The Lifecycle of an Atmospheric River – from Moisture Sources to Socioeconomic Impacts

Francina Dominguez

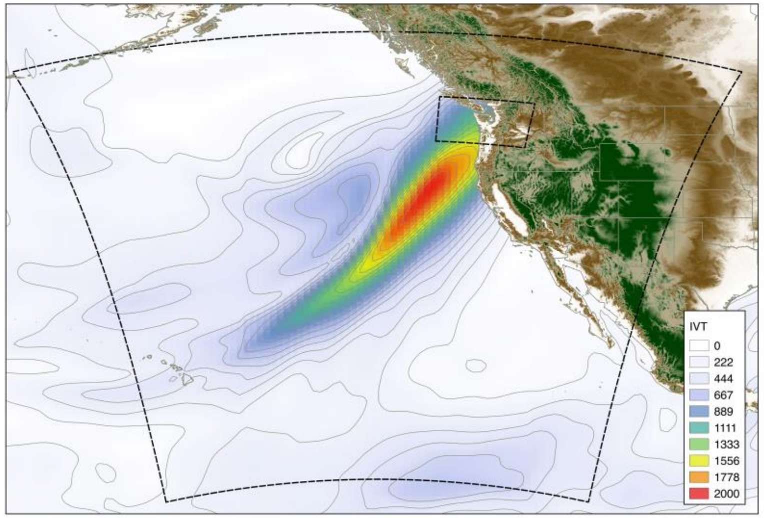
Co-authors

Huancui Hu, Jorge Eiras-Barca

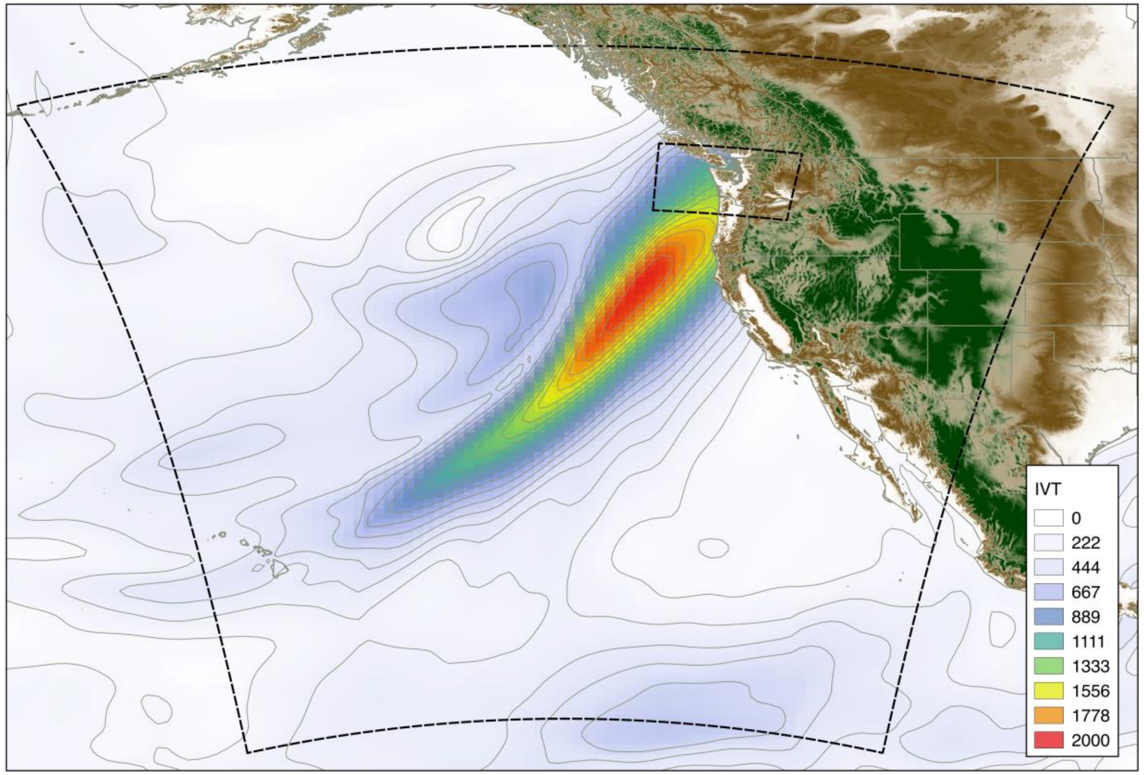
Dennis Lettenmaier, Ali Mehran

Shuyi Huang

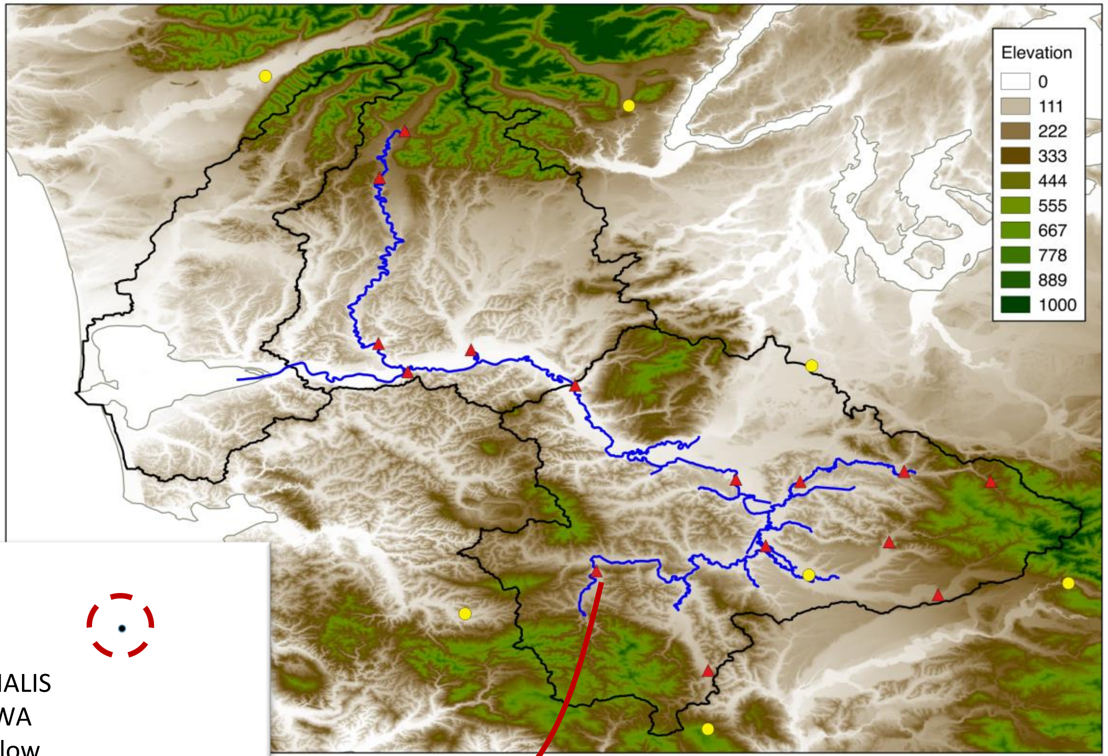
Sandy Dall'erba, Andre Avelino

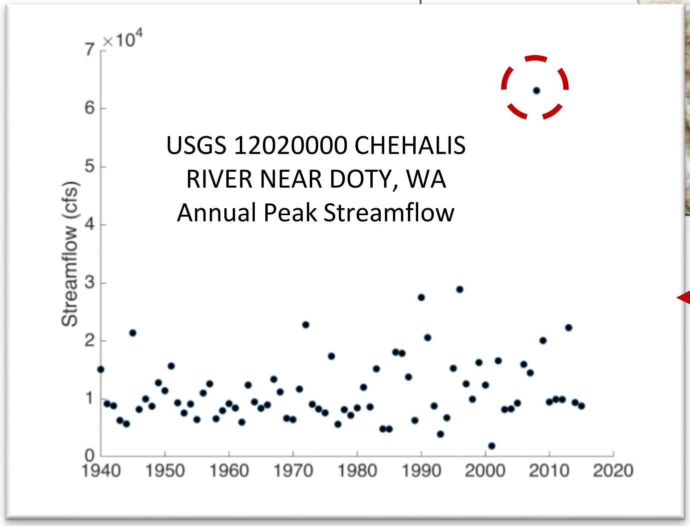


On December 3, 2007 an AR event made landfall on the west coast of the US. It carried an ~70,000 m3/s of liquid water across its core.



