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Regime view of Teleconnection: Euro-Atlantic Winter Regimes in ECMWF Seasonal Forecasts

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Regime View of Teleconnection:

Euro-Atlantic Winter Regimes in ECMWF Seasonal Forecasts

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Intra-Seasonal Atmospheric Variability:

Teleconnections vis-à-vis Circulation Regimes

"Teleconnection … refers to climate anomalies being related to each other at large distances (typically thousands of kilometers)."*

- **Physical explanation in terms of propagation mechanisms**
- **Often diagnosed through "linear" analysis of anomalies**

Circulation Regimes: Preferred organization of large-scale anomalies over a wide region.

- **Physical explanation: involves feedback between planetary and synoptic waves to produce "quasi-equilibrium" states**
- **Diagnosed through "non-linear" algorithms**

*from Wikipedia

Phenomenological Motivation for Circulation Regimes

Existence of extended periods of one type of (possible extreme) weather has been recognized for many years (papers going back to the 1950s at least) - Examples: droughts, stormy periods, cold periods

These periods occur intermittently, and must be related to persistence in the “large-scale” flow

Example: European Heat Waves of summer 2003 - were they related to regimes in the summertime Euro-Atlantic region?

Cassou and Terray, 2005: J Clim, 18, 2805-2811

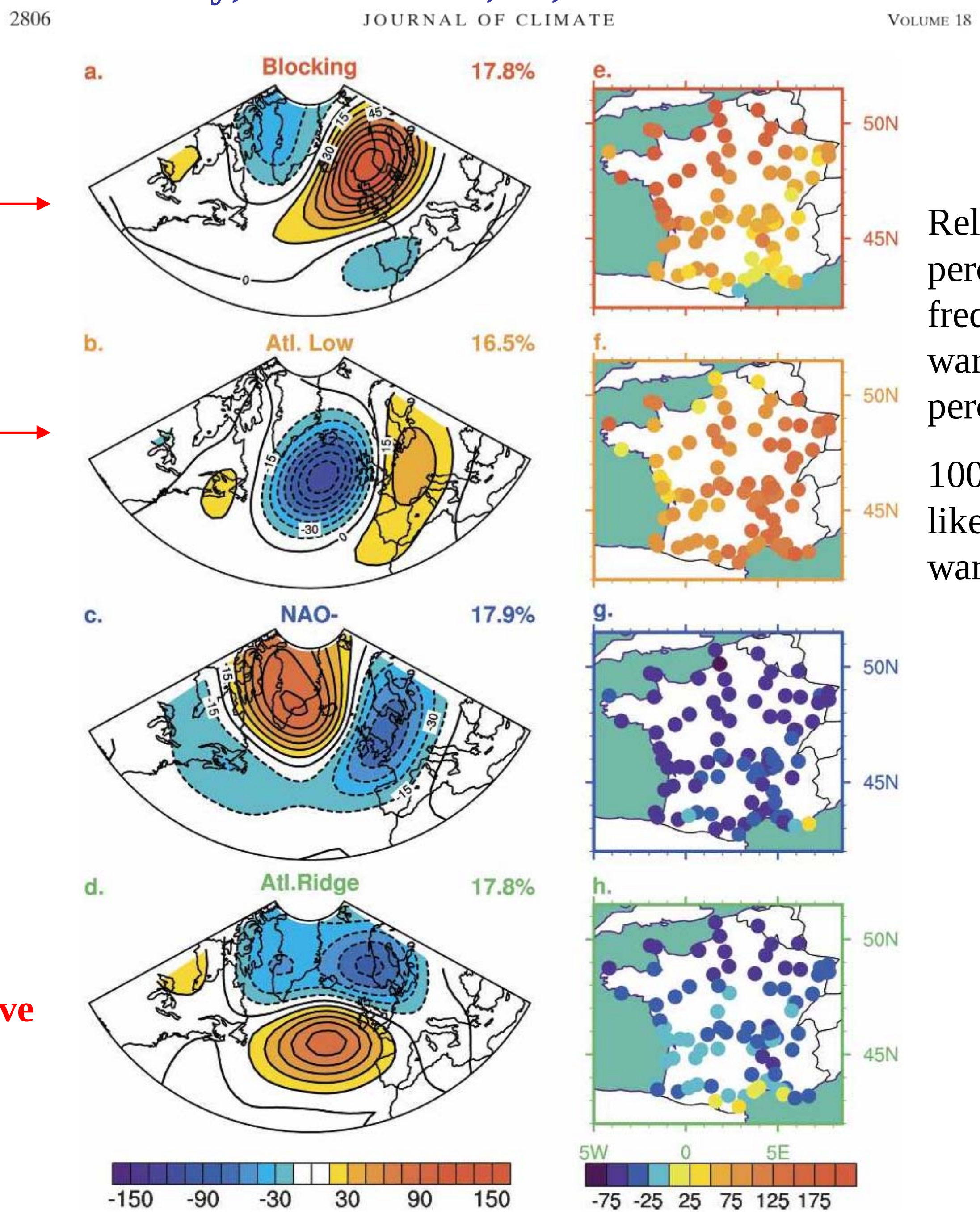
Early Aug 2003 - Blocking

June 2003 - Atl. Low

Clusters (regimes) of *daily* 500 Z from 1950-2003 JJA (CI=15m)

2003 European Heat Wave

June and early August extreme T



Relative changes (in percent) in the frequency of extreme warm days (95% percentile):

100% means twice as likely to have extreme warm day

Regimes and Synoptic-Scale Feedback

Notion that weather regimes involve mutual feed-back between the (quasi-stationary) large scales waves and the smaller-scale baroclinic, synoptic disturbances was developed theoretically by Reinhold and Pierrehumbert (1982) and Vautard and Legras (1988).

