2022 CIROH Annual Science Meeting

Summary Notes from Roundtable Discussions and Breakout Sessions 10/3/2022-10/5/2022

Facilitators and rapporteurs compiled the notes in this document from two sessions of the 2022 CIROH Annual Science Meeting: (1) Education, Outreach, and Engagement (EOE) Roundtable Discussions and (2) Research Breakout Sessions. The notes capture the input of participants, contributions of facilitators and rapporteurs, and additional comments and questions provided in slack.

EOE Roundtable Discussion Notes

Following are the notes from the 10 education, outreach, and engagement roundtable discussions, organized by table/topic. Each table summary includes the table topic/question, facilitator name and affiliation, and transcribed notes.

Table 1- Growing collegiality & collaboration across CIROH and the broader hydrologic prediction community (Facilitator: Dr. Sagy Cohen, University of Alabama)

- Primary discussion focused on the CIROH sponsored Users Conference:
    - Consider name change to include "App" to broaden from NextGen Water Resources Modeling Framework
    - Include basics of technical tasks supporting CIROH – such as BMI
    - Create users manuals and tutorials
    - Include hands on demos
    - Ngen – discord, slack, youtube video, online forums, etc. To accompany users conference
    - Workshops – register online
    - Subset of data – local applications (data, setup), contest for techniques – hackathon
    - Clarify objectives and what participants will be able to do – up front so potential attendees know
- Other community building activities CIROH could sponsor
    - Newsletter
    - Consulting/office hours with CIROH experts
    - Hack week (see above – visualization, subsetting of data)
    - Website

    - 2 min videos – how we use CIROH computing; new model in engine, etc.
    - Self learning course – credit for student (CUAHSI Virtual University) - build a model during the semester
    - One on one with NWC

Table 2- Recommendations for strategies for CIROH to collaborate/use existing sharing platforms (HydroShare) (Facilitator: Dr. David Tarboton, Utah State University)

- What are important things we do as part of/to facilitate collaboration?
    - Multiphysics. Build Code to APIs for sharing. Use APIs to preserve and share the best parts of individual code bases and combine them into something new. Divide code into components (modularity) so that parts can be re-used without needing to use the whole.
    - Does such a compartmentalized model all need to run on the same computer, or can this be distributed across platforms?
        - A tasking infrastructure for weak coupling across computers.
        - The research community needs access to curated ready to go data from operations.
        - Standardized inputs
        - RestAPI level access to input and output data from NWM
        - Cloud-based trial environment for simple tests and educational use cases, event, or region to highlight outcomes
- Suggest a "living document" of institute-wide progress over several years, that integrates advances from different research themes
    - Focus on an event, like Hurricane Ian, Ida, Harvey etc.
    - Make it clear that this is something everyone is working towards from the beginning
    - Shared vocabularies
- Forum, communication challenges, facilitating engagement channels. Many things CUAHSI has done and extend beyond universities. Student exchanges. Bringing people together.
- Technical tools to deal with differences in computational infrastructure and dependency problems. Share model(s) through (Docker) container; track code through Git(Hub).
    - Hire software engineers to provide support for model sharing, reproducibility, containerization
    - Understand NOAA expectations = define collaborations
- Some sort of incentive to individual developers to encourage reproducibility across platforms
    - Requirement to prove (achieve) reproducibility of results
        - Concise definition of "reproducibility." Binary or more general.
    - Provide support to learn technical skills

    - Requirements might be too strict, due to limited access to infrastructure, data, etc.
- Platform to store and visualize initial results. Gallery to showcase capabilities of different models, tools, etc.
    - Standardized file formats, units, vocabulary, good documentation
    - Remember that the work is being done to be used by others. Do as much in std ways that others can use. Model-agnostic & model-specific
    - Shared portal/database with CIROH members and expertise, so that finding the right expert for your problem is easy
    - Should get support from seniors to actually do this stuff (document, modularize code). Too easy for junior to feel overwhelmed by the need to do all this

Table 3- Activities for CIROH to outreach to a broader cross section of water forecast providers (Facilitators: Dr. Jay Cordeira and Dr. Ming Pan, University of California, San Diego)

- CIROH supports coordination between NWC and RFCs for R&D and R2O2R
- Showcase projects using NWM to end users
- Define end users and how their R&D may be folded into CIROH
- Develop an outreach committee
- Identify end user needs to inform project proposals
- Emphasize inclusion/collaboration
- Workshops to engage providers
- CIROH more than NWM
- Seek to enhance/improve, NOT replace, what is currently being used
- CIROH should facilitate interagency collaboration/coordination with respect to research, education, and outreach

Table 4- Ideas for international exchanges/interactions w/research community (Facilitator: Dr. Martyn Clark, University of Saskatchewan)

- Strong science needs to gather models/resources to address key hydrologic prediction issues.
    - Understand/reduce institutional constraints
- USA has fallen behind in hydrologic prediction - globally (issues using probability prediction ensembles)
    - Need to develop models/methods that are used by the global community (NextGen, NWM)
    - Contribute to international initiatives (WMO)
    - Rebuild support for global communities (HEPEX)

    - Build an international visitor program. Embed scientists in international orgs.
        - Host international visitors/send CIROH people to international groups.
- Develop global requests for information
- Consider organizing an annual state of water
- Provide synthesis functions in areas of global interest
- Define export control rules to guide collaboration
- Emphasize specific collaborations: US-Canada, US-Europe, etc.
- Work with entities to create datasets important for forecasting
- Understand and reduce constraints for collaboration
- Take leadership in the coordination across models/resources
- Need to consider global community in the development of tools, data, resources
- Contribute to international initiatives through WMO, etc.
- Provide international exchange program for two-way exchange
- Extend CIROH to all things water/hydrology to increase collaboration opportunities internationally – water security, water sustainability, climate resilience
- Questions about how to use funds for foreign nationals need to be answered

Table 5- Community Building – Collaboration related to teaching & learning across CIROH (Dr. Grey Nearing, University of California, Davis)

- Create wider master student professional pipeline – how-to courses for professionals, masters students, DEI from HECCHO Community; define audience and approaches
- Support faculty by sharing teaching tech, create cross-institutional courses, develop drop-in elements – university for-credit courses
    - CIROH funding used for:
        - Cross university settings
        - Modular course components to incorporate in courses
- Create course, contest, bootcamp for first year undergrads – part of users conference, youth summit, etc.
- Offer courses that teach practical skills in hydrologic context:
    - Containerization, Kubernetes, Docker
    - Message passing interfaces: BMI, ESMF
    - ML
    - Python
    - R20 best practices
- Develop assessment tools for recruiting & outreach programs
    - Especially programs w/long timeline
- CIROH Sponsored Activities/Courses/Modules/Learning activities:
    - Module for 1st yr undergrad class = importance of hydrology

    - Website for 'self-learning'
        - Providing professionals material to present in GitHub/etc.

