Origin of Seasonal Predictability for Summer Climate over the Northwestern Pacific

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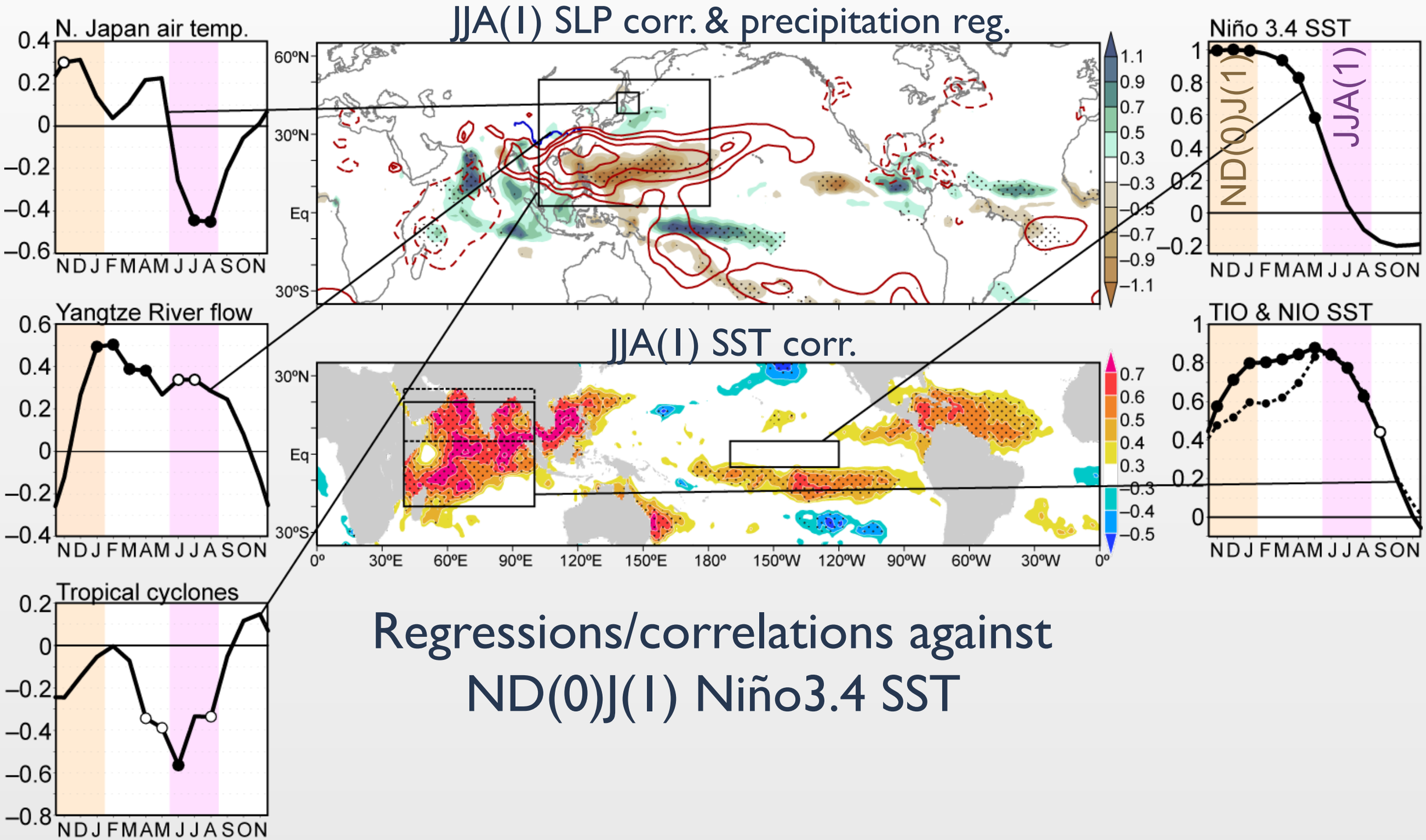
Why are the last echoes of ENSO found in Indo-NWP?

- ENSO peaks in boreal winter, decays by subsequent summer



Regressions/correlations against
ND(0)J(1) Niño3.4 SST

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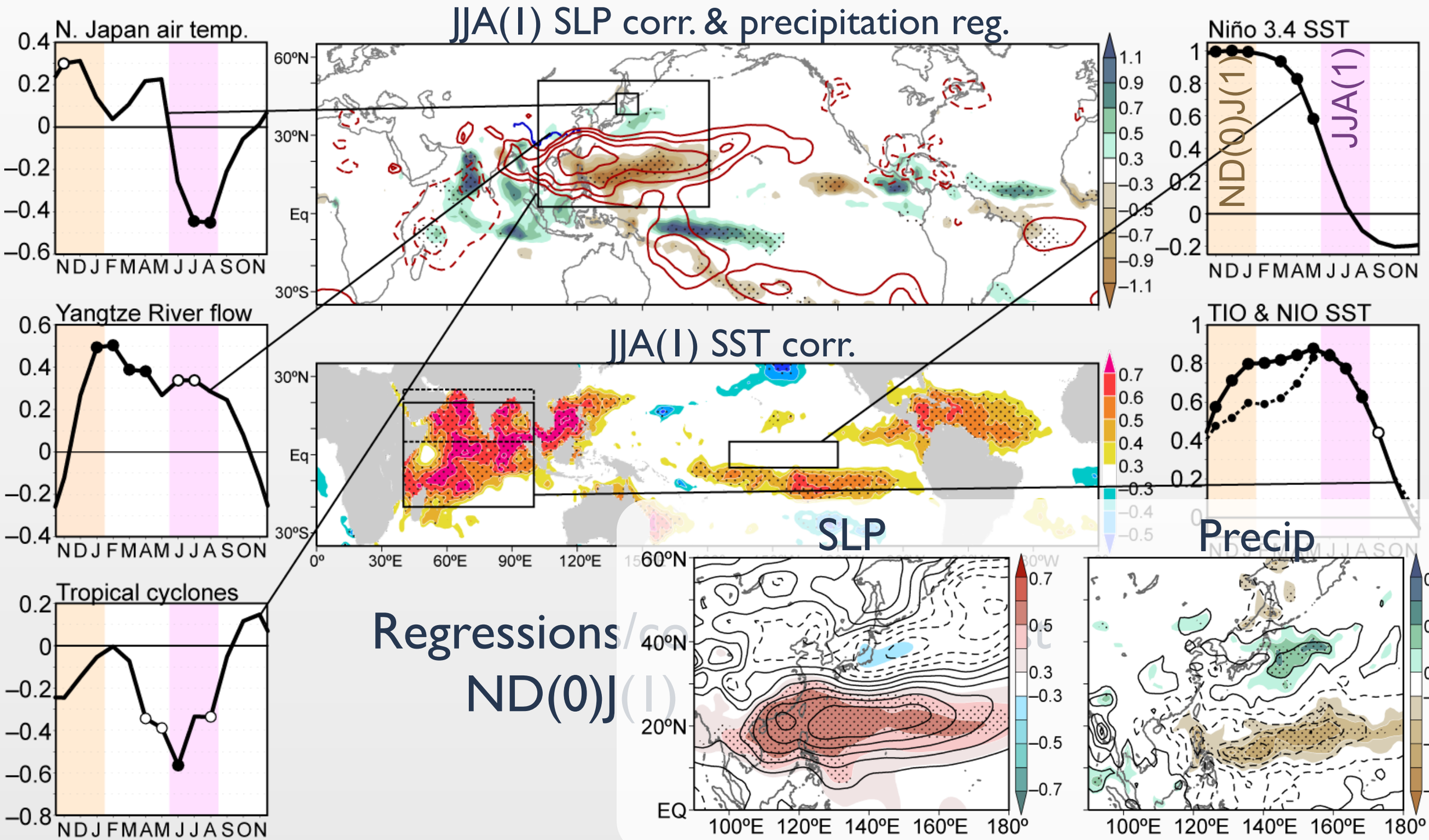


The PJIO coupled mode

We show ...

