Ocean Sci. Discuss.,
https://doi.org/10.5194/os-2020-102-AC2, 2021

Interactive comment on "Imprint of chaotic ocean variability on transports in the Southwest Pacific at interannual timescales" *by* Sophie Cravatte et al.

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Received and published: 2 January 2021

This paper described results from an ensemble of model simulations for the Southwest Pacific Ocean. The experiment design is very sensible, and clearly described. Readers might appreciate a few more details of how the ensemble was set up, but this is easily addressed. The authors analyse results from their ensemble to estimate how much interannual variability can be attributed to chaotic processes. They find that this can be 40-60% in some regions. This is higher than I expected. I wonder if there is a subtlety to their ensemble that needs to be considered. Specifically, I wonder whether there is a phase difference of interannual signals could be introduced between ensemble

members – owing to the different initial conditions – that could explain some of the differences they attribute to chaotic processes. The authors go some way to look at this with their analysis, but I think it would be worth looking at this before the paper is finalised. I expect that even if this is a factor, this study will be well worth publishing. It's very thought-provoking, and helps me think a bit differently about the circulation of this region. Some specific comments follow.

We thank the reviewer for his/her comments, that helped to improve the manuscript.

Re: ensemble perturbations Perhaps the readers would be grateful for a bit more information on the perturbations to the initial ensemble.

Yes, this is done. The draft mentioned: "the 50 members of the ensemble are generated in 1960 by activating a small stochastic perturbation in the equation of state within each member [Brankart et al. 2015; Bessières et al. 2017]. This perturbation is only applied for one year: it is switched off at the end of 1960, when the 50 members are restarted from slightly perturbed initial conditions and driven by the same atmospheric forcing." We changed to: "the 50 members of the ensemble are generated in 1960 by activating a small stochastic perturbation in the equation of state within each member (Brankart et al. 2015; Bessières et al. 2017). The small perturbations simulate the unresolved fluctuations of potential temperature and salinity. These fluctuations are generated using random walks [see Brankart et al., 2015 for details]. The initial perturbations are applied within each member for only one year in 1960: they are purely stochastic. The differences that grow between the members are therefore random by construction.."

Re: separation of interannual and chaotic variability According to equations (1), all deviations from the time-varying ensemble mean are considered part of the chaotic ocean variability. But I wonder whether there could be some phase differences between members that are deterministic and unrelated to chaotic signals. Perhaps the different initial conditions could have some influence on the timing of interannual changes. Perhaps that interannual variability is equivalent, but just offset by some phase. Using the calculations outlined in section 2.2, I suspect these would be wrongly associated with chaotic variability. I wonder if this could be checked by calculating the auto-correlation of transports, for example, at a few key locations to see if there is simply a phase-lag. Calculation of the coherence-squared and phase of the spectra may also help see whether this is a factor. The EOF analysis (Figure 9 and 10) could perhaps be extended to look at this. Maybe you could look closely at the PCs of modes that are analogous between members. Does this show any offset in phase? Maybe the authors would regard a shift in phase of an interannual signal as evidence of a chaotic process. If that's the case, I'm not sure I fully agree. Perhaps this could be more fully discussed in the paper.

We thank the reviewer for asking this important question. The small initial perturbations that are applied within each member during year 1960 are not just differences in phase: they are purely stochastic. These small perturbations are applied on the equation of state, and these random perturbations impact the geostrophic currents at the grid scale. Intrinsic variability is by construction seeded by small random fluctuations, which remain out-of-phase among the members and out-of-phase with the prescribed atmospheric variability throughout the run.

These small random velocity perturbations then progressively grow in amplitude due to oceanic non-linearities, generating the emergence of out-of-phase mesoscale perturbations among the members. As the ensemble spread tends to saturate in amplitude, the spatial and temporal scales of the intrinsic variability continue to grow (not shown) through non-linear inverse cascades of kinetic energy (Arbic et al. 2014; Sérazin et al (2018)). These are presumably the main processes that feed the interannual (small and large scale) intrinsic anomalies that we investigate.

To show that the transports in the various members are not just "offset by some phase", we computed the lagged correlations between low-frequency intrinsic variabilities of specific transports (time series in any member of this transport minus its ensemble

mean) within members i and j, with i=1-50 and j>i. For each couple (i,j) of members, we picked the maximum correlation C(i,j) with the associated lag lag(i,j). We thus obtained 49*50/2=1225 pairs of lag and correlations for these transports; as an example, we show the results for the SCJ 0-1000m transport as a scatterplot in the Figure below.