Table 6- Training workforce/Emerging topics/Opportunities for hydrologic forecast community (Facilitators: Dr. Katie van Werkhoven and Michael Kane, RTI)

- Broad topic that requires focus (white paper/theme area for CIROH investment)
- Workforce classes
    - NOAA/NWC scientific developers
    - Core stack developers (public/private)
    - Translators (WFOs/private)
    - End-users (emergency managers)
- Workforce engagement/training opportunities
    - Core curricula influence = CIROH supported university networking
    - Shadowing program
    - Internships (stand along or part of program)
    - Certificates (tech cert to complement science degree)
    - Early student outreach

Table 7- Building CIROH Partnerships/Programs/Activities for Undergrad students (Facilitator: Dr. Beverley Wemple, University of Vermont)

- Partner w/hydrology section student subcommittee – develop cyber seminar series on navigating the pathway to grad school
    - Model off the 'Navigating Academic Waters' for early career academics
- Weeklong, site-based programming (LTERs, CZOs, National Labs)
    - Exposure to research sites/large scale collaborative projects
        - Alternative to 10-wk style REU program model (invest in shorter duration "intensives")
            - Cultivate community/expose students to research enterprises, leverage place-based & integrated research programs.
- Develop teaching materials for undergrad students in areas needed for success to graduate
    - Data science applications for geosciences/geography
    - Social science fluency for engineers
    - Collaborate w/SERC or HydroLearn
- Develop a parallel to Summer Institute focused on training undergrads in operationally relevant water science, sensors & measurement techniques, & data science concepts.

    - Focus on preparing undergrads for multiple pipelines instead of just research (graduate school – including professional masters programs, technicians, consulting etc.)
- Need topics to attract undergrad students = increase domestic student engagement from underserved/represented groups
    - Ways to fund graduate school
    - Career pathways/opportunities after graduate school
    - Models of graduate students/faculty who look like them (BIPOC, Women)
    - Stipends/paid opportunities (esp. Critical to draw students from historically underrepresented groups)

Table 8- Ideas for CIROH to advance hydrologic forecasting in underserved areas (Facilitator: Dr. Tom Giambelluca and Dr. Guiseppe Torri, University of Hawai'i at Mānoa)

- What are cases, people, places that CIROH should leverage from Consortium?
- What new initiatives should CIROH pursue?

Table 9- Ways for CIROH to increase DEI in programming/hydrologic forecasting workforce (Facilitator: Dr. Melissa Kenney, University of Minnesota)

- Be intentional
- Multilevel mentoring- Look at SOARS program for model/guidance
- Find ways to "Juice" existing projects and programs
- Support prestigious postdoc – based at any location; support pursuit of NOAA postdocs and fellowships
- Hydrology for non-hydrologists – courses and research experiences, breadth of hydrology, field experiences, etc.
- Infuse DEI into research projects
- Directed engagement at non-traditional venues (outside of typical professional circuit)
- Intentional selection of webinar speakers, etc.
- Strengthen partnerships with MSIs
- Intentional recruitment and engagement – social media
- Data science engagement and training – meet students where they are; and extend to K-12
- Open informal networks to connect to pipelines of DEI
- Use REU to strengthen DEI and collaboration
- Build infrastructural capacity
- Professional societies focused on BIPOC
- Ideas for innovative approaches or ways to leverage existing programs.

- Ways to rethink traditional pathways to hydrologic forecasting careers.
- Hands on science experience by utilizing existing initiatives
    - Meaningful Watershed Educational Experience
- Online curricula & resources to share CIROH research to educators/community
    - SPLASH, OLLI, Transition CIROH, COMET/GLOBE (databytes), LTER Data Nuggets
- Relate to the National Next Generation Science Standards
    - Help teachers achieve mandated objectives
    - Workforce development
- Sponsor teacher/University interaction
    - Research mentor program w/AWI
    - STEM Ecosystems
    - National Sea Grant College Program
        - Water/watershed education for K-12
    - SciRen
    - Reimaging STEM Workforce Development
- Could require a lot of resources, need to understand what is already in action & leverage
- Find ways to be creative for inclusion and think about hurdles/barriers and break them down

Table 10- Activities to build on active K-12 & public education programs (Facilitator: Dr. Breck Bowden, University of Vermont)

- Hands on science experience by utilizing existing initiatives
- Meaningful Watershed Educational Experience
- Online curricula & resources to share CIROH research to educators/community
    - SPLASH, OLLI, Transition CIROH, COMET/GLOBE (databytes), LTER Data Nuggets
    - Relate to the National Next Generation Science Standards
        - Help teachers achieve mandated objectives
        - Workforce development
    - Sponsor teacher/University interaction
        - Research mentor program w/AWI
        - STEM Ecosystems
        - National Sea Grant College Program
            - Water/watershed education for K-12
        - SciRen
        - Reimaging STEM Workforce Development

Research Breakout Session Notes

The following notes are organized by CIROH research theme. Within each research theme, there are two parts – providing summary notes for the morning session and the afternoon session. Each part includes the breakout session topic/question, facilitator name and affiliation, and transcribed notes.

Research Theme 1: Advancing Operational Prediction Systems

Part 1: What are ideas for a national scale research infrastructure for the hydrologic science community that aligns CIROH efforts in areas such as hydrologic information systems, real-time observation networks, satellite data, crowdsourcing, etc.? Facilitated by: Dr. Jerad Bales, CUAHSI.

- Current sensing networks are sparse
    - Increase spatial density of sensors. Citizen science and crowdsourcing can enhance where sensors are lacking
    - How do we advance next generation sensor networks to optimize information that is needed for models and balance the cost of maintaining and sustaining the networks?
        - Need advancements in existing infrastructure
    - Standardization of sensors and observations to support modeling
    - Ensure metadata compatibility for datasets
- Snow modeling
    - Need a greater dataset to test and validate different snow models
    - Standardize framework for model performance evaluation
    - Provide room for exploratory work to improve the operational modeling
    - Need standards and formats for crowdsourcing information
        - Example is snow-depth - how to standardize and make use of this type of data?
        - How can we use this type of information to "nudge" the national water model
- Need infrastructure for hydroinformatics
    - Need access to multiple buckets of data
        - CUAHSI HIS
        - USGS NWIS
        - NWC - e.g., FIM products, NWM outputs, forcing data
        - EPA?
        - Other agency data that can enhance
        - Need data storage, which means infrastructure
- GENERAL DISCUSSION: Potential research idea: how to compare forecasts with standard simulations vs. data assimilated simulations with different data?? Consider particle filtering, genetic algorithms etc. to accurately characterize the uncertainty reduction in

posterior space. How to perturb priors to generate posteriors for climate change forecasts?

- Need a layer that connects all the data sources in a way that researchers can access and use them. API, data model, formats are needed to enable this
- Cloud infrastructure at a base level that enables all this data access. Connects people to buckets of data.
- Likely also need some computing/supercomputing for computational work. Not all hydro-informatics work is supercomputing, but it is in the cloud.
- Data access efficiency
    - Need to be able to access data quickly and on the fly
    - Quick display and analysis
    - Standard ways to access data for validation
    - Connection with users and stakeholders where they help develop API in the way they want it - how do they want to access and use data?
        - Spatial and temporal aggregations
- Incentives for standardizing APIs versus having people maintaining their own APIs, formats, encodings, interfaces, etc. There is a need for approaching this more broadly to promote standards.
- How do the regional centers handle data?
    - They are consumers and producers of data
    - They consume data from a lot of local efforts - they contact individual groups and ask how they can access and use more local data
    - A lot of knowledge at the regional river forecast centers with respect to data - and particularly local data products
- Extending NASA satellite precipitation and comparing with ground resolution data to downscale
    - Trying to produce better precipitation data products for CIROH
    - This is a new, major input that could support modeling efforts
    - Take NextGen and do benchmark testing with the new products
- Sensor network deployments
    - Sensors are expensive! Can we move toward much cheaper and more widely deployed sensors without $$ concerns.
    - Get more spatially distributed data to better inform modeling efforts
        - Deploy sensors in relevant stakeholder locations where they have forecasts from NWM
        - Template how we can leverage emerging technologies
- Need a one-stop place/shop for all the water information the RFCs need. There are many other “buckets” for data. Get data in the format and the resolution they need
    - Would help them and users who approach them for data and other information
    - Probably needs to be a user-informed front-end user interface that facilitates retrieval by public and others
- RFCs have areas that are data-blind - long stretches of river with no data
    - Could use lower cost sensors to enhance information
    - Lower quality, but still useful

