



**THE FUTURE OF
THE ARAL SEA: IS
THE GLASS HALF
FULL OR HALF
EMPTY?**

**Image: MODIS 250
meter resolution
natural color
July 20, 2009
Bands 1-4-3
Terra satellite**

**Prepared for the
International
Conference
*Aral: Past,
Present and
Future - Two
Centuries of
the Aral Sea
Investigations*
12-16 October
2009
Saint
Petersburg
Scientific
Centre of
Russian
Academy of**

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I want to thank the organizers of this conference and the Lucia Harrison Fund of the Dept. of Geography, Western Michigan University, Kalamazoo, Michigan, USA, for providing support for me to attend and participate in this conference.

ORGANIZATION OF TALK

- I. The Aral's Past: Lessons for the future.**
- II. The Modern Desiccation (1960-2010): Facts and Myths**
- III. The Future: Good News and Bad News.**

THE ARAL'S PAST

- Most recent expression of lake Aral appeared only at end of Pleistocene (10-15,000 years B.P.) as the terminal water body of Syr Dar'ya.
- Later, Amu Dar'ya, which flowed westward to Caspian, changed course to Aral and filled it to modern form.
- During past 10,000 years (Holocene Epoch), lake repeatedly dried and refilled owing to climatic fluctuations and changes in the Amu Dar'ya's direction of flow from Aral to Caspian (via Sarykamysh Depression and Uzboy Channel) and back again.
- But, without doubt, changes in Amu's direction of flow, some of human origin, have been the major cause of level fluctuations.
- Last major desiccation of Aral occurred from late 13th to middle 16th century and was likely human related. Sea, level probably fell to at least 30 meters asl and possibly lower.

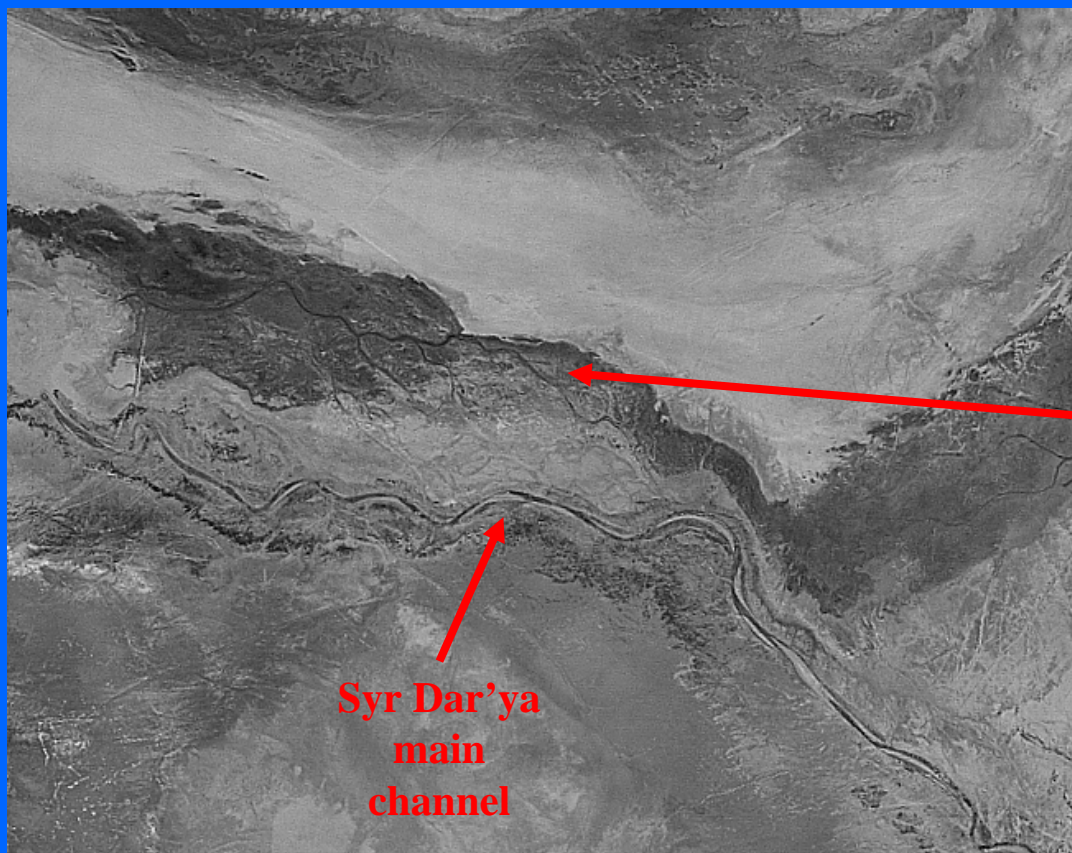
THE ARAL'S PAST (continued)

- Extensive irrigation practiced here for several thousand years, but does not appear to have been a significant factor in reducing river inflow and lowering lake levels until recent decades (post 1960).
- Aral was in a “high standing” period from mid 1600s until 1960s with level above 49 meters asl. For 1911 to 1960, annual average level was stable, ranging from 52.5 (1920) to 53.4 (1960) meters asl.
- *Key point: Aral is resilient and has come back from major recessions several times in past.*

ARCHEOLOGICAL SITES AND OLD BED OF SYR DAR'YA

LANDSAT5 IMAGE OF DRIED BOTTOM OF
NORTHERN PART OF EASTERN ARAL
ACQUIRED SEPT. 11, 2007 SHOWING FORMER
BED OF SYR DAR'YA DATING TO 13TH- 16TH
CENTURIES (BAND 5, 30 METER
RESOLUTION)

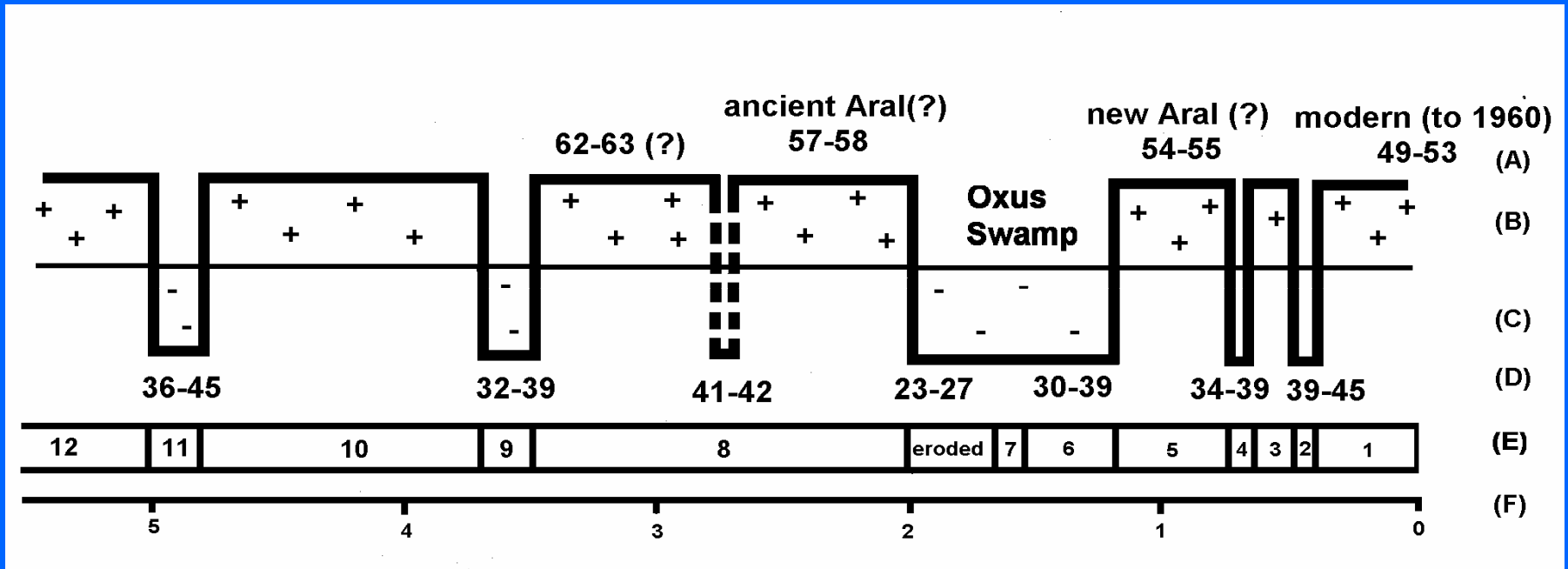
RUINS OF KERDERY 1
MASOLEUM WITH FORMER
BRANCH OF SYR DAR'YA IN
BACKGROUND; UNDER 18
METERS OF WATER IN 1960
(AUGUST 2005)





**PRESERVED
SAKSAUL (*Haloxylon
aphyllum*) STUMP 20
← METERS BELOW
1960 SEA LEVEL
(Western Basin Large
Aral, Sept. 2005)**

TRANSGRESSIVE AND REGRESSIVE STAGES OF THE ARAL SEA DURING THE MIDDLE AND LATE PLEISTOCENE (according to Mayev, Mayeva and Karpychev)



Legend: (A) Transgressive stage and level in meters above sea level (based on literary data). (B) Transgressive stage. (C) Regressive stage. (D) Estimate of the regressive stage level in meters above sea level. (E). bottom sediment layers. (F) Radiocarbon age in 1000s of years before present (B.P.) “+” = transgressive stage; “-“ = regressive stage

Source: Modified and redrawn from Mayev, E.G., S.A. Mayeva, and Yu.A. Karpychev (1991). “The Aral Sea in the Holocene.” In *Aral Crisis*. Moscow: Academy of Sciences of the USSR: 85-86. [in Russian]

