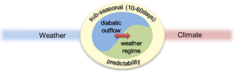

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Flow-dependent sub-seasonal forecast skill for Atlantic-European weather regimes and its relation to planetary- to synoptic-scale processes

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Motivation

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- Sub-seasonal forecast skill for a classic set of 4 seasonal Atlantic-European weather regimes (WRs) is relatively well known, particularly for winter (e.g., Ferranti et al., 2018, QJRMS)
- However, the increasing use of operational sub-seasonal weather forecasts requires a systematic understanding on year-round skill
- Furthermore, there are often situations in which the 4 WRs are too coarse to explain the regional surface weather modulation in Europe (e.g., Grams et al., 2020, ECMWF)

- *In this study, we address these two gaps by systematically verifying a novel set of 7 year-round Atlantic-European WRs in sub-seasonal forecasts* *→ p.3*

Atlantic-European weather regimes (WRs)

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4 classic seasonal WRs

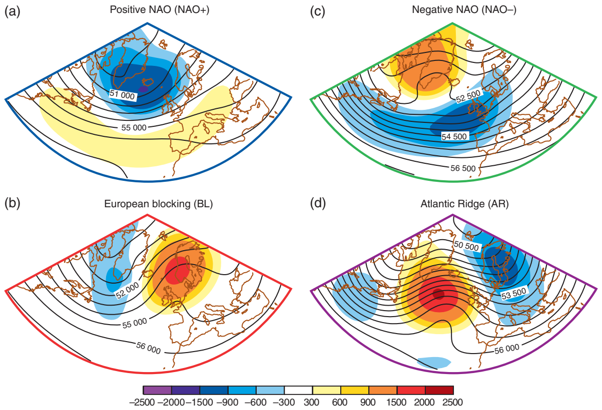
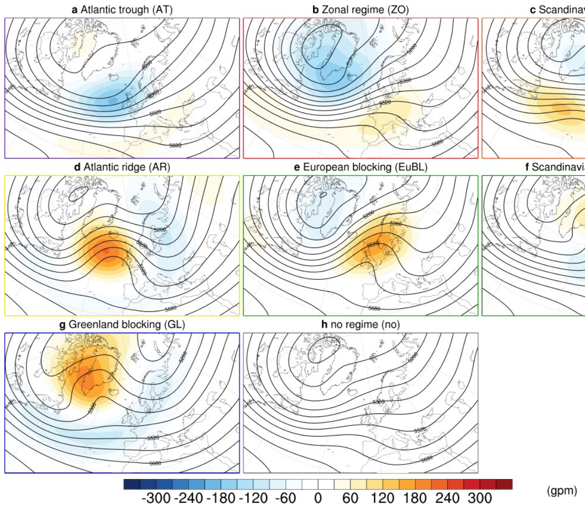


Fig. 1 from Ferranti et al., 2015, [QJRMS]

Novel set of 7 year-round WRs



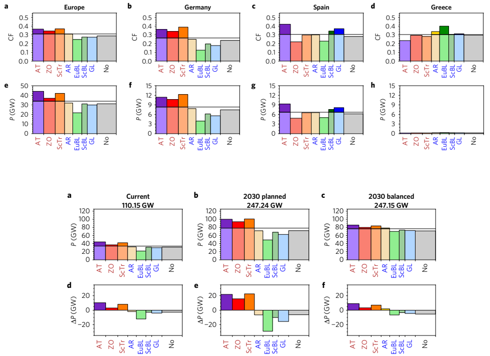
Grams et al., 2017, [NATCLIM]

Main advantages

- Year-round definition
- Explain surface weather modulation better in situations in which 4 WRs are too coarse (Grams et al., 2020, [ECMWF])

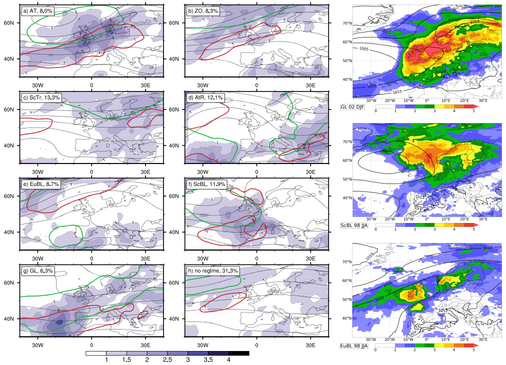
Example applications of 7 WRs

WRs drive variability of wind electricity generation



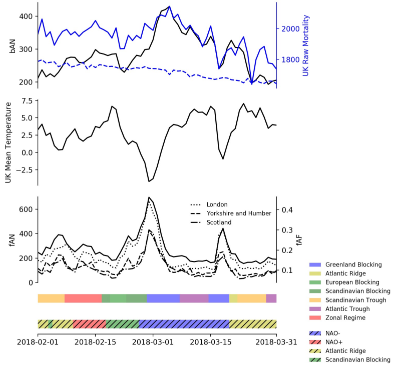
Grams et al., 2017, NATCLIM

WRs influence occurrence of extreme weather



Pasquier et al., 2019, GRL
BSc thesis J. Gerighausen, KIT

WRs can cause enhanced mortality (e.g., in UK)



Charlton-Perez et al., 2021, in preparation for QJRMS

Research questions

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- How well do sub-seasonal forecasts predict the 7 year-round Atlantic-European WRs?
  - Role of forecast calibration for WR representation
  - Verification of WR duration, number, and transitions
  - Verification of WR forecast skill

- How do lower-frequency planetary-scale processes affect WR forecast skill?

- How might synoptic-scale processes affect WR forecast skill?

Sub-seasonal forecast data

- ECMWF IFS reforecasts (S2S project database) (Vitart et al., 2017, BAMS)
- Reforecast period: 1997 – 2017, init. from ERA-Interim every ~2 days → 4080 in total
- 11 ensemble members (10 perturbed, 1 control)
- Daily output

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Weather regime identification

