Climatic changes or regional human activities? Explaining the environmental tragedy of Lake Urmia desiccation

Sina Khatami

https://about.unimelb.edu.au/newsroom/news/2016/november/water-research-program-to-renew-lake-urmia-in-iran
https://twitter.com/KavehMadani/status/1057157725933555712

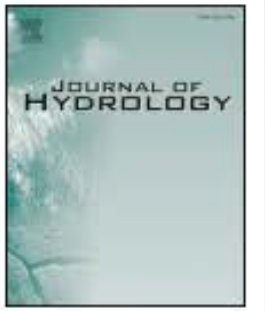
THE UNIVERSITY OF MELBOURNE

Journal of Hydrology 569 (2019) 203–217

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol



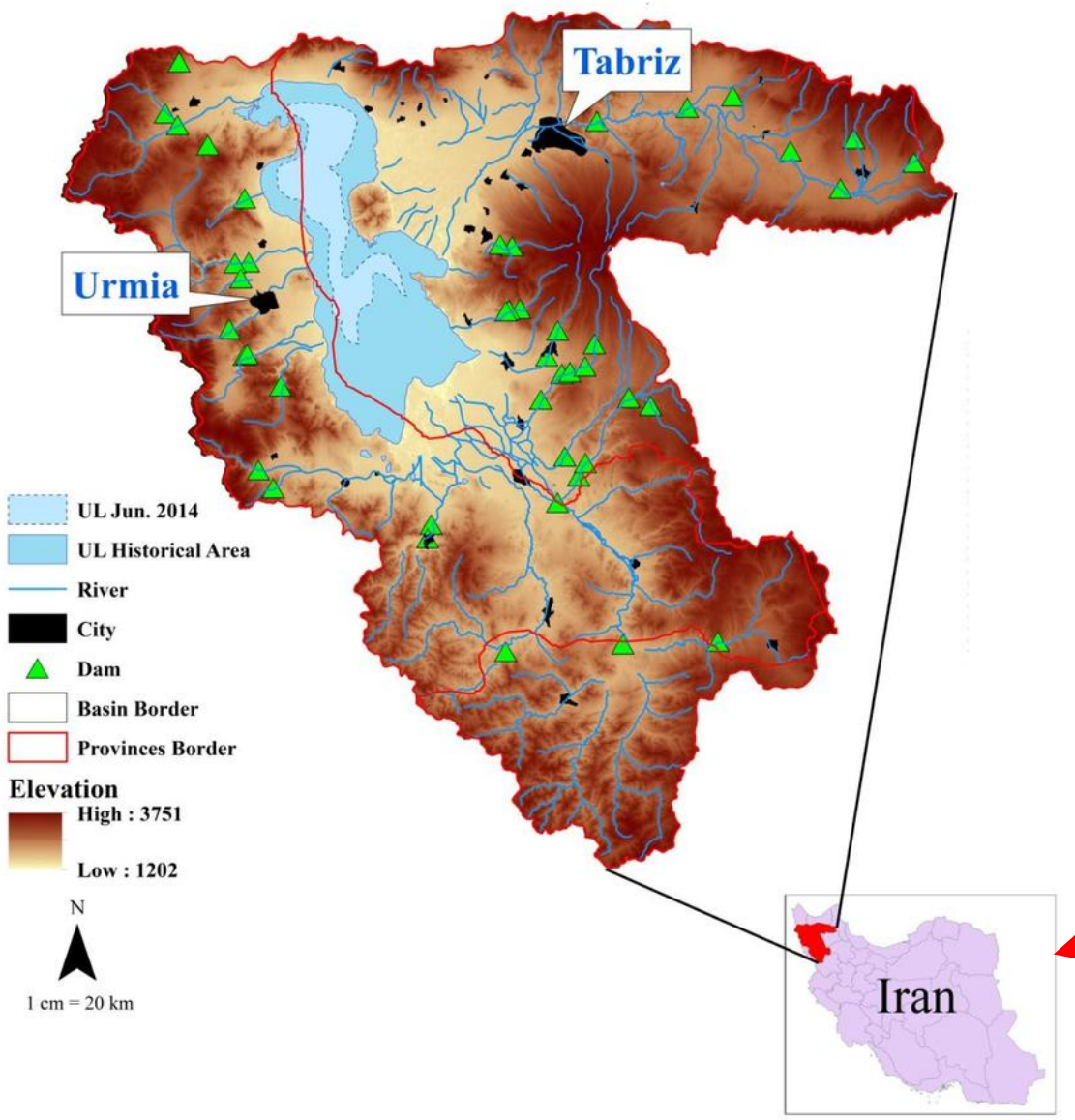
Research papers

Climatic or regionally induced by humans? Tracing hydro-climatic and land-use changes to better understand the Lake Urmia tragedy

Bahram Khazaei[a,*], Sina Khatami[b], Seyed Hamed Alemohammad[c], Lida Rashidi[d], Changshan Wu[e], Kaveh Madani[f,g], Zahra Kalantari[g], Georgia Destouni[g], Amir Aghakouchak[h,i]

[a] Department of Civil and Environmental Engineering, University of Wisconsin-Milwaukee, USA
[b] Department of Infrastructure Engineering, University of Melbourne, Australia
[c] Radiant.Earth, USA
[d] Department of Computing and Information Systems, University of Melbourne, Australia
[e] Department of Geography, University of Wisconsin-Milwaukee, USA
[f] Centre for Environmental Policy, Imperial College London, UK
[g] Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Sweden
[h] Department of Civil and Environmental Engineering, University of California, Irvine, USA
[i] Department of Earth System Science, University of California, Irvine, USA

A drying lake



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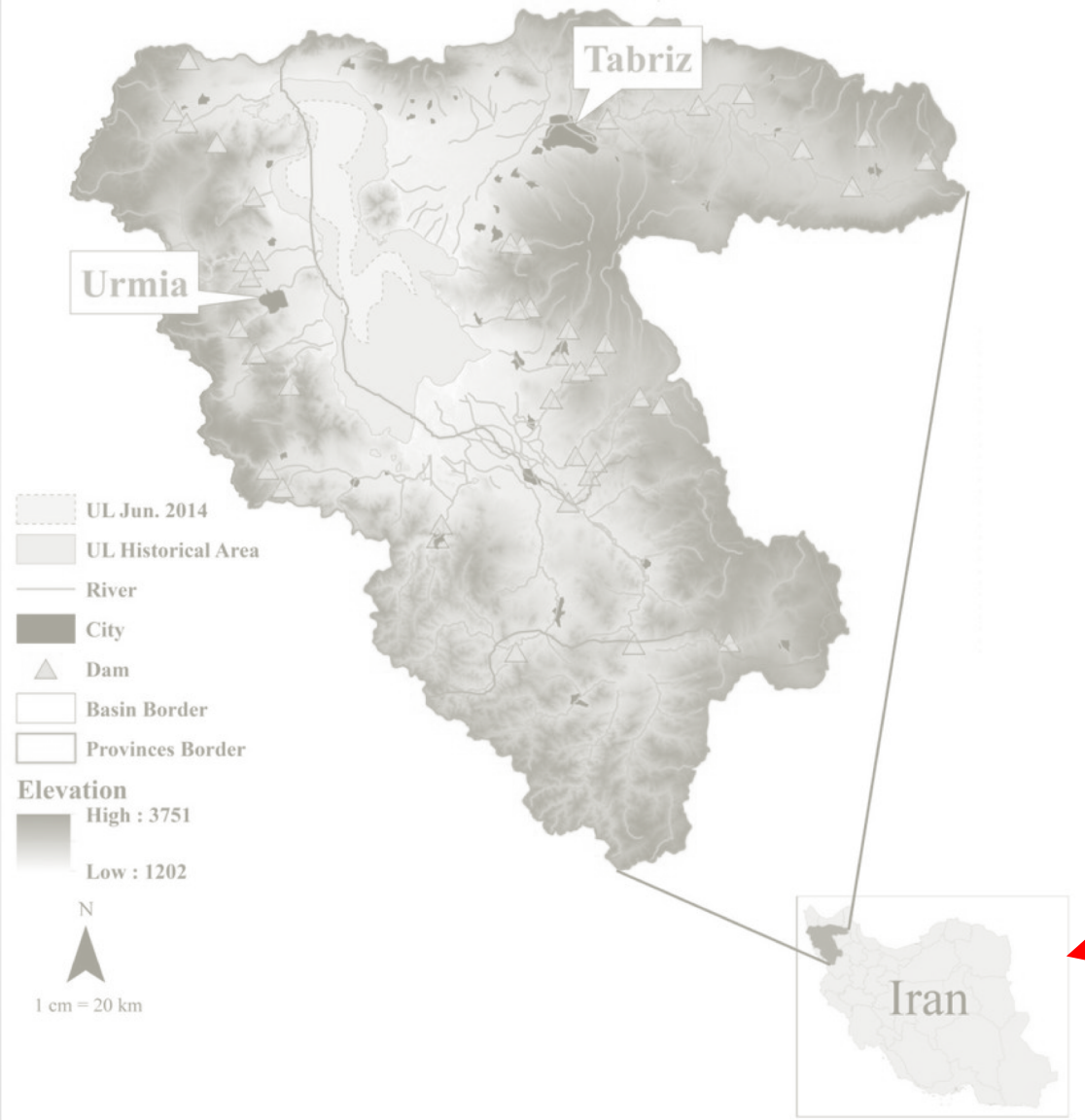


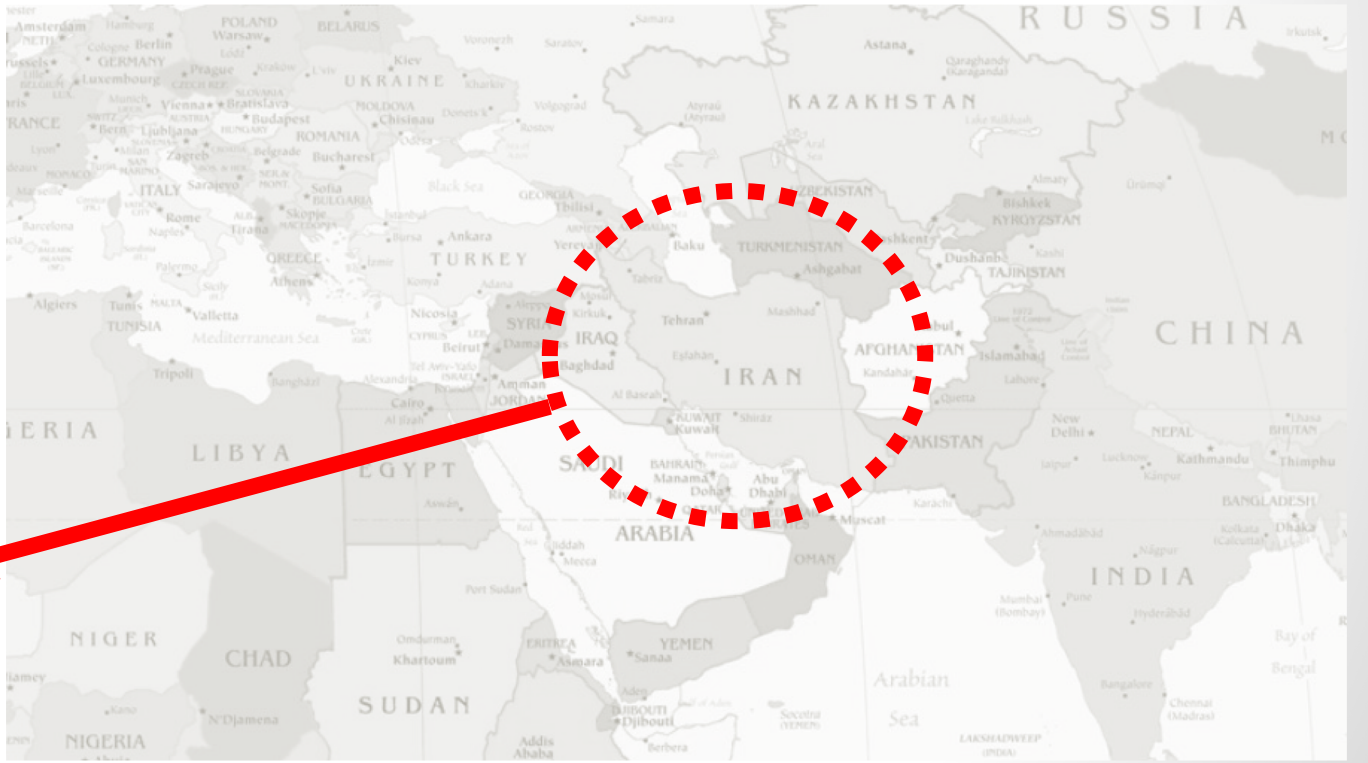
A unique aquatic ecosystem

Hypersaline (hist average ~160 *g/l*)

UNESCO Biosphere Reserves (1976)

United Nations Educational, Scientific and Cultural Organization

Man and the Biosphere Programme



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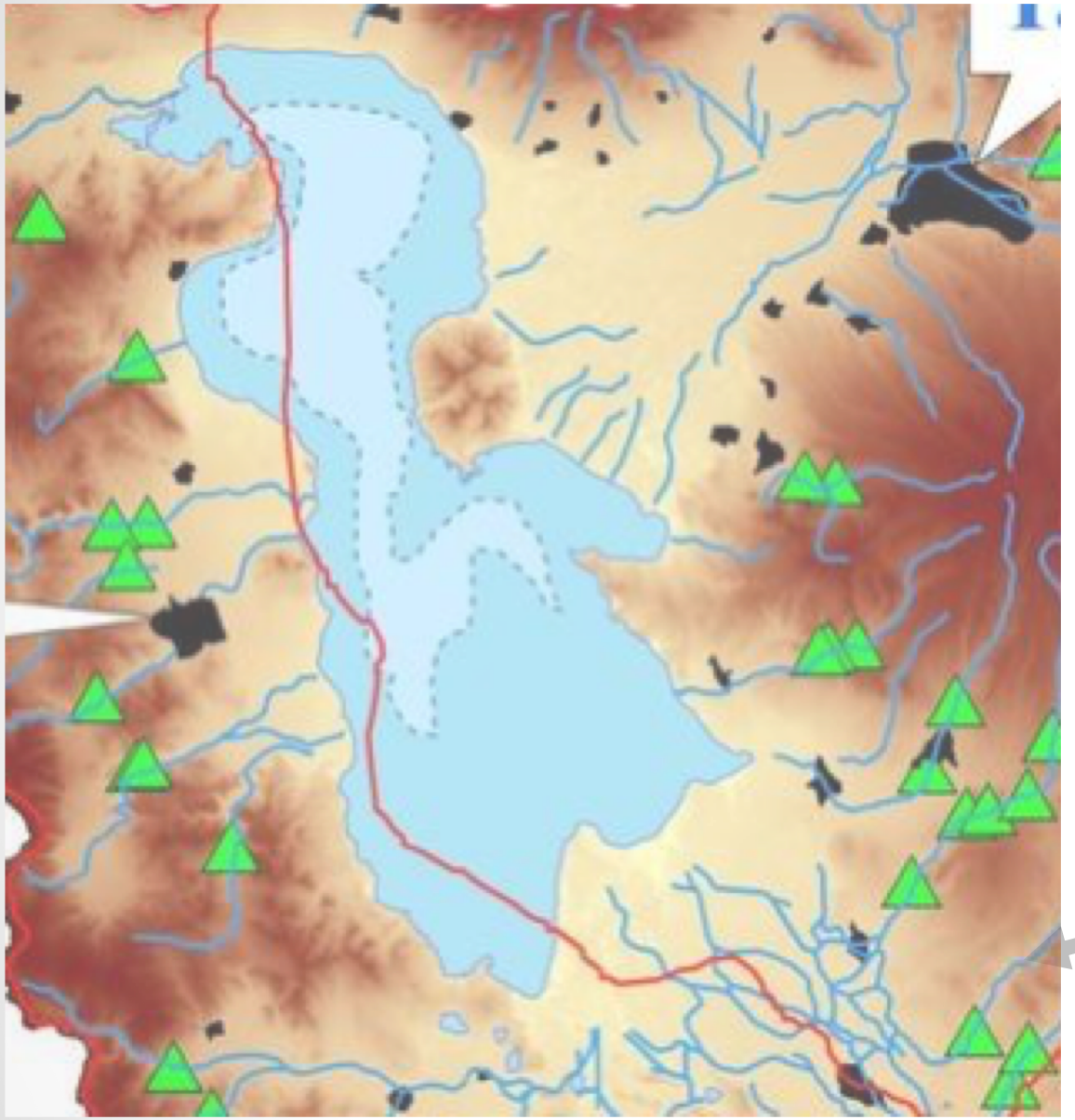

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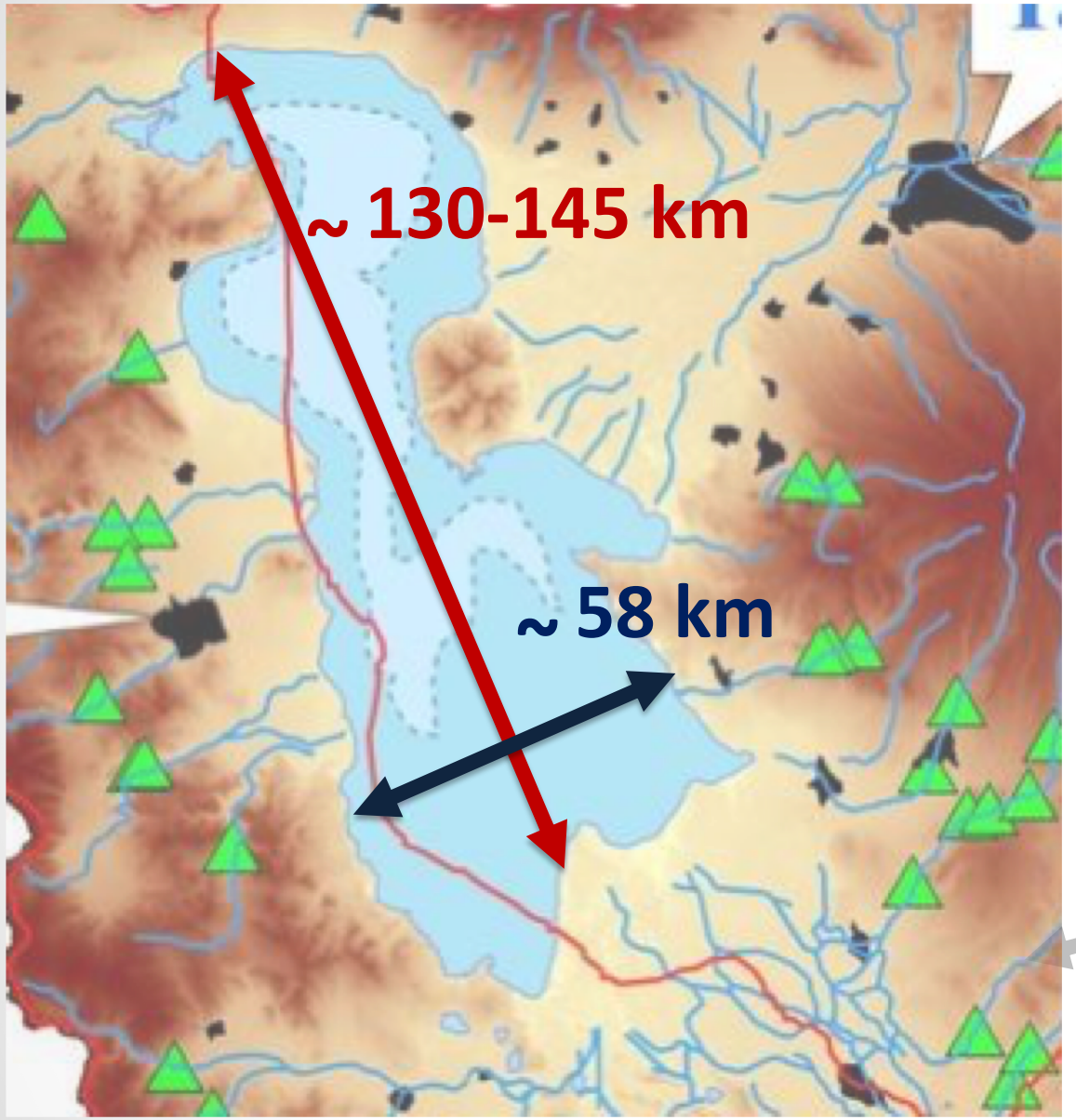

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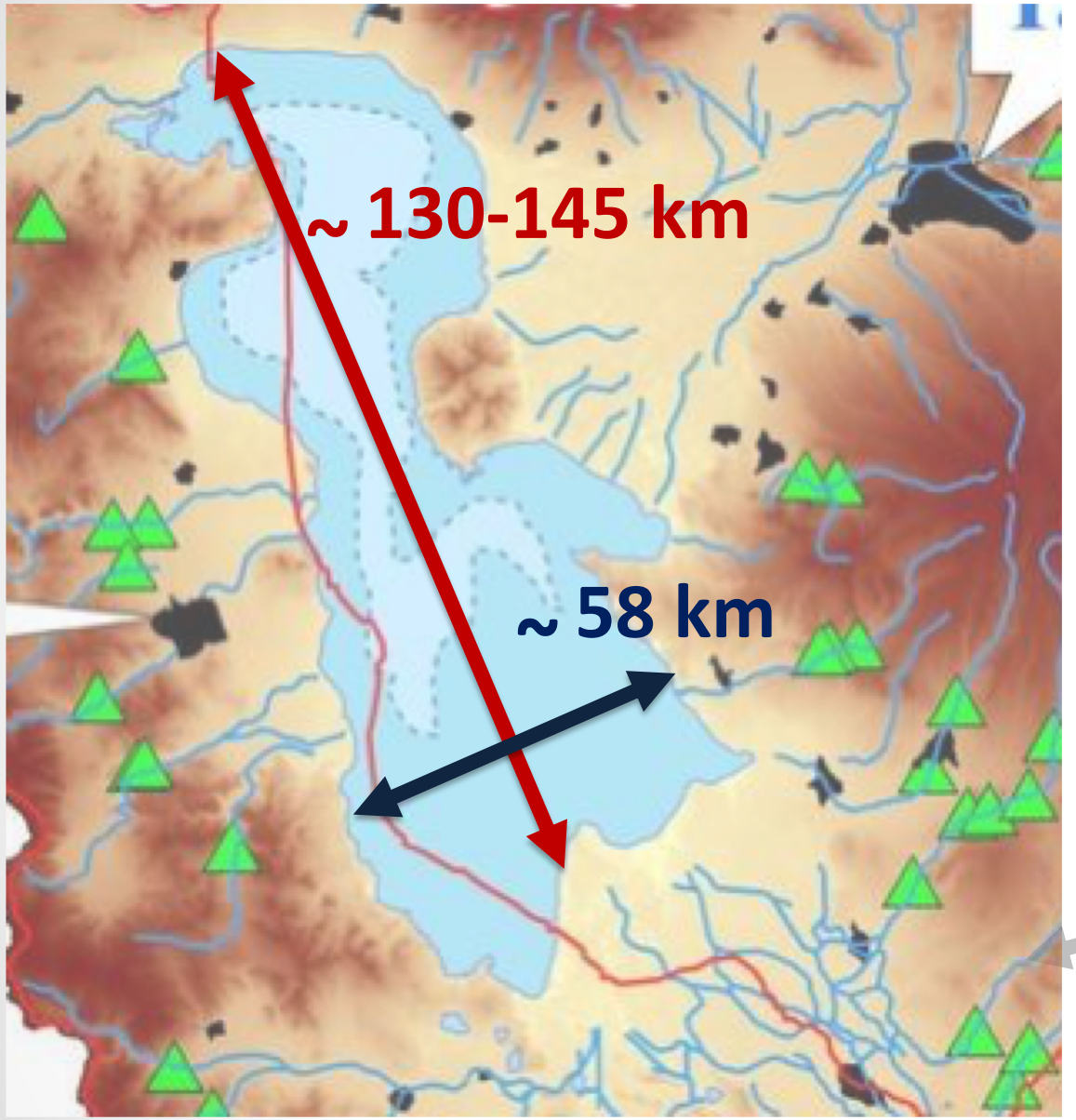
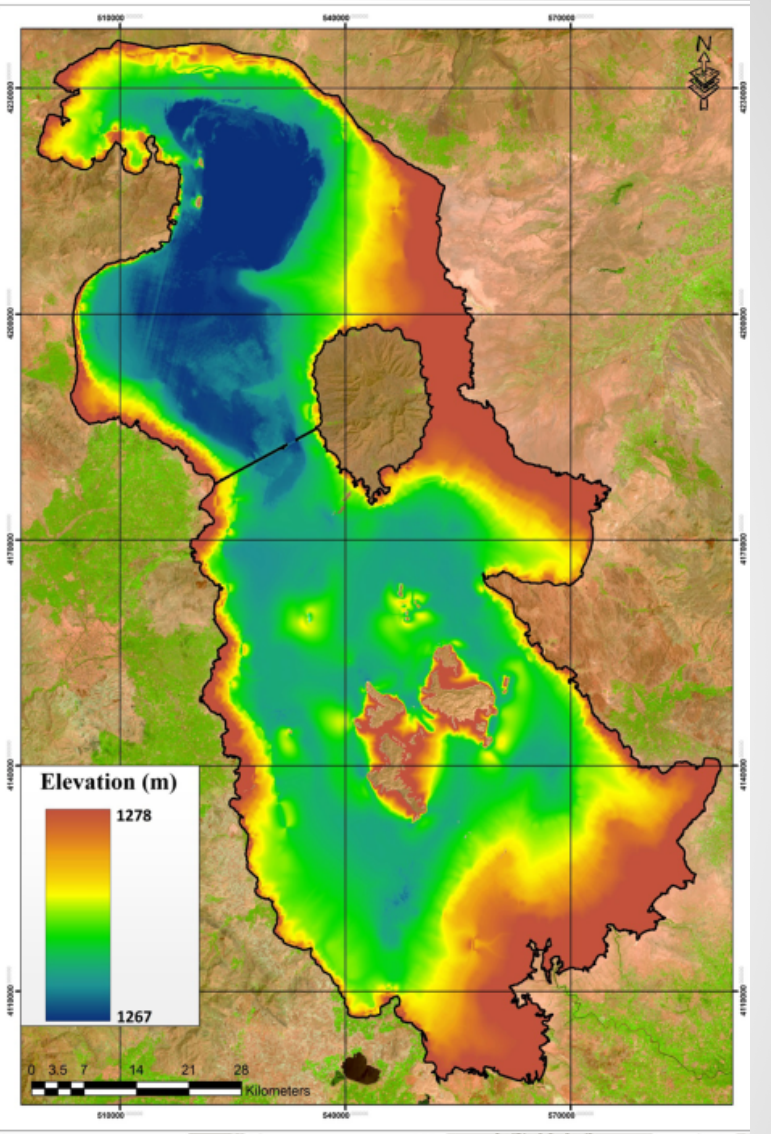