The feedback from the baroclinic waves to the planetary waves can be parameterized:

Purely dynamically (RP)

Semi-empirically (VL)

Completely statistically (multiplicative noise: Sura, Newman, Penland and Sardeshmukh, 2004: J. Atmos. Sci., 62, 1391-1409)

Some Methodologies

1) Partitioning of PC-based state space to maximize in-cluster variance

2) Mixture model method: modeling entire *pdf* with a sum of Gaussian *pdfs*

3) Neural-Network related methods

-Each method has advantages and disadvantages

-Synoptic scale feedback usually not accounted for

Significance Testing

a) Significance vis-à-vis a single Gaussian pdf

b) robustness to sampling errors (reproducibility)

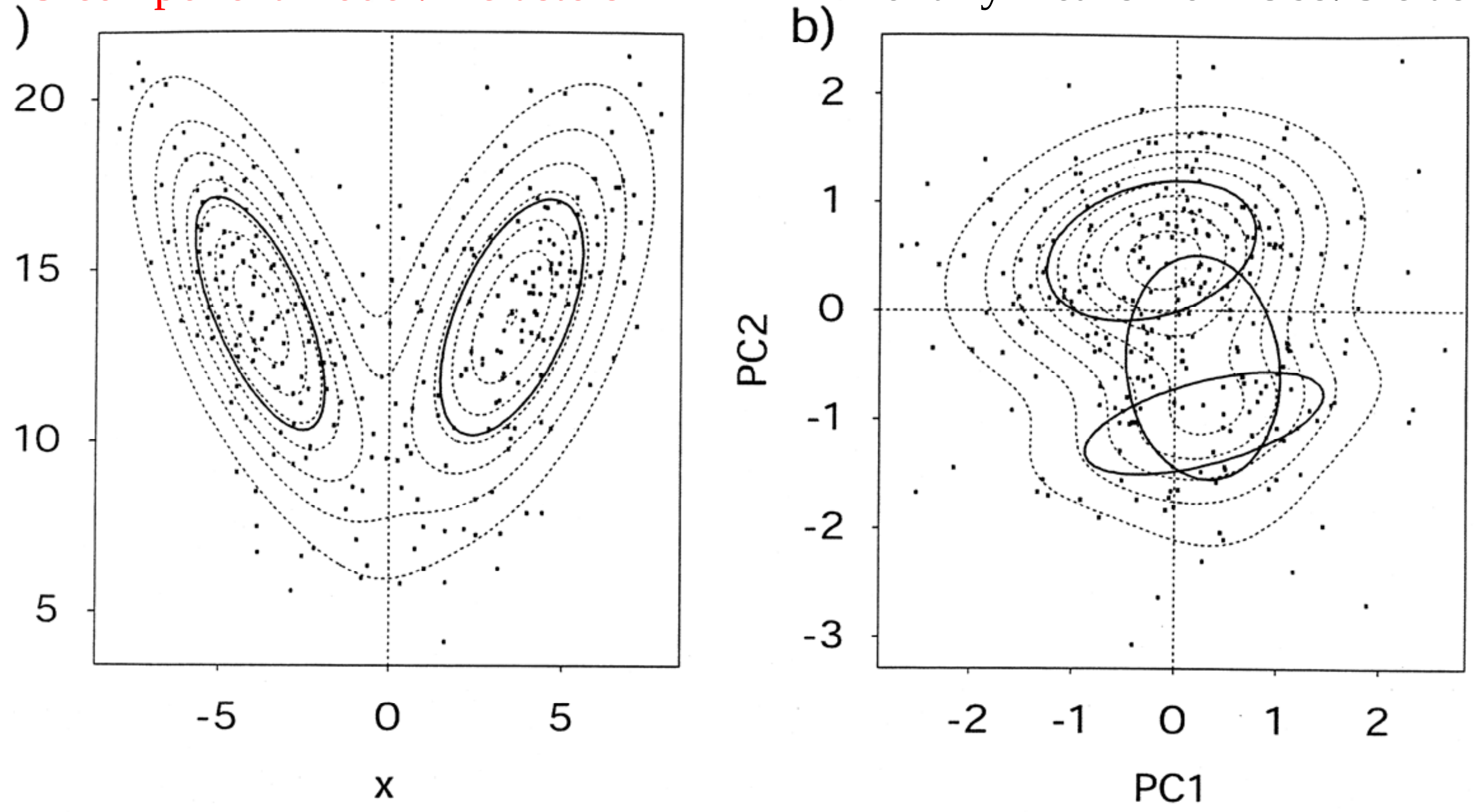
c) Significance easier to establish in large simulated datasets than in short observational record

Example of partitioning in PC state space: Maximize within-cluster variance

(Stephenson, Hannachi, and O'Neill, 2004: *QRMS*, **130**, 583-605)

Lorenz 3-component model: 2 clusters

Monthly means from Obs: 3 clusters????



