ON DETERMINATION OF MEAN VALUES OF OBSERVED QUANTITIES ACCORDING TO O. Ya. ORLOV

M. Tyshchuk, A. Gozhy

Poltava Gravimetrical Observatory, NAS of Ukraine
27/29 Myasoedova Str., 36029 Poltava, Ukraine
e-mail: pgo@poltava.ukrtel.net

The definition of O. Ya. Orlov for mean values of observed quantities for any epoch suits for application not only in astronomy, and in geophysics, geodesy, meteorology. The method of seasonal decomposition and adjustment Census X-11 for realization of Orlov's definition in various areas of researches is used.

INTRODUCTION

In the scientific work [1] O. Ya. Orlov wrote: "In astronomy such definition is accepted: if any quantity has secular and periodic changes, its "mean" value for the given moment is equal to such its value, which this quantity would have, if there were no its periodic changes. This clear standard concept should use to define, what is "mean latitude" at the given moment: it is such value of latitude, which it would have at this moment, if there were no its periodic changes... Similarly told, "mean pole" at the given moment is named such position of pole, which it would occupy at the moment, if there were no its periodic fluctuations".

PURPOSE

It is necessary to note that O. Ya. Orlov's definition of "mean latitude" and "mean pole" is possible to generalize on any other observable quantities. Then it can be used not only in astronomy, and in other areas of researches, such as geodesy, geophysics, meteorology, *etc.* In particular, it can be applied for calculation of mean values of coordinates, gravity, atmospheric pressure, external temperature, levels of reservoirs, and other spatial, geophysical, and meteorological parameters for any given point and epoch of observation.

The determination of mean value of parameters for various epoch is very important to study of different evolutionary processes. It is also necessary for precision reductions of observations to basic points of various spatial, geophysical and other networks. If there are stations of complex diverse observations (for example astronomical, geodetic, geophysical), the knowledge of mean values of measured quantities is necessary very much for reduction of these observations to the certain geometrical centres in each epoch of observations and for common using and interpretation of results of observations.

O. Ya. Orlov's definition can be used not only in natural sciences, but in socio-economic sphere also.

METHOD

O. Ya. Orlov has developed the formulas for calculation of values of "mean latitudes" of points and positions of "mean pole" for any epoch of observations. These formulas (filters) were subsequently advanced by other authors. For discovering and exception of periodic fluctuations of the polar motion and other phenomena, the spectral analysis is also widely applied. But to take into account time variability of some fluctuations parameters is very difficult.

For calculation of the mean values of observable quantities we have applied a known method of seasonal decomposition and adjustment Census II (version X-11) [2]. Its program realization is in the STATISTICA 6 package [3]. The basic idea of seasonal decomposition is simple. In general, a time series can be thought of as consisting of four different components:

1. a seasonal component S_t, where t stands for the particular point in time;
2. a trend component T_t;
3. a cyclical component C_t;
4. an irregular component I_t.

