



Maximization of Historical Severe  
Precipitation Events  
over  
American, Yuba and Feather  
River Basins

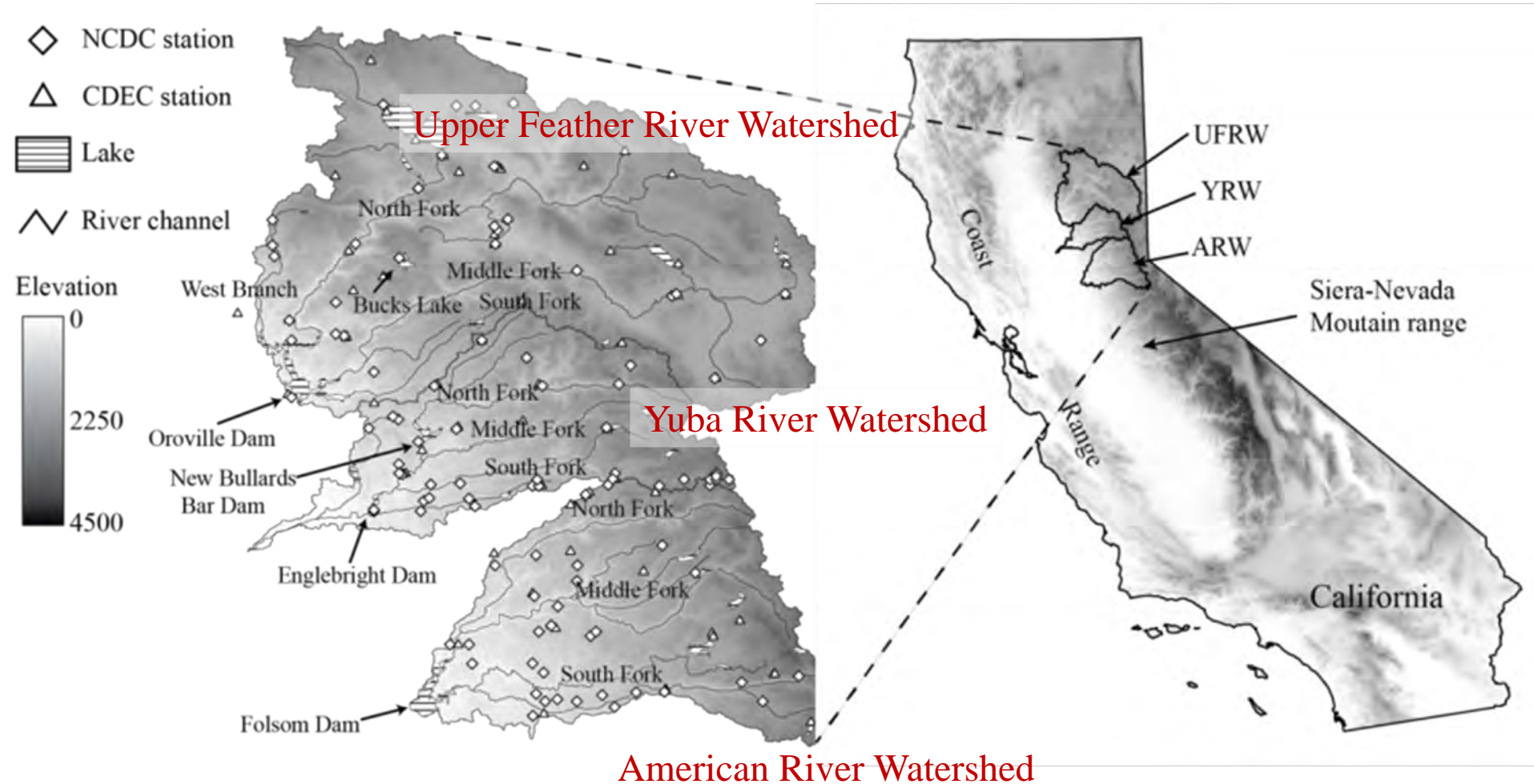
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**1 University Of California, Davis**

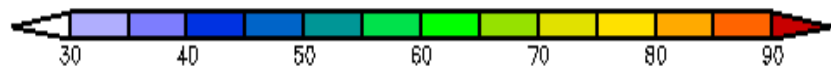
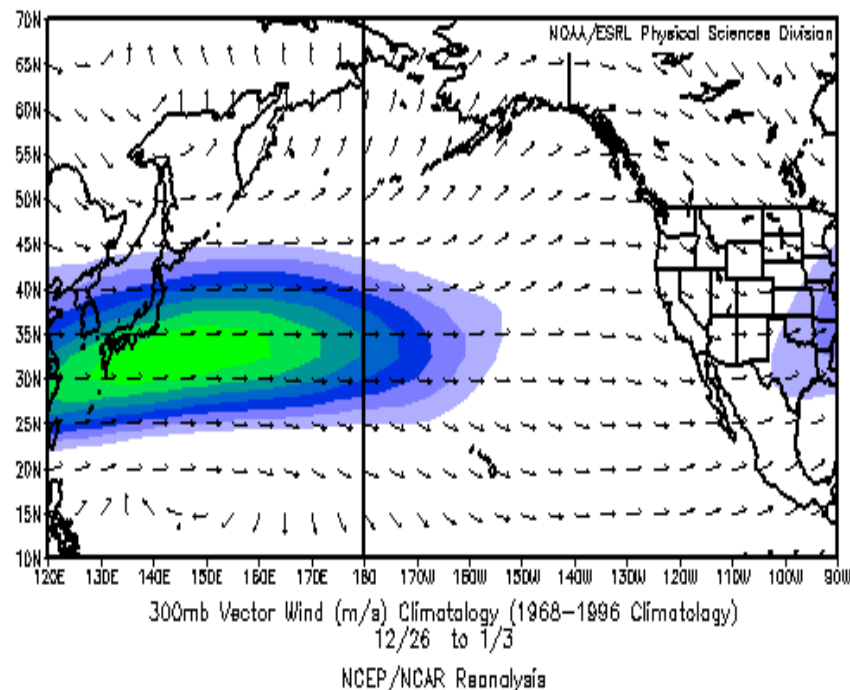
**2 University of Wyoming**

**3 California Department of Water Resources**

# Target watersheds



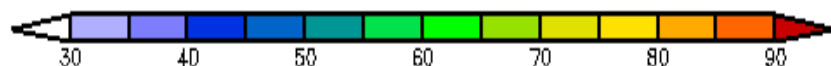
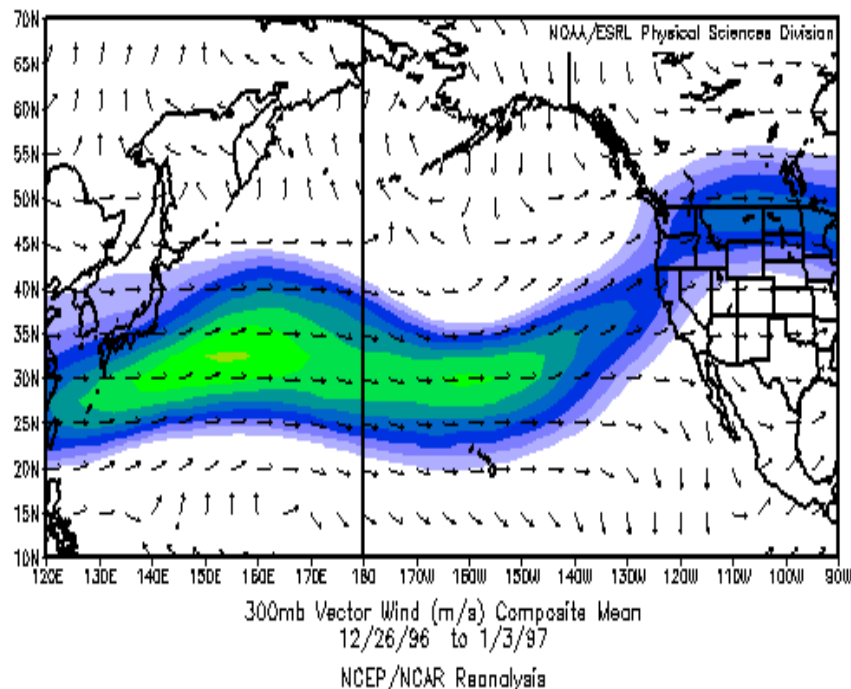
### 300 mb Wind Vector Climatology (1968 to 1996 data) for December 26 - January 3



The upper jet stream across the Pacific during the late December and early January timeframe is typically strongest from just off the Asian continent eastward to the International Dateline, between 30° and 35° North

(From NWS California-Nevada RFC)

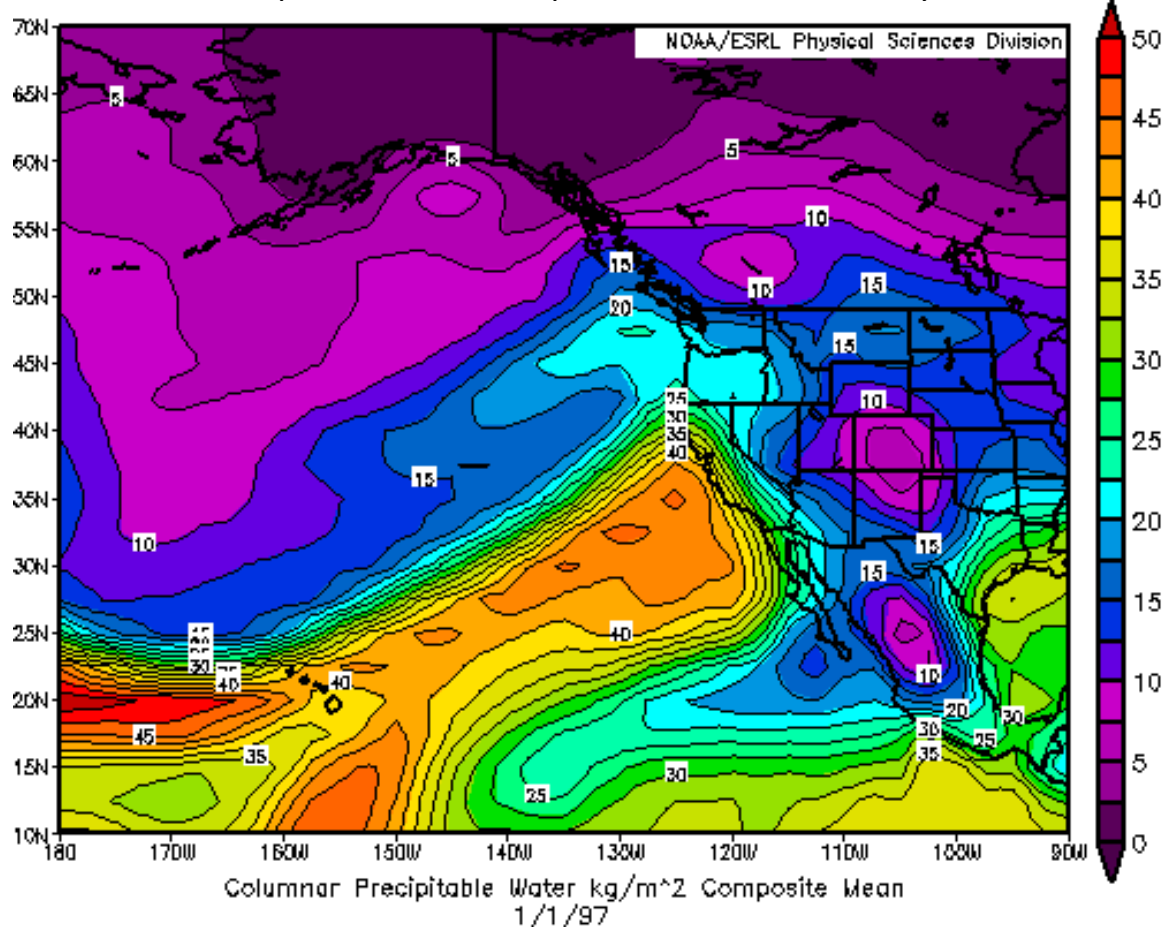
### 300 mb Wind Vector Analysis for December 26, 1996–January 3, 1997



However, during the December 26, 1996 through January 3, 1997 period, the upper jet stream extended across the eastern Pacific and arched from just north of the Hawaiian Islands toward the Pacific Northwest and northern California

An influx of lower latitude moisture played a key role in the generation of significant precipitation across the region. Two distinct moisture sources were evident on the precipitable water analysis between December 26, 1996 and January 3, 1997. The first source advected eastward from the western Pacific toward the Hawaiian Islands. The second advected northward from near the equator between 150° and 160° West. These two moisture plumes merged near the Hawaiian Islands, and shifted northeast toward the west coast of the United States. Composite daily mean precipitable water values just off the California coast exceeded 1.6 inches (40 mm) and peaked near 1.8 inches (45 mm), as shown in Figure below. Given the tropical origin of the air mass that accompanied these storms, efficient warm rain processes dominated during the event, reducing the snow pack already in place from previous storms ( From NWS California-Nevada RFC).

Composite Mean Precipitable Water for January 1, 1997



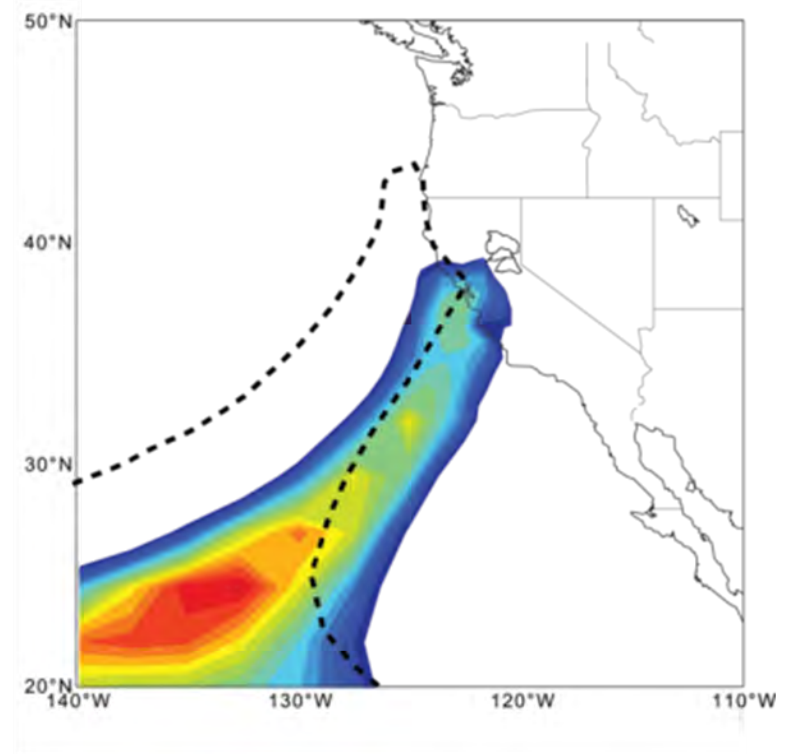
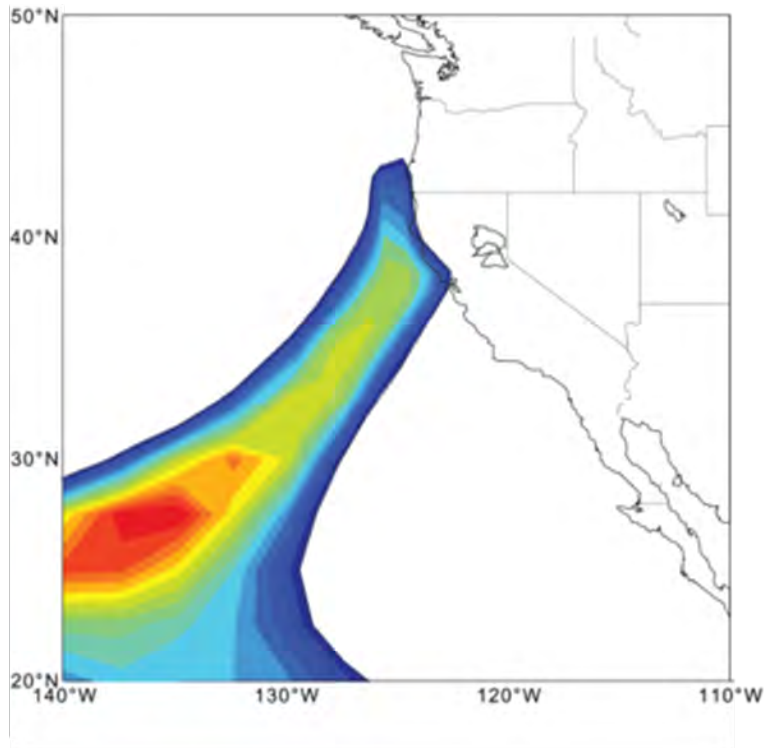
# Methodology

- In northern California, severe storms are mainly caused by a high-moisture atmospheric flow coming from a tropical zone of the Pacific Ocean, and referred to as “atmospheric river (AR)”.



- The contribution of ARs to precipitation over each of the target watersheds is maximized to estimate maximum precipitation.

