CLIMATE CHANGE INSTITUTE

Solar Forcing of Climate Through Changes in Atmospheric Circulation

Although the sun is the driver of Earth's climate, demonstrating a direct connection between solar variability and climate change has proved difficult. One of the problems is that while solar particle emissions and short wave radiation change by large amounts in a solar cycle, total irradiance varies minimally and accurate measurements have only been available in the satellite era. Some associations however have been observed between historical records of solar activity and climate change and also between variability in cosmogenic proxies for solar variability and millennial scale variability in paleoclimate records from moraine sequences, Greenland ice cores, and lake sediments by Climate Change Institute researchers (Denton and Karlen, 1973; O'Brien et al., 1995; Mayewski et al., 1993, 1997, 2004; Stager et al., 2004).

Although considerable attention has been paid to the record of temperature change over the last few centuries, the range and rate of change of atmospheric circulation and hydrology remain elusive. Examination of globally distributed (pole-equator-pole), high resolution, climate proxy records by Climate Change Institute researchers demonstrates major changes in these variables over the last 10,000 years (see summaries by Mayewski et al., 2004; Maasch et al., in press). Further this work reveals a first-order relationship between a variable Sun and changes in atmospheric circulation and hydrology (Figure 1) that is not as apparent with other climate forcing agents (Figures 2).

