MWR-MRC-IWMI joint research

Hydrological impacts of the Lancang Hydropower Cascade on Downstream Extreme Events

Comparative analysis of the droughts of 2009-2010 and 2012-2013

Speaker: LI Xiang, IWHR, China

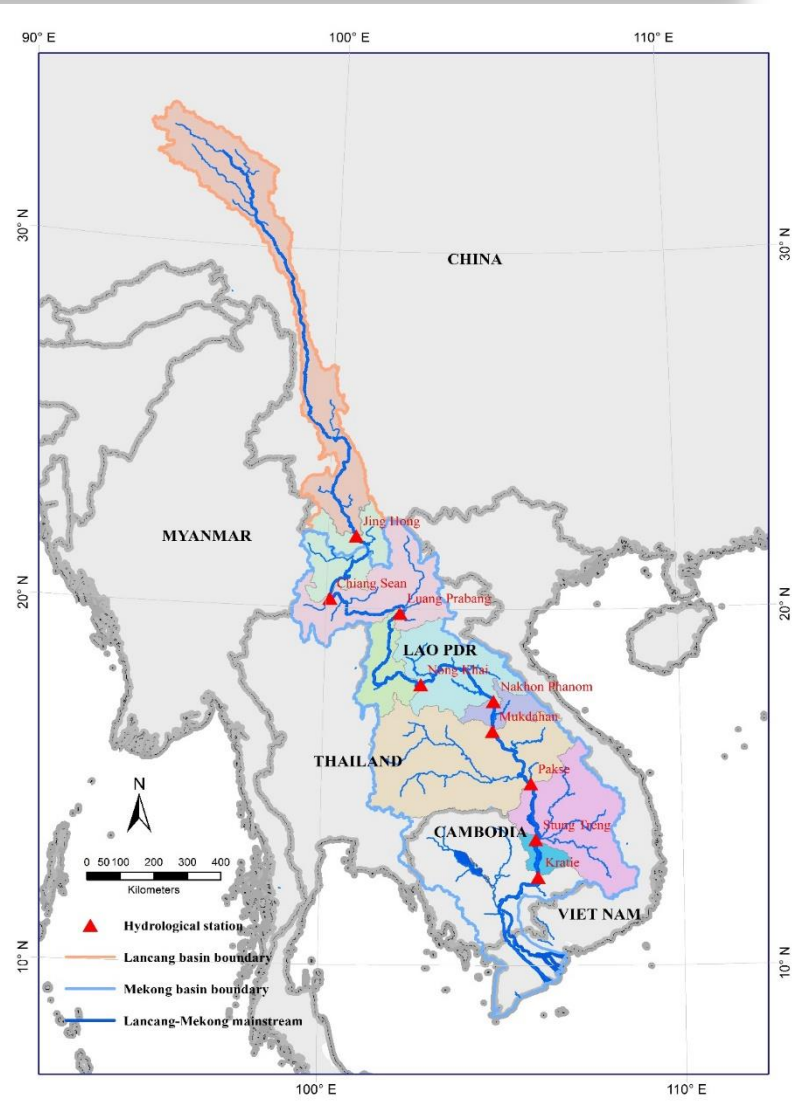
Contents

1.Materials and methods

1. Materials and methods

Objectives

- The Lancang-Mekong Basin experienced a severe drought from October 2012 to April 2013. This drought was similar in terms of spatial distribution and magnitude to that from 2009 to 2010.
- The main hydrological difference between these two droughts is likely caused by the Xiaowan Dam that was not completed during 2009-2010, but was operational after July 2010. It releases additional water during the drought from 2012 to 2013.
- This study compares the two drought events from the meteorological and hydrological perspective, and analyzes the impact of water supplement from Lancang hydropower cascade on the hydrological process of the Mekong River during the dry season of 2012-2013.



1. Materials and methods

Data

Rainfall data

Historical daily rainfall data of the Mekong River Basin in the recent 70 years (1948-2014)

Collected and compiled on the basis of the GLDAS（Global Land Data Assimilation System）global precipitation product

Spatial resolution is 0.25°×0.25°

Hydrological data

Historical daily flow data (1985-2016) of major hydrological stations:

Chiang Saen,
Luang Prabang,
Nong Khai,
Nakhon Phanom,
Mukdahan,
Pakse,
Stung Treng

was collected from MRCS.

1. Materials and methods

Methods

SPI

SPI expresses the probability of precipitation occurrence in a given period,

is applicable to meteorological drought monitoring and evaluation,

on or above the monthly scale

SRI

SRI expresses the probability of runoff occurrence in a given period,

is used in hydrological drought diagnosis and evaluation,

on and above monthly scale

Hydrological Frequency Analysis

Based on 32-year (1985-2016) long time series flow data, Minimum daily, monthly, 3-month average flow, during the two drought events was calculated,

corresponding frequency was calculated by Pearson-III Frequency Curve Fitting.

Category	SPI	Severity of event
Mild dryness	(-1.0, 0)	1 in 3 yrs
Moderate dryness	(-1.5, -1.0)	1 in 10 yrs
Severe dryness	(-2.0, -1.5)	1 in 20 yrs
Extreme dryness	≤-2.0	1 in 50 yrs

$$SPI = S\frac{\text{t-}(c_2t + c_1)t + c_0}{[(d_3t + d_2)t + 1.0]} \qquad t = \sqrt{\ln\frac{1}{G(x)^2}}$$

$$G(x) = \frac{2}{\beta^{\gamma}\Gamma(\gamma_0)}\int_0^x x^{\gamma-1}e^{-x/\beta}dx, \qquad x > 0$$

2.Drought analysis

2.Drought analysis

2.1Hydrological process during the two events

2.2Meteorological Drought

- **Inter-annual Variation**
- **Temporal and spatial distribution of the two droughts**

