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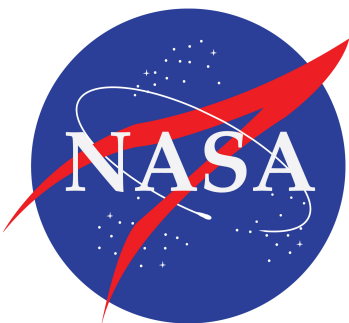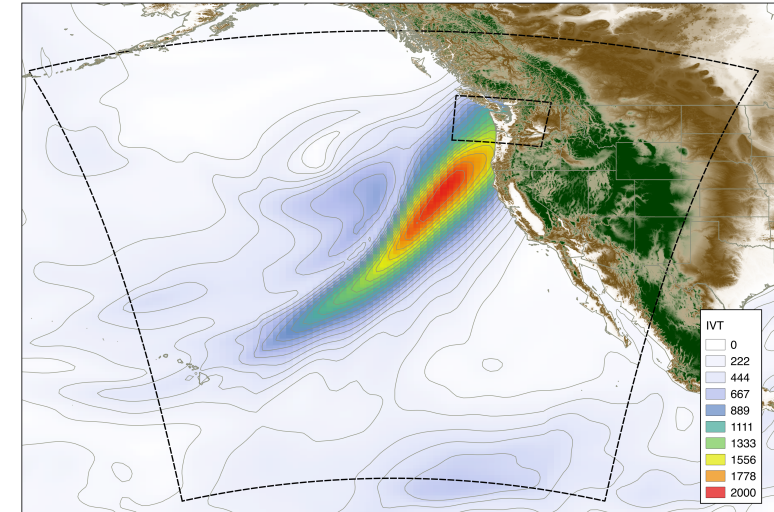
Francina Dominguez

Co-authors
Huancui Hu, Jorge Eiras-Barca
Dennis Lettenmaier, Ali Mehran
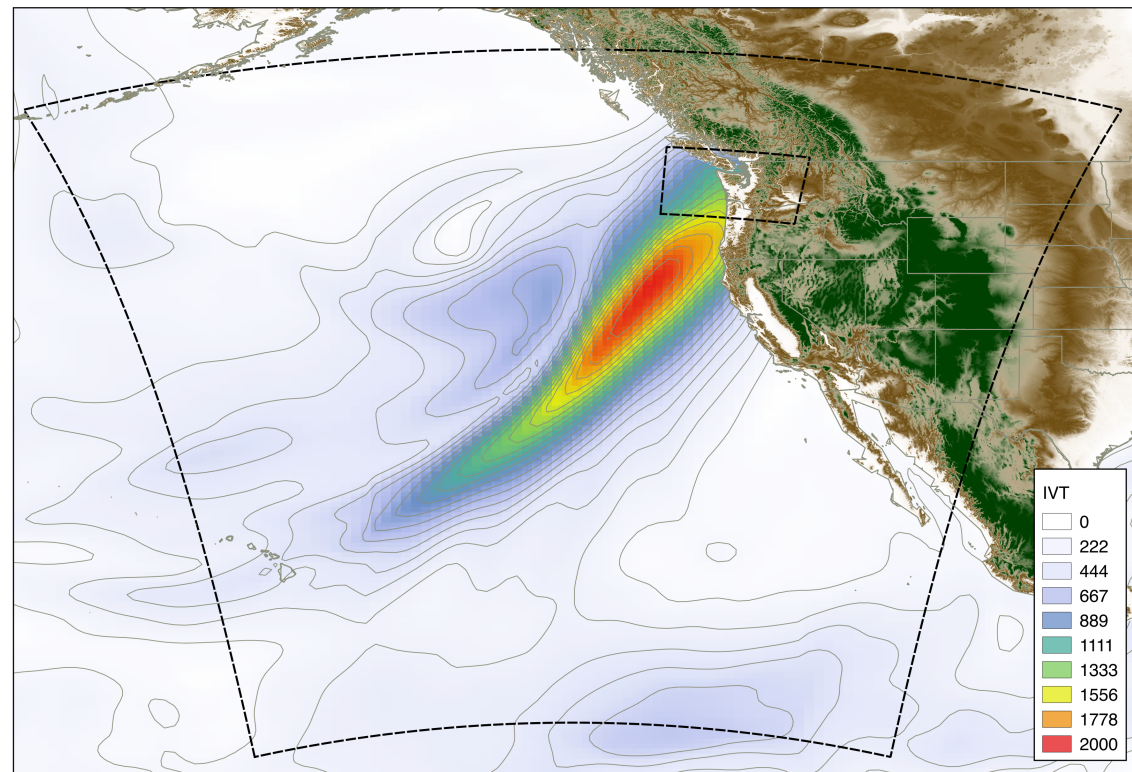Shuyi Huang, Art Schmidt
Sandy Dall'erba, Andre Avelino

**Presented at the
8th EGU Leonardo Conference
Ourense, Spain
25-27 Oct. 2016**

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.

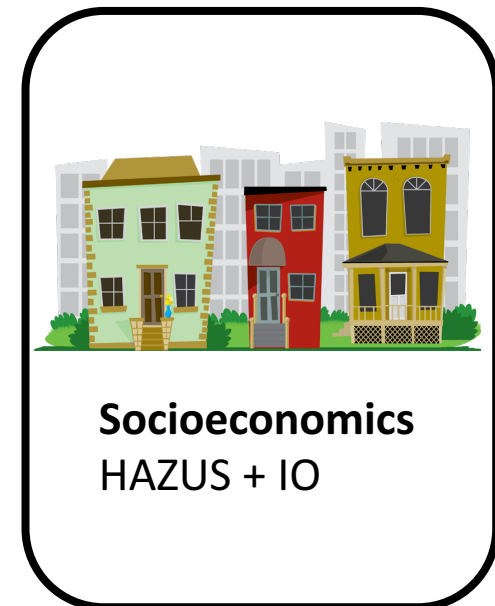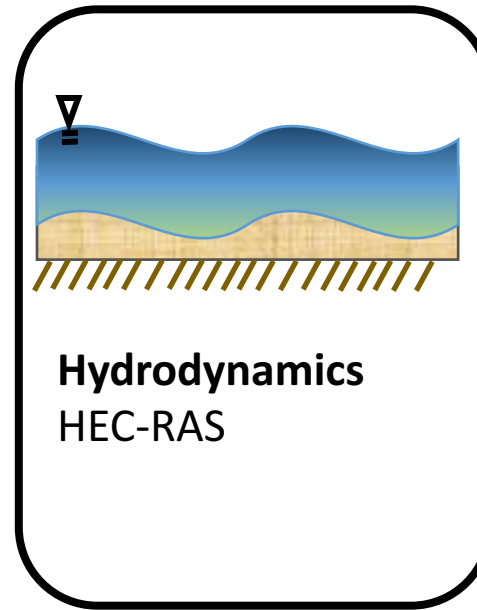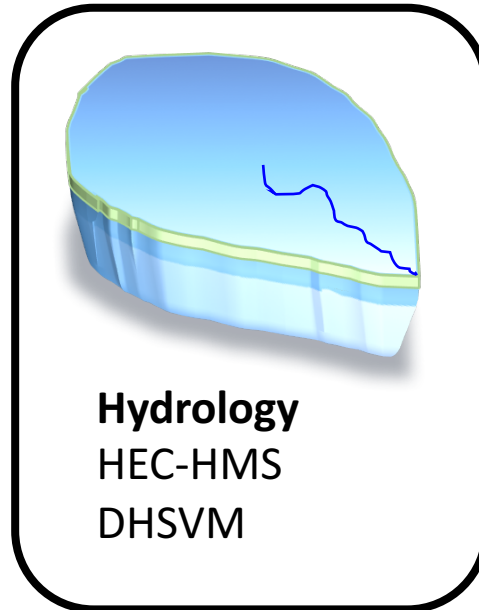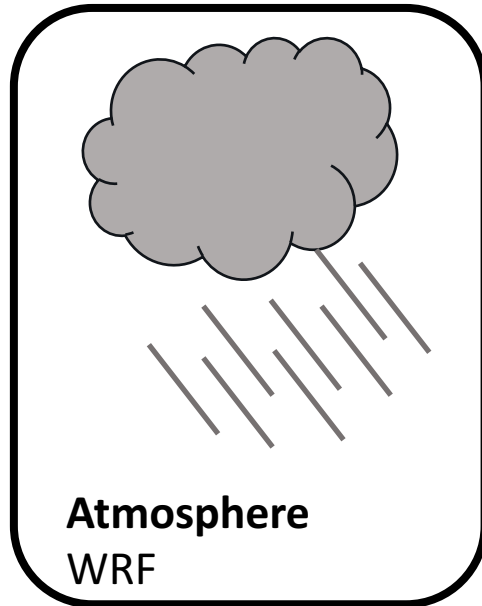**40 times the average discharge at the mouth of the Mississippi River**