Euro-Atlantic Winter Regimes in ECMWF Seasonal Forecasts

Explicit coupling between planetary and synoptic scale "envelope" is incorporated

Data:

- **Model - System 3: T159 AGCM coupled to HOPE 1-deg Ocean**
- **Historical Forecasts: Nov 1 starts for 25 years: 1981-2005**
- ***Daily* 200 hPa height analyzed: December-March**
- **11 ensemble members for each forecast start date**
- **Observational comparison: ERA40 + continuation for same winters**

Envelope Function: Tracks low-frequencey variations of synoptic scale activity

Computation of envelope at 20W 50N for DJFM 1982/83

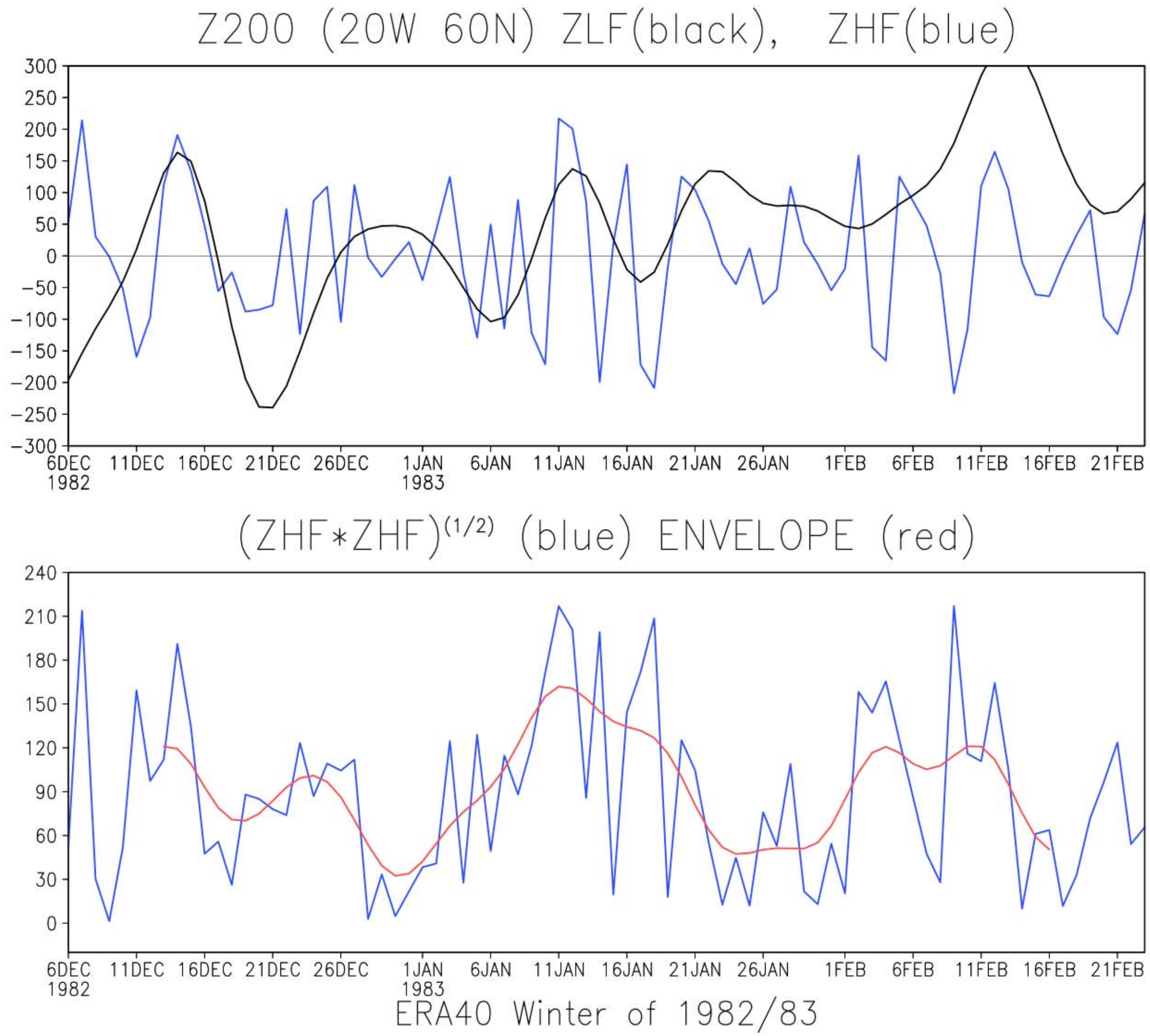
Filtered Z200

Z_{LF}: τ = 10-90 day (black)

Z_{HF}: τ = 2-10 day (blue)

$(Z_{HF}\ Z_{HF})^{(1/2)}$ = blue

envelope function = $\{(Z_{HF}\ Z_{HF})^{(1/2)}\}_{LF}$



Euro-Atlantic Winter Regimes in ECMWF Seasonal Forecasts

Analysis:

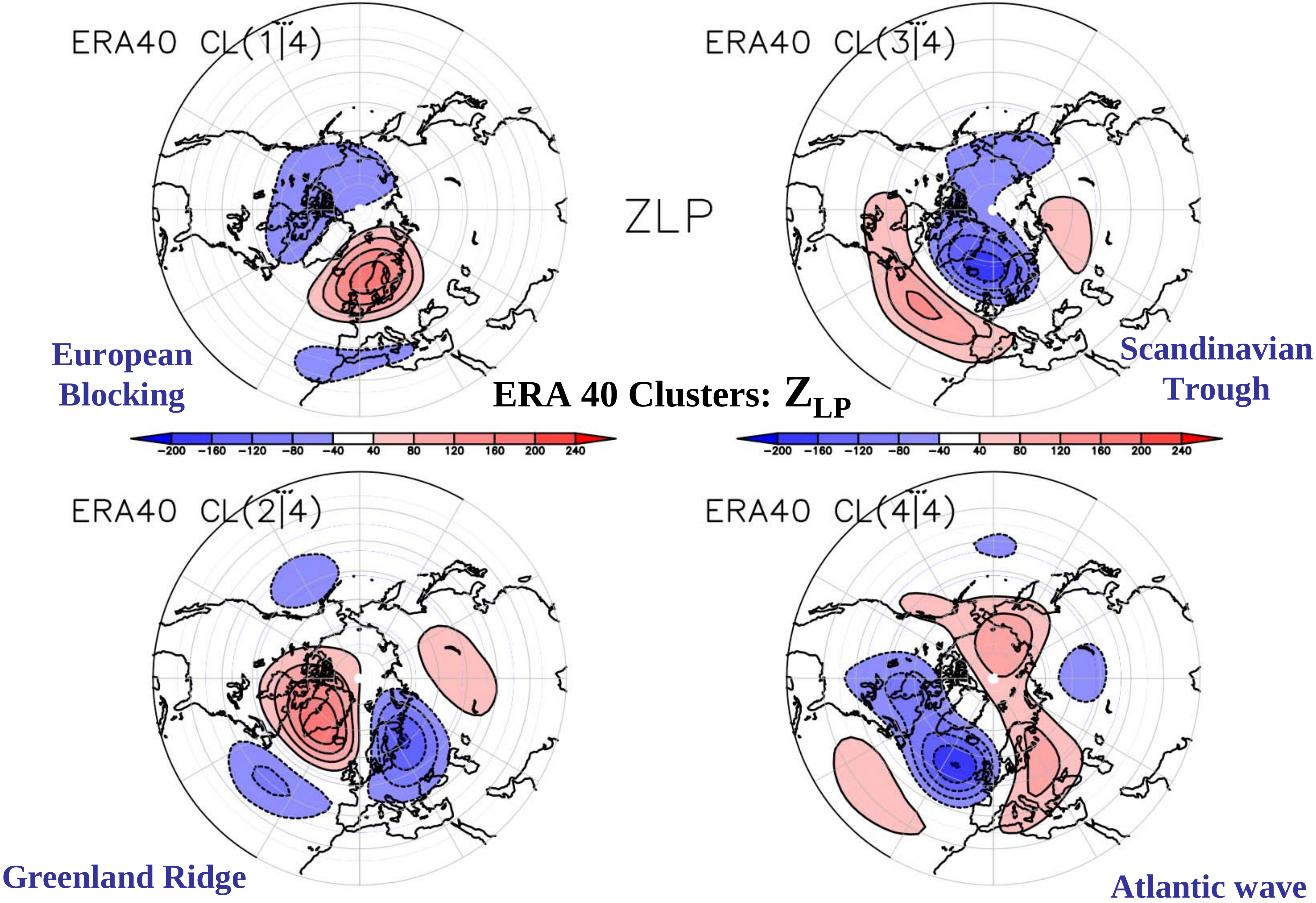
- **Traditional low-pass (10-90 day) filter on Z 200 ⇒ ZLP**
- **Envelope function of band-pass (2-10 day) filtered data ⇒ ZENV**
- **Compute EOFs and PCs of ZLP**
- **Compute EOFs and PCs of ZENV**
- **Compute Singular Value Decomposition using leading N PCS of ZENV and ZLP**
- **SVD patterns very robust to changes in N from 6 to 20**
- **Leading 3 SVD modes capture ~ 87 - 90% of squared covariance (little dependence on N)**
- **Use SVD-defined coordinates - keep only 3 modes:**
- **Apply quasi-stationary filtering (following pioneering studies by Toth)**
- **Apply partitioning algorithm**

- **Technical note: Algorithm is insensitive to orthogonal rotation defined by SVD, but the SVD analysis leads to a unique truncation (N) in state space**

