# Warm phase of the AMV damps ENSO through weakened thermoclined feedback

**Paloma Trascasa-Castro,** Yohan Ruprich-Robert, Frederic Castruccio and Amanda Maycock

*GRL (2021), DOI: 10.1029/2021GL096149*

UNIVERSITY OF LEEDS
Barcelona Supercomputing Center
Centro Nacional de Supercomputación
NCAR
UCAR

ICTP, July 2022

## *Modulation of ENSO and its impacts by the mean climate state*

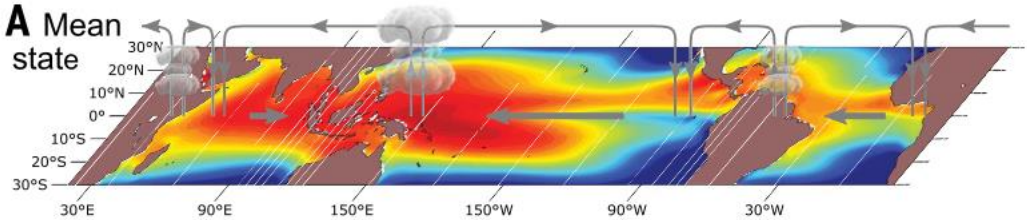
**Anthropogenic**


Strong El Niño pacemaker simulations with EC-Earth

- Past
- Present
- Future

**Internal climate variability**

Intrabasin teleconnections




Cai *et al.* (2019)

ee17pt@leeds.ac.uk

# The Atlantic Multidecadal Variability (AMV)

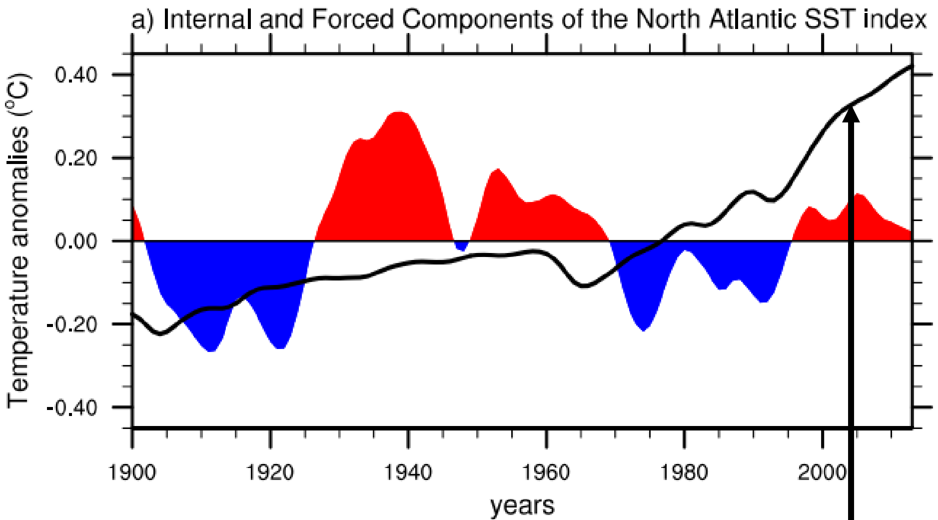
**Observed warming** trend in the North Atlantic (AMV+) since 1990s

↓

tropical Pacific cooling
and global warming hiatus

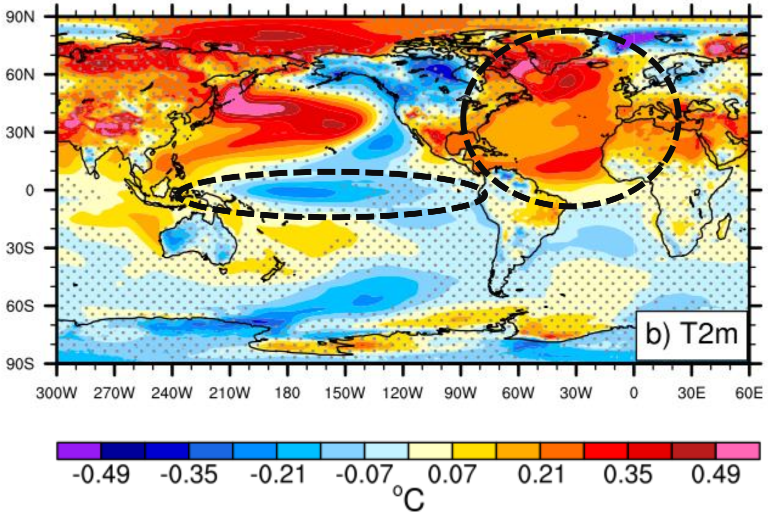
*(McGregor et al. 2014, Li et al. 2016)*

**NCAR-CESM1 model**

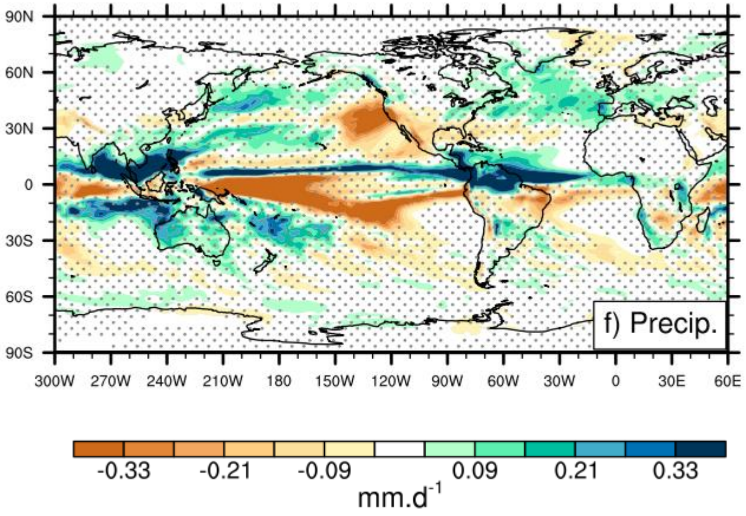



Externally forced

AMV temperature impacts in DJFM
[AMV+ - AMV-]




AMV precipitation impacts in DJFM
[AMV+ - AMV-]




*Ruprich-Robert et al. (2017)*

***Also at interannual timescales*** *(Dong et al. 2006, Rodriguez-Fonseca et al. 2009, Martin-Rey et al. 2012, Ham et al. 2013, Polo et al. 2014)*



