中国科学院新疆生态与地理研究所

XINJIANG INSTITUTE OF ECOLOGY AND GEOGRAPHY CHINESE ACADEMY OF SCIENCES

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Climate Change and Human Activities Exacerbate Water Stress in the Aral Sea Basin, Central Asia

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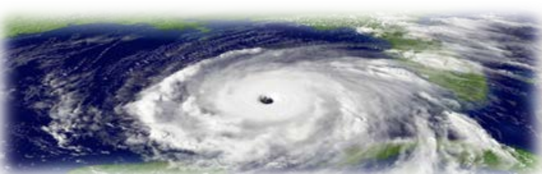
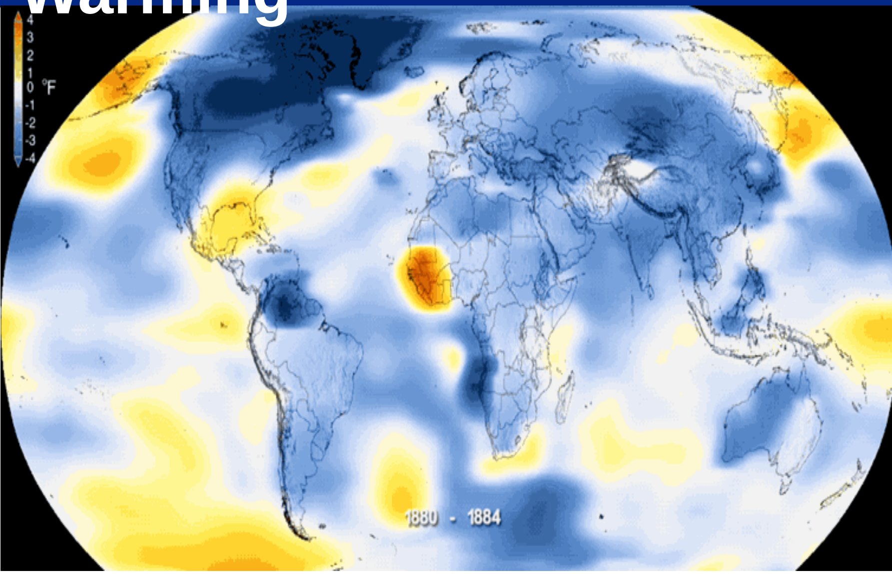



Topics Presented

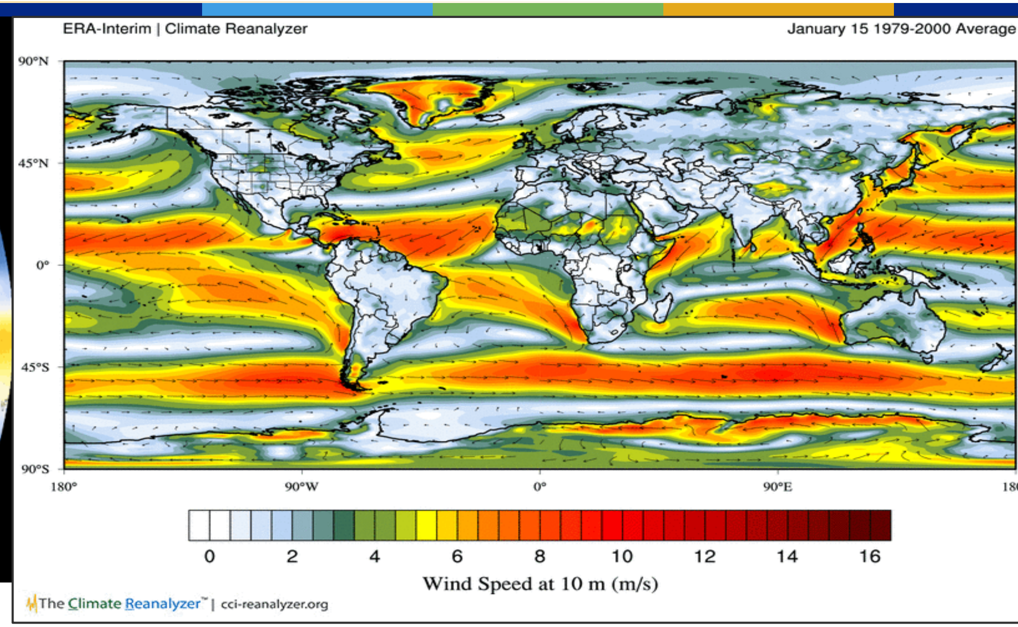
1. Background
2. Problem Statement
3. Datasets & Methods
4. Results & Discussion
5. Conclusions

Background

Global Warming

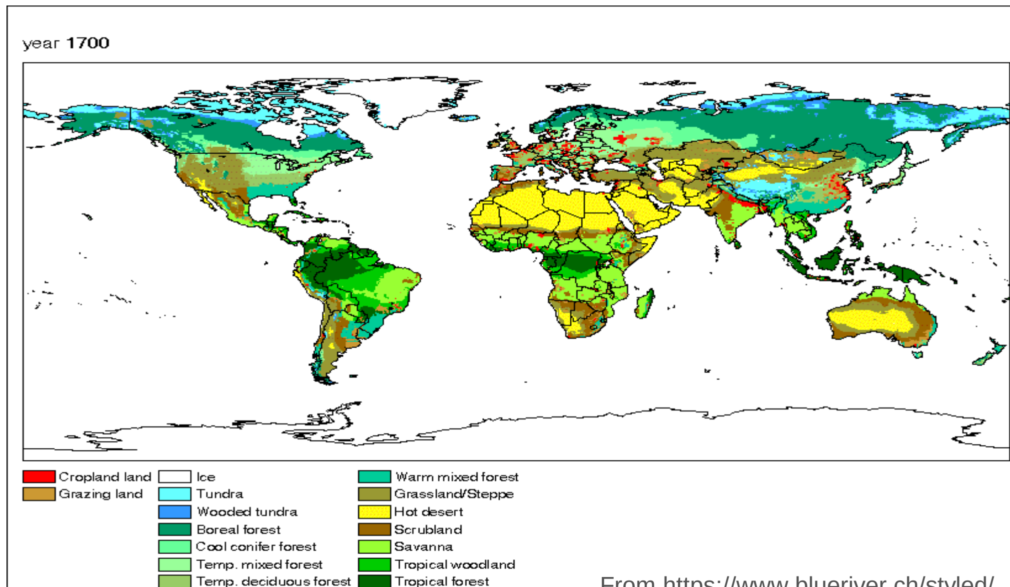


From NASA's Scientific Visualization Studio/Kathryn Mersmann
https://www.nbcnews.com/mach/science/2018-was-fourth-hottest-year-record-nasa-says-ncna967306



(1) Global environmental change include climate change, land-cover change, population growth, etc (Stern et al., 1992; Obrist et al., 2018). **Global warming** has become an indisputable fact (IPCC, 2007).

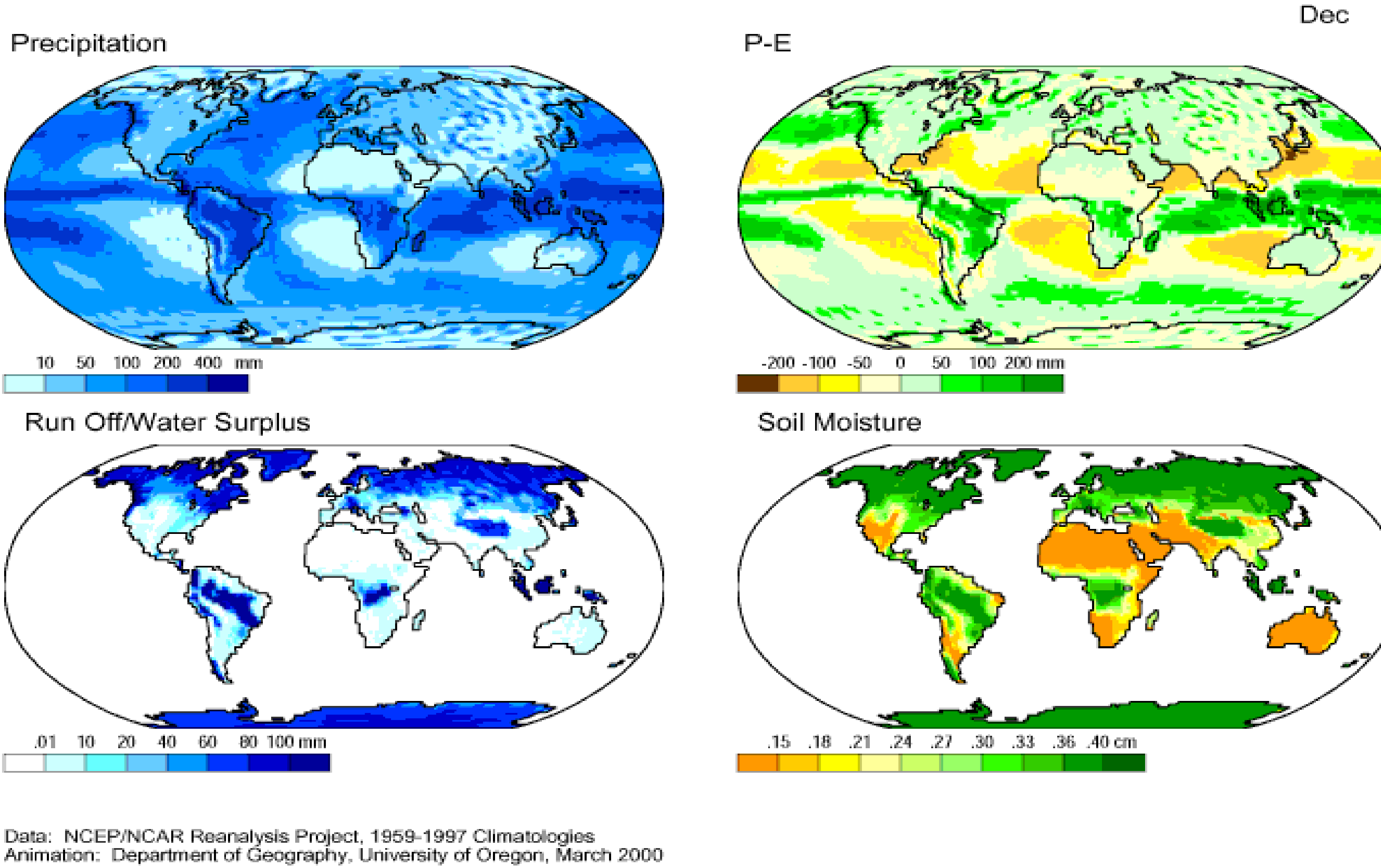
(2) Land-cover change



From https://www.blueriver.ch/styled/

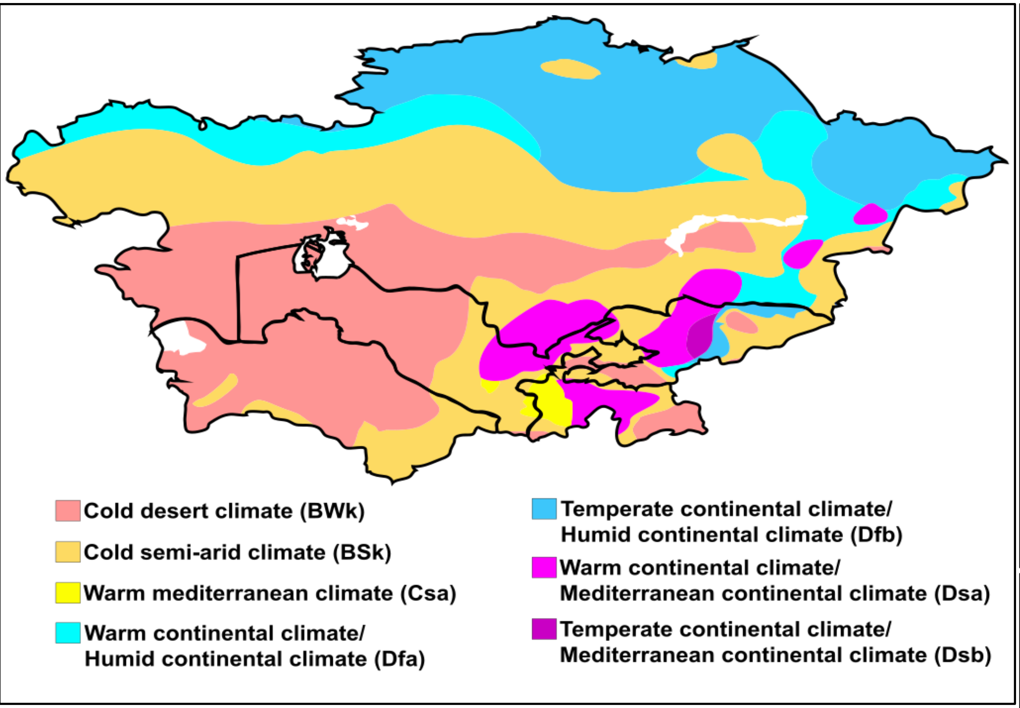
Background

(3) Global environmental change has a extremely profound impact on the hydrological cycle and water resources.

