Author's response to "Interactive comment on "Precessional and half-precessional climate forcing of Mid-Devonian monsoon-like dynamics" by D. De Vleeschouwer et al.".

by David De Vleeschouwer

The authors want to thank "anonymous referee n°1" for the helpful review. The reviewer points to 4 weaknesses, confusions or shortcomings in the manuscript published in "Climate of the Past Discussions". We believe that we can eliminate all 4 caveats in the next round of revisions and that will improve the paper.

1. **Lack of information on the paleolocation of the record**: The reviewer correctly notes that all the discussion is based on tropical equatorial dynamics and monsoons. Therefore, a quantitative estimate of the paleolatitude is essential. Unfortunately, remagnetization hinders the determination of the paleolatitude of the studied section (Zegers et al., 2003). Currently, to our knowledge there is no precise paleolatitude reconstruction for the Devonian of Southern Belgium. Nevertheless, the section can be referenced in paleolatitude fairly accurately based on information obtained from contemporaneous, fairly proximal sections in Britain, France, Germany, etc.

   The paleo-environment of the section corresponds to a mixed carbonate-siliciclastic ramp (Mabille and Boulvain, 2007), located in the Rhenohercynian basin, on the southern margin of the Avalonian microcontinent (Cocks et al., 1997). This basin was limited by the Euramerican Old Red Continent to the north and by the Normannian and Mid-German highs to the south (Ziegler, 1990). The apparent polar wander paths (APWP) of Avalonia and Euramerica are well established (Torsvik et al., 1993; Mac Niocaill and Smethurst, 1994). Indeed, Torsvik et al. (1993) estimated the paleolatitude of Southern Britain at 389 Ma to be 6.9°S. Since during the Middle-Devonian the studied section and Southern Britain were only a few hundred kilometers apart (Cocks et al., 1997), this value serves as a good estimate for the paleolatitude of the section. This information will be included in the revised version of the manuscript.

2. **No reference / discussion of Devonian climate simulation for the monsoon extent and intensity:** The reviewer asks for a more quantitative discussion of the paleoclimate of the studied section. Until today, no General Circulation Model (GCM) has been applied to the Devonian configuration. Therefore, we will supply the revised manuscript with some references indicating that the climate of the southern subtropics on the southeast coast of Euramerica was characterized by monsoon-like dry and wet seasons.

   As early as 1916, Joseph Barell interpreted the red sandstones, shales and conglomerates of the Devonian system in the British Isles as "*fluviatile in origin; laid down over river flood plains by streams in times of flood, exposed to air in times of drought. They record in this way the existence of an alternation of seasons of rainfall and drought -a climate with an arid season, but not an arid climate. [...] Sediment was brought into these basins by rivers from the bordering uplands and from the more distant regions to the northwest. The excess beyond what was laid down by the rivers in time of flood to maintain their grade across the sinking basins was carried through to the shallow sea which lay on the surface of the continent to the southwest*". As the studied section is located in this shallow sea, in the Rhenohercynian basin, the flux of detrital material into this depositional environment will reproduce a seasonal pattern. Ever since Barell's interpretation (1916), paleoclimatic indicators confirmed this view (e.g. Woodrow et al., 1973; Heckel and Witzke, 1979; Woodrow, 1985; Witzke and Heckel, 1988; Sageman et al., 2003; Cressler, 2006, 2010), and a consensus on the seasonal wet-and-dry climate model for the Devonian of the Euramerican coastal plains exists. The paleolatitude combined with the proximity of large continental areas (as well Euramerica as Gondwana) play an important role in determining the potential for an intense monsoonal circulation over Euramerica (Witzke, 1990). This information will be included in the revised version of the manuscript to reinforce the argument about the existence of a monsoon-like climate at the paleolocation of the studied section.

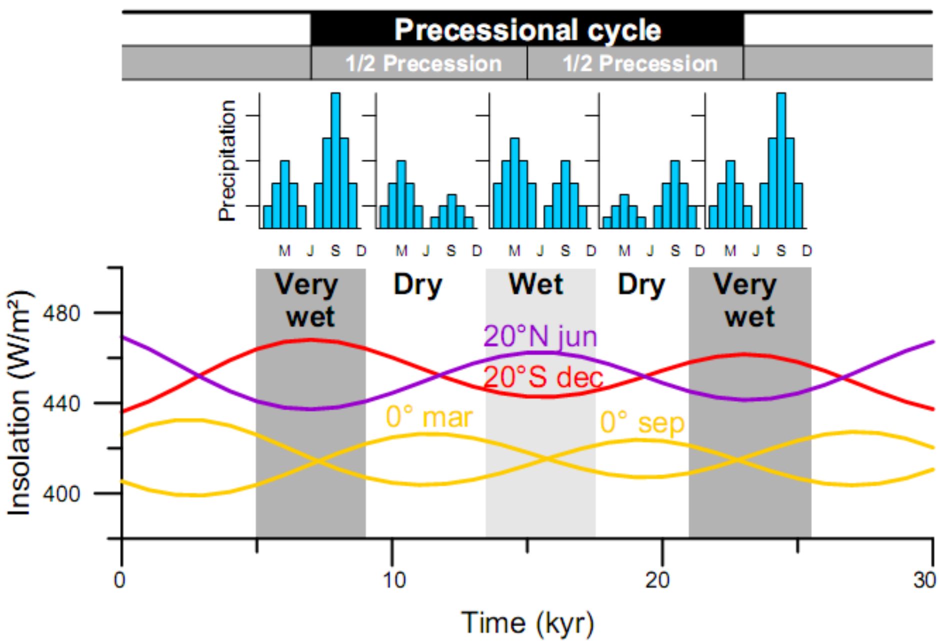
3. **No real discussion on error of dating and accumulation rate and no clear discussion on tuning the peak on precession cycle:** We are pleased that the reviewer thinks that this methodology is honestly described in the discussion paper and we agree with him/her that the "tuning" of the chrono-biostratigraphically derived accumulation rate (11.3 cm/kyr) to the astronomically derived accumulation rate (8.8 cm/kyr) deserves more discussion.

