2019-2020 Australian bushfire smoke and the early-2020s multi-year La Niña

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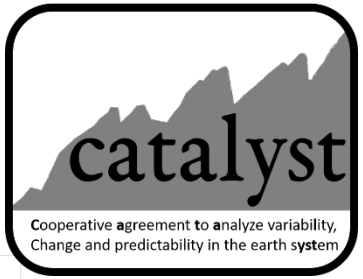

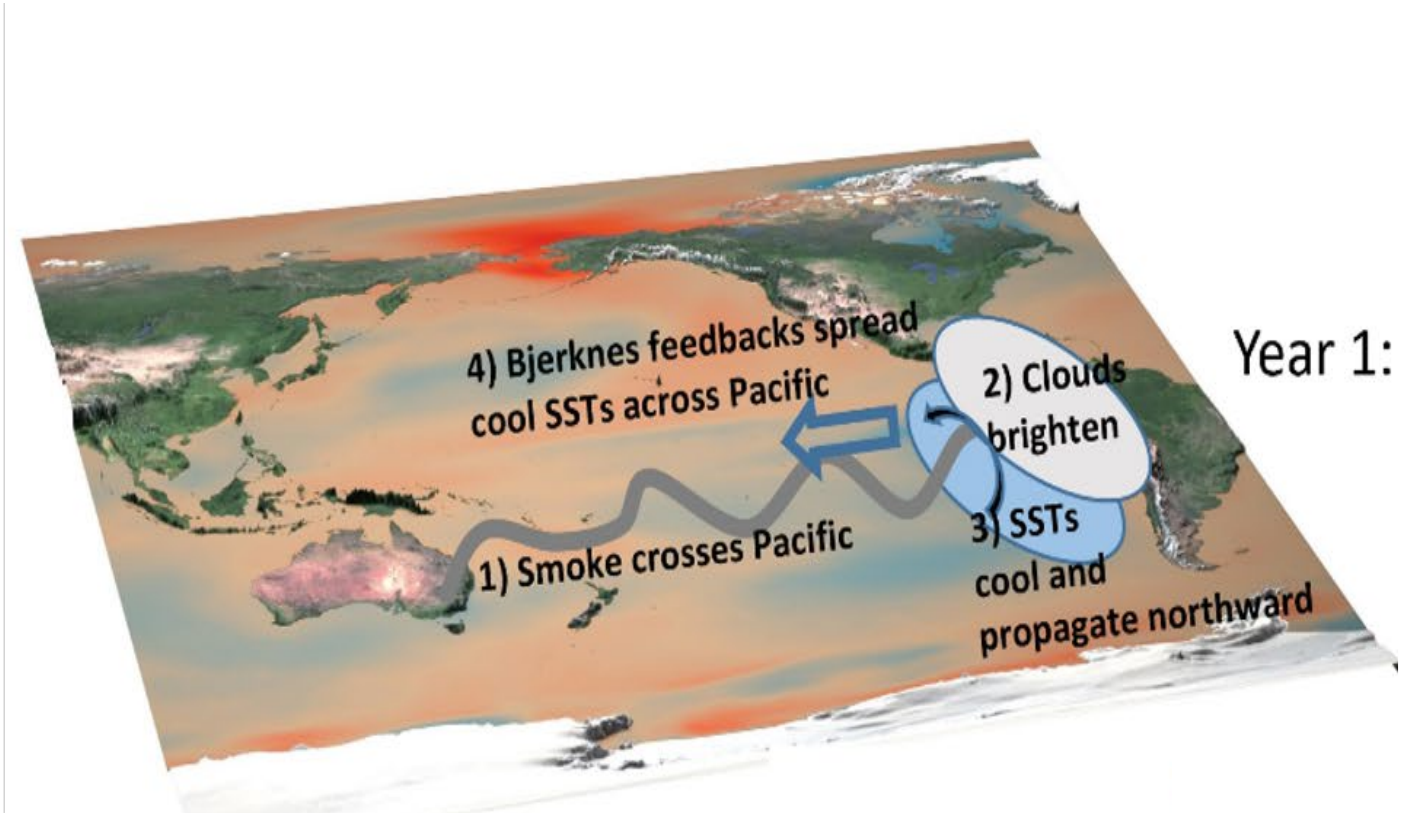

There is evidence that smoke from the massive Australian bushfires in late 2019 and early 2020 contributed to the onset of a La Niña event in 2020 (Fasullo et al., 2023)

This event lasted for three years. What processes and mechanisms sustained that multi-year La Niña event?

Perform two sets of initialized hindcasts with CESM2 and E3SM2 as a sensitivity experiment to test the effects of the Australian bushfire smoke on the multi-year La Niña of the early 2020s

Both initialized in August 2019, and run for three years to July, 2022;
Each has 30 ensemble members (results here shown for annual averages, August to July);
the models include an aerosol scheme whereby CCN and cloud albedo can be affected by smoke aerosols

--One set is run without Australian bushfire smoke emissions (standard “SMYLE”, or “no-smoke” simulation);

--One set is run with the observed Australian bushfire smoke emissions from GFED (“smoke”, otherwise the same as the standard SMYLE experiment)

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--Differences between these two initialized Earth system prediction experiments ("smoke minus no smoke") show only the effects of the wildfire smoke

--By performing differences of parallel initialized experiments, model drift is identically removed

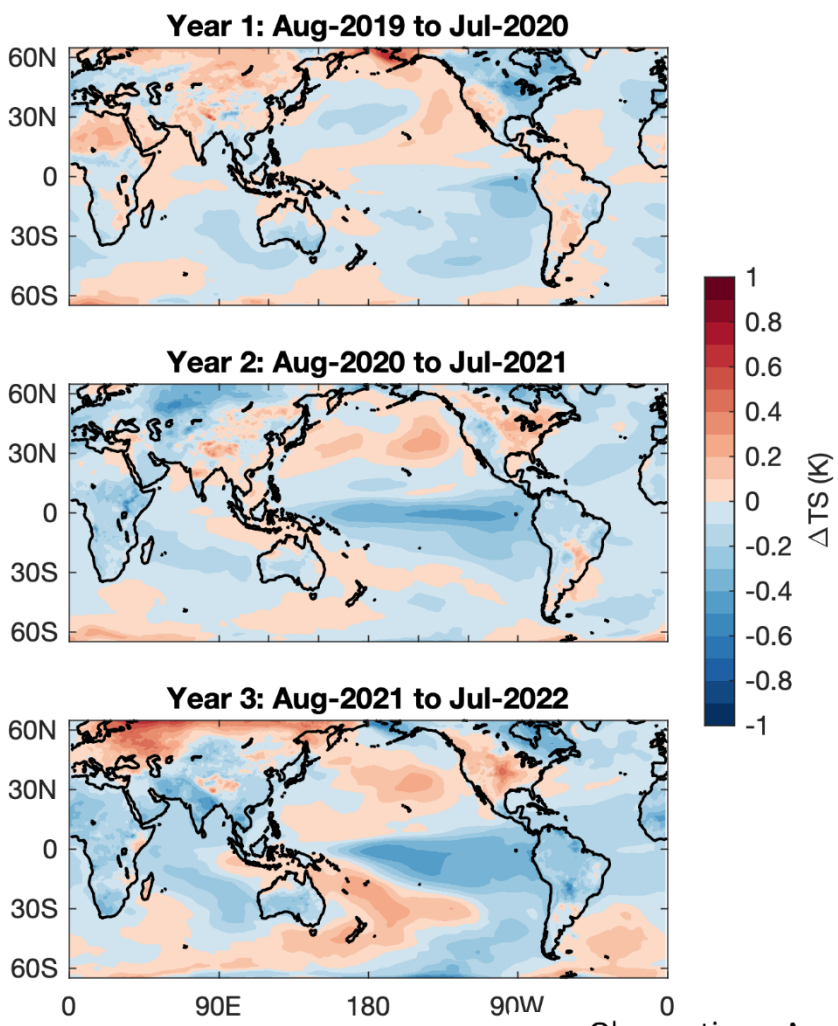
Surface temperature

The La Niña-like SST anomalies persist for three years in the smoke minus no-smoke model differences

