# Water level variations in the Issyk-Kul Lake and the role of climate variables

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1

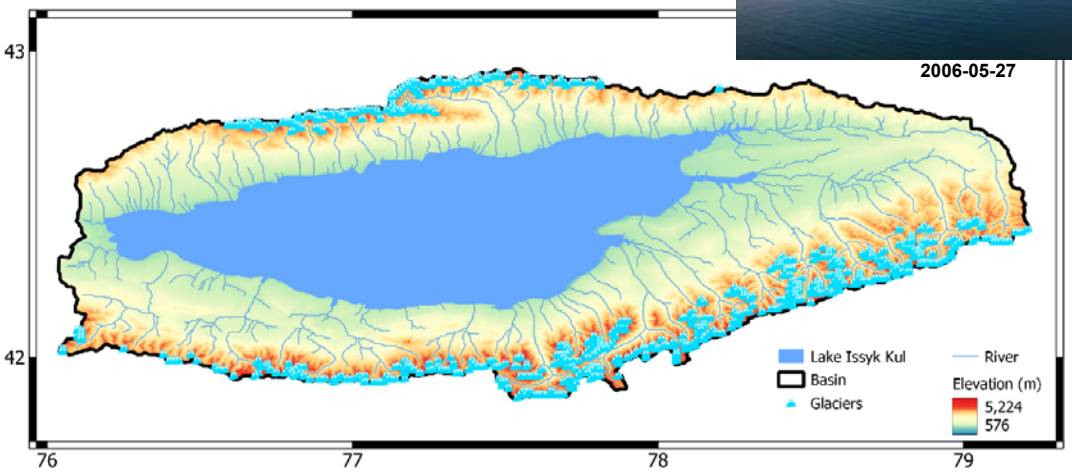
## Outline

- Measuring water level variations in Issyk-Kul Lake
- Lake water level versus climate factors
- Lake water level versus total water mass estimated from GRACE
- Summary of conclusions

2

## Issyk-Kul Lake

2006-05-27




3

3

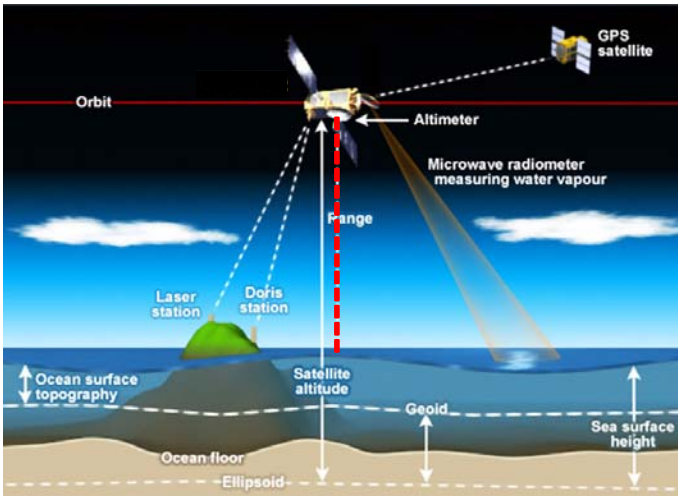
## Recording of sea level at tide gauge stations



4

4

# Meauring water level using satellite altimetry










# Satellite Altimetry Missions

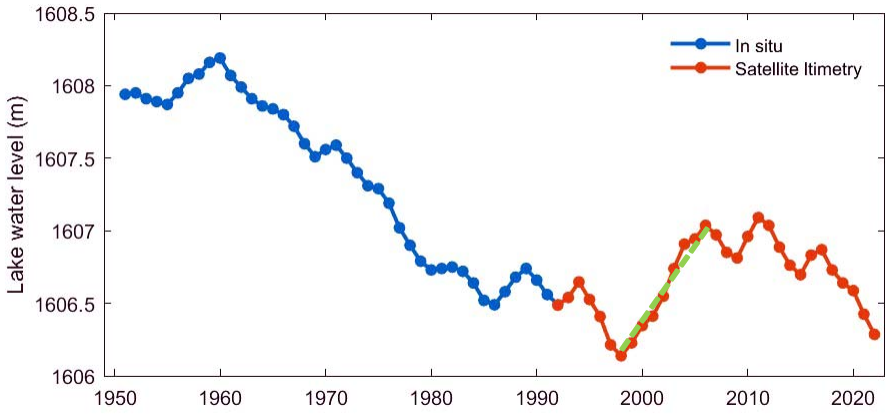
European Earth Observation Satellites Sentinel 1-6