- A new ocean-atmosphere coupled mode
  - Atmosphere: the Pacific-Japan (PJ) pattern
  - Ocean: northern Indian Ocean warming/cooling
- This coupled mode dominates without ENSO, but
- ENSO can trigger this mode → last echo & predictability

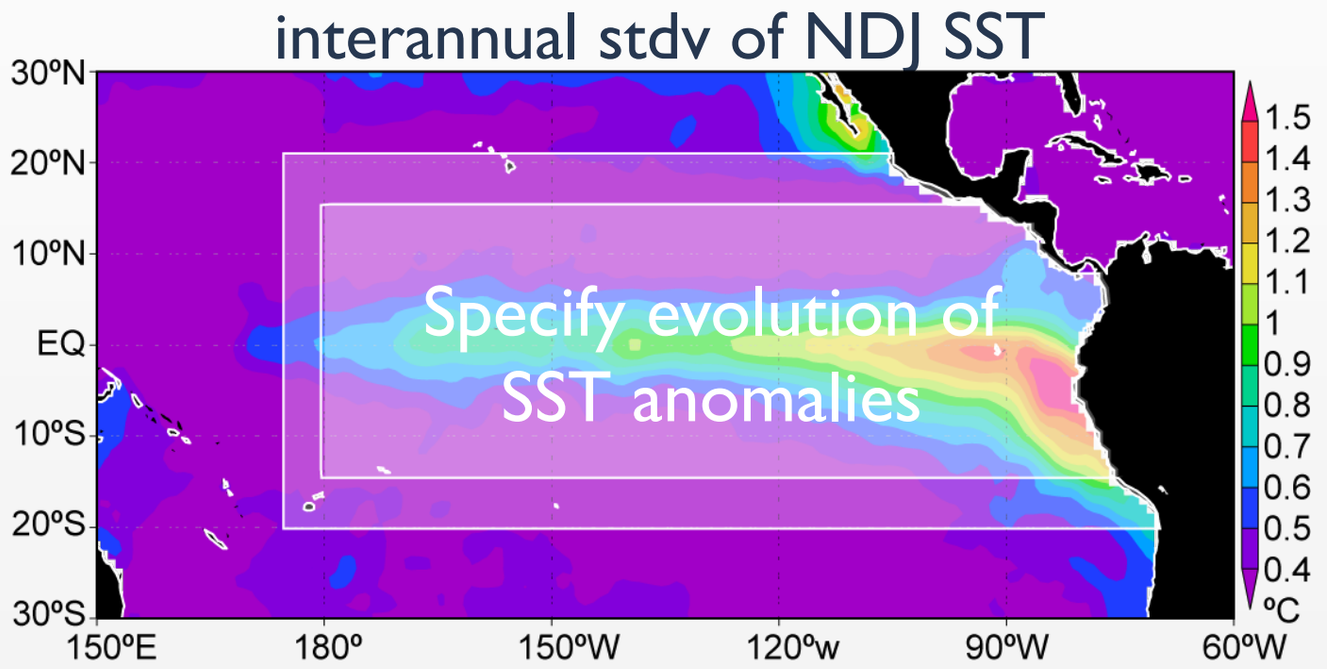
by using

- GFDL coupled model CM2.1
- Its atmospheric component AM2.1
- Seasonal predictions by 14 coupled prediction models initialized at May 1

Experimental design: GFDL CM2.1 & AM2.1

- AM2.1
  - aCLIM: climatological SST
- CM2.1: SST is restored over the eq. Eastern Pacific (ENSO region)

  e-folding time: 10days for top 50m
  - NoENSO
    - SST is restored toward model climatology (suppress ENSO)
- Pacific Ocean-Global Atmosphere (POGA)
  - SST is restored toward model climatology + historical anomalies
  - 9 members, 1979-2010

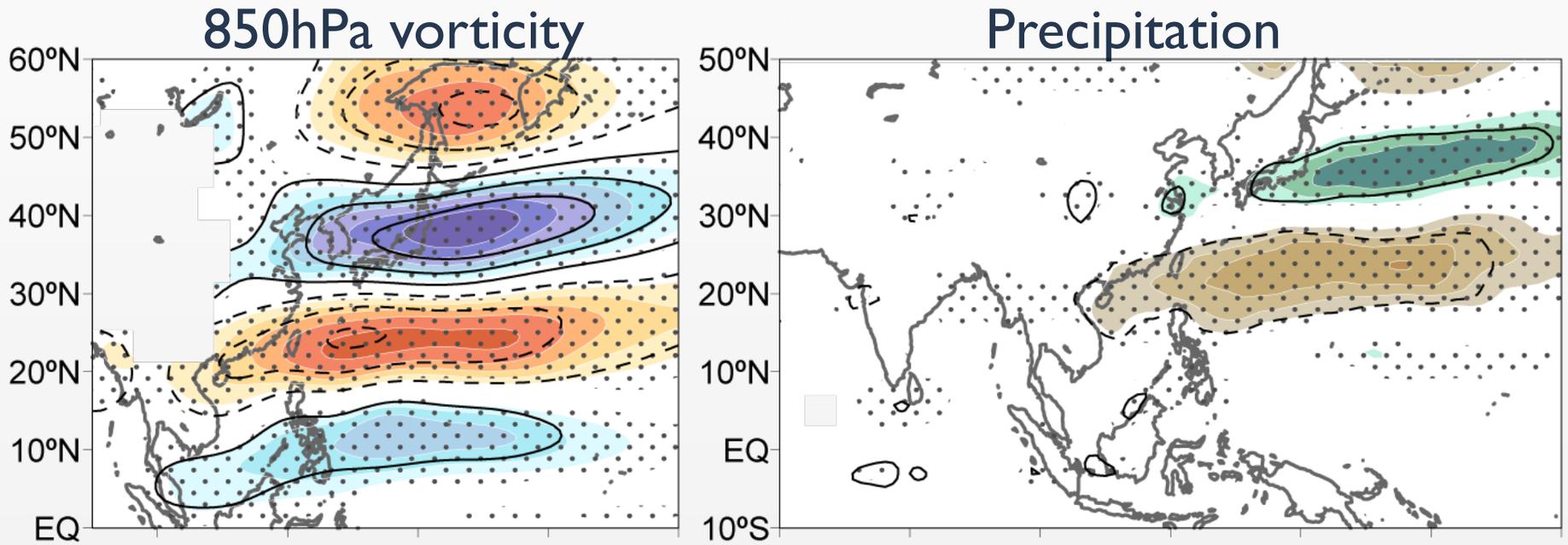


aCLIM	atmos. internal
NoENSO	atmos. internal + air-sea coupled, ENSO-free
POGA ensemble mean	air-sea coupled, ENSO-forced