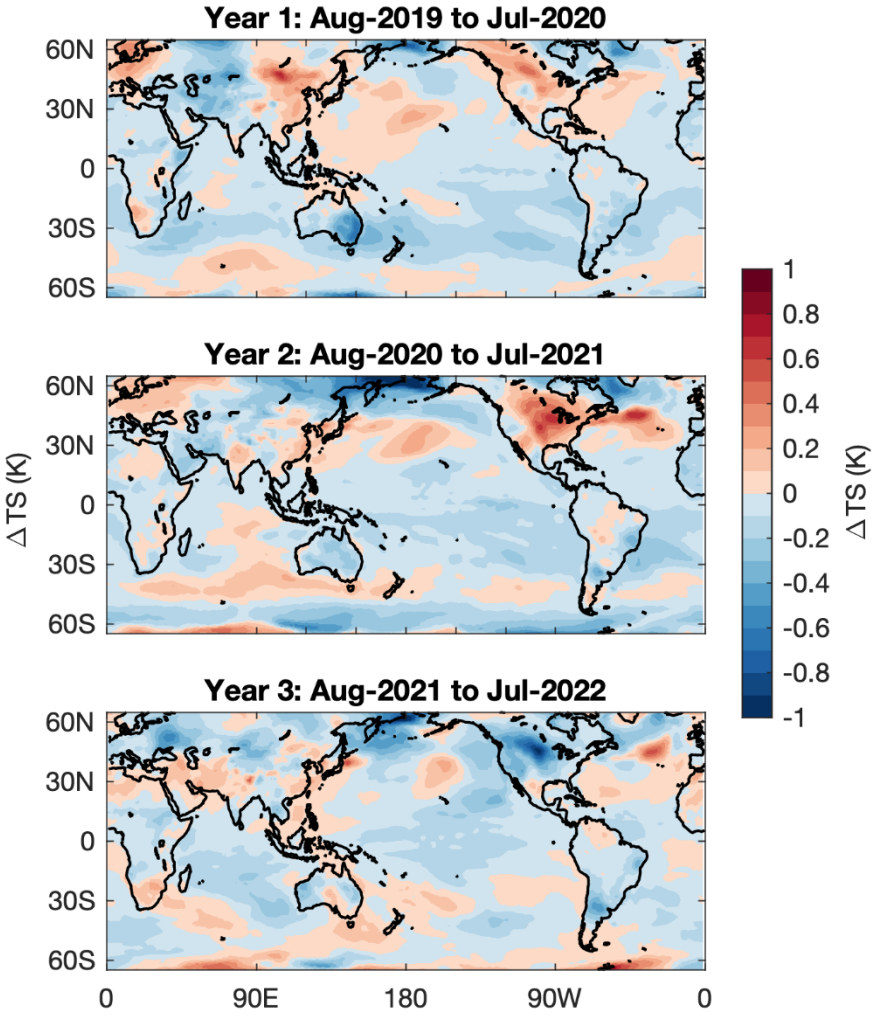
If the Australian wildfire smoke contributed to the initial La Niña-like response, and the smoke dissipated by March, 2020…

Then what made the La Niña-like anomalies persist and grow into year 3?

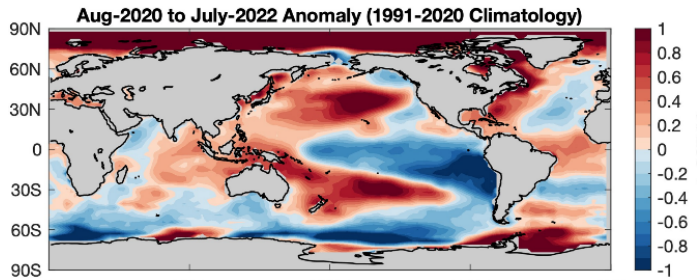
CESM2 Smoke- No smoke



E3SMv2 Smoke-No smoke



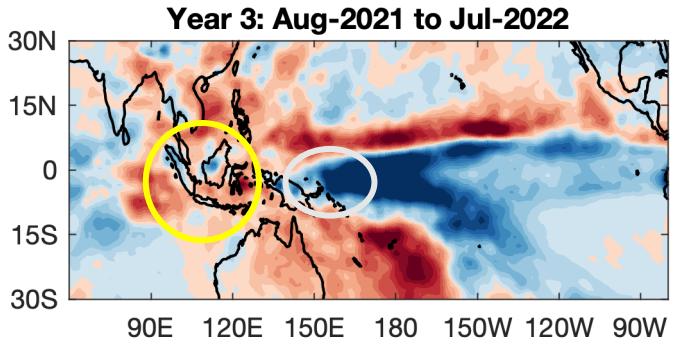
Observations, Aug. 2020-July 2022

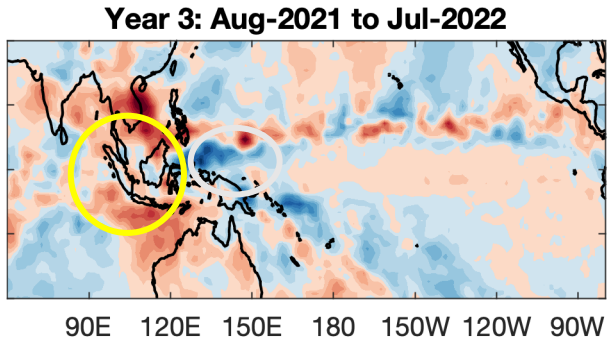


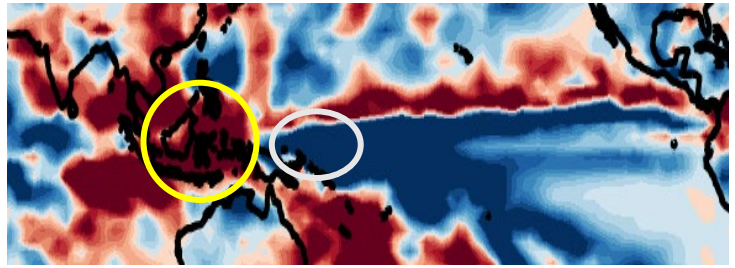
Smoke minus no-smoke: **CESM2** **E3SM2** **Observed**

Year 3

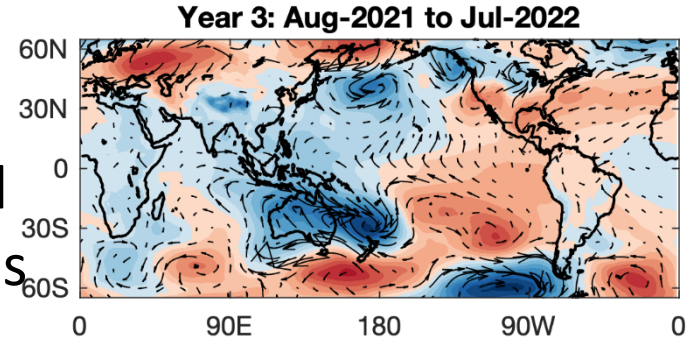
Precipitation

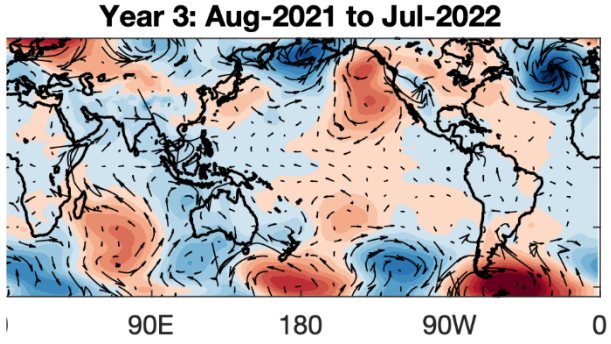




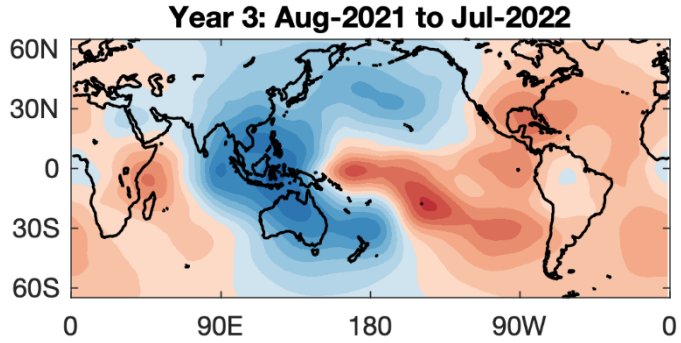


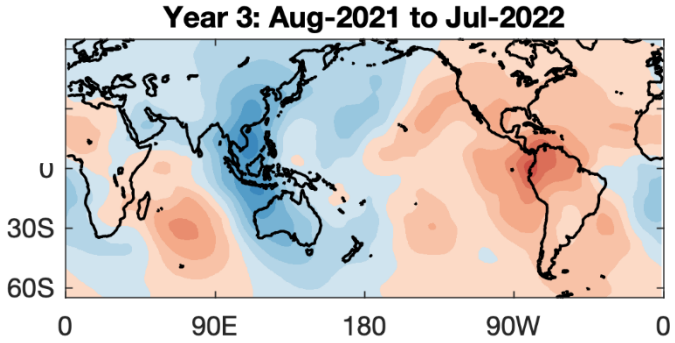
Sea level pressure and surface winds





200 hPa velocity potential





What are the processes that maintain the multi-year La Niña or make it dissipate?

