TUESDAY 3 AUGUST 2004 PM

Tilt, Strain: Aperiodic and Long Period Signals

Conveners: T. Jahr, J. Arnoso, G. Mentes

PRESIDING

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Paper No	Time	Type	Title	Authors
ETS-05-01	13:30-14:00	I/O	Aperiodic and long period signals from crustal deformation observations at the NE border of the Adria plate	C. Braitenberg, I. Nagy, S. Papacchioli
ETS-05-02	14:00-14:15	C/O	Quarter-Diurnal waves observed with a long-base water-tube tiltmeter in the Grand Duchy of Luxembourg	N. d'Oreye de lantremange, W. Zürn
ETS-05-03	14:15-14:30	C/O	Well level data analysis in Hungary near a fault region	Rotár-Szalkai, L. Ó. Kovács, I. Eper-Pápai. G. Mentes
ETS-05-04	14:30-14:45	C/O	The ASKANIA borehole tiltmeter array at the KTB location / Germany	T. Jahr, H. Letz, G. Jentzsch
ETS-05-05	14:45-15:00	C/O	Earth-tide Tilt Measurements in Canada Revisited	P. M. Rouleau
	15:00-16:00		**COFFEE BREAK and POSTER VIEWING**	
ETS-05-06	16:00-16:30	I/O	Observing Long Term FCR Variation by Using Esashi Strainmeter	J. Ping, T. Tsubokawa, Y. Tamura, K. Heki, T. Matsumoto, T. Sato
ETS-05-07	16:30-16:45	C/O	Complex Investigation of Mt. Elbrus Magmatic Center from Relative Gravity and Tidal Strain Data	A. Kopaev, A. Gurbanov, V. Milyukov, S. Takemoto
ETS-05-08	16:45-17:00	C/O	Tidal Strain Observations in Chu-Chi, Taiwan	S. Takemoto, Min Lee, Chih-Yen Chen, Ming-Chien Kao, A. Mukai,
	17:00		**END OF SESSION**	
			POSTERS	
ETS-05-09		C/P	Parallelisms of regional tectonic and climatic processes for 1400-2000.	B.L. Berry (Berri)
ETS-05-10		C/P	Parallelisms of global tectonic and climatic processes for 1600-2000.	B.L. Berry (Berri)
ETS-05-11		C/P	Strainmeter observations at Moxa	T. Jahr, C. Kroner, A. Walther
ETS-05-12		C/P	Study of Tidal Components in Electrotelluric Potential Data	Yu. Kugaenko
ETS-05-13		C/P	On Relation of Ground Deformations Observed at Donzurubo Observatory to Sea-Level Changes	K. Onoue
ETS-05-14		C/P	Variations of the Tidal Components in the High-Frequency Seismic Noise and Strong Earthquakes Prediction	V. Saltykov, Yu. Kugaenko, V. Sinitsyn, V. Chebrov
ETS-05-15		C/P	Long term thermal effects on strain measurements at the Geodynamics Laboratory of Lanzarote	A.P. Venedikov, J. Arnoso, R. Vieira, W. Cai

C: *Contributed*; **I:** *Invited*; **O:** *Oral*; **P:** *Poster*

ETS-05-01

Aperiodic and long period signals from crustal deformation observations at the NE border of the Adria plate

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The observations of subsurface crustal deformation at the NE border of the Adria plate cover a time interval of near to 40 years with long base and short base tiltmeter stations and a station of horizontal and vertical strainmeters. The exhaustive database gives an excellent opportunity to approach a full understanding of the different aspects that characterize deformation signals. The stations are located near to a seismic active area and partly close to the sea, so a broad spectrum of deformations of tectonic and non-tectonic origin can be isolated from the data. Regarding the tectonic short-period deformations, we show the pre-co-and postseismic observations of those events, which occurred at favourable distance-magnitude relations. As far as possible, we present a model of the observations and discuss the observations also taking into account the hydrologic induced deformation. Regarding the observed long-period observations, these are presented and discussed in the frame of their tectonic and possible non-tectonic origin. The comparative analysis of the observations of the long base and short base tiltmeter installed in the same station is discussed for time constants of several hours to months, and it is shown that the difference in response is strongly dependent on the nature of the causative parameter generating the observed deformation. In view of the results, the general advantages of a long base instrument are discussed.

