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A sensitivity study of the fog fraction scheme employed in the ACCESS NWP models

Richard A. Dare and Rodney Potts

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EXECUTIVE SUMMARY

The ACCESS NWP model, based on the UKMO's Unified Model, provides forecasts of visibility and fog fraction, diagnosed from meteorological fields predicted by the NWP model. The visibility scheme has been examined and a new set of configuration parameters has been recommended for implementation in the APS3 ACCESS model to improve its performance across Australia. The changes in the visibility scheme impact on the fog fraction scheme and in this study, we examine the resulting behaviour of the fog fraction.

In the ACCESS model the visibility scheme operates by hydrating the aerosol field in the grid box and computing the visibility based on the fog droplet size and number density. In addition, the probability that a model grid box will have a visibility below a specified threshold (1000 m for fog and 5000 m for mist) is computed. This may also be considered as the fraction of a grid box with a visibility below the threshold, recognising that sub-grid processes may result in fractional coverage.

In the current work, the fog fraction scheme is isolated from the ACCESS model to allow experiments to be conducted efficiently without the need to operate the model. Like the visibility scheme the fog fraction scheme depends on air temperature, moisture, pressure, and aerosol mass mixing ratio at the screen level height. It also depends on user defined configuration parameters, including the visibility threshold (1000 m for fog and 5000 m for mist), the critical relative humidity (above which fractional cloud starts to appear in the grid box), the air density, aerosol number density and the activation parameter that controls hydration of the aerosols.

For the sensitivity experiments, a range of values for the input variables and configuration parameters are employed to examine the behaviour of the fog fraction scheme and demonstrate the combinations of values required to produce low visibilities. This includes the new set of configuration parameters for the visibility scheme, with an increase in the default value for aerosol mass mixing ratio to 15 µg.kg^{-1}, a more realistic value for the air density (1.2 kg.m^{-3}) and an increase in the value for the activation parameter to 0.5. This shows there is a relatively minor impact on the fog fraction. However, there is a large impact for the mist fraction with values approaching 1 at values of RH* just a few percent lower.

The fog fraction and mist fraction are sensitive to the aerosol mass mixing ratio. When very high values, such as 50 or 100 µg.kg^{-1}, are applied, the fog fraction approaches 1 at values of RH* that are slightly lower. However, the mist fraction approaches 1 at unrealistically low values of RH*. Such high values of the aerosol mass mixing ratio are not representative of the mean atmospheric conditions across Australia and a value of 15 µg.kg^{-1} is recommended.

The fog fraction and mist fraction are also sensitive to the critical relative humidity (RHcrit) above which fractional cloud appears in the grid box. This has a lower value in the global ACCESS-G model (0.92) compared to the city-scale ACCESS-C model (0.96) to allow for greater sub-grid variability at the lower spatial resolution. This means that for a given area fog (or mist) will start to develop at lower values for RH* in the global model but the fog fraction (or mist fraction) will approach 1 more slowly than in the city model.

1. INTRODUCTION

Low visibility is the prominent characteristic of fog and mist. Fog is defined by cloudy conditions near the ground in which the visibility is less than 1 km, while mist is defined by visibilities of 1 to 5 km. Fogs that occur over airports, particularly when unpredicted, can lead to safety issues, flight delays and cancellations that have negative economic impacts on the aviation industry. Accurate forecasting of low visibilities associated with fog over airports provides improved safety and economic benefits to the aviation industry.

Combinations of satellite data, numerical weather prediction (NWP) model guidance, and knowledge of characteristic meteorological conditions for a location of interest may be utilised to maximise the accuracy of forecasts of fog and mist. The Australian Bureau of Meteorology (ABOM) operates the Australian Community and Climate Earth System Simulator (ACCESS) NWP model (ABOM 2010, Puri *et al*. 2013) and this is based on the Unified Model developed by the United Kingdom Meteorological Office (Cullen 1993, Davies *et al*. 2005, Rawlins *et al*. 2007). The ACCESS model provides predictions for meteorological fields and then computes diagnostic fields, including the visibility and fog fraction.

The sensitivity of the visibility scheme has been described by Dare and Potts (2019a). The first aim of the current work is to provide information regarding the sensitivity of the fog fraction scheme to a range of variables and parameters. These experiments will demonstrate the range of values of fog fraction that a user of the scheme may expect to find for particular conditions. The second aim is to examine the different values of fog fraction and mist fraction that are produced depending on whether the visibility threshold of interest is 1000 or 5000 metres, the two values employed in the operational version of the ACCESS NWP model. The third aim is to examine potential changes in values of the fog fraction that may result from adopting the set of parameters recommended following recent tuning of the visibility scheme (Dare and Potts, 2019a).

Brief descriptions of the visibility and fog fraction schemes follow in Section 2. The framework developed to operate the fog fraction scheme, isolated from the ACCESS NWP model, is described in Section 3. In Section 4, sensitivity experiments are discussed and results are presented. Findings are summarised in Section 5, followed by recommendations in Section 6.

