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Analysis of the Computer, Meteorological Data – Profiler's (CMD-P) Capability to Assimilate Regional Radiosonde Data

by P. Haines, J. Cogan, T. Jameson, and J. Swanson

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1. Introduction

The Battlefield Environment Division, Computational and Information Sciences Directorate, U.S. Army Research Laboratory (ARL) has been involved in the development and testing of the U.S. Army's artillery meteorology (MET) systems for many years and currently receives support from the Army and Marines for these efforts. This work is important not only because it involves a fielded system (Meteorological Measuring Set – Profiler [MMS-P] Block1, commonly known as the Block-1 system) currently used by the U.S. Army Field Artillery and the new system now being fielded, the Computer, Meteorological Data – Profiler (CMD-P), but also because it impacts development and test of the U.S. Army's artillery MET system of the future, the Profiler Virtual Module (PVM). The Block-1 system consists of three computers and a satellite antenna to receive large-scale MET data used to initialize the Block-1 numerical model. It was fielded beginning in 2004 and continues to support the U.S. artillery with timely and accurate MET data for artillery targeting. In 2010, the follow-on development to replace the Block-1 with the CMD-P began. CMD-P incorporates all the Block-1 processing on a single common hardware system (CHS) laptop. The CMD-P typically obtains its large-scale data via the Global Broadcast System (GBS), which operates in a classified environment while the Block-1 uses an unclassified system, Tactical VSAT (TVSAT). ARL was the lead organization for the CMD-P Developmental Test (DT), a major goal of which was to verify that the CMD-P essentially replicates the Block-1 processing and accuracy. This was accomplished by analyzing a large number of CMD-P and Block-1 artillery MET messages for the same model domains, model start times, and message locations.

The Product Manager for Meteorological and Target Identification Capabilities (PM-MaTIC) developed the laptop-based version of the MMS-P to replicate the capabilities of the latest currently fielded version, the MMS-P Block I – Version 2 (B1v2). The laptop is a standard dual-processor VT Miltope CHS laptop used by the Army. The B1v2 can generate four types of messages including the Computer Meteorological Message (METCM). The PM funded ARL to evaluate the MET accuracy of this laptop system in terms of its ability to generate essentially the same messages as those from the B1v2 system, as part of the overall DT. Both the B1v2 and the CMD-P are initialized with U.S. Navy's Navy Operational Global Atmospheric Prediction System (NOGAPS) forecast model data and assimilate World Meteorological Organization (WMO) soundings and surface data reports, if available. In an earlier report (Cogan et al., 2012), the analysis stemming from comparing the various artillery MET reports produced by both the B1v2 and the CMD-P using only NOGAPS data was reported. In this report, the analysis is extended to METCMs produced by a B1v2 using both NOGAPS and WMO data, a CMD-P using the same data as the B1v2 and a CMD-P using only NOGAPS model data. The points brought out in this report are based on the accuracy evaluation by ARL. Because the earlier report verified that all artillery MET reports produced by the B1v2 and the CMD-P are essentially the same, this report analyses METCMs produced by the B1v2 and CMD-Ps with and without assimilation of WMO reports. The objective of this report is to verify that when the CMD-P and B1v2 assimilate WMO reports they produce essentially the same messages, but not when the CMD-P omits the WMO reports.

NOGAPS produces the input data, which are then routed to the CMD-P via the Air Force Weather Agency (AFWA). These data provide the initialization gridded data and updates to the lateral boundaries of the onboard model, the Mesoscale Model – Generation 5 (MM5). The MM5 along with post-processing software, the Unified Post Processing System (UPPS), developed by Pennsylvania State University, provides a three-dimensional (3-D) grid of atmospheric data to the onboard database. Additional software extracts data from the database and generates MET messages such as the METCM. When new or recent WMO data are available, they are quality controlled, and then assimilated by an observations nudging approach (Stauffer and Seaman, 1994) for up to 4 h after they have been received.