ETS-05-02

Quarter-Diurnal waves observed with a long-base water-tube tiltmeter in the Grand Duchy of Luxembourg

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We analyzed 6 years of Earth tide measurements performed with a 43m long water-tube tiltmeter in the Underground Laboratory for Geodynamics in Walferdange (Luxemburg). The high performance of that instrument led to results in excellent accordance with the tidal models and with the lowest root mean squares among all the results obtained with other tiltmeters in Walferdange. The high signal-to-noise ratio allowed for instance to estimate the amplitude of the M2 wave with a RMS as small as 0.003 masec (i.e. a signal-to-noise ratio of 1700 for that wave) and a phase uncertainty lesser than 0.028 degrees, which represents 3.3 seconds only.

In addition it was possible to successfully separate some of the small constituents of the ter- and quarter-diurnal band. The presence of these very small waves (with amplitudes of less than a few microarcseconds) is, as we will show, most likely due to the effects of the shallow-water tides known to be remarkable in the North Sea (distant of 300 km).

ETS-05-03

Well level data analysis in Hungary near a fault region

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Short periodic fluctuations of water levels recorded in wells or boreholes are often identified as earth tidal variations. It is known that the earth tidal strain fluctuations cause pressure variations in well-acquifer system. The response of this system may provide a tool to obtain quantitative information of the earth strain under favourable conditions. In our paper we analyse data from an array of monitored wells located in the vicinity of a fault area in Hungary. Tidal data processing was carried out from well level oscillations and tidal parameters were investigated from data series measured in different wells at different depths. During the analysis we estimated the strain sensitivity of the wells to reflect tectonic strain changes.

ETS-05-04

The ASKANIA borehole tiltmeter array at the KTB location / Germany

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In 2003, five ASKANIA borehole tiltmeter (ABTM) were installed in the surrounding of the Continental Deep Borehole (KTB) location. This research project sponsored by the German Research Foundation intends to quantify the relationship between changes in pore pressure, modifications of the fluid state and depressions of the surface, reflecting induced deformation by a large scale injection experiment at the KTB site. The superior aim of the project is to improve the knowledge of the coupled geomechanic-hydraulic processes and to quantify important process parameters of variations of the fluid-states and the geodynamic parameter field. Both parameters are to be quantified: the deformation of the upper crust (tilt) and estimation of material parameters and their changes at the KTB location (modelling). Thus, the understanding of processes of cleft fracture dominated changes of hydrogeological parameters will be improved, geomechanic parameter changes and the heterogeneity of the parameter field quantified. Deformation of the upper continental crust will be recorded by ABTM at five locations with a resolution of 0.2 msec (~1 nrad). This resolution makes the ABTM to the most sensitive tiltmeter worldwide. To date these instruments were used only at single locations or along profiles. To use ABTMs in an array configuration is tried out for the first time. Distances between the ABTM stations and the injection borehole (KTB- exploration hole) vary between 1.8 and 3.3 kilometers. Tilt data is sampled at a rate of 0.1 Hz using a highly stable A/D converter (PREMA) and send via a wireless local area network (WLAN) to the KTB drill rig. Data is received by internet in Jena, where data processing is carried out (incl. pre-processing, corrections, calibration, filtering, and analysis). First spectral and tidal analyses are available and the quality of the observed data is assessed daily. Preliminary results of the tidal analyses can be given. The observed deformations will be investigated with regard to fluid flow behaviour and the induced geodynamic effect and modeled using a coupled hydro- geomechanical finite-element model (ABAQUS). With the numerical model both effects can be quantified: a) the deformation of the upper crust (tilt measurements) and b) the changes of material parameters in the KTB area.

ETS-05-05

Earth-tide Tilt Measurements in Canada Revisited

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In Canada, ground tilts have been measured in various underground settings using liquid-level sensors, horizontal and vertical pendulums, and a Canadian-designed borehole mercury-level tilt-meter. The associated studies have contributed markedly to the earth-tide and tidal-loading discipline throughout the 1970's and 1980's, but such studies have virtually ceased in the late 1980's. Since then, however, major advances in several elements of the loop signal-source -> earth-structure -> surface-loads -> data-analysis have occurred. In particular, the LITHOPROBE Project has contributed detailed seismic images of the crust and upper mantle in areas nearby which tilt signals had been recorded, and satellite geodesy has significantly constrained and improved ocean-tide models. Moreover, studies elsewhere have led to a better understanding of ground-noise effects, to an appreciation for the intrinsic permeable nature of rock-materials, and to the realisation that local ground-tilts are relevant to precise measurements of GPS-based displacements and to the stability of referential monuments. Ground tilts recorded round the Bay of Fundy and in Western Canada are reviewed here in light of those advances. Thusly, it is shown how better constrained inferences can now be obtained from the existing data. Several promising avenues for further ground-tilt studies are also pointed-out, in an effort to revive interest in the matter in Canada.