**SEASAT (1978)**
**GEOSAT (1985)**
**Topex/Poseidon (1992)**
**JASON 1-3 (fr 2001)**
**Sentinel 1-6 (fr 2014)**

**Sentinel-3 (2018)**

- Measurements of sea surface topography, land/ocean temperature
- Near-polar, sun-synchronous, high inclination orbit (98.65°)
- Orbit altitude: 815 km
- **Altimeter range accuracy: 3 cm**

## Lake water level variations in Issyk-Kul Lake




Hiatus - abnormal rise in water level (1998-2011)

7

## What might affect the lake water level (LWL) ?

**External factors – climate variables**

- Precipitation
- Runoff, i.e. basin water inflow
- Evaporation
- ……

*ERA5 Data Set 1950-2021*
*From **European Center for Mid-Range Weather Forecasts** (ECMWF)*

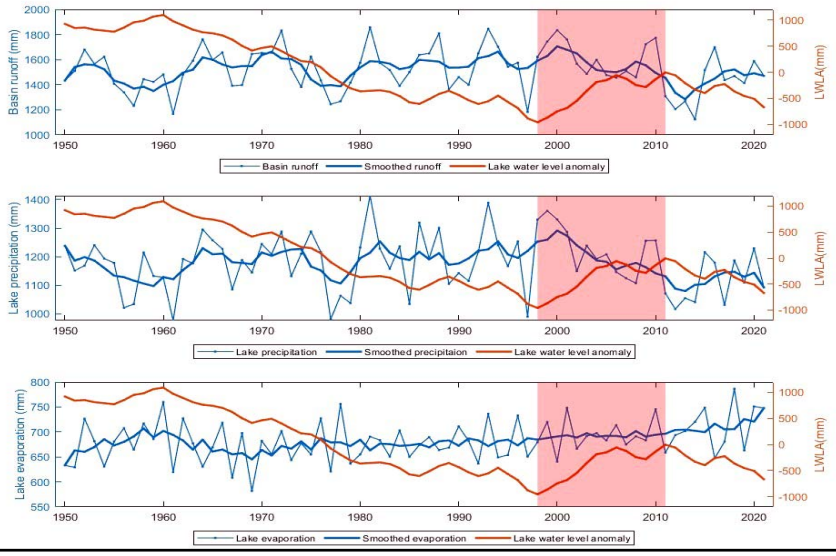
**Internal factors**

- Water withdrawal from feeding rivers for agriculture etc
- Glacier melting
- ……

8

8

## Lake water level variations vs climate variables




9

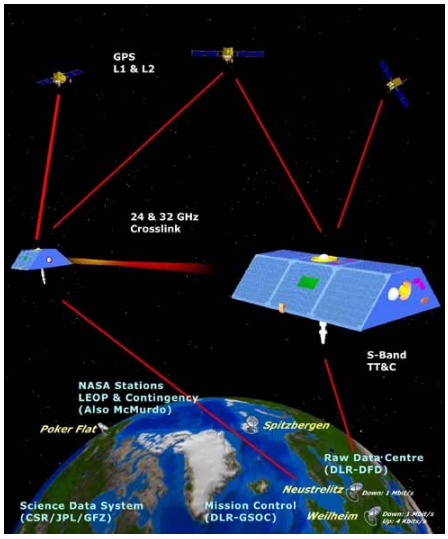
## Linear trend in lake water level vs climate variables

(mm/year)

| | 1950-1997 | 1998-2011 | 2012-2022 |
|---|---|---|---|
| Lake level | -42 ± 2 | 68 ± 10 | -49 ± 10 |
| Runoff | 1.7 ± 1.76 | -16 ± 10 | 34 ± 16 |
| Precipitation | 0.9 ± 1 | -15 ± 4 | 12 ± 8 |
| Evaporation | 0.1 ± 0.4 | 0.2 ± 2 | 4 ± 5 |

