Block Versus Continuum Descriptions of Continental Deformation: For Heaven's Sake, How are We Ever Going to Decide Which is Better?

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After decades of research and partisan debate there is still no agreement on how best to describe the widespread deformation occurring in central Asia and elsewhere on the continents. Two alternative end-member models have been proposed. At one extreme, in analogy with the global tectonic model of rigid plates, it has been suggested that actively deforming regions are composed of blocks or microplates. Most deformation then occurs along major block-bounding faults, with minor faulting but little internal deformation of the blocks themselves. At the opposite extreme, continental deformation is viewed as quasi-continuous, governed by the fluid-like, solid-state flow of a viscous material. In this view, discrete slip in the brittle upper crust occurs on many faults with roughly equivalent slip rates. Global positioning system (GPS) and interferometric synthetic aperture radar (InSAR) data may ultimately be decisive in distinguishing between block and continuum models, at least for describing present-day deformation, but thus far there is no consensus. In this paper I discuss a possible resolution to this debate that focuses on the practical utility of both approaches rather than a decision about which is intrinsically "better."

First, it is generally agreed that at least upper-crustal deformation is discontinuous, occurs largely on faults, and is often block-like. There is also no disagreement that determining the sense and magnitude of fault slip is useful for characterizing active tectonic deformation and assessing earthquake hazard. The block/continuum debate then turns on whether the kinematics can be usefully described by a relatively small number of blocks or whether many are required. If slip rates on all active faults were well determined, upper-crustal kinematics would be known. The issue is then a practical one: how accurately can fault slip rates be determined in any region of interest? GPS data and continental block kinematics offer several advantages in providing useful constraints of fault slip rates. First, if the relative motions of the blocks can be constrained by data, the slip rates on block-bounding faults are specified, including any along-strike changes in rate and in the partitioning between fault-parallel and fault-normal motions. Second, the description is simple and feasible if only a small number of blocks are required to characterize any region of interest. And thirdly, the block modelling formalism permits inclusion of other Earth science constraints such as geologically determined, late Quaternary and Holocene slip rates and style of deformation, InSAR fault slip rate estimates, earthquake slip vectors, and current motions of major bounding plates. Block kinematics has several practical limitations. First, the description is cumbersome if many blocks are needed to match data. Second, even when GPS stations are densely distributed, block models cannot distinguish slip rates on closely spaced faults, and/or where blocks are small (characteristic dimension of ~50 km or less). However, good independent geologic slip-rate estimates will alleviate or resolve this indeterminacy (for example, the sub-parallel strike-slip faults of the San Andreas System in northern and southern California and the Marlborough faults of northern South Island, New Zealand). A kinematic description in terms of a spatially variable strain-rate field may well be preferable where many active faults occur, where numerous blocks are required, or where data constraints are limited. Candidate regions I believe currently fulfil these criteria include the southern California Transverse Ranges, western Anatolia, and southern Tibet. It is noteworthy that probabilistic seismic hazard assessment (PSHA) methodologies can be equally applied using either fault slip rates or locally averaged estimates of surface strain rate.

In many parts of central Asia it is hard to be sure how many blocks are needed to describe surface kinematics because of the incomplete and inhomogeneous distribution of existing GPS sites. This shortcoming is likely to be largely overcome during the next decade or so by new networks, especially in central and western Tibet, and by InSAR imagery from the new generation of radar satellites scheduled for launch between 2012 and 2017.

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