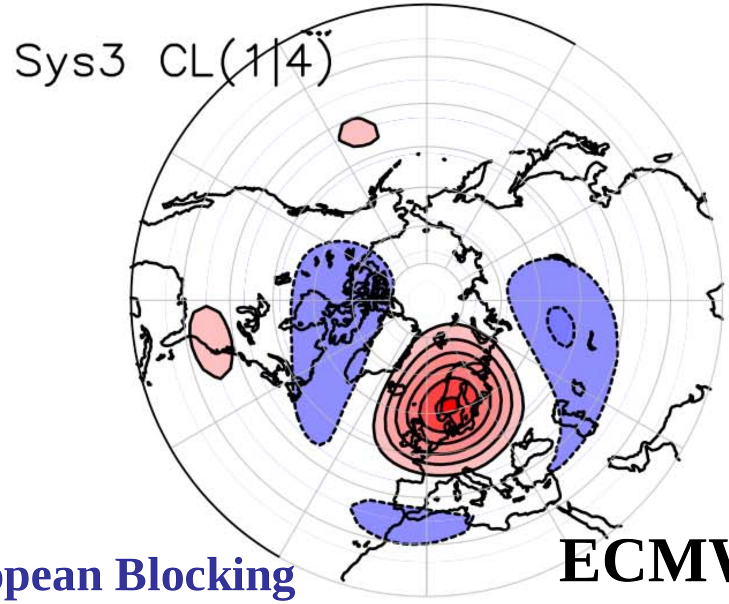
Presentation of cluster patterns

- **Classify all quasi-stationary states into one of 4 clusters,**
- **Full-field composite anomalies of ZLP based on cluster assignment**
- **Full-field composite anomalies of the envelope function based on cluster assignment**
- **Examination of envelope function anomalies shows storm track shifts in association with low-pass height shifts**