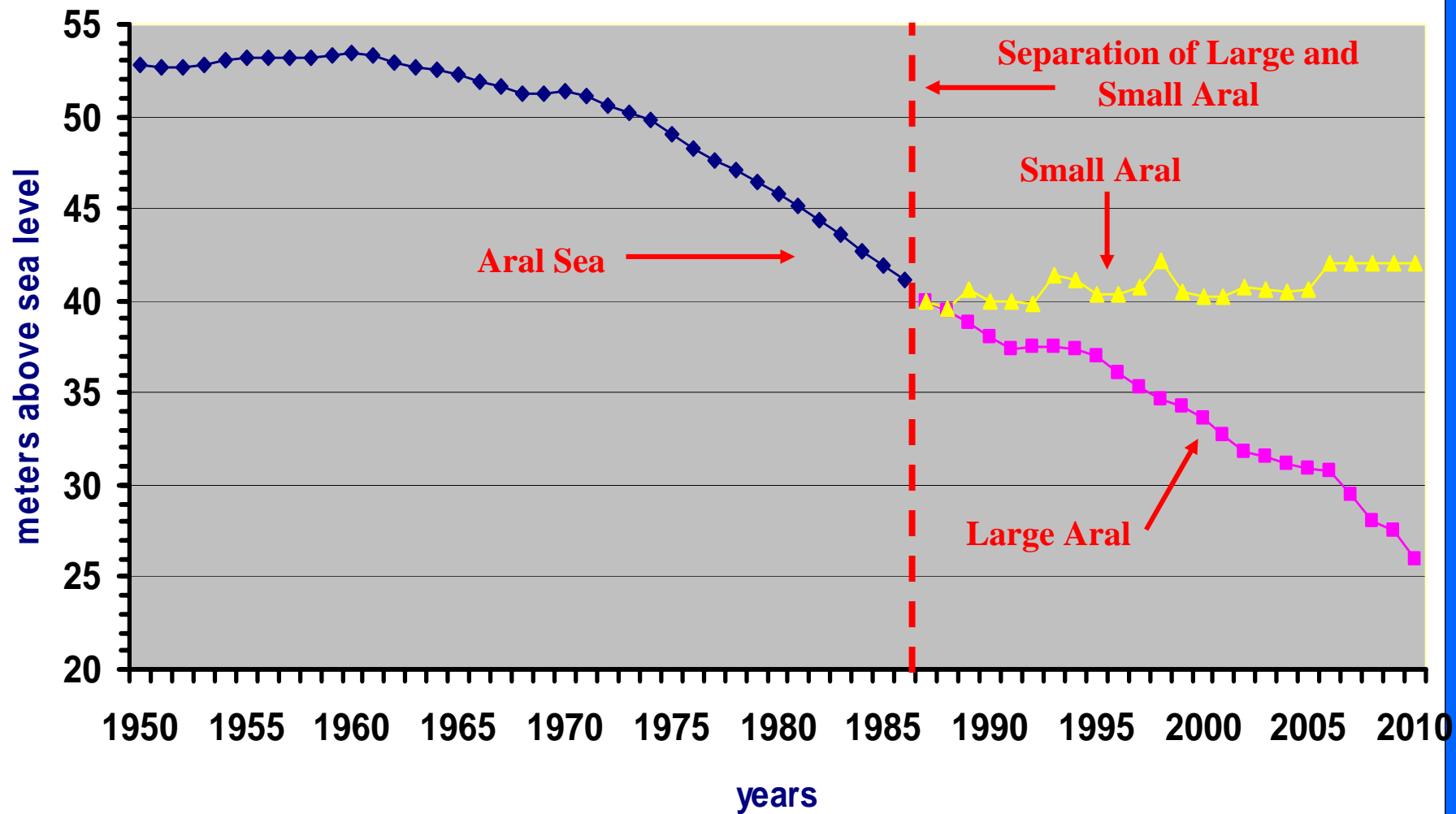
THE MODERN DESICCATION (1960-2010)

- Began in early 1960s and continues unabated.**
- Aral was high from 1911-1960, so some “natural” drop in level (4 to 5 meters maximum?) from reduced river inflow and/or increased evaporation from sea surface could have been expected.**
- But, clear most of level drop (>80%) owes to increased withdrawals of water for irrigation that greatly reduced river inflow.**
- “Climate change” (global warming) has been put forward by some as a significant contributor to Aral drying . May have played a minor role over past several decades. Will be much more important factor affecting Aral levels in future.**

THE MODERN DESICCATION (continued)

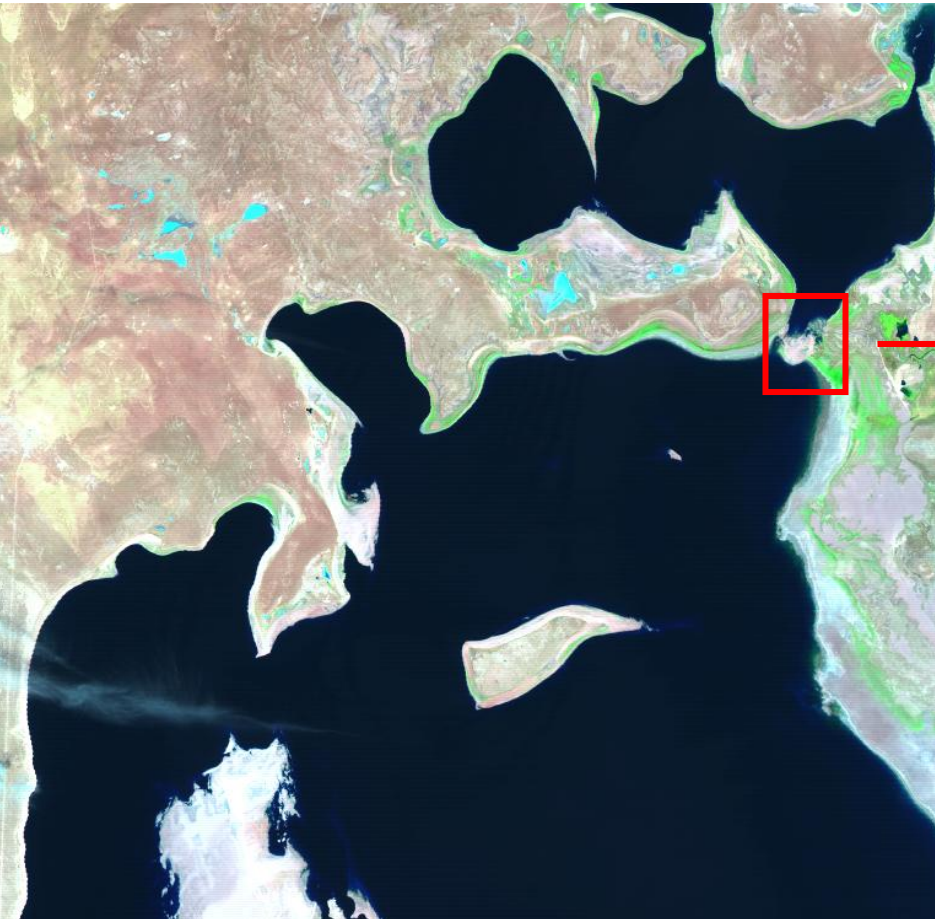
- Irrigation was expanded beyond point of sustainability and overwhelmed natural factors that earlier had acted to compensate for withdrawals. Also water losses were much greater as irrigation expanded far out into the deserts and much more of irrigation drainage water ended up in terminal lakes (e.g., Arnasay and Sarykamysh) where it evaporated and much less was returned to Syr and Amu.
- In 1950s, 1960s and 1970s, negative impacts (ecological, social, economic) of expanded irrigation on Aral Sea & surrounding region and population were not fully identified and speed of occurrence and magnitude of these was grossly underestimated.
- But clear that irrigation expansion had some positive social and economic effects that must also be given consideration in any balancing of gains and losses.

