Quick Discussion before Presentation on National Water Model

Vision for Working Group

Upgrade hydrologic forecasting in the bay area, and better understand how to use AQPI to do so, by cooperation and knowledge sharing with other agencies, NWS, & NOAA Research.

(to distinguish) user groups will be created to .. "Exchange technical information and provide feedback for the continued improvement of the AQPI system usability and the information it provides."

What do we want (your answers from Watershed WG Meeting #1):

- *Brainstorming on "chat" platform*
- *Shared lessons learned so we don't make the same mistakes*
- *Having a sounding board for new ideas and approaches*
- *A platform for asking questions or discussing ideas/issues with others*
- *Comparing standards, procedures and approaches*
- *Just knowing what others are doing. Also a common set of modeling and design standards for the design community, at least to the extent possible. Same set of boundary conditions for modelers (like tides) so infrastructure around the bay is designed somewhat coherently.*
- *Appreciated hearing about the various data sources available to others, and how they analyze the data to make better predictions*
- *I am interested in seeing how other agencies utilize AQPI data for their models.*

Goals:

AQPI

- ➔ Get agencies talking to each other
- ➔ Problem solving
- ➔ Helping each other increase capacity of aqpi use
- ➔ Concept of operations examples
- ➔ Iterative feedback/improvement of aqpi system
- ➔ Case studies

What's next -- how will AQPI transition?
Next phase ownership

Agency

- ➔ Education
- ➔ Standards and best practices
- ➔ Sharing knowledge
- ➔ Networking

Preeminence/expertise

Name: ______ ______ Working Group (voting on via email)

Watershed Modeling
Machine to Machine
AQPI Powers Users
Data Implementation
Boaty McBoatface Weed Users Group

Collaboration Platform (chatting, sharing):

~~Quip~~
Slack?
~~Google~~
~~MS Teams~~
Basecamp

Sharing Documents/Code:

Shared Drive SFPUC https://sfpuc.sharefile.com/Authentication/Login

Recordings, Agendas, Presentations:

AQPI Website > User Resources https://psl.noaa.gov/aqpi/

National Water Model Overview

Watershed Modeling Group Discussion

June 17, 2020

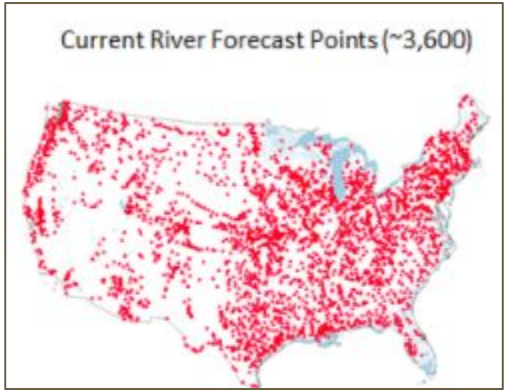
Rob Cifelli, Jungho Kim, Lynn Johnson

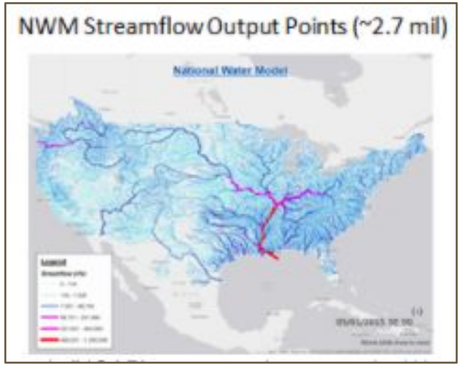
Many good questions about the model

- What is it ?
- How does it handle water management and hydraulics?
- How well does it do?

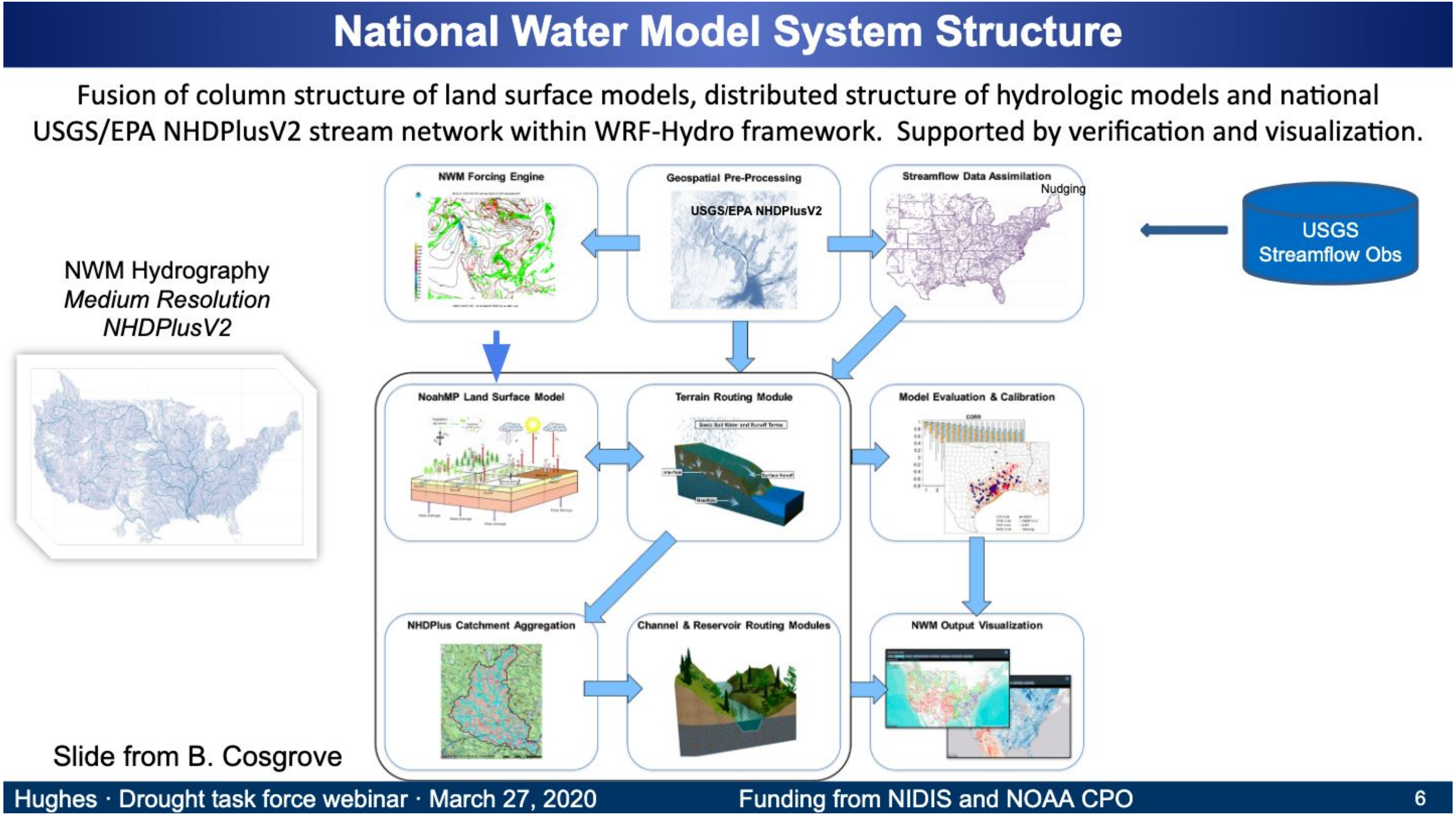
What is it?

