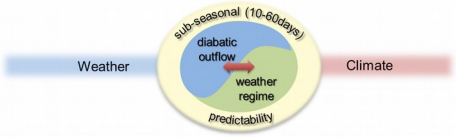
Karlsruhe Institute of Technology

*Helmholtz Young Investigator Group VH-NG-1243: "**S**ub-seasonal **PRE**dict**A**bility: understanding the role of **D**iabatic **OUT**flow" (SPREADOUT)*

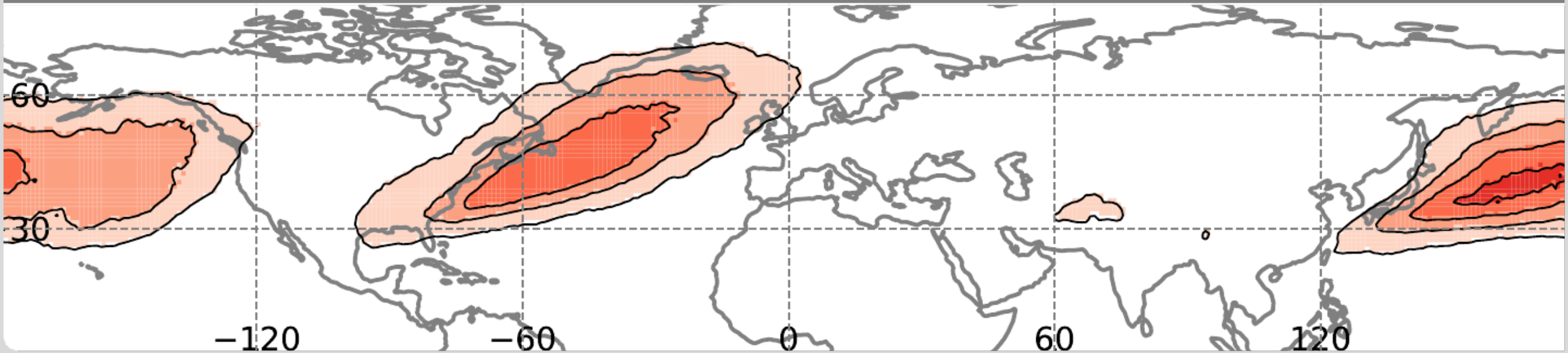


HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

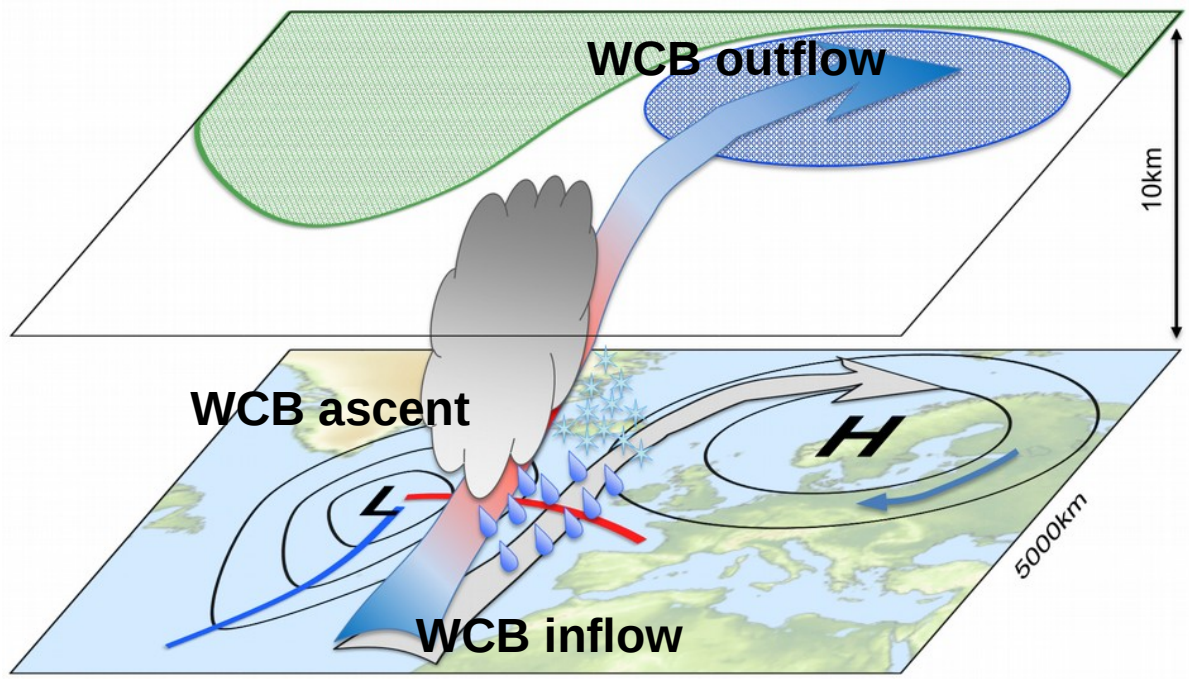
Development of a logistic model to study warm conveyor belts on sub-seasonal time scales

Julian F. Quinting[1] and Christian M. Grams[1]

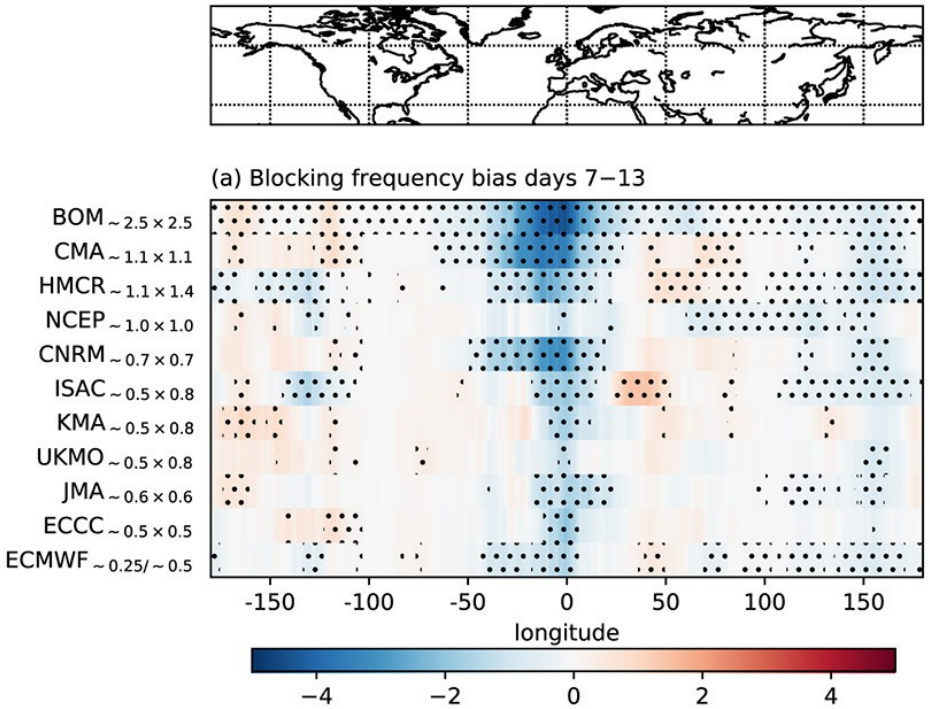
[1]Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Germany (julian.quinting@kit.edu)



WCBs affect lifecycle of blocking and blocking regimes



Pfahl et al. 2015; Steinfeld and Pfahl 2019



Quinting and Vitart 2019

Does a misrepresentation of WCBs dilute forecast skill on sub-seasonal time scales?

Systematic verification of WCB in S2S models still missing

Issue 1: Data amount

- ERA-Interim: 40 years * 365 days * 4/day

  ~**58,400 time steps** amount to **252 GB trajectory data**

- S2S reforecast: 21 years * 66 fc/year * 101 ensemble members * 46 day fc lead time (Vitart et al. 2017)

  ~**6,439,356 time steps** would amount to **25 TB trajectory data**

Systematic verification of WCB in S2S models still missing

Issue 1: Data amount

- ERA-Interim: 40 years * 365 days * 4/day

  ~**58,400 time steps** amount to **252 GB trajectory data**

- S2S reforecast: 21 years * 66 fc/year * 101 ensemble members * 46 day fc lead time (Vitart et al. 2017)

  ~**6,439,356 time steps** would amount to **25 TB trajectory data**

Issue 2: Data availability

- S2S reforecast: Temporal resolution 24-hourly, 11 pressure levels

Systematic verification of WCB in S2S models still missing

Issue 1: Data amount

- ERA-Interim: 40 years * 365 days * 4/day

  ~**58,400 time steps** amount to **252 GB trajectory data**

- S2S reforecast: 21 years * 66 fc/year * 101 ensemble members * 46 day fc lead time *(Vitart et al. 2017)*

  ~**6,439,356 time steps** would amount to **25 TB trajectory data**

Issue 2: Data availability

- S2S reforecast: Temporal resolution 24-hourly, 11 pressure levels

Build a statistical model to identify WCBs from Eulerian fields!

