Numerical Weather Prediction

Impact of tropical surface-based profile data on NWP forecasts

Forecasting Research Technical Report No. 479

Richard Dumelow

email: nwp_publications@metoffice.gov.uk

Document History for NWP Technical Report No. 479

Date	Version	Action/Comments	Approval
15/03/04	0.1	Draft for consideration by D. Richardson.	-
27/09/05	0.2	Updated following comments from D. Richardson.	D. Richardson
20/04/06		Approval for issue from A. Lorenc.	A. Lorenc

ABSTRACT

An Observing System Experiment was run to assess the impact of tropical surface-based profile data. Radiosonde data were denied from a region of South-east Asia that was chosen because it is the most densely observed area of the tropics. Two data denial scenarios were investigated: (i) removing all ‘in-situ’ profile data i.e. radiosonde data and aircraft data below flights levels (ii) removing radiosonde humidity data only. The experiment was run using July 2001 observations and 30 forecasts ranging from one to six days were assessed. The results from the two data denial scenarios were compared with a control run that used all available observational data.

The study was carried out in response to a request from the WMO Expert Team on the Observational Data Requirements and Redesign of the GOS (ET-ODRRGOS) who requested an assessment of the likely benefit of improving the coverage of surface-based profile data in data-sparse regions of the tropics, such as Africa. Scenario (i) approximates to the current situation over some parts of tropical Africa, scenario (ii) investigates the likely benefit of AMDAR ascent/descent profiles over tropical Africa and the control run investigates the likely impact of a full radiosonde network.

The results from the study indicate that there is clear positive impact from temperature and wind profiles on wind forecasts at most levels in the tropical region where the profile observations are taken. A positive impact of temperature and wind profile observations on wind and height forecasts can also be seen in adjacent extra-tropical regions, although the impact is smaller.

The impact of the humidity profile observations from radiosondes on wind and height forecasts in the tropical region where the observations are taken is variable and depends on level and forecast range. Overall the impact is neutral to slightly negative. The impact of the tropical humidity profile observations on wind and height forecasts in the adjacent extra-tropical regions is very small.

CONTENTS

1. Introduction Page 5
2. Description of the Experiment Page 5
3. Results Page 6
4. Discussion and conclusions Page 7

References Page 9

Figures Page 10

Appendix Page 26

1. Introduction

'In-situ' profile observations have a significant impact on NWP forecasts, despite the use of increasing amounts of satellite data that can be effectively assimilated using variational techniques (Bouttier and Kelly, 2001). Currently, and for the next few years, improvements in the benefit of satellite data for NWP are likely to be limited whilst further challenges in the use of satellite data are overcome. For example, there are problems in obtaining useful information in cloudy areas, which are highly correlated with initial condition sensitivity (McNally, 2000), and using radiances over land where the modelling of surface emissivity is difficult . A complimentary, global network of 'in-situ' observations will be necessary to ensure continuing improvements in NWP forecasts (WMO, 2004).

It can be seen from recent plots of global radiosonde and aircraft distribution (Figures 1(a) & 1(b)) that there are large land areas of the tropics where the coverage of 'in-situ' observations is sparse, particularly over tropical Africa. This led the WMO Expert Team on Observational Data Requirements and Re-design of the Global Observing System (ET-ODRRGOS) to request that NWP centres investigate the potential value of an enhanced 'in-situ' profile network in the tropics. The purpose of this study is to answer the questions posed by the Expert Team.

Given the relatively dense coverage of radiosonde data in South-East Asia (see Figure 1(a)), the Expert Team suggested that impact studies be carried out in which radiosonde data was denied from an area covering South-East Asia. Should it be found that the data have a positive impact on NWP forecasts, for the local region or outside, then it may be concluded that an improved surface-based profile network over say, tropical Africa, would have a similar benefit. The Expert Team suggested two experimental scenarios designed to assess the impact of adding either profile measurements from aircraft or radiosonde TEMP reports that include humidity data.

2. Description of the Experiment

An Observing System Experiment was run using the Met.Office operational forecast model and 3-D variational data assimilation scheme. In order to reduce the computational expense, the forecast model was run used at reduced horizontal resolution (90 km compared with 60 km operational). A one month trial was performed using July 2001 observations and thirty 6-day forecasts were verified against both radiosondes and analyses. The verification areas used include those shown in the Appendix.

The area of South-East Asia over which data were denied is shown in Figure 1(a). Three runs were performed:

(i) using all available observations of all data types (ALL DATA)

(ii) as (i) but with no radiosonde or aircraft profile data from South-East Asia (NO SE ASIA SONDES)

(iii) as (i) but with no radiosonde humidity information from South-East Asia (NO SE ASIA SONDE HUMIDITY).

Scenario (ii) represents the current situation over some parts of the tropics, for example, Africa. Scenario (iii) represents the inclusion of AMDAR profile reports in data sparse tropical areas, and scenario (i) the inclusion of radiosonde data.
Note that the analysis fields from run (i) (ALL DATA) were used in calculating the anomaly correlation coefficients since it is considered that this run produces the most accurate analysis

.

3. Results

3.1 Impact on wind forecasts

RMS errors against radiosondes within the South-East Asian region for high (250 hPa) and low (850 hPa) level wind forecasts are plotted in Figure 2. It can be seen that a both levels, but particularly 250 hPa, profile data have a positive impact on forecasts at most forecast ranges. Since the effect of removing humidity data is approximately neutral, it appears as though the benefit of the profile data comes largely from temperature and wind measurements. Note that the large analysis error in the NO SE ASIA SONDE run shown in Figure 2 is due to the use of radiosondes for verifying analysis fields from which radiosonde data have been excluded. Figure 3 shows the vertical distribution of wind RMS errors for 24-hr and 120-hr forecasts. The impact of full profile information, including humidity, is positive or neutral at all levels and both forecast ranges. In contrast, the impact of the humidity profile information is either neutral or negative; the most negative impact being seen at most levels of the 120-hr forecast.

The impact of the tropical profile data on forecasts in regions adjacent to where the observations were made is indicated in Figures 4 and 5. A small positive impact from the radiosonde data can be seen at some levels (e.g. 250 hPa) and forecast ranges (e.g. T+96) when verifying against either Asian or Australian/New Zealand radiosondes. However, for both regions, the impact of humidity data is neutral or slightly positive suggesting that most of the positive impact of the full profile is due to the temperature and wind components.

Looking at forecasts verifying in a region well away from South-East Asia, namely Europe (see Figure 6), it can be seen that the impact of the tropical profile data is neutral.

3.2 Impact on geopotential height forecasts

Some results are presented showing impact of the data on RMS errors versus radiosondes and Anomaly Correlation Coefficient (ACC) scores using the analysis from the 'ALL DATA' run.

RMS errors against radiosondes within the South-East Asian region for high (250 hPa) and low (850 hPa) level height forecasts are plotted in Figure 7 (ACC scores were not calculated for this region). At 850 hPa the impact of the full profile data is negative at all forecast ranges whereas at 250 hPa the impact is positive at all forecast ranges. By comparing the NO SE ASIA SONDES lines with the NO SE ASIA

SONDE HUMIDITY lines, it can be seen that most of the impact is caused by the humidity profile data, which thus has a negative impact at low levels and a positive impact at high levels.

Figure 8 shows the impact in RMS height errors versus radiosondes in South-East Asia over standard pressure levels for T+24 and T+120 forecasts. Positive impact can be seen from the full profile data at most levels although a small negative impact can be seen at low levels (850 hPa – 600 hPa) in the T+24 forecast. A small positive impact from humidity data can be seen at high levels (400 hPa – 100 hPa) in the T+24 forecast.

Figures 9 and 10 show the forecast ACC scores for geopotential height versus pressure level and for different forecast ranges over the Asia and Australia/New Zealand. For both regions, the tropical profile data have a neutral or positive impact up to T+96, but a negative impact can be seen at T+120 and T+144, particularly in the Australia/New Zealand region. As would be expected, the impact of the tropical profile data over the European region is neutral (Figure 11). RMS errors versus radiosondes for these extra-tropical regions have also been examined and show qualitatively the same results.

4. Discussion and conclusions

The results presented here are based upon an analysis of 30 forecasts from a single month and thus definitive conclusions cannot be drawn from them. However, this limited study indicates that the impact of tropical temperature and wind profile data is positive in the region where it is taken. Therefore, more aircraft profile data containing such information taken in data sparse tropical areas (such as Africa and South America) is likely to be beneficial for forecasts in those regions.

The impact of the tropical profile data in the extra-tropics is generally positive or neutral although some negative impact is seen in height forecasts at the five and six-day range. The negative impacts in the mean ACC scores for height over the Australia/New Zealand region at T+120 and T+144 appear to be due to a small number of poor forecasts one of which verifies at 12z on 1st August 2001 (Figures 12 & 13). It is assumed that if a longer trial was run some forecasts showing positive impact would be found, giving approximately neutral or slightly positive impact on the mean height scores similar to the impact on the RMS vector wind error (Figure 5). It should be noted that the noticeable difference in the ACC scores is not necessarily reflected in synoptic features seen on maps. For example, in Figure 14 the main differences between the T+144 forecasts of 850 hPa height are in a small part of the verification region over New Zealand where neither forecast compares precisely with the verifying analysis.

In this study the impact of humidity profile data was neutral although there was a negative impact on RMS height errors at low levels in the tropics. Such neutral impacts from humidity data, particularly in the tropics, have been observed by other NWP centres [e.g. WMO (2004)]. It has been noted that errors grow rapidly in the tropics and that it is difficult to get a positive impact from tropical humidity data that lasts more than a few hours into the forecast. The lack of positive impact may be due to a number of factors. Humidity varies on small spatial and temporal scales so observed values may contain large representivity errors. In NWP models, the parametrization of moisture sensitive physical processes such as surface exchanges and convection, which are critical for tropical forecasts, is difficult. Thus any initial errors in humidity may be amplified by the forecast model giving forecasts of variable quality.

Although it would be expected that the quality of humidity observations and their assimilation will improve in the future, the evidence presented in this study does not support the provision of an ‘in-situ’ network of humidity profile measurements, using existing technology, in data sparse tropical areas.

REFERENCES

Bouttier, F. & Kelly, G. (2001). Observing System Experiments in the ECMWF 4D-Var data assimilation system. *Q.J.R. Meteorol. Soc.*, 127, 1469-1488.

McNally, A.P. (2000). The occurrence of cloud in meteorologically sensitive areas and the implications for advanced infrared sounders. *Technical proceedings of the 11th International TOVS Study Conference*, Budapest, Hungary, 20-26 Sep. 2000.

WMO (2004). *Proceedings of the Third WMO Workshop on the Impact of Various Observing Systems on NWP.* Alpbach, Austria, 9-12 March 2004. WMO/TD No. 1228.