# Atmospheric boundary condition shifting



# Methodology

1. Select the historical severe storm events from the reconstructed historical precipitation record at a target watershed;
2. Identify the ARs that hit California during each of the selected historical severe storm events;
3. Shift the atmospheric BCs with respect to only latitude (Shift1D) and then also with longitude (Shift2D);
4. Shift the atmospheric BCs along an identified AR until the basin-average precipitation reaches a maximum and then starts to decrease.
5. Relative humidity maximization
  - Set the relative humidity on the boundaries of the outer simulation domain at 100 %: Shift2D+RH100

The numerical atmospheric model for  
American, Yuba and Feather River Basins

is taken as

MM5 (Fifth Generation Mesoscale Model)

from NCAR (National Center for Atmospheric Research) and Penn State Univ.

because,

MM5 is a nonhydrostatic model which can be  
downscaled even to 1km spatial resolution,  
which makes it very desirable for downscaling  
coarse-resolution historical atmospheric data  
to the scale of American River Watershed,

and be able to capture

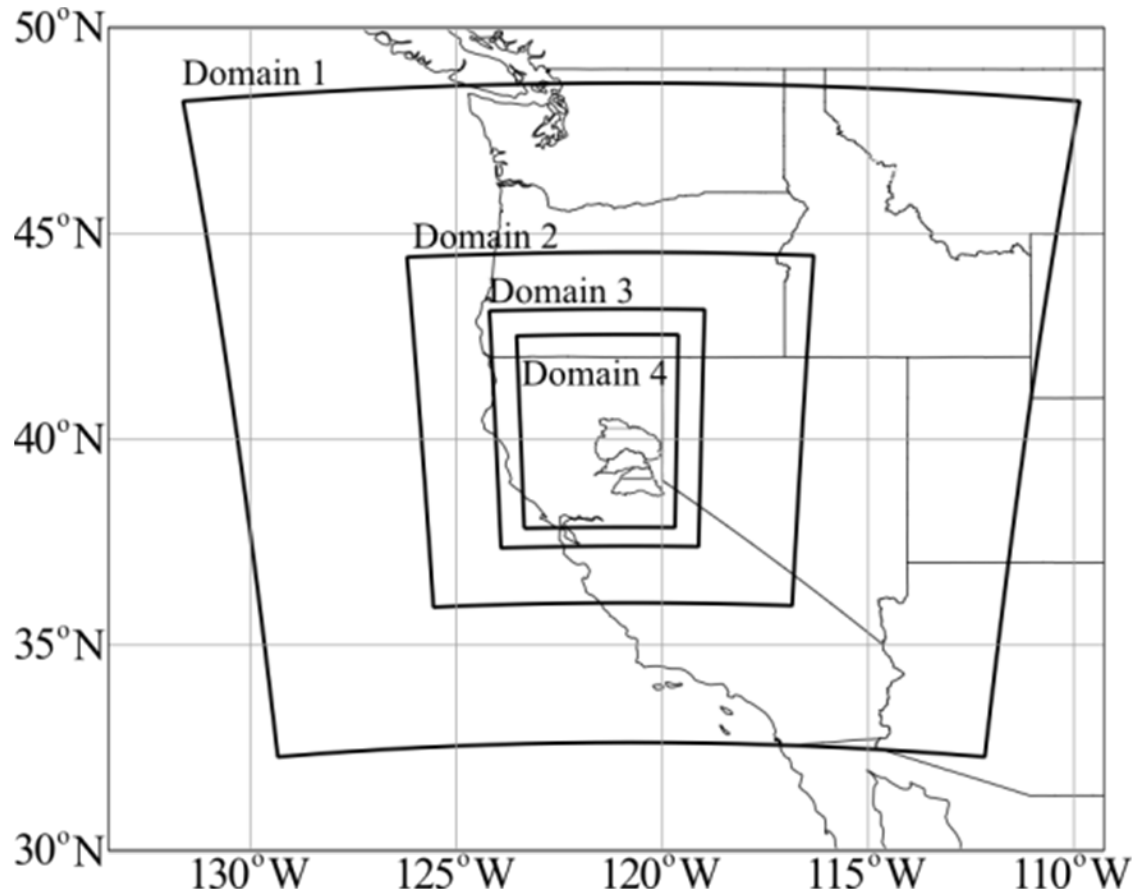
the impact of

steep topography and land surface/land use conditions of

American, Yuba and Feather river basins on the local atmospheric conditions.

# Regional atmospheric model

- Model: MM5
- Input atmospheric Data: NCAR/NCEP Reanalysis I



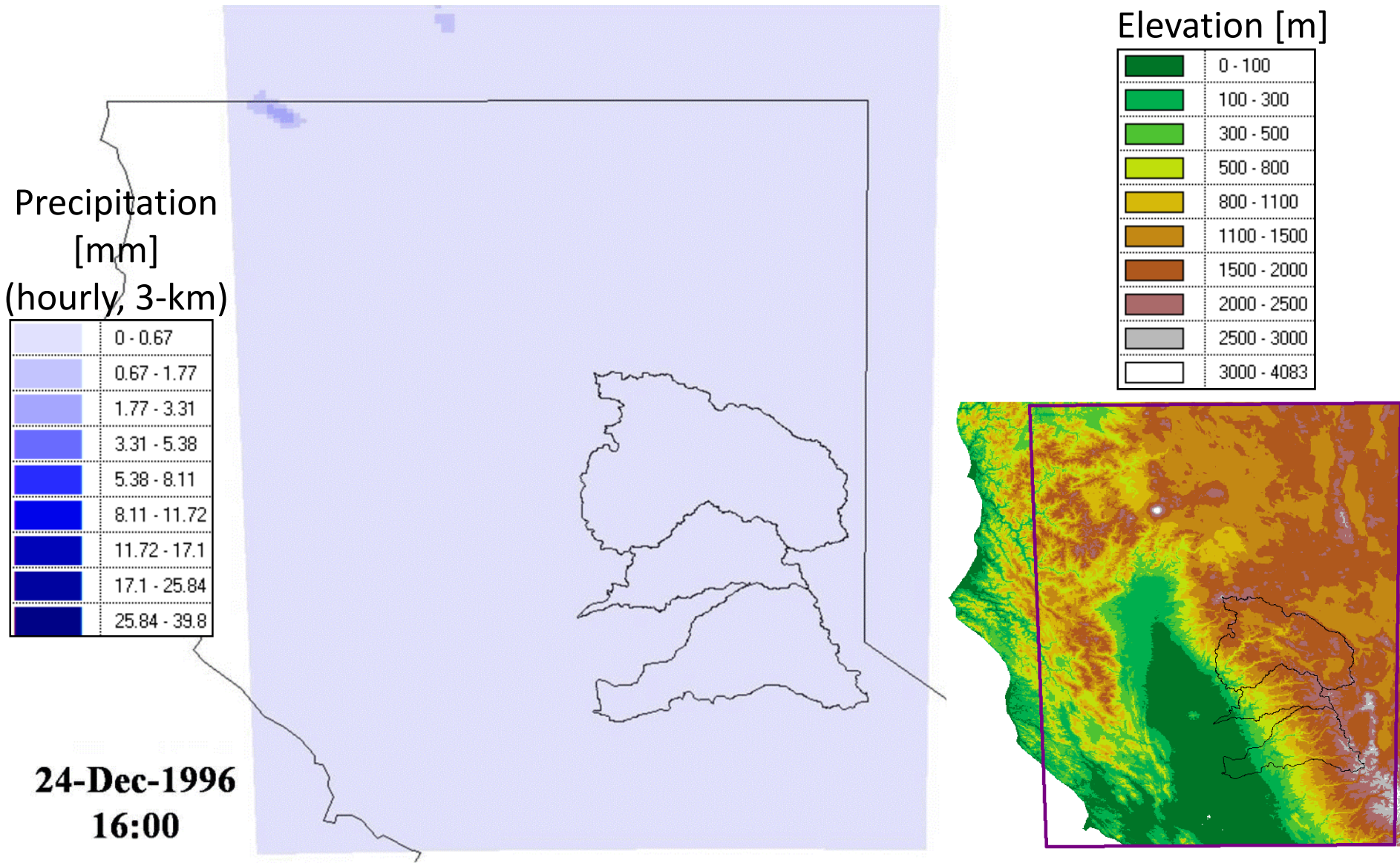
# Configuring the atmospheric model

	Cumulus Parameterization	Cloud Microphysics	PBL Schemes
Case1	Kain-Fritsch 2	Mixed-Phase (Reisner1)	MRF
Case2	Grell	Mixed-Phase (Reisner1)	MRF
Case3	Kain-Fritsch 2	Reisner graupel (Reisner2)	MRF
Case4	Grell	Reisner graupel (Reisner2)	MRF
Case5	Kain-Fritsch 2	Mixed-Phase (Reisner1)	Gayno-Seaman
Case6	Grell	Mixed-Phase (Reisner1)	Gayno-Seaman
Case7	Kain-Fritsch 2	Reisner graupel (Reisner2)	Gayno-Seaman
Case8	Grell	Reisner graupel (Reisner2)	Gayno-Seaman

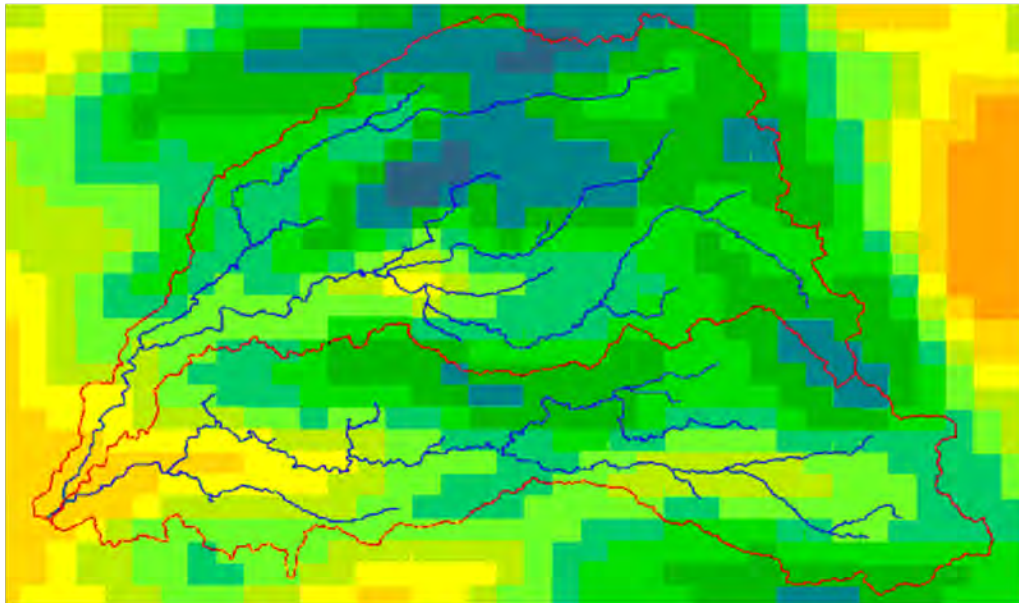
Evaluation results:

Monthly Comparison		PRISM	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7	Case-8
Dec	Precipitation (in)	27.70	27.62	28.57	27.43	28.52	27.35	27.62	27.11	27.81
	Dif. (%)	-	-0.27	3.15	-0.99	2.94	-1.28	-0.30	-2.14	0.40
Jan	Precipitation (in)	23.27	26.95	27.41	25.23	25.94	27.68	28.26	26.86	26.81
	Dif. (%)	-	15.84	17.81	8.43	11.48	18.96	21.48	15.44	15.23