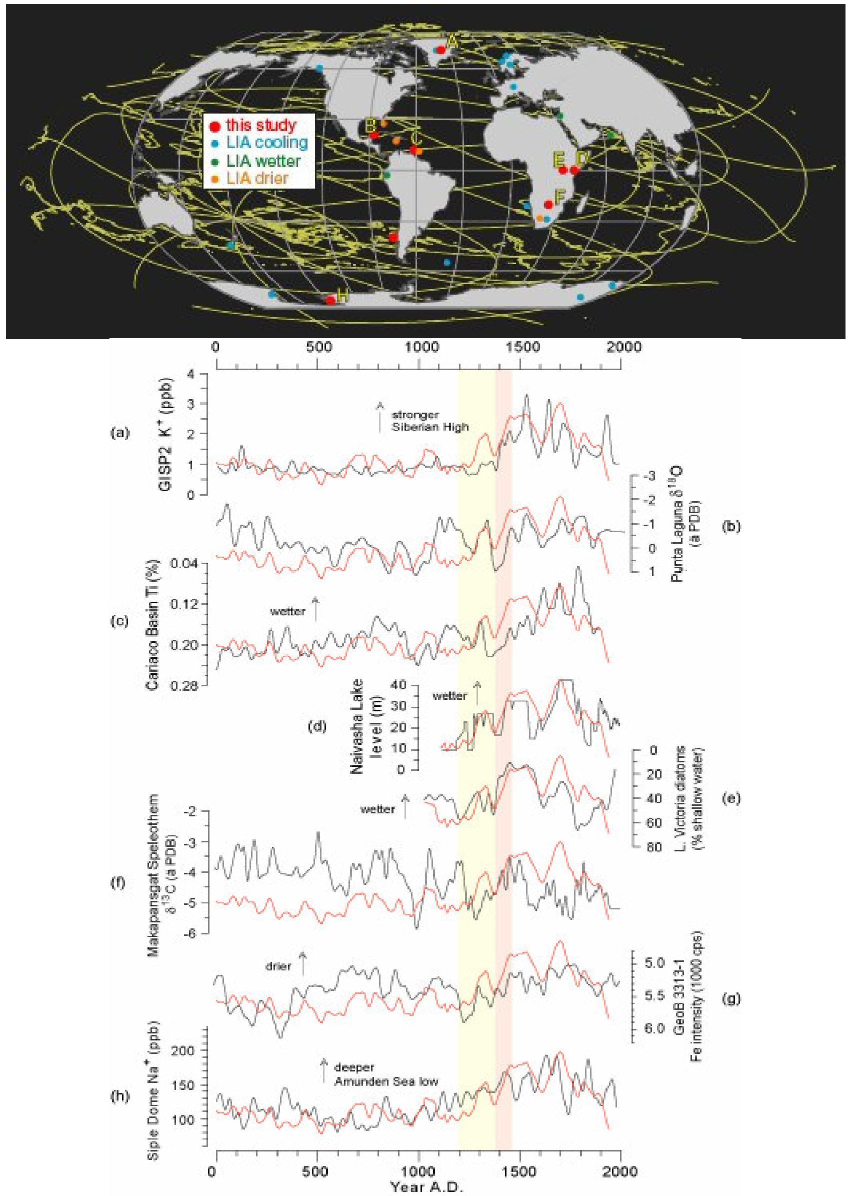


FIG. 1

From Maasch et al., in press 2005 – Eight paleoclimate records from locations corresponding to red dots on map overlay arranged by latitude from north to south: (a) GISP2 K^+, (b) Punta Laguna $\delta^{18}O$, (c) Cariaco Basin %titanium, (d) Naivasha Lake level, (e) Lake Victoria % shallow water diatoms, (f) Makapansgat speleothem $\delta^{13}C$, (g) Core GeoB 3313-1 iron intensity, (h) Siple Dome Na^+ demonstrating a first order relationship to solar variability ($\Delta^{14}C$ proxy for solar variability (red, from Stuiver and Braziunas, 1989)).

Annually dated, instrumentally calibrated, proxies for atmospheric circulation from several Antarctic ice cores (ITASE, Siple Dome, Law Dome) reveal decadal-scale associations with a South Pole ice core ^{10}Be proxy (from Bard et al., 2000) for solar variability over the last 600 years (Figure 3) and annual scale associations with solar variability since AD 1720. Increased (decreased) solar irradiance is associated with increased (decreased) zonal wind strength near the edge of the Antarctic polar vortex. The association is particularly strong in both the Indian and Pacific Oceans and as such may contribute to understanding climate forcing that controls drought in Australia and other Southern Hemisphere climate events. The mechanism for the association between solar variability and atmospheric circulation suggested by Mayewski et al. (in press 2005) may be found through previous empirical and modeling studies whereby increased solar ultra-violet (UV) radiation leads to increased production of stratospheric ozone, resulting in increased (decreased) temperatures in the lower stratosphere (troposphere) (McCormack and Hood, 1996; Chandra and others, 1996; Randel and Cobb, 1999), and consequently an increase in the thermal gradient from high to low latitudes attended by an increase in lower tropospheric zonal wind speeds over the Northern Hemisphere (Shindell and others, 1999).

