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Modernizing Probable Maximum Precipitation Estimation

Consensus Study Briefing

James A. Smith and the Committee for Modernizing Probable Maximum Precipitation Estimation

18 JUNE 2024

Take-home messages

PMP is important and major changes are needed to assure the safety of high-hazard infrastructure.

The committee recommends a **model-based approach to estimate PMP** in the long term.

Model-based PMP estimation has advantages for computing Probable Maximum Flood (PMF).

Recommended new PMP definition is based on extremely low exceedance probabilities, not upper bounds on rainfall.

The committee recommends a phased approach to modernizing PMP with near-term enhancements leading to model-based PMP estimation.

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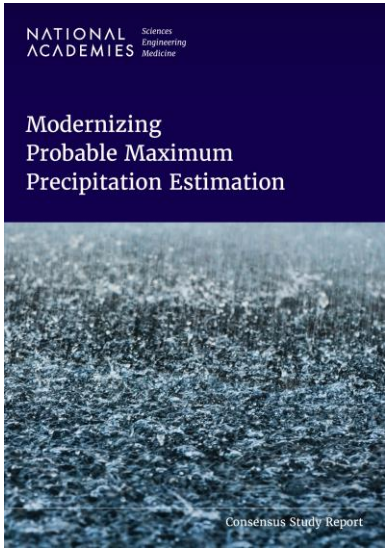

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Our vision

Model-based probabilistic estimates of extremely low exceedance probability precipitation depths under current and future climates will be attainable at space and time scales relevant for design and safety analysis of critical infrastructure within the next decade.

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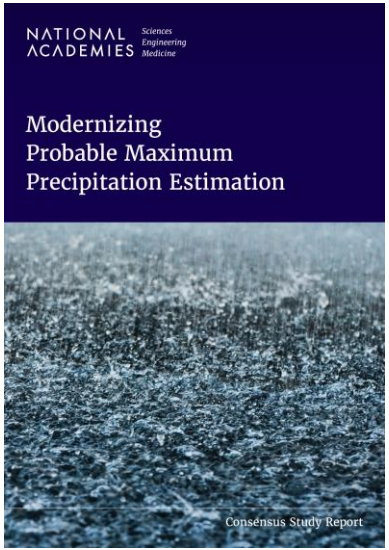

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Statement of Task: Key Elements

Key components of the Committee's Charge

- Establish a common understanding of PMP
- Review and assess: 1) existing and emerging approaches for PMP estimation, and 2) approaches to incorporate the impacts of climate change on extreme precipitation into PMP estimation.
- Assess data needs and sources, for PMP estimation and evaluation
- **Recommend a preferred approach for PMP estimation that incorporates the impacts of climate change and the characterization of uncertainty.**

The Committee will make recommendations for the development of an updated approach that can serve as a national standard for estimating probable maximum precipitation in a changing climate.

Full Statement of Task in report Box 1-1

Committee composition

James A. Smith, Princeton University

Daniel Cooley, Colorado State University

John England, U.S. Army Corps of Engineers

Efi Foufoula-Georgiou, U.C. Irvine

Kathleen Holman, U.S. Bureau of Reclamation

Shih-Chieh Kao, Oak Ridge National Laboratory

Ruby Leung, Pacific Northwest National Laboratory

Robert Mason, U.S. Geological Survey

John W. Nielsen-Gammon, Texas A&M University

Jayantha Obeysekera, Florida International University

Chris Paciorek, U.C. Berkeley

Russ Schumacher, Colorado State University

Inputs to PMP Study

Feb 2023: NOAA and PMP stakeholder perspectives on statement of task

Public Information Gathering

- April 2023: Data requirements, developers
- May 2023: Stakeholder Needs: PMP Users, Regulators, and PMP Data Developers
- May 2023: Modeling Extreme Precipitation in a Changing Climate
- Oct 2023: Potential Contributions of AI and ML Assisted Techniques for Extreme Precipitation Modeling

Current PMP, in brief

- PMP is defined as an upper bound on rainfall.
- PMP is estimated using observations of extreme rainfall from storm catalogs.
- PMP is used as engineering design and safety criterion for high hazard dams and nuclear facilities.
- Core procedures are more than 80 years old.

