

SECURE Water Act Section 9505 Assessment

Effects of Climate Change on US Federal Hydropower

June 10, 2019

Shih-Chieh Kao

Senior Research Staff
Environmental Sciences Division
Oak Ridge National Laboratory
kaos@ornl.gov; <http://web.ornl.gov/~kaos>

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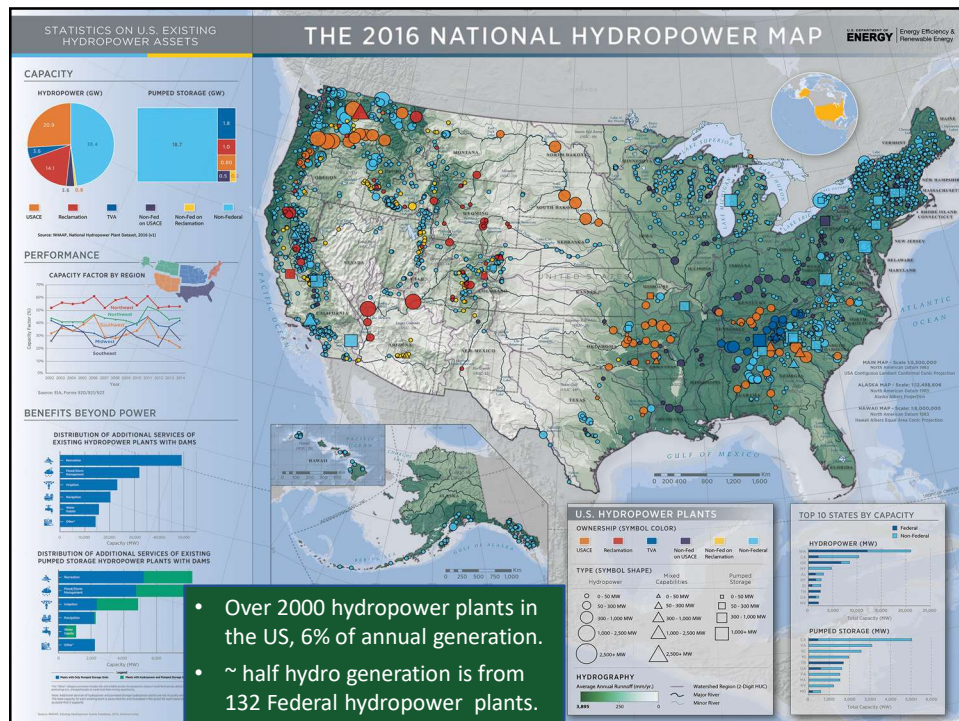
U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

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A Challenge for Energy-Water Management

- How may climate change affect water management?
- Need to store more water for summer
 - Increasing temperature
 - Increasing energy demand
 - More cooling water
 - Earlier snowmelt and runoff
- Need to drain more water for safety and environment
 - Intensified extreme precipitation
 - More direct runoff due to urbanization
 - Environmental flow requirement
- How can we evaluate climate change impacts on hydropower generation at regional/national scale?
 - Overall 2000 hydropower plants in the US



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US Congress Authorized a Study of Climate Impacts on Federal Hydropower in 2009

The SECURE (Science and Engineering to Comprehensively Understand and Enhance) Water Act has multiple parts, assigned to different agencies

Section 9501. Findings

Section 9502. Definitions

Section 9503. Reclamation Climate Change and Water Program

– Reclamation's 9503 Report to Congress

Section 9504. Water Management Improvement

Section 9505. Hydroelectric Power Assessment

– DOE's 9505 Report to Congress

This study

Section 9506. Climate Change and Water Intragovernmental Panel

Section 9507. Water Data Management by the U.S. Geological Survey

Section 9508. National Water Availability and Use Assessment Program

– USGS Report to Congress

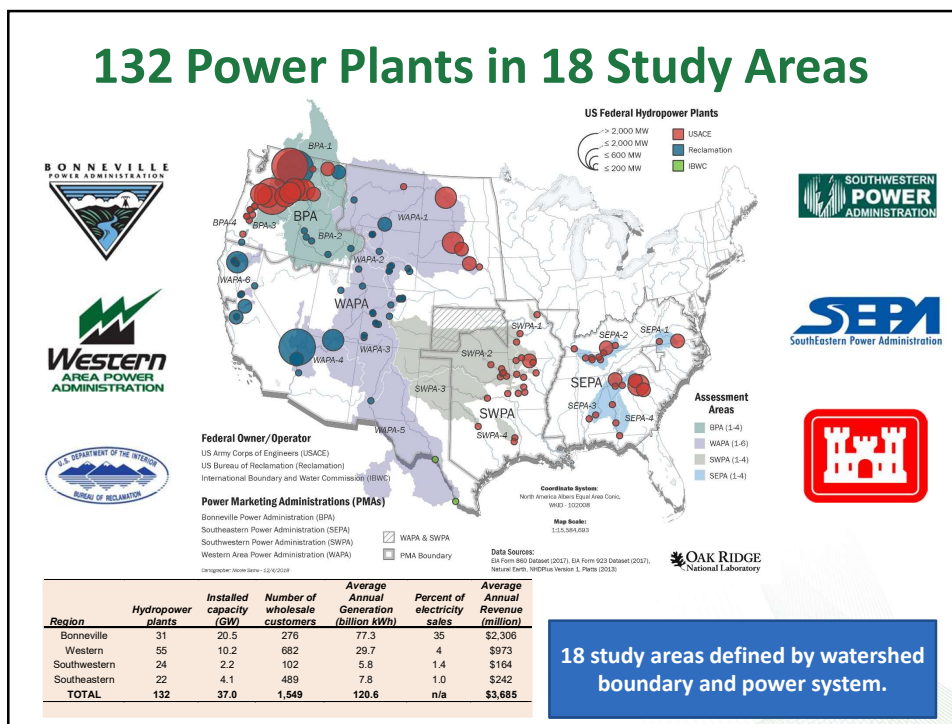
Section 9509. Research Agreement Authority

