SECULAR TRENDS IN POLAR MOTIONS: A NEW TOOL FOR PROBING THE VISCOSITY OF THE LOWER MANTLE.

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Abstract: Transient flow in the mantle, induced by glacial cycles, produce small but discernible variations in the Earth's rotational wobble and in the length of the day. These geophysical observables, which arise solely as a consequence of strain fields endowed with low order spherical harmonics ($\ell = 0$ and $\ell = 2$), can be useful in distinguishing the viscosity structure of the lower mantle, potentially more so than inferences drawn from relative sea level and gravity anomaly data, whose spectral contents are dominated by much higher angular orders ($\ell \geq 6$). Results from dynamical calculations, which are constraint to fit both the speed of recent polar wander and the non-tidal acceleration of the Earth's rotation rate, suggest that some amount of shrinkage of the Antarctic ice sheet since the late Wisconsin has occurred and that disintegration of Arctic marine ice sheets in the past may be a distinct possibility.

Keywords: Mantle viscosity, ice ages, polar wandering.

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The subject of mantle viscosity is both vast and one in which there is at present a great deal of research activity. Indeed it is one in which there have been recently published a number of authoritative works /1-3/ many times the length of this article. Any attempt, therefore, at a comprehensive and devoted coverage would be so superficial as to make it valueless to researchers outside the field.

Hence, we intend to devote this paper to a general discussion of the recent resurgence in the usage of small irregularities in the Earth's rotation to provide new and important insights into the rheological state of the Earth's mantle. We begin by discussing some of the limitations encountered by the more traditional means of measuring the viscosity of the lower mantle, an important parameter in the theory of mantle convection. In the second section of the paper several topics of current interest, concerning rotational dynamics and mantle rheology are selected for discussion in more detail.

Finally, it should be emphasized that no inversion of the geophysical observations to provide a rigorously defensible rheological structure for the mantle exists. The external observations provide a series of tests which must be satisfied by a family of rheological models which are to be seriously entertained. However, much of the uncertainties in the determination of the rheological properties of the mantle may be due to the history of glacial forcings, which must be interpreted in the light of other climatological and geological evidences as well.

The phenomenon of postglacial rebound was first recognized in the form of rising shorelines around the Baltic. Using a purely viscous, half-space model, Haskell /4/ found the viscosity of the mantle to be about 9x10^{21} P. Since then the relative sea level data, which measures the time-dependent history of the surface displacement from deglaciation, have been the chief source of information with which theoretical models can be compared. Following this approach, Cathles /1/ and Peltier and Andrews /5/ on the basis of a self-consistent spherical model found that the viscosity of the mantle to be relatively uniform, again very close to 10^{22} P. Recently Wu and Peltier /6/ have employed the free air gravity anomaly data from the Laurentide region in conjunction with the relative sea level data to constrain better the lower mantle viscosity. They found that a modest increase of