MEETING

Understanding Slow Slip, Tremor, and Quakes

Aseismic Slip, Tremor, and Earthquakes Workshop; Sidney, British Columbia, Canada, 25–28 February 2008

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The frequent occurrence and importance of slow slip and tremor have only recently become apparent, owing largely to advances in seismic and geodetic monitoring. At some plate boundaries, slow slip relaxes a significant fraction of accumulated tectonic stress. The radiation of seismic waves as tremor, which often accompanies the geodetically detected slow slip, arises from underlying physical processes that are poorly understood but appear to differ from those governing earthquake-generated waves.

To further understanding of aseismic slip, tremor, and earthquakes, more than 52 participants contributed to a workshop with the goals of improving research coordination, assessing the earthquake hazard implications, and identifying ways to capitalize on the education and outreach opportunities these phenomena present.

Several potentially significant relationships among slow slip, tremor, and earthquakes emerged at this workshop. Slow slip and tremor appear to delineate the downdip limit of the locked zone, as indicated by megathrust rupture models in Japan and Alaska. Analyses of both steady plate motion and slow slip events from New Zealand map the locked portions of the subduction interface with unprecedented resolution. In the Cascade Mountains, slow slip and tremor appear anticorrelated with crustal earthquakes, while in Hawaii and New Zealand slow slip is not accompanied by tremor but instead by increased seismicity rates. These variations within and between regions provide clues about the properties of faults in different environments, including those capable of producing damaging earthquakes.

A consensus also emerged at the workshop that low effective stress prevails where tremor and slow slip occur. Passing surface waves and tidal forces can modulate tremor, and thermal and petrologic models and tomographic images indicate the presence of fluids in tremor and slow slip source regions. Theoretical frictional models require low effective stress to simulate slow slip observations. Frictional models that incorporate high fluid pressures and dilatant strengthening may explain the unique amplitude-duration scaling of slow slip.

The practical implications of any direct causal relationship between slow slip, tremor, and damaging earthquakes remain unclear. While slow slip events transfer stress to the base of the locked zone, thereby raising conditional weekly probabilities, the latter are still below thresholds that might motivate societal action. No observations to date confirm that large earthquakes can be triggered by slow slip.

Nonetheless, the possibility of causal connections warrants discussions between the research community and emergency managers, as well as planning across agency and geographic boundaries. The frequency and regular recurrence of some slow slip and tremor also present the opportunity to share the excitement and enthusiasm that come with anticipated discovery, particularly in Cascadia, where pronounced episodes occur somewhere in the region approximately every 3 months.

Conference attendees focused their recommendations for future studies and instrumentation deployment on areas where they expect great earthquakes and on broadening the range of tectonic environments examined for slow slip and tremor. This will entail improved monitoring of major fault zones globally, with continuous recording of seismic and geodetic data.

The workshop was sponsored by the U.S. Geological Survey, the U.S. National Science Foundation's Earthscope Program and University NAVSTAR Consortium (UNAVCO), and the Geological Survey of Canada. Abstracts, presentations, and other workshop information are posted at http://www.earthscope.org/science/cascadia.

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BOOK REVIEW

Lagrangian Analysis and Prediction of Coastal Ocean Dynamics

Annalisa Griffa, A. D. Kirwan Jr., Arthur J. Mariano, Tamay Özgökmen, and H. Thomas Rossby, Editors
Cambridge University Press; 2007; 500 pp.; ISBN 978-0-521-87018-4; $170.

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The basic governing equations of geophysical fluid dynamics have been known for many years, but how meaningful these equations are to our understanding of coastal and open oceans depends crucially on the accuracy of constitutive equations that relate the internal and external forces acting on these bodies of water. Field measurements, whether Eulerian or Lagrangian, have played and continue to play a central role in two important aspects of geophysical fluid dynamics. First, the data collected often point to the presence of various stable and coherent structures, eddies, or streams, whose study naturally becomes the focus of analytical and computational efforts. Second, the availability of good data serves to calibrate how the response of bodies of water to forces should be modeled. This book provides a substantial collection of well-written articles on how Lagrangian data are collected, analyzed, and eventually assimilated into models.

The book consists of 13 chapters written by more than 40 contributors with backgrounds in physical oceanography, biology, and mathematics, and with expertise in experimentation, theory, and computation. The majority of the contributors have been working closely together since the initial Lagrangian Analysis and Prediction of Coastal Ocean Dynamics (LAPCOD) meeting, held in October 2000 in Ischia, Italy. Some of the chapters are reviews by LAPCOD researchers providing comprehensive summaries of their efforts in the past 10 or so years. Other chapters include techni-