Co-Robotic Systems for GeoSciences Field Research

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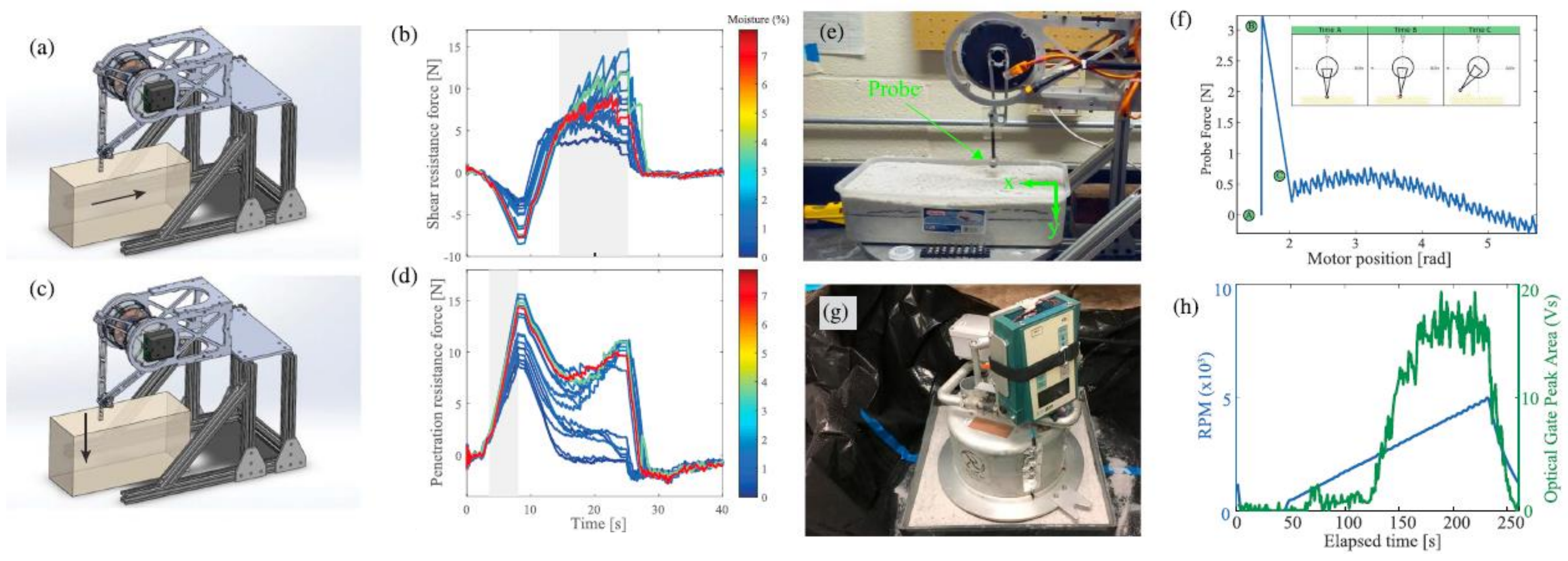
Goal of this project is to integrate environmental science, robotics, and cognitive science to enable heterogeneous teams of autonomous robots to flexibly support the daily agenda of geoscientists in their field experiments. Environmental sciences research concerning desertification and sediment loss present urgent social value. Due to the high spatial and temporal variability of the driving and resistive forces during sediment transport, novel high-resolution and event-driven data sets are required to enhance existing and new empirical and theoretical models of such dynamic processes. Legged robots have demonstrated great potential for using legs as embodied sensors to provide such novel datasets, while the imperative for useful, autonomous mobile manipulation in unstructured, broken and unstable natural terrains drives fundamental advances in the theory and practice of robotics. In the meantime, growing insight from cognitive science concerning human spatiotemporal reasoning urges its engagement in a new frontier of real-time, perceptually mediated decisions epitomized by scientifically motivated outdoor field research on the motion of waters, winds and sands.

