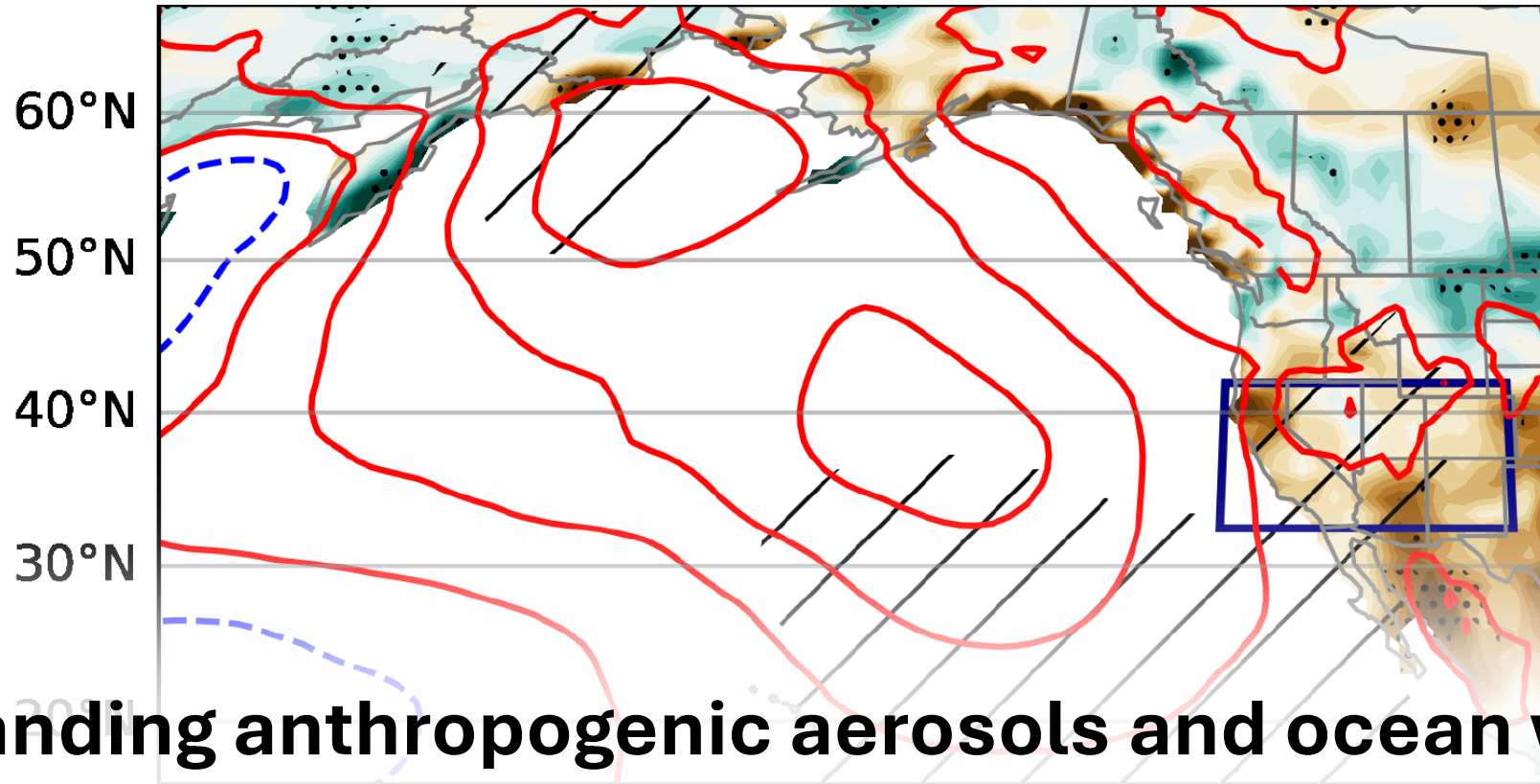


1980-2014 Observed *psl*, *pr* Trends (DJFMAM)



Understanding anthropogenic aerosols and ocean warming as drivers for Southwestern U.S. current drought

Yan-Ning Kuo, Flavio Lehner, Isla Simpson, Clara Deser, Adam Phillips,
Matthew Newman, Sang-Ik Shin, Spencer Wong and Julie Arblaster

Earth and Atmospheric Sciences

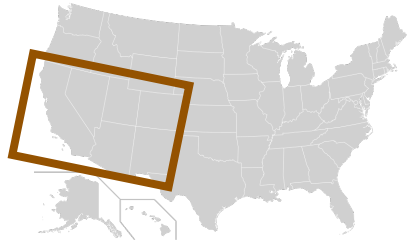
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Cornell **CALS**

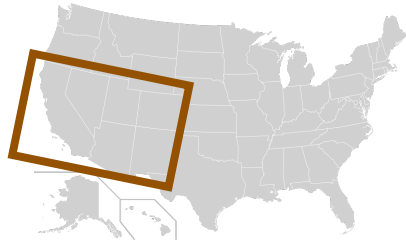
College of Agriculture
and Life Sciences



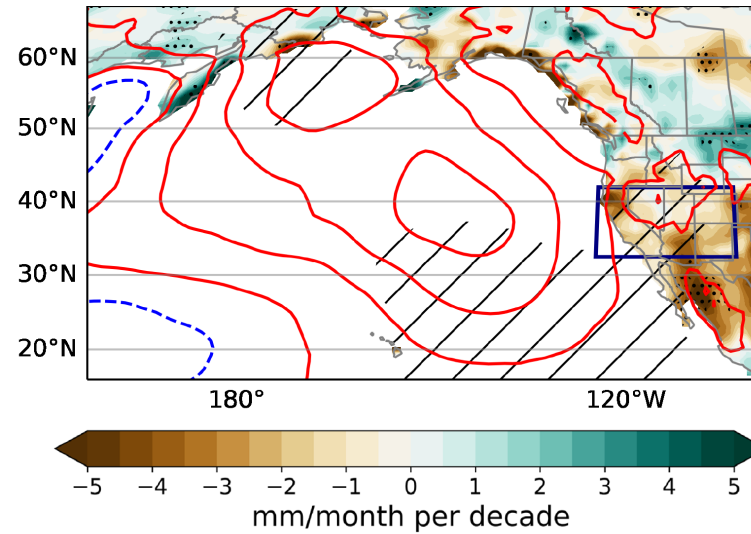
Introduction

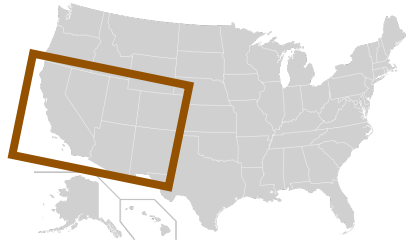


Introduction

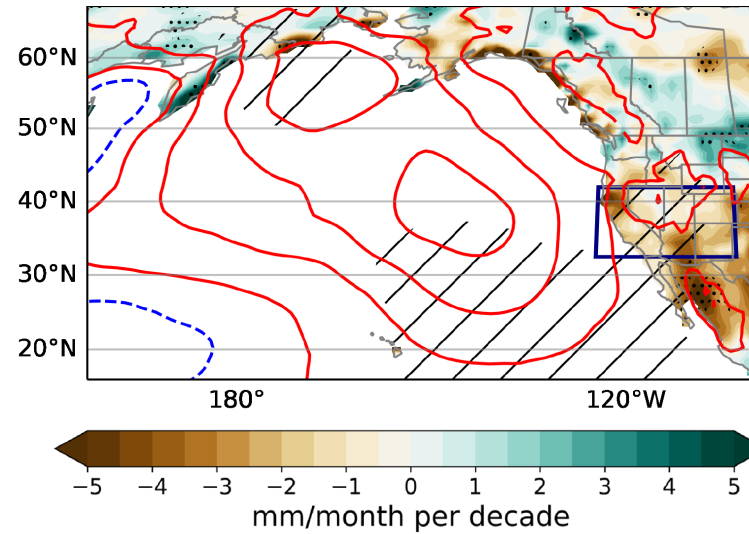


1980-2014 Observed *psl*, *pr* Trends (DJFMAM)

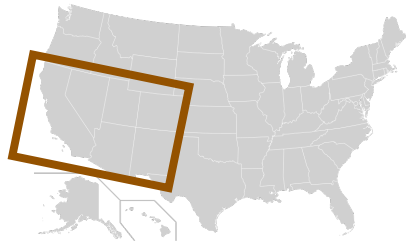




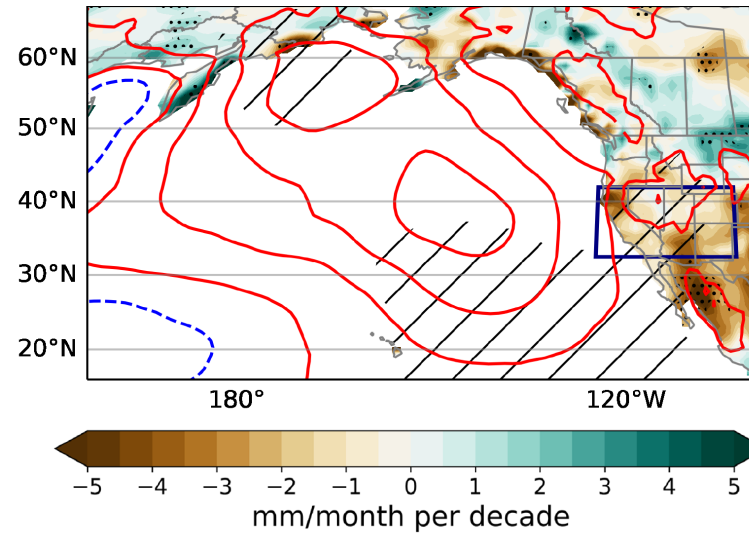
1980-2014 Observed psl , pr Trends (DJFMAM)



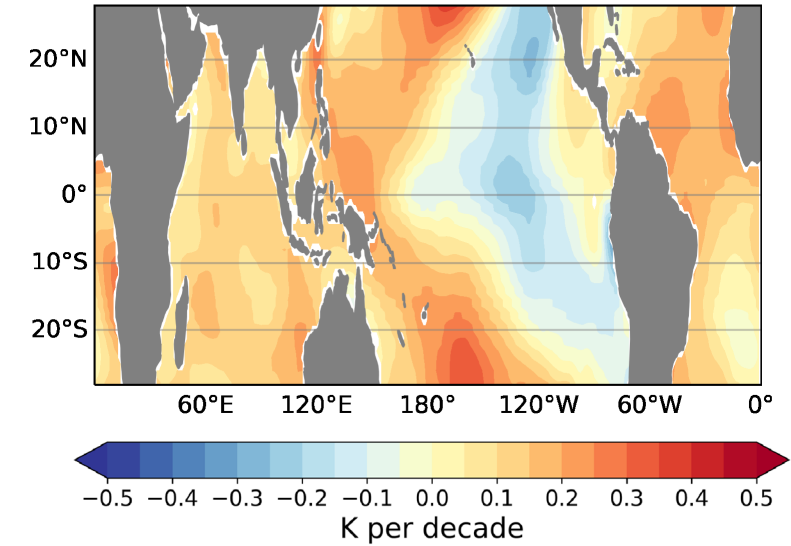
- Southwestern U.S. (SWUS) winter-spring precipitation declines since 1980s, creating both natural and socioeconomic impacts *Juang et al., 2022; Jacobson et al., 2023; Jacobson et al., 2024; Gleick, 2010; Gleick, 2016*



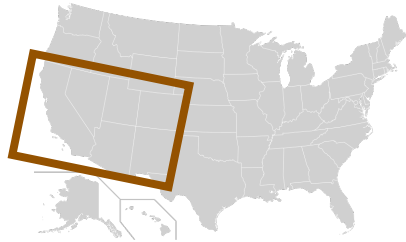
1980-2014 Observed *psl*, *pr* Trends (DJFMAM)



