Supplemental Material for:

The potential for snow to supply human water demand in the present and future

Justin S. Mankin[a,*], Daniel Viviroli[b], Deepti Singh[c], Arjen Y. Hoekstra[d], and Noah S. Diffenbaugh[c,e]

[a] Emmett Interdisciplinary Program in Environment & Resources, Stanford University, California, USA

[b] Department of Geography, University of Zurich, Zurich, Switzerland

[c] Department of Earth System Science, Stanford University, California, USA

[d] Dept. of Water Engineering & Management, University of Twente, Enschede, The Netherlands

[e] Woods Institute for the Environment, Stanford University, California, USA

*** Corresponding author:**
Justin S. Mankin
473 Via Ortega, Suite 226
Jerry Yang & Akiko Yamazaki Environment & Energy Building,
Stanford, CA 94305-4216, USA
Email: jsmankin@stanford.edu

Supplementary Methods

Calculation of snowmelt and rainfall runoff

We focus our analysis on the six months of boreal spring and summer for two reasons. First, in the NH, boreal spring and summer are when water demands are highest (Hoekstra et al. 2012). Second, because the snow season length varies by altitude and latitude, it is necessary to capture a large calendar window of NH snowmelt (Mankin & Diffenbaugh 2014). Glacial contributions are relatively small at the basin scales that we consider, with the exception of very dry regions, such as the Aral and Syr Darya basins (Kaser et al. 2010; Viviroli et al. 2011). We therefore do not consider glacial melt in this analysis.

Snowmelt runoff (surface and subsurface) is not standard output from most coordinated climate model experiments. Instead, the land surface components in climate models often provide the snowmelt rate. Typically, snowmelt runoff is estimated as some function of temperature and elevation (Viviroli et al. 2007), while high-resolution daily-scale snowmelt runoff estimates can be estimated with a snowmelt runoff model (SRM), forced with observations or a climate model (Ashfaq et al. 2010; Rauscher et al. 2008; Immerzeel et al. 2010). However, because of the computational cost to provide a large number of simulations with an SRM and the coarse temporal and spatial scales we analyze, we estimate snowmelt runoff directly from the monthly values of snowmelt rate fields from 49 ensemble members at the basin-scale.

At each grid-point for each ensemble member, we estimate a "snow runoff coefficient" in a manner similar to the calculation made by an SRM (Martinec et al. 2008). We use the ratio of grid-scale snowmelt flux to rainfall flux to estimate the coefficient, which approximates the ratio of snowmelt runoff ($Q_{snowmelt}$) to rainfall runoff (Q_{rain}), β:

$$\frac{Q_{snowmelt}}{Q_{rain}} \approx \frac{snowmelt\ rate}{rainfall\ rate} = \beta$$

We interpret total runoff as the basin-scale precipitation that does not evaporate. We therefore do not distinguish the different runoff pathways (surface versus subsurface) such runoff takes. Thus total runoff is the sum of runoff from rainfall and from snowmelt, ($Q_{total} = Q_{snowmelt} + Q_{rain}$), the above relation above gives,

$$Q_{total} = \beta \cdot Q_{rain} + Q_{rain}.$$

Therefore, rainfall runoff can be calculated as

$$Q_{rain} = \frac{Q_{total}}{(1+\beta)}$$

and snowmelt runoff can be calculated as

$$Q_{snowmelt} = Q_{total} - Q_{rain}.$$

Details of the CMIP5 and LENS climate simulations

Analysis of snowmelt contributions to total runoff requires fields from either land-ice or land surface models, limiting our analysis to 19 CMIP5 models (Table S1). To ensure that the CMIP5 fields can be readily compared within each basin, we interpolate all CMIP5 models to 1°×1° in the horizontal via a patch recovery method (Gu et al. 2004).

Both CMIP5 and LENS are run using observed greenhouse gas concentrations over the historical period and the RCP8.5 forcing pathway (Riahi et al. 2011) over the 21st century. RCP8.5 prescribes an additional 8.5 W·m^{-2} of radiative forcing over the pre-industrial radiative balance (~1370 CO_2-equivelent) by 2100 (Moss et al. 2010). CMIP5 shows a median global mean warming of ~3.5°C by 2080 (Rogelj et al. 2012) (relative to the late-20th century baseline). Some CMIP5 GCMs also include upper atmospheric dynamics, interactive carbon cycle, and land vegetation (Taylor et al. 2012; Flato et al. 2013).

Variables used in GLDAS reanalysis and the CMIP5 and CESM LENS simulations

From the GLDAS, we use the sum of monthly surface and subsurface runoff (Qs + Qsb), snowmelt rate (Qsm), and rainfall rate (Rainf) to calculate snowmelt runoff ($Q_{snowmelt}$) and unmet demand. From CMIP5, we use precipitation (pr) and snowfall flux (prsn) to estimate the rainfall rate, and total runoff (mrro) and snowmelt (snm) to estimate snowmelt runoff and rainfall runoff. From LENS, we use the sum of surface and subsurface runoffs (QRGWL, QDRAI, and QOVER), as well as snowmelt (QSNOMELT) and the rainfall rate (RAIN).

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Supplementary table

	Model Name
1	CCSM4
2	CESM1-BGC
3	CESM1-CAM5
4	CESM1-WACCM
5	CMCC-CMS
6	CanESM2
7	GFDL-ESM2G
8	GFDL-ESM2M
9	GISS-E2-H-CC
10	GISS-E2-R
11	GISS-E2-R-CC
12	MIROC-ESM
13	MIROC-ESM-CHEM
14	MIROC5
15	MPI-ESM-LR
16	MPI-ESM-MR
17	bcc-csm1-1
18	bcc-csm1-1-m
19	inmcm4

Table S1 Models used from the CMIP5 ensemble.

Supplementary figure

Fig. S1 Present and future March-August snow resource potential. a, 1955-2005 mean snowmelt to unmet demand ratio (same as Fig. 1e). b, The CMIP5 ensemble mean 2060 projection. c, The LENS ensemble mean 2060 projection. Stippled basins in [b] and [c] indicate where the ensemble mean is less than 1 SD of the ensemble variability. Note that grey basins in Fig. 2a and b have their snowmelt supply potentials shown here.