Parameterizing convectively-driven surface wind gusts in CESM

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AMWG

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https://ncas.ac.uk/our-science/climate-high-impact-weather/convective-storms/

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Deep convection initiates downdrafts that influence surface fluxes

- Gust fronts enhance near-surface turbulence and spur stronger latent and sensible heat fluxes (Garstang 1967; Jabouille et al. 1996; Redelsperger et al. 2020; Harrop et al. 2018; Rochetin et al. 2021)

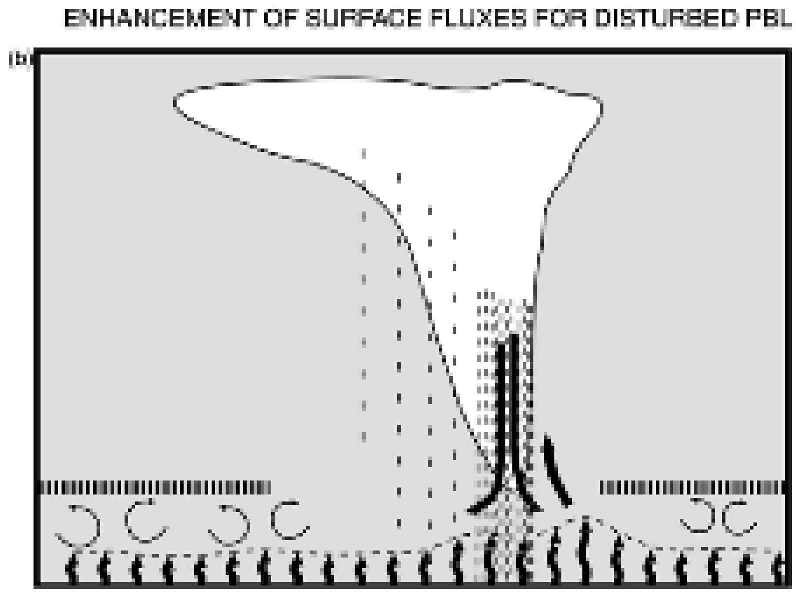

Fig. 1 of Redelsperger et al. (2000)

How can we capture the impacts of convective outflows on surface meteorology?

Observations

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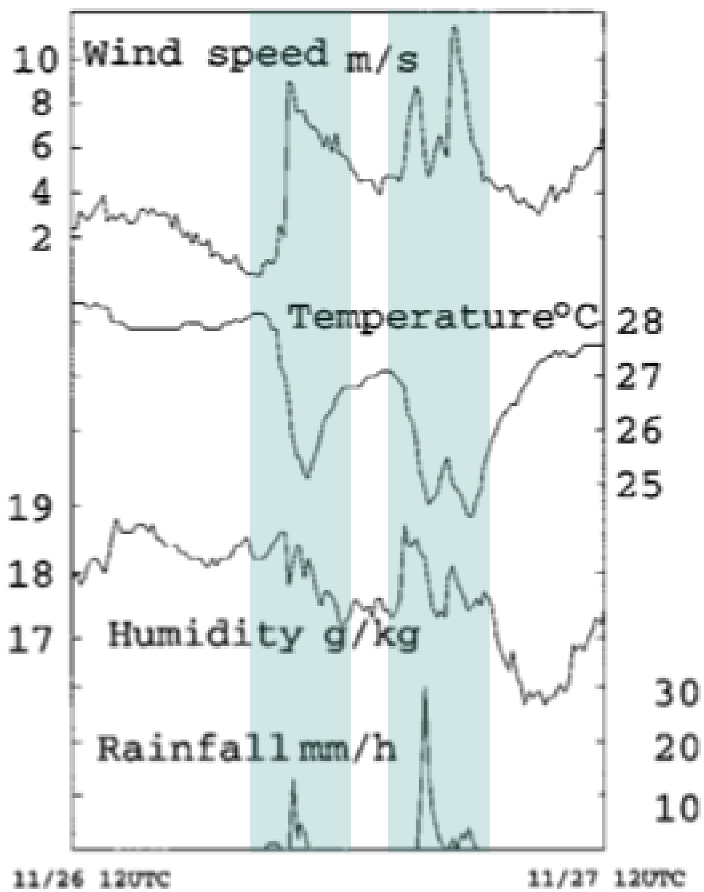


Figure 9 of Jabouille et al. (1996): Observed meteorological parameters during 24 hours of TOGA-COARE, recorded on board the Moana Wave.

