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Seasonal Variability of Relationship between Main Ionospheric Characteristics and Solar/Geomagnetic Indices via CIG

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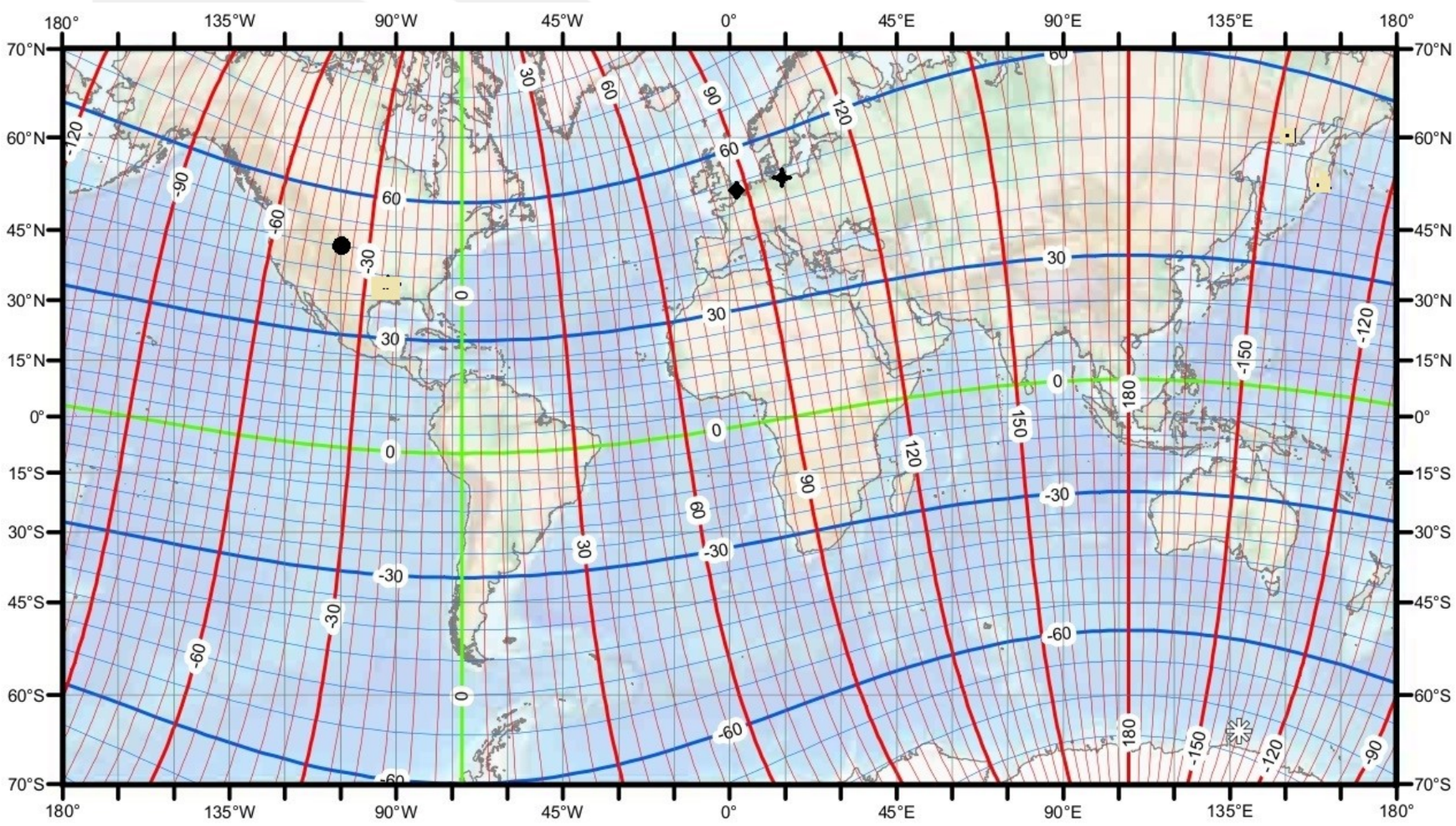
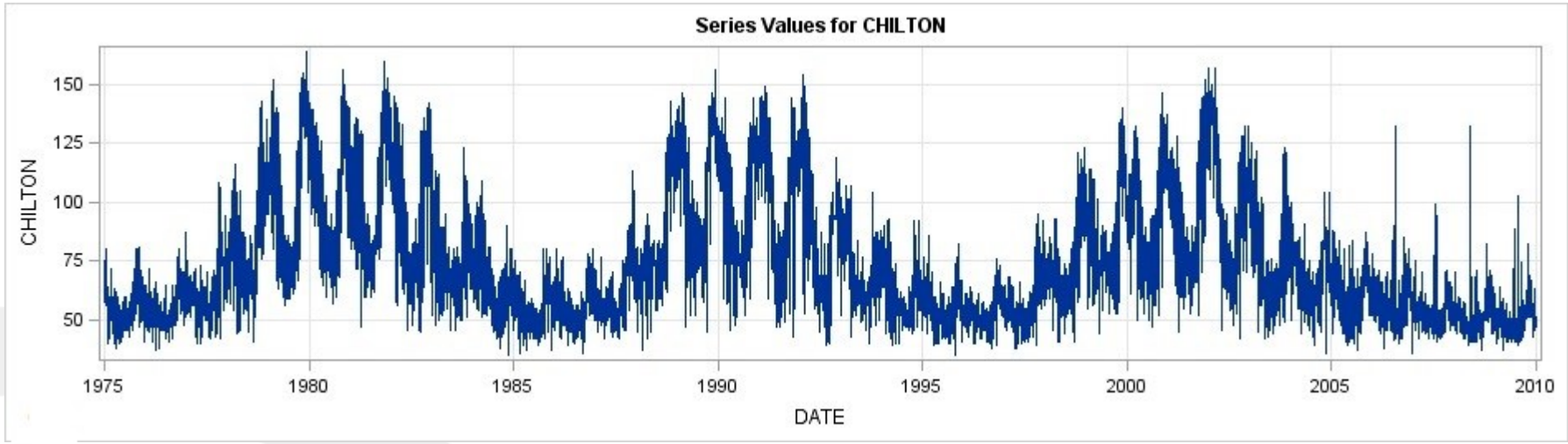
The timeseries F10.7, foF2 (5-hours noon means), Kp and R period 1975 – 2010

