Spectrum network optimization model for agricultural water resources management

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Introduction

停灌休耕 v.s. 環境永續發展

一.公告停灌範圍

(一)正辦理公告停灌範圍

1.苗栗水利會-明德水庫灌區
面積：1,175公頃（12%）
2.臺中水利會-大安溪流域北岸（下灌區）
面積：4,625公頃（18%）

(二)本次公告停灌範圍

1.桃園水利會-大漢溪流域灌區
面積：22,677公頃（100%）
2.新竹水利會-頭前溪流域含圓山溪灌區4小組
面積：4,606公頃（73%）
3.嘉南水利會-曾文溪流域嘉義灌區及白水溪部分灌區
面積：8,493公頃（45%）

二.104年1月底前決定

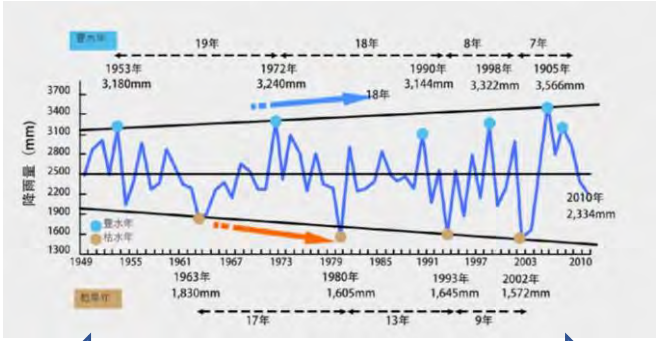
苗栗水利會-中港溪流域灌區

農民收成前遭停灌 抗議政院拒絕再被犧牲

三、2020/11/04 苦苓網專

張智琦 苦苓網記者

「缺水是天災，停灌是人禍！」因用水不足，經濟部及農委會日前無預警公告，自10月15日對桃竹苗地區實施停灌，受影響農民超過2萬5千人，今日（11/4）農民團體和環境團體一同前往行政院抗議，強調停灌、休耕對當地農產業及農戶將造成莫大衝擊，政府不該隨便停水，犧牲農民權益。



國立臺灣大學生物環境系統工程學系

台積電確定高雄設廠 陳其邁：完成不可能的任務

2021/11/9 21:20（11/10 10:30 更新）

台積電9日董事會決議核准公司將向高雄市政府遞件租地設廠。（中央社檔案照片）

■The purpose of the water resources system main pipe series connection is to strengthen the stable water supply, and improve the water resources scheduling and source backup capacity,

■but how to analyze the main pipe series connection that has been built or planned, the problems to be solved include:

1. How to systematically analyze the water supply capacity of the water resource system main pipe series project?
2. How to quantify the impact of water resource system main pipe series connection on dispatching and backup capacity?
3. Climate change has greatly increased the intensity and frequency of extreme events, resulting in a high degree of uncertainty in rainfall, reservoir water storage, river flow, and water supply.
4. How should uncertain water resources be allocated to improve the stability of water supply?

