Tragaldabas-3: Modes of the variability of the new Tragaldabas data set: atmospheric, cosmic rays and geomagnetic effects

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Main results:

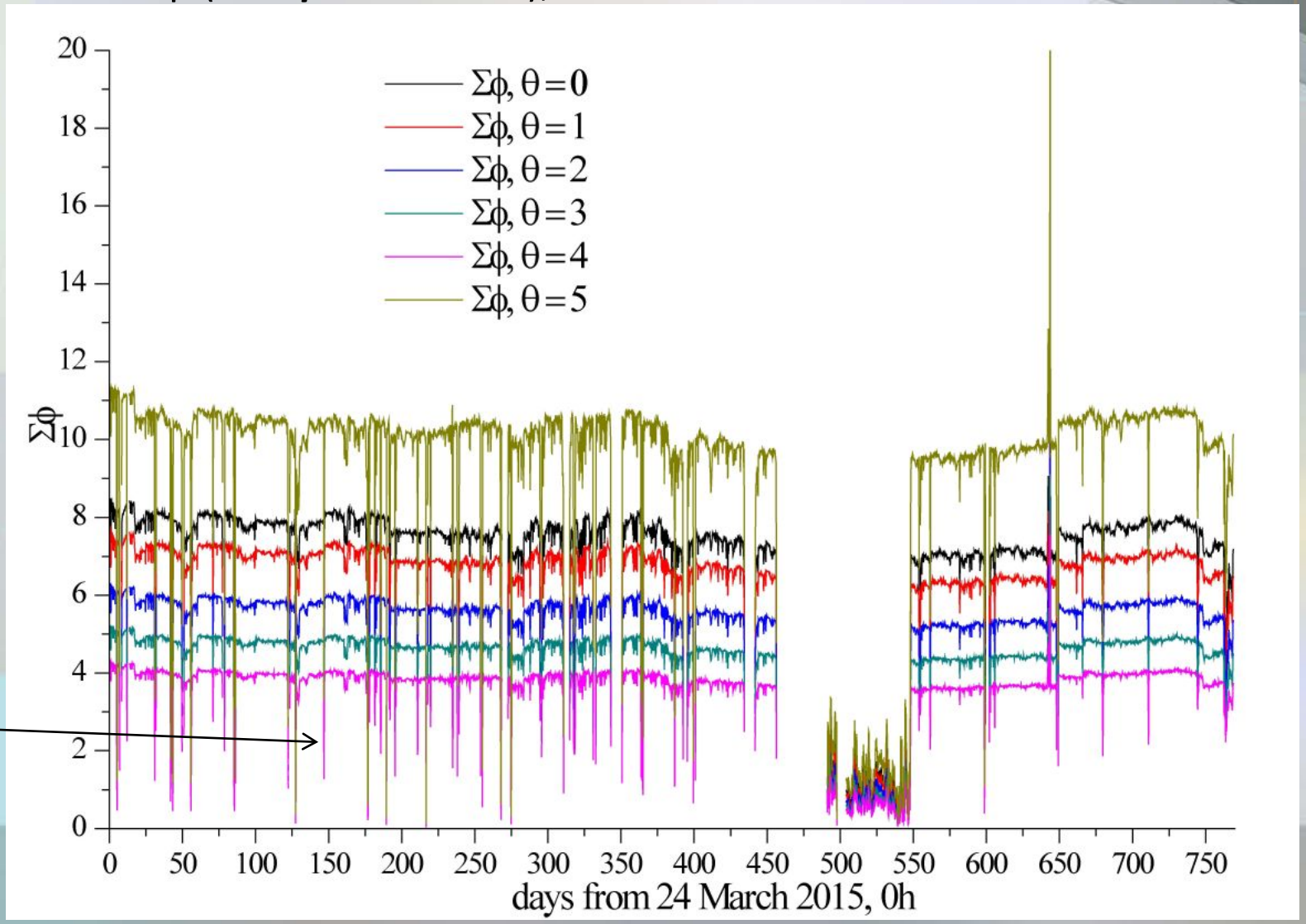
- The new 6h binned Tragas data set (March 2015 – April 2017) is analysed for modes th co-vary with CR flux measured by a neutron monitor, geomagnetic field and meteorological parameters.
- Correlations between the Tragas data and CR & geomagnetic field are high
- On the whole, the still existing atmospheric effect do not exceed 5-6% of the total variability of the Tragas data measured for different zenith angles and averaged for all azimuthal angles

Input data sets:

- new 6h ***Tragas*** data set (March 2015 – April 2017)
- Outdoor temperature ($\boldsymbol{T_{ext}}$) and pressure ($\boldsymbol{p_{ext}}$) measured at Santiago de Compostela, same time resolution
- CaLMa Neutron monitor (***CR NM***) data from the NMDB (same time resolution)
- Horizontal component of the geomagnetic field (***COIH***) measured at the Coimbra Geomagnetic Observatory (daily means)

Tragas data pre-processing:

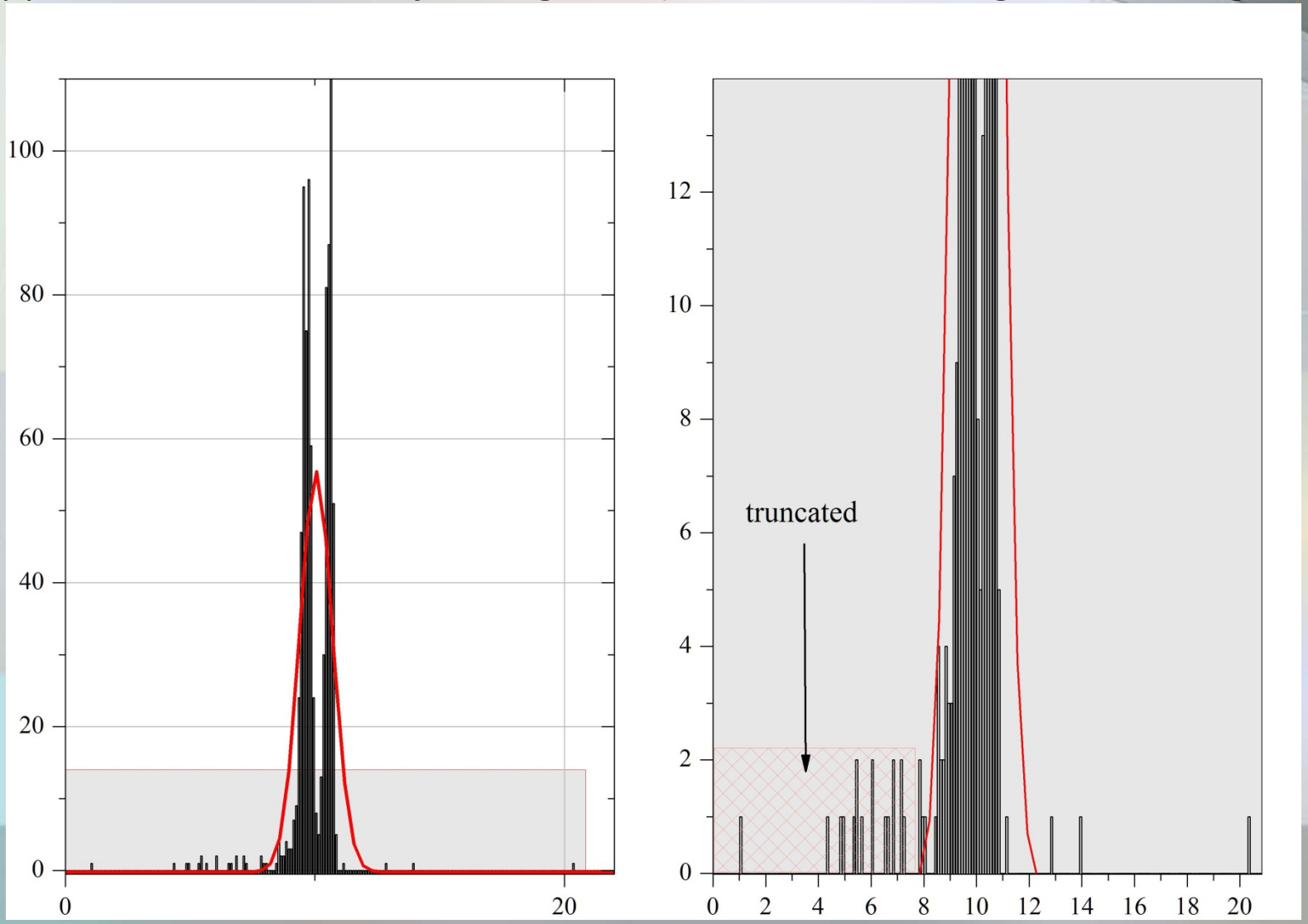
- For each of the six θ-angle bins, the data from all the eight φ channels are summed up (six $\boldsymbol{\Sigma\varphi}$ data series);



"fringe"

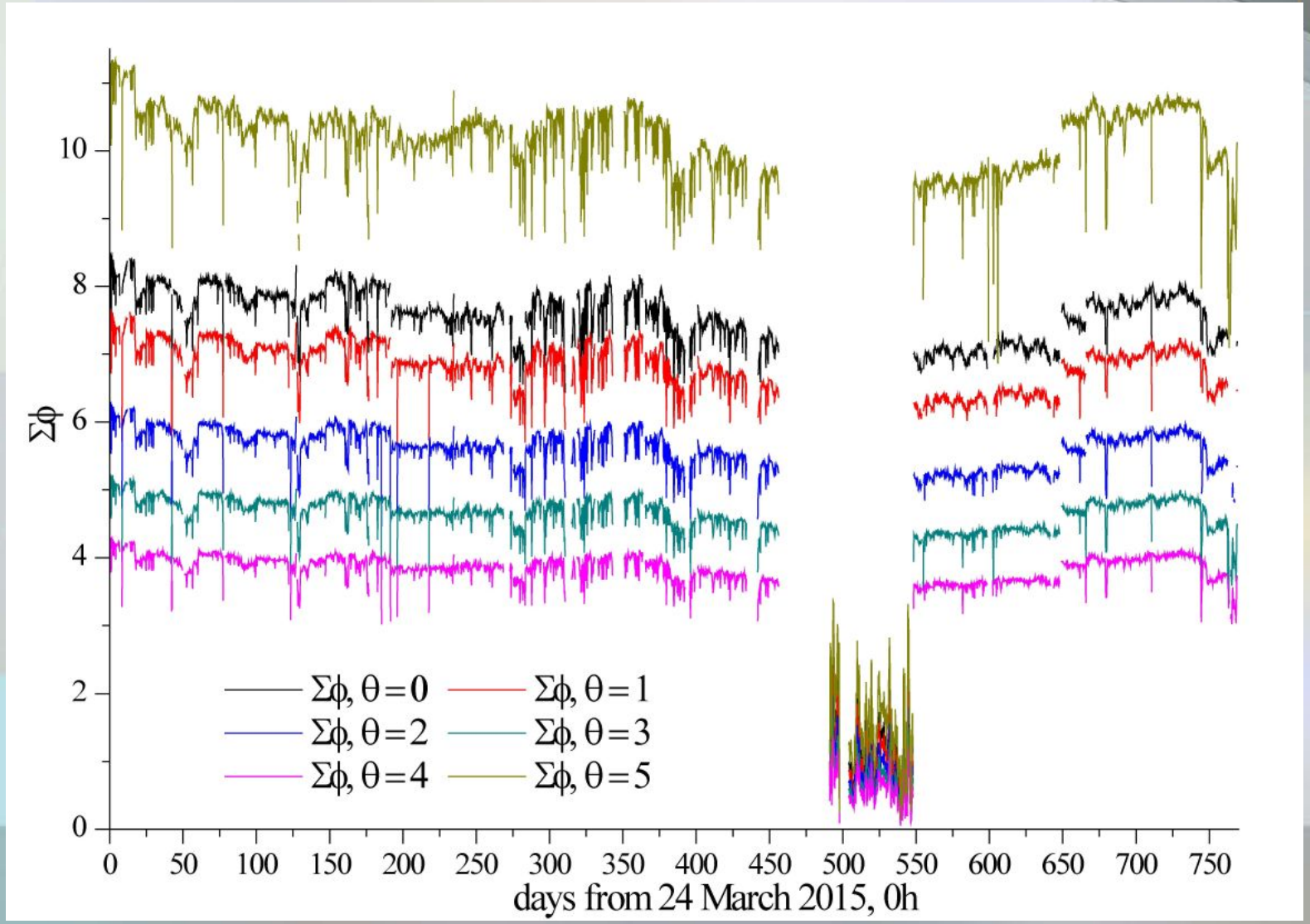
Tragas data pre-processing:

- The ***Σφ*** data are truncated to remove the “fringe” using a Gaussian approximation for the ***Σφ*** histograms (truncated left wing of the histograms);



