Weather regime dependent verification of ECMWF Ensemble Prediction System

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submitted

Aim of the study:

Identifying the configurations that lead to a more or less accurate forecast

Quantifying the skill changes in these situations.

Concepts:

Use of the concept of weather regimes to classify which flow configuration leads to a more/less skilful forecasts.

Focus:

The focus is on the Euro-Atlantic sector during the extended winter period when the atmospheric regime structure is most pronounced.

Data:

ECMWF operational Ensemble forecasts and the ECMWF operational analyses of daily geopotential height at 500 hPa.

Period:

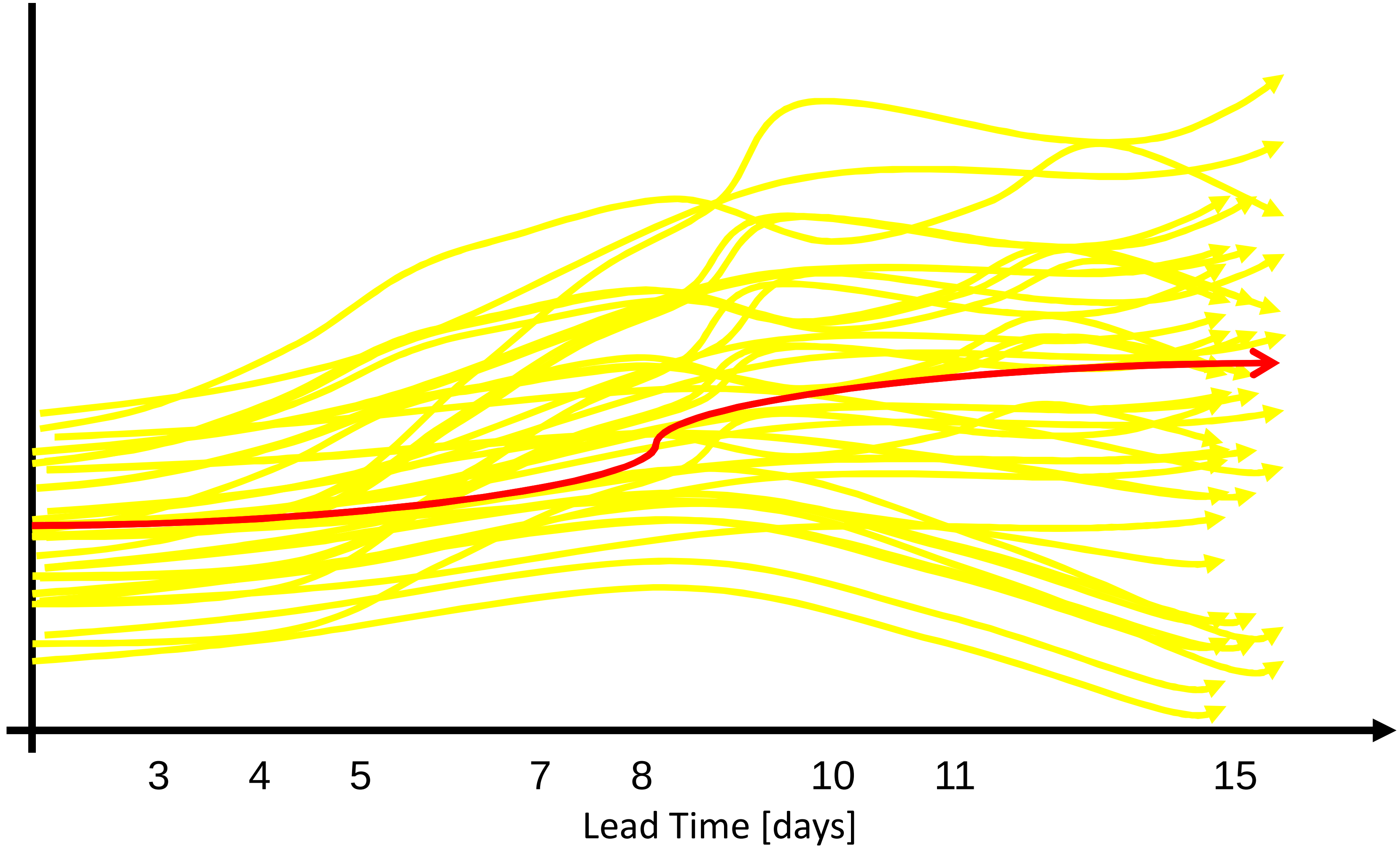
The most recent five cold seasons spanning from October to April from 2007 to 2012.

Since the ECMWF forecasting system is in continuous evolution, the analysis is confined to the most recent winters in order to reduce discontinuities associated with the impact of model changes in the forecast data.

Resolution:

About 32-km horizontal resolution up to forecast day 10, and 65-km thereafter.

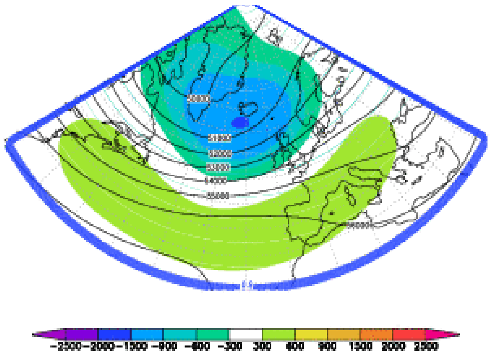
ECMWF Ensemble Prediction System: 1 control (+ 50 ensemble members)



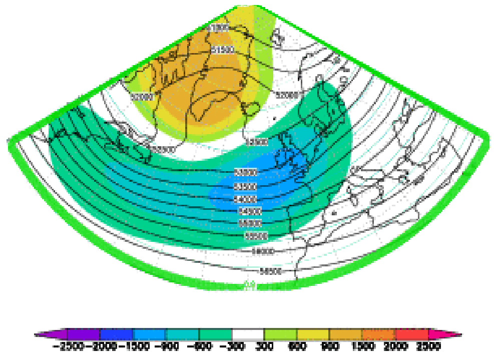
Climatological Regimes in the cold season
Euro-Atlantic Region