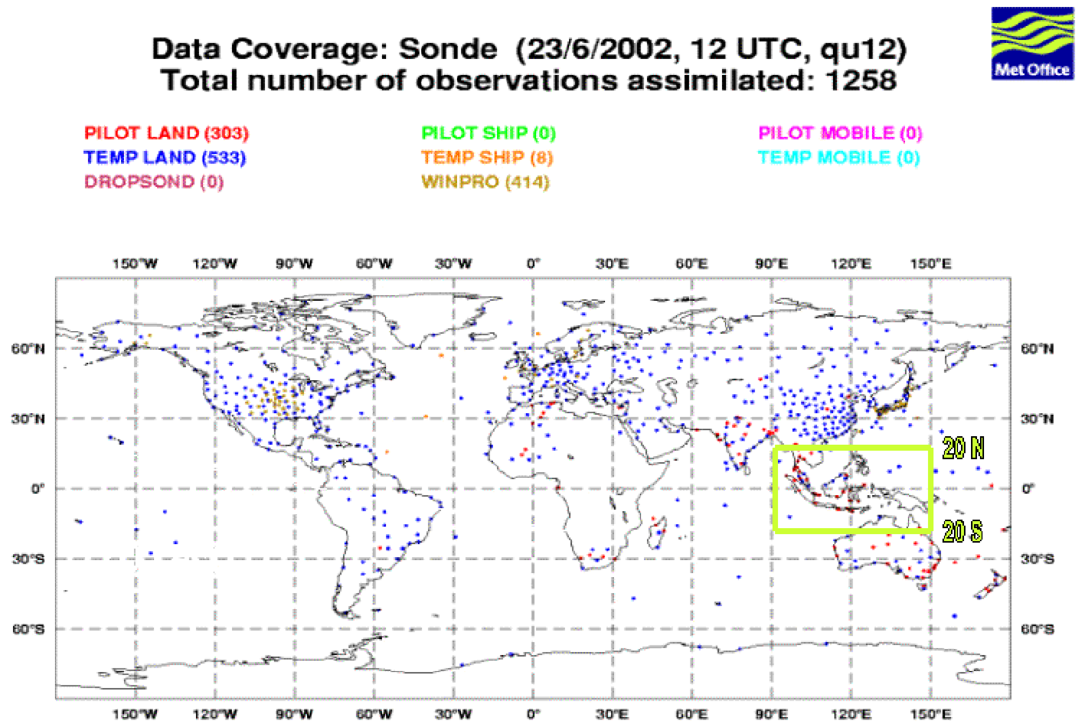


Figure 1 (a). Global distribution of radiosondes. Box indicates the area of South-East Asia from which reports were denied.

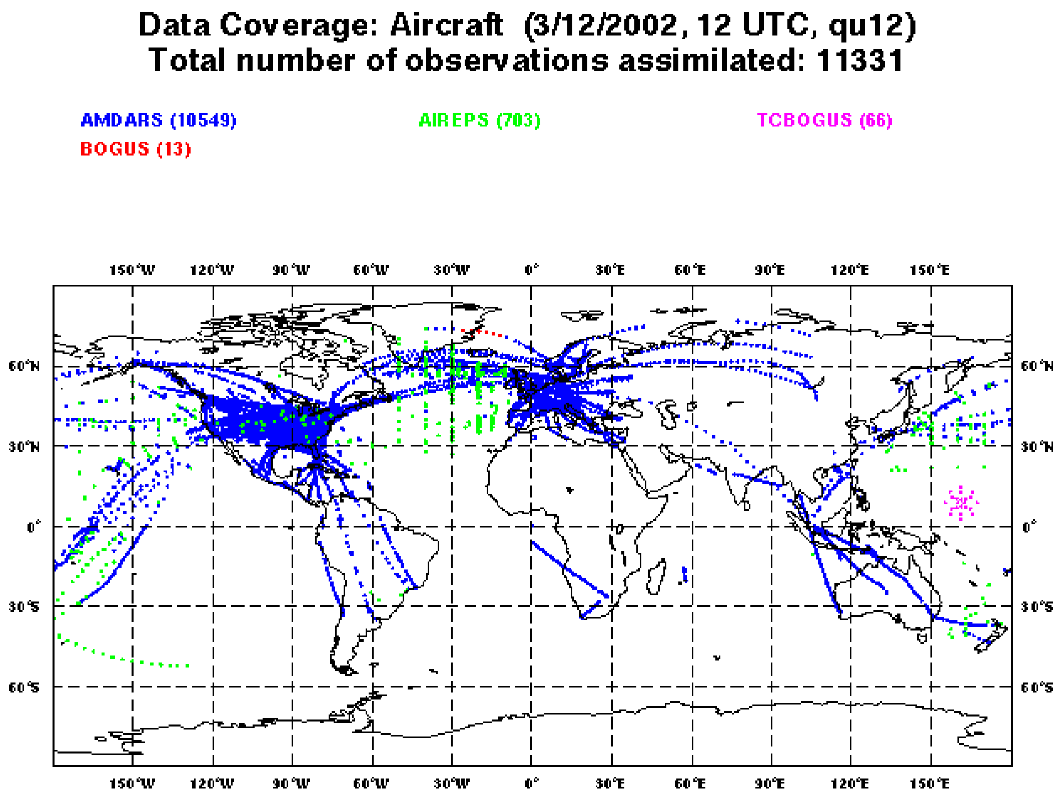
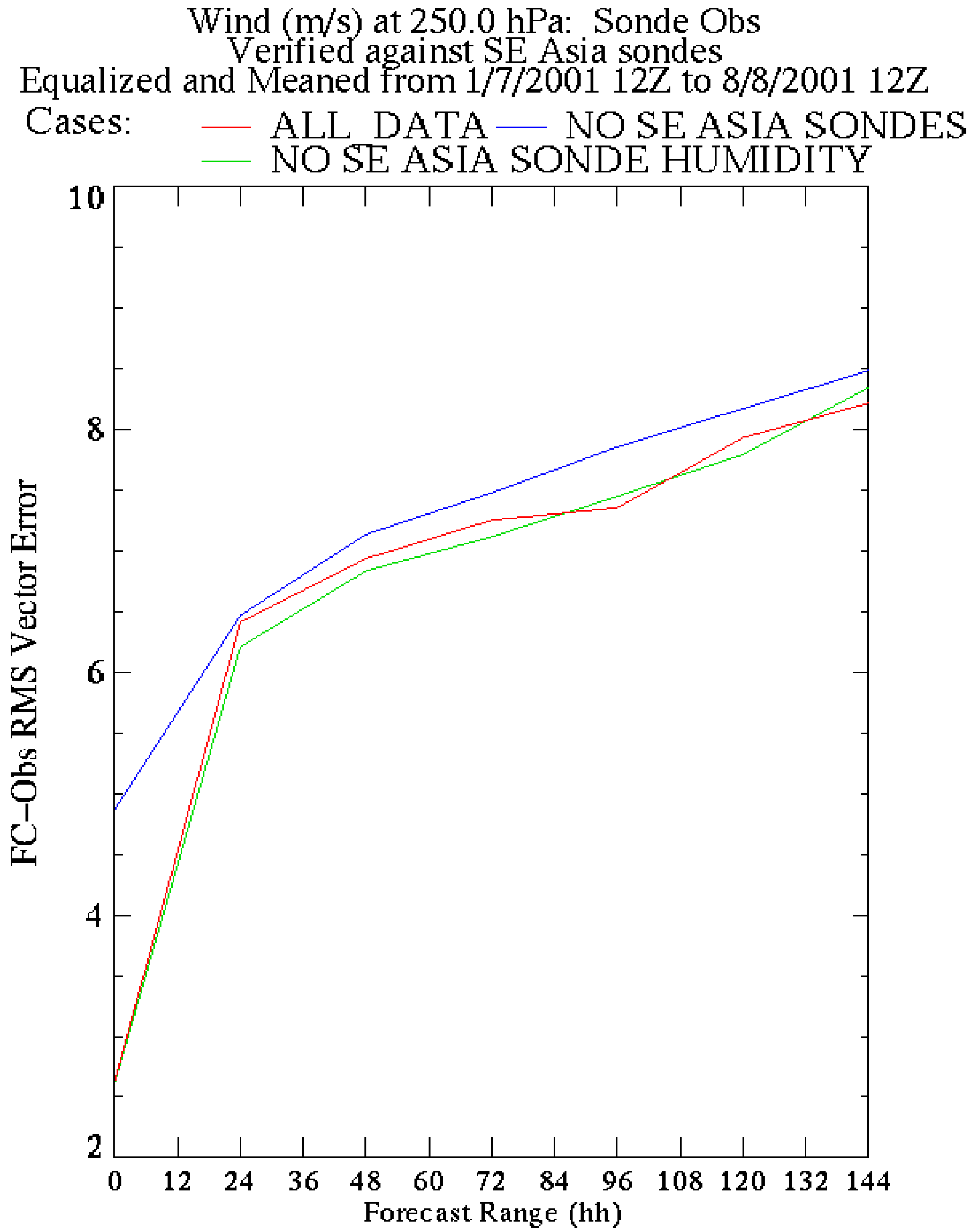


Figure 1 (b). Global distribution of aircraft reports.



.

Figure 2 (a). Mean RMS vector wind errors (m/s) at 250 hPa verified against radiosondes in South-East Asia. Mean calculated over 30 forecasts.

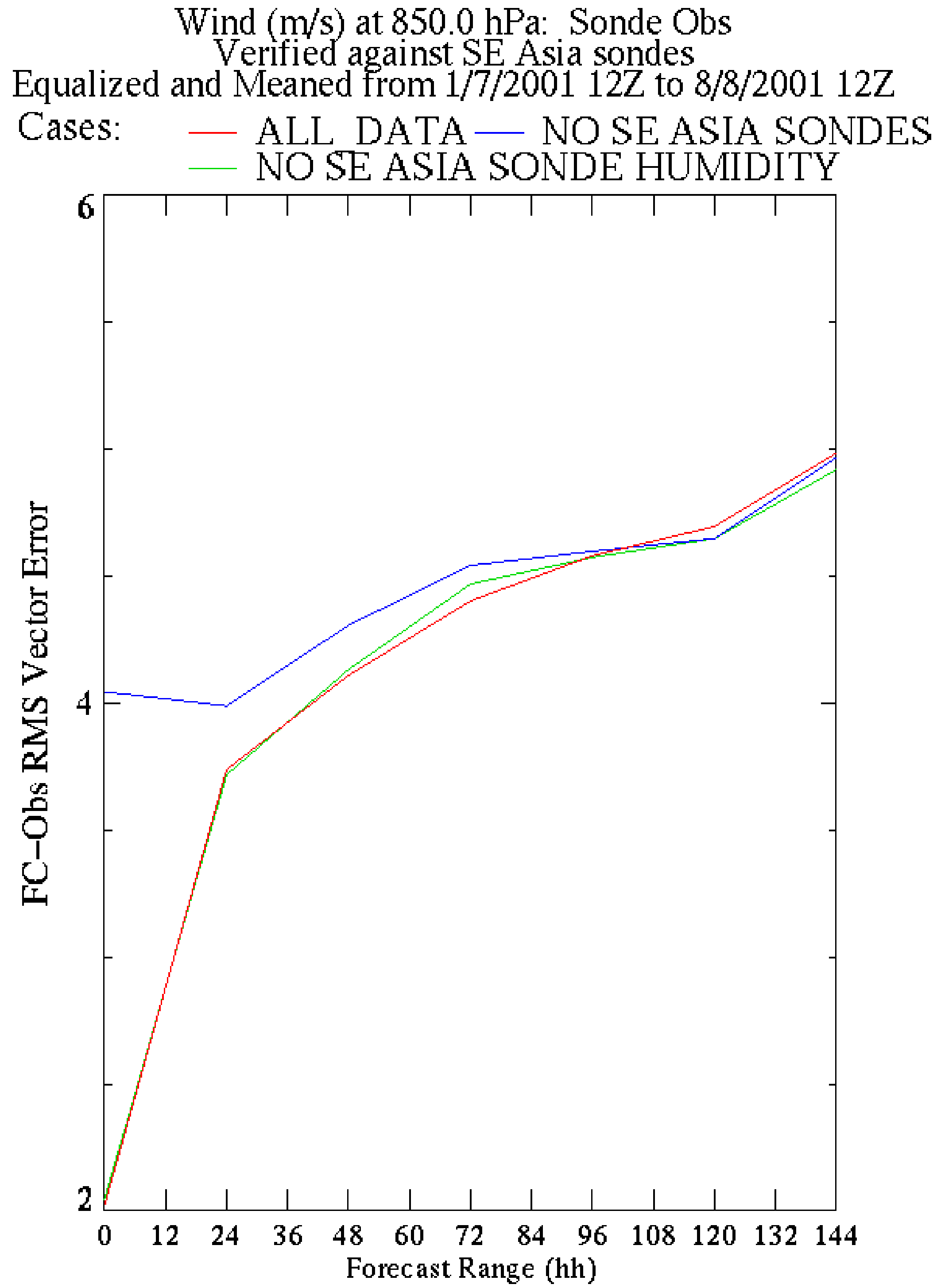


Figure 2 (b). Mean RMS vector wind errors (m/s) at 850 hPa verified against radiosondes in South-East Asia. Mean calculated over 30 forecasts.

