Annual Report by Work Group 2 on Uncertainty Analysis and Parameter Estimation

Tom Nicholson, U.S. Nuclear Regulatory Commission

Professor Mary Hill, University of Kansas

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October 21 - 22, 2014
U.S. Army Corps of Engineers, Baltimore, MD

Outline

- Work Group 2 (WG2) Objective and Goals
- Members and Participants
- Seminars at the WG2 Meetings
- Activities and Technical Projects
- Methodologies, Tools and Applications
- Forward Strategy
- Recommendations for FY2015

Work Group Objectives

- Coordinate ongoing and new research conducted by U.S. Federal agencies on:

  parameter estimation

  uncertainty assessment

  in support of environmental modeling & applications
- Focus on strategies and techniques
- Includes sensitivity analysis

What is needed to achieve this objective?

Coordination of research staff and their management thru efficient and targeted use of our limited resources.

Work Group Goals

- Basics:

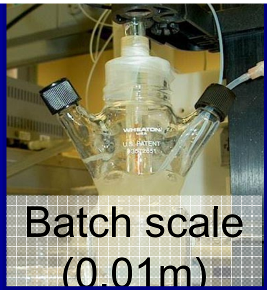
✓ Develop a creative, collaborative environment to advance

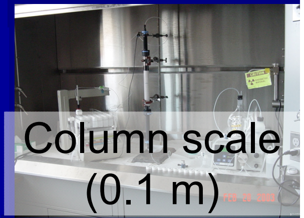
  - ➢ parameter estimation in the context of model development .
  - ➢ sources of uncertainty in the context of model predictions.

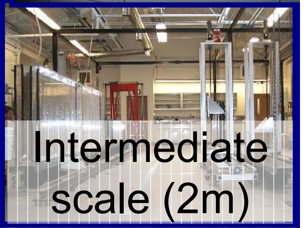
✓ Develop a common terminology.

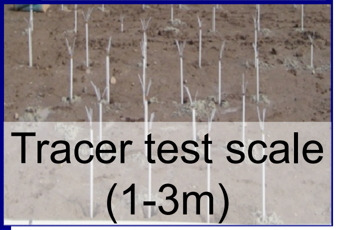
✓ Identify innovative applications.

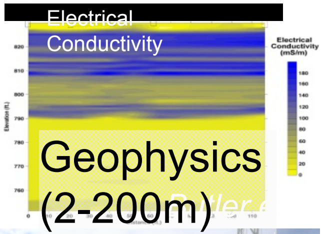
- Existing Tools: Identify, evaluate, and compare available analysis strategies, tools and software.
- New Tools: Develop, test, and apply new theories and methodologies.
- Exchange: Facilitate exchange of techniques and ideas thru teleconferences, technical workshops, professional meetings, interaction with other WGs and ISCMEM
- Communicate: Develop ways to better communicate uncertainty to decision makers (e.g., evaluation measures, visualization).

