THE AUSTRALIAN AIR QUALITY FORECASTING SYSTEM:
EXPLORING FIRST STEPS TOWARDS DETERMINING
THE LIMITS OF PREDICTABILITY FOR SHORT-TERM
OZONE FORECASTING

M. E. COPE\textsuperscript{1,2}, G. D. HESS\textsuperscript{3,*}, S. LEE\textsuperscript{1}, K. J. TORY\textsuperscript{3}, M. BURGERS\textsuperscript{3,4},
P. DEWUNDEGE\textsuperscript{4} and M. JOHNSON\textsuperscript{5}
\textsuperscript{1}CSIRO Atmospheric Research, PMB 1, Aspendale, VIC 3195, Australia; \textsuperscript{2}CSIRO Energy Centre, P.O. Box 330, Newcastle, NSW 2304; \textsuperscript{3}Bureau of Meteorology Research Centre, GPO Box 1299K, Melbourne, VIC, 3001, Australia; \textsuperscript{4}Environment Protection Authority of Victoria, GPO Box 439QQ, Melbourne VIC 3001, Australia; \textsuperscript{5}Department of Environment and Conservation (NSW), GPO Box 29, Lidcombe, NSW 1825, Australia

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Abstract. Physical parameterisations of turbulent transfer processes in the atmospheric boundary layer, such as the stability parameterisations developed by Joost Businger, and recent advances in computing capabilities, have been important factors leading to the emergence of operational, numerical air quality forecasting systems. The present paper investigates the performance of the Australian Air Quality Forecasting System (AAQFS) in forecasting the peak 1 h ozone for the current or next day. These 24/36 h forecasts are generated for the Sydney and Melbourne regions and issued twice daily. Quantitative evidence is presented of the potential for the AAQFS to provide accurate numerical air quality forecasts. A second goal is to provide an initial benchmark for investigating the limits of predictability for air quality in the Sydney and Melbourne regions by looking at the dependence of the forecasts on the domain spatial scale (while maintaining the same model grid resolution), the starting time and length of the forecast (0000 UTC starts are 36-h forecasts and 1200 UTC starts are 24-h forecasts), and the sophistication of the photochemical mechanism (simple chemistry, Generic Reaction Set (GRS) and complex chemistry, Carbon Bond IV (CBIV)). The probability of

* This paper is dedicated to Joost Businger, who had strong ties with the atmospheric boundary-layer community in Australia over the past 40 years. It was while visiting CSIRO in Aspendale, Victoria, in 1965–1966 that Joost determined the stability dependence of the Monin-Obukhov surface-layer profiles. He immediately walked over to Arch Dyer’s office to show Arch his results. Arch carefully examined them, and then opened his desk drawer and pulled out his own plots of the stability dependence that he and Bruce Hicks had obtained. They showed the same curves, and thus the Businger-Dyer-Hicks stability functions were born. Arch and Bruce at the time were struggling with how to handle the internal politics; they needed Bill Swinbank’s approval, as Assistant Divisional Chief, before they could submit their results for publication. Bill had his own very strong ideas that conflicted with observations. Joost’s independent confirmation of their results provided a way forward (Bruce Hicks, personal communication, 2003). Joost has contributed significantly, either directly or indirectly, to experimental field programs both within Australia and overseas and to the development of parameterisations of turbulent transfer processes in the boundary layer.

* E-mail: d.hess@bom.gov.au
detection by the forecast model is much better than persistence, showing considerable skill. The normalised bias, in general, decreases going from regional scale to sub-regional scale and becomes negative at the station scale. In Melbourne the gross error increases as the domain spatial scale decreases, but in Sydney there is a dip in the error at the sub-regional scale due to a sampling artifact. Better results are obtained at the smaller domain scales for 1200 UTC forecasts in Sydney. These are attributed to the shorter forecast period and secondarily to greater model spin-up effects at 0000 UTC. In Melbourne the results are ambiguous. Similar conclusions are derived from scatter plots of forecasts versus observations. Dividing the scatter plots into four sections by plotting vertical and horizontal lines (at 60 ppb) forms contingency tables for categorical forecasting. These plots show the increase in missed forecasts due to underprediction and the decrease in the number of extreme events detected as the spatial scale decreases. A comparison of the highly condensed GRS photochemical mechanism with the comprehensive CBIV mechanism indicates that, in general, GRS performs well for predicting ozone in urban situations provided that the background concentrations are appropriately specified. The potential to improve the forecasts at the smaller spatial scales, particularly for extreme events at high ozone concentrations, may require moving to a more complex mechanism as computer resources become available.

Keywords: Limits of predictability, Model performance, Ozone forecasting, Photochemical smog.

1. Introduction

Since the 1960s a great deal of effort has gone into developing parameterisations of turbulent transfer processes in the atmospheric boundary layer. These parameterisations were initially incorporated into one-dimensional (1D) boundary-layer models, but over time their use, particularly the Businger-Dyer-Hicks stability functions, spread to 2D and 3D mesoscale meteorological models, numerical weather prediction models, and climate models. With recent advances in supercomputing, it is now possible to perform high-resolution, numerical meteorological forecasts incorporating these physical parameterisations on a real-time, operational basis. These models are now beginning to emerge as an important component for a variety of numerical air quality forecasting systems. These include Eulerian models (e.g. McHenry et al., 2000), Lagrangian models (e.g. Souto et al., 2001), hybrid Eulerian-Lagrangian models (e.g. Draxler, 1999), and adaptive-grid models (Bacon et al., 2000); some models are of moderate resolution and are regional in scale (e.g. McHenry et al., 2000) whilst others resolve urban traffic patterns with a horizontal resolution of 2 km (e.g. Rufeger et al., 1997).

The Australian Air Quality Forecasting System (AAQFS) is an Eulerian numerical forecasting system that has been operating since August 2000 (Cope et al., 2004; Hess et al., 2004; Tory et al., 2004). The development of AAQFS has been a collaborative effort between CSIRO Atmospheric Research (CAR), CSIRO Energy Technology (CET), the Bureau of Meteorology (BoM), the Environment Protection Authority of Victoria (EPA-VIC), and the Department of Environment and Conservation (N.S.W.) (DEC) with