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

USGS 12020000 CHEHALIS RIVER NEAR DOTY, WA
Annual Peak Streamflow
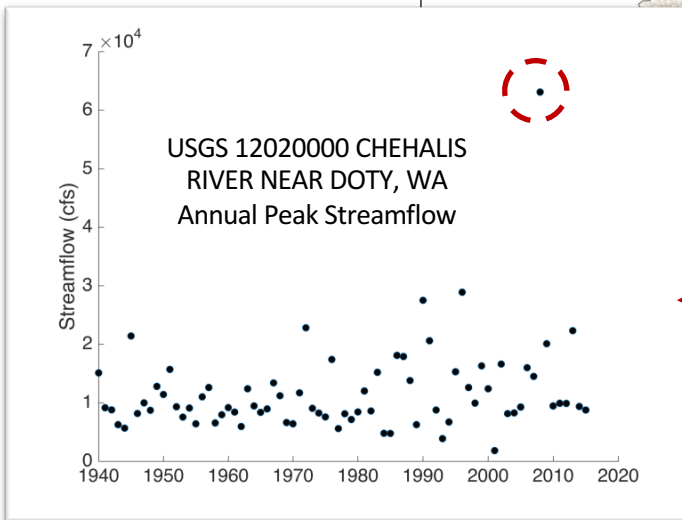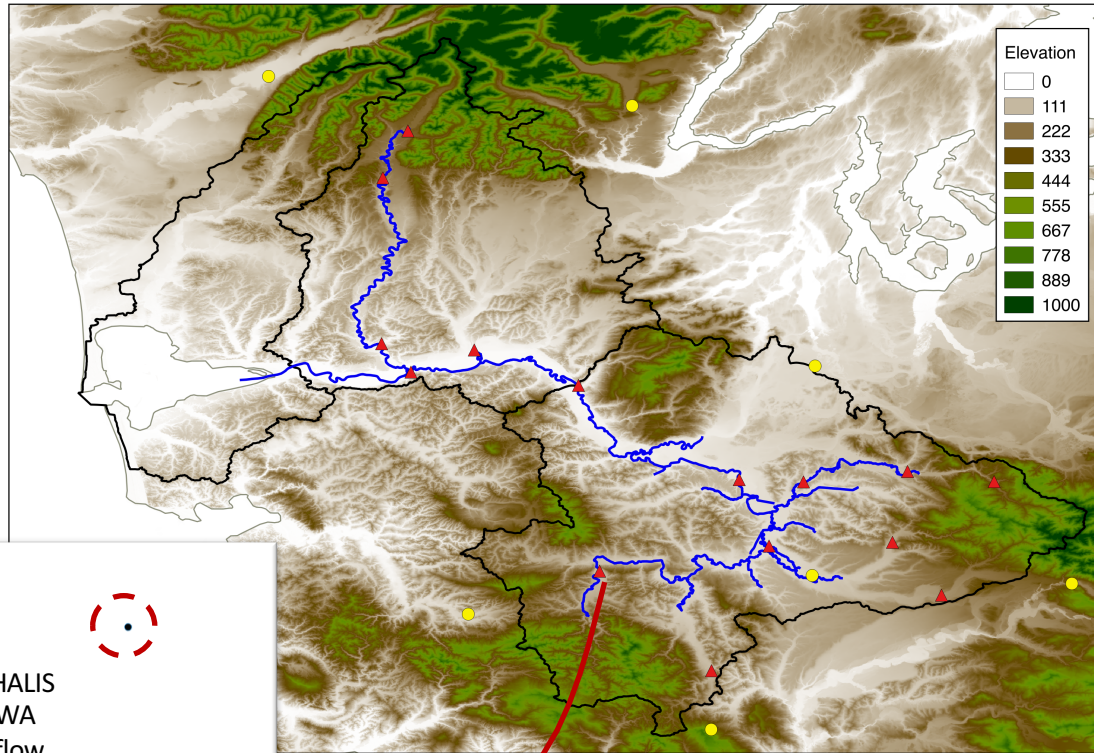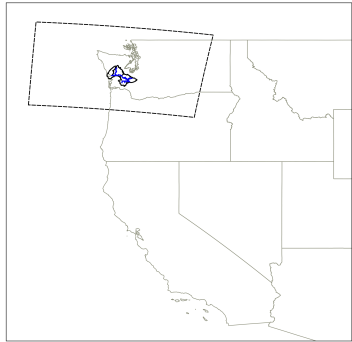
Source: WES engineering report.

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.
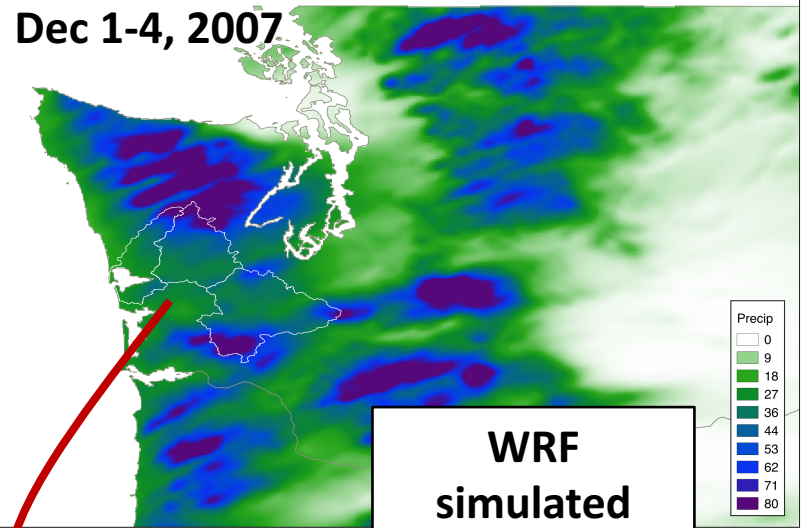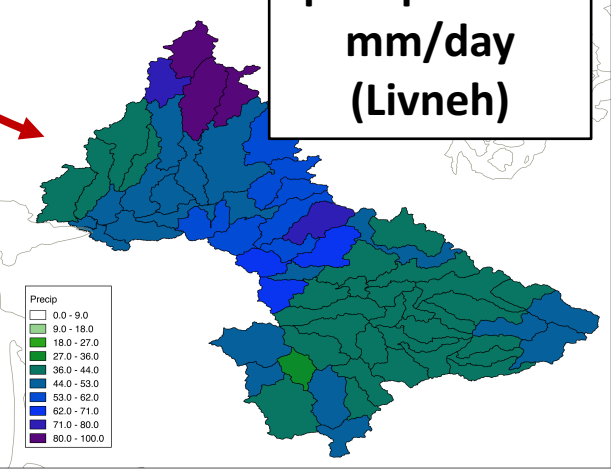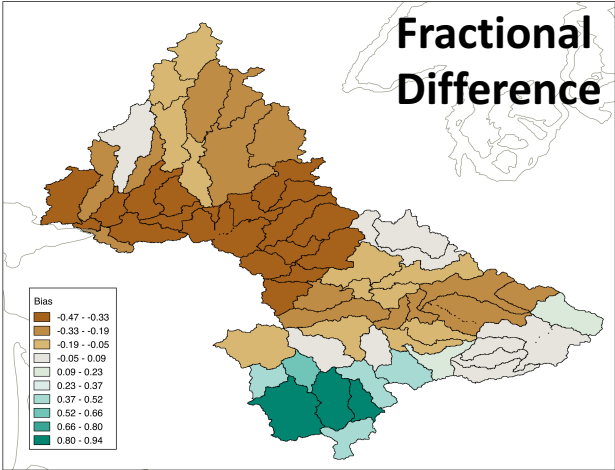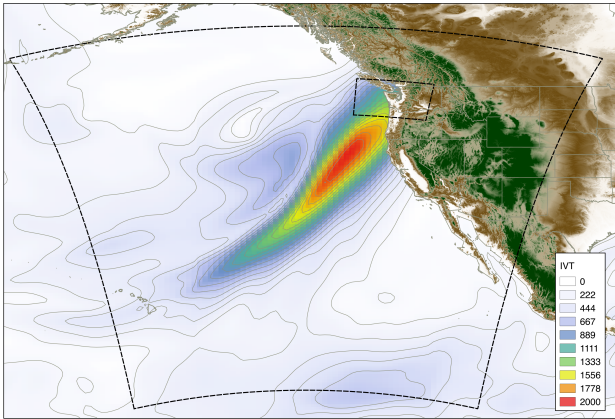