Section 9510. Effect

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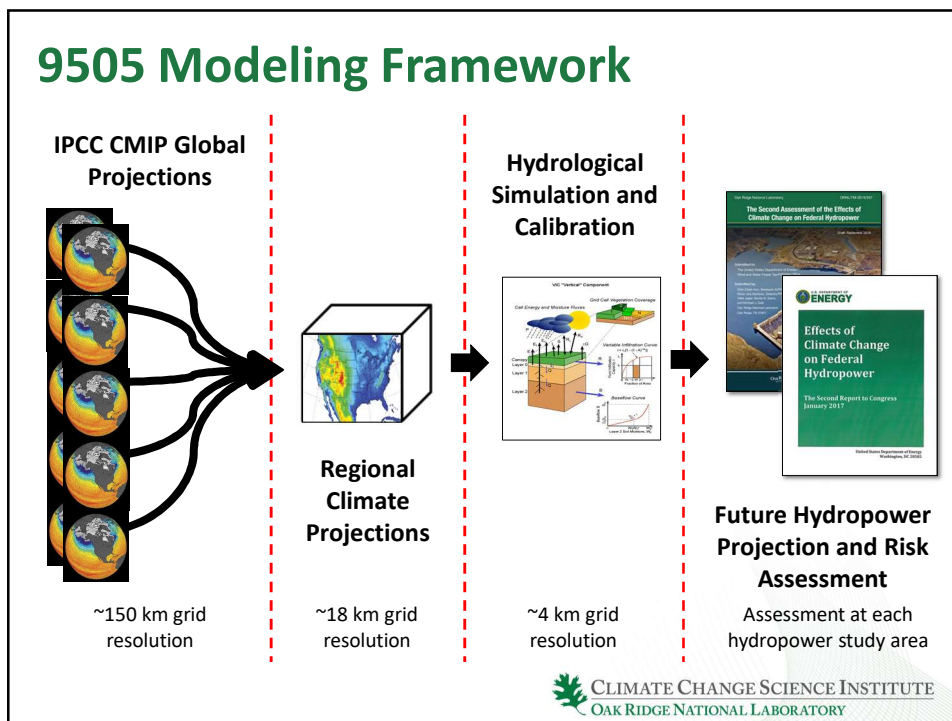
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132 Power Plants in 18 Study Areas