Model development and predictor selection

- Predictand y: binary fields (0/1 flag) of WCB inflow, ascent and outflow
  (Madonna et al. 2014; Thanks to ETH Zurich Atmospheric Dynamics group for sharing the data.)
- Predictors $x_1 ... x_n$ based on ERA-Interim fields of U, V, T, Z, Q on pressure levels available in S2S
- stepwise forward predictor selection using 10x 10-fold cross validation and likelihood-ratio test
- for each grid point on a 5°x5° latitude longitude grid

Model development and predictor selection

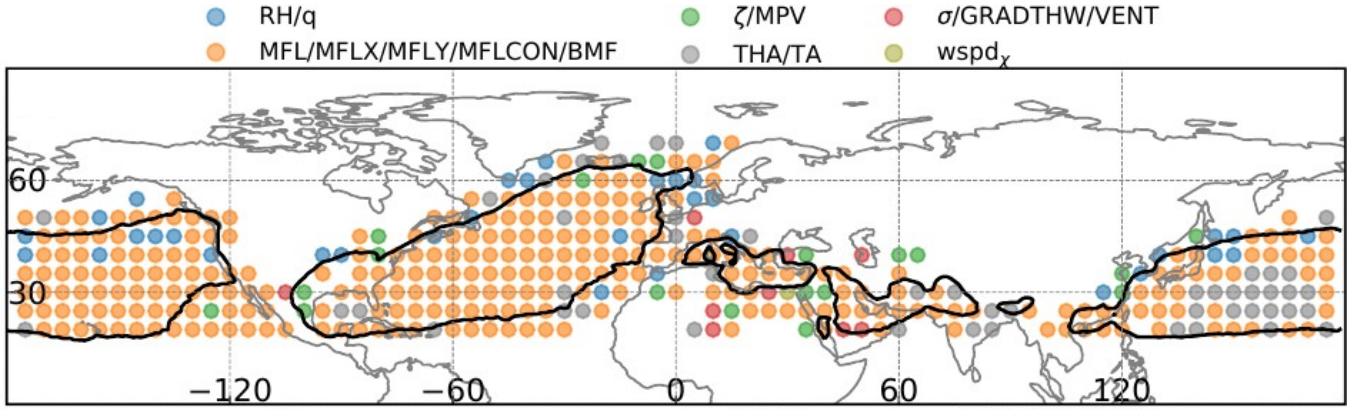
- Predictand y: binary fields (0/1 flag) of WCB inflow, ascent and outflow
  (Madonna et al. 2014; Thanks to ETH Zurich Atmospheric Dynamics group for sharing the data.)
- Predictors $x_1 ... x_n$ based on ERA-Interim fields of U, V, T, Z, Q on pressure levels available in S2S
- stepwise forward predictor selection using 10x 10-fold cross validation and likelihood-ratio test
- for each grid point on a 5°x5° latitude longitude grid

Multiple logistic regression model

$$p(WCB|x) = \frac{1}{1+e^{-g(x)}} \quad \text{with} \quad 0 \le p(x) \le 1 \quad \text{and} \quad g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n$$

Model development and predictor selection

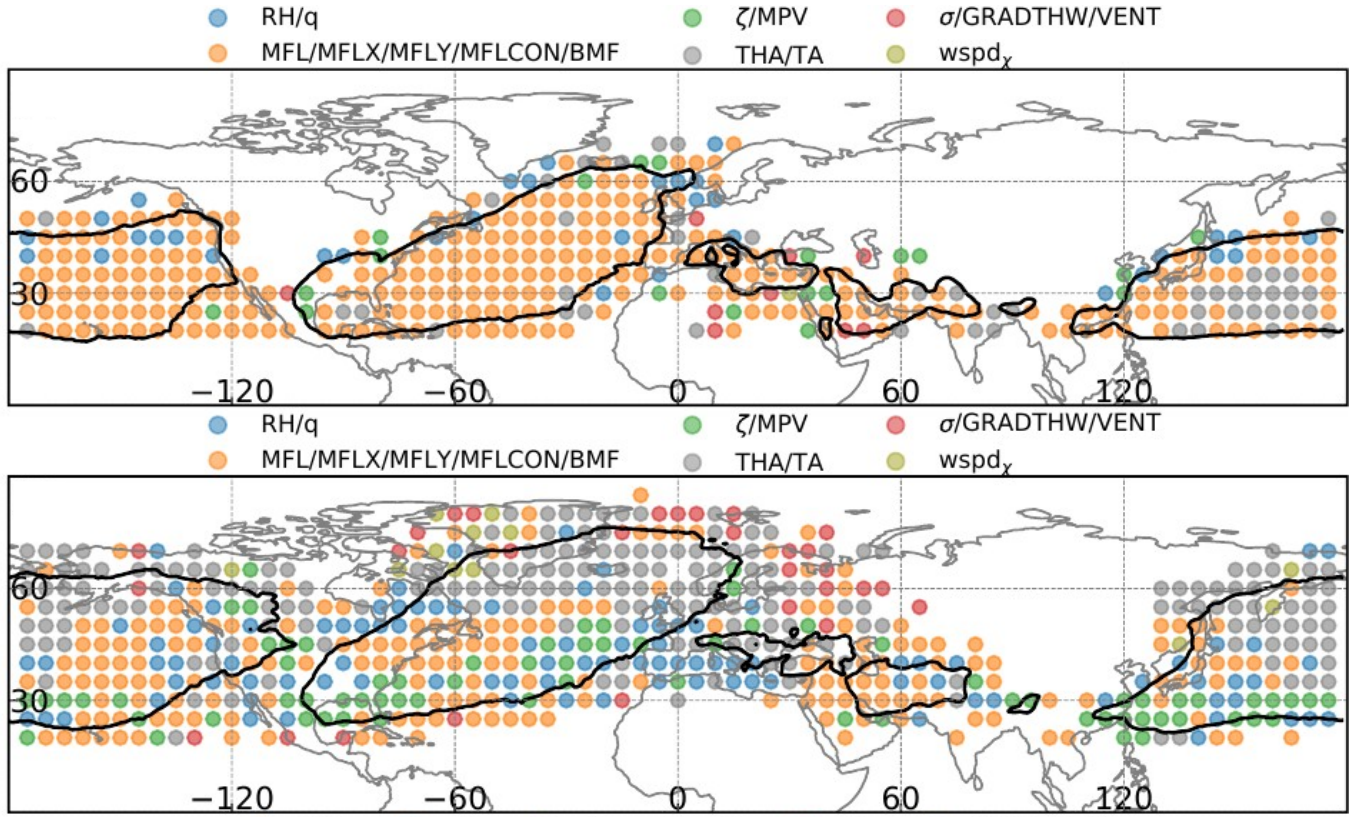
WCB inflow
Predictors are related to moisture flux