- **Historical (Control)**
- **Future**

Atmosphere
WRF

Hydrology
HEC-HMS
DHSVM

Hydrodynamics
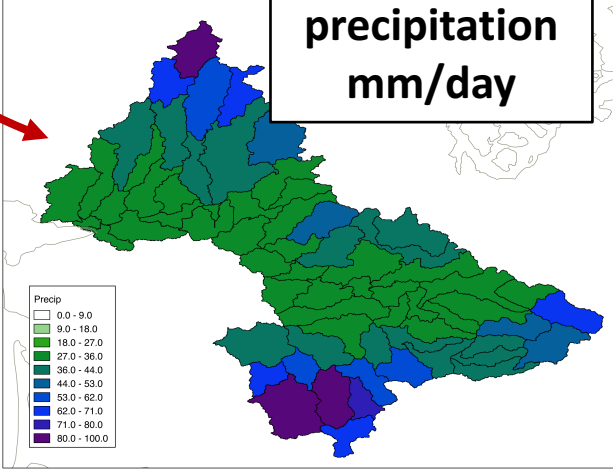HEC-RAS

Socioeconomics
HAZUS + IO

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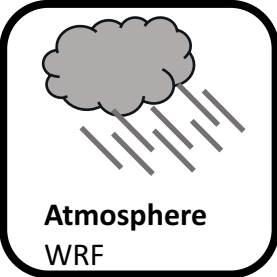

Dec 1-4, 2007
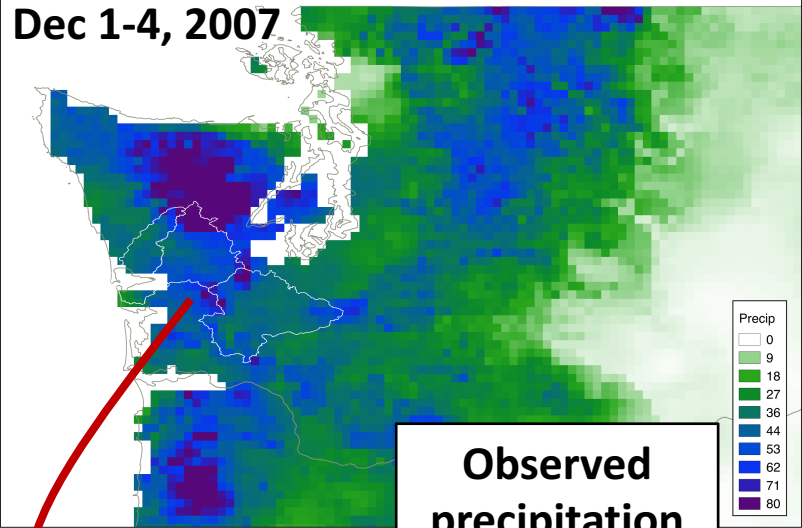
Observed precipitation mm/day (Livneh)

Dec 1-4, 2007

**WRF simulated precipitation mm/day**

Fractional Difference

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.
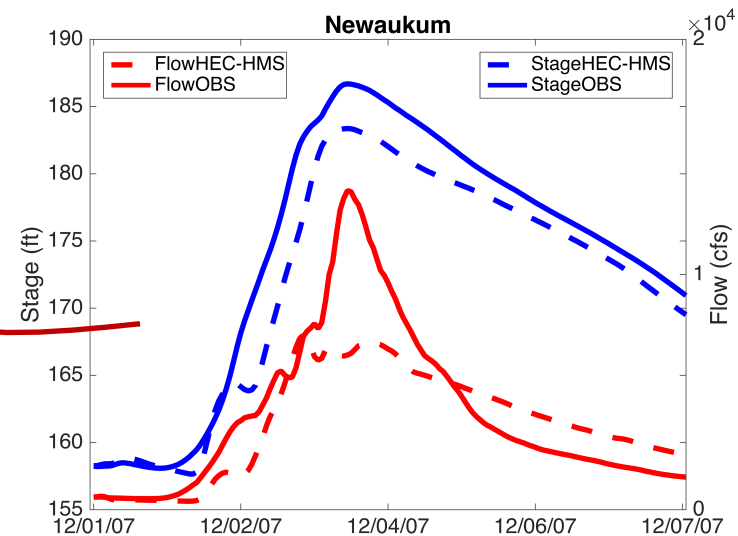
Atmosphere
WRF

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.
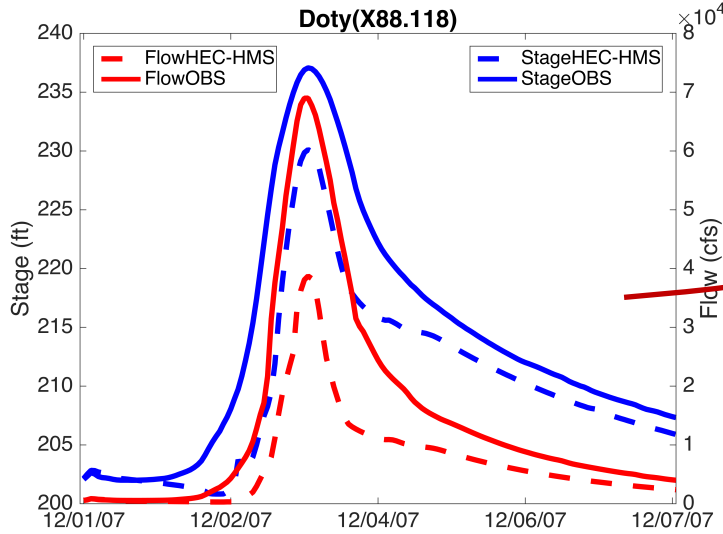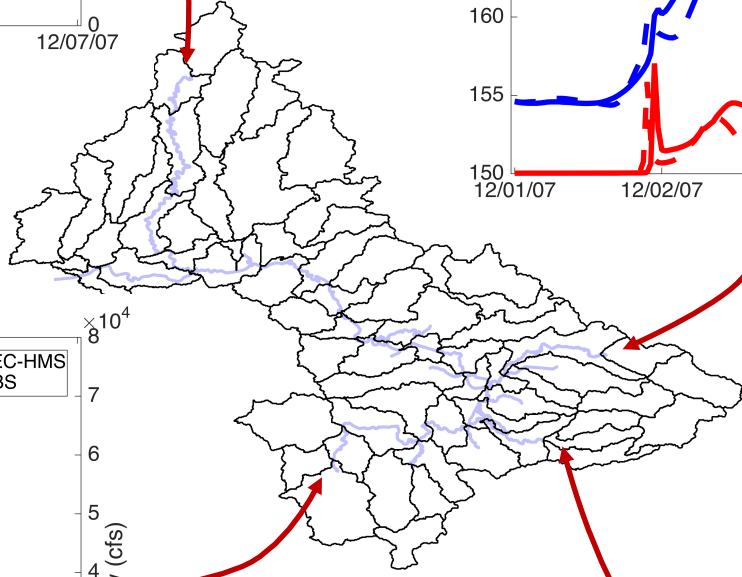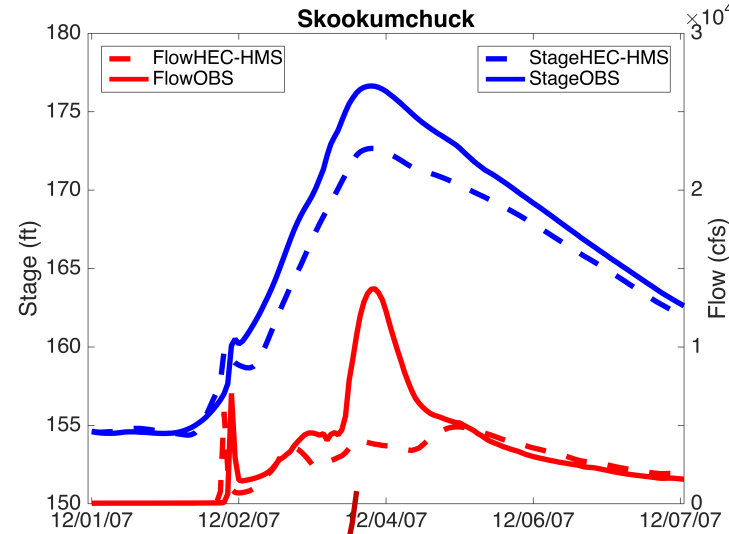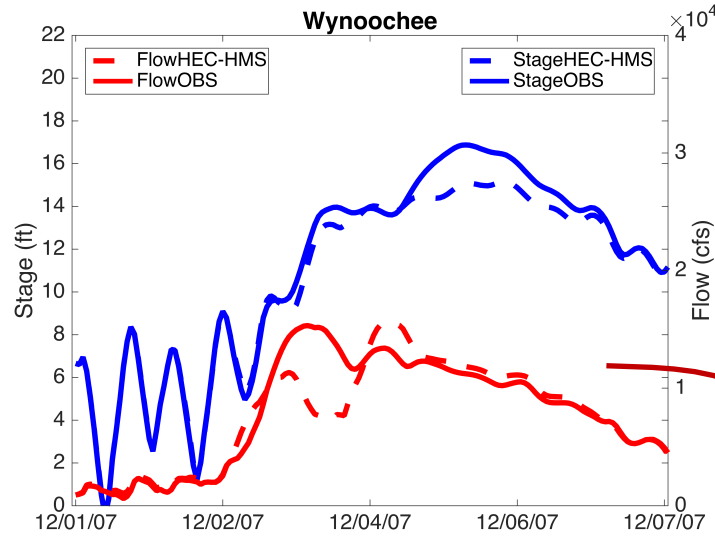
Precipitation in Doty is significantly low.

