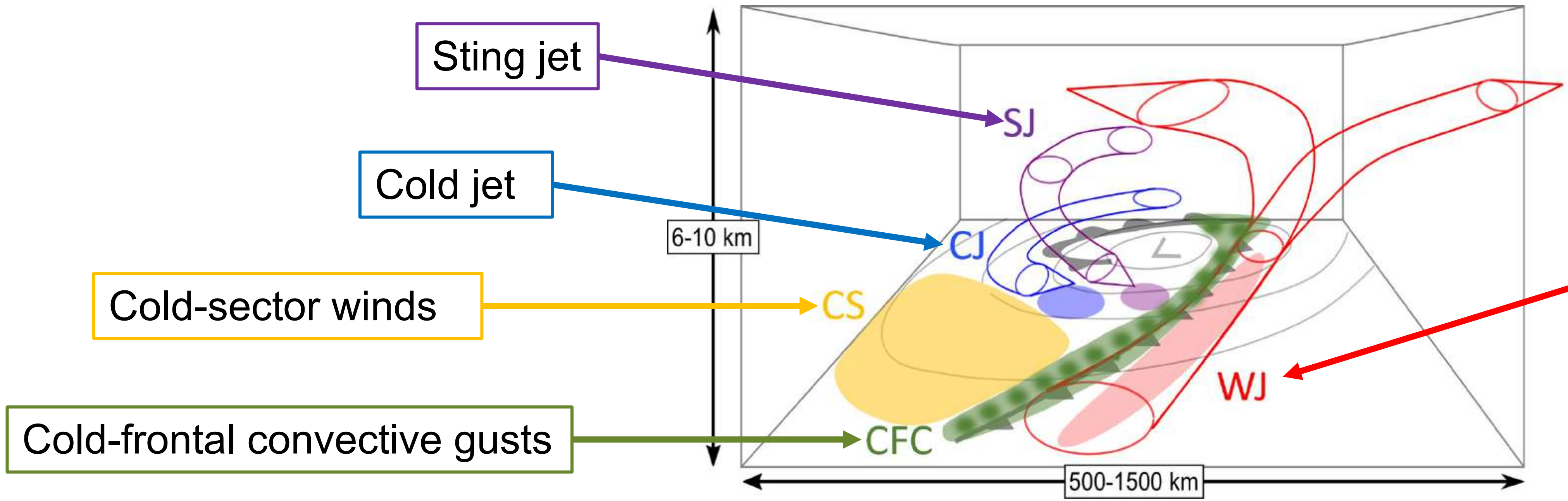
9th European Storm Workshop

Identification and climatology of high-wind features within European winter storms

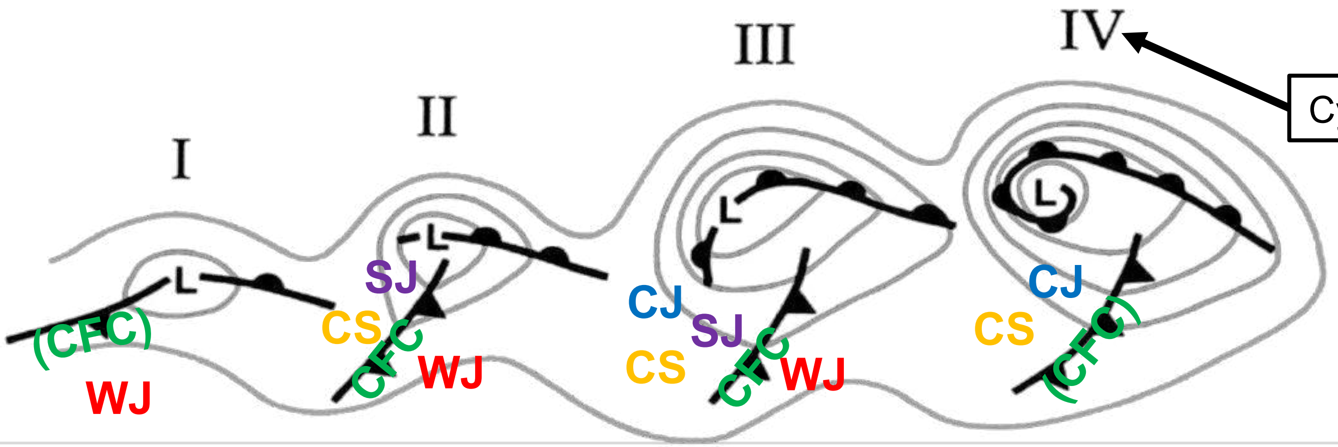
Lea Eisenstein, Benedikt Schulz, Joaquim G. Pinto, Peter Knippertz

Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research

CAUSES OF HIGH WINDS



Eisenstein et al. (2022); adapted from Clark and Gray (2018)



adapted from and Schultz et al. (1998)

→ Do forecast errors differ?

→ Can feature-dependent post-processing improve the forecast?

DATA

Karlsruhe Institute of Technology

- Dataset of hourly **surface observations** (2001 – 2020):
  - Mean-sea level pressure (*p*), temperature, precipitation (*RR*), wind speed (*v*) and wind direction (*d*)

  → Computation of potential temperature θ

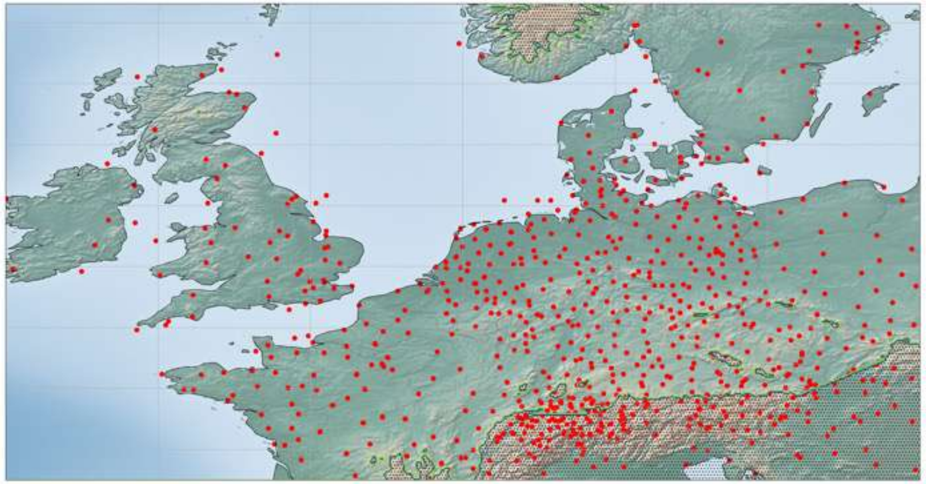
  → Normalising θ and v by the median and 98th percentile, respectively