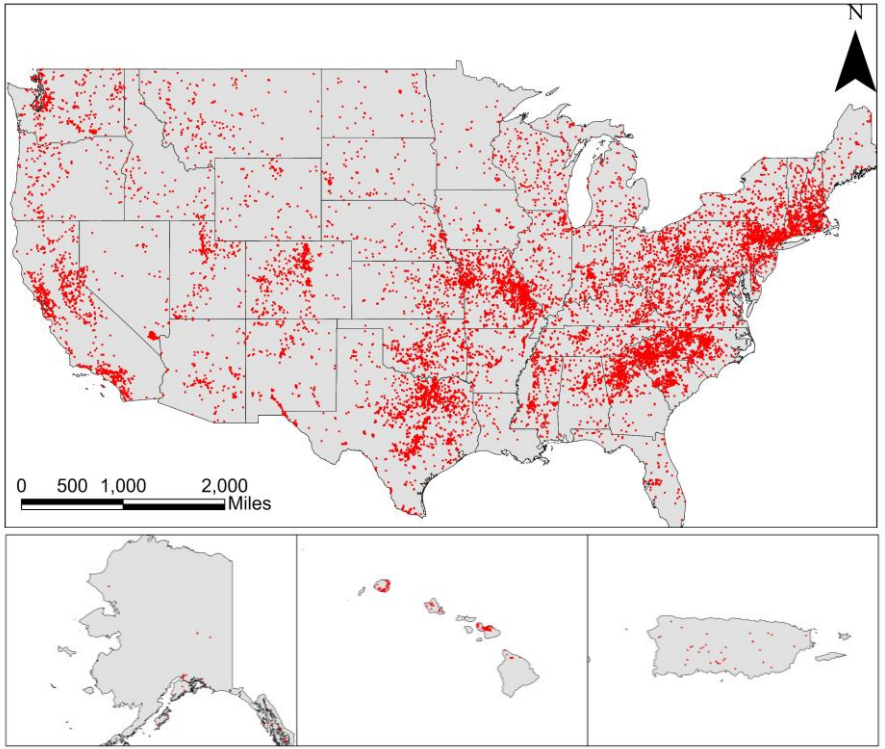

Figure 2-6: 16,564 high-hazard dams in the U.S.

Stakeholders and audience

PMP is of interest to:

- Federal and state regulatory agencies
- Nuclear regulatory agencies
- Dam owners and operators
- Federal agencies involved in development of PMP procedures
- Private engineering firms and consultants

This report has valuable information for groups interested in climate extremes:

- Infrastructure safety
- Societal hazards associated with climate change
- Climate modeling
- Extreme precipitation

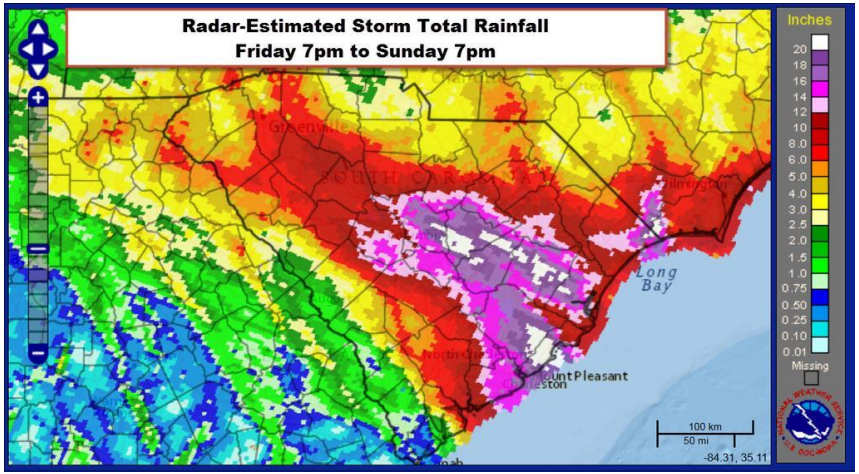

Figure 2-3: Gross Dam, near Boulder CO
Figure 2-4: South Carolina rainfall totals for 2–4 Oct 2015