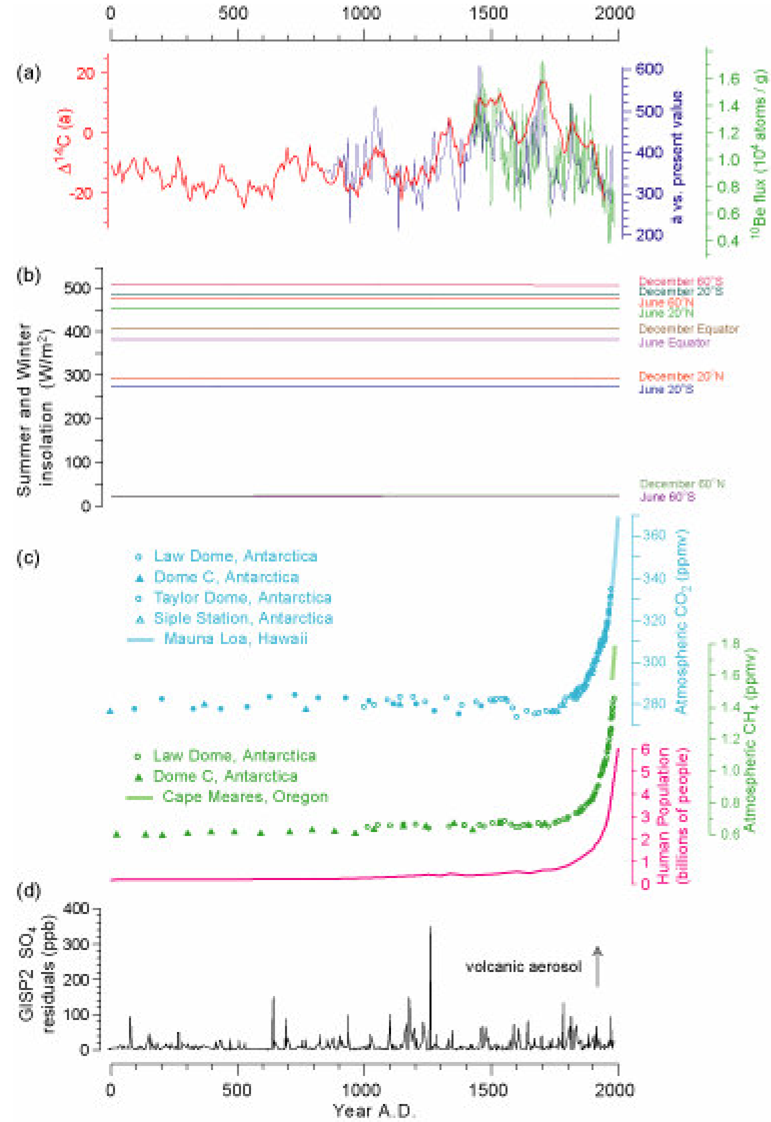


FIG. 2

From Maasch et al., in press 2005 - Examination of several climate forcing agents: (a) proxies for solar variability including $\Delta^{14}C$ measured in tree rings (red, from Stuiver and Braziunas, 1989) and ^{10}Be measured in ice from Greenland (green, from Beer, 2000) and South Pole (blue, from Bard et al., 2000), (b) summer and winter insolation at latitudes 60˚N, 20˚N, equator, 20˚S, and 60˚S (from Berger, 1978), (c) greenhouse gas concentration, atmospheric CO_2 (light blue, from Etheridge et al., 1998) and CH_4 (green, from Etheridge et al., 1998) along with human population (pink), and (d) SO_4 residuals (volcanic aerosols) measured in ice from Greenland (from Zielinski et al., 1996).