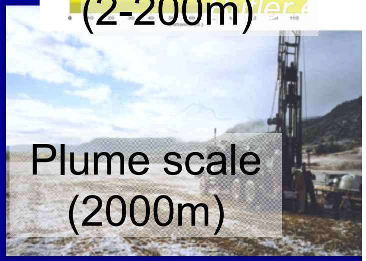








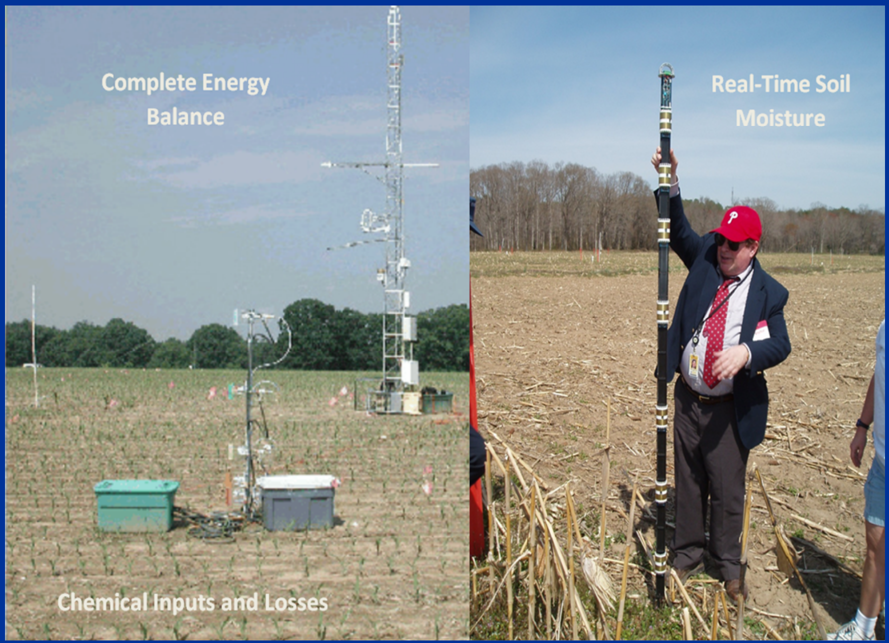




Members and Participants

from U.S. Federal agencies, universities, and industry

- Tom Nicholson, NRC, co-Chair
- Mary Hill, USGS, co-Chair
- Ming Ye, Florida State U
- Ming Zhu, DOE
- Gary Curtis, USGS
- Yakov Pachepsky, USDA-ARS



- Tom Purucker, EPA-Athens
- Brian Skahill, USACOE
- Matt Tonkin, SSPA
- Gene Whelan, EPA-Athens
- Steve Yabusaki, PNNL
- Sanja Perica, NOAA/NWS
- Larry Deschaine, HydroGeologic, Inc.
- Boris Faybishenko, LBNL
- Pierre Glynn, USGS
- Philip Meyer, PNNL
- Bill Cooper, NSF
- Debra Reinhart, NSF
- Bruce Hamilton, NSF