2. VISIBILITY AND FOG FRACTION DIAGNOSTIC SCHEMES

The ACCESS visibility diagnostic uses values of five meteorological variables (pressure, temperature, specific humidity, cloud liquid water, and aerosol mixing ratio (A)) at screen level height, plus several other parameters, to estimate visibility. The scheme operates by hydrating the provided aerosol field so that it is in equilibrium with the atmospheric humidity, and the visibility is then computed based on the fog droplet size and the number density. Details of the scheme are provided by Wright (1997a, b), Clark *et al*. (2008), and Claxton (2013). A brief summary based on these sources is provided by Dare (2017). The sensitivity and tuning of the visibility scheme for nine Australian airports is described by Dare and Potts (2019a).

While the visibility scheme produces an estimate of visibility for a given set of meteorological variables, it is also possible to compute the probability that a model grid box will have a visibility less than a specified threshold, based on those variables. For example, one could compute the probability that a model grid box would have a visibility below a threshold of 1 km (corresponding to the definition of fog). This probability could also be considered the fraction of a model grid box where the visibility is below the selected threshold (Wright 1997a, b). In the ACCESS model code, this fraction is produced by the fog fraction scheme in a model subroutine named "fog_fr". The value produced by this scheme is generally referred to as "fog fraction" regardless of the selected visibility threshold.

When the specified value of the visibility threshold is not equal to 1 km, the fraction (0 to 1) produced by the fog fraction scheme is not strictly a "fog fraction". For example, a specified visibility threshold equal to 5 km would return a fraction that could reasonably be referred to as a "mist fraction" rather than a "fog fraction". For clarity in this report, a fraction produced by the fog fraction scheme that corresponds to a specified visibility threshold of 1 km is referred to as a "fog fraction" while the fraction corresponding to a specified visibility threshold of 5 km is referred to as a "mist fraction". Note that this clarification is relevant only to this report, and values produced by the ACCESS NWP model are not labelled as such.

The fog fraction scheme requires values of pressure, temperature, specific humidity, cloud liquid water content, aerosol mixing ratio, critical relative humidity, and the visibility threshold. Three main steps are involved in diagnosing the value of the fraction. First, temperature and pressure are used to compute the saturated specific humidity (q_{SAT}). Second, the relationship between aerosol mixing ratio, visibility, and total water content is inverted. That is, it is an inversion relative to the calculation conducted by the visibility scheme. This means that the value of the saturated specific humidity (q_{SAT}) computed in the first step, the specified visibility threshold, and the aerosol mixing ratio are combined to estimate the total water mixing ratio threshold ($q_{THRESHOLD}$). This is the amount of moisture that would be required to produce the specified visibility corresponding to the values of aerosol mixing ratio and saturated specific humidity.

Third, the total water threshold produced from the inversion in the second step is compared with the total water present (q_{TOTAL} equal to specific humidity plus cloud liquid water) to estimate the fog fraction. A triangular distribution is assumed (Figure 1), with liquid water present above the critical relative humidity (RHcrit). The half width of the distribution (q_{HALF}) is defined by multiplying the saturated specific humidity (q_{SAT}) by the difference (RHcrit–1). The centre of the distribution is equal to the total water, q_{TOTAL}. This means that the fog fraction will be equal to zero when the total water threshold for the specified visibility ($q_{THRESHOLD}$) is greater than the sum of the total water plus the half width of the distribution. The fog fraction will be equal to one when the total water threshold

($q_{THRESHOLD}$) is less than the total water minus the half width of the distribution. Values of the fog fraction ranging between 0 to 1 are found when the total water threshold lies within the distribution.

The three steps described above are summarised in Table 1.

Table 1 Summary of steps used to compute fog fraction.

Step	Variables required	Variable produced
1	Temperature, pressure	q_{SAT}
2	q_{SAT}, Visibility threshold, A	$q_{THRESHOLD}$
3	$q_{THRESHOLD}$, q_{TOTAL}	Fog and mist fraction