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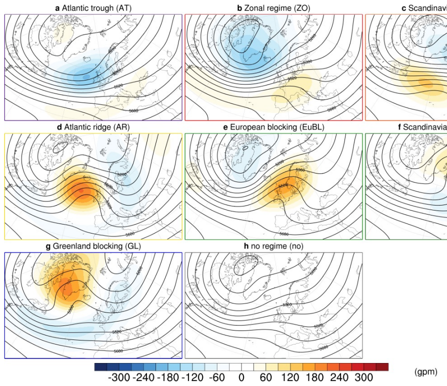
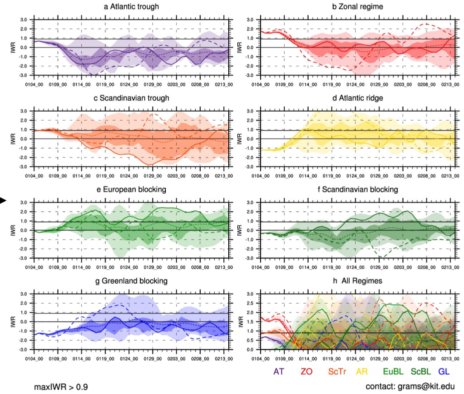
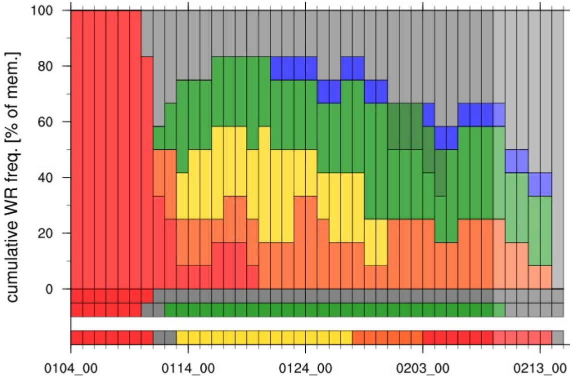
Z@500hPa cluster mean WR anomalies in ERA-Interim



WR index in ensemble forecast



WR life cycle frequency in ensemble forecast



Atlantic Trough (AT) Zonal (ZO) Scandinavian Trough (ScTr) Atlantic Ridge (AR) European Blocking (EuBL) Scandinavian Blocking (ScBL) Greenland Blocking (GL) no regime (no)

Projection of low-pass-filtered and seasonally normalized Z500 anomalies in forecast on 7 cluster mean Z500 anomalies to obtain 7 WR indices

Apply life cycle criteria (WR index maximum and above threshold for at least 5 consecutive days) to obtain WR life cycle probability at each lead time

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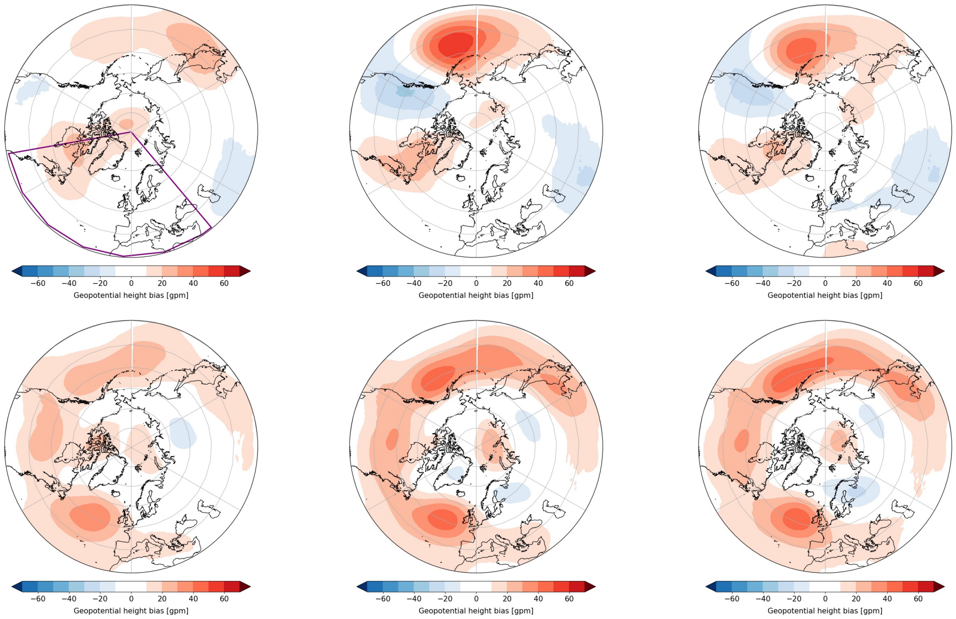
Role of forecast calibration for weather regime frequency biases and forecast skill

500 hPa geopotential height biases

10 d lead time | **20 d lead time** | **30 d lead time**

1 Jan

2 Jul



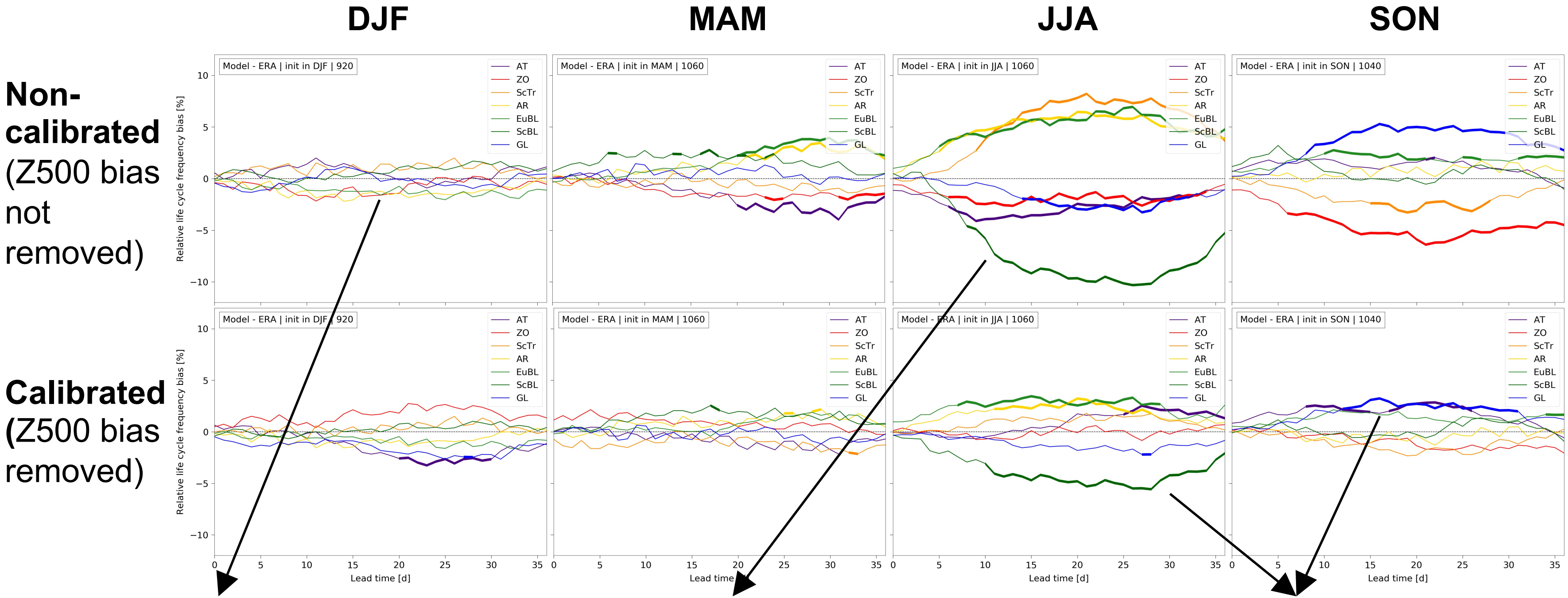
Z500 biases tend to saturate on sub-seasonal lead times