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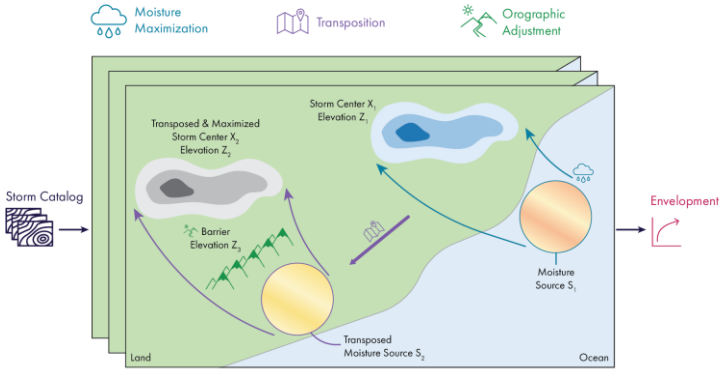
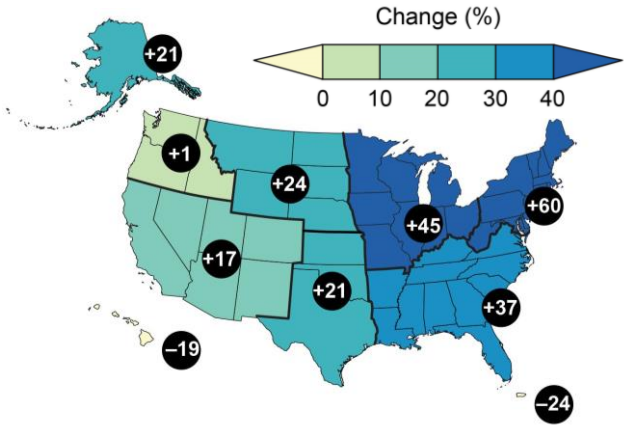
Current PMP methodology: Weaknesses

- Assumption that rainfall is bounded
- Absence of procedures to account for climate change
- Incomplete storm catalogs
- Inherent subjectivity in storm transposition
- Lack of scientific foundation for moisture maximization
- Empirical correction factors used to account for the effects of complex terrain
- Inability to quantify uncertainty





Upper: Figure 2-1: Fundamental components of PMP
Lower: Figure 3-3: Change in total precipitation falling on the heaviest 1% of days from 1958-2021 (from NCA5)

Current PMP definition

Theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year

HMR 52 (Hansen et al., 1982)

A first-principles theory has not emerged to support the existence and characterize the magnitudes of upper bounds on precipitation. *[Conclusion 3-12]*

Recommended definition

The depth of precipitation for a particular duration, location and areal extent, such as a drainage basin, with an extremely low annual probability of being exceeded, for a specified climate period. *[Recommendation 5-3]*

NOAA and the FEMA National Dam Safety Program, in partnership with federal agencies, states, and ASDSO, should develop guidance for specifying AEPs for PMP that are acceptable for infrastructure decisions and society. *[Recommendation 5-4]*