        - Validation is a challenge -
            - flood extent methods
            - Drones for flood extents
            - Any information that helps them validate flood inundation
    - Sizeable barrier to handing model and other products into other people's hands
    - Support and standards would save them time - they expend significant effort getting people set up to do hindcasting
    - Delivery of existing models to other users could be part of the infrastructure
    - Put a local model in cloud infrastructure so they can enable others to interact with it
    - TXDOT is putting water level sensors on about 50 or 80 bridges. That type of data would be useful, and comes with engineering scale flood maps as a library
    - Access to data could really streamline things
    - Operations is really the important part - streamline research to get things to operations
    - Getting things into the hands of the operational forecasters themselves
- Categorizing datasets in terms of how they could be used
    - Operational versus other
    - Calibration/verification
    - Certain categories of data might be useful
    - Two user-facing interfaces - one for public and one for operational people. This could potentially be the same
    - If we are targeting operational use, we must address operational reliability of data
        - When things break, they need to be fixed
        - What is operational reliability of portal/web system
        - Notices to users when down for maintenance
- Sensor technology - need algorithms that transform observations/data into predictions
    - Providing data but also methods that go along with data
    - Link to repositories of methods that can be used with sensors
- Modelers need to download data and connect to hydrologic models repeatedly
    - Jupyter notebooks that can interface with data and execute models would be helpful
- Incorporation of storm reports
- Challenge to evaluate the NWM outputs because of lack of available data or information
    - Even anecdotal information and non-traditional information can be helpful
    - FEMA post event damage reports - standardizing and compiling
- Edge computing scenarios
    - Localized data servers
    - How to do this?
    - Need to do large quantities of data for evaluation
    - There are potential security issues here
    - "Data poisoning" - how do we know that the data has not been messed with?

    - Some data are sensitive - e.g., how to address privacy in the geospatial aspect of the data and not expose vulnerable people
- Discovery of data –
    - Testing NextGen framework in different settings - e.g., tropical Hawaii
    - Easy data accessibility is crucial
    - Hawaii MesoNet
        - Realtime stations important for weather/precip forecasts
        - Developing a data portal for bringing in all data in Hawaii
        - Automated QA/QC is a challenge along with gap filling
        - They are thinking about a hackathon to address this
    - How to tie in state or regional climate data portals?
- Code ownership?
    - What are intellectual property rights?
    - What is CIROH's perspective on open source?
- Water quality
    - Regional test beds
    - Sensor networks

Part 2: What are new ways to use climate information to improve hydrologic prediction? Facilitated by: Dr. Hamid Moradkhani, University of Alabama

- Climate information (from models such as Sacramento model, CFS etc.) being used for spring/snow melt, as well as for water supply and agricultural entities; also, being used for drought forecasting; soil moisture forecasts (monthly…at daily timescale)
- Types of biases are also being investigated; some models also incorporate bias-corrected forcings
- Customer base, power companies, army corps of engineers; 3-month range historical analysis…
- Different QPS scenarios
- Also working with nuclear power plants, extremely sensitive to water. As well as the water supply.
- Challenges: runtimes can be challenges for long range runs…14-day runs take 2.5 hours, would like to do longer runs if possible.
- Smaller scale reservoir forecast; also using retrospective climatological ensembles;
- Negligible skill with existing products
- Novel sensor tech development
- Measuring soil moisture; temperature as a driver of soil moisture
- Issue ensembles of 5-40 day forecast lead times; lot of energy traders, hydropower is big in NW…but skill is poor. Improving skills is important. Info is needed to make plans, but skill in precip is poor and little skill in temporary forecasts. Plan to get into S2S scales.
- Model interoperability across models from different agencies is a big challenge. Coordination is very time-consuming with agencies such as NRCS.

- Getting to connect climate info with current river forecast centers is a major challenge. Whatever is developed by CIROH needs to be transferred to RFCs in 2-year/shorter time frames.
- Lack of information about how to use models other than CFSv2 for ensemble forecasting.
- One key partner is NY city water supply. Provide ensemble forecast for up to one-year
    - (But only using meteorological model input that affects about 1 month of hydrology)
    - Beyond ~1 month, no specific skill is available beyond climatology.
- ENSO and other indicators could also be used to enhance the model skill.
- Do not do analyses of climate change impacts!
- Climate change has less emphasis in CIROH…important gap for S2S, climate prediction info.
- Many assorted products are used but, don't always want to reinvent the wheel.
- Lots of discussion on this topic and new products have come up, but no analysis about their skill is done yet.
    - It's an important project for CIROH to start looking into improving the skill of climate prediction products.
    - In the US, using GFS is good for 1-2 weeks, but important to improve prediction beyond a 3-week period.
    - Next step is to go to 3-4 week and S2S climate forecast products.
    - Conditional skill periods may be available during some other time of the year.
    - Relatively coarse scale models need to be downscale to local or regional scales through statistical or dynamical approaches.
        - Resource intensive approaches…may need up to 500TB to 1PB data for 20-year forecasts.
        - Specific workflows and benchmark approaches could be used to improve the bias-correction processes.
    - Conditional skills (forecasted skill opportunity) need to be exploited more often.
    - From user perspective, hindcasting could be useful.
    - Involved with seasonal water supply forecasting; work with met, weather forecast, S2S and machine learning teams to produce 6-monthly water supply forecasts at 40+ points in the state.
    - WRF-Hydro and machine learning…trying to find machine learning surrogates for process-based models.
        - Differences between research vs operational forecasts
        - Challenges with adjusting process-based models!
- In CIROH, efforts could be made to think from operational standpoint vs research standpoint.
- Move behind testbeds…make specific forecasts for next year or so and evaluate the skill.
- Operational forecasts may include adjustments based on specific context in RFCs. (This is hard to integrate in Research)
- Working on weather, hydrology, S2S..also atmospheric rivers…cover lots of systems! Have atmospheric river reconnaissance programs.
- 3-4 week to seasonal scale forecasts are very challenging to address.

