CLIMATE CHANGE ANALYTICAL SERVICES

Scalable Modeling Framework to Summarize Impacts of Climate Change on Flow and Flood Impacts

cbec eco engineering has long recognized the need to plan and adaptively manage river systems for changes in streamflow projected to occur under future climate scenarios. In reponse to this, we have implemented a Climate Initiative to develop the technical solutions needed to plan for a changing future.

One result of this effort is a custom modeling framework to leverage an ensemble of downscaled General Circulation Models to predict how streamflow is expected to change relative to historical conditions. This synthesis of the climate projections is a scientifically robust, repeatable method for resource managers to understand how design flows will change across all climate projections at a local scale.

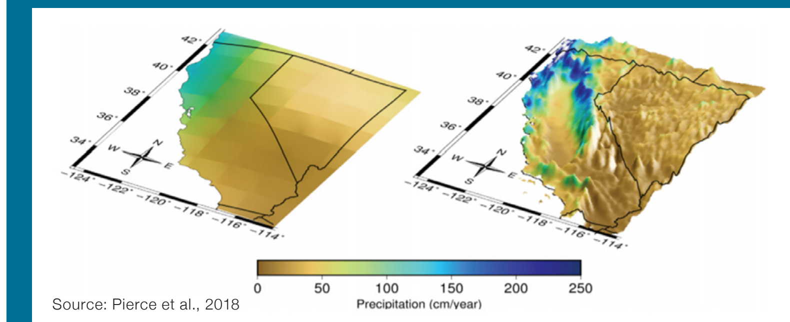
This analysis of relative change in flow regimes can be integrated with hydraulic models to evaluate risk to critical infrastructure under future climate scenarios. cbec's Climate Initiative uses the best available climate projections in a rigorous hydrologic / hydraulic modeling process to clearly communicate how flow regimes are expected to change. This flexible and scalable modeling process allows for water resource managers to make informed decisions while adaptively managing and designing critical infrastructure.

cbec

eco engineering

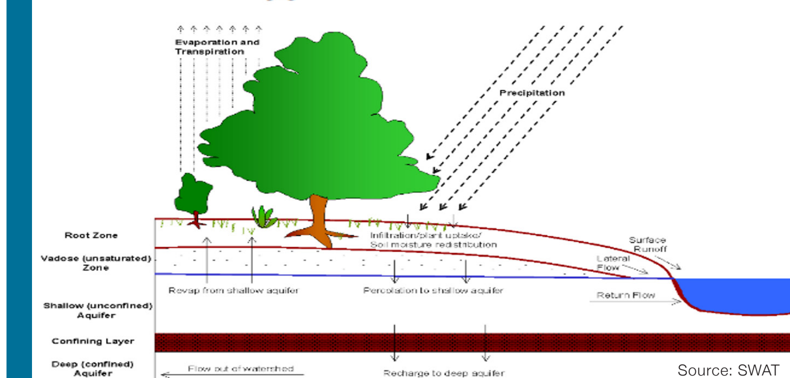
Pioneers in hydrologic climate change modeling

