happens during a reversal? Geologically speaking, the field takes very little time to reverse, 1 to 10 kyr as generally inferred from sedimentary records, and the various rock magnetic recorders are imperfect. Thus, paleomagnetic records are always incomplete and give only lower bounds on how rapidly changing and complex the behavior of the reversing field may have been. What we know with greatest certainty is that the field intensity is much reduced during a reversal, usually falling as low as 10-20% of the average value it had during full polarity. In most other regards, reversal records exhibit great variety. The intensity decrease may lead or accompany the departure of direction from full polarity, and its recovery may accompany or lag reestablishment of full polarity. Although the change in field direction might be relatively simple and progressive during some reversals, several of the highest resolution records suggest complex behavior with episodes of rapid directional oscillations. It seems reasonable that the boundary conditions imposed by the lowermost mantle on the core could confer some regularity on the transitional field morphology, but whether they do and to what degree is debated. The transitional field is almost certainly much more multipolar in character than is the full polarity field, but the equatorial dipole may nonetheless exert considerable influence on directional systematics at the earth's surface during some reversals. Prominent non-dipole field features during a transition could cause records of the same reversal at different places to to start and finish at different times, making the global duration of a reversal significantly longer than the local duration. Increasingly accurate radiometric dating of transitional lava flows is beginning to suggest this to be true for some reversals, and sophisticated geodynamo simulations also exhibit reversals that vary greatly from one to another and possess many of the above-described characteristics. Is the field starting to reverse? Today we are indeed witnessing a pronounced decrease in field strength. From a broad maximum about 40% higher than today, intensity experiments on archeological materials of fired clay and on young lava flows show that the dipole field has been weakening monotonically for the past 2 kyr. Direct measurements during the modern era confirm that the field is diminishing and indicate that the decay is accelerating: from 5.5% per century from 1850-1950, to 6.8% per century from 1945-1995, to 8.0% per century from 1965 to 1995. However, paleomagnetic records show that the geomagnetic intensity has dropped dramatically many times in the past and recovered without reversing, so that an actual reversal this time is far from certain. The more important societal question is whether the field intensity will continue to diminish down to very low values comparable to the transitional field, or instead turn around uneventfully. Since the last reversal we know that it has decreased to very low values quite a number of times, often accompanied by large excursions of field direction. The environmental effects of such an excursion would likely be very similar to that of a successful reversal.

U42A-06 1510h

Do The Paleomagnetic Records Tell Us Something About The Next Occurrence of a Field Reversal?

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It has been occasionnally repeated that the present collapse of the geomagnetic field would predict the future occurrence of a field reversal. The historical field variations represent a very short period of time but the archeomagnetic records tell us that a more or less regular decrease of the field has effectively been going on over the past 1 kyr. Yet this feature depends on the geographical location as a result of the competitive effects of the dipole and non dipole components. Prior to this period (roughly from 1500 to 1000yr BP) there was a field recovery which occurred more or less at a similar rate. Further back in time the field intensity changes revealed by the sedimentary records seem to exhibit large amplitude variations with time scales of a few thousand years. The closest major collapse of the field occurred 38-40 ka ago during the Laschamp event but the most detailed records indicate that other large fluctuations followed until the present period. The last major and worldwide field reversal occurred 780 kyrs ago. In this case as for other reversals, the paleomagnetic records converge to indicate a long-term decrease of the dipole prior to the transition. However this process does not appear to be regular and all detailed records (from sediments as well as from volcanics)show the existence of short-term fluctuations occurring on the millenial scale. In addition the rate of changes appears to be faster during the field recovery which immediatley follows the reversals than during the preceeding decrease of the dipole. In other words, it is evidently necessary to deal with a long time sequence (at least a few tens of thousand years) to ascertain the issue of the collapse. Thus the existing database for the archeomagnetic and paleomagnetic field tells us that no prediction can be made regarding the next occurrence of a geomagnetic reversal from the present collapse of the field.

U42A-07 1525h

Field Behavior During the *Next* Geomagnetic Event: Clues From Paleomagnetic and Geomagnetic Data