WMO data in the form of balloon-borne soundings and surface reports are received by both systems and used in making numerical model forecasts and post-processing; they affect the data used to produce the artillery messages. The CMD-P receives such data via the GBS, while the Block-1 Profiler can use either GBS or TVSAT. The original CMD-P DT test plan did not include analysis of messages in which WMO data were involved; analyzing messages from both systems in which WMO data were used was added just prior to commencement of formal DT in September 2011.

The data assimilation of WMO data is a complex process. WMO upper air soundings are usually made twice a day (0000 and 1200 UTC) at several hundred locations around the world, but are made four times (0000, 0600, 1200, and 1800 UTC) a day at a few sites. In particular, there are several sites in central Europe where soundings are made at 1800 UTC. To test assimilation of regional soundings requires several hours on a given day. The test systems must first be initialized with large-scale model data and run a few modeling cycles; at that point, a preliminary comparison of MET messages can be done to show that they are virtually identical. After that, regional soundings are introduced or withheld to the test systems. The soundings are assimilated over an extended period of time, at the end of which a comparison is done of the effect.

A typical sounding has 50–100 measurements of winds, temperature, and water vapor mixing ratio between the ground and 30 km above ground. The data are disseminated through a world-wide network. For Profiler, the data go to the AFWA and are broadcast to the field via TVSAT and GBS. The data arrive sporadically over a period of up to 3 h after the nominal observation times mentioned above. Meanwhile, both test systems that receive the soundings, assimilate the data from the time it is received until 4 h after the observation time for upper air soundings and

2⅔ h after for surface observations. At the same time, one of the test systems receives no soundings and continues with its forecast and post-processing cycles. Even small differences in the amount of data received or the time it is received between systems causes differences in the respective artillery MET messages that are large enough to exceed DT test criteria. Consequently, systems must receive the data at nearly the same time (there is a less than 2-min interval between when data is transferred on the Block-1 to an intermediate directory from which it can be written onto a CDROM to when it must be transferred to the corresponding directory on the CMD-P). Otherwise, as mentioned previously, the messages produced by the two systems differ enough to result in a test failure.

2. Approach

The overall approach is different from that described in Cogan et al. (2012) and Jameson et al. (2011) because of the complexity in ingesting WMO reports and the need to ensure that the compared systems are run in the same way. The latter requirement is especially difficult because the CMD-P receives data via GBS instead of TVSAT. For the testing reported here, the B1v2 had a TVSAT connection with which to receive data, but since GBS was unavailable, there was no extant means to provide the CMD-P with WMO data. As with prior studies, we obtained METCMs from the B1v2 and one of the CMD-Ps that was run in the same way and with the same starting time for assimilating the WMO reports, but the other CMD-P was run the same but without the WMO soundings. Large-scale initialization and lateral boundary data were provided to the B1v2 and CMD-Ps by downloading the NOGAPS data from the AKO Web site (https://nogapsprofiler.us.army.mil) onto a DVD. Under a typical scenario, the prior evening's 00 UTC NOGAPS data for the appropriate sector (or "tile," e.g., Europe or Southwest Asia) were archived onto a DVD on the case-study day. The NOGAPS data were copied to the test systems at around 15–16 UTC and used to initialize all systems. The system times on the B1v2 and the CMD-Ps were carefully synchronized just prior to model-startup to ensure that they had essentially the same starting conditions. This is necessary since the CMD-P and the B1v2 differ in the amount of time taken to initialize their systems and additionally the CMD-P laptops' internal clocks can vary somewhat. A number of preliminary trials were conducted to establish typical timing differences amongst the test systems. These were then used to start the test systems so that they all had very close (to within a few seconds) start times.