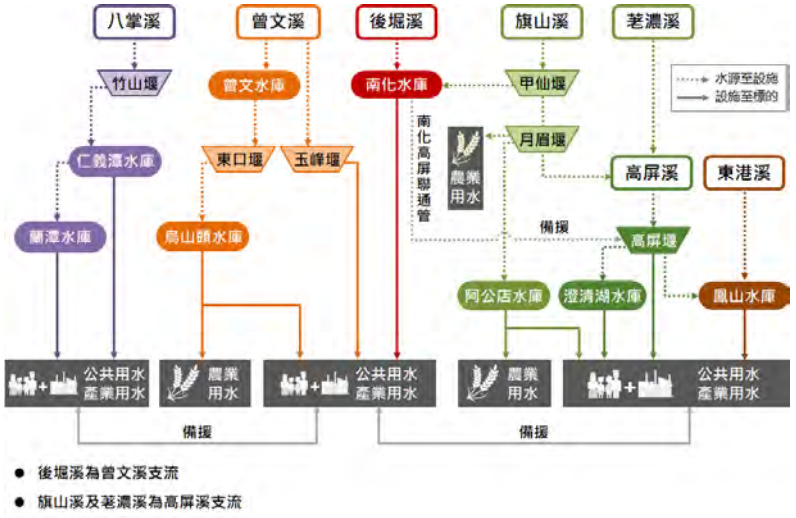
Methodology

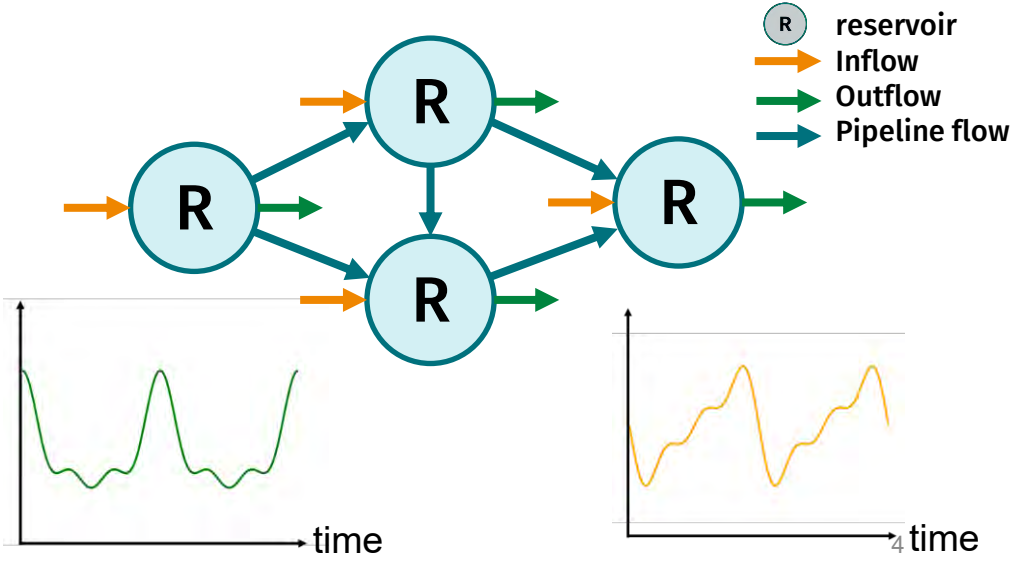
$$\text{Minimize} \quad \sum_{i=1}^{m}\sum_{j=1}^{m} c_{ij}x_{ij}$$

$$\text{subject to} \quad \sum_{j=1}^{m} x_{ij} - \sum_{k=1}^{m} x_{ki} = b_i, \qquad i = 1,\ldots,m$$

$$x_{ij} \geq 0, \qquad i,j = 1,\ldots,m.$$

time series data?





a. Incorporating the temporal function into reservoir optimization （加入時間觀念的水庫最佳化模型)

$$\text{Minimize } Z = \sum_i \sum_t (f_i^{DEF}(t))^2 + (f_i^{SUR}(t))^2 \quad (1)$$

subject to:

$$\frac{dF_i^{ST}}{dt} = F_i^{IN} - F_i^{OUT} \ \forall i \quad (2)$$

$$F_i^{OUT} - F_i^{SUR} + F_i^{DEF} = F_i^{DE} \ \forall i \quad (3)$$

$$StorageCapacity_i \geq F_i^{ST} \geq 0 \ \forall i \quad (4)$$

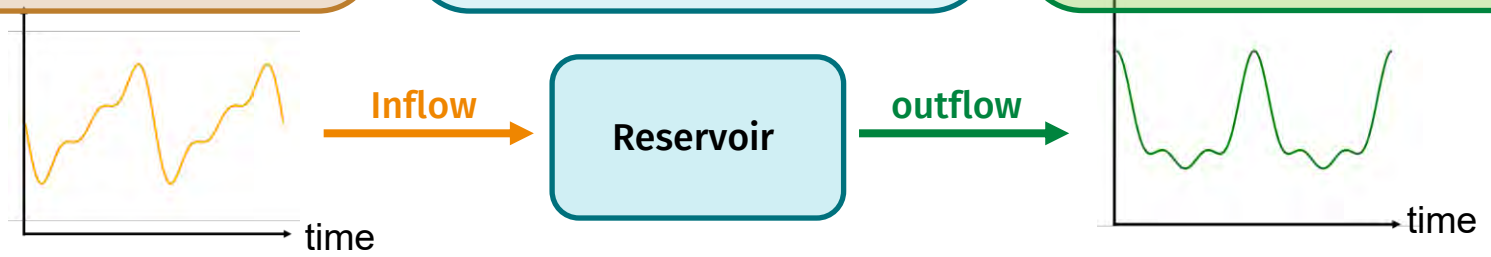
$$F_i^{OUT}, F_i^{SUR}, F_i^{DEF} \geq 0 \ \forall i \quad (5)$$