# Precipitation on ground surface simulated by MM5 at 3km grid during December 24, 1996 – January 3, 1997

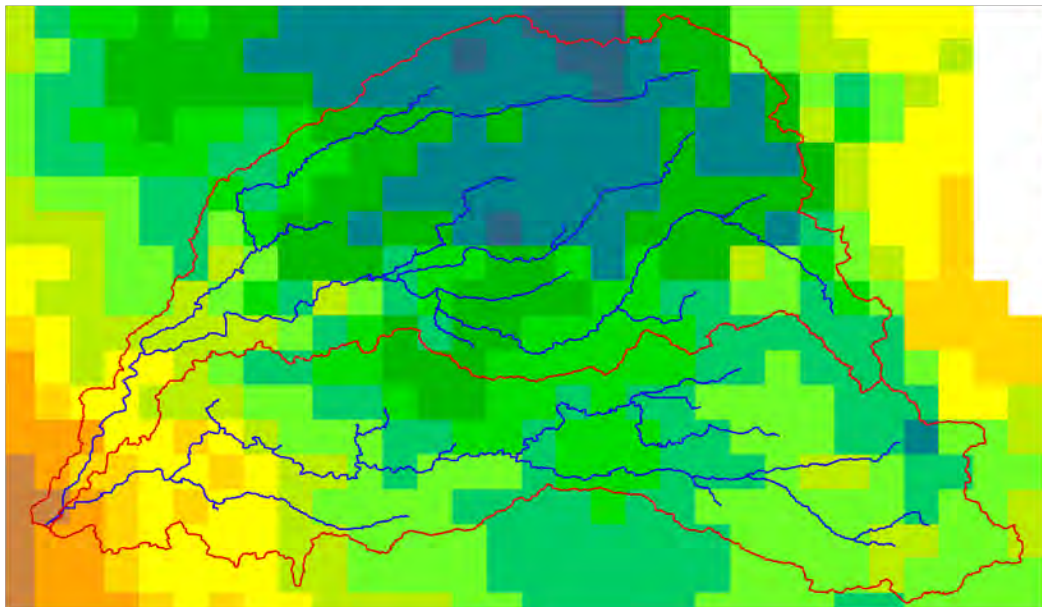


**Reconstructed (Dec 2006)**











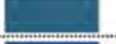



December 2006

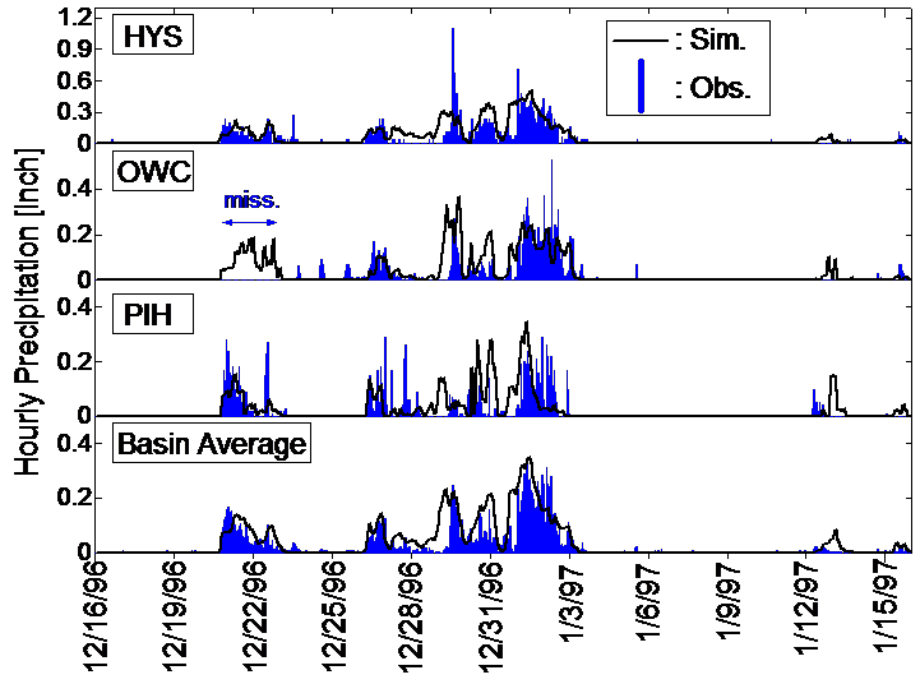
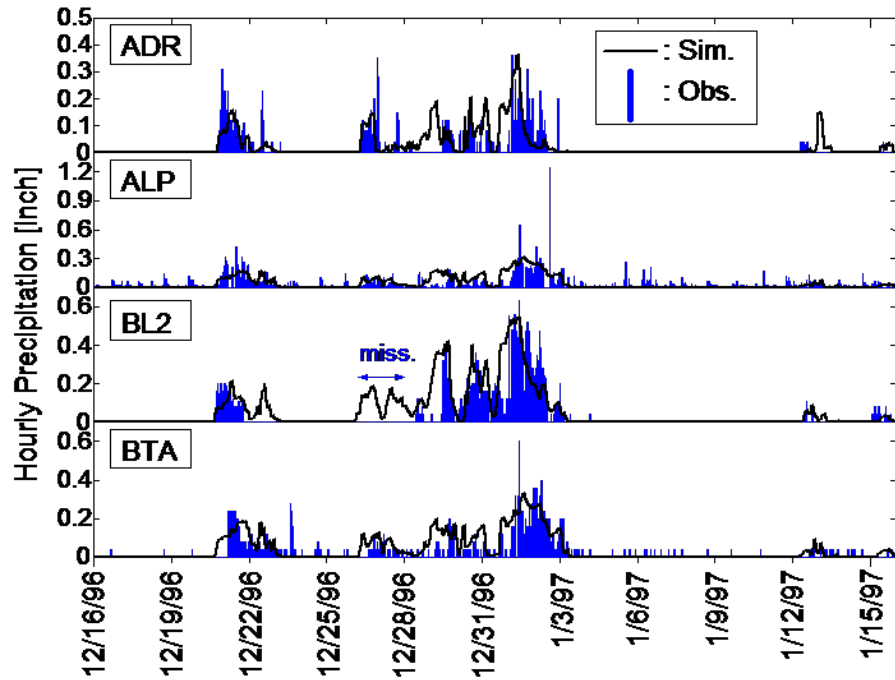
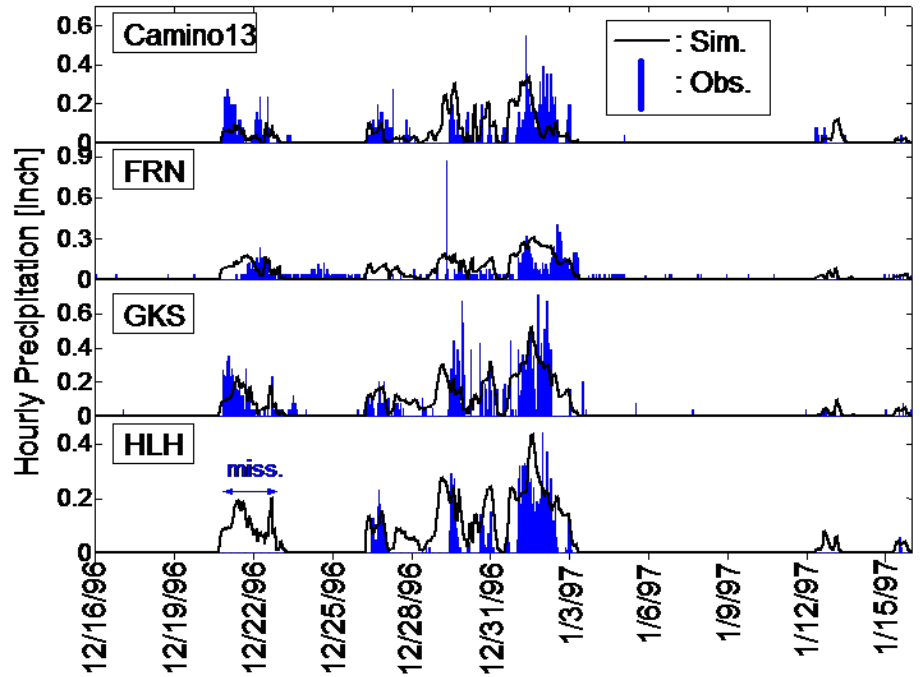
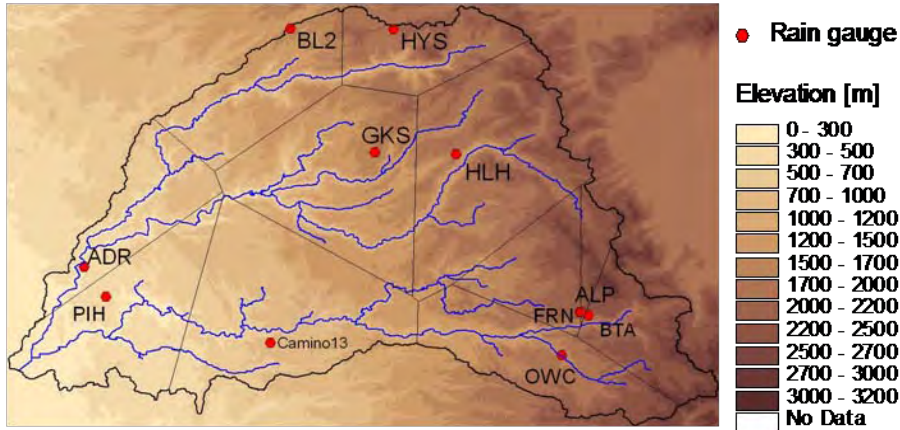
**PRISM (Dec 2006)**



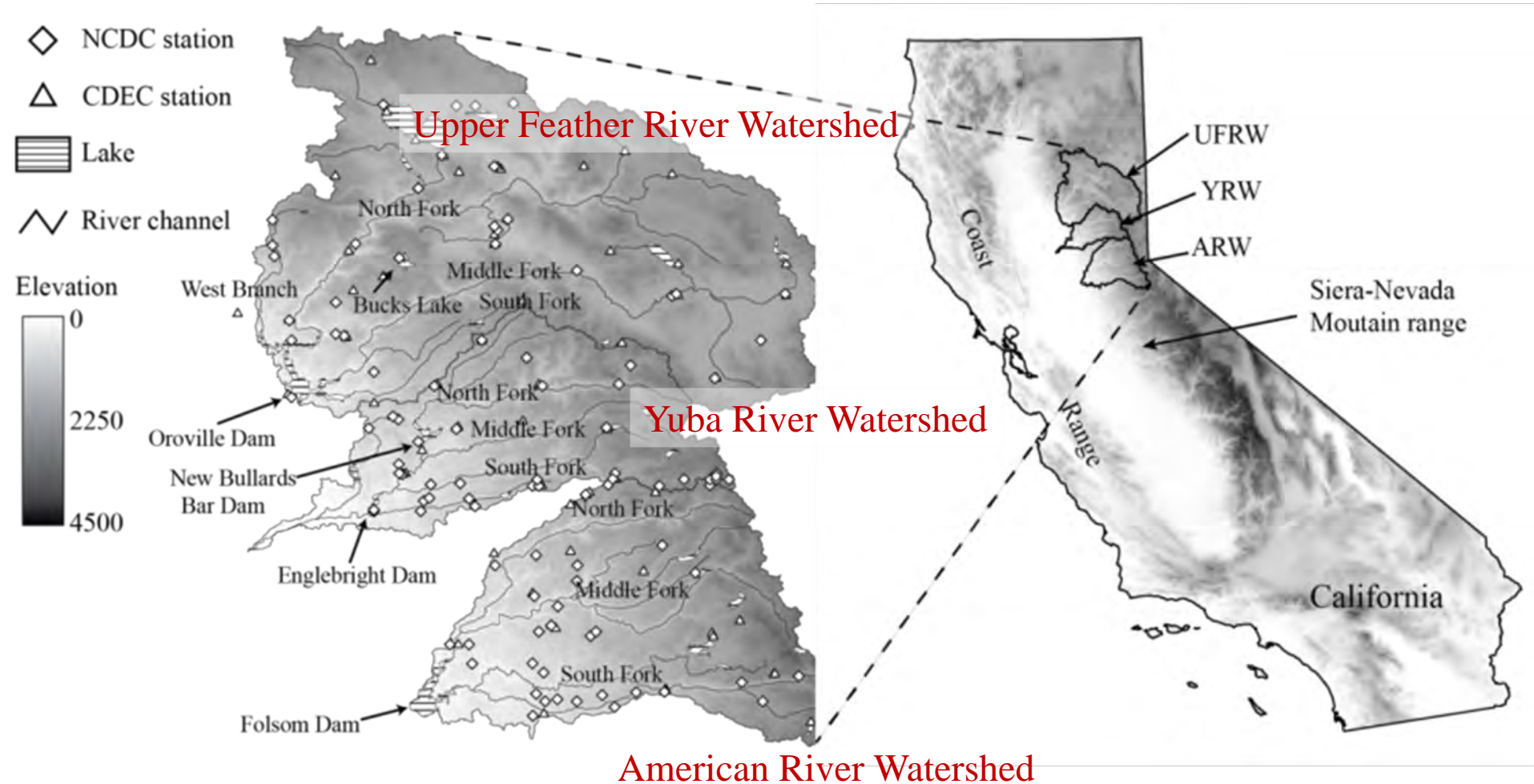
(mm)

	127 - 178
	178 - 254
	254 - 330
	330 - 406
	406 - 483
	483 - 584
	584 - 686
	686 - 787
	787 - 914
	914 - 1067
	1067 - 1245
	1245 - 1397

# Model validation at point locations during the storm event



# Target watersheds



# Selection of extreme storm events

## American River watershed

Event	Period	Event	Period	Event	Period
A5011	11/14/1950 - 11/24/1950	A7403a	02/27/1974 - 03/06/1974	A9301a	01/06/1993 - 01/19/1993
A5201	01/07/1952 - 01/19/1952	A7403b	03/27/1974 - 04/04/1974	A9301b	01/20/1993 - 01/25/1993
A5402	02/12/1954 - 02/21/1954	A7502	01/31/1975 - 02/16/1975	A9501	01/04/1995 - 01/18/1995
A5512	12/17/1955 - 12/30/1955	A7801	01/03/1978 - 01/22/1978	A9503a	03/09/1995 - 03/18/1995
A5702	02/21/1957 - 03/08/1957	A7802	02/05/1978 - 02/16/1978	A9503b	03/20/1995 - 03/26/1995
A5804	03/29/1958 - 04/09/1958	A7803	03/01/1978 - 03/08/1978	A9512	12/11/1995 - 12/18/1995
A5902	02/15/1959 - 02/24/1959	A8001	01/09/1980 - 01/20/1980	A9602	02/18/1996 - 03/03/1996
A6002	02/01/1960 - 02/13/1960	A8002	02/14/1980 - 02/26/1980	A9611	11/17/1996 - 11/25/1996
A6202	02/07/1962 - 02/23/1962	A8101	01/23/1981 - 02/02/1981	A9612	12/05/1996 - 12/15/1996
A6210	10/11/1962 - 10/17/1962	A8111	11/13/1981 - 11/20/1981	A9701a	12/26/1996 - 01/06/1997
A6302	01/30/1963 - 02/06/1963	A8202	02/14/1982 - 02/19/1982	A9701b	01/20/1997 - 01/29/1997
A6412	12/19/1964 - 01/10/1965	A8204a	03/26/1982 - 04/09/1982	A9902	02/06/1999 - 02/12/1999
A6512	12/24/1965 - 01/08/1966	A8204b	04/10/1982 - 04/17/1982	A0002	02/10/2000 - 02/19/2000
A6701	01/20/1967 - 02/03/1967	A8303	02/25/1983 - 03/05/1983	A0211	11/07/2002 - 11/12/2002
A6703	03/10/1967 - 03/20/1967	A8403	03/13/1984 - 03/20/1984	A0212	12/13/2002 - 12/24/2002
A6801	01/27/1968 - 02/03/1968	A8602	02/12/1986 - 02/23/1986	A0303	03/14/2003 - 03/20/2003
A6901a	01/12/1969 - 01/17/1969	A8603	03/07/1986 - 03/19/1986	A0601	12/18/2005 - 01/06/2006
A6901b	01/19/1969 - 02/02/1969	A8811	11/22/1988 - 11/28/1988	A0801	01/03/2008 - 01/12/2008
A6902	02/12/1969 - 03/06/1969	A9103	03/01/1991 - 03/08/1991	A0903	03/01/2009 - 03/07/2009
A6912	12/19/1969 - 12/28/1969	A9212	12/28/1992 - 01/04/1993	A1001	01/17/2010 - 01/29/2010
A7311	11/05/1973 - 11/25/1973				

# Selection of extreme storm events

## Yuba River watershed

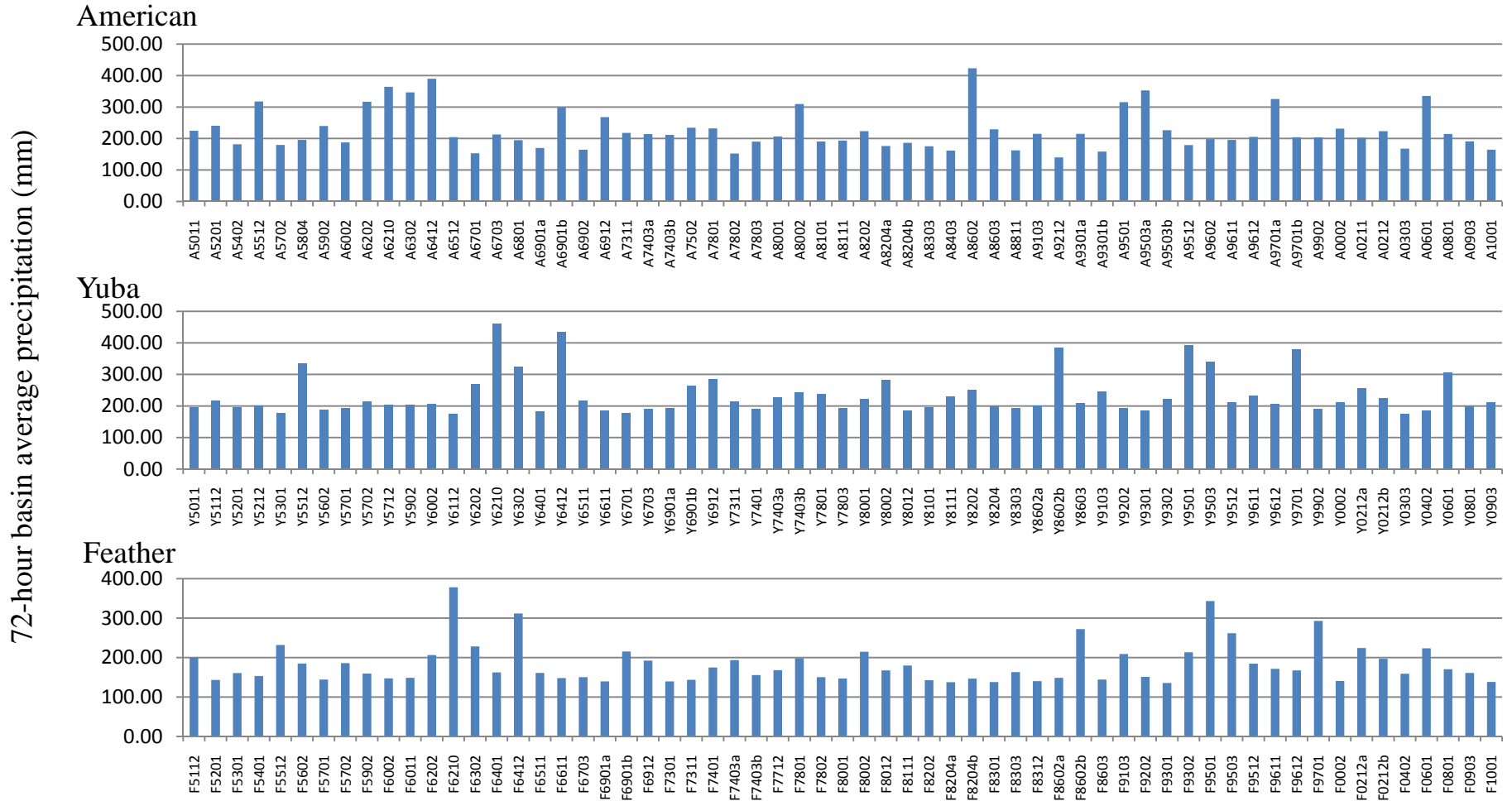
Event	Period	Event	Period	Event	Period
Y5011	11/14/1950 - 11/24/1950	Y6703	03/10/1967 - 03/20/1967	Y8603	03/07/1986 - 03/19/1986
Y5112	12/23/1951 - 01/02/1952	Y6901a	01/11/1969 - 01/16/1969	Y9103	02/28/1991 - 03/08/1991
Y5201	01/07/1952 - 01/19/1952	Y6901b	01/19/1969 - 02/04/1969	Y9202	02/08/1992 - 02/25/1992
Y5212	12/01/1952 - 12/14/1952	Y6912	12/19/1969 - 12/28/1969	Y9301	01/06/1993 - 01/25/1993
Y5301	01/06/1953 - 01/23/1953	Y7311	11/05/1973 - 11/28/1973	Y9302	02/17/1993 - 02/27/1993
Y5512	12/17/1955 - 12/30/1955	Y7401	01/12/1974 - 01/22/1974	Y9501	01/03/1995 - 01/19/1995
Y5602	02/19/1956 - 03/03/1956	Y7403a	02/26/1974 - 03/05/1974	Y9503	03/09/1995 - 03/18/1995
Y5701	01/12/1957 - 01/18/1957	Y7403b	03/26/1974 - 04/04/1974	Y9512	12/11/1995 - 12/18/1995
Y5702	02/20/1957 - 03/20/1957	Y7801	01/03/1978 - 01/22/1978	Y9611	11/17/1996 - 11/25/1996
Y5712	12/15/1957 - 12/25/1957	Y7803	03/01/1978 - 03/08/1978	Y9612	12/05/1996 - 12/15/1996
Y5902	02/08/1959 - 02/24/1959	Y8001	01/09/1980 - 01/20/1980	Y9701	12/26/1996 - 01/06/1997
Y6002	01/18/1960 - 02/13/1960	Y8002	02/14/1980 - 02/26/1980	Y9902	02/06/1999 - 02/12/1999
Y6112	11/29/1961 - 12/05/1961	Y8012	11/30/1980 - 12/07/1980	Y0002	02/09/2000 - 02/19/2000
Y6202	02/06/1962 - 02/23/1962	Y8101	01/22/1981 - 02/01/1981	Y0212a	12/13/2002 - 12/24/2002
Y6210	10/10/1962 - 10/17/1962	Y8111	11/12/1981 - 11/20/1981	Y0212b	12/26/2002 - 01/03/2003
Y6302	01/29/1963 - 02/06/1963	Y8202	02/14/1982 - 02/19/1982	Y0303	03/14/2003 - 03/20/2003
Y6401	01/17/1964 - 01/28/1964	Y8204	04/10/1982 - 04/17/1982	Y0402	02/16/2004 - 02/21/2004
Y6412	12/19/1964 - 01/10/1965	Y8303	02/25/1983 - 03/05/1983	Y0601	12/18/2005 - 01/07/2006
Y6511	11/13/1965 - 11/21/1965	Y8602a	01/29/1986 - 02/06/1986	Y0801	01/03/2008 - 01/12/2008
Y6611	11/19/1966 - 11/25/1966	Y8602b	02/12/1986 - 02/23/1986	Y0903	03/01/2009 - 03/08/2009
Y6701	01/20/1967 - 02/03/1967				

