Earth Rotation: Insights into Global Change and Climate Variations

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Highly accurate observations of Earth rotation provide a unique and truly global measure of natural and man-made changes in the atmosphere, oceans, and interior of the Earth. The principle of conservation of angular momentum requires that changes in the Earth's rotation must be manifestations either of (a) torques acting on the solid Earth, or (b) changes in the mass distribution within the solid Earth, which alter its moment of inertia. Torques arise from angular momentum transfer between the solid Earth and the fluid regions (the underlying metallic core and the overlying hydrosphere and atmosphere) with which it is in contact. Changes in the inertia tensor of the solid Earth are brought about by interfacial stresses and the gravitational attractions associated with astronomical objects and mass redistributions in the fluid regions of the Earth, and also by processes that redistribute the material of the solid Earth, such as earthquakes, postglacial rebound, and mantle convection. Geodetic observations of Earth rotation changes provide insights into these geophysical processes, which are often difficult to obtain by other means.

These changes occur over a broad spectrum of time scales indicating a wide variety of geophysical and astronomical processes. Earth rotation variations over time scales of a few years to days are dominated by atmospheric effects with a strong seasonal cycle and significant variability on intraseasonal time scales. Studies have linked interannual LOD variations to the El Niño/Southern Oscillation (ENSO) phenomenon through correlation studies with the widely used Southern Oscillation Index (SOI). High correlation is observed from 1930 to present indicating that LOD can be used as a proxy index for interannual variations in global wind systems after 1930. The bimodal nature of the ENSO phenomena as seen in both LOD and SOI allows new insights in the ENSO phenomenon.

On longer time scales, climate models used to study the effects of atmospheric greenhouse gases predict an overall increase in the global temperature over the next century of from 1 to 4 degrees centigrade. An increase of this magnitude could have numerous catastrophic effects, including a global rise in sea level due to a combination of melting polar ice caps and continental glaciers, and the thermal expansion of sea water. The global rate of sea level rise during the last century is at the 1-2 mm/year level. The Earth's shape and its moment of inertia are modified by the mass redistribution of these ice sheet volumes into ocean basins and by the associated rebound of the Earth's crust and mantle, which results in Earth rotation changes by conservation of angular momentum.

Global atmospheric temperature fields are anticipated to change nonuniformly with respect to geographical location and atmospheric height, and thus will change the pole-to-equator temperature gradient. By the thermal wind equation, the wind-driven axial atmospheric angular momentum (AAM) will be modified, which in turn results in length-of-day (LOD) changes by angular momentum conservation. Analyses of seasonal LOD variations indicate, significant correlation with the Southern Oscillation Index and trends suggestive of long-term global changes. Initial studies suggest seasonal LOD variations may provide a new phenomenon and index to investigate the effect of climate change.

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