On the use of a Regression Model for Trend Estimates from Ground-based Atmospheric Observations in the Southern Hemisphere

H. Bencherif, N. Mzé, N. Bègue, N. Calonne, R. Diab, V. Sivakumar, P. Keckhut

Laboratoire de l'Atmosphère et des Cyclones, UMR 8105, Université de la Réunion, CNRS-INSU, St-Denis, Reunion Island, France
University of KwaZulu-Natal, Durban 4041, South Africa
National Laser Centre, Council for Scientific and Industrial Research, Pretoria 0001, South Africa.
Laboratoire Atmosphères, Milieux, Observations Spatiales, UMR 8190, Institut Pierre-Simon Laplace, Université Versailles St-Quentin, CNRS-INSU, Paris, France

Abstract

The present paper reports on the use of a multi-regression model adapted at Reunion University for temperature and ozone trend estimates. Depending on the location of the observing site, the studied geophysical signal is broken down in form of a sum of *forcings* that explain most of its variability. The trend values are then derived from the residual terms as a linear function. The paper discusses different case-studies by using different parameterisation, and reports on retrievals of temperature and ozone trend estimates over different sites in the southern hemisphere: South Africa (Durban and Upington), Reunion Island and Argentina (Buenos-Aires).

The Trend-Run model

Contrary to the Northern Hemisphere, trend estimates in the Southern Hemisphere (SH) are under-reported. The present paper is based on results from a research project carried out at Reunion University (LACy, a CNRS research unit for atmospheric sciences). The study was initially developed in the frame of a PhD project (Portafaix, 2001) from an adaptation of AMOUNT (Adaptive MOdel UNambiguous Trend Survey) and AMOUNTS-O_3 models developed for ozone and temperature trend assessments (Hauchecorne et al., 1991; Keckhut et al., 1995; Guirlet et al., 2000). The adapted version is named Trend-Run. The Trend-Run model is hence a regression model based on the principle of breaking down the variations of a time series *Y(t)* at a specific height, *z*, into the sum of different *forcings* that explain the variations of *Y(t)*:

$$Y(z,t) = \sum_{i=1}^{p} a_k(z) \times X_k(t) + r \qquad \text{(Eq.1)}$$

where:

- X_k describes the temporal evolution of the *forcing k:* X_k represents the matrix of *forcing*;
- a_k is a coefficient computed by the model for the *forcing k*;
- *r* is the residual term, assumed containing trend and noise.

The Trend-Run model is based on the principal of a linear multi-regression between *Y* and *X*. It consists in finding the linear function $X.a + r$ which describes best the variations of *Y* depending on *X*, i.e., following the Eq.1 in its matrix presentation: $\boldsymbol{Y} = \boldsymbol{X.a} + \boldsymbol{r}$. The least-square method used for the regression calculates the coefficients *a* by minimizing the sum of the residual squares, so that:

$$r^2 = [Y - X.a]^2 \qquad \text{(Eq.2)}$$

Once the coefficients *a* are retrieved, the associated parameters *X* are removed from the studied geophysical signal *Y*.

In its initial version, as used by Bencherif et al. (2006), the Trend-Run model considers the main *forcings*, i.e., annual and semi-annual oscillations (AO, SAO), quasi-biennale oscillation (QBO), El-Nino Southern Oscillation (ENSO), and the 11-years solar cycle. AO and SAO are taken as being the mean seasonal cycles. Moreover, the monthly mean zonal wind speed at Singapore at 40-hPa level and the South Oscillation Index are used to parameterize the QBO (Li et al., 2008) and the ENSO cycles respectively, while the 11-year solar cycle is defined as a linear function correlated with the solar flux at 10.7cm.

A statistical parameter that is used to quantify how well the regression fitting model describes the geophysical signal is the coefficient of determination R^2. It is defined as the ratio of regression sum of squares to the total sum of squares. R^2 measures the proportion of the total variation in the studied signal *Y* explained by the regression model. When the regression model explains the total variation in the geophysical signal *Y*, the value of R^2 is close to unit; while, on the contrary, when the model does not picture all the contributing *forcings*, R^2 tends to zero.

