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# Report on PhD thesis by Wojciech Szkolka

## Reviewer: Professor Adrian Matthews

The candidate has demonstrated a comprehensive general theoretical knowledge of the main aspects of meteorology that pertained to their thesis. The introduction to the thesis contained a well summarised overview of the relevant physical principles, along with mainly up to date references. This included discussion of the main meteorological phenomena: Walker circulation, El Nino-Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), Quasi-Biennial Oscillation (QBO), monsoon circulations, Madden-Julian Oscillation (MJO), convectively coupled Kelvin waves (CCKWs), and the diurnal cycle.

The candidate has clearly shown the ability to independently carry out scientific research. They have identified that a major unknown in meteorology, especially tropical meteorology, is that of multi-scale interactions. Specifically, how does the local meteorology (e.g., rainfall/precipitation at a certain location) interact with and depend on the larger-scale forcing (from the various phenomena listed in the previous paragraph). Understanding of these multi-scale interactions is a major research challenge in meteorology, and the focus of many efforts at national meteorological centres in making improvements to their weather forecasts and climate simulations. This is particularly important in the tropics, where the cumulonimbus cloud is the (small-scale) building block of atmospheric convection there. The environment within which cumulonimbus clouds grow is largely set by the large-scale processes described above, while the latent heat release and cloud radiation interactions within the cumulonimbus clouds feeds back onto the large scale, giving two way interactions.

This thesis takes advantage of a unique data set, the Equatorial Atmospheric Radar (EAR) operating on the west coast of Sumatra. This supplies very high resolution, high quality data over a relatively long time period, relating to the local, small-scale meteorology. The candidate has done an excellent job of relating the local-scale meteorology from the EAR data to the larger scale, using various indices of the large-scale flow derived from publicly available global meteorological data sets. The EAR data set

In the first research chapter (chapter 4), the diurnal cycle of the tropospheric winds from the EAR and their moderation by the large-scale modes is evaluated. Clear patterns of moderation are found for nearly all the large-scale modes. This provides guidance as to how these large-scale modes operate on the small scales. There is also a novel analysis where the EAR data is used to diagnose the changes in amplitude of the three main modes of tropical cloud formation (congestus, deep convective and cloud formation). This is particularly important, as these three modes of cloud formation have very different vertical profiles of heating, which is how the local (cloud) scale meteorology feeds back onto the large scale. Overall, this chapter was well researched

and written. The published paper that results from it, and the chapter itself, should act as a useful analysis to help validate the high-resolution convection resolving model experiments that the major national meteorological centres now routinely run.

In the second research chapter (chapter 5), a comparison is made between the in situ local EAR data, and the global atmospheric reanalysis ERA5 product. ERA5 is the current state of the art best estimate of the physical state of the atmosphere (along with other modern reanalysis products like MERRA-2). It is widely used in the meteorological community as the "truth", when evaluating forecasts and climate simulations. However, it is not perfect, especially in the tropics. The comparison of ERA5 to the in situ observed EAR data is an excellent test of the strengths and weaknesses of the ERA5 system. The horizontal component of the wind in ERA5 is found to perform well, against the EAR data. However, it was found that there are major discrepancies in the vertical component of the ERA5 winds. This is likely due to the ERA5 model component having parameterised convection, which is not capturing the true vertical profiles of heating and vertical wind components well. This can be discussed in the thesis defence.

The third research chapter (chapter 6) focuses on one of the large-scale modes of variability, the convectively coupled Kelvin waves (CCKWs). CCKWs are a particular type of weather system that often bring extreme weather (precipitation) to the Maritime Continent. Two indices are developed from the EAR horizontal wind data to measure CCKW activity. This is novel work, and can be explored more in the thesis defense.

Overall, the candidate has shown a comprehensive knowledge of the underlying meteorological principles, and a recognition of the outstanding research questions in the field. They have carried out a competent, comprehensive piece of research that will be of great interest to the international meteorological community. I support the candidate's admission to public defence.

Signed: A. Hall

Date: ~~7 February 2025~~ 19/02/2025