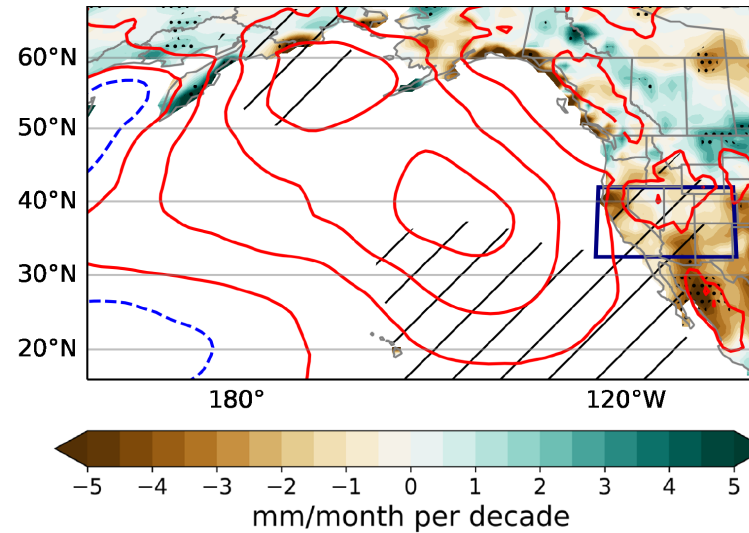
Observed SST Trends (DJFMAM)



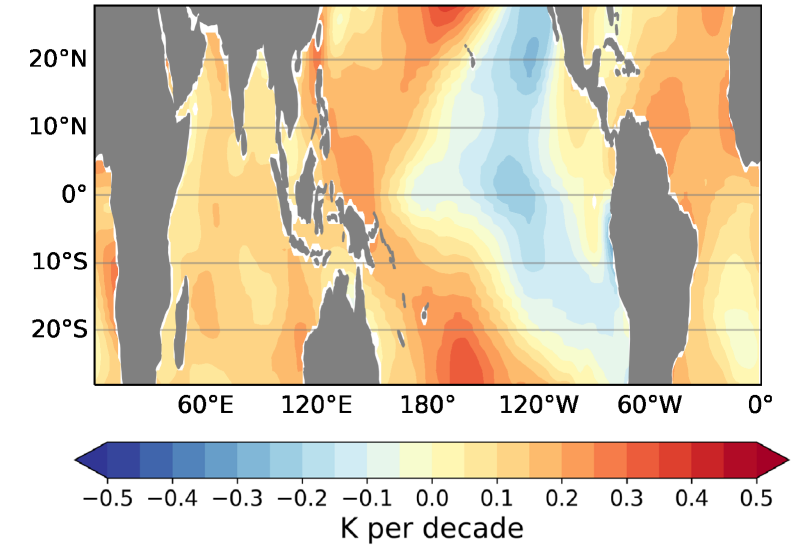
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Observed SST Trends (DJFMAM)



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Hwang et al. 2023; Allen et al. 2020; Allen and Zhao 2022; Dow et al. 2021; Dittus et al. 2021; Oudar et al. 2018; Kang et al. 2024;



Figure 1 is a contour map of the tropical Pacific region, showing the projected temperature change (K per decade) under the A1B scenario. The map covers the area from 20°N to 20°S latitude and 60°E to 0° longitude. The color scale ranges from -0.5 K per decade (dark blue) to 0.5 K per decade (dark red). The map shows a significant cooling (blue) in the central Pacific, particularly around 180° longitude, while the surrounding areas show warming (orange/red).

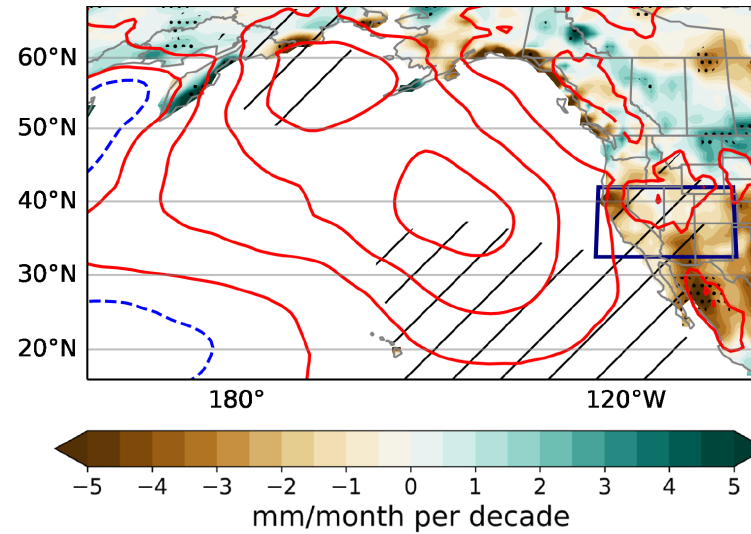
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Observed attribution does not work in modeled forced response

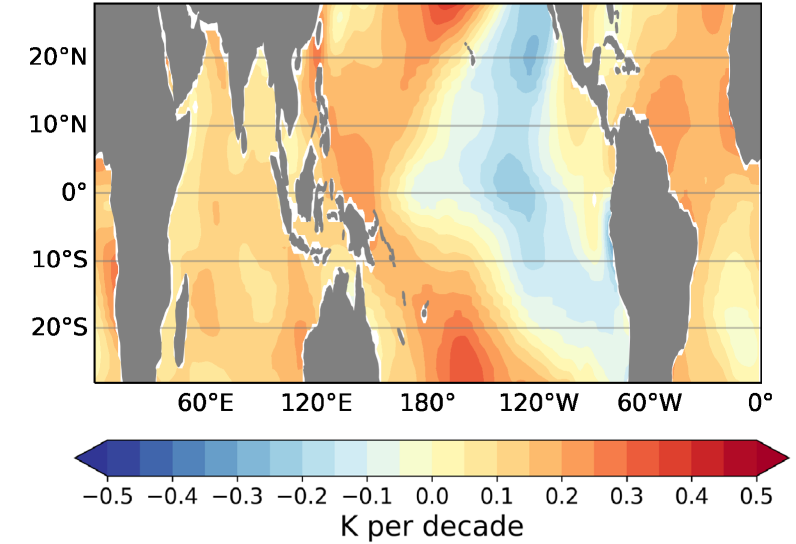


- Observed SWUS precipitation trend is attributed to tropical **La Niña-like trend**

1980-2014 Observed *psl*, *pr* Trends (DJFMAM)



Observed SST Trends (DJFMAM)

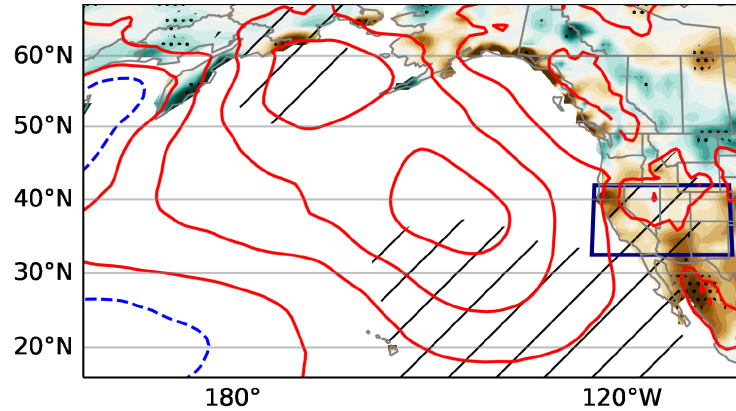


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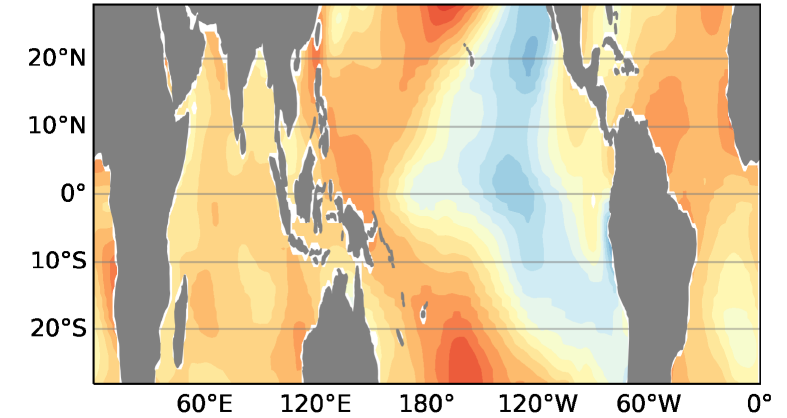


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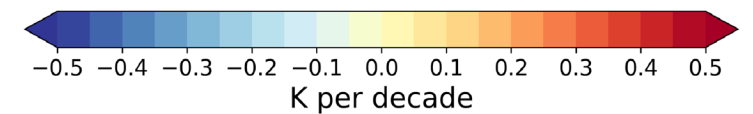
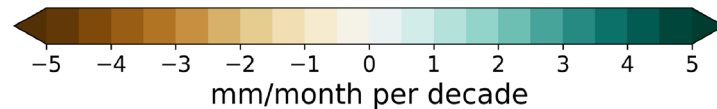
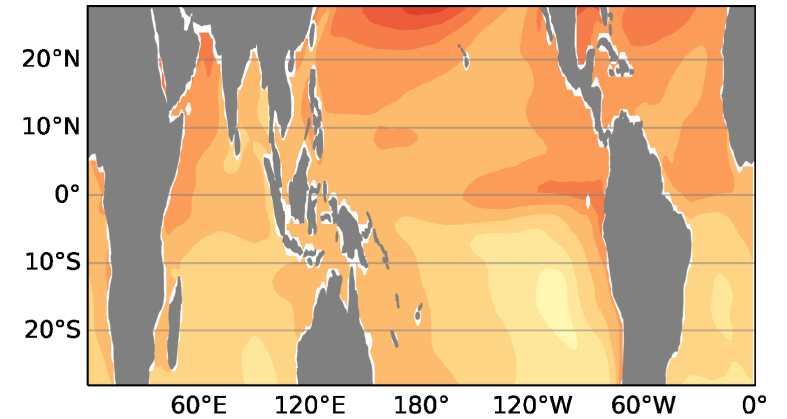
1980-2014 Observed *psl*, *pr* Trends (DJFMAM)



Observed SST Trends (DJFMAM)



CESM2-LE SST Trends (DJFMAM)



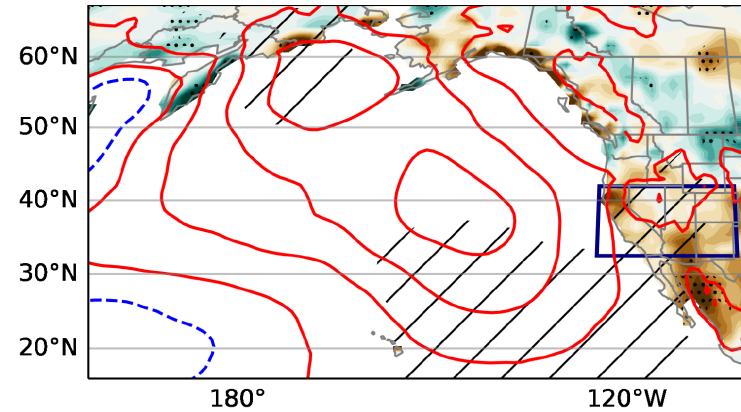
Kuo et al. (2025 in press Nat. Geo.)