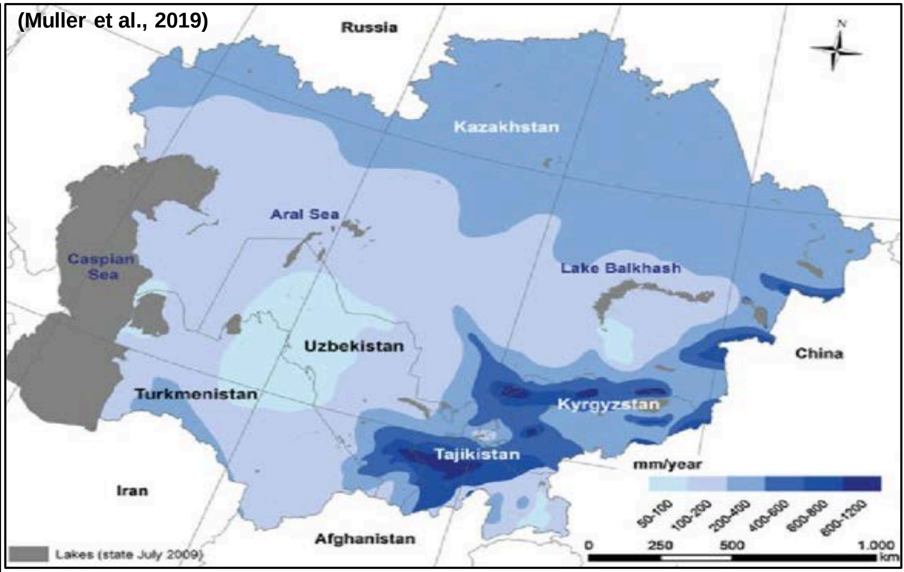


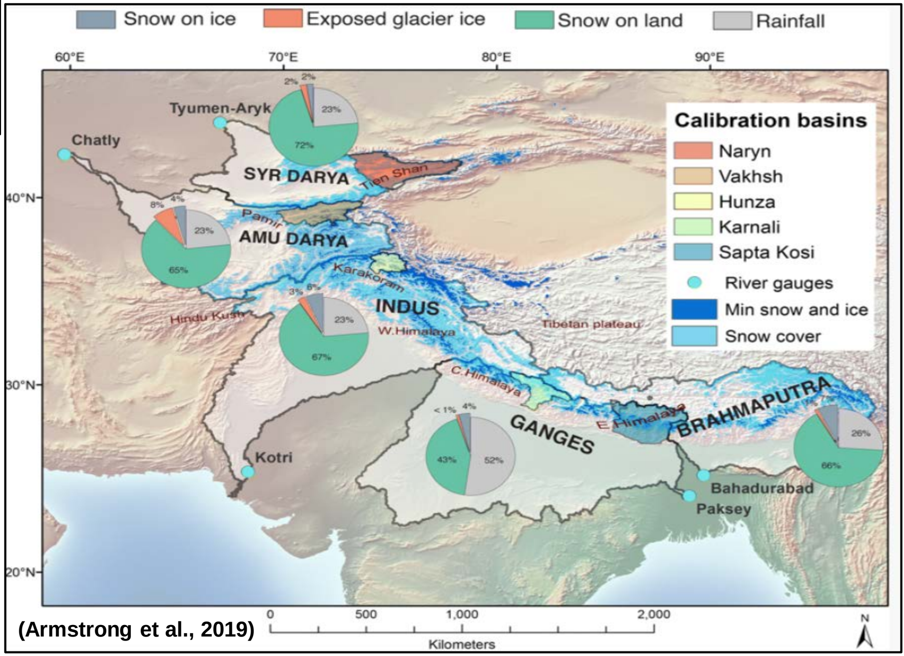
Background

In Central Asia



Central Asia map of Köppen climate classification (From Wikipedia)





■ **Features :**

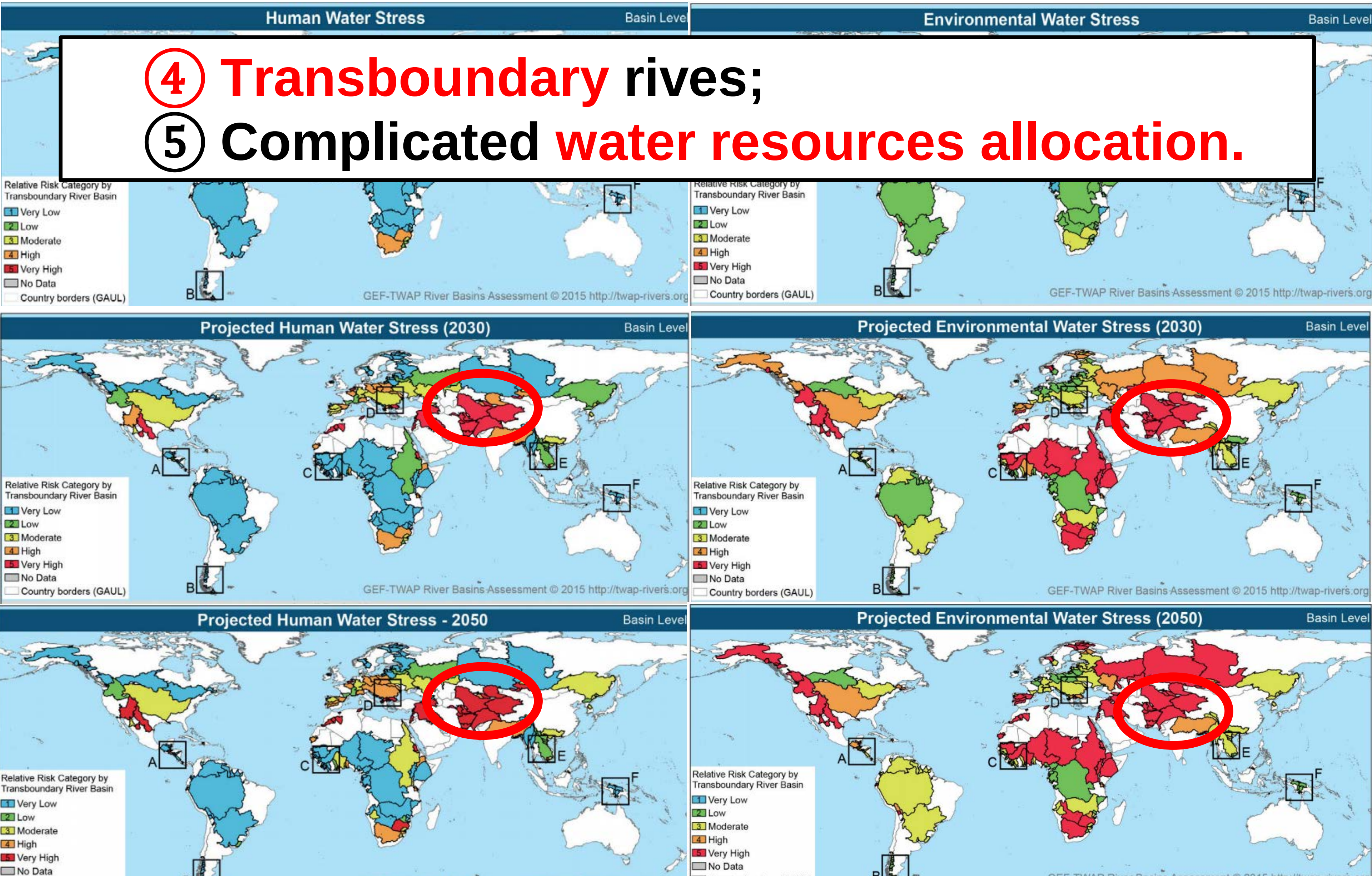
1. **Arid regions;**
2. **Extremely uneven in spatio-temporal distribution;**
3. **Ice and snow melt to river discharges;**

In Central Asia

Background

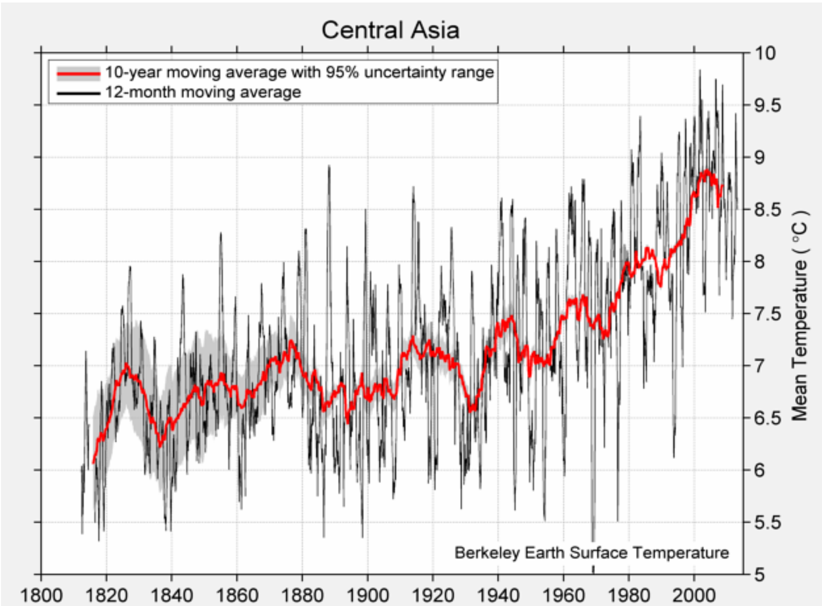
④ **Transboundary rives;**

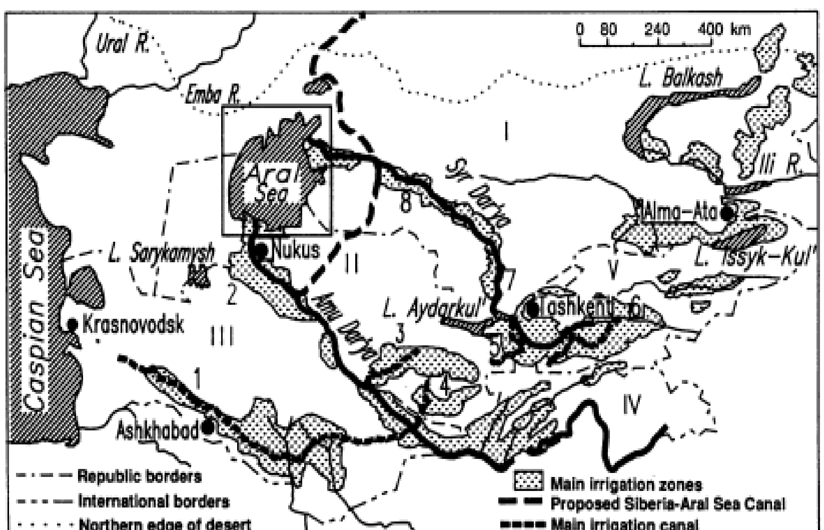
⑤ **Complicated water resources allocation.**



Background

In Central Asia





(Olli, Nature, 2014; Philip, Science,1988)

