


# Investigation of the Intense Mass Depletion Trend in Northwest China

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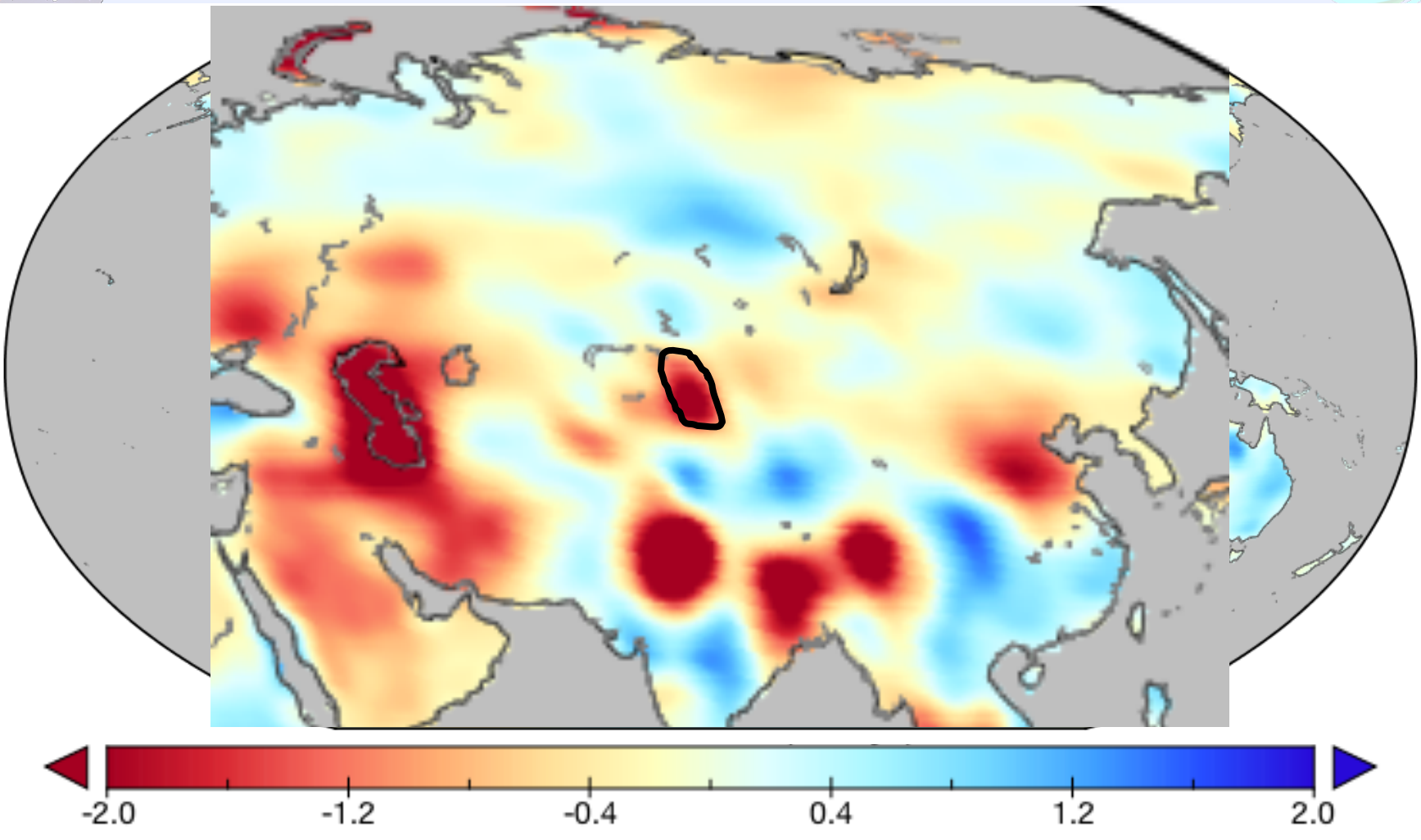
# “Trends” in Terrestrial Water Storage*, 2002-2016




*Linear rate of change of TWS (cm/yr) after removing the seasonal cycle based on JPL GRACE Tellus mascon product (Watkins et al., *JGR*, 2015)

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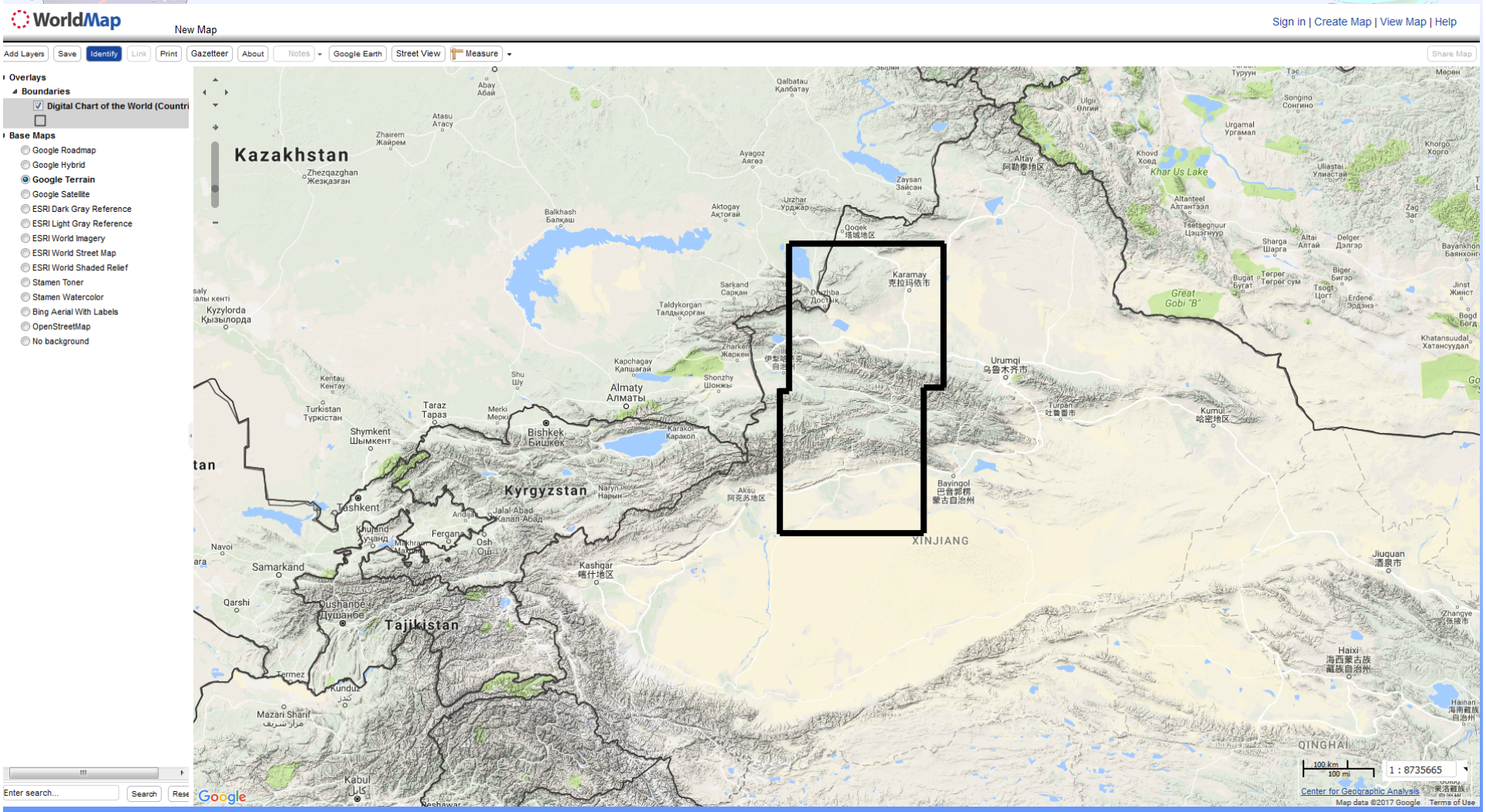
# Northwest China Region