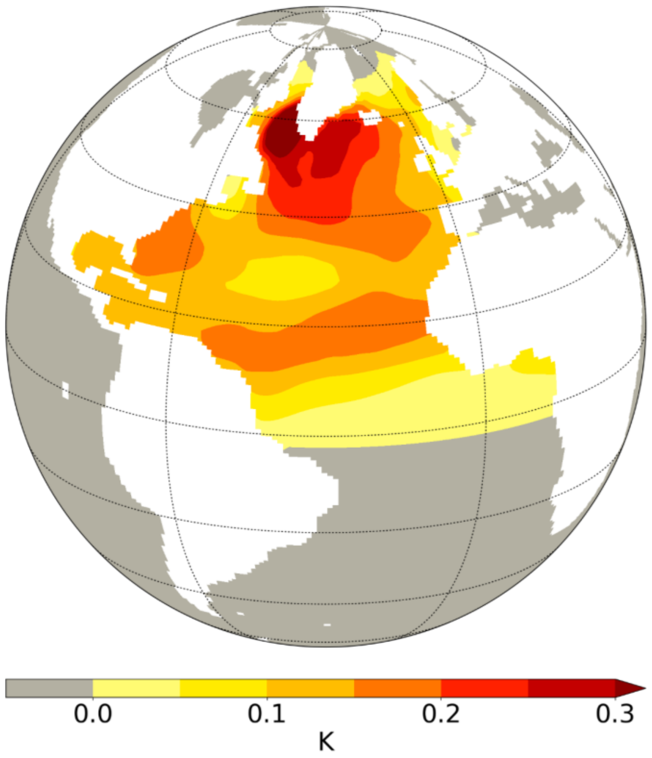
ee17pt@leeds.ac.uk

# How does the AMV impact ENSO variability?

Idealised AMV simulations, run for Component C of the **Decadal Climate Prediction Project** (DCPP) from CMIP6

*(Boer et al. 2016)*

AMV+ target pattern




| Model | Ensemble size | At. Res. | Years | Niño AMV+ | Niño AMV- | Niña AMV+ | Niña AMV- |
|---|---|---|---|---|---|---|---|
| **NCAR-CESM1** | **30** | **192x288** | **270** | **77** | **79** | **91** | **103** |

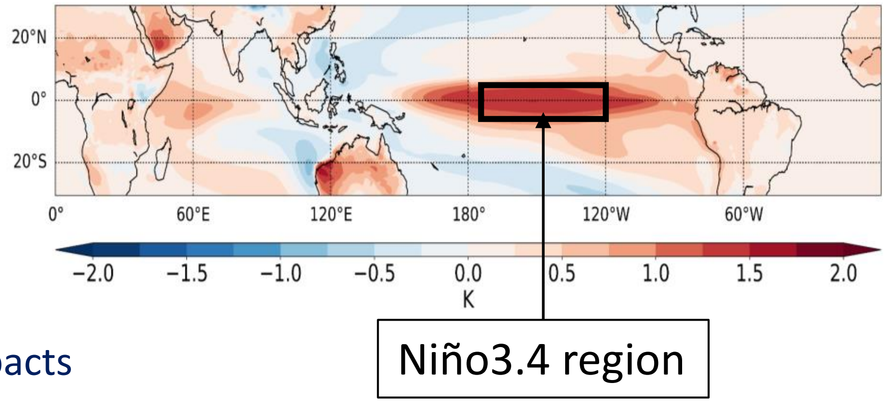
- Observed AMV pattern (ERSSTv4) was imposed to preindustrial SSTs via **surface flux restoring**
- **Fixed pattern** does not vary in time nor account for AMV seasonality

ee17pt@leeds.ac.uk

# Experimental design

## ENSO definition

SST anomalies in **DJF** in the Niño3.4 region
(5 °S – 5 °N, 170 - 120 °W)
**El Niño** > 0.5 °C   **La Niña** < -0.5 °C




## El Niño impacts

El Niño impacts − AMV impacts

$$\frac{ElNino_{AMV+} + ElNino_{AMV-}}{2} - \frac{\mu_{AMV+} + \mu_{AMV-}}{2}$$

Same methodology applies to La Niña

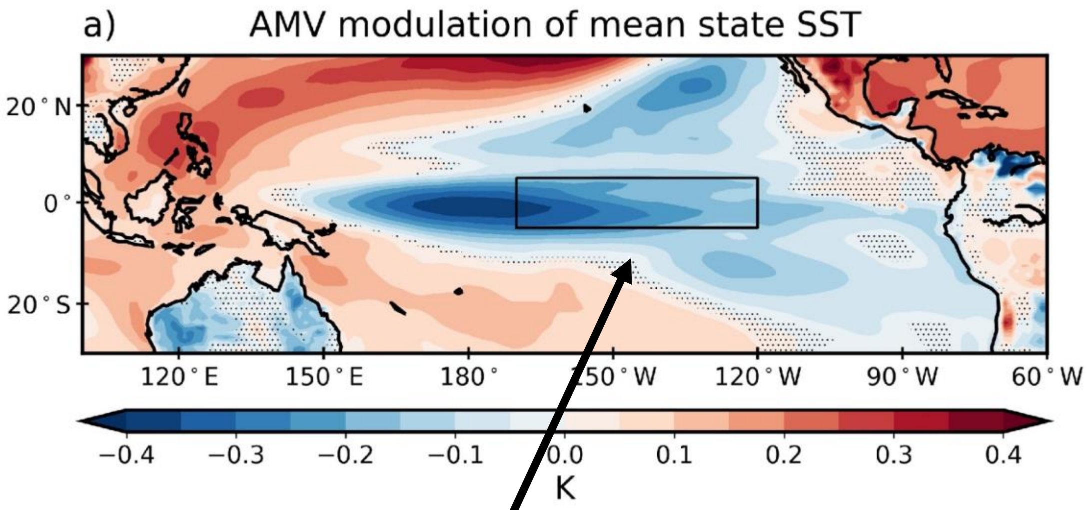
## AMV modulation of El Niño impacts

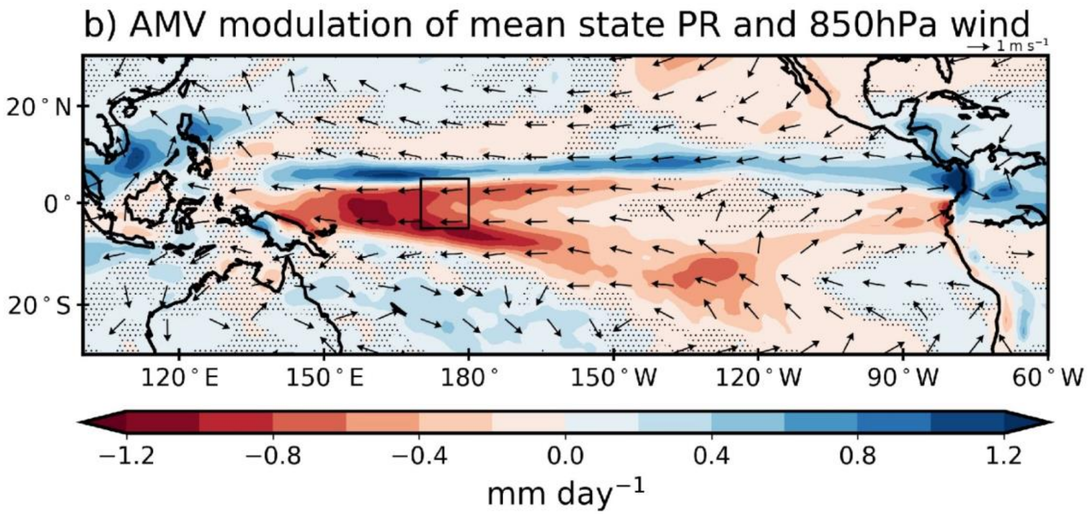
El Niño impacts in AMV+ − El Niño impacts in AMV-

