Review of: Tian et al. (2001), “Experimental and Numerical Studies of an Eastward Jet Over Topography.” *J. Fluid Mech.,* **438**, 129-157.

**Brian Matilla**

MPO 611- Geophysical Fluid Dynamics I

Dr. Tamay Özgökmen

10 November 2015

Order of review:

1) Summary of Work

2) Importance and Broader Impacts

3) Originality of Research

4) Methodology

5) Key Points and Originality of Results

6) Criticisms and Comments

7) Reviewer Recommendation to the Editor

1) In the study performed by Tian et al., laboratory experiments and numerical simulations were conducted to better analyze the dynamical structure of an eastward jet flowing over topographic features. Using a barotropic, rotating annulus, fluid flow over two emulated ‘mountain’ features were studied. The authors then proceeded to use a barotropic model with quasi-geostrophic characteristics and similar conditional parameters in an attempt to recreate the results from the physical experiment. Parameters such as the height of the topographic features and bottom friction of the fluid flow were also available to be adjusted within the model, changes that may prove to be rather difficult to manipulate in the laboratory setting.

2) One of the fundamental questions of geophysical fluid dynamics rests within interactions of rotational flows over topography and how the concepts connect to the actual patterns exhibited by Earth’s atmosphere. There are various larger-scale implications that this research could serve, and so this study focuses on the significance of the variance in the low-frequency oscillations, which have been previously identified as a key marker for the general circulation of the atmosphere. This too can provide an insight into bettering applications for long-range weather forecasting.

3) Dating back to the 1970s, previous research has identified the significant push in analyzing the interaction of rotating flows with underlying topographic features. In fact, the breadth of research extends past Earth into Mars and Jupiter, thus implying that the physics of rotational fluid may share commonalities across planetary bodies (further analysis and experimentation helps to answer the underlying questions, as said in the manuscript). There are subtle differences that help to set this paper apart from previous studies. For instance, other trials involved a baroclinic setup in order to test for blocked and/or zonal flows with similar setups; the authors selected a barotropic environment. Also, the authors’ claim that a baroclinic setup is challenging since it may lead to a three-dimensional flow system that is difficult to explain. Along the same thread, large Reynolds numbers may prove to be difficult to determine under a baroclinic setup. Thus, the authors believe that parameterizations are the recommended approach.

The authors’ paper tries to advance research in an area that has already been hashed out in previous publications in many facets. For instance, the rotating annulus has been used before to study zonal and blocked flows under baroclinic conditions. Even though the authors claim to utilize barotropic characteristics, the concept remains the same as those attempting to examine rotational flow with topographic features. This may lead to speculation that the research is in fact, not original. To the authors’ credit, this research does seek to narrow the gap by introducing barotropic characteristics with the rotating annulus, mechanical forcing of flow, and a numerical model simulation to compare the outcomes, which hasn’t been done previously.

4) *a) Experimental Design*

A water-filled, large rotating annulus with a flat, rigid top and a flat, conical bottom of constant radial slope is built such that the β-effect could be simulated. In order to emulate some of Earth’s topography in the Northern Hemisphere, two symmetric and rigid “mountains” of Gaussian and flat profiles in the azimuthal and radial directions, respectively, were introduced. For flow to take effect in the apparatus, a mechanical pump forces the fluid through the two concentric forcing rings (large and small in that order) such that the flow reaches the wall of the annulus. The counter-clockwise motion of the annulus will then allow for the ‘simulated’ Coriolis force to take effect, deflecting the flow into a “co-rotating, ‘eastward’ jet.” Fluid flow motion is captured by a video camera following the trajectory of neutrally buoyant particles, while two hot-film probes (thermal heating) help to collect data for velocity field fluctuations.

There are two independent control parameters; they are given by the forcing flow rate and angular velocity as F and Ω, respectively. Two distinct non-dimensional numbers measure forcing within the tank: The Rossby number (Ro = U/fL), and the Ekman number [E*k* = (Tannulus/TEkman)2], where U is the characteristic flow velocity, L is given by the spacing of the two forced rings, f defines the Coriolis parameter, and the expression for E*k* is given by the fraction of the annulus rotational period and relaxation time for unforced disturbances. While both Ro and E*k* depend on Ω, E*k* is independent of F, which sets the physical experiment apart from the numerical simulation.