Those TOGA-COARE observations have informed a parameterization of gust effects for ESMs

- Jabouille et al. (1996): combined observations and cloud resolving models (open and filled squares in figure)
- Redelsperger et al. (2000): expanded that analysis for 2 additional weeks and a squall line in a CRM
  - Also develop a fit based on updraft/downdraft MF

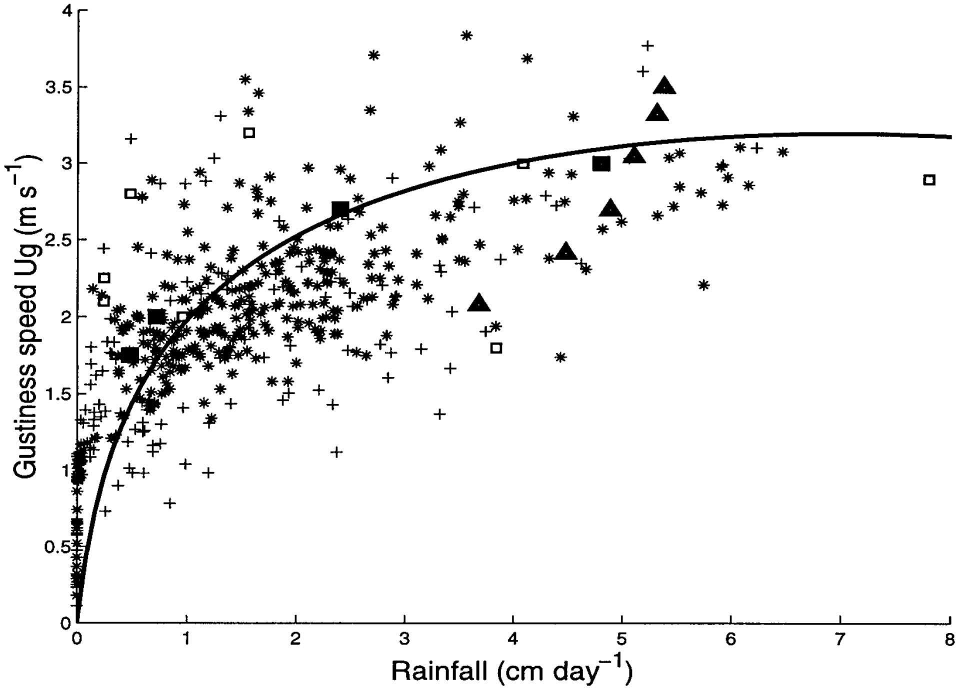


Figure 10 of Redelsperger et al. (2000): Observations (open square), and a series of CRM simulations from current study (,+, ^), and Jabouille et al. (solid squares).*

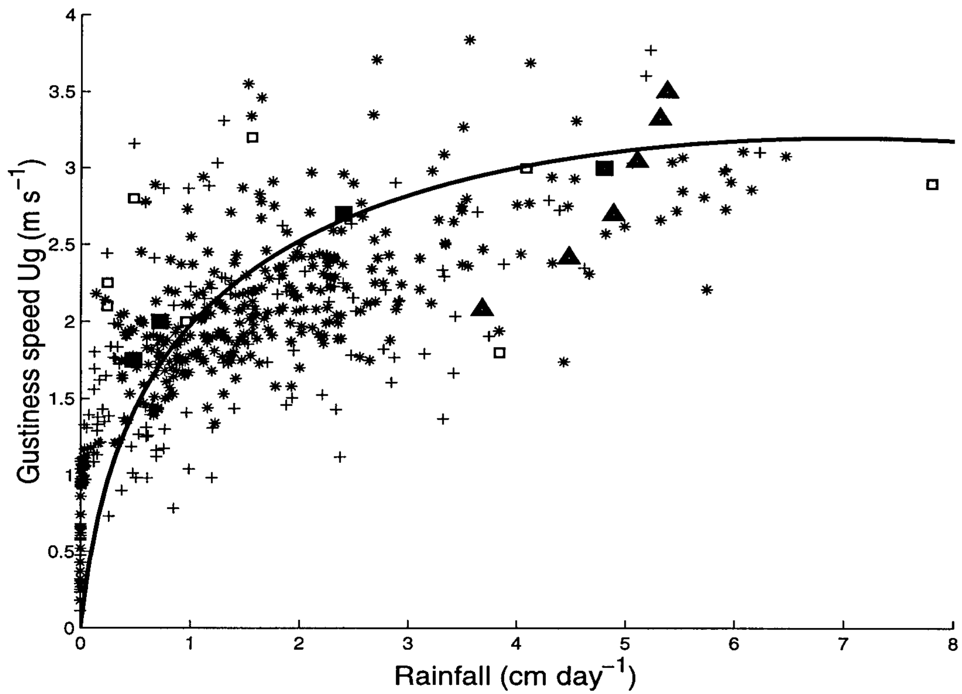
Those TOGA-COARE observations have informed a parameterization of gust effects for ESMs

$$U_g = \begin{cases} log(1 + 6.69R - 0.476R^2), & R < 6cm\ d^{-1} \\ 3.2ms^{-1}, & R \geq 6cm\ d^{-1} \end{cases}$$

$$\overline{U}^2 = U_0^2 + U_g^2. \quad *$$

$$\overline{U}^{X} = U_0^{X} + U_g^{X}.$$

Thanks to Adam Herrington & Sean Santos for highlighting



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$$\overline{U}^{\cancel{2}} = U_0^{\cancel{2}} + U_g^{\cancel{2}}.$$

Implemented in ESM model coupler (applies only over ocean)