Hydrology
HEC-HMS
DHSVM

Calibrated HEC-RAS Hydrodynamic Model was provided by USACE. Using observed USGS inflow hydrographs, the model performs very well.
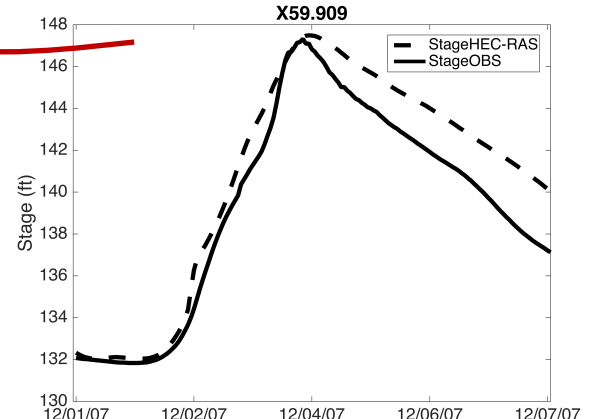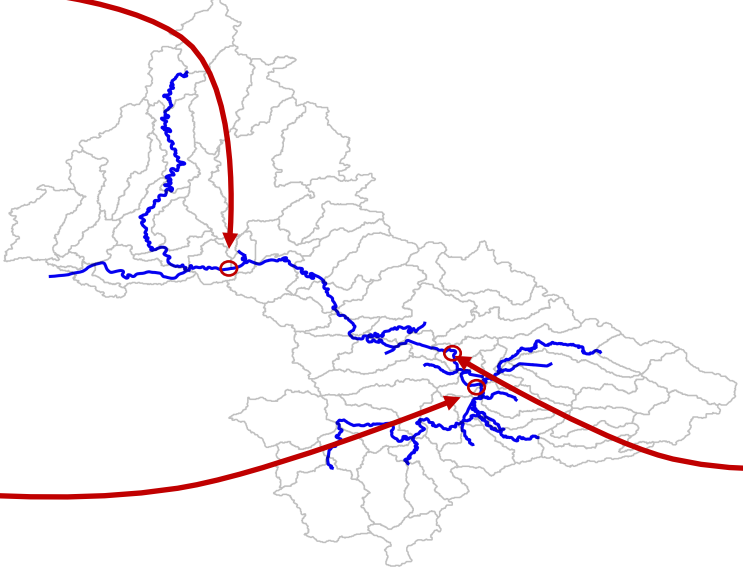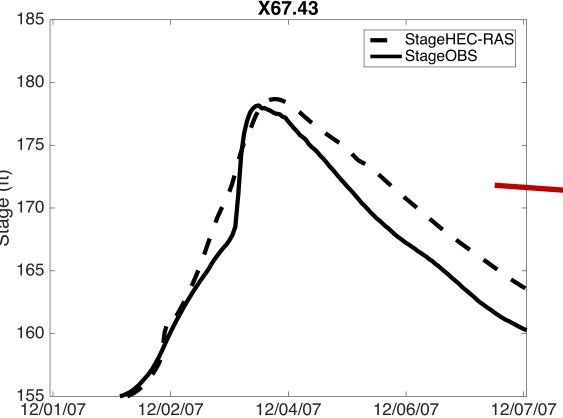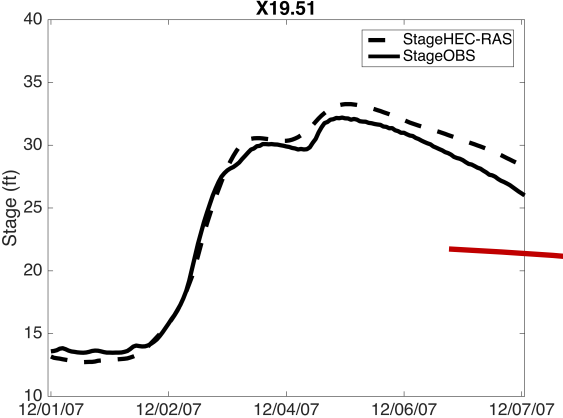
Chehalis River Hydraulic Model Development Project
WATERSHED Science & Engineering and WEST Consultants
2012

Hydrodynamics
HEC-RAS

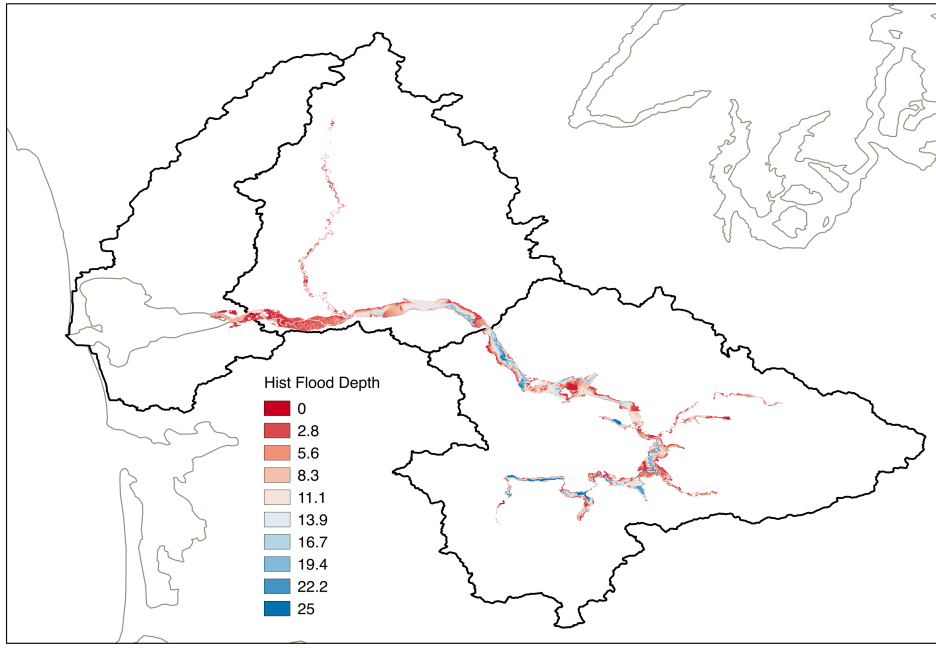# HAZUS + IO estimated damages of $731 million for Grays Harbor, Lewis and Thurston counties. Estimates of damages are $1 billion for the states of Washington and Oregon combined (Department of Comerce).
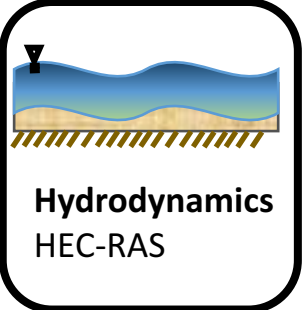
	Grays Harbor	Lewis	Thurston
Stock Damages (private and public buildings & content, infrastructures, vehicles)	$ 177,336,000	$ 426,221,000	$ 76,011,000
Net loss in local production and trade (including reconstruction)	$ 7,120,000	$ 36,920,000	$ 4,050,000
Total	$ 184,456,000	$ 463,141,000	$ 80,061,000
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)
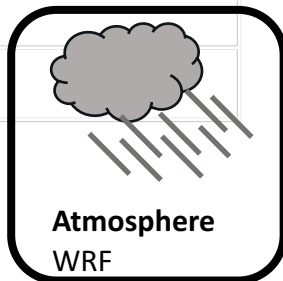Dollars are in 2008 value

Grays Harbor

Thurston

Lewis

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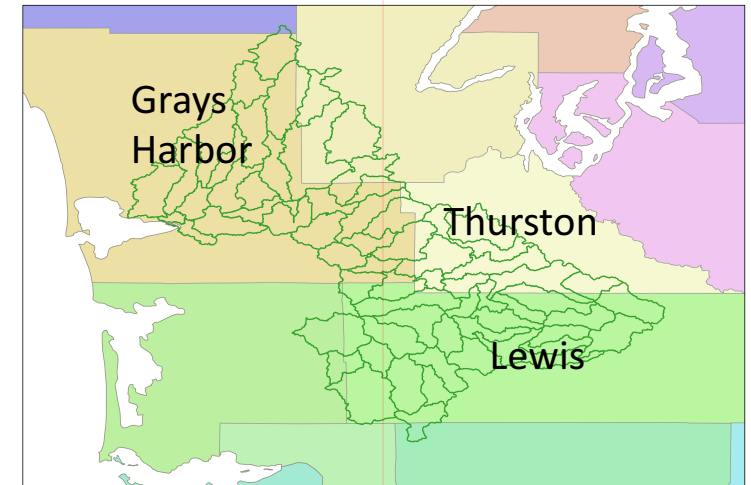
What if this same event had occurred in
a warmer climate?

