Virtual microscopy enhances the reliability and validity in histopathology curriculum: Practical guidelines [version 2]

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Abstract
This article was migrated. The article was marked as recommended. Digital pathology innovation and application in medical education have paved the path for a significant shift in the advancement of the medical curriculum. The new technology of virtual microscopy is a proven reliable and valid pedagogy method for histopathology learning objectives, and assessments. The current transformation has brought educators around the globe nearer towards the goal of achieving competence in Curriculum Inventory in the medical curriculum. This paper emphasises the practical tips and guidelines for cost-effective implementation and the successful use of Virtual Microscope technology to enhance the histopathology curriculum in a medical school.

Keywords
Computer-based Assessment, Digital Pathology, Learning outcomes, Undergraduate education, e-learning/computers, Teaching & Learning

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1. Ken Masters, Sultan Qaboos University
2. Ashwani Naaz, Health department pb. Govt.
3. sudesh naaz, pb.govt. Health department
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Introduction

Virtual Microscopy (VM) is one facet that has revolutionized the learning of histopathology worldwide. Whole Slide Imaging (WSI) technique makes use of modern slide scanners and Virtual Microscopy (VM) software. The process involves digitization of glass slides to a high-resolution format which can be conveniently viewed using specialized VM software on a computer or handheld tablet devices. VM software reproduces a high-quality image with meticulous clarity and added features that allow students to highlight, annotate, and pan and zoom (up to a maximum of 100X) WSI (Banavar et al., 2016).

To enhance the readability and understanding of the topic, the authors would like to present some terms (Table 1) which may be unfamiliar to the non-technical readers.

VM in undergraduate histopathology education promotes various integrated active learning and discussion activities during small-group laboratory sessions. It has also been adopted in the field of cytology, hematology, continuing medical education (CME) and delivering of research journal content (Dee, 2009). There is ample research data to prove that the use of VM has enhanced student learning and overall performance in a more clinically oriented and dynamic learning environment (Triola and Holloway, 2011; Pantanowitz et al., 2012; Brierley et al., 2017; Vainer et al., 2017; Dominick et al., 2018). This proven beneficial learning technology has been highly accepted and adopted by several medical schools across the globe. The United States Food and Drug Administration (USFDA) recently approved the use of VM for diagnostic purposes (Boyce, 2017). Thus, VM can also provide a modality that helps to bridge the gap for students with inadequate clinical exposure.

The accreditation governing committee is advancing curriculum inventory (mapping) in medical schools to standardize the educational objectives of the required medical curriculum (Russ et al., 2013; Knollmann-Ritschel et al., 2017). Several Medical Programs around the world have adopted the VM to compliment the effectiveness of competency-based education (CBE) in medical education (Lurie, 2011; Gruppen et al., 2012; Jolly et al., 2013; Russ et al., 2013). Digital pathology has paved a path to address some of these core competencies and collaborative models in various medical education programs (Triola and Holloway, 2011; Saco et al., 2016). However, the utilization of VM is entirely new to some medical school pedagogy at the basic science level. Table 2 shows few recent applications of this system at the undergraduate level by various universities around the globe.

Recently, the USFDA has authorized the marketing of the Philips IntelliSite Pathology Solution (PIPS), which is the first WSI system for interpreting digital surgical-pathology slides from biopsy tissue samples (Boyce, 2017). This approval of business-endeavor will increase the availability and the use of VM for histopathology diagnosis in medical schools. Therefore, it is imperative that medical students become familiar and proficient in the VM system applications.

The author would like to present the practical tips on how this transition can be successfully achieved for a medical school. Table 3 presents an outline of these tips and the impact of implementation at each step.

Tip 1 Consider technology requirements and initial setup

The high cost of slide scanners is still a significant disadvantage for adopting the system. However, a medical school can very quickly acquire a high-quality slide box at a meager price. The easy availability of the online resource which is cloud-based can also be used for teaching purposes at the basic science level. The pathology department at our University acquired the IOWA online slide box which is an inexpensive option available for teaching purposes. The Aperio ImageScope is a commonly used VM software and is available for a free download from the internet (Aperio ImageScope - Pathology Slide Viewing Software: Leica Biosystems 2019).

