BUREAU OF RECLAMATION

CVP Water Temperature Modeling Platform

Modeling Technical Committee (MTC) Meeting #9

July 6, 2023; 1:00 p.m. – 4:00 p.m.

Only one MTC meeting remaining on October 5, 2023

Welcome!!

- We are looking forward to a productive meeting.
- Virtual meetings can be challenging and frustrating, especially with a large groups - please be patient and flexible. If you are having technical difficulties, please chat with Sarah Hamilton, or Sarah.Hamilton@stantec.com
- Chat Panel will be used for participants to provide comments and queue up questions. Use Raise Hand functions in Q&A session.
- Feedbacks on meeting logistic and suggestions: Yung-Hsin Sun, PhD, PE; sun.yunghsin@sunziconsulting.com

MTC #9: Objectives

- Provide updates on WTMP development, activities and schedule
- Establish common understanding on post-project continued implementation
- Provide updates on the approach, progress on characterizing model uncertainty, and communication protocols

MTC #9: Agenda

1:00 p.m.	Meeting Logistics, Welcome Remark, and Announcements
1:10 p.m.	Project Update and Post-Project Outlook
1:50 p.m.	Check-in: Key Responses and Clarification for MTC Review Comments
2:10 p.m.	Break (10 min; the only break)
2:20 p.m.	Model Uncertainty: 1. Source, Approach, and Characterization; 2. Communication and Protocols
3:30 p.m.	Open Forum: Continued Engagement Opportunities
3:50 p.m.	Next Steps
4:00 p.m.	Adjourn

Note that the Agenda contains the registration link of October MTC meeting for your early registration convenience.

Agenda Topics for the 2022 MTC Meetings (Done and Info Posted on Website)

Topic	7/1/2021	10/7/2021	1/6/2022	4/7/2022	7/7/2022	10/6/2022
MTC Orientation	1/2/3	-	-	-	-	-
Project Purposes, Goals, Anticipated Outcomes	1/2/3	3	-	-	-	-
Modeling Framework Selection	1	2	3	-	-	-
Water Temperature Model Selection	1	2	3	-	-	-
Consistency between System Model and Detailed Models	-	1	2	3	-	-
Common Model Preparation and Considerations	-	1	2/3	-	-	-
Sacramento/Trinity River Water Temperature Model	-	-	1	2	2/3	3
American River Water Temperature Model	-	-	-	1	2	2/3
Stanislaus River Water Temperature Model	-	-	-	-	1	1/2
Modeling Framework Implementation	1	-	2	-	-	-
Mid-term Peer Review Outcomes	-	-	-	-	-	1/2/3
Phase II Activities (Introduction only)	-	-	-	-	1/2/3	-

Key: 1 – Introductory Presentation; 2 – Comments and Discussion; 3 – Closure Discussion

Agenda Topics for the 2023 MTC Meetings (Mostly Done; Subject to Change)

Topic	7/7/2022	10/6/2022	1/5/2023	4/6/2023	7/6/2023	10/5/2023
Sacramento/Trinity River Water Temperature Model	2/3	3	-	-	-	-
American River Water Temperature Model	2	2/3	-	-	-	-
Stanislaus River Water Temperature Model	1	1/2	2/3	3	-	-
Modeling Framework Implementation	-	-	2/3	-	3	-
Mid-term Peer Review Outcomes	-	1/2/3	-	-	-	-
Phase II Activities (introduction only)	1/2/3	-	-	-	-	-
Follow-up Model Discussions (as needed)	-	-	-	1/2	2/3	-
Characterization of Model Uncertainty	-	-	1	2	3	-
Communication of Model Uncertainty	-	-	1	1/2	2/3	3
Output and Visualization	-	-	1	1/2	2/3	3
Final Peer Review Outcomes	-	-	-	-	-	1/2/3
Celebration	-	-	-	-	-	1/2/3

Key: 1 – Introductory Presentation; 2 – Comments and Discussion; 3 – Closure Discussion

Communication Channels

- Project website with continued updates: https://www.usbr.gov/mp/bdo/cvp-wtmp.html
  - Meeting information/Fact sheets/Deliverables
- Project contact: mppublicaffairs@usbr.gov
- Interim deliverable comments and suggestions: RField@usbr.gov
- MTC: sun.yunghsin@sunziconsulting.com

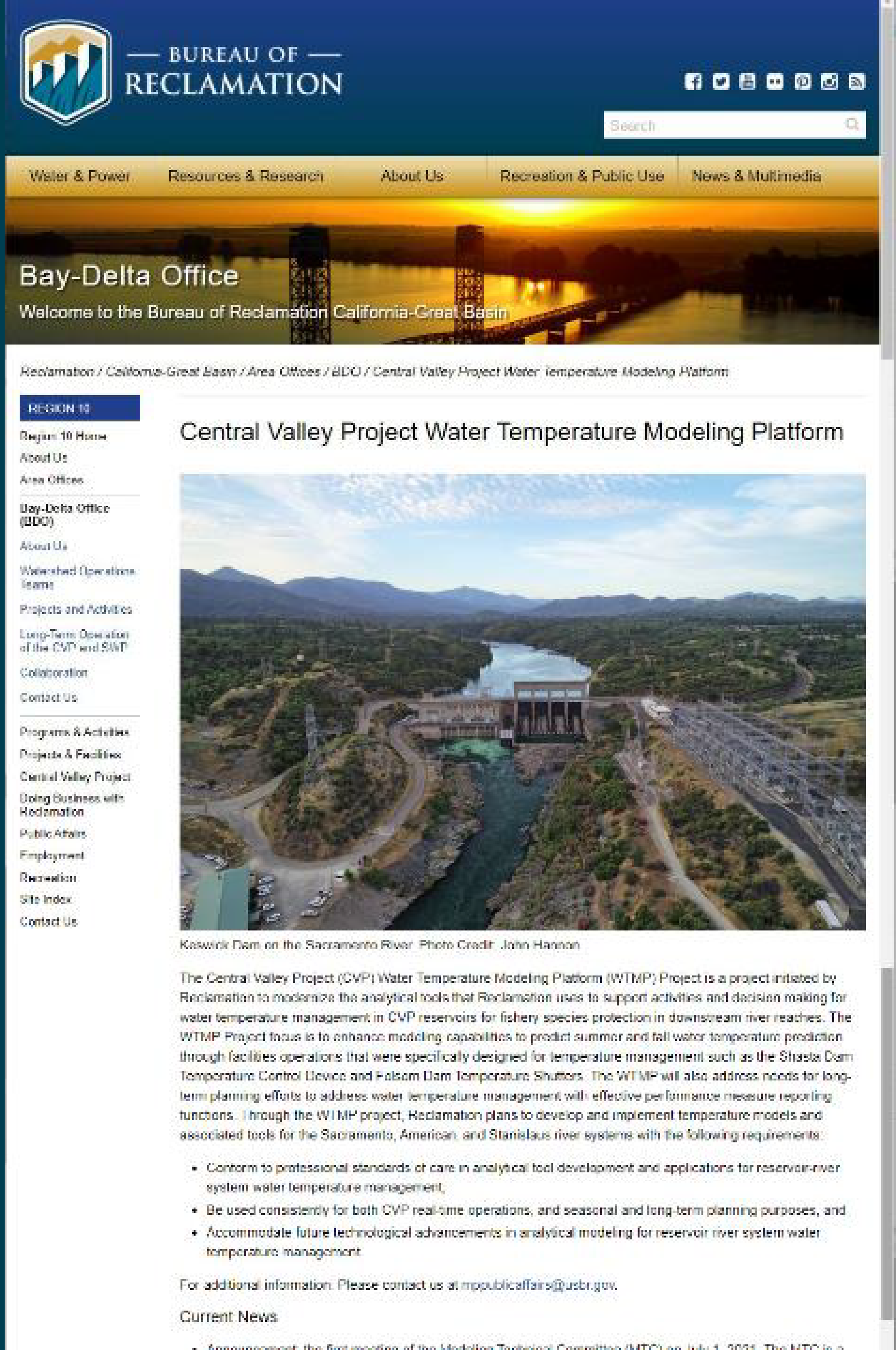


Photo credit: John Hannon, Reclamation

Project Updates and Post-Project Outlook

Randi Field, Hydrologic Engineer, CVO, Reclamation
Yung-Hsin Sun, PhD, PE, Sunzi Consulting

Vision for the WTMP Project (part 1)

- Goal: Deliver quality products to support Reclamation's mission – predict water temperature to support CVP operations
  - Modernize systemwide water temperature modeling and analytics
  - Develop to professional standards and foster transparency
  - Consistent use: real-time, seasonal, and long-term planning
  - Address modeling uncertainty
  - Design for flexibility to accommodate technical advancement
  - Build expertise in Reclamation

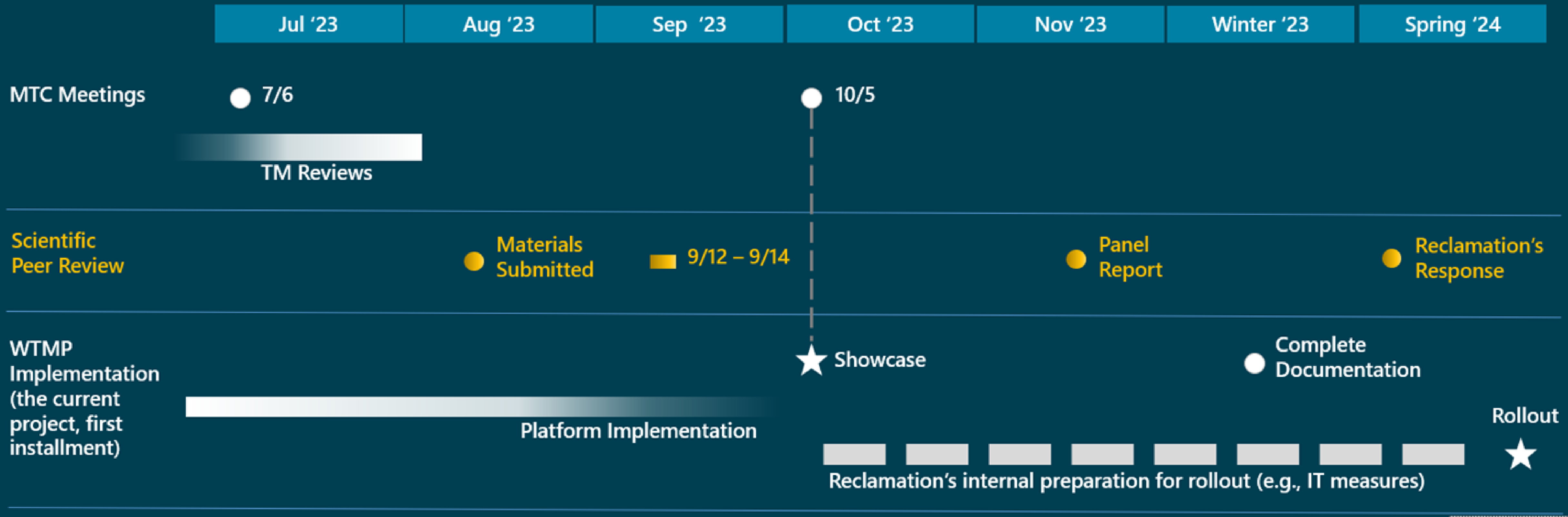
Vision for the WTMP Project (part 2)

- Tool: The WTMP project is the technical tool development effort to build the model and supporting mechanisms for water temperature management analysis
- Use: The long-term operation (LTO) teams establish how to apply tools and analysis for water temperature management

Vision for the WTMP Project (part 3)

- Outcome: A living modeling platform to support long-term CVP operations by addressing water temperature modeling needs and challenges.
- Major products:
  - Complete model and platform documentation based on the current installation
  - Water Temperature Modeling Platform
    - Implemented models/model framework with built-in functions to support modeling needs
    - Data Management System and associated data (raw and processed)
  - Outcomes from independent scientific peer review (mid-term and final)
  - Outcomes from the MTC collaboration (communications and participations in product review)

WTMP Major Milestones



MTC Activities Since MTC 08 in April

- MTC WTMP Output Subgroup (June 1, 2023; 2 - 3:40 p.m.)
- MTC Technical Memoranda Reviews
    - A session later for clarification and general responses to certain critical comments
- MTC 09: July 6, 2023 (today)
    - Solicit opinions on continued engagement after the current project
- MTC 10: October 5, 2023 (our last one with demo and celebration; thank you)
    - WTMP Roll Out Plan – what products to expect, where to get them, when data and information are anticipated to be available/frequency from Reclamation
    - Developing protocols and timelines for requesting special analyses to be evaluated by Reclamation

Active and Upcoming Review Requests

WTMP Technical Memoranda	Team Draft	MTC Review	Team Revision	Final Draft Posting	Peer Review Ready
Model Framework Selection and Design	Completed	Completed	Completed	Completed	Completed
Model Selection	Completed	Completed	Completed	Completed	Completed
Data Management Plan	Completed	Completed	Completed	Completed	Completed
Data Development	Completed	Completed	Completed	late July	late July
Model Development	Completed	Completed	mid-July	late July	late July
WTMP Implementation	mid-July	late July	early August	mid-August	mid-August
Model Uncertainty: Sources and Estimates	early July	mid-July	late July	early August	early August
Model Uncertainty: Communication and Protocols	mid-July	late July	early August	mid-August	mid-August

- Team Draft and Team Revision includes Reclamation review and sign-off for next steps
- Peer Review Ready prior to 8/11/2023 unless otherwise noted

Final Independent Scientific Peer Review

- Host: Delta Stewardship Council
- Review materials available to the panel by August 11, 2023
- Peer review penal convening and deliberation scheduled: 9/12/23 – 9/14/23
- Anticipated final report in early November 2023

WTMP Implementation Status

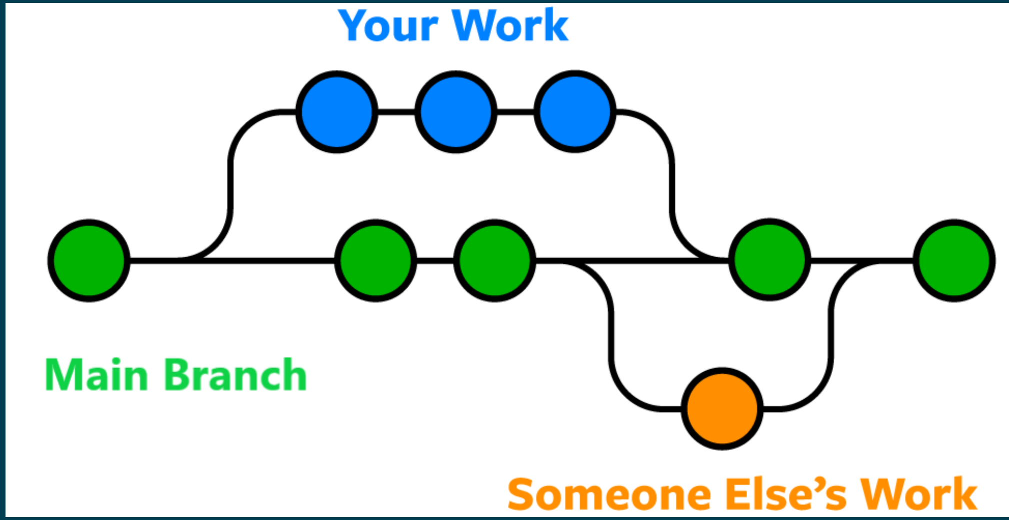
- Current focus is on implementing procedures and processes required for two types of application below for consistent implementation.
- Real-time and seasonal management planning
  - Mostly completed; in wrap-up mode
- Long-term operation (LTO) planning
  - Proof of concept for integrating CalSim 3 and other LTO modeling procedures and processes was completed and to be documented in TM
  - Additional efforts beyond the current project are required for full implementation; in discussion.

Post-Project Prospects

- Perspectives after the WTMP's first deployment and rollout:
  - The products from the current implementation will continue to evolve with additional development/refinements on individual models and overall platform.
  - Continued supporting activities include:
    - Continued/improved data collection for improving quality of model analytics
    - Model refinement as facilities are upgraded/modified and new facilities are constructed, if applicable
    - Re-assessment of modeling needs, associated model development and refinements, and model evaluation and calibration/re-calibration
    - Response to advancement in technology
    - A potential user group evolved from the current MTC structure (to be discussed further in the next MTC meeting)

Reclamation GitHub for WTMP

- What is GitHub?
  - https://en.wikipedia.org/wiki/GitHub
- Software organization and downloading capabilities
- Plan to post models/plug-ins versions here
- Opportunity for community development
- More in October MTC meeting



Reclamation Information Sharing Environment- RISE

- What is RISE?
  - https://data.usbr.gov/
- Database searching and downloading capabilities
- Plan to post project studies here
- RISE API
- More in October MTC Meeting

Questions on Project Update and Post-Project Prospect

Photo credit: John Hannon, Reclamation

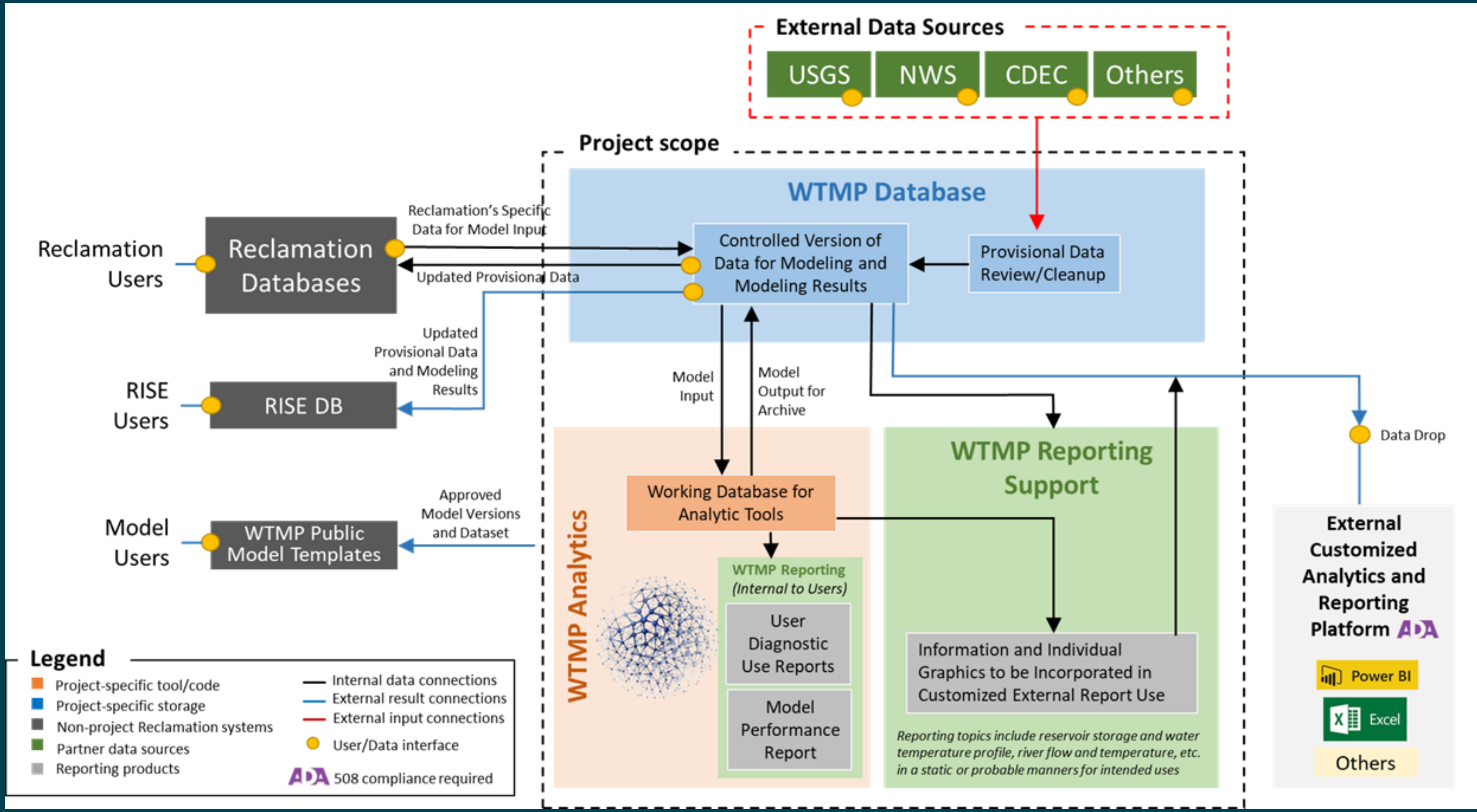
Output Subgroup Reporting

Yung-Hsin Sun, PhD, PE, Sunzi Consulting LLC

Randi Field, Hydrologic Engineer, CVO, Reclamation

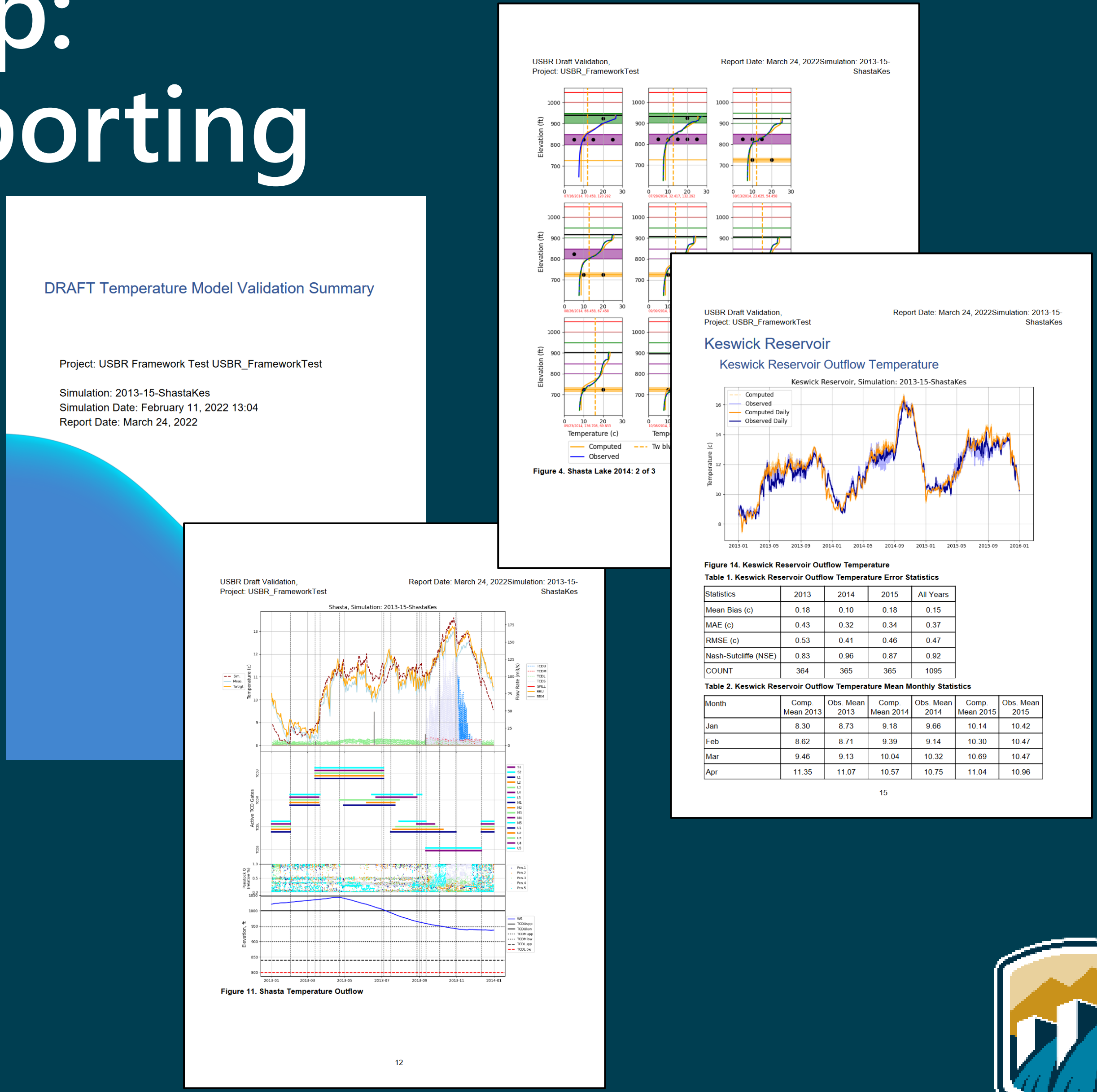
MTC Output Subgroup

- June 1, 2023; 2:00 p.m. – 4:00 p.m.
- Objectives:
  - Build common understanding and receive feedback on WTMP planned features for output.
  - Explore options for future enhancements.