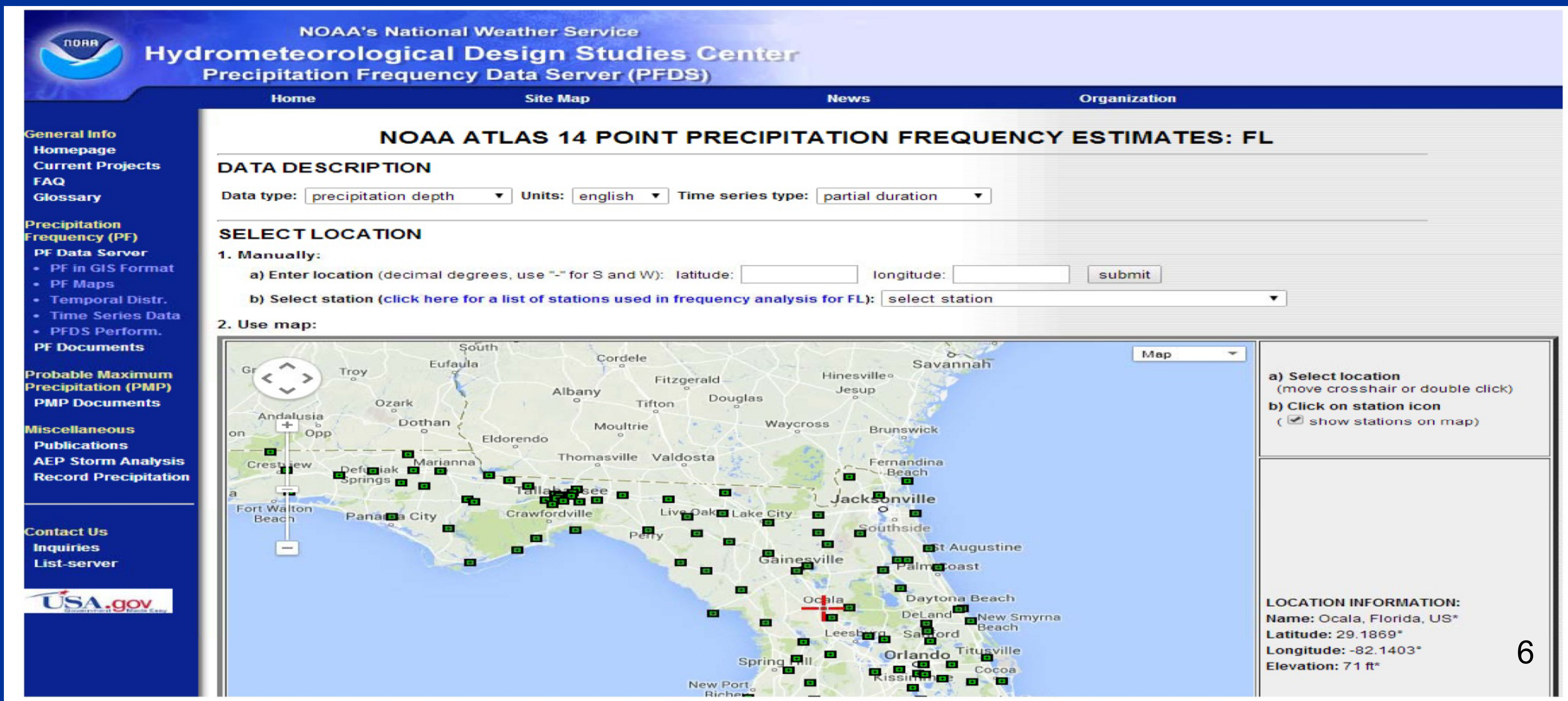
- You?

Activities: Seminars

We conduct seminars to:

- review and discuss ongoing research studies and software development
- formulate proposals for field applications

How to retrieve Precipitation Frequency estimates with confidence limits?



NOAA Atlas 14 Precipitation-Frequency Atlas of the United States

Parameter estimation and uncertainties in estimates

Sanja Perica, Ph.D.
Director of Hydrometeorological Design Studies Center (HDSC)/NWS/NOAA
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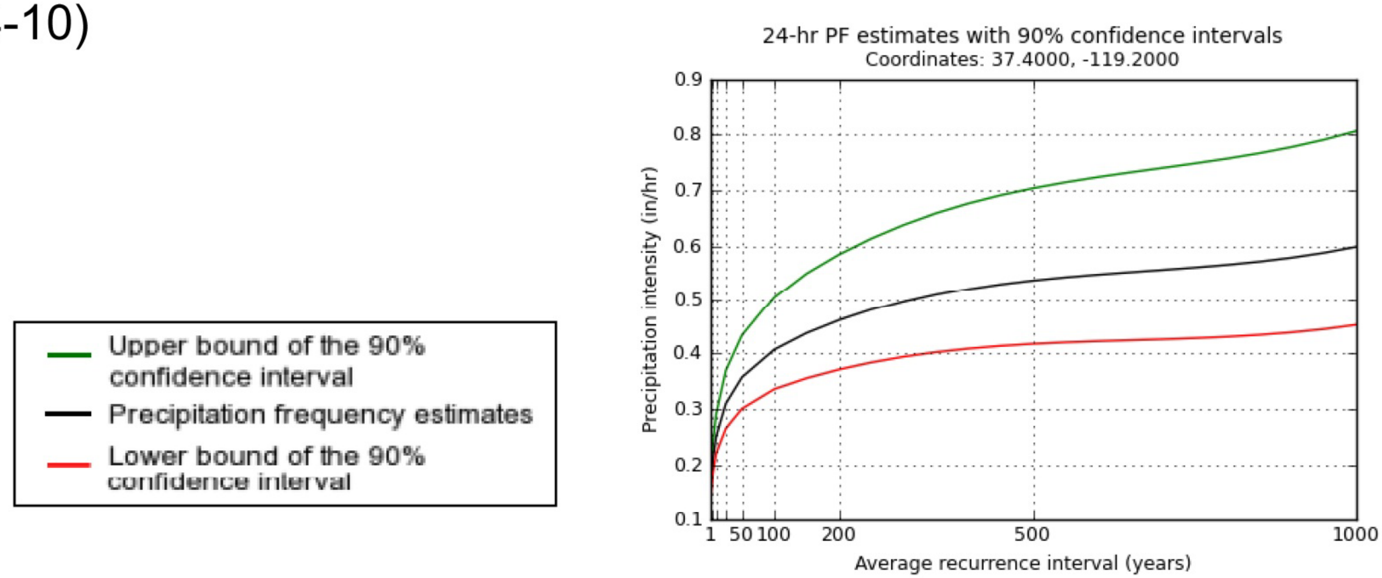
Phone: 301-713-0640 (161)
Web: www.nws.noaa.gov/oh/hdsc

