Obliquity signals at low latitudes

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1. Research Aims

Changes in Earths obliquity (tilt of the rotational axis) have a small effect on incoming solar radiation (insolation) at low latitudes (see 2). Yet many sediment records at low latitudes reveal an obliquity signal. Various mechanisms have been invoked to explain this signal, such as:

- the remote influence of high-latitude obliquity-driven glacial variability (e.g. Refs 1-5)
- obliquity-induced changes in mid- to high-latitude temperature and humidity, affecting lower latitudes without changes in ice sheets (ref 6)
- obliquity-driven changes in the summer inter-tropical (cross-equatorial) insolation gradient (SITIG, ref 7)

Here we use a coupled ocean-atmosphere high resolution global climate model, EC-Earth, to investigate how tropical climate responds to changes in obliquity without ice sheets. We focus on the SITIG-mechanism (see 2).

2. Model Set-up & Insolation Forcing

EC-Earth is a fully coupled ocean-atmosphere global climate model, with an atmospheric resolution of ~1.1 ° x1.1 ° and 62 vertical levels, and an oceanic resolution of ~1 °x1 ° with 42 levels. The atmosphere is based on a weather forecast model (IFS C31R1, ECMWF) and therefore has sophisticated parametrisations of atmospheric processes (ref 8, 9). Ice sheets are kept fixed at their present-day extent.

We focus on the effect of obliquity by prescribing a round orbit around the Sun (i.e. no precession) and performing two experiments with high obliquity (24.45 °, **Tmax**) and low obliquity (22.05 °, **Tmin**, see Fig. A1 and ref 6).

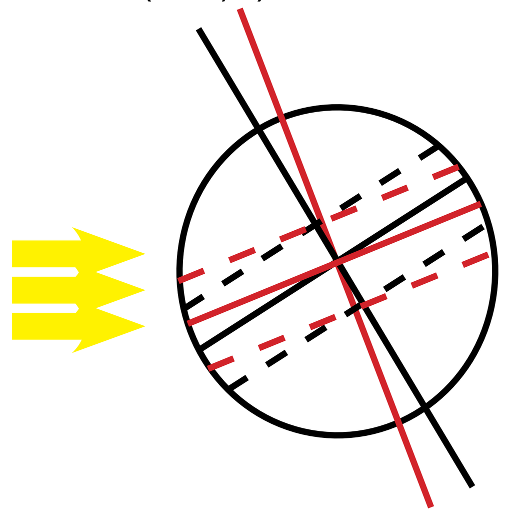

Fig. A1: *Sketch showing Earth at high obliquity (24.45 °, **Tmax**) and low obliquity (22.05 °, **Tmin**).*

A higher obliquity (tilt) causes higher summer insolation and lower winter insolation on both hemispheres (Fig. A2). Also, at higher obliquity the summer cross-equatorial insolation gradient is stronger (Figs. A1, A2). This Summer Inter-Tropical Insolation Gradient (SITIG) may strengthen the winter Hadley cell circulation (refs 7, 10).

