Attribution of freshening in the central-equatorial Pacific Ocean during El Niño

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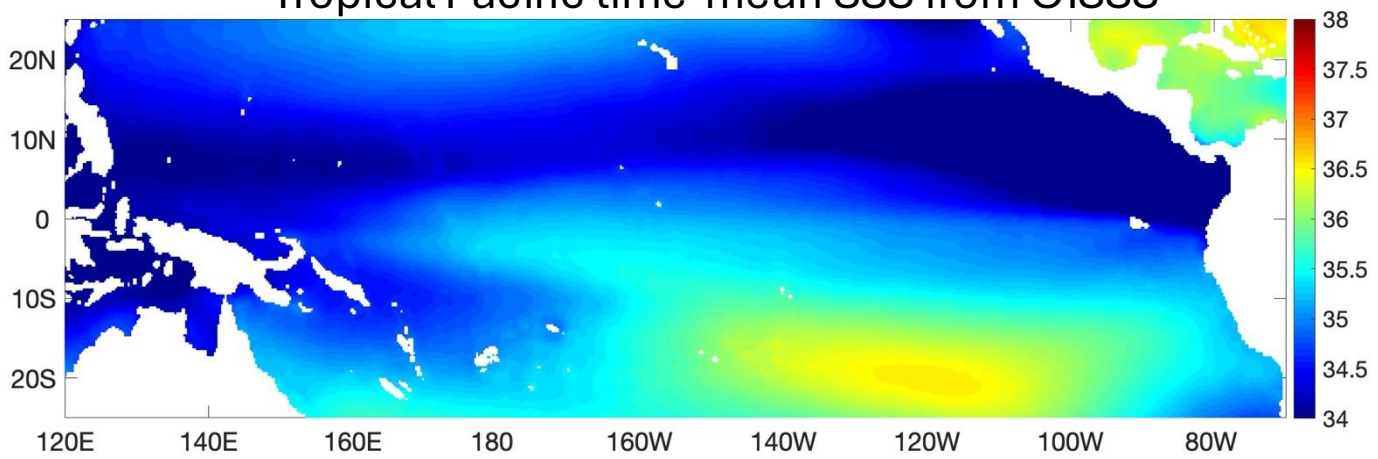
Tropical Pacific time-mean SSS from OISSS



Motivation

The phenomenon:

Large freshening (~1 psu) in the central equatorial Pacific during El Niño.

Importance:

Affects El Niño development by amplifying ocean-surface warming, which triggers atmos. convection & provides feedback to the trade winds, ….

Known processes:

- Westerly wind bursts -> eastward current anomalies -> eastward extension of the fresh-pool edge.
- Warm-pool edge moved eastward -> shifting atmos. convection & rain.

Knowledge gap:

Relative importance of wind stress vs. E-P poorly quantified, esp. for the **dependence on the phase & type of El Niño, or geographical dependence.**