Co-Robot for Environmental Science: Understanding the world by making every step an experiment

We develop novel geoscientific instrumentation embodied in robots' legs, and deploy the robots at White Sands, NM, Oceano, CA, and Wissahickon, PA to characterize the mechanical properties of soil that determine its resistance to erosion and transport by overland flow and creep. Such information is critical in understanding sediment loss to wind and rivers, and provides insights on soil stability in landslides and desertification processes.

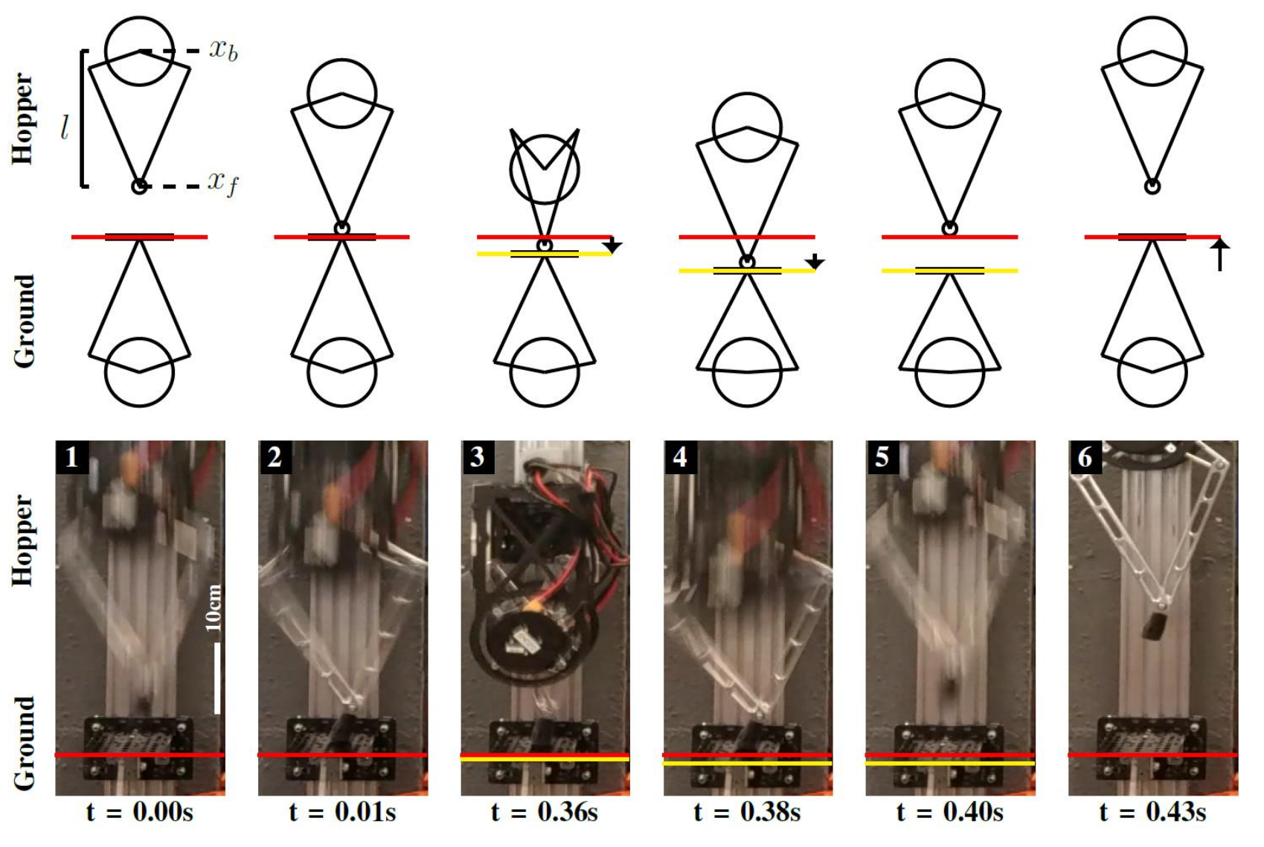
Integrating proprioceptive sensing information to understand environment properties



- Soil responses depend sensitively on dominant environmental controls as well as robotic leg interaction-based inquiry protocols.
- We combine lab and field experiments to design sensing strategies and analyzing protocols to effectively identify and isolate environmental controls.

