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Inter-hemispheric linkages in climate change: paleo-perspectives for future climate change

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Abstract. The Pole-Equator-Pole (PEP) projects of the PANASH (Paleoclimates of the Northern and Southern Hemisphere) programme have significantly advanced our understanding of past climate change on a global basis and helped to integrate paleo-science across regions and research disciplines. PANASH science allows us to constrain predictions for future climate change and to contribute to the management of consequent environmental changes. We identify three broad areas where PEP science makes key contributions.

1. *The pattern of global changes.* Knowing the exact timing of glacial advances (synchronous or otherwise) during the last glaciation is critical to understanding inter-hemispheric links in climate. Work in PEPI demonstrated that the tropical Andes in South America were deglaciated earlier than the Northern Hemisphere (NH) and that an extended warming began there ca. 21 000 cal years BP. The general pattern is consistent with Antarctica and has now been replicated from studies in Southern Hemisphere (SH) regions of the PEPII transect. That significant deglaciation of SH alpine systems and Antarctica led deglaciation of NH ice sheets may reflect either i) faster response times in alpine systems and Antarctica, ii) regional moisture patterns that influenced glacier mass balance, or iii) a SH temperature forcing that led changes in the NH. This highlights the limitations of current understanding and the need for further fundamental paleoclimate research.

2. *Changes in modes of operation of oscillatory climate systems.* Work across all the PEP transects has led to the recognition that the El Niño Southern Oscillation (ENSO) phenomenon has changed markedly through time. It now appears that ENSO operated during the last glacial termination and during the early Holocene, but that precipitation teleconnections even within the Pacific Basin were turned down, or off. In the modern ENSO phenomenon both inter-annual and seven year periodicities are present, with the inter-annual signal dominant. Paleo-data demonstrate that the relative importance of the two periodicities changes through time, with longer periodicities dominant in the early Holocene.

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3. *The recognition of climate modulation of oscillatory systems by climate events.* We examine the relationship of ENSO to a SH climate event, the Antarctic cold reversal (ACR), in the New Zealand region. We demonstrate that the onset of the ACR was associated with the apparent switching on of an ENSO signal in New Zealand. We infer that this related to enhanced zonal SW winds with the amplification of the pressure fields allowing an existing but weak ENSO signal to manifest itself. Teleconnections of this nature would be difficult to predict for future abrupt change as boundary conditions cannot readily be specified. Paleo-data are critical to predicting the teleconnections of future changes.

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