Regarding the trend, it is derived from the residual term *r*, and it is parameterised as a linear function:

$$Trend(t) = \alpha_0 + \alpha_1.t \qquad \text{(Eq.3)}$$

where *t* denotes the time range, α_o is a constant, α_1 is the slope of *Trend(t)* line that estimates the trend over the time scale.

Figure 1 shows an example (see figure caption) and depicts the studied geophysical signal (blue line) together with the simulated signal by Trend-Run regression model (red line). Note that the coefficient of determination R^2 obtained for that case study is ~0.80. It suggests that the model reproduces most of the variability of the studied signal.

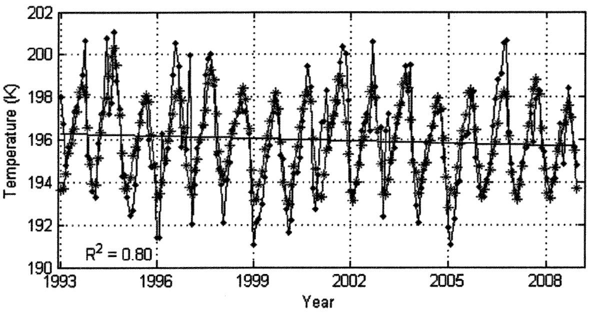

Figure 1:

Time evolution of monthly temperature values as observed over Reunion Island at CPT (Cold Point Tropopause) by weekly radiosonde observations from January 1993 to December 2008 (blue line), the superimposed red star line represents CPT values as simulated by Trend-Run regression model, while the black straight line illustrates a decreasing temperature trend at the local tropopause. The corresponding coefficient of determination R^2 is showed, $R^2 = 0.80$.

One should note that Eq.1 and Eq.2 above depict the theoretical parameterisation of the geophysical signal *Y*. Actually, that parameterisation depends on the *forcings* that contribute significantly to the signal, indeed on the location of the observing site.

In the present study, we report on temperature and ozone trend estimates as derived from the Trend-Run regression model over different sites in the SH: South Africa (Durban and Upington), Reunion Island and Argentina (Buenos-Aires).

Acknowledgement

The authors are grateful to the South African Weather Service (SAWS) for providing upper-air data, to the National Meteorological Service of Argentina (NMSA) for ozone data available on the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) and to the Observatory of Atmospheric Physics of Reunion Island (OPAR) for their cooperation in radiosonde launching and data processing, within the framework of the NDACC and SHADOZ networks.

References

Bègue N., H. Bencherif, V. Sivakumar, G. Kirgis, N. Mzé, and J. Leclair de Bellevue, Temperature variability and trend estimates at tropopause and UT-LS over a subtropical site: Reunion (20.8°S, 55.5°E), *Atmos. Chem. Phys. Diss.*, 10, 10113–10143, 2010

Bencherif H., Diab, R.,. Portafaix, T., Morel, B., Keckhut, P., and Moorgawa, A., Temperature climatology and trend estimates in the UTLS region as observed over a southern subtropical site, Durban, South Africa, *Atmos. Chem. Phys.*, 6, 5121-5128, 2006

Guirlet M., Keckhut, P., Godin, S., and Megie, G., Description of the long-term ozone data series obtained from different instrumental techniques at a single location: the Observatoire de Haute-Provence (43.9° N, 5.7° E), *Ann. Geophys.*, 18, 1325–1339, 2000

Hauchecorne, A., Chanin, M.L., and Keckhut, P., Climatology and trends of the middle atmospheric temperature (33-37 km) as seen by Rayleigh lidar over the south of France, *J. Geophys. Res, 96,* 15,297-15,309, 1991

Keckhut, P., Hauchecorne, A., and Chanin, M.L, Midlatitude long-term variability of the middle atmosphere: Trends and cyclic and episodic changes, *J. Geophys. Res.,* 100 D9, 18,887-18,897, 1995

Li, T., Leblanc, T. and. McDermid, I..S., Interannual variations of middle atmospheric temperature as measured by the JPL lidar at Mauna Loa Observatory, Hawaii (19.5°N, 155.6° W), *J. Geophys. Res.*, 113, D14109, doi: 10.1029/2007JD009764, 2008

Portafaix, T., Ozone stratosphérique en zone tropicale sud: transport meridien et effet de barrière dynamique, thèse de Doctorat, Université Paris VI (UPMC), 2001