

Supplementary Materials

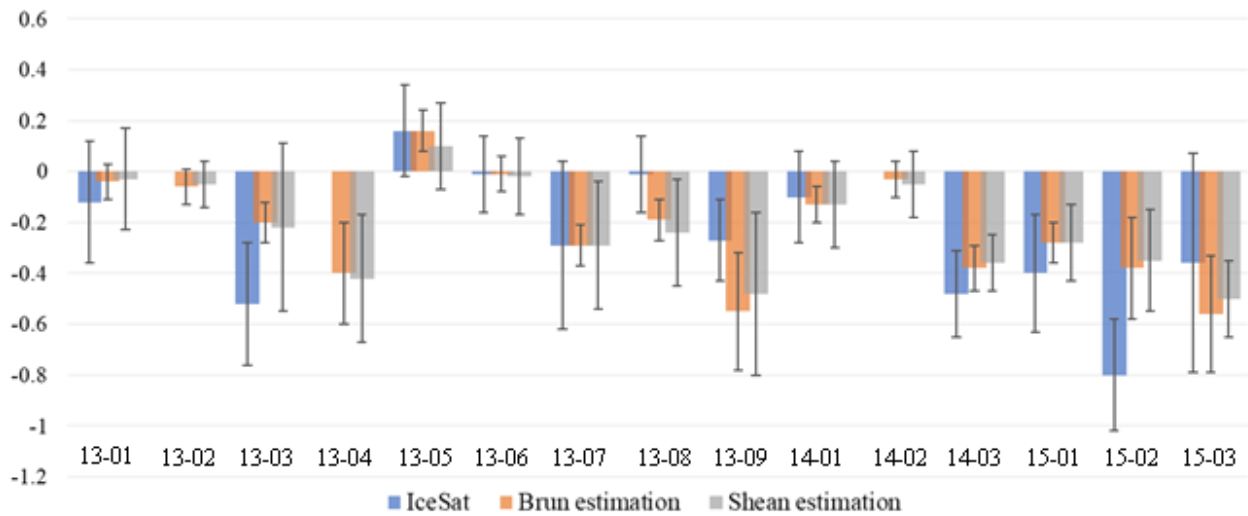


Figure S1. Mass balance in different glacier regions. Note. While the ICESat data do not reflect small glaciers, the data were used to calculate the elevation changes of glaciers larger than 5 km² in area and then to interpolate elevation variations across the entire region, and the satellite no longer provided data in 2009. As the algorithms of the Brun and Shean estimations were analogous, we focus on comparing the Shean and Brun estimations to handle a more appropriate dataset. There was little difference in the overall mass balance between the two datasets (−0.87 from Brun estimation and −0.98 from Shean estimation for our study area), but there was great variation in uncertainty in some regions, such as the western Tien Shan (0.08 from Brun estimation and 0.33 from Shean estimation) and Qilian Shan (0.08 from Brun estimation and 0.25 from Shean estimation). We applied Shean estimation since it provided the mass balance of each glacier in the RGI, while Brun provided distribution images with a resolution of 30 m.