Model development and predictor selection

WCB inflow
Predictors are related to moisture flux

WCB ascent
Predictors are related to moisture flux and thickness advection

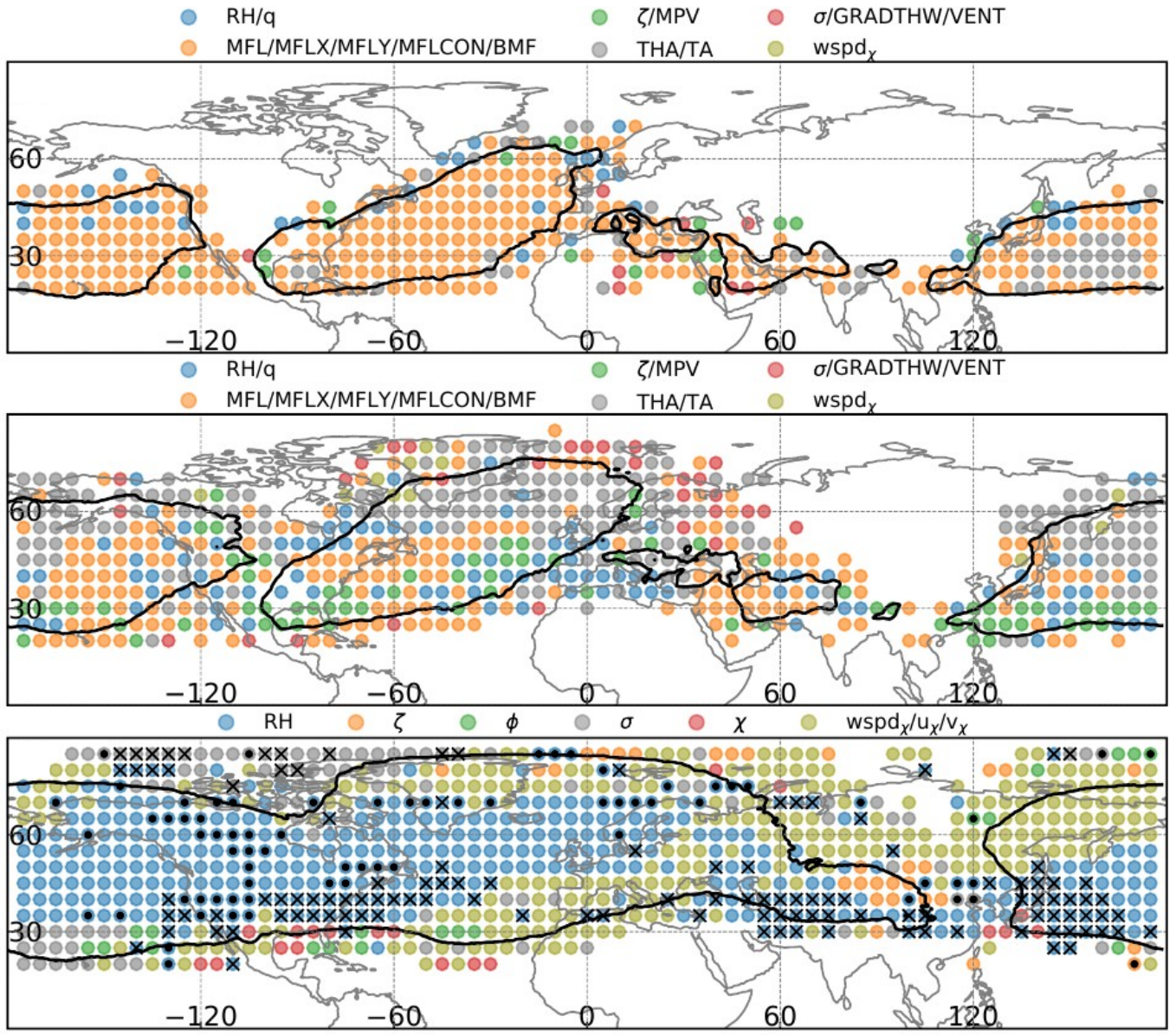


Model development and predictor selection

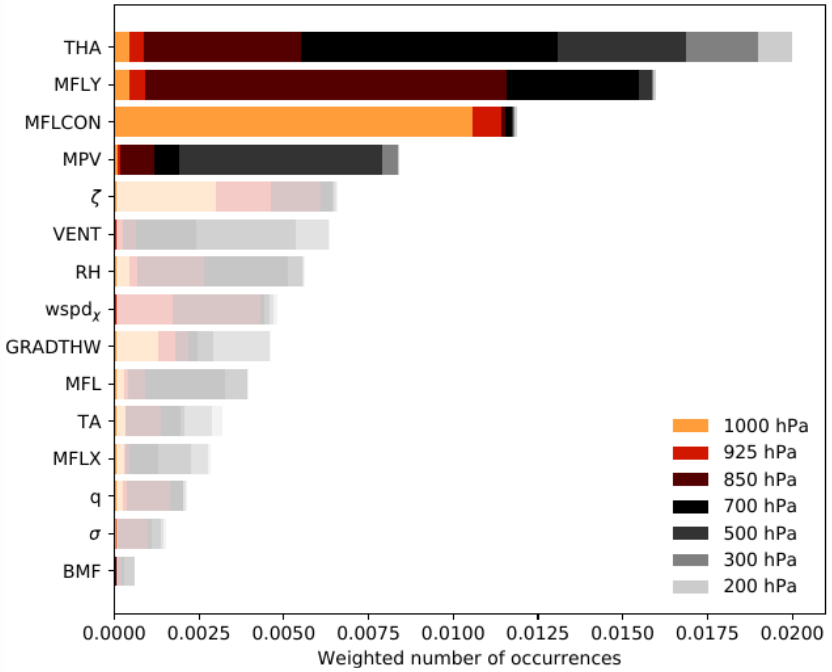
WCB inflow
Predictors are related to moisture flux

WCB ascent
Predictors are related to moisture flux and thickness advection

WCB outflow
Predictors are related to relative humidity and irrotational wind speed



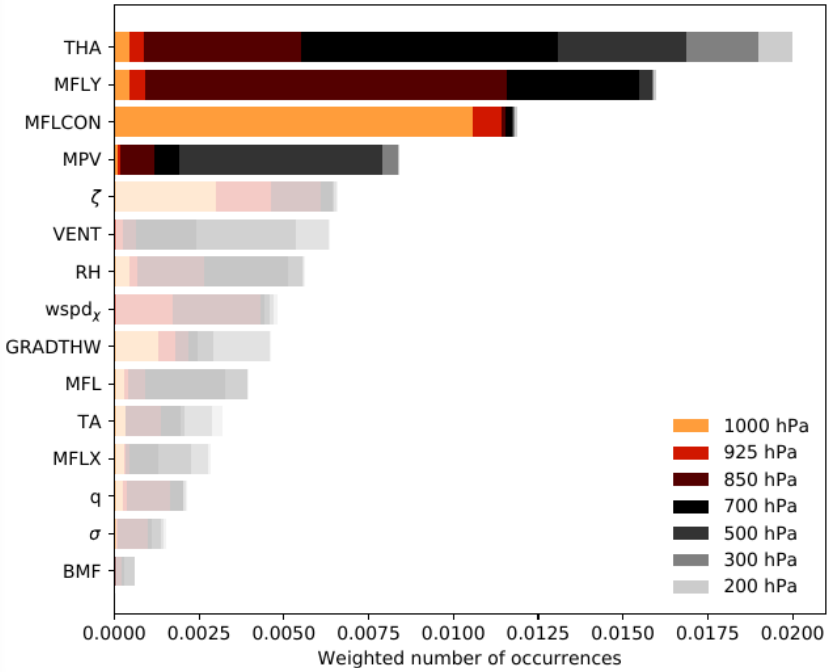
Model development and predictor selection

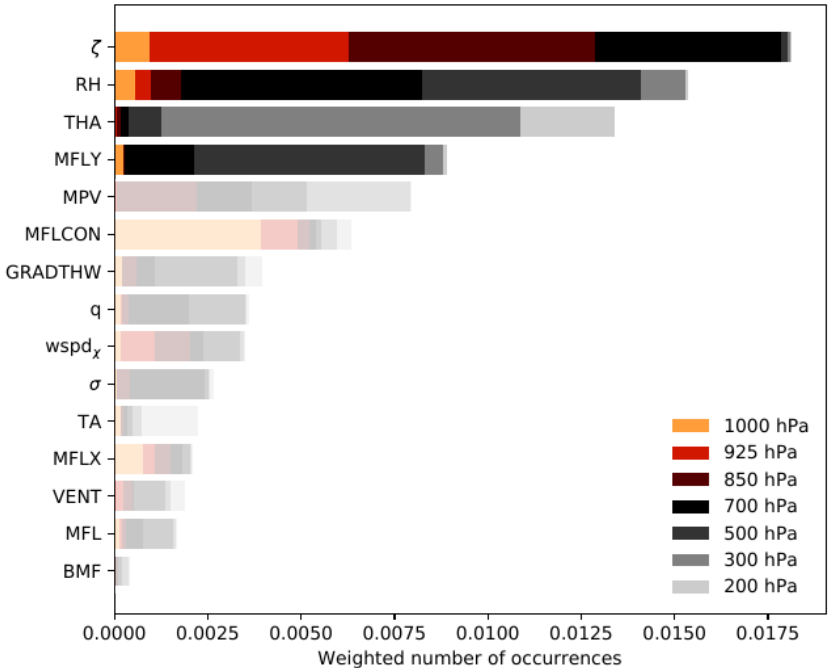


WCB inflow

- thickness advection at 700 hPa
- meridional moisture flux at 850 hPa
- moisture flux divergence at 1000 hPa
- moist PV at 500 hPa

Model development and predictor selection





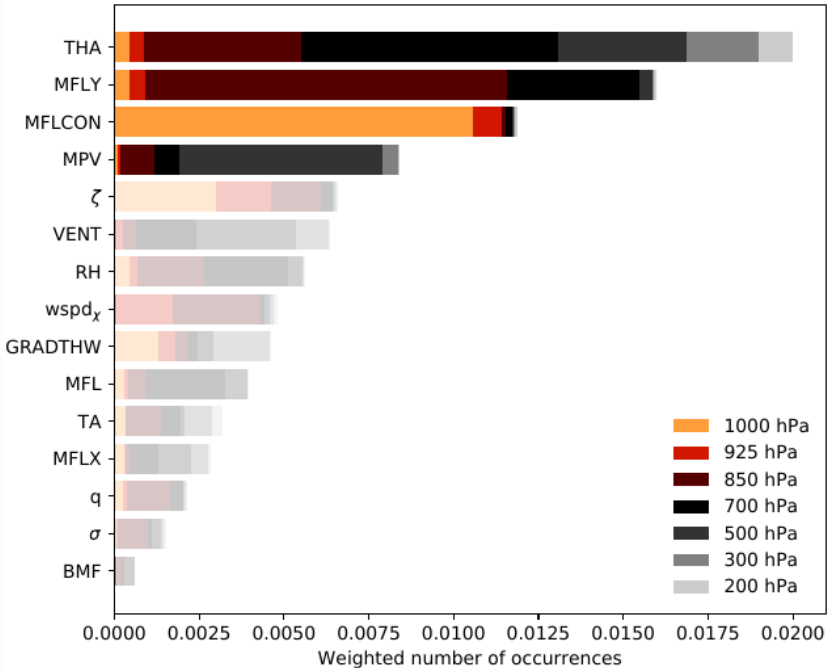
WCB inflow

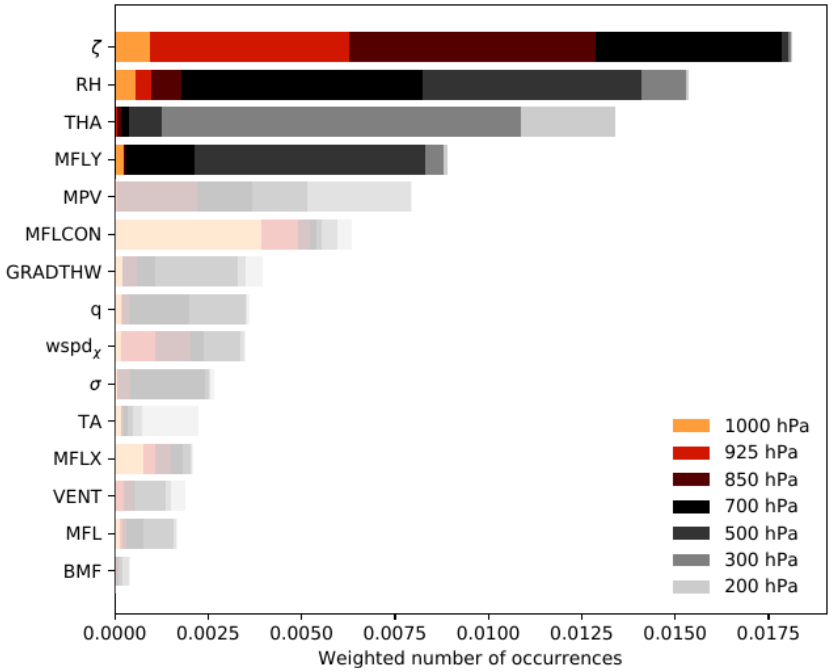
- thickness advection at 700 hPa
- meridional moisture flux at 850 hPa
- moisture flux divergence at 1000 hPa
- moist PV at 500 hPa

