# TROPICAL REGIONAL PRECIPITATION ANOMALIES: Global warming and El Niño cases

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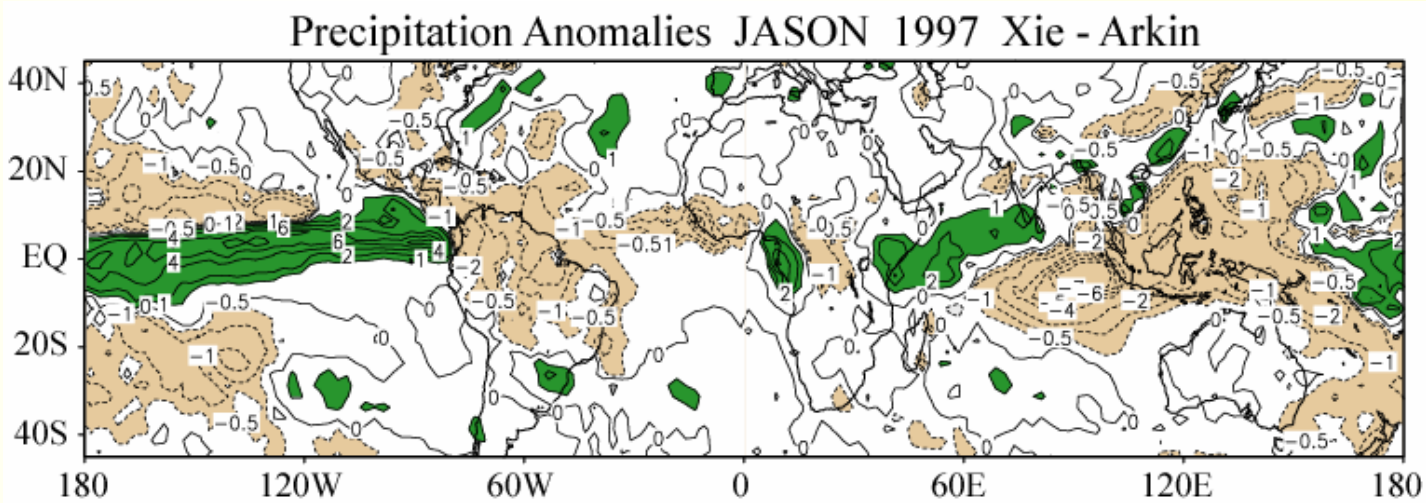
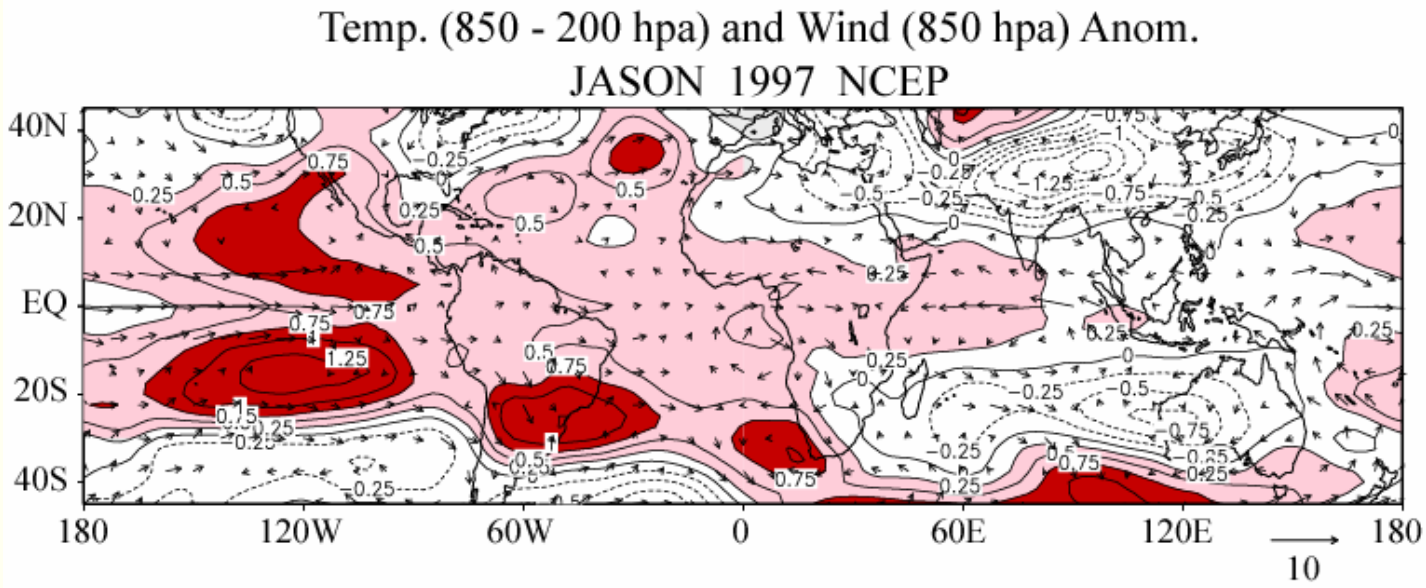
- Tropical regional precipitation anomalies associated with changes in deep convection zones: including drought regions in global warming case; mechanisms?; any similarities in El Niño case?
- Intermediate complexity climate model QTCM (Quasi-equilibrium Tropical Circulation Model)