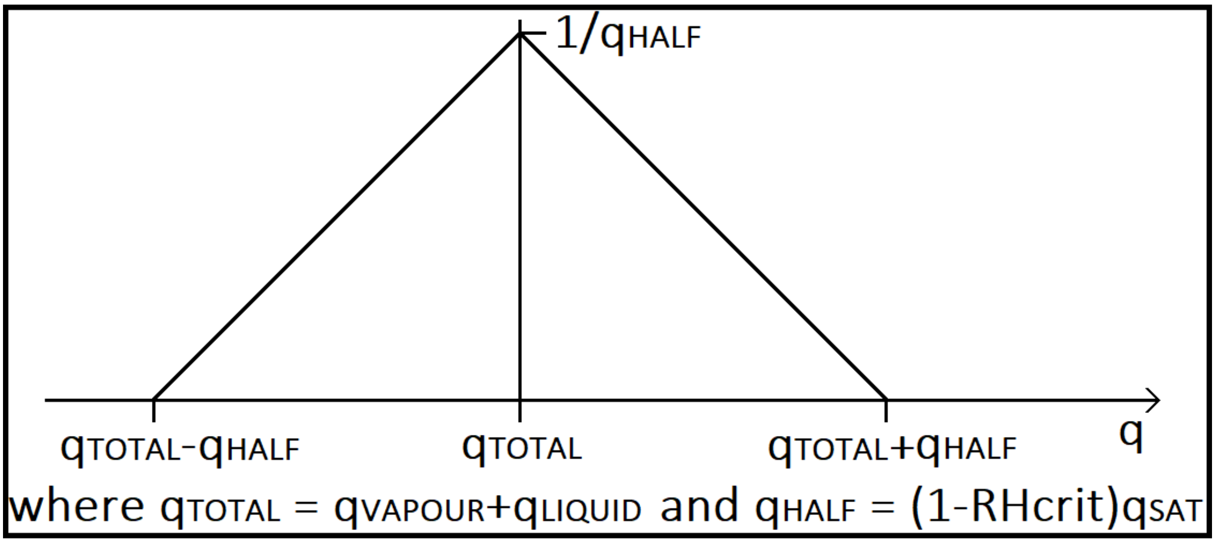

Figure 1 Triangular distribution used to compute fog fraction based on the value of q_{TOTAL} relative to $q_{THRESHOLD}$.

3. FRAMEWORK FOR OPERATING THE FOG FRACTION SCHEME

In the current work, the fog fraction scheme is isolated from the ACCESS model and interfaced within a separate framework for the purpose of conducting sensitivity experiments. There are two advantages to this approach. First, this allows the fog fraction scheme to be operated without the need to employ a computationally intensive NWP model. Second, the framework allows user-defined hypothetical values to be input to the fog fraction scheme. This means that specific variables and configuration parameters can be selected by the user for input to the scheme rather than allowing the NWP model to provide values depending on the meteorological situation that is being simulated.

The practical use of the fog fraction scheme requires the definition of eight arguments. Six of these are meteorological variables (pressure, temperature, specific humidity, cloud liquid water, and aerosol mixing ratio), while two are user-defined parameters (critical relative humidity and the visibility threshold). Note that cloud ice is not used in any calculation within the scheme. Also note that the probability parameter (calc_prob_of_vis) used in the visibility scheme, examined by Dare and Potts (2019a), is not employed by the fog fraction calculations in the ACCESS NWP model. The critical relative humidity (RHcrit) is the value of relative humidity (RH) above which saturated states exist. That is, aerosol particles are hydrated and water vapour is converted to cloud droplets. The visibility threshold has been discussed in Section 2. In addition to the eight arguments listed above, the impacts of varying three additional configuration parameters are considered in the sensitivity experiments conducted in this report. The three additional parameters are the air density (ρ_{AIR}), the aerosol number density (N_0) and the activation parameter (B). The activation parameter is related to the solubility of the aerosol (Claxton 2013). It represents a measure of the aerosol water uptake, and ranges from 0 to 1.4 (Petters and Kreidenweis 2007). The values of these three parameters (ρ_{AIR}, N_0 and B) are selected based on the findings of Dare and Potts (2019a).

To simplify the experiments conducted, it is convenient to reduce the number of input variables considered. This is done by assuming constant values of pressure (1013.25 hPa) and temperature (10ºC). The saturation specific humidity q_{SAT} is effectively constant because constant values of temperature and pressure have been assumed. A range of values of RH is defined for use in the sensitivity experiments (Table 3). For each specified value of RH, the specific humidity is computed from the combination of RH and saturation specific humidity. Cloud liquid water is set equal to zero because specific humidity is used alone to define the total atmospheric moisture. This approach is possible because the fog fraction scheme functions using a single moisture variable, which it computes by adding together the specific humidity and the cloud liquid water. Using this approach, experiments are conducted based on variations in just two meteorological variables (RH and A). These are combined with variations in RHcrit, the visibility threshold, B, ρ_{AIR}, and N_0. The values of each parameter considered in the sensitivity experiments are discussed in Section 4.1.

Although some supersaturation (RH > 1) is possible in the atmosphere, it may be reasonable to assume in general that there is no supersaturation, and therefore RH does not exceed 1. However, when the fog fraction scheme is operating within the ACCESS model, it can receive as input positive values of both the specific humidity and cloud liquid water. This means, for example, that the value of the specific humidity may be approximately equal to the saturation specific humidity and, in addition, there may be a positive value of the cloud liquid water. In this example, the total moisture (specific humidity plus cloud liquid water) used within the fog fraction scheme may exceed the value of the saturation specific humidity. Although the atmosphere might not be supersaturated with respect to water vapour, it is necessary to represent a situation described in the example above when testing the sensitivity of the scheme. That is, some representation of the possible presence of cloud liquid water should be included. This means that the maximum value of RH specified for use in testing the scheme should exceed 1. Note that the specified RH used in the experimental framework differs from the general use of RH based on atmospheric vapour. To differentiate between these two parameters, the specified RH is subsequently referred to as RH*. The maximum required value of the RH* can be estimated by obtaining observed values of cloud liquid water mixing ratio and combining them with saturation values, as shown by Equation (1). Some examples of moderate and relatively large values of cloud liquid water observed in fogs are compiled in Table 2. Combining Equation (1) with the data in Table 2 indicates that RH* due to the inclusion of cloud liquid water would increase by less than 1 % for the values at the lower end of each range, for a temperature of 10ºC. For the cloud liquid water values at the higher end of each range shown in Table 2, RH* would increase by approximately 1 to 6 %. Therefore, an upper limit of 10 % is selected and the maximum RH* value employed in these sensitivity experiments is 1.1.