$$(ElNino_{AMV+} - \mu_{AMV+}) - (ElNino_{AMV-} - \mu_{AMV-})$$

Remove the direct AMV impacts

# AMV modulation of tropical Pacific mean state [AMV+ — AMV-]




## Warm phase of AMV

Tropical Pacific cooling
Niño3.4 SST anomaly = - 0.23 K

Northward shift of the ITCZ

Strengthening of the Walker Circulation

**ITCZ = Intertropical Convergence Zone**

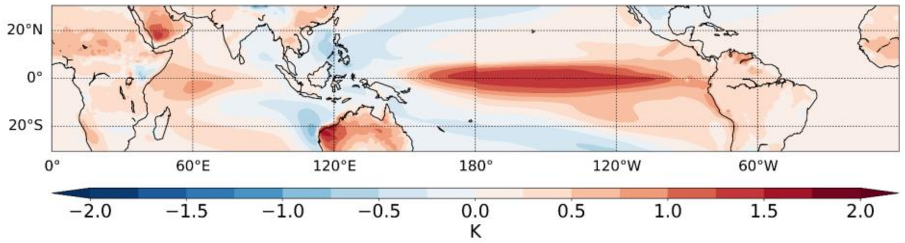
ee17pt@leeds.ac.uk

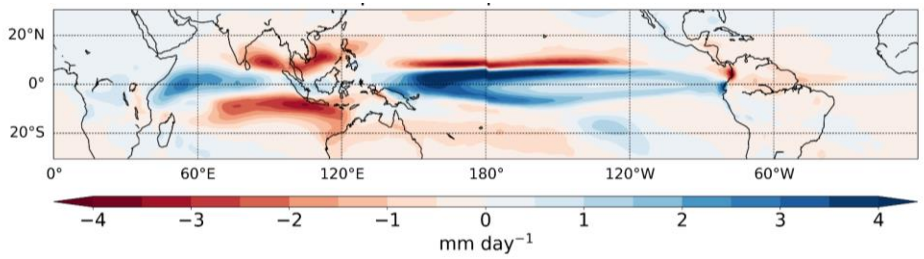
# El Niño

Differences in ENSO impacts between AMV+ and AMV-

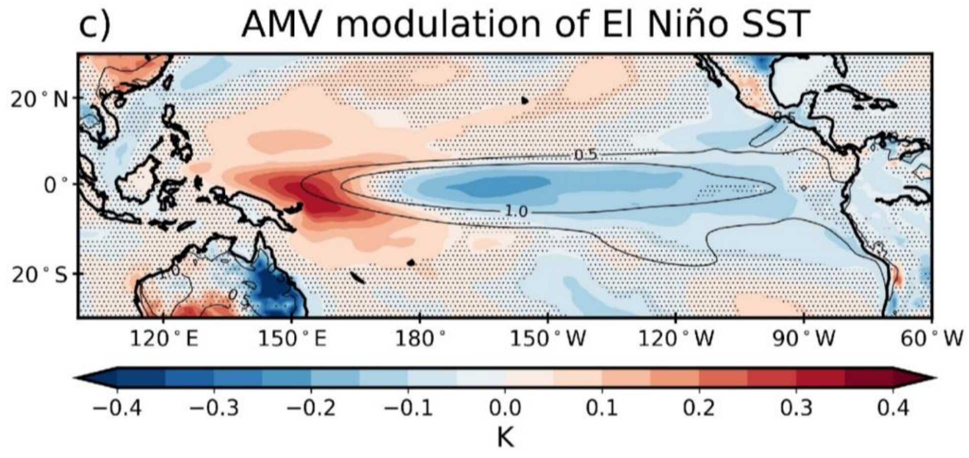
**SST** | **Precipitation**

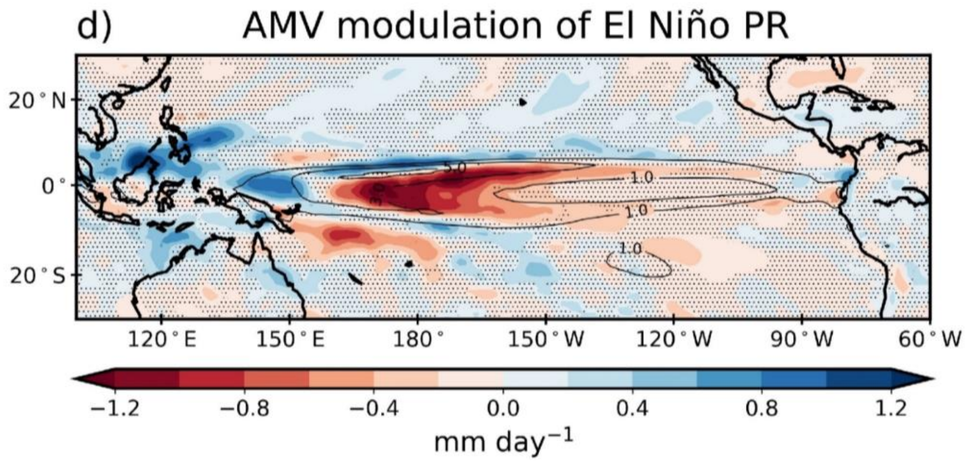
El Niño




AMV modulation of El Niño




↓ Niño3.4 SSTs by ~10%

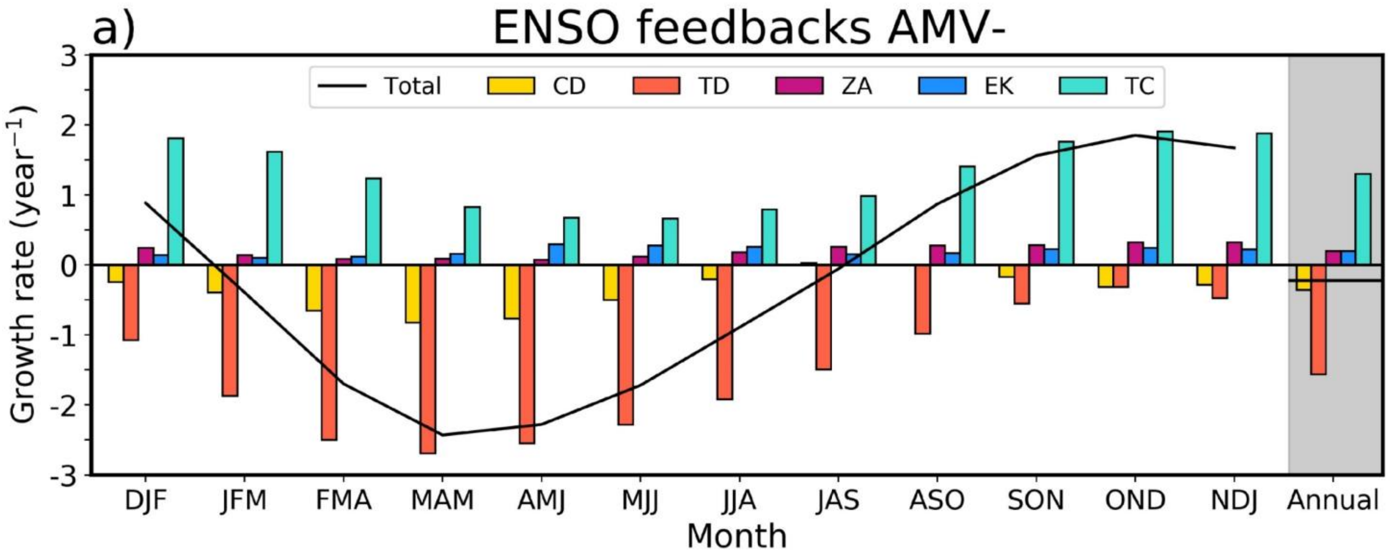
↓ CP precipitation by ~40%

*90% of the El Niño PR modulation is explained by SST changes*



ee17pt@leeds.ac.uk

# The Bjerknes Stability index (Jin *et al.* 2006)




Current damping | Thermodynamic | Zonal advective | Ekman | Thermocline

$$2BJ = -\left[a_1 \frac{\langle\Delta\bar{u}\rangle_E}{L_x} + a_2 \frac{\langle\Delta\bar{v}\rangle_E}{L_y}\right] - [\alpha_s] + \left[\mu_a \beta_u \langle -\frac{\partial \overline{T}}{\partial x}\rangle_E\right] + \left[\mu_a \beta_w \langle -\frac{\partial \overline{T}}{\partial z}\rangle_E\right] + \left[\mu_a \beta_h \langle -\frac{\overline{w}}{H_1}\rangle_E \, a_h\right]$$