2.3Hydrological Drought

- **SRI**
- **Hydrological Frequency Analysis**

2.4Comparison of Meteorological and Hydrological drought

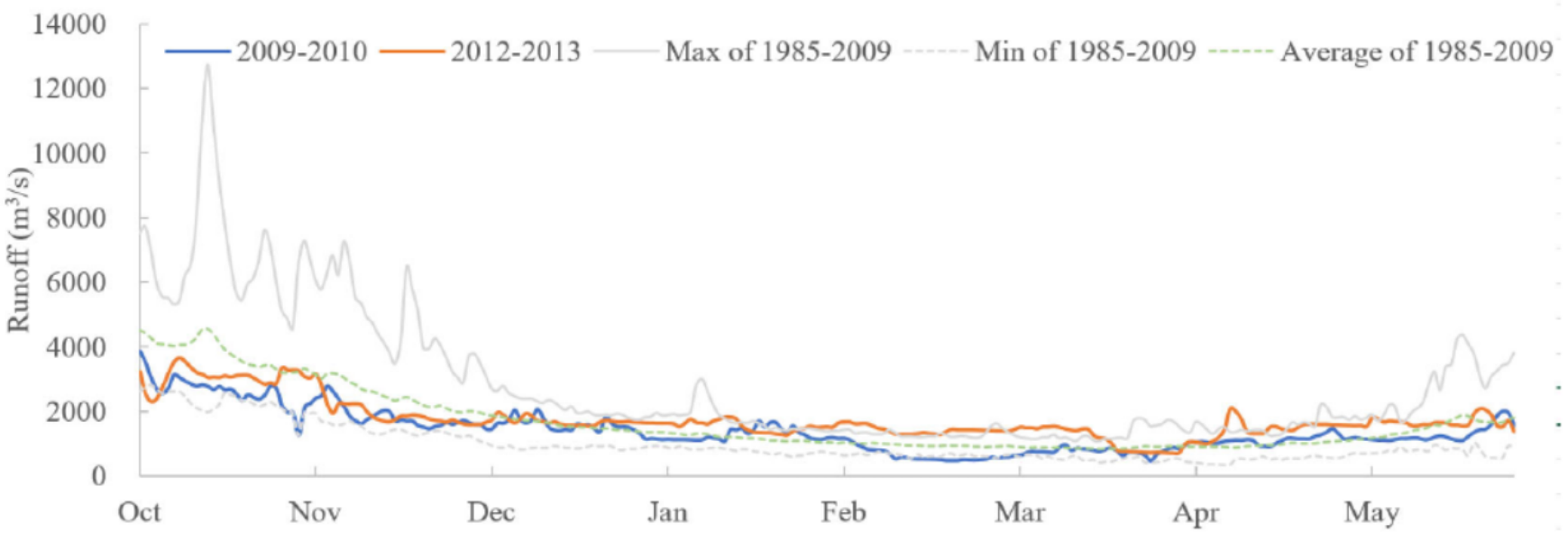
2.Drought analysis

2.1Hydrological process during the two events

a) Compared with the drought in 2009-2010, the flow of each station during dry season of 2012-2013 is relatively higher.

b) The most upstream station, Chiang Saen, is very important to understand the flow characteristics of the Lancang River and its impact on the downstream.

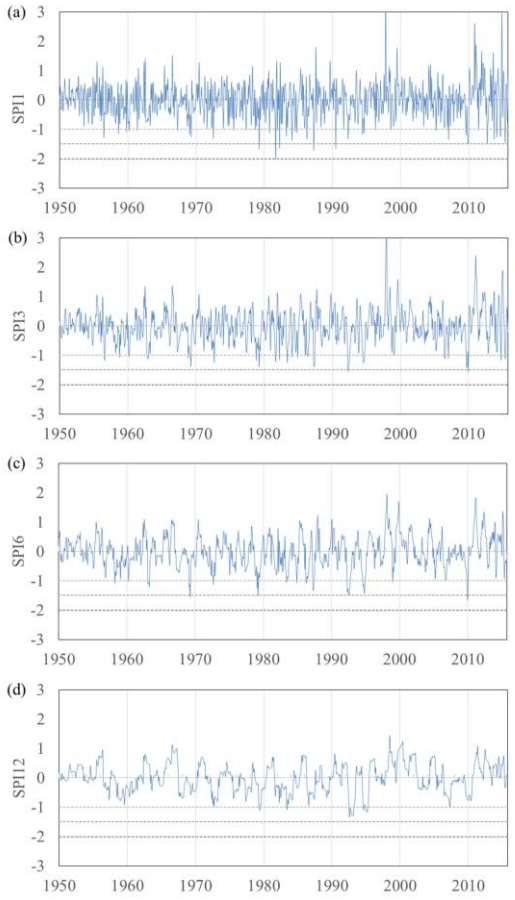
c) The flow at Chiang Saen from January to March 2013 was significantly higher than that of the same period in 2010



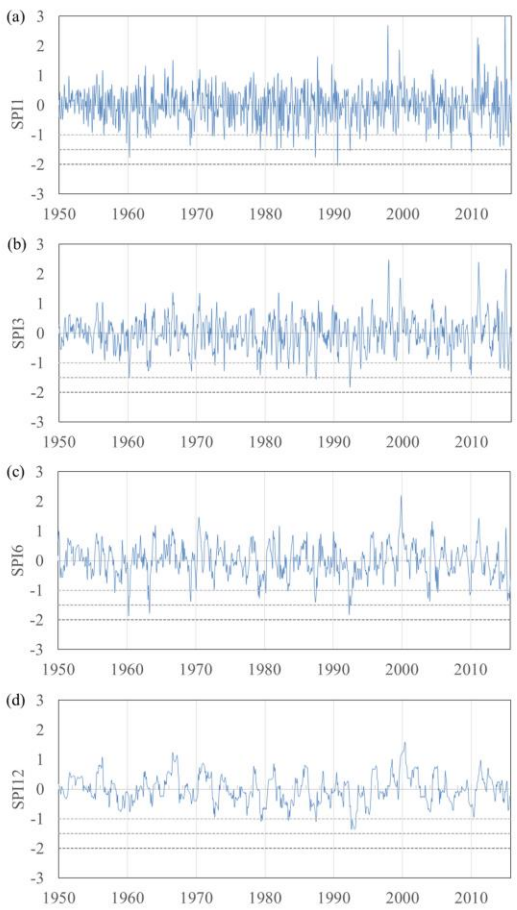
2.Drought analysis

2.2Meteorological Drought

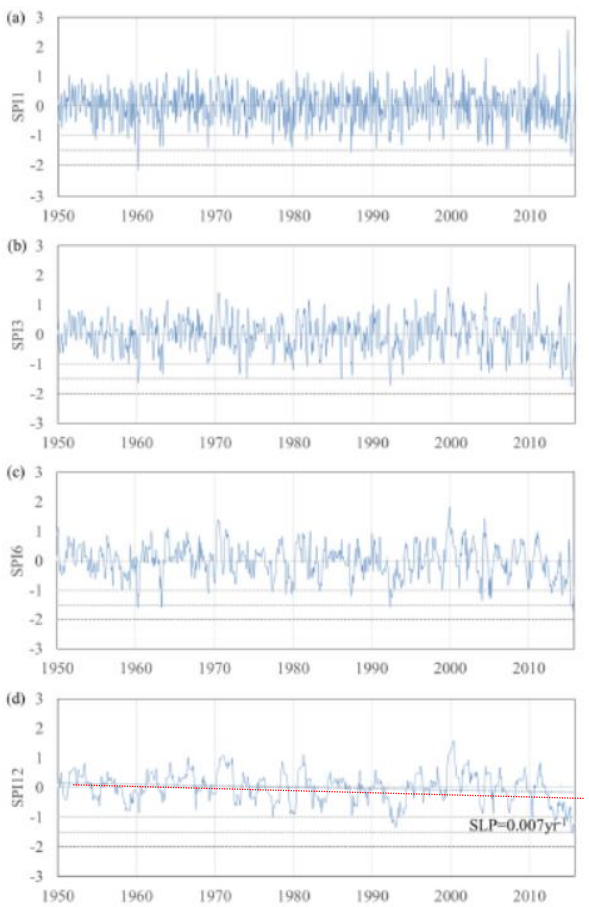
Inter-annual Variation-SPI sequences of the drainage area of mainstream stations