- Hydrologic model run by NOAA (Office of Water Prediction) over whole U.S. to simulate observed and forecast streamflow
- Complements the guidance produced by River Forecast Center at ~4000 points across the U.S. and guidance at ~2 million other locations
- Attempts to use “physically based” representation of infiltration, snow, etc
- Brief overview of the NWM in this handout and at this website





https://water.noaa.gov/


National Water Model System Structure
Fusion of column structure of land surface models, distributed structure of hydrologic models and national USGS/EPA NHDPlusV2 stream network within WRF-Hydro framework. Supported by verification and visualization.
NWM Hydrography
Medium Resolution
NHDPlusV2
NWM Forcing Engine
Geospatial Pre-Processing
USGS/EPA NHDPlusV2
Streamflow Data Assimilation
Nudging
USGS
Streamflow Obs
NoahMP Land Surface Model
Terrain Routing Module
Model Evaluation & Calibration
NHDPlus Catchment Aggregation
Channel & Reservoir Routing Modules
NWM Output Visualization
Slide from B. Cosgrove
Hughes · Drought task force webinar · March 27, 2020
Funding from NIDIS and NOAA CPO
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Enhancing the NWM: Development Trajectory

v1.0

Foundation: 2016
Water resource model
2.7 million reaches

v1.1/1.2/2.0

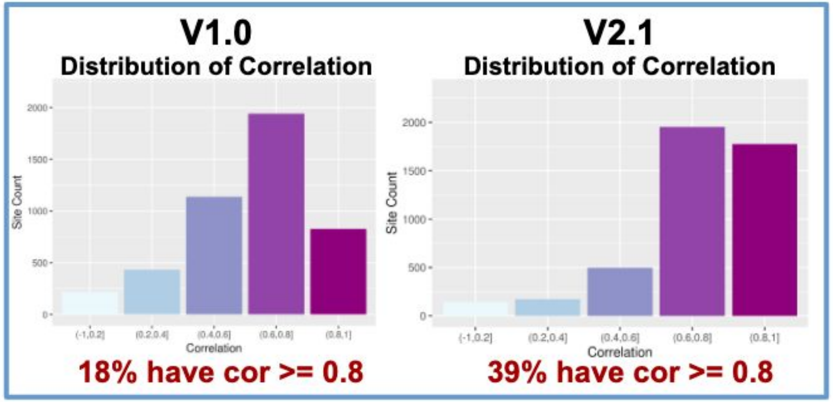
Upgrades: 2017/2018/2019
Hawaii, medium range ens., physics upgrades, improved modularity, MPE ingest

v2.1

Next Upgrade: Early 2021
Expansion to PR and Great Lakes, reservoir modules, forcing upgrades, open-loop, and improved Hawaii forcing

v3.0

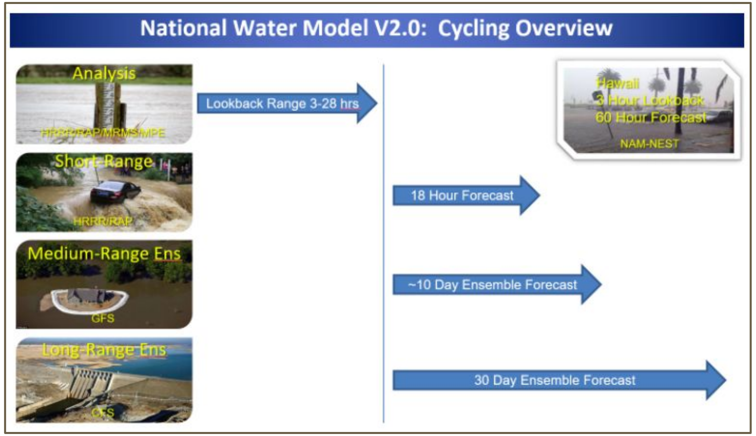
Future Upgrade: 2022
Coastal coupling, expansion to Alaska, improved groundwater and infiltration, hydro-fabric upgrades