During startup and for the first few model forecast cycles, the B1v2's TVSAT receiver was turned off and it and the two CMD-P systems relied exclusively on NOGAPS data. After their modeling and post-processing cycles had run for at least 1 h and preferably longer, METCMs were requested at Meiningen, Germany, for all three systems as described in the following paragraph. As this was prior to any receipt and influence of upper air or surface reports, we were able to verify at this point in time that all systems gave the same result. Just after 18 UTC, the B1v2's satellite receiver was turned on and WMO reports began arriving. The raw reports arrive in the directory */h/data/global/sdc/IncomingData/Tvsat* and, from there, are moved to hourly dated directories by the script *wmo_nogaps_rename.sh*, where they are accumulated in hourly directories. For example, the directory: */h/data/global/sdc/IncomingData/Wmo/*2012082118 contains all the reports received between 18 and 19 UTC on August 21, 2012. There is also a link from /h/data/global/sdc/IncomingData/Wmo/Mm5/dateddirectories to the aforementioned dated directories. These directories become fairly sizeable because of ACARS and other reports from commercial aircraft, which are not currently used in Profiler. At 5, 10, 20, 25, 35, 40, 50, and 55 min of the hour a cron (a cron is the time-based job scheduler in Unix-like computer operating systems; it enables users to schedule jobs [such as commands or shell scripts] to run periodically at specified times) initiates a script, collectrawdata. This script decodes the upper air and surface reports into ttaa, ttbb, ttcc, and ttdd report formats for the upper air and sfc format for the surface reports. At the completion of this process, the upper air (ttaa.dat and ttbb.dat) and surface reports (surface.dat) are placed on /h/data/global/sdc/MPMM5/data/gempak/armynow. Every 15 min, this directory is refreshed; within 2 min, the new data are transferred to /h/data/global/sdc/MPMM5/data/army_nowcast/GATEKEEPER_realtime/output.

Analysis of the steps between /h/data/global/sdc/IncomingData/Tvsat and /h/data/global/sdc/MPMM5/data/gempak/armynow showed that there was insufficient time in which to write a CD on the B1v2, read it into the corresponding directory on the CMD-P, and obtain the same results on both systems. However, the analysis also showed that there was just enough time to transfer data from /h/data/global/sdc/MPMM5/data/*gempak/armynow* on the B1v2 to the CMD-P and obtain the same results on both systems. Therefore, we did a number of transfers from the B1v2's */h/data/global/sdc/IncomingData/Wmo/Mm5/dateddirectories* to the CMD-P to verify that the intermediate processing was done correctly on the CMD-P. Then we transferred B1v2 files from: */h/data/global/sdc/MPMM5/data/gempak/armynow* to the corresponding directory on the CMD-P to verify that both systems carried on the same from that point. Figure 1 shows the steps involved in processing regional upper air soundings.