- Coupling national water model with coastal models…how will coastal flooding evolve in future under different climate change scenarios? Coastal flood inundation models could be improved with climate information models. Sea Level rise must be incorporated, but sea level variability is huge in sub-annual scales. Sea level variability shifting from September/October to Jan/Feb timeframe in terms of highest sea levels. Also looking at future rainfall events…
- Utility of machine learning methods. Targeted at RFCs to account for contextual RFC features, there is room for improvement with machine learning approaches at finer scales (e.g., Flash floods)
- Climate based flows
    - how to look at floods vs droughts
    - can look at the risk in different ways, e.g. infrastructure risk (Account for long term planning horizons)
- Issues of non-stationarity need to be incorporated in infrastructure designs
- Benchmarking data. What timeframe and how to select the baseline makes a huge difference
- Timescale of predictions (e.g. short to long term predictions). We are talking about two timescales: long-term coming from climate models
- Challenges in statistical vs dynamical downscaling. Which downscaling methods to pick could be helpful in CIROH. Statistical downscaling ignores issues of non-stationarity!
- CMIP has done better job in EU than US…we don't have a strategy for CMIP6!!
- Applying CMIP-5 and WRF to predict HABs in decadal timescales. Evaluating the impact of climate change on seasonal HABs shifts
- Water availability…working with NASA on aquifer storage change using machine learning and ground water historical data. Found important correlations in long term baseflows and climatic records. Want to couple streamflow with groundwater modeling to identify impacts of climate change.
- Using bias corrected forecasts e.g., MME1 and 2 to make these products ready for operational forecasts.
- Need to move away from subjective experience to more automated products that can use widely available information for improving forecast skill
- How to use bootstrapping to identify ensemble members that have higher forecast skill at downscaled levels??
- UFS integration?
- Combining machine learning & physics? Parameter learning?
- How many of these ideas have been outlined as plans for exact experiments & simulations at NWC?
    - NWC = contractual work
    - CIROH = exploratory, methodological work
    - OWP
        - Framework
        - Calibration -> envisioning CIROH to explore these foundational science challenges (what are the routines that help calibrate? Ex. What are the calibrations we need for the upper Midwest? Calibrate using headwaters?

        - Optimization of the environment
- Multiple models can be running together, which will enable data assimilation? Heterogenous models running simultaneously? Both, the sky is the limit, but efficiency matters. CIROH will answer this, NWC will not approach w/preconceived notions.
- Test bed idea: Will the test bed be a function of the questions we are asking? Thought of breaking test beds into "boxes"?
    - If the products are BMI-compliant, we can use it for the optimization environment.
    - GUI will be developed to be flexible and robust. (AGU- rollout Chicago in December)
    - Data assimilation – yes?
    - Model uncertainty?
    - Redundancy among models?
- RFC Question: We use a community hydrological forecast system -> What kind of opportunities are there to support our current system?
    - Hydrologic Ensemble Forecast Service – opportunities are endless.
    - We should wrap these BMI, Etc. We have not infused run-off or snow accumulation into models in the past ~30 years. We should make every effort to infuse that.
    - Research often begins in well observed environments. Where data is sparse (Alaska), it will work well in other places where there is more data. Cold regions are a needed area which is underrepresented.

Research Theme 2: Supporting Community Water Modeling

Part 1: What research ideas should CIROH pursue to stimulate broad research community participation in hydrologic studies supporting or using the Community Water Model? Facilitated by Martyn Clark, University of Saskatchewan.

- Need to improve routing. Data problem (bathymetry) and model problem (backwater effects)
    - Lot of coastal coupling happens in the forecaster's head
    - forecaster simulates backwater effects in their heads
- Need for process-based synthesis across continent
- Need for more formal use of conceptual models
- Need for better (dominant) process representation (tile drainage, glaciers, snow, etc.)
- Need for better/renewed calibration approaches
- Improve perceptual model
- Improve representation of dominant processes
- Improve interoperability with CHPS (and other frameworks)
- Appetite to move away from Sacramento model. Interest in using CHIPS as rapid testbed. Need for interoperability across frameworks
- Encapsulate knowledge in O2R

    - Deltares has expertise with BMI and CHIPS/FEWS. Who can pay for that expertise to connect NWM/NextGen with CHIPS?
    - interoperability is a key feature for practice. CHIPS can be fast
- Machine learning boosts process-based models
- Social problem – encapsulate the knowledge O2R
- Research advances are compatible with NWM/NextGen for easier implementation across Technical Readiness Levels
- Forecasters have a lot of expertise for their model/domain that may be lost when they retire. We are working on ways to capture expert knowledge through interviews and AI semantics models. There was also talk of creating a database of big failures.
- Some forecasters have outsourced their calibration and little intuitive understanding of what the models do when they start turning knobs. Capturing experience before it is lost would be helpful
- Hydroinformatics breakout group. Discussion on how to submit models evaluate and incorporate changes.
- Model validation group. I like to see error bounds on new components added to NextGen. Lots of discussion on improving model accuracy. Questions about which metrics to use and discussion on how there's comparatively little data so need to get creative
- Cyber-infrastructure group. The subset of the group needs access to infrastructure for providing web views, hosting, servers. Other groups need access to HPC resources for computing. Evaluation and teaching to be combined.
- Do hydro regions exist?
- Quantify error propagation
- Tension between right results for right reasons and helpful answers
- Physiographic indicators for model selection and regionalization
- How to find near-optimal mixture of models for a given region through calibration/objective-functions. What's the most important for a forecaster for a given region? High flow, droughts
- Can hindcasting provide insight into forecasting performance?
- Is it possible to develop meaningful gridded high-res (250m) estimates of hydrological states from lumped catchment models?
    - There is a need because we currently produce this output, and we need to continue producing them.
    - can produce info on a grid if you have spatially constant info over a catchment. Simple mapping. Next idea: utilize hydrologic similarity and map back onto grid.
- What models lend themselves well to drought predictions?
    - Might need to run multiple model formulations side by side and blend somehow
    - How can natural uncertainty in rainfall and hydro processes propagate into reservoir management uncertainties?
- Can ice-cover models and hydraulic models provide more accurate water level simulations? How will climate change impact cold region processes and how can we integrate that into operational models?

- Things are changing too fast to use traditionally calibrated models. Need some physical basis for dominant processes or need to recalibrate. physics-based models don't do too badly but those are not ready for operational deployment
- Real-world processes change beyond what might be included in models. E.g., snow cover disappears from glacier, changing albedo, melt rate, etc.
- Climate-analogues might help to prepare models for different climate conditions. Some work by parameter estimation folks (e.g., Thorsten Wagener) does this
- river ice and urban environments are hard to predict. Should be thinking about urban. urbanization makes parameter estimation obsolete. impacted by local ordinances and regulations: cannot have more runoff from land than before. Other places don't have this at all and hence development changes runoff and requires model updates. How do you track this across a large country?
- How far was computational scaling investigated? Are there proof of concepts that we can in fact run all these ensembles on available infra?
- Using hydrofabric to decompose problem in separate domains. CONUS into 160,000 catchments on cluster, linear scaling barring communication costs.
- Follow-up on discretization. Assumption that lateral groundwater flow isn't there?
- First step is gridded forcing capabilities that overlap catchment boundaries. This extends to anything that spans boundaries, e.g., groundwater.
- There's still a difficult question of how to effectively distribute work to cores. Straight MPI decomposition might not be effective enough.
- Got a request from the BMI council for an update to the BMI standard to allow better parallelization. need to experiment with more agile parallelization approaches?
- Is there an engine that runs BMI components in certain sequence? E.g., hydrologic model, routing, hydraulics? One tricky thing is output time resolution. It all must sync up. Adding implicit coupling to BMI? This should instruct two tightly coupled models to go off and do their own thing, and report back when finished.
- Related question, when does BMI stop? Bio-geophysics models with multiple components in it; can that do its own thing internally or does it all need to be BMI. BMI thinks of a component as a PDE. Imagine you need irrigation from some complex farm model. BMI doesn't necessarily account for a PDE constructed out of multiple sub-models.
- research question: how do we process-representations into NextGen at various levels of granularity? When does it make sense to include complex solvers into modules? BMI doesn't have to be the only system. Within or between components there can be different methods of coupling.
- Does the entire country need to be run in one chunk or can we decompose the domain? Hard to say right now. Alaska could run on its own thing.
- CIROH can experiment with different ways of turning things into a shadow proving ground.
- If there are different realizations you might get efficiency benefits if you can run on multiple locations.