MTC Output Subgroup: WTMP Automatic Reporting

- Purposes
  - Rapid creation of key output tables and graphics to facilitate results review by modelers
  - Creation of tables and graphics that could be incorporated in other reporting and presentation products
- Implementation
  - Every defined report is scripted and accessible through WTMP user interface


DRAFT Temperature Model Validation Summary

Project: USBR Framework Test USBR_FrameworkTest

Simulation: 2013-15-ShastaKes
Simulation Date: February 11, 2022 13:04
Report Date: March 24, 2022

USBR Draft Validation,
Project: USBR_FrameworkTest

Report Date: March 24, 2022Simulation: 2013-15-ShastaKes

Figure 4. Shasta Lake 2014: 2 of 3

USBR Draft Validation,
Project: USBR_FrameworkTest

Report Date: March 24, 2022Simulation: 2013-15-ShastaKes

Figure 11. Shasta Temperature Outflow

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USBR Draft Validation,
Project: USBR_FrameworkTest

Report Date: March 24, 2022Simulation: 2013-15-ShastaKes

Keswick Reservoir

Keswick Reservoir Outflow Temperature

Figure 14. Keswick Reservoir Outflow Temperature

Table 1. Keswick Reservoir Outflow Temperature Error Statistics

Statistics	2013	2014	2015	All Years
Mean Bias (c)	0.18	0.10	0.18	0.15
MAE (c)	0.43	0.32	0.34	0.37
RMSE (c)	0.53	0.41	0.46	0.47
Nash-Sutcliffe (NSE)	0.83	0.96	0.87	0.92
COUNT	364	365	365	1095

Table 2. Keswick Reservoir Outflow Temperature Mean Monthly Statistics

Month	Comp. Mean 2013	Obs. Mean 2013	Comp. Mean 2014	Obs. Mean 2014	Comp. Mean 2015	Obs. Mean 2015
Jan	8.30	8.73	9.18	9.66	10.14	10.42
Feb	8.62	8.71	9.39	9.14	10.30	10.47
Mar	9.46	9.13	10.04	10.32	10.69	10.47
Apr	11.35	11.07	10.57	10.75	11.04	10.96

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MTC Output Subgroup: Automatic Reporting Implementation (part 1)

- Configuration files (XML format) (i.e., the script)
  - Separated by sections, report table of contents will show headings for chapters and sections
  - Sections contain one or more report objects
  - Syntax reference implemented models and observed data

MTC Output Subgroup: Automatic Reporting Implementation (part 2)

- Currently available report objects
  - Text blocks with string substitution
  - Profile plots
  - Time series plots
  - Error statistics table
  - Monthly statistics table
  - Single statistics table
  - Profile statistics table
  - Contour plots
  - Reservoir contour plots
  - Buzz plots (American River Basin only)
  - Shasta outlet operations plot

MTC Output Subgroup: Takeaways

- Useful output requires a design process for its intended use (e.g., short-live QA/QC process or outward facing dissemination), targeted recipients (e.g., modelers or stakeholders), and necessary contextual information that are often output specific.
- The platform is flexible but customization of a report the first time would need advanced user's assistance. Additional option menu may be added in the future.
- In many cases, WTMP output provides only an insert to a larger package for multi-disciplinary group discussion or decision making

Automatic Output per Application Type

Application	Examples	Implementation Status
Calibration/validation/Model Preparation and Update	Those you MTC members have reviewed in the model development TM, especially those in the appendices.	Completed
Real-time and seasonal temperature management planning and subsequent implementation and monitoring (including hindcast)	Estimated facility cold water management and temperatures at downstream locations under different scenarios in SRTTG and ARG group package, with limited characterization and visualization of uncertainty.	Pending; refining concepts based on subgroup discussion and suggestions
Long-term CVP operation (in coordination with SWP) planning	Most modelers use customized XL workbooks that are consistent with those used for CalSim 3 studies. The output by year for QA/QC process and documentation purpose may be useful.	Ongoing discussion; temperature management is only a component

Questions on Output Subgroup

Photo credit: John Hannon, Reclamation

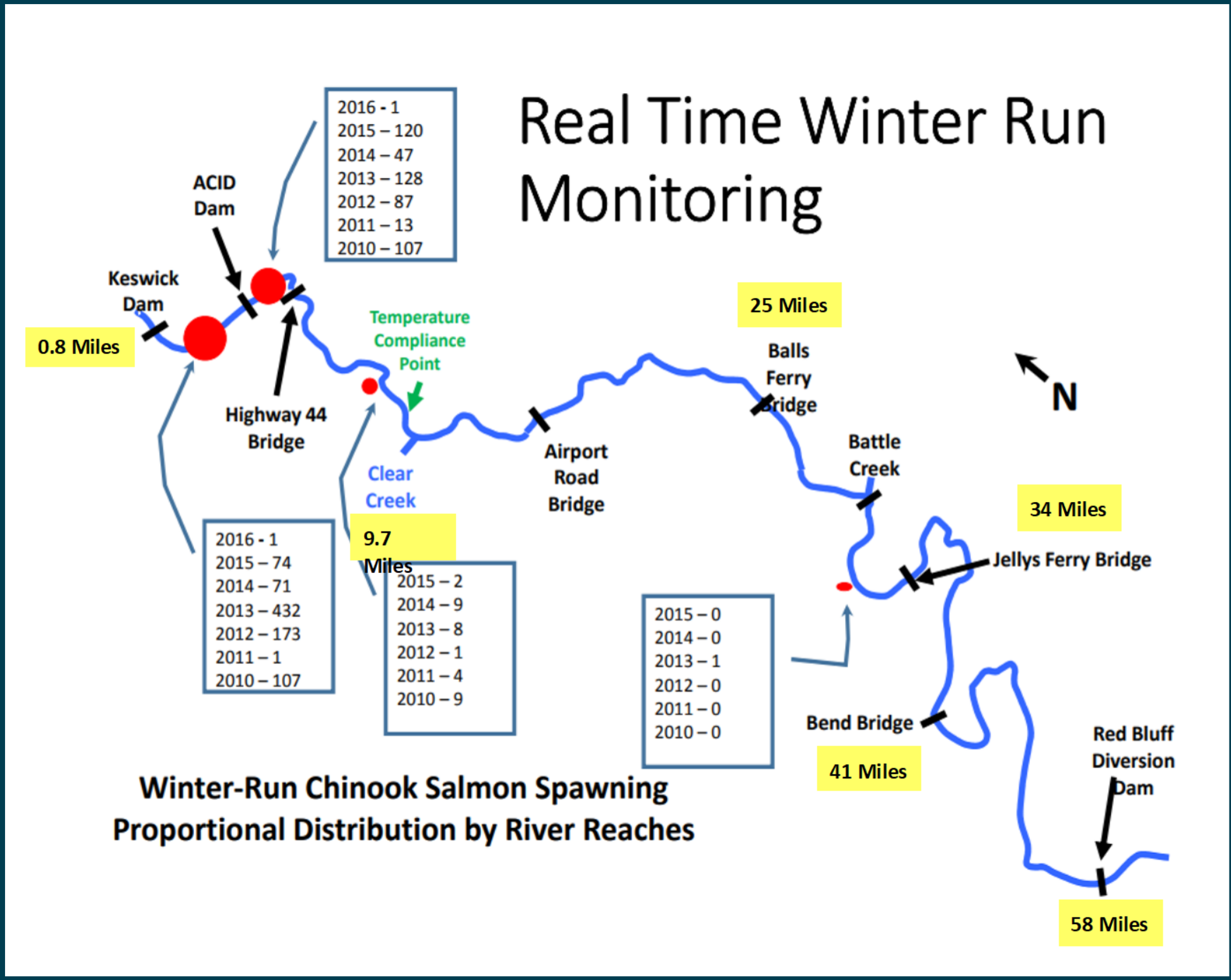
Update on NCAR's Meteorology Forcing Datasets/Inflow Temperature Project

Andy Wood, Project Scientist, NCAR

Randi Field, Hydrologic Engineer, CVO, Reclamation

SacMetTemp Project Overview

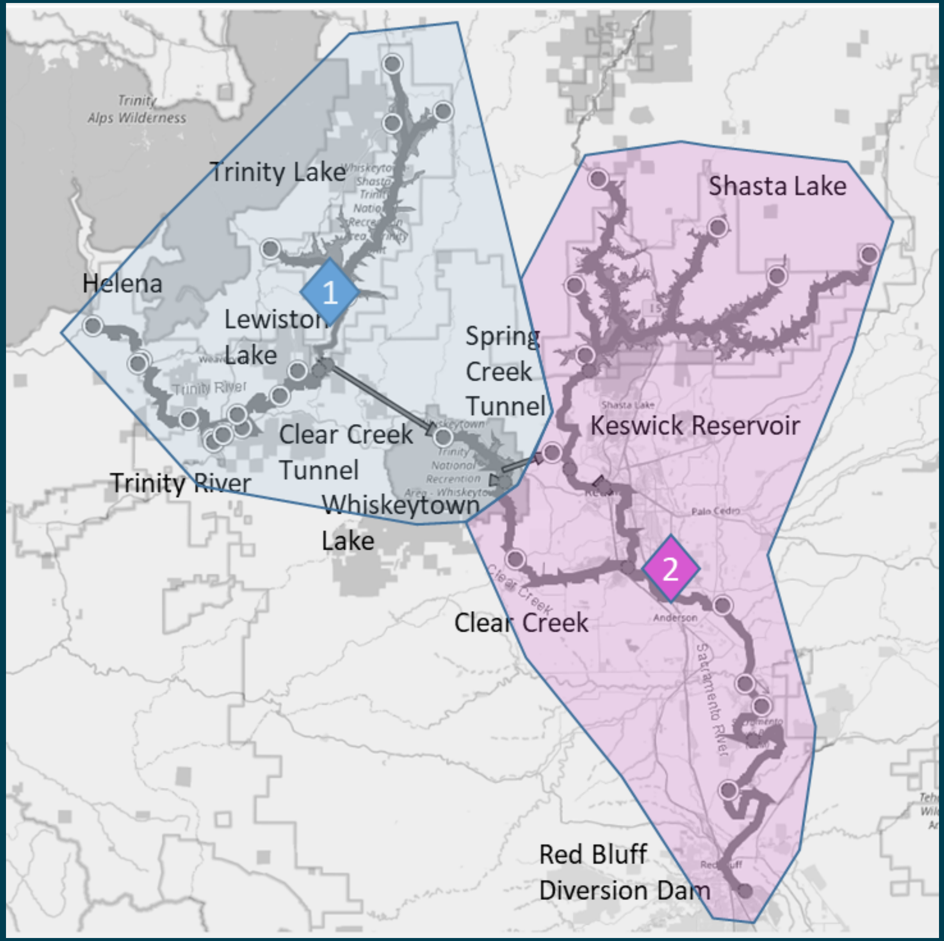
- Motivation
  - Long lead stream temperature outlooks are central to seasonal operations planning
  - Updates the data and approach for sub-seasonal to seasonal (S2S) climate forecasts are required for water temperature model inputs as the WTMP is under development
- This project centers on research to review the existing datasets and approach to identify and explore potential areas for improvement.



Meteorologic Boundary Conditions of Interest

1. Trinity Center
   - Trinity Lake
   - Lewiston Lake/Clear Creek Tunnel
   - Trinity River to Helena
   - Whiskeytown Lake/Spring Creek Tunnel
2. RDD Redding Airport
   - Shasta Lake
   - Keswick Reservoir
   - Clear Creek
   - Sacramento River to Red Bluff Diversion Dam

- Upper Sacramento System



Project Tasks / Schedule

Evaluation of current operational datasets and temperature outlook approach

Assessment of new gridded meteorological input datasets

Assessment of alternative potential S2S climate forecast approaches

Experimentation with S2S reservoir inflow and inflow temperature predictions using S2S climate forecasts

Research Strategy Tasks

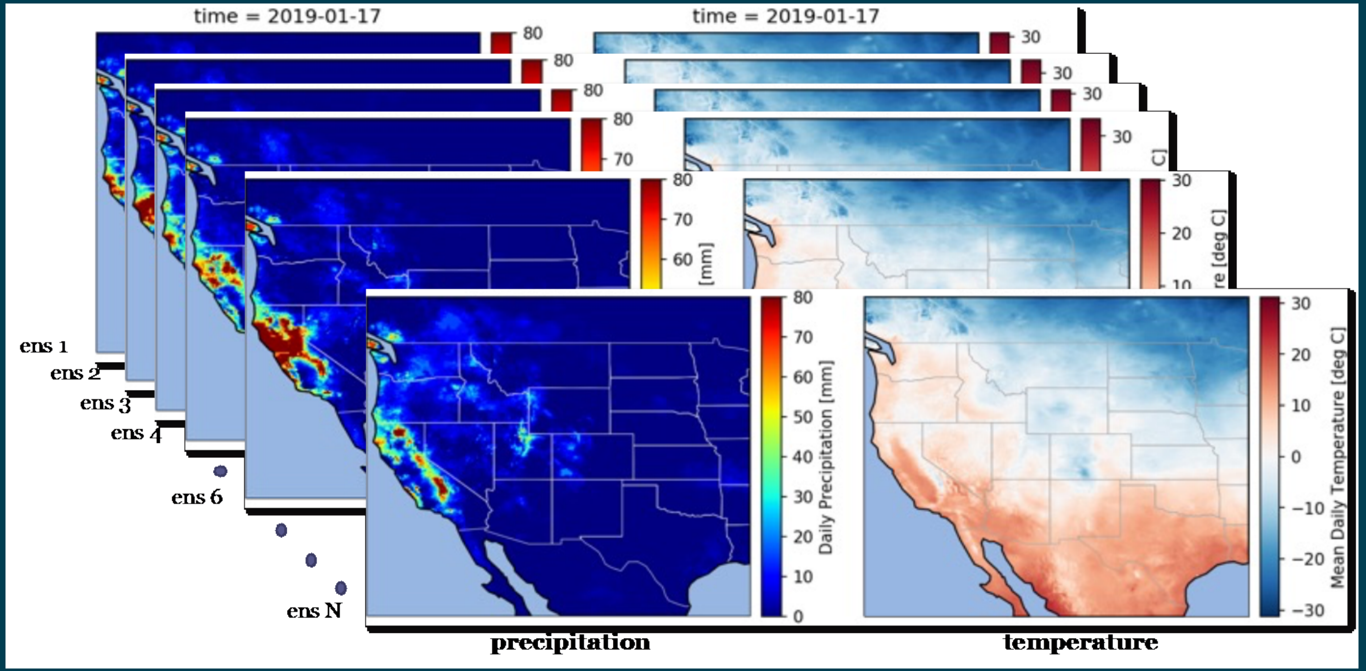
Task Number	Task Name	FYB	FYE	Task Description
Task-0	Project Management	2022	2024	• C/GB Region funding agreement development • IA with NSF to fund NCAR • Research Office Updates • Team meetings and updates • Progress tracking
Task-1	Gather datasets and define assessments	2022	2022	• Gather datasets used in current operations related to stream temperature • Gather potential in-situ and gridded independent datasets for validation purposes • Team meetings to outline specifics of validation and analysis plans, given available datasets
Task-2	Evaluation of current operational datasets	2022	2023	• Based on Task 1 plans, assess (1) the strengths and weaknesses of the datasets used in CVO temperature modeling and prediction, including the accuracy and/or skill of current stream temperature predictions, the reliability of spread estimates, and the quality of S2S climate predictions. • Characterize trends and variability in the stream temperature model inputs and outputs.
Task-3	GMET application to the upper Sacramento River basin for temperature modeling	2022	2023	• Implement GMET at 3-6 sq. km resolution over the upper Sacramento River basin for a multi-decadal retrospective period • Map and disaggregate GMET output to temperature model input variable/space/time resolutions • Characterize trends and variability in the GMET-based model inputs • Run/validate temperature model with GMET based input
Task-4	New S2S climate forecast processing and evaluation	2023	2024	• Assess S2S climate skill for the upper Sacramento River basin, out to seasonal lead times, from raw and post-processed S2S climate forecasts. • Assess whether S2S climate forecasts can be used to condition ESP-type long range temperature model input projections to improve stream temperature prediction skill
Task-5	Stream temperature inflow modeling and prediction	2023	2024	• Calibrate existing SUMMA/mizuRoute model implementation for Shasta Reservoir inflow tributaries • Apply and evaluate the RBM stream temperature model • Create a set of seasonal inflow hindcasts conditioned by S2S climate for assessing inflow temperature forecast potential.
Task-6	Documentation and Closeout Process	2024	2024	• Write and submit publication on the application of observational and climate forecast datasets for stream temperature modeling • Preparation of final report and bulletin for Research Office • Present in S&T webinar to share results and available tools. • Update tools and methods in GitHub as needed

SacMetTemp Project Overview of Task

- In the third task, we will develop and evaluate a high resolution (~2 km) surface meteorology dataset across California, based on the ensemble 'GMET' approach
  - Can ensemble meteorology give better estimates of uncertainty for the conditional climate forecast approach?
  - Can the spatially detailed dataset provide useful inputs for hydrologic and stream temperature modeling?

SacMetTemp Project Overview of GMET

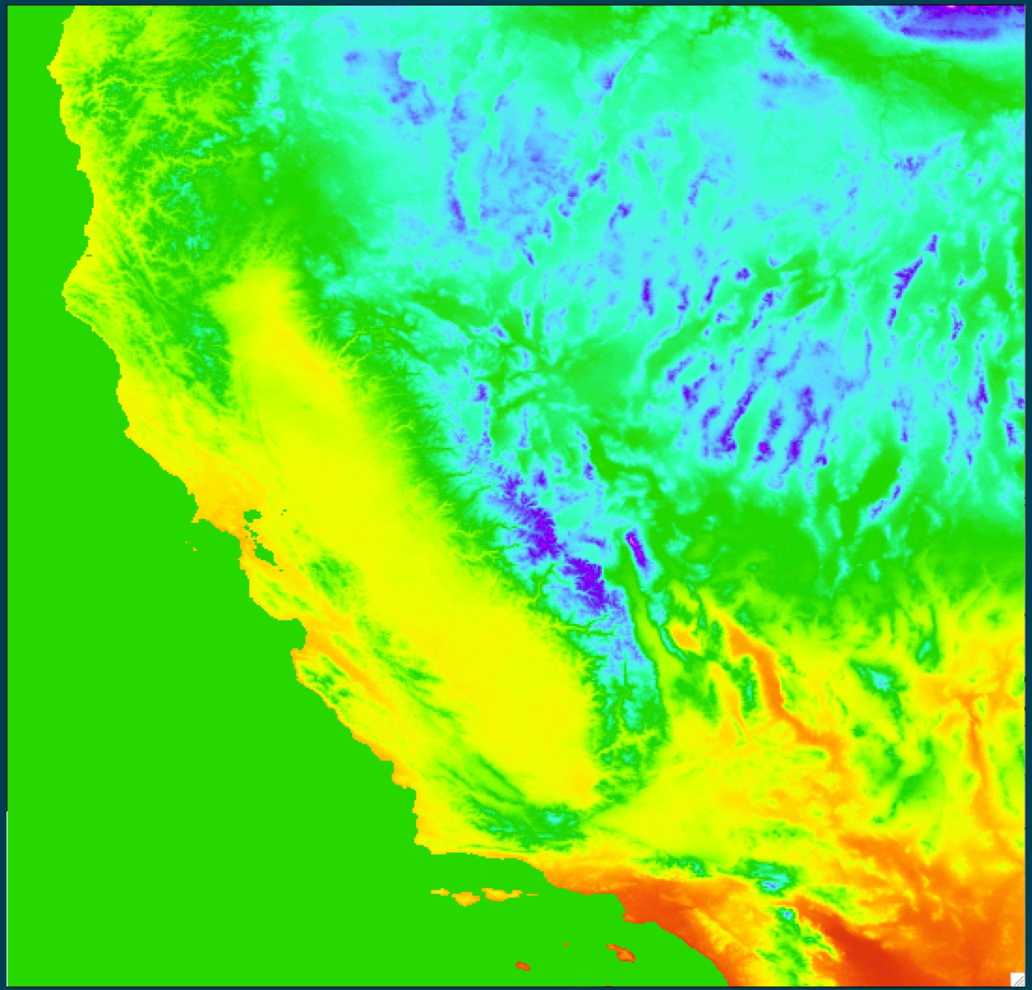
- GMET (Gridded Meteorological Ensemble Tool) is currently used in modeling/forecasting research for Reclamation, USACE and other agencies.
- There is a real-time 1/16th degree ensemble for the western US running at NCAR (1970-present) as well as other GMET datasets.
- A new Python version (PyGMET) is being developed – will include machine learning methods.
  - https://github.com/NCAR/GMET



GMET Task Status

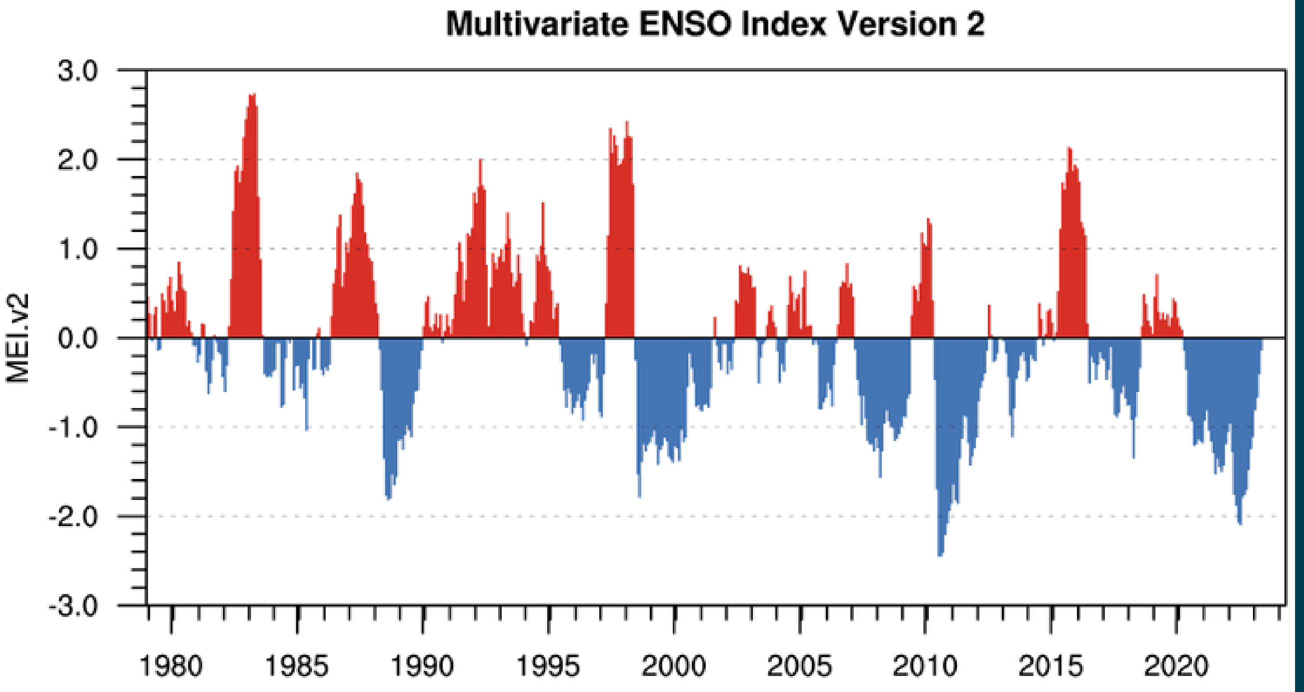
- A California 2-km GMET ensemble forcing dataset has been generated
  - initially only 10-members, but easy to increase
  - station-only (mostly GHCN-D)
  - sub-daily disaggregation still to do
  - 1970-2022
  - not yet connected to NCAR real-time system
  - domain includes all of CA plus connected basins