Roadmap for modernizing PMP

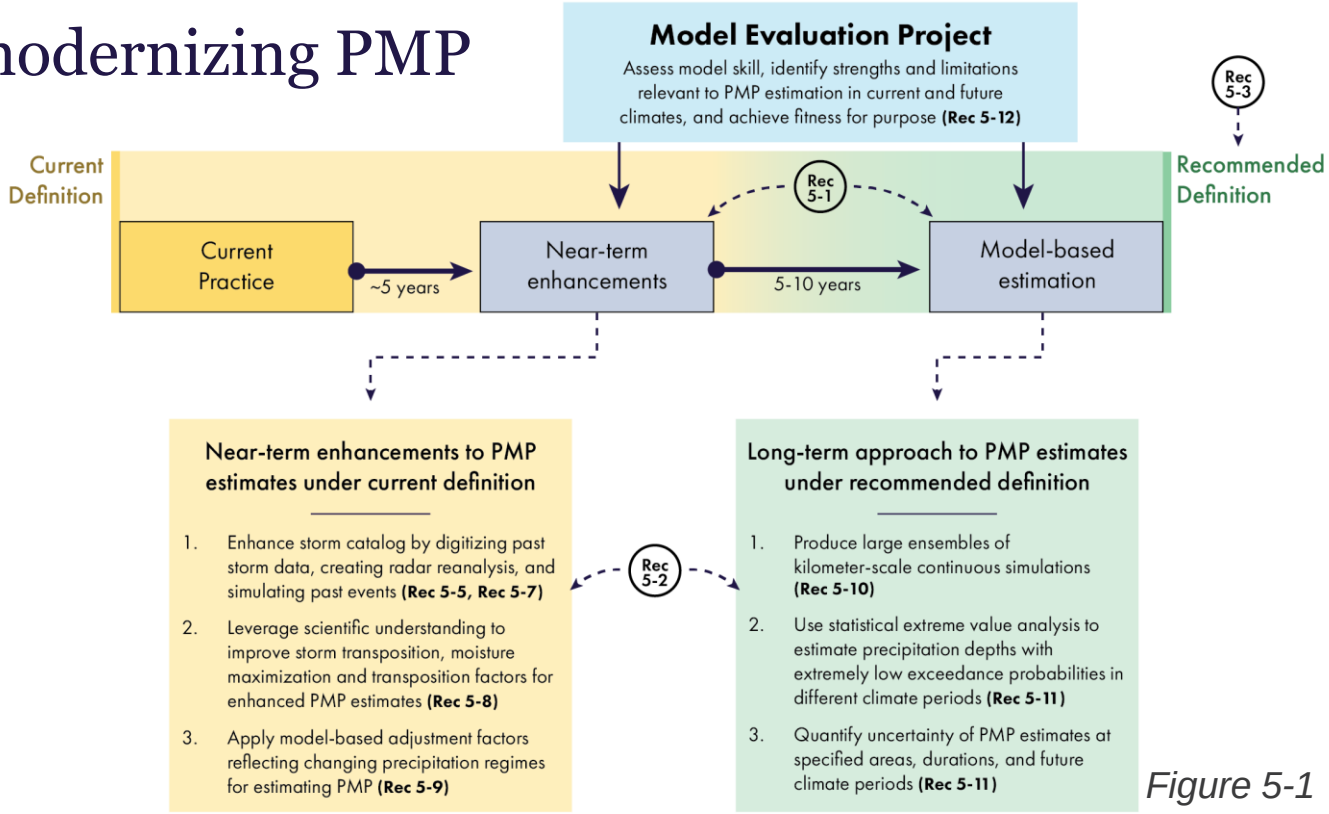
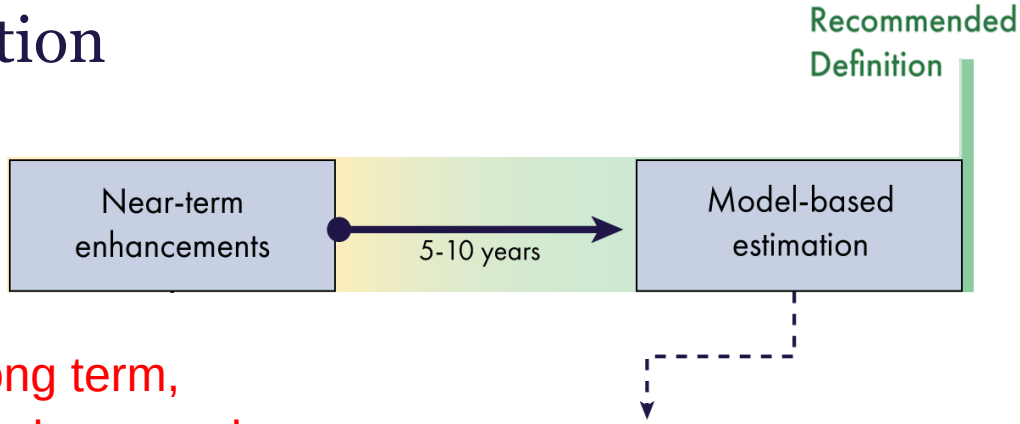


Figure 5-1

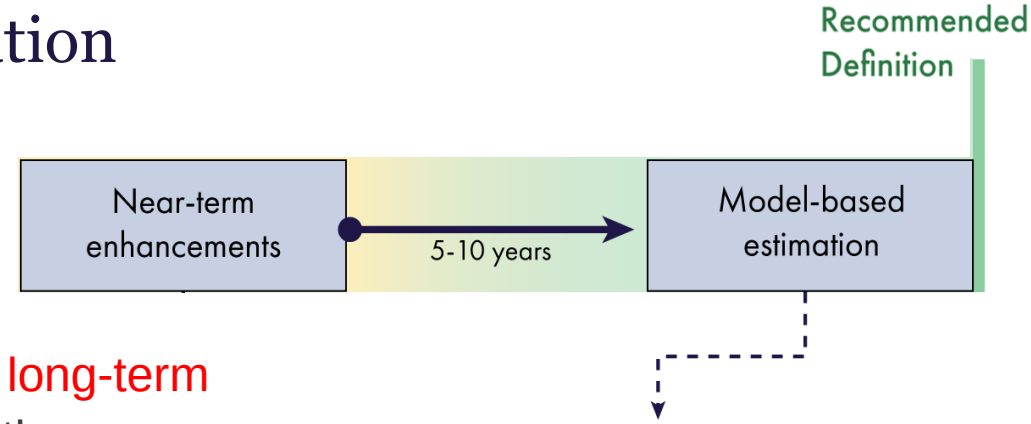
Recommendation 5-1: NOAA should pursue a phased approach to modernizing PMP estimation, with the *near-term approach* building on enhancements to conventional PMP procedures and leading to a *long-term model-based framework* that can provide uncertainty characterization of PMP estimates, fully incorporating the effects of climate change.

