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Probing the Earth's core dynamics through geomagnetic observations and dynamo simulations

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The geodynamo is a complex nonlinear system taking place at the Earth's core, which can be solely observed through its magnetic field at and above the Earth's surface. Although direct observations of the surface geomagnetic field are only available through the past four centuries, indirect observations from the remanent magnetization of human artifacts and rocks can provide insights on the magnetic field over much longer time scales. These observations are often affected by errors due to either difficulties in separating the different geomagnetic field sources, or considerable experimental and dating errors. Retrieving information on all of the core dynamics, for instance the deep core liquid iron flow, from such noisy surface magnetic field observations is, therefore, a challenging dynamic inverse problem. This ill-posedness calls for robust prior information, which can be supplied by dynamo simulations and combined through data assimilation methods. Although data assimilation is commonly applied for atmospheric and ocean dynamics, its application to geomagnetism remains exploratory. One of the great challenges lies on the description of the prior model covariance, which is responsible for bringing information from the surface to the deep hidden dynamo fields. In this talk, we will show how the correlations in the dynamo models and its dynamics can be best used for probing the core interior from surface observations using an ensemble Kalman Filter approach. Within synthetic experiments, we explore how instabilities inherent from the ensemble method can be circumvented, and assess the resolution of the dynamo fields given the different available observations. Lastly, we will discuss the possibility of jointly assimilating geo and paleomagnetic databases in order to improve our understanding of the core dynamics over different time scales.