where i is index of reservoir

- Normal optimization not involving time
- Inflow and outflow are functions of time.

- Discretization in respect of time.
- Vector optimization problem such as $[f(t1), f(t2), f(t3) \ldots]^T$

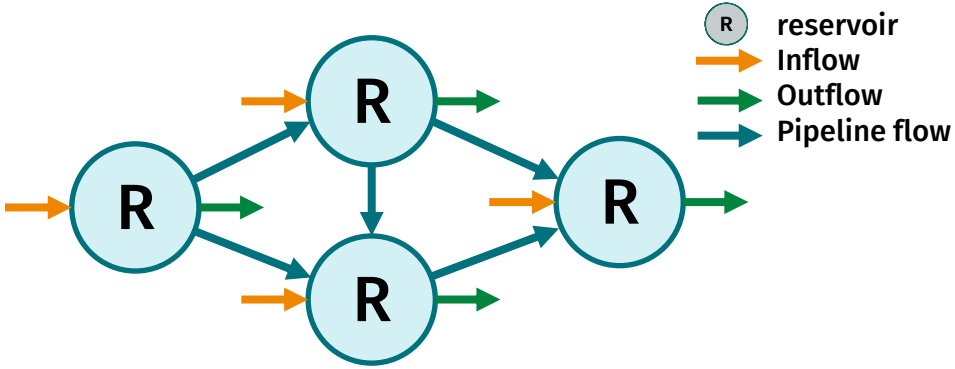
- The objective is to minimize the different between the outflow and the water demand

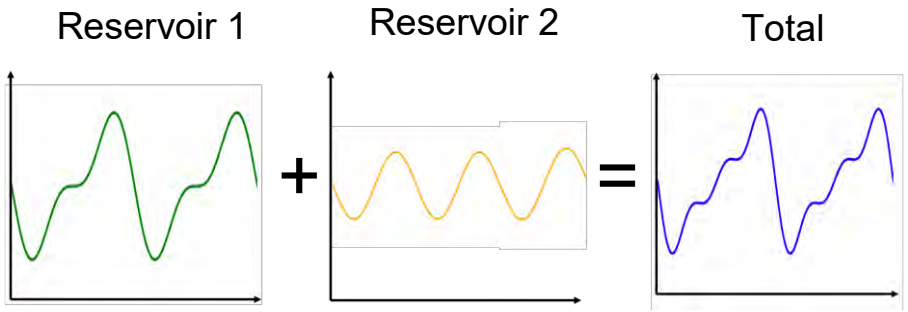


b. Connection of water resources systems (水資源系統串連的效益評估)

- Pipelines connection in “Pearl chain” plan
- Network optimization problem

- Pipelines make reservoirs have connection to other reservoirs
- Hydrograph can be superposed in respect of time.





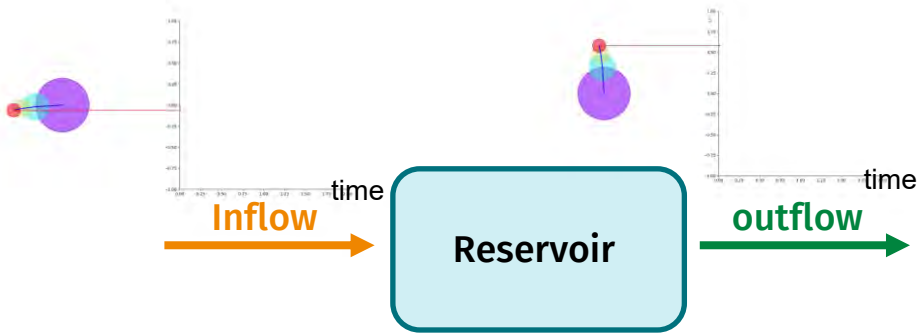
c. Water resouces network optimization on frequency domain (運用傅立葉級數的正交座標系統進行水庫串接系統頻率域最佳化)