Shallow lake

(Average depth ~5.4 m – deepest ~14 m)

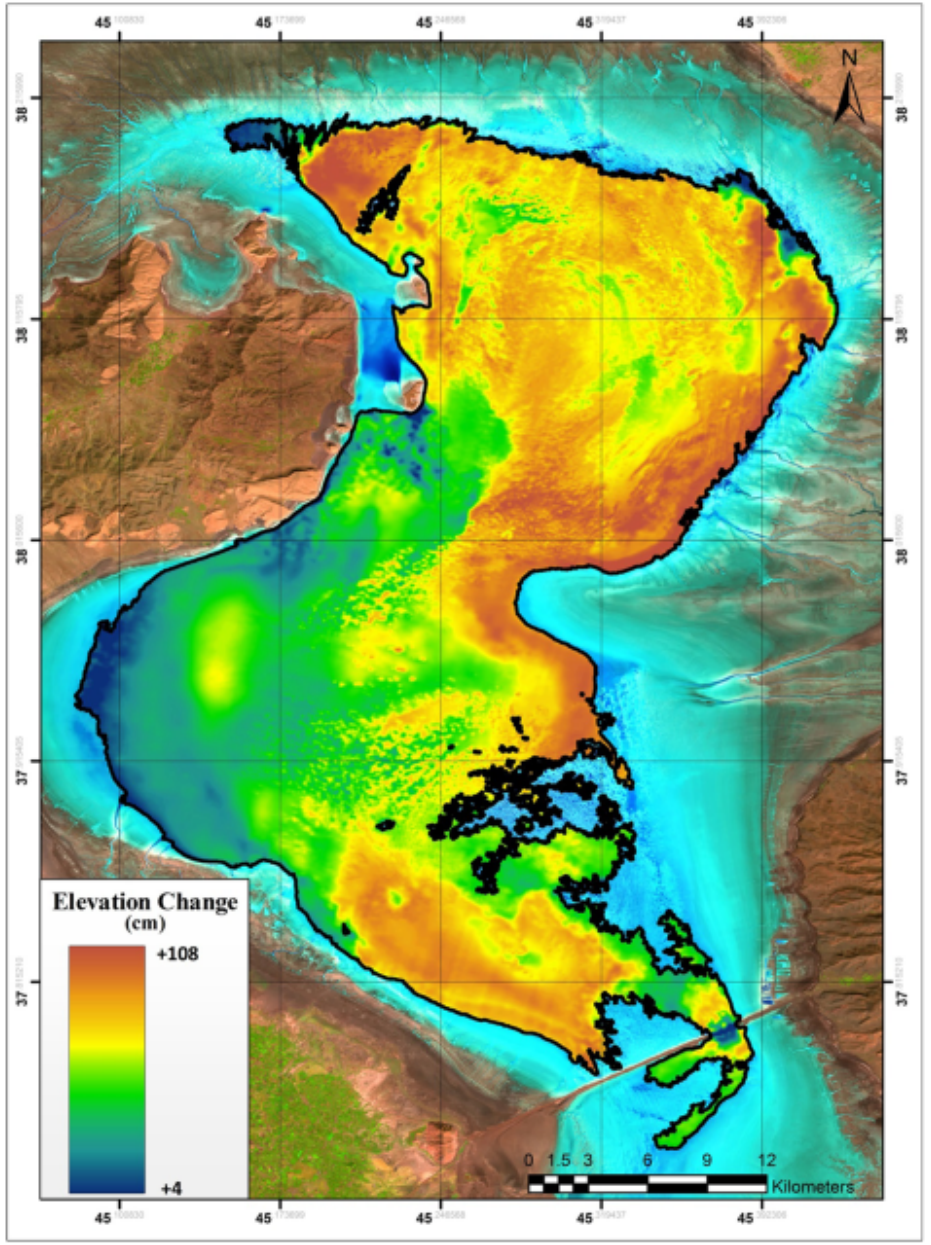
→ Lake Water Level – Area – Volume

A drying lake



Bathymetric map of Urmia Lake derived from Landsat OLI image - 2013

Karimi et al. (2016) Water Resour Manage

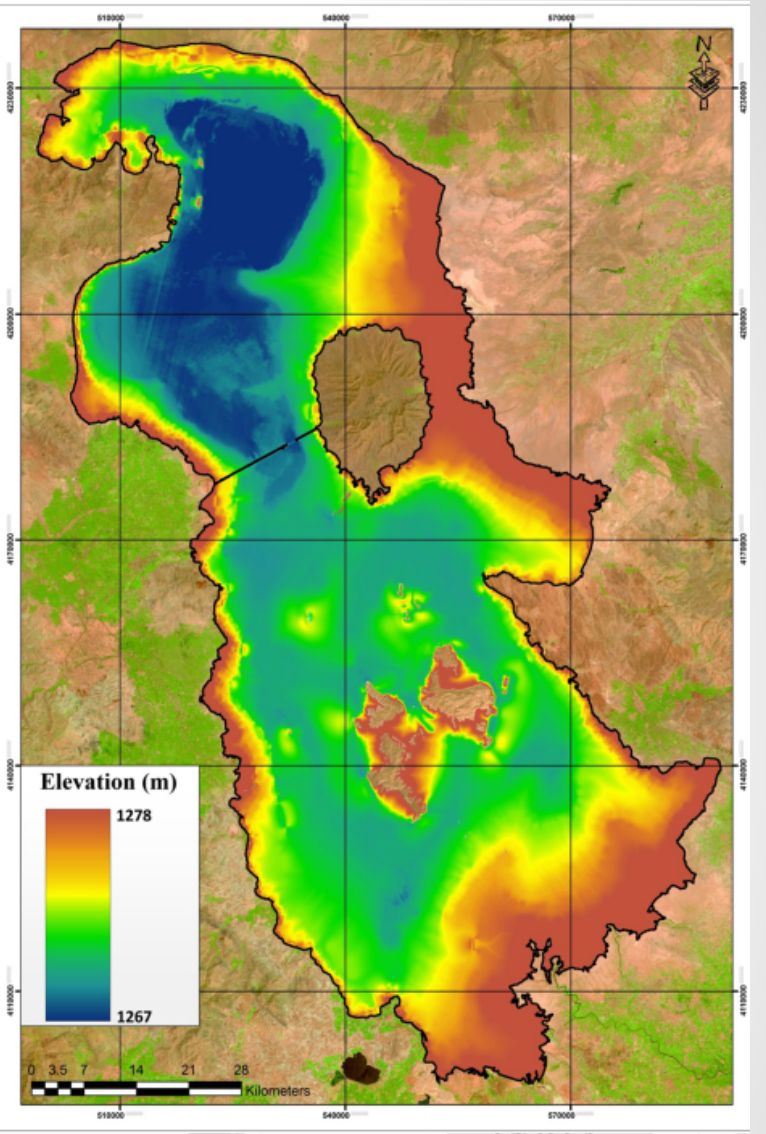


Elevation change (sedimentation) map of Urmia Lake bed from April 2013 to Sep. 2015

Elevation change of the Lake bed due to sedimentation

~64 cm salt deposition on average

Apr 2013 - Sep 2015



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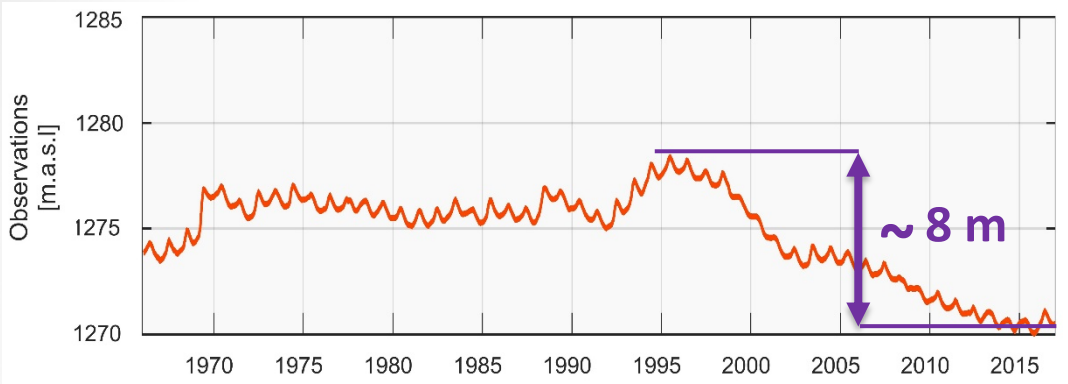

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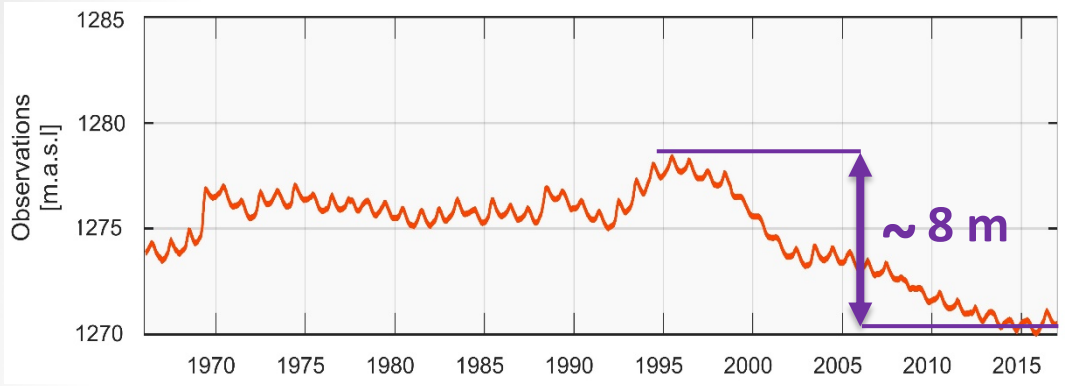
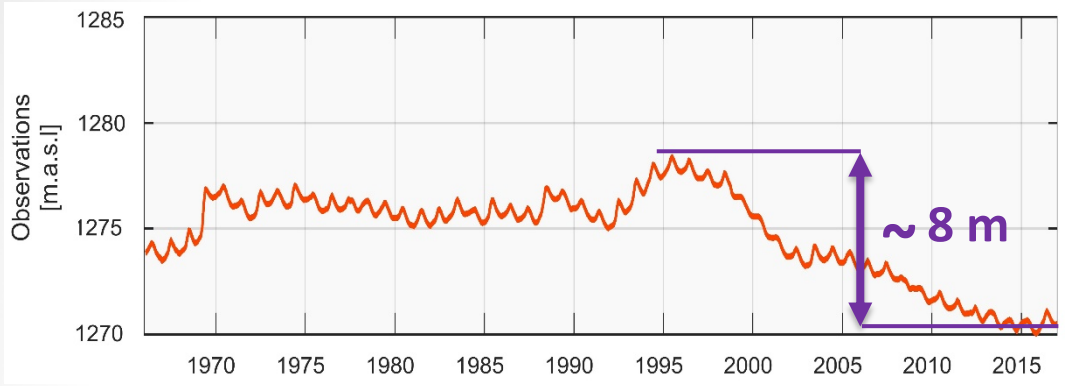
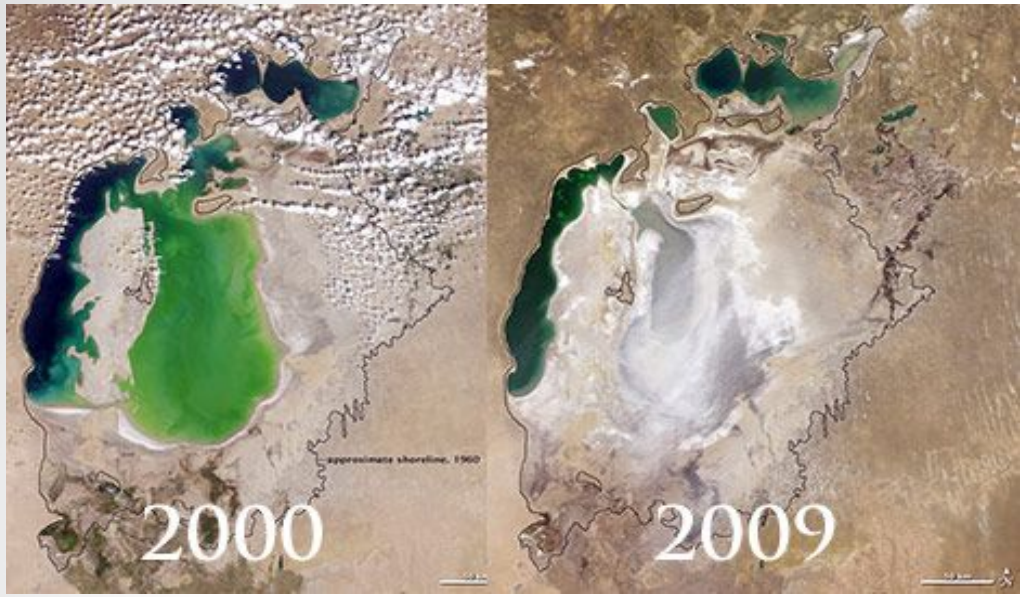


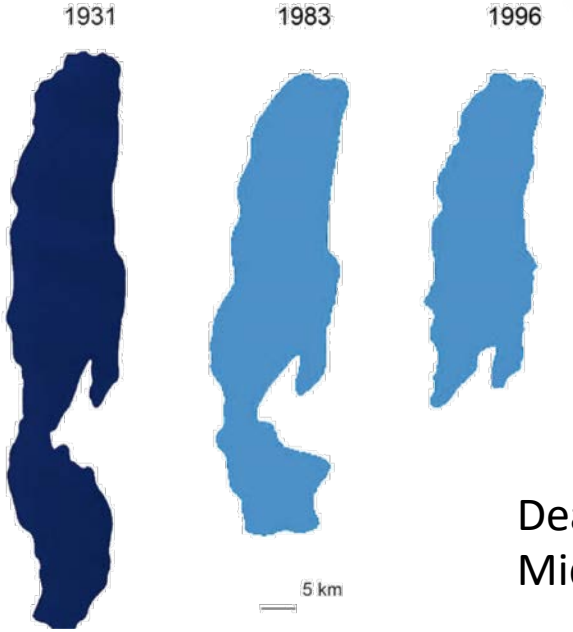
A drying lake – symptom of environmental catastrophe



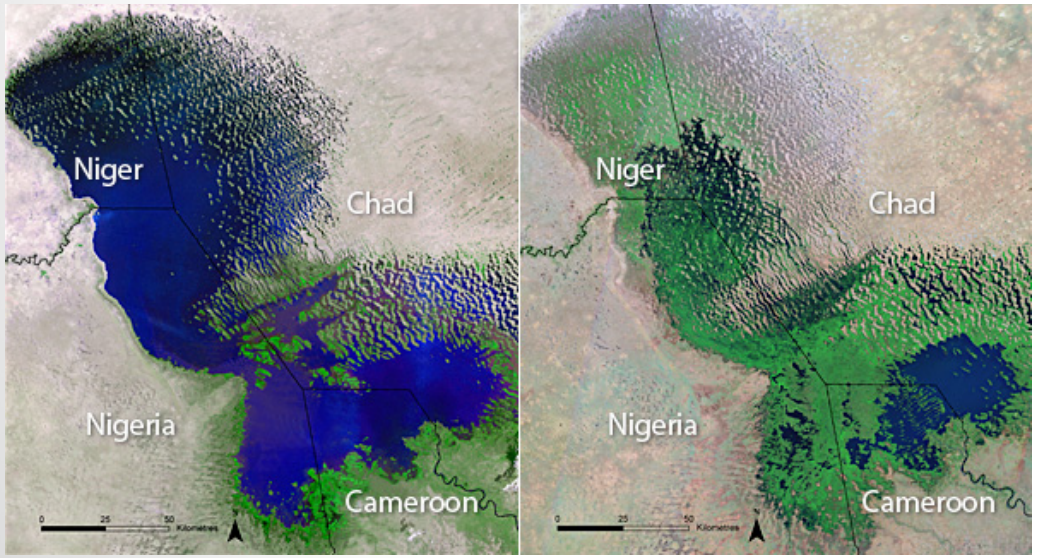
Drying lake syndrome – a global phenomenon



Aral Sea,
Central Asia



Dead Sea,
Middle East



Chad Lake,
Central Africa

Laguna de Aculeo,
Chile

What is driving the lake desiccation?

Climatic Changes

Regional Human Activities

What is driving the lake desiccation?

Climatic Changes

- More frequent/prolonged climate-driven droughts
- Less precipitation
- More evapotranspiration

Regional Human Activities

What is driving the lak

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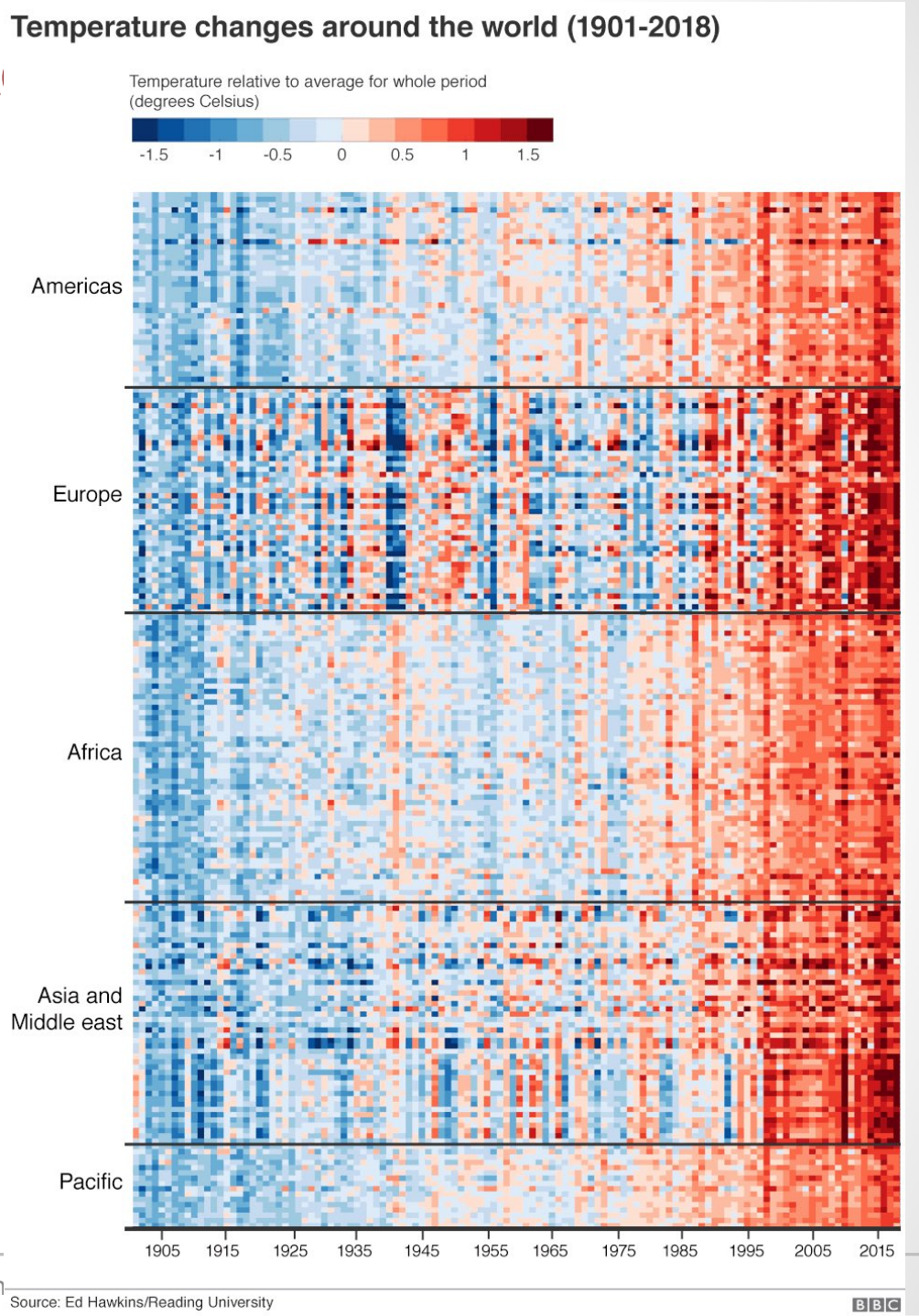

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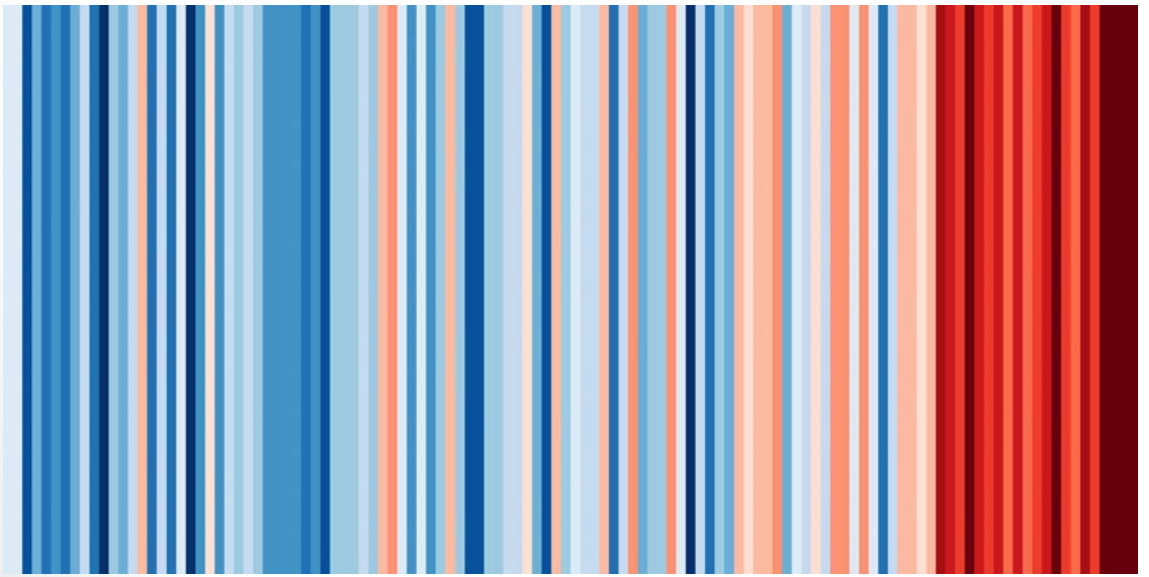
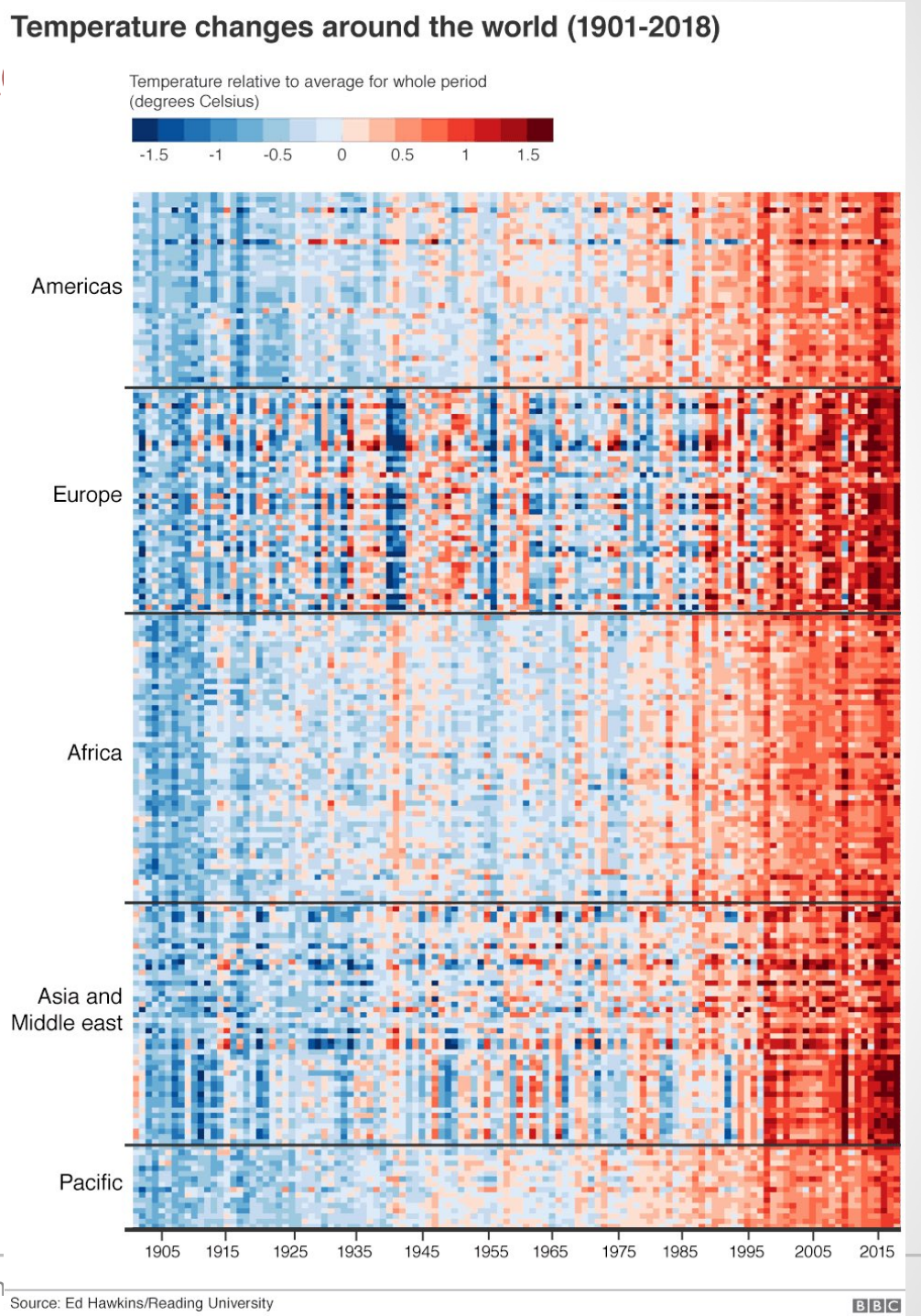
Warming Stripes for Iran from 1901-2018



(https://showyourstripes.info/)



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- Water resources projects: dams, diversions
- Groundwater overexploitation
- Obsolete management

Madani, K. (2014). Water management in Iran: what is causing the looming crisis?. *Journal of environmental studies and sciences*, *4*(4), 315-328.