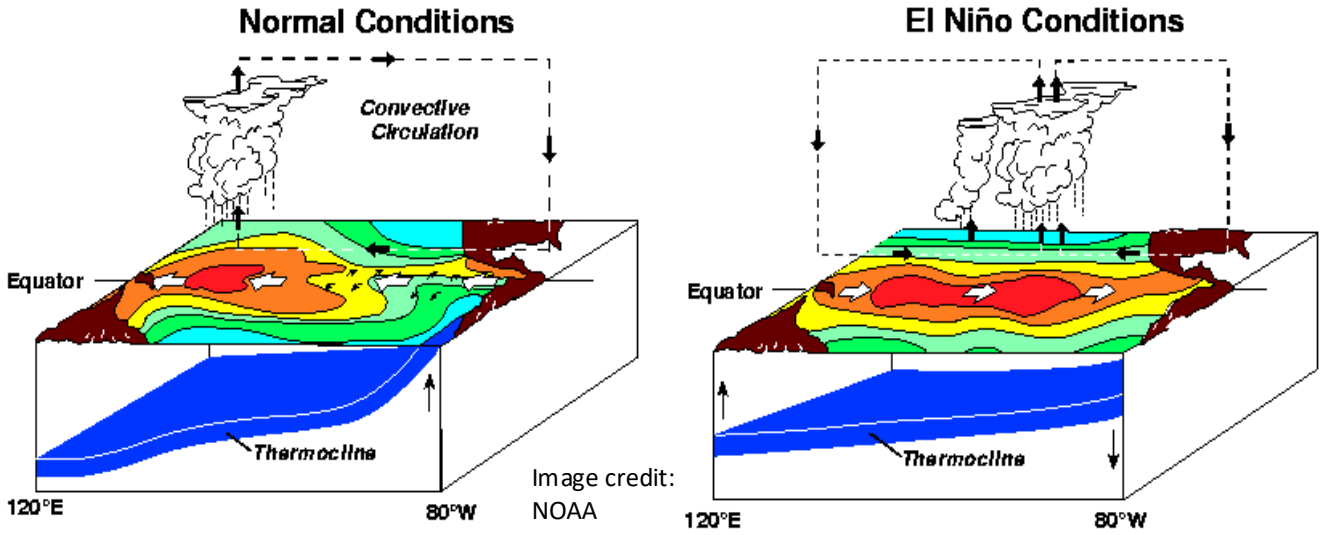
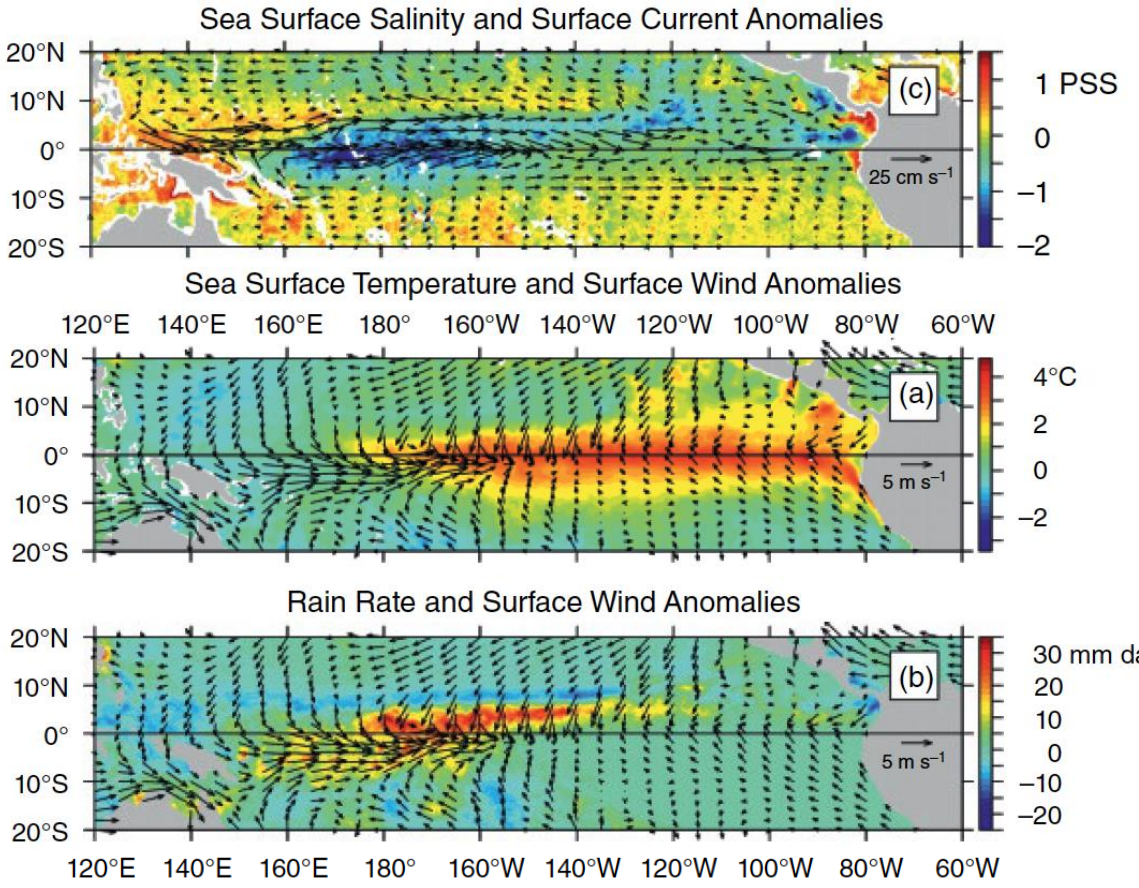


Image credit: NOAA

Peak of the 2015-16 El Niño

McPhaden, Lee, Fournier, & Balmaseda (2020)



Method

Perform **ECCO**-based global **forward forcing sensitivity runs** to isolate the effects of wind stress & E-P.

Estimating the Circulation & Climate of the Ocean (ECCO) ocean state estimate:
least-square fit of the 4-D state of the global coupled ocean-ice model (MITgcm) & surface forcing estimates to satellite & in-situ ocean observations.