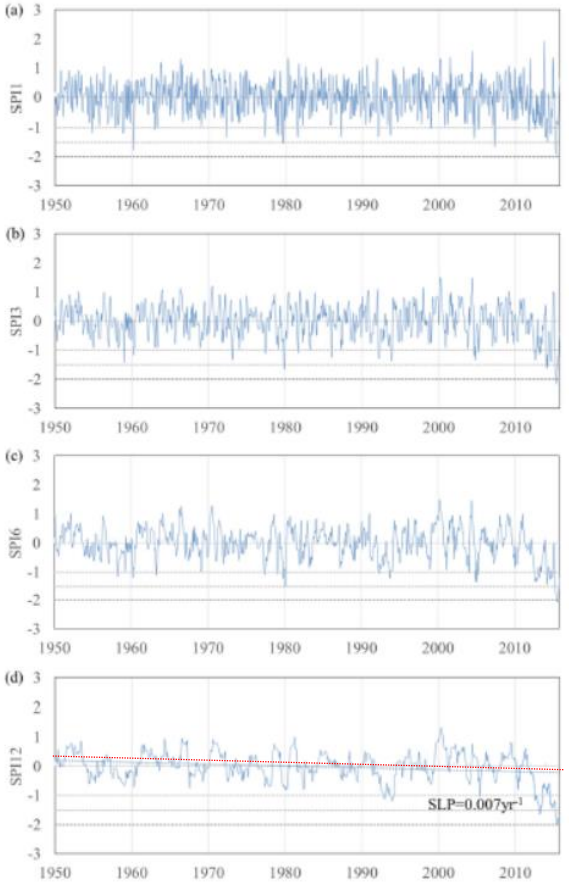
Jinghong



Chiang Saen



Mukdahan

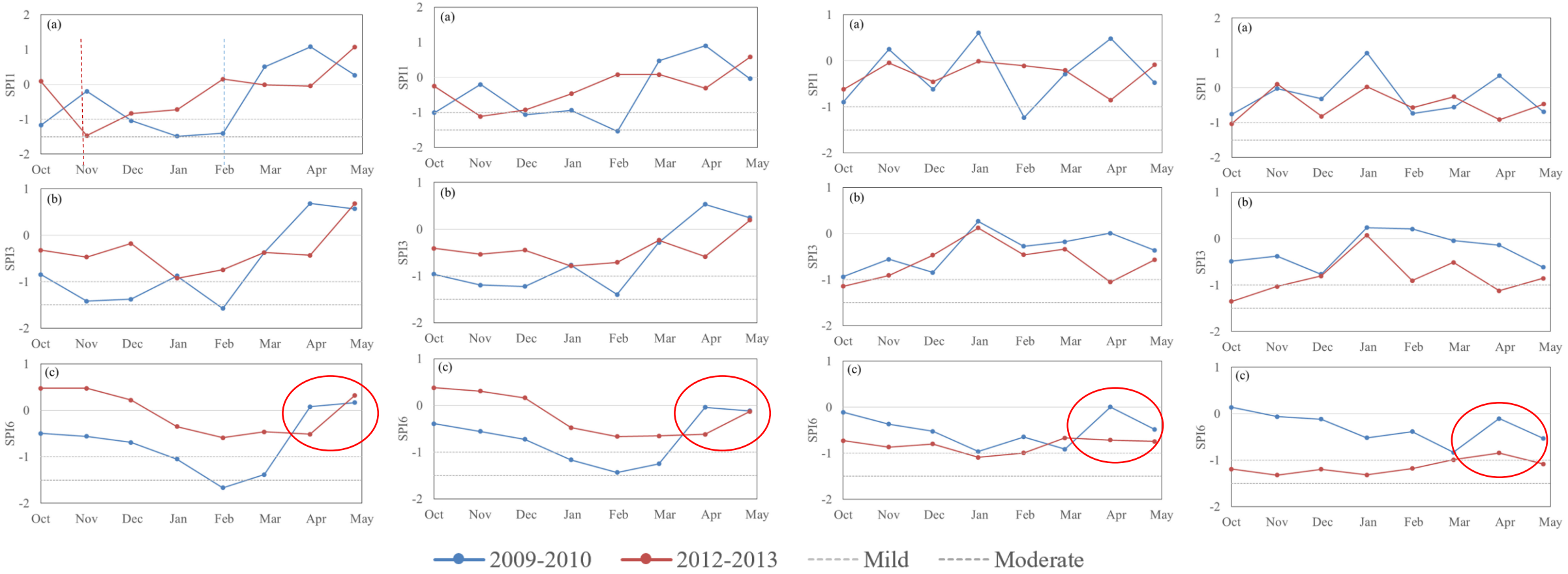


Stung Treng

2.Drought analysis

2.2Meteorological Drought

Monthly SPI values of the drainage area of mainstream stations

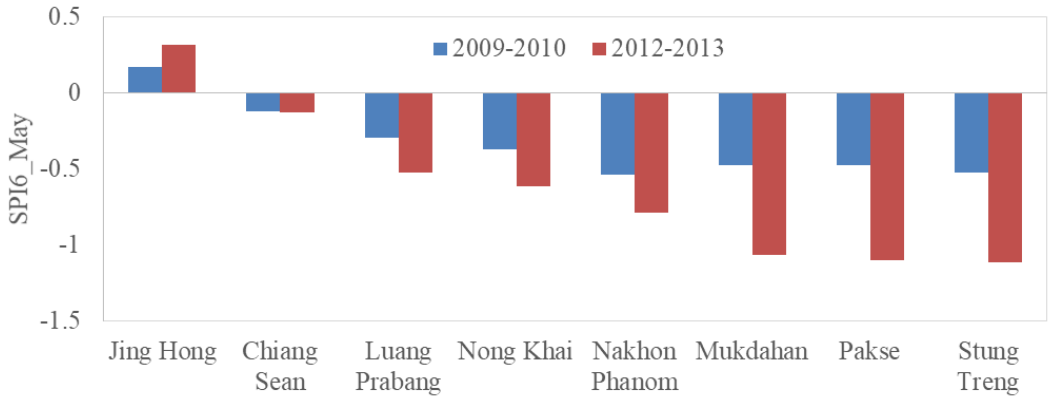


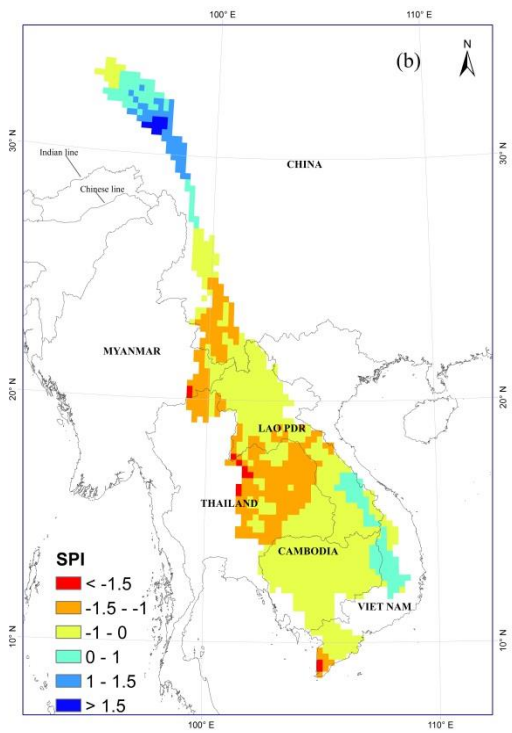
Jinghong　　Chiang Saen　　Mukdahan　　Stung Treng

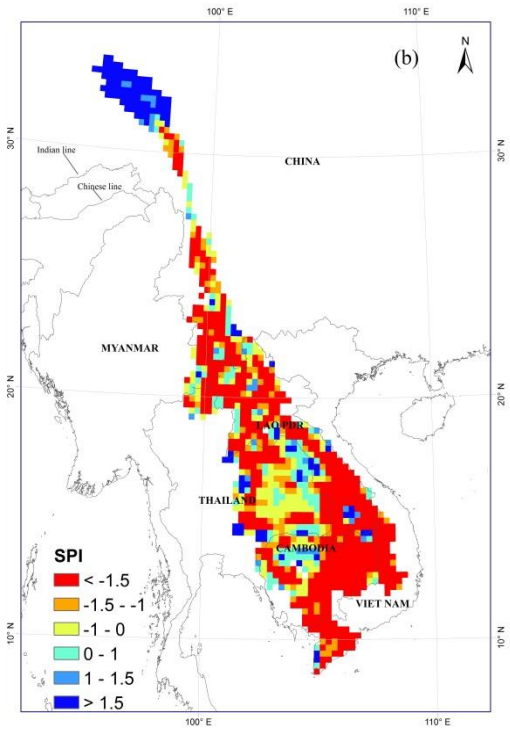