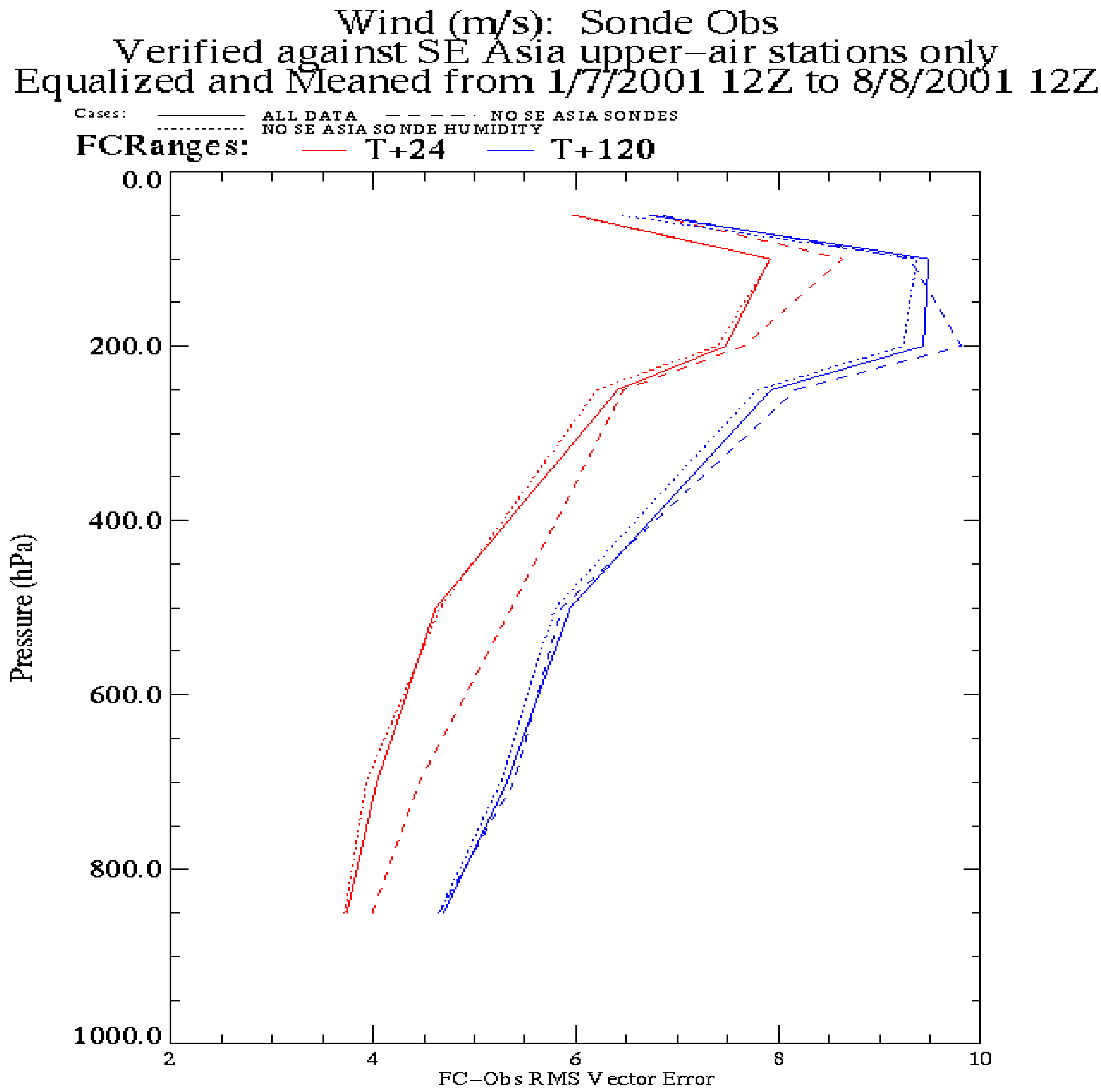


Figure 3. Mean RMS vector wind error (m/s) for 24-hr and 120-hr forecasts verified against radiosondes in South-East Asia plotted for selected pressure levels. Mean calculated over 30 forecasts.

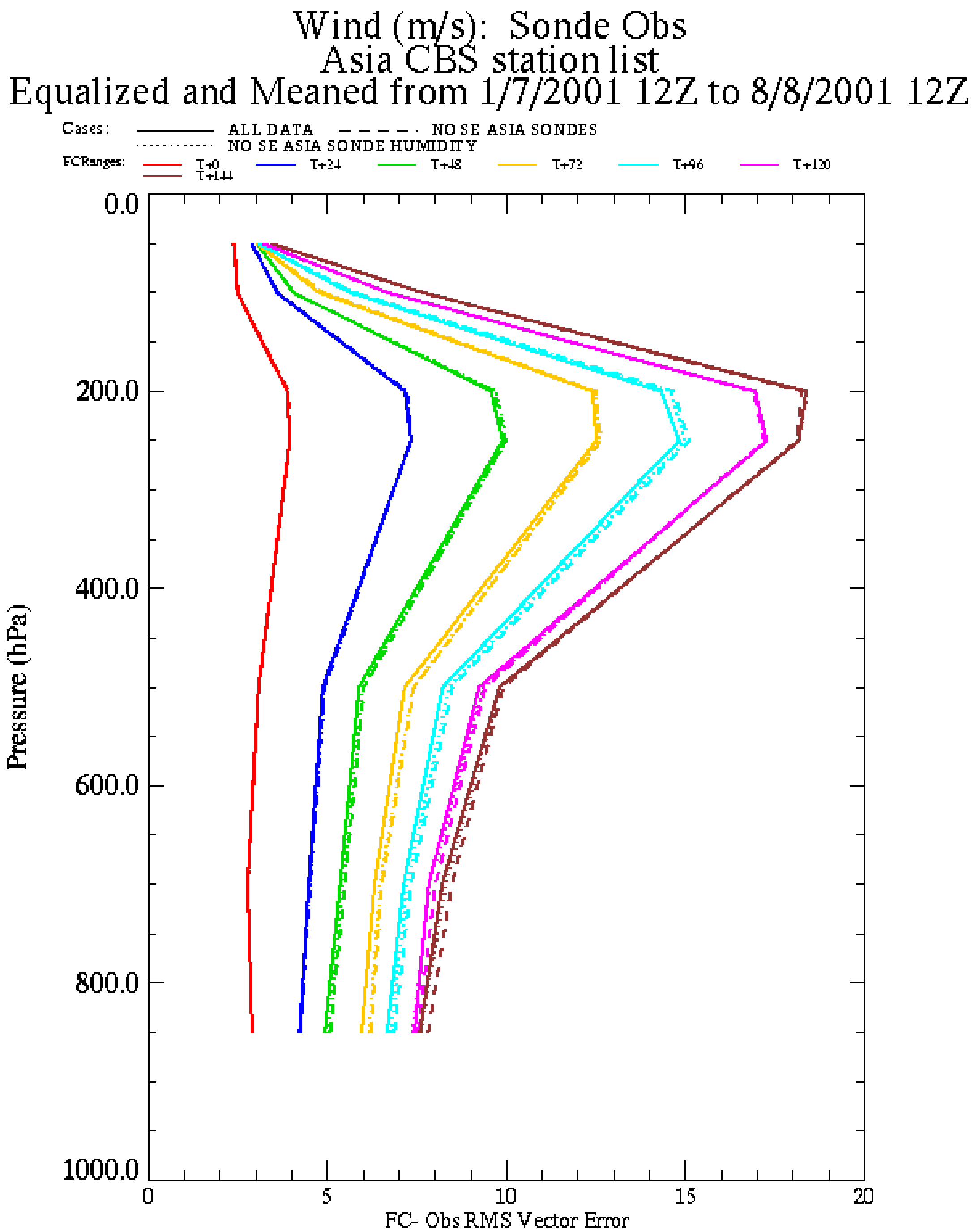


Figure 4. Mean RMS vector wind error (m/s) verified against Asian radiosondes plotted for selected pressure levels. Mean calculated over 30 forecasts.

