HOKKAIDO UNIVERSITY

SOIL'S ROLE IN RESTORING ECOSYSTEM SERVICES

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Coupled Control of Land Use and Topography on Suspended Sediment Dynamics in an Agriculture-Forest Dominated Watershed, Hokkaido, Japan.

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INTRODUCTION

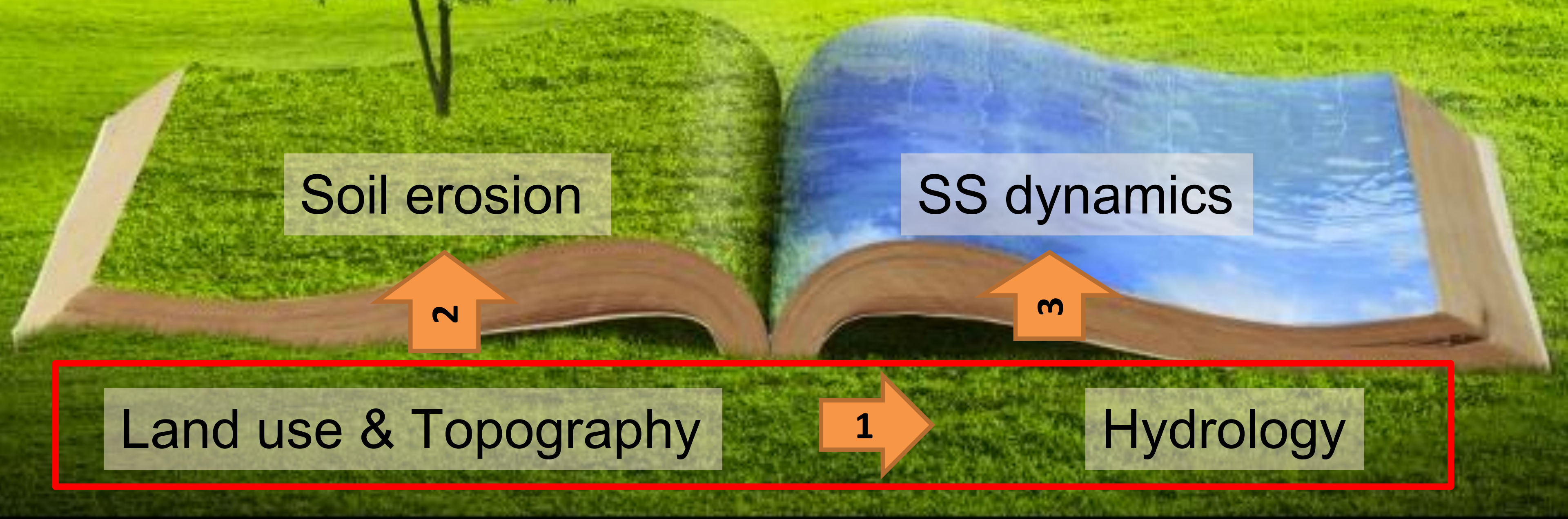
- **Suspended sediment (SS)** transport from land to watercourse is an immense problem that has threatened soil and water conservation in the world (Alexandrov et al., 2003).
- Influence of land use and topography on SS dynamics and yields at different spatial and temporal scales have been reported (Bakker et al., 2008, Casali et al., 2010 and Tang et al., 2011).
- Understanding the dynamics of SS transfer is essential in controlling soil erosion and in implementing appropriate mitigation practices (Heathwaite et al., 2005).

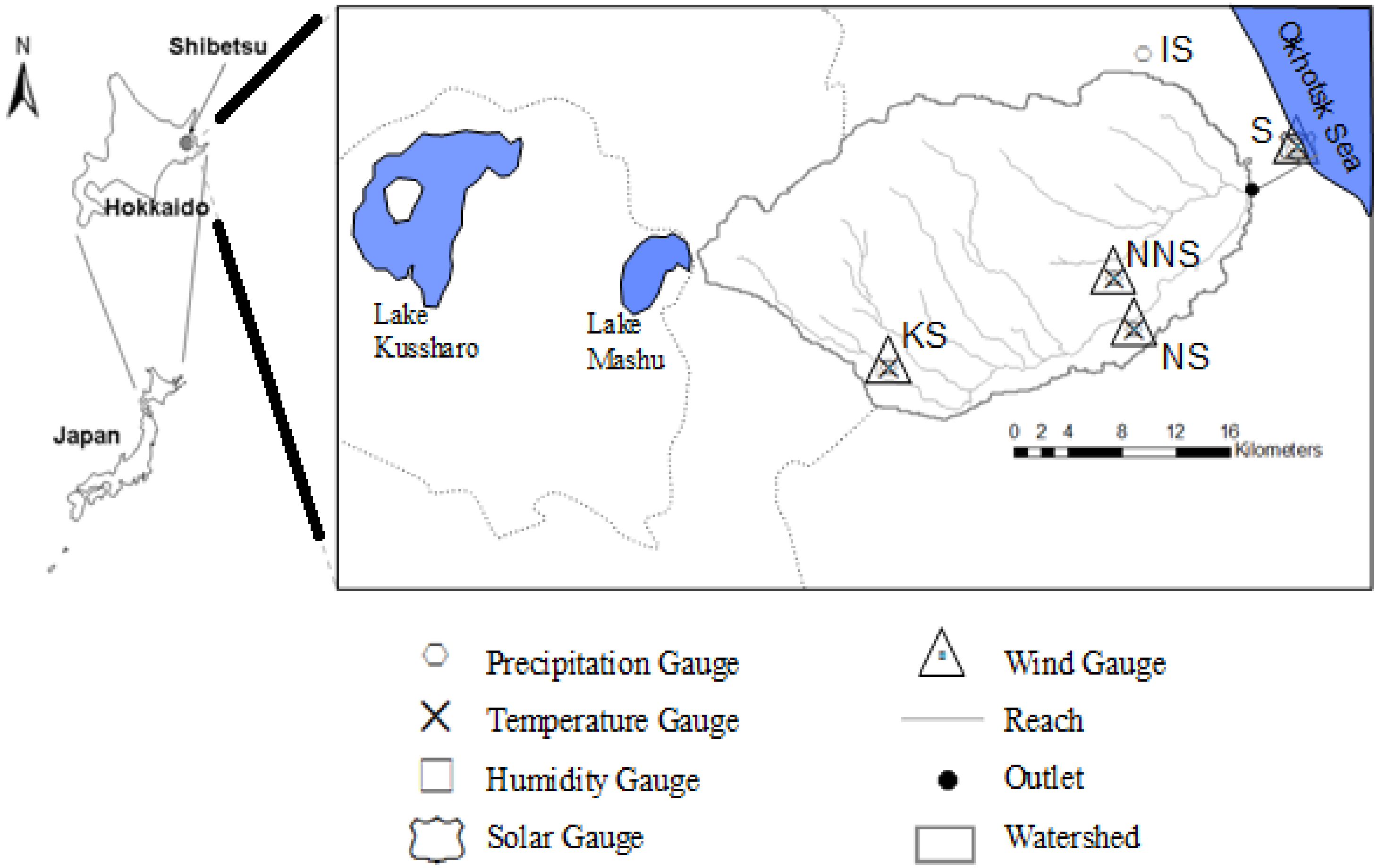
OBJECTIVES

(1) Assess land use and topography influence on surface runoff and lateral flow response to precipitation.

