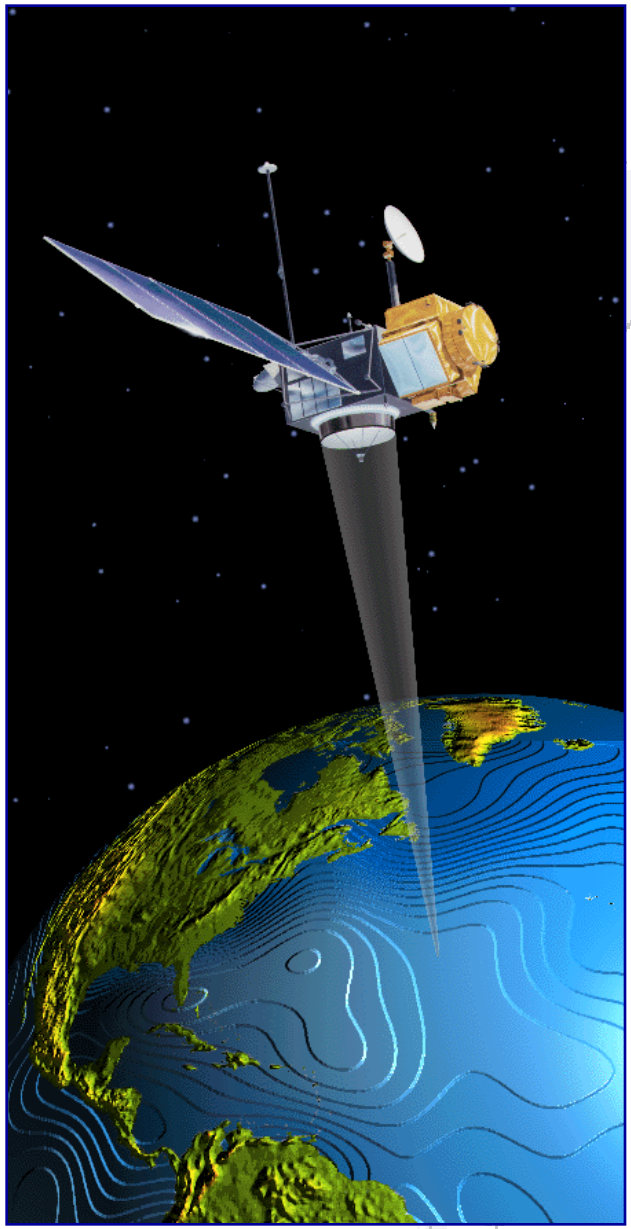
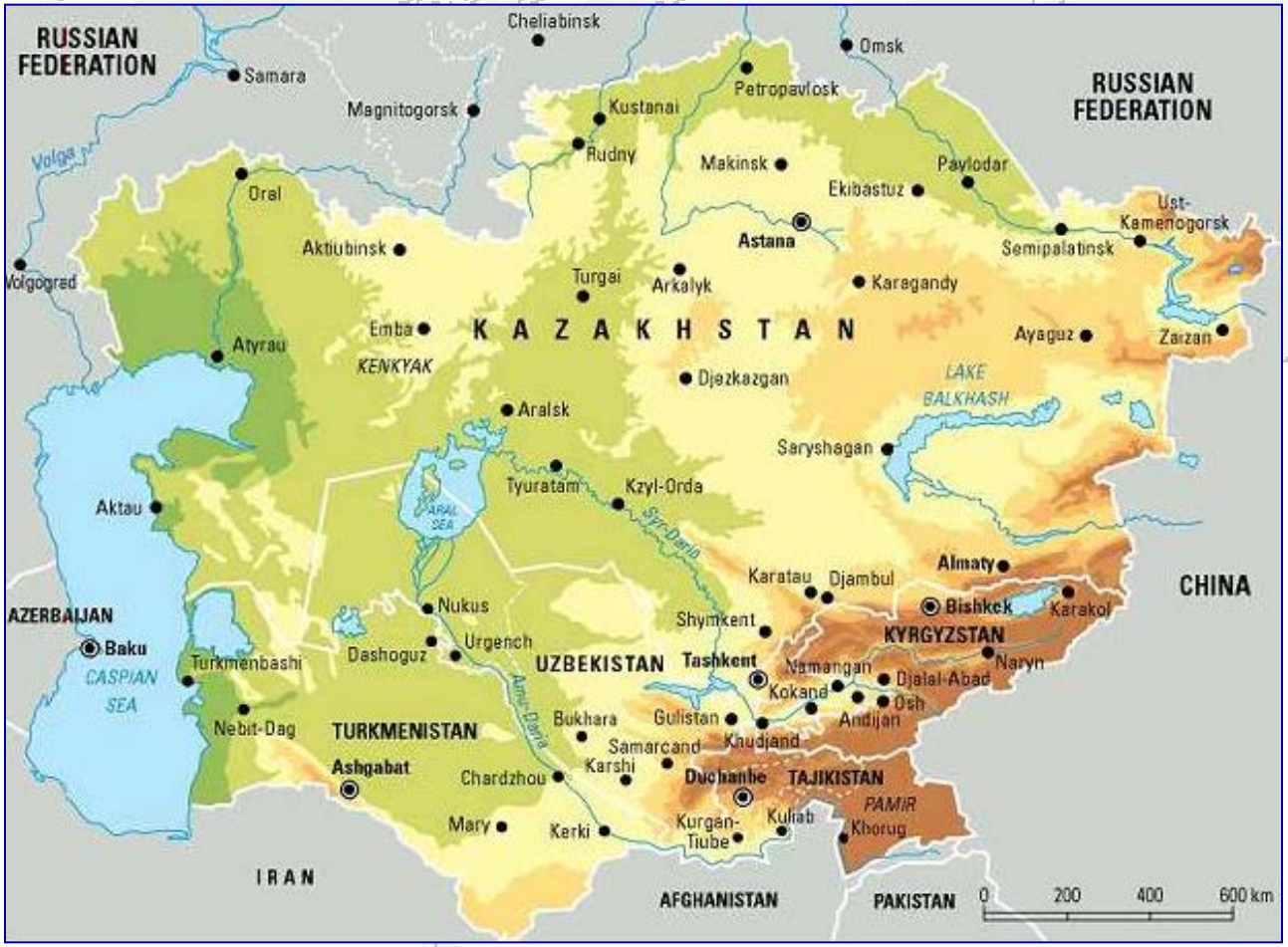


42nd International Liege Colloquium on Ocean Dynamics
"Multiparametric observation and analysis of the sea"
26-30 April 2010, Liege, Belgium

Complex Satellite Monitoring of the Aral Sea Region

Prof. Andrey G. Kostianoy
Dr. Anna I. Ginzburg
Dr. Nickolay A. Sheremet
P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences
Dr. Valentina I. Kravtsova
Faculty of Geography, Moscow State University

The Aral and Caspian Seas and Lakes of Central Asia



- Aral Sea
- Lake Sarykamysh
- Caspian Sea
- Kara Bogaz Gol Bay
- Lake Balkhash
- Lake Issyk-Kul
- Chardarinskoye Res.

A.G. Kostianoy, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences

Motivation

Desiccation of the Aral Sea in the so-called anthropogenic period (since 1961) led not only to considerable changes in its morphometric, physical, chemical, biological and other parameters, but to disappearence of the infrastructure in the coastal zone as well, including meteo and sea level gauge stations. The current lack of reliable in situ measurements and time series for sea surface temperature (SST), sea level and ice cover parameters since the mid-1980-s may be successfully replaced by using corresponding satellite information available through the World data bases.

Methods

Multi-Channel Sea Surface Temperature (MCSST) data (since November 1981) and data of the Pathfinder project (a joint NOAA/NASA project devoted to the production of a high quality global SST dataset from 1985 to the present) can be the base of tracing of long-term variability of SST in different parts of the Aral Sea. These data bases with high spatio-temporal resolution (1 km, daily) and temperature resolution (0.1°C) are based on measurements of Advanced Very High Resolution Radiometer (AVHRR) onboard satellites of National Oceanic and Atmospheric Administration (NOAA).

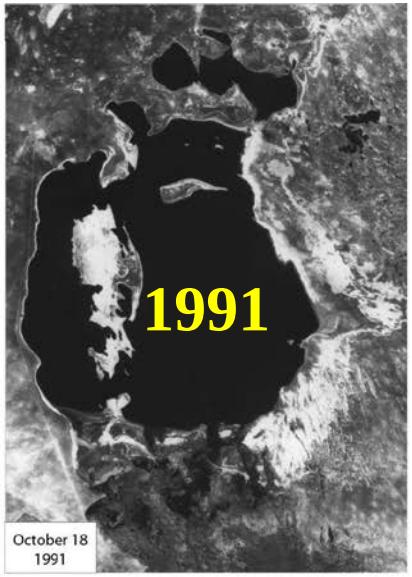
Methods

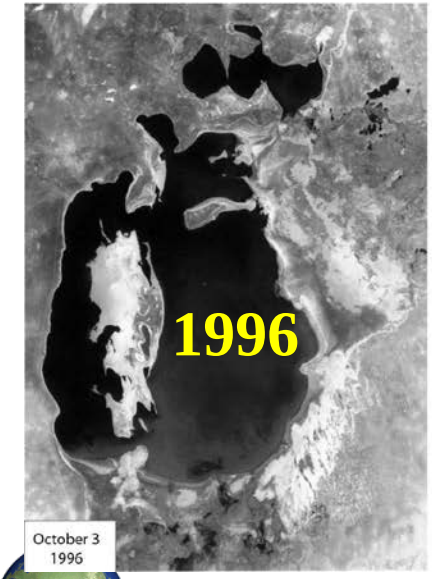
Radar altimeters from the TOPEX/Poseidon (T/P) and Jason-1 (J1) satellites provide reliable, regular, frequent, and weather-independent data for monitoring of sea level in the Large and Small Aral seas since 1992. Altimeter data and data of the Special Sensor Microwave/Imager (SSM/I) radiometer enable us to study interannual variability of ice regime of the Aral Sea.

