1. Title. Improving Surface Water Availability Estimates by Accounting for Projected Changes of Reservoir Evaporation: A Case Study in Upper Trinity River Basin

2. Project Type. Research

3. Focus Categories. HYDROLOGY, WATER SUPPLY, DROUGHT

4. Research Category. Climate and Hydrologic Processes

5. Keywords. Climate change, reservoir evaporation, water availability

6. Start Date. 3/1/2020

7. End Date. 2/28/2021

8. Principal investigator(s).
Huilin Gao, Associate Professor
Texas A&M University, Zachry Department of Civil Engineering, College Station, TX
Email: hgao@civil.tamu.edu; Phone: 979-845-2875

Manqing Shao, Doctoral student (started in 2019 and expected to graduate in 2022)
Texas A&M University, Zachry Department of Civil Engineering, College Station, TX
Email: wunderbarbonbon@tamu.edu; Phone: 979-383-9776

9. Congressional District 17th Congressional District of Texas

10. Abstract.
Texas regional water planning considers projected water demand and reservoir sedimentation when evaluating future surface water availability, but not the impacts of climate change on hydrologic conditions and reservoir evaporation losses. Our objective is to assess the effects of reservoir evaporative losses on reservoir firm yield and water supply reliability under different future climate change scenarios. A total of 12 major reservoirs in the Upper Trinity Basin (UTB) are selected as the study sites. UTB supplies water to about a quarter of Texas' population, including the Dallas-Fort Worth Metropolitan. A distributed hydrological model with a reservoir module, which accounts for both energy budget and mass transfer in the calculation of open water evaporation, will be used in this research. The model is to be forced by statistically downscaled CMIP5 climate forcings to simulate future reservoir evaporation. The projected reservoir evaporation is then used to as input to Water Availability Model (WAM) – a tool to assess water availability for regional water planning – for estimating future reservoir firm yield and water supply reliability. Results from this research can inform modifications to existing reservoir operations and inform revisions to guidance material related to the regional water planning process in Texas.

11. Budget Breakdown.

Cost Category	Federal	Non-Federal	Total
1. Salaries and Wages	$		
- Principal Investigator(s)		$4,030	
- Graduate Student(s)	$4,465		
- Undergraduate Student(s)			
- Others			
Total Salaries and Wages	$4,465	$4,030	$8,495
2. Fringe Benefits			
- Principal Investigator(s)		$970	
- Graduate Student(s)	$535		
- Undergraduate Student(s)			
- Others			
Total Fringe Benefits	$535	$970	$1,505
3. Tuition			
- Graduate Student(s)			
- Undergraduate Student(s)			
Total Tuition			
4. Supplies			
5. Equipment			
6. Services or Consultants			
7. Travel			
8. Other direct costs			
9. Total direct costs			
10a. Indirect costs on federal share	XXXXXXXX XXXXXXXX	$2,500	$2,500
10b. Indirect costs on non-federal share	XXXXXXXX XXXXXXXX	$2,500	$2,500
11. Total estimated costs	$ 5,000	$ 10,000	$ 15,000
Total Costs at Campus of the University on which the Institute or Center is located.	$ 5,000	$ 10,000	$ 15,000
Total Costs at other University Campus Name of University:	$	$	$

12. Budget Justification.

Salaries and Wages for PIs. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual.

Non-Federal: PI Dr. Huilin Gao, $147,756 annually, is committing 0.32 months to the project as cost share.

Salaries and Wages for Graduate Students. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual. (Other forms of compensation paid as or in lieu of wages to students performing necessary work are allowable provided that the other payments are reasonable compensation for the work performed and are conditioned explicitly upon the performance of necessary work. Also, note that tuition has its own category below and that health insurance, if provided, is to be included under fringe benefits.)

Federal: Request $4,500 for graduate student salary at a rate of $1,650 per month for 2.72 months

Salaries and Wages for Undergraduate Students. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual. (Other forms of compensation paid as or in lieu of wages to students performing necessary work are allowable provided that the other payments are reasonable compensation for the work performed and are conditioned explicitly upon the performance of necessary work. Also, note that tuition has its own category below and that health insurance, if provided, is to be included under fringe benefits.)

n/a

Salaries and Wages for Others. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual.

n/a

Fringe Benefits for PIs. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. . Note: include health insurance here, if applicable.

