

HOMOGENIZATION OF THE STARA ZAGORA STRATOSPHERIC NO₂ TIME SERIES

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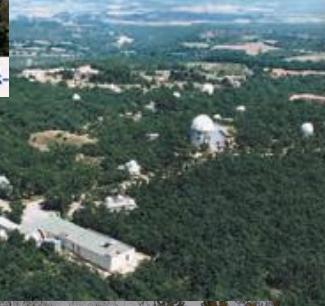
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Introduction

The global change includes changes in the trends of trace and greenhouse gases

Changes of Nitrogen dioxid (NO_2) are related to N_2O and O_3 – both greenhouse gases

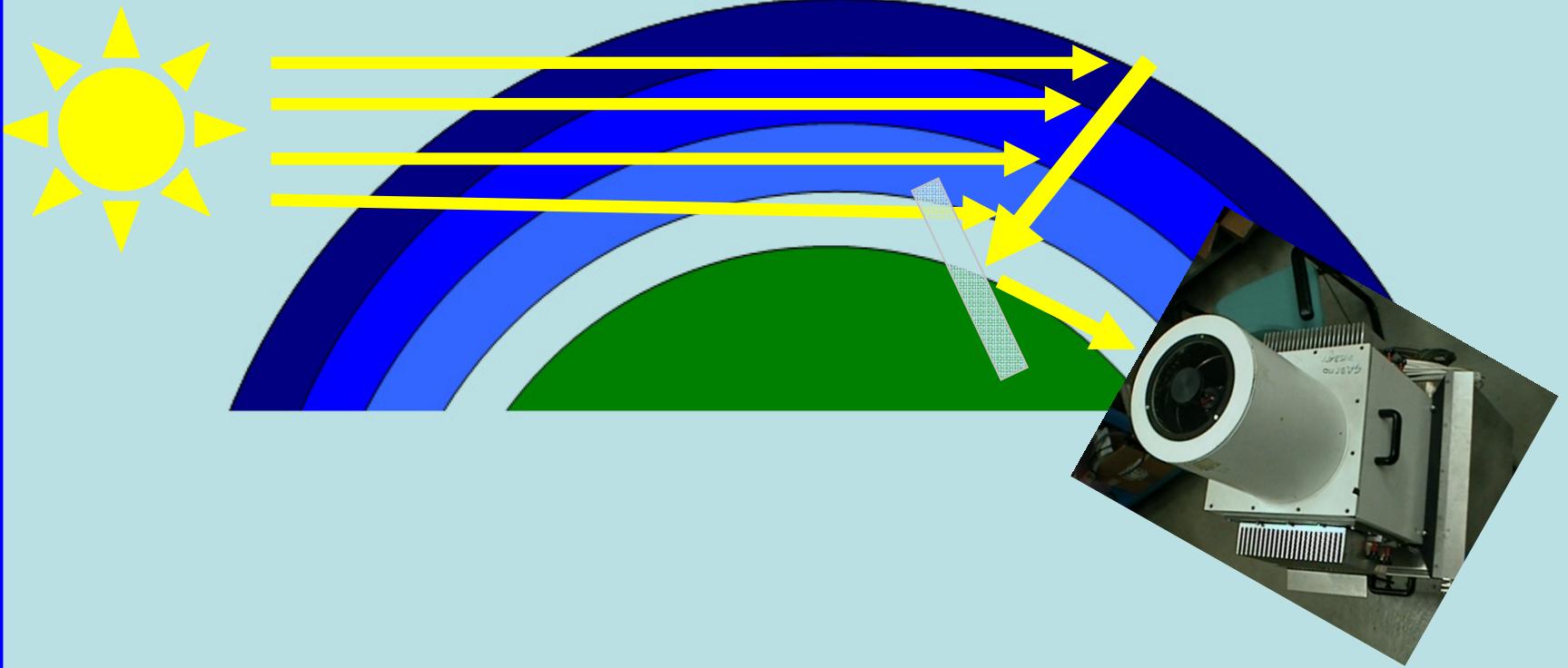
The observed trends of NO_2 at different stations are varying in the range of -15% per decade up to 15% per decade (Gruzdev, 2008).

The trends have strongly regional character. Therefore long time global measurements from ground based stations are need to determine the global trend. The ground based measurements are also needed to calibrate satellite data.

Measurement geometry

NO₂ measurements are carried out in Stara Zagora since 1999 using a method based on DOAS

Sun set or sun rise



GASCOD-BG instrument

Telescope:

$f = 50 \text{ cm}$, $d = 20 \text{ cm}$

Holographic grating:

1200 grooves/mm

CCD: Hamamatsu

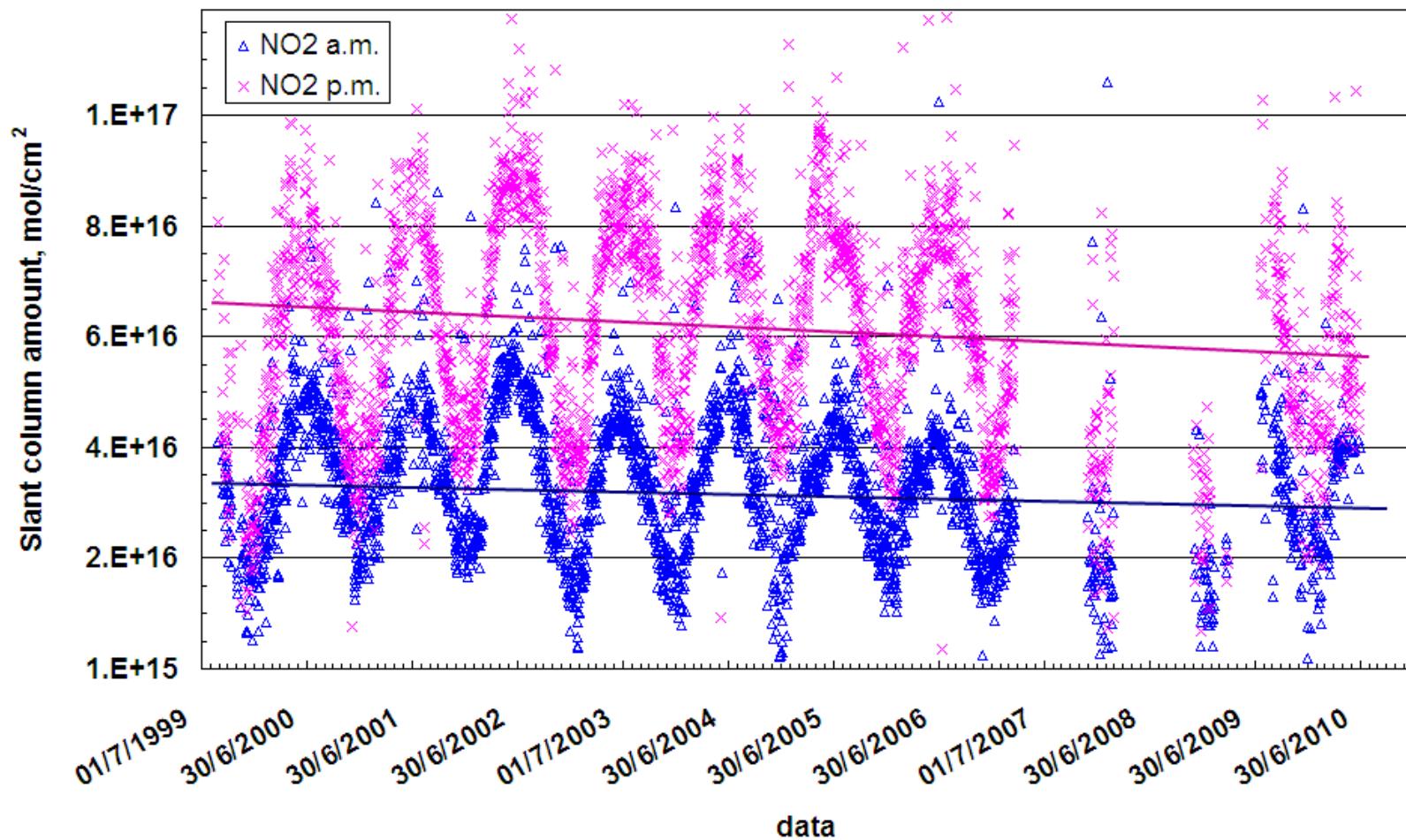
512 diode array



45° zenith mirror

Solar influences on the magnetosphere, ionosphere and atmosphere,
Sozopol, Bulgaria, 6-10 June 2011