# Observed anomalies during July-Nov 1997

**Precipitation**
**(mm/day)**

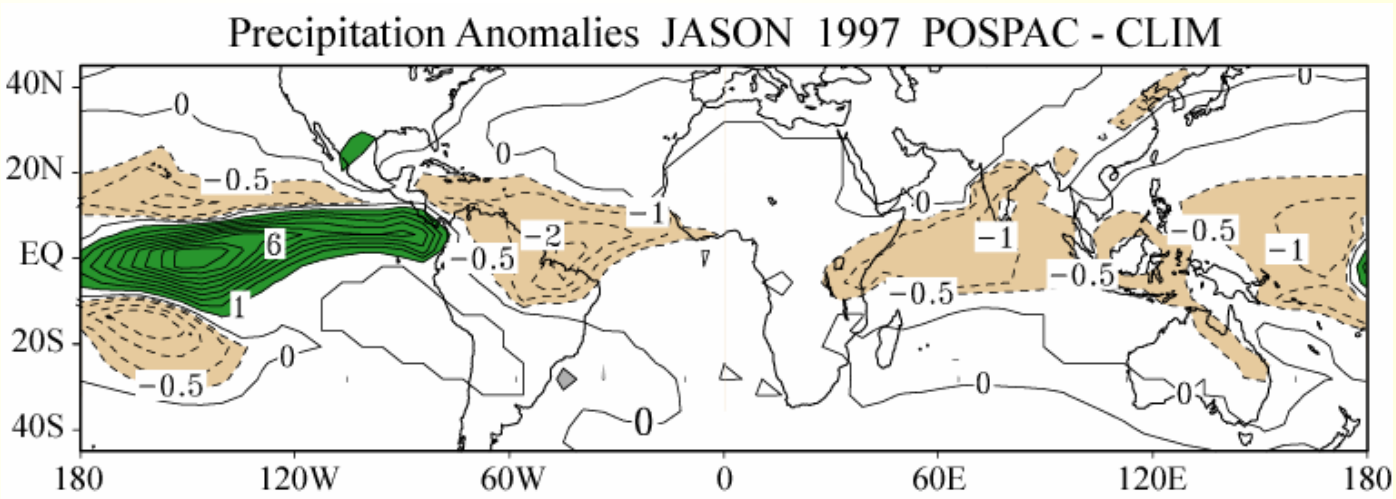



**Tropospheric Temperature**

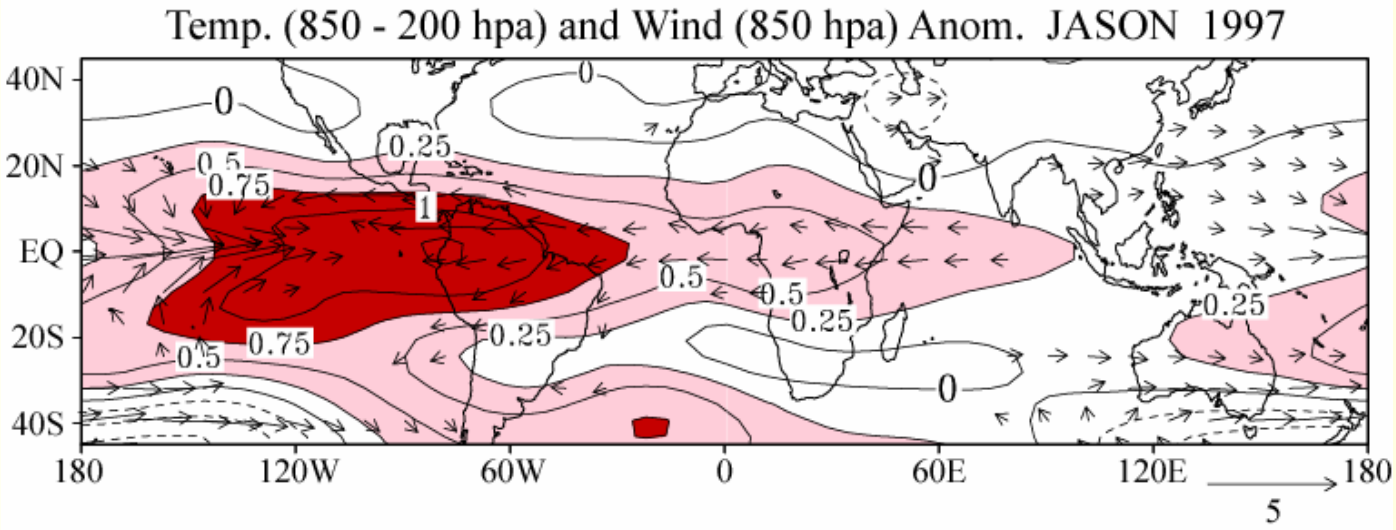


# QTCM anomalies forced by Pacific positive SST anomalies July-Nov 1997

**Precipitation**
**(mm/day)**

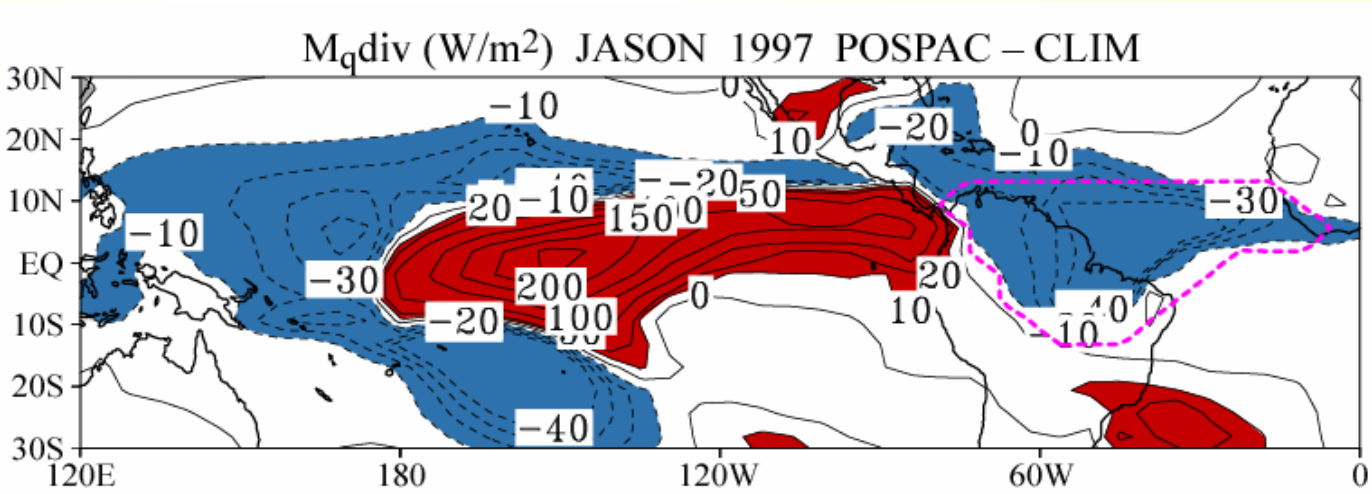



**Tropospheric Temperature**

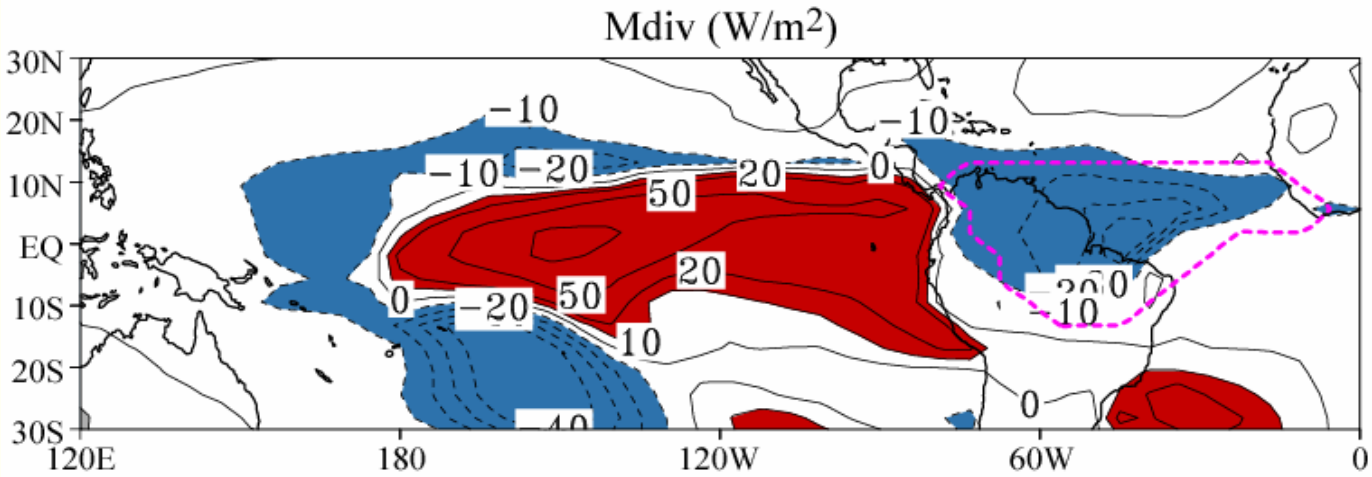


# QTCM July-Nov 1997: Anomaly budget contributions

**Moisture convergence $M_q \nabla \cdot v$ (by divergent flow)**



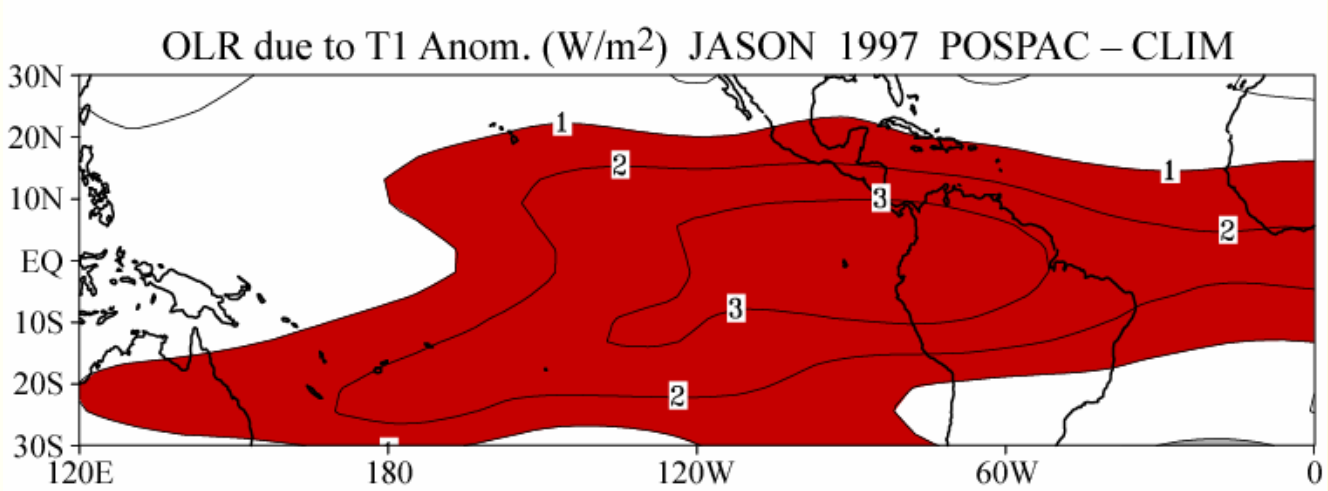

**Moist static energy divergence* $M \nabla \cdot v$**




* Gross moist stability $M=M_s-M_q$ is an effective stability that includes partial cancellation of adiabatic cooling by diabatic heating