Catastrophic flooding occurred along the Chehalis River Basin, WA. Ten USGS observation stations experienced record flooding.

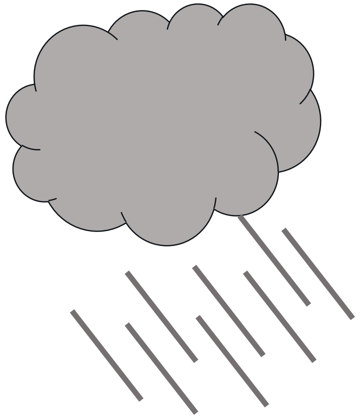




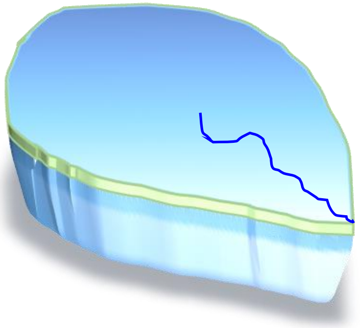
Source: WES engineering report.

We are developing an integrated modeling system to simulate this AR - from its formation in the subtropical Pacific Ocean to the resulting flooding and socioeconomic impacts.

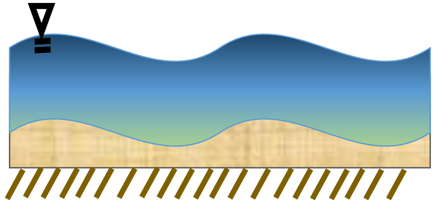
- **Historical (Control)**
- **Future (Pseudo Global Warming)**



Atmosphere
WRF



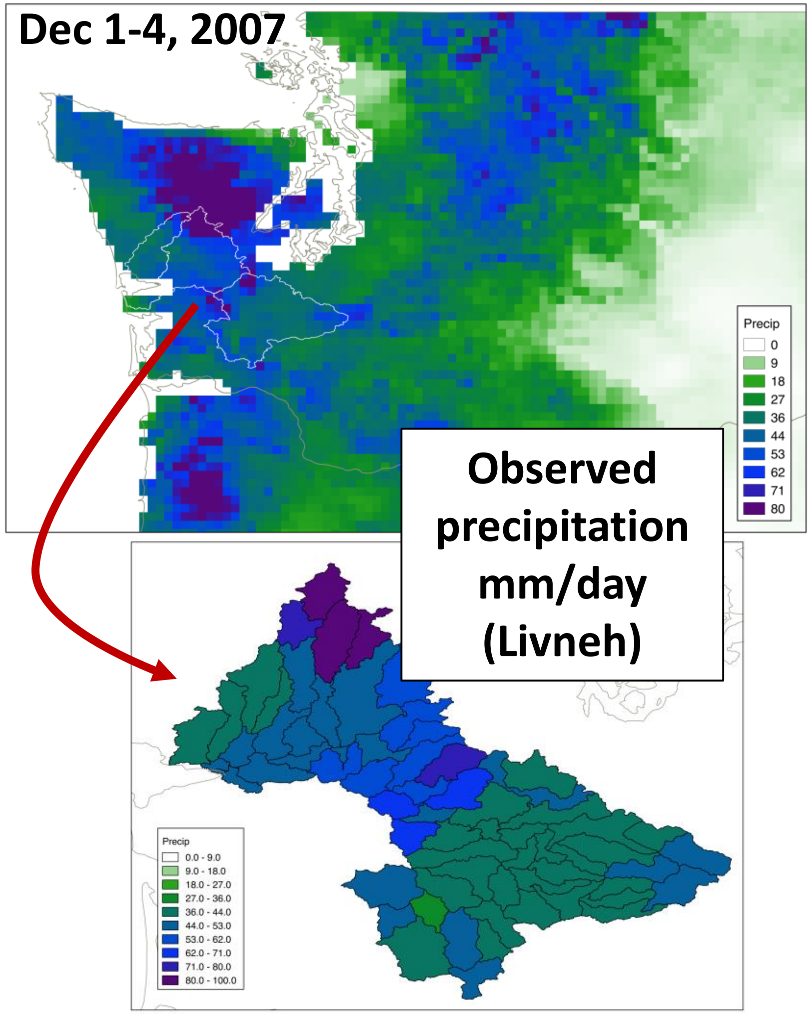
Hydrology
HEC-HMS
DHSVM

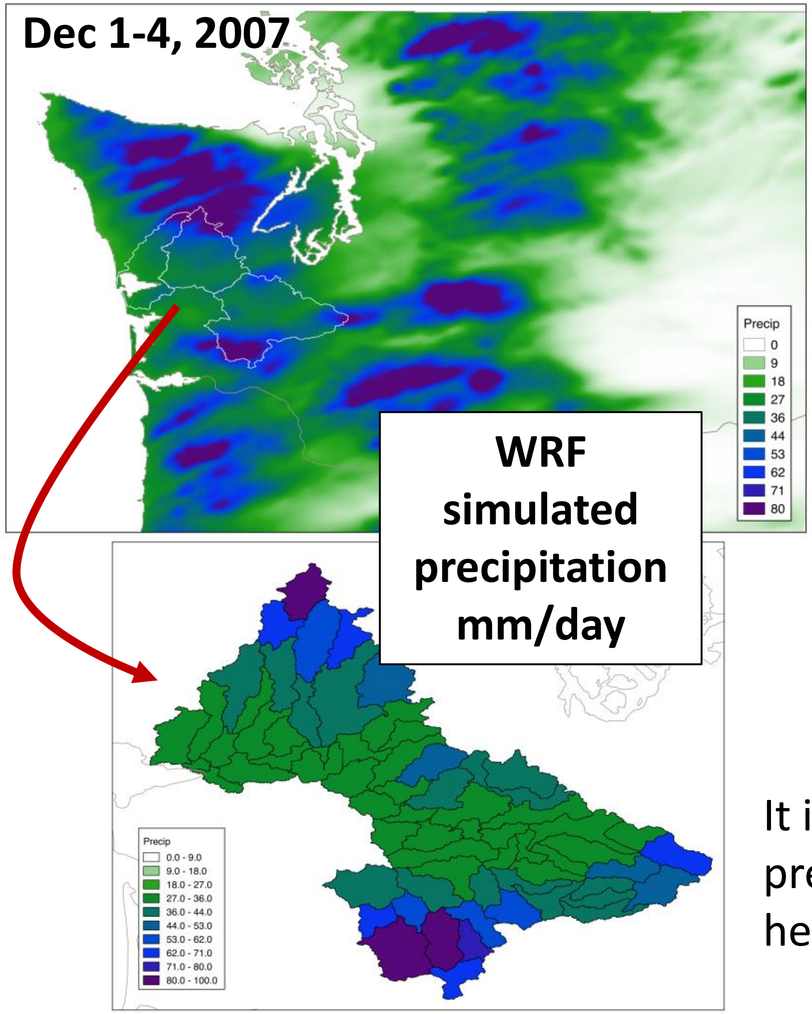


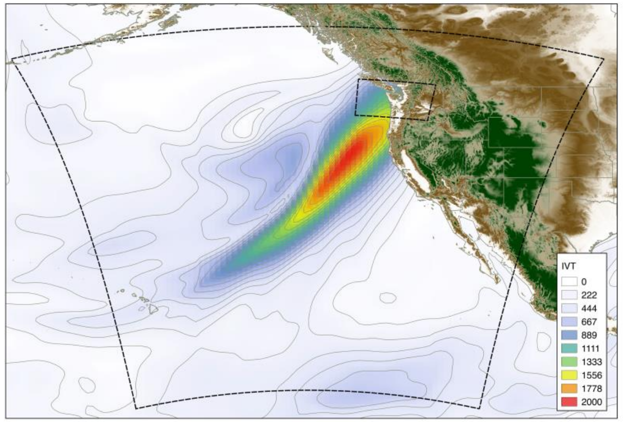
Hydrodynamics
HEC-RAS

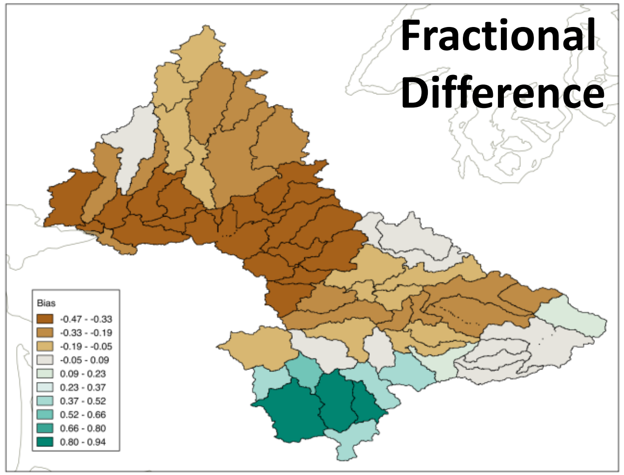
Socioeconomics
HAZUS + IO

WRF captures precipitation over the Olympics, underestimates precip. in the central part of the basin.