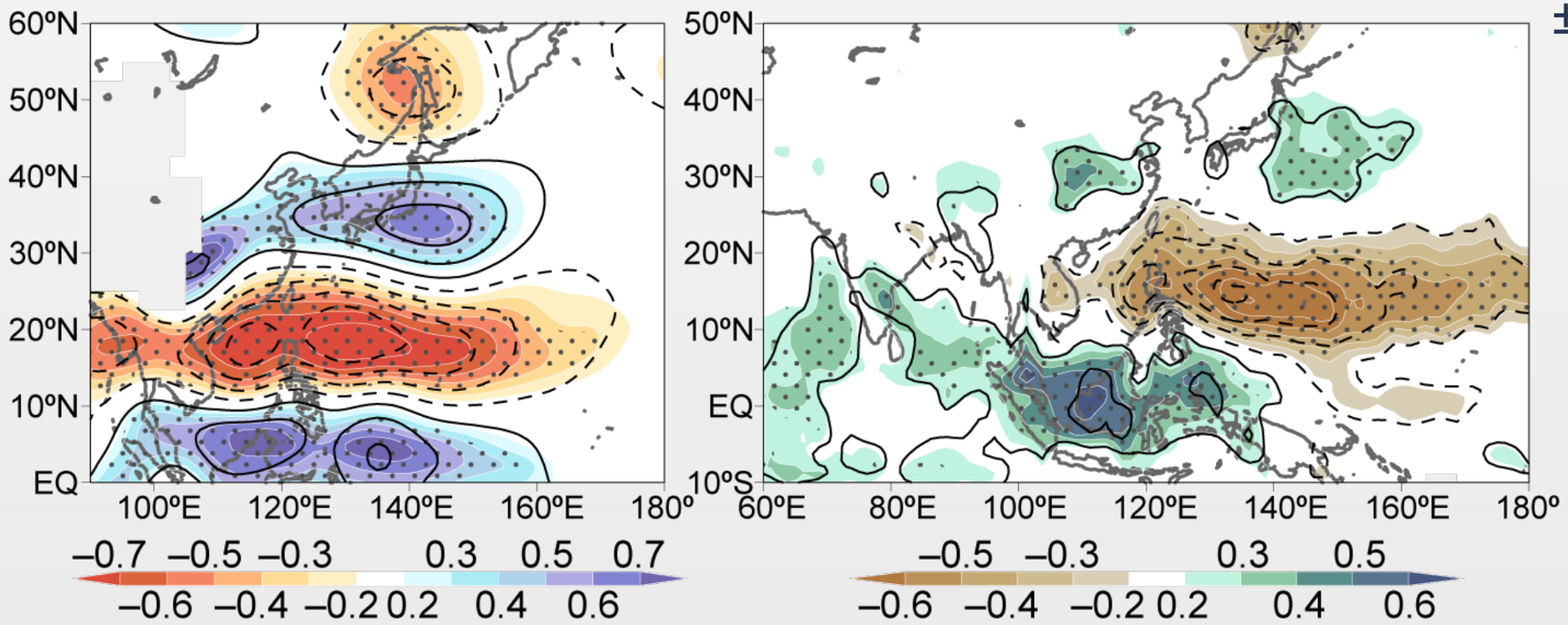
The PJ pattern as an atmospheric internal mode

EOF1 of monthly 850hPa vorticity over the NWP in JJA

aCLIM



Obs.



Shade: corr.

Contour: reg.
±0.5, ±1.5, …
[$\times 10^6$ s^{-1}]
[mm day^{-1}]

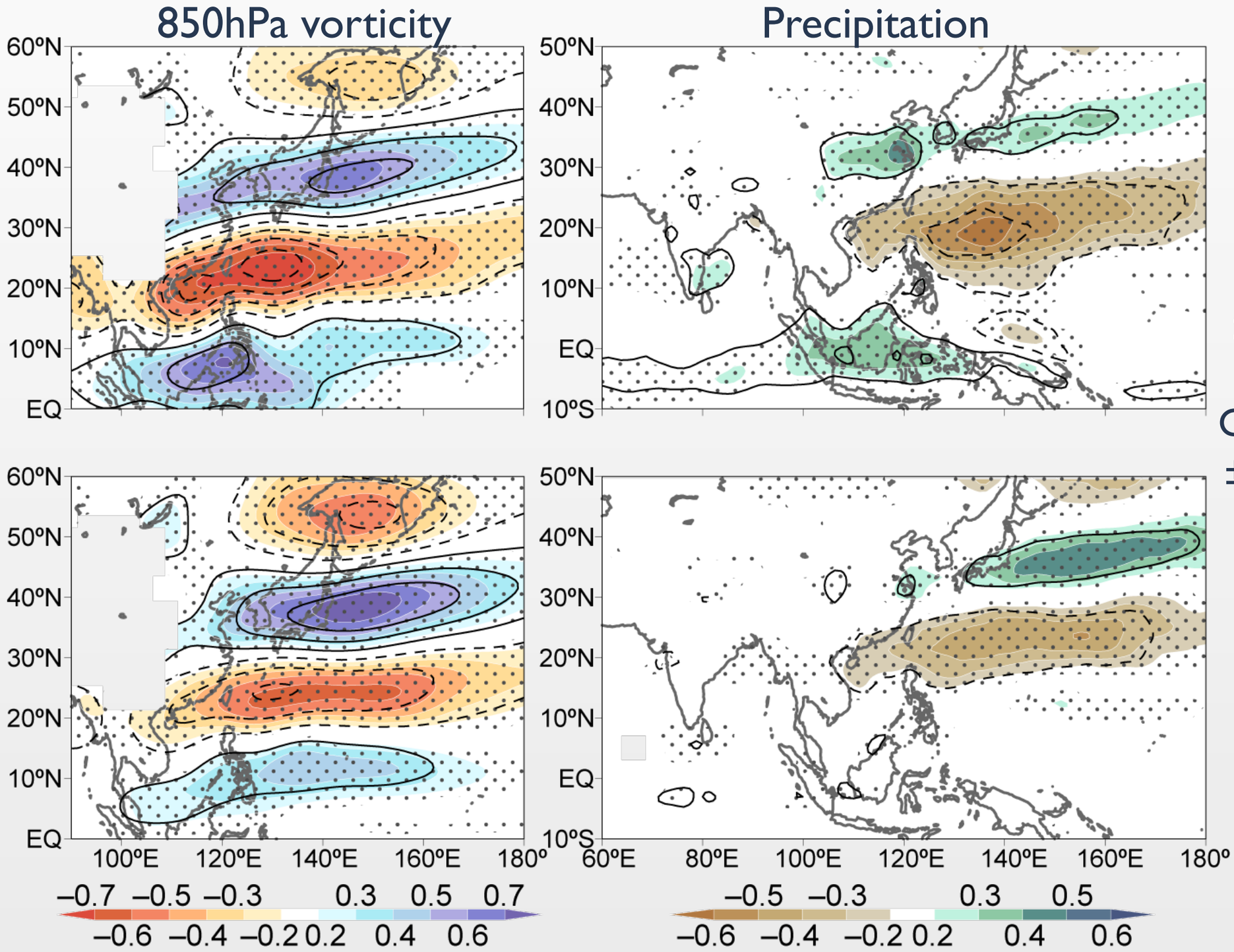
- The PJ pattern is the leading mode of atmospheric internal variability