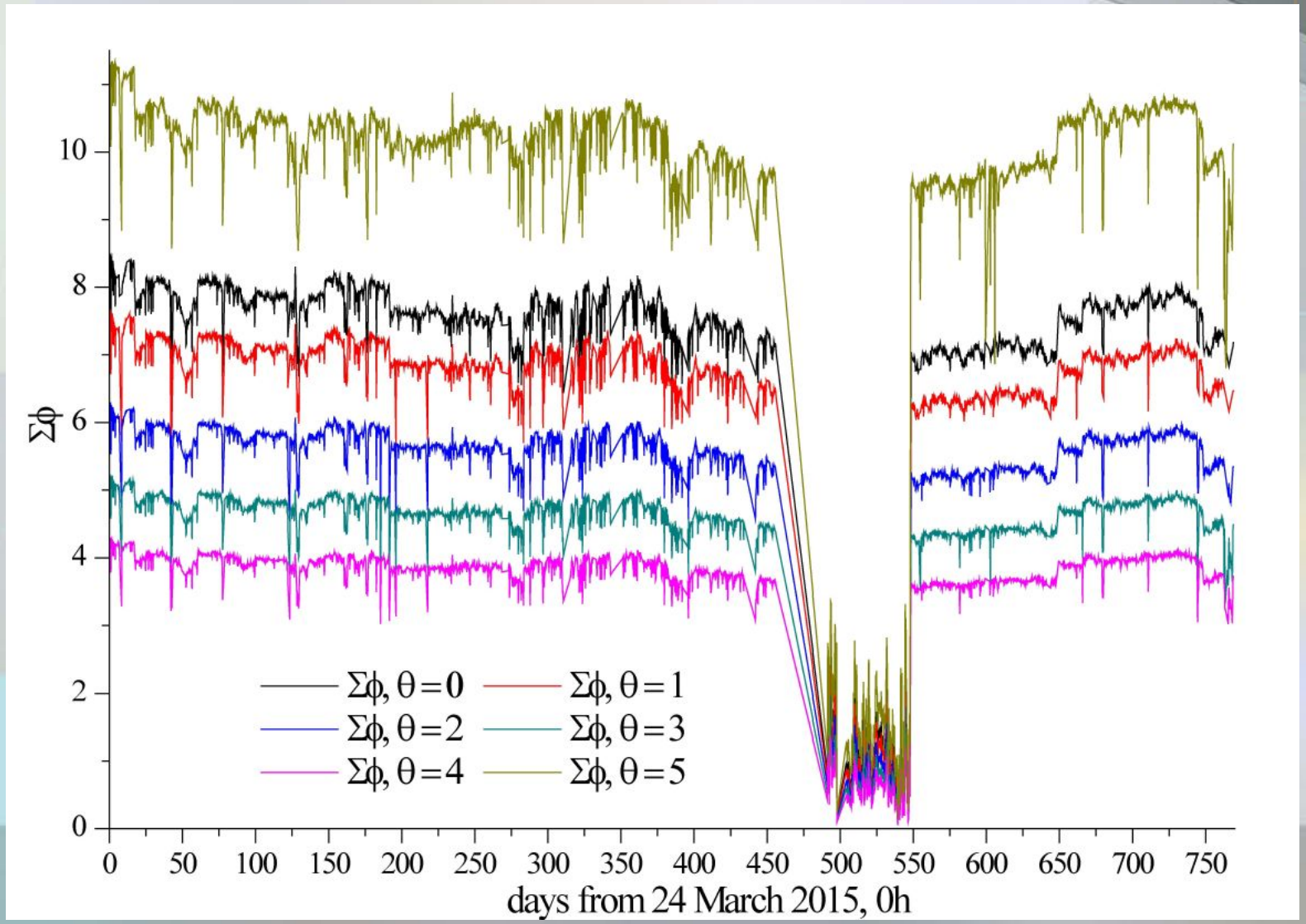
Tragas data pre-processing:

- The ***Σφ*** truncated series:



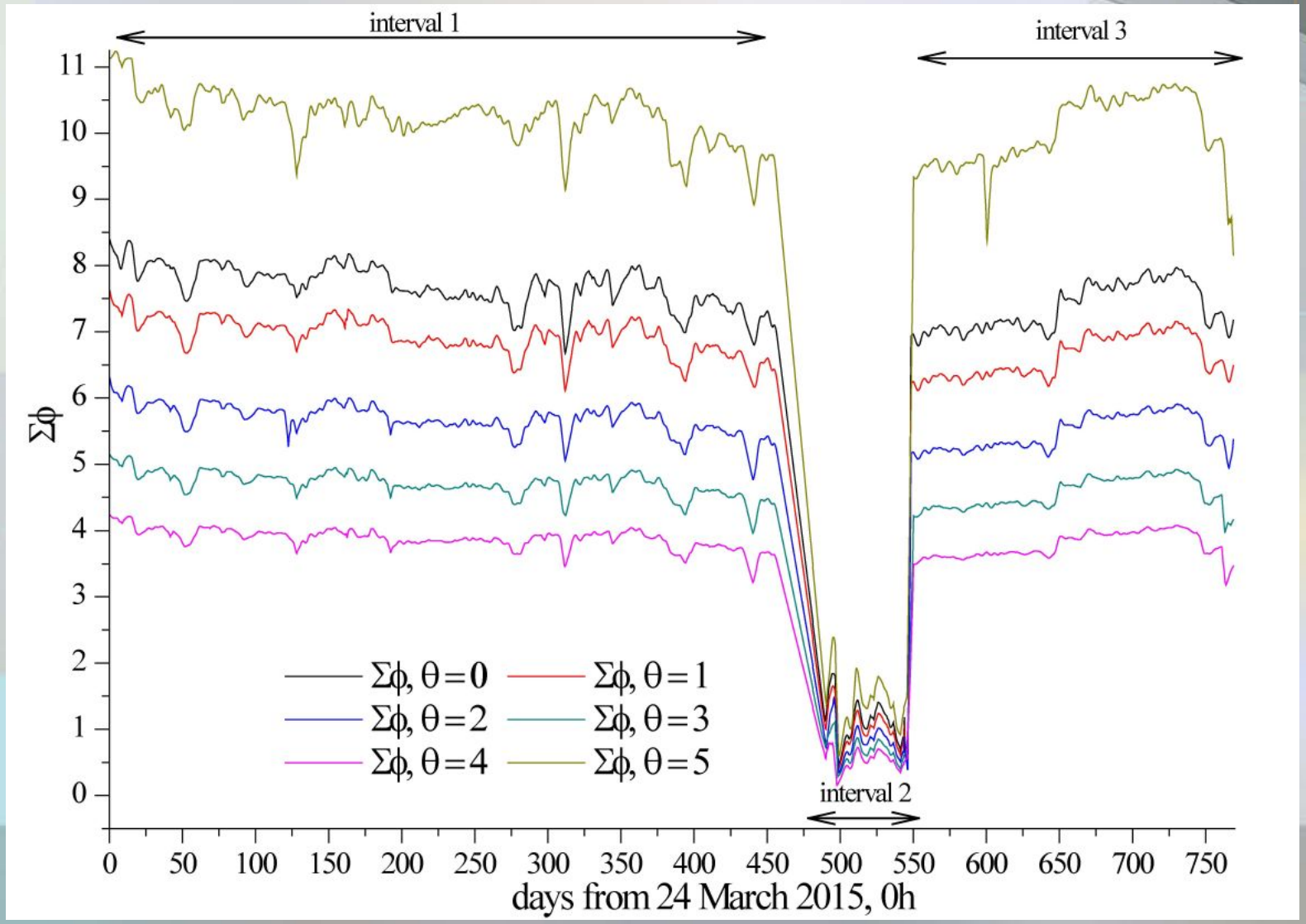
Tragas data pre-processing:

- All truncated data and all “0” are linearly interpolated;



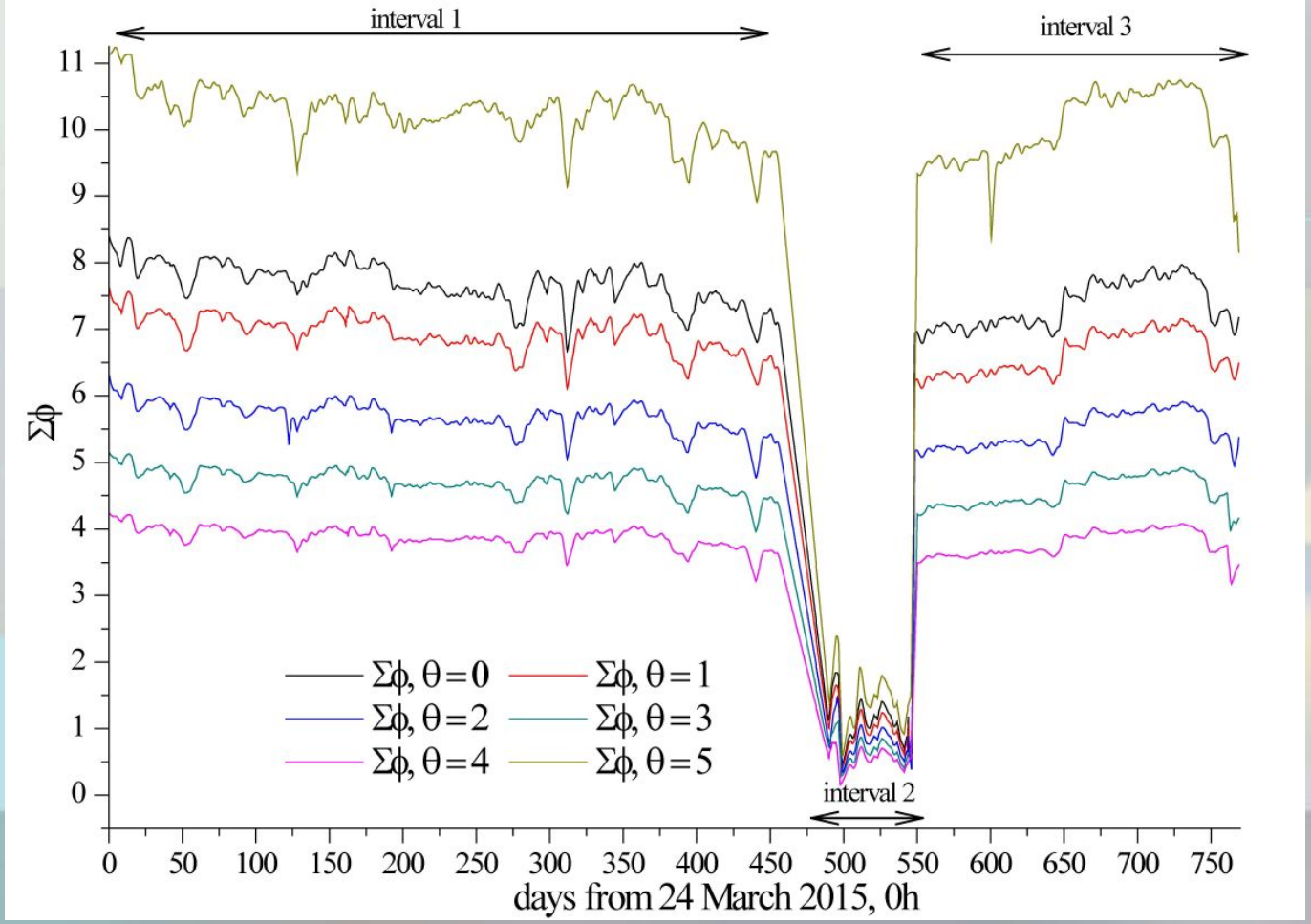
Tragas data pre-processing:

- Interpolated series are smoothed (approx. 1-day smoothing procedure);



Tragas data pre-processing:

- Three time intervals are defined:
  - 2015 March 24 (DOY83) 0h – 2016 June 22 (DOY 174) 6h
  - 2016 July 27 (DOY 209) 0h – 2016 September 21 (DOY 265) 12h
  - 2016 September 21 (DOY 265) 18h – 2017 April 30 (DOY 120) 18h)



Other data pre-processing:

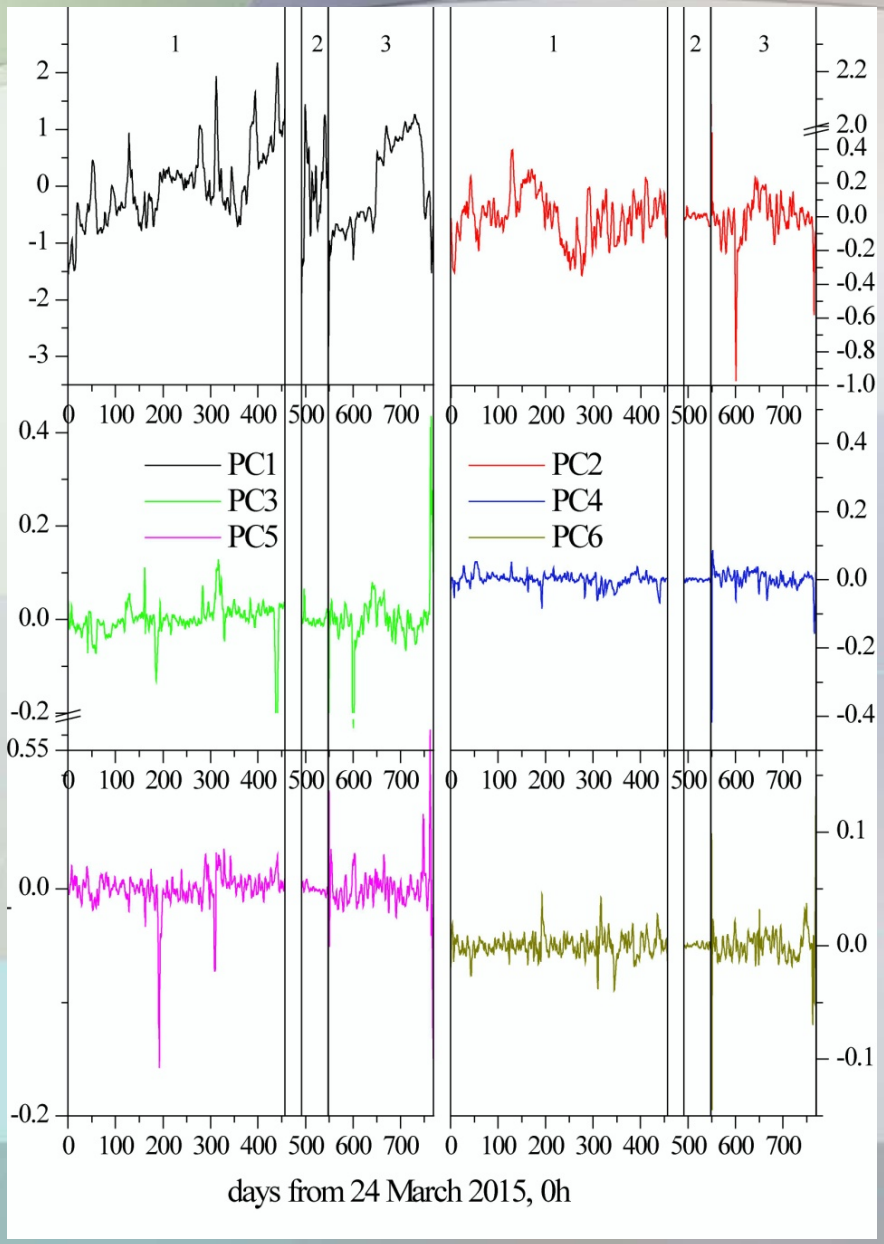
- All gaps are linearly interpolated;
- All data are smoothed same way as Tragas data

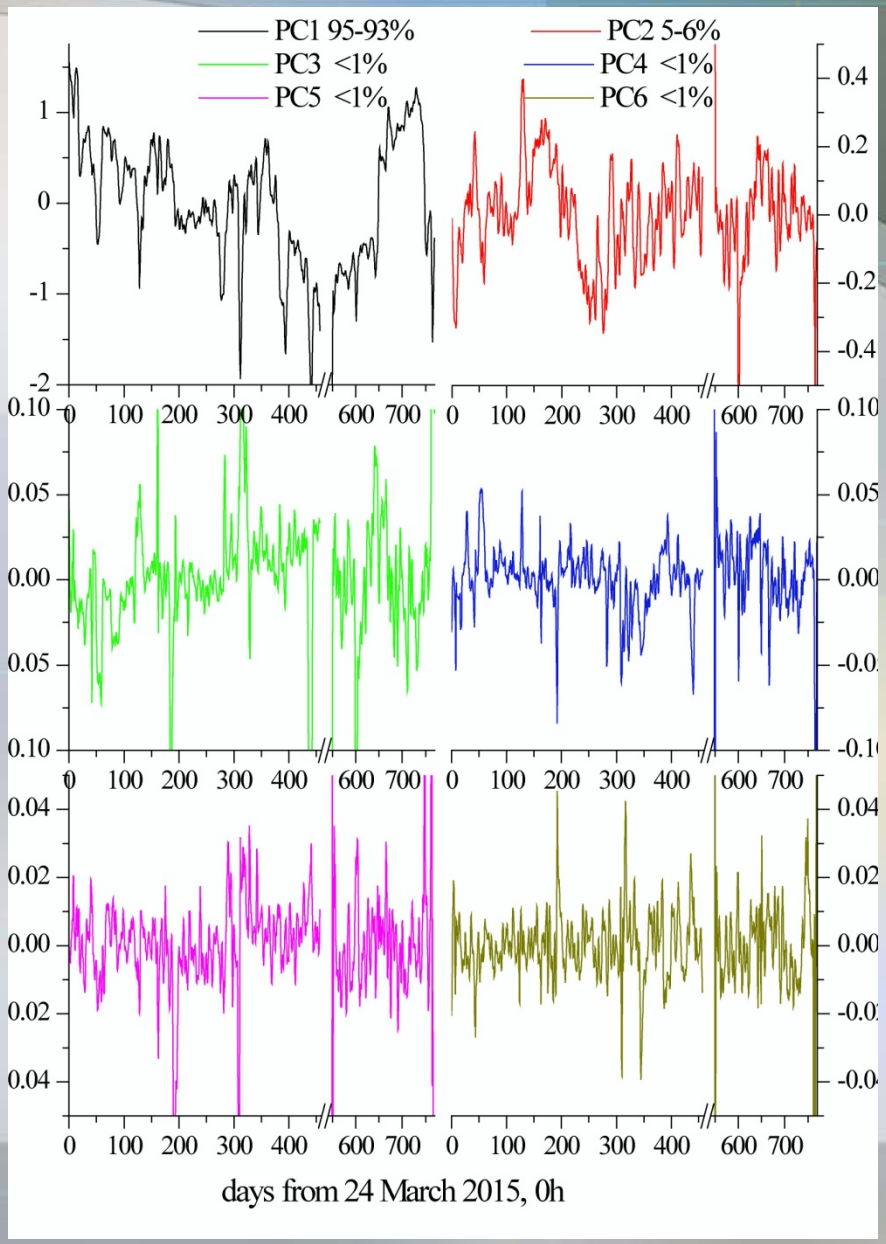
PCA analysis:

- The Tragas smoothed series are submitted to the principal component analysis (PCA): six ***Σφ*** series for each of the three time intervals);
- Percentage of the total variability explained by each of the PCs:

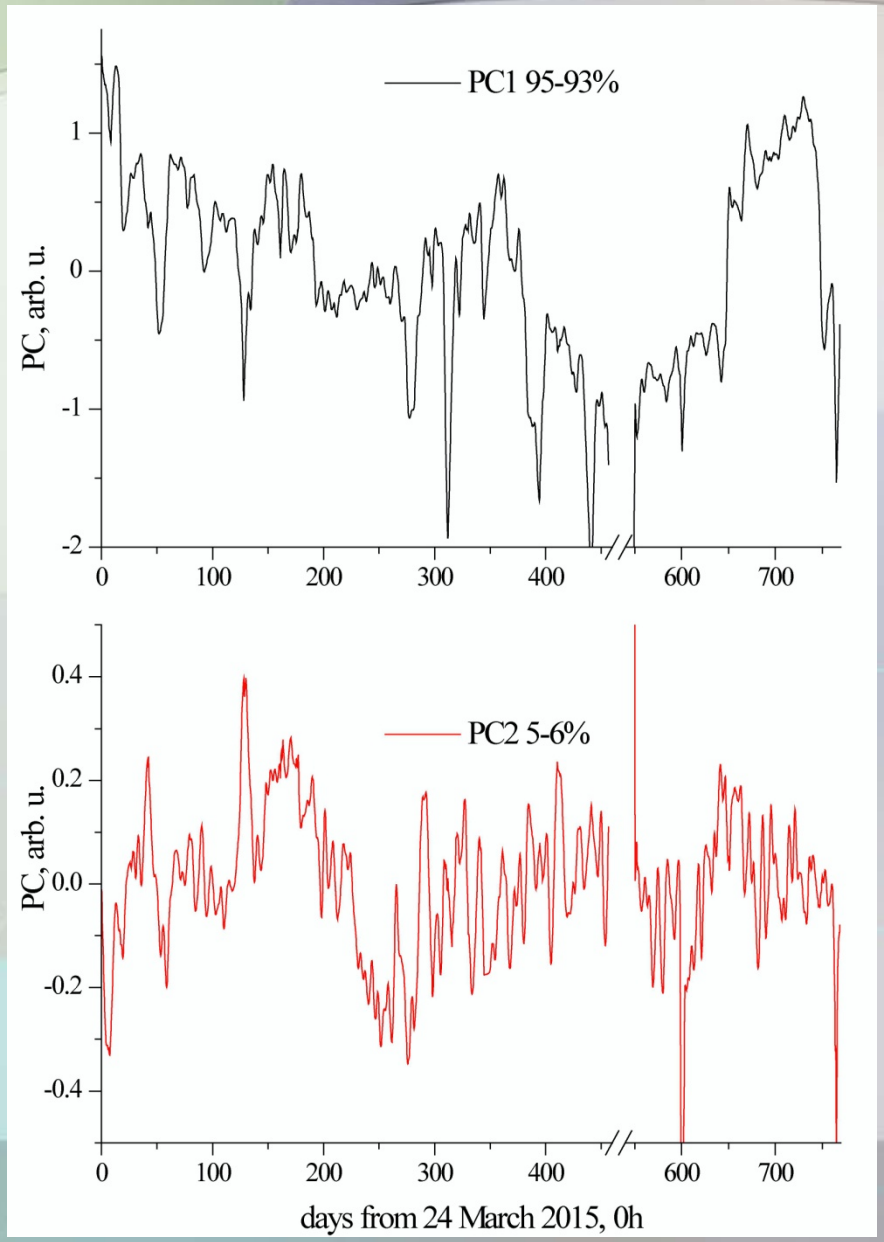
PC #	interval 1	Interval 2	Interval 3
1	**94.78%**	**99.87%**	**92.79%**
2	***4.68%***	0.09%	***5.95%***
3	0.38%	0.03%	0.9%
4	0.08%		0.26%
5	0.06%		0.06%
6	0.02%		0.04%

PCA analysis - PCs:





PCA analysis:



- Only PC1 and PC2 are significant for the time intervals 1 and 3;
- For the 2nd time interval there is only one significant PC – PC1;
- 2nd time interval was excluded from the further analysis (also because it's too short relatively to others);

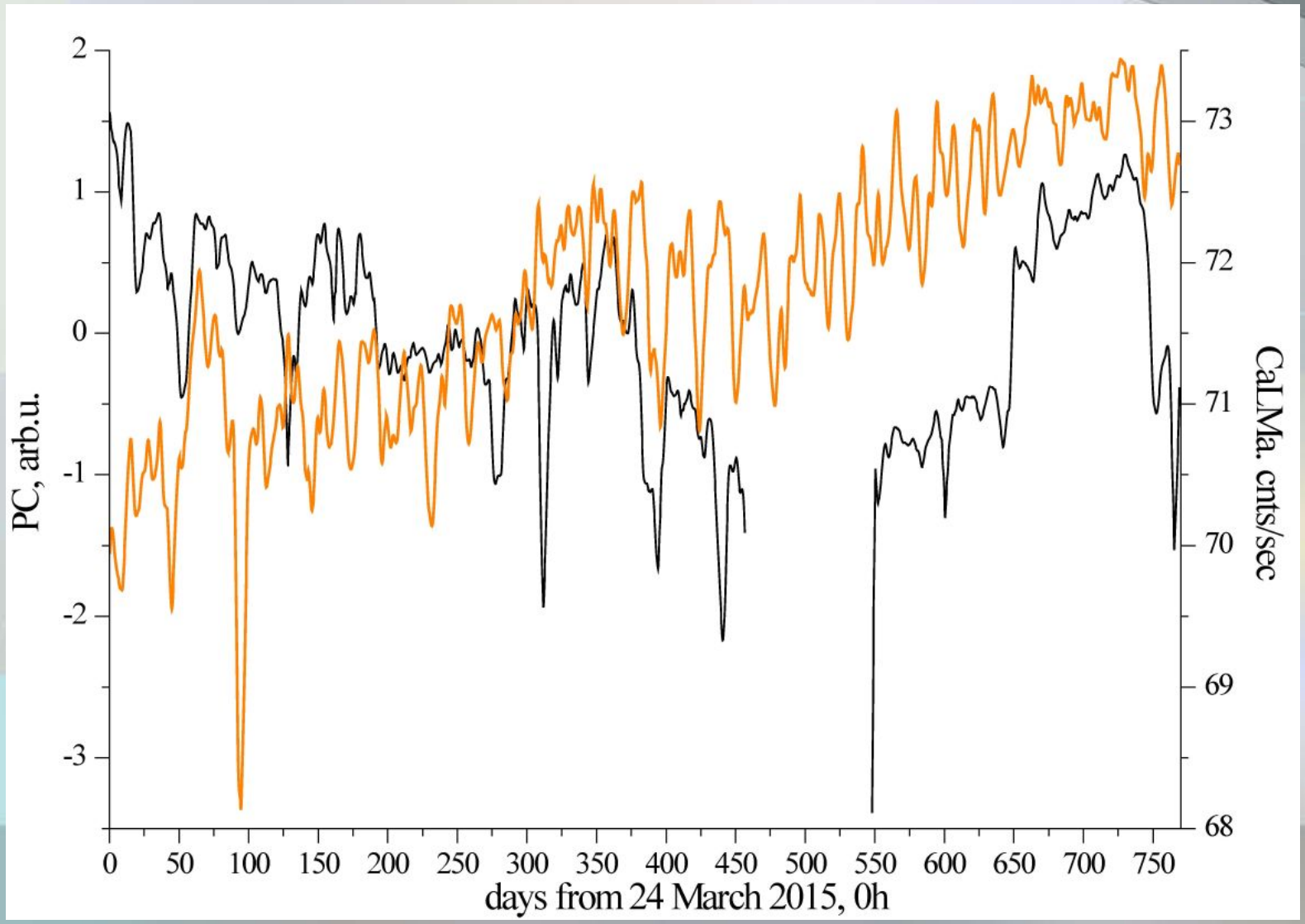
Correlation analysis:

- PC1 and PC2 for the 1st and the 3rd time intervals were correlated wit the CR NM, COI H, T_{ext} and p_{ext} series;
- NB: The 3rd time interval can be also divided into two (before and after 2017 January 1) – see Figures;
- Correlation coefficients (***r***) for different time intervals

	interval 1	Interval 3	interval 1	Interval 3
	PCs vs NM		PCs vs COI H	
PC1	**0.34**	**0.72** **0.51 0.55**	**0.5**	**0.52** **0.63 0.00**
PC2	0	0	0	0
	PCs vs T_{ext}		PCs vs p_{ext}	
PC1	0	0.44 0.68 0.18	0	0 0.00 0.38
PC2	0.4	0 0.00 0.00	**0.67**	**0.35** **0.41 0.90**

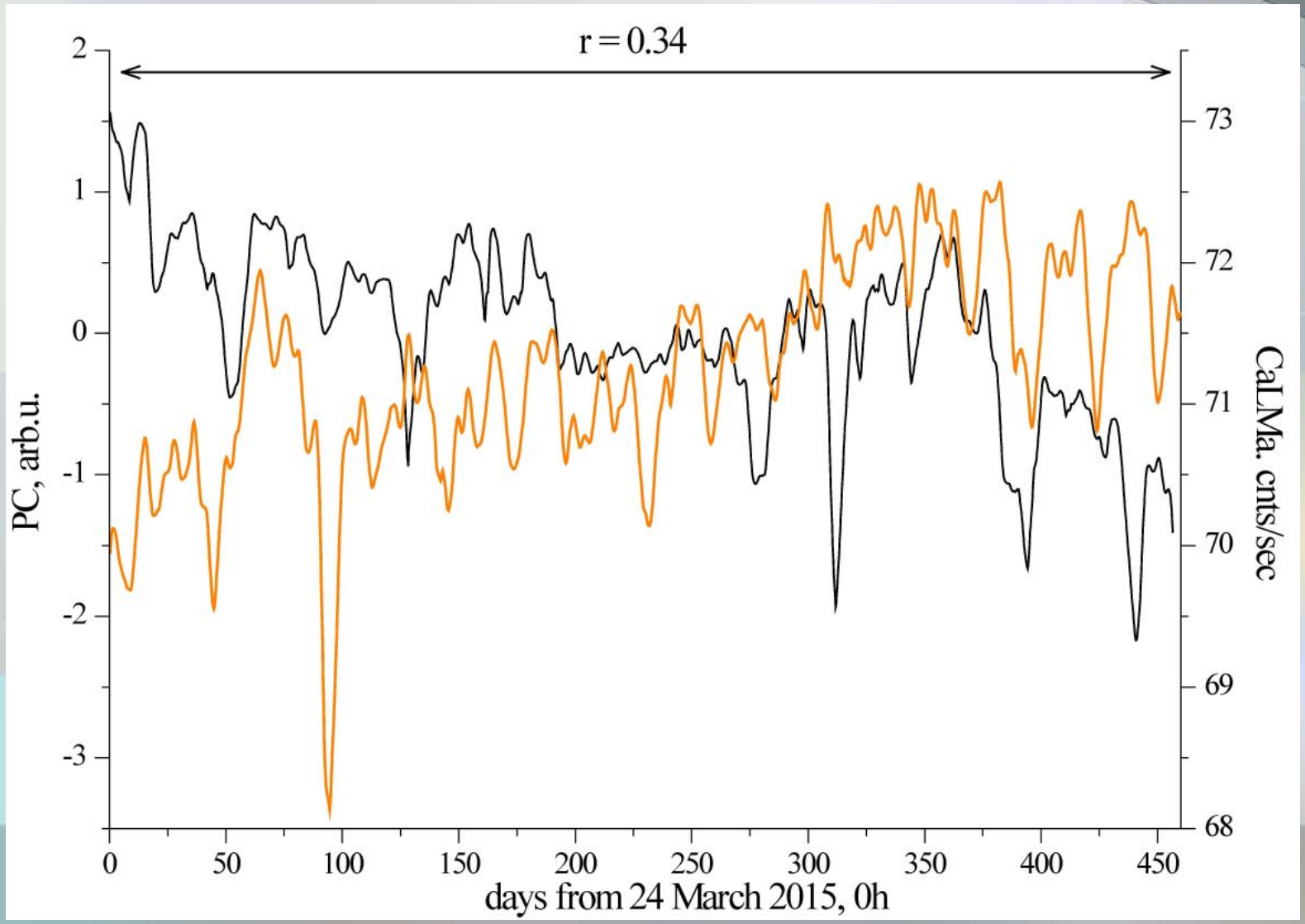
PC1:

- PC1 is the component of the Tragas Σϕ series that correlate quite well with the CR flux measured by the NM;



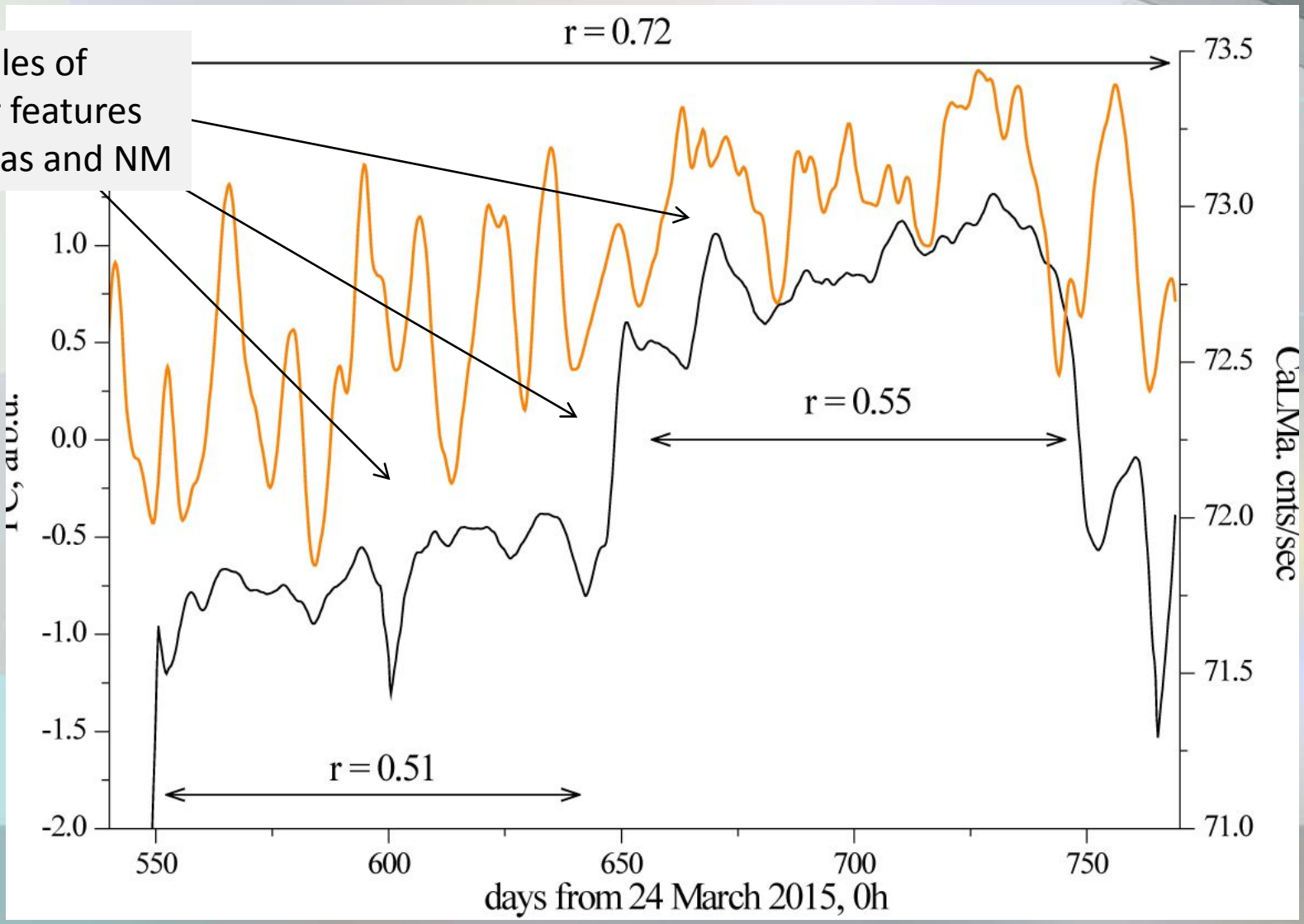
PC1 (1st time interval):

- For the 1st time interval the correlation coefficient is relatively low due to different trends of the Tragas and NM series, mostly for the first ~300 days);



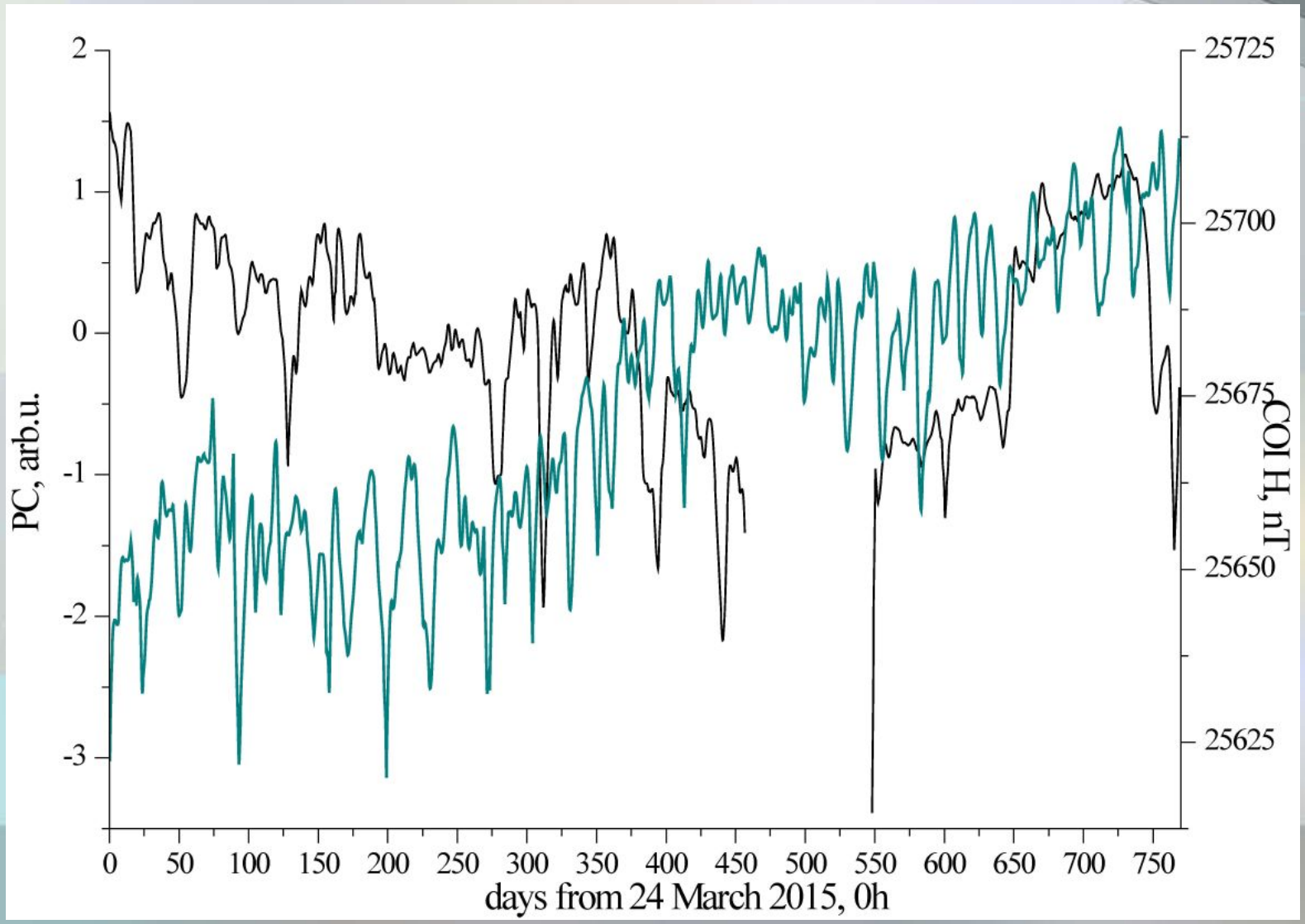
PC1 (3rd time interval):