(2) Assess influence of land use and topography on SS yield.

(3) Assess effects of land use, topography and hydrological processes on sediment dynamics in streams.

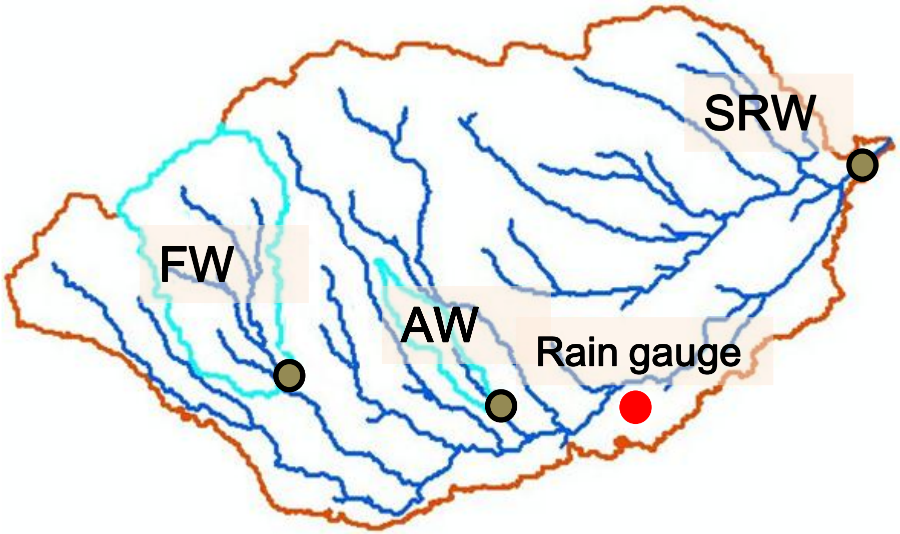




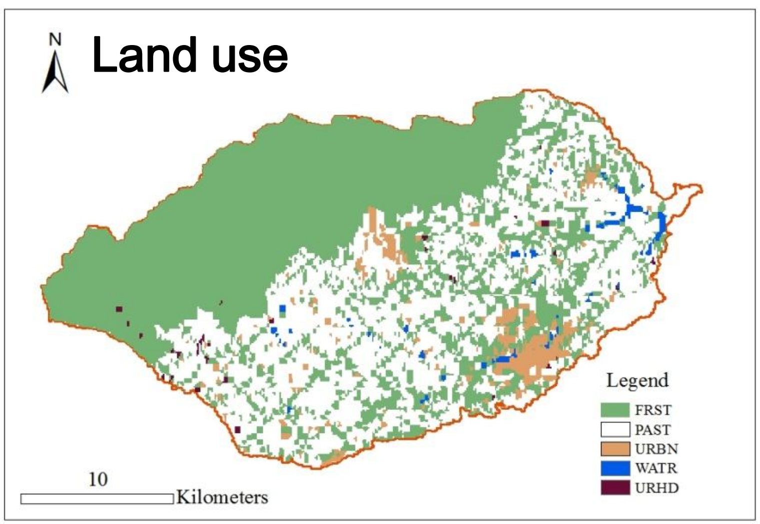
Shibetsu River Watershed (SRW), Hokkaido, Japan

MATERIAL & METHODS

Study site



SRW and two sub-basins **FW** and **AW**



		AW	FW	SRW
	Area (km^2)	10.4	71.3	675
Land Use	Forest	18.8	**83.7**	53.7
	Pasture	**80.2**	15.1	40.8
	Urban	0.3	0.6	4.3
Slope	0-5	**82.0**	22.8	54.9
	>5	18.0	**77.2**	45.1

MATERIAL & METHODS

Sampling

Stream water table (H)

Stream discharge (Q)

Calibrated H-Q equations

Water samples

Automatic sampler

(high frequency for flood events)

SS concentration (SSC)

0.7µm Glass Microfiber filters.

Continuous Wavelet Transform (CWT)

To characterize the temporal variability of rainfall and runoff events.

Wavelet Coherence (WTC)

To clarify relationship between rainfall and runoffs.

SSC – Q dynamics during flood events

Hysteretic loop:

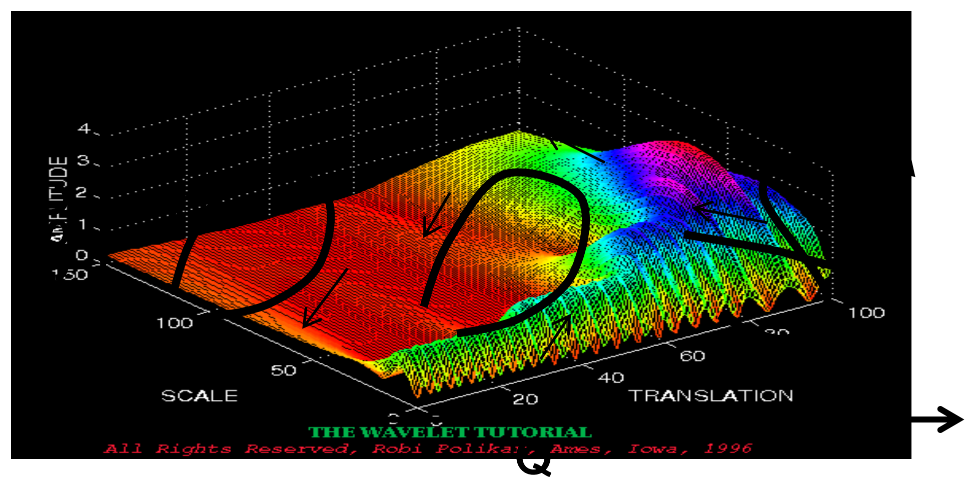
Interval between the SSC and Q peaks.