Observed attribution does not work in modeled forced response

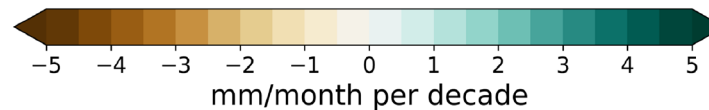
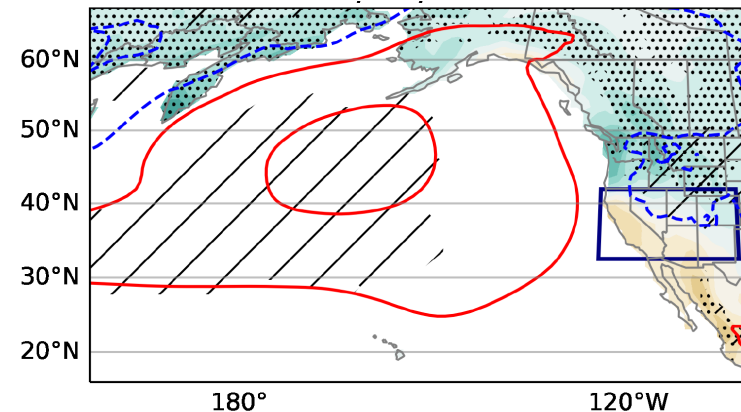


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- Modeled North Pacific trends are *not* explained by **El Niño-like trend**

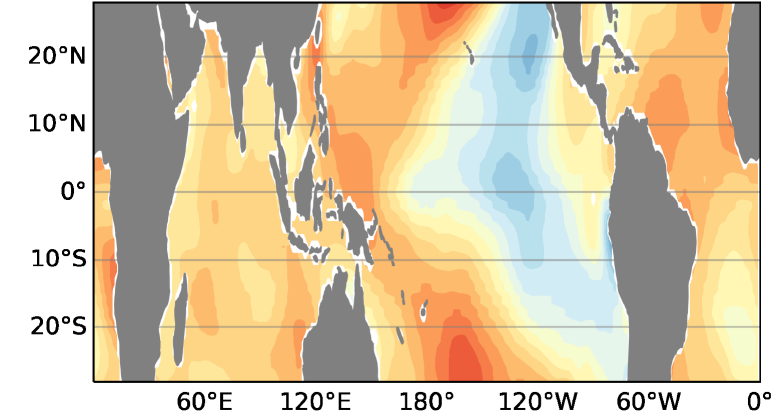
1980-2014 Observed *psl*, *pr* Trends (DJFMAM)



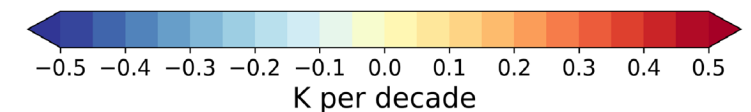
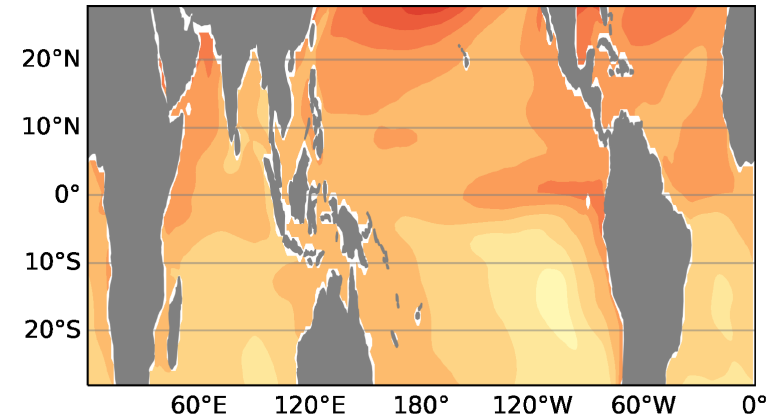
CESM2-LE *psl*, *pr* Trends (DJFMAM)



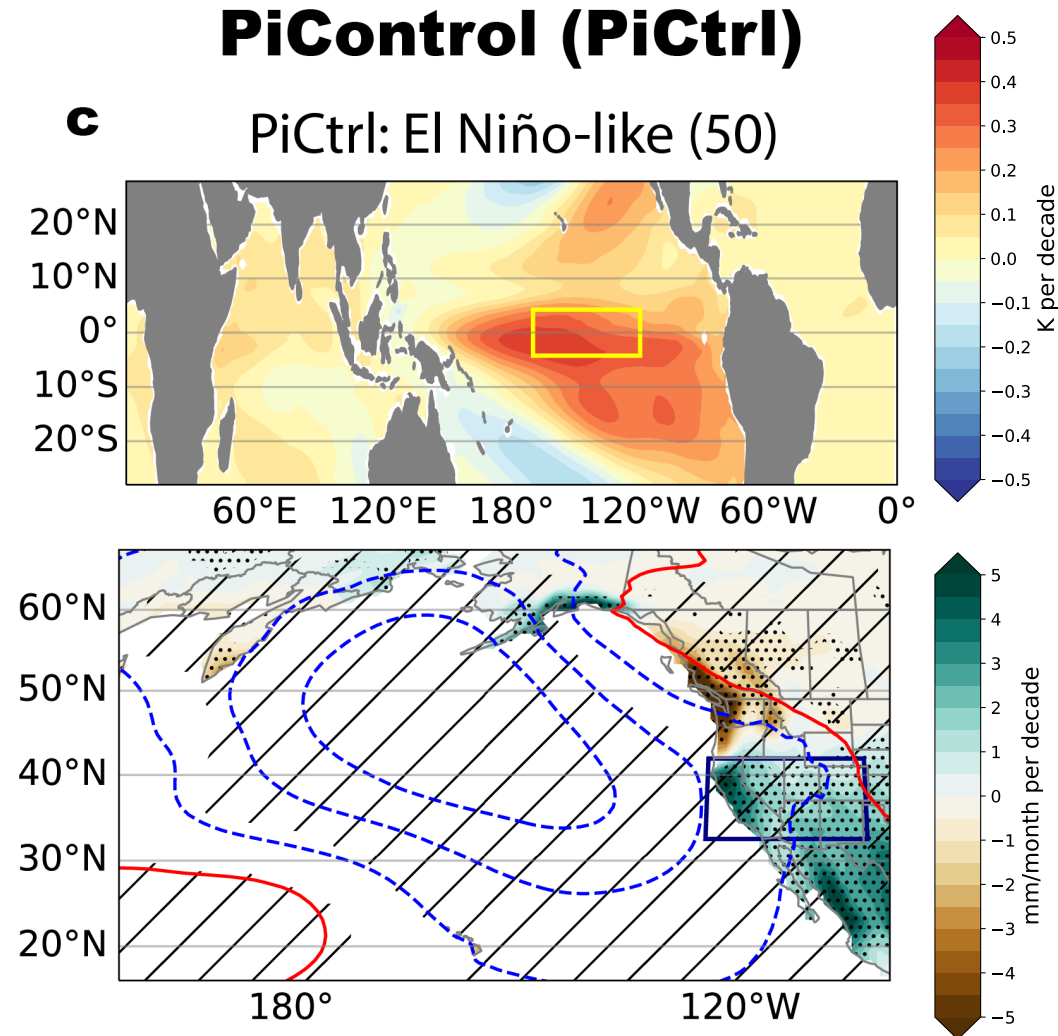
Observed SST Trends (DJFMAM)



CESM2-LE SST Trends (DJFMAM)

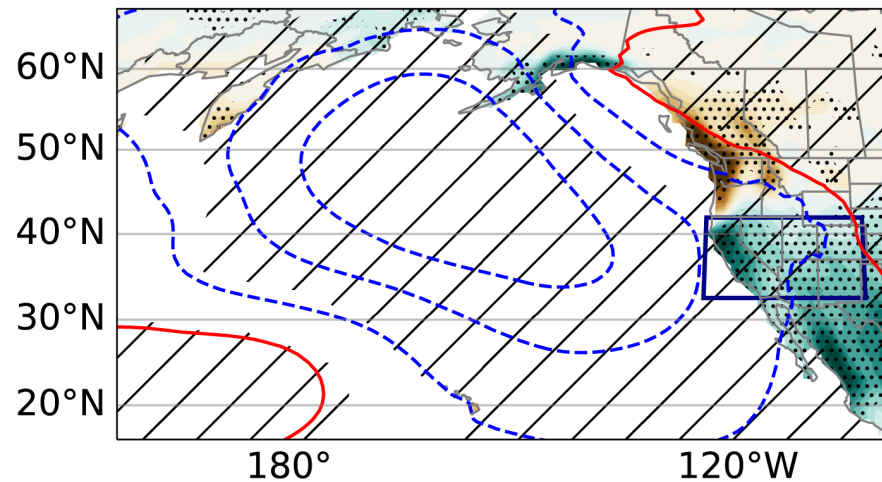
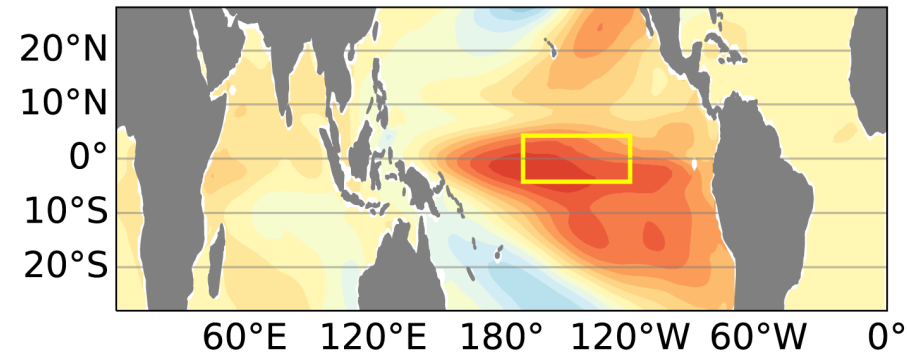


Kuo et al. (2025 in press Nat. Geo.)



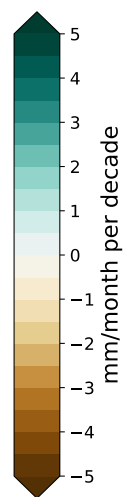
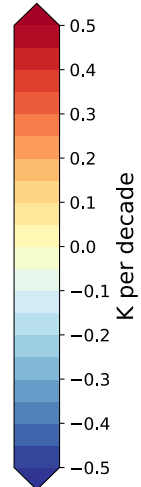
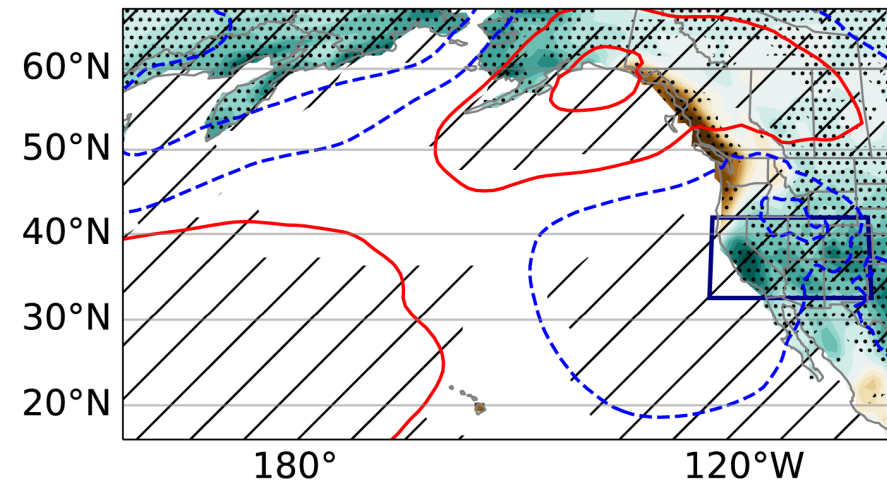
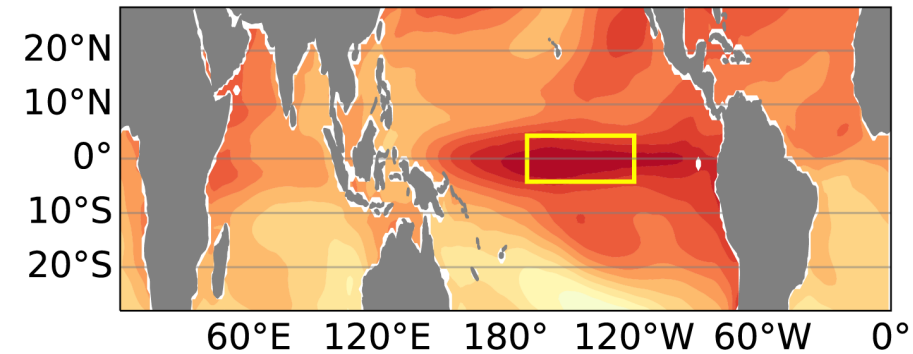
PiControl (PiCtrl)