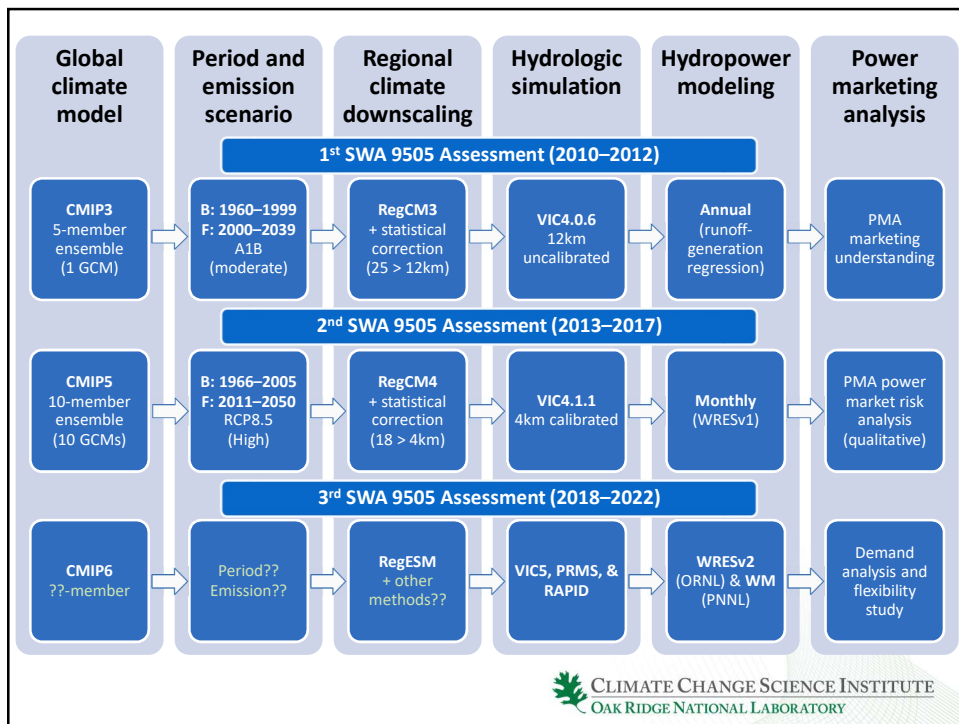


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9505 Modeling Framework

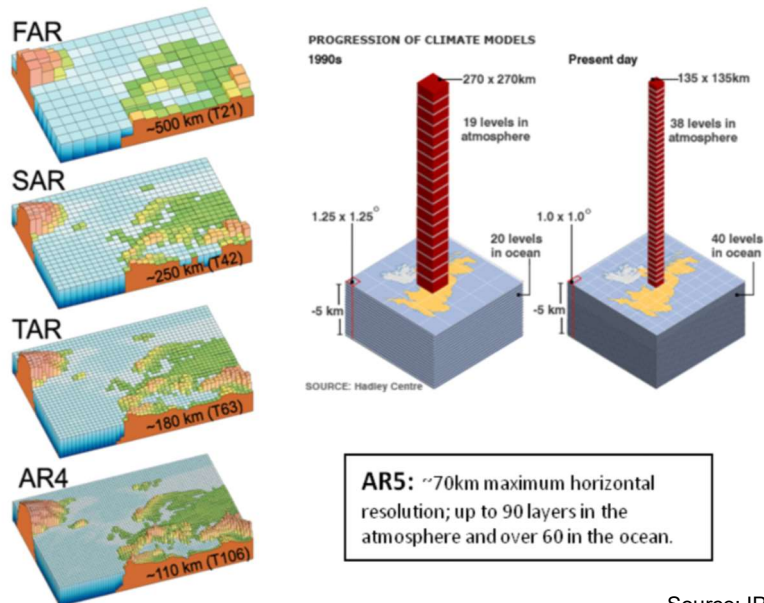


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Why Do We Need Downscaling?

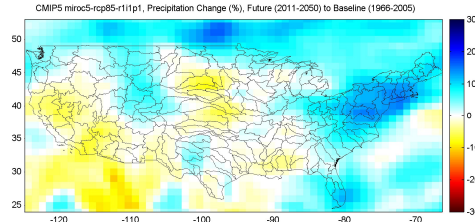


Source: IPCC

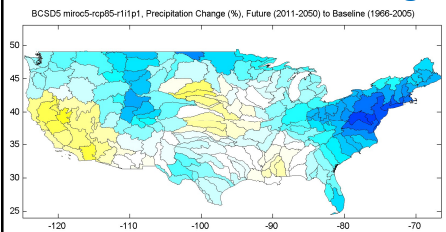
8

Effect of Different Downscaling Approaches

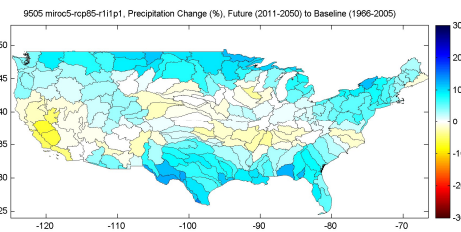
GCM Projection



Statistical Downscaling



Dynamical Downscaling



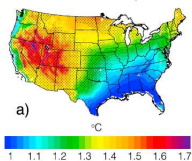
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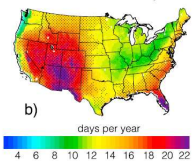
ORNL High-resolution CMIP5 Ensemble Projections

Projected changes (2011-2050 minus 1981-2005)

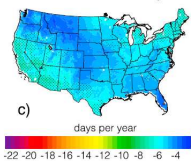
Annual Mean Temperature



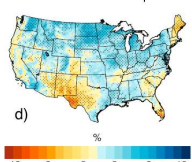
Extreme Hot Days



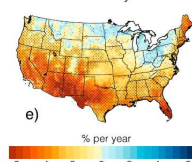
Extreme Cold Days



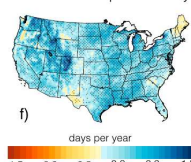
Annual Mean Precipitation



Wet Days



Extreme Precipitation Days



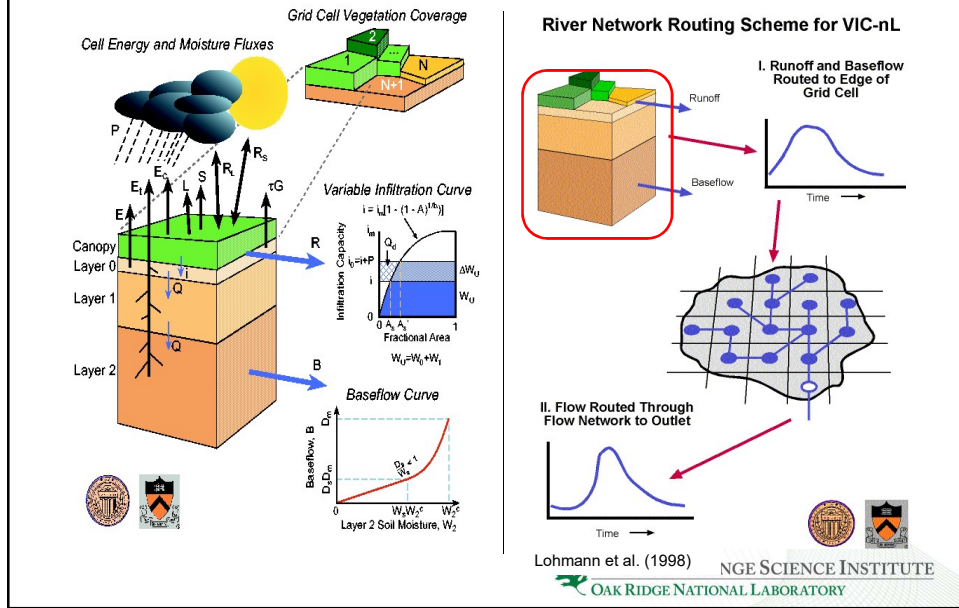
- 11 CMIP5 GCMs
- Baseline period
— 1966–2005
- Future (RCP8.5)
— 2011–2050
- Dynamically
downscaled by
RegCM4 to 18km
- Statistical
correction (quantile
mapping) to 4km
- ~15 Million
computation hours,
200 Terabytes
storage

Ashfaq, M., D. Rastogi, R. Mei, S.-C. Kao, S. Gangrade, B. S. Naz, and D. Touma (2016), High-resolution Ensemble Projections of Near-term Regional Climate over the Continental United States, *J. Geophys. Res.-Atmos.*, 121, 9943-9963, doi:10.1002/2016JD025285.