(1) Clockwise (C): SSC>Q

(2) Anticlockwise (A): Q>SSC

(3) 8-shaped (8): Several peaks in SSC

Matlab-software package (WTC-R15)



Characteristics of rainfall events

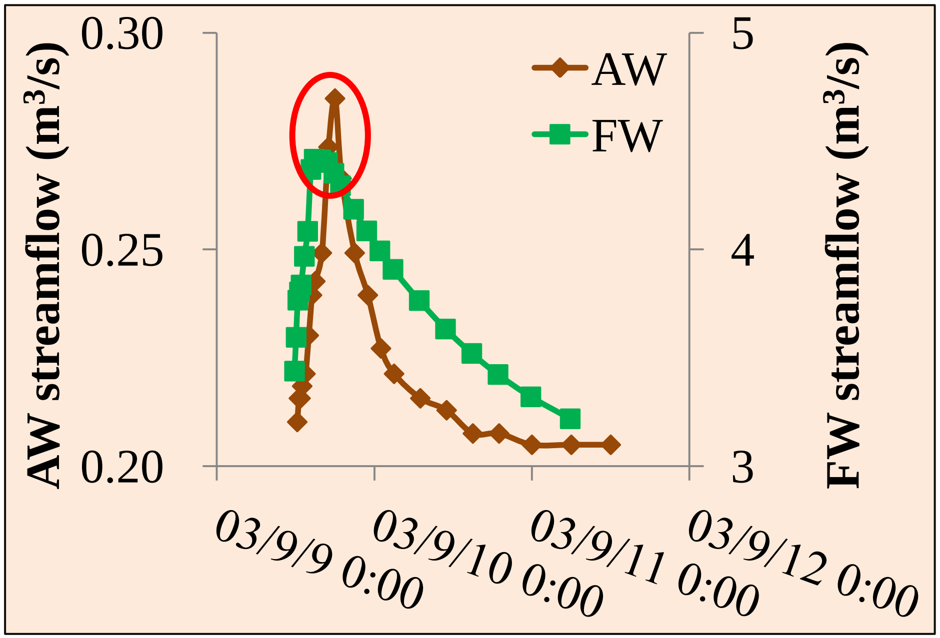
	Rainfall events	Snowmelt events
2003	3	
2004	2	1 (April)
2006		1 (May)
2007	1	

Rainfall events	Total rainfall (mm)	Maximum intensity (mm/h)
29-31 Jul 2003	44	7
8-10 Aug 2003	178	35
9-11 Sep 2003	31	9
30-31 Aug 2004	28	7
7-9 Sep 2004	27	6
22-24 July 2007	46	12

Characteristics of the rainfall events

RESULTS & DISCUSSION

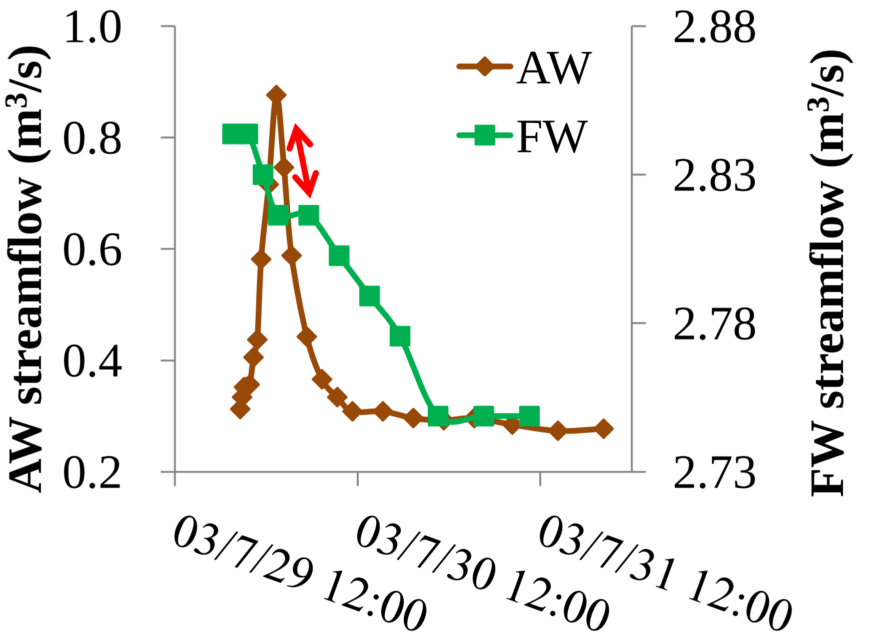
Land use and topography influence on surface runoff and lateral flow response to precipitation ?

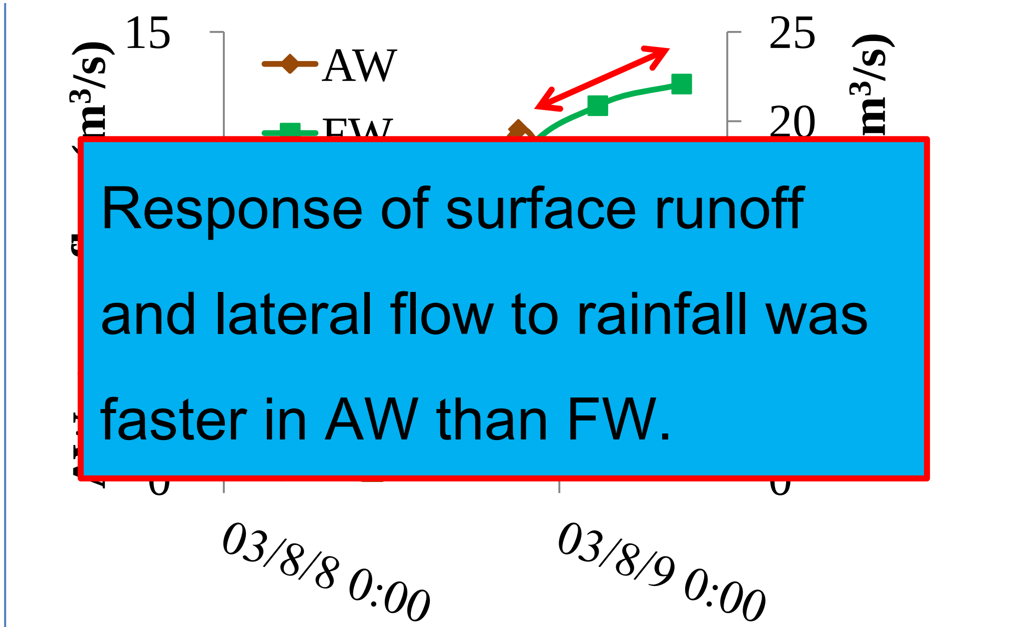


Response of surface runoff and lateral flow to rainfall in AW was similar with FW.