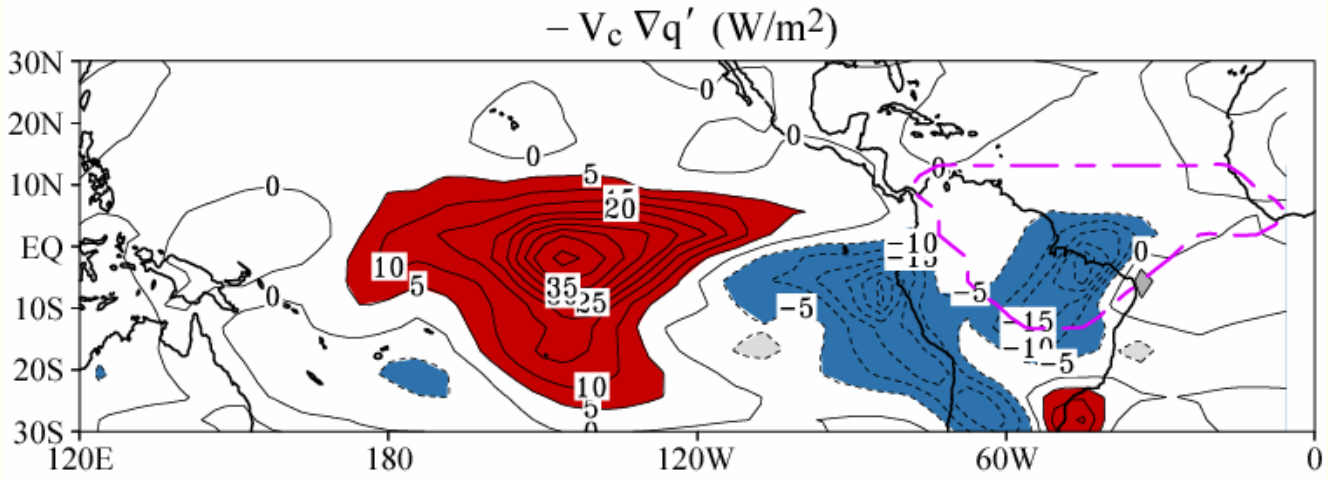
# QTCM July-Nov 1997: Anomaly budget contributions

