Temporal pattern in afterslip and mechanical relaxation of rocks

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Temporal pattern in afterslip associated with interplate earthquakes is generally studied using the models based on the constitutive law for friction or creep behavior of rocks. In contrast, we investigate the temporal pattern using simple equations (power- or exponential-law having few parameters). Analyzing the time-series in afterslip (cumulative displacement) calculated from the seismic moments of small repeating earthquakes in the northeast Japan subduction zone, the temporal pattern is expressed by a temporal power-law. This power-law relation is a special case of the constitutive law for mechanical relaxation (viscoelastic behavior) of rocks. This constitutive law is obtained from the non-equilibrium thermodynamics with internal state variables (i.e. state variables on irreversible processes such as brittle or ductile damage evolution and chemical processes) and described by the relaxation modulus decaying with a power-law of deformation time. This temporal power-law appears as a collective dynamics of internal states having the respective relaxation times in various time-scales. The exponent of the temporal power-law is identical to the reciprocal of the exponent of the flow law of rocks, so the constitutive law can represent not only steady-state behavior of rocks but also transient behaviors in response to sudden changes in stress and strain-rate by the difference in the exponent. Based on the backgrounds of the constitutive law, we suggest that the temporal power-law pattern of afterslip is a summation of lots of transient responses associated with various sizes of seismic events.