Solar Influence on climate:
Evidences of the geomagnetic modulation of the tropical atmospheric circulation during last fifty years

MPS Solar Group Seminar - November, 2007
Outline

- Geomagnetic modulation of large-scale structures in the Pacific Ocean
- Westward drift of tropical convection
- Lower atmosphere response to the October-November, 2003 events
Surface Temperature
Sun-Climate Mechanisms

- The variability of the total solar irradiance causing a change in the total energy input to the earth’s atmosphere and consequent warming/cooling;
- The variability of the solar ultraviolet emission and its effects on the stratospheric ozone and thermal structure;
- High energy particle precipitation effects on mesospheric and stratospheric ozone in the auroral and/or southern hemisphere magnetic anomaly regions; and,
- The cosmic rays effects on the cloud coverage.
Sea-level Pressure

- The ISCCP D2 data/images were obtained from the International Satellite Cloud Climatology Project web site http://isccp.giss.nasa.gov maintained by the ISCCP research group at the NASA Goddard Institute for Space Studies, New York, NY.

Sea-Surface Temperature

TRMM Microwave Imager (TMI) satellite observations
The Geodynamo

The data were collected by the South Atlantic Anomaly Detector (SAAD) aboard ROSAT at 560Km. Credit: S. L. Snowden
Geomagnetic modulation of large-scale structures in the Pacific Ocean

Long-wavelength (5 to 200 microns) cloud effects on the net radiative flux in the atmosphere for (a) December and (b) June, averaged for the years 1984-2001. The superposed black lines show the iso-intensity contours of the geomagnetic field at ground for year 1990. The magnetic field intensity (B) was estimated using the International Geomagnetic Reference Model (IGRF).
Geomagnetic modulation of large-scale structures in the Pacific Ocean

Figure: Vertical p-velocity (w) at 400 hPa in Pa s⁻¹ for (a) SON and (d) DJF, averaged for the years 1984-200.
Cloud properties in the Southern Hemisphere Magnetic Anomaly Region

- Annual means of the cloud top temperature and pressure for the period July 1983 to December 2004. The superposed black lines show the iso-intensity contours of the geomagnetic field at ground for year 1990.
Seasonal variations of cloud top temperature

DJF and JJA of the cloud top temperature for the period July 1983 to December 2004. The superposed black lines show the iso-intensity contours of the geomagnetic field at ground for year 1990.
Seasonal variations of cloud top pressure

DJF, JJA Means of the cloud top pressure for the period July 1983 to December 2004. The superposed black lines show the iso-intensity contours of the geomagnetic field at ground for year 1990.
Cloud Coverage

• Annual global maps for the IR High, Middle, and Low cloud cover amount from July/1983 to December/2004.

• The ISCCP D2 data/images were obtained from the International Satellite Cloud Climatology Project web site http://isccp.giss.nasa.gov maintained by the ISCCP research group at the NASA Goddard Institute for Space Studies, New York, NY.
Cloud Effects

• Annual means of the short-wavelength, long-wavelength and total cloud effects on radiative flux in the atmosphere for the period July 1983 to June 2001. The superposed black lines show the iso-intensity contours of the geomagnetic field at ground for year 1990.

• The ISCCP D2 data/images were obtained from the International Satellite Cloud Climatology Project website http://isccp.giss.nasa.gov maintained by the ISCCP research group at the NASA Goddard Institute for Space Studies, New York, NY.
Cosmic Rays Modulation of Cloud Effects

• From top to bottom it is shown the anomalies in the LW Net Flux for the defined regions (green line). Superposed it is shown the cosmic ray data observed at Huancayo (cutoff rigidity 12.91 GeV). Notice that LW Net Flux anomalies in Regions 4-6 follow quite well the behavior of cosmic rays.
Schematic sketch of important atmospheric circulation features over the South America region

- IL -> Instability line;
- CL -> Chaco low;
- LLJ -> low-level jet;
- ET -> Equatorial trough;
- AR -> Arid region;
- SAR -> Semiarid region;
- MCC -> Mesoscale convective complex;
- CONV -> Convective activity;
- CG -> Cyclogenesis;
- STH -> Subtropical high;
- EA -> Extratropical anticyclone;
- L -> low pressure center;
- CV -> Cyclonic vortex;
- BH -> Bolivian high;
- CCV -> Cold-core vortex;
- CO -> Cirrus outflow;
- STJ -> Subtropical jet;
- PJ -> Polar Jet.