Location of JPL mascons (641 & 726) in NW China

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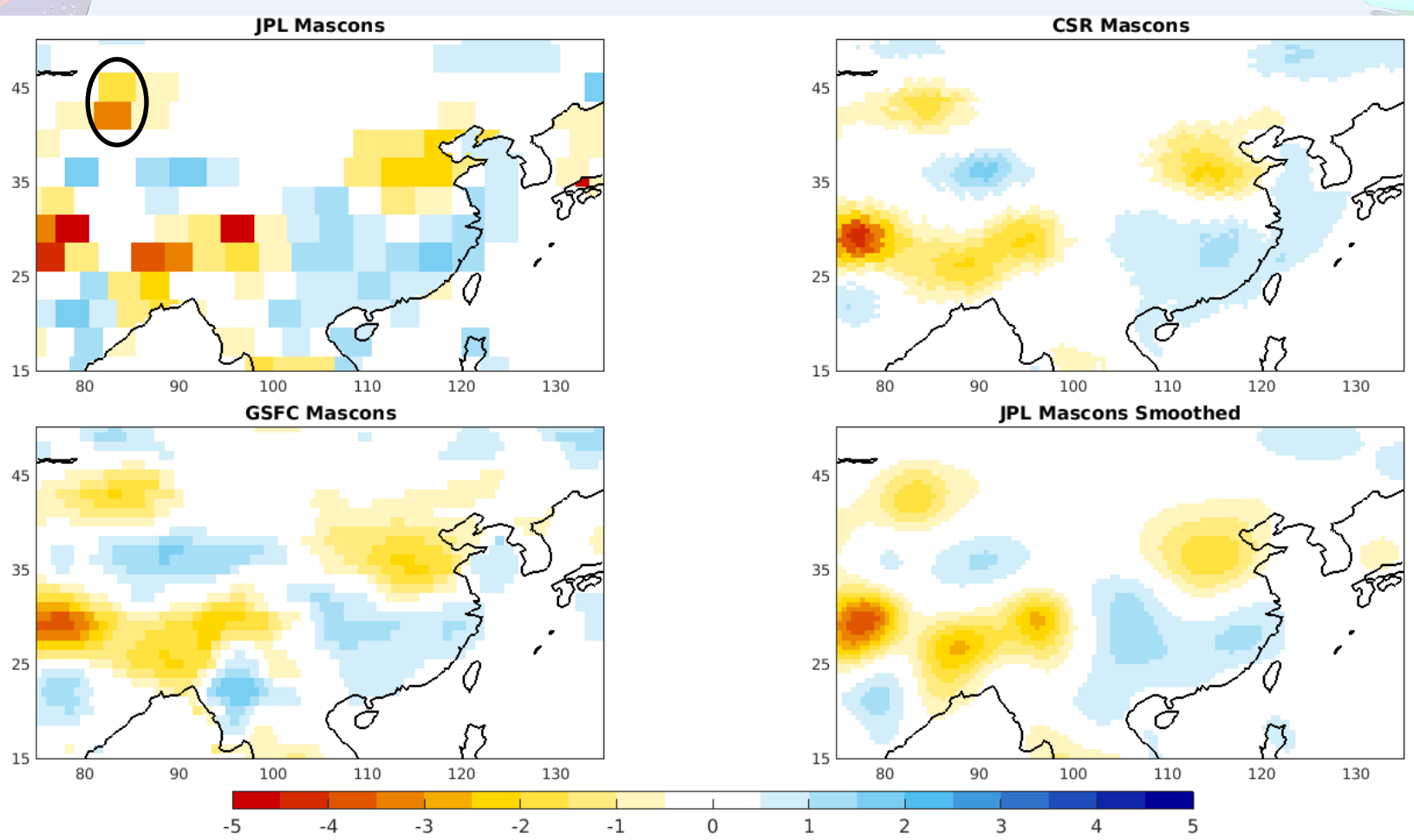
# Comparison of Trends in Three Mascon Products




NW China region linear trend estimates

| | | | |
|---|---|---|---|
| -5.4 Gt/yr | JPL mascon (3°) | -2.2 Gt/yr | CSR mascon (1°) |
| -1.7 Gt/yr | GSFC mascon (1°) | -2.8 Gt/yr smoothed | JPL mascon 200 km |