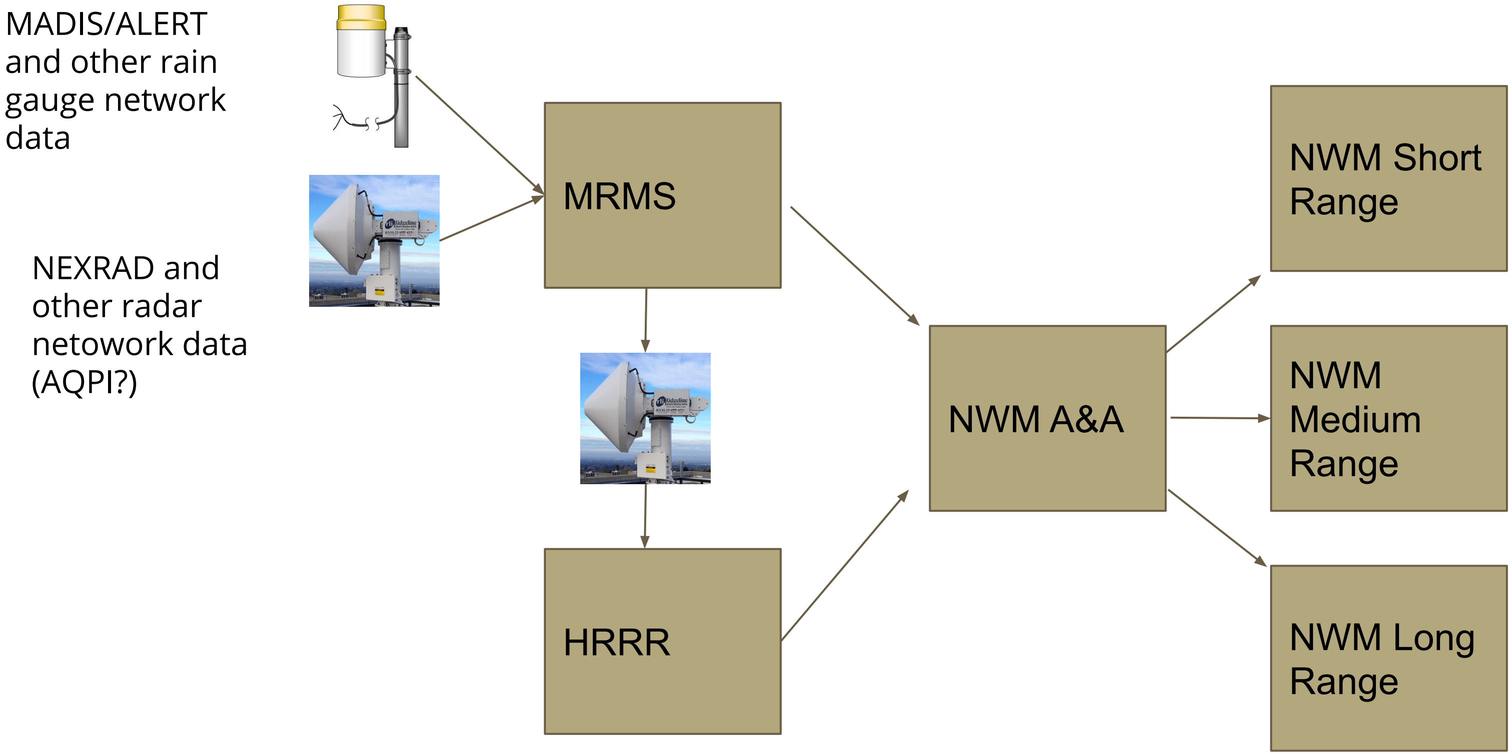
Slide from B. Cosgrove

What is it forced with? (Strudley)

- NWM is run over 4 different simulation cycles:
- A&A (i.e, observed streamflow): every hour using MRMS and HRRR forcing
- Short range forecast streamflow (out to 18 hrs): every hour using HRRR
- Medium range forecast streamflow (out to 10 days) using GFS
- Long range forecast streamflow (out to 30 days) using CFS

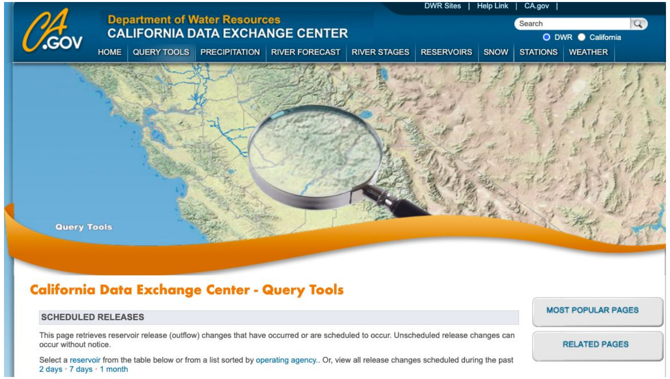


How is MADIS/ALERT data integrated (Strudley)?



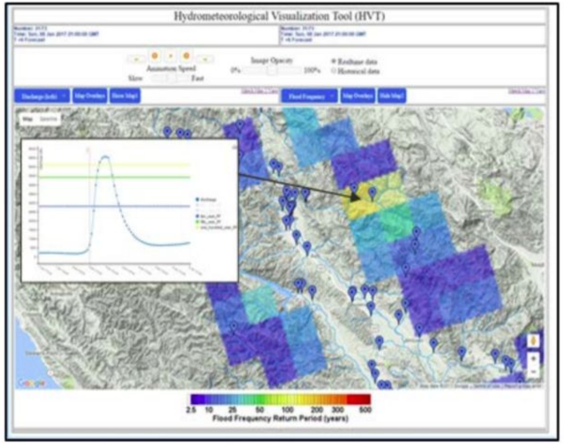
How does NWM treat reservoirs? (Strudley)

- Right now - not very well "Spill and fill"
  - Level pool routing
  - Update release with USGS gage observation if available
- Next version (2.1) will use release schedules posted by USACE on some reservoirs
- Can releases posted on CDEC eventually be included?



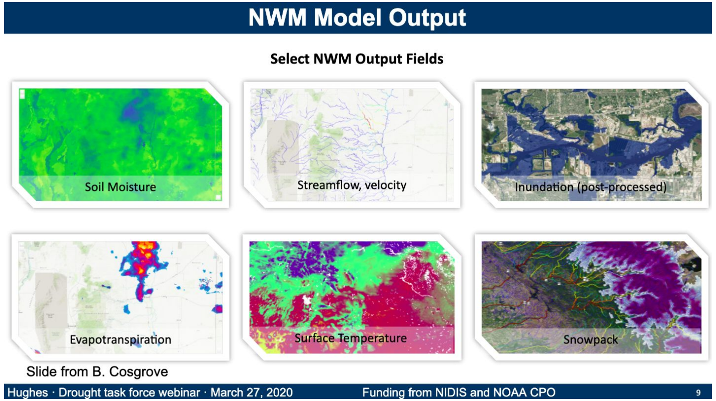
How are flood thresholds set? (Strudley)