Texas A&M's fringe rate for faculty and staff is 18.2% of salary and the insurance rate is $746 per month.

Fringe Benefits for Graduate Students. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. Note: include health insurance here, if applicable.

Texas A&M's fringe rate for graduate students is 10.7% of salary

Fringe Benefits for Undergraduate Students. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. Note: include health insurance here, if applicable

n/a

Fringe Benefits for Others. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. . Note: include health insurance here, if applicable.

n/a

Tuition for Graduate Students.

n/a

Tuition for Undergraduate Students

n/a

Supplies. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies. Provide a breakdown of the supplies in each category.

n/a

Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items. A detailed breakdown is required.

n/a

Services or Consultants. Identify the specific tasks for which these services, consultants, or subcontracts would be used. Provide a detailed breakdown of the services or consultants to include personnel, time, salary, supplies, travel, etc.

n/a

Travel. Provide purpose and estimated costs for all travel. A breakdown should be provided to include location, number of personnel, number of days, per diem rate, lodging rate, mileage and mileage rate, airfare (whatever is applicable).

n/a

Other Direct Costs. Itemize costs not included elsewhere, including publication costs. Costs for services and consultants should be included and justified under "Services or Consultants (above). Please provide a breakdown for costs listed under this category.

n/a

Indirect Costs. Provide negotiated indirect ("Facilities and Administration") cost rate.

Texas A&M Engineering Experiment Station's federally negotiated indirect cost rate is 50% MTDC.

Items 13 through 19 shall not exceed 10 single-spaced pages, 12-point font, exclusive of resumes (item 19).

13. Statement of regional or State water problem.
In Texas, around 67% of the available surface water is from reservoirs (TWDB 2019). As for reservoir storage losses, water surface evaporation is a major component in semi-arid/arid regions. For example, in 2011, which was the worst one-year drought of record for the state, the net evaporation loss from 188 major water supply reservoirs in Texas was 5.83 million acre-feet, which was greater than the state's highest annual municipal water use (4.97 million acre-feet) recorded in 2011. Based on the 2017 State Water Plan, if only considering the increasing water demand and decreasing reservoir storage due to sedimentation, municipal water users might face water shortages over six times greater in 2070 (3.4 million acre-feet) than in 2020 (511,000 acre-feet). However, the situation might be worse because climate change is projected to intensify short-term and long-term droughts risks across most of the U.S (Environmental Protection Agency 2019). Increased drought can significantly elevate reservoir evaporation, reduce the firm yield of reservoirs, and harm water supply reliability. Unfortunately, potential fluctuations in reservoir net evaporation volume and inflow due to climate change are not considered in current regional water planning in Texas (TWDB 2018). Additionally, surface water availability assessments for drought planning only consider drought of the 1950s as the benchmark (TWDB 2018). Recent droughts, such as the 2011 drought, which is ranked as the worst one-year drought on record, are not included in the hydrological inputs for WAM (Texas Commission on Environmental Quality 2019). Thus, understanding how climate change could impact Texas surface water availability, particularly through changes in reservoir evaporation, is essential for developing new strategies in response to potential water shortages. This research can directly address the TWRI's research priorities in "Impacts of climate variability, climate change and drought on Texas water resources" and can provide insights in "Developing innovative water management strategies to aid in implementing the Texas State Water Plan".

14. Statement of results or benefits.
The information expected to be gained from the research includes projected reservoir net evaporation rate, projected reservoir firm yield and water supply reliability, as well as regional water shortage assessment for the 12 reservoirs and UTB region. Combining DHSVM-Res with WAM can develop a comprehensive water availability assessment framework at local basin scale. This framework will provide modeling tool, data, and information, in regard to water availability, for water management agencies. It can facilitate water resources managers and regional water planners to: 1) evaluate the future long-term trends in water availability of UTB; 2) develop regional drought planning and response strategies; 3) update information for water resources management decision-making; 4) formulate adaptive methods to conserve the storage of individual reservoir.