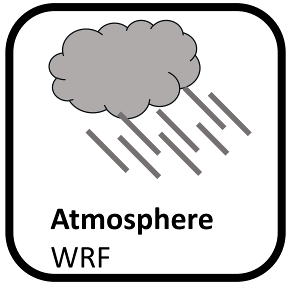




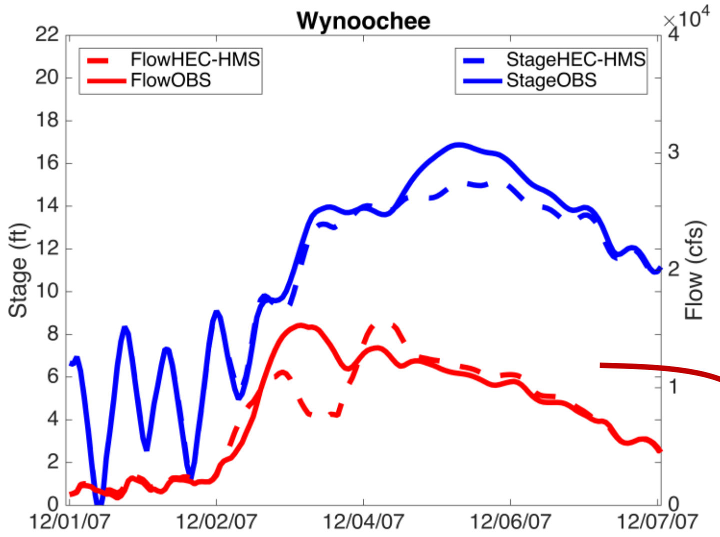


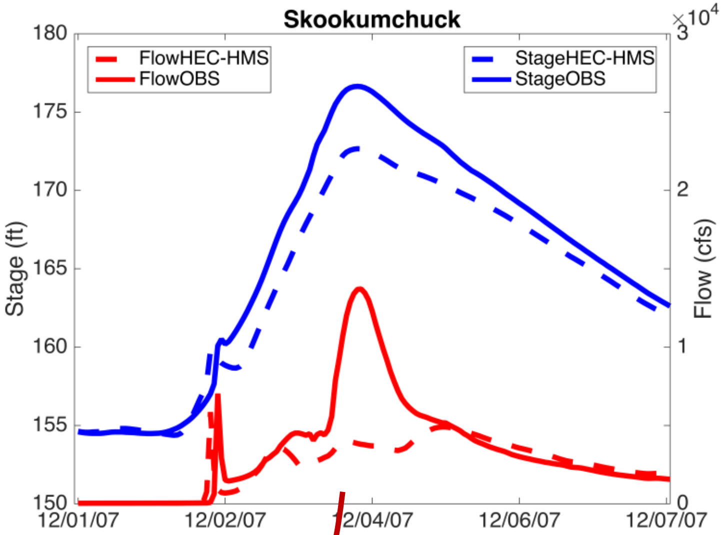
It is important to highlight that Livneh precipitaiton might be biased low along headwaters.

WRF significantly overestimates precipitation in the headwaters of the Willapa Hills.

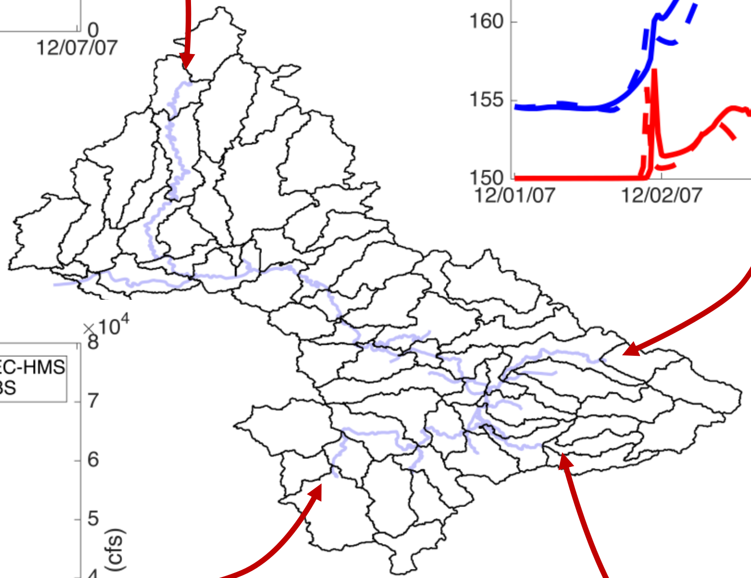


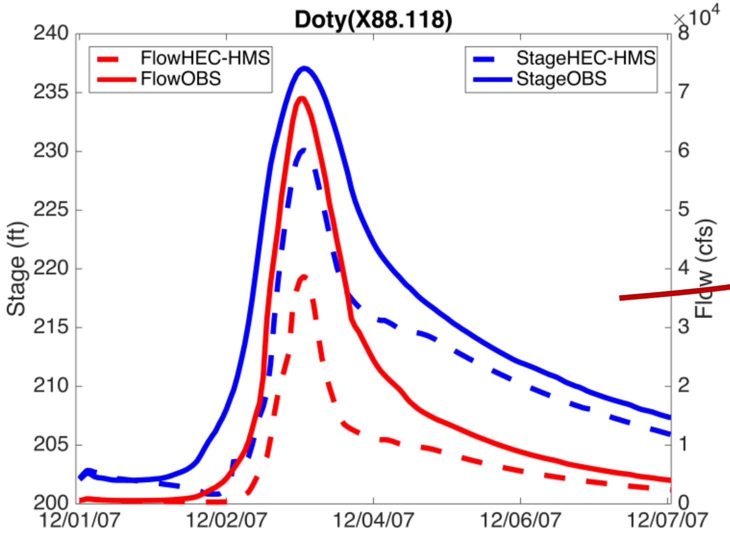
We use Livneh + station precipitation for calibration of HEC-HMS.



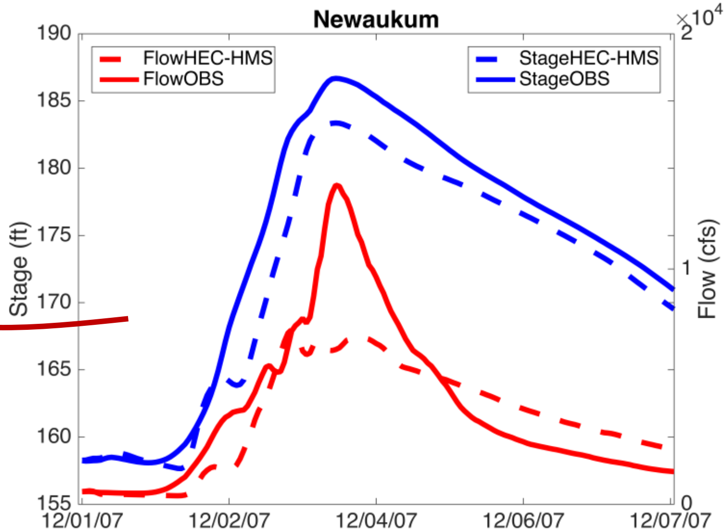


HEC-HMS generally captures hydrograph stage and flow, but is biased low – main issue is precipitation.