Hardly biases in Atlantic-European domain (purple) in winter (except upstream)

Strongest biases in Atlantic-European domain in summer

WR frequency biases in non-calibrated forecasts (without Z500 biases being removed) compared to calibrated forecasts (with Z500 biases being removed)? → p.10

WR life cycle frequency biases



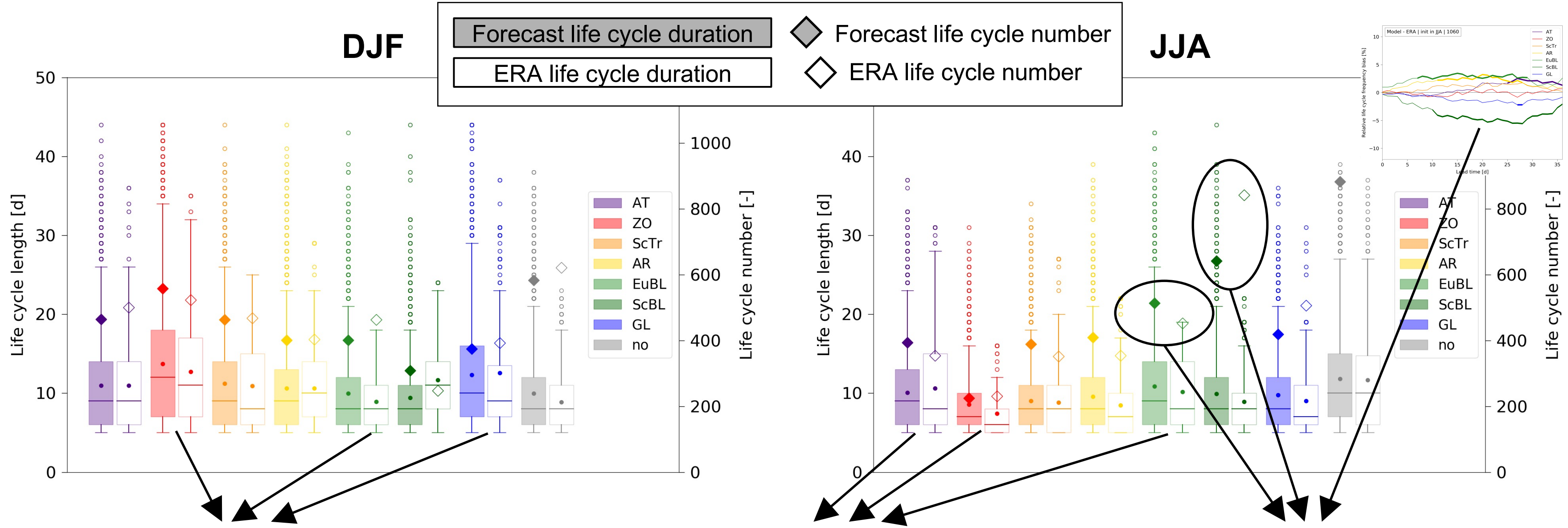
No significant (bold lines) WR frequency biases in winter

Most significant biases in summer (consistent with Z500 biases; p.9)

Forecast calibration most effective in summer, but important biases remain

Verification of weather regime duration, number, and transitions

WR life cycle duration and number



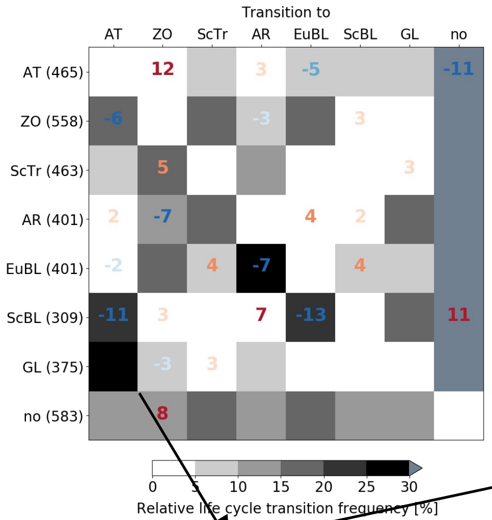
Winter: Zonal regime and Greenland Blocking most persistent, European Blocking least persistent

Summer: European Blocking and Atlantic Trough most persistent, Zonal regime least persistent

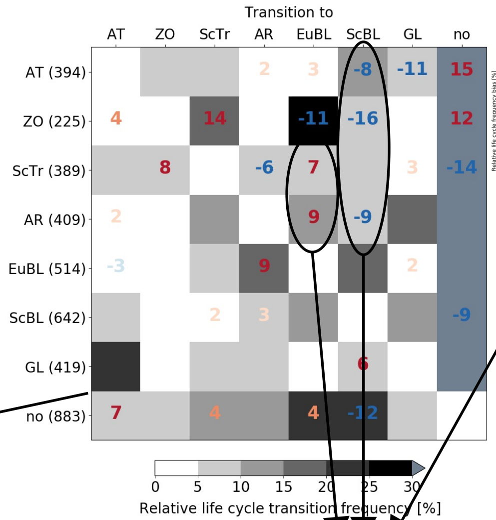
E.g., remaining positive (negative) EuBL (ScBL) frequency biases in calibrated forecast (p.10) can partly be explained by too many (few) life cycles

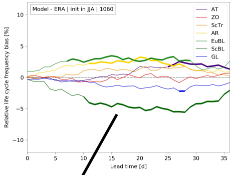
WR life cycle transition frequencies and biases

DJF



JJA





ERA frequencies

Model biases

Some very frequent transitions without biases (e.g., Greenland Blocking to Atlantic Trough in all seasons) → useful information to judge forecast performance in advance?