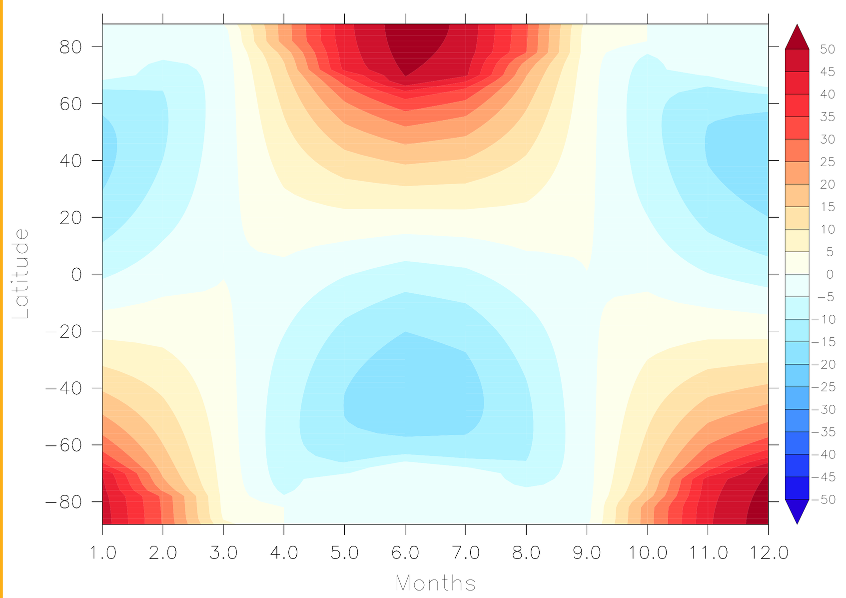

Fig. A2: *Insolation difference between high obliquity (**Tmax**) and low obliquity (**Tmin**), in W/m^{-2}.*

3. Results

B. Net precipitation (P-E) difference **Tmax** - **Tmin** in mm/day. Wind vectors for **Tmax** in m/s, purple vectors indicate where winds are stronger during **Tmax** than during **Tmin**.

C. Zonal mean meridional surface wind speed during **Tmax** and **Tmin** in m/s.

D. Zonal mean vertical velocity during **Tmax** (contours) in 10^{-2} Pa/s. Colors indicate the **Tmax** - **Tmin** difference.

E. Zonal mean moisture transport *Q* during **Tmax** and **Tmin**, vertically integrated, in kg/(ms).

F. Moisture transport for **Tmax** in kg/(ms), vertically integrated. Purple vectors indicate where moisture transport is stronger during **Tmax** than during **Tmin**.

Boreal summer (JJA)

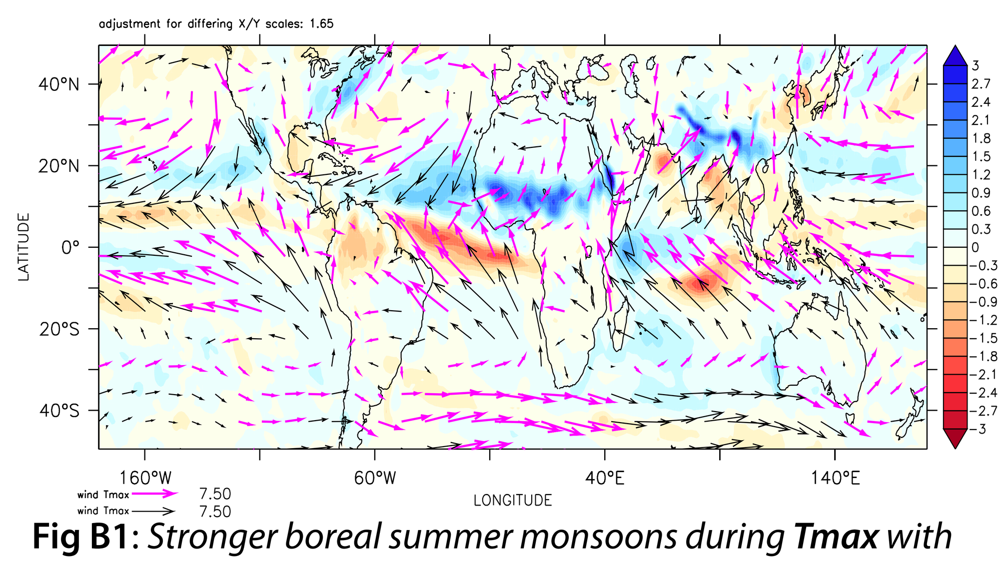

Fig B1: *Stronger boreal summer monsoons during **Tmax** with stronger winds, redistribution of net precipitation from ocean to land.*