Aral Sea Level: 1950-2010

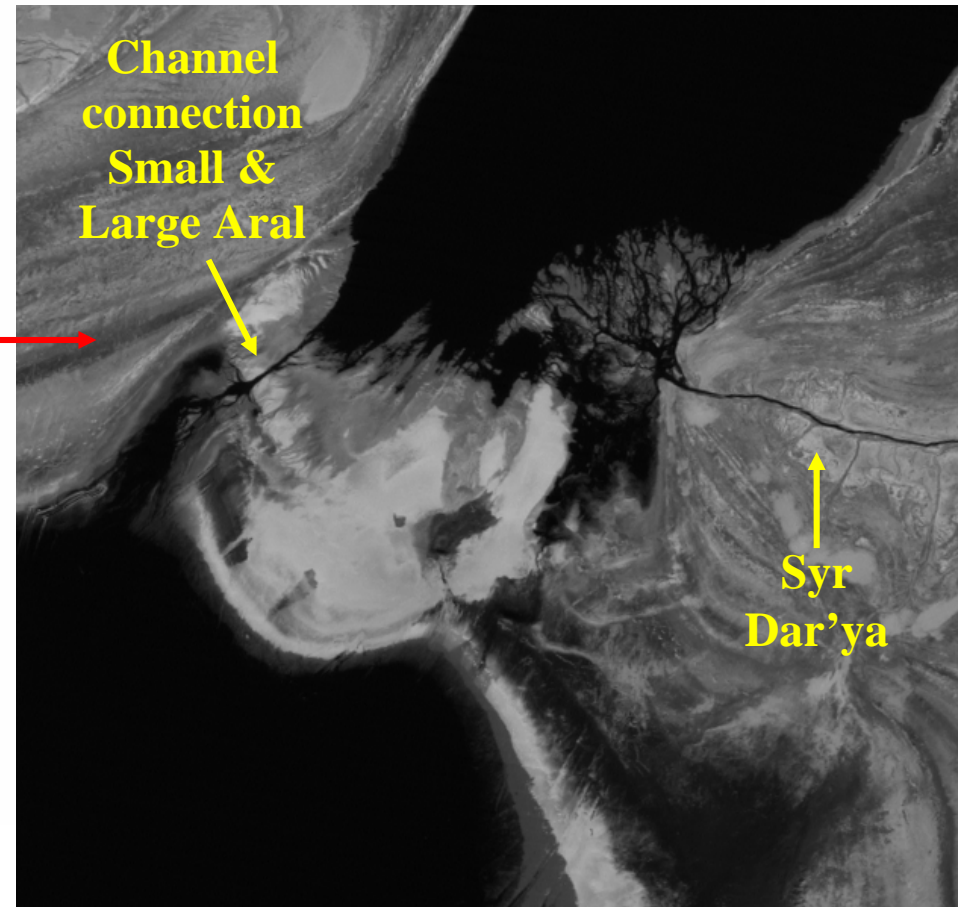


BERG STRAIT AFTER SEPARATION OF SMALL ARAL FROM LARGE ARAL SEA

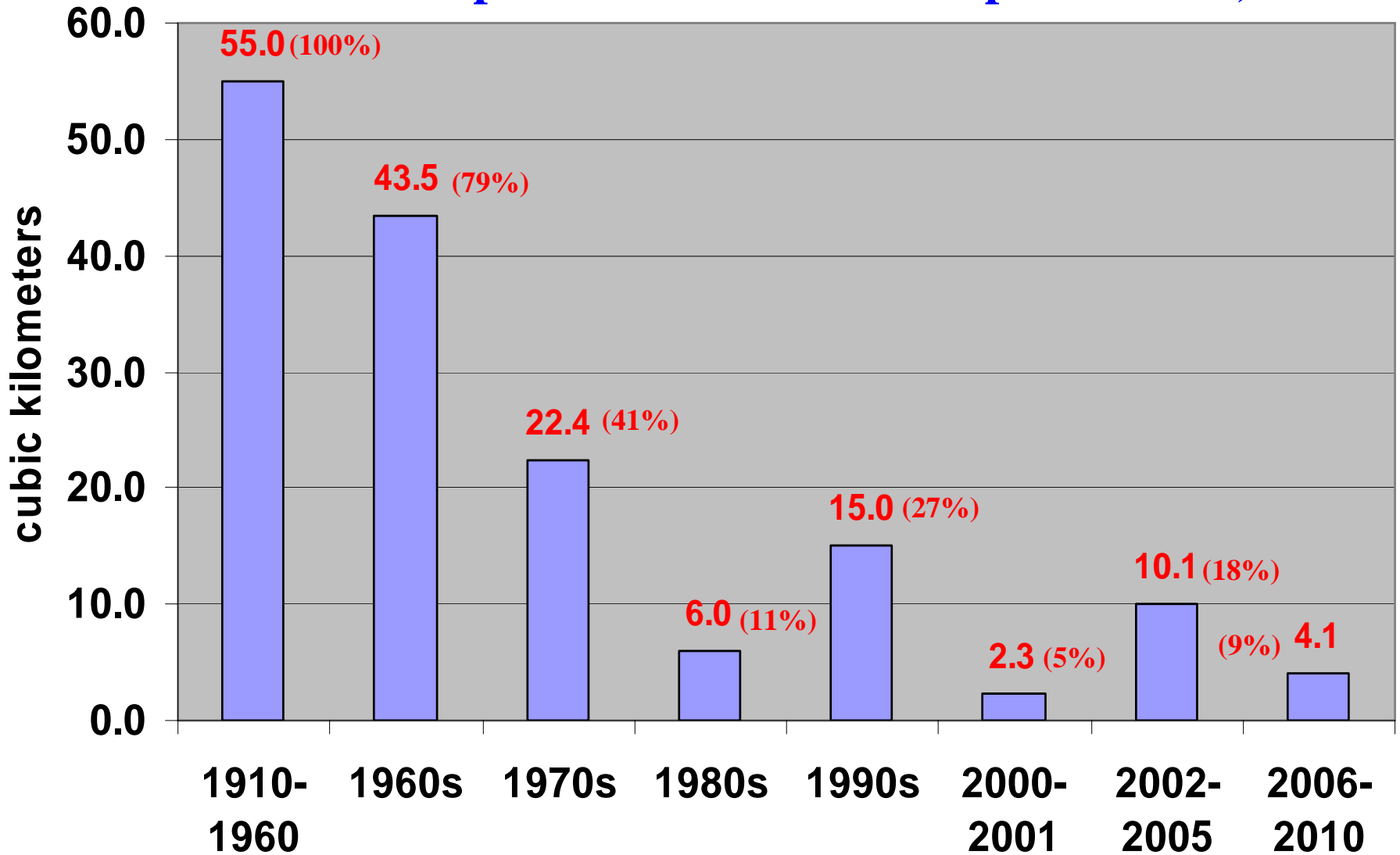
LANDSAT4, 8-16-89, NATURAL
COLOR COMPOSITE, BANDS 4-3-1,
240 METER RESOLUTION



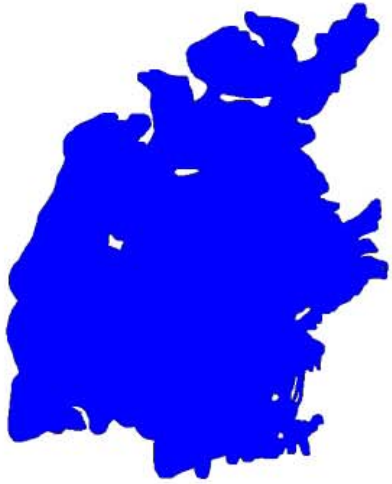
LANDSAT4, 8-16-89, BAND 5, 30
METER RESOLUTION



ESTIMATED AVERAGE ANNUAL RIVER FLOW (SYR + AMU) INTO THE ARAL SEA (figures in red indicate km³ on left and percent of 1910-1960 in parentheses)



THE CHANGING PROFILE OF THE ARAL SEA



1960



1971



1976



1989



2009
(Oct.)



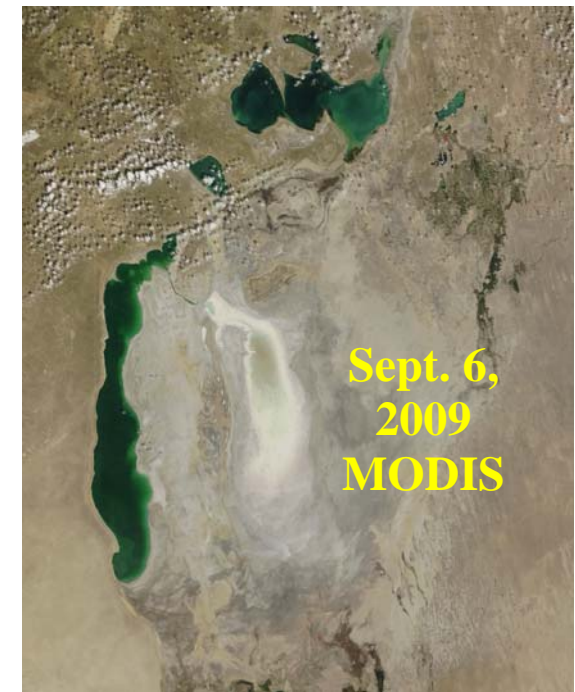
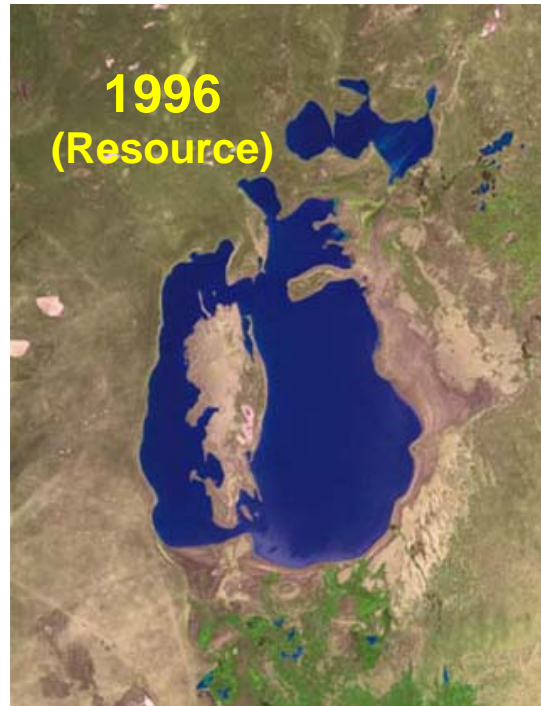
2025?