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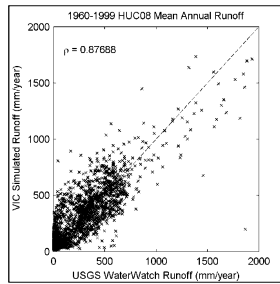
Hydrologic Simulation – VIC model



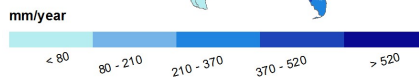
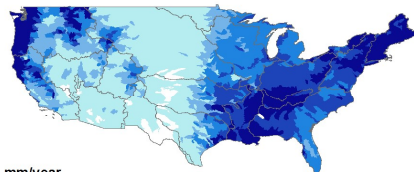
11

Runoff Calibration

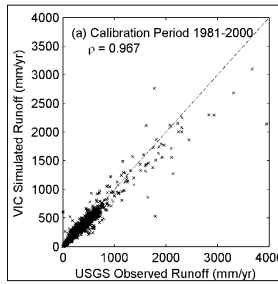
12-km VIC simulation (used in 9505-1)



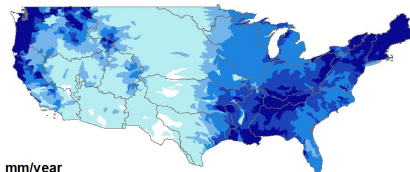
(a) Simulated Runoff (1981 – 2000)



4-km VIC simulation



(b) Observed Runoff (1981 – 2000)



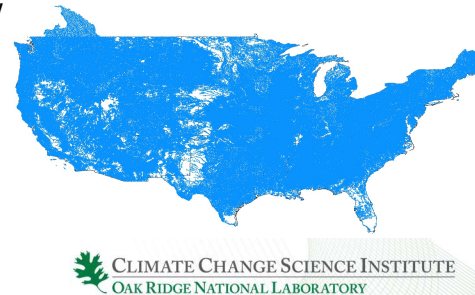
Naz, B. S., S.-C. Kao, M. Ashfaq, D. Rastogi, R. Mei, and L. C. Bowling (2016), Regional Hydrologic Response to Climate Change in the Conterminous United States Using High-resolution Hydroclimate Simulations, *Global Planet. Change*, 143, 100-117, doi:10.1016/j.gloplacha.2016.06.003.

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River Network Routing

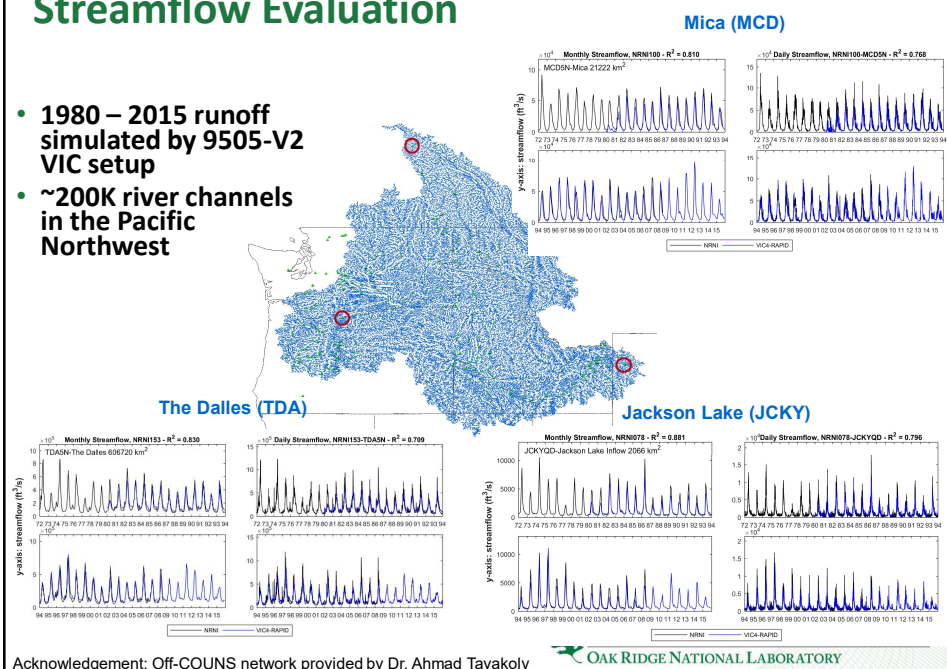
- **Routing Application for Parallel computation of Discharge (RAPID; David et al., 2011)**
 - Routing component in the National Water Model
 - Matrix-based Muskingum method
 - Accumulate runoff and baseflow through prescribed river network
 - Can leverage the ~3M NHDPlus river network/segments
 - Allows input of upstream inflow
 - Don't need to run the entire CONUS model
 - Enable new calibration approach
 - We are planning to use the RAPID platform to account for further 9505 related river routing issues (e.g., water withdrawal, diversion, evaporation loss, etc.).