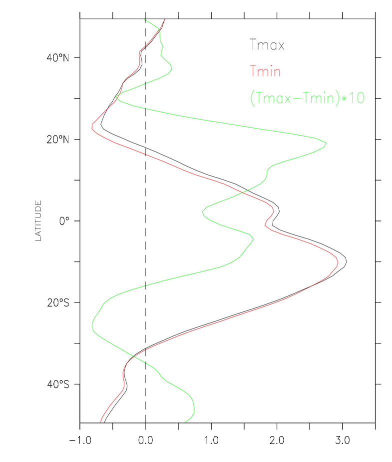

Fig C1: *Stronger northward cross-equatorial surface winds*

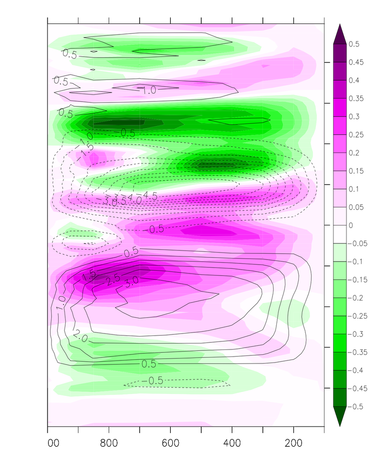

Fig D1: *Stronger winter Hadley cell extending slightly further north.*

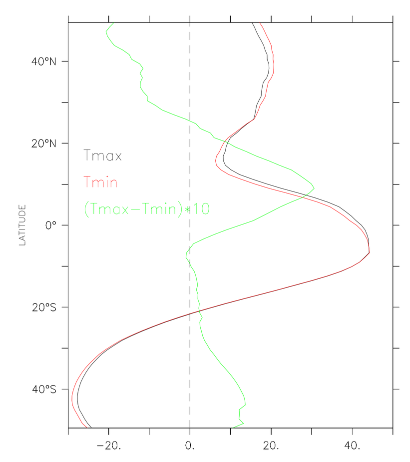

Fig E1: *Stronger northward moisture transport, especially in NH tropics.*

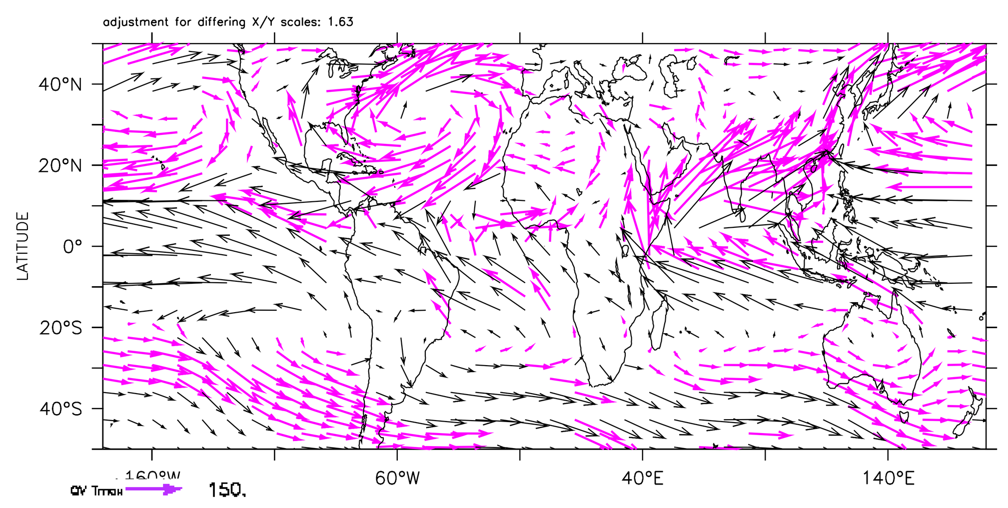

Fig F1: *Stronger moisture transport into the monsoon regions, cross-equatorial moisture transport enhanced mostly over the Indian Ocean.*

Austral summer (DJF)

