Role of Tropical SST anomalies on the seasonal predictability of the Northern Hemispheric Winter of 2019/20

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INTRODUCTION

- The **winter of 2019/20** was marked by consistent seasonal forecasts from many operational systems (Lee et al. 2020), including the European Centre for Medium-Range Weather Forecasts (ECMWF) seasonal forecasting system (SEAS5).
- A **positive phase of the North Atlantic Oscillation (NAO)** and mild European winter, and the subsequently observed record warm conditions were well predicted. The situation was unusual in having a strong European forecast signal despite the lack of significant ENSO anomalies.
- A major anomaly preceding the DJF 2019/20 season was an **exceptionally strong positive Indian Ocean Dipole** event (Lu and Ren 2020), whose positive SST anomaly in the west Central Indian Ocean persisted into the winter and was well captured by SEAS5.
- Here, we carry out a series of attribution/deconstruction experiments to elucidate the **role of Tropical SST forcing** on European seasonal mean anomalies for winter 2019/20.

DATASETS and EXPERIMENTS

December-January (DJF) seasonal means from the following are used:

- **ERA5**: ECMWF Fifth Generation Reanalysis (ERA5) dataset (Hersbach et al. 2020).
- **SEAS5**: Operational coupled forecasts from the ECMWF Seasonal Forecasting System 5 (Johnson et al. 2019) initialised on 01-Nov-2019 with 51 ensemble members.
- **SEAS5-ObsSST**: Atmosphere-only experiment forced by daily ERA5 SST initialised on 01-Nov-2019 with 51 ensemble members. Identical in all other aspects to SEAS5.
- **ClimSST-IND**, **ClimSST-ATL**, **ClimSST-PAC**: Atmosphere-only experiments initialised on 01-Nov-2019 with 51 ensemble members. The daily SST forcing is replaced by daily climatology over the tropical Indian (ClimSST-IND), Atlantic (ClimSST-ATL) and Pacific Ocean (ClimSST-PAC) respectively. Identical in all other aspects to SEAS5.
- Seasonal climate anomalies are calculated relative to the 1981-2016 climatology.

SEASONAL CLIMATE ANOMALIES

- Both SEAS5 and SEAS5-ObsSST predicted the DJF 2019/20 seasonal anomalies well, particularly in the Euro-Atlantic sector (Figure 1). An exception was the inability to capture the cold anomaly over Alaska (Figure 1e).

- In view of the good performance of the SEAS5 winter forecast for the positive NAO, a series of attribution experiments were conducted to isolate the impact of various tropical SST anomalies on the DJF 2019/20 response.

- In these forced SST experiments, the observed anomalies were replaced by climatology over the tropical Indian (ClimSST-IND), Atlantic (ClimSST-ATL) and Pacific (ClimSST-PAC) Ocean basins (see boxes in Figure 1a above).