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Although it is unclear whether the present weakening of the axial dipole will ultimately result in a geomagnetic event or complete reversal of polarity, particular subsets of paleomagnetic transition data suggest that the pattern of flux emanating from the core today is not so unlike that which dominated transitional fields over the past few million years. We focus first on the Plio-Pleistocene records obtained from lavas erupted at the Society Island hotspot. With the newly-reported record of the 600 ka Big Lost Event exposed on Tahiti, there now exist five reasonably detailed transition records spanning 2.3 myr between 2.9 Ma and 0.6 Ma from the islands of Tahiti and Huahine. All five of these records contain a sequential clustering of virtual geomagnetic poles (VGPs) found near western Australia. The same is the case for several records of the Matuyama-Brunhes transition, the last reversal, from sites about the globe. In order to compare these findings with the modern-day and historic fields, first, at the Society Island hotspot, we removed the axial dipole term from the 1900, 1950, and 2000 IGRF models and found that the three associated "transitional" south VGPs resided within the same Australian patch. Applying these non-axial dipole field models to sites throughout Australasia, we again found the synthetic VGPs to lie along a narrow north-south line through western Australia. In fact, VGPs associated with the modern-day non-dipole field for the same Australasian sites run in a similar fashion through Australia. These findings suggest strongly that the location of the modeled VGPs is not simply fortuitous, due to the current orientation of the geocentric equatorial dipole. Rather they suggest strongly that the flux pattern involved is far more complex, yet stationary, and most likely due to physical variations of the core-mantle boundary region beneath Australasia. Given this correspondence between recorded transitional paleomagnetic data and modeled geomagnetic data, we propose that the onset of an event or reversal attempt involves the near-vanishing of the axial dipole, leaving a residual field whose source is the pattern of flux fixed to the mantle about the surface of the core. Since it appears that the basic features of this pattern are long-lived, serious investigation of global field changes associated with the next geomagnetic event may now be possible.

U42B MCC: 3001-3003 Thursday 1600h

Earth's Collapsing Dipole II

Presiding: **J Tarduno,** University of Rochester**; C Constable,** Institute of Geophysics and Planetary Physics, SIO, University of California, San Diego

U42B-01 1600h

Is the Recent Decrease in the Geomagnetic Dipole a Precursor of a Reversal?

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Given the remarkable decrease observed in the strength of the geomagnetic dipole, two end members scenarios that may develop are (1) the dipole recovers and secular variation continues and (2) the field reverses within several thousand years. An argument for former is that the dipole has fluctuated in strength repeatedly throughout geological time without reversing. To justify advocating the latter scenario, one needs to show that the present behavior is particularly like the behavior of the geomagnetic field in the early stages of a reversal. However, to establish the transition field during reversals has proved very difficult. Efforts have concentrated on the simpler, but still difficult task of determining the VGP distributions during reversals. These distributions will be reviewed and new analyses presented that confirm earlier suggestions of preferred VGP paths during reversals. Models of the transition field will also be presented. From these, it appears that a region in the southern hemisphere plays an important role in reversals. It has frequently been noted that this is an area that is generating reversed magnetic field at present. Such behavior in the present field might be regarded as indicative of the onset of a reversal, or of an excursion.

U42B-02 1615h

Earth's Collapsing Dipole in the Context of Long-term Geomagnetic Field Behavior

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Over the time interval for which direct geomagnetic field measurements have been made the strength of the geomagnetic dipole has been monotonically decreasing, at the rate of several percent per century. The significance of this decrease (collapse?) must be considered in the light of what is known about geomagnetic field behavior over longer timescales, behavior which includes mean strength, variance, and temporal correlation, in addition to the rates of occurrence of and time taken to accomplish individual geomagnetic reversals. Paleomagnetic data suggest that the decreasing trend has been present at least since 1000 AD, although estimation of the actual dipole moment becomes increasingly difficult as one goes further back in time because of sparse temporal and spatial data coverage. However, it is also abundantly clear from paleomagnetic data that the present dipole is not anomalously low, and that even if it were, extreme DIPs (Decreases in Paleointensity) are not necessarily accompanied by full geomagnetic reversals. Such DIPs may nevertheless have important influences on Earth's immediate magnetic environment. This work adopts a statistical approach in attempting to answer the following questions: Is the next geomagnetic reversal overdue? Is the current rate of decrease of the dipole moment anomalously large? Is the variance in the geomagnetic field related to reversal rate? What does the spectrum of secular variation look like? Paleomagnetic datatsets drawn from times that include both low and high reversal rates are evaluated in the context of Gaussian statistical models for paleosecular variation.

