FRIDAY 6 AUGUST 2004 AM/PM

Interplanetary Tidal Interactions and Gravity

Conveners: X. Wu, C.K. Shum, S. Takemoto

PRESIDING

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ETS-04-01	10:45-11:15	I/O	Gravity Fields and Interior Structure for Equilibrium Bodies in the Outer Solar System	J.D. Anderson
ETS-04-02	11:15-11:30	C/O	Solar system oscillations and models of natural processes.	B.L. Berry (Berri)
ETS-04-03	11:00-11:45	C/O	A New Theory on the Determination of the Gravity Field	W. Shen, J. Ning
ETS-04-04	11:45-12:00	C/O	Tides, Subsurface Oceans and Jupiter Icy Moons Orbiter	X. (Frank) Wu, J.G. Williams
	12:00-13:30		**LUNCH BREAK**	
ETS-04-05	13:30-13:45	C/O	Temporal variation of geodynamical properties due to tidal friction	P. Varga, Gy. Mentes
ETS-04-06	13:45-14:00	C/O	Sea Level And Surge Along Alexandria Coast , Egypt	H. Emam
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	14:30-16:30		**Conference Resolutions**	
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ETS-04-08		C/P	Space – time classification of mountainous and glacier relief.	B.L. Berry (Berri)
ETS-04-09		C/P	KSM03 Harmonic Development of the Earth TGP in Terrestrial Reference System	S.M. Kudryavtsev

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

ETS-04-01

Gravity Fields and Interior Structure for Equilibrium Bodies in the Outer Solar System

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Measurement of the external gravitational field for a body in static equilibrium under rotation and tides yields information on the internal distribution of mass. This paper contains a review of findings for the four Galilean satellites and Amalthea as a result of analysis of line of sight Doppler data. These data were generated by the Deep Space Network (DSN) with the Galileo Obiter at Jupiter between December 1995 and November 2002.

Rock and metal have separated inside Io to form a metallic core and silicate mantle. Europa and Ganymede are similar except that they contain deep outer layers of water ice. As the gravity data determine only the density of the icy shell, no information is obtained on the presence or absence of a subsurface ocean. Callisto has no metallic core. Rock, metal, and ice are mixed throughout much if not all of its deep interior.

Future possibilities for equilibrium gravity analysis include Saturn's satellites Titan and Rhea and the planets Jupiter and Saturn. The four-year Cassini tour of the Saturn system is expected to provide interior information on Titan and Rhea and a 100-fold improvement in the second, fourth, and sixth zonal gravitational harmonics for Saturn. Future missions to Jupiter could provide significant determinations of zonal gravity harmonics through at least degree 15. Information on core mass could become available from the lower degree harmonics, and the higher harmonics could provide a discrimination between solid-body rotation and differential rotation with deep zonal flows.

This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA.

ETS-04-02

Solar system oscillations and models of natural processes

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A new paradigm connects the stable oscillations in different processes of the Sun and planets with periodical movements and interactions of the celestial bodies of the Solar System (SS). The intrinsic cycles of the SS are created by the tidal and momentum interactions of the celestial bodies. The forces of the interactions periodically accelerate the Sun and planets and create multiperiodic processes and stresses in their fluid and solid strata, the history of which have been registered by instrumental observations and by natural proxy indicators.

We can analyse the registered series of the processes to detect stable oscillations and to compose their harmonic models. Cycles of the Northern Hemisphere Temperature Anomalies (NHTA) coincide with intrinsic periods of the SS, with original harmonics of the planet conjunctions, with harmonics of the Solar Activity (SA) in Wolf and Hale numbers, in the ^{14}C records, with harmonics of the Global

Seismicity (GS) and Length Of the Days (LOD). The Moon-Sun tidal forces evidently participate in the forming of these climatic cycles together with other forces of the SS

The modelled series of the SA, GS, and NHTA were verified by independent reconstructed data from 1400. The models' verifications show that the time intervals of the reconstructions and predictions can be equal to or more than the intervals of the proxy data, which were used for models' formations. Using harmonic models the systematic parts of these processes were predicted for the current century and the limits of their random annual variations were shown.