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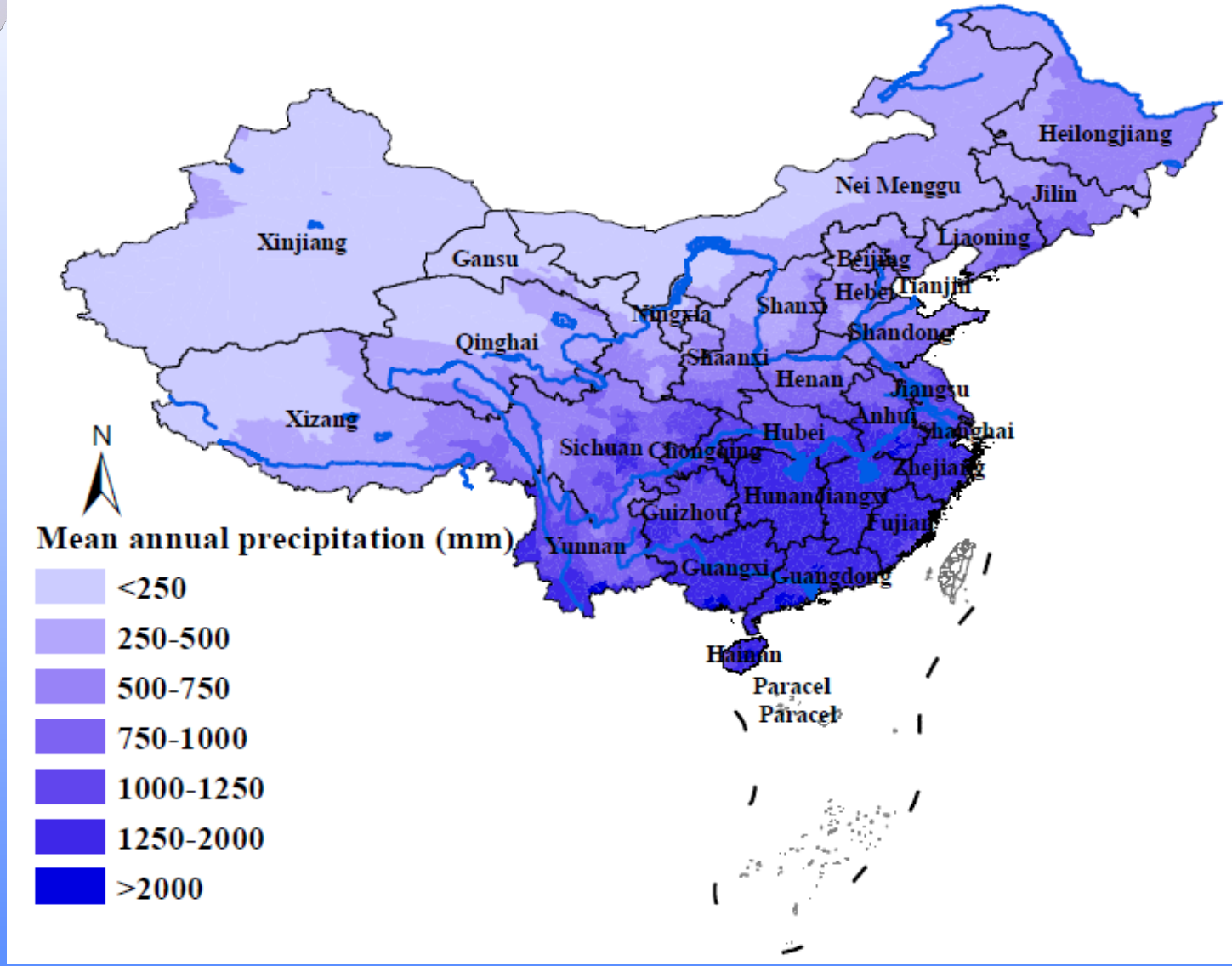
# Mean Annual Precipitation in China




Chen, X., Naresh, D., Upmanu, L., Hao, Z., Dong, L., Ju, Q., ... & Wang, S. (2014). China's water sustainability in the 21st century: a climate-informed water risk assessment covering multi-sector water demands. *Hydrology and Earth System Sciences*, *18*(5), 1653.

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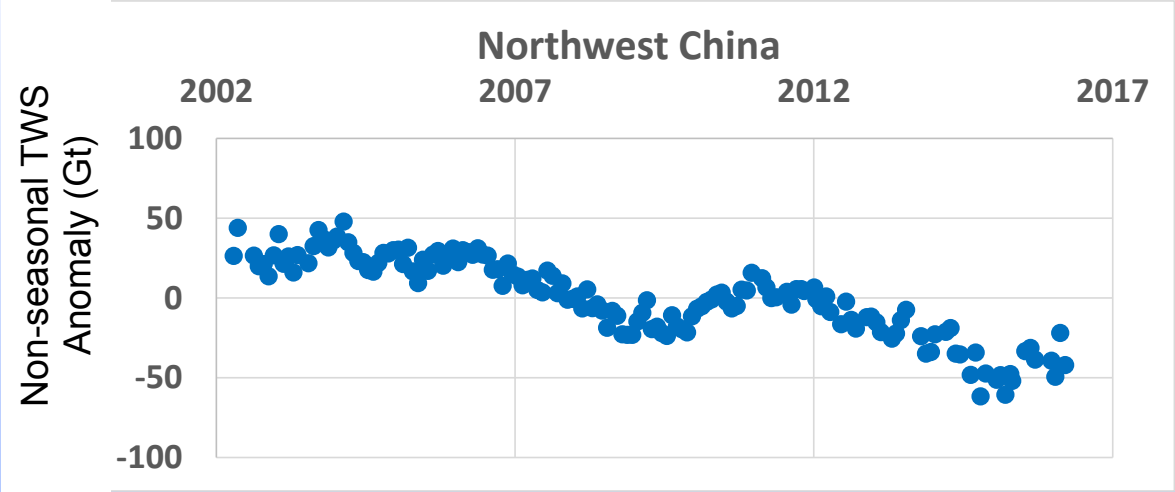
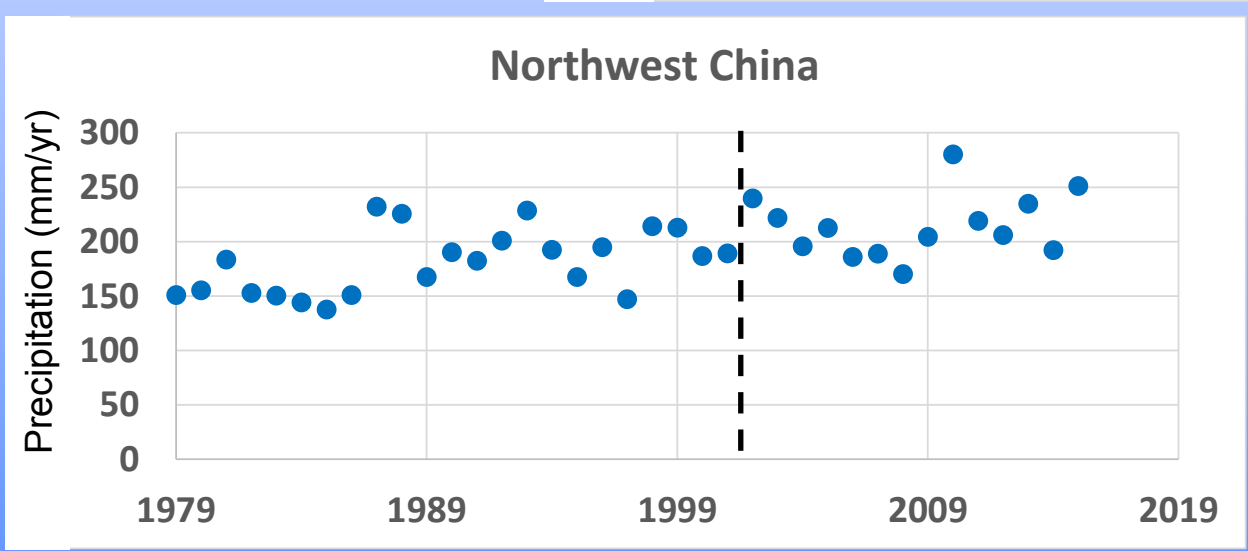
# TWS and Precipitation Time Series