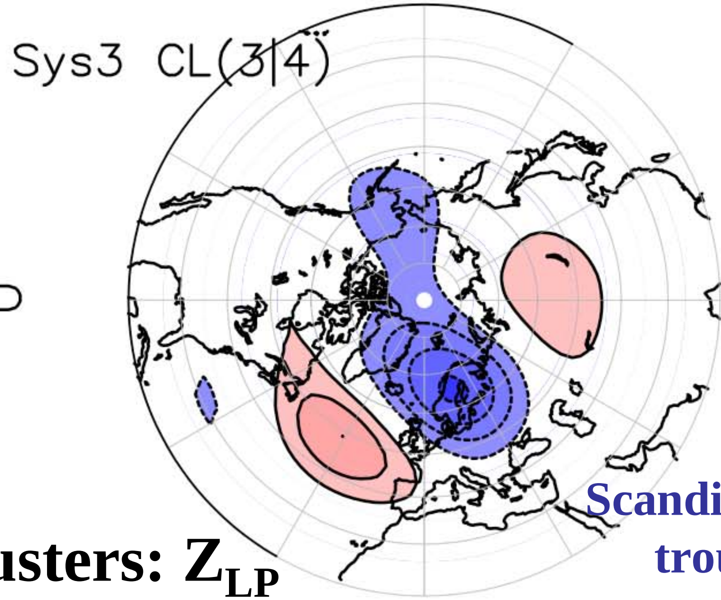
ERA 40 Clusters: Z_{LP}



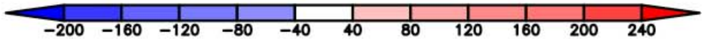
ECMWF Clusters: Z_{LP}

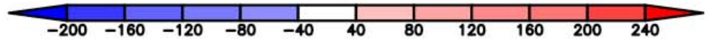


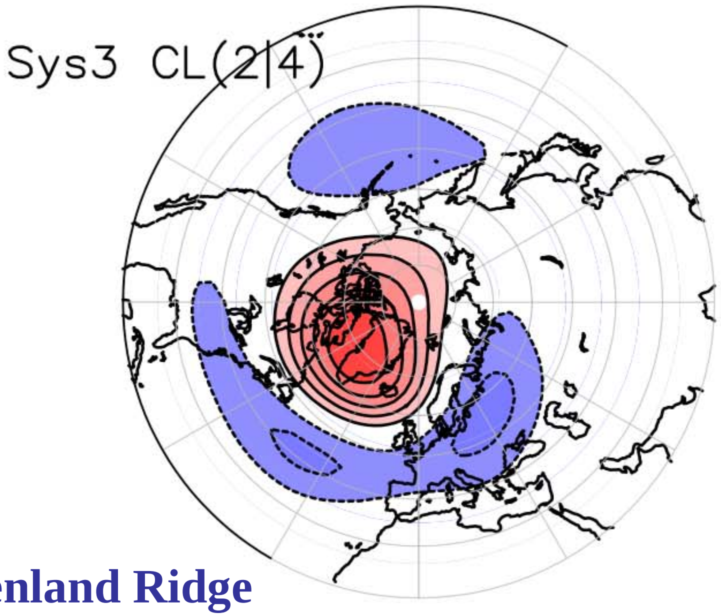
European Blocking



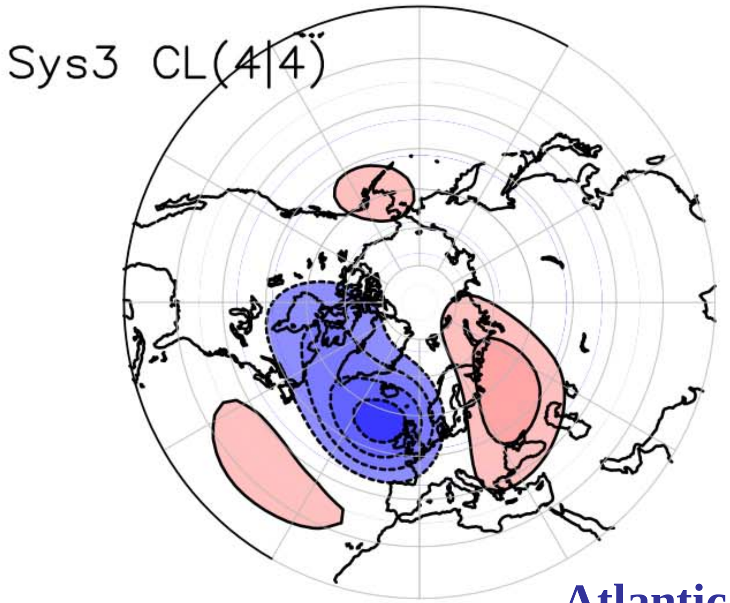
Scandinavian trough



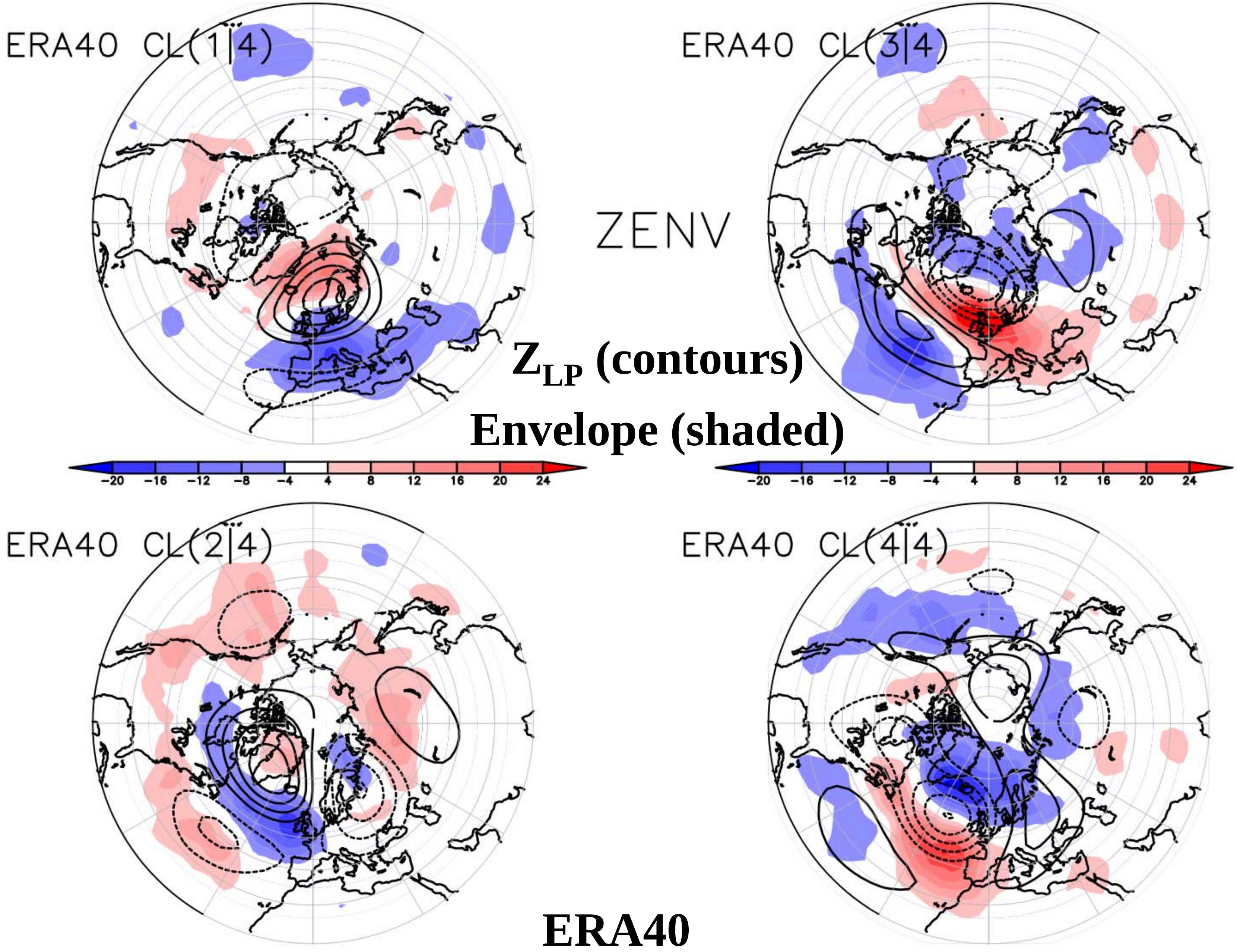


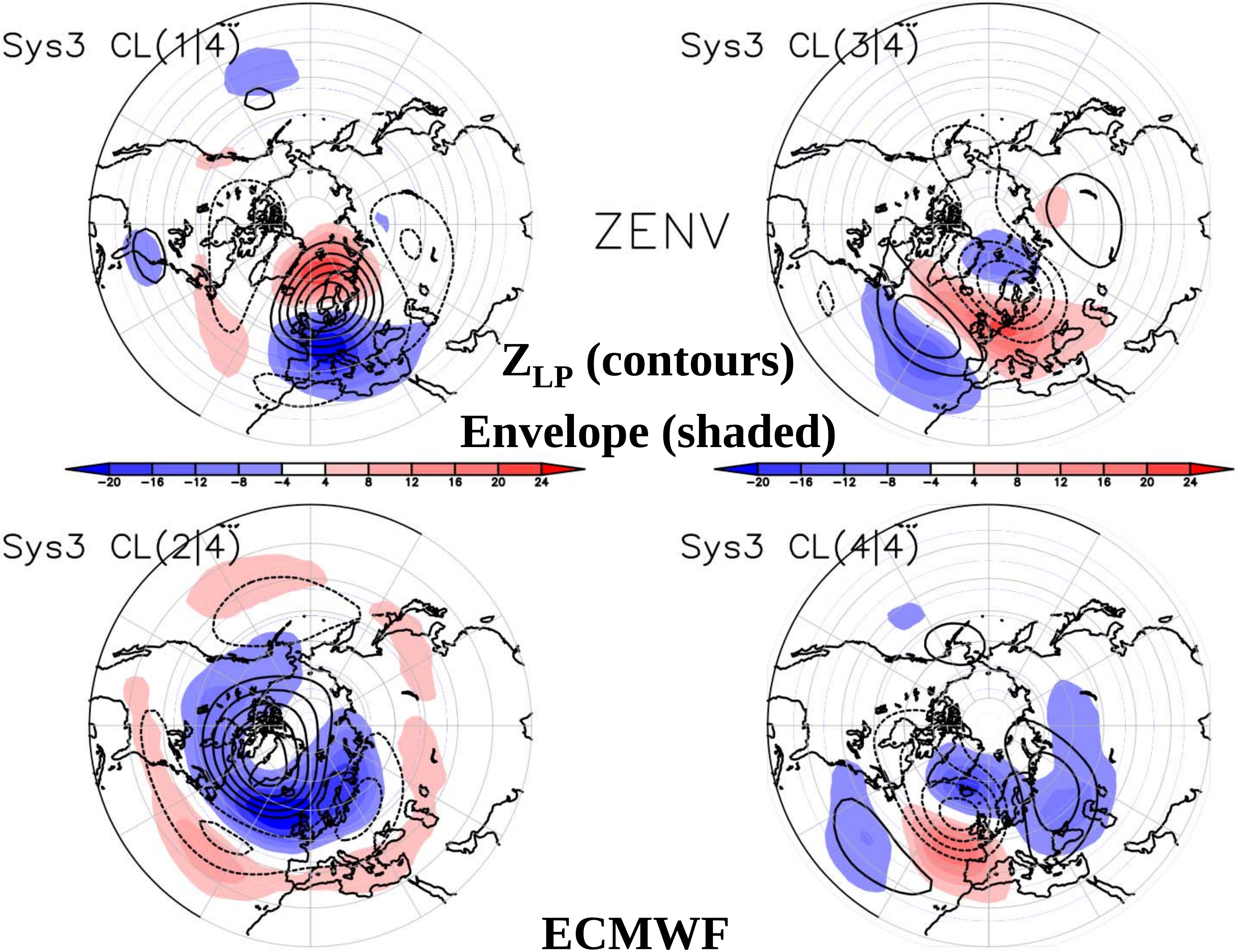


Greenland Ridge



Atlantic/wave


ERA40 CL(1|4)
ERA40 CL(3|4)
ZENV
Z_{LP} (contours)
Envelope (shaded)
−20 −16 −12 −8 −4 4 8 12 16 20 24
−20 −16 −12 −8 −4 4 8 12 16 20 24
ERA40 CL(2|4)
ERA40 CL(4|4)