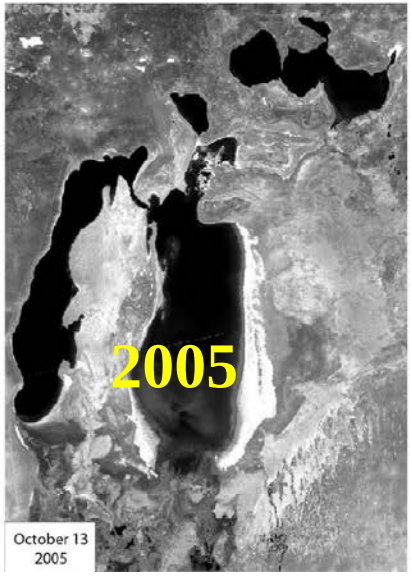
Images from AVHRR NOAA and MODIS (onboard Terra and Aqua satellites) radiometers provide a possibility to follow the changes in the sea coastline and observe interesting phenomena in water, atmosphere and on the dried parts of the Aral Sea.

The report discusses dynamics of various parameters of the Aral Sea during its desiccation which was traced with different type of satellite information. The consideration includes changes in morphometric characteristics (shoreline, sea area and volume), sea level, SST, and ice regime. Besides, we look at phenomena associated with changes in the Aral Sea coastline and salinity, water and atmosphere dynamics, dust storms, etc.

Morphometry







The change of the Aral Sea coastline configuration since 1957 till 2008

Mapping of changes in the Aral Sea shoreline with satellite images was initiated by Kazakh Aero-Geodesy Department (space photos from the Resurs-F satellites for 1977, 1984, and 1989, spatial resolution R~30 m).

Department of Cartography and Geoinformatics of Faculty of Geography of Lomonosov Moscow State University (MSU-SK/ Resurs-O images, R=170 m, scan swath of 600 km for 1989-1998; images obtained with digital photocamera from Russian module of International Space Station in 1999, R=50 m).

Since 2000/2002, regular images are available from the Terra/Aqua satellites, which perform daily global survey by MODIS images in visible and near infra-red bands (R=250 m).

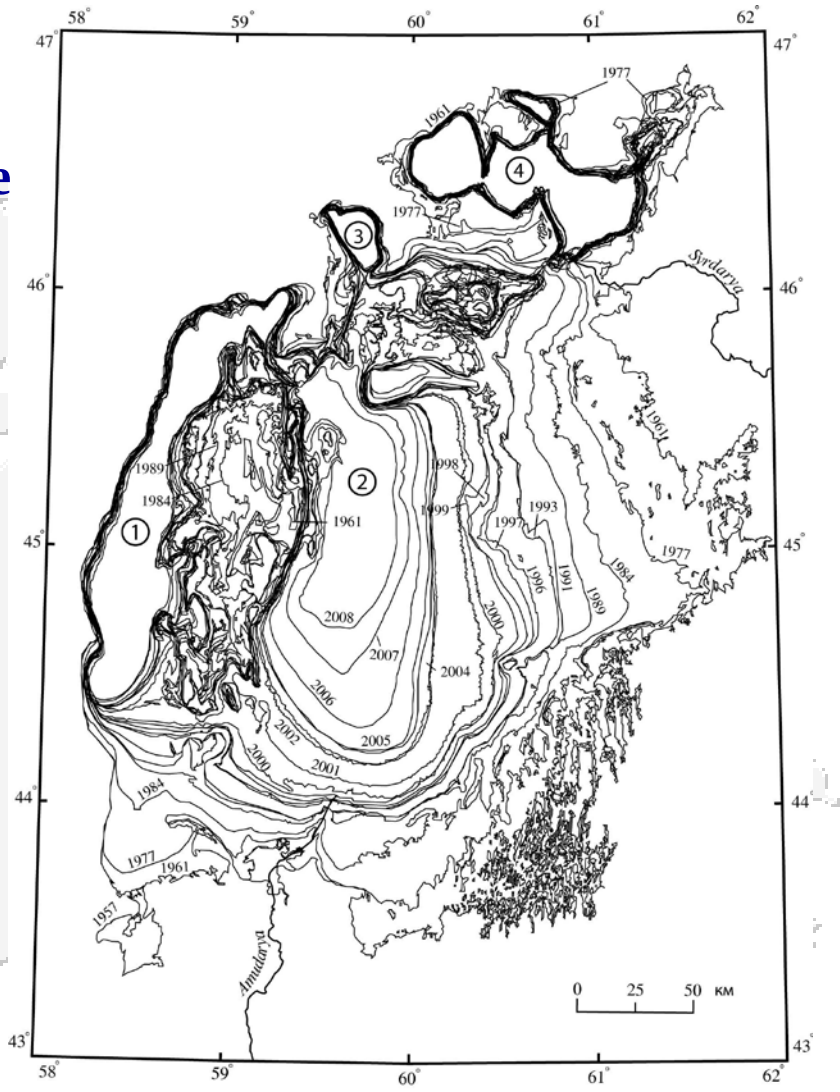
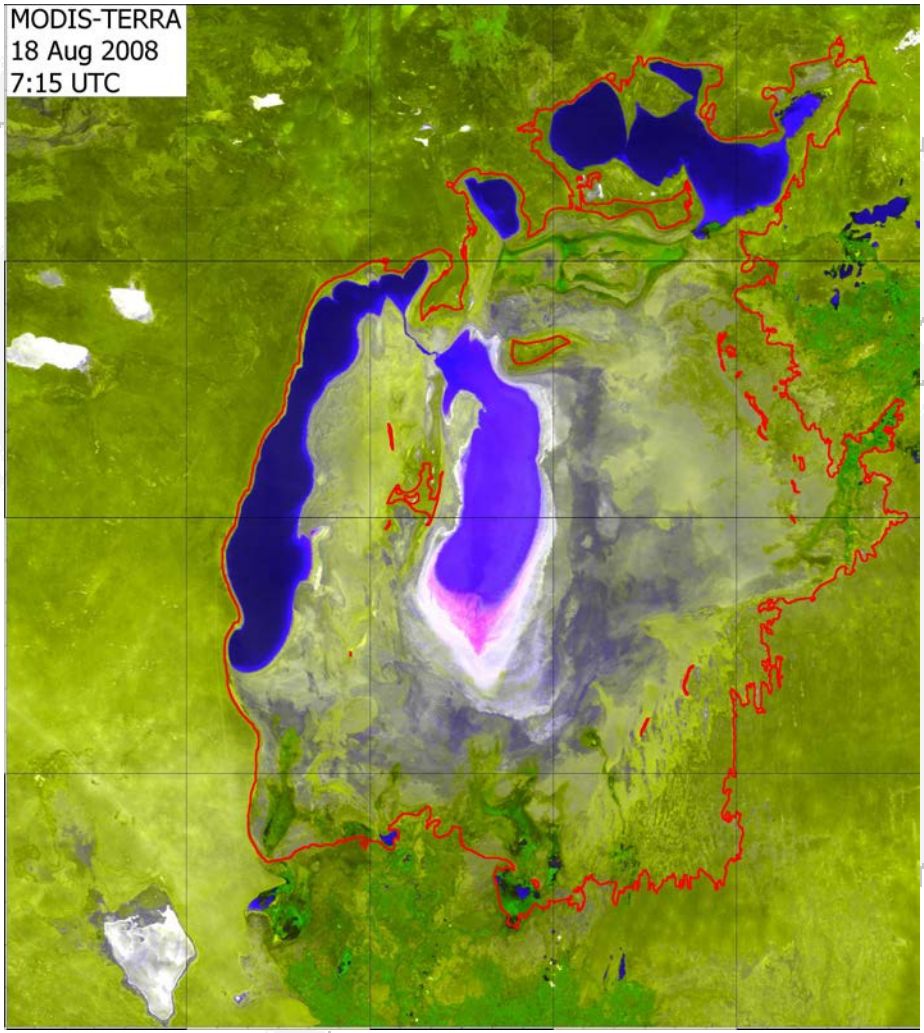


Table 1 Changes of the area of the Aral Sea and its parts (km^2) in 1957–2008

Year	Aral Sea as a whole	Large Sea					Small Sea
		As a whole	Western part	Eastern part			
				As a whole	Basic basin	Detached reservoirs	
1957	**67,100**	61,200					5,900
1961	**66,400**	60,500					5,900
1977	**54,900**	50,600					4,300
1984	**47,400**	43,700					3,700
1989	41,500	**38,400**	9,400	29,000			**3,100**
1991	36,600	**33,800**	8,200	25,600			**2,800**
1993	36,000	**33,000**	7,900	25,100			**3,000**
1996	31,300	**28,600**	7,100	21,500			**2,700**
1997	31,200	**28,100**	7,000	21,100			**3,100**
1998	29,700	**26,500**	6,700	19,800			**3,000**
1999	29,300	**26,300**	6,500	19,800			**3,000**
2000	26,700	**23,900**	6,200	17,700			**2,800**
2001	22,100	**19,400**	5,500	13,900			**2,700**
2002	19,900	**17,000**	5,200	11,800			**2,900**
2003	19,700	**16,800**	5,000	11,800			**2,900**
2004	17,900	**15,100**	4,800	10,300	9,500	*800*	**2,800**
2005	16,900	**14,100**	4,800	9,300	8,700	*600*	**2,800**
2006	15,700	**12,400**	4,600	7,800	6,800	*1,000*	**3,300**
2007	12,200	**8,900**	4,200	4,700	4,400	*300*	**3,300**
2008	10,400	**7,200**	4,000	3,200	2,900	*300*	**3,200**

Setting of numbers in bold reproduces the real separation of the Aral Sea into the Large and Small seas in 1989