- Time-series data lacking a describable coordinate system

- Orthogonal trait of Fourier series
- Fourier series is suitable for time data project to orthogonal coordinate system.

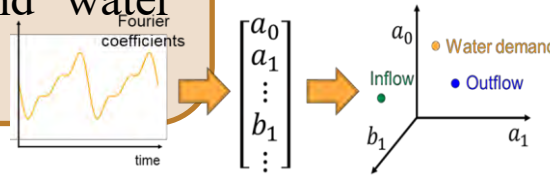
Fourier series:

$$f(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos\left(\frac{n\pi t}{L}\right) + \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi t}{L}\right)$$



c. Water resources network optimization in Fourier frequency domain (運用傅立葉級數的正交座標系統進行水資源系統頻率網路最佳化)

- Fourier series can depict periodic functions through Fourier coefficients.
- Both hydrology and water usage are periodic.



- Use Fourier coefficients to depict the objective and constraints in optimization model.
- The simulate outflow will have **similar oscillation** of the water demand.

$$\text{Minimize } Z = a_{0i}^{DEF^2} + \sum_{n,i}(a_{ni}^{DEF^2} + a_{ni}^{DEF^2}) + a_{0i}^{SUR^2} + \sum_{n,i}(a_{ni}^{SUR^2} + a_{ni}^{SUR^2}) \quad (1)$$

subject to:

$$a_{0i}^{IN} - a_{0i}^{OUT} + \sum_j a_{0ji}^{FL} - \sum_j a_{0ij}^{FL} = 0 \ \forall i \quad (2)$$

$$a_{ni}^{IN} - a_{ni}^{OUT} + \sum_j a_{nji}^{FL} - \sum_j a_{nji}^{FL} = \frac{n\pi}{L} b_{ni}^{ST} \ \forall n,i \quad (3)$$

$$b_{ni}^{IN} - b_{ni}^{OUT} + \sum_j b_{nji}^{FL} - \sum_j b_{nji}^{FL} = -\frac{n\pi}{L} a_{ni}^{ST} \ \forall n,i \quad (4)$$

$$a_{0i}^{OUT} - a_{0i}^{SUR} + a_{0i}^{DEF} = a_{0i}^{DE} \ \forall i \quad (5)$$

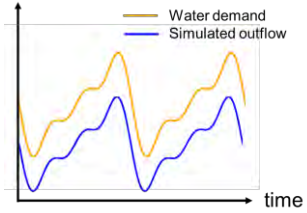
$$a_{ni}^{OUT} - a_{ni}^{SUR} + a_{ni}^{DEF} = a_{ni}^{DE} \ \forall n,i \quad (6)$$

$$b_{ni}^{OUT} - b_{ni}^{SUR} + b_{ni}^{DEF} = b_{ni}^{DE} \ \forall n,i \quad (7)$$

