

Interactive comment on “Changes in the strength and width of the Hadley circulation since 1871” by J. Liu et al.

Anonymous Referee #2

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The manuscript presents a study on the evolution of the Hadley circulation in the last 120 years as simulated by the 20CR meteorological reanalysis. The motivation is based on the prediction obtained with climate simulations for this century that the Hadley circulation would tend to weaken and broaden as response to the increase of greenhouse trace gases in the atmosphere. The authors attempt to identify this signal in the climate evolution of the last 120 years. Their main conclusion is that in the 20CR reanalysis the relationship between temperature and the Hadley circulation is not as simple as could be derived from climate simulations, and it seems to be different in the Northern and the Southern Hemispheres.

The manuscript is well written and I think it addresses the quite important question of the changes of the large-scale circulation patterns in a climate driven by increased

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concentrations of greenhouse gases. The Hadley circulation certainly influences the precipitation regimes in the Tropics and the extratropics- and therefore is relevant for climate impact studies - and also may strongly modulate the formation of clouds and thus influence the cloud-feedback with rising temperatures, the largest single source of uncertainty for climate projections.

I have some suggestions that the authors may want to consider.

The main comments pertains to the confidence the authors place on the 20CR reanalysis. The manuscript explains rightly that the 20CR reanalysis only assimilates surface observations. Its main advantage in comparison with other reanalysis is the long period covered. However, the 20Cr reanalysis are not free from problems and some recent publications have pointed out possible inhomogeneities due to the changing number of surface stations that are assimilated through the 20th century and that may give rise to spurious trends. For instance, the paper by Fergusson et al indicates that inhomogeneities in the 20CR data over the United States are quite likely present and recommend not to use data pre-1940 should be used to determine long-term trends. I think the authors should comment on the potential inhomogeneity in other areas more relevant for the Hadley Circulation and in which the density of stations is more scarce than in the United States

20 version 2 (20CR2), which provides the first estimates of global tropospheric variability from 1871 to 2008 (Compo et al., 2011). Preliminary validations suggest that the 20CR2 depicts more realistic vertical structures of temperature trends in the tropics and subtropics, and probably suffers less from spurious trends than any previous re-analyses (see more detailed discussion of the key differences between the 20CR2 and previous reanalyses, and the evaluations of the 20CR2 in Sect. 2).

see my comment above

'25 between that pressure level and the top of the atmosphere. Note that the Hadley Circulation is a zonal-mean quantity, although there is considerable zonal asymmetry

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of the Hadley Circulation.'

This sentence sounds contradictory. If the Hadley Circulation is defined as a zonal-mean quantity it cannot display zonal asymmetry

:10 Figure 2d shows the width of the Hadley Circulation, which is defined as the distance between the northern and southern edges of the Hadley Circulation. It appears that the width of the Hadley Circulation has not yet completed a cycle since 1871. Specifically, I do not fully understand what 'complete a cycle' means. There is no guarantee that the behavior of the Hadley Circulation has to be cyclical. So which is the 'cycle' ?

'come stronger and narrower. Moreover, the width of the Hadley Circulation has not finished a full life-cycle since the 1870s, which indicates the observed expansion in recent decades might be a reflection of a long-period oscillation. To further confirm the identified secular variability, we perform a spectral analysis on the time series of the width of the Hadley Circulation. The spectral analysis indicates that the width of'

The inclusion of new results in the conclusion section is misplaced, in my opinion.

'the width of the Hadley Circulation. The spectral analysis indicates that the width of the Hadley Circulation exhibits a clear secular peak indicative of centennial-scale variability that is distinct from the null hypothesis of a red-noise stochastic process, statistically significant (>99 %, not shown).

Which red-noise null-hypothesis ? I guess the authors mean an autoregressive process of order one, but this is not clear. Why is this null-hypothesis realistic ? In any case, to infer a centennial-scale cycle from a 120-year long record is clearly adventurous. I guess that another null-hypothesis, for instance long-term memory processes would yield a different level of significance. The length of the records is just too short to infer any cyclic behavior at these long time scales

In Figure 5 the authors present a correlation analysis between some measures of the

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Hadley circulation and tropical temperatures, separately for a warm and a cold period. The wide scatter of the data points is evident, and I think that the authors should include the uncertainties in the regression lines. Also consider that these uncertainties are quite sensitive to assumptions about the normal distribution of data. For instance, in Fig 5, my visual impression is that the regression line for the warm period (red dots) is dominated by a high temperature outlier. It may be worth exploring how sensitive the regression line is to trimming outliers. Since Fig 5 is being used to support claims about the relationship between the strength and width of the Hadley circulation on tropical temperature, I think it is important to have a robust handle on the uncertainties of these regressions.

This is related also to the correlations indicated in Table 1. and the trends shown in Fig 1. The level of significance or the width of the uncertainty ranges depends quite strongly on the null-hypothesis. For instance, I guess that the level of significance in Table has been estimated assuming as null-hypothesis uncorrelated white noise. However, tropical temperatures are clearly serially correlated and even display a quasi cyclic behavior related to ENSO. The authors should explain briefly how they have determined the level of significance.

Ref. Detecting inhomogeneities in the Twentieth Century Reanalysis over the central United States. Ferguson CR and Villarini G. JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D05123, doi:10.1029/2011JD016988, 2012

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