The Aral Sea on 18 August 2008 and 16 August 2009



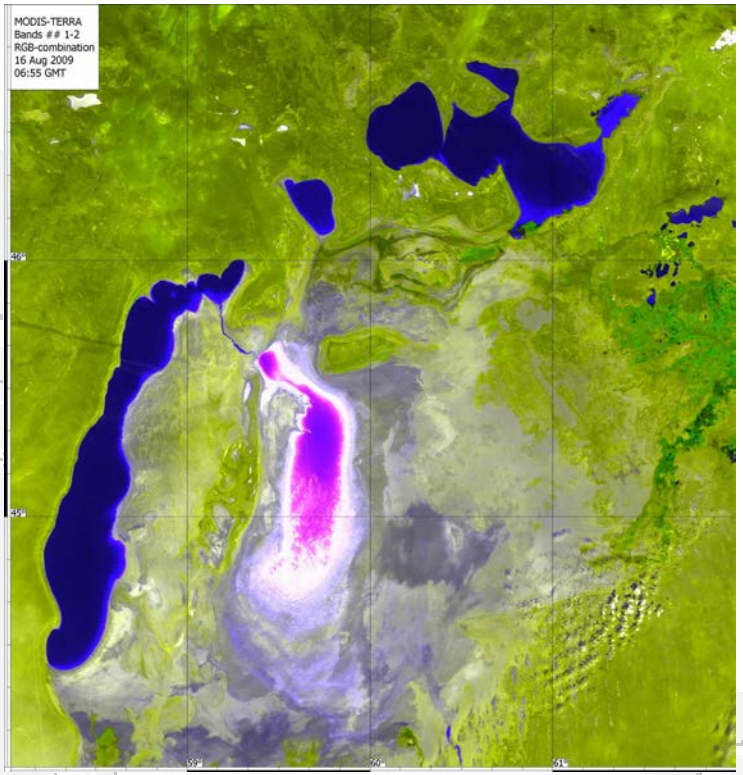
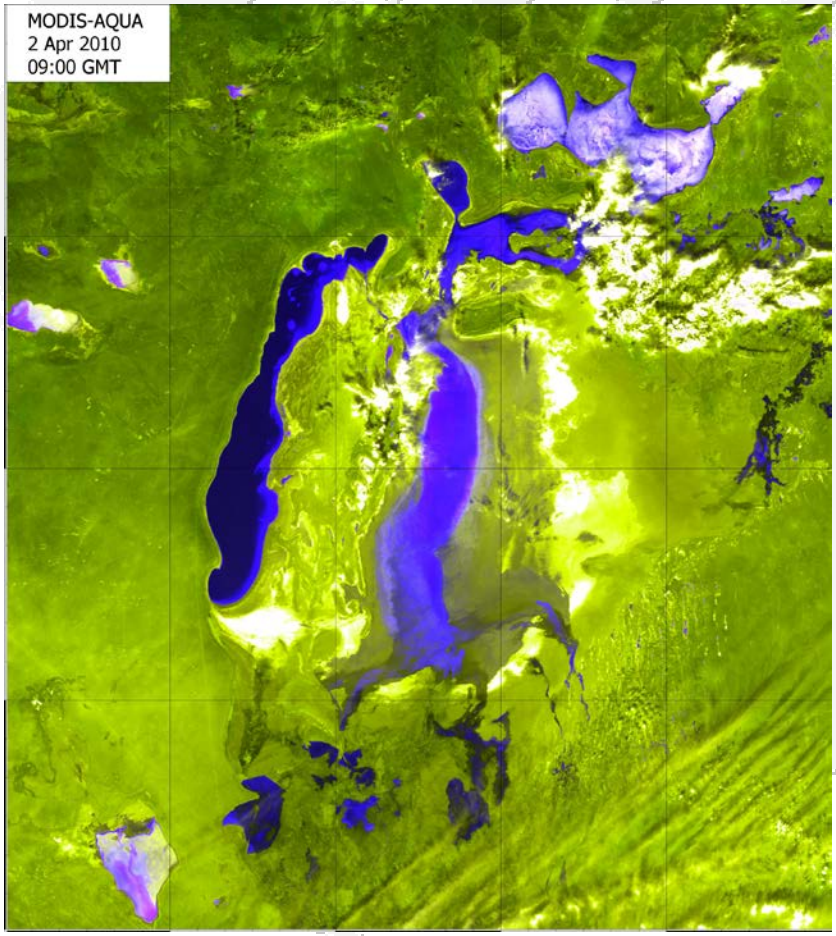


Image courtesy by D.M. Solovyov, Marine Hydrophysical Institute, Ukraine

A.G. Kostianoy, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences

The Aral Sea on 2 April 2010 (left). The shallow Large Eastern Aral Sea is flooded by water after winter snow and spring rains. By 18 April 2010 (right) this sea area became almost dry. It will completely desiccate by August 2010.



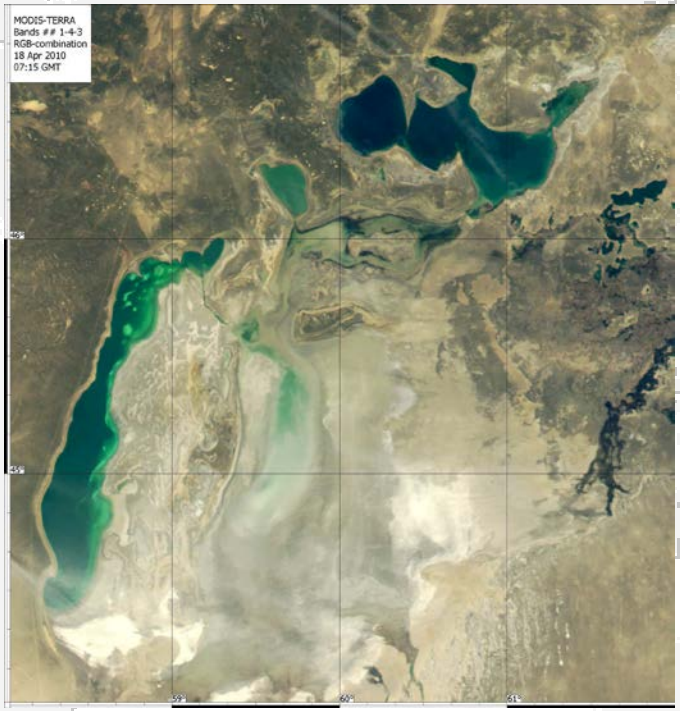


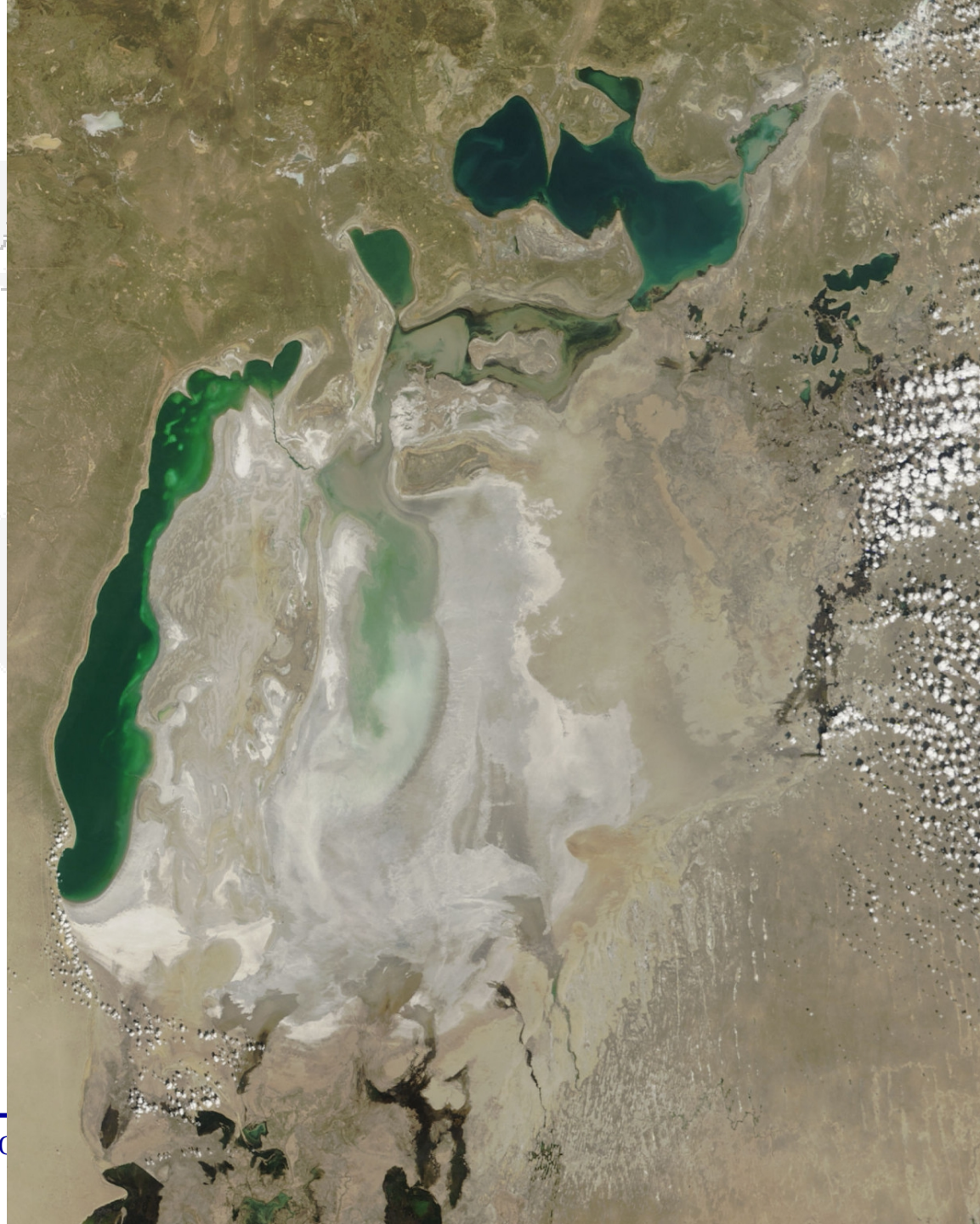
Image courtesy by D.M. Solovyov, Marine Hydrophysical Institute, Ukraine