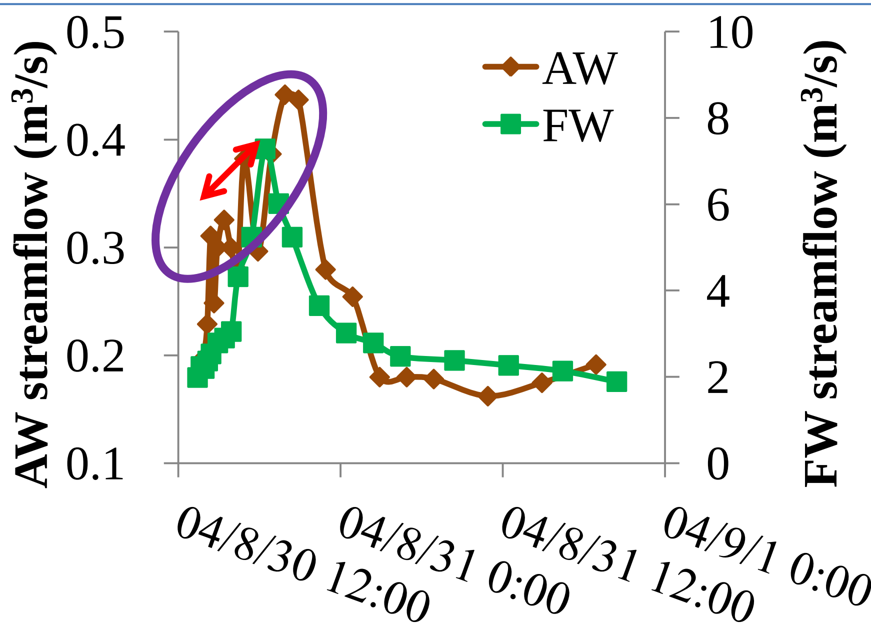
RESULTS & DISCUSSION

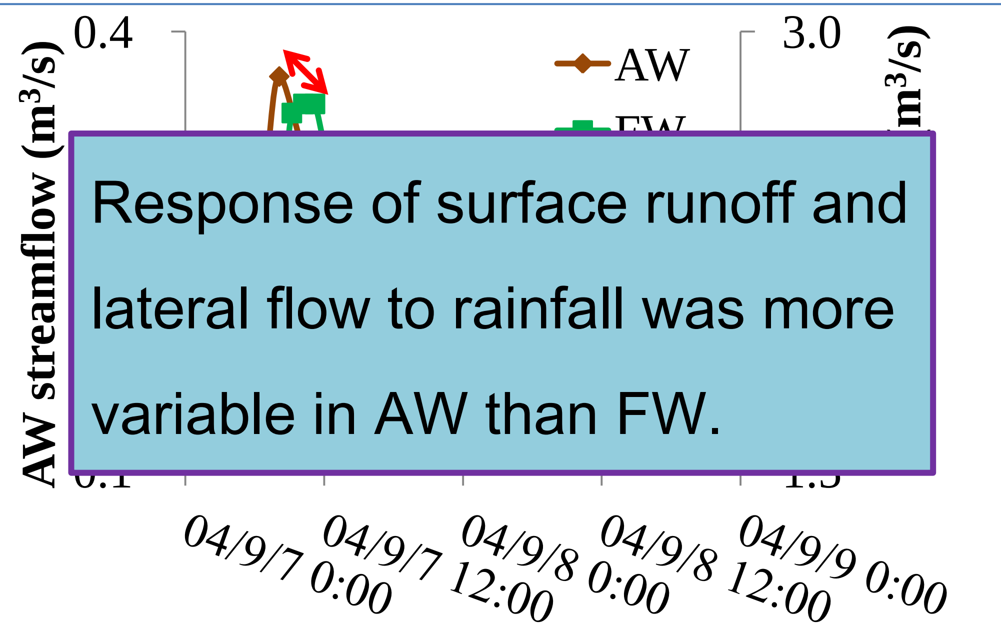
Hydrograph of flood events





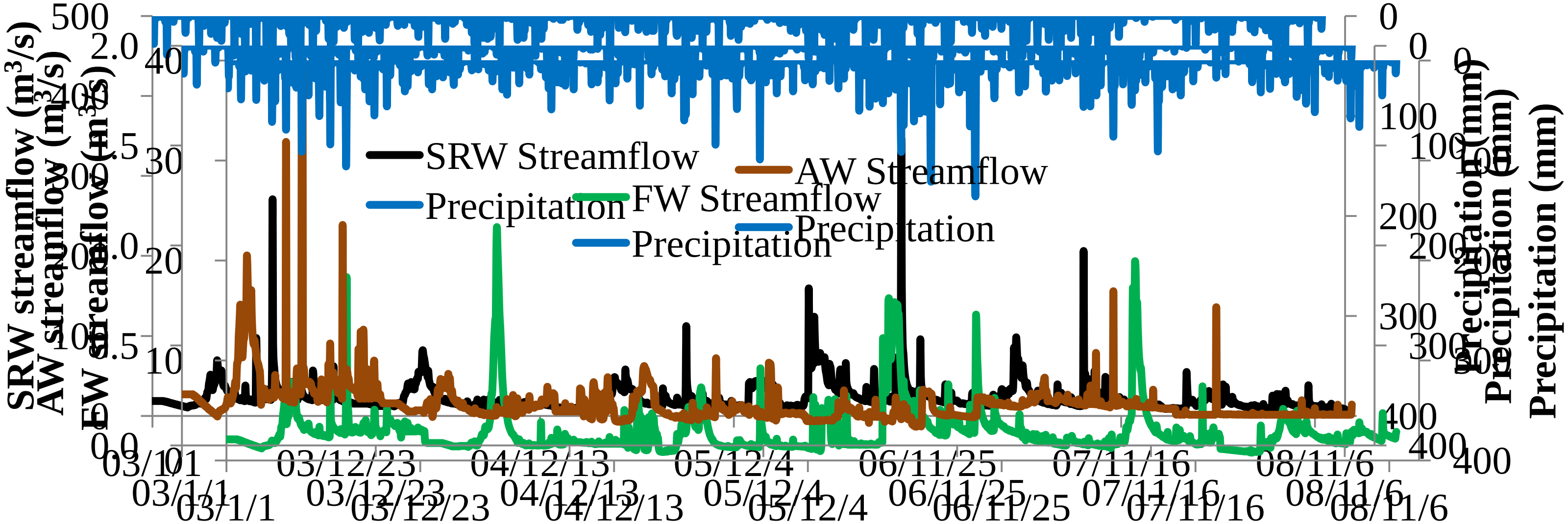
Response of surface runoff and lateral flow to rainfall was faster in AW than FW.





Response of surface runoff and lateral flow to rainfall was more variable in AW than FW.