cbec Modeling Process

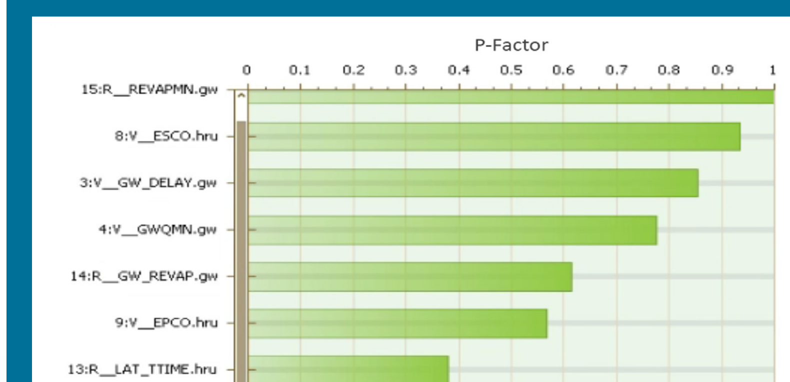


1 Leverage best available downscaled climate products

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$



2 Flexible hydrologic modeling process



3 Calibration and validation process to ensure results represent hydrologic processes

Month	Historic	gfdl-cm3.1 (cms)	gfdl-cm3.2 (% diff)	microc5.1 (cms)	microc5.1 (% diff)	cnrm-cm5.1 (cms)	cnrm-cm5.2 (% diff)	access1-0.1 (cms)	access1-0.1 (% diff)	canesm2.1 (cms)	canesm2.1 (% diff)	hadgem2-cc.1 (cms)	hadgem2-cc.1 (% diff)	ccsm4.6 (cms)	ccsm4.6 (% diff)	cesm1-bgc.1 (cms)	cesm1-bgc.1 (% diff)	cmcc-cms.1 (cms)	cmcc-cms.1 (% diff)	hadgem2-es.1 (cms)	hadgem2-es.1 (% diff)
Jan	5.30	7.51	34%	6.95	27%	6.95	27%	4.51	-16%	15.31	97%	6.33	18%	8.09	42%	9.45	56%	6.23	16%	6.11	14%
Feb	5.87	4.77	-21%	4.12	-35%	8.70	39%	6.14	5%	11.81	67%	6.48	10%	7.82	28%	11.90	68%	5.81	-1%	9.35	46%
Mar	4.02	4.55	12%	3.95	-2%	4.16	3%	3.06	-27%	4.46	10%	3.99	-1%	3.34	-18%	6.29	44%	4.16	4%	4.09	2%
Apr	1.90	1.48	-25%	1.92	1%	2.19	14%	1.66	-14%	2.03	7%	2.11	10%	1.70	-11%	2.40	23%	1.38	-31%	2.15	12%
May	1.09	0.97	-12%	0.96	-12%	1.36	22%	0.90	-19%	1.49	30%	0.91	-18%	1.11	1%	1.58	37%	0.94	-15%	1.21	10%
Jun	0.79	0.76	-3%	0.73	-8%	1.07	30%	0.69	-13%	1.18	40%	0.74	-6%	0.86	9%	1.24	45%	0.74	-5%	0.89	12%
Jul	0.65	0.61	-6%	0.63	-3%	0.92	35%	0.57	-13%	1.02	45%	0.63	-2%	0.73	12%	1.06	48%	0.59	-9%	0.75	15%
Aug	0.55	0.52	-7%	0.54	-3%	1.03	60%	0.48	-14%	0.86	43%	0.52	-6%	0.61	10%	0.88	45%	0.57	3%	0.62	11%
Sep	0.50	0.51	2%	0.57	14%	1.05	72%	0.48	-3%	0.83	49%	0.59	17%	0.72	36%	0.83	49%	0.48	-3%	0.94	61%
Oct	0.69	0.65	-6%	0.45	-41%	0.93	30%	0.62	-11%	0.81	16%	0.54	-24%	0.86	22%	1.29	61%	0.84	19%	0.74	7%
Nov	1.79	0.73	-85%	2.40	29%	2.82	45%	2.10	16%	1.44	-22%	1.03	-54%	1.78	-1%	2.19	20%	1.17	-42%	1.35	-28%
Dec	3.36	2.92	-14%	3.15	-7%	6.53	64%	4.58	31%	4.58	31%	3.60	7%	4.23	23%	4.74	34%	2.99	-12%	4.45	28%
Annual	2.21	2.16	-2%	2.20	-1%	3.14	35%	2.15	-3%	3.82	53%	2.29	4%	2.65	18%	3.65	49%	2.16	-2%	2.72	21%

4 Statistics that interpret future climate scenarios to show relative change across all GCM outputs

Need standard methodology to predict changes in streamflow

Water resource managers need standard methods to plan and adaptively manage river systems for changes in streamflow projected to occur under future climate scenarios. The statistical methods used to compare future projections of streamflow are inconsistent between studies and do not always effectively show relative change in streamflow. A process is needed to evaluate changes in streamflow that is repeatable in any area of California. The process should analyze changes in streamflow in a way that acknowledges the complexity and uncertainty with climate projections, but still provides a robust assessment of relative change that is accessible to water resource managers.

Innovation and Highlights

cbec has developed a modeling framework to project how streamflow is expected to change relative to historical conditions.

- The best available downscaled climate products are used. The modeling process is flexible so that improved climate products can be incorporated seamlessly as they are released in the future.
- cbec developed a tool to process the data from downscaled climate models so that they can be efficiently integrated into the hydrologic model.
- Established open source software was used to model hydrology, calibrate the model, and interpret the results. The modeling framework uses a water budget approach, which provides key insight to water resource managers that is useful to consider independently of the impacts of climate change.
- An ensemble of ten general circulation model (GCM) projections that were selected for fit in California by the DWR are simulated in the calibrated hydrologic model to represent a range of future climate scenarios.
- Each GCM and the average of the 10 GCM's are compared for monthly streamflow between a historical and future 30-year dataset.
- A standard statistical method is applied to concisely summarize relative changes in design flows for a range of event durations and frequencies.
- Changes in design flows can be used to evaluate 2-D flood risk using cbec's expertise in hydraulic modeling.

