Community Whitepaper on Uncertainty Quantification

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POS Panel Breakout Session on Uncertainty Quantification

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ESIP Information Quality Cluster

- Vision: "Become **internationally recognized** as an **authoritative and responsive information resource** for guiding the implementation of **data quality standards and best practices** of the science data systems, datasets, and data/metadata dissemination services."
- Information Quality = {Science Quality, Product Quality, Stewardship Quality, Service Quality}
- What do we do?
  - Share experiences; collaborate internationally; invited speakers at monthly telecons; sessions and/or presentations at AGU, AMS, ESIP, E2SIP, and OGC meetings
  - Maintain wiki site with many useful references http://wiki.esipfed.org/index.php/Information_Quality
- Publications
  - Peng, G. *et al.,* 2016: Scientific stewardship in the Open Data and Big Data era - Roles and responsibilities of stewards and other major product stakeholders. *D.-Lib Magazine,* **22** (5/6), doi: https://doi.org/10.1045/may2016-peng.
  - Ramapriyan, H K, Peng G, Moroni D, Shie C-L, Ensuring and Improving Information Quality for Earth Science Data and Products. *D-Lib Magazine*, **23** (7/8), July/August 2017, DOI: https://doi.org/10.1045/july2017-ramapriyan
  - Moroni, et al.(22 authors), "Understanding and Communicating Uncertainty in Earth Science Data Informatics", White Paper (in preparation)

Information Quality - Definition

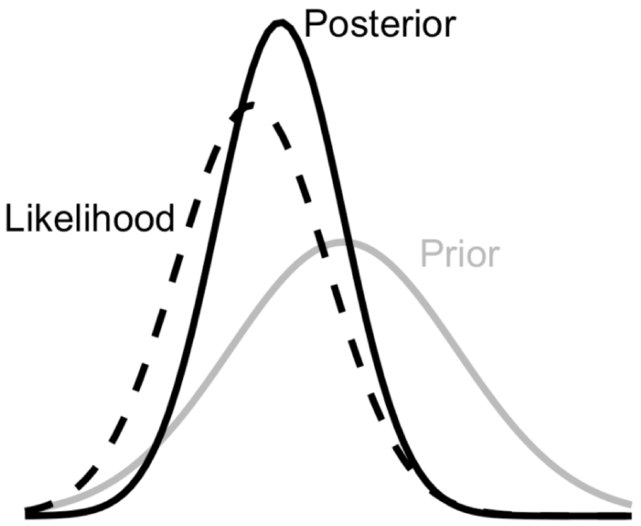
- Scientific quality
  - Accuracy, precision, uncertainty, validity and suitability for use (fitness for purpose) in various applications
- Product quality
  - How well the scientific quality is assessed and documented
  - Completeness of metadata and documentation, provenance and context, etc.
- Stewardship quality
  - How well data are being managed, preserved, and cared for by an archive or repository
- Service Quality
  - How easy it is for users to find, get, understand, trust, and use data
  - Whether archive has people who understand the data available to help users.

White Paper Scope

- Began as a pilot plenary/breakout session at the ESIP 2017 meeting, featuring invited researchers: Carol Anne Clayson (WHOI), Isla Simpson (NCAR), and Amy Braverman (JPL).
- Primary focus on “discovery” of the breadth of approaches with regard to Earth science data UQ, UC, and the dissemination/utilization of UQ/UC information by data providers and end users.
- Considers 4 perspectives: Mathematical, Programmatic, Observational, User.
- Will identify both commonalities and differences between perspectives.
- Authors and co-authors represent various aspects of Earth science data informatics, metrology, data science/statistics, remote sensing, in situ, and disciplinary fundamental research.
- Numerical modeling was considered for the sake of use case discussion, but was decided to be left out for the sake of focusing on approaches using observational data.

Mathematical

- Championed by Jonathan Hobbs - JPL
- Considered to be the foundational section of the paper, establishing the key mathematically-based definitions of uncertainty and related constructs such as UQ, UC, mean square error, PDFs, quantiles, confidence intervals, confidence levels, etc…
- Presents directly applicable use cases by which these mathematical definitions are applicable to observational Earth science data, primarily from a remote sensing perspective, but much of which utilizes consistent metrology for a variety of measurement types, including in situ and sub-orbital.



Schematic implementation of Bayes' theorem for a univariate QOI. The prior distribution is combined with information from an observation (via the likelihood) to produce a posterior distribution.