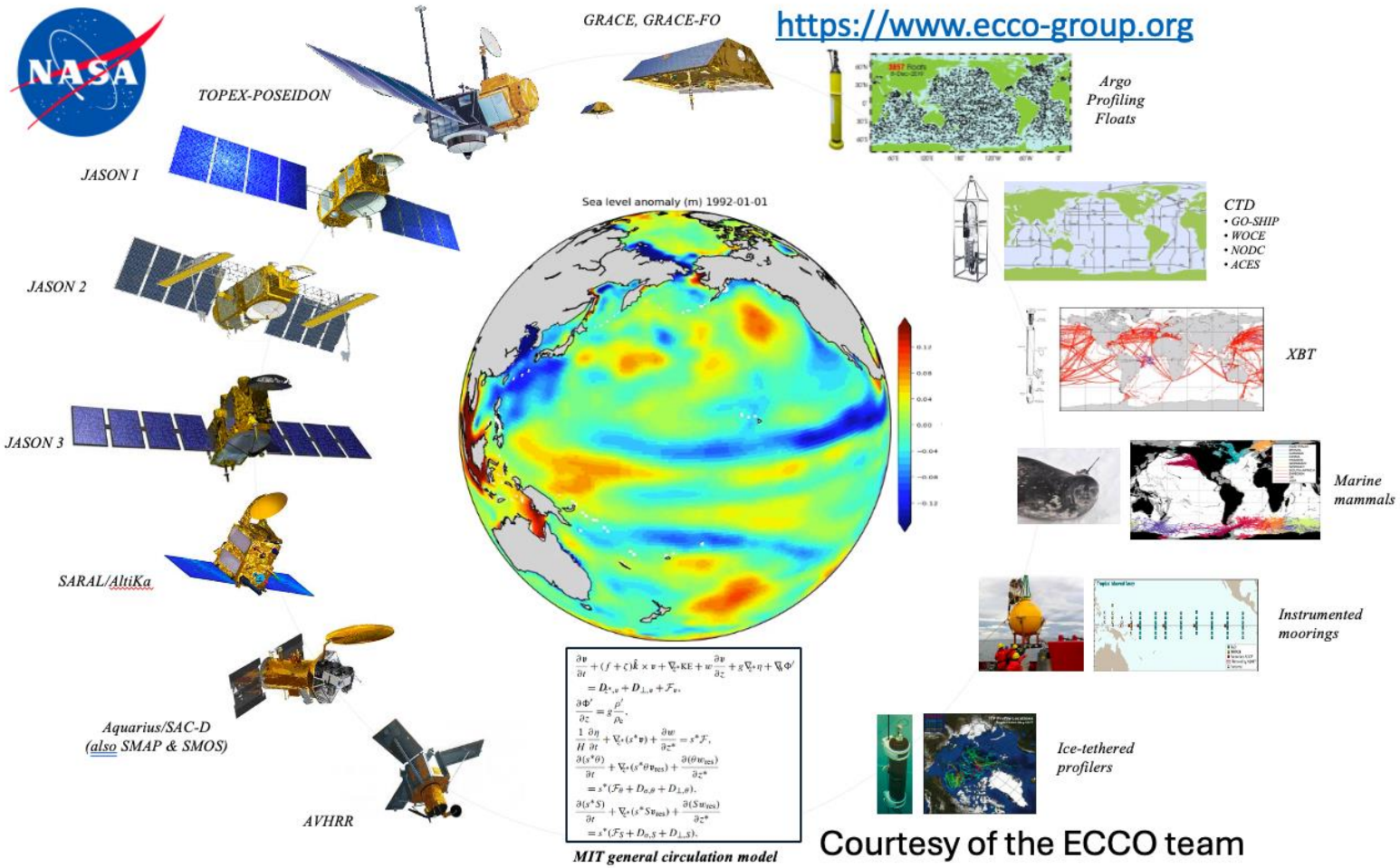
Control Run (0):
ECCO solution using all interannual surface fluxes (wind stress, E-P, heat flux).

Sensitivity run 1:
Replace E-P with its seasonal climatology.

Sensitivity run 2:
Replace wind stress with its seasonal climatology.

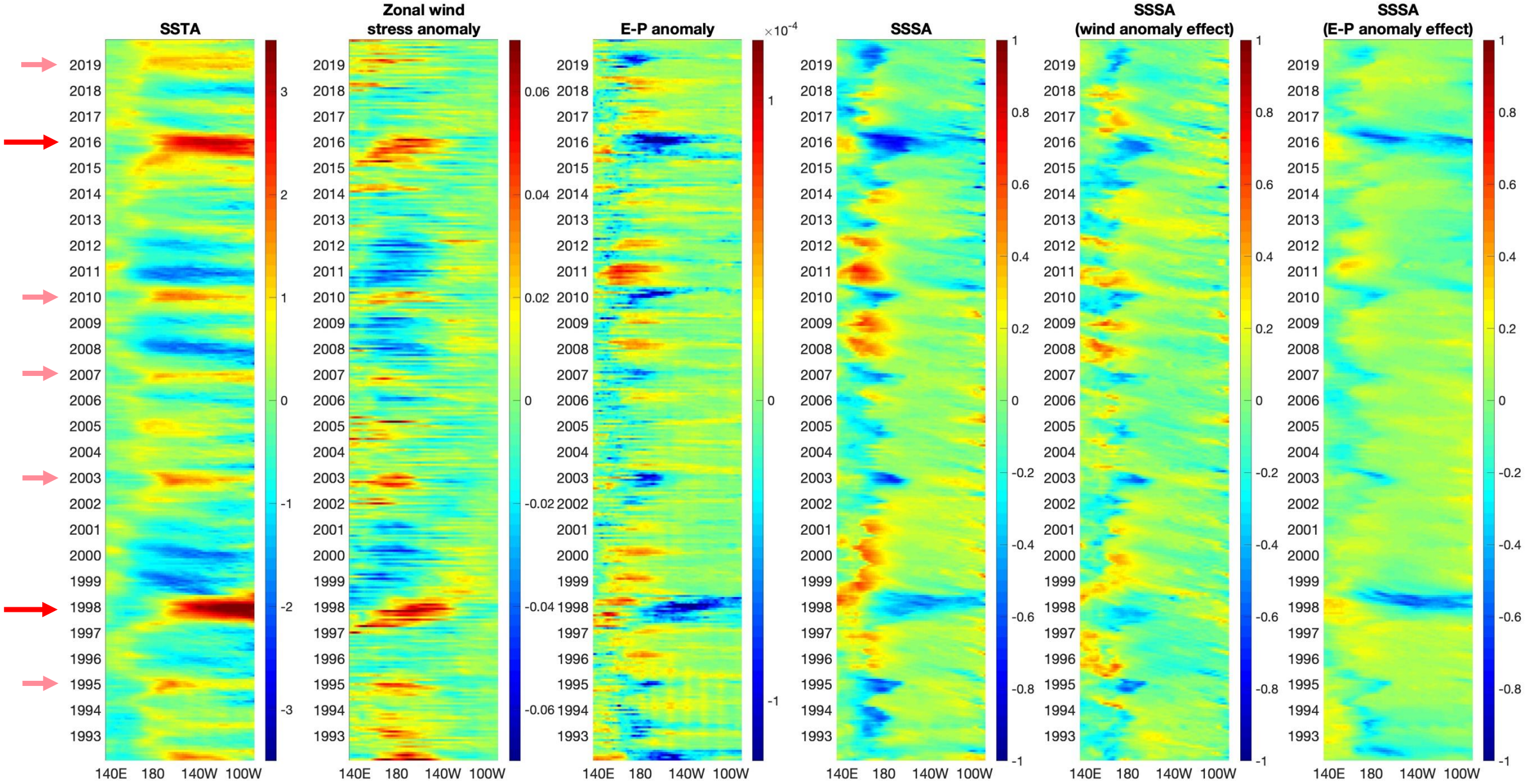
Control minus Run 1 isolates effects of nonseasonal E-P anomalies.

