Geosci. Model Dev. Discuss., 6, C2350–C2354, 2014
www.geosci-model-dev-discuss.net/6/C2350/2014/

Geoscientific Model Development Discussions
Open Access

Interactive comment on "A 24-variable low-order coupled ocean–atmosphere model: OA-QG-WS v2" *by* S. Vannitsem and L. De Cruz

Anonymous Referee #1

Received and published: 10 January 2014

article

1 General comments

The authors introduce a low-order ocean-atmosphere model consisting of 24 ordinary differential equations. The atmosphere is coupled to the ocean through momentum terms. The authors briefly investigate the behaviour of the model in terms of its physics and its dynamics.

A particular strong point of the paper is the careful description of the model. All equations and parameter choices are presented in detail, which makes it possible for read-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

ers to use this model in their own research. Hence, I recommend this paper for publication in *Geoscientific Model Development*.

2 Specific comments

1. Title: about the name "OA-QG-WS". I understand that OA stands for ocean-atmosphere and QG stands for quasi-geostrophic. But what does WS stand for?

2. P. 6581, L. 27-29: "Interestingly, different attractors seem to emerge for ... (panel a)." (**MINOR REVISION REQUESTED**)

   Multistability (i.e. co-existence of different attractors) can indeed occur in nonlinear systems, but in my opinion this conclusion is not supported by Figure 3a. In Figure 3a I see eight different curves. I assume that the time averages of the A_i ($i = 1, 2, 3, 4$) are plotted versus time for two different initial conditions, right? Indeed, the final values of the two curves for A_4 are not as close as the final values for the other A_i. But the curves for A_3 still show a positive trend, which I would interpret that the time series is too short to obtain a good average.

   In panel b I see no convergence at all. Hence, I find the caption of the figure "Convergence of the mean values ... " somewhat misleading. I would rather call it the evolution of time averages.

   Side remark: for long-term integrations (3.5×10^8 days) I would never have used Heun's method, which is only second order accurate in time. In addition, Heun's method uses a fixed time step and has no ability to control the errors during integration. Since the authors intend to pursue more detailed investigations on the dynamics, I recommend them to use more sophisticated methods using Taylor expansions. For more information, see:

GMDD

6, C2350–C2354, 2014

- A. Jorba and M. Zou. A software package for the numerical integration of ODE by means of high-order Taylor methods. Experimental Mathematics 14: 99–117, 2005. Website: `http://www.maia.ub.edu/ angel/taylor/`

3. P. 6583, L. 17-19: "Two different main regimes emerge, with periodic or stationary regimes and chaotic regimes...".

   Figure 5a shows that the first three Lyapunov exponents are zero for $\Theta^* < 0.065$. Hence, I would call this a quasi-periodic regime: the attractor is (at least) a 3-torus. A stationary regime is characterized by all Lyapunov exponents being negative.

   On the other hand, I am not quite sure whether the first three LE's are really zero. A theorem by Newhouse, Ruelle, and Takens states that flows (in the mathematical sense of the word, nl. evolutions of a differential equation) on a 3-torus can produce strange attractors by small perturbations. I think it is more likely that the first LE is zero, and the next two are very small. (The second 2 LE's only appear to be zero due the scale on the vertical axis.) This would be something to investigate in more detail.

4. P. 6584, L. 7: "... with sharp transition from (quasi-)periodic solutions to chaotic behaviors ..."

   Transitions from quasi-periodic to chaotic behaviour have been observed in several models originating from (geophysical) fluid dynamics. Possible bifurcation scenario's are cascades of quasi-periodic doublings (aka torus doublings) and breakdown of tori. For quasi-periodic doublings see:

   - H.W. Broer, C. Simó, and R. Vitolo. Bifurcations and strange attractors in the Lorenz-84 climate model with seasonal forcing. Nonlinearity , 15(4):1205–1267, 2002.

- H.W. Broer, H.A. Dijkstra, C. Simó, A.E. Sterk, and R. Vitolo. The dynamics of a low-order model for the Atlantic Multidecadal Oscillation. DCDS-B, 16(1):73–102, 2011
- L. van Veen. The quasi-periodic doubling cascade in the transition to weak turbulence. Physica D 210: 249–261, 2005.

For the breakdown of a 2-torus see:

- A.E. Sterk, R. Vitolo, H.W. Broer, Simó, and H.A. Dijkstra (2010) New nonlinear mechanisms of midlatitude atmospheric low-frequency variability. Physica D, 239(10):702–718, 2010

It is up to the authors whether they include any of these references; they are rather beyond the scope of the present paper and journal. However, these references might be useful for the authors' future research (as announced on P. 6584, L. 11).

3 Technical corrections

1. I think it would be very helpful to the reader to present the parameter ranges in a table.
2. P. 6578, formula 10: the symbol f is used for many different quantities:
   - f_0 denotes the constant part of the Coriolis force
   - f_1 is a constant defined in Appendix A
   - $f(1), \dots, f(6)$ denote forcing tendencies (in particular, $f(1)$ does not mean the same as f_1)

I do not recommend to change notation since this might introduce errors or new conflicts in notation. However, it might be a good idea to include a short sentence which explicitly points out that there is a difference between the different f's. Upon reading the manuscript I got a little bit confused about them.

3. P. 6570, L. 13: remove the comma in "... coupling, for low"
4. P. 6572, L. 9: The last name is "Van Veen", not "Veen" (perhaps a LaTeX/BibTeX issue)
5. P. 6572, L. 25: "referred as" should be "referred to as"
6. P. 6574, L. 19: The last name is "Van Veen", not "Veen"
7. P. 6578, formula 8: $-\alpha x$ should be $-\alpha x'$ (missing prime)?
8. P. 6581, L. 24: "... would have not ... " should be " ... would not have ..."
9. P. 6582, L. 23: "Parker (1989)" should be "Parker & Chua (1989)"
10. P. 6584, L. 17: "... opposite tp these..." should be "... opposite to those..."

GMDD

6, C2350–C2354, 2014

Interactive Comment