Workshop on Climate Change Science and Adaption
City University of Hong Kong

Detection of Droughts under the Conditions of Climate Change in South China

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1 Introduction

1.1 WSD Project Introduction

- ✓ The consultancy services of "Study on Impacts of Climate Change on the Water Resources of Hong Kong" was officially commenced on **27 February 2014**. The agreement period is from **27 February 2014 to 3 June 2015 inclusive**.
- ✓ The study area is **the Pearl River basin and Hong Kong**. Since about 80% fresh water presently consumed in Hong Kong is diverted from **the East River**, which is a tributary of the Pearl River basin, the understanding of the status of water resources of the basin is essential for evaluating water resources security of Hong Kong.

1.2 Study Area

Location of the Pearl River basin and Hong Kong

2. GCMs and Droughts

- 55 datasets of climate scenarios from 18 climate models were adopted (0.5°×0.5°)
  - (16×3 = 48; + 3 (an RCM (Regional Climate Model)-PRECIS under SRES A1, B1, and A1B), + 4 (IPCC AR5-RCPs (Representative Concentration Pathways)
  - SRES emissions scenarios cannot report entirely the goal of stabilization GHG concentration set by the United Nations Framework Convention on Climate Change (UNFCCC). To improve this situation, the IPCC suggested using RCPs (Representative concentration Pathways). RCPs are referred to as pathways in order to emphasize that their primary purpose is to provide time-dependent projections of atmospheric greenhouse gas (GHG) concentrations. 4 RCPs are defined according to radiative forcing level and pathways, RCP 2.6/4.5/6.0/8.5 of which the last 3 scenarios are approximately corresponding respectively to SRES B1/A1B/A1
- AR4-16 GCMs projections with A1, B1 and A1B
- We have the Regional Climate Model - PRECIS to add more information of future climate change
- For a potential comparison with the latest work around the world, we collected the data simulated by HadGEM2-ES, a GCM used in IPCC AR5, under RCPs scenarios

Drought Index

- For the analysis of droughts over the Pearl River basin, the drought index DI_j is employed. The equation of computing DI_j is given as follows:

$$DI_j = Ano_j / Std_j,\ j = 1, \ldots\ldots, n$$

- where DI_j is the drought index on a given time series j (month or year), Ano_j is the precipitation anomaly on a given time series j, and Std_j is the precipitation standard deviation on a given time series j.
- Drought occurs when DI is less than or equal -1.0. The smaller DI is, the severer the drought is.
- The baseline period is from 1961 to 1990

The statistical results of the frequency (the number of the designated drought per year) of drought month with DI≤-1.0 (Level 1), DI≤-2.0 (Level 2) and DI≤-3.0 (Level 3) and the frequency of drought year with DI≤-1.0 over the Pearl River basin

Model	DI<=-1 Drought month	DI<=-2 Drought month	DI<=-3 Drought month	DI<=-1 Continuous drought (Three months or more)	DI<=-1 Drought year	DI<=-1 Continuous drought (Three years or more)
OBS	0.9	0.13	0	0.03	0.1	0
HadGEM2-ES	0.87	0.1	0	0.03	0.2	0.03
PRECIS	0.7	0.03	0	0	0.1	0
bccr_bcm2_0.1	1	0.03	0	0	0.1	0
cccma_cgcm3_1.1	1.03	0.1	0	0	0.13	0
cnrm_cm3.1	0.9	0.07	0	0.03	0.17	0
csiro_mk3_0.1	0.93	0.07	0	0	0.1	0
gfdl_cm2_0.1	0.97	0.07	0	0.03	0.07	0
gfdl_cm2_1.1	1.1	0.1	0	0.07	0.13	0
giss_model_e_r.1	0.73	0.1	0	0.03	0.17	0
inmcm3_0.1	1	0.1	0	0.03	0.23	0
ipsl_cm4.1	0.93	0.1	0	0.03	0.2	0
miroc3_2_medres.1	0.9	0.13	0	0	0.1	0
miub_echo_g.1	0.93	0.03	0	0	0.2	0
mpi_echam5.1	0.9	0.03	0	0	0.2	0
mri_cgcm2_3_2a.1	1	0.03	0	0	0.2	0
ncar_ccsm3_0.1	0.87	0.07	0	0	0.17	0
ncar_pcm1.1	1.07	0.1	0	0.03	0.17	0
ukmo_hadcm3.1	1	0.07	0	0	0.2	0