Original time series of CWT and WTC

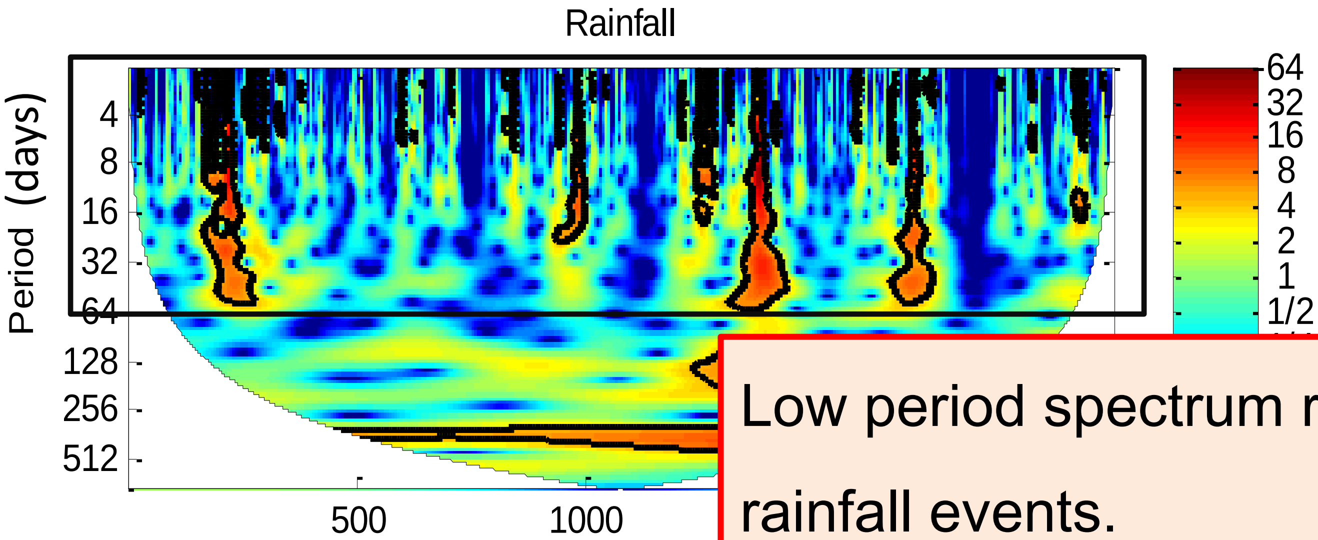


Continuous Wavelet Transform (CWT)

Wavelet Coherence (WTC)

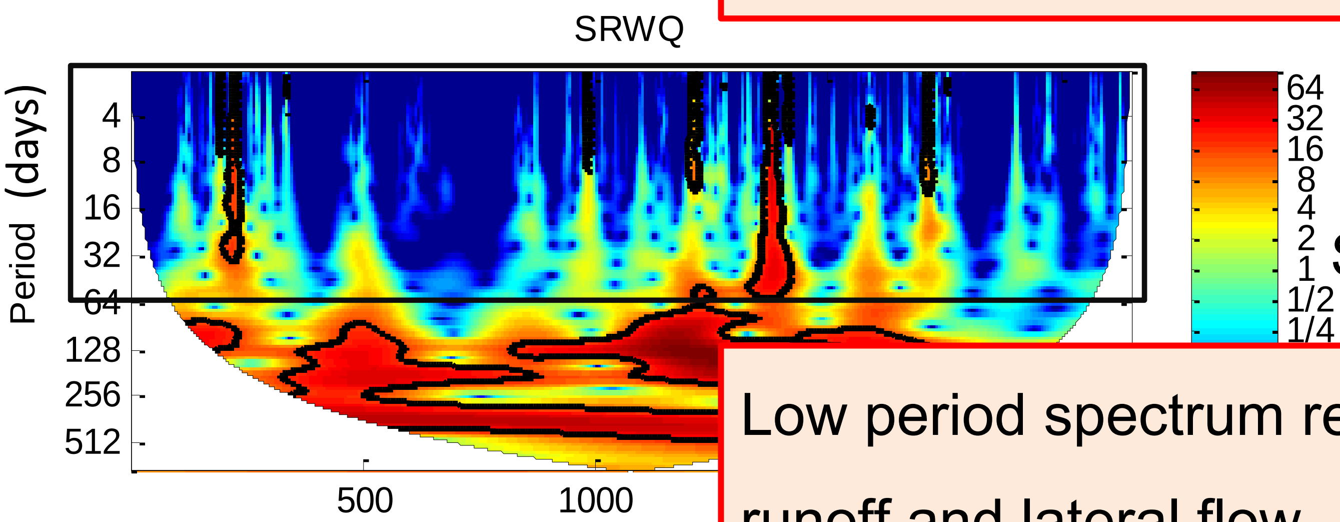
RESULTS & DISCUSSION

CWT: Variability of rainfall and streamflow



Daily rainfall

Low period spectrum represents high rainfall events.