These slides are set up on a network drive attached to the server. The local server is linked to computer systems in the histopathology lab by virtual computing (N-computing). This cost-effective process is easily adaptable to any medical institutional computing system. A primary server is sufficient to handle a load of around 30-40 students at one time which can be upgraded as required. A cloud-based server is a better alternative but its efficiency varies with the internet speed. A minimum connection speed of 10mbps is sufficient to handle cloud-based WSI. The cloud-based server is configured for remote access allowing the student to access these slides at a time and place of their choice in addition to the histopathology lab. Few advantages of using VM are outlined in Table 4.

Tip 2 Acquisition of slides: Ensure quality and credibility

Make sure that the acquired set of WSI is a high-quality slide set, which contains slides that depict microscopic features from common cellular changes seen during a disease process. The IOWA Virtual Slide Box contains around 1000 slide images for teaching both histology and pathology in basic-science courses. In the modern Internet era, medical
informatics around the globe has facilitated rapid communication among medical students and their ability to discuss and share strategies across institutions, regions and countries. The development of VM and its adaptation in medical education has accommodated to the need for standardization in tissue sections by maximizing the comparability, reliability, repeatability and validity in learning objectives (Dee et al., 2003; Kumar et al., 2004; Pinder et al., 2008; Farah and Maybury, 2009; Husmann et al., 2009; Weaker and Herbert, 2009; Fónyad et al., 2010; Barisoni et al., 2017).

**Tip 3 Faculty development for technology use**

The lab instructors need to be trained initially to operate the computer system and navigate slides through the VM software. The current Aperio ImageScope VM software used at our university comes with a cost-free option for viewing the slide images. The software allows the students to adjust magnification, pan and zoom, annotate, perform image analysis, and compare different stains. A minimal effort of time with a basic level computer system and software skill is sufficient to operate VM software. Additional demonstration and training sessions can be requested from the software vendor. A reasonable motivational factor for teaching faculty is that less effort and time is required to deliver VM based interactive sessions (Dee, 2009; Foster, 2010; Pantanowitz et al., 2012; Tian et al., 2014; Fonseca et al., 2015; Sagol et al., 2015; Saco et al., 2016).

**Tip 4 Address student bias towards this new technology**

Student bias must be addressed immediately and effectively against the use of WSI and VM software. After the USFDA approval of this technology for diagnosis in 2017, the students are bound to encounter this system sometime in their medical career. The early introduction of the VM software can provide a modality that will bridge the gap of inadequate clinical exposure during the career of a student.

Moreover, the WSI and VM system allow physicians from anywhere in the world to consult and collaborate to confirm a diagnosis. Thus, early exposure to VM will prepare students to work efficiently with advanced patient health information systems which include viewing histopathology images and assist in the appropriate diagnosis of a patient.

**Tip 5 Orientation to the slide box and software**

The next important step is to familiarize the student to the VM software and the WSI slide box. The faculty should demonstrate the use of this technology in real time on a bigger screen or projector connected to a computer. Ensure that all
students can access slides and the related clinical information associated with a slide. It is vital to prepare students for what they are about to see in the slide box and software. Questions or discussions before exposure to this new methodology will achieve the necessary knowledge for students to process the learning objective from each slide (Neill and Wyness, 2005).

**Tip 6 Slide selection for a session: Align with course objectives**

The course director can select and identify the slide which depicts the microscopic features aligned to the specific learning objectives discussed in a didactic lecture. These can further be mapped to the institutional and medical education objectives. Brierley *et al.* (2017) have discussed VM use for enhancing the medical curriculum in a CBE system by the successful integration of pathology into clinical scenarios. The interactive learning will elevate student learning and making histopathology more consequential to students.

Kumar *et al.* (2006) have used this teaching methodology for vertically integrating histology and pathology courses by providing access to normal histology slides along with slides depicting disease processes. This creates an opportunity to improve the understanding of the relationship between morphological changes and the clinical manifestations of a disease.