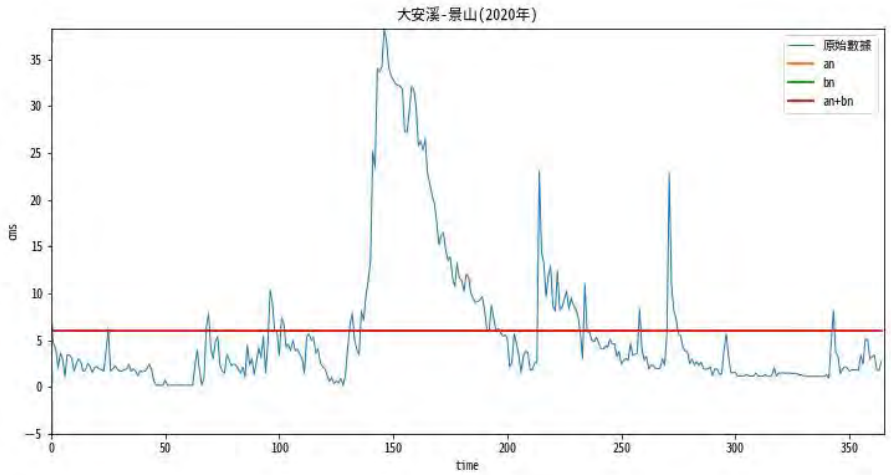
$$StorageCapacity_i \geq a_{0i}^{ST} + \sum_{n=1}^{\infty} a_{ni}^{ST} cos\frac{n\pi t}{L} + \sum_{n=1}^{\infty} b_{ni}^{ST} sin\frac{n\pi t}{L} \geq 0 \ \forall i \quad (8)$$

$$FlowCapacity_{ij} \geq a_{0ij}^{FL} + \sum_{n=1}^{\infty} a_{nij}^{FL} cos\frac{n\pi t}{L} + \sum_{n=1}^{\infty} b_{nij}^{ST} sin\frac{n\pi t}{L} \geq 0 \ \forall i,j \quad (9)$$

$$f_i^{OUT}(t), f_i^{SUR}(t), f_i^{DEF}(t) \geq 0 \ \forall i \quad (10)$$

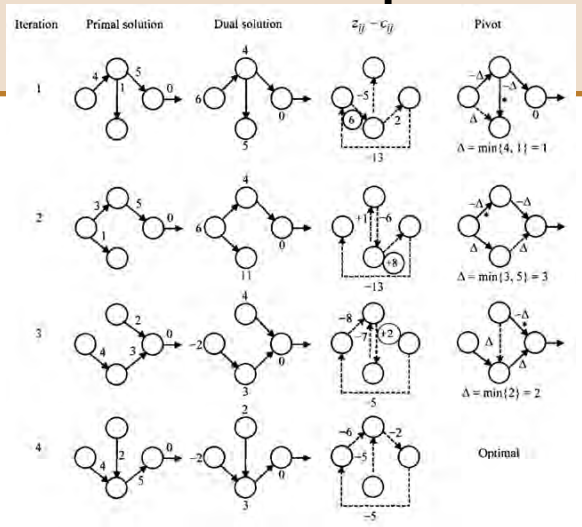


1. A network flow model for the series connection of main pipes in water resources system
2. Fourier Spectrum Analysis of Hydrological Time Series Data
3. Spectrum Optimum Analysis of Trunks in Water Resources System
4. Case study: data collection and analysis of pipeline connection in water resources system

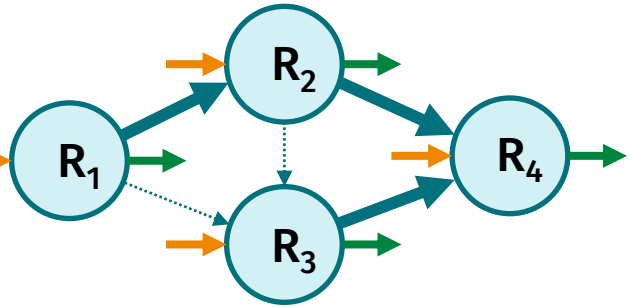


d. Optimization using network simplex method
(在時域或頻率域下運用網路單形法分析幹管最佳流線)-

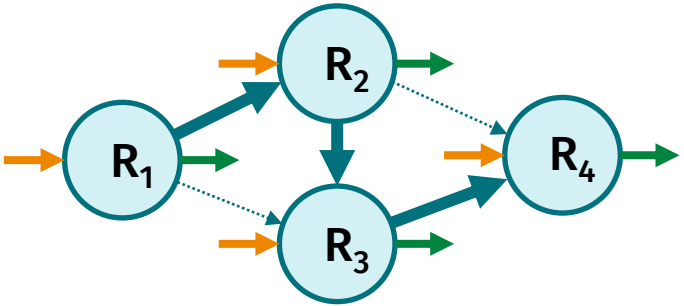
- The network simplex method is applied simplex method in network flow problem.
- Determine the optimal flow network solution (spanning tree) in network optimization.
- The result will exhibit **variation over time** in time domain and **over frequencies** in frequency domain



