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# THE SMALL ARAL IS FALLING AGAIN: TWENTY YEARS AFTER THE KOK-ARAL DAM, SATELLITE LEVEL, LAKE AREA AND SYR DARYA INFLOW, 1993-2026

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**Abstract:** In 2005 the Kok-Aral dam separated the northern part of the Aral Sea, the Small Aral, from the drying southern part. This study uses satellite altimetry from 1992 to 2026, Landsat measurements of the lake's area in 2016-2024 and the winter inflow of the Syr Darya recorded by the Interstate Commission for Water Coordination to ask whether the gain from the dam has lasted. The summer level of the Small Aral rose by 1.52 m in the first year after the dam, from 40.64 m in 2005 to 42.16 m in 2006, and stayed at about 42.48 m on average until 2020. After 2020 it fell to 41.64 m on average in 2021-2025, and the lake's area fell by about 7%. The fall is not an artefact of a change of satellite: at each of the four changes of satellite the old and new instruments agree within a few centimetres. It coincides with less water reaching the lake: the winter inflow at the Karateren gauge fell from 3.32 km3 on average in the winters of 2015/16-2017/18 to 1.35 km3 in 2018/19-2024/25, and the lake's area follows the sum of the last two or three winters (r = 0.81 and 0.91) more closely than the last winter alone, although with only seven or eight years these figures are uncertain. The results do not support the author's view that the dam brought little change, but show that its gain is not permanent.

**Keywords:** Aral Sea, Small Aral, Kok-Aral dam, satellite altimetry, Landsat, Syr Darya, water balance

## 1. Introduction

The drying of the Aral Sea is one of the largest environmental disasters of the twentieth century. In 2005 Kazakhstan completed the Kok-Aral dam, which keeps the water of the Syr Darya in the northern part of the sea, the Small (North) Aral, and the level of that part rose; an earlier, simpler dike built in 1992 had raised the level for a few years before it was breached in 1999, and the new dam releases surplus water through a spillway [1]. Satellites make it possible to follow such lakes from space: altimetry satellites measure the height of the water surface and optical satellites such as Landsat show its area, and the two have been combined to track the water of the Aral Sea [2]. The fast changes of the surface there between water, salt and land also complicate other satellite measurements, such as those of rainfall [3].

Twenty years after the dam, it is not clear whether its effect has lasted. This study asks two questions: did the Small Aral keep the level it gained after 2005, and if it has started to fall again, does the fall follow the water arriving from the Syr Darya?

## 2. Hypothesis

Before any data were analysed, the author wrote (23 September 2026): "I believe the dam did not really save the situation. Perhaps the northern part of the Aral restored its fish stocks thanks to the dam, but as far as I know the water level since that year is recovering only slightly and has stayed mostly unchanged. And the southern part dried up strongly because of the lack of inflow from the north" (original in Russian).

## 3. Data and methods

Water level comes from the G-REALM global reservoir and lake monitor of NASA and the U.S. Department of Agriculture [4], target 001442 (Aral Sea 3, the Small Aral, 46.31 N, 61.03 E): 691 ten-day measurements without ice from 1992 to September 2026 by the TOPEX/Poseidon, Jason-1, Jason-2, Jason-3 and Sentinel-6A satellites, as heights in the EGM2008 datum. The median of the June-September measurements was taken for each year; 2026 is included only up to 13 September and is shown separately. To test whether the changes of satellite affect the series, measurements of the old and the new satellite taken within three days of each other, while both flew the same track, were compared at each of the four handovers.

The area of the lake comes from Landsat Collection 2 Level-2 images (footprint WRS-2 160/028) read through the Microsoft Planetary Computer [5]. A lake mask was defined from the data as the pixels that were water in at least 10% of clear observations in 2016-2024; for each image clouds and shadows were masked, only images in which at least 80% of the mask was clear were kept, and the median water area of July 1 - September 15 was taken for each year. The inflow to the lake is the winter (October-March) "delivery to the Aral (Karateren gauge)" in the channel balance tables of the Syr Darya in the bulletins of the Interstate Commission for Water Coordination (ICWC) of Central Asia [6]; where the text of a bulletin gives a different figure from its table, the table was used. The summer level and area of each year were compared, with the Pearson correlation, with the inflow of the preceding winter and with the sums of the two and three preceding winters.

## 4. Results

### 4.1. The dam and after

Before the dam, in 1993−2004, the summer level of the Small Aral averaged 41.02 m, or 40.92 m without 1998, when the earlier dike briefly held the level at 42.11 m. It rose from 40.64 m in 2005 to 42.16 m in 2006, by 1.52 m in one year, and stayed between 42.16 and 42.93 m until 2020 (average 42.48 m), with the highest summer level in 2014 (42.93 m), the plateau being held by the dam's spillway. Both 2005 and 2006 were measured by the same satellite, Jason−1. After 2020 the level fell: 42.06 m in 2021, 41.40 m in 2022 and 41.38 m in 2023, with 41.64, 41.70 m in 2024−2025 and 41.27 m in the incomplete summer of 2026 (Table 1). The area of the lake measured by Landsat fell at the same time, from 2,700 km2 on average in 2017−2020 to 2,500 km2 in 2021−2024 (−7.4%).

