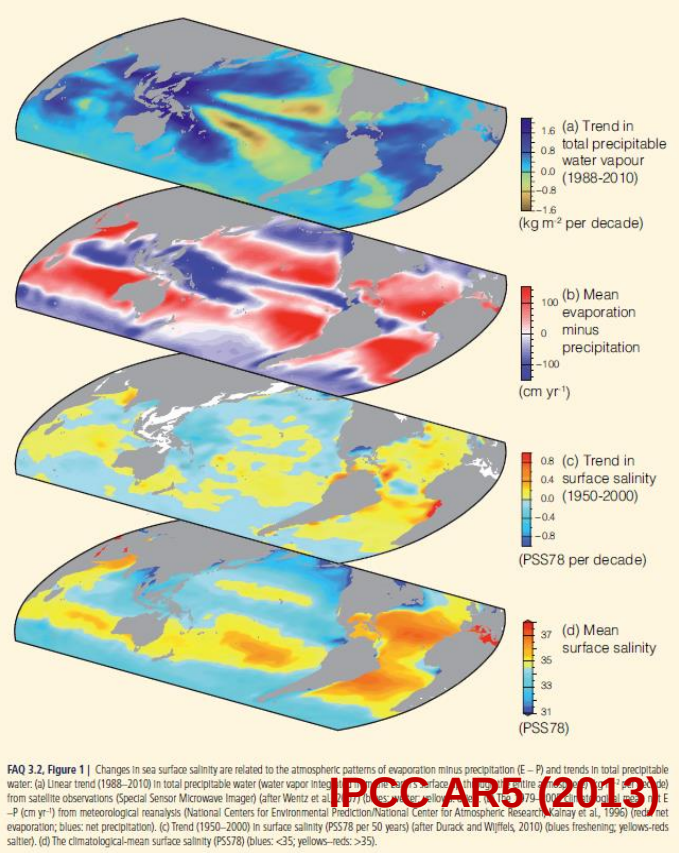
Trans-basin water vapor transport and ocean salinity changes between the Atlantic and Pacific under global warming

Qiwei SUN, Yan Du

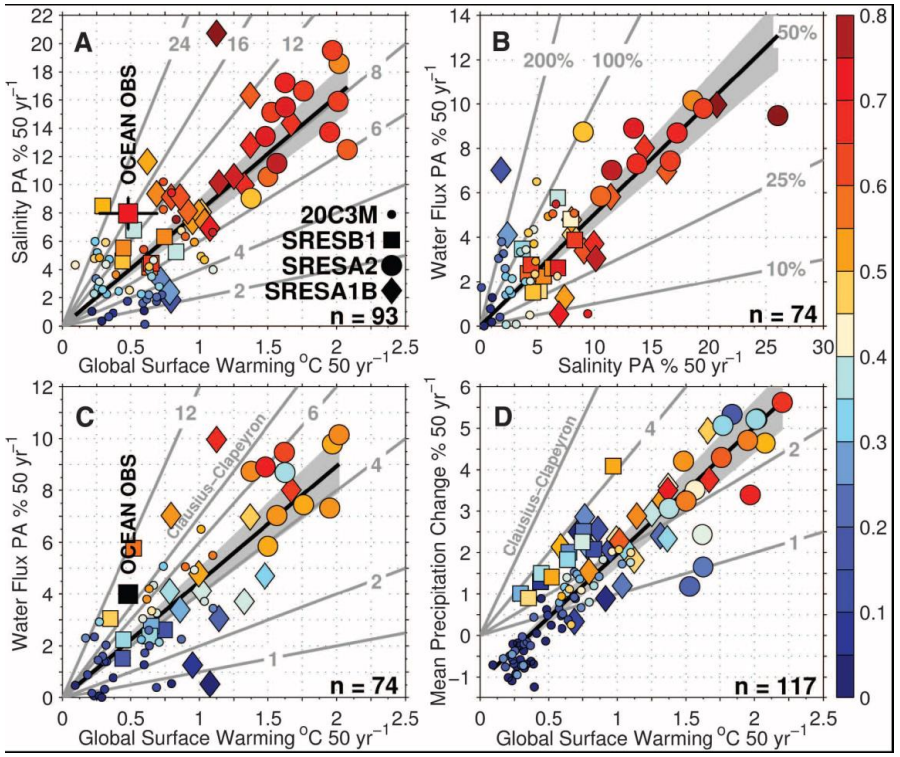
Southern Marine Science and Engineering
Guangdong Laboratory, Guangzhou, China

Water cycle intensification and SSS changes



IPCC AR5 (2013)

"wet-get-wetter"