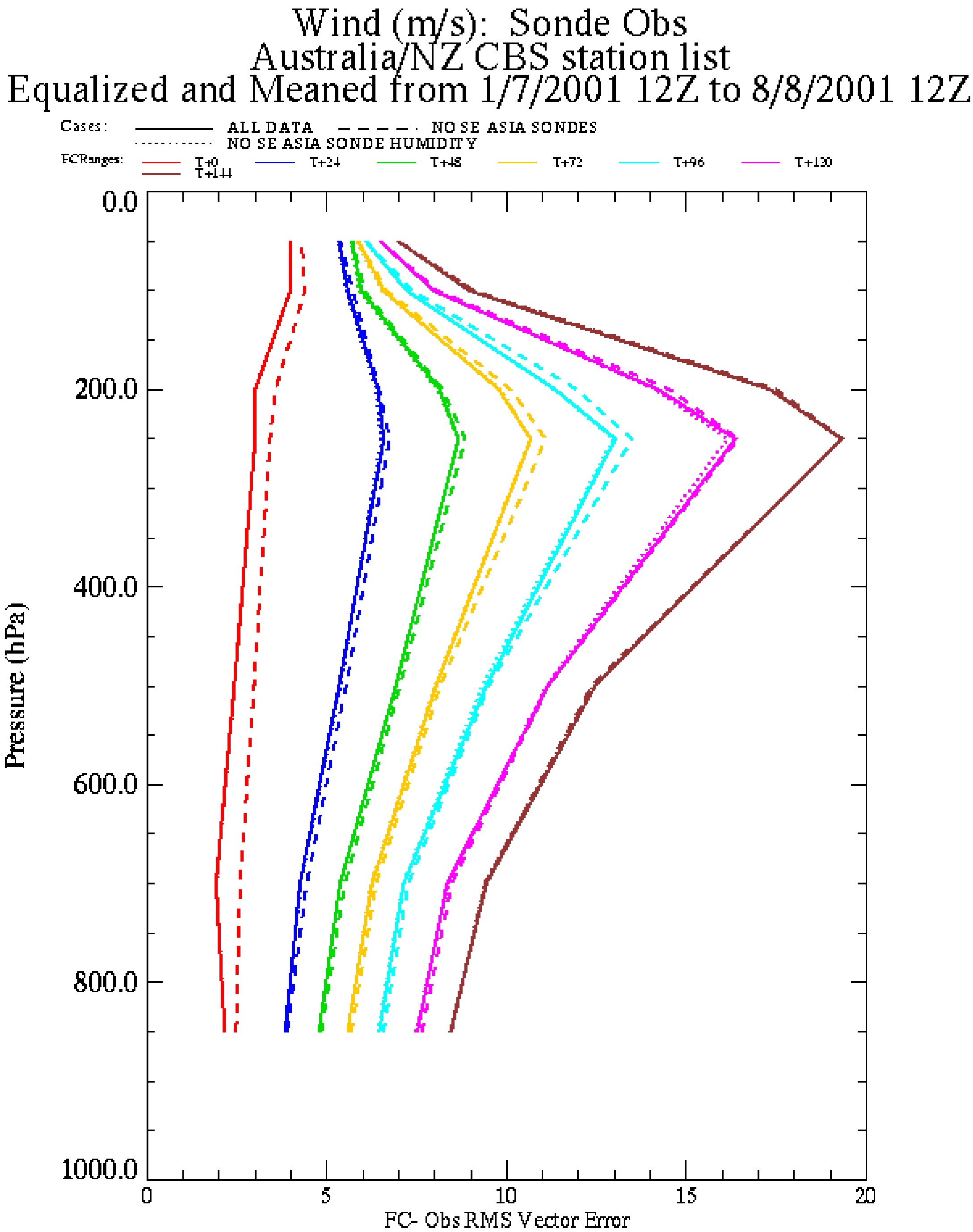


Figure 5. Mean RMS vector wind error (m/s) verified against Australia/New Zealand radiosondes plotted for selected pressure levels. Mean calculated over 30 forecasts.

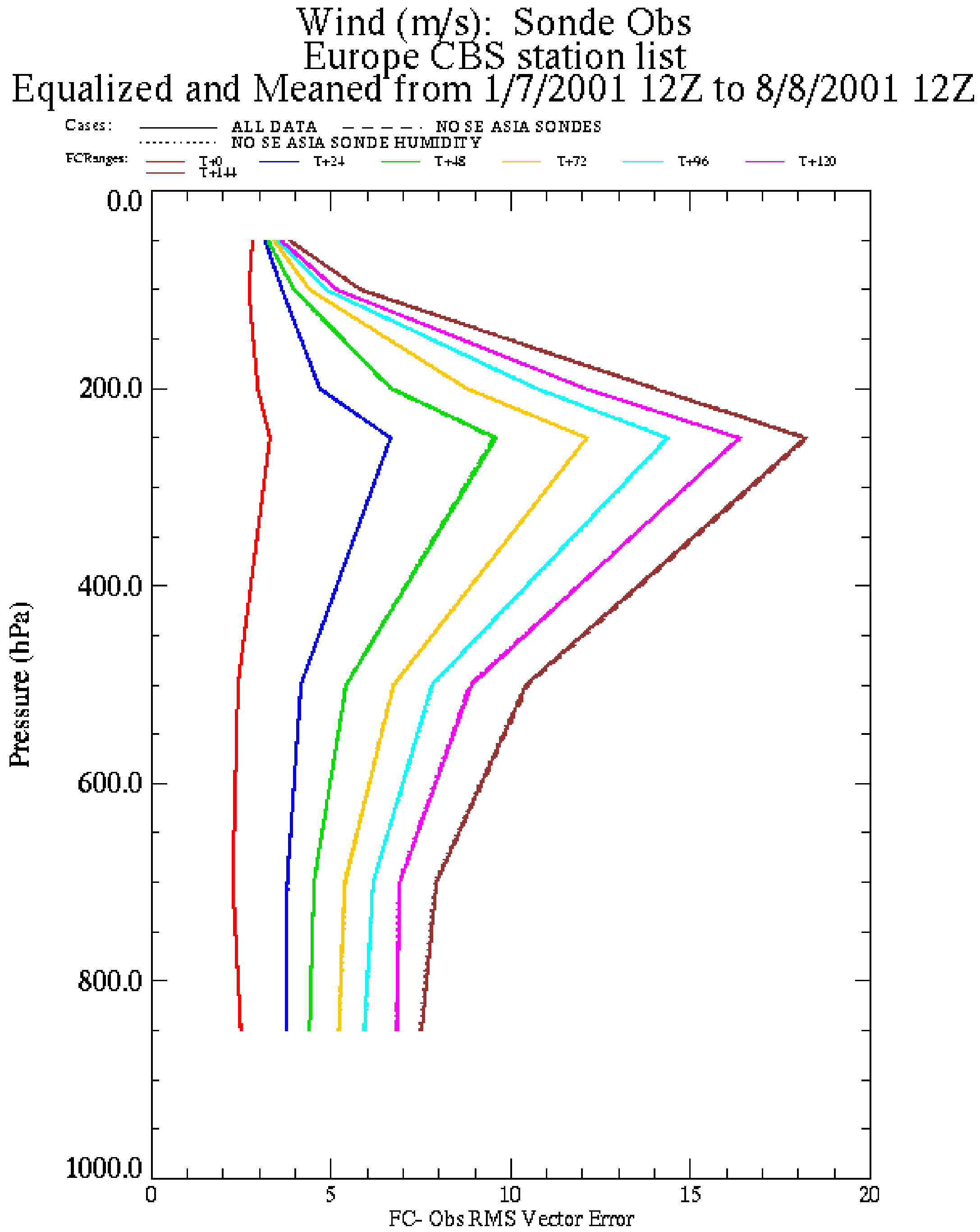


Figure 6. Mean RMS vector wind error (m/s) verified against European radiosondes plotted for selected pressure levels. Mean calculated over 30 forecasts.

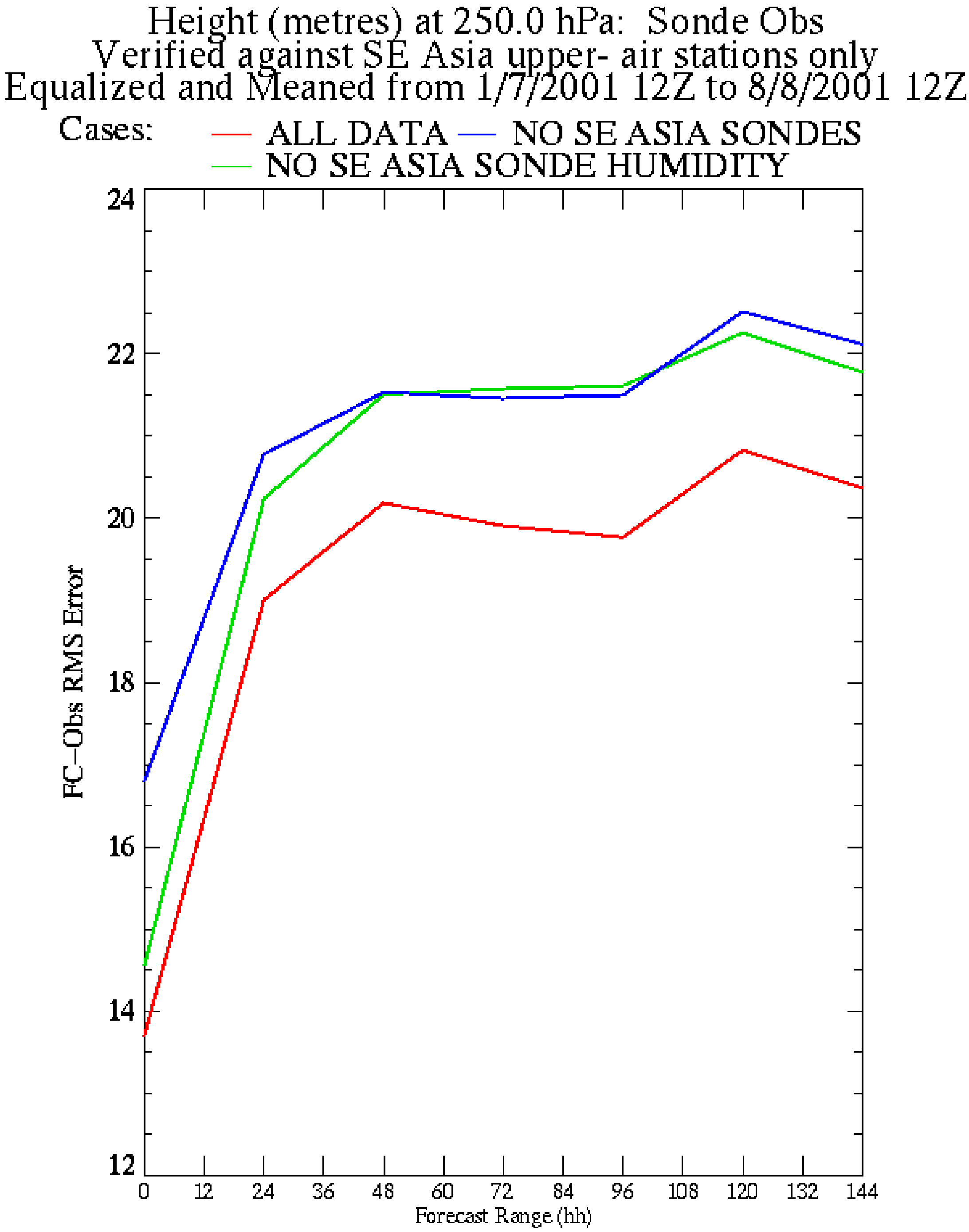


Figure 7 (a). Mean RMS height errors (m) at 250 hPa verified against radiosondes in South-East Asia. Mean calculated over 30 forecasts.