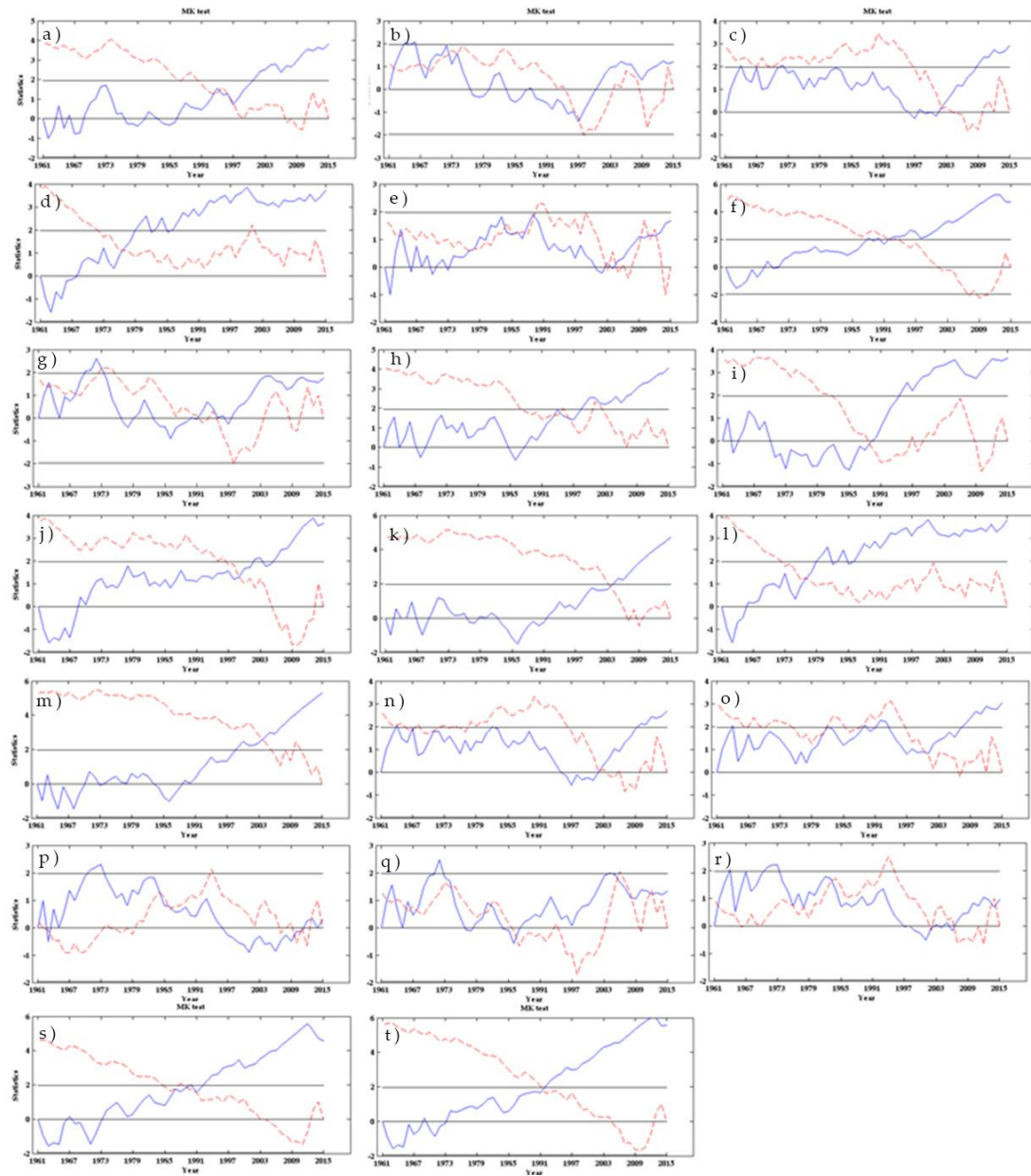


Figure S2. Mann-Kendall test of delayed runoff with a confidence level of 95%. The a)Ebinur River System, b)Aksu River Basin, c)Eastern Qaidam Basin, d)Hami Basin, e)Heihe River Basin, f)Hotan River Basin, g)Ili River Basin, h)Kaikong River Basin, i)Kashgar River Basin, j)Kriya Rivers Basin, k)Middle Rivers Basin, l)Pai Basin, m)Turpan Basin, n)Qinghai Lake River System, o)Shule River Basin, p)Qarqan Rivers Basin, q)Ili River Basin, r)Western Qaidam Basin, and s)Yarkand River Basin and t)all basins. Blue lines represent UF curves and red lines represent UB curves.