C-C Theoretical results

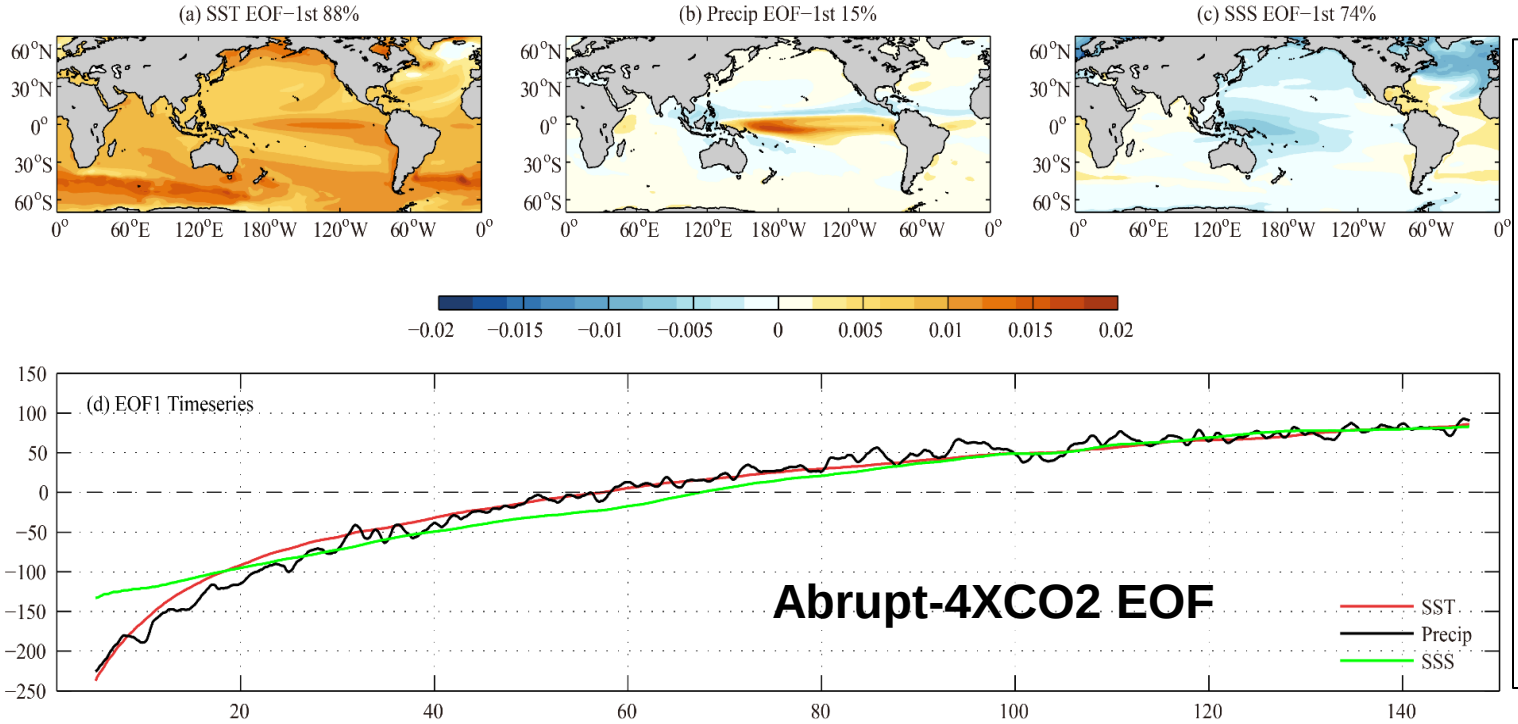
1. A uniform SST warming
2. Thermodynamic processes

1. SST warming patterns?
2. Dynamic processes?

Saline surface waters in the evaporation-dominated mid-latitudes have become more saline, while relatively fresh surface waters in rainfall-dominated tropical and polar regions have become fresher.

(Chou and Neelin 2004; Held and Soden 2006; Chou et al. 2009; Durack et al., 2012)

Spatial patterns of SST, P-E and SSS change



Scientific Questions

- Rainfall/SSS changes in response to **global warming**?
- The role of **dynamic processes** (SST warming patterns) to explain SSS/rainfall changes ?

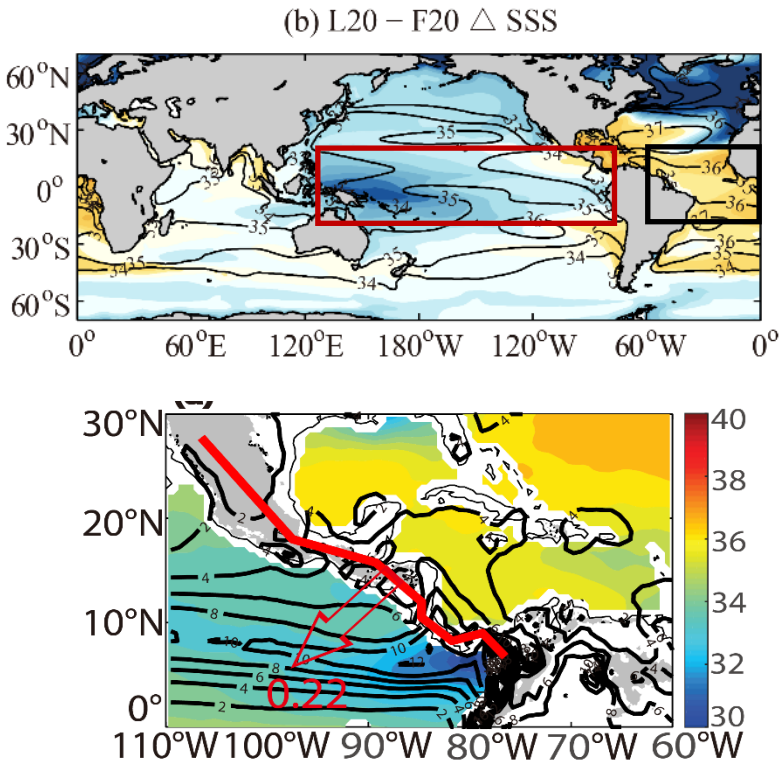
El Nino-like warming Patterns in CMIP6 4XCO2

