series. The hypothesis of a single complex solar variation not only offers a testable cosmogenic isotope production and climatic forcing but may provide a guide to the parameterization of more computationally complex coupled ocean-atmosphere general circulation models.

THE PHYSICS AND ASTROPHYSICS OF COSMIC-RAY VARIATIONS

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Cosmic rays striking the Earth are observed to vary on a wide variety of time scales. Variations over periods up to several tens of years are primarily caused by the Sun and its varying activity. Variations over larger time scales are, at least in part, due to the same causes, although geomagnetic variations also play a significant role. Extra-solar-system processes such as supernova explosions may play a role at the largest time scales.

The physical processes underlying the variations caused by the Sun and the interstellar medium, and their observational support, will be discussed.

CONSTRAINING THE INITIATION AND EVOLUTION OF ANOXIA IN THE BLACK SEA BY AMS RADIOCARBON DATING

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The Black Sea is the only extant, relatively large ocean basin containing substantial volumes of anaerobic deep waters. Bottom sediments collected from the deeper portions of this basin exhibit a lithological succession, from banded organic-poor lutites to finely laminated sapropelic muds to laminated organic-rich coccolith marls. This basin is an important natural laboratory for understanding the formation mechanisms of black shales, so widely distributed in the geological record. Despite numerous geological and chemical studies, there still remains considerable uncertainty about the temporal and chemical evolution of the deep anoxic waters and its imprint on the bottom sediments preserved in this basin. Central to this uncertainty has been the lack of a well-constrained chronology.

Early attempts at deriving a chronology for these sediments were based on a limited number of beta-decay radiocarbon analyses. Later chronological studies using varve counting showed that the radiocarbon ages appeared older by several thousand years. Some argue that the radiocarbon chronology is anomalously old due to input of detrital carbon and carbonates; others assert that each varve is an annual couplet, consisting of a lithogenic dark laminae deposited in late winter/spring, and a biogenic light laminae deposited in summer/fall. However, a varve is not produced every year due to a much reduced biogenic flux in some years, thus making age determinations by varve counting anomalously young.

In an attempt to further constrain this controversy, we have obtained 100 AMS radiocarbon analyses on both organic carbon and carbonates preserved in Black Sea sediments collected in 1988 from throughout this basin and along a 200–2200 m depth transect. Results from seven cores show that the age of the Unit II/I boundary, which defines the transition from sapropelic muds to varved sediments, is AMS radiocarbon dated at 3100 BP in both the organic carbon and carbonate fractions. This closely agrees with the older ^{14}C ages and differs from the varve chronology by

some 2000 years. The age of the Unit III/II transition, which defines the transition from lacustrine to marine conditions, is dated in nine cores at 7350 BP in the organic carbon fraction, and 14,000 BP in the carbonate fraction. The organic carbon dates agree closely with the earlier ages and disagree with the varve chronology by some 2000 years. Most important, we see no change in the age of this boundary with water depth, as has been observed with varve counting, and as has been assumed in many models of the temporal development of anoxia in this basin. This result suggests the varve record is incomplete due to sedimentological processes, and that models of anoxia development need to be rethought.

MEASUREMENT OF COSMOGENIC ^{14}C PRODUCED BY SPALLATION IN TERRESTRIAL ROCKS AND IN METEORITES

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The production of radioisotopes at the earth's surface by cosmic-ray effects has been discussed for many years. Only in the past few years, with more sensitivity for the radioisotopes by accelerator mass spectrometry (AMS), detection of ^{10}Be, ^{26}Al and ^{36}Cl produced in this way have been measured by several groups. We report here on our efforts to measure cosmogenic ^{14}C in terrestrial rocks at high altitude, and comparisons to other exposure-dating methods.

The production of ^{14}C by cosmic-ray spallation effects in extraterrestrial samples, such as meteorites is well known. The amount of ^{14}C left in a meteorite can be used to determine its terrestrial residence time at the earth's surface. In this paper, we will discuss measurements of spallogenic ^{14}C in small meteorite samples from Antarctica, and the significance of the ages calculated. These ages allow us to place limits on infall rate of meteorites, and movement of the meteorites in ice.

A MINIVIAL FOR SMALL SAMPLE ^{14}C DATING

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A 0.3 ml teflon minivial has been designed for ^{14}C dating of small samples in a liquid scintillation counter. A special adaptor of standard vial size is used to optimize the position of the vial with respect to the phototubes and to intercept the light path between them, thus reducing optical cross-talk.

Better performance can be achieved by using customized vials than by diluting small samples for counting in large vials. Counting efficiencies up to 80% have been achieved in 0.3 ml vials typically with 0.05 cpm background.

We discuss the application of the minivial design criteria to other materials and demonstrate the power of electronic background reduction devices.