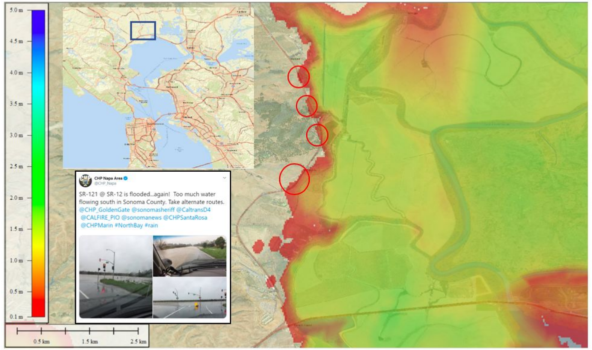
- NWM does not include thresholds at present
- AQPI plan is to include flood frequency level for every stream reach
    - USGS approach
- AQPI could include local users' information on thresholds



Is there Routing and Flood inundation Modeling capabilities now? (Strudley)

- Yes on the routing - see previous slide
- Inundation - under development - shared internally within NWS
- Inundation will be available via CoSMoS



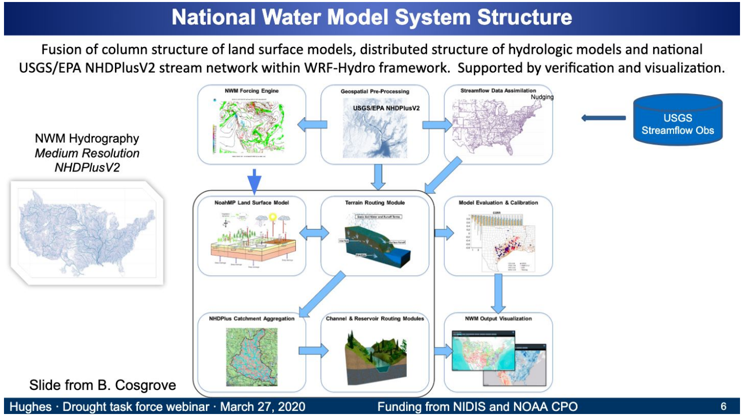


What's the NWM resolution? (Boucher)

- Water balance (i.e. infiltration) computed at 250 m grid
  - Based on WRF-Hydro Noah-MP Land Surface Model (LSM)
  - See: https://ral.ucar.edu/solutions/products/noah-multiparameterization-land-surface-model-noah-mp-lsm
- Excess runoff accumulated to 1 km grid and routed to stream reach
- Stream reaches have variable length, but ~1 km
  - ~11,000 stream reaches in AQPI 9 counties
- Forecast hydrograph available for every stream reach

How are streams represented in a distributed model? (Boucher)

- River/stream network based on USGS NHD-Plus
  - ~11,000 stream reaches in AQPI 9 counties
- Separate water routing modules perform
  - Diffusive wave surface (hillslope) routing and saturated subsurface flow routing on a 250m grid
  - Muskingum-Cunge channel routing down National Hydrography Dataset (NHDPlusV2) stream reaches
- Baseflow from groundwater added along stream reach
  - Relevant for low flows and flood flow recessions

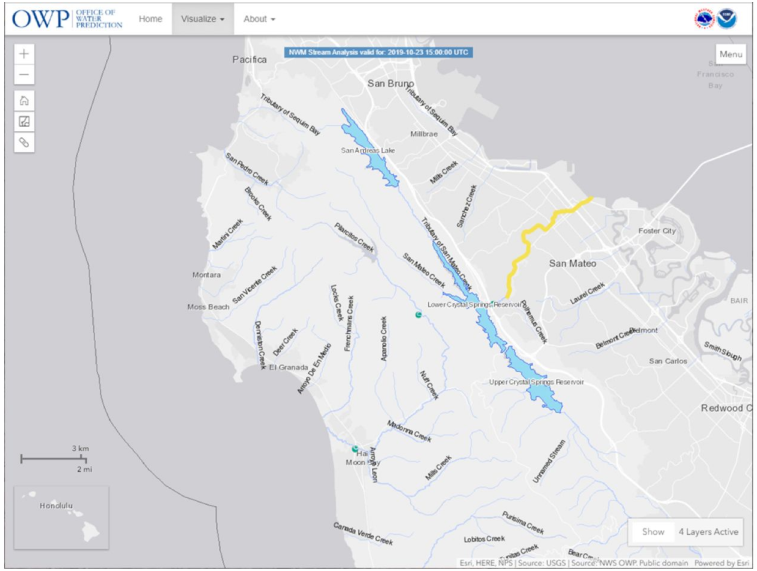


Can local input be used to change the flow directions and, if so, how would this work? (Boucher)

- In theory - yes - but the process is not entirely clear (to us)
- Who work with?
  - For errors in the stream network (NHD+), probably USGS
  - For the NWM calibration and identification of large errors, NCAR and Office of Water Prediction
- How contact them
  - Suggest we develop a process for this using the Watershed Modeling Group
- Are they doing this elsewhere
  - Ventura County, CA and maybe other places as well
- Is there a formal process - what do they need from us
  - The AQPI team has reached out on this and is waiting for a response

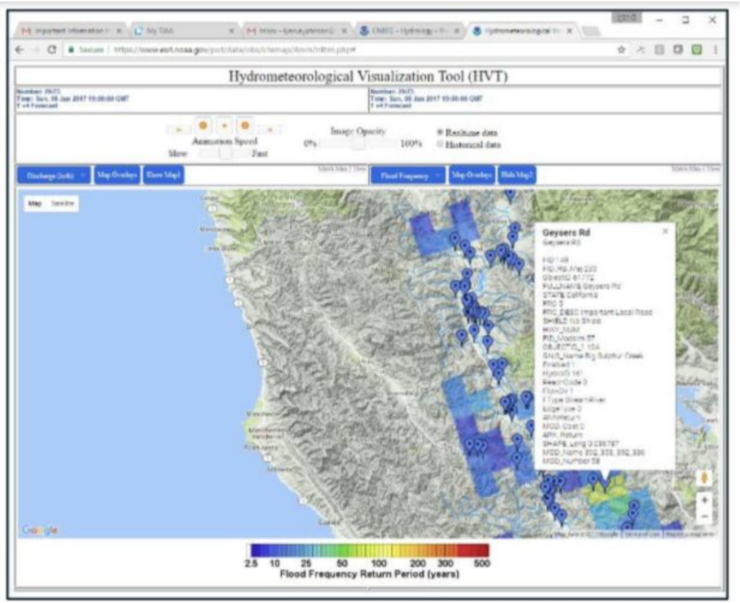
Can the stream network lines be revised (Boucher)?