NO_2 a.m. and NO_2 p.m. time series

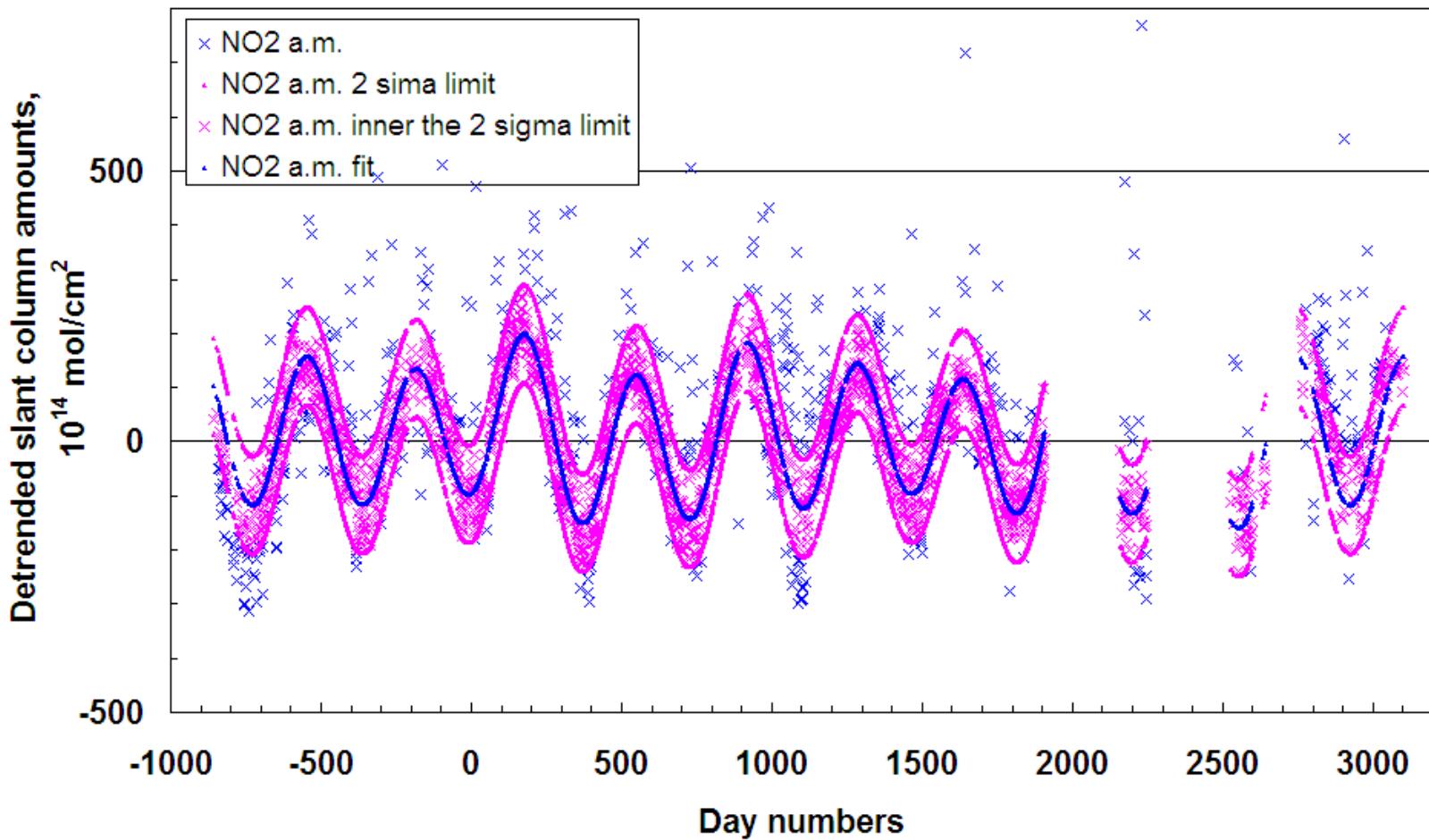


Data preprocessing

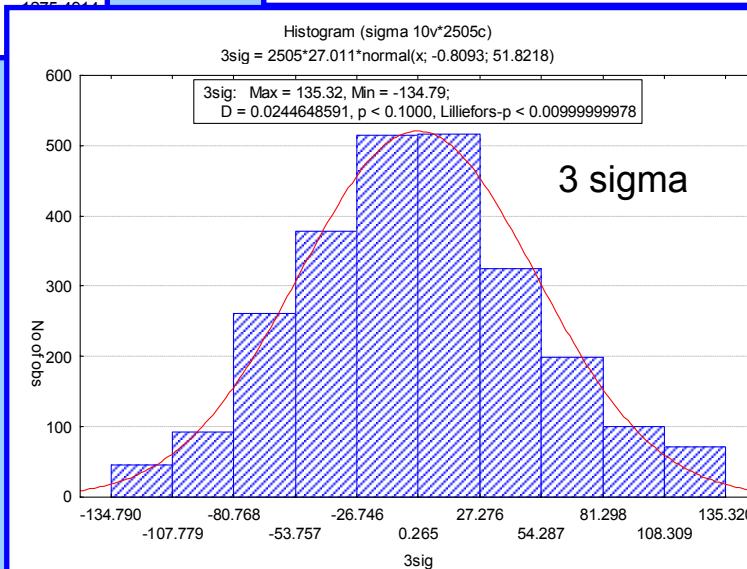
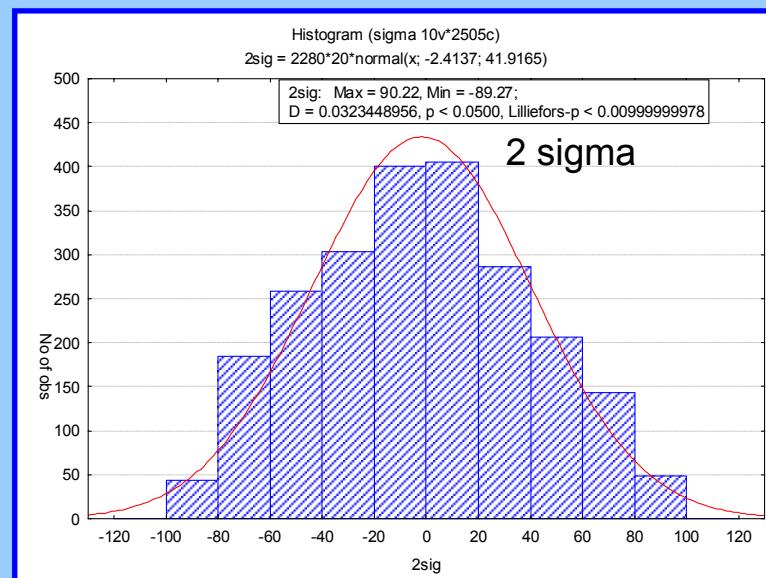
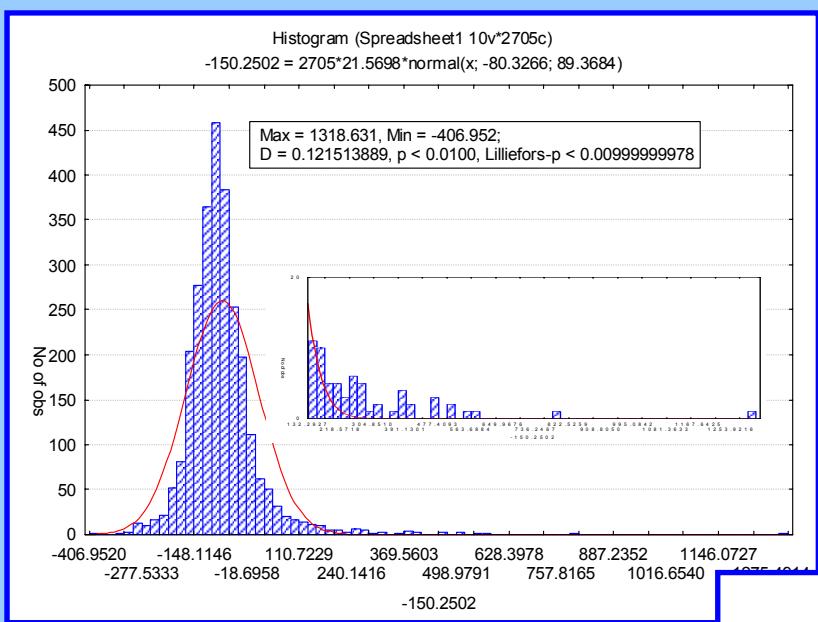
To apply methods based on least squares we remove extreme values:

1. median filter (7 points)
2. removing of the lin. trend.
3. Determination of low order harmonic fit ($T=10$ years, $n=20$, shortest period 1 year)
4. Determination of the standart deviation of the harmonic fit and the original data
5. Extreme values are outside of the area determined by the fit and the 2 sigma limit (variant by 3 sigma limit)