• **Area:** 1960 = 67,500 km² (4th in World); Sept. 6, 2009 = 8,409 km² (88% loss)

• **Level:** 1960 = 53.4 meters; Sept. 6, 2009 = Large Sea = 26.5 meters; Small Sea = 42 meters (26.5 m drop for the Large Sea)

• **Volume:** 1960 = 1090 km³; Sept. 6, 2009 = 84.5 km³ (92% loss)

• **Avg. salinity:** 1960 = 10 g/l (brackish); in 2009 Large Sea >100 g/l in western basin and probably >200 g/l in eastern (hypersaline); Small Sea = 10-14 g/l



THE FUTURE OF THE ARAL SEA

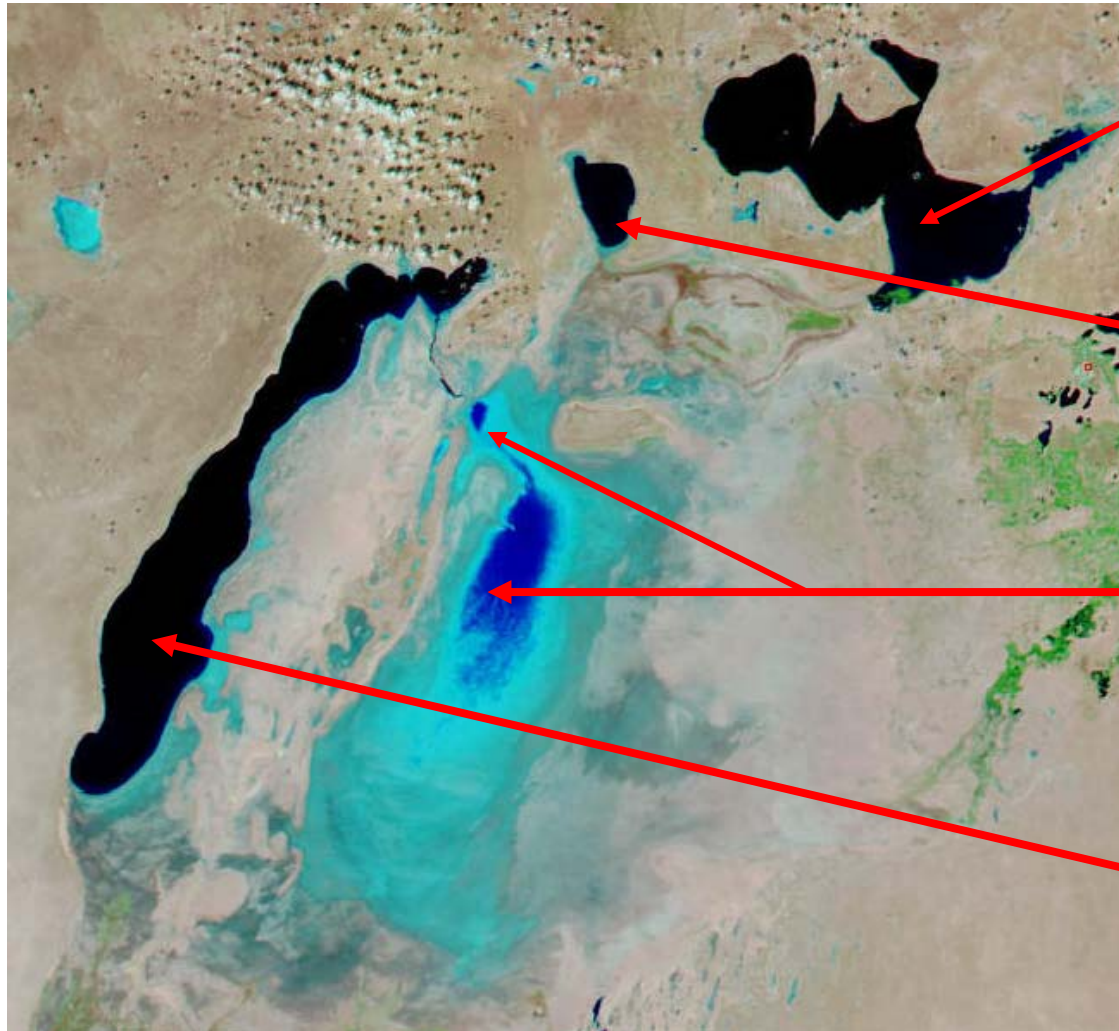
- **Modern recession of Aral is already most serious in several thousand years and will soon, if present trends continue, become the most severe in past 10 millenia.**
- **Restoration of sea to 1960s size in foreseeable future extremely unlikely as it would require not only very expensive improvements in irrigation efficiency, but sizable cutbacks in irrigated area in Aral Sea Basin to free sufficient water for Aral.**
- **Partial restoration of Small Aral Sea completed in Sept. 2005 and so far is a success. Further stages of restoration are to be implemented.**
- **Partial restoration of the deeper Western Basin of the Large Sea should be investigated, but preservation and restoration of Eastern Basin appears hopeless as it has nearly disappeared.**

THE FUTURE OF THE ARAL SEA (continued)

- **Very important to preserve what is left of Amu Dar'ya and Syr Dar'ya deltas to preserve ecosystems and biodiversity. Major efforts have been and are underway to restore important lakes and wetlands in both.**
- **Programs to improve health and welfare of local population of critical importance. Uzbekistan and Kazakhstan, regional organizations, and international donors have devoted substantial efforts to these.**

THE ARAL SEA IS NOW FOUR SEPARATE LAKES

MODIS 500 meter, bands 7-2-1, Sept. 6, 2009,
Aqua Satellite



Small Aral Sea: 42 meters, 3487 km², 27 km³, sal. = 10-14 g/l, 17 fish species

Tshche-bas Gulf: 28 meters, 363 km², 0.51 km³, sal. >100 g/l? 0 fish species

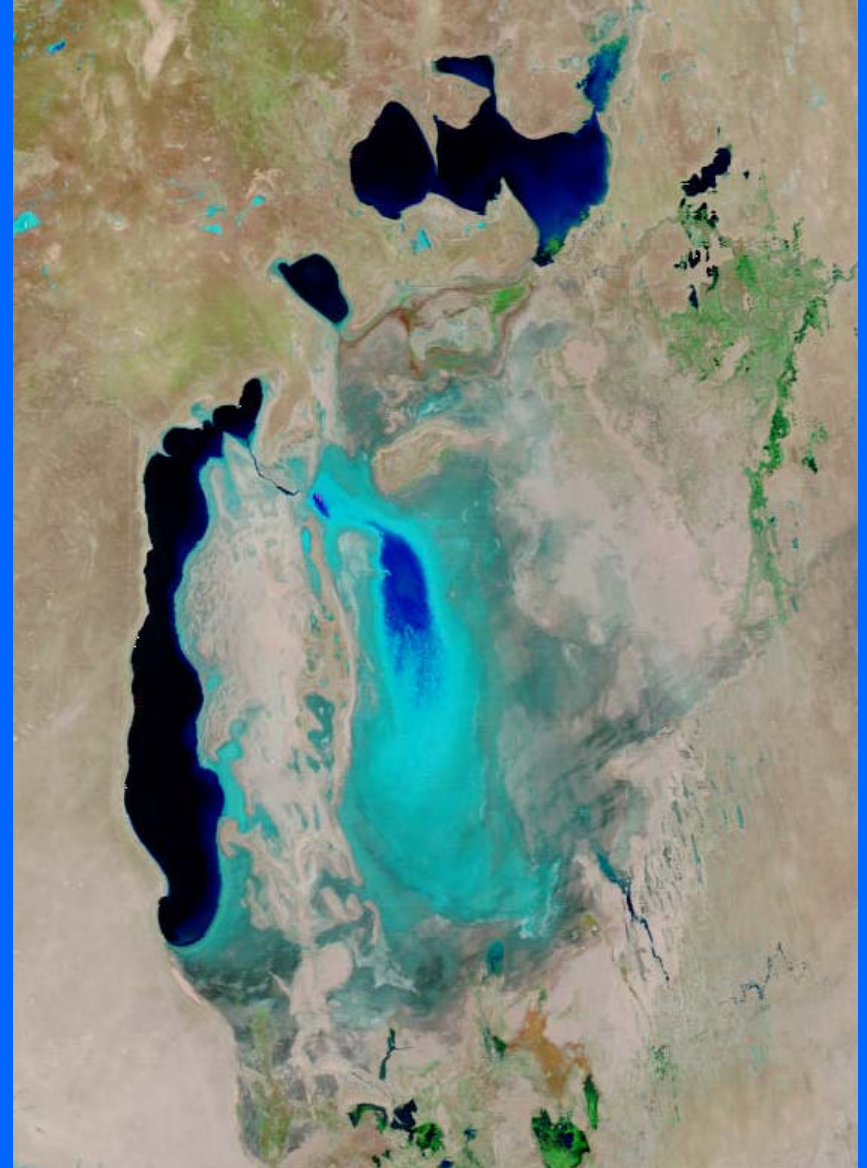
Eastern Basin of Large Aral: 26.5 meters, 857 km²; 0.64 km³, sal. >200 g/l, 0 fish species

Western Basin of Large Aral: 26.5 meters, 3702 km², 56.4 km³, sal. >100 g/l, 0 fish species

**ARAL SEA, OCT. 8, 2009,
MODIS 250 meter NATURAL
COLOR**



**ARAL SEA, OCT. 8, 2009,
MODIS 500 meter, BANDS 7-2-1**



RESTORATION SCENARIO 1: RETURN ARAL TO PRE-DESICCATION CONDITION

- **Would need average annual inflow (Syr + Amu) near 55 km³, much more than actual flows since 1960s.**
- **Given current state of Aral, would require about 37 years (refill would follow logistics curve: fast at first, slowing with time).**
- **Would necessitate not only massive, expensive improvements in irrigation efficiency, but huge cutback (on order of 50-60%) in irrigated area.**
- **Such a cutback would lead to economic and social havoc (unless done slowly and carefully).**
- **Very unlikely scenario for foreseeable future.**