$U10 = sqrt(u^2 + v^2) + Ug$

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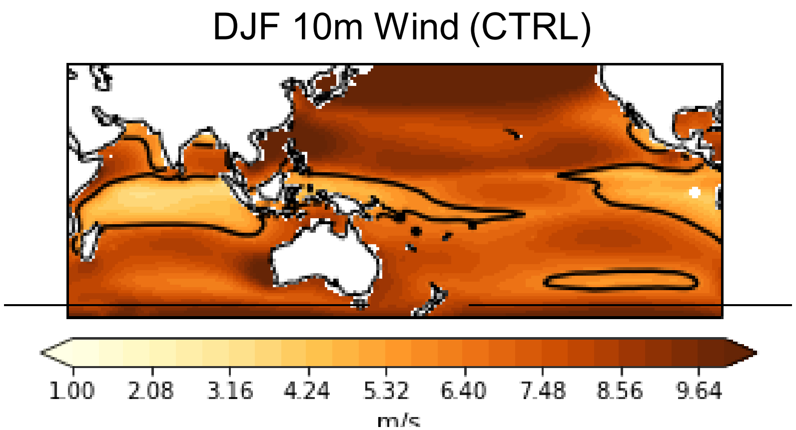
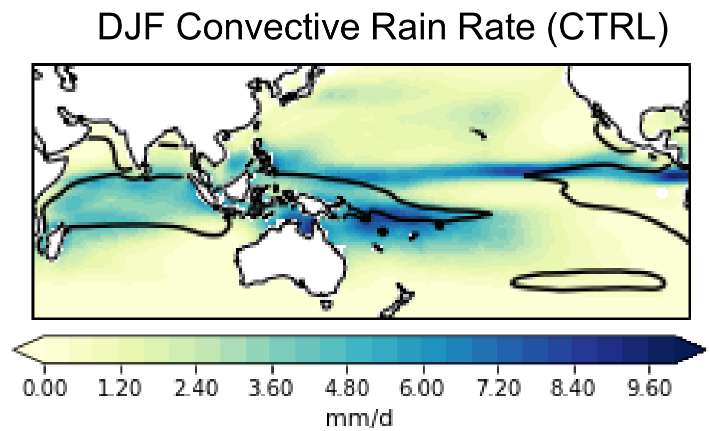
How do ESMs respond?

- First added to E3SM (*Harrop et al., 2018*) – improved precipitation biases in Tropical West Pacific (JJA)

The CESM implementation:
Where do gusts play a role?

- CTRL and GUST AMIP simulations with historical forcing 1996 - 2014 (58 levels, cam_dev physics)





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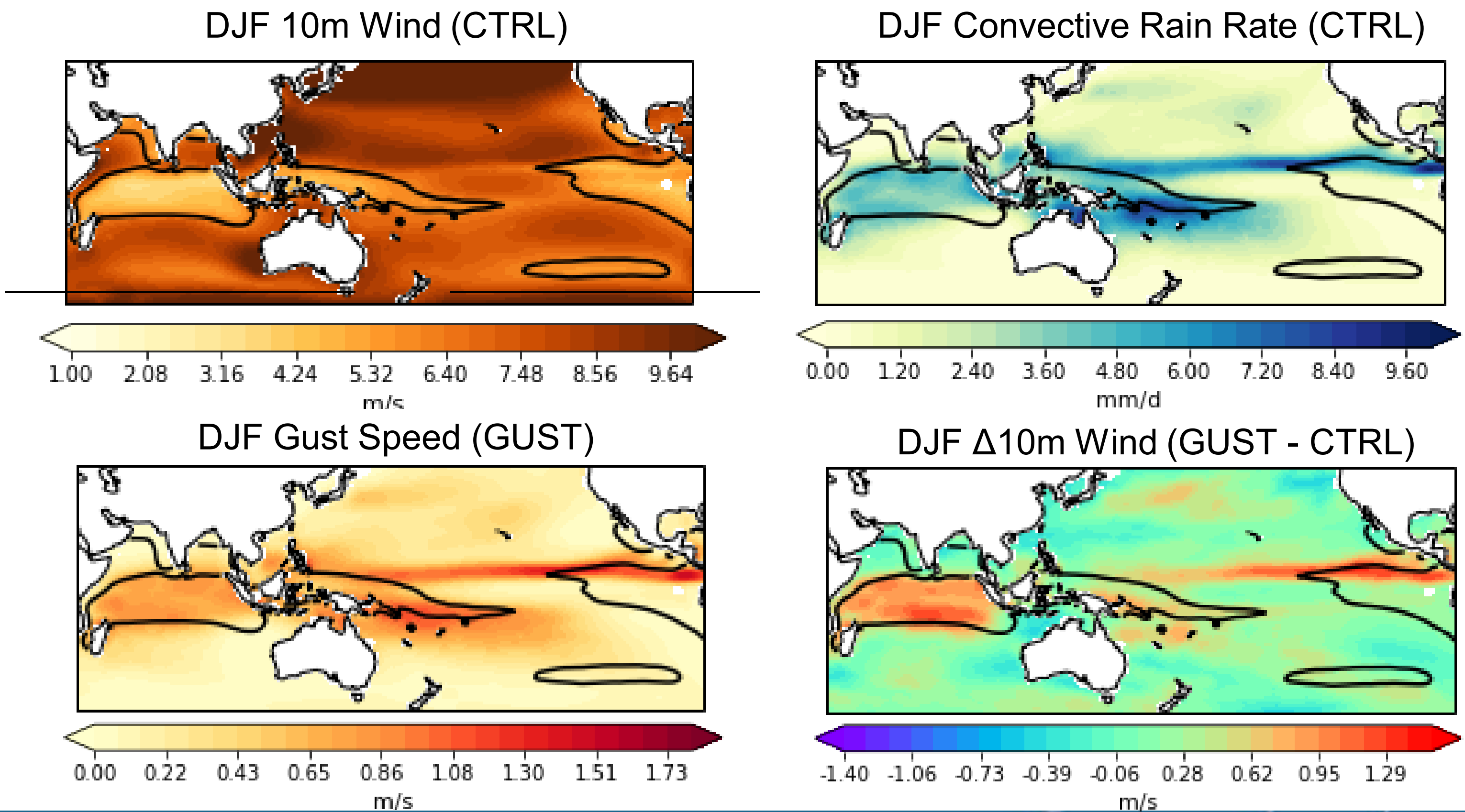