- **1. Inter-basin gradient between TAO/TPO**
- 2. W-E tropical Pacific gradient
- **3. EP and TAO N-S meridional Mode**

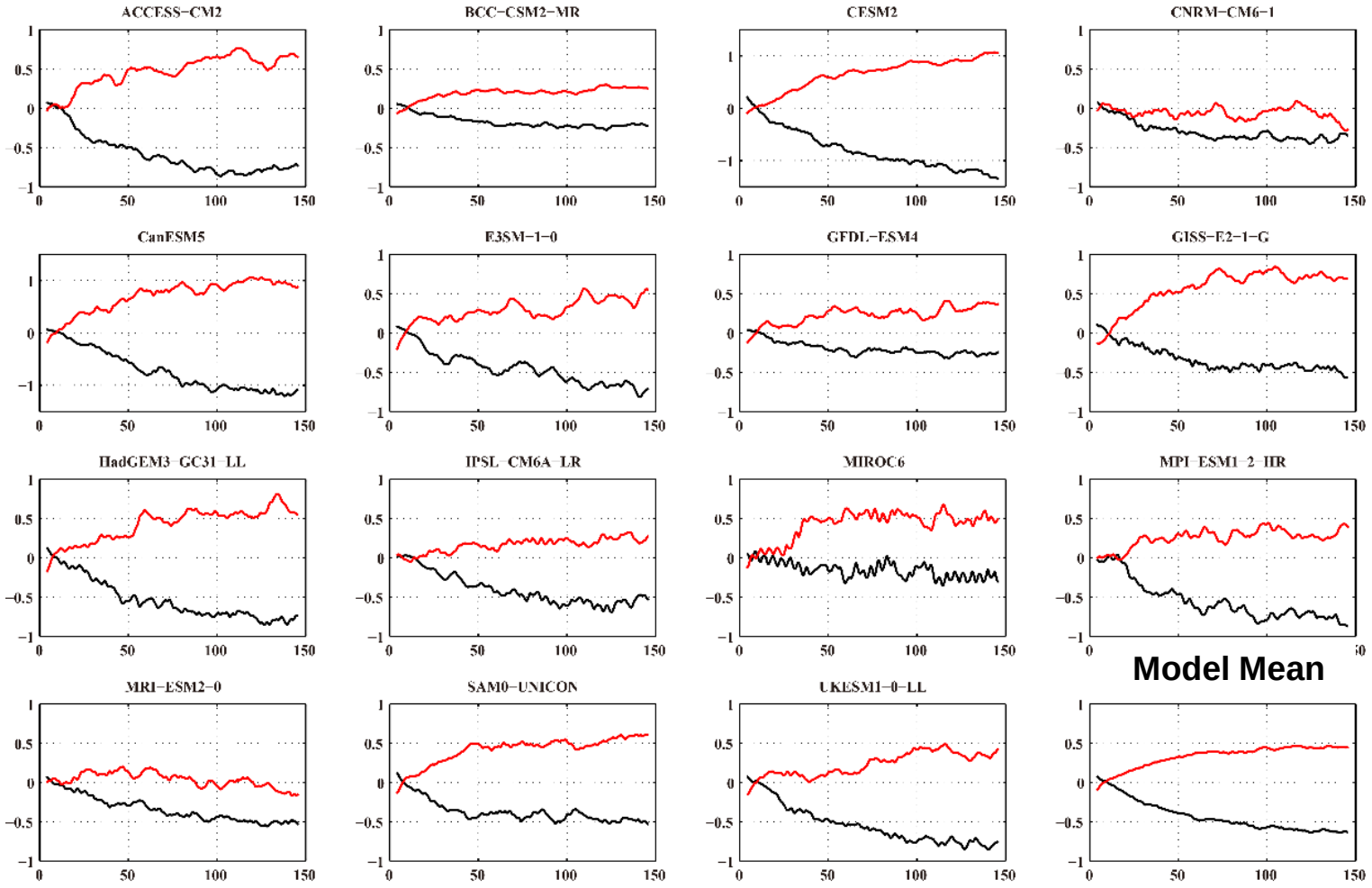
Spatial pattern of SSS changes in CMIP6 4XCO2

1. TAO salinity increase and NAO salinity decrease
2. WP salinity decrease
3. EP N-S Meridional Mode

Part I: SSS changes between Pacific and Atlantic



Tropical Pacific SSS decreases and Tropical Atlantic SSS increases, **inter-basin water cycle enhance, following "wet-get-wetter" .**



