第五章:

大气环流中的纬向环流系统

5.3 Walker Circulation

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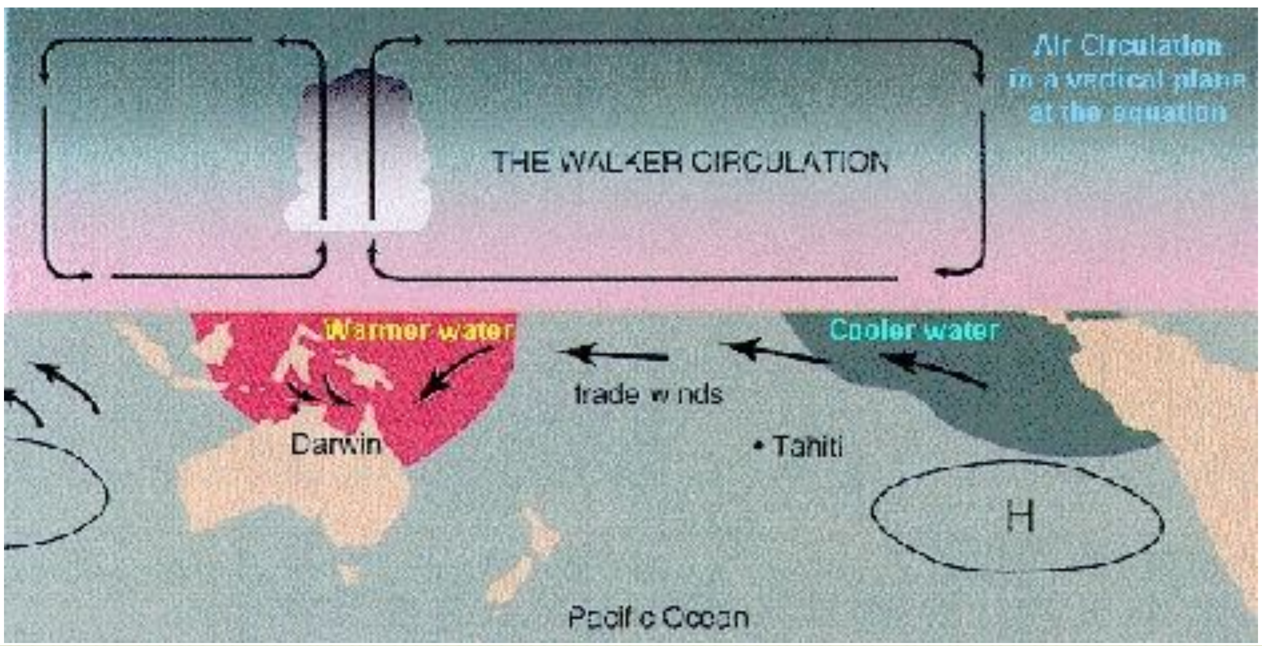
Outline

- Introduction
- Features of Walker circulation
- Seasonal variation of walker circulation
- ENSO and Walker circulation (inter-annual variation)
- The two-box model of Walker circulation
- Summary

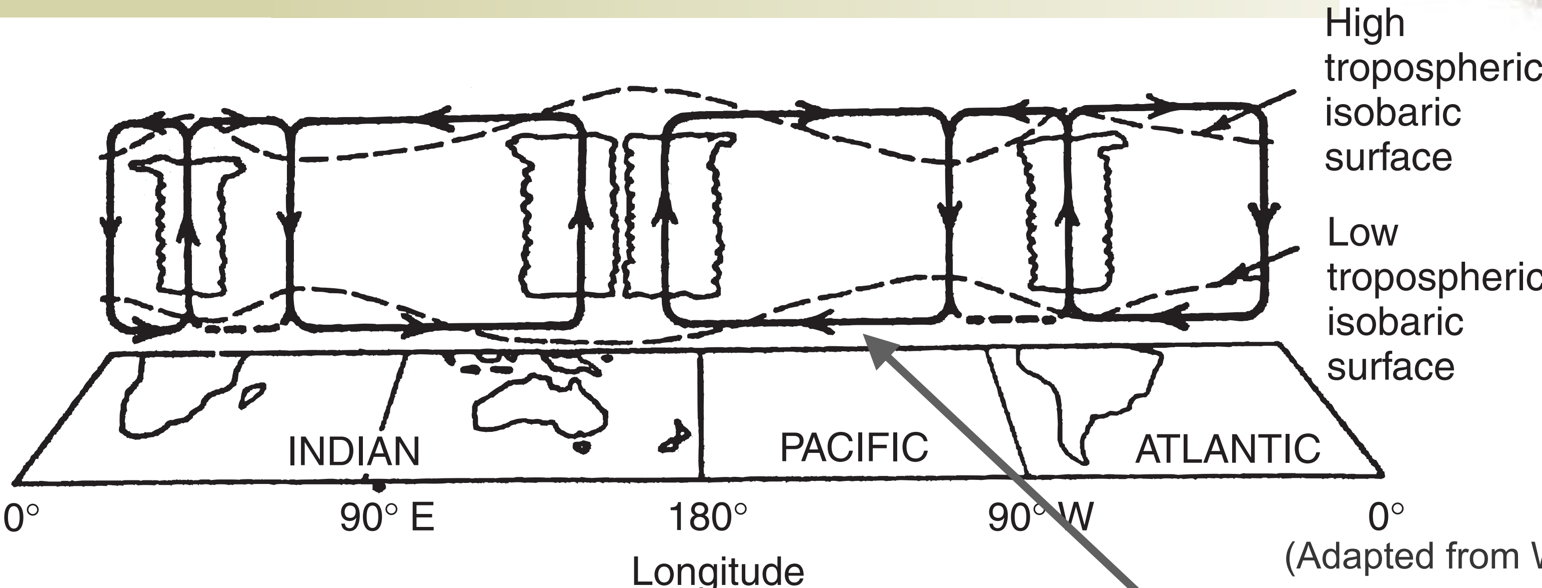
Introduction

- **Walker Circulation** was first introduced in 1966 by Prof. Jacob Bjerknes, referring to the large scale atmospheric circulation along the **longitude-height plane** over the **equatorial Pacific Ocean**.

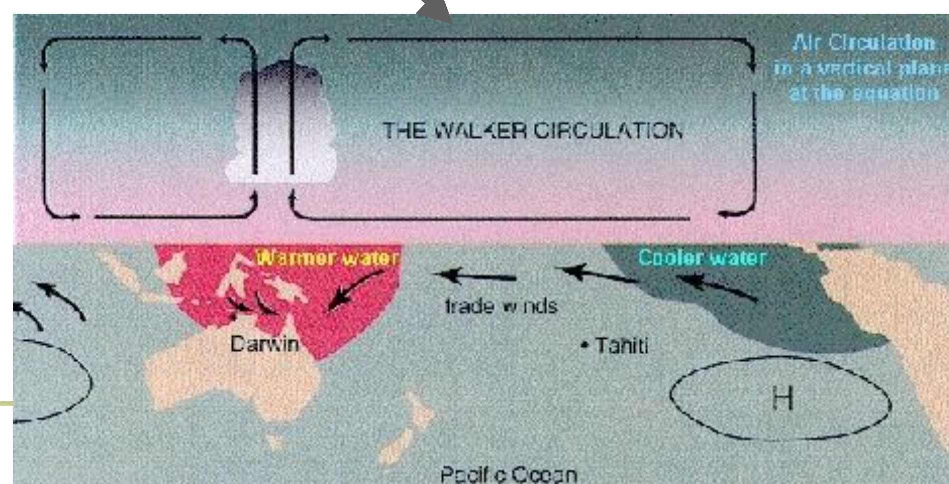


Named after Gilbert Walker, a key contributor to Southern Oscillation.