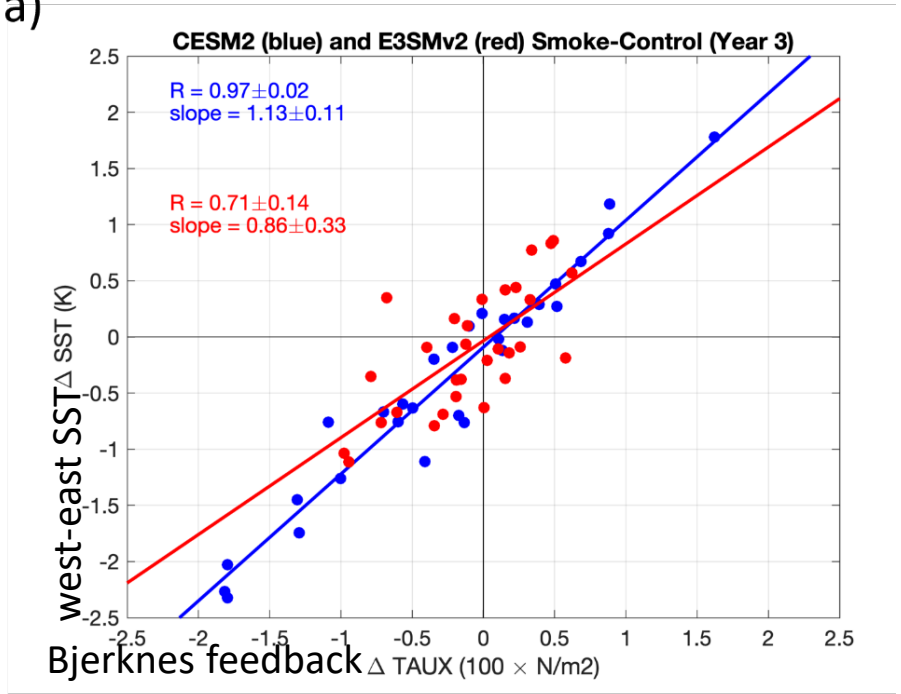
Bjerknes feedback plays a major role in sustaining the La Niña to 3 years in both models

In year 3, strongest Bjerknes feedback ensemble members produce strongest La Niña events (lower left quandrant of top panel), but some ensemble members with weaker Bjerknes feedback produce El Niño events in year 3 (upper right quadrant of top) as opposed to weaker La Niña events

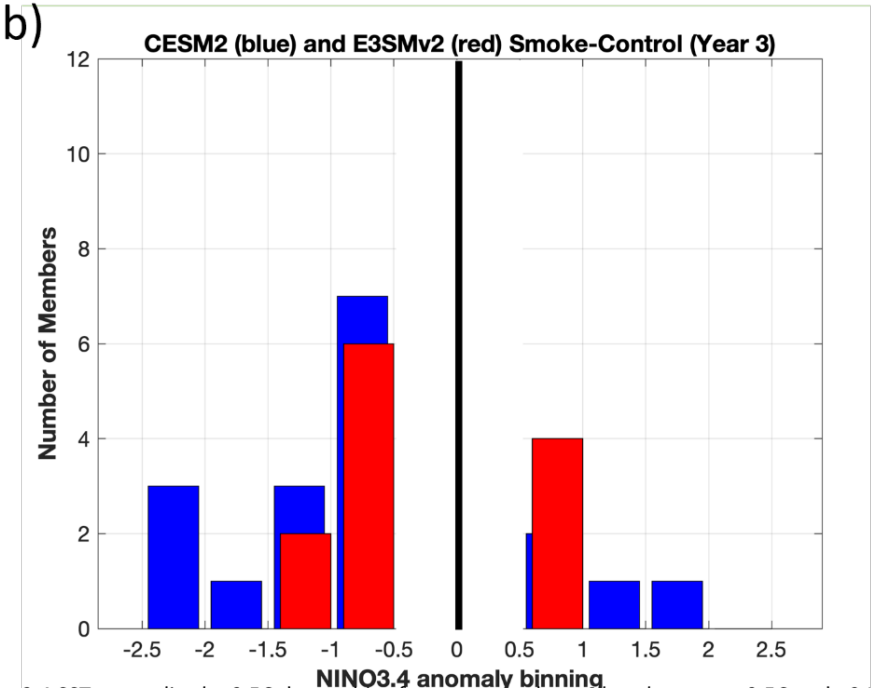
This indicates that some ensemble members transition from La Niña to El Niño in year 3

But there is a preponderance of 3 year La Niña events in both E3SMv2 (red) and CESM2 (blue) (bottom)

a)



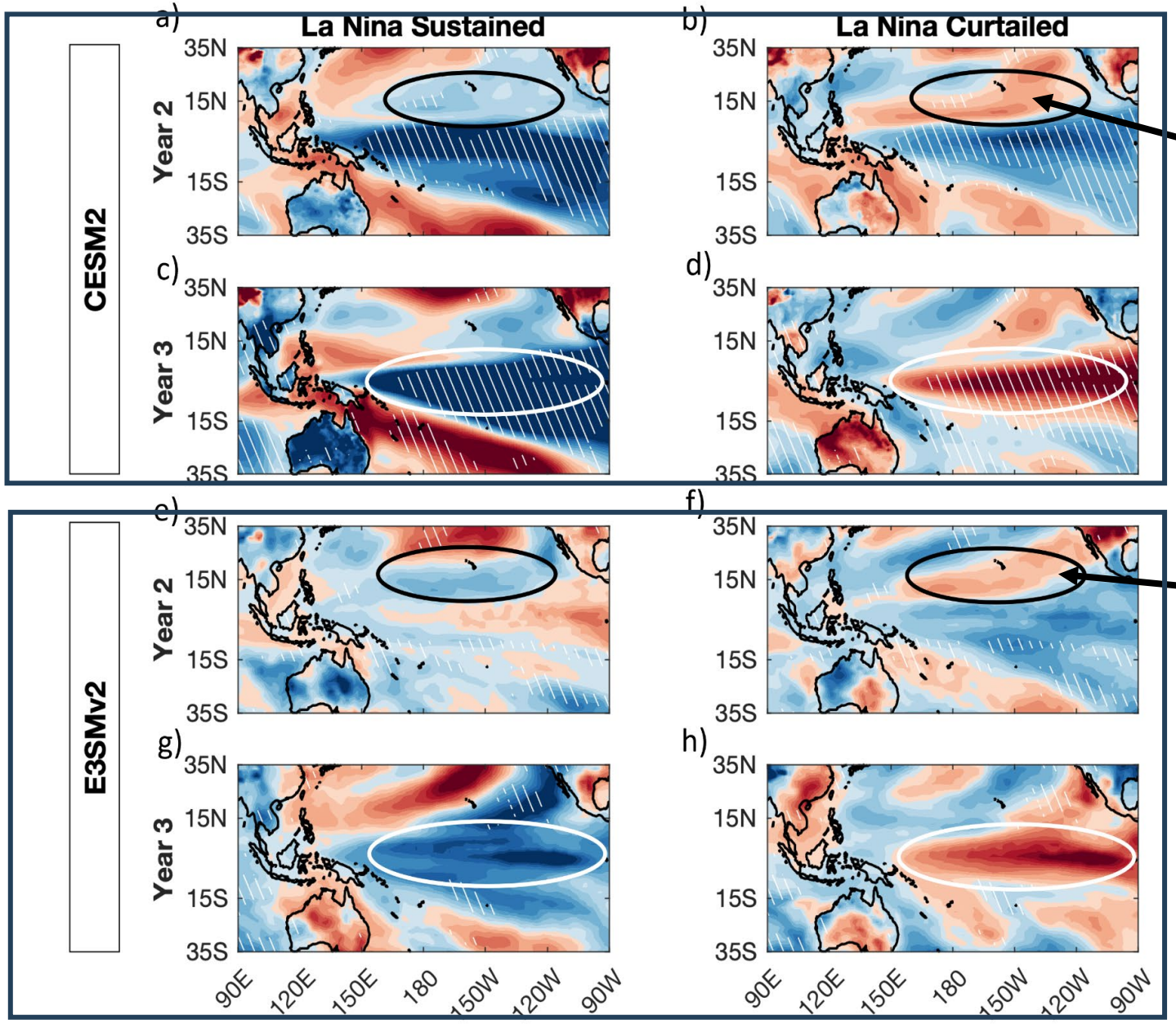
b)



