Seasonal Climate Signals in an Earth System Model of Intermediate Complexity.

Universiteit Utrecht

H.J. de Boer, S.C. Dekker and M.J. Wassen

H.deBoer@geo.uu.nl

Utrecht University, Faculty of Geosciences, Environmental Sciences. Heidelberglaan 2, P.O. Box 80115, 3508 TC Utrecht, the Netherlands

Introduction

Earth System Models of Intermediate Complexity (EMICs) are climate models which simulate the general circulation of the atmosphere, but use parameterizations to reduce computational cost[1]. These properties make EMICs popular tools for palaeo-climate simulations. However, in comparison to the more complex General Circulation Models, EMICs simulate a limited atmospheric response to changes in Sea Surface Temperatures (SSTs)[2].

Our goal is to quantify to ability of the EMIC PUMA-2 to simulate atmospheric teleconnections to changes in SSTs at a seasonal time scale.

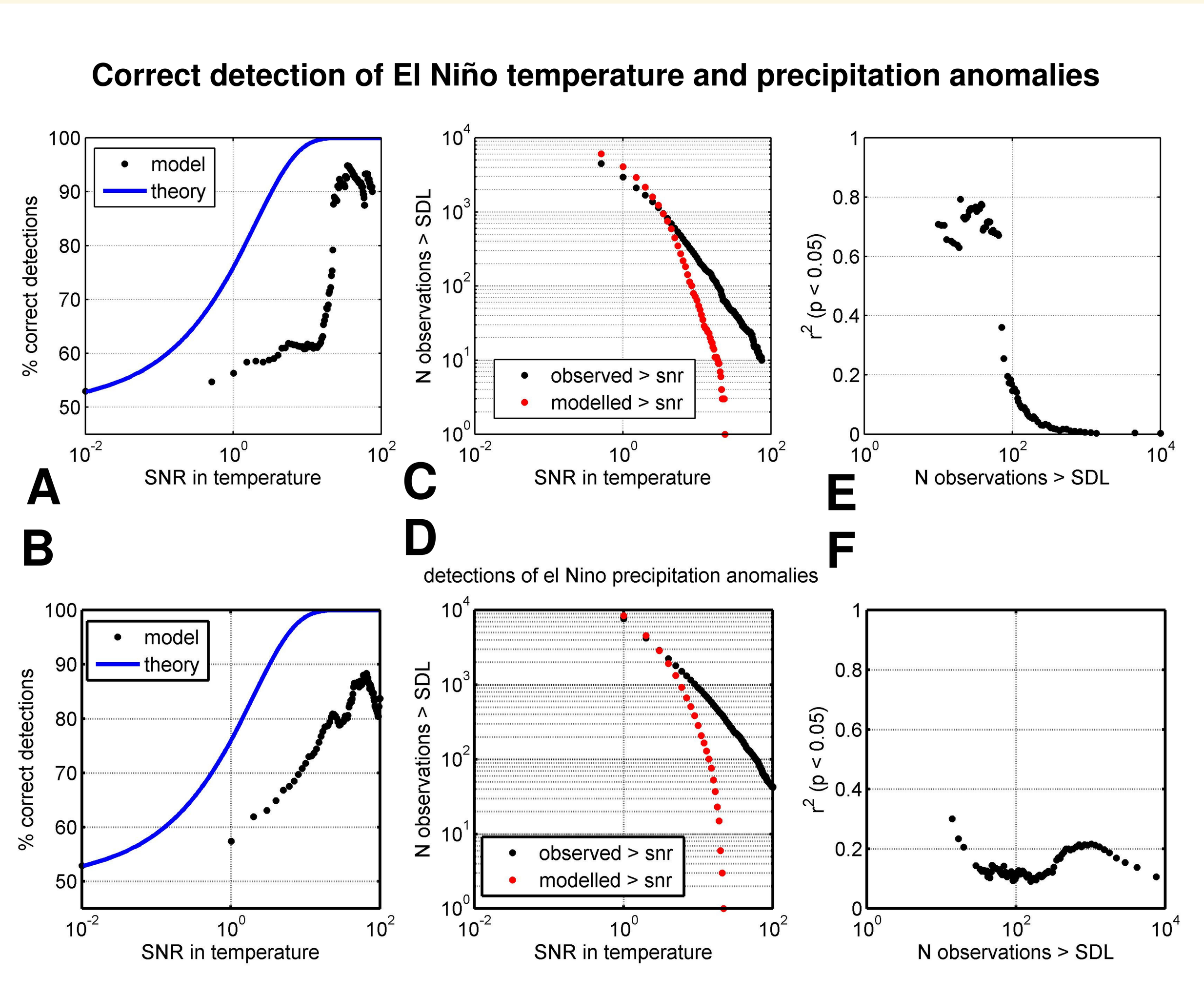

Figure 3: Correct detection of simulated temperature and precipitation anomalies during the 1998 El Niño (A&B). The number of observations surpassing the specified signal-to-noise ratio (C&D) and the correlation (p <0.05) between simulated and observed surface temperature anomalies (E&F) indicate the performance of the model.