- Ventura County engaged Office of Water Prediction to do something similar to this
- Told to work with USGS to revise the NHD+ network
- Required filling out forms...
- Not sure they followed through but it sounds like it can be done



If establish flood watch or warning for a location (Boucher)

- How would that show up on the map?
  - Developed prototype several years ago for how this might be done
- Would the NWM be automated to send a warning message?
  - AQPI can be configured to send out message when threshold is exceeded
  - Watches/warnings would come through NWS



What rainfall-runoff transformation is being used (Leventhal)

- Unit hydrographs?
  - No. Unit hydrographs (for lumped and semi-distributed models, a conceptual model) not used
  - The NWM is a distributed hydrologic model
- Water balance for R-R transformation is physics based.
  - WRF-Hydro Noah-MP CFS System Land Surface Model (LSM)
    - A separate vegetation canopy and surface radiation dynamics
    - Multi-layer snow pack with liquid water storage and melt/refreeze capability
    - Multiple options are available for surface water infiltration and runoff and groundwater transfer and storage including water table depth to an unconfined aquifer
  - https://ral.ucar.edu/solutions/products/noah-multiparameterization-land-surface-model-noah-mp-lsm
  - https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2010JD015139

Does it include real hydraulics? (Leventhal)

- WRF-Hydro is configured to use the Noah-MP Land Surface Model (LSM) to simulate land surface processes.
- Separate water routing modules perform diffusive wave surface routing and saturated subsurface flow routing on a 250 m grid, and
- Muskingum-Cunge channel routing down National Hydrography Dataset (NHDPlusV2) stream reaches.
- No stormwater management simulation system for urban areas

Calibration: Period and Forcing

- Spin up with the default parameters: (2007-10 to 2016-10)

- Iteration 1 to n (max number of iterations)
  - Spin up: 1 year (2007-10 to 2008-10)
  - Calibration: 5 years (2008-10 to 2013-10)

- Final Parameters
  - Validation: 3 years (2013-10 to 2016-10)

- What to use as forcing data?
  - Ideally, it is preferred to calibrated using the same forcing as what is used in for the final application.
  - Downscaled NLDAS-2 in NWMv1.1 and NWMv1.2.
  - A mountain-mapper adjustment to the precipitation data of downscaled NLDAS-2 in NWMv2.0.
  - Analysis of Record for Calibration (AORC) introduced by Kitzmiller et al. 2019 in NWMv2.1.

Calibration: Methodology

- Dynamically Dimensioned Search (DDS) algorithm
  - Search strategy in model parameter space is scaled to the maximum number of iterations specified by the user.
  - In initial iteration the algorithm search globally and as the procedure approached the maximum user-defined number of iterations, the search transition from a global to a local search.

Water Resources Research

Regular Article | Free Access

Dynamically dimensioned search algorithm for computationally efficient watershed model calibration

Bryan A. Tolson, Christine A. Shoemaker

First published:17 January 2007 | https://doi.org/10.1029/2005WR004723 | Citations: 299

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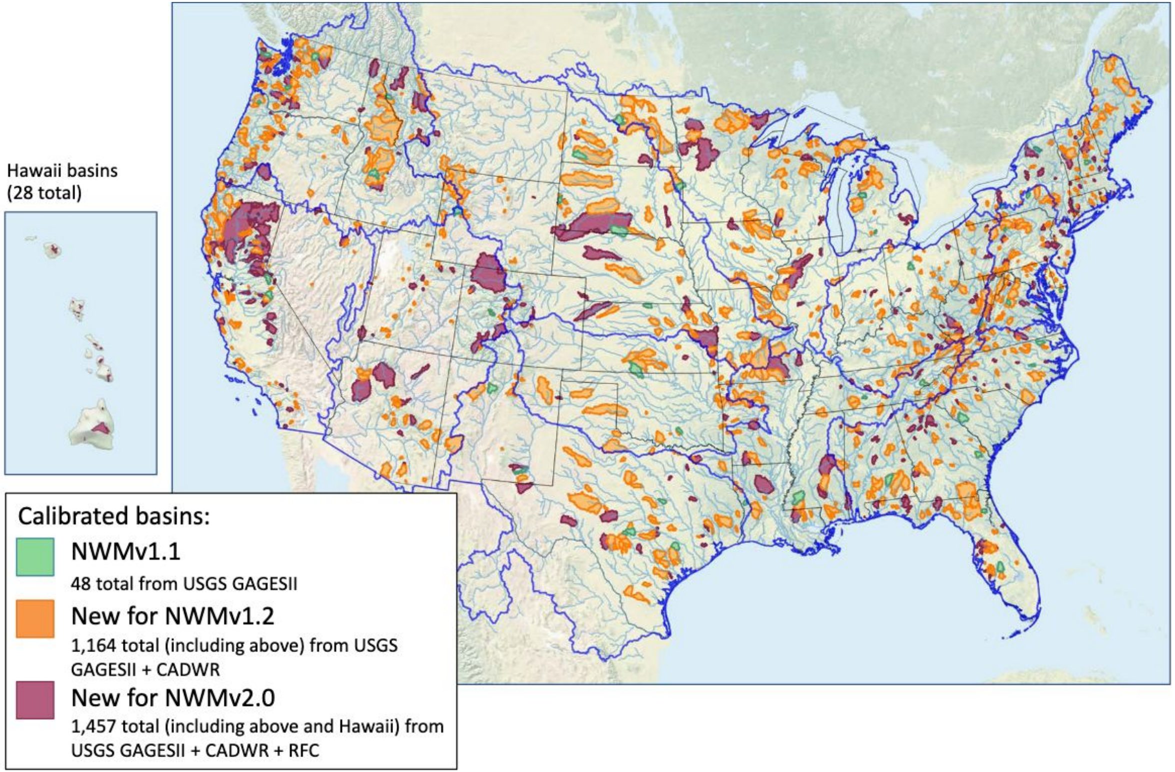
Abstract