Madani, K., & Khatami, S. (2015). Water for energy: inconsistent assessment standards and inability to judge properly. *Current Sustainable/Renewable Energy Reports*, *2*(1), 10-16.

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Socio-economic drought

Anthropogenic drought

Water Bankruptcy

AghaKouchak, A., Feldman, D., Hoerling, M., Huxman, T., & Lund, J. (2015). Water and climate: Recognize anthropogenic drought. *Nature*, *524*(7566), 409.

Madani, K., AghaKouchak, A., & Mirchi, A. (2016). Iran's socio-economic drought: challenges of a water-bankrupt nation. *Iranian Studies*, *49*(6), 997-1016

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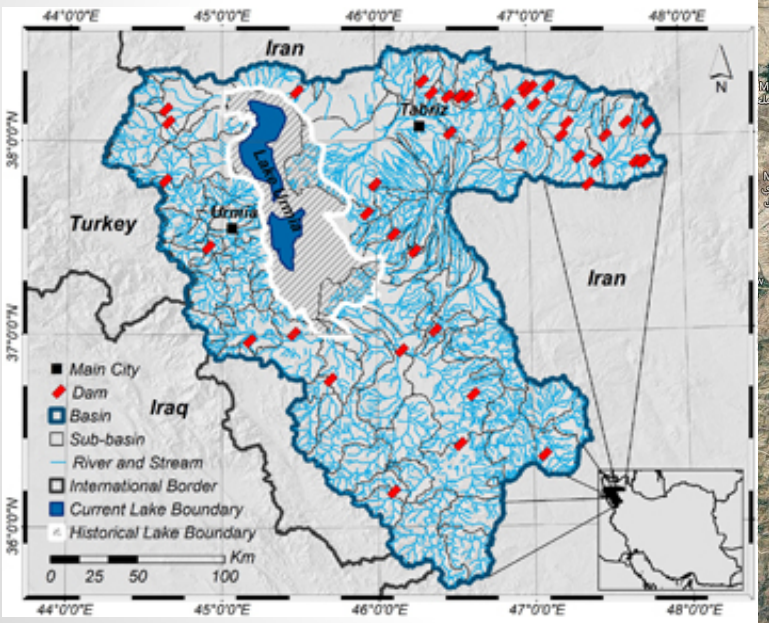
In 2011, 230+ projects have been approved



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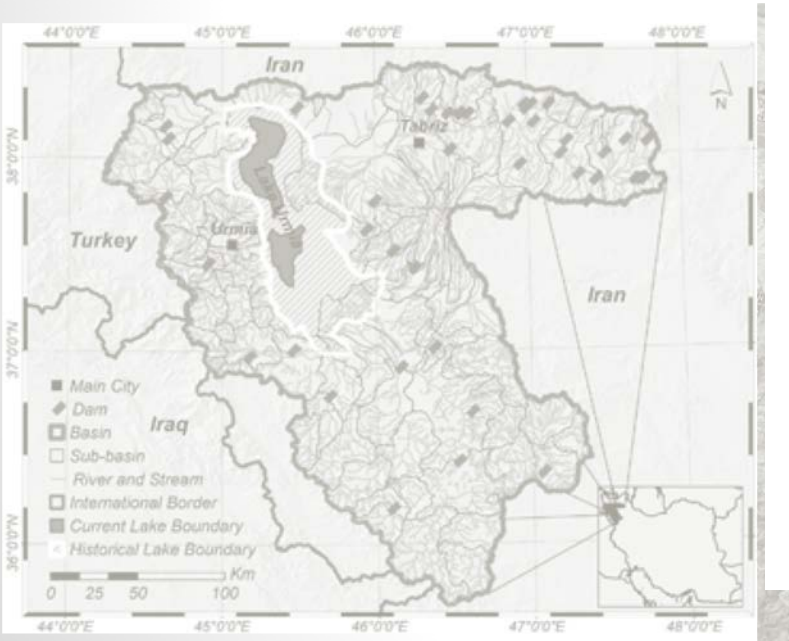

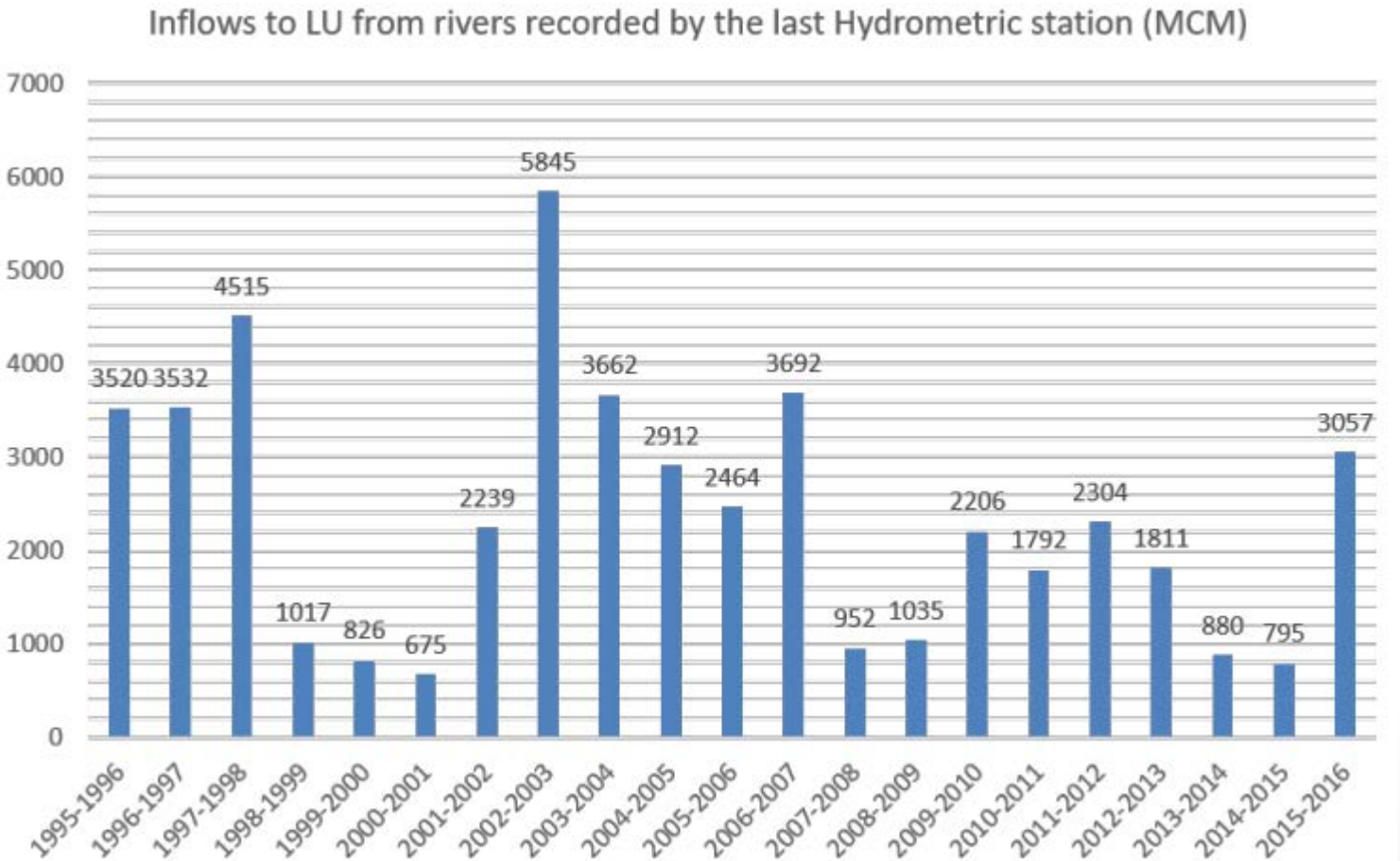

Khatami (2018) HESSD

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Climatic Changes

- ed climat
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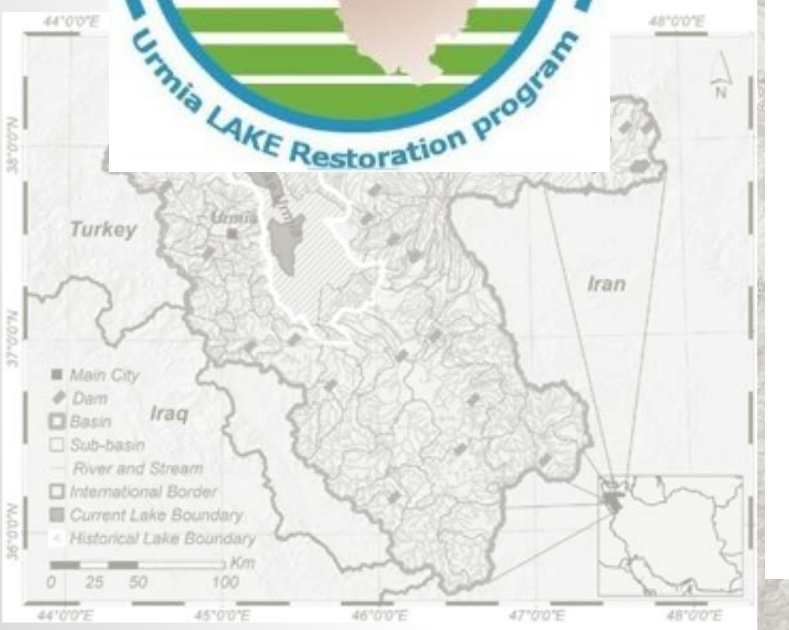
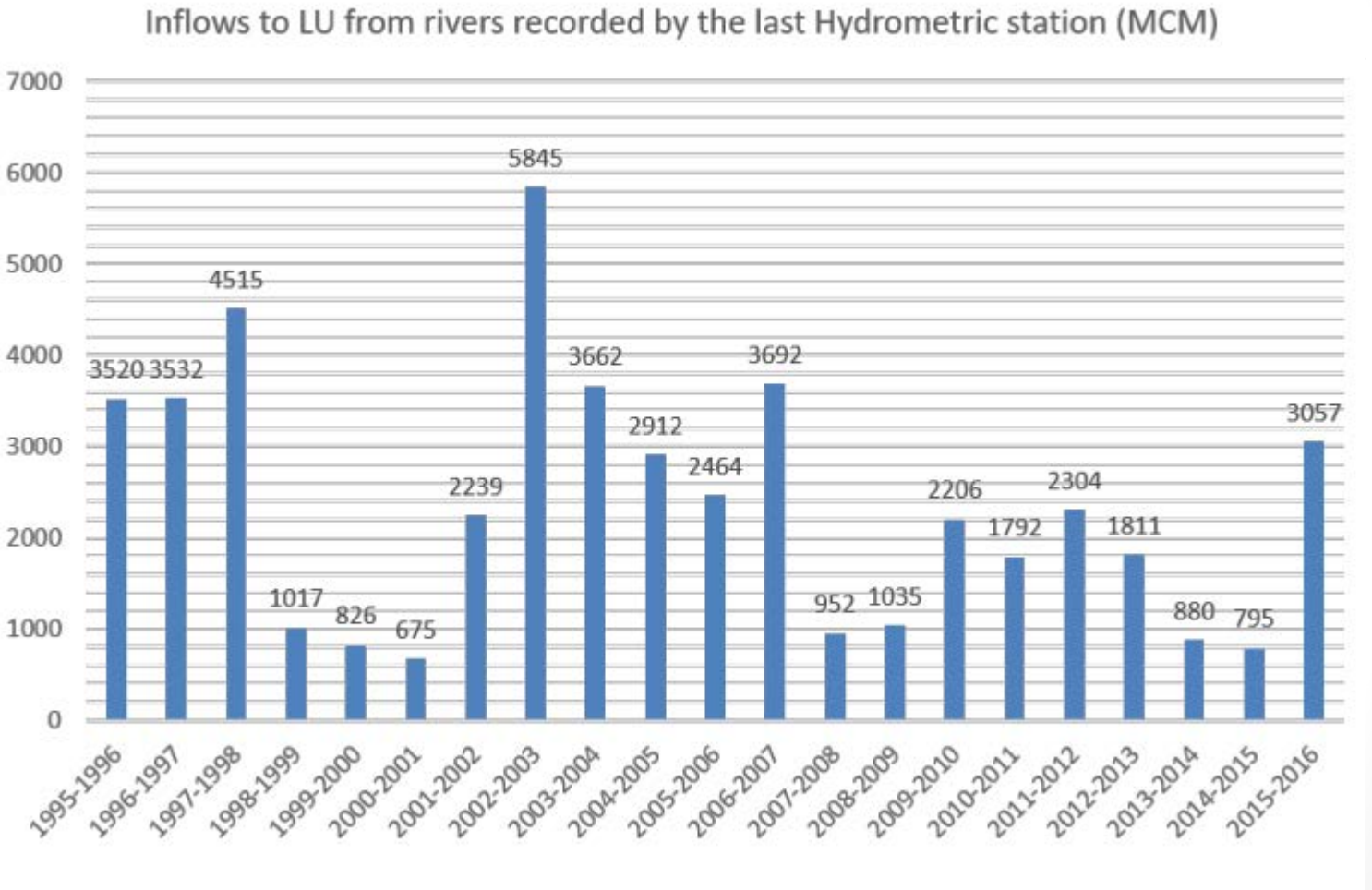
- n

Regional Human Activities

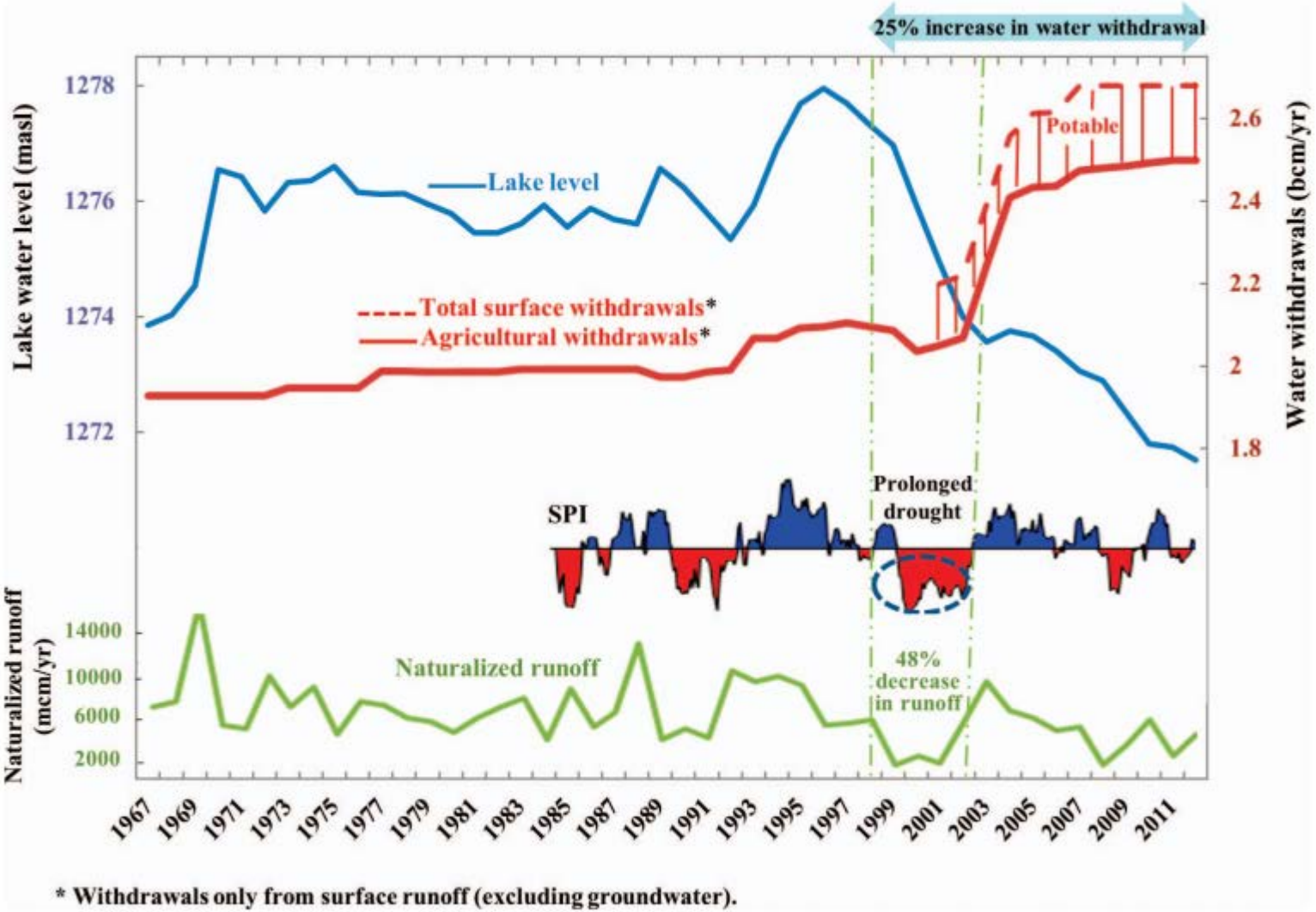




water supply

Khatami (2018) HESSD

Hypothesis: climatic or human driven?



Alborzi, A., et al. (2018). Climate-informed environmental inflows to revive a drying lake facing meteorological and anthropogenic droughts. *Environmental Research Letters*, *13*(8), 084010.