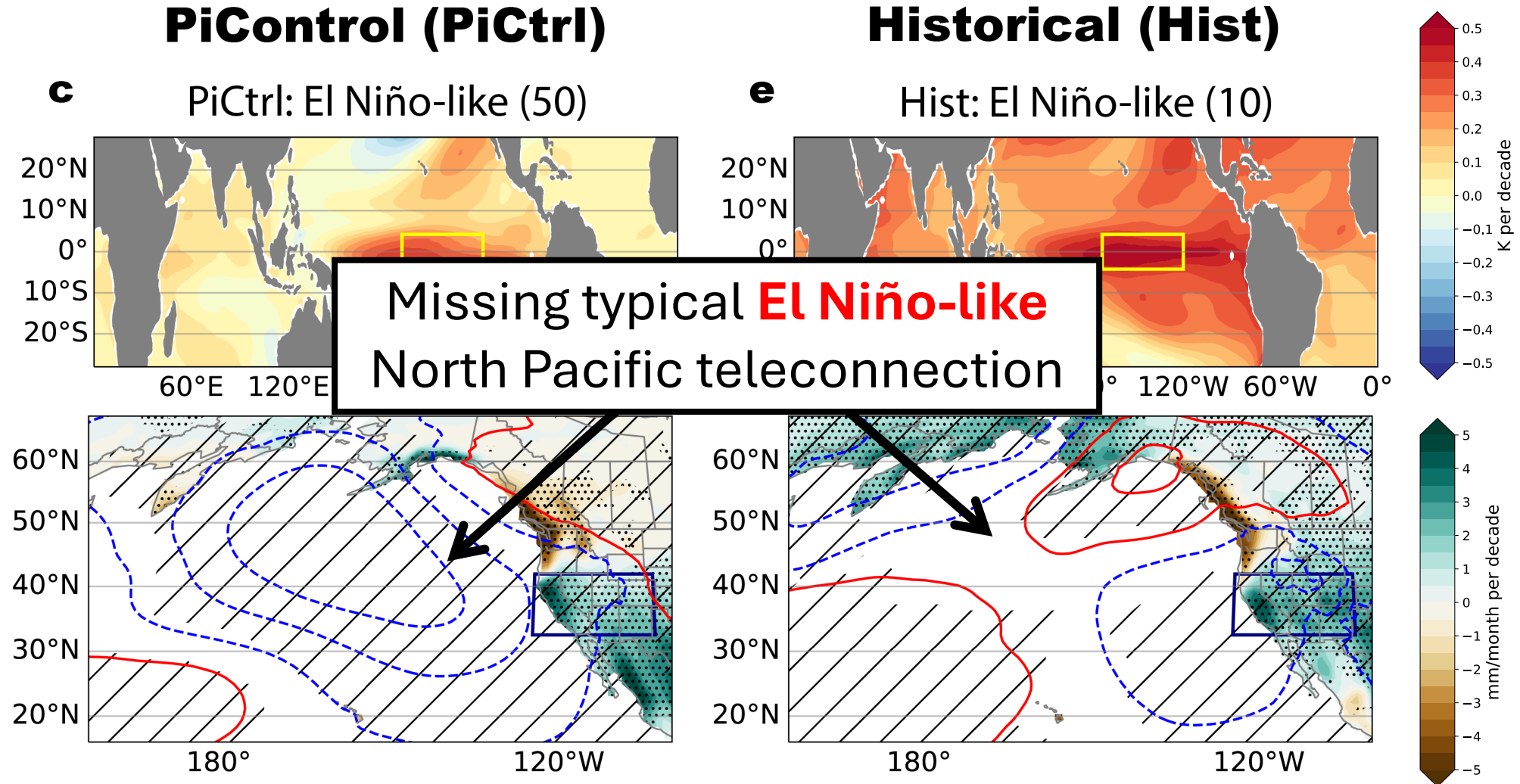
c PiCtrl: El Niño-like (50)

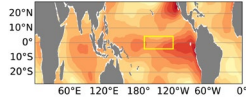


Historical (Hist)

e Hist: El Niño-like (10)

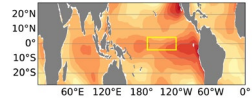






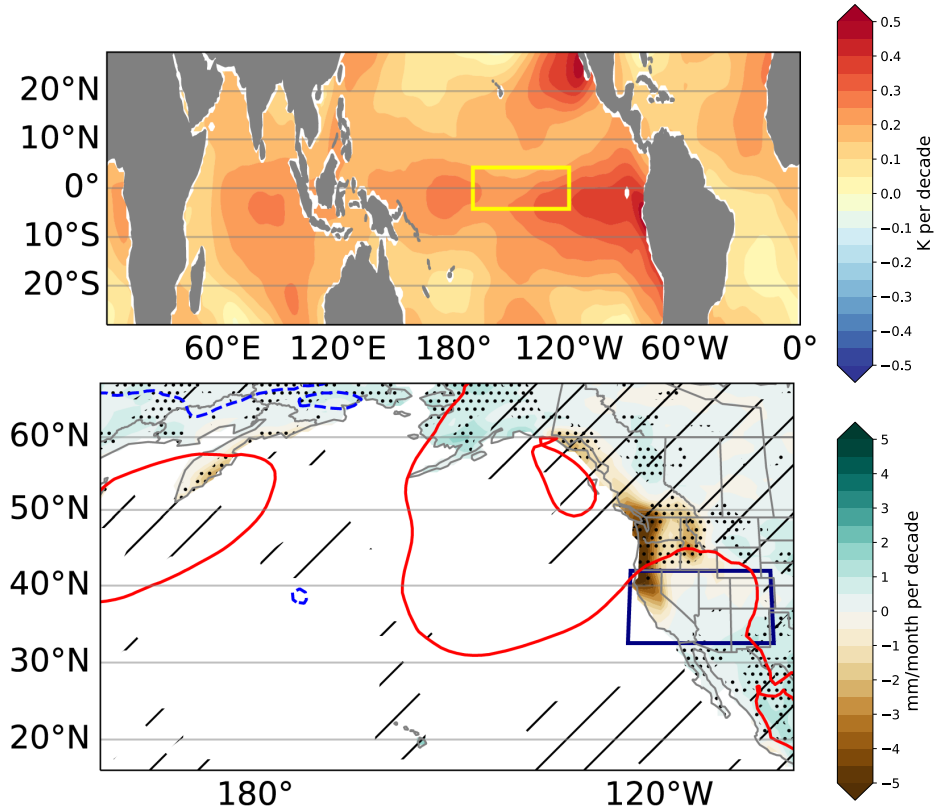
El Niño-like trend +RF

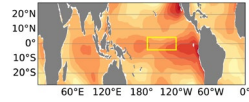
AMIP-type experiment with an **El Niño-like trend** + post-1980 radiative forcings (RF)



El Niño-like trend + RF

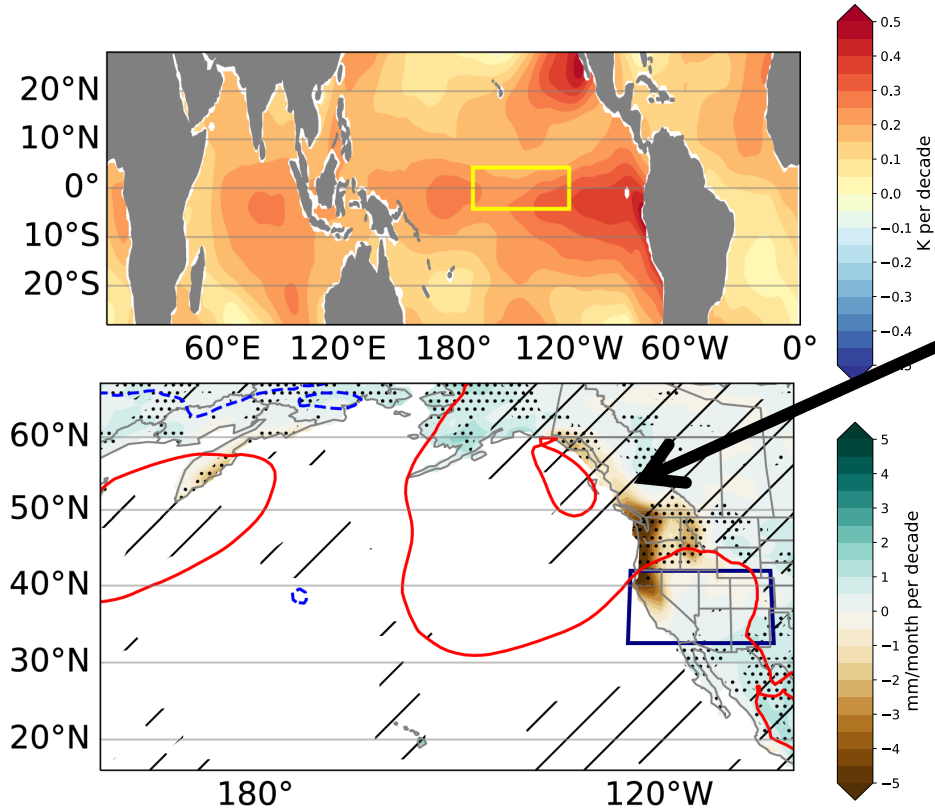
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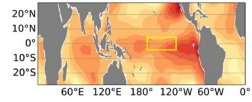


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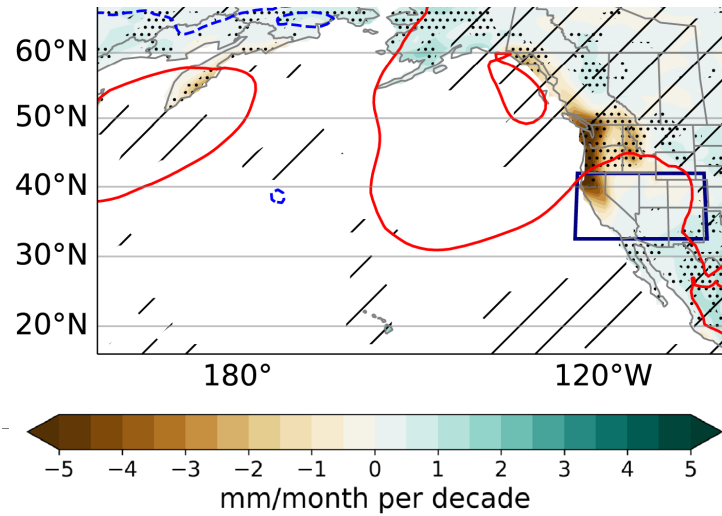
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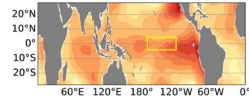
Consistent missing typical **El Niño-like** North Pacific teleconnection



El Niño-like trend +RF

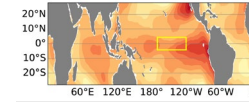


Understanding the North Pacific **El Niño-like** teleconnection change with AMIP

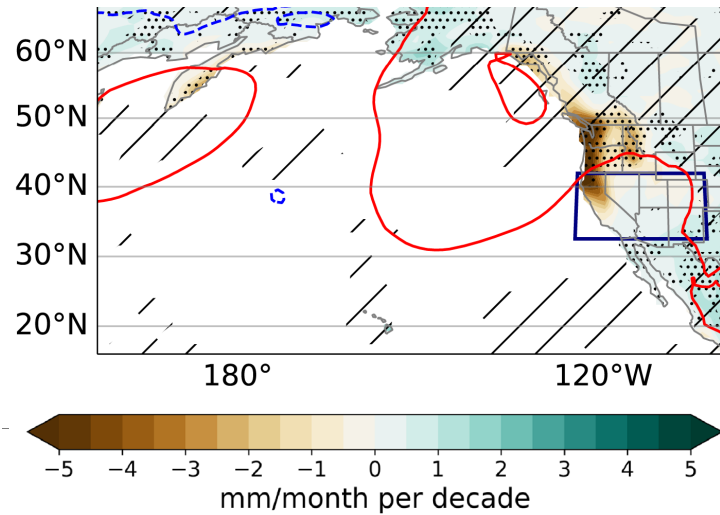


El Niño-like trend +RF

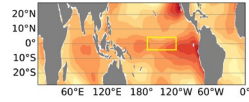
RF w/o SST trend



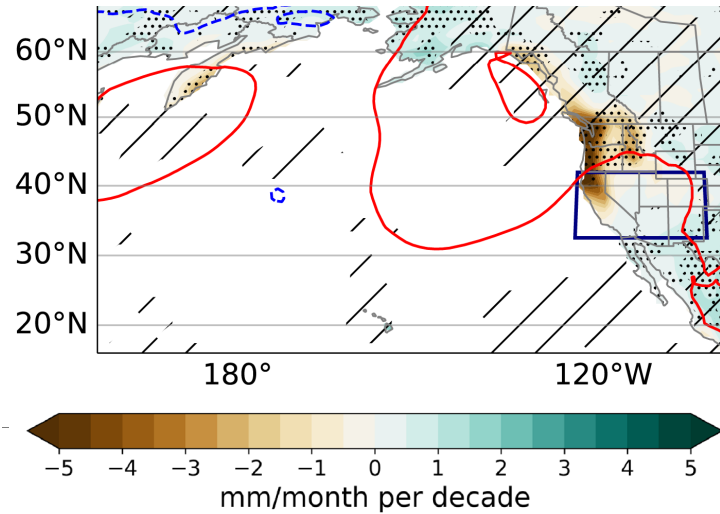
El Niño-like trend w/o RF



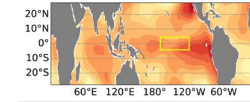
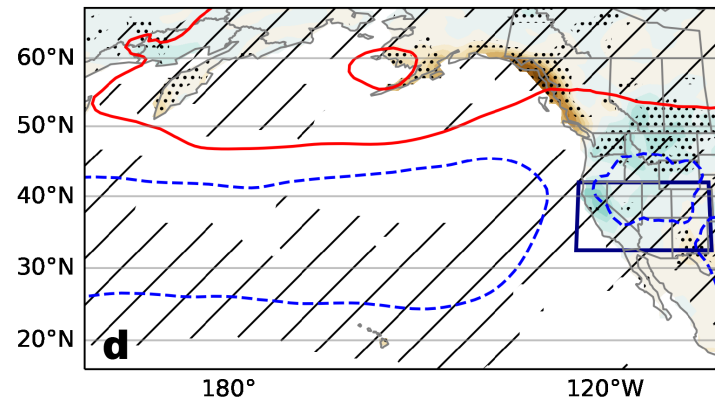
Understanding the North Pacific **El Niño-like** teleconnection change with AMIP