3 Streamflow and Droughts

- The study area is the East River (Boluo station)
- The following two variables were adopted as the threshold values
  - The minimum river flow (474.5 m^3/s) to sustain and support the different functions in the East River (Wu and Chen, 2013), where the monthly runoff smaller than this value is regarded as drought month
  - The Standardized Runoff Index (SRI), where the monthly SRI value smaller than zero is regarded as drought month (Khedun et al., 2011)
- The maximum numbers of the continuous drought month were detected by using the above two threshold values, and the corresponding periods were identified by using the cumulative water deficit
- Wavelet analysis was carried out using the Morlet Power wavelet based on monthly runoff data

Khedun, C.P., Chowdhary, H., Giardino, J.R., Mishra, A.K., and Singh, V.P. (2011) Analysis of Drought Severity and Duration Based on Runoff Derived from the Noah Land Surface Model. *2011 Symposium on Data-Driven Approaches to Droughts*, Paper 42.

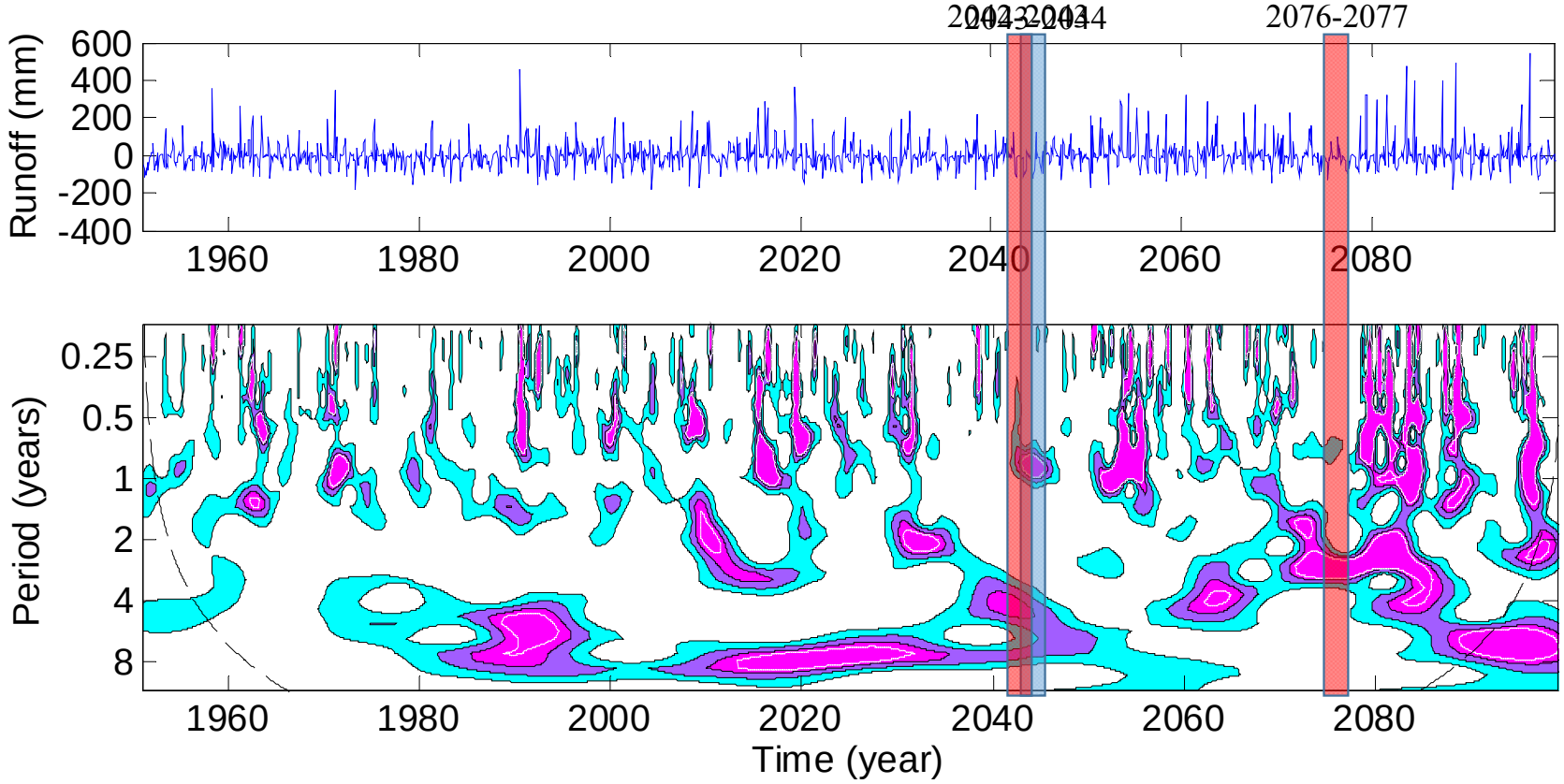
Wu, Y.P., and Chen, J. (2013). Estimating irrigation water demand using an improved method and optimizing reservoir operation for water supply and hydropower generation: A case study of the Xinfengjiang reservoir in southern China. *Agricultural Water Management*, 116, 110-121.