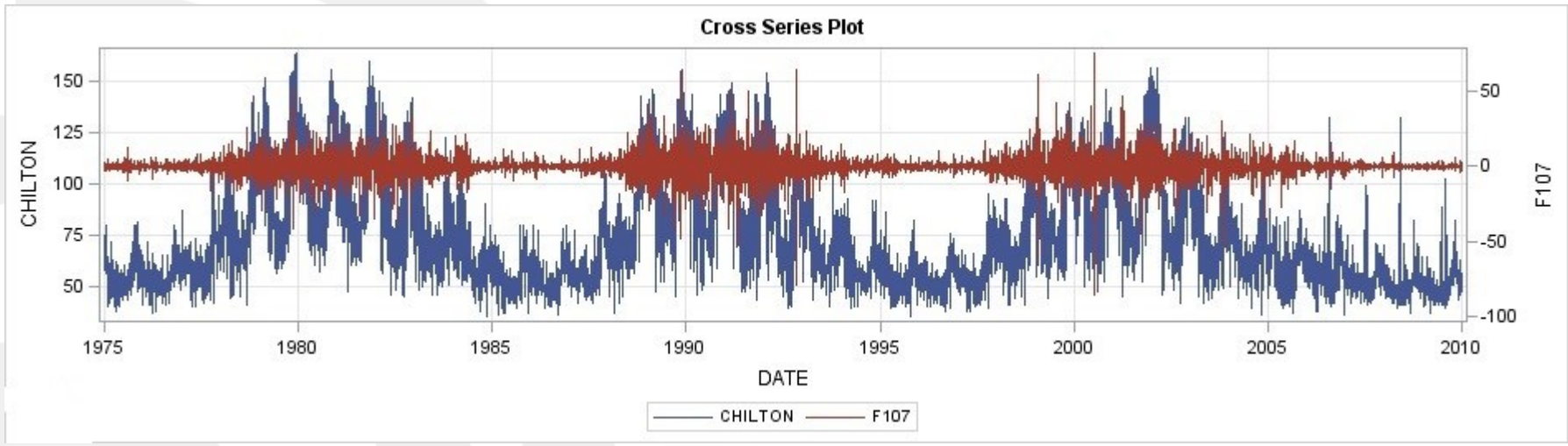
foF2 used noon daily data were measured
by mid-latitude (41.4°N – 54°N) ionosondes:
Boulder (BC840), Colorado, USA, 40.0 N, 105.3 W
Chilton, Slough (RL052/SL051), UK, 51.6 N, 1.3 W
Juliusruh/Rugen (JR055), Germany, 54.6 N, 13.4 E

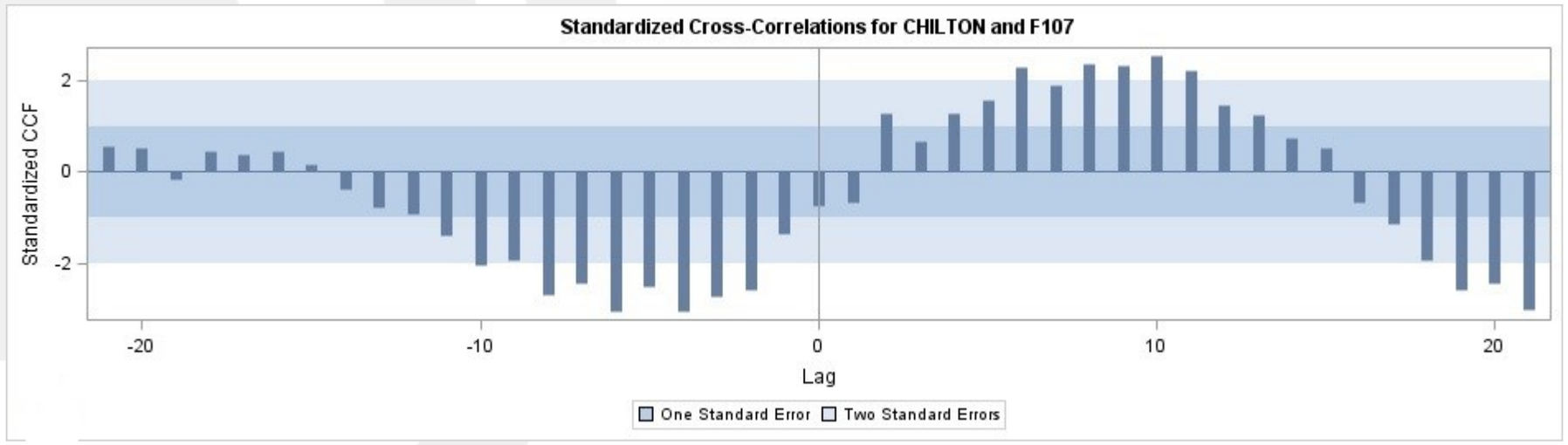


Cross-correlation analyses for F10.7 and foF2 station Chilton

recorded in 1975 – 2010 (SCs 21 – 23)

