Predictability of Long-lived of Rossby Wave Packets during Southern Hemisphere Summer

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1) INTRODUCTION

Rossby Wave Packets or RWPs are synoptic scale perturbations located in the upper atmosphere of mid latitudes, these packets manifest as high amplitude meanders of the jet stream and travel by downstream development mechanisms, (Chang and Yu 1999; Chang 2000). They are linked to storm track variability (Souders *et al.*, 2014) and are considered as precursors of extreme weather events, such as extratropical cyclone development, (Chang *et al.*, 2005, Sagarra and Barreiro 2020), heatwaves, coldspells and extreme rainfalls, (Chang *et al.*, 2005; Grazzini and Vitart 2015). Under certain conditions, these packets can gain enough stability to last from several days to 2-3 weeks in the atmosphere before disappearing, when a RWP lasts more than 8 days in the atmosphere, it is referred as a long-lived RWPs or LLRWPs, (Grazzini and Vitart 2015). Because RWPs are linked to extreme weather events and atmospheric predictability, (Zeng and Colle 2013), an accurate representation of RWPs in numerical models is needed to obtain skillful middle range forecasts and improve extreme weather events detection between 10-30 days in advance.

Quiting and Vitart 2018 studied RWPs representation in sub-seasonal to seasonal models (S2S) for the Northern hemisphere (NH) winter, however, this study only focused on NH winter and did not consider the difference between long and short-lived packets. Recent studies characterized RWPs in the Southern Hemisphere (SH), and highlight that during austral summer, LLRWPs represent about 10 % of the total RWPs (Sagarra and Barreiro 2020, Perez *et al.*, 2021). This study aims to analyze the predictability of long-lived Rossby Wave Packets in S2S models by assessing their skill at forecasting the development of LLRWPs. To do so, we compared the observed LLRWPs trajectories tracked in ERA 5 reanalysis against the forecasted trajectories of LLRWPs in the S2S models, and studied under which conditions the models show high/low LLRWPs forecast skill.

2)METHODOLOGY

The datasets used in this study are the ERA 5 Reanalysis (Hans *et al.*, 2020), and reforecast datasets from the NCEP CFSV2 ensemble model, hereafter NCEP (Saha *et al.*, 2014), and CAS FGOALS f2 V1.3 model, hereafter IAP-CAS (Bao *et al.*, 2020). All datasets were regridded to a spatial resolution of 2.5º with daily frequency, and the length of the forecast was limited to 45 days. The time period of study is the SH austral summer, (December to March, hereafter DJFM) between 1999-2010.

We characterized RWPs in the reanalysis by computing the wave packet wind envelope at 300 hPa or V_{300env} (m/s), following the methodology of Perez *et al.*, 2021. Then, in order to track RWPs, we applied a tracking algorithm based in the maximum envelope technique (Grazini and Vitart 2015, Sagarra and Barreiro 2020, Perez *et al.*, 2021) to ERA 5 dataset. Next, we retain RWPs that lasted more than 8 days (LLRWPs), and saved their detection dates (Td). Afterwards, we downloaded reforecast datasets starting at days Td, and applied the tracking algorithm to register the forecasted trajectories of the LLRWPs or FRWPs. Then, we keep FRWPs that started their propagation between forecast lead days 1-3, and compared the characteristics of FRWPs against the observed LLRWPs.

3)RESULTS AND DISCUSSION

Figure 1 shows the zonal displacement between the FRWPs and the observed LLRWPs for the first 9 days of lifespan. FRWPs detected in the NCEP (IAP-CAS) model show an eastward (westward) bias that decreases as the simulation advances. A reduction of the bias with lead day suggests that FRWPs detected in NCEP (IAP-CAS) model propagate with slower (faster) speeds compared to observed LLRWPs.

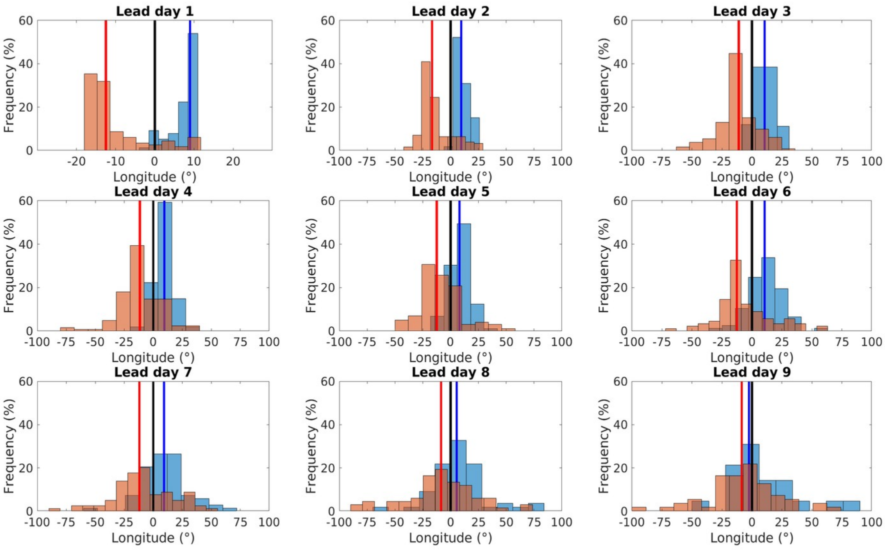

Figure 1: Frequency histogram of FRWPs displacement from the observed LLRWPs per lead day. Blue (red) bars show the results obtained for the IAP-CAS (NCEP) model. Positive (negative) bias signals that the FRWPs appear more eastwards (westwards) compared to the observed LLRWPs. Black lines signal the area of 0 bias whereas red (blue) lines show the median location of the FRWPs tracked in the ensemble mean for IAP-CAS (NCEP) model.