# Selection of extreme storm events

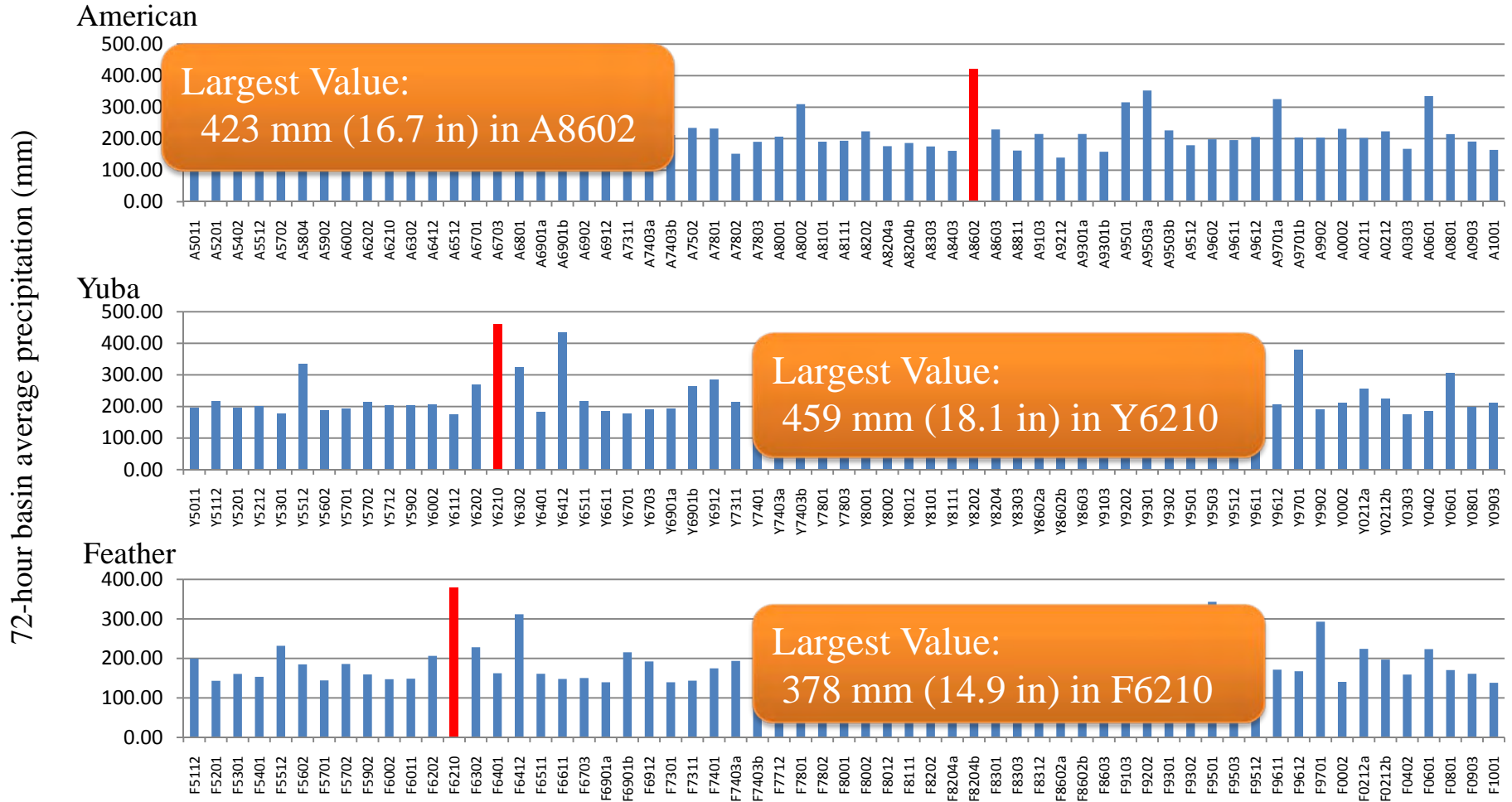
## Upper Feather River watershed

Event	Period	Event	Period	Event	Period
F5112	12/23/1951 - 01/02/1952	F6912	12/19/1969 - 12/28/1969	F8602b	02/12/1986 - 02/24/1986
F5201	01/07/1952 - 01/19/1952	F7301	01/09/1973 - 01/22/1973	F8603	03/07/1986 - 03/19/1986
F5301	01/06/1953 - 01/23/1953	F7311	11/05/1973 - 11/27/1973	F9103	02/28/1991 - 03/08/1991
F5401	01/15/1954 - 01/22/1954	F7401	01/12/1974 - 01/22/1974	F9202	02/08/1992 - 02/24/1992
F5512	12/17/1955 - 01/13/1956	F7403a	02/26/1974 - 03/05/1974	F9301	01/06/1993 - 01/25/1993
F5602	02/19/1956 - 03/03/1956	F7403b	03/27/1974 - 04/04/1974	F9302	02/17/1993 - 02/27/1993
F5701	01/12/1957 - 01/18/1957	F7712	12/21/1977 - 12/26/1977	F9501	01/03/1995 - 01/18/1995
F5702	02/20/1957 - 03/21/1957	F7801	01/03/1978 - 01/22/1978	F9503	03/09/1995 - 03/17/1995
F5902	02/08/1959 - 02/24/1959	F7802	02/05/1978 - 02/16/1978	F9512	12/11/1995 - 12/18/1995
F6002	01/18/1960 - 02/12/1960	F8001	01/09/1980 - 01/19/1980	F9611	11/17/1996 - 11/25/1996
F6011	11/24/1960 - 11/29/1960	F8002	02/14/1980 - 02/26/1980	F9612	12/05/1996 - 12/15/1996
F6202	02/06/1962 - 02/22/1962	F8012	11/30/1980 - 12/07/1980	F9701	12/26/1996 - 01/05/1997
F6210	10/10/1962 - 10/17/1962	F8111	11/12/1981 - 11/20/1981	F0002	02/10/2000 - 02/19/2000
F6302	01/30/1963 - 02/07/1963	F8202	02/14/1982 - 02/19/1982	F0212a	12/13/2002 - 12/24/2002
F6401	01/17/1964 - 01/28/1964	F8204a	03/27/1982 - 04/09/1982	F0212b	12/26/2002 - 01/03/2003
F6412	12/19/1964 - 01/10/1965	F8204b	04/10/1982 - 04/17/1982	F0402	02/16/2004 - 02/21/2004
F6511	11/13/1965 - 11/21/1965	F8301	01/22/1983 - 02/01/1983	F0601	12/18/2005 - 01/06/2006
F6611	11/19/1966 - 11/25/1966	F8303	02/24/1983 - 03/16/1983	F0801	01/03/2008 - 01/13/2008
F6703	03/10/1967 - 03/20/1967	F8312	12/23/1983 - 01/02/1984	F0903	03/01/2009 - 03/07/2009
F6901a	01/11/1969 - 01/16/1969	F8602a	01/29/1986 - 02/06/1986	F1001	01/17/2010 - 01/29/2010
F6901b	01/19/1969 - 02/04/1969				

The maximum 72-hour basin-average precipitation values that were computed by the reconstruction of the 61 selected severe historical storm events over each of the three target watersheds.



# Identification and quantification of the maximum 72-hour basin-average precipitation events based solely on the reconstruction of the 61 selected historical severe storm events over each of the three target watersheds



# Shift2D

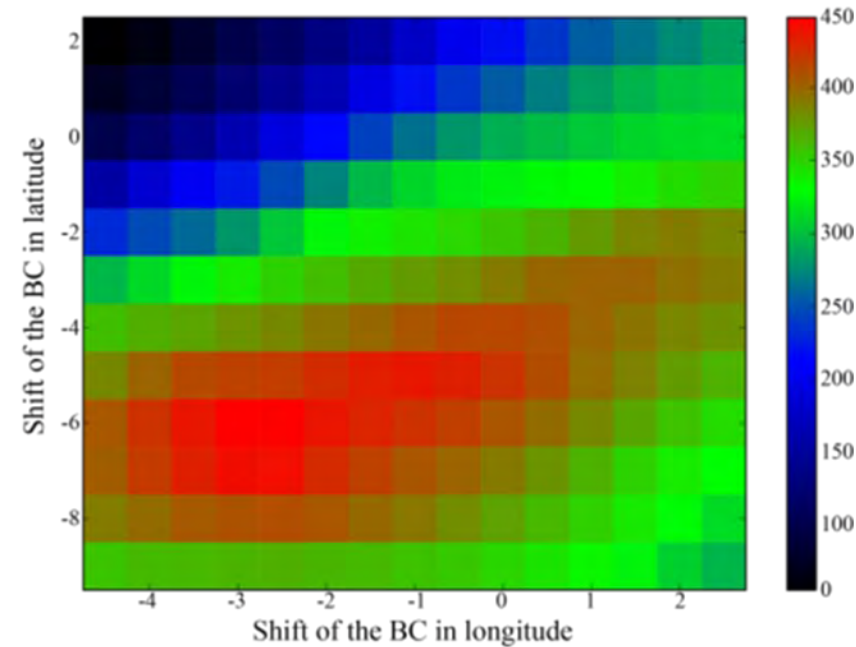


Figure: Field of maximum 72-hour basin-average precipitation estimates over Upper Feather River watershed computed by shifting the atmospheric boundary conditions in space with respect to latitude and longitude by different degrees.

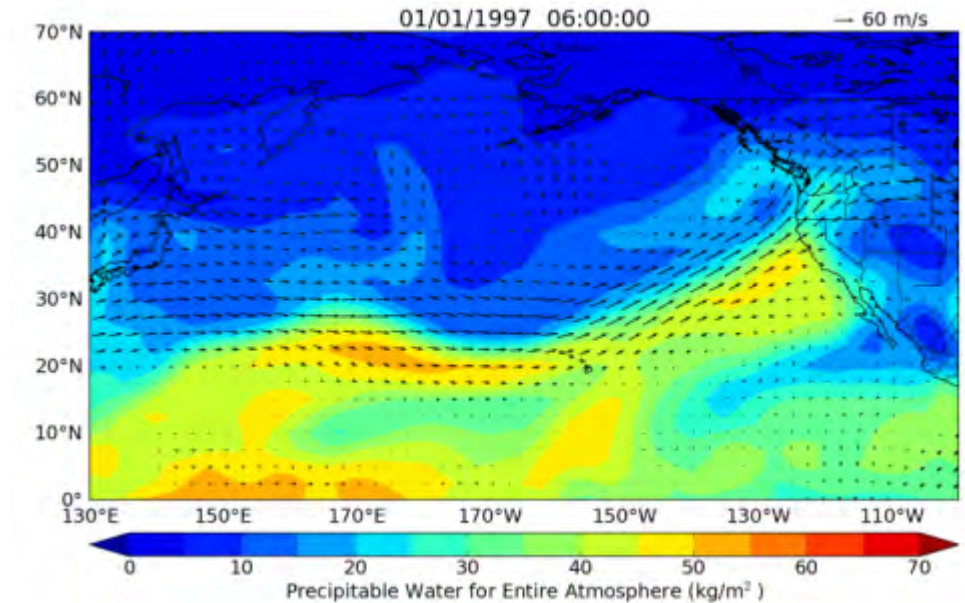


Figure: Precipitable Water together with the wind fields at the 500 hPa level over Pacific Ocean at 6:00hr on January 1, 1997 based on the NCAR/NCEP Reanalysis I data.

# Shift2D

American

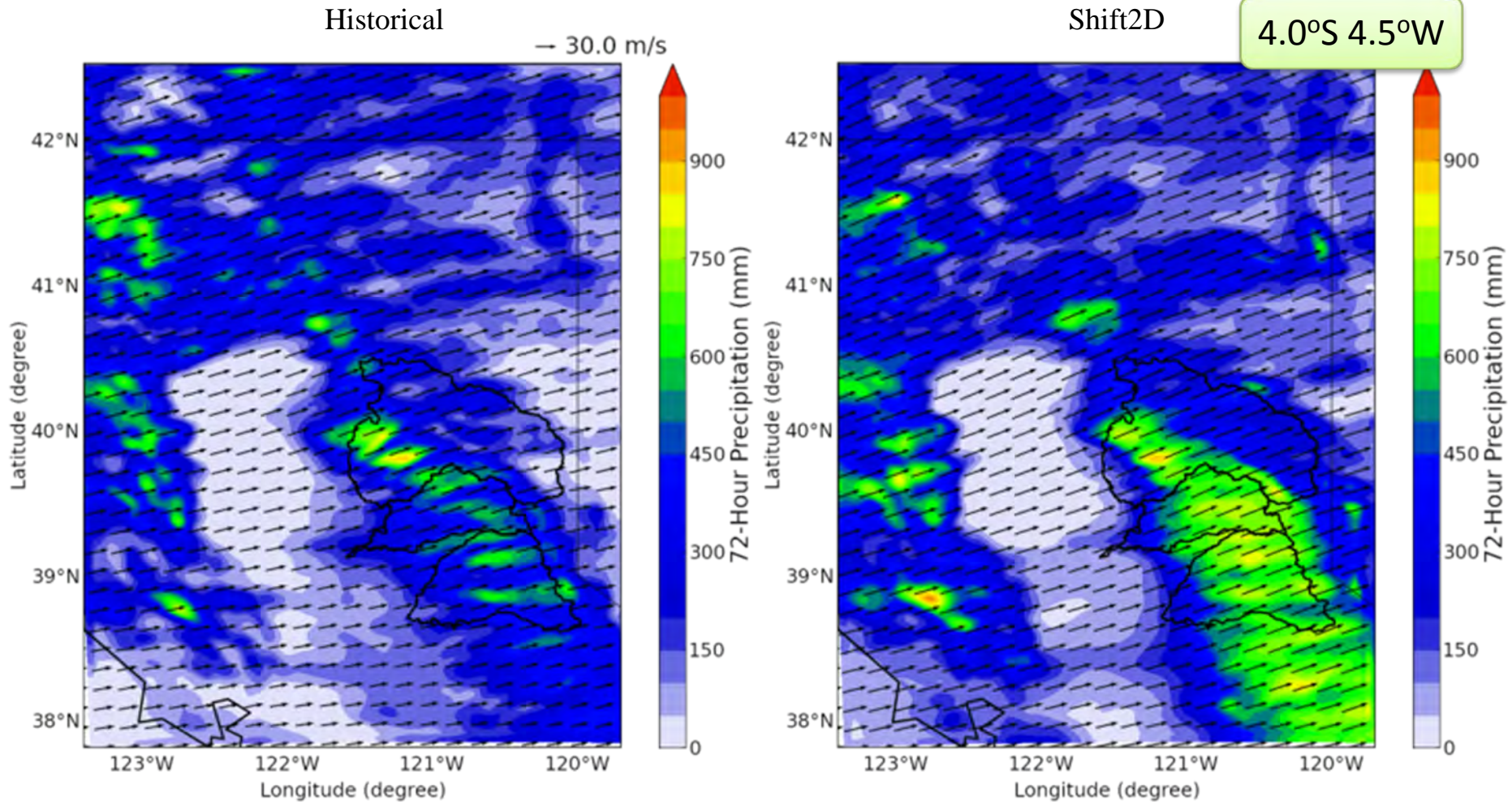


Figure: The spatial distributions of the accumulated precipitation together with the time-average horizontal wind fields are shown on the 500 hPa level from 13:00hr on December 20, 1964 to 13:00hr on December 23, 1964 during the A6412 storm event.