10

## Gravity Recovery And Climate Experiment (GRACE)




- US-German project launched 2002
- two low satellites at 200km distances, 250 km altitude
- relative velocity has been measured with accuracy of about **0.001 mm/s**
- in order to determine the **gravitational potential V of the Earth** at monthly interval (2002-2022)

- **Bjerhammar**(1968): Energy integral

11

## Estimation of changes in *total water mass* from GRACE data

**Gravitational potential of the Earth**

$$V(r,\overline{\phi},\lambda) = \frac{GM}{r} + \frac{GM}{R}\sum_{n=2}^{n_{\max}}\left(\frac{R}{r}\right)^{n+1}\sum_{m=0}^{n}\left(\overline{A}_{nm}\cos m\lambda + \overline{B}_{nm}\sin m\lambda\right)\cdot\overline{P}_{nm}(\sin\overline{\phi})$$

**Changes in gravitational potential of the Earth**

$$\Delta V(r,\overline{\phi},\lambda) = \frac{GM}{R}\sum_{n=2}^{n_{\max}}\left(\frac{R}{r}\right)^{n+1}\sum_{m=0}^{n}\left(\Delta\overline{A}_{nm}\cos m\lambda + \Delta\overline{B}_{nm}\sin m\lambda\right)\cdot\overline{P}_{nm}(\sin\overline{\phi})$$

**Changes in surface density on the Earth**

$$\Delta\sigma = \frac{\rho_{ave}}{3}\frac{GM}{R\,\gamma}\sum_{n=2}^{n_{\max}}\left[\frac{2n+1}{1+\ell_n}\sum_{m=0}^{n}\left(\Delta\overline{C}_{nm}\cos m\lambda + \Delta\overline{S}_{nm}\sin m\lambda\right)\cdot\overline{P}_{nm}(\sin\overline{\phi})\right]$$

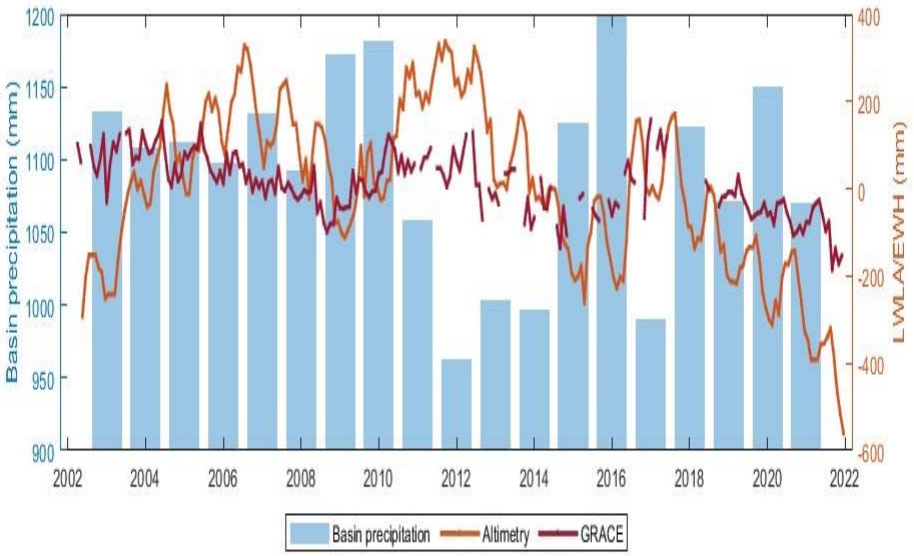
**Changes in *total water mass*, expressed as *Equivalent Water Height*:**

$$EWH = \frac{\Delta\sigma}{\rho_w}$$

12

12

## Water level, total water mass vs basin precipitation




13

## Summary

- Satellite altimetry is an effective method to monitor LWL variations
- ERAS5 data sets indicate that climate factors might **not** explain LWL variations in Issyk-Kul region, including the hiatus period 1998-2011
- GRACE-derived total water mass changes can **not** explain the hituas during 1998-2011. But total water mass changes and LWL changes have **consistent trend** during the last 16 years period (2007-2022).
- More studies are needed:
  - ✓ Effects of glacier melting, water consumption, etc
  - ✓ Regional data sets: precipitation, runoff, water consumption, glacier melting, etc etc

14