**Radiative cooling anom. (top of atmosphere) due to temp. anom.**

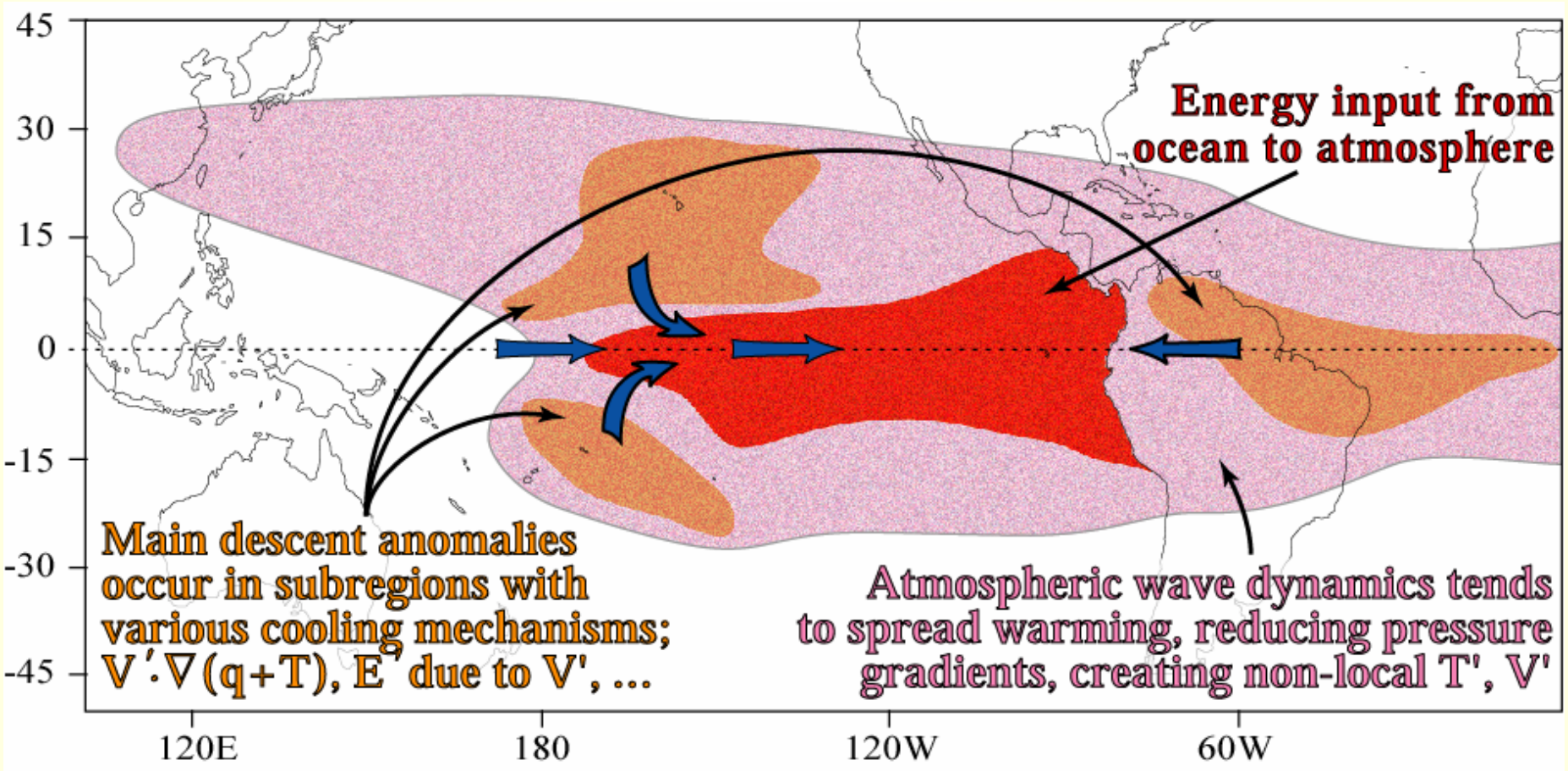



**Mean wind advection of moisture anomaly**

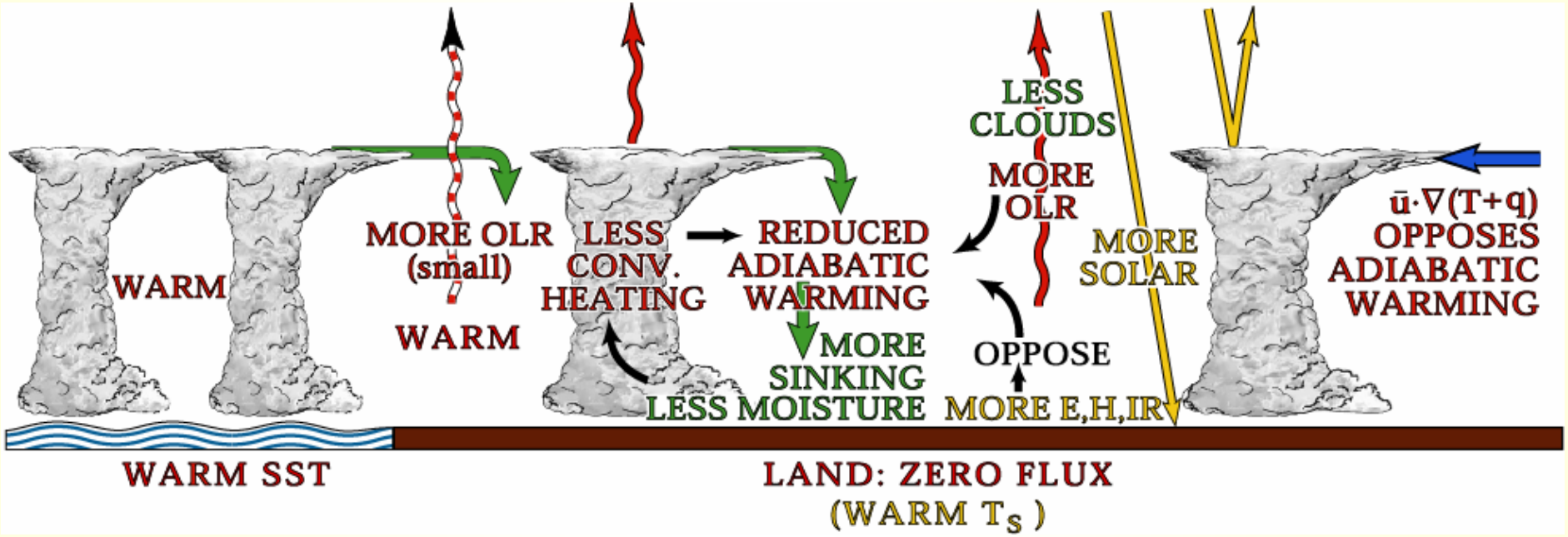
$v \cdot \nabla q'$



# ENSO teleconnections to regional precip. anomalies



# ENSO teleconnections to regional precip. anomalies

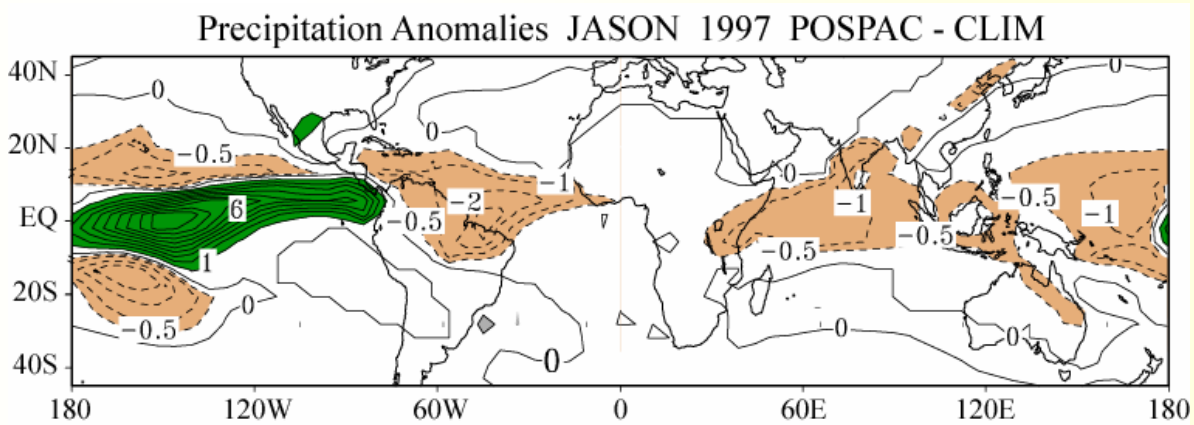



- a small zoo of mechanisms with moist convective and cloud radiative feedbacks

# QTCM experiments suppressing various mechanisms

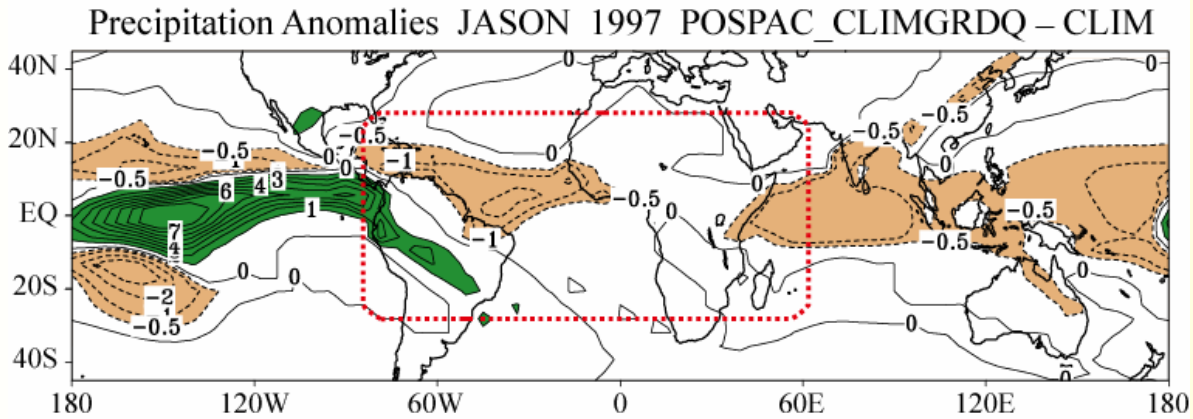
## Precipitation Anomalies

**Control**

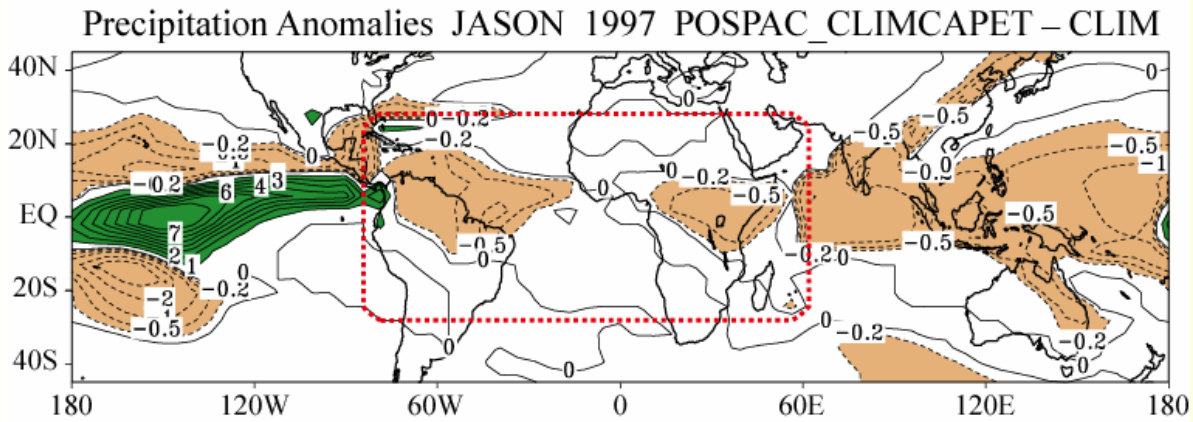



