Geosci. Model Dev. Discuss., 6, C2856–C2865, 2014
www.geosci-model-dev-discuss.net/6/C2856/2014/

Geoscientific Model Development Discussions Open Access

Interactive comment on "Earth Orbit v2.1: a 3-D visualization and analysis model of Earth's orbit, Milankovitch cycles and insolation" *by* T. S. Kostadinov and R. Gilb

T. S. Kostadinov and R. Gilb

tkostadi@richmond.edu

Received and published: 21 March 2014

March 20, 2014

Note: The revised model files are attached as Supplement to this comment.

Responses to Anonymous Referee #1

Comment: This paper does not provide new scientific breakthrough however it has two important contributions. On the one hand it gives an accurate and detailed overview of the science behind the computation of the solar energy received at the top of the atmosphere (insolation). This first part of the paper is more theoretical. All the different

parameters involved in the computation of the insolation are clearly identified and explained. Some more critical aspects are also pointed out. A second part of the paper is devoted to the explanation of the software allowing the users to make this computation easily. The interface and the output are described in detail. Moreover, the figures and graphs displayed have also an educational dimension. At last a section is devoted to the validation of the tool.

General comments Comment: 1. Paillard, D., L. Labeyrie and P. Yiou (EOS, 1996) developed a tool including the computation of the orbital parameters and the insolation (although it is not the major purpose of the tool). This tool also includes a graphical interface. I would like to suggest the authors to mention this work and to point out their additional contribution.

Response: We thank the reviewer for this comment. We now mention the AnalySeries software in the text and emphasize that the Earth orbit model presented here is developed independently of AnalySeries or other similar efforts. Earth Orbit v 2.1 uses first principles and its own internal geometry. The unique contributions of our model are detailed in a paragraph in the Introduction, but specifically as relates to AnalySeries, the additional contributions/differences are as follows: at the heart of the model of our model is a 3D visualization of Earth's orbit that is geometrically and astronomically accurate and has pan-tilt-zoom capabilities. In the GUI and text we focus on detailed understanding of the geometry of the orbit, and the effect of Kepler's Laws. Our GUI is meant to be very user-friendly and one of our main goals is use in educational settings. We also focus on the user's ease of selecting a demo mode with user-chosen orbital parameters that can be greatly exaggerated to visualize imaginary extreme orbits. The user can easily create many imaginary orbits and study them in 3D. This is an important additional contribution compared to AnalySeries. We focus on attractive, color-enhanced 3D visualizations. Our source-code is open and platform-independent and allows more advanced users and students to study and modify it. Finally, we note and acknowledge that AnalySeries has a somewhat different focus and many more capabilities that are not included in Earth Orbit v2.1 (such as spectral analyses, SSA, MTM; choosing seasonal insolation, defining time as true longitude vs. a date). In summary, we posit that the main additional contribution here is the 3D pan-tilt zoom visualization of the actual orbit, the ability to create imaginary orbits, and the higher level of user-friendliness and applicability to educational settings. We now point the reader to AnalySeries so they can compare and verify our solutions and have access to many more insolation computation options.

Comment: 2. The authors propose two starting dates for the calendar, either vernal equinox (20 March) or perihelion (3 January). The first one is commonly used while the second one is hardly used for the paleo purpose. Could the authors elaborate on the significance of choosing one or the other. Although I think that astronomers commonly use the second choice, I can hardly imagine how it can be used for computation of past insolation.

Response: The reviewer is correct that the calendar start date of Jan. 3 can be confusing and is not likely to be used in paleoclimate studies. We nevertheless elect to include that option because it is in our view of great educational value, and the model's target audience is much wider than paleoclimatologists. The ability to illustrate the relativity of the calendar with respect to the physical reality of the orbit is important. Users can see that it really matters whether we select to fix perihelion or the equinox as the calendar start date. We note that insolation time series are indeed computed only for the calendar start date fixed at vernal equinox being March 20. This is stated in the GUI next to the button plotting insolation time series, to avoid confusion.

Comment: 3. This is a technical comment but I think it is really very important. Through the paper and even in the software, time units are sometimes yr and sometimes kyr. This is very confusing. I urge the authors to use one OR the other (not both).

Response: This has been fixed and all relevant units are now thousands of years (kyr).

Comment: 4. Insolation is depending on the latitude, the day in the year and the time.

The authors provide insolation computation for a given time and the corresponding figure, either absolute values or deviation from present. They also provide insolation computation for a given latitude and the corresponding figure for the absolute values (but not for the deviation from the present). At last, there is no computation and no figure in the case of a given day, which is scientifically very important as well. Therefore I was wondering whether the 'missing' possibilities could be added or will be added in forthcoming releases.

Response: The insolation for a given day at a given latitude is indeed computed and as is stated in the text, this is the fundamental quantity from which the other insolation quantities are computed. This value is always displayed and updated in the GUI ancillary outputs. A paleo-time series of insolation on a given date and latitude is indeed computed and displayed (Fig. 4A in the paper). There are multiple possibilities for further options of plotting and displaying absolute values and anomalies on various time and space scales. We do intend to expand these options in future releases, as the author suggests. We also state in the text that for best options for insolation computations on various scales, and time intervals defined in various ways, the solutions of Berger et al. (2010) and Laskar et al. (2004) should be used. We now also point the user to AnalySeries, which also offers more insolation computation capabilities.

