Short-period variations in the Erath rotation and global deformation processes in the lithospere

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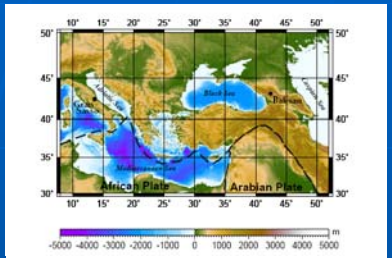
ABSTRACT

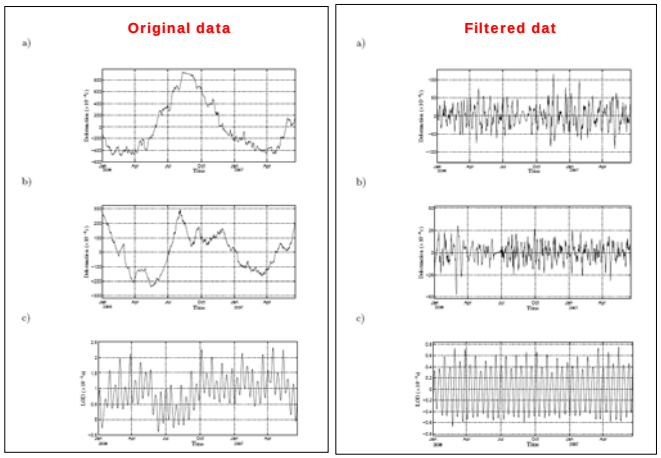
Strain data recorded by two laser interferometer-strainmeters operating in the Baksan (Russia) and Gran Sasso (Italy) underground observatories, and the length-of-day (LOD) data describing the variable rate of the Earth's rotation are used to study the relation between the deformation processes in the lithosphere and the global geodynamics of the Earth over short time intervals. The methods applied are based on analysis of the coherence of the studied processes, and correlation analysis. A significant (90%) correlation is revealed between the local deformation fields at two remote observation stations, which proves the existence of a global (at least on the scale of the Eurasian plate) component in the Earth's deformation field that manifests itself at characteristic time intervals of up to 1–2 months. At the same level of significance, the correlation between the local deformation fields and variations in the rate of the Earth's rotation has also been identified. The found correlations in the tidal low-frequency range are caused by the direct impact of the long-period tidal loading (M_f and M_{tm} waves) on the lithosphere and the length-of-the-day (LOD). On the contrary, the significant correlation in the non-tidal range is probably linked to irregular perturbations of the continental character, which create a coherent interference in the studied processes. The global mechanism that causes this coherent noise requires further study.

EXPERIMENTAL DATA



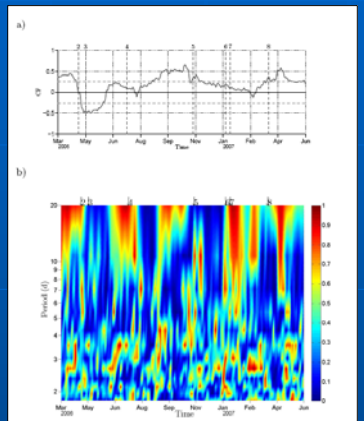
Geographical positions of the stationary deformation stations Baksan (Russia) and Gran Sasso (Italy).

The records of the majority of geophysical processes are characterized by a falling trend at low frequencies (flicker-noise), which causes nonstationarity of the observation data. In the original Baksan and Gran Sasso deformation series there is also a flicker component. Such a feature renders these records unsuitable for the correlation analysis in terms of both their correlation with each other and their correlation with the LOD time series that are free of the flicker noise. To obtain the quasi-stationary series to which the classical correlation analysis can be applied correctly, the original deformation data were filtered in the narrow band of 1.8–20 days. LOD variations have been also filtered in the specified frequency band.

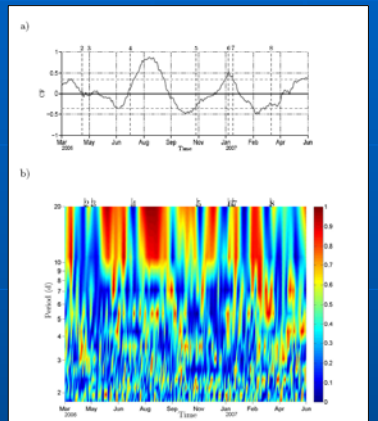


Experimental data: (a) lithospheric deformations at the *Baksan* station; (b) lithospheric deformations at the *Gran Sasso* station ; (c) length-of-the-day variations (LOD). Observation time from January 1, 2006 to June 19, 2007.