- For the 3rd time interval the correlation coefficient is high due to similar trends of the Tragas and NM series, but for a shorter time interval the ***r*** is ~0.5



PC1:

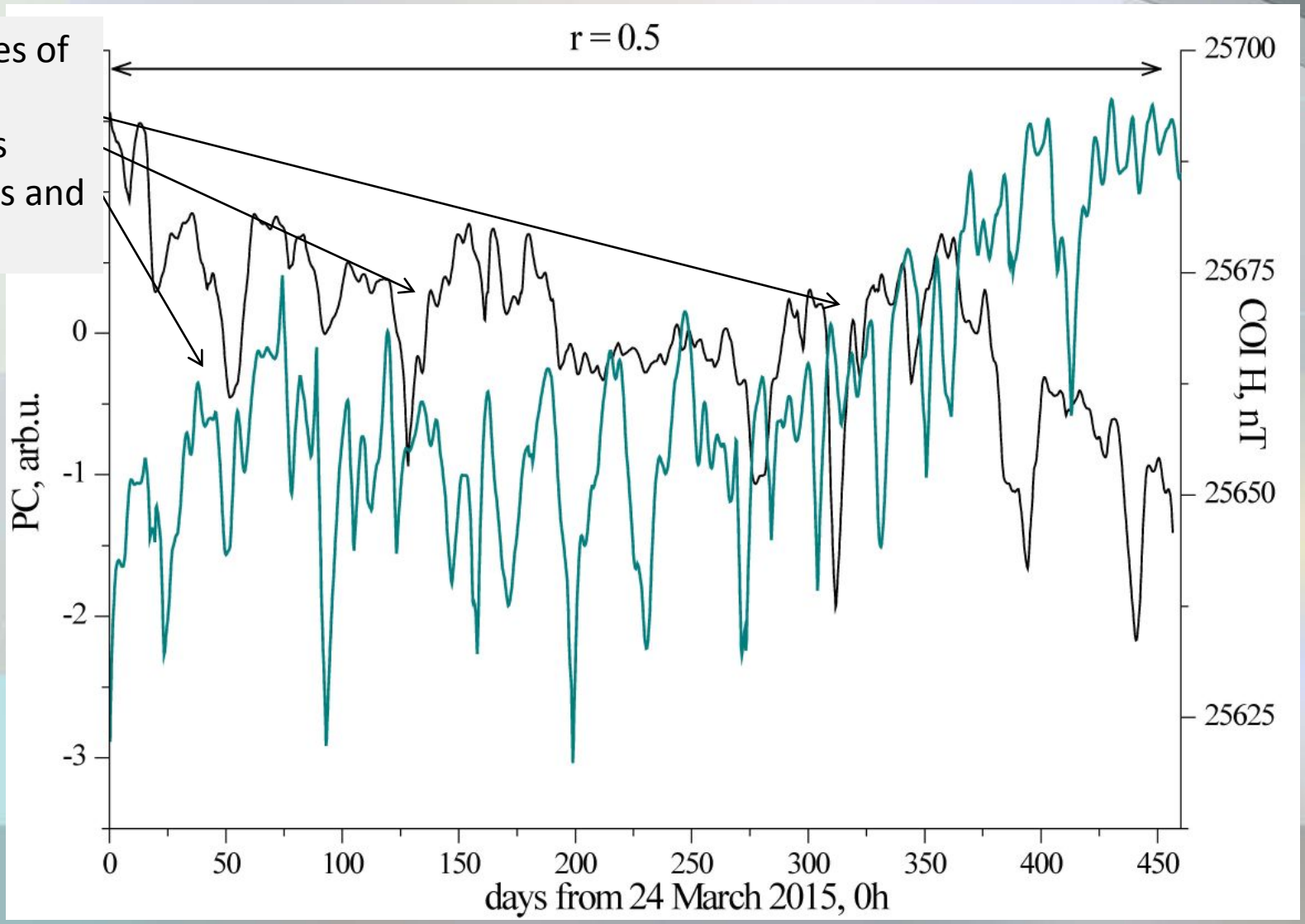
- PC1 is the component of the Tragas Σϕ series that correlate well with the geomantic field (COI H);



PC1 (1st time interval):

- The correlation coefficients are similar for the 1st and the 3rd time intervals;
- In many cases some characteristic features in COI H and Tragas series coinside;

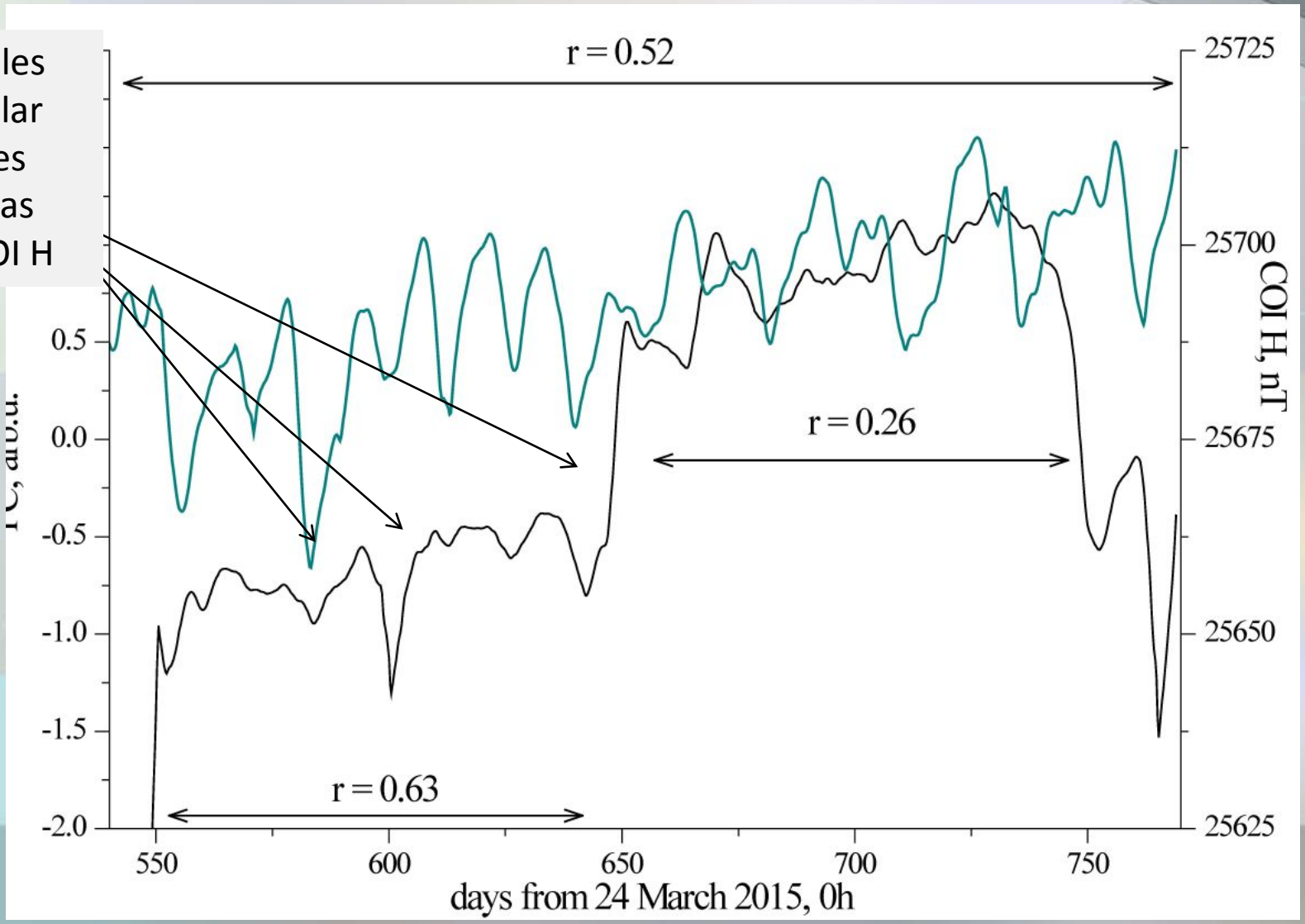
Examples of similar features in Tragas and COI H



PC1 (3rd time interval):

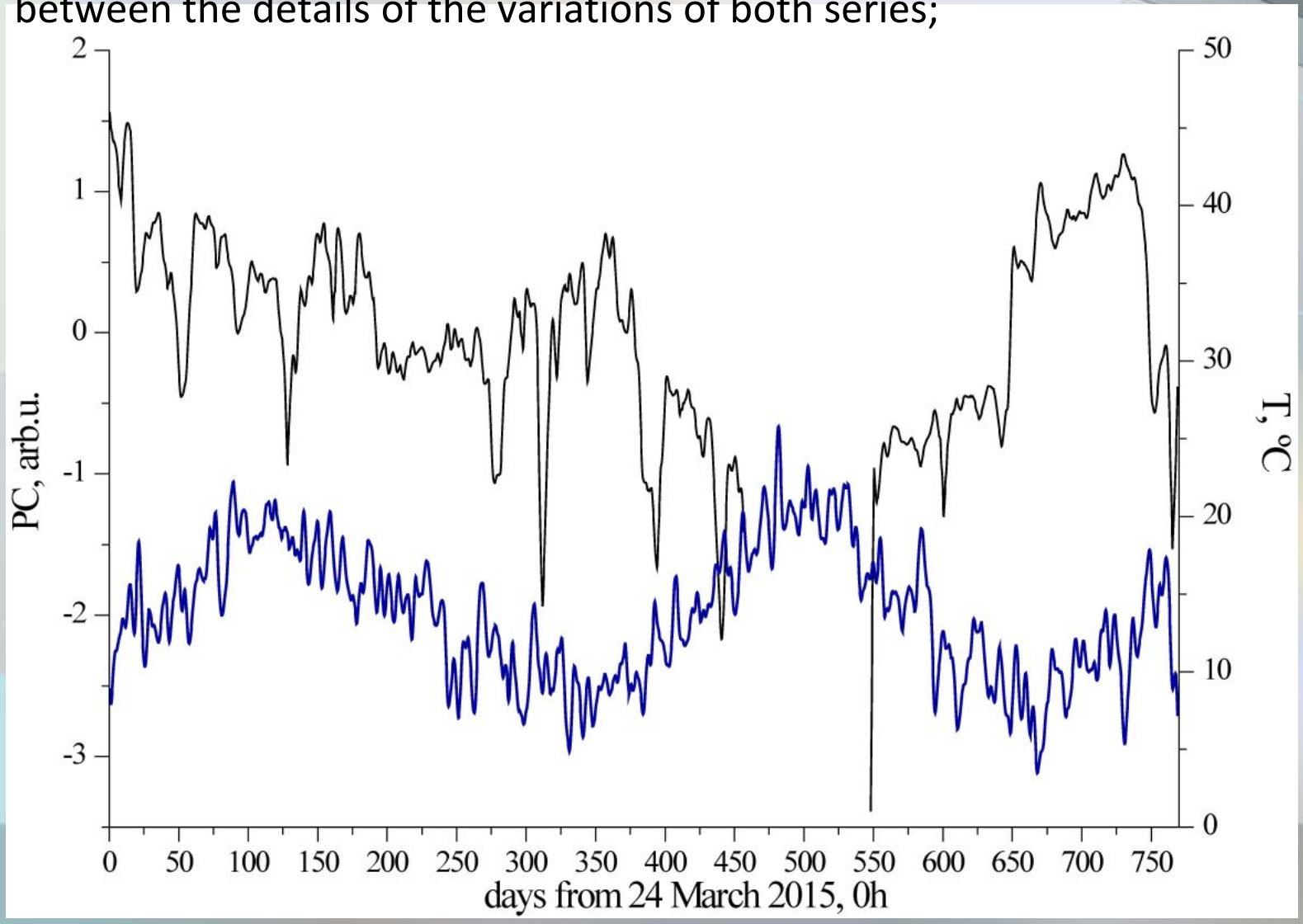
- Starting from around January 2017 the correlation is less prominent;