Drought is not a valid explanation for the observed trend

194 mm/yr Mean annual precipitation 1979-2015
213 mm/yr Mean annual precipitation 2003-2015
+1 mm/yr Linear precipitation trend 2003-2015

*Data from the Global Precipitation Climatology Project (GPCP) v. 2.3 (Adler et al., 2016)*

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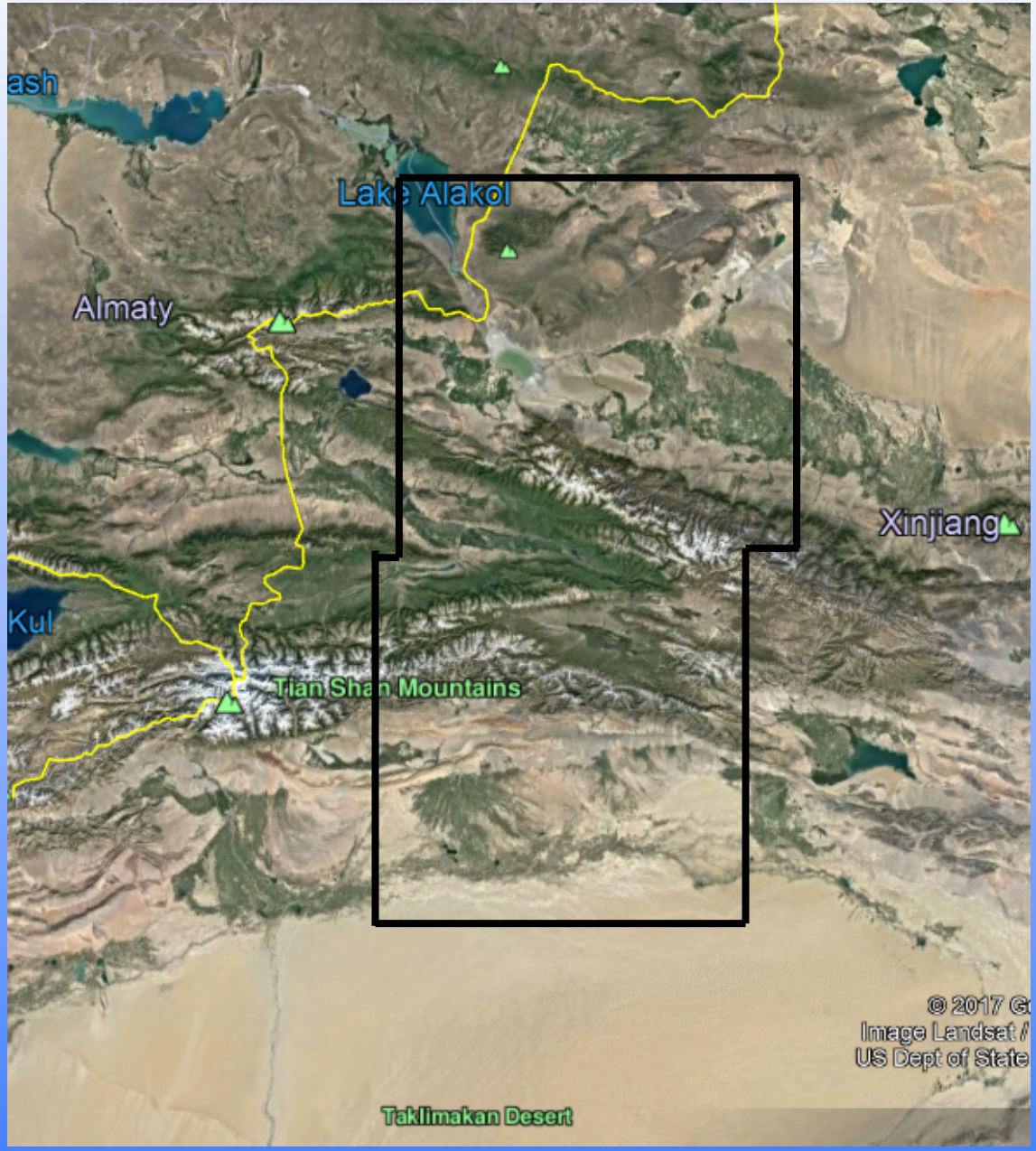
# Satellite Imagery

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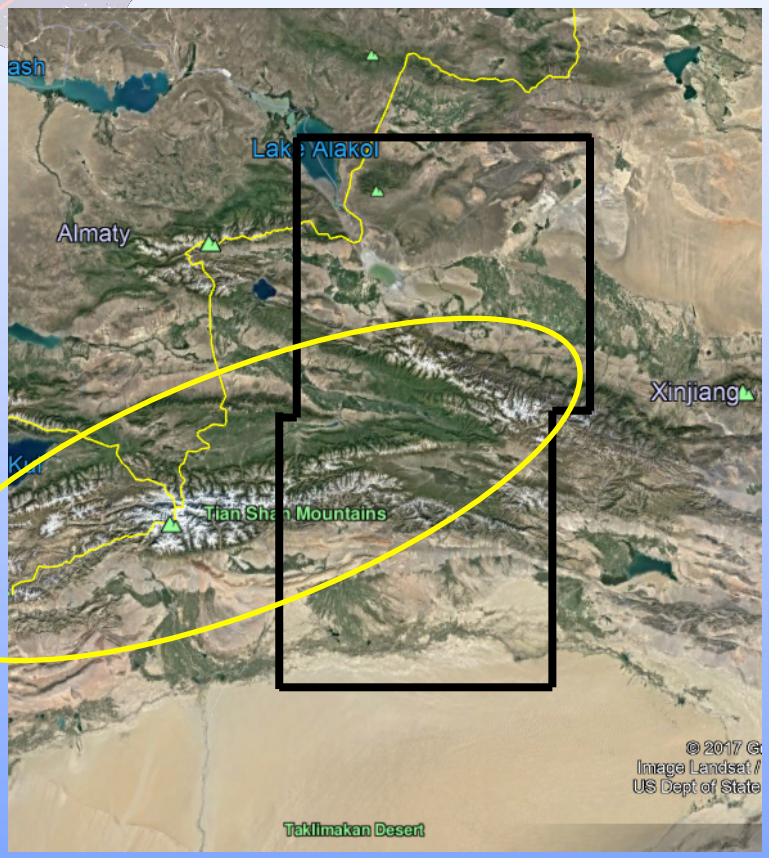
# Glacier Loss over the Tien Shan Mountain Range




Tien Shan glacier loss estimates based on ICESat observations (2003 to 2009):

5.4 ±2.9 Gt/yr *Farinotti et al. (2015)*

7.5 ±3.4 Gt/yr *Gardner et al. (2013)*

TWS decline in the NW China region based on GRACE (2003-2009):

8.3±3.5 Gt/yr *This study*

Our NW China region encompasses less than half of the area of glacier melt, which suggests that melting glaciers do not fully explain the observed mass loss.