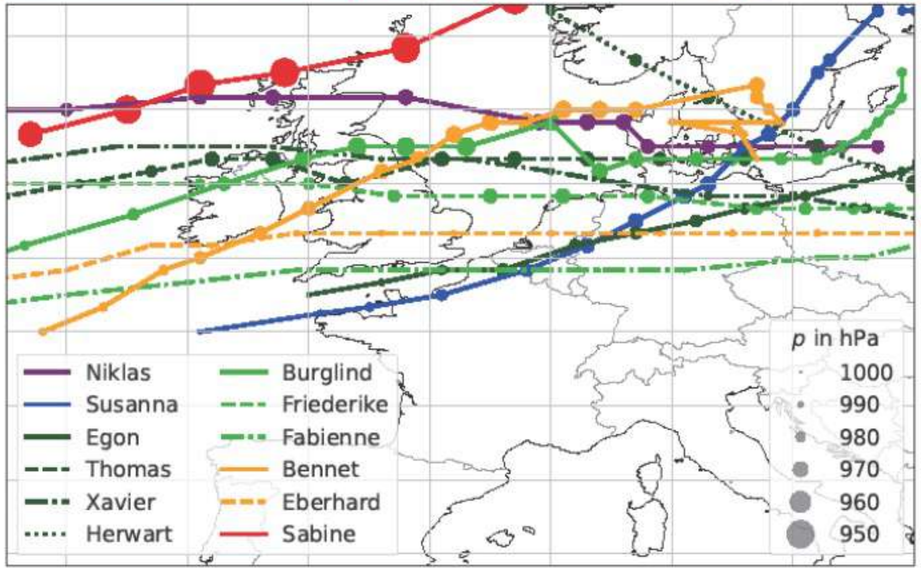
  → Calculating tendencies ($\Delta x = x_0 - x_{-1h}$) for p, θ and d

- **COSMO-REA6** (CORDEX area, 1995–2019)
  - Same parameters + gust speed (v_{gust}), relative humidity (*RH*), specific humidity (*q*) and total cloud cover (*cc*)

  → Calculating gust factor $g_v = v_{gust}/v$

→ 12 case studies (2015 – 2020)



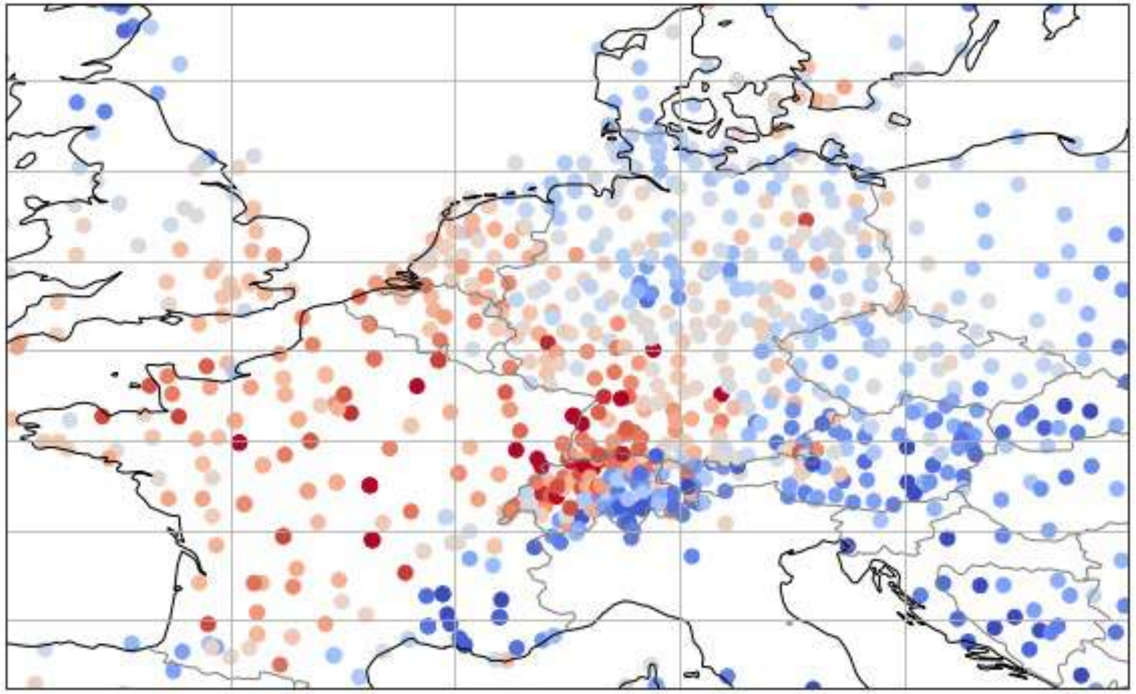


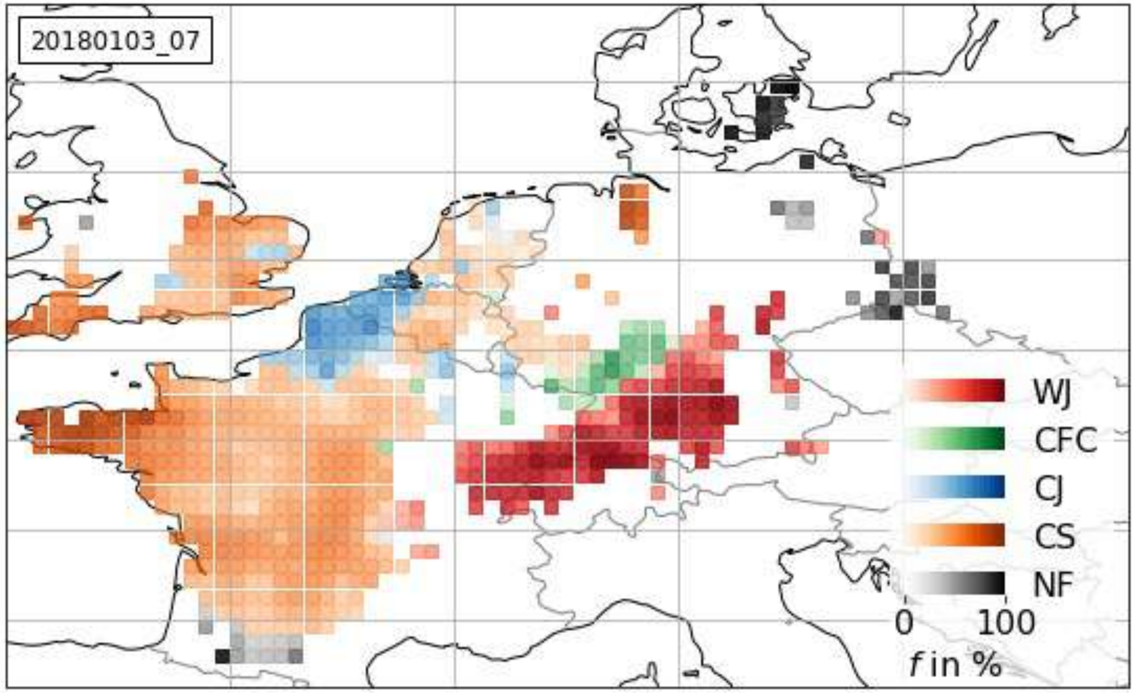
OBJECTIVE IDENTIFICATION

Eisenstein, L., Schulz, B., Qadir, G. A., Pinto, J. G. and Knippertz, P. (2022): Identification of high-wind features within extratropical cyclones using a probabilistic random forest – Part 1: Method and case studies. *Weather and Climate Dynamics*, **10.5194/wcd-3-1157**.