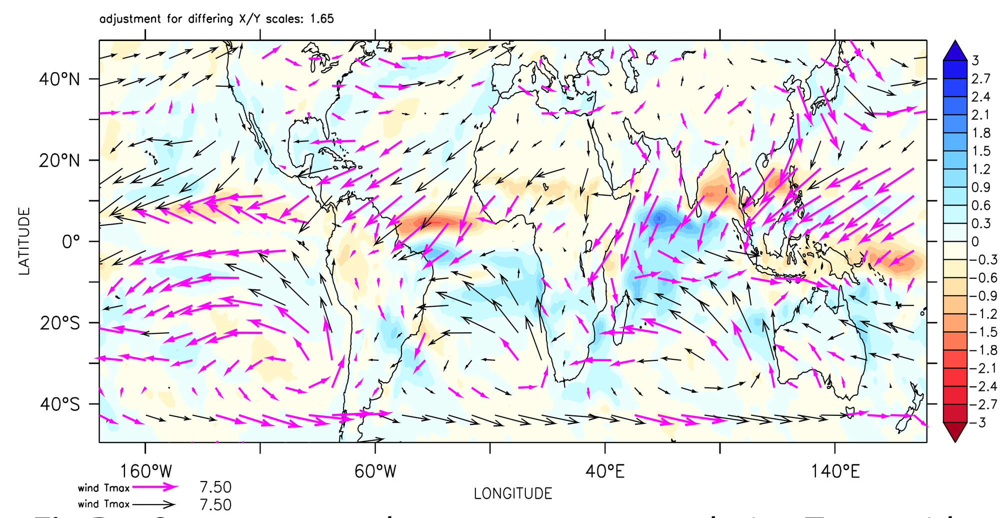

Fig B2: *Stronger austral summer monsoons during **Tmax** with stronger winds, redistribution of net precipitation from ocean to land.*