（a）SPI1；(b)SPI3；(c)SPI6

2.Drought analysis

2.2Meteorological Drought







2009-2010 2012-2013

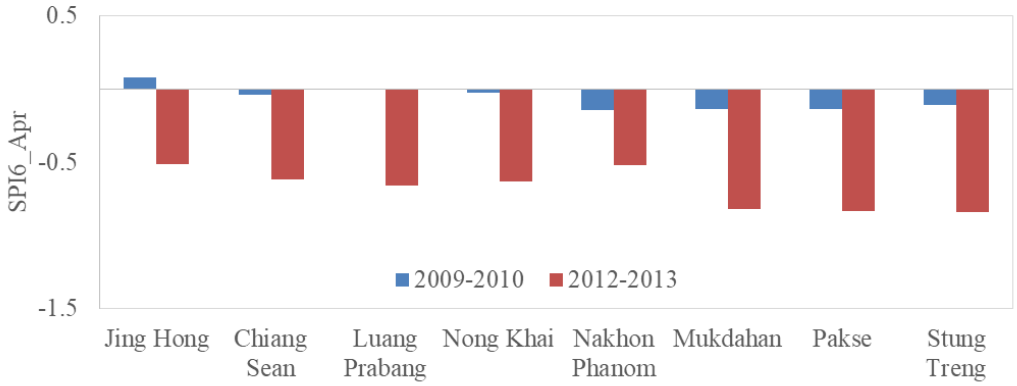
SPI6 result on catchment area of Lancang-Mekong main stream hydrological stations in dry season of 2009-2010 and 2012-2013(December to May)

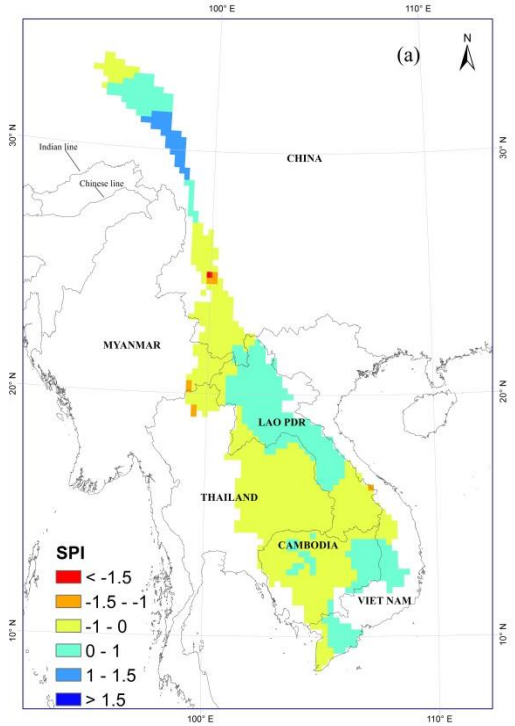
Above Nakhon Phanom station: SPI decreases from upstream to downstream

