Multi-mission monitoring of the desiccation of Lake Urmia in Iran

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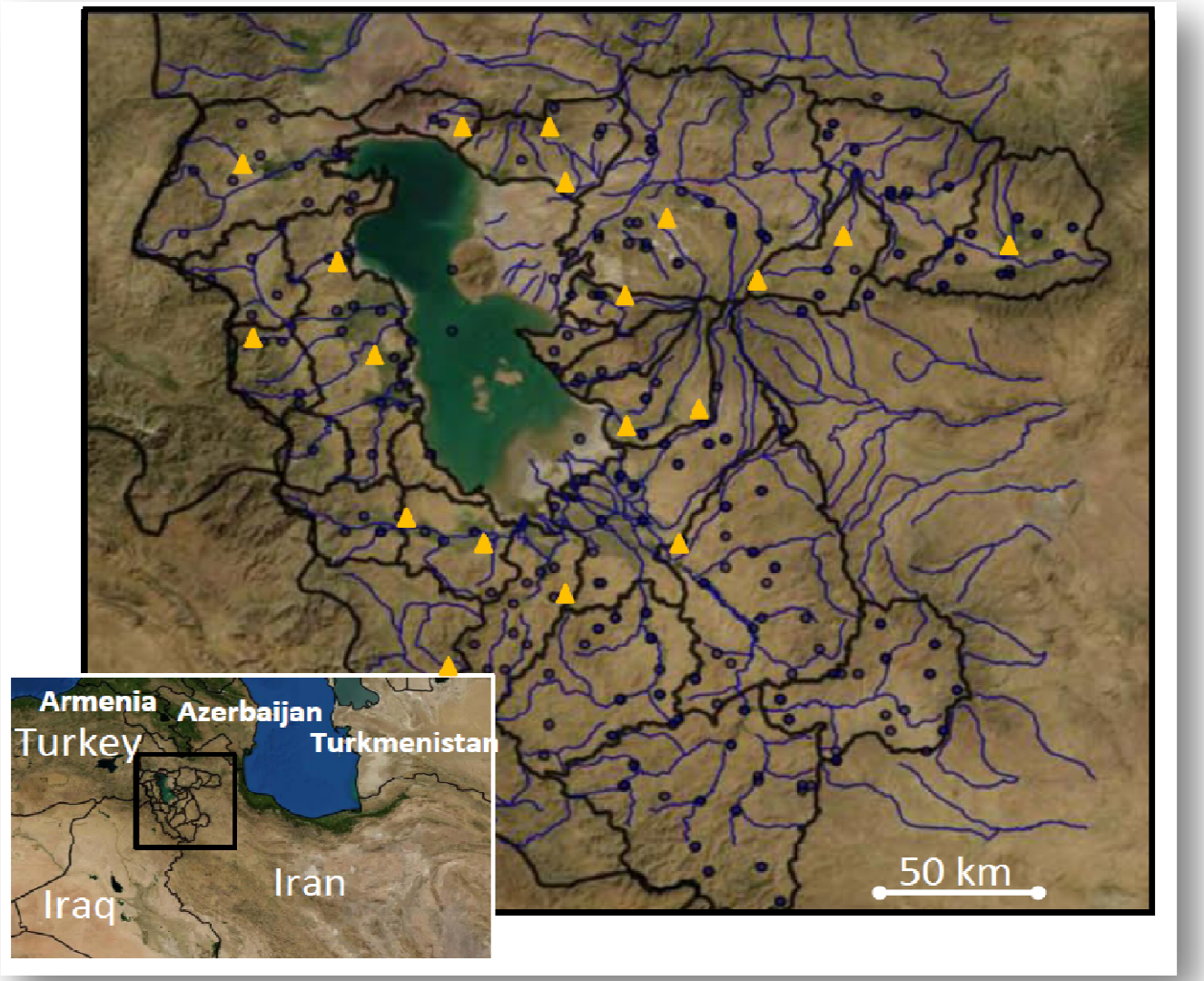
Konstanz, Germany

GIS

Why lake Urmia?

Urmia basin



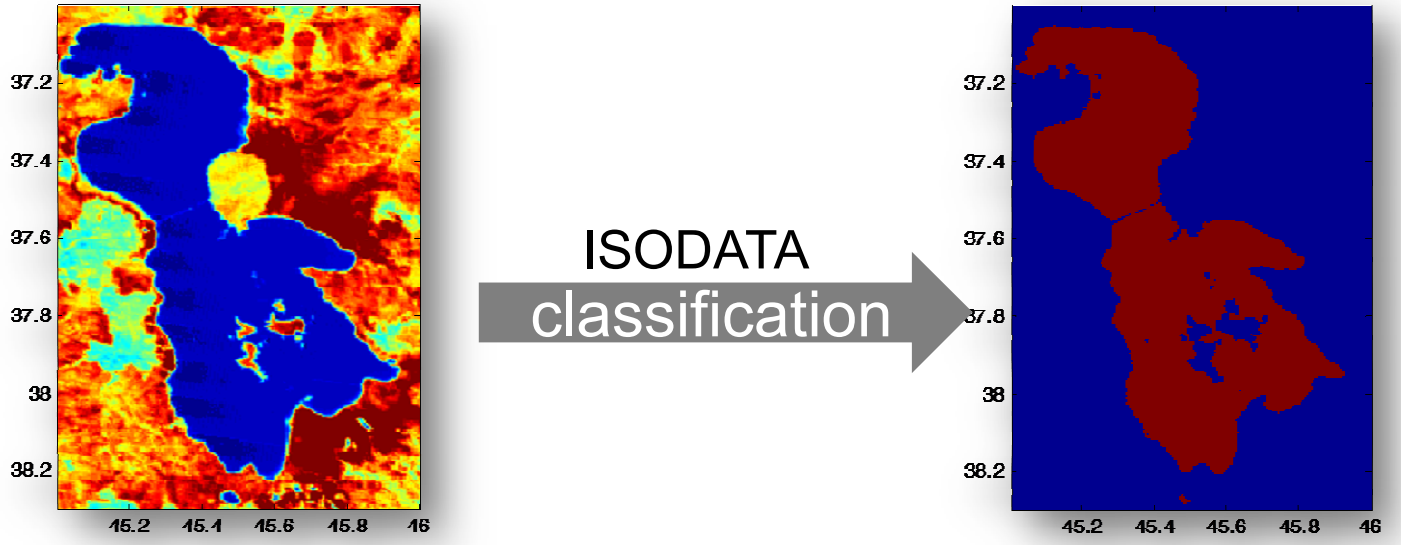
spaceborne monitoring

Monitoring the lake using spaceborne sensors

Variable	Dataset	Version	Resolution		Time period
			Spatial	Temporal	
Precipitation P	GPCP	2.2	2.5° × 2.5°	1 mo	2000 – 2014
Evapotranspiration ET	ECMWF	–	0.75° × 0.75°	1 mo, 1 d, 6 h	2000 – 2012
Groundwater level	WRC	–	–	1 mo	2003 – 2011
lake area S	MODIS	–	250.0 m × 250.0 m	8 d	2000 – 2014
water level H_{alt}	ENVISAT	–	–	35 d	2002 – 2010
	ENVISAT XT	–	–	30 d	2010 – 2012
	CryoSat-2	–	–	3–50 d	2012 – 2014
water storage ΔM	GRACE GFZ	R5	–	1 mo	2003 – 2014
	WGHM	IRR70	0.5° × 0.5°	1 mo	2002 – 2009