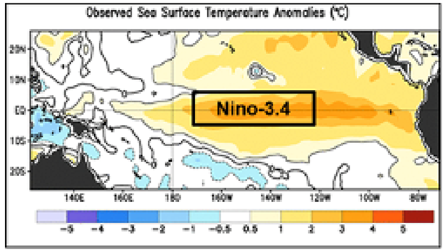
- Daily mean temperature snapshot



Sub-seasonal to Seasonal (S2S), Meteorological Prediction

- Most applications approaches now use a 2-phase approach
  - Climate prediction
  - Conditional weather generation
    - Empirical climate prediction uses observational climate indices to estimate future S2S climate
      - Nino3.4, an index of ENSO
      - Sub-seasonal: week 2 to month 2
      - Seasonal: 3 to 12 months
      - S2S prediction is defined in various ways by different agencies, countries, and intergovernmental groups

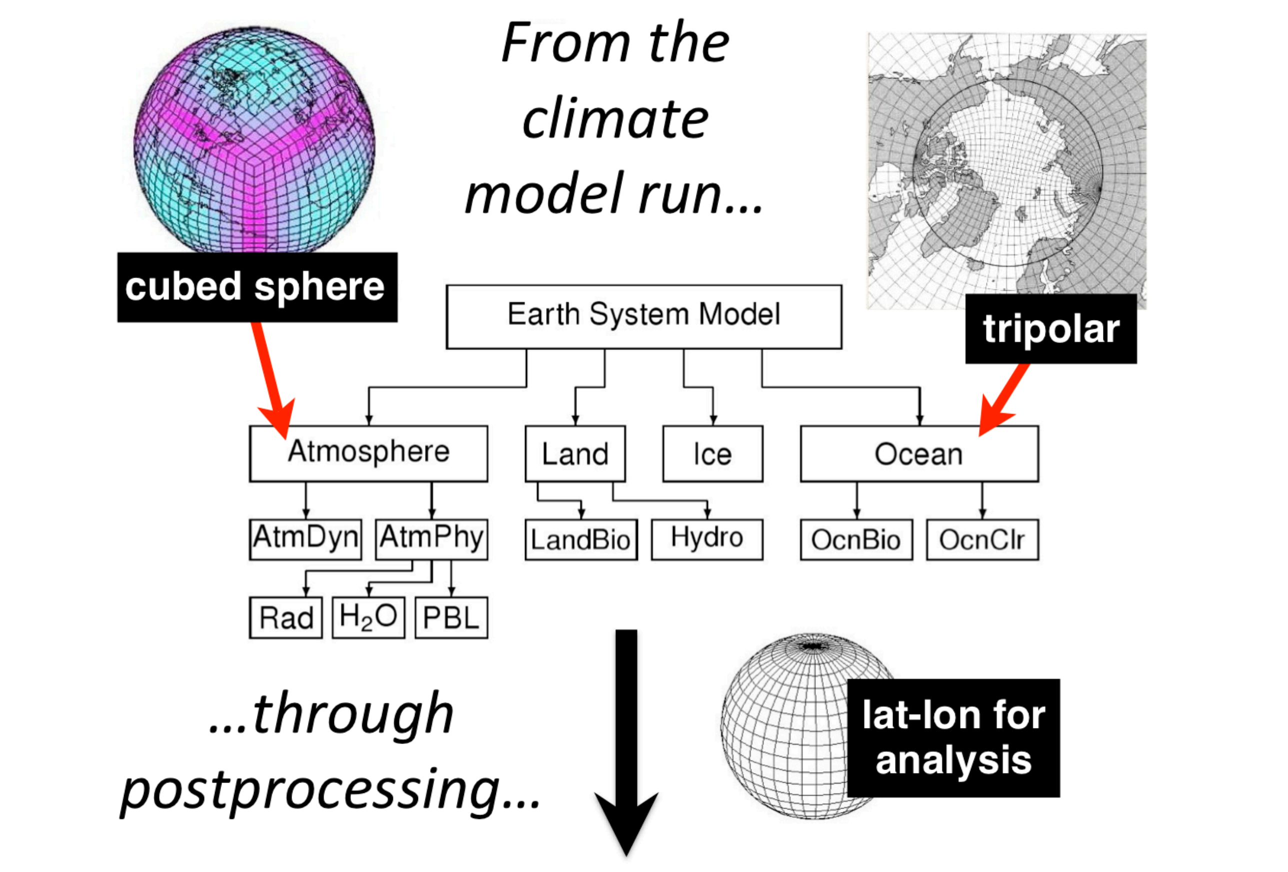




The index is based on the deviations from usual sea surface temperature in the NINO 3.4 region of the equatorial Pacific Ocean.

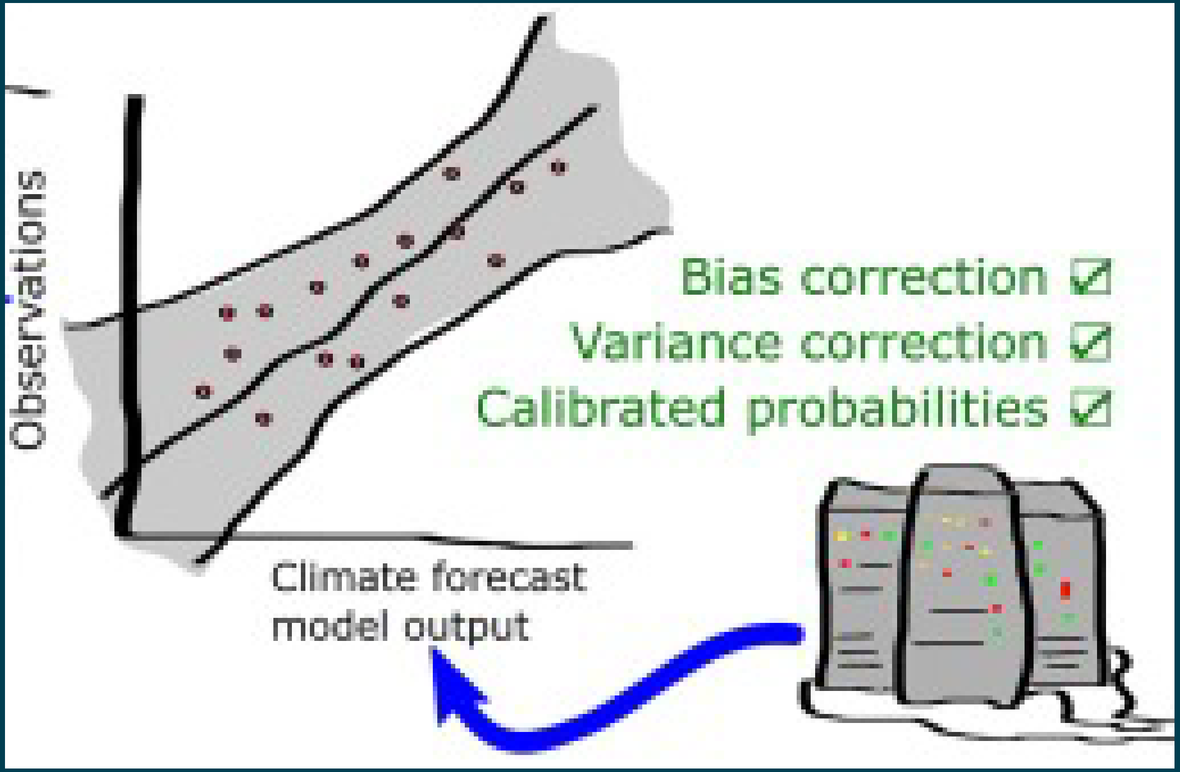
Sub-seasonal to seasonal meteorological prediction (part 1)

- Most applications approaches now use a 2-phase approach
  - Climate prediction
  - Conditional weather generation
    - Dynamical climate prediction uses global coupled climate system models or earth system simulation models to generate climate forecasts
      - NOAA CFSv2
      - ECWMF Sys5
      - GFDL SPEAR
      - NCAR CESM2



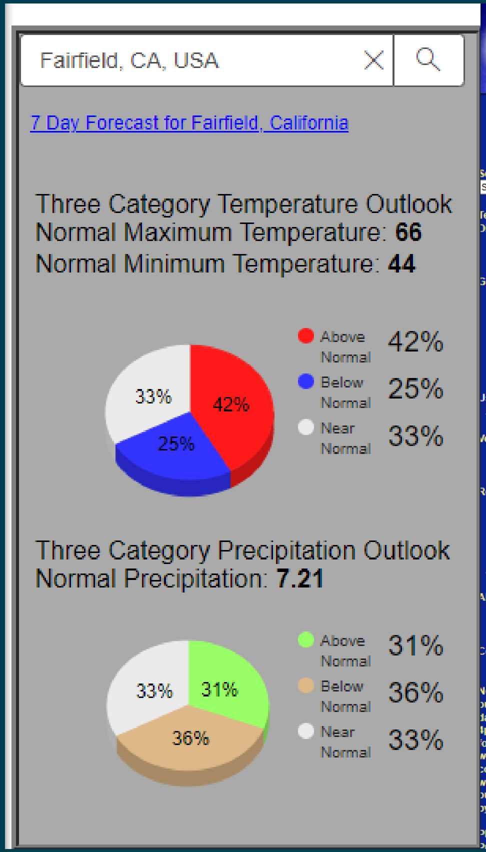
Sub-seasonal to Seasonal Meteorological Prediction (part 2)

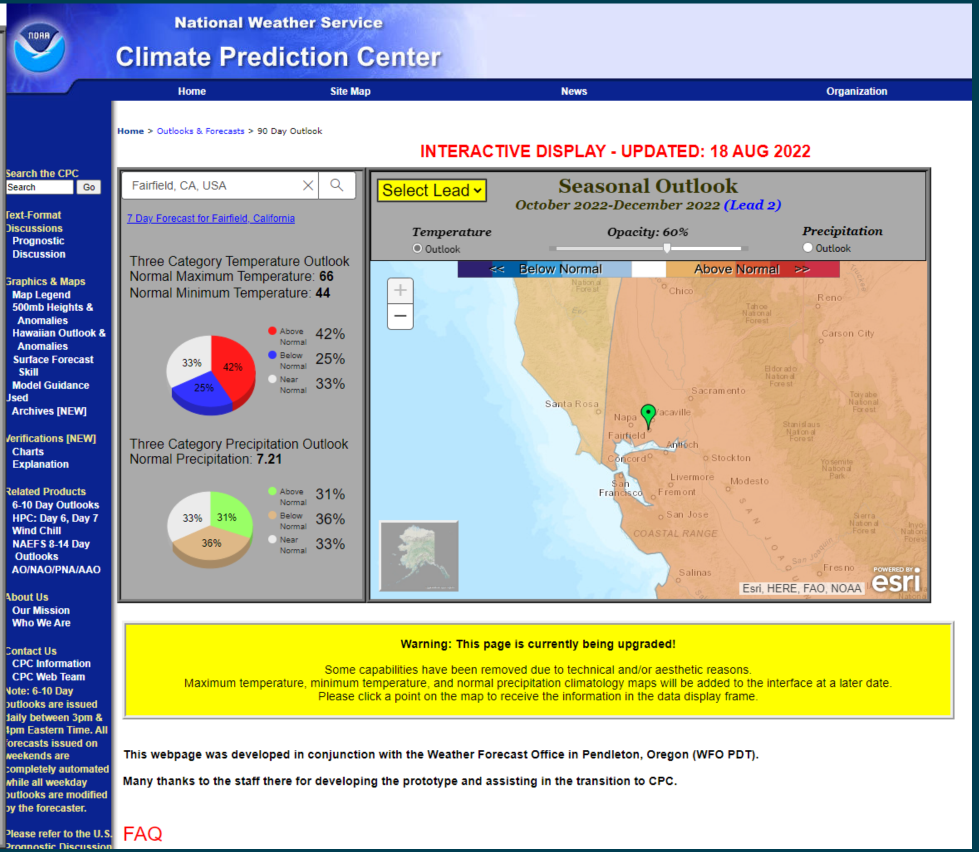
- Most applications approaches now use a 2-phase approach
  - Climate prediction
  - Conditional weather generation
    - Weather generation involves translating a climate forecast signal (e.g., wet, warm) into a local meteorological timeseries that can be used to drive an applications model
  - Common methods of wx-generation
    - Stochastic multi-variate/multi-site models
    - Weighted resampling of observations



Current Approach for Sacramento Stream Temperature Forecast Inputs

- Use official climate forecasts from the US Climate Prediction Center (CPC)
  - These are based on dynamical models and empirical climate forecast methods
  - L3MTO tercile product
- Weather generation
  - Weighted resampling method





L3MTO, local 3-month temperature outlook spreadsheet

1. **Enter L3MTO Tercile Probabilities (multiplied by 100) into table below, for the Below Normal and Near Normal categories only (overwrite existing values), Above Normal values will automatically calculate. Press F9 key. See results in "Assigned Like-Years (computed)" section below and the plots of section 2.**

L3MTO Tercile	May-June-July (MJJ)	June-July-August (JJA)	July-August-September (JAS)	August-September-October (ASO)	September-October-November (SON)
Below Normal	17	20	20	22	16
Near Normal	29	31	32	31	31
Above Normal	54	49	48	47	53

2. **Instructions - PART II: Assign L3MTO forecast information to Plan Months, marking assignments with an "x". This determines with L3MTO product determines like-month selection for the given Plan Month. Please make only one assignment per month.**

Plan Month	May-June-July (MJJ)	June-July-August (JJA)	July-August-September (JAS)	August-September-October (ASO)	September-October-November (SON)
May	x				
June	x				
July	x				
August		x			
September			x		
October				x	
November					x

3. **Choose five exceedence thresholds to report in the tables of section 3, and then mark the simgle planning exceedence threshold with an "x".**

Exceedence Threshold	Planning Exceedence Threshold
10%	
25%	x
50%	
75%	
90%	

4. **Enter plan year.**

2020

Assigned Like-Years (computed)

2002
2002
2002
1977
2008
2008
2001

SacMetTemp Project, Current Approach in Python

- The approach was recoded into a Python notebook / script
  - automatable, less hardwired
  - run easily to test many options, many past forecast scenarios

Sacramento-Valley L3MTO-based Like Year Selection and Meteorological Sequencing Tool for supporting MP-CVOO Stream Temperature Planning: **mid-April Issue**

(scroll down)

USER CONTROL

Step 1	Follow weblink to L3MTOs issued in Fairfield, CA
Step 2	Identify L3MTO forecasts for upcoming seasons, as noted
Step 3	(1) Enter L3MTO forecast values in table, (2) Indicate forecast exceedence threshold of interest, (3) Assign Forecast Season to Plan Month, (4) Enter Planning Year

OUTPUT

SAVE TO DSS	These are the four 6-hourly Gerber meteorology data required by SRWQM. These data reflect resampled historical, consistent with seasonal temperature forecasts (i.e. L3MTO-conditioned climatology) and forecast exceedence preference.

Calculations

1a.	Historical Monthly Temperature Data at **Shasta Dam**, and calcs to fill data-gaps. Note that Shasta Dam temperature is being forecast using the L3MTO *at Fairfield* based on forecast reliability analysis (see red sheets, end of workbook). Shasta Dam is most proximate to the Gerber meteorological station used by SRWQM.
1b.	Historical Seasonal Temperature Data at **Shasta Dam** for 4 seasons: Jun-Jul-Aug (JJA), Jul-Aug-Sep (JAS), Aug-Sep-Oct (ASO), Sep-Oct-Nov (SON). Two distributions of seasonal T time series are then tabulated: 1971-2000 (consistent with L3MTO forecast-model calibration period) and 1961-2005 (consistent with full data period).
1c.	Historical Seasonal T Data (1961-2005), by Season, **sorted**, and **classified** 1, 2, and 3, corresponding to L3MTO tercile seasonal T categories (Above Normal (AN), Near Normal (NN), Below Normal (BN)) defined relative to Historical Seasonal T Data (1971-2000).
Fig 1a	Historical Seasonal T, 1961-2005, and L3MTO forecast-model development window shown (1971-2000).
Fig 1b	Sorted Historical Seasonal T, from 1971-2000 sub-period, on Fig. 1.
2a.	Forecast-resampled T for JJA season, resampled from historical in proportion to L3MTO. E.g., L3MTO = 50/30/20 for AN/NN/BN. Resampled data pool would be 50 replications of AN historical tercile set (warmest 10 T from 1971-2000 data), 30 replications of NN historical tercile set, and 20 replicationns from BN historical tercile set.
2b.	Same as 2a., but for JAS season
2c.	Same as 2a., but for ASO season
2d.	Same as 2a., but for SON season
2e.	Organization of plot data (from sheets 1b and 2a-2d) for Figs 2a-2e.
Fig. 2a	1971-2000 Historical and Forecast-resampled distributions of seasonal T data, all Seasons
Fig. 2b	1971-2000 Historical and Forecast-resampled distributions of seasonal T data, JJA only
Fig. 2c	Same as 2a., but for JAS season
Fig. 2d	Same as 2a., but for ASO season
Fig. 2e	Same as 2a., but for SON season
3a.	Identify historical years having observed seasonal T most similar to the forecast seasonal T at the given forecast exceedence (i.e. Like Years). Season in this case is the JJA season. Five exceedences

1. Settings for L3MTO-based process

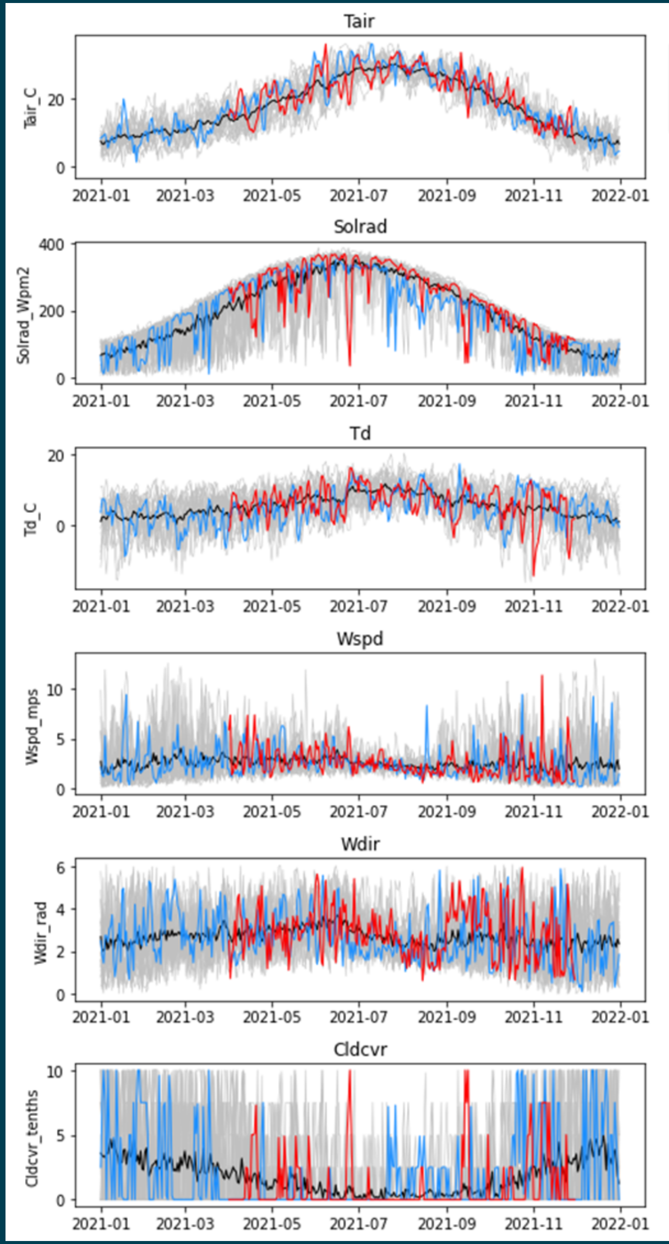
```
[2]:
fcstYear        = 2003
fcstMon         = 4
fcstLen         = 8
seas2monNdx     = [1, 1, 2, 3, 4, 5, 6, 7]                                # index of forecast seasons that are assigned to each plan month (lead)
                                                                          # i.e., if fcstMon=4, the first element = 1 will assign AMJ to lead 1 (Apr)
planningThresh  = [0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25]        # percentile of the forecast distribution used to select closest year
climoYears      = [1971,2000]                                             # climatology years for calculating tercile thresholds
sampleYears     = [1961,2005]                                             # sampling period years from historical record
nSample         = 1000                                                    # size of sample to use in estimating quantiles
nAnalog         = 5

tercFcstFile    = '../cpc_fcst/sflist.Apr2003.cpc_terc_fcst.74516.csv'   # CSV file containing tercile forecasts
outMetFile      = 'Gerber_met.cpc_terc.thr-0.25.apr2003.alt-seq.csv'     # output file
```

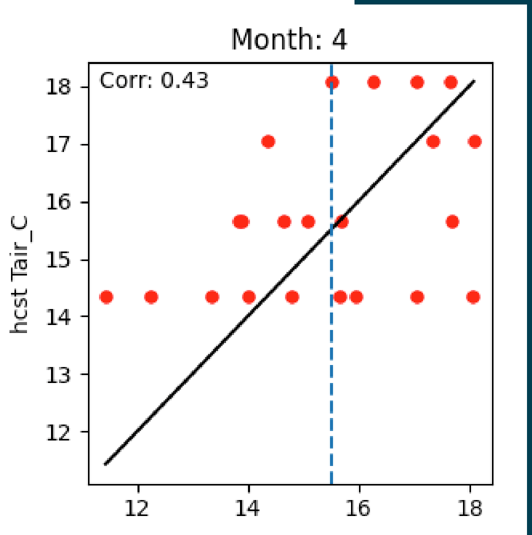
Current Approach Assessment

- The Python version of the method will allow for running the current method easily across a range of variations and expanded usage modes
  - past forecast dates (to enable verification/skill assessment)
  - different methodological choices
  - choice of exceedance percentile from the climate ensemble
  - season to month assignments
  - facilitates broader visualization and analysis
  - facilitates ensemble forecasting of stream temp. model inputs
  - community input: host the scripts/notebooks in a Github repository to invite contributions (https://github.com/NCAR/SacMet, currently private)

SacMetTemp Project, Current Approach Assessment

- Updated
  - Example hindcast output
  - Apr 2021 forecast
  - CEQualW2 model inputs
  - Github repo for method collaboration
  - Current year experimental forecast (NCAR ftp site)
- Analysis
  - Using the spreadsheet to assess L3MTO performance (2000-21)
  - Some skill for season 1 temperatures, not at longer lead time
  - Resampling/analog method limitations

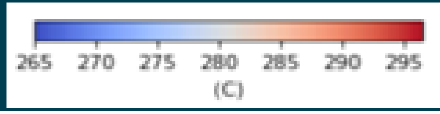


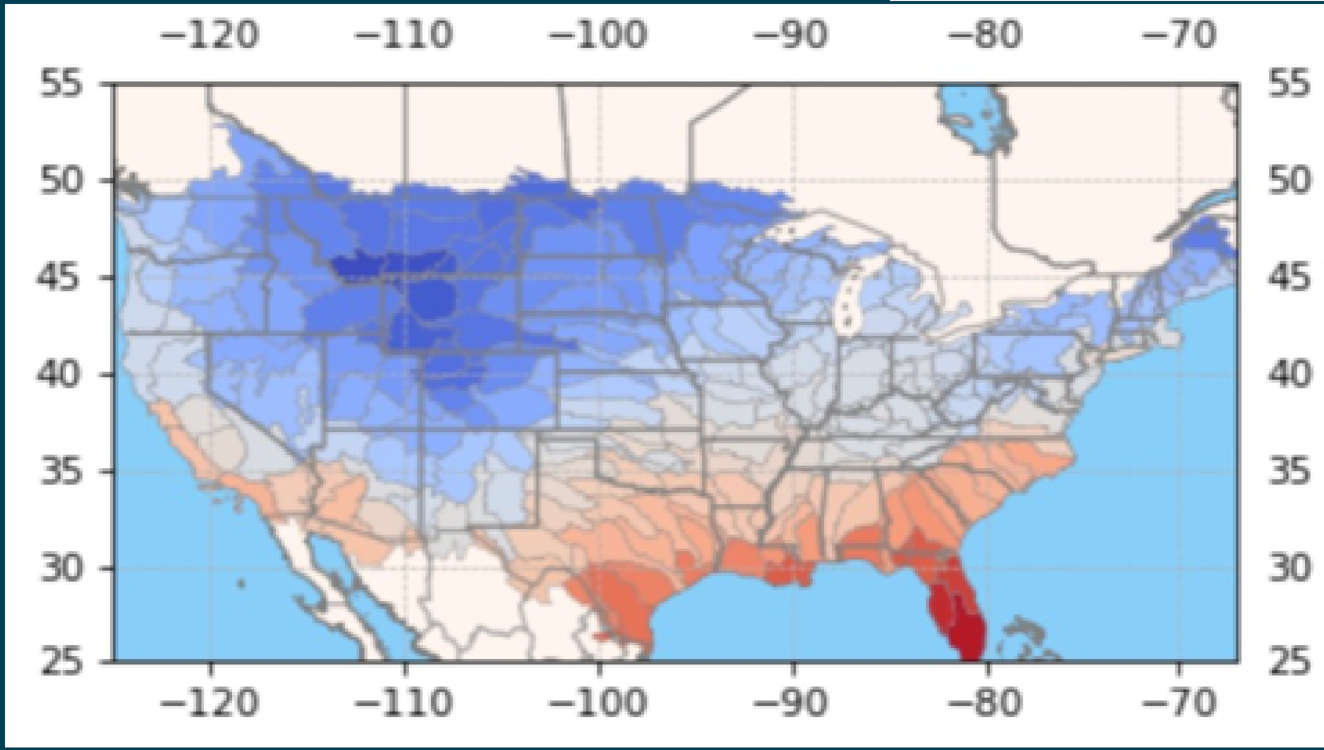


Focus on S2S climate inputs

- Evaluate alternative climate forecast inputs and methods
  - CPC monthly?
  - IRI seasonal or sub-seasonal?
  - NMME?
  - GEFS and Sub-X for shorter lead times?
  - ECWMF Seas5?
  - Reclamation ML-based (Rodeo)?
  - CADWR?
  - NCAR CESM2?
  - CNRFC HEFS?
  - Tailored empirical forecasts?
  - A combination?