(a) Optimal spanning tree 1



(b) Optimal spanning tree 2



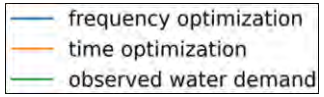
Case study

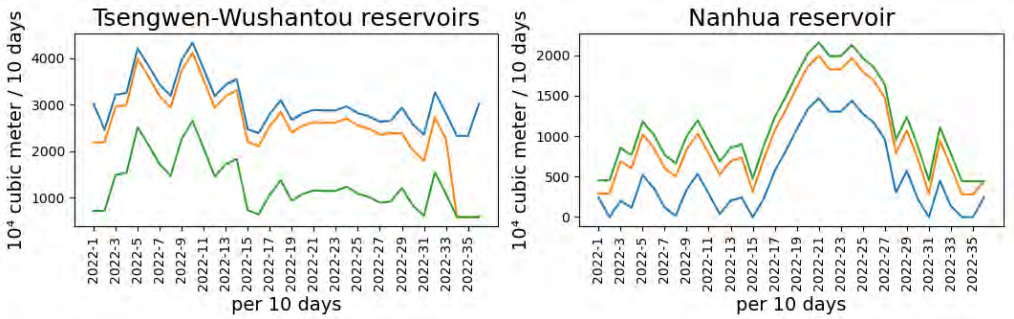
- Agricultural policy can adjust the agricultural water demand.
- In “Tsengwen-Nanhua Interconnection Pipeline Project” as known as “Pearl chain” plan in Southern region water resources system, the connecting pipeline is constructed between Tsengwen Reservoir and Nanhua reservoir, aiming to transmit the surplus water and alleviate the regional water shortage.
- With the existing Nanhua-Gaoping Interconnection Pipeline, the interconnection system can integrate the water allocation system of mainly Tainan and Kaohsiung and enhance the water supply backup system in the Southern area.

Results and discussion

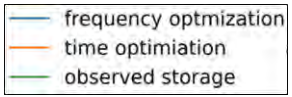
(1) Scenario with one existing pipeline between Nanhua Reservoir and Gaoping River Weir