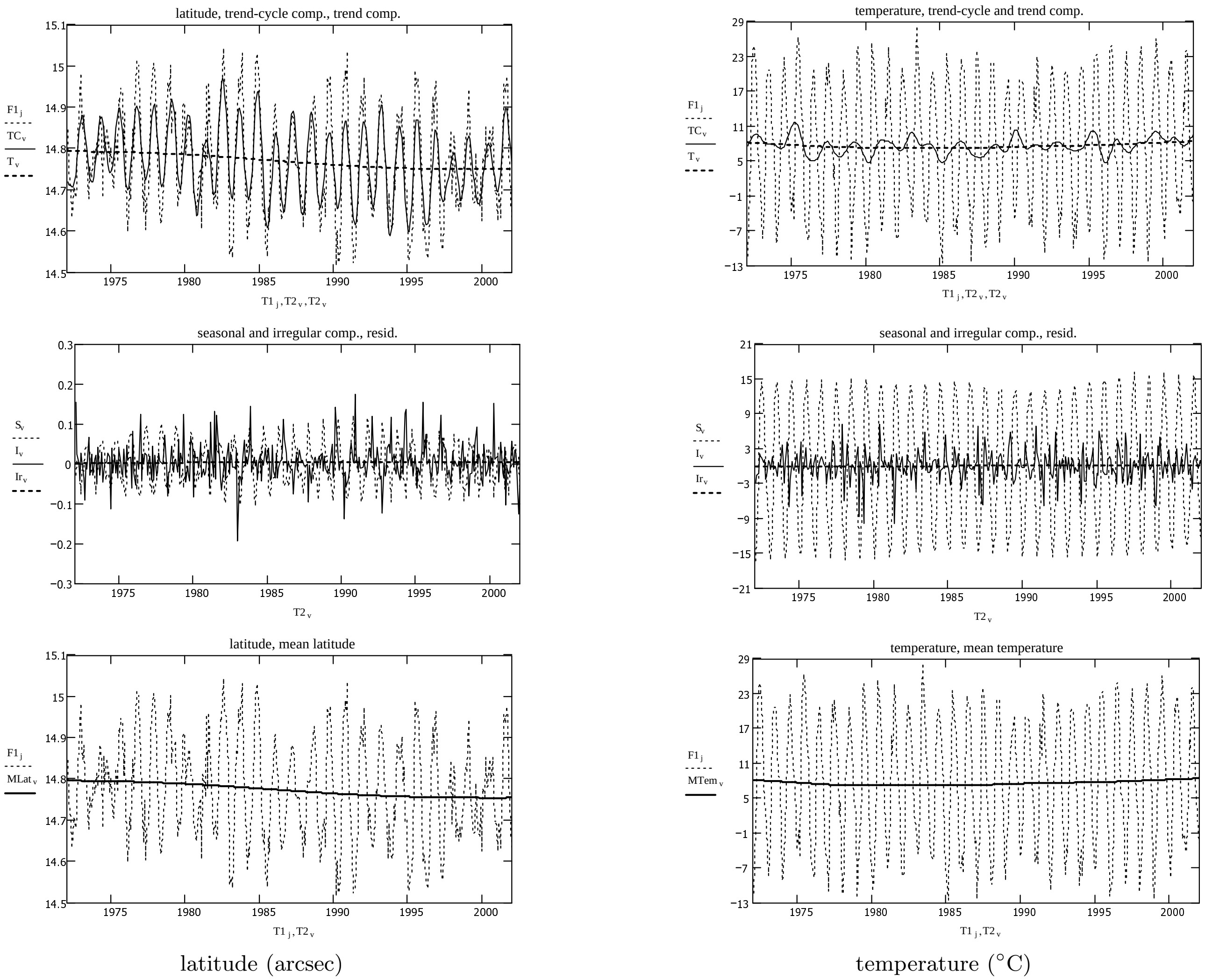


Figure 1. Results of the analysis of the astrometric and meteorological data

The difference between a cyclical and a seasonal component is that the latter occurs at regular (seasonal) intervals, while cyclical factors usually have a longer duration that varies from cycle to cycle. The trend and cyclical components are combined into a trend-cycle component (TC_t) in this realization of Census II method. An irregular component represents residual movement and errors of observations. The specific functional relationship between these components can assume different forms. However, two straightforward possibilities are that they combine in an additive or a multiplicative fashion. We used additive model:

$$X_t = TC_t + S_t + I_t, \tag{1}$$

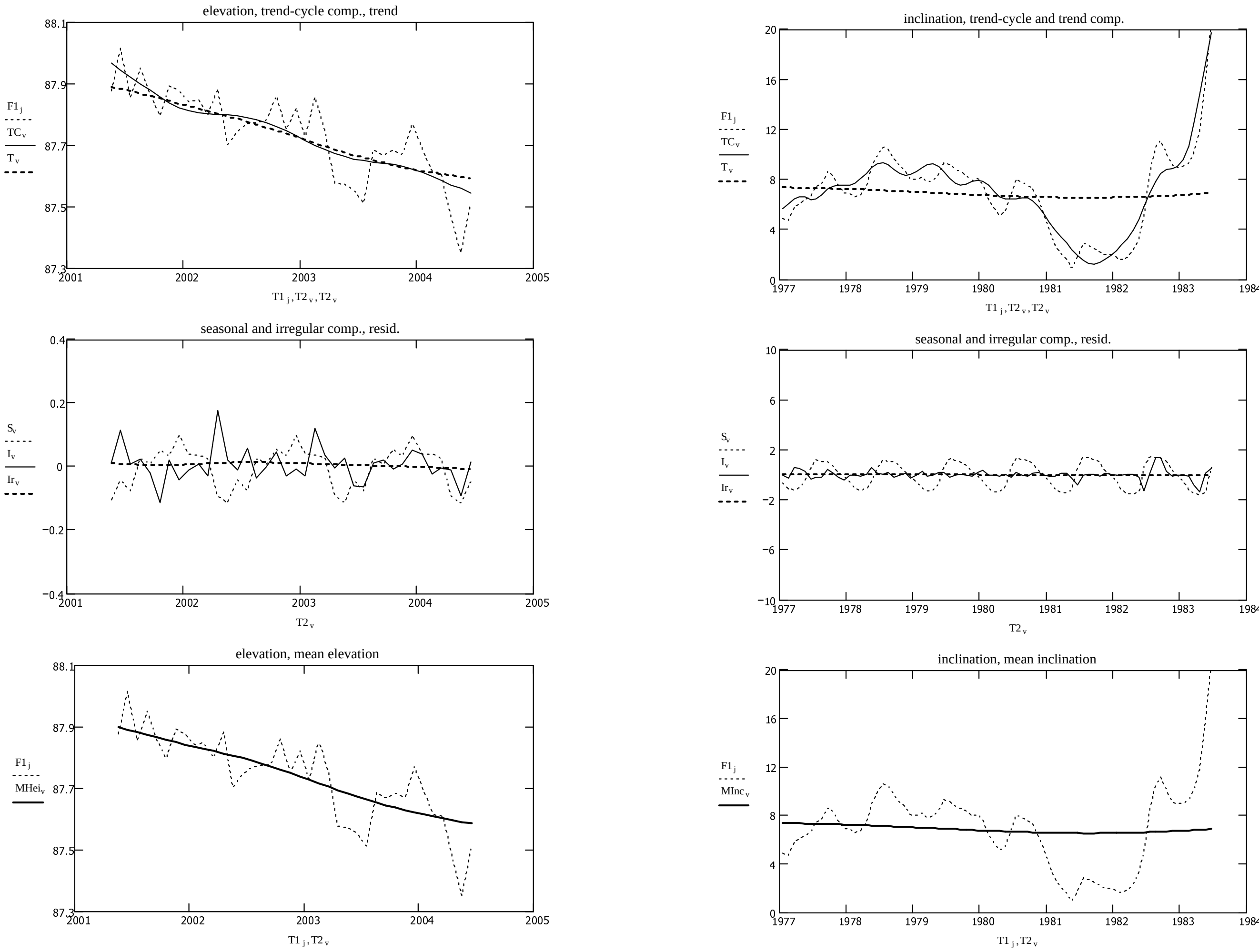
where X_t designates value of a time series at the moment of time t.