A.G. Kostianoy, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences

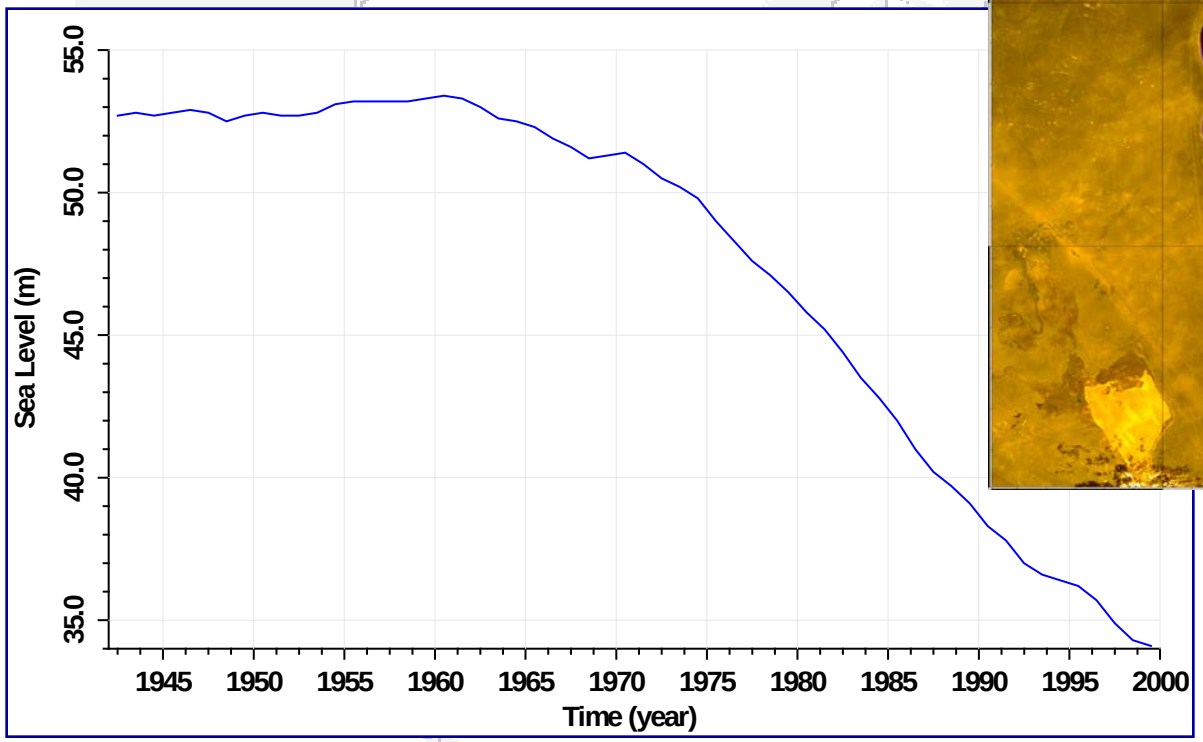
During Liege Colloquium the Aral Sea continues to desiccate

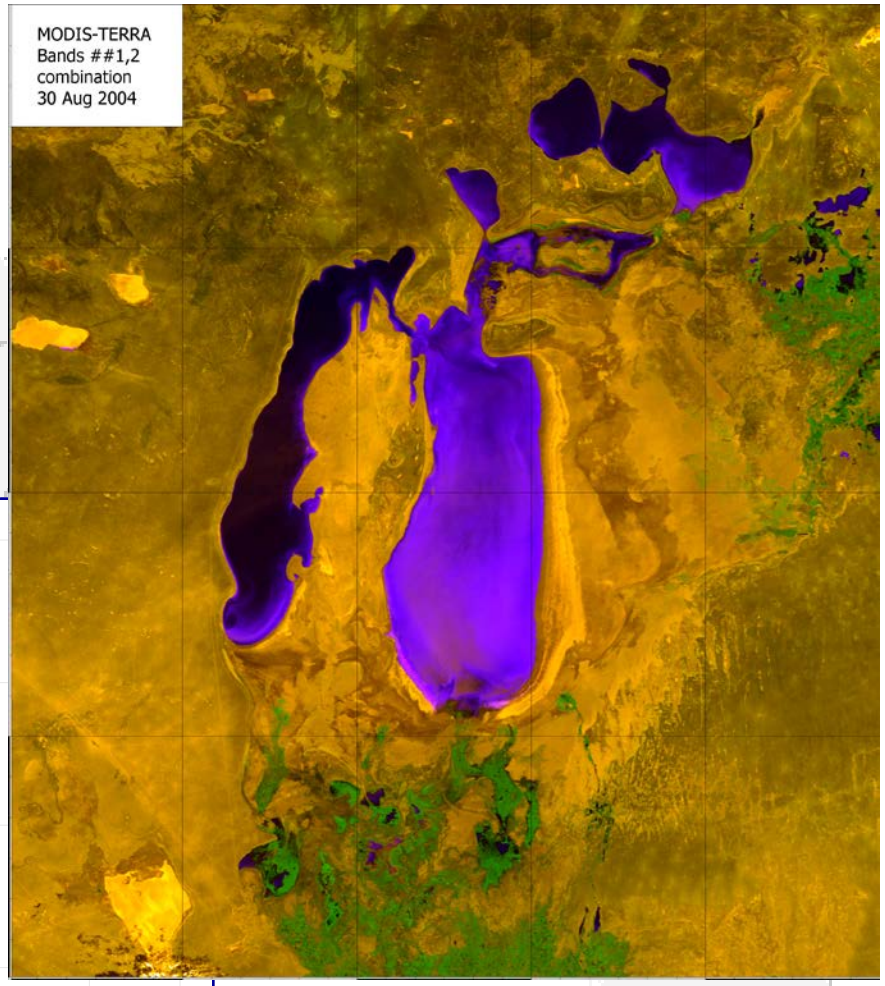
MODIS-Terra,
250 m resolution
27 April 2010

Image courtesy by Sergey Stanichny, Marine Hydrophysical Institute, Ukraine



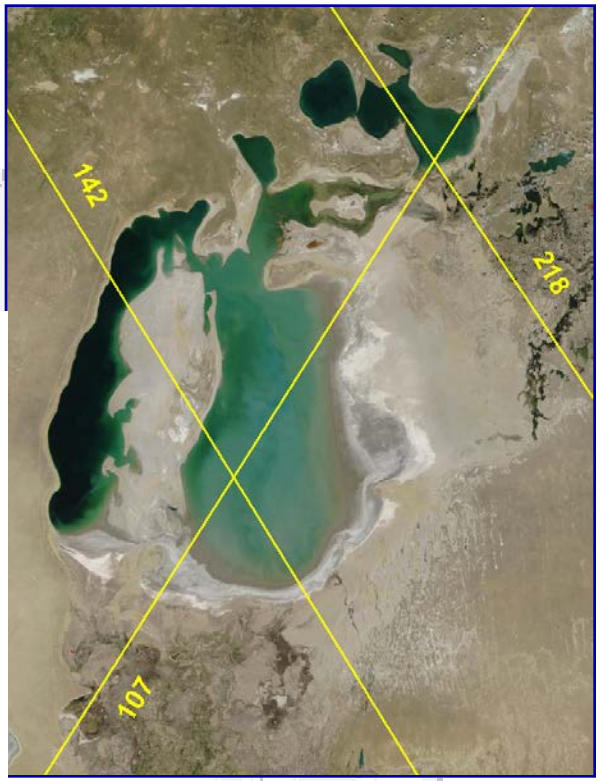
Time variation of the Aral Sea level in 1940-2000 (gauge and satellite data)

