Analysis of the variability of African easterly waves in simulations with ARPEGE-Climat

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- Presentation of the simulations
- Methods of analysis (CEOF)
- Interannual variability of the mean mode patterns
- Intraseasonal modulation of AEW activity
- Conclusions and perspectives

Purposes of the present study

- To identify the propagation and variability of African Easterly Waves in analyses and simulations
- To extend the study of Céron and Guérémy (1999) and Céron et al (2001) by applying the same statistical analysis methods on more extensive sample of simulations and observations
  - Space-time spectral analysis (STSA)
  - Complex Empirical orthogonal function analysis (CEOFA)
- To document the capacity of the ARPEGE-Climat GCM in reproducing the main characteristics of AEW
  - Spatial structure
  - Intraseasonal fluctuations
  - Interannual variability
- To start an analysis of the mechanisms that can modulate the variability of the AEWs (MJO?)

Description of the AGCM

- ARPEGE-Climat AGCM version 3
  - Cycle 22a
- Uniform T63 spectral truncation
  - 128 x 64 reduced linear grid
- 31 vertical levels
- Physical parametrizations (Morcrette, Bougeault, Louis et al, statistical clouds, variable boundary layer height, etc..)
- ISBA land-surface scheme
- Forced by observed monthly mean sea surface temperatures (SSTs) from Reynolds analyses

Description of the simulations

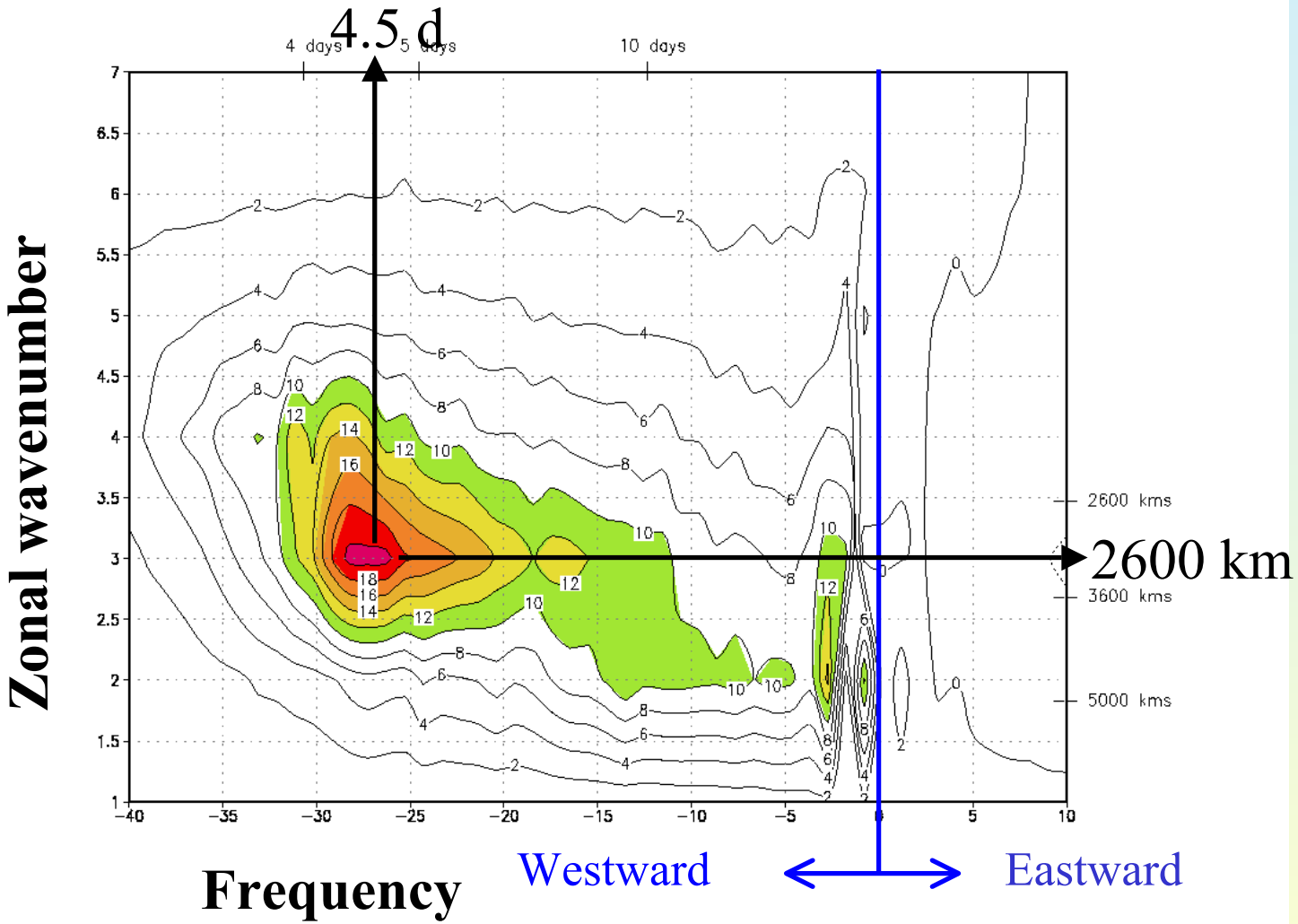
- Seasonal forecast control experiments made by H. Douville for a study of the influence of soil moisture relaxation

  (Douville, 2003, J. Hydrometeorology, in press)
- Seasonal cycle simulations June-September (JJAS)
- 15 years 1979-1993
- 10 member ensembles
  - Initialised from ECMWF reanalyses (27 May)
  - Random atmospheric perturbations in initial conditions
  - Identical initial land surface conditions
- Validation data: ECMWF 15 year reanalysis (ERA15)

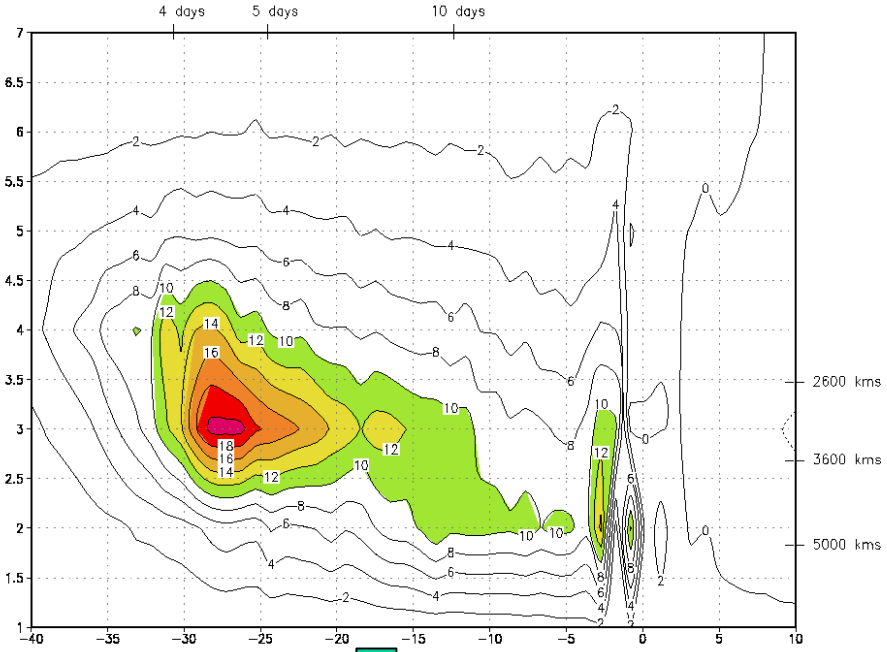
Statistical methods of analysis

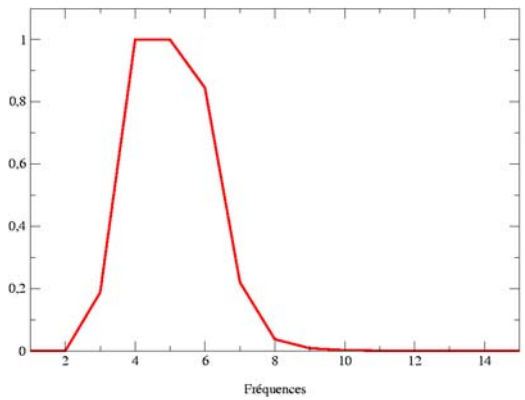
- Applied to daily times series over the period June-September (123 days)
- Relative vorticity at 850 hPa
- Spatial domain restricted to:
  - 40°W-40°E, 5°S-34°N (29 x 14 gridpoints)
- Space-time spectral analysis
  - Hayashi (1977, 1979, 1982)
  - Integration of the time cross-spectrum between real and imaginary part of a Fourier transform
  - Partition of variance between standing and travelling waves (eastward and westward)
- Time filtering by a Butterworth 4-th order lowpass filter
  - 3.5- 6 day bandwith

Space-time variance

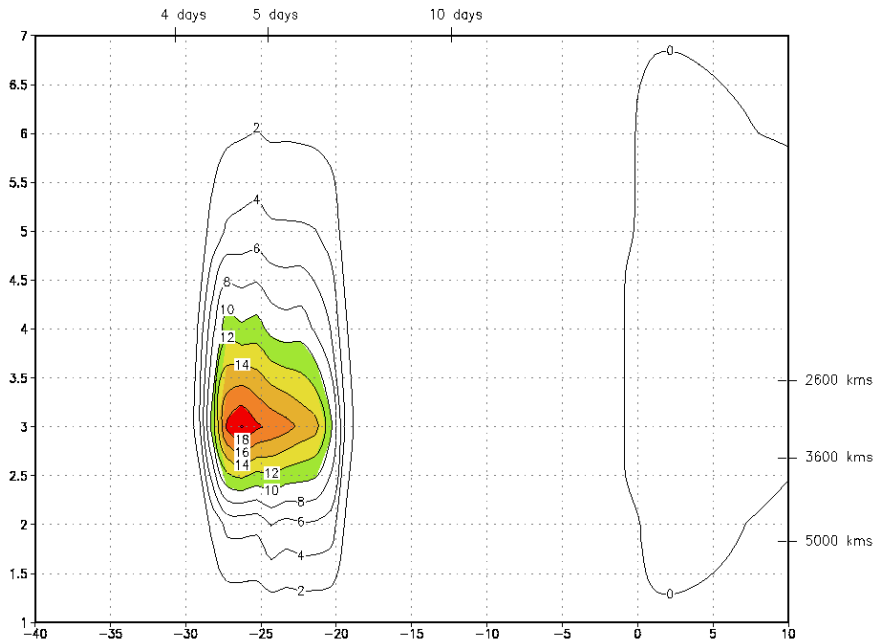


Effect of time-filtering on the wavenumber-frequency spectrum





Butterworth 4-th order filter



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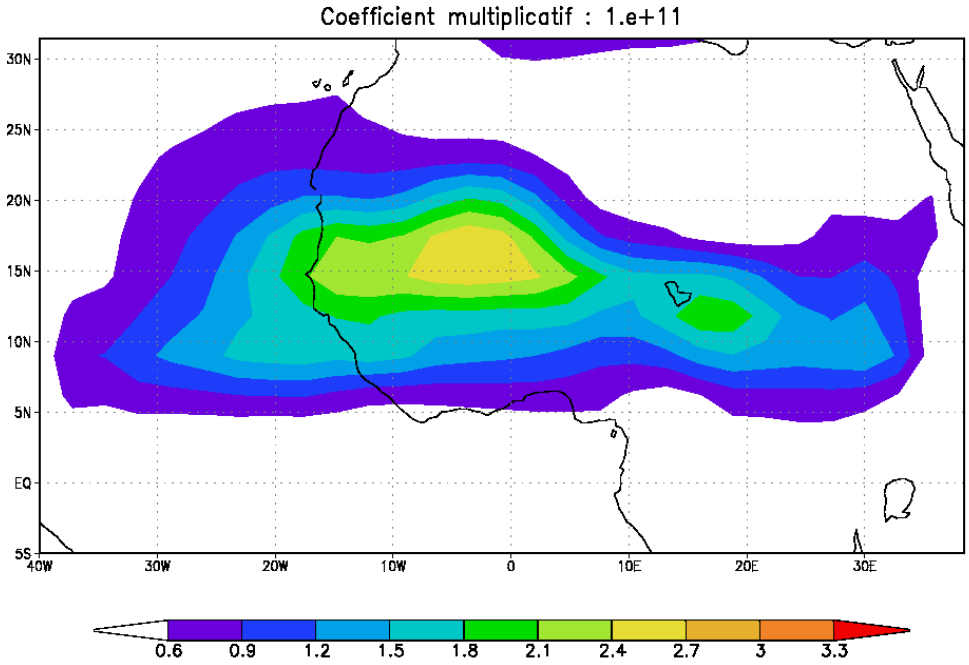
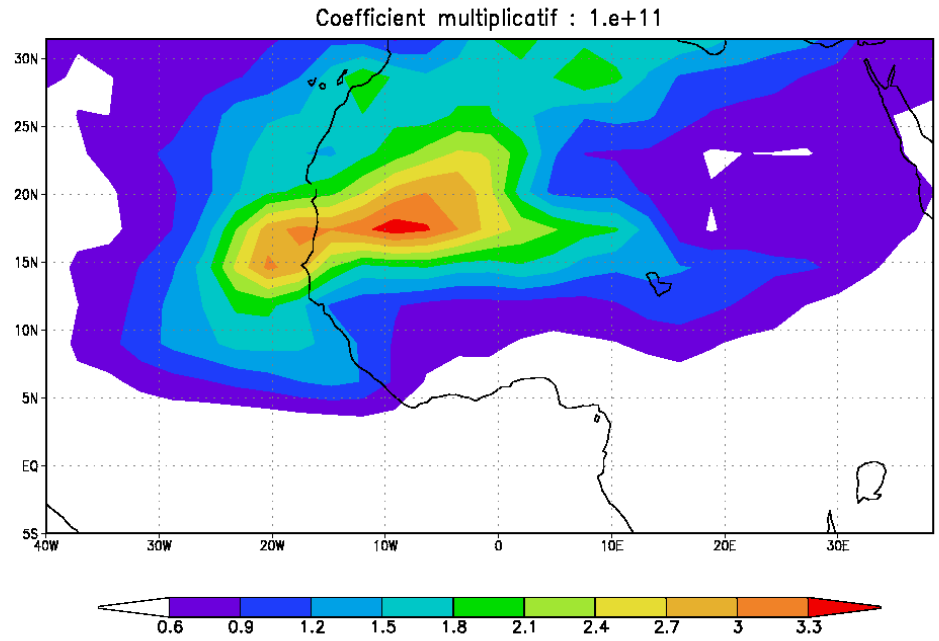
Distribution of the filtered intraseasonal variance