We used a pseudo-global warming approach to estimate the changes in future ARs due to increasing temperature.
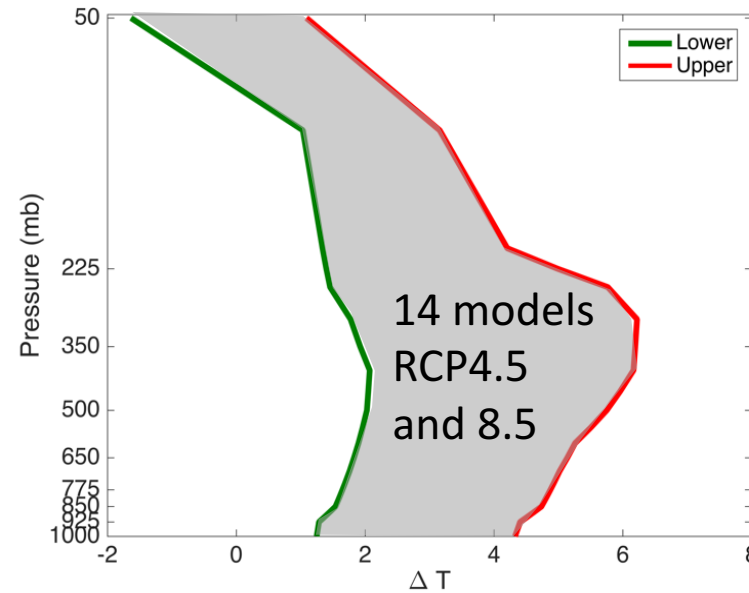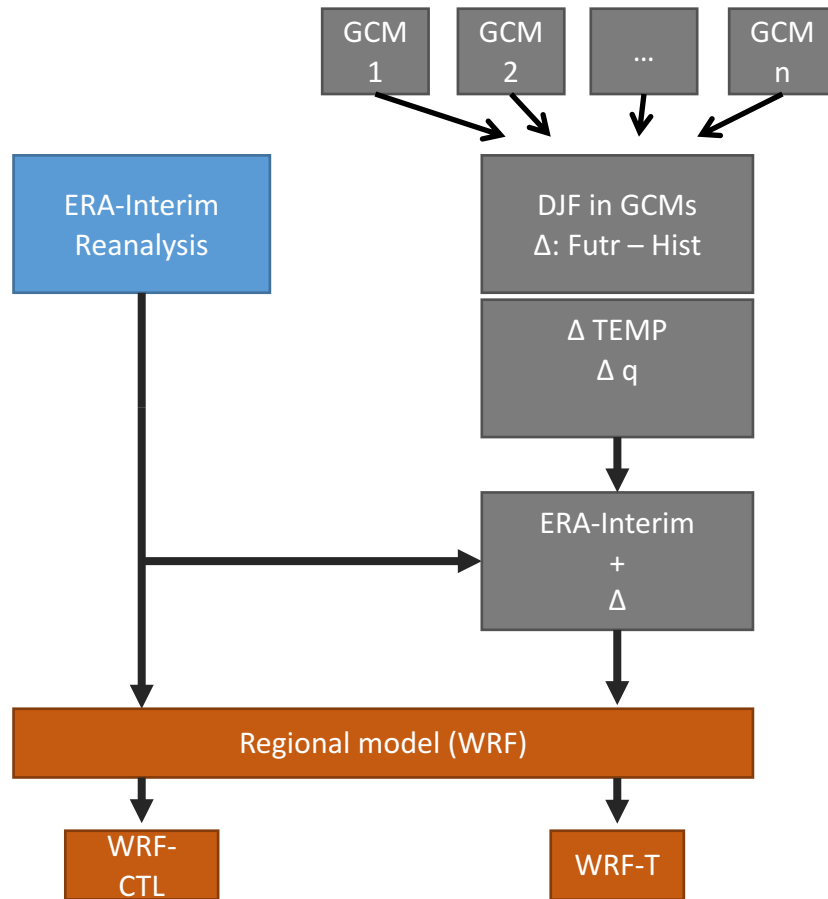
We changed the lateral boundary conditions of WRF using 14 CMIP5 Climate Models to calculate the projected temperature changes at different levels in the atmosphere.

Why use a PGW approach?
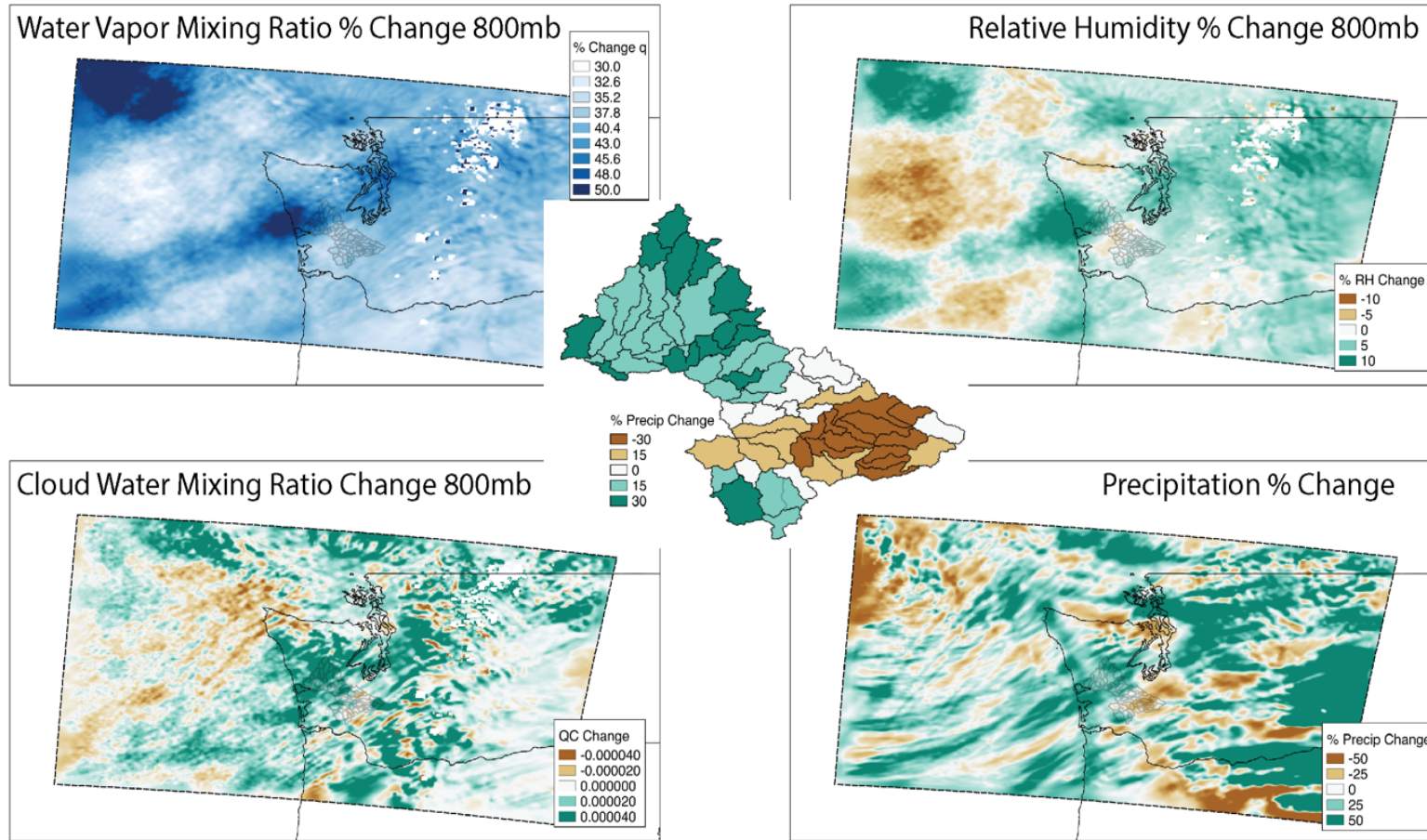
1. The angle of impingement on the local topography is critical and we want to maintain this unchanged.