Farinotti, D., Longuevergne, L., Moholdt, G., Duethmann, D., Mölg, T., Bolch, T., Vorogushyn, S., & Güntner, A. Substantial glacier mass loss in the Tien Shan over the past 50 years. *Nature Geoscience* **8**, 716-722 (2015).

Gardner, A. et al. A reconciled estimate of glacier contributions to sea level rise: 2003 to 2009. *Science* **340**, 852-857 (2013).

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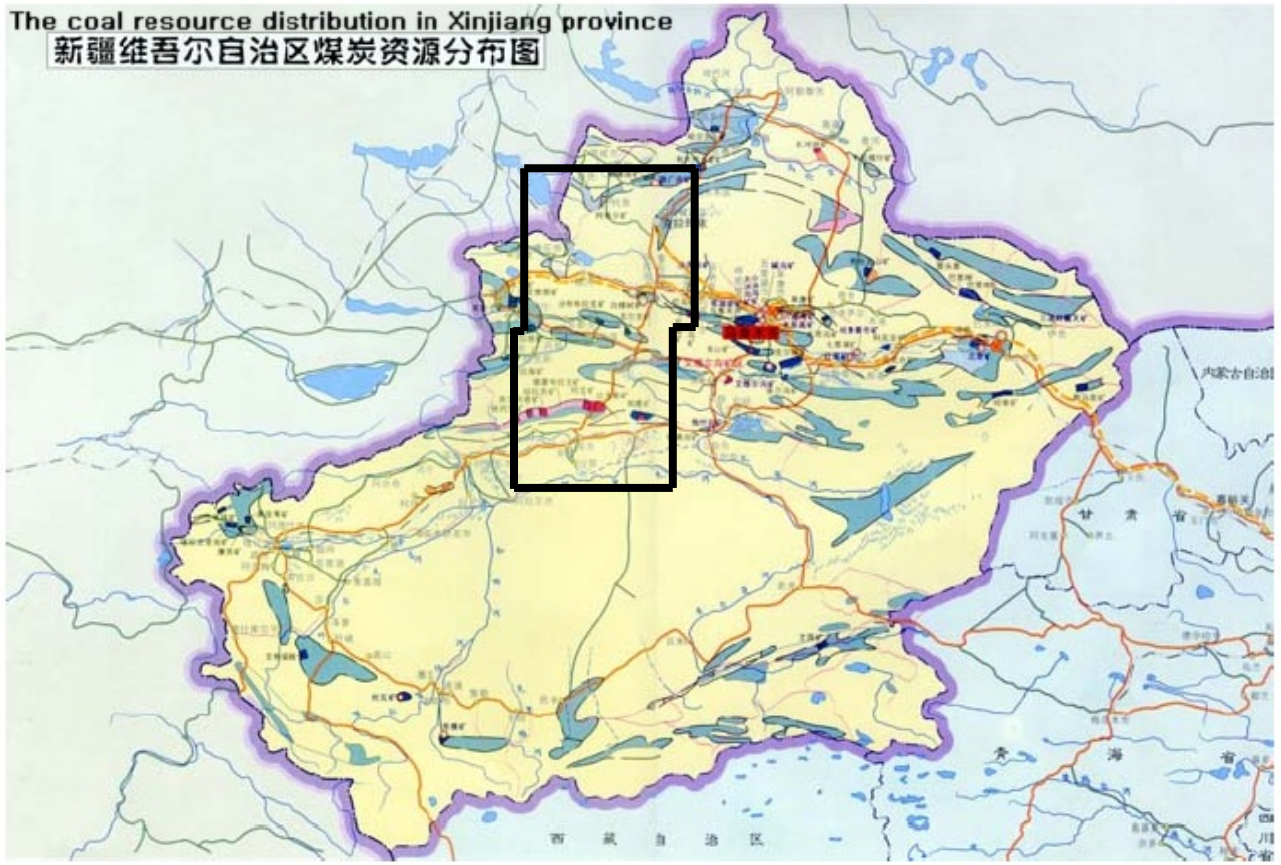
# Coal Mining




Tang, L. (2009). *Mapping the Energy Use in Xinjiang, Province of China*, Masters Thesis, Gavle University, Gavle, Sweden.

Xinjiang province is one of the world's largest producers of coal. Coal mining involves dewatering the aquifers that the mines intersect, such that consequent groundwater depletion is probable.

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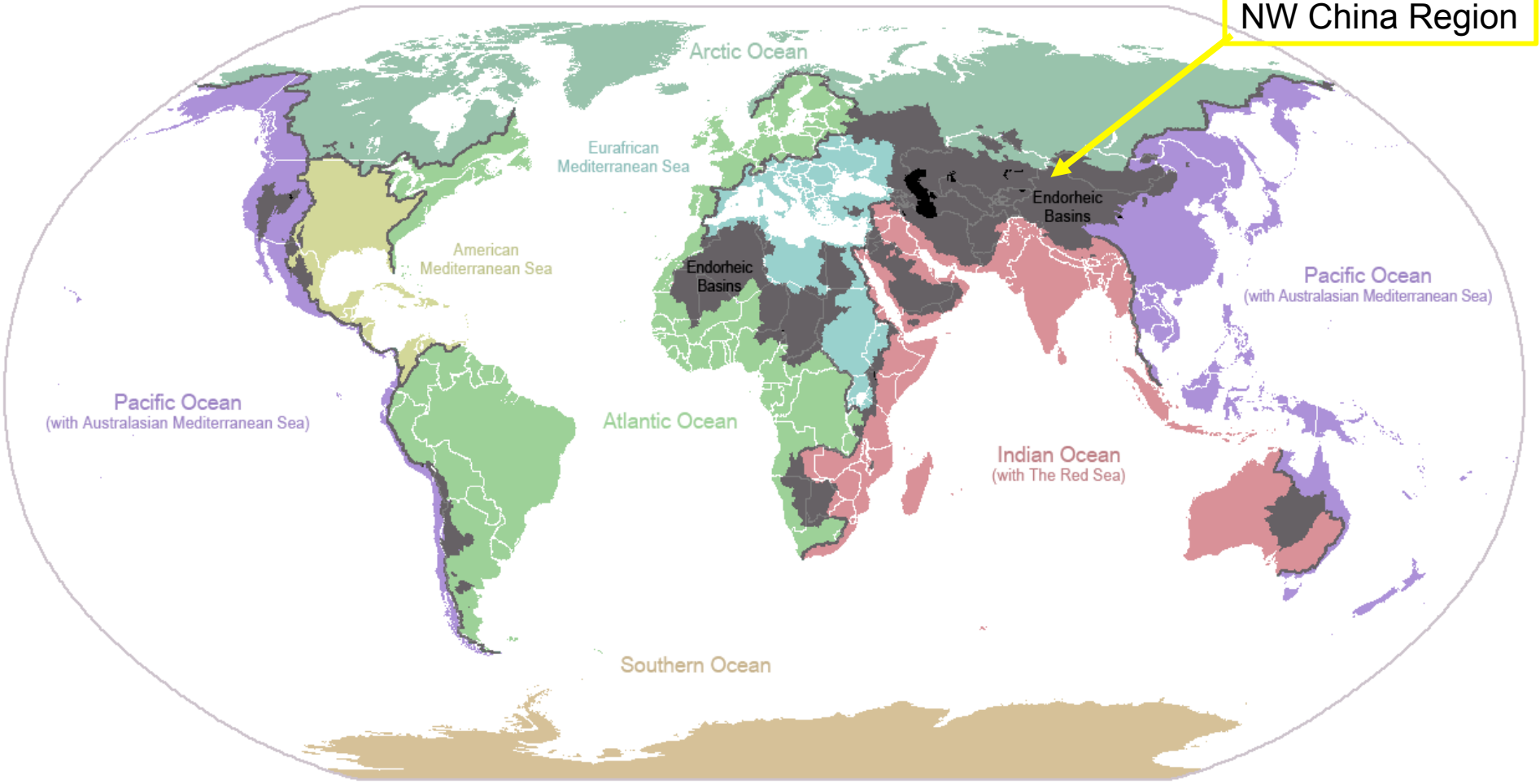
# Global Drainage Basins