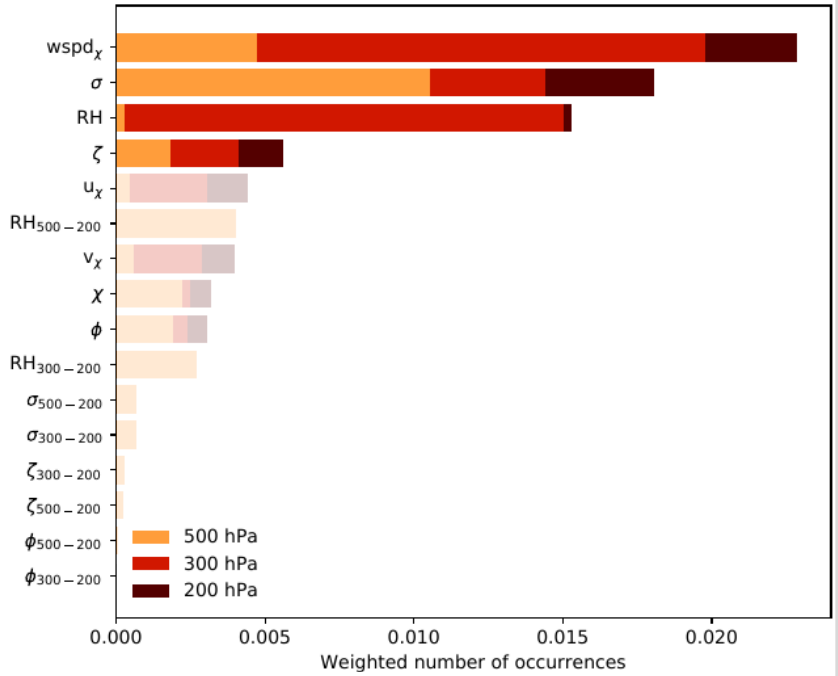
WCB ascent

- rel. vorticity at 850 hPa
- rel. humidity at 700 hPa
- thickness advection at 300 hPa
- meridional moisture flux at 500 hPa

Model development and predictor selection







WCB inflow
- thickness advection at 700 hPa
- meridional moisture flux at 850 hPa
- moisture flux divergence at 1000 hPa
- moist PV at 500 hPa

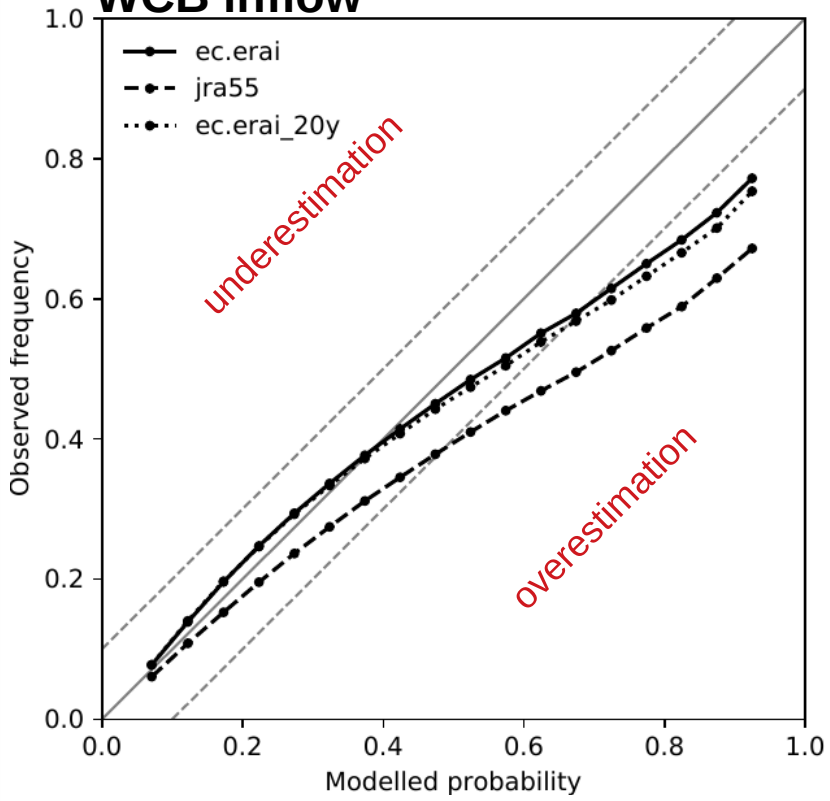
WCB ascent
- rel. vorticity at 850 hPa
- rel. humidity at 700 hPa
- thickness advection at 300 hPa
- meridional moisture flux at 500 hPa

WCB outflow
- irr. wind speed at 300 hPa
- static stability at 500 hPa
- rel. humidity at 300 hPa
- rel. vorticity at 300 hPa

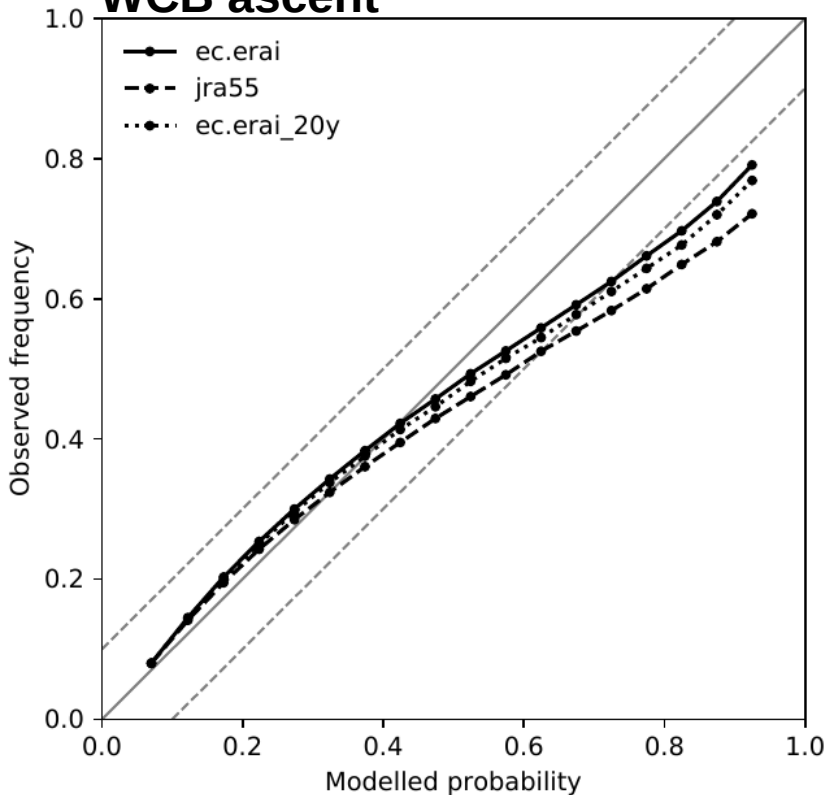
Development of one model per grid point and season