2. We use PGW in order to isolate the thermodynamic effect (the dominant effect).

3. It is a computationally efficient way to incorporate different scenarios/models (uncertainty).

4. We need very high resolution modeling to realistically represent topography.

The changes in temperature cause changes in the integrated water vapor transport over the region.
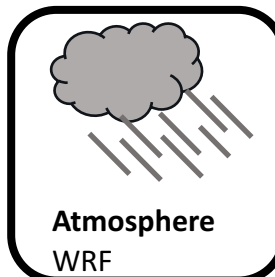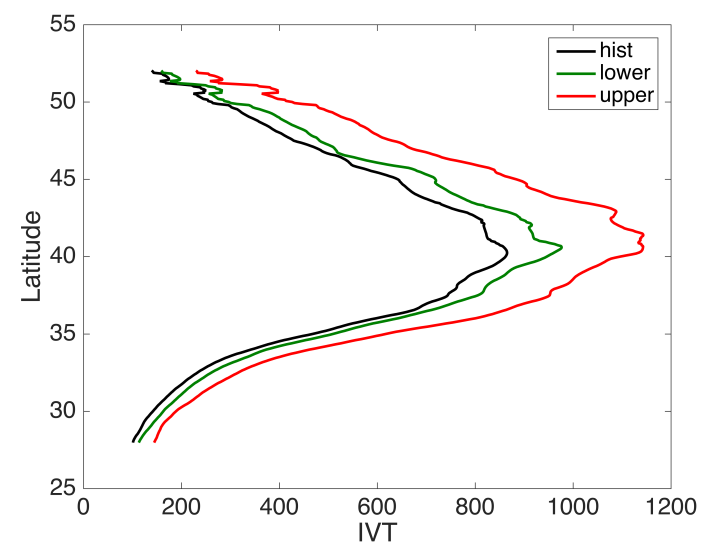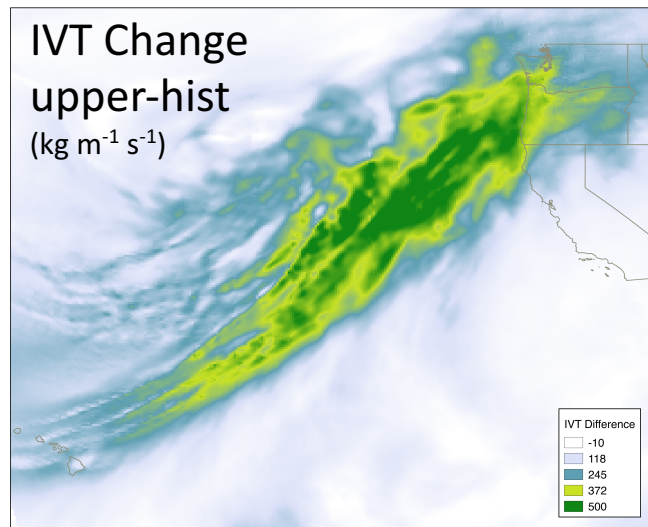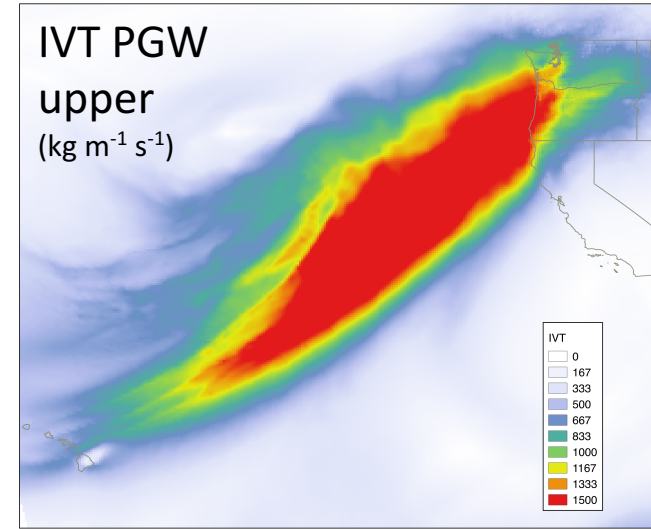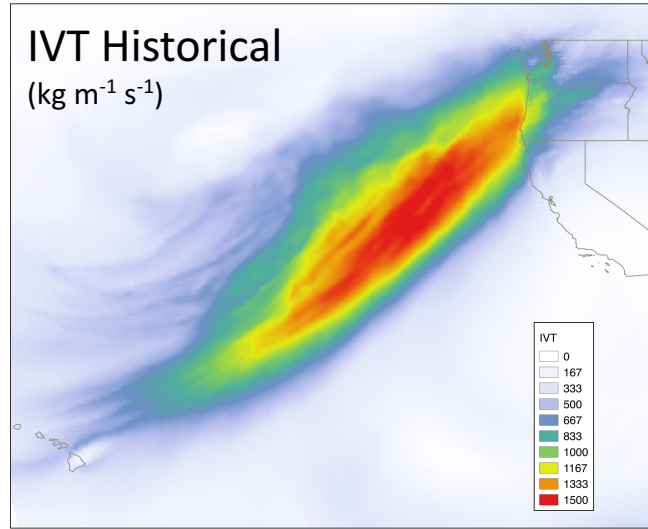
Changes in water vapor mixing ratio are positive everywhere. However, the RH and cloud water mixing ratio changes can be either positive or negative.

Water Vapor Mixing Ratio % Change 800mb

% Change q
30.0
32.6
35.2
37.8
40.4
43.0
45.6
48.0
50.0

Relative Humidity % Change 800mb

% RH Change
-10
-5
0
5
10

% Precip Change
-30
15
0
15
30

Cloud Water Mixing Ratio Change 800mb

QC Change
-0.000040
-0.000020
0.000000
0.000020
0.000040

Precipitation % Change

% Precip Change
-50
-25
0
25
50

17% area-average increase.