RESTORATION SCENARIO 2: PARTIAL REHABILITATION OF SMALL ARAL

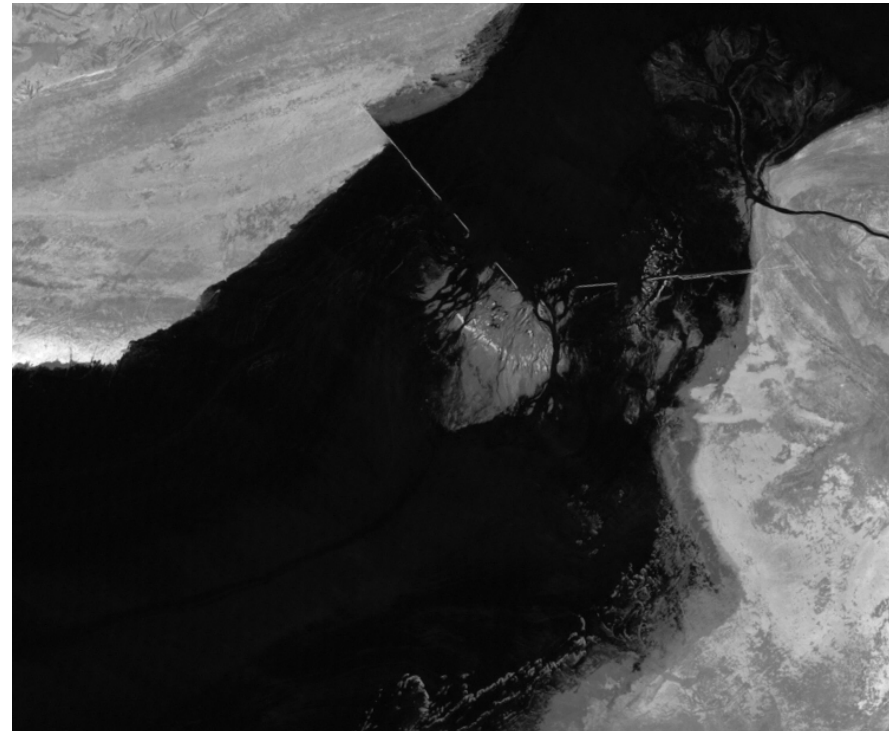
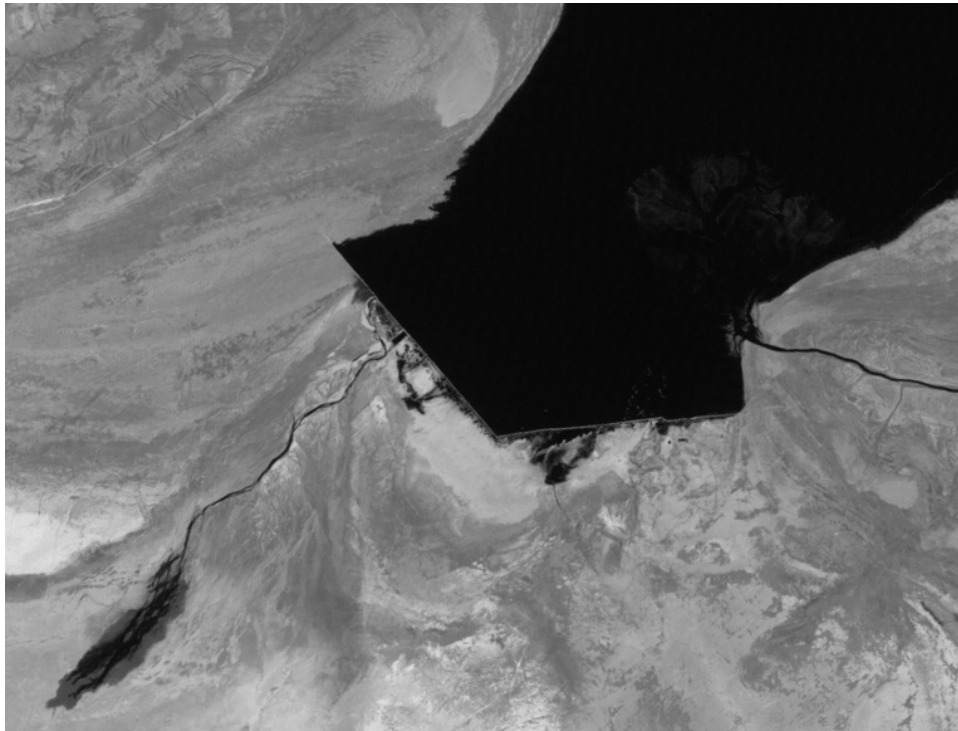
- **Local efforts to dike-off Small Aral begun in 1992, but dikes suffered periodic failures, including a catastrophic failure in April 1999.**
- **Small Sea project costing 85 million, funded by World Bank and Government of Kazakhstan finished in Fall 2005.**
- **Sea Level raised and stabilized at 42+ meters by March 2006. So far, major success: endemic fish species have returned from Syr and deltaic lakes and fish catches have grown considerably.**
- **2nd phase supposed to be started soon to raise level of Saryshaganak Gulf to about 46 meters at cost of \$250 million.**
- **North Aral Project did significantly reduce flow to Eastern Large Aral and contributed to its drying.**

BERG STRAIT DIKE BEFORE AND AFTER BREAK

(sea level of Small Aral fell 2.8 meters from April to October and Small Aral lost about 10 km³ of water; 2 people killed)

**LANDSAT 5, April 14, 1999
(band 5)**

**LANDSAT 5, April 30, 1999
(band 5)**



**Source: USGS Global Visualization Viewer (Glovis), Landsat 4-5 TM
(<http://glovis.usgs.gov/>); 30 meter resolution**

JAPAN SPACE AGENCY (JAXA) IMAGE OF NEW KOK-ARAL (BERG STRAIT) DIKE (October 10, 2006)



KOK-ARAL DAM FROM LOWER SIDE (Sept. 2007)
(photo by P. Micklin)



RESTORATION SCENARIO 3: PRESERVE AND REHABILITATE WESTERN BASIN OF LARGE ARAL

- **Western Basin of Large Aral could be stabilized and slowly freshened if Amu flow diverted to it. Overtime, salinity could be lowered enough for salt-tolerant fish (e.g. kambala) to be stocked here and perhaps even endemic species.**
- **Makes no sense to send residual flow of Amu toward Eastern Large Aral as this water body is “lost”.**
- **Project would require increasing flow of Amu in lower reaches, but could be done via improvement of irrigation efficiency in basin of Amu.**
- **Project needs much further study as costs and benefits not well known.**
- **Would require some “trade-off” between use of water to restore and preserve more wetlands/lakes in lower Amu Delta and to preserve Western Basin.**
- **Also, potential conflict with oil and gas extraction.**

OPTIMISTIC SCENARIO:

ARAL IN 2025

Small Aral Sea

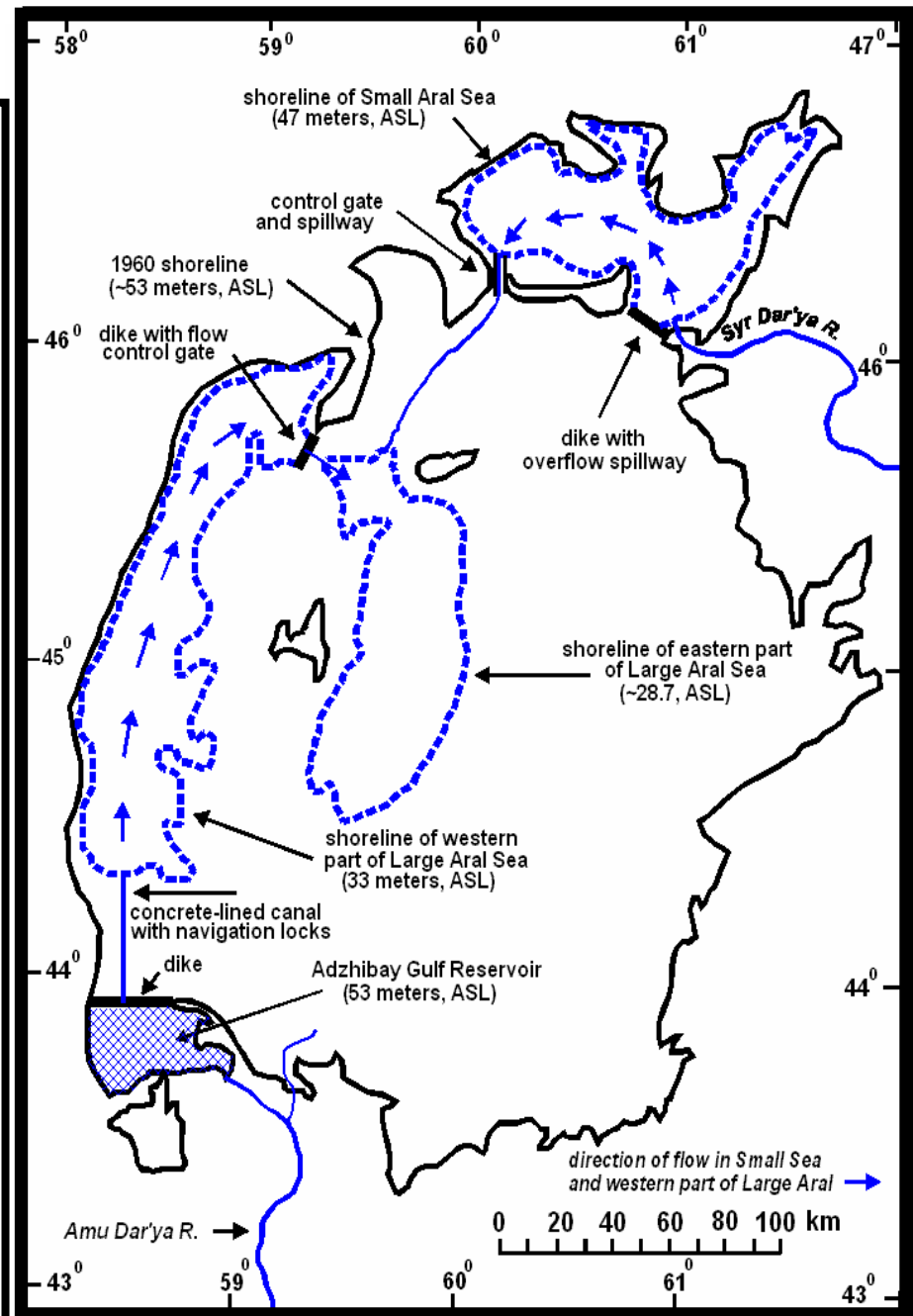
level 47 m, area 4310 km²,
vol. 46.5 km³, river inflow 4.5
km³, outflow toward L. Aral
1.4 km³, salinity 7.59 g/l

