Creation Mean Sea Surface Model GCRAS06 and Investigation of Hydrodynamic Regime of the Caspian Sea Based on TOPEX/Poseidon and Jason-1 Satellite Altimetry Data

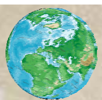
2007 Ocean Surface Topography Science Team Meeting
Wrest Point • Hobart, Australia • March 12 - 15, 2007

Sergey A. Lebedev

Geophysical Center, Russian Academy of Sciences
lebedev@wdcb.ru

State Oceanographic Institute

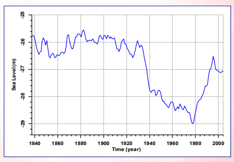
www.alticore.eu



The Caspian Sea

The Caspian Sea presents the world's largest isolated water reservoir, with only an isolation being its significant dissimilarity from the open seas. The other features of the Caspian Sea including its size, depth, chemical properties, peculiarities of the thermohaline structure and water circulation enable to classify it as a deep inland sea. Currently its level is at -27 m measured against the World Sea Level. The sea occupies an area of 392,600 km^2, with mean and maximum depths being 208 m and 1025 m, respectively. The Caspian's longitudinal extent is three times larger than its latitudinal one (1000 km vs. 200-400 km), resulting in great variability of climatic conditions over the sea. The isolation of the Caspian Sea from the ocean and its inland position are responsible for a great importance of the outer thermohydrodynamic factors, specifically, the heat and water fluxes through the sea surface, and river runoff for the sea level variability, formation of its 3D thermohaline structure and water circulation.

Over the past half-century, there was a regression of the Caspian Sea until 1977 when the sea level lowered to −29 m. This drop is considered to be the deepest for the last 400 years. In 1978 the water level started to rise rapidly, and now it has stabilized near the −27 m level. There has been increasing concern over the Caspian Sea level fluctuations. Estimates provide support for the view of these fluctuations as climatically conditioned and show their intimate connection with components of the Caspian water budget, especially Volga River run-off.



The Caspian Sea level variability by instrumental measurements (1837-2006)

GCRAS06 MSS Model for the Caspian Sea which includes temporal variability

Table 1. Data sets used in different MSS models

MSS Model	Satellite	Data	Time period *(month/year)*	Grid	Latitude range
CSR95	ERS-1	1 – 18 Cycles of Phase C	04/1992 – 12/1993	2.5' x 2.5'	–79° ? +82°
		Phase E (Geodetic Mission)	04/1994 – 09/1994		
		Phase F (Geodetic Mission)	10/1994 – 03/1995		
	TOPEX/Poseidon	1 – 73 Cycles	09/1992 – 10/1994		
OSU95	GEOSAT	1 – 22 Cycles of Exact Repeat Mission	11/1986 – 11/1987	3.75' x 3.75'	–80° ? +82°
	ERS-1	7 – 17 Cycles of Phase C	11/1992 – 11/1993		
		Phase E (Geodetic Mission)	04/1994 – 09/1994		
	TOPEX/Poseidon	17 – 53 Cycles	02/1993 – 03/1994		
GSFC00	GEOSAT	Geodetic Mission	03/1985 – 10/1986	2' x 2'	± 80°
		1 – 42 Cycles of Exact Repeat Mission	11/1986 – 10/1988		
	ERS-1	1 – 18 Cycles of Phase C	04/1992 – 12/1993		
		1 – 13 Cycles of Phase G	04/1995 – 06/1996		
		Phase E (Geodetic Mission)	04/1994 – 09/1994		
		Phase F (Geodetic Mission)	10/1994 – 03/1995		
	ERS-2	1 – 29 Cycles	04/1995 – 01/1998		
	TOPEX/Poseidon	11 – 232 Cycles	01/1993 – 12/1998		
CLS_SHOM98	GEOSAT	1 – 44 Cycles of Exact Repeat Mission	11/1986 – 11/1988	3.75' x 3.75'	± 82°
	ERS-1	7 – 17 Cycles of Phase C	11/1992 – 11/1993		
		2 – 12 Cycles of Phase G	05/1995 – 05/1996		
		Phase E (Geodetic Mission)	04/1994 – 09/1994		
		Phase F (Geodetic Mission)	10/1994 – 03/1995		
	TOPEX/Poseidon	11 – 121 Cycles	01/1993 – 12/1995		
CLS01	GEOSAT	1 – 44 Cycles of Exact Repeat Mission	11/1986 – 11/1988	2' x 2'	–80° ? +82°
	ERS-1	6 – 18 Cycles of Phase C	12/1992 – 12/1993		
		1 – 2 Cycles of Phase G	04/1992 – 05/1993		
		Phase E (Geodetic Mission)	04/1994 – 09/1994		
		Phase F (Geodetic Mission)	10/1994 – 03/1995		
	ERS-2	1 – 49 Cycles	04/1995 – 12/1999		
	TOPEX/Poseidon	11 – 280 Cycles	01/1993 – 04/2000		