15. Nature, scope, and objectives of the project, including a timeline of activities.
The effects of reservoir evaporative losses on projected water availability under future climate change remain poorly understood in the current Texas water planning process. The scope of the research is to apply the projected reservoir evaporation and naturalized flow from the Distributed Hydrology Soil Vegetation Model with a reservoir module (DHSVM-Res; Wigmosta et al. 1994; Zhao et al. 2016) to WAM, and to assess future surface water availability using the WAM for

UTB. The WAM projected water availability metrics (e.g., reservoir firm yield) will provide actionable information that Regional Water Planning Group C could consider when developing water management strategies for inclusion in the 2027 round of regional water planning. Moreover, with few reservoirs slated to be built in the near future, and with the diminishing capacity of existing reservoirs due to sedimentation, methods to improve the management of existing available surface water become more important. Thus, the improved estimation of water availability and projected reservoir evaporation will be helpful in guiding the implementation of strategies for better managing existing and future available surface water in Texas. The objectives of the research are: a) calculating the projected reservoir evaporation for 12 major reservoirs of UTB under climate change impacts; b) conducting a quantitative assessment of regional water availability using WAM; c) estimating the regional water shortage based on the projected regional water availability metrics and historical State Water Plans. Another activity is to use a web page to disseminate water availability information under different climate scenarios (for each of the 12 reservoirs and the region of UTB). Information from the web will be useful for local and regional water planners. Considering the collaborative nature of the research, the projected data will be shared with Texas Water Department Board.
A project timeline is summarized below:

Calendar Year	2020			2021
Task / Season	Spring	Summer	Fall	Spring
Modify DHSVM-Res and literature review	x	x		
Project reservoir evaporation and water availability metrics		x	x	
Assess future regional water shortage			x	
Write manuscript			x	x

16. <u>Methods, procedures, and facilities</u>.
DHSVM-Res will be modified to include both energy budget and mass transfer terms in reservoir evaporation. The modification includes adding sub-modules to represent heat storage (McMahon et al 2013) and wind function (McJannet et al. 2012). DHSVM-Res was already calibrated over the Trinity River Basin by Zhao et al. (2018) at a 200-meter spatial resolution and a 3-hourly time step. This research will adopt the calibrated parameters and run the model at the same spatial and temporal resolutions. Future climate forcings to drive DHSVM-Res will be generated based on MACAv2-METDATA (Abatzoglou 2013). This forcing dataset can better represent the occurrence of climate extremes than other statistically downscaled climate dataset (Jiang et al 2018). It contains daily meteorological variables (e.g., temperature, downward shortwave radiation, specific humidity, wind speed) for the historical period (1950-2005) and the future Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios (2006-2100) over the CONUS. The reservoir evaporation from DHSVM-Res will be validated from 1985 to 2010 by comparing DHSVM-Res simulations, pan-based evaporation dataset (TWDB 2019), and remotely sensed evaporation dataset (Zhao and Gao 2019). Then, reservoir evaporation and naturalized flow (without human influence) will be projected by DHSVM-Res. This research will include the extended (through 2018) WAM hydrology datasets that have been compiled by the TWDB for the Trinity. This dataset is an auxiliary dataset that regional water planning groups can use until the official extended hydrology datasets are compiled and released by the TCEQ. The TWDB has agreed to provide us with this extended WAM hydrology dataset for the

Trinity. Meanwhile, the TWDB will provide other WAM inputs, including the projected reservoir sedimentation, and reservoir rating curves. Historical water diversion data have been obtained for reservoirs managed by the Tarrant Regional Water District. We will take steps to obtain historical water diversion data from other reservoir operators in the UTB and derive water demand coefficients for these reservoirs based on the historical diversion data. For reservoirs that do not have consistent records of water diversions, the TWDB has agreed to provide us with water demand coefficients. Afterwards, the DHSVM-Res simulations and other WAM input data files will be input to the Trinity WAM to calculate water availability metrics. The assessment of future regional water availability will be conducted for the period of 2020–2100 and for the most severe future droughts over UTB (Zhao et al. 2018). In the end, regional water shortage will be estimated based on the projected water availability metrics and the historical State Water Plans. The data processing and the model simulations will be facilitated by High Performance Research Computing (HPRC) at TAMU and the computer cluster hosted by Dr. Gao's group.