From Mukdahan to Stung Treng: drought severity close to each other

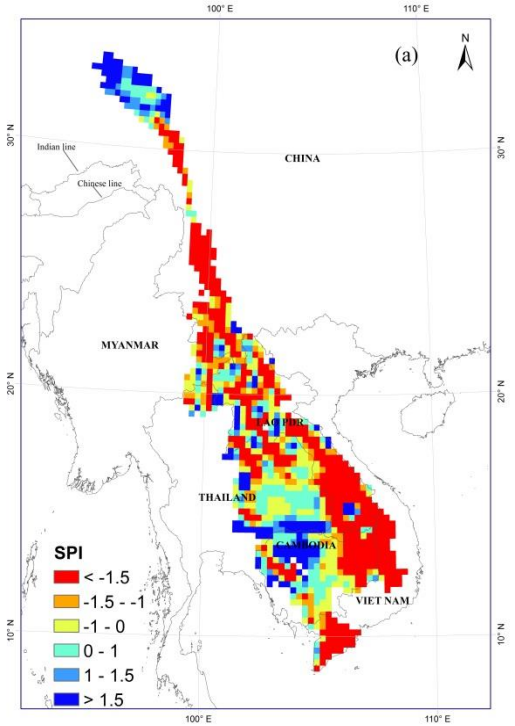
2.Drought analysis

2.2Meteorological Drought





2009-2010年



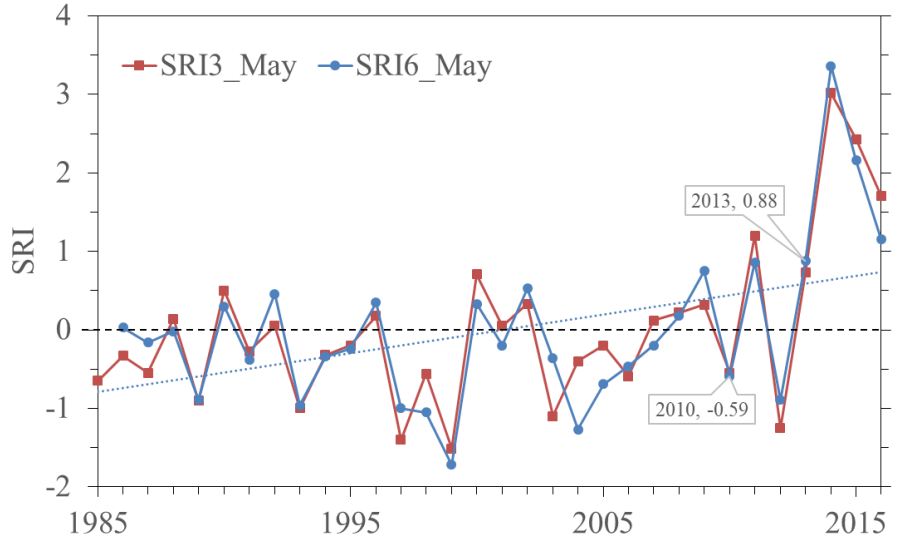
2012-2013年

SPI6 result on catchment area of Lancang-Mekong main stream hydrological stations in dry season of 2009-2010 and 2012-2013 (November to April)

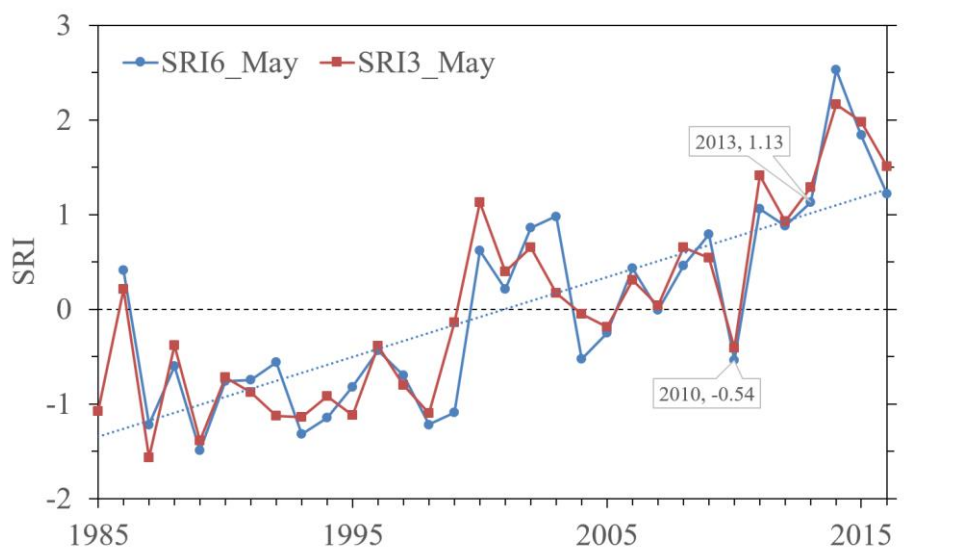
Close to normal in 2009-2010; basically light drought in 2012-2013

2.Drought analysis

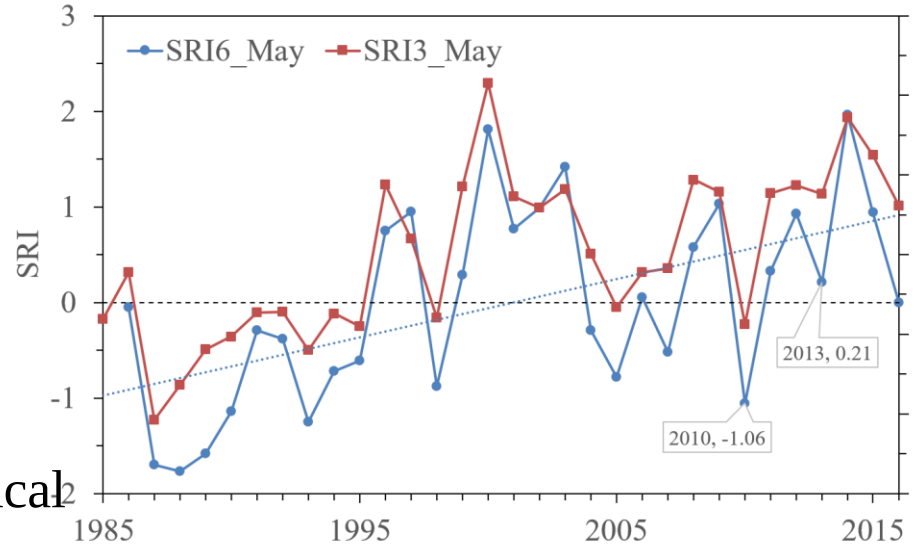
2.3Hydrological Drought



SRI sequences at Chiang Saen station



Mudahan



Stung Treng

SRI value of Chiang Saen station shows an obvious upward trend, indicating that the severity of hydrological drought in dry season are significantly reduced

2.Drought analysis

2.3Hydrological Drought

SRI6 results at mainstream stations during the two drought events (December to May)

	Chiang Saen	Luang Prabang	Nong Khai	Nakhon Phanom	Mukdahan	Pakse	Stung Treng
2009-2010	-0.59	-0.88	-0.99	-1.16	-0.54	-1.03	-1.06
2012-2013	0.88	0.68	0.30	0.75	1.13	0.91	0.21

It shows no hydrological drought occurred in 2012-2013

2.Drought analysis

2.3Hydrological Drought

The recurrence period of minimum daily average flow

Drought	Chiang Saen	Luang Prabang	Nong Khai	Nakhon Phanom	Mukdahan
2009-2010	12.7	3.8	9.1	7.7	2.9
2012-2013	2.0	1.5	3.1	1.5	1.1

The recurrence period of minimum monthly average flow

Drought	Chiang Saen	Luang Prabang	Nong Khai	Nakhon Phanom	Mukdahan
2009-2010	12.8	4.3	10.5	7.9	2.7
2012-2013	1.3	1.2	1.7	1.3	1.2