Presentation for ISCMEM Work Group 2
2 October 2014

NOAA Atlas 14

Assessment of accuracy: confidence intervals

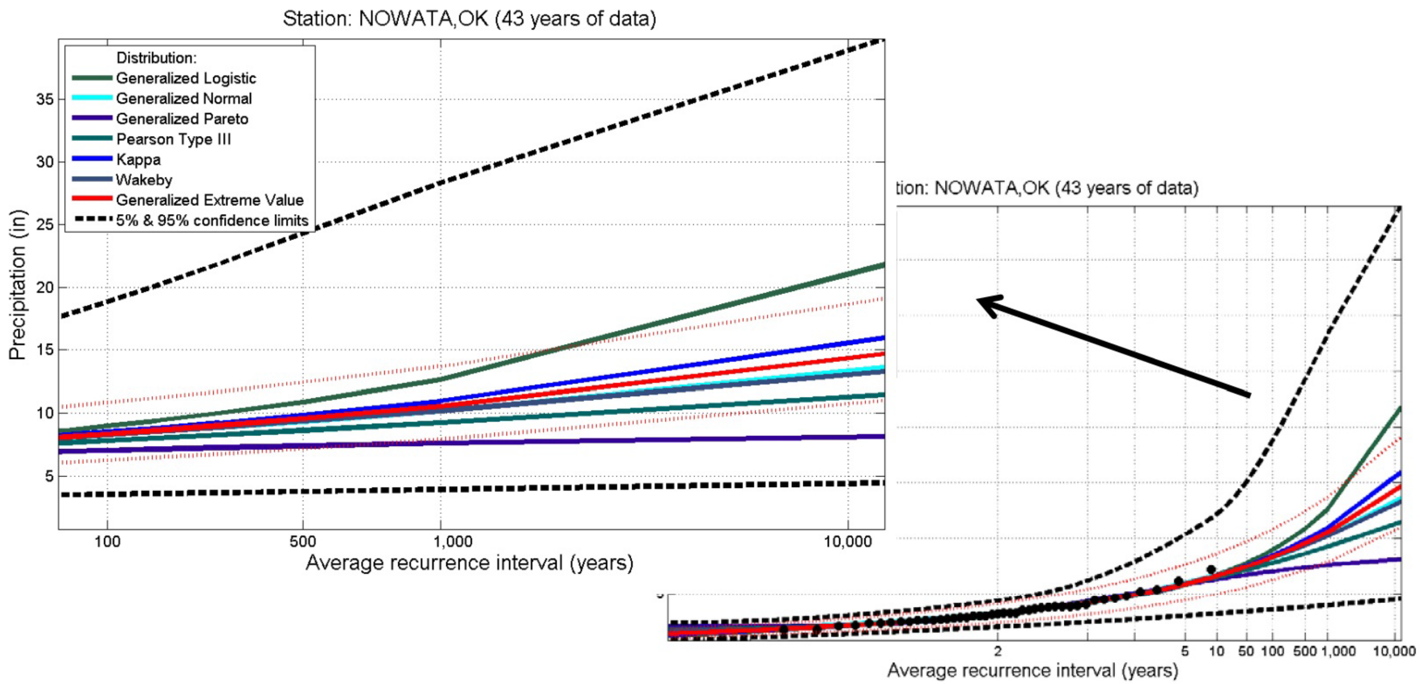
- ❑ Simulation used to construct 90% confidence intervals (i.e., 5% and 95% confidence limits) at stations.
- ❑ Confidence limits account for errors in sample moments
- ❑ Algorithm adjusted to account for inter-station correlation (Volumes 4-10)