500 hPa Geopotential height – 29 years of ERA INTERIM ONDJFM 1980-2008

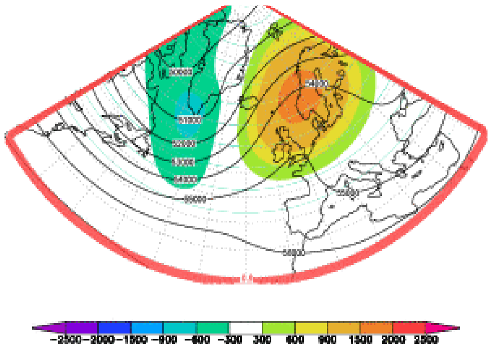
Positive NAO 32.3%



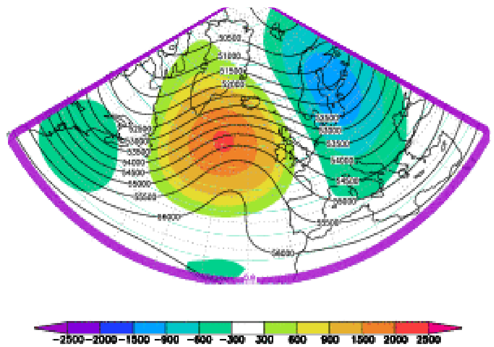
Negative NAO 21.4%



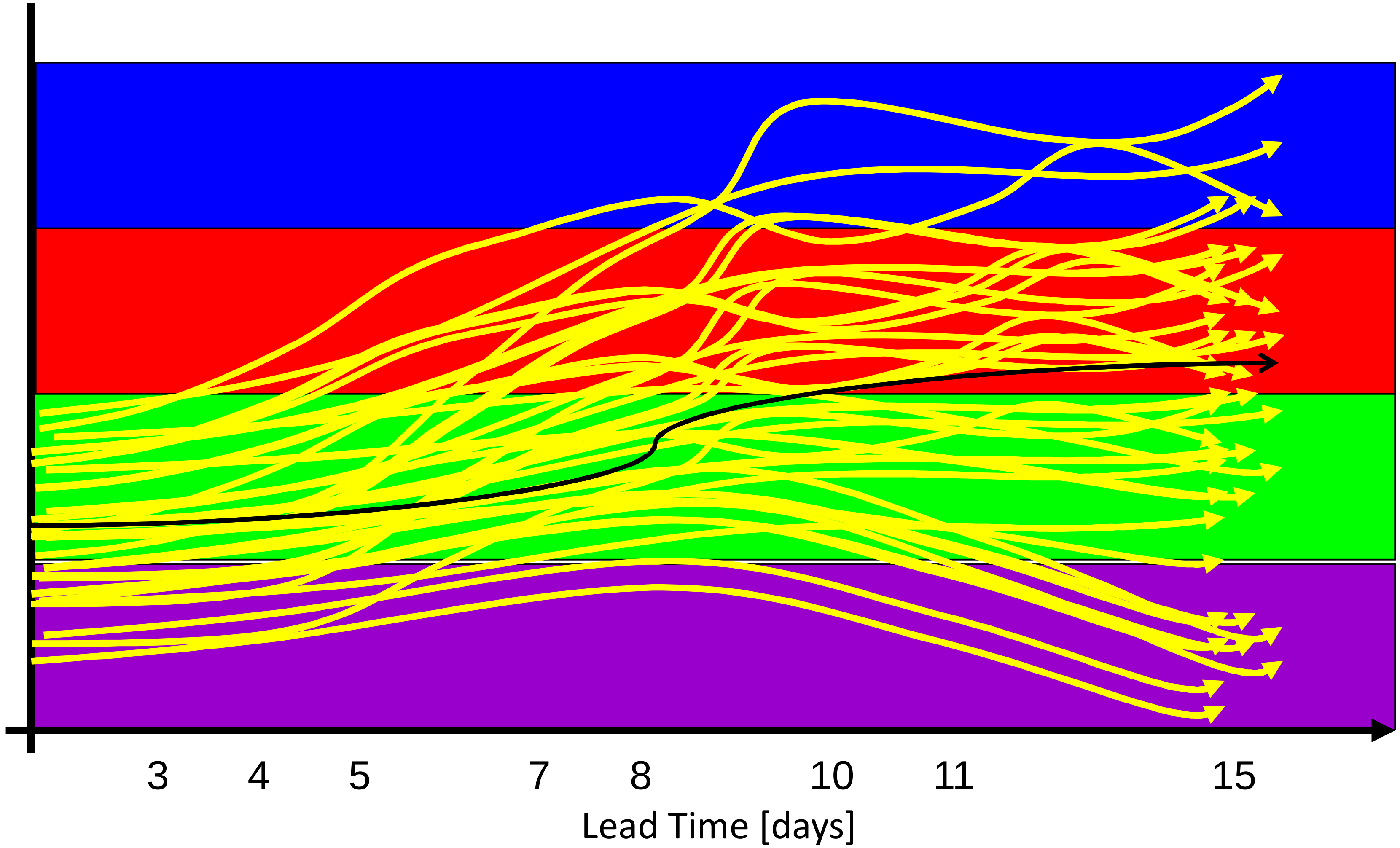
Euro-Atlantic Blocking 26.1%



Atlantic Ridge 20.2%



ECMWF Ensemble Prediction System: 1 control (+ 50 ensemble members)