U42B-03 1630h

The Long-term Strength of the Geomagnetic Field

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The long-term strength of the geomagnetic field, an essential parameter constraining the nature and history of the geodynamo, has been defined on the basis of Thellier-Thellier paleointensity experiments using igneous whole-rock samples. However, many of the virtual dipole moments derived from the Thellier data are comparable to values that characterize geomagnetic excursions and reversal transitions. The low field stability implied by these values represents a paradox: it is in stark constrast to what is known from the history of paleosecular variation and frequency of geomagnetic reversals. Taken at face value, the paleointensity data imply the field has been extraordinarily energetic during the last 10 million years. Because factors that could change the magnetic field energy are characterized by time scales orders of magnitude longer than this apparent signal, we suggest natural processes that lead to underestimates of field values (natural and experimental alteration) are far more common than is usually supposed (resulting in a bias toward low values in paleointensity databases). Using secular variation as a guide, we conclude that the mean strength of the field since Mesozoic times was probably similar to that of the last 10 million years (7 to 8 x 10^{22} Am^2), except during periods of very low (superchron) and very high (e.g. the Late Jurassic) reversal frequency. Paleointensity estimates for the latter interval are anomalously low relative to all data and, together with Thellier estimates based on analyses of single plagioclase crystals from the Cretaceous Normal Polarity Superchron, suggest that reversal rate and field intensity are inversely related. These interpretations suggest that the modern decay of the dipole should be viewed relative to the "threshold" value of paleointensity, estimated from analyses of sediments. At this threshold value (approximately 1/2 the modern field strength), excursional field behavior can be expected.

U42B-04 1645h INVITED

Geomagnetic Variations and Their Possible Effects on System Earth

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The Earth magnetic field exhibits a variety of temporal variations with time scales ranging from a few seconds up to millions of years. The most pronounced variation is certainly a polarity transition during which the geomagnetic field strength decays down to about 10-20 % of its current value. A question of immediate interest is whether and in which way System Earth reacts on such a dramatic event. First the magnetosphere changes its size and shape. Due to the decreasing geomagnetic field the magnetopause is located much closer to the surface of the Earth. If the field exhibits strong quadrupole components magnetic reconnection can happen in the northern dayside magnetosphere with the southern hemisphere featuring a closed magnetosphere. Also the magnetotail structure changes drastically. Energetic particle entry occurs not only in dipolar cap regions but over much enlarged areas. As the ionospheric conductivity depends on the geomagnetic field strength first estimates furthermore indicate that externally driven geomagnetic variations are stronger during times of a polarity transition. The weaker field also makes the middle atmosphere much more sensitive to energetic particle events and large natural ozone holes are very likely during polarity transitions as first model calculations indicate.

U42B-05 1700h INVITED

A Model Study of the Impact of Magnetic Field Reversal on Atmospheric Composition During Solar Proton Events

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During a polarity transition of the Earth's magnetic field, the structure and strength of the field change significantly from their present values. This will alter the global pattern of charged particle precipitation into the atmosphere. Thus, particle precipitation is possible into regions that are at the moment effectively shielded by the Earth's magnetic field. A two-dimensional global coupled chemistry, radiation, and transport model of the atmosphere has been used to investigate how the increased particle precipitation affects the chemical composition of the middle and lower atmosphere. Ozone losses resulting from large energetic particle events are found to increase significantly, with resultant losses similar to those observed in the Antarctic ozone hole of the 1990s. This results in significant increases in surface UV-B radiation as well as changes in stratospheric temperature and circulation over a period of several months after large particle events.

U42B-06 1715h

Do Lunar Soils Tell us When the Geomagnetic Field First Appeared?

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When did the Earth's geomagnetic field first appear? Paleomagnetic studies trace the geomagnetic field back only to about 3.5 Ga ago [1]. It has been taken for granted that the development of the geomagnetic field was concomitant with the formation of the Earth's core, but the time of core formation is not well known, nor is the role of the inner core in the generation of the geodynamo, so this fundamental issue remains enigmatic. We show that the isotopic compositions of N implanted in ancient lunar soils may reflect admixture of solar wind and terrestrial atmospheric component, suggesting transport of atmospheric components to the Moon. The geomagnetic field would prevent any effective ion loss from the atmosphere [2], but if the geomagnetic field was absent in the early Earth the escape of ions from the ionosphere would be enhanced considerably, and a substantial amount of terrestrial atmospheric ions may have been transported to lunar soils. Therefore, we propose that close examination of N isotopic compositions in ancient lunar soils may provide clues concerning the time of the appearance of the geomagnetic field. The PVO (Pioneer Venus Orbiter) observations have suggested the loss of 1E6 - 1E8 O+ cm-2s-1 from the Venus atmosphere [3]. This substantial ion loss is understood to reflect direct interaction between the solar wind and the upper atmosphere in the absence of a permanent dipole field. For N+/O+ of about 0.02 around the ionopause [4], we would expect N+ loss of about 2E5 cm-2s-1. Venus's atmosphere may serve as a proxy for the primitive atmosphere in the early Earth, which was likely to consist predominantly of CO2/CO [5]. We thus expect that a similar amount of N+ would escape from the Earth in the absence of the geomagnetic field. Also considering that the Earth was much closer to the Moon in the first several hundred Ma [6], we infer from simple geometrical considerations that a few percent of escaping ions from the Earth's ionosphere may have directly hit the lunar surface. Isotopic inventory considerations suggest that the implantation of about 1E4cm-2s-1 of N of terrestrial origin would suffice to explain the hypothesized non-solar N in ancient lunar soils. This amount of non-solar N could be attributed to terrestrial N that was transported to the Moon if the Earth did not have a geomagnetic field. It is known that the dynamical coupling between the Earth and the Moon is so stable that the near side of the Moon has remained facing the Earth for nearly the whole history of the Earth-Moon system [7]. Therefore, we predict that a considerable amount of terrestrial N would be observable in near side lunar soils whose exposure times predate the commencement of the geomagnetic field, whereas soils from the far side should not show terrestrial components. We propose that comparison of N isotopic components in ancient lunar soils from the far side with those from the near side could help resolve the time of the appearance of the geomagnetic field.