The NW China region lies within an internally draining basin.

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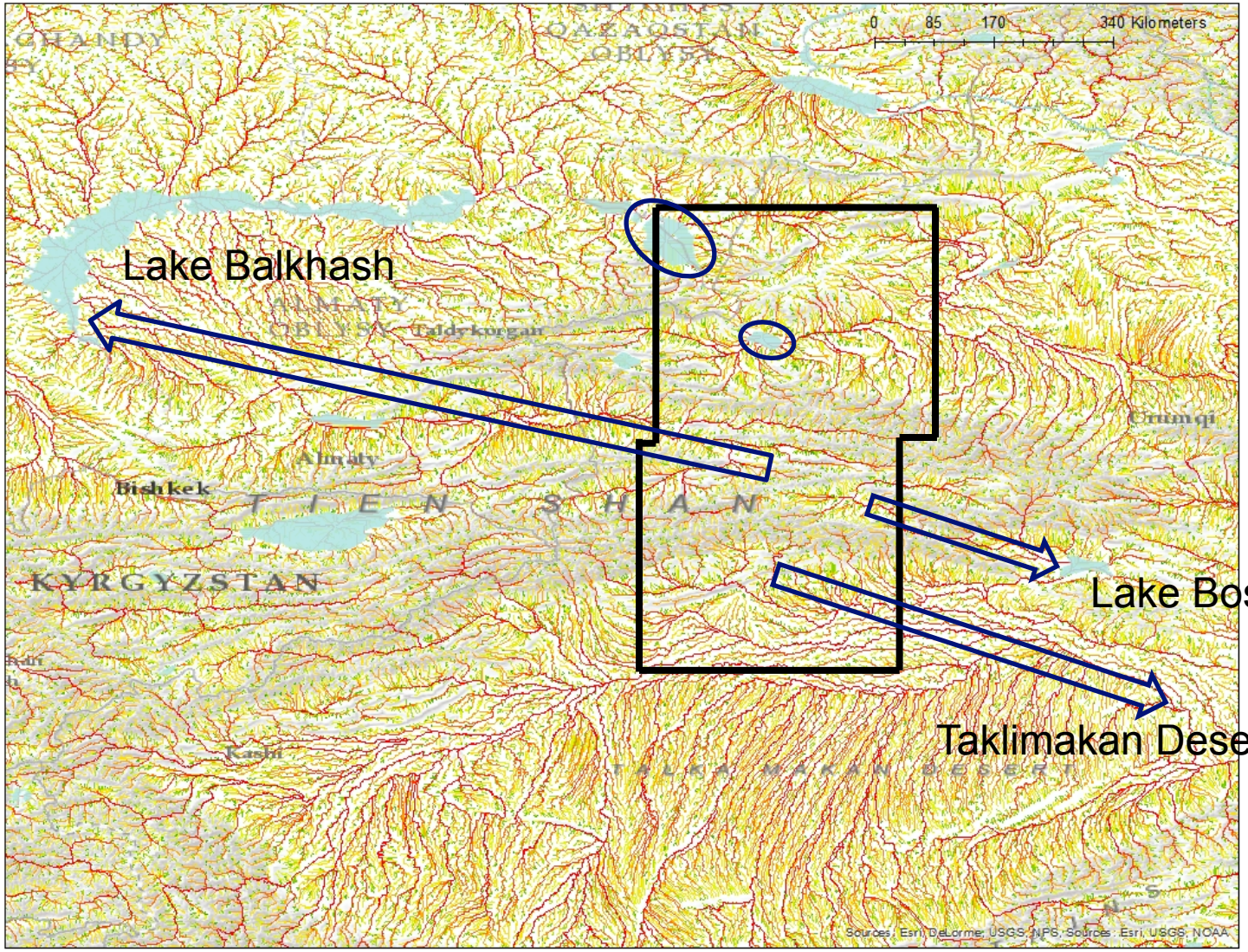
# River Runoff




Drainage from the NW China region does not go far.