The coupled mode in NoENSO

- When coupled, the PJ pattern gains amplitude and persistence

NoENSO

aCLIM



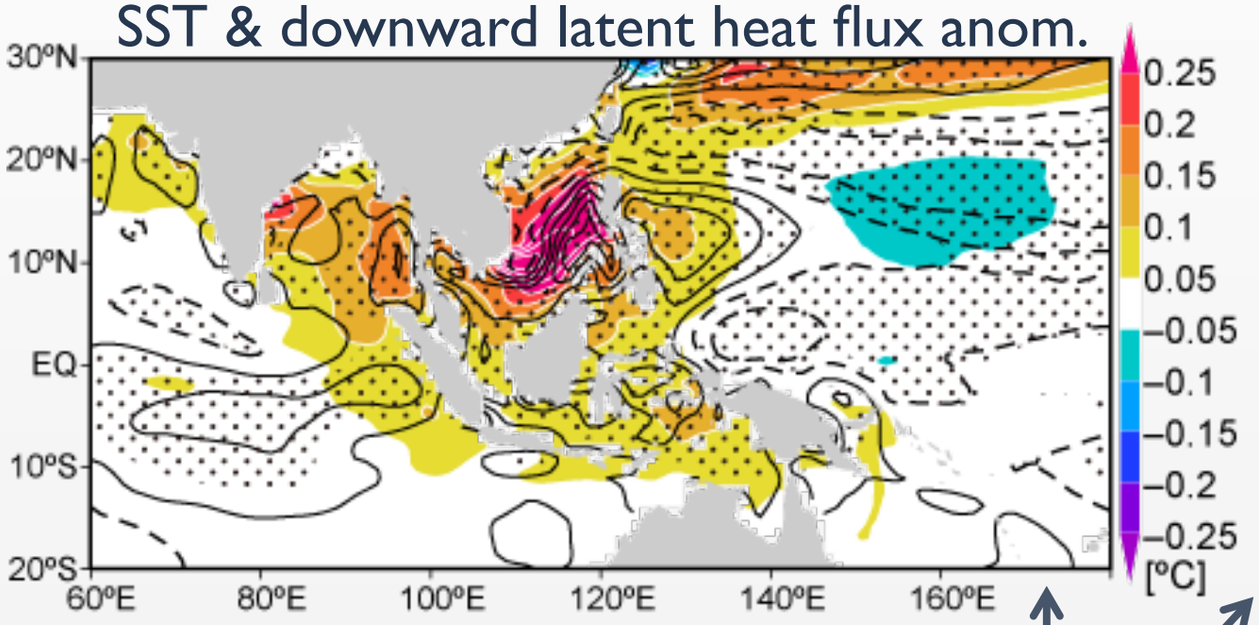
Shade: corr.

Contour: reg.
±0.5, ±1.5, …
[$\times 10^6$ s^{-1}]
[mm day^{-1}]

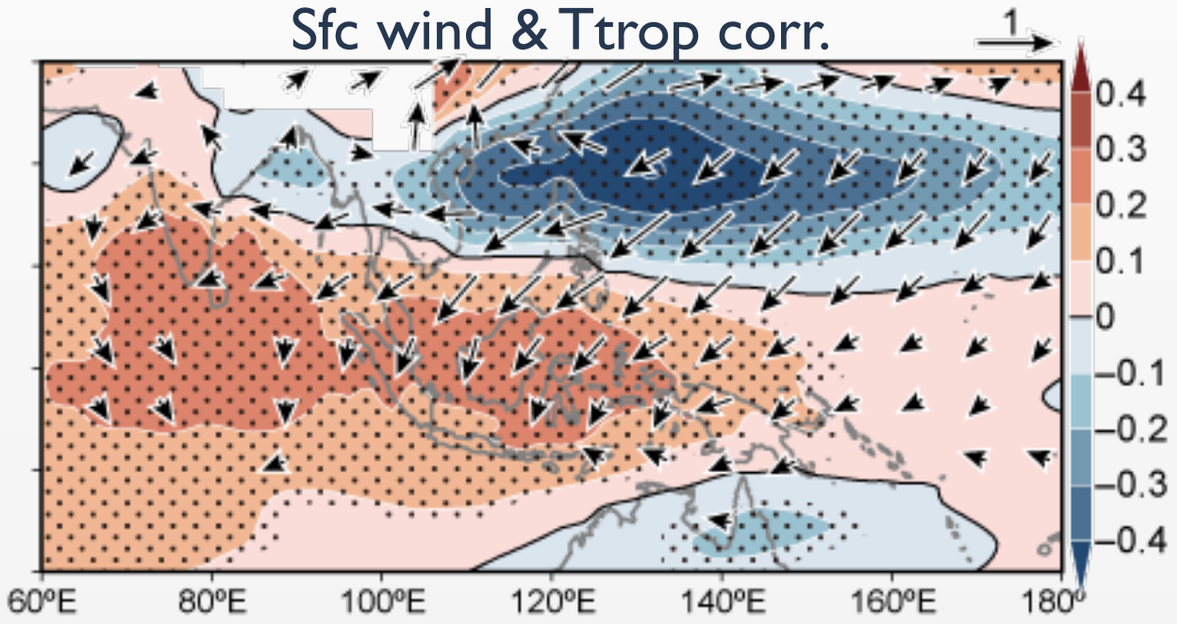
- Variance: 40-80% increase, Lag one-month autocorr: –0.0 → 0.2 (p <0.05)

IO warming coupled with the PJ pattern in NoENSO

SST & downward latent heat flux anom.