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U42B-07 1730h INVITED

Solar Activity and Climate - in Light of the Decay of the Dipole

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The geological history shows that climate has always been changing. The climate is the result of very complex interactions between various atmospheric processes, which are not well understood. Variations in solar activity seem to have a significant - but not simple - effect on climate. Recently it has been suggested that solar activity modulation of cosmic rays influences the formation and properties of clouds and thereby the radiation balance of the Earth. This topic was selected as one of six 'Areas to Watch in 2003' in the 20th December 2002 edition of Science. Since the Earth's magnetic field also has a modulating effect on the cosmic ray flux into the atmosphere, one might expect an effect on climate as well. A review of solar activity variations and climate changes will be given with emphasis on those aspects that may be affected by the varying geomagnetic field.

U51A MCC: 3001-3003 Friday 0800h

Human-Induced Climate Variations Linked to Urbanization: From Observations to Modeling I

Presiding: **J Shepherd,** NASA Goddard Space Flight Center**; M Jin,** University of Maryland, College Park

U51A-01 0800h INVITED

Promise and Capability of NASA's Earth Observing System to Monitor Human-Induced Climate Variations

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The Earth Observing System (EOS) is a space-based observing system comprised of a series of satellite sensors by which scientists can monitor the Earth, a Data and Information System (EOSDIS) enabling researchers worldwide to access the satellite data, and an interdisciplinary science research program to interpret the satellite data. The Moderate Resolution Imaging Spectroradiometer (MODIS), developed as part of the Earth Observing System (EOS) and launched on Terra in December 1999 and Aqua in May 2002, is designed to meet the scientific needs for satellite remote sensing of clouds, aerosols, water vapor, and land and ocean surface properties. This sensor and multi-platform observing system is especially well suited to observing detailed interdisciplinary components of the Earth's surface and atmosphere in and around urban environments, including aerosol optical properties, cloud optical and microphysical properties of both liquid water and ice clouds, land surface reflectance, fire occurrence, and many other properties that influence the urban environment and are influenced by them. In this presentation I will summarize the current capabilities of MODIS and other EOS sensors currently in orbit to study human-induced climate variations.

U51A-02 0830h INVITED

Urban Aerosol-Induced Changes of Precipitation

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Precipitation has been shown often to be enhanced over and downwind of major urban areas. These effects were most noticeable in convective clouds of the warm season, and were ascribed to dynamic causes, such as the urban heat island and the urban topography. In contrast, recent observations have shown that urban and industrial aerosols suppress rain and snow, by providing large concentrations of small cloud condensation nuclei (CCN), which when ingested into the clouds create large number of small cloud droplets. The clouds need to grow to greater depth and colder cloud top temperatures for the onset of precipitation. Therefore it was expected that precipitation would be most suppressed when the pollution is ingested into relatively shallow and short-living clouds. Such clouds occur in winter over orographic barriers downwind of coastal cities. This was examined by measuring the orographic enhancement factor (RO, ratio of rainfall over the hills versus the upwind lowland rainfall) of the precipitation downwind of the urban areas in California and Israel. It was found that in both locations RO has decreased by 15 to 25 percent during the last century whereas no change occured in side wind little urbanized areas. Some compensation occurred further downwind on the drier downwind side of the mountains. The aerosols suppress the onset of precipitation also in warm-base convective clouds that develop in moist tropical air masses, such as occur during the summer in Houston and St. Louis. Simulations of clouds with explicit microphysical processes show that the delay of the onset of the warm rain in such clouds delays also the onset of the downdraft, and by that allows the updraft to invigorate further and produce more violent and precipitation producing thunderstorms. This is proposed as an additional enhancement mechanism that works at the same direction of the urban heat island. The conversion from warm to ice precipitation processes advects