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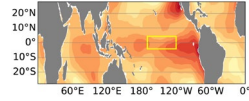


RF w/o SST trend

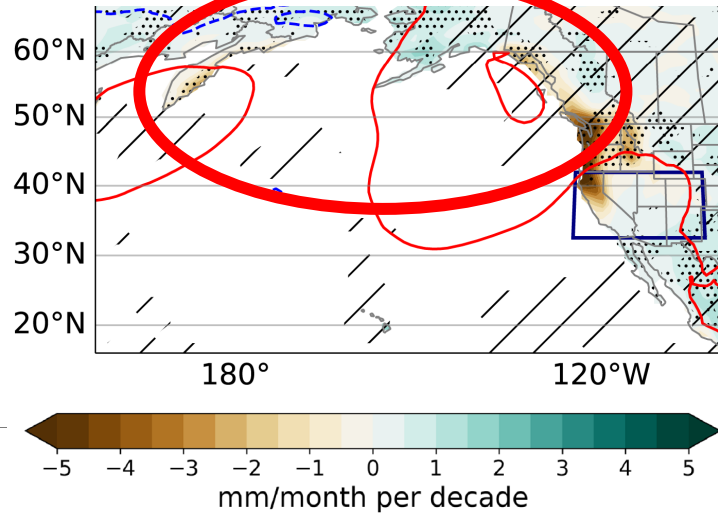


El Niño-like trend w/o RF

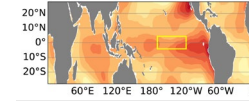
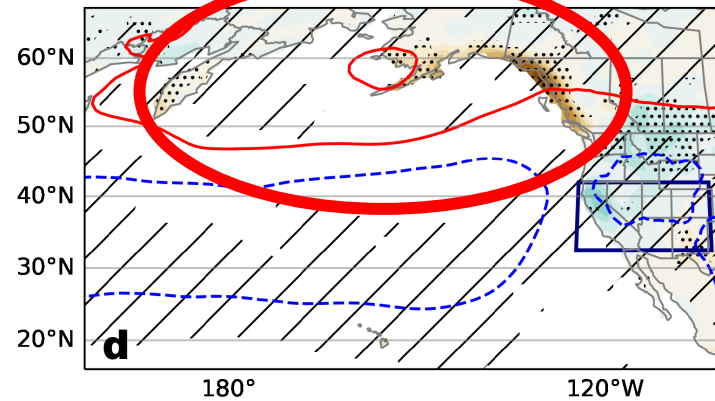
Understanding the North Pacific **El Niño-like** teleconnection change with AMIP



El Niño-like trend +

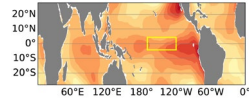


RF w/o SST trend

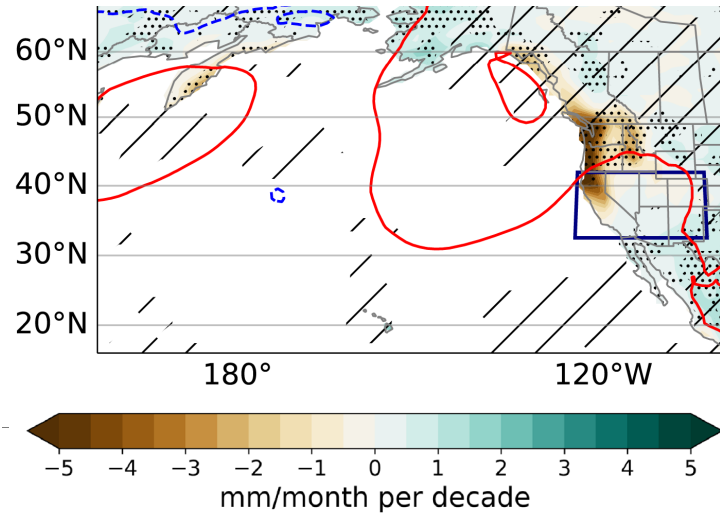


El Niño-like trend w/o RF

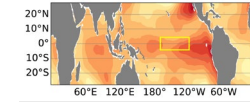
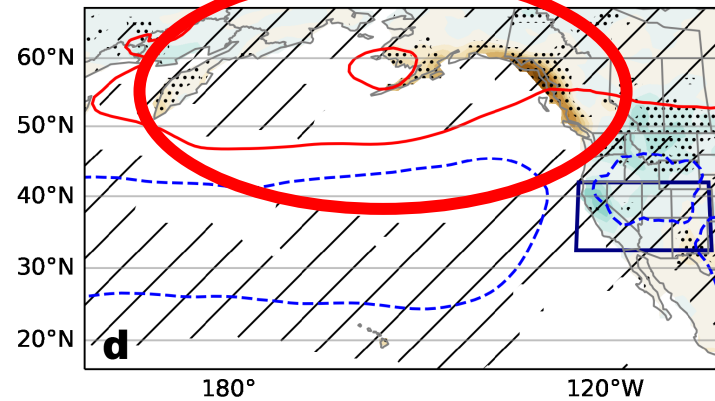
Understanding the North Pacific **El Niño-like** teleconnection change with AMIP



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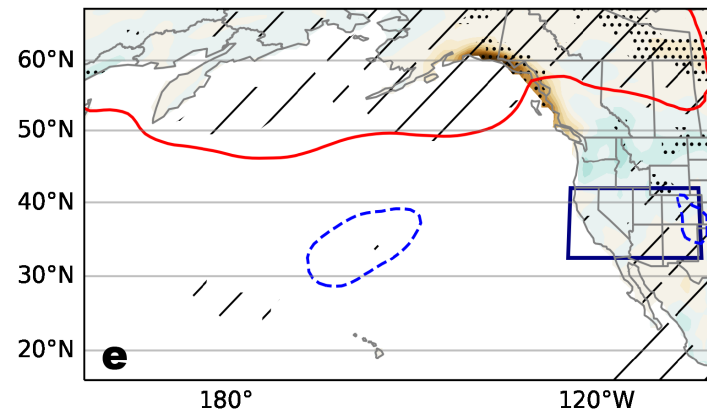


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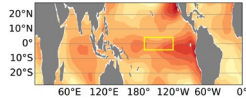


El Niño-like trend w/o RF

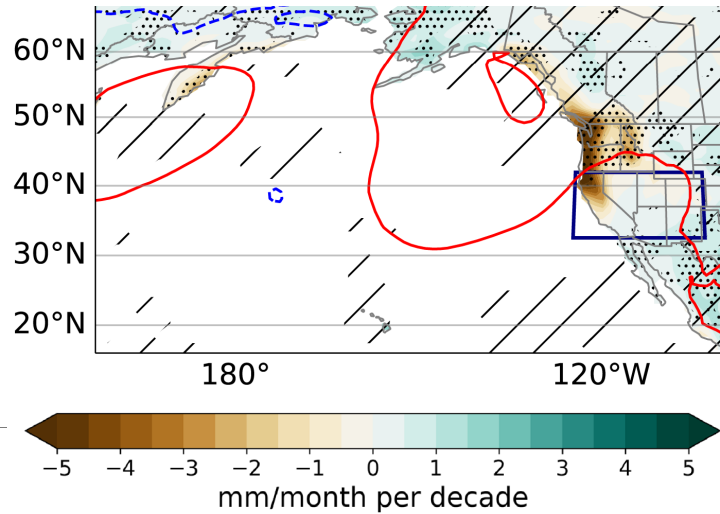
Anthropogenic aerosols (fully coupled)



Understanding the North Pacific **El Niño-like** teleconnection change with AMIP

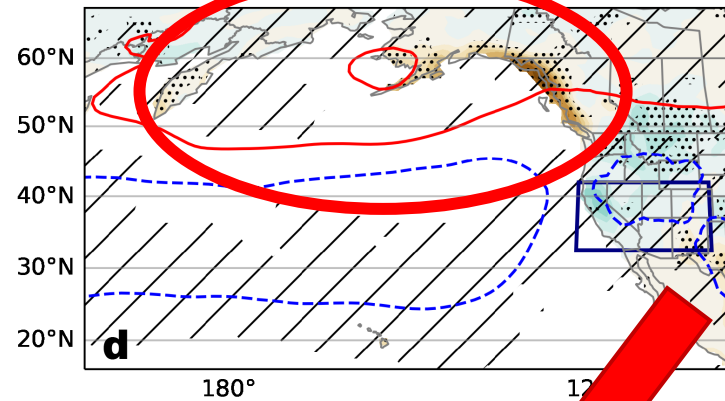


El Niño-like trend +RF

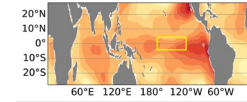
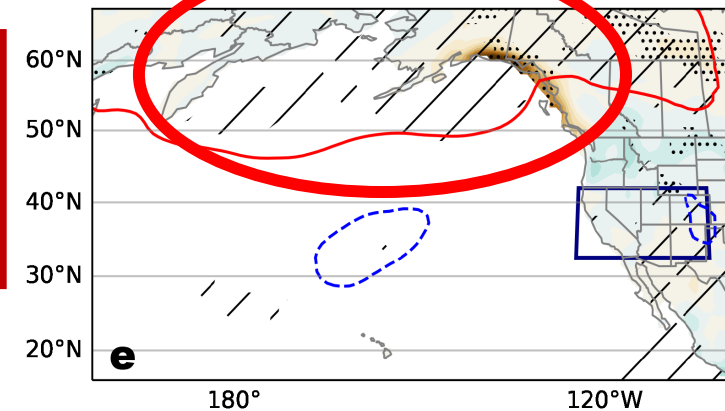


- anthropogenic aerosols-forced circulation change independent of SST

RF w/o SST trend

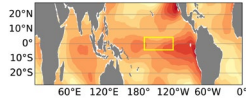


Anthropogenic aerosols (fully coupled)