ERA15

Simulation



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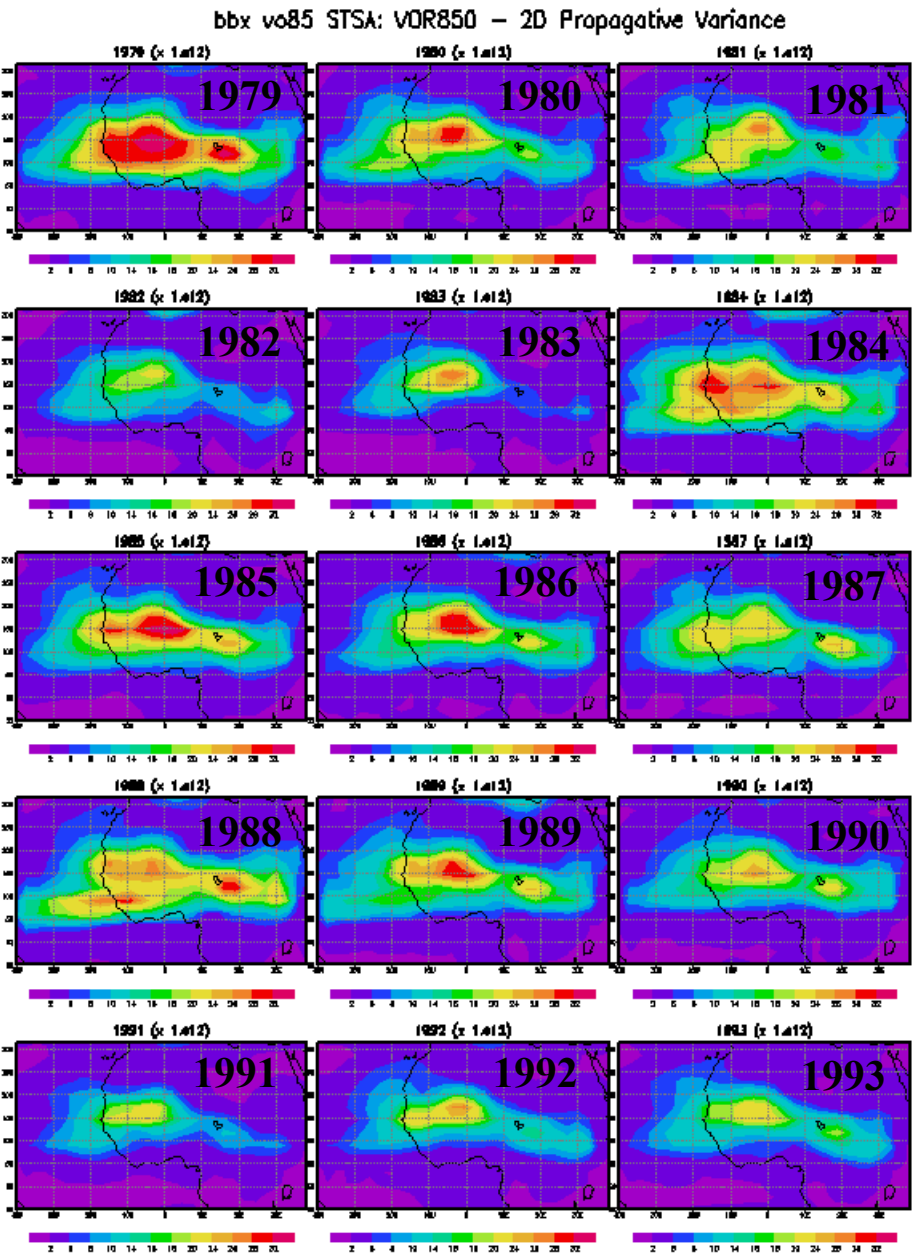
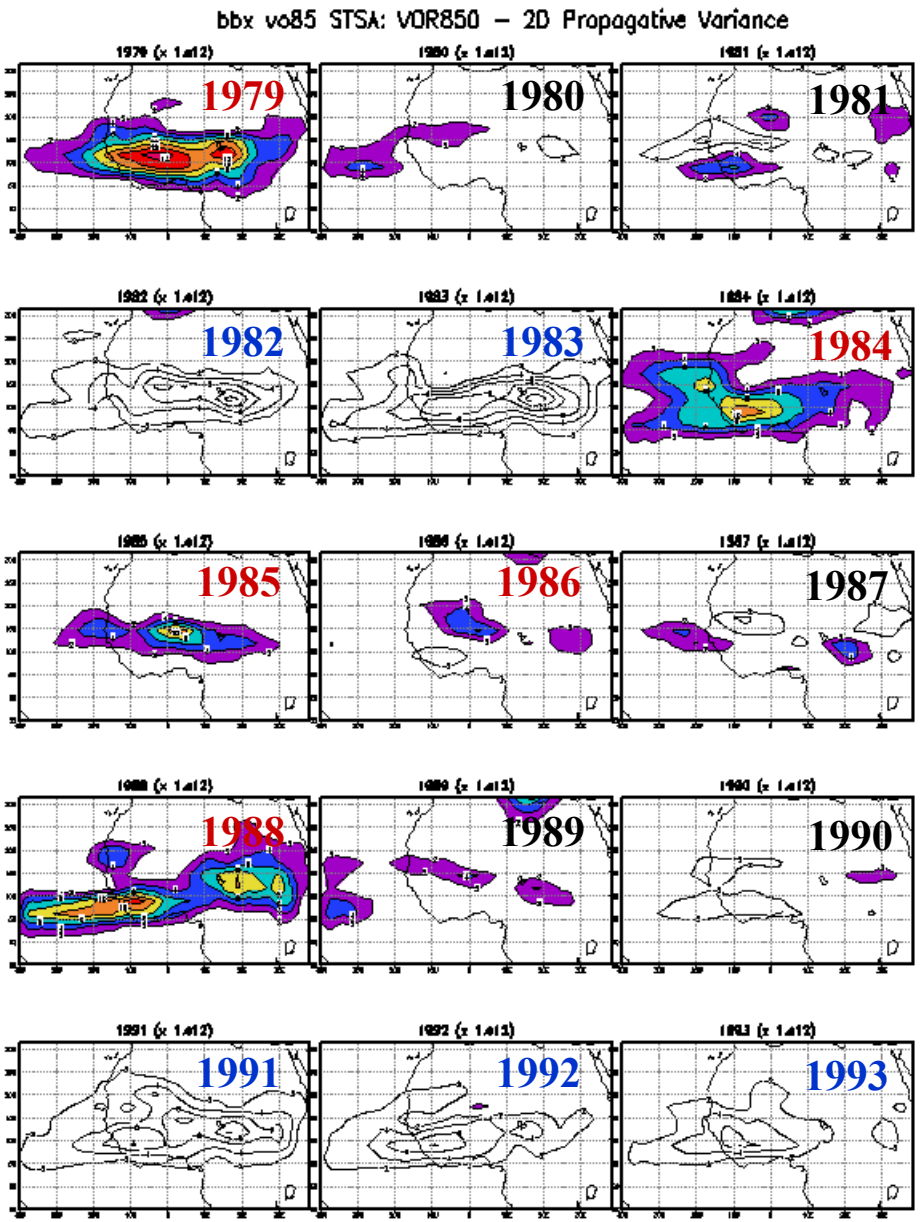
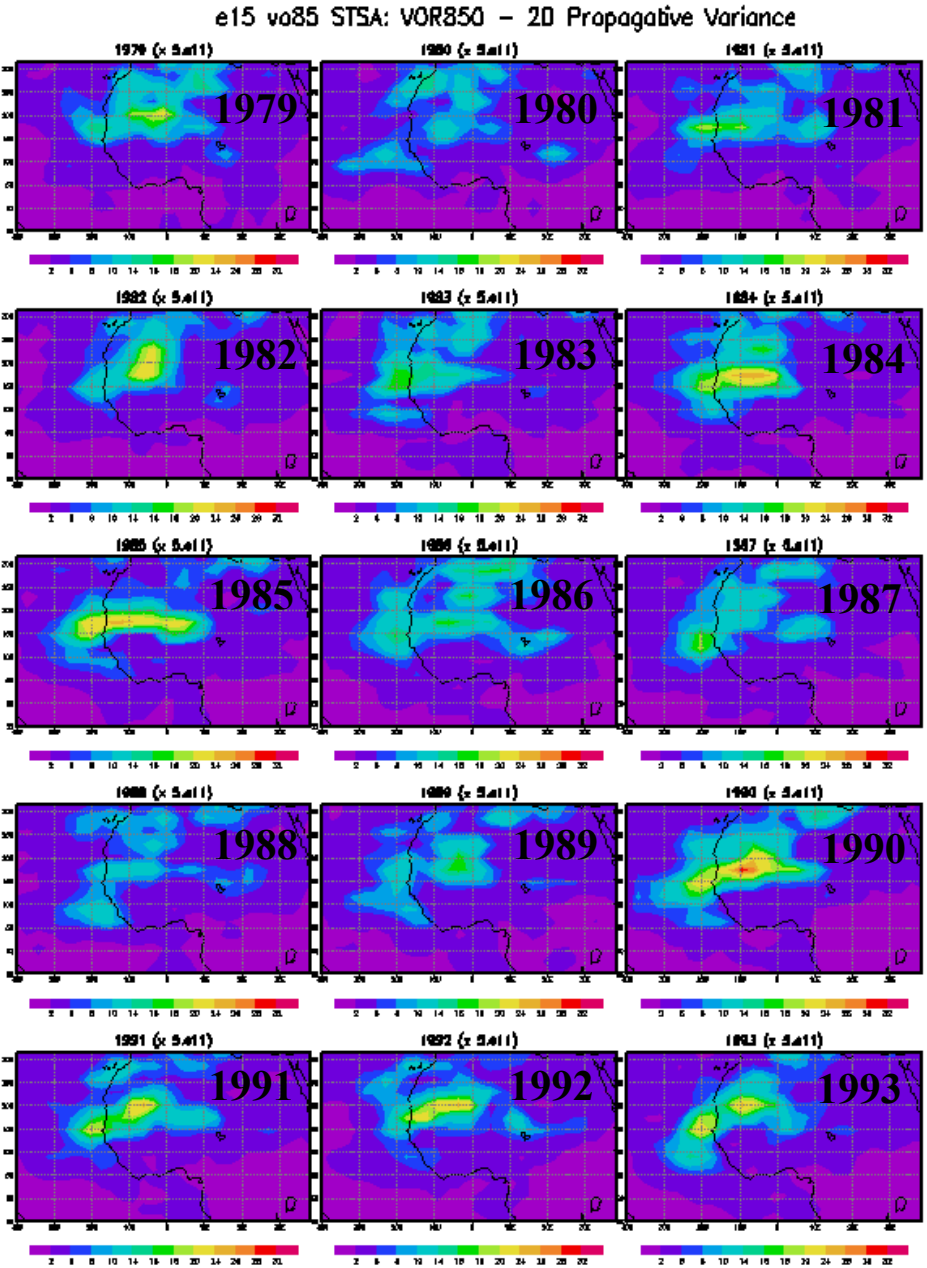
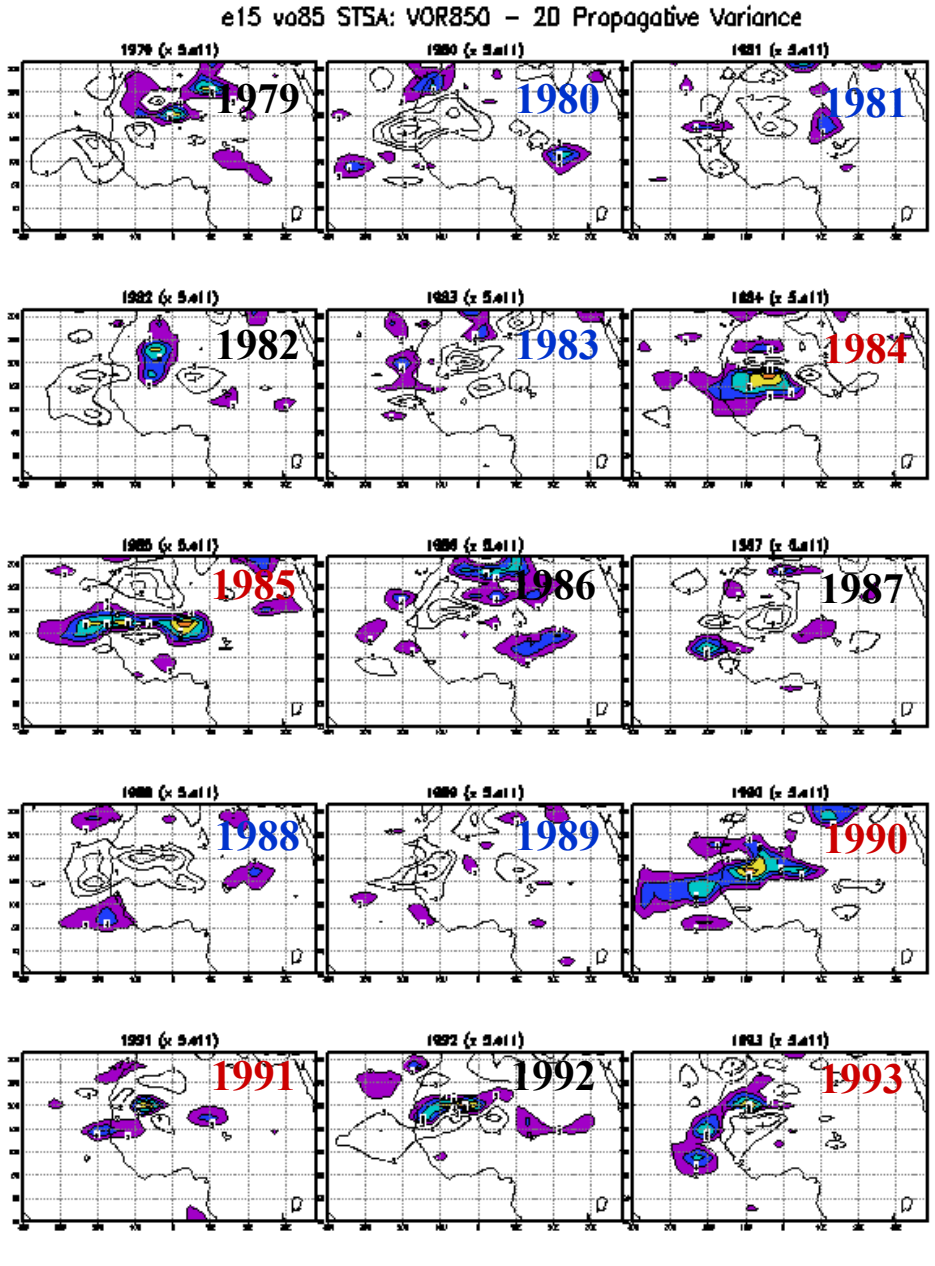
Interannual variations of the propagative variance in the simulation