NOAA ATLAS 14

- Confidence limits should account for all sources of uncertainty!

- Estimates affected by:
  - errors in sample moments
  - distribution selection (LP3, GEV, …)
  - parameterization method (MoM, L-mom, MLE)



NOAA Atlas 14

- Simulation used to construct 90% confidence intervals (i.e., 5% and 95% confidence limits) at stations.
- Algorithm adjusted to account for inter-station correlation.
- Estimates interpolated on 30 arc-sec grid.
- *Uncertainty analysis and sensitivity analyses are included in the simulation result analyses.*

Seminar at WG2 in FY2014

- NOAA Atlas Precipitation – Frequency Atlas of the U.S.: Parameter Estimation and Uncertainties in the Estimates by Sanja Perica, Director, Hydrometeorological Design Studies Center, Office of Hydrology, National Weather Service, NOAA.

Current NOAA/NWS Precipitation Frequency (PF) documents by State location at:
http://www.nws.noaa.gov/oh/hdsc/currentpf.htm

Access NOAA/NWS's Precipitation Frequency Data Server (PFDS) at:
http://hdsc.nws.noaa.gov/hdsc/pfds/index.html

Exploring how parameter importance to prediction changes in parameter space

Oldrich Rakovec, Wageningen Univ, UFZ
Mary C. Hill, USGS
Martyn P. Clark, NCAR

A.H. Weerts and R. Uijlenhoet, Wageningen Univ.
A. J. Teuling, Wageningen Univ and Deltares

Rakovec et al 2014 Water Resources Research
(+ some new plots)

Seminar at WG2 in FY2014

- Exploring How Parameter Importance to Predict Changes in Parameter Space by Professor Mary Hill, University of Kansas.

- Presents a novel hybrid local-global method that measures how model parameter importance is distributed as parameter values change.
- DELSA (Distributed Evaluation of Local Sensitivity Analysis) is demonstrated using rainfall-runoff models constricted using FUSE (Framework for Understanding Structural Errors).
- Results are compared to the Sobol's (Russian mathematician, I. M. Sobol) global sensitivity analysis method.
- Insights from DELSA can be combined with field data to identify the most relevant parts of parameter space to focus data collection and model development.

Sensitivity analysis

New DELSA. Compare to global SA methods

USGS-NCAR collaborative study with Mary Hill, USGS; Martyn Clark, NCAR; Olda Rakovec, U of Wageningen, and others from his university.

- Rakovec et al., 2014 WRR
- New DELSA multi-scale statistic (1,000 model runs)
  - DELSA: Distributed Evaluation of Local Sensitivity Analysis
- Compare to global variance-based Sobol' statistics (10,000 model runs)
- Rainfall-runoff problem
  - FUSE modular model (Clark et al., 2008, WRR)

New method: DELSA

- DELSA: Distributed Evaluation of Local Sensitivity Analysis.
  - Multiscale. Some similarity to Method of Morris, but goal is not one global measure
  - DELSA general. Here, local first-order stat: $|\partial\psi/\partial b_j|^2 \times (s_j^2/V_L(\psi))$
  - ~1,000 model runs
- Can be applied using any local statistic
  - To guide data collection, use statistics that identify observations important to simulated values (for calibration or prediction)