RCP 2.6 scenario

Use minimum river flow

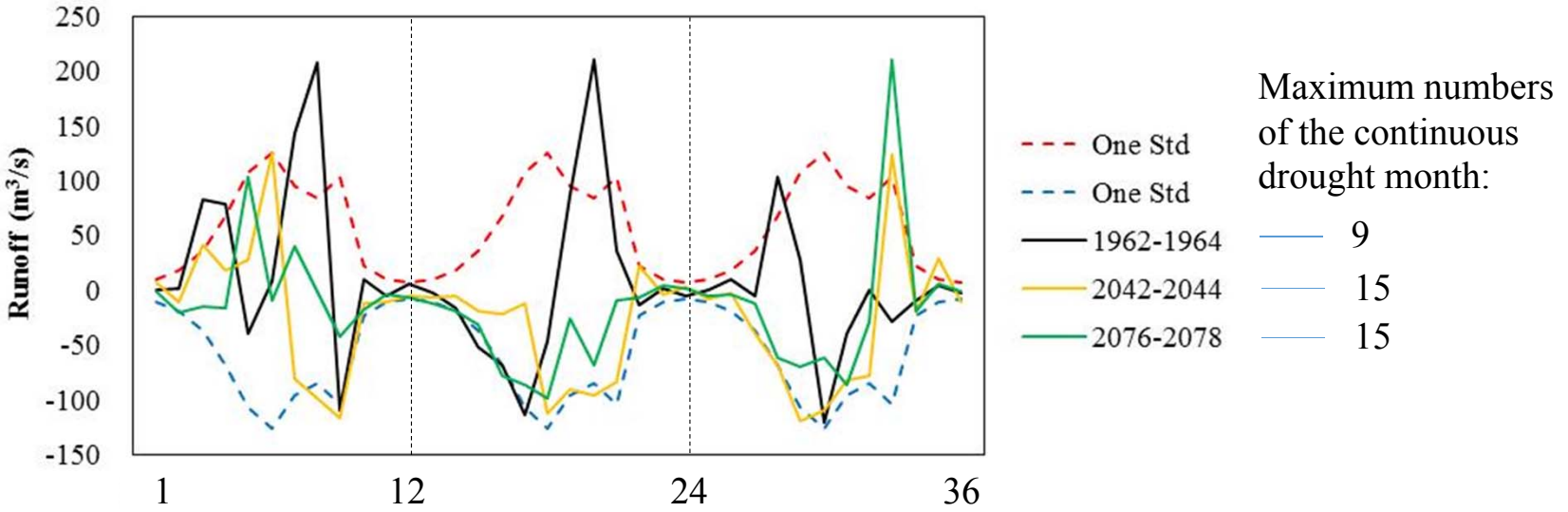
Use SRI

Upper: The monthly runoff anomaly time series in the East River from the projection of RCP 2.6 scenario
Lower: The local wavelet power spectrum using the Morlet wavelet, normalized by $1/\sigma^2$. The white contour closes regions of greater than 95% confidence for a red-noise process.