Moisture transport and moisture budget

Moisture transport → $\boldsymbol{Q} = \int_0^{ps} q\vec{\boldsymbol{V}}\, dp$

$q = \bar{q} + q'$

$q\boldsymbol{V} = \bar{q}\bar{\boldsymbol{V}} + q'\bar{\boldsymbol{V}} + \bar{q}\boldsymbol{V}' + q'\boldsymbol{V}'$

Moisture budget → $P - E \sim -\left[\nabla \cdot \int_0^{ps} q\vec{\boldsymbol{V}}\, dp\right]$

$q = \bar{q} + q'$

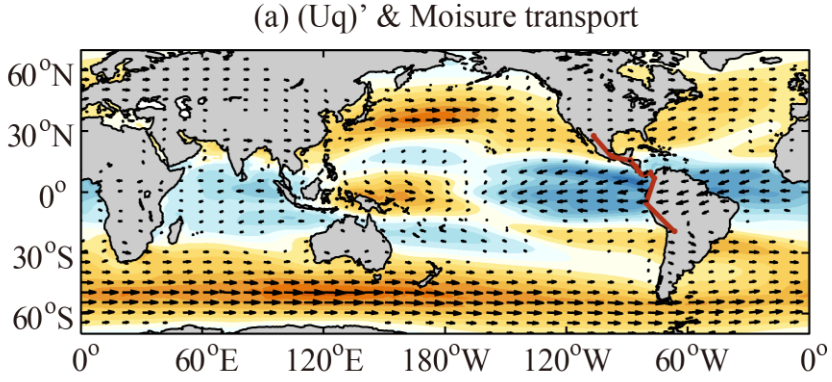
$(P - E)' \sim -\left[\nabla \cdot \int_0^{ps} \left(q'\bar{\boldsymbol{V}} + \bar{q}\boldsymbol{V}' + q'\boldsymbol{V}'\right) dp\right]$

Separate the specific humidity change (thermodynamic process)

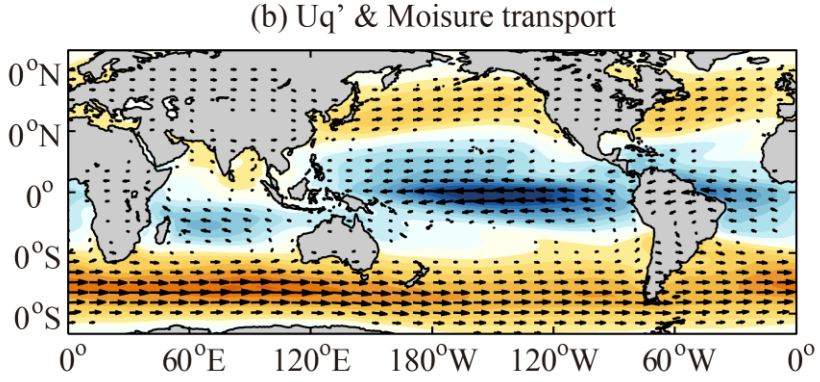
and wind change (dynamic process) to study their respective effects