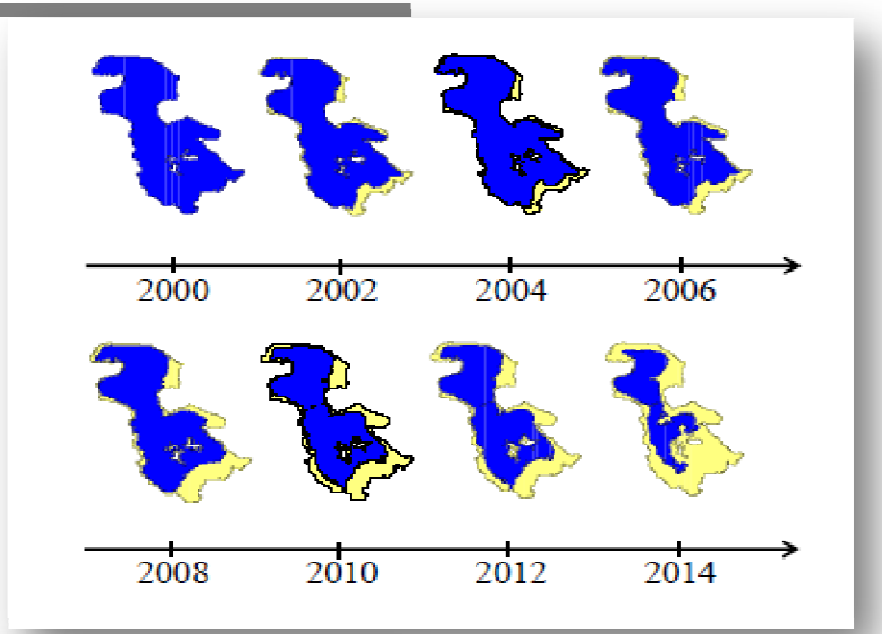
Surface water extent from satellite imagery

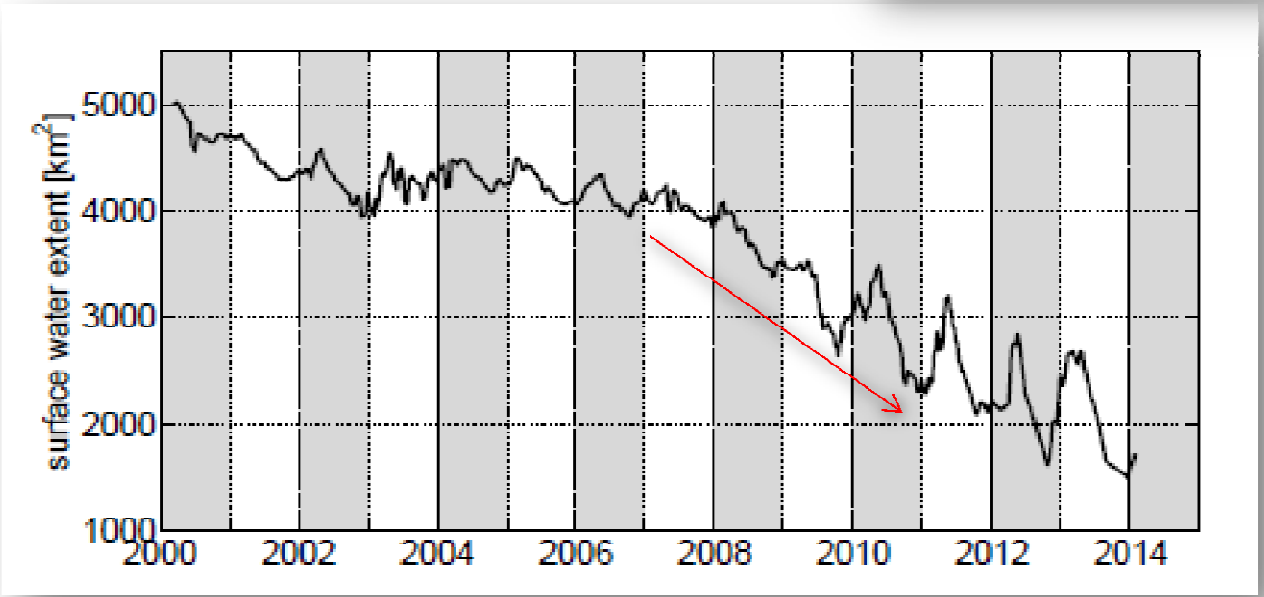
data type	MODIS surface reflectance
time period	2000–2014
temporal resolution	8 day
spatial resolution	250 m



Surface water extent from satellite imagery

- Overall trend 220±6 km²/yr
- Lost 70% of its area!