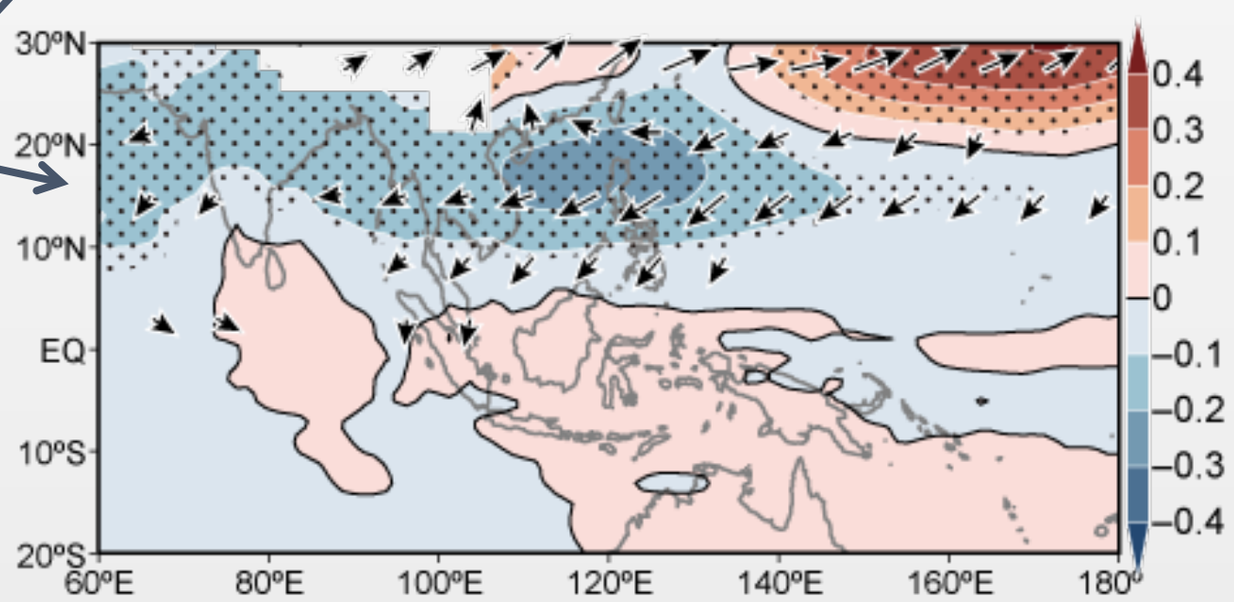


Sfc wind & Ttrop corr.



NoENSO

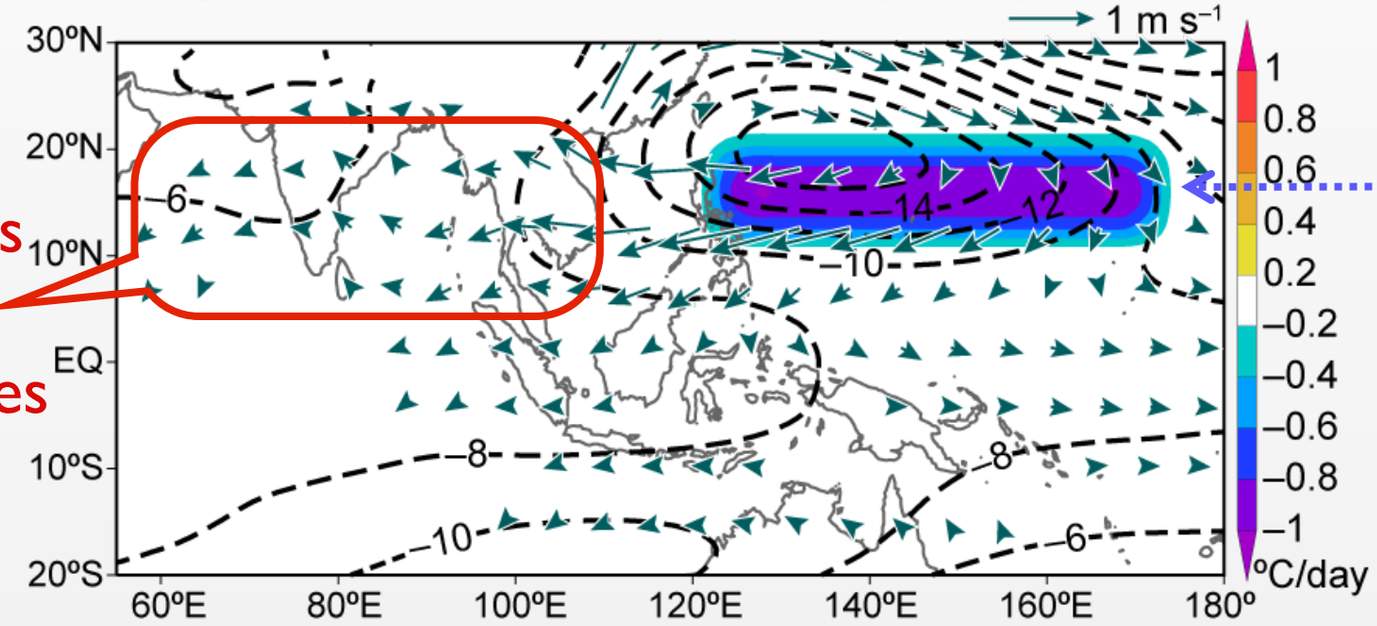
aCLIM



- Northern IO warming (not forced by ENSO)
- Latent heat flux and insolation warms the northern IO
- Warm atmospheric Kelvin wave
- The Kelvin wave signal is missing in the atmospheric internal mode

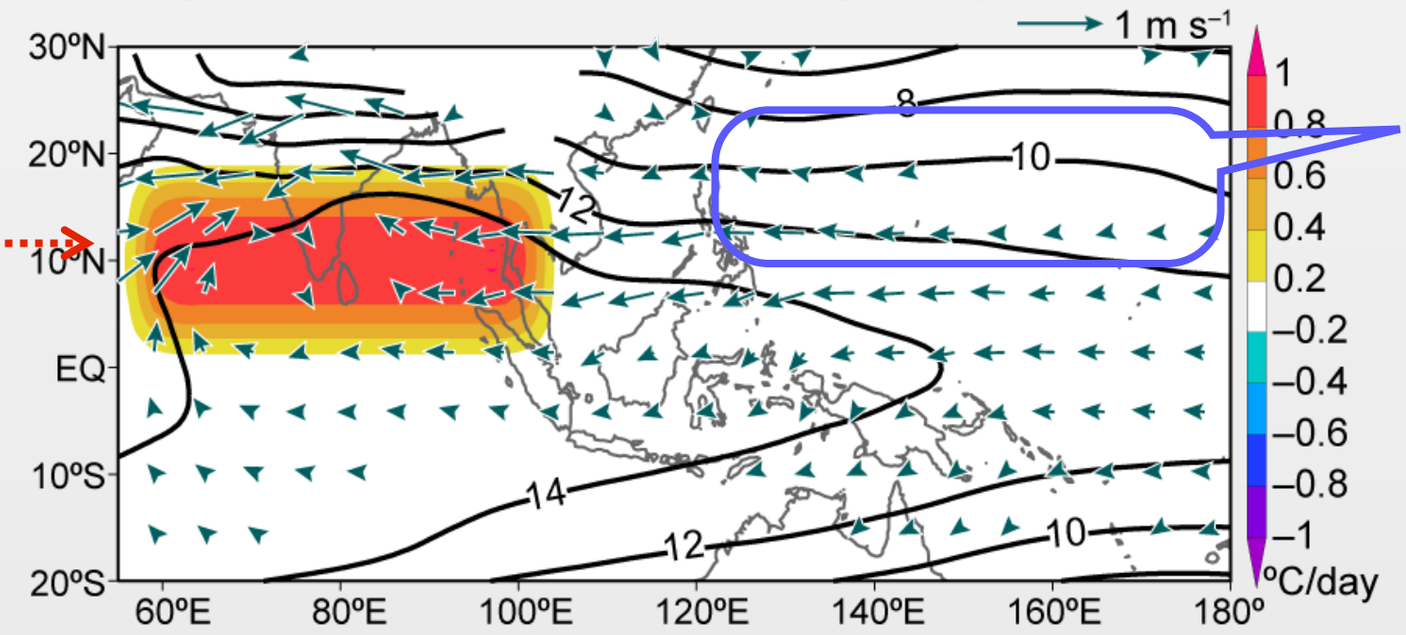
Feedback in the PJ-IO mode: Inter-basin interactions

