ETH zürich

Institute for Atmospheric and Climate Science

Validation of extratropical cyclone characteristics in sub-seasonal ECMWF forecasts

Dominik Büeler[1], Michael Sprenger[2], Heini Wernli[3]
[1]Institute for Atmospheric and Climate Science, ETH Zurich

1 Introduction

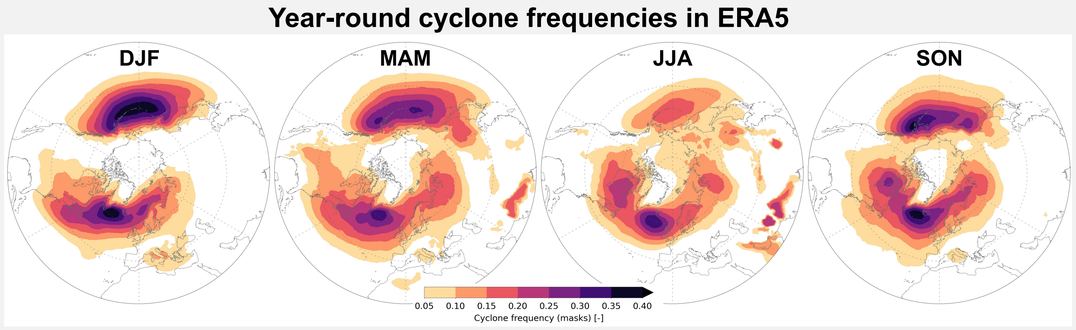
- Meaningfully, lots of research regarding **sub-seasonal prediction (~ 15-60 days)** is done on how lower-frequency planetary-scale processes (stratosphere, MJO, ENSO, …) drive/influence sub-seasonal predictability and forecast skill (e.g., Vitart & Robertson, 2019).
- Although **higher-frequency synoptic-scale processes, most importantly extratropical cyclones**, are driven by sub-seasonal variability, **they feed back upscale and can even actively influence onset, maintenance, and decay of weather regimes** (e.g., Hoskins 2013, Rivière & Orlanski 2007, Grams et al. 2011). Furthermore, they **drive the variability of surface weather.**
- This ongoing study thus for the first time investigates **how well year-round extratropical cyclone life cycle characteristics are captured by sub-seasonal ensemble (re)forecasts**.
- Understanding cyclone biases might help to further improve the still moderate to weak sub-seasonal forecast skill (e.g., Büeler et al. 2021).

2 Data and methods

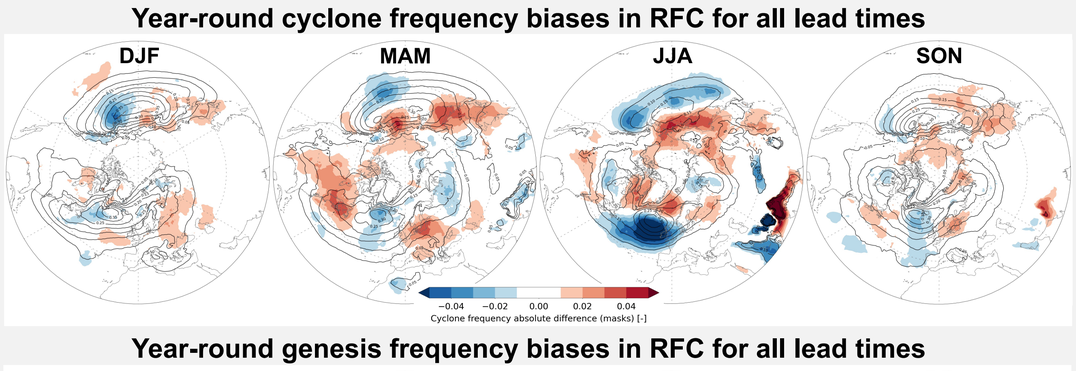
- **ECMWF sub-seasonal ensemble reforecast (RFC) data**: 2060 RFCs over 21 years (2000-2020), 10 members, initialized twice-weekly from ERA5, 46d lead time, retrieved with 6h and 1° resolution, versions CY46R1 and CY47R2; **ERA5 reanalysis data for verification** retrieved with same temporal and spatial resolution
- **Cyclones** are identified as areas bounded by outermost closed **sea level pressure (SLP)** contours surrounding local SLP minima. **Cyclone tracks** are defined by concatenation of cyclone centers in time based on a search area depending on the previous cyclone trajectory (algorithm by Wernli & Schwierz 2006 / Sprenger et al. 2017). → **Cyclones selected for statistics:** genesis within 25-75°N, lifetime of >24h, minimum SLP of <1000hPa