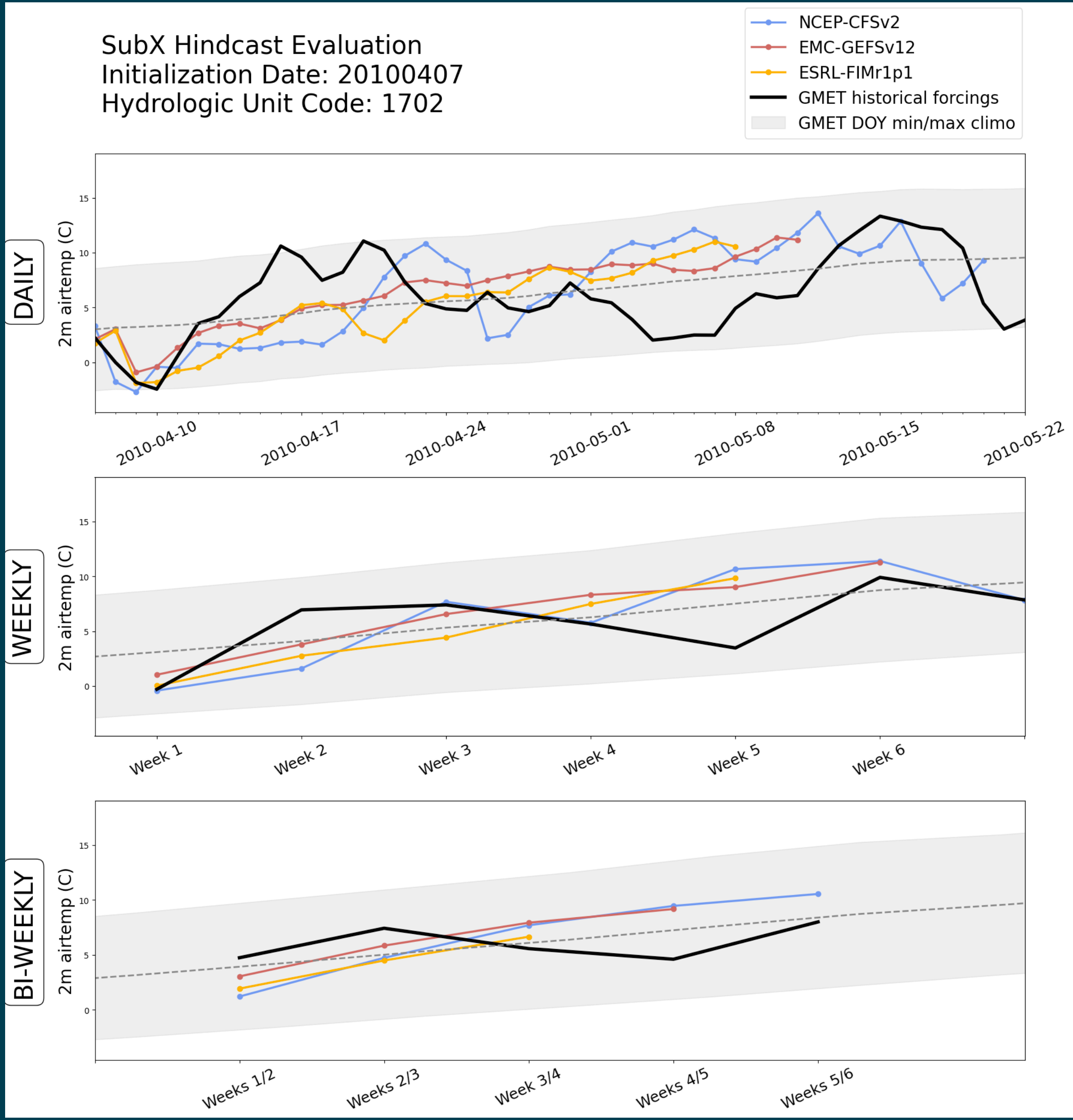
- For several projects, we are creating an S2S climate forecast testbed to inter-compare S2S skill from different approaches (with J. Sturtevant, Lynker)





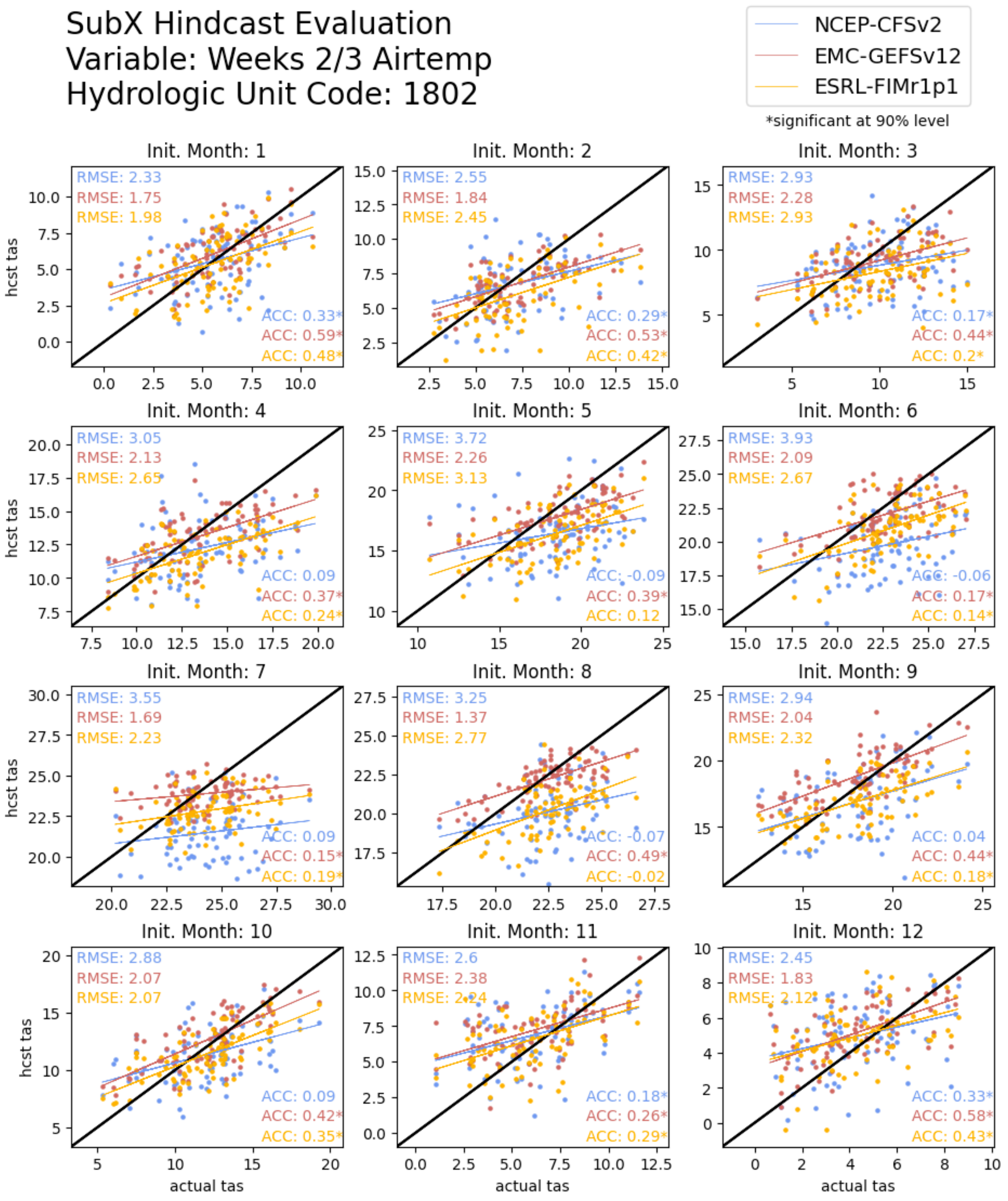
SacMetTemp Project – S2S Climate Testbed

- Currently validating different sources of sub-seasonal climate forecast information
  - Week 1 – GFS/GEFS
  - Weeks 2-4
  - Months 2-3 and beyond



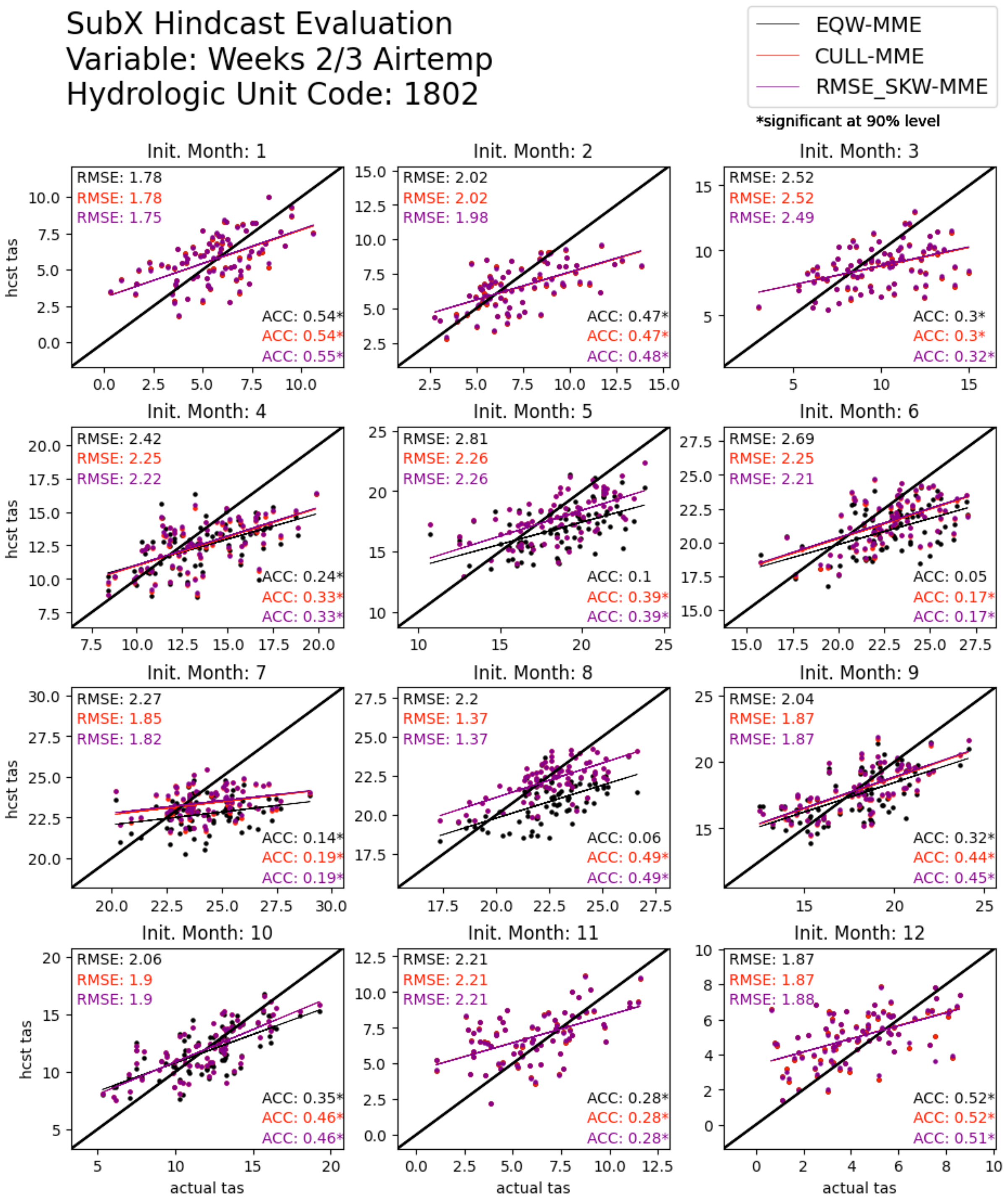
SacMetTemp Project, S2S Climate Testbed (part 1)

- Example of Assessing different climate model forecast skill
- CFSv2, GEFSv12, and FIMr1p1 are different S2S forecast models



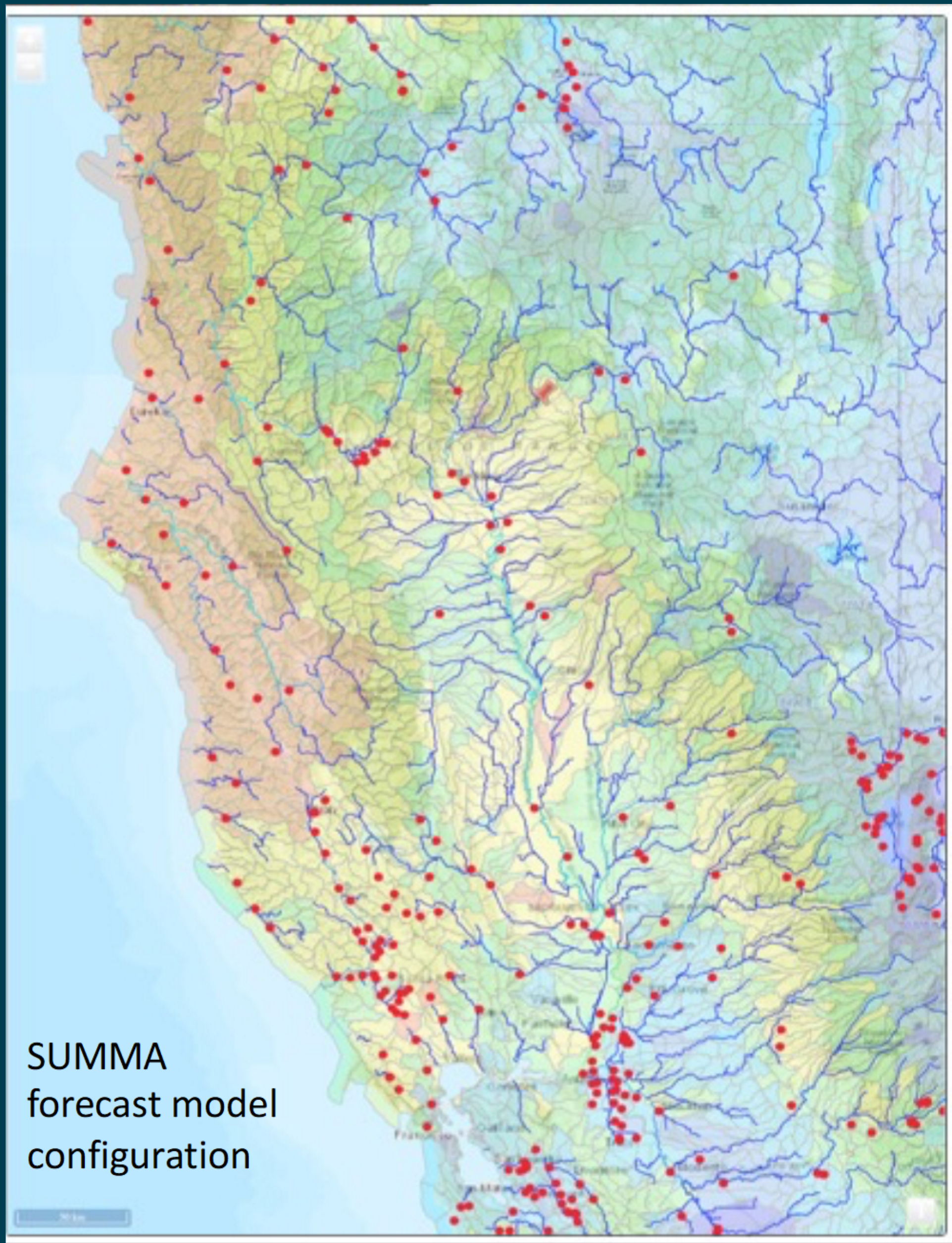
SacMetTemp Project, S2S Climate Testbed (part 2)

- Example of assessing different climate forecast model combination methods
  - EQW-MME: equal weighting
  - CULL-MME: removing the lowest skilled models
  - RMSE_SKW-MME: weighting the models by their forecast skill



Planned activities for next 6 months

- Generate experimental CE-Qual-W2 met. forecast inputs with climate conditioning
  - monthly updates (posted to NCAR ftp site)
  - some methods may produce ensembles
  - explore approaches to enforce consistency between ST model met. inputs and streamflow ensemble traces (a long-term goal)
  - expand to other locations as needed
  - assess forecast skill versus benchmarks (perfect/ climatology) and other alternative methods
- Calibrate seasonal inflow forecast model for Lake Shasta and add extension for inflow temperature (RBM model)



Q&A: NCAR's Meteorology Forcing Datasets/Inflow Temperature Project

- Contact Information:
  - Randi Field rfield@usbr.gov
  - Andy Wood andywood@ucar.edu
- Other contributors:
  - Yifan Chen, Andy Newman, NCAR RAL
  - Donna Garcia, Mechele Pacheco, USBR

Future Action: Facilitated Implementation with WTMP

- Favorable results will be shared with the Watershed Monitoring Workgroups for acceptance and potential integration with seasonal water temperature planning.
- SacMetTemp was designed with potential to expand to other watersheds.
- Testbed and forecast benchmarks are being developed to frame implementations and manage evolving technologies in the future.

Photo credit: John Hannon, Reclamation

Key Response and Clarification on MTC Review Comments

Yung-Hsin Sun, PhD, PE, Sunzi Consulting LLC

Randi Field, Hydrologic Engineer, CVO, Reclamation

Recap: Active and Upcoming Review Requests

WTMP Technical Memoranda	Team Draft	MTC Review	Team Revision	Final Draft Posting	Peer Review Ready
Model Framework Selection and Design	Completed	Completed	Completed	Completed	Completed
Model Selection	Completed	Completed	Completed	Completed	Completed
Data Management Plan	Completed	Completed	Completed	Completed	Completed
Data Development	Completed	Completed	Completed	late July	late July
Model Development	Completed	Focus Completed	mid-July	late July	late July
WTMP Implementation	mid-July	late July	early August	mid-August	mid-August
Model Uncertainty: Sources and Estimates	early July	mid-July	late July	early August	early August
Model Uncertainty: Communication and Protocols	mid-July	late July	early August	mid-August	mid-August

- Team Draft and Team Revision includes Reclamation review and sign-off for next steps
- Peer Review Ready prior to 8/11/2023 unless otherwise noted

Key Responses and Clarifications (part 1)

- Peer review status for HEC Res-Sim, especially WQ application
  - Experiencing unforeseen delay in HEC's documentation and other model development tasks
  - Reclamation in discussion with HEC for a peer review
    - Tentatively, focus on water temperature modeling component as the basic HEC Res-Sim model has been widely used for different applications with improvements made throughout the history of use. The focus is also consistent with WTMP purposes.
    - More details in October 2023 MTC meeting

Key Responses and Clarifications (part 2)

- Current initial implementation of WTMP and associated models
  - Focus on functional development for initial rollout in Spring 2024
  - With an expectation for continued improvement after the current project and deployment
    - Continued engagement opportunities: A discussion topic later in the Agenda
- Comments and track-change suggested edits were received and under review for incorporation
  - For efficiency, if interested in setting a meeting for streamlining the discussion on comments and resulting revisions, please reach out to Randi and/or Yung-Hsin for arrangement; we will reach out to the commenter(s) if needed too.

Questions on MTC Comments

Break (10 min)

Photo credit: John Hannon, Reclamation

Model Uncertainty:

1. Sources, Approach, and Characterization
2. Communication and Protocols

Mike Deas, PhD, PE, Watercourse Engineering, Inc.

Yung-Hsin Sun, PhD, PE, Sunzi Consulting LLC

Why We Care about Uncertainty?

- Properly informed decisions/actions require understanding of uncertainty associated with the predicted quantity of interest.