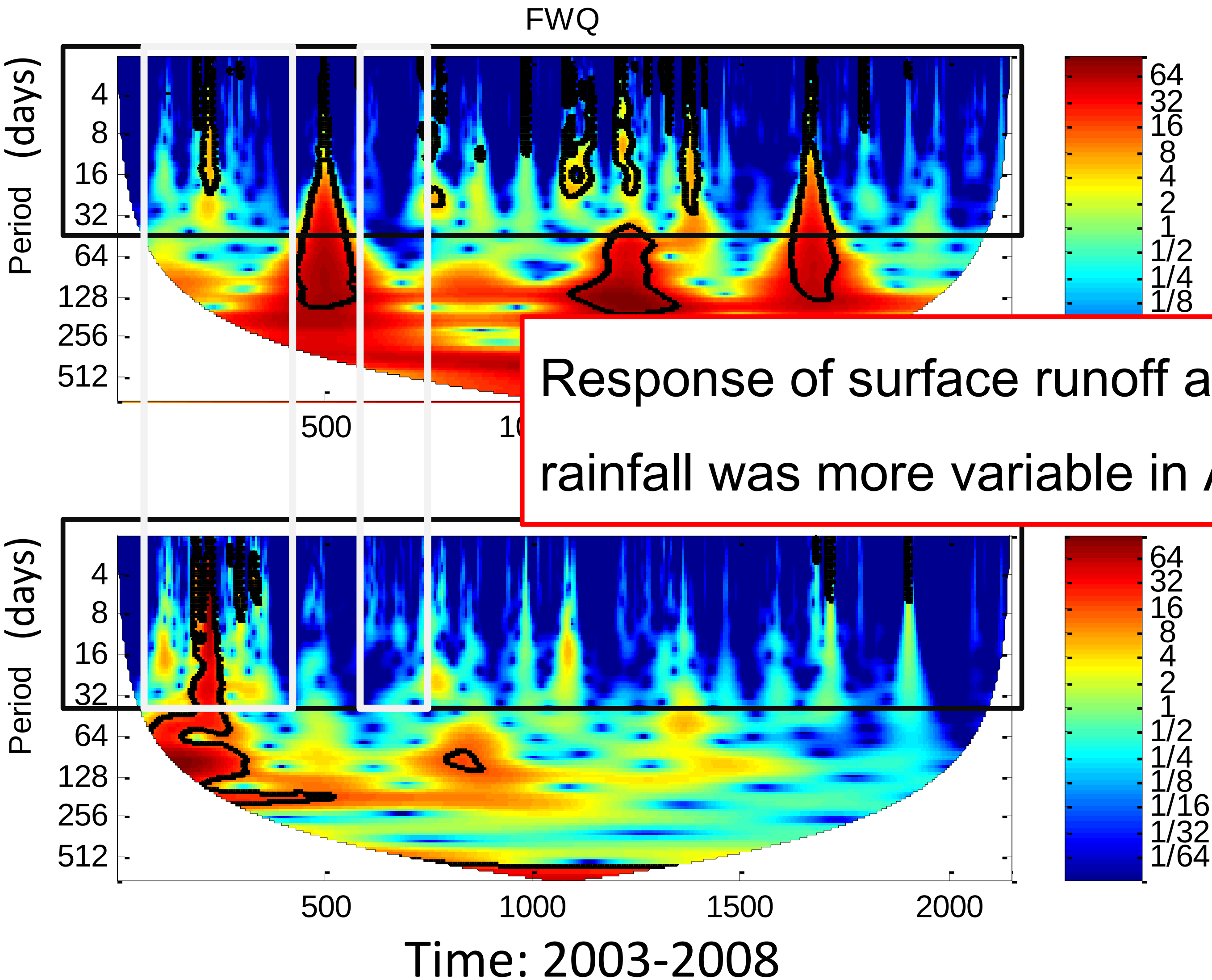
SRW daily streamflow

Low period spectrum represents surface runoff and lateral flow.

Time: 2003-2008

RESULTS & DISCUSSION

CWT: Variability of rainfall and streamflow



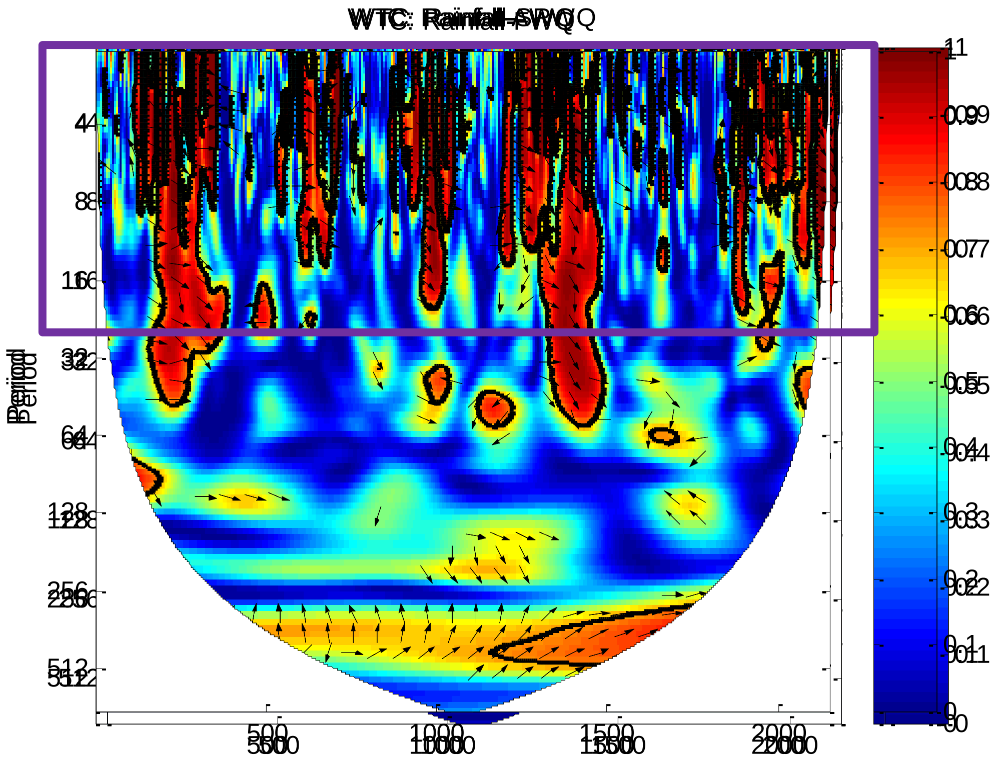
FW daily streamflow

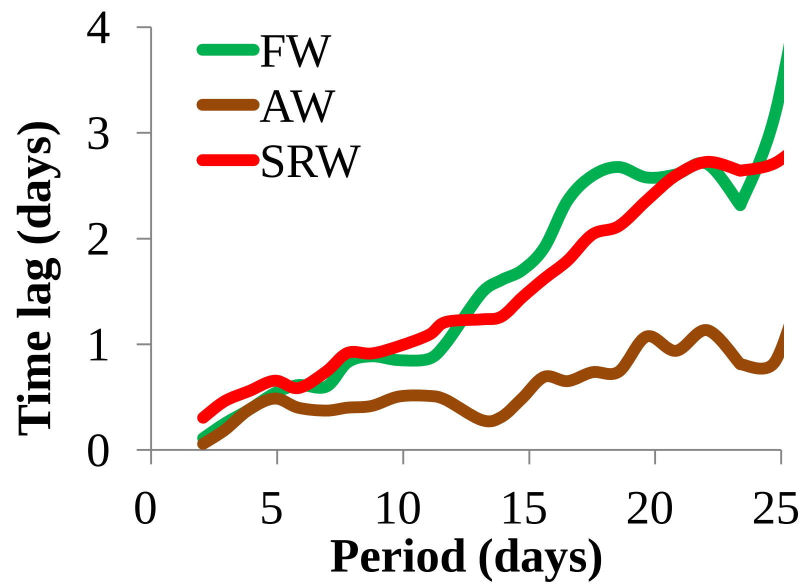
AW daily streamflow

Response of surface runoff and lateral flow to rainfall was more variable in AW than FW.

RESULTS & DISCUSSION

WTC: Time-lag between rainfall and Q





WTC: Time-lag between Q and rainfall

(1) Time-lag in SRW (675 km^2) was similar with FW (71.3km^2), indicating catchment size was not the dominant factor controlling the time-lag.

(2) Results of WTC showed that response of surface runoff and lateral flow to rainfall was faster in AW than FW.

RESULTS & DISCUSSION

Characteristics of snowmelt events

Influence of land use on soil erosion ?

Mean and maximum SSC were higher in AW than FW, soil erosion was more serious in pasture land (plant cover).

Snowmelt events	1-29 **April** 2004			9-19 **May** 2006		
	AW	FW	SRW	AW	FW	SRW
Flood duration (h)	624	638	679	252	264	276
Total water yield (mm/h)	0.10	0.9	11.7	0.06	5.2	25.2
Q_m (m^3/s)	0.29	2.70	33.78	0.18	15.15	72.72
Q_{max} (m^3/s)	0.52	4.58	46.92	0.23	17.08	80.99
SSC_m (mg/l)	1375	142	36	791	359	29
SSC_{max}(mg/l)	11813	496	110	4416	1877	86
SS yield ($kg/h/km^2$)	138	19	6	49	275	11

Q_m : mean discharge; **Q_{max}** : maximum discharge
SSC_m : mean SSC; **SSC_{max}** : maximum SSC

Characteristics of snowmelt events

Influence of land use on SS yield ?