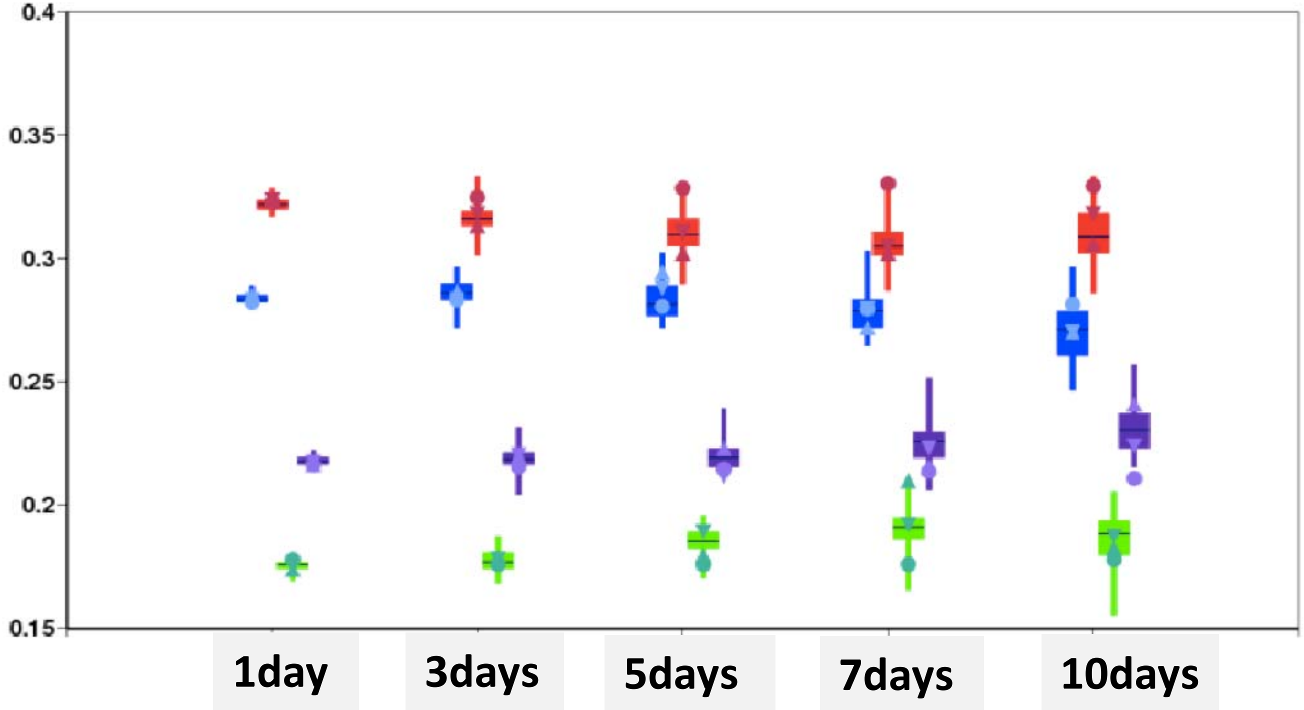


Prerequisite to get high forecast skill: The forecast system should be able to reproduce correctly the statistics of weather regimes.

↓

How good is the simulated climatological frequency of weather regimes at different forecast times?

Climatological frequency distribution for the 4 Euro-Atlantic regimes as simulated by the ECMWF ensemble at different forecast ranges

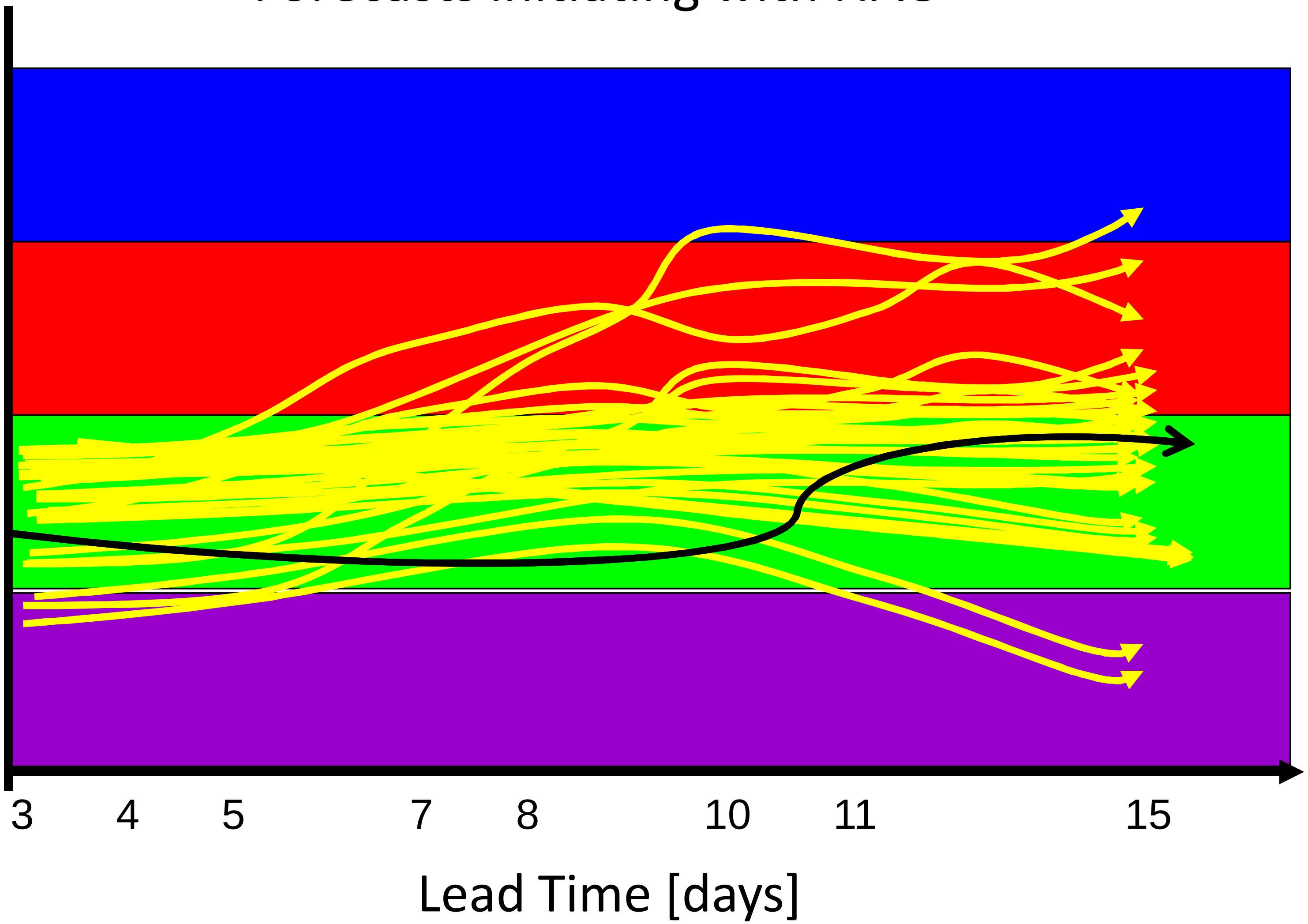


Red indicate the frequency of the BL regime, blue (green) the frequency of the NAO+ (NAO-) and violet the frequency of the AR regime. The observed frequencies are indicated by a circle while the frequencies from the ECMWF operational high resolution and the unperturbed forecasts are indicated by a pointing down and a pointing up triangle respectively.