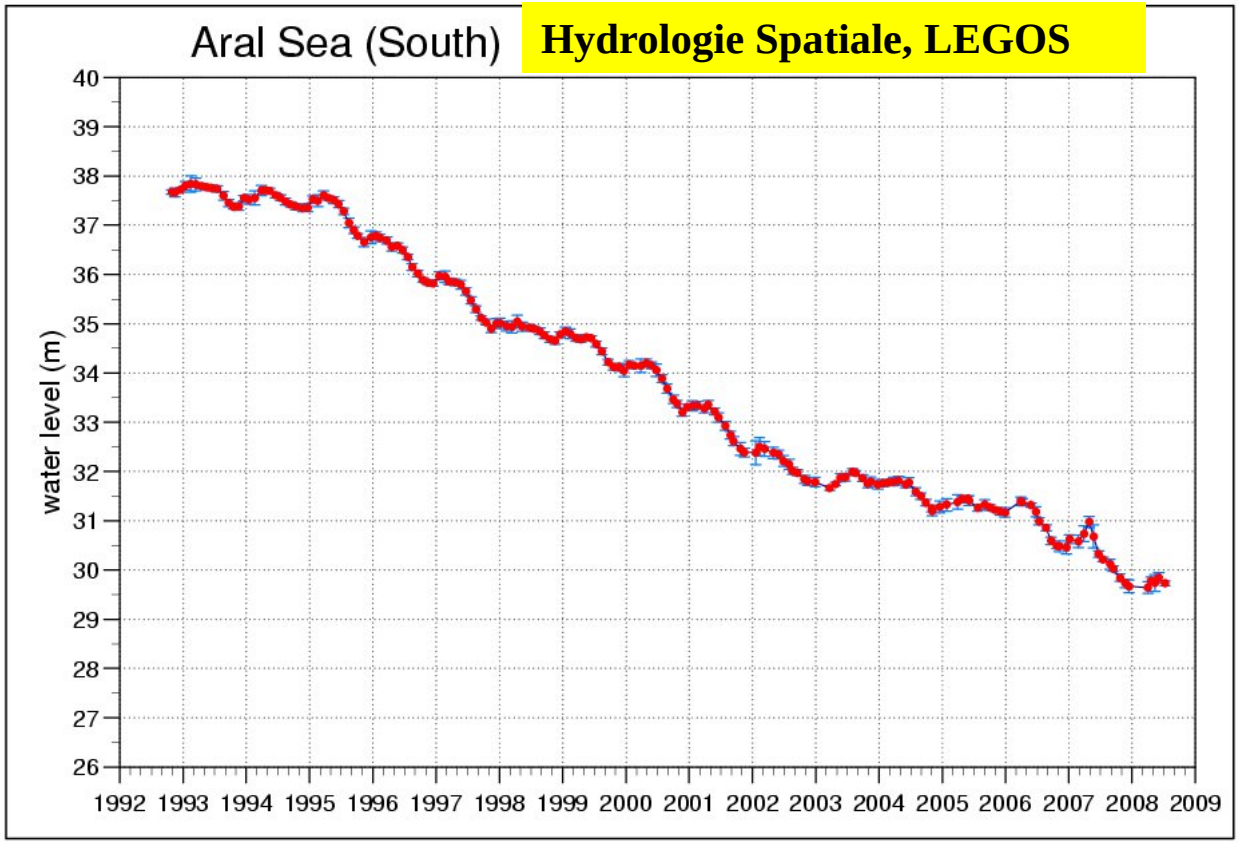




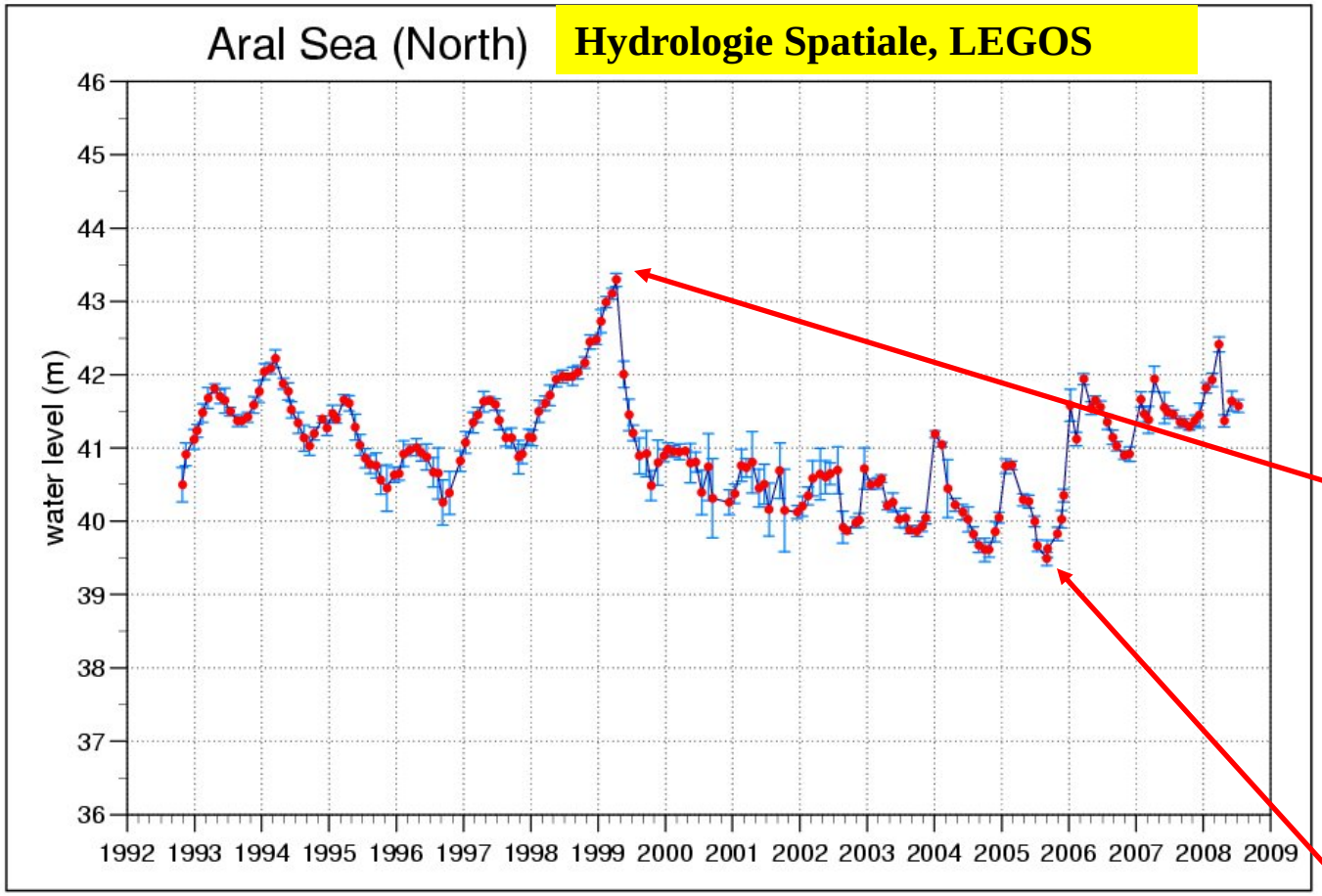
30 August 2004
MODIS Terra,
250 m resolution

Time variation of the Large Aral Sea level (1992-2009) by TOPEX/Poseidon and Jason-1 satellite altimetry data





Time variation of the Small Aral Sea level (1992-2009) by TOPEX/Poseidon and Jason-1 satellite altimetry data

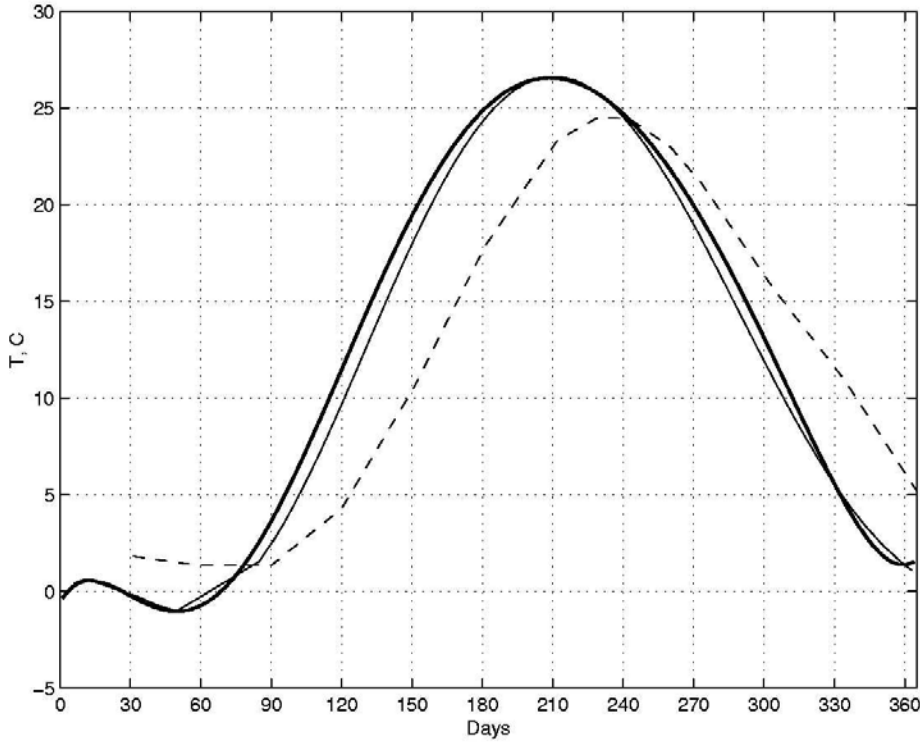


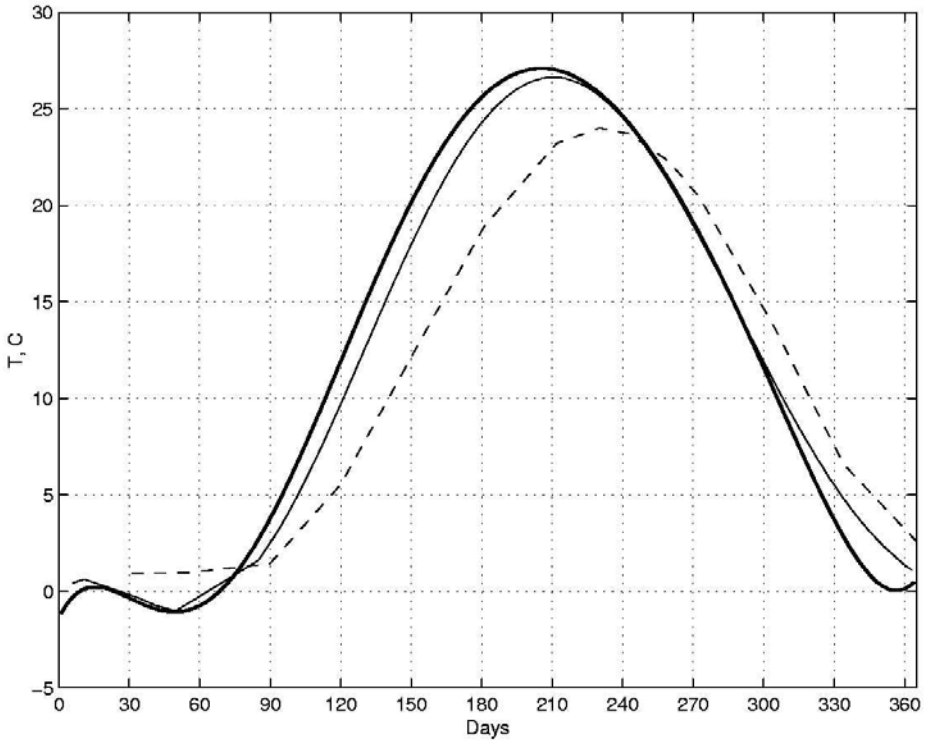
Early 1992 - first dam. August 1992 - second dam. Since then there have been several breaks in the dam. In 1996 the local authorities began to strengthen the dam and in 1998 the International Foundation for Saving the Aral Sea started financing the construction of the Kokaral Dam. In April 22, 1999 the big strong storm raced through all territory of Kazakhstan. Unfortunately, this weather once more damaged the Kokaral dam in the Aral Sea. By September 1999 the sea level decreased by 2.5 m. In August 2005 a solid dam was constructed.