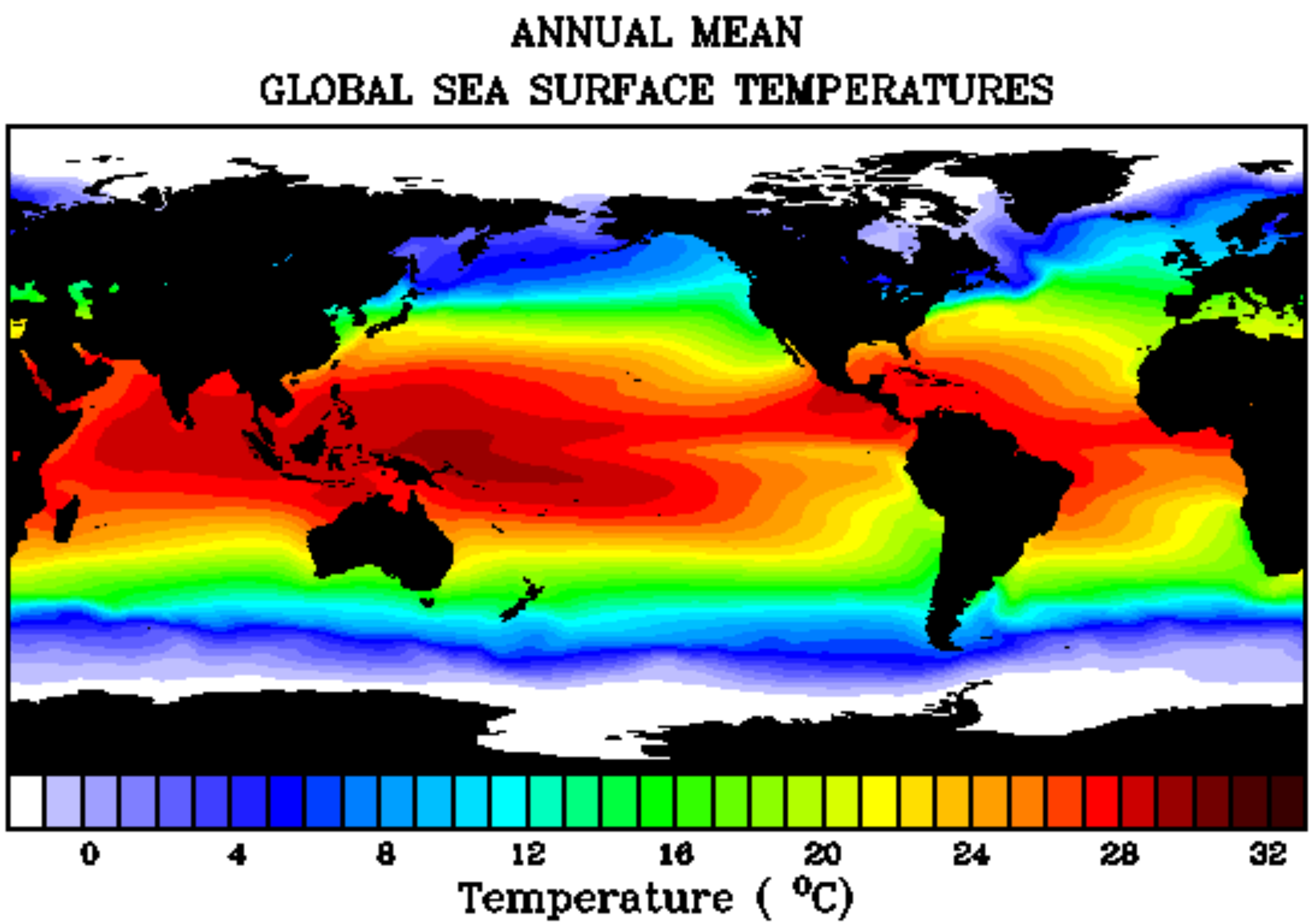
Introduction



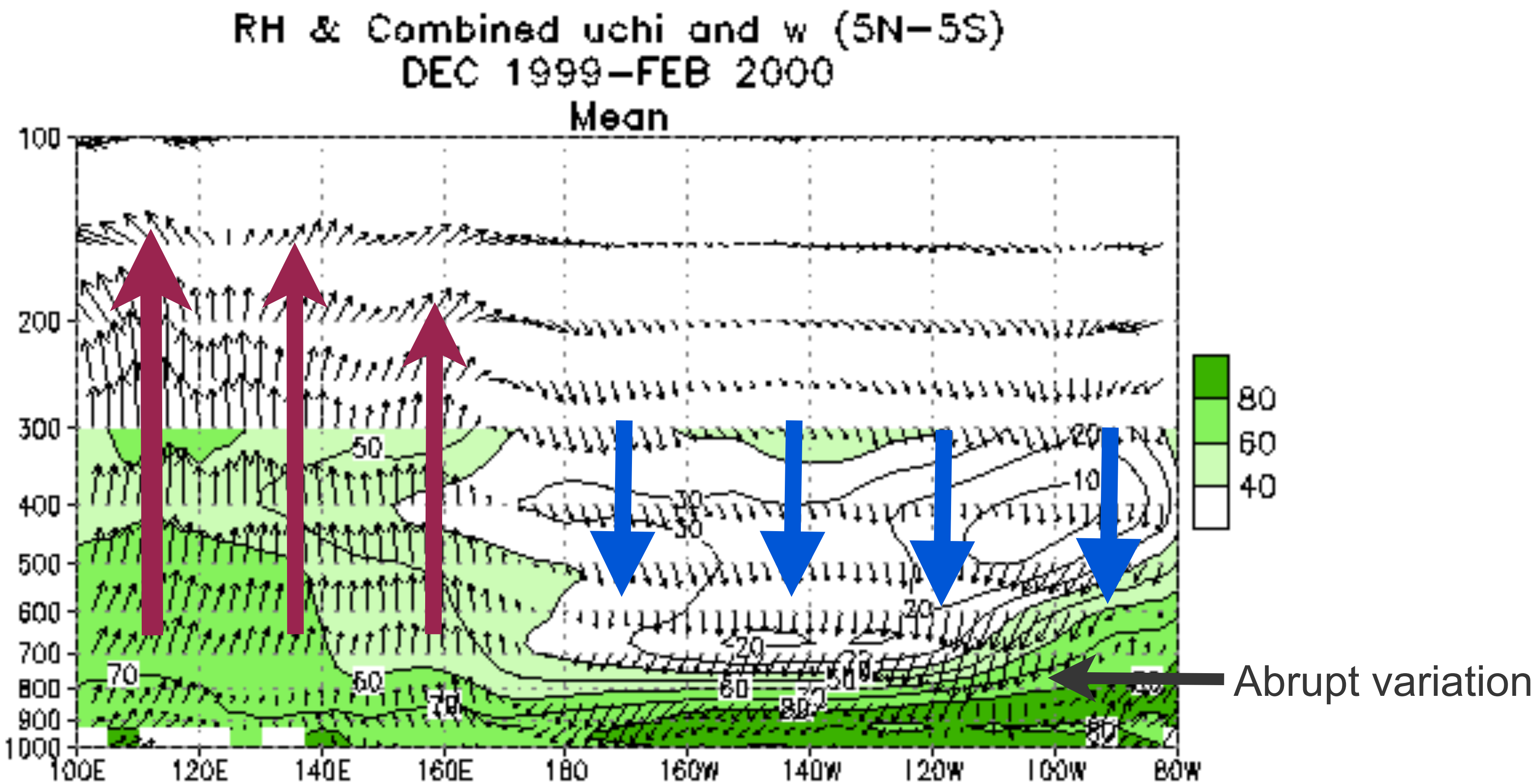
(Adapted from Webster 1983)