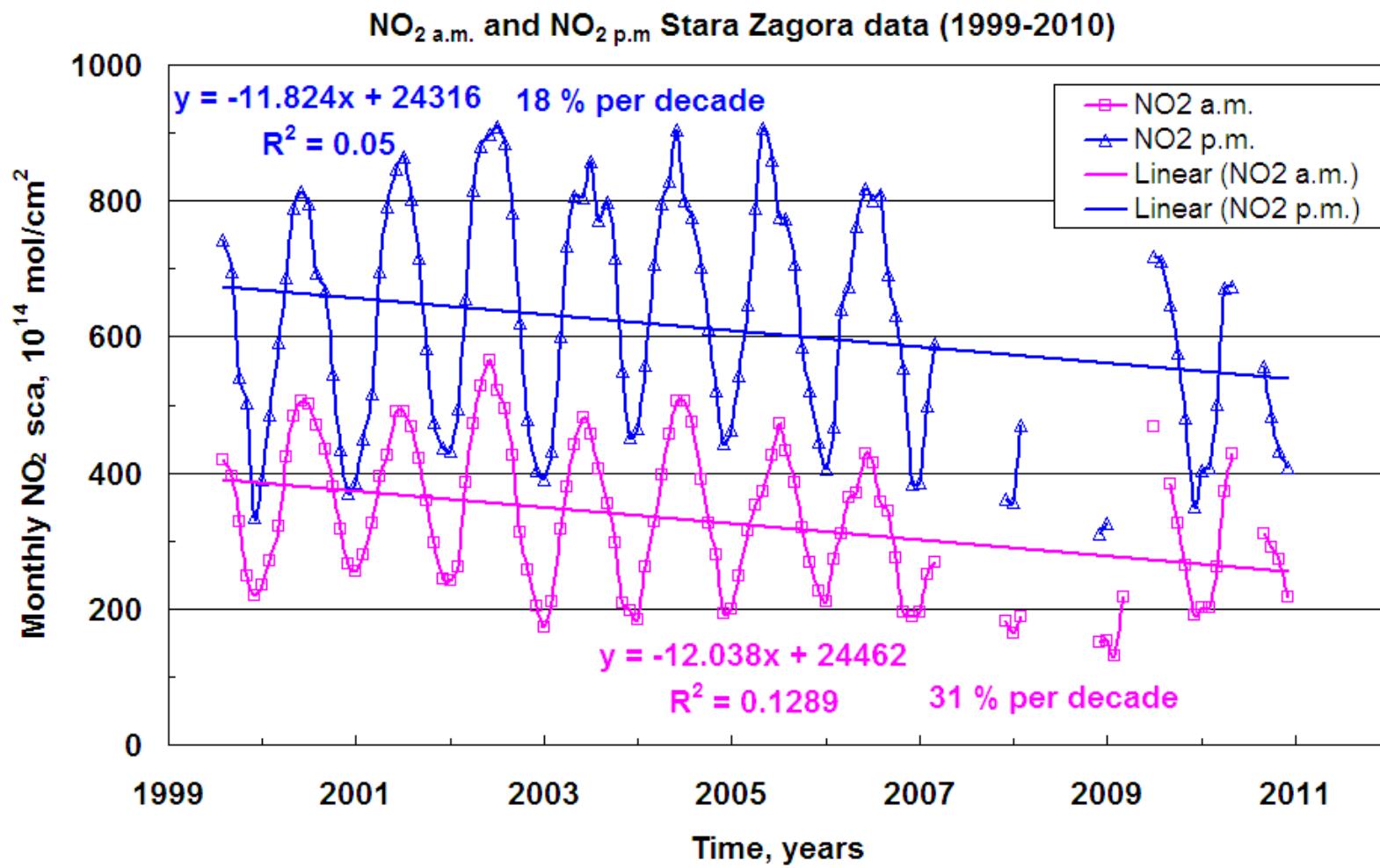
Data processing



Data processing



NO_2 monthly data



Global NO₂ distribution

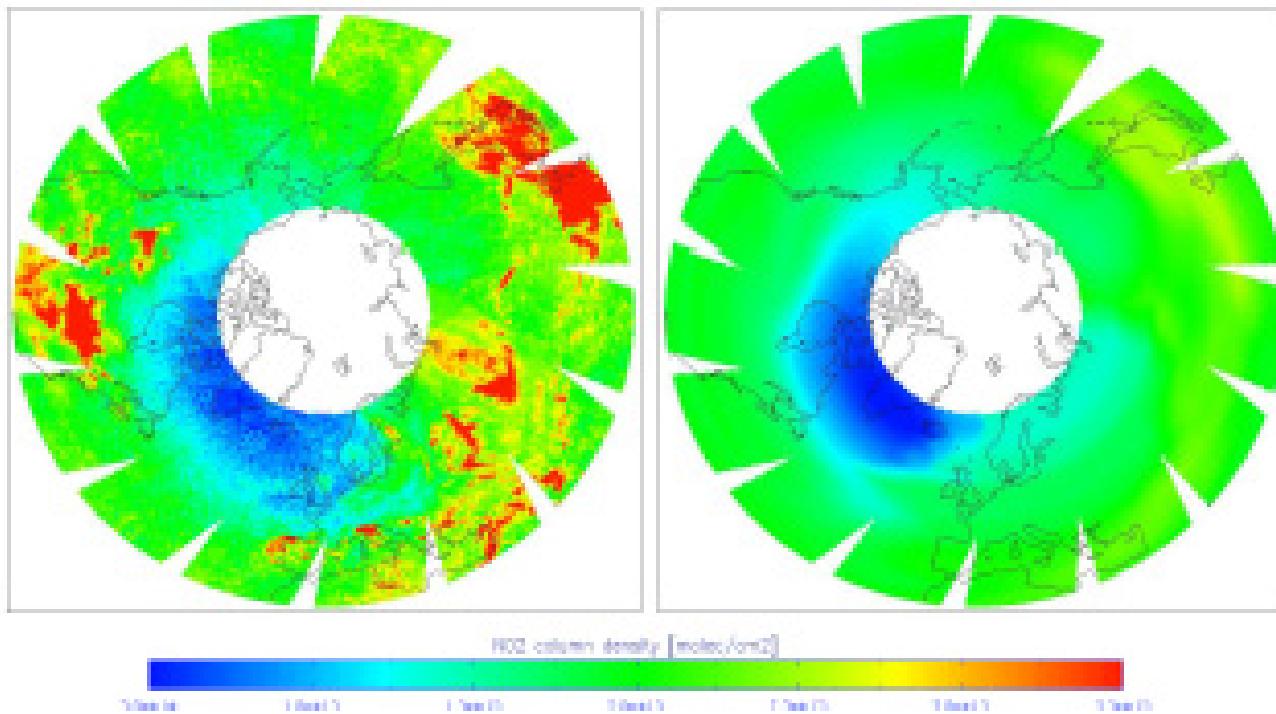
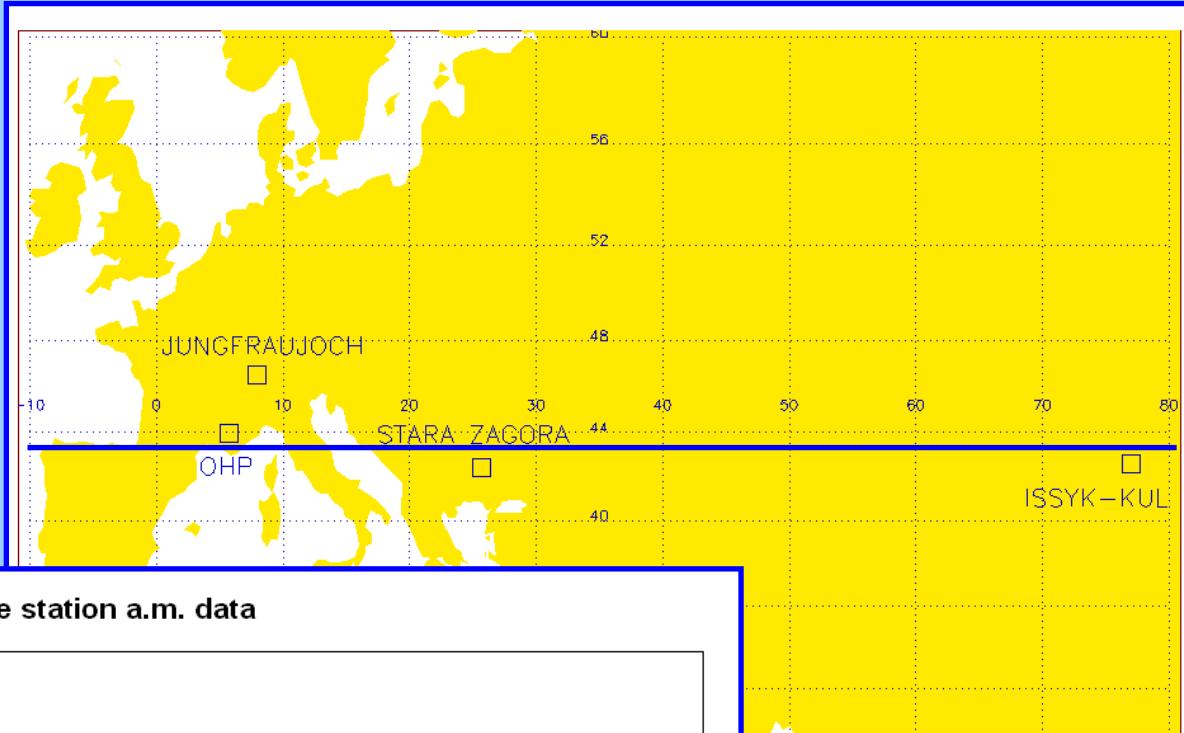


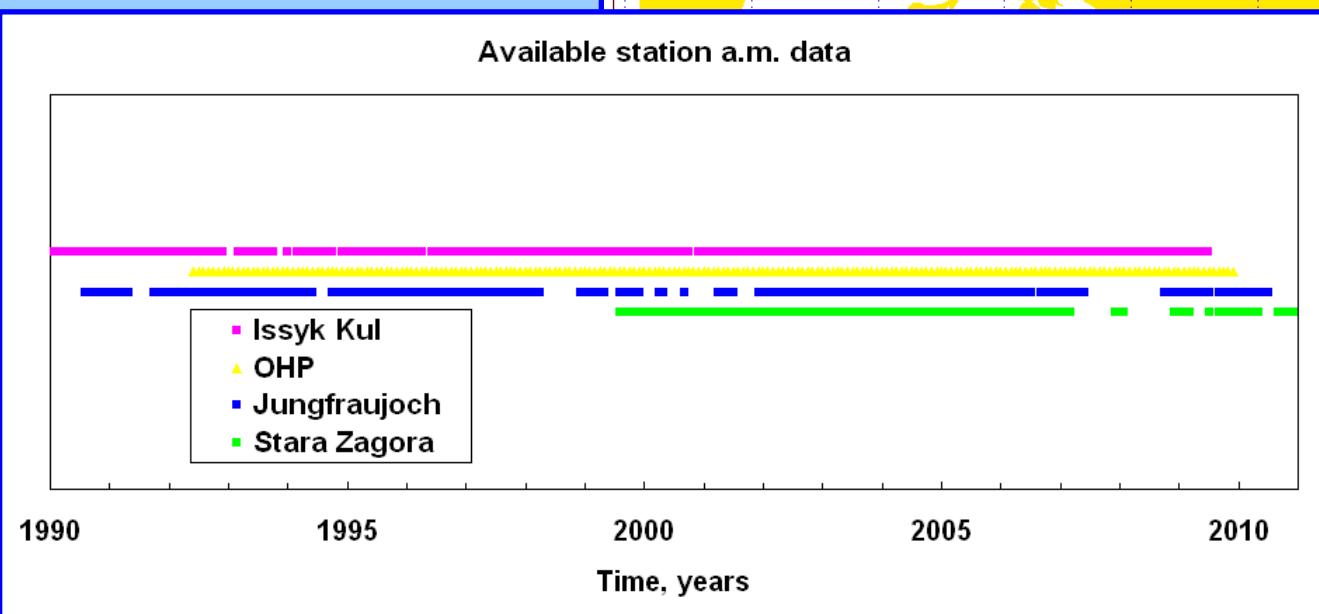
Fig. 1. Total NO₂ distribution from GOME-2 for 22 February 2008 (left) and the corresponding stratospheric NO₂ distribution as obtained with the spatial filtering approach (right).