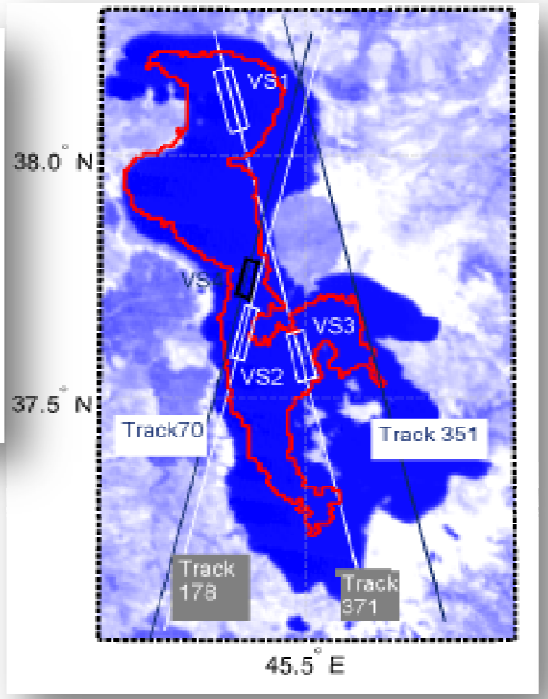


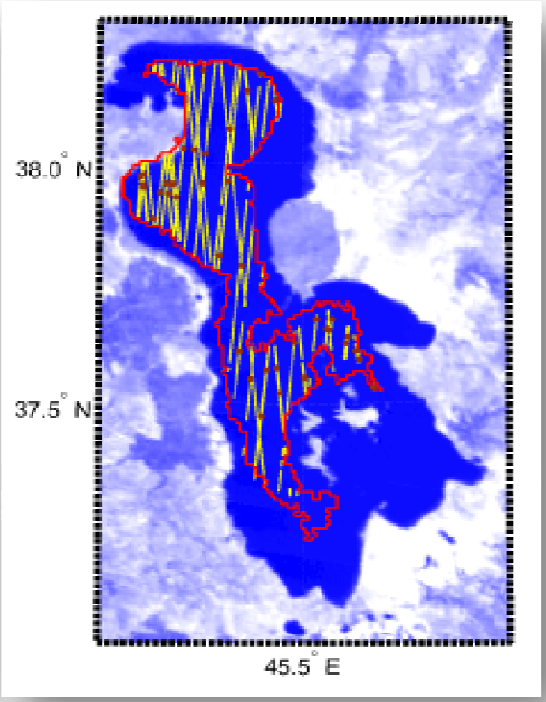


Lake level from satellite altimetry

satellite mission	ENVISAT	ENVISAT ext.	CryoSat-2
time period	2002–2010	2010–2011	2012 –2014
temporal resolution	35 day	30 day	uneven

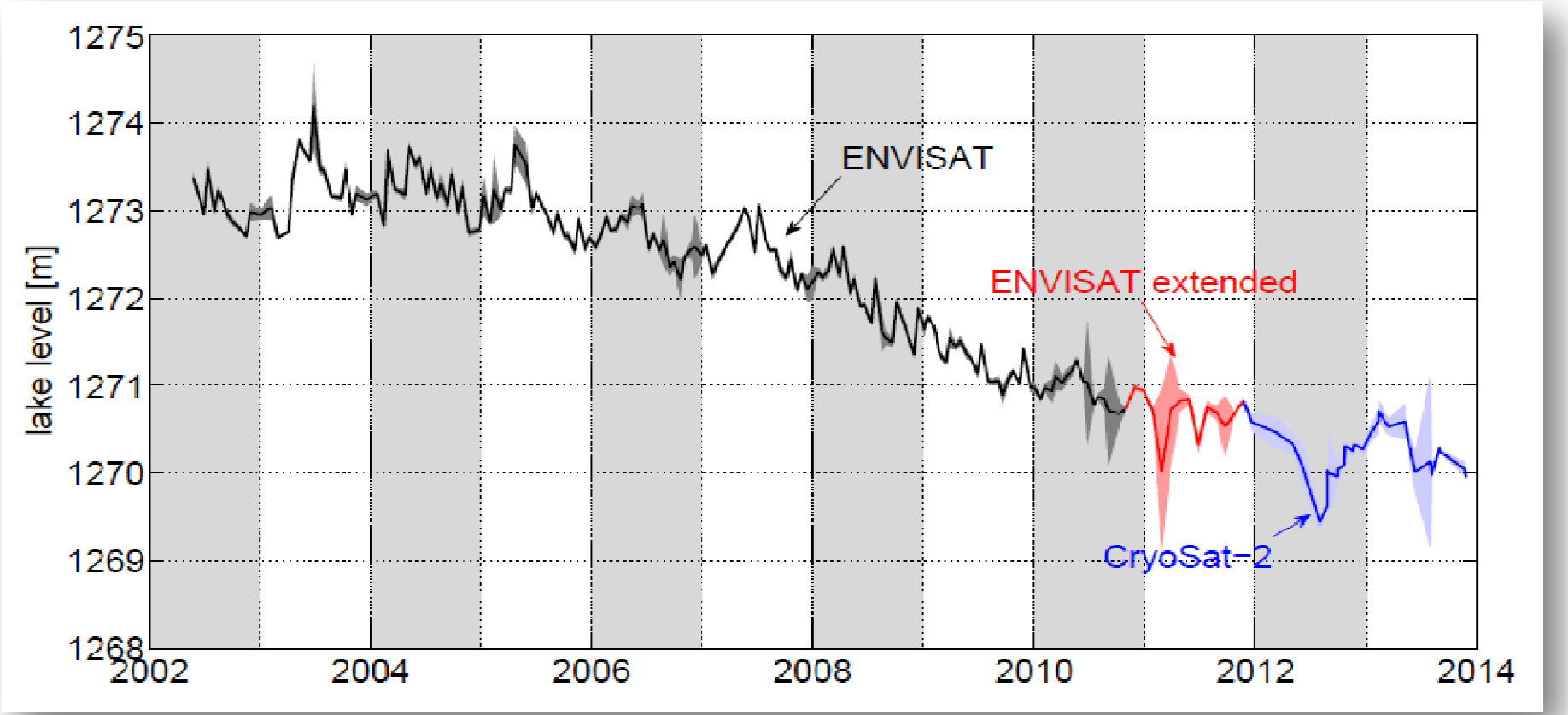
virtual station	track	lat. [°]	lon [°]	box length [km]
VS1	371	38.139	45.315	6
VS2	178	37.641	45.352	6
VS3	371	37.619	45.470	6
VS4	70XT	37.688	45.338	4