GOAL

Karlsruhe Institute of Technology





$\tilde{v}$ < 0.8 $\tilde{v} \geq 0.8$

Find the cause of high wind speeds at a single station or grid point at a given time step

→ independent of space (resolution, gradients, etc.) and temporal evolution (of more than 1h)

Subjective Identification → Probabilistic Random Forest → Kriging

RANDOM-FOREST-BASED **ME**SOSCALE WIND **F**EATURE **I**DENTIFICATION (RAMEFI)

- Subjective labelling of 12 case studies including ‚no feature' (NF) category

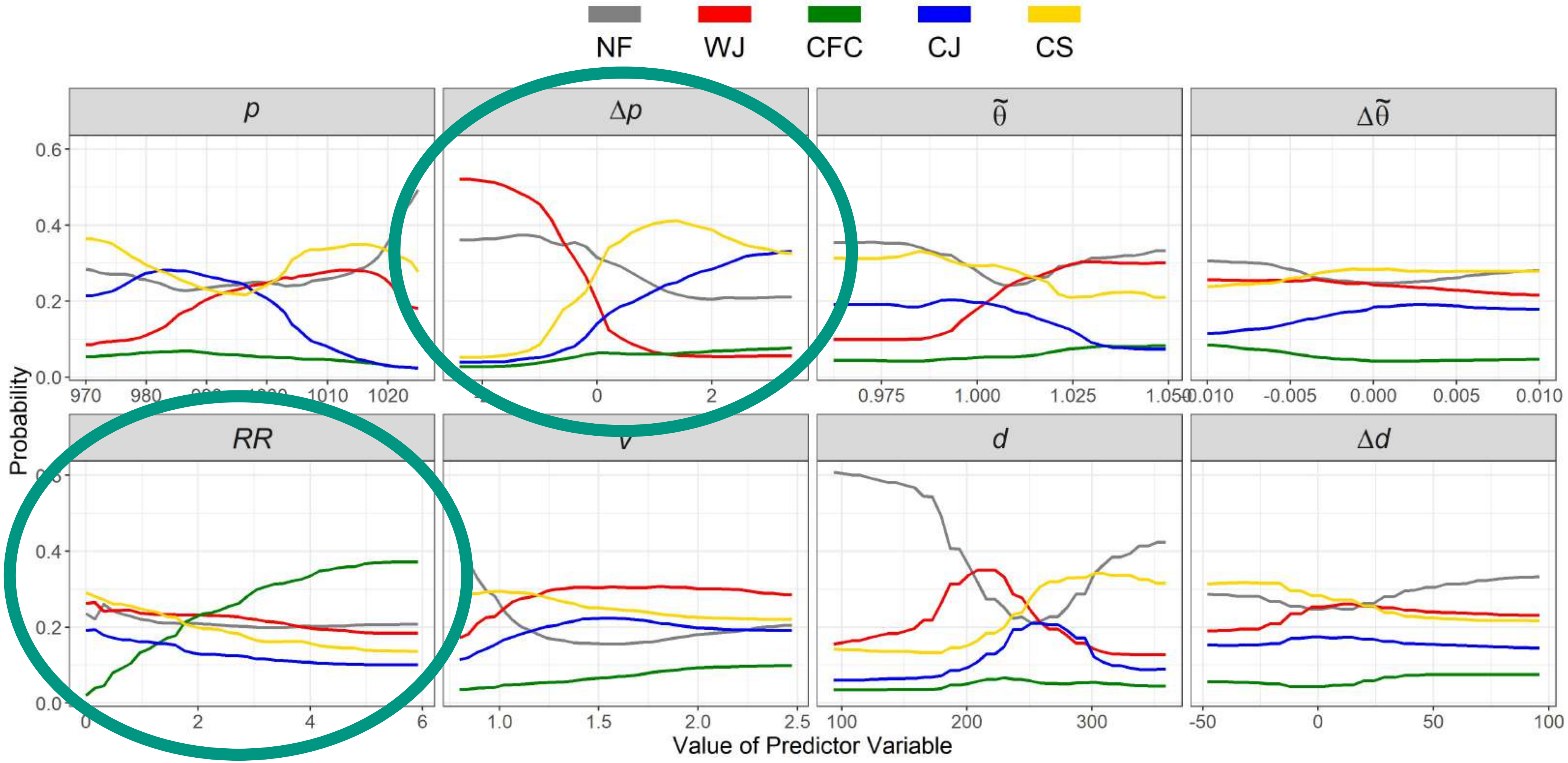
⇨ Training of a probabilistic random forest independent of spatial distribution

- 8 surface predictor variables:
  - Normalised wind speed
  - Wind direction + tendency
  - Precipitation
  - Mean sea level pressure + tendency
  - Normalised potential temperature + tendency

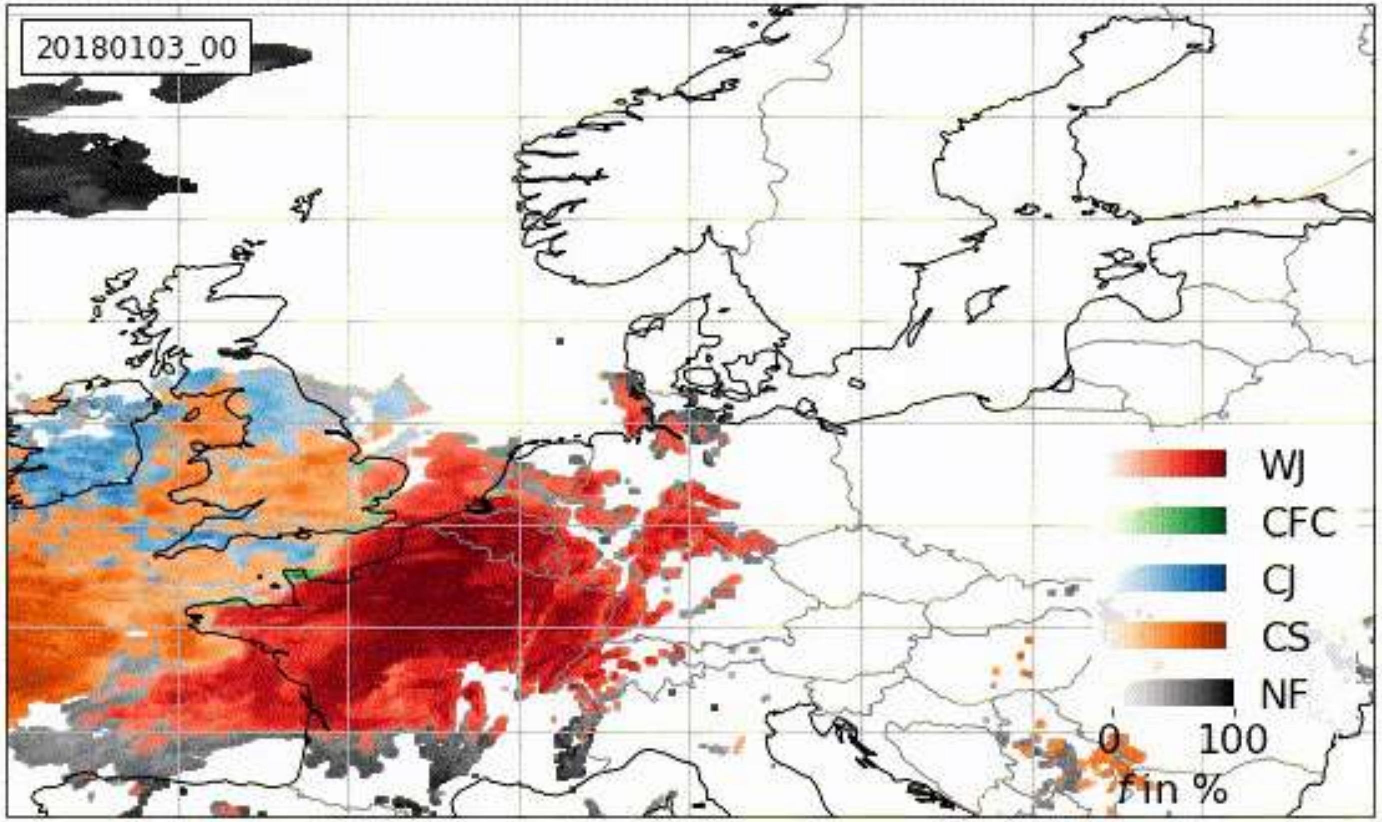
→ **Once trained, RAMEFI can also be used on gridded data!**

