Development and Effects of the Northward-Displaced ITCZ

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First satellite cloud climatology (January 1967-70)

- WES & low-cloud feedback → Northward displaced ITCZ
- Consequences: (1) equatorial annual cycle;
  (2) asymmetric ocean circulation.
Halley 1686

**Halley wrote about the ITCZ:** “it were improper to say there is any Trade Winds, or yet a Variable; for it seems condemned to perpetual Calms, attended with terrible Thunder and Lightning, and Rains so frequent, that our Navigators from thence call this part of the Sea the *Rains*.”
NS asymmetry in East Pacific:
Nicaragua (12N): 1208 mm/yr
Peru (12S): 11 mm/yr
Outgoing longwave radiation (OLR) in the Western Hemisphere

Mitchell and Wallace (1992, JC)
Tropical convection is confined to SST > 27°C.

Manabe et al. (1974, JAS)
A secondary rainbelt forms just south of the equator around April when a secondary maximum of sea surface temperature appears in the Southern Hemisphere. The monthly charts of brightness, compiled by Tayler and Winston (1968), as observed by satellites, is most pronounced around April in qualitative agreement with the features of the model atmosphere.
Wind-Evaporation-SST (WES) Feedback

Equator

Xie & Philander (1994, Tellus)
Two-strip model for WES feedback

\[ \delta U = f \frac{V}{\varepsilon} \]

\[ V = \alpha (T_N - T_S) \]

\[ \frac{\partial T}{\partial t} = aU - bT \]

Continental forcing triggers WES, displacing ITCZ.

\[ \sigma = f \frac{a\alpha}{\varepsilon} \]

coupling coefficient
Tilted coastline breaks the equatorial symmetry
Continental asymmetry excites a westward-traveling coupled wave front.

Xie and Saito, J. Climate (2001)
Westward control by continental geometry

Cloud effects

COADS annual mean

SST & Wind

Low cloud cools the SE ocean

Strength meridional asymmetry

Deep cloud

Low cloud
Consequence 1: Annual cycle

![Graph showing annual cycle of sea surface temperature and precipitation in Galapagos, 90W, Eq.](image-url)
SST: Mean (>26°C) & Annual Harmonic
Xie (2004, in Hadley Circulation ...
Equatorial Annual Cycle

- Why annual?
- Why Strong in the east?
- Why propagate westward?
Annual $V'$ in both cases
Temperature along equator

SST' & u' at Eq

V_{eq}
Consequence 2:

**Asymmetries in ocean circulation:**
North Equatorial Countercurrent (NECC)


(WH05)
Asymmetry in ocean currents

Fig. 7.38. Schematic meridional section across the equator with (top) plan view showing the mean trade winds, surface circulation, and (bottom) vertical section with surface slopes, basic temperature structure and meridional circulation below the surface. (N.B. “Countercurrent” = “NECC” in our notation.) (From Wyrski and Kilonsky, 1984.)
Subtropical cells

- Equatorial upwelling as manifested in SST minimum
- Cold/salty water converges onto the equator to compensate the upwelling, along the thermocline from the subtropics.
- The ventilation and upwelling maintain a sharp thermocline in the equatorial oceans.

**Fig. 7.33.** Mean distributions of surface dynamic height (ΔD dyn. cms.) relative to 1000 db (dyn. cm.) and vertical meridional sections of zonal geostrophic flow (U cm/s), temperature (t°C) and salinity (S) between Hawaii and Tahiti, for 12 months from April 1979. (Wyrtyki and Kilonsky, 1984.)
Atlantic Meridional Overturning Circulation (AMOC)

Europe's heating system: warmer Gulf Stream (red) transports heat north while cold deep water flows south underneath (blue).
Rapid Climate Change

Ice sheet discharge

Gulf Stream shut down

Holocene maximum

Younger-Dryas

Thousands of Years Ago

Temperature Change (°C)

Ice sheet discharge

THE DAY AFTER TOMORROW
WHERE WILL YOU BE?
IN THEATRES WORLDWIDE MAY 28, 2004
VISIT THE OFFICIAL SITE
Close connection between the subpolar and tropical North Atlantic

Peterson et al. (2000, *Science*)

• Meridional (WES) mode & reduced NS asymmetry
• Southward displaced ITCZ, indicating a role of AMOC
Summary

- Coupled (WES/cloud) feedback
- Continental geometry
- Northward-displaced ITCZ
- Equatorial annual cycle
- Circulation asymmetry (NECC)
- AMOC

January 1967-70
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Bjerknes feedback & zonal asymmetry

SST & Precip

Z20