Interannual variations of the propagative variance in ERA15





Complex EOF analysis

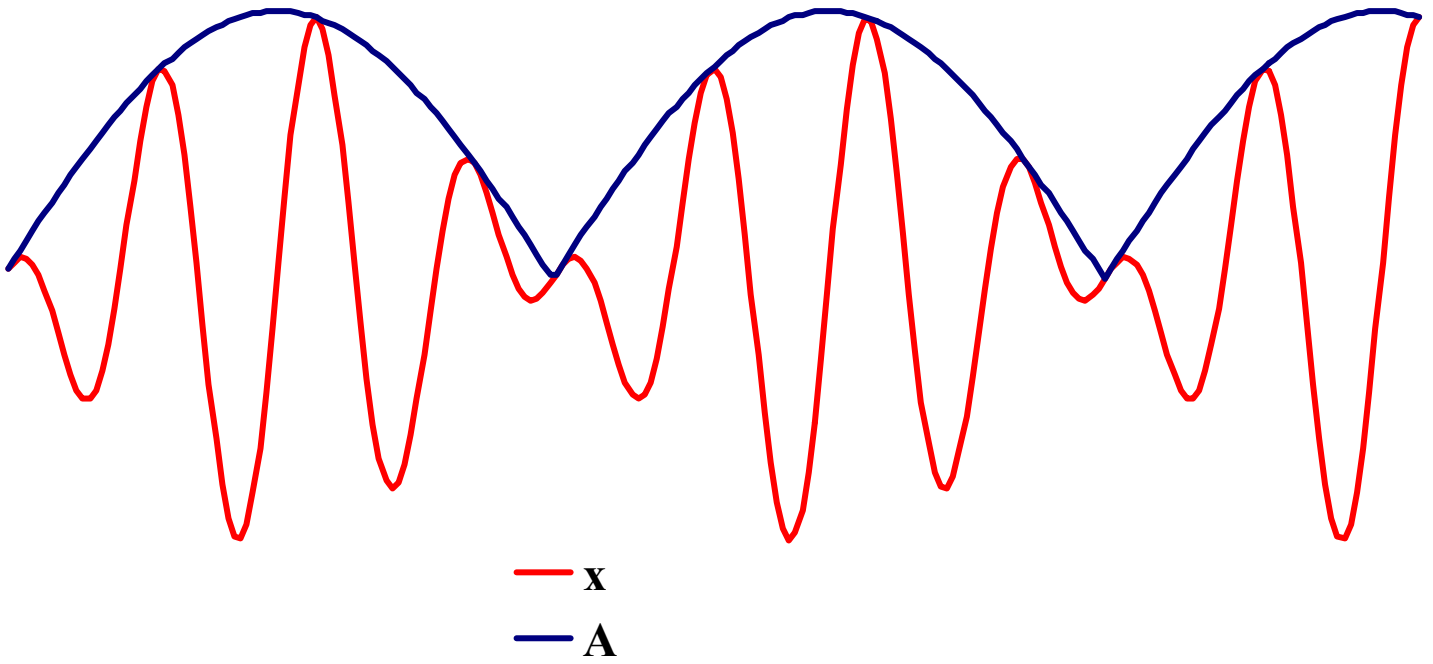
- Appropriate for analysing travelling phenomena
  - Wallace and Dickinson (1972)
  - Céron and Guérémy (1999
- Computation of a complex covariance matrix
  - Computation of the imaginary part by Hilbert transform
  - Integration of the cross-spectrum matrix over frequency
- Classical EOF on the complex covariance matrix
  - Determination of the eigenvectors
  - Complex modes of variability
  - Gives information on amplitude and phase

$$Z(t,M) = X(t,M) + i\, Y(t,M)$$

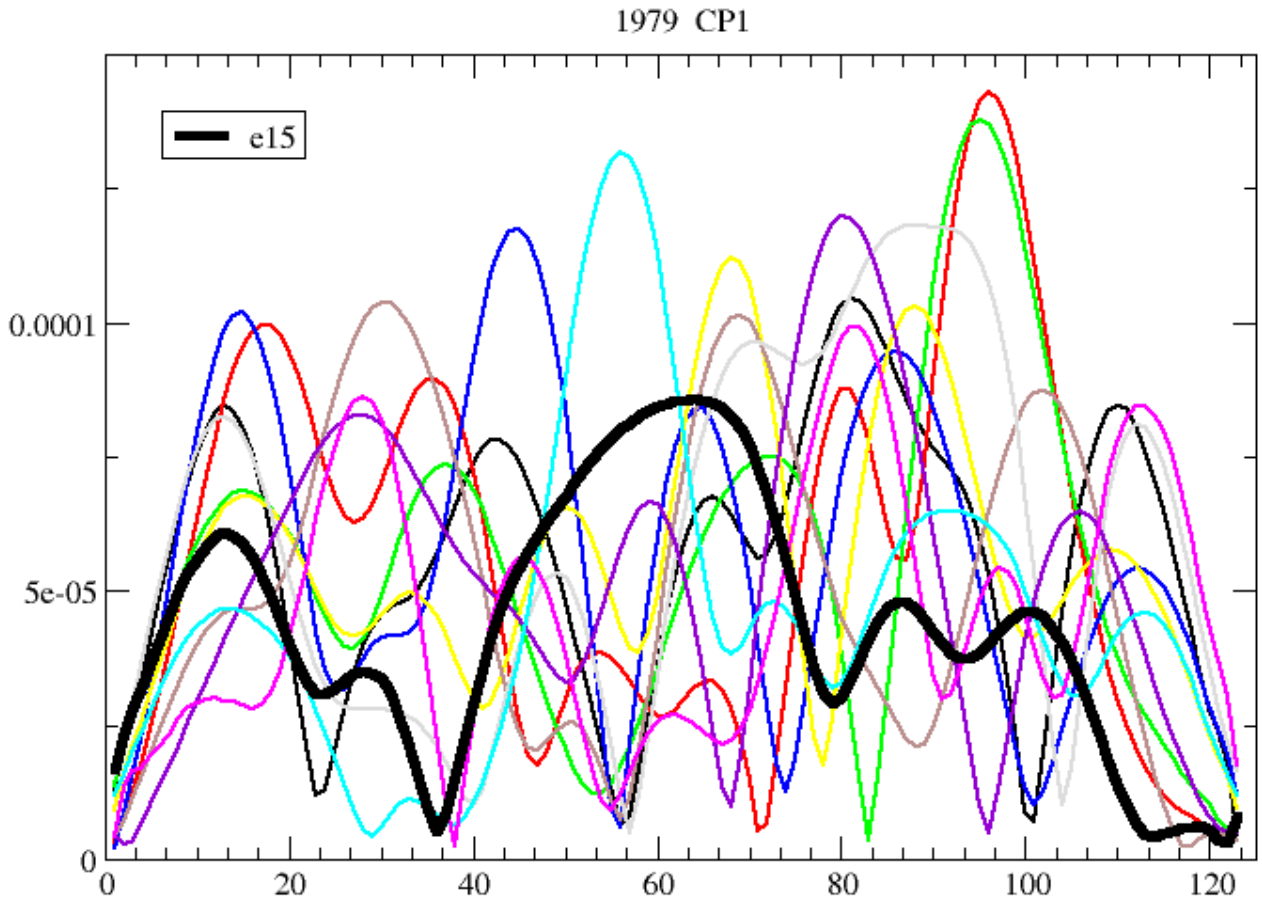
$$Z(t,M) = \sum^{k} \lambda_k\, V_k(M)\, v_k(t)$$

$$V(M) = A(M)\, \exp\{ i\, \Phi(M) \}$$

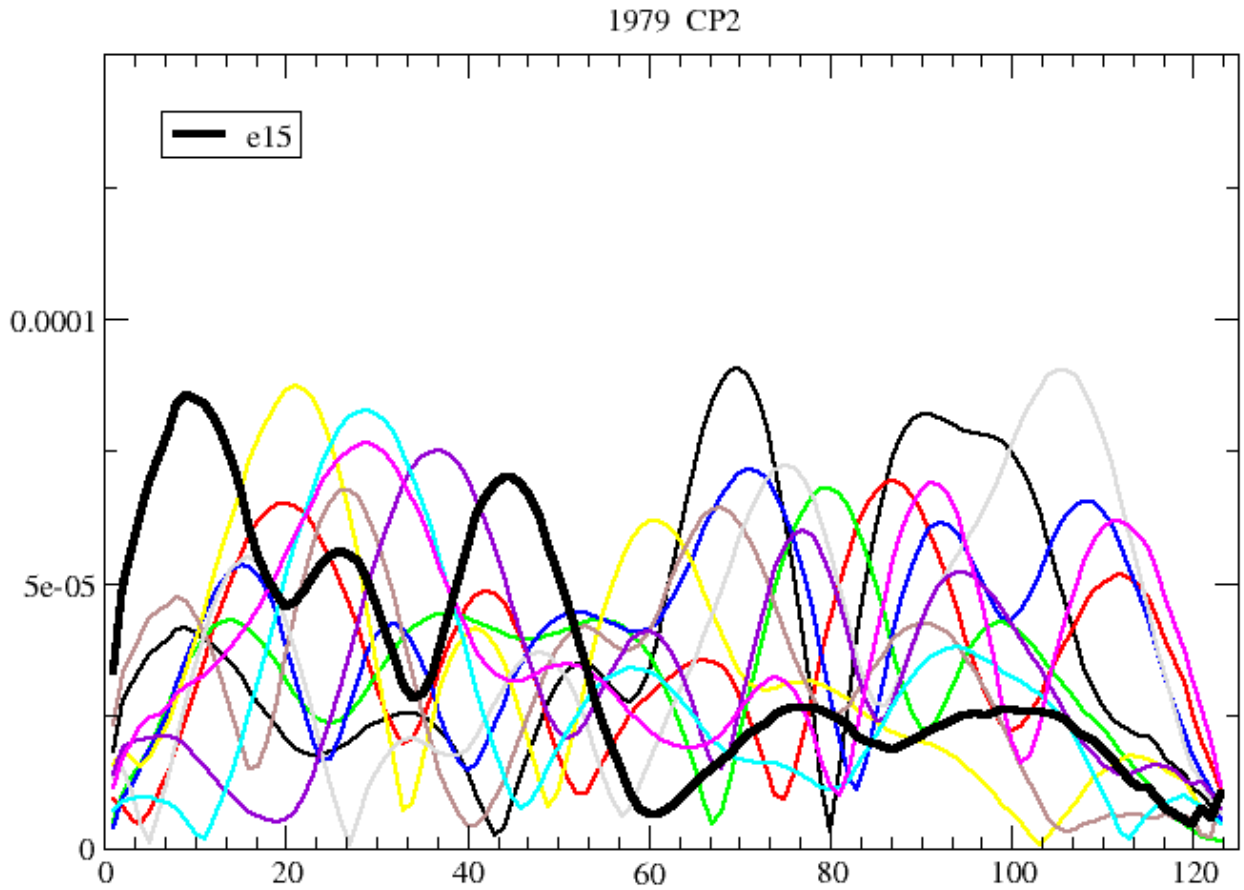
$$v(t) = a(t)\, \exp\{ i\, \varphi(t) \}$$