Programmatic

- Championed by Rama – SSAI/NASA GSFC.
- Captures the governmental and intergovernmental approaches, starting with specific US-based agencies and moving into the international arena.
- Considers US law that drives policy at key agencies, including but not limited to NASA and NOAA.
- Considers international agreements, such as by the U.N, IPCC, WMO, and CEOS.
- Considers multi-lateral agreements, statements and policies by EU-sponsored agencies/organizations, such as by: ESA, FIDUCEO, UncertWeb, and MetEOC.

Observational

- Championed by Justin Goldstein – NOAA.
- Discusses the foundational approaches to UQ and UC from an Earth observation perspective, including perspectives from both point-based studies, invariant in space but not in time (e.g., Eulerian Specifications), and those that conduct observations varying in *both* space and time (e.g., Lagrangian Specifications).
- Cal/Val: looks at UQ and UC approaches from a calibration and validation perspective and the role played by "ground truth" data.
- Product Development: examines a variety of approaches and considerations toward making uncertainty information available for common types of observational data products, with a focus on making this information available at the production stage of data.

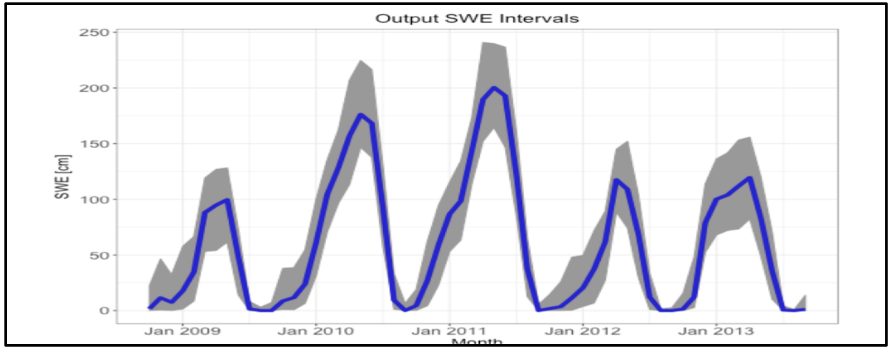


Figure: Snow water equivalent with uncertainty shaded with 95% confidence intervals. Blue line represents the point estimate. Hobbs et al. 2017, unpublished.

User

- Championed by Bob Downs – Columbia University.
- Focuses on the ways in which uncertainty information can be effectively or ineffectively consumed, interpreted and ultimately leveraged by the typical data user.
- Provides insights in to methods of communication, dissemination, visualization tools/services, and multi-variate analysis.
- Examples considered include: ISO-19157, UncertML, CO2SYS, and OGC's Testbed-12 innovation program (OGC, 2017).

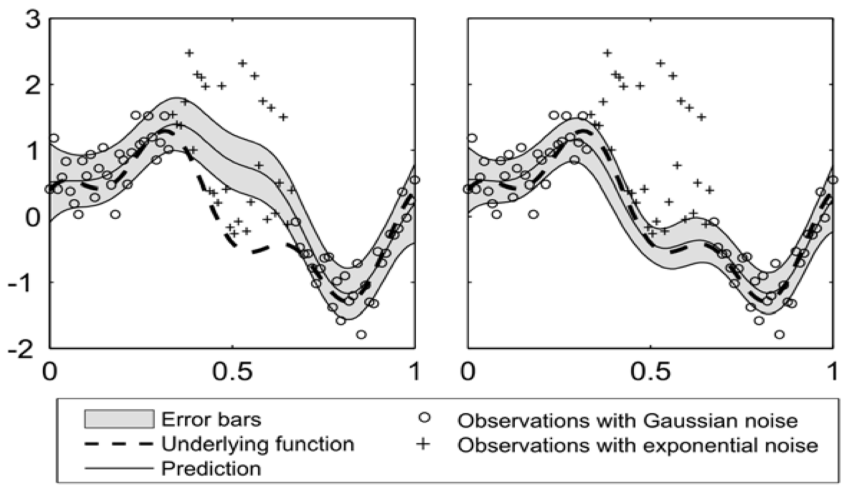


Figure: Applying UncertML to automated Bayesian interpolation algorithm. Left plot assumes Gaussian random error while right plot incorporates obs-specific error characteristics via UncertML encoding, improving the performance of interpolation. Williams et al. 2009.

Next Steps

- Complete by August:
  - Commonalities, differences, conclusions.
  - Re-write the introduction to better align with main sections.
  - Include more graphics/figures.
- Complete by September
  - Prep for white paper publication; consult with ESIP student fellow to apply improved styling and consistent references/citation styling adhering to AGU standard.
  - Publish on ESIP Figshare site.

Ideas beyond this publication…

- Draft and publish a shortened “executive summary” paper in a more prominent journal, such as Data Science or EOS.
- Draft a part-2 paper, focusing on recommendations and actionable solutions.

Authorship Acknowledgements (19)

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