**Anomaly $(\ )'$ term suppressed in region:**

$(v \cdot \nabla q)'$




**$T'$ contribution to CAPE**



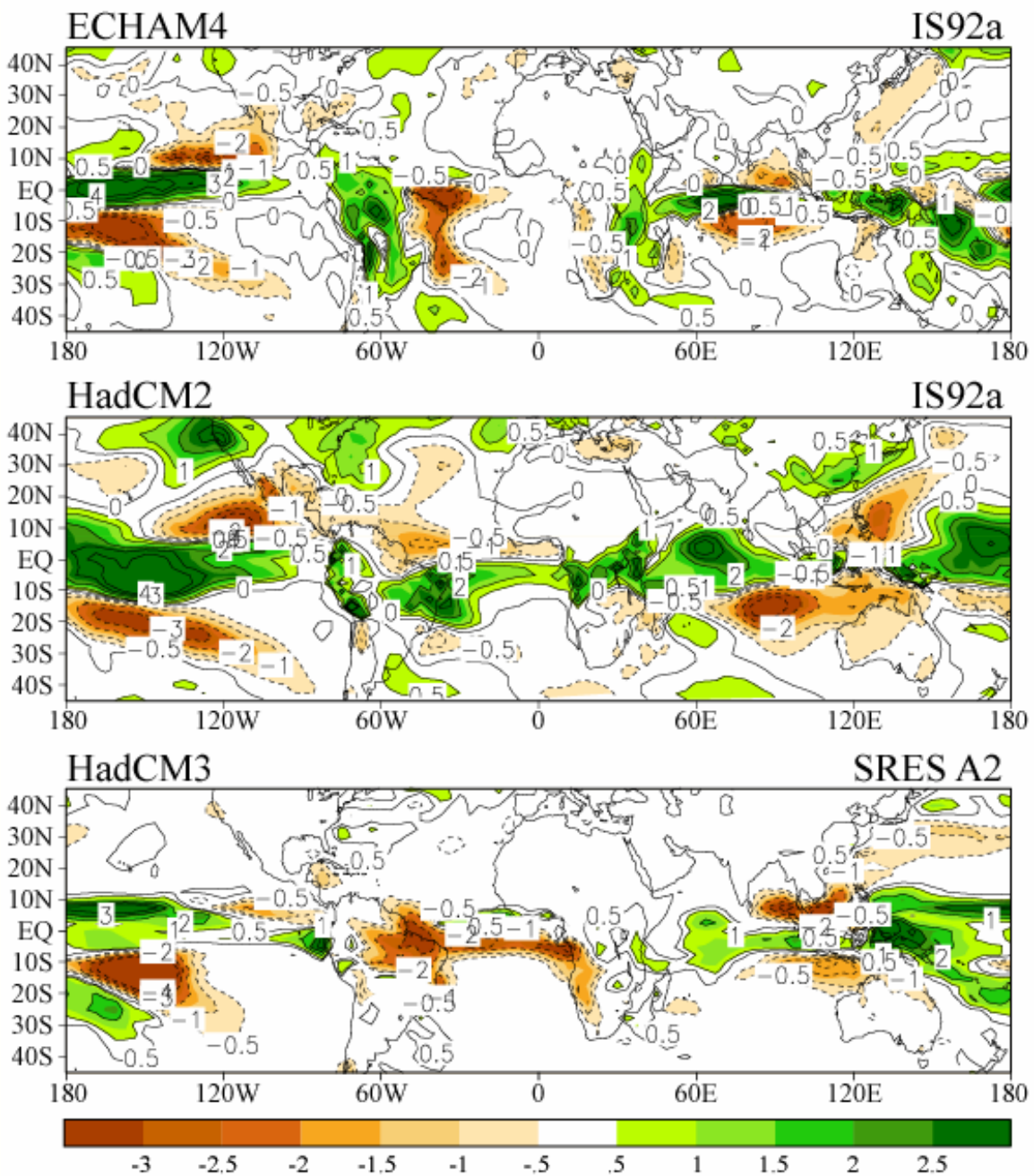
# GCM Precip. Anom. Dec-Feb

**Global warming case precipitation anom.**

**Greenhouse gas scenarios for**

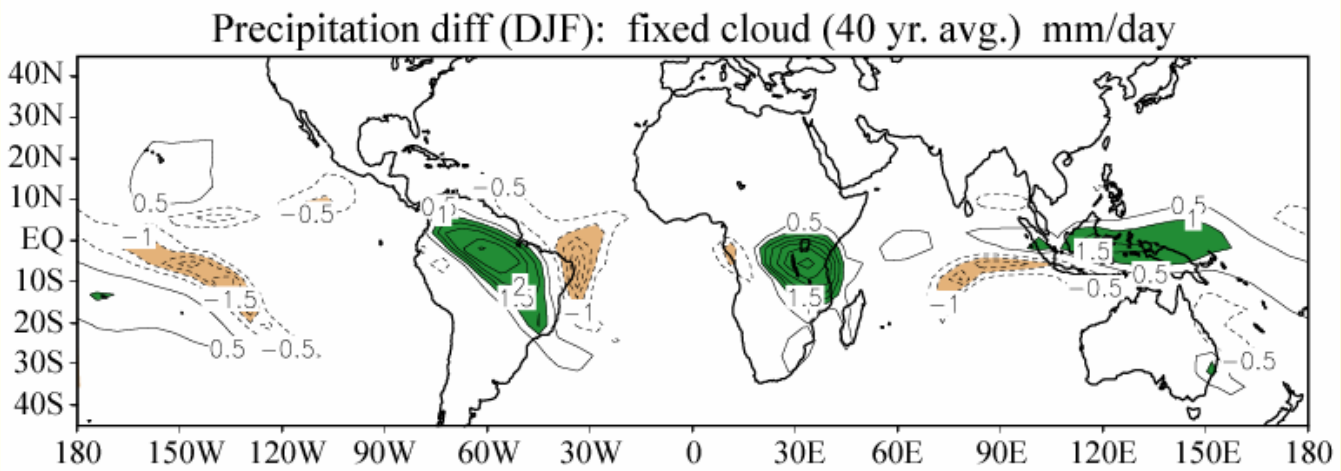
**2070-2090**

**rel. to 1961-1990 clim**

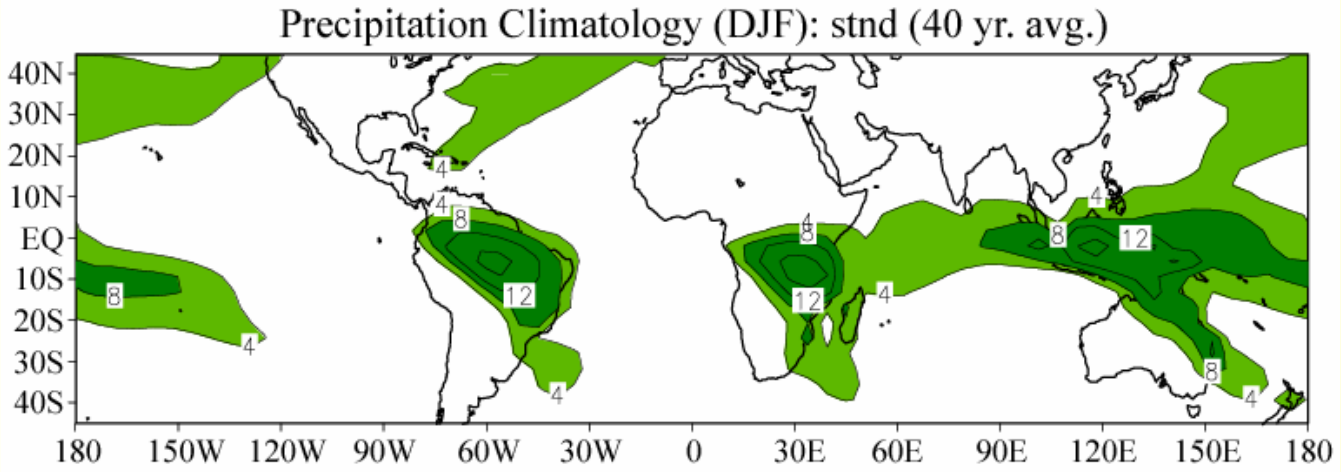


# QTCM doubled $CO_2$ experiments
# Qflux mixed-layer ocean

**Dec - Feb**
**Precip change**



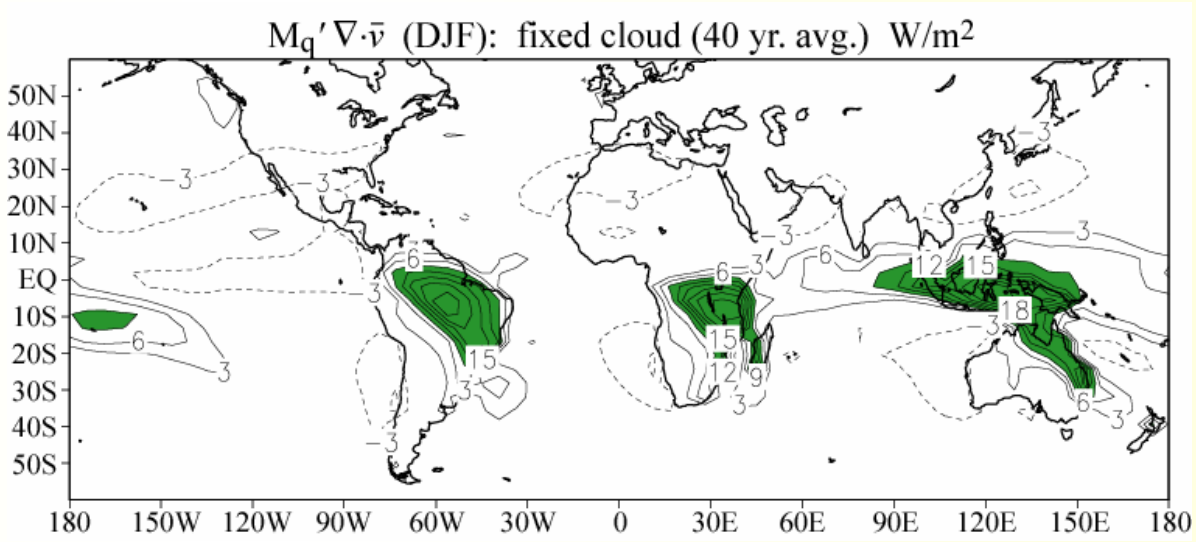

