Forecast Error Attributed to Synoptic Features

ECMWF

BJERKNES CENTRE for Climate Research

Qidi Yu[1], Clemens Spensberger[1], Linus Magnusson[2], Thomas Spengler[1]

[1]Geophysical Institute, University of Bergen, Norway. [2]ECMWF, UK.

Email: qidi.yu@uib.no

Motivation

Numerical weather prediction models remain deficient in forecasting specific weather events that contribute significantly to the overall model error. We quantify the forecast error associated with five specific weather features in the ERA5 reanalysis, and quantify contributions to the climatological model error and bias associated with these different features.

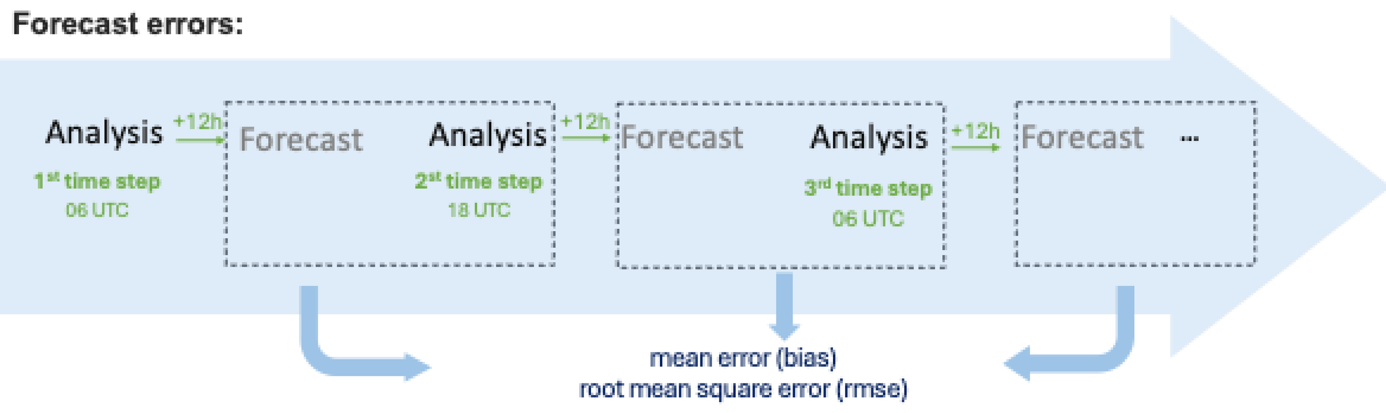
Data and Methods

We use the 12-hour forecast and analysis for 00 and 12 UTC from the ECMWF ERA5 reanalysis, 1991 – 2020.

Attribute forecast RMSE and bias to the following weather features:

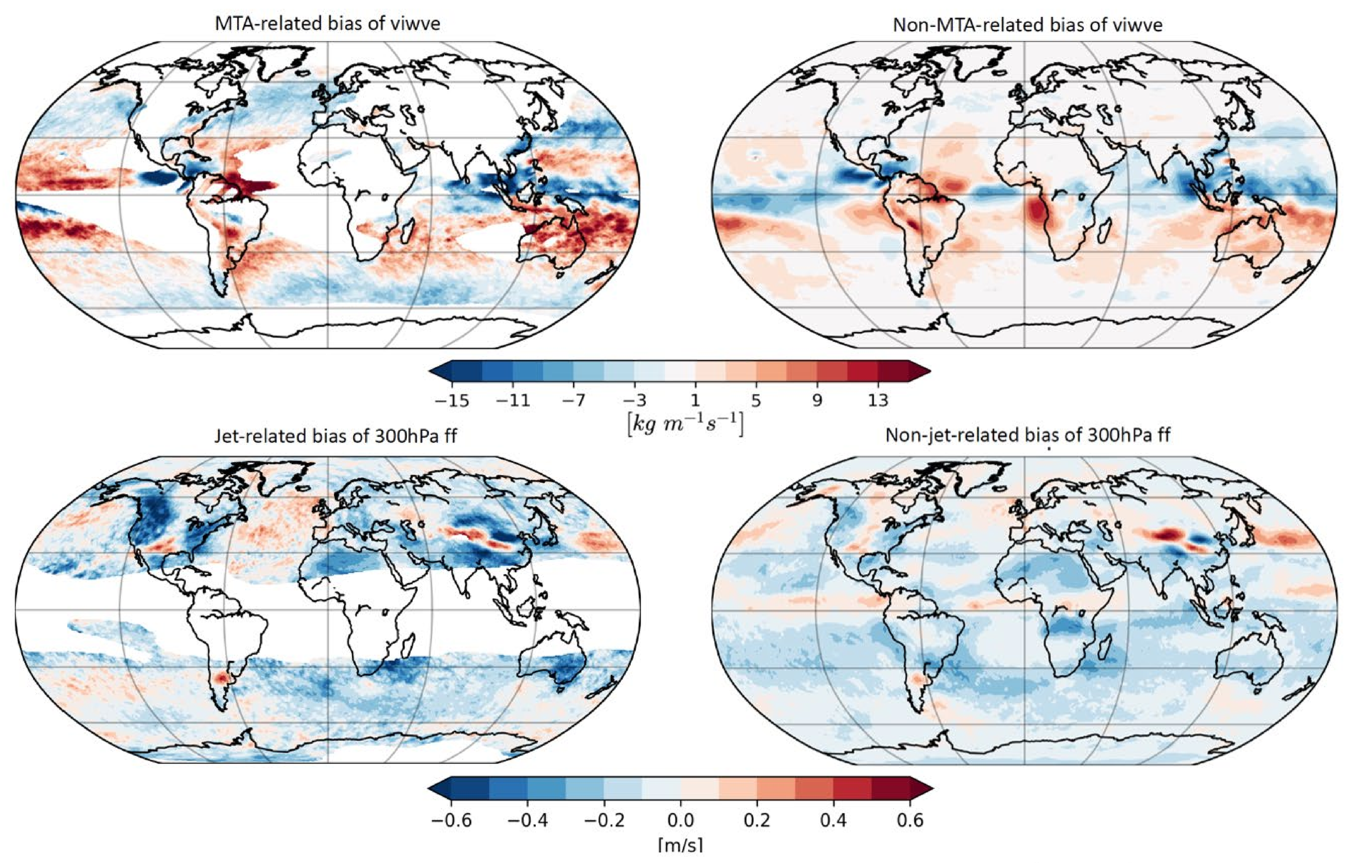
- **Cyclones** (CAO, Papritz and Spengler, 2017)
  outermost closed contour
- **Atmospheric Fronts** (Wernli and Schwierz, 2006)
  equivalent potential temperature gradient
- **Upper tropospheric Jets** (Spensberger and Sprenger, 2018)
  instantaneous maxima on 2-PVU
- **Moisture transport axes (MTA)** (Spensberger and Spengler, 2020)
  axes of maximum vertical integrated water transport
- **Cold air outbreaks (CAO)** (MTA, Spensberger et al., 2023)
  $CAO\_index_{plev} \equiv \theta_{skt} - \theta_{plev}$

Forecast errors:



Results

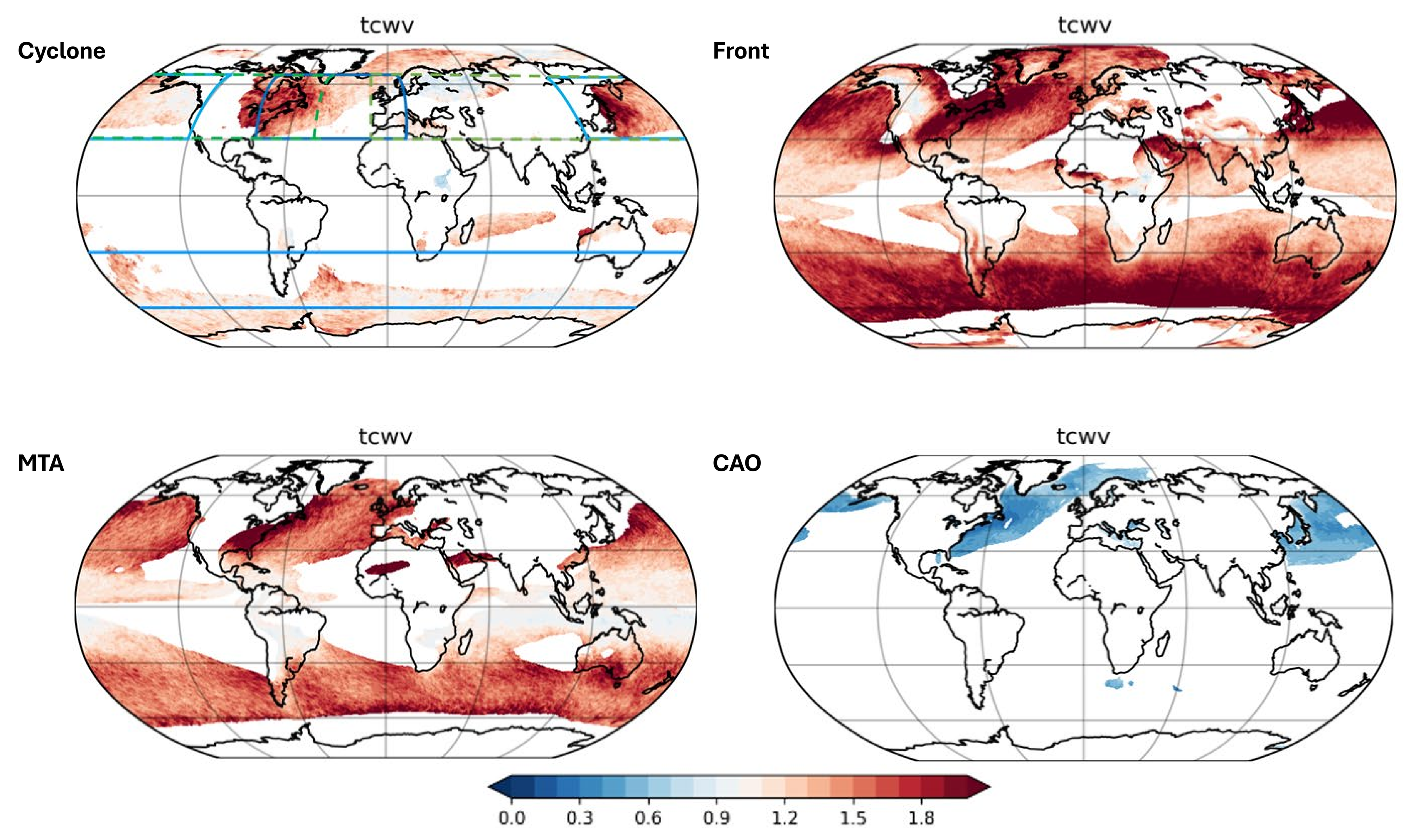
Global bias



DJF Vertical intergral water vapor flux eastward
- Mid-lat bias mainly from insufficient moist transport
- Similar for northward