Large Aral Sea

Western Sea: level 33 m, area
6203 km², vol. 85 km³, river
inflow 7.35 km³, outflow to E.
Aral 3.05 km³, salinity 45 g/l
(21 g/l by 2050)

Eastern Sea: level 28.7 m,
Area 5710 km², vol. 21 km³,
inflow from W. Aral 2.95 km³,
inflow from Small Aral 1.03
km³, salinity >200 g/l

Adzhibay Gulf Reservoir: level
53 m, area 1147 km², vol. 6.43
km³, inflow from Amu Dar'ya
8.26 km³, outflow to western Aral
basin 7.35 km³, salinity ~ 2 g/l



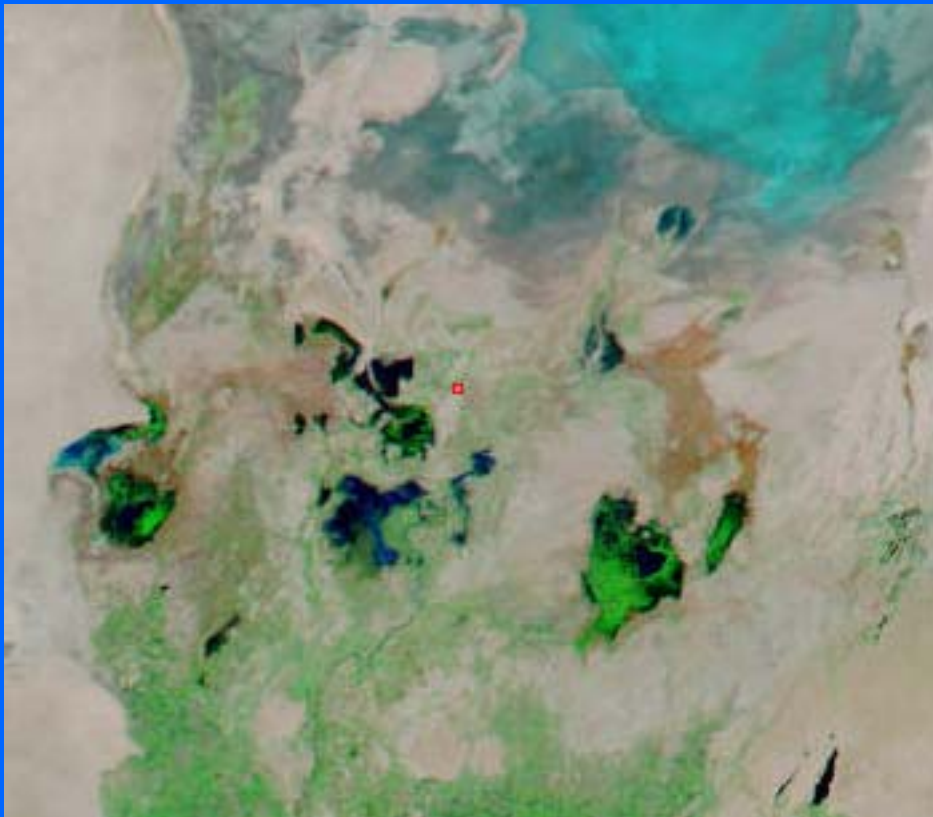
RESTORATION SCENARIO 4: CREATE, REHABILITATE AND PRESERVE LAKES AND WETLANDS IN SYR AND AMU DELTAS

- **Lower reaches of Syr and Amu ecologically rich and biologically diverse.**
- **Lakes/wetlands such as Sudochye, Mezdurechye, Muynak and Adzhibay in Amu Delta and Kamyslybas, Karashalan, and Tushchibas in Syr Delta provide valuable fisheries, harvest of reeds, resting, nesting, breeding places for aquatic fowl, etc.**
- **Efforts to create/rehabilitate underway since 1989 in Amu later in Syr.**
- **More water for lakes/wetlands in deltas means less water for Small Aral and (potentially) Western Basin of Large Aral and vice-versa.**

LAKES AND WETLANDS IN SYR AND LOWER AMU DELTAS

SEPTEMBER 22, 2009 (MODIS 500 meter, bands 7-2-1)

AMU DELTA



SYR DELTA



RESTORATION SCENARIO 5: SIBERIAN RIVER DIVERSION PROJECT

- Large-scale, long distance transfers of water from Siberian rivers to Central Asia seriously studied since 1940s.
- By mid-1980s, project (“*Sibaryl*”) to send 27 km³/yr 1500 km from Irtysh and Ob’ rivers to Aral Sea Basin appeared on the verge of construction.
- Water mainly intended to expand irrigation, but would have helped Aral also.
- Project postponed indefinitely in 1986 by Gorbachev.
- Soviet Union’s collapse in 1991, greatly lessened possibility of implementation of project.
- Since 2002 renewed talk of project, but faces huge obstacles: cost (at least 40 billion USD), strong opposition in Russia, forging acceptable agreements between Russia and Central Asian countries, lack of international donor support, environmental impacts downstream on Ob, etc.

PROPOSED SIBERIAN DIVERSION PROJECT (27 km³/yr.)



CONCLUSIONS

- 1. Full restoration of Aral in foreseeable future very difficult and highly unlikely. But in the distant future may be possible (Aral has come back before).**
- 2. Small (north) Aral has been partially restored with great success; more to be done in near future.**
- 3. Preservation/partial restoration of Western Large Aral possible, but needs much further study of costs and ecological and economic benefits.**
- 4. Preservation/partial restoration of deltas underway. Very important as biologic refugia for fauna and flora.**
- 5. Climate change as influence on Aral Sea has now become important, needs research as to range and magnitude of impacts.**

The end

**AMU DAR'YA DELTA WITH PRESERVED/RESTORED LAKES
AND WETLANDS (MODIS false color, June 2003)**



POTENTIAL WATER SAVINGS FROM IRRIGATION IMPROVEMENT

Scenario	Irrigated area (ha * 10 ⁶)	Specific withdrawal (m ³ /ha)	Total withdrawal (km ³)	Gross water savings (km ³)	Net water savings (km ³)	cost	Comments
2007 (business as usual)	7.94	11,500 (2007)	91.3	0	0	0	Most likely scenario for near to mid term
Major improvement	7.94	10,600	84.2	15.8	12	~24 billion (USD)	Poor prospects for regional or international funding
Maximum improvement	7.94	8,000	63.5	36.5	27.7	huge	Same as above

¹ gross water savings minus estimated reduction in irrigation return flows to rivers;

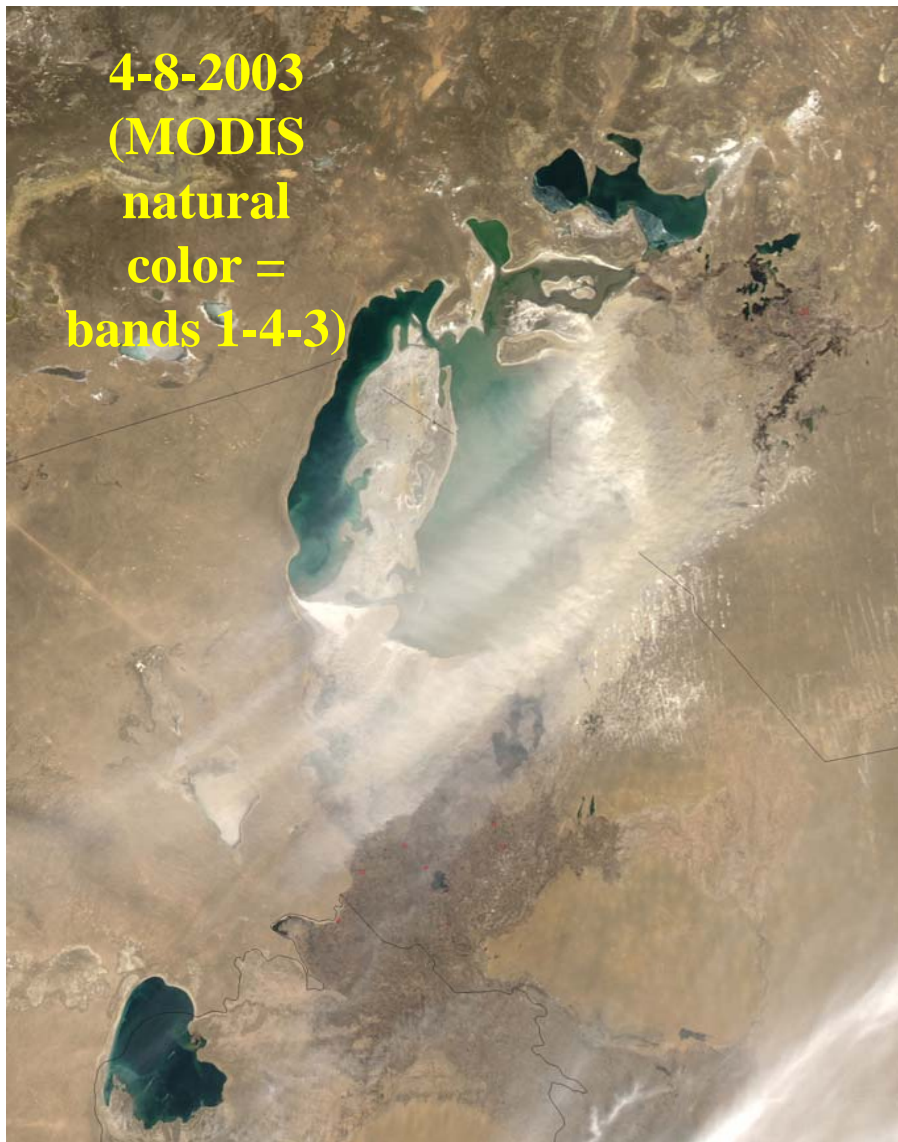
² irrigation systems on 5.94 million acres renovated (canal lining, laser leveling of fields, and installation of drainage systems) plus improvement of system management, introduction of water pricing and crop substitution.