Control minus Run 2 isolate effects of nonseasonal wind stress anomalies.



Temporal evolution of equatorial (5S-5N) Pacific SST, zonal wind, E-P, and SSS anomalies

- SSSA during large El Niño has broader zonal extent than that during small El Nino.
- Wind effect more important near the dateline, while E-P effect is essential in the east.

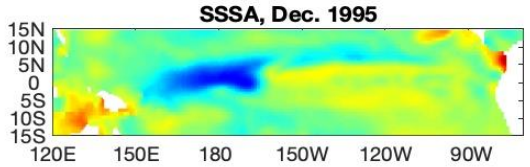


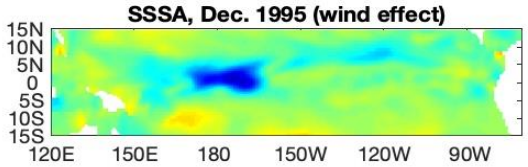
SSSA maps during the peak of El Niño events

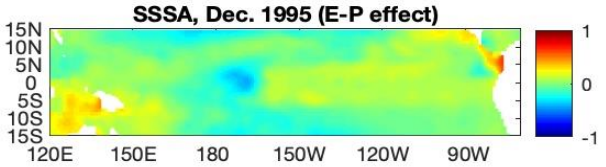
Wind anomaly effect

E-P anomaly effect

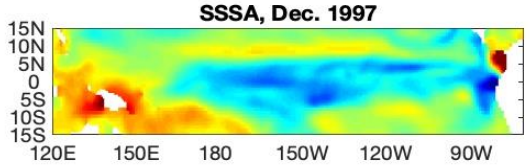
1994-95
small El Niño