ETS-04-03

A New Theory on the Determination of the Gravity Field

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Since Shen (1998) proposed an idea of the fictitious compress recuperation for determining the Earth's external gravity field, it was not paid attention until recently, this idea has been further developed by Shen (2004). Exactly saying, a new theory of determining the Earth's external gravity field has been established. The basic idea of the new theory is the fictitious compress recuperation, which could be stated as follows: Choose a fictitious sphere which is entirely enclosed in the Earth, whose center coincides with the Earth's center; compress the observed gravitational potential value (or any regular harmonic function's value), which is the value on the Earth's surface (boundary), on the fictitious sphere surface, getting a fictitious solution V*(1), which is a regular harmonic function outside the fictitious sphere; then, on the Earth's boundary make a subtraction between the original ``observed'' boundary value and the theoretically calculated value V*(1) (so that one gets a difference T(1)), and compress the difference (residual) value T(1) on the fictitious sphere surface, getting a regular harmonic solution V*(2) outside the fictitious sphere; further, on the Earth's boundary make a subtraction between T(1) and V*(2), compress the difference (residual) value T(2)=T(1)-V*(2) on the fictitious sphere surface, getting a regular harmonic solution V*(3).....; this procedure can be executed until one gets a series solution V*= V*(1)+V*(2)+V*(3)+.....; and it has been proved that the series solution coincides completely with the Earth's real field V outside the Earth (Shen 2004). The present paper summarizes the main context of the above mentioned theory and discussed its various applications; further, based on the theory of the fictitious compress recuperation, several theorems (including the Runge theorem, the Runge-Krarup theorem and the Keldysh-Lavrentiev theorem), which are important and widely applied in theoretical physical geodesy especially in the explorations of the geodetic boundary value problems, will be simply derived out as conclusions.

ETS-04-04

Tides, Subsurface Oceans and Jupiter Icy Moons Orbiter

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Galileo flyby observations of Europa, Ganymede, and Callisto suggest that the icy moons may have subsurface liquid water oceans. The icy Galilean satellites also have tidal environments that are among the strongest for large solar system satellites. Since a planetary body with internal fluid deforms more than an otherwise solid body, a comprehensive tidal measurement experiment on NASA's Jupiter Icy Moons Orbiter (JIMO) will provide exciting opportunities to infer the presence of oceans and other interior structures. We compute tidal potential and displacement Love numbers as functions of interior structures of all 3 icy moons. Tide-raising potentials and solid-body librations are accurately catalogued using Lieske's analytic ephemerides E15. We also conduct simulations for spacecraft orbiting the 3 moons to assess possible measurement accuracies for tidal potential Love numbers, librations in longitude, spacecraft orbits, and their dependences on orbit and tracking configurations. Our results indicate that the k2 Love numbers can be measured extremely well for all 3 icy moons with the smaller tidal signatures of Ganymede and Callisto partially compensated by the longer mapping durations allowed by less radiation. We will also address how the tidal measurements will be used to infer the parameters describing oceans and interiors.

ETS-04-05

Temporal variation of geodynamical properties due to tidal friction

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With the use of fossil and tidal deposit data length of day (l.o.d) values were deduced for the Proterozoic (Ptz) and Phanerozoic (Pz). It was found that the despinning rate was 5 times smaller during the Ptz than in the Pz. Moreover between 250 and 100 million years ago, there was a slight nonlinear variation superimposed on the overall linear trend of the long-term variation of l.o.d. For the study of the role of these observational facts

1. The time derivative of the second-degree zonal geopotential was investigated first of all due to the fact that it is related to the inner structure of the Earth through the MacCullagh equation.
2. The long-term variations of the geometrical flattening and of the Earth-Moon distance due to the tidal friction were obtained for the Ptz and Pz.
3. The role of the long-term l.o.d. variation in the energetic household of the Earth was estimated.

It was found that during his lifetime our planet lost more than half of its rotational energy. The annual energy dissipation by tidal friction is similar to the energy released by earthquakes during one year. A possible explanation is given, how the seismicity and the flattening variations due to l.o.d. are related together.

ETS-04-06

Sea Level And Surge Along Alexandria Coast, Egypt

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Lack of sufficient knowledge of coastal wave climates hinders management and treatment of coastal problems. This limits the data applicability for describing the basic stochastic processes, which govern beach changes along the Egyptian coast of the Mediterranean Sea. Different studies were done on the sea level (tides and surge) in the Western Harbor of Alexandria and significant results are available on the early records. This paper will consider recent data (1999 to 2002) to compare the present conditions with previous ones. Harmonic tidal constants will be calculated using 31 day, hourly records, and the daily mean surge will be calculated and discussed. The monthly mean sea level will also be correlated and compared with the means of the atmospheric pressure and wind speed.