New method: DELSA

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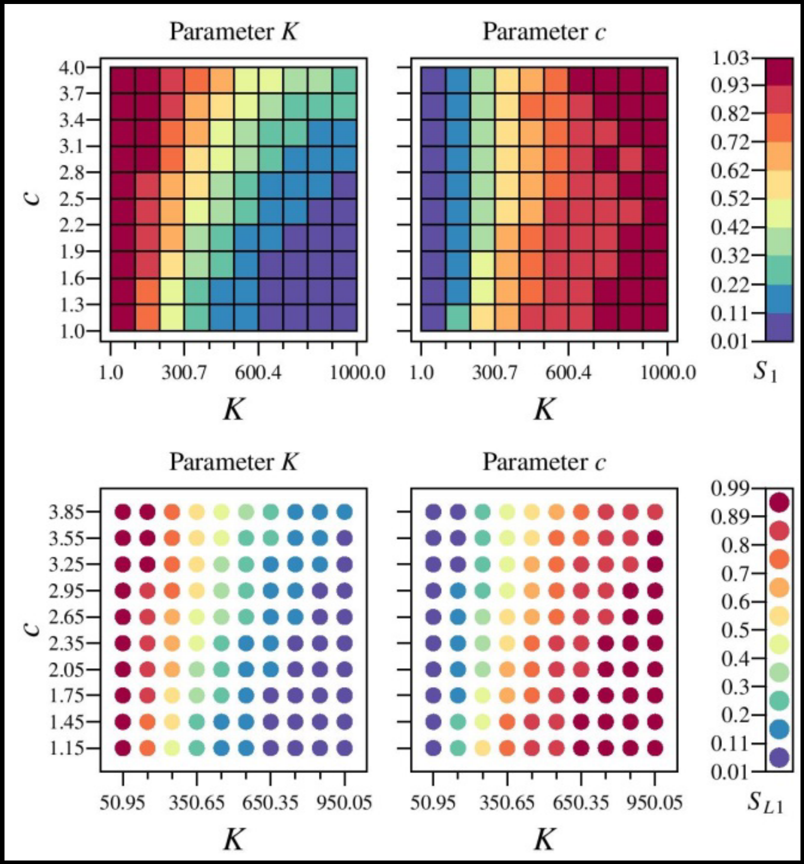
  - Multiscale. Some similarity to Method of Morris, but goal is not one global measure
  - DELSA general. Here, local first-order stat: $|\partial\psi/ \partial b_j|^2 \times (s_j^2/V_L(\psi))$
  - ~1,000 model runs
- Compare to global Sobol' statistics
  - ~10,000 model runs
- Initial tests with 2 parameters
  - Is our local first order stat identical to Sobol's under ideal conditions?

Sobol'