Observed features



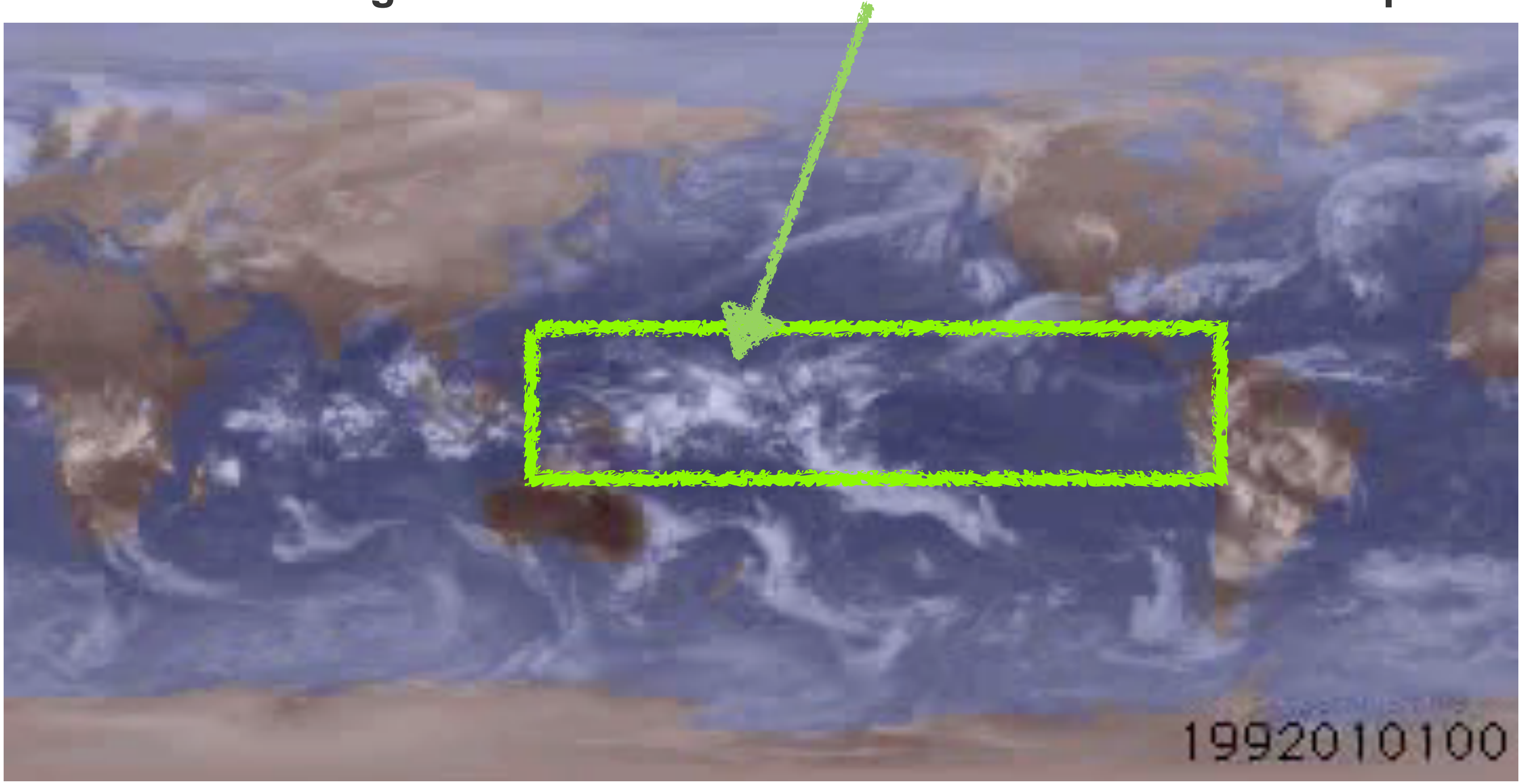
Observed features



Adapted from Emanuel, 2005

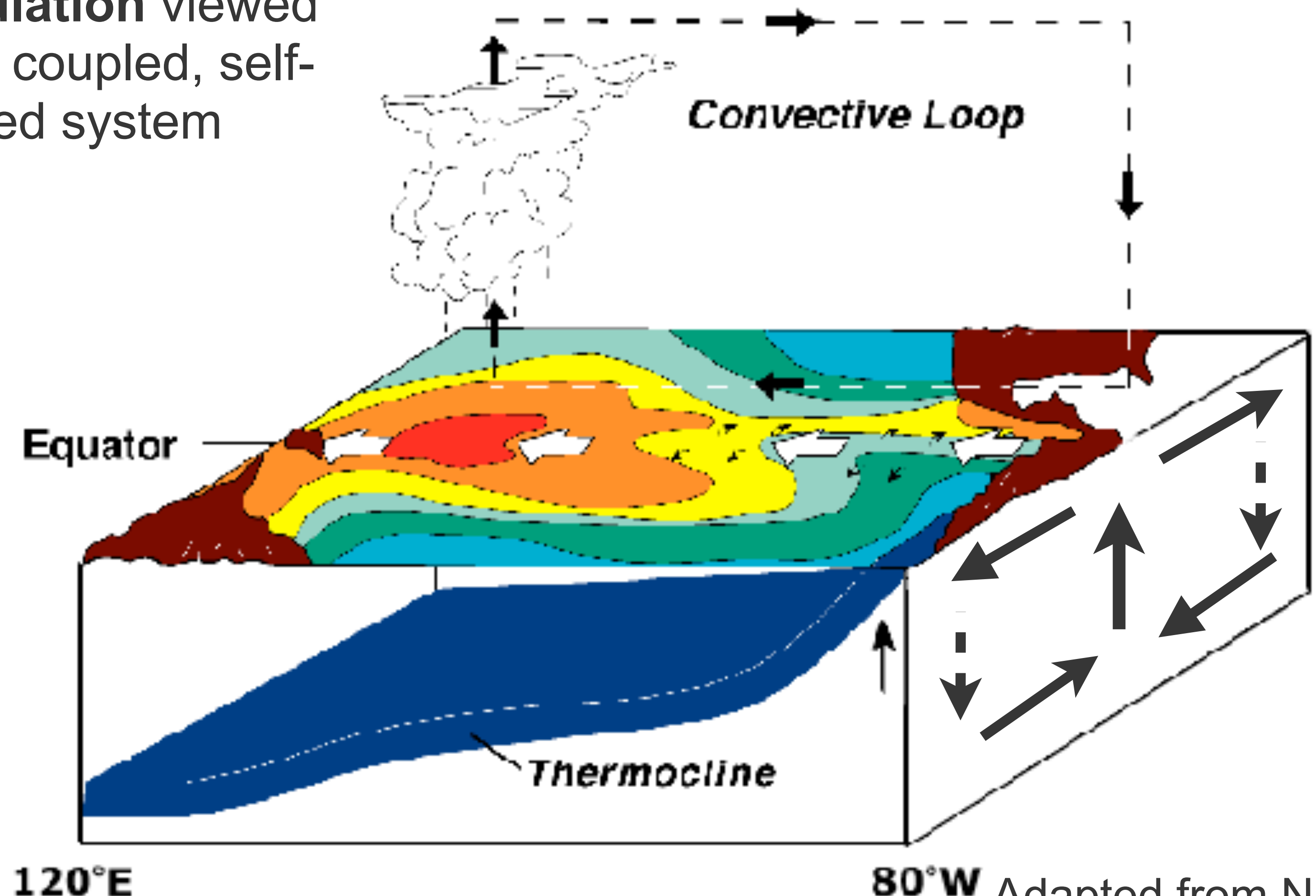
Observed features

great amount of convective cloud in the western pacific



Observed features

Walker Circulation viewed as an air-sea coupled, self-maintained system



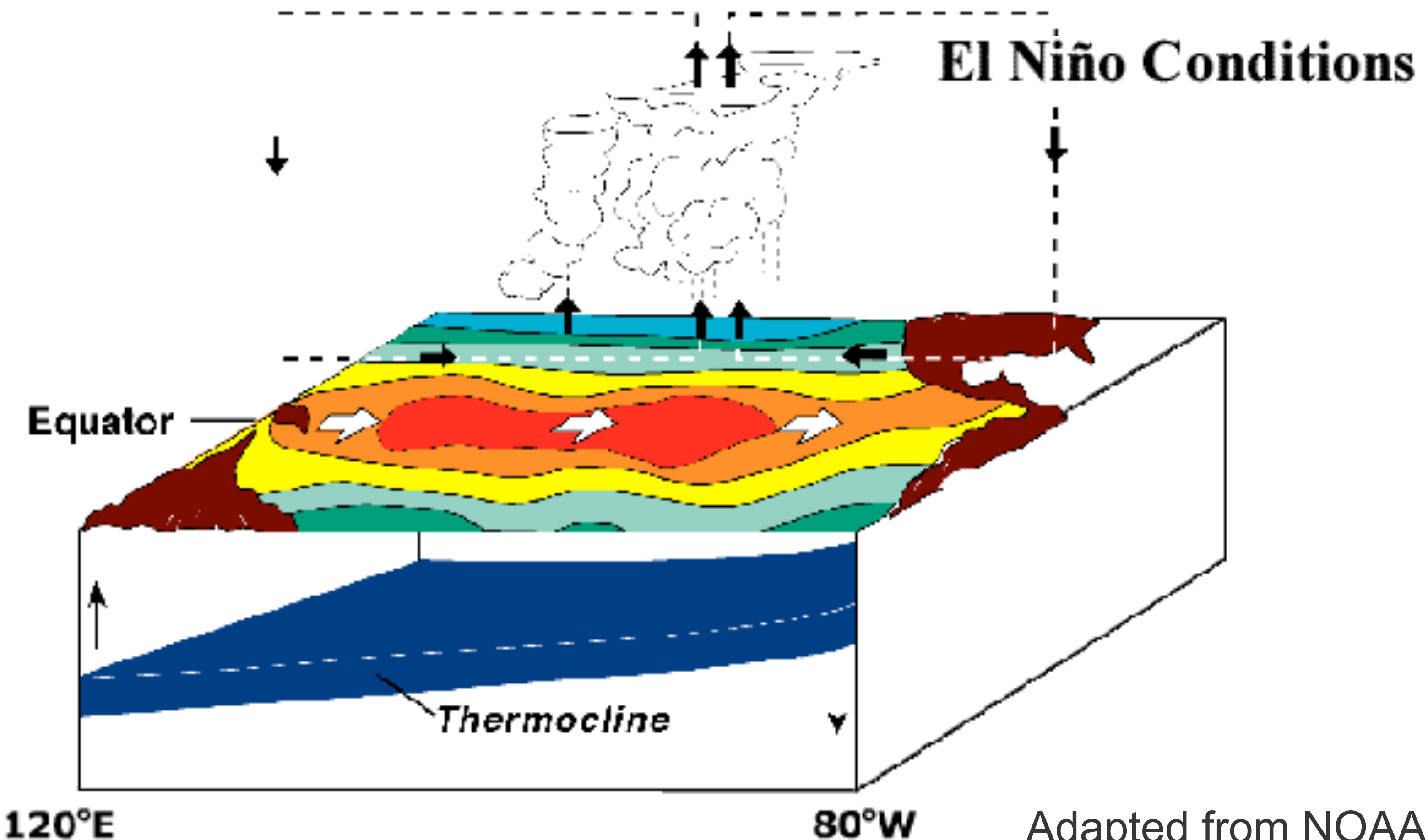
Adapted from NOAA

ENSO and Walker Circulation

- **El Niño** is defined by prolonged differences in **tropical Pacific Ocean SST** when compared with the average value. The accepted definition is a warming or cooling of at least 0.5 °C averaged over the east-central tropical Pacific Ocean. Typically, this anomaly happens at irregular intervals of 2–7 years and lasts nine months to two years.