Time variation CEOF-1 amplitude for 1979 in ERA15 and in the 10 simulations

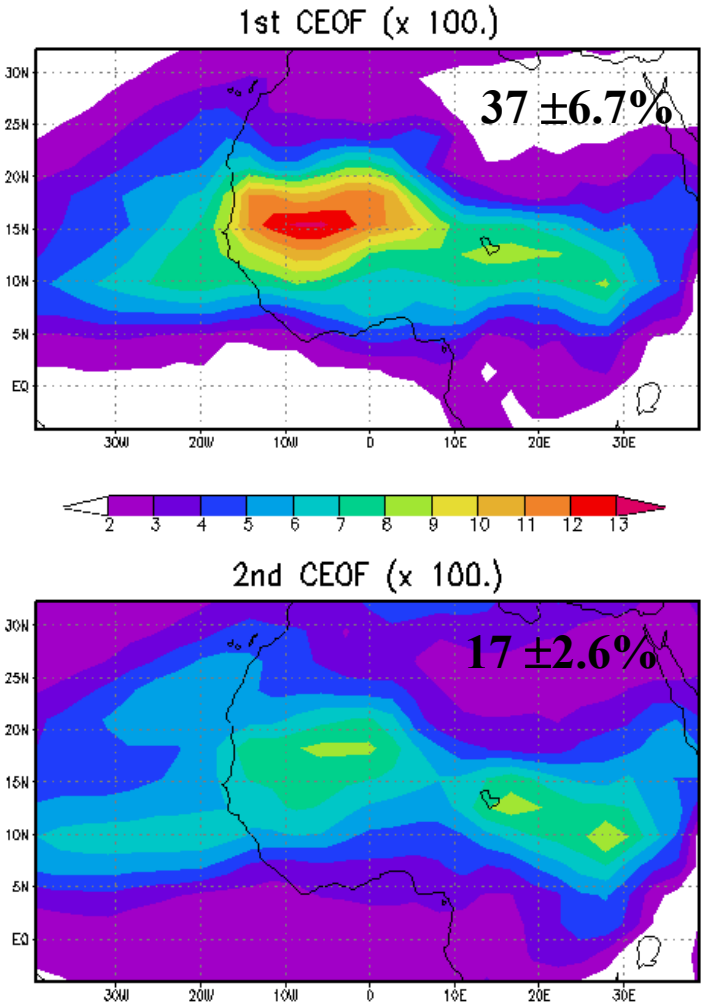


Time variation CEOF-2 amplitude for 1979 in ERA15 and in the 10 simulations

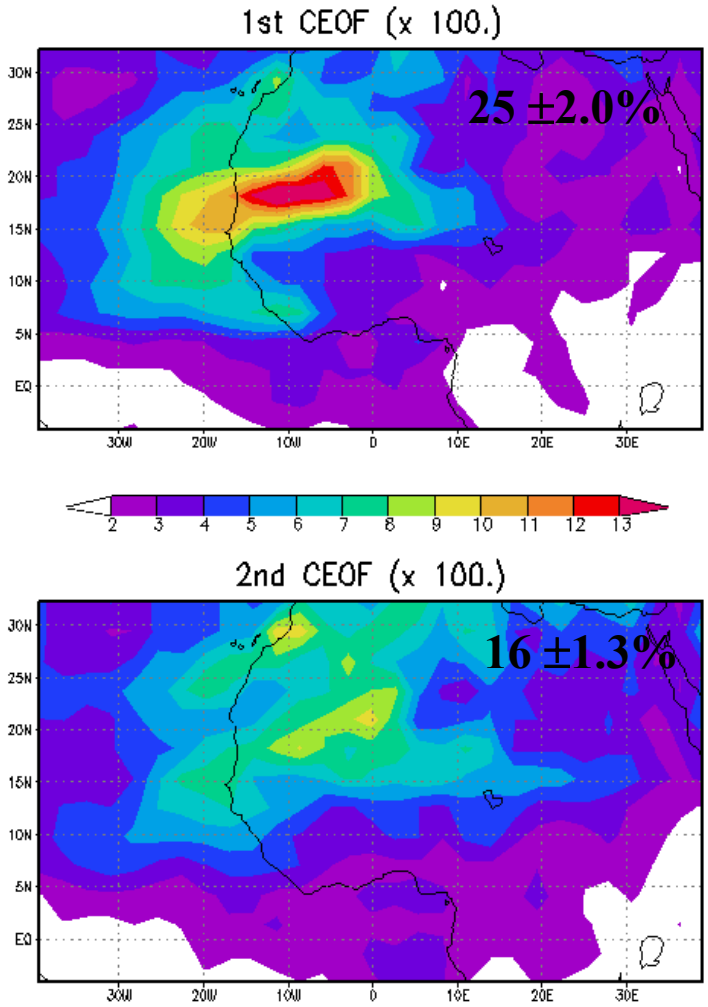


First and second mean mode pattern (MMP)