- LBM (Watanabe and Kimoto 2000) experiments
- Tropical NWP cooling ⟶ westward-propagating cold Rossby wave



Easterly anomalies weaken monsoon westerlies

- Northern IO warming ⟶ eastward-propagating warm Kelvin wave

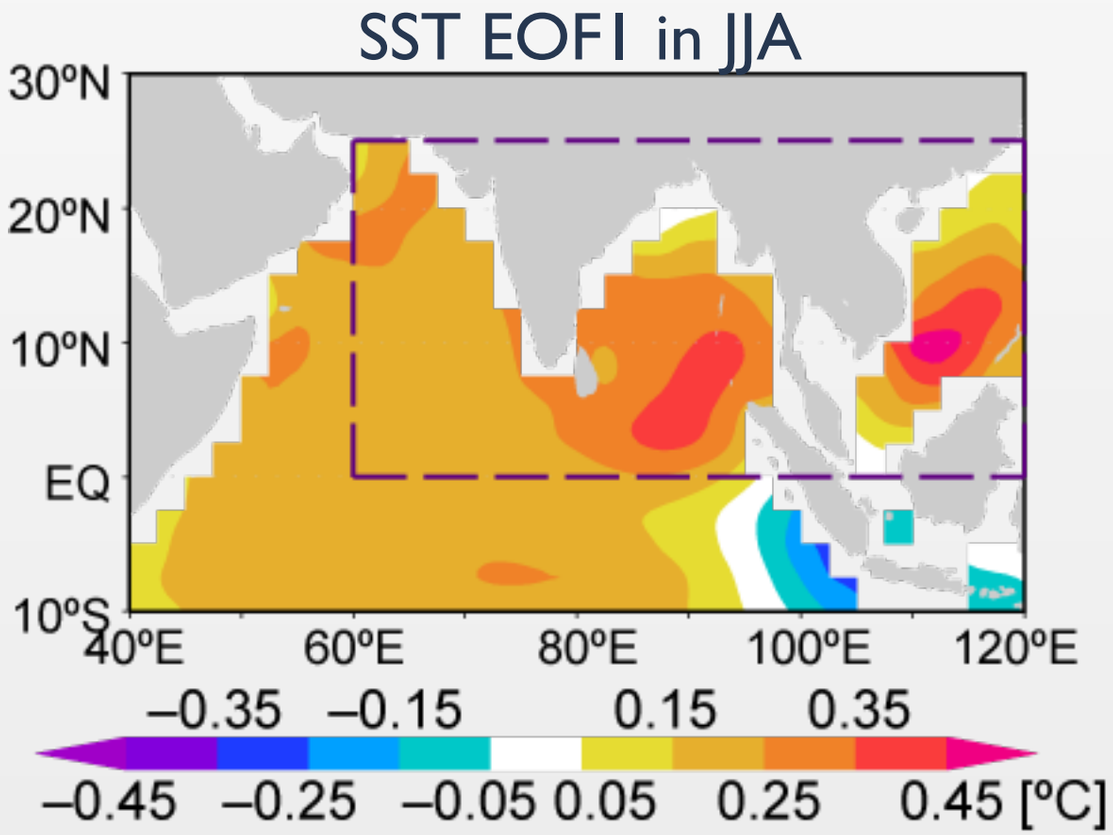


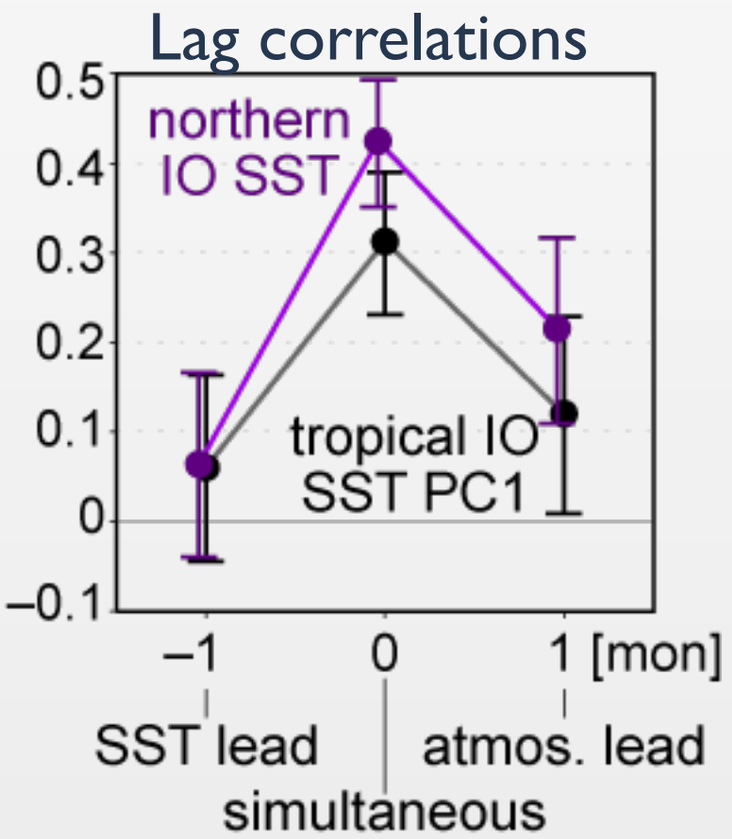
Sfc Ekman divergence

Contours: 250-850hPa thickness response Arrows: 925hPa wind response

Lead-lag correlations of ocean and atmosphere anomalies

- Cross-correlations of the PJ pattern and SST anomalies in NoENSO
- Positive ocean-atmosphere feedback → Correlation will peak at zero lag
- Negative → change sign