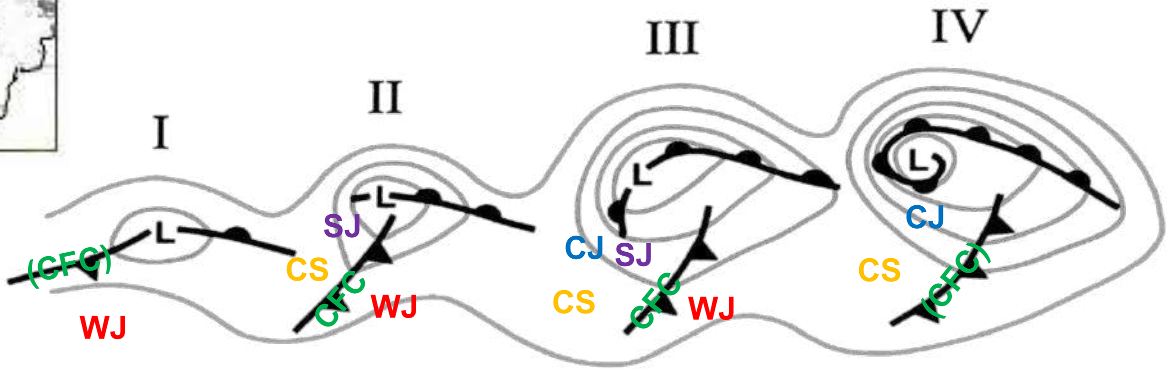
Code available at
10.5281/zenodo.6541303

PREDICTOR IMPORTANCE



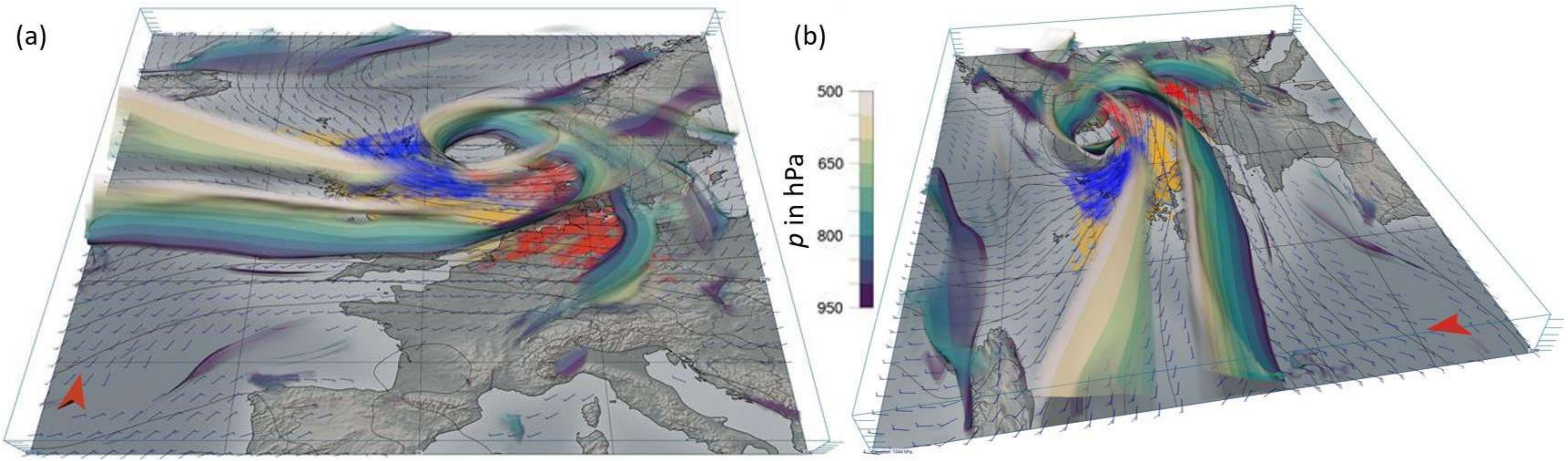
BURGLIND (03 JANUARY 2018)





adapted from
and Schultz et al. (1998)

NEAR-REAL-TIME PRODUCT



Combining RAMEFI with the 3D front detection of Met.3D (Beckert et al., *GMD*, 2023)

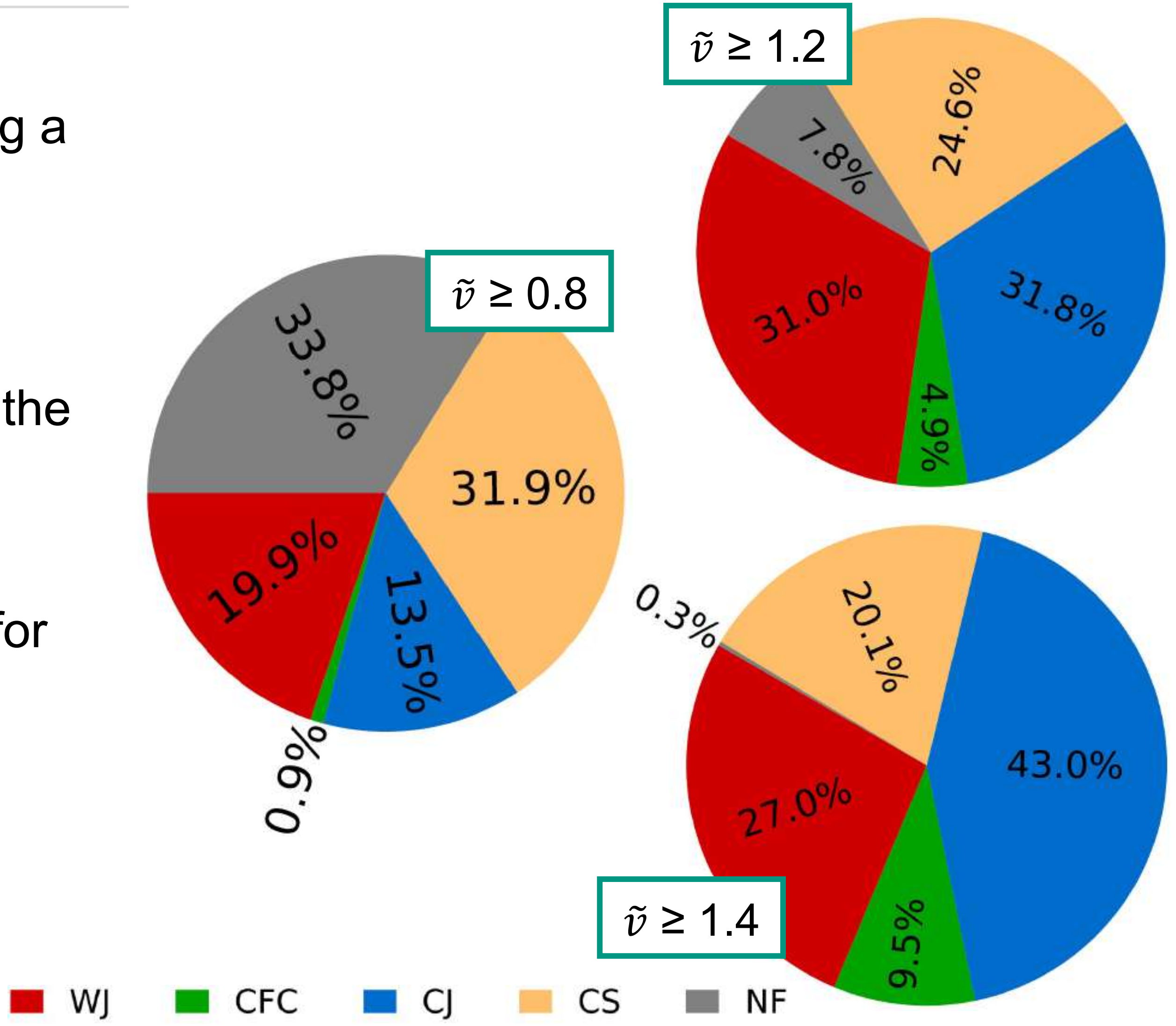
Coming soon to www.kit-weather.de !