water vapor transport by Q and wind

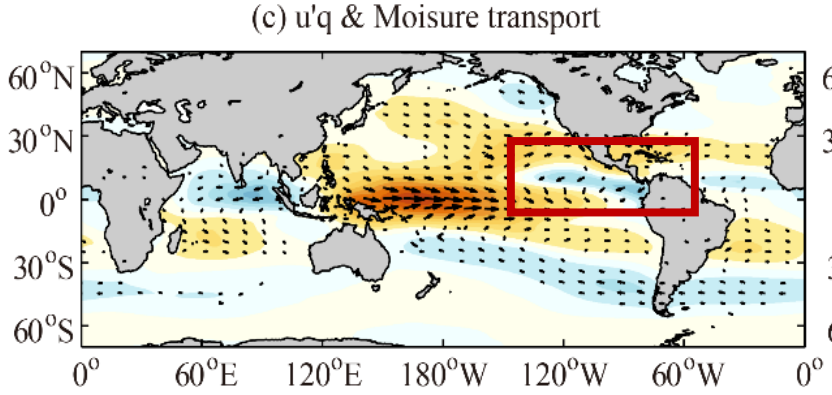
Total water vapor transport



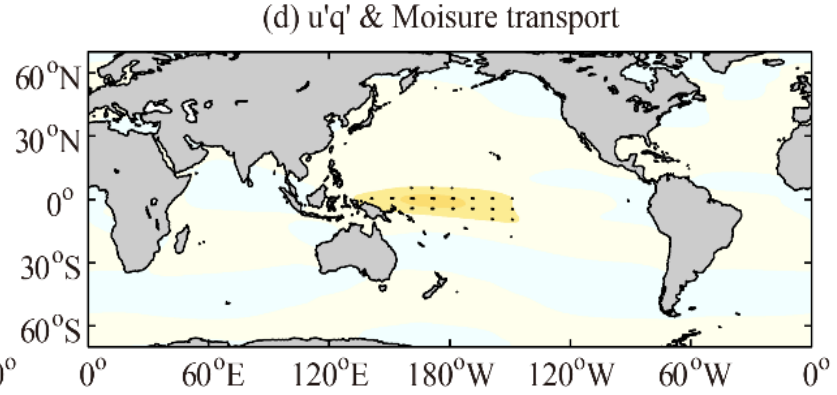
Thermodynamic processes



Dynamic processes



Higher order term



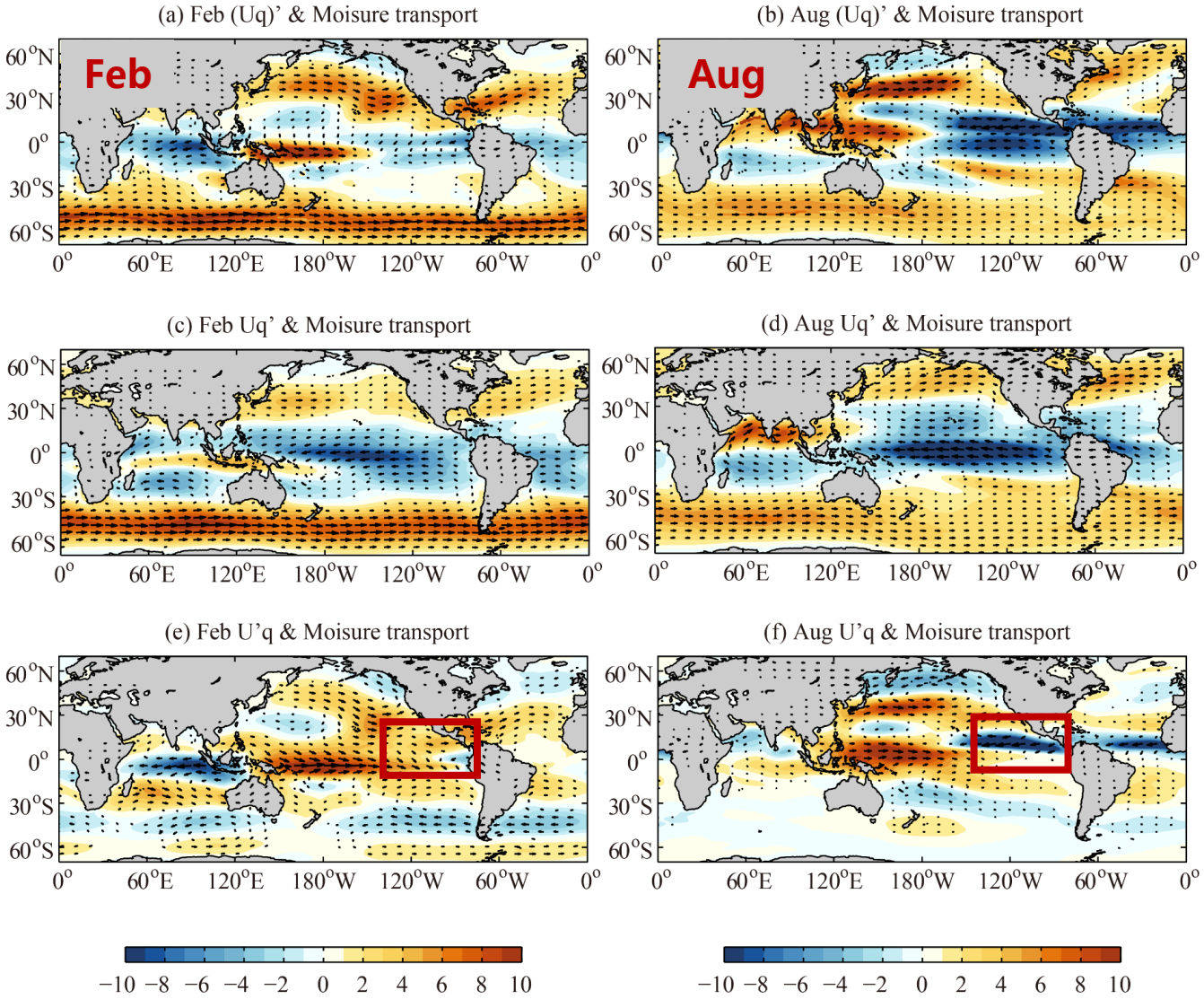
Thermodynamic processes

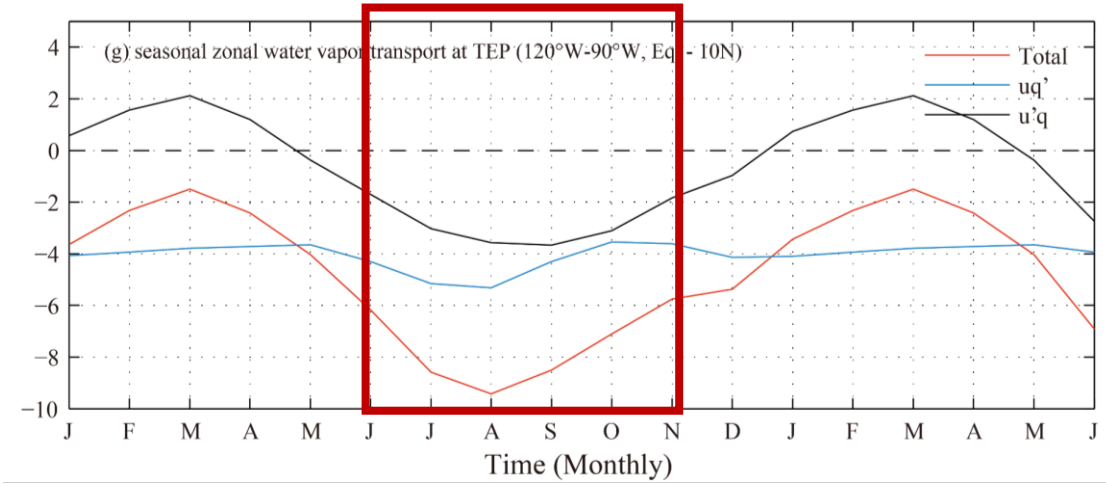
Specific humidity increase → inter-basin water vapor transport enhance → rainfall/ SSS changes **(dominance)**