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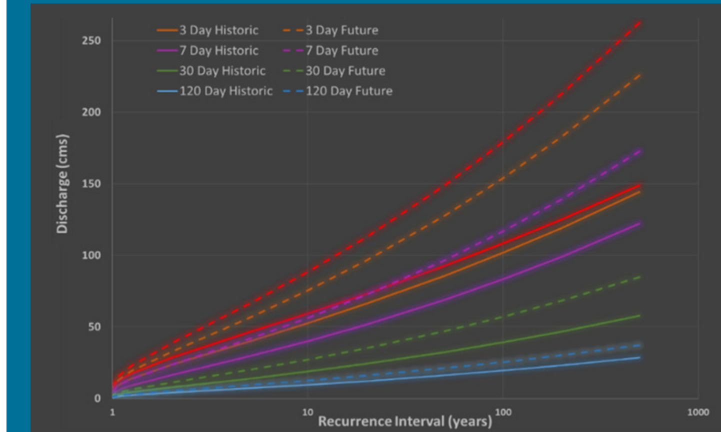
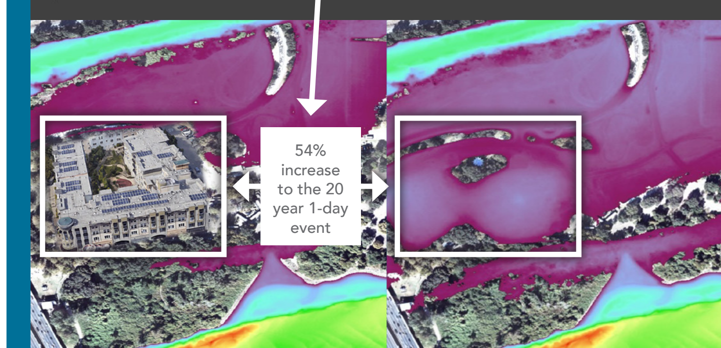
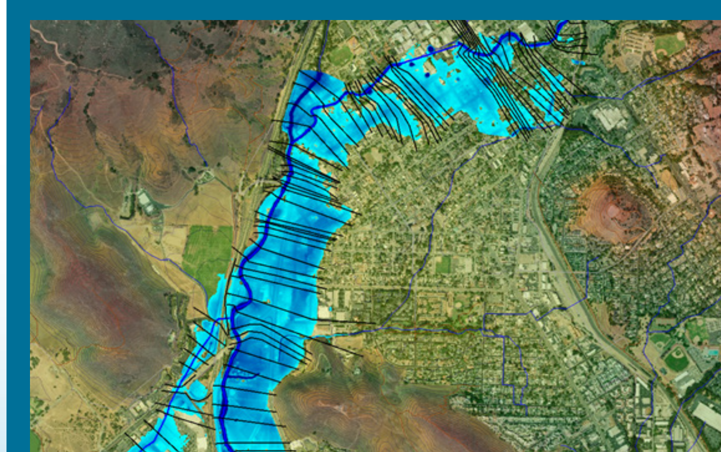
Change in Flood Frequency Resulting from Climate Change



Frequency		Duration (days)				
% Exceedance	RI	1	3	7	30	120
0.2	500	76%	57%	41%	47%	31%
0.5	200	70%	54%	41%	46%	31%
1	100	65%	51%	40%	46%	31%
2	50	61%	49%	40%	45%	31%
5	20	54%	46%	40%	45%	31%
10	10	49%	44%	41%	44%	30%
20	5	44%	41%	41%	44%	31%
50	2	36%	39%	44%	44%	34%
80	1.25	30%	39%	47%	45%	35%
90	1.111	29%	39%	50%	49%	41%
95	1.052	27%	39%	53%	51%	36%
99	1.010	27%	42%	61%	54%	44%



Relative change in flood exceedance probability is calculated for an ensemble of GCM's. Change in flood exceedance can be used to evaluate risk to critical infrastructure.



Future flood risk mapping (e.g. future 100-yr event)