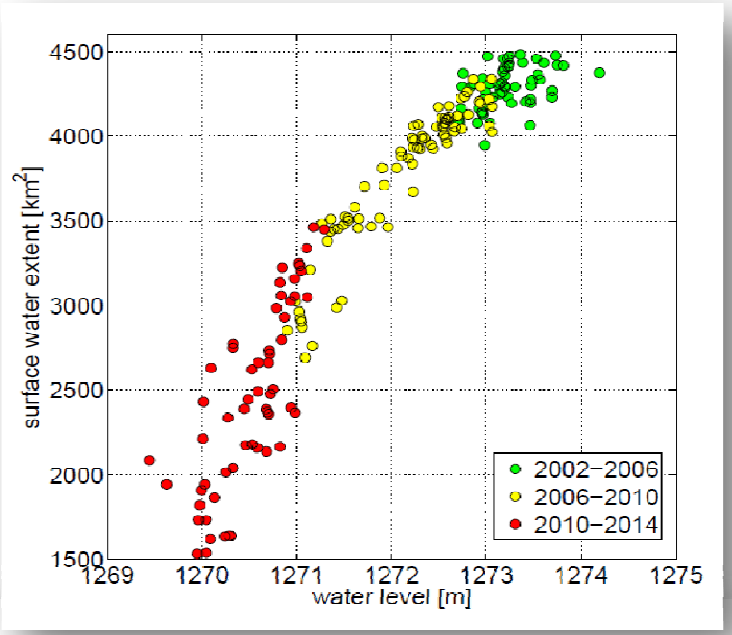


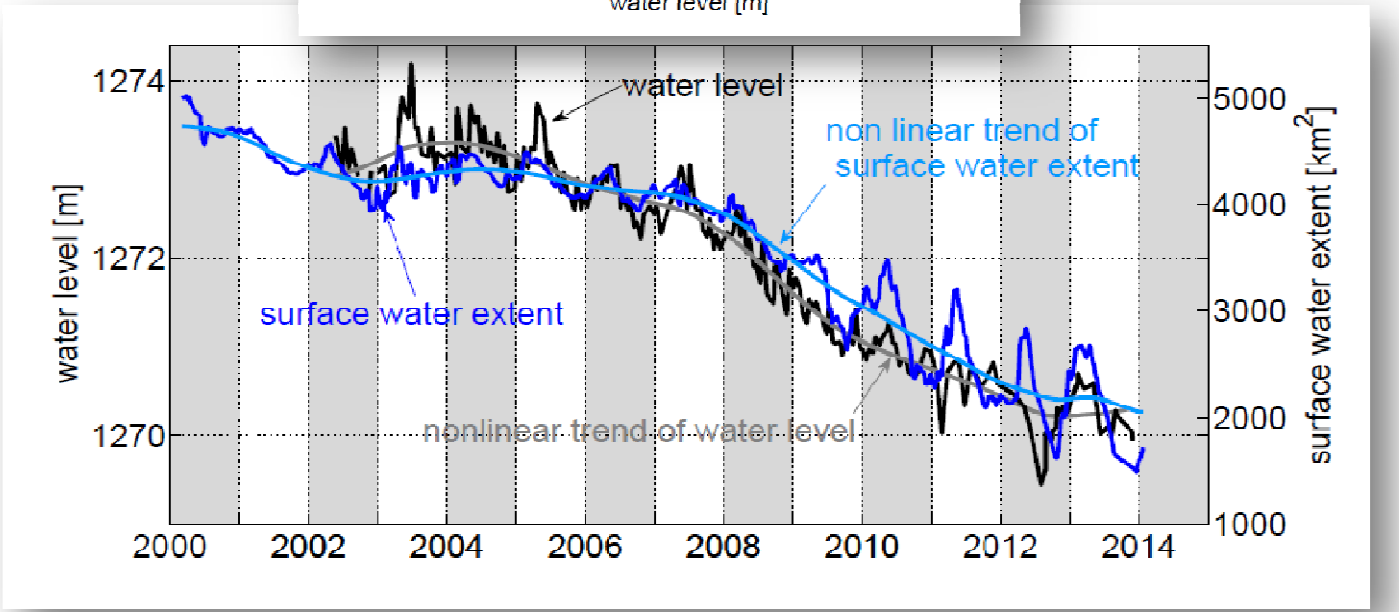
Lake level from satellite altimetry

- Overall trend 34±1 cm/yr



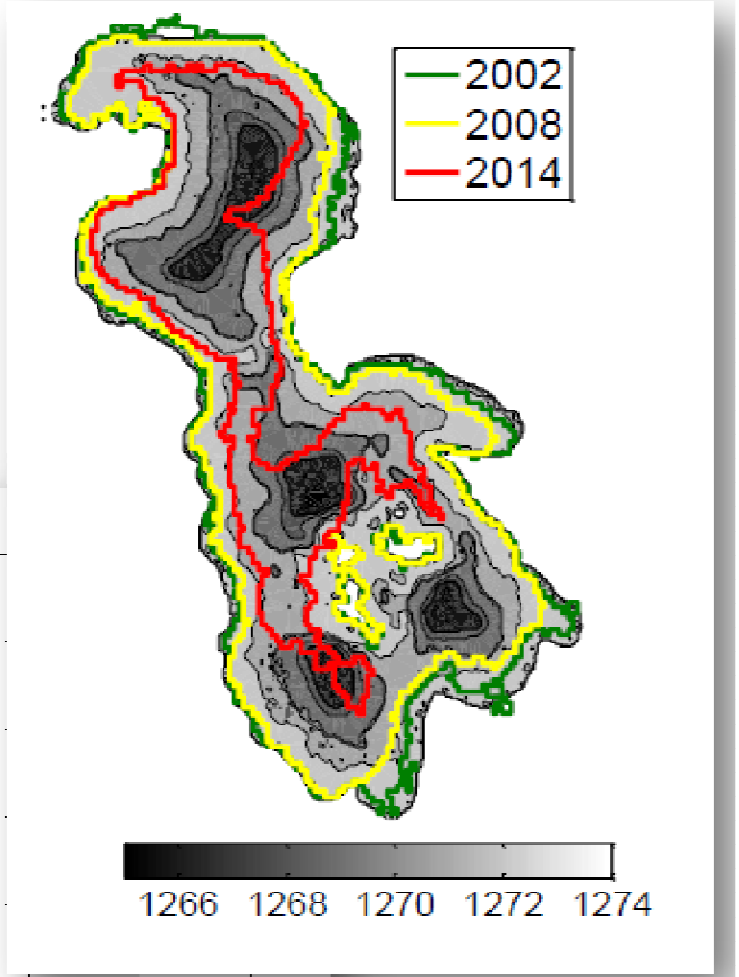
Level-area relationship

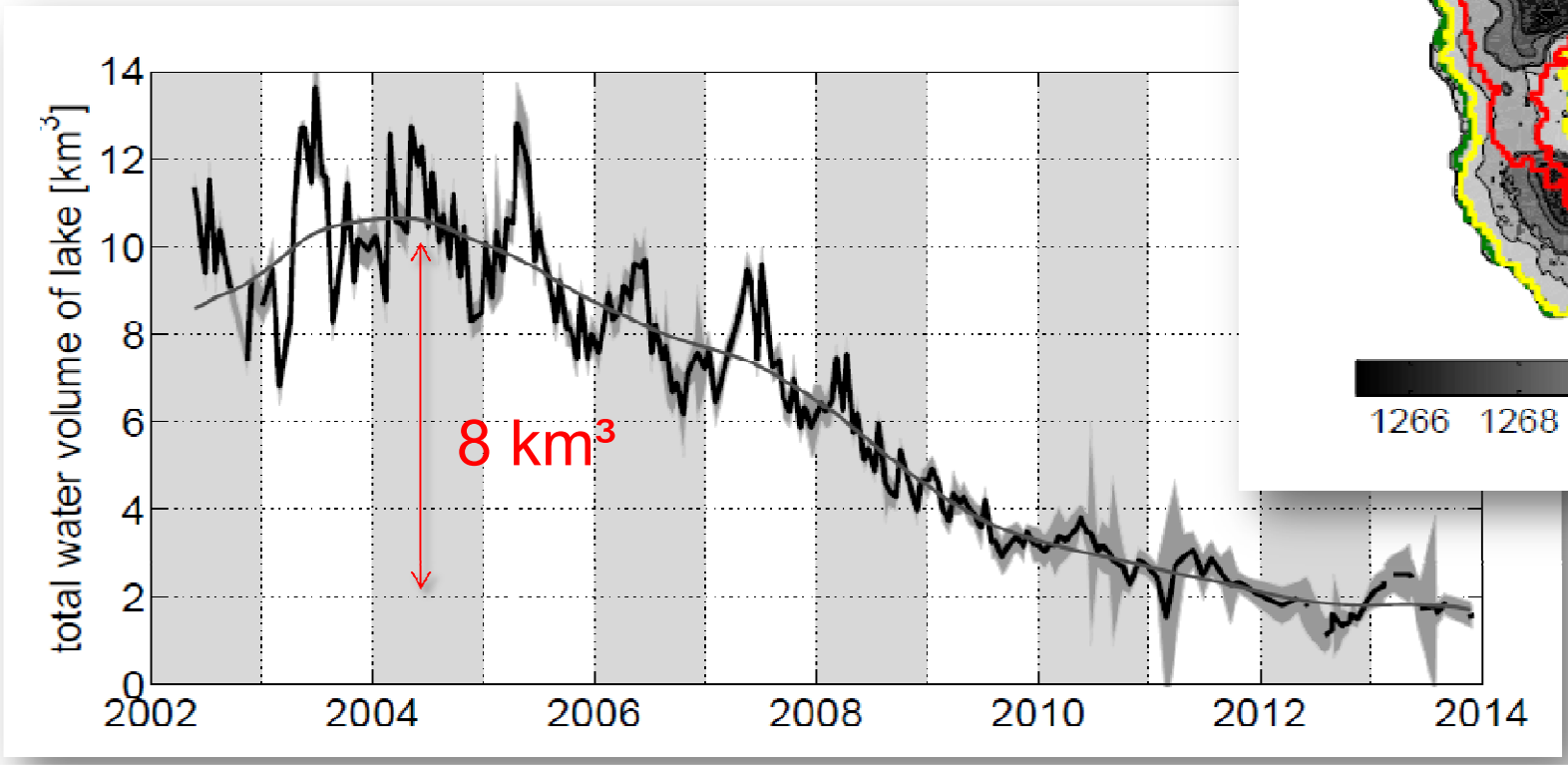




