P4.1

DEVELOPMENTS IN THE CORRECTION OF RADIOSONDE RELATIVE HUMIDITY BIASES AT THE MET OFFICE

Martin C. Sharpe* and Bruce Macpherson
Met Office, Bracknell, United Kingdom

1. INTRODUCTION

Assimilation of radiosonde relative humidity (rh) data directly into the Met Office operational forecast models can result in spurious depletion of analysed cloud cover. A number of factors contribute to this effect. Instruments from the various radiosonde manufacturers show different degrees of dry bias near saturation and this can vary by batch number and the pre-launch storage conditions. Model vertical resolution and the method chosen to interpolate from reported levels to model levels affect the representation of thin cloud sheets in the analysis. Another potential source of error is the model's cloud overlap used to derive total cloud cover from a profile of cloud fractions on model layers.

A bias correction is therefore applied to these measurements before they are assimilated. This was derived statistically in 1994. Recent work has focused on developing a real-time scheme to assess and correct the bias for each individual radiosonde ascent.

In essence, the bias correction scheme compares surface reports of cloud cover with the total cloud implied by the radiosonde, which is calculated using the model cloud scheme relationship between humidity and cloud followed by an overlap assumption. The methods of deriving either the statistical or real-time correction from this comparison are outlined in section 2. Since the model's humidity-cloud relationship is not constant for ice cloud, a 'calibration' of the relationship used in the real-time bias correction is attempted from a local assessment of the model background field.

Testing and tuning of the bias correction in assimilation and forecast experiments is described in section 3. These experiments will focus primarily on verification of cloud amount, screen temperature, precipitation and visibility. Full results will be presented at the conference.

* *corresponding author address:* Martin C. Sharpe, Met Office, London Road, Bracknell, Berkshire, RG12 2SZ, United Kingdom;
e-mail: martin.sharpe@metoffice.com

2. SCHEME OUTLINE

2.1 Statistical Correction

This scheme is described by Lorenc et al. (1996) in a paper that also presents an example of the depletion of analysed cloud cover due to assimilating radiosonde rh data. To derive the correction, the rh-cloud relationship (See Figure 1) applied in the Met Office Unified Model (UM) is used to obtain implied cloud profiles for a large sample of radiosonde ascents whose data have been interpolated to model levels. Maximum random overlap is then assumed, to diagnose a total cloud fraction, C_{sonde}, for each of these profiles. Taking collocated SYNOP reports of total cloud cover C_{obs}, and using Equation 1 gives a mean correction for the $rh(C_{sonde})$ value corresponding to each $rh(C_{obs})$. A piece-wise linear fit to these data points is then used to define the rh correction (as shown in Figure 2).

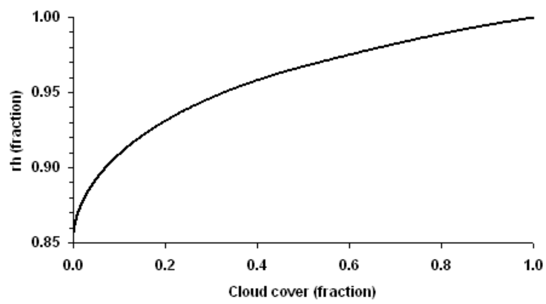

FIGURE 1. Relative humidity-cloud relationship in the Met Office Unified Model

$$\Delta rh = rh(C_{obs}) - rh(C_{sonde}) \qquad (1)$$

Initially, this method was applied using all radiosonde reports passing quality control in a given period, giving a general correction for all radiosondes. The statistical scheme was then used to derive corrections specific to each radiosonde instrument type. This identified corrections for six groups of instrument types that, over a one-year period, showed similar bias characteristics. The corresponding graphs are broadly similar to Figure 2 but have maximum corrections ranging from 1-7%. When processed for the mesoscale model, which has relatively fine vertical resolution, VIZ radiosondes were judged to require no correction.

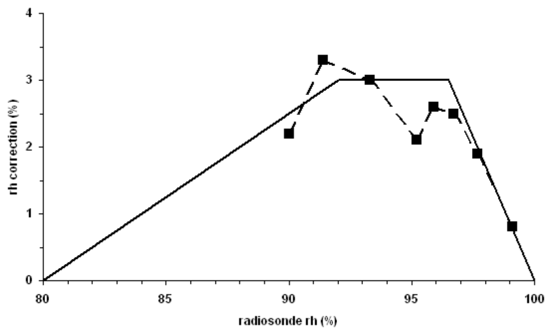

FIGURE 2 Statistically derived relative humidity correction

2.2 Real-time Correction

Various factors point to the need to correct radiosonde rh measurements in real-time. Statistical corrections need revision following the introduction of new or modified instruments, model resolution and physics schemes. The difference in bias characteristics across batches of instruments or with various storage procedures also has an impact on the effectiveness of a statistical scheme. In addition, the possible dependence of rh bias on synoptic conditions makes a real-time correction attractive. The alternative would be an unwieldy implementation of statistical correction sets applied according to a real-time assessment of the prevailing synoptic situation.