17. Related research. (Research projects only) Show by literature and communication citations the similarities and dissimilarities of the proposed project to completed or on-going work on the same topic.
Helfer et al. (2012) analyzed the evaporation rates from a large water supply reservoir in Australia, under different climate conditions. A one-dimensional processed-based model DYRESM was used to predict water temperatures and evaporation rates. Zhao et al. (2018) conducted a study to evaluate water supply resilience under climate and population change in metropolitan area. They used the integrated hydrological-water management modeling framework to study the resilience under multi-year droughts. However, heat storage effects and wind function were not considered in the reservoir simulation. Our study adopted a distributed hydrological model with an improved reservoir module, which accounts for both energy budget and mass transfer in the calculation of open water evaporation. This work could provide accurate evaporation estimates to the local water management agencies and lay a foundation for the future water planning.

18. Training potential. Estimate the number of graduate and undergraduate students, by degree level, who are expected to receive training in the project.
Graduate student: 1 (PhD)

19. Investigator's qualifications. Include resume(s) of the principal investigator(s). No resume shall exceed two pages or list more than 15 pertinent publications.

HUILIN GAO
Associate Professor
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Phone: 979-845-2875 Email: hgao@civil.tamu.edu

A. PROFESSIONAL PREPARATION

Peking University	Atmospheric Sciences	B.S. 1997
Peking University	Atmospheric Sciences	M.S. 2000
Princeton University	Hydrology & Water Resources	M.A. 2002

Princeton University	Hydrology & Water Resources	Ph.D. 2005
Georgia Institute of Technology	Atmospheric Sciences	2005-2007
University of Washington	Hydrology & Water Resources	2008-2012

B. APPOINTMENTS

2018-present Associate Professor, Department of Civil Engineering, Texas A&M University
2012-2018 Assistant Professor, Department of Civil Engineering, Texas A&M University
2008-2012 Research Associate, Department of Civil and Environmental Engineering, University of Washington
2005-2007 Research Scientist II, Department of Earth and Atmospheric Sciences, Georgia Institute of Technology

C. RECENT PUBLICATIONS (45 peer-reviewed articles published as of December 2019, # indicates corresponding author)

1. Zhao, G. and H. Gao#, Towards global hydrological drought monitoring using remotely sensed reservoir surface area, *Geophysical Research Letters*, https://doi.org/10.1029/2019GL085345, 2019.
2. Li, Y., C. Hu, A. Quigg, and H. Gao#, Potential influence of the Deepwater Horizon oil spill on phytoplankton primary productivity in the northern Gulf of Mexico, *Environmental Research Letters*, DOI: 10.1088/1748-9326/ab3735, 2019.
3. Li, Y., H. Gao#, M. F. Jasinski, S. Zhang, and Jeremy D Stoll, Deriving High-Resolution Reservoir Bathymetry From ICESat-2 Prototype Photon-Counting Lidar and Landsat Imagery, *IEEE Transactions on Geoscience and Remote Sensing*, https://doi.org/10.1109/TGRS.2019.2917012, 2019.
4. Zhao, G. and H. Gao#, Estimating reservoir evaporation losses for the United States: Fusing remote sensing and modeling approaches, Remote Sensing of Environment, *226*, 109-124, 2019.
5. Naz, B., W. Kurtz, C. Montzka, W. Sharples, K. Goergen, J. Keune, H. Gao, A. Springer, H. Franssen, and S. Kollet, Improving soil moisture and runoff simulations over Europe using a high-resolution data-assimilation modeling framework, *Hydrology and Earth System Sciences*, https://www.hydrol-earth-syst-sci.net/23/277/2019/, 2019.
6. Zhao, G., H. Gao#, N. Voisin, S.-C. Kao, and B. Naz, A modeling framework for evaluating the drought resilience of a surface water supply system under non-stationarity, *Journal of Hydrology*, vol. 563, 22-32, 2018.
7. Zhao, G and H. Gao#, Automatic correction of contaminated images for assessment of reservoir surface area dynamics, *Geophysical Research Letters*, https://doi.org/10.1029/2018GL078343, 2018.
8. Naz, B., S. Kao, M. Ashfaq, H. Gao, B. Rastogi, and R. Gangrade, Effects of climate change on streamflow extremes and implications for reservoir inflow in the United States, Journal of Hydrology, vol. 556, 359-370, 2018.
9. McCabe, M.F., M. Rodell, D.E. Alsdorf, D.G. Miralles, R. Uijlenhoet, W. Wagner, A. Lucieer, R. Houborg, N.E.C. Verhoest, T.E. Franz, J. Shi, H. Gao, and E.F. Wood, The Future of Earth Observation in Hydrology, *Hydrology and Earth System Sciences*, https://doi.org/10.5194/hess-2017-54, 2017.
10. Lee, K, H. Gao#, M. Huang, J. Sheffield, and X. Shi, Development and Application of Improved Long-Term Datasets of Surface Hydrology for Texas, Advances in Meteorology, Article ID 8485130, 2017.