# Shift2D

American

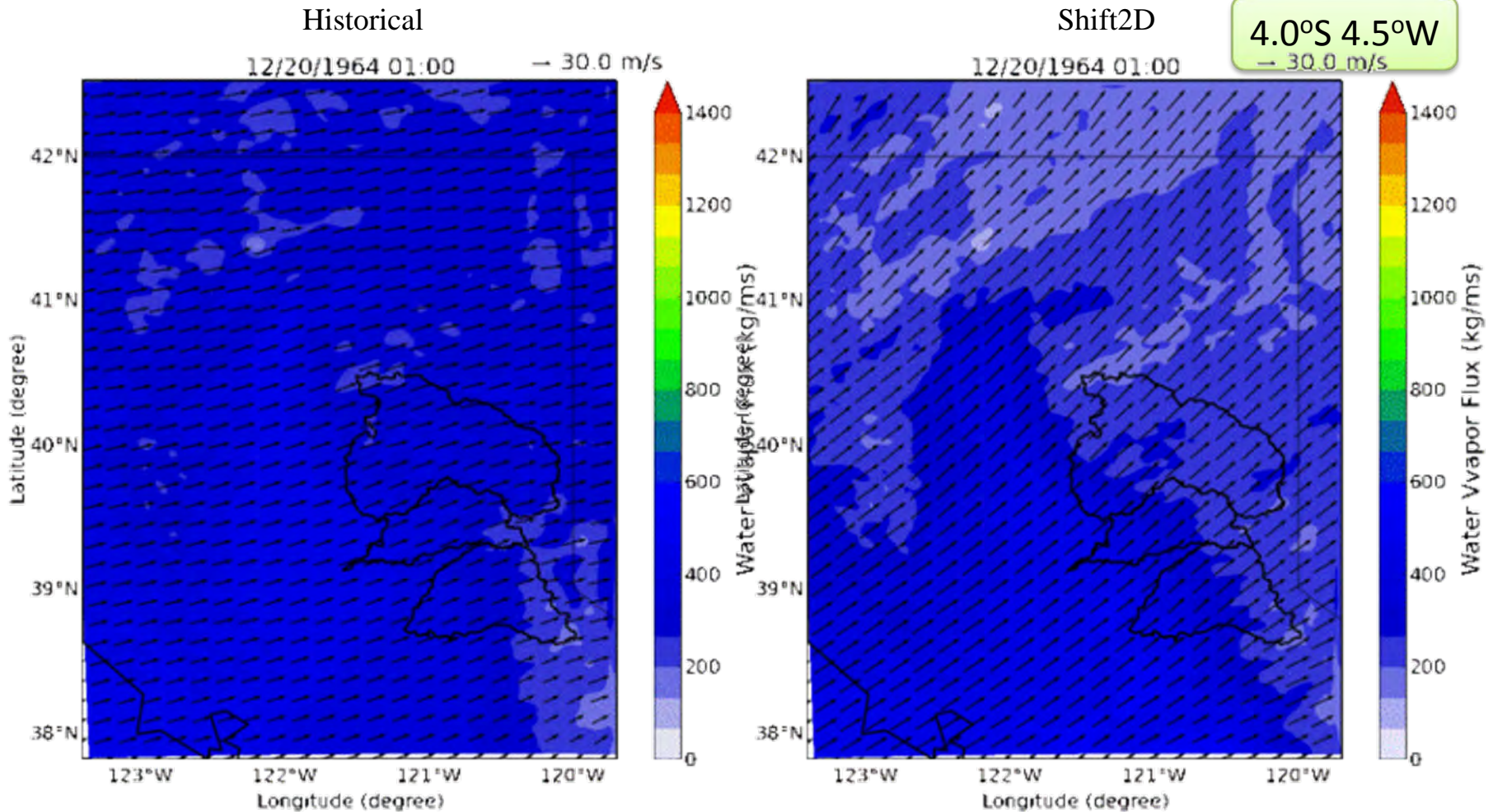


Figure: Spatial distributions of the absolute value of the water vapor flux together with the horizontal wind fields at the 500 hPa level from 1:00hr on December 20, 1964 to 0:00hr on December 24, 1964 for a) the historical case and b) the maximized case by Shift2D approach over American River watershed.

# Shift2D

American

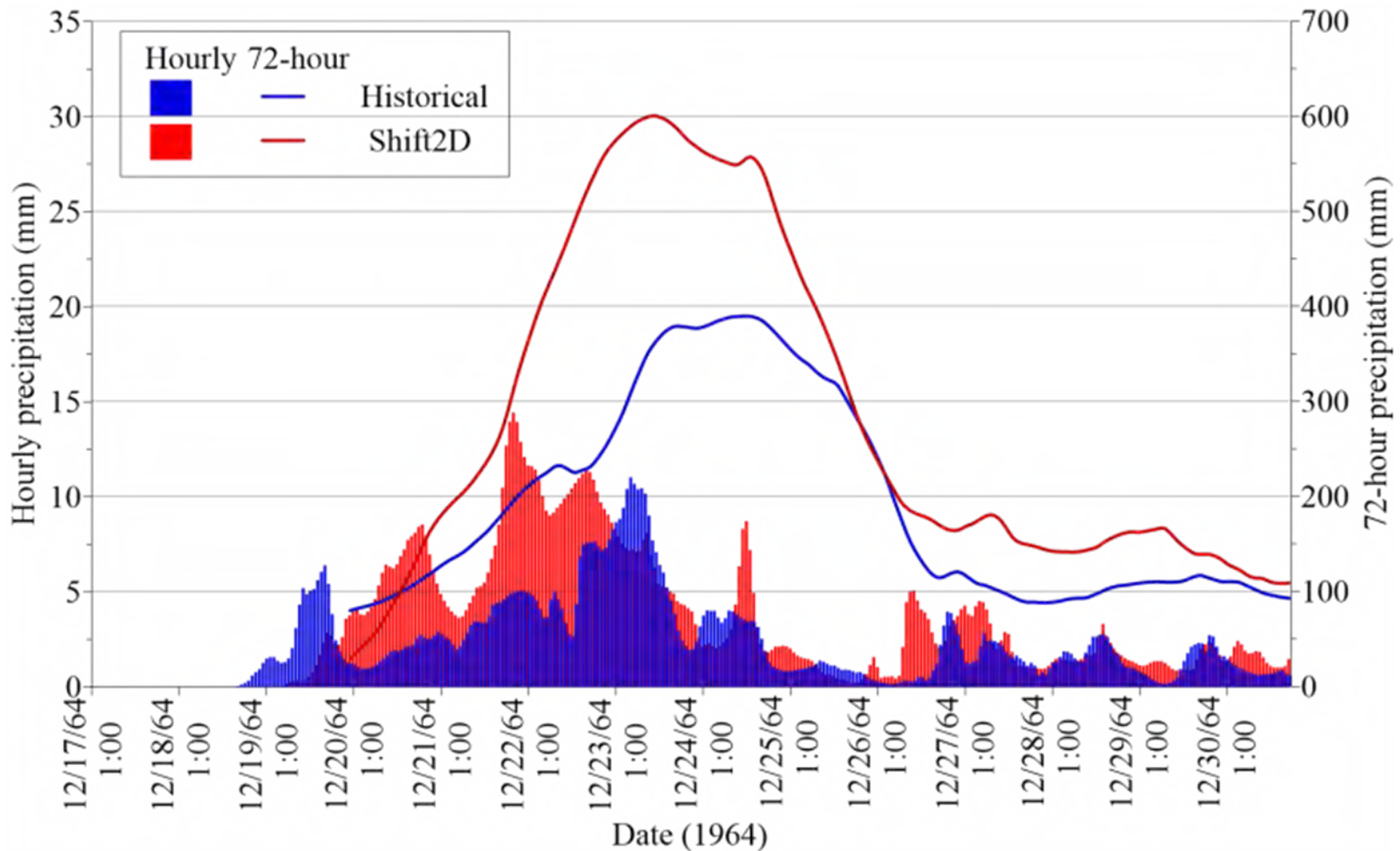


Figure: Hourly basin-average precipitation (bar) and its 72-Hourly basin-average precipitation (bar) and its 72-hour moving summation (line) over American River watershed during A6412 event, for the historical case (blue) and for the maximized case by Shift2D (red).

# Shift2D

Yuba

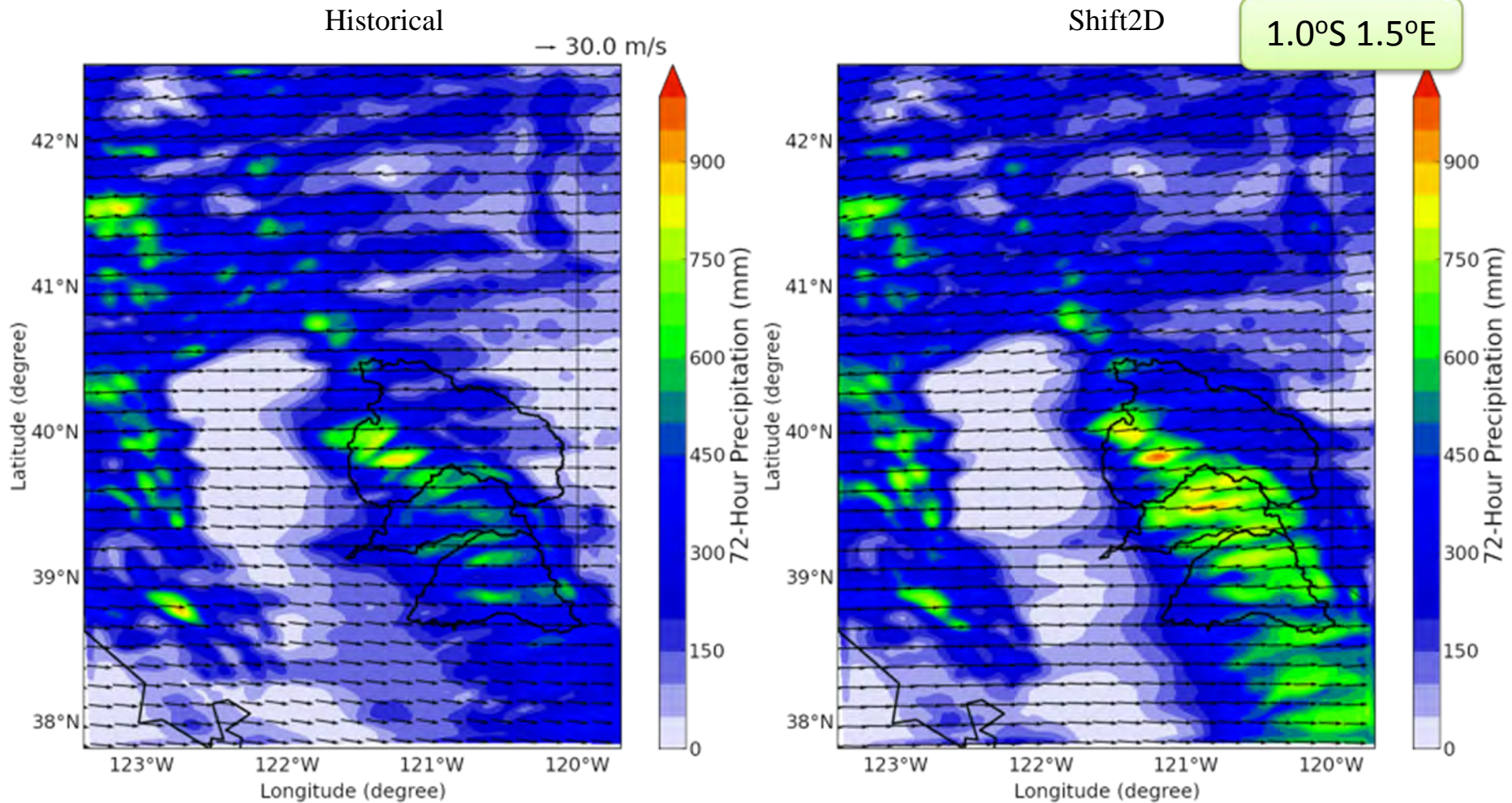


Figure: The spatial distributions of the accumulated precipitation together with the time-average horizontal wind fields at the 500 hPa level are shown from 5:00hr on December 21, 1964 to 5:00hr on December 24, 1964 during the Y6412 storm event.

# Shift2D

Yuba

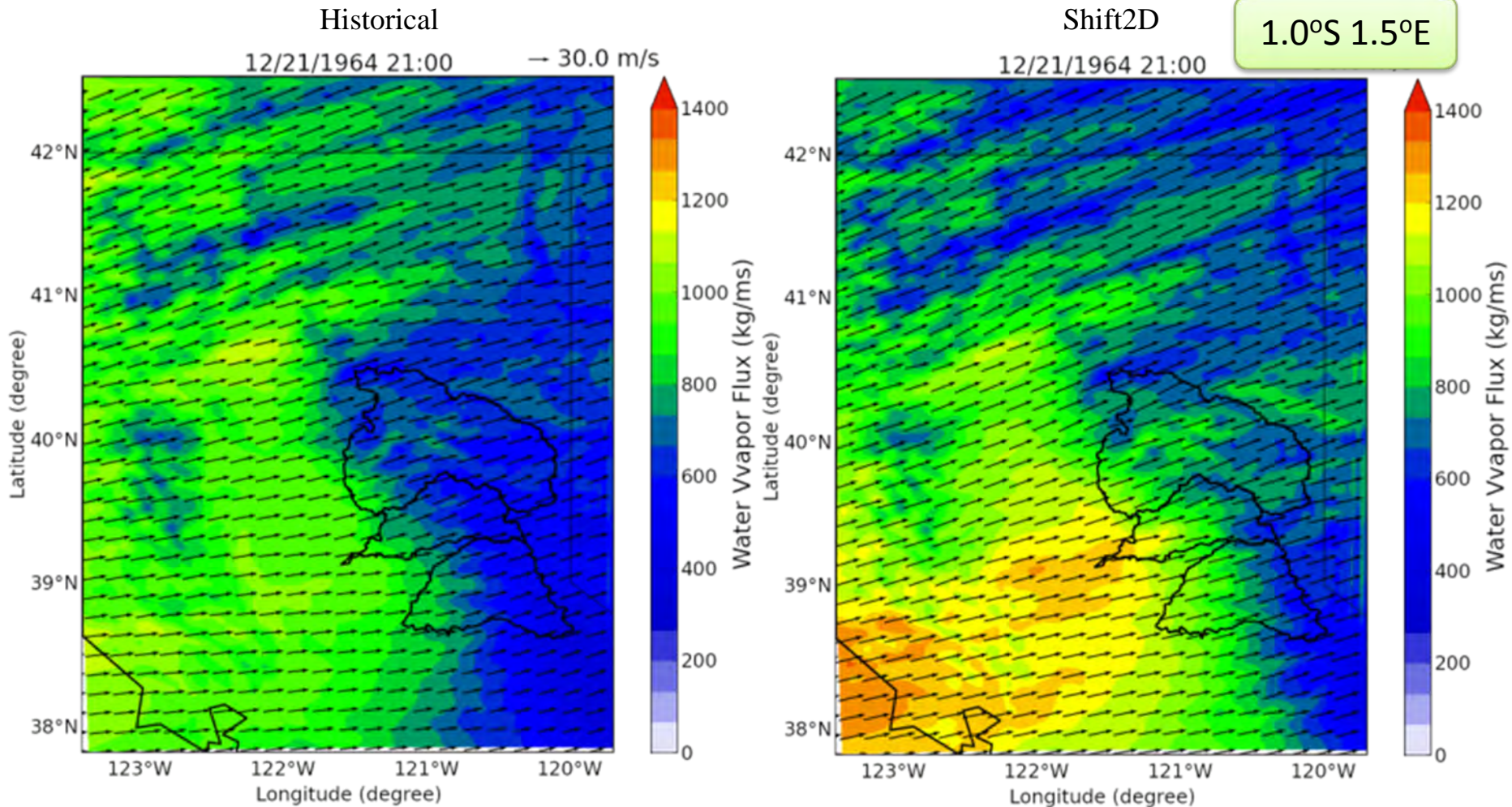


Figure: Spatial distributions of the absolute value of the water vapor flux together with the horizontal wind fields at the 500 hPa level at 21:00hr on December 21, 1964.

# Shift2D

Yuba

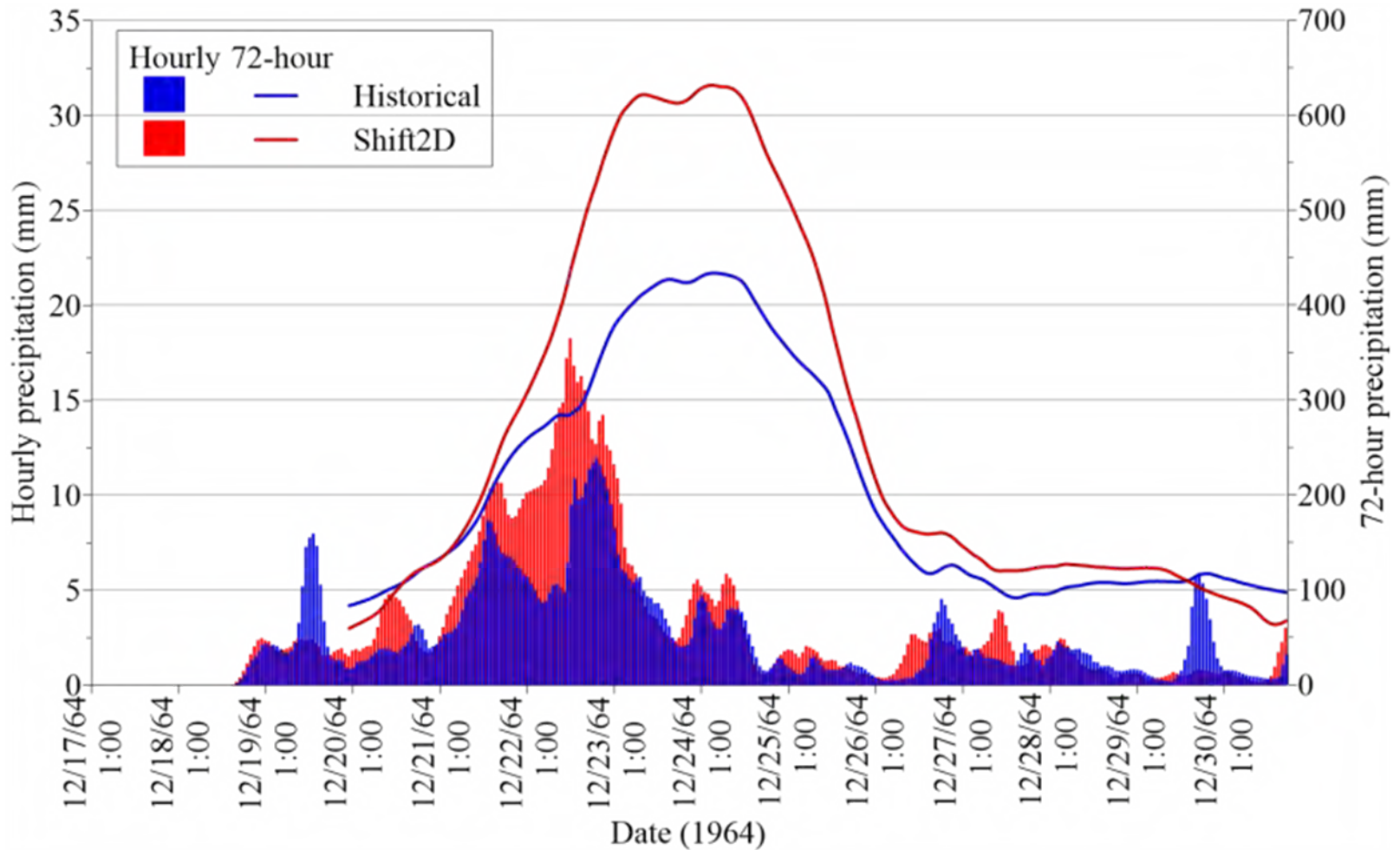


Figure: Hourly basin-average precipitation (bar) and its 72-hour moving summation (line) over Yuba River watershed during the A6412 storm event for the historical case (blue) and for the maximized case by Shift2D approach (red).