**Dec - Feb**
**QTCM Precip**
**climatology**



# QTCM doubled $CO_2$ experiments
# Moisture budget contributions

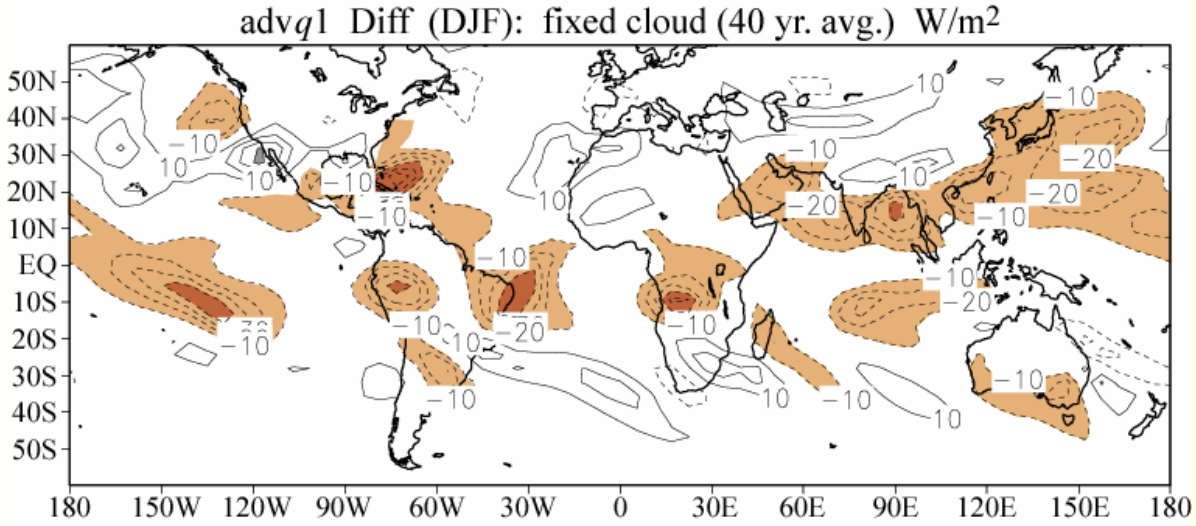
$M_q' \nabla \cdot \bar{v}$

**Anomalous moisture convergence due to moisture anom. $q'$**




$(v \cdot \nabla q)'$

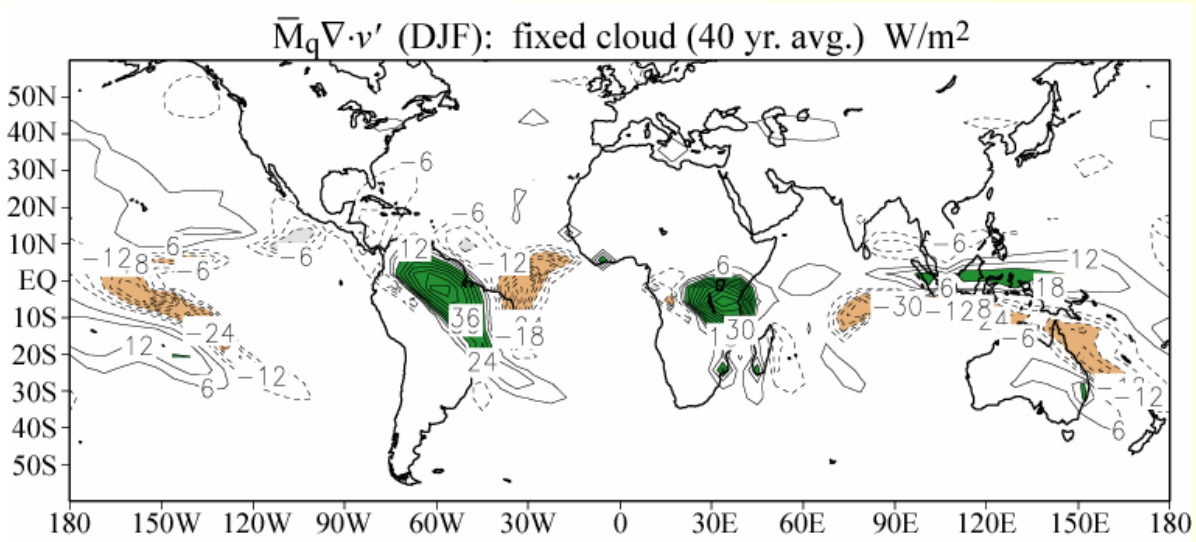
**Anomalous moisture advection**



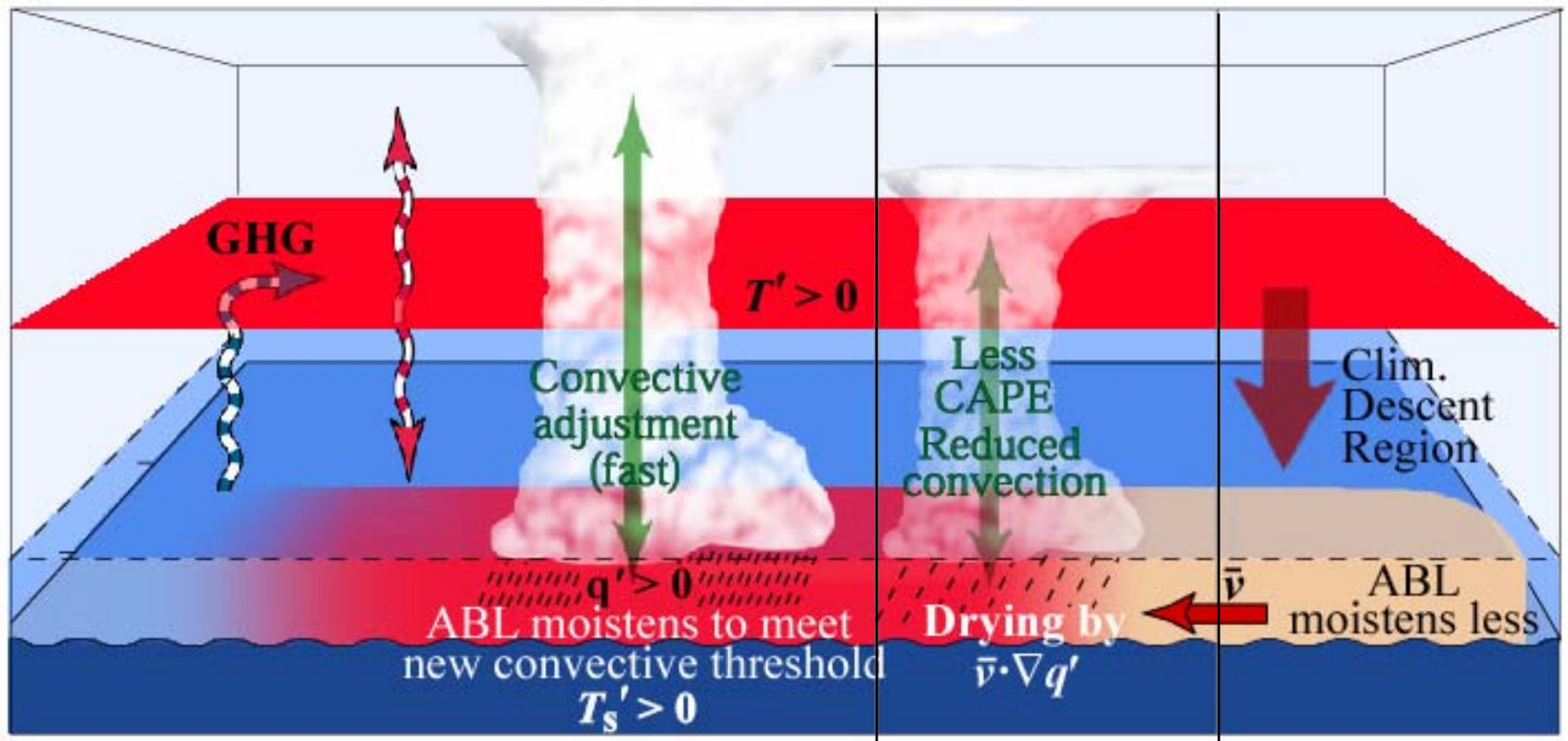
# QTCM doubled $CO_2$ experiments
# Moisture budget contributions

$\bar{M}_q \nabla \cdot v'$

**Anomalous moisture convergence due to anomalous divergence (feedback)**



# The "upped-ante" mechanism



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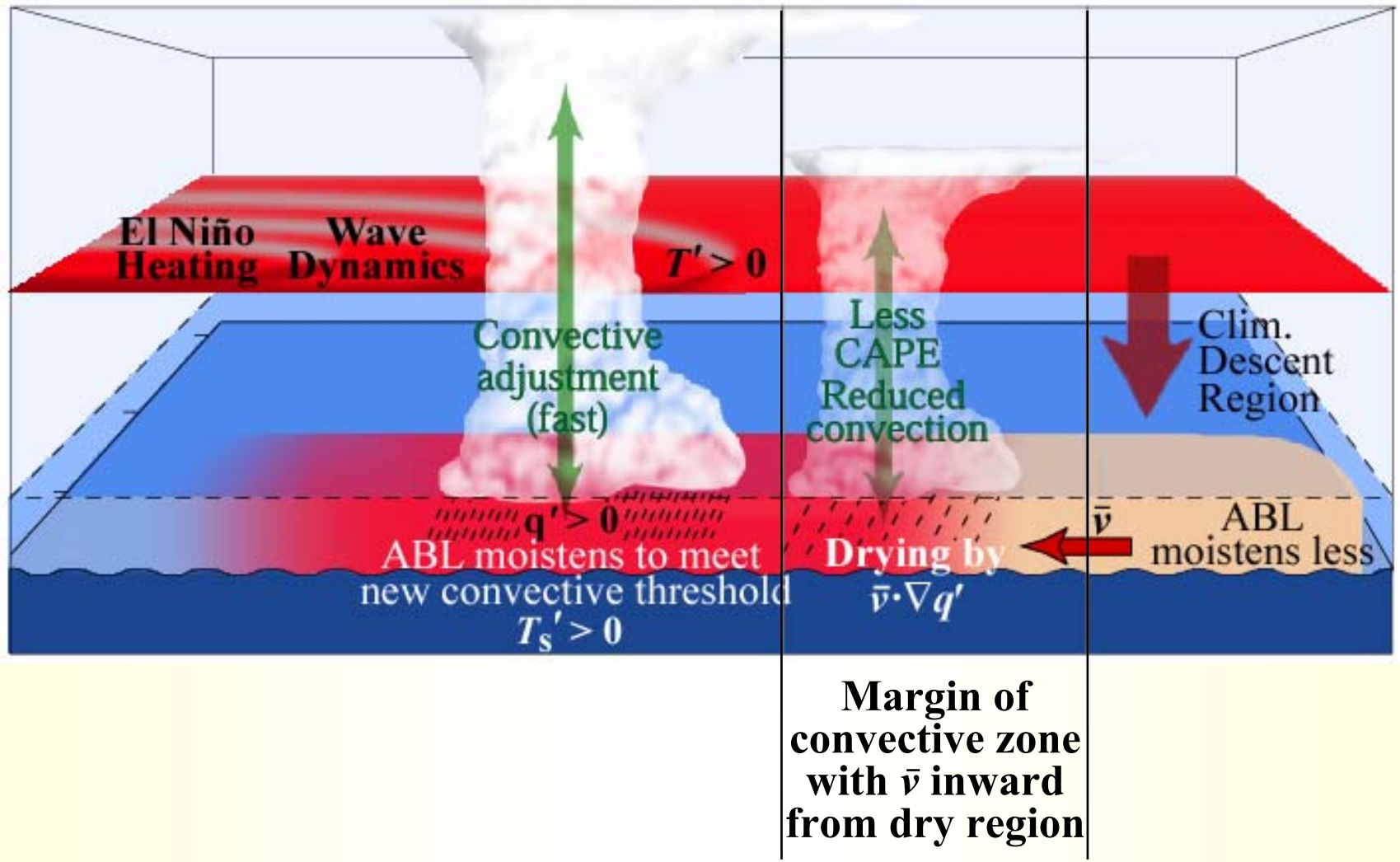