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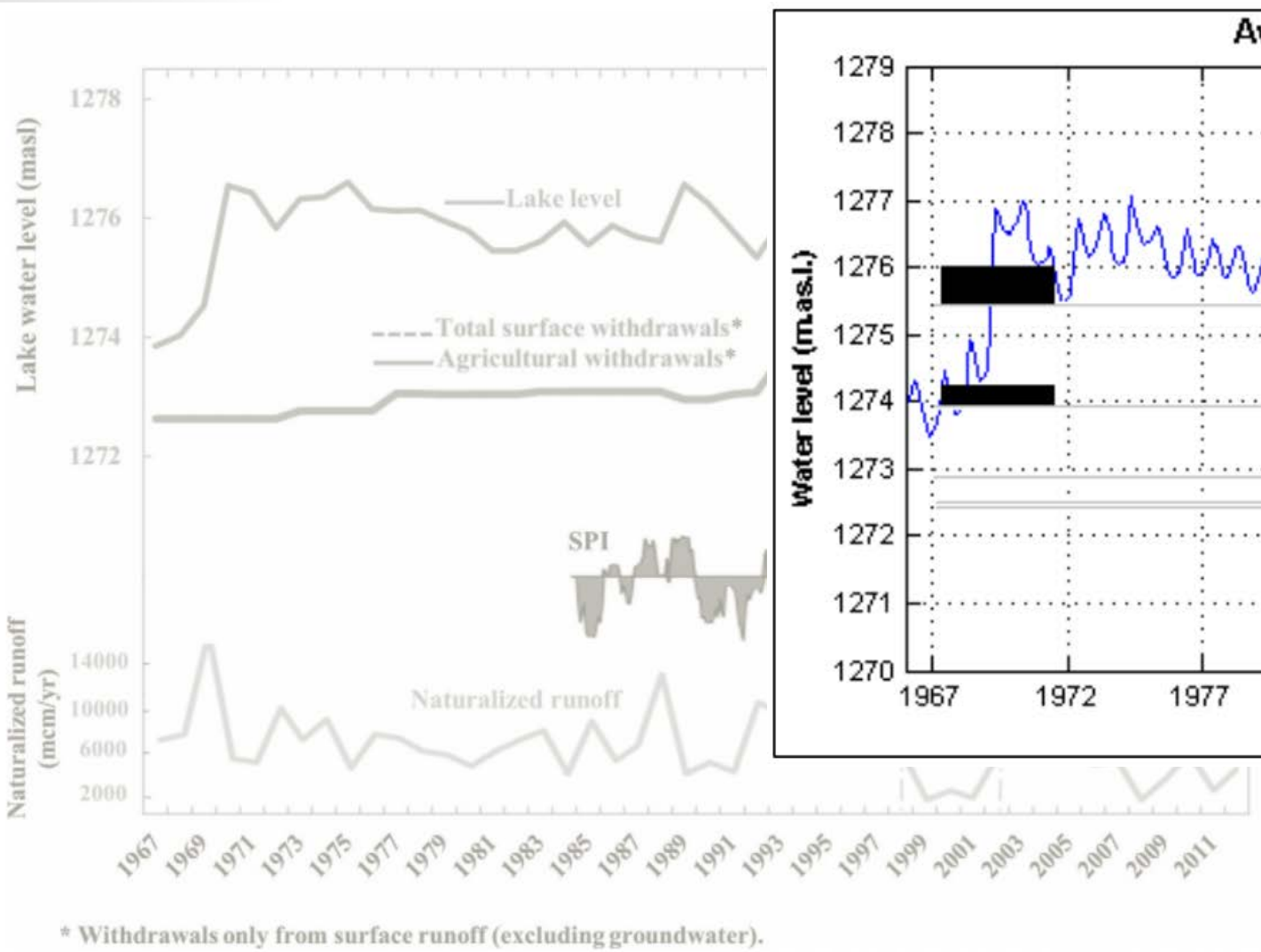
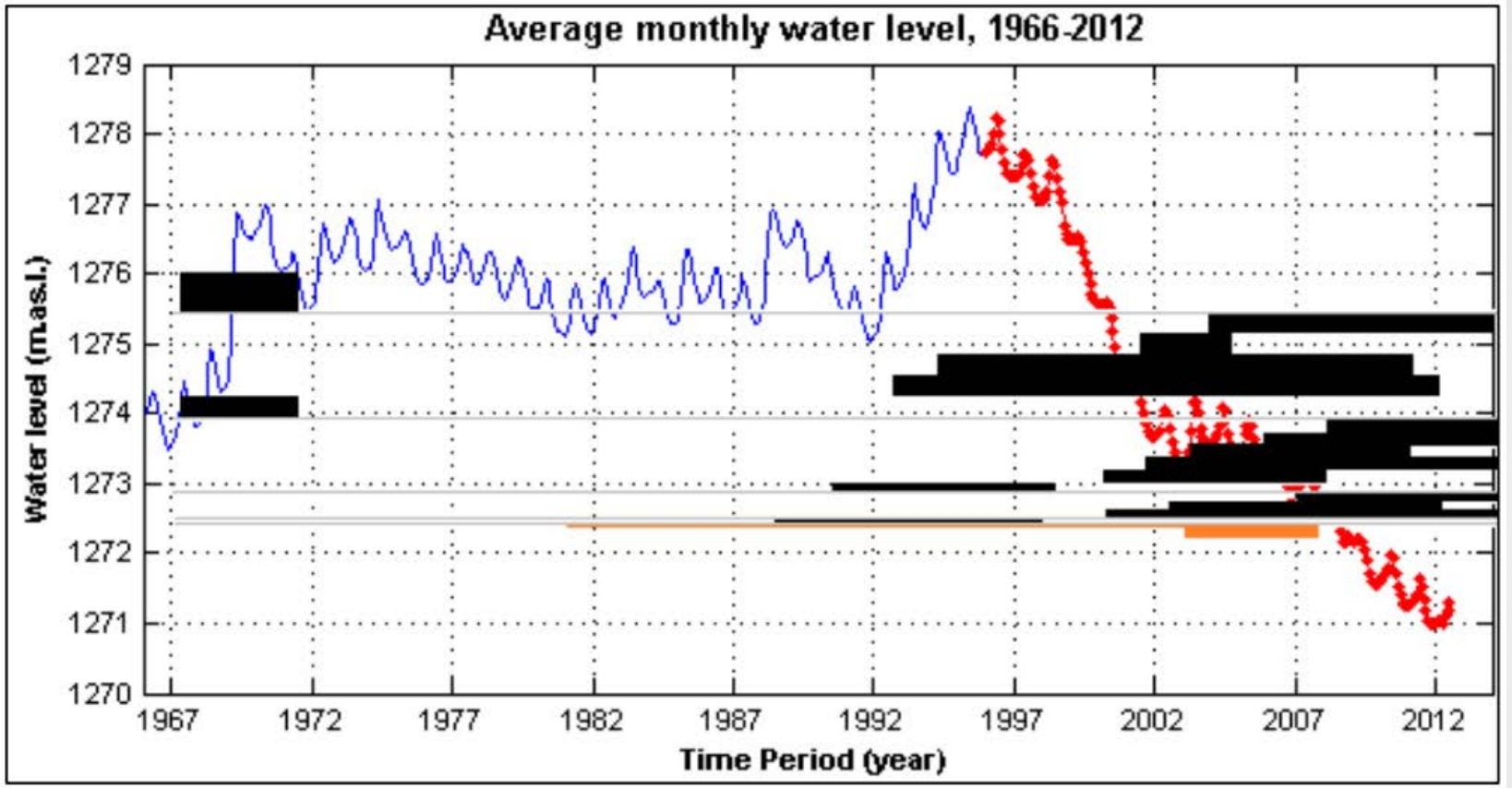
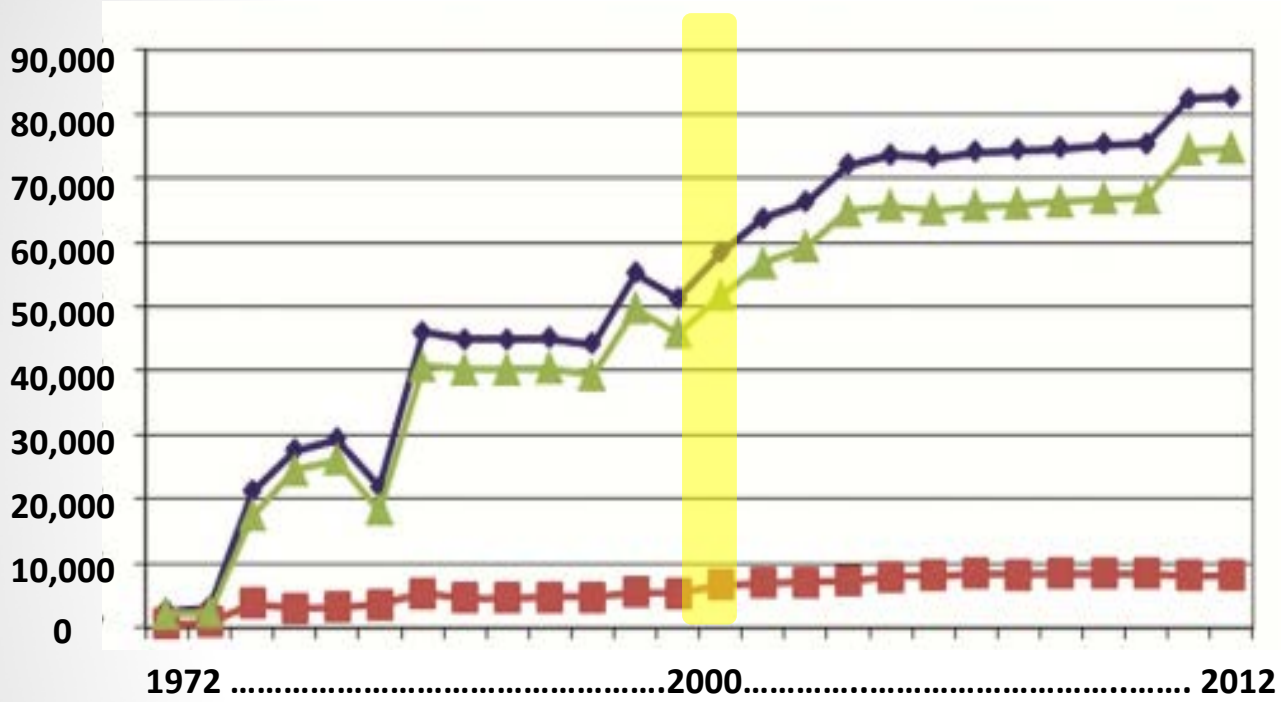




Khatami, S., 2013. Nonlinear Chaotic and Trend Analyses of Water Level at Urmia Lake, Iran. Nonlinear Chaotic Trend Anal. Water Lev. Urmia Lake, Iran. M.Sc. Thesis Rep. TVVR-13/5012, ISSN1101–9824. Lund University, Lund, Sweden.

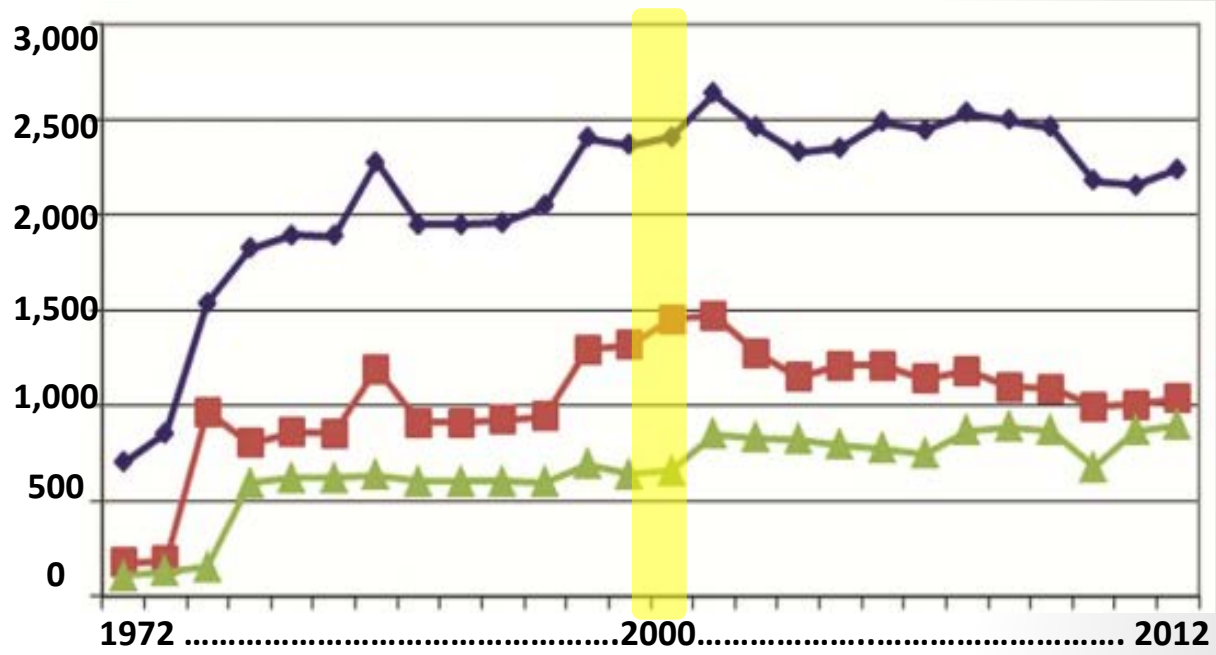
Hypothesis: climatic or human driven?

Number of wells



Volume of GW withdrawal

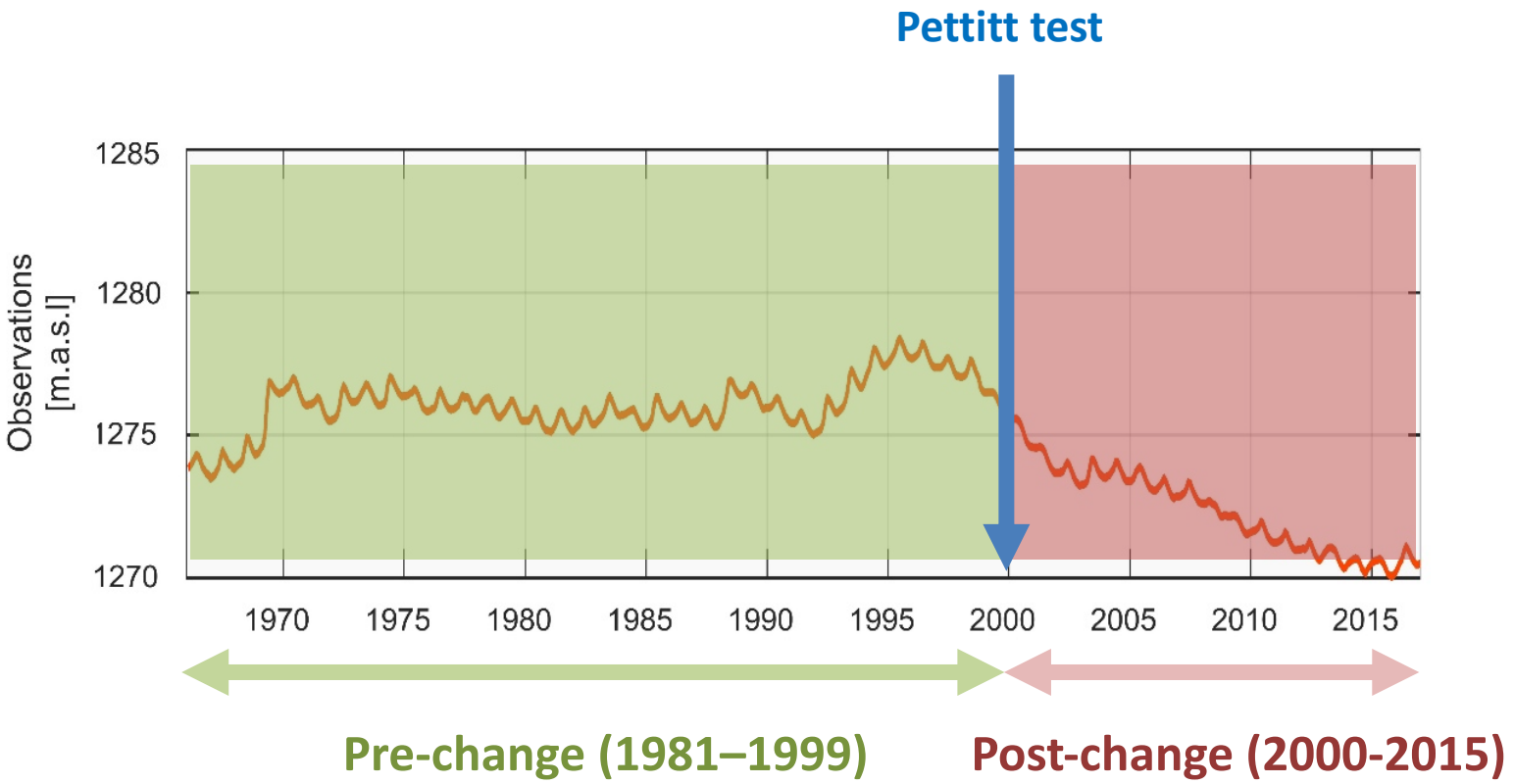
(MCM)



Total number/volume **Deep GW** **moderately-deep GW**

ULRP. (2015). *Groundwater and restoration of Lake Urmia*. Retrieved from http://ulrp.sharif.ir/sites/default/files/field/files/3.pdf

Hypothesis: climatic or human driven?

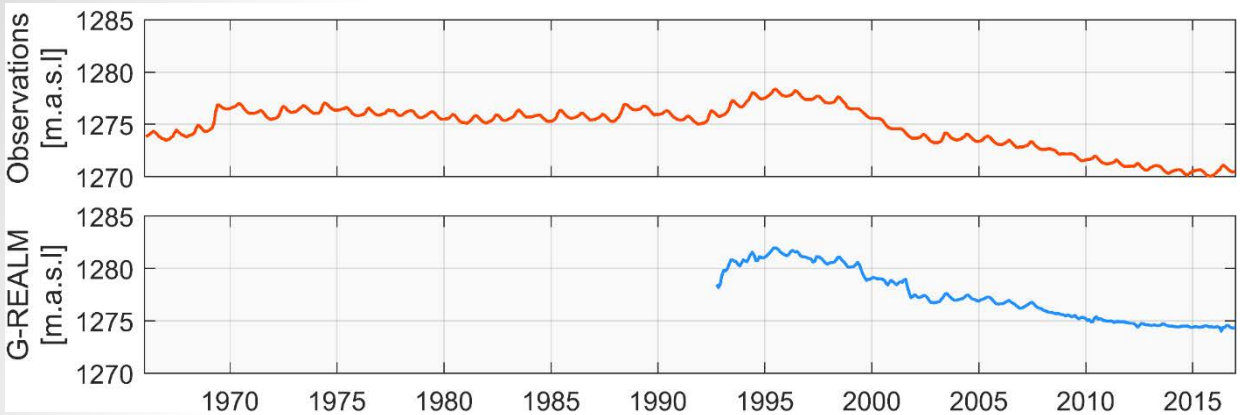


Hydrological changes

Atmospheric climatic changes

Land-use changes

Hydrological changes → Lake Water Level (WL)



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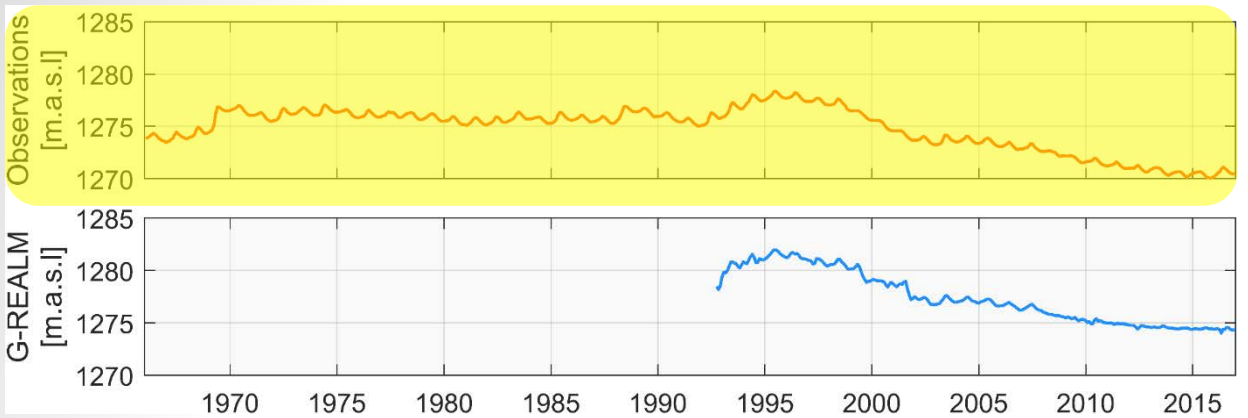

Atmospheric climatic changes

Land-use changes

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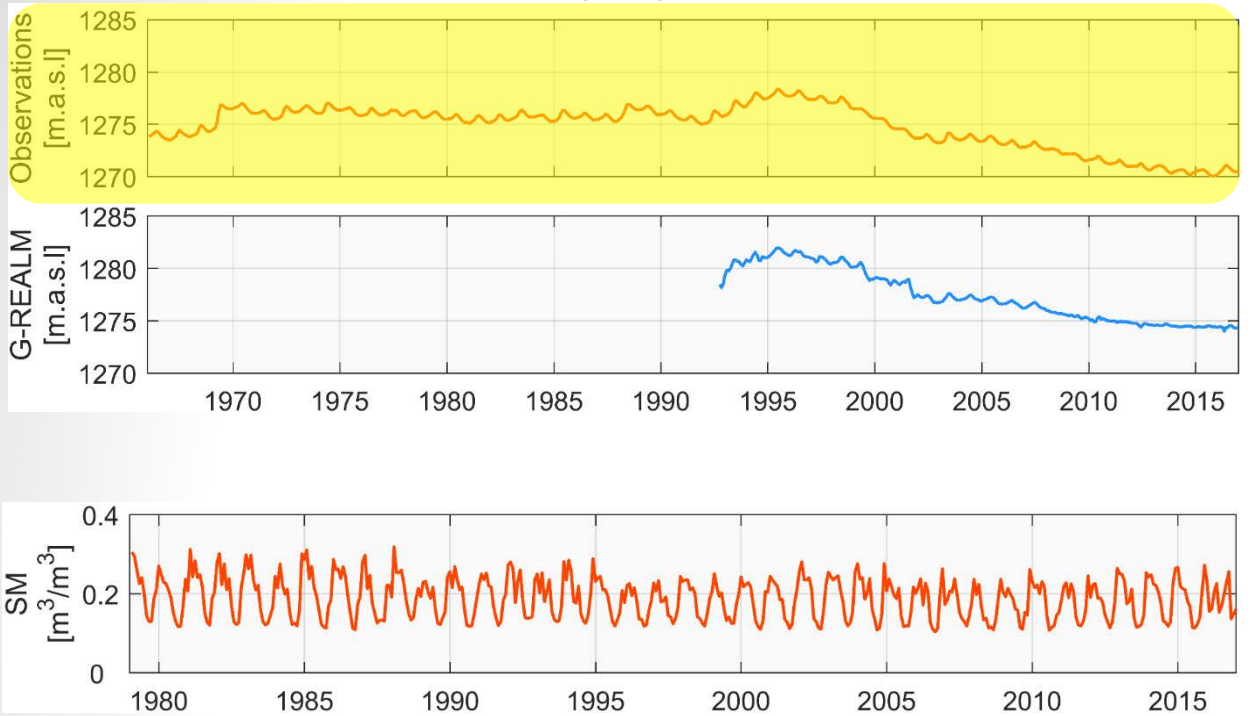

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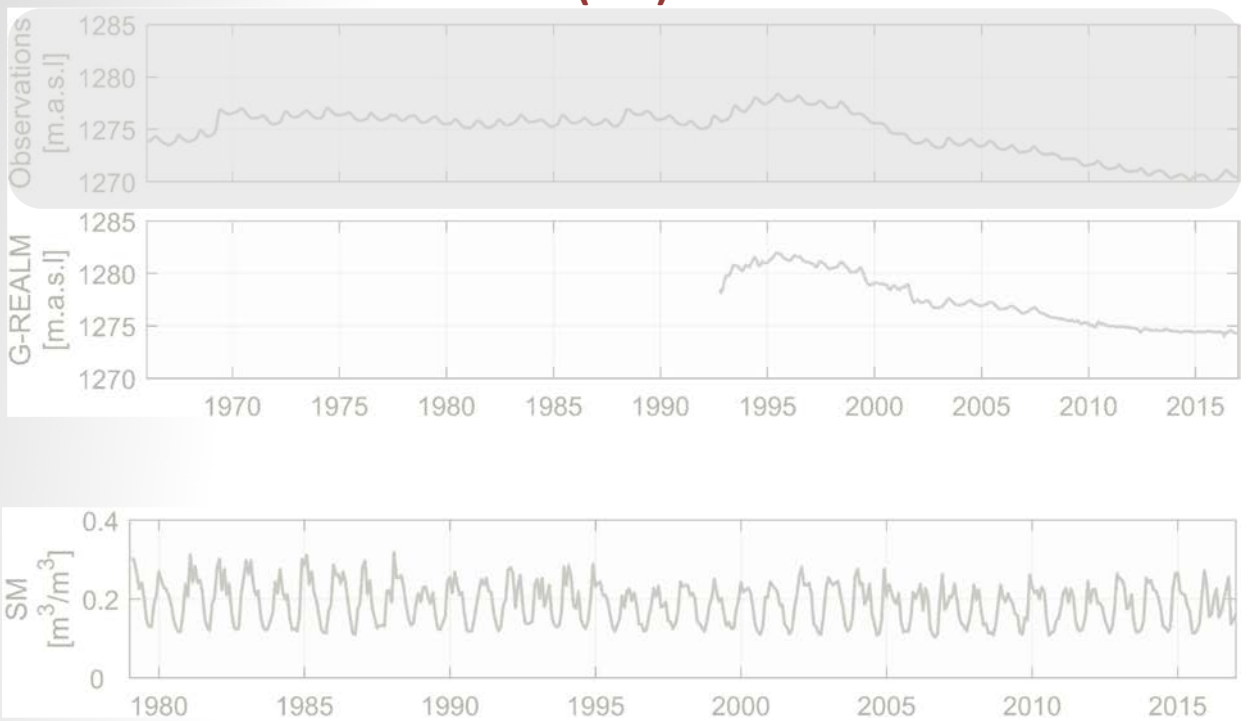
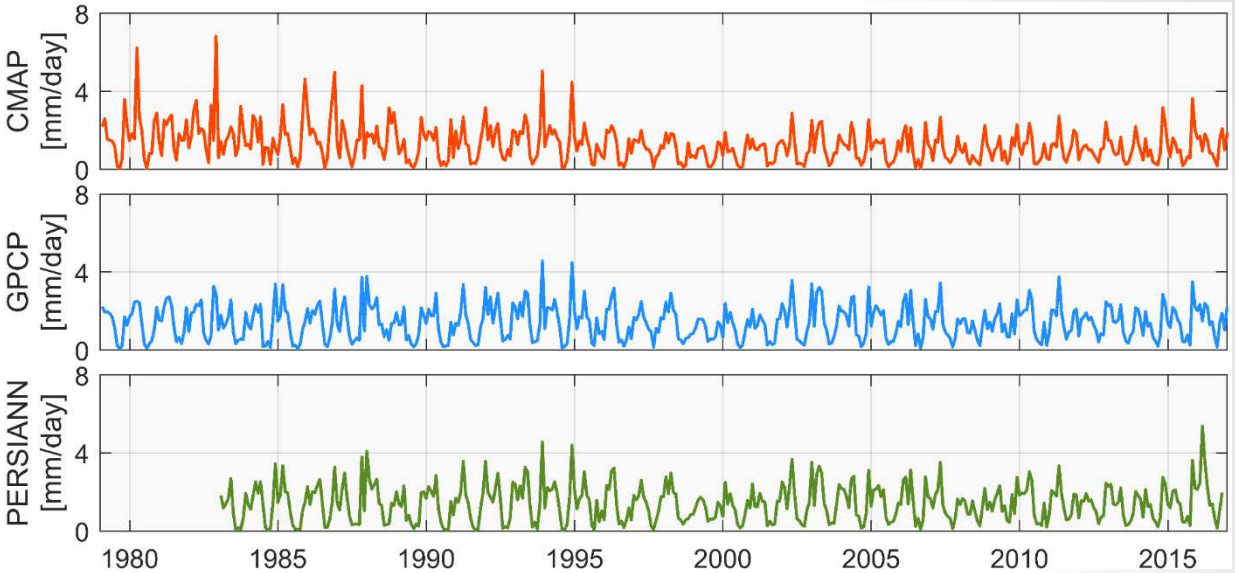