Figure 2 displays differences in V_{300env} between the observed LLRWPs minus the FRWPs in each lead day of simulation. In the initial conditions, NCEP model does not differ greatly from the reanalysis. However after the 1st week of simulation, the energy of FRWPs detected in NCEP model rapidly decreases. On the other hand, IAP-CAS underestimates the energy contained in the observed wave packets, specially after the 6th lead day.

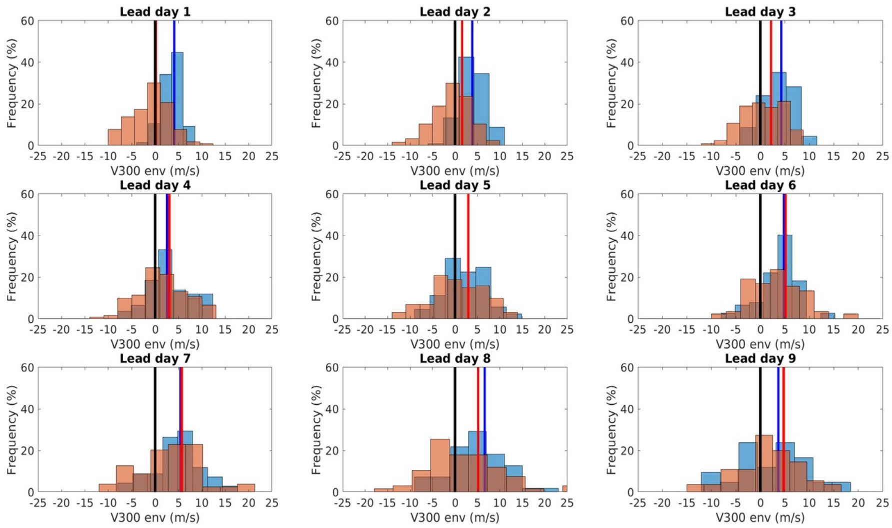

Figure 2: Analogous to figure 2, but for V_{300env} differences at the center of the wave packet on the observed LLRWPs against its forecasted trajectory. Positive (negative) values signal that the FRWPs have higher (lower) V_{300env} , thus, RWPs forecasted by the models are less (more) energetic compared to the observed LLRWPs.

Previous studies have shown that forecast models underestimates the potential vorticity fields where RWPs propagate, (Gray *et al*., 2014), as well as the strength and area of the waveguide with lead time (Gianaki and Martius 2016) at the NH. It is plausible to think that the same processes can be at work at the SH, therefore, LLRWPs forecast is limited to the synoptic scale.

Lastly, Figure 3 shows the difference between V_{300env} in the reanalysis 10 days after a observed LLRWPs begins its propagation minus its forecast during high and low skill simulations. We referred as low (high) skill simulations to those where 0 % (75 % or above) of simulations predicted a FRWPs that surpassed the 8 day threshold. Negative (Positive) values signal that the model overestimates (underestimates) the observed V_{300env}. For high skill simulations, IAP-CAS model does not differ greatly from the reanalysis. By contrast, NCEP model shows a similar structure for both high and low skill forecasts; forecasted V_{300env} is significantly higher than the observed in the reanalysis at the south-southwest of Argentina and South-Southeast of Indian Ocean. Nonetheless, high skill forecasts tend to show values of V_{300env} significantly higher in the area of maximum intensity of the jet stream. Therefore, high LLRWPs forecast skill simulations could be related to the apparition of very energetic RWPs, that manifest as broader amplitude meanders of the jet stream.

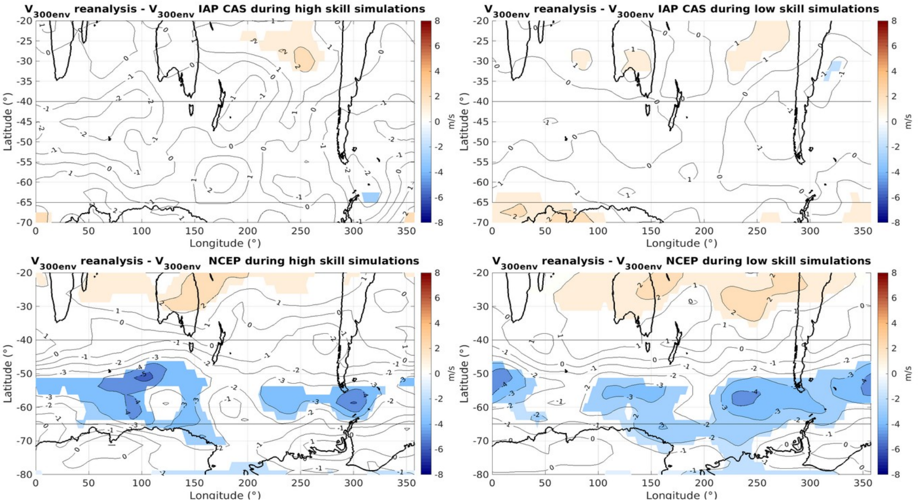

Figure 3: Differences of V_{300env} from the reanalysis during the first 10 days of LLRWPs propagation minus V_{300env} forecast from IAP (up) and NCEP (down) model for the first 10 days of forecast, retaining data from areas with at least 5 % of statistical significance. Orange (blue) areas signals that the forecasted V_{300env} is significantly lower(higher) than V_{300env} detected in the reanalysis.

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