Signal-to-Noise Ratio (SNR)

To attribute a shift in modelled climate to a realistic response in the climate system, the 'signal' should be detectable above the 'noise' related to the internal variability of the model. Depending on the ratio between the signal and the noise (SNR), the chance to accurately detect a change (Dc) can be calculated following Eq. 1&2[3].

$$SNR = \frac{(\Delta S)^2}{\sigma_N^2} \qquad (1)$$

$$D_c = \tfrac{1}{2}\left[1 + erf\sqrt{\frac{SNR}{4}}\right] \qquad (2)$$

Model validation: El Niño teleconnections

We investigated the ability of the EMIC PUMA-2 by simulating the atmospheric teleconections to SSTs representative for the 1998 El Niño. We then compared the simulated anomalies to observations at seasonal timescales (Fig 3).

The chance to accurately detect a change in temperature and precipitation increases with increasing SNRs (Figs 4A&B). Considering the regions and seasons with highest SNRs, the simulated El Niño anomalies show good agreement with observations (Figs. 4E&F). The amount of observations which are considered drastically reduces with increasing SNRs (Figs. 4C&D).

Seasonal climate noise

We calculate seasonal climate noise (σ) from a 29 member simulation with the EMIC PUMA-2[4,5,6]. The model generally reproduces the seasonality in climate noise from observations (Figs 2A&B)[7,8].

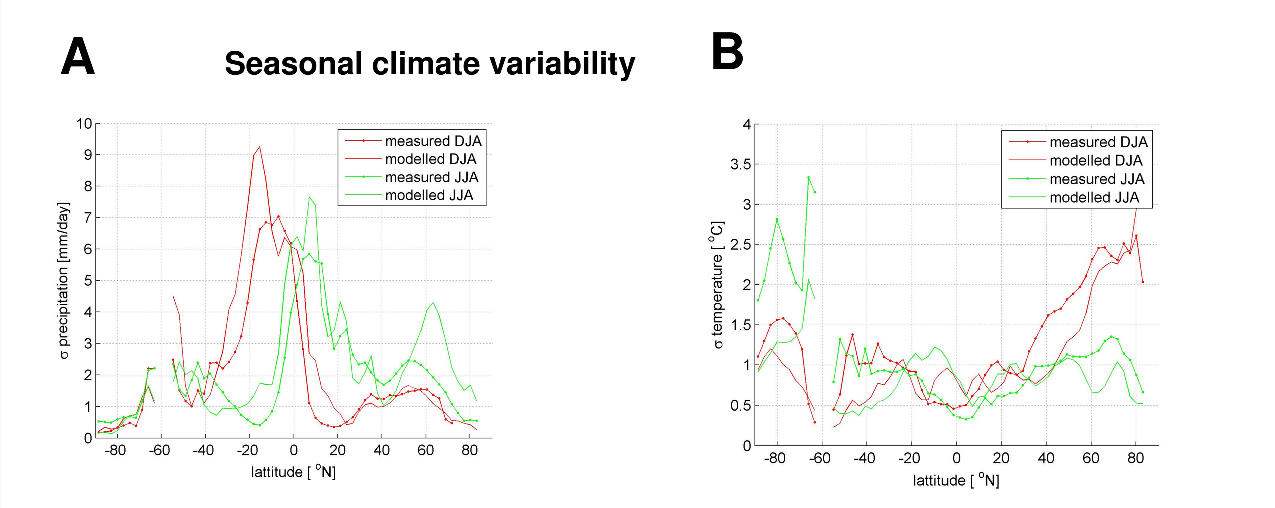

Figure 1: Simulated and measured noise (std. σ) of winter (DJF) and summer (JJA) temperature (A) and precipitation (B)