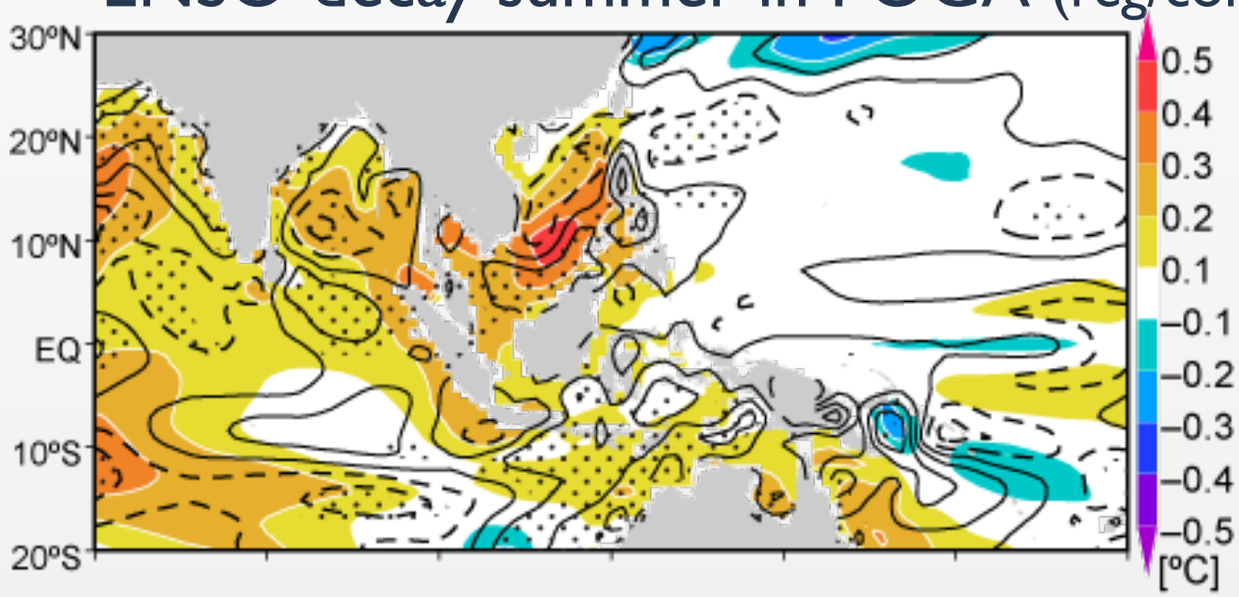


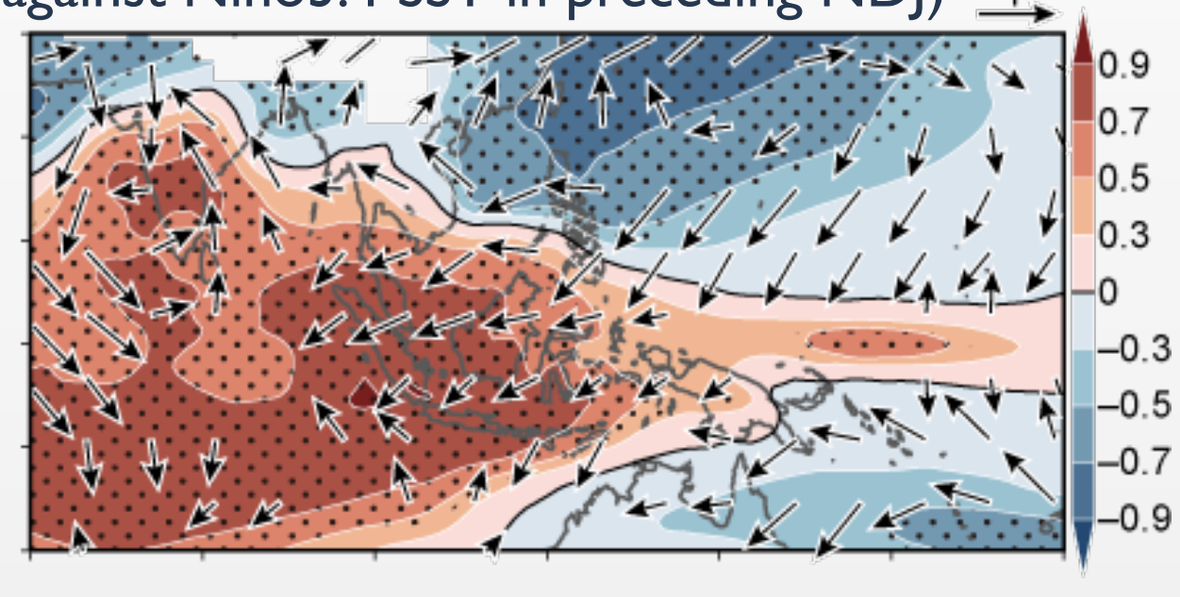
- The cross-correlations strongly suggests positive o-a feedback

Triggering of the PJIO mode by ENSO in POGA

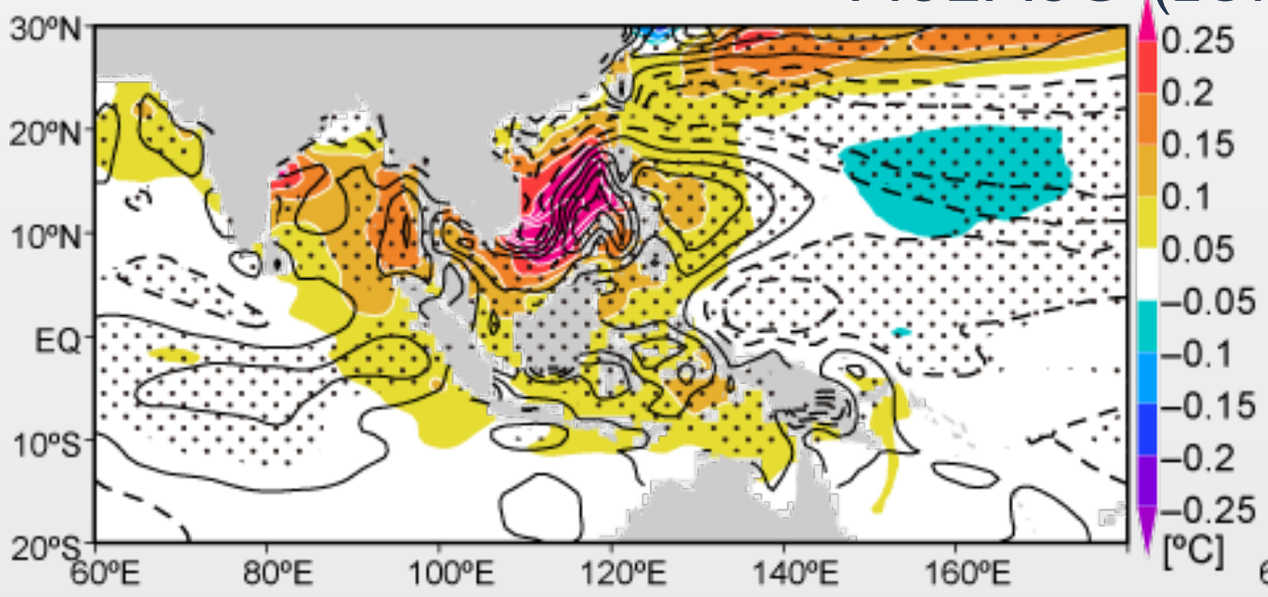
- ENSO can force the PJIO mode in its decay summer by inducing IO warming as an initial perturbation