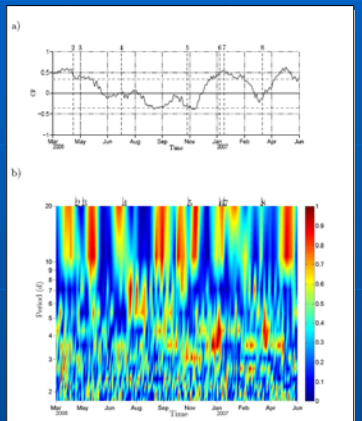
RESULTS OF THE ANALYSIS



Results for the pair *Baksan* and *Gran Sasso*: (a) cross-correlation function; the 90% confidence level is shown by the horizontal lines; (b) time diagram of coherence. The marks on top of figures correspond to the moments of the strongest earthquakes (Table 1).



Results of the analysis for the pair *LOD* and *Baksan*: (a) cross-correlation function; the 90% confidence level is shown by the horizontal lines; (b) time diagram of coherence. The marks on top of figures correspond to the moments of the strongest earthquakes (Table 1).



Results for the pair *LOD* and *Gran Sasso*: (a) cross-correlation function; the 90% confidence level is shown by the horizontal lines; (b) time diagram of coherence. The marks on top of figures correspond to the moments of the strongest earthquakes (Table 1).

Table 1: Earthquakes with a magnitude greater than 7.4 occurred in the period from January 1, 2006 to June 19, 2007. Data from the catalogue NEIC USGS.

No.	Date	Magnitude	Location
1.	2006-01-27	7.6	Banda Sea
2.	2006-04-20	7.6	Koryakia, Russia
3.	2006-05-03	8.0	Tonga Region
4.	2006-07-17	7.7	Java, Indonesia
5.	2006-11-15	8.3	Kuril Islands, Russia
6.	2007-01-13	8.1	Kuril Islands, Russia
7.	2007-01-21	7.5	Moluccа Sea
8.	2007-04-01	8.1	Solomon Islands

The time intervals of significant correlations and their maximum values.

Correlation pair	Interval		Duration (d)	C_{xy}
Baksan/Gran Sasso	2006-03-05	2006-04-18	44	0.53
	2006-04-27	2006-06-05	39	-0.50
	2006-09-01	2006-11-11	71	0.66
	2006-11-13	2006-12-05	22	0.41
	2007-03-25	2007-03-28	3	-0.49
	2007-03-29	2007-05-20	52	0.59
	2007-05-21	2007-06-08	18	0.30
	Total: 249 (47%)			
LOD/Baksan	2006-03-11	2006-03-14	3	0.36
	2006-03-28	2006-03-30	2	0.36
	2006-04-01	2006-04-03	2	0.36
	2006-06-25	2006-06-30	5	-0.36
	2006-07-25	2006-09-19	56	0.87
	2006-10-14	2006-11-15	32	-0.48
	2007-01-08	2007-01-23	15	0.54
	2007-02-27	2007-03-19	20	-0.48
	2007-03-21	2007-03-24	3	-0.38
	2007-05-26	2007-06-09	14	0.39
	Total: 152 (29%)			
LOD/Gran Sasso	2006-03-05	2006-04-28	54	0.60
	2006-04-30	2006-05-22	22	0.45
	2006-05-25	2006-05-27	2	0.36
	2006-09-14	2006-09-22	8	-0.37
	2006-11-23	2006-12-03	10	-0.39
	2007-11-19	2007-02-14	48	0.54
	2007-02-16	2007-03-01	13	0.46
	2007-04-26	2007-06-03	38	0.62
	2007-06-07	2007-06-09	2	0.38
	Total: 197 (37%)			

SUMMARY

The relationship between the local strain fields relating to a large tectonic structure, the Eurasian plate (the Baksan station, Northern Caucasus, Russia, and the Gran Sasso station, Italy) and variations in the Earth's rotation rate has been studied. At the statistically significant level the existence of the correlated disturbances of the deformation field on large spatial scales, that is, the existence of the global (at least on the scale of the Eurasian plate) component of the deformation field of the Earth was shown. This global deformation component manifests a quasi-periodic nature, with the typical lifetime of 1–2 months for the present one-and-a-half year observation interval. The significant correlation between the local manifestations of the global component of the deformation field and the variation in the rate of the Earth's rotation has also been revealed.

These relationships between local deformation fields and deformation field and LOD have a frequency-dependent nature. They manifest themselves most strongly in the low frequency tidal range (periods of 8–20 days). The main contribution in this frequency range is due to a regular long-period tidal loading produced by the group of tidal waves Mf and Mtm which has a direct impact on the lithosphere and the LOD. Despite the global and permanent nature of this loading, the relationships are not constant in this range.In the majority of the cases the character of relationships are essentially changed after strong seismic events. In this case, one can say that the strong earthquakes coincide with the moments of the data mismatch or indirectly provide the disconcerting contribution.

On the contrary, the significant correlation in the non-tidal range (2–7 days) is probably linked to irregular perturbations of the continental character, which create a coherent interference in the studied processes. The global mechanism that causes this coherent noise requires further study. As candidates, the atmospheric influence, the strongest earthquakes, and other global geodynamic processes can be considered.

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