11. Zhang, S., H. Gao#, A. Quigg and D. Roelke, Remote Sensing of Spatial-Temporal Variations of Chlorophyll-a in Galveston Bay, Texas, *IEEE International Geoscience and Remote Sensing Symposium*, 5841-5844, 2016.
12. Zhao, G., H. Gao#, B. Naz, S. Kao, and N. Voisin, Integrating Reservoir Regulation Scheme into a Spatially Distributed Hydrological Model, *Advances in Water Management*, 98, 16-31, 2016.
13. Zhao, G. , H. Gao#, and L. Cuo, Effects of Urbanization and Climate Change on Peak Flows over the San Antonio River Basin, Texas, *J. Hydrometeorology*, 17, 2371-2389, 2016.
14. Zhou, T., B. Nijssen, **H. Gao**, and D.P. Lettenmaier, The contribution of reservoirs to global land surface water storage variations, *J. Hydrometeorology*, 17, 309-325, 2016.

D. SYNERGISTIC ACTIVITIES

1. **Teaching:** Developed a new graduate course (CVEN689-sptc: Remote Sensing in Hydrology). This interdisciplinary course has been offered every spring since 2014. Students enrolled in the class have come from eight different departments/programs of three colleges at TAMU.
2. **Editorial:** Serving as an Associate Editor of *Water Resources Research*.
3. **Scientific Committees:** Served as a Committee Member for the Hydrology-Remote Sensing Technical Committee of American Geophysical Union (AGU).
4. **Conferences:** Served as convener/co-convener for 7 AGU fall meeting sessions (2010 – 2019).
5. **Outreach:** Contributed to the "Camp BUILD" program conducted by the Civil Engineering Department, worked with high school teachers through the RET program to promote environmental sustainability, and hosted undergraduate student through the College of Engineering Undergraduate Summer Research Grant (USRG) program (funded by NSF CAREER). Presented seminars to communities of interest, including the Galveston chapter of Masters Naturalists (2016), the Students for the Exploration and Development of Space organization at TAMU (2018), and the American Water Resources Association (AWRA) TAMU Student Chapter (2019).

MANQING SHAO

EDUCATION

Ph.D Candidate in Water Resources Engineering January 2019 – Present (1st year)
Civil Engineering Department, Texas A&M University, College Station, Texas

M.S. in Water Resources Engineering September 2016 – December 2018
Civil Engineering Department, Texas A&M University, College Station, Texas

Exchange Undergraduate Student October 2012 – June 2013
Civil and Environment Department, University of Stuttgart, Stuttgart, Germany

B.S. in Hydrology and Water Resources September 2011 – June 2016
Water Resources and Hydropower Engineering Department, Wuhan University, Hubei, China

PROFESSIONAL EMPLOYMENT

NSF-supported Non-academic Program Intern June 2019 – Present
Water Availability Group, Water Science and Conservation Division, Texas Water Department Board, Austin, Texas

- Designed model scenarios to simulate reservoir evaporation under various climate change and water demand conditions.