May, snowmelt water recharge stream as groundwater, more water yield in FW resulted in more SS yield.

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Q_m : mean discharge; **Q_{max}** : maximum discharge
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Flood events

Influence of land use on soil erosion ?

Mean and maximum SSC were higher in AW than FW due to the land cover , grazing or harvest.

Flood events	29-31 Jul 2003			8-10 Aug 2003			9-11 Sep 2003		
	AW	FW	SRW	AW	FW	SRW	AW	FW	SRW
Flood duration(h)	48	39	46	29	29	56	48	48	64
Total water yield (mm/h)	0.12	0.14	0.15	1.66	0.67	0.79	0.08	0.18	0.14
Q_m (m^3/s)	0.35	2.78	28.52	4.79	13.21	148.94	0.22	3.63	25.68
Q_{max} (m^3/s)	0.88	2.84	44.38	11.73	22.09	370.49	0.28	4.42	32
SSC_m (mg/l)	779	38	46	6114	595	297	1972	13	193
SSC_{max}(mg/l)	4890	132	250	11983	1646	11517	3323	31	460
SS yield ($kg/h/km^2$)	94	5	7	10137	397	236	150	2	26

RESULTS & DISCUSSION

Characteristics of flood events

Flood events	30-31 Aug 2004			7-9 Sep 2004			22-24 July 2007		
	AW	FW	SRW	AW	FW	SRW	AW	FW	SRW
Flood duration(h)	34	31	30	46	48	64	45	27	63
Total water yield (mm/h)	0.08	**0.15**	0.11	0.07	0.09	0.09	0.08	0.13	0.14
Q_m (m^3/s)	0.23	2.95	21.14	0.20	1.85	16.9	0.24	2.63	26.67
Q_{max} (m^3/s)	0.44	7.28	31.29	0.37	2.75	24.1	0.33	3.29	61.70
SSC_m (mg/l)	3391	2145	79	818	15	21	111	19	80
SSC_{max}(mg/l)	17938	3887	425	5715	110	90	905	69	235
SS yield (kg/h/km^2)	270	**319**	9	57	1	2	9	3	11

SS yield in AW was higher than FW.

August, 2004, more water yield in FW resulted in more SS yield.

RESULTS & DISCUSSION

Hysteretic loops during flood events

Flood events	AW	FW	SRW
29-31 Jul 2003	8※	A※	**C**※
8-10 Aug 2003	A	C	**C**
9-11 Sep 2003	A	8	8
30-31 Aug 2004	8	8	C
7-9 Sep 2004	A	C	C
22-24 July 2007	C	C	8

8: SSC peak before and after Q peak

C: SSC peak before Q peak

A: SSC peak after Q peak

※8: Complex 8 shaped hysteresis;

C: Clockwise shaped hysteresis;

A: Anti-clock wise shaped hysteresis

(1) Earlier sediment supply from pasture land due to

(a) Its faster response of streamflow to precipitation as the results of measured hydrograph and WTC showed.

(b) Pasture land located nearer to SRW compared with forest.

(2) Higher sediment concentration and SS yield from pasture land.

CONCLUSIONS

(1) Response of surface runoff and lateral flow to rainfall was faster and more variable in AW than FW during flood events.

(2) During snowmelt and flood events, soil erosion was more serious in agriculture land due to the plant cover and management practices (e.g., grazing, harvest).

(3) Earlier sediment supply from agriculture land with higher sediment concentration resulted in "C" hysteresis at SRW, while "A" and "8 " hysteresis happened in AW and FW.

Thanks for
your attention !

MATERIAL AND METHODS

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Daily stream water table (H)

Daily stream discharge (Q)

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0.7μm Glass Microfiber filters.

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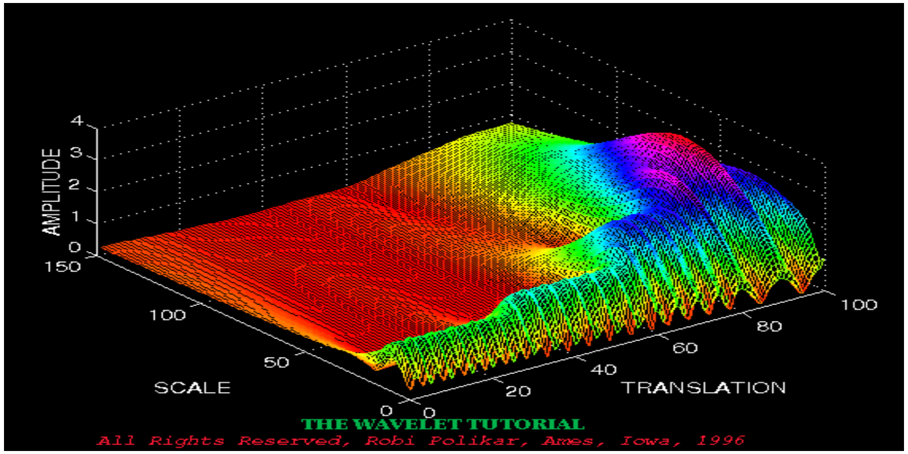

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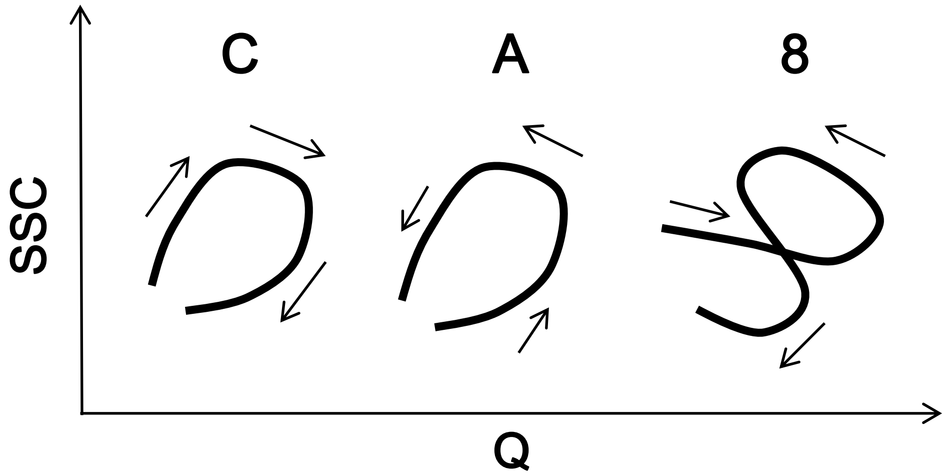
(3) Figure 8 (**8**): Several peaks



Characteristics of rainfall events

	Rainfall events	Snowmelt events
2003	3	
2004	2	1
2006		1
2007	1	

Antecedent precipitation index (API)