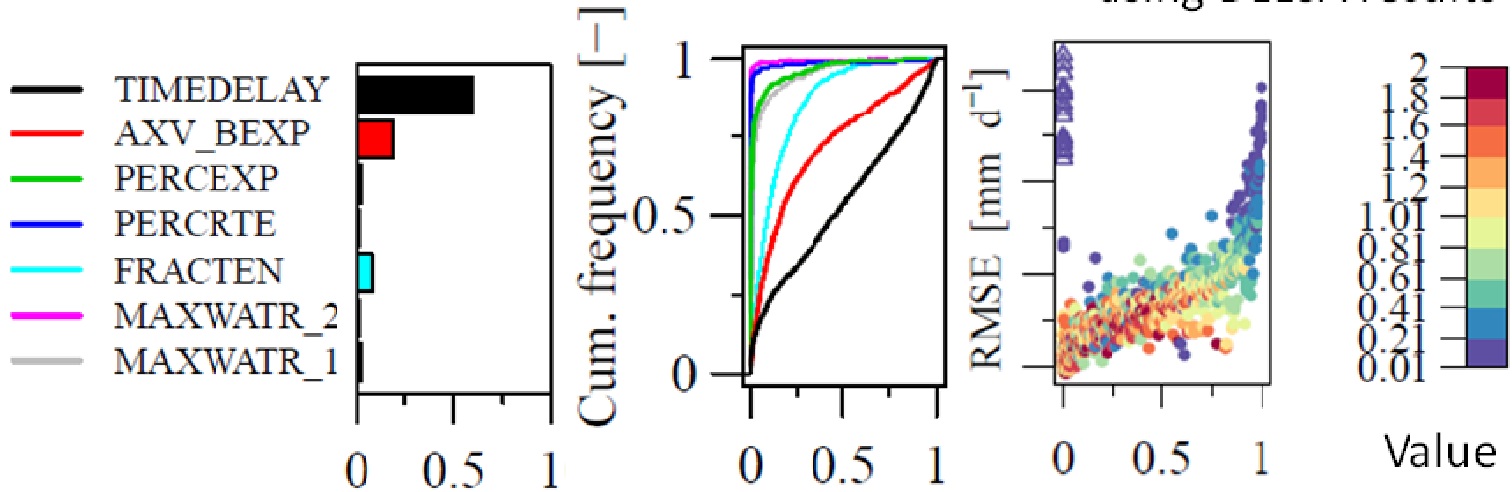
DELSA



- Reservoir storage $S(t)=S_{sc}(q(t)/\mathbf{K})^{1/c}$
  $\psi = \int S(t)dt$

Parameter importance to prediction changes in parameter space

Examine TIMEDELAY using DELSA results



Value of TIMEDELAY

DELSA for TIMEDELAY

Sobol' gives one value for each parameter, showing "average" importance over parameter space

DELSA gives a distribution of values that can be plotted against, for example, RMSE

TIMEDELAY is most important for poor fitting models and when the value of TIMEDELAY is very small. Come to the talk to find out why!

Sensitivity analysis

- Sensitivity analysis is a critical step in UQ
- Identify what is important. Here,
  – parameters important to ψ, a simulated value or a function of simulated values
  – If ψ is RMSE, identify parameters important to (and thus informed by) observations
- Look for surprises
- Surprises can indicate

  New understanding about reality

  or

  Model limitations or problems

Need sensitivity analysis tools that reveal surprises (like DELSA) instead of averaging them out (like Sobol')

- Computationally frugal, parallelizable methods enable routine evaluation

Selected New Features

- Evaluate Uncertainty with Markov-Chain Monte Carlo (MCMC)
  - Use for non-Gaussian distributions. Often this means nonlinearity produces local minima
- New stacked sensitivity graphs
  - Show parameter importance and contributions from different types of observations

Forward Strategy

Energize the science and technology thru closer linkage to decision making:

- better understand the methods being used in parameter estimation and uncertainty analyses
- *establish a base set of model sensitivity analysis and uncertainty evaluation measures, in addition to the other performance measures*
- use and compare different methods in practical situations

Recommendations for FY2015

- Expand multimedia scope and WG2 membership
- Assist development and creation of other working groups
  - Take advantage of the relevance of uncertainty and parameter estimation to all environmental modeling and monitoring fields.
  - Develop and conduct joint ISCMEM teleconferences
    - WG1 (Software System Design; design of uncertainty and parameter estimation software and data fusion)
    - WG3 (Reactive Transport Models and Monitoring; support decision making)
  - Act as an incubator to build support for new ideas
    - Proposed WG on monitoring based on the importance of monitoring to uncertainty and parameter estimation, and visa versa
- Sponsor technical workshops on endorsed studies
- ISCMEM Website
  - Develop a new Website to enhance Information Transfer of Technical Reports and Data Sources

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