Atmospheric climatic changes → P & T



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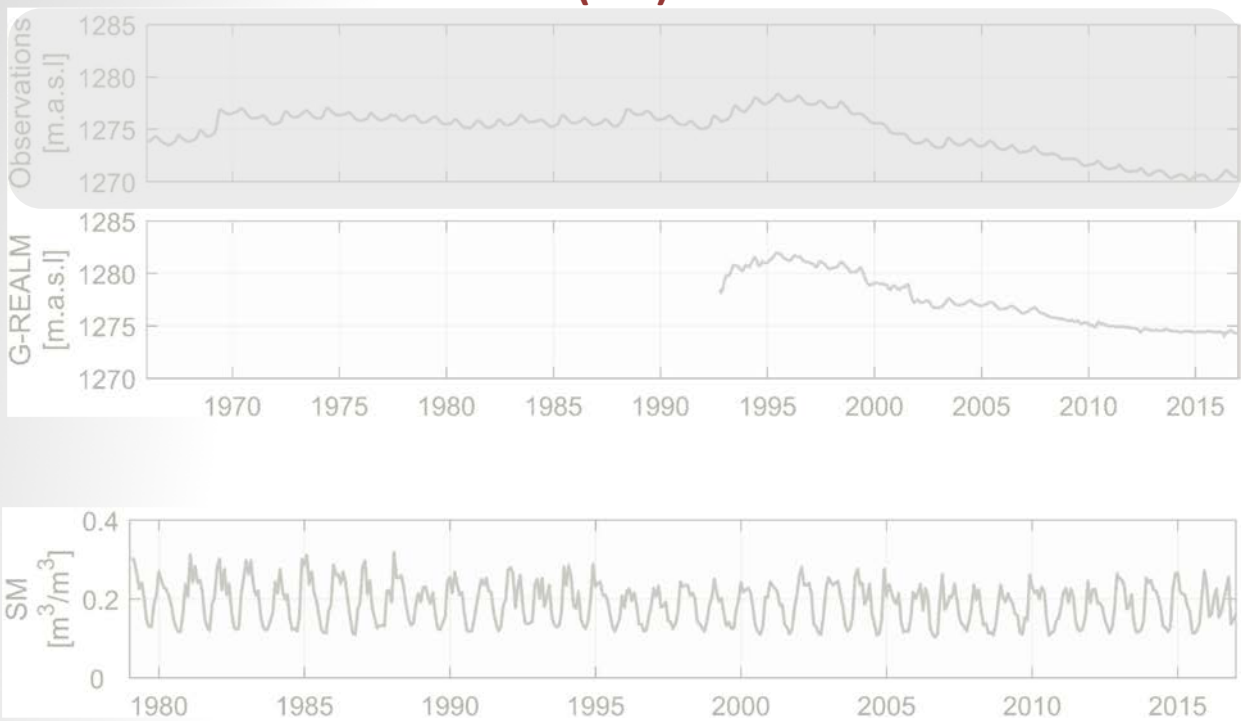

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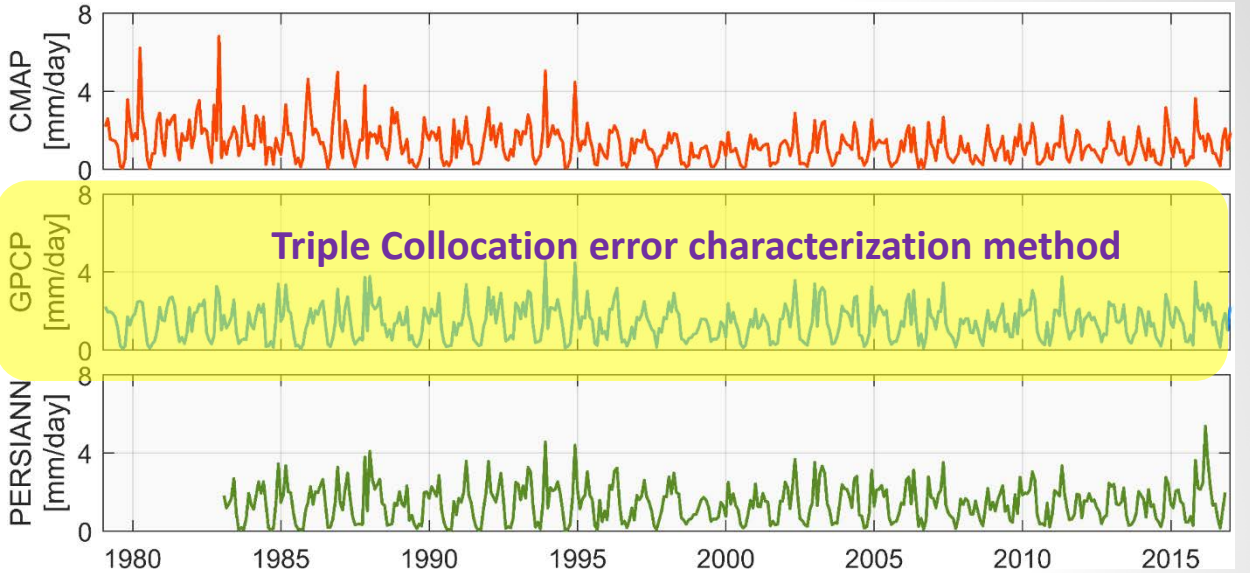

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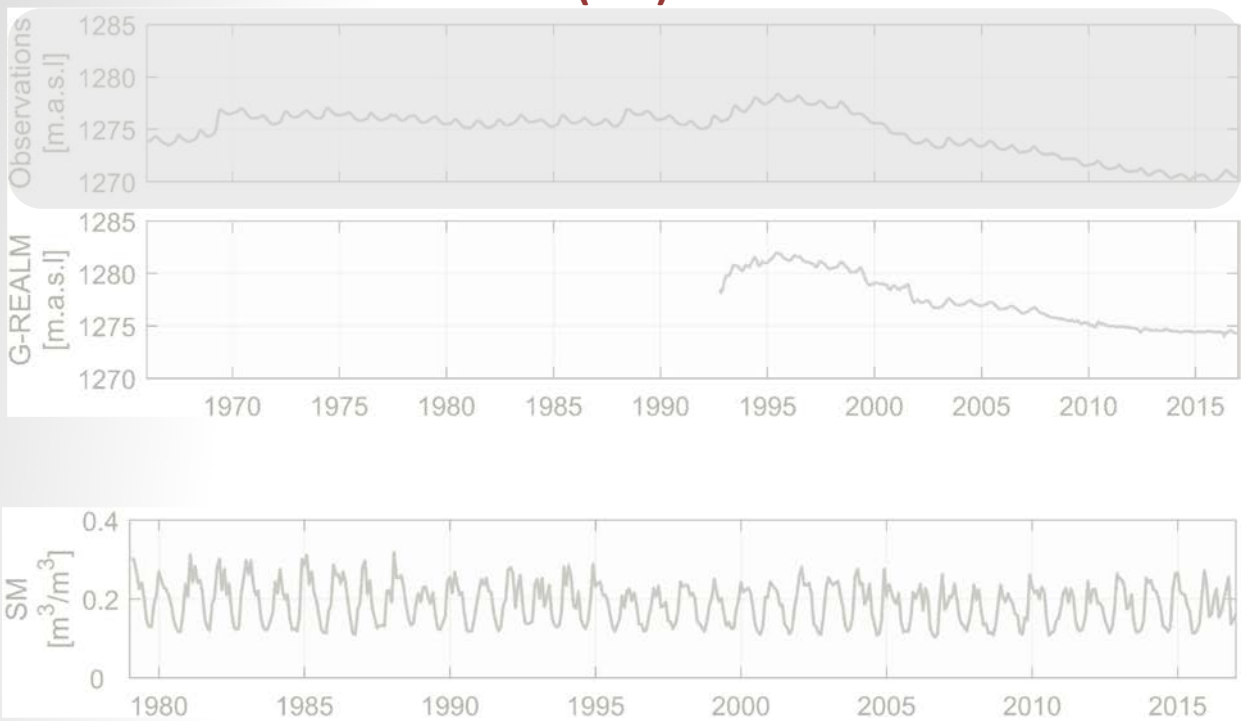

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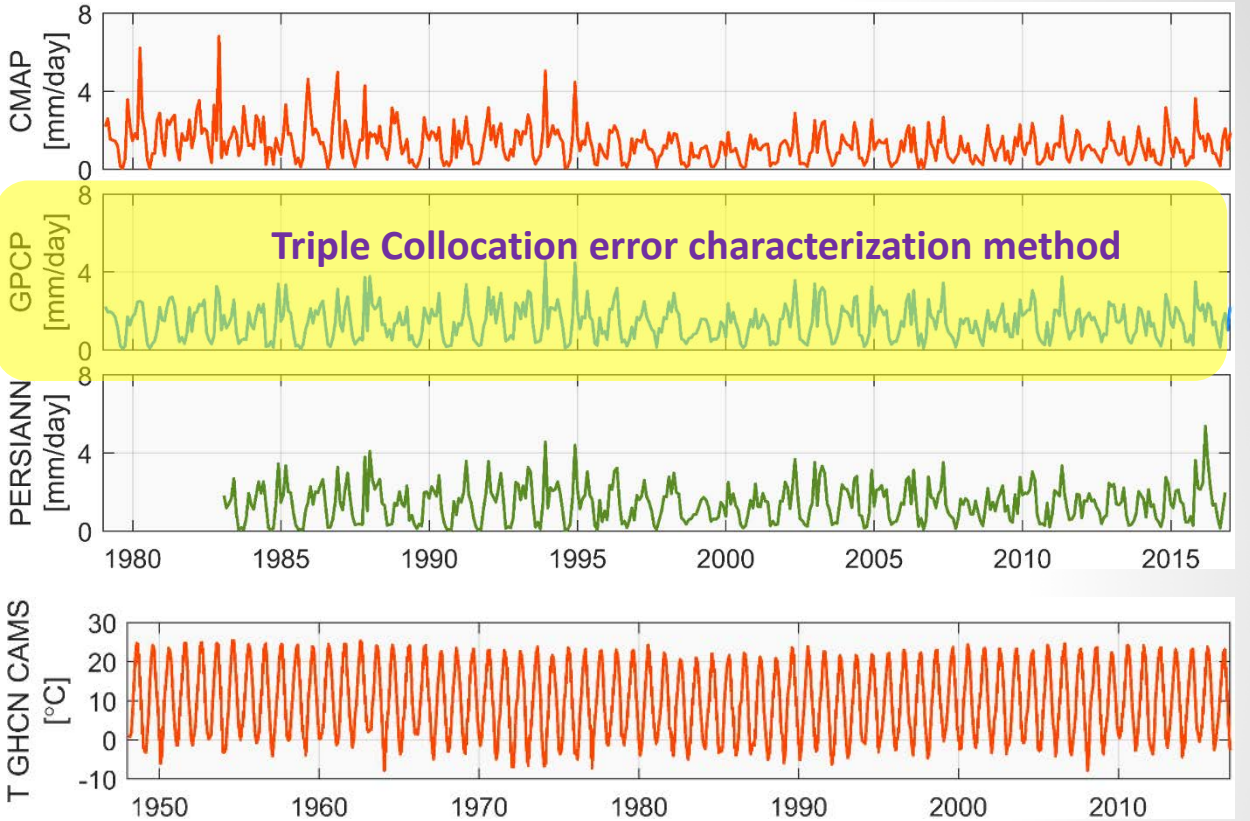

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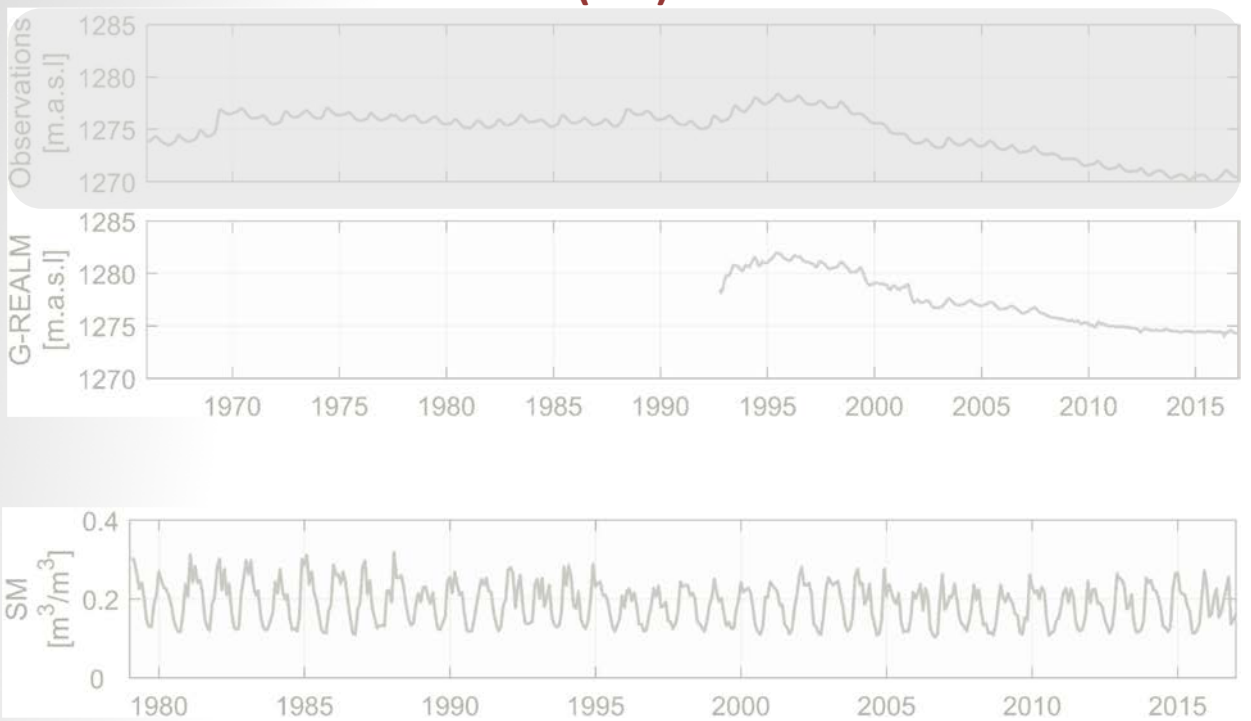

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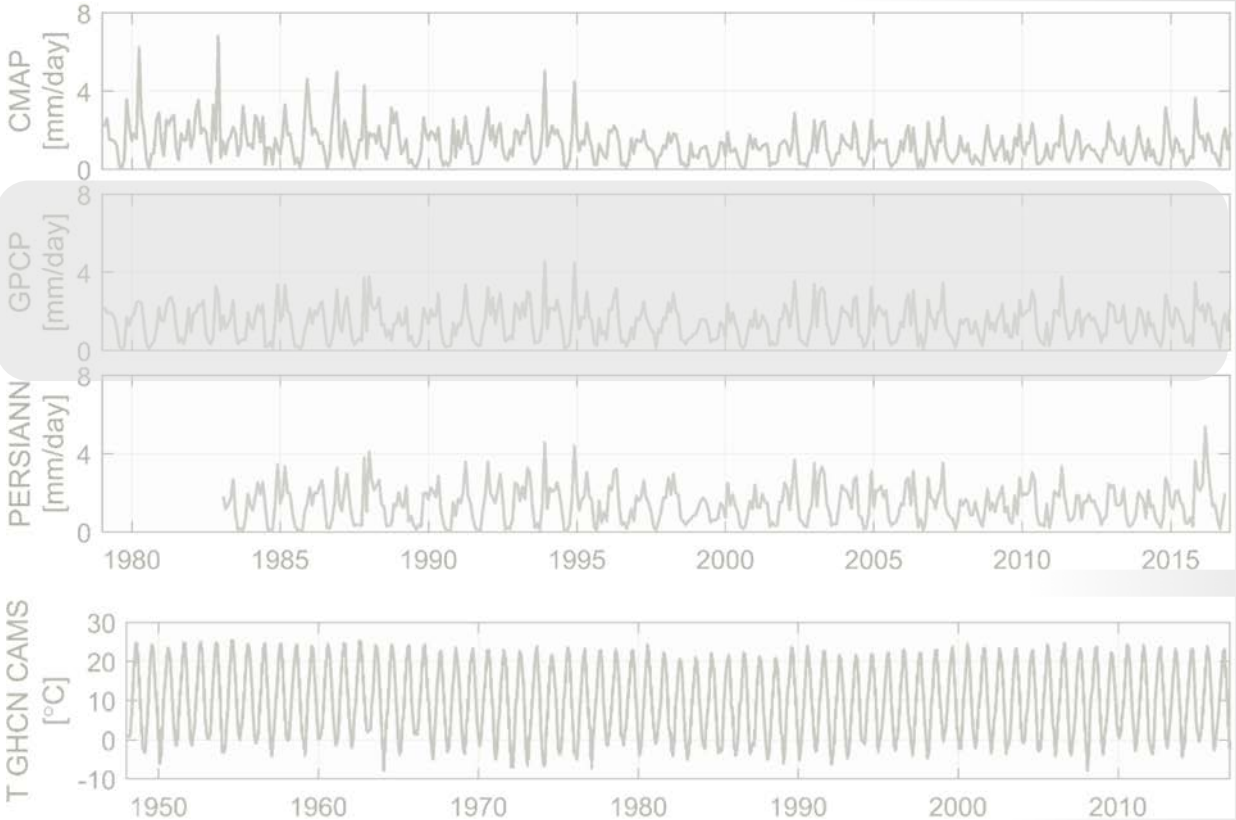
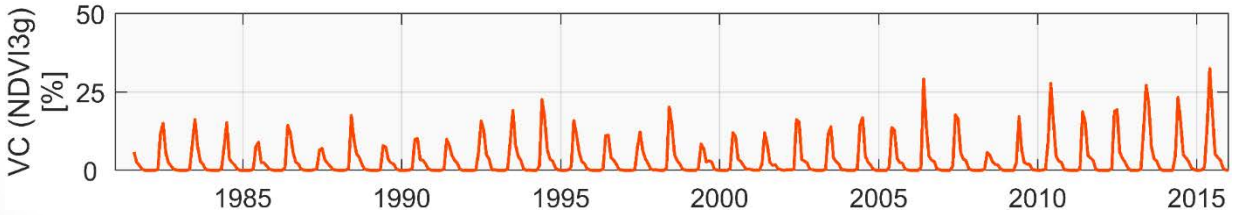
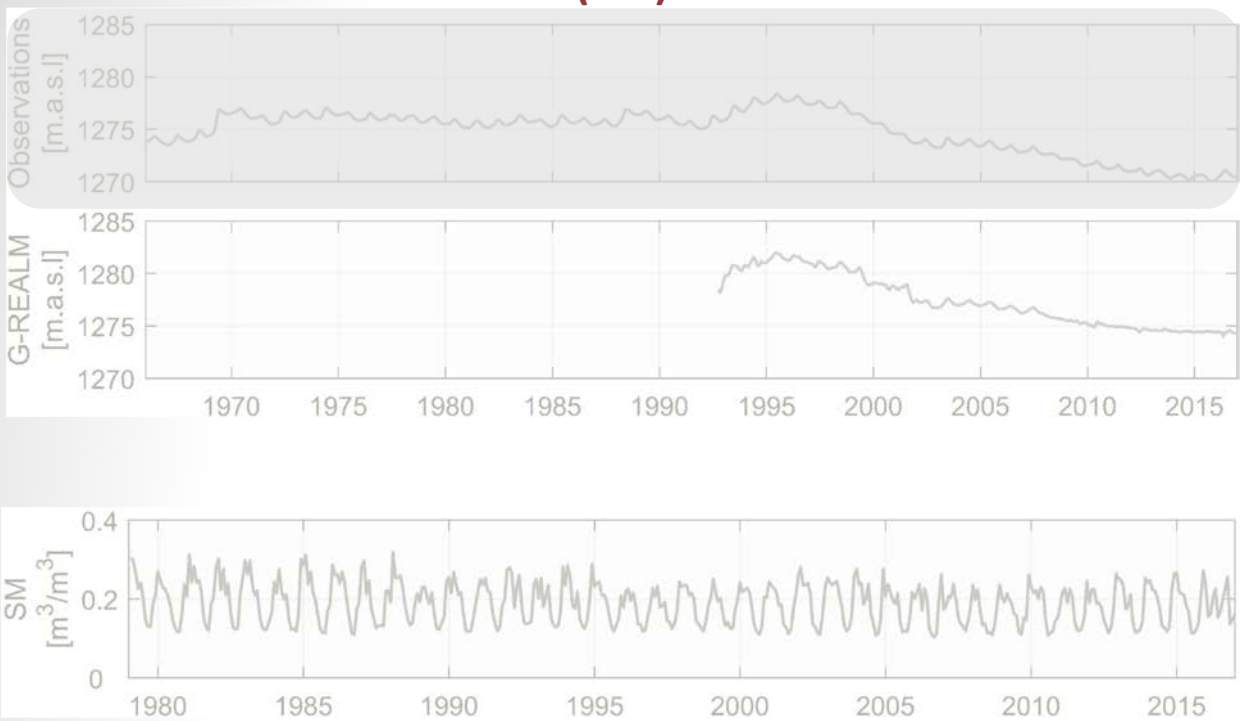


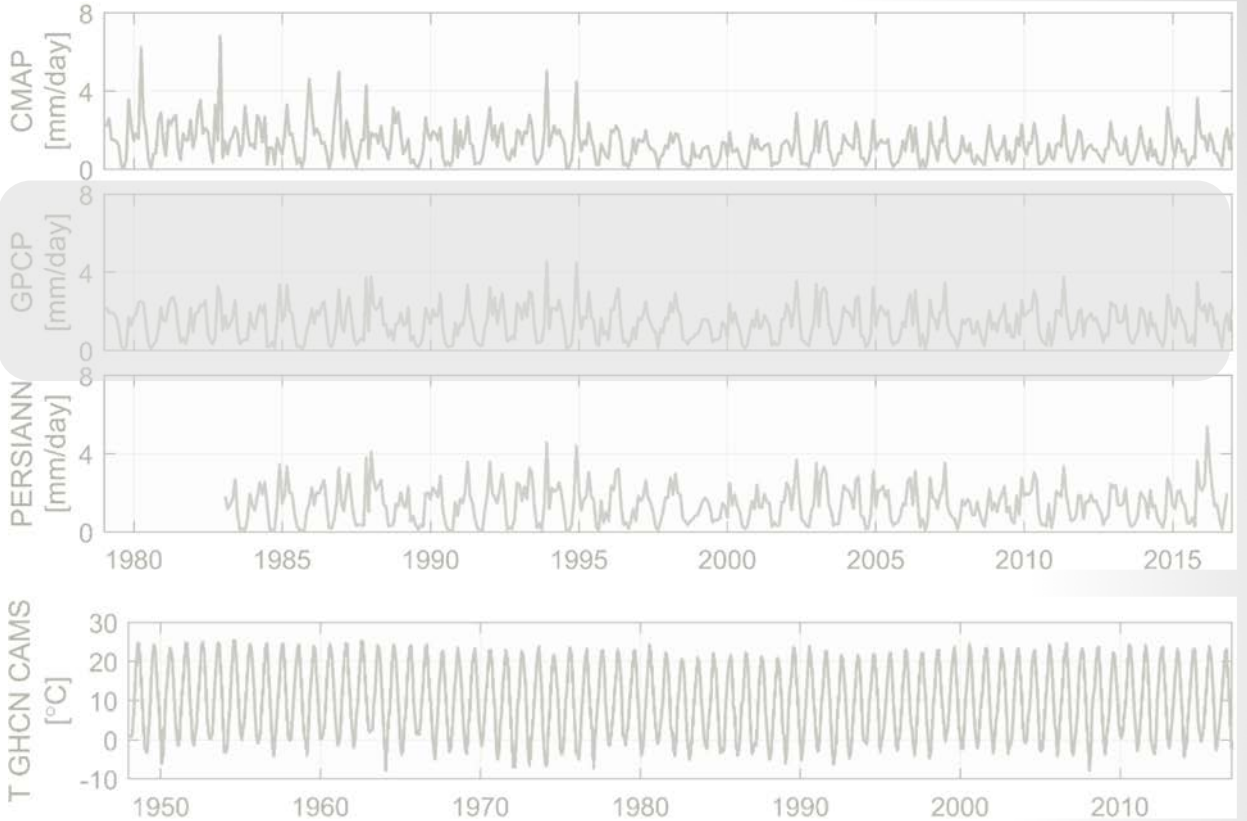
Land-use changes → Vegetation Coverage (VC)



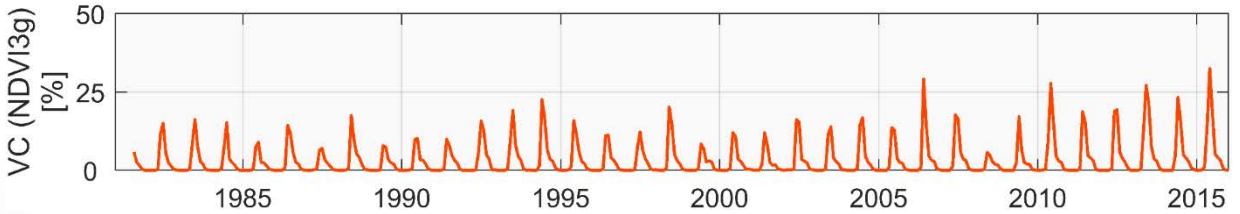
Hydrological changes → Lake Water Level (WL) & soil moisture (SM)



Atmospheric climatic changes → P & T



Land-use changes → Vegetation Coverage (VC)