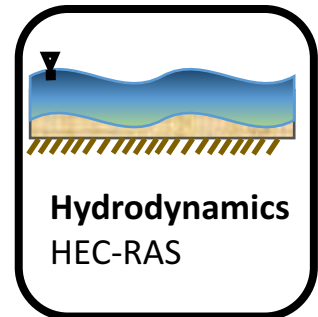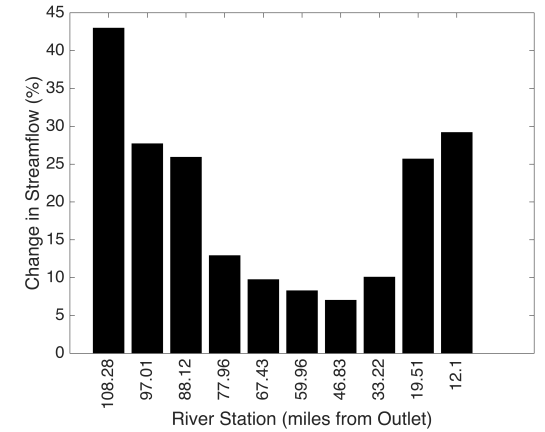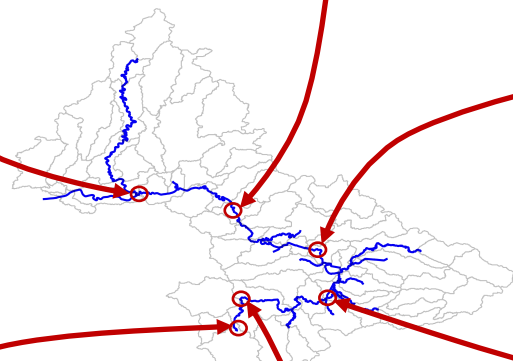**Changes in precipitation are positive in the northern basin and negative in the eastern part of the Chehalis.**
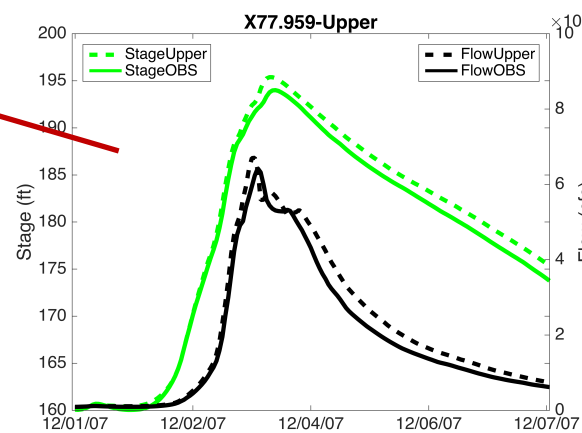
Atmosphere
WRF
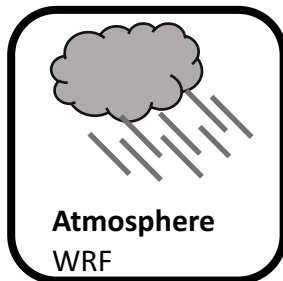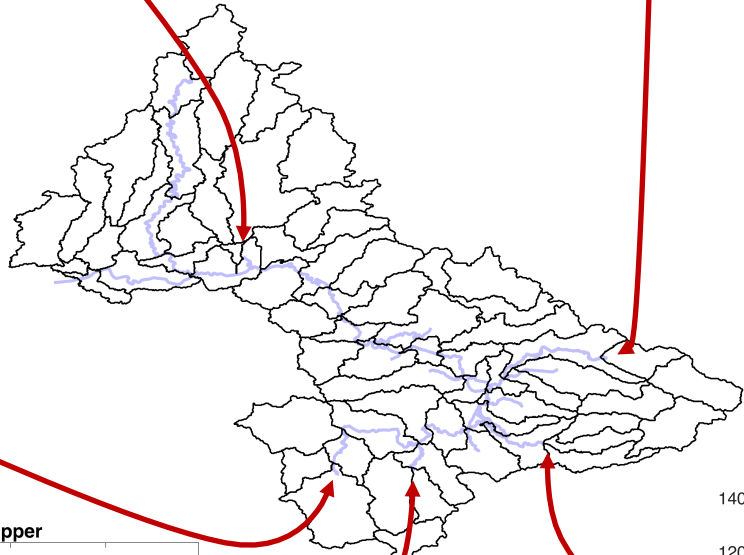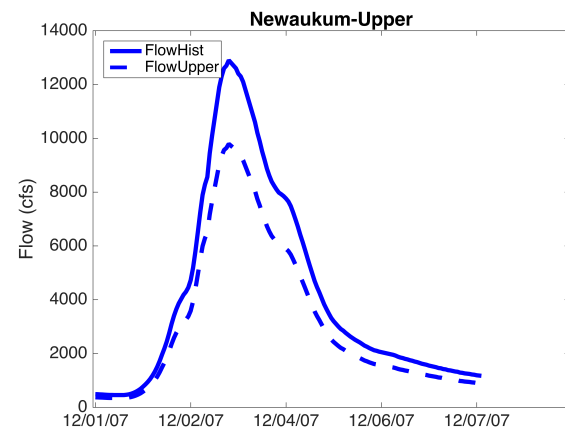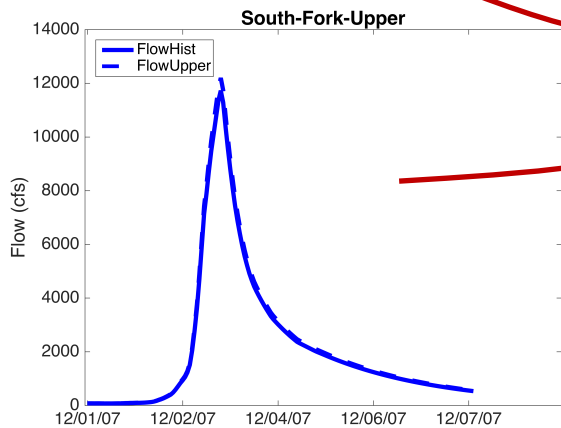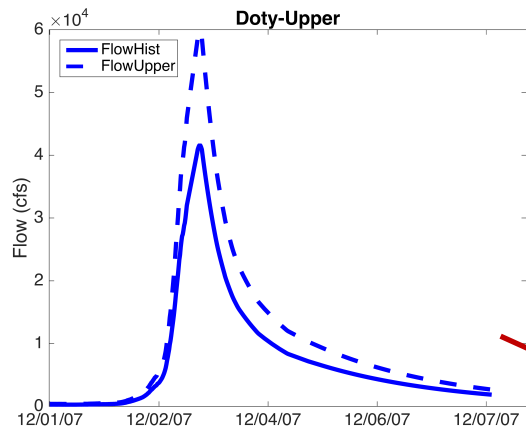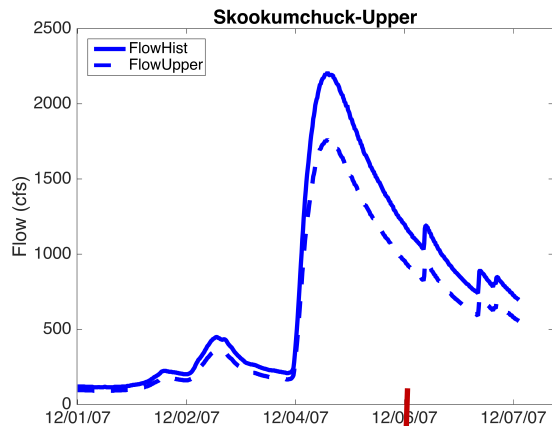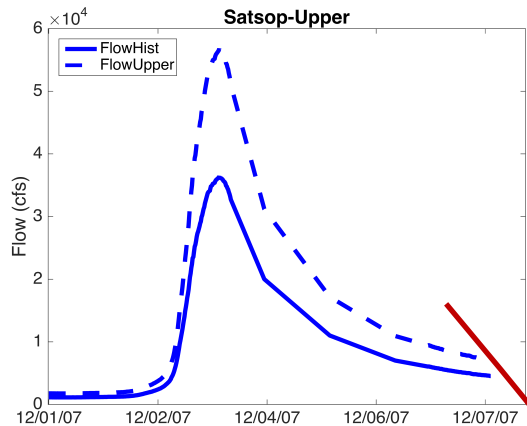
Consequently, some watersheds generate more, but others less runoff.

Streamflow and stage increase throughout the length of the channel.

Hydrodynamics
HEC-RAS
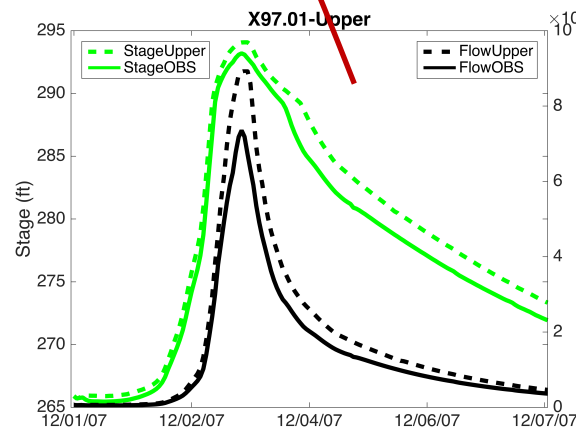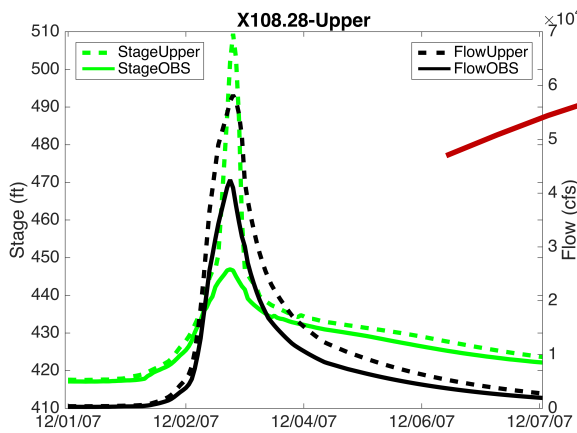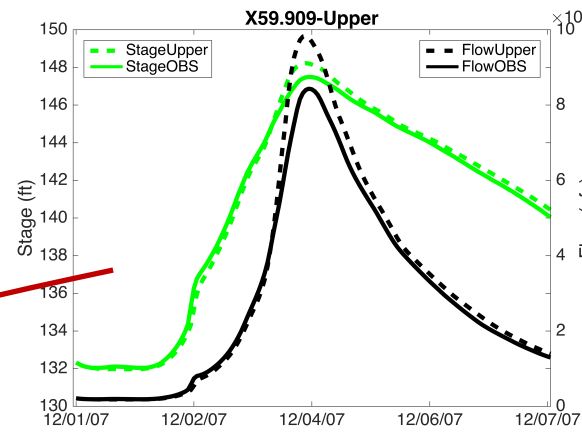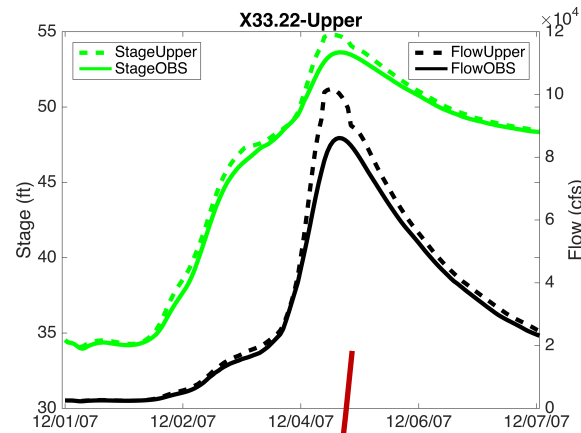
Changes in inundation extent are not large*, but there is change in depth.