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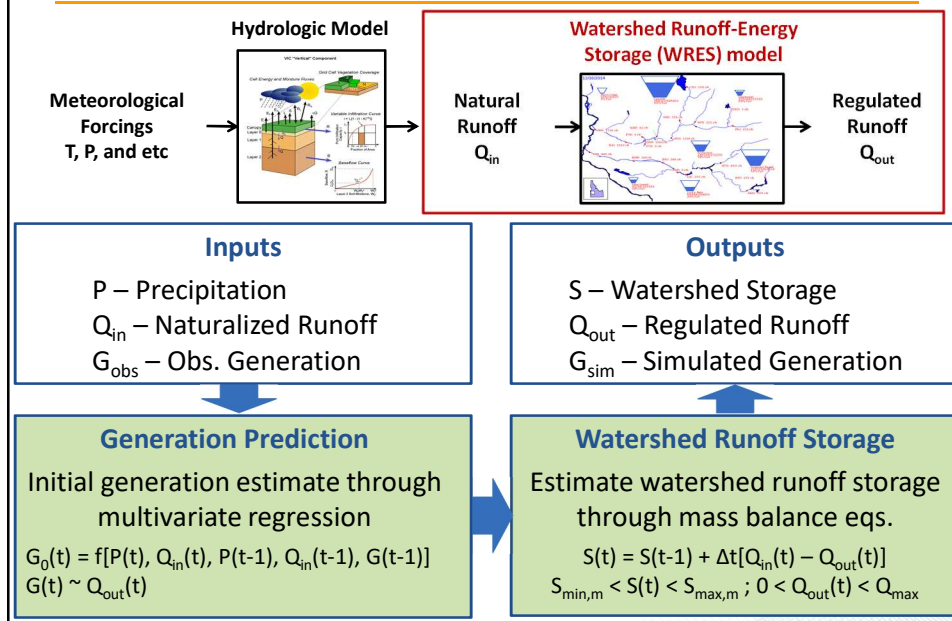
Streamflow Evaluation

- 1980 – 2015 runoff simulated by 9505-V2 VIC setup
- ~200K river channels in the Pacific Northwest



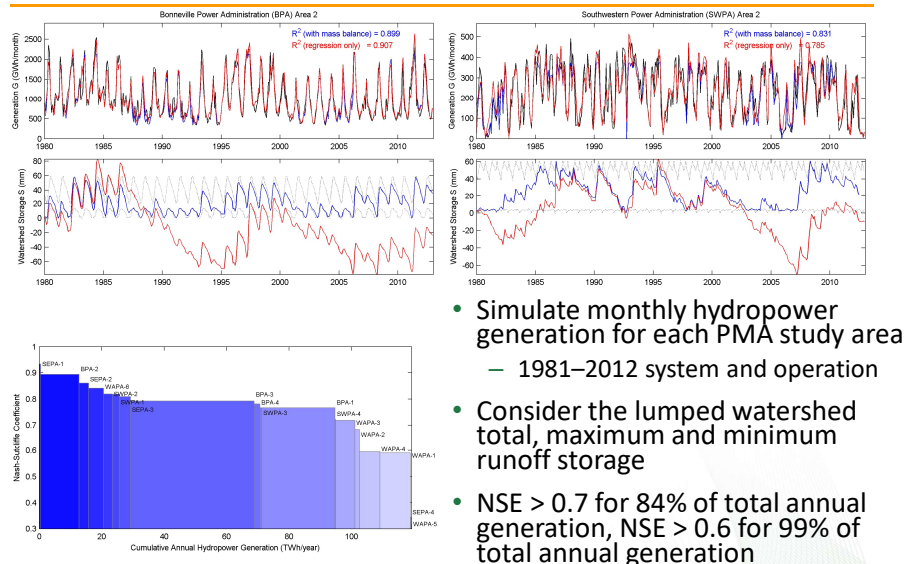
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Simulation of Regional Hydropower Generation



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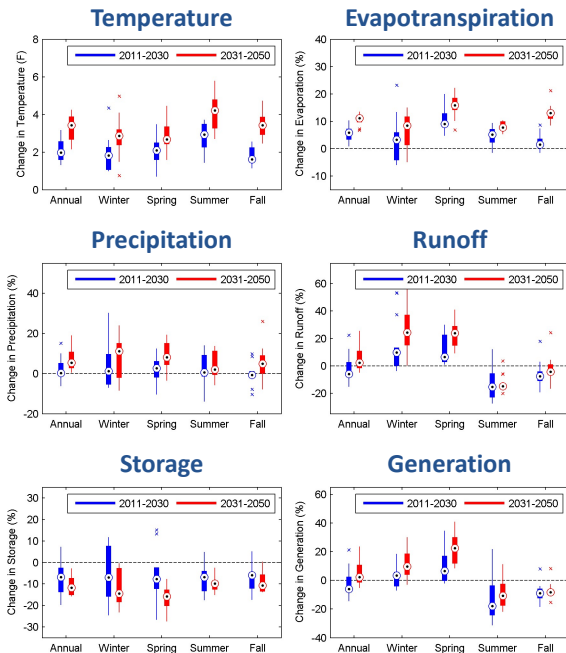
WRES Performance



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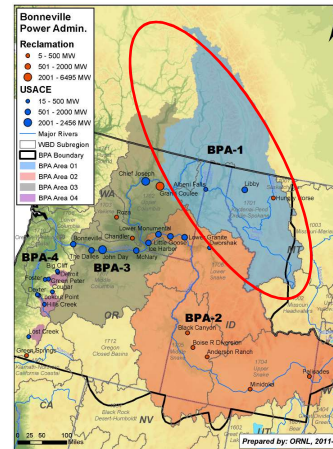
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Projected Change by 10 ORNL simulations