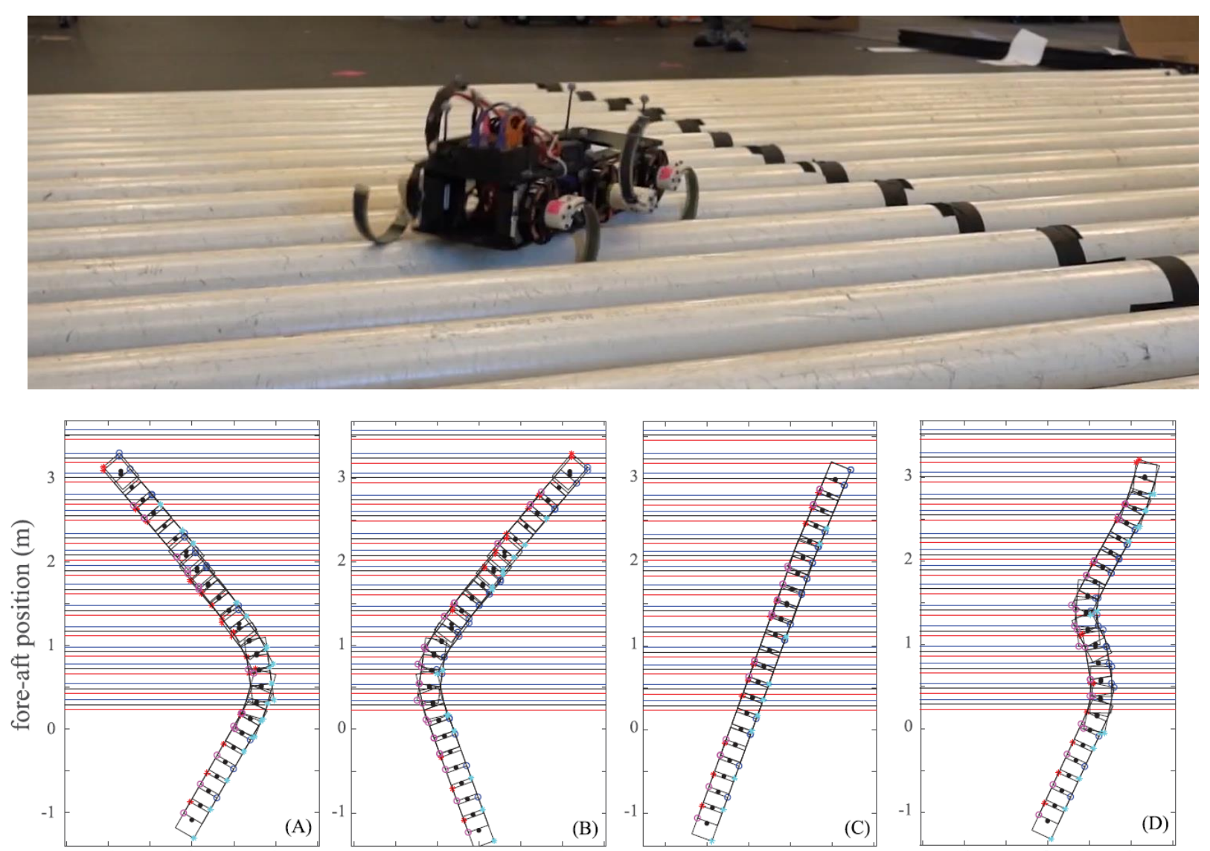
Qian, Lee, Nikolich, Koditschek, and Jerolmack., *Journal of Geophysical Research: Earth Surface* 2019