### Table 2. Recent applications of VM use for teaching at the undergraduate level

| Author, Year | Participants and Institution | Application of VM | Outcome/Advantages |
|--------------|-----------------------------|-------------------|--------------------|
| (Nauhria and Ramdass, 2019) | First and Second-year medical students at Windsor University, Saint Kitts | Use of IOWA University WSI to replace the light microscope based Pathology Laboratory VM based clinical case discussions | Significant (p<0.001) improvement in student learning Lesser time and effort by faculty Enhanced student interest |
| (Dominick *et al.*, 2018) | First-year medical school students at Kirksville College of Osteopathic Medicine, Kirksville, Missouri. Kirksville College of Osteopathic Medicine, Kirksville, Missouri. Kirksville College of Osteopathic Medicine, Kirksville, Missouri. | Gastrointestinal module for Histopathology Laboratory Clinical case-based laboratory assignments for student groups | Significant improvement for two quiz questions from pre-laboratory to post-laboratory Combined histology, pathology laboratory helped students improve their understanding of gastrointestinal histology and pathology |
| (Carrilho *et al.*, 2018) | Collaboration between the University of Porto, Portugal and Eduardo Mondlane University in Mozambique | Practical sessions and seminars, integrated into the Moodle platform Face-to-face class in small groups with the teacher | The number of in-person class sessions reduced from 150 to 85 hours per student, by reducing the number of theoretical classes and the number of in-person microscopy sessions Increased student’s motivation for learning Reduced staff personnel required |
| (Brierley *et al.*, 2017) | The School of Clinical Dentistry, University of Sheffield, Sheffield, UK | Use of annotated WSISmall groups discussions | Lesser time and lesser input by faculty Students more confident about their learning Less taxing on their eyesight |
| (Saco *et al.*, 2016) | Teaching tools based on WSI with clinical information, imaging studies (conventional radiology, CT, ultrasound and MRI) macroscopic images, as well as histochemical or immunohistochemical stains | Use of WSI is easier for students Improved collaboration between students and self-learning Homogenization of learning, as all students can visualize the same slide Significant reduction in the time spent by faculty |
Tip 7 Slide annotations allow for Standardization, Reliability and Validity
VM technology has allowed medical schools to establish digital laboratories, which allow students and teachers to build unique and personalized learning materials (i.e. annotations) (Pinder et al., 2008; Husmann et al., 2009; Fónyad et al., 2010; Triola and Holloway, 2011; Helle et al., 2013; Tian et al., 2014).

All advanced VM software allows individual student annotations on slide images, which can be saved for further discussion and can also be reviewed by the faculty for assessments. The disadvantage of annotating the traditional glass slide would require as many glass slides as the number of students. There is no possibility of standardization as different glass slides depict different features and a student may lose out on the opportunity to view and identify the same features. The possibility of annotations by VM software provides an avenue to annotate the slide, discussion of the microscopic features, assessments and future use as these annotations can be deleted from the software.

Annotations facilitate the implementation of comparable and collaborative learning activities involving both student and faculty. The student can share annotations on a common image using any device, from any location achieving the need for standardization, reliability and validity in medical pathology education (Helle et al., 2013; Sahota et al., 2016). Comparable deployment of annotation activities using VM software in the medical curriculum will positively improve the student understanding of microscopic morphology in pathology pedagogy (Sahota et al., 2016).

Tip 8 Clinical case-based group discussions enhance knowledge and communication
At our university, a clinical case-based learning vignette is provided along with the supporting slides. The associated clinical history, lab values and radiological findings along with other relevant clinical information are assimilated at different levels of discussion, thus provoking self-centered and team-based learning. This is followed by group
Tip 9 Online take home MCQ based quizzes enhance formative assessment

Lab assessments based on Multiple Choice Questions (MCQ’s) can be used to trigger further interest in the students. At our University, we use questions from an existing question bank comparable to the NBME questions. The assessment consists of MCQ’s and short-answer type questions based on the microscopic description, differential diagnosis, or clinical features of the disease. This activity thus measures different aspects of learning, which includes medical knowledge, combined comprehension and application, and problem-solving ability of the student.