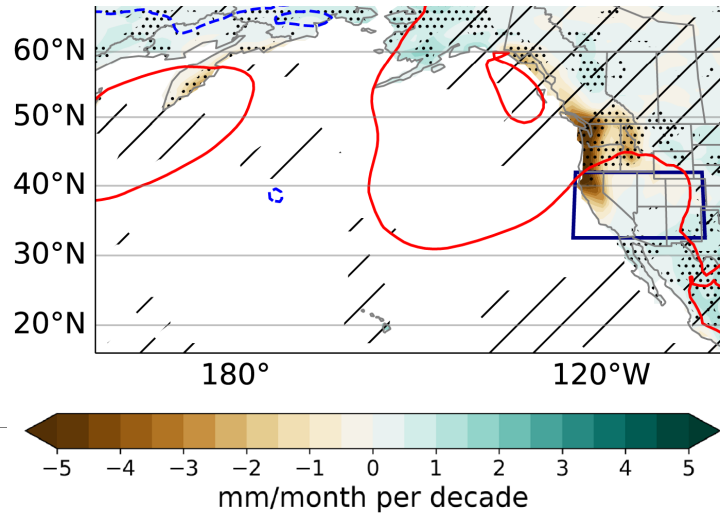


El Niño-like trend w/o RF

Understanding the North Pacific **El Niño-like** teleconnection change with AMIP

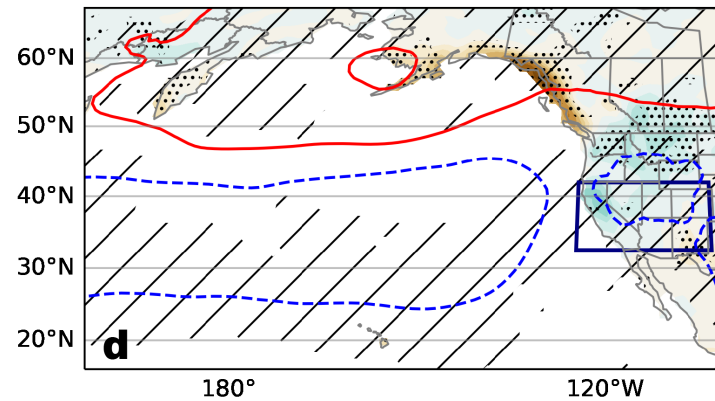


El Niño-like trend +RF

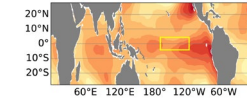
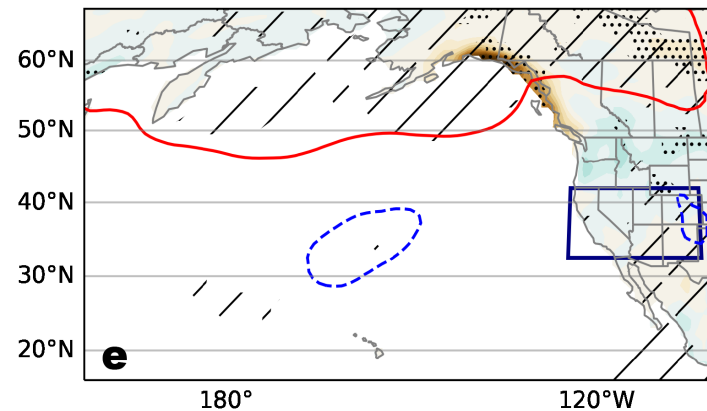


- anthropogenic aerosols-forced circulation change independent of SST

RF w/o SST trend

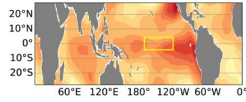


Anthropogenic aerosols (fully coupled)

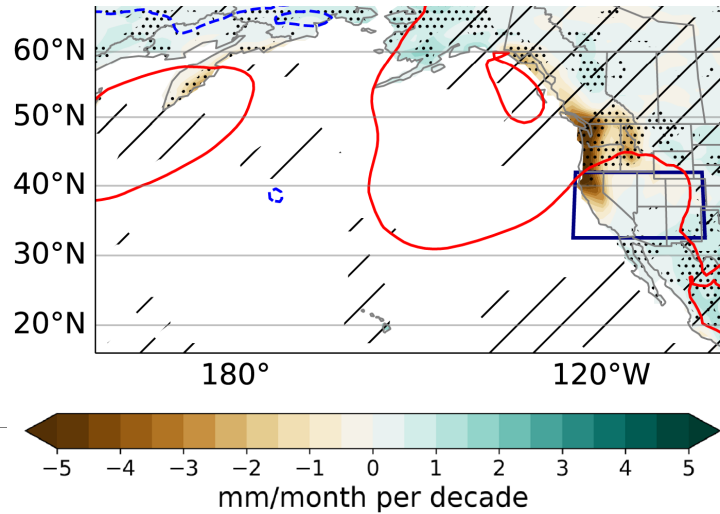


El Niño-like trend w/o RF

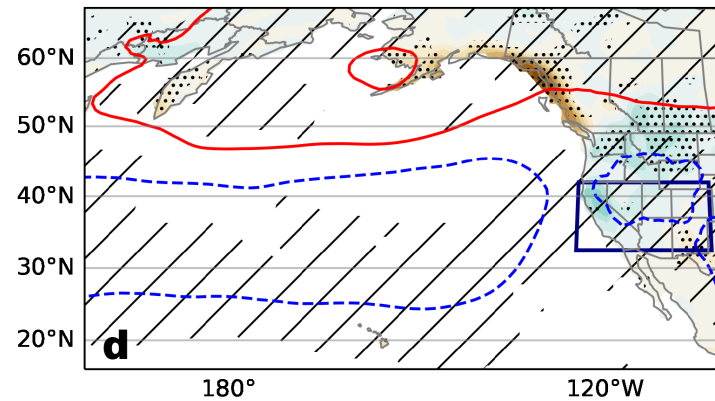
Understanding the North Pacific **El Niño-like** teleconnection change with AMIP



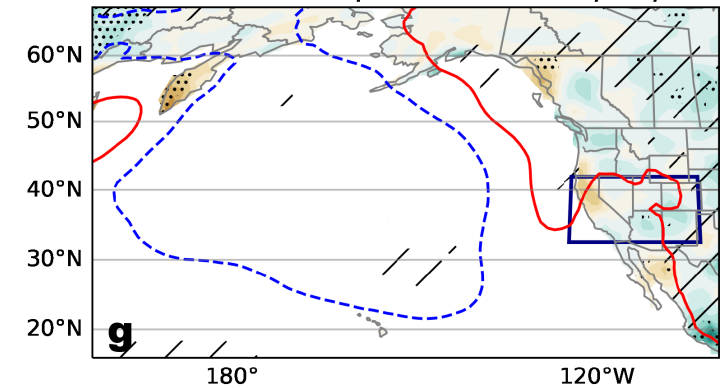
El Niño-like trend +RF



RF w/o SST trend

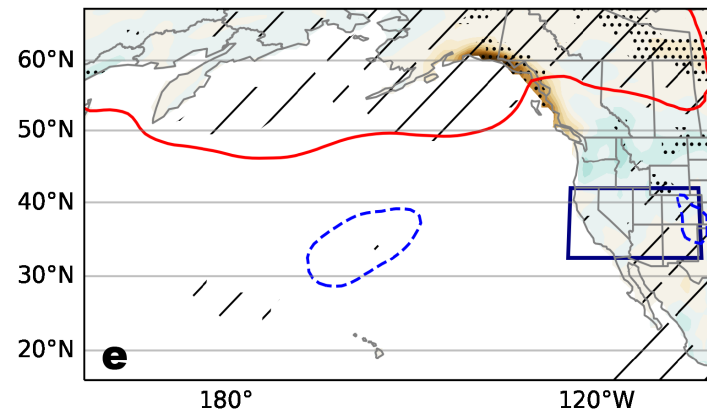


El Niño-like trend w/o RF

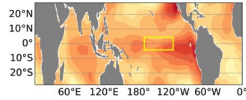


- anthropogenic aerosols-forced circulation change independent of SST

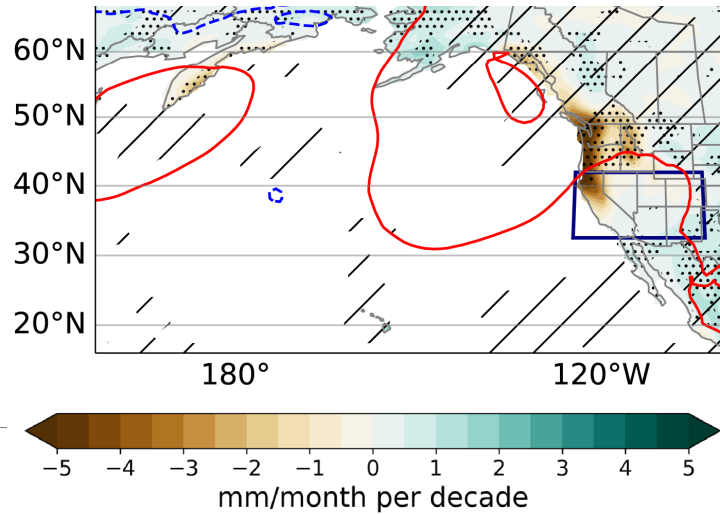
Anthropogenic aerosols (fully coupled)



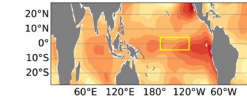
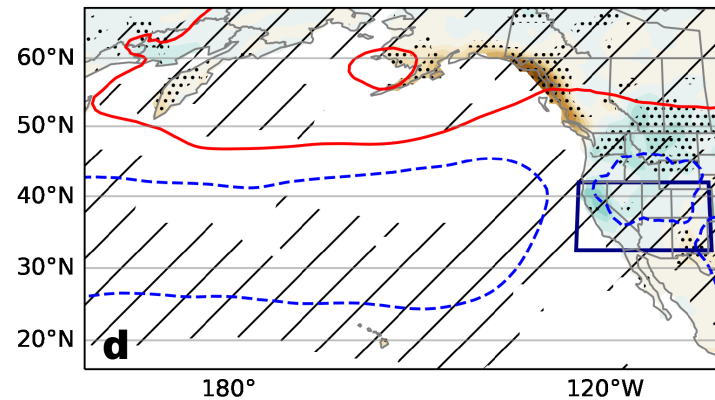
Understanding the North Pacific **El Niño-like** teleconnection change with AMIP



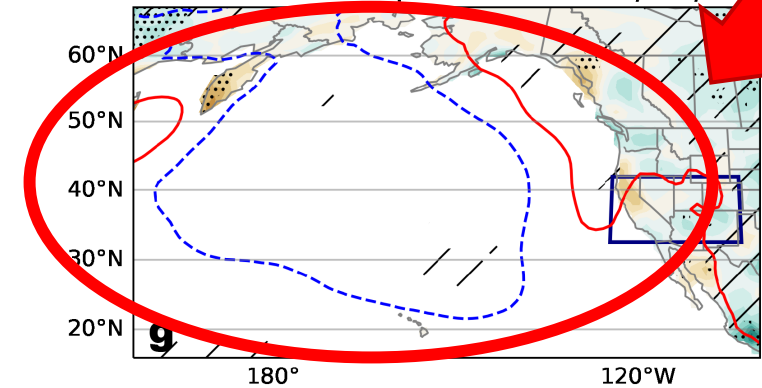
El Niño-like trend +RF



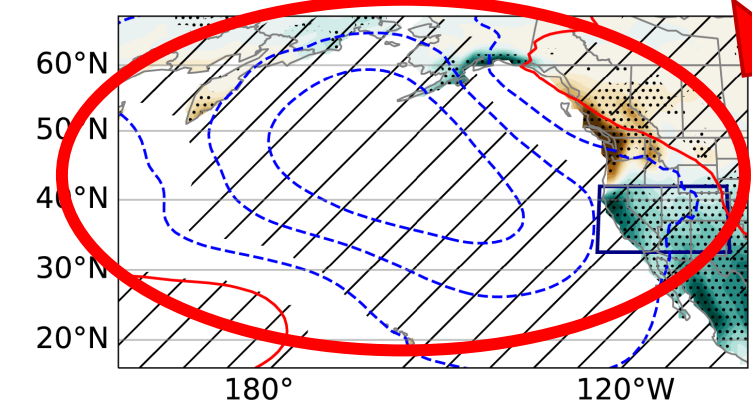
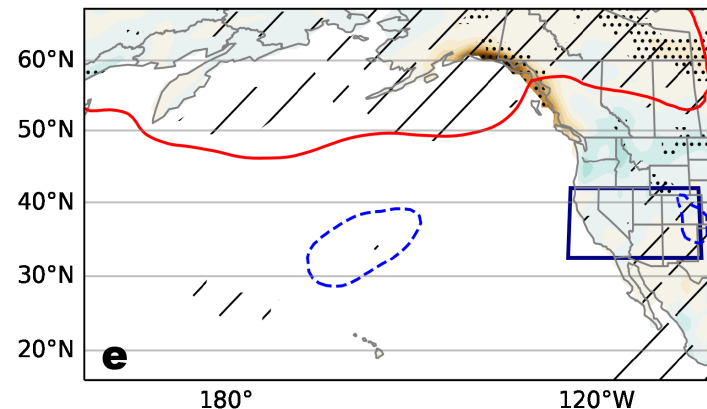
RF w/o SST trend



El Niño-like trend w/o RF



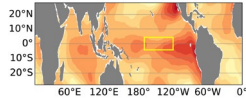
Anthropogenic aerosols (fully coupled) El Niño-like composite in PiControl



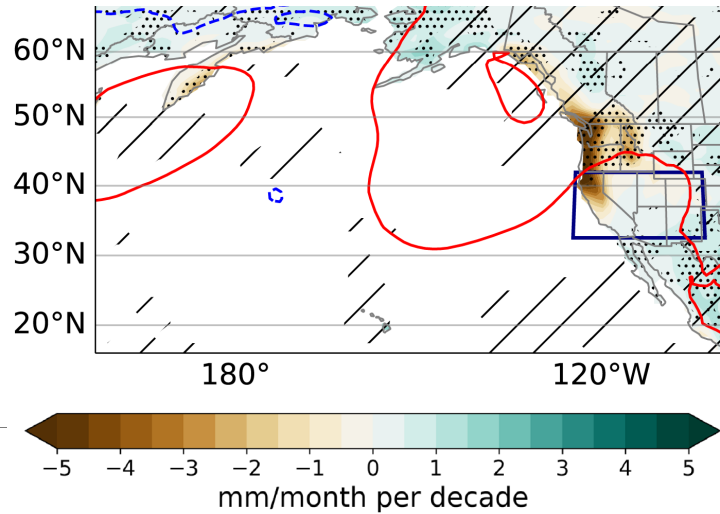
- anthropogenic aerosols-forced circulation change independent of SST
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Kuo et al. (2025 in press Nat. Geo.)