Valks P., et al., Atmos. Meas. Tech. Discuss. 4, 1617-1676, 2011

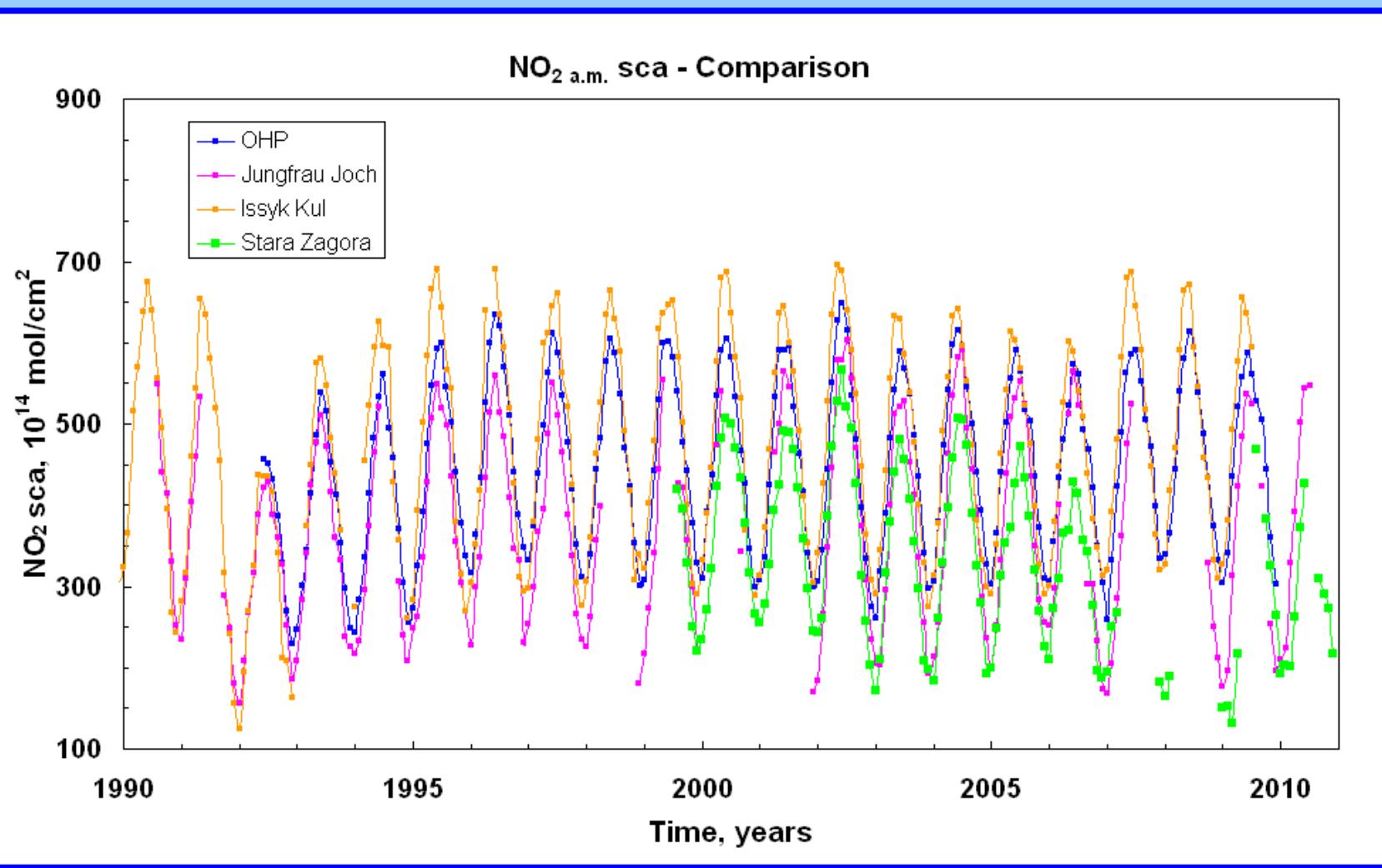
Stations localization and available data