The real-time correction is a development of the statistical scheme, using the UM rh-cloud relationship to derive the cloud profiles implied from each radiosonde ascent that has a collocated SYNOP cloud report. (The statistical scheme is applied by default for those ascents with no SYNOP cloud data to compare against.) All levels (i) of the implied cloud profiles are then iteratively scaled using Equation 2 such that the total cloud fraction diagnosed from a maximum random overlap assumption is within a fixed tolerance of C_{obs} for each ascent. In cases where $C_{obs} = 1$, a single scaling is performed to ensure that complete cover is implied from the rh profile. The corrected rh values are then obtained from the scaled cloud profiles by the inverse of the UM rh-cloud relationship. Since we attempt to correct only for effects giving rise to a dry bias, only positive rh corrections are permitted.

$$C_{sonde}^{n+t} = MaxRandom\left\{ C_i^n \frac{C_{obs}}{C_{sonde}^n} \right\} \qquad (2)$$

One tuneable parameter in the scheme is the tolerance to which the implied cloud profiles are matched to the SYNOP cloud reports. This should be small compared with a typical mean bias in the analysis, of -0.5 octas in the case of the mesoscale configuration of the UM. Currently a value of 0.1 octas is set.

Two complexities of the model cloud physics call for a modification to the simple use of the rh-cloud curve in Figure 1. The rh-cloud relationship applies only to layer cloud, and convective cloud may be present in the model background. Secondly, the relationship applies exactly in the model only for liquid cloud. For ice cloud, it is only an equilibrium condition, and the amount of ice cloud may be different to that implied from the rh according to whether the cloud is growing or decaying.

Our approach to this complexity is to include a 'calibration' of the rh-cloud relationship based on the difference between the total cloud cover in the model background field (C_{BG}) and that implied by the background rh profile (C_{BG_rh}). This leads to Equation 3 where we redefine the target for the scaling algorithm, and replace C_{obs} by C_{target} in the iterative scaling in Equation 2 and the tolerance test which follows it.

$$C_{target} = C_{obs} - (C_{BG} - C_{BG\_rh}) \qquad (3)$$

This formulation has the advantage of allowing automatically for any future changes to the model physics without modifying the sonde rh correction scheme.

While all departures from Figure 1 which affect total cloud cover in the model can be swept into Equation 3, the specific example of the presence of convective cloud is more naturally handled through the overlap assumption. The model total cloud cover C_{BG} is obtained by combining the layer cloud and convective cloud fractions at each level of the profile before applying the overlap assumption. So if we use this approach in deriving C_{sonde}, and if the model background convective cloud is a realistic indicator of observed convective cloud, then we account (at least partially) for one source of discrepancy between C_{sonde} and C_{obs} before any rh correction is estimated. For consistency we calculate C_{BG_rh} in the same way and so restrict the 'calibration' of Equation 3 to compensating for the effects of ice cloud.

The scheme relies on both rh profiles that imply non-zero cloud fractions and the availability of SYNOP cloud data for the majority of radiosonde locations. It cannot correct unusually dry ascents and will revert to the statistical form in the absence of the required SYNOP data.

Mesoscale model runs to date have shown that approximately 70% of radiosonde ascents in the model domain do have collocated SYNOP reports.

2.3 Application of real-time scheme

The table shown below indicates the steps to be followed in order to implement the real-time correction scheme described in section 2.2.

<table>
<tr><td colspan="4">Is C_{sonde} > 0?</td></tr>
<tr><td colspan="3">Yes</td><td>No</td></tr>
<tr><td colspan="3">Is there a collocated SYNOP report?</td><td rowspan="5">Do not correct</td></tr>
<tr><td colspan="2">Yes</td><td>No</td></tr>
<tr><td colspan="2">Is C_{obs} > threshold</td><td rowspan="3">Apply statistical correction</td></tr>
<tr><td>Yes</td><td>No</td></tr>
<tr><td>Apply profile scaling</td><td>Do not correct</td></tr>
</table>

A second tunable parameter in the scheme is the threshold for observed cloud below which we do not attempt any rh correction, but at present all non-zero SYNOP cloud covers are used within the profile scaling.

3. TRIALS

Mesoscale model runs out to T+36 over for a 2-day assimilation period in January 2000 were used for preliminary tests of the scheme. This period had shown sensitivity to radiosonde rh data in data impact experiments. Further tests in progress involve a 2-3 week trial running in parallel with the operational mesoscale model, a longer rerun from January 2000, and a batch of cases chosen from a variety of synoptic conditions.

4. CONCLUSIONS

Preliminary results suggest that the real-time scheme performs, at least as well as the statistical version, considering cloud amount, screen temperature, precipitation and visibility. Full results from the trials described in section 3 will be presented at the conference.

Even if tuning the scheme does not show an improvement on the statistical correction, the real-time formulation is preferable, as it does not need new derivations in the light of changes to model physics or instrumentation technology and performance. However, for ascents with no collocated SYNOP report, the scheme could be made more robust to such changes by automatically updating the default statistical correction from the history of real-time time corrections.

5. ACKNOWLEDGEMENT

We are grateful to Andrew Lorenc for suggesting the 'calibration' in equation 3.

6. REFERENCES

Lorenc, A.C., Barker D., Bell R.S., Macpherson B and Maycock A.J.,1996: On the use of Radiosonde Humidity Observations in mid-Latitude NWP *Meteorology and Atmospheric Physics*, **60,** 3-17