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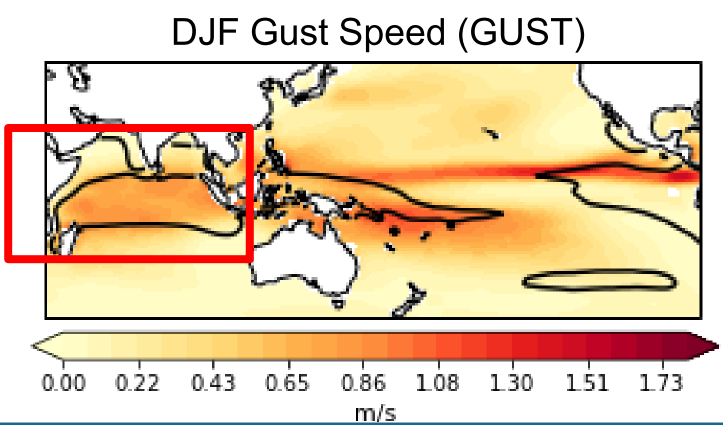
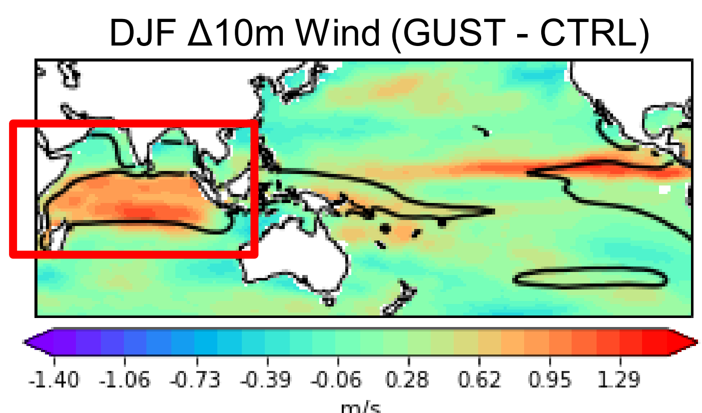
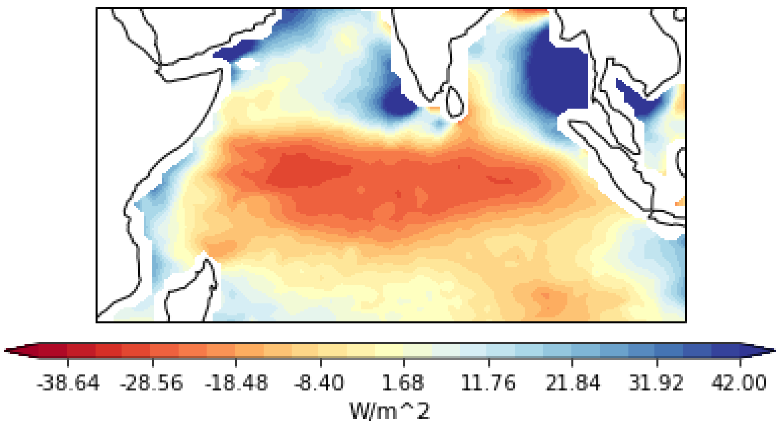
Indian Ocean