Model evaluation - Reliability

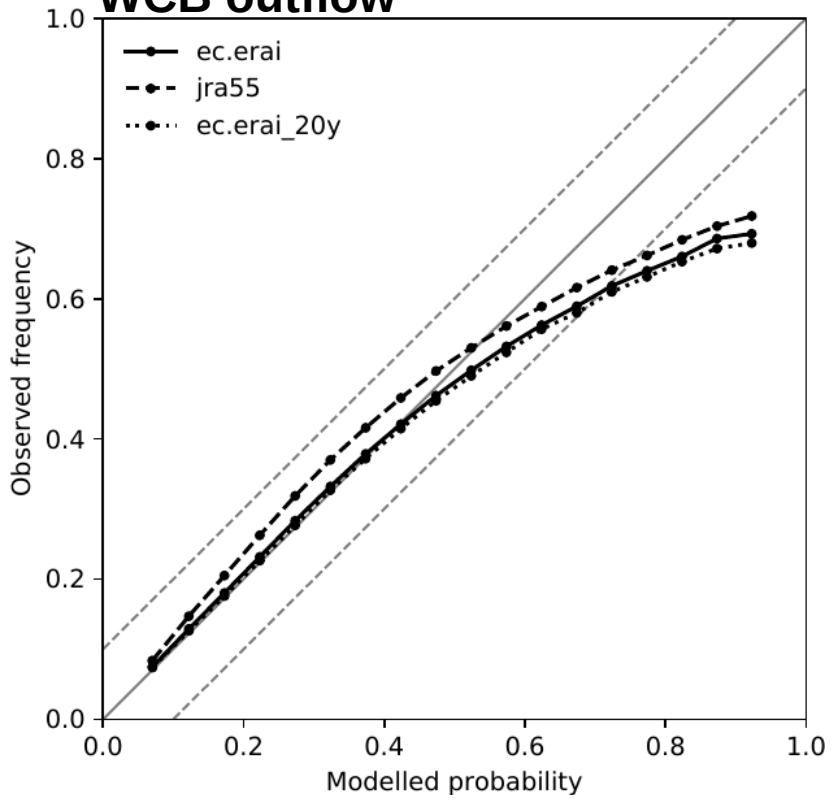
WCB inflow



WCB ascent



WCB outflow



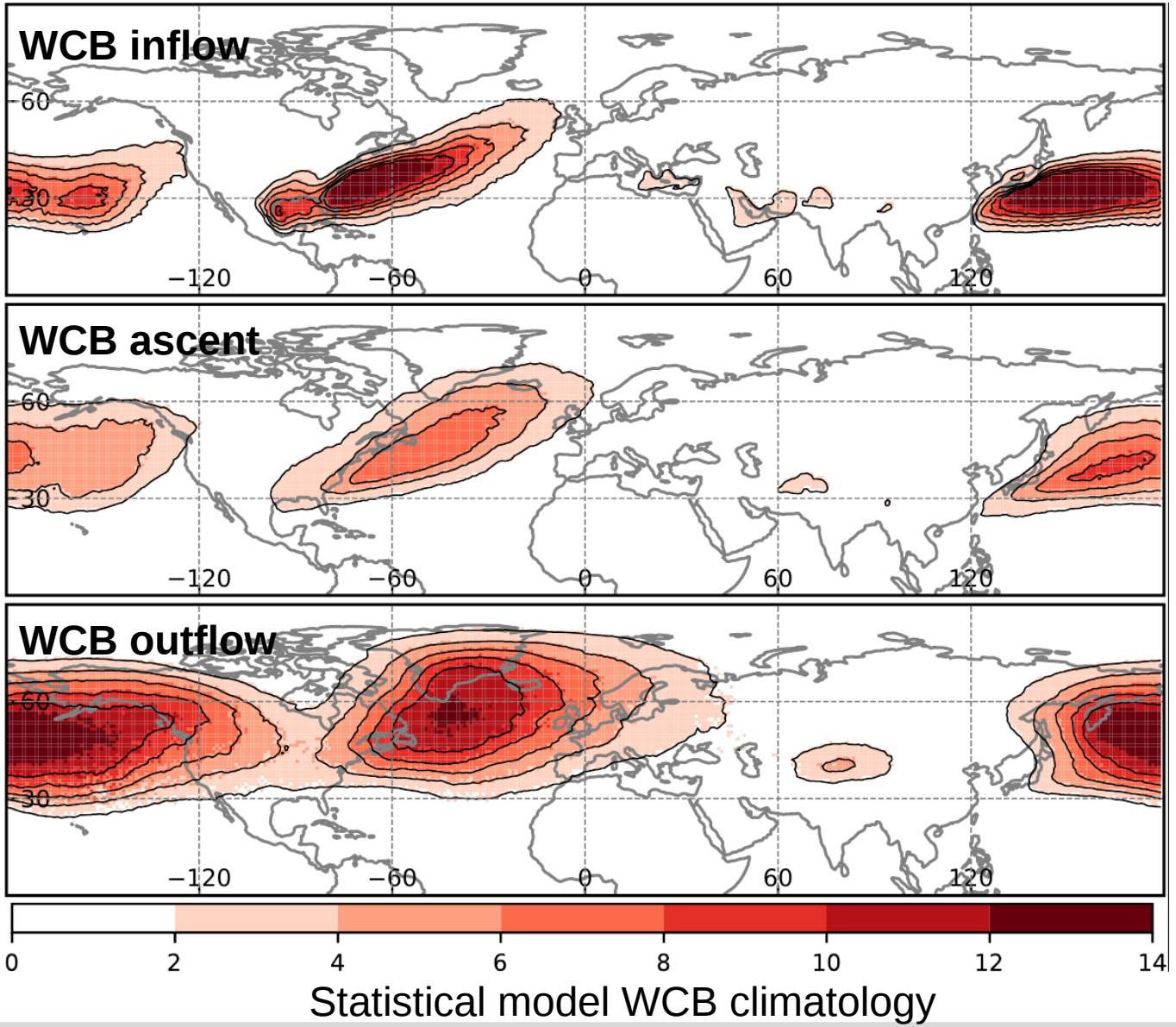
Model reliably predicts WCB frequency for probabilites < 0.5
Model overestimates WCB frequency for probabilities > 0.5 (artifact of WCB definition?)

ec.erai = 40 years of training data | ec.erai_20y = 20 years of training data | jra55 = ec.erai applied to jra55 reanalysis

Model evaluation - Climatology

- convert predicted probabilities to binary prediction by minimizing climatological bias at each grid point and for each season

- by definition climatology for WCB inflow, ascent and outflow is well reproduced.



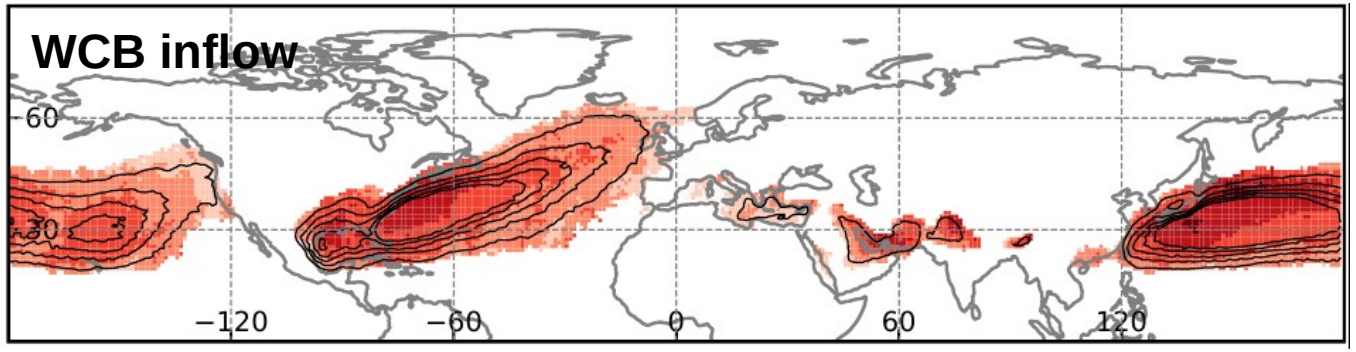
Lagrangian DJF WCB climatology

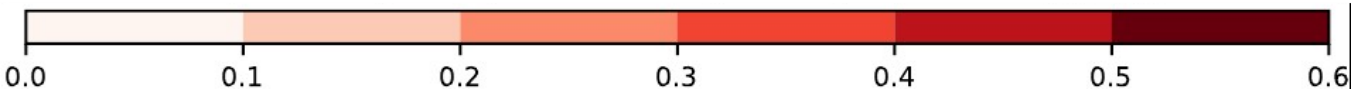
Statistical model WCB climatology

Model evaluation – Matthews correlation coefficient

$$MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP+FP)(TP+FN)(TN+FP)(TN+FN)}}$$

- MCC=+1 → perfect forecast
- MCC=-1 → total disagreement between forecast and observation
- useful for imbalanced data
- high score only if good results for TP, TN, FP, FN





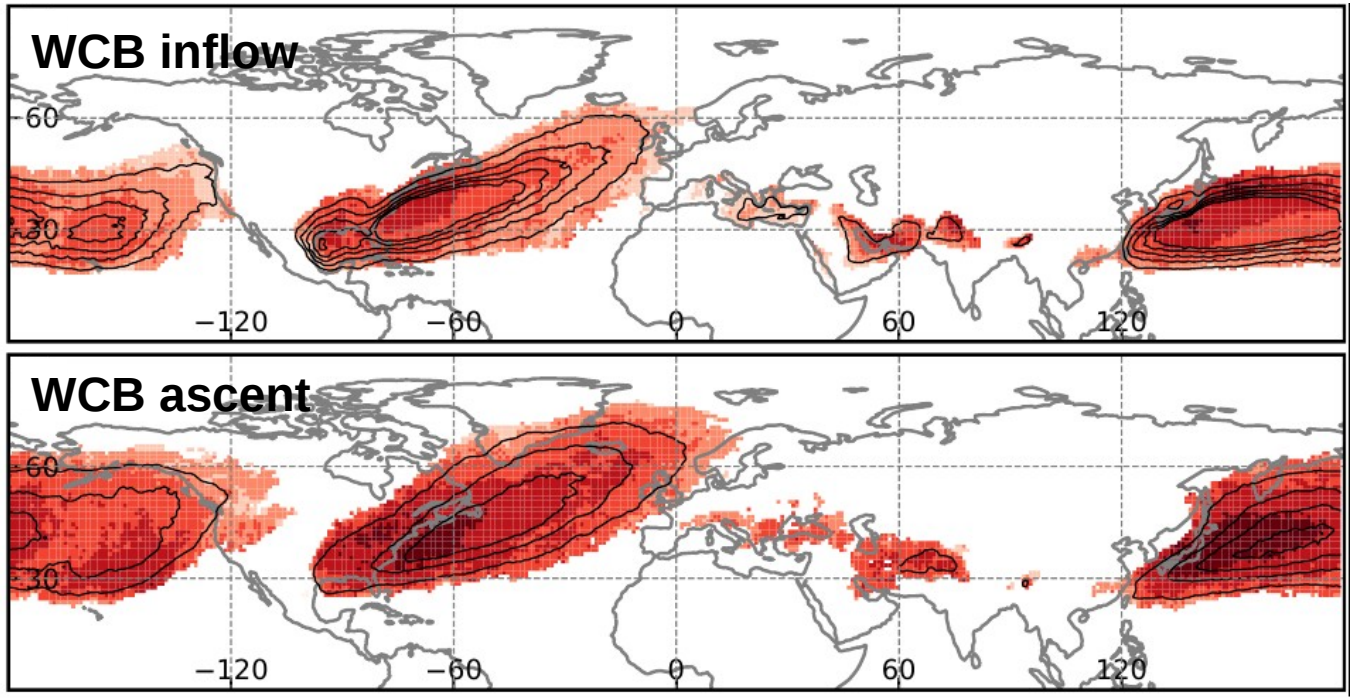
Matthews correlation coefficient

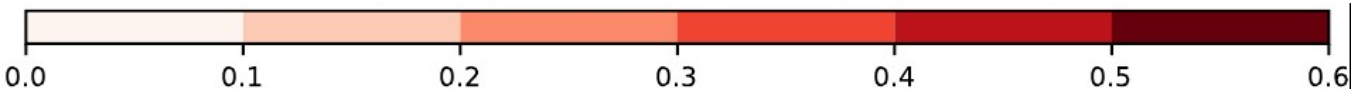
Lagrangian DJF WCB climatology

Model evaluation – Matthews correlation coefficient

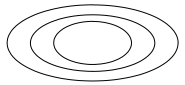
$$MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP+FP)(TP+FN)(TN+FP)(TN+FN)}}$$

- MCC=+1 → perfect forecast
- MCC=-1 → total disagreement between forecast and observation
- useful for imbalanced data
- high score only if good results for TP, TN, FP, FN