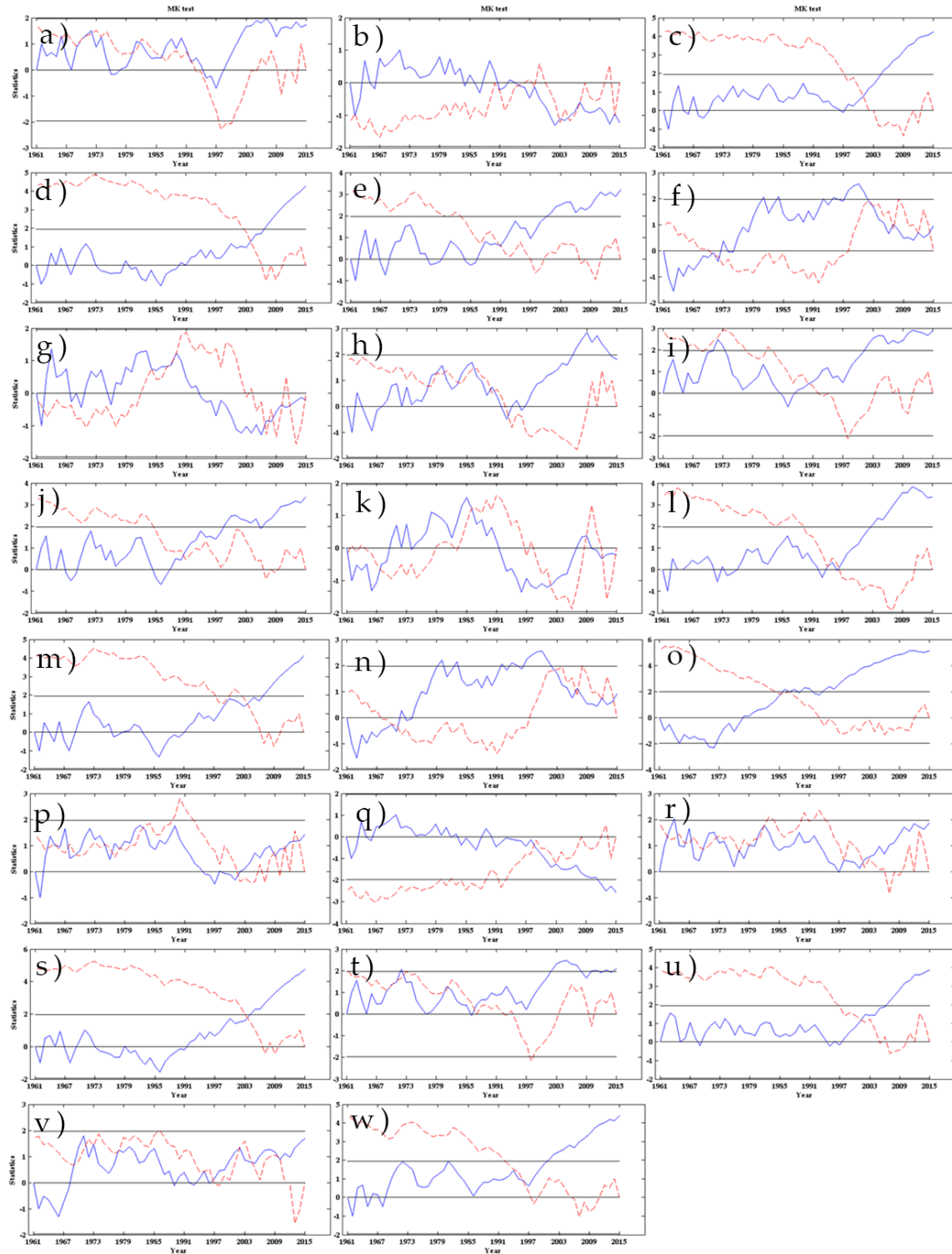


Figure S3. Mann-Kendall test of meltwater runoff with a confidence level of 95%. The a) Aksu River Basin, b) Datong River Above Hall, c) Eastern Qaidam Basin, d) Eastern Rivers Basin, e) Ebinur Lake Drainage System, f) Hami Basin, g) Heihe River Basin, h) Hotan River Basin, i) Ili River Basin, j) Kai-kong River Basin, k) Kashgar River Basin, l) Kriya Rivers Basin, m) Middle Rivers Basin, n) Pai Basin, o) Qarqan Rivers Basin, p) Qinghai Lake Drainage System, q) Shiyang River Basin, r) Shule River Basin, s) Turpan Basin, t) Weigan River Basin, u) Western Qaidam Basin, and v) Yarkand River Basin and w) all basins. Blue lines represent UF curves and red lines represent UB curves.