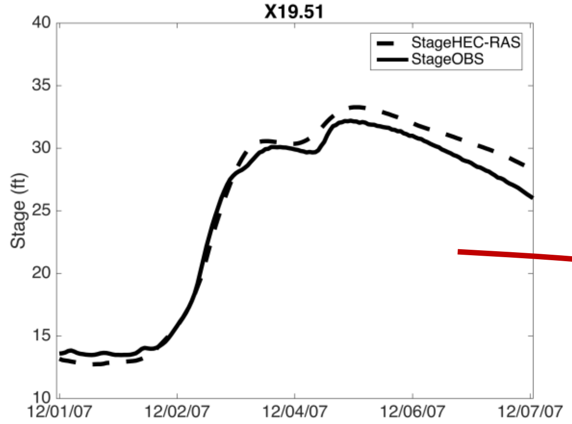


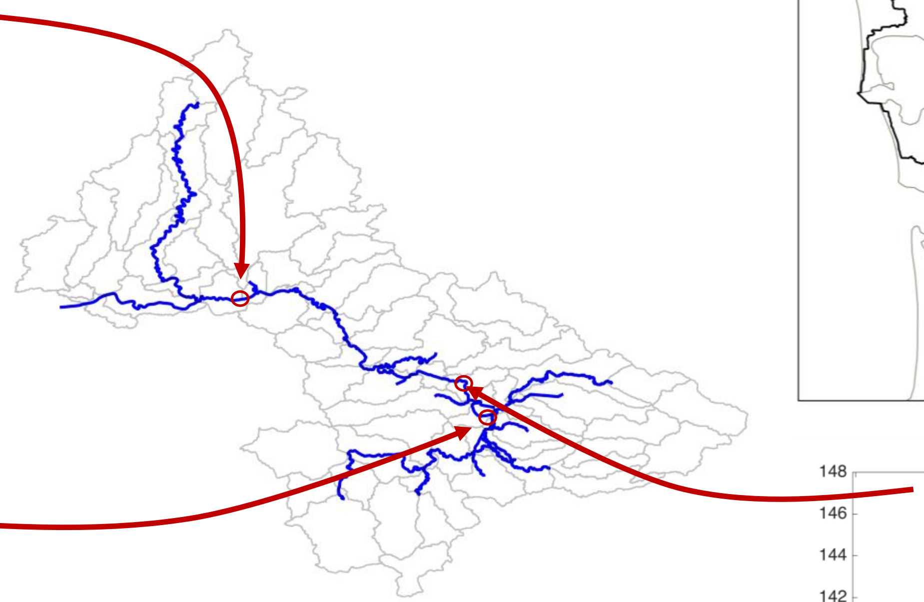
Precipitation in Doty is significantly low.

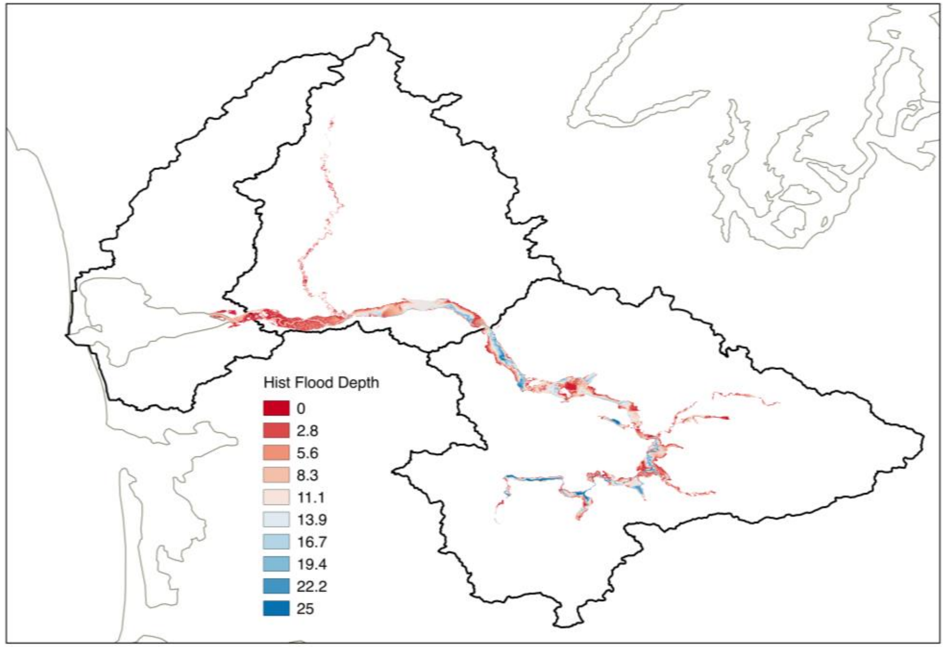


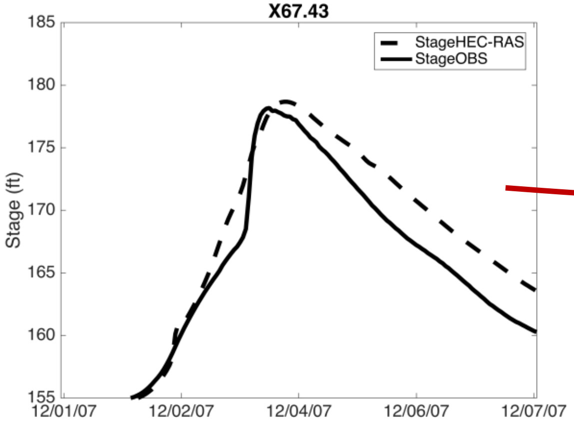
Hydrology
HEC-HMS
DHSVM

Claibrated HEC-RAS Hydrodynamic Model was provided by USACE. Using observed USGS inflow hydrographs, the model performs very well.

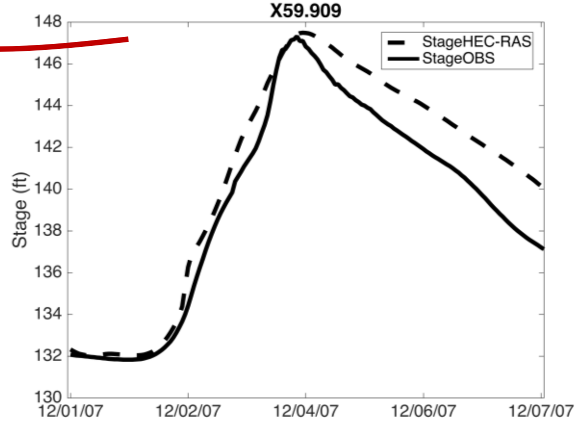








Chehalis River Hydraulic Model Development Project
WATERSHED Science & Engineering and WEST Consultants
2012

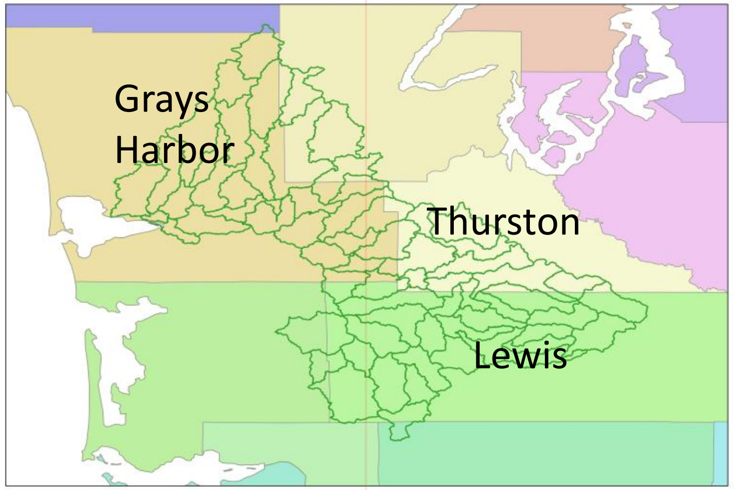


Hydrodynamics
HEC-RAS

HAZUS + IO estimated damages of $731 million for Grays Harbor, Lewis and Thurston counties. Estimates of damages are $1 billion for the states of Washington and Oregon combined (Department of Comerce).