- Attended a quarterly agency board meeting and a division meeting
- Interviewed staff from different divisions to learn about the process of water planning projects and project financing activities undertaken by the agency

Research Assistant September 2018 – Present
Civil Engineering Department, Texas A&M University, College Station, Texas
- Investigated the continuous urban land cover change of the San Antonio City using remote sensing technique
- Studied the impacts of urbanization and climate variability on floods using DHSVM-Res over the Guadalupe River Basin and the San Antonio River Basin in Texas
- Modified the reservoir module of DHSVM-Res and studying the impacts of climate change on reservoir evaporation losses

Summer Intern June 2018 – August 2018
Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee
- Studied the characteristics of the major reservoirs in the Alabama-Coosa-Tallapoosa River Basin
- Calibrated the storage volume using DHSVM-Res based on remote sensing products
- Presented the research work of internship in the meeting of "Weekly Young Researcher Sharing"

Student Worker June 2017 – May 2018
Civil Engineering Department, Texas A&M University, College Station, Texas
- Processed hydrology and climate data using BASH and Python
- Calibrated and validated DHSVM-Res over the Guadalupe River Basin in Texas

PUBLICATIONS

Thesis

Shao, M. "The Amplification Effect of Urban Impervious Area on Urban Flood – Experiment and Simulation", *B.S.,* Wuhan University, June 2016

Shao, M. "Evaluating the Impacts of Urbanization and Climate Change on Streamflow by Comparing Two Neighboring Basins in Texas", *M.S.*, Texas A&M University, October 2018

Conference Presentations

Shao, M., N. Fernando, J. Zhu, G. Zhao, and H. Gao, Improving Surface Water Availability Estimates by Accounting for Projected Changes of Reservoir Evaporation, EOS Trans. AGU Suppl. 99(61), 2019.

Holmes, C., S. Gangrade, G. Zhao, K. Lander, N. Voisin, S.-C Kao, **M. Shao**, and H. Gao, Evaluating the Effects of Forecast Lead Time on Streamflow and Inundation Predictions in Brays Bayou, Houston, Texas through Coupled Hydrologic-Hydraulics Models, EOS Trans. AGU Suppl. 99(61), 2019.

Shao, M., G. Zhao, and H. Gao, Quantifying the Individual and Combined Impacts of Urbanization and Changing Climate on Hydrological Processes – A Case Study of Two Adjacent Basins, EOS Trans. AGU Suppl. 98(60), 2018.

Holmes, C., **M. Shao**, G. Zhao, and H. Gao, Evaluating the Impacts of Urbanization on Hydrological Processes that Contribute to Flooding in Brays Bayou, Houston, Texas, EOS Trans. AGU Suppl. 98(60), 2018.

Shao, M., G. Zhao, Holmes, C., S.-C Kao, and H. Gao, Evaluating the Impacts of Urbanization on Hydrological Processes and Water Resources by Comparing Two Neighboring Basins, EOS Trans. AGU Suppl. 97(59), 2017.

Gao, H., G. Zhao, K. Lee, S. Zhang, X. Shen, **M. Shao**, and C. Nickelson, Why understanding the impacts of the changing environment on river basin hydrology matters in Texas EOS Trans. AGU Suppl. 97(59), 2017.

Journal Publication

Shao, M., Zhao, G., Kao, S.-C., Cuo, L., Rankin, C., and H. Gao, "Quantifying the Effects of Urbanization on Floods in a Changing Environment to Promote Water Security — A Case Study of Two Adjacent Basins in Texas", to J. Hydrology (submitted).

References

[1] Abatzoglou, J. T. (2013). Development of gridded surface meteorological data for ecological applications and modelling. Int. J. Climatol., 33: 121-131.
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[13] Zhao, G., Gao, H., Naz, B., Kao, S.-C., & Voisin, N. (2016). Integrating a Reservoir Regulation Scheme into a Spatially Distributed Hydrological Model. Advances in Water Resources, 98, 16-31.
[14] Zhao, G., Gao, H., Kao, S.-C., Voisin, N., & Naz, B. S. (2018). A modeling framework for evaluating the drought resilience of a surface water supply system under non-stationarity. Journal of Hydrology, 563, 22-32.
[15] Zhao, G.; Gao, H. Estimating reservoir evaporation losses for the United States: Fusing remote sensing and modeling approaches. Remote Sens. Environ. (2019). 226, 109-124.