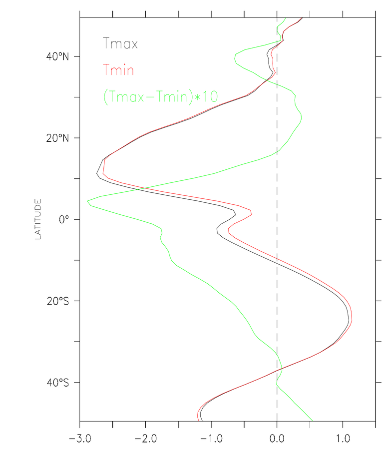

Fig C2: *Stronger southward cross-equatorial surface winds*

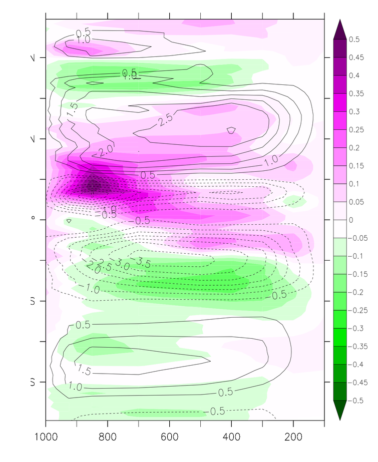

Fig D2: *Stronger winter Hadley cell extending slightly further south.*

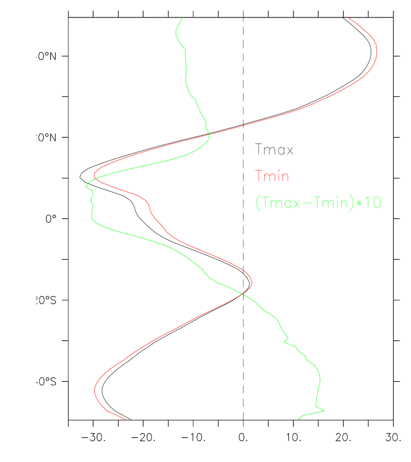

Fig E2: *Stronger southward moisture transport.*

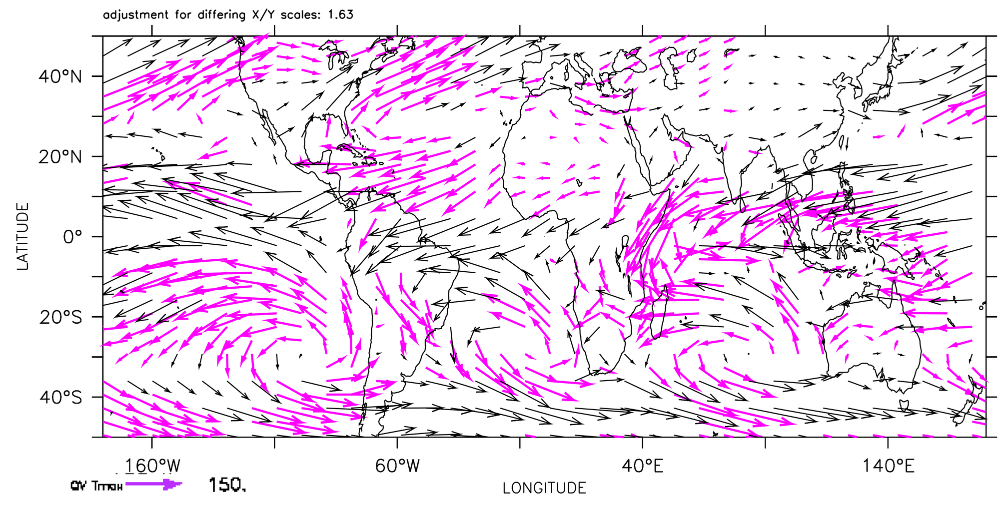

Fig F2 *Stronger moisture transport towards the south across the tropics, cross-equatorial moisture transport enhanced mostly over the Indian Ocean.*

Annual mean

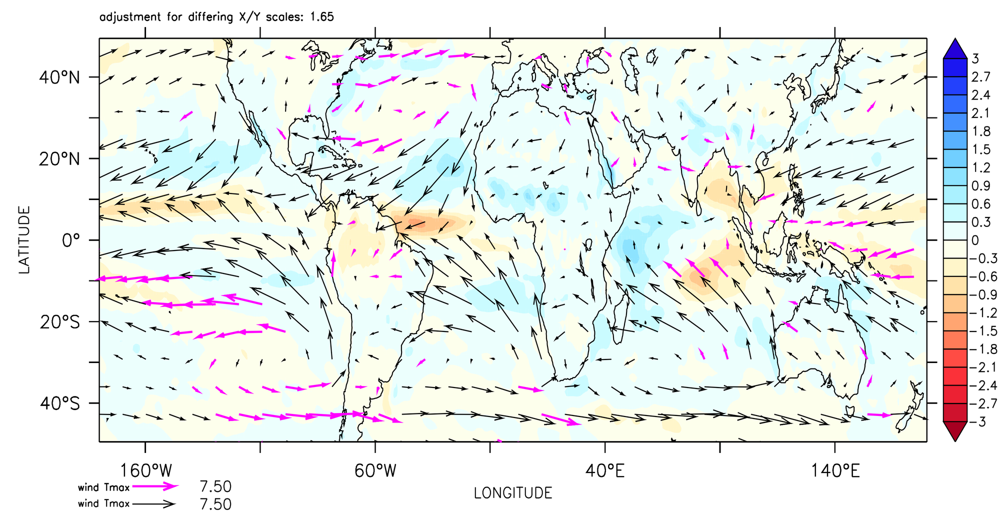

Fig B3: *Winds generally weaker during **Tmax**, precipitation changes resemble mostly boreal summer changes.*