	Grays Harbor	Lewis	Thurston
Stock Damages (private and public buildings & content, infrastructures, vehicles)	$ 177,336,000	$ 426,221,000	$ 76,011,000
Net loss in local production and trade (including reconstruction)	$ 7,120,000	$ 36,920,000	$ 4,050,000
Total	$ 184,456,000	$ 463,141,000	$ 80,061,000
Most negatively affected sectors	Agriculture, forestry, construction, manufacturing, accounting	Health and social services, agriculture, forestry, manufacturing, finance, real estate	Government services, construction, agriculture, forestry, finance, real estate, accounting
Estimated time for complete business recovery	10 months	30 months	3 months

Source: Avelino and Dall'erba (2016)
Dollars are in 2008 value



Direct Physical Damage by County, in 2008 Thousand dollars (USACE Raster)

		Grays Harbor		Lewis		Thurston
Agriculture						
Crops	$	-	$	-	$	-
Building Stock						
Capital Stock Losses						
Building Loss	$	71,449	$	142,845	$	22,282
Contents Loss	$	52,366	$	192,622	$	23,731
Inventory Loss	$	977	$	8,079	$	357
Vehicles						
	$	18,413	$	46,452	$	9,601
Infrastructure						
Transportation	$	-	$	-	$	-
Utilities	$	26,719	$	31,567	$	20,040
Essential Facilities						
Fire Station	$	-	$	-	$	-
Police Station	$	-	$	-	$	-
Hospitals	$	-	$	-	$	-
Schools	$	7,412	$	4,657	$	-
Total Physical Damage						
	$	**177,336**	**$**	**426,221**	**$**	**76,011**

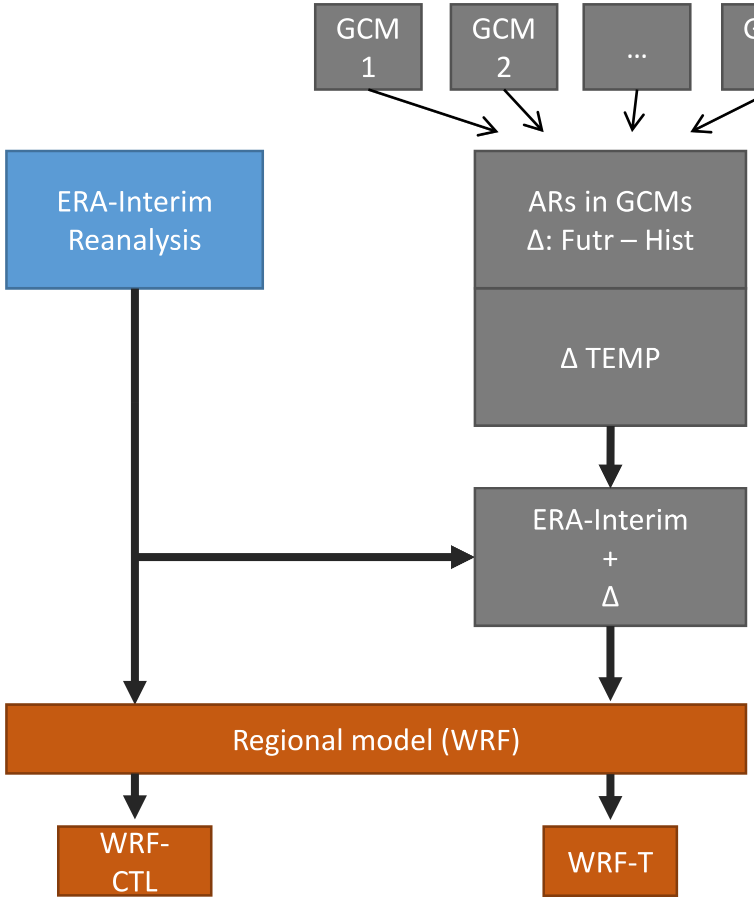
Source: Simulation ran on HAZUS 3.0

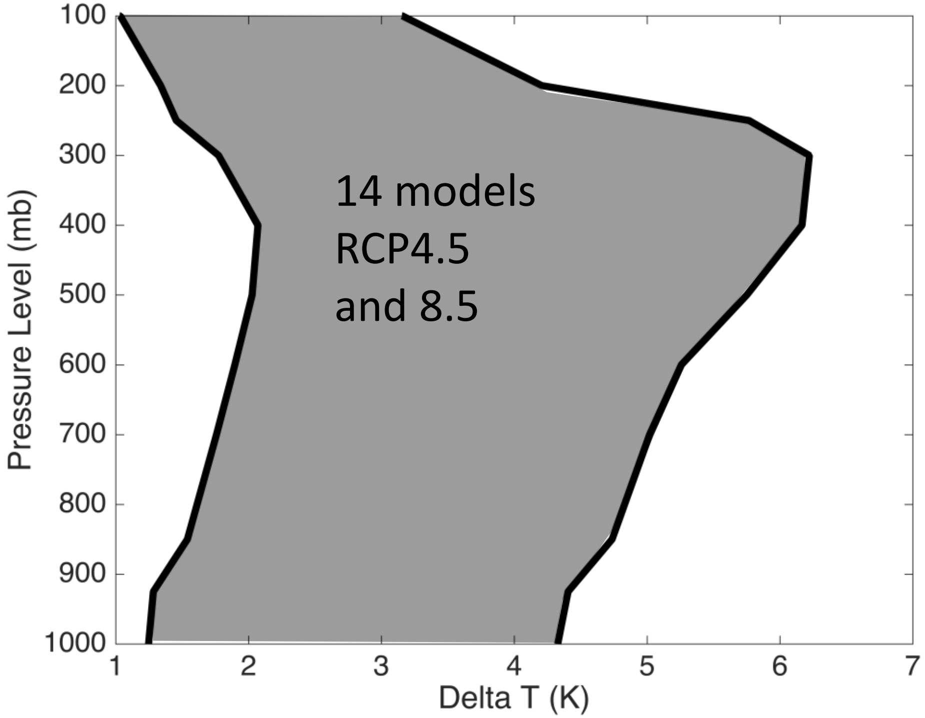
Compare to $166 million in our study.

Socioeconomics
HAZUS

What if this same event had occurred in a warmer climate?

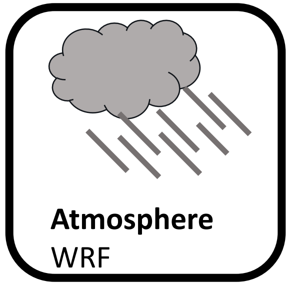
We used a pseudo-global warming approach to estimate the changes in future ARs due to increasing temperature.



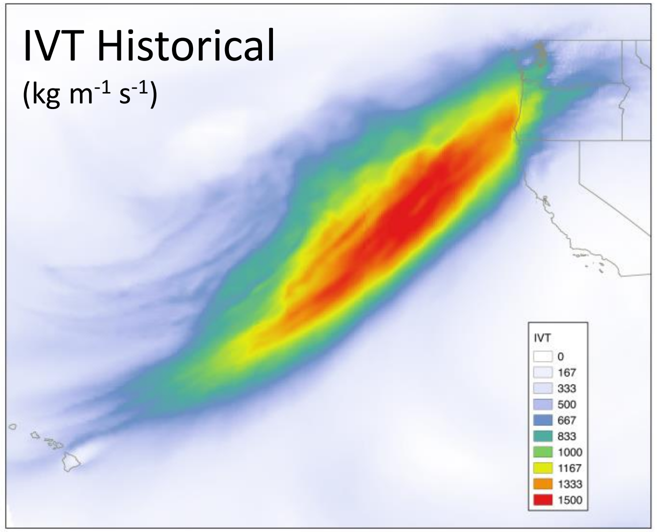


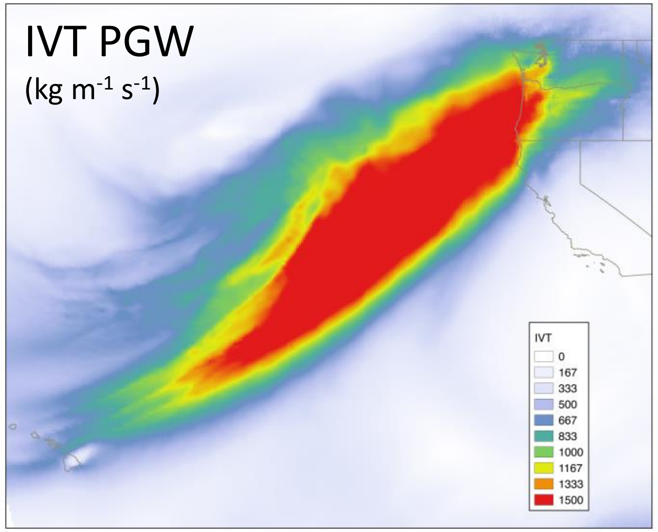
BCC-CSM1.1
CanESM2
CCSM4
CNRM-CM5
CSIRO-Mk3.6.0
INM-CM4
IPSL-CM5A-LR
MIROC5
MIROC-ESM
MPI-ESM-LR
NorESM1-M
GFDL-CM3
GFDL-ESM2M
HadGEM2-ES