RCP 2.6 scenario

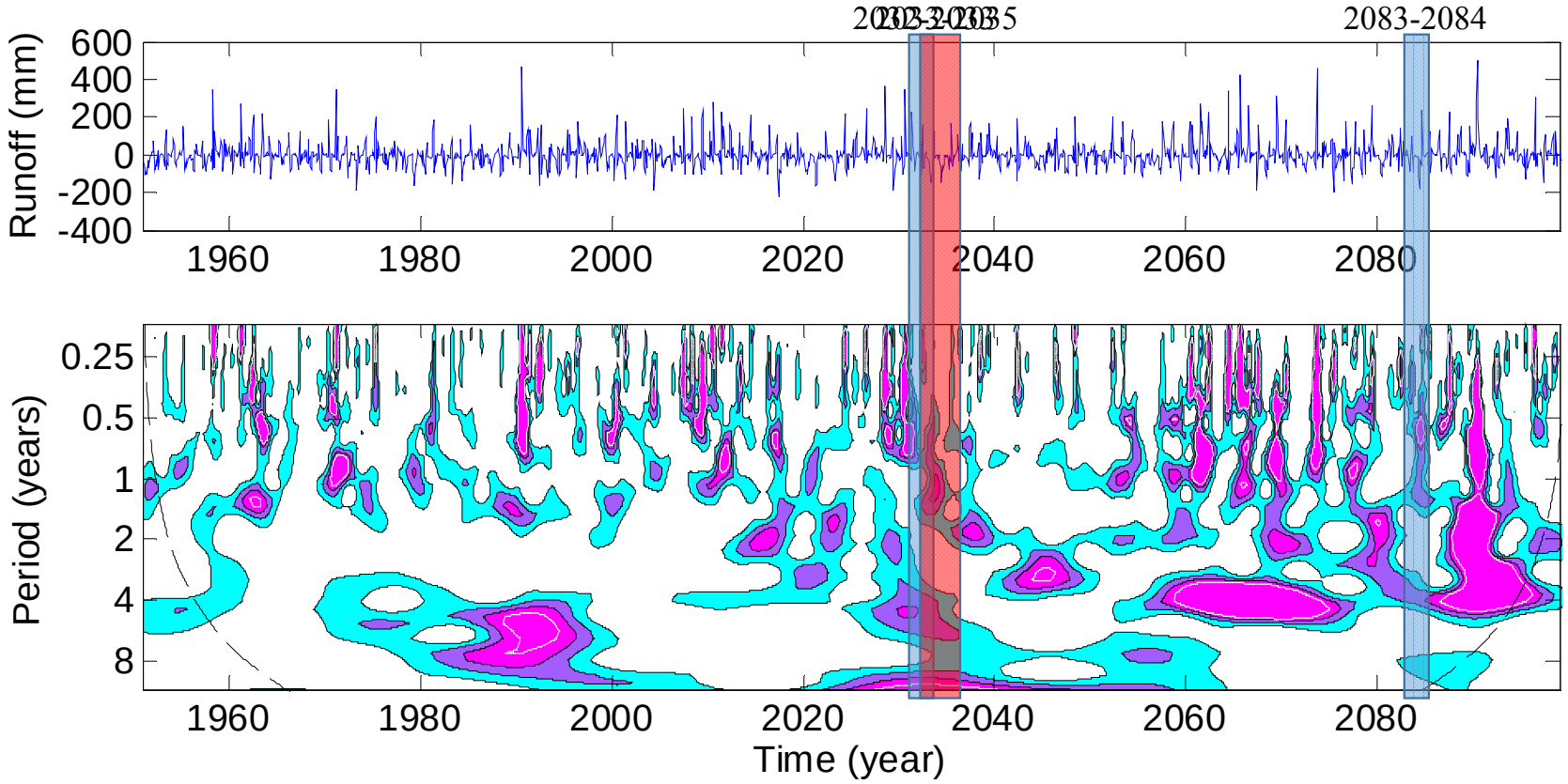
- The comparison of the continuous drought month periods
- The study period is from 1951 to 2099



RCP 4.5 scenario

Use minimum river flow Use SRI

Upper: The monthly runoff anomaly time series in the East River from the projection of RCP 4.5 scenario
Lower: The local wavelet power spectrum using the Morlet wavelet, normalized by $1/\sigma^2$. The white contour closes regions of greater than 95% confidence for a red-noise process.