Making these MCQ based assessments accessible and available online provide an opportunity for self-learning, cognitive acquisition and clinical competency in the student. Hartman (2015) has described the use of a smartphone and personal mobile device are popular digital pathology platforms to decrease contact hours without eliminating content while maintaining effective pedagogical methods (Thompson and Lowrie, 2017). Several universities adopted this methodology has shown a reduction of time spent in conducting VM based laboratory sessions (Triola and Holloway, 2011; Gatumu et al., 2014).

Tip 10 Avoid cognitive overloading: limit slides per session

Ensure a limited number of available slides per session will avoid cognitive overloading. During a two-hour interactive session, our students will discuss and review information from 4-5 histopathology slides. The student is required to describe the clinical or radiographic image, suggest a differential diagnosis, describe the histopathological image, and attempt to determine a final diagnosis with a treatment plan.

It is imperative to optimize the design of instructional technology to avert cognitive overload. Verbal and visual channels in our brain are processed separately thus limiting the amount of simultaneous information assimilation (Martin, 2014). Mayer and Moreno (2003) have discussed a detrimental impact on memory if the information presented exceeds an individual attainable capacity.

The structure of the VM session should facilitate students’ ability to organize content into a coherent cognitive structure, to integrate it with relevant prior knowledge, and to apply the information in a new situation to solve problems.
**Tip 11 Storage of data and backup**

It is advisable to store the entire data on the firewalled server with updated antivirus software. A properly configured firewall will restrict access to everything except the specific services that need to remain open. Backing-up and protecting the server with a secure and reliable storage solution is essential to ensure that data is not lost.

At our University, the Instructional Technology Committee (ITC) serves as the Information Technology (IT) needs of both faculty and students. The ITC department regularly communicates with the concerned faculty and students for a smooth operation.

**Tip 12 Collect student feedback and surveys**

Collecting student feedback is an important aspect of a successful implementation of this technology for teaching in a medical school. Various studies have concluded with positive feedback from students regarding the use of VM (Goldberg and Dintzis, 2007; Triola and Holloway, 2011; Cogdell et al., 2012; Tian et al., 2014; Bridge et al., 2015; Leifer, 2015; Van Es et al., 2015).

Wayne et al. (2013) report that regardless of prior academic ability, students who reported a positive perception of their school’s learning environment performed better on a standardized exam than students who reported less positive perceptions.

At our university, student feedback is collected at the end of the semester using google forms. The questionnaire is based on modified statements adapted from the six ACGME competency criteria that a student should acquire during his/her medical career (Table 5). After the student feedback, some of the original histopathology cases are amended for continuous improvement in a student-centered instructional program.

**Summary and Conclusion**

With the evolution of digital pathology, this technology will undoubtedly serve as a valuable tool for improving the standardization, reliability, and validity in the histopathology pedagogy. There are numerous documented advantages of

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**Table 5. Sample survey questionnaire used for student feedback**

| Overall use and benefits | I prefer VM in comparison to the LMl is a better method of learning histopathology while preparing for the NBME/USMLE examination |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Ease of use              | The directions for use of VM software were clearly understood by the students It is easy for the students to navigate the slides through the VM software The VM had the required magnification for identification of tissue details |
| Medical knowledge        | The program structure of the VM pathology lab helps the student in understanding the core concept areas VM Pathology lab exposure helps to develop an investigatory and analytic thinking approach to clinical situations |
| Patient care             | Acquiring this lab information will help the students while treating a patient VM pathology lab helps students in understanding the role of information technology in patient care decisions and patient education |
| Communication skills     | The lab discussion contributes to work effectively with others as a member or leader in various work settings VM pathology lab sessions help in developing effective nonverbal, explanatory, questioning and writing skills of the students |
| Problem-based learning improvement | VM Pathology lab helps the students in using information technology to manage information, access on-line medical information and support their education VM pathology lab facilitates the learning of students |
| Systems based practice   | The discussion of clinicopathological vignette based on WSI helps the students to grasp the specific concept areas & assists in formulating a concept matrix Using VM pathology lab in the hospital scenario could be a cost-effective diagnostic platform in comparison to the conventional pathology lab The use of virtual slides in practice is a great option as a healthcare resource that does not compromise the quality of care |
| Professionalism          | The students can view all case related WSI at the required magnifications in the allotted time for a session Exposure to a clinical vignette-based comprehensive case helps the students to experience real-world healthcare scenarios |
using this new technology assisting physicians in the medical diagnosis of clinical-pathology diseases. The benefits of VM are undoubtedly essential for medical students, pathologists, lab technicians and researchers to be proficient in using this new technology.