Examples of similar features in Tragas and COI H



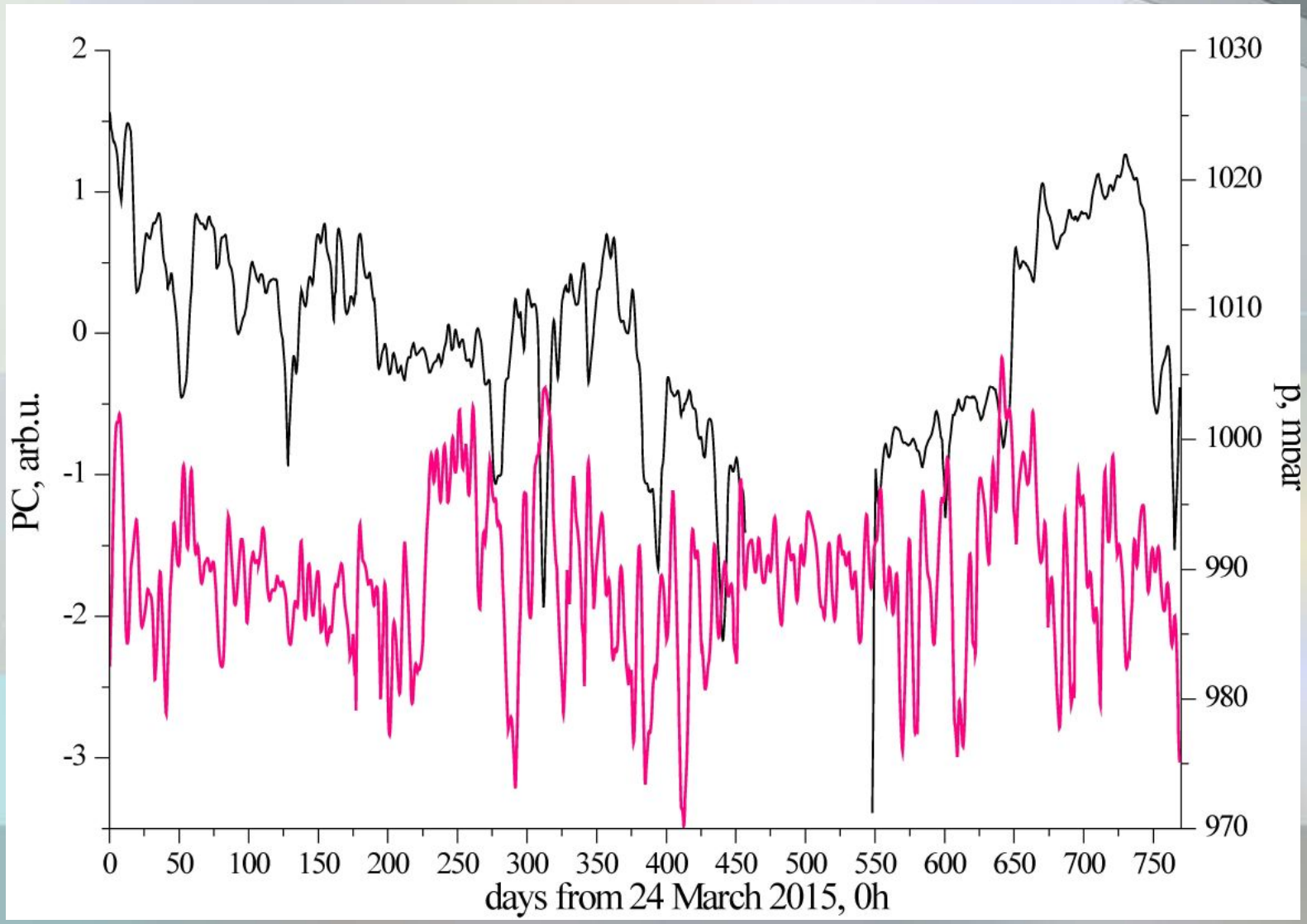
PC1:

- Though the ***r*** between the PC1 and the T_{ext} series are high for some time intervals, they seem to appear from the similar global; There is no similarity between the details of the variations of both series;



PC1:

- Correlation between the PC1 and pressure variations is close to zero;

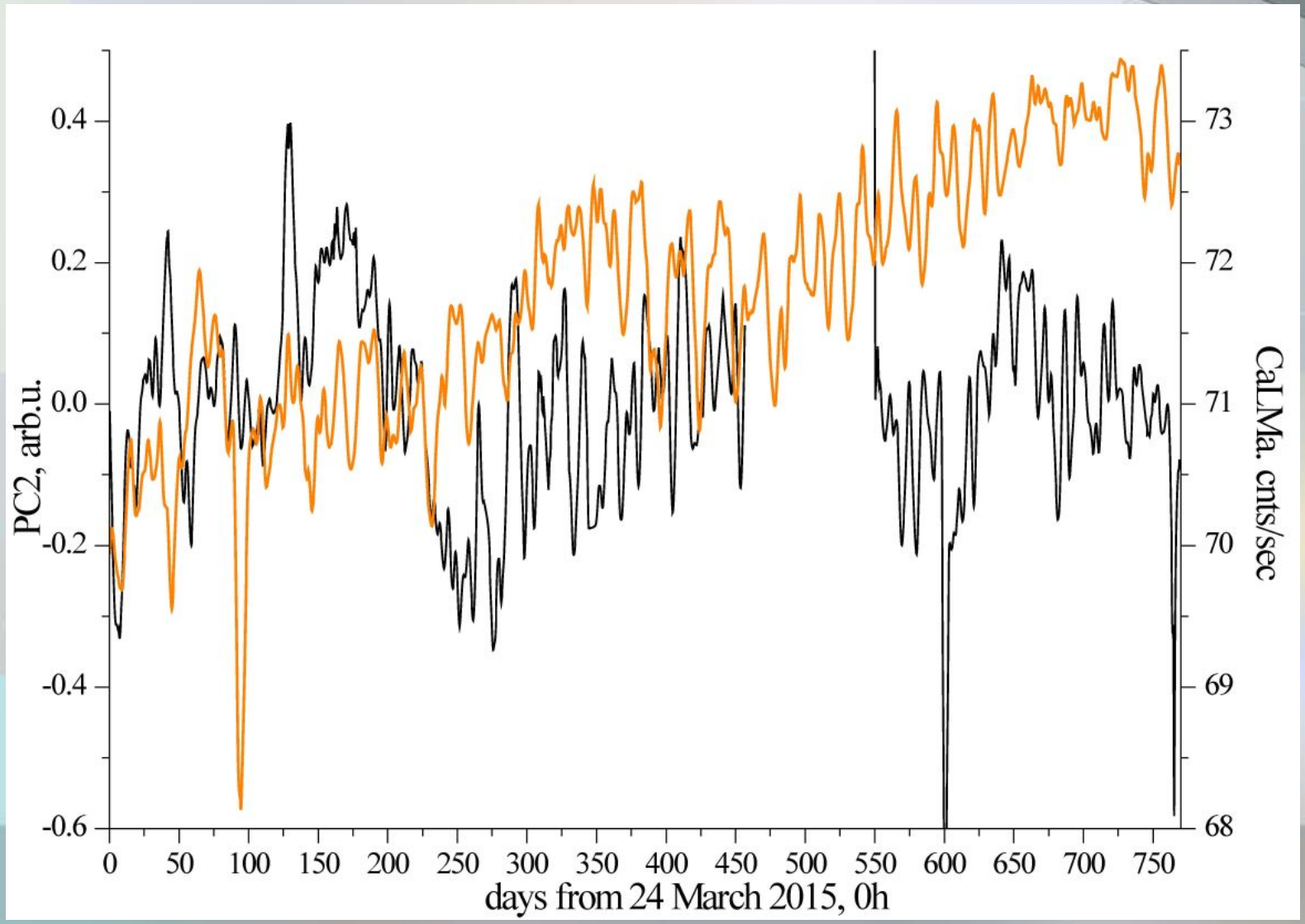


PC1 - conclusion:

- The 1st mode of the variations of the Tragas Σϕ series explains 93-95% of the variability of the input data;
- This is the component related to the geophysical parameters: cosmic rays, geomagnetic field solar wind etc.;
- This component show no significant/persistent co-variations with the meteorological parameters measured at the ground level;

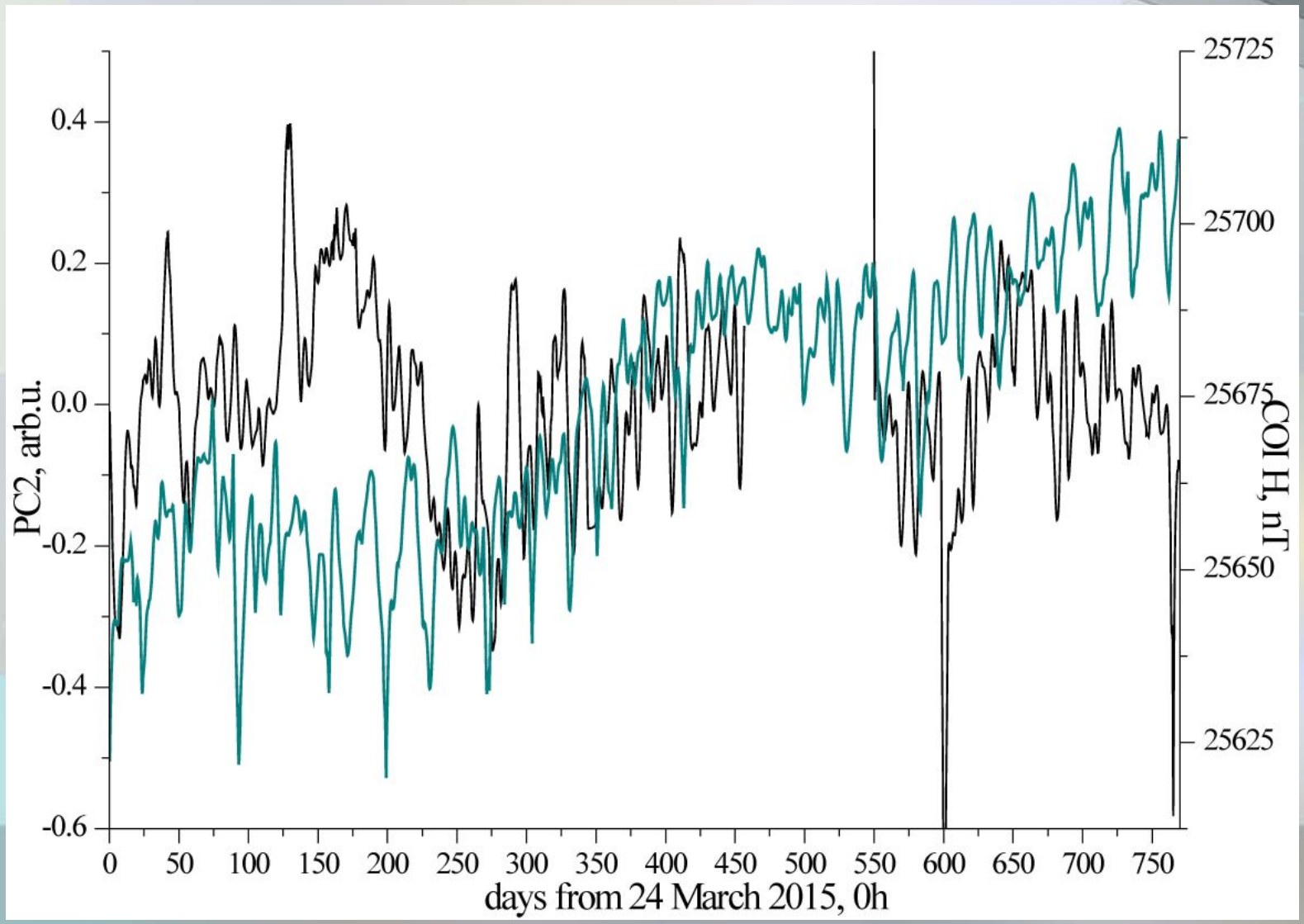
PC2:

- PC2 shows no correlations with the NM series;



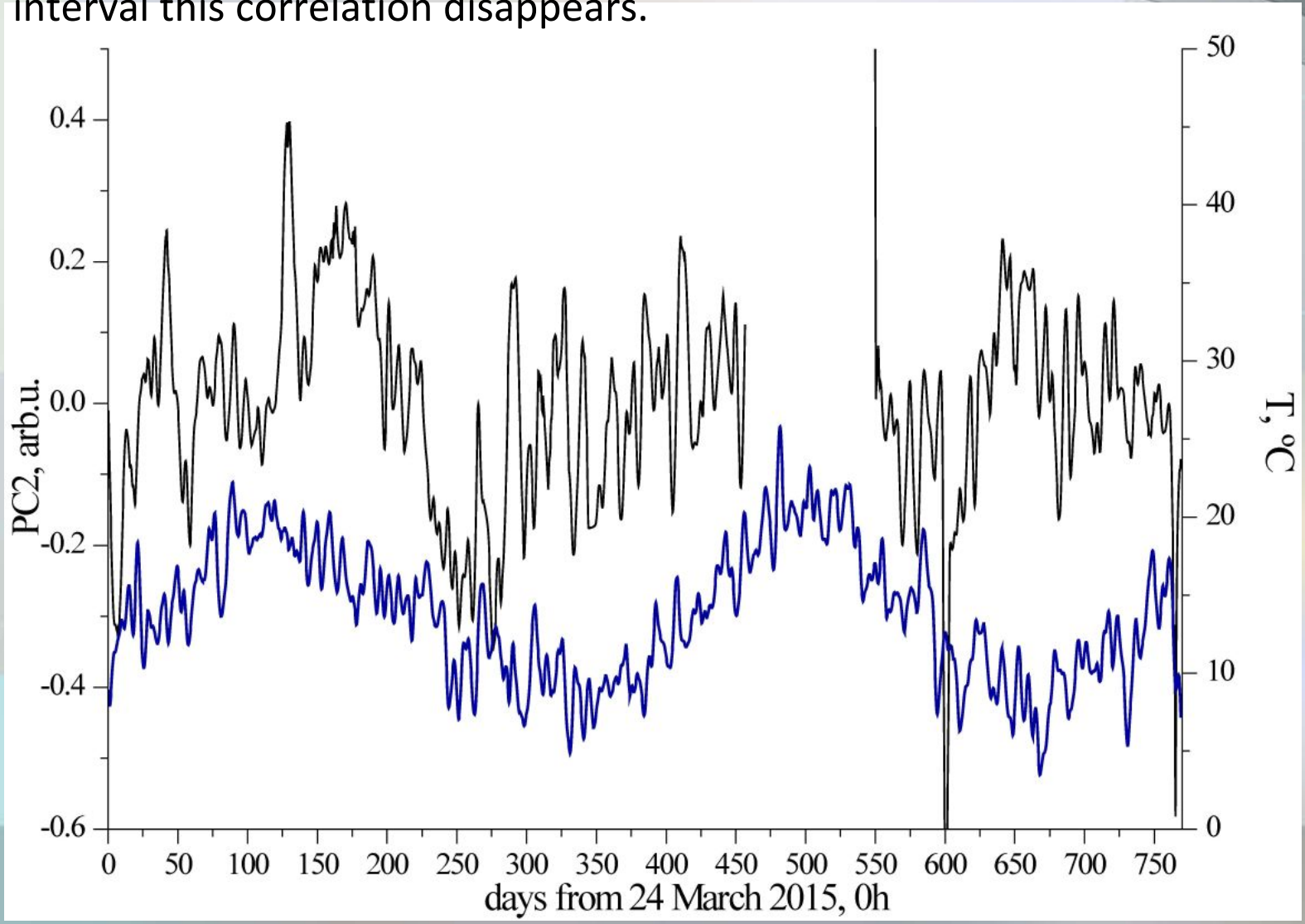
PC2:

- PC2 shows no correlations with the COI H series (except, occasionally, for global trends, but these correlations don’t persist);



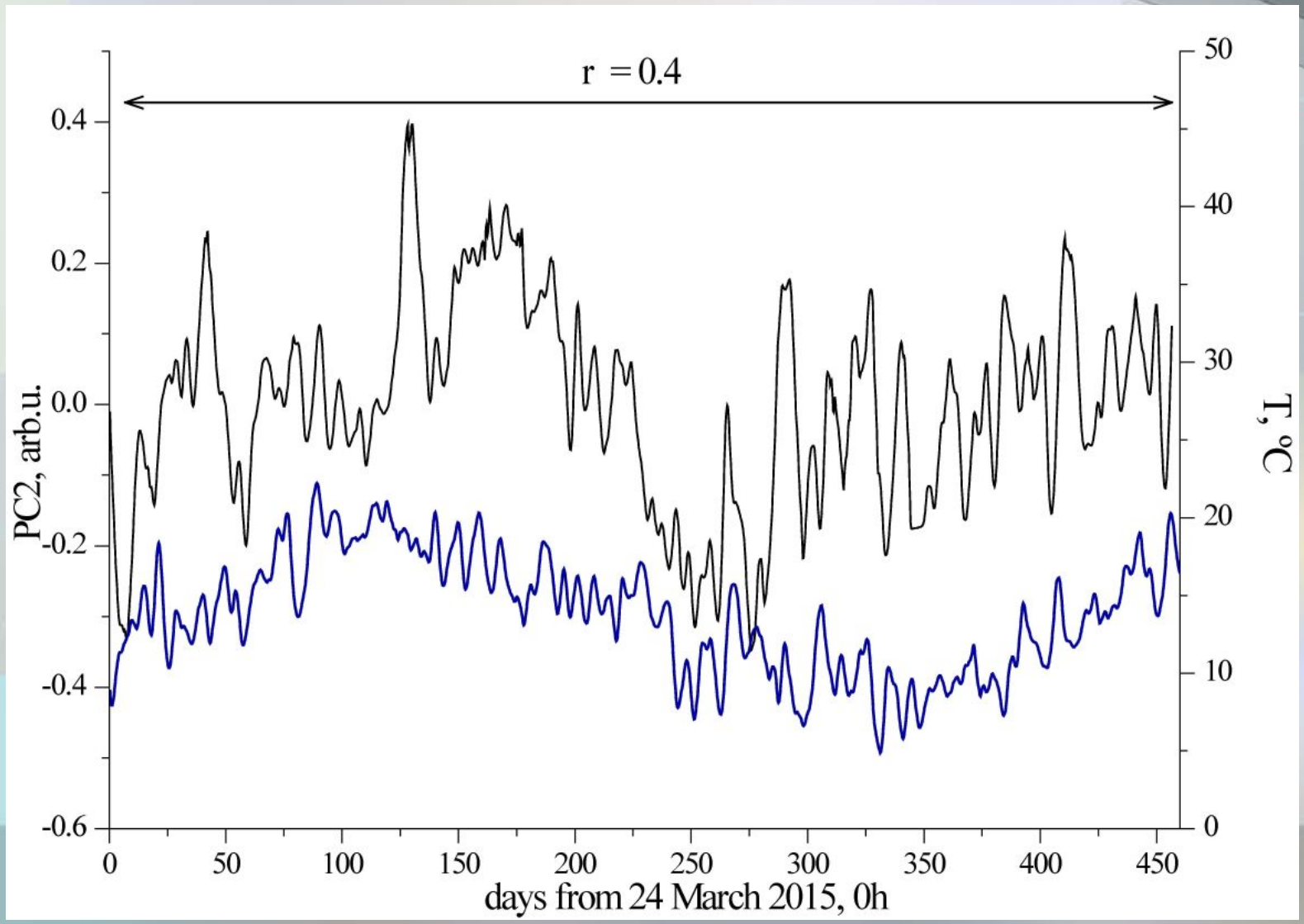
PC2:

- PC2 shows correlates relatively well with T_{ext} series for the 1st time interval (March 2015 – June 2016), before the long break. However, in the 3rd time interval this correlation disappears.



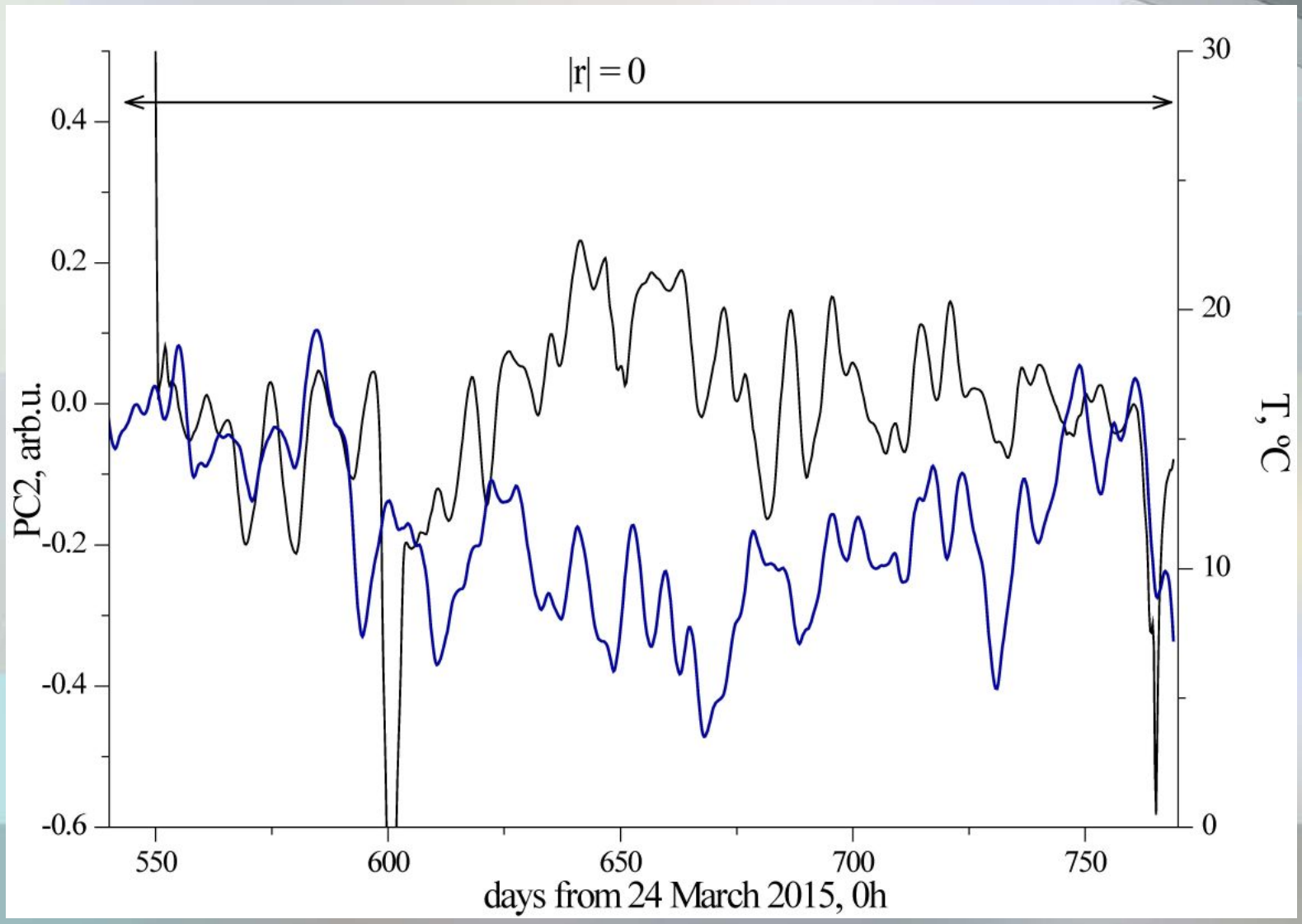
PC2 (1st time interval):

- Correlations:



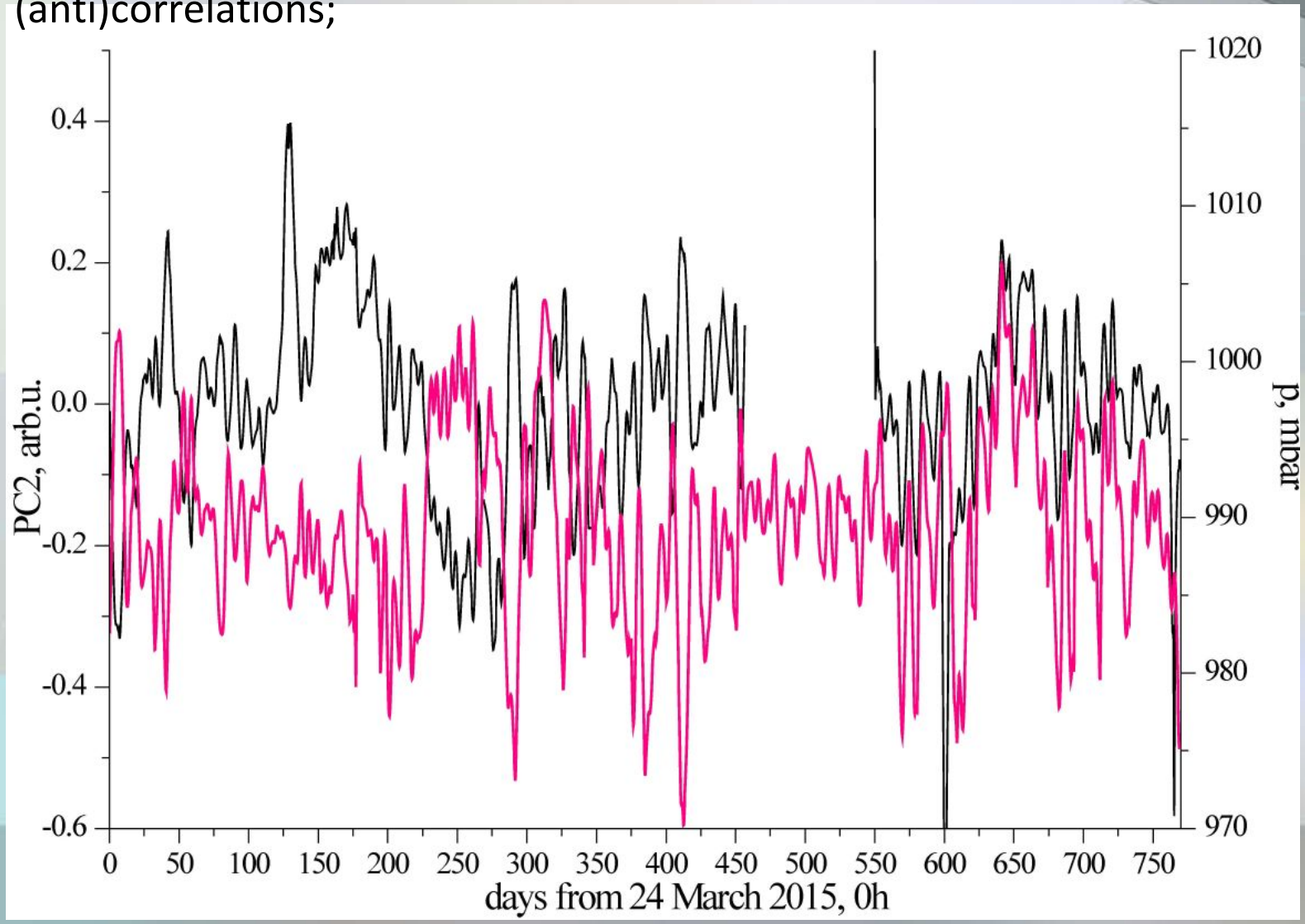
PC2 (3rd time interval):