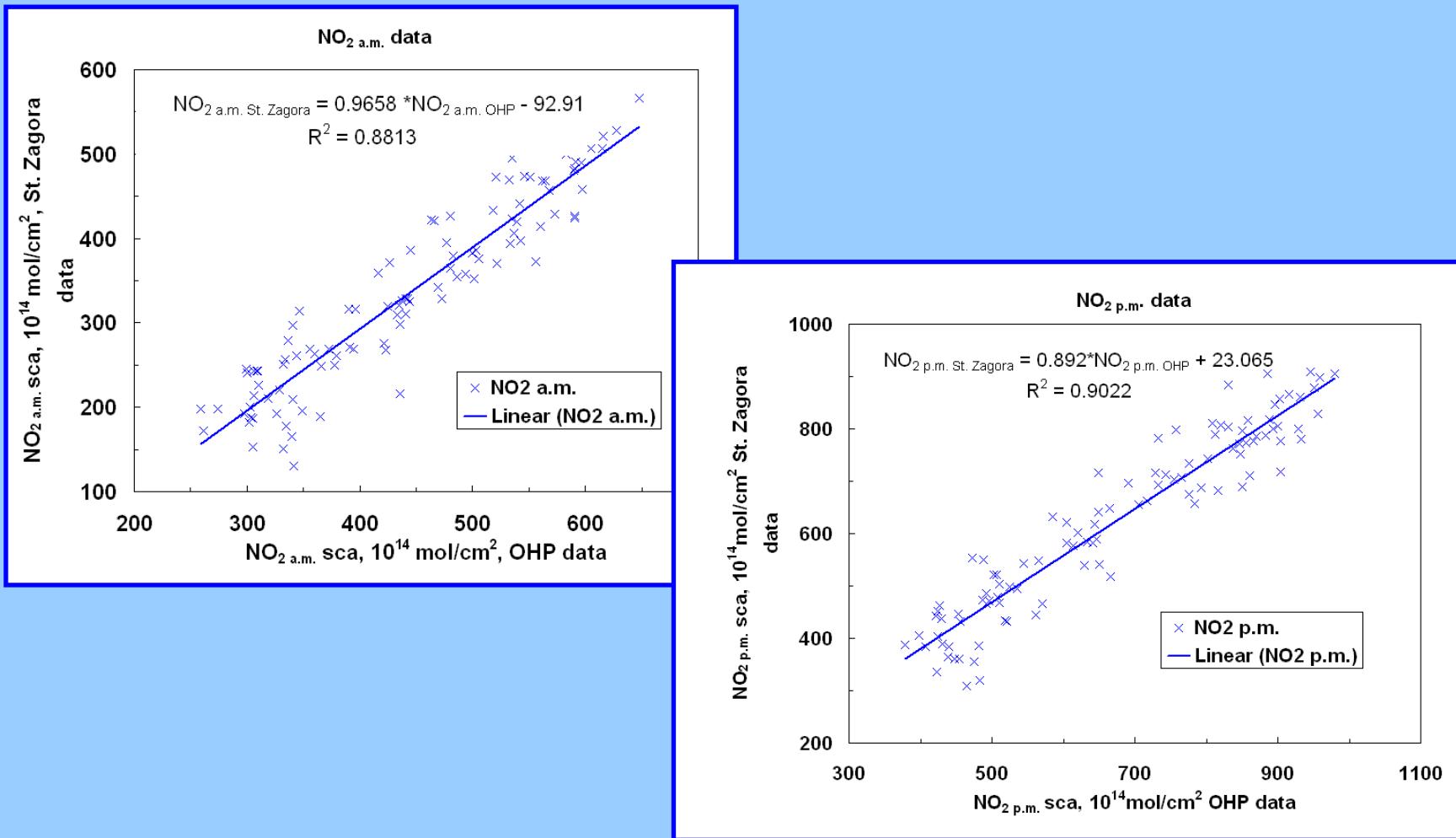
Available station a.m. data



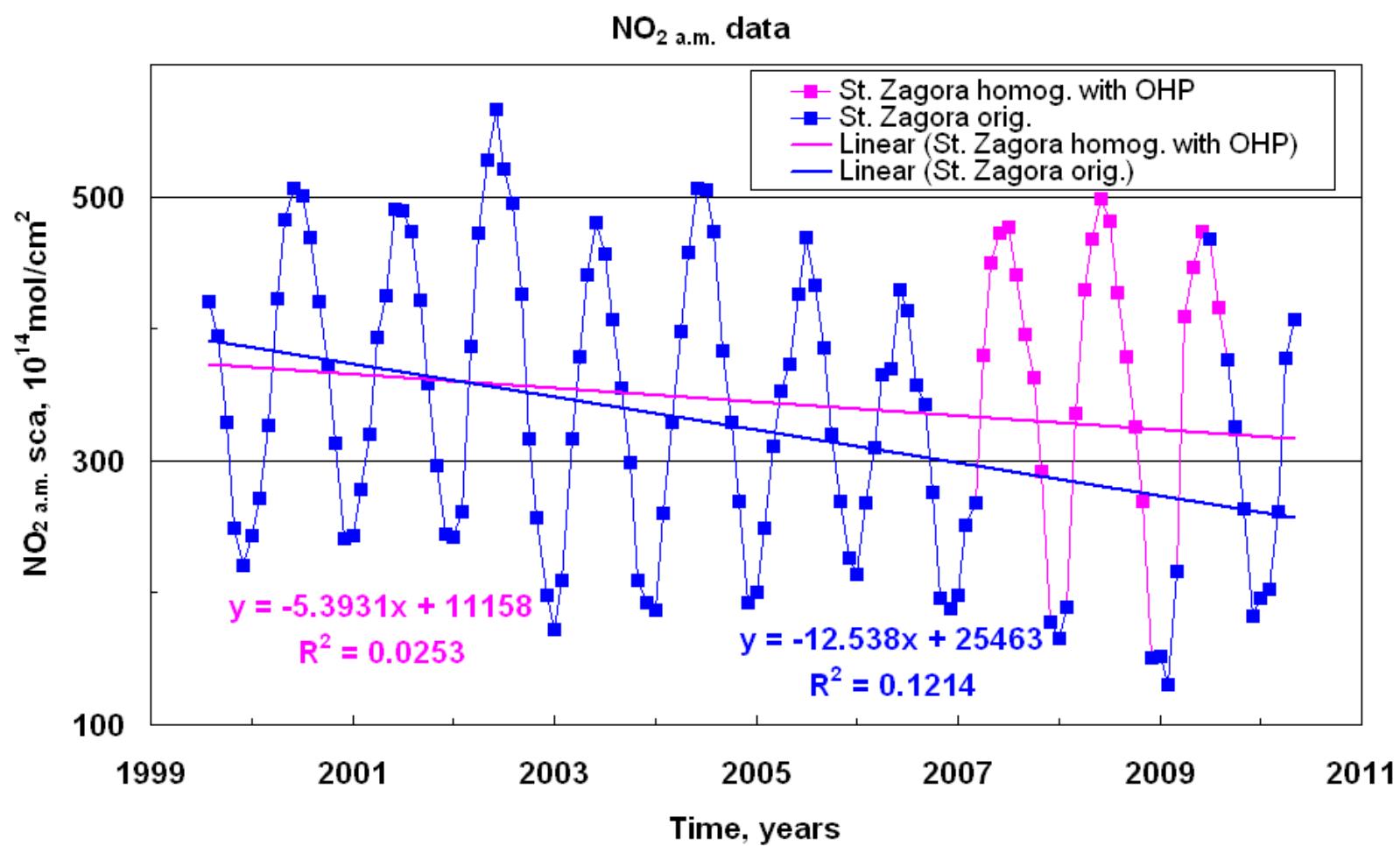
Total NO₂ a.m. sca data



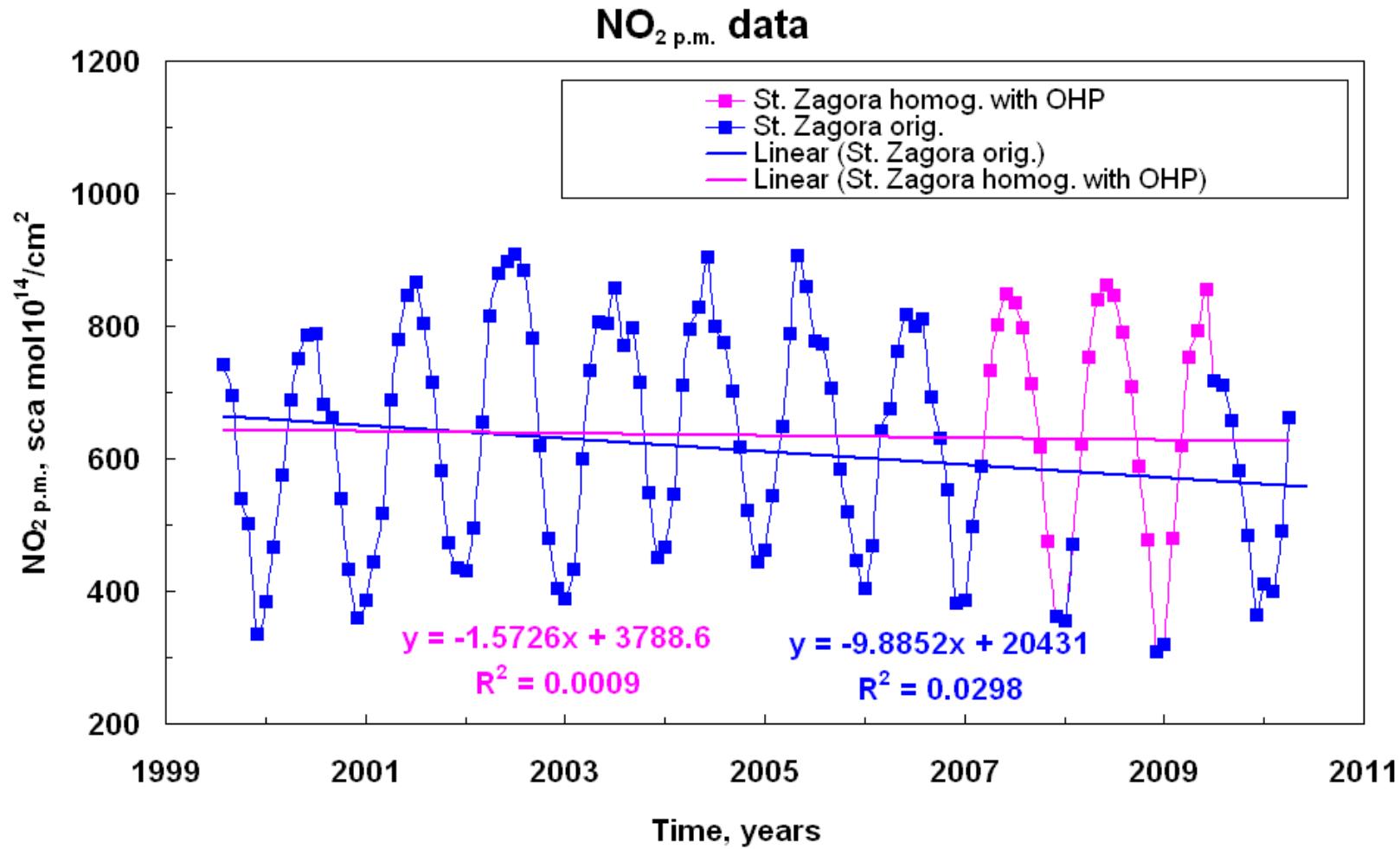
NO_2 a.m. sca- linear regression



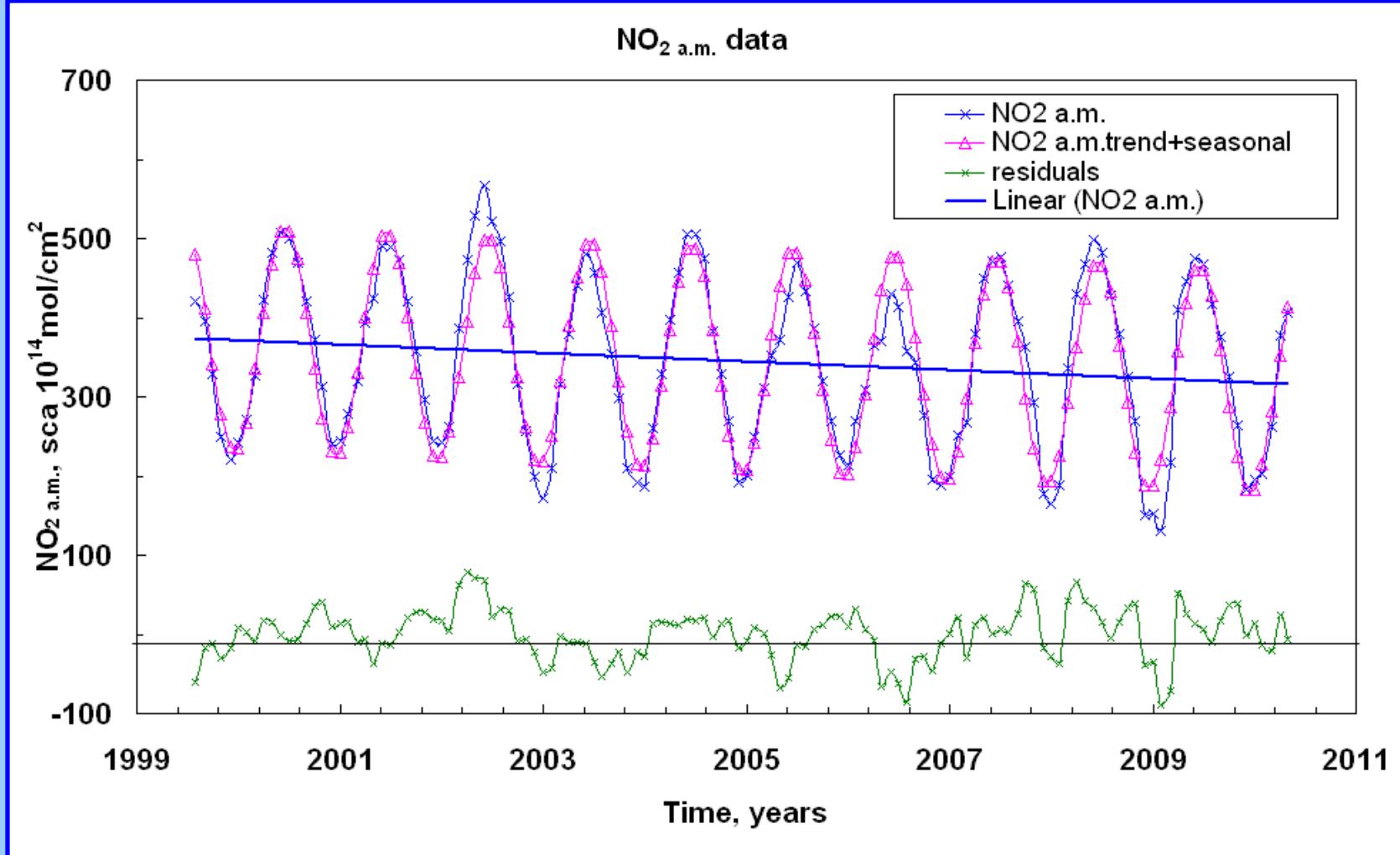
Total NO₂ a.m. sca, homogenized Stara Zagora data



Total NO₂ p.m. sca, homogenized Stara Zagora data



Total NO₂ a.m. sca, homogenized Stara Zagora data



FFT has not a degree of freedom

→ Normalization and comparison with a statistical process (white noise or AR-process e.g.)

$$\frac{N|\hat{x}_k|^2}{2\sigma^2} \Rightarrow \frac{1}{2} \chi_2^2(p) P_k(\rho)$$

Torrence, Bul.
Amerc. Meteor.
Soc. , 1997

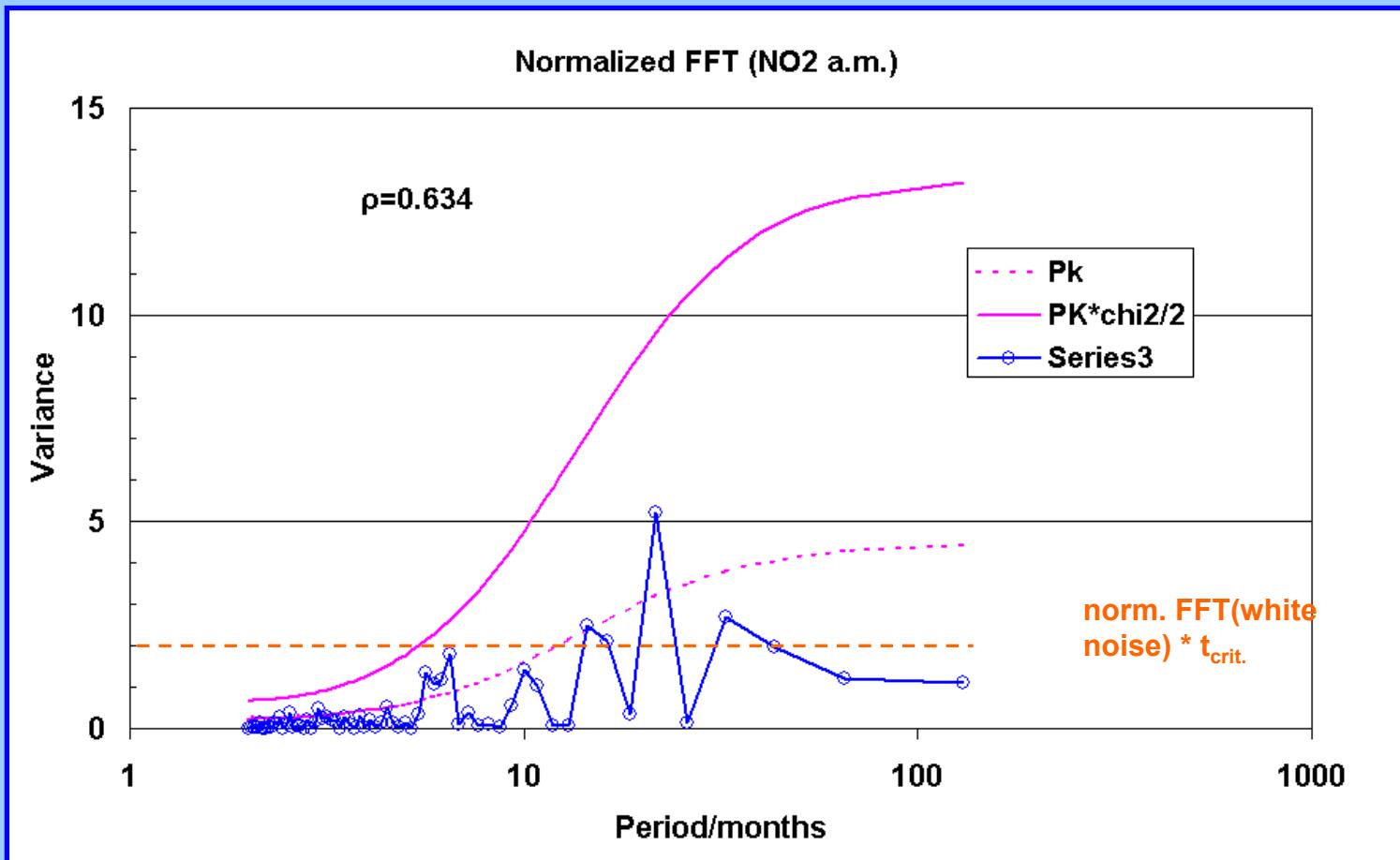
White noise: $P_k = 1$

AR(1)-process:

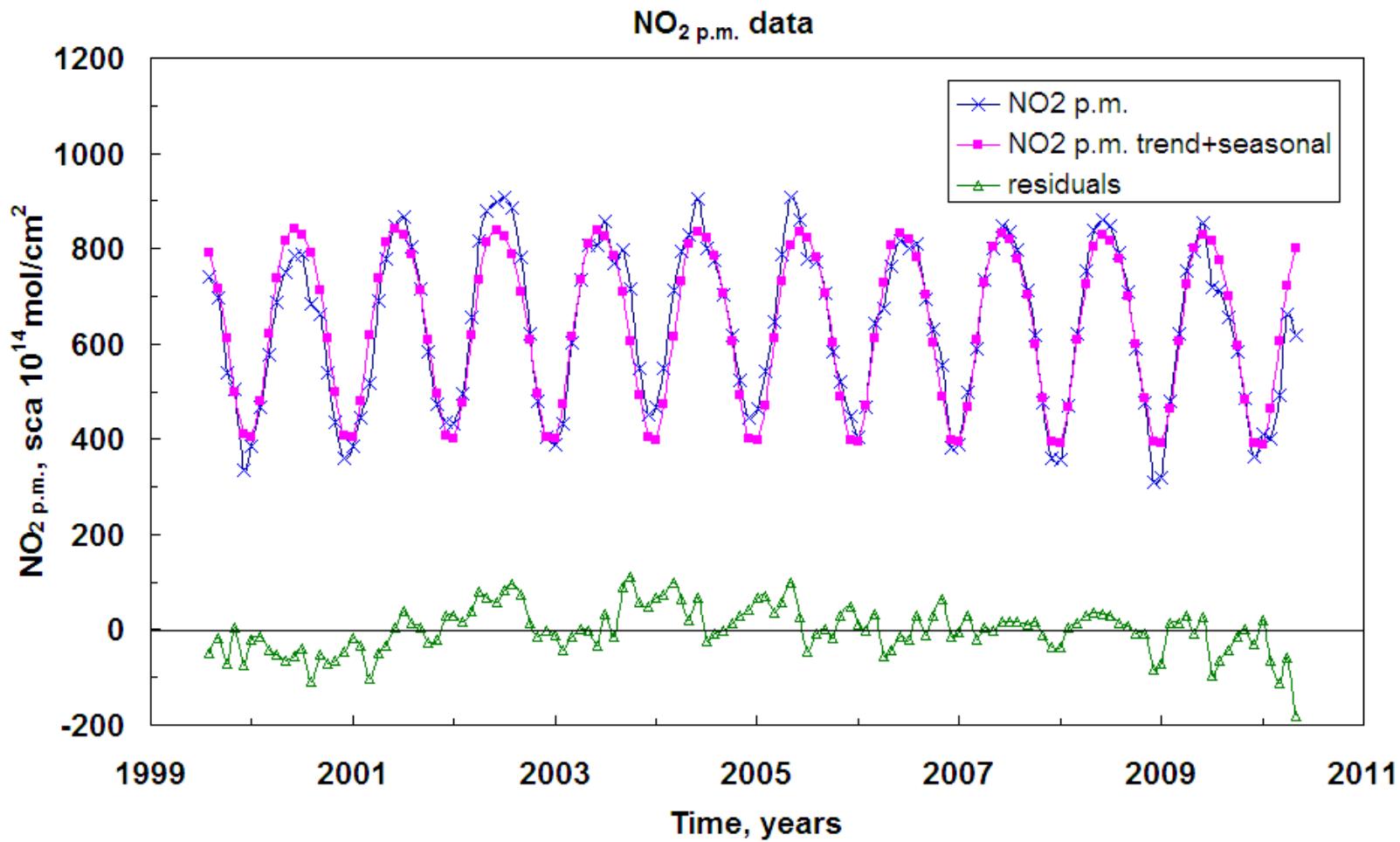
$$P_k = \frac{1 - \rho^2}{1 + \rho^2 - 2\rho \cos(2\pi k / N)}$$

Gilman, Journ.
Atm. Sci., 1962

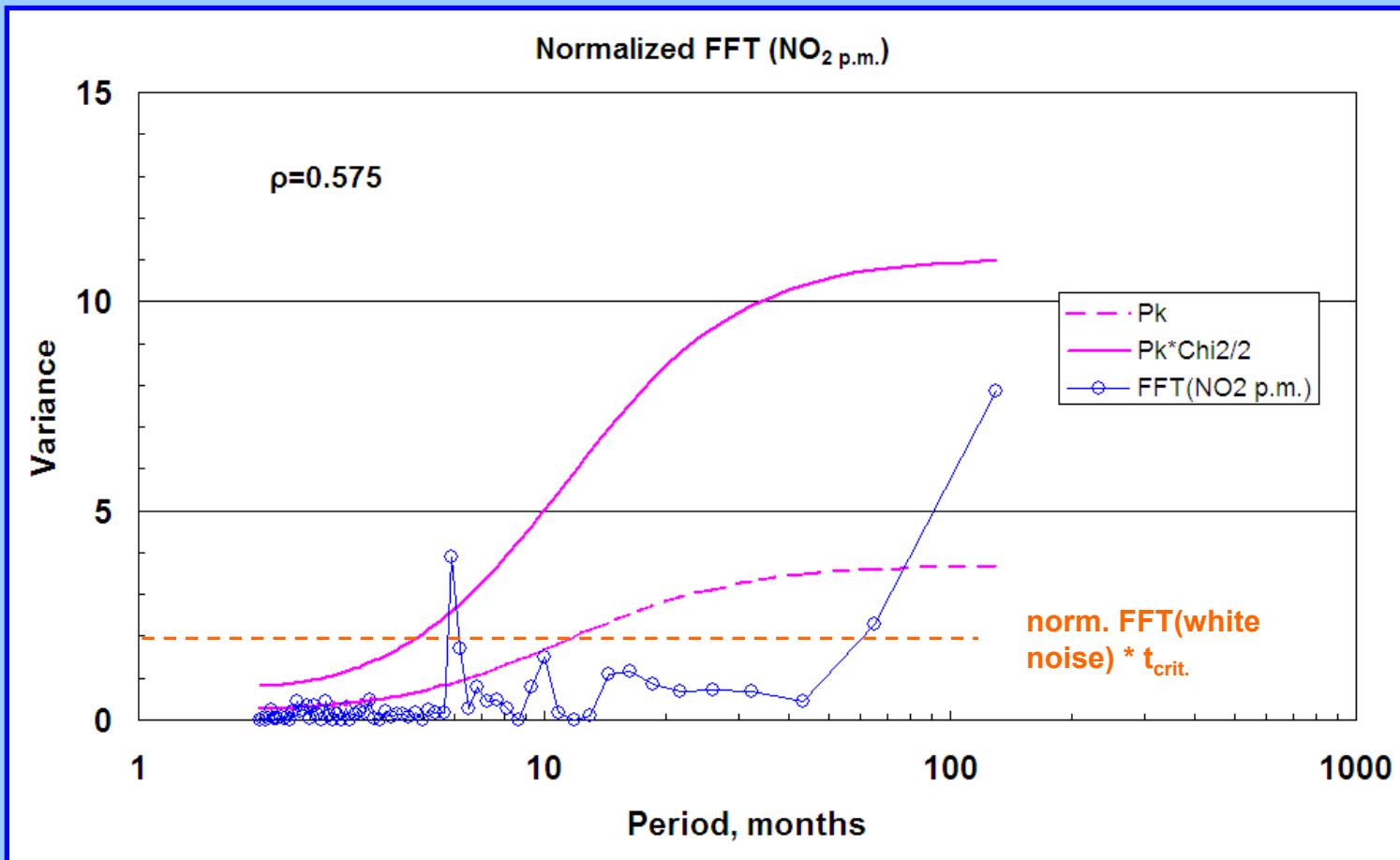
Normalized FFT



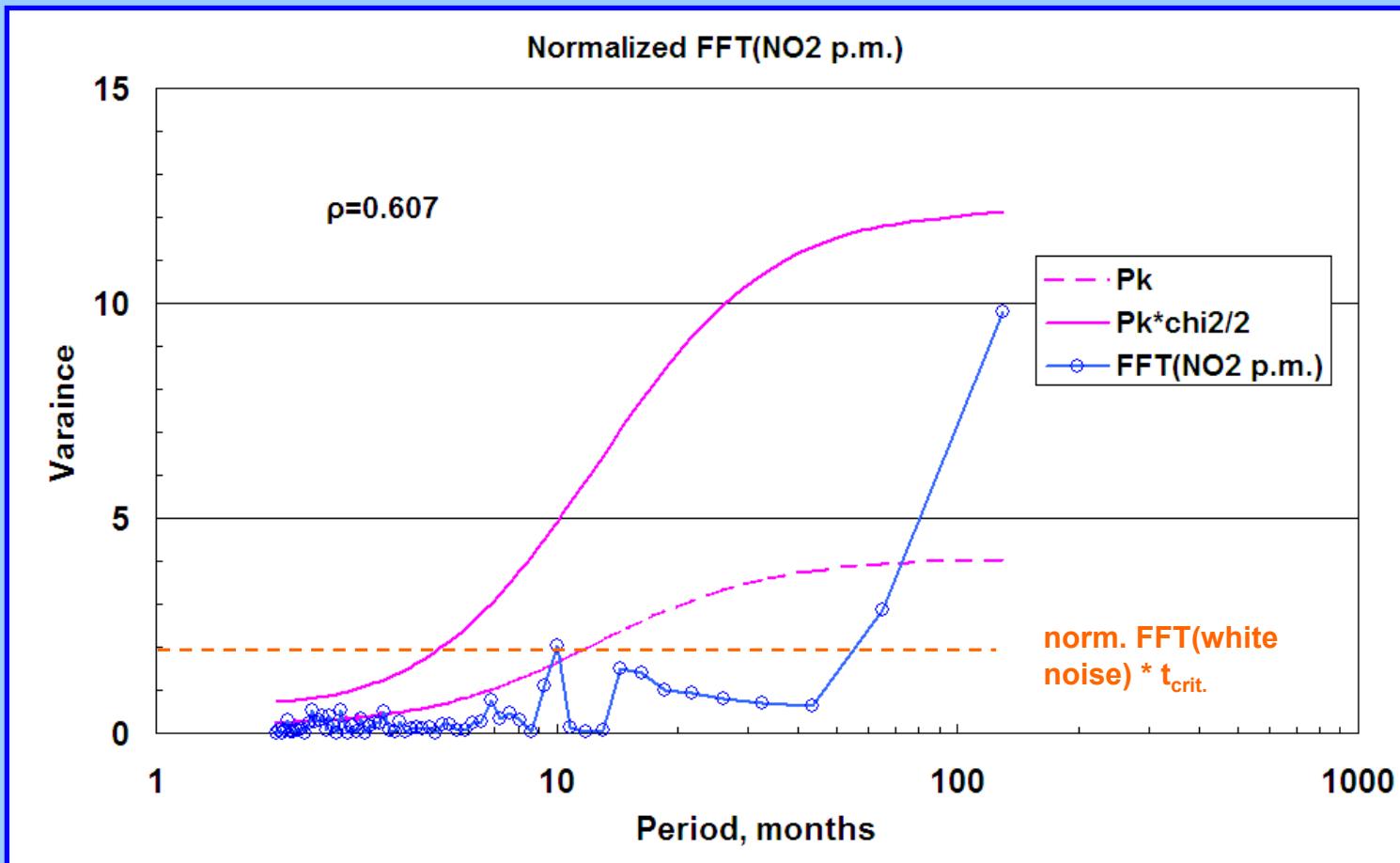
Total NO₂ p.m. sca, homogenized Stara Zagora data