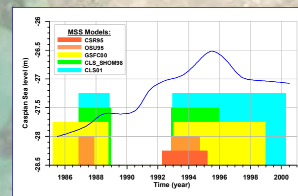
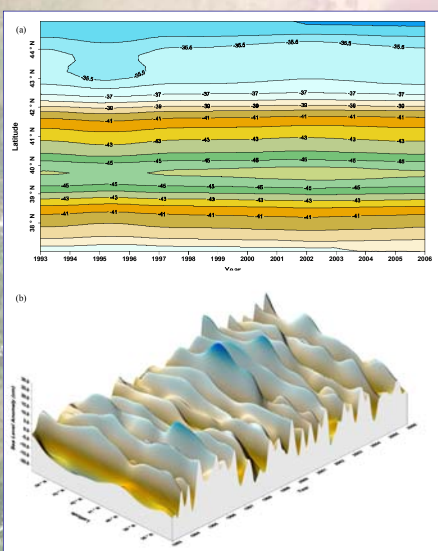


Table 2. Correlation coefficients between different MSS and EGM96 models

	CSR95	OSU95	GSFC00	CLS_SHOM98	CLS01	EGM96
CSR95	-	0.681	0.698	0.702	0.689	0.714
OSU95	0.681	-	0.992	0.994	0.998	0.991
GSFC00	0.698	0.992	-	0.990	0.995	0.999
CLS_SHOM98	0.702	0.994	0.990	-	0.702	0.990
CLS01	0.689	0.998	0.995	0.702	-	0.994
EGM96	0.714	0.991	0.999	0.990	0.994	-

The GCRAS06 Mean Sea Surface of the Caspian Sea was calculated according to the following scheme. At first, synoptic and seasonal variations of sea surface height were removed from the T/P and J1 data for all passes along each track. Then the mean dynamic topography, calculated by hydrodynamic model, was subtracted from the obtained data. Finally, the GCRAS06 MSS Model was constructed as a function of latitude, longitude and time. Example temporal variation of GCRAS06 MSS Model and SLA which calculate relative to GCRAS06 MSS Model presents on this poster. This GCRAS06 MSS Model allows to calculate spatial and temporal variability of SSH for the Caspian Sea. Two figures below show the SSH difference between 1995 and 1993, and 1997 and 1995 (see Table 3).



Temporal variation GCRAS06 mean sea surface height (a) and sea level anomaly (b), calculated relative to GCRAS06 MSS model along 092 track TP/J1

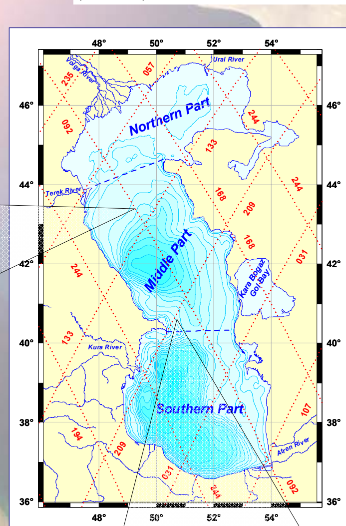
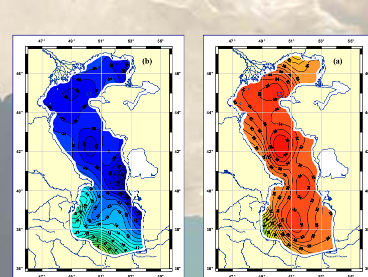
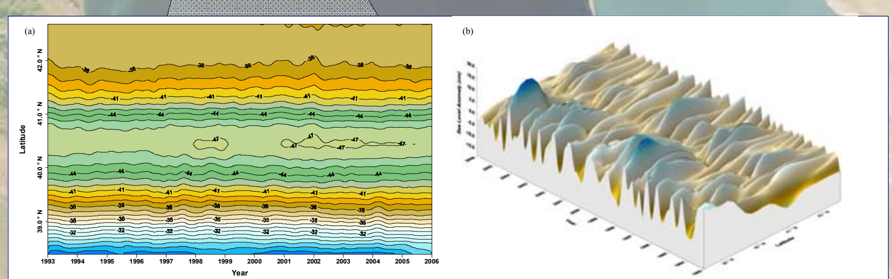