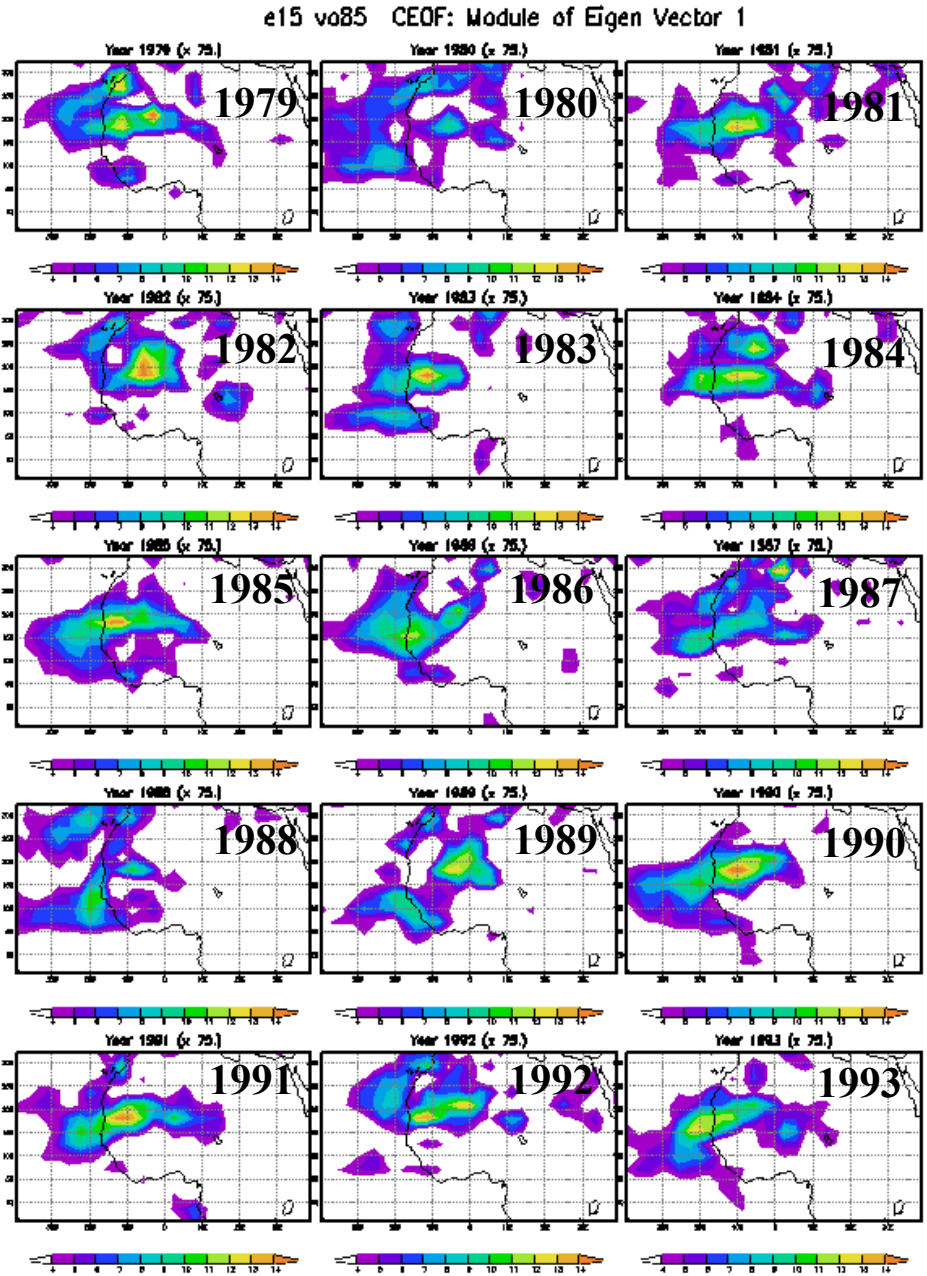
GCM

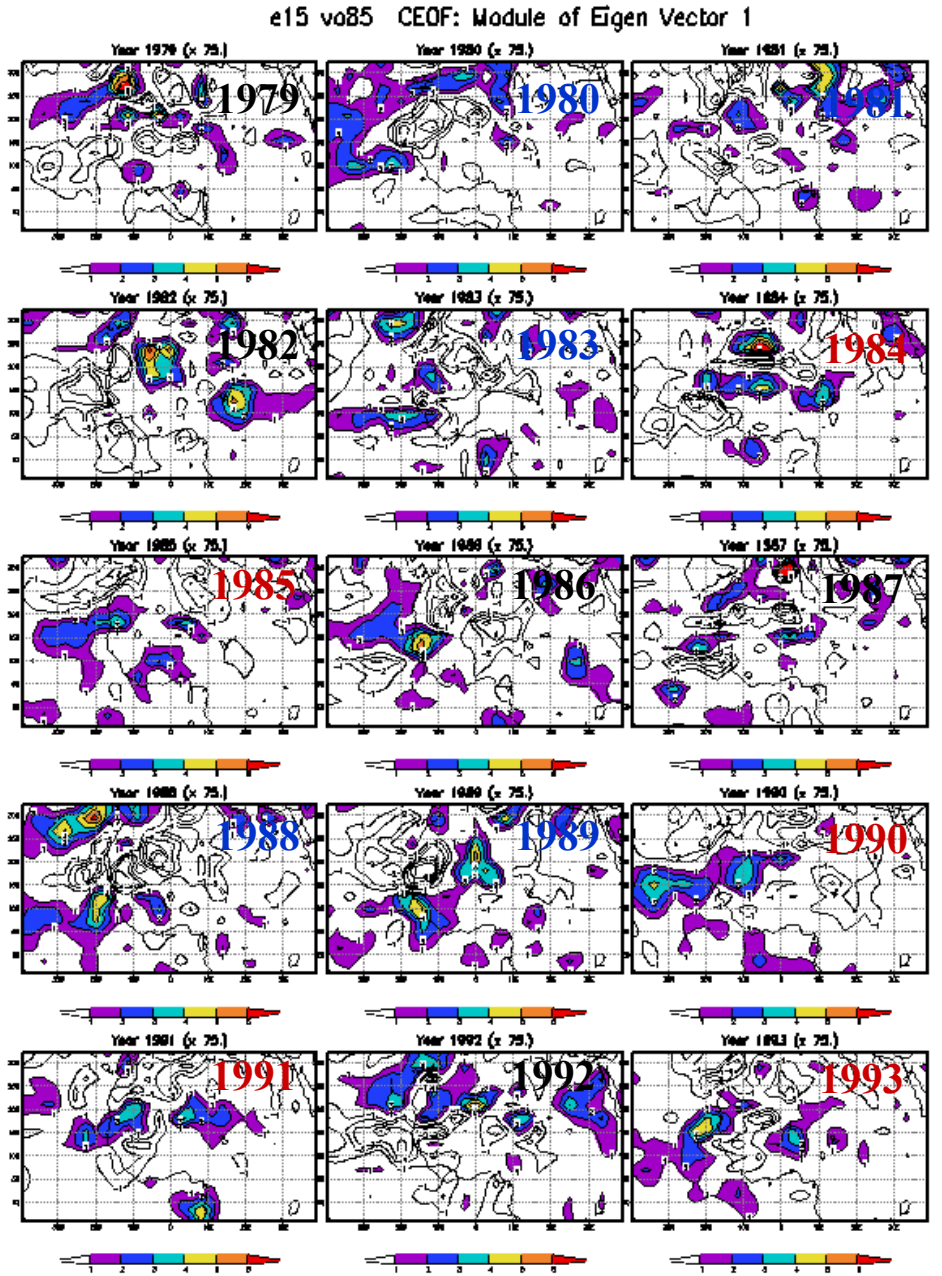


ERA 15

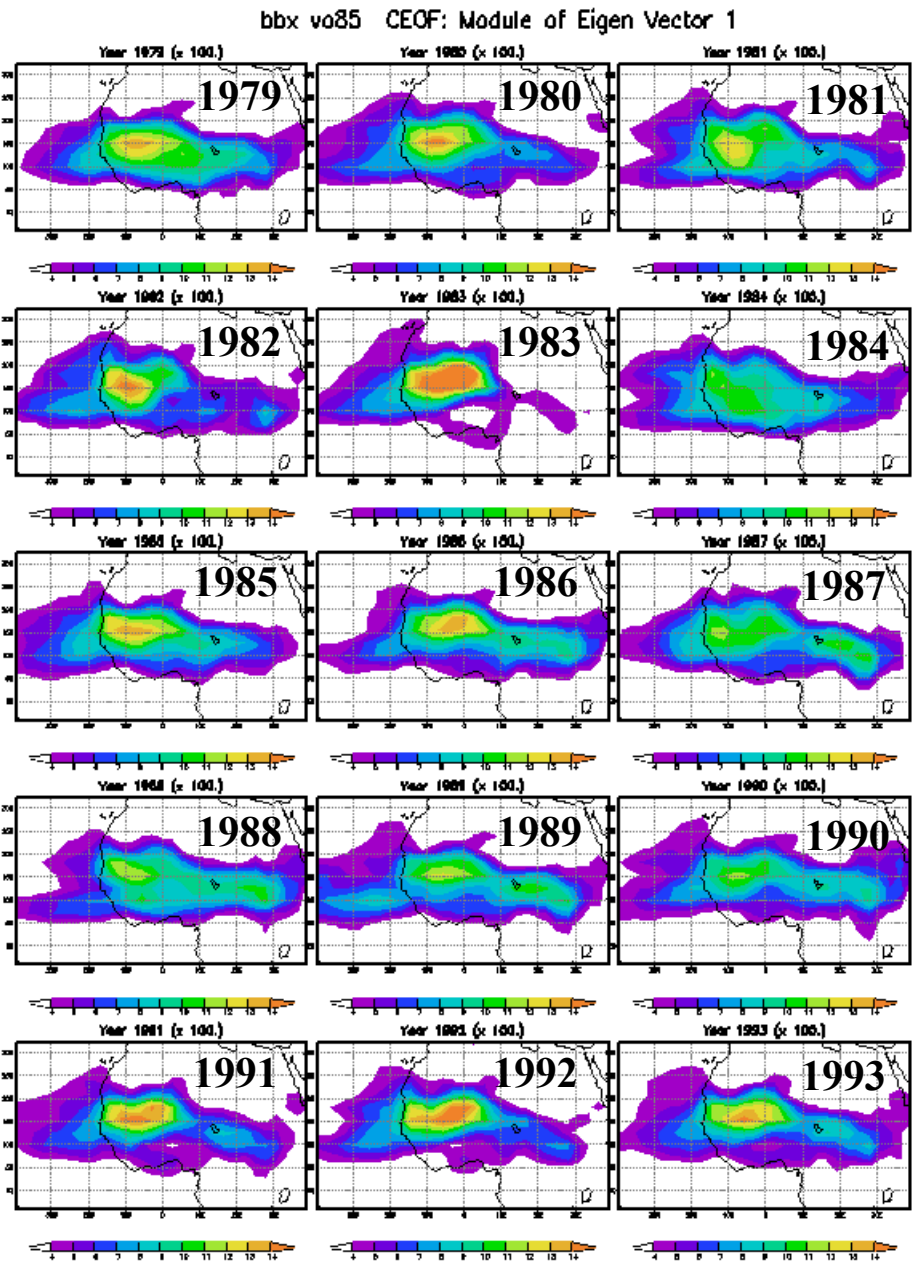


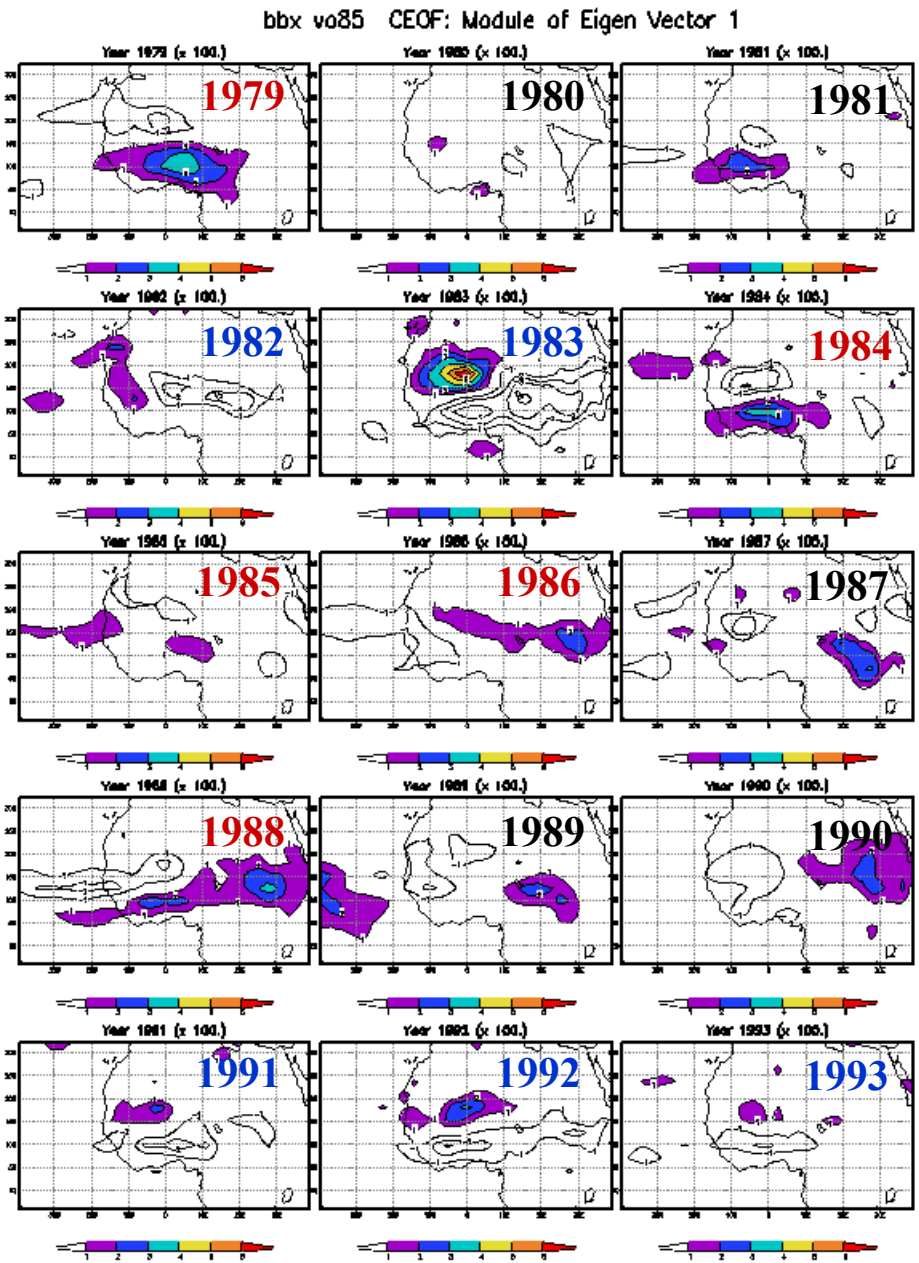
Interannual variation of CEOF-1 amplitude in ERA15



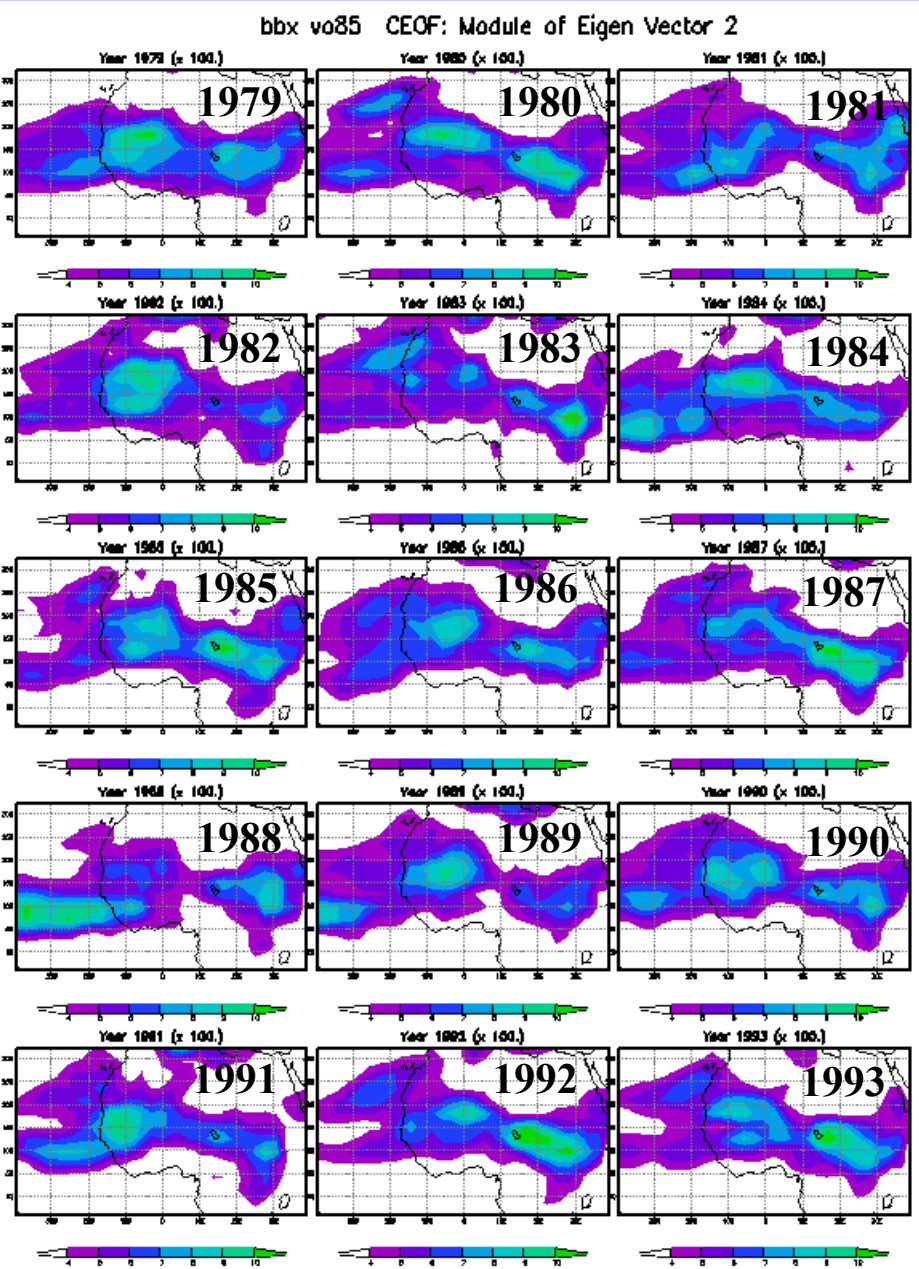


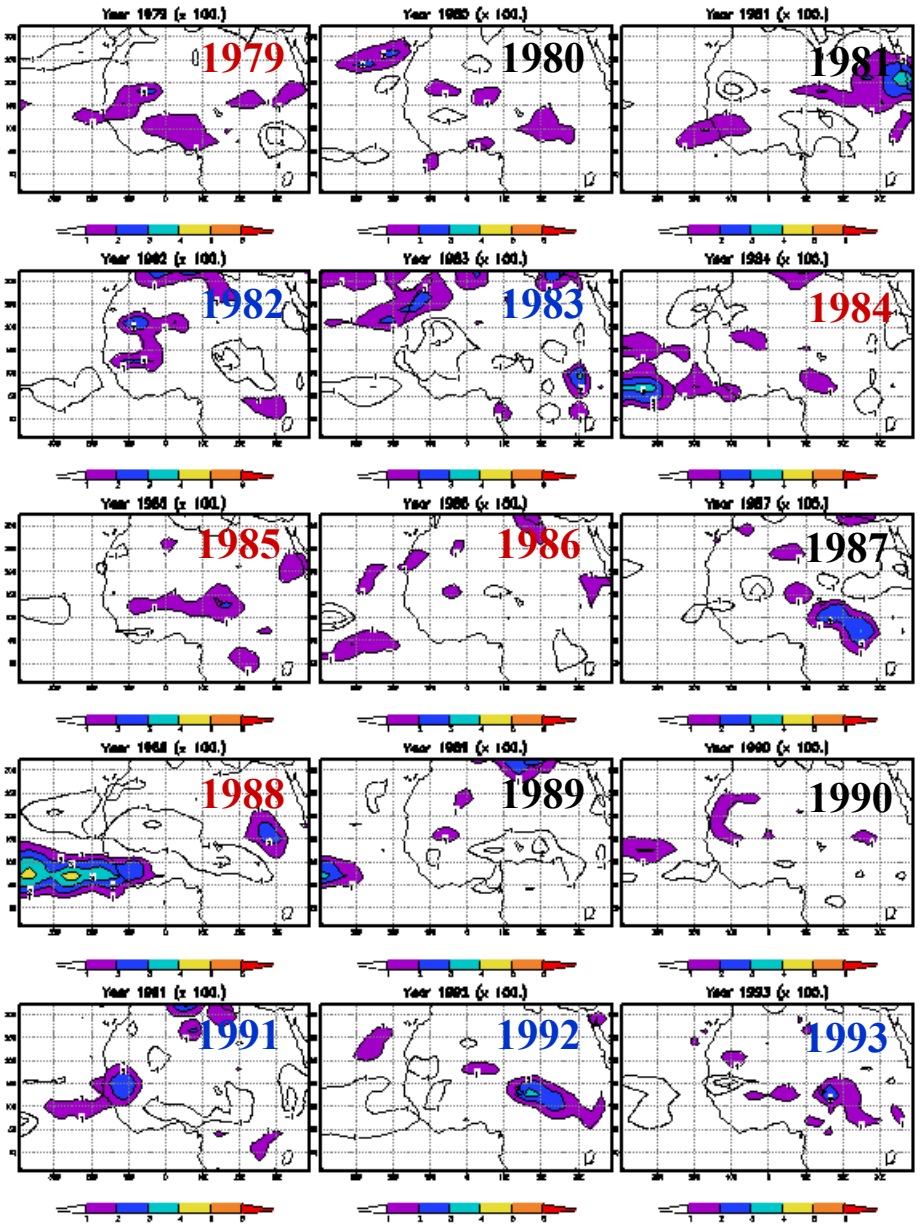
Interannual variation of CEOF-1 amplitude in the GCM





Interannual variation of CEOF-2 amplitude in the GCM



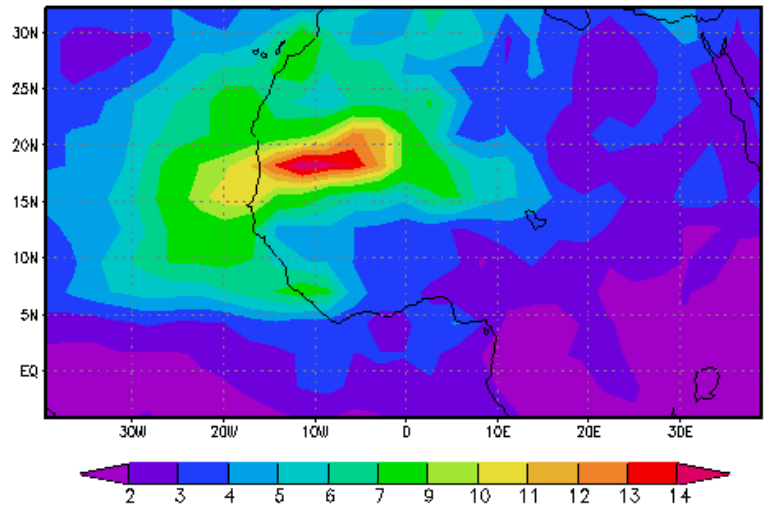


15-year mean and sigma of mode amplitude in ERA15

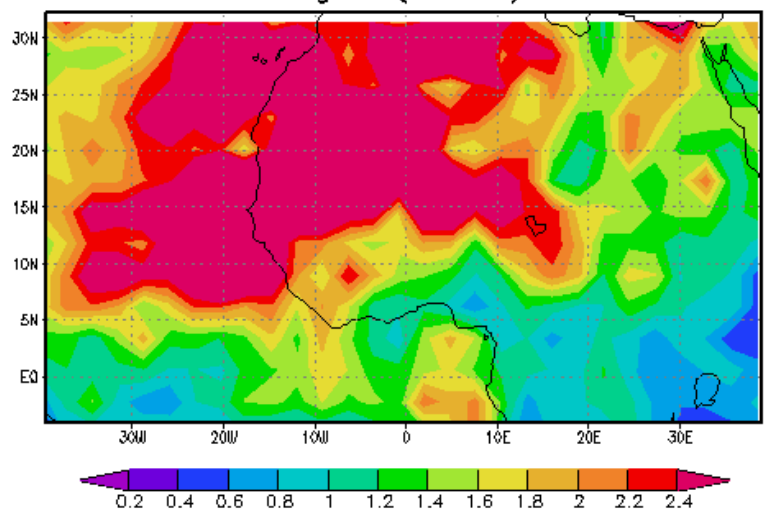
e15 va85 CEOF: VOR850 – Year glob Module of Eigen Vector 1

Mode 1

Mean (x 100.)