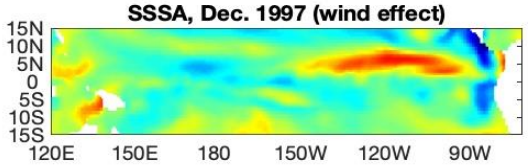


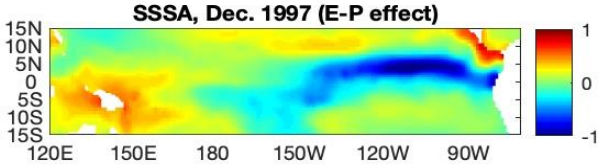




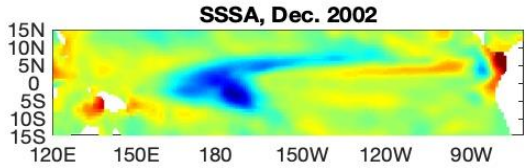
1997/98
large El Niño

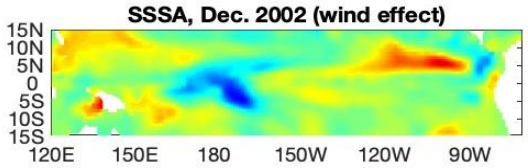


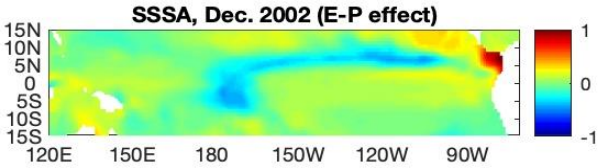




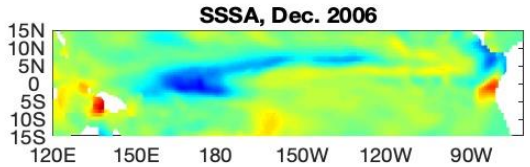
2002/03
small El Niño

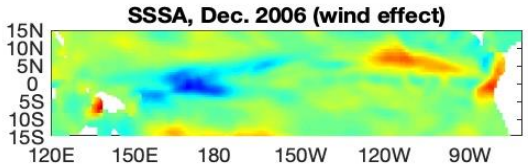


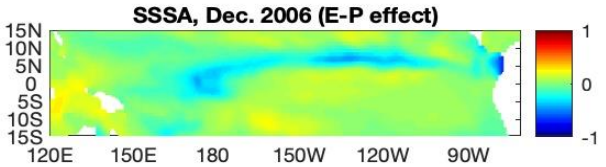




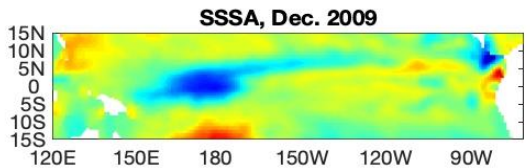
2006/07
small El Niño

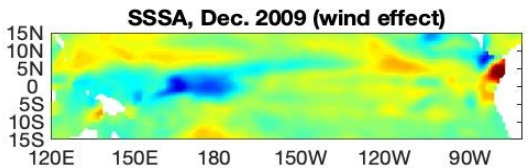


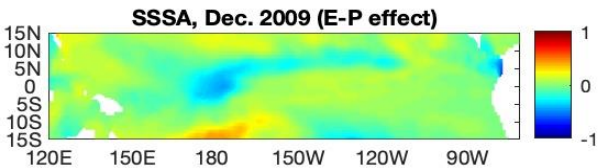




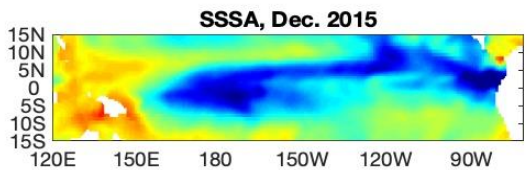
2009/10
small El Niño

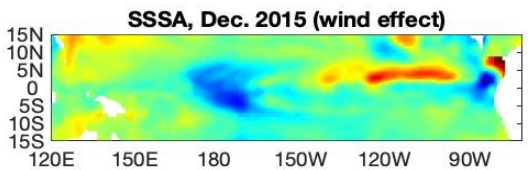