Exploiting environment responses to improve mobility on unstructured and unstable natural terrains



Significant energy savings in dynamic hopping with active damping controller

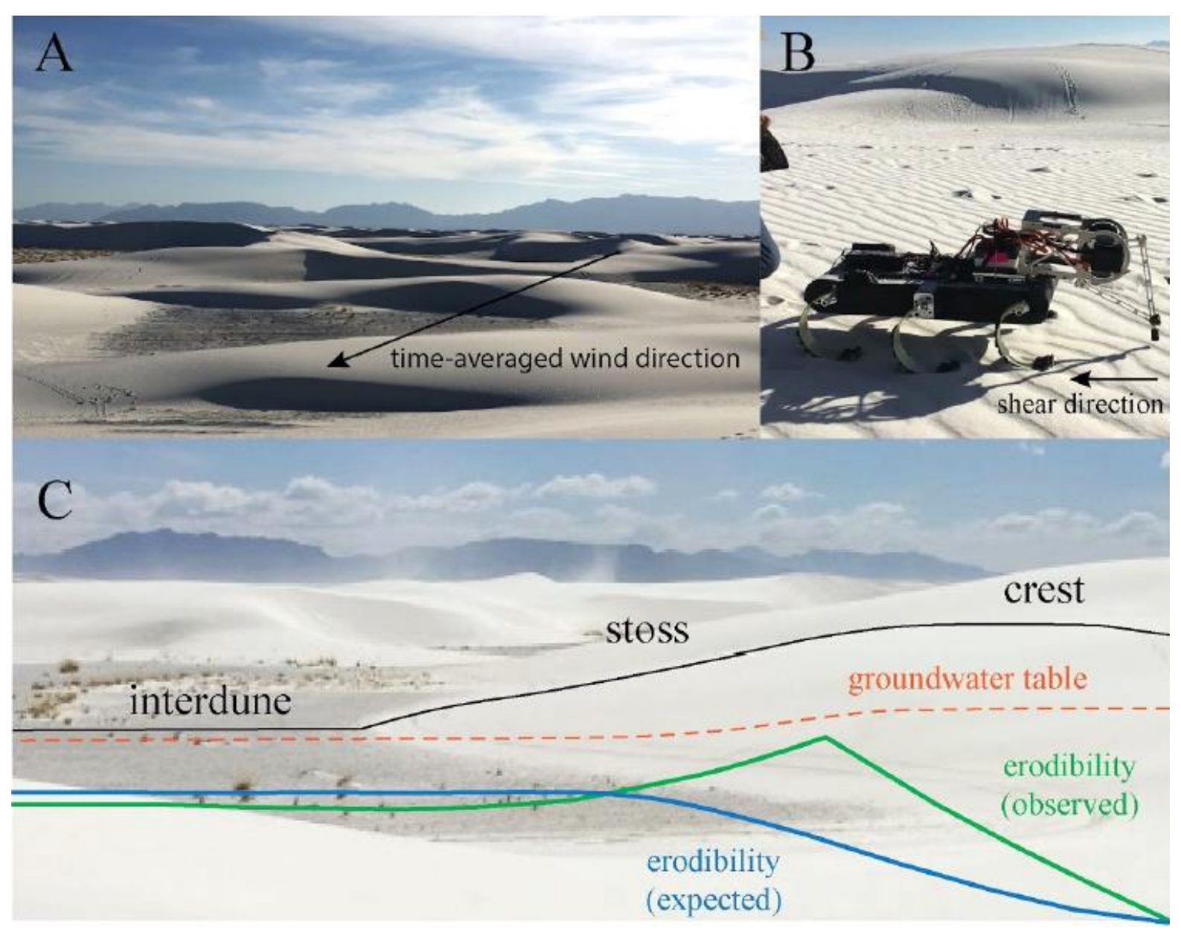
Roberts and Koditschek, *IEEE ROBIO, 2018*
Roberts and Koditschek, *ICRA 2019*