³ 5.94 million hectares renovated at an estimated cost of \$4,000/ha

⁴ entire irrigation system rebuilt to best available technology, drip irrigation installed wherever possible, use of precision farming techniques widely introduced, etc. (“Israeli model”)

MODIS IS EXCELLENT FOR TRACKING DUST/SALT STORMS

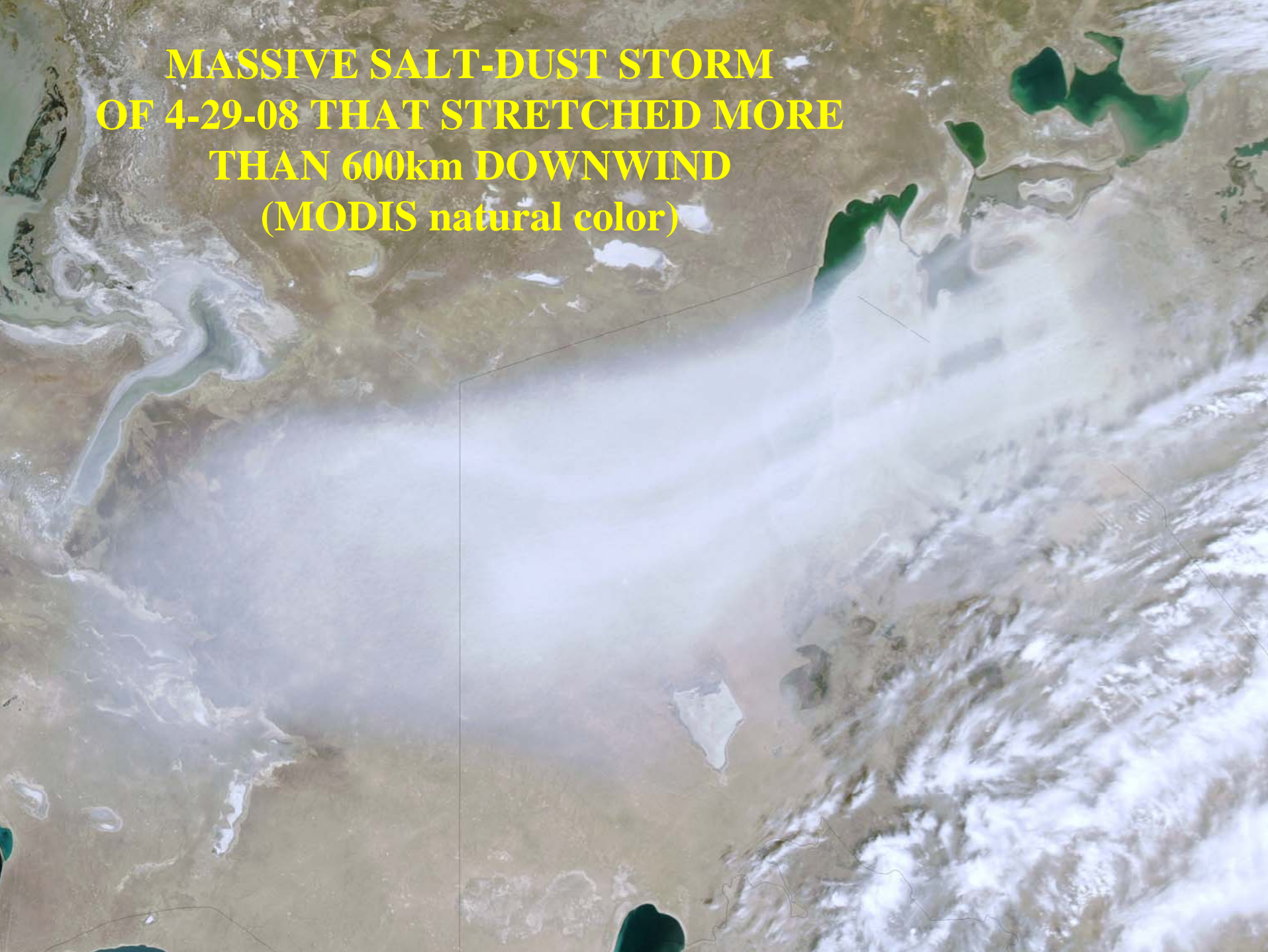
4-8-2003
(MODIS
natural
color =
bands 1-4-3)



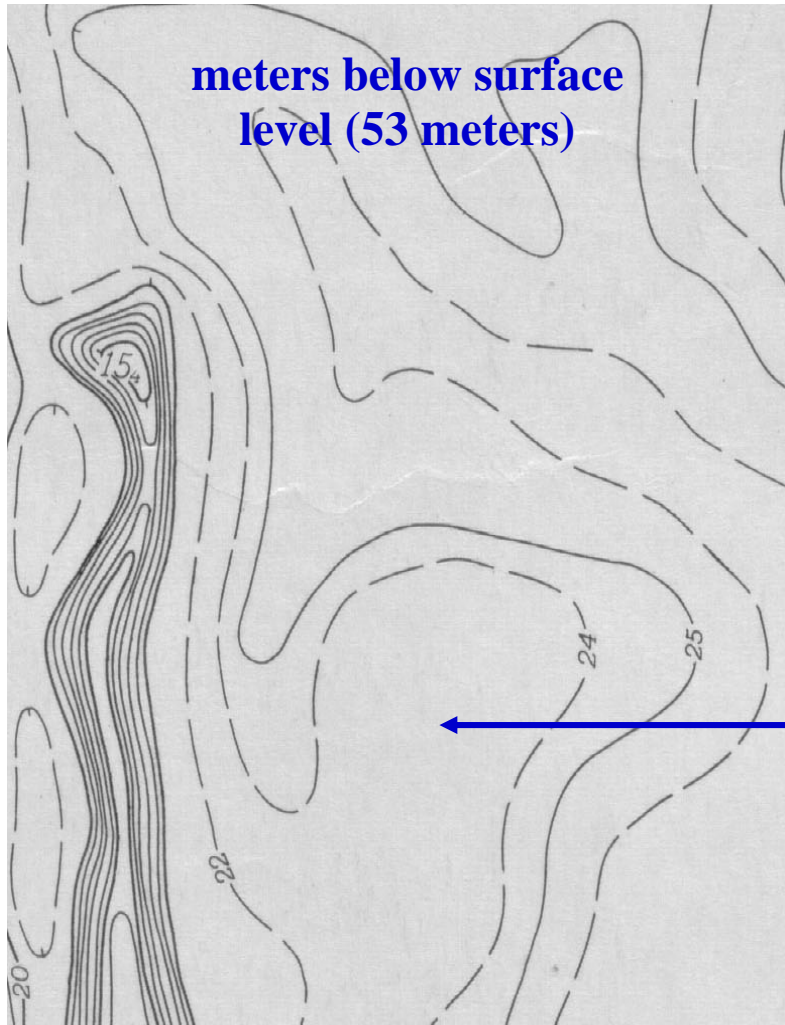
5-9-2007
(MODIS
natural
Color)



**MASSIVE SALT-DUST STORM
OF 4-29-08 THAT STRETCHED MORE
THAN 600km DOWNWIND
(MODIS natural color)**

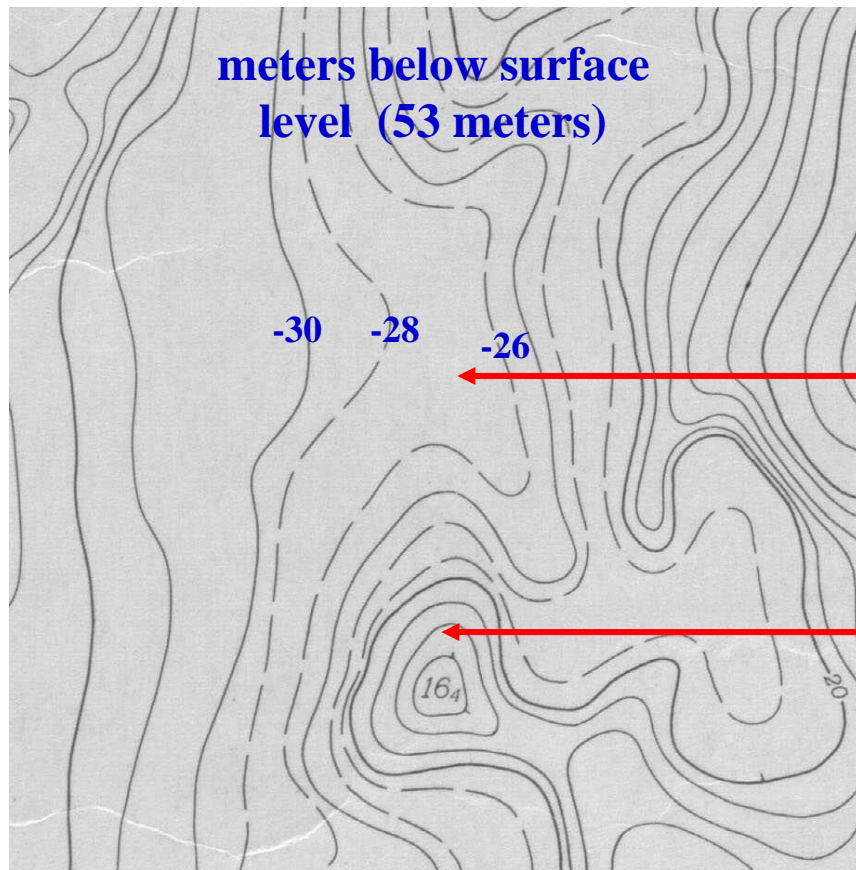


**MODIS 250 METER RESOLUTION IMAGE CAN BE USED
ALONG WITH 1:500,000 SOVIET ERA BATHYMETRIC MAP TO
DETERMINE SEA LEVEL WITH REASONABLE ACCURACY**