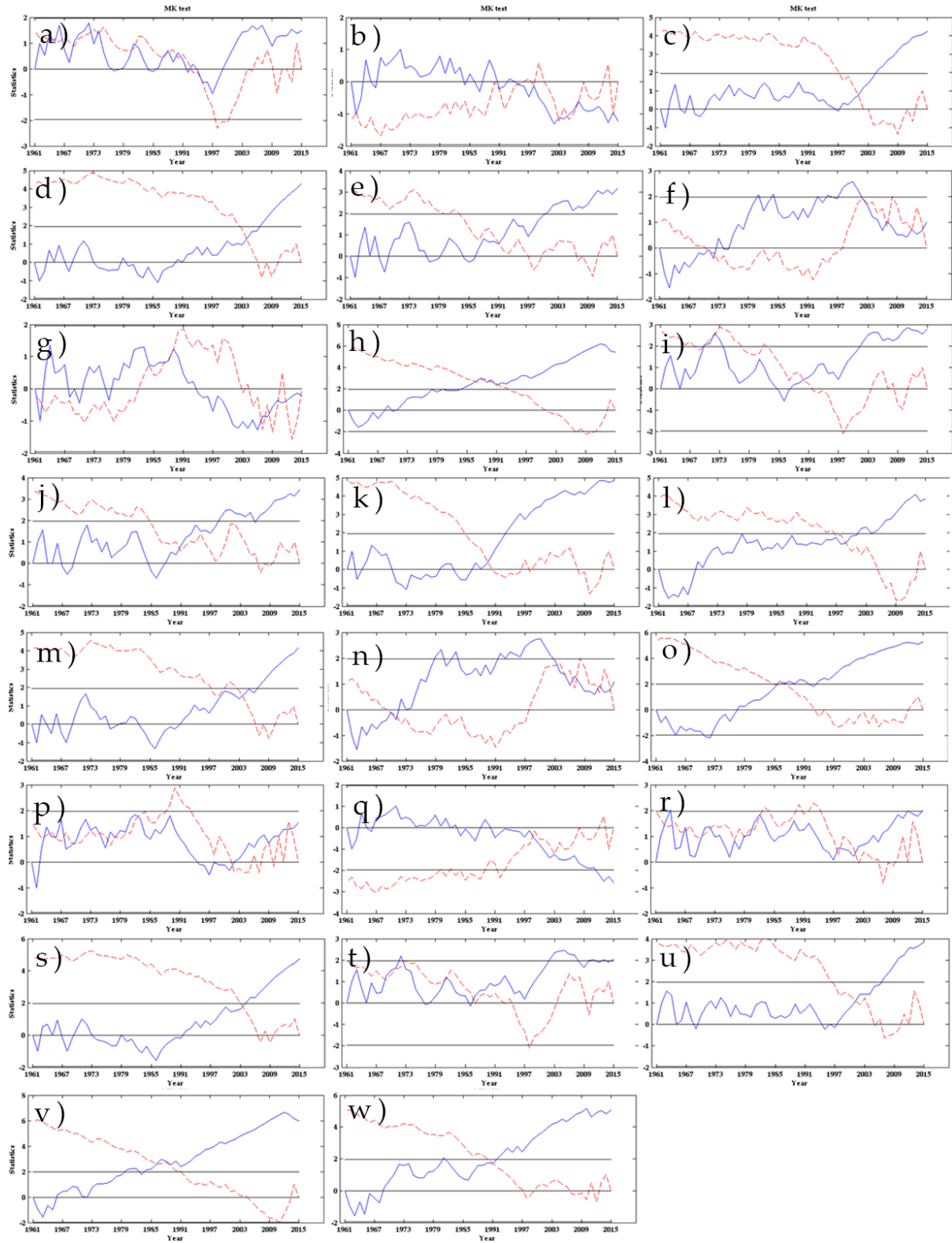


Figure S4. Mann-Kendall test of glacier runoff with a confidence level of 95%. The a) Aksu River Basin, b) Datong River Above Hall, c) Eastern Qaidam Basin, d) Eastern Rivers Basin, e) Ebinur Lake Drainage System, f) Hami Basin, g) Heihe River Basin, h) Hotan River Basin, i) Ili River Basin, j) Kaikong River Basin, k) Kashgar River Basin, l) Kriya Rivers Basin, m) Middle Rivers Basin, n) Pai Basin, o) Qarqan Rivers Basin, p) Qinghai Lake Drainage System, q) Shiyang River Basin, r) Shule River Basin, s) Turpan Basin, t) Weigan River Basin, u) Western Qaidam Basin, and v) Yarkand River Basin and w) all basins. Blue lines represent UF curves and red lines represent UB curves.