**Take Home Messages**

- This article is focussed primarily on the easy implementation process of virtual microscopy for teaching purpose in medical schools.
- The article highlights the increasing use of digital pathology VM based systems for teaching at the undergraduate level.
- VM use has proven to be a practical solution and has the potential to transform the process of both teaching and learning histopathology.
- With the increasing use of VM for pathology diagnosis, it is imperative that students become proficient in using these systems.

**Notes On Contributors**

Dr. Samal Nauhria, M.D. Pathology, is the Chair of Pathophysiology department at Windsor University School of Medicine, Saint Kitts. His research is focussed on using computer-assisted instruction and implementation of newer applications to enhance or replace traditional teaching strategies and address many new pragmatic and pedagogical challenges in medical education. ORCID: https://orcid.org/0000-0001-7373-2606

Dr. Lee Hangfu, M.D., is the Dean of Clinical Sciences at Windsor University School of Medicine, Saint Kitts. In addition to teaching clinical medicine, his research is focussed on student-based integrated medical pedagogy. ORCID: https://orcid.org/0000-0001-7626-6268

**Declarations**

The author has declared that there are no conflicts of interest.

**Ethics Statement**

Ethics approval was not required for a practical guidelines paper and involves no human data or information

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Version 2

Reviewer Report 26 March 2020

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Manish Khazane
SRM UNIVERSITY, RAMAPURAM, CHENNAI.

This review has been migrated. The reviewer awarded 4 stars out of 5

The authors have aptly putforth their views in the present article about the aid by technology in medical education. In the coming months, we can believe that medical education and the whole aim of equipping medical personals for the future can be achieved more prominently. The spread of the COVID-19 has brought a stark reality to the human kind that change is constant. And this should spring us back in action with better ways of teaching, learning and treating our patients. The ubiquitous availability of video and audio accessories in all our technologies including laptops, mobile phones has eased this difficult phase. The use of VM as a aid to teach seems one of the promising ways in the present scenario. Achieving our aim of continuity in medical learning as well as safeguarding our resources ( in the form of health care workers of the future ) against any harm.

Competing Interests: No conflicts of interest were disclosed.

Reviewer Report 15 October 2019

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Trevor Gibbs
AMEE
This review has been migrated. The reviewer awarded 3 stars out of 5

I would agree with my co-reviewers and reflect upon my original review, which considers this paper to be an interesting and important paper for those faculty tasked to teach histology. Its teaching elements appear innovative and effective, with the paper written in a clear fashion. I do however still worry that such a paper needs to expand on how the teaching of histology (an important subject) can and should be integrated into the modern curricula which has the danger of being over-crowded with often unused scientific knowledge.

**Competing Interests:** No conflicts of interest were disclosed.

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**Reviewer Report 24 June 2019**

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**Daniel Brierley**  
University of Sheffield

This review has been migrated. The reviewer awarded 4 stars out of 5

I enjoyed reading this paper which summarised some of the key areas which require attention before implementing VM into curricula. There are certainly many areas to consider if the technology is to be used to its maximum potential. The ability to acquire virtual teaching sets is especially beneficial to those centres that don't have access to large databases of previously scanned material.