ETS-05-06

Observing Long Term FCR Variation by Using Esashi Extensometer

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Esashi Earth Tides Station of Mizusawa Observatory of NAOJ has been operating for tidal observations since 1979. Among the observations, a long term extensometer data for 3 components of both free end point recorders and middle point recorders are calibrated and corrected to solve the tidal drift and tidal admittances. Based on the estimated admittances of diurnal tidal constituents, the fluid core resonance parameters are obtained with very high precision to compare with the results obtained from other independent methods. Also, its time variation is obtained. For the overlap observation together with co-located SG, they are identical. Additionally, periodic like signal is noticed in FCR variation time series. Finally, comparisons with other GGP SG observations are discussed.

ETS-05-07

Complex Investigation of Mt. Elbrus Magmatic Center from Relative Gravity and Tidal Strain Data

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Relative gravity surveys on and around the top of the Europe sleeping volcano Mt. Elbrus have been carried out using Sodin gravimeters and GPS in extreme conditions with precision of 0.2-0.5 mGal. Resulting Bouguer anomalies obtained using detailed DTM reach -150 mGal near the Elbrus summit at

the height of 5600 m and could be interpreted in terms of a shallow magma chamber. Regional gravity data imply also the presence of long (some 50-60 km) structure associated with the main magma-generating fault system connecting three magmatic centers in region young and sleeping Mt. Elbrus (last eruption took place about 1700 years ago), old Syltran (7-8 000 years) and Tchegem (25 000 years).

The same magmatic structure is clearly visible in careful analysis of the tidal strain data from large Baksan laser strain meter (located 15 km apart from Mt. Elbrus) from 1998-2004 period and processed using the optimized combination of PRETERNA, TSOFT and ETERNA programs with careful taking into account for atmospheric and temperature perturbations. After applying the correction for tidal deformations of topography, resulting anomaly reaches -20 % and could be explained by reducing the DVp/Vp ratio by 25 %. Our investigation has been supported by the RFBR grant# 02-05-65012.

ETS-05-08

Tidal Strain Observations in Chu-Chi, Taiwan

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In Chu-Chi, Taiwan, tidal strain observations with a borehole strainmeter system have been carried out since 2001. The Chu-Chi station (N23° 31’39", E120°35’59", h=300m) is located in the central part of Taiwan and is about 40km away from the epicenter of a destructive Chi-Chi earthquake (M=7.3) which occurred on September 21, 1999. The strainmeter system manufactured by AKASHI Corporation, Japan, detects three components of horizontal strain using magnetic sensors. The three components (N000, N120 and N240) of the strainmeter system were installed in the borehole at the depth of 77m from the surface. Orientations of three components are 82° (N000), 202° (N120) and 322° (N240), respectively, measured from the North in clockwise directions. We analyzed tidal strains and determined amplitudes and phase lags of 12 major constituents by applying the tidal-analysis program BAYTAP-G (Tamura et al., 1991) to the one year data of 2003. The “observed” tidal strain amplitudes were compared with the “theoretically expected” ones that were obtained from the GOTIC2 program (Matsumoto et al., 2001). As a result, ratios of the observed amplitudes and the theoretically expected amplitudes show scattering between 0.3 and 7.8. These discrepancies may be caused by the complicated geological effect and topographic effect around the observation site.

ETS-05-09

Parallelisms of regional tectonic and climatic processes for 1400-2000.

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Independent Scientist

The laws of conservation of angular and linear momentum are common reasons for synchronous variations of the Length of the Days (LOD), currents in the atmosphere and mantle when the inner core shifts. Strong zonal and meridional southward (for the Northern Hemisphere, NH) circulations increase compression of the atmosphere and create the warm NHTA (Temperature Anomalies) when LOD is shorter. Simultaneous zonal and meridional southward stresses (deformations) of the lithosphere generate strong earthquakes in the belt between latitudes +/-40°. When LOD is longer, additional northward (for the NH) circulations of the air in the meridional planes decrease the compression of the atmosphere, mix

up cold and warm air volumes and create the global cold air anomalies. Similar movements of the mantle produce earthquakes in the regions situated to the north and to the south of latitudes +/-40 degrees.

The magnitudes (M>=6.0) of the 46 earthquakes, which occurred in the Vrancea tectonic area at latitude of about 46 degrees, compared with amplitudes (Am) of the Model NHTA for the same years from 1400 to 2000. Highly significant correlations between these two series of independently calculated data tell us not only about the common reasons for the tectonic and atmospheric processes but also about the high quality of the reconstructed seismic and modeled climatic data. The slopes of the correlation lines were used for researching the focal mechanisms of the Vrancea earthquakes. The long-period planetary interactions explain the reasons for the existing correlations between climatic and tectonic processes and build a new basis for their investigations.