- It’s CIROHs place to recommend new ways to do operations but CIROH will never do the actual work. This goes to contractors. Recommend that CIROH avoids the final step of operational implementations
- should we know about implementation procedures? go wild. Run with scissors. Implementation is NWS challenge.
- how do multiple ways of coupling come together? The main way is BMI. Models in the framework are not aware of the others. Framework is the main communication controller, so everything accessed by the framework must be BMI compliant. Sub-modules don't need BMI but that means the framework cannot access it directly.
- What about dependencies and implicit solving in NextGen? that cannot be done currently
- Model is combination of hypotheses and subjective decisions. Many of these will be inside a BMI component. How do we expose these decisions so that they can be evaluated? it’s possible to extract a model down to its fundamental processes at any discretization. Higher dimensions are of course more complicated. Starting at lumped, ET/infiltration/groundwater/etc. are important processes. From this you can create a complete formulation as a meta-model and from this select various methods/approaches to solve the thing. How can we do higher dimension meta-modeling over arbitrary discretization's?
- Conceptual coupling of processes happens at BMI level? yes, CSDS (land map) has examples
- Implicit solutions/coupling: you cannot get away without this at high spatial/temporal res. where this really comes into play is in things like different physics components within a single hydrofabric element.
- If we lump various fluxes into a single (BMI compliant) model (e.g., canopy domain), how do we get access to the individual decisions in there?
- how do we build the computational infra to do hypothesis testing at multiple levels of process granularity? Noah-MP: land surface to top of canopy. Separate calls for ET and interception. ET would interact with other modules?
- is there a driver that controls execution order in BMI? If not, that could be a problem. those fluxes change that much per timestep so it shouldn’t matter much
- more controlled operator splitting strategies can be useful.
- some figures on NextGen performance. Endorheic regions are hard. Plans for models to work there?
- organized preferential flow is often missing
- NWM currently doesn’t work well for longer-term predictions. Currently 30 days but needs (Cali) for 1-2 years and for climate change we need 30 years. How do we formulate some NextGen model that addresses these needs? Need forcings, but also an effective way to set up a model that can go that far out into the future.
    - Forcing will be very uncertain, what is still meaningful? something probabilistic.
    - DOE works on this, 10-year, 50-year projections. Looking at land cover change etc. Running hyper-res models at daily out to 50 years over HUC8, HUC4. Goal to do full river basins. Hope there’s room to meet in the middle with NOAA and USGS

    - Over shorter timescales, where does predictability come from? Initial conditions mostly
    - Precise predictions are impossible, but statistics can still be helpful
    - Real need for predictions beyond traditional flood forecasting time scales
- how does CIROH stuff work with the rest going on in the national Water Center? congress tasked NOAA with planning to evaluate water resources across the US on 5-year interval. Recommending that agencies cooperate with NextGen but there's some pushback. BMI stuff is low-hanging fruit. England/London just came out with their own coupling (Martyn; HydroJULES effort). The hard part is convincing everyone to adopt an interface at all (rewrite code to do so). Coupling between interfaces after isn't that hard. Unsure what's happening globally but some countries/agencies are.

Part 2: What are strategies and techniques to advance the representation of human effects into national scale hydrologic/hydraulic modeling? Facilitator: Dr. Fred Ogden, NOAA OWP Chief Scientist.

- Critical to do this at the catchment and reach scale, nationally
- Human impacts: Reservoirs. Land use landcovers. Irrigation. Diversion.
- Dams
    - What are the strategies for including dams, reservoirs? → NWC not there yet
    - Data intensive. Needs lot of input data, but for many dams there is no data. Actual operations not in handbooks. Not really following the rules.
    - Use some existing reservoir models w/ parameters learn/calibrate. Some models from Michigan State Yadu Pokhel's model. Saskatchewan has a model. NWM has some reservoir modules that have evolved over time.
    - Too many dams without data. Rules unclear. Options: encode operation rules into models
- Tile drainage
    - The Hy features workflow (USGS/NOAA; hy refactor tools) — include access to open DAP (protocol for sharing large datasets; https://www.gim-international.com/content/article/opendap) — large are through this protocol, land cover, gridded soil productions, 14000 datasets. Envision a workflow that uses a catchment hydrofabric + refactor channel configuration that uses the datasets to estimate parameters. CFE model as a null hypothesis. e.g., land use change as a primary driver.
    - Simulate how farmers allocate water. Land use. Irrigation. Positive mathematical programming method.
        - These models are calibrated and validated with recent data to be relevant. Calibration was not the right word ---> parameter estimation. Process presentations.
        - Learning from downstream discharge. Utilize as much data as possible --- data science approach
        - 9000 reservoirs: too hard. Learn the rules with physics-informed ML approach w/ downstream discharge. Direct ML (not interpretable).

        - Withdrawal: difficult to predict
- Dredging
        - Downstream Mississippi hydraulic geometry
    - Bathymetry does not matter to routing but could be important for flood inundation.
    - Topobathy data: inundation mapping application.
        - Land use land cover
            - Hyper resolution for urban areas. Rapid development of urban areas.
            - Are there ways to know where we can capture impacts of land use and urban environment without hyper resolution?
    - The city of Charlotte has lots of data for flood inundation. Water depth. Post event analysis.
- Need a social scientist in the room.
        - What are the human impacts on hydraulics? Levees, bridges, channelization, dredging, dams, reservoirs & operations?
        - To account for dominant processes, we must compare data. What is your take on this for consistency of the perceptual model? How can we "test" that the features we need to include are included and is complete? Perceptual model sows mistakes.
- Standard of proof for inclusion of models in NextGen: What is the weight of other stakeholders' views and values? Does this factor into the "proof" needed? That is outside of the operational framework of objective measures. What is the priority? Fidelity, time ranges, computational efficiency, etc. Not decided yet. In NextGen, Sacramento model will be included. We have a vast array of metrics that we use, not a scorecard.

Research Theme 3: Innovating Hydroinformatics Applications

Part 1. What are unique hydroinformatics applications that extend the NextGen National Water Resources Modeling Framework Benefits for new Users? Facilitators: Dr. Ibrahim Demir and Dr. Witek Krajewski, University of Iowa.

- Economic potential of National Water Model data
    - There is a large potential for NWM data
    - Most users will look to industry for the tools and data; rather than going directly to NOAA
    - Needs:
        - Data access at scale
        - Service Level Agreement / Uptime
    - The private sector is in the cloud, so the data needs to be there too to support commercial applications
- CUAHSI Current capabilities
    - Researching how to provide access to large datasets
    - The way we divide up data in files in time and space is part of the problem

    - Partitioning can depend on the users. Municipal applications vs Watershed level applications vs National applications.
- Who are the users?
    - Research community (CIROH)
    - NWC
        - Operations
        - R&D
        - RFCs
    - General public
        - Different levels of decisions
        - GPS reroute if normal route is flooded
        - Emergency operators need to know where it is safe to deploy and which resources to deploy for response efforts
        - Voice assistant tools for general public
- What are the needs from the NWC?
    - NWM output
        - Streamflow
        - Flood Inundation
    - Need to support both internal development and public safety products
- Should this theme have a part in mobilizing the open source community? e.g. Pangeo
    - Water Center and CUAHSI have both had interactions with Pangeo
    - ESRI is being used for dissemination, processing and NextGen are open source / use open source tools.