DJF 300 hPa wind speed
- Land-sea contrast
- topographic influence

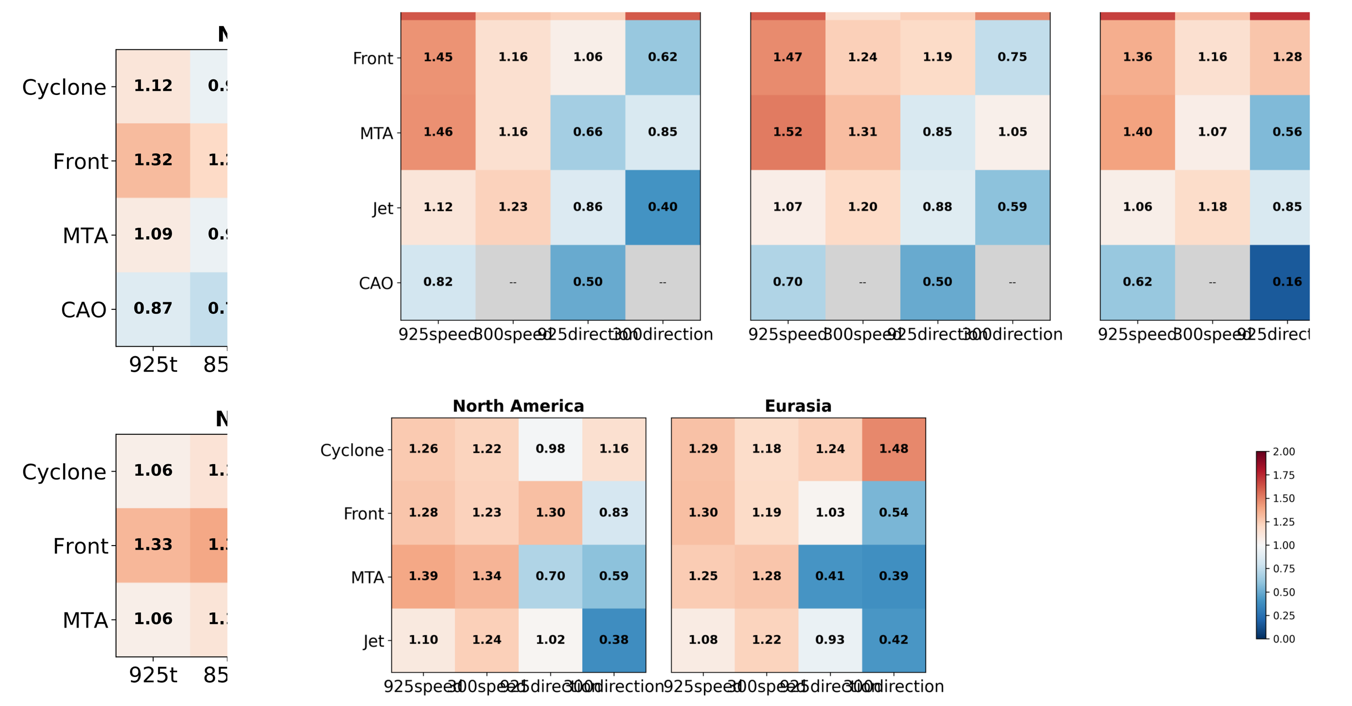
RMSE ratio



ratio = RMSE with feature / RMSE without feature

DJF total column water vapour
- Front -> most pronounced impact on increase error
- Key-regions for cyclone error: northeast coast of North America & northwest Pacific
- Larger MTA error near coastal regions
- CAO reduce error