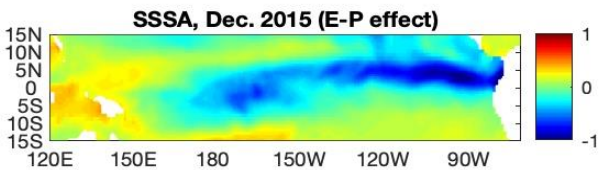




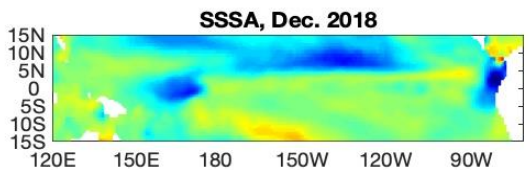
2015/16
large El Niño

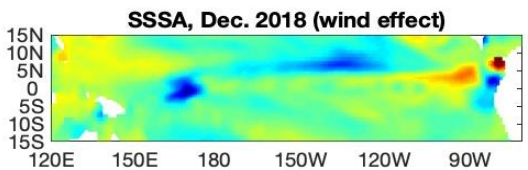


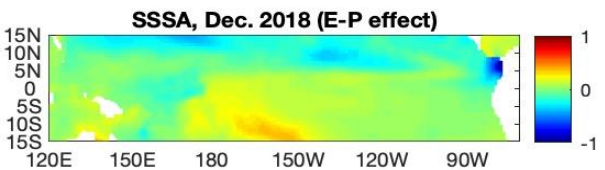




2018/19
small El Niño



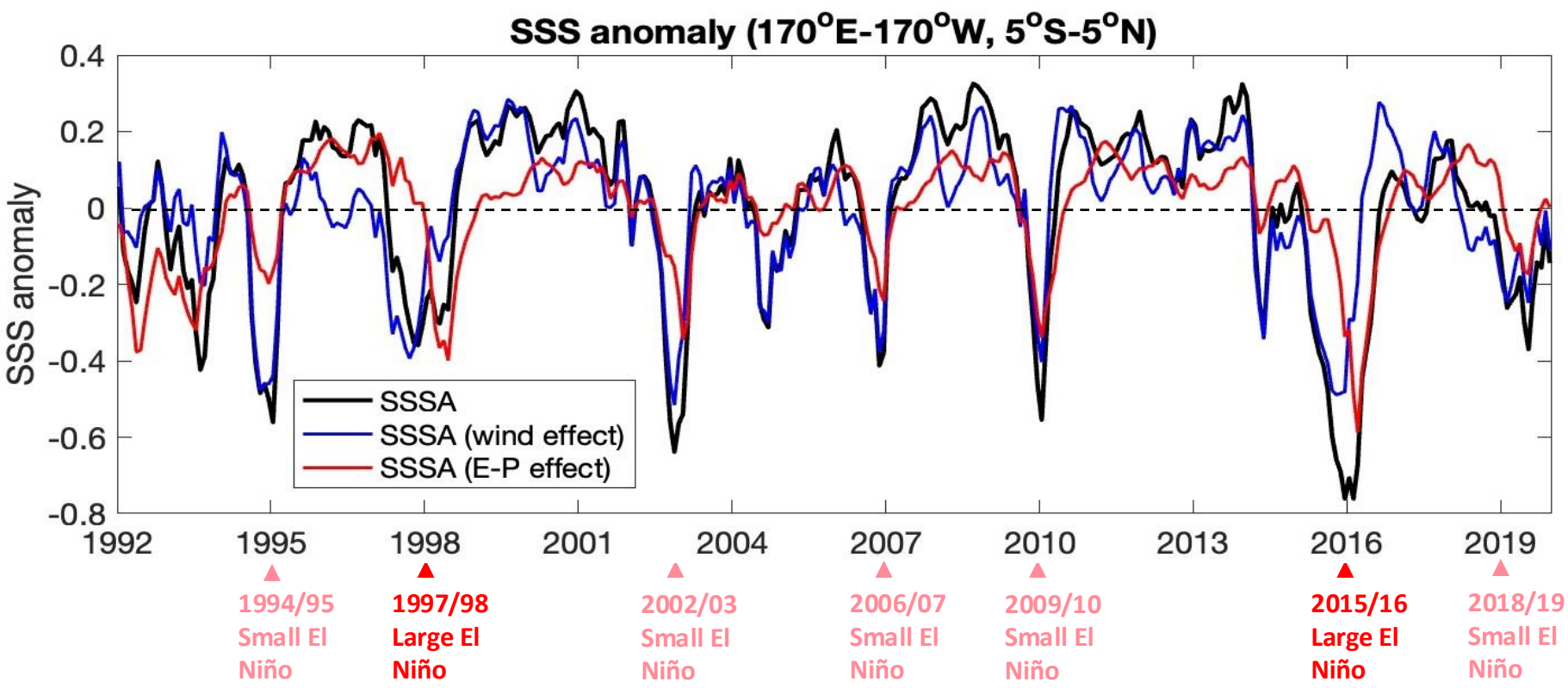


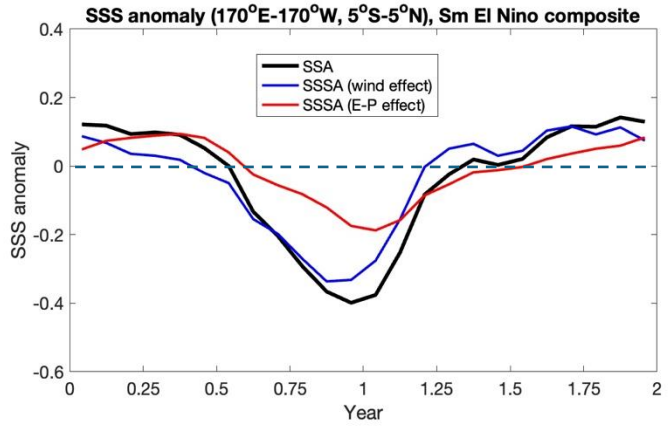


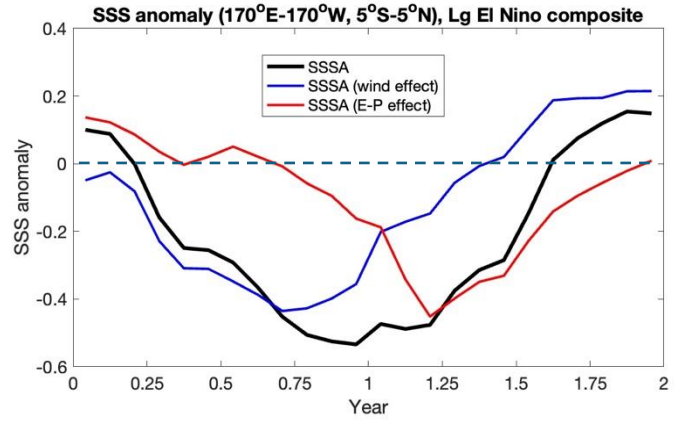
(same key messages as the previous slide)

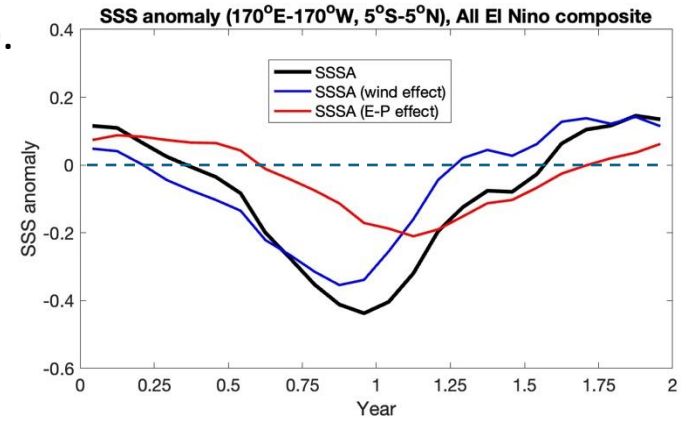
- SSSA during large El Niño has broader zonal extent than that during small El Nino.
- Wind effect more important near the dateline, while E-P effect is essential in the east.