Decisions/Actions

Supporting (along with other information)

Data → Model(s) → Quantity of Interest

Predictive Estimation Process (each piece includes uncertainty)

Uncertainty in the WTMP: Recap

- Considerations when characterizing uncertainty in the WTMP framework
  - WTMP is a tool, not a decision-making body
  - WTMP models represent an approximation of a combination of complex natural processes and built river-reservoir systems
  - Pragmatic for implementation and ability to assess resulting benefits
- Objective: Develop and communicate sources of uncertainty in estimates of water temperature downstream of regulating reservoirs
- Description: Identify potential sources of variability and uncertainty within the modeling approach, particularly significant sources. Explore potential impacts on applications that include forecasting

Uncertainty in Models

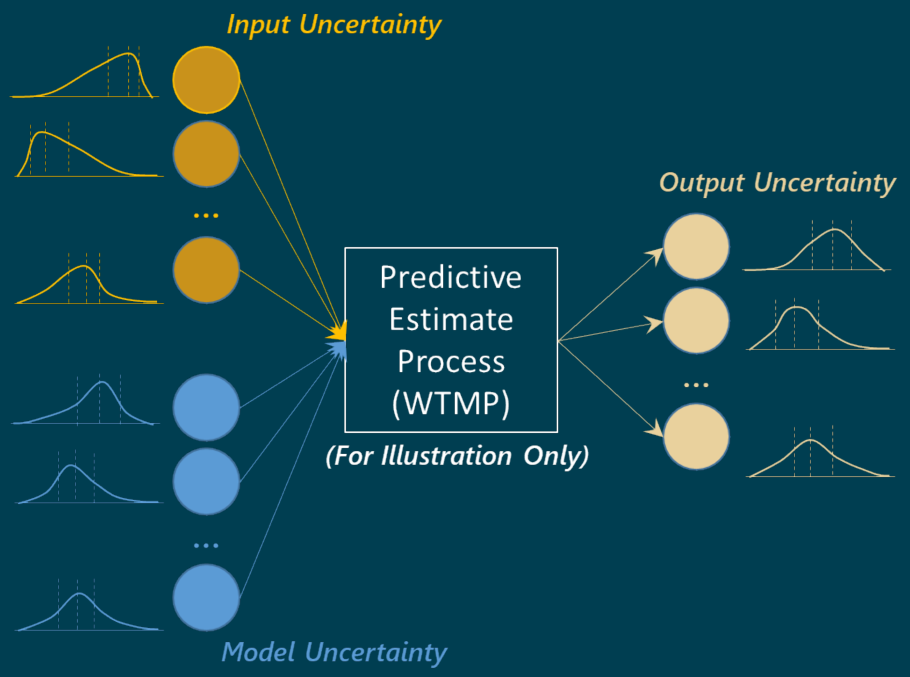
- Model conceptualization
  - Identify key processes and features
- Model development
  - Formulations, process representations error
  - Specific infrastructure representation error (TCD, shutters, curtains)
- Data development
  - Measurement error
  - Forecast error
- Parameter estimation (Calibration)
  - Calibration parameters error (and all other error)

WTMP, Addressing Model Uncertainty

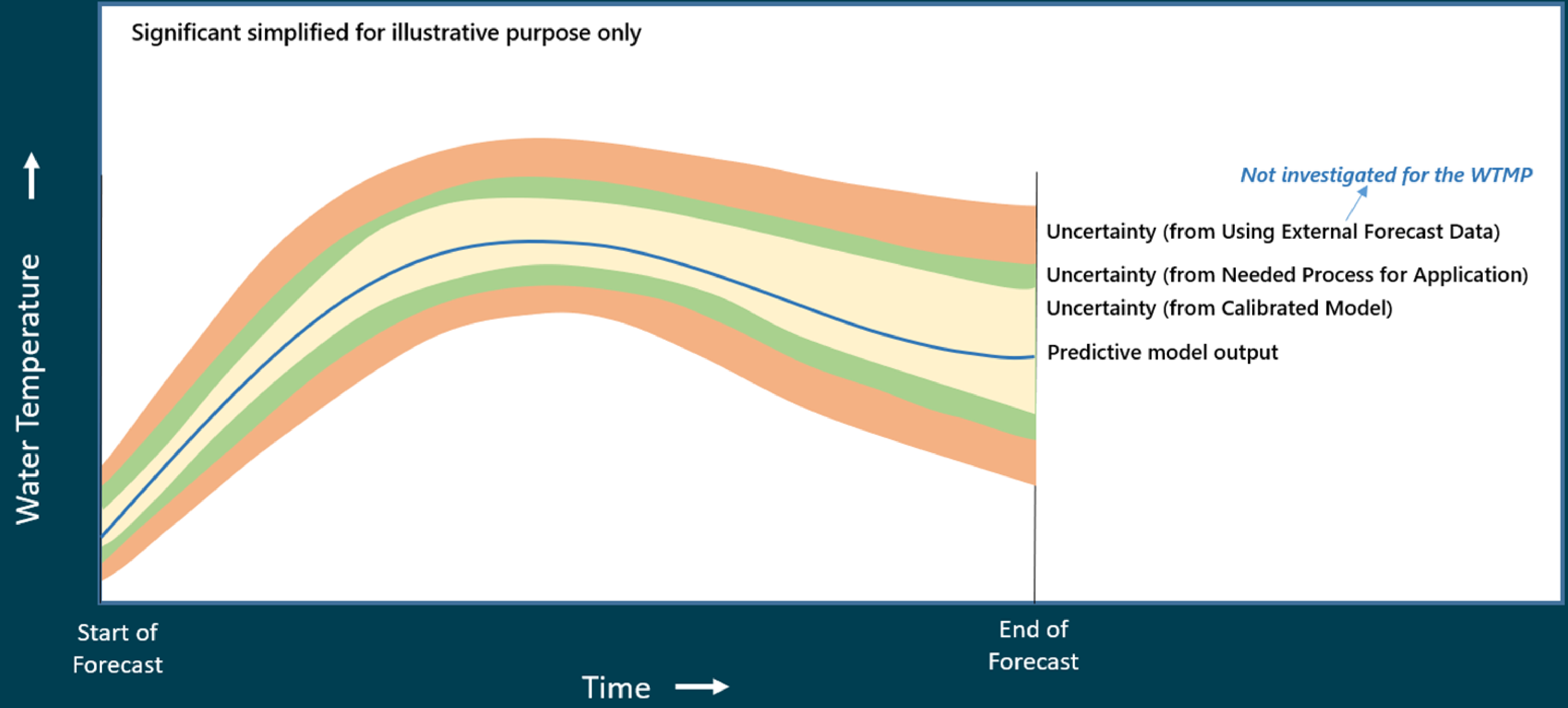
- Build Models and Test Models
  - Calibration Mode
    - Quantification of uncertainty associated with the data and parameter estimation was included in calibration (e.g., calibration parameters)
    - Resulting predictive errors were assessed using model performance metrics to determine the fitness and acceptability of the calibrated model.
    - Encompasses all previous stages (conceptualization, development, data)
- Apply (Calibrated) Models
  - Forecasting Mode
    - Uncertainty of the calibrated model is accepted as is for contributing the overall uncertainty of model results.
    - Initial and boundary conditions (i.e., data) are the focus for examining uncertainty of the predictive/ forecasting processes and estimates

Model Application Uncertainty

- Propagation of Uncertainty
  - Inherited uncertainty from the calibrated model
  - Forecast uncertainty
- Forecast uncertainty
  - Uncertainty in flow and operations, temperature, meteorological forecast
    - External to WTMP (not investigated; may be subject to user preference)
  - Uncertainty in additional necessary processes required for applications to accommodate available input (as currently configurated)
    - Internal for WTMP (investigated; discussed later)



Conceptual Sketch on Accumulation of Uncertainty



Forecasting: Approach to Explore Uncertainties in WTMP Application

- A range of approaches
  - Position analysis
  - Ensemble analysis
  - Monte Carlo analysis
  - Other

Single Scenario Forecast	Selective Scenario Forecasts	Ensemble Forecasts	Multi-Model Ensemble Forecasts
One representative realization of the future scenario (representative, hopefully)	Currently used multiple but selective exceedance points (e.g., 50%, 75%, 90%, 95%, 99%) for hydrologic and meteorological conditions, with paired water temperature boundary conditions. Scenarios are not considered equally possible.	A large number of scenarios with a representative range and probability of hydrologic and meteorological conditions. All scenarios are considered equally possible.	Using different models in the predictive estimation process for ensemble forecast.
Not used as it provides insufficient information for modern decision making, but implementable in the WTMP	To be implemented in WTMP. Results can be used to bracket possible outcomes with risk consideration, but no formal risk assessment can be done. Not probabilistic.	Could be implemented in WTMP in the future [the platform can accommodate it].	Same as ensemble forecasts. Potential for future inclusion in WTMP driven by the needs and benefits of using different models.

Photo credit: John Hannon, Reclamation

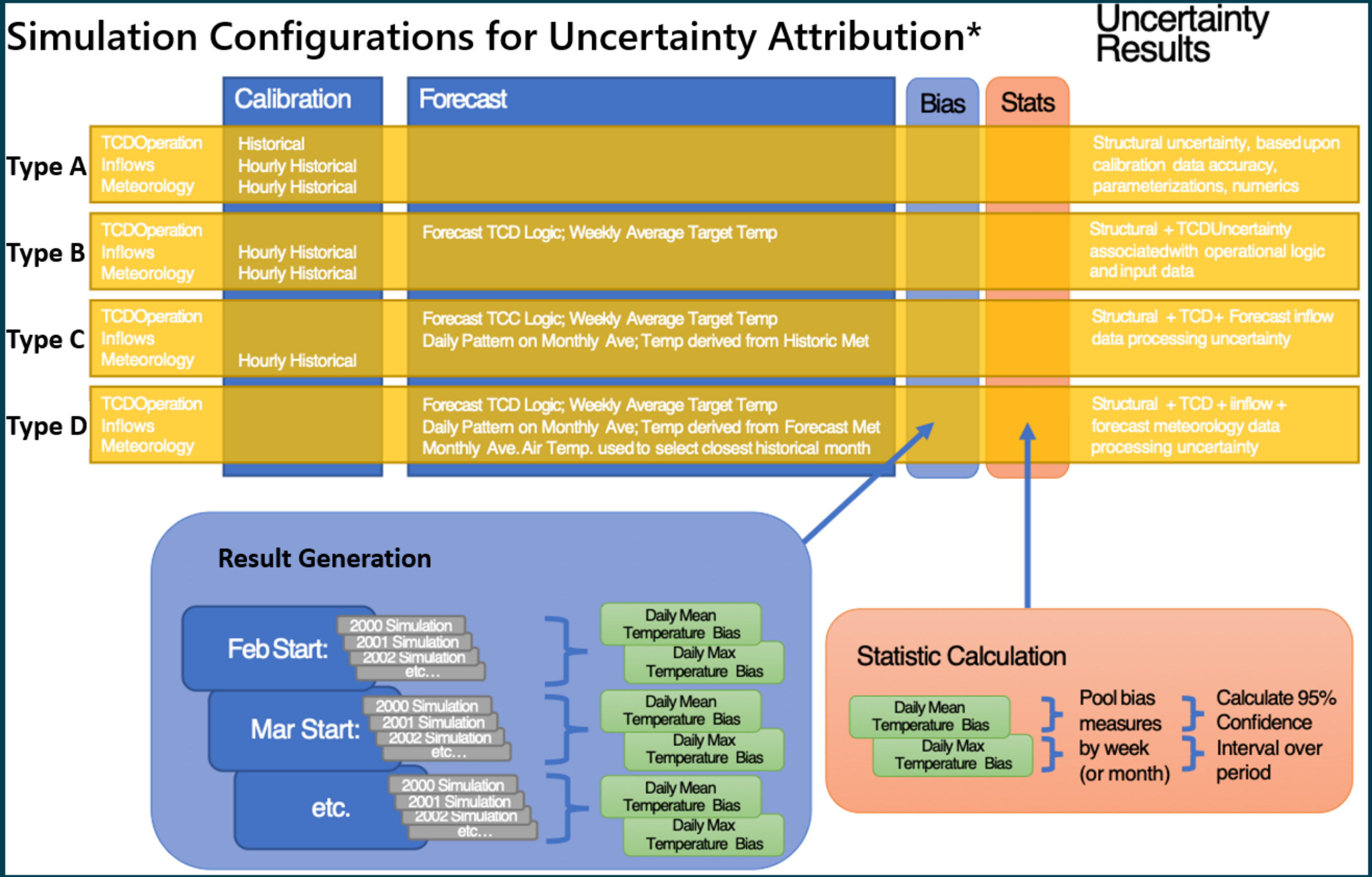
Uncertainty Investigation:
Incorporating Necessary Processes for Applications

John DeGeorge, PhD, PE, Resource Management Associates, Inc.
Mike Deas, PhD, PE, Watercourse Engineering, Inc.

Uncertainty Related to Forecast Data Processing

- Models have been carefully calibrated using the best available historical data
- What additional uncertainty is added with data estimation techniques required when performing forecast simulations (based on the current implementation)
  - Operation of TCD and temperature control shutters by model logic
  - Use of monthly average boundary inflows and reservoir releases
  - Estimation of meteorological conditions
  - Estimation of inflow temperatures
- Approach – develop "perfect forecast" boundary conditions from historical data and compare forecast simulation results to historical observations

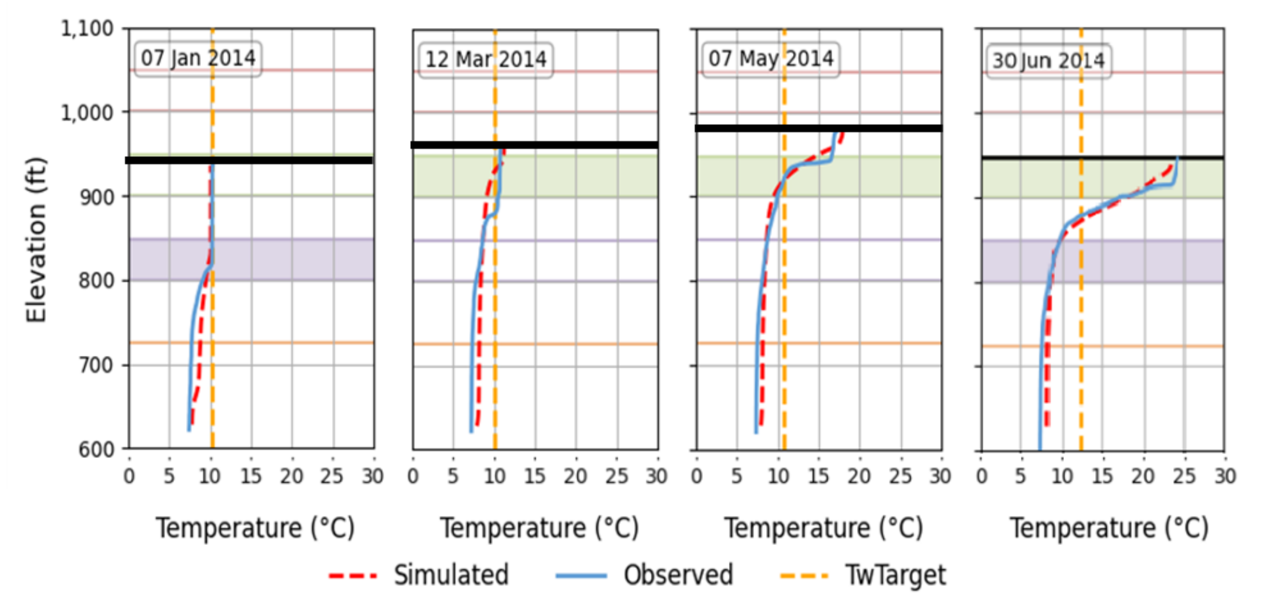
Simulation Configurations for Uncertainty Attribution



- Note, this is not a forecast skill examination

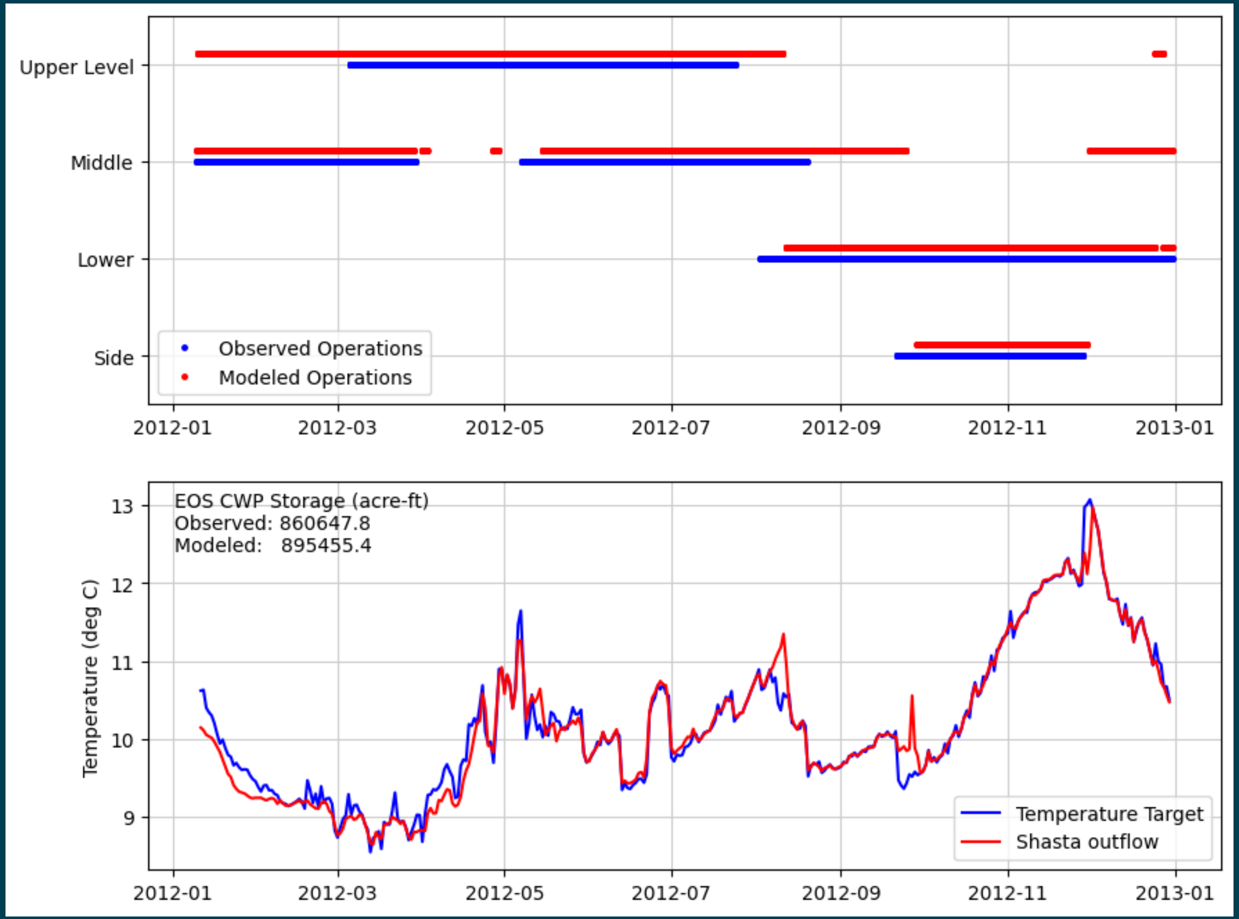
Forecast Boundary Condition Processing: Initial Conditions

- Initial Reservoir Storage
  - Historical value at start of simulation
- Initial Reservoir Thermal Profile
  - Start on the date of a valid Shasta profile. If there is a measure profile within 10 days of the Shasta profile, use it. Otherwise, use ResSim calibration model results for initialization
- Initial River Reach Temperature
  - 10 Celsius constant