Matthews correlation coefficient

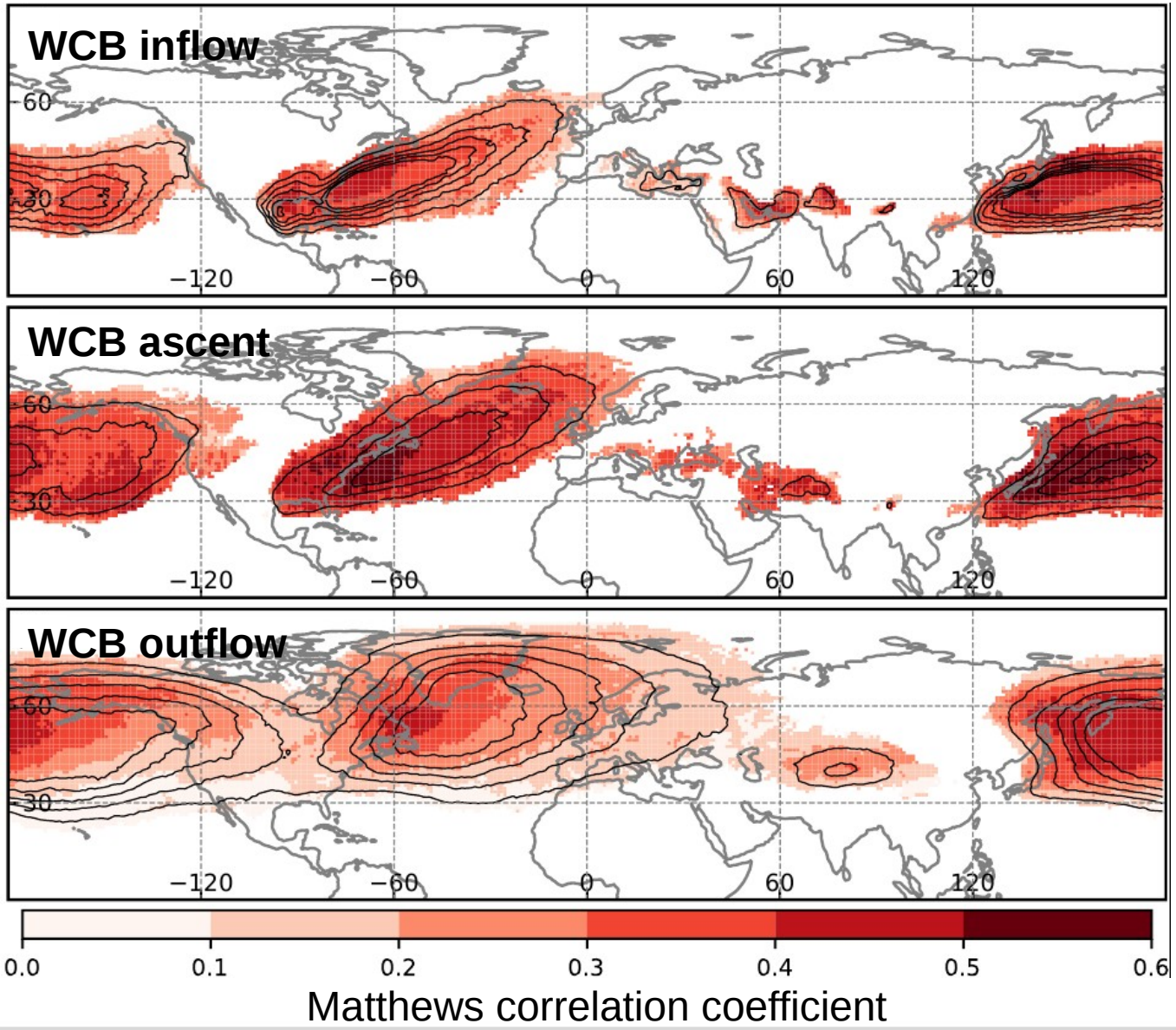


Lagrangian DJF WCB climatology

Model evaluation – Matthews correlation coefficient

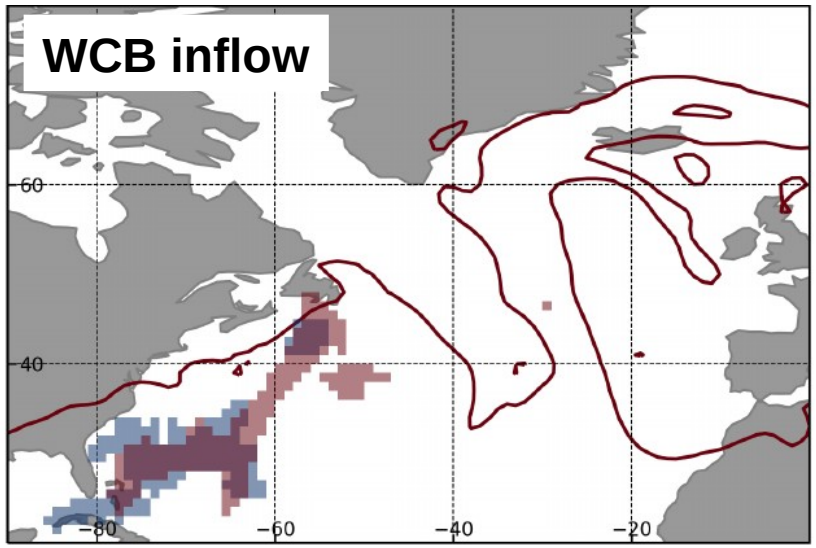
$$MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP+FP)(TP+FN)(TN+FP)(TN+FN)}}$$

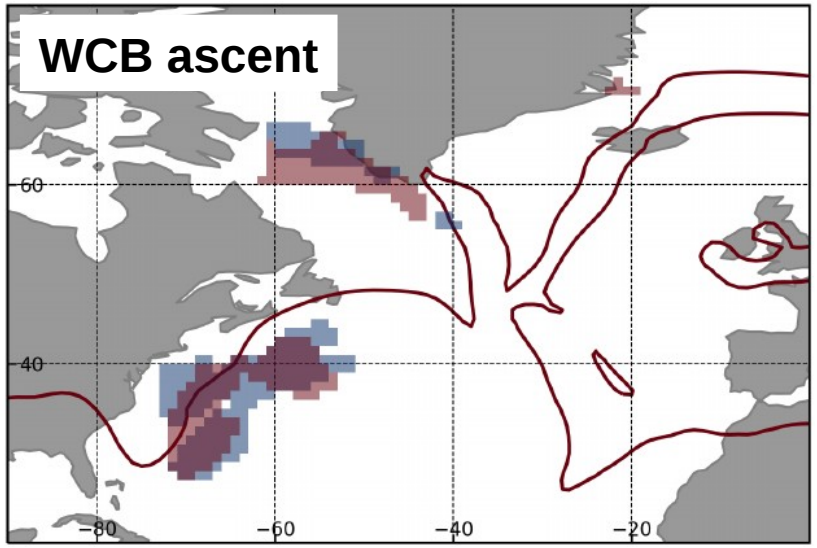
- MCC=+1 → perfect forecast
- MCC=-1 → total disagreement between forecast and observation
- useful for imbalanced data
- high score only if good results for TP, TN, FP, FN

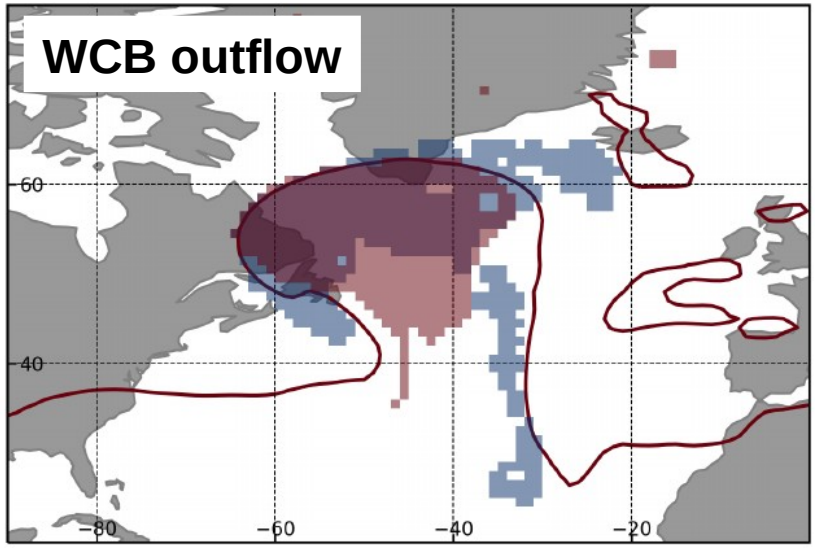


Lagrangian DJF WCB climatology

Case study – January 2011 (Martinez-Alvarado et al. 2016)