ee17pt@leeds.ac.uk

# Current damping feedback

Current damping | Thermodynamic | Zonal advective | Ekman | Thermocline

$$2BJ = -\left[a_1 \frac{\langle \Delta \bar{u} \rangle_E}{L_x} + a_2 \frac{\langle \Delta \bar{v} \rangle_E}{L_y}\right] - [\alpha_s] + \left[\mu_a \beta_u \langle -\frac{\partial \bar{T}}{\partial x} \rangle_E\right] + \left[\mu_a \beta_w \langle -\frac{\partial \bar{T}}{\partial z} \rangle_E\right] + \left[\mu_a \beta_h \langle -\frac{\bar{w}}{H_1} \rangle_E a_h\right]$$

**Negative feedback**

Eastern equatorial Pacific

a2 = Meridional temperature gradient


a1 = Zonal temperature gradient

ee17pt@leeds.ac.uk

# Thermodynamic feedback

Current damping | **Thermodynamic** | Zonal advective | Ekman | Thermocline

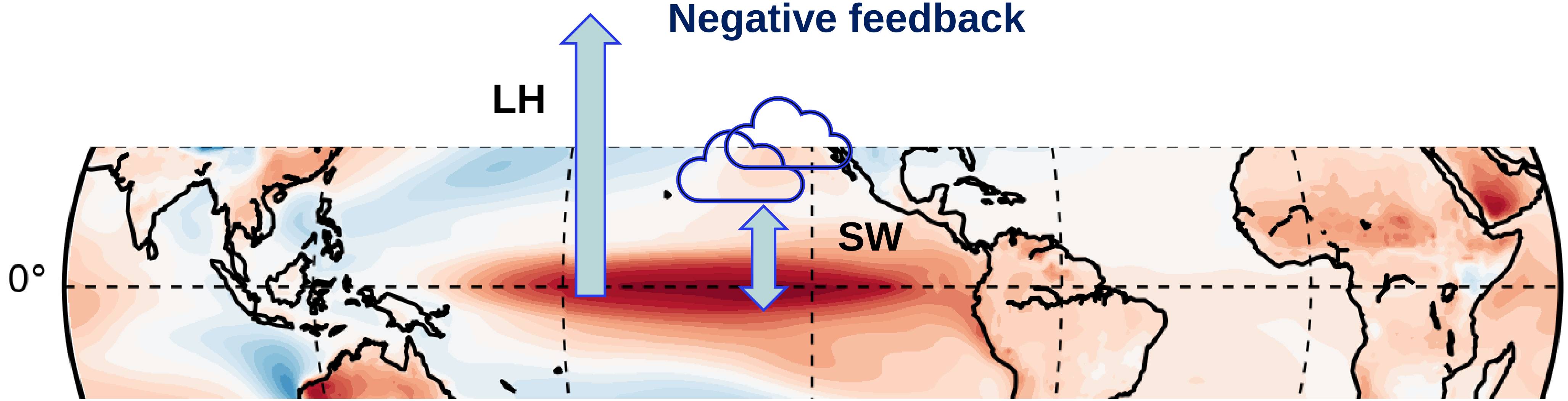
$$2BJ = -\left[a_1 \frac{\langle \Delta \bar{u} \rangle_E}{L_x} + a_2 \frac{\langle \Delta \bar{v} \rangle_E}{L_y}\right] - [\alpha_s] + \left[\mu_a \beta_u \langle -\frac{\partial \bar{T}}{\partial x} \rangle_E\right] + \left[\mu_a \beta_w \langle -\frac{\partial \bar{T}}{\partial z} \rangle_E\right] + \left[\mu_a \beta_h \langle -\frac{\bar{w}}{H_1} \rangle_E a_h\right]$$

$\sum$

Latent heat flux
Sensible heat flux
Longwave flux (surface)
Shortwave flux (surface)