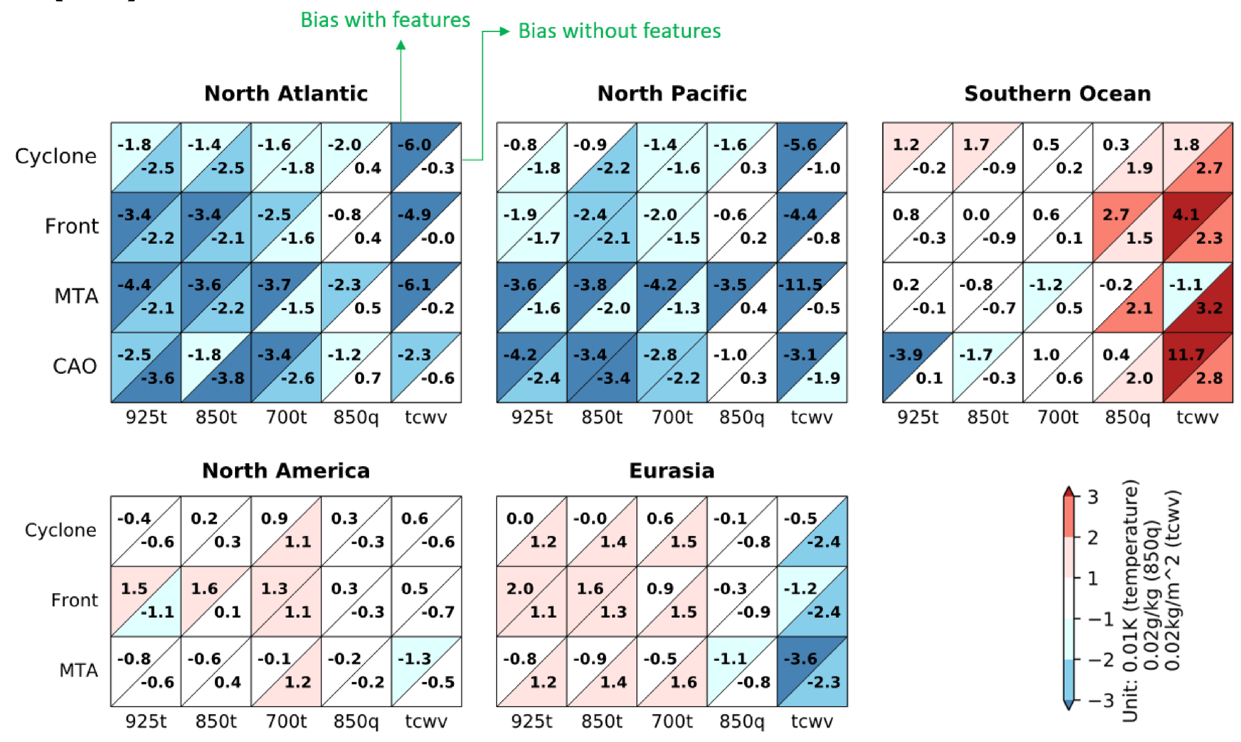
Regional aggregation (DJF)



Temperature
Oceans
- Only CAO reduce error, other increase error
- Front contributes more error