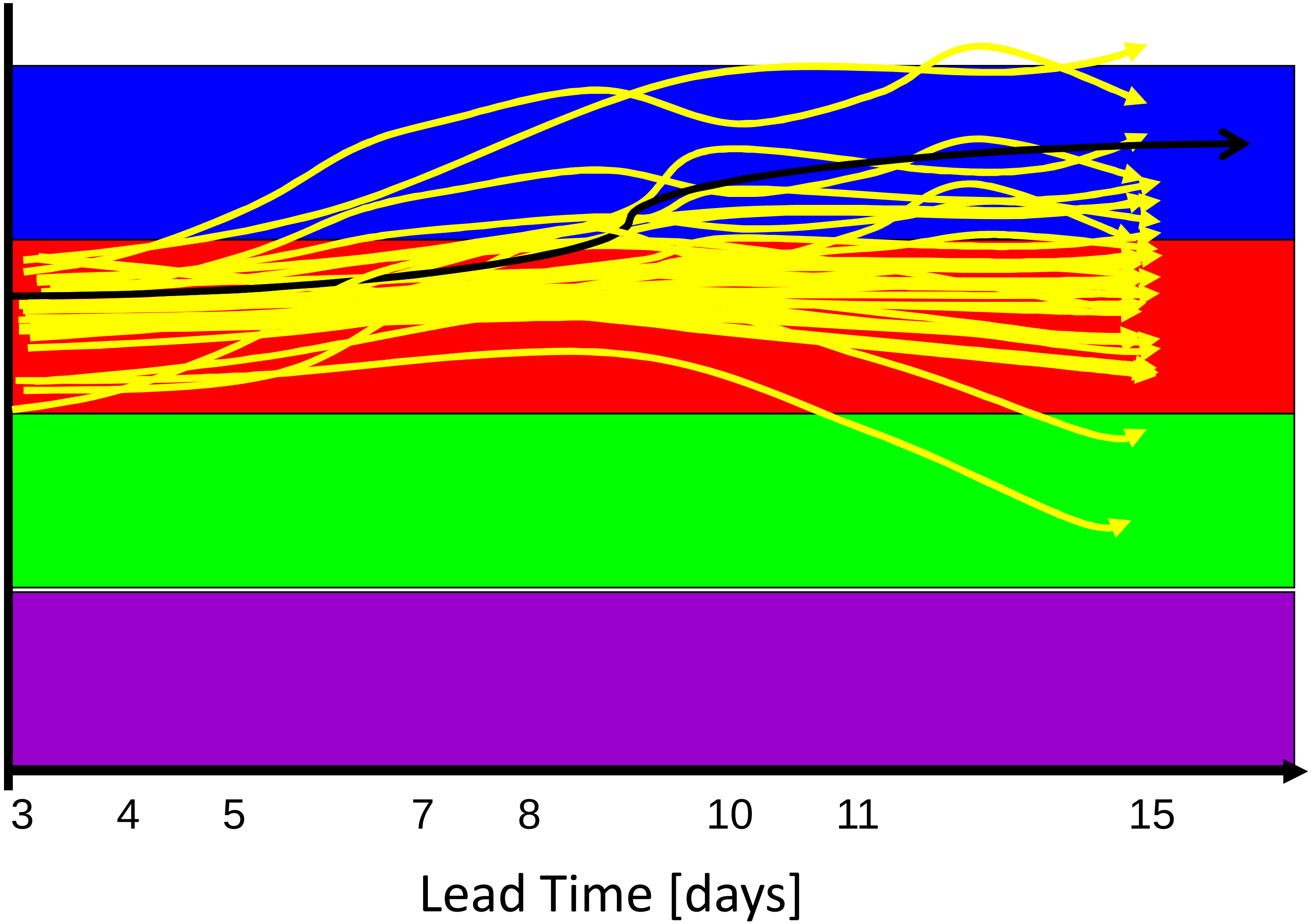
Which flow regime leads to less skilful predictions?

We stratify all forecasts according to the flow configuration at the initial conditions.

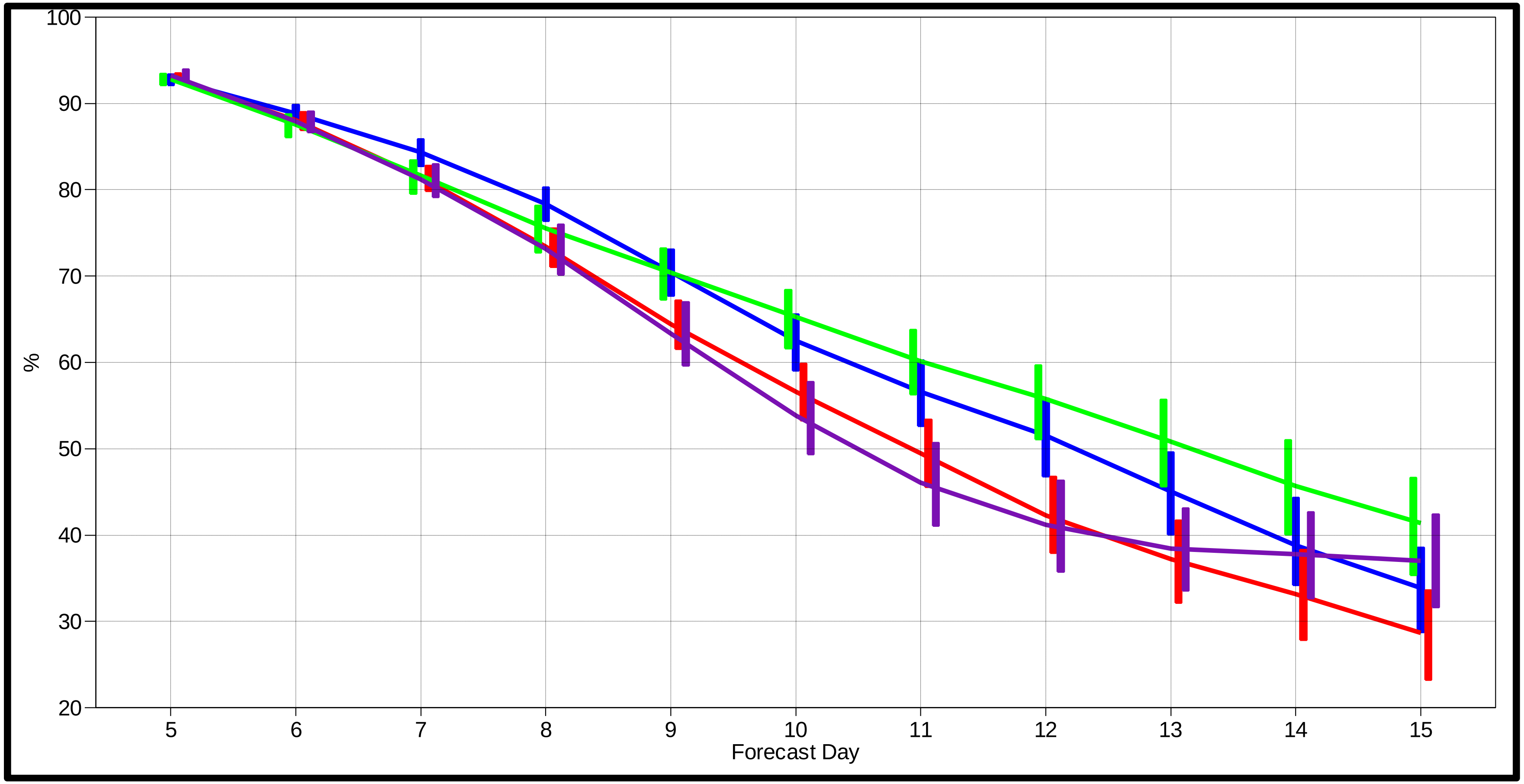
ECMWF Ensemble Prediction System: 1 control (+ 50 ensemble members) Forecasts initiating with NAO-



ECMWF Ensemble Prediction System: 1 control (+ 50 ensemble members) Forecasts initiating in blocking