Example end results
from 9505-V2

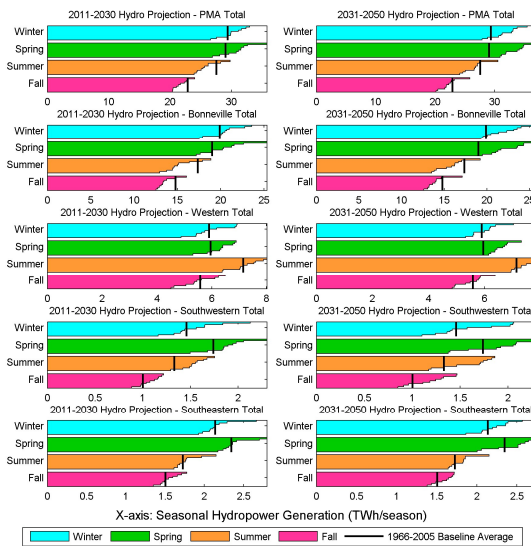
Bonneville – Area 1



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Example end results from 9505-V2

Impacts on Seasonal Hydropower Generation



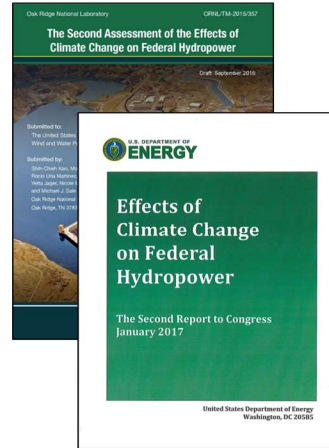
- In general, more hydropower generation during winter and spring while less during summer and fall.
- Earlier snowmelt and change of runoff seasonality are the main factors affecting future hydropower generation.
- The relatively larger reservoir storage of federal hydropower fleet may help buffer the increasing future runoff variability.
- The site-specific challenges are to be better understood in the future assessment.

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The 2nd 9505 Assessment (2013–2017)

- Conducted during 2013–2017, based on downscaled IPCC-CMIP5 global climate projections.
- Focused on regional scale and provided a first-order assessment to identify areas with the highest risk.
- Provide updated modeling tools and near-term future hydropower projections (2011–2050) for 132 US federal hydropower plants.
- Results suggested that earlier snowmelt and change of runoff seasonality are the main factors affecting future U.S. federal hydropower generation.



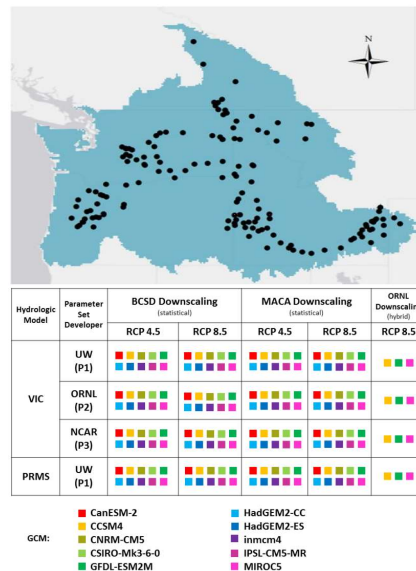
<http://nhaap.ornl.gov/9505-2>

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9505-V2 Support for Regional Planning

- The 2nd Columbia River Management Joint Operating Committee Long-term Planning Study (RMJOC-II)
- Provide hydrologic model parameters (VIC-P2) to support Univ. of Washington's multi-ensemble simulation
 - VIC-P1: calibrated by UW
 - VIC-P3: calibrated by NCAR
- Provide dynamically downscaled future climate projection data for 3 overlapping GCMs
 - Alternatives to BCSD and MACA (both are statistical downscaling approaches).
- The ensemble streamflow datasets are used for further flow regulation studies and other applications.



RMJOC-II Part I Final Report (<https://www.bpa.gov/p/Generation/Hydro/hydro/cc/RMJOC-II-Report-Part-I.pdf>)

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What's New with 9505-V3 (2018–2022)

- **Will be based on the upcoming IPCC CMIP6 projections**
- **Better quantify / inform uncertainties**
 - Multiple observational data sets (Daymet, PRISM, Livneh)
 - Multiple hydrologic models (VIC, PRMS)
 - Multiple hydropower models (ORNL's WRES & PNNL's WM)
- **In-depth power marketing analysis**
 - PMA energy demand analysis
 - PMA operational flexibility study
- **Potential non-federal analysis**
 - Extension to cover non-federal fleet
 - Hydropower simulation will remain regional (HUC02), but can provide site-specific streamflow projections to support other applications
 - Engage non-federal stakeholders through CEATI-CCORA



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Timeline of the 3rd 9505 Assessment

Phase 1 – Initial Methodology Development (FY2018)

- 9505-V3 Kick-off Meeting (3/23/2018)
- Methodology Development: Climate Projection and Downscaling (5/17/2018)
- Methodology Development: Historic Observation and Hydrologic Modeling (7/26/2018)
- Methodology Development: Hydropower Simulation & Power Marketing Analysis (9/25/2018)

Phase 2 – Simulation and Analysis (FY2019)

- **Methodology Workshop (scheduled 3/27 – 3/28/2019)**
- 1st Review of Technical Assessment Results (webinar)
- 2nd Review of Technical Assessment Results (webinar)
- Finalization of Technical Assessment Results (webinar)

Phase 3 – Report Development and External Review (FY2020)

- PMA Early Review of ORNL Technical Assessment Report
- Finalization of Draft ORNL Technical Assessment Report and External Review
- Finalization of ORNL Technical Assessment Report
- Finalization of Draft DOE Report to Congress