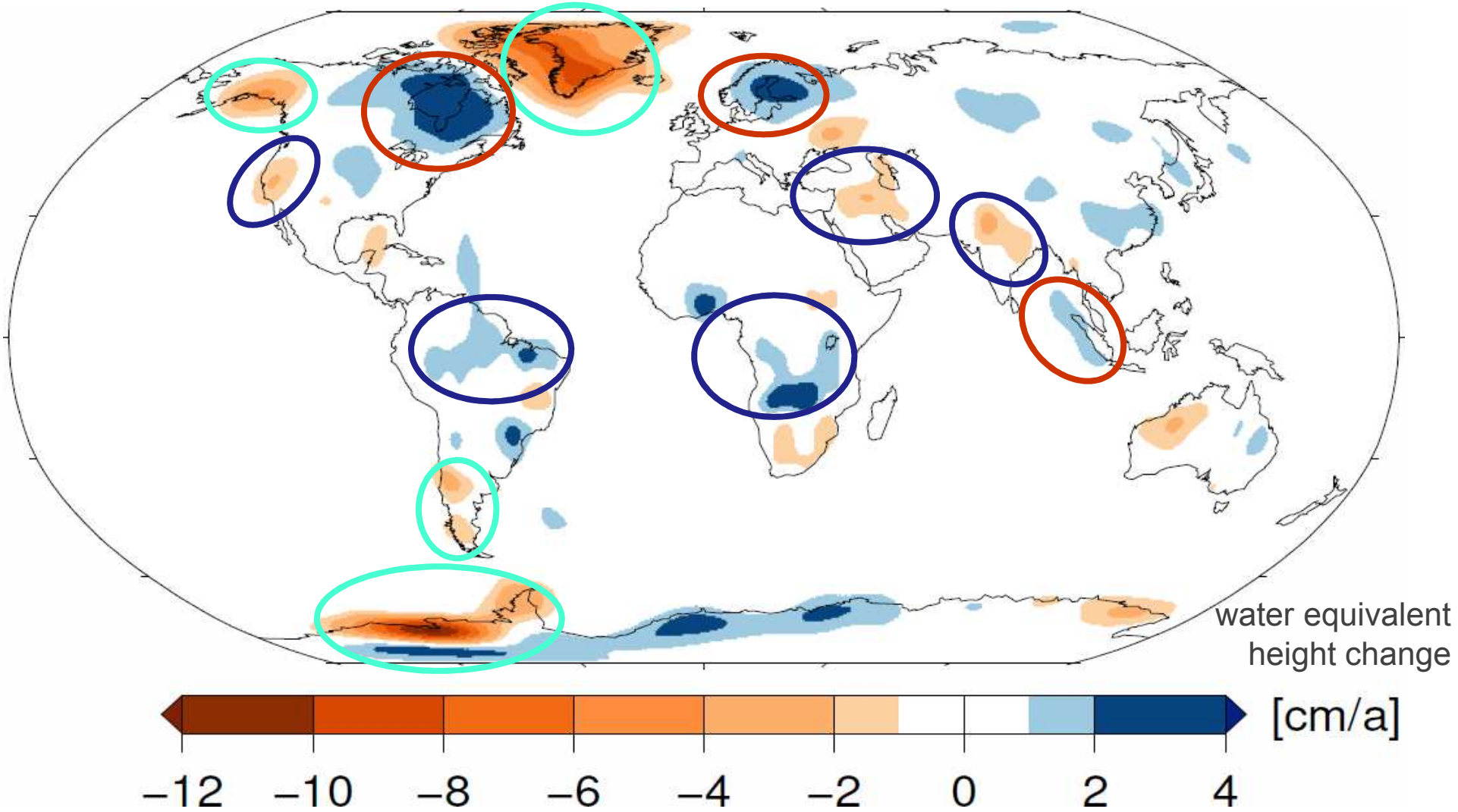
Lake volume

- combining
  - water level from satellite altimetry
  - surface water extent from satellite imagery
  - bathymetry
- Overall trend of 1.03±0.02 km³/yr
- Current rate of 0.44±0.02 km³/yr





