

International Workshop held on The Role of Information Theory in the Earth Sciences

Uwe Ehret¹, Hoshin Gupta², Grey Nearing³, Ben Ruddell⁴, Florian Wellman⁵, Rohini Kumar⁶, Steven Weijs⁷, Beth Jackson⁸ and Gab Abramowitz⁹
(Workshop Organizers)

There is a growing understanding that “*information*” is both a fundamental aspect of the *nature and workings* of reality, and also of our *understanding* of reality (Knuth, 2010, 2004). This realization has driven a resurgence of interest in the topic of Information Theory (IT) and its implementation in the Earth and Environmental Sciences (EES). Because IT analyses are essentially general in nature, they can be applied to all aspects of the scientific endeavor -- complex systems (Tononi, 2011), models of those systems (Nearing and Gupta, 2015), observational data (Dacu et al., 1998), and the synthesis of all of these (MacKay, 2003). Being rooted firmly in mathematics and statistical theory, IT provides a compelling basis for expanding upon methods that make simplifying assumptions such as linearity and Gaussianity to address problems of inference. Because of this, IT has the potential to facilitate enhanced understanding of the emergent behaviors of complex Earth Systems in ways that traditional analyses cannot (Ruddell, Brunsell, and Stoy, 2013). Additionally, IT enables the study of any and all parts of a system (real or modeled) under a common dynamical framework, so that minimal priori assumptions need be made to understand the relationships between large numbers of diverse dynamical processes



Fig 2: Views from the conference room
es (Ruddell and Kumar, 2009).

During the last week of April 2016 (24-27), an international group of 29 Earth Scientists convened at the beautiful “Schneefernerhaus” research center (<http://www.schneefernerhaus.de/en/home.html>) at the summit of the *Zugspitze*, the highest place in Germany, to discuss the growing role of *Information Theoretic* concepts in scientific investigations related to EES. The remote location provided the perfect opportunity for lengthy discussions, and also for an energetic and hard-fought *foosball/kicker* tournament that was, perhaps not unexpectedly, won by members of the German contingent.

The impetus to convene this workshop arose out of a series of recent AGU and EGU sessions titled “*On the Interface between Models and Data*”, and “*Data & Models, Induction & Prediction, Information & Uncertainty: Towards a Common Framework for Model Building and Predictions in the Geosciences*”, and the goal was to promote the innovative use of IT concepts in service of discovery, modeling and decision-making in EES. Designed around a



Fig 1: Ascent to the Schneefernerhaus

¹KIT Karlsruhe Institute Of Technology, ²University of Arizona, ³NASA Goddard, ⁴Arizona State University, ⁵RWTH Aachen, ⁶Helmholtz Center for Environmental Research – UFZ, ⁷University of British Columbia, ⁸Victoria University Wellington, ⁹University of New South Wales

small number of targeted presentations, most of the workshop was devoted to moderated discussion and brainstorming, with a view to inspiring revolutionary advances in the theories of modeling/learning, inference, and diagnostic evaluation. Each participant also brought along a poster and gave a brief “*Speed Presentation*” on their current research ideas. The major topics of discussion were: What is IT and why should we care?, How can IT be used to inform the core questions in the Earth Sciences?, and How can IT help us understand the interface between models and data?

- The information content in *Data* (G Nearing), *Models* (W Gong), and *Networks* (B Ruddell)
- IT and the *Hydrological Sciences* (H Gupta), *Eco-Hydrological Modeling* (P Kumar and A Goodwell) and the use of *Entropy-based Metrics* to evaluate physical models (B Jackson)
- Applications of the *Maximum Entropy Approach* to EES modeling (J Wang)

Apart from the inspiring exchange of concepts and ideas, outcomes of the workshop included a jointly composed draft of a paper making the argument for why Earth System Scientists should embrace the Information Paradigm in their modeling, field work, and conceptualization of uncertainty. A follow-up workshop is in preparation.

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Fig 3: The foosball/kicker tournament

The targeted presentations used to stimulate the discussions included talks about:

- The relationships between IT and Physics (K Knuth), *Uncertainty* (M Branicki), and *Complexity* (S Weijs)



Fig 4: Workshop participants