CLIMATOLOGY OVER EUROPE FOR 19 WINTER SEASONS

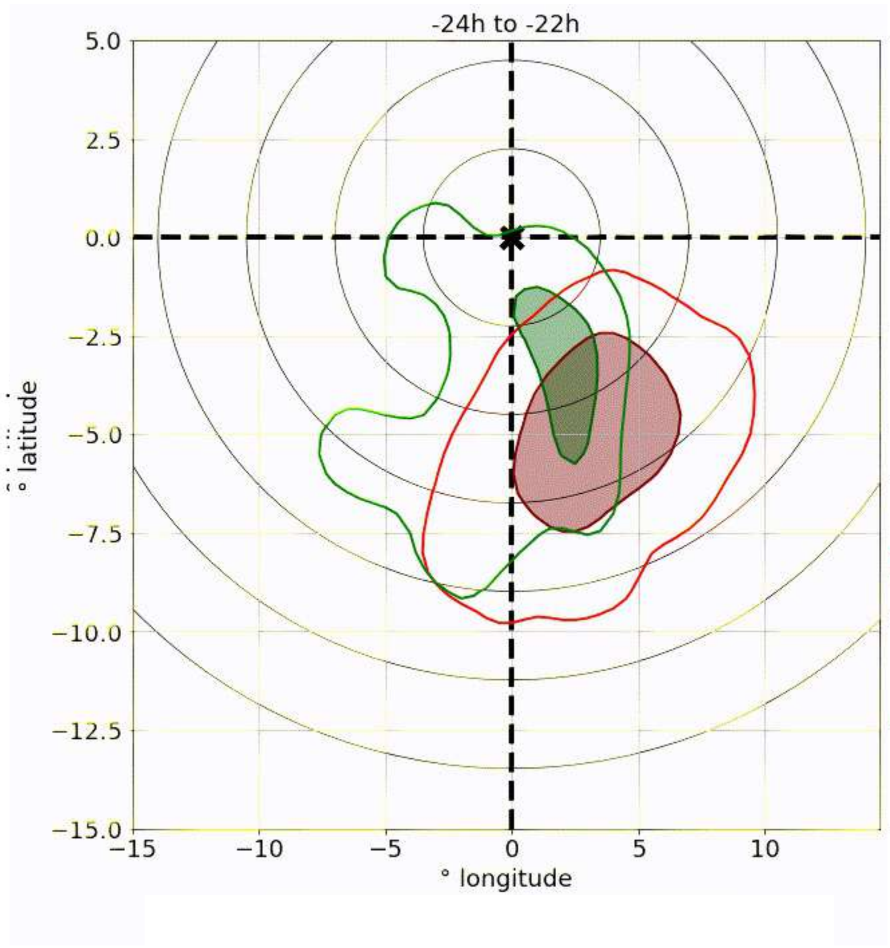
Eisenstein, L., Schulz, B., Pinto, J. G. and Knippertz, P. (2023): Identification of high-wind features within extratropical cyclones using a probabilistic random forest – Part 2: Climatology [preprint]. *Weather and Climate Dynamics Discussions*, **10.5194/wcd-2023-10**.

RELATIVE OCCURRENCE

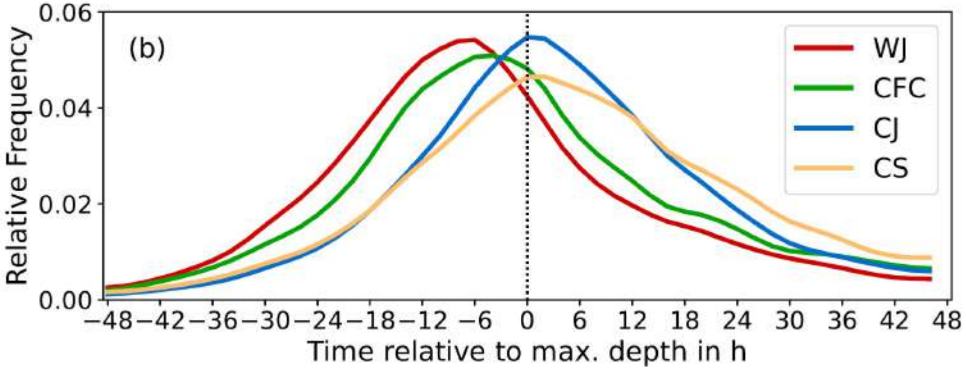
- CS: most frequent cause of high winds affecting a large area
- CFC: small-scale and less frequent
- NF: very high proportion but mostly situated in the outskirts of a cyclone area and decreases for higher wind speeds
- CJ and CFC proportion increase substantially for higher wind speeds



SYSTEM-RELATIVE COMPOSITE



- WJ: mostly in **south-eastern** quadrant and **first** to occur
- CFC: high case-to-case **variability** and occurring shortly after the WJ
- CS: mostly in **south-western** quadrant and usually the **last** feature to vanish
- CJ closer to cyclone centre and peak occurrence around time of **maximum depth**



Lea Eisenstein et al. (lea.eisenstein@kit.edu)

CHARACTERISTICS

- CJ: highest wind and gust speeds → low gust factor
- CFC: highest gust factor
- WJ and CS similar wind characteristics

- CFC: highest humidity levels
- CS: large cloud cover distribution due to spotty convection in otherwise quite sunny conditions

SUMMARY

RAMEFI enables a probabilistic identification of WJ, CFC, CS and CJ+SJ …

- independent of spatial distribution and temporal evolution (of more than 1h)
- using only surface parameters based on temperature, pressure, wind, precipitation
- suitable for a near-real-time product

10.5194/wcd-3-1157

RAMEFI was used to compile a 19-year climatology over Europe

- CS: most common cause of high winds
- CJ: causes highest wind speeds
- CFC: less frequent, high case-to-case variability, but highest gust factor