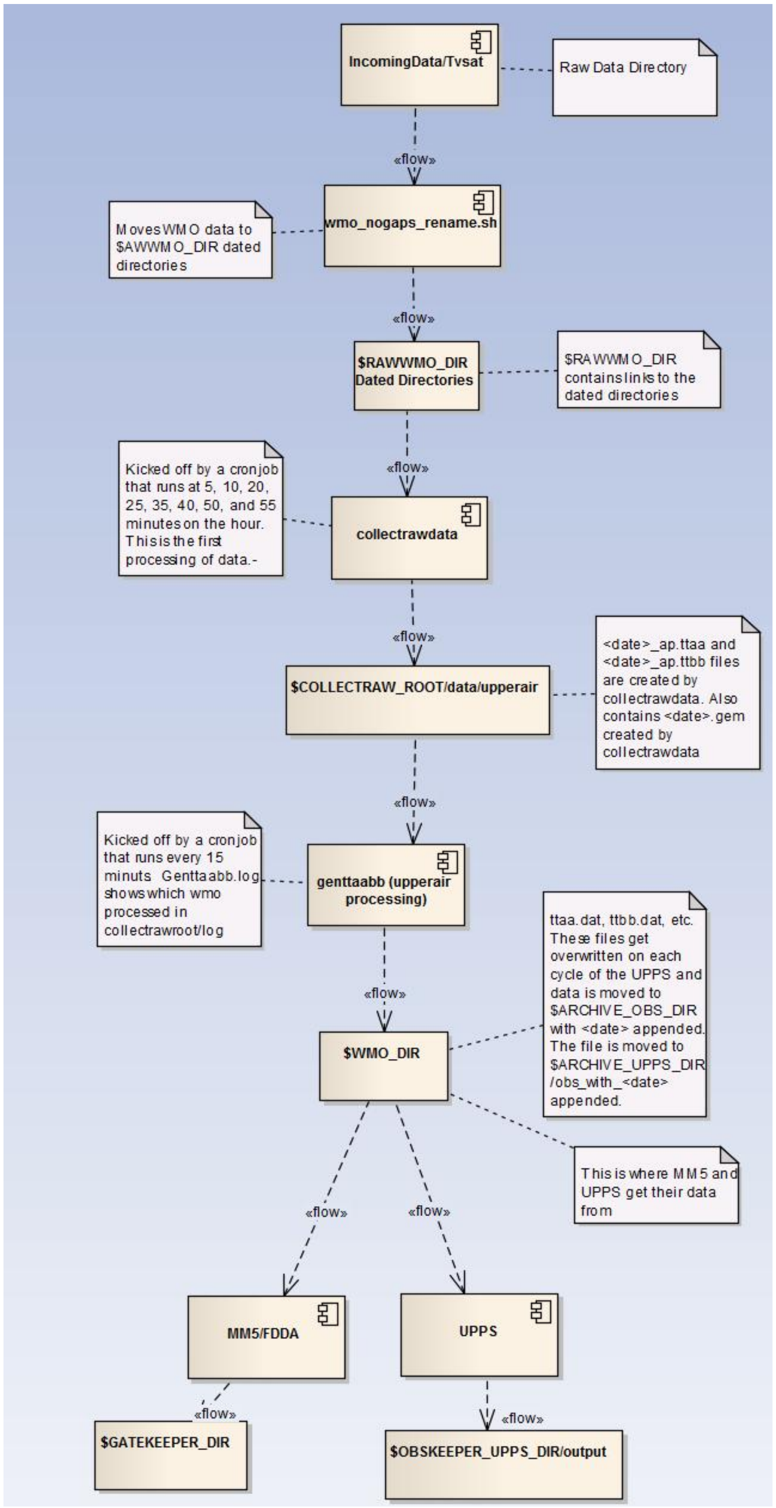

Figure 1. Processing of regional upper air soundings in the CMD-P (SDD, 2011).

Prior to refresh, the CD was seated on the B1v2's CD drive well in advance of data refresh to give it ample time to mount. This was important, because any delay in the transfer process could result in late placement of the reports on the CMD-P, which would delay their assimilation. As mentioned, such delays produce discernible model forecast differences between the B1v2 and CMD-P systems. Immediately after the B1v2 directory had been completely refreshed, a "*BurnIt*" script was run to write the WMO reports onto the mounted CD. Depending on how many reports were written to the CD, about one minute of time was required. Immediately after the CD had been written, it was ejected, and then very quickly placed on the CMD-P's CD/ DVD drive. Mounting it on the CMD-P consumed another few precious seconds. Once mounted, a second script "*dtrans*" was run which placed the WMO files on the CMD-P directory */h/data/MPMM5/data/gempak/armynow*. More details on the data transfer process appear in appendix B.

Assimilation of the regional radiosonde observations (RAOBs) begins when the files are placed on this directory; the MM5 forecast model and UPPS obtain their assimilation data from it. Assimilation continues until the data are aged-out 4 h after nominal observation time. In and around Germany, there are typically 6–7 RAOB soundings made at 18 UTC. These are as follows:

- Bergen, Germany: 52.81 N: 9.93 E
- Idar-Oberstein, Germany: 49.7 N; 7.33 E
- Meiningen, Germany: 50.56N; 10.38 E
- Kuemmersbruk, Germany: 49.43 N; 11.90 N
- Lindenberg, Germany: 52.51 N; 14.11 E
- Praha-Libus (Prague), Czech Republic: 50.00 N; 14.45 E
- Udine/ Campoformido, Italy: 46.03 N; 13.18 E

Meiningen was chosen as a Profiler domain center point because of its central location amidst and among the other WMO sounding sites. After letting the systems assimilate the soundings for at least 2 h, we computed METCMs for three selected WMO RAOB sites located in Germany, specifically Bergen (BER), Meiningen (MEI), and Idar-Oberstein (OBE). We did this during April 2012.