E.g., remaining positive (negative) EuBL (ScBL) frequency biases in calibrated forecast (p.10) can also partly be explained by too many (few) transitions into EuBL (ScBL)

Verification of weather regime forecast skill

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Year-round skill for all WRs on average

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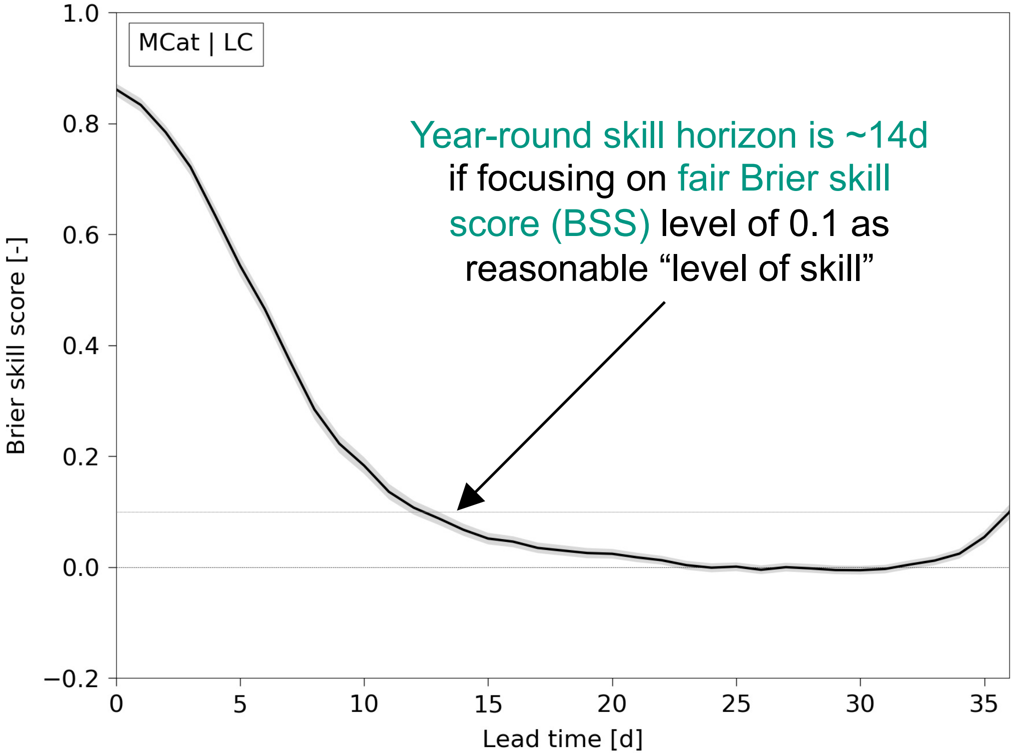
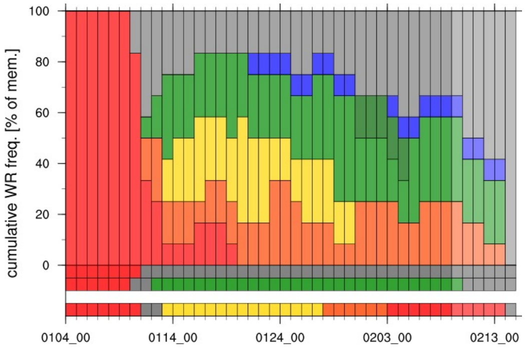
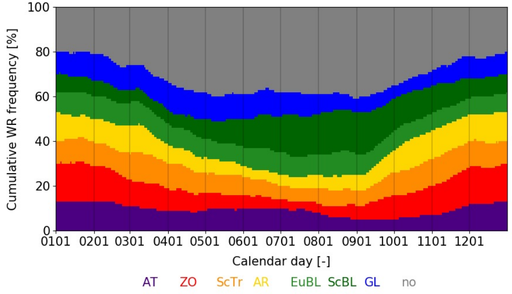




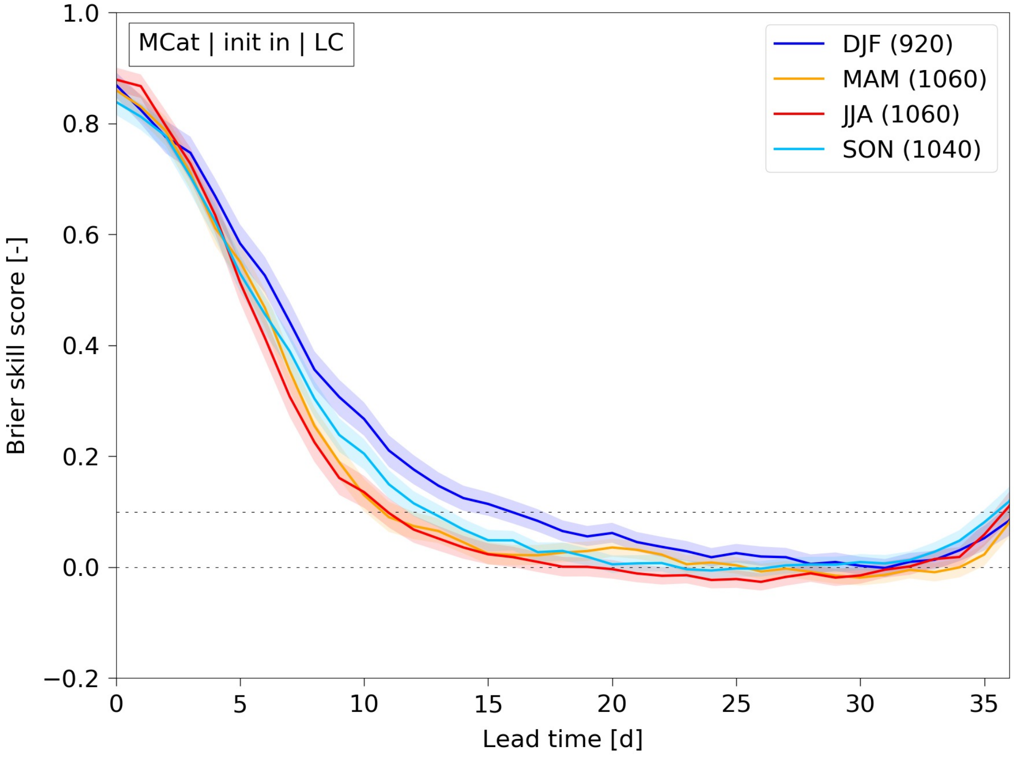
Model forecast (example)

BSS

Clim. reference forecast (clim. frequency in ERA)



Seasonal skill for all WRs on average



Skill horizon in winter ~5d longer than in summer and spring, ~3d longer than in autumn

Some of these differences are explained by differences in intrinsic predictability → nevertheless, e.g., summer skill can likely be further improved considering its largest WR frequency biases (p.10)