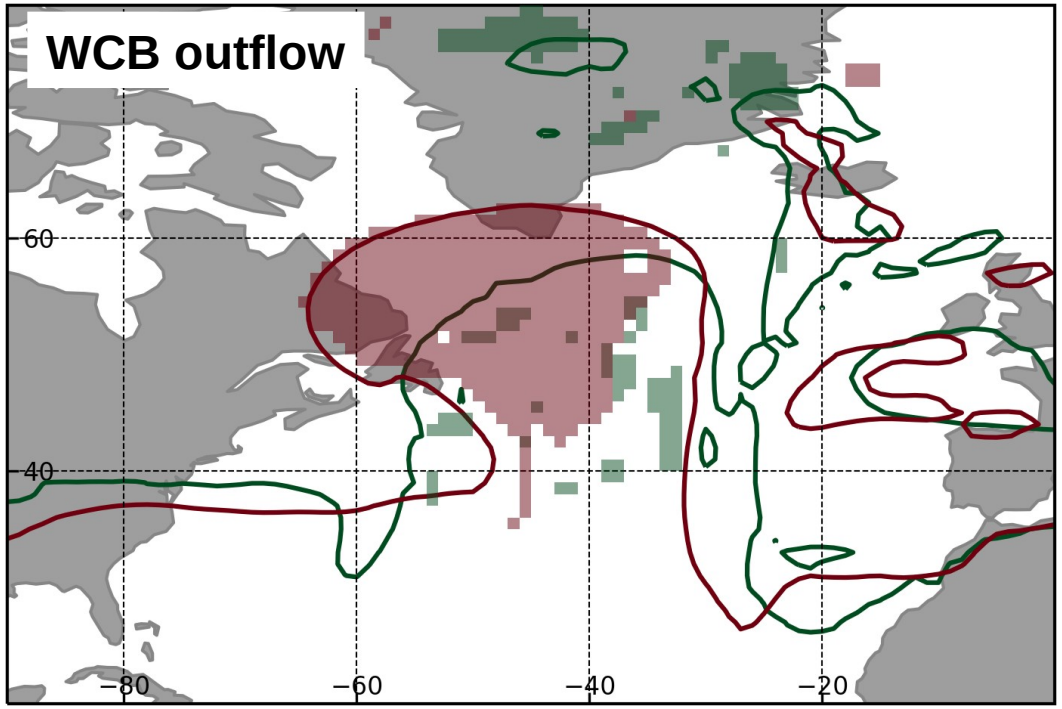






Lagrangian WCB mask Statistical model WCB mask

Case study – January 2011 (Martinez-Alvarado et al. 2016)



+114 hour forecast

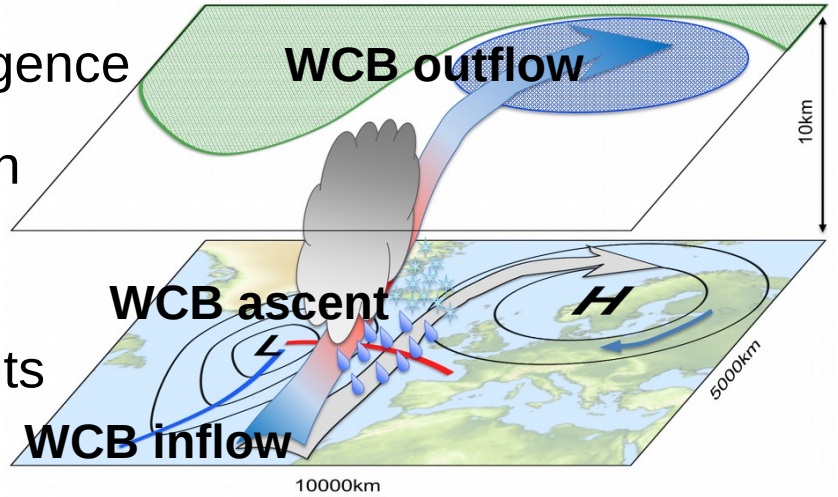
Systematic evaluation of WCBs in ECMWF IFS forecasts see next talk by Jan Wandel

Forecast WCB mask

Analysed WCB mask

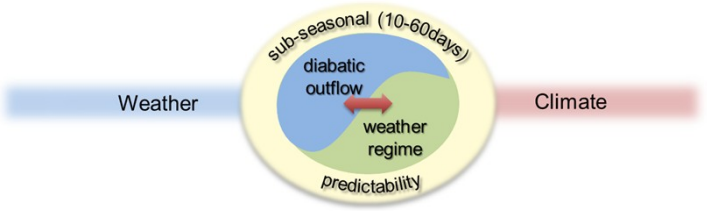
Conclusion

- First attempt of a Eulerian WCB diagnostic via logistic regression model
- Stepwise forward selection identifies most important predictors
  - Inflow: thickness advection, moisture flux, moisture flux convergence
  - Ascent: vorticity, rel. humidity, moisture flux, thickness advection
  - Outflow: rel. humidity, divergent wind speed, static stability
- Model skillfully identifies WCB inflow, ascent and outflow footprints