RCP 4.5 scenario

- The comparison of the continuous drought month periods
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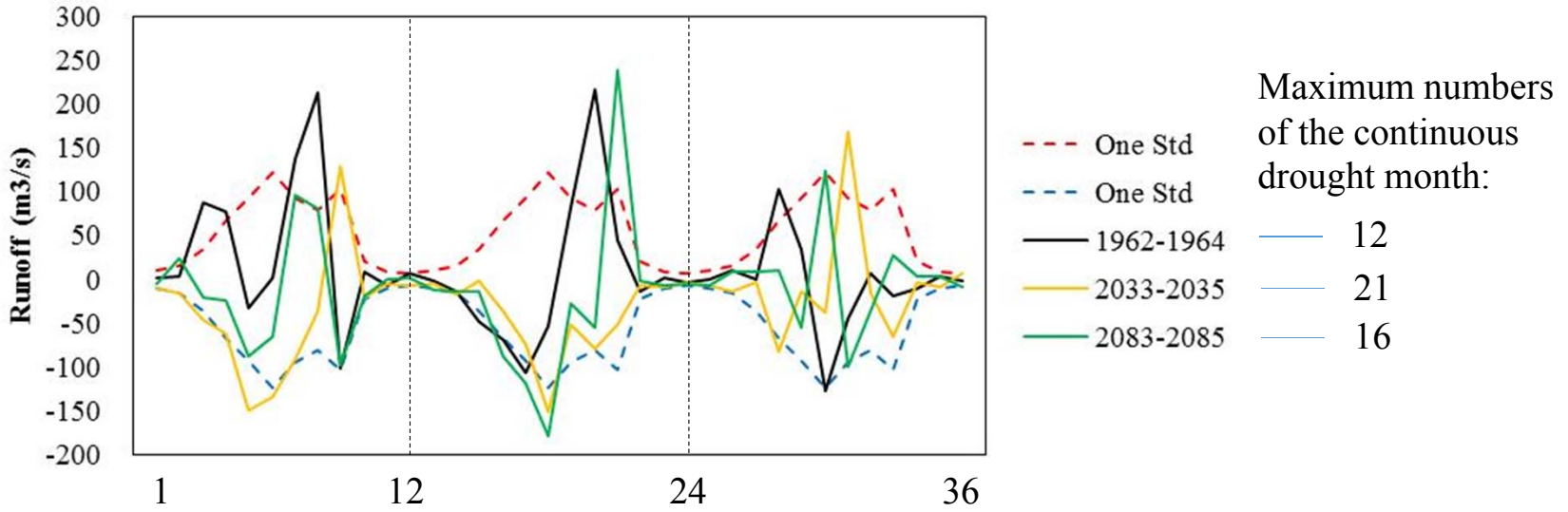
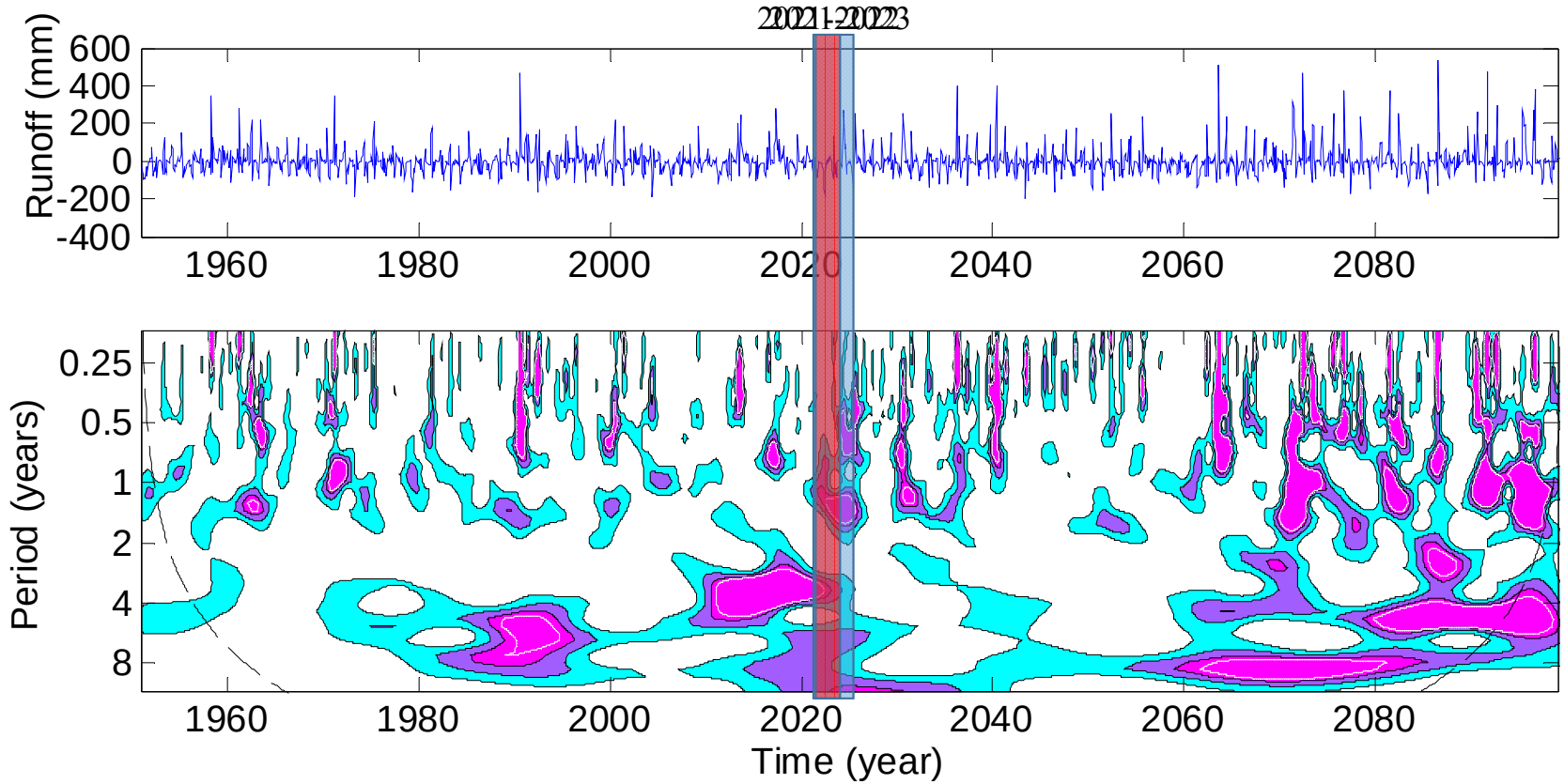