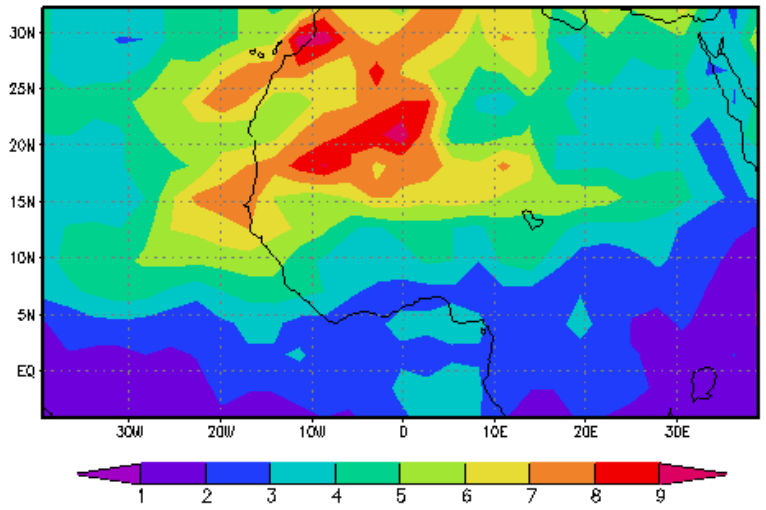
Sigma (x 100.)



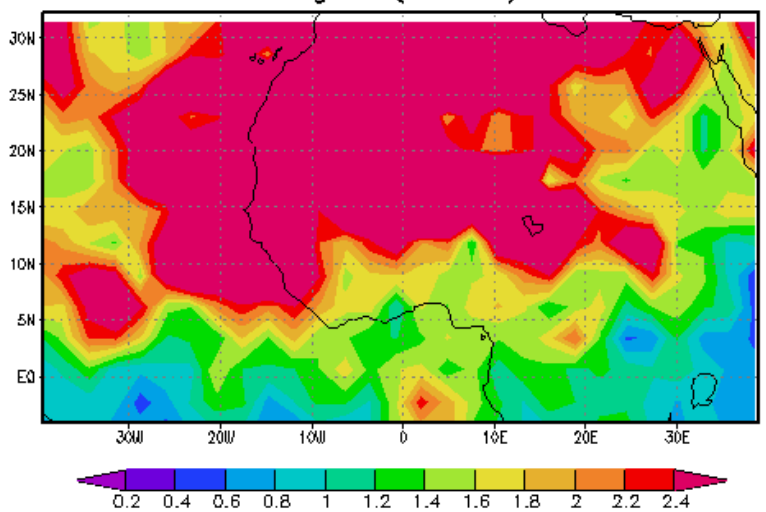
e15 va85 CEOF: VOR850 – Year glob Module of Eigen Vector 2

Mode 2

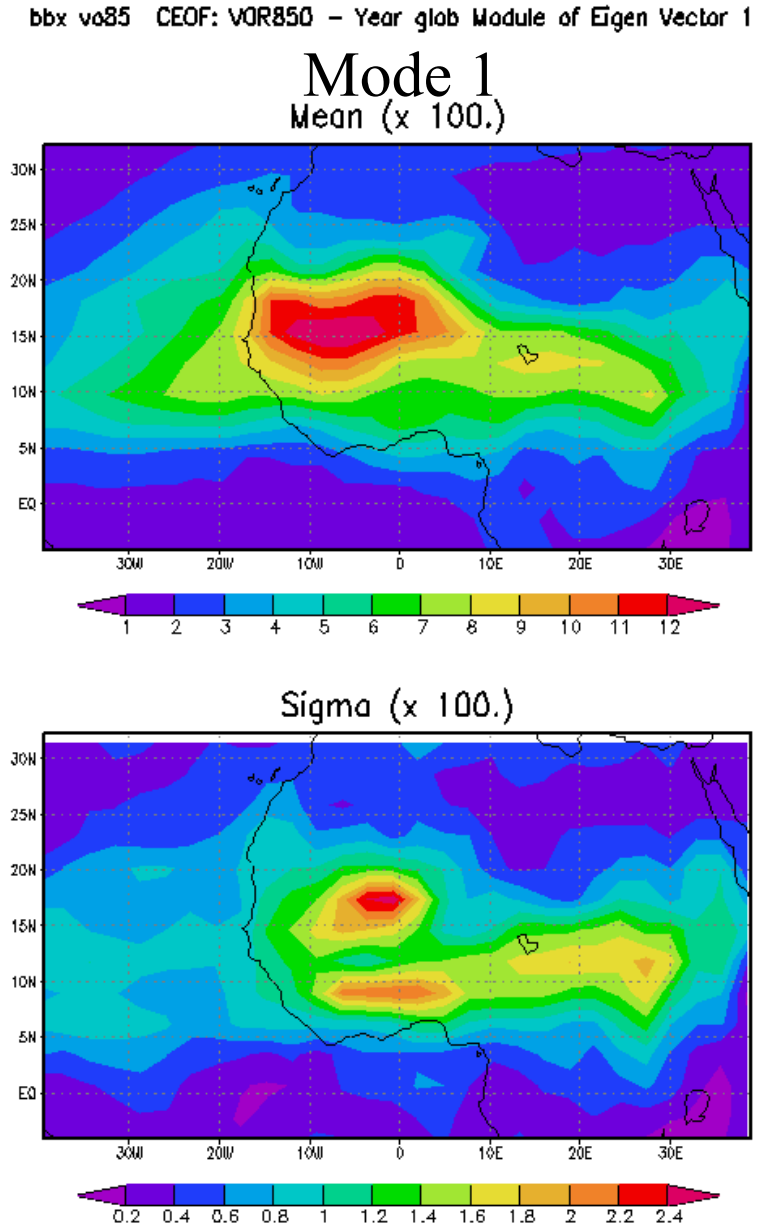
Mean (x 100.)

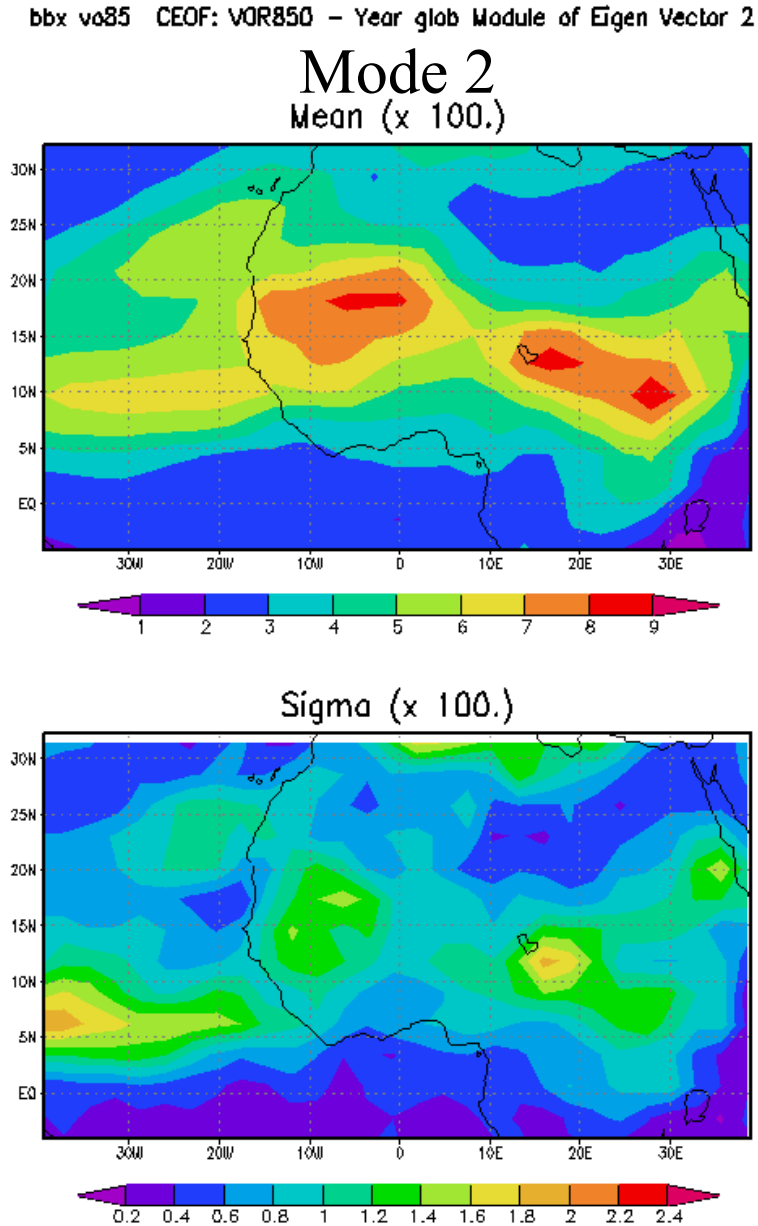


Sigma (x 100.)



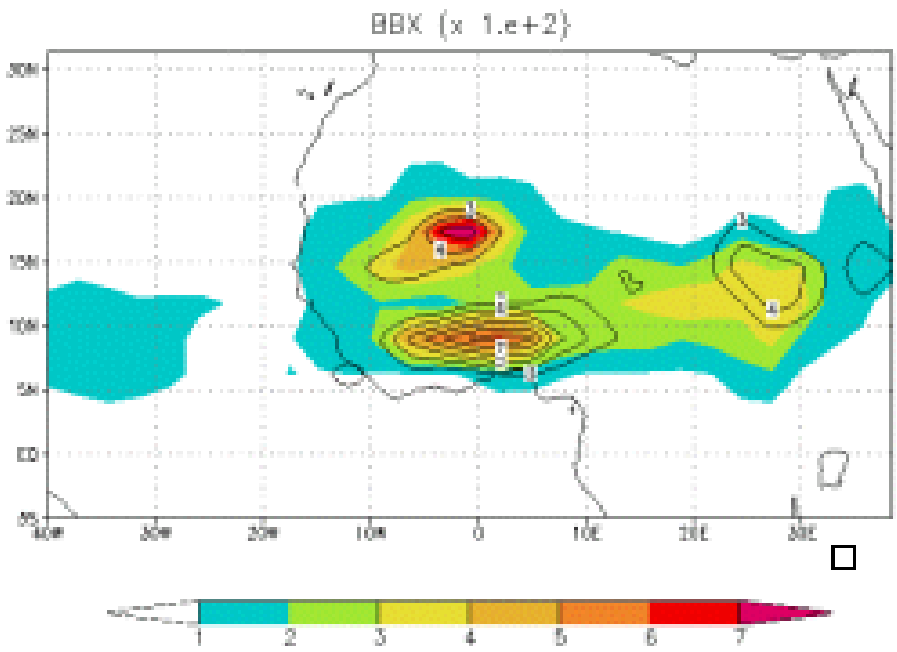
15-year mean and sigma of mode amplitude in the GCM



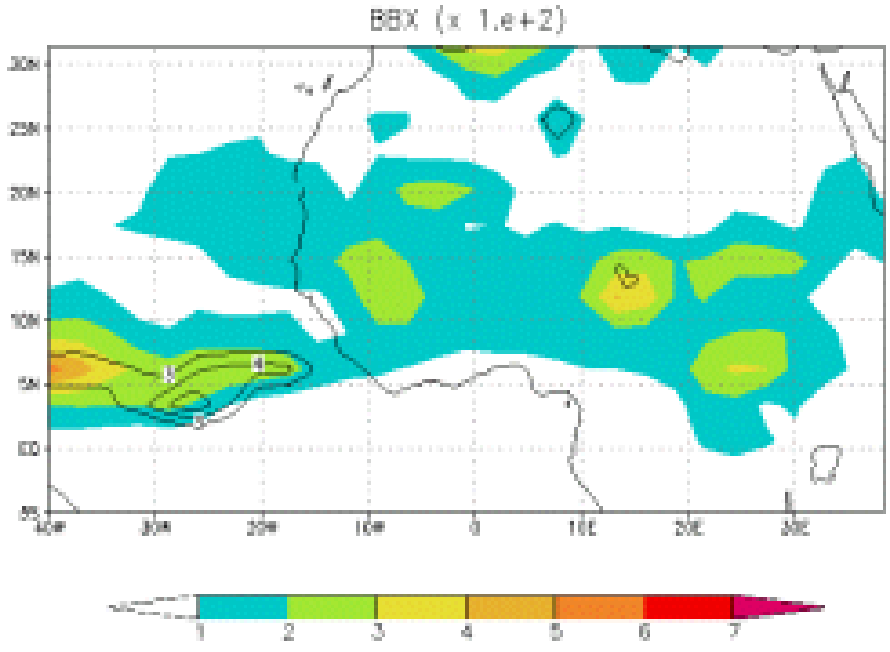


Sum of squares of annual MMPs and F factor (Significance > 95 %)

MMP 1



MMP 2

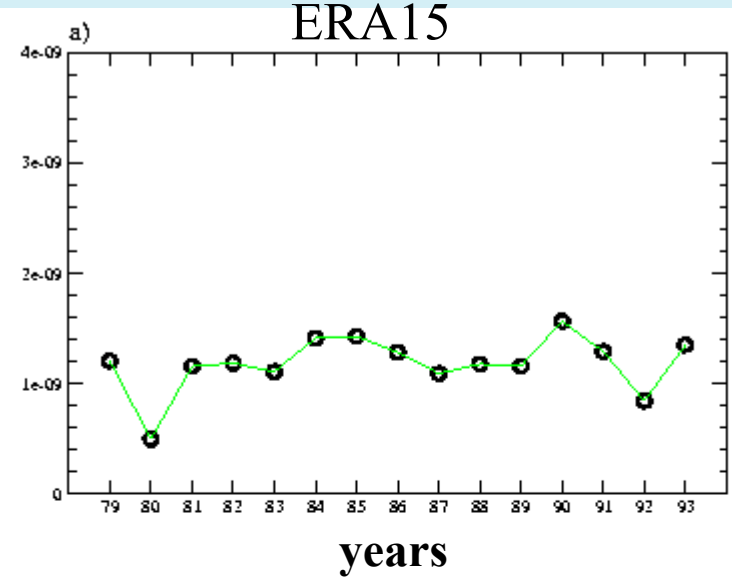


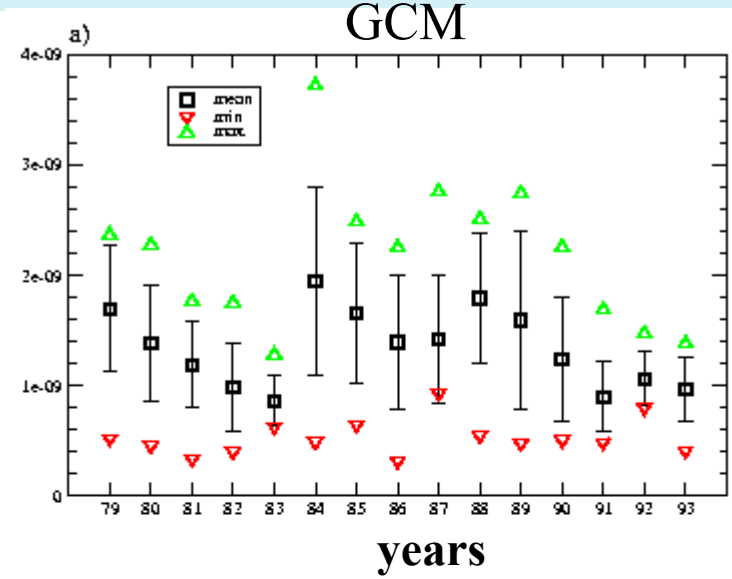
Interannual variability of total variance of the first two mean modes amplitude in ERA15 and in the GCM