ETS-05-10

Parallelisms of global tectonic and climatic processes for 1600-2000.

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The Length of the Days (LOD) changes with any alternating of the momentum of inertia of the Earth, in particular, under the actions of the solar-lunar tidal forces, which deform the geoid and displace the inner core and axis. The changes in the inner core positions influence on all fluid and solid strata of the Earth. That explains parallelisms of the LOD changes with tectonic and climatic processes. But the LOD and climate are global parameters. To compare them with strong earthquakes' activity we created the homogenous series and harmonic Model (M) of the global seismicity (GS). There are highly significant correlations between the LOD and tectonic processes for the 20th century and between MGS and Volcanic Aerosols (VA) for the last 400 years. The cold temperature periods of the Little Ice Age, which coincide with solar Maunder (1645-1715) and Dalton (1790-1830) minima can be explained by the simultaneous influences of the variations of the sunspot numbers and VA.

ETS-05-11

Strainmeter observations at Moxa

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Since 1997, two quartz tube strainmeters at the Geodynamic Observatory Moxa are in use to observe longperiod strain signals. Both strainmeters measure 26 m in length and have been installed with exact orientation NS and EW. The system was supplemented by a third component in 1999, which connects the ends of the quartz tubes diagonally. This component is realized as a laser strainmeter, running through a 38 m long horizontal borehole. The analyses of the main tidal waves show good signal-to-noise ratios. It can be shown that the quartz strainmeter extending in EW direction contains significant more barometric induced noise than the NS-component. The laser strainmeter record shows strong influences of the changing barometric pressure, due to the fact that the beam does not run in a vacuum. But this influence has been minimized by sealing the ends of the horizontal borehole with high quality glass. In addition, the observations are clearly temperature dependent, on the temperature within and from outside the gallery. In the context of current investigations the observed strain signals were modeled with the finite element method. Beside the static air pressure load, barometric pressure waves passing over the observatory are also investigated. Results to all aspects are presented.

ETS-05-12

Study of Tidal Components in Electrotelluric Potential Data

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Natural electric field of the Earth is determined by the complicated set of geophysical and space phenomena. So the detection of some specific variations, connected with earthquakes preparation is intricate problem. For problem-solving it is necessary to study not only precursors directly but properties of background anomalies not connected with seismicity too. Interaction of geophysical fields and processes in different geospheres have not been studied enough yet. So application of Earth tides as internal influence upon geophysical fields (in our case - upon telluric currents) is actual. In given report the example of geoelectrical response on different internal influences with periods of main tidal waves is present: 1) ionosphere and magnetosphere inductive influence determined by processes of non-gravitational origin (S, S2), 2) lithosphere tides caused changes of medium stress state (O1, Ì2, Ê1, Ð1). In present research data of electrotelluric potential recording on the complex geophysical observatory "Karymshyna" on the Southern Kamchatka (Russia) was used. This observatory is remote from anthropogenic activity and suitable for investigation of weak variations in telluric currents. For two dipoles positioned in series on the same line, crossed local fault differences in geoelectrical response on inductive and gravitational influences were revealed. Both amplitude and phase differences were found. Observed effect we connect with local geological and hydrological heterogeneity of the investigated area. It is perspective to use tidal components of electrotelluric field for control of medium tensiosensibility by slowly changes of local and regional stress.

ETS-05-13

On Relation of Ground Deformations Observed at Donzurubo Observatory to Sea-Level Changes

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Continuous observations of ground deformations at Donzurubo Observatory (34□‹32.4□ŒN, 135□‹40.2□ŒE, h=117m), located in the central part of the Kii Peninsula in Japan, have been carried on for more than 35 years since 1968. In order to investigate the effect of regional deformation of Kii Peninsula to long-period variations of ground deformations observed at Donzurubo Observatory, we analyzed the strain data of three horizontal extensometers oriented at E4.5□‹S(SE-1)□AN4.5□‹E(SE-2) and N40.5□‹E(SE-3), respectively and compared the strain data with tide gauge records at in and around the Kii Peninsula.

The spectra of strain changes by applying an MEM (maximum entropy method) to the high-cut filtered strain data for up to one year show the predominant peaks of strain amplitude about 22-23 year. The turning point of ground deformation for the observation period is found in about 1984-1986. SE-1 shows a maximum contraction of the deformation and SE-2 shows a maximum extension of it. The strain amplitude of SE-2 is about two times the size of SE-1.