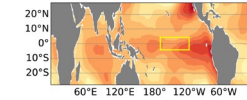
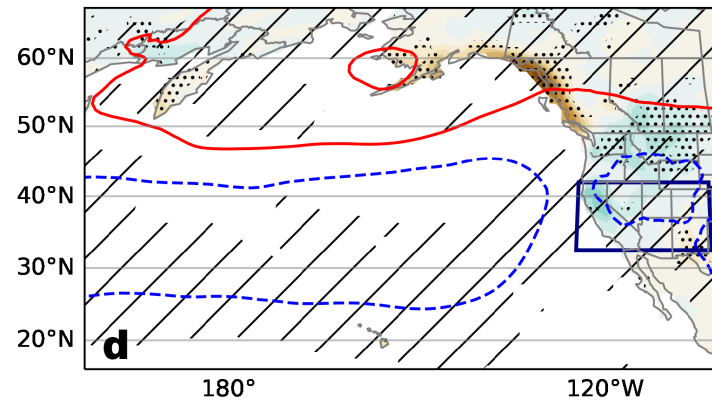
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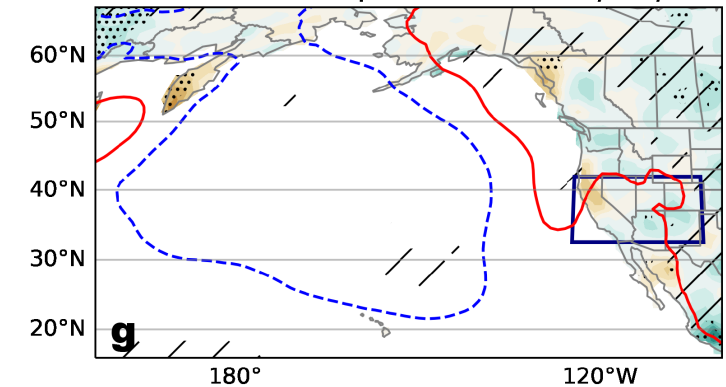
El Niño-like trend +RF



RF w/o SST trend

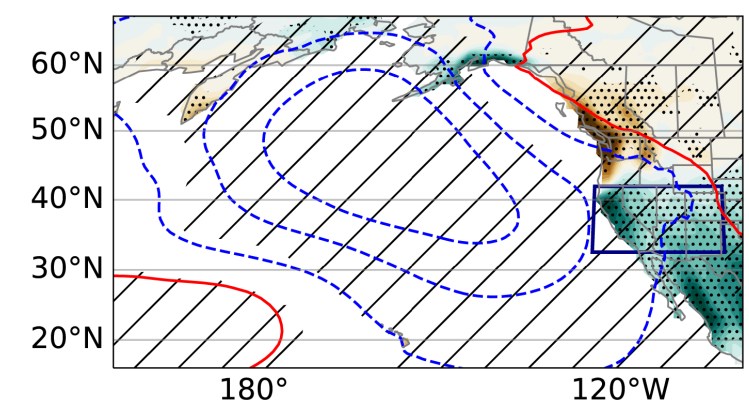
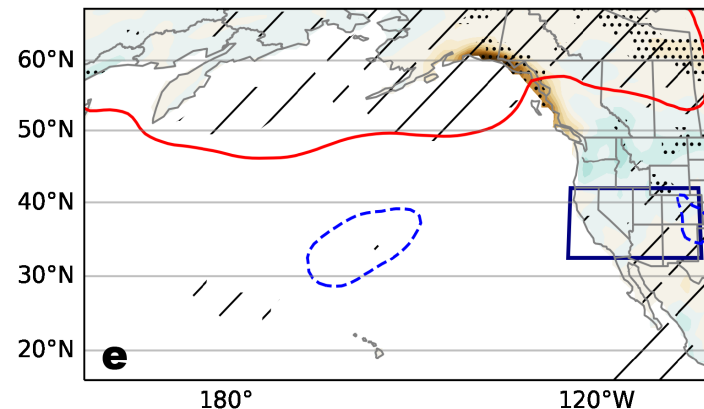


El Niño-like trend w/o RF



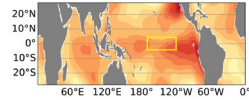
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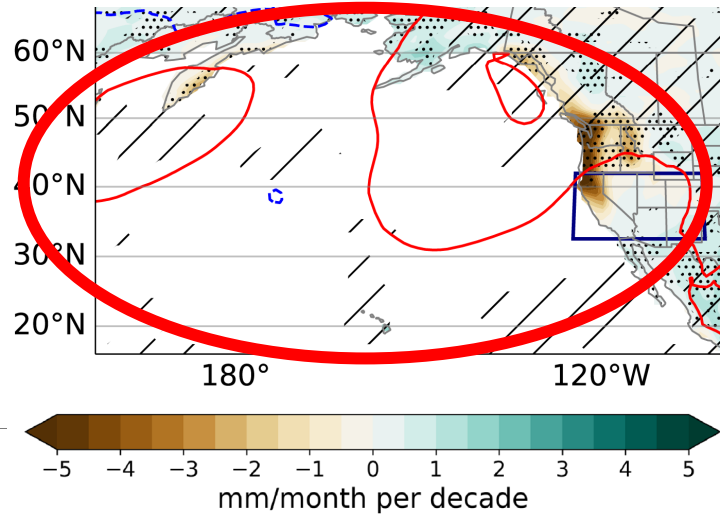


Kuo et al. (2025 in press Nat. Geo.)

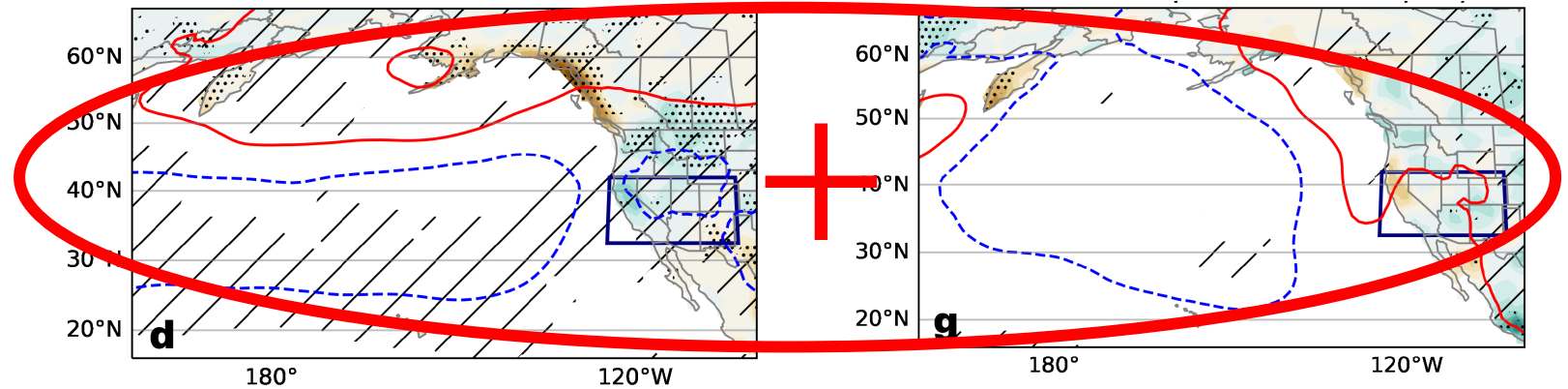
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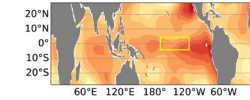
El Niño-like trend +RF



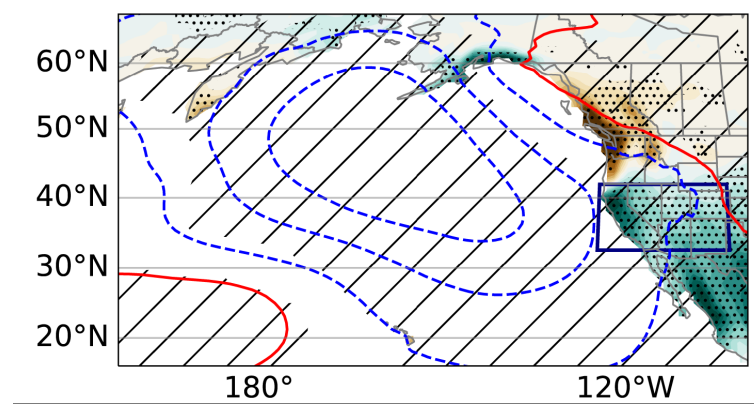
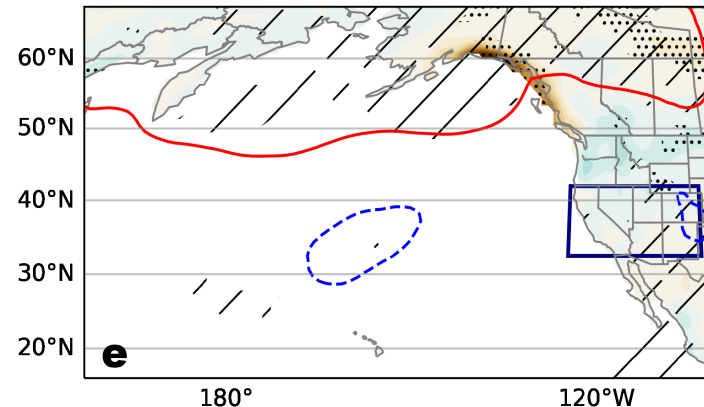
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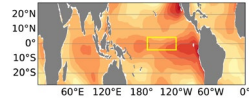
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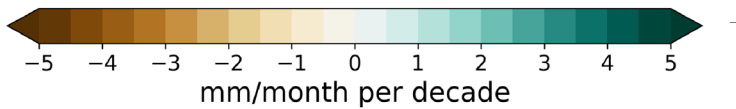
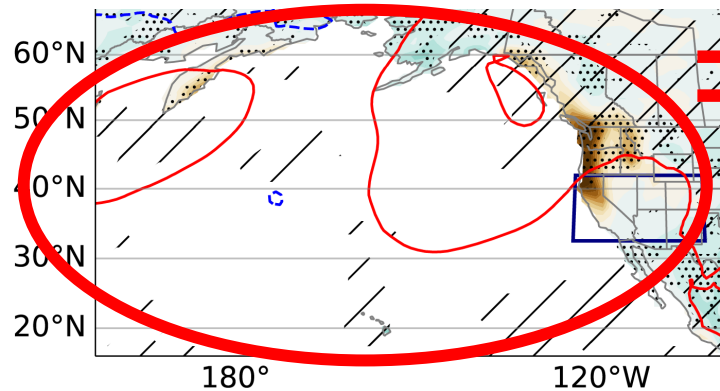
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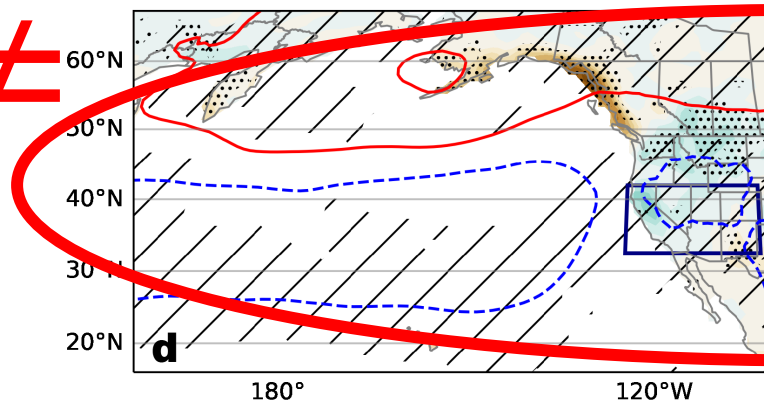
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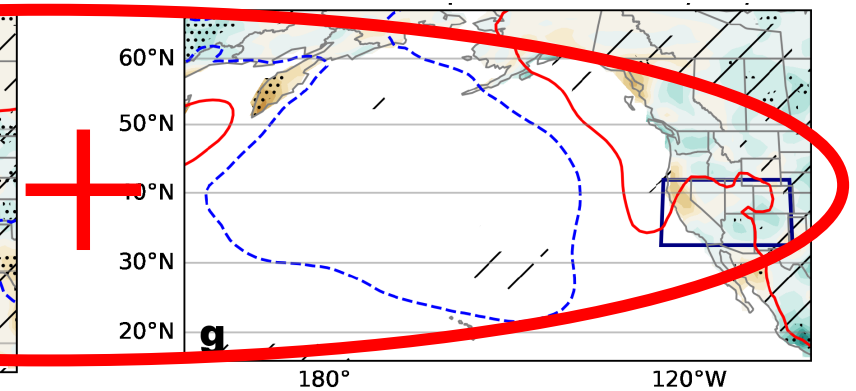
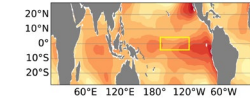
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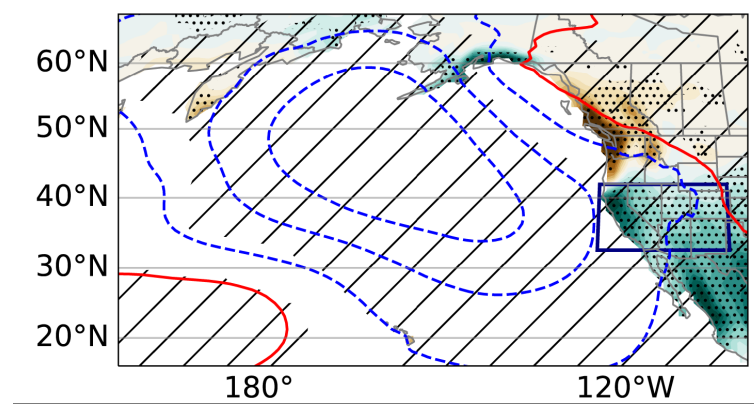
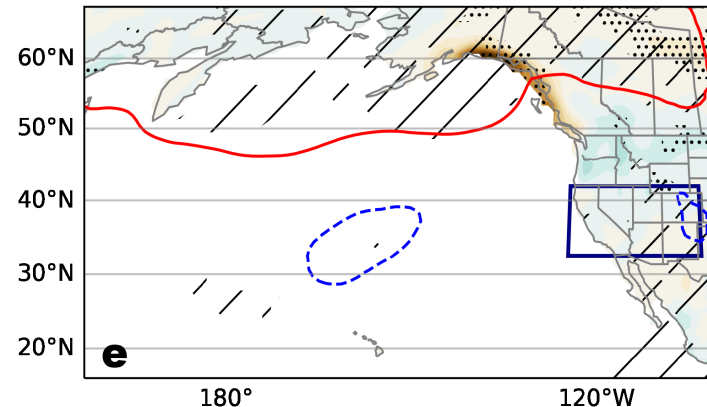
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El Niño-like trend w/o RF