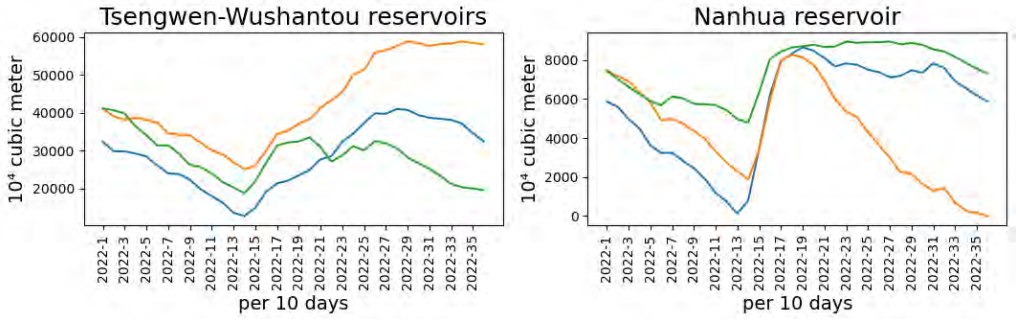
Simulated outflow

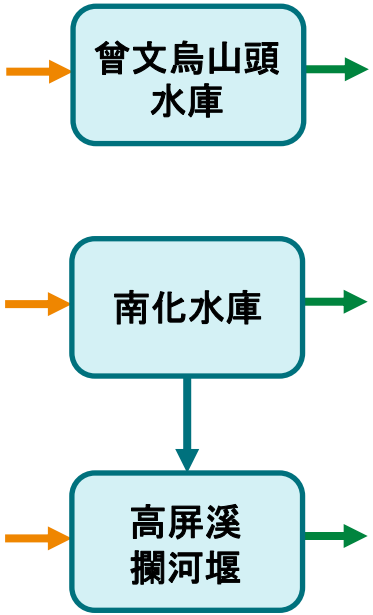




Simulated storage



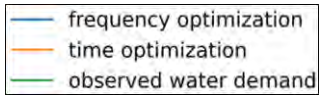


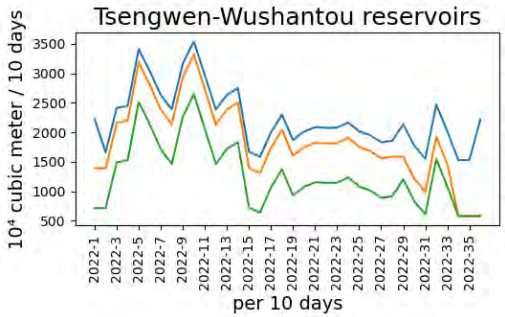


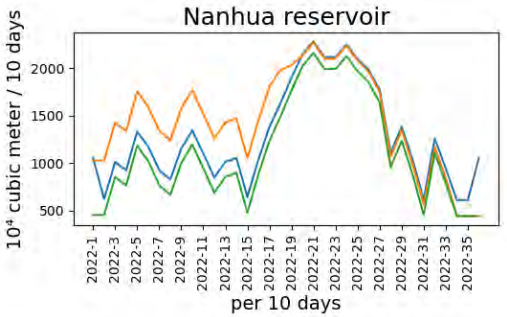
Results and discussion

(2) Scenario with two existing pipelines connecting reservoirs

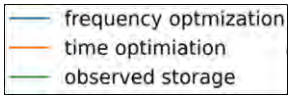
Simulated outflow

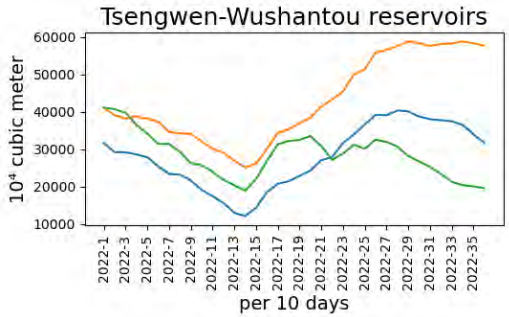


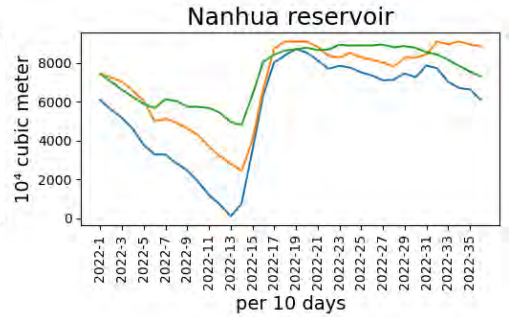


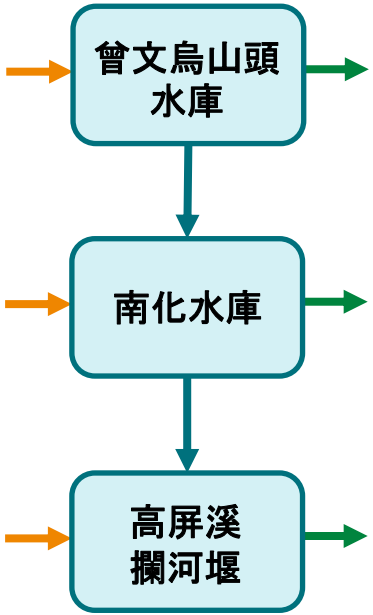


Simulated storage









Results and discussion

- Agricultural policy, and connectivity of water resources systems really can alleviate the regional imbalanced water allocation.

- Time and frequency optimization models both can simulate the water outflow from reservoirs to oscillate in response to water demand. But only frequency optimization can ensures that the water storage maintains an appropriate level after a period.

- Though not applied in our study, network simplex method in the frequency perspective can identify the primary frequency components of the interconnected flow, and thus much reasonable to filter the noise which could result from climate extreme events.

Questions and comments?

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