3 Results

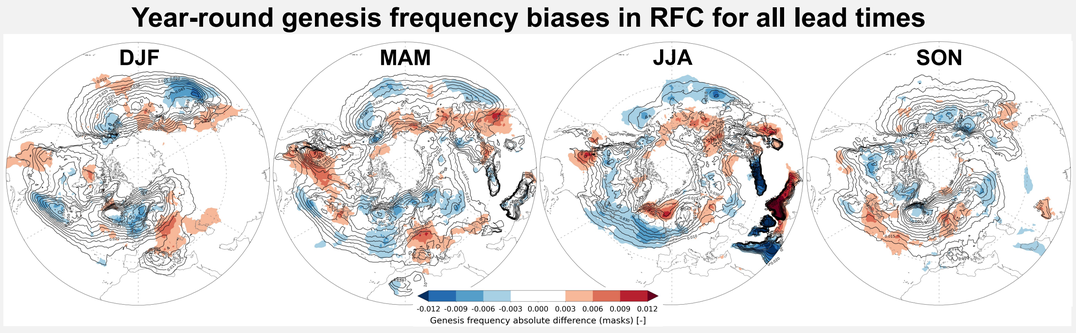
Year-round cyclone frequencies in ERA5



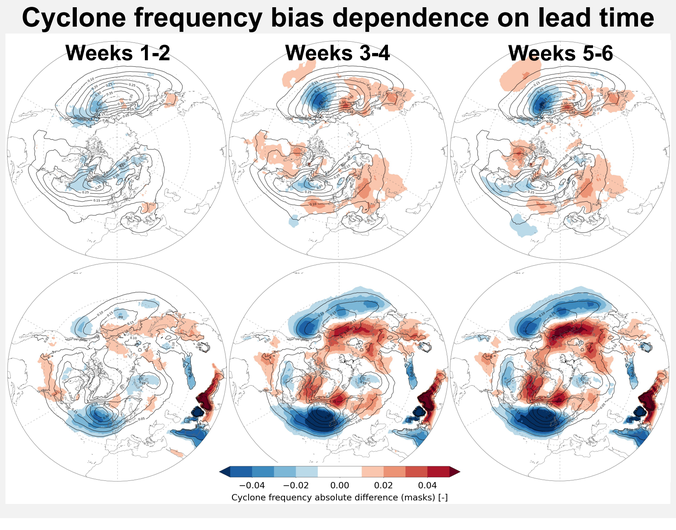
Year-round cyclone frequency biases in RFC for all lead times



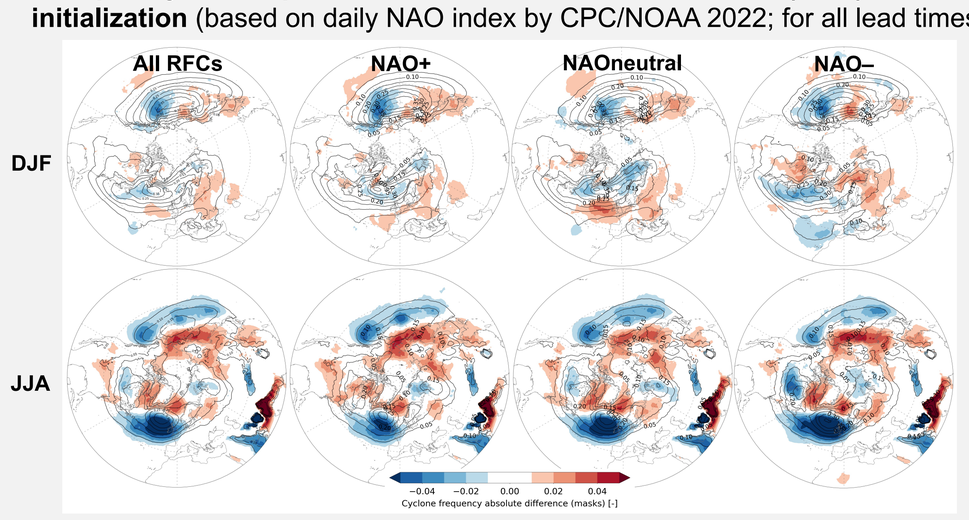
Year-round genesis frequency biases in RFC for all lead times