Table 3. The rate of the Caspian Sea SSH change revealed from the T/P and J1 satellite altimetry data calculated by GCRAS06 MSS (October 1992 - December 2006).

Time period	Rate of Change, *(cm/yr)* Northern Part	Middle Part	Southern Part	Whole Sea
1993 –1995	18.2 ± 3.8	22.8 ± 2.5	20.9 ± 4.9	21.1 ± 4.1
1995 –1997	-18 ± 1.4	-13.9 ± 1.8	-18 ± 5.6	-24 ± 5.0
1997 –1999	-3.6 ± 1.5	-6.2 ± 1.7	-5.4 ± 4.3	-5.3 ± 3.2
1999 –2001	-8.7 ± 2.7	-8.4 ± 1.7	-12 ± 2.4	-9.3 ± 2.9
2001 –2003	8.9 ± 4.6	7.0 ± 5.3	10.6 ± 6.3	9.1 ± 4.4

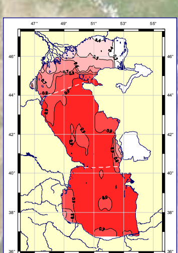


Mean SSH difference between:
(a) – 1995 and 1993; (b) – 1997 and 1995, revealed from the MSS Model

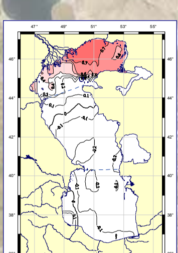


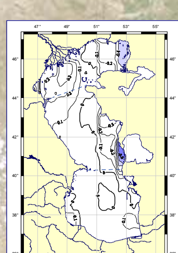
Temporal variation GCRAS06 mean sea surface height (a) and sea level anomaly (b), calculated relative to GCRAS06 MSS model along 209 track TP/J1

Decomposition of SLA on Empirical Orthogonal Function

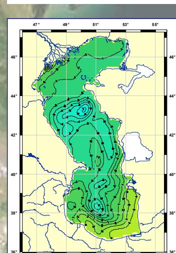


Decomposition of SLA, which calculate relative to GCRAS06 MSS Model, on empirical orthogonal function (EOF) has shown, that the basic contribution (more than 85 %) can be described EOF1. Especially it is expressed in the Middle and Southern Caspian Sea. However EOF2 and EOF3 functions also make essential influence to change of SLA, but they are reflected basically on the Northern Caspian Sea and area nearby the Kara Bogaz Gol Bay





Analysis of Spatial and Temporal Variability of Dynamic Topography



Mean dynamic topography (cm) from numerical hydrodynamic model (Popov, 2004)

Dynamic topography maps were used to analyze the spatial and temporal variability of the general dynamics in the Caspian Sea. They were constructed on the basis of the superposition of the sea level anomalies distribution over the climatic dynamic topography.

The sea level anomalies were calculated on the base of GCRAS06 Mean Sea Surface of the Caspian Sea The climatic dynamic topography (or hydrodynamic level) was calculated from three dimensional baroclinic model with free surface. Average monthly fields of temperature and salinity, climatic Volga River run-off and irregular evaporation from sea surface were taken in consideration. Also atmospheric pressure and wind fields from the regional model over the period from 1948 to 2006 were used. This model was developed in Laboratory of Sea Applied Research of Hydrometeorological Research Center of Russian Federation.

ACKNOWLEDGEMENTS

This study was supported by the grant of the Russian Foundation for Basic Research (06-05-64871), and by the INTAS Project "ALTImetry for COastal REgions" (ALTICORE).

Dynamic Topography Seasonal Variability