Proceeding from definition, that the mean value is such value, in which there are no periodic fluctuations, the formula (1) can be written down in the following kind:

$$Xmean_t = T_t + Ir_t, \tag{2}$$

where $Xmean_t$ is the mean value of quantity of a time series at the moment of time t, Ir_t is the residual movement in an irregular component.

To select trend component from trend-cycle component we used Gaussian smoothing method. It is difficult to separate residual movement from errors of observations, therefore, we have entered an additional condition, having admitted, that the smoothed irregular component is a residual movement. The same method of smoothing in this case was used.



elevation (mm) inclination (arcsec)

Figure 2. Results of the analysis of the geodetic and geophysical data

DATA FOR THE ANALYSIS

To illustrate calculation of mean values of observable quantities, we used time series of observations of various length and from different fields of knowledge. In accordance with the rules of processing of time series by the STATISTICA 6 package we used not individual values of the measured quantities, but their monthly average values. These time series are following:

1. astrometric (7723 latitude observations of bright zenith stars α Per and η UMa with the ZTL-180 zenith-telescope for the 30 years period (1972.0–2002.0) in Poltava (360 monthly average values));
2. geodetic (152 precision determinations of the elevation between two deep bench mark $A1$ and $A4$ (depth of laying is 6.0 m) by a geometrical levelling method for the 3.1 years period (4.05.2001–30.06.2004) in Poltava (38 monthly average values));
3. geophysical (2372 daily determinations of inclination of a terrestrial surface with pitchmeter in a direction “north–south” for the 6.5 years period (1.01.1977–30.06.1983) in excavation of 6 m depth near the field of hydrochloric mine in Soledar (78 monthly average values));
4. meteorological (3878 determinations of air temperature during the latitude observations of bright zenith star α Per with the ZTL-180 for the 30 years period (1972.0–2002.0) in Poltava (360 monthly average values)).

RESULTS

After seasonal decomposition of time series for each kind of observations the trend-cycle, seasonal and irregular components are received. Thus, the trend-cycle and seasonal components have complex structure and well reflect changes of observed quantities. To select trend component from trend-cycle component and residual movement from irregular component we used Gaussian smoothing method. Width of a smoothing window was selected individually for each time series to exclude its long-period fluctuations.

After analysis three diagrams are constructed for each kind of observations (Figs. 1 and 2). There are curves of monthly average values of observable quantity (dotted line), trend-cycle component (solid line) and trend (dashed heavy line) on the first diagram. Seasonal component (dotted line), irregular component (solid line), residual movement (dashed heavy line) are submitted on the second diagram. Curves of monthly average values (dotted line) and mean values of observable quantity (solid heavy line) are shown on the third diagram.

As it is seen from results of calculations and diagrams the seasonal decomposition method is quite suitable for determination of mean values of various spatial, geophysical and meteorological parameters. It has the following advantages in comparison with other ways. It is not necessary in this case to know beforehand , what components make general change of quantity, and so is not necessary to know their characteristics. Besides, in this method a changeability of the characteristics of the basic periodic components (seasonal and cyclical) are taken into account. It allows rather precisely to exclude them.

The defects of the Census X-11 method in its program realization STATISTICA 6 are following. The irregular component is not separated into residual movement and errors of observations, trend is not selected separately, long-period component is not determined. But last two obstacles can easily be bypassed, for example, how it is shown above.

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[1] *Orlov A. Ya.* Service des latitudes.–Moscou, 1958.–126 p. (in Russian).

[2] *Shiskin J., Young A. H., Musgrave J. C.* The X-11 variant of the Census Method II seasonal adjustment program // U. S. Dept. of Commerce, Bureau of the Census, Technical Paper.–1967.–N 15.

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