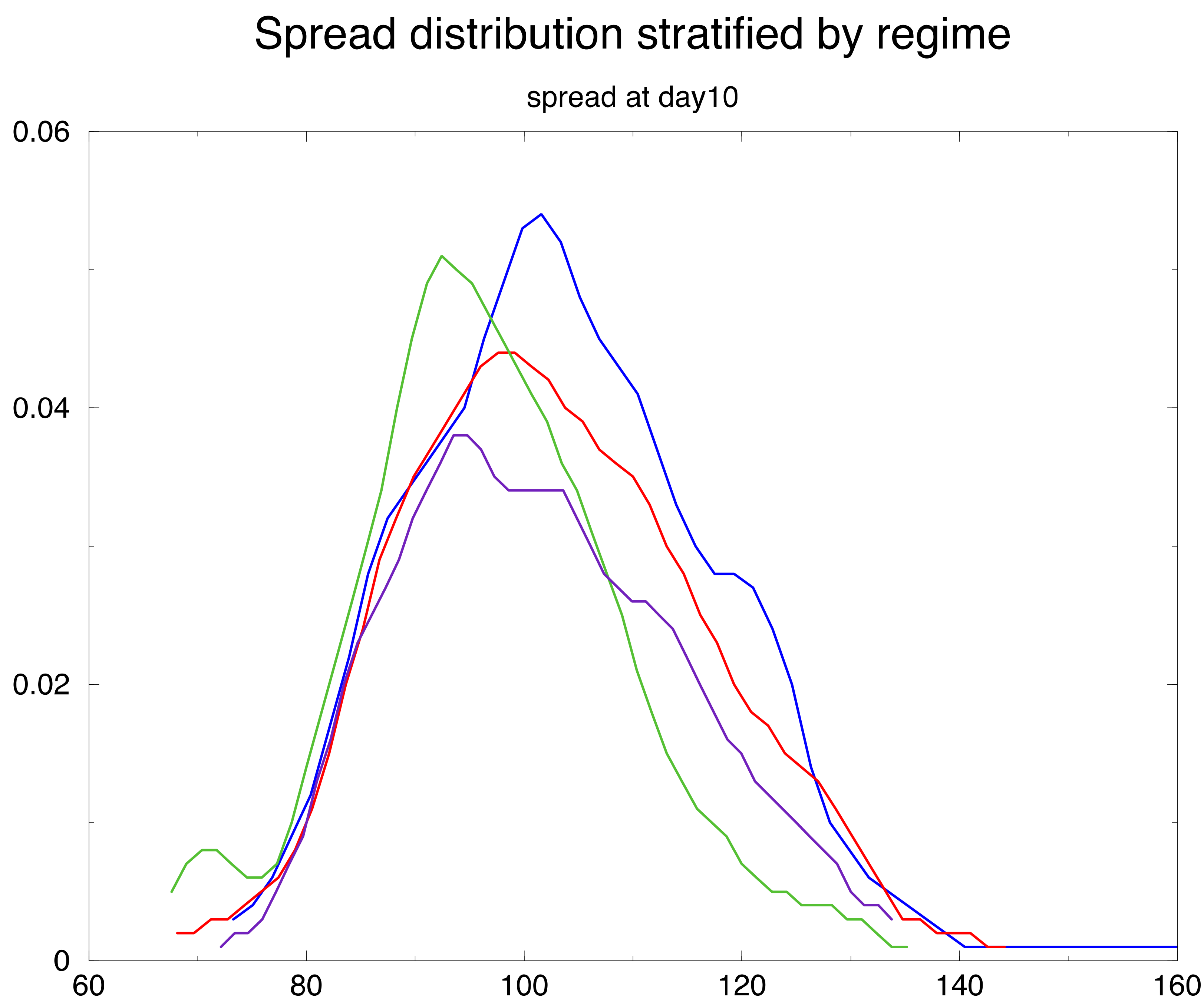
Anomaly correlation for ensemble means



Forecast Day

5 6 7 8 8 10 11 12 13 14 15

Anomaly correlation of the ensemble means for the four forecast categories as a function of forecast range. The bars, based on 1000 subsamples generated with the bootstrap method, indicate the 95% confidence intervals.



Spread distribution stratified by regime
spread at day10
0.06
0.04
0.02
0
60
80
100
120
140
160

Bad forecasts at day 10

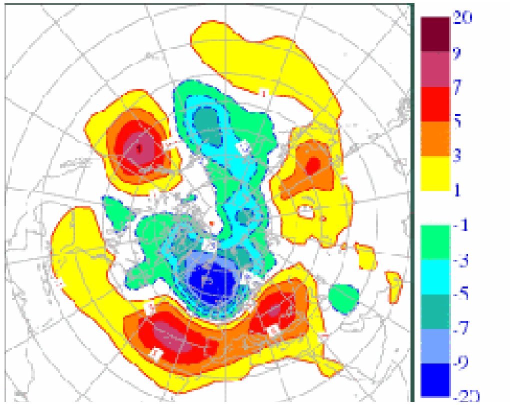
The performance of the operational ECMWF Ensemble forecasting system is further assessed by stratifying the cases according to their initial conditions as well as their accuracy at forecast day 10.

Bad (good) forecasts => RMSE of the ensemble mean larger (smaller) than the upper (lower) fifth of the whole RMSE distribution.

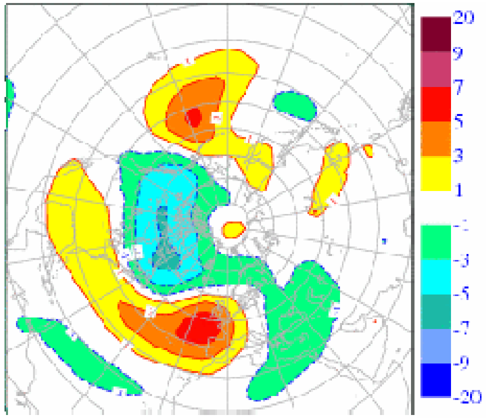
The RMSE is computed over the European domain at day 10. For each group and each category we compute composites maps of z500 anomalies at several time steps.

Z500 anomaly composites for the bad forecasts initiated during a positive phase of the NAO

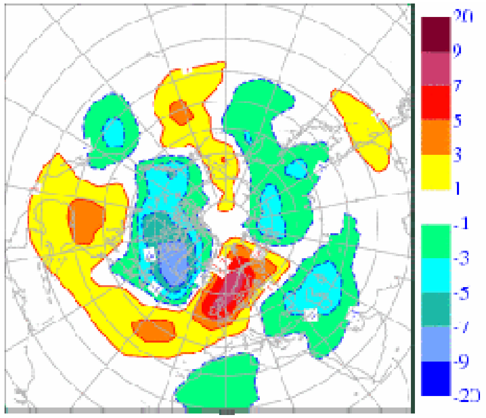
a) – day 0



b) – forecast day 10



c) – verifying analysis



a) anomaly composites at the initial conditions;
b) anomaly composites for the forecasts at day 10;
c) anomaly composites of the corresponding verifying analysis.