- What can we do to better communicate this data for planning and emergency response?
- Is there a similar model in the NWS/NOAA that we could use as a pattern/blueprint?
- National Water Model
    - Difficult to retrieve and visualize for research
    - Roll out of official forecast data publicly from NWC by 2026; It will be released in phases
    - Need time to bring field offices up to speed as data is released so they are prepared to answer questions and offer guidance to public
    - Counter argument - public has access to USGS gage data already, and there isn't much interest/concern. Should release the data sooner, than later so it gets more exposure and feedback
- Run a mirror execution for CIROH research?
    - Code is publicly available on GitHub for NextGen
    - Don't worry about the current version of NWM (or version 3, which is still WRF-Hydro)
    - Research should focus on NextGen, which will be released in version 4 (circa 2025, 2026)
    - NextGen operations environment will be in the cloud
    - Is it possible for CIROH members to get early access to the FIM products?

        - FIM workflows and the data are public and well documented
- How can remote sensing data be incorporated? SWOT satellite for water surface elevation and slope
- What can we do for community / education outreach in this theme?
    - 3D maps are good tool for communicating results in an intuitive way
    - Sandbox tools that let them change parameters and see the results to allow them to get a sense for the modeling
    - Avoid code and Jupyter Notebooks - should be simple enough to be explained in 5 minutes and allow them to start exploring
    - Voice Recognition - Iowa's Flood Assistant - answer question
    - Opportunity for cross-cutting work with Theme 4
- Summary and Takeaways
    - Data access facilitates everything
    - Need CIROH mirror of NWC products
        - FIM and other services (data won't be public until 2026)
        - Visualization / communication tools - 3D maps, voice recognition tools, education out research tools
        - Research should focus on NextGen, not current versions of the NWM
- Research ideas: Data Access and APIs
    - Cloud Data Processing workflow for API-based historical forecast data access. Use case is creating a cloud workflow and APIs that allow researchers and users to quickly access historical model simulations through an API for doing historical analysis, model validation, etc.
    - Cloud data processing workflow for API-based access to NWM forcing data. Use case is getting the forcing data to run a subset of the NWM for a particular area of the US. Users need the ability to get the forcing data for the domain that they want to run.
    - API for FIM extents and depths
        - Expose FIM extents and depths for public consumption
        - These products would be super helpful for apps that might want to incorporate this information for public presentation
    - Combined API for NWC data access (model/map)
        - How to design a unified standard API framework that exposes all the inputs and outputs
        - Server-side operations for getting data that are fast and do not require pulling a post processing data that is not needed to get what you do need
    - Public sharing and access to the US HydroFabric
        - There is currently a public GitHub repo for this
        - How can people contribute to the HydroFabric? Refine the fabric in certain areas of the country where people have high-resolution, local data
        - Really expose any of the model inputs, but the HydroFabric itself
        - Expose search and discovery tools/API for retrieving parts/regions of the HydroFabric

        - Testing and validation applications - (re)run model using “enhanced” fabric
    - Actionable Catalog for NWM-Related data and products
        - How do people know where all the data products live?
        - How do people and applications know what the mechanisms are for accessing the products?
    - What metadata are required to describe products for the purpose of data discovery and data interpretation
- Data clearinghouse for curated inputs and data products in cloud ready formats accessible via common API’s.
    - Data would be reformatted to facilitate use case specific access
- Research ideas
    - Web-based Computation Library. Client side (low code) hydrological data, analysis, and visualization library. No server-side resource needed. Easy to adopt and use in educational - classroom settings
    - HydroLearn - Training and Education on use of Data, Forecasts, Inputs, and API’s, of NWM. Open access training material and education. Training in how to use NWM APIs and data products
    - Flood Prediction Bias Correction - Using Observed Flow and Water Level Data. NOAA only validates models on USGS points. This project could provide additional information for validation. Utah State University has a current CIROH project related to integrating observed data - moving in a direction similar to what exists for distributed weather observation/contribution system, but that we do not have for water data. Bias correction could use data from the system created by USU.
    - Curated Library of Local Scale Models for Validation and Testing of National Scale Model(s). Currently using local-scale engineering models like HEC-RAS to compare results of the NWM. Models come from FEMA, but could also come from federal highway models. Create a curated library of high-quality, local-scale models that can be used. Consider the information in these local-scale models - what is being used? Can the information from the local-scale models be extracted into a national-scale layer of validation information (so model testers don’t have to keep processing HEC-RAS models repeatedly) - “Enhanced HAND product” for generating synthetics rating curves + information about where the enhancement came from (e.g., HAND, Local-scale modeling, LIDAR data, etc). Use HydroShare as a repository for this information?
    - Data Model for Evaluating Model Results. HAND vs 2D models. Client-side tools for comparison and evaluation (Ibrahim - early work available)
    - Regionalized Tethys Forecast Data Viewers and Scenario Explorer for RFCs/Users. Iowa does tabletop experiments; NOAA uses Tethys for operating dashboards. BYU is creating extensions to plug and play elements - don’t have to recreate parts. Build apps with drag n drop or other means. BYU, Iowa, Jupiter
    - Realtime HAND-based Flood Analysis. Develop app/widget with a backend that allows to run user-initiated processes on the database for real time simulation,

scenario analysis and quick visualization of outcomes. Including API access to HAND data.
    - NextGen Modeling Access to Inputs and Outputs (Horsburgh, Ames, others?) There will be an operational version of NextGen model. What is the data model for the inputs and outputs to NextGen modeling? What organization of the data facilitate modeling and what facilitates sharing. Standardized metadata and indexing

Part 2: What hydroinformatics tools will enable broad research community engagement and help them to advance hydrologic prediction? Facilitators: Dr. Jeff Horsburgh Utah State University and Dr. Dan Ames, Brigham Young University.

- How can a platform like HydroShare enable the CIROH community? Repository? Linked computations? What enhancements need to be made to better serve a community like CIROH?
- Need to take advantage of Communities option in HydroShare. Create a CIROH community. How could we take advantage of these capabilities in HydroShare? People within CIROH will be generating data and other content - How do we share these and organize access to them? Do we need training or a CIROH workshop on using HydroSHare for collaborative hydrologic research? Building training capacity for HydroShare and other tools that people are going to want to use. Organize a webinar series? Will we get in a situation where there is too much stuff on HydroShare - how do we focus on communicating results (the stuff we want people to see versus the stuff that is just intermediate results that we may not want to keep). Access control is a feature of HydroShare that can be used for controlling who can see and who has access to what. Create a curated set of data/products that we want people to see and use. Do we need a designated curator of products for CIROH?
    - TODO: Have a webinar on HydroSHare capabilities, groups, communities, and other HydroShare capabilities - talk to Steve about this
    - Could we use some recommendations on “governance” of products to help contributors to understand how to contribute content and where it will go?
    - How can HydroShare support content stored in multiple places?
        - Storage that is not inside of HydroShare
        - Can we support reproducible computational workflows using notebooks and available computational resources based on data that may be inside of our outside of HydroShare (e.g., storage from Amazon, google, etc.)
    - HydroShare has been focused on the research community - is there a role for HydroShare operationally?
    - River forecast centers have needs for local data
    - Can we use HydroShare to bring data together in one place? Local information that is hard to get?