Bjerknes feedback index: zonal surface wind stress anomalies averaged across the equatorial Pacific basin (160°E–130°W; 5°S–5°N)

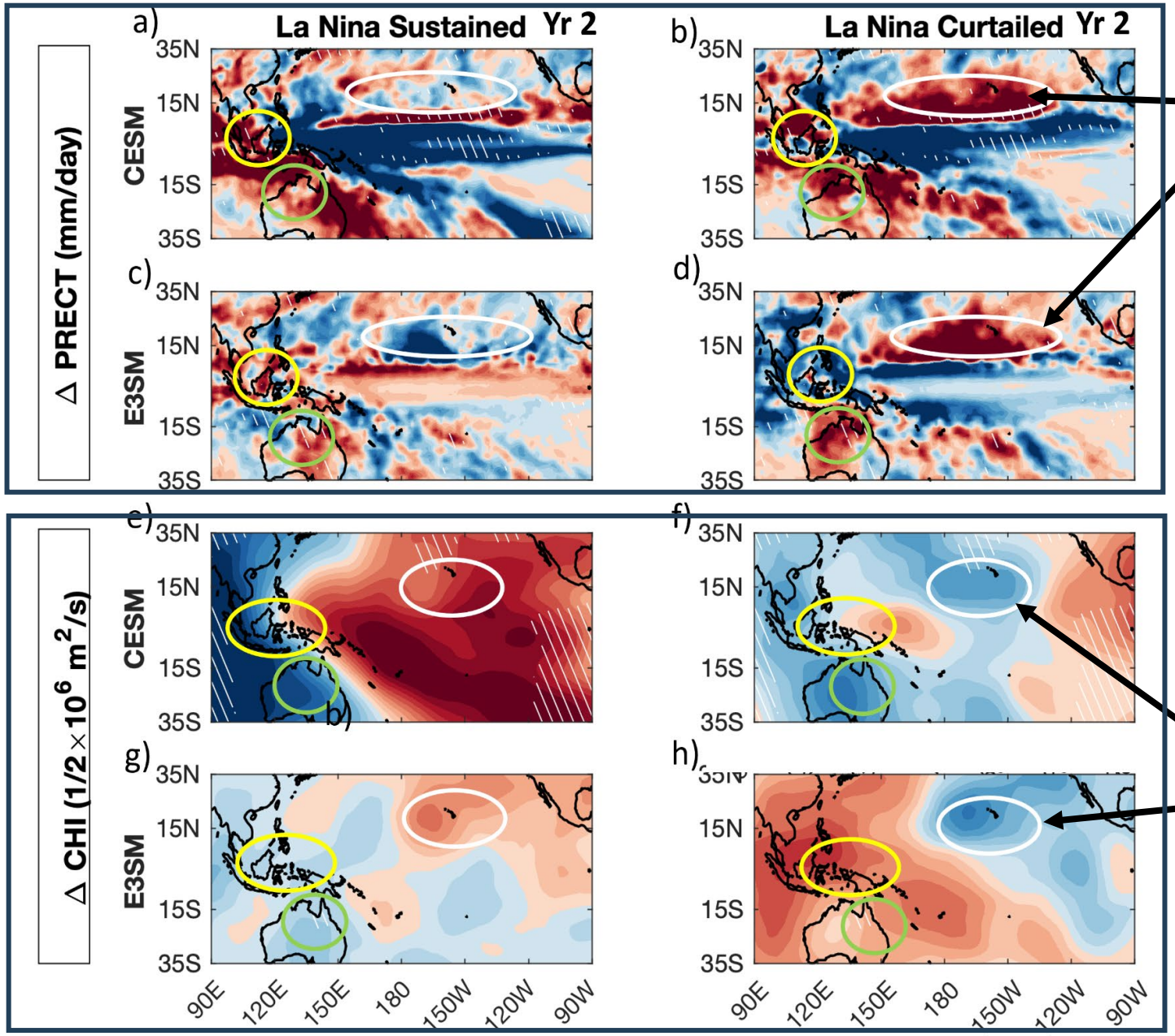
West-east SST gradient: difference of the SST anomaly for a western Pacific region (5°S–5°N and 110°E–150°E;) minus an eastern Pacific region (5°N - 5°S and 180°–110°W).

Composite 5 strongest sustained La Niña events, and the 5 strongest curtailed events that transition to El Niño