RCP 6.0 scenario

Use minimum river flow Use SRI

Upper: The monthly runoff anomaly time series in the East River from the projection of RCP 6.0 scenario
Lower: The local wavelet power spectrum using the Morlet wavelet, normalized by $1/\sigma^2$. The white contour closes regions of greater than 95% confidence for a red-noise process.



RCP 6.0 scenario

- The comparison of the continuous drought month periods
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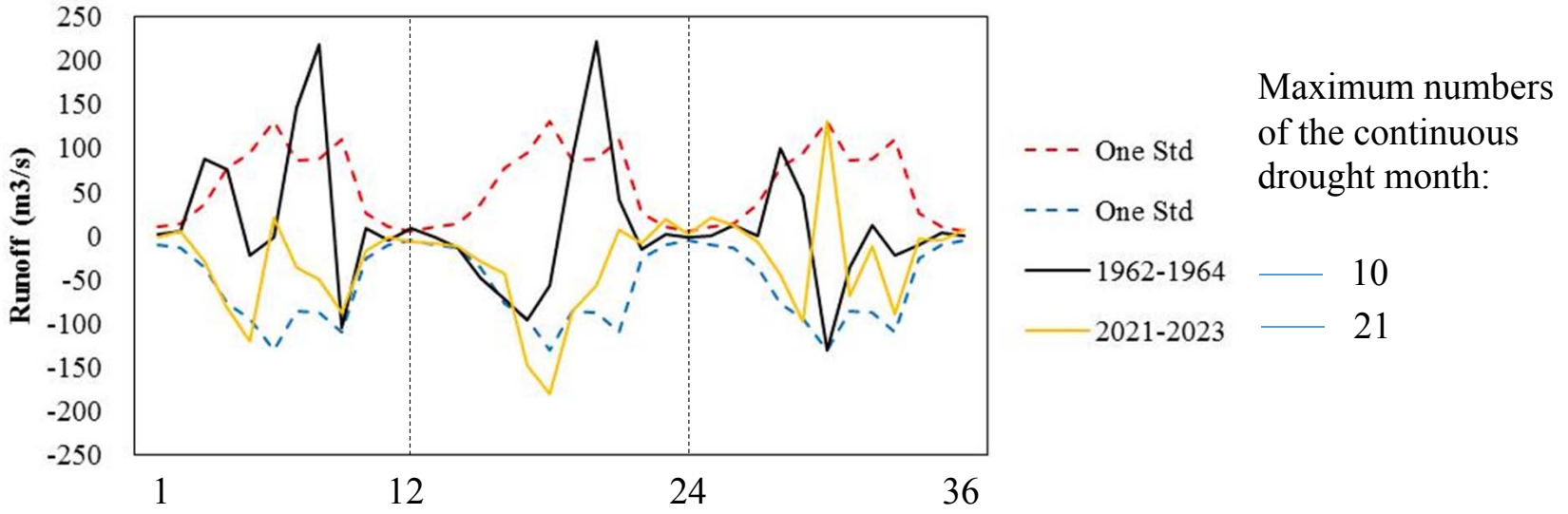
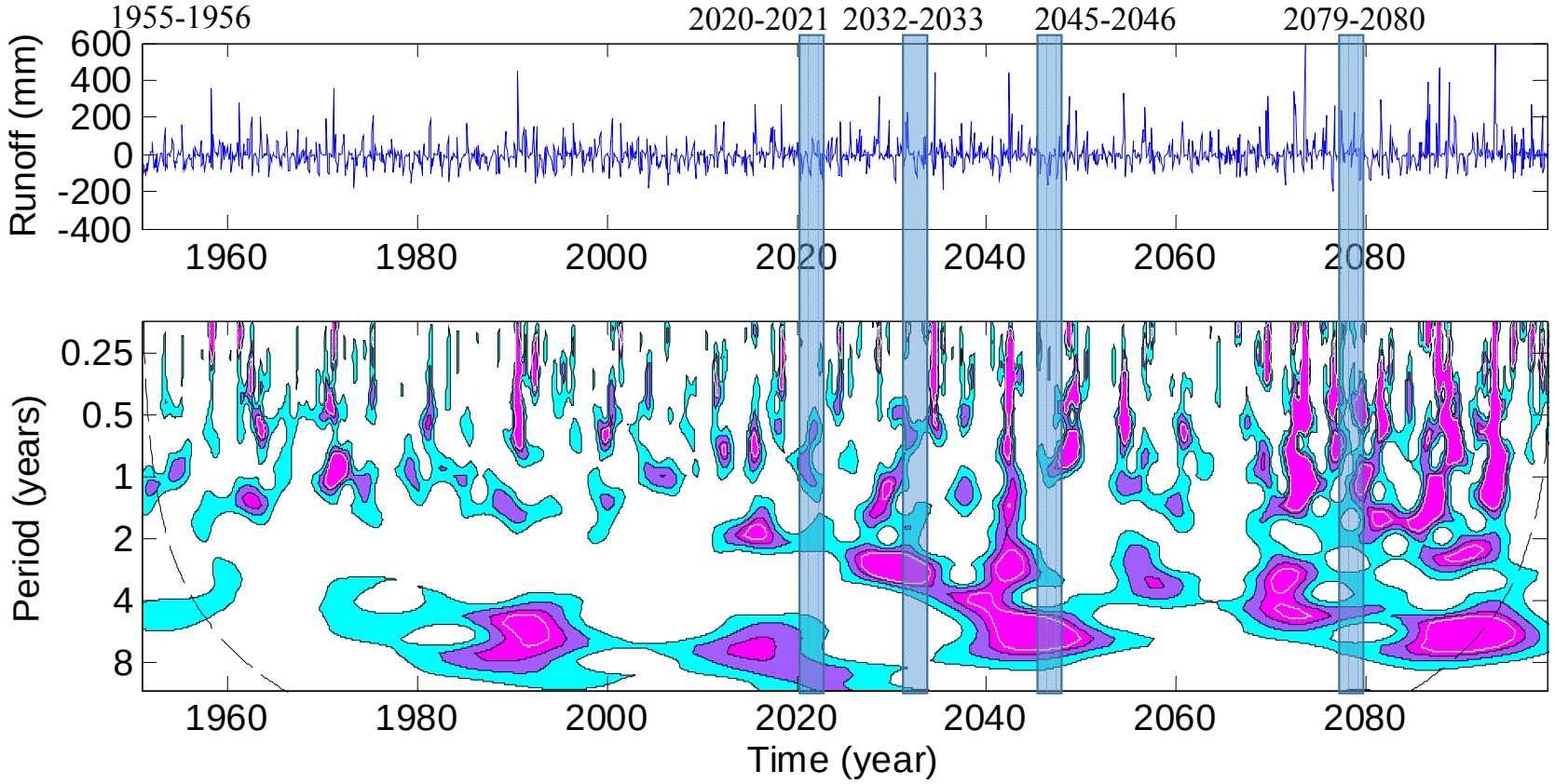