Dynamic processes?

Sandwich structure: wind changes in equatorial region impact the rainfall pattern.

The role of seasonal wind changes in water vapor transport





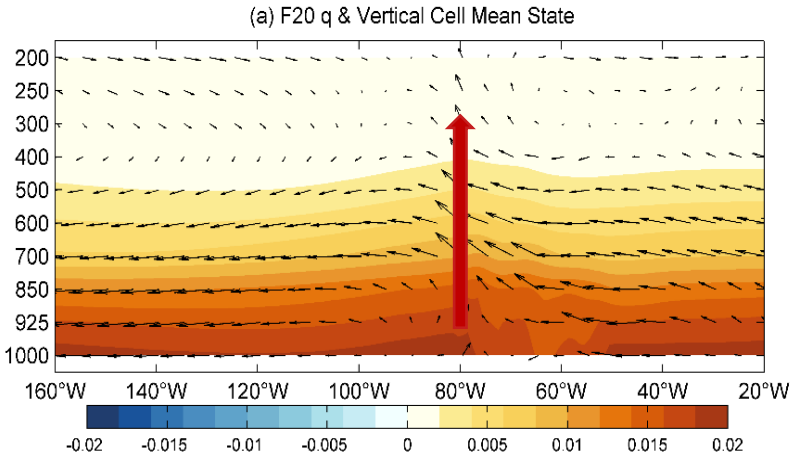
Seasonal dynamic processes

Summer and autumn: strong westward moisture transport 31% (Aug) – 47% (Nov)

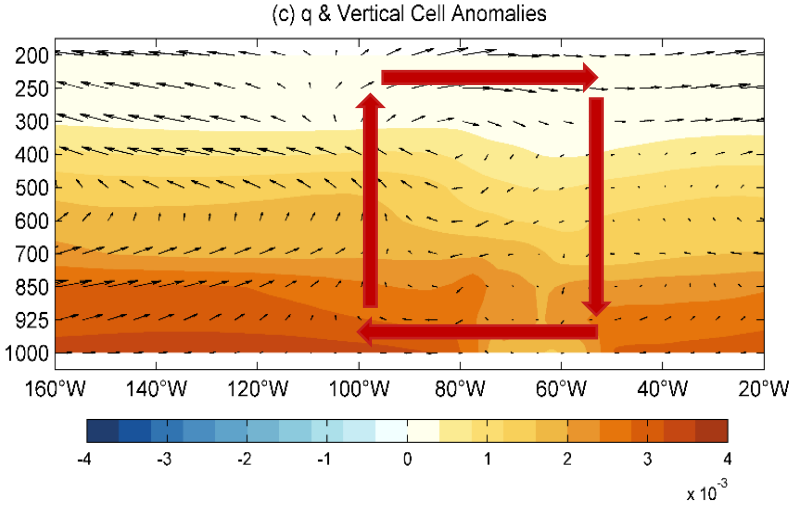
Winter and spring: weak eastward moisture transport