Shift of SST Seasonal Variability

Seasonal cycles of SST in the Large Sea averaged over the period 1982-2000: (a) in the western part, (b) in the eastern part. Thick (thin) solid lines correspond to averaging over 1994-2000 (1982-1993); dashed lines correspond to seasonal cycles of SST in the conventionally natural period.

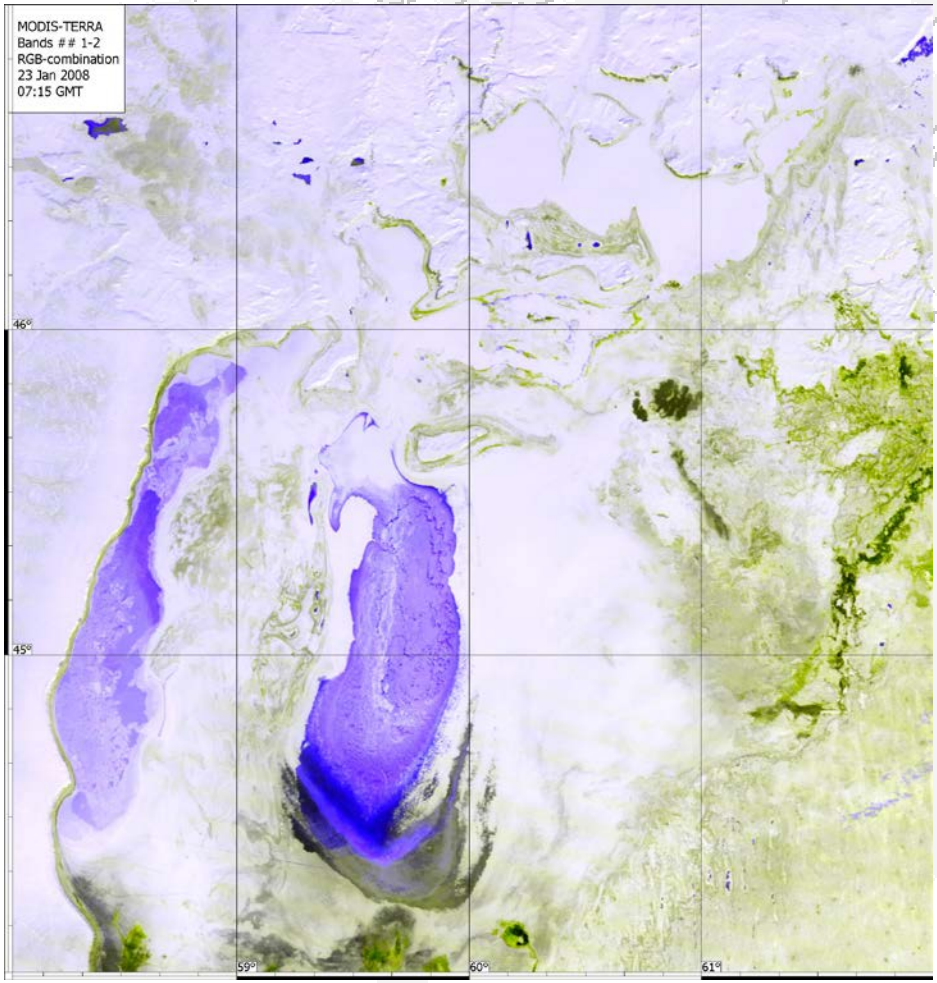
(a) **(b)**





Ice Cover in the Aral Sea

on 23 January and 9 March 2008



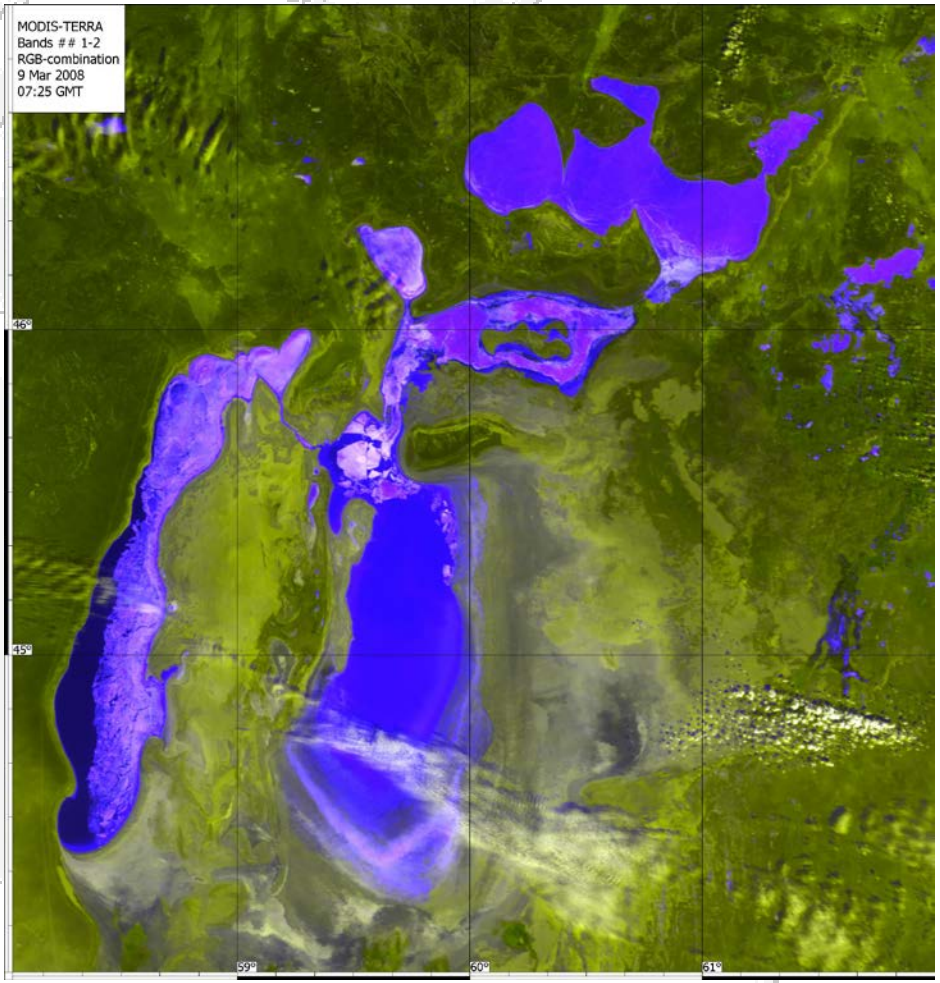


Image courtesy by D.M. Solovyov, Marine Hydrophysical Institute, Ukraine

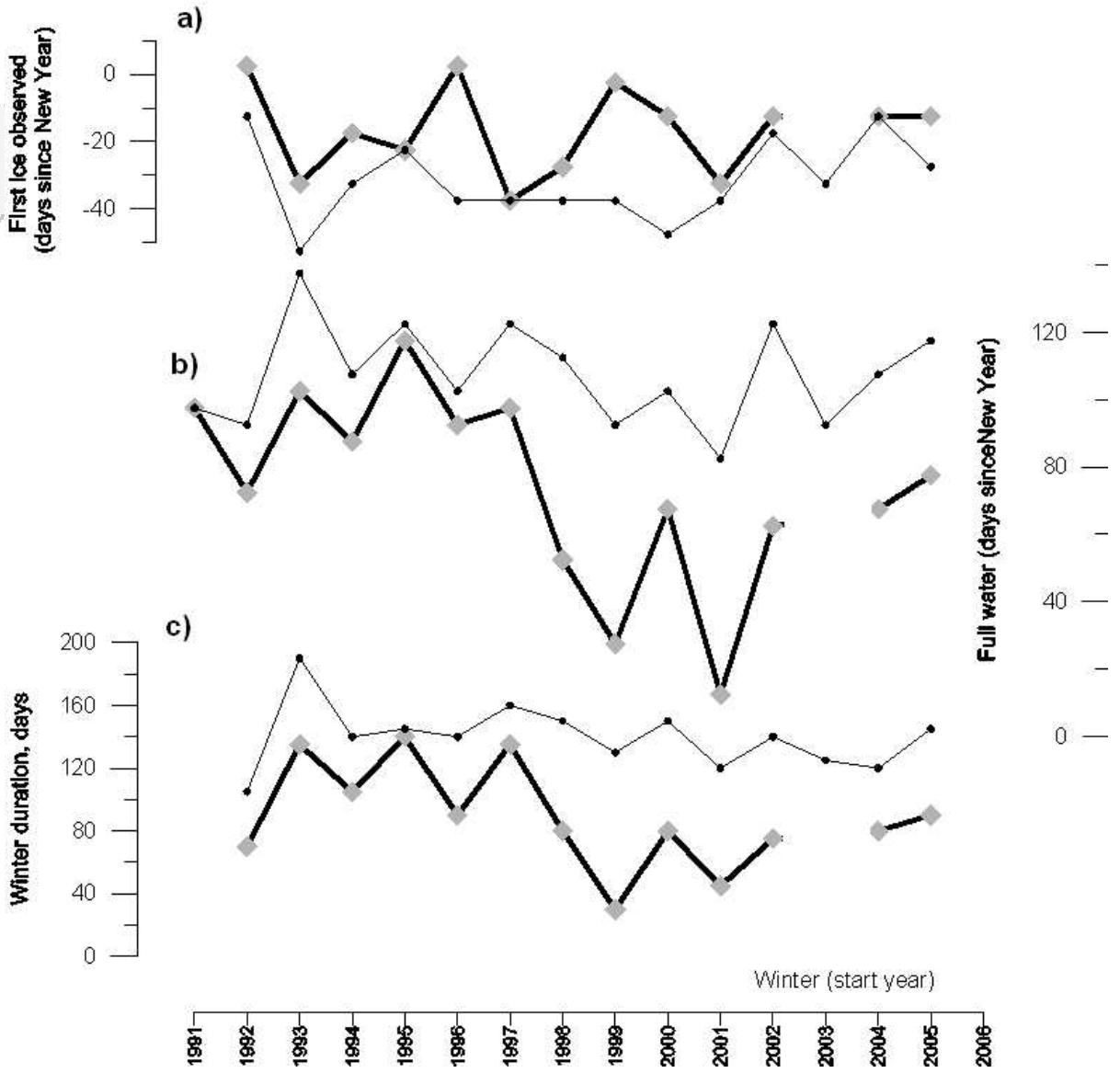
A.G. Kostianoy, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences

Ice Cover

Date of first ice observed

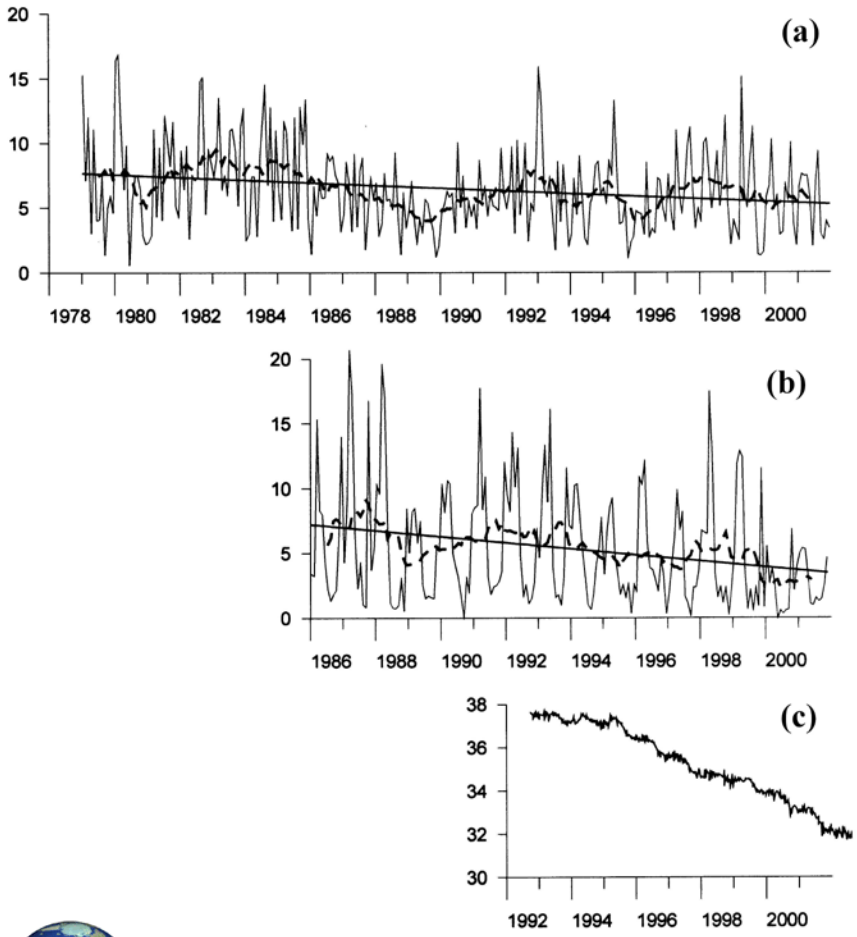
Duration of open water (days)

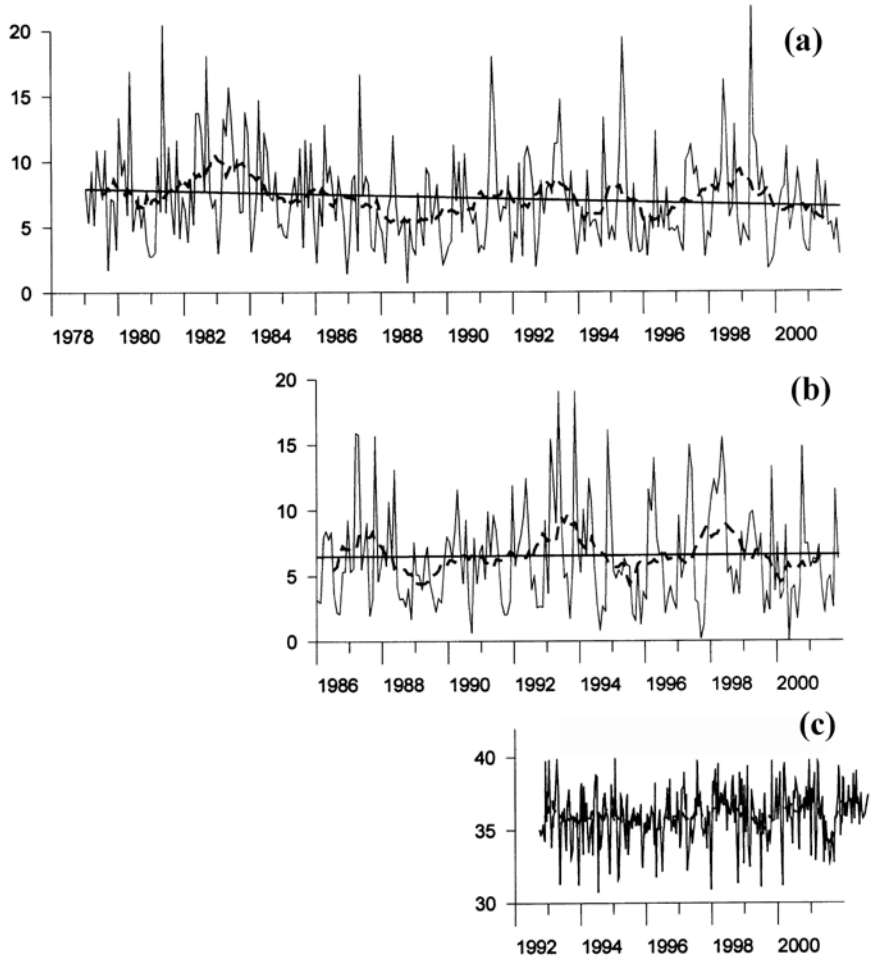
Winter duration (days)



Interannual variations of the discharge of Amu Darya (left) and Syr Darya (right) Rivers derived from precipitation integrated over its catchment area.

(a) Satellite-measured (GPCP) precipitation (km^3/month); (b) gauge-measured (GPCC) precipitation (km^3/month); (c) satellite-measured (T/P) level of the Large Sea (m); Dashed line is moving average of about 1 year (13-point) period