# Shift2D

Feather

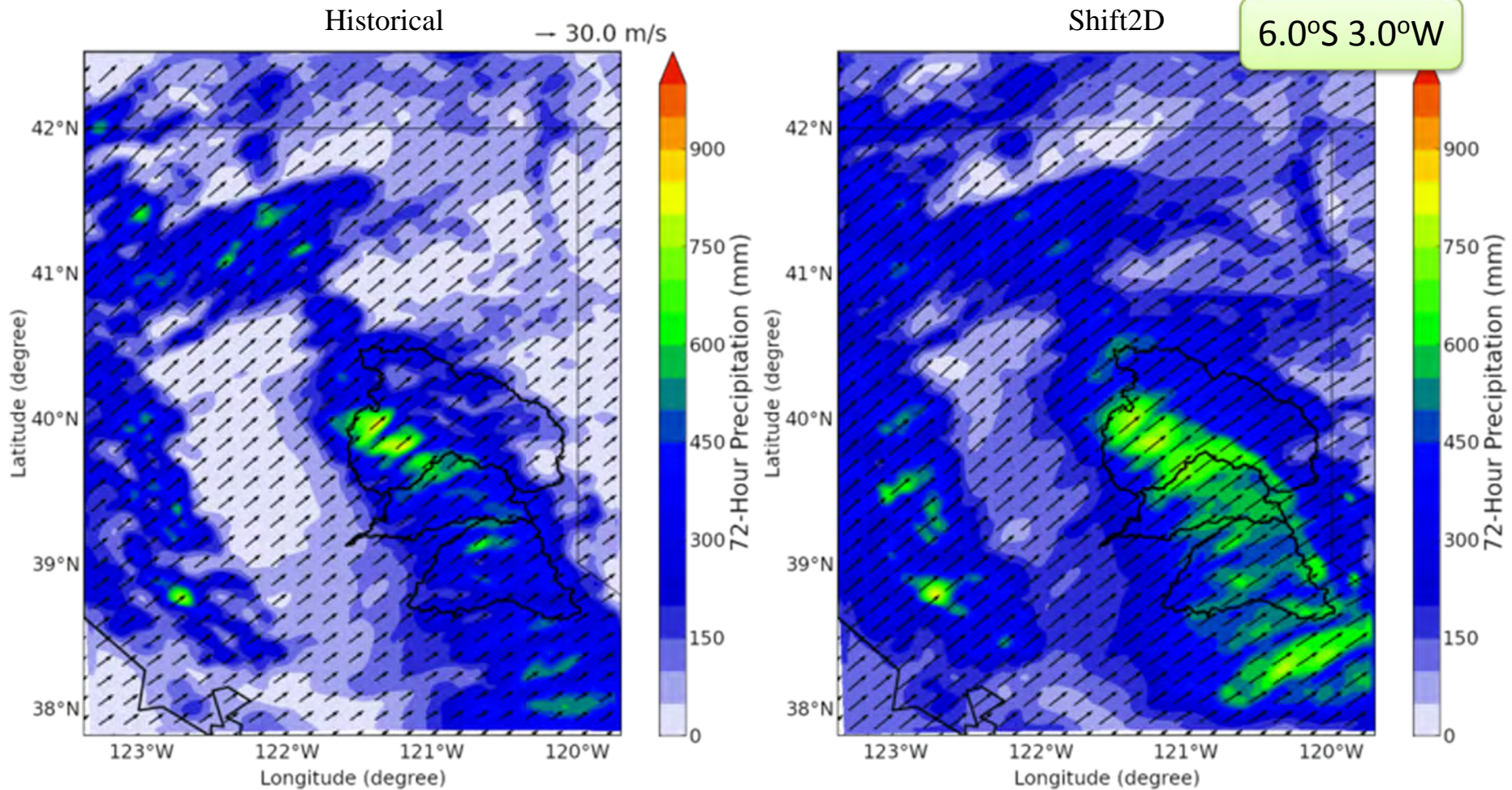


Figure: The spatial distributions of the accumulated precipitation together with the time-average horizontal wind fields at the 500 hPa level are shown from 15:00hr on December 29, 1996 to 15:00hr on January 1, 1997 during the F9701 storm event.

# Shift2D

Feather

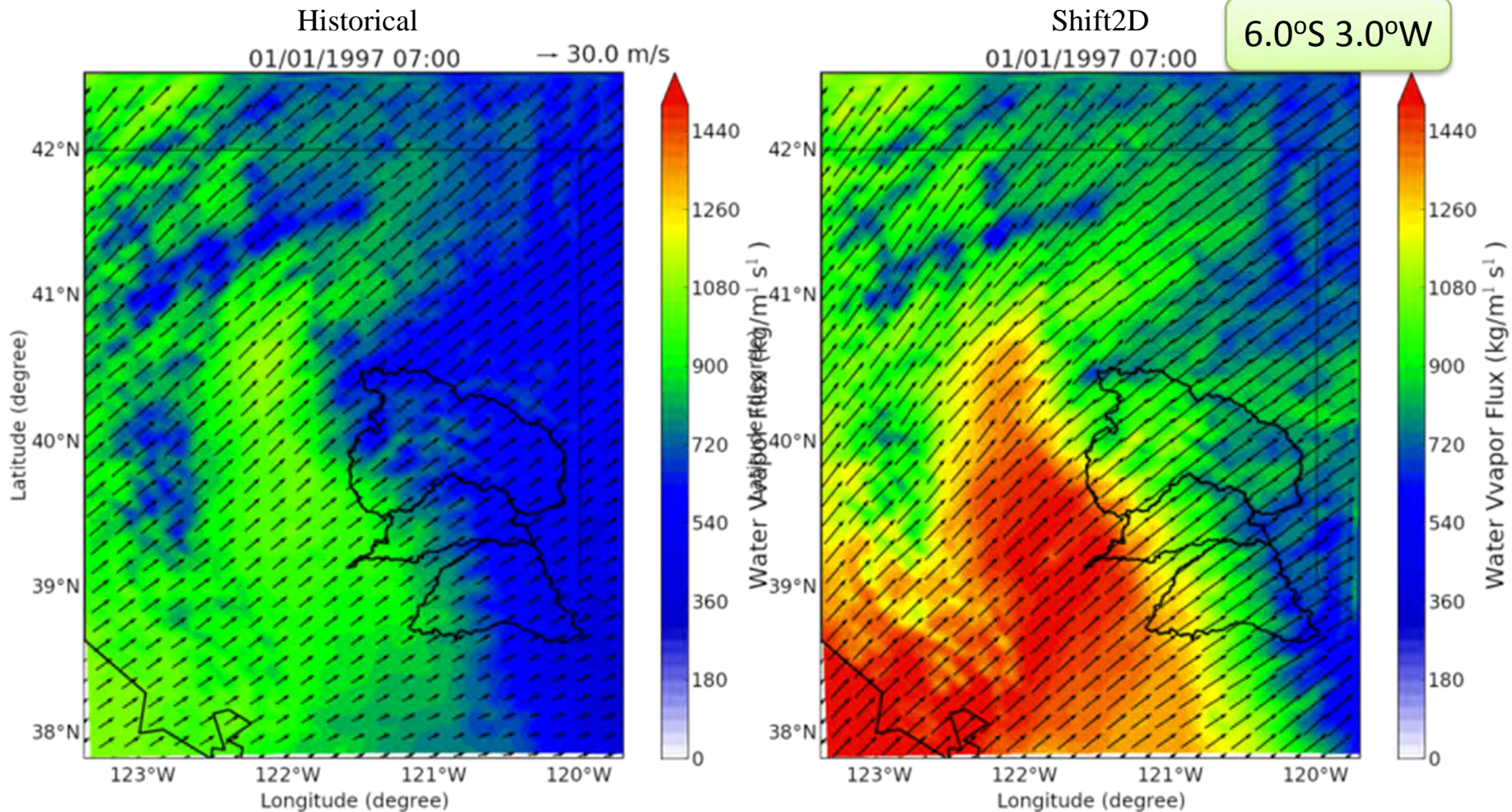


Figure: Spatial distributions of the absolute value of the water vapor flux together with the horizontal wind fields at the 500 hPa level at 7:00hr on January 1, 1997 for a) the historical case and b) the maximized case by Shift2D approach over Upper Feather River watershed.

# Shift2D

Feather

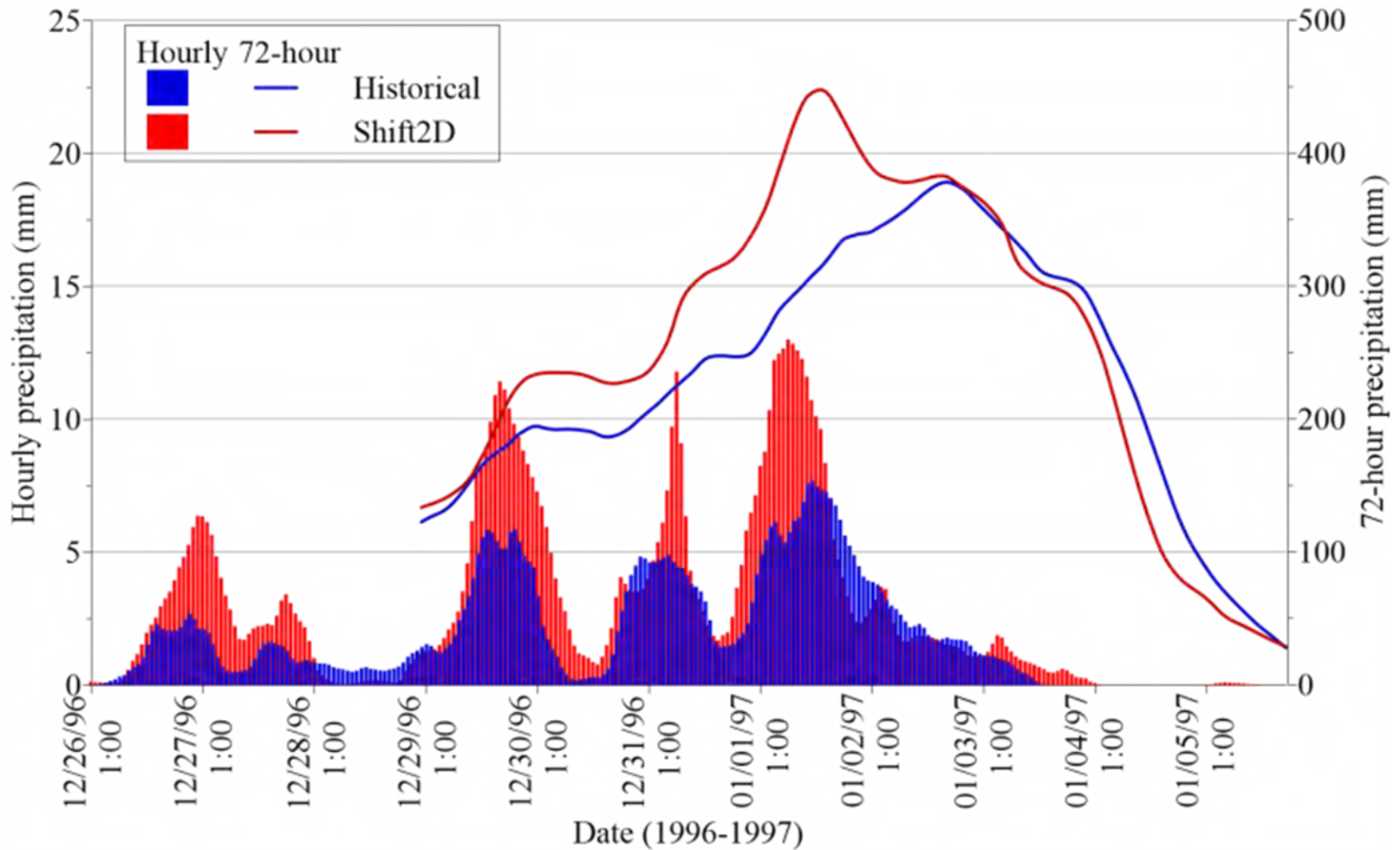


Figure: Hourly basin-average precipitation (bar) and its 72-hour moving summation (line) over Upper Feather River watershed during the F9701 storm event, for the historical case (blue) and for the maximized case by Shift2D approach (red).



# Shift2D

72-hour moving summation of basin average precipitation (mm)



Figure: 72-hour moving summation of basin average precipitation maximized by Shift2D in the selected storm events over the three targeted watershed.

# Shift2D+RH100

American

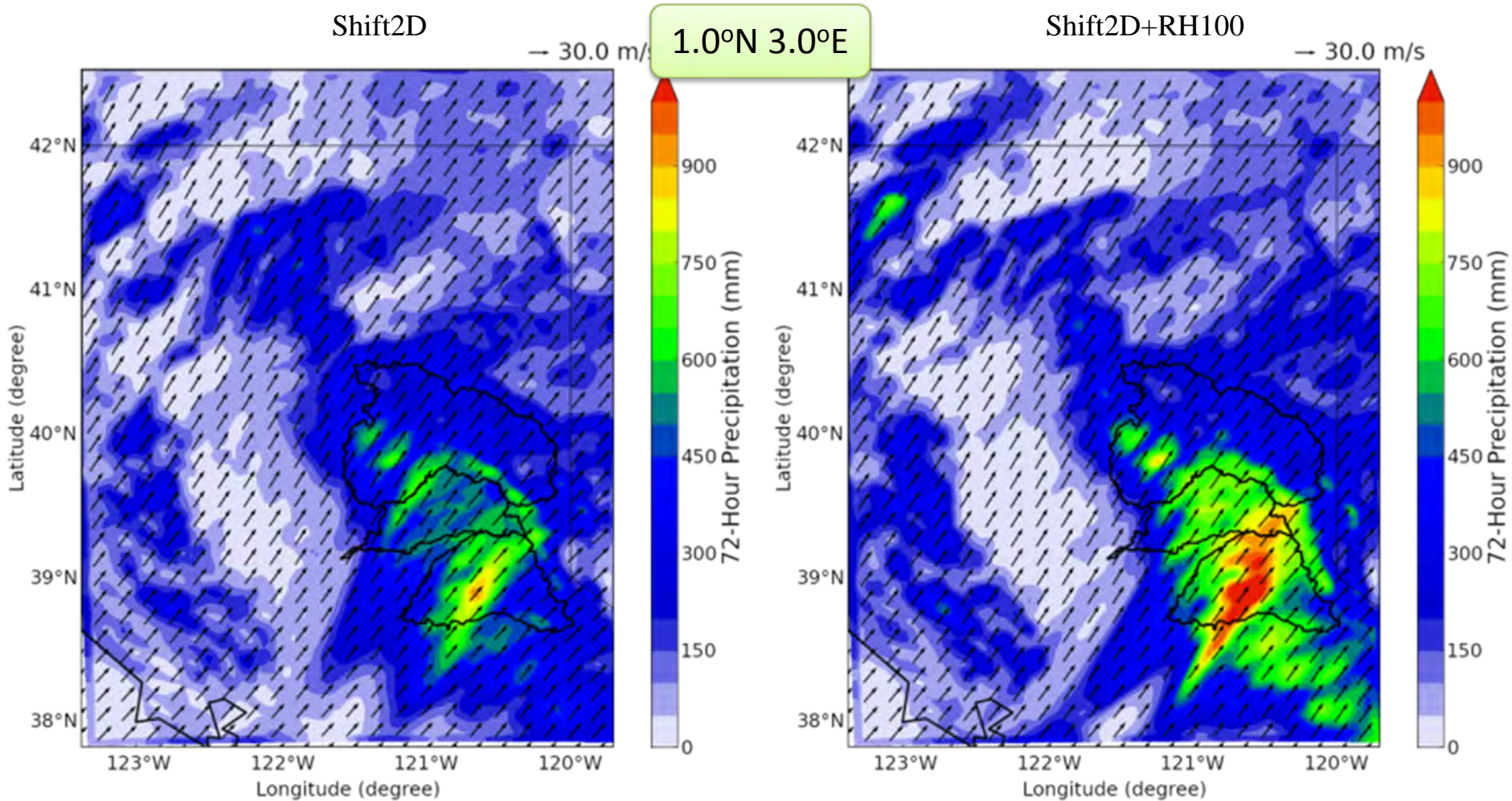


Figure: The spatial distributions of the accumulated precipitation together with the time-average horizontal wind fields at the 500 hPa level are shown from 23:00 January 7, 1995 to 23:00 in January 10, 1995 in the A9501 storm event.