Positive North Pacific Meridional Mode (NPMM) forms in curtailed year 2

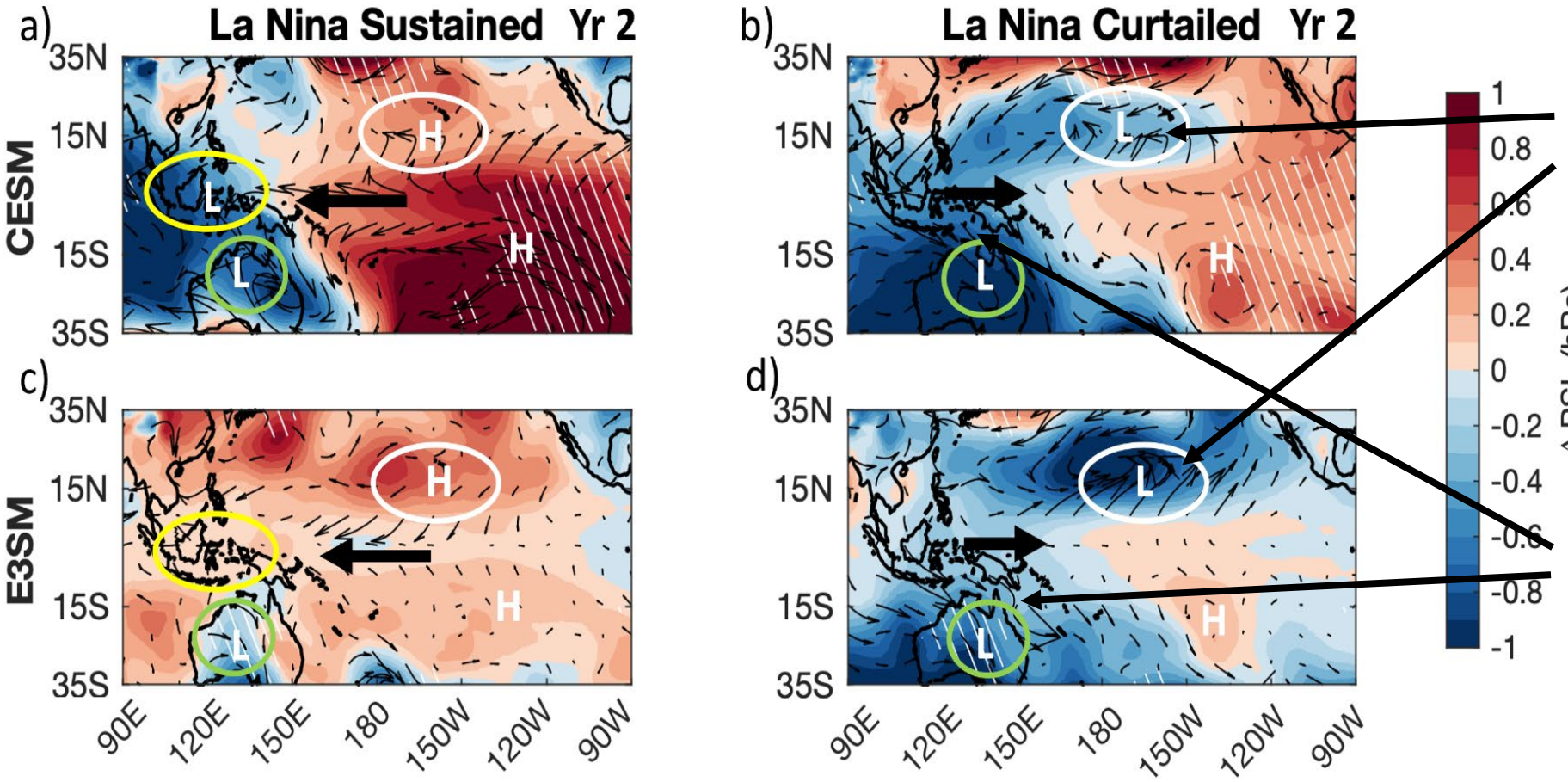
Positive NPMM forms in curtailed year 2



Positive precip anoms over positive NPMM SST anoms in curtailed year 2

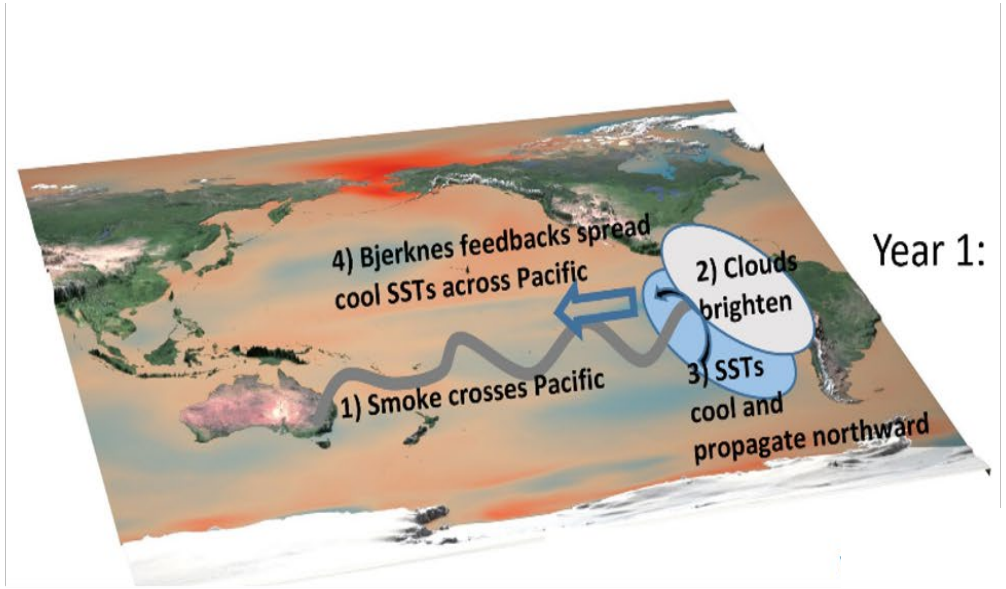
Anomalous upper level outflow over positive precip anoms in curtailed year 2 produces negative 200 hPa Chi, and upper level convergence to west

Sea level pressure and surface wind vectors



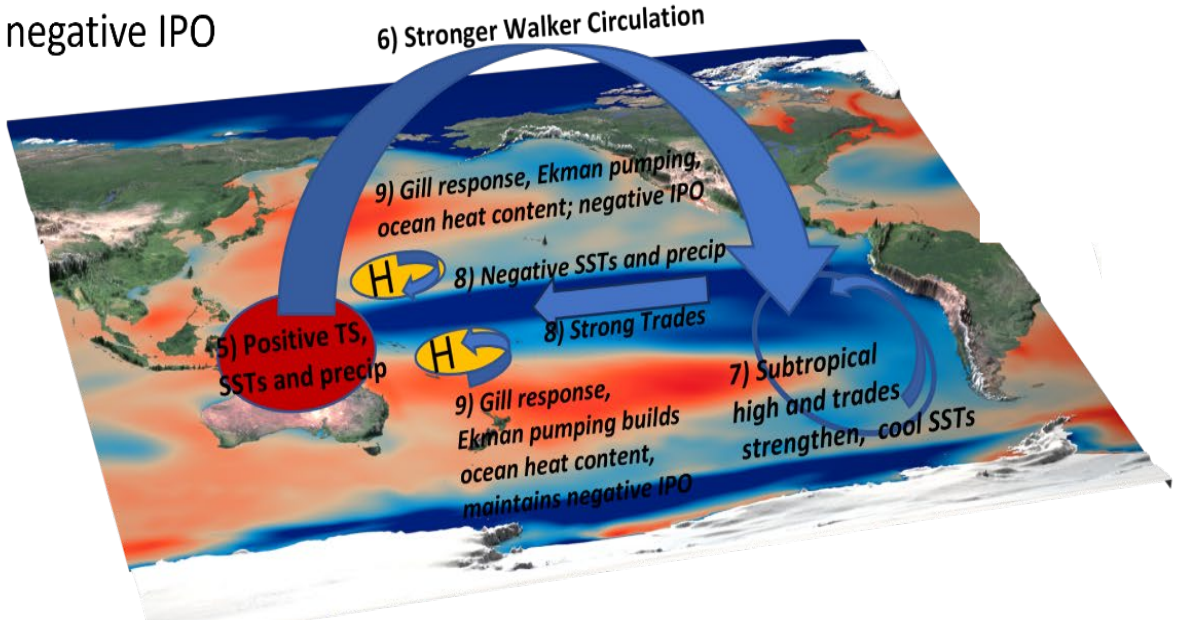
Negative SLP anoms with positive precip anoms contribute to weakened Trades in Eq. Pac

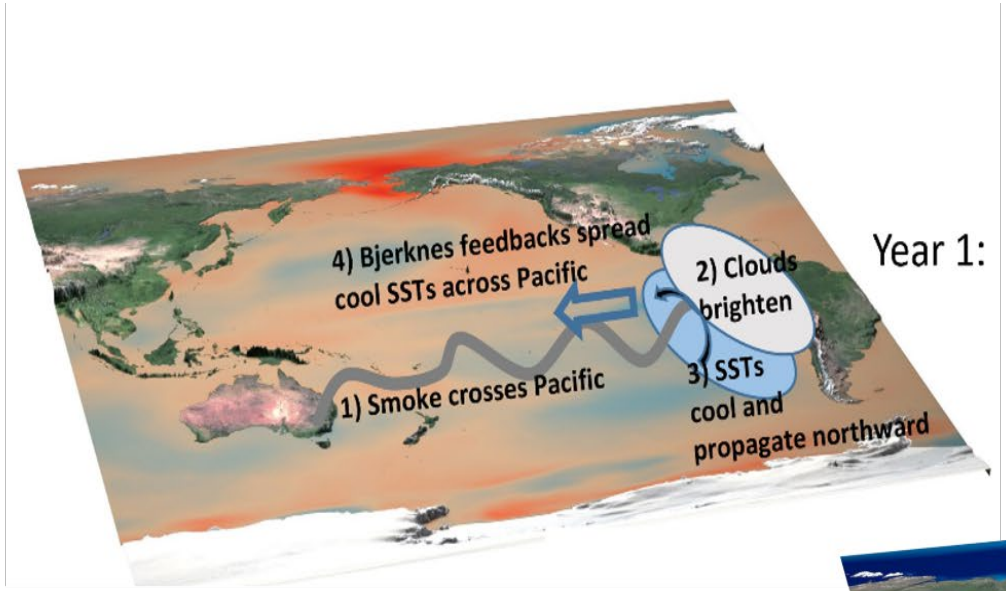
Stronger low pressure over northern Australia contributes to westerly surface wind anomalies in Eq. W. Pac., downwelling ocean Kelvin waves, deepened thermocline in E. Eq. Pac. and transition to El Nino