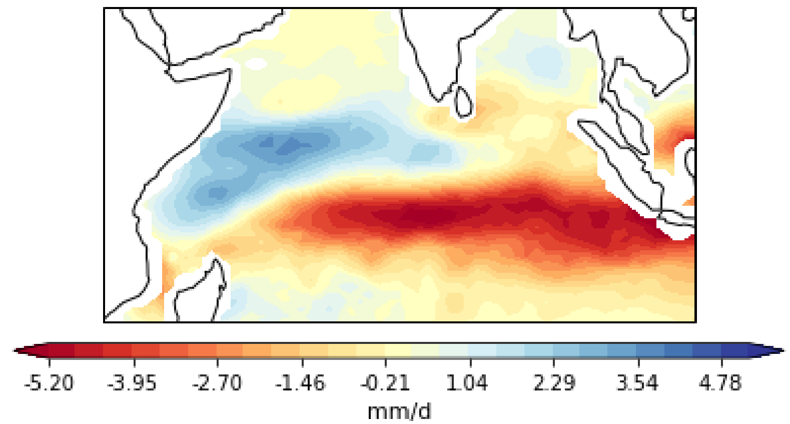


Indian Ocean biases have largely improved

DJF LHFLX (CTRL) Bias (from ERA5)



DJF PRECT (CTRL) Bias (from ERA5)



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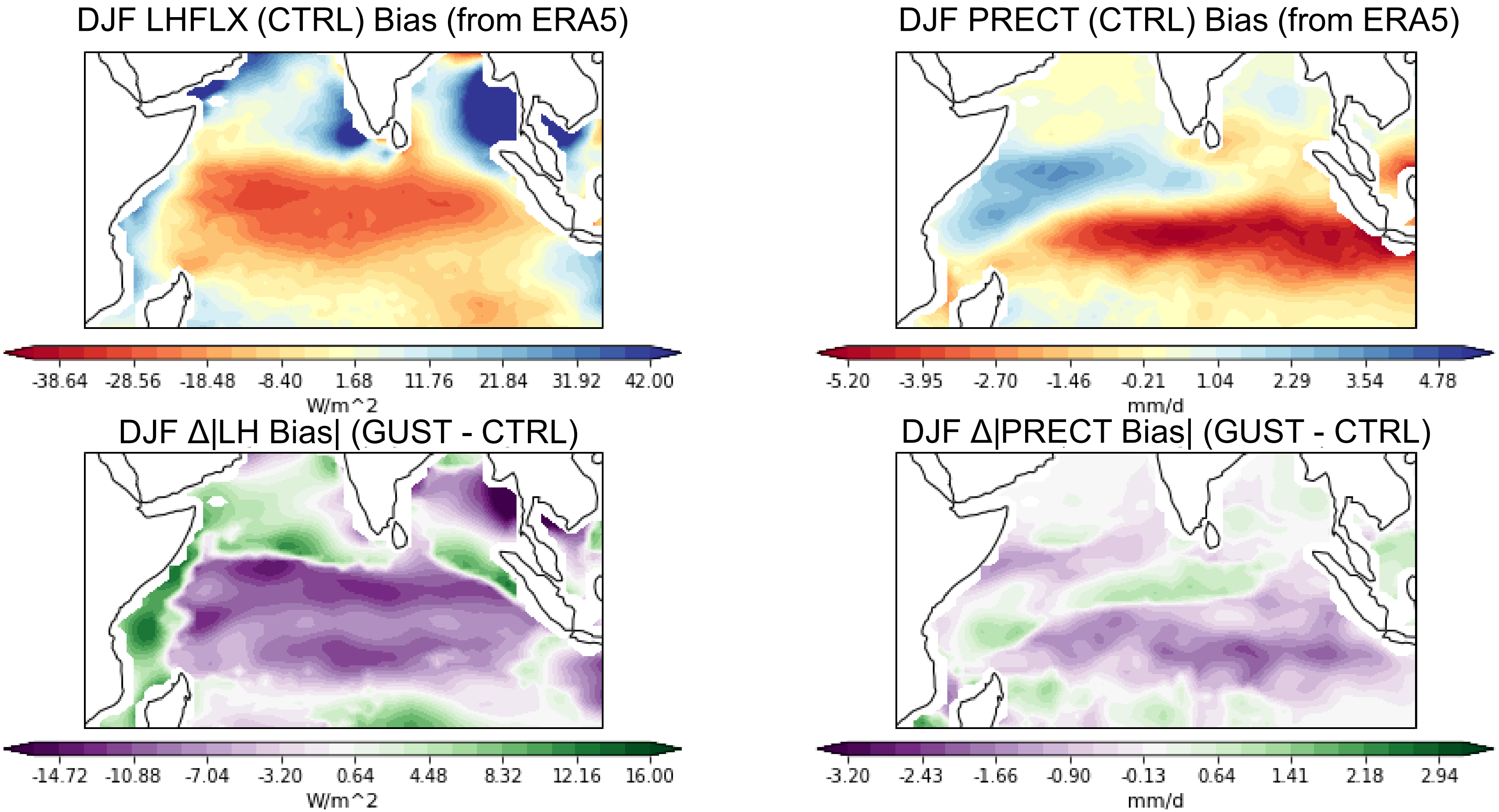

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Indian Ocean *West Pacific*

- Stronger U10 drives larger LHFLX (reducing dry bias)
- Encourages stronger vertical ascent, and more rainfall (reducing dry bias)