Continents
- Features increase error
- Front more

Moisture
Similar to temperature fields, but front and MTA contribute more

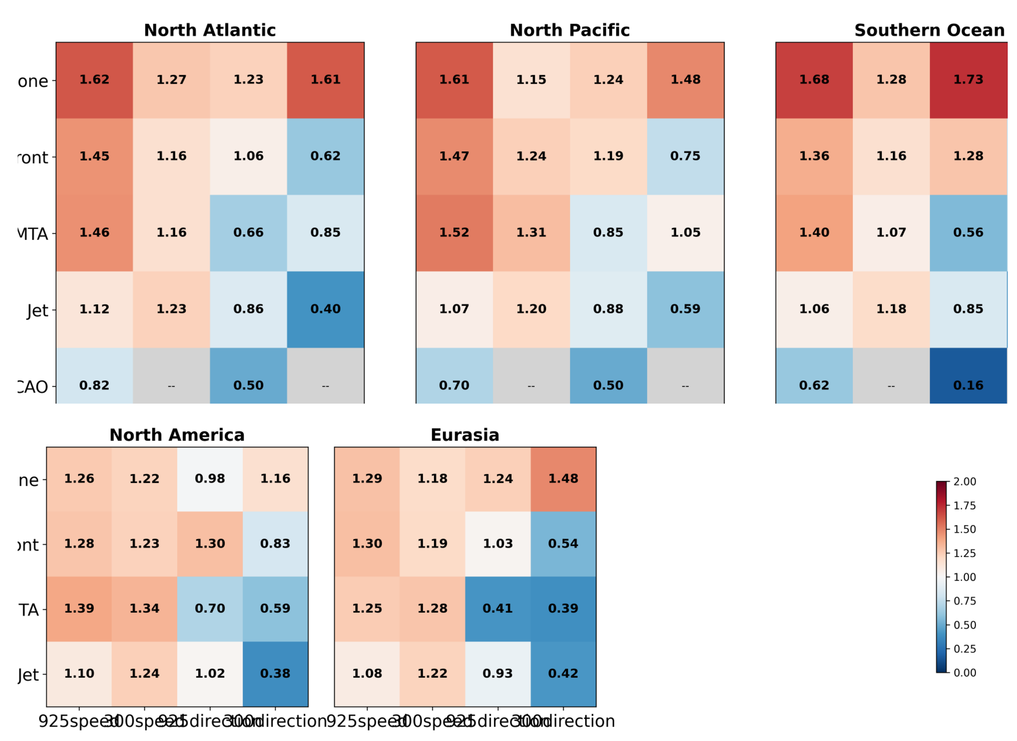


Temperature
Oceans
- Front & MTA increase negative bias
- Cyclone reduce lower-level error

Continents
- Cyclone & MTA reduce Eurasia error
- Front flip lower-level bias sign

Moisture
Oceans
- All features increase negative bias in NH
- Front increase positive bias in SH

Continents
- Cyclone & front reduce Eurasia error

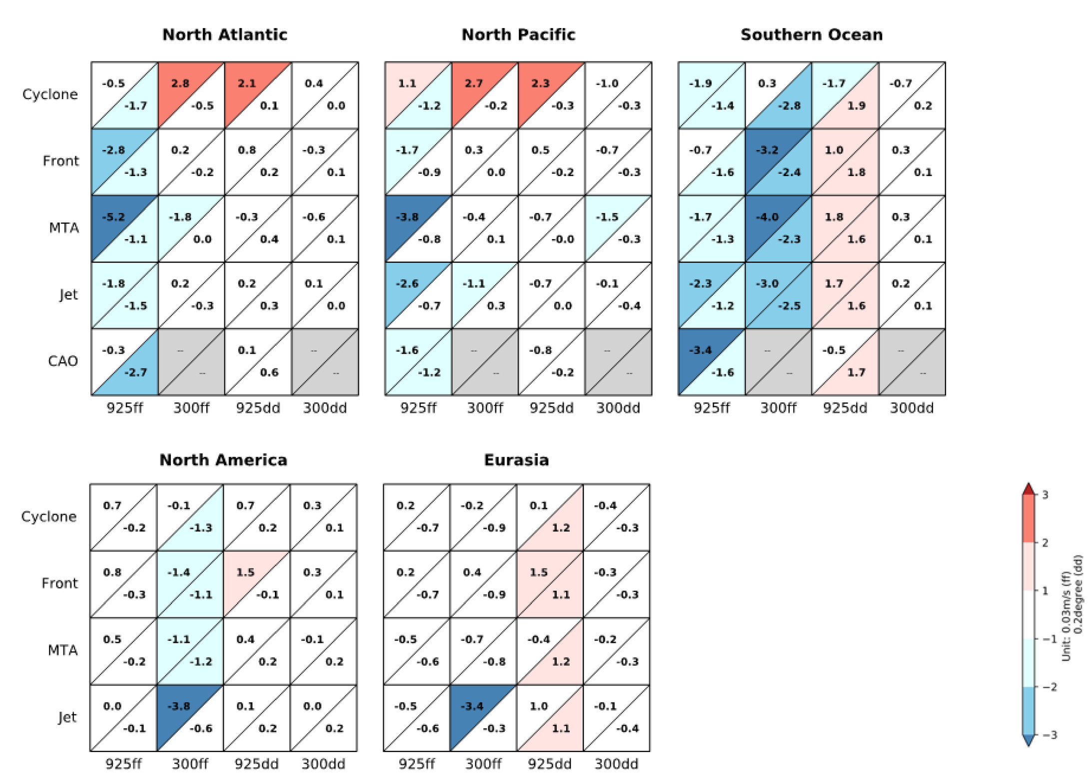


Wind speed
Oceans
- Cyclone, front, MTA increase error in Lower-level speeds
- CAO reduce error