Year 1: Onset

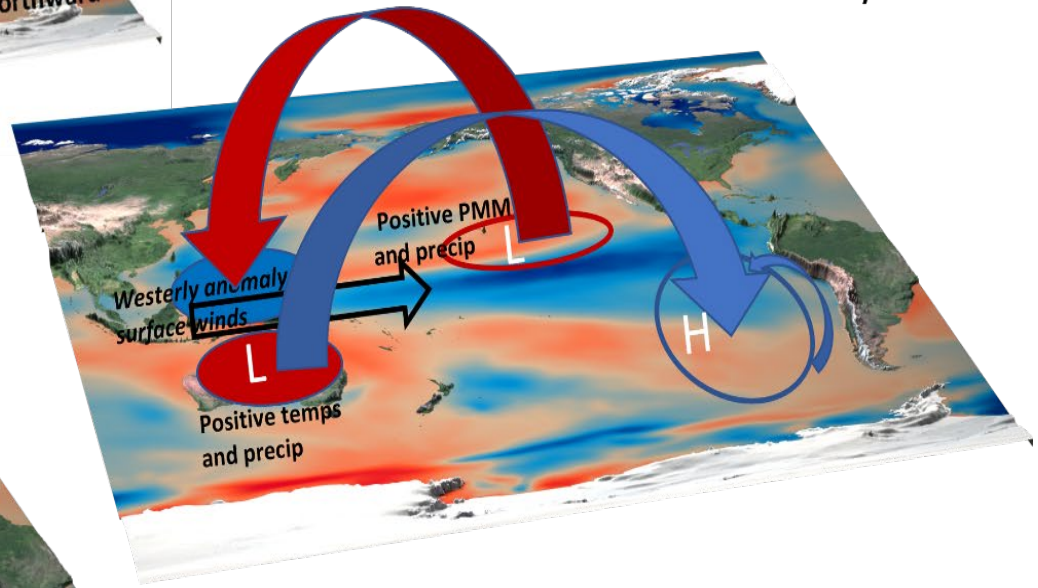
Years 2 and 3: Sustained 3-year La Niña and negative IPO



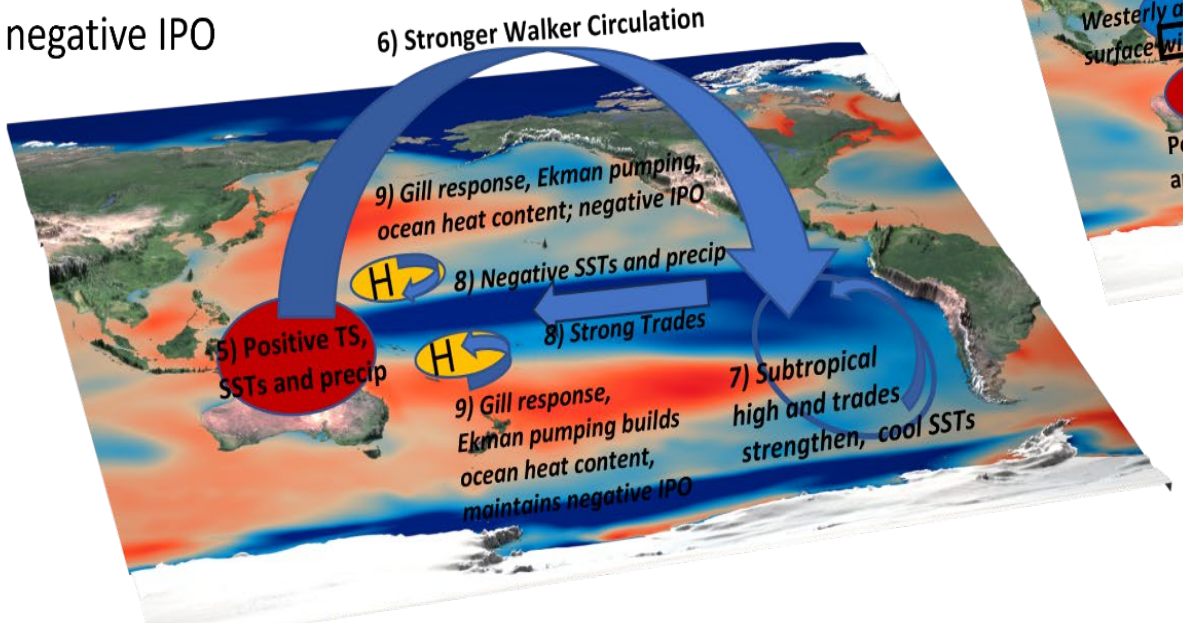


Year 1: Onset

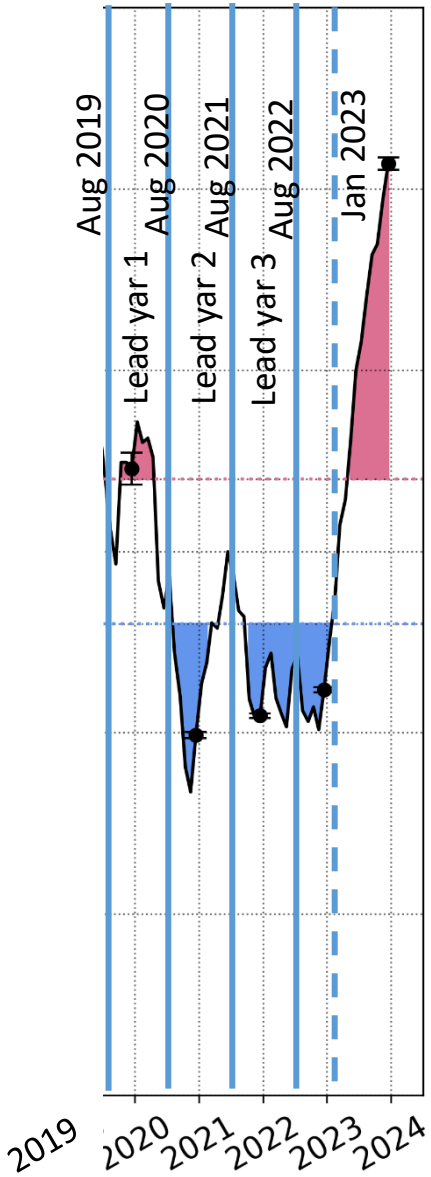
Year 2: Curtailed La Niña in year 2 and transition to El Niño in year 3