10.5194/wcd-2023-10

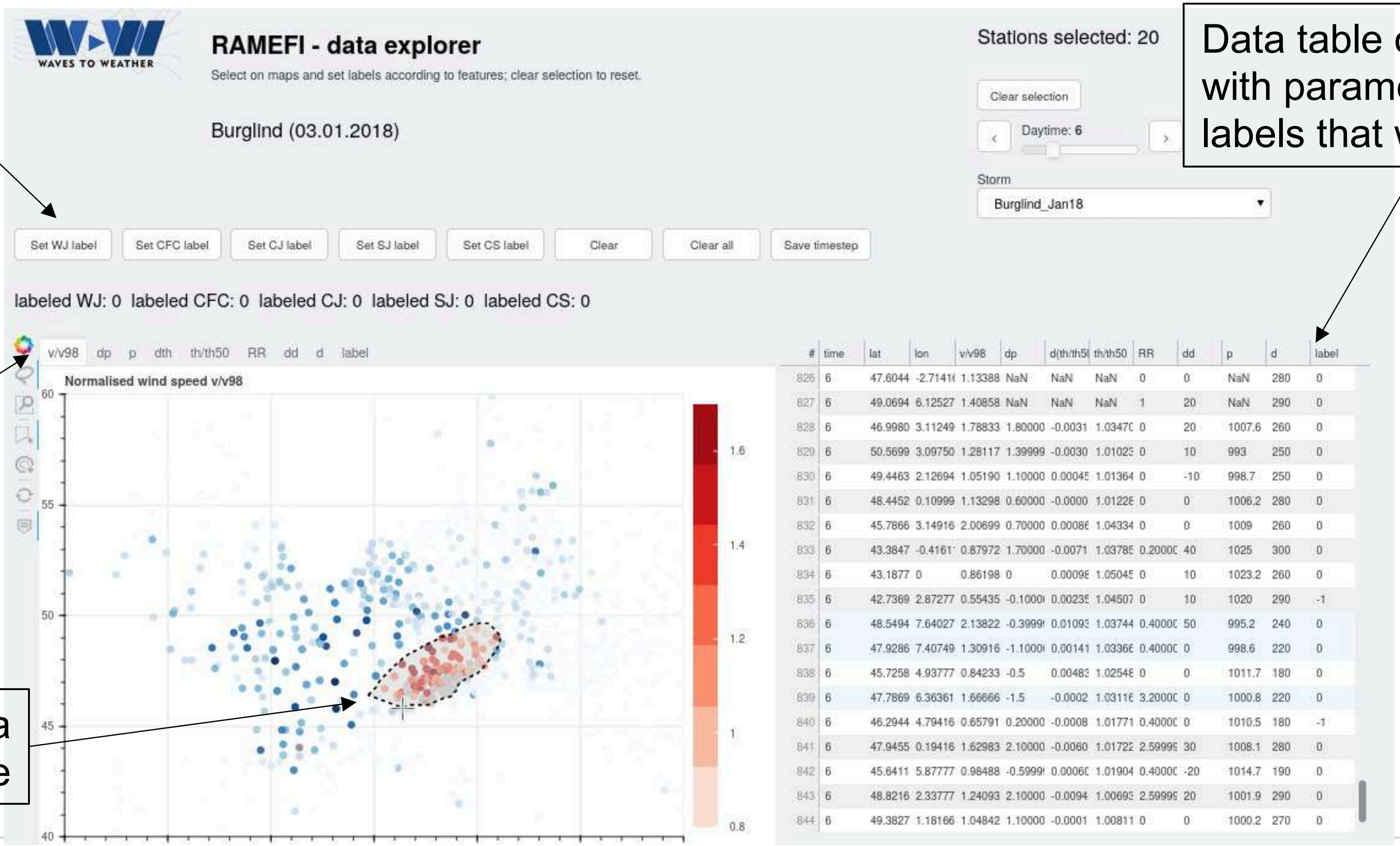
INTERACTIVE IDENTIFICATION

How does a meteorologist identify dynamical features with their synoptic knowledge?

→ Building an interactive tool to select feature areas by hand

Set label of selected stations in the table to a specific feature

Code available at
10.5281/zenodo.6541303



Data table of all stations with parameters and set labels that will be saved

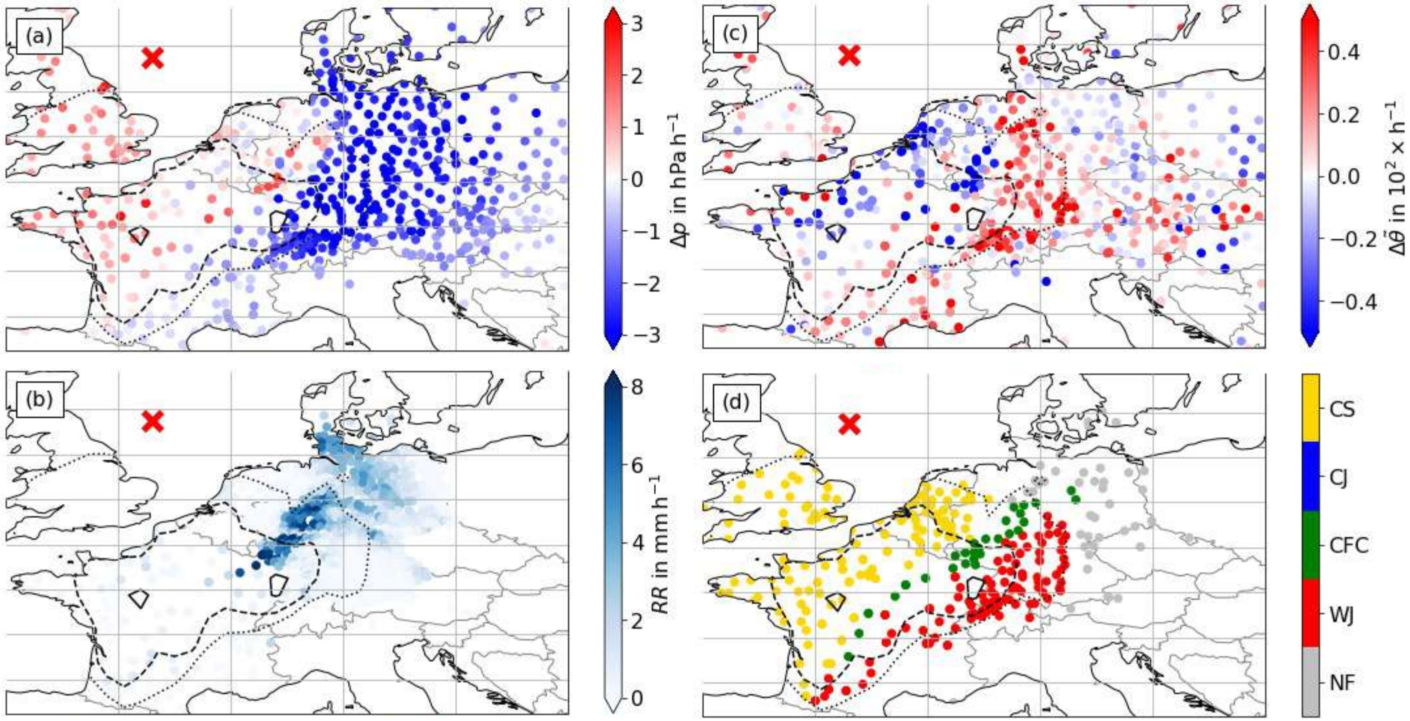
Choose which variable you want to see

Select area with mouse

SUBJECTIVE LABELLING

- **MSLP** decreases ahead of the cold front, such that the tendency is $\lesssim 0$ for the WJ while it becomes positive when CFC arrives
- While CFC shows heavy **precipitation**, there is almost none ahead of the front, i.e. in the WJ region
- For CFC, **θ** decreases with the onset of precipitation
- The **wind direction** changes with arrival of the cold front, hence CFC