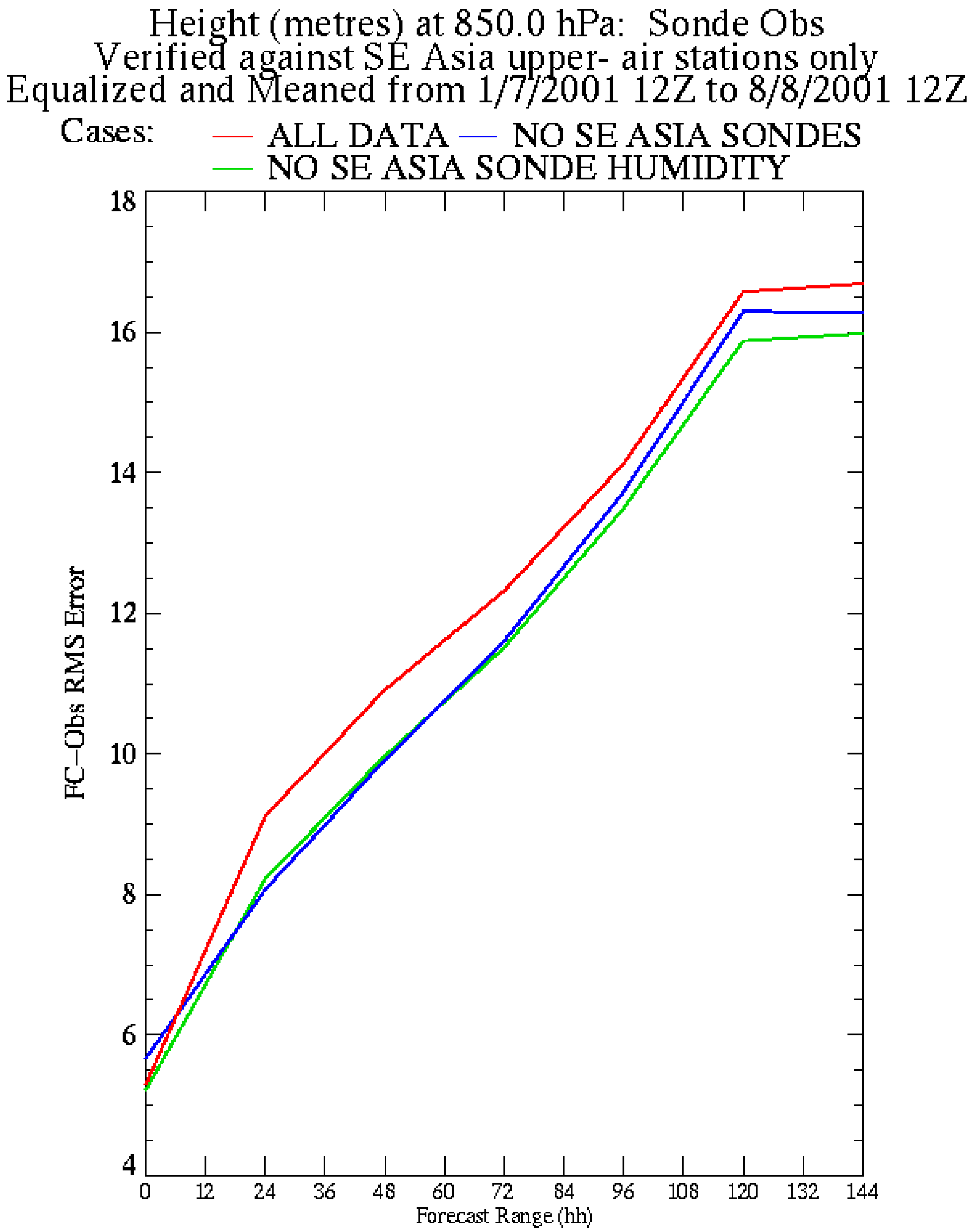


Figure 7 (b). Mean RMS height errors (m) at 850 hPa verified against radiosondes in South-East Asia. Mean calculated over 30 forecasts.

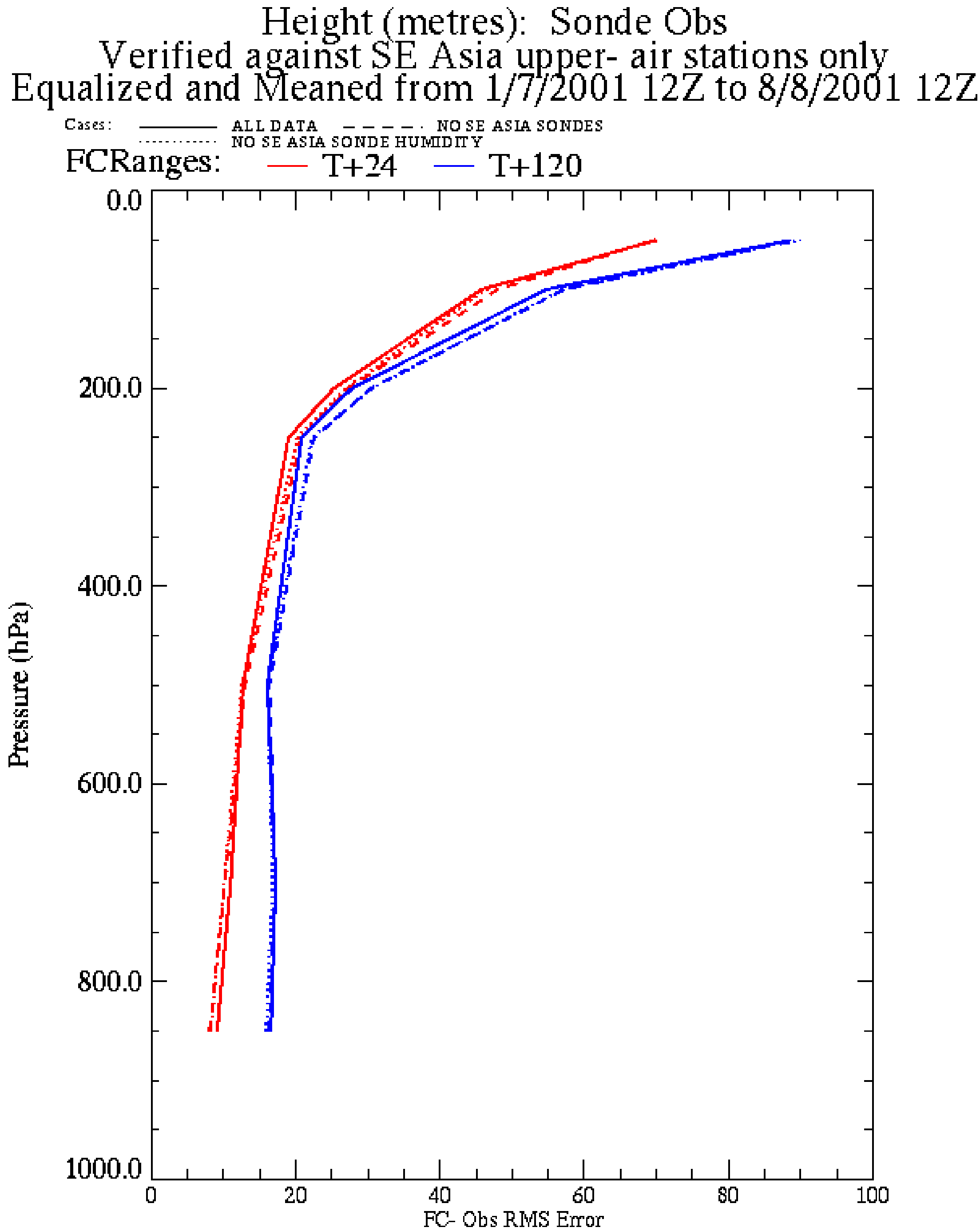


Figure 8. Mean RMS height error (m) for 24-hr and 120-hr forecasts verified against radiosondes in South-East Asia plotted for selected pressure levels. Mean calculated over 30 forecasts.

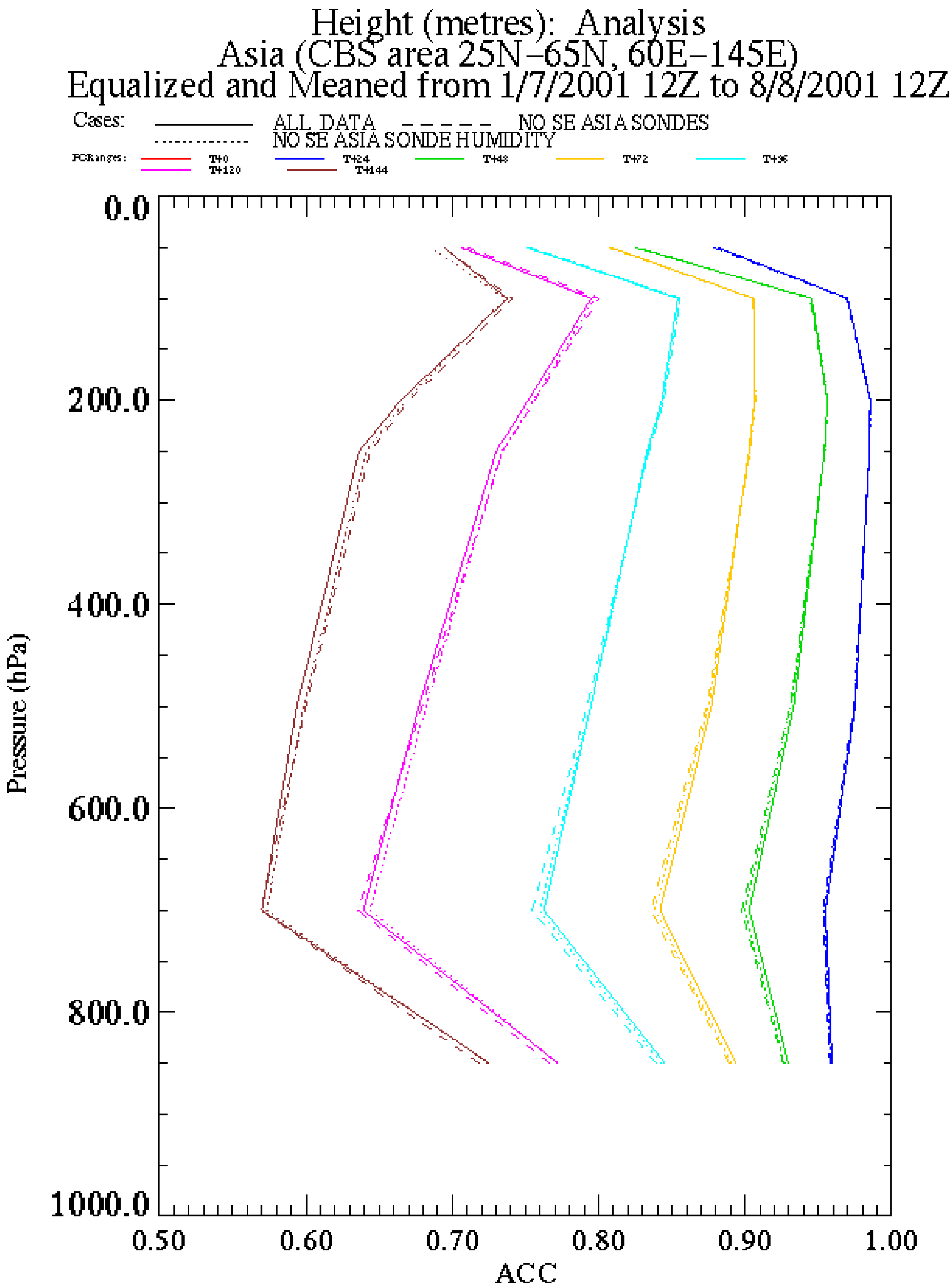


Figure 9. Mean Anomaly Correlation Coefficient for geopotential height (using the 'All data' analysis) for the 'Asia' region. Mean calculated over 30 forecasts.