Effect of wind stress anomaly vs. effect of E-P anomaly near the dateline









- E-P effect generally lag wind effect (by 1-2 months for sm. El Niño, 6 months for lg. El Niño).
- Wind effect initiates the freshening during the growth of El Niño.
- E-P becomes more important during the peak & decay of El Niño, prolonging freshening.
- For small El Niño, wind effect is larger than E-P effect.
- For large El Niño, wind & E-P effects have similar magnitudes.

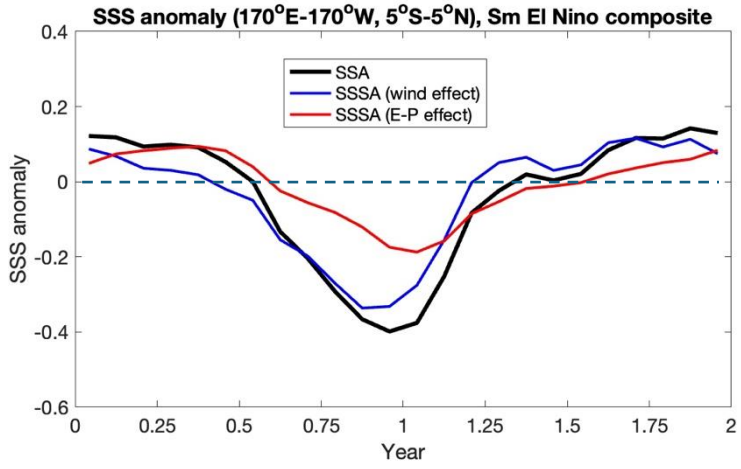
Why does the E-P effect lag the wind effect?
Why the lags are different for small & large El Niño?

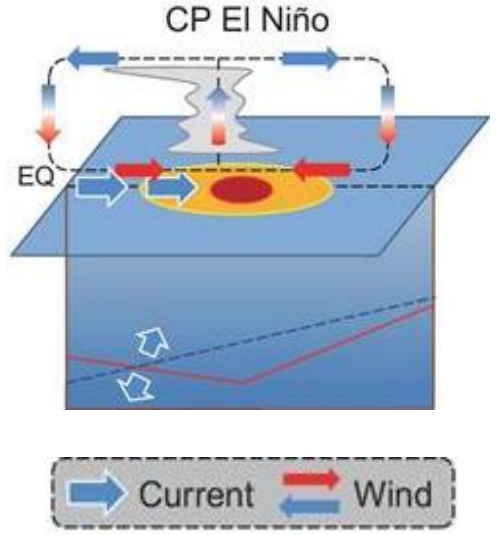
Why E-P effect lags wind effect by ~1-2 months for sm. El Niño?

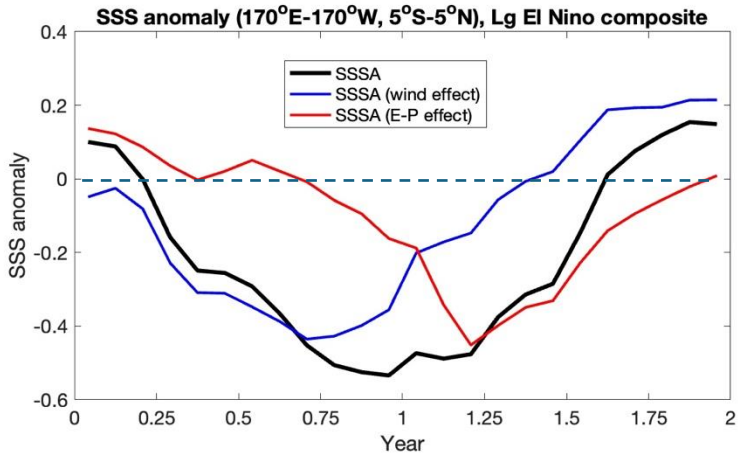
- Small El Niño are mostly central-Pacific (CP) El Niño with anomalous warming near the dateline that has relatively high background SST.
- It takes little time for the "zonal advective feedback" mechanism to raise SST above the threshold for anchoring atmospheric convection (e.g., ~28°C).

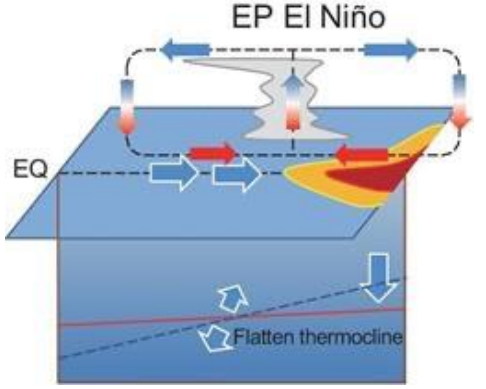
Why E-P effect lags wind effect by ~6+ months for lg. El Niño?