10 years of GRACE: secular mass changes



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Water storage changes from GRACE

satellite mission	GRACE
data type	satellite-to-satellite tracking / range-rate spherical harmonics, Release 5
time period	2003–2014
temporal resolution	monthly
spatial resolution	approx. 5° / Gaussian 350-km filter

Voss, K. A., Famiglietti, J. S., Lo, M., de Linage, C., Rodell, M., Swenson, S. C., 2013. Groundwater depletion in the middle east from grace with implications for transboundary water management in the tigris-euphrates-western iran region. Water Resources Research 49 (2), 904–914.

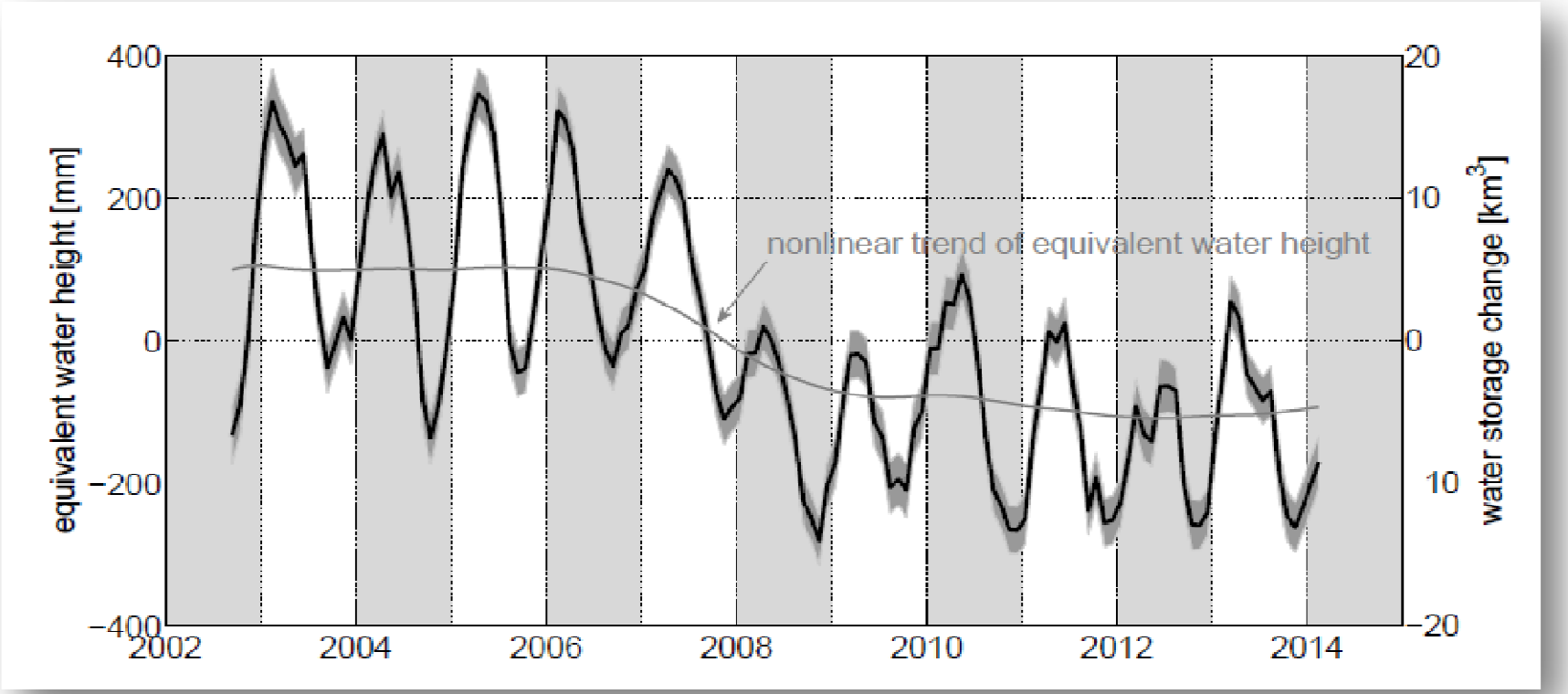
Forootan, E., Rietbroek, R., Kusche, J., Sharifi, M., Awange, J., Schmidt, M., Omondi, P., Famiglietti, J., 2014. Separation of large scale water storage patterns over Iran using GRACE, altimetry and hydrological data . Remote Sensing of Environment 140 (0), 580–595.

Joodaki, G., Wahr, J., Swenson, S., 2014. Estimating the human contribution to groundwater depletion in the Middle East, from GRACE data, land surface models, and well observations. Water Resources Research 50 (3).

RMS of GRACE signal [mm]

Water storage changes from GRACE

- Two equilibrium level
- Clear drop in equivalent water height between 2007—2008
- Average water loss at rate of 1.4±0.09 km^3/yr