# Shift2D+RH100

American

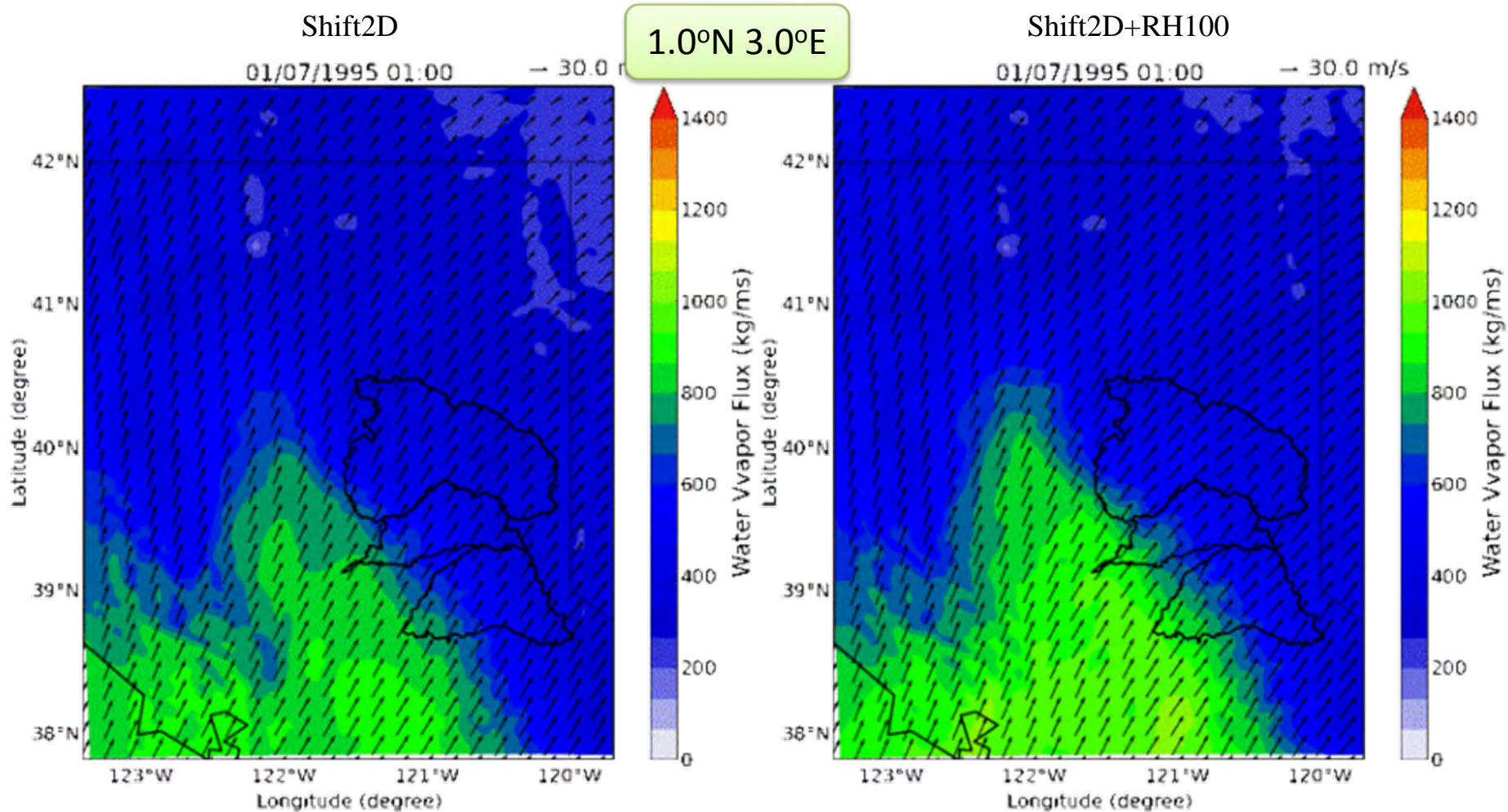


Figure: Spatial distributions of the absolute value of the water vapor flux together with the horizontal wind fields at the 500 hPa level from 0:00hr on January 7, 1995 to 23:00hr on January 10, 1995 for the maximized case a) by Shift2D approach and b) by Shift2D+RH100 approach over American River watershed.

# Shift2D+RH100

American

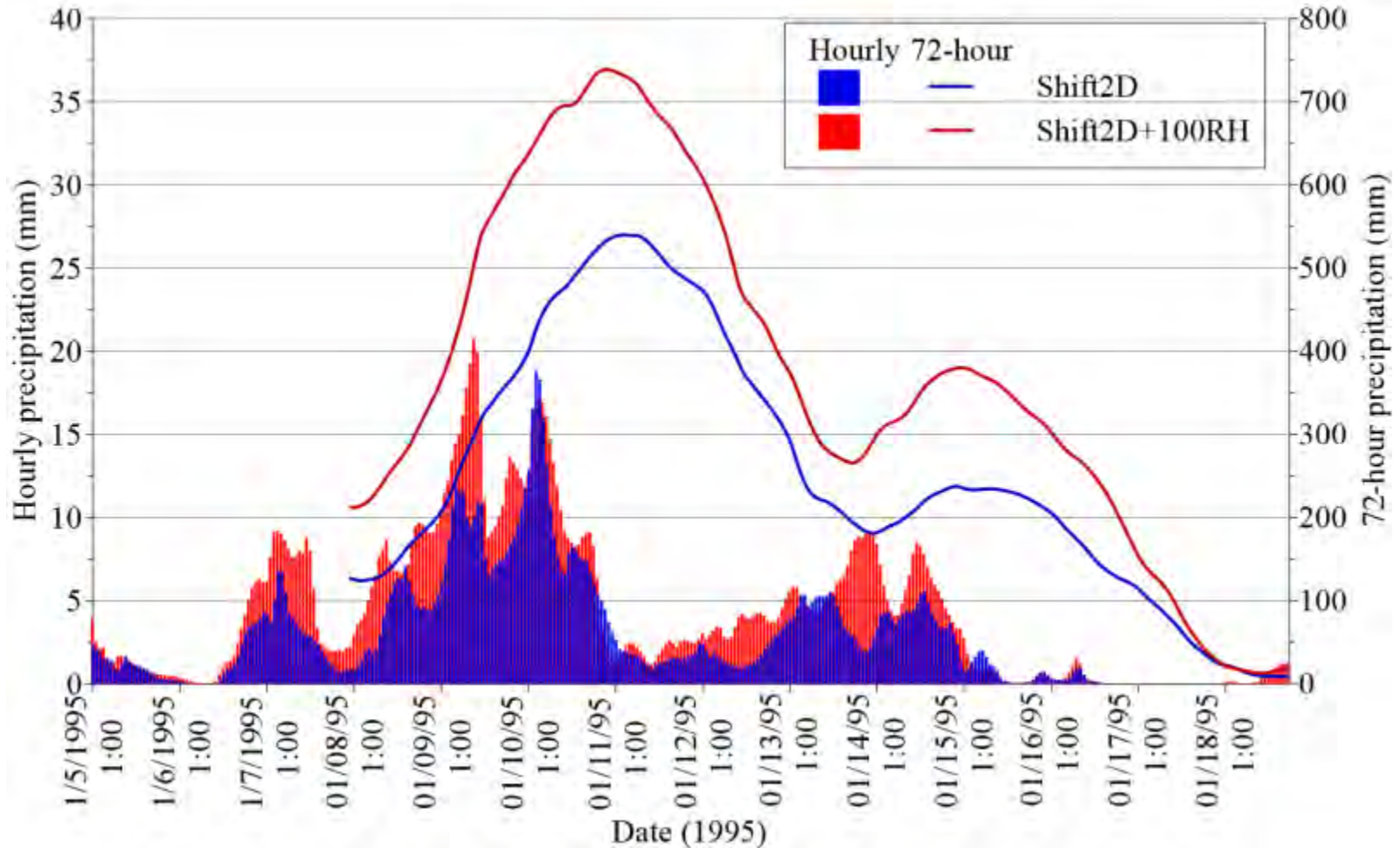


Figure: Hourly basin-average precipitation (bar) and its 72-hour moving summation (line) over American River watershed during the A9501 storm event for the maximized case by Shift2D approach (blue) and by Shift2D+RH100 approach (red).

# Shift2D+RH100

Yuba

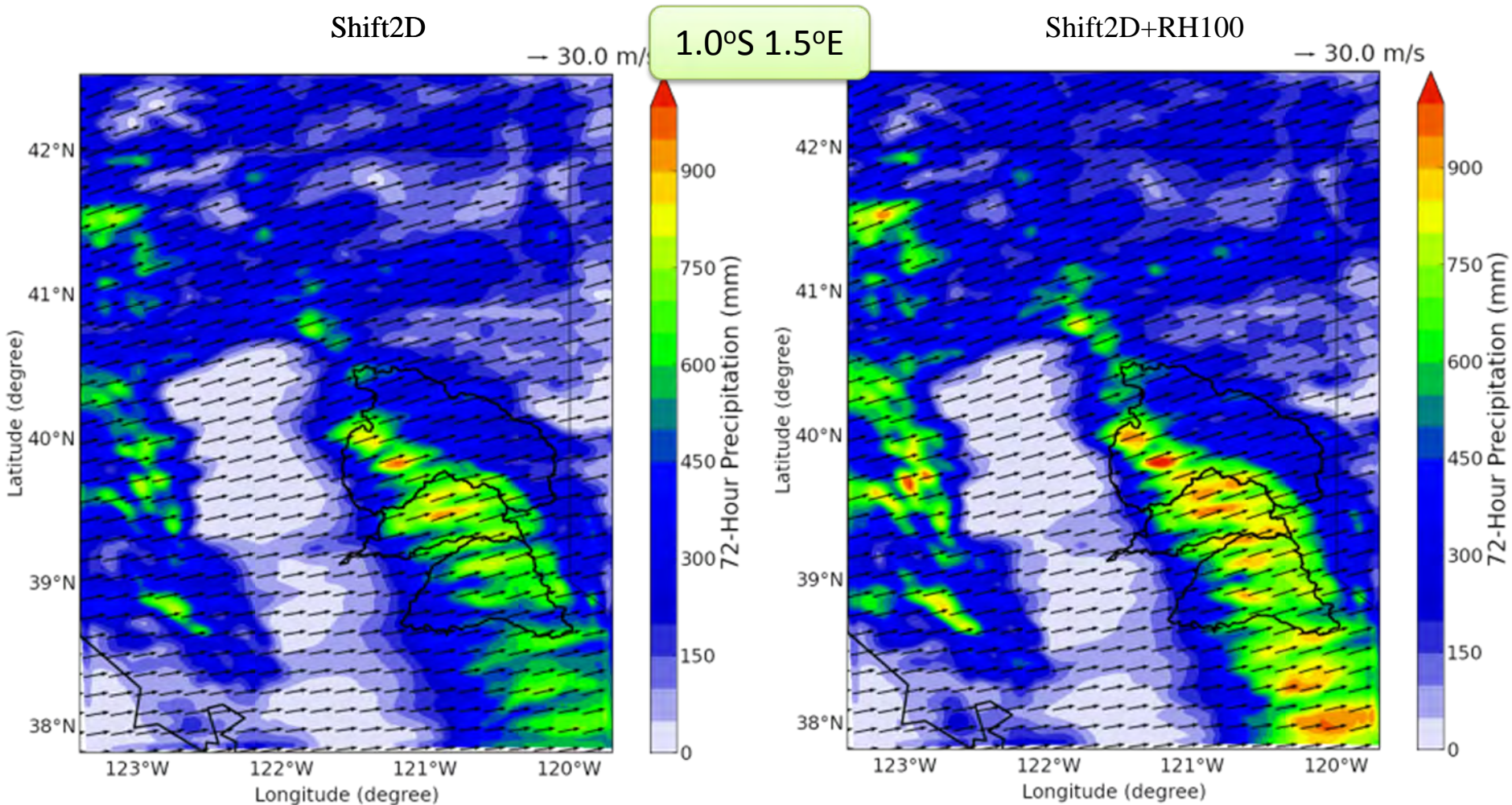


Figure: The spatial distributions of the accumulated precipitation together with the time-average horizontal wind fields at the 500 hPa level are shown from 2:00 December 21, 1964 to 2:00 in December 24, 1964 in the Y6412 storm event.

# Shift2D+RH100

Yuba

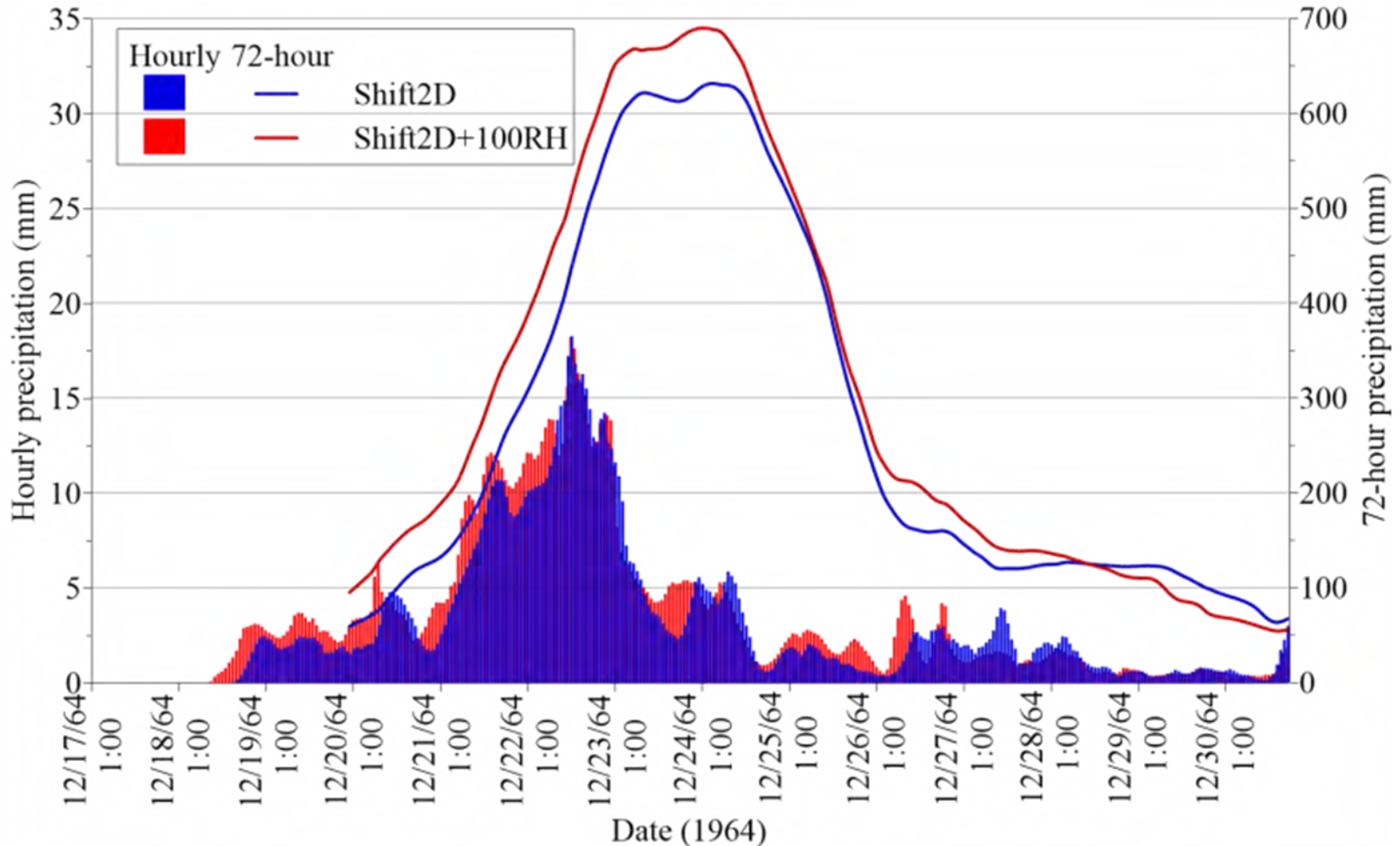


Figure: Hourly basin-average precipitation (bar) and its 72-hour moving summation (line) over Yuba River watershed during the Y6412 storm event for the maximized case by Shift2D approach (blue) and by Shift2D+RH100 approach (red).