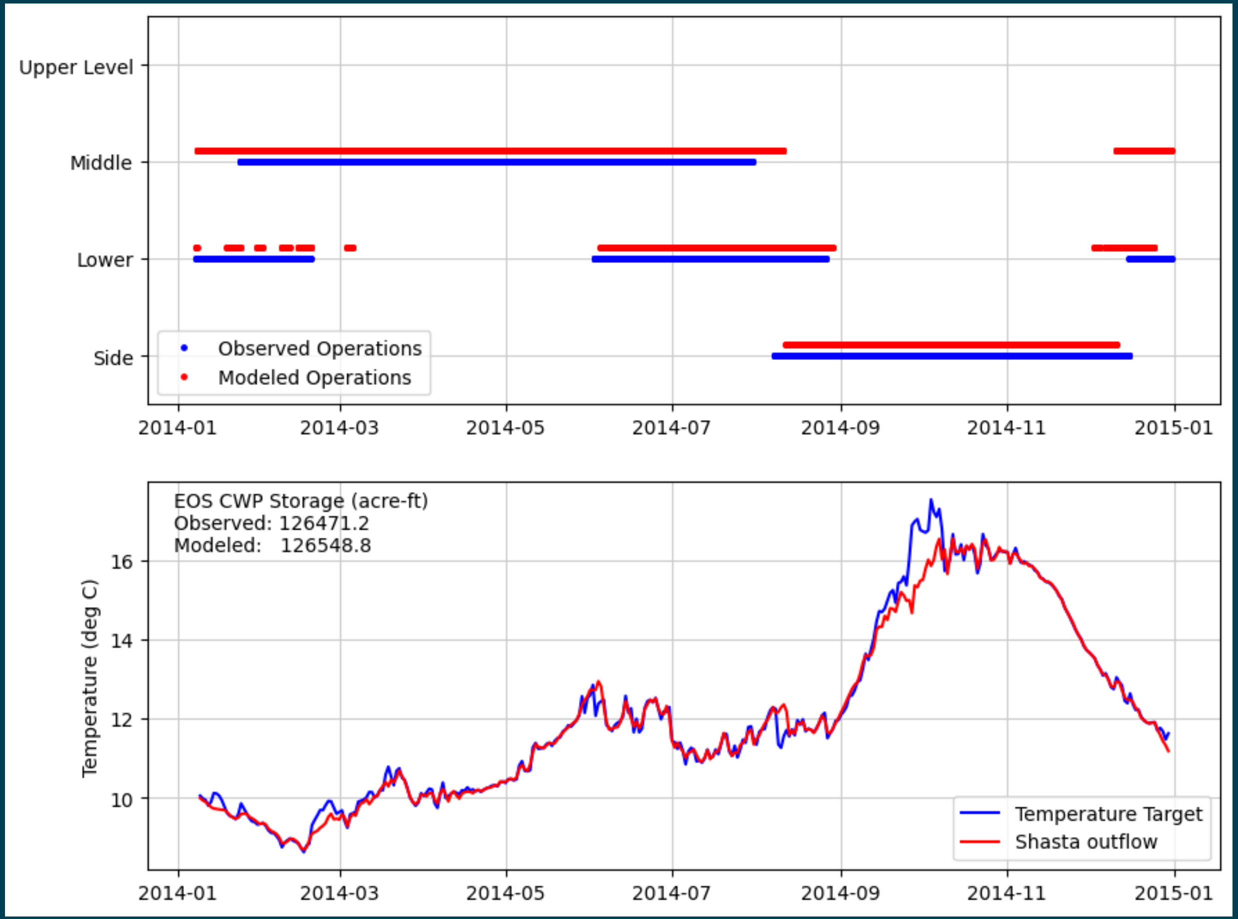


Forecast Simulation: TCD Operation Logic

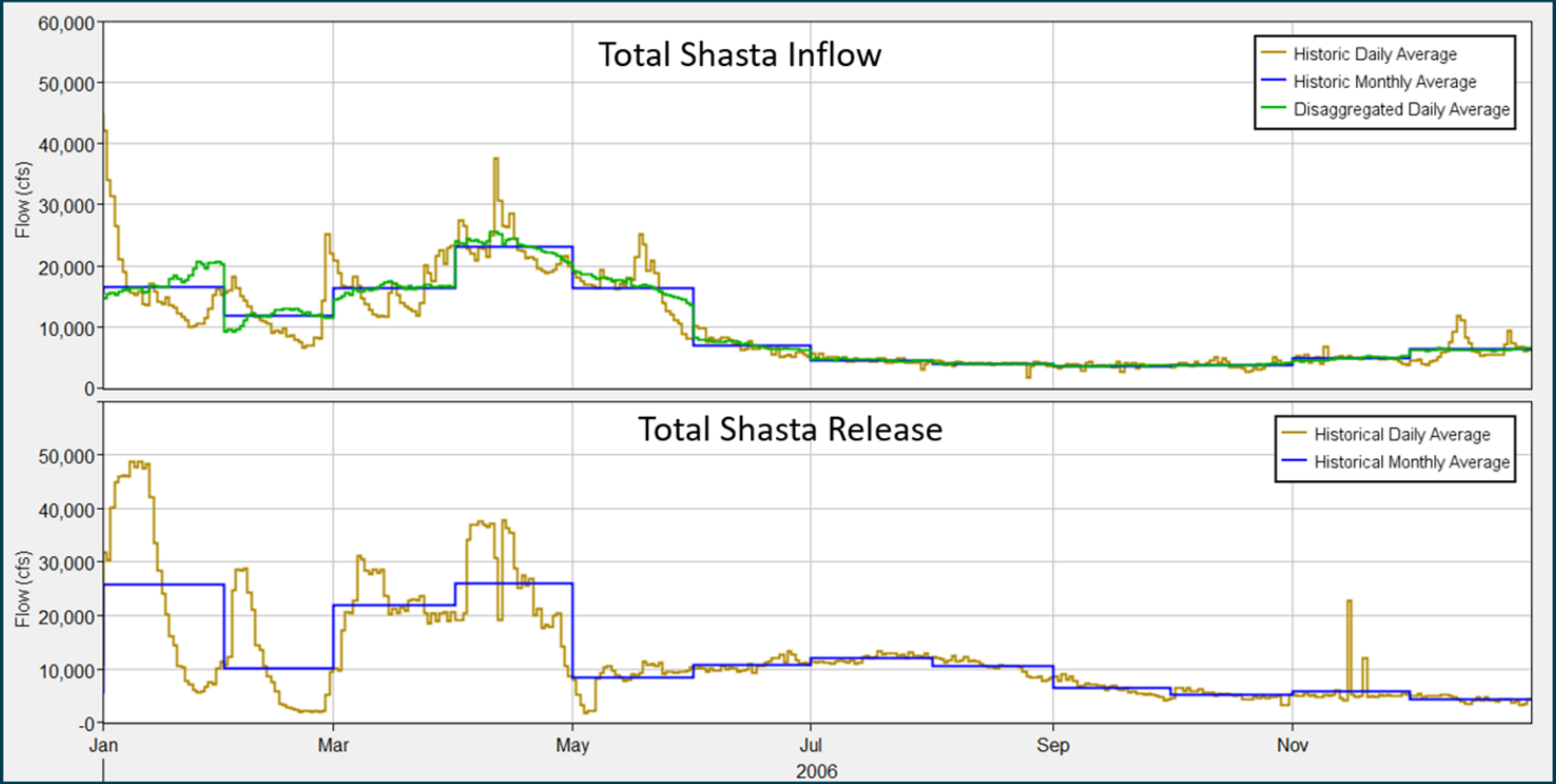
- Example - 2012



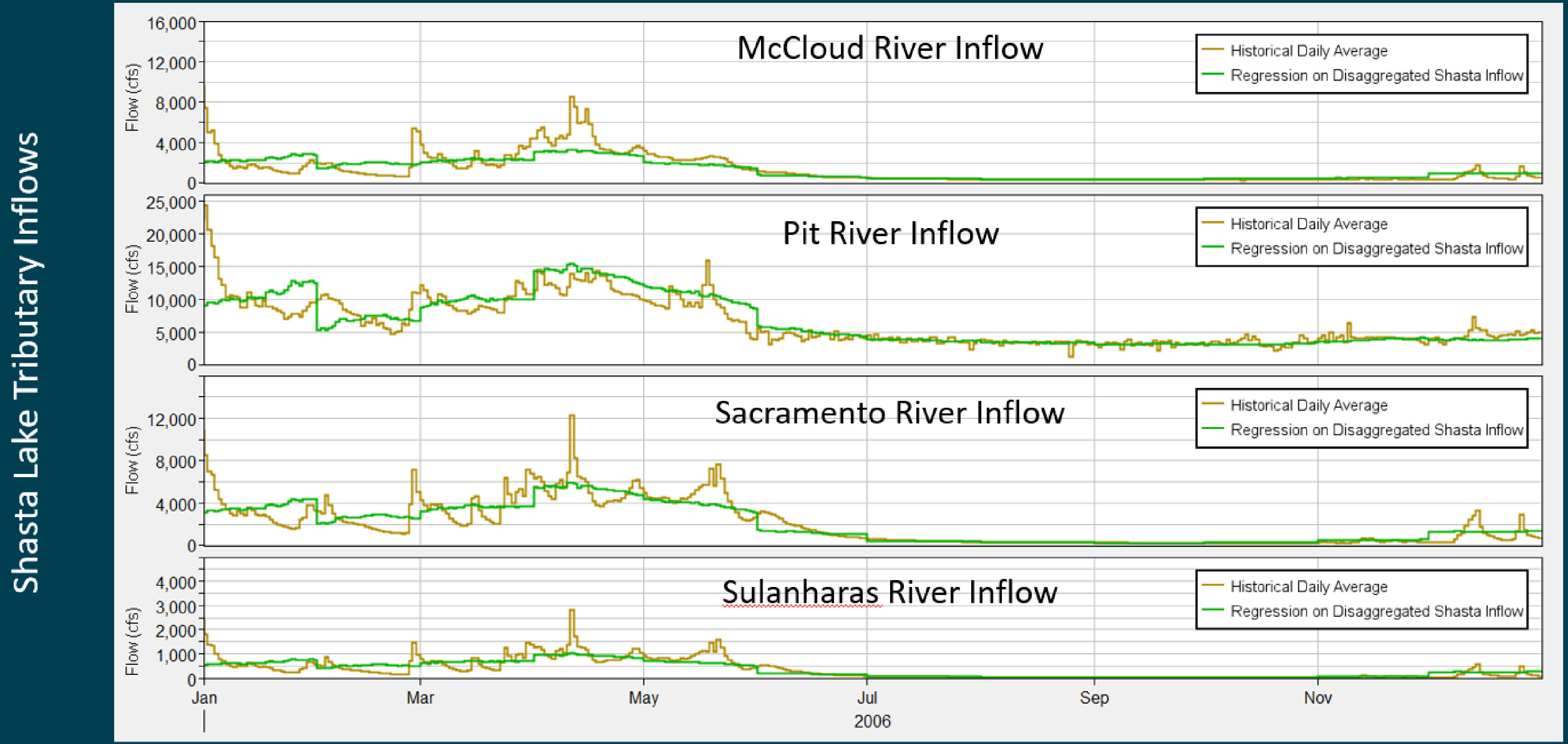
- Example - 2014



Forecast Boundary Condition Processing: Reservoir Inflow and Release (Example 2006)

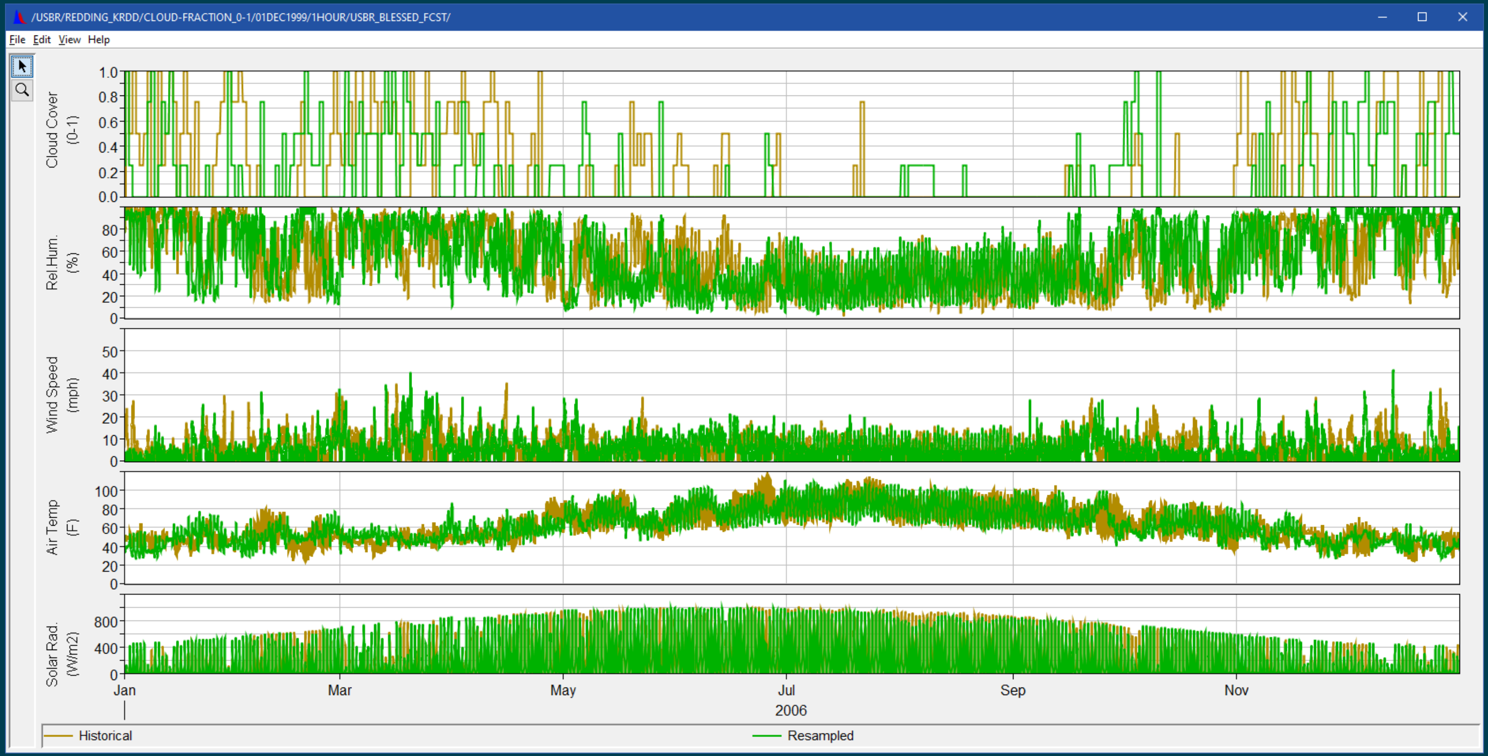


Forecast Boundary Condition Processing: Reservoir Tributary Inflow Distribution (Example 2006)

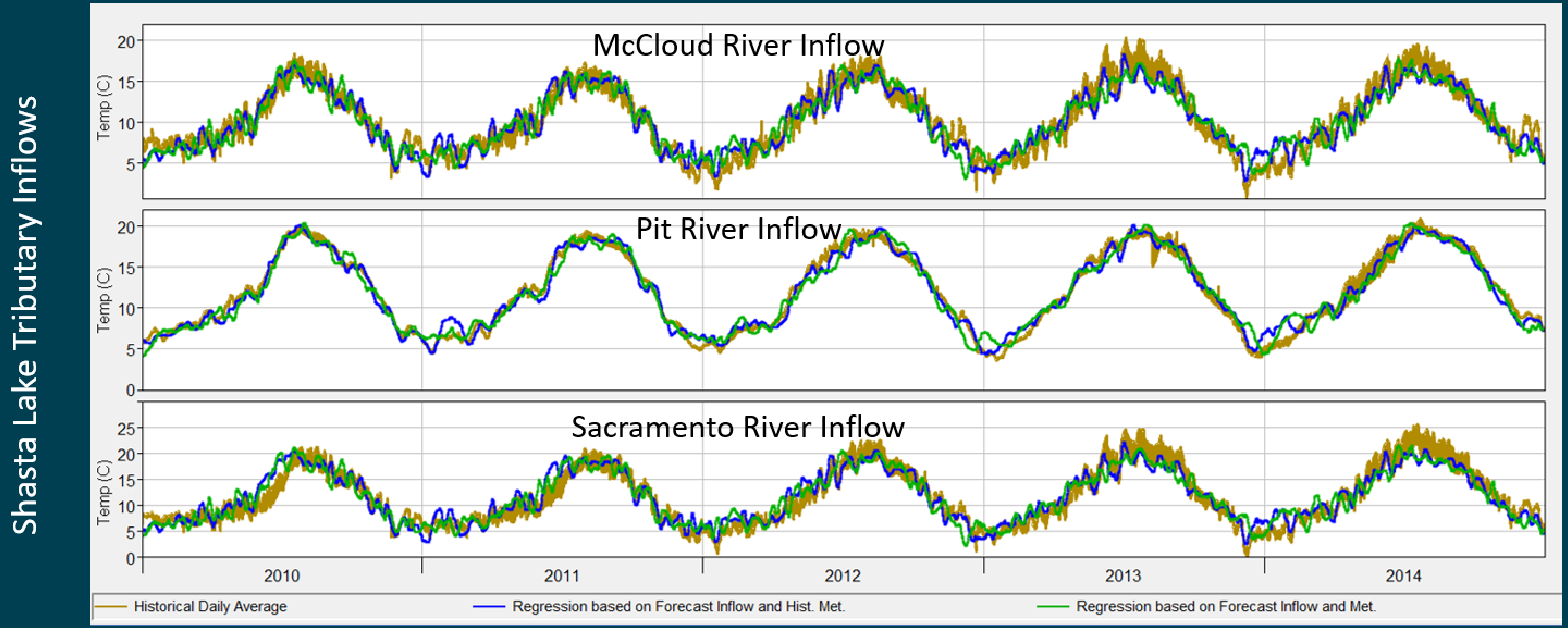


Forecast Boundary Condition Processing: Meteorologic Data (Example 2006)

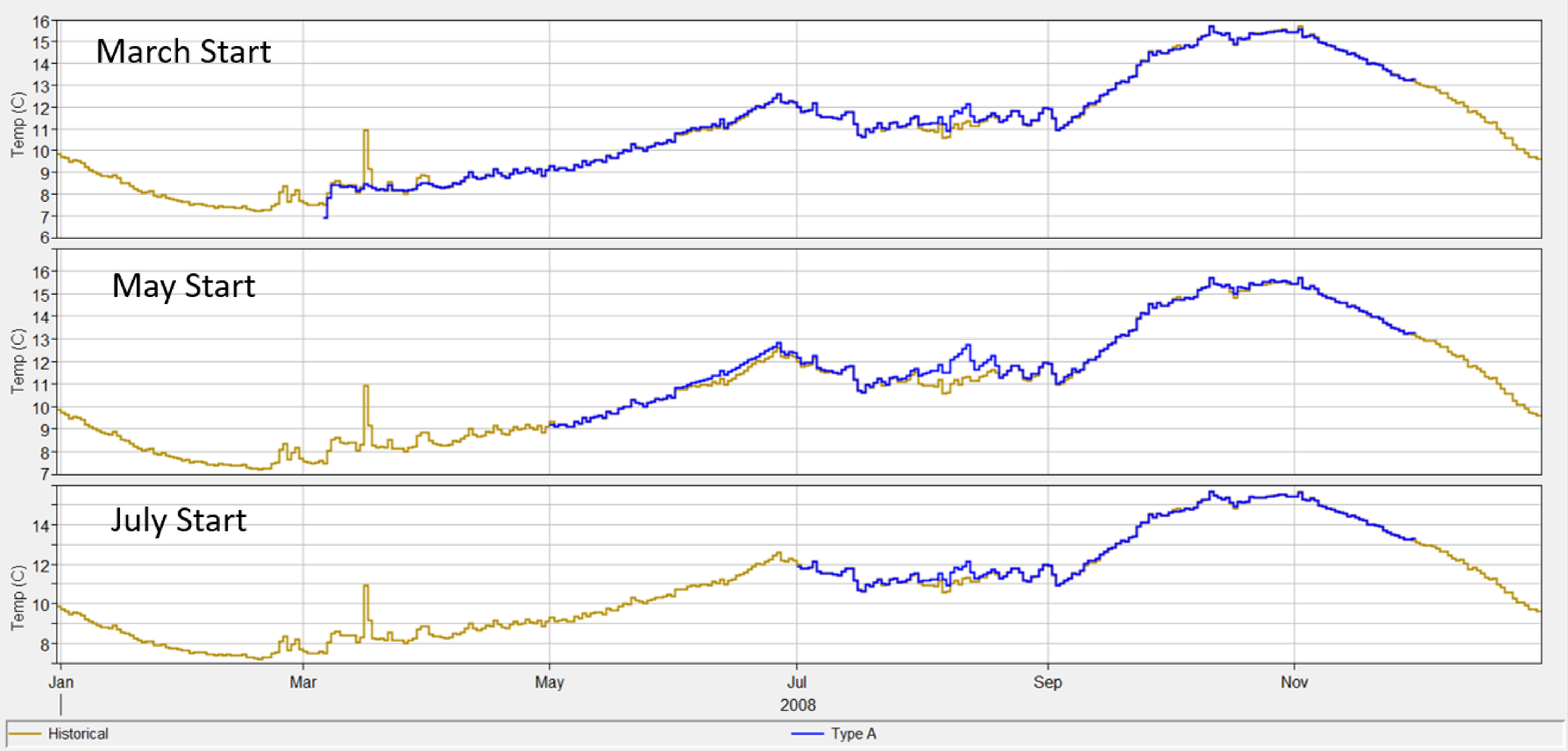
- Resampled based on Monthly Average Air Temperature
  - For each month:
    - Find closest match from same month of another historical year base on monthly average air temperature
    - Copy all met data records from the identified month/year to forecast met data input



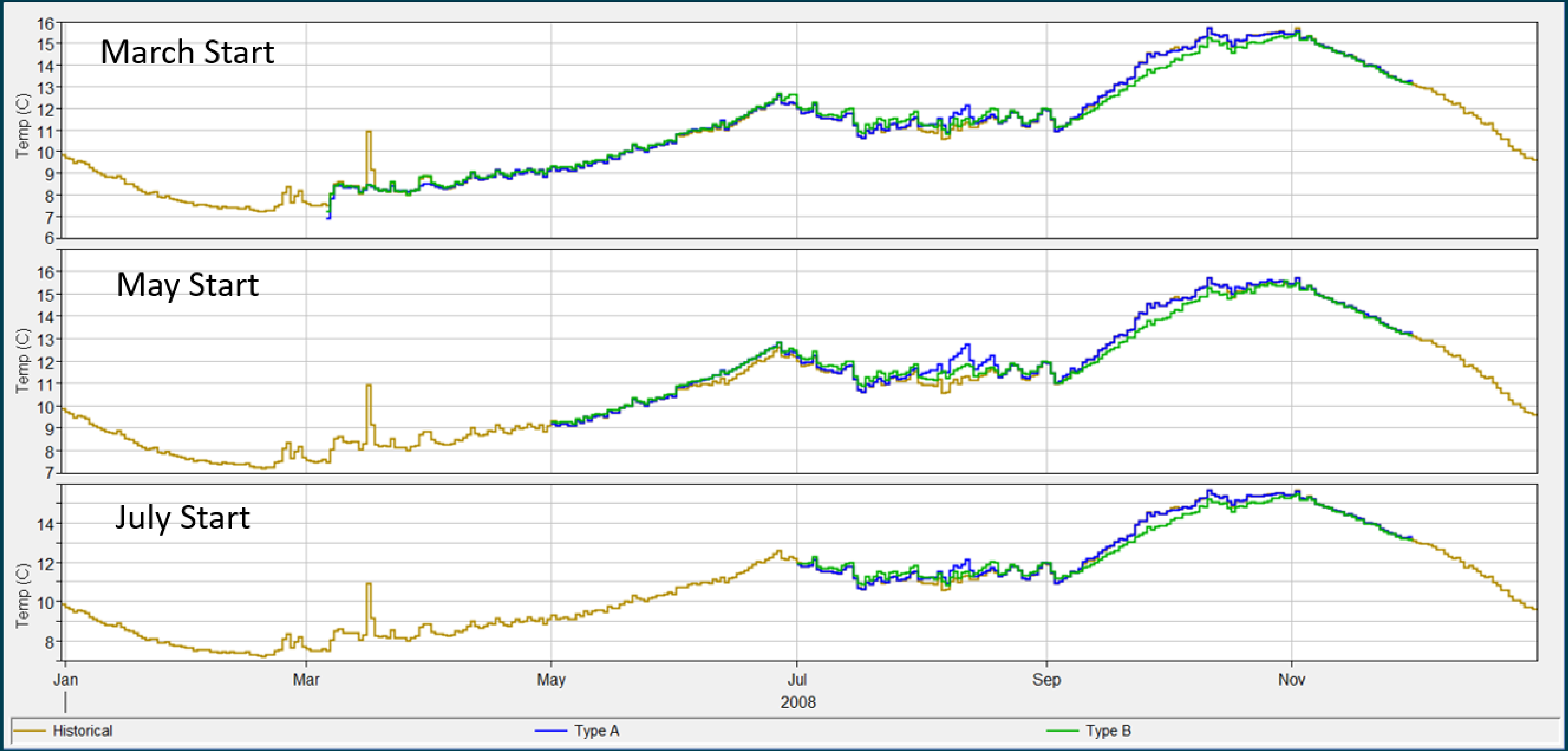
Forecast Boundary Condition Processing: Estimation of Inflow Temperature (Example 2010 to 2014)



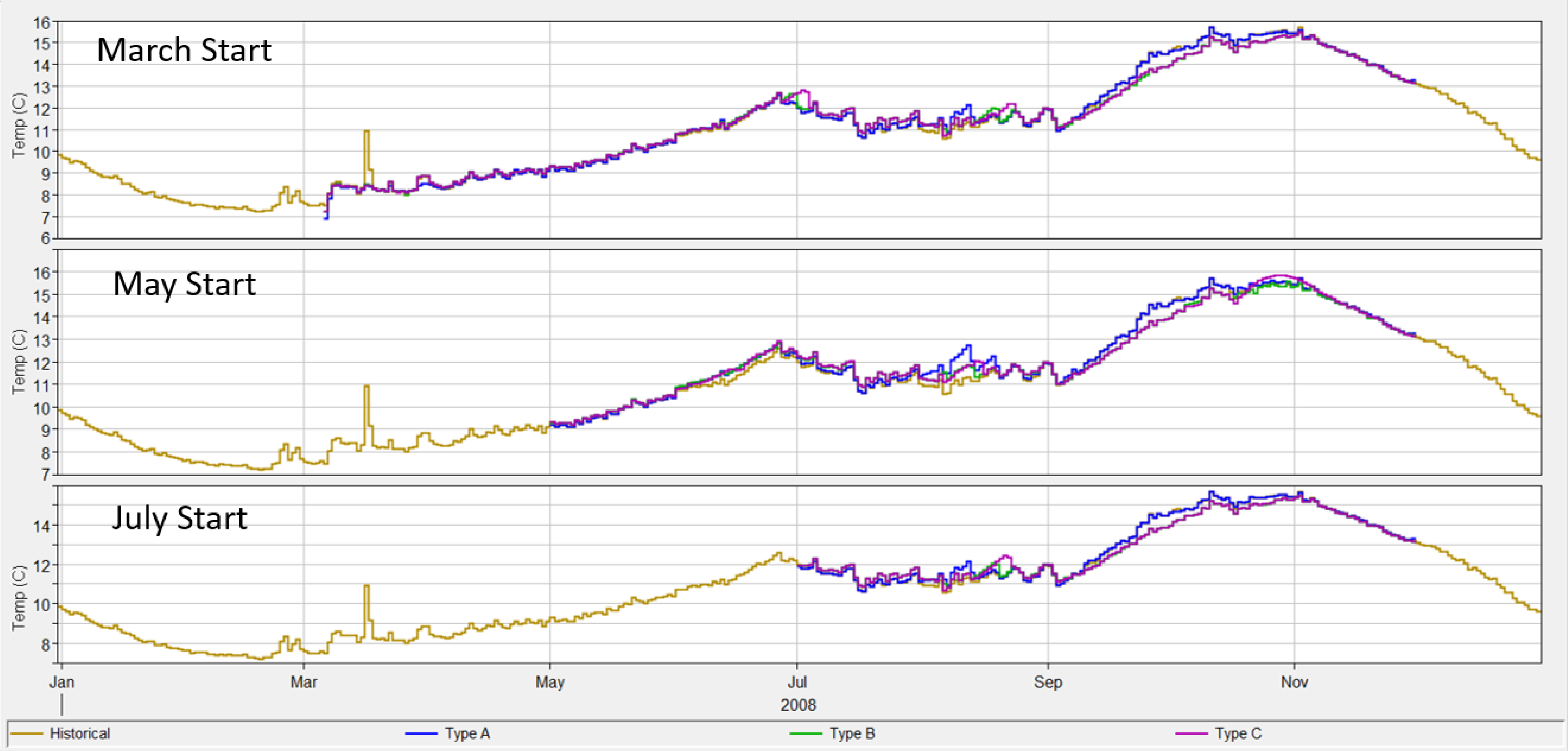
Example Simulation Result: Type A Shasta Outflow Temperature (2008)



Example Simulation Result: Type A and B Shasta Outflow Temperature (2008)