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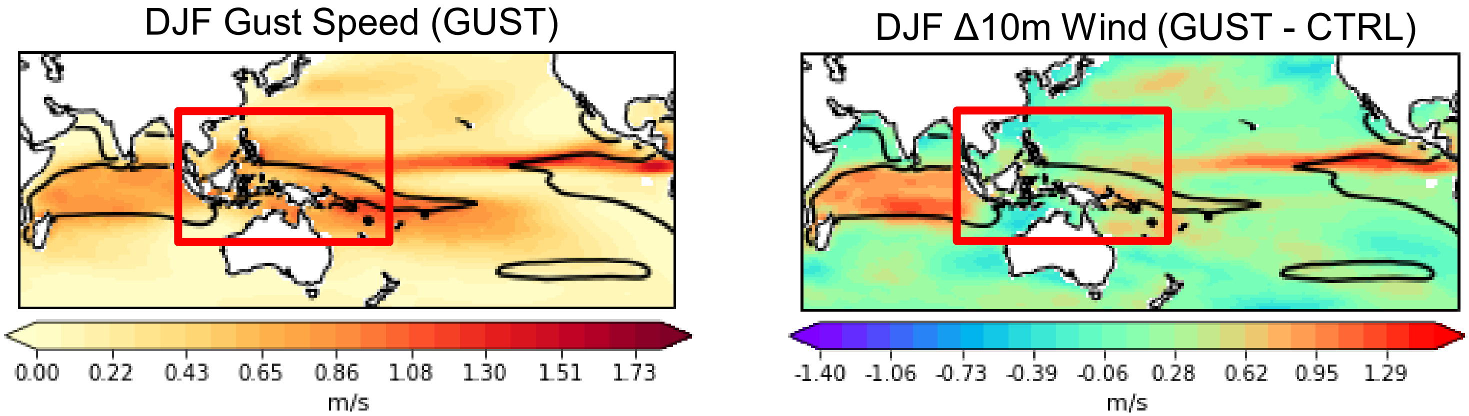
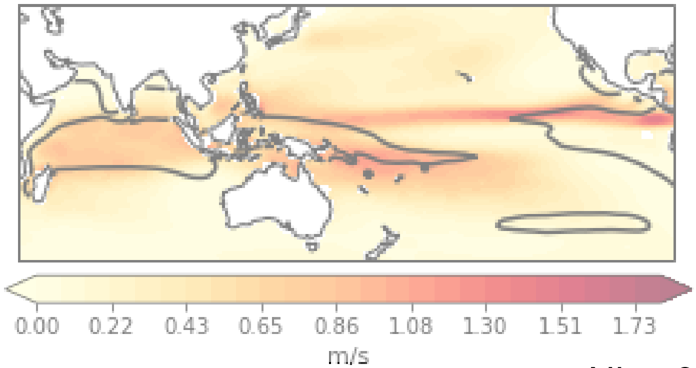
But wait… *was* there much of a change in the W Pac??

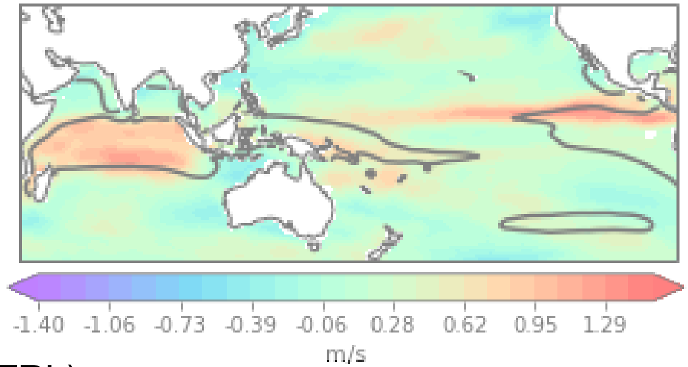


Does the response change depending on ENSO?

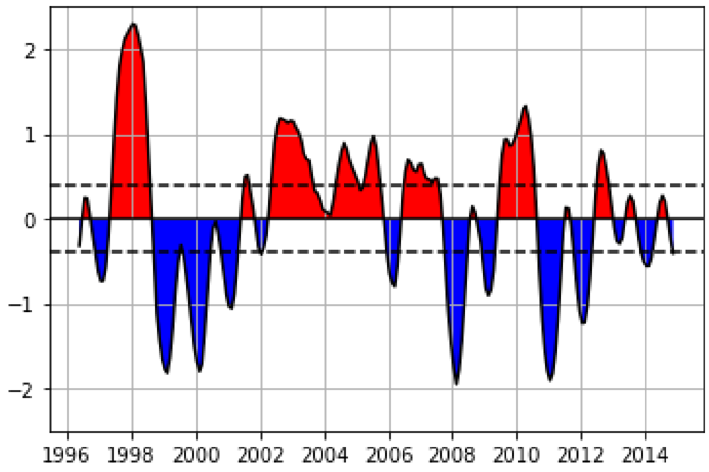
DJF Gust Speed (GUST)



DJF Δ10m Wind (GUST - CTRL)



Nino 3.4 (CTRL)



<u>DJF Months in each phase</u>

El Nino: 13

La Nina: 21

Neutral: 20

Signs point to yes

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Indian Ocean:

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West Pacific:

- U10 response differs based on ENSO phase
- Drives unique flux/rain responses as a result (not shown)