The METCMs were compared three different ways: B1v2 versus the assimilating CMD-P; B1v2 versus the non assimilating CMD-P; and assimilating CMD-P versus the non assimilating CMD-P. We then converted these comparisons into tabular formats suitable for entry into spreadsheets. The spreadsheets were used to compare the METCMs, where for each case we generated a table of differences between the METCMs.

These tables were used to compute the root mean square error (RMSE) and mean absolute error (MAE) for each variable over the vertical extent of the METCMs. All the CMD-P and B1v2 METCMs extend from the surface (zone 0) to 30 km above ground level (AGL) (zone 31). There were no ground truth soundings available at the time the METCMs were generated so no GTRAJ runs were done.

3. Results

The comparisons of the spreadsheet results appear in appendix A. The first set (tables A-1, A-2, and A-3) shows the CMD-P and B1v2 results when both systems assimilated upper air soundings. There are very slight (less than 10 mills or about 0.5°) differences in wind direction for a few zones. These differences result from even smaller actual directional differences that are rounded up or down to the nearest 10 mills of direction, so the actual wind direction difference is a fraction of 10 mills. Other than a 0.1° temperature difference for zone 20 and a 1 knot difference in wind speed for zone 0, there are no other differences between the two. Great care was taken to ensure that both systems were run as close as possible in the same way with the same timing, but it was impossible to make the timing absolutely identical. Nevertheless, the very small differences indicate that the two systems are performing assimilation of regional upper air soundings in the same way. Table 1 shows the summary statistics of difference data (CMD-B1) with assimilation of regional RAOBs.

Table 1. Summary statistics of difference data (CMD-B1) with assimilation of regional RAOBs.

	WD(mils)	WS(knots)	Tv (K)	P(mb)
RMSE:	**0.71**	**0.18**	**1.77**	**0.00**
MAE:	**0.31**	**0.03**	**0.31**	**0.00**

The summary statistics show very slight overall differences. When run through GTRAJ, these differences should result in trajectory impact points of much less than 10 m based on our experience as described in Cogan et al. (2012).

The second set (tables A-5, A-6, and A-7) show the CMD-P and B1v2 results when the B1v2 assimilated the regional upper air soundings and the CMD-P did not. There are significant differences of several 10s of mills in wind direction for a number of zones. There are also wind speed differences of up to a few knots in many zones. Meanwhile, the differences in temperature and pressure are relatively small and limited to just a few zones. Table 2 shows the summary statistics of difference data (CMD-B1) with and without assimilation of regional RAOBs.

Table 2. Summary statistics of difference data (CMD-B1) with and without assimilation of regional RAOBs.

	WD(mils)	WS(knots)	Tv(K)	P(mb)
RMSE:	**15.58**	**1.57**	**3.54**	**0.25**
MAE:	**10.16**	**1.09**	**1.25**	**0.06**

The summary statistics for this second set of comparisons show significant overall differences in wind speed and direction, smaller differences in temperature, and small differences in pressure. When run through GTRAJ, differences of these magnitudes have resulted in trajectory impact points of more than 10 m.

The third set of comparisons (tables A-8, A-9, and A-10) show the CMD-Ps results when one CMD-P assimilated the regional upper air soundings and the other CMD-P did not. The differences are very close to those between the B1v2 assimilating and a CMD-P not assimilating. Table 3 shows the summary statistics of difference data (CMD-P-CMD-P) with and without assimilation of regional RAOBs.

Table 3. Summary statistics of difference data (CMD-P-CMD-P) with and without assimilation of regional RAOBs,

	WD(mils)	WS(knots)	Tv(K)	P(mb)
RMSE:	**15.45**	**1.54**	**3.95**	**0.25**
MAE:	**9.97**	**1.06**	**1.56**	**0.06**

The summary statistics shown in table 3 are very close to those shown above in table 2.