Model-based PMP estimation



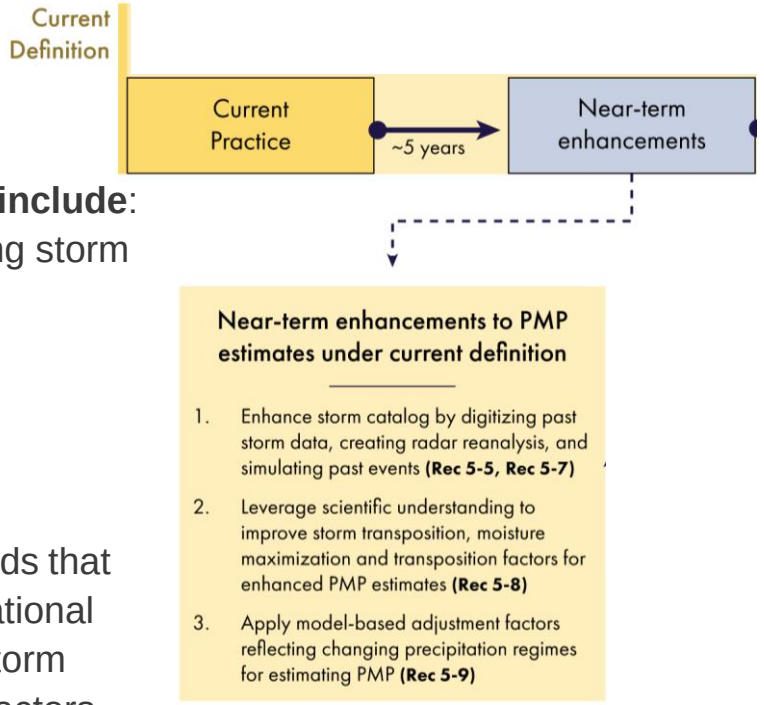
Recommendation 5-10: In the long term, NOAA should adopt a model-based approach to PMP estimation that aligns with the revised PMP definition, consisting of multi-model large ensemble kilometer-scale or finer-resolution modeling to construct the probability distribution of precipitation for PMP estimation under different climates.

Model-based PMP estimation



Recommendation 5-11: For the long-term approach and in agreement with the recommended PMP definition, NOAA should use statistical approaches to estimate PMP (with associated uncertainty) as the precipitation depth corresponding to an extremely low AEP from the model-simulated precipitation distribution, with particular consideration of extreme value analysis based on threshold exceedance levels.

Near-term Enhancements to PMP methodology



Data enhancements **Recommendations 5-5 and 5-7 include**:

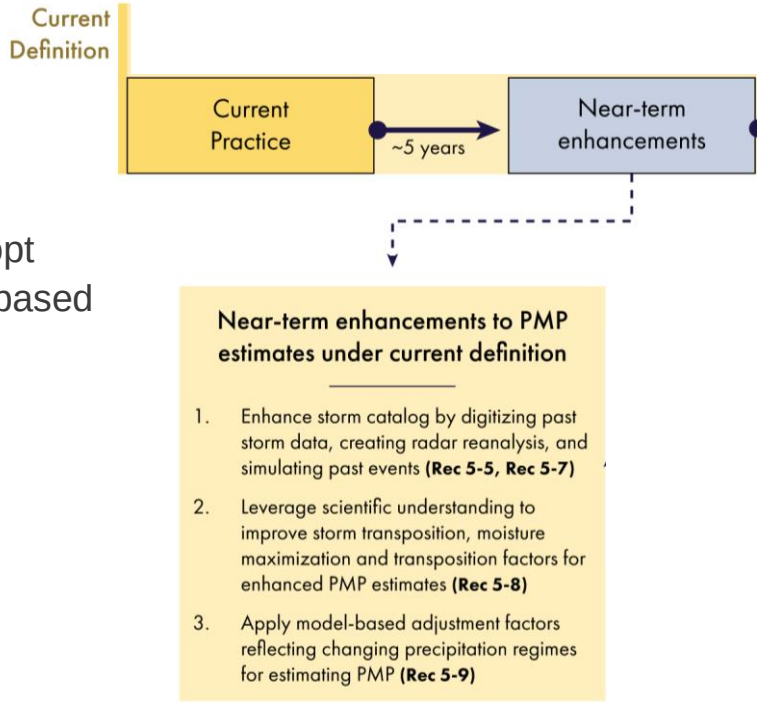
- NOAA and USACE: facilitate digitization of the existing storm catalog of historical extreme storms.
- NOAA: facilitate enhancement of storm catalog using observations from US weather radar network.
- NOAA: facilitate enhancement of storm catalog using model reconstructions of historical storm events.