Burglind, 03 Jan 2018, 6 UTC



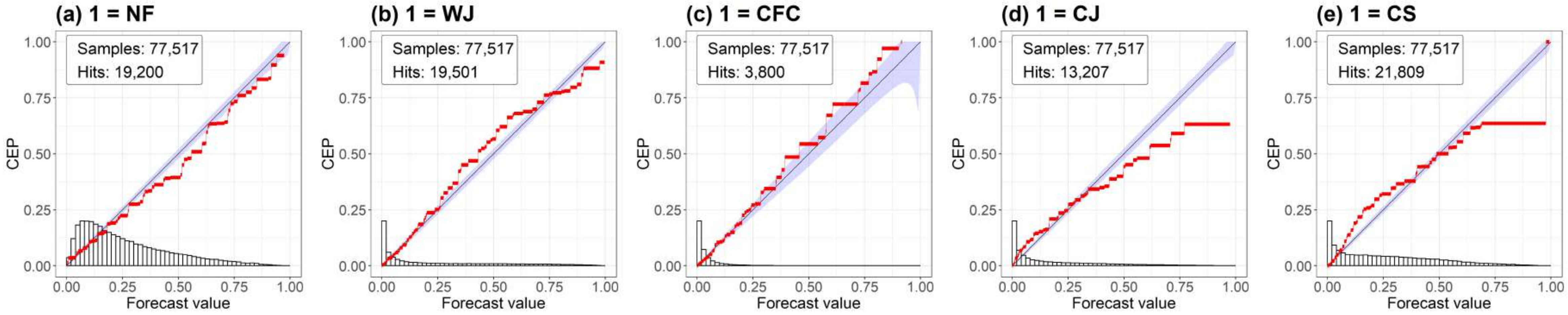
- CJ usually noticable due to **hook-shaped** structure SW of cyclone center
- Everything behind CFC that is not CJ is labelled CS

CALIBRATION OF RF FORECASTS

Overall improvement (Brier score) over Climatology: 24.7 %.

But: How well does the RF forecast the individual wind features?

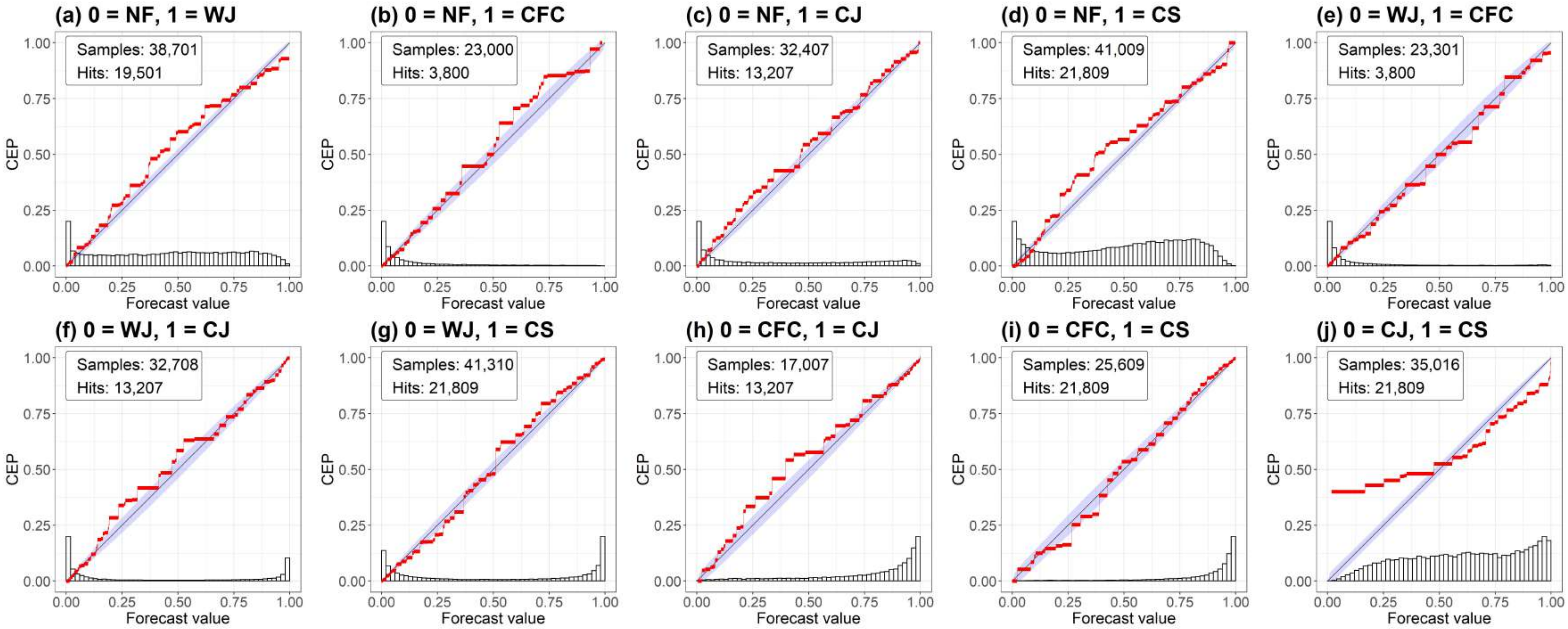
➡ Use **reliability diagrams** to evaluate the probability forecasts. The forecasts are calibrated if the calibration curve follows the diagonal (meaning that if, for example, a 20%-forecast is issued 100 times, the event should occur ca. 20 times).



The RF forecasts are (mostly) **well-calibrated**. Only for larger probabilities of the CJ and CS the forecasts miscalibration can be observed.

DISTINCTION OF WIND FEATURE

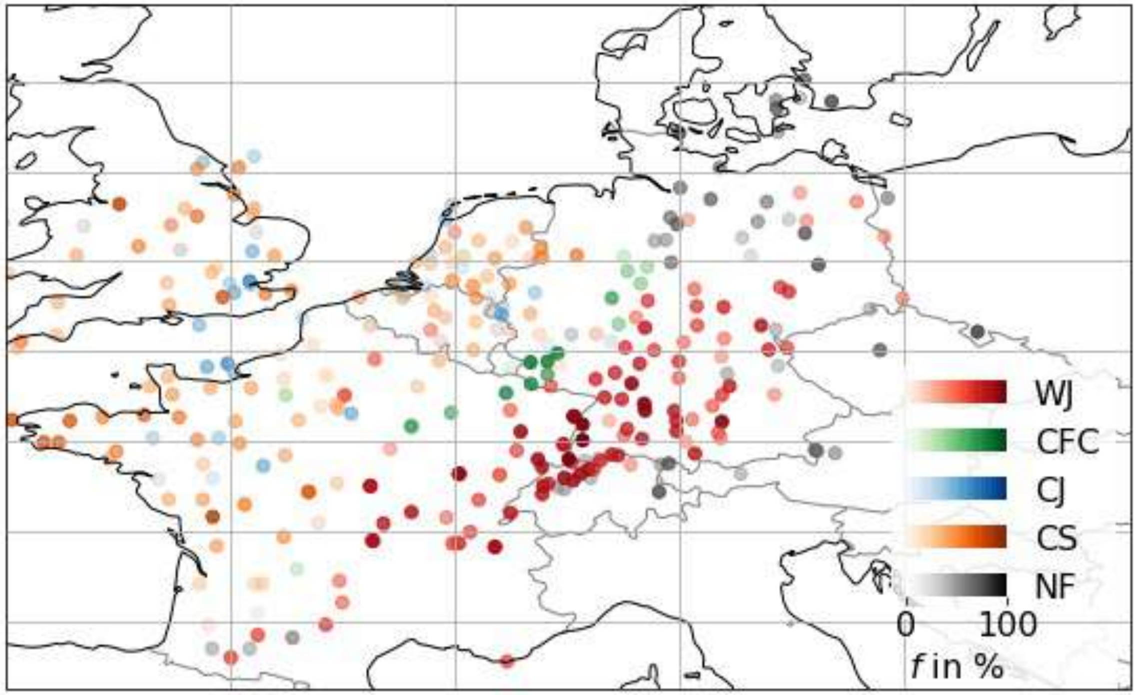
How well does the RF **discriminate** two wind features?