$$RH^*_{MAX} = (q_{SAT} + q_{CLOUD})/q_{SAT} \quad (1)$$

Table 2 Sample values of cloud liquid water observed in fogs, from published literature.

q_{CLOUD} (g kg^{-1})	Reference
0.0023 to 0.09	Eldridge (1966)
0.00016 to 0.16	Pinnick *et al*. (1978)
0.00083 to 0.417	Corradini and Tonna (1980)
0.015 to 0.218	Kunkel (1984)
0.1 to 0.3	Duynkerke (1999)

4. SENSITIVITY EXPERIMENTS

4.1 Method

The experiments conducted in this section examine the sensitivity of the fog fraction scheme to combinations of parameters, as the value of RH* approaches 1.1. This not only provides a demonstration of the relative sensitivity to particular parameters but also provides a demonstration of the essential functioning of the fog fraction scheme. Data for the sensitivity experiments are based on values of seven parameters (RH*, A, B, ρ_{AIR}, N_0, RHcrit, and the visibility threshold). The values used in the experiments are shown in Table 3. A mean air temperature of 10ºC is employed in all experiments.

Table 3 Values of parameters employed in sensitivity experiments.

Parameter and acronym	Values
Specified relative humidity (RH*)	0.8 to 1.1
Aerosol mass mixing ratio (A)	5, 10, 15, 50, 100 µg kg^{-1}
Activation parameter (B)	0.14, 0.5, 0.9
Air density (ρ_{AIR})	1.0, 1.2 kg m^{-3}
Aerosol number density (N_0)	2 x 10^8, 2 x 10^9, 2 x 10^{10} m^{-3}
Critical relative humidity (RHcrit)	0.92, 0.96
Visibility threshold	1000, 5000 metres

4.2 Results

Each of the lines shown in Figures 2a to 6a represent the value of the fog fraction (0 to 1) corresponding to relative humidity (RH*) values ranging from 0.8 to 1.1. As noted in Section 2, the fog fraction is the fraction, or probability, of a model grid box containing visibilities less than 1000 metres for the set of meteorological variables and parameters employed.

Figure 2a shows the fog fraction as a function of RH* for four sets of the parameters A, RHcrit, N_0, ρ_{AIR} and the activation parameter B, with values for each shown in the legend. The first is the default set employed in the ACCESS model in recent years (black dashed line). The second line (red dashed) differs from the first in that the value of A is increased from 10 µg.kg^{-1} to 15 µg.kg^{-1}, which produces a small increase in the value of the fog fraction. For example, at RH*=1, the fog fraction is 0.46 for the first line, but is equal to 0.47 for the second line. For the third and fourth lines, the values of the fog fraction at RH*=1 are 0.52 and 0.53, respectively, due to cumulative changes in B from 0.14 to 0.5, followed by an increase in air density from 1.0 kg.m^{-3} to 1.2 kg.m^{-3}. Overall, the values of the fog fraction corresponding to RH*=1 range from 0.46 to 0.53 between the four lines in Figure 2a. Only when RH* is increased above 1, due to the presence of cloud water, does the fog fraction increase above 0.53, reaching a value of 1 when RH* is approximately 1.04.

Subsequent results in the diagrams that follow (Figures 3a to 6a) examine the impact on fog fraction of further parameter variations. Note that in all five diagrams concerning fog fraction (Figures 2a to 6a), the solid red line uses the same set of parameters recommended for implementation in the APS3 ACCESS model and provides a reference for comparing the impact of different parameters.

Using the same combinations of parameters as in Figure 2a, the specified visibility threshold is increased from 1000 metres to 5000 metres to produce the mist fractions shown in Figure 2b. In all figures presented here, the left and right frames employ identical sets of parameters, differing only in the value of the specified visibility threshold. The mist fractions in Figure 2b at RH*=1 range from 0.54 to 1, considerably higher than the corresponding fog fractions in Figure 2a (range from 0.46 to 0.53). The four mist fraction lines shown in Figure 2b reach a value of 1 corresponding to values of RH* ranging from 1 to 1.04. Although three different parameters are varied here, and they all have some impact, the largest influence is that of B. The parameter combination that produces the highest mist fraction is shown by the solid red line. Note that for Figures 2b to 6b the solid red line is also based on the same set of parameters recommended for implementation in the APS3 ACCESS model (Dare and Potts, 2019a) and provides a reference for assessing the impact of changes in both the configuration parameters and the visibility threshold.
For the results presented in Figure 3, A and air density are held constant for all lines with values of 15 $\mu g.kg^{-1}$ and 1.2 $kg.m^{-3}$, respectively, while the impact of varying B is examined. Although somewhat similar to the lines in Figure 2a, the lines in Figure 3a cover a relatively wider range of values of fog fraction. At RH*=1, for example, the fog fractions range from 0.47 to 0.60, corresponding to a change in B from 0.14 to 0.9. For mist fraction (Figure 3b), the impact of these changes in B is greater than that for fog fraction, with values of the mist fraction ranging from 0.68 to 1 at RH*=1. For B=0.9, the mist fraction reaches 1 at RH*=0.965. The data produced by this combination of parameters (B=0.9) may be of limited use because variations in the mist fraction are absent for values of RH* between 0.965 and 1.