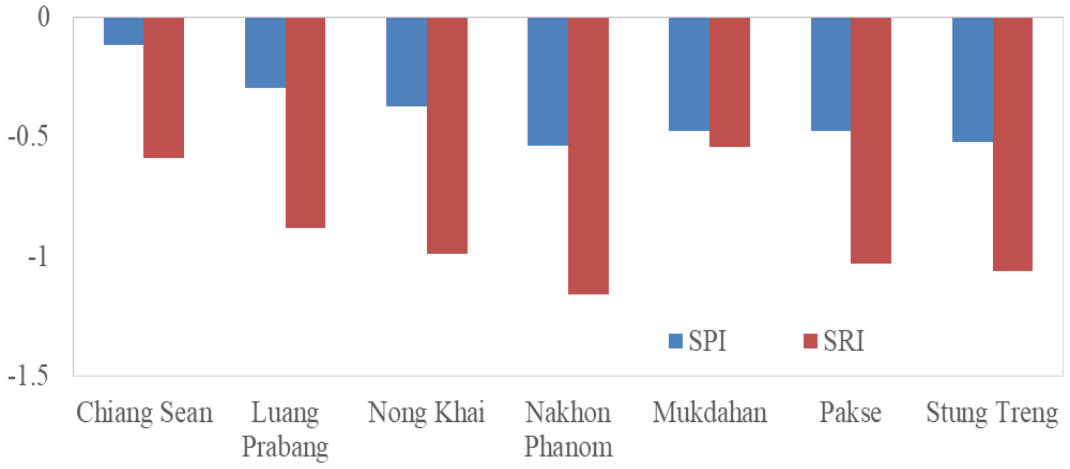
The recurrence period of minimum 3-month average flow

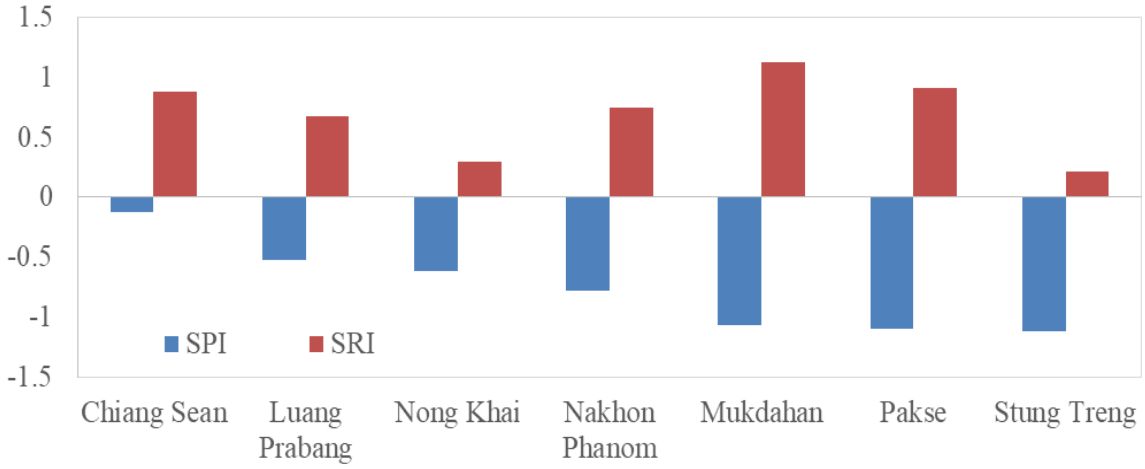
Drought	Chiang Saen	Luang Prabang	Nong Khai	Nakhon Phanom	Mukdahan
2009-2010	3.6	3.0	4.8	5.8	2.2
2012-2013	1.2	1.2	1.4	1.2	1.1

Hydrological drought in dry season of 2012-2013 is less severe than that of 2009-2010.

2.Drought analysis

2.4Comparison of Meteorological and Hydrological drought





SPI6 and SRI6 (December to May) at mainstream stations for the dry season of 2009-2010 showed good consistency

SPI6 and SRI6 (December to May) at mainstream stations for the dry season of 2012-2013 showed significant differences

The hydrological conditions were normal or relatively abundant. This indicates the actual inflow from the upper reaches is larger than the natural runoff

3.Effect of Water Supplement of Lancang Hydropower Cascade on the Lower Reaches

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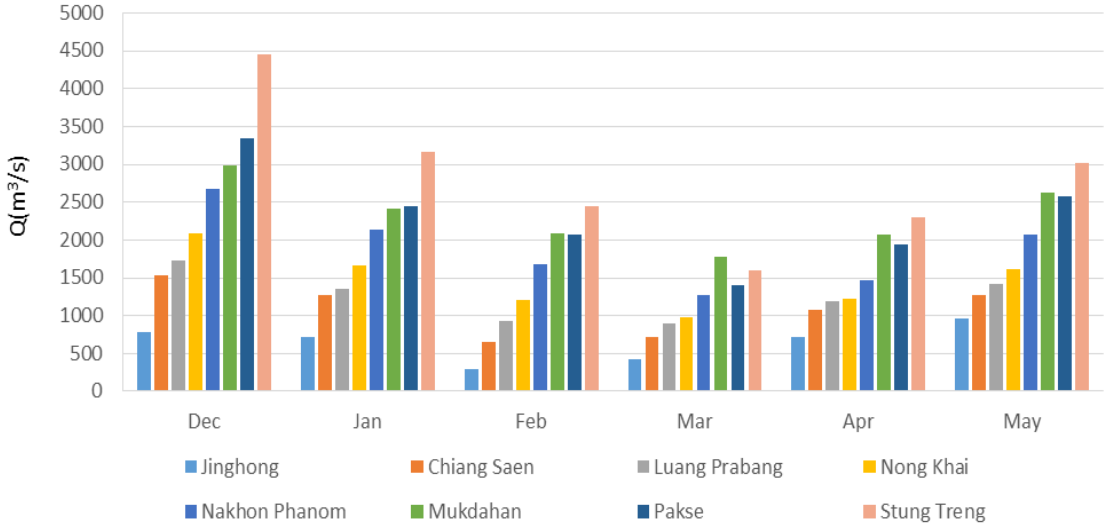
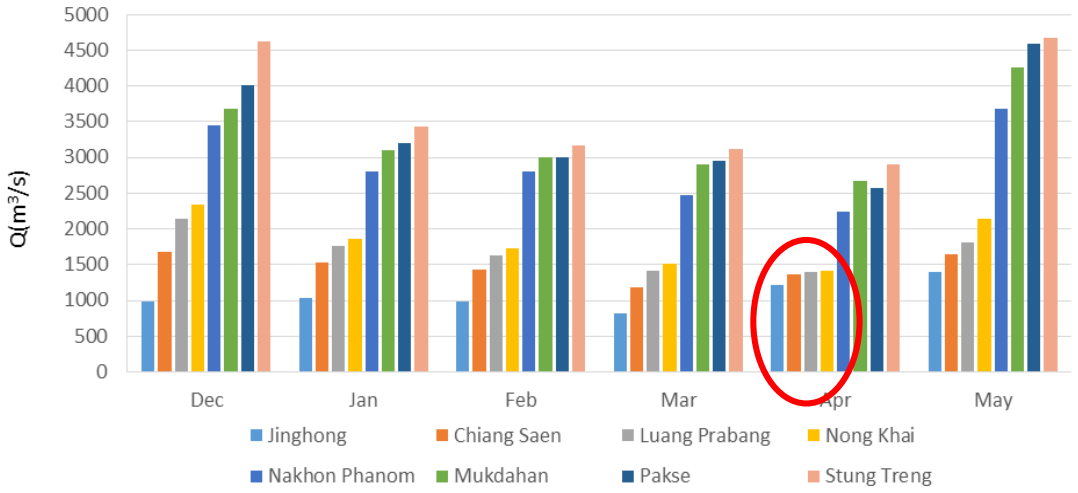
Impact on the Mainstream Flow