   The only time-constraint available in the studied section is the delineation of the *ensensis* biozone. In the discussion paper, we use a duration of ~300 kyr for this biozone in order to determine a constant average accumulation rate (~11.3 cm/kyr) for the first 33.75 m of the section. Then, we recalibrate this accumulation rate so that the observed cyclicity matches the duration of a precession cycle (8.8 cm/kyr). To better justify the adjustment of the average accumulation rate, the error bars on the duration of the *ensensis* biozone will be taken into account in the revised manuscript. In the well-studied nearby Eifel sections, the *ensensis* biozone covers about 8% of the duration of the Eifelian (Weddige, 1977; Bultynck et al., 1988; Kaufmann, 2006). As the Eifelian lasted for 3.8 ± 6 Myr (Kaufmann, 2006), the *ensensis* biozone has a duration of 304 ± 480 kyr. Therefore, the chrono-biostratigraphically derived accumulation rate is most likely around 11.1 cm/kyr and certainly not less than 4.3 cm/kyr. The huge spread in these values clearly demonstrates the large uncertainties on the chrono-biostratigraphy of the Devonian. However, this time-constraint is sufficient for the observed cyclicity to be interpreted as precession cycles. Indeed, under these preconditions, one of the 21.5 observed 1.31 - 1.86 m cycles in the *ensensis* biozone most probably lasted around 13.2 kyr, but certainly no longer than 34.1 kyr. This result suggests very strongly the assignation of the observed persistent cyclicity to the ~18-kyr Middle-Devonian precessional cycle (quasiperiods of 16824 and 19886 kyr (Berger and Loutre, 1989; Berger et al., 1992)), which implies a revised, astronomically calibrated average accumulation rate of 8.72 cm/kyr for the *ensensis* biozone in the studied section. Given the huge uncertainty on the biostratigraphical time-scale this 21% revision of the accumulation rate is anything but unlikely, nor speculative.

Because of sedimentological reasons, the 2.9 - 3.56 m cycles in the fore-reef environment are interpreted as precessional cycles (see discussion paper for details). With precessional cycles distinguished over the whole section, this information is used to construct a time-series, which is used for spectral analysis. The authors are well-aware about the fact that the strong spectral peak at the frequency of precession is partly due to the procedure of time-axis computation, and this is also mentioned in the manuscript. For this reason, no further conclusions are drawn from the magnitude of this peak. Rather, the main purpose of Fig. 5 is to illustrate two important results: (1) the statistical significance of the half-precessional cycles and (2) the eccentricity modulation. The observed amplitude modulation of the precessional component of the MS and microfacies curves corresponds to what is expected from astronomical theory, and therefore strengthens the interpretation of the observed cyclicity as due to precession. Since this message was not entirely clear to the reviewer, section 4.1 will be rewritten in order to be more clear and convincing.

4. **No clear discussion of why the analogy with PD monsoon and half precession could be robust and appropriate:** As stated in the answer to questions 2, paleoclimatic indicators suggest a seasonal rainfall distribution for the studied section. At the present day, in equatorial regions, rainfall is associated with the twice-annual passage of the Intertropical Convergence Zone. (ITCZ) Considering the paleolatitude of the section, one might expect a similar rainfall distribution. In the discussion paper, we listed strong paleoclimate evidence to illustrate that today's monsoonal systems are intensely controlled by precession, we discuss the most important climatological processes responsible for the astronomical forcing of monsoonal dynamics, we demonstrate that during the Devonian these processes act in the same way compared to today, and so we conclude that the Devonian monsoonal system is (at least) equally sensitive to precessional

forcing. However, we agree with the reviewer that in the revised manuscript the causes and consequences of the half-precession cycles should be presented in a clearer way. Therefore, we will add the figure below to Fig. 10. With this extra figure, we show that every ~9 kyr the summer insolation peaks in either the northern or the southern tropics. As a consequence, every ~9 kyr, the inter-hemispheric insolation gradient is at a maximum and either the southeasterly or northeasterly monsoon is intensified. When summer insolation is intermediate for both hemispheres, neither monsoon is intensified and dry conditions prevail. Moreover, low March or September insolation weakens the corresponding rainy season (Berger et al., 2006; Verschuren et al., 2009). For the tropical paleoenvironment of the studied section, this means that the flux of detrital material not only exhibits maxima during precession maxima, but it also exhibits a more modest maximum during precession minima. The analogy of our results, based on 388 million years old sediments, with the half-precessional cycles found in lacustrine sediments of the past 25000 years in East-African (Verschuren et al., 2009) is far-reaching: Both sedimentary archives are located in the ITCZ migration belt, at almost the same latitude, both archives are positioned on the eastern coast of a large continent and thus influenced by a northeastern and southeastern monsoon and both archives document the role of half-precessional cycles in determining monsoonal dynamics.



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