ERA40



Z_{LP} (contours)

Envelope (shaded)

ECMWF

Reproducibility of the clusters

- **Construct 121 winter *samples* from ensemble data set:**

- **Each *sample* consists of one forecast per winter for the 25 winters, and is strictly comparable to the ERA reanalysis**

- **For each sample:**

  - **From the full set of PCs of ZLP and the envelope function, choose the subset corresponding to the given sample**

  - **Compute the SVDs based on the subset of PCs**

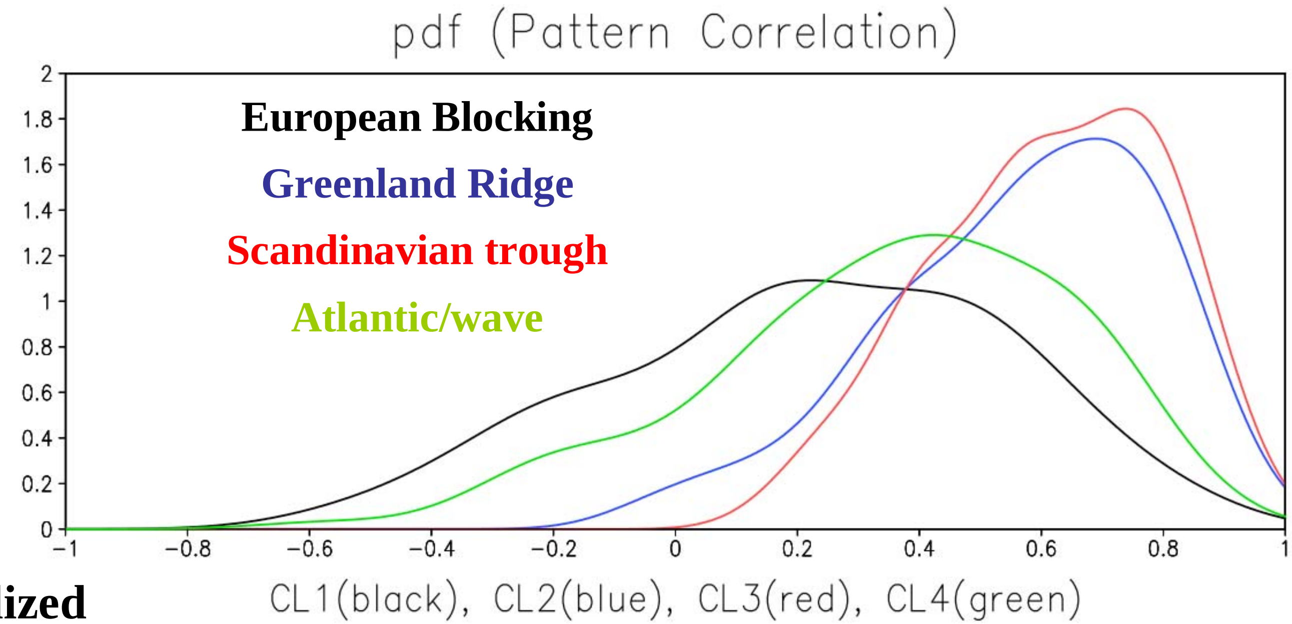
  - **Apply the quasi-stationary filtering and partitioning to the SVDs**