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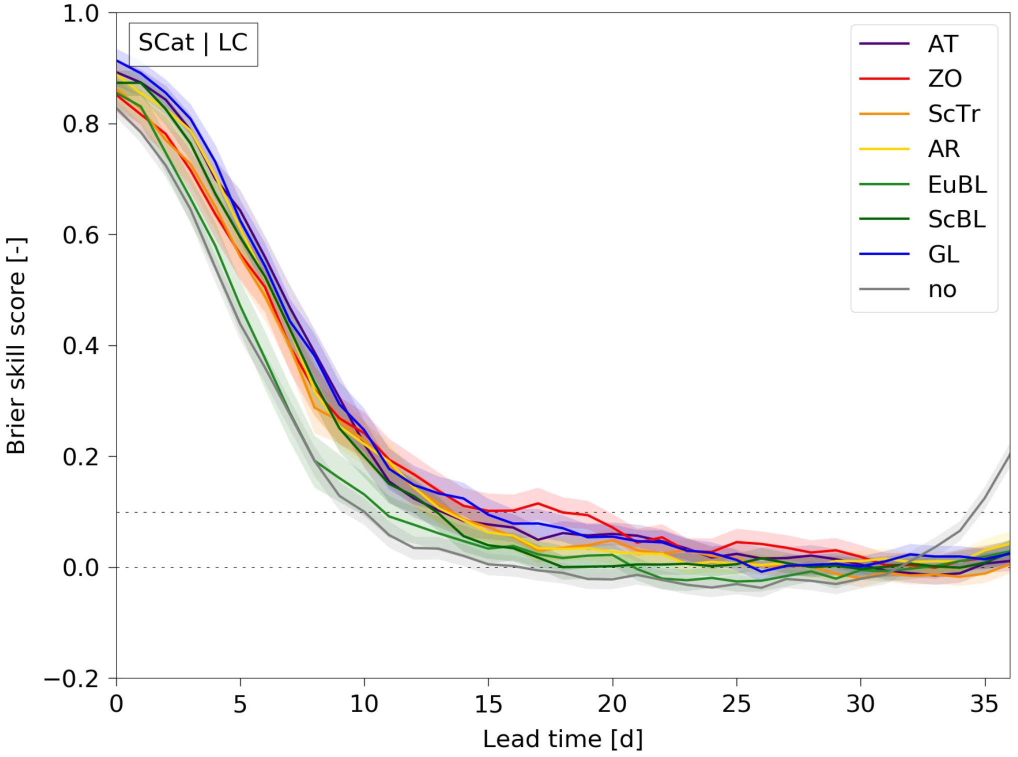
Year-round skill for individual WRs

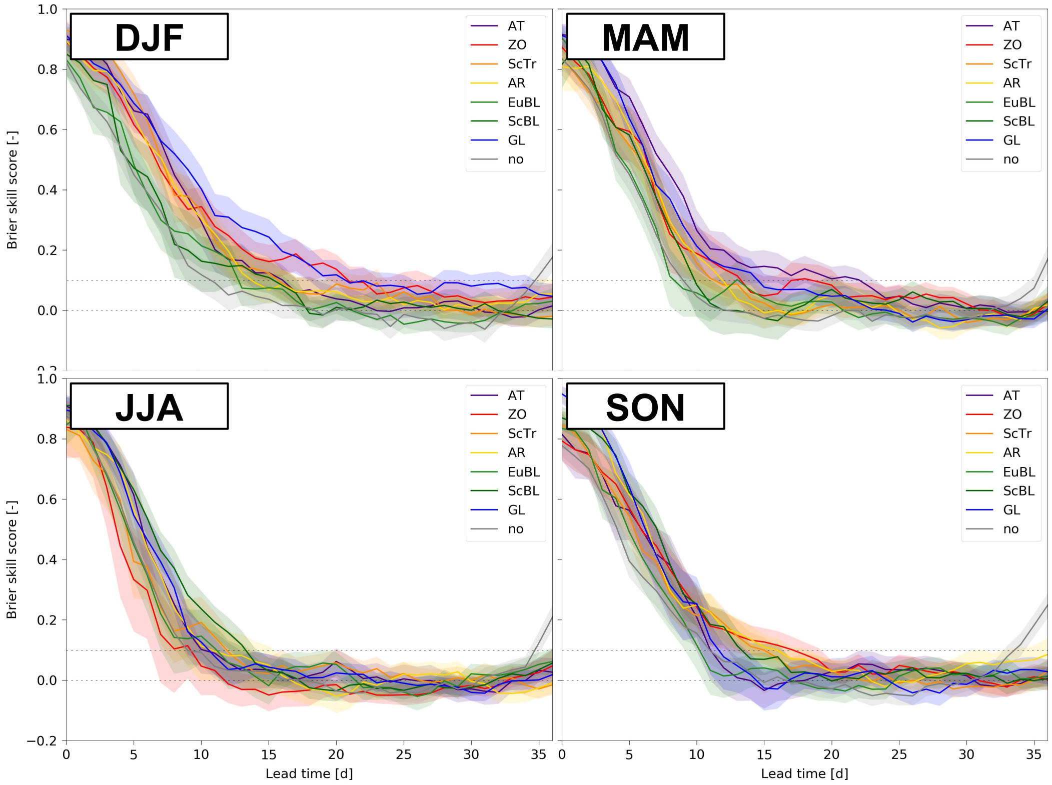


Skill horizon for European Blocking 3-5d shorter (significant!) than for all others, including related Scandinavian Blocking

Skill horizon for Zonal regime and Greenland Blocking generally longest

How do the individual seasons explain this year-round pattern?
→ p.18

Seasonal skill for individual WRs



Skill for European Blocking among the lowest in all seasons

Difference in year-round skill between European and Scandinavian Blocking (p.17) driven by summer and autumn, but skill is similarly low in winter and spring → improving well-known continental blocking problems requires a better understanding of the dynamics of these two blocking types

High year-round skill for Zonal regime and Greenland Blocking driven by winter, likely due to high persistence (p.12) and stratospheric influence

Role of lower-frequency planetary-scale processes for weather regime forecast skill

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Stratospheric polar vortex (SPV)