- **Mainly agricultural**
- **Proxy for ET and water use in the basin**

Change-Attribution Analysis

Objective → attributing (explaining) main drivers/causes of observed changes

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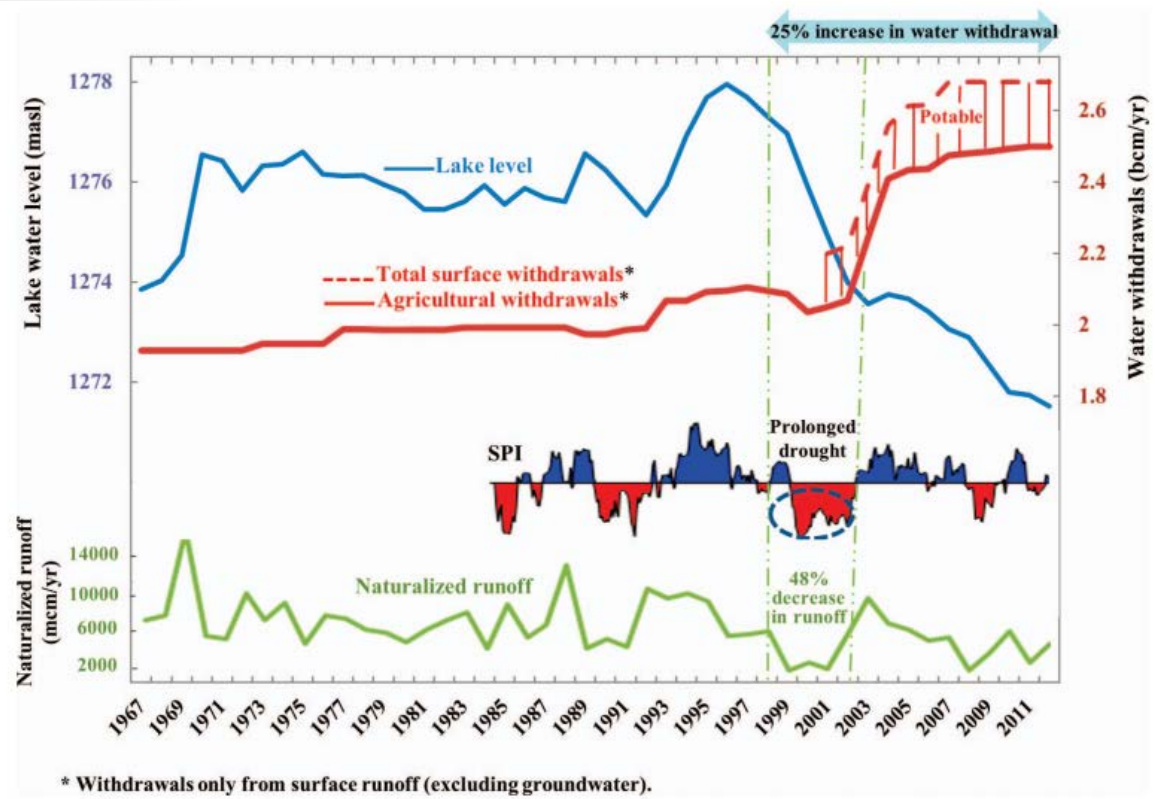
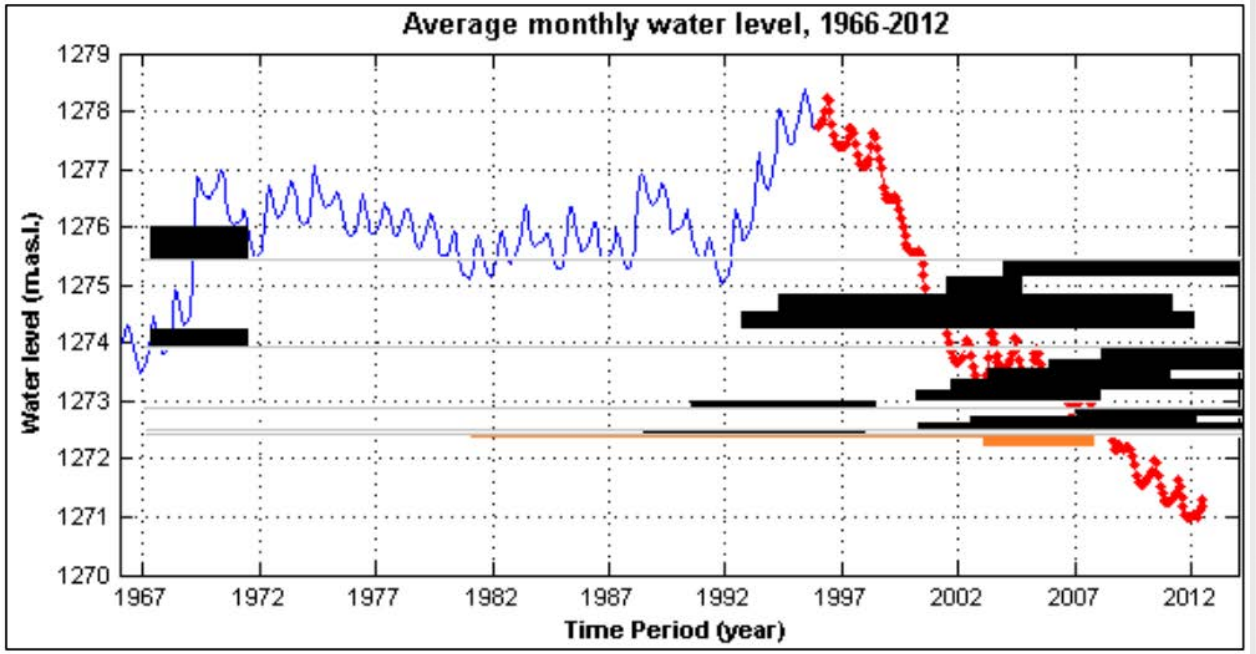


Alborzi, A., et al. (2018). Climate-informed environmental inflows to revive a drying lake facing meteorological and anthropogenic droughts. *Environmental Research Letters*, *13*(8), 084010.



Khatami, S., 2013. Nonlinear Chaotic and Trend Analyses of Water Level at Urmia Lake, Iran. Nonlinear Chaotic Trend Anal. Water Lev. Urmia Lake, Iran. M.Sc. Thesis Rep. TVVR-13/5012, ISSN1101–9824. Lund University, Lund, Sweden.

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Analysis approach → classical paradigm of statistical analysis (frequentist inference)

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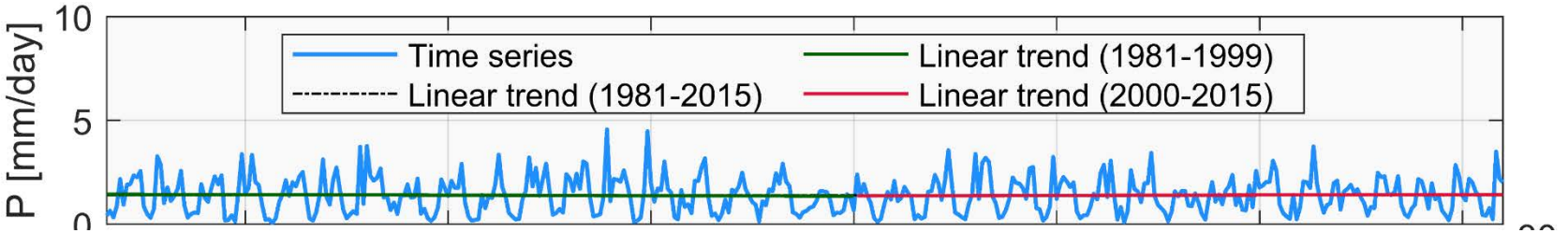
Spatial variability → aggregated into a single representative time series for the whole watershed

Temporal variability → analysis across time scales

long-term (the entire record) *VS* **short-term** (pre- and post-change periods)

overall (the entire short- or long-term record) *VS* **seasonal** (wet and dry months)

Results – Change Analysis



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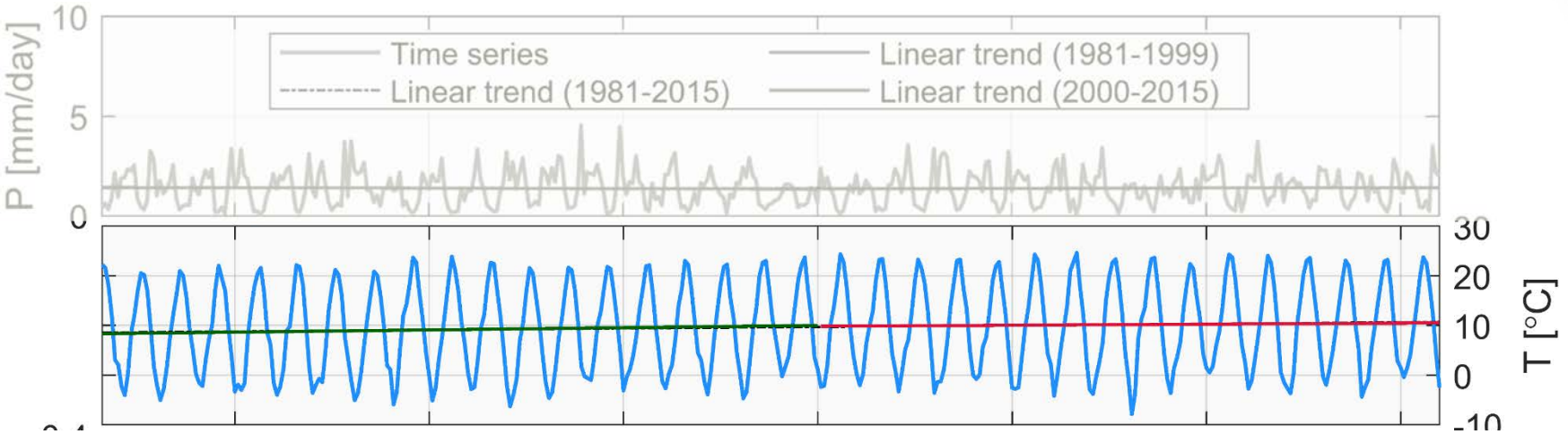

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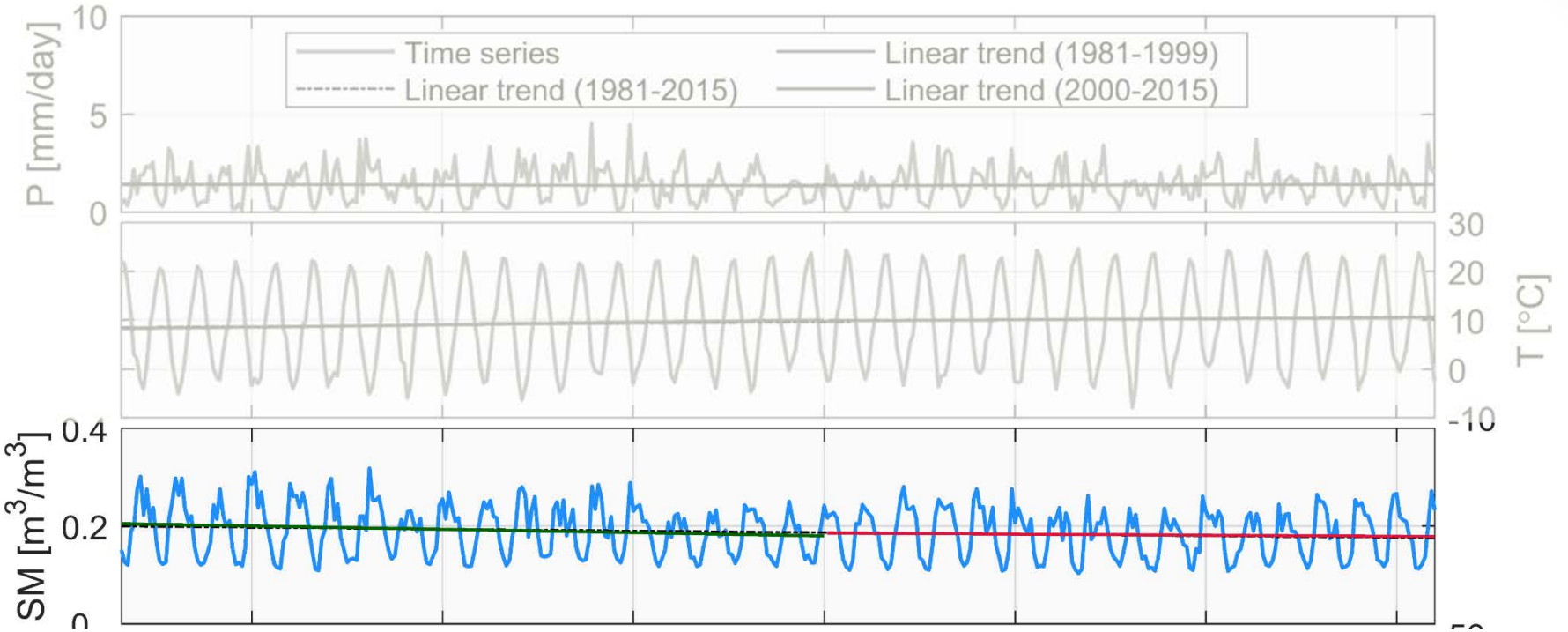

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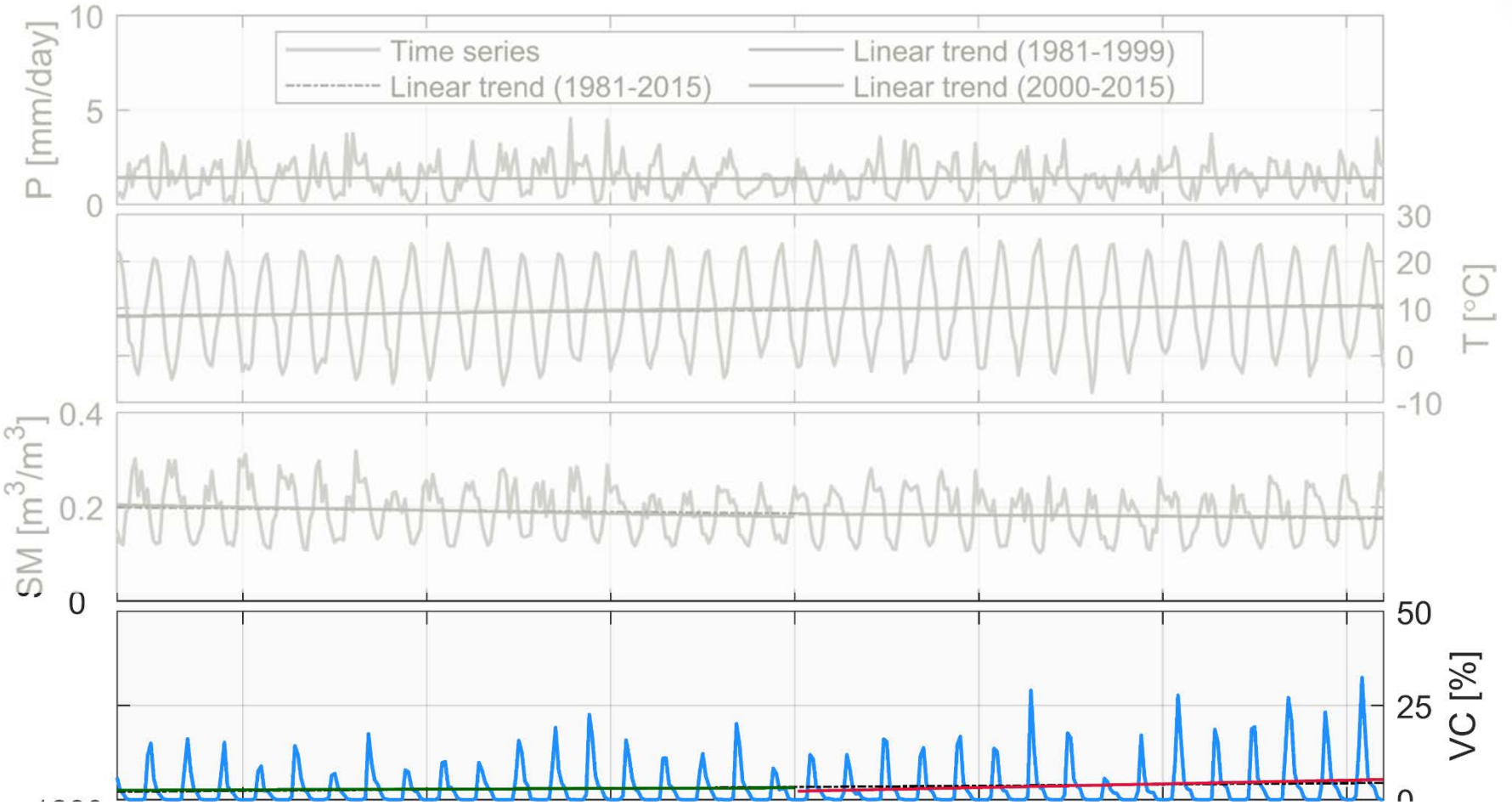

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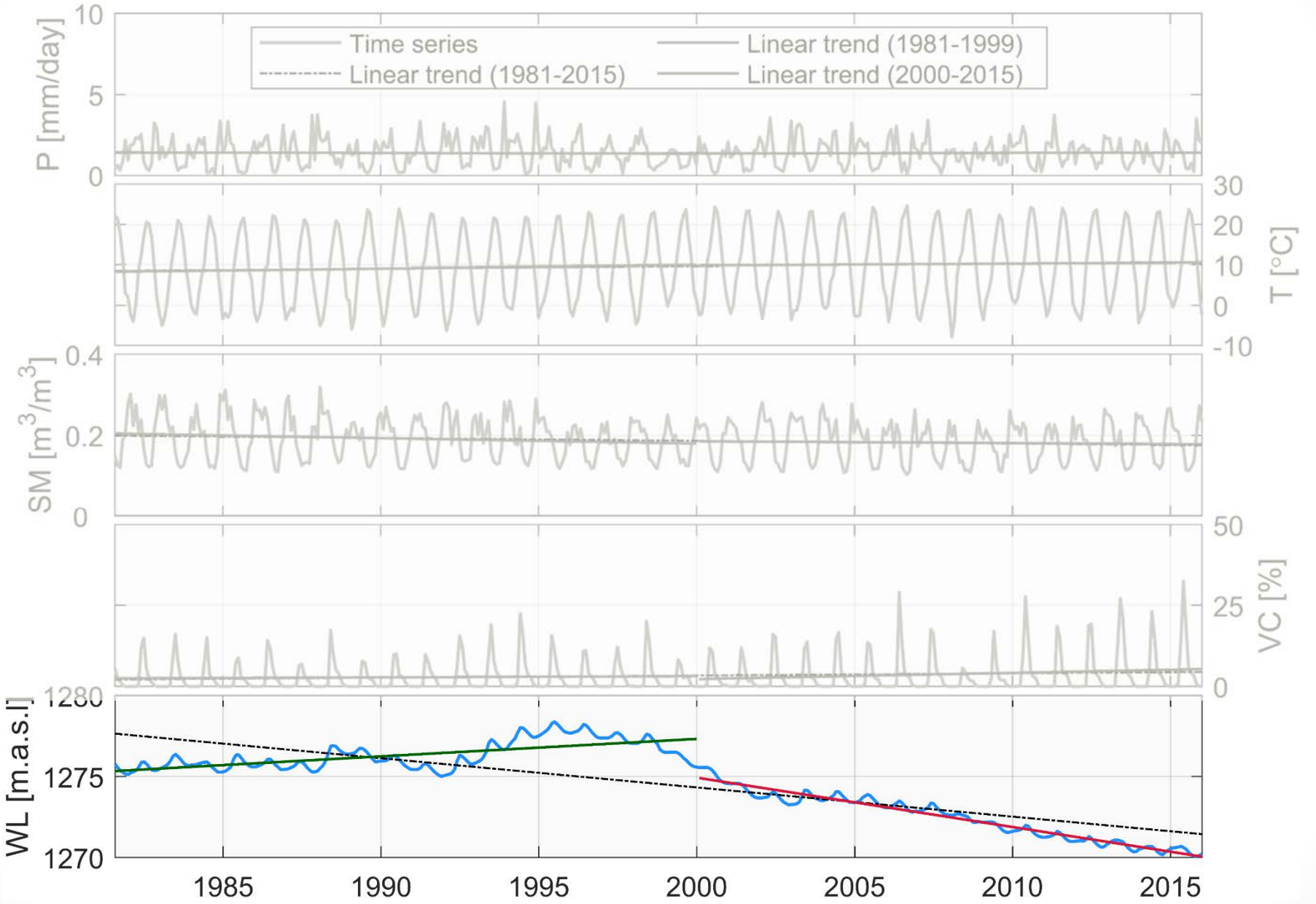
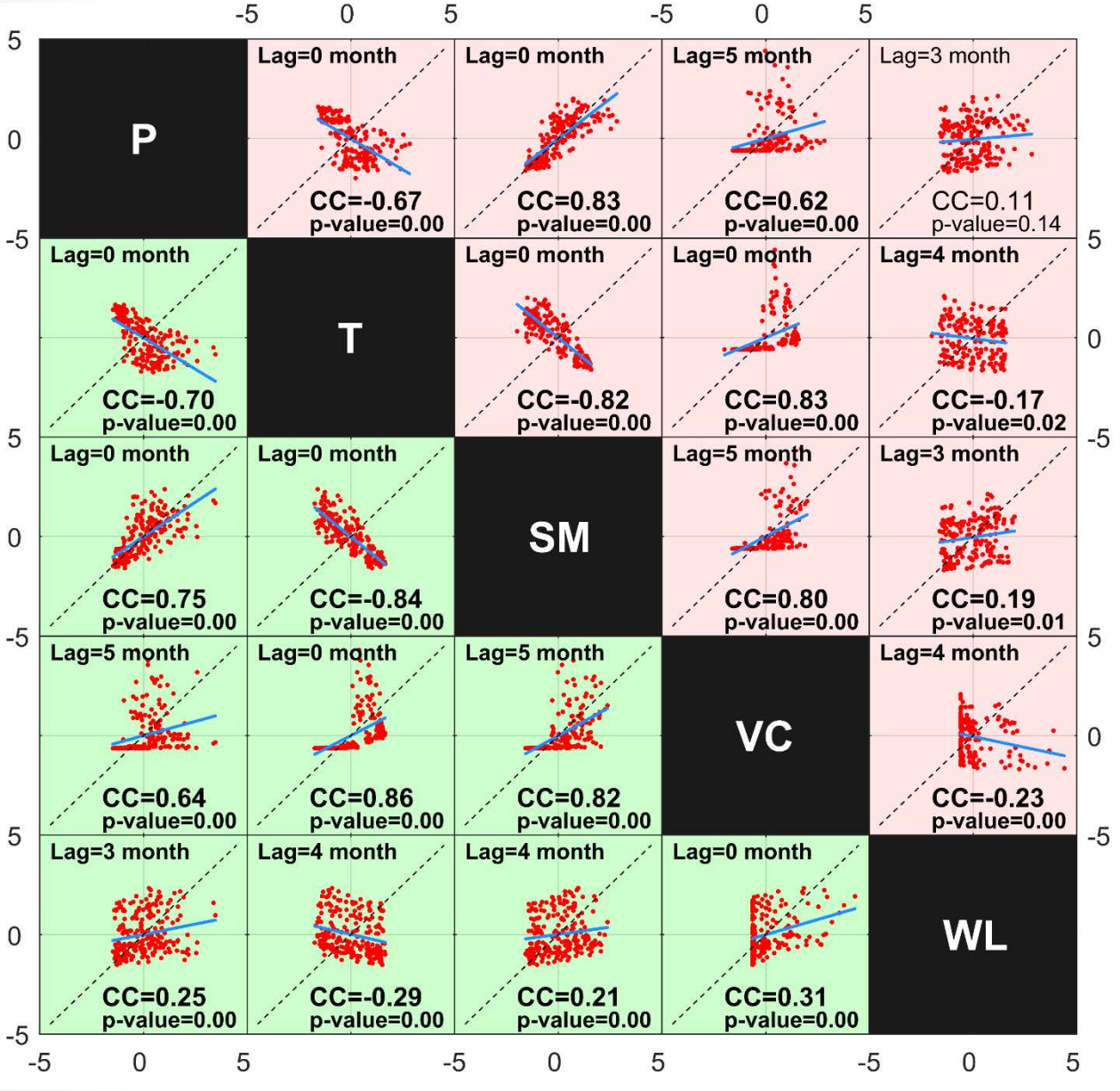
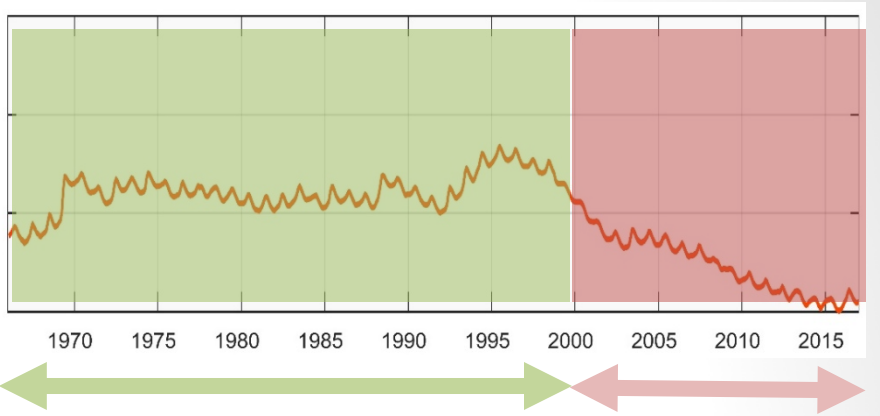