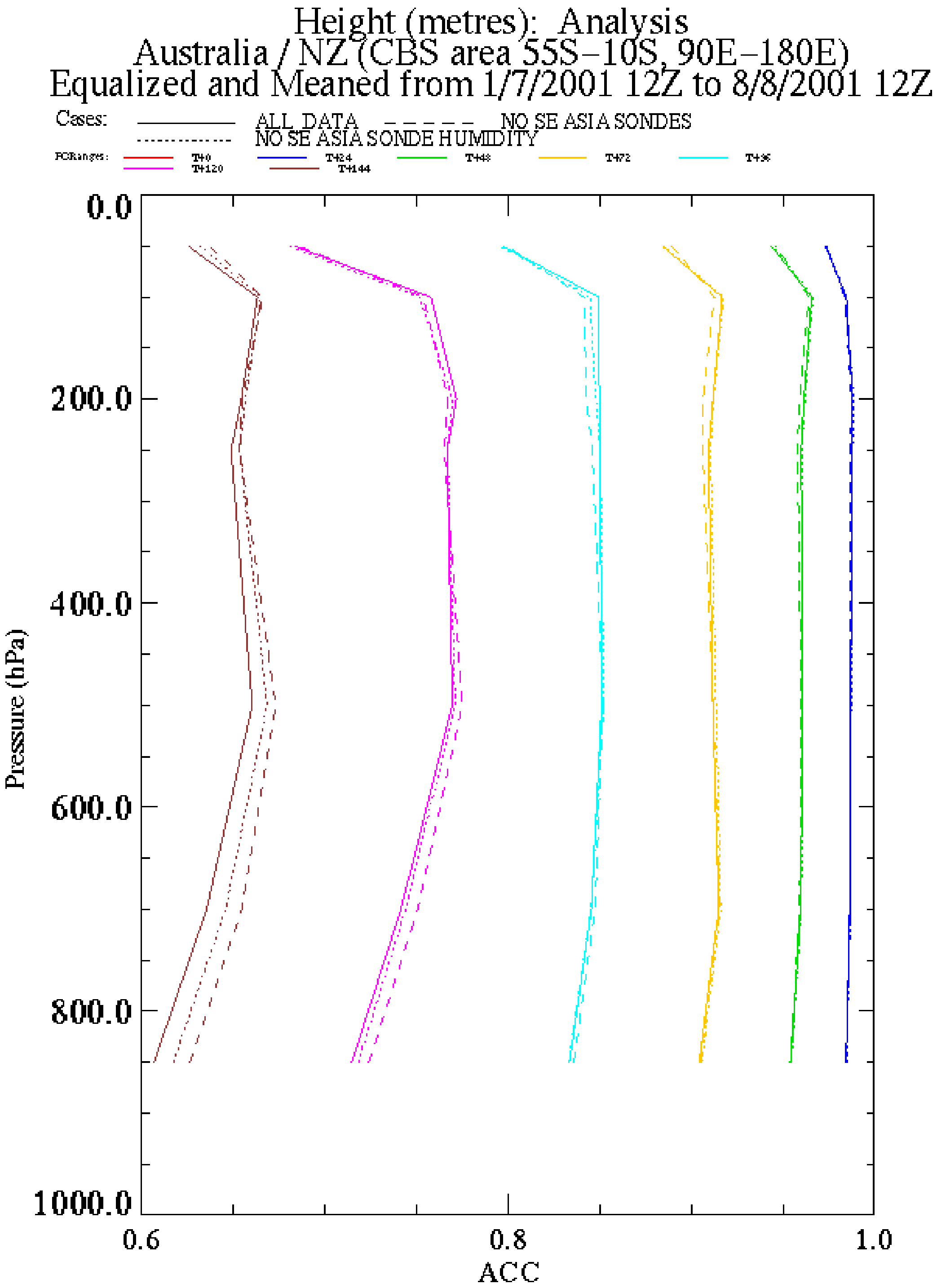


Figure 10. Mean Anomaly Correlation Coefficient for geopotential height forecasts (using the 'All data' analysis) for the 'Australia/New Zealand' region. Mean calculated over 30 forecasts.

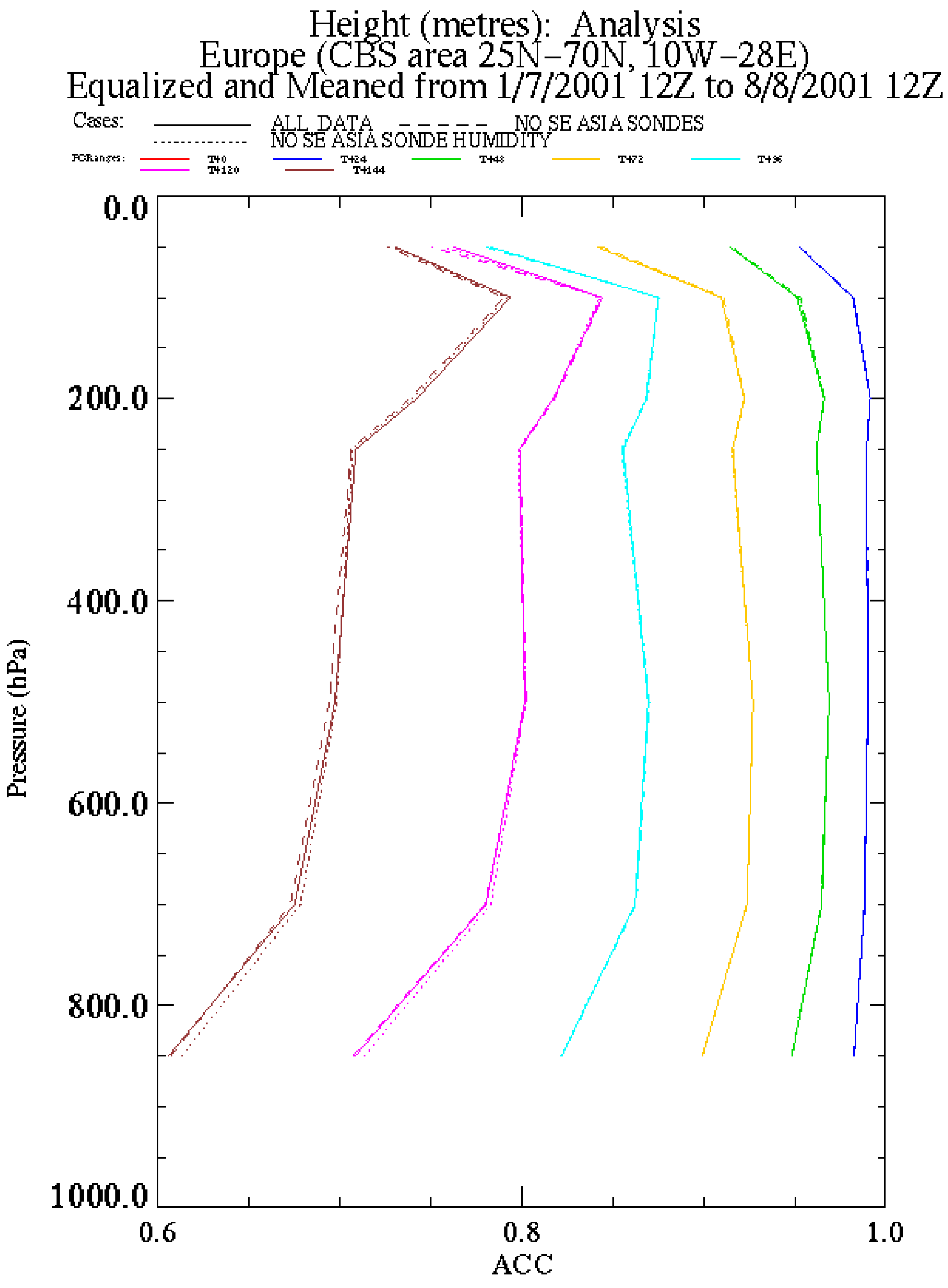


Figure 11. Mean Anomaly Correlation Coefficient for geopotential height forecasts (using the 'All data' analysis) for the 'Europe' region. Mean calculated over 30 forecasts.

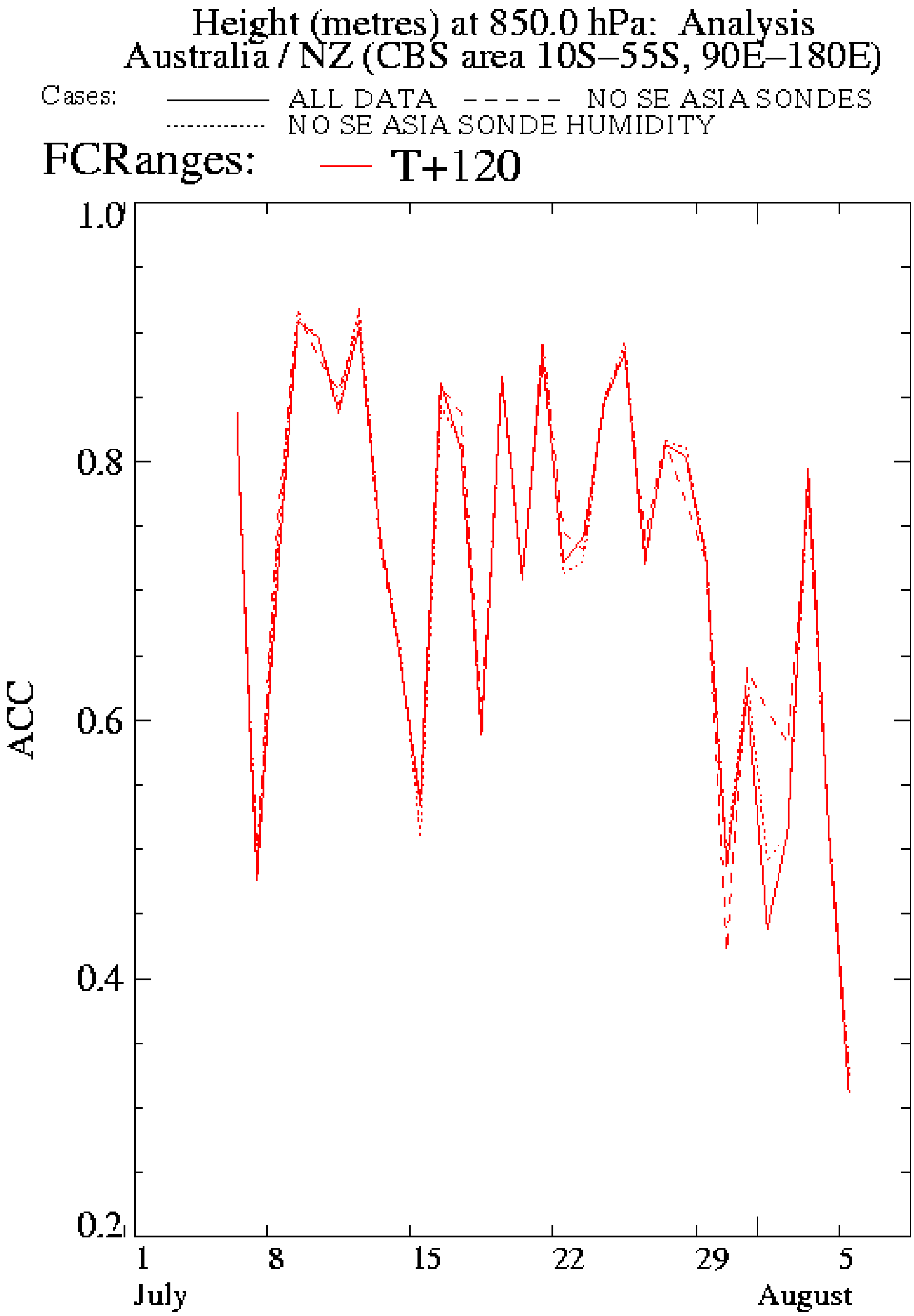


Figure 12. Time series of anomaly correlation coefficient for 850 hPa geopotential height forecasts at T+120 averaged over the Australia/New Zealand region.