ERA15

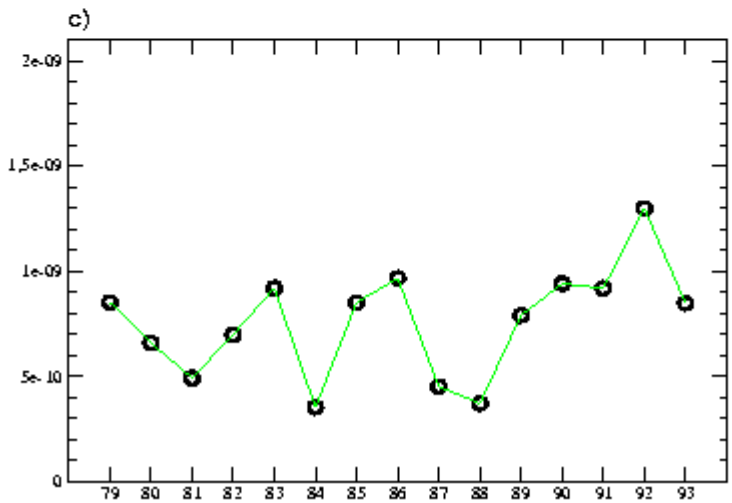
GCM

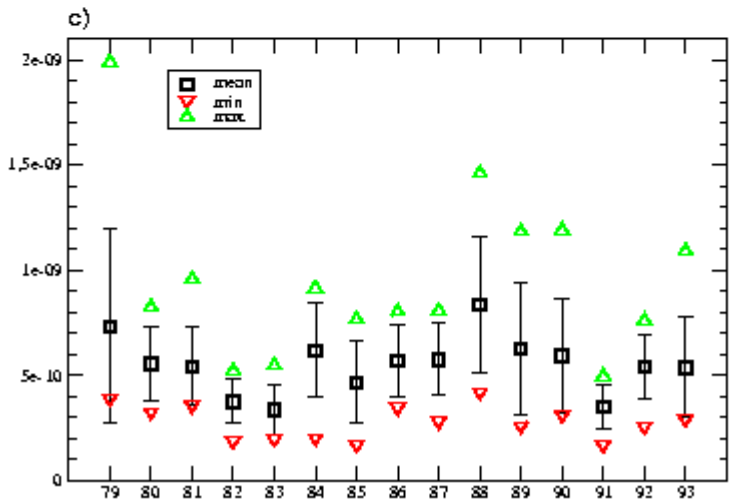
MMP 1





MMP 2





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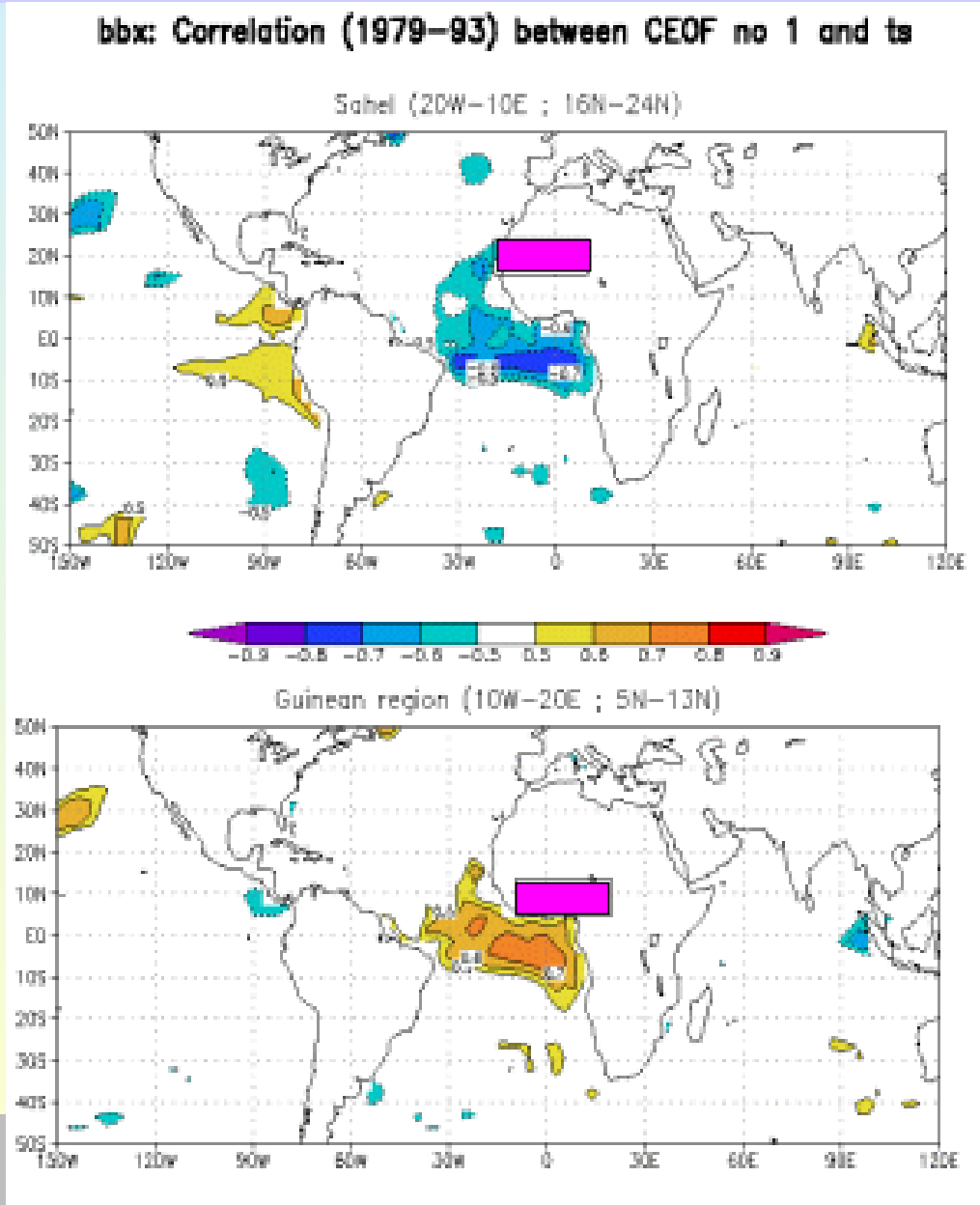
Correlation between MMP1 anomalies over Sahel and Guinea and SST anomalies



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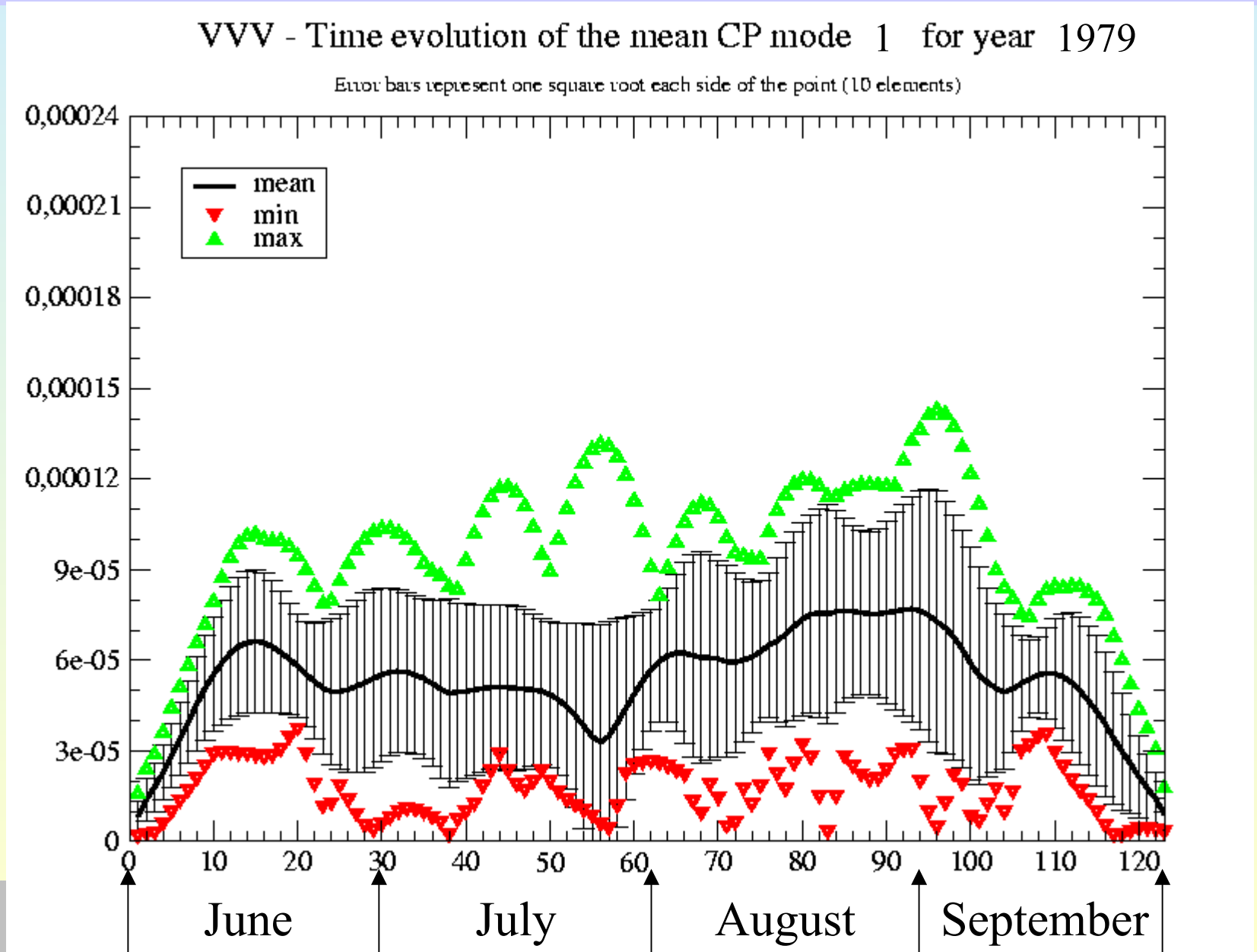
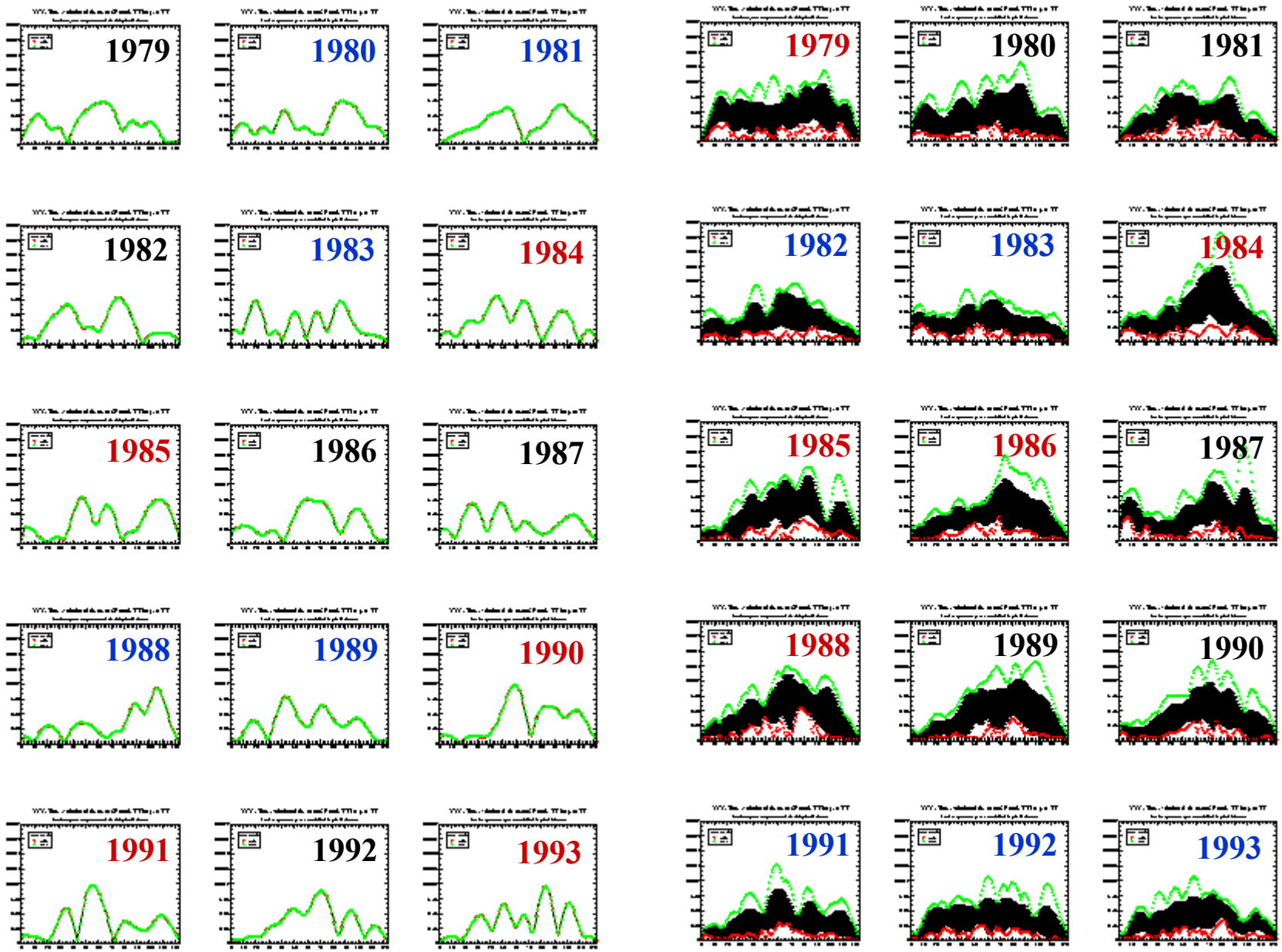
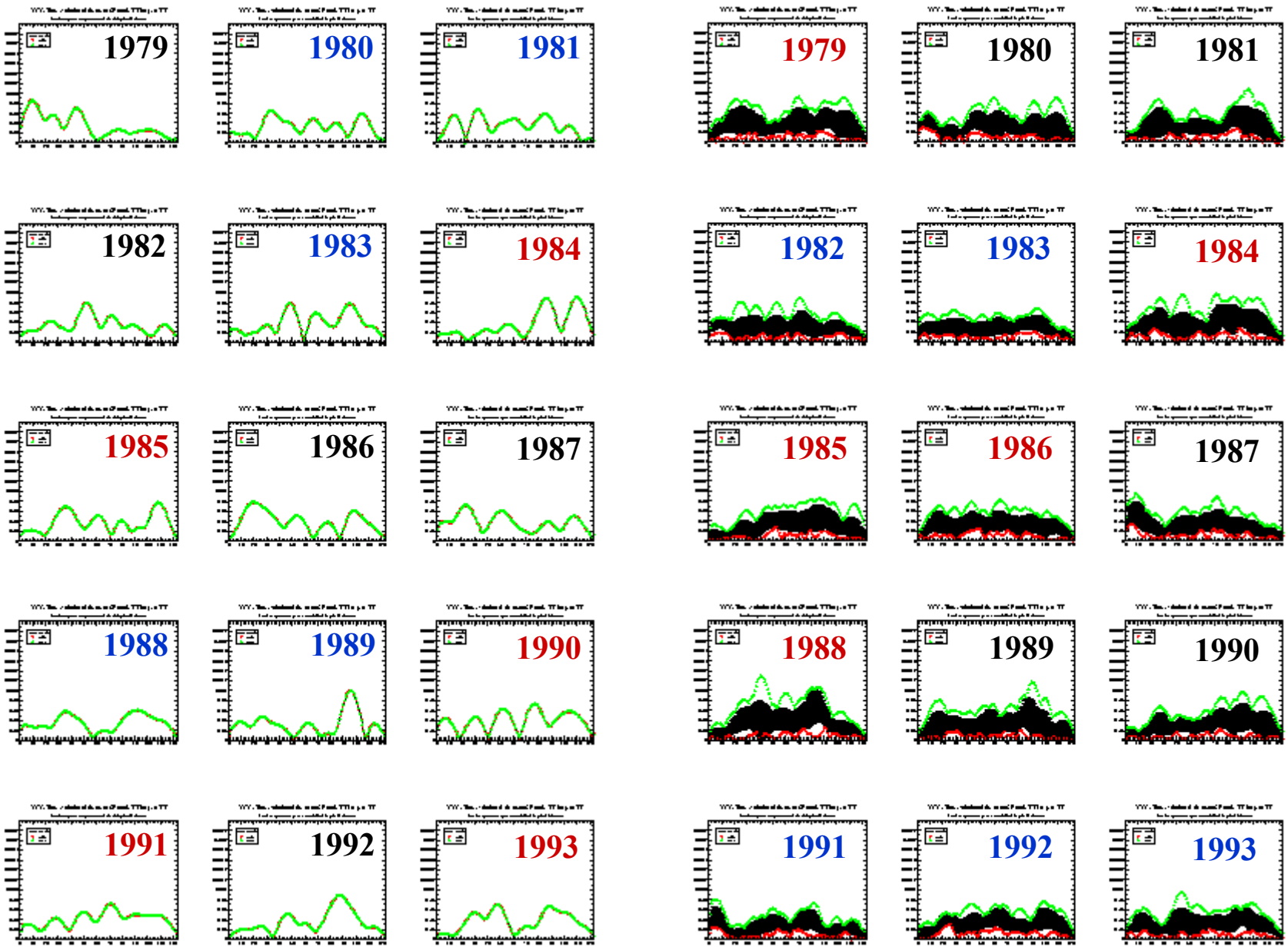
intraseasonal evolution of CEOF-1 amplitude