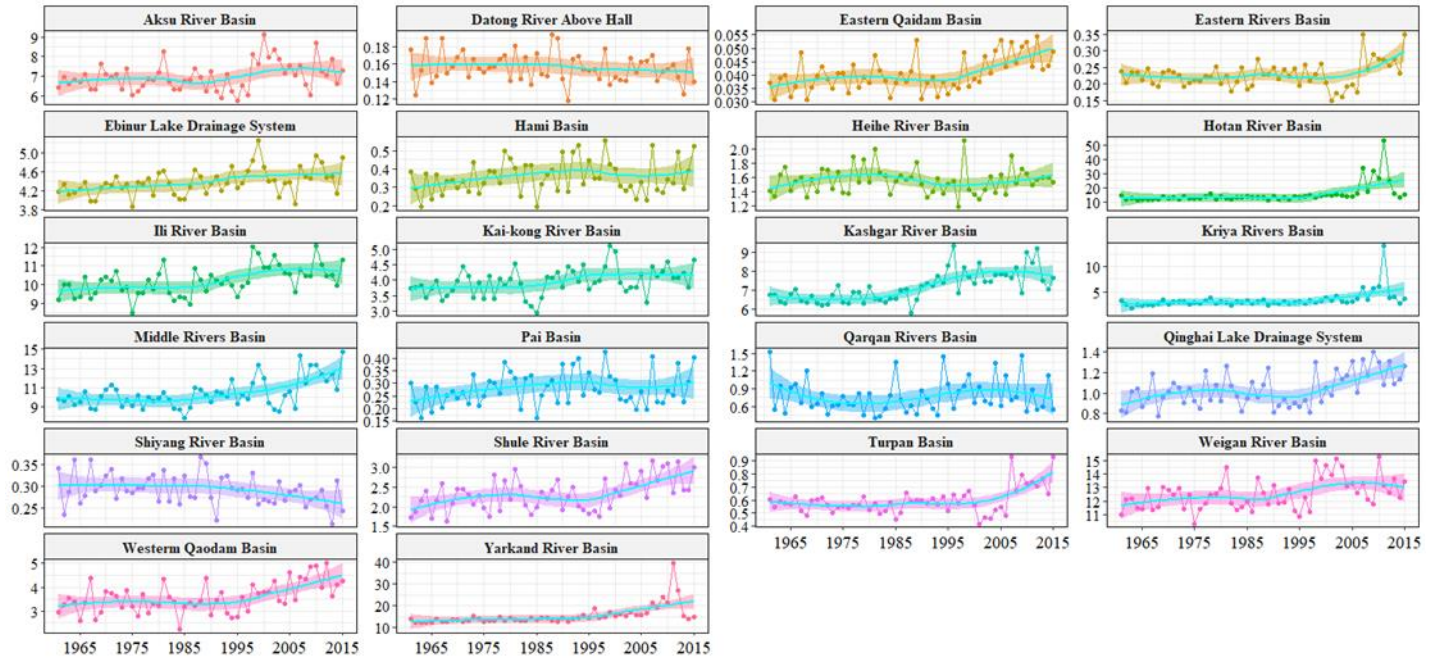


Figure S5. Time series of MR in each watershed.