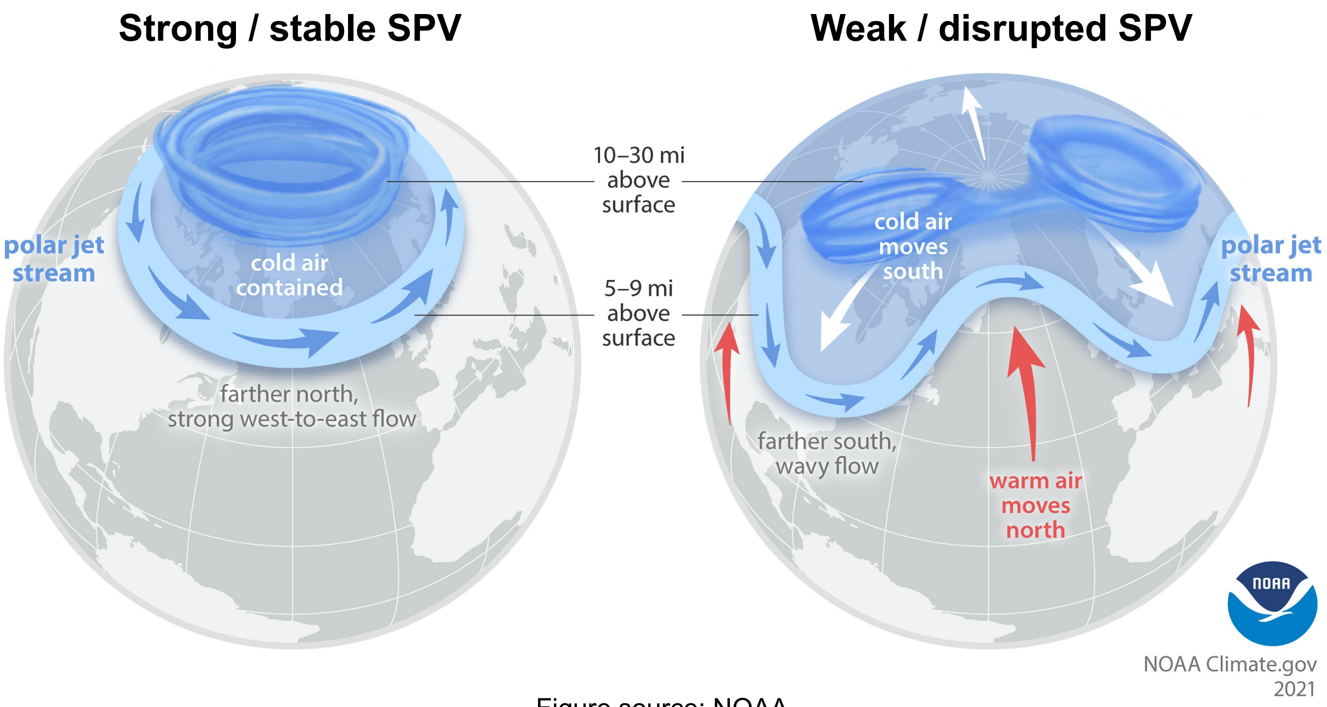
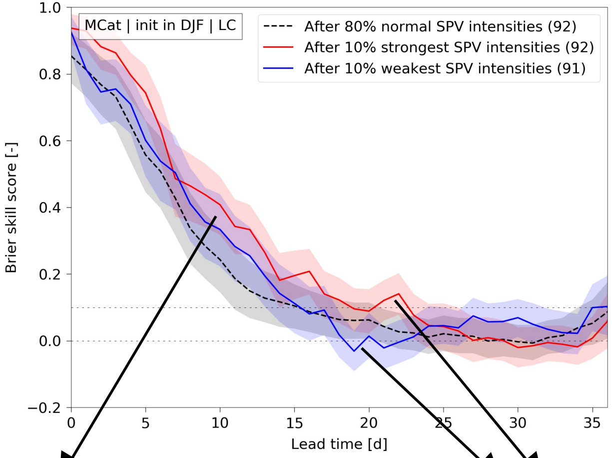