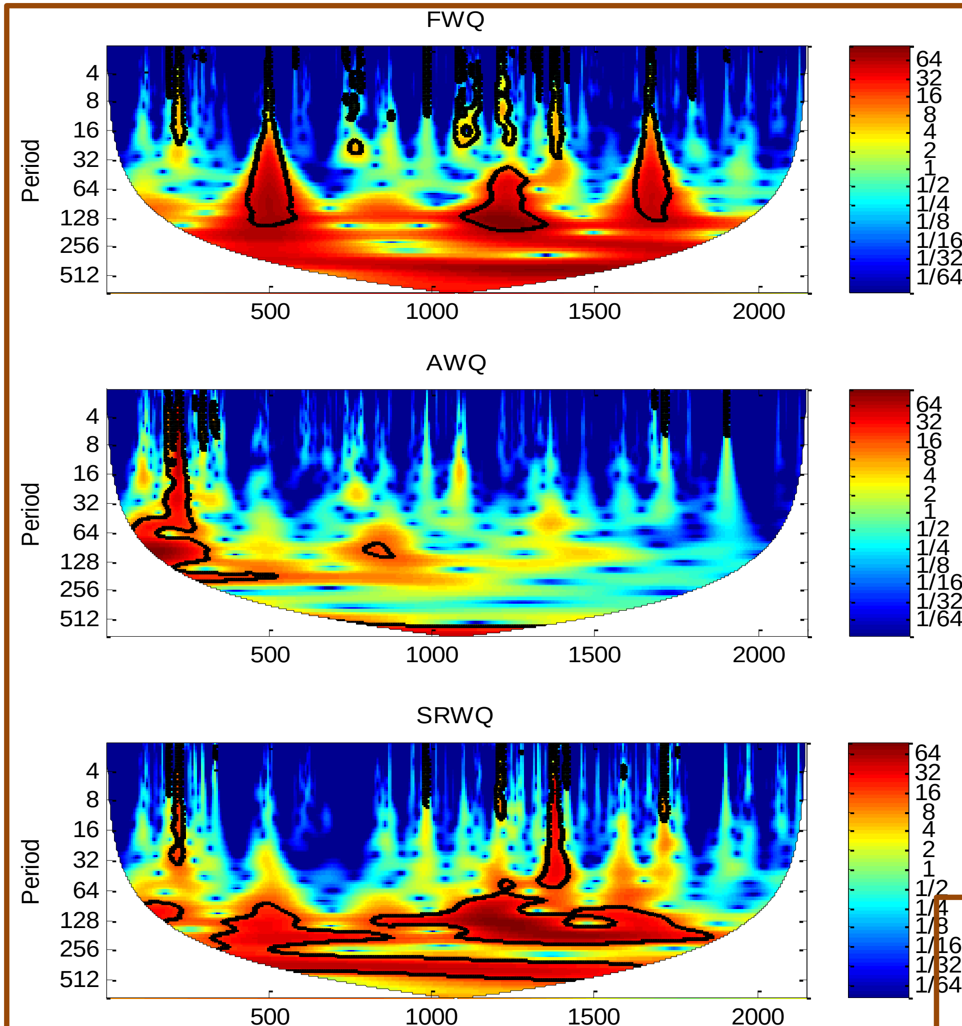
APIx : where x=7 or 21 days before a rainfall event and API (mm) is the average precipitation on the xth day before the event.

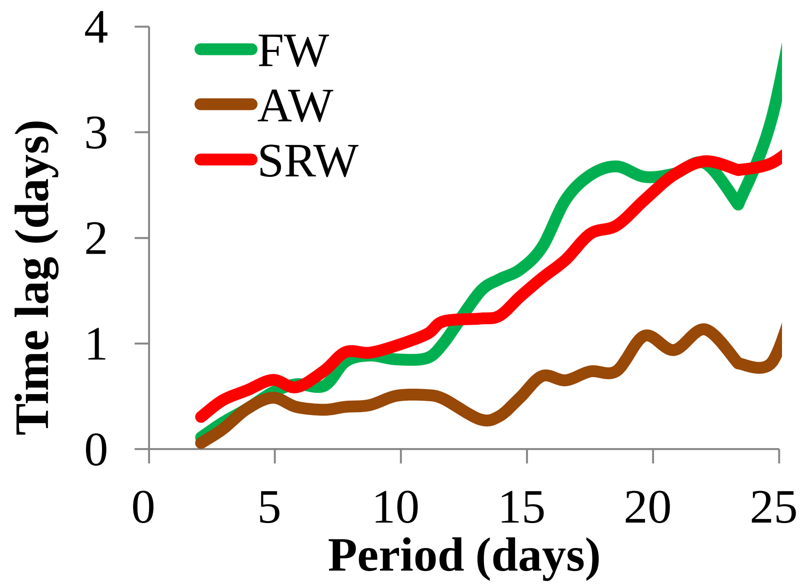
Flood events	Total rainfall (mm)	Maximum intensity (mm/h)	API7	API21
29-31 Jul 2003	44	7	6.11	0.17
8-10 Aug 2003	178	35	1.29	2.76
9-11 Sep 2003	31	9	5.62	3.67
30-31 Aug 2004	28	7	9.3	0.58
7-9 Sep 2004	27	6	7.97	4.14
22-24 July 2007	46	12	3.57	2.52

Characteristics of the rainfall events

RESULTS & DISCUSSION

WTC: Time-lag between Q and rainfall





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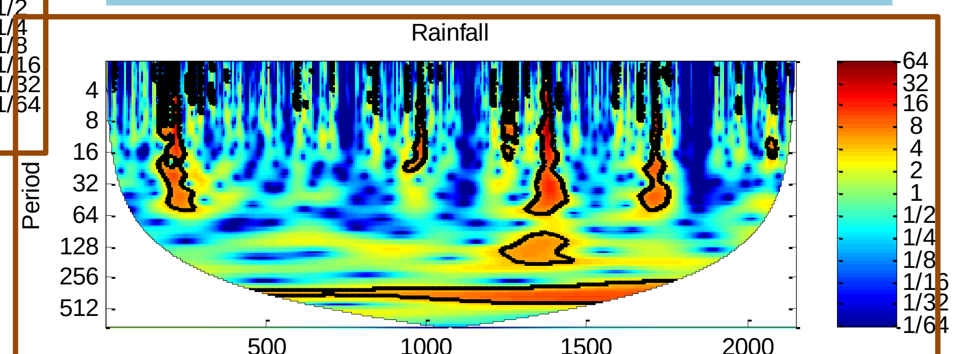

Time-lag

RESULTS & DISCUSSION

Climatic conditions and streamflow

Climatic conditions of SRW during the study period

	Rainfall (mm)		Annual snow fall (cm)	Maximum snowpack depth (cm)
	Annual	Maximum daily		
2003	1276	106	626	71
2004	931	49	612	109
2006	1326	133	465	65
2007	1038	90	362	53
30-yr average	1147	89	480	71