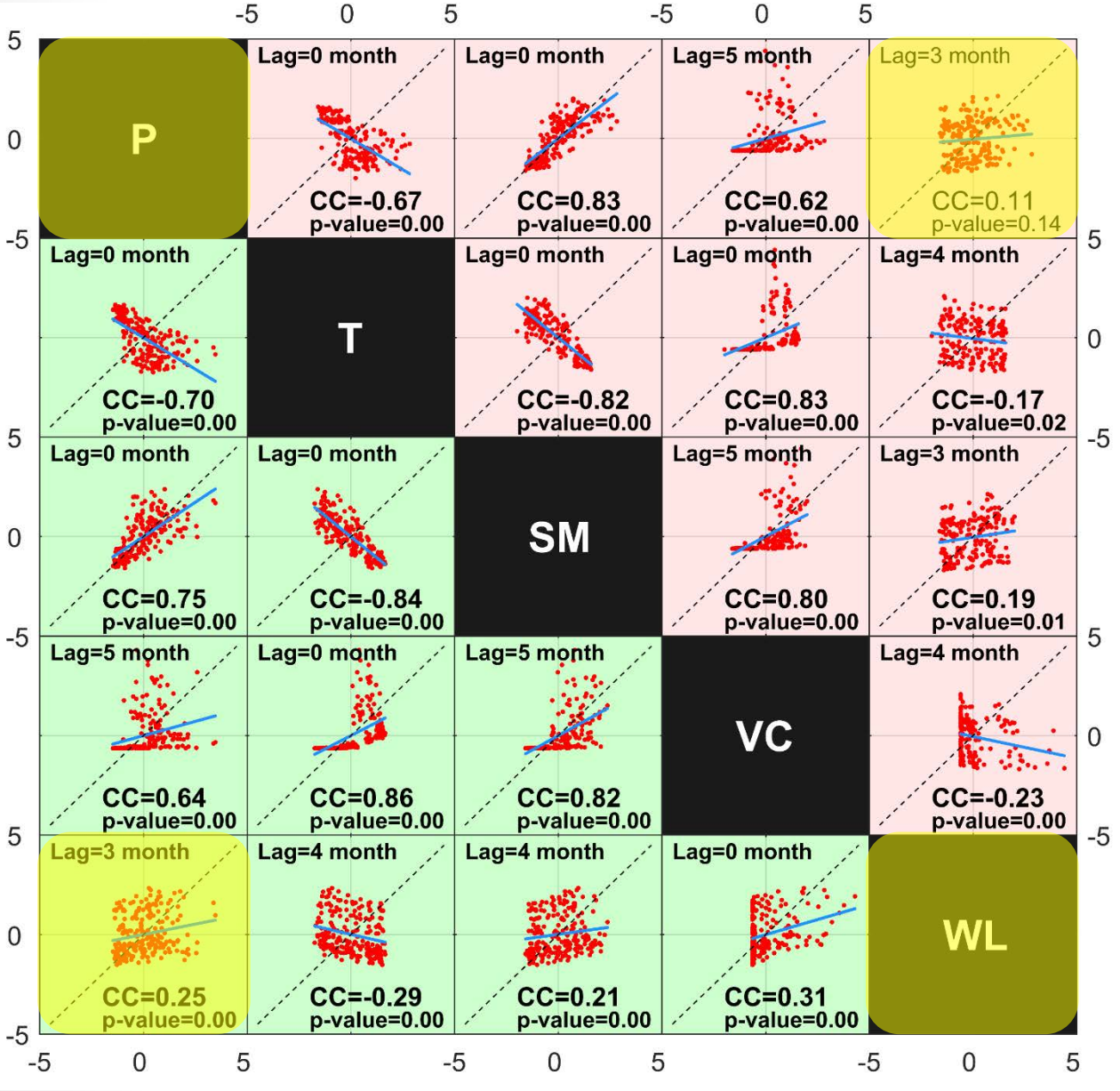
Results – Attribution Analysis

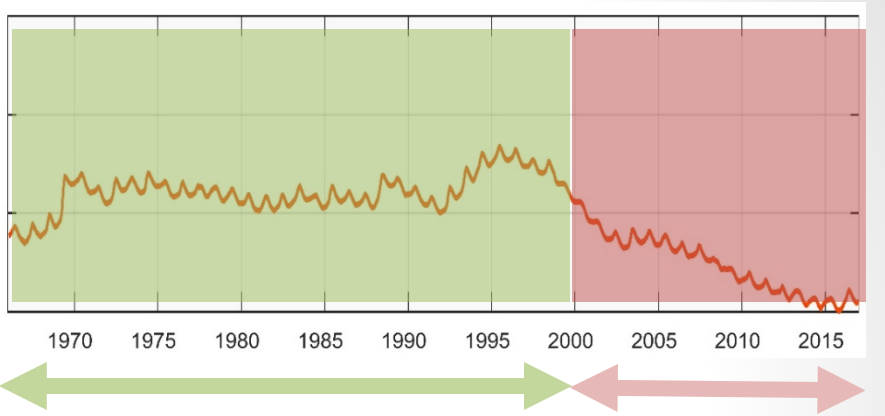




- Spearman correlation
- Monthly scale
- Mention the lags
- *p*-value

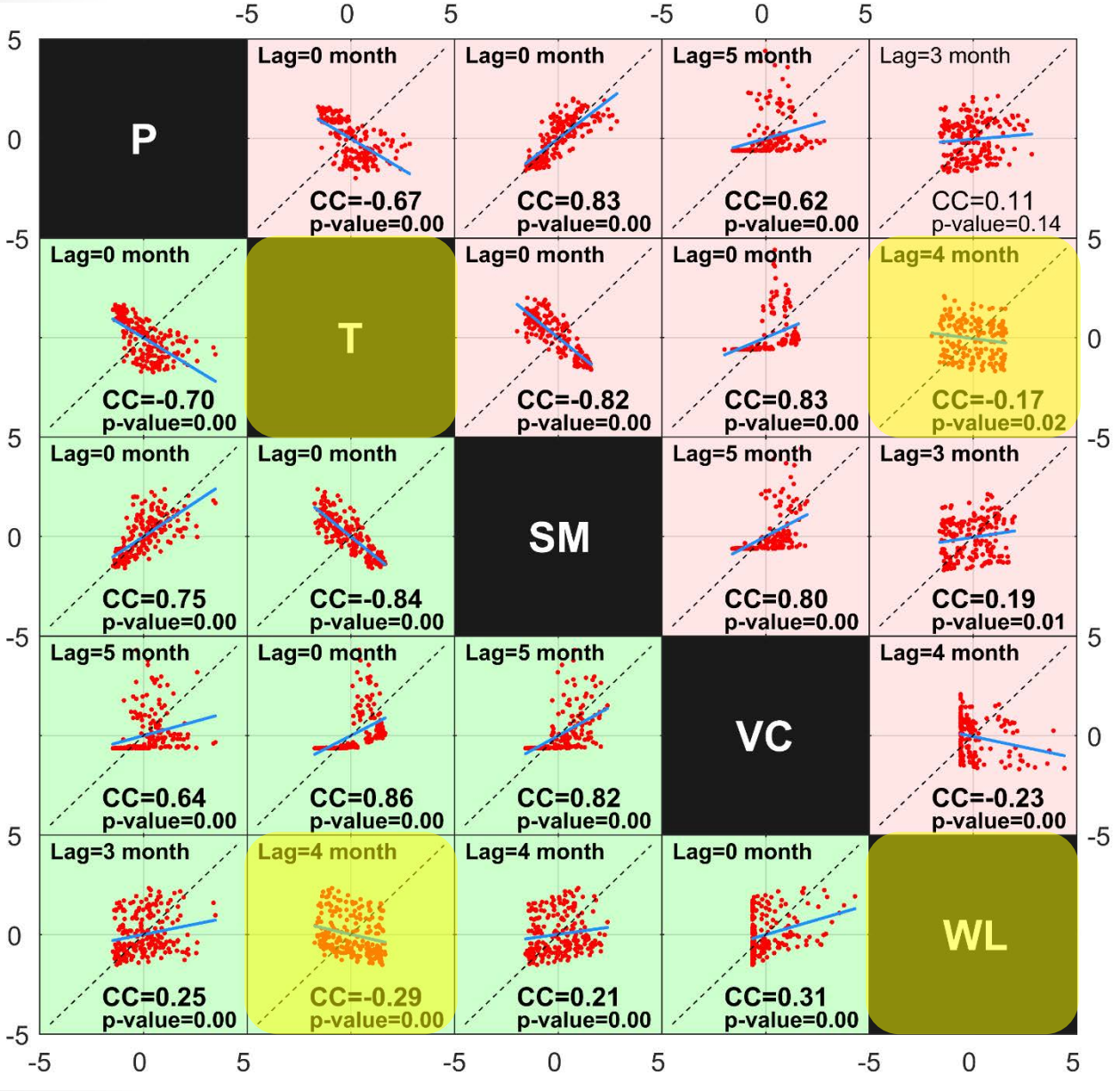
Results – Attribution Analysis

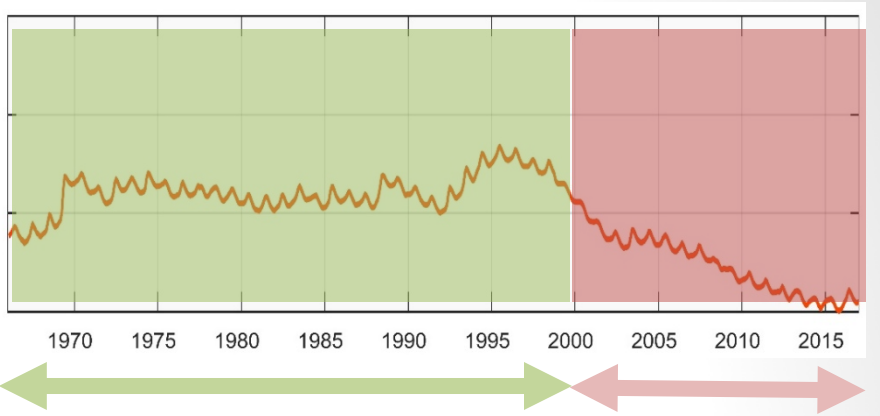




P-WL not statistically significant anymore

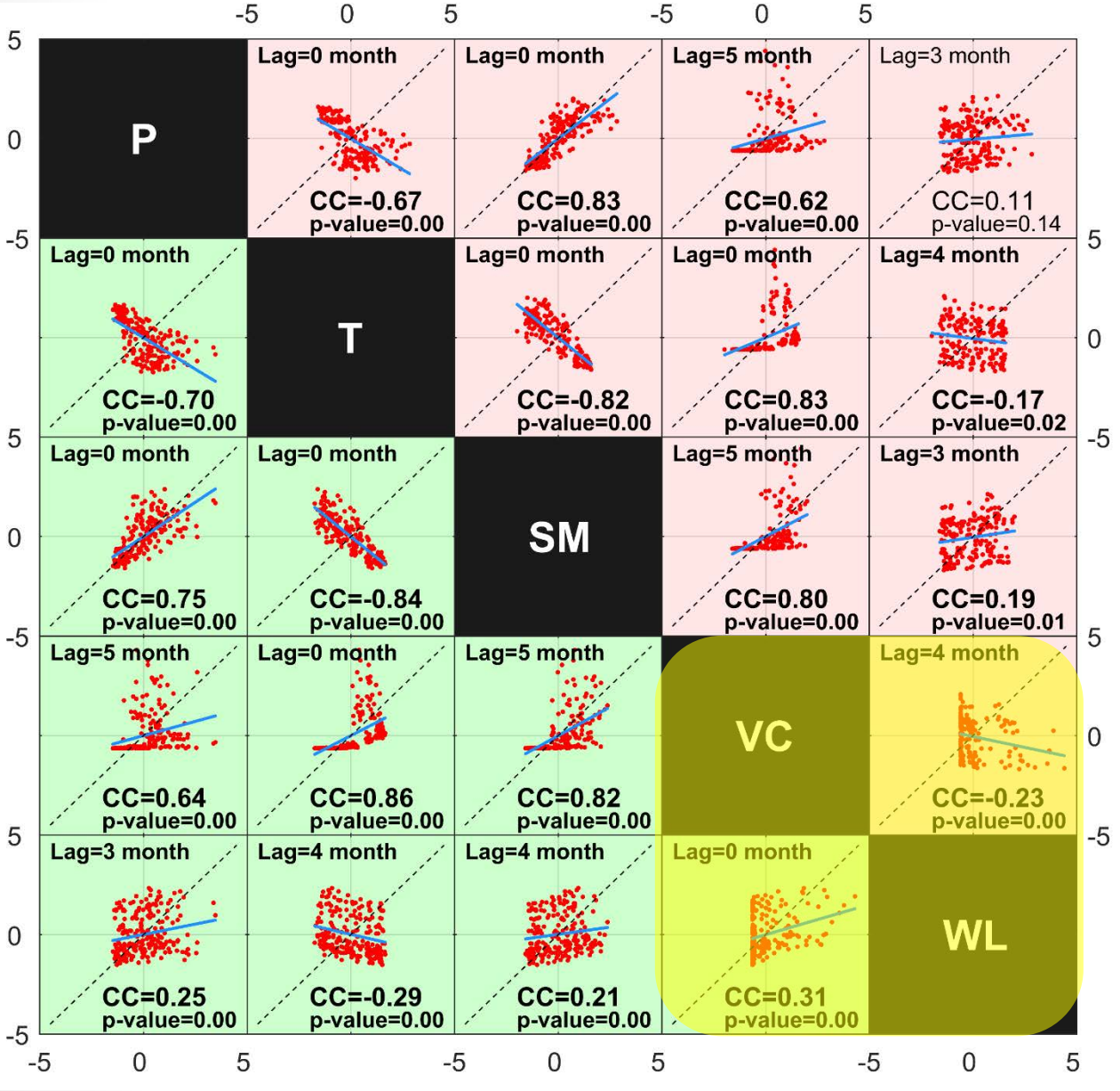
Results – Attribution Analysis

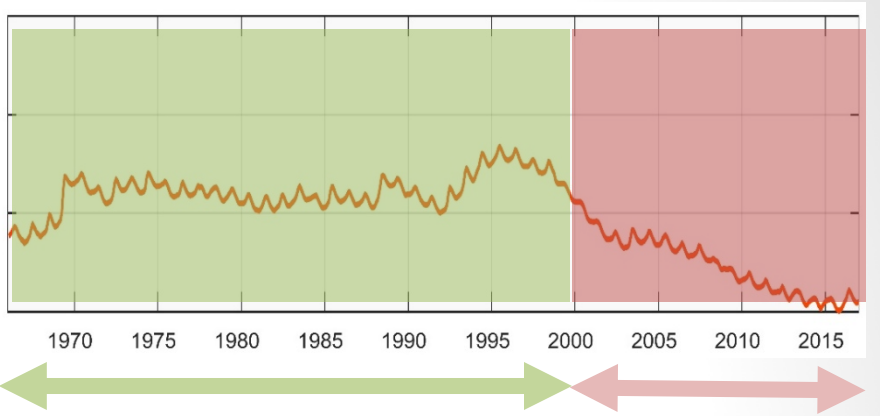




T-WL diminished

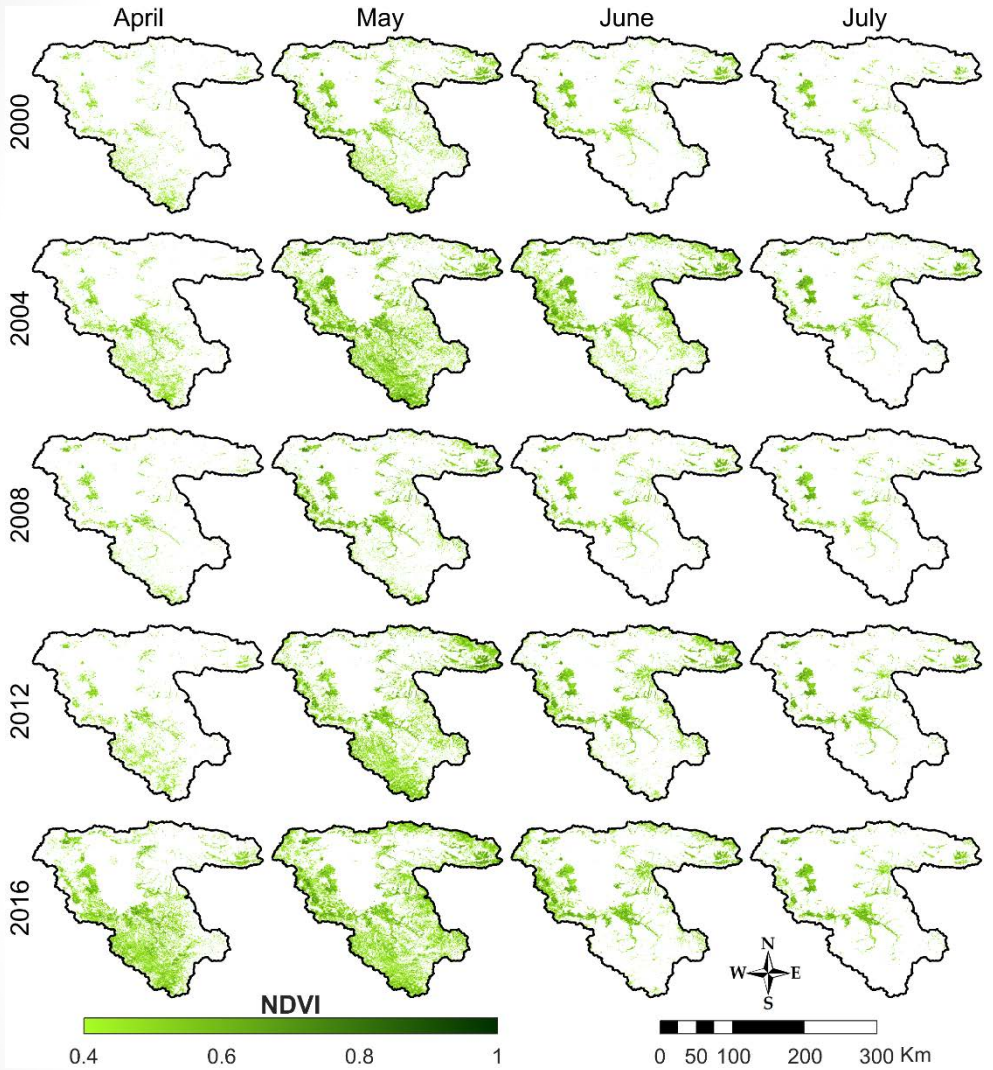
Results – Attribution Analysis

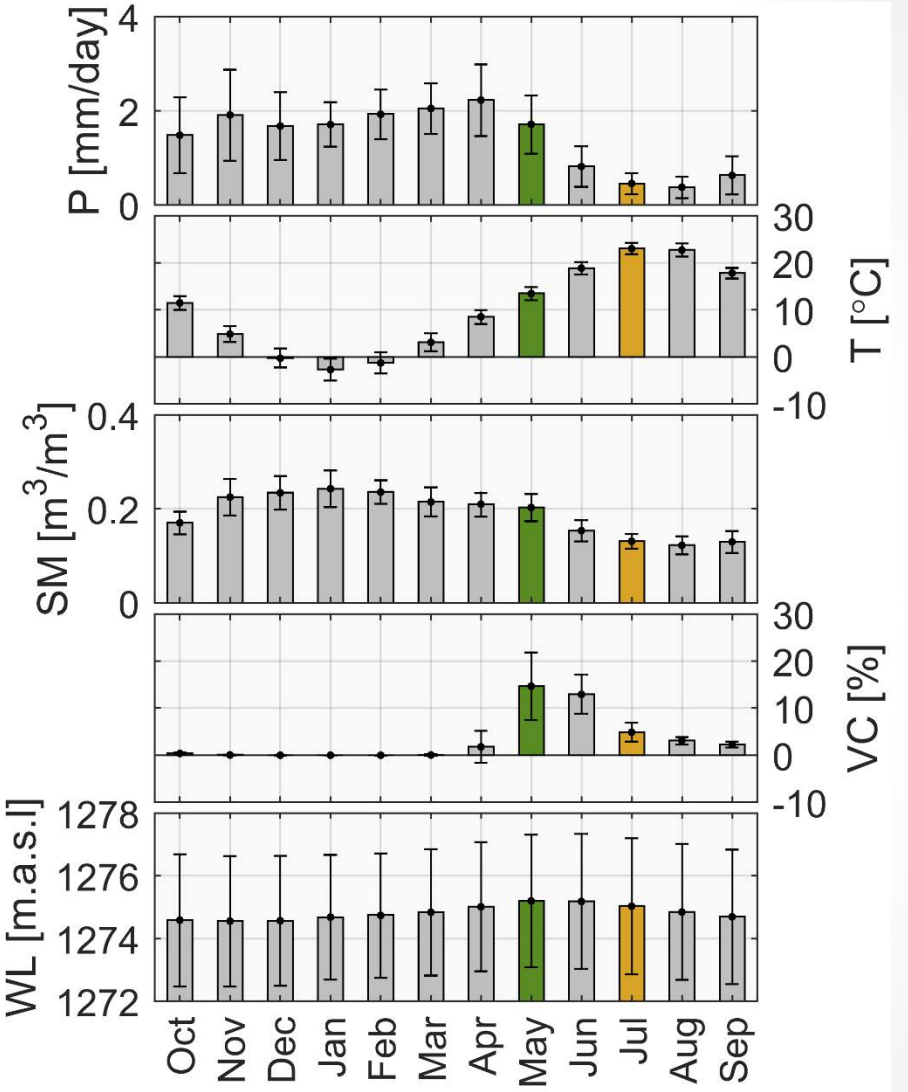




VC-WL reversed!

Results – Wet and Dry Spells

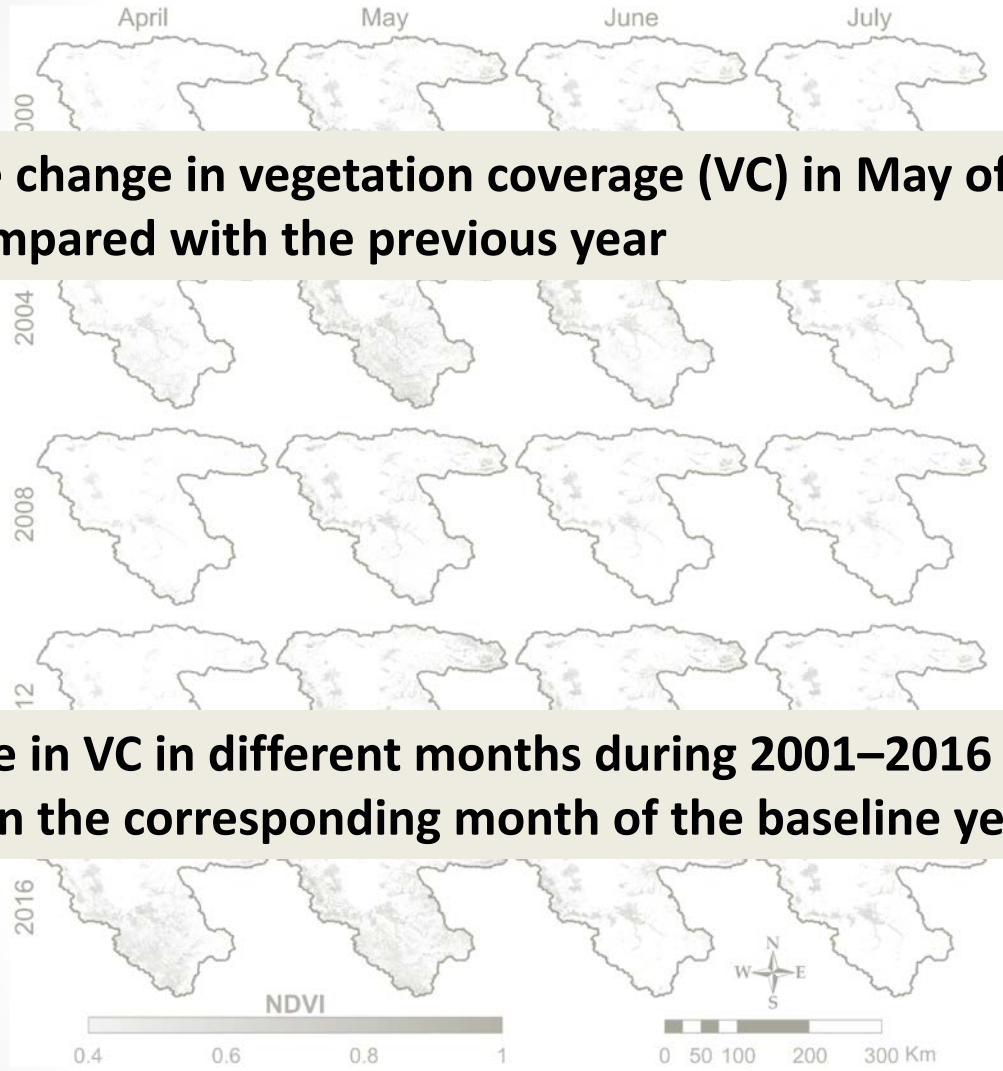




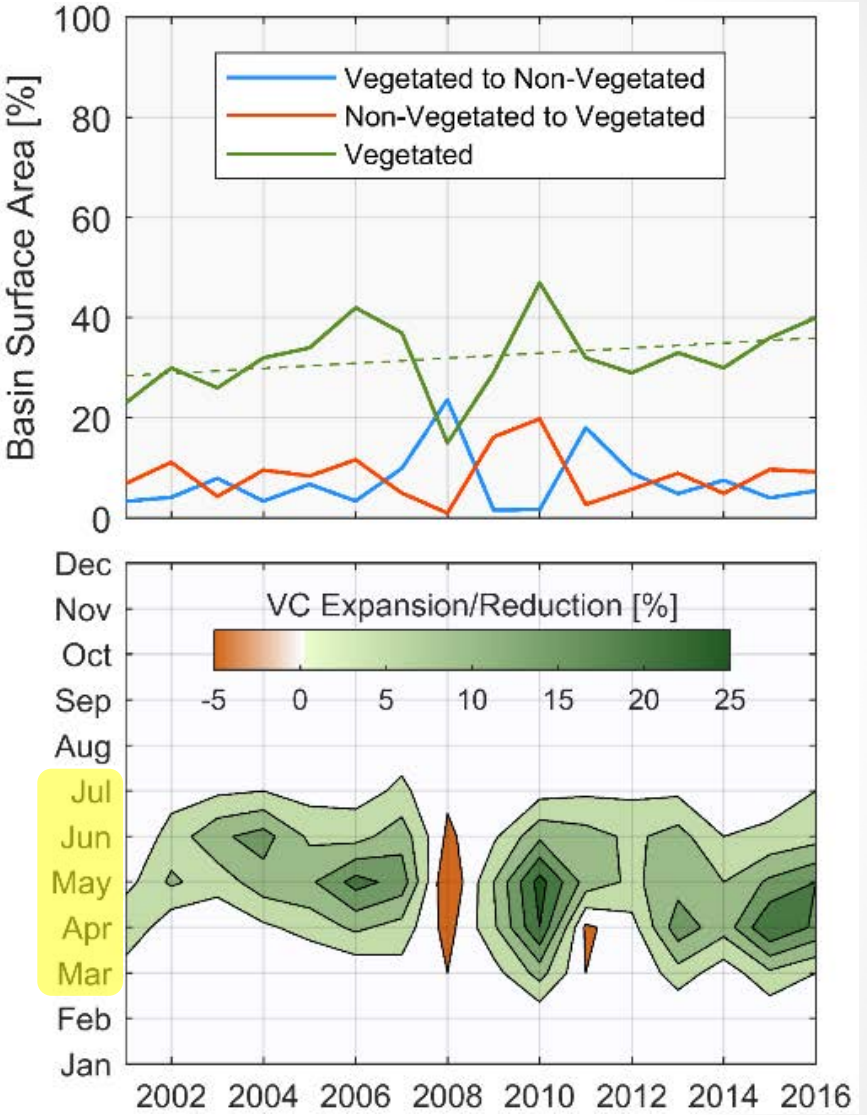
Consistent results with pre- and post-change analyses!