    - RFCs save a lot of data locally that they use to answer questions and field requests later - it would be good to have a place to point people NCEI - National Center for Environmental Information (responsible for all archiving)
- Gaps in hydroinformatics tools (or issues) that NOAA is experiencing now
    - Validation and verification of inundation mapping with all different data types - this is a need now.
        - They have done the lower hanging fruit - e.g., model comparisons. They haven't done much validation and it's a big country.
        - Forecast verification is a need.
        - Need a quantifiable way to measure skill through the whole process - methods to do this and data to support this?
        - Need an automated avenue for crowd sourced and citizen science information to get in and to the forecasters
        - Using standards to facilitate the data flow - start to end supporting data needs, but also making products easily accessible
        - A bunch of evaluation efforts also on the modeling side using gage data. This is more mature. There are challenges getting into the operational evaluation system. There may be an opportunity for making evaluation data available.
        - Library of benchmark datasets, but incomplete
        - For FIM they are mostly working on spatial agreement and have done less with depth, but they want to do depth predictions and evaluations
        - Need ways to feedback information into FIM estimates
    - Are there data/CI needs for NextGen modeling that could be met, but have not been yet?
        - 3D data model for channel data?
        - NHD+ is a good 2D product, but isn't sufficient for 3D hydraulics
        - Building a plan to evolve to 3D would be good
        - Lots of different types of channel data out there - cross section, bathymetric profiles, - this could all come together to create a 3D product, but working through edge cases is needed.
        - Connects NextGen modeling efforts with flood mapping - hydraulics plays a role in both
        - Currently modeling efforts are doing hydraulics separately than the FIM work based on HAND
        - Lots of terrain data with LIDAR - inland Bathy is a huge data gap
        - They have pretty good skill for large events, but smaller events with smaller events have bigger errors (confidence goes down)
        - Channel and friction properties of the channel are probably the biggest sticking points right now
        - Descriptions of the channel bathymetry would be helpful, but the model needs to be able to take advantage of this too
    - Probabilistic flood mapping
        - BYU has someone working on this now

        - Usefulness of this depends on the user - many users may not know how to interpret these
        - It's difficult to express where the uncertainty is coming from - inputs, model representation, etc.
        - Have started talking in terms of "most likely", "worst case", etc.
        - Hide quantitative uncertainty behind an index - an intermediate step before showing maps
        - Could we just "light up the transportation network" - if you are in this general area, pay attention!
    - Getting the forcing data and examining NWM output has been a particular challenge - we've talked a lot about how we can improve that.
    - What will be different with forcing data and output with NextGen modeling? How can we plan for this?
        - Forcing input will likely not change much for what will go into nextgen - may depend some on models that are chosen
        - When they disseminate data in NOMADS in real time, they are limited to NetCDF files
        - Opportunity is for how data is post processed to support other applications
        - Ultimate goal is to map forecasts back to NHD+ because this is a common dataset that entities use
        - Want to replicate the same output types that the current model does
        - If we fully embrace the approach of different models in different areas, we may not be able to standardize outputs
    - What Initiatives of NOAA, NASA, USGS, etc. Should we be connecting with?
        - Rimorphis - river morphology information system (Venkatesh at Purdue, Ibrahim Demir and Marian Muste at Iowa)
        - Highway departments/DOTs for river morphometry data and design 2D models
        - FEMA for local-scale hydraulic models
        - USGS HIF - all different types of instrumentation and new ways of making observations - operationalizing new technologies More could be done to interface with NASA. BYU and Aquaveo have been working on Tethys apps using NASA data
        - USGS FIM - they have flood maps all over the country already online, but messy
        - Insurance flood mapping
        - Insurance claims?
        - Big Data Program putting data in the cloud
        - CDC Social Vulnerability Index data. what areas are most vulnerable and how does that overlap with flood predictions? CDC does this after, but from an operational context this might help make warnings earlier for populations that need them earlier
        - Building footprints and impacts

Research Theme 4: Improving Decision Making & Community Resilience

Part 1. What are opportunities and ideas for CIROH research to advance forecast delivery to underserved communities? Facilitator: Melissa Kenney, University of Minnesota.

- Need clarity around term "underserved community" vs. "vulnerable community" - See Executive Order definition –
    - Different communities face different risks and communicate in different ways including language styles
- Need help of communities to share forecast information (amplifiers), e.g. door to door communicating - What is the water risk? Flood? Water quality? Drought? Unavailability
- "Floods kill people, drought kills civilizations"
- Map literacy isn't clear to exist across the board so be careful in how we present information
- Challenges in the meteorological community are driven by certain instances, can we use this information on where we need to help and provide additional information
- A culture change needs to be initiated specifically around application of information to operations
- How do you communicate risk equitably?
- How to message weather/water information across many different populations?
- Body of literature on hazard vulnerability (Susan Cutter)
- Help agencies and service providers understand vulnerable populations
- Nuances of terms- underserved vs. vulnerable
- Conveying messages based on receptivity and source of communication
- Need community ambassadors
- Regardless of how effective your messages are, some populations hesitant
- Where's the line between State vs. freewill on evacuations?
- Locations – how to have people leave in advance of disaster for good (e.g. not have mobile home parks existing there- pre planning in disaster life cycle is key)

- Tribal community response- government information may not be the most effective - social science perspective to understand what works best for these communities –
- Community asset mapping- reference types of things that the community values
- Reference cultural assets when messaging including the idea of what gets people out of harm's way before an event
- Learn from societies that have resisted colonization in the past
- How to help assist forecast level folks get message across – ambassador program- e.g. community science, Weather Ready Nation program - include the idea of cultural independence and bring in boundary spanners in this work (someone that understands NOAA's information and the local communities allowing for the earn from their communities for the coproduction of knowledge)

- Need creative, innovative ways to incorporate tribal knowledge, skills and resilience back into agencies
- Co-production NOT transmittal of knowledge with tribes- recognize what they bring - The ecosystem services, cultural assets, government intervention is not always helpful in these underserved communities - this is of the utmost importance in communication
- Indigenous communities don't necessarily see natural disasters in the same way as "Westerners" do, which is important to remember when interacting with these communities

Priority areas for research and engagement in the next two years?

- What's the definition for underserved for the purpose of NWS? Guiding light for research under CIROH. Another challenge is looking at the issue from a national perspective as the federal government. Where should the federal government reach end? Need to grow, mature and inject energy into hydroFsufederal mandate end spatially or temporally
    - we can take some lessons from the meteorological community on this
    - Public health offices can also help to provide guidance –
- Research to Operations- need to be practical and ensure successful transitions. Developing training or curriculum to NWS forecasters would be valuable (build awareness and education to result in better service delivery).
- Framework to deploy that includes a training and pilot areas.
- Balance what we apply nationally with that which is regional or local. Criteria for pilot case to see recent water events that will make communities want to work with NOAA (e.g. Ellicott City, MD!) - Explore Video and image effectiveness in communicating - could help to serve several different audiences including those on social media
- Window of opportunity – how is climate risk given to decision makers? NOAA environmental intelligence maturing.
- Trust of science vs. trust of federal government- many of our organizations are about getting data into the hands of people who can conduct grassroots education and training.
- Ensure kids are educated and engaged in STEM disciplines- education gap, create a presence especially in focused on primary education
- Digital divide is an important concept in regards to under-represented communities, many communities still don't have reliable cell or internet service, how do we deliver information to these communities
- Incorporation of more socioeconomic information is important, NWM currently provides a poor representation of water information and could be contributing to community division based on where the forecasts are better represented vs. those that aren't as well as what events are well represented
    - Study bulletins and responses that can help to improve our language in messaging

- Understand how to properly communicate that we're working in the underserved populations?