Monthly average discharge along the mainstream for the dry season of 2009-2010



Monthly average discharge along the mainstream for the dry season of 2012-2013

The flow of Chiang Saen is close to that of Nong Khai, indicates high contribution rate of Chiang Saen inflow to Chiang Saen-Nong Khai stretch

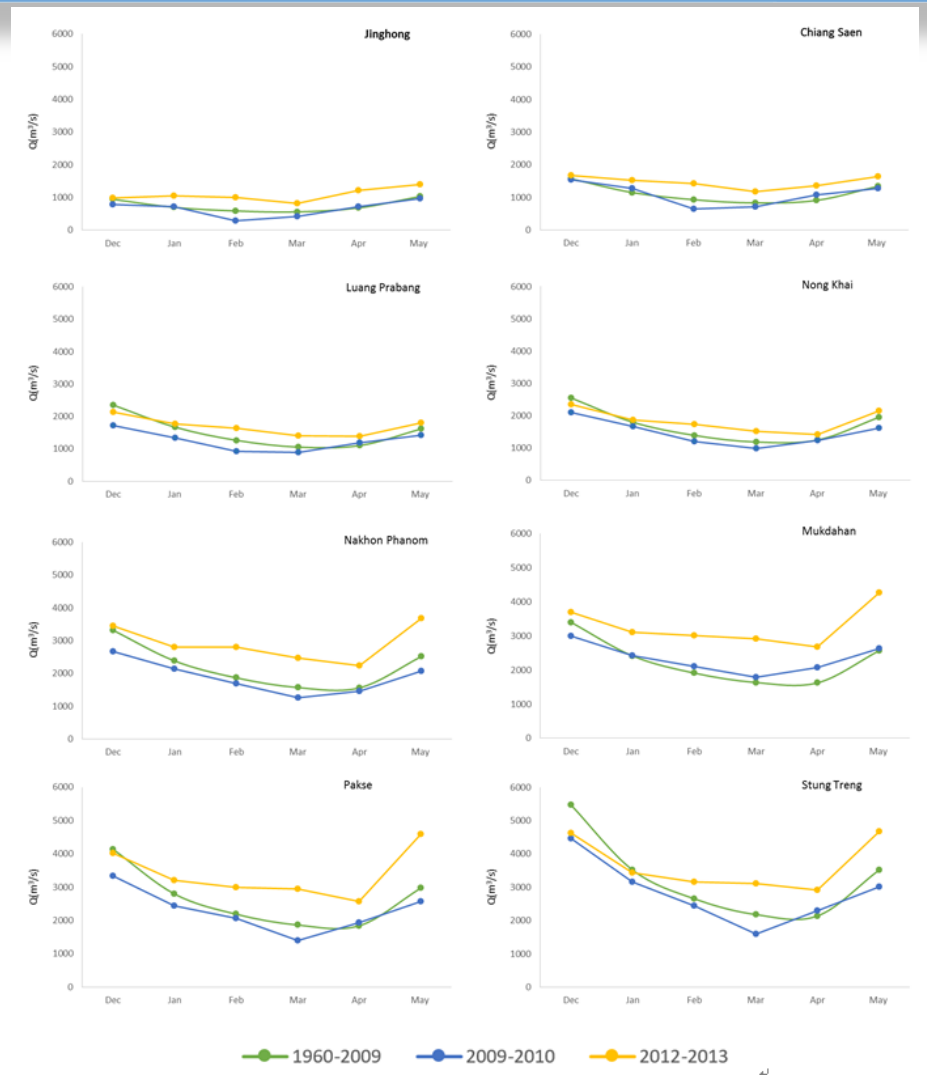
3.Effect of Water Supplement of Lancang Hydropower Cascade on the Lower Reaches

Impact on the Mainstream Flow

The monthly discharge of Jinghong station in 2012-2013 is higher than that of 2009-2010 and the multi-year average

The monthly discharge of Chiang Saen in the dry season of 2012-2013 was higher than the multi-year average

which should be due to the water supplement from Lancang hydropower cascade



Comparison of monthly average discharge along the mainstream for the dry seasons of 1960-2009, 2009-2010 and 2012-2013

3.Effect of Water Supplement of Lancang Hydropower Cascade on the Lower Reaches

Impact on the Mainstream Water level

In the dry season of 2012-2013, the water level of most stations is higher than the historical average level

The water levels of Jinghong and Chiang Saen are 0.30-0.71 and 0.46-1.11 meter higher than the historical average respectively, during January and May, 2013

Deviation of monthly average water levels in the dry season of 2009-2010, 2012-2013, and 1960-2009