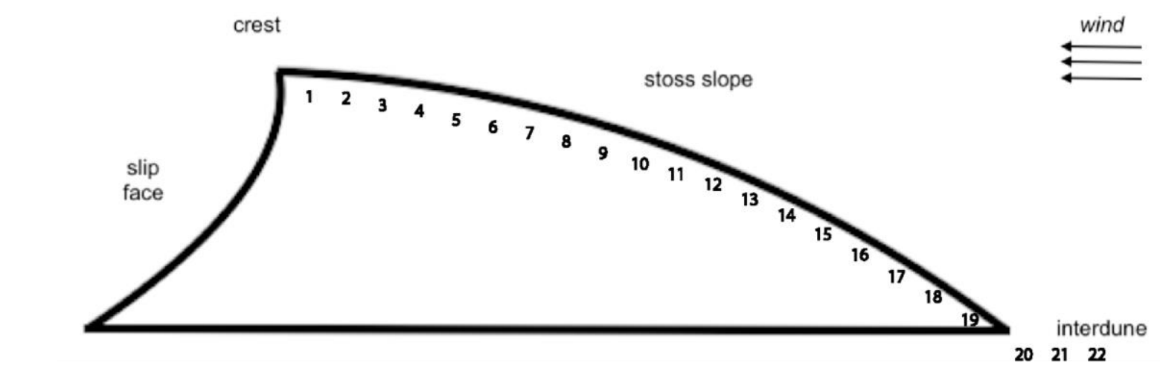


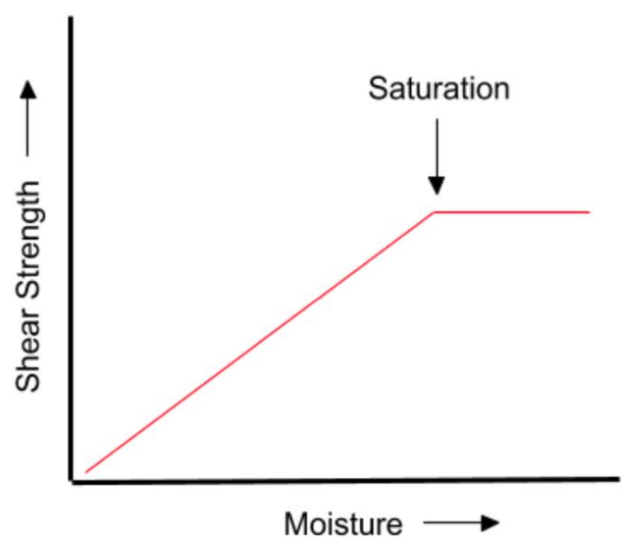
Robustly navigating in cluttered environments by selecting the desired obstacle collisions

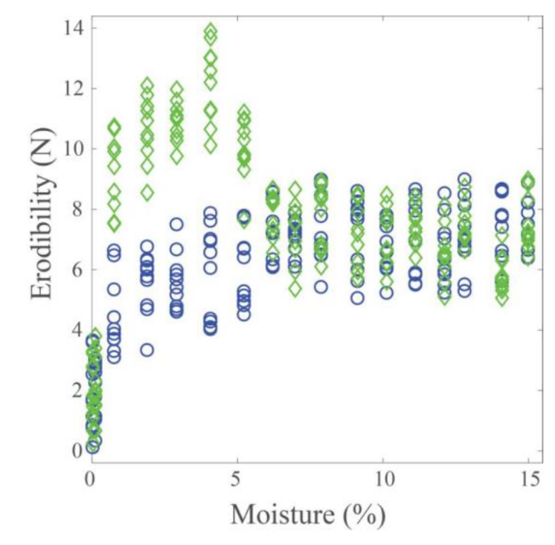
Ramesh, Kathail, Koditschek, and Qian, *IEEE RA-L 2020*
Qian and Koditschek, *IJRR* (in revision)