Regressed onto → Eastern equatorial Pacific SST anomalies

**Negative feedback**




ee17pt@leeds.ac.uk

# Zonal advective feedback

Current damping | Thermodynamic | **Zonal advective** | Ekman | Thermocline

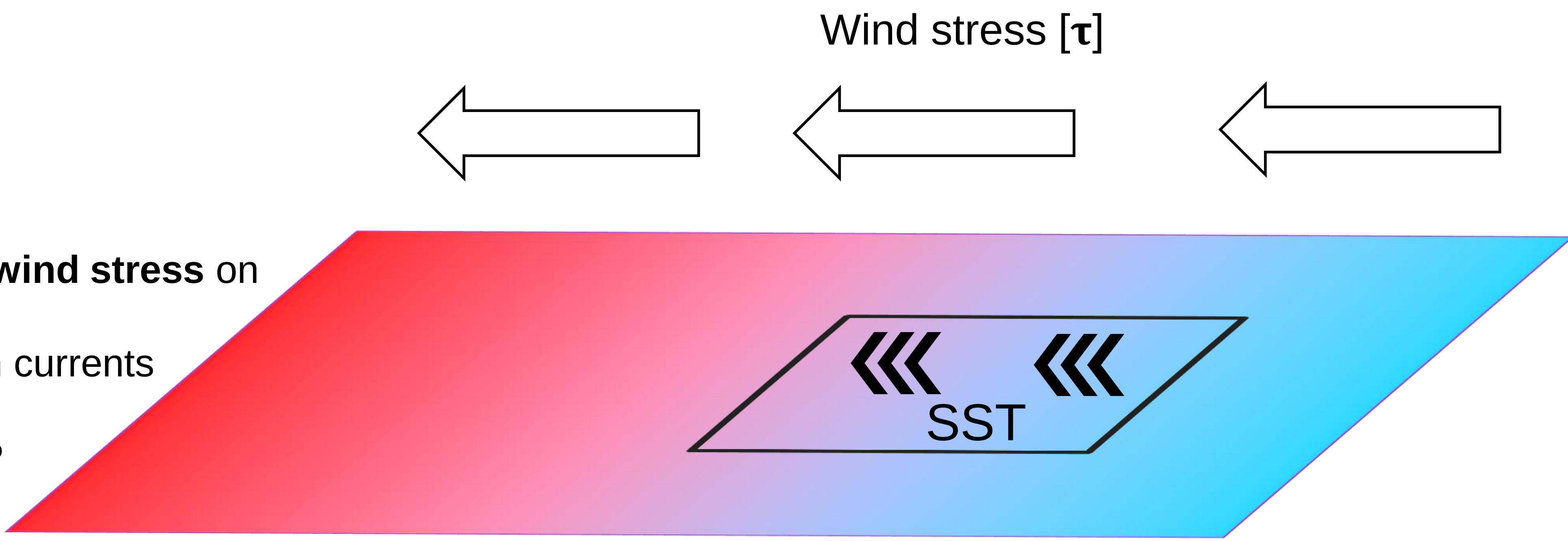
$$2BJ = -\left[a_1 \frac{\langle \Delta \bar{u} \rangle_E}{L_x} + a_2 \frac{\langle \Delta \bar{v} \rangle_E}{L_y}\right] - [\alpha_s] + \left[\mu_a \beta_u \langle -\frac{\partial \overline{T}}{\partial x} \rangle_E\right] + \left[\mu_a \beta_w \langle -\frac{\partial \overline{T}}{\partial z} \rangle_E\right] + \left[\mu_a \beta_h \langle -\frac{\overline{w}}{H_1} \rangle_E a_h\right]$$

**Positive feedback**

Effect of equatorial Pacific **wind stress** on
- East Pacific SSTs
- East Pacific zonal ocean currents

↓

Temperature gradient in EP



# Ekman feedback

Current damping | Thermodynamic | Zonal advective | **Ekman** | Thermocline

$$2BJ = -\left[a_1\frac{\langle\Delta\bar{u}\rangle_E}{L_x} + a_2\frac{\langle\Delta\bar{v}\rangle_E}{L_y}\right] - [\alpha_s] + \left[\mu_a\beta_u\langle-\frac{\partial\bar{T}}{\partial x}\rangle_E\right] + \left[\mu_a\beta_w\langle-\frac{\partial\bar{T}}{\partial z}\rangle_E\right] + \left[\mu_a\beta_h\langle-\frac{\bar{w}}{H_1}\rangle_E\, a_h\right]$$

**Positive**

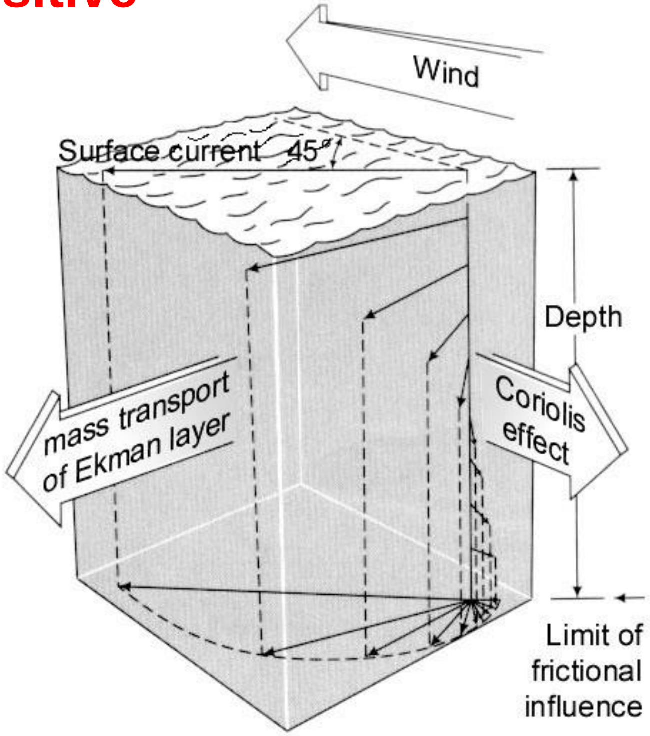
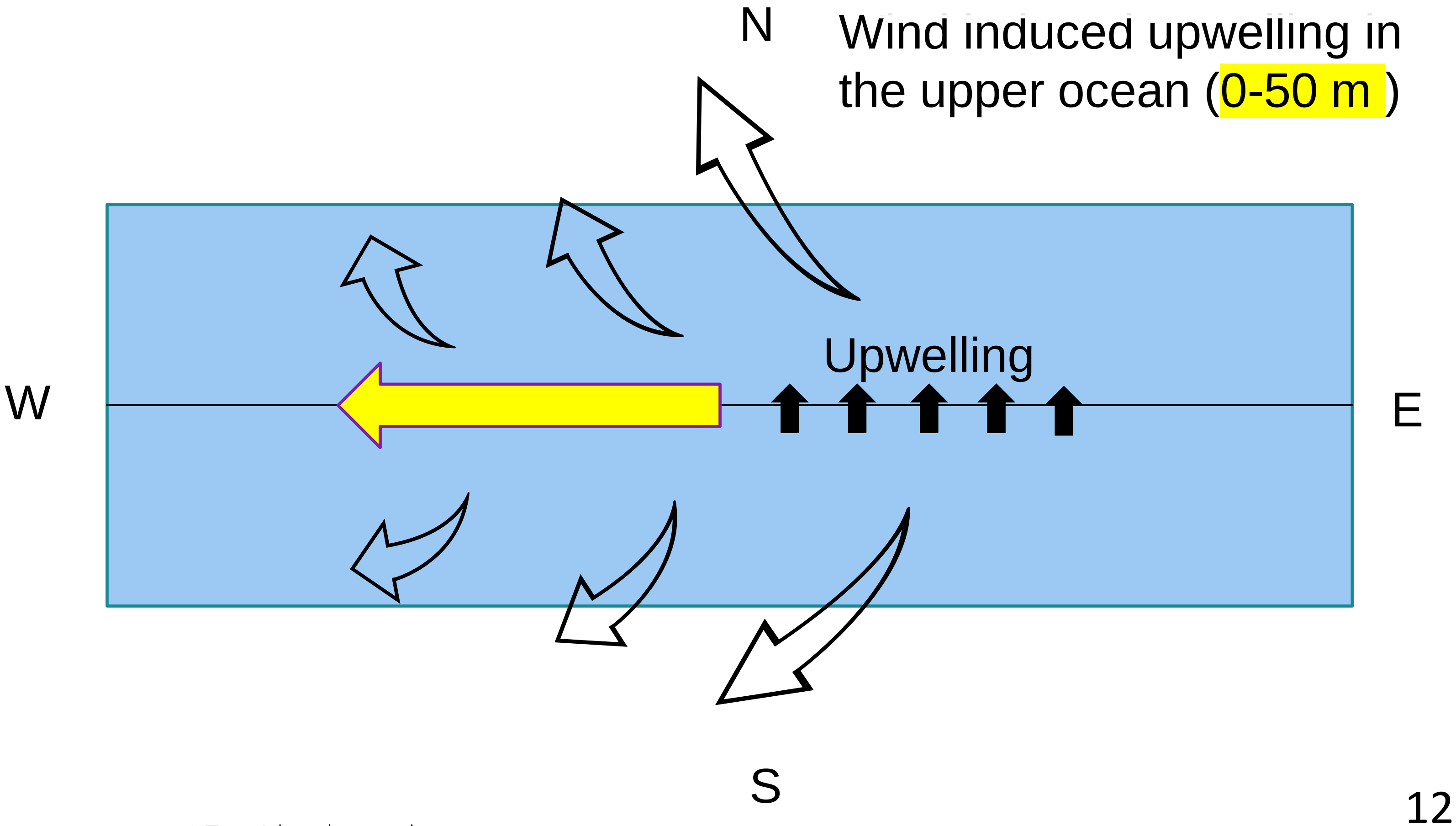