Summer wind changes in EQ – 10N

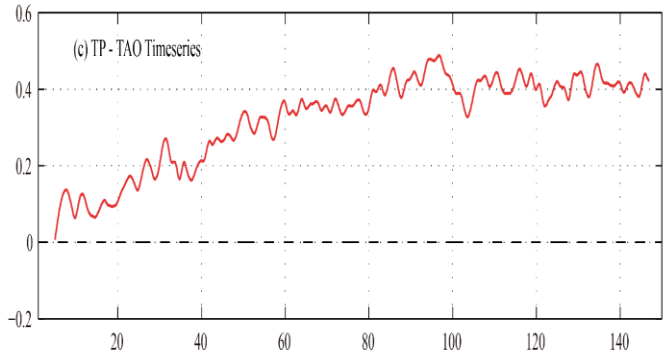
Walker Cell Mean state

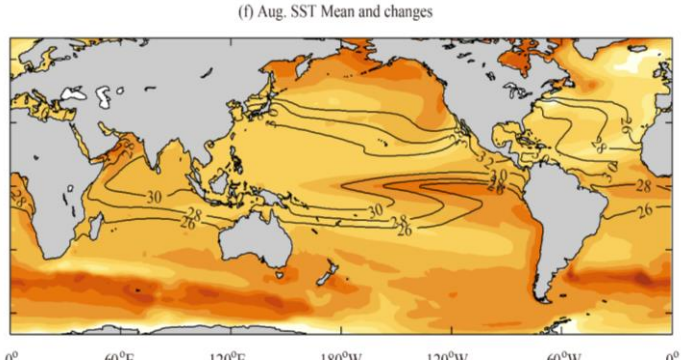


Walker Cell changes



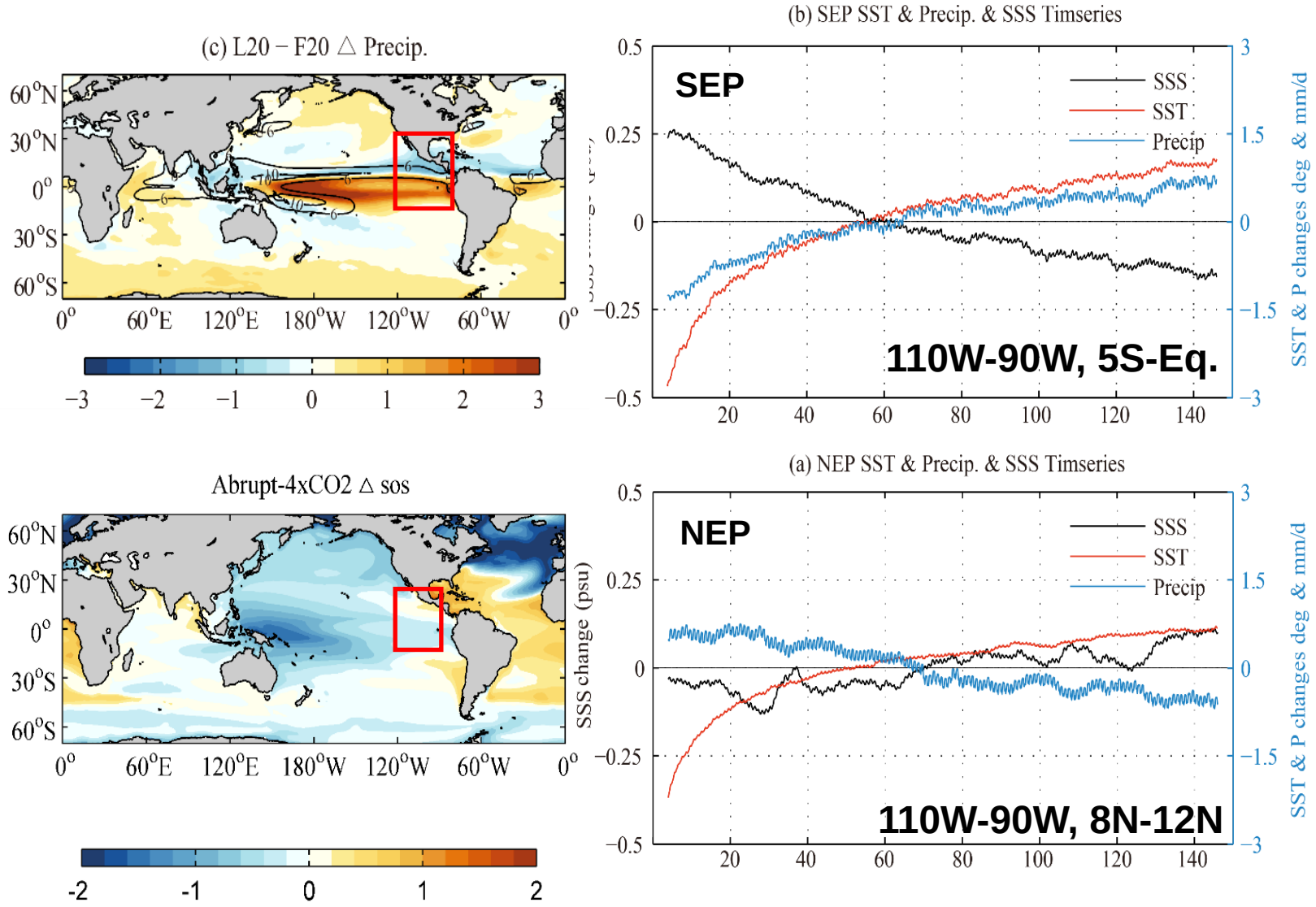
SST Gradient between tropical Pacific and Atlantic





- SST warmer in tropical eastern Pacific → SST Gradient increasing → **Walker Cell enhance and westward shift**
- Work together with water vapor transport → tropical eastern Pacific SSS decrease and Atlantic SSS increase

