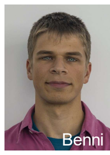
Can we tune parametrisations to reproduce relationships that control ENSO?

Mike Bell, Benni Buchenau, John Edwards (Met Office)



1. Introduction

Strong correlations (box 2) : Interannual variations in the net surface heat flux (NSHF) into the equatorial Pacific ocean are well correlated with the zonal wind stresses

Weak variances (box 3): But they are weaker in CMIP6 models than reanalysis products

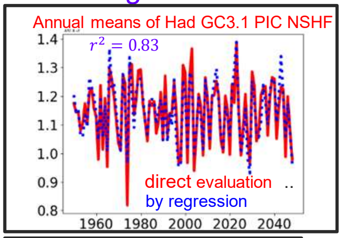
Does this matter? (box 4): It seems this may affect ENSO teleconnections

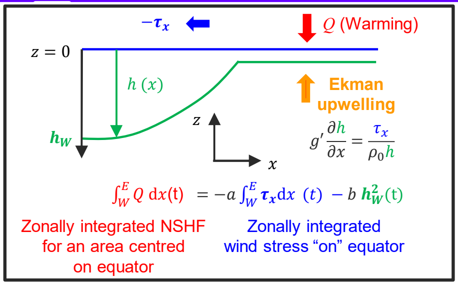
Spatial patterns of El Nino anomalies (box 5): in ERA5 and AMIP and coupled HadGEM3

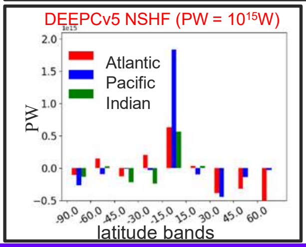
How heat flux components relate to SST (box 6): in eastern equatorial Pacific (Nino3) GC5

Summary and open questions (box 7) and References (box 8)

2. Strong correlations

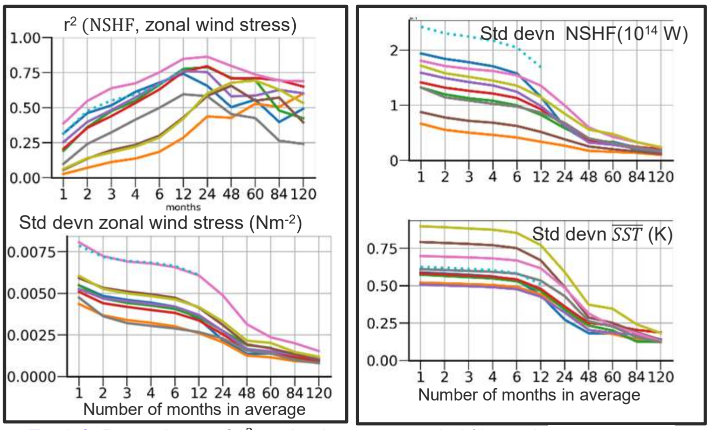




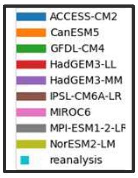


- Top left: Zonal wind stresses account for 83% of variance of annual mean NSHF fluctuations. Time-series are averages in red box in box 4 top left plot
- Top right: Steady state conceptual model of wind-driven ocean heat uptake on equator. This motivated the choice of time series
- Bottom left: The equatorial Pacific dominates the time-mean uptake of heat by the ocean (Forget & Ferreira 2019). The time-mean NSHF in CMIP6 models (box 3) ranges from 1 PW to 1.4 PW

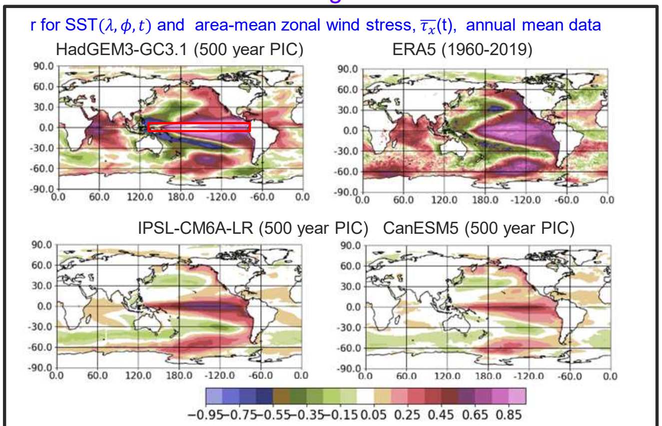
3. Weak CMIP6 NSHF and zonal wind fluctuations