Population in percentage of the four climatological regimes at different time ranges for the good and bad forecasts initiated in NAO+.

	Day 0	Day 1	Day 5	Day 7	Day 10
Forecasts with large RMSE at day 10					
NAO+	**100**	**81**	**56, 44**	**54, 40**	**37, 21**
BL	**0**	**8**	**28, 40**	**35, 53**	**42, 51**
NAO-	**0**	**2**	**0**	**2**	**2, 5**
AR	**0**	**9**	**16**	**9, 5**	**19, 23**
Forecast with small RMSE at day 10					
NAO+	**100**	**65**	**40, 35**	**28, 33**	**37, 35**
BL	**0**	**24**	**30, 33**	**30**	**28**
NAO-	**0**	**2**	**19, 23**	**28**	**23, 21**
AR	**0**	**9**	**11, 9**	**14, 9**	**12, 16**

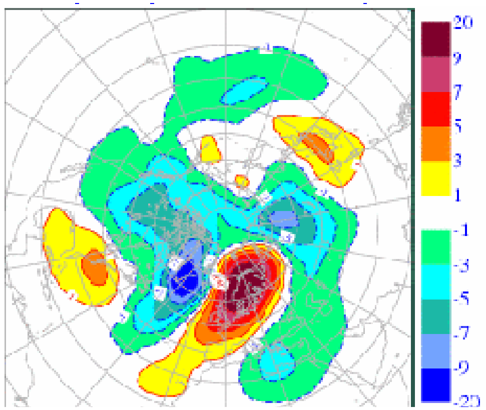
Bad cases

Good cases

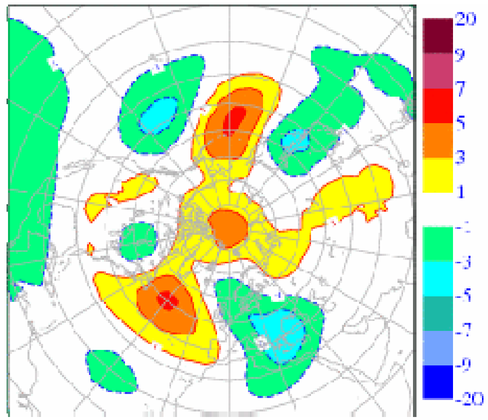
Table 1 shows the population in percentage of the four climatological regimes at different time ranges for the good and bad forecasts initiated in NAO+. The numbers in black indicate the forecast values and in red the verification values.

Z500 anomaly composites for the bad forecasts initiated during Euro-Atlantic blocking

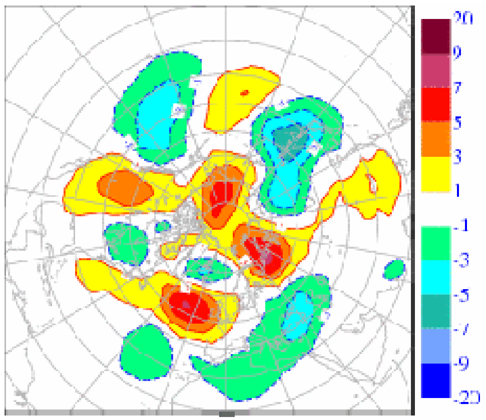
a) – day 0



b) – forecast day 10



c) – verifying analysis



a) anomaly composites at the initial conditions;
b) anomaly composites for the forecasts at day 10;
c) anomaly composites of the corresponding verifying analysis.

Population in percentage of the four climatological regimes at different time ranges for the good and bad forecasts initiated in blocking

	Day 0	Day 1	Day 5	Day 7	Day 10
Forecast with large RMSE at day 10					
NAO+	**0**	**20**	**25 , 18**	**28 , 25**	**28 , 18**
BL	**100**	**70**	**44 , 52**	**36 , 47**	**29 , 41**
NAO-	**0**	**2**	**2 , 7**	**3 , 8**	**5 , 21**
AR	**0**	**8**	**29 , 23**	**33 , 20**	**38 , 20**
Forecast with small RMSE at day 10					
NAO+	**0**	**11 , 8**	**18 , 20**	**23 , 19**	**23 , 30**
BL	**100**	**74 , 77**	**49**	**44 , 38**	**41 , 36**
NAO-	**0**	**10 , 11**	**20 , 16**	**20**	**20 , 16**
AR	**0**	**5 , 4**	**13 , 15**	**13 , 23**	**16 , 18**

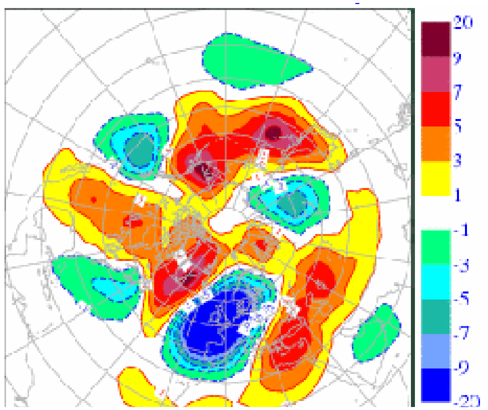
Bad cases

Good cases

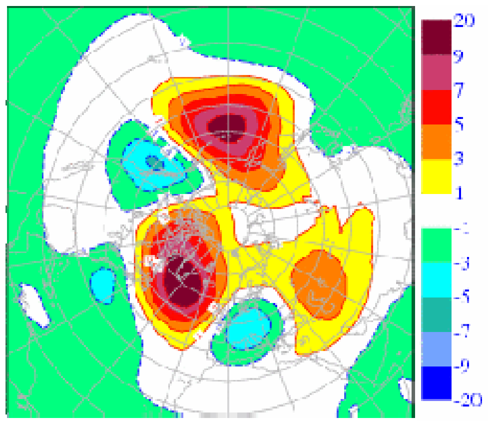
Table 2 shows the population in percentage of the four climatological regimes at different time ranges for the good and bad forecasts initiated in BL.

Z500 anomaly composites for the bad forecasts initiated during a negative phase of the NAO

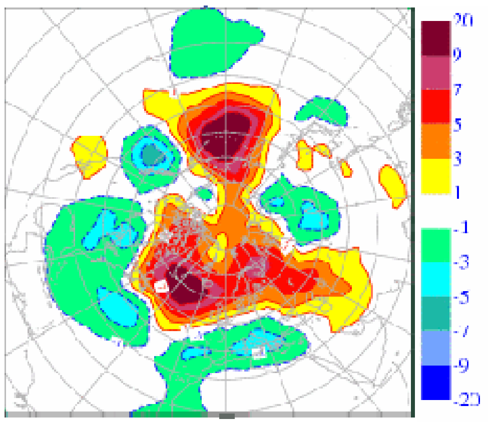
a) – day 0



b) – forecast day 10



c) – verifying analysis



a) anomaly composites at the initial conditions;
b) anomaly composites for the forecasts at day 10;
c) anomaly composites of the corresponding verifying analysis.