Part II: SSS changes in tropical eastern Pacific

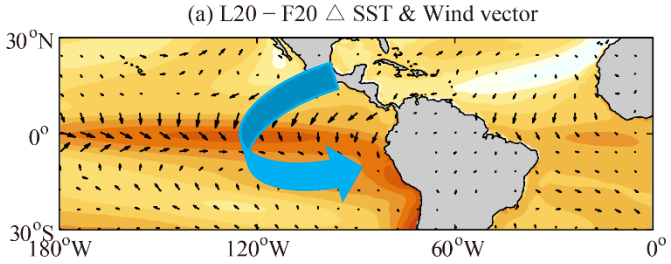


Meridional SST, precipitation and SSS changes in tropical eastern Pacific

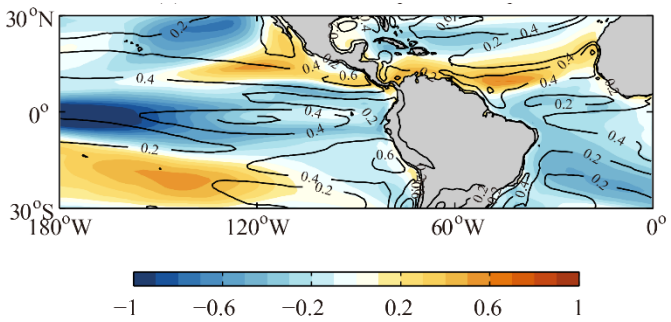
- Robust SST Warming in Equatorial eastern Pacific and cold tongue regions (+ 4 ℃ VS. 2-3 ℃), **Meridional SST gradient decrease**
- Meridional mode of Precipitation changes (SEP: increase VS. NEP decrease) **(ITCZ changes)**
- Salinity increase in the NEP and decrease in Eq.-SEP., contrary to precipitation change.

Part II: SSS changes in tropical eastern Pacific

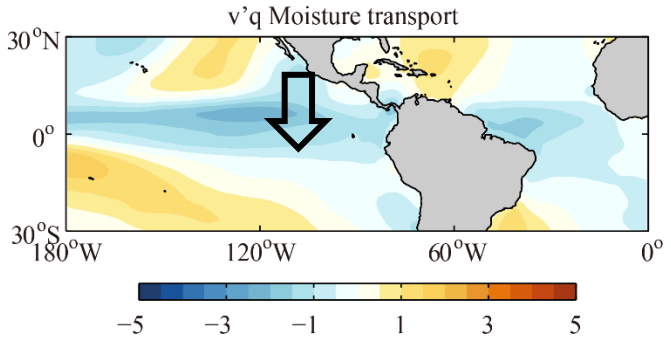
SST and wind changes

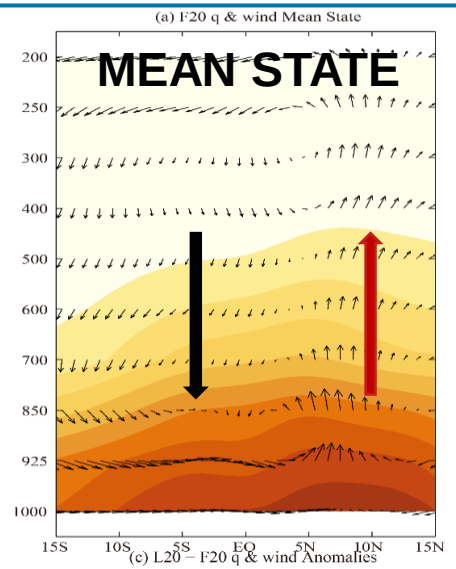


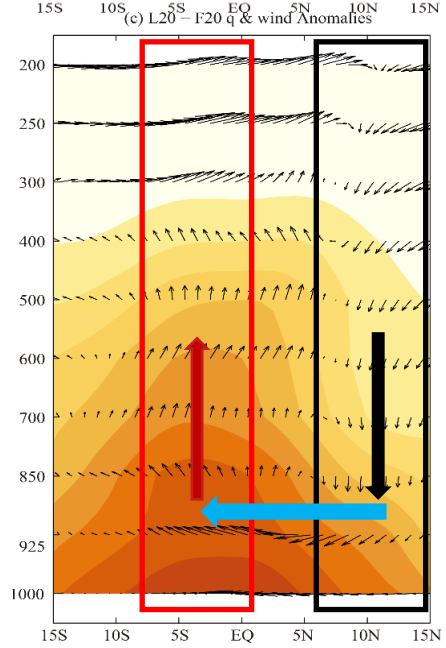
Wind speed and E Changes



Meridional water vapor transport







q and Cell anomaly

physical process of SSS changes in tropical eastern Pacific

- **WES Feedback** (El Nino-like warming, Meridional SST gradient decrease, C-shape wind anomalies, wind speed and evaporation decrease, SST warmer in SEP)
- SEP： Upward； NEP: downward, opposite to background, cross-equatorial circulation weaken, leading to **ITCZ weaken and southward shift.**
- Specific humidity increase and the southward water vapor provides more sufficient water vapor for the Southeastern Pacific
- Rainfall increase in SEP and decrease in NEP, contrary to SSS changes.

Summery and discussion

Part I. SSS increase in tropical Atlantic and decrease in Pacific

- Inter-basin water vapor transport **strengthen**
- Summer Walker Cell **strengthen and westward shift**

Part II. SSS increase in NEP and decrease in SEP regions

- WES feedback (SST gradient and C-shape wind)
- cross-equatorial Cell and ITCZ changes
- precipitation meridional mode → Salinity changes

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THANK YOU

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