**Table 1. Summer level and area of the Small Aral and winter inflow at the Karateren gauge [4-6]**

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|
| Summer level, m (EGM2008) | 42.63 | 42.38 | 42.52 | 42.40 | 42.06 | 41.40 | 41.38 | 41.64 | 41.70 |
| Summer area, km2 (Landsat) | 2,710 | 2,684 | 2,683 | 2,722 | 2,524 | 2,478 | 2,463 | 2,536 | - |
| Winter inflow, | 2.90 | 3.95 | 1.36 | 1.95 | 1.15 | 0.24 | 1.67 | 1.27 | 1.79 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| km3 (Oct-Mar before) | | | | | | | | | |

**4.2. Is the fall real?**

The fall coincides with the change from the Jason-3 to the Sentinel-6A satellite. While both measured the lake, 21 pairs of measurements taken on the same days differed by a median of +0.02 m, so the change of satellite did not shift the series. The earlier changes agree as well (Jason-1 vs TOPEX: 4 pairs, -0.02 m; Jason-2 vs Jason-1: 13 pairs, +0.02 m; Jason-3 vs Jason-2: 16 pairs, +0.00 m). Jason-3 alone shows the beginning of the fall: its summer median was 42.40 m in 2020 and 42.08 m in 2021. The independent Landsat measurements also show the lake shrinking from 2021. The fall of the lake is therefore real.

**4.3. Does the fall follow the inflow?**

The winter inflow at Karateren averaged 3.32 km3 in the winters of 2015-16 to 2017-18 and 1.35 km3 in 2018-19 to 2024-25, two and a half times less; the lowest was 0.24 km3 in 2021-22. The summer area of the lake is only moderately related to the inflow of the preceding winter ($r = 0.65$, 8 years, $p = 0.08$), but more strongly to the sum of the two preceding winters ($r = 0.81$, $p = 0.015$) and of the three preceding winters ($r = 0.91$, 7 years, $p = 0.004$). The summer level shows the same pattern ($r = 0.59$, 0.85 and 0.90; 9, 9 and 8 years). Because sums over several years overlap, these p-values are optimistic, and a simple split into before and after 2021 matches the area just as closely ($r = 0.97$), so the data cannot separate the inflow from any other change that began in 2021. Local reports describe the same shortage: in April-September 2021 the Shardara reservoir on the Syr Darya received 2.3 km3 instead of the agreed 4.1 km3, and the Toktogul reservoir upstream in Kyrgyzstan held 11-12 km3 instead of 18 [7].

## 5. Discussion

The author expected the dam to have changed little. The level record does not support this: the Small Aral rose by about one and a half metres in the first year after the dam and kept that gain for fifteen years. Her doubt turns out to be justified in a different way, however, because the gain is not permanent: since 2021 the lake has lost almost a metre of level and about 7% of its area. The fall coincides with a shortage of water arriving from the Syr Darya, which is the most likely cause, although with so few years and no measurement of evaporation this cannot be proven. The southern part of the sea, which she expected to have dried strongly, is outside the scope of this study.

When she saw that the lake responds to several winters rather than one, the author explained (24 October 2026) that "water accumulates below, underground, and some of it evaporates, so it takes several years for the water to fill not only the bottom but also the surface" (original in Russian). The data are consistent with a lake that integrates its inflow over several years, as any lake does whose evaporation and outflow depend on its size, but they cannot show the role of groundwater or evaporation, which were not measured.

Limitations. Only eight years of area and inflow overlap, so the correlations are uncertain, and sums over several years share years and are not independent. In 2016 and 2020 only one clear Landsat image passed the quality filter, and the single 2020 image gives the highest area of the series; the images of one summer differ by up to about 200 km2, close to the size of the fall. Water was detected from the Landsat quality flag at 300 m resolution. The bulletins give different figures in their text and tables for some years. The altimetry measures one track across the lake, not the whole surface.

## 6. Conclusion

The Kok-Aral dam did what it was built for: the Small Aral rose by about one and a half metres and held that level until 2020. Since 2021 it has been falling again, by almost a metre in level and about seven percent in area, at a time when much less water from the Syr Darya reaches it,

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and the lake appears to respond to the inflow of several years rather than one. Keeping the Small Aral therefore depends on the water delivered to it every year, not on the dam alone.

**Data availability**

All data are public [4-6]. The yearly series and the analysis scripts are available from the author or her mentoring team on request.

**Author contributions and use of AI tools**

The author chose the research direction, proposed the hypothesis quoted in Section 2 before any data were analysed, found the study [3] and the reports on the Syr Darya shortage [7], and proposed the explanation discussed in Section 5. The data were analysed and the text was drafted by her mentor with the help of a generative AI assistant (Claude, Anthropic). Every number was computed by the analysis scripts from the sources listed below.

**Conflicts of interest**

The author declares no conflicts of interest. No funding was received for this study.

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