*b) Numerical Investigation*

Due to the two-dimensional, nearly geostrophic nature of the numerical model, the study utilizes a quasi-geostrophic, barotropic potential-vorticity equation as the governing equation. A straight-channel, numerical approach was undertaken for this portion of the study. However, a consequence of this is the negation of any degree of curvature within the tank, and side friction on the walls of the tank as well. This may prove to be concerning for lack of representation in the atmosphere. Moreover, the authors do not attempt to explain their selection of ignoring curvature and side friction, which may leave the reader confused as to the actual purpose of trying to resemble the flows found in real situations. The authors proceed to say that both the turbulent velocity and Ekman friction coefficient (Av and κ, respectively) could not be determined in the physical experiment, and so they were arbitrarily determined such that the parameters could match up. The paper also states that two heights for the mountains were tested: h0 = 0.1 and ho= 0.15. As a result, different data could be obtained due to varying topographic height in the flow.

5) Both the laboratory experiments and numerical simulations reveal two flow patterns resembling atmospheric high-index (zonal) flows as well as atmospheric low-index (blocking) flows. Characteristics of the zonal flow include large azimuthal velocities and small-amplitude fluctuations in the oscillatory frequencies, while the opposite could be said about blocking flows. Topographic resonance affects the flows such that blocking flows are sub-resonant while zonal flows are super-resonant. Jet velocities of zonal flows were found to be greater than the critical velocity for linear resonance, while the opposite was found for blocked flows. At low Ro and E*k* values, blocked flows appeared to be generally stable. However, the authors note that an intermittent switch in flow was found where the two flows were stable.

The authors note that similar flow patterns were found in the numerical model. Zonal flows exist over the higher range of forcing, while blocked flows exist in the lower range of forcing. Parameters ho and κ were crucial in determining the stability of the flow. Also, the authors discussed how there was a lack of two-way spontaneous transitions between both the zonal and blocked flows. In spite of these results, the authors mention that a three-dimensional model is required to better understand the processes behind the flow forcing patterns, leaving the results with plenty of unsolved questions to the reader.

6) Although the science behind the authors’ plan to compare a numerical model analysis with a physical laboratory experiment is justifiable, the execution of the overall experimental procedure lacked necessary depth and background. One of the major issues facing this study is that the experiment neglects sidewall friction and curvature in the two-dimensional model. As a result, it does not take into consideration actual characteristics of atmospheric flows. Also, the authors’ mention only a qualitative comparison could be done between the physical experiment and numerical results because forcing and κ were undeterminable. The stress on the necessity of the three-dimensional model indicates that the authors were not prepared adequately to explain this unexpected outcome.

One of the larger drawbacks in the paper is how the authors failed to connect their research to the real atmosphere, which was essentially the motivation behind the study. The authors state that zonal and blocked flows were qualitatively similar in the model, but there is a failure in the explanation of such occurrence. This is especially evident in the discrepancy between the introduction and conclusion; the authors introduce that barotropic conditions are present in low-frequency atmospheric dynamics, but cannot support this hypothesis through the analysis. In fact, it renders the authors’ claim as rogue by stating that baroclinic conditions would best represent the atmospheric dynamics (similar to previous publications, particularly Weeks et al., 1997). It is problematic since one of the end-goals was to attempt to close in on real atmospheric connections.

7) The authors attempt to narrow the gap in understanding rotational flow with topographic features. However, a similar study (i.e. Weeks et al., 1997) has already been done to some extent, which does unfortunately take away from the originality of this study. The authors do also mention some of the shortcomings in finding key parameters, which leads the reader to question what real conclusions or advancements were actually present in the work. In addition, the failure to connect the experimental observations and results to the atmospheric flows is disappointing.

Despite the subtle differences from previous work and a generally good scientific idea, a compilation of major flaws in the organization of this manuscript and a lack of significant evidence in advancing knowledge within the field is evident. Thus, the reviewer renders a decision of **rejecting** this paper for publication into the journal at this time. It is strongly encouraged that the authors revisit and restructure their experiment so that more complete results are obtained.