Phase 4 – Concurrence Review and Report to Congress Delivery (FY2021)

- DOE Concurrence Review Starts
- DOE Delivery of Report to Congress (**by March 31, 2021***)

***Could be delayed due to IPCC 6th assessment schedule**



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NHM-PRMS Implementation

- **USGS Precipitation-Runoff Modeling System (PRMS; Markstrom et al., 2015)**

- Deterministic, distributed-parameter, process based modeling system
- Computes energy & water balance at each hydrologic response unit (HRU)
- Simulate hydrologic water budgets at the watershed scale for temporal scales ranging from days to centuries

- **National PRMS Implementation (NHM-PRMS)**

- Built upon the national geospatial fabric (Viger and Bock, 2014) within the NHM infrastructure (Regan et al., 2018)
- Calibrated version by Hay (2019)
- A multiple-objective, step-wise, automated calibration procedure was used to identify the optimal set of parameters for each HRU.

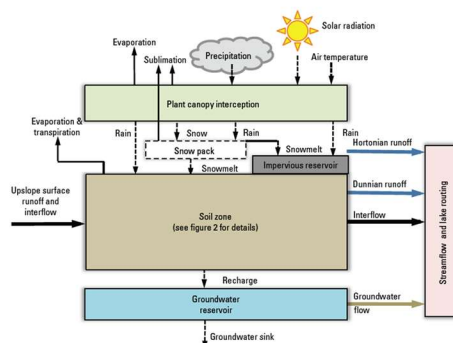


Figure 1. Hydrological processes simulated by the Precipitation-Runoff Modeling System (modified from Markstrom and others, 2008).

Markstrom et al. (2015)

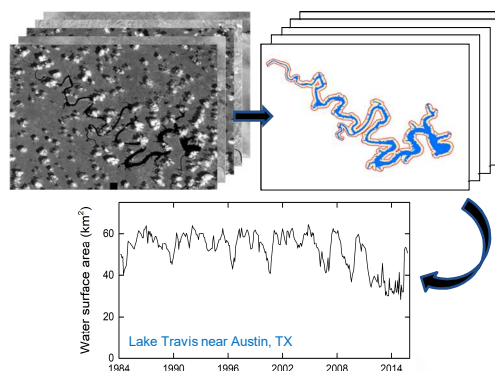
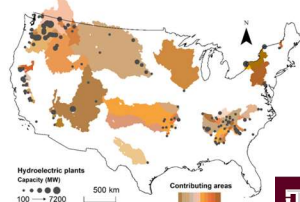
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Remote Sensing Based Reservoir Area / Storage Estimation

- **Provide alternative reservoir area / storage estimations to overcome data limitation**

- Provide 1984–2017 monthly images, values, and analyses for over 130 CONUS reservoirs
- To be validated by in situ observation
- Important input for enhancing hydrologic modeling



Zhao, G., and H. Gao (2018), Automatic correction of contaminated images for assessment of reservoir surface area dynamics, *Geophys. Res. Lett.*, 45, <https://doi.org/10.1029/2018GL078343>.

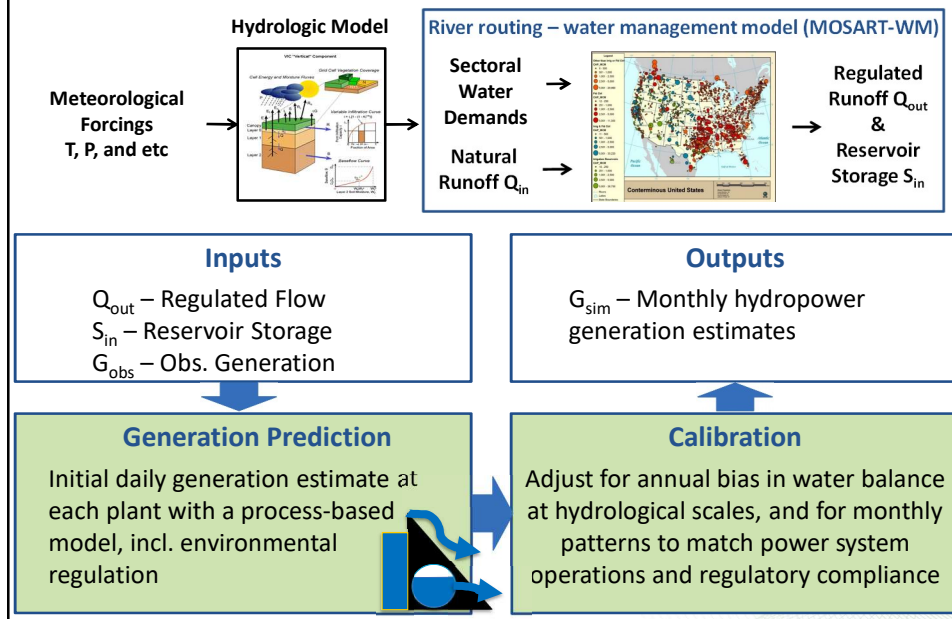
Lead: Dr. Huilin Gao, Texas A&M

ATM TEXAS A&M UNIVERSITY

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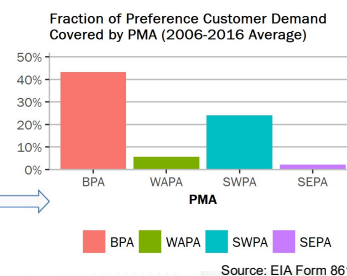
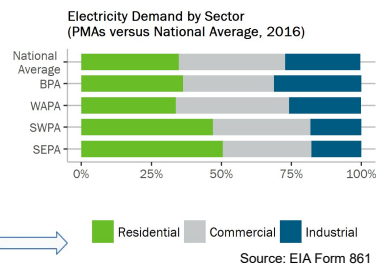
PNNL's Regional Hydropower Model – WM