Problem Statement

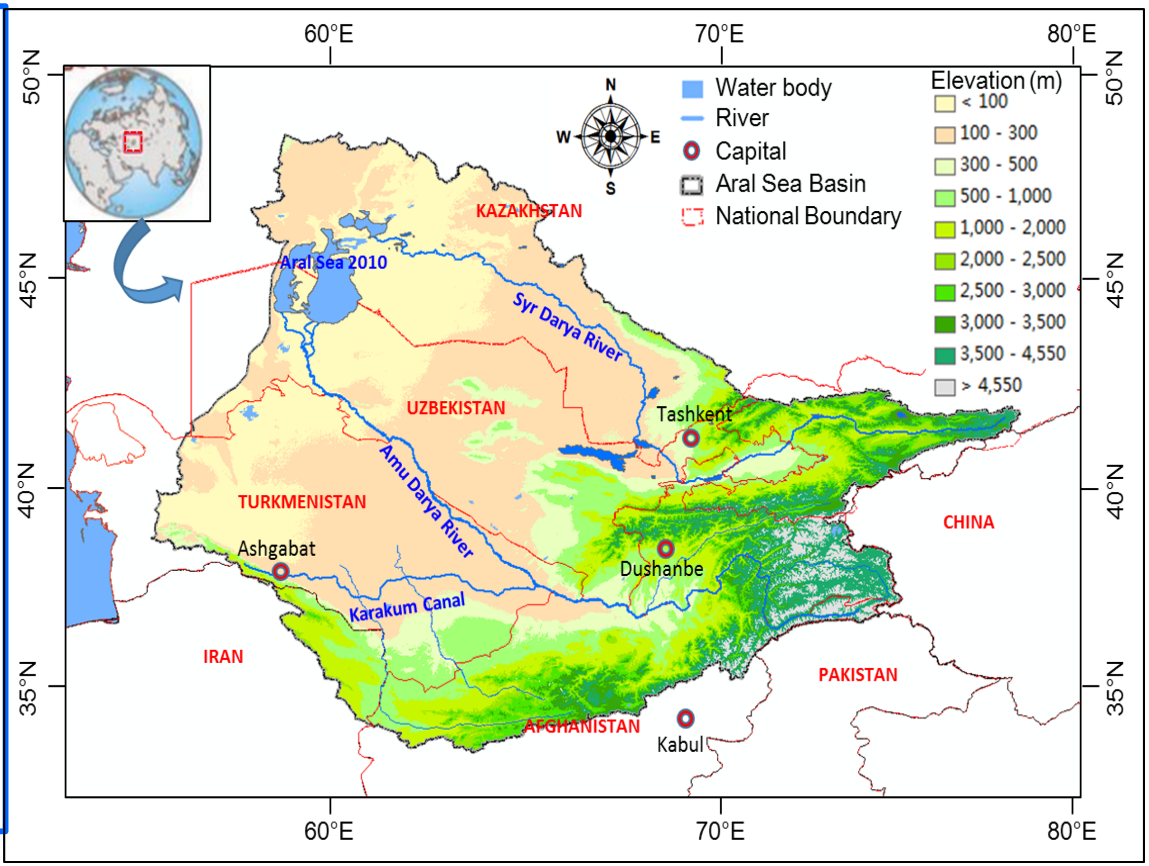
- ☐ How to better recognize the changes of climate factors (e.g., precipitation and temperature) and surface water resources in the whole Aral Sea Basin?

- ☐ How to simulate water resources for the whole Aral Sea Basin?

Datasets & Methods

Datasets

- **Hydrological data including Sea levels, water volume, and river discharge from Amudarya River and Syrdarya River;**
- **CRU TS v.4.01, gridded dataset with 0.5° resolution, covering 1901 to 2016;**
- **Yearly land-cover data for 1992-2015 from the European Space Agency (ESA) climate change initiative (CCI) (Hollmann et al., 2013) .**



Shared by Tajikistan (about 99 percent), Turkmenistan (about 95 percent) and Uzbekistan (about 95 percent), Kyrgyzstan (about 59 percent), Kazakhstan (about 13 percent), northern Afghanistan (about 38 percent) and a very small part of Iran. The Aral Sea is mainly fed by the Syr Darya and Amu Darya rivers, and both rivers originate from Kopet Dag, western Tien Shan and Pamirs.

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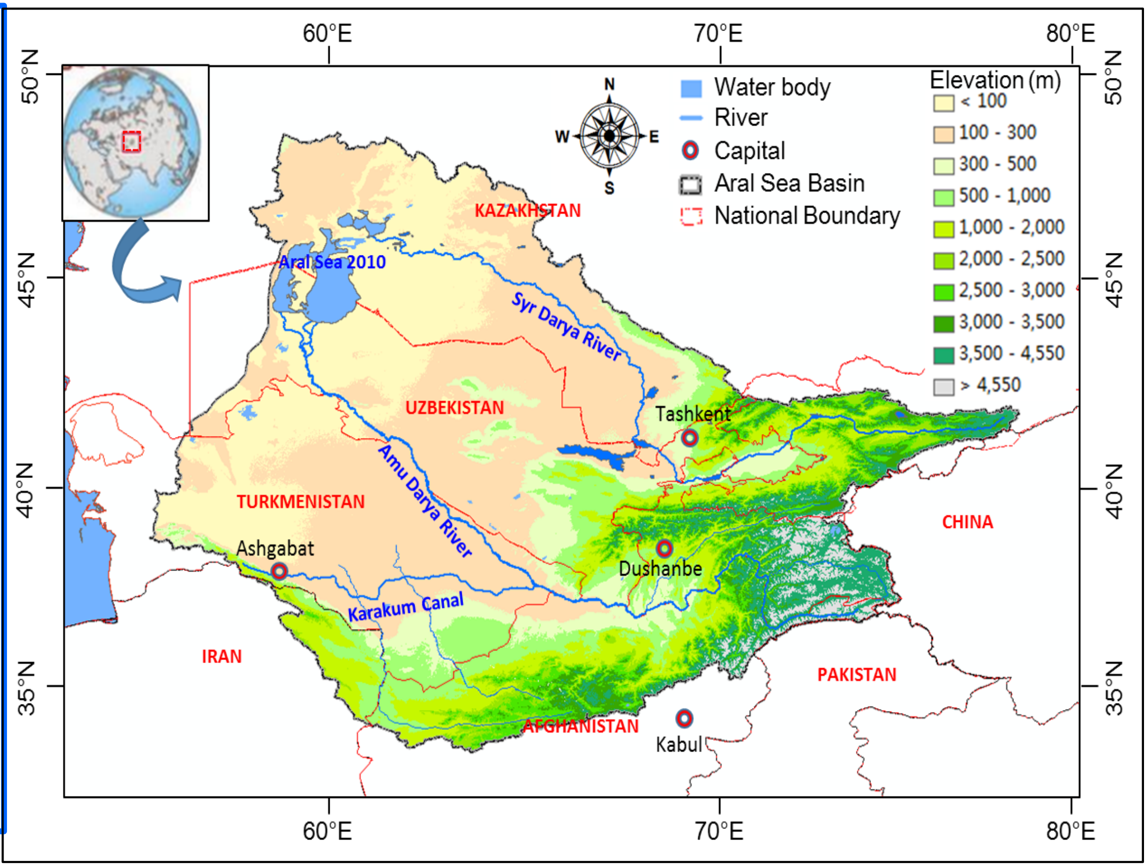

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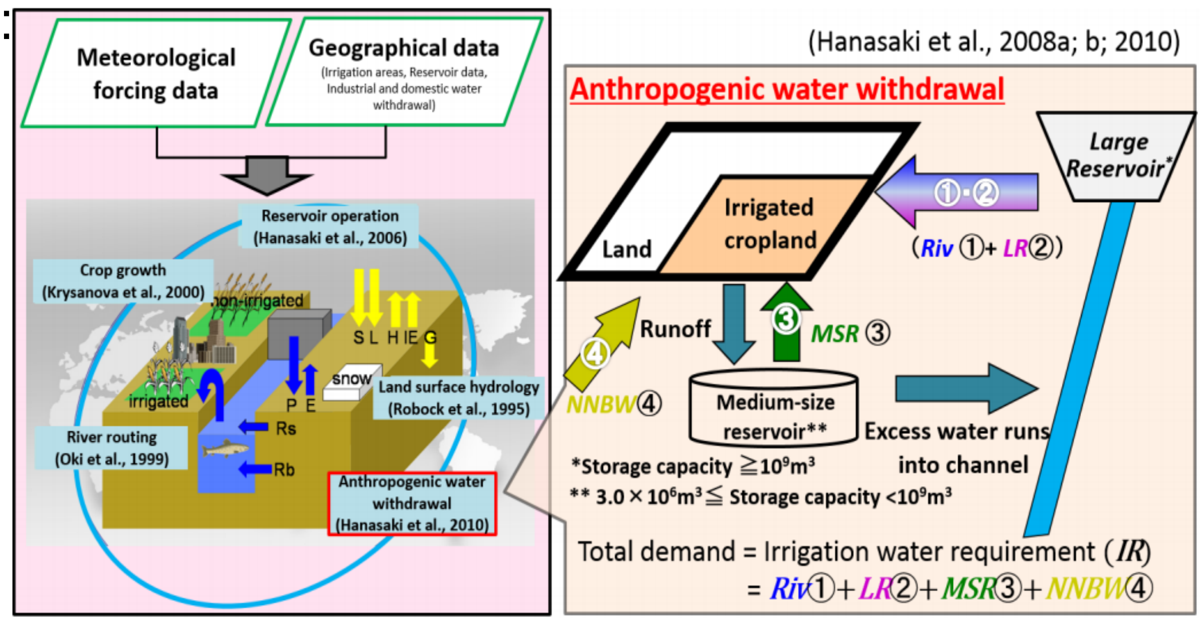
Datasets & Methods

Datasets for simulations

- Model: H08+PCR-GLOBWB
- Meteorological forcing: CRU 3.2、ERA-Interim
- Topographical parameters: HydroSHEDS、GTOPO30、Hydro1k
- Land cover: ESA climate change initiative (CCI)
- Lakes: GLWD1、FAO
- Reservoirs: GRanD、FAO
- Groundwater: GLHYMPS map
- Soil store parameters: FAO soil map
- ……



Datasets & Methods

Methods

- Trends were calculated by linear least-squares regression (Hess et al., 2001), and their significance were estimated by the Mann-Kendall trend test (Kendall, 1975).

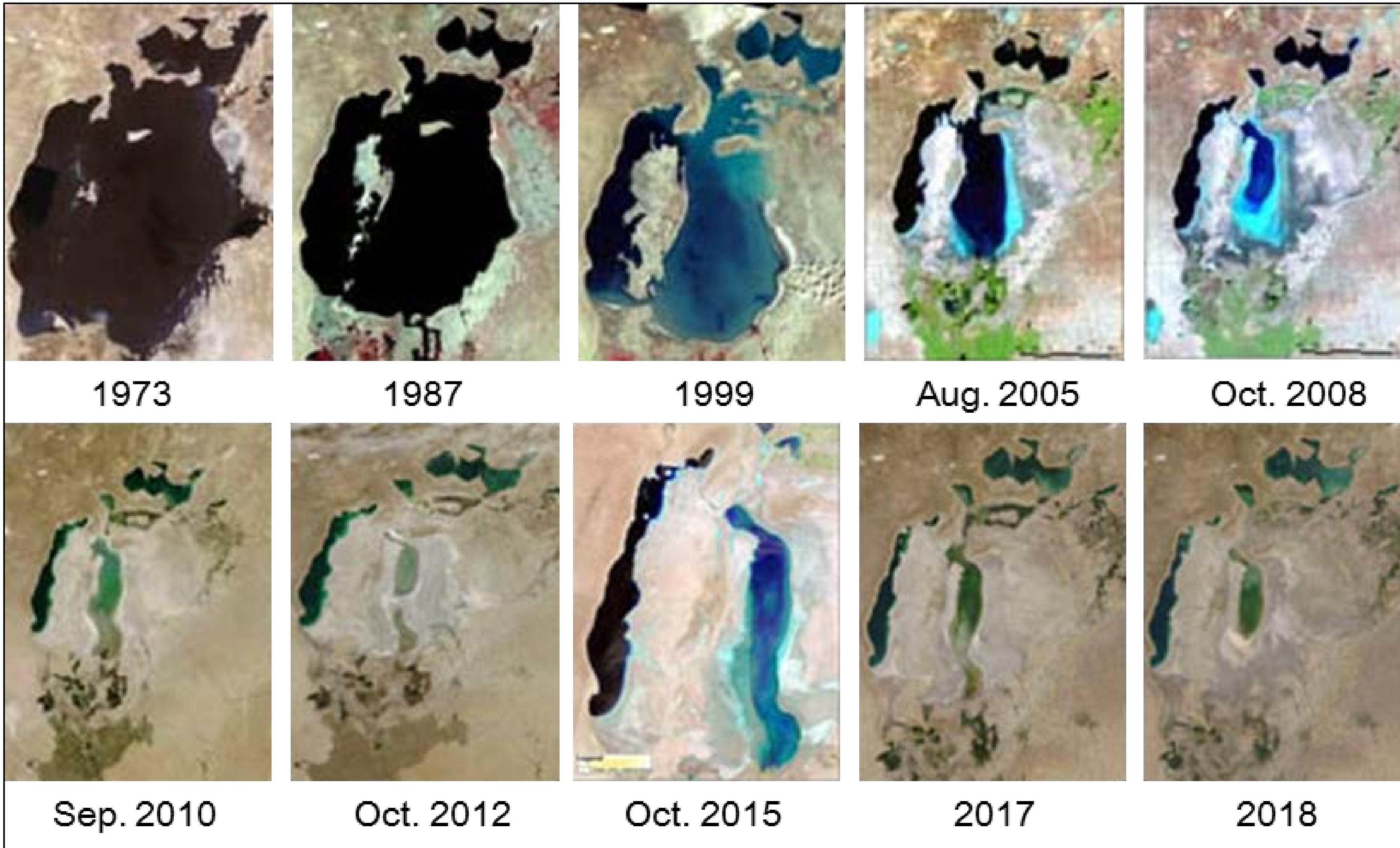
- Two indices including land use variation amplitude and land use transition matrix were calculated to evaluate the space-time variation characteristics of land use. The land use variation amplitude was computed by

$$\boldsymbol{P_i} = \frac{\boldsymbol{LU_{i1} - LU_{i0}}}{\boldsymbol{LU_{i0}}} \times \mathbf{100\%} \qquad (1)$$

where LU_{i0} and LU_{i1} indicate the area at the beginning and ending year of the ith land use type, respectively.