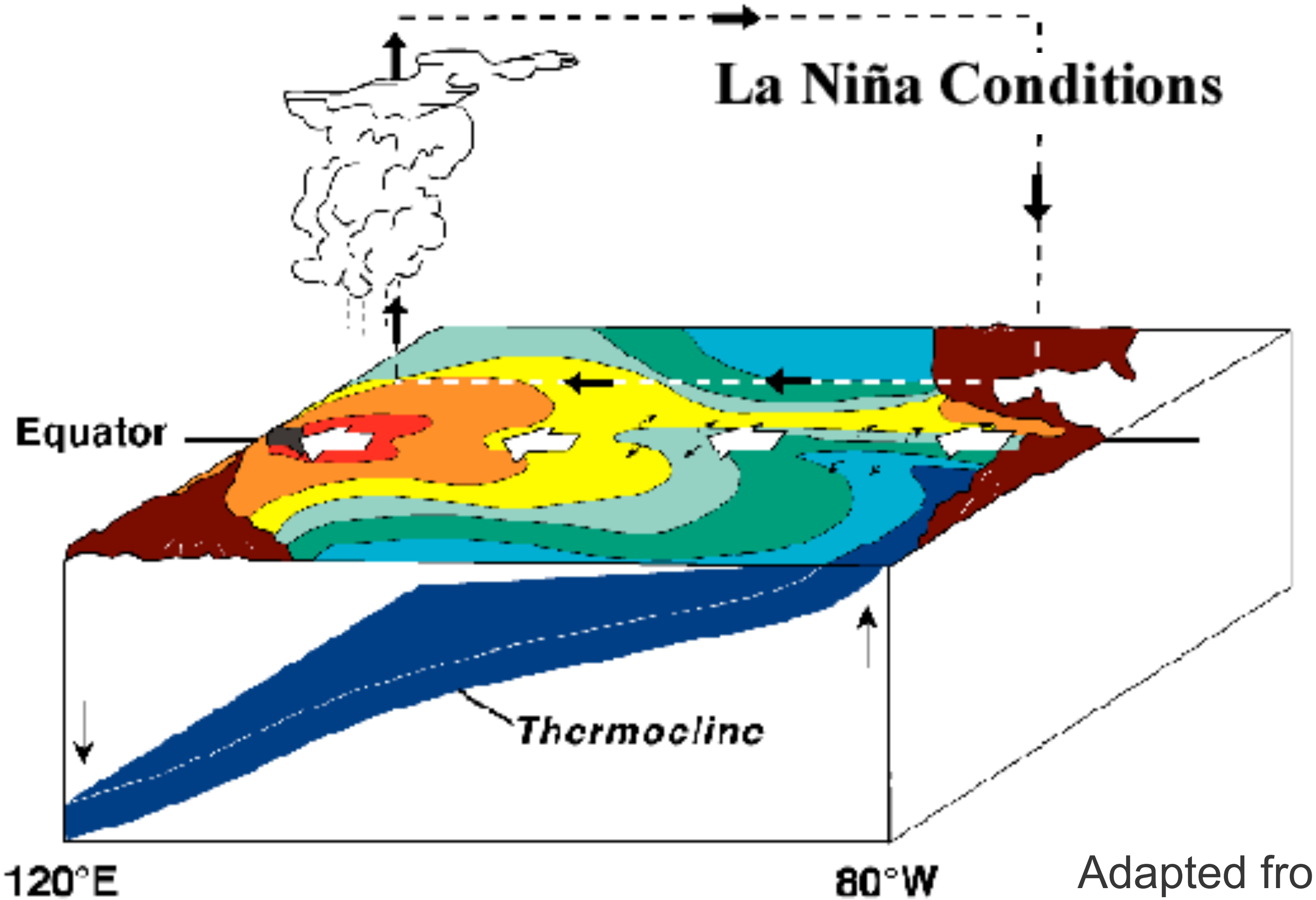
- The **Southern Oscillation** is the atmospheric component of **El Niño**. This component is an **oscillation in surface air pressure** between the tropical **eastern and the western Pacific Ocean waters**. The strength of the Southern Oscillation is measured by the **Southern Oscillation Index** (SOI). The SOI is computed from fluctuations in the surface air pressure difference between Tahiti and Darwin, Australia.

ENSO and Walker Circulation



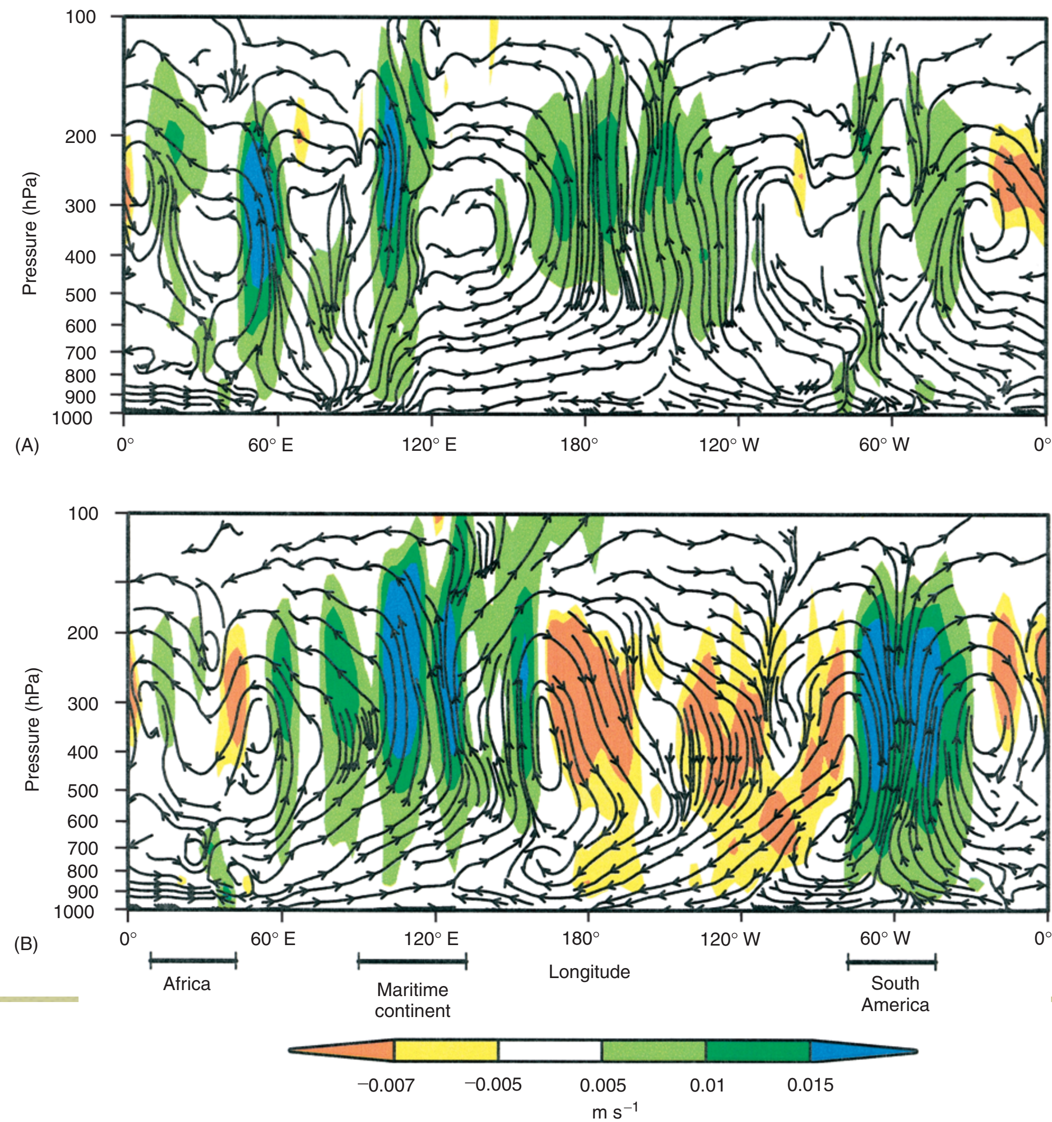
Adapted from NOAA

ENSO and Walker Circulation



Adapted from NOAA

ENSO and Walker Circulation



El Nino years:

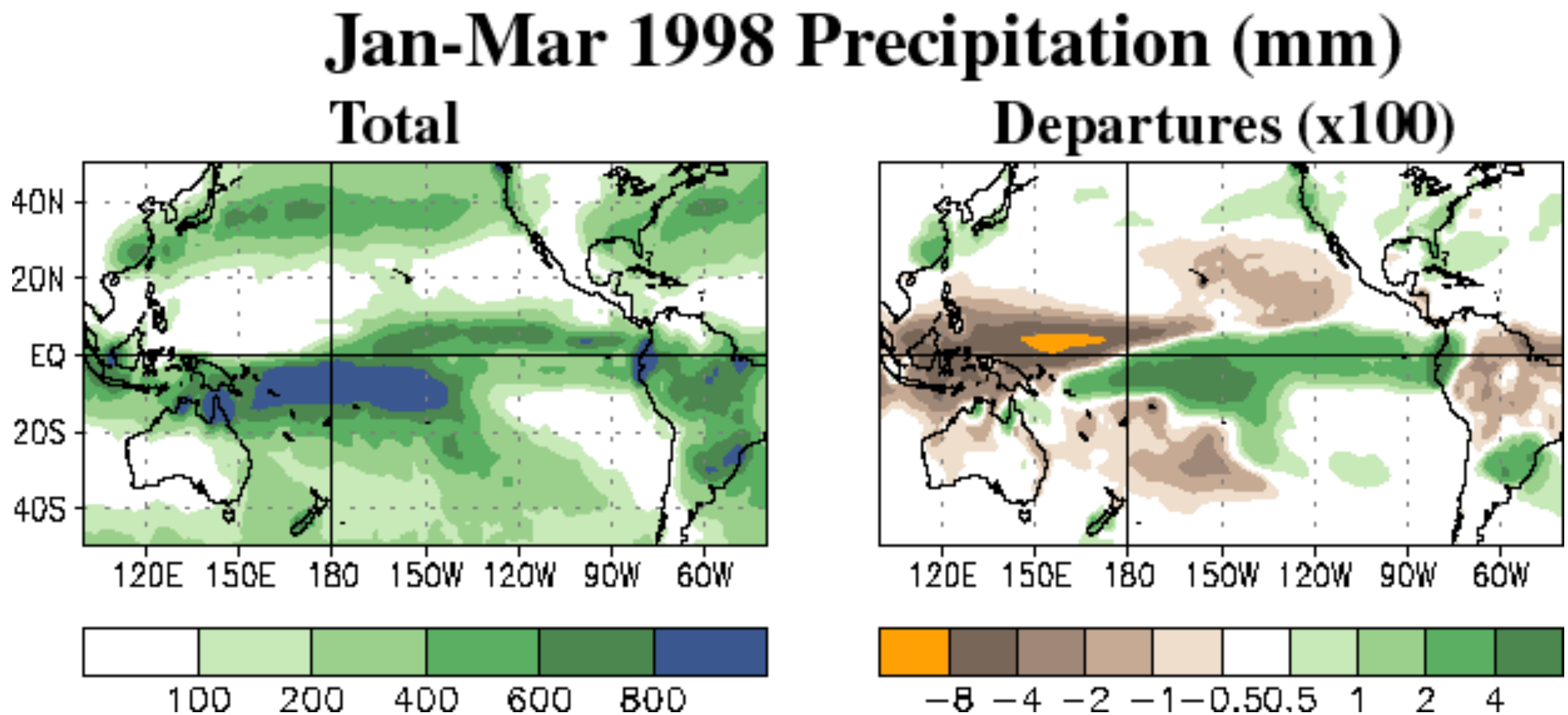
Raising motion prevailed at almost all longitudes with a peak in central pacific.