Co-Robot for Decision Science: Optimizing data foraging by deciphering human decision-making









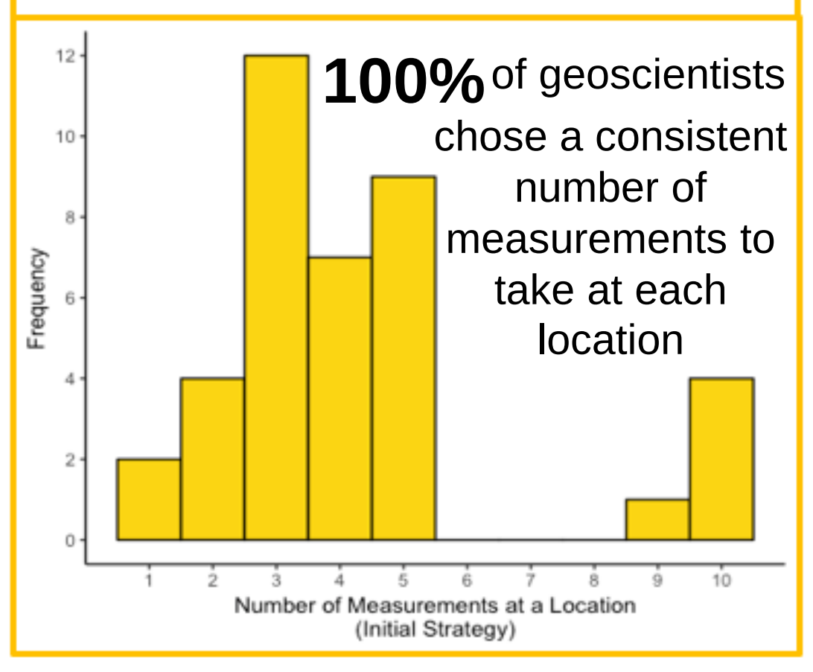
How do experts make decisions on where to collect data?

EQUAL SPACING HEURISTIC

85% of geoscientists chose locations at roughly equal intervals

***defined as average interval discrepancy less than .08*

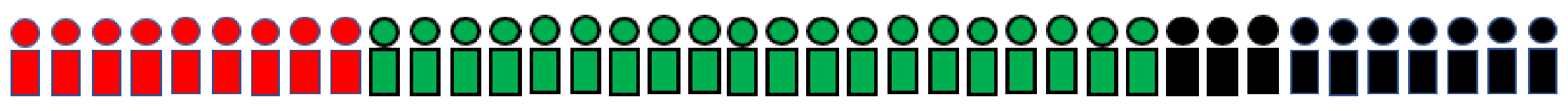
MAGIC NUMBER HEURISTIC



100% of geoscientists chose a consistent number of measurements to take at each location

Experiences or biases?

In absence of in-situ measurement feedback:
Strong heuristic-based
-- equal spacing heuristic
-- magic number heuristic