The impact on the fog fraction of varying N_0 is shown in Figure 4a. The lines produced using values of N_0 ten times lower (solid black) and ten times higher (dashed black) than that of the solid red reference line (N_0=2 x 10^9 m^{-3}) cover a range of fog fractions that is less than those in both Figures 2a and 3a. At RH*=1, for example, the fog fractions in this frame range from 0.51 to 0.56. For the mist fractions in Figure 4b, the differences between the lines are much more distinct than those found for the fog fractions.

Figure 5 contains data from experiments that assess the impact on fog and mist fractions of varying the aerosol mass mixing ratio, A. For the first time in the results presented here (Figures 2a to 5a), the fog fraction reaches a value very close to 1 (0.99) corresponding to RH*=1. This is shown by the red dashed line that employs A=100 units. Such a value of A is very high, as judged by the definitions of various values of A from the work of Haywood *et al*. (2008), compiled in Table 4. Such a value of A is not recommended for general use in the model because it is not representative of mean conditions within the Australian atmospheric environment. In addition, the mist fraction reaches 1 at values of RH* as low as 0.79 and 0.06, for A=50 and 100 $\mu g.kg^{-1}$, respectively. Such excessively high values of the mist fraction mean that it would be of no value as a forecasting tool because it does not vary for values of RH* ranging from 0.9 to 1, the range that is of relevance in assessing the development and presence of fog or mist.

The final sensitivity test examines the impact of the value of RHcrit, the grid box mean relative humidity above which fractional cloud starts to appear (Figure 6). This is relevant because RHcrit has a lower value in the global ACCESS-G model (0.92) compared to the city scale ACCESS-C model (0.96) to allow for greater sub-grid variability in the lower resolution global model. In previous experiments (Figures 2 to 5), the various sets of parameters that were tested generally produced lines within each frame that were approximately parallel, while here in Figure 6, changes in RHcrit produce lines with distinctly different gradients. For fog fraction, Figure 6a shows the black line (RHcrit=0.92) and the red line (RHcrit=0.96) cross near RH*=1 and fog will start to develop at lower values for RH* in the global model but the fog fraction will approach 1 more slowly than in the city model. Similarly, Figure 6b shows the black line (RHcrit=0.92) and the red line (RHcrit=0.96) cross near RH*=0.96 so mist will start to develop at lower values for RH* in the global model but the mist fraction will approach 1 more slowly than in the city model.

Table 4 Aerosol mass mixing ratios and corresponding descriptions from Haywood *et al*. (2008).

A (μg kg^{-1})	Description
~5	Very clean
~10	Clean
~20	Lightly polluted
30-40	More polluted
>60	Polluted / High aerosol concentrations

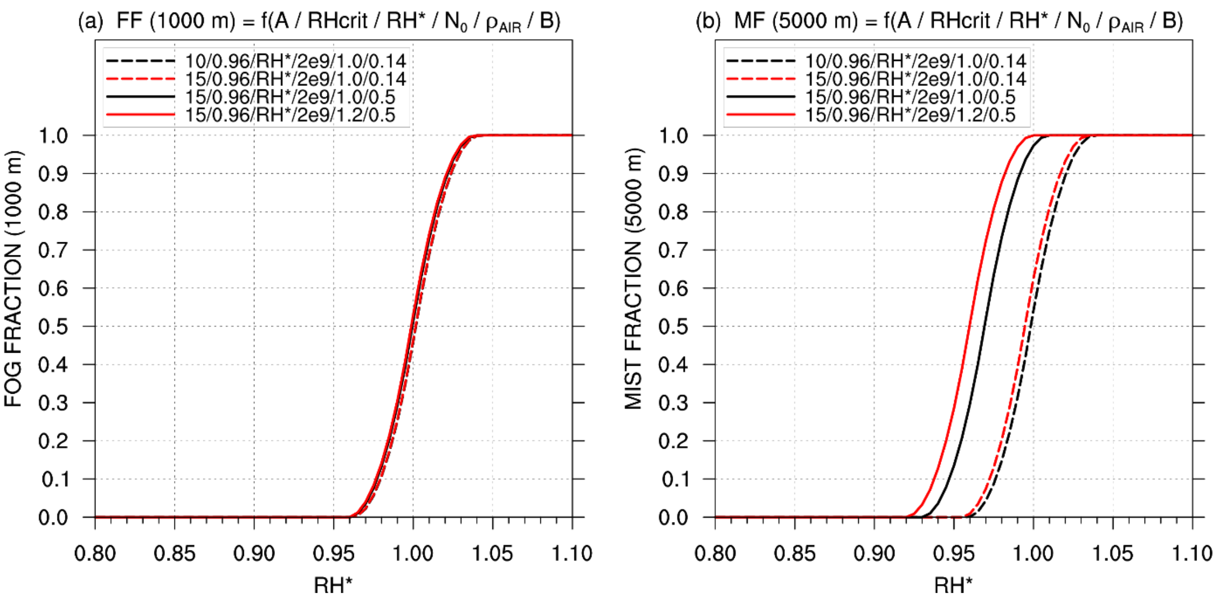

Figure 2 (a) Fog fraction, and (b) mist fraction, computed as a function of RH* for four distinct combinations of A, air density, and B.