La Nina years:

An enhanced Walker Circulation.

Adapted from Lau et al, 2002

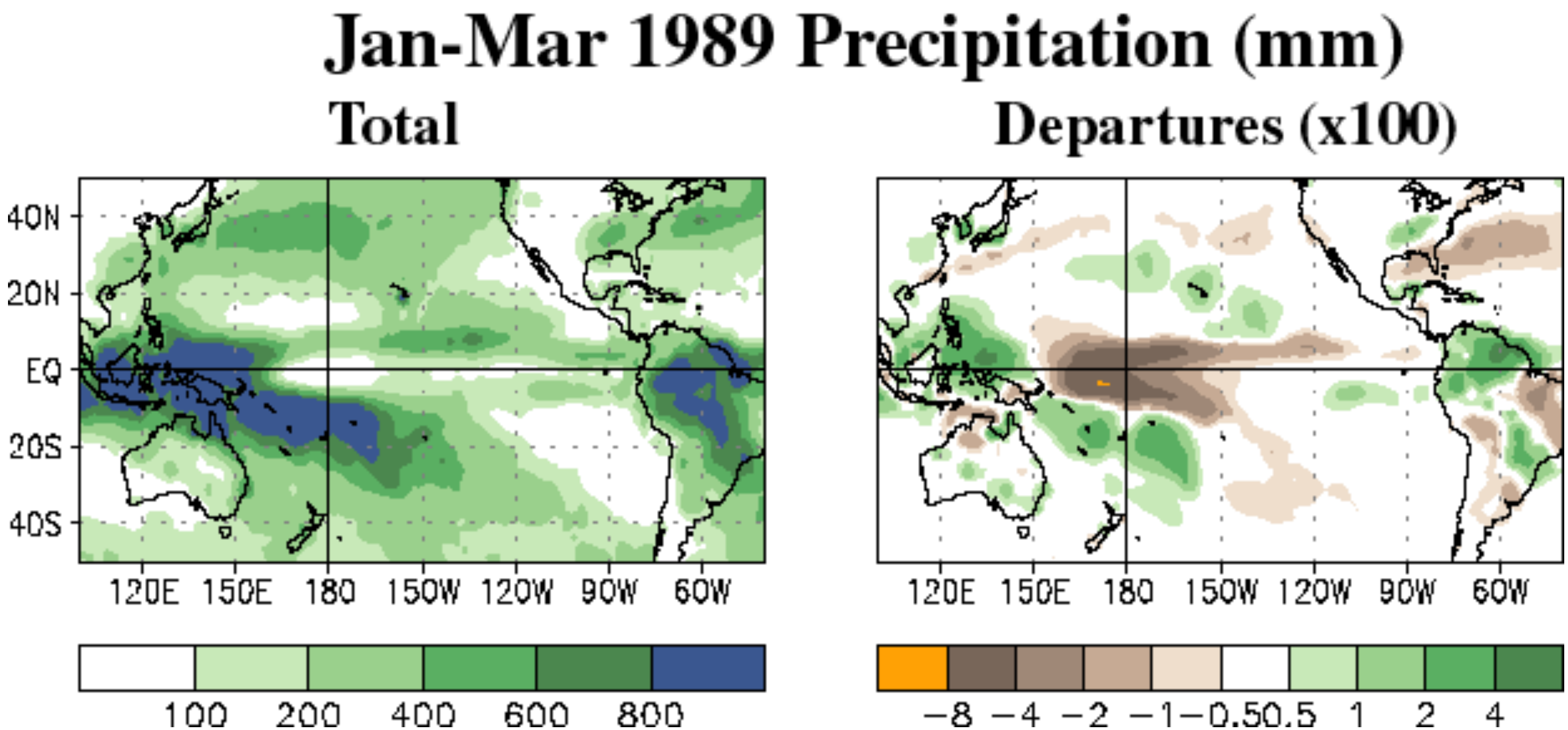
ENSO and Walker Circulation



El Nino years

Adapted from NOAA

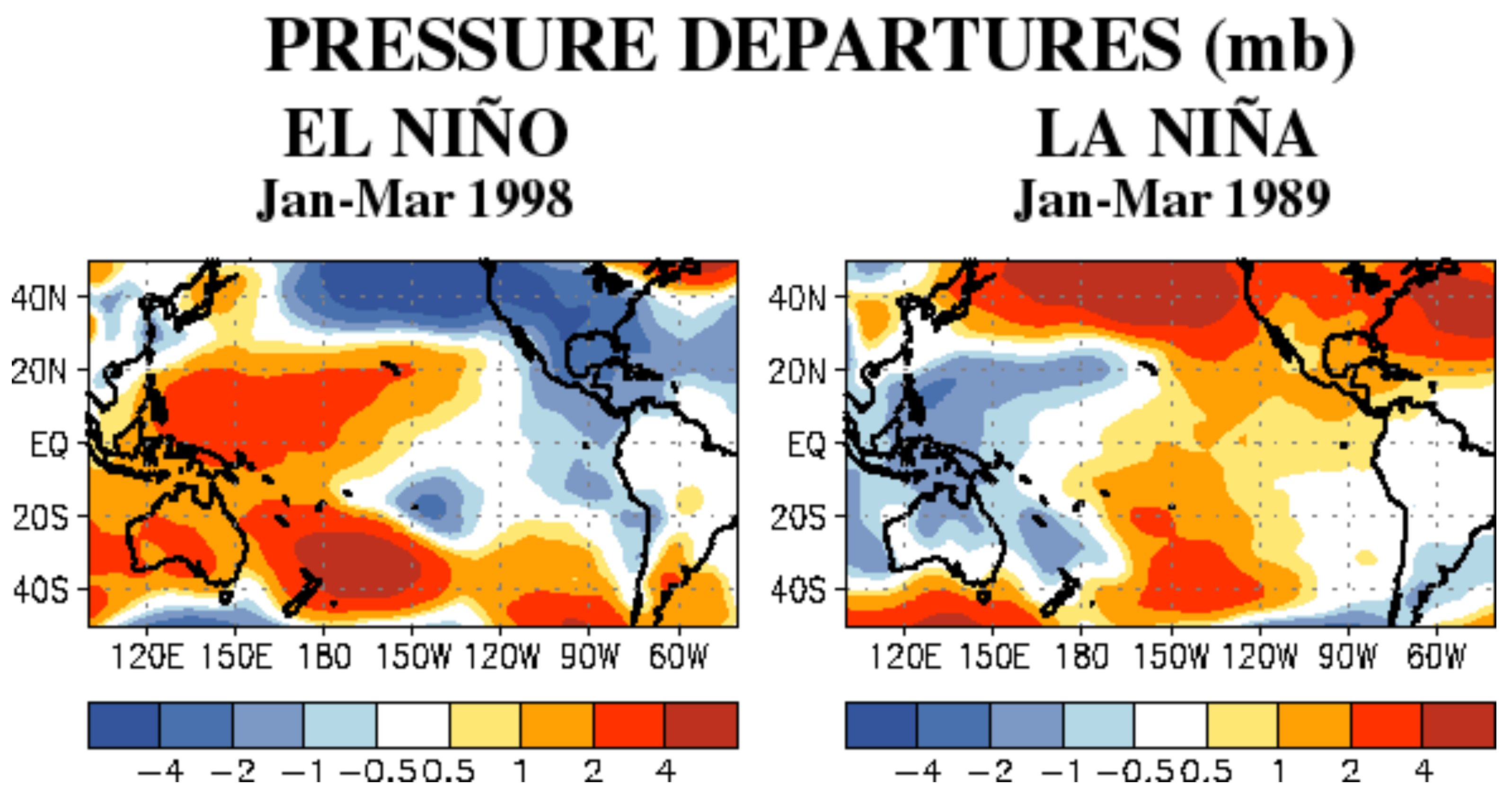
ENSO and Walker Circulation