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Power Marketing Analysis

- **PMAs balance federal hydropower supply and preference customer demand in their day-to-day operations**
 - Other 9505 tasks focus on effects of climate trends on federal hydropower supply
 - Power marketing analysis task explores:
 - effects on PMA customer (i.e., preference customer) demand
 - Preference customers are mostly municipalities & cooperatives with large % of temperature-sensitive residential demand
 - flexibility mechanisms to balance supply & demand
- **What is the net (supply + demand) effect of projected climate trends in the value of federal hydropower to its current customers?**
 - What percentage of preference customer demand does PMA contract cover?
 - Can vary a lot year to year due to hydrology and also depends on how the PMA markets the energy
 - Is federal hydropower available when most valuable to the customer?

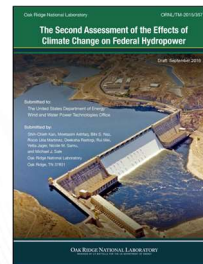
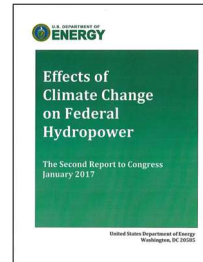


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Expected 9505-V3 Outcome

- **The 3rd SECURE Water Act Section 9505 Department of Energy (DOE) Report to Congress (RtC)**
 - ~20 page high-level summary about the findings
 - Published by DOE, includes recommendations from PMA Administrators
 - Will go through the full DOE concurrence review
 - Targeted 2021 (if possible, to be consistent with Reclamation's 9503 report timeline)
- **Companion ORNL Technical Memorandum**
 - Over 200 pages capturing all technical details
 - Lead by ORNL with inputs from other partners
 - Will be reviewed by over 20 internal/external experts
 - To be completed ~ half year before the RtC
- **Also provide related new models, parameters, future water availability scenarios, and regional hydropower projections to support further national / regional studies**
- **Additional analysis for non-federal fleet (separate report)**



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Thank you Questions?

Shih-Chieh Kao (kaos@ornl.gov)

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Backup Slides / References



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SECURE Water Act (SWA), Pub. L. 111-11

Section 9505. HYDROELECTRIC POWER ASSESSMENT.

(a) Duty of Secretary of Energy- The Secretary of Energy, in consultation with the Administrator of each Federal Power Marketing Administration, shall assess each effect of, and risk resulting from, global climate change with respect to water supplies that are required for the generation of hydroelectric power at each Federal water project that is applicable to a Federal Power Marketing Administration.

(b) Access to Appropriate Data-

(1) IN GENERAL- In carrying out each assessment under subsection (a), the Secretary of Energy shall consult with the United States Geological Survey, the National Oceanic and Atmospheric Administration, the program, and each appropriate State water resource agency, to ensure that the Secretary of Energy has access to the best available scientific information with respect to presently observed impacts and projected future impacts of global climate change on water supplies that are used to produce hydroelectric power.

(2) ACCESS TO DATA FOR CERTAIN ASSESSMENTS- In carrying out each assessment under subsection (a), with respect to the Bonneville Power Administration and the Western Area Power Administration, the Secretary of Energy shall consult with the Commissioner to access data and other information that--

(A) is collected by the Commissioner; and

(B) the Secretary of Energy determines to be necessary for the conduct of the assessment.

(c) Report- Not later than 2 years after the date of enactment of this Act, and **every 5 years** thereafter, the Secretary of Energy shall submit to the appropriate committees of Congress a report that describes--

(1) each effect of, and risk resulting from, global climate change with respect to--

(A) water supplies used for hydroelectric power generation; and

(B) power supplies marketed by each Federal Power Marketing Administration, pursuant to--

(i) long-term power contracts;

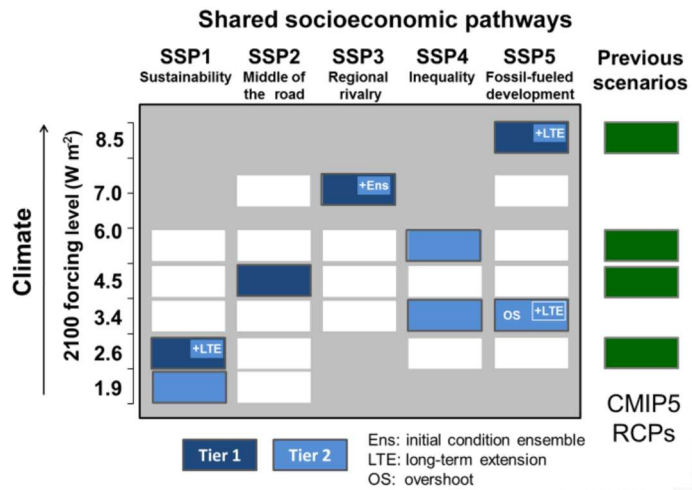
(ii) contingent capacity contracts; and

(iii) short-term sales; and

(2) each recommendation of the Administrator of each Federal Power Marketing Administration relating to any change in any operation or contracting practice of each Federal Power Marketing Administration to address each effect and risk described in paragraph (1), including the use of purchased power to meet long-term commitments of each Federal Power Marketing Administration.

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New IPCC RCPs for AR6



Historical period : 1850-2014
Projections period : 2015-2100

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