**Competing Interests:** No conflicts of interest were disclosed.

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**Reviewer Report 20 June 2019**

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**Ken Masters**  
Sultan Qaboos University
This review has been migrated. The reviewer awarded 5 stars out of 5

A much-improved paper on the topic. I am pleased to see that the authors have addressed the issues raised about Version 1. Table 1 might seem a little strange, and possibly would be better delivered as an end glossary, but it does serve the very useful purpose of explaining the technical terms. Those readers who are unfamiliar with the terminology can refer to it, whereas others can gloss over it. Table 2 is also a fine contribution to the paper, enhancing the points made later and providing a strong literature basis. (It is a pity that there is some information missing from the listing (Saco et al., 2016), but that is minor issue.) With these as background context (and some of the language changes made in the main text), the rest of the paper immediately becomes far more accessible and valuable to the reader.

**Competing Interests:** No conflicts of interest were disclosed.

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**Version 1**

Reviewer Report 18 February 2019

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Trevor Gibbs
AMEE

This review has been migrated. The reviewer awarded 3 stars out of 5

There is no doubt that this paper is of value to those considering setting up an histology programme in a health Sciences programme. I would support my co-author in his comments about the technology description and the need for both clarity of defining the terms and the use of English. However my worry with this paper and its relationship to modern approaches to medical education is how it fits into our approach to relevance if subjects within a crowded undergraduate programme and how it integrates into future learning needs. Are we not / should we not be moving away from such silo approaches to learning. Of course this approach probably counts more within a postgraduate programme that is specifically designed more for the postgraduate pathologist.

**Competing Interests:** No conflicts of interest were disclosed.

Reviewer Report 14 February 2019

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Amrinder Singh
Millcreek Medical Clinic

This review has been migrated. The reviewer awarded 5 stars out of 5

This paper is complete and thorough. Very nicely written. I highly recommend this article.

**Competing Interests:** No conflicts of interest were disclosed.

Reviewer Report 14 February 2019

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Ashwani Naaz
Health department pb. Govt.

This review has been migrated. The reviewer awarded 5 stars out of 5

This artical is too good and precise . I recommend all connected with the field to read .

**Competing Interests:** No conflicts of interest were disclosed.

Reviewer Report 14 February 2019

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sudesh naaz
pb.govt. Health department

This review has been migrated. The reviewer awarded 5 stars out of 5
This article is very beneficial to the medical students. I strongly recommend this for all medical students to read this article.

**Competing Interests:** No conflicts of interest were disclosed.

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Ken Masters
Sultan Qaboos University

This review has been migrated. The reviewer awarded 3 stars out of 5

The paper is a valuable contribution to guiding faculty in the use of this crucial technology. Because of the nature of the topic, the paper is necessarily technical in nature, and is also reasonably well-grounded in the technical and educational literature. Two areas of weakness, however, would need to be addressed in a revised version of this paper:

• Technical references: I have already referred to the fact that the paper is necessarily technical in nature. The authors need to remember, however, that the average reader of the journal would have little experience with sophisticated computing terminology. Concepts like virtual and cloud-based computing are not standard terms in medical education, and many educators would have their eyes glaze over at some of the discussion. These terms need to be explained, carefully, and clearly. (In this vein, in the line “by virtual computing (N-computing)”, it would be unclear whether the “N” is an error, or whether it is a brand or technical term (referencing thin-client NComputing)). The authors need to clarify this, especially considering the audience most likely to be readers of the journal. Similarly, a line that speaks of “A minimum connection speed of 10mbps” is mostly meaningless to the average reader. The authors are advised to compare this speed to something with which the reader may be familiar, or give an indication of how long a 10 Mb file would take to download at this speed, and perhaps give an indication of a cost. Without points of comparison, these are just numbers. I would recommend that the authors have a non-technical colleague read through the paper, and identify all areas that are problematic.

• The paper also suffers from a large number of small, but irritating, errors of language, punctuation and expression. I would strongly recommend that authors have the paper closely proof-read by an English mother-tongue speaker to remove these errors. Although I feel that the content of the paper is valuable, I am awarding three stars only. I feel that, once the authors have had a chance to address these issues (and issues raised by other reviewers) in a revised paper, then a higher star-rating may be awarded.
Competing Interests: No conflicts of interest were disclosed.