NO ADJUSTMENT

23% of geoscientists did not alter their initial data collection strategy at all

ADJUSTED STRATEGY

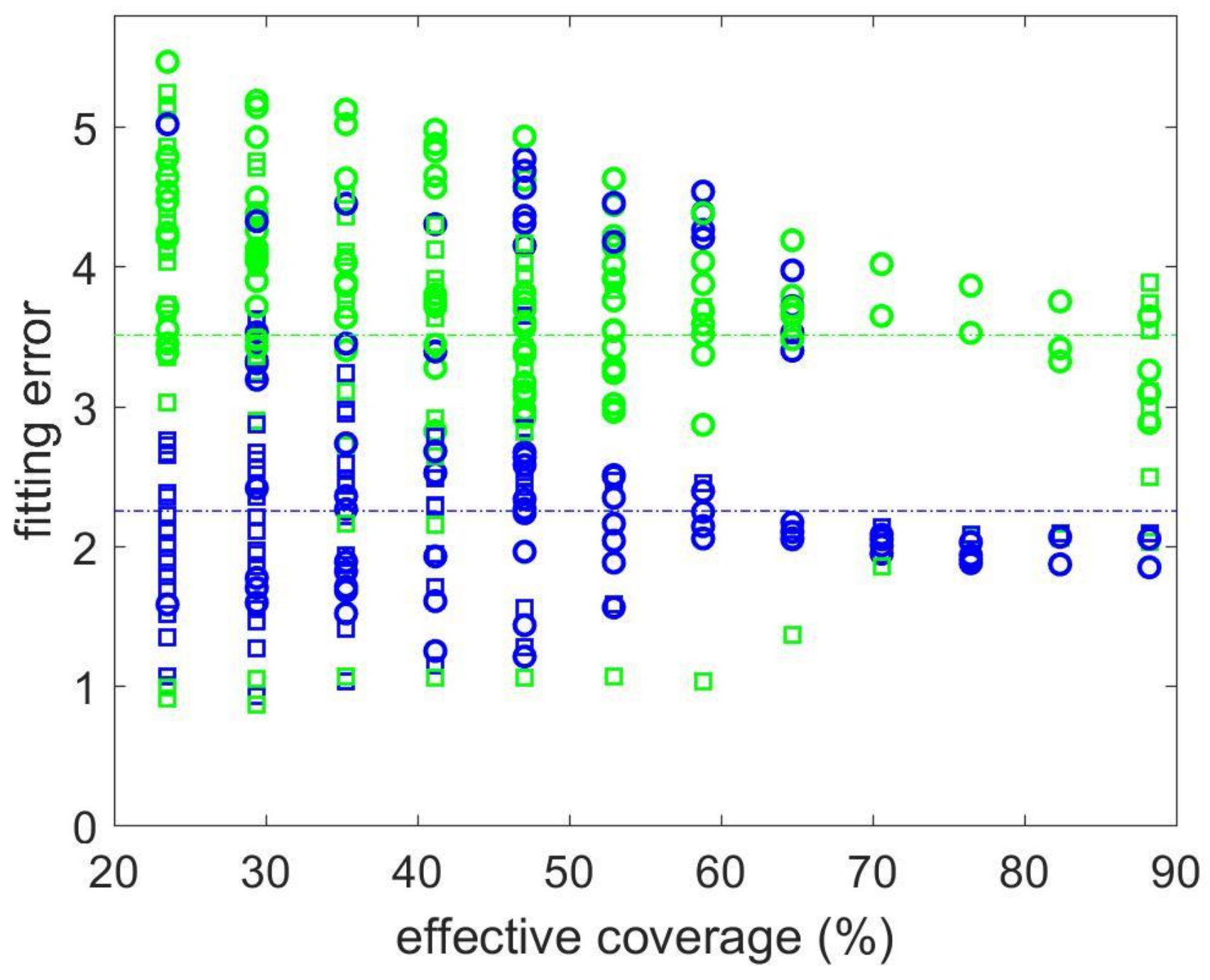
77% of geoscientists who adjusted waited until their initial strategy was complete before collecting more data

67% of geoscientists who adjusted kept using the same magic number

Uncertainty and conflict?

In response to incoming data that are noisy or are potentially unsupportive of hypothesis, how do experts adapt sampling strategies?

From reduced vulnerability to decision biases to human-level intelligence in hypothesis-based reasoning



Human-machine co-decision making to optimize data foraging?

- Robots provide statistical feedback (e.g., effective coverage, fitting error) to reduce heuristic anchoring biases
- Understanding the cognitive underpinning of adaptive data collection decisions (e.g., hypothesis testing vs. exploration) to better support human scientific agenda

Wilson, Qian, Jerolmack, Shipley, Roberts, Ham, and Koditschek, *QJEP* (in review)

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