La Nina years

Adapted from NOAA

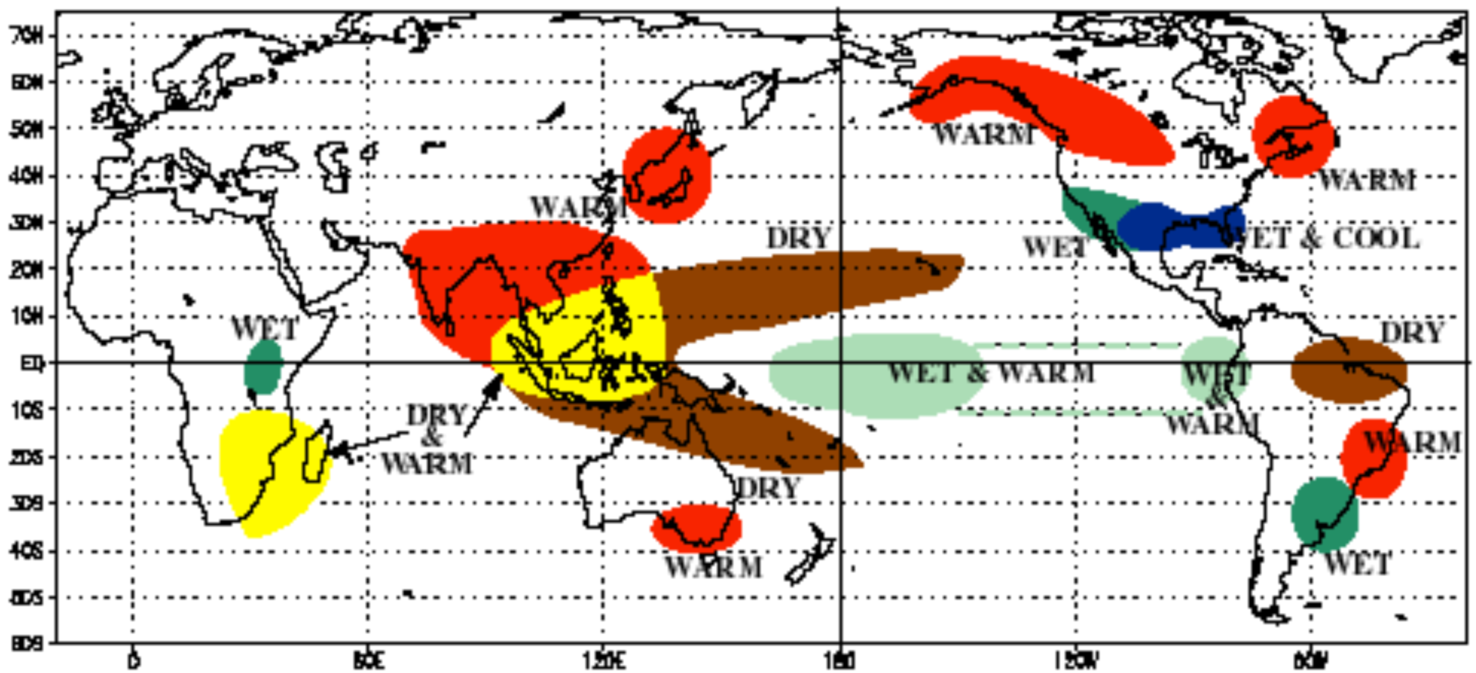
ENSO and Walker Circulation



Adapted from NOAA

ENSO and Walker Circulation

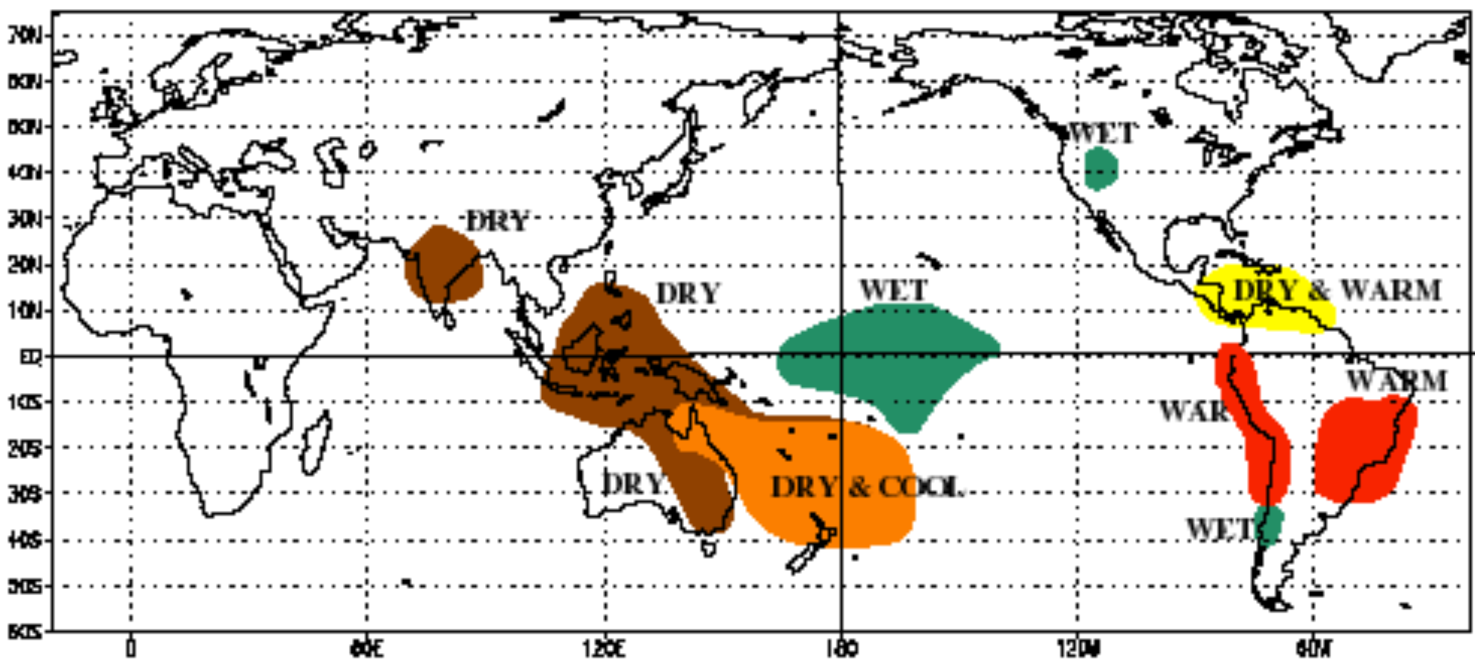
WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