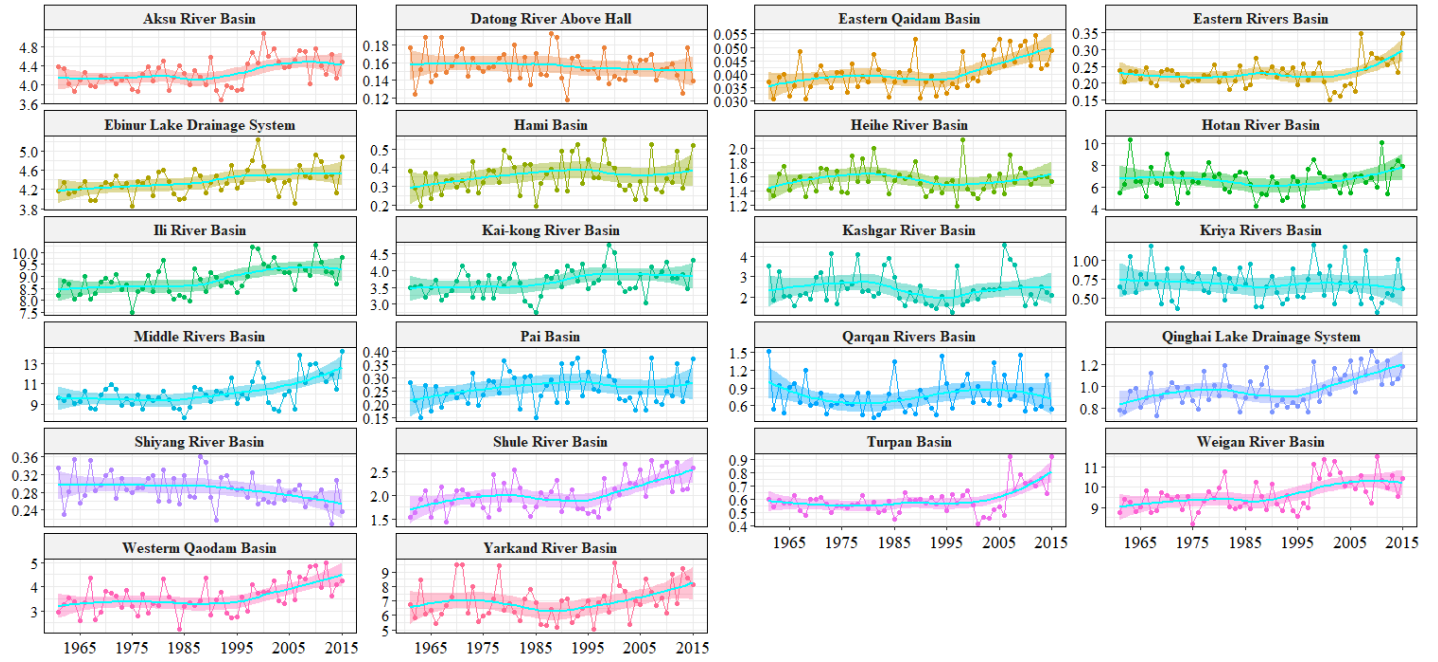


Figure S6. Time series of GR in each watershed.

Table S1. Comparison of mass balance datasets for different glacier regions.

| RGI regions | MB from IceSat [2003–2009] | MB from Brun (Aster) [2000– 2016] | MB from Shean (Aster- SPOT) [2000–2018] |
|-------------------|-------------------------------|--------------------------------------|---|
| 13-01 Hissar Alay | | -0.04 ± 0.07 | -0.03 ± 0.20 |
| 13-02 Pamir | -0.12 ± 0.24 | -0.06 ± 0.07 | -0.05 ± 0.09 |
| 13-03 W Tien Shan | | -0.20 ± 0.08 | -0.22 ± 0.33 |
| 13-04 E Tien Shan | -0.52 ± 0.24 | -0.40 ± 0.20 | -0.42 ± 0.25 |
| 13-05 W Kun Lun | 0.16 ± 0.18 | 0.16 ± 0.08 | 0.10 ± 0.17 |
| 13-06 E Kun Lun | -0.01 ± 0.15 | -0.01 ± 0.07 | -0.02 ± 0.15 |
| 13-07 Qilian Shan | -0.29 ± 0.33 | -0.29 ± 0.08 | -0.29 ± 0.25 |

| | | | |
|---------------------|------------------|------------------|------------------|
| 13-08 Inner Tibet | -0.01 ± 0.15 | -0.19 ± 0.08 | -0.24 ± 0.21 |
| 13-09 S an E Tibet | -0.27 ± 0.16 | -0.55 ± 0.23 | -0.48 ± 0.32 |
| 14-01 Hindu Kush | -0.10 ± 0.18 | -0.13 ± 0.07 | -0.13 ± 0.17 |
| 14-02 Karakoram | | -0.03 ± 0.07 | -0.05 ± 0.13 |
| 14-03 W Himalaya | -0.48 ± 0.17 | -0.38 ± 0.09 | -0.36 ± 0.11 |
| 15-01 C Himalaya | -0.40 ± 0.23 | -0.28 ± 0.08 | -0.28 ± 0.15 |
| 15-02 E Himalaya | -0.80 ± 0.22 | -0.38 ± 0.20 | -0.35 ± 0.20 |
| 15-03 Hengduan Shan | -0.36 ± 0.43 | -0.56 ± 0.23 | -0.50 ± 0.15 |

Table S2. Dates of Landsat imagery used in the RGI.