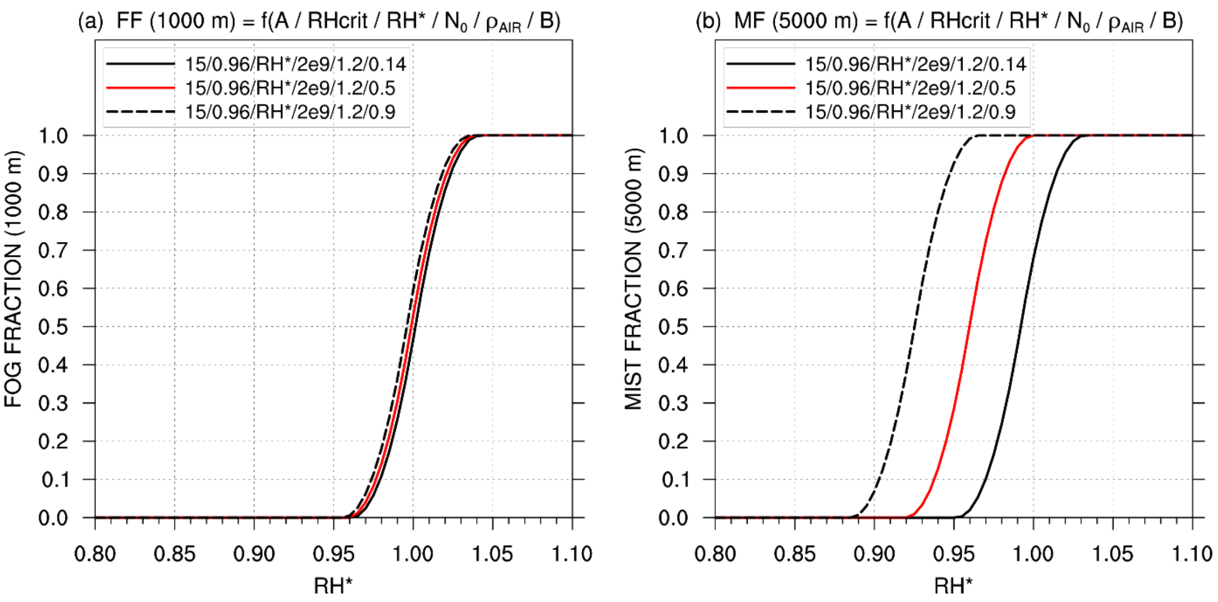

Figure 3 (a) Fog fraction, and (b) mist fraction, computed as a function of RH* for three distinct values of B.

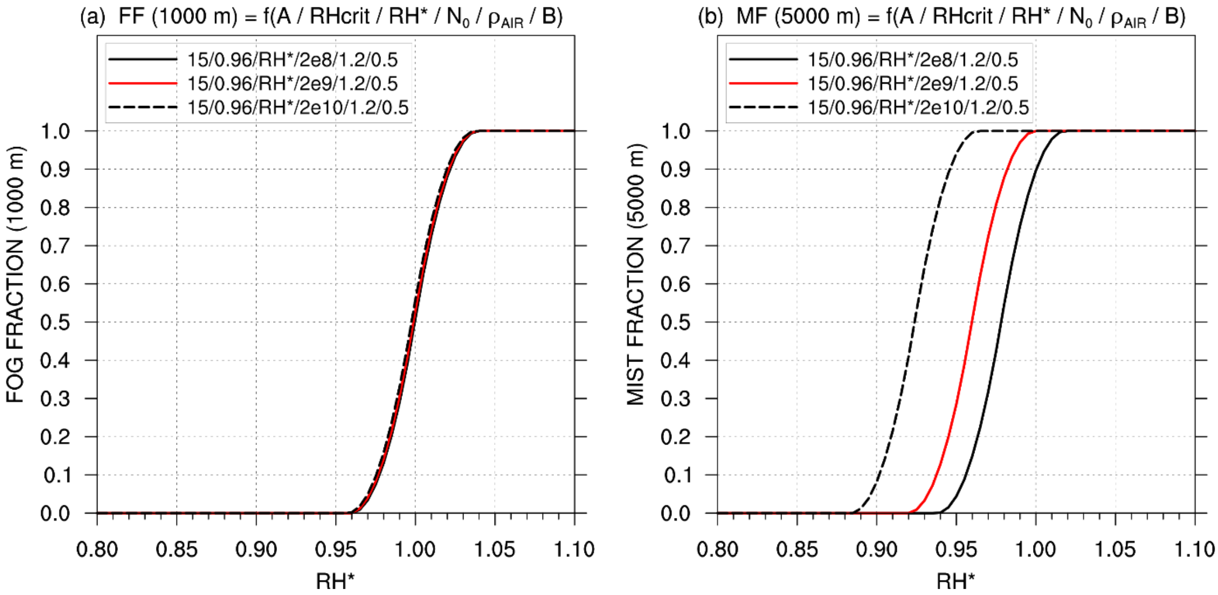

Figure 4 (a) Fog fraction, and (b) mist fraction, computed as a function of RH* for three distinct values of N_0.