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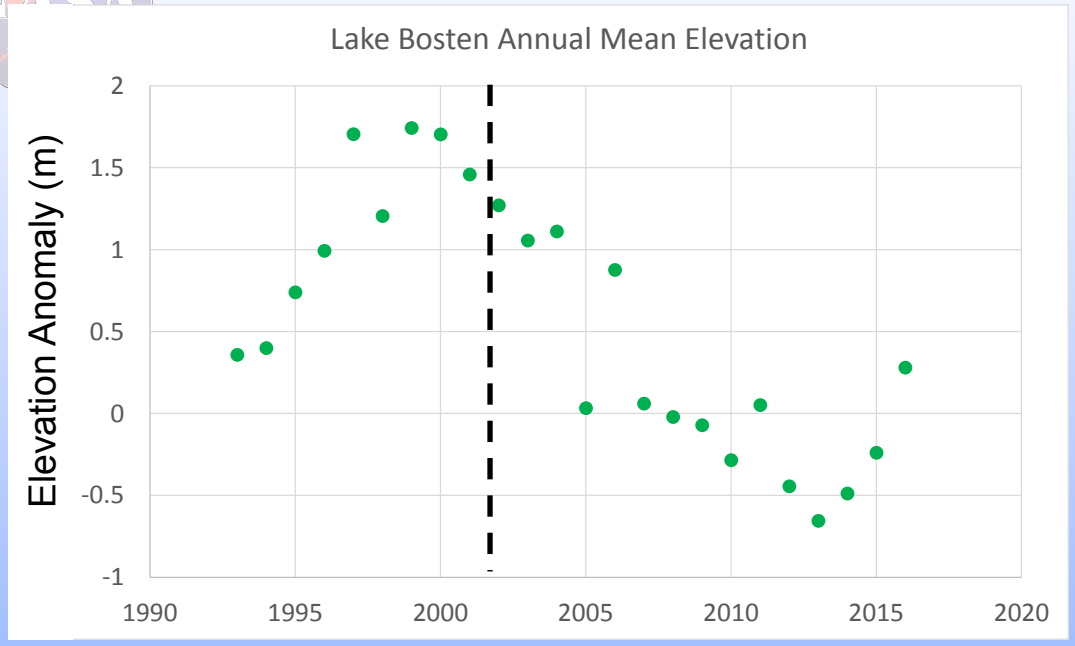
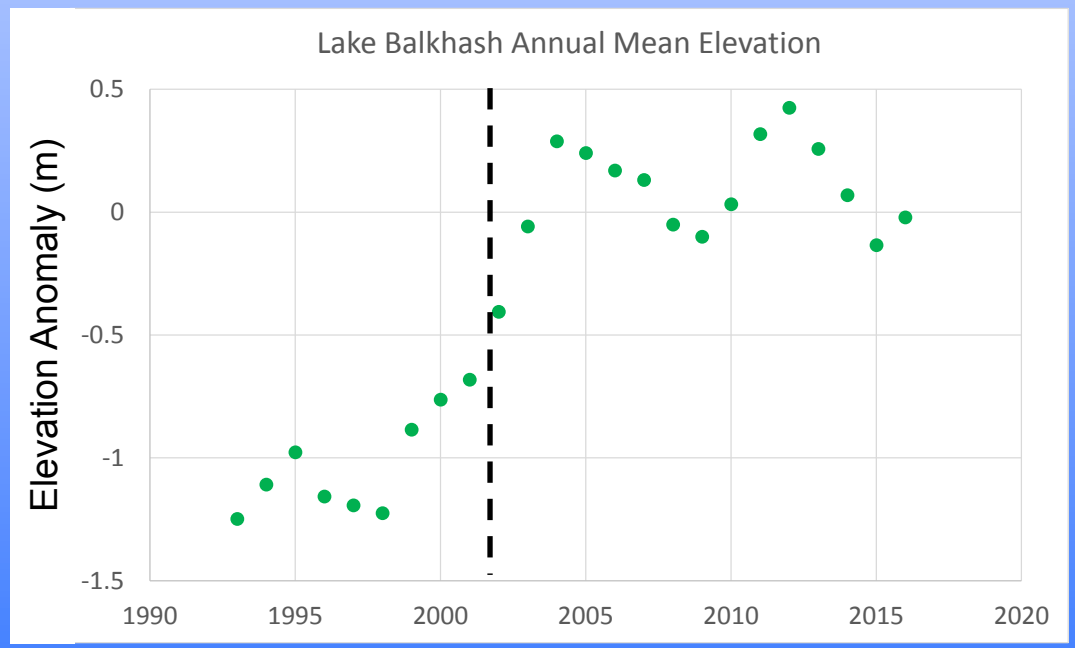
# Lake Elevations




Lakes to which the NW China region drains have not been gaining water during the study period.

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# Lake Elevations


**Vulnerable watershed.** Scientists predict that Balkhash will break up into several small lakes if inputs from the Ili River continue to decline.

Stone, R. (2012). For China and Kazakhstan, no meeting of the minds on water. *Science*, **337** (6093), 405-407.

"Since the mid-1980s, rain and snow have increased at the river's headwaters in the Tian Shan mountains in western China's Xinjiang Uygur Autonomous Region, Chinese data show. Yet in the past several years, the Ili's flow has declined precipitously, says Murat Nurumbetov, a Kazhydromet engineer in Almaty. The 'inescapable conclusion,' he asserts, is that Xinjiang is drawing more heavily for irrigation, industrial use, and drinking water."

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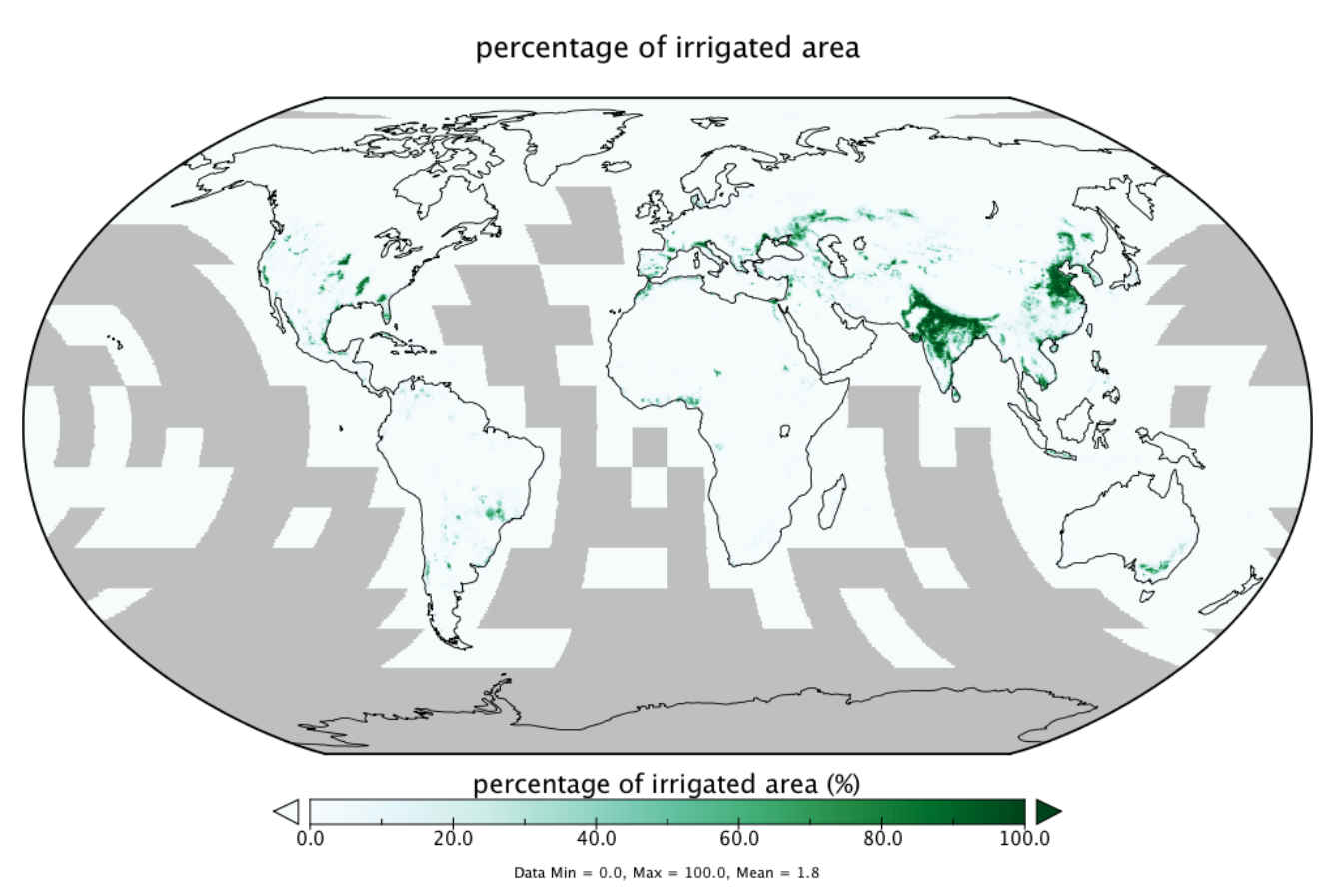
# Crop Irrigation