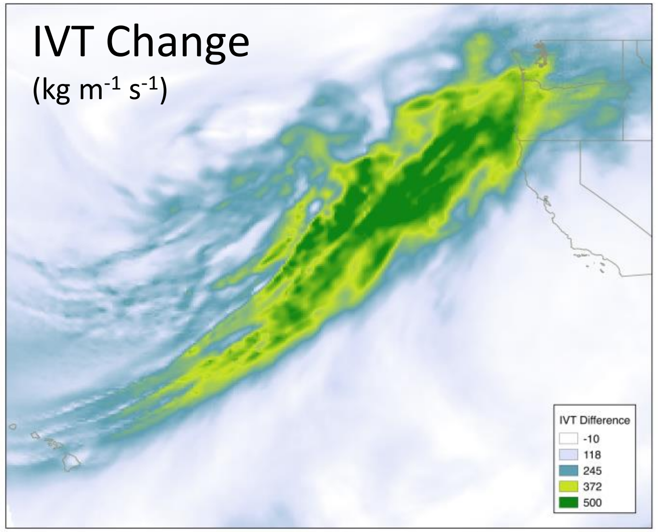
We changed the lateral boundary conditions of WRF using 14 CMIP5 Climate Models to calculate the projected temperature changes at different levels in the atmosphere.

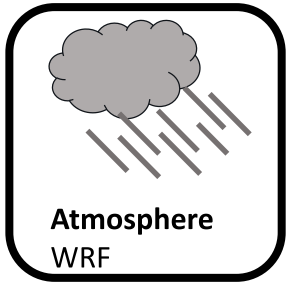


The changes in temperature cause changes in the integrated water vapor transport over the region.



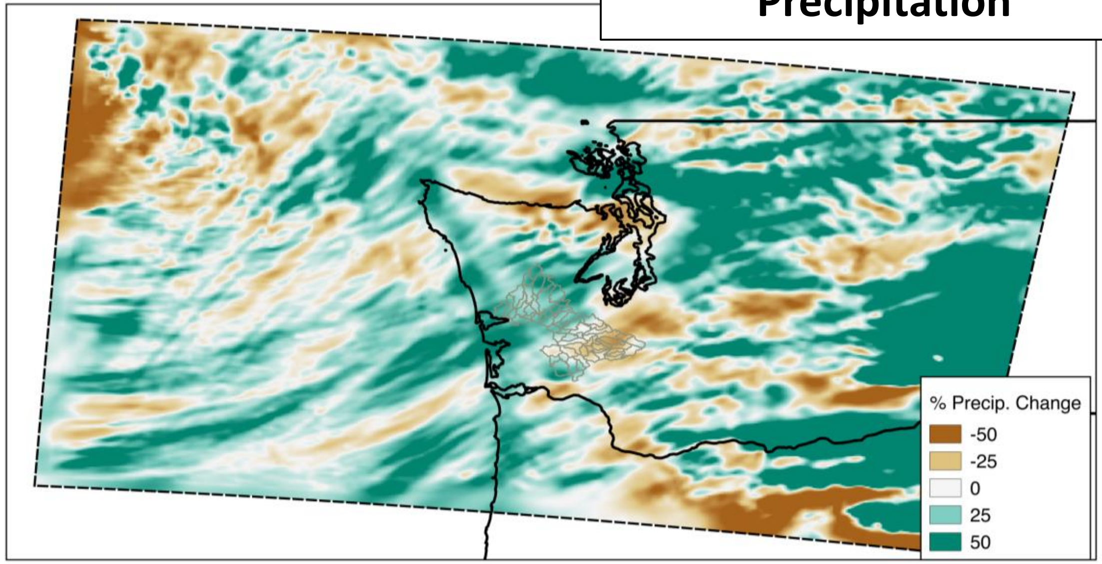




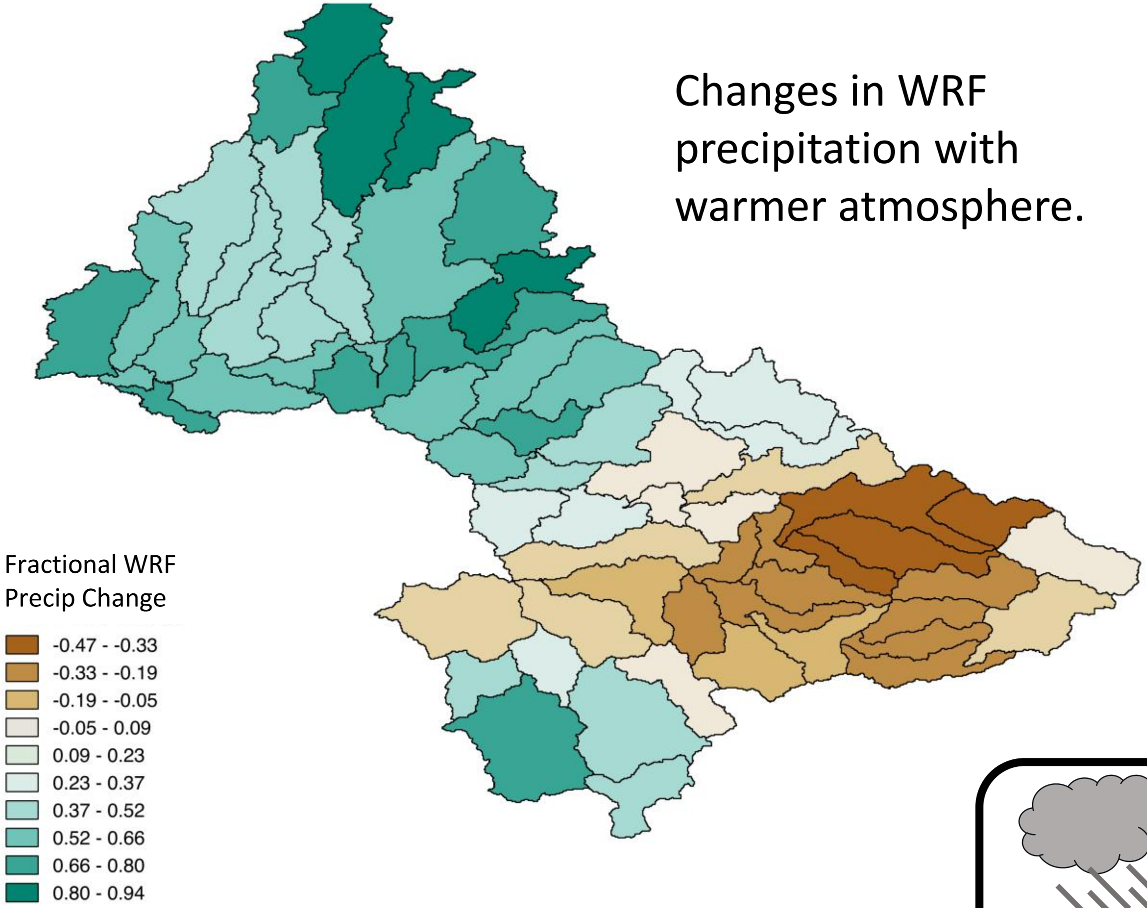


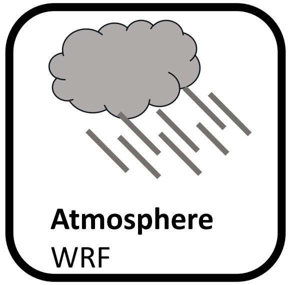
Despite increased IVT, some regions receive more, but others less precipitation.