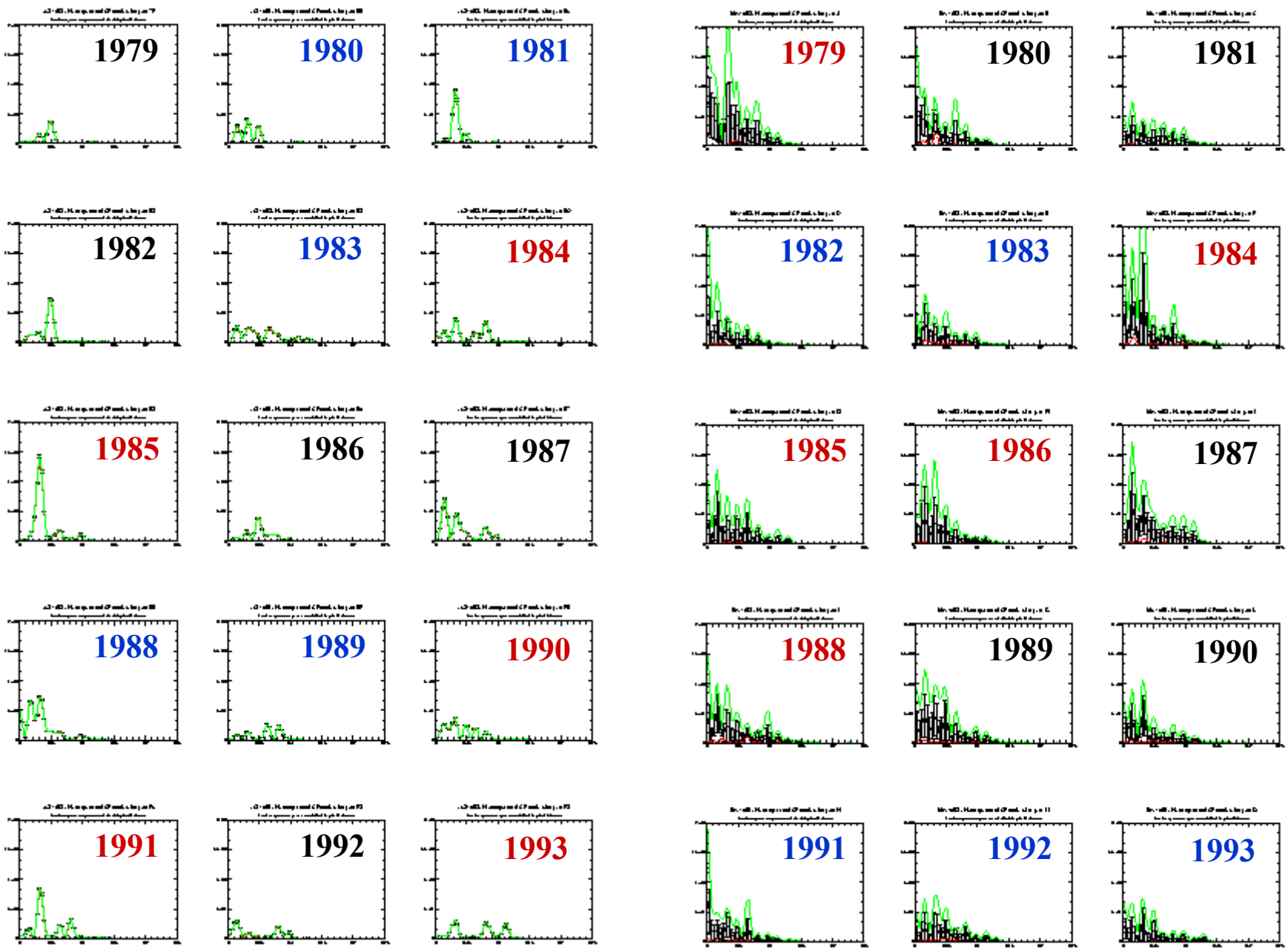
Interannual variability of the intraseasonal evolution of CEOF-1 amplitude in ERA15 and the GCM



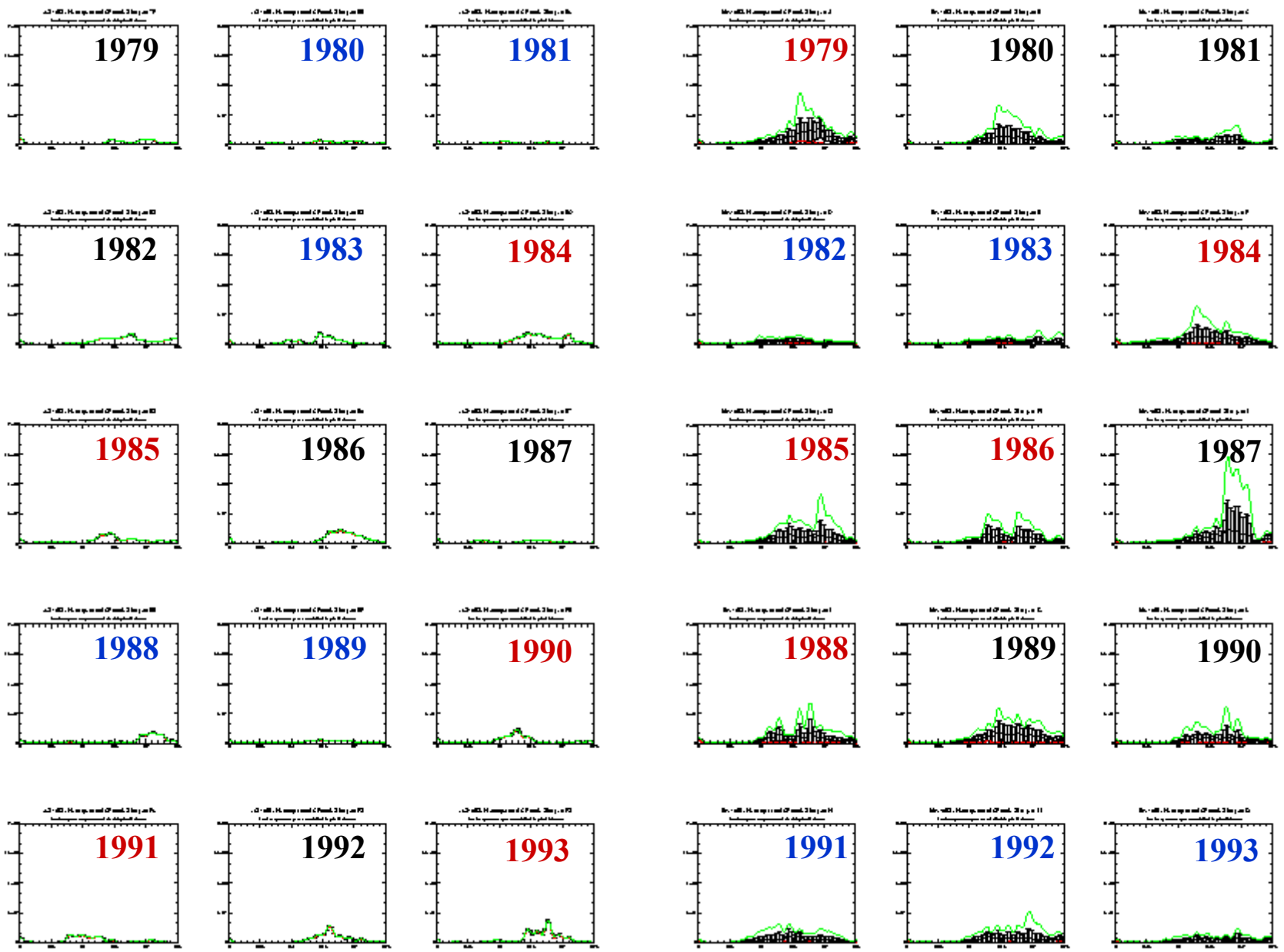
Interannual variability of the intraseasonal evolution of CEOF-2 amplitude in ERA15 and the GCM



Interannual variability of the spectra of CEOF-1 amplitude in ERA15 and the GCM



Interannual variability of the spectra of CEOF-2 amplitude in ERA15 and the GCM



Conclusions …

- Application of CEOF methods to analyse AEW has allowed to identify:
- Interannual variability of the spacial distribution of the wave activity
  - The two modes isolate significant interannual variability in different two separate areas (continent for CEOF-1, ocean for CEOF-2)
  - Correlations with SST patterns in the Atlantic
  - Warm anomalies in the Atlantic produce generally more southerly tracks of the AEW

… Conclusions

- The temporal distribution of the CEOF amplitude shows:
  - A seasonal variation with a maximum in August for CEOF-1
  - Considerable low-frequency intraseasonal modulation of the AEW variability
  - Interannual variability of the seasonal and intraseasonal evolution
- Spectral analysis of the intraseasonal variability confirms the very different spectra of CEOF-1 and CEOF-2
  - Red noise background with several peaks with periods in the range 20, 30, 60 days for CEOF-1
  - A broad maximum from 5-10 days for CEOF-2
  - Interannual variability of the spectra

Perspectives

- Developments and improvements of the analysis method
  - Rotation of the CEOFs ?
  - Different aggregation of the modes
  - Improved methods for spectral analysis
- Study of the intraseasonal variability of the modes
  - Associations between the monsoon circulation over Africa (AEJ, TEJ, ZCIT, precipitation) and CEOF variability
  - Possible links of CEOF-1 with the MJO?
  - Relationship of CEOF-2 with the 9-day mode of AEWs?
  - Impact of soil moisture on the AEW variability

Thank you !

For your attention

- Ackowledgements

  - Arpege-Climat team (M Déqué et al.)
  - JP Céron and JF Guérémy
  - PROMISE project from EU (J Slingo)
  - PNEDC project on African monsoon (S Janicot)
  - ECMWF (ERA15, workshop)