Fig.4 The Ekman spiral (southern hemisphere) is believed to be the result of the action of steady wind on surface waters.



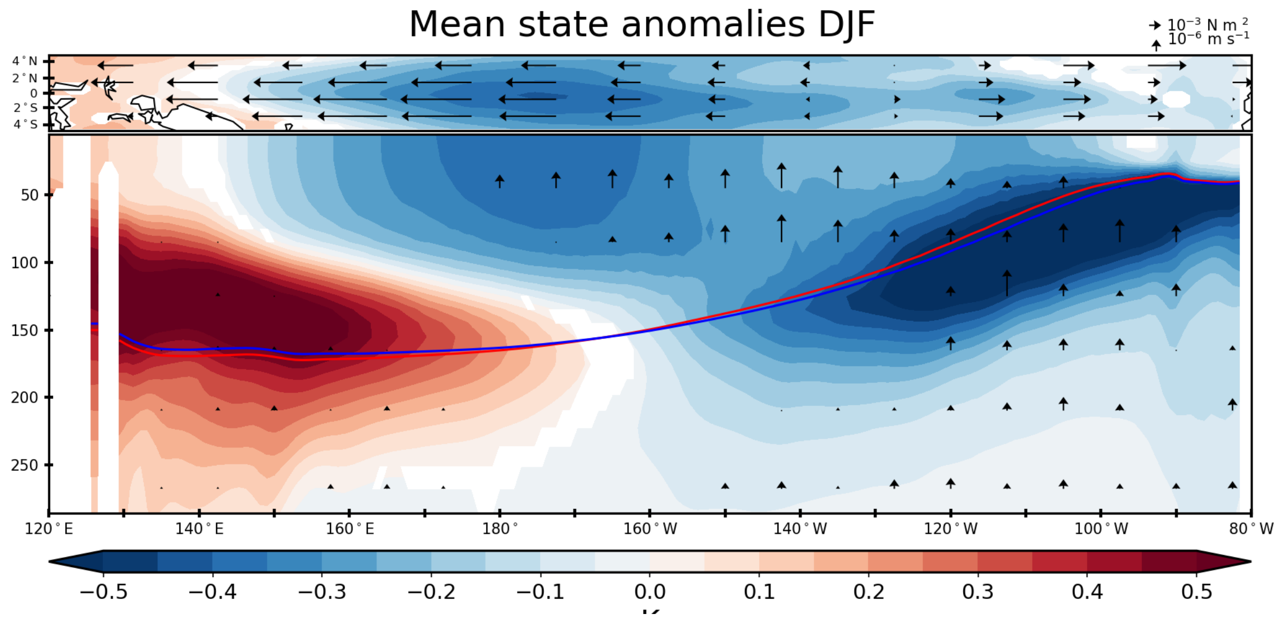

ee17pt@leeds.ac.uk

# Thermocline feedback

Current damping | Thermodynamic | Zonal advective | Ekman | Thermocline

$$2BJ = -\left[a_1 \frac{\langle \Delta \bar{u} \rangle_E}{L_x} + a_2 \frac{\langle \Delta \bar{v} \rangle_E}{L_y}\right] - [\alpha_s] + \left[\mu_a \beta_u \langle -\frac{\partial \overline{T}}{\partial x} \rangle_E\right] + \left[\mu_a \beta_w \langle -\frac{\partial \overline{T}}{\partial z} \rangle_E\right] + \left[\mu_a \beta_h \langle -\frac{\overline{w}}{H_1} \rangle_E \, a_h\right]$$

**Positive**




- SST response to wind stress
- Thermocline slope response to wind stress
- Climatological upwelling
- Upper ocean heat content