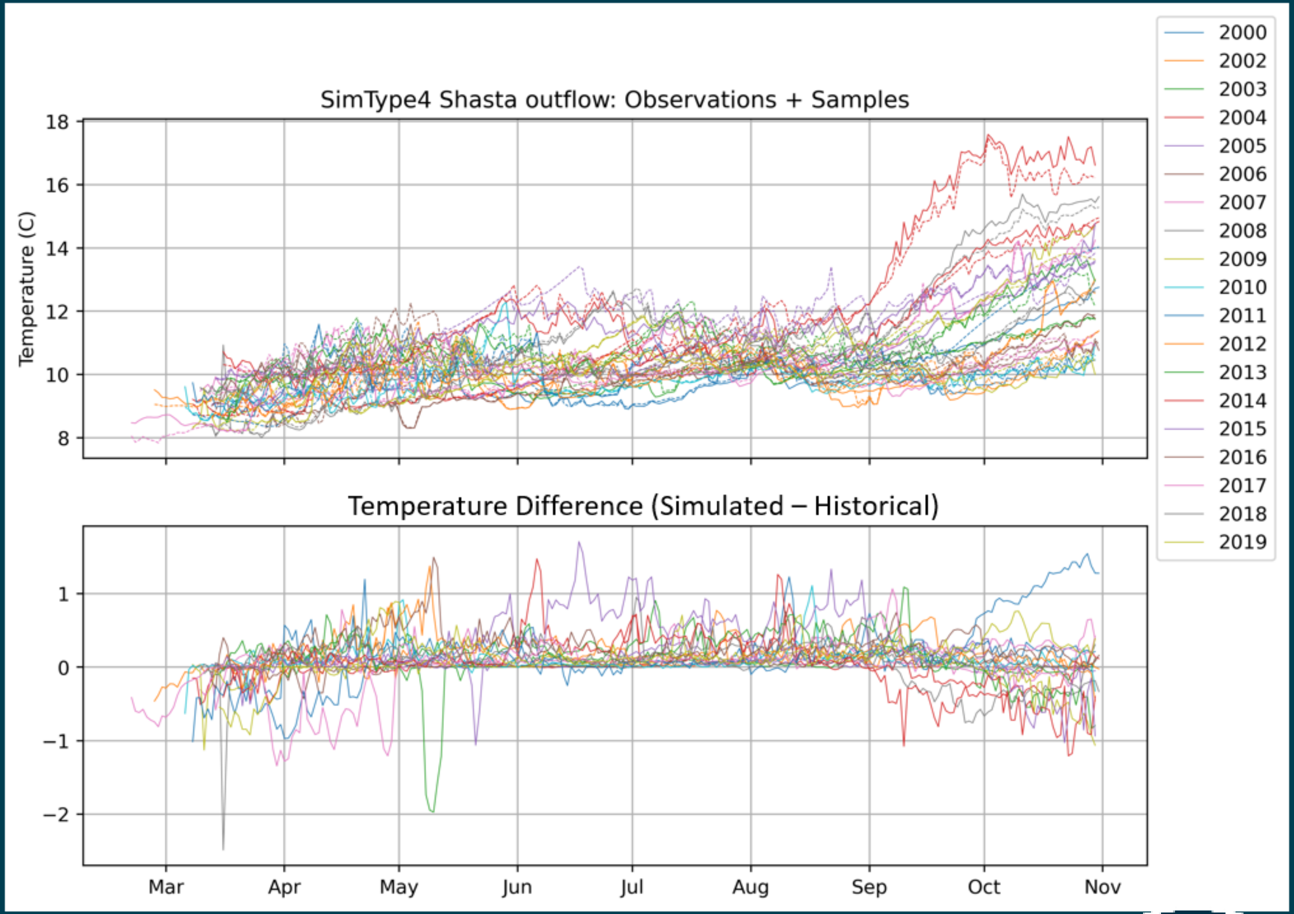
Example Simulation Result: Type A, B, and C Shasta Outflow Temperature (2008)



Example Simulation Result: Type A, B, C, and D Shasta Outflow Temperature (2008)

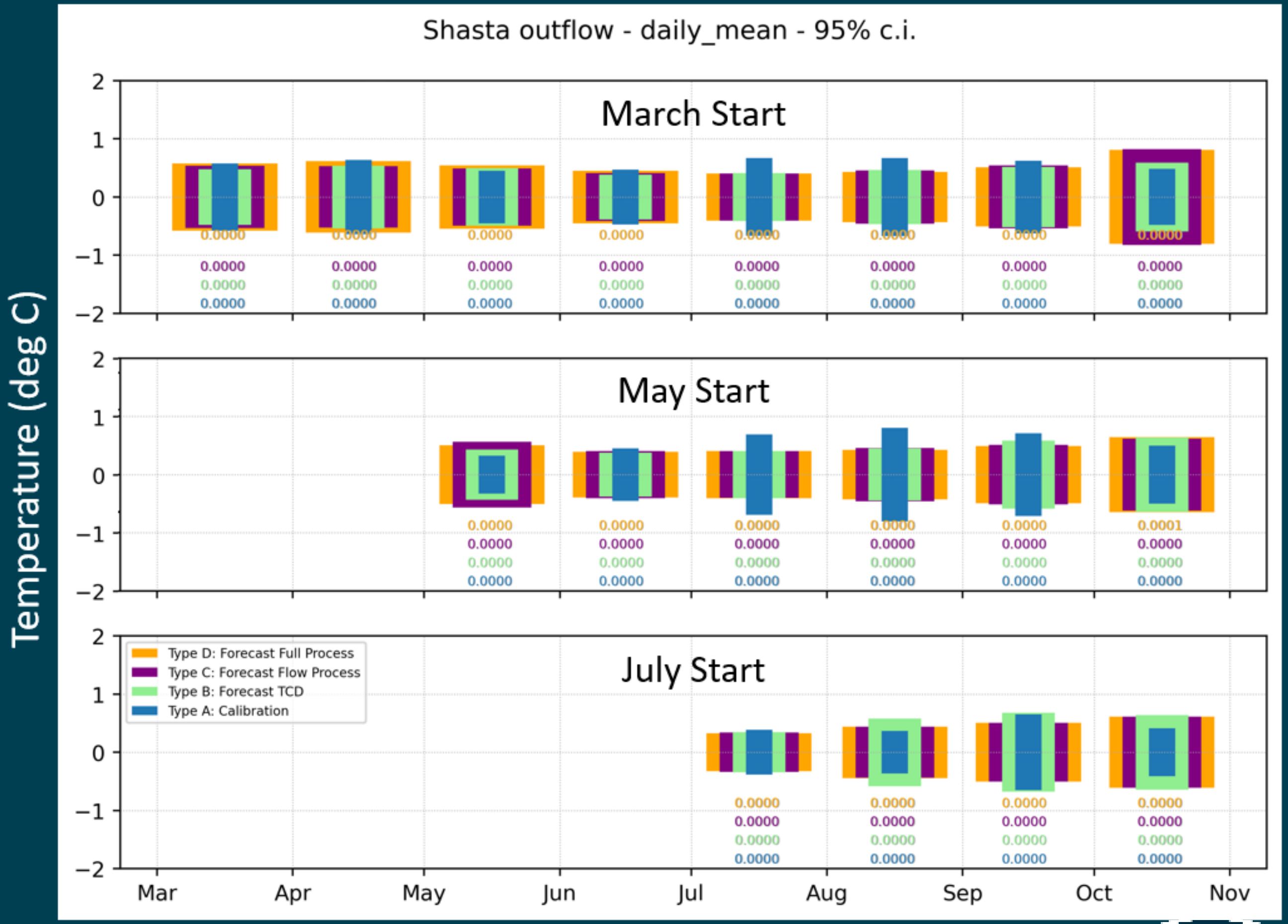
Shasta Outflow Temperature Type D Simulation Results, 2000-2019 March Start

- Top panel: Historical (solid) and Modeled (dashed) daily mean temperatures
- Bottom panel: Difference in daily mean temperature, Simulated – Historical
- Differences before May and in late Fall are often due to profile differences
- In May through September outflow temperature differences are mostly associated with TCD operations



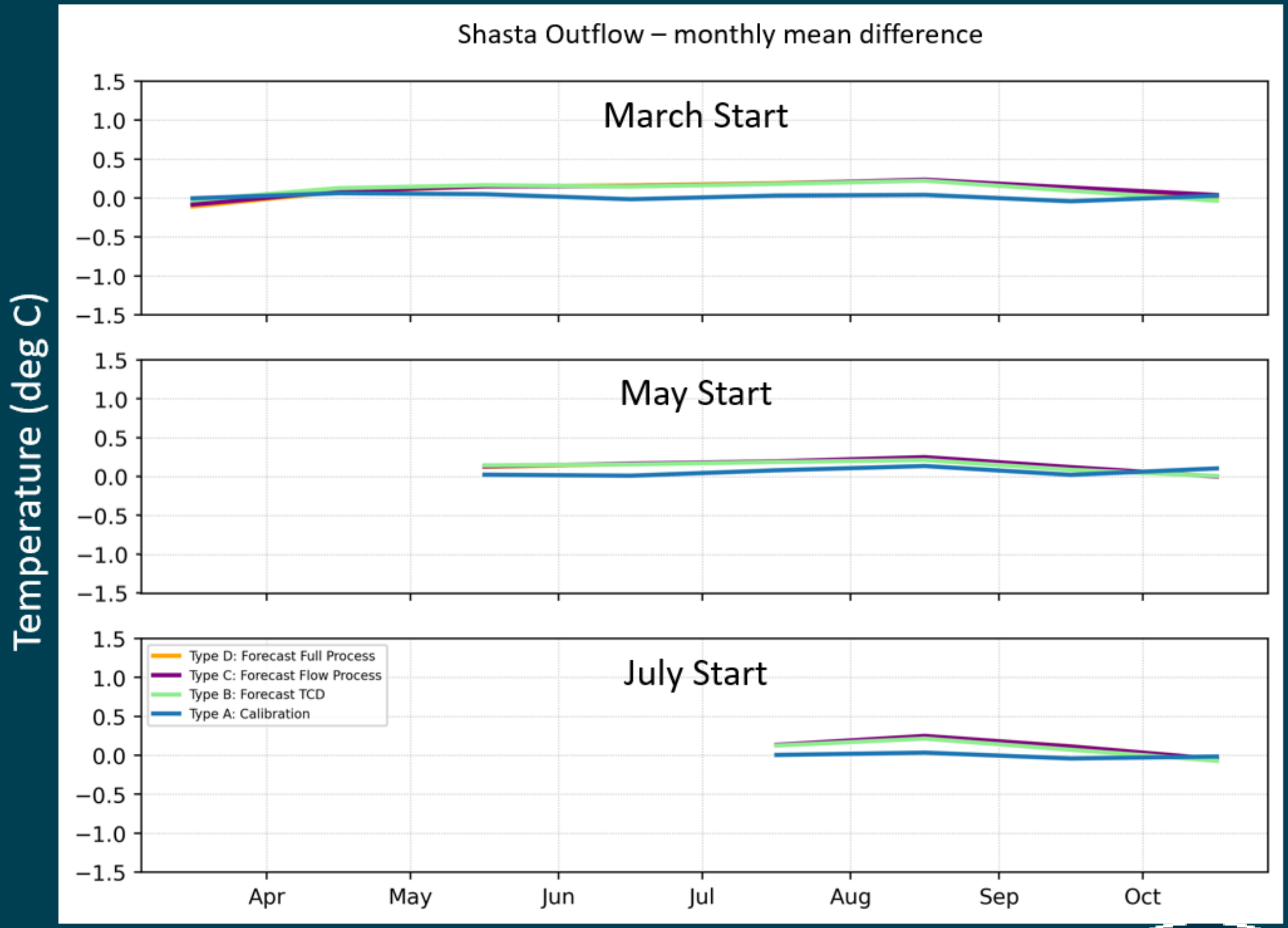
Forecast Process Uncertainty Estimate: Shasta Outflow Temperature

- Vertical height of monthly box = 95% confidence interval
- Numbers below box show p-value of normality test
- Samples are the simulated daily mean temperature minus historical daily mean
- Calibration = Type A
- Forecast TCD = Type B
- Forecast Flow Process = Type C
- Forecast Full Process = Type D



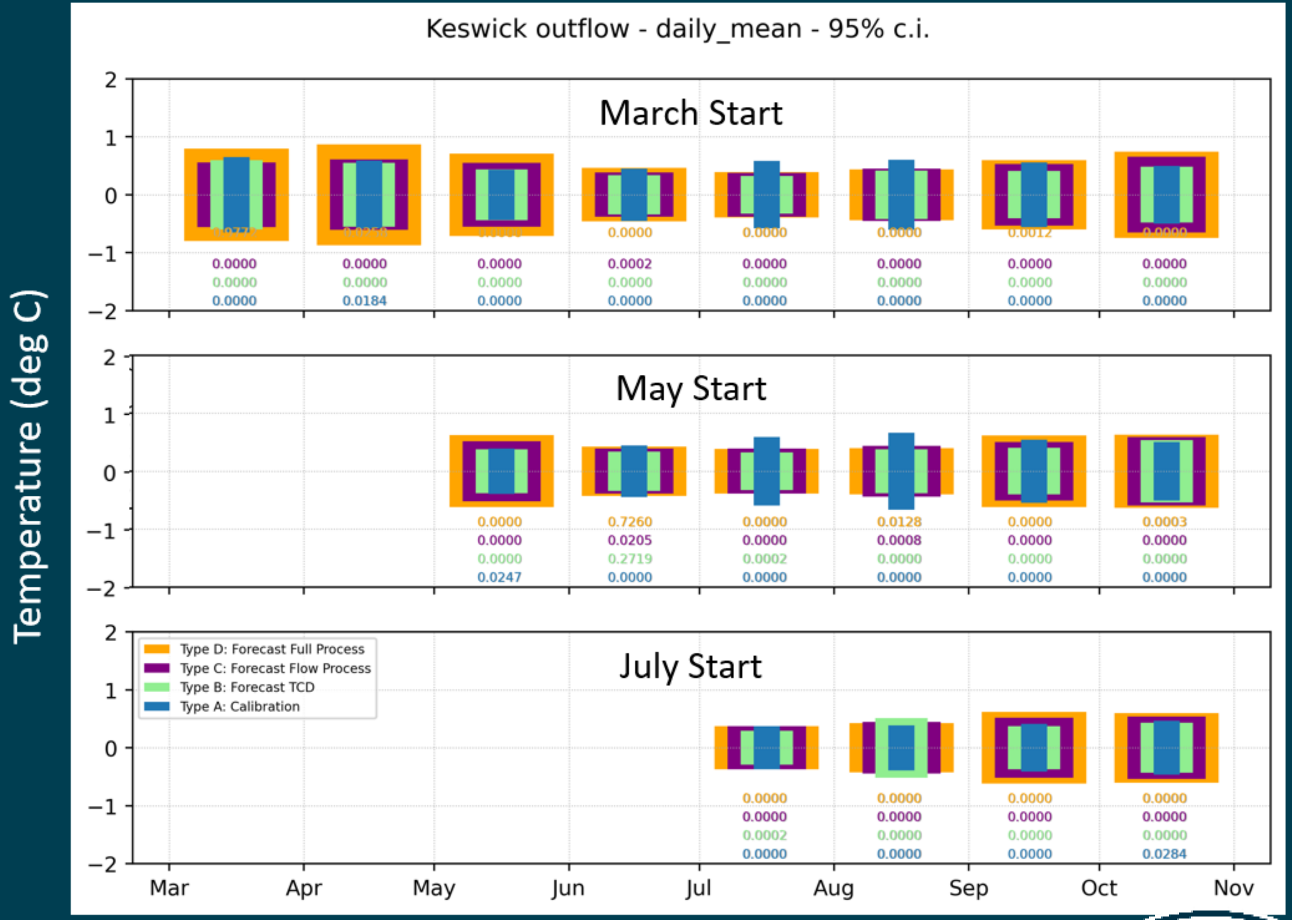
Forecast Process Mean Difference Estimate: Shasta Outflow Temperature

- Samples are the simulated daily mean temperature minus historical daily mean
- Mean difference is calculated as the average of all samples within each month grouped by forecast start
- Calibration = Type A
- Forecast TCD = Type B
- Forecast Flow Process = Type C
- Forecast Full Process = Type D



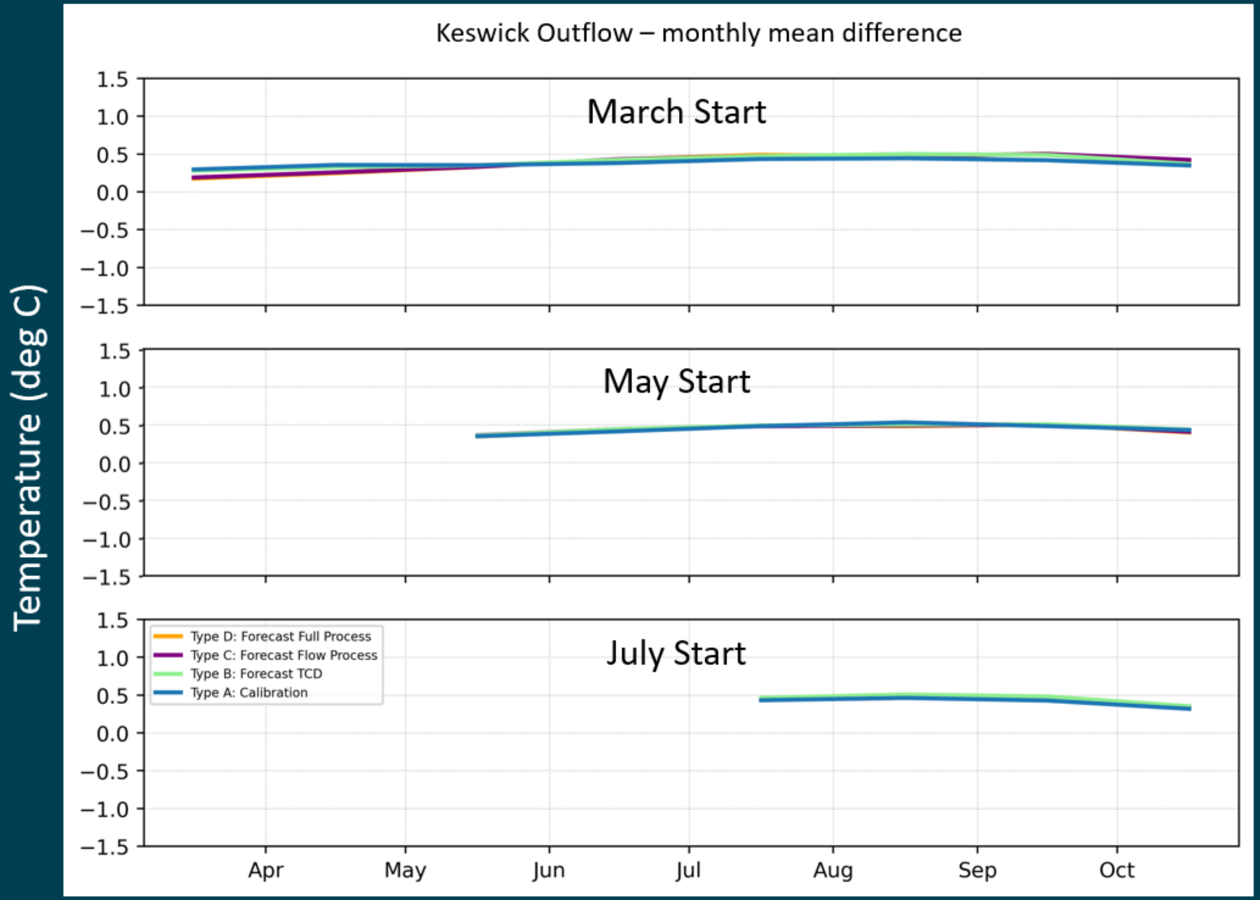
Forecast Process Uncertainty Estimate: Keswick Outflow Temperature

- Vertical height of monthly box = 95% confidence interval
- Numbers below box show p-value of normality test
- Samples are the simulated daily mean temperature minus historical daily mean
- Calibration = Type A
- Forecast TCD = Type B
- Forecast Flow Process = Type C
- Forecast Full Process = Type D



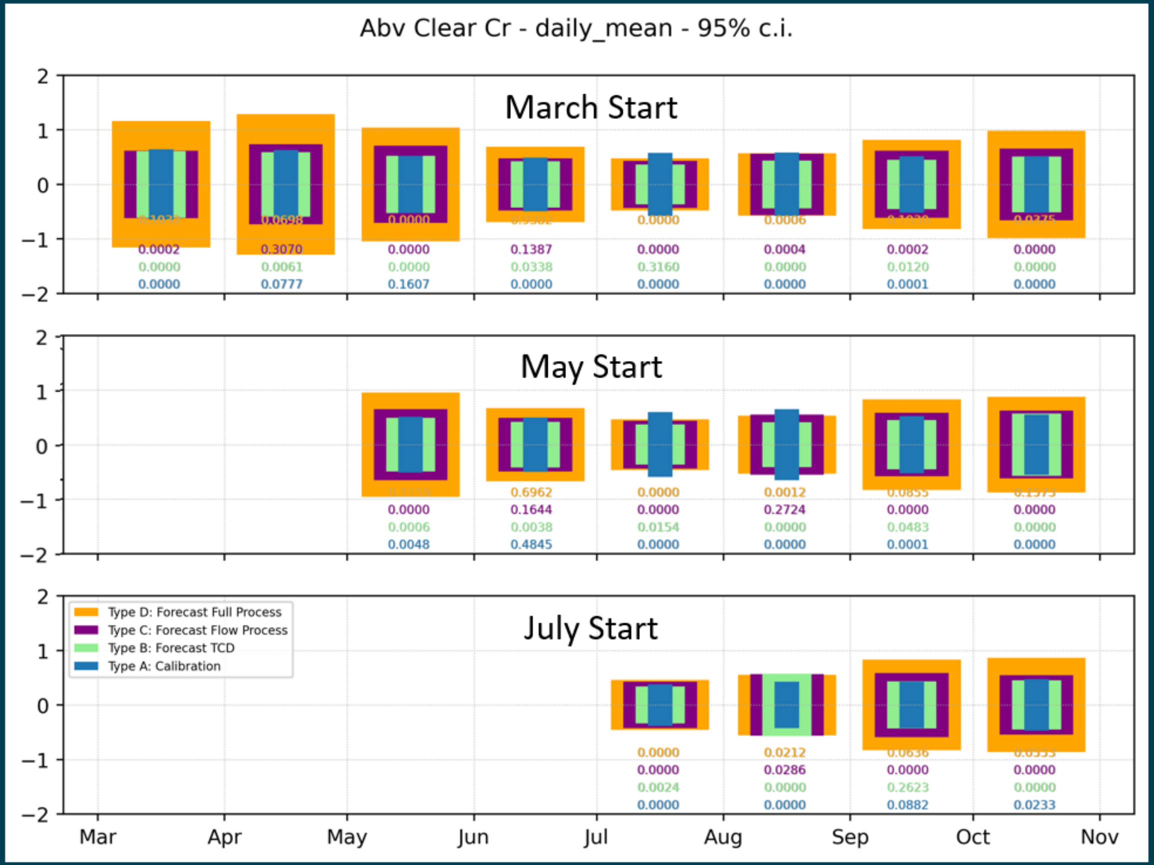
Forecast Process Mean Difference Estimate: Keswick Outflow Temperature

- Samples are the simulated daily mean temperature minus historical daily mean
- Mean difference is calculated as the average of all samples within each month grouped by forecast start
- Calibration = Type A
- Forecast TCD = Type B
- Forecast Flow Process = Type C
- Forecast Full Process = Type D



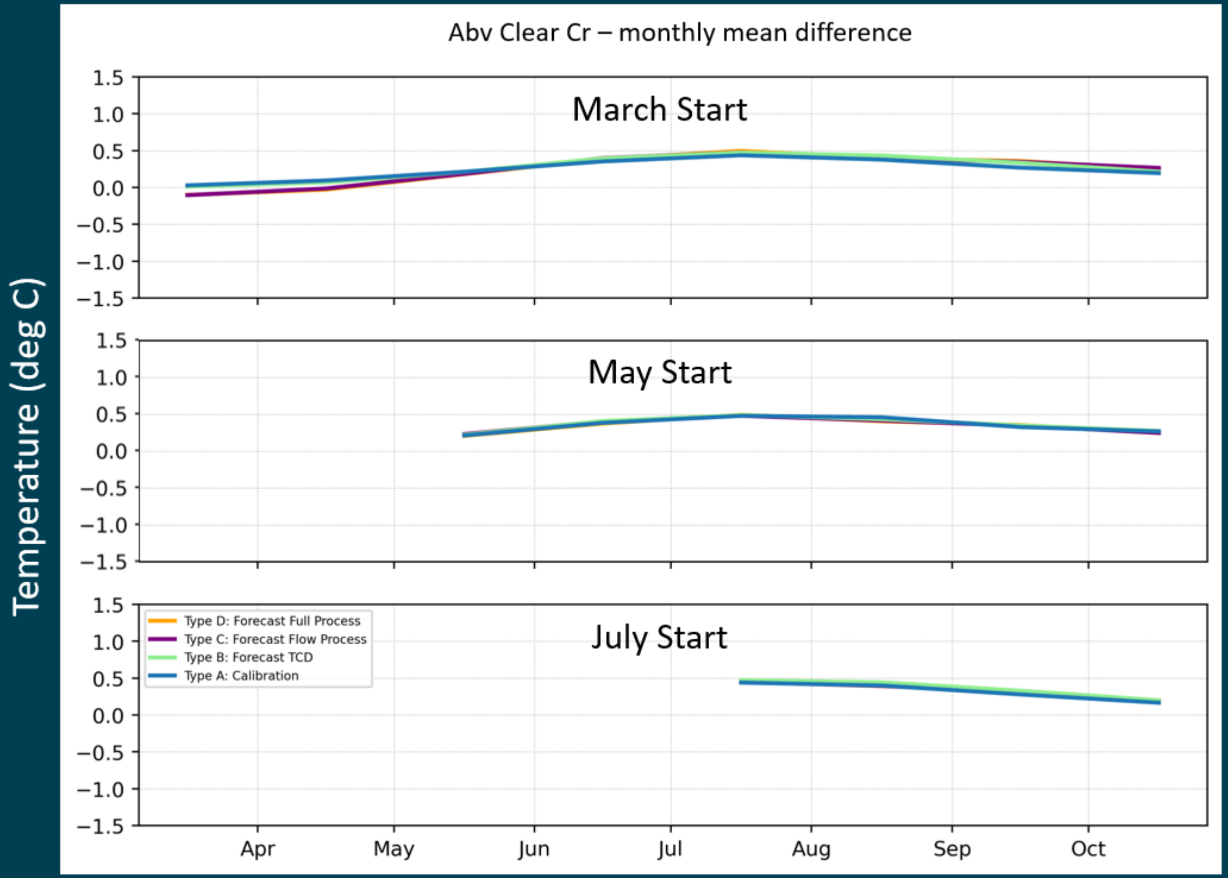
Forecast Process Uncertainty Estimate: Sacramento River above Clear Creek

