Mechanisms of tropical Atlantic variability and response to CO_2 doubling

Wim-Paul Breugem, Wilco Hazeleger and Rein Haarsma[†]

KNMI

Koninklijk Nederlands Meteorologisch Instituut

A numerical study has been made of the mechanisms of Northern Tropical Atlantic (NTA) variability and the response to CO_2 doubling. The model consists of an AGCM (T30L7) coupled to a slab mixed-layer model for the ocean. Results from 2 simulations are shown: a control run with present-day CO_2 and a run with a doubled CO_2 concentration. The results show that the Wind-Evaporation-SST (WES) feedback acts only in the deep NTA, and that it is phase-locked with the seasonal cycle of the climatological Intertropical Convergence Zone (cITCZ). The WES feedback is weaker in the double-CO_2 run, related to a northward shift of the cITCZ.

1. Introduction

The warming of the earth's climate may affect the dominant patterns of climate variability. This study is concerned with the effect of increasing CO_2 on the interhemispheric mode in the NTA. We make use of an NTA SST index defined as the averaged SST anomaly over boreal spring (MAM) and the region 55-20°W, 5-25°N.

2. Results

2.1 Change in NTA climatology

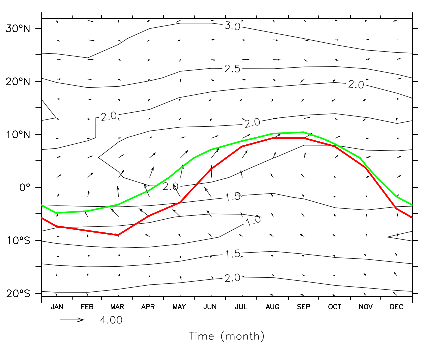

Figure A. *Time-latitude diagram of the change in climatological SSTs (thin contours, in °C) and near-surface winds (vectors, in m/s), both averaged over the Atlantic from 55-20°W. The two thick lines indicate the cITCZ in the control (red) and double-CO_2 run (green).*

The enhanced northward SST gradient and near-surface winds in the double-CO_2 run near the equator in boreal winter and spring, suggest that the northward displaced cITCZ is related to a positive WES feedback in the deep TA.

2.2 Mechanisms and change of interhemispheric mode

Figure B shows the structure of the interhemispheric mode in April. In the double-CO_2 run the SST anomalies extend less far towards the southwest and the anomalies in the deep NTA are weaker.

The interhemispheric mode in the NTA displays a pronounced seasonal cycle (figure C). Externally forced trade wind anomalies initiate growth of SST anomalies in the northern NTA in boreal winter by reducing wind-induced evaporation. In the southern NTA a WES feedback is at work. The WES feedback is positive only in boreal winter and spring, while it is negative in summer and fall. The sign change in the WES feedback is related to the seasonal cycle of the cITCZ, as illustrated in figure D.

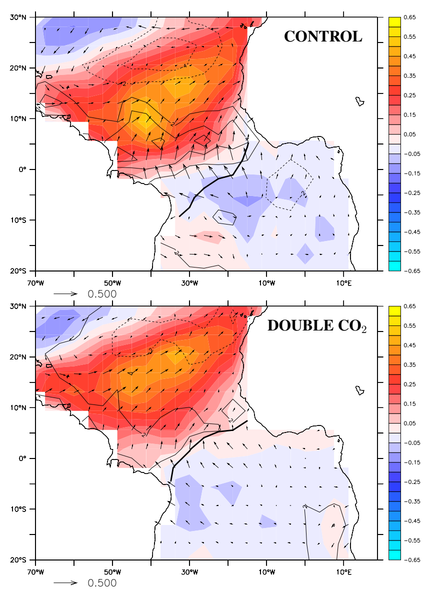

Figure B. *Regressions of SSTs (colors, in °C), near-surface winds (vectors, in m/s) and net downward heat flux anomalies (thin contours, in W/m²) in APRIL onto the NTA SST index for boreal spring. The thick black line represents the location of the cITCZ.*

In the double-CO_2 run the SST, wind and heat flux anomalies in the southern NTA are weaker than in the control run (figures B,C). Furthermore, the SST anomalies propagate less far towards the south. This suggests that the WES feedback in the deep NTA is weaker. Due to the northward shift of the cITCZ in the double-CO_2 run, the cITCZ stays less long south of the deep NTA and hence the positive WES feedback in the deep NTA acts less long.

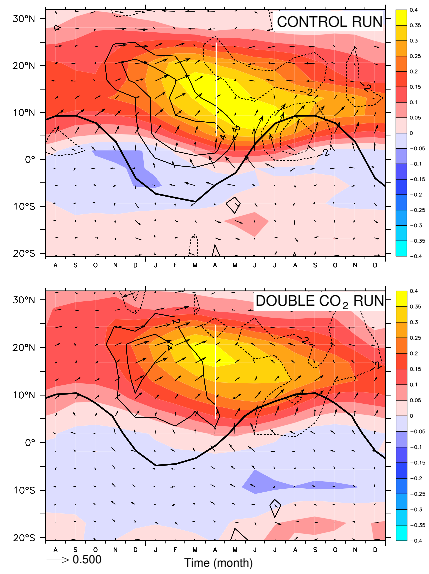

Figure C. *Same as in figure B, but the regressions are now zonally averaged over the Atlantic from 55-20°W and are shown in a Hovmueller diagram as function of lag. The months prior to (after) April, indicated by the white line, correspond to negative (positive) lags. The thick black line represents the location of the zonally averaged cITCZ.*

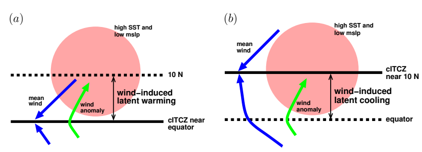

Figure D. *Phase-locking of the WES feedback in the deep NTA (0-10°N) with the seasonal cycle of the cITCZ. The WES feedback is positive when the cITCZ is near the equator (a), but negative when the cITCZ is north of the deep NTA (b).*

3. Conclusions

a) The cITCZ shifts towards the north as a result of strong warming at high northern latitudes and a positive WES feedback in the deep NTA.

b) The WES feedback is phase-locked with the seasonal cycle of the cITCZ, being positive when the cITCZ is south of the deep NTA and negative when the cITCZ is located north of the deep NTA.

c) The cITCZ stays less long south of the deep NTA and consequently the positive WES feedback acts less long and the interhemispheric mode is weaker.

References

W.-P. Breugem, W. Hazeleger and R. Haarsma. Mechanisms of Northern Tropical Atlantic variability and response to CO_2 doubling. Submitted to J. of Clim., March 2006

[†] *Royal Netherlands Meteorological Institute (KNMI), Oceanographic Research Department, P.O. box 201, 3730 AE De Bilt, Netherlands, e-mail: breugem@knmi.nl*