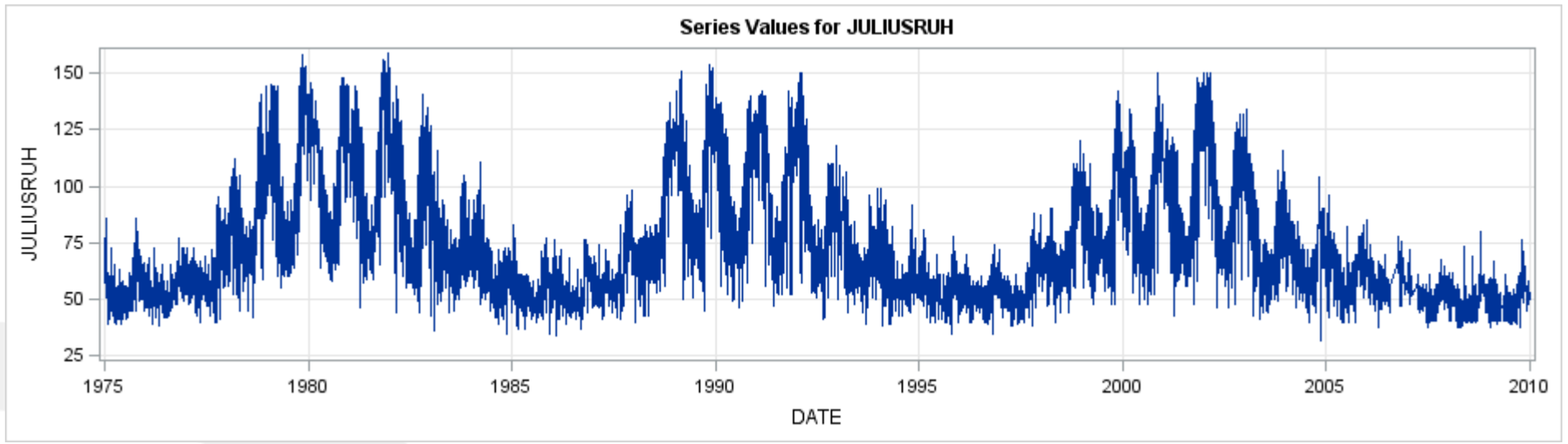


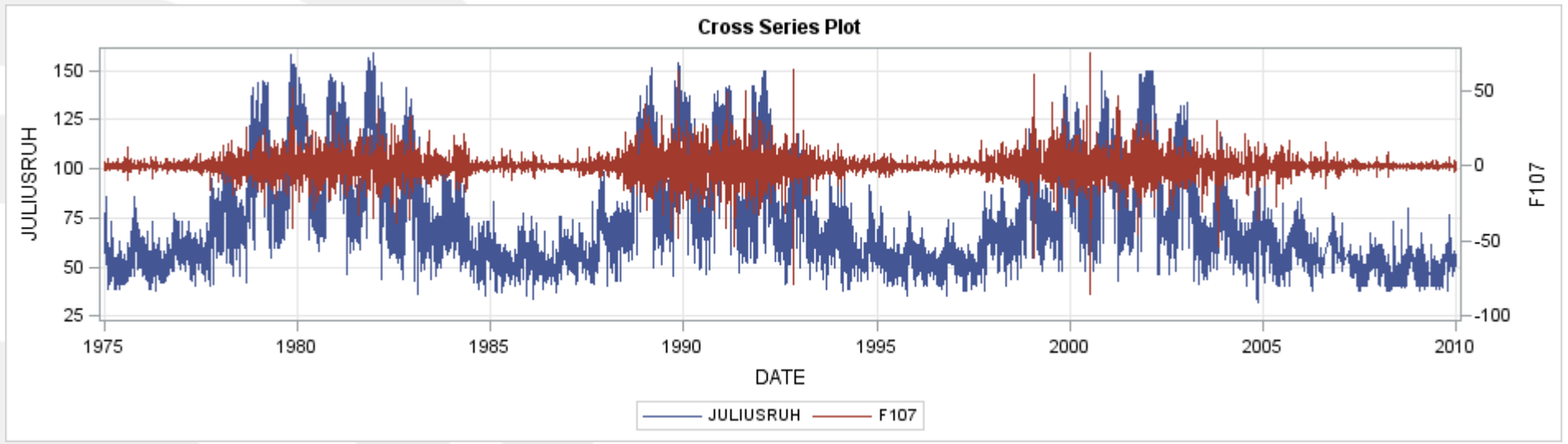


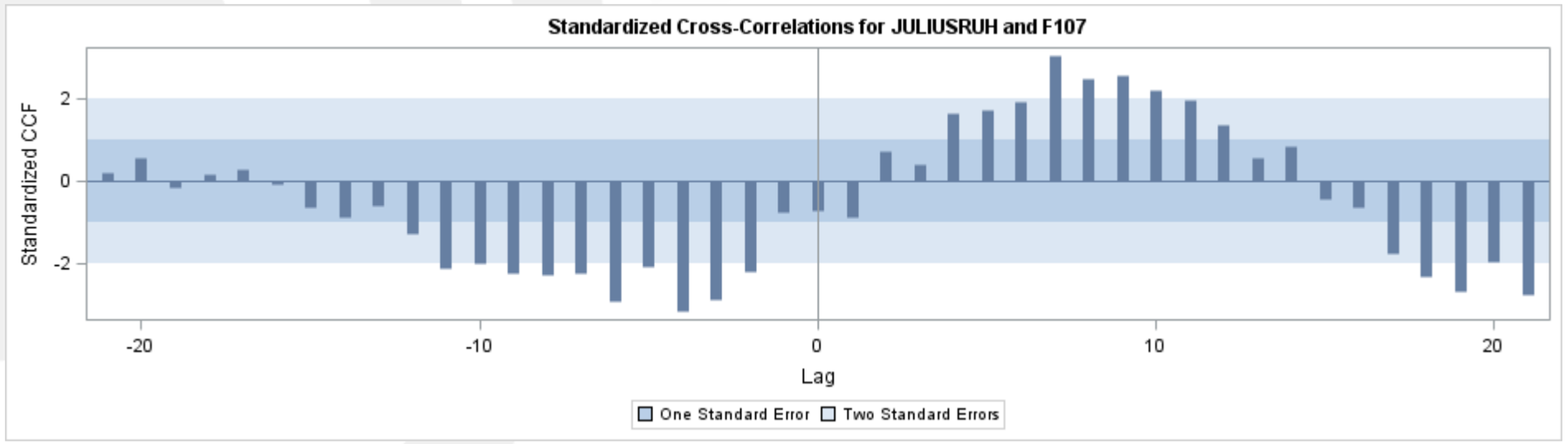


Cross-correlation analyses for F10.7 and foF2 station Juliusruh

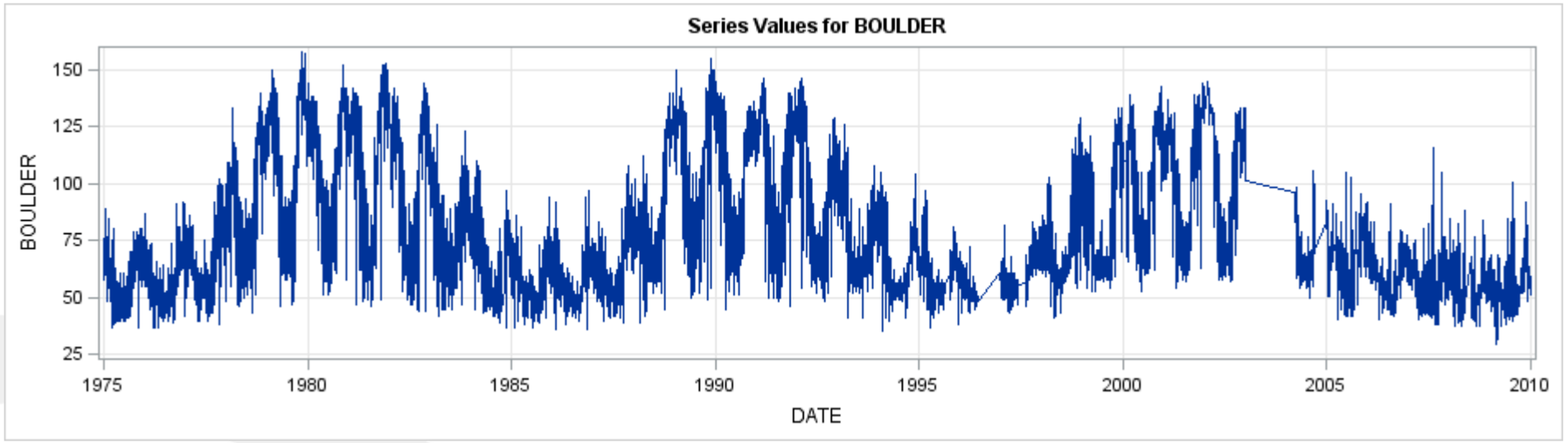
recorded in 1975 – 2010 (SCs 21 – 23)