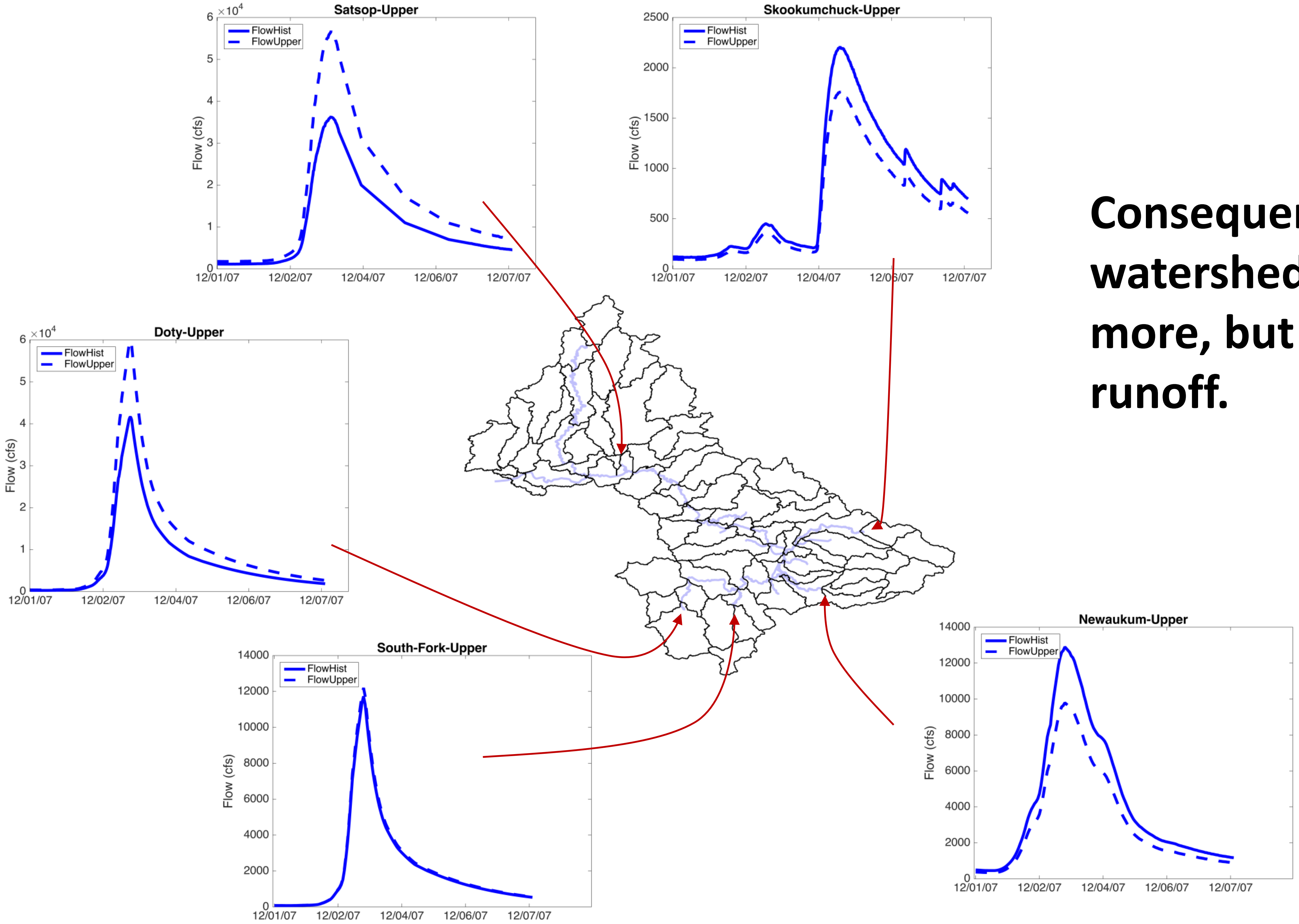
WRF-simulated changes in Precipitation



Changes in WRF precipitation with warmer atmosphere.

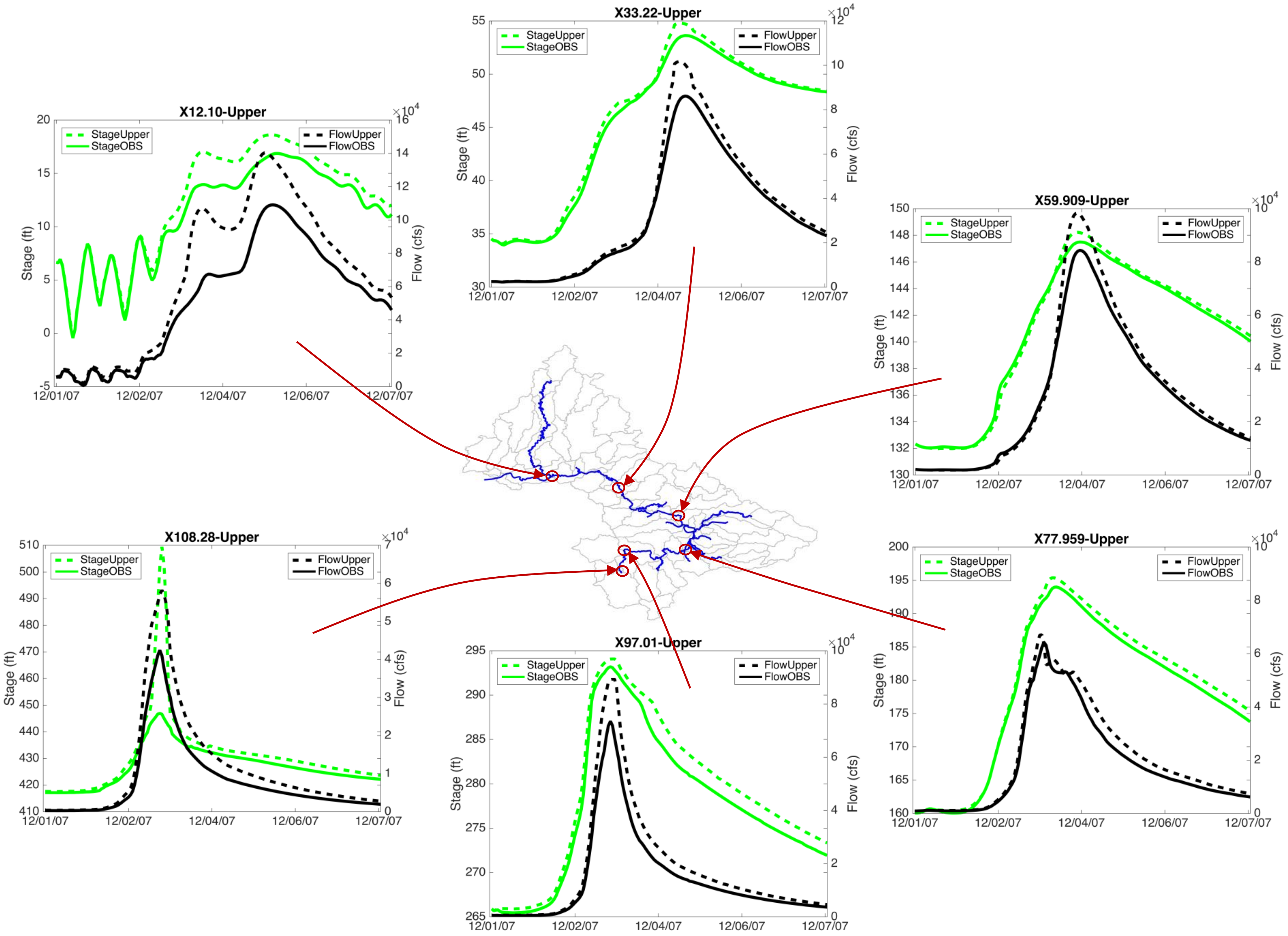




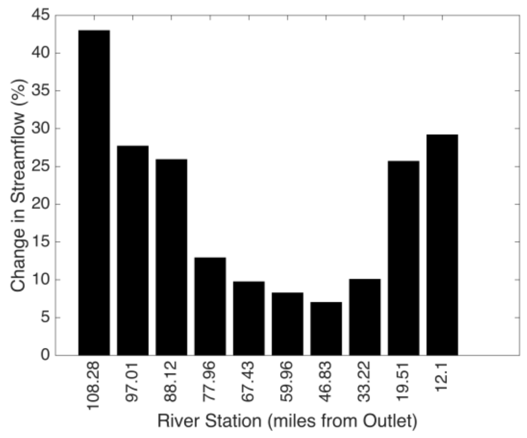


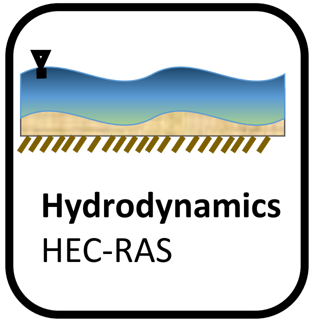
Consequently, some watersheds generate more, but others less runoff.