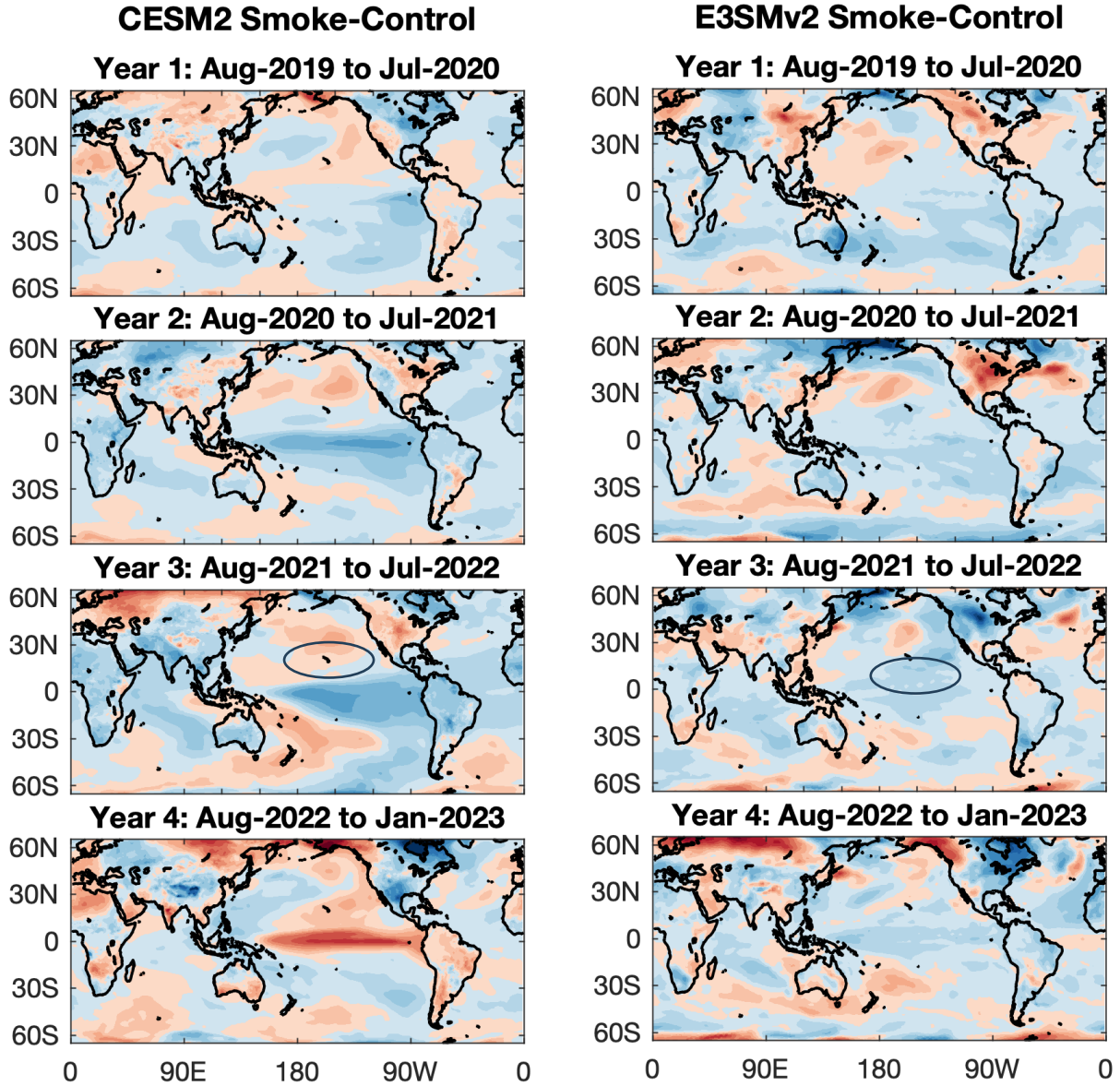


Years 2 and 3: Sustained 3-year La Niña and negative IPO



Aug 2022 - Jan 2023 for “lead year 4“
Note positive NPMM in CESM2 in yr 3 leads to transition in yr 4
But negative NPMM in E3SM in yr 3 leads to continuation in yr 4





Summary

Smoke from the 2019-2020 Australian wildfires contributed to the initiation of a multi-year La Niña event

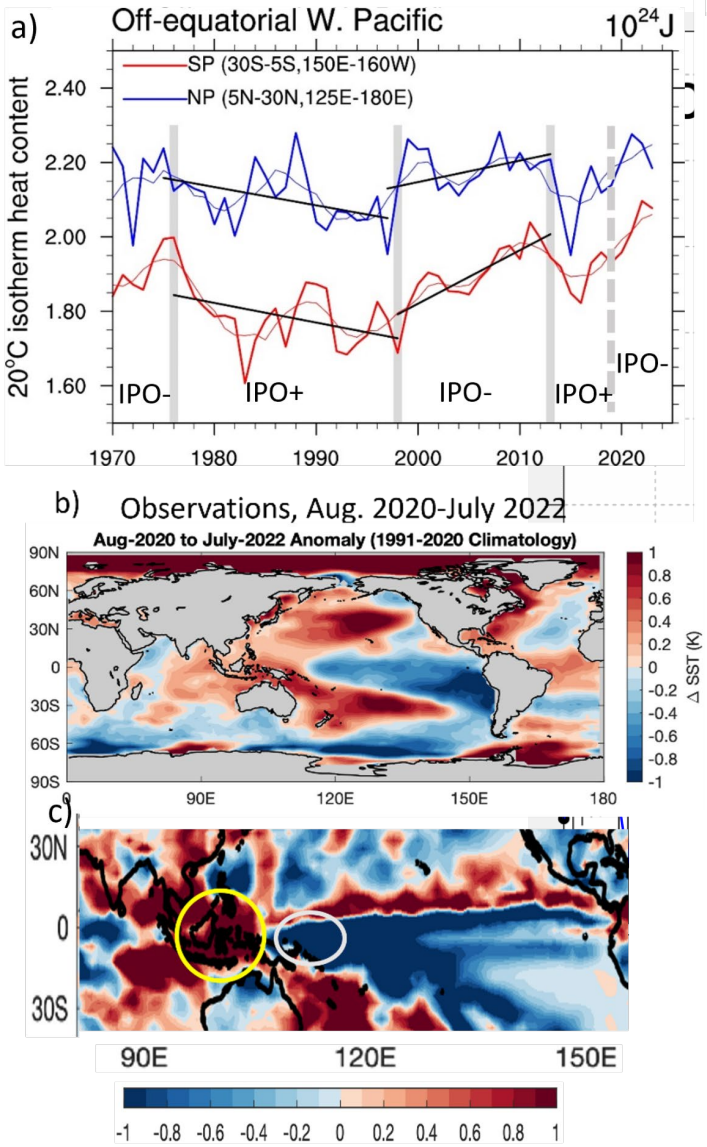
The main process that sustains the multi-year event:

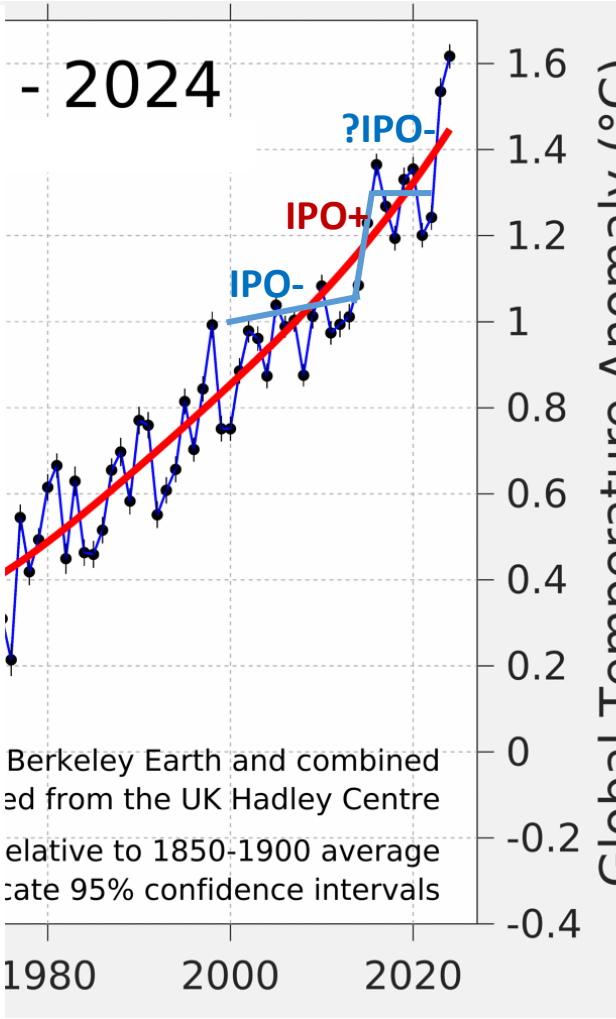
Bjerknes feedback that connects strong trade winds across the equatorial Pacific, which act to cool tropical Pacific SSTs, with warm SSTs and increased precipitation in the western Pacific and a strong subtropical high in the eastern Pacific through the Walker Circulation

Processes that can end the multi-year event:

Positive North Pacific Meridional Mode that results in an anomalous low in the north-central Pacific with westerly anomaly Trades, as well as an altered Walker Circulation with weakened low pressure north of Australia, an anomalous meridional surface pressure gradient and westerly anomaly surface winds in the western equatorial Pacific to trigger downwelling Kelvin waves and a transition to positive equatorial Pacific SST anomalies