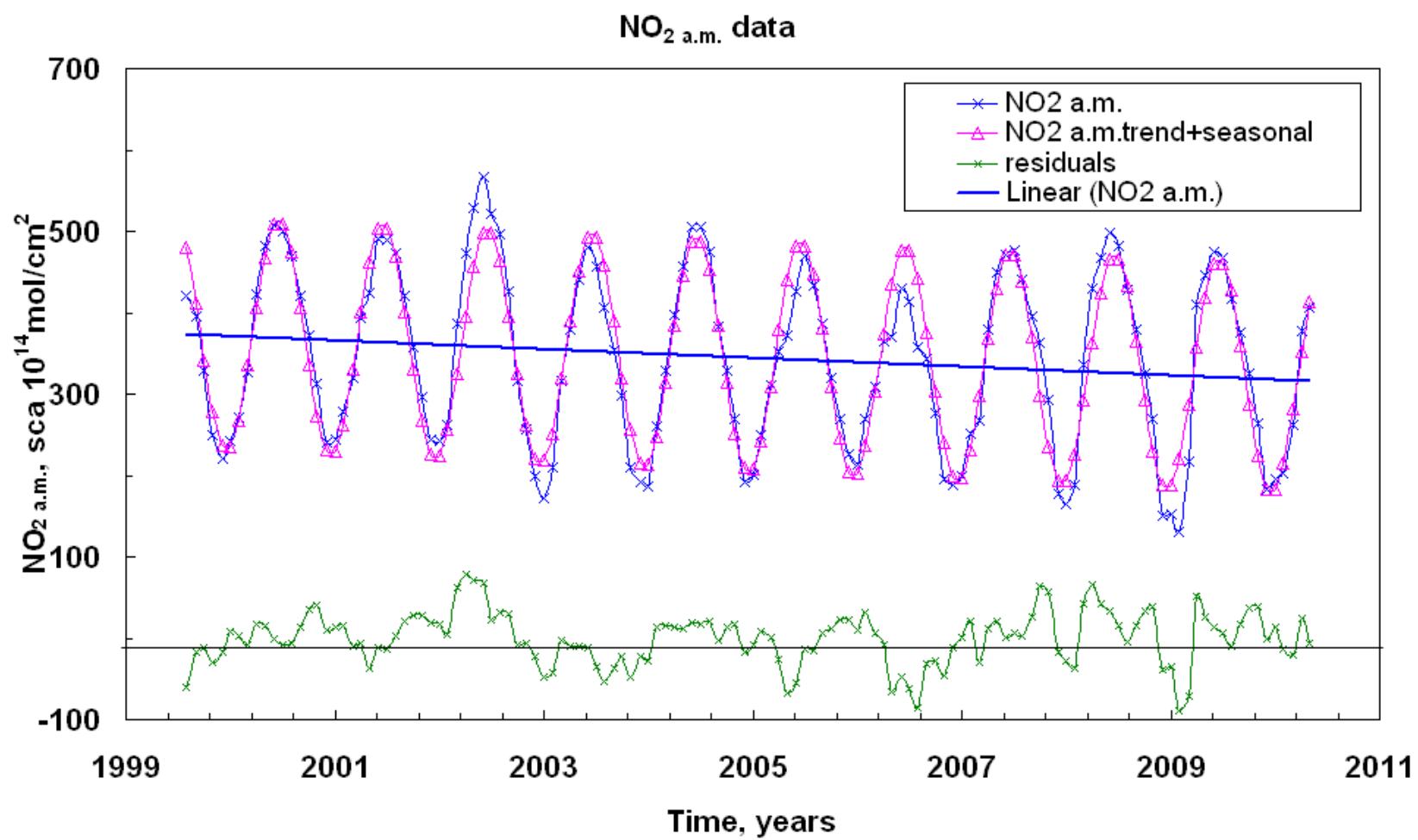
Normalized FFT



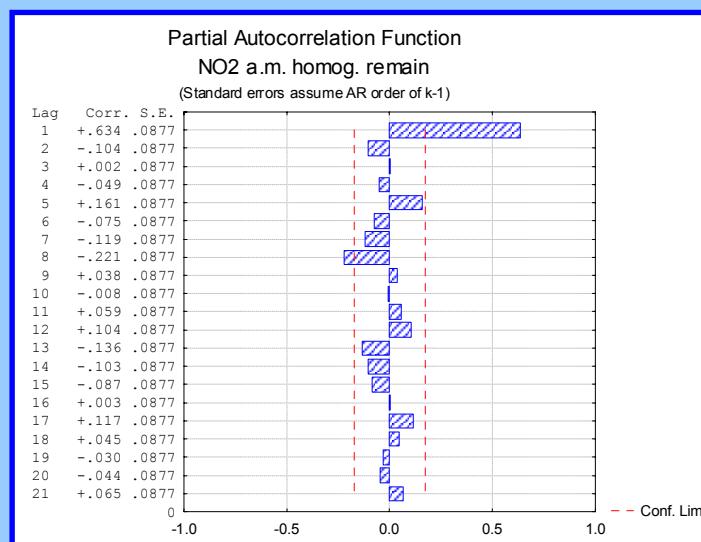
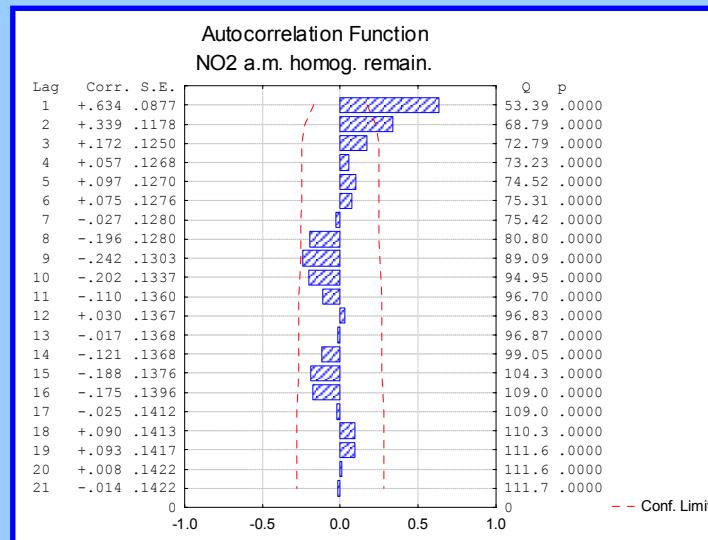
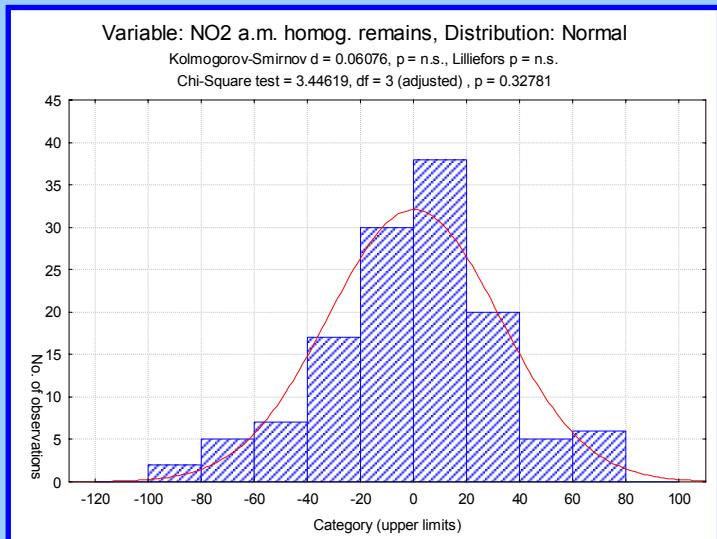
Normalized FFT



Total NO₂ a.m. sca, homogenized Stara Zagora data



Histogram, autocorr. function and partial autocorr. function



Cochrane-Orcutt method

method to overcome

the error term auto-correlation:

What we have to do?

$$y_t = \alpha + \beta x_t + \varepsilon_t$$

$$\varepsilon_t = \rho \varepsilon_{t-1} + u_t$$

$$y_{t-1} = \alpha + \beta x_{t-1} + \varepsilon_{t-1} \quad /* -\rho$$

$$y_t - \rho y_{t-1} = \alpha(1-\rho) + \beta(x_t - \rho x_{t-1}) + \varepsilon_t - \rho \varepsilon_{t-1}$$

