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Obliquity signals at low latitudes: a result of the cross-equatorial tropical insolation gradient?

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Despite the near-zero obliquity-induced insolation changes at the tropics, an obliquity signal is present in various sediment records at low latitudes. A number of hypotheses have been brought forward to explain the presence of obliquity at the tropics, especially in North-African records of monsoon strength. Firstly, the latitude of the tropics changes from 22° to 24.5°, shifting the area under the influence of the monsoon by $\sim$300 km, which could influence its poleward penetration. A second hypothesis involves the strengthening of the austral winter insolation gradient at times of high obliquity, forcing stronger trade winds which become part of the North-African monsoonal south-westerlies, intensifying the North-African summer monsoon. Thirdly, influences of higher latitudes, where obliquity-induced changes in insolation are larger, could strengthen the North-African monsoon through increased northerly moisture transport into the monsoon region and a strengthened Asian low pressure system. The fourth hypothesis is based on the insolation gradient, specifically the cross-equatorial insolation gradient between the Tropics of Cancer and Capricorn. This insolation gradient drives the differential sensible heating between the two limbs of the winter hemisphere Hadley Cell and therefore the strength of the monsoon. This hypothesis suggests that the obliquity signal in the tropics arises without influence from higher latitudes.

Using a high-resolution coupled climate model, EC-Earth, we can oppose the first three hypotheses. Comparing two experiments of low and high obliquity we find a more northward North-African monsoon during high obliquity, as suggested by the first hypothesis. However, we find that precession has a much larger effect on the northward extend of the North-African monsoon. Also, we find a very small increase in trade wind strength over the South-Atlantic for obliquity. Furthermore, spectral analysis shows that the winter hemispheric insolation gradient varies mostly with precession and very little with obliquity, contradicting the second hypothesis. Concerning the third hypothesis, in our EC-Earth experiments we find only small changes in moisture transport from the north into North-Africa which are negligible compared to changes in moisture transport from the tropical Atlantic. We also do not find evidence that the North-African monsoon strength is influenced by the Asian continental heat low. The lack of influence from higher latitudes on the North-African monsoon and the increased moisture transport from the tropical Atlantic suggest that the obliquity signal arises from the tropics themselves. Furthermore, across the whole tropics we find that during high obliquity cross-equatorial winds and moisture transport as well as the Hadley circulation are stronger during both boreal and austral summer. This is in agreement with a strengthened cross-equatorial insolation gradient, suggesting that this gradient forces the obliquity variations in the tropics without requiring the higher latitudes.