**Comparison above shows level on 8-11-07 of Eastern Basin of Large Sea
around 29 meters above sea level (53 meters – 24 meters)**

MODIS 250 METER RESOLUTION IMAGE CAN BE USED IN CONJUNCTION WITH 1:500,000 SOVIET ERA BATHYMETRIC MAP TO DETERMINE SEA LEVEL WITH REASONABLE ACCURACY



Comparison above shows level of Western Basin of Large Sea on Sept. 6, 2009 between 26 and 27 meters above sea level (53 meters – 26/27 meters)

BERG STRAIT DIKE BEFORE AND AFTER BREAK

(sea level of Small Aral fell 2.8 meters from April to October and Small Aral lost about 10 km³ of water; 2 people killed)

LANDSAT 5, April 14, 1999
(natural color = bands 3-2-1)

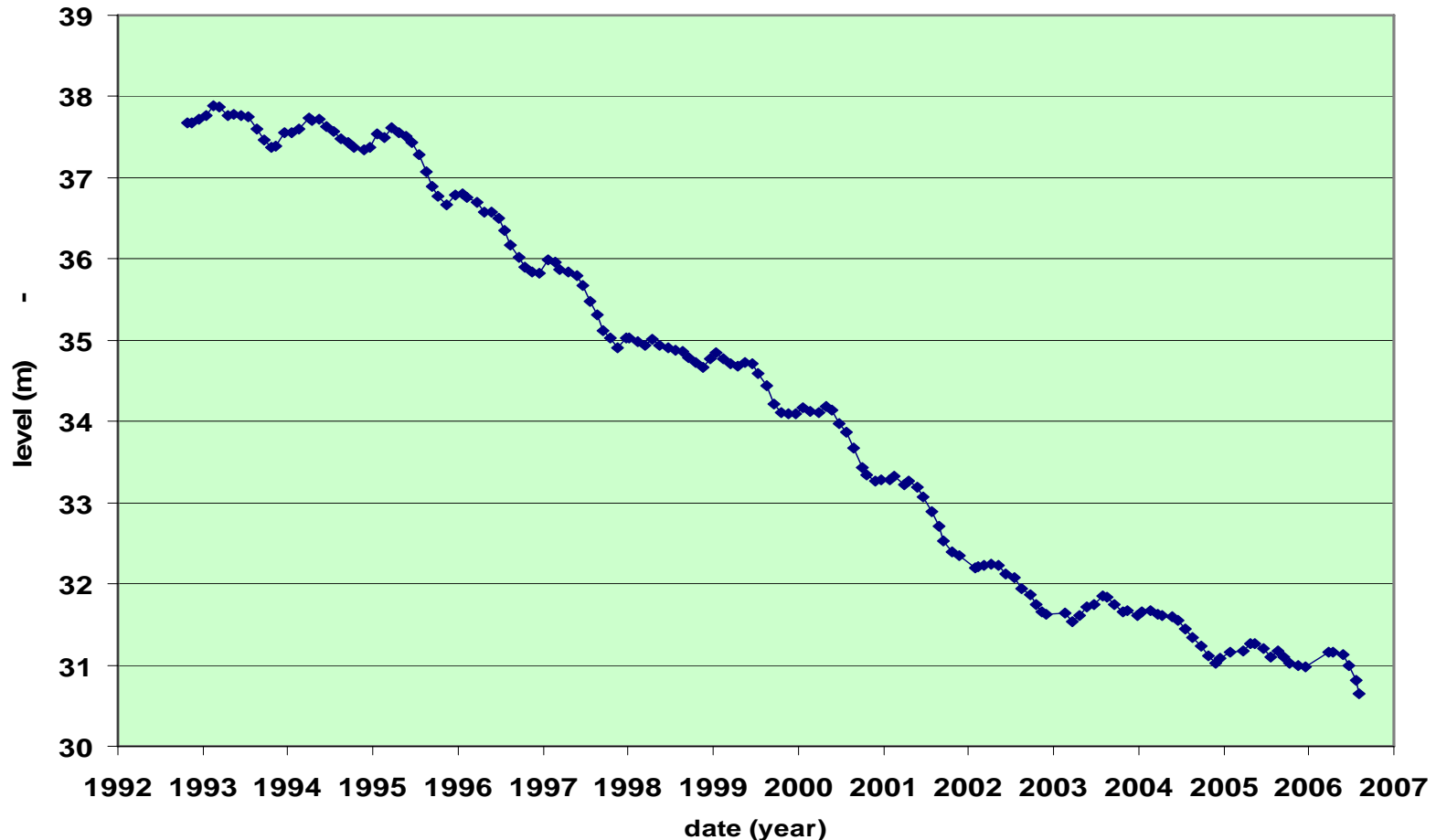


LANDSAT 5, April 30, 1999
(natural color = bands 3-2-1)



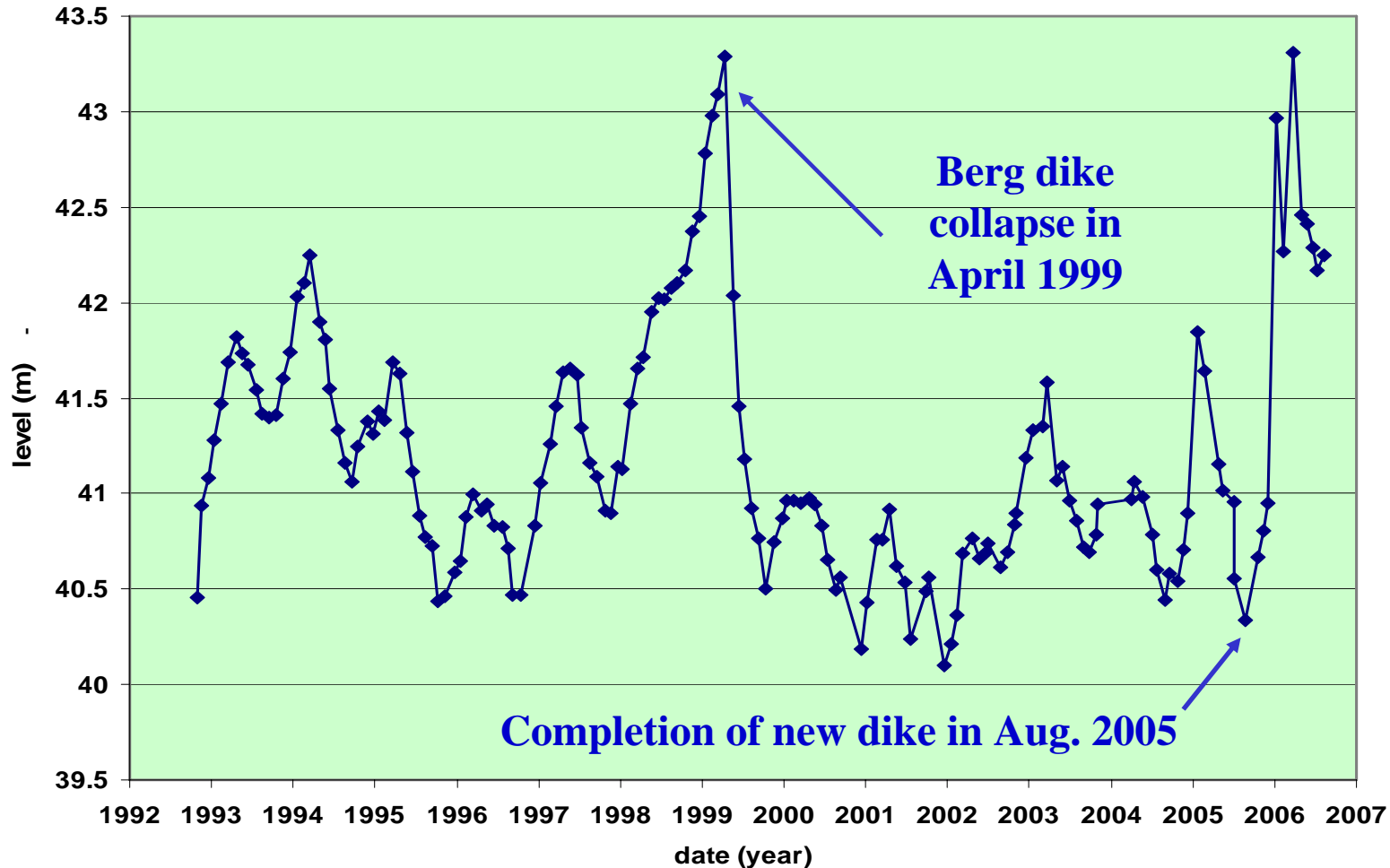
Source: USGS Global Visualization Viewer (Glovis), Landsat 4-5 TM
(<http://glovis.usgs.gov/>); 240 meter resolution

LARGE ARAL SEA LEVELS FROM RADAR ALTIMETRY (Poseidon/Topex/Jason)



**Excel graph courtesy of Jean-Francois Cretaux, Laboratoire d'
Etudes en Geophysique et Oceanographie Spatiales,
Toulouse, France**

SMALL ARAL SEA LEVELS FROM RADAR ALTIMETRY (Poseidon/Topex/Jason)



**Excel graph courtesy of Jean-Francois Cretaux, Laboratoire d'
Etudes en Geophysique et Oceanographie Spatiales,
Toulouse, France**

ARAL SEA
AUGUST 18, 2008
TERRA
SATELLITE
MODIS SENSOR
500 METER
RESOLUTION
TRUE COLOR
(bands 1-4-3)