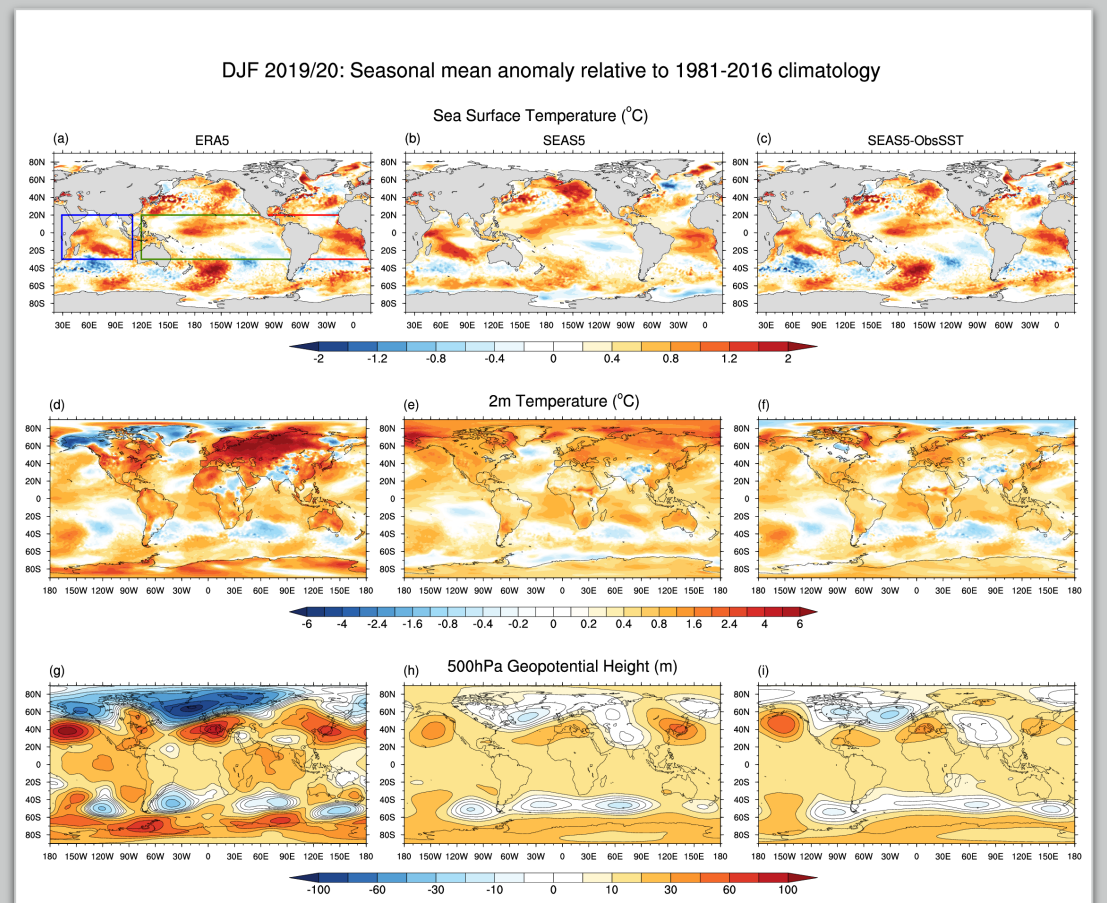

Figure 1: DJF 2019/20 seasonal mean anomaly relative to 1981-2016 climatology: (a-c) SST (d-e) 2m Temperature (g-i) 500 hPa Geopotential height in ERA5 (left columns), SEAS5 (middle columns) and SEAS5-ObsSST (right columns). The tropical ocean domains over which the SST anomalies were replaced by climatology are marked in colour.

ROLE OF TROPICAL SST HEATING

- The difference between SEAS5-ObsSST and the regional SST attribution experiments (CLIMSST-XXX) shows the impact of the regional tropical heating anomaly on the DJF 2019/20 response:
- The impact of the Indian Ocean SST anomaly is consistent with a response to the diabatic heating in the Indian Ocean (Figure 2a) that drives both a local cross-equatorial Hadley-cell response (Figure 2g, Baker et al., 2018) and northern hemispheric circulation changes, with a strong projection onto a positive NAO pattern.
- The impact of the Pacific SST anomaly is in the form a North Pacific short-wave train (Figure 2i) that is usually associated with ENSO-related tropical Pacific SST anomalies (Chen, 2002). This response appears to cause the erroneous warm anomalies over Alaska (Figure 2c).
- Compared to the Indian and Pacific anomaly, the response to the Atlantic SST anomaly is weaker (Figure 2 b,e,h).