  - **Match the corresponding clusters to the clusters of the full ensemble on the basis of error "energy" (squared amplitude); compute error energy and pattern correlation for each cluster**

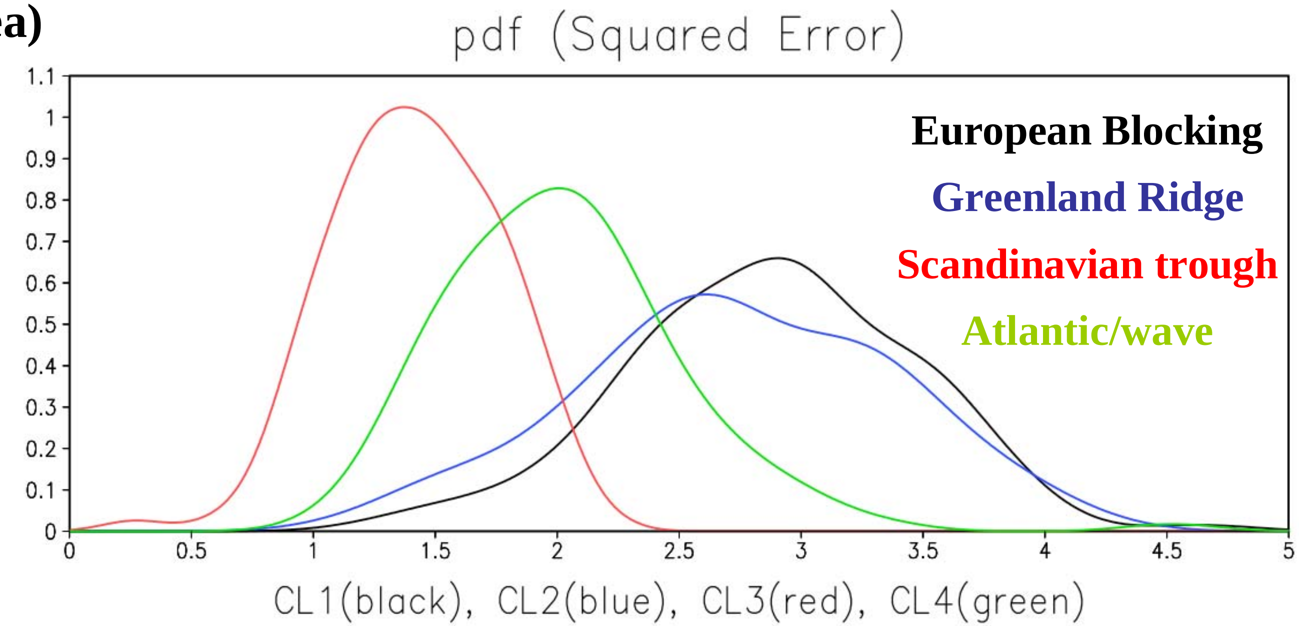
  - **Archive the 121 sets of cluster error energy and pattern correlation measures**

- **From this archive compute pdfs**

- Note: The SVD defining each sample defines a unique rotation and truncation of the original PC state space



(pdfs normalized to unit area)



Reproducibility

- Scandinavian Trough most reproducible: generally highest pattern correlation and lowest error energy
- European Blocking least reproducible: lowest pattern correlation and highest error energy

Some Conclusions

- ECMWF seasonal forecast model simulates European-Atlantic clusters which are very similar in pattern to those in reanalyses

-The Scandinavian trough is the most reproducible across forecasts; European blocking is the least reproducible

- Using SVD between low-pass height field and the envelope storm track fluctuations yields a unique truncation level (3 modes) for cluster calculations - removing one source of arbitrariness

- Other amibiguities remain: Number of clusters?

Appendix: Some details about SVD calculations

Data source	N PCs	squared covariance	% sq cov explained in first 3 modes
EC forecasts	6	1.1×10^{11} m^4	37, 33, 20
EC forecasts	10	1.2×10^{11} m^4	35, 32, 20
EC forecasts	20	1.2×10^{11} m^4	35, 32, 20
ERA 40	6	8.6×10^{10} m^4	43, 30, 19