- Model: H08+PCR-GLOBWB

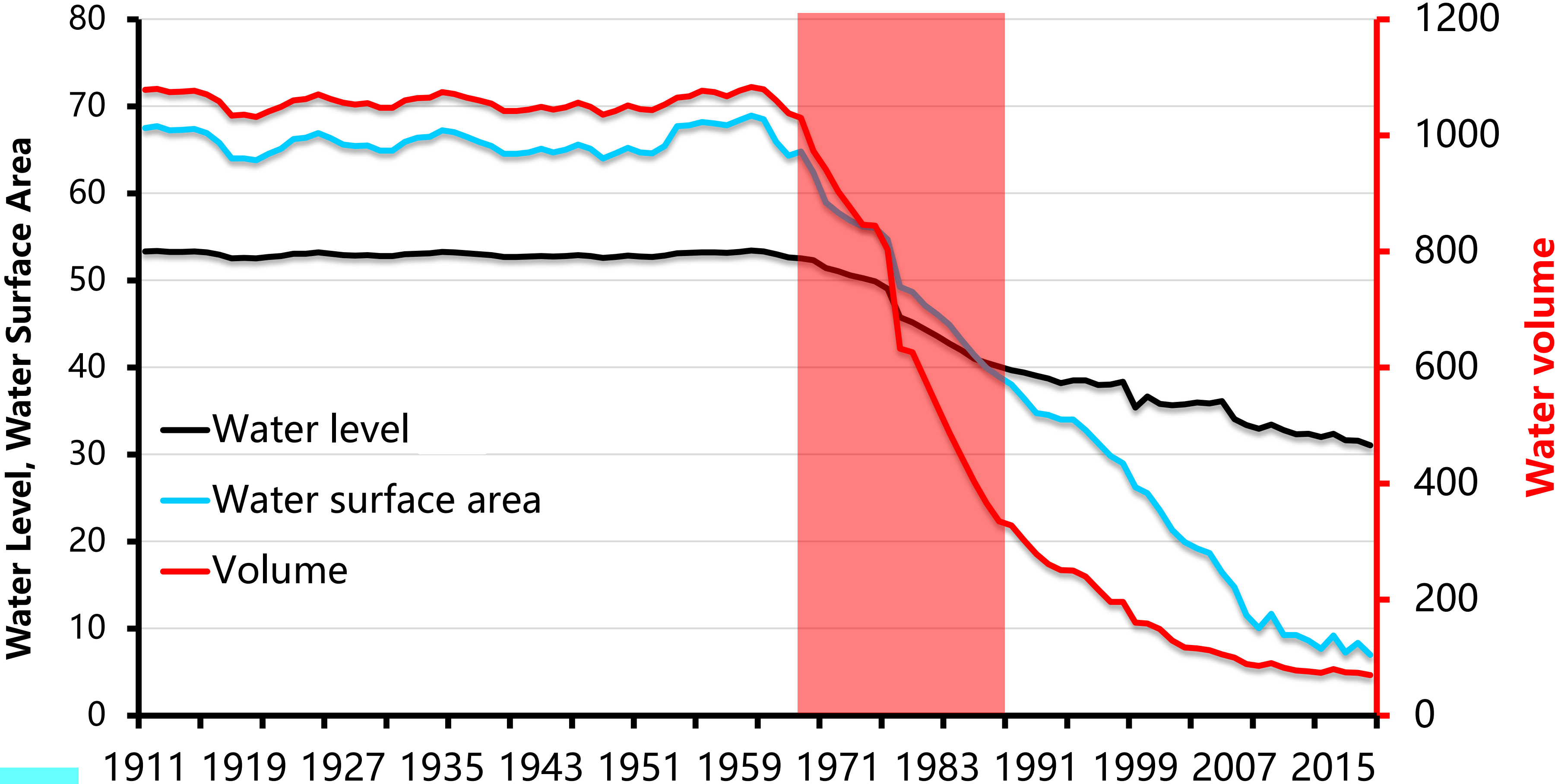
Results & Discussion



One-tenth

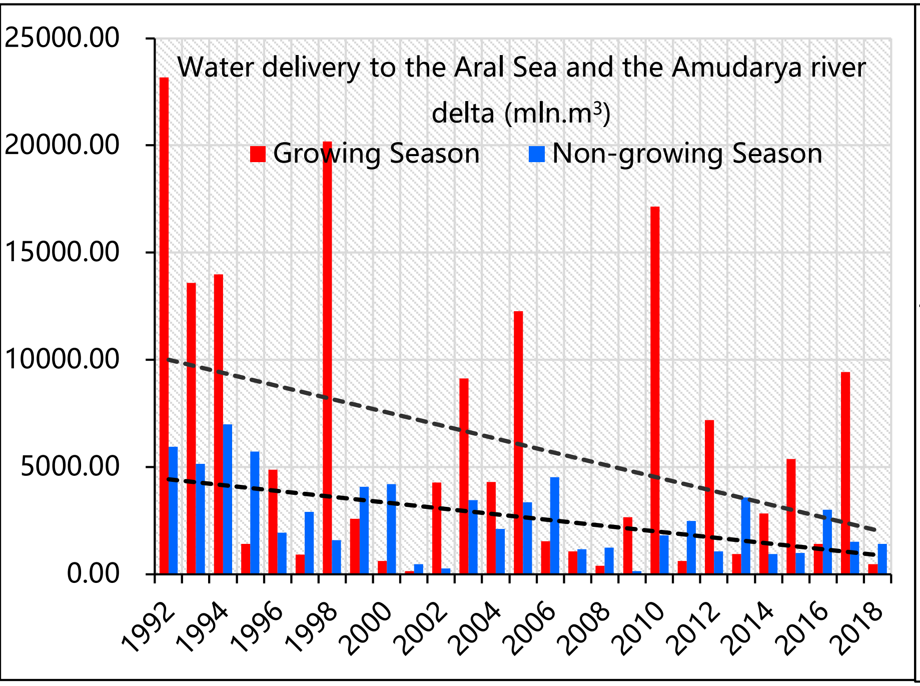
Results & Discussion

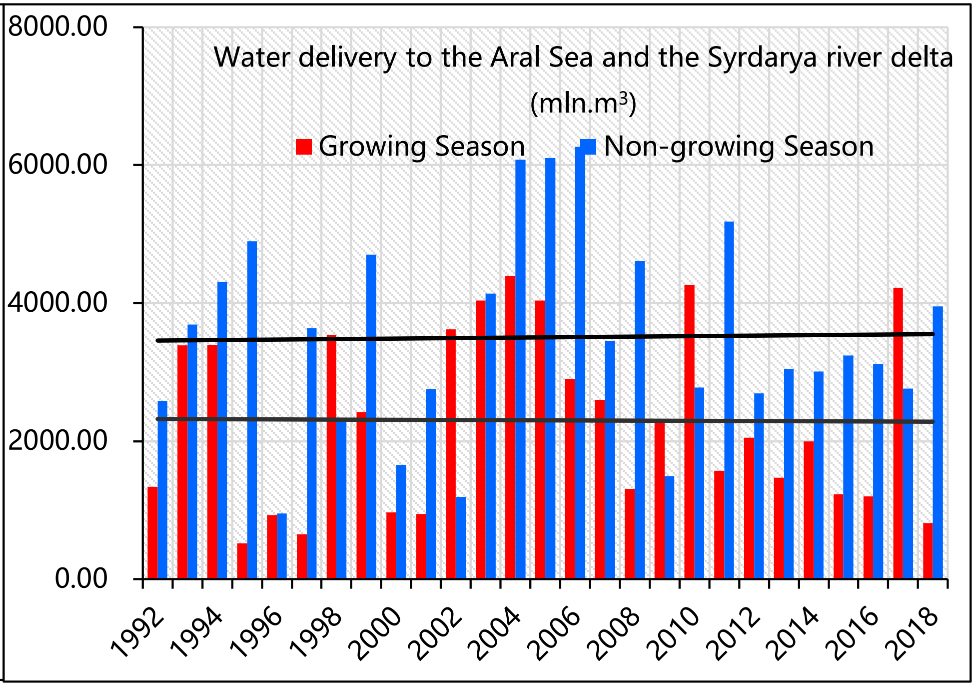
- The water surface area decreased from **67.5×10³ m²** in 1911 to **6.99×10³ m²** in 2018; the water volume decreased from **1078 km³** in 1911 to **69.31 km³** in 2018; and the water level decreased from **53.32** m in 1911 to **31.03** m in 2018.