# The Bjerknes Stability index

Total

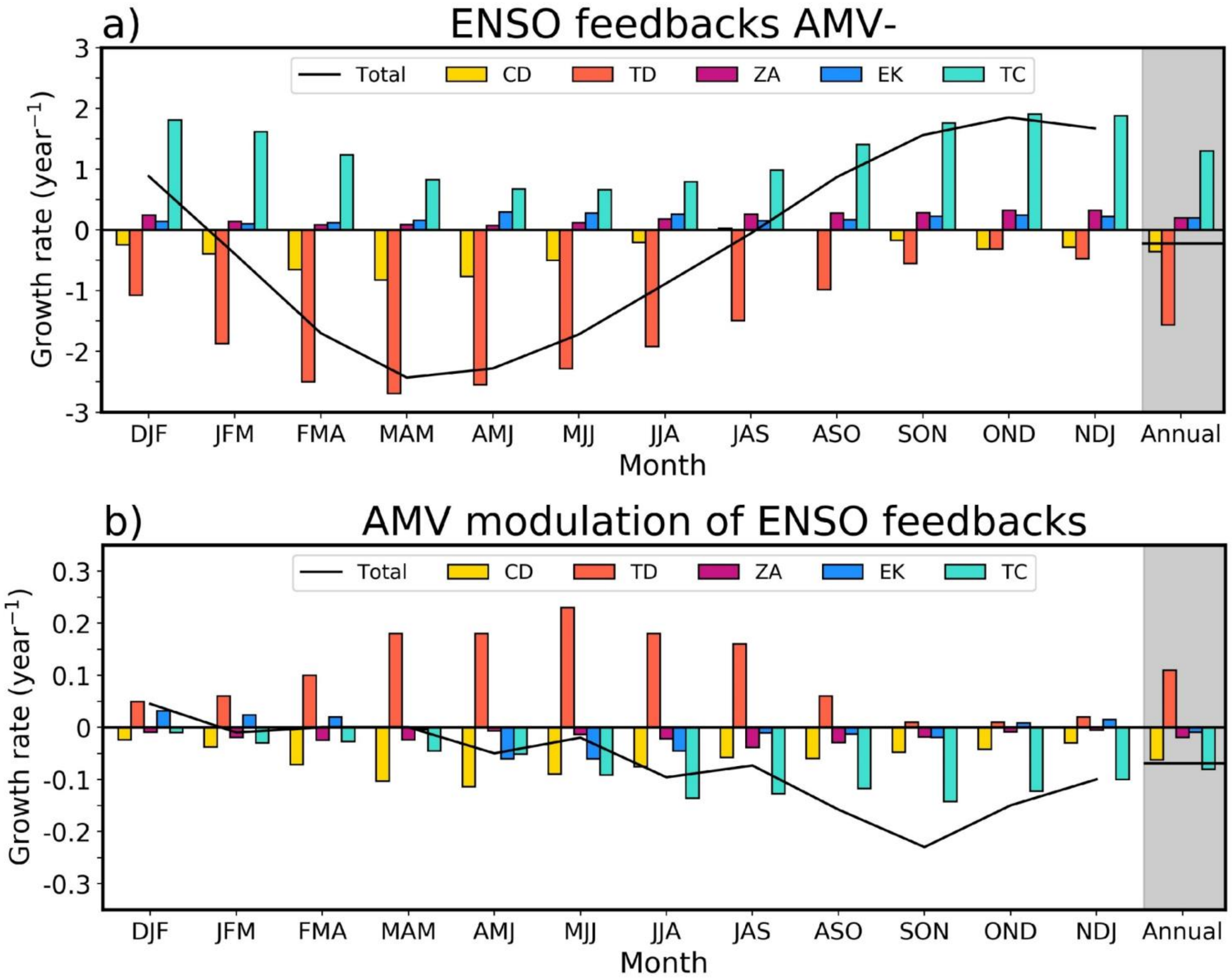
CD
Current damping

TD
Thermodynamic

ZA
Zonal advective

TC
Thermocline

EK
Ekman



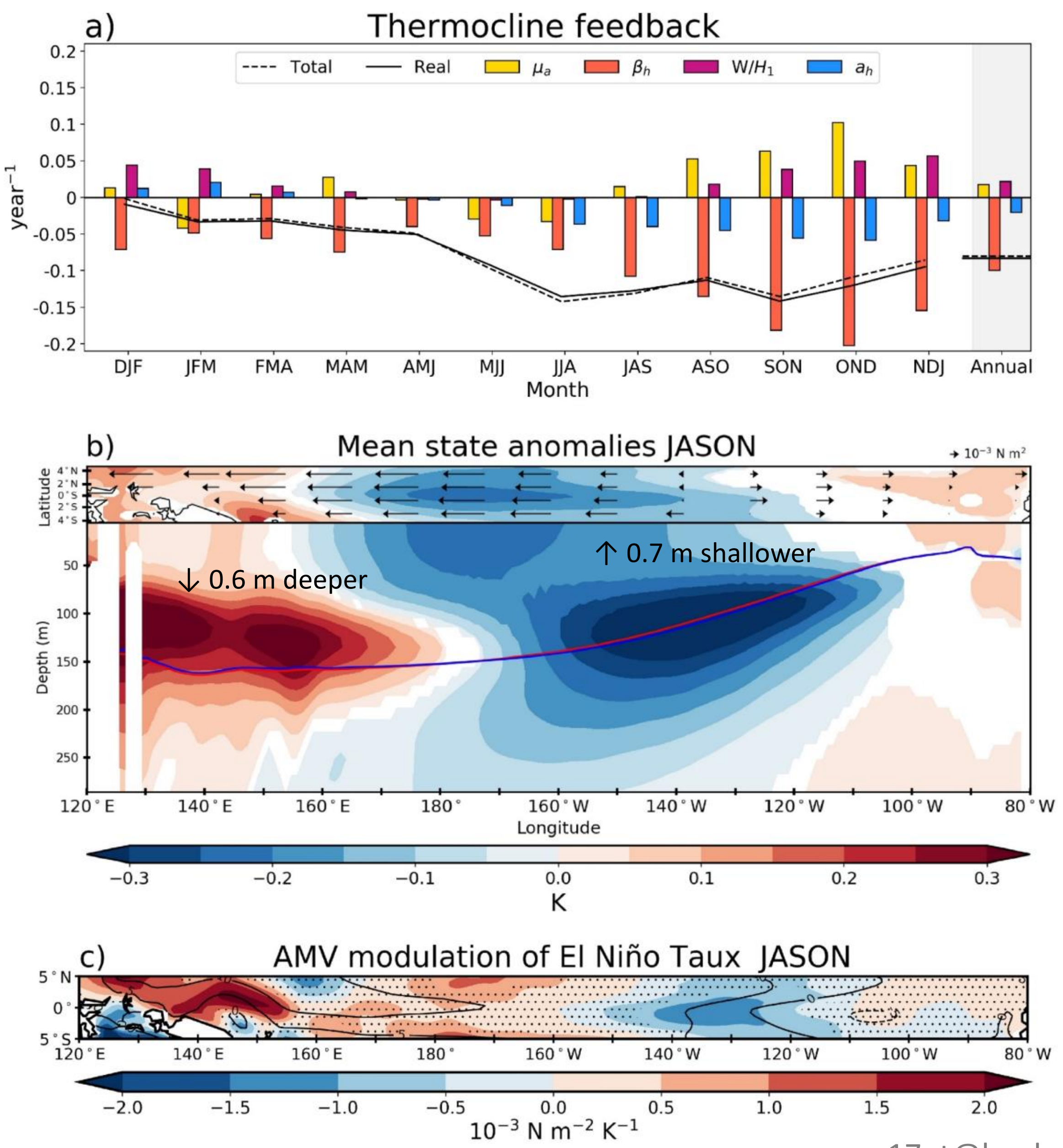

Annual ENSO growth rate **decreases by 0.07 year $^{-1}$** (-30%) in AMV+ compared to AMV-



ee17pt@leeds.ac.uk

# Weakening of the thermocline feedback

UNIVERSITY OF LEEDS




$\beta_h$ is the largest contributor to the weakening of the thermocline feedback