On the other hand, tide gauge records of Wakayama, Shirahama, Kainan and other tide stations by Coastal Movements Data Center show that periodic changes with long periods of sea-levels and vertical

movements of ground calculated by Tumura method from sea-level changes show the temporary uplift of ground in about 1985 at Wakayama, Shirahama, Kainan and so on. We can infer ground uplift in the central part of the Kii Peninsula from the ground deformations of Wakayama, Shirahama, Kainan and other regions by tide gauge records in about 1985 and it will generate extension of ground strains near the North- South direction at near Donzurubo Observatory in 1984-1986.

ETS-05-14

Variations of the Tidal Components in the High-Frequency Seismic Noise and Strong Earthquakes Prediction

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The main directions of the seismic noise investigation on Kamchatka are modulation of high-frequency seismic noise (HFSN) by the Earth tides and temporal variations of HFSN parameters connected with the strong earthquakes preparation. HFSN is the seismic oscillations in frequency range of the first tens of Hz with the amplitudes about 1.0E-9-1.0E-12 m. The seismic noise is a superposition of microearthquakes and macrocrashes appearing spontaneously in a medium under the influence of external and internal factors. The ability to radiate a microseismic noise is one of the fundamental properties of the geophysical medium along with heterogeneity, nonlinearity, variability in time, vibro-sensibility, tensio-sensibility. For last years seismic noise has been considered as high sensitive and informative geophysical field containing the unique information about a crust structure and stress state. For getting of the statistically significant characteristics of HFSN and tides connection it was necessary to create the recording station and to carry out the long-term regime HFSN observation in the point, removed from anthropogenic handicaps as far as possible. HFSN is continuously registered and researched on Kamchatka since 1990. The narrow-band piezoelectric high-sensitive geophone was used (f=30 Hz, Q=100). Sensitivity of the seismometric channel is about 1.0E-12 m. Signal envelope is recorded and analyzed. The study of HFSN structure gave the opportunity to extract HFSN components connected with wind influence, the Earth surface warming-up, the anthropogenic factors, and also with Earth tides. Last factor is most important, as confirmation of the endogenous origin of the seismic noise. The largest waves in the tidal potential were examined and detected in HFSN data. HFSN phase component connected with a tidal wave O1 (T=25.8 h) was chosen as parameter for medium stress state controlling because of its high hindrance-immunity. It was show! n that the phase of O1 tidal component of the HFSN envelope become stabilize during several months before strong earthquake. Such effect took place before earthquakes with M>6.0, occurred on the distance up to 250 kms from the HFSN registration point. The stabilized phase shift of the HFSN Î1-component before strong earthquakes has fixed values. The results suggest a possibility of HFSN application for intermediate-term earthquake prediction. In given report we present examples shown the connection of HFSN tidal variations with 17 strong Kamchatkan earthquakes M>6,0 since 1992 to 2003 including results of simultaneous registration by two stations since 2000. The estimations of the seismic situation in Kamchatka region received by the analysis of HFSN data are weekly represented to the Kamchatkan Center of Earthquakes Forecasting.

ETS-05-15

Long term thermal effects on strain measurements at the Geodynamics Laboratory of Lanzarote

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We have analyzed the non-tidal component (NTC) of a series of strain- meter data, obtained in the Geodynamics laboratory of Lanzarote (Canaries, Spain). The strain-meter is a kind of ceramic tube, with a baseline of 38.22 m length, and has been recording since 1992. The long-term strain changes observed are mainly produced by the effect of the local air temperature variations. We have investigated this effect by means of the program VAV. The general picture shows an obvious annual component, with opposite phases with respect to the air temperature variations. There is also a non-periodic component that can be conventionally called instrumental drift (ID).

The NTC has been submitted to a regression analysis included in the VAV program. We have accepted a regression model of NTC on the temperature, with a single regression coefficient R and on polynomials, representing the ID. It has been established that the ID has points of rapid changes in the drift behavior, that is, discontinuities in the derivatives, as well as jumps. Due to this, the polynomial model of ID consists of different polynomials in several segments. The regression has experimentally included an annual component, composed by frequencies 1, 2 … cycles per year. It appeared that it does not help the analysis, because the main periodic part is better explained by the effect of the temperature variations.

The main result of the analysis is the regression coefficient on the temperature, whose value has been estimated as R = - 182.01 ± 0.95024 nstr/° C.

The analysis has allowed detecting several anomalies. A further investigation is necessary to establish whether the anomalies represent geophysical signals and thus they can be used as potential precursors of volcanic or seismic activity.