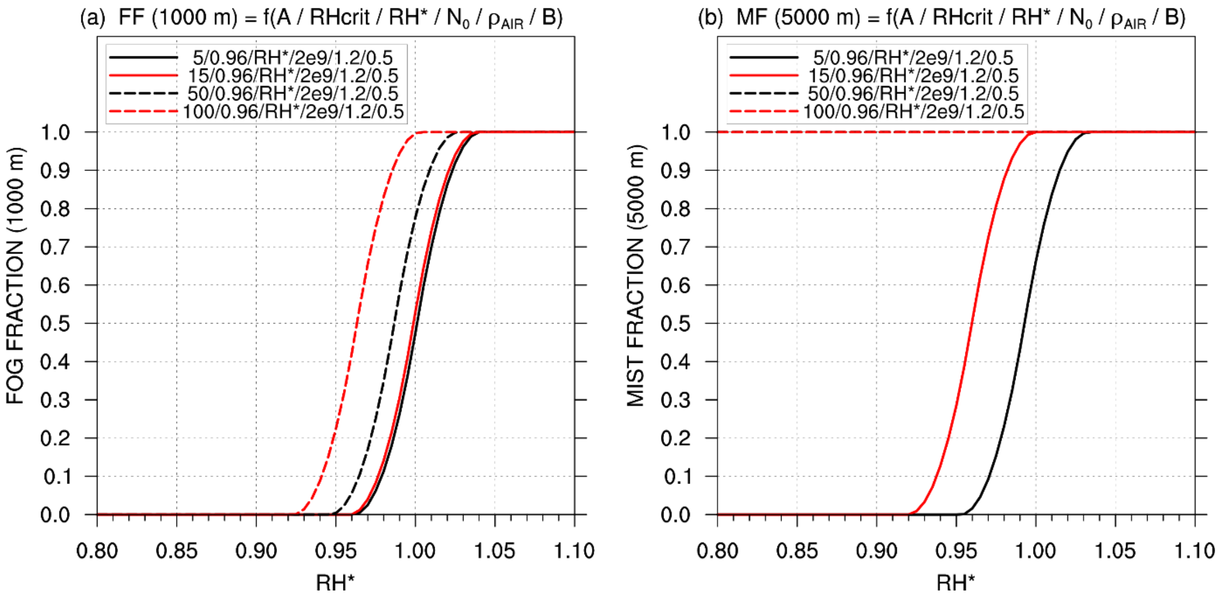

Figure 5 (a) Fog fraction, and (b) mist fraction, computed as a function of RH* for four distinct values of A.

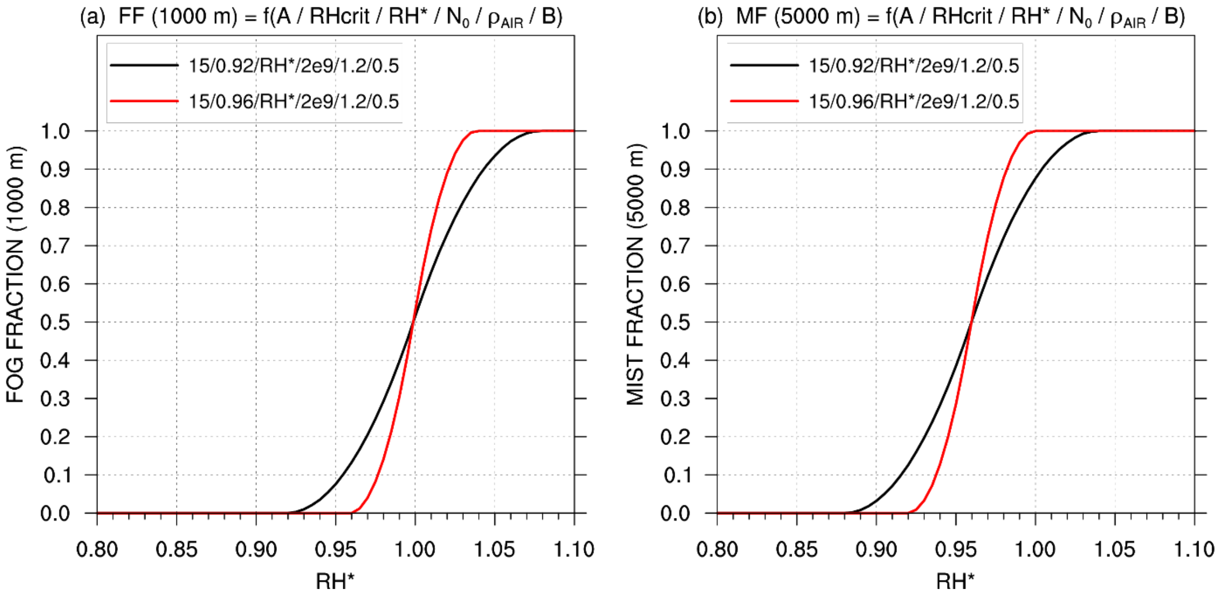

Figure 6 (a) Fog fraction, and (b) mist fraction, computed as a function of RH* for two distinct values of RHcrit where RHcrit=0.92 for the global APS3 ACCESS model and RHcrit=0.96 for the city scale APS3 ACCESS model.