In AMV+, the thermocline is steeper and less sensitive to wind stress

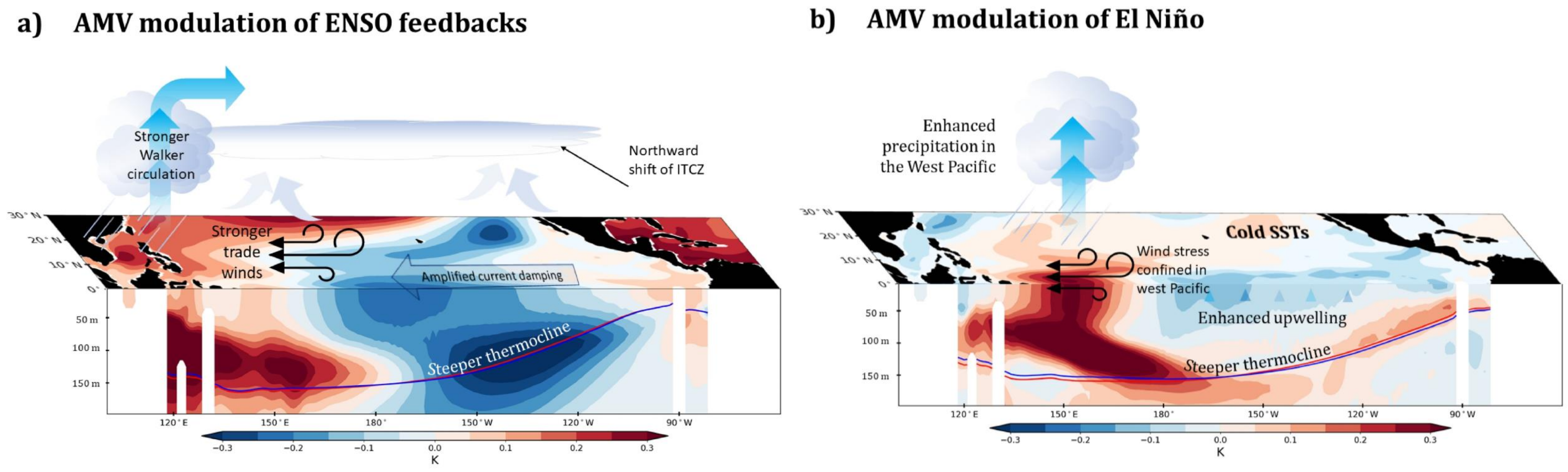
Wind stress forcing is confined to the west of the equatorial Pacific

*Lübbecke and McPhaden (2014)*

Stronger zonal SST gradient in the equatorial Pacific

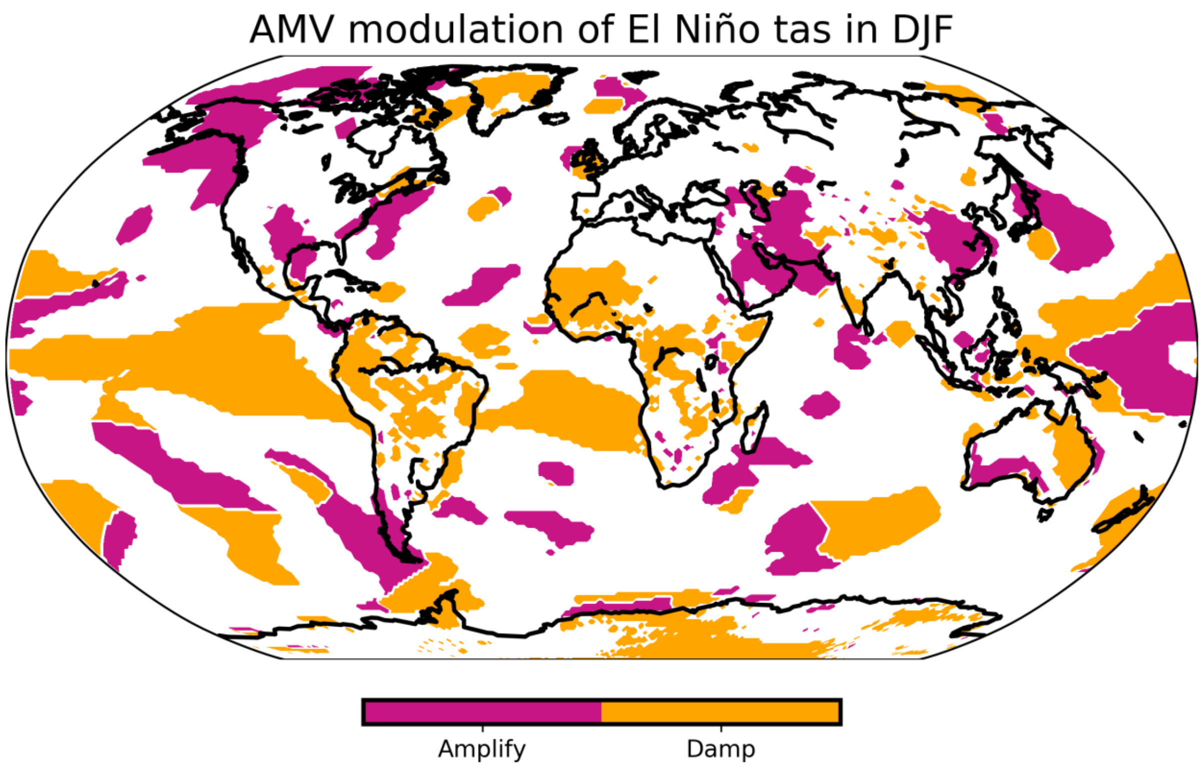
# Conclusions

- Warm phase of AMV reduced the amplitude of ENSO SSTs by 10% and precipitation by 40%
- Wind slackening associated with El Niño confined to the west → Thermocline is less sensitive to wind stress

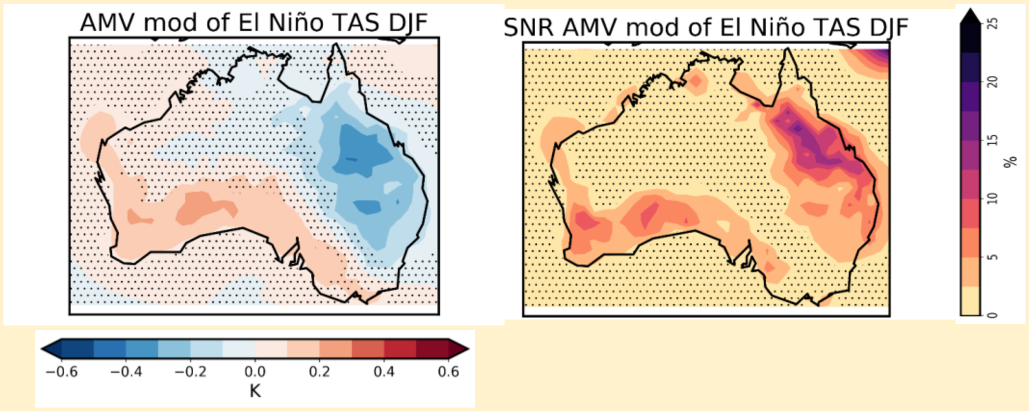



Multidecadal climate variability outside the tropical Pacific is important for future ENSO predictions!!

- AMV also modulates the regional climate response to ENSO




**Case study: Australia**




AMV+ weakens the climate response to ENSO in Australia

↓

Changes in circulation

↓

Precipitation and temperature impacts

↓

Extremes -> Frequency and intensity of **fires**

AGU ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2021GL096149

# Warm Phase of AMV Damps ENSO Through Weakened Thermocline Feedback

Paloma Trascasa-Castro[1], Yohan Ruprich-Robert[2], Frederic Castruccio[3], and Amanda C. Maycock[1]

[1]School of Earth and Environment, University of Leeds, Leeds, UK, [2]Barcelona Supercomputing Center, Barcelona, Spain, [3]National Center for Atmospheric Research, Boulder, CO, USA

**Key Points:**

- AMV weakens ENSO sea surface temperature anomalies by 10% and local ENSO precipitation anomalies by up to 45%
- The thermocline feedback in the

# Thanks for listening!

ee17pt@leeds.ac.uk
paloma.trascasa@bsc.es

PTrascasaCastro