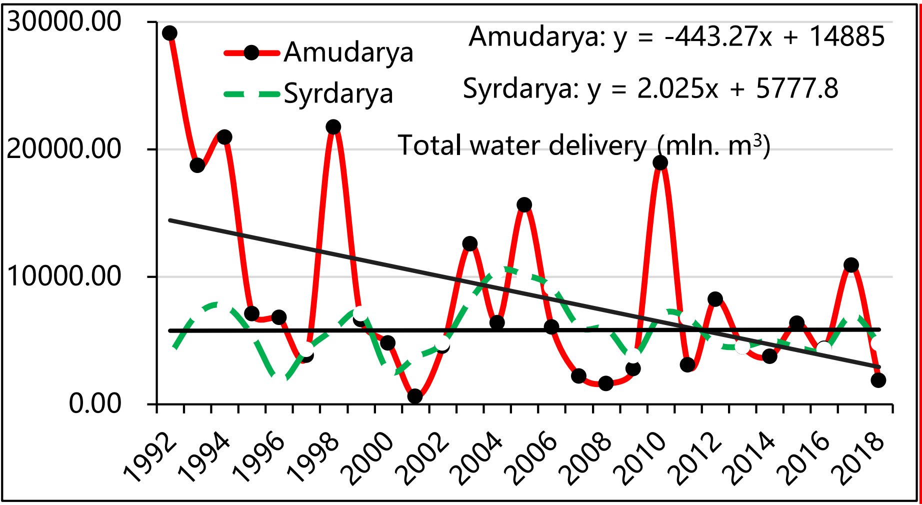


Lakes

Results & Discussion

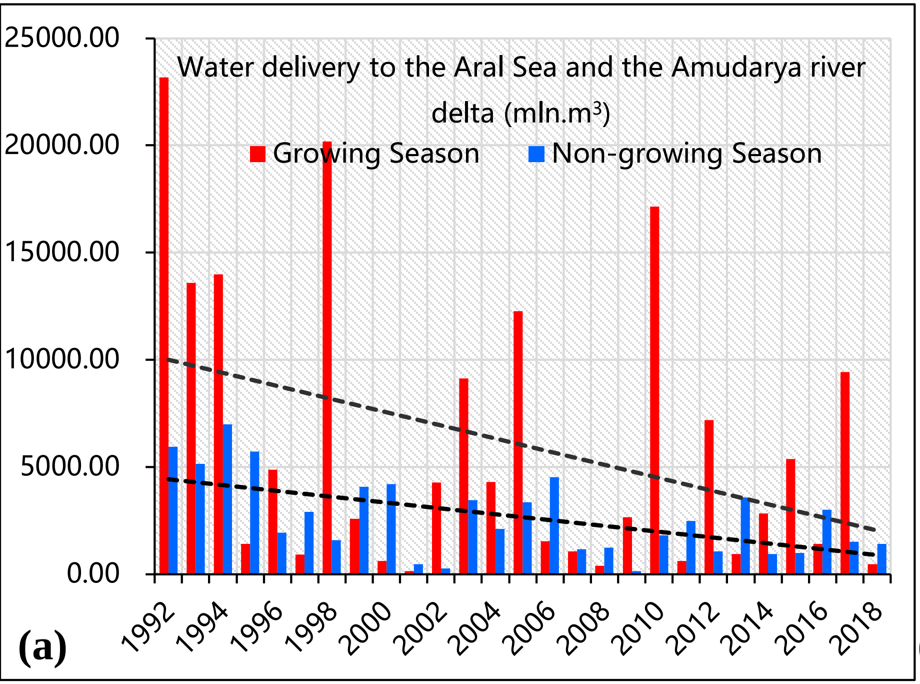




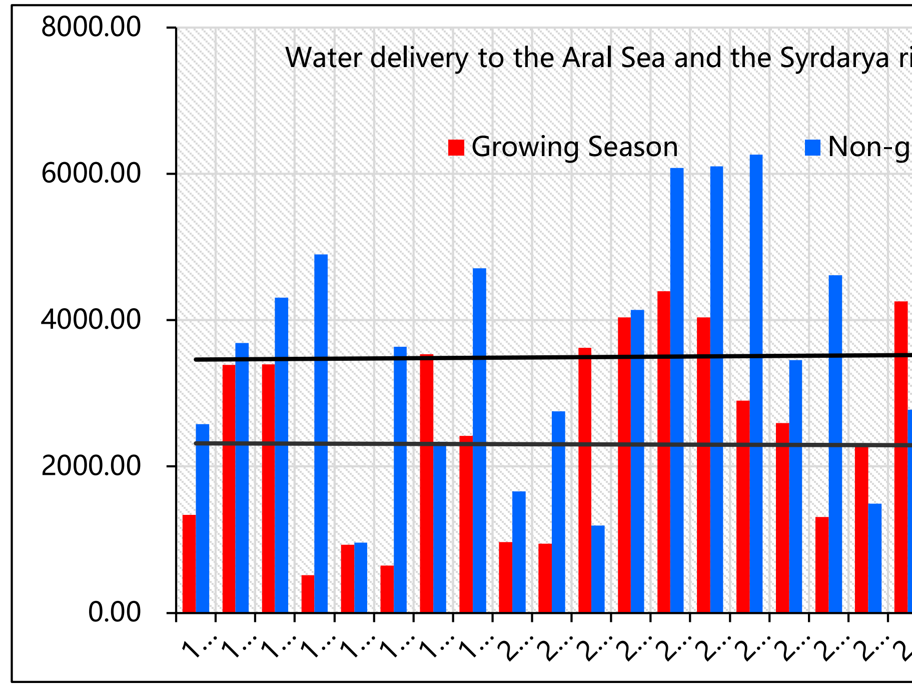


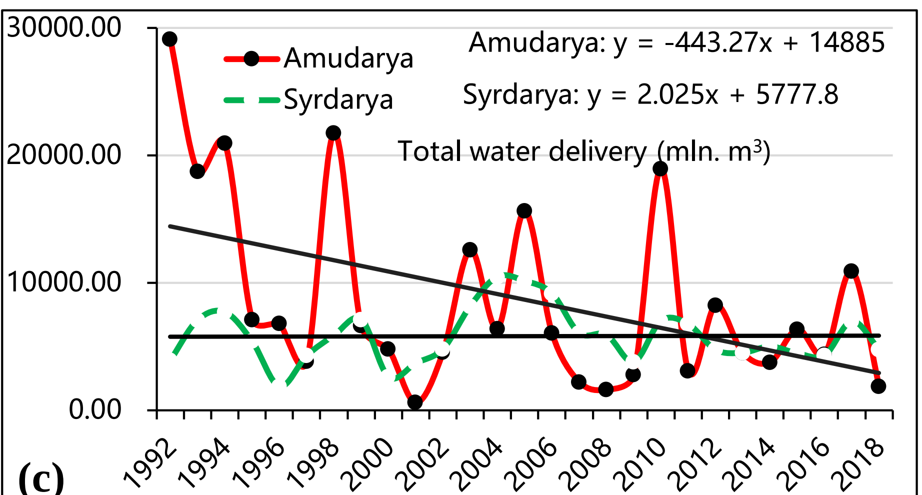
- During the period 1992-2018, the water delivery to the Aral Sea and the Amudarya river Delta decreased significantly for both growing season and non-growing season.

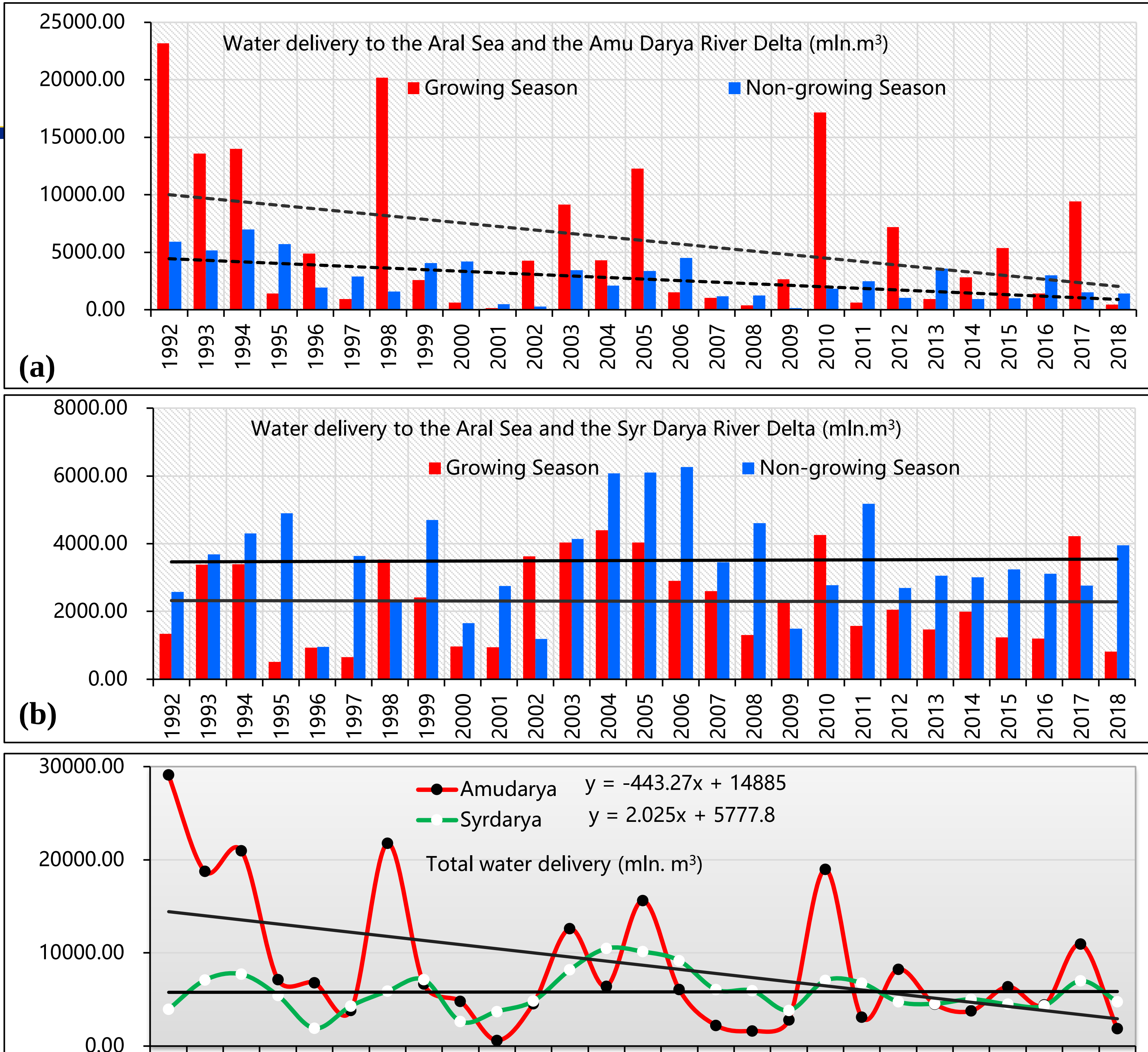
Results & Discussion



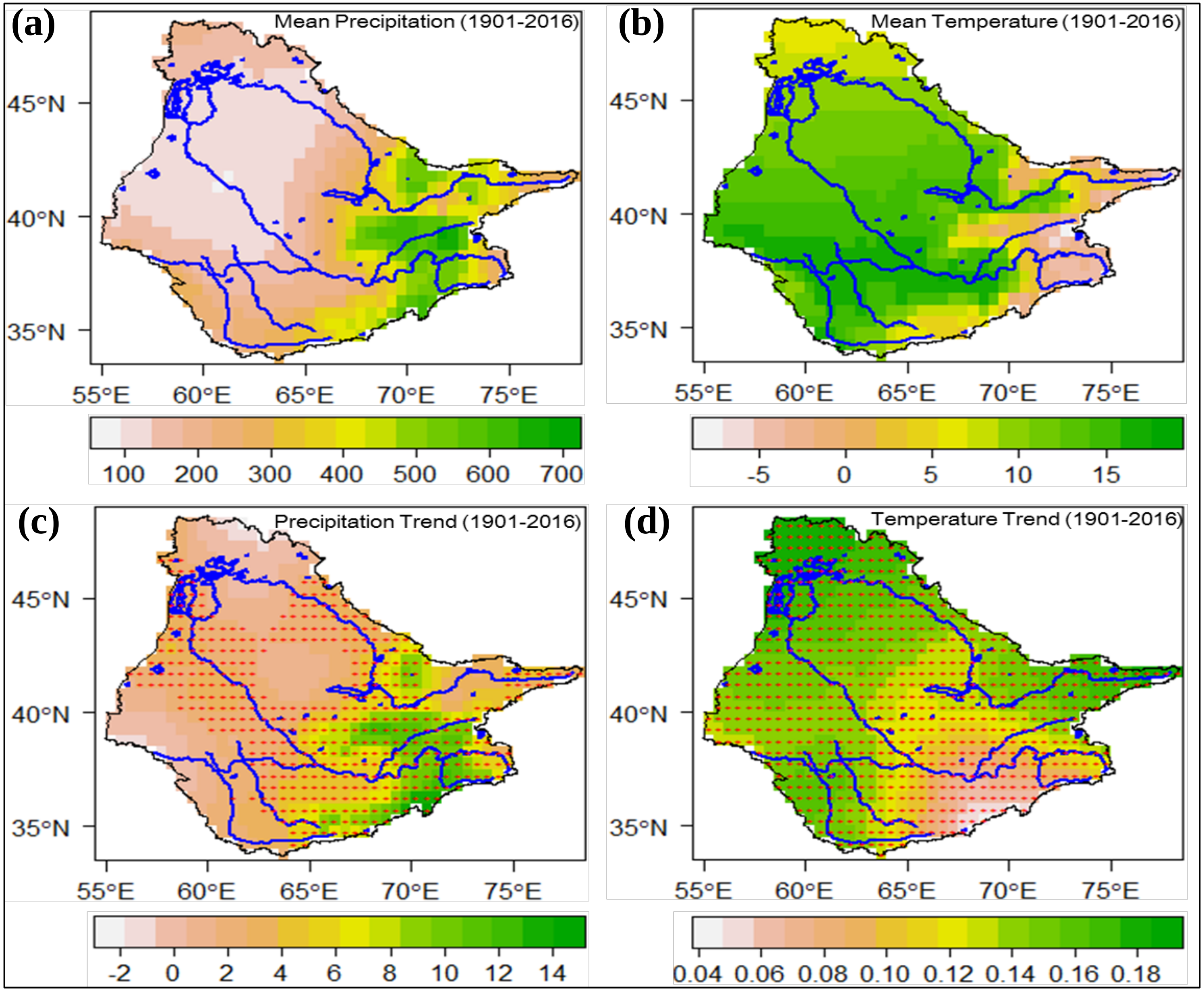
(b)