5. SUMMARY

The ACCESS model provides forecasts of visibility and fog fraction and these are diagnosed from meteorological fields predicted by the model. In order to improve the performance of the visibility scheme for the Australian environment the sensitivity of the scheme was examined in detail and new configuration parameters were recommended for implementation in the APS3-ACCESS model (Dare and Potts, 2019a). The changes in the configuration parameters for the visibility scheme impact on the fog fraction scheme and in this study, we examine the sensitivity of the fog fraction scheme to required input variables and assess the impact of the changes in the visibility scheme.

To conduct the sensitivity experiments efficiently, the fog fraction scheme is removed from the ACCESS NWP model and placed in a separate framework. The sensitivity of the scheme is then assessed based on variations in the following seven parameters: the specified visibility threshold (1000 m for fog and 5000 m for mist), specified relative humidity (RH*), critical relative humidity (RHcrit, the grid-box mean relative humidity above which cloud starts to appear), aerosol mass mixing ratio (A), air density (ρ_{AIR}), aerosol number density (N_0), and the activation parameter (B, related to the solubility of the aerosol).

Values of the fog fraction produced using the default set of configuration parameters employed in the ACCESS NWP model in recent years (A = 10 µg.kg^{-1}, B = 0.14, ρ_{AIR} = 1.0 kg.m^{-3}) have been compared with those produced using a new set of parameters recommended following tuning of the visibility scheme (A = 15 µg.kg-1, B = 0.5, ρ_{AIR} = 1.2 kg.m^{-3}) (Dare and Potts, 2019a). Adoption of this new set of parameters has a relatively minor impact on fog fraction values (compare the dashed black and solid red lines in Figure 2a).

For the mist fraction (computed using a specified visibility threshold equal to 5000 metres instead of 1000 metres), the new set of parameters has a large impact, with values approaching 1 at values of RH* just a few percent lower (compare the dashed black line and solid red line in Figure 2b). These changes occur primarily due to an increase in the value of the activation parameter (B), with some additional influence from increasing the air density and the aerosol mass mixing ratio (A).

The fog fraction is sensitive to the aerosol mass mixing ratio and when very high values, such as 50 or 100 µg.kg^{-1}, are applied, values of the fog fraction approach 1 at lower values of RH* (compare dashed lines with solid red line in Figure 5a). Such values of the aerosol mass mixing ratio are not representative of the mean atmospheric conditions across Australia (refer to Table 4) and a value of 15 µg.kg^{-1} is recommended.

Within the APS3-ACCESS NWP model the critical relative humidity (RHcrit) is the grid-box mean relative humidity above which fractional cloud starts to appear. This has a lower value in the global ACCESS-G model (0.92) compared to the city-scale ACCESS-C model (0.96) to allow for greater sub-grid variability at the lower spatial resolution. Assuming the same input variables this will result in differences in the fog fraction and mist fraction fields, such that for a given area, fog (or mist) will start to develop at lower values for RH* in the global model but the fog fraction (or mist fraction) will approach 1 more slowly than in the city model, (compare the red line with black line in Figure 6a and 6b).

6. FUTURE DIRECTIONS

It is known that the diagnostic scheme for visibility and fog fraction in the ACCESS model has limitations that arise from a sensitivity to small errors in the prognostic temperature and humidity field from the model, a lack of suitable information on aerosols across Australia and limitations in the visibility diagnostic itself. Dare and Potts (2019a) and this study examine the sensitivity of the scheme to the input variables and configuration parameters and recommend a new set of configuration parameters for implementation in the APS3-ACCESS model. These new parameters are more applicable to Australia and improve the available guidance.

Based on the results presented in this report the following recommendations are made:

1. To provide a more comprehensive evaluation of the fog forecasting guidance from ACCESS arrangements for routine verification of the visibility and fog fraction fields from the APS3-ACCESS global and city models should be established. This should also investigate the guidance provided for fog onset and clearance noting this may require the development of appropriate metrics.
2. Scientists at the UK Met Office have been developing a new visibility scheme, Vera (**V**isibility **e**mploying **r**ealistic **a**erosol), to be implemented in the Unified Model and this is designed to be more robust and less sensitive to small errors in the prognostic variables. The most significant change with this scheme is that it uses a distribution of dry aerosol particles with varying particle sizes and hygroscopies rather than the monodisperse distribution in the current VISBTY scheme. It is recommended that, when available, this new scheme should be tested in a framework similar to that used in Dare and Potts (2019a), to assess its accuracy and determine appropriate configuration parameters that optimise its performance across Australia.

7. ACKNOWLEDGMENTS

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