7% of the NW China region is irrigated, and there is evidence that the irrigated area is increasing to support rapid population growth in Xinjiang Province.

https://earthengine.google.com/timelapse/#v=41.70341,85.51696,7.659,latLng&t=3.25




Salmon, J. M., Friedl, M. A., Frolking, S., Wisser, D., & Douglas, E. M. Global rain-fed, irrigated, and paddy croplands: A new high resolution map derived from remote sensing, crop inventories and climate data. *Int. J. Applied Earth Observation and Geoinformation* **38**, 321-334 (2015).

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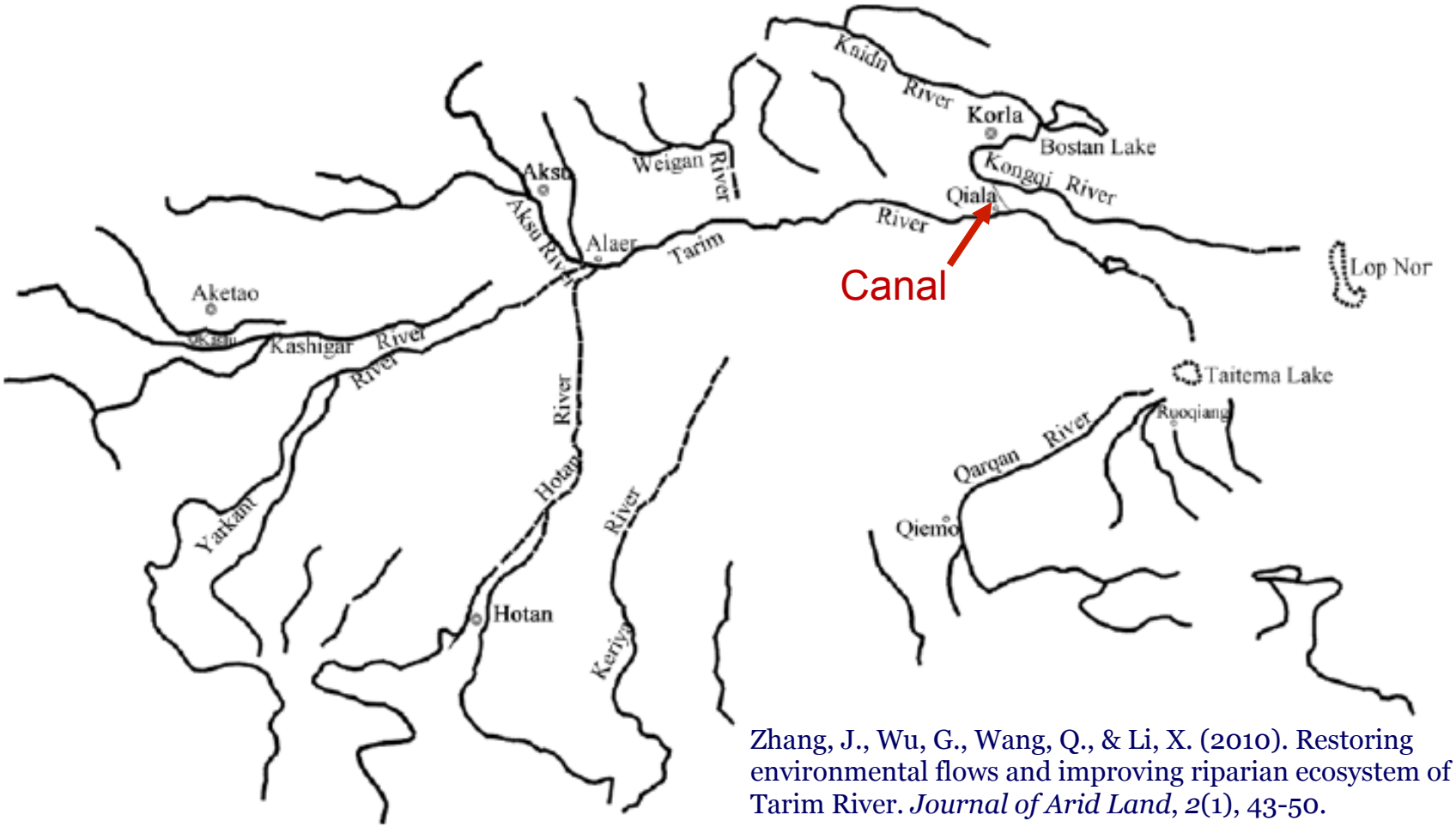
# Inter-basin Water Transfer from Lake Bosten




Zhang, J., Wu, G., Wang, Q., & Li, X. (2010). Restoring environmental flows and improving riparian ecosystem of Tarim River. *Journal of Arid Land*, *2*(1), 43-50.

In 2000, an artificial canal was dug as part of the Emergency Water Transfer Project (Tarim River Restoration Project) which diverted an average of 0.32 Gt/yr of water from Lake Bosten through the Kongqi River to the Tarim River, which supports irrigated agriculture and terminates in the desert.

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# Summary and Conclusion

- GRACE detects a mass loss of 5.5 ±0.6 Gt/yr in a small region of NW China.
- Precipitation has been above normal and trending upward during the GRACE period, so drought does not explain the observed signal.
- Glacier loss may account for half or more of the signal.
- Dewatering of aquifers that intersect coal mines may also contribute.
- However, the region exists within an endorheic basin, so that meltwater and pumped groundwater cannot go far.
- The lakes that accumulate runoff from the region have not been filling during the period.
- Irrigated agriculture is widespread and growing in the region.
- Water that drains to the south, including via an inter-basin water transfer, is either consumed by crops or evaporates from the desert floor.
- In conclusion, glacier melt and groundwater withdrawals in NW China become surface waters which are subsequently consumed by irrigated agriculture and evaporated from the desert floor, resulting in the observed 5.5 ±0.6 Gt/yr mass loss.

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