Adapted from NOAA

ENSO and Walker Circulation

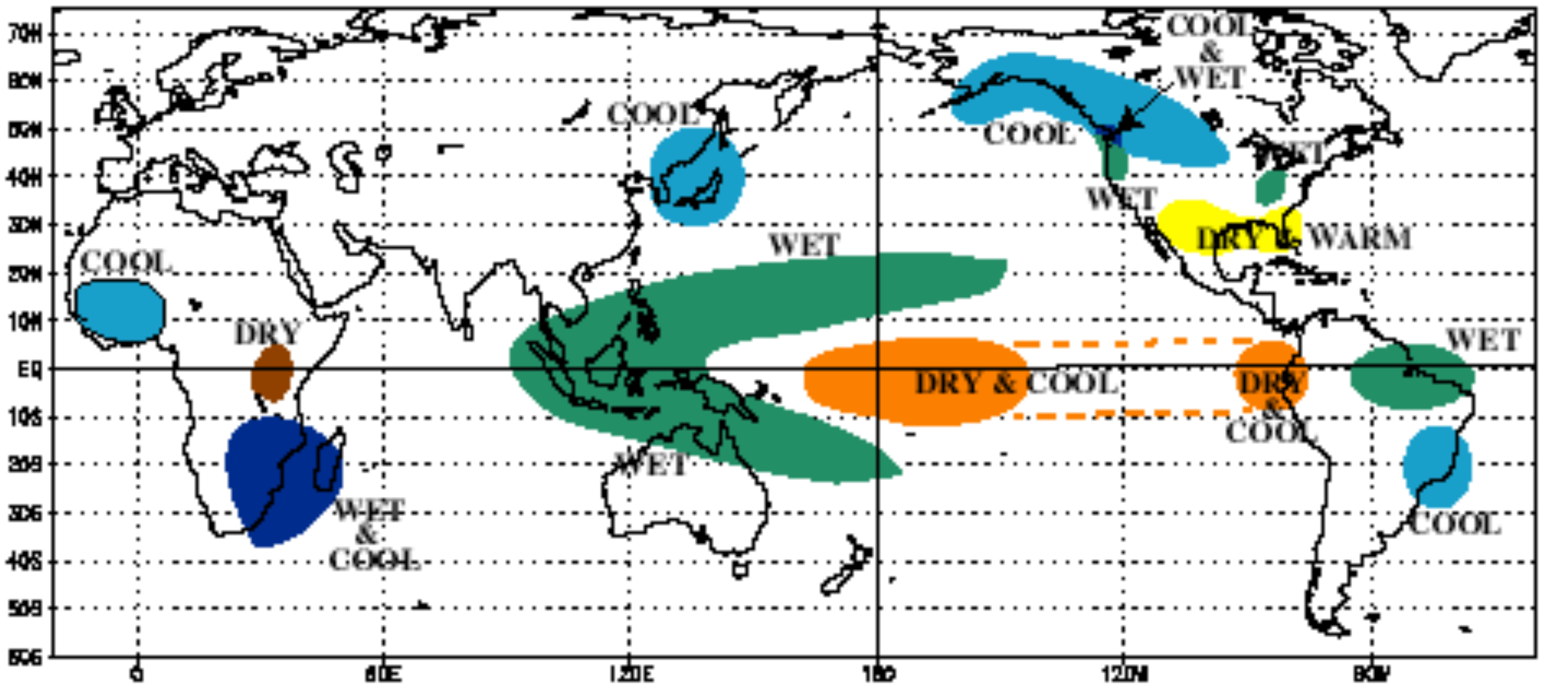
WARM EPISODE RELATIONSHIPS JUNE - AUGUST



Adapted from NOAA

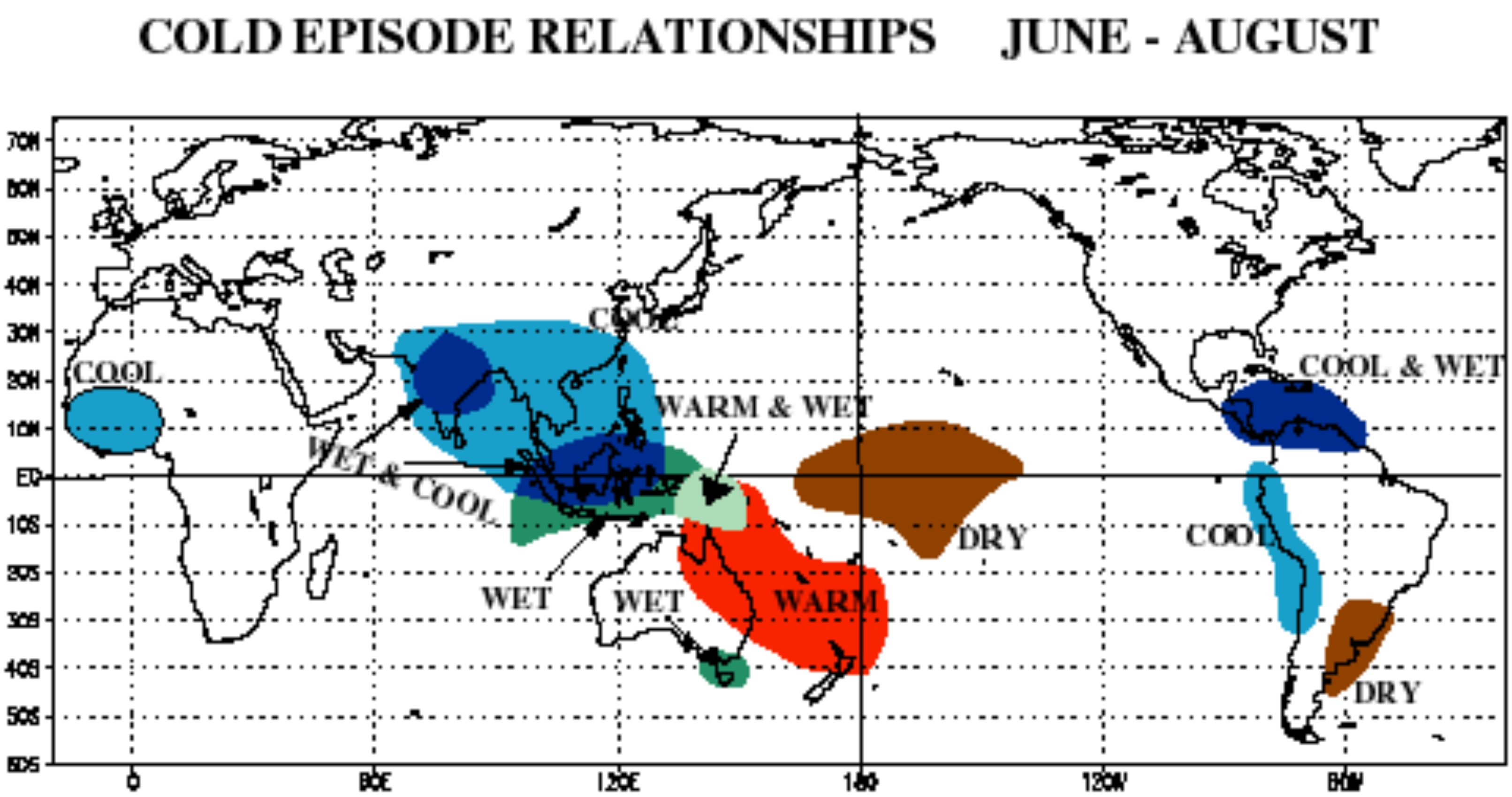
ENSO and Walker Circulation

COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



Adapted from NOAA

ENSO and Walker Circulation



Adapted from NOAA

Outline

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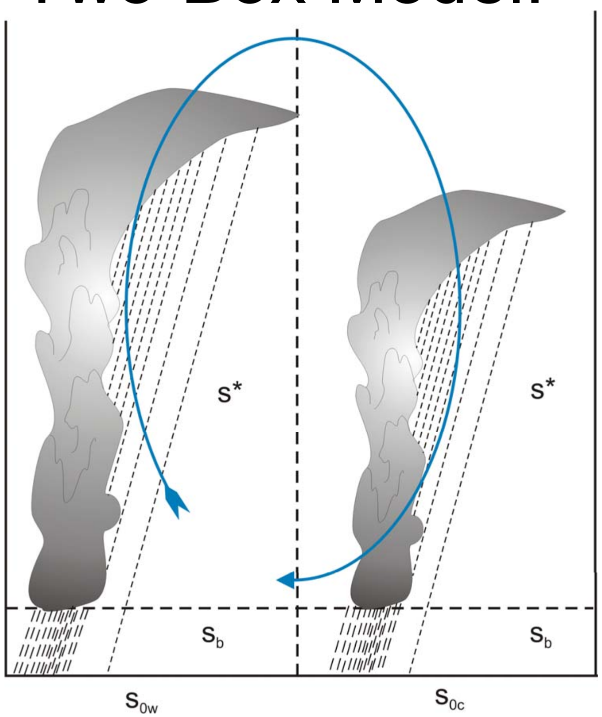
Two-box model

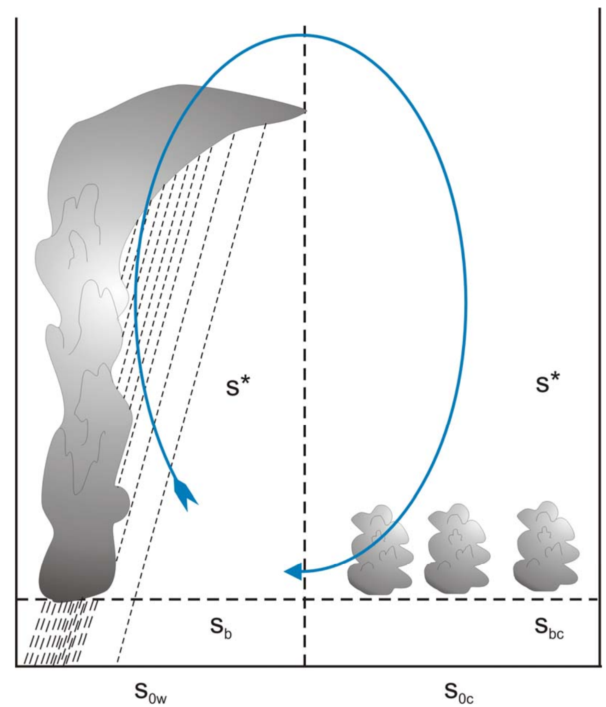
Walker Circulation

Interaction between convection and large-scale circulation

Two-Box Model:



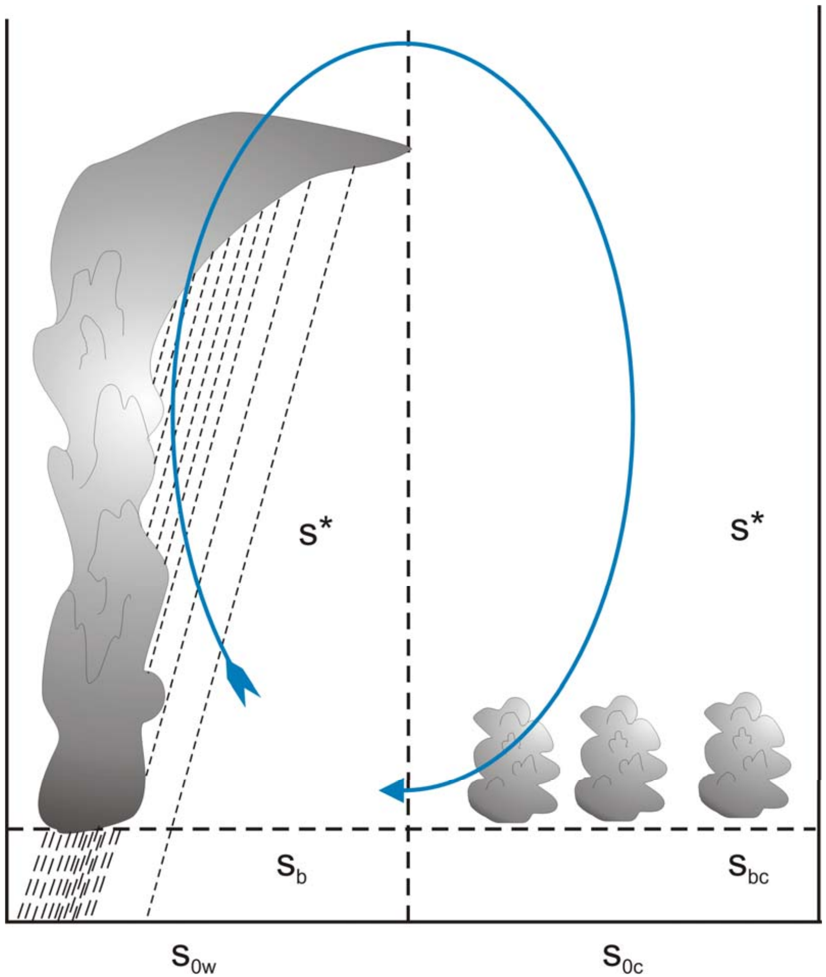
Weak circulation: Deep convection in both boxes