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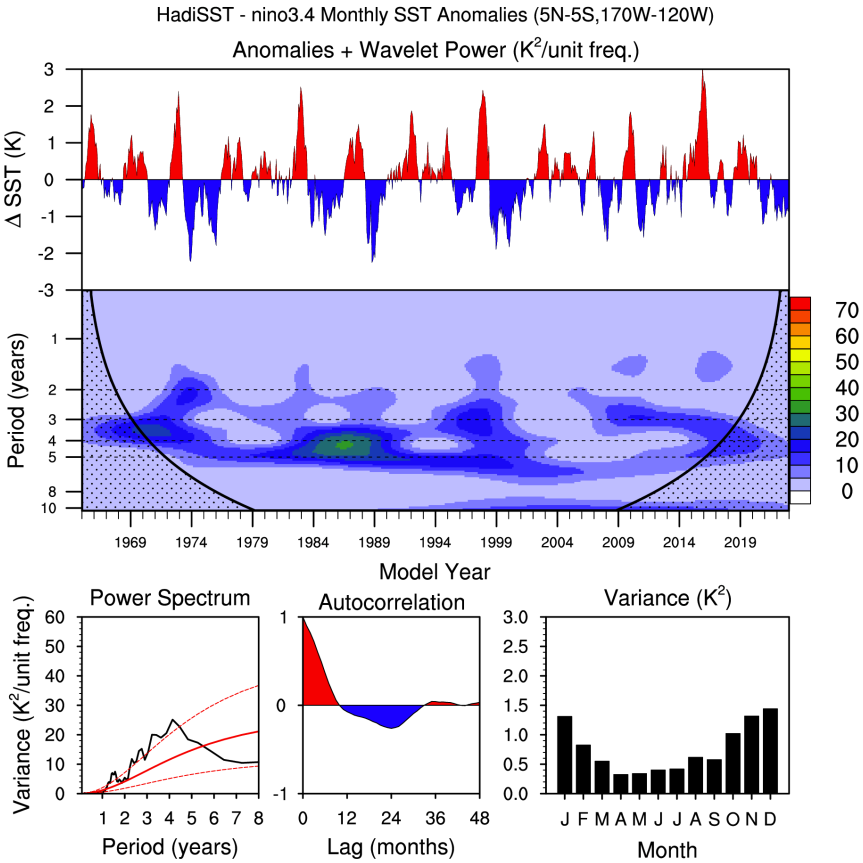
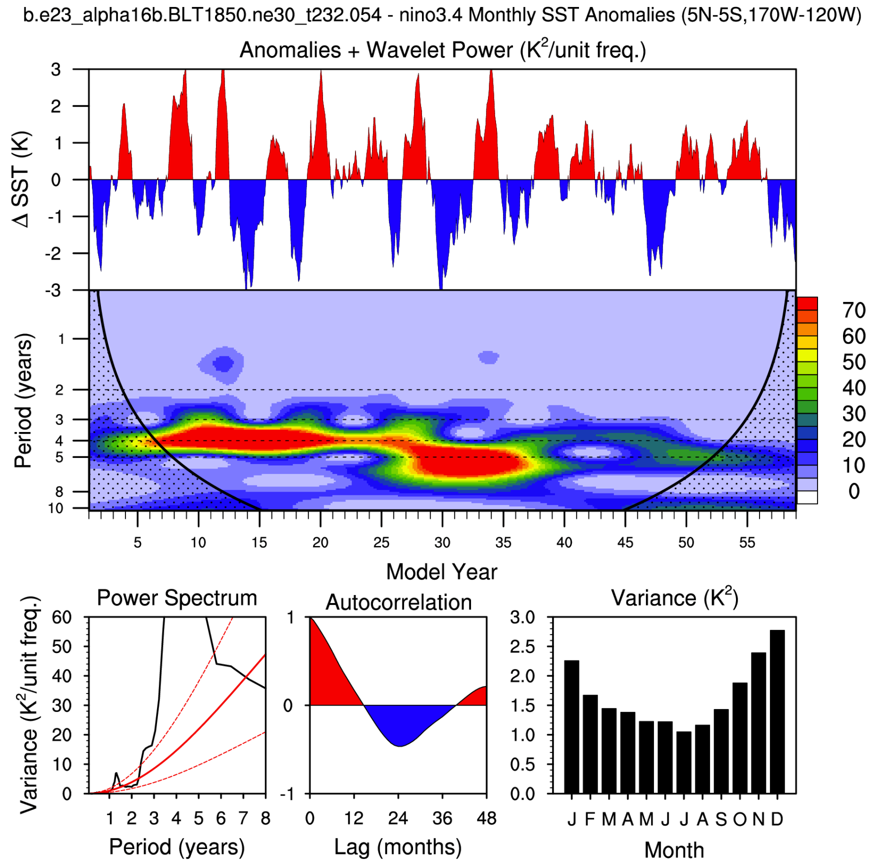
ENSO amplitude in previous CAM too strong

HadISST (obs., last 58 years)