RCP 8.5 scenario

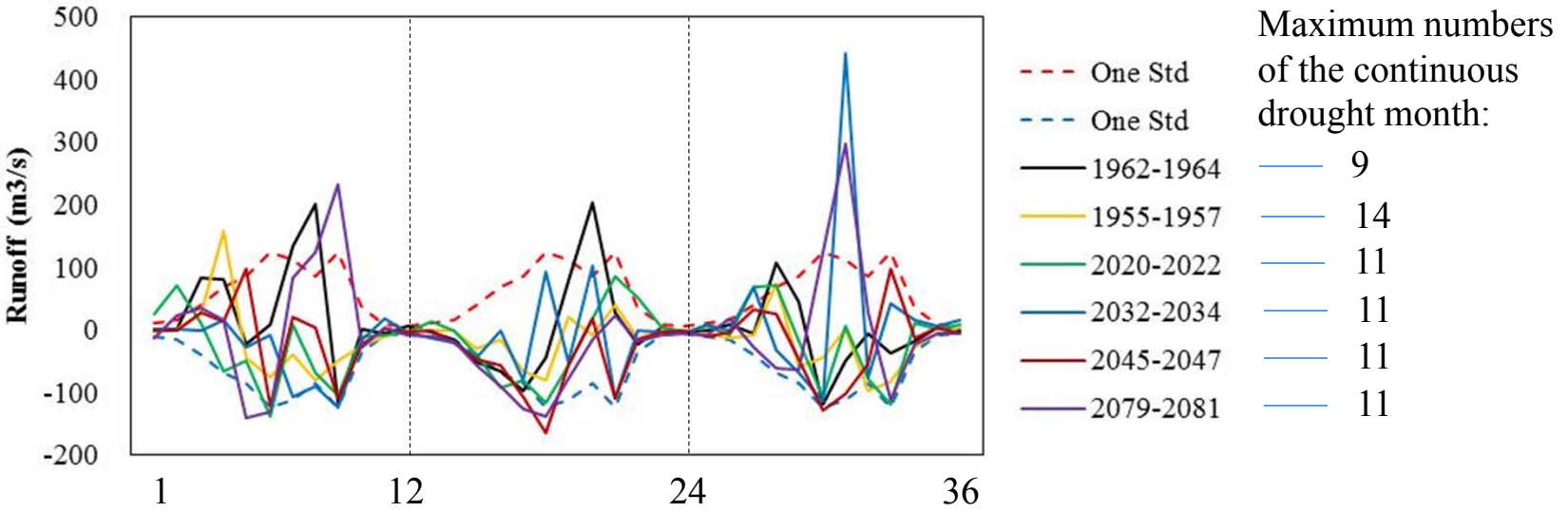
Use minimum river flow Use SRI

Upper: The monthly runoff anomaly time series in the East River from the projection of RCP 8.5 scenario
Lower: The local wavelet power spectrum using the Morlet wavelet, normalized by $1/\sigma^2$. The white contour closes regions of greater than 95% confidence for a red-noise process.



RCP 8.5 scenario

- The comparison of the continuous drought month periods
- The study period is from 1951 to 2099



4 Concluding Remarks

- The historical droughts in the Pearl River basin, the East River basin and Hong Kong were analyzed
- The future droughts under different carbon emission scenarios in the Pearl River were presented
- The results showed that a number of droughts which are more severe than that occurred in 1963 will occur in the future

THANK YOU