ETS-04-07

Estimation and Validation on non-tidal oceanic contributions on annual polar wobble

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Based on two different ocean data assimilations (SODA and ECCO), monthly OAM variability during 1992-2001 are estimated, respectively. On the basis of the principle of angular momentum conservation in the whole Earth system including the solid Earth, atmosphere, ocean, hydrology, and etc., the residual between the solid Earth and geophysical fluids (atmosphere and hydrology) can be the constraint on OAM variability. Results indicate that at annual scale, the equatorial OAM variability could possibly be over-estimated from the ECCO data source along the 900East meridian direction, which is currently regarded as an evidence to show the oceanic significant contribution on annual wobble of Earth Rotation. The over estimation from ECCO assimilation will be probably shown by the GRACE observation.

ETS-04-08

Space - time classification of mountainous and glacier relief.

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The laws of conservation of momenta of the Earth create spectra of terrestrial processes: $A_J = C\ T_J^{1/2}$, where A_J - amplitudes, T_J – time periods and C - constants for series of cycles. The spectra are detected in all climatic, glaciological and geological processes. It is important that the coefficients C be used to classify them.

The values of C were estimated for main periods of Pleistocene (P) for Northern Hemisphere Temperature Anomalies (NHTA): $C_{PNHTA} = 0.0061°C/y^{1/2}$; for the shortest time of forming a Glacier (G) with Average (A) thickness: $C_{GA} = 14.1m/y^{1/2}$; for the time of formation of thickness of Loesses (L): C_{LT}=0.129 (Tajikistan), $C_{LWS} = 0.110$ (Western Siberia), $C_{LH} = 0.077$ (Hungary), $C_{LP} = 0.025m/y^{1/2}$ (Poland); for the time of formation of Geomorphologic (GEO) objects: $C_{GEO} = 0.83m/y^{1/2}$. The Maximum (M) depths or heights (H) of the objects are known, so we are interested in the time of Relief (R) formation, i. e., in another coefficient $C_{GEO}\,(y/m^2) = 1/\ C_{GEO}^2$: $T_{RJ} = C_{GEO}*H^2_{RMJ} = 1.45\ y/m^2\ H^2_{RMJ}$.

The average longitude (dimension) of continent, ocean, and other terrestrial objects (D) is a space period of the wave and the maximum height or depth is the amplitude (H), i.e. $H_{RMJ}=K_{GEO}*(D_{RJ})^{1/2}$, where K_{GEO}

$km^{1/2}$-is the coefficient for the planetary relief, $D_{RJ}=S_{RJ}^{1/2}$, S_{RJ}-the area of an object. When $K_{GEO}=0.0906km^{1/2}$, the standard error of determination H_{RMJ} equals about 10% for all oceans and continents. A similar relationship can be found for average and maximum sicknesses of glaciers: $K_{GA}=0.309\ km^{1/2}$ and $K_{GM}=0.671\ km^{1/2}$. These data are the base of the unite space-time relief classification. Ice sheets can arise (disintegrate) relatively quickly. They create positive and negative feedback with climatic and tectonic processes.

ETS-04-09

KSM03 Harmonic Development of the Earth TGP in Terrestrial Reference System

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The new harmonic development of the Earth tide generating potential (TGP), KSM03, is represented in the Terrestrial reference system (TRS). The original development (Kudryavtsev, 2004) includes 26,753 terms of amplitudes down to the level of 1*10^{-8} m^2/s^2 and was made in a reference system defined by the true geoequator of date with an origin at the point that being the projection of the mean equinox of date. The TGP series developed in that system have TDB time argument and do not include a much less stable UT1 time argument (which is necessary to calculate the TGP in the TRS). Such an approach makes the series of KSM03 development valid over a long-term interval of time (1000AD-3000AD), and the relevant accuracy of the gravity tides calculation is estimated to be at the sub-nGal level. However, for practical applications it is valuable to represent the new TGP development in a rotating Terrestrial reference system. For that we have first processed some 15,000 values for UT1-TAI time differences (tabulated by IERS over 1962-2004) to find the mean rate of the Greenwich Mean Sidereal Time (which is a function of UT1 by definition) in TT time scale at epoch J2000. (The latter can exchange TDB time scale to sufficient accuracy in tidal theories.) Then coefficients of KSM03 series for the Earth TGP in the TRS have been calculated with use of the only time argument TT. The new representation of the KSM03 series can be used in nutation theories and precise calculations of various tidal effects observed in the TRS. The amplitudes of major terms of the KSM03 expansion are also converted to the equivalent tide heights of the Cartwright-Tayler convention. The work is supported in part by grant 02-02-16887 from the Russian Foundation for Basic Research.

Reference: Kudryavtsev S.M., Improved Harmonic Development of the Earth Tide Generating Potential, Journal of Geodesy, 2004, in press