Comment: 5. Along the same line, it would be interesting to add the possibility to compute the insolation integrated over several days.

Response: We thank the reviewer for this suggestion. More insolation computation options are planned for future releases (see above response to comment #4).

Specific comments Comment: P5949 – l17-28 : the discussion about the period of insolation variations is a bit fuzzy. Short period (11-yr sunspot cycle) and multi-millennial variability are discussed. How-ever, the short term variability of the orbital parameter is not mentioned. Moreover, the amplitude of these variations and their relative importance in insolation changes is not discussed.

Response: Bertrand et al. (GRL, 2002) discuss these high frequency orbital fluctuations in the context of their effect on insolation and climate. They conclude that high-frequency orbital variability is of very low amplitude and its effect on insolation and surface temperature is negligible, essentially equivalent to model noise. The intrinsic solar variability (11-yr cycle) is shown to have a larger effect on both insolation and climate. This is now discusses briefly in the manuscript.

Citation: Bertrand, C., M. F. Loutre, and A. Berger, High frequency variations of the Earth's orbital parameters and climate change, Geophys. Res. Lett., 29(18), 1893,10.1029/2002GL015622, 2002.

Comment: P5950 – l2 : : : : the longitude of perihelion relative to the moving vernal equinox : : :

Response: Fixed.

Comment: P5950 – l8 : kyr should be used (and maybe defined) instead of Ky.

Response: Fixed.

Comment: P5950 – l17 : ": : : derived for several tens of million years : : :". Of course the mathematical computation can be done over such period. However, it would be more interesting to given an order of magnitude for time interval of validity/reliability of the solutions. Berger's (1978) is definitely much less than several tens of million years.

Response: We have now specified the period of validity for both the Berger and the Laskar solutions, which corresponds to the allowable years since J2000 that can be selected in the GUI.

Comment: P5952 – l4 :"insolation computation logic". I do not understand what the authors are referring to.

Response: This was paraphrased to state "no insolation computation code". We mean that we have not borrowed any code or derived formulae from the above solutions;

rather we start from first principles.

Comment: P5955 – equation 1. There is some potential confusion here. The authors mention that the model uses a heliocentric Cartesian coordinate system. However, the equation is the equation of the ellipse in a polar coordinate system with one of the foci at the origin. Moreover, it seems (although I may be wrong) that the authors discuss several coordinate systems, depending on what they are computing.

Response: This paragraph has been rewritten to properly reflect that Eq. 1 is in polar coordinates, which are then converted to Cartesian heliocentric for plotting, because the main model coordinate system is Cartesian heliocentric. We also explicitly state that the Earth itself is parameterized in its own coordinate system which is then oriented properly in 3D and translated to Earth's chosen position on the orbit, and the plotted.

Comment: L5961 – l25 : please remind the reader what J2000 means.

Response: J2000 is now defined in the Introduction and readers are also reminded of the definition here.

Comment: P5963 – l3 : 'Figure 2b illustrate an imaginary orbit : : :' It would be nice to discuss further this orbit. It is indeed very surprising at first to see that July 1 occurs already during Fall.

Response: We have added a detailed discussion of this imaginary orbit. We have also added a third example orbit, for the case of 10 kyr in the future, to illustrate what happens to the real orbit due to precession effects. We agree this adds an important component to the discussion.

Comment: P5964 – l2-6 : I wouldn't have added some data at this stage. The software is indeed very interesting for the computation of the orbital parameters and the insolation, but the data (whatever they are) are a completely different story, very complex as well. In particular the chronology of the data is a full story by itself. On the other hand I can hardly see the added value of these specific data. Why not choosing other data?

For example, Lisiecki and Raymo (2005) provide a much longer climate record.

Response: We have now added a separate button in the GUI for optional plotting of paleoclimate data in its own separate figure window. In addition to the EPICA ice core data, we have now added the Lisiecki and Raymo (2005) benthic stack and the Zachos et al. (2001) oxygen isotope data sets, both of which go further back in time than the EPICA data. We have also added discussion in the text addressing the fact that it is provided here for information and educational purposes only and is not a focus of the model at this stage, and the chronology of the data itself needs to be treated with caution. In the future, some added functionalities may use the data more extensively. We now end this paragraph with the following statement: "These paleoclimatic data are included for convenience of the user and no further interpretation or analyses are provided. Users are cautioned that the interpretation of these paleoclimatic signals and their uncertainties, time-resolution and chronology (age models) is fairly complex and beyond the scope of this model. They are provided here for illustrative purposes only, e.g. it enables users to easily visualize the last few glacial-interglacial cycles (and the mid-Pleistocene transition to 100-kyr cyclicity, see Introduction), or to visually correlate these paleoclimatic time series with the corresponding Milankovitch parameter and insolation curves."

