“Coupling” Semantics and Science in Earthquake Research

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"Coupling" Semantics and Science in Earthquake Research

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Coupling is a convenient word that describes a wide variety of interactions or feedback processes, including those that we do not fully understand. Examples in Earth science include ocean-atmosphere coupling, climate-tectonics coupling, and core-mantle coupling. The word is also very popular in discussions of plate boundary earthquake processes.

As a vague expression, fault coupling is a perfectly adequate term, describing some kind of mechanical interaction between rocks of each side of a fault. For those of us who try to infer fault processes from geodetic measurements, coupling usually indicates a state of no or low current slip. If a fault is fully locked, we may say it is "coupled" or "fully coupled." If a plate boundary fault is slipping at the long-term plate convergence rate, we may say it is "decoupled." Fault segments that are slipping more slowly than the plate convergence rate are then "partially" coupled. To avoid awkward expressions such as "negatively" or "overly" coupled, an equivalent description has been used in the literature; that is, to define a "coupling ratio" with values ranging from negative to greater than unity. For describing kinematics, these expressions would not be wrong. However, with one additional step, our usage of the word coupling can lead to confusion. That step is to describe a fault that is not slipping as "strongly coupled.

"Strong" and "weak" describe forces of interaction. Very often, when an author says "strongly coupled," the intention is to emphasize that the fault is "not slipping at all," purely kinematical description. However, the sense of the discussion has now moved from pure kinematics to include the concepts of stress or fault properties. At this point, relations between the current fault slip rate and properties like fault zone material, pore fluid pressure, long-term upper-plate deformation, etc., may be inferred, possibly incorrectly. "Strongly coupled faults" have been used to infer a strong (high-friction coefficient) fault zone, large shear stress, low pore fluid pressure, high rates of long-term upper-plate deformation, and other interesting things.

Whether or how fast a fault is currently slipping depends on many factors. If we put a book on a level table, the book does not move because nothing drives it. It has nothing to do with whether the book is strongly or weakly attached to the table. Similarly, a fault segment may not be slipping simply because surrounding segments are also not slipping, regardless of fault frictional properties. In other words, the kinematics of the fault may tell us nothing directly about its frictional properties. Additional information is required.

Fault kinematics, frictional properties, and state of stress are three distinct and important concepts. A term like coupling, which has been used to describe all three, can lead to confusion if it is not carefully defined.

The confusion of concepts and terminology sometimes carries over into our thinking about fault zone processes and how we model our data, as shown by the following example.

In a typical two-dimensional application of the elastic dislocation model (Savage, 1983), one segment of the fault is assigned a zero slip rate and is called the locked zone. Beyond a certain depth, the fault is assumed to be slipping at the plate convergence rate. By subtracting steady state plate motion, the locked part becomes a zone of "back-slip" at the plate convergence rate, and the deeper full-slip part (no strain accumulation) becomes a zone of no backslip.

In terms of mechanical coupling, one may argue that the most up-dip segment of the fault may be very weak [e.g., Byrne et al., 1988] due to high fluid content and soft sediment. In a number of publications, this segment is then assigned a zero back-slip rate, implying that it is slipping at the plate convergence rate (Figure 1a). Thus, a condition of weak mechanical coupling (stress and frictional properties) has been used to define a slip rate (kinematics).

As in our book-on-the-table example, the frictional conditions and lack of mechanical coupling do not give us any information on the kinematics. It seems to us just as likely (perhaps more likely) that if its immediate down-dip neighbor is not slipping, this upper segment is also stuck no slip rate at all) no matter how weak it is. If not slipping, it probably belongs to the locked (full back-slip rate) zone in the dislocation model (Figure 1b).

Obtaining a slipping up-dip segment using an inversion method is not significant, because land geodetic data usually have little resolving power for the slip rate of an up-dip fault segment. The point is, slipping at the plate convergence rate, as often modeled, is unlikely to be sustained over the entire interseismic period. Occasionally, interseismic deformation models show small parts of the nominally seismogenic part of the fault slipping at high rate between fully locked segments. Depending on their size, these segments also likely represent transient features.

Another "coupling" confusion is to associate interplate earthquakes with force interaction between converging plates. The classical plate-
coupling concept, with Chile and Mariana as end members, is about force interaction. If the subducting plate provides a harder push on the upper plate, because of a larger contact area or other reasons, the coupling is said to be stronger. In contrast, "seismic coupling factor," the seismic fraction of total plate convergence in a given time period, addresses the predominant mode of fault motion: seismic or aseismic, a purely kinematical concept. If all of the convergence takes place as earthquake fault slip, then the seismic coupling factor is one.

A high seismic coupling factor does not necessarily mean stronger force interaction or plate coupling. For example, the seismic coupling factor is high in the southwestern Japan subduction zone, but low in the northeastern Japan subduction zone, [Kamamori and Astiz, 1985]. However, the degree of force interaction as reflected by upper-plate stresses is the other way around [Wang and Suyehiro, 1999]. "Seismic coupling" (without the word "factor") has never had a clear definition, but has been frequently, and possibly incorrectly, used to imply stress conditions and fault properties.

It is interesting to note that what is considered "coupled" by one community may be considered "decoupled" by another. For those who study subduction zone earthquakes, "coupling" occurs at the shallow, seismicogenic part of the plate interface, as described above. However, this part of the plate interface is called the zone of decoupling by those who model viscous flow and heat transfer in the subduction zone mantle wedge [Furukawa, 1993]. The latter community "coupling" occurs at greater depths; that is, where the fault is considered decoupled by the former community. What the mantle-wedge community means by "coupling" is that the mantle wedge material in contact with the subducting slab flows continuously at the same velocity as the slab. Clearly, use of the term "coupling" has not led to increased understanding between these communities.

Scientists usually do not dwell on semantics for good reasons (we have more important things to do). But when words become so confusing that we no longer understand each other, and when loose use of language leads to conceptual confusion and possibly incorrect analyses, it is time to pause and clarify. For example, if "slipping more slowly than plate convergence" is sufficiently clear, do we really need to confuse ourselves by saying "weakly coupled"?

Table 1, shortened from Wang et al. [2003], gives some suggested usage.

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References


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It stated "[Sauvons la Recherche] called... for a 'significant increase' in the number of full-time, permanent positions available to young researchers in the 2004 recruiting season."

In fact, no "increase" per se was requested by SLR. Originally, 550 permanent positions were planned for recruitment in public research institutes in 2004; in numbers (but not in contents), they would be equal to retirements. To reduce the number of public employees, the current government transformed these positions into temporary ones. SLR asked for these positions to be reinstated as permanent to ensure continuity of expertise in the labs. This also extended to the renewal of thousands of university positions.

Facing widespread dissatisfaction and the dramatic results in the recent regional elections in favor of the main opposition party, the government agreed to open the 550 positions in public research institutes and 300 in universities to recruitment in 2004 (700 more in 2005). Please note also that these positions are opened internationally.

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**LETTERS**

French Research

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The article "Review of French Research Enterprise Underway in Light of Mass Resignations" (6 April, pp. 134–135) calls for a clarification.