| ID | Basin | Image Date |
|----|--------------------------------|--|
| 1 | Middle Rivers Basin | 20070911, 20070913, 20090723, 20090725, 20090808, 20090826, 20100813 |
| 2 | Yarkand River Basin | 19980813, 19980820, 20000902, 20000904, 20000911, 20010721, 20020802, 20070729, 20080731, 20090726, 20090811, 20090921, 20090930, 20100823, 20100917 |
| 3 | Western Qaidam Basin | 20060723, 20060909, 20060914, 20070504, 20070731, 20070811, 20070825, 20070903, 20070919, 20070921, 20090830, 20090901, 20100428, 20100806, 20100831, 20100902 |
| 4 | Eastern Qaidam Basin | 20060723, 20070921, 20080830 |
| 5 | Datong River Above Xiangtang | 20070813, 20090617 |
| 6 | Eastern Rivers Basin | 20060811, 20100813 |
| 7 | Ebinur Lake Drainage System | 19990918, 20070824, 20070911, 20070916, 20070918, 20070920, 20090723, 20090808, 20090813 |
| 8 | Hami Basin | 20070825, 20100824 |
| 9 | Heihe River Basin | 20050909, 20060909, 20060918, 20060920, 20070813, 20070822, 20100727 |
| 10 | Hotan River Basin | 20020802, 20080903, 20090603, 20090813, 20090907, 20090921, 20090930, 20100823, 20100917, 20101129, 20101208, 20110805 |
| 11 | Ili River Basin | 20020818, 20070824, 20070911, 20070916, 20070918, 20070925, 20090723, 20090808, 20090813, 20091002 |
| 12 | Kai-kong River Basin | 20070515, 20070911, 20070913, 20090723, 20090801, 20090808, 20090817 |
| 13 | Kashgar River Basin | 20000824, 20000902, 20000911, 20010726, 20010820, 20010928, 20070923, 20090701, 20090726, 20090910, 20090919 |
| 14 | Kriya Rivers Basin | 20070819, 20090907, 20101208, 20110805 |
| 15 | Pai Basin | 20070825, 20100824 |
| 16 | Qarqan Rivers Basin | 20070508, 20070517, 20070625, 20070819, 20100806, 20100813, 20100831, 20100907 |
| 17 | Qinghaihu Lake Drainage System | 20060918, 20070813, 20080830 |
| 18 | Shiyang River Basin | 20090617 |
| 19 | Shule River Basin | 20060909, 20060918, 20070813, 20070825, 20070903, 20090901 |
| 20 | Turpan Basin | 20060811, 20070913, 20090801, 20090817, 20090819, 20090826, 20100813 |
| 21 | Weigan River Basin | 20020818, 20070824, 20070911, 20070918 |
| 22 | Aksu River Basin | 19990808, 20020724, 20020818, 20020825, 20021003, 20070824, 20070907, 20070916, 20070923 |

Table S3. Coefficients of potential predictors based on the LASSO regression method.

| Basin | Coefficients | Potential predictors |
|--------------------------|--------------|----------------------|
| Eastern Qaidam Basin | −0.14** | DDFice |
| | 0.21** | DDFsnow |
| | 0 | AAP |
| | 0.1 | Area |
| | 0.01 | Slope |
| | 0 | Zmed |
| | 0 | Aspect |
| | −1.71** | MT(JJAS) |
| | 1.9** | AMT |
| Qarqan Rivers Basin | 0.06** | DDFice |
| | −0.03** | DDFsnow |
| | 0** | AAP |
| | 0** | Area |
| | 0** | Slope |
| | 0 | Zmed |
| | 0 | Aspect |
| | 0.11** | MT(JJAS) |
| | −0.1** | AMT |
| Western Qaidam Basin | 0.06** | DDFice |
| | −0.03** | DDFsnow |
| | 0 | AAP |
| | 0 | Area |
| | 0** | Slope |
| | 0 | Zmed |
| | 0 | Aspect |
| | −0.03 | MT(JJAS) |
| | 0.04* | AMT |
| Eastern Rivers Basin | −0.07 | DDFice |
| | 0.01** | AAP |
| | 0.16** | Area |
| | −0.01** | Slope |
| | 0* | Zmed |
| | 0* | Aspect |
| | −1.56** | MT(JJAS) |
| | 2.02** | AMT |
| Ebinur Lake River System | 0.03 | DDFice |
| | 0 | DDFsnow |
| | 0** | AAP |
| | 0.01* | Area |
| | 0* | Slope |
| | 0** | Zmed |
| | 0 | Aspect |
| | 0.38** | MT(JJAS) |
| | 0.39** | AMT |
| Ili River Basin | 0 | DDFice |
| | 0.03* | DDFsnow |
| | 0** | AAP |
| | 0 | Area |
| | 0* | Slope |
| | 0** | Zmed |