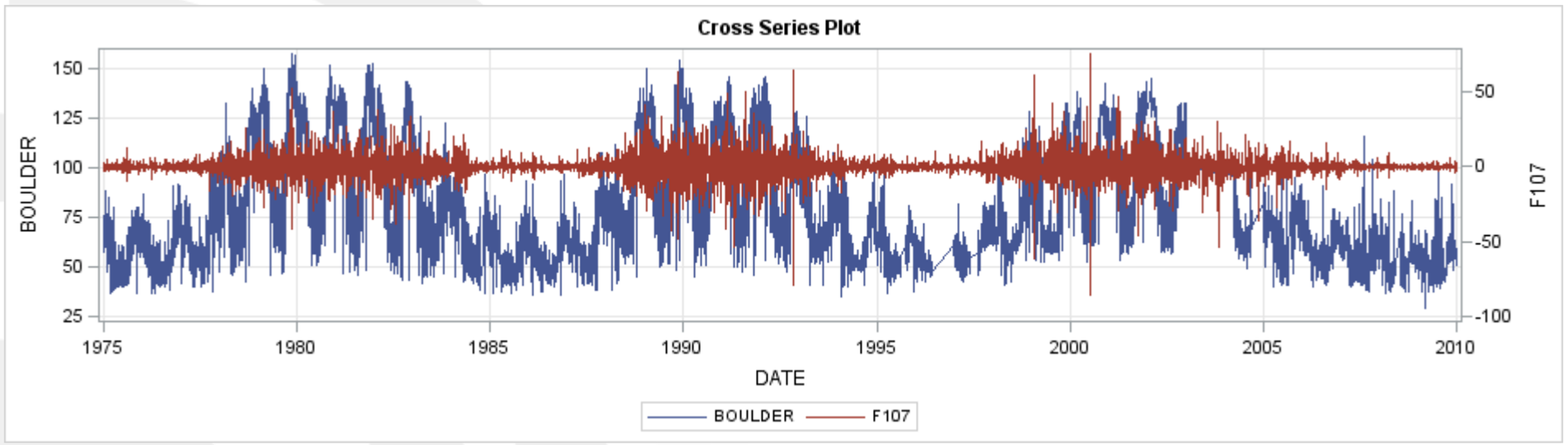


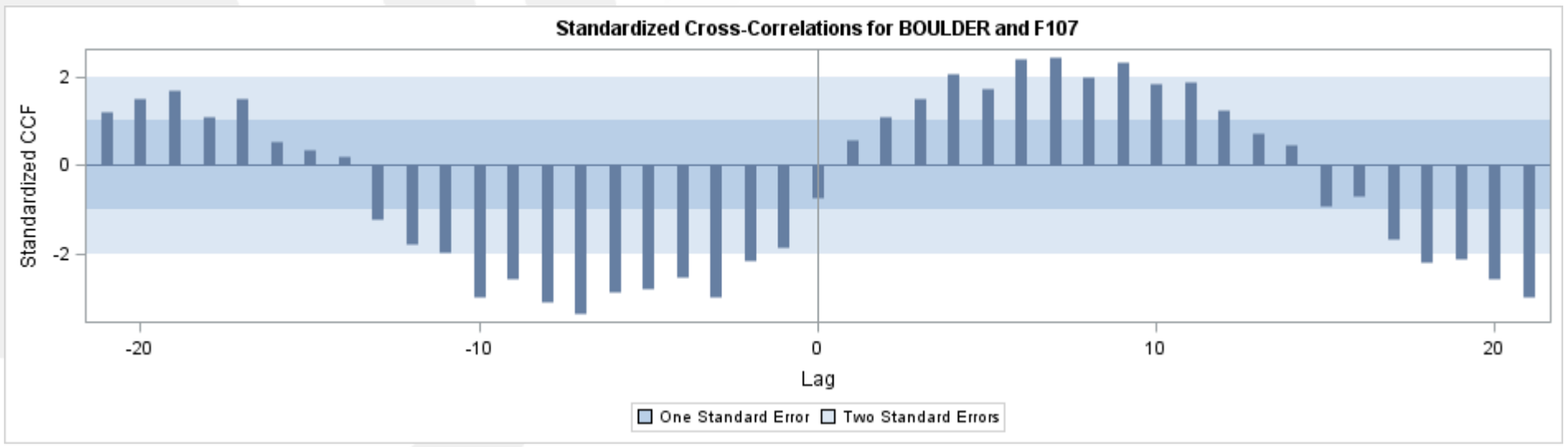




Cross-correlation analyses for F10.7 and foF2 station Boulder
recorded in 1975 – 2010 (SCs 21 – 23)

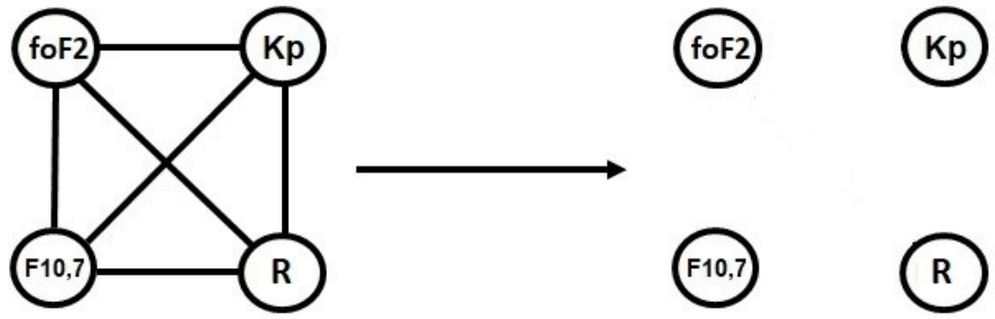






Graphical models compendium

- Graphical models are used for description and representation of structure of the dependence relationships in a given set of random vectors .
- Graph vertex V represents the variable of a random vector, edge E between two vertices represents dependence of these variables.



- Conditional independence graph of a random vector X is the undirected

graph G = (V, E), where V={1, 2, …., k}.

- Deviance dev of a graphical model G is the generalised likelihood ratio test statistic for testing G against the maximal model that the graph is entire:

$$dev\ f = 2\ [\ l(S) - l(\hat{W})\ ],$$

S maximum likelihood estimator of model with entire graph, sample variance matrix $\hat{W}$ maximum likelihood estimator of model with entire graph G, l logarithmic likelihood function.

- Diference deviances of entire and minimalized graphs is

$$dev^* = -[\ dev\ f2 - dev\ f1\ ],$$

where dev f1 (dev f2) deviance of graph with f1 (f2) excluded edges.