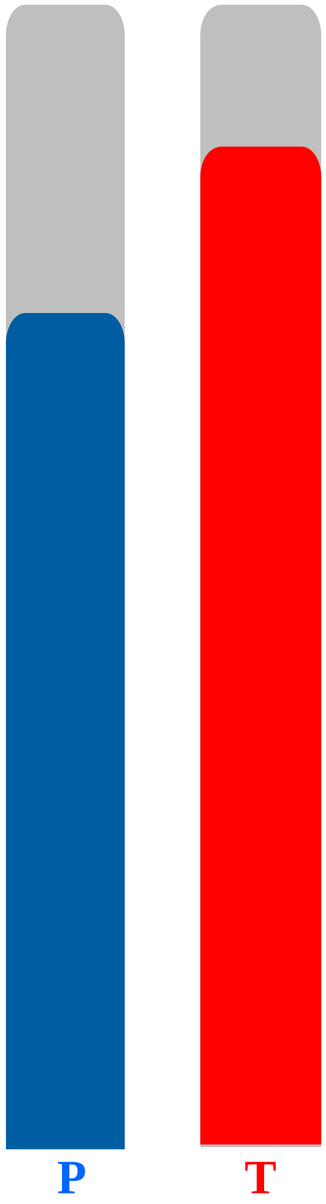




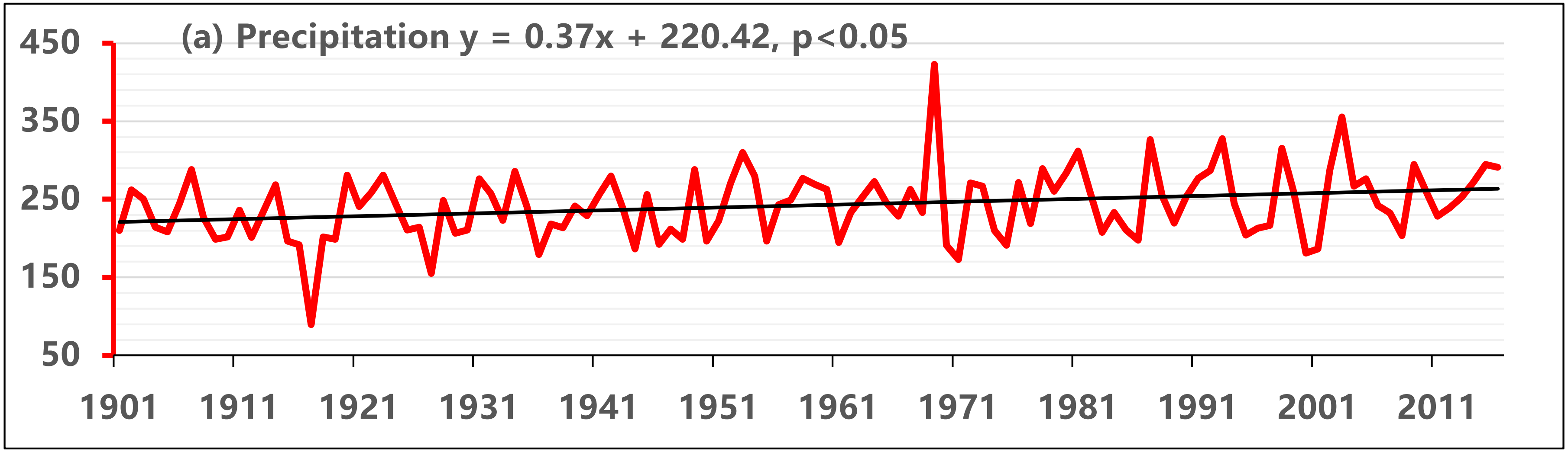

Water delivery to the Aral Sea and the Amu Darya River Delta (mln.m³)
Growing Season
Non-growing Season
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
(a)
Water delivery to the Aral Sea and the Syr Darya River Delta (mln.m³)
Growing Season
Non-growing Season
8000.00
6000.00
4000.00
2000.00
0.00
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
(b)
Amudarya
y = -443.27x + 14885
Syrdarya
y = 2.025x + 5777.8
Total water delivery (mln. m³)
30000.00
20000.00
10000.00
0.00

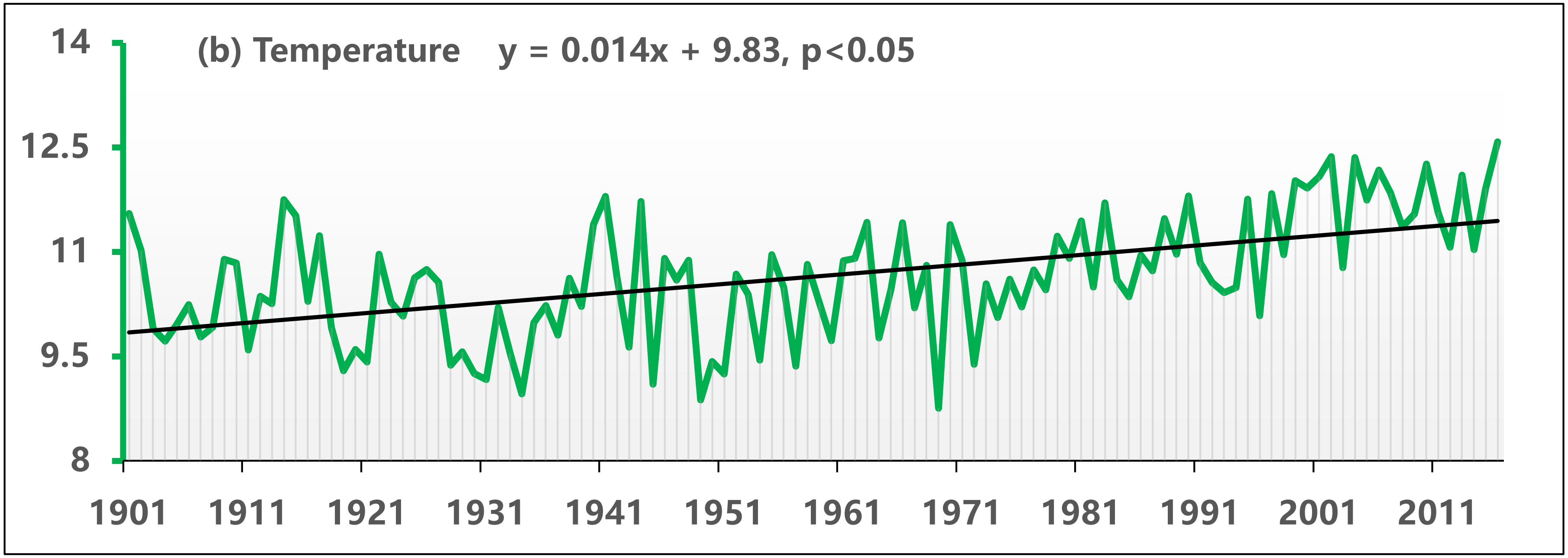
Results & Discussion





Results & Discussion





Results & Discussion

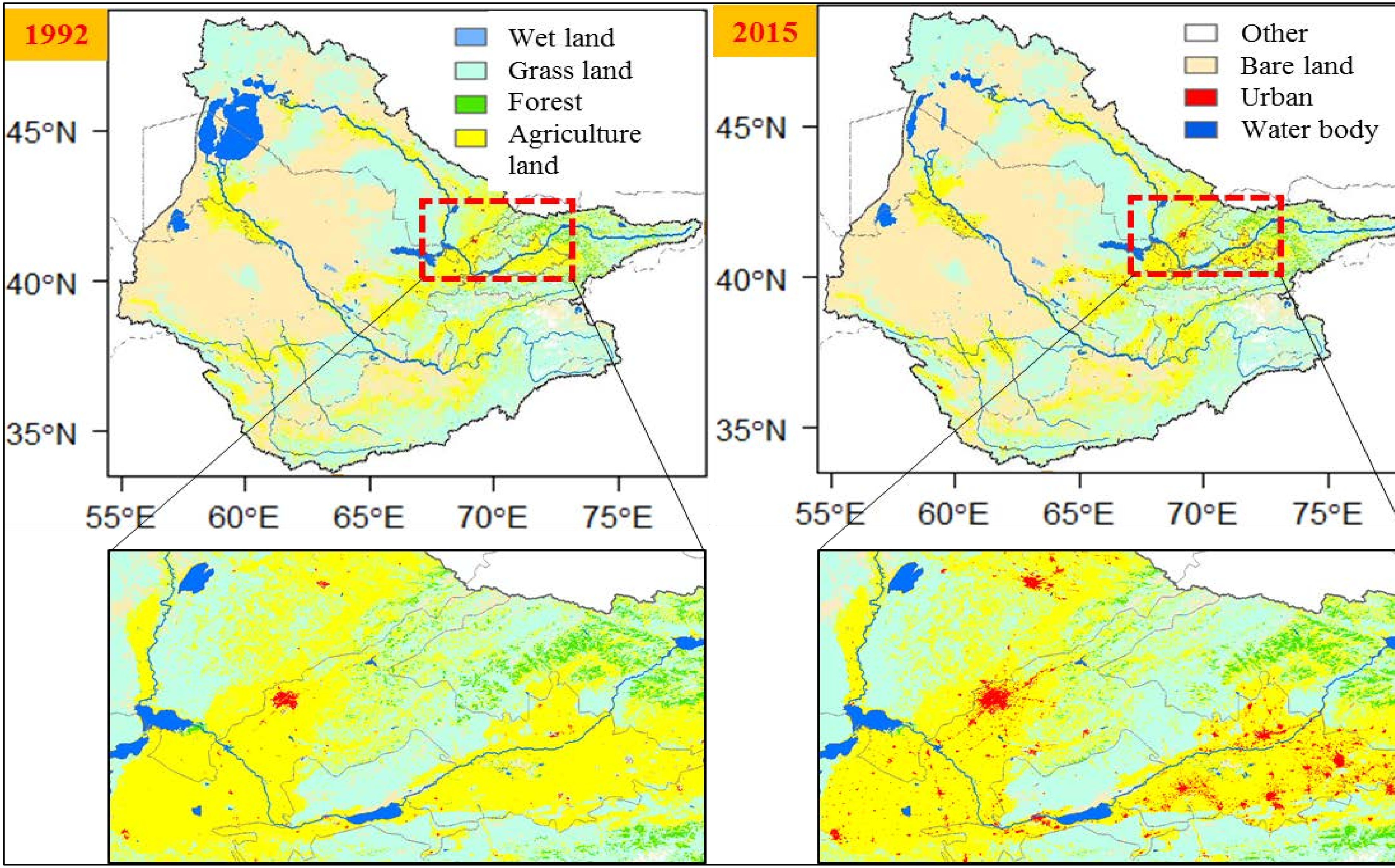
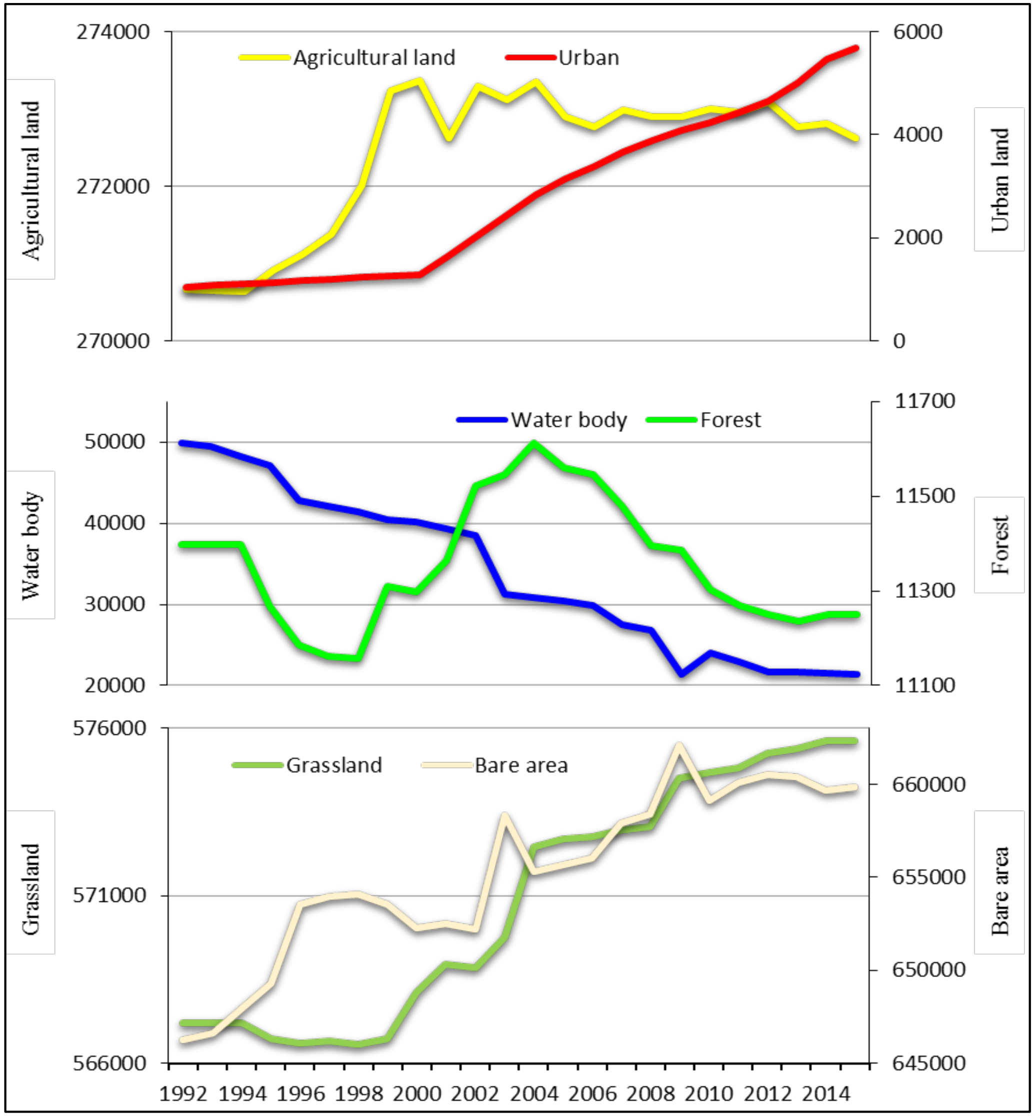