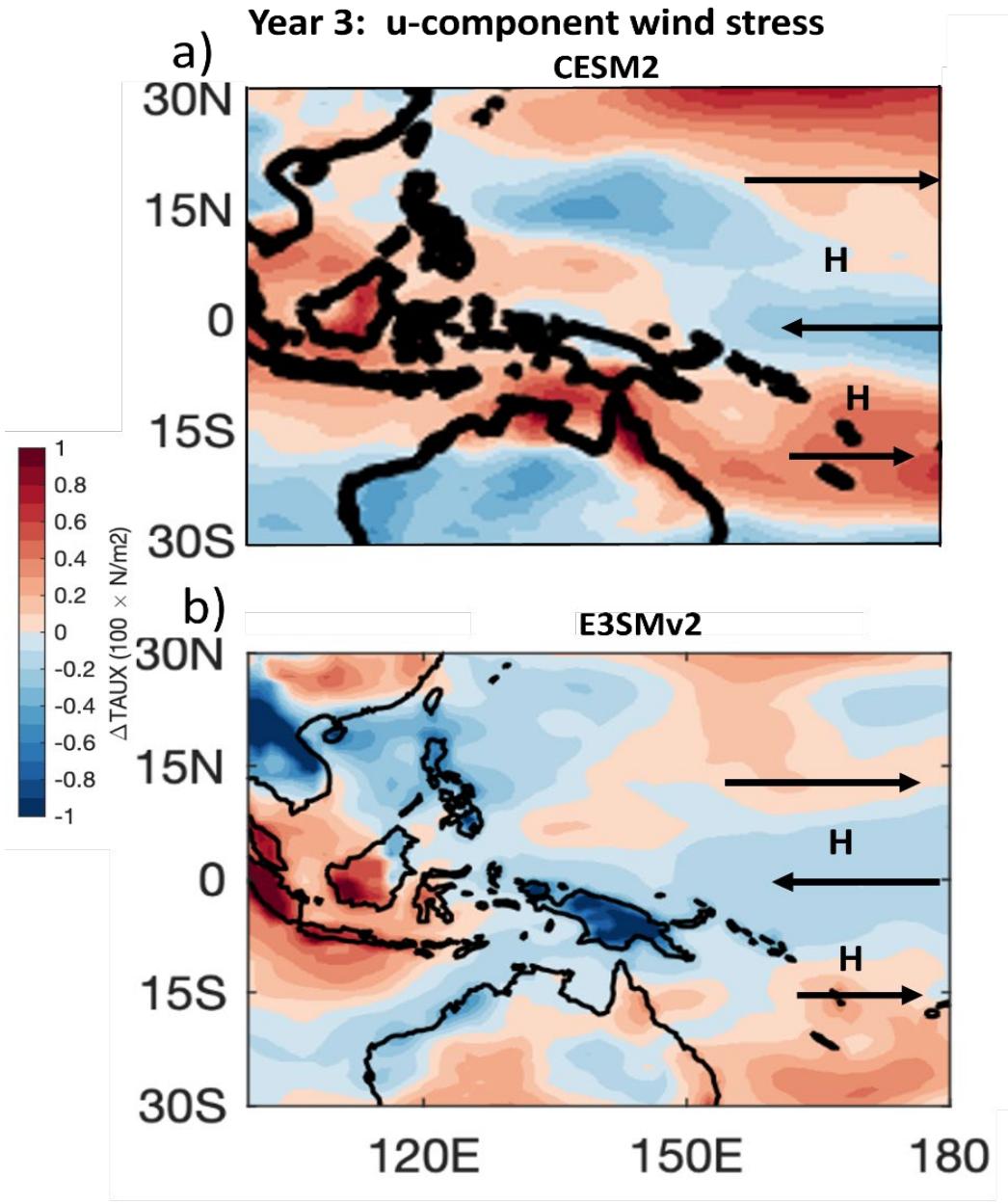
Something happened around 2019-2020 and turned around the declines of off-equatorial Western Pacific ocean heat content, and rate of global warming decreased, all signs of a negative IPO





https://berkeleyearth.org/global-temperature-report-for-2023/

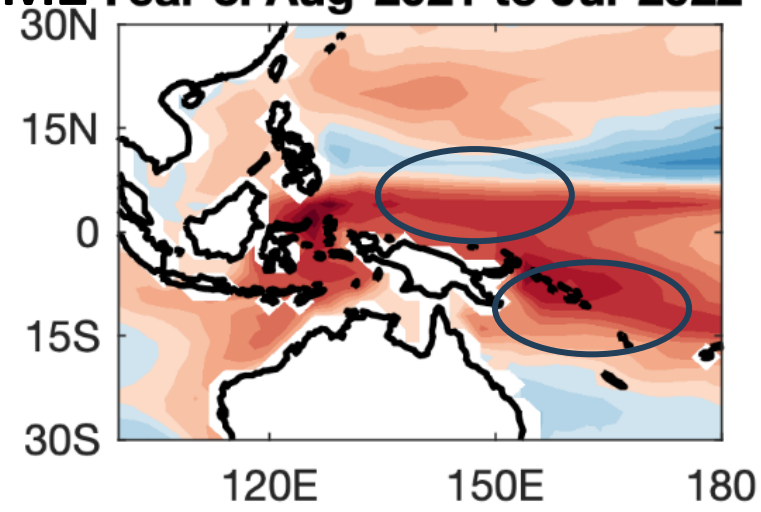
Negative convective heating anomaly near 165E produces u-component wind stress anomalies in off-equatorial western Pacific to sustain ocean heat content anomalies



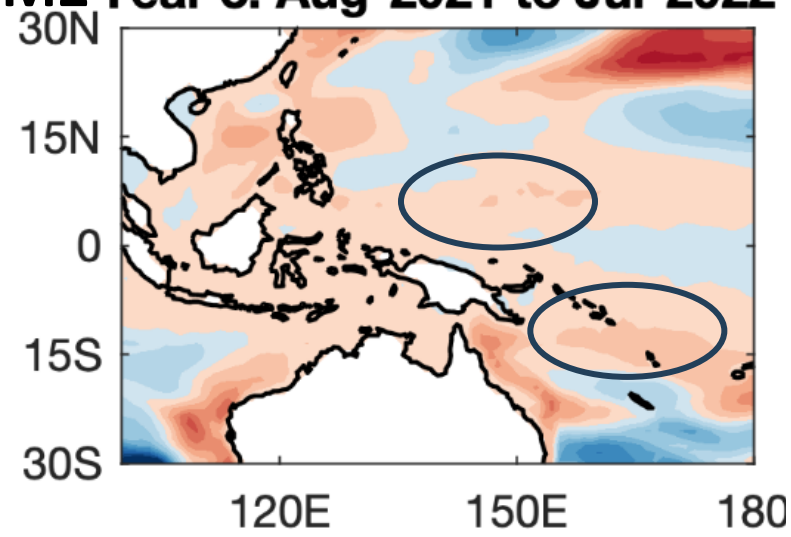
Ocean heat content

Smoke minus no-smoke

CESM2 Year 3: Aug-2021 to Jul-2022

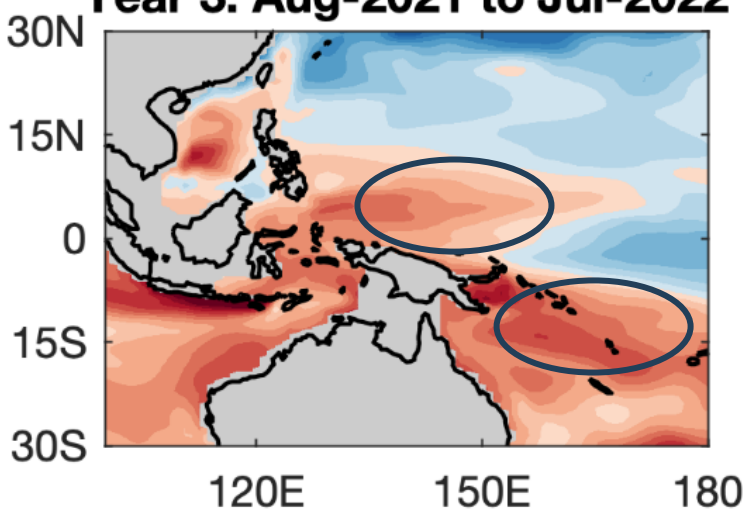


E3SM2 Year 3: Aug-2021 to Jul-2022



Observed (GODAS)

Year 3: Aug-2021 to Jul-2022



Off-equatorial westerly wind stress anomalies:

Ekman pumping builds up ocean heat content in the off-equatorial western Pacific:

the signature of negative IPO