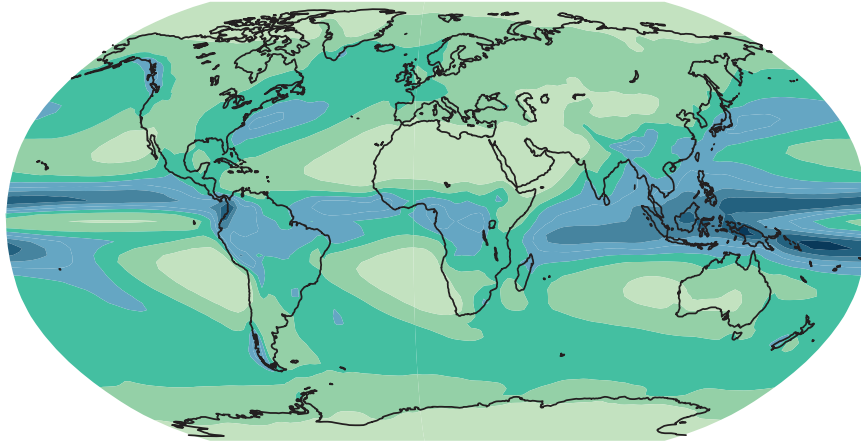
(b) Multi Model Mean Bias

(mm day⁻¹)

(mm day⁻¹)