See page 292 for additional Business Staff

EDITORIAL

Large Scale Measurements

Fundamental astrophysical and geophysical processes such as expansion of the universe and global climate change operate at large scales. Direct measurements have been difficult; therefore, understanding has primarily come from studies at small scales and from consideration of many local observations. For example, the record of global climate change has been built up from analysis of many local climate records and studies of many microscopic grains in meteorites have provided information on the evolution and age of the solar system. Although measurements over large space and thus time scales have long been fundamental to astronomy, observations of distant objects and of many interactions have been limited by available resolution.

New technologies that permit accurate measurements over great spatial scales or detection of faint objects and interactions are now allowing direct study of large scale dynamics. Many of the advances are related to the use of satellites for terrestrial observations and new telescopes for astronomical observations. In this issue of *Science* we survey some of these advances and the impact they are having on our understanding of the fundamental processes.

In the late 1920s, Edwin Hubble discovered that the universe is expanding; the largest large scale measurements in astronomy are designed to determine its age and size. Both characteristics are expressed in the eponymous Hubble constant, which relates a galaxy's velocity away from us to its distance. As Huchra explains, the value of this essential constant is controversial, in part because measurements are difficult and the uncertainties are great. The related issue of the so-called "cosmological" constant, which appears in Einstein's gravitational model of the universe and which may explain some of the more curious measurements, is discussed in a news story by Finkbeiner.

Gravitational waves are ripples in space-time generated when massive objects such as black holes interact. Abramovici *et al.* describe the planned Laser Interferometric Gravitational-Wave Observatory (LIGO), which will detect the perturbations of suspended mirrors as gravitational waves pass by. The laser beams, marked by unprecedented stability and purity, will travel a distance of 4 kilometers between mirrors arranged in an "L." Successful detection of gravitational waves by LIGO will shed light on the nature of black holes, dense stellar matter, and the quantum properties of gravity itself. Optical interferometry is also being used to measure sizes and positions of astrophysical objects with great accuracy, as described in a news story by Bartusiak.

Space geodesy, which includes very long baseline radio interferometry, satellite laser ranging, and the global positioning system, provides a means of accurately measuring the separation of distant points on Earth's surface; relative displacements can be resolved after a few years. The data can thus be used to test and extend theories of plate interactions that are based on geologic estimates of rates operating over thousands to millions of years and on many small scale studies of rocks and earthquakes. Gordon and Stein describe these applications and focus in particular on the study of plate boundaries where deformation extends over hundreds to thousands of kilometers. Space geodesy is also finding other applications in oceanography, atmospheric sciences, and geophysics; in a news story Kerr describes a proposed application to study variations in Earth's upper atmosphere.

Satellite measurements are now providing the means to monitor a wide variety of changes of Earth's atmosphere on a global scale. Of particular concern are changes in stratospheric ozone levels and the possibility that the depletions observed in springtime in the Antarctic may have parallels at other latitudes. Stolarski *et al.* review evidence for changes in ozone levels obtained through 1991 from both satellite and ground-based measurements. Ground-based measurements, although concentrated in the Northern Hemisphere, are still critical in the evaluation as they provide the only evidence for changes occurring before 1978 (one record extends from 1926) and are necessary for calibrating the satellite data. Together, the data reveal a long-term decline in stratospheric ozone levels over the mid-latitudes and that most of the change has taken place in the lower stratosphere.

As illustrated by all of these articles, recent and planned technologies are providing means to make large scale measurements and test and extend many of the theories and records derived from small scale observations. The next generation of telescopes, detectors, and satellites should reveal even more about nature at the largest scales.

Brooks Hanson and **David Voss**