[1] A new global optimization algorithm, dynamically dimensioned search (DDS), is introduced for automatic calibration of watershed simulation models. DDS is designed for calibration problems with many parameters, requires no algorithm parameter tuning, and automatically scales the search to find good solutions within the maximum number of user-specified function (or model) evaluations. As a result, DDS is ideally suited for computationally expensive optimization problems such as distributed watershed model calibration. DDS performance is compared to the shuffled complex evolution (SCE) algorithm for multiple optimization test functions as well as real and synthetic SWAT2000 model automatic calibration formulations. Algorithms are compared for optimization problems ranging from 6 to 30 dimensions, and each problem is solved in 1000 to 10,000 total function evaluations per optimization trial. Results are presented so that future modelers can assess algorithm performance at a computational scale relevant to their modeling case study. In all four of the computationally expensive real SWAT2000 calibration formulations considered here (14, 14, 26, and 30 calibration parameters), results show DDS to be more efficient and effective than SCE. In two cases, DDS requires only 15–20% of the number of model evaluations used by SCE in order to find equally good values of the objective function. Overall, the results also show that DDS rapidly converges to good calibration solutions and easily avoids poor local optima. The simplicity of the DDS algorithm allows for easy recoding and subsequent adoption into any watershed modeling application framework.

Calibration: Version-to-Version Changes



How is calibration happening? (Leventhal)

- Calibration, to what storms and how

- ➢ Calibrated area (in yellow) in V.1.2 and V.2.0
- ➢ Keep updating calibrated areas
- ➢ **More details available from here.**

- How well does it work for flash flood type systems
  - Not verified yet
- Is there probabilistic forecasting being used at all
  - The NWM to produce ensemble streamflow forecasts (seven members for medium-range, out to 10 days, four-members for long-range, out to 30 days)

How well does it do?: Model Performance

- Hydrological Assessment Tool (HAT) developed for evaluating the NWM
- 5 years data from 2013 to 2017 applied
- HAT provides objective and reasonable for the NWM simulated streamflows with the observed precipitation data.

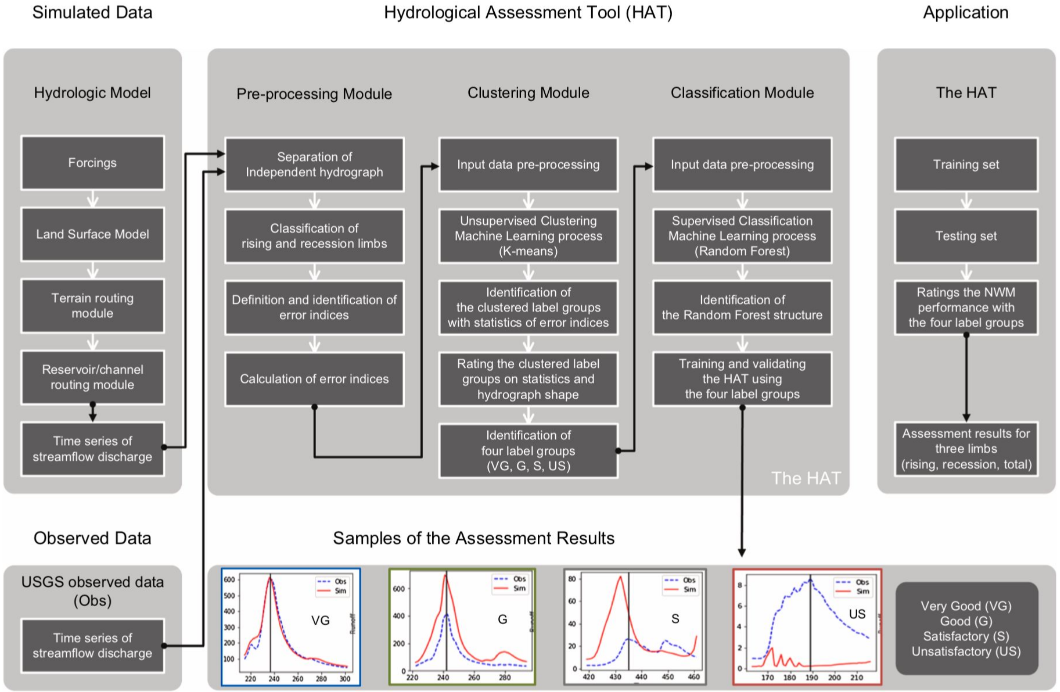
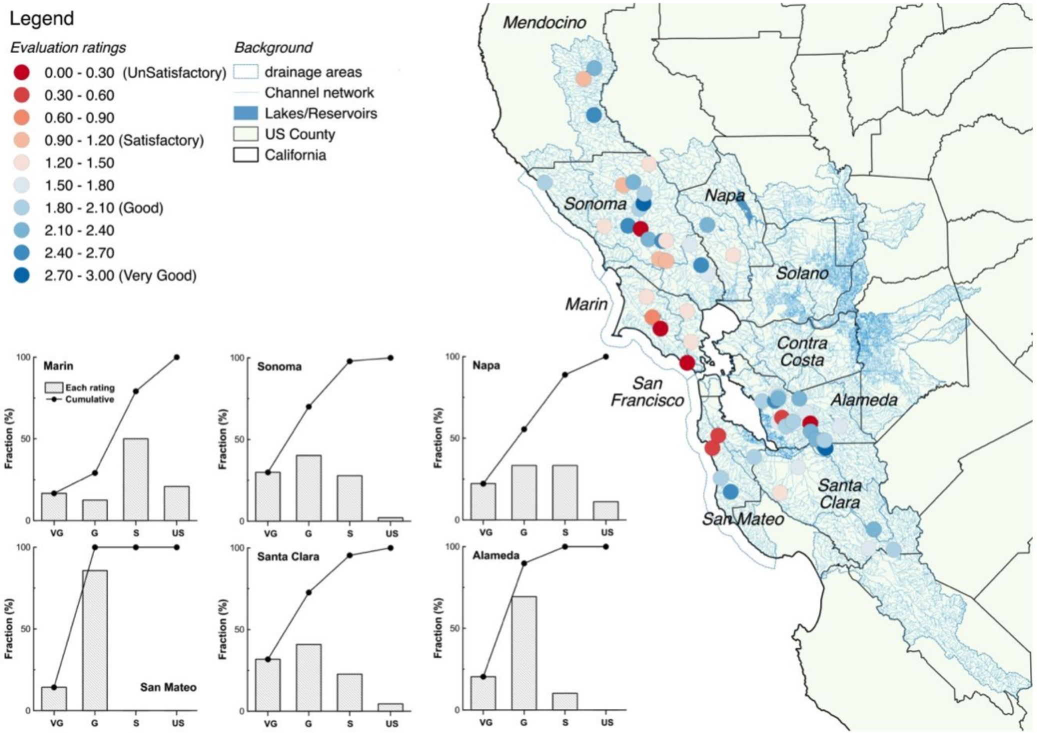