Station	December	January	February	March	April	May
Average water level in 1960-2009*(m, local datum)						
Jinghong	535.69	535.20	534.96	534.89	535.11	535.70
Chiang Saen	2.22	1.65	1.28	1.10	1.24	1.90
Luang Prabang	5.63	4.57	3.82	3.37	3.45	4.37
Nong Khai	3.05	2.17	1.60	1.26	1.34	2.23
Nakhon Phanom	2.35	1.59	1.15	0.91	0.93	1.75
Mukdahan	2.50	1.86	1.51	1.31	1.29	1.9
Pakse	1.93	1.26	0.94	0.75	0.74	1.31
Stung Treng	3.14	2.58	2.27	2.07	2.03	2.52
Deviation of average water level between 1960-2009 and 2009-2010 (m)						
Jinghong	-0.54	-0.06	-0.78	-0.35	0.05	-0.17
Chiang Saen	0.30	0.55	0.01	0.33	0.71	0.29
Luang Prabang	-1.08	-0.71	-0.90	-0.50	0.09	-0.38
Nong Khai	-0.69	-0.39	-0.58	-0.63	-0.25	-0.52
Nakhon Phanom	-0.77	-0.45	-0.42	-0.58	-0.40	-0.67
Mukdahan	-0.67	-0.43	-0.32	-0.37	-0.11	-0.33
Pakse	-0.54	-0.32	-0.21	-0.40	-0.07	-0.30
Stung Treng	-0.21	-0.03	0.05	-0.04	0.24	-0.02
Deviation of average water level between 1960-2009 and 2012-2013 (m)						
Jinghong	-0.20	0.36	0.54	0.30	0.71	0.38
Chiang Saen	0.46	0.86	1.11	0.95	1.06	0.74
Luang Prabang	-0.37	0.06	0.58	0.59	0.49	0.35
Nong Khai	-0.28	-0.12	0.26	0.27	0.03	0.19
Nakhon Phanom	0.22	0.09	0.52	0.51	0.29	0.54
Mukdahan	-0.24	0.04	0.33	0.46	0.32	0.69
Pakse	-0.22	0.06	0.29	0.45	0.26	0.65
Stung Treng	-0.17	0.05	0.28	0.46	0.44	0.46

3.Effect of Water Supplement of Lancang Hydropower Cascade on the Lower Reaches

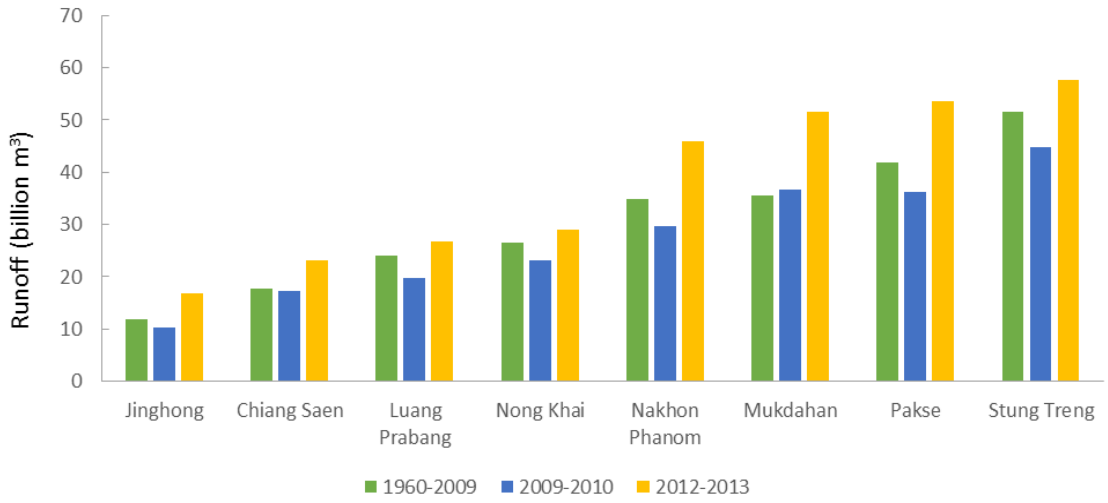
Impact on the Mainstream Water Volume

The water supplement of Lancang hydropower cascade has increased the water volume in the mainstream in dry season.

At Jinghong station, water volume for the dry season in 2012-2013 was 5.08 billion m^3 higher than multi-year average, and 6.7 billion m^3 more than that of 2009-2010.

At Chiang Saen station, water volume for the dry season in 2012-2013 was 5.36 billion m^3 higher than multi-year average, and 5.89 billion m^3 more than that of 2009-2010.

Station	Volume of the dry season (billion m^3)			Deviation of volume between (billion m^3)	
	1960-2009* (% annual volume)	2009-2010 (% annual volume)	2012-2013 (% annual volume)	2012-2013 and 1960-2009	2012-2013 and 2009-2010
Jinghong	11.82 (21%)	10.20(-)	16.90(-)	5.08(-)	6.70(-)
Chiang Saen	17.79 (21%)	17.27(24%)	23.15(33%)	5.36(12%)	5.89(9%)
Luang Prabang	23.99 (19%)	19.83(21%)	26.74(25%)	2.75(6%)	6.91(4%)
Nong Khai	26.57 (18%)	23.12(18%)	28.87(22%)	2.30(4%)	5.75(4%)
Nakhon Phanom	34.85 (15%)	29.69(14%)	45.87(19%)	11.02(4%)	16.17(5%)
Mukdahan	35.59 (14%)	36.71(15%)	51.56(19%)	15.97(5%)	14.85(4%)
Pakse	41.74 (13%)	36.26(13%)	53.49(17%)	11.75(4%)	17.23(14%)
Stung Treng	51.41 (13%)	44.65(15%)	57.66(14%)	6.25(1%)	13.02(-1%)



Accumulated volume in the dry season at mainstream stations

4.Conclusions

4.Conclusions

（1）**The inter-annual variation of meteorological drought is not significant**. The SPI results show that the rainfall in the drainage area of Chiang Saen is characterized by alternation of high and low period, with no obvious trend. The rainfall in the drainage area of Mukdahan and Stung Treng has a slightly downward trend.

（2）In the **upper reaches, the meteorological droughts in 2009-2010 and 2012-2013 are comparable**. The two droughts reached moderate or severe level. In the **lower reaches, drought in 2012-2013 is more severe** than that of 2009-2010. The SPI6 results in the drainage area of Stung Treng station show that the dry season of 2012-2013 mostly belongs to moderate drought, and that of 2009-2010 mostly belongs to light drought.

4.Conclusions

（3）**The inter-annual variation of dry season runoff along the Mekong mainstream shows a significant upward trend.** The results of SRI6 (1985 to 2016) show the most severe period of hydrological drought in the upper reaches of the Mekong River was in the late 1990s, and that of the middle and lower reaches was in the late 1980s and early 1990s.

（4）**In the dry season of 2012-2013, no hydrological drought occurred along the Mekong mainstream.** The results of dry season SRI6 show that the discharges of mainstream stations were slightly or significantly greater than the multi-year average. The analysis of hydrological frequency shows that the drought recurrence period of the minimum daily and monthly discharge of Chiang Saen Station in 2009-2010 is more than 12 years, while the discharge of 2012-2013 dry season has reached the multi-year average.

4.Conclusions

（5）**The Lancang hydropower cascade has a positive impact on the discharge and water level of the Mekong mainstream in dry season**. The monthly discharge of Chiang Saen station in dry season of 2012-2013 is higher than the multi-year average, and the water level is 0.46-1.11 meter higher than the average; the monthly discharge and water level of other hydrological stations along the mainstream after January 2013 is higher than the multi-year average.

（6）**The water supplement of Lancang hydropower cascade has increased the water volume** of the Mekong mainstream in dry season.

Thank you for your attention

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