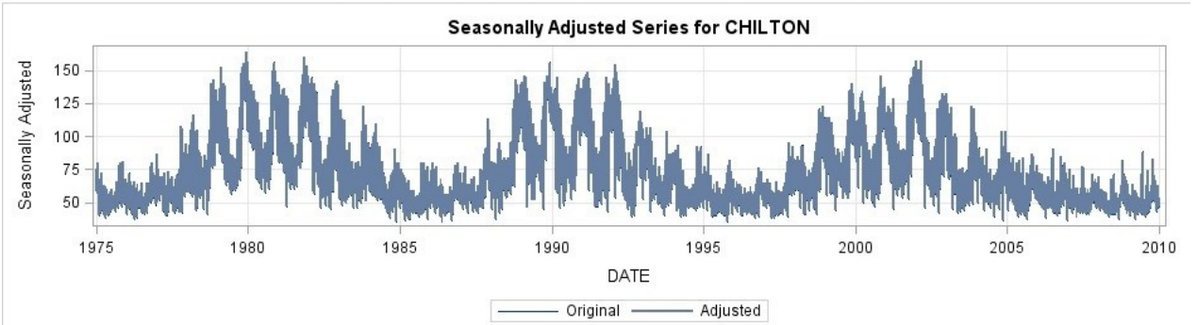
Method of graphical model computing

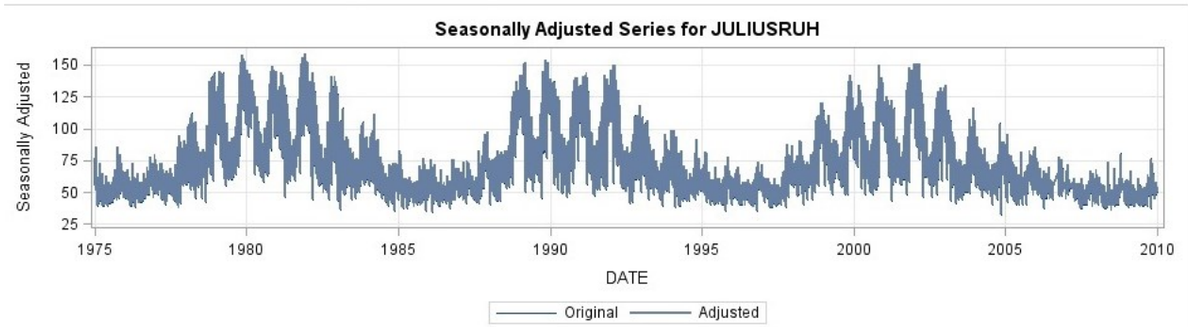
- Construction of the logarithmic likelihood function:

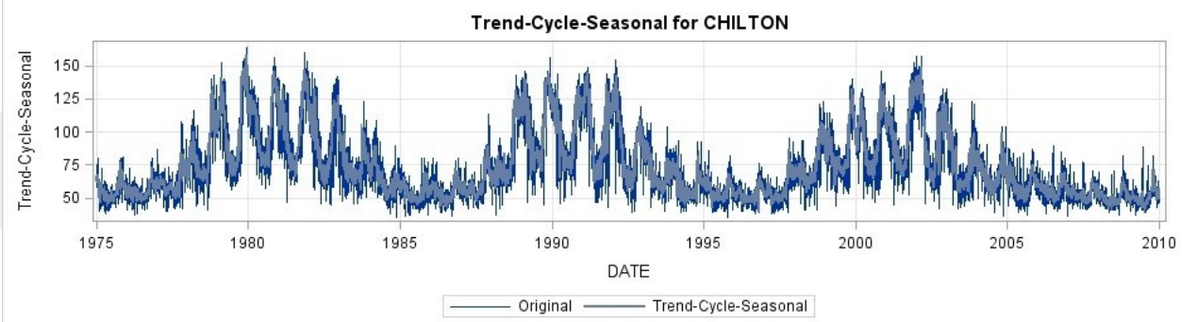
$$2 \log l(W) = \vartheta - N (W^{-1}S)^T - N \log \det W,$$

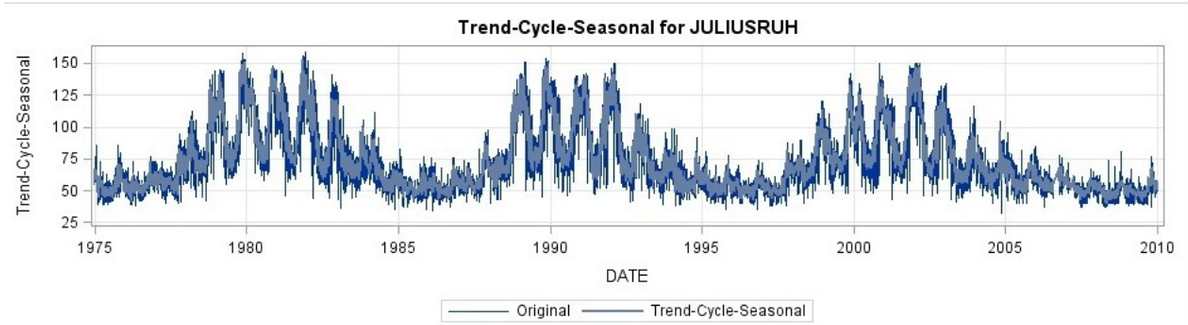
  where N random sample size, ϑ unknown parameter, S likelihood estimator.
- Setting the unknown parametres ϑ_i by maximalization of the likelihood function through unknown parametres set.
- Likelihood function requirements follow from the graphical model selection.
- Using the goodness-of Ht test to selected the graphical model with data.
- The test statistics is the deviance with χ^2
- Asymptotic probability distribution -> Decision whether the graphical model fits the data.
- The deviance of the excluded edge was computed by IPF (Iterative Proportional Fitting) algorithm.
- For selecting the particular graphical model by goodness-of Ht test we used the program Backward2 realised in Mathematica 8.0.
- Model selection: all edges with computed deviance < 3.84 were excluded
- Significance level: 0.05