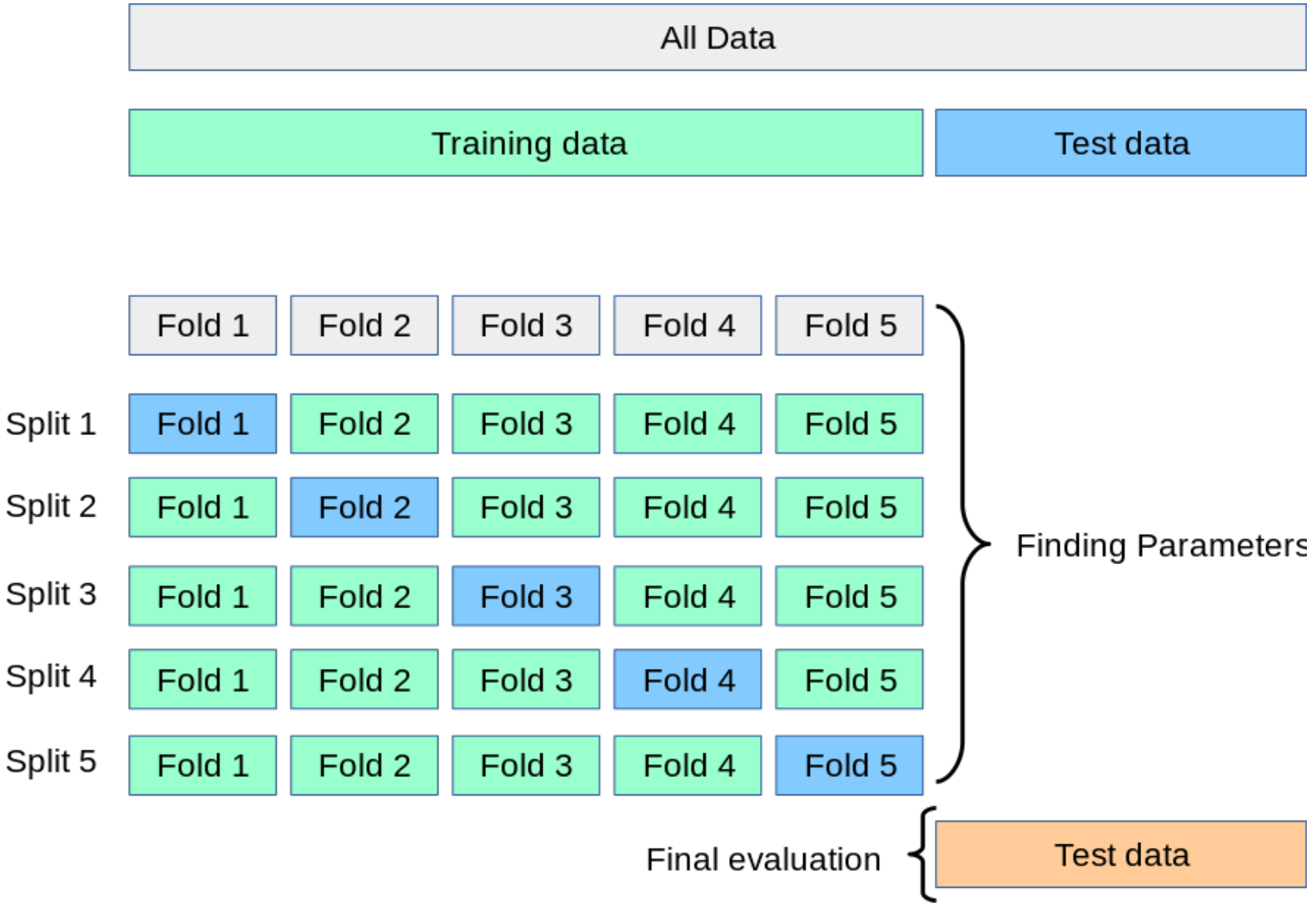


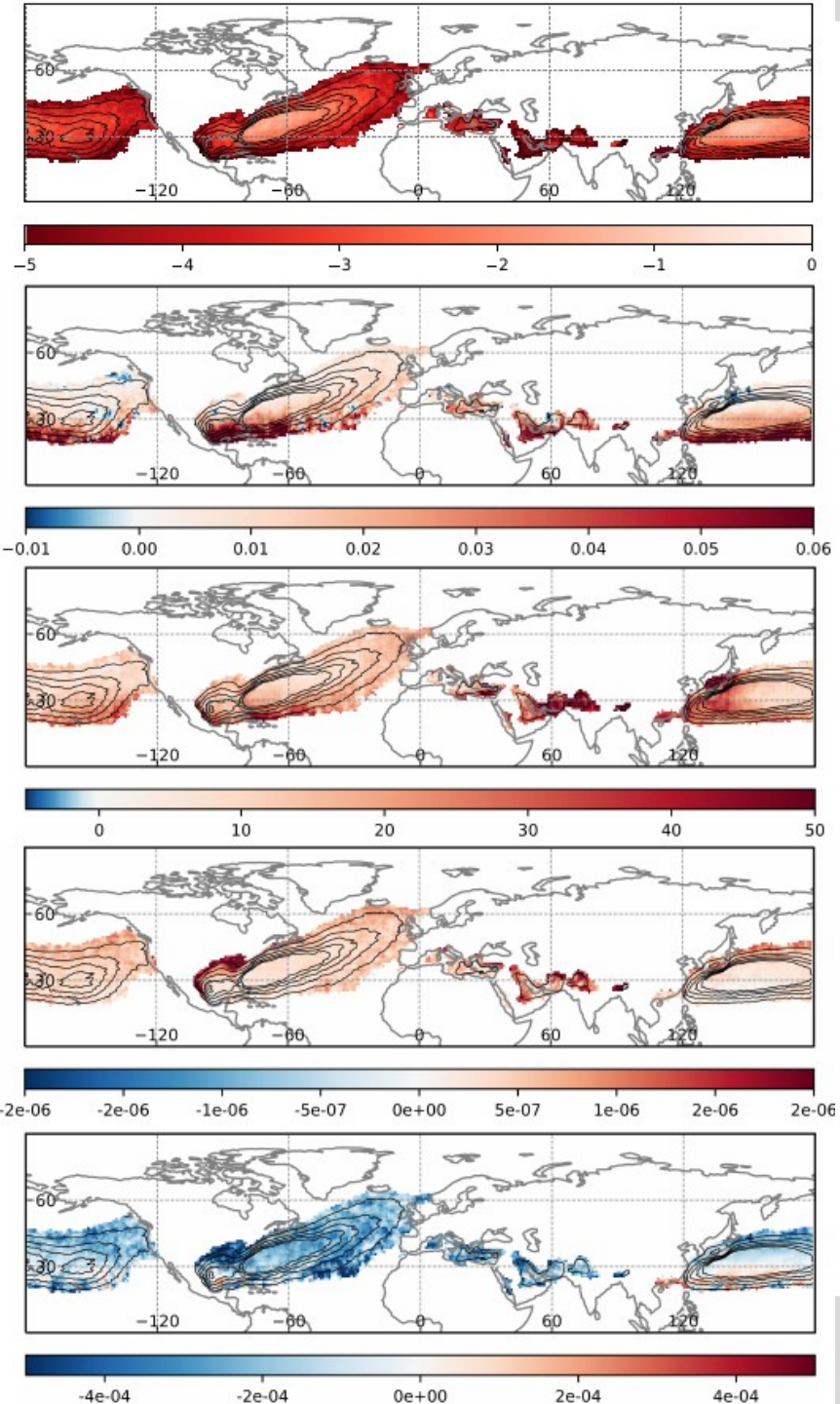
Outlook

- verify WCB footprints in S2S forecast (Jan Wandel)
- finalize WCB diagnostic V2.0 using convolutional neural network
- process studies



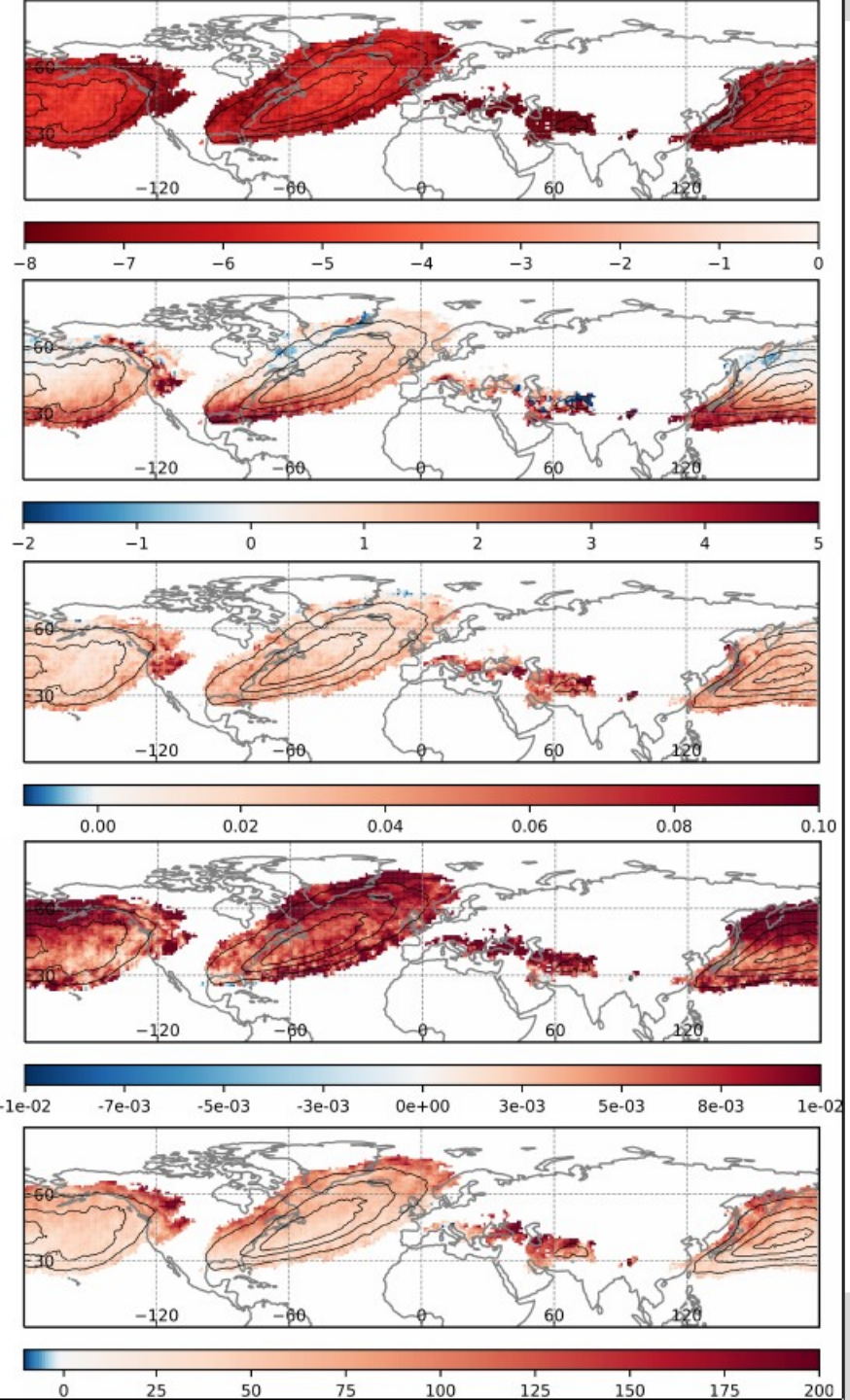
Part II: k-fold cross validation





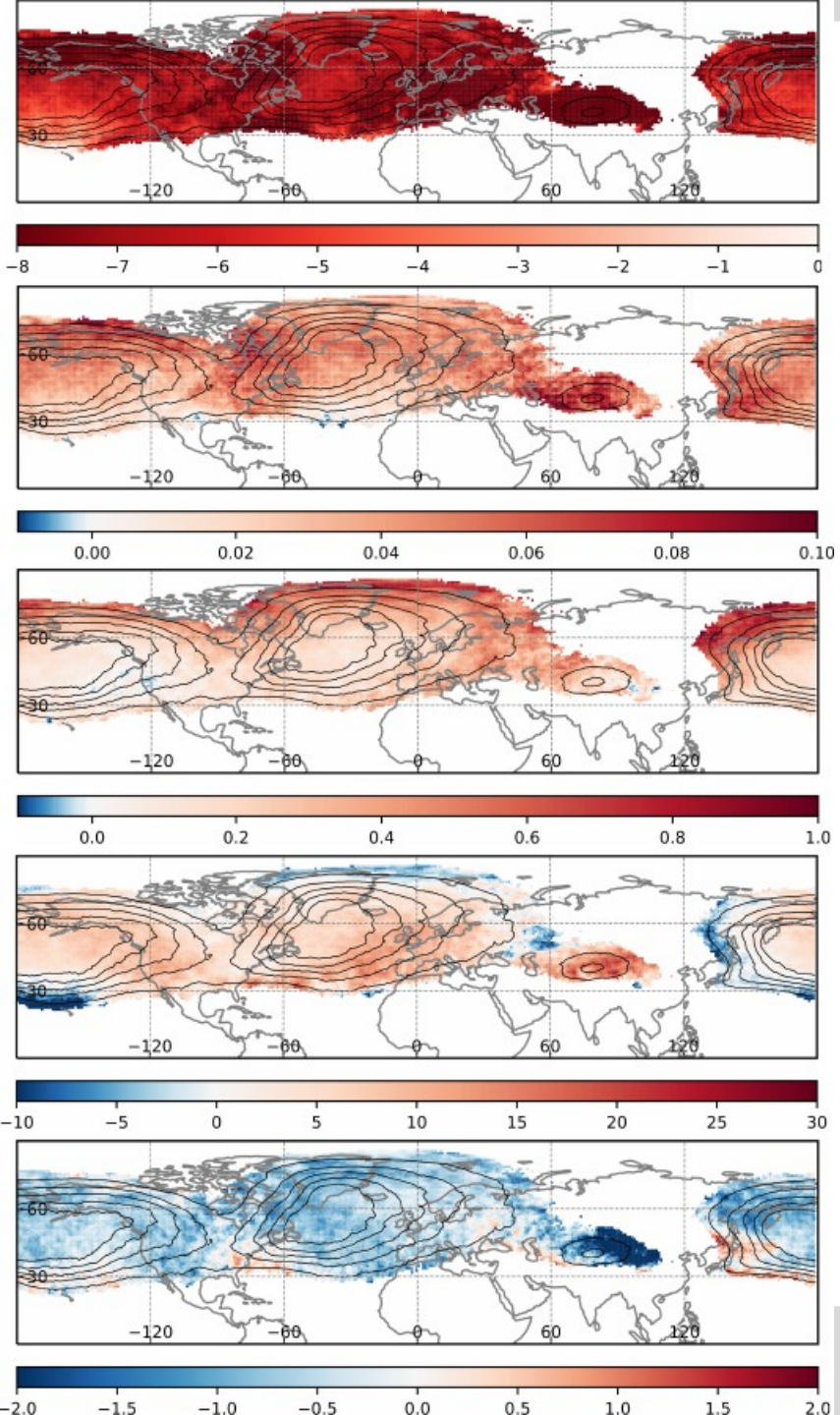
WCB inflow

- thickness advection at 700 hPa
- meridional moisture flux at 850 hPa
- moisture flux divergence at 1000 hPa
- moist PV at 500 hPa



WCB ascent

- relative vorticity at 850 hPa
- relative humidity at 700 hPa
- thickness advection at 300 hPa
- meridional moisture flux at 500 hPa



WCB outflow

- relative humidity at 300 hPa
- irrotational wind speed at 300 hPa
- static stability at 500 hPa
- relative vorticity at 300 hPa