# Anomalous Gross Moist Stability (M′) mechanism

- **Moist static energy transport by divergent flow $\approx M\nabla\cdot v$**
- **$M = M_s - M_q$**

  **$M_s$ increases with increasing moisture, tends to reduce M**

  may partially compensate if cloud top rises

- $\bar{M}\nabla\cdot v' + M'\nabla\cdot\bar{v} = F'_{net} - (v\cdot\nabla q)' + \ldots$

  **$\bar{M}$ increases to compensate**

  **$M'$ reduced**

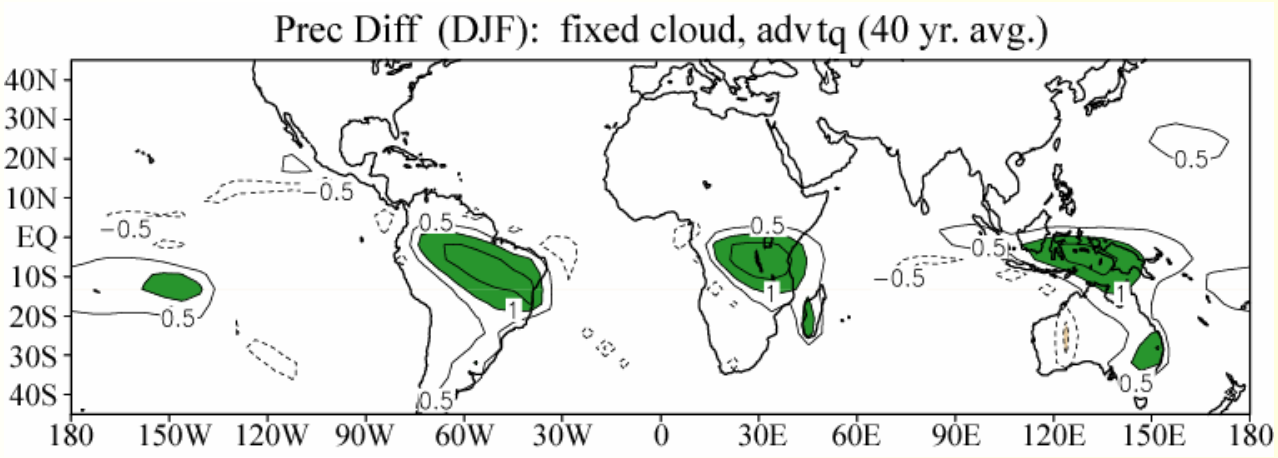
- $P' \approx \frac{\bar{M}_q}{\bar{M}} \nabla\cdot\bar{v}(-M')$