Figure 9. Maps of the land covers in the Aral Sea Basin in 1992 and 2015.

Results & Discussion



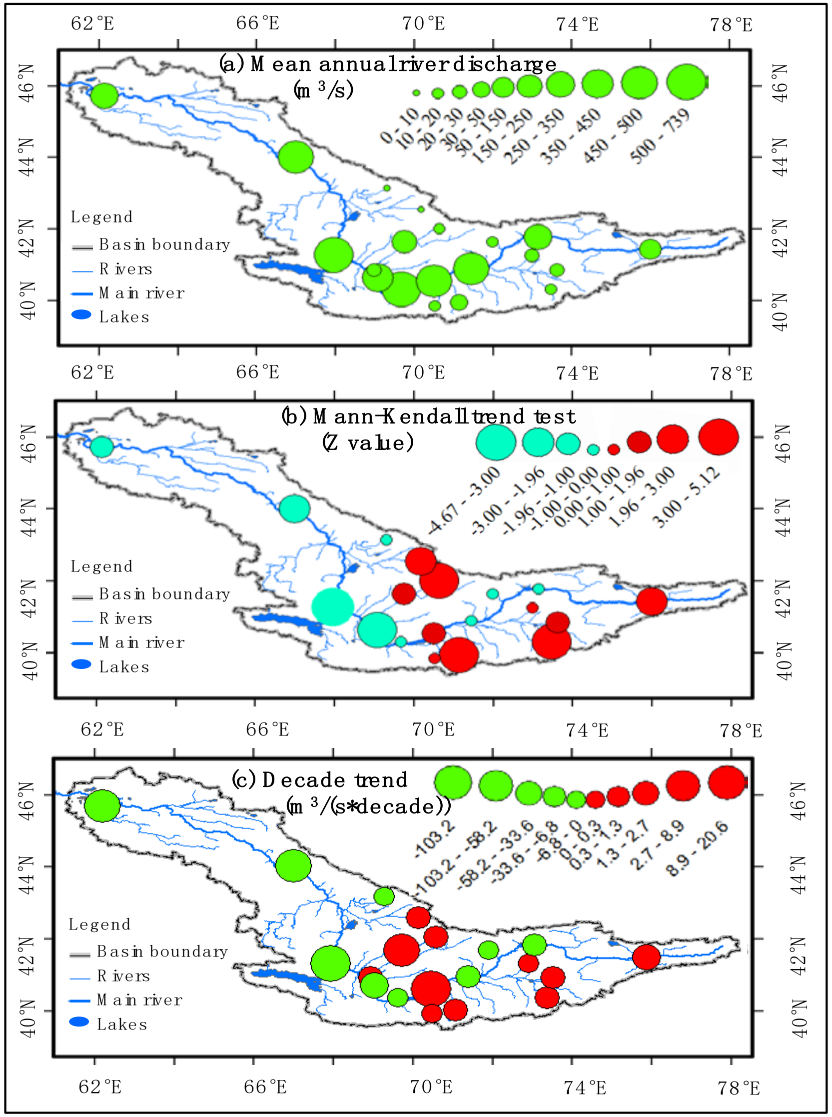


Figure 10. Maps of the land covers in the Syr Darya River Basin in 1992 and 2015.

(From Zou et al. 2019)

Figure 11. Map of (**a**) the mean annual river discharge (m^3/s), (**b**) the Mann–Kendall trend test (Z), and (**c**) the trend for each decade ($m^3/(s_*decade)$)

Results & Discussion

An abrupt point (in 1973) was detected at Station 8, dividing the record into two time periods, including 1930–1973 and 1974–2006. The main reason is that in 1973, the largest dam (Toktogul Dam) was finished in order to control the river discharge to provide sufficient irrigation water. The annual average river discharge of these two intervals at station 8 were 565.7 and 355.3 m^3/s, respectively, a decrease of 210.5 m^3/s between these two time periods.

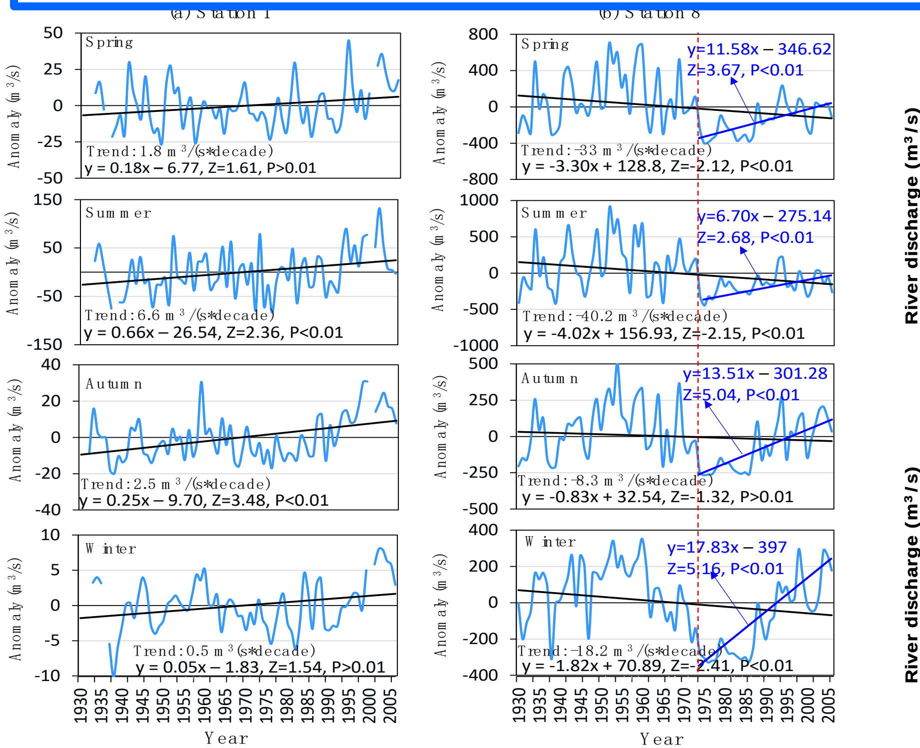


Figure 12. Time series, trends, and abrupt changes of the seasonal river discharge anomaly (m^3/s) at (a) station 1 and (b) station 8 during the study period. (From Zou et al. 2019)

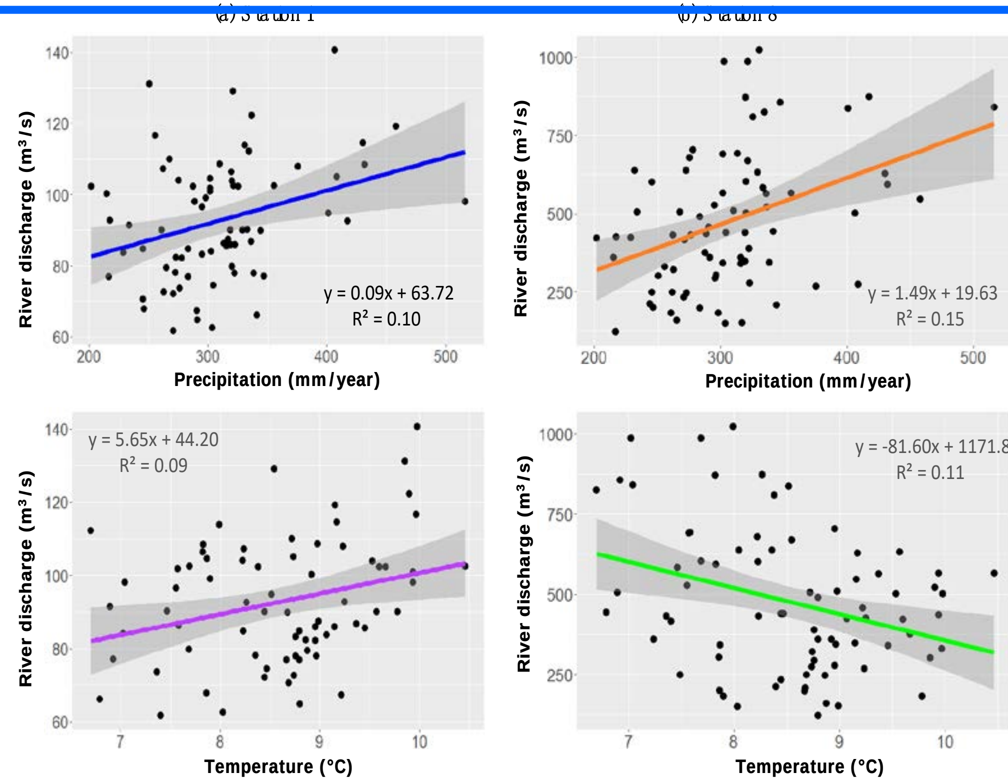


Figure 13. Correlations between the annual precipitation, temperature, and river discharges at stations 1 and 8 in the Syr Darya River Basin. The straight line represents the linear regression lines and the black shade is a 95% confidence band.

Results & Discussion

Table 1. Multiple linear regression of the river discharge (m^3/s) against the precipitation (mm) and temperature (°C) in the Syr Darya River Basin.