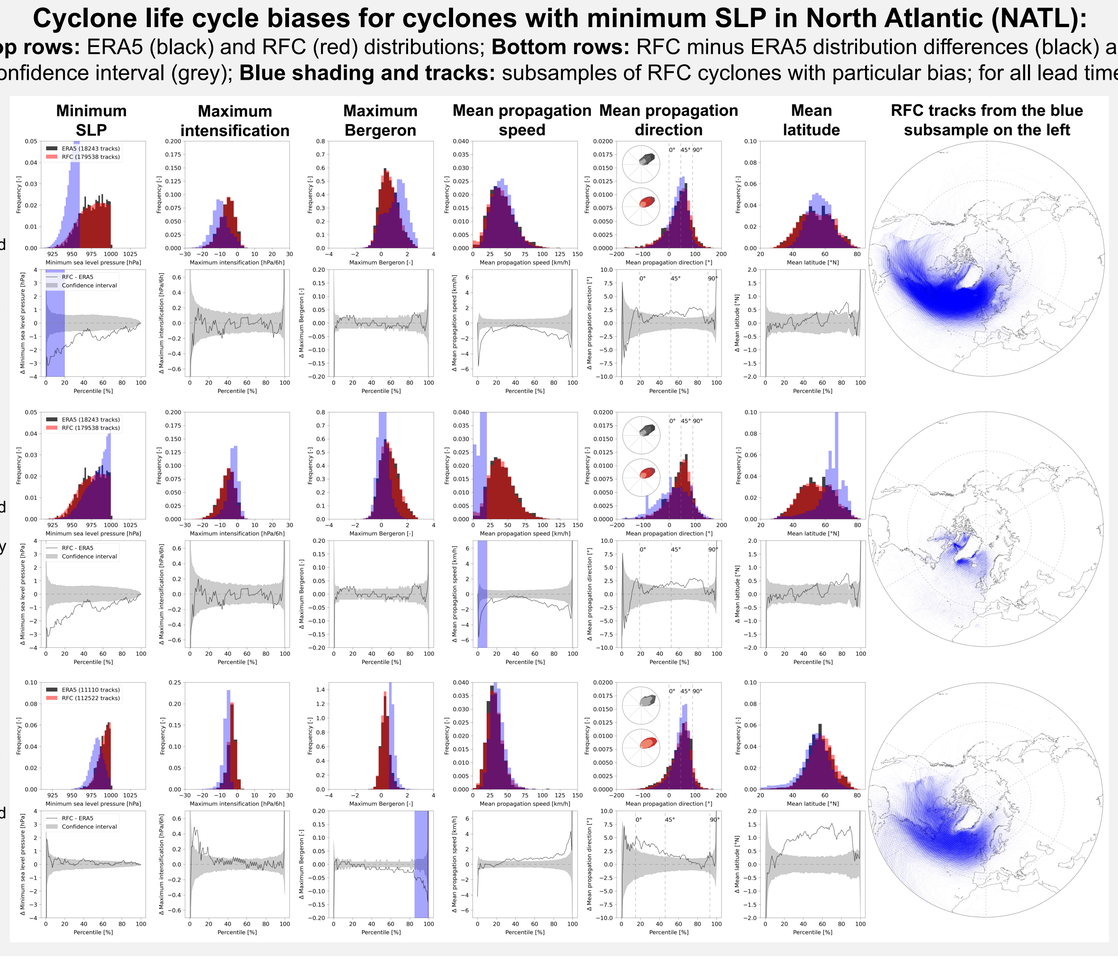
Cyclone frequency bias dependence on lead time