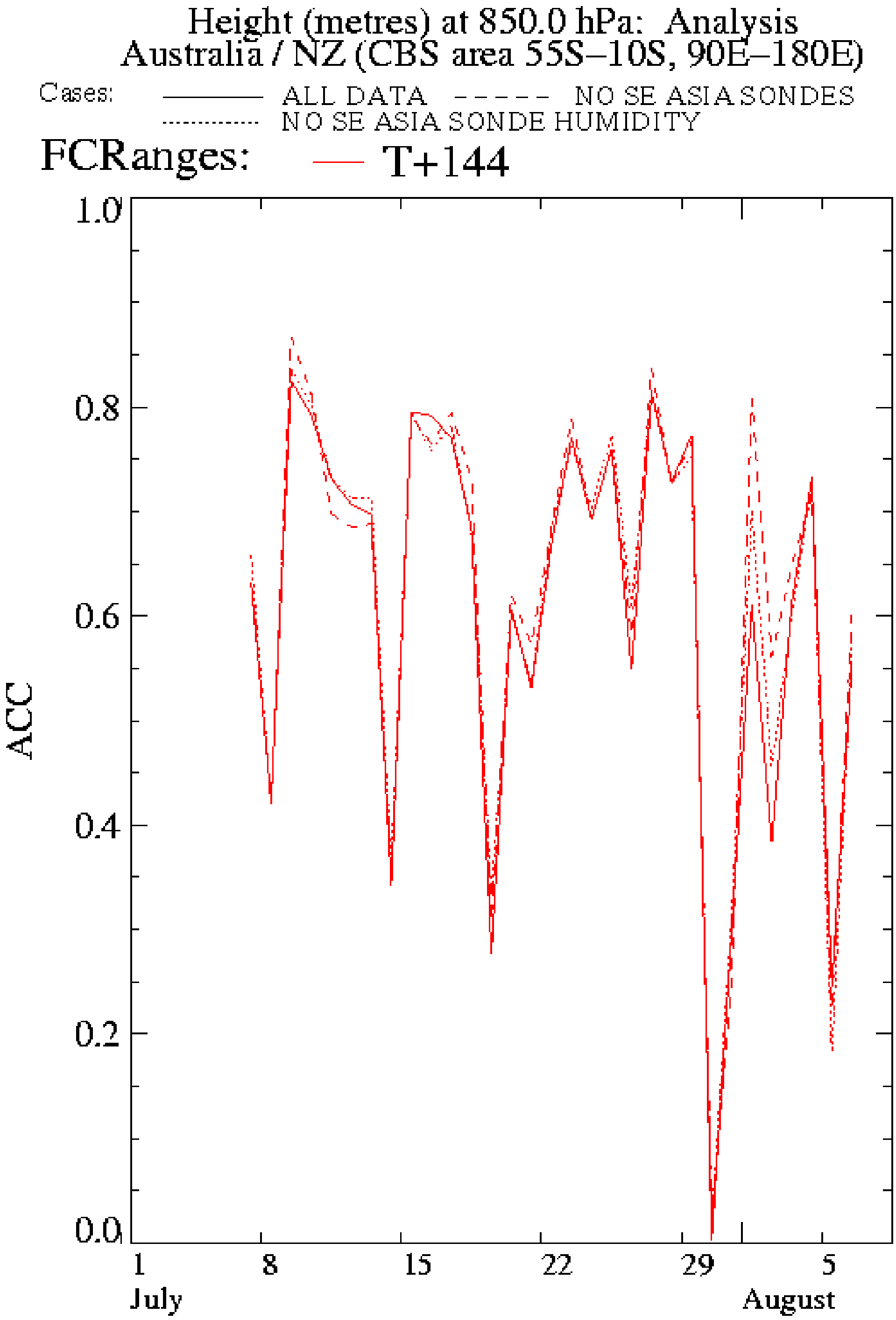
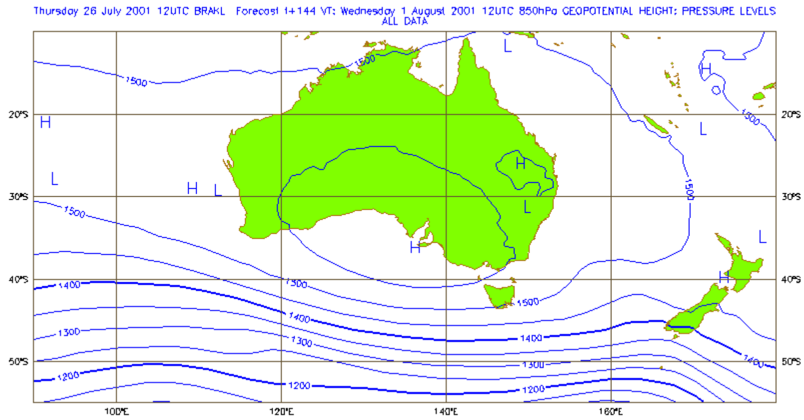
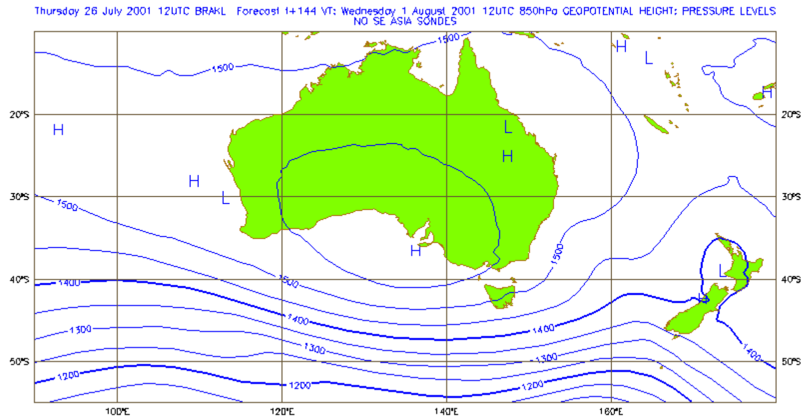


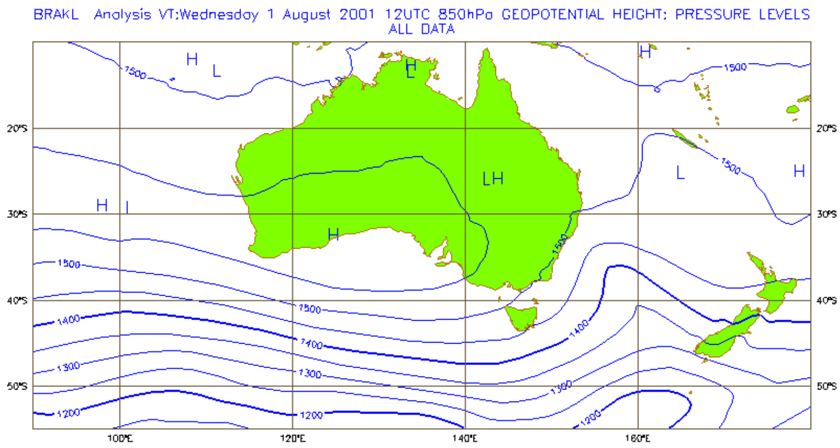
Figure 13. Time series of anomaly correlation coefficient for 850 hPa geopotential height forecasts at T+144 averaged over the Australia/New Zealand region.



(a)



(b)



(c)

Figure 14. T+144 forecast of 850 hPa geopotential height over the Australia/New Zealand verification area from (a) the ‘ALL DATA’ run and (b) the ‘NO SE ASIA SONDES’ run compared with (c) ‘ALL DATA’ analysis.

APPENDIX - VERIFICATION AREAS

A1. Verification versus radiosondes

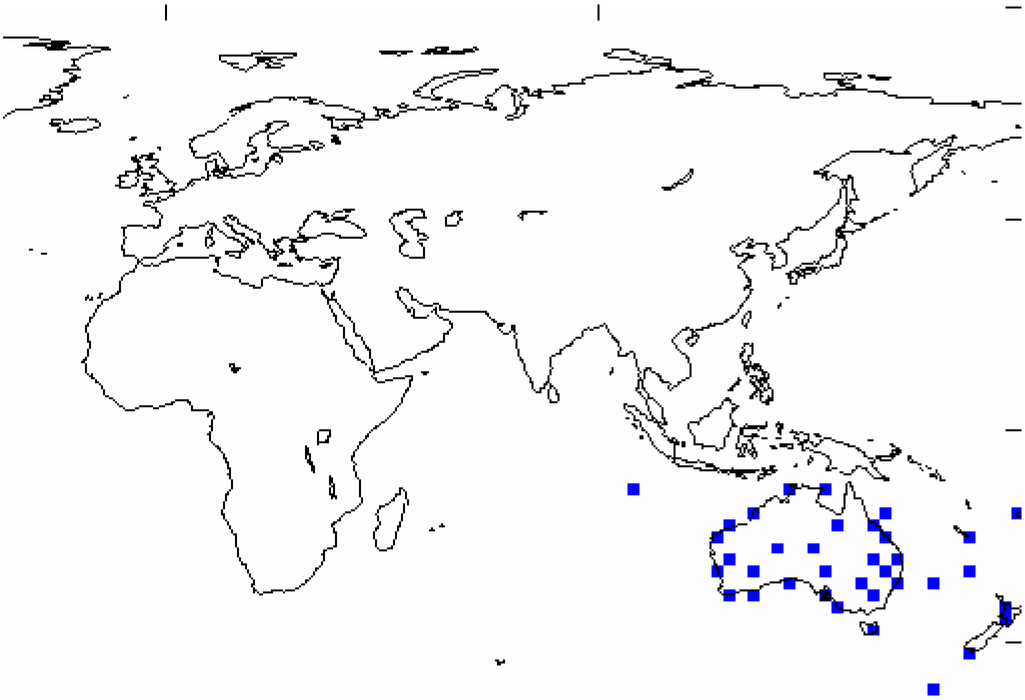


Figure A1 (a). Location of radiosonde stations used for verification over Australia and New Zealand

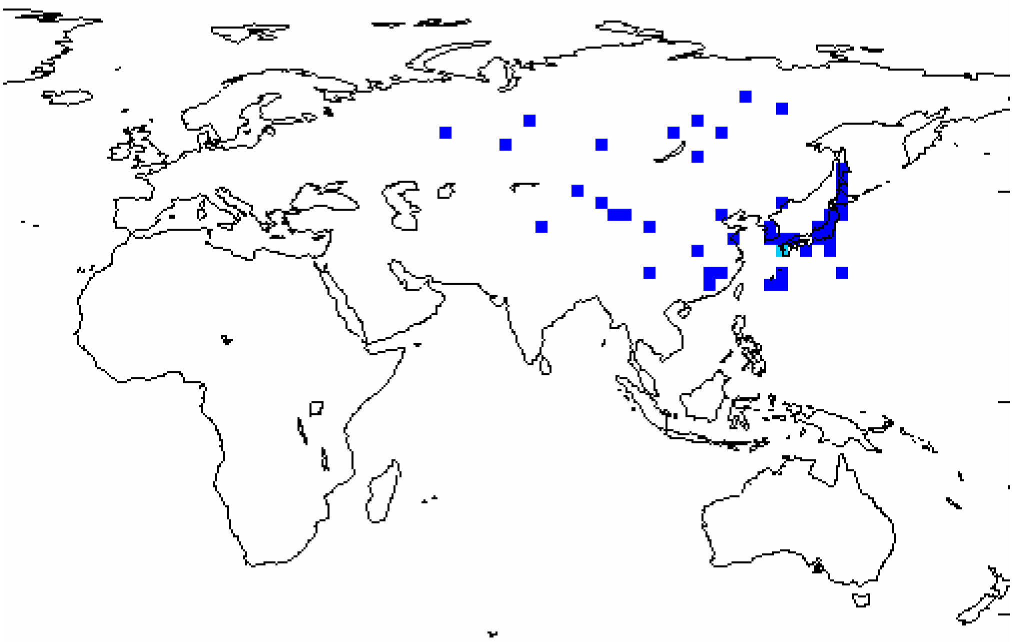


Figure A1 (b). Location of radiosonde stations used for verification over Asia.