Hydrology
HEC-HMS
DHSVM

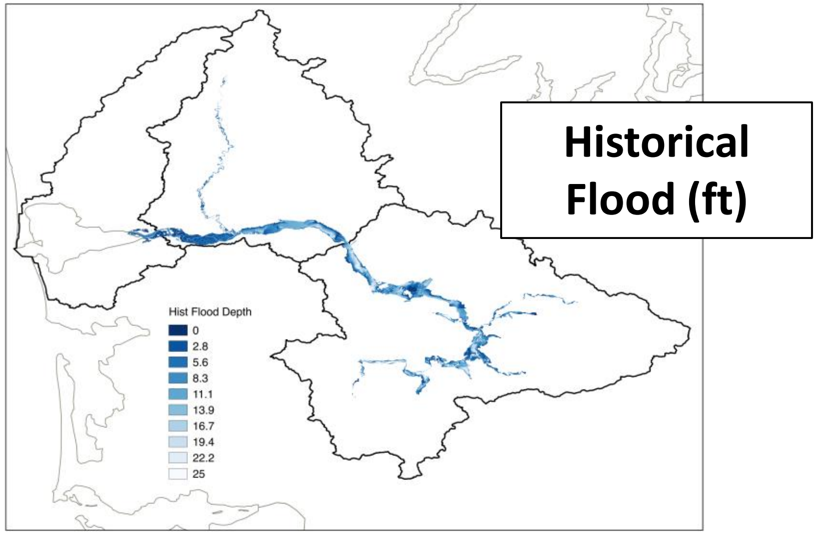


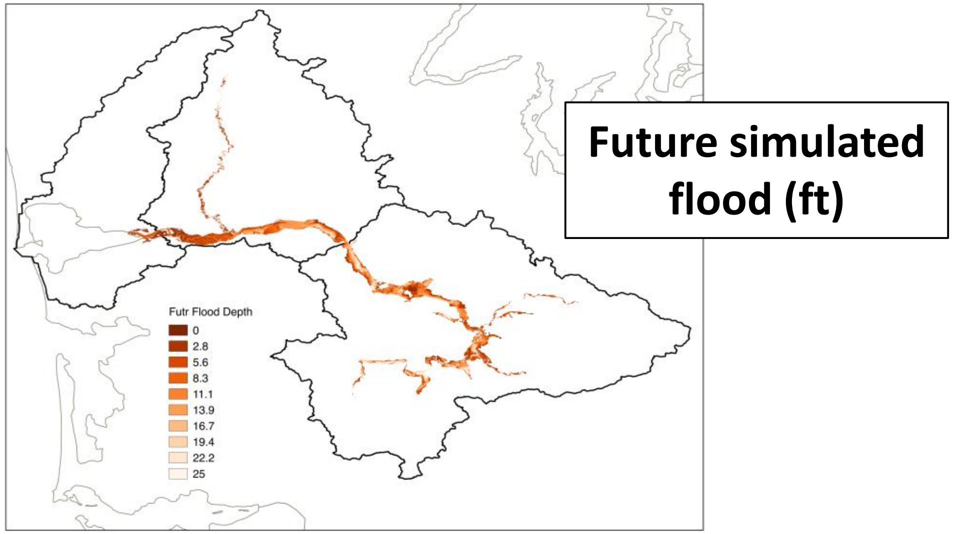
Streamflow and stage increase throughout the length of the channel.

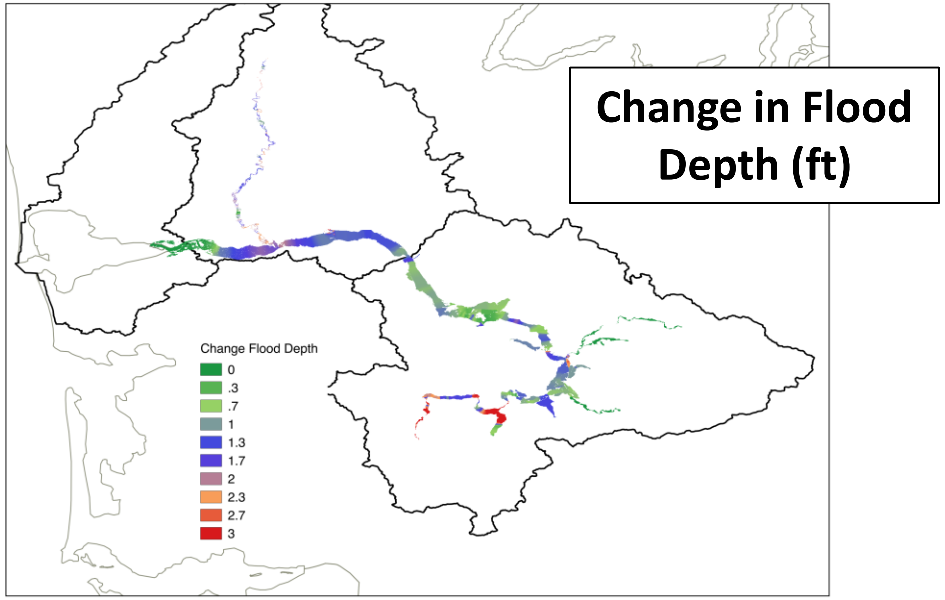


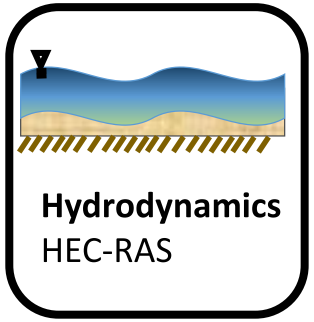


Changes in inundation extent are not large, but there is change in depth.





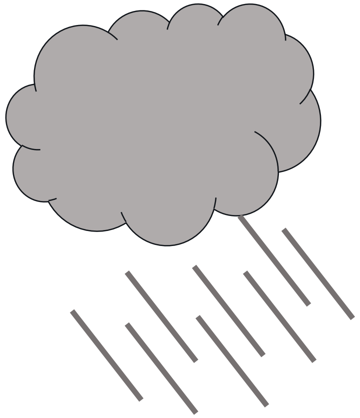




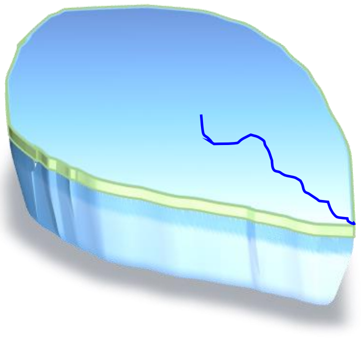
The changes in inundation depth and extent do result in socioeconomic damages due to both stock damages and net loss in local production and trade.

		Grays Harbor		Lewis		Thurston	
Stock Damages (Private and Public buildings, Content and Inventory; Infrastructure; Vehicles)	Base	$177,336,433		$426,220,784		$76,011,268	
	Upper Bound	$191,869,744	8%	$473,545,310	11%	$79,047,620	4%
	Lower Bound	$180,924,914	2%	$463,148,473	9%	$81,733,084	8%
Net Loss in Local Production and Trade	Base	$7,842,131		$39,030,168		$4,972,059	
	Upper Bound	$11,342,467	45%	$44,627,716	14%	$7,504,891	51%
	Lower Bound	$9,981,959	27%	$43,688,793	12%	$7,249,785	46%
Total	Base	$185,178,563		$465,250,952		$80,983,327	
	Upper Bound	$203,212,210	10%	$518,173,026	11%	$86,552,511	7%
	Lower Bound	$190,906,874	3%	$506,837,266	9%	$88,982,869	10%

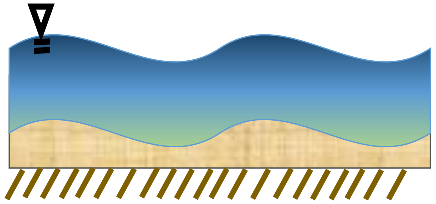
In conclusion, we have developed an integrated modeling system that allows us to estimate changes in ARs and their socioeconomic consequences.



Atmosphere
WRF



Hydrology
HEC-HMS
DHSVM



Hydrodynamics
HEC-RAS

Socioeconomics
HAZUS

Warmer atmosphere results in more IVT but spatial changes in precipitation.

Some areas show more runoff, but others less.

We have increased streamflow throughout the channel.

Changes in economic losses range between +3% and +10%