Fig. 5. Structure and flowchart of the HAT.

How well does it do?: Model Performance

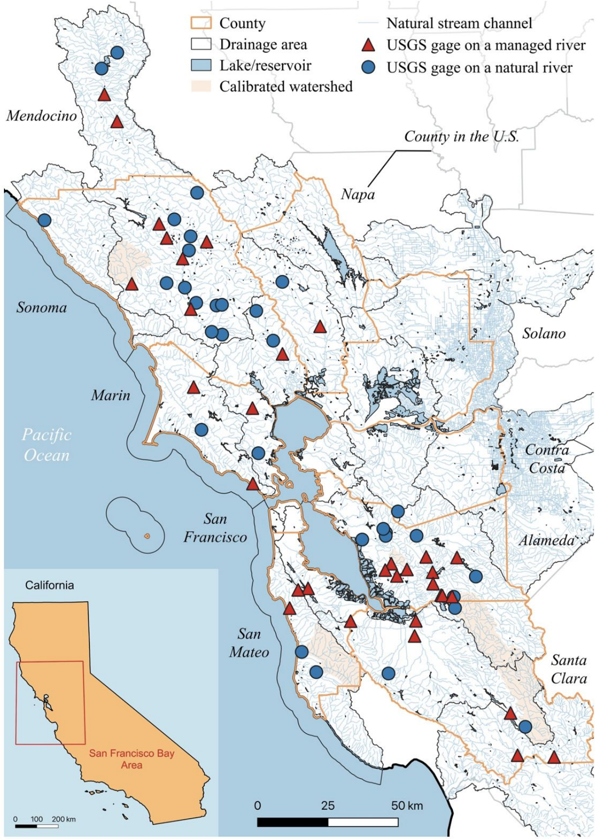
- The NWM performs
  - Good to Very Good for at least 60% of hydrographs (events), regardless of the watershed size.
  - Outstanding simulations for the rising limb of the hydrographs



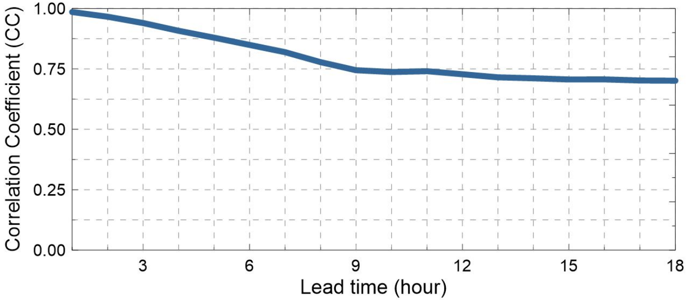
What level of verification has occurred nationwide (Diaz)?

- Various references address NWM verification
  - Nationwide:
    - Salas, Fernando R., Marcelo A. Somos-Valenzuela, Aubrey Dugger, David R. Maidment, David J. Gochis, Cedric H. David, Wei Yu, Deng Ding, Edward P. Clark, and Nawajish Noman, 2018. Towards Real-Time Continental Scale Streamflow Simulation in Continuous and Discrete Space. Journal of the American Water Resources Association (JAWRA) 54(1): 7-27. https://doi.org/10.1111/1752-1688.12586
  - San Francisco Bay Area: AQPI (see the AQPI web page - science tab)
    - **Kim, J**., Han, H., **Johnson, L. E.**, Lim, S., **Cifelli, R.** (2019): Hybrid Machine Learning Framework for Hydrological Assessment, Journal of Hydrology, Vol. 577.
    - Han, H., **Kim, J., Chandrasekar, V.**, Choi, J., Lim, S. (2019): Modeling Streamflow Enhanced by Precipitation from Atmospheric Rivers using the NOAA National Water Model: A Case Study of Russian River Basin on February 2004, Atmosphere, Vol. 10, No. 8.
    - **Johnson, L.E. and J. Kim**. 2019. National Water Model, Retrospective Simulation Assessment, AQPI Case Study – Tributary Hydrologic Model. NOAA PSD Project Report. Available at: https://psl.noaa.gov/aqpi/ (User Resources)
    - **Kim, J., L.E. Johnson**. 2020. Assessment of NOAA Operational Short-Range Streamflow Forecast. Available at: https://psl.noaa.gov/aqpi/users/meeting1/Assessment_Operational_Short-Range_Streamflow_Forecast-JKim-AGU-December-2019.pdf
    - **Kim, J., Read, L., Johnson, L., Cifelli, R.,** Gochis, D. (2020): An Experiment of Reservoir Representation Schemes to Improve Hydrologic Prediction: Based on Coupling the National Water Model with the HEC-ResSim. Hydrological Sciences Journal, Accepted on March 9, 2020.
  - Maryland
    - Viterbo, F., K. Mahoney, L. Read, F. Salas, B. Bates, J. Elliott, B. Cosgrove, A. Dugger, D. Gochis and R. Cifelli, 2020: A Multiscale, Hydrometeorological Forecast Evaluation of National Water Model Forecasts of the May 2018 Ellicott City, Maryland, Flood. *J. Hydrometeor.*, **21**, 475–499. https://doi.org/10.1175/JHM-D-19-0125.1

What level of verification has occurred nationwide (Diaz)?