Historical Flood (ft)
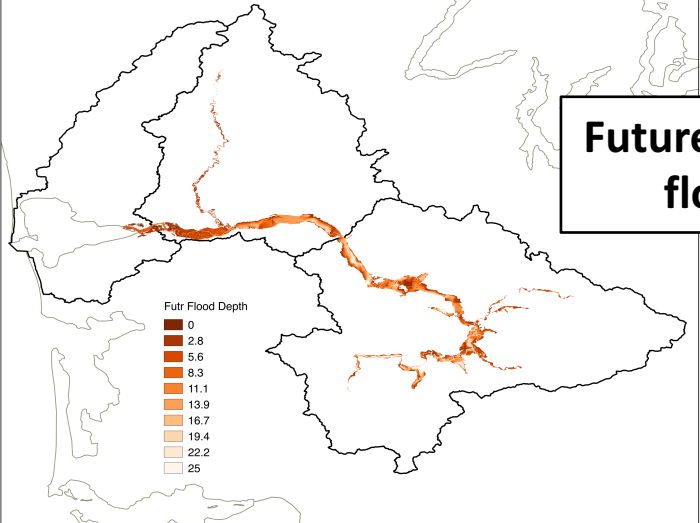
Future simulated flood (ft)

Change in Flood Depth (ft)

*Dec 2007 event was so large, all available inundation planes were flooded.

Hydrodynamics
HEC-RAS

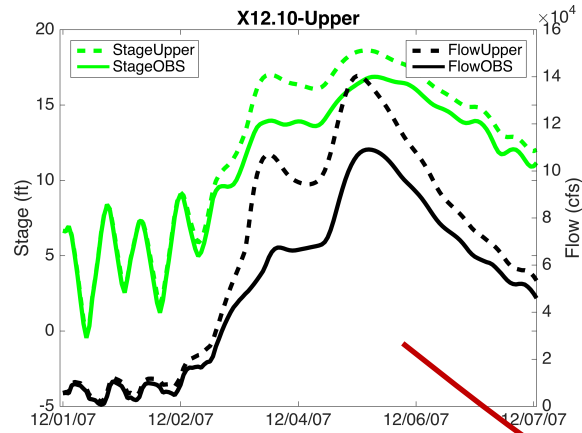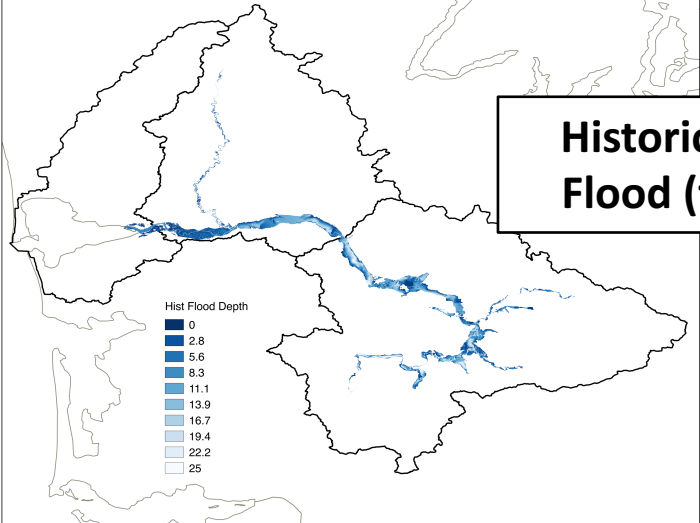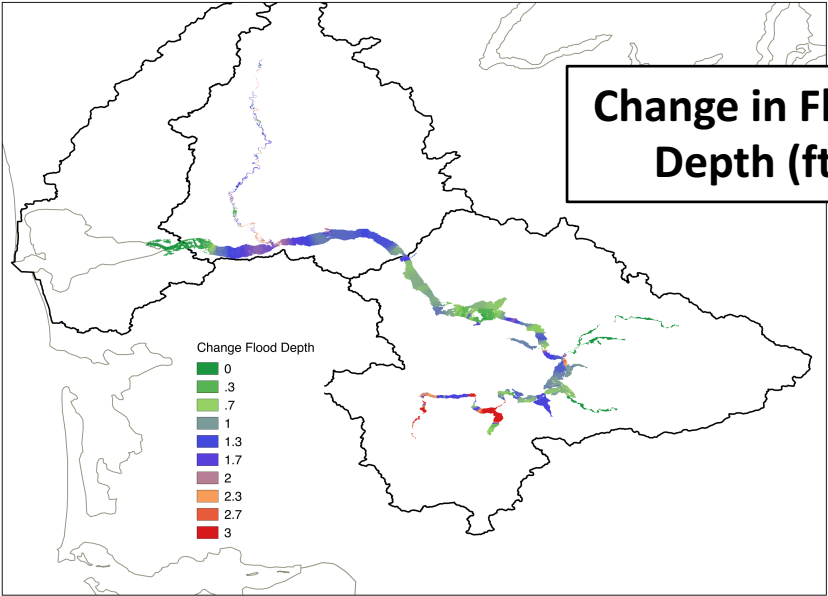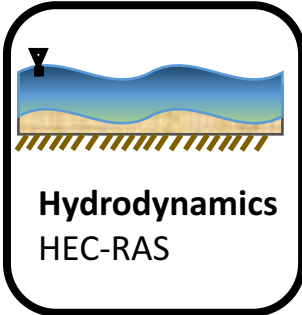# The changes in inundation depth and extent do result in socioeconomic damages due to both stock damages and net loss in local production and trade.

		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		HAZUS
	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		IO
	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%	

Socioeconomics
HAZUS

In conclusion, we have developed an integrated modeling system that allows us to estimate changes in ARs and their socioeconomic consequences.
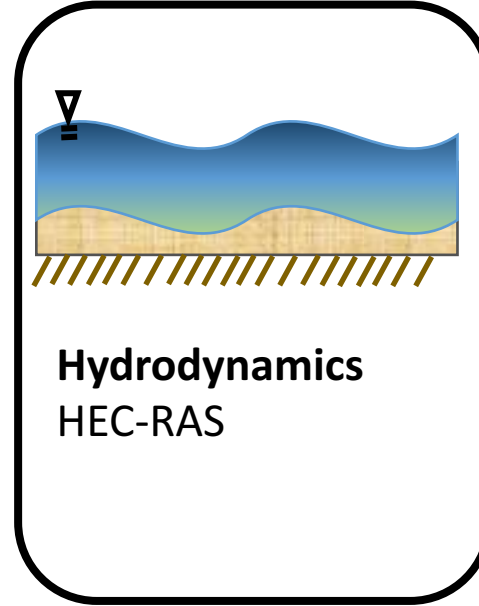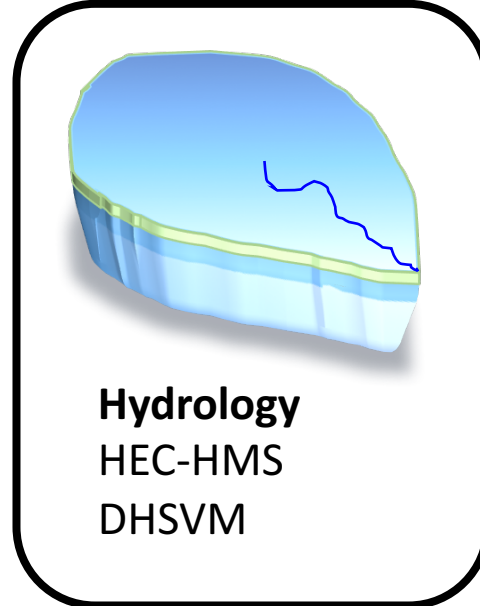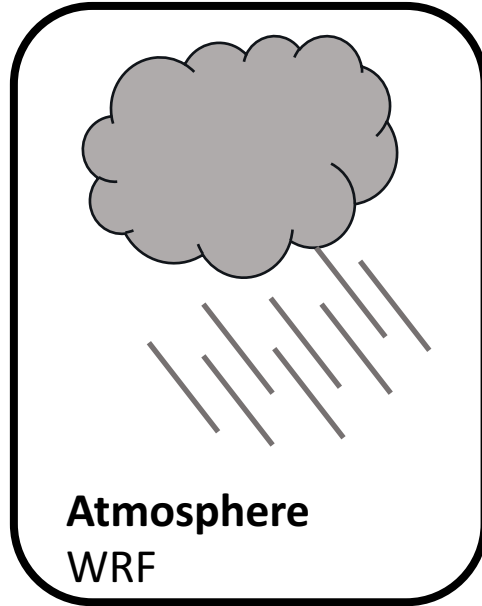
For the Dec 2007 AR event in the Chehalis:

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.

Streamflow increases throughout the channel.

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