- Top left: Dependence of r^2 on the time-mean period (1 month to 10 years) and the CMIP6 model for 500-year pre-industrial control (PIC) simulations for same area means as in box 2.
- Others: Same for standard deviations of NSHF (top right), zonal wind stress (bottom left) and SST (bottom right)
- Dotted blue curves based on ERA5 reanalyses. All CMIP6 models under-estimate the standard deviation of NSHF
- The standard deviations of depths of 20°C are very weak in HadGEM3 compared to EN4 (not shown)

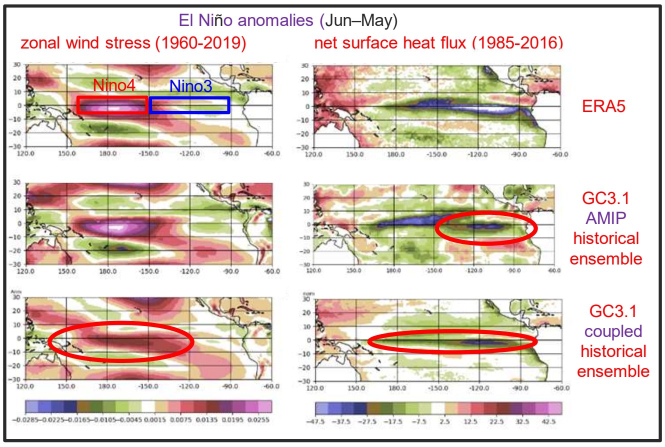


4. Does this matter?: Strength of teleconnections



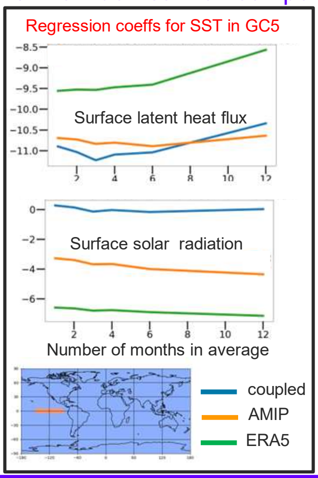
- Models with weak std devn NSHF (box 3 top right) have weak teleconnections
- Physically, heat sources rather than SST patterns drive atmospheric motions

5. Spatial patterns of El Nino anomalies



- AMIP El Nino zonal wind stress anomalies match ERA5 very well
- AMIP El Nino NSHF anomalies match ERA5 less well in eastern equatorial Pacific
- Coupled El Nino zonal wind stress anomalies are weaker than ERA5
- Coupled El Nino NSHF anomalies are very weak
- Coupled SST anomalies are well simulated (not shown)

6. How do heat flux components relate to SST?



- Co-variation of latent heat flux is stronger in GC5 than ERA5
- Co-variation of surface solar is very weak in coupled GC5 (and GC3.1)
- Time variations in surface sensible heat & long-wave are small
- The strength of NSHF variation with SST (feedback) varies widely across CMIP5 (Bayr et al 2018)
- Watanabe et al (2011) tune MIROC5 boundary layer and convection schemes to match SST, wind stress and NSHF variations

7. Summary and open questions

- The area-mean net surface heat flux (NSHF) into the equatorial Pacific ocean is well correlated with the zonal wind stress for annual to 5-year time-means in most CMIP6 models (boxes 2, 3)
- Interannual variations in these NSHFs and winds are weaker in CMIP6 models than ERA5 (box 3)
- Models with weak interannual NSHF variations in the equatorial Pacific seem to have weak ENSO teleconnections (box 4) Above results are described in more detail in Bell & Baker (2025)
- The El Nino NSHF anomaly in eastern eq. Pacific is weaker in GC3.1 AMIP than ERA5 (box 5)
- The regression coefficient for surface solar on SST in eastern eq. Pacific is weak in GC3.1 & GC3.5 AMIP and almost zero in coupled simulations. (box 6)

- Is the weak surface solar feedback closely related to the weak NSHF standard deviations?
- Does the strong latent heat feedback generate strong zonal pressure gradients (Lindzen & Nigam 1987) and influence recharging of the warm water pool ?
- Can perturbed parameter ensembles be used to explore and improve these feedbacks?
- Can adjustment of monthly mean feedbacks be used to tune ENSO behaviour?

8. References

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