Comment: P5966 l7 : "+10000 yr since present". Does it mean in the future?

Response: Yes. This usage is now avoided in the text and it is clearly stated in the GUI that negative years are in the past and positive – in the future.

Comment: P5966 – l18 : the assumption already discussed should be reminded instead of quoting the section where they are discussed.

Response: This sentence has been modified to remind the reader what the section referred to is discussing.

Comment: P5966 – l23 : The time interval of reliability of the solutions should be

reminded here.

Response: Done.

Comment: P5967 – l27 : "K-12 classroom". I do not know what it is. Does it correspond to the age of some pupils/students?

Response: This has been rephrased so it is understandable to an international audience.

Comment: Table 1 and figure 1 : the value of the AU is not the same in the table and in the figure.

Response: We have fixed this and the Table 1 value is the same as the one used in the model/displayed in the GUI.

Comment: Figure 5 : Does the authors really mean 1ïĄş computed over three data points? Is it meaningful? Wouldn't it better to give the values for each of the three dates? Or (if possible) make the computation over 365 days.

Response: We have now performed a much more extensive validation (our model with La2004 orbital parameters vs. Laskar's software) for two dates and three latitudes over the entire period of 200 kyr in the past to 200 kyr in the future, with a 1 kyr step. We also superimpose the difference between the Be78 and La2004 solutions as computed by our model. We show the results as absolute difference and percent difference. Results indicate that generally inter-solution differences are larger than the model validation differences. This is now discussed in the text, and the validation figure has been replaced with the figure attached below (Fig. 1, which replaces Fig. 5 in the manuscript).

Comment: Figure 6 : What causes the discontinuity? Is it related to February 29?

Response: The short answer is yes. The discontinuities are caused by two factors. First, the Meeus (1998) data discontinuity in the rate of change and standard deviation of declination are caused by the way Feb. 29 is treated in the leap year – it is removed from the data and dates are counted in the four-year average, not days of year. Thus, for the mean declination for July 1 across all 4 years, all July 1 values were averaged, including the one for the leap year. Second, the Earth orbit model treats March 19 as a longer day to account for the fact that the sidereal year is ∼365.25 days. This is the case when the calendar is fixed to start on vernal equinox on March 20 (when declination in the model is always exactly 0 degrees). Thus, the modeled declination has a discontinuity in its rate of change on March 19. Because of the above, the Meeus (1998)-based curves (green and red) exhibit a discontinuity on Feb.28/March 1, and the validation difference curve (black curve) exhibits discontinuities both on Feb.28/March 1 and March 19/March20. We note that these discontinuities are very small. A brief discussion of this is added in the main text.

Please also note the supplement to this comment:
http://www.geosci-model-dev-discuss.net/6/C2856/2014/gmdd-6-C2856-2014-supplement.zip

---

Interactive comment on Geosci. Model Dev. Discuss., 6, 5947, 2013.

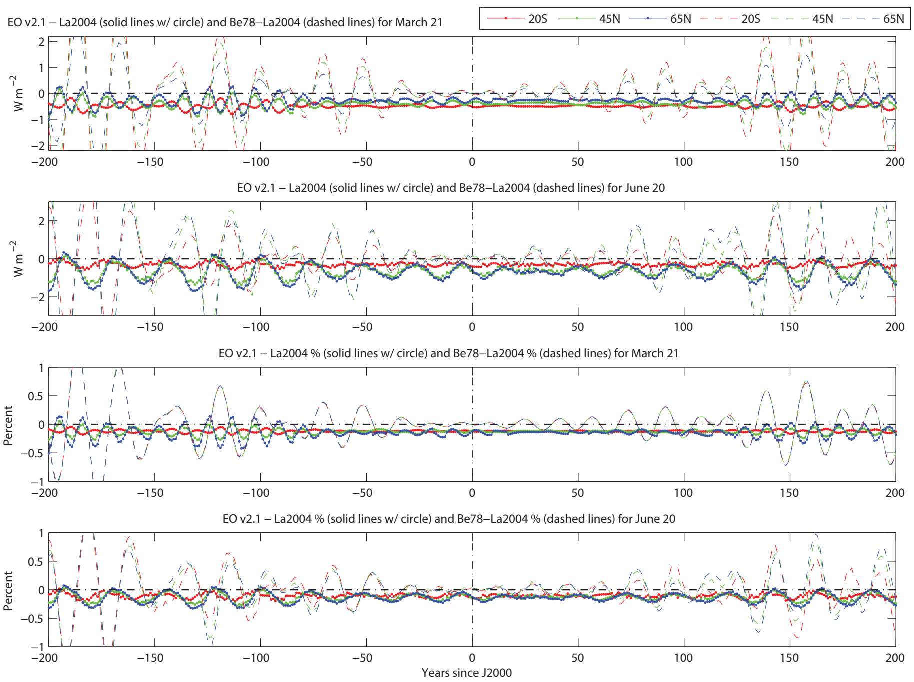

Fig. 1.