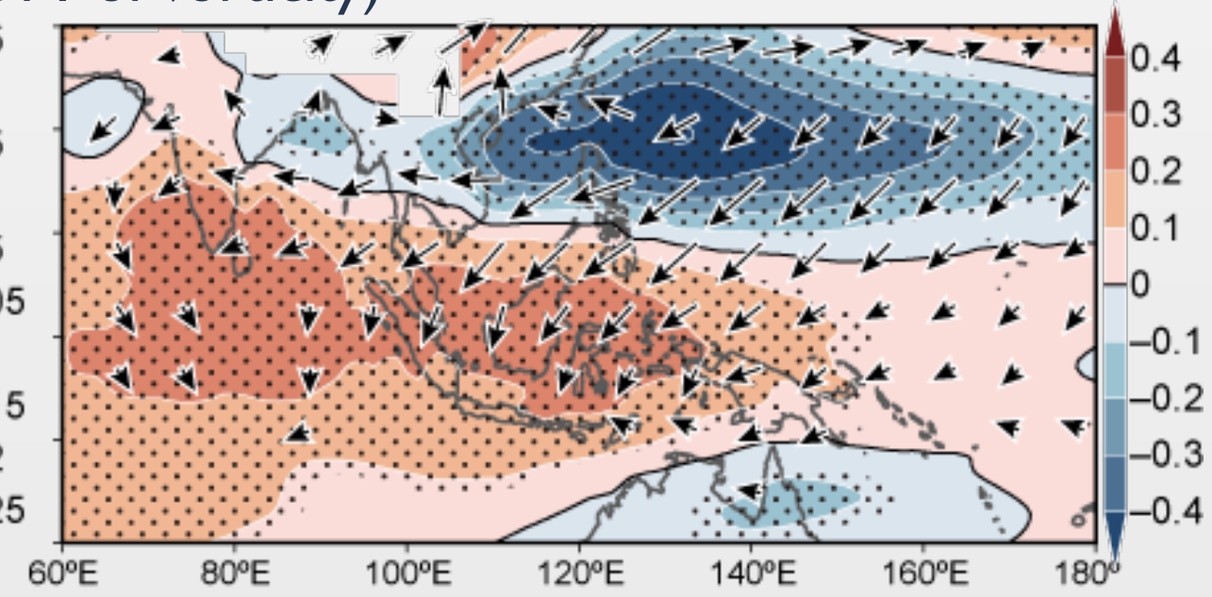
ENSO-decay summer in POGA (reg/cor against Niño3.4 SST in preceding NDJ)





NoENSO (EOF1 of vorticity)





SST & downward latent heat flux

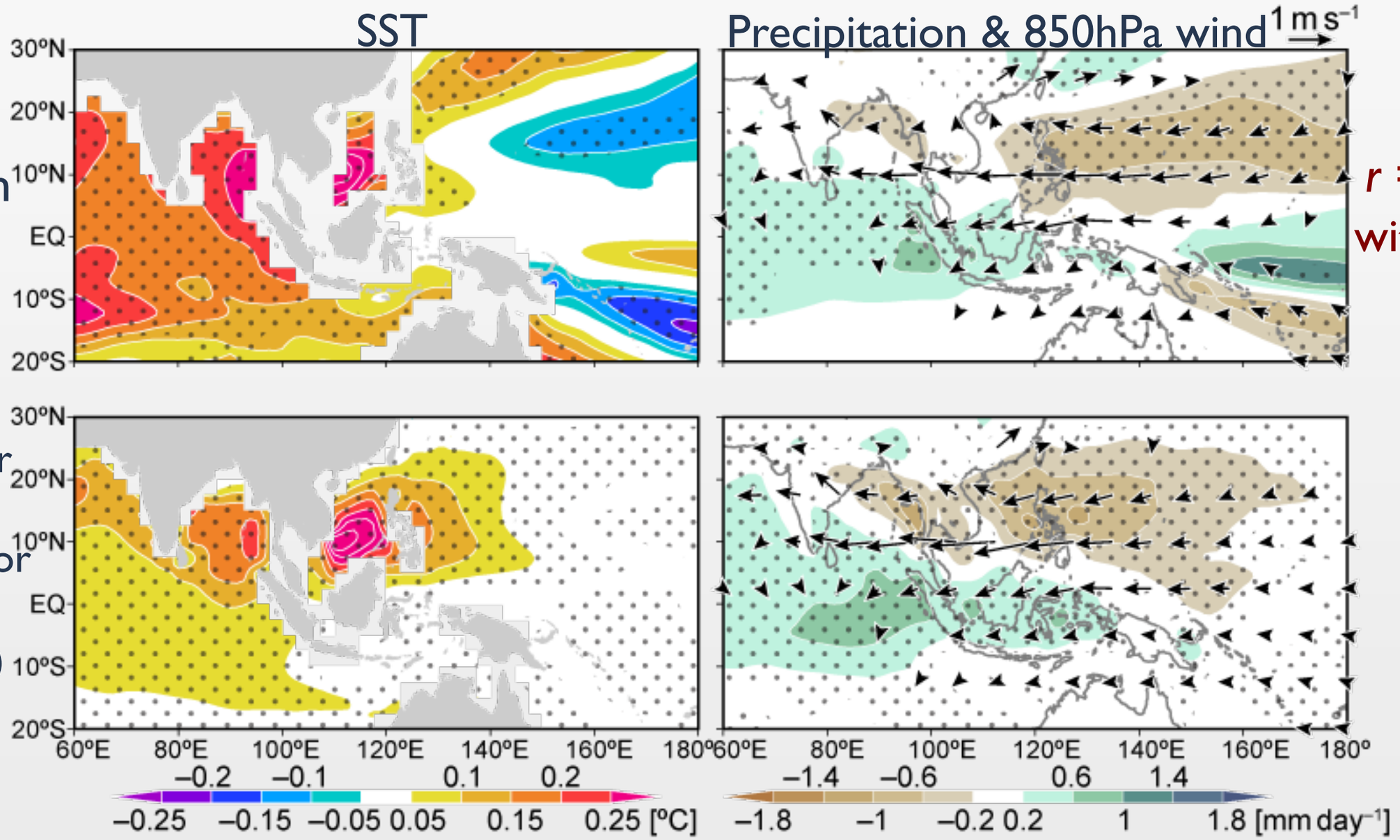
Ttrop & Sfc wind

Seasonal predictions

- 14 seasonal prediction models (CliPAS & DEMETER) initialized on May 1st each year
- SVD1s of NWP 850hPa vorticity and northern IO SST in JJA

MME mean (signal)

Inter-member variance accumulated for 14 models (uncertainty)



r = 0.72 with obs.

- Structural similarity again indicates the internal coupled mode

Seasonal predictability

- Variance components of the PJ pattern in CM2.1/AM2.1 experiments

ENSO-forced, air-sea coupled		39.2%	POGA ensemble mean
non ENSO-forced	air-sea coupled	24.5%	NoENSO
	atmospheric internal	36.3%	aCLIM

- The three variance components are comparable
- ENSO-forced component is predictable (even statistically; ~40%)
- Additional predictability from non-ENSO-forced but air-sea coupled component (~25%)

  Example: For 5 weak/no ENSO summers, MME of seasonal predictions can hindcast the observed PJ events with $r = 0.85$

Summary: the PJ-IO mode and predictability

- A new ocean-atmosphere coupled mode in the summer NWP (the PJ-IO mode)
  - Atmosphere: the PJ pattern
  - Ocean: northern Indian Ocean warming/cooling
  - Inter-basin interactions through atmospheric Rossby and Kelvin waves
- This mode dominates without ENSO, but
- ENSO can trigger this mode → last echo & seasonal predictability

- The coupled mode enables ENSO to induce its last echoes in the summer IO-NWP
- Additional predictability from coupled model with IO initialization

Kosaka et al., 2013: Origin of seasonal predictability for summer climate over the Northwestern Pacific. *PNAS*