Population in percentage of the four climatological regimes at different time ranges for the good and bad forecasts initiated in NAO-.

	Day 0	Day 1	Day 5	Day 7	Day 10
Forecast with large RMSE at day 10					
NAO+	**0**	**13**	**16 , 11**	**13 , 5**	**19 , 13**
BL	**0**	**13**	**24 , 32**	**35 , 54**	**32 , 46**
NAO-	**100**	**60**	**22 , 24**	**22 , 16**	**19 , 13**
AR	**0**	**13**	**38 , 32**	**30 , 24**	**30 , 27**
Forecast with small RMSE at day 10					
NAO+	**0**	**22**	**8 , 5**	**5**	**5, 11**
BL	**0**	**8**	**19 , 16**	**19**	**27**
NAO-	**100**	**67**	**67 , 73**	**59 , 57**	**49 , 40**
AR	**0**	**3**	**5**	**16 , 19**	**19 , 22**

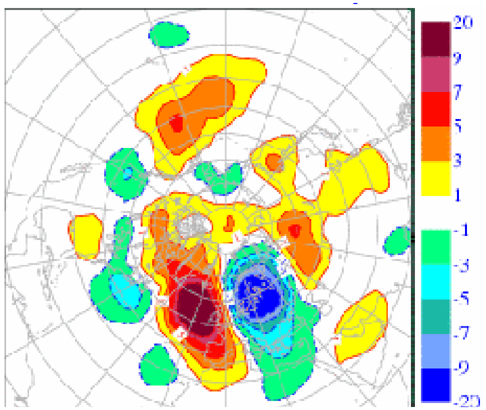
Bad cases

Good cases

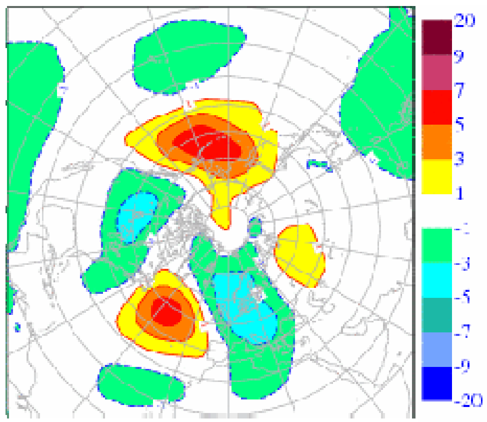
Table 3 shows the population in percentage of the four climatological regimes at different time ranges for the good and bad forecasts initiated in NAO-.

Z500 anomaly composites for the bad forecasts initiated during Atlantic Ridge

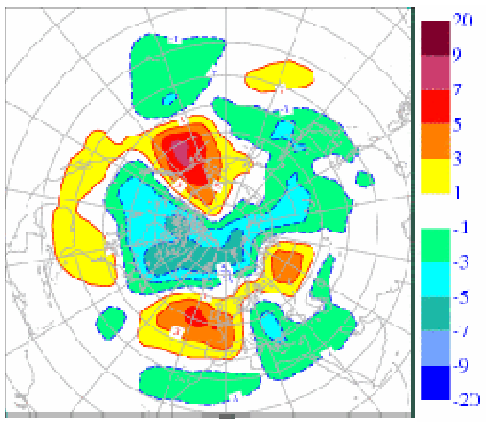
a) – day 0



b) – forecast day 10



c) – verifying analysis



a) anomaly composites at the initial conditions;
b) anomaly composites for the forecasts at day 10;
c) anomaly composites of the corresponding verifying analysis.

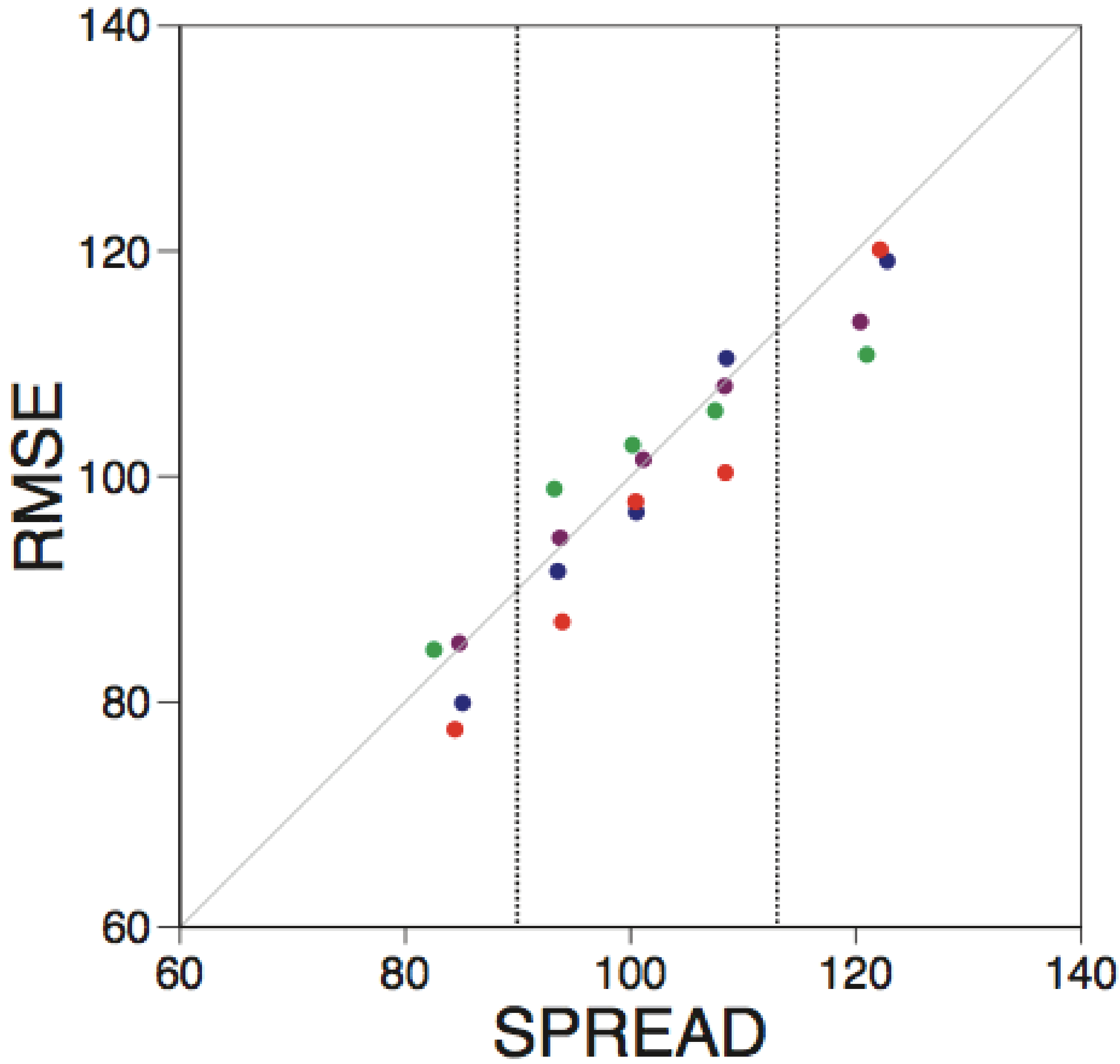
Population in percentage of the four climatological regimes at different time ranges for the good and bad forecasts initiated in AR.