Substit.: $y^* = y_t - \rho y_{t-1}$

$$x^* = x_t - \rho x_{t-1}$$

$$\alpha^* = \alpha(1-\rho)$$

$$u_t = \varepsilon_t - \rho \varepsilon_{t-1}$$

1. Determination of regr. coef. α and β by ord. least square

2. Determination of ρ by the help of the autocorrelation function

3. Transform y , x and α in to y^* , x^* and α^*

4. Regression of y^* on x^* , estimation of α^* and β and the standard errors

5. Test the residuals for autocorrelation → autocorrelation function, DW-test, if u autocorrelated → 3 with new ρ

$$y_t^* = \alpha^* + \beta x_t^* + u_t$$

Results

Trend NO₂ a.m. Stara Zagora

	After OLS	1. iteration	2. iteration
ρ	0.634	0.087	0.008
β	-5.2	-6.0	-5.8
σ_β	± 0.92	± 1.9	± 2.1
$\Delta\beta = \sigma_\beta * t_{\text{crit.}}$	± 1.8	± 3.7	± 4.1
$(\beta \pm \Delta\beta)$ relative	$(-13 \pm 5) \%$ per decade	$(-15 \pm 10) \%$ per decade	$(-15 \pm 11) \%$ per decade

$$t_{\text{crit.}} = 1.96$$

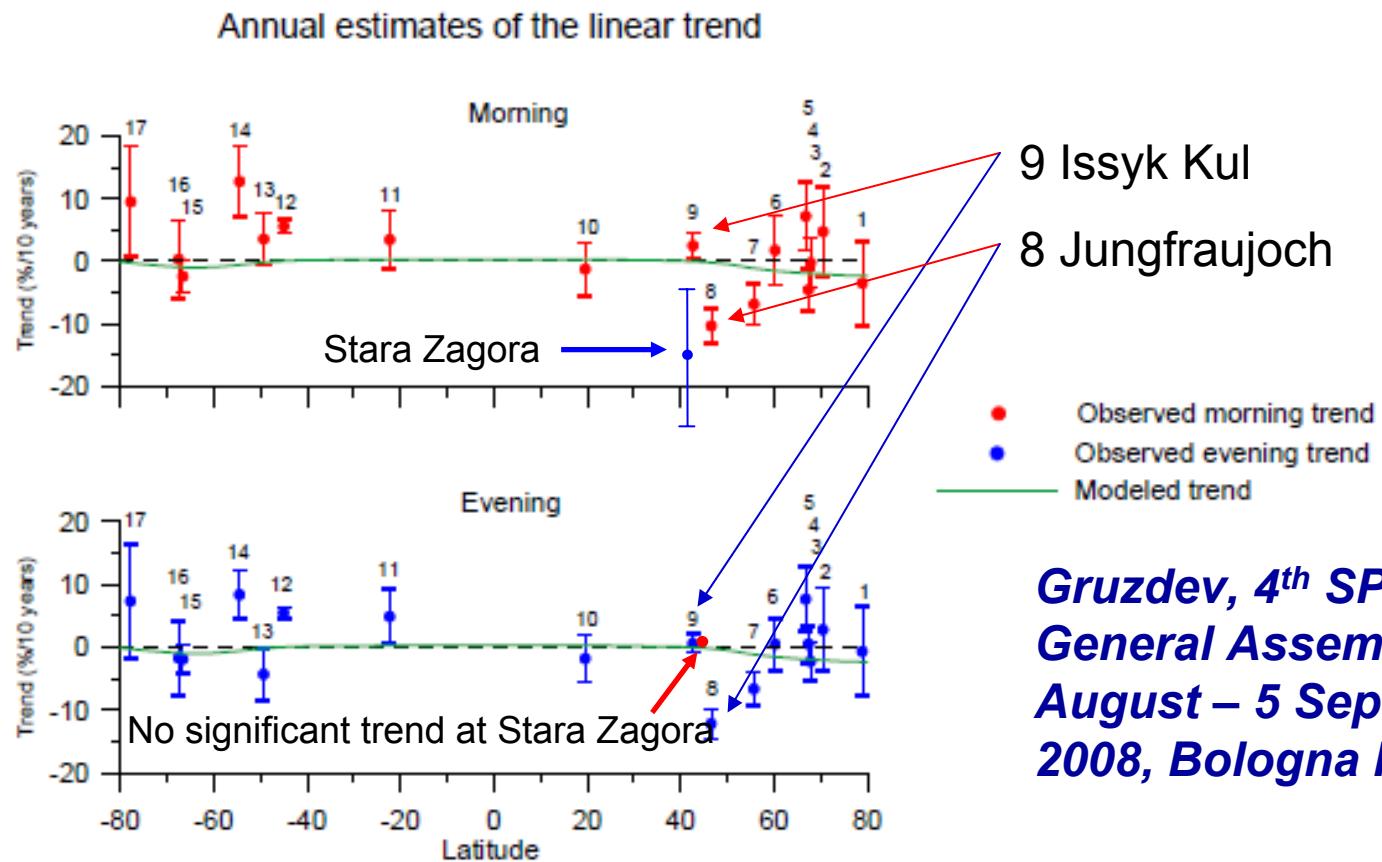
Results

Trend NO₂ p.m. Stara Zagora

	After OLS	1. iteration	2. iteration
ρ	0.607	0.047	0.003
β	-1.7	-3.5	-2.7
σ	± 1.4	± 2.8	± 2.7
$\Delta\beta = \sigma^* t_{\text{crit.}}$	± 2.8	± 5.4	± 5.3
$(\beta \pm \Delta\beta)$ relative	$-2.7 \pm 4.3\%$ per decade	$-5.4 \pm 8.4\%$ per decade	$-4.2 \pm 8.2\%$ per decade

$$t_{\text{crit.}} = 1.96$$

Stratospheric linear trends as function of the latitude



*Gruzdev, 4th SPARC
General Assembly, 31
August – 5 September
2008, Bologna Italy*

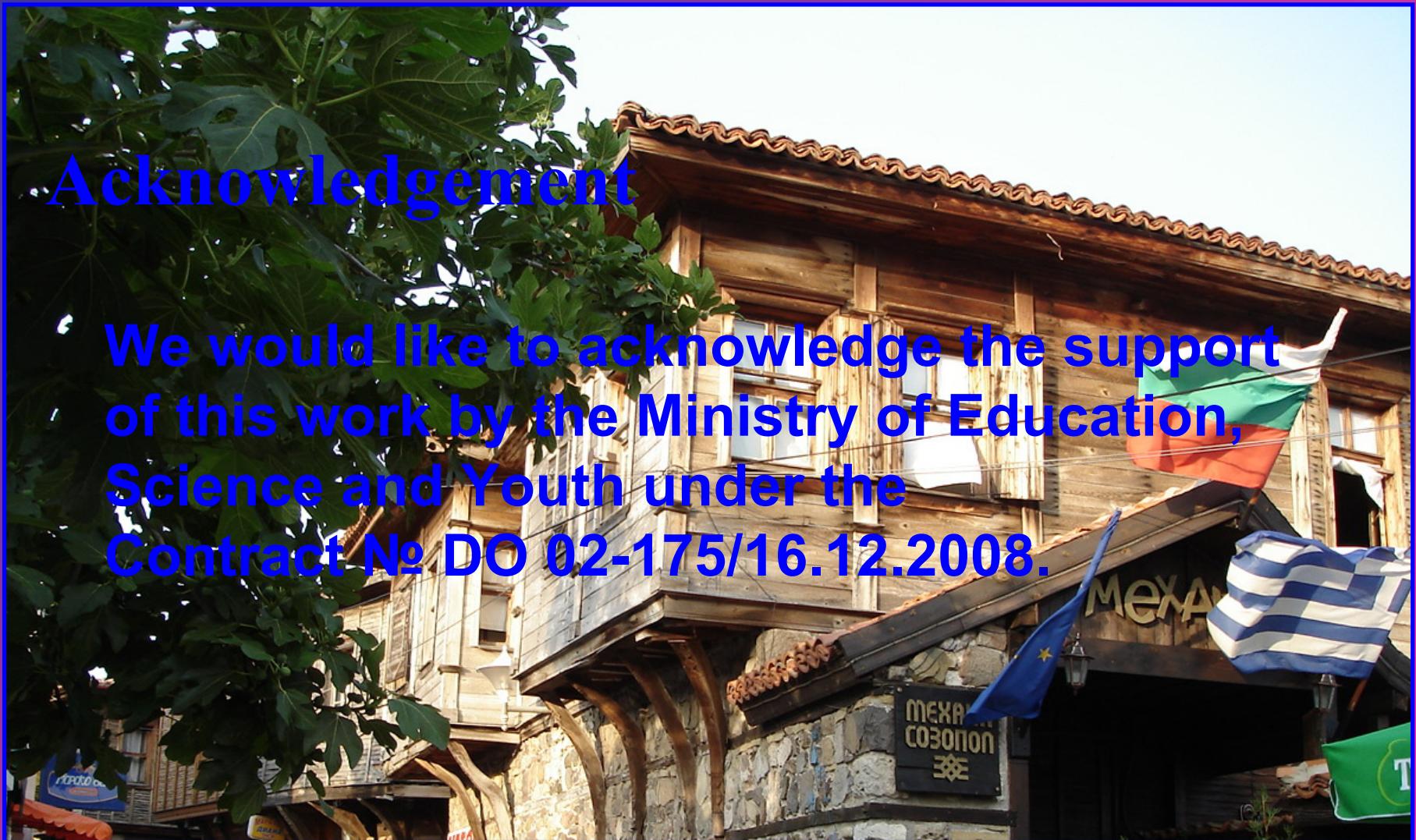
Fig. 3. Annual estimates of the stratospheric NO₂ linear trends as function of latitude according to morning and evening measurements and SOCRATES model calculations. The vertical segments are 95% confidence intervals. The numbers are station numbers in Table.

Conclusions

- The obtained monthly time series can be described by a simple model, containing a linear trend and a seasonal component, which consists of a harmonic annual term for the a.m. series and twelve and six month periodic terms for the p.m. series.
- The slopes depending strongly from the missing data
- It was demonstrated that the remaining part corresponding to an error term is autocorrelated in order of 0.6.
- By the application of the Cochrane-Orcutt-Method this autocorrelation was removed allowing estimation of the confidence interval based on the Student's *t*-distribution.
- Taking in account the autocorrelation the obtained confidence interval is twice related to interval obtained by the regression based on the OLS without removal of the autocorrelation.

Acknowledgement

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Solar influences on the magnetosphere, ionosphere and atmosphere,
Sozopol, Bulgaria, 6-10 June 2011



A scenic coastal town is built on a rugged, rocky cliff overlooking the deep blue sea. The town features several multi-story buildings with red-tiled roofs, some with balconies. In the foreground, large green leaves from a fig tree partially obscure the view. The sky is clear and blue.

Thank you
very much for
your attention

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Manny thanks
to the
organizers
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and
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and to
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for the
technical
assistance