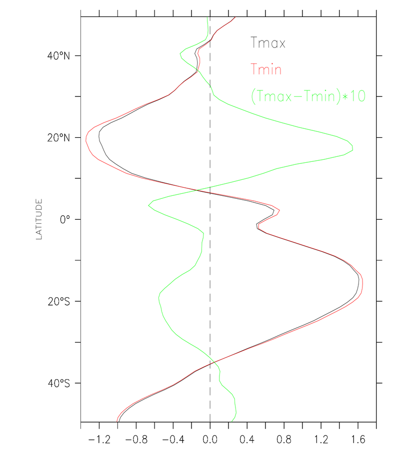

Fig C3: *Weaker meridional winds, weaker trade winds.*

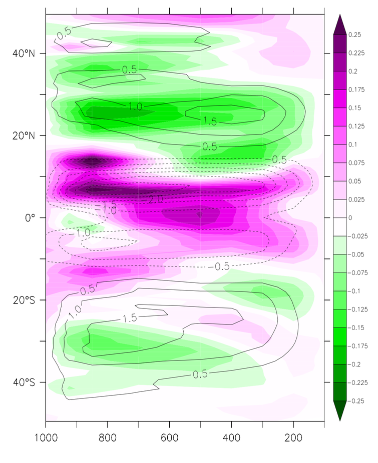

Fig D3: *Weaker circulation in the Hadley cells.*

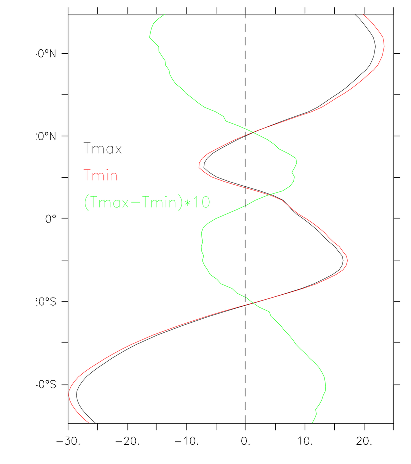

Fig E3: *Weaker meridional moisture transport.*

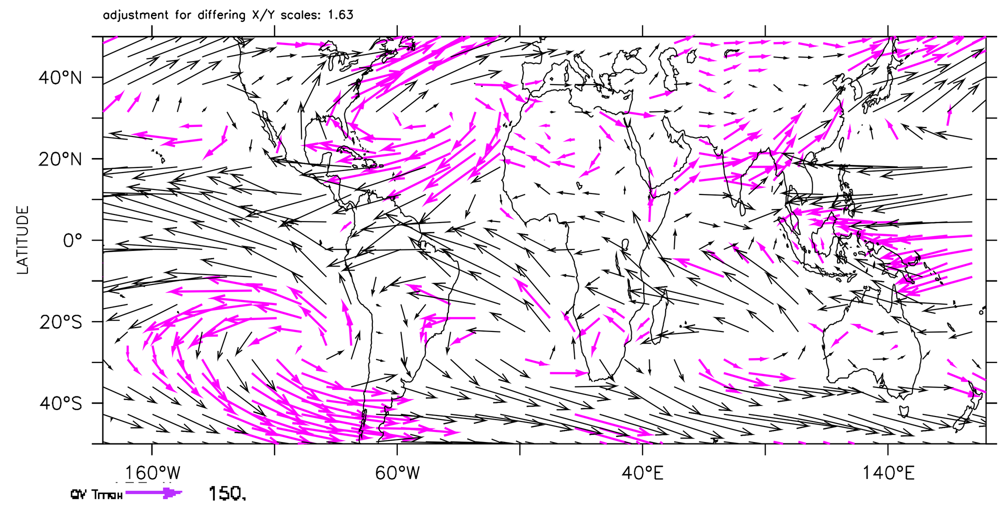

Fig F3: *Moisture transport across the tropics generally weaker.*

4. Discussion and conclusions

We show that tropical circulation can be affected by obliquity without any changes in high-latitude ice sheets. During boreal and austral summer, the zonal mean tropical circulation changes are in line with obliquity-induced changes in cross-equatorial insolation gradient. Surface winds, and moisture transport into the summer hemisphere is increased, as proposed by the SITIG-hypothesis (ref 7). However, the response is not uniform across all longitudes. The annual mean changes are not related to the insolation gradient, but reflect the annual mean redistribution of insolation from low to high latitudes and the corresponding decrease in the equator-to-pole temperature gradient. The obliquity-induced changes in boreal and austral summer that we find in our model suggest that tropical circulation may respond to obliquity without high-latitude influences. Also, this may imply that changes in the insolation gradient (SITIG) instead of the 65 ° N insolation (remarkably similar in pattern) could be used to interpret low latitude sediment records.

References

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