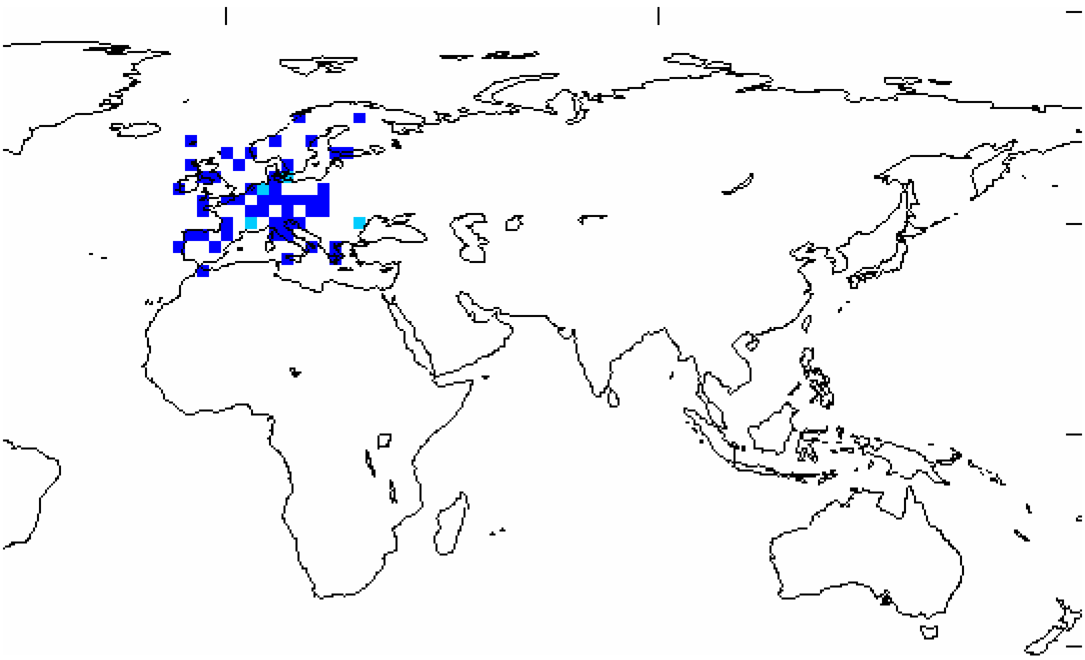


Figure A1 (c). Location of radiosonde stations used for verification over Europe.

A2. Verification versus analysis

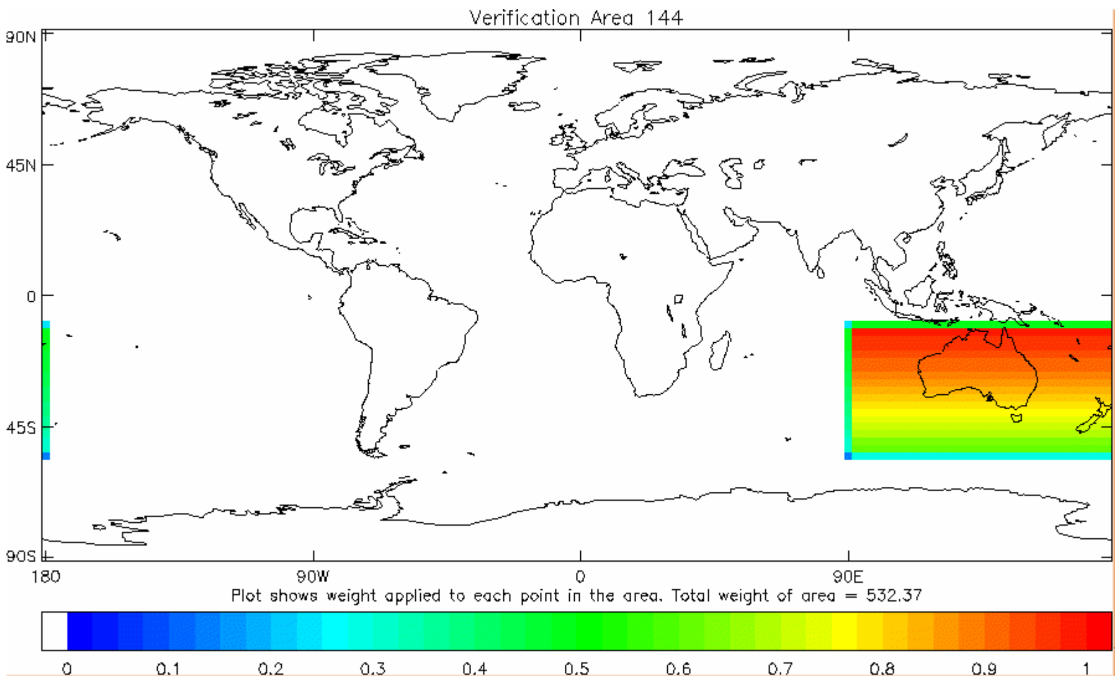


Figure A2 (a). Verification area for Australia and New Zealand

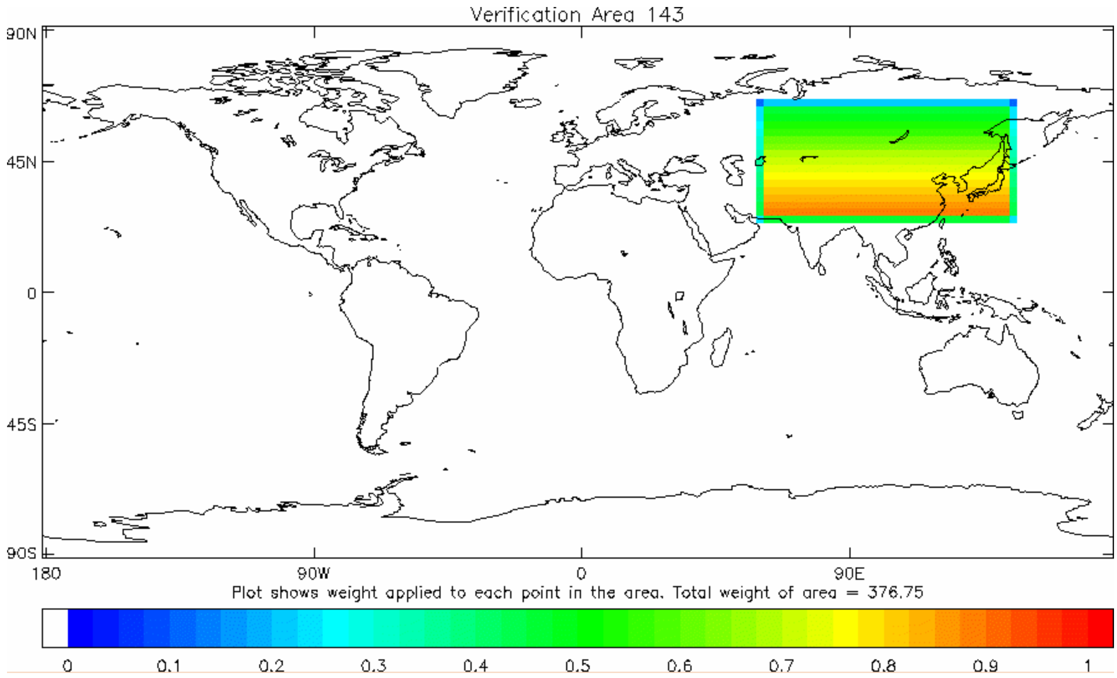


Figure A2 (b). Verification area for Asia

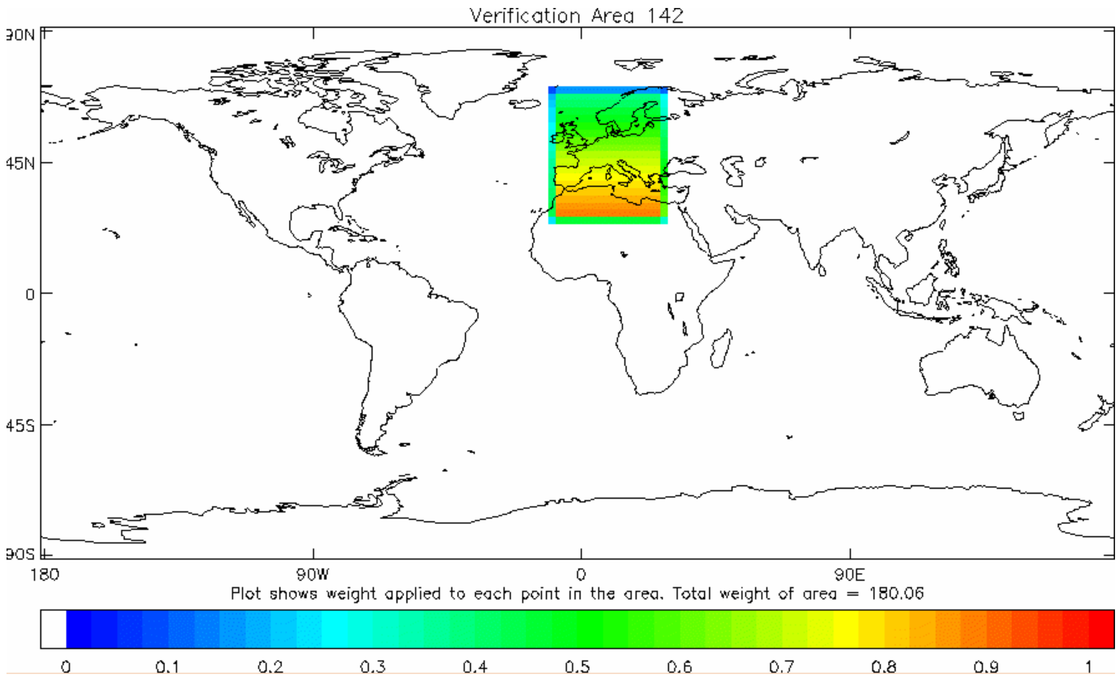


Figure A2 (c). Verification area for Europe.