Continents
Features increase error

Wind direction
Oceans
- Cyclone increase error , especially higher level
- Others reduce error

Continents
- Cyclone increase error
- Others reduce error (except front at lower-level)



Wind speed
Oceans
- Cyclone increase positive bias
- Front & MTA increase lower-level negative bias in NH, higher-level negative bias in SH

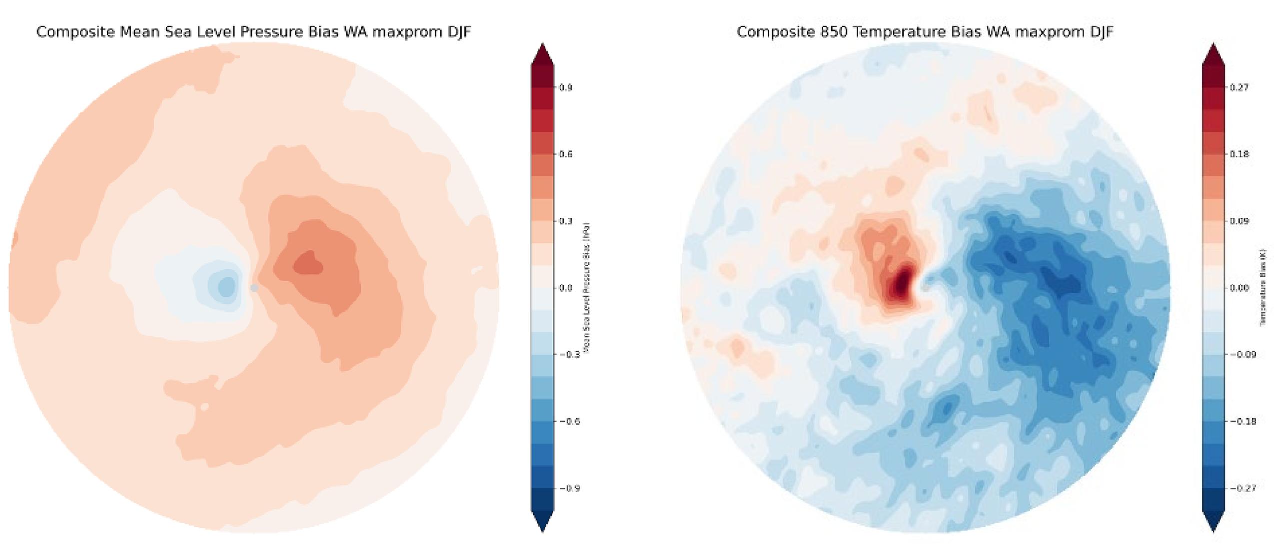
Continents
- Jet increase higher-level negative bias

Wind direction
Oceans
- Cyclone increase lower-level positive bias

Continents
- Cyclone, MTA, jet reduce Eurasia error

Future research

Cyclone-centered composites



Key findings

- Errors related to most weather features are generally larger than non-feature errors
- In general, humidity field show larger feature-related errors
- For humidity, errors associated with fronts and moisture transport axes can be even more than twice as large compared to errors without these features present
- CAO occurrence reduces forecast error
- Feature impacts are clearer over Oceans

Reference

- Spensberger, C., Konstali, K. and Spengler, T., Moisture transport axes and their relation to atmospheric rivers and warm moist intrusions.
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