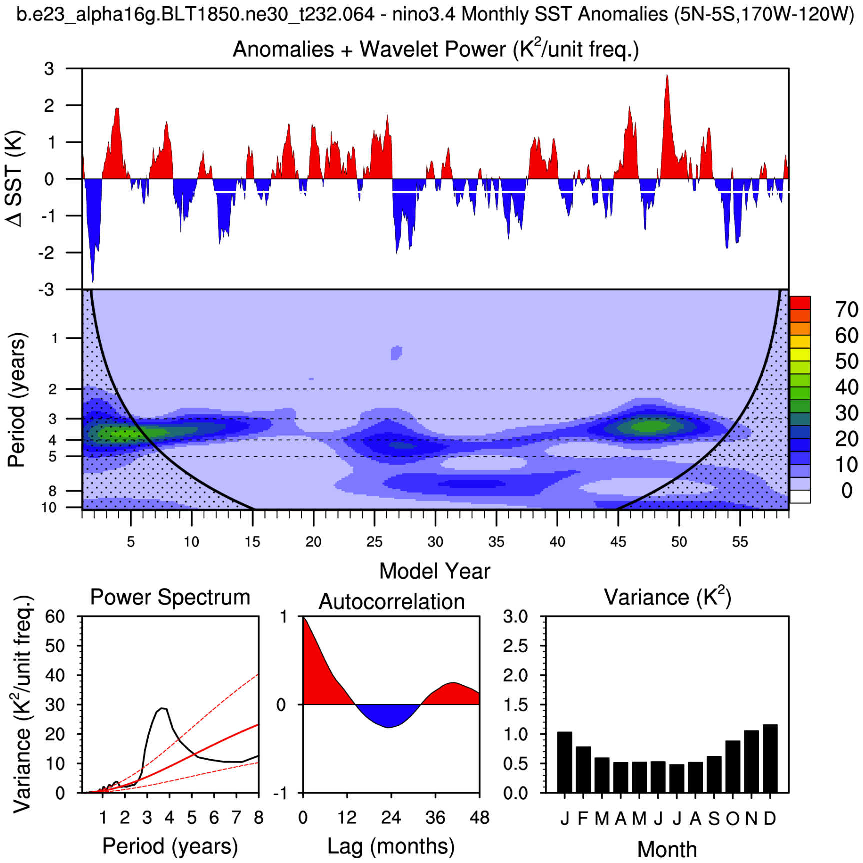
~Recent PI Control (#54)



Addition of gustiness reduces amplitude

Ongoing work to understand mechanism

#64 (#54 + Gustiness)



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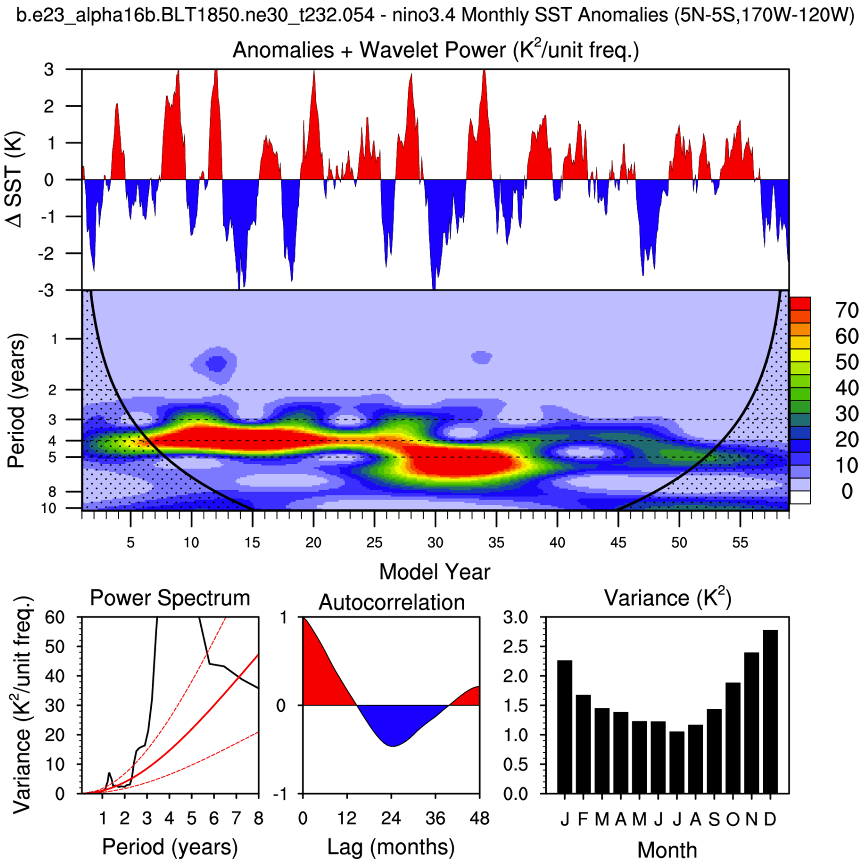

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- What’s the impact of changing the way U_g is added?
- How should this adapt to land?

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But enough encouraging signs that it's expected to be in CAM7

Thank you!

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