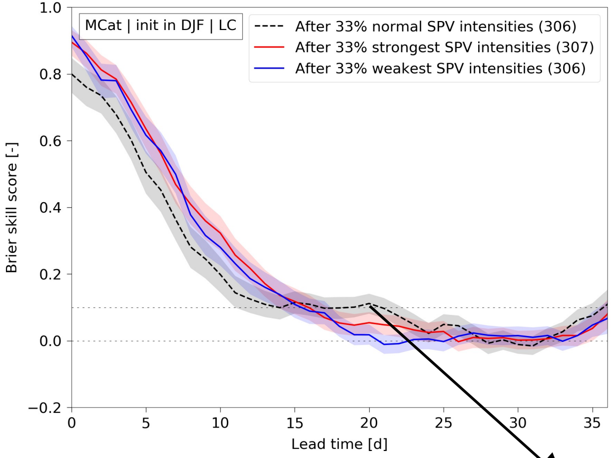
Figure source: NOAA

Role of SPV for average WR winter forecast skill

Very strong vs. very weak SPV at forecast initial time



Stronger- vs. weaker-than-normal SPV at forecast initial time

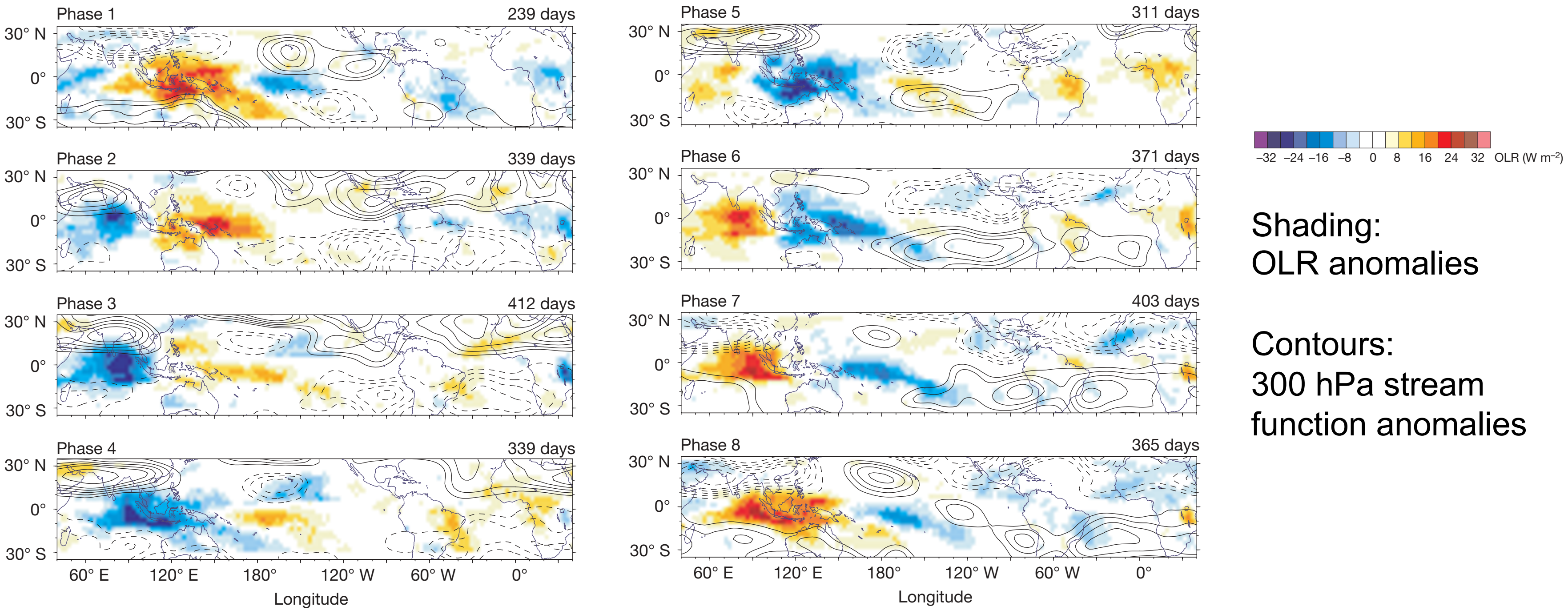


Medium-range skill tends to be enhanced following strong and weak SPVs

However, sub-seasonal skill tends to be increased following strong but reduced following weak SPVs (consistent with Büeler et al., 2020, [QJRMS])

Sub-seasonal skill tends to be enhanced following normal SPVs for tercile definition → interesting, but we have no explanation for this yet

Madden-Julian Oscillation (MJO)

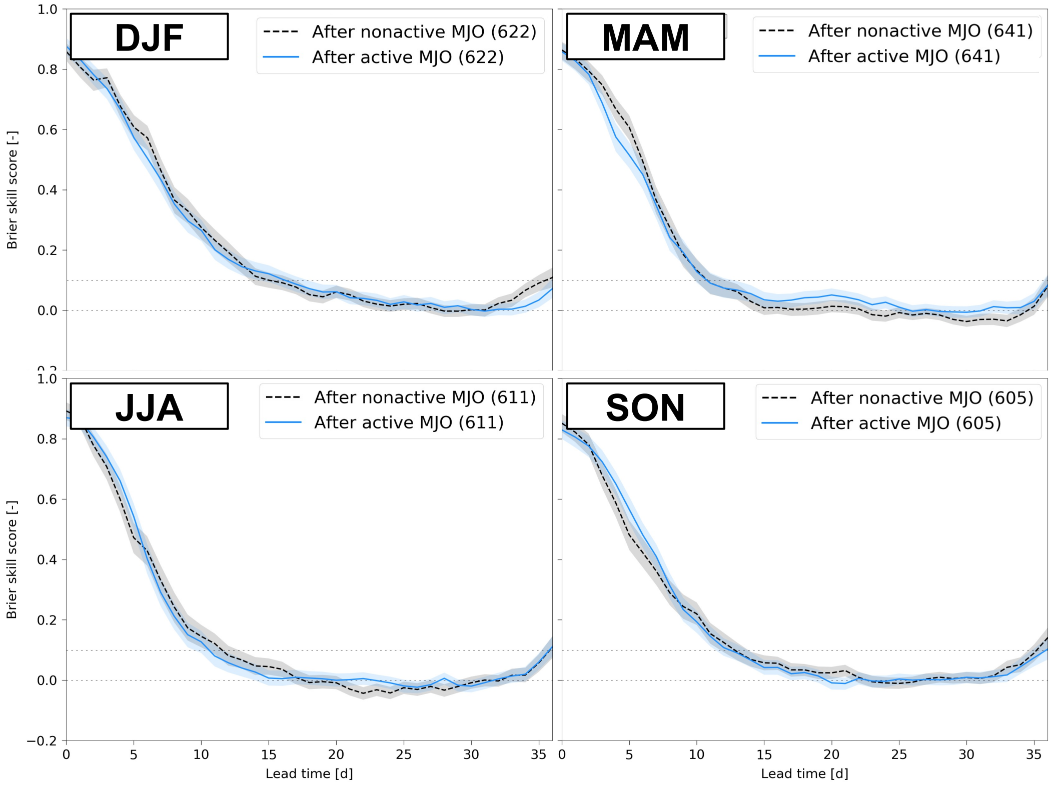


Shading:
OLR anomalies

Contours:
300 hPa stream function anomalies

Fig. 2 from Cassou, 2008, NAT

Role of active MJO for average WR forecast skill



Active MJO at forecast initial time hardly modifies average regime skill compared to non-active MJO in all seasons – even in winter, when the MJO effect tends to be highest

However, this results from a balance between enhanced skill following some MJO phases but reduced skill following others → p.24

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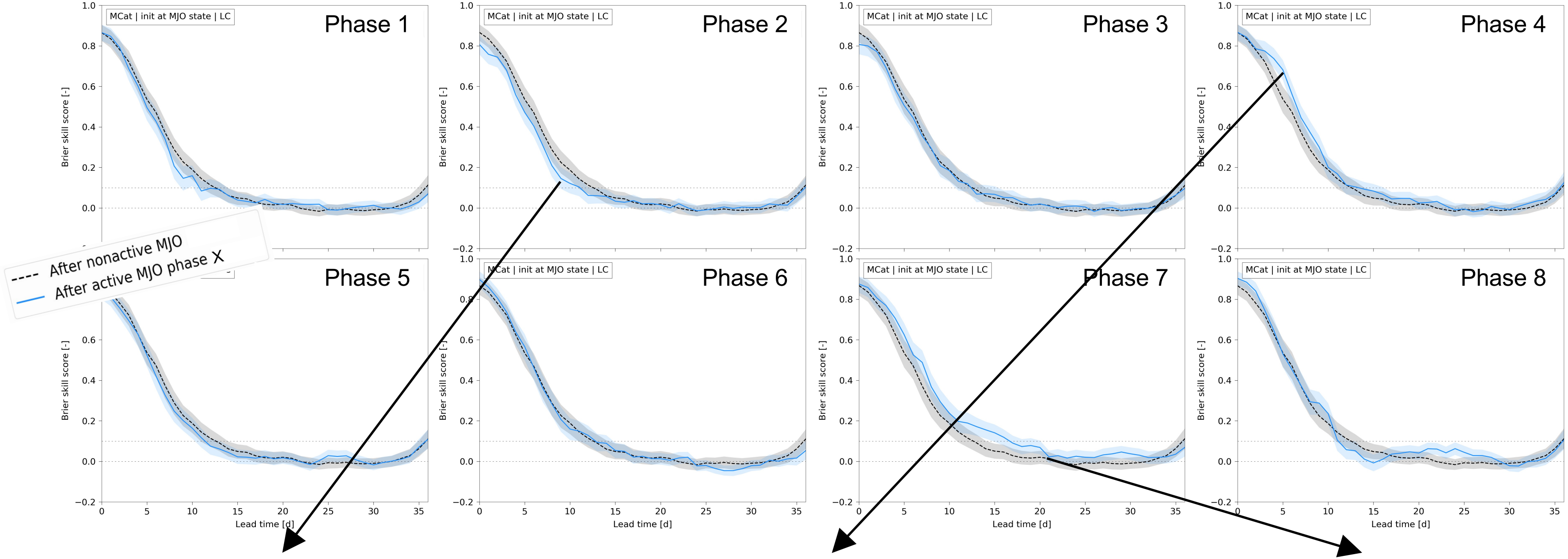
Role of MJO phases for year-round average WR forecast skill