Scientific guidance **Recommendation 5-8** recommends that NOAA include a summary of scientific principles in its national guidance for near-term PMP estimation—including for storm transposition, moisture maximization and transposition factors.

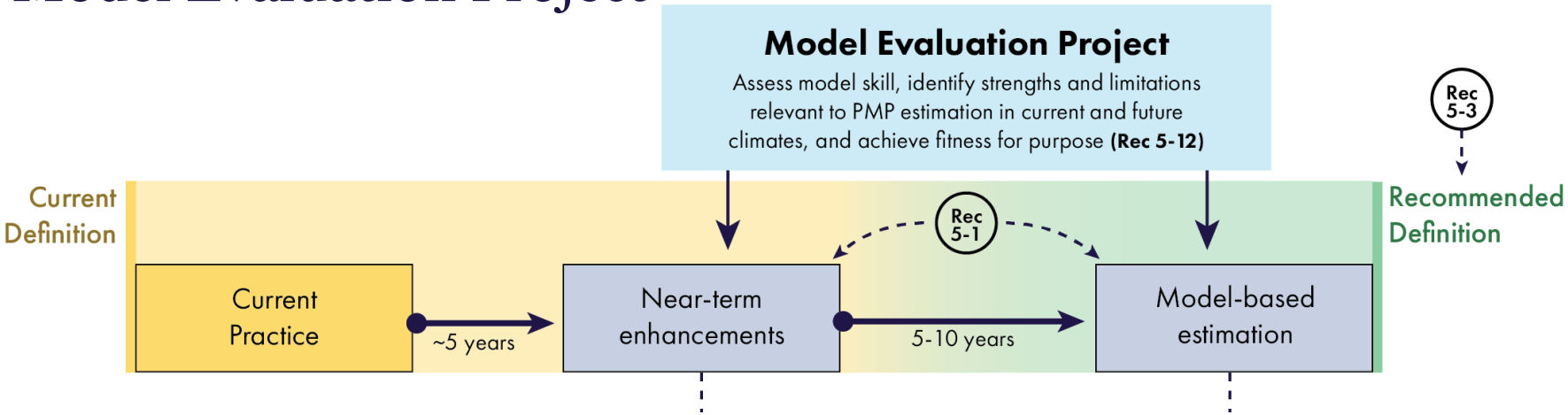
Near-term Enhancements to PMP methodology

Climate change (Recommendation 5-9)

For near-term enhancements to PMP, NOAA should adopt climate change adjustment factors based on the model-based scaling relationship between extreme precipitation and temperature.



Getting from here to there: Model Evaluation Project



Recommendation 5-12: NOAA should embark on a Model Evaluation Project to assess model skill, identify strengths and limitations relevant to PMP estimation in current and future climate states, and achieve fitness for purpose, which is necessary for community confidence in models for estimating PMP.

Our vision

Model-based probabilistic estimates of extremely low exceedance probability precipitation depths under current and future climates will be attainable at space and time scales relevant for design and safety analysis of critical infrastructure within the next decade.

Challenges and opportunities

Achieving the Vision requires significant research and modeling advances, and collaboration between federal agencies, academia, and the private sector.

Undertaking this effort would benefit not just PMP but myriad applications in climate research.

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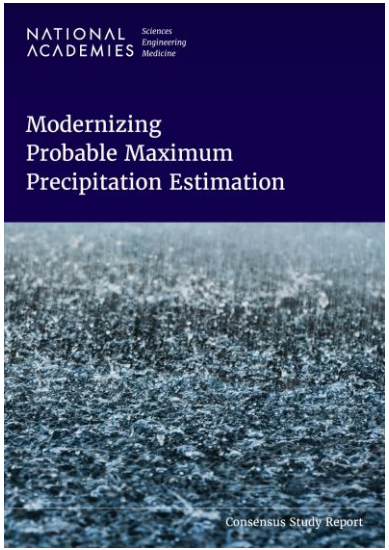

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