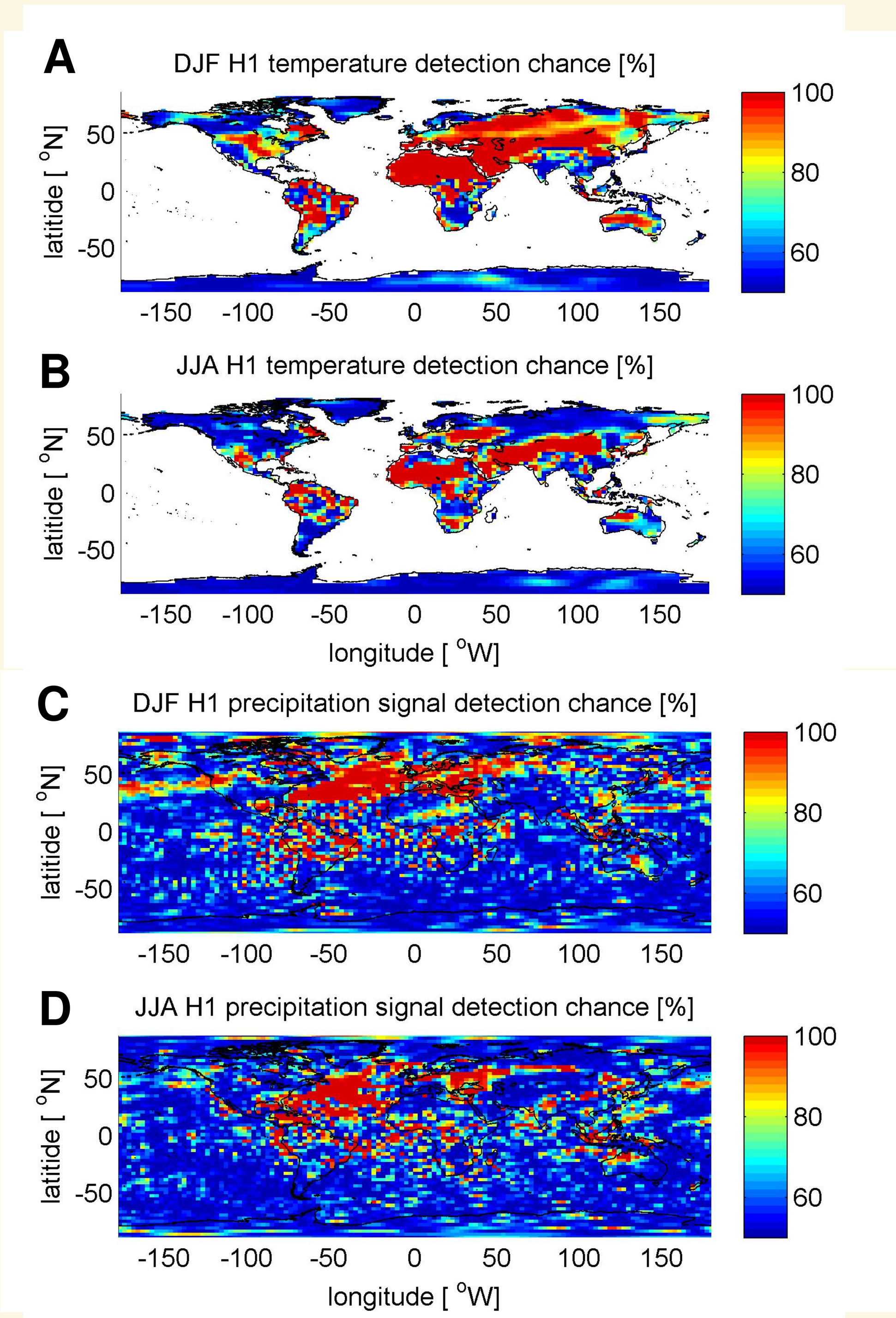

Figure 4: Simulated temperature (A&B) and precipitation (C&D) signal detection chance (%) for an idealized Heinrich Event.