Global Change
Numerical Simulation

Pressure Distribution at 400 hPa

- 3D hydrodynamical model
- Isothermal
- Uniform density distribution

Reference:

15/11/2007

Global Change
Schematic sketch of important atmospheric circulation features over the South America region.
Deceleration of atmospheric vertical overturning circulation over the tropical Pacific

Source:
SHMA Evolution

IGRF Model

15/11/2007

Global Change
The evolution of the Sea-Level Pressure in the Pacific SHMA region

Figure: It is shown in the upper panel the climatology of the sea-level pressure from 1948-2005. The superposed black lines show the difference of the geomagnetic field intensity at surface between years 2000 and 1940.
Statistical analysis of the Sea-level Pressure for the defined regions

Figure: Statistical analysis of the Sea-level Pressure for the defined regions from January/1948 to December/2005.
The monthly SLP averages estimated for the regions 5 – 8

- The continuous red lines show the linear models and the dotted lines show the 1-sigma error.
Region averaged magnetic field intensity for years 1940 - 2000 at surface, estimated using the IGRF model
Composition of the scatter plots of the SLP versus B for the 12 regions

Figure: It is shown in the left upper panel the scatter plot of the Sea-level Pressure versus the Magnetic field intensity. The black line shows the best linear fit for the whole data set. The dotted black lines show the 1-sigma model error. It is shown in the right panel the frequency distribution of the Model Error. Scatter plotter of the Sea-level Pressure versus the Magnetic field intensity for regions 3-9. The continuous blue line shows the best linear fit and the dotted blue lines show the 1-sigma error. The black lines are the 36-month running means for regions 3-9. The slopes for these regions are not significantly different at the confidence level of 95%.

Sea-Level Pressure (hPa) vs Magnetic Field Intensity (Gauss)

Sea-Level Pressure Model Error (hPa) vs Frequency Distribution (x 10^3)
Model Results
GISS II Model

Surface wind – 1950_f02

Surface wind – 2000_f02

Annual Sea level pressure

Annual Sea level pressure

\[ \text{SST}_{\text{pert}} = \text{SST} - f \frac{(B_{2000} - B_{\text{year}})}{B_{2000}} \cdot \text{SST} \]
Model Results

**Annual High level cloud cover**


**Annual Precipitation**

Sea Surface Temperature Climatology (February)

\[ SST_{pert} = SST - f \cdot \frac{(B_{2000} - B_{year})}{B_{2000}} \cdot SST \]
Halloween Events

Satélite SOHO/LASCO C3
Global Change
Halloween Events

Satélite SOHO/LASCO C3
Global Change
EIT Observations

Oct 28 2003  11:12:10

Oct 30 2003  11:27:15

Nov 4 2003  19:48:11

15/11/2007

ppmv (parts per million by volume)
Figure 2: The Sea Level Pressure and the streamlines at 1000 hPa for October 27th, October 31st, November 2nd and November 6th, 2003. The superimposed red lines are the 0.31 Gauss iso-intensity contours of the magnetic field at surface. The green lines are the 1000 cm-2s-1 iso-intensity contour of the proton flux at 1200 km.
Figure 3 and 4: Columnar Water Vapor, Cloud Liquid Water and Sea Surface Temperature distributions for October 26th and November 11th, 2003, respectively. The superimposed black lines are the 0.31 Gauss iso-intensity contours of the magnetic field at surface. The green lines are the 400 and 1000 cm-2s-1 iso-intensity contours of the proton flux at 1200 km.
Figure 5: Evolution of the Sea Level Pressure, Sea Surface Temperature, Columnar Water Vapor and Cloud Liquid Water calculated in the selected regions (see text for the definition of the regions). For reference, it is shown in the upper panel the proton fluxes observed by the GOES 11 satellite. The dotted lines show the onset of the main events.
Streamlines at 200 hPa
Solar Cycle and the El Niño-Southern Oscillation (ENSO) phenomena
Preliminary analyzes have shown that the south hemisphere temperature during last century is increasing proportionally to the increase of the area of the magnetic anomaly over the magnetic Pacific Ocean.
SHMA Evolution from 1600
Conclusions

- Large-scale structures in the Pacific Ocean are modulated by the presence of the SHMA
- The SHMA and the convective systems are drifting westward at the same rate
- The lower atmosphere circulation responds to extreme solar events
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Walker Circulation