Cyclone frequency bias dependence on North Atlantic Oscillation (NAO) state at forecast initialization (based on daily NAO index by CPC/NOAA 2022; for all lead times)



Cyclone life cycle biases for cyclones with minimum SLP in North Atlantic (NATL):
Top rows: ERA5 (black) and RFC (red) distributions; **Bottom rows:** RFC minus ERA5 distribution differences (black) and confidence interval (grey); **Blue shading and tracks:** subsamples of RFC cyclones with particular bias; for all lead times



4 Conclusions

- ECMWF sub-seasonal ensemble RFCs **capture Northern Hemisphere year-round cyclone frequency and life cycle characteristics remarkably well in a qualitative sense** but have **potentially important regional biases.**
- **Cyclone frequency biases** tend to be **largest in summer (particularly in the NATL), moderately large in spring and autumn, and smallest in winter**. Some biases can be **explained by cyclone genesis frequency biases**, but others require further research.
- Cyclone frequency biases are **strongly lead-time-dependent and maximize on sub-seasonal lead times only**. Furthermore, **some biases are flow-dependent (particularly in the NATL), as they vary depending on the (forecast) initial state of the main modes of midlatitude variability** such as the NAO (NAO– tends to yield largest biases) or the Pacific-North American pattern (not shown here).
- In the NATL (NPAC not shown here), **intense winter cyclones are too deep** despite well captured cyclone intensification (→ formation in zones with negative background SLP bias?), **quasi-stationary winter cyclones are too frequent** (→ mainly occurring along Nunavut and Greenland coasts), **strongest summer cyclone intensification rates are too weak** (→ partly linked to cyclones undergoing extratropical transition), and **winter storm track has a slight zonal bias and summer storm track a slight poleward bias**.

5 Open questions

- Link between cyclone biases and **larger-scale biases** such as in **jet regimes** (Winters 2021, Balmaseda 2022), **Rossby wave breaking** (Quinting & Vitart 2019), or **low-/mid-tropospheric temperature** (Balmaseda 2022), but also **warm conveyor belt biases** (Wandel et al. 2021) → active or passive role of cyclones?
- Link between cyclone biases and **surface weather biases**?

6 References

Büeler et al., 2021, QJRMS: Year-round sub-seasonal forecast skill for Atlantic-European weather regimes.
Balmaseda, 2022: Understanding systematic error growth across timescales. In ECMWF Newsletter 172, Summer 2022.
Grams et al., 2011, QJRMS: The key role of diabatic processes in modifying the upper-tropospheric wave guide: a North Atlantic case-study.
Hoskins, 2013, QJRMS: The potential for skill across the range of the seamless weather-climate prediction problem: a stimulus for our science.
CPC/NOAA, 2022: Daily NAO index since January 1950. Retrieved from https://ftp.cpc.ncep.noaa.gov/cwlinks/.
Quinting & Vitart, 2019, GRL: Representation of synoptic-scale Rossby wave packets and blocking in the S2S prediction project database.
Rivière & Orlanski, 2007, JAS: Characteristics of the Atlantic storm-track eddy activity and its relation with the North Atlantic Oscillation.
Sprenger et al., 2017, BAMS: Global climatologies of Eulerian and Lagrangian flow features based on ERA-Interim.
Vitart & Robertson, 2019, Elsevier: Introduction: why sub-seasonal to seasonal prediction (S2S)? In Sub-Seasonal to Seasonal Prediction.
Wandel et al., 2021, JAS: Toward a systematic evaluation of warm conveyor belts in numerical weather prediction and climate models. Part II: verification of operational reforecasts.
Wernli & Schwierz, 2006, JAS: Surface cyclones in the ERA-40 dataset (1958 - 2001). Part I: novel identification method and global climatology.
Winters, 2021, JGRA: Subseasonal prediction of the state and evolution of the North Pacific jet stream.

7 Contact

@ dominik.bueeler@env.ethz.ch
dombueeler

SCREEN CAPTURE WELCOME