# Shift2D+RH100

Feather

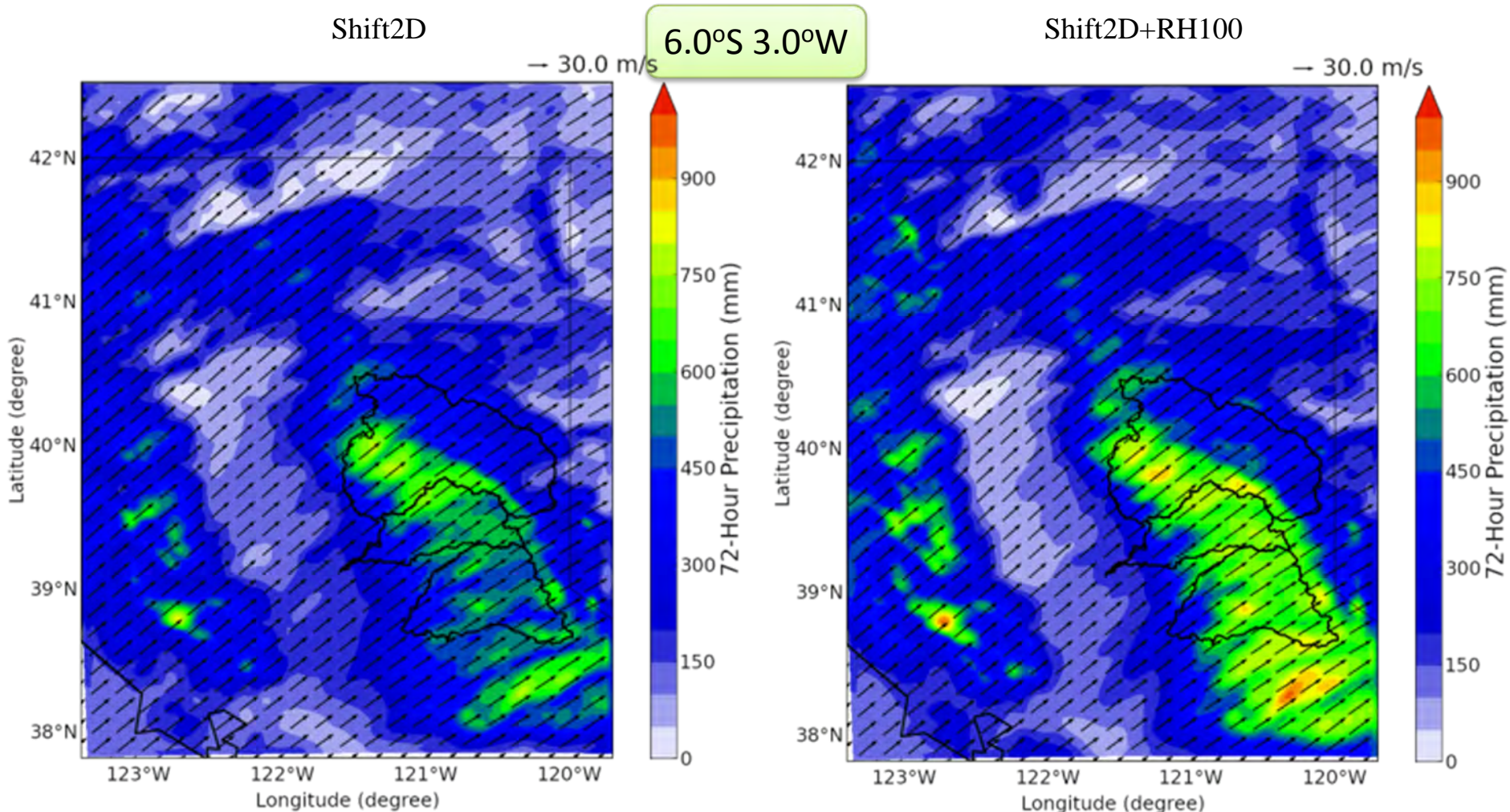


Figure: The spatial distributions of the accumulated precipitation together with the time-average horizontal wind fields at the 500 hPa level are shown from 14:00 December 29, 1996 to 14:00 in January 1, 1997 in the F9701 storm event.

# Shift2D+RH100

Feather

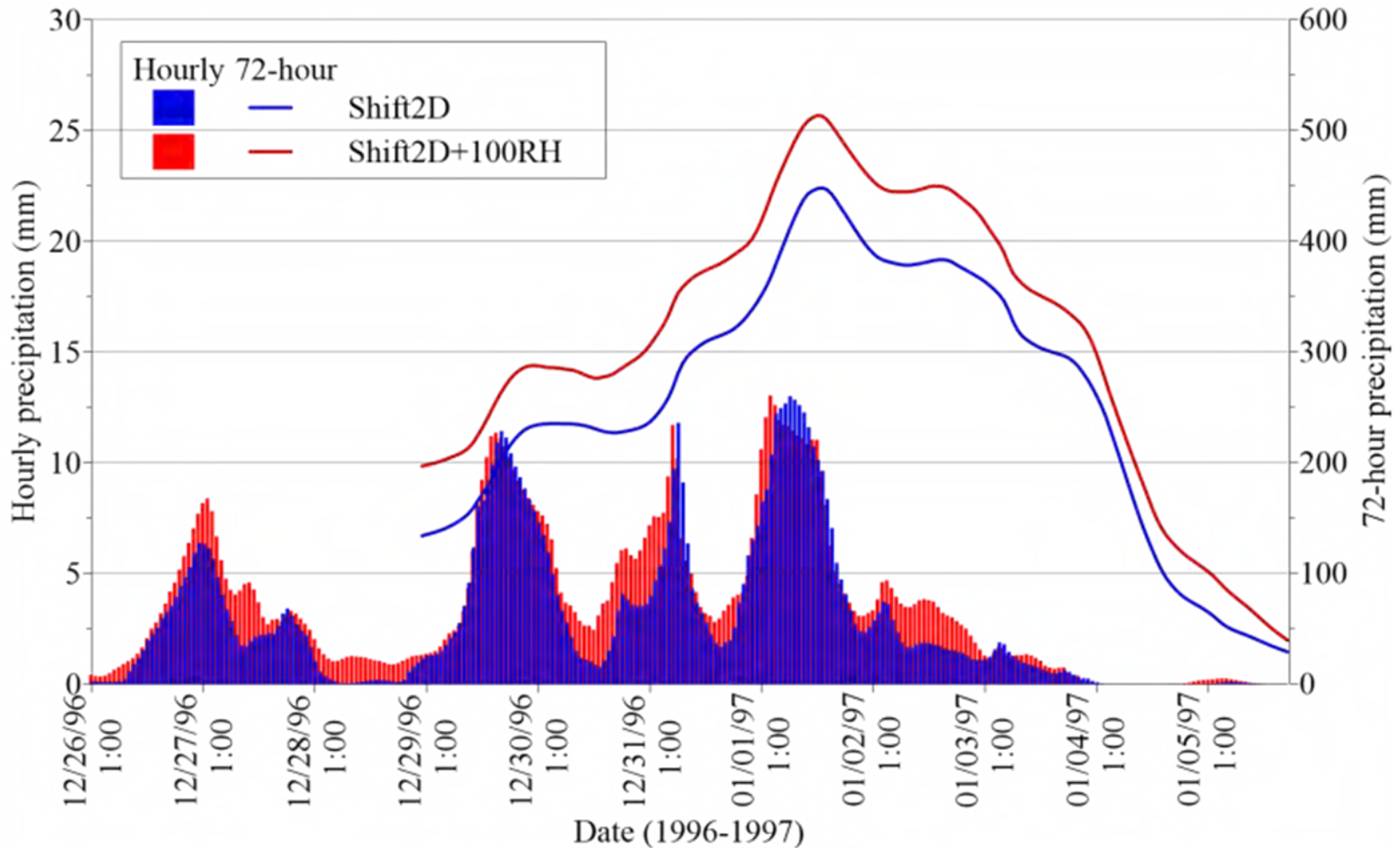


Figure: Hourly basin-average precipitation (bar) and its 72-hour moving summation (line) over Upper Feather River watershed during the F9701 storm event for the maximized case by Shift2D approach (blue) and by Shift2D+RH100 approach (red).

# Shift+RH100

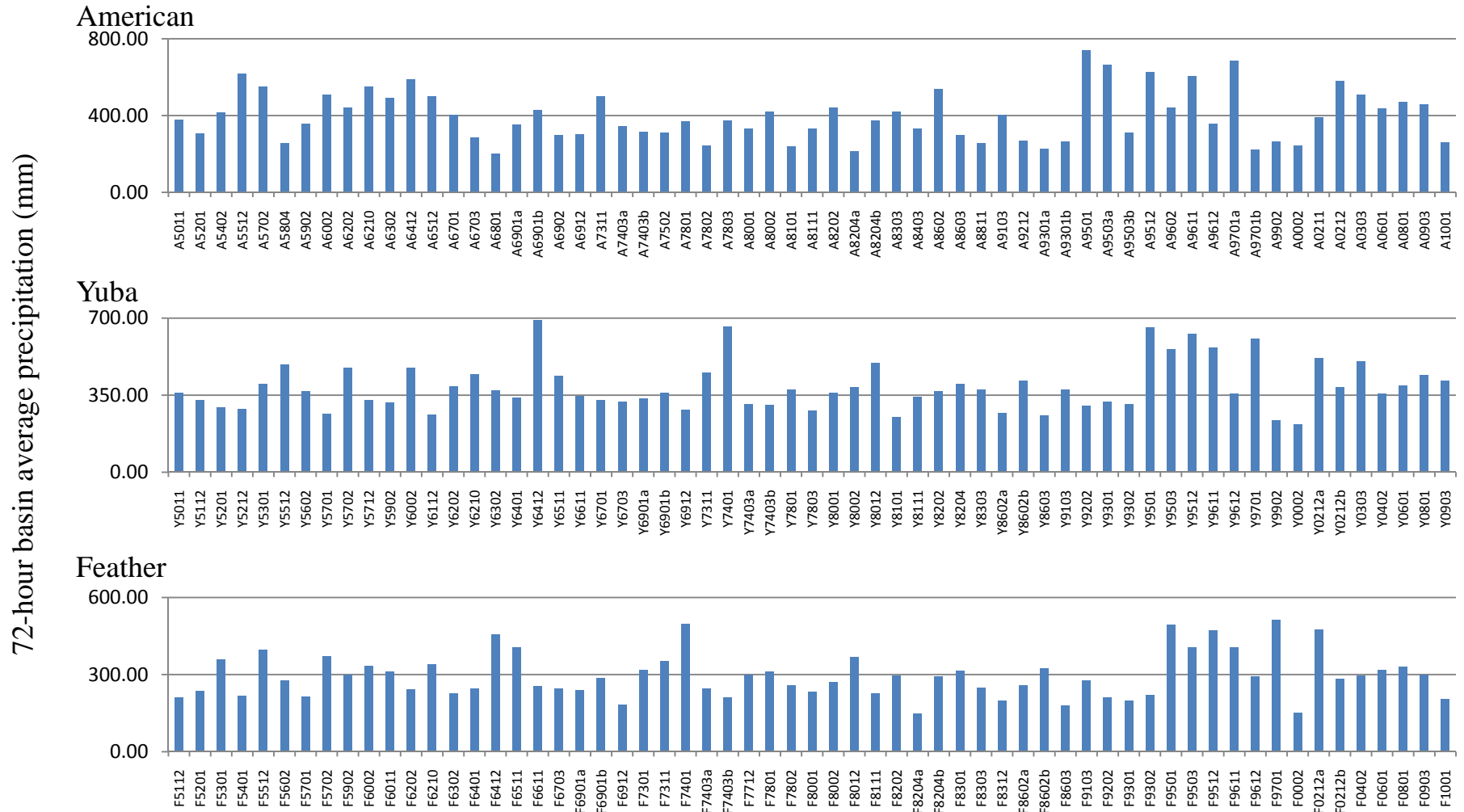


Figure: 72-hour moving summation of basin average precipitation maximized by Shift+RH100 in the selected storm events over the three targeted watershed.

# Shift+RH100

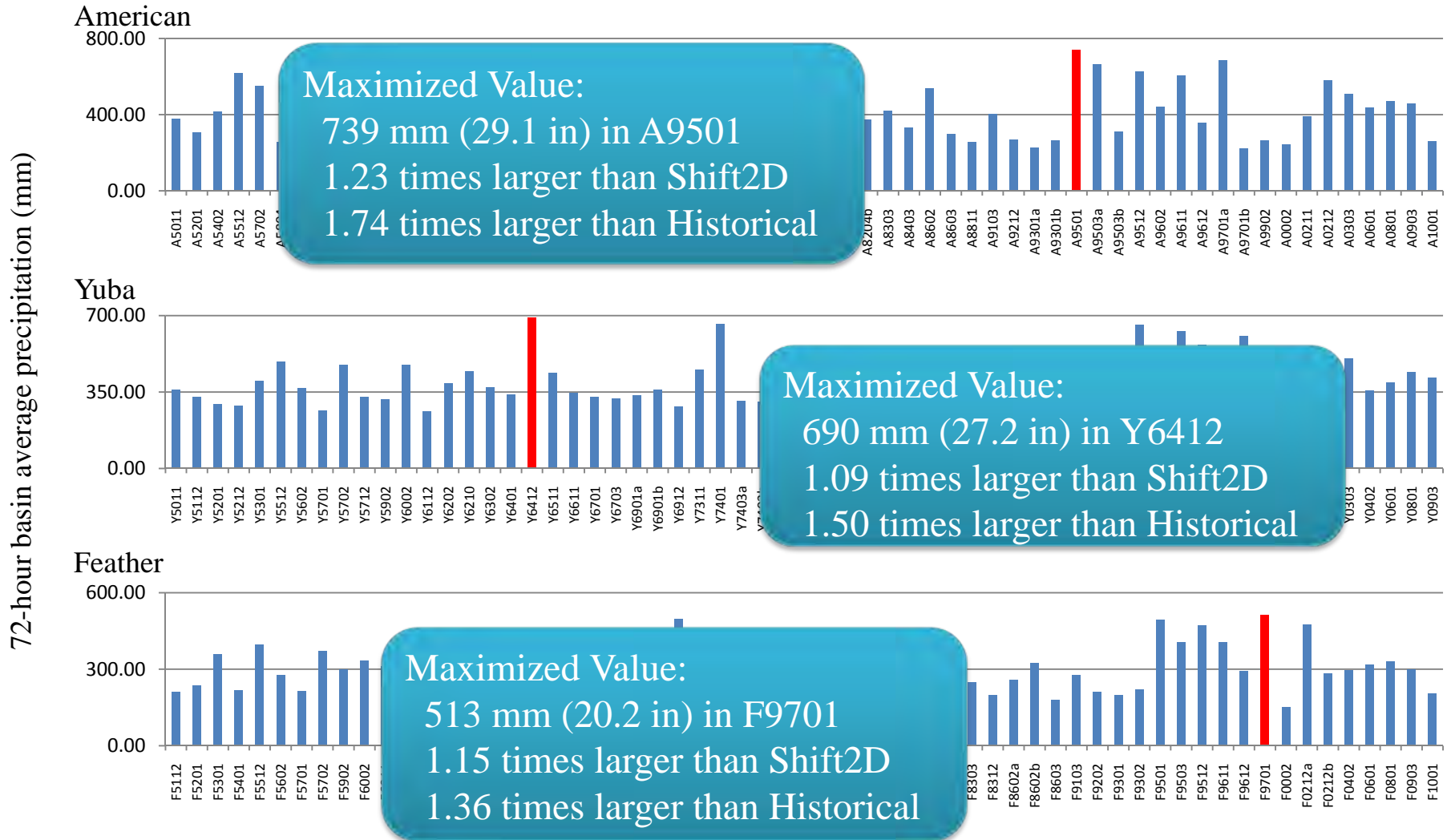


Figure: 72-hour moving summation of basin average precipitation maximized by Shift+RH100 in the selected storm events over the three targeted watershed.

# Comparison with PMP values over ARW

Approach	MP value
Shift2D	600 mm
Shift2D + RH100	739 mm
Report	PMP value
U.S. Weather Bureau- HMR36 (1961)	800 mm
Corrigan et al. – HMR59 (1999)	726 mm
USACE (2001)	752 mm

## CONCLUSIONS

1. By shifting the 3D atmospheric boundary conditions in the meridional and zonal directions and then elevating the relative humidity at the model boundaries to 100%, the developed method determines the optimal location and orientation of the moisture convergence mechanism for a particular severe storm and creates the saturated conditions for the storm in order to contribute the maximum precipitation from that storm to the specified geographical region.
2. The developed method is applicable to any geographical region where the severe precipitation events can be identified by particular moisture convergence mechanisms.
3. The shifting of the 3D atmospheric boundary conditions also optimizes the direction and the speed of the corresponding wind field once the moisture convergence field's location and orientation are optimized to produce the maximum precipitation over a target region.