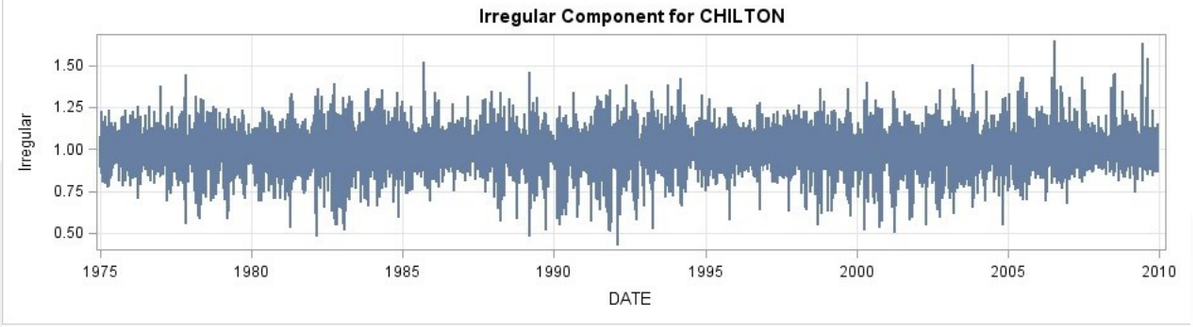
Seasonal decomposition of critical frequency foF2 time series for Chilton, Juliusruh, and Boulder 1975 – 2010