hydrological analysis

Variable	Dataset	Version	Resolution		Time period
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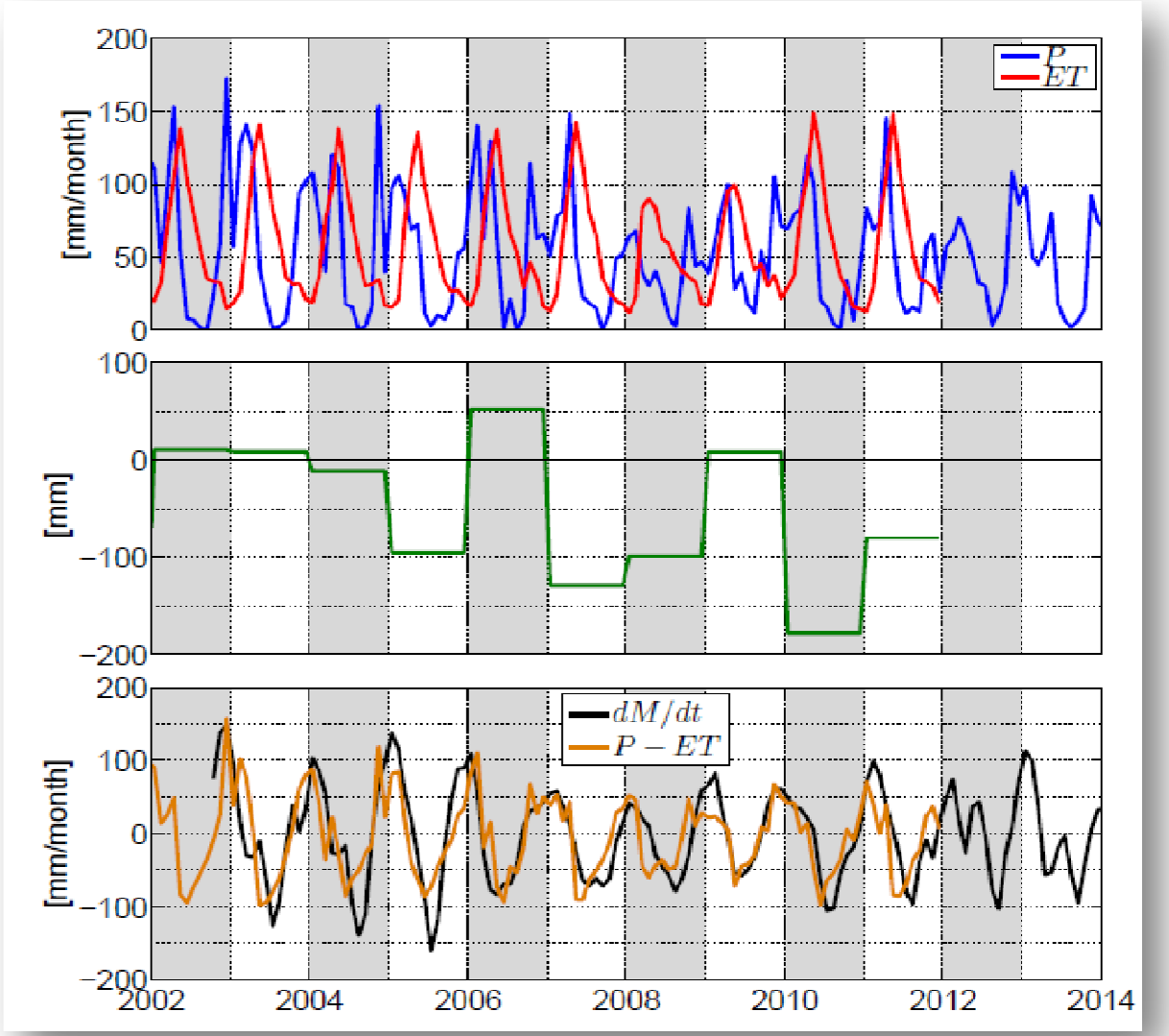
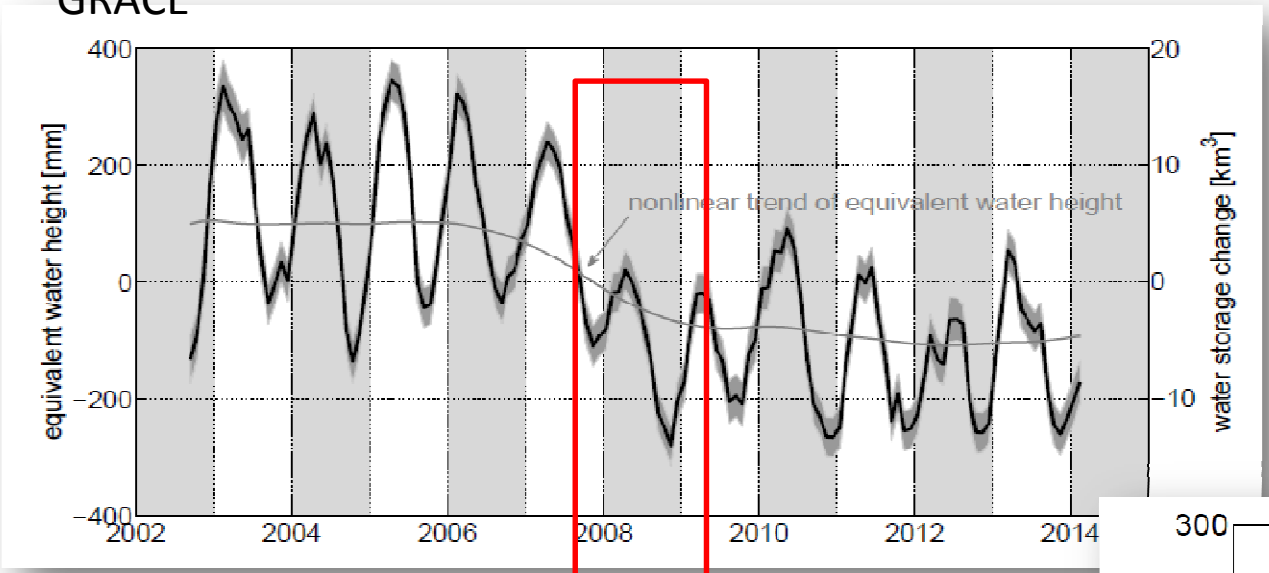
Water storage changes, hydrological investigation