Strongest reduction in medium-range skill following phase 2 (primarily in spring and autumn)

Strongest increase in medium-range skill following phase 4 (primarily in winter and autumn)

Strongest increase in sub-seasonal skill following phase 7 (primarily in winter and spring)

Role of synoptic-scale processes for weather regime forecast skill?

Warm conveyor belts (WCBs)

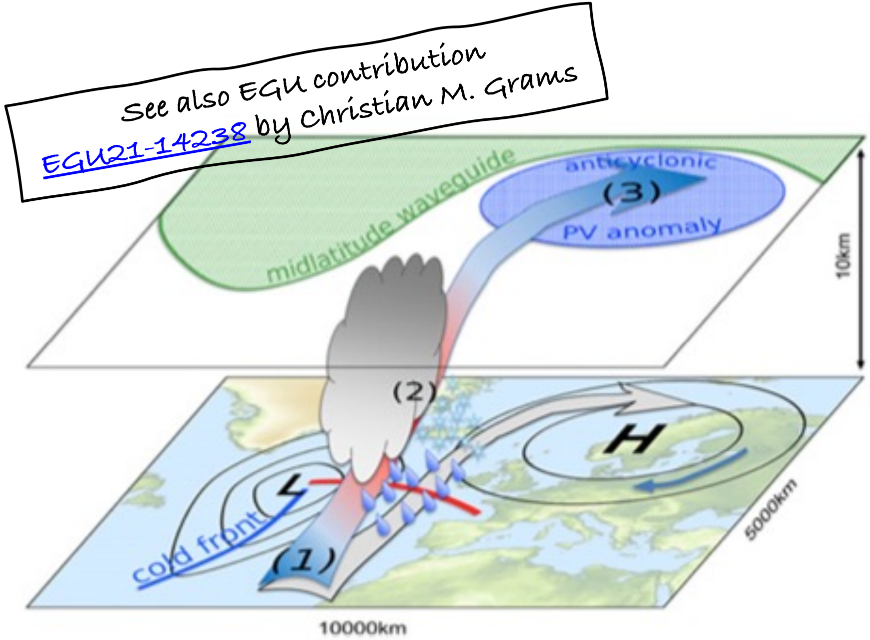


Fig. 1 from Quinting and Grams, 2021, JAS

Warm conveyor belts (WCBs) = pole- and upward ascending airstreams in extratropical cyclones, with strong cloud-diabatic processes involved

WCBs efficiently pump air from the lower into the upper troposphere and thereby often contribute to a downstream ridge amplification and onset / maintenance of blocking (e.g., Grams et al., 2011, QJRMS; Pfahl et al., 2015, NATGEO)

How do sub-seasonal models represent WCBs and what might be the role of associated biases for blocking forecasts?
→ p.27

Role of WCBs for blocking forecast skill?

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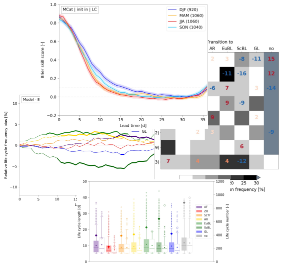
Recently done in our research group

- Development of a sophisticated statistical model to identify WCBs in reanalysis or model data in a simple and Eulerian way (Quinting and Grams, 2021, JAS)
- Verification of WCBs in sub-seasonal forecasts (biases, skill) (Wandel et al., 2021, submitted to JAS)

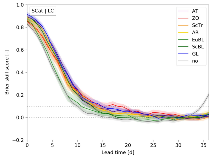
Next steps

- Relate representation of WCBs to WR skill → for instance, how are WCB biases over the North Atlantic related to the relatively low sub-seasonal skill for the European Blocking?

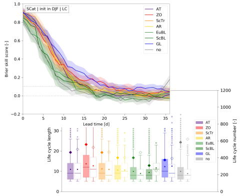
Take-home messages (Büeler et al., 2021, soon submitted to QJRMS)



- Overall best sub-seasonal forecast performance in winter and worst in summer (Z500 biases, WR frequency biases, WR skill) → forecast calibration most important for summer, but some WR biases remain (which can partly be explained by biases in WR life cycle duration, number, and transitions)

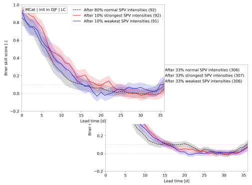


- Year-round skill horizon for European Blocking ~3-5d shorter than for other WRs, including Scandinavian Blocking but only in summer and autumn → better understanding of the dynamics of these two blocking types needed to improve continental blocking forecasts

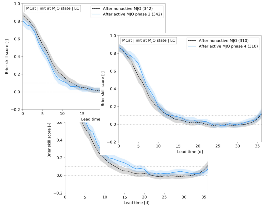


- Year-round skill horizon for Zonal regime and Greenland Blocking longest (driven by winter, probably influenced by enhanced persistence and stratosphere-troposphere coupling)

Take-home messages (Büeler et al., 2021, soon submitted to QJRMS)



- Average winter WR skill horizon longer after strong SPV, but shorter after weak SPV (but only for “truly strong” SPV) (see also Büeler et al., 2020, QJRMS)



- Average year-round WR skill enhanced after MJO phases 7 and 4, but reduced after phase 2 (driven by winter, but also spring and autumn)

→ Overall: There is promising potential for year-round WR skill improvement, for instance by removing large biases in summer and by improving model response following weak SPVs and certain MJO phases in winter and the transition seasons

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Further information

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Content of this study will be submitted soon as

Büeler, D., Ferranti, L., Magnusson, L., Quinting, J. F., and Grams, C. M., 2021: Flow-dependent sub-seasonal forecast skill for year-round Atlantic-European weather regimes, QJRMS

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