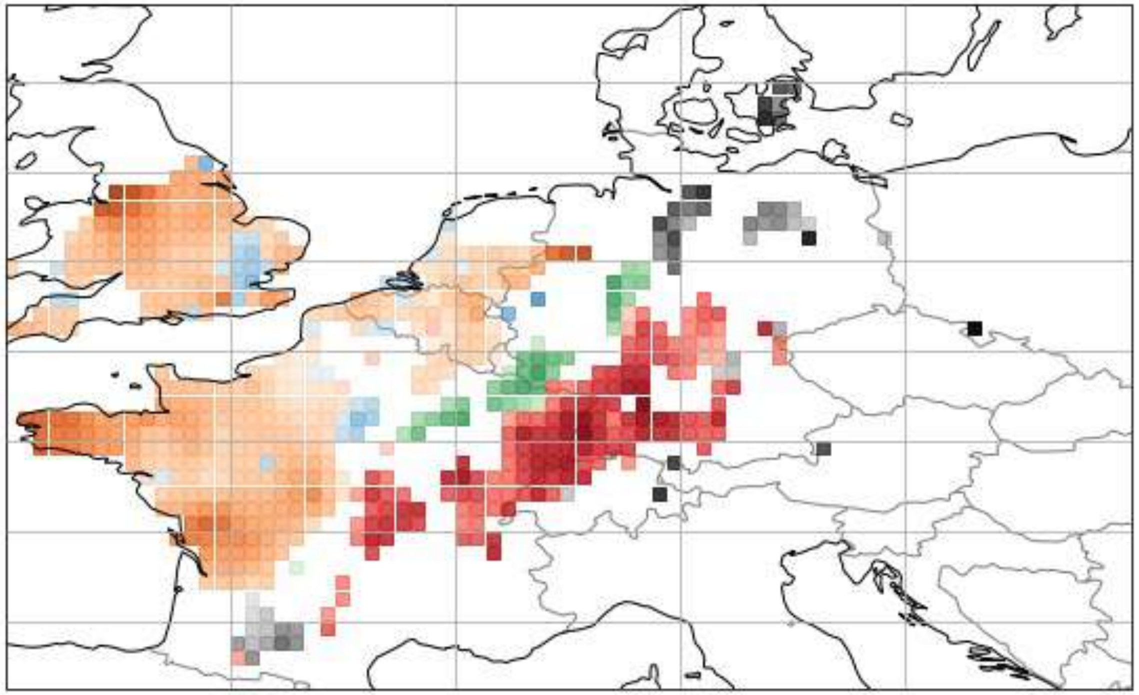


The RF forecasts are **well-calibrated** besides the distinction of CJ and CS.

GENERATION OF PROBABILITY MAPS

Use **Kriging** to spatially interpolate the forecasts from the stations to the grid

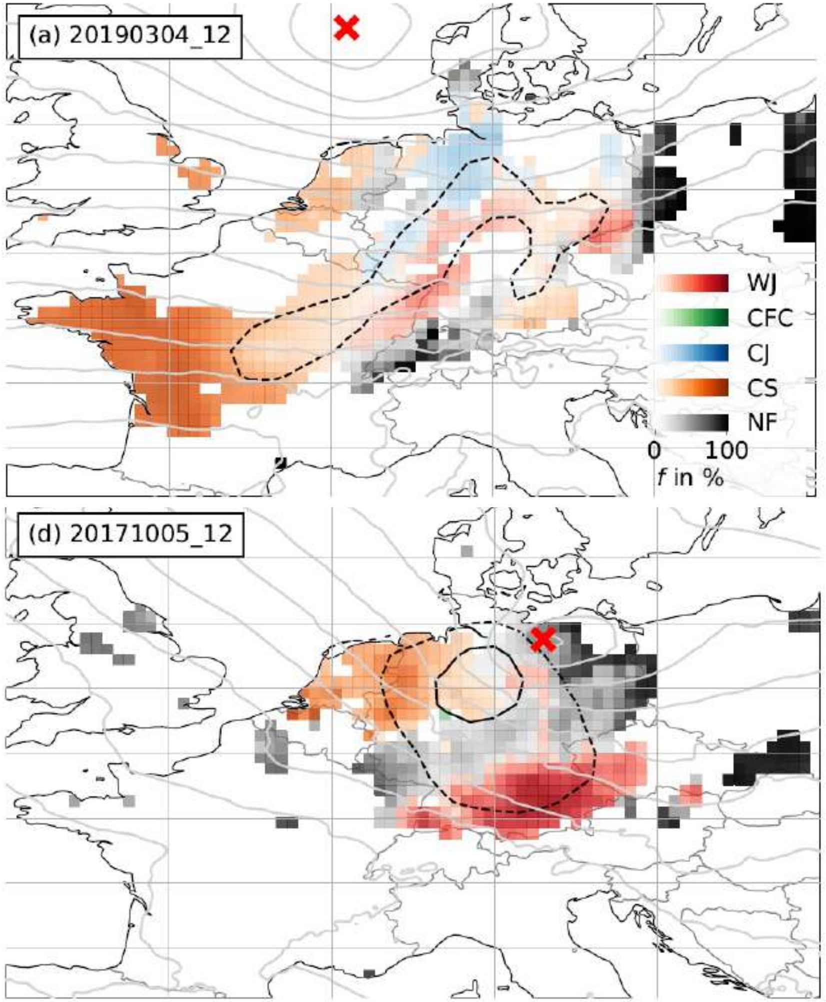




(in collaboration with Ghulam A. Qadir)

EXAMPLES & POSSIBLE SHORTCOMINGS

- Double fronts and convergence lines
  → Area in between can show characteristics of both warm and cold sector
- Strong background pressure gradient
  → May cause or enhance high wind speeds and make identification of features more difficult
- Shapiro-Keyser cyclones
  → Differ in cyclone evolution and rarely show CFC
- Spatial independence
  → No knowledge about intensity of the cyclone and more difficult to indentify warm sector



SOURCES

- Clark, P.A. and Gray, S.L. (2018): Sting jets in extratropical cyclones: a review. *Q J R Meteorol Soc.*, 144, 943–969. doi: 10.1002/qj.3267
- Schultz, D. M., Keyser, D. and Bosart, L. F. (1998): The Effect of Large-Scale Flow on Low-Level Frontal Structure and Evolution in Midlatitude Cyclones, *Monthly Weather Review*, 126(7), 1767–1791. doi: 10.1175/1520-0493(1998)126<1767:teolsf>2.0.co;2.
- Eisenstein, L., Schulz, B., Qadir, G. A., Pinto, J. G., and Knippertz, P. (2022): Identification of high-wind features within extratropical cyclones using a probabilistic random forest – Part 1: Method and case studies, Weather Clim. Dynam., 3, 1157–1182, https://doi.org/10.5194/wcd-3-1157-2022.
- Eisenstein, L., Schulz, B., Pinto, J. G., and Knippertz, P. (2023): Identification of high-wind features within extratropical cyclones using a probabilistic random forest – Part 2: Climatology, Weather Clim. Dynam. Discuss. [preprint], https://doi.org/10.5194/wcd-2023-10, in review.
- Beckert, A. A., Eisenstein, L., Oertel, A., Hewson, T., Craig, G. C., and Rautenhaus, M. (2023): The three-dimensional structure of fronts in mid-latitude weather systems as represented by numerical weather prediction models, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2022-278, in review.