- Vertical height of monthly box = 95% confidence interval
- Numbers below box show p-value of normality test
- Samples are the simulated daily mean temperature minus historical daily mean
- Calibration = Type A
- Forecast TCD = Type B
- Forecast Flow Process = Type C
- Forecast Full Process = Type D



Forecast Process Mean Difference Estimate: Sacramento River above Clear Creek

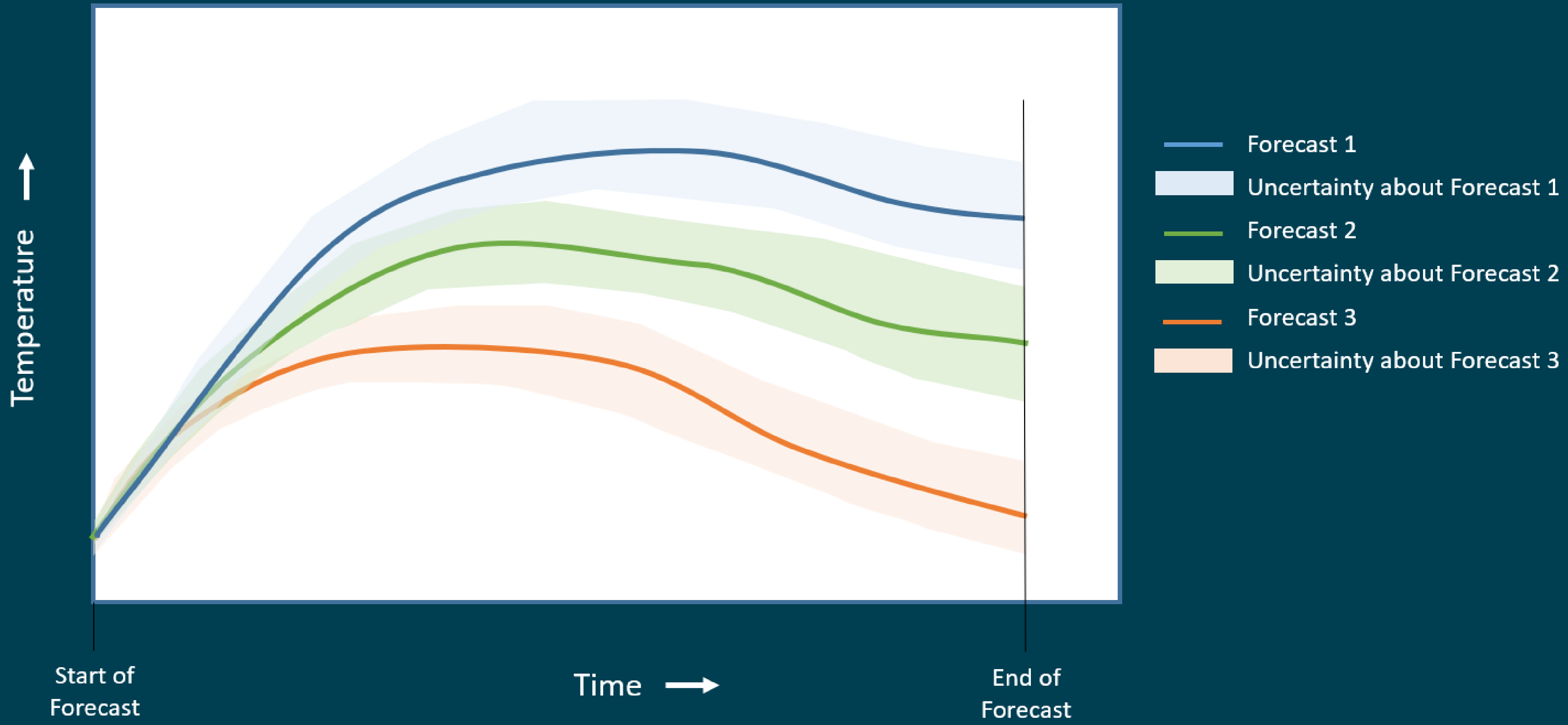
- Samples are the simulated daily mean temperature minus historical daily mean
- Mean difference is calculated as the average of all samples within each month grouped by forecast start
- Calibration = Type A
- Forecast TCD = Type B
- Forecast Flow Process = Type C
- Forecast Full Process = Type D



Summary of Forecast Process Uncertainty Results

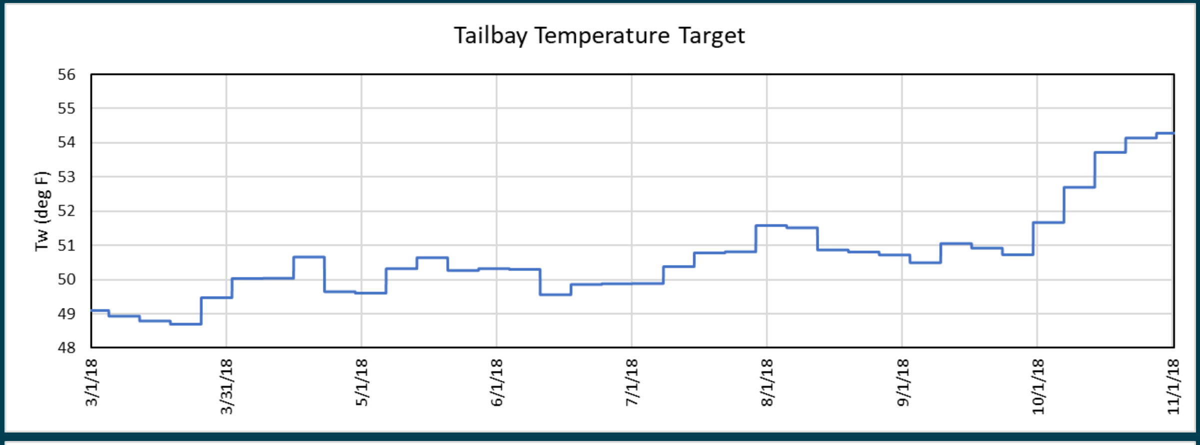
- Early forecasts tend to have moderately greater uncertainty in late fall predictions
- When the model is allowed to operate the TCD to meet target temperatures, error is typically reduced mid-year but possibly at the expense of missing targets later in the year
- Estimation of meteorologic data has a relatively greater impact on downstream locations
- The “structural” uncertainty of the calibrated model as measured by 95% confidence interface is generally on the order 0.5 deg C
- Considering all aspects of the forecast data processing, the 95% confidence interval at the Sacramento River above Clear Creek Station increases to approximately 1 deg C, not an excessive increase

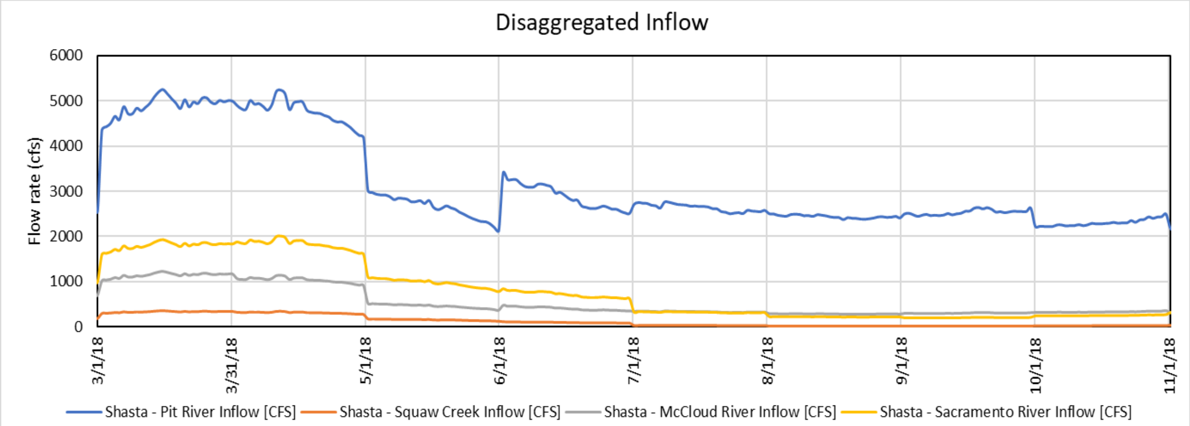
Rough Sketch suggesting application of forecast process uncertainty onto individual forecast traces



Shasta Lake – W2

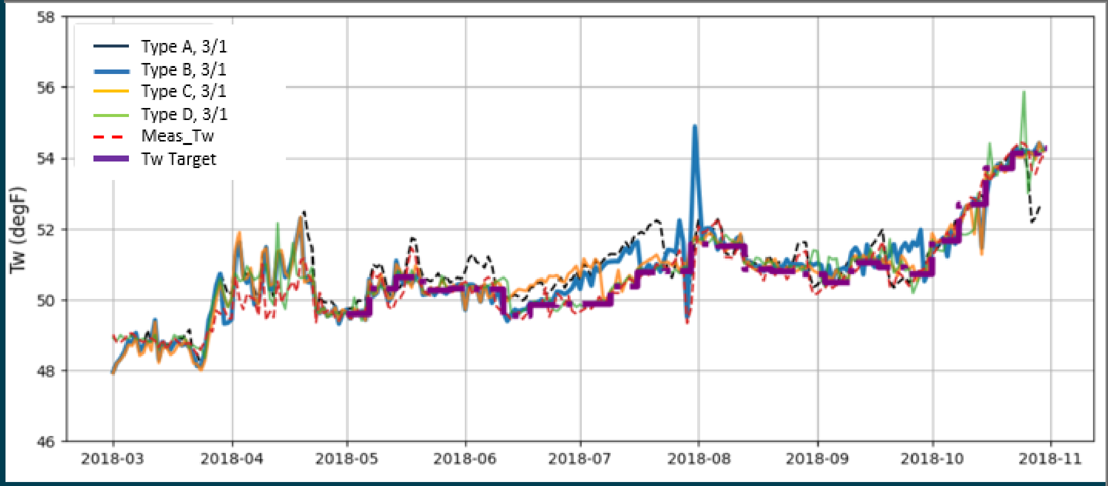
- Single year (no distribution)
- Similar assumptions for Type A-D
  - A: Calibration
  - B: TCD gate operations logic (weekly)
  - C: Flow disaggregation/tributary
  - D: Meteorology (and water temperature)
- Results
  - Shasta Only
  - March 1 and May 1 start dates
  - Time series results

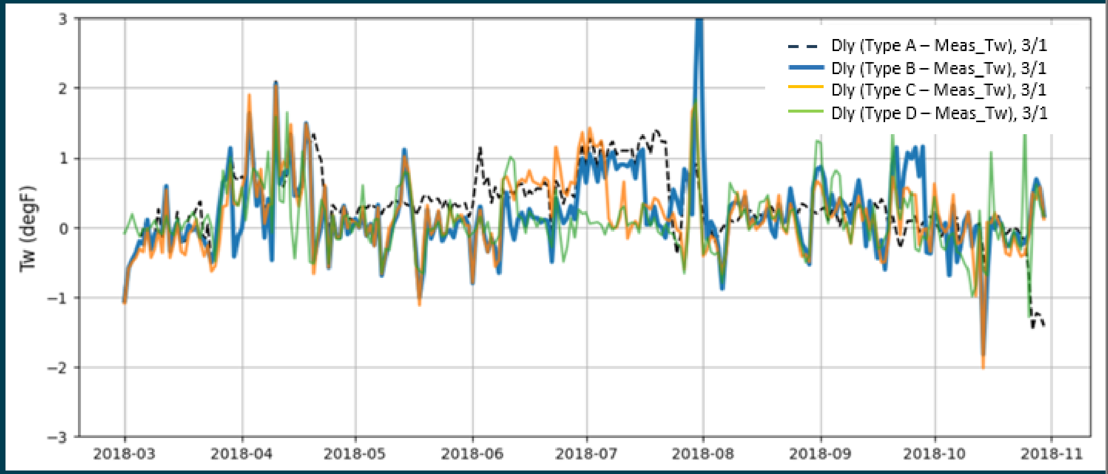


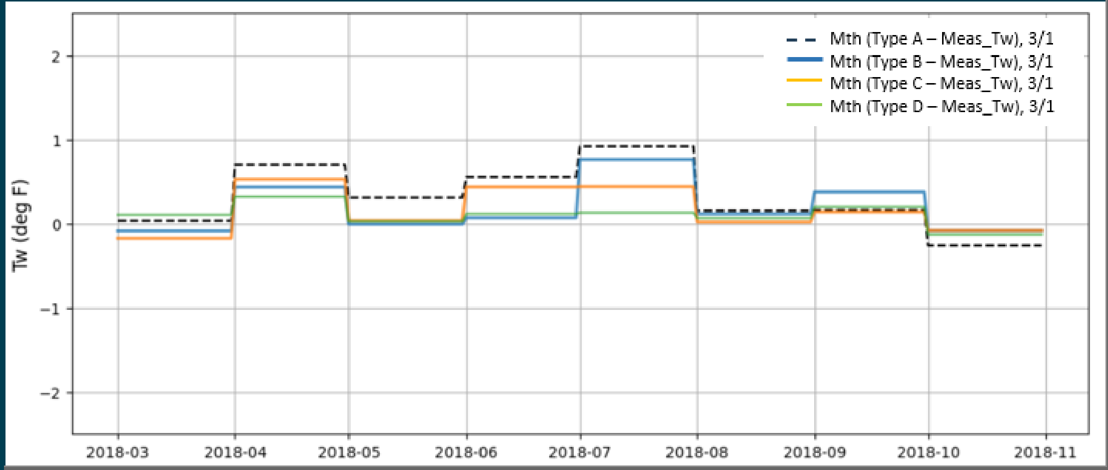


Results: March 1

- Simulated Shasta Dam release temperature (top)
- Difference between Simulated Shasta Dam release temperature and measured
  - Daily average (middle)
  - Monthly average (bottom)
- Forecasts uncertainty response varies
  - Maximum Type A (1.0F)
  - Maximum Type D (0.3F)

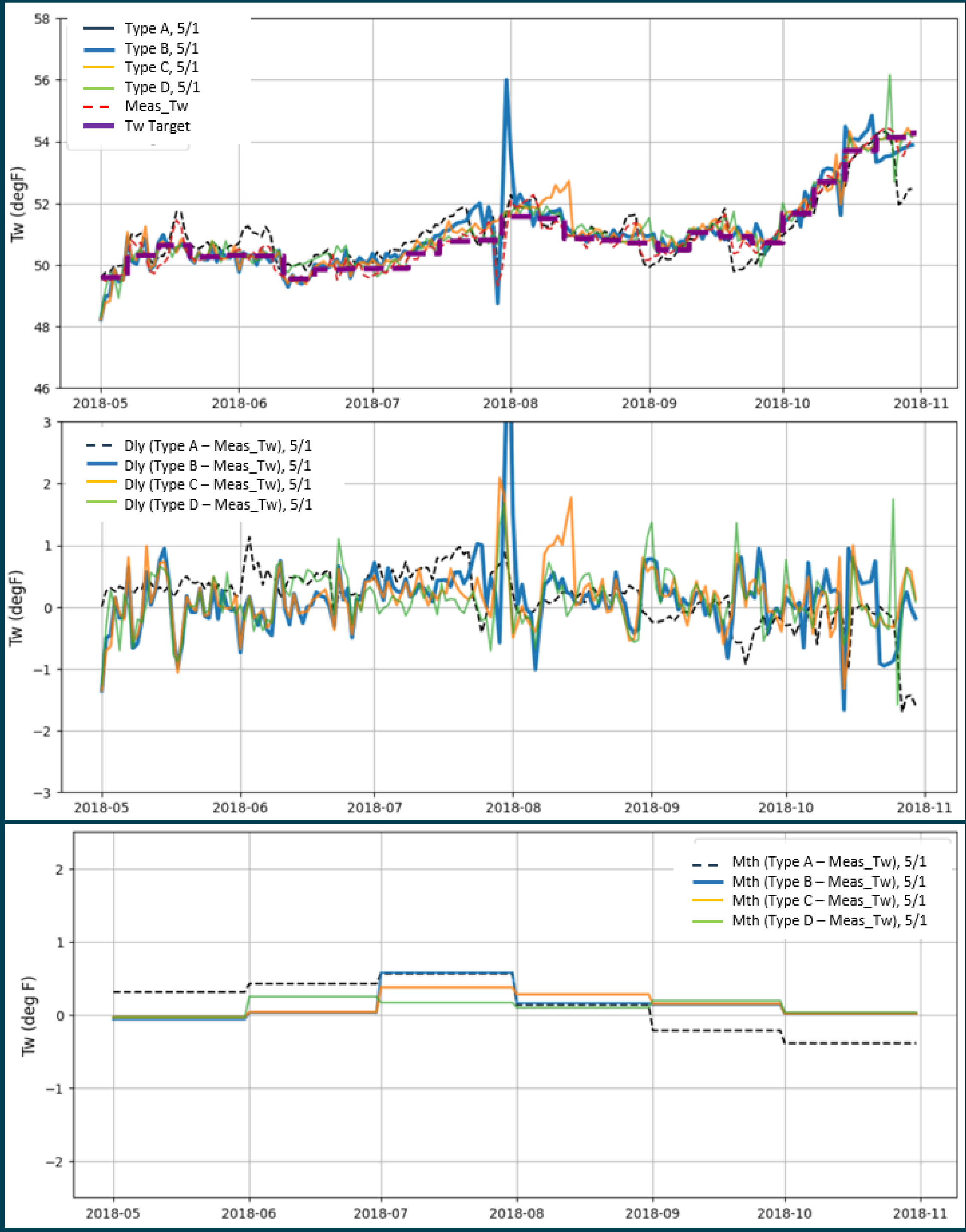






Results: May 1

- Simulated Shasta Dam release temperature (top)
- Difference between Simulated Shasta Dam release temperature and measured
  - Daily average (middle)
  - Monthly average (bottom)
- Forecasts uncertainty response varies
  - Maximum Type A (0.6F)
  - Maximum Type D (0.2F)



Summary

- Generally, forecasts starting in May avoid uncertainty in March and April (lower average difference)
- Forecast runs often had results with lower error in tailbay target temperature than the calibration runs because automatic TCD gate selection
- While tailbay temperatures are largely similar, in-reservoir conditions change under different simulations (B, C, D)
- Exploring metrics to assess these in-reservoir differences

Questions?

Photo credit: John Hannon, Reclamation

Open Forum: Continued Engagement Opportunities

Yung-Hsin Sun, PhD, PE, Sunzi Consulting LLC

Continued Engagement – Why?

- Positive experience with MTC engagement for the current WTMP Project - Last MTC meeting on October 5, 2023; 1 – 4 pm
- Reclamation commits to long-term investment for the development and maintenance for WTMP – Rollout is planned in Spring 2024
- Reclamation is open to sponsor a user group for continued engagement and sharing experience and knowledge

Strawman Concept for a WTMP User Group

- Premise: The User Group belongs to users as a networking and support group.
- Convenor: Reclamation (with light facilitation support)
- Format: TBD (e.g., virtual café with user contributed agenda and topics for discussion; or a hybrid format with optional gathering location(s) if users prefer)
- Frequency: TBD (e.g., twice per year; users may initiate their own ad-hoc discussions)
- Record keeping: TBD
- Members: All with interests in contributing/learning/sharing knowledge; opt-in required

Open Discussion

- Zoom polling on the level of interest for joining a user group (1 to 5): 1 means extremely unlikely; 5 means extremely likely.

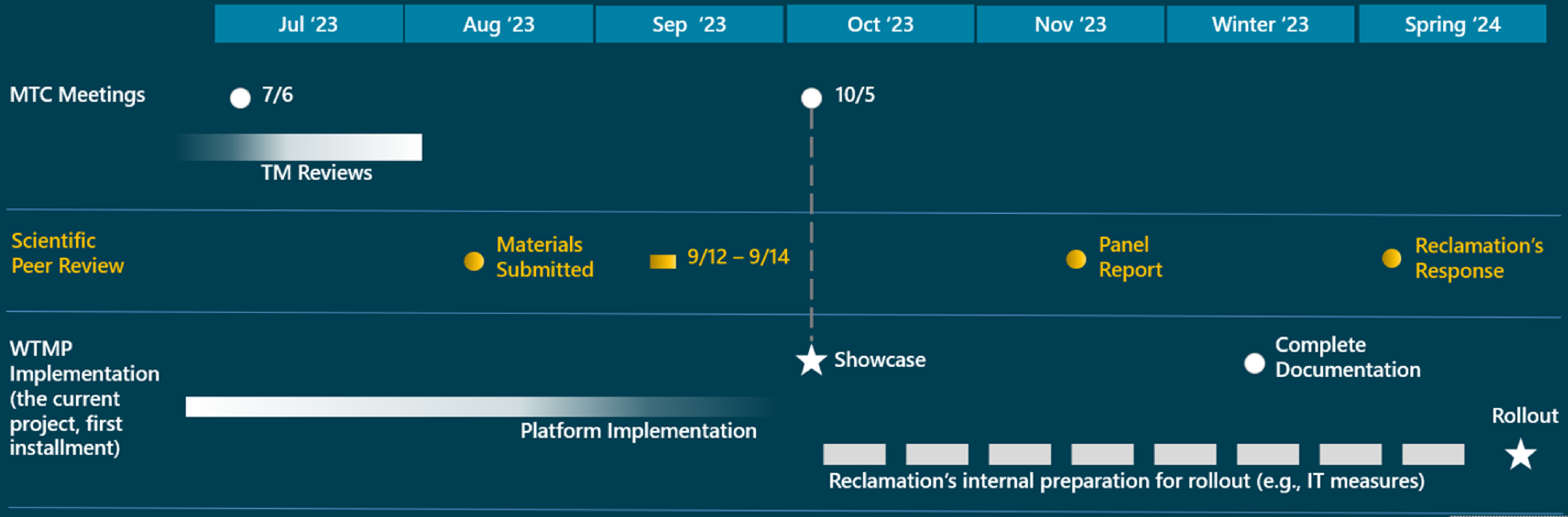
Photo credit: John Hannon, Reclamation

Next Steps

Randi Field, Hydrologic Engineer, CVO, Reclamation

Yung-Hsin Sun, PhD, PE, Sunzi Consulting LLC

Recap: WTMP Major Milestones



Upcoming MTC and Topics

- MTC 10 Meeting: October 5, 2023; 1:00 p.m. – 4:00 p.m.
- Upcoming topics:
  - Model uncertainty
  - WTMP showcase
  - Where we go from here
- You have the registration link already in the Agenda – do it today.

Information Sharing and Contacts

- Key WTMP team members
  - Randi Field, RField@usbr.gov
  - Mike Deas, Mike.Deas@watercourseinc.com
  - John DeGeorge, jfdegeorge@rmanet.com
  - Craig Addley, Craig.Addley@stantec.com
  - Jeff Schuyler, Eyasco, Inc. jeff@eyasco.com
  - Yung-Hsin Sun, sun.yunghsin@sunziconsulting.com
- Project Information:
  - Contract: mppublicaffairs@usbr.gov
  - Website link - https://www.usbr.gov/mp/bdo/cvp-wtmp.html

FINAL MTC MEETING: October 5, 2023; 1:00 p.m. – 4:00 p.m.

BUREAU OF RECLAMATION