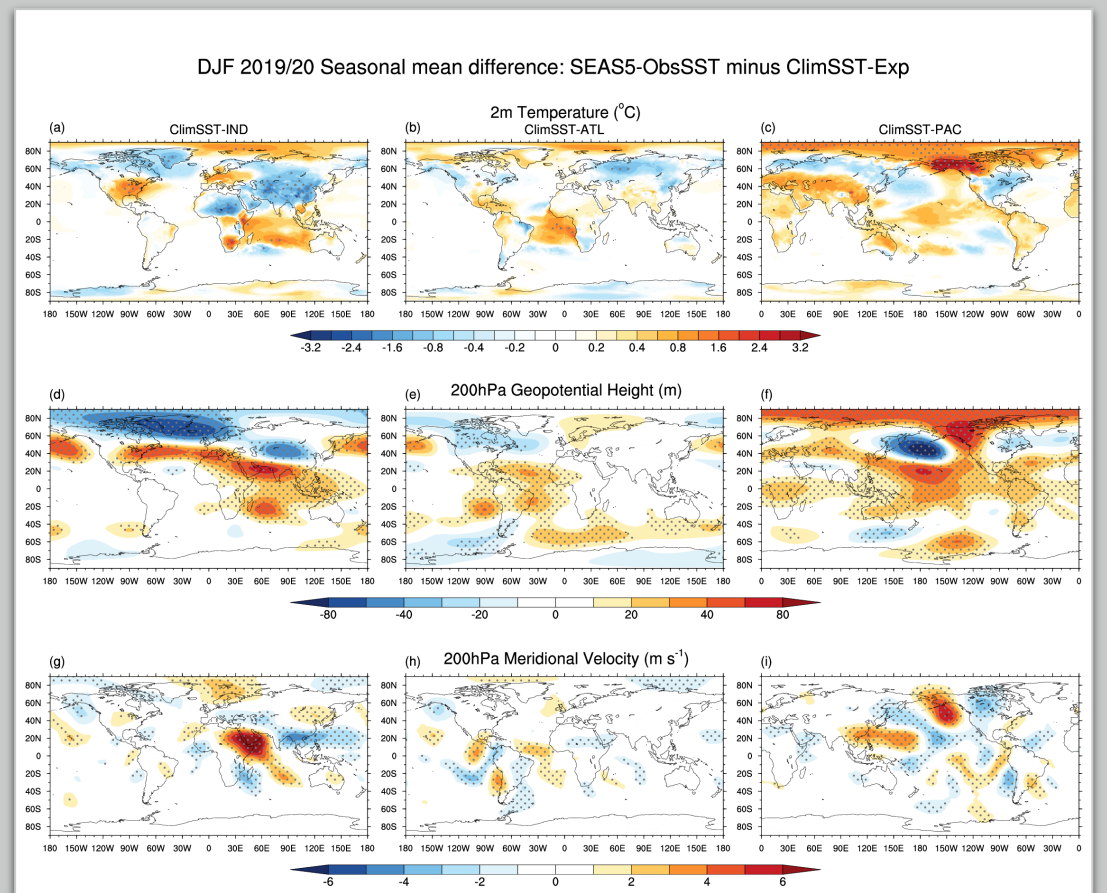

Figure 2: DJF 2019/20 seasonal mean difference of SEAS5-ObsSST relative to experiments with regional climatological SSTs: (a-c) 2m Temperature (d-f) 200 hPa Geopotential height (g-i) 200 hPa Meridional velocity in the SST sensitivity experiments: ClimSST-IND (left columns), ClimSST-ATL (middle columns) and ClimSST-PAC (right columns). Stippled areas are significant at 95% based on a Students' T-test.

DISCUSSION and CONCLUSIONS

- Past studies have demonstrated the important role of the Asian mid-latitude jet waveguide in mediating tropical-extratropical teleconnections that affect the positive phase of NAO via eastward propagating Rossby waves (e.g., Bader and Latif 2005; Fletcher and Cassou 2015).
- Such a mechanism is one of the pathways identified in the study of Hardiman et al. (2020) who show that the strong positive IOD event of October-November 2019 was a key driver of the NAO response in Winter 2019/20. Our attribution experiments show that the persistent diabatic heating of the tropical Indian Ocean in DJF associated with the positive IOD is a key driver of the DJF NAO response. However, our results do not show evidence of an eastward Rossby wave response to the tropical Indian Ocean heating.
- A plausible alternative teleconnection pathway involves an equilibrium response by which the rotational flow compensates the divergent circulation, and it is associated with a direct influence on the curvature of the jet over Central Asia. This direct westward path does not involve the jet acting as waveguide and could explain the exceptionally strong response and seasonal predictability during this year.
- Further experimentation and analysis are underway to ascertain the role of seasonal mean state in comparison to regional heating anomaly on the extra-tropical response.

References

- *Bader J, Latif M (2005) North Atlantic Oscillation Response to Anomalous Indian Ocean SST in a Coupled GCM. J Clim 18:5382–5389. https://doi.org/10.1175/JCLI3577.1*
- *Baker HS, Mbengue C, Woollings T (2018) Seasonal Sensitivity of the Hadley Cell and Cross-Hemispheric Responses to Diabatic Heating in an Idealized GCM. Geophys Res Lett 45:2533–2541. https://doi.org/10.1002/2018GL077013*
- *Chen T-C (2002) A North Pacific Short-Wave Train during the Extreme Phases of ENSO. J Clim 15:2359–2376. https://doi.org/10.1175/1520-0442(2002)015<2359:ANPSWT>2.0.CO;2*
- *Fletcher CG, Cassou C (2015) The Dynamical Influence of Separate Teleconnections from the Pacific and Indian Oceans on the Northern Annular Mode. J Clim 28:7985–8002. https://doi.org/10.1175/JCLI-D-14-00839.1*
- *Hardiman SC, Dunstone NJ, Scaife AA, et al (2020) Predictability of European winter 2019/20: Indian Ocean dipole impacts on the NAO. Atmospheric Sci Lett 21:e1005. https://doi.org/10.1002/asl.1005*
- *Hersbach H, Bell B, Berrisford P, et al (2020) The ERA5 global reanalysis. Q J R Meteorol Soc 146:1999–2049. https://doi.org/10.1002/qj.3803*
- *Johnson SJ, Stockdale TN, Ferranti L, et al (2019) SEAS5: the new ECMWF seasonal forecast system. Geosci Model Dev 12:1087–1117. https://doi.org/10.5194/gmd-12-1087-2019*
- *Lee SH, Lawrence ZD, Butler AH, Karpechko AY (2020) Seasonal Forecasts of the Exceptional Northern Hemisphere Winter of 2020. Geophys Res Lett 47:e2020GL090328. https://doi.org/10.1029/2020GL090328*
- *Lu B, Ren H-L (2020) What Caused the Extreme Indian Ocean Dipole Event in 2019? Geophys Res Lett 47:e2020GL087768. https://doi.org/10.1029/2020GL087768*