Results – Wet and Dry Spells

Relative change in vegetation coverage (VC) in May of each year compared with the previous year



Change in VC in different months during 2001–2016 relative to VC in the corresponding month of the baseline year 2000



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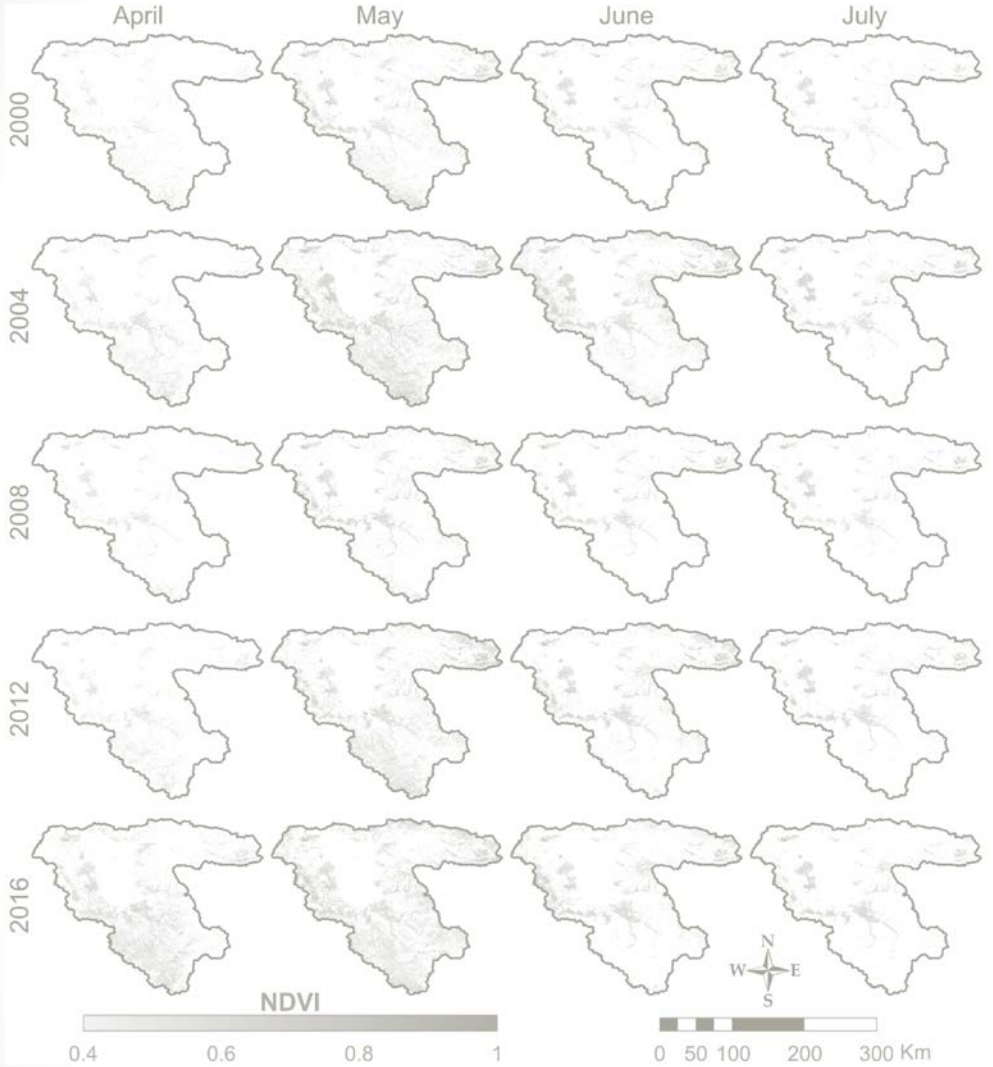
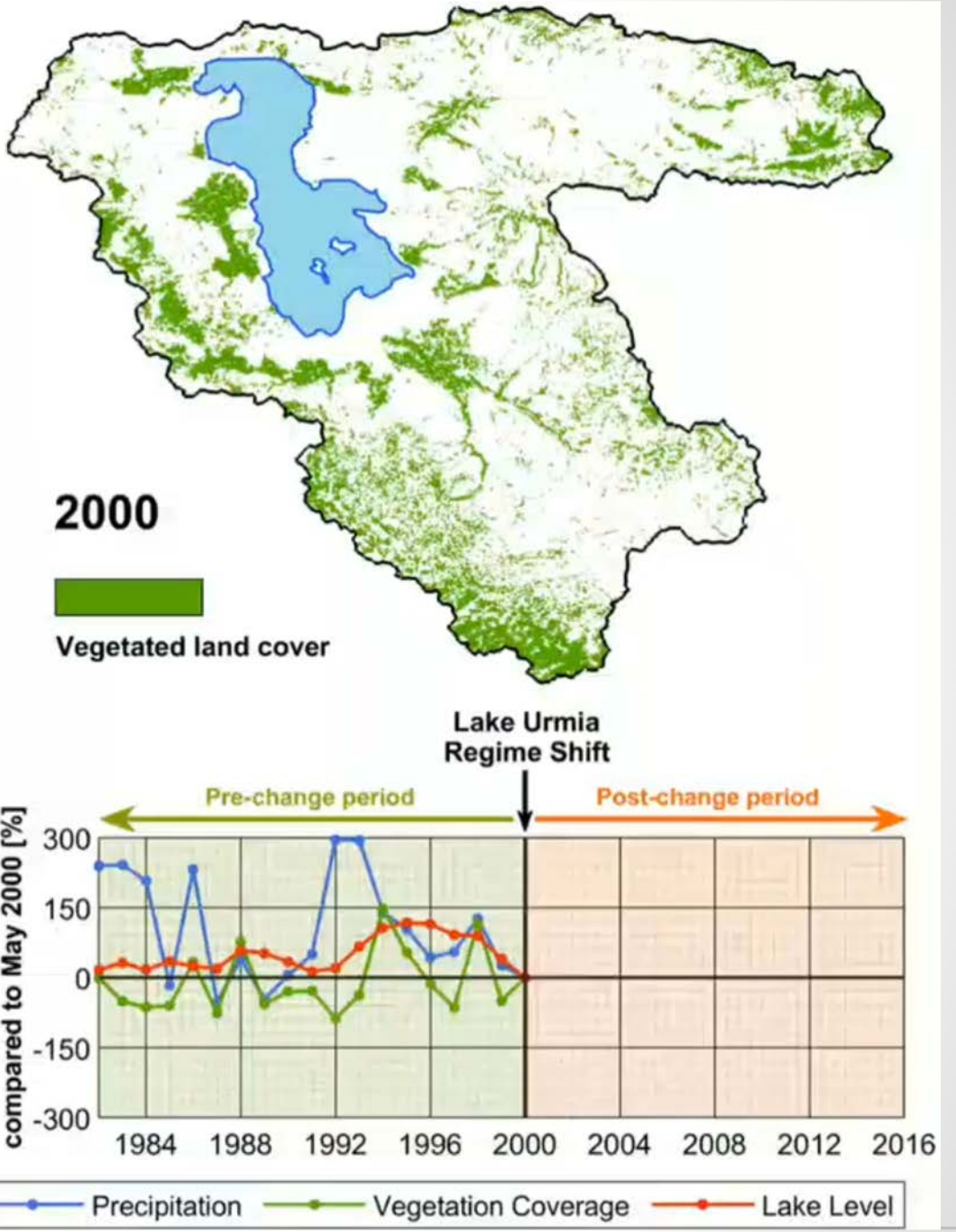
Results – Wet and





Consistent results with pre- and

Kaveh Madani | کاوه مدنی
@KavehMadani

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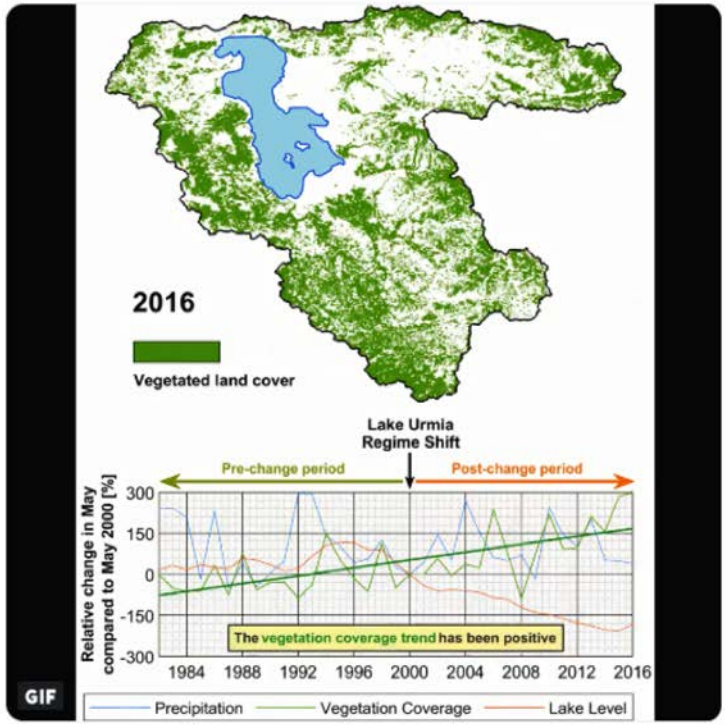
Our recent paper (authors.elsevier.com/c/1YEun_WGi1yCM) suggests that #ClimateChange IS NOT the main cause of #LakeUrmia shrinkage. The dramatic increase in upstream #water use due to massive agricultural vegetation expansion is the likely driver of this major environmental disaster in Iran.



10:30 PM - 13 Jan 2019

80 Retweets **459** Likes

Peter Gleick
@PeterGleick

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Replying to @KavehMadani @waltonwater

This is a superb analysis, showing that the dessication of #LakeUrmia in Iran has been driven by the expansion of irrigation #water withdrawals upstream, and that climatic factors have played only a small or negligible role so far. This is what destroyed the Aral Sea.

11:07 PM - 20 Jan 2019

5 Retweets **31** Likes

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Sina Khatami
@SinaKhatami

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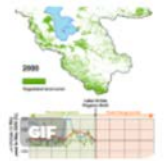
While there are #politicians who deny/question the #anthropogenic nature of #ClimateChange & its substantial implications; others blame CC for the detrimental impacts of their #policies on the #environment. We disentangle these two relevant yet distinct concepts in this #paper.



Kaveh Madani | کاوه مدنی @KavehMadani
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3:49 PM - 12 Feb 2019

11 Retweets **40** Likes

Blöschl, G., Bierkens, M. F., Chambel, A., Cudennec, C., Destouni, G., Fiori, A., ... & Stumpp, C. (2019). Twenty-three Unsolved Problems in Hydrology (UPH)–a community perspective. *Hydrological Sciences Journal*

International Association of Hydrological Sciences

IAHS AISH

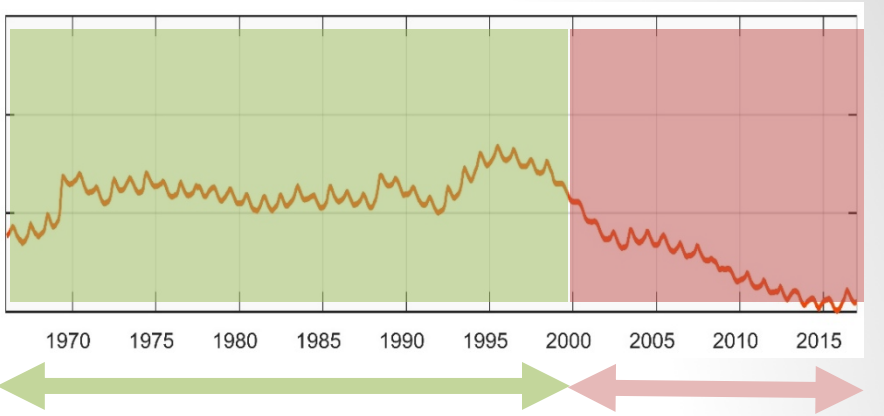
Panta Rhei

Everything Flows

Change in Hydrology and Society

Conclusions

- Atmospheric climatic changes cannot *primarily* explain dramatic decline in LU WL → stable P and T variations during both periods



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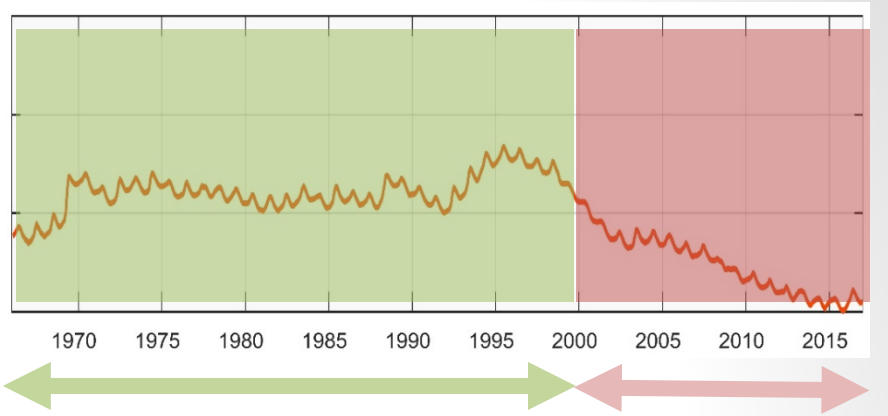

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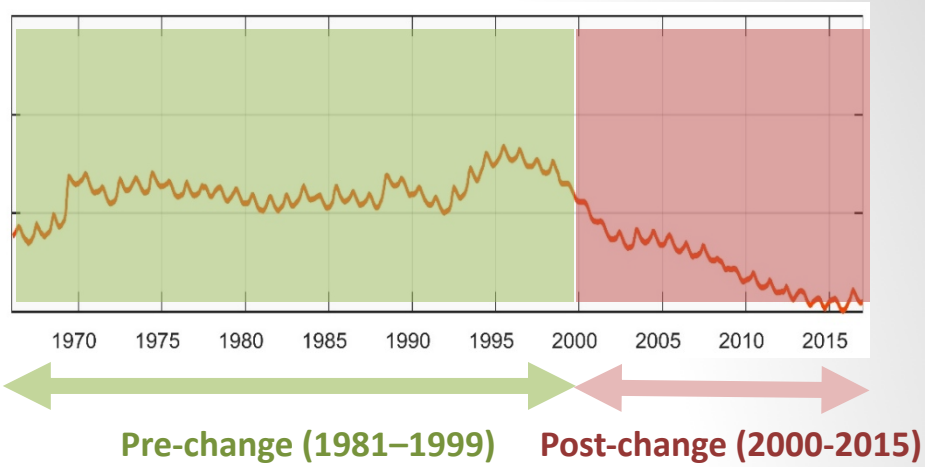

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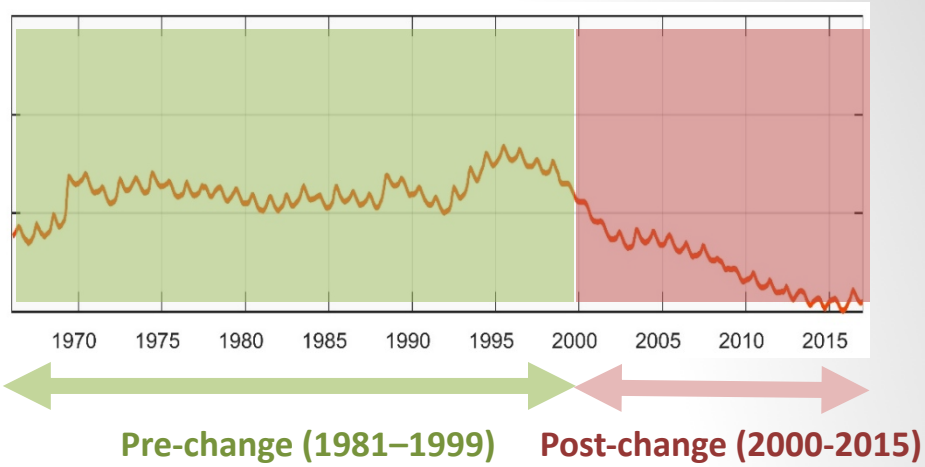

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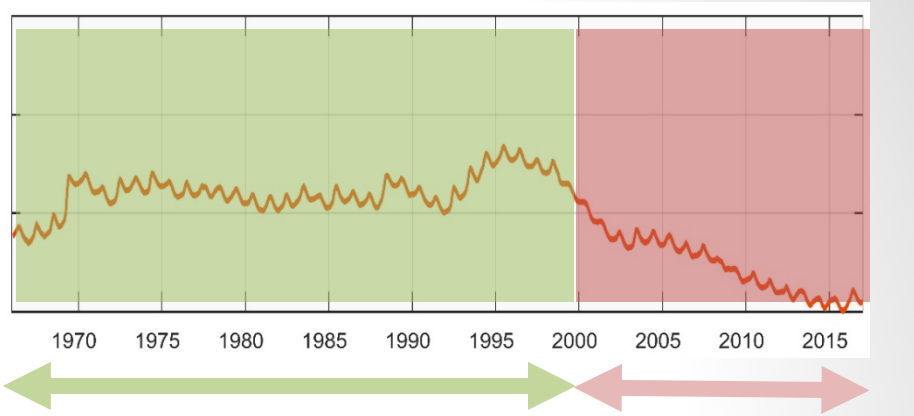

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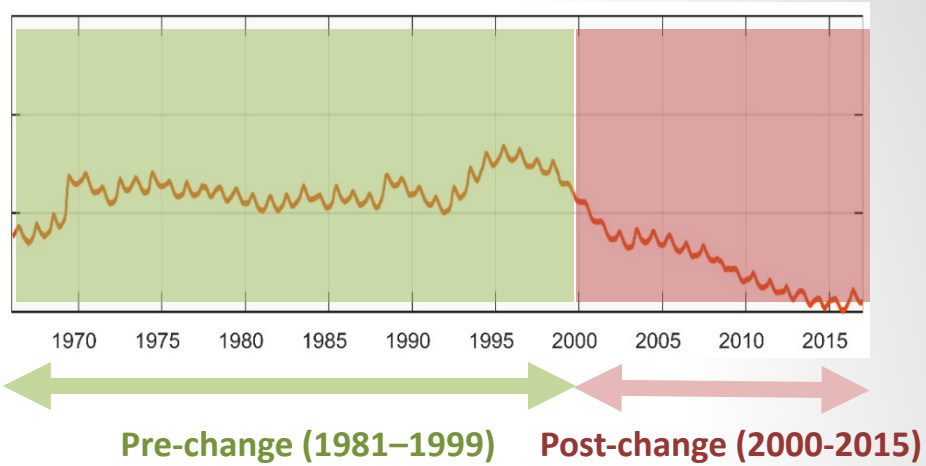
  - **The role of GW?** ~2,200 MCM extraction in 2013-2014 (~1,000 MCM from deep groundwater)



And… Upcoming Seminars

Kira Rundel: *Organic Solar Cells: Challenges and Opportunities for Enhanced Uptake*, Mon 1 July (6.30pm) @ Fritz Loewe

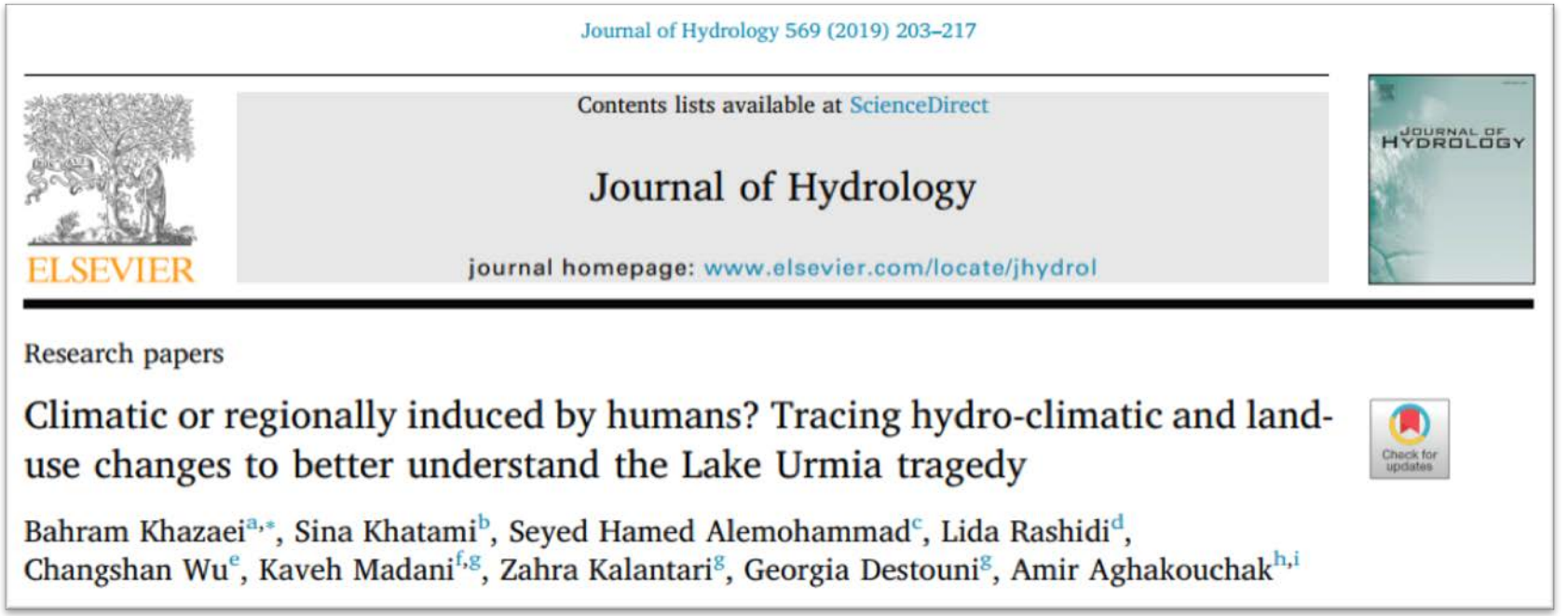
Manoj Datta: *Smart Grid and Renewable Energy Integration: Challenges, Mitigation Strategies, and Associated Grid Codes*, Weds 10 July (11am) @ the College

And… any post-doc opportunities?

I'm looking for post-doc opportunities from the end of this year…

Image Source: Science doi:10.1126/science.caredit.aaw6975

Thank you Climate College!



Journal of Hydrology 569 (2019) 203–217

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Research papers

Climatic or regionally induced by humans? Tracing hydro-climatic and land-use changes to better understand the Lake Urmia tragedy

Bahram Khazaei[a,*], Sina Khatami[b], Seyed Hamed Alemohammad[c], Lida Rashidi[d], Changshan Wu[e], Kaveh Madani[f,g], Zahra Kalantari[g], Georgia Destouni[g], Amir Aghakouchak[h,i]

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Sina.Khatami