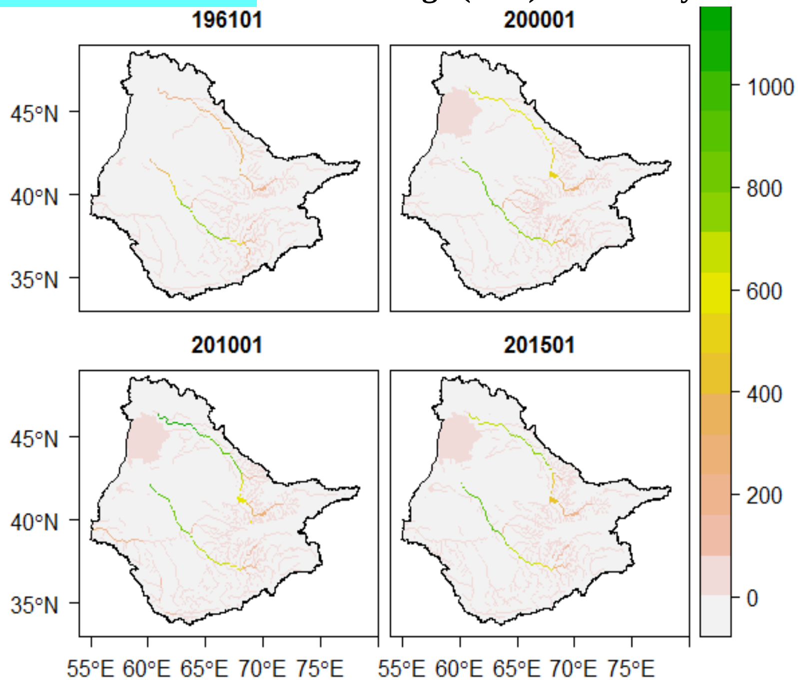
Station	Parameter	Interception	Precipitation	Temperature
Station 1 (on the Upper Sya Darya River)	Coefficients	0.55	0.11	6.85
	Standard error	19.78	0.03	1.97
	t value	**0.02**	**3.56**	**3.48**
	p value	>0.05	<0.001	<0.001
Station 8 (on the down Sya Darya River)	Coefficients	684.42	1.40	−74.95
	Standard error	257.13	0.39	25.57
	t value	**2.66**	**3.60**	**−2.93**
	p value	<0.001	<0.001	<0.005

A multiple linear regression analysis was performed with the river discharge as the dependent variable (and the precipitation and temperature as independent variables). The regression t values for the precipitation and temperature at station 1 were 3.56 (p < 0. 001) and 3.48 ($p < 0.001$), respectively, reflecting a positive correlation between the climatic factors (both the temperature and precipitation) and the river discharge. Additionally, the magnitude of the t values at stations 1 and 8 indicates that the effects of the interannual variability in precipitation on the river discharge are the same as those of the interannual variability in temperature.

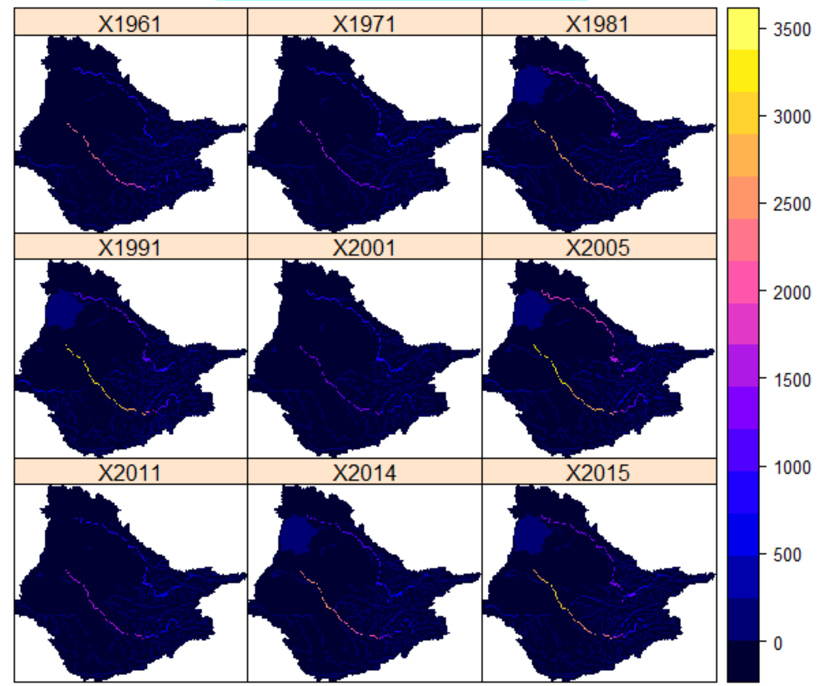
Results & Discussion

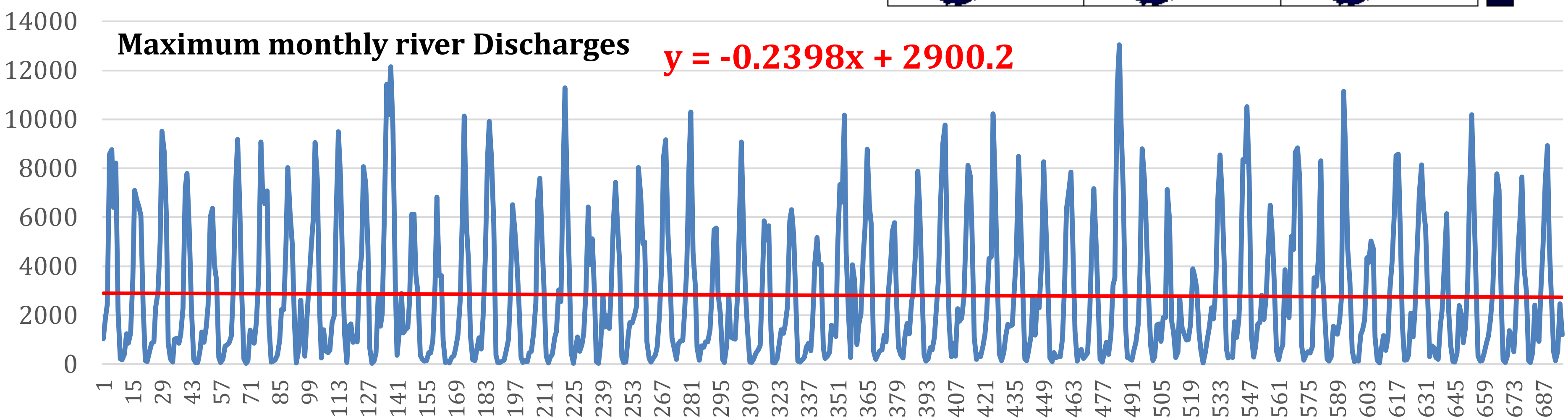
Discharge simulations

Discharge (m^3/s) in January



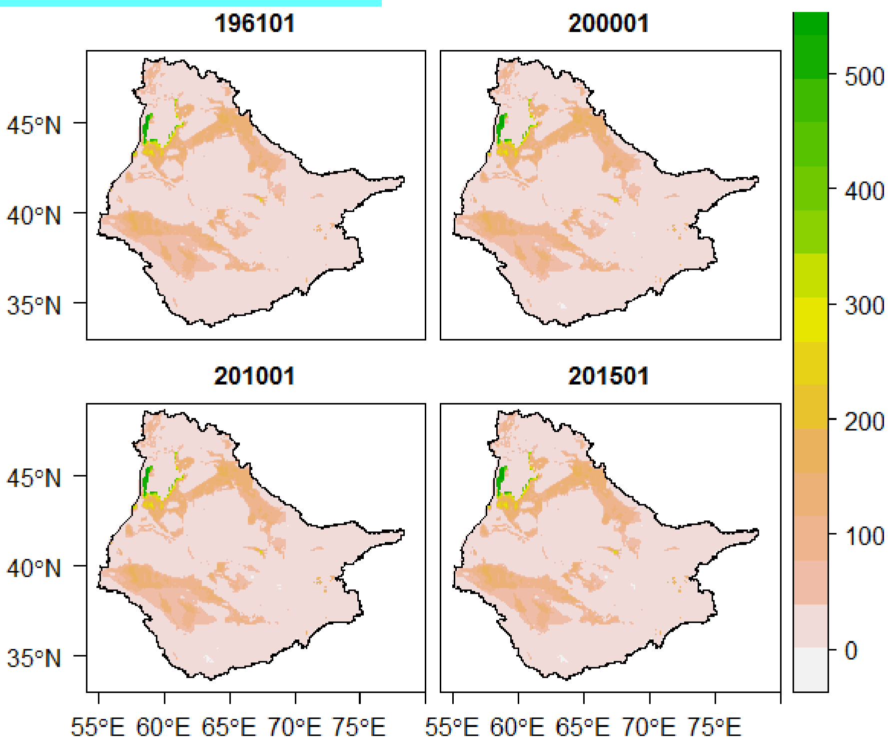
Annual discharge (m^3/s)

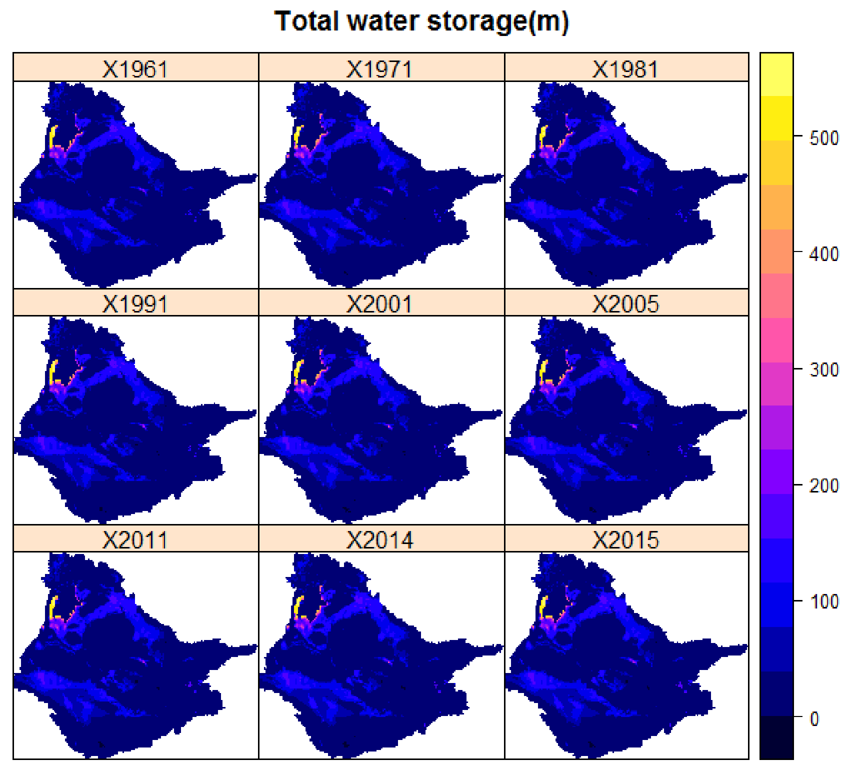


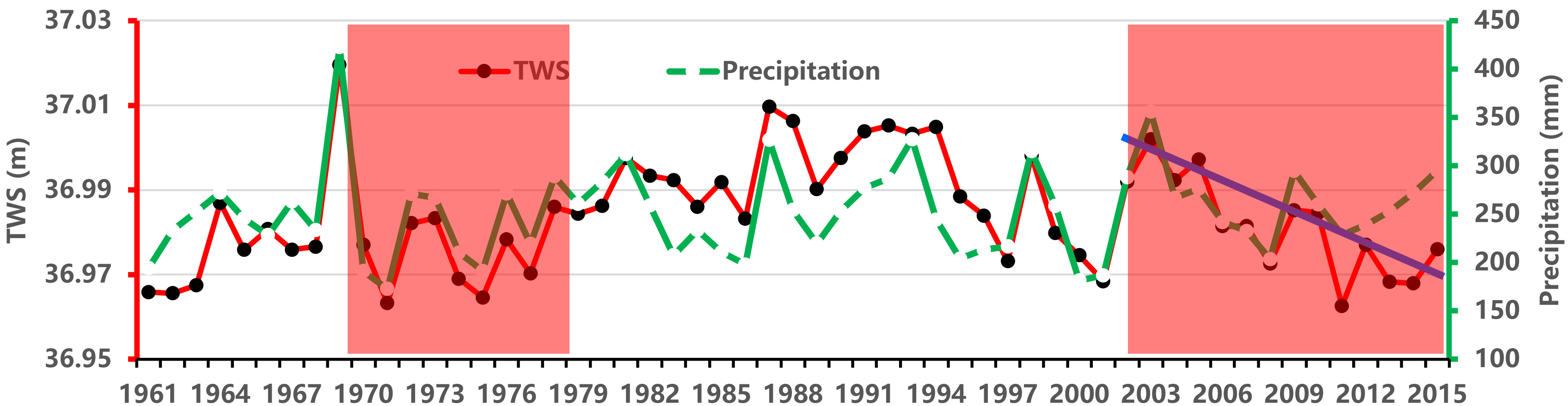


Results & Discussion

Water storage simulations







Conclusions

- **Increased precipitation and melting water led to an increase in that flows from upper rivers to middle and lower rivers.**

- **Expansion of urban land (219.76 km^2/year) and agricultural land (96.03 km^2/year) from 1992 to 2015 has increased water consumption, exacerbating the stress of water resources in the Aral Sea Basin.**

- **Establishment of reservoirs and irrigation canals had significantly cut off the river discharge, especially from the 1960s.**

TNANKS FOR YOUR ATTENTION!

QUESTIONS?