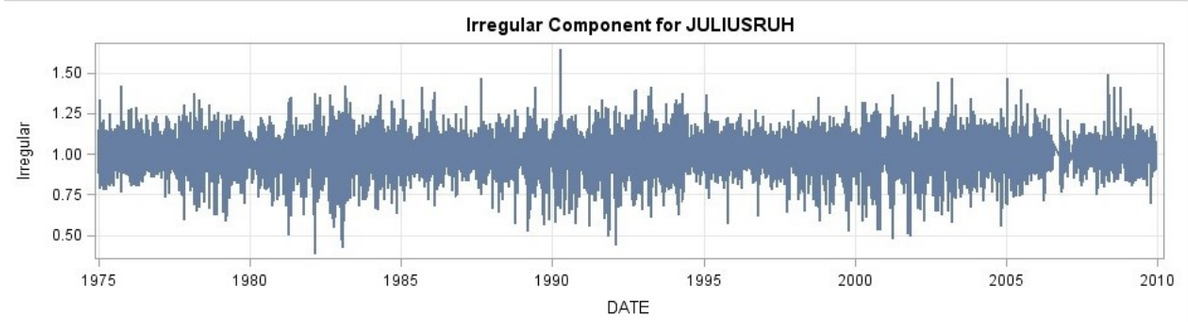


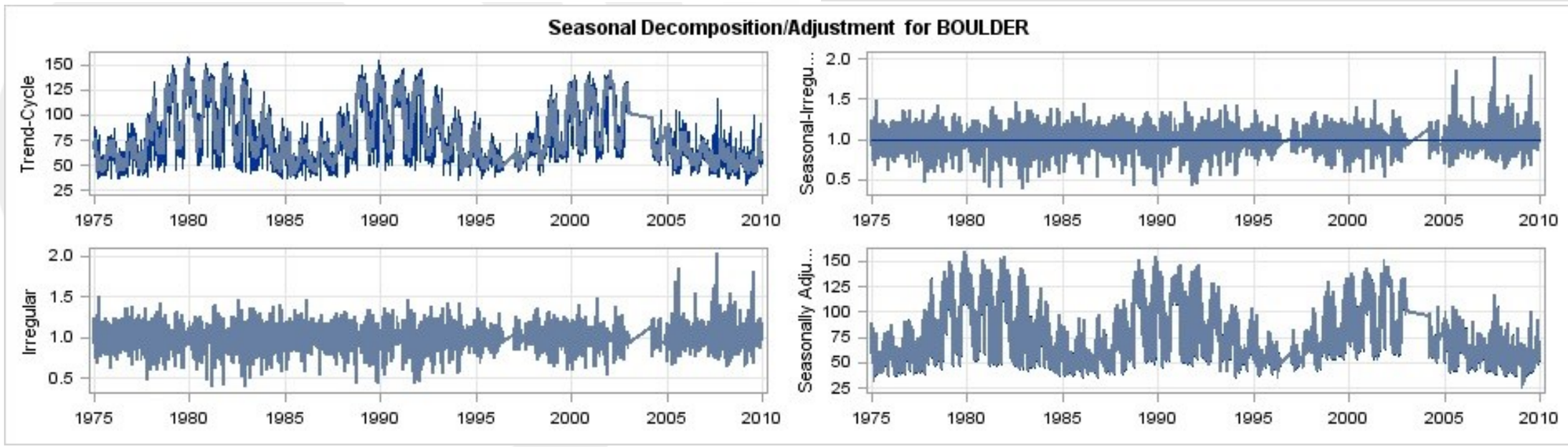










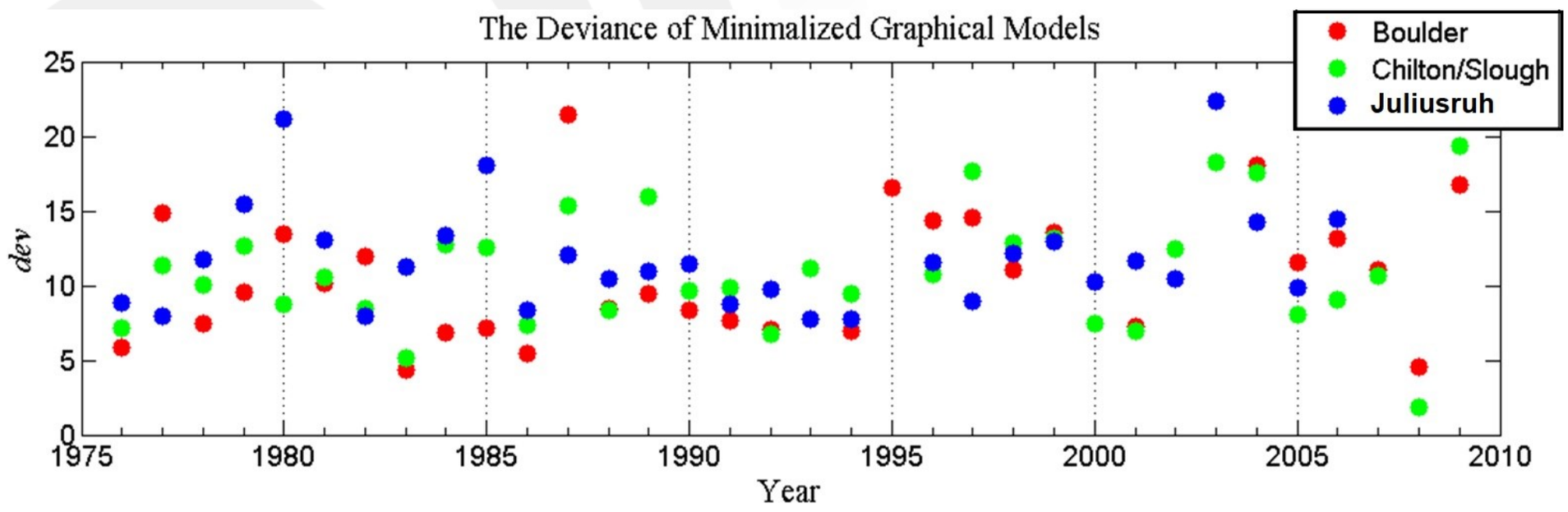


The results of analysis by CIG - seasonality

Boulder Parameter Estimates foF2							
Variable	**Standard Error**	**Stochastic model test statistic**	**Deviace sum winter**	**Deviace sum summer**	**Standardized Estimate**	**95% Confidence Limits**	
F10.7	0,13	2,24	54,05	11,79	0,57	0,54	0,04
KP	0,32	4,69	50,35	51,84	0,07	0,86	2,10
R	0,02	10,40	25,53	25,53	0,46	0,28	0,19

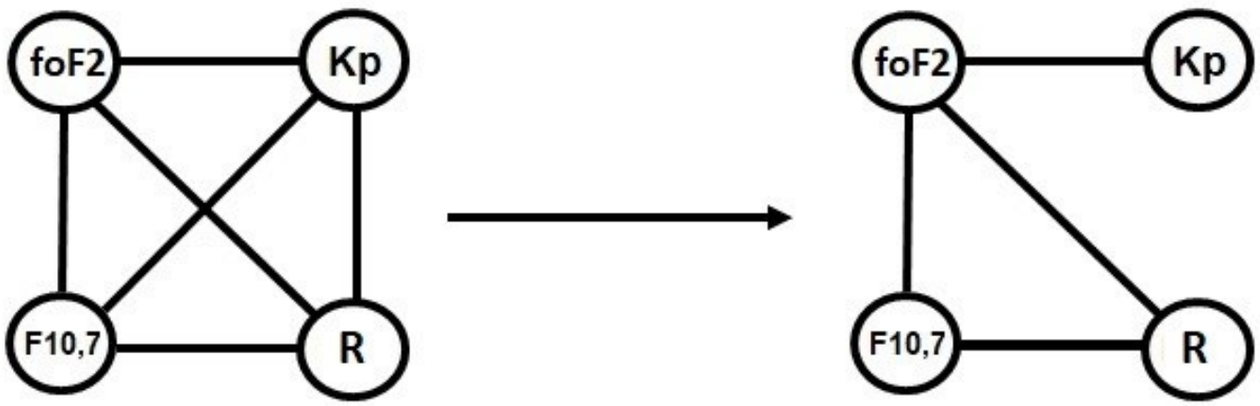
Chilton/Slough Parameter Estimates foF2							
Variable	**Standard Error**	**Stochastic model test statistic**	**Deviace sum winter**	**Deviace sum summer**	**Standardized Estimate**	**95% Confidence Limits**	
F10.7	0,11	3,24	61,30	20,47	0,72	0,56	0,14
KP	0,28	8,46	13,68	13,95	0,12	2,96	1,85
R	0,02	9,27	16,73	16,73	0,38	0,22	0,14

Juliusruh Parameter Estimates foF2							
Variable	**Standard Error**	**Stochastic model test statistic**	**Deviace sum winter**	**Deviace sum summer**	**Standardized Estimate**	**95% Confidence Limits**	
F10.7	0,13	2,91	39,55	26,28	0,77	0,65	0,13
KP	0,37	5,90	10,25	10,78	0,10	2,93	1,47
R	0,02	9,80	29,74	29,74	0,47	0,28	0,19



The results of analysis by CIG

Station	Deviance of minimalized graphical model	F10.7	R	Kp	Edge number	test p-value
Boulder (BC840)	7.56	✓	✓	✓	4	0.037
Chilton, Slough (RL052)	9.14	✓	✓	✓	4	0.033
Juliusruh (JR055)	7.38	✓	✓	✓	4	0.039



- Significant seasonal variations are visible for conditional dependence of foF2.
- There are changes in the variance of deviances between Solar cycles.
- Unconditionally independent components or subvectors of geophysical index vectors appear in none of the resulting graphical models.

Thank you for your reading

Whittaker J.: Graphical models in applied multivariate statistics, Wiley, New York, 1990.
Jordan M.I. : Graphical models. Statistical, Science 19; 140–155, 2004.
Buhl S.: On the existence of maximum likelihood estimators for graphical Gaussian models, Scand. J.Statist. 20, 263–270, 1993.