If intrinsic signals were just offset by some constant phase, one would find a lag for each (i,j) couple that would correspond to large (and significant) values of correlations C. If intrinsic signals actually have time-varying random phase differences, then the C values would be randomly distributed, presumably around zero.

Figures R1: scatterplot between the lag of the maximum correlation, and the maximum correlation between the interannual intrinsic variability of the SCJ transport in all ensemble members. Red points are significant at the 90% level. The red dashed line shows the average of the maximum correlation for all lags.

The results show that the intrinsic variabilities in certain couples of members are correlated, but that most members do not show a significant correlation, at any lag. The correlations seem randomly distributed, with widely and randomly distributed lags. It should be noted that we correlate two low-frequency timeseries with a limited number of degrees of freedom. We purposely pick the lags (from -24 months to 24 months) at which the correlations are different from zero, and that is why there are few occurrences of maximum correlation lower than 0.1. Also, some members do exhibit a significant correlation at 90% confidence, but this is far from systematic. This result shows that we can rule out a systematic shift in phase of the interannual signals. We added sentences on this in the text, in section 2.1, 5 and 6.

Re: definition of transports The term, "transport" is used to describe the "0-1000m integrated zonal and meridional transports . . . computed from monthly mean velocities". I presume the velocities are integrated over depth, yielding units of mËĘ2/s. This is consistent with the units in Figure 1 (mËĘ2/s). I would be happy to see this stated explicitly. Yes, Indeed. These are in fact vertically integrated currents. This is now explicitly stated. “0-1000m integrated zonal and meridional currents are computed from monthly velocities for each member. We call these quantities “vertically integrated transport”, and their unit is m2 s-1 . Âż This is a slightly unusual variable. It means that for the same “transport” value, points in coarser regions (eg at lower latitudes – at least for meridional transports) the volume transport is greater. Is there a reason why the volume transports are not used? These would simply require the multiplication of the zonal or meridional grid spacing, yielding units of mËĘ3/s.

This choice is made because it gives transports that are not dependent on the model grid size, and can thus be easily compared to observations (see Kessler and Cravatte, 2013) and other transports in models with $\frac{1}{2}^{\circ}$ or 1/12° resolution, for example. Otherwise, if multiplied by the meridional or zonal grid spacing, it would be less easy to interpret. Transports in Sv (m3/s) are more meaningful for zonal and meridional sections, as shown in Figure 4 (previously Figure 3).

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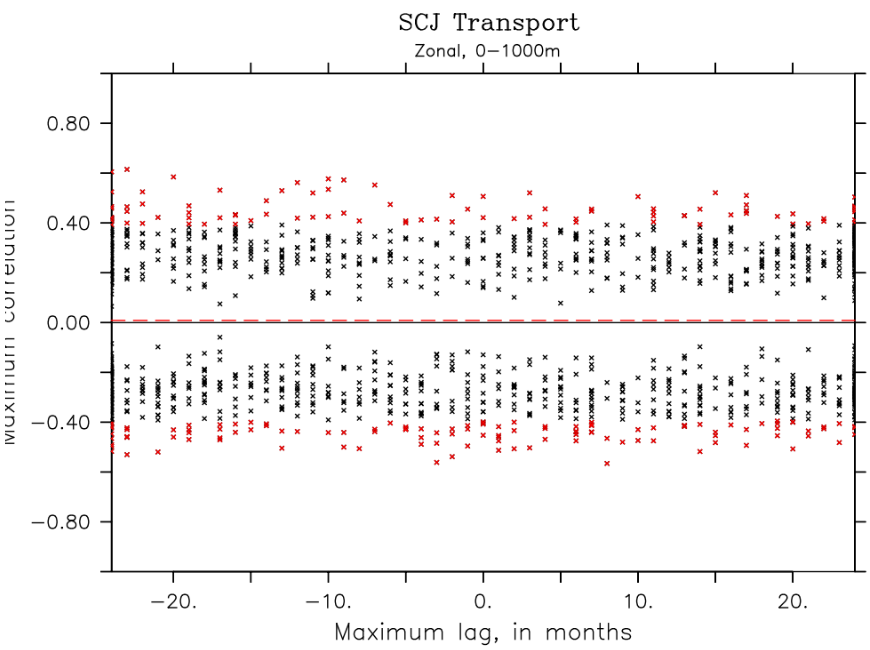

Fig. 1.