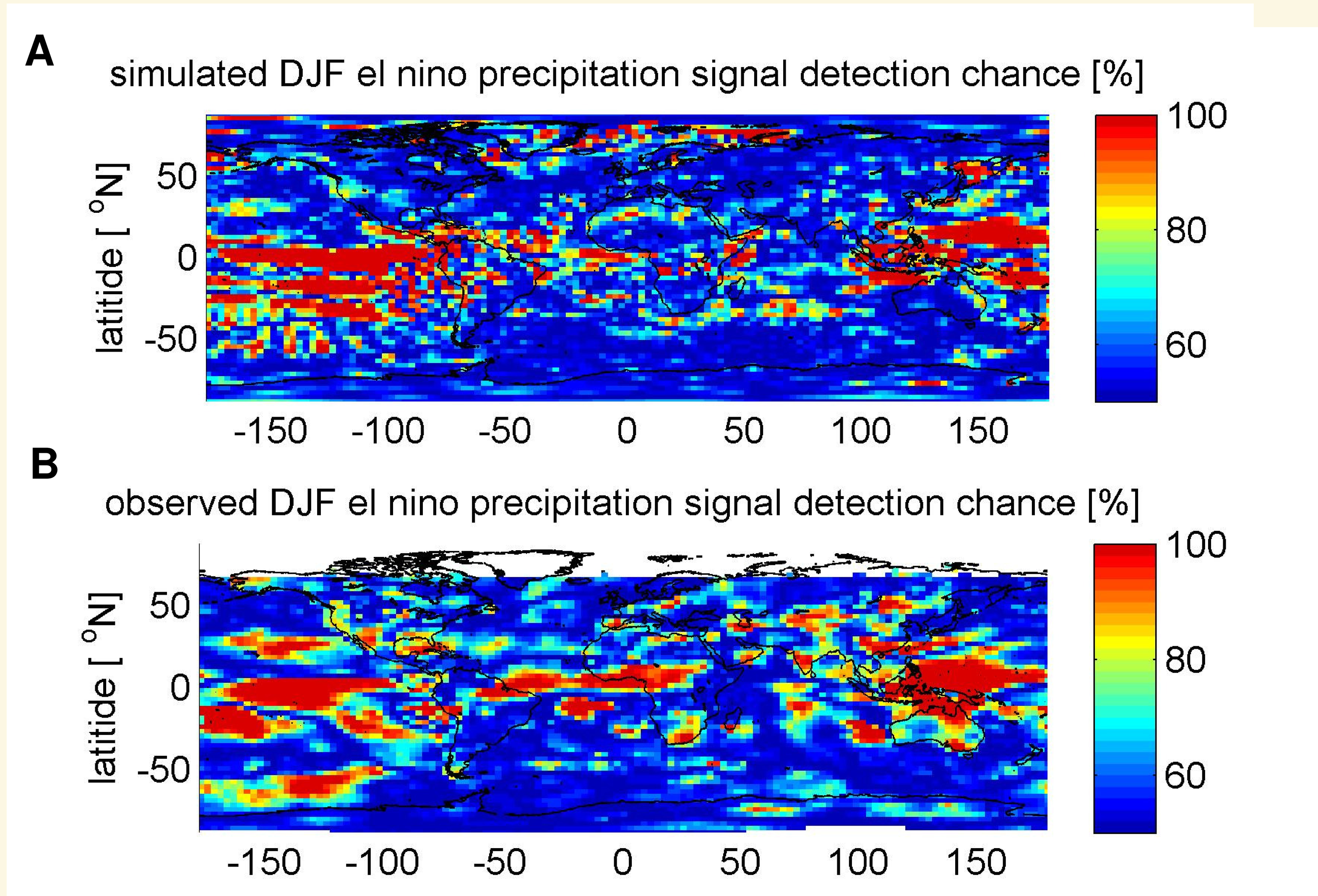

Figure 2: Simulated (A) and measured (B) winter (DJF) precipitation anomalies related to the 1998 El Niño.

Model application: Idealized Heinrich event

Heinrich events are intense cooling events which occurred periodically in the North Atlantic during the last glaciation[9,10]. Current research focuses on understanding potential teleconnections to the tropics and the southern hemisphere[11,12].

We simulated the atmospheric teleconnections to SST anomalies representative for an idealized Heinrich event. Fig. 4 indicates the chances to accurately detect these teleconnections. The idealized Heinrich event has a global imprint on surface temperatures during boreal winter. During summer, the imprint is reduced in the northern high latitudes, when the cooling is masked by summer heating (Figs. 4A&B). Precipitation changes are best detected over the North Atlantic regions, but strong teleconnections with monsoon regions appear outside the North Atlantic basin during summer and winter (Figs 4C&D).

Conclusions

The EMIC PUMA-2 accurately simulates the most pronounced atmospheric teleconnections to El Niño SST anomalies, but underestimates their strength. These results give confidence for correctly detecting changes in simulated paleao climates during times when global scale atmospheric alterations occurred.

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