- Large El Niño are generally eastern-Pacific (EP) El Niño with anomalous warming in the cold-tongue region that has low background SST (~24°C).
- It takes several months for the "Bjerknes feedback" mechanism to raise the cold-tongue SST to the atmospheric convection threshold.







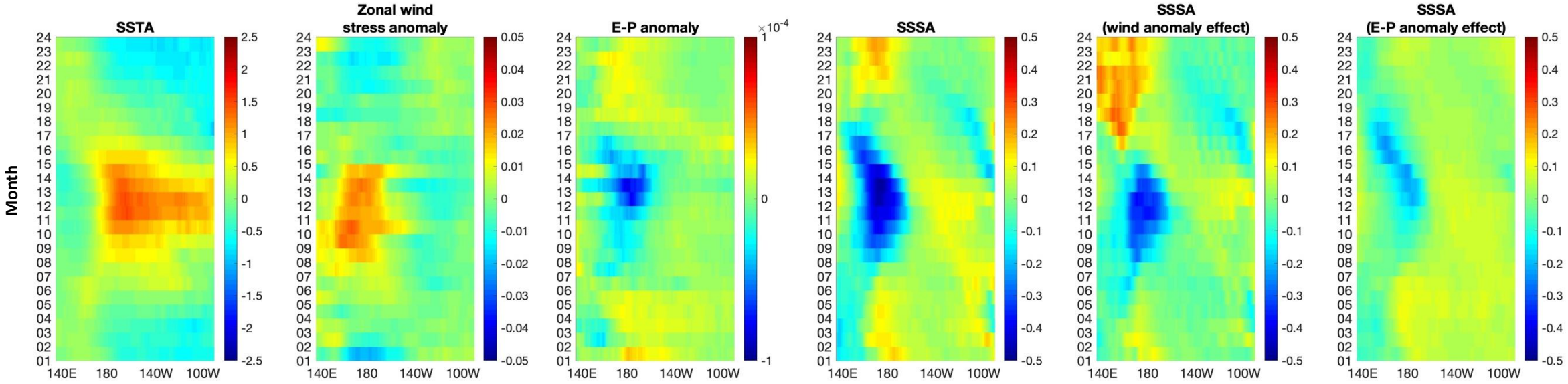


Graphics credit:
Song et al. (2018)

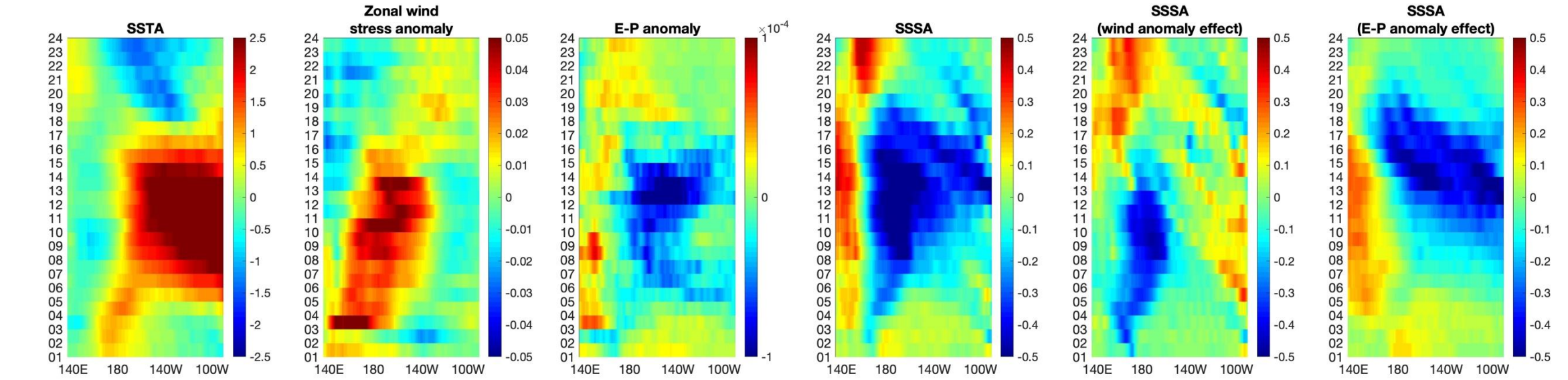
El Nino composite: Temporal evolution of equatorial (5S-5N) Pacific SST, zonal wind, E-P, and SSS anomalies

A different graphic presentation for recapping the key points made in previous slides

Small El Niño composite



Large El Niño composite



Summary

The relative importance of wind stress and E-P effects on freshening in the central-equatorial Pacific Ocean during El Niño depends on the phase and type of El Niño and on region.

Dependence on the phase of El Niño:

- Wind stress effect is the largest during the growing phase of El Niño, while E-P effect is the largest during the peak & decay phases, prolonging the freshening.
- The lag of E-P effect is consistent with theories of zonal advective feedback for small El Niño and Bjerknes feedback for large El Niño.

Dependence on the type of El Niño:

E-P effect is smaller than wind effect for small El Niño but as important as wind effect for large El Niño.

Geographical dependence:

Wind effect is more important near the dateline, while E-P effect is more important further east.

Food for thoughts:

How well do climate models (including ENSO forecast models) represent these processes/effects?