- **Mechanism increases convergence & precip. in strong convergence zones: "rich-get-richer"**

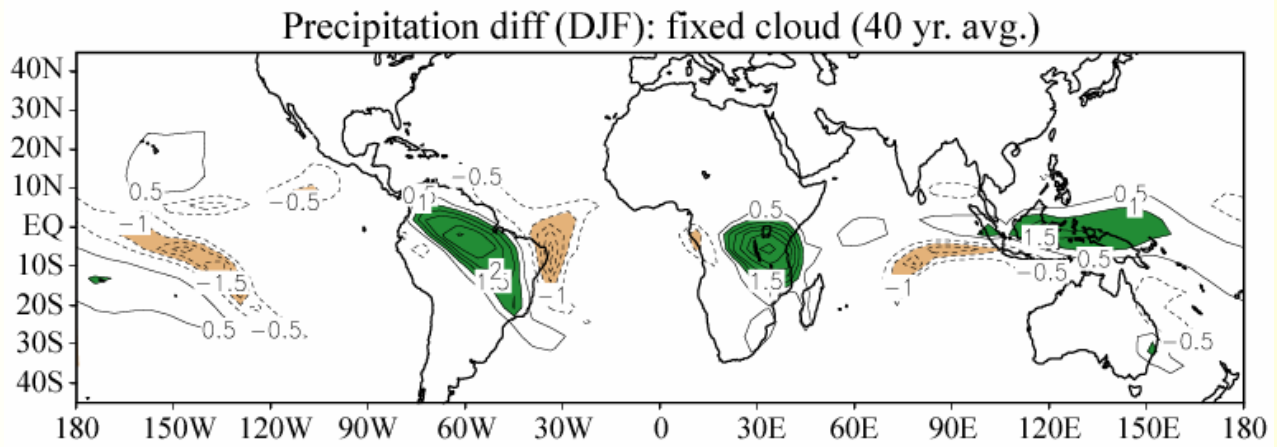
# QTCM 2x$CO_2$ Expt. suppressing change in moisture advection

## (testing the upped-ante mechanism)

**Experiment**
**2x$CO_2$ Precip. change**
**(mm/day)**




**Control**
**2x$CO_2$ Precip. change**



# QTCM 2x$CO_2$ Expt. suppressing change in gross moist stability, M

## (testing the M′ mechanism)

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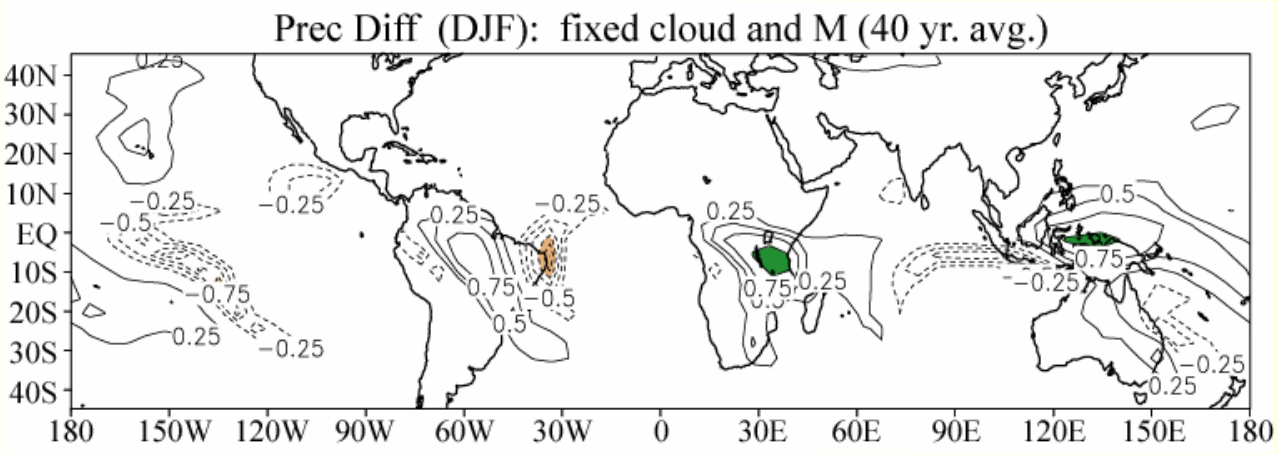


**Control**

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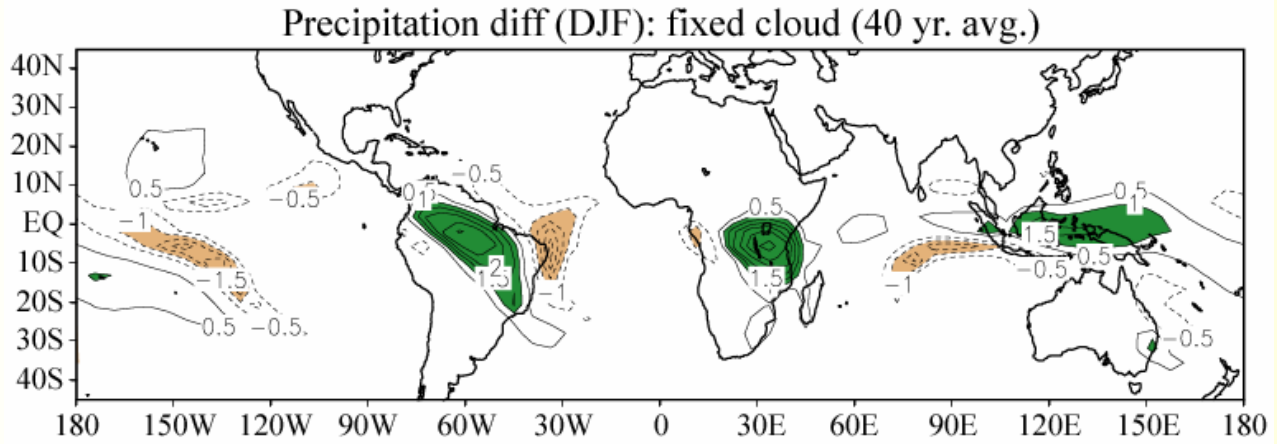

# Summary

- analysis of tropical regional precipitation anomalies in ENSO teleconnection case ⇒ a handful of contributing mechanisms
- $2XCO_2$ case, mixed-layer ocean case ⇒ set of mechanisms with some cross-over to ENSO case
- the "upped-ante mechanism":
  - contributes substantial negative precipitation anomaly regions in both cases
  - drought occurs at margins of convection zones with climatological wind inflow from dry zone into convection zone
- the "anomalous gross moist stability (M') mechanism":
  - contributes positive precipitation changes in strong precipitation regions in global warming case (rich-get-richer)
  - but theory for M' is very poor
- caveat Tropical mean precipitation anomaly mechanisms appear to differ between ENSO and global warming cases

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# MOIST DYNAMICAL FEEDBACKS IN TROPICAL CLIMATE SENSITIVITY: ENSO vs. Global warming

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- Tropical regional precipitation changes associated with shifts of or anomalies within deep convection zones: mechanisms for ENSO case; any similarities in global change case?
- Intermediate complexity climate model QTCM (Quasi-equilibrium Tropical Circulation Model)

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