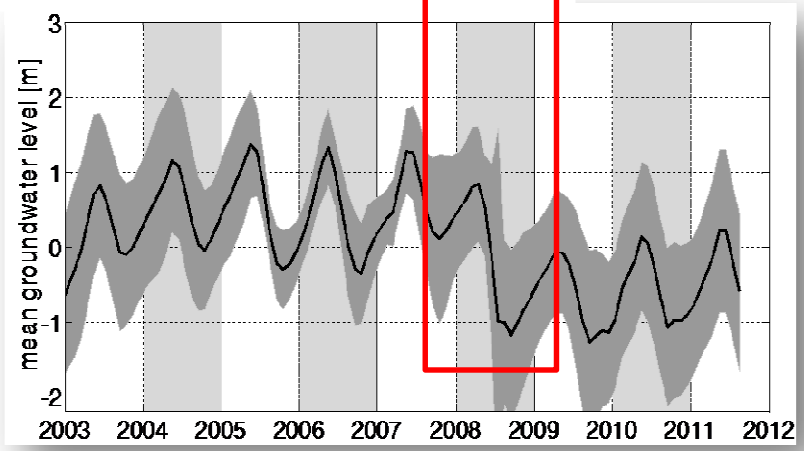


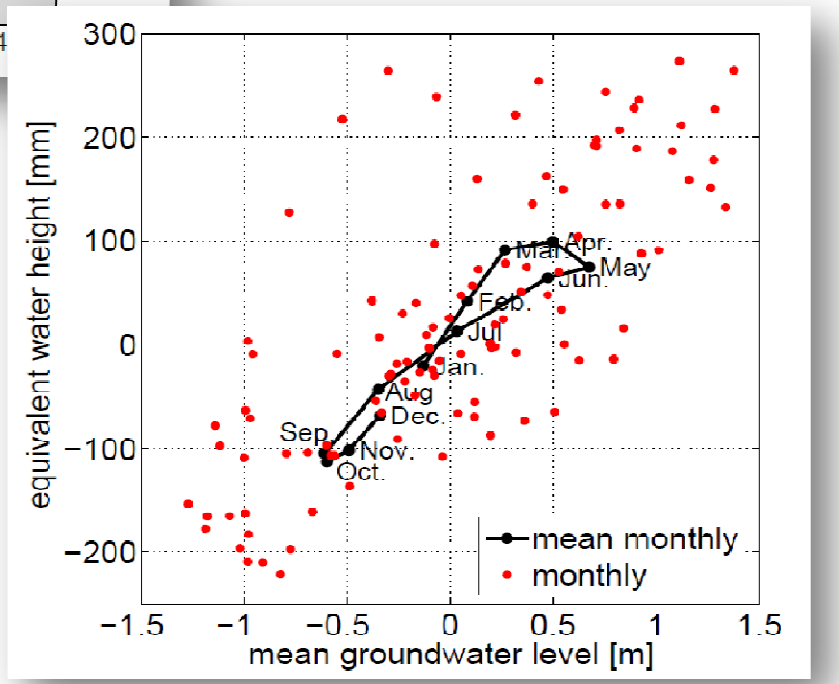
Drop in water storage

GRACE



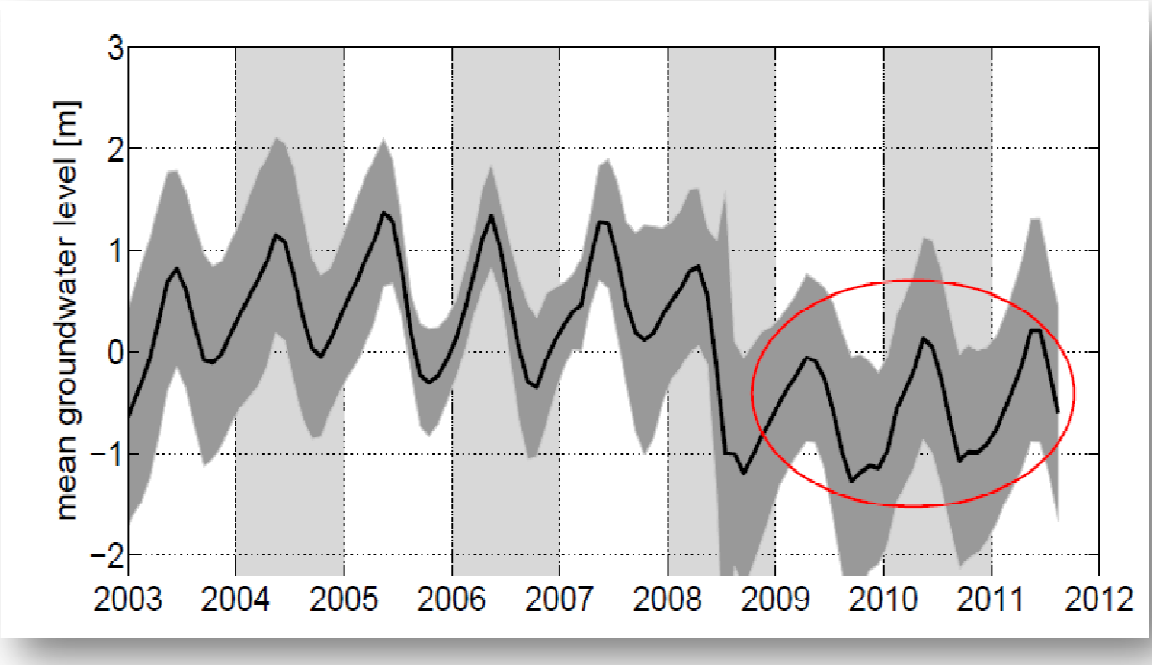
Mean groundwater level





Lake dries up faster than its basin after 2009?

- After 2009 the lake has continuously lost 0.62±0.03 km^3/yr of its water volume, while the rate of water loss in the whole basin is less, namely 0.44±0.02 km^3/yr and
- The mean groundwater level of the basin outside the lake shows a slight positive trend (recharge)



Lake dries up faster than its basin after 2009?

- Scenario 1:
  Induced leakage (lateral flow) as the groundwater level becomes lower than the lake level

- Scenario 2:
  Storage of water behind dams leading to a reduction of lake inflow

- Or (more likely):
  Combination of both scenarios

Lake Urmia's future?

Aral Sea

Lake Urmia's future?

- Given the current water volume trend and the bathymetry, the lake will divide into two minor lakes (Northern and Southern) in the near future
- Current rate of water volume loss 0.44±0.02 km^3/yr (2011–present)
- Intuitive prediction:
  lake will dry up in 5 years (around 2020)

Summary and conclusion

- Urmia Lake has lost on average 34±1 cm/yr of its water level every year from 2002–2014
- The lake has lost about 70% of its water extent within the last 14 years
- The lake water volume down from 8 km^3 to less than 2 km^3 in 10 years
- The results from GRACE reveal that the basin of Lake Urmia faces a water loss at an average rate of 1.4±0.1 km^3/yr
- Equivalent water height from GRACE agrees very well with the mean groundwater level
- Urmia Lake dried up faster than its watershed between after 2009
- A regional environmental monitoring system is required to track water availability and consumption in this region, where the geodetic spaceborne sensors presented in this study would play an important role in augmenting the understanding of the water cycle in the basin.

GIS

Thank you

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Tourian MJ, O Elmi, Q Chen, B Devaraju and N Sneeuw (2014)

A spaceborne multisensor approach to monitor the desiccation of Lake Urmia in Iran

Journal of Remote Sensing of Environment, accepted

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