Breakout Session 2- Big Social Science Questions –

- NOAA endeavors currently include or will in the future include FIM services, NWM services, and visualization services
- Previously only engaged NWS services/forecasts with forecasters, have not engaged the public yet- ripe and rich for research and feedback
- Backbone is education- starting to train the forecasters for 10%, later will train partners and the media (next nine months) including are many opportunities to learn and determine how to better engage as OWP moves forward toward covering 100% by FY 26
- Late next summer early fall version 3 of NWM coming- will cover parts of Alaska and looking toward including different types of domain in FIM in the coming years –
- Education/outreach budget in CIROH accounts for 1% of the total funding - there is a need to determine if this is sufficient and how to expand if needed
- Consideration around continued collaboration that could provide other sources of funding outside of CIROH that can be utilized to help with this work
    - There are mechanisms that overlap with BIL as a consideration, but we must manage projects clearly to make sure there is alignment and not overlap
    - Service delivery work ideas on phasing of next steps would be helpful including matchmaking within NOAA to make community connections is important
    - Could be with regions or if a nation scope could work with headquarters

Broad Social Science Questions:

- How do people want to use NOAA's information? Who do and don't NOAA serve information to – evaluation is needed in this realm
- What about exploring quantifying the value of flood inundation mapping
- How can we improve the communications of messages and how do those change your decisions?
- Key struggle with flood mapping- public and EMs have different needs. How good is good enough? What will those groups accept and react differently with super accurate map vs not super accurate?
- Looking at frequency of flooding, social vulnerability, where are the communities at risk?
- How do we work toward greater empowerment of a larger group? – more people are needed to facilitate communications with the broader community, which may be broader than just visualization
    - This could be a place that the private sector (enterprise) can help support the facilitation/distribution of information
    - There is a need for prioritization here within NOAA and what we can support and what other groups should be taking the lead on

- Question on how do we engage with communities that have previously received incorrect water information and regain trust; uncertainty communication is one way to proceed, but consider audience on how this is communicated
    - Educating the public is important but this group typically wants less information and fewer tools that per say the emergency management community who wants everything they can get their hands on
    - Sagy's group is working on a technical solution, but this group (social scientists can work on how to best communication the probabilistic language; This is currently done with temperature and salinity but in a somewhat tricky way
- What is the best way to work with different agencies and not duplicate efforts acknowledging there is some benefit to "duplication" in order to get different perspectives on a similar problem

Forecast-Specific Key Questions –

- 2 forecast services that go out 5 days one with far less aerial extent AND NWM solution. Going to be disseminated as 2 independent services- is that the right way to do it? –
- "Relational based" translation of information- highly contextualized in information sharing. What do we do when we bring a FIM map to a community and are wrong?
- How do we engage with that community in the future? - How do we communicate uncertainty? Concern is we're giving people a false sense of certainty. Qualitative statement of uncertainty is what is currently used. Cross-pollination opportunity with Sagy Cohen on communicating technical solution
- Temperature and precipitation maps now have probabilistic language
- Now NWS has single deterministic forecast
- Timing on flooding- has different maps- for experienced users. NWC compiles in briefings to focus attention
- This group desires similar outcomes as is seen in coastal regions where most people know their flood zones and associated risks, people typically know how they should respond in these zones (though they don't actually necessarily respond even with the information)
    - It is the enterprise's (private sector) to get alerts to the public but we can look at the best ways to get the information out there
    - Who actually delivers these types of alerts?

FIM Communication Key Questions

- USGS water watch – color ramps
    - Melissa Kinney has interesting results- important and interesting questions need to be teased out- has webinar that can be shared
    - RFCs could also provide some information on absolute error that could be leveraged –
- Would love to connect and think about how to collaborate on low hanging best practices and more rigorous testing methods
- What is meaningful to a community? Photos- if it floods or doesn't flood

- Think about communities that haven't experienced flood but have a likelihood; How does the proposed information from FIM and other products affect decisions made in local areas?
- Leverage success stories and share on social media
- For videos, FIM may need depth units
- Partner with ASFPM and Silver Jackets
- Pathways of impact- where will you get the biggest impact given the current goals and how we share through different networks?
    - Providing the most actional information for the largest number of people is preferable. Customize information.
    - Can't design something that is all things for all people but when done well- most things for many people
    - All specifics on water level information are not as important for the general public
    - Create a "FIM for dummies" for the general public was a suggestion
- Opportunity to be nuanced in audience in how information is structured and delivered.
- Highly technical users- lots of sophistication and detail that many people don't care about but also don't want to lose the opportunity to share information that empowers people.
- 3 flavors of FIM- NWM 5 day forecast, RFC-based 5 day FIM (only mainstem), analysis/QPE (rainfall observed estimation)- what will be public FIM?
- Opportunities to lean into important redundancies? Sometimes important redundancies because we are approaching something from different angles
- What will be different after we have these new products? - Ellicott City, MD- socialized warning system to minimize mortality during flash floods
- Now NWC shares FIM directly with FEMA only. FIM only available for river reaches –
- Media communication could be multiplication/amplification of FIM
- Perhaps have flood service directors like climate service directors? Training SMEs- 2 people/office, trained at FIM interpretation and deriving messaging for briefing to partners
- Citizen science to fill gaps? Google- when you find issue with map you report it. Crowd source and Matchmaking within NOAA may also be helpful
    - Could help to move forward with FIM in a faster manner so that it's not all on NOAA
- Public and emergency managers have different needs and how good is good enough in our products and services
    - The next step in the value chain is where does the information go down the chain
    - Prioritization is an important step from the NOAA perspective
    - What's going to happen if NOAA provides a map that isn't quite up to par?
    - Another way to state "What information should actually be disseminated and to what communities"?

    - The emergency management community wants to see all information available but there are still some questions about what else or different information do they need?
- The level of sophistication among emergency managers is also really varied and there are high levels of turnover, need to be sure that information is understood across different skill sets

Misc

- Define underserved. CDC vulnerability. Level of disaster. Literature synthesis needed here.
- National study to define where reach of federal forecasts ends? Define where it should end.
- Weather vs. Water – how to learn and share responsibility of delivery to underserved communities.
- R2O – training curriculum, frame research to deploy, pilot programs focused on implementation.
- What are ways to communicate risk equitably?
- How do you reach diverse audiences?
- Body of literature on how to identify vulnerable and underserved populations. Cutter for example has done significant work on this. Study of receptivity of the information – co-production by health advocates.
- Tribal communities. Cultural assets. Indigenous practices.
- Ambassador programs – weather-ready nation
- Synthesize best practices
- Cultural change needed – how?
- Frame research without bias from western views
- Language matters.
- Determine why communities are underserved.
- Review public health guidelines for ideas and approaches to reach underserved populations.