

## ***Interactive comment on “Drastic shrinking of the Hadley circulation during the mid-Cretaceous supergreenhouse” by H. Hasegawa et al.***

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Review of the paper entitled “Drastic shrinking of the Hadley circulation during the mid-Cretaceous supergreenhouse by H. Hasegawa, R. Tada, X. Jiang, Y. Suganuma, S. Imsamut, P. Charusiri, N. Ichinnorov, and Y. Khand.

General comment

This paper deals with an important and unsolved question: the cause of a flatter meridional gradient of temperature from Equator to Pole during Mid-Cretaceous. Indeed, there are now some evidences of diagenesis in O18 of carbonate that could provide wrong temperature reconstructions, these new informations are given by the O18 of apatite (PO<sub>4</sub>) which may be more reliable to reconstruct temperature (Puceat, 2007).

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Nevertheless, the distribution of meridional temperature is still a challenge during very warm climates (LPTM, early Eocene and Mid-Cretaceous). The authors suggest here, that desert could be an appropriate “proxy” to understand Hadley cell variation, tropical dynamics and energy distribution. The major input of the paper is therefore to reconstruct from deserts, location and divergence axis, the descending branch of the Hadley cell and to correlate the width of the Hadley cell (mainly in Northern Hemisphere which is better constrained) to different CO<sub>2</sub> levels during mid Cretaceous. More precisely this width decreases from early to mid-Cretaceous and increases again from mid to late Cretaceous (around 10°). This is an interesting contribution to our understanding of atmospheric dynamics during the Cretaceous. Nevertheless, I have some questions and comments, I'll like the authors answer before publication. I give below a detailed review on these points.

Detailed review

1. Introduction In the introduction, the authors give a good summary of Cretaceous climate and suggest that this study could bring new constraint on subtropical high pressure belt and divergence axis.

2. Cretaceous eolian sandstones in Asia I'm not an expert on these measurements, but this is indeed crucial for the paper. the latitudinal shift for the deserts poleward for late and early Cretaceous and the shrinking equatorward for mid Cretaceous have to be robust. Despite large error bars, it seems to be reliable. Nevertheless, this section is not clear and not very easy to read. Especially, the methodology allowing inferring this shift in sandstone distribution should be more clearly addressed.

3. Results

For Section 3.1 (Latitudinal shift of the subtropical high pressure belt) and 3.2 (Changes in the width of the Hadley circulation), the link between the sandstone distributions in the different basins and the width of Hadley cell is well described.

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In the section 3.3 (Possible cause of changes in the width of the Hadley circulation), the authors describe the possible causes of the Hadley cell shrinking. The modelling part of the discussion could be enhanced: 1- A previous study in a glacial climate of such a possibility was first published in 1998 by Ramstein et al. This was done in another context (LGM) using an AGCM model but it did show the possibility of changes in the width of the Hadley cell related to changes in Equator to Pole temperature gradient. This study may be cited because, in contrast with Poulsen simulations which are, more appropriate Cretaceous simulations (Poulsen, 2003), Ramstein et al. (1998) show changes in the Hadley cell width. 2- Concerning the Mid Cretaceous, the authors should care on the fact that Poulsen (2003) uses an AOGCM and Fluteau et al. (2007) prescribed the SST. This is indeed a major difference and should be discussed.

Whereas section 3.4 (Drastic shrinking of the Hadley circulation and intensified Mid-latitude humidity), is fine for me. I'm not at all convinced by section 3.5 (Relationship with variations of ocean circulation during the Cretaceous). The relationship between changes in deep water circulation and width of the Hadley cell is not really convincing as far as simulations available do not show such a correlation. Moreover, as honestly, shown by the authors, this hypothesis is not supported by Nd data (MacLeod, 2008) and therefore I'll remove this section and replace it by a shorter discussion.

Concerning section 3.6 (Hypothesis: non-linear response of the width of the Hadley circulation), the authors should discuss seriously the possibility of such phenomenon during LPTM and Early Eocene in data and models. Indeed, the CO<sub>2</sub> threshold may be dependant on paleogeography and therefore, the same pCO<sub>2</sub> will not lead to the same Hadley cell behaviour, nevertheless this point should be discussed more deeply.

Last but not least point concerns the need for non linear response to explain the data which is not clearly demonstrated.

Conclusion The paper is interesting; the idea to use desert location and sandstones distribution to constrain the tropical atmosphere circulation is appealing. Neverthe-

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less, there are some minor caveats in the paper that the authors should modify before publication.

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