Strong circulation: Deep convection only in warm box

Adapted from Emanuel, 2005

Walker Circulation



$$s \equiv c_p(T_s - \bar{T})ln(\theta_e^*)$$

θ_e^* -- saturation equivalent potential temperature

s_{oc} - entropy on the cold ocean surface

s_{bc} - entropy in the boundary layer over the cold ocean surface

s^* - entropy in the free troposphere, recall the weak temperature gradient in the tropics

Assume:

Quasi-equilibrium of the entropy in the boundary layer

Mass continuity

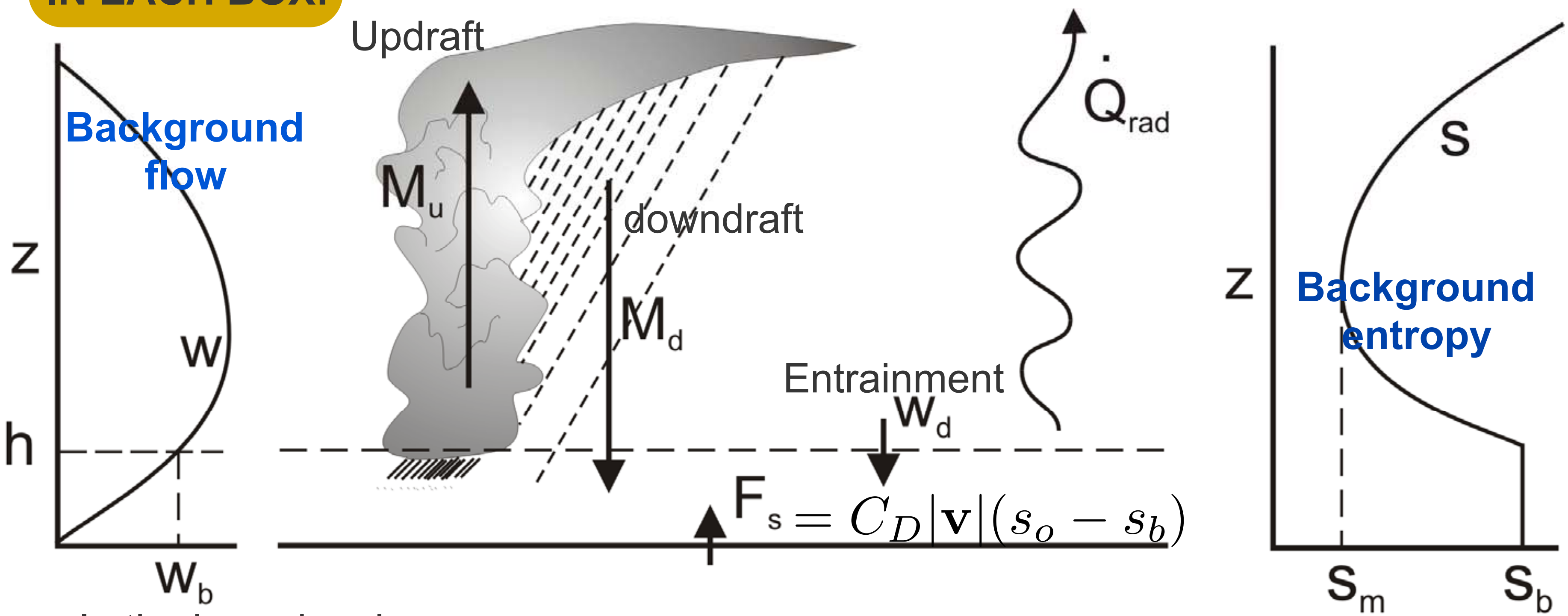
Strong circulation: Deep convection only in warm box

Adapted from Emanuel, 2005

Two-box model

Walker Circulation

IN EACH BOX:



In the boundary layer of the convecting zone, assume equilibrium :

$$h\frac{\partial s_b}{\partial t} \approx 0 = F_s - \left(M_d + (1-\sigma)w_d\right)(s_b - s_m)$$

Mass continuity:

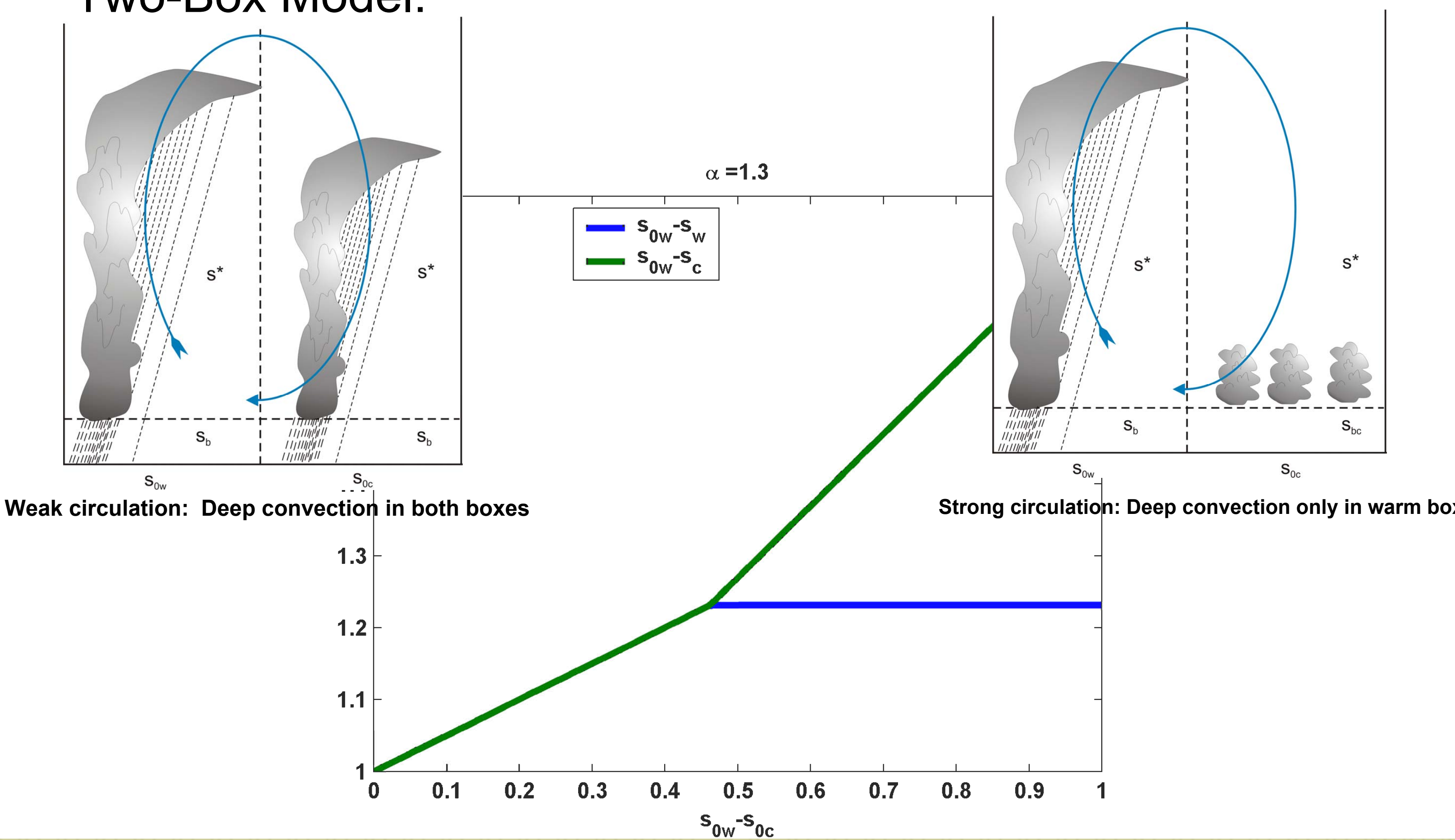
$$M_u - M_d - (1-\sigma)w_d = w_b = \gamma w$$

area covered by cloud

Adapted from Emanuel, 2005

Walker Circulation

Two-Box Model:



Adapted from Emanuel, 2005

Summary

- Walker circulation is the large-scale atmospheric overturning circulation along the longitude-height plane over the equatorial Pacific Ocean.
- Walker circulation is a zonal temperature gradient driven, air-sea coupled phenomena.
- Walker circulation shows seasonal migration in its location.
- Walker circulation is strongly affected by the ENSO events, with broad impact on the climate in the tropical and extratropical regions.
- The two-box model: the strength of walker circulation is determined by the entropy difference between the warm pool and the cold tongue, and the precipitation efficiency in the convective zone.