| | | |
|----------------------|---------|----------|
| Hami Basin | 0 | Aspect |
| | 0.06** | MT(JJAS) |
| | 0.03* | AMT |
| | −0.45* | DDFice |
| | −0.02** | AAP |
| | 0.06 | Area |
| | 0.03** | Slope |
| Kai-kong River Basin | 0** | Zmed |
| | 0 | Aspect |
| | 0.15 | MT(JJAS) |
| | 0.25** | DDFice |
| | −0.26** | DDFsnow |
| | 0** | AAP |
| | 0.03 | Area |
| Middle Rivers Basin | 0* | Slope |
| | 0** | Zmed |
| | 0 | Aspect |
| | 0.25** | MT(JJAS) |
| | −0.29** | AMT |
| | 0.42** | DDFice |
| | −0.3** | DDFsnow |
| Pai Basin | 0 | AAP |
| | 0.01** | Area |
| | 0 | Slope |
| | 0** | Zmed |
| | 0 | Aspect |
| | 0.05 | MT(JJAS) |
| | −0.08** | AMT |
| Turpan Basin | −0.18* | DDFice |
| | −0.03** | AAP |
| | 0.1* | Area |
| | 0.02** | Slope |
| | 0 | Zmed |
| | 0 | Aspect |
| | 0 | DDFsnow |
| Kashgar River Basin | 0** | AAP |
| | 0.02 | Area |
| | 0** | Slope |
| | 0** | Zmed |
| | 0 | Aspect |
| | 0 | DDFsnow |
| | 0.04** | AMT |
| Hotan River Basin | −0.07** | DDFice |
| | 0.04** | DDFsnow |
| | 0** | AAP |
| | 0* | Area |
| | 0** | Slope |
| | 0 | Zmed |
| | 0 | Aspect |
| | 0.06** | MT(JJAS) |
| | 0.07** | AMT |
| | −0.07** | DDFice |
| | 0.05** | DDFsnow |
| | | |
| | | |
| | | |

| | | |
|--|---------|----------|
| | 0 | AAP |
| | 0** | Area |
| | 0** | Slope |
| | 0 | Zmed |
| | 0 | Aspect |
| | 0.05** | MT(JJAS) |
| | -0.03** | AMT |
| | 0.02 | DDFice |
| | 0.03** | DDFsnow |
| | 0 | AAP |
| | 0** | Area |
| | 0** | Slope |
| | 0** | Zmed |
| | 0* | Aspect |
| | 0.05** | MT(JJAS) |
| | -0.04** | AMT |
| | -0.16* | DDFice |
| | 0* | AAP |
| | 0.15* | Area |
| | 0.01 | Slope |
| | 0** | Zmed |
| | 0 | Aspect |
| | 0.07* | MT(JJAS) |
| | -0.01 | DDFice |
| | -0.03 | DDFsnow |
| | 0** | AAP |
| | 0.05** | Area |
| | 0 | Slope |
| | 0 | Zmed |
| | 0 | Aspect |
| | 0.42** | MT(JJAS) |
| | -0.42** | AMT |
| | 0.08* | DDFsnow |
| | 0** | AAP |
| | 0.01 | Area |
| | 0 | Slope |
| | 0** | Zmed |
| | 0.01 | MT(JJAS) |
| | 0.01** | AAP |
| | 0 | Aspect |
| | 0.01 | DDFice |
| | 0** | AAP |
| | 0** | Zmed |
| | 0* | Aspect |
| | -0.17** | DDFice |
| | 0.12** | DDFsnow |
| | 0** | AAP |
| | 0** | Area |
| | 0** | Slope |
| | 0** | Zmed |
| | 0 | Aspect |
| | -0.18** | MT(JJAS) |

| | | |
|--------------------|---------|----------|
| Aksu River Basin | 0.2** | AMT |
| | 0.15** | DDFice |
| | -0.15** | DDFsnow |
| | 0** | AAP |
| | 0 | Area |
| | 0* | Slope |
| | 0** | Zmed |
| | 0 | Aspect |
| | 0.7** | MT(JJAS) |
| | -0.68** | AMT |
| Weigan River Basin | 0.06 | DDFice |
| | -0.09** | DDFsnow |
| | 0** | AAP |
| | 0 | Area |
| | 0 | Slope |
| | 0** | Zmed |
| | 0 | Aspect |
| | 0.34** | MT(JJAS) |
| | -0.33** | AMT |

Note. Significance levels: ** $p < 0.05$, * $p < 0.01$.