- Verification of forecast skill
    - NWM V.1.2
    - The wet season from Oct. to Mar. 2018-2019
    - 65 USGS gauges used
    - <u>**Short-range forecast, out to 18 hours (done)**</u>
    - Medium-range forecast, out to 10 days (done)
- Lead time-based verification



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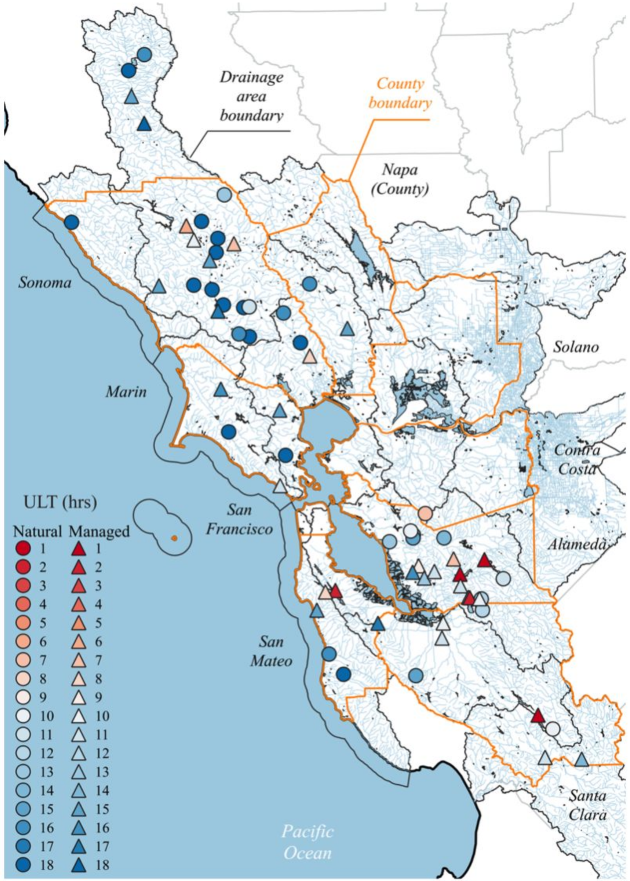
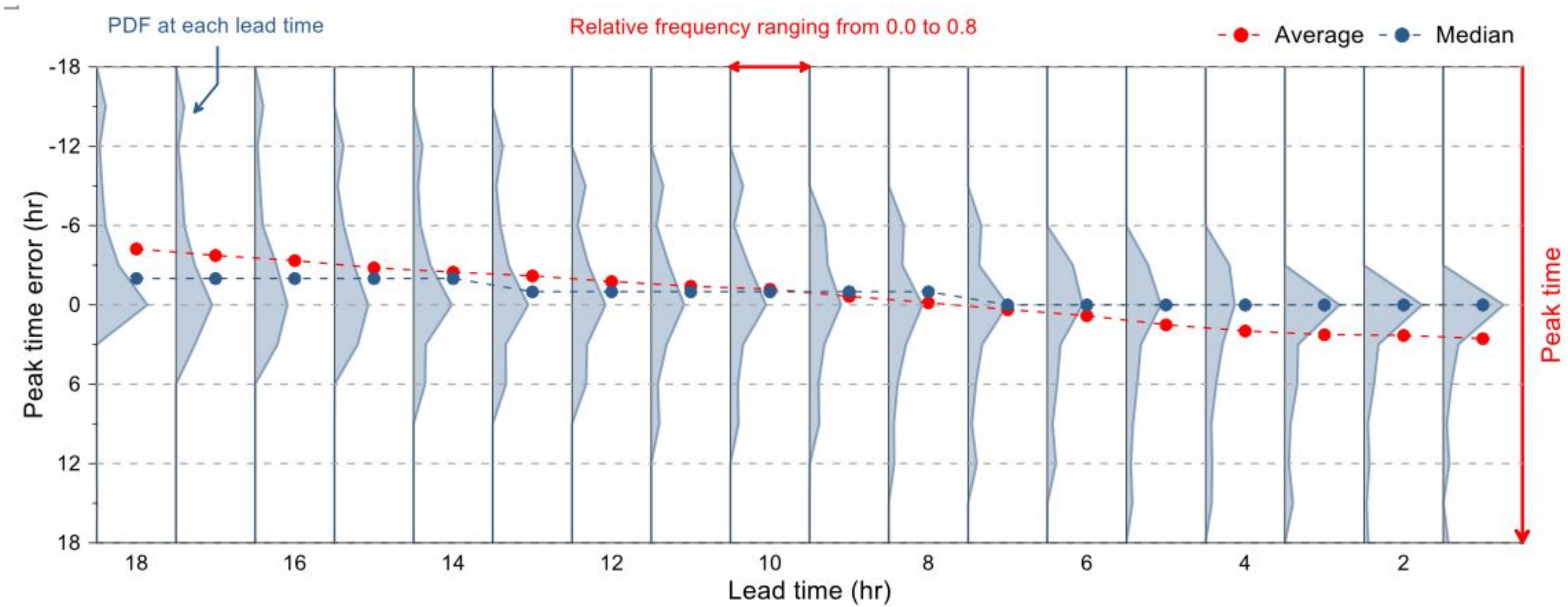


- Can results be shared?
  - Small urbanized regions vs larger rivers
    - Larger area > small urbanized area
    - Unmanaged > managed
    - High flow > low flow
  - Threshold beyond which model is useful
    - The median **useful lead time (ULT)**, 18 hours in natural watersheds and 8 hours in managed watersheds
  - Santa Rosa creek vs Russian River
    - Overall good forecast skill for Russian River
    - Not verified yet for Santa Rosa Creek
  - Use for estimating inflows (Lake Mendocino, Lake Sonoma)
    - Overall good forecast skill for Lake Mendocino
    - Not verified yet for Lake Sonoma

What level of verification has occurred nationwide (Diaz)?

- Predicted time to peak in natural watersheds was considered accurate for all lead times.



Thank you!