	Day 0	Day 1	Day 5	Day 7	Day 10
Forecast with large RMSE at day 10					
NAO+	0	21 , 19	32 , 26	28 , 23	30
BL	0	19 , 21	30 , 37	28 , 47	23 , 40
NAO-	0	2	5 , 7	9 , 5	16 , 7
AR	100	58	33 , 30	35 , 25	30 , 23
Forecast with small RMSE at day 10					
NAO+	0	23 , 21	42	53 , 47	30 , 44
BL	0	9 , 12	19	16 , 25	32 , 28
NAO-	0	9	23	28 , 21	30 , 28
AR	100	58	16	2 , 7	7 , 0

Bad cases

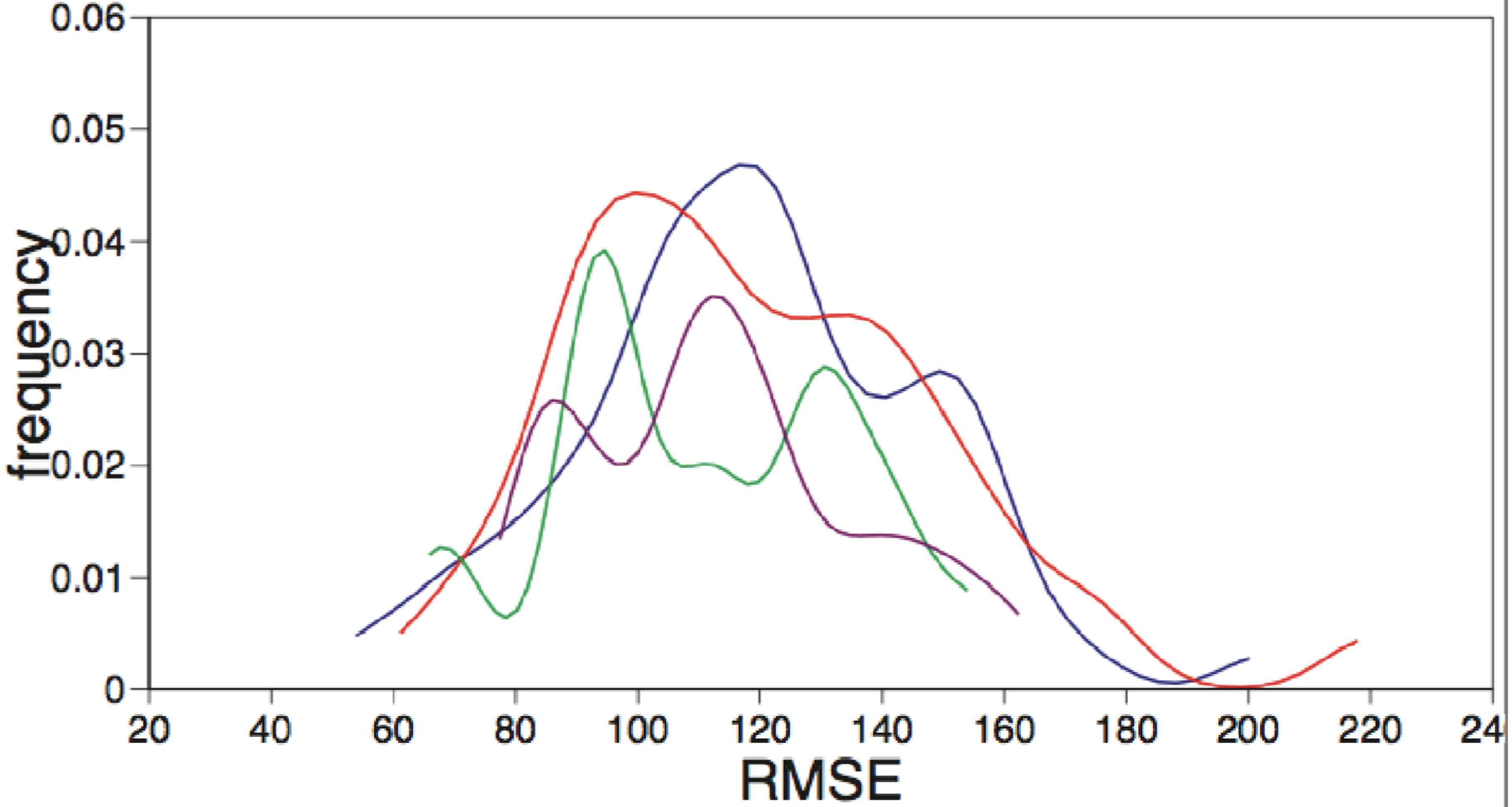
Good cases

Table 4 shows the population in percentage of the four climatological regimes at different time ranges for the good and bad forecasts initiated in AR.



140
120
100
80
60
RMSE
60
80
100
120
140
SPREAD

RMSE distributions for the cases of spread exceeding the outer quantile thresholds



Summary

- The blocking regime as the flow configuration that leads to the least accurate forecasts. The loss of predictability of the forecasts initiated in blocking seems partially due to model deficiency. This is suggested by the fact that from day 3 the blocking frequencies are systematically underestimated by the model
- Transitions to blocking have been shown very difficult to predict as well. In the sample considered, the least skilful predictions are in fact mainly associated with missing the transitions to a blocking regime circulation.
- Forecasting transitions to blocking is particularly difficult when, at the initial state, the westerly jet across the Atlantic is in its Southern (NAO-) or Northern location (AR). Forecasts underestimate the blocking persistence while overestimate the maintenance and transitions to an enhanced zonal flow (NAO+)
- The AR is the other flow configuration that leads to reduced accuracy in the forecasts. Most of the bad forecasts initiated in AR missed the transitions to a blocking type of circulation and tend to persist in the same regime.