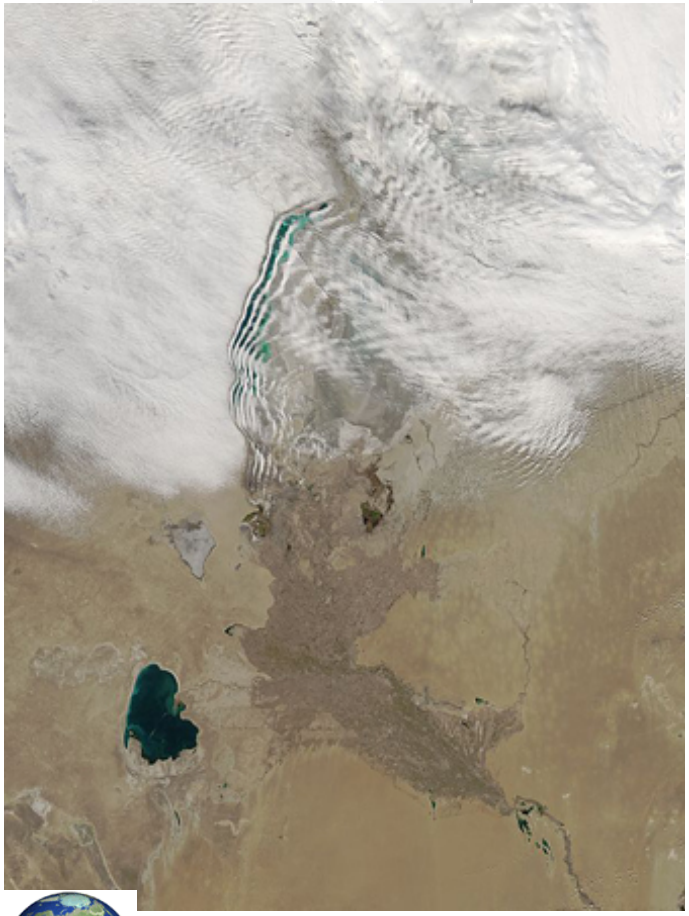


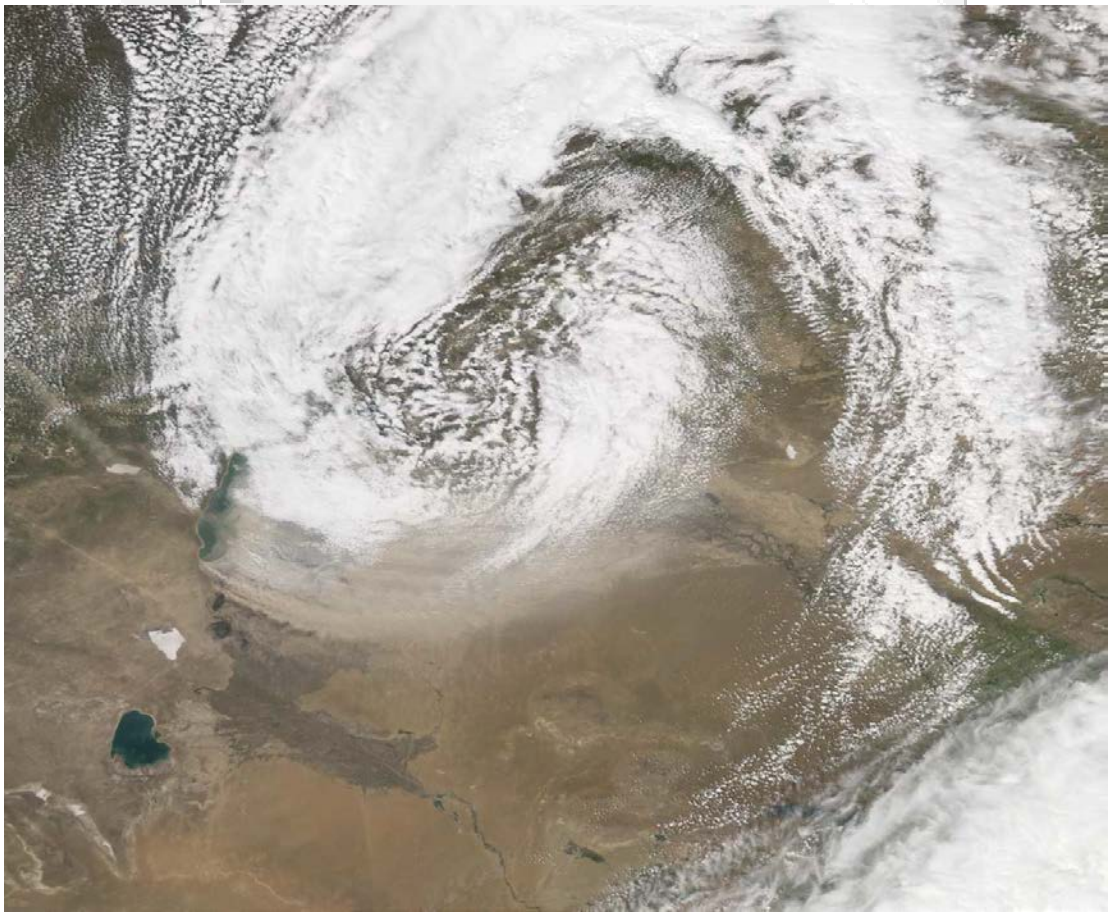
A.G. Kostianoy, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences

Atmospheric phenomena

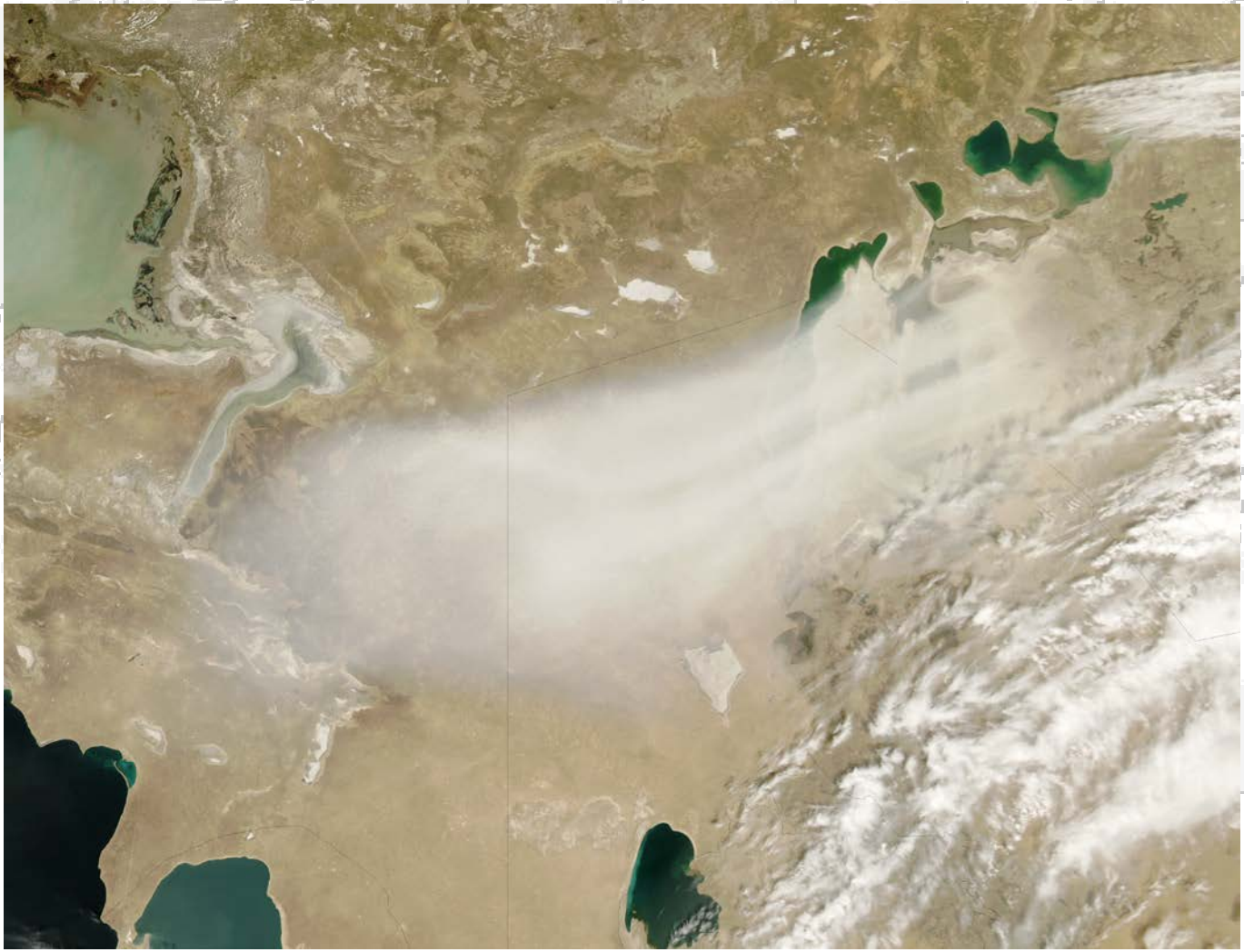
Left: unusual wave clouds over the Aral Sea, which conform exactly to the shape of the western shore (12 March 2009).

Right: Intense atmosphere cyclone generates dust/salt storm from the Aral Sea (7 May 2007).





Dust/salt storm from the Aral Sea to the Caspian Sea
MODIS/Aqua image for 29 April 2008, courtesy of NASA



What else?

The Aral Sea surface, volume and sea level

Interannual variability of SST

Freezing point

Salinity

Wind surge events: flooding and dewatering

Upwelling and eddies

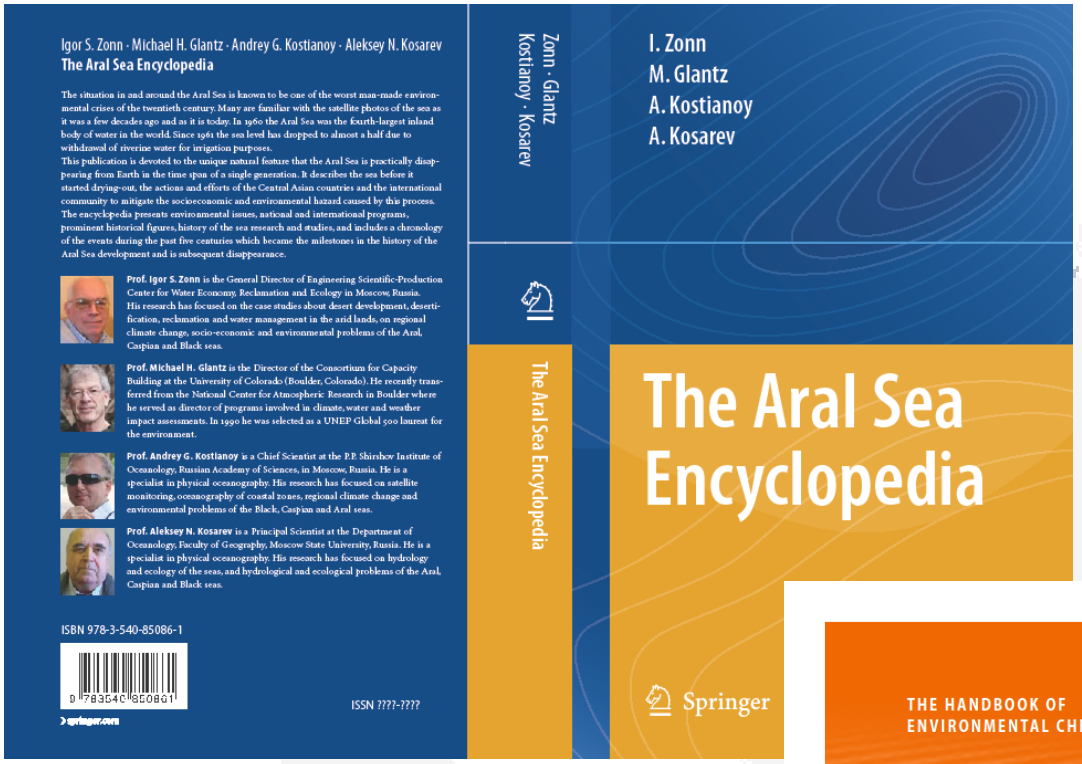
Amudarya runoff

Seasonal and interannual variability of NDVI

Seasonal and interannual changes in landscapes

Mapping of natural complexes (marsches, solonchaks, salt crusts, sands, desert, reed vegetation, etc)

Desertification and salinization of soils



I. Zonn, M. Glantz, A. Kostianov, A. Kosarev
Springer, 2009

A. Kostianov, A. Kosarev (Eds.)
Springer, 2010

Acknowledgements

Radar altimeter data from the NASA/CNES Topex/Poseidon and Jason-1 satellite missions

Time series of altimetric lake level variations from the USDA Reservoir Database at

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir

La base de données hydrologiques du LEGOS

http://www.legos.obs-mip.fr/soa/hydrologie/hydroweb/

NASA's Earth Observatory