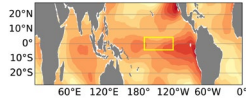
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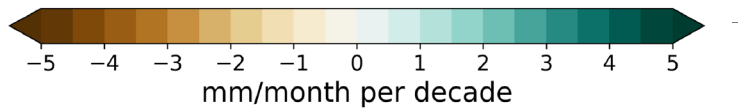
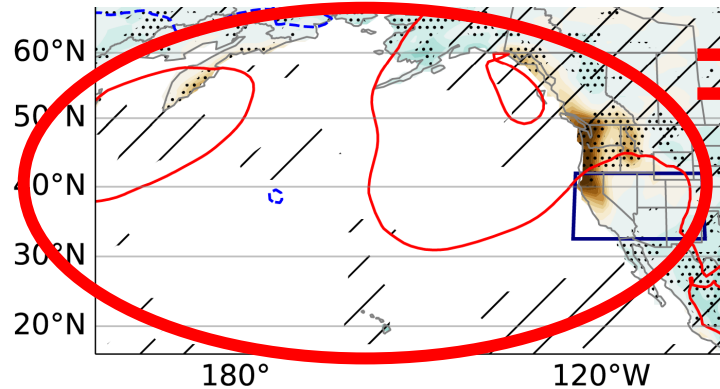
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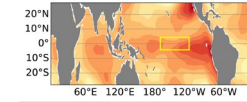
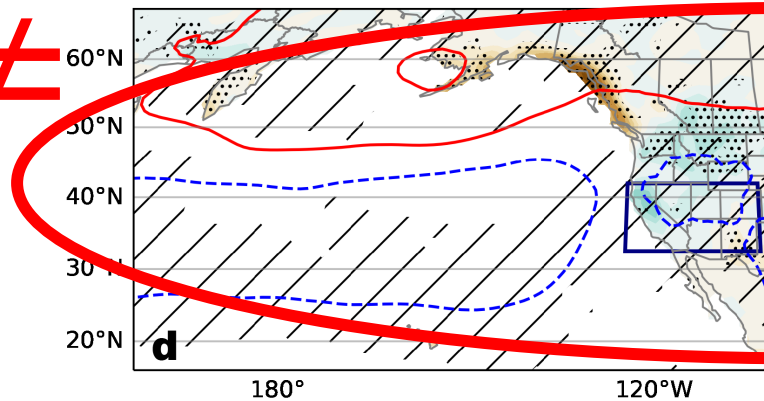
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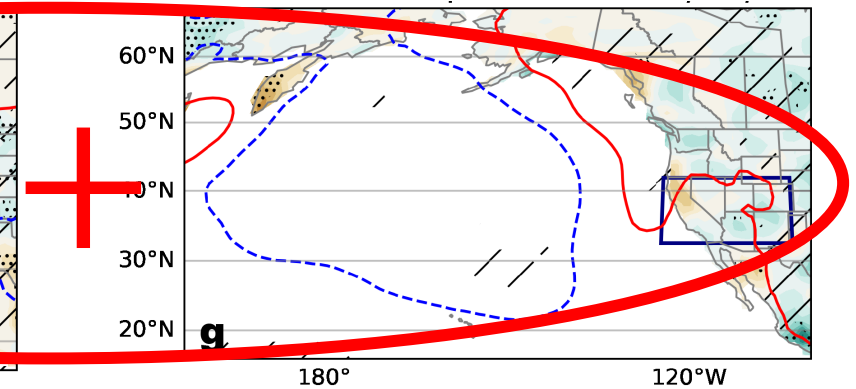
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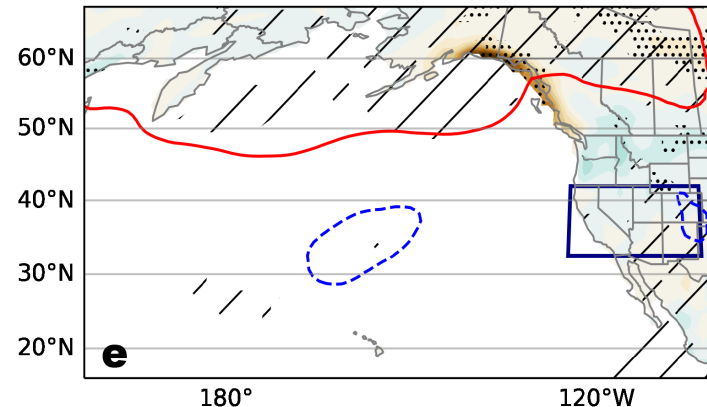
RF w/o SST trend



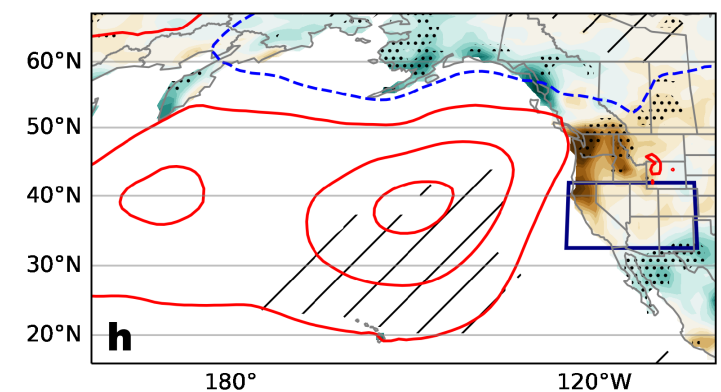
El Niño-like trend w/o RF



Anthropogenic aerosols (fully coupled)



Residual (nonlinearity)



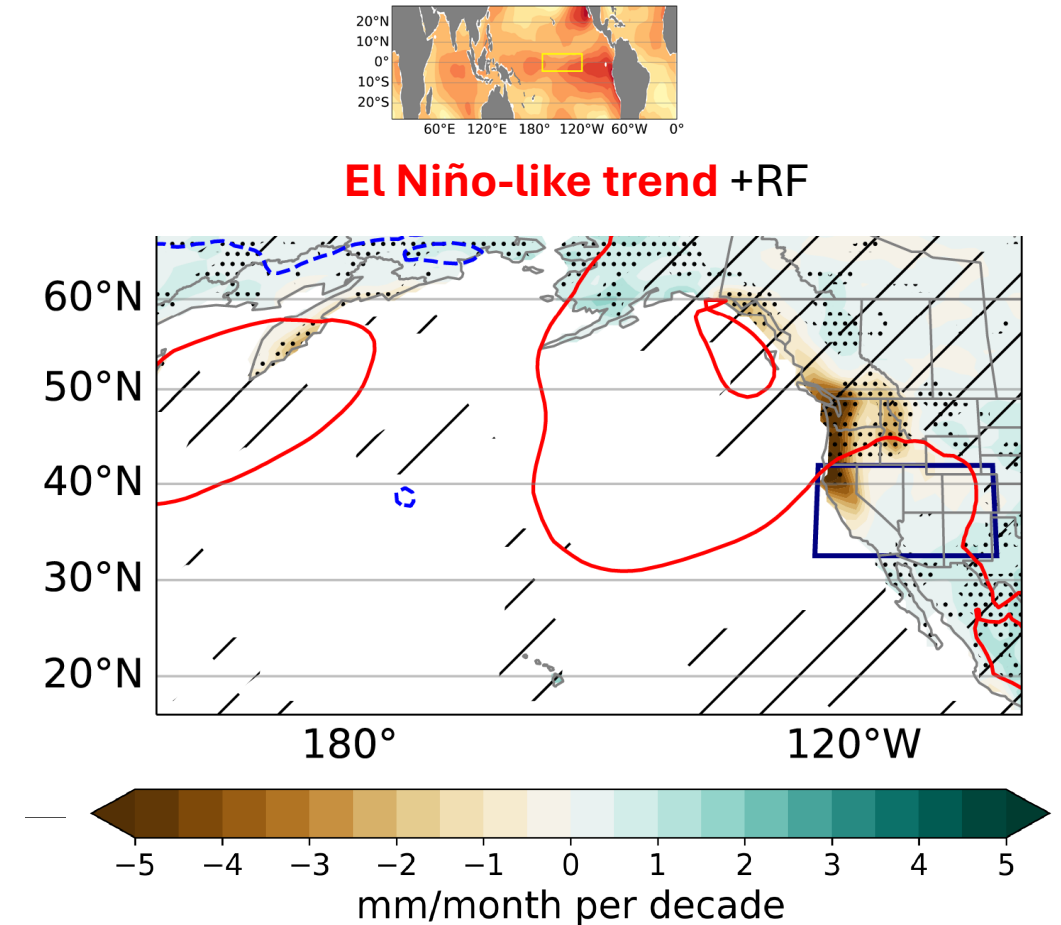
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- **Anthropogenic aerosols** and **mean tropical warming** combine to increase North Pacific sea level pressure, **reducing SWUS precipitation.**



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- **Anthropogenic aerosols** and **mean tropical warming** combine to increase North Pacific sea level pressure, **reducing SWUS precipitation.**
- The post-1980 SWUS drought was thus more inevitable than previously thought