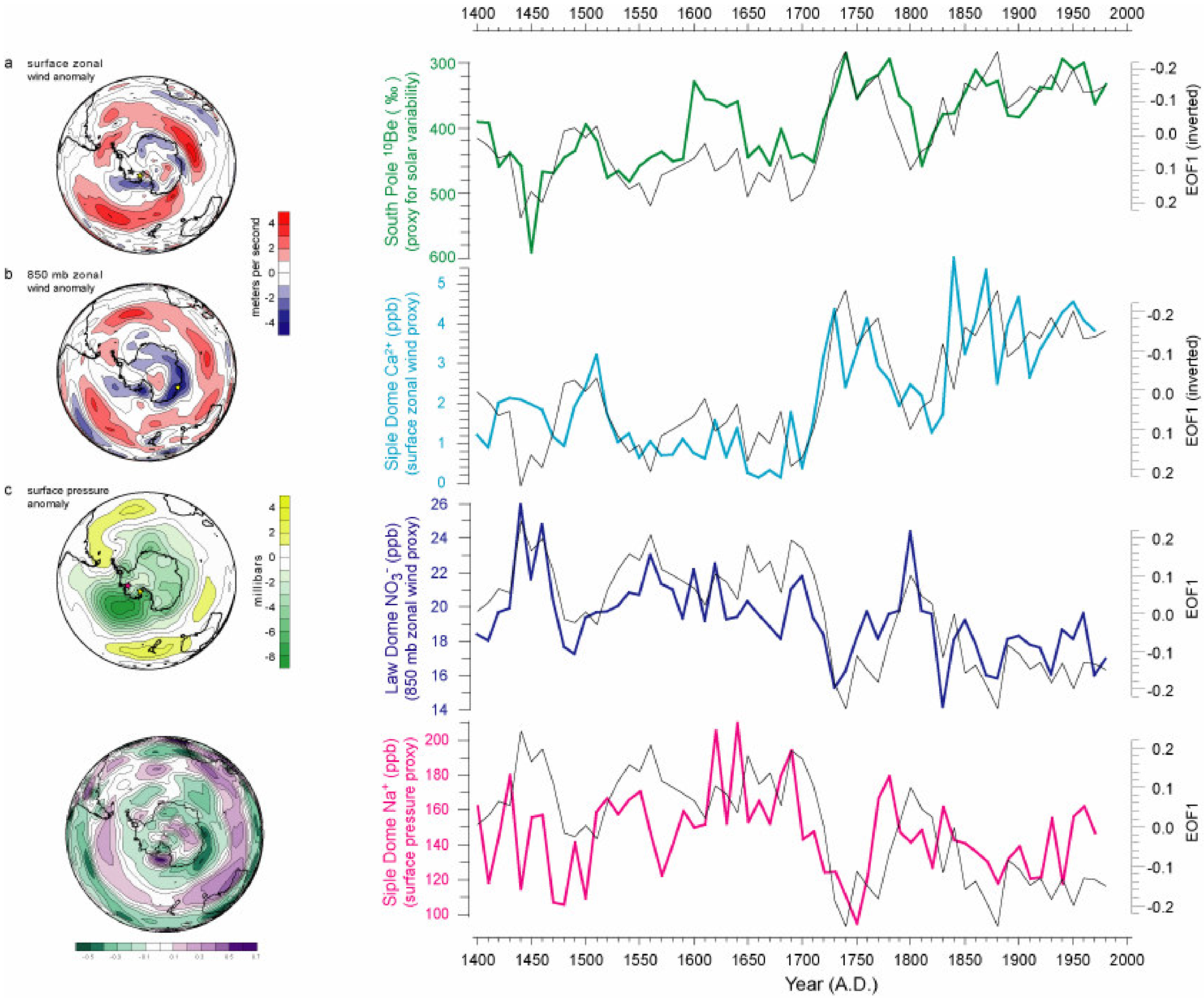
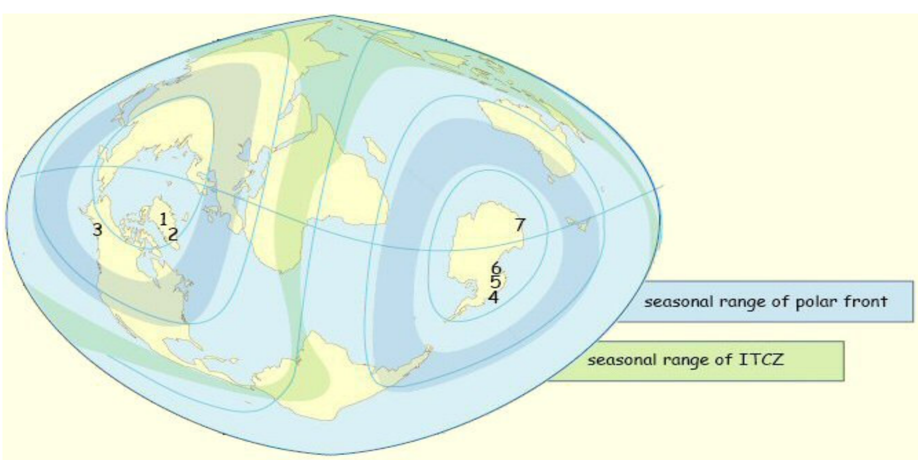


FIG. 3

From Mayewski et al., in press 2005. Left side(first three) – correlation between ice core glaciochemical series and NCEP/NCAR climate reanalysis data. Right side – comparison between solar variability (^{10}Be measured in ice from South Pole (from Bard et al., 2000) and ice core climate proxy series. Left side (bottom) – modern association between solar flux and zonal wind in the Southern Hemisphere utilizing NCEP/NCAR reanalysis data is similar to climate proxies developed from ice core series (left side).



From Mayewski et al., in press 2005. Eckert-Greifendorff global projection displaying the location of ice core sites utilized in this study as well as the position of the seasonal range of both the northern and southern polar fronts and the ITCZ for general perspective. 1 (GISP2), 2 (20D), 3 (Mt. Logan), 4 (ITASE 01-2), 5 (ITASE 00-1), 6 (Siple Dome), and 7 (Law Dome).

FIG. 4

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