- No correlation/anti-correlation (even on short time intervals);

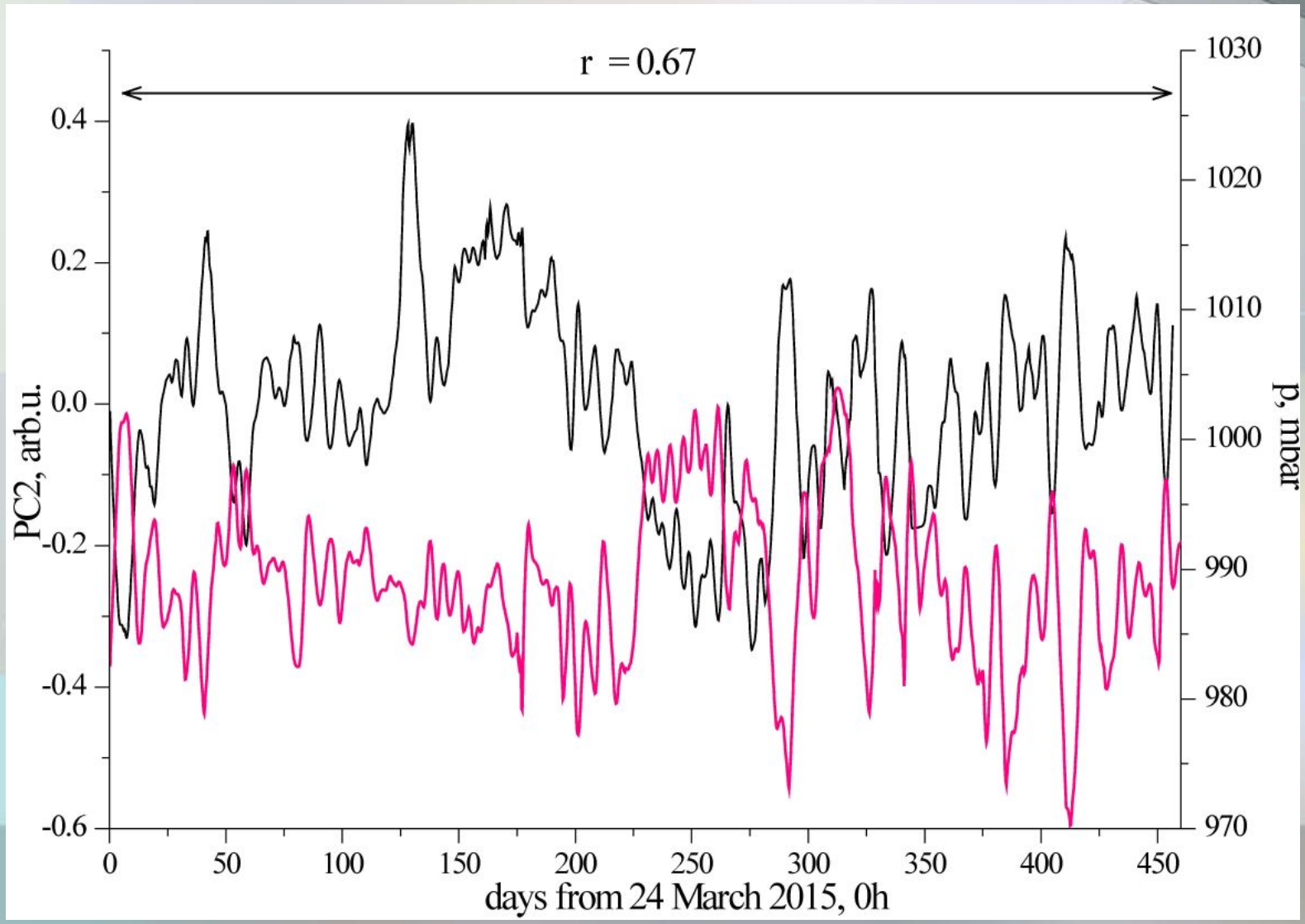


PC2:

- From the correlation analysis is seems that the PC2 is the “pressure” mode: for both studied intervals and on the long- and short-terms there are high (anti)correlations;

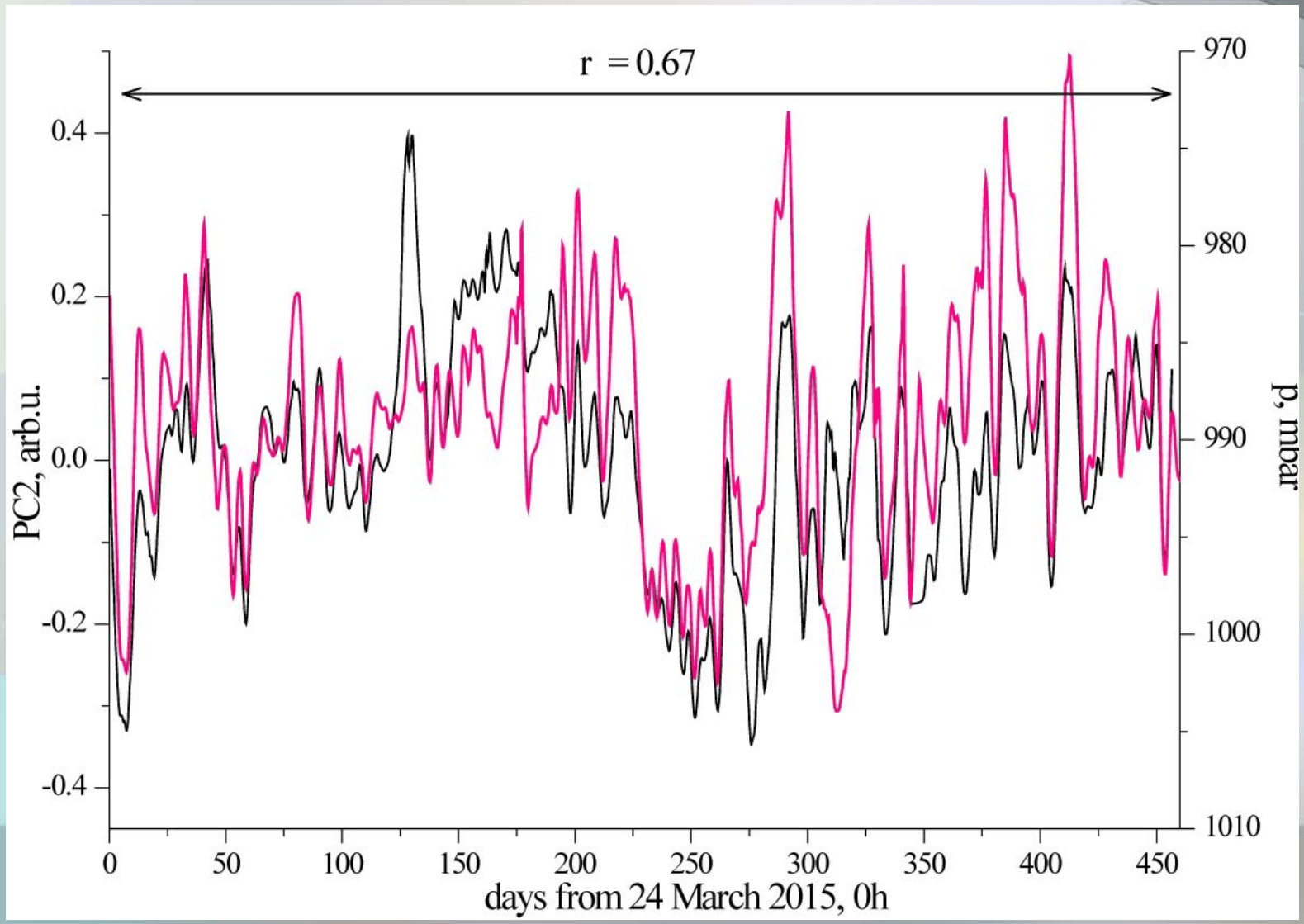


PC2 (1st time interval):



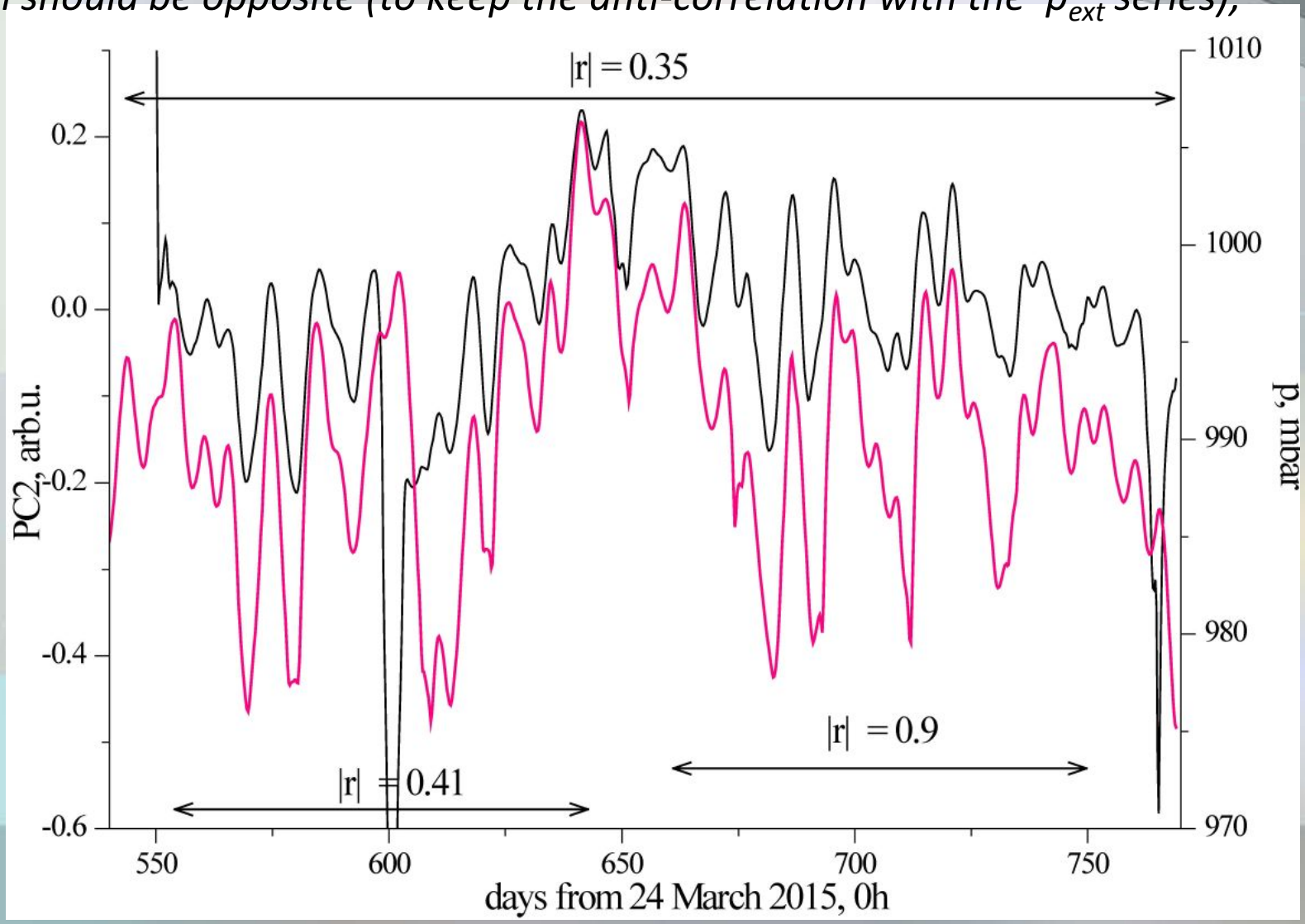
PC2 (1st time interval):

- Same as previous Figure but with reversed pressure Y-axis for better visualization:



PC2 (3rd time interval):

NB: please note that the sign of the PCs are arbitrary and based on some assumption of the data variability. Probably, in this case the sign for the PC2 for the 3rd time interval should be opposite (to keep the anti-correlation with the p_{ext} series);



PC2 - conclusion:

- The 2nd mode of the variations of the Tragas Σϕ series explains 5-6% of the variability of the input data;
- This is the component related to the atmospheric pressure variations;
- No significant correlations with ground measured atmospheric temperature as well as with geophysical parameters (CR, geomagnetic field) are found;

Final notes:

- It is still possible that a temperature effect exists – it was shown that in the previous version of the Tragas data this effect was prominent only when all the θ and ϕ channels are submitted to the PCA (not just Σϕ series) → further analysis of the new Tragas data is needed;
- 6h time resolution is OK (for the PCA and correlation analyses), but some way to treat the "fringe" – outliers to the directions of the lower data, is needed (the outliers to the "higher" directions are easier to treat since they are quite rare and well identified);
- Probably, the "fringe" could be a smaller problem when ϕ-channels are considered separately.

Sorry I couldn't manage to come to the Tragas meeting this year... ☹