4. Conclusions

For the testing reported here, the B1v2 had a TVSAT connection by which to receive data, but since GBS was unavailable, there was no extant means to provide a CMD-P with WMO data at the outset of the DT. The B1v2 and CMD-P processes for assimilating upper air soundings were thoroughly examined and procedures to archive upper air soundings on the B1v2 were created as well as transfer them onto a CMD-P. In contrast with prior studies, we obtained METCMs from the B1v2 and one of the CMD-Ps that were run in the same way and with the same starting time assimilating the WMO reports. The second CMD-P was run the same way as the B1v2 and the first CMD-P, but did not receive or use WMO reports. Large-scale initialization and lateral boundary data were provided to the B1v2 and CMD-Ps by downloading the NOGAPS data from the AKO Web site. The results show that the CMD-Ps assimilate regional upper air data equivalently to the B1v2s.

5. References

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Stauffer, D. R.; Seaman, N. L. Multiscale Four-Dimensional Data Assimilation. *J. Appl. Meteor*. **1994**, *33*, 416–434.

Jameson, T.; Haines, P.; Cogan, J.; Luces, S. Computer, Meteorological Data-Profiler (CMD-P/ Block III Developmental Test Plan, ARL, 36 pp, 2011.

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Appendix A. RMSE and MAE Statistics for CMD Profiler Regional RAOBs

Tables A-1 through A-10 show comparisons of the spreadsheet results.

Table A-1. CMD vs. B1 METCMs: with regional RAOBs CMD METCM with assimilation of regional RAOBSs.

Zone	Wind Dir (Mils/10)	Wind Speed (Knots)	Virtual Temp (Deg K*10)	Air Pressure (mb)
0	273	9	2760	957
1	299	13	2760	946
2	349	17	2750	917
3	356	20	2730	872
4	355	20	2700	819
5	363	20	2660	768
6	362	20	2640	720
7	361	19	2620	675
8	372	20	2600	632
9	390	19	2570	592
10	394	17	2540	554
11	372	17	2510	517
12	358	21	2460	467
13	361	29	2380	405
14	371	35	2310	350
15	375	38	2240	301
16	376	39	2190	258
17	378	38	2190	221
18	379	34	2210	189
19	378	27	2230	162
20	371	22	2240	139
21	362	18	2230	119
22	353	17	2220	102
23	354	16	2210	88
24	357	14	2210	75
25	355	13	2210	64
26	347	10	2210	55
27	332	6	2220	44
28	230	2	2240	32
29	132	7	2240	24
30	114	11	2240	17
31	93	13	2270	13

Table A-2. CMD vs. B1 METCMs: with regional RAOBs B1v2 METCM with assimilation of regional RAOBs.

Height (m AGL)	Zone	Wind Direction (tens of mils)	Wind Speed (knots)	Virtual Temp (Deg K*10)	Air Pressure (mb)
0	0	273	9	2760	957
200	1	298	13	2760	946
500	2	348	17	2750	917
1000	3	356	20	2730	872
1500	4	355	20	2700	819
2000	5	363	20	2660	768
2500	6	363	20	2640	720
3000	7	361	19	2620	675
3500	8	372	19	2600	632
4000	9	390	19	2570	592
4500	10	394	17	2540	554
5000	11	372	17	2510	517
6000	12	358	21	2460	467
7000	13	361	29	2380	405
8000	14	371	35	2310	350
9000	15	376	38	2240	301
10000	16	376	39	2190	258
11000	17	378	38	2190	221
12000	18	378	34	2210	189
13000	19	377	27	2230	162
14000	20	371	22	2230	139
15000	21	362	18	2230	119
16000	22	353	17	2220	102
17000	23	353	16	2210	88
18000	24	357	14	2210	75
19000	25	355	13	2210	64
20000	26	347	10	2210	55
22000	27	332	6	2220	44
24000	28	233	2	2240	32
26000	29	132	7	2240	24
28000	30	114	11	2240	17
30000	31	93	13	2270	13

Table A-3. CMD vs. B1 METCMs: with regional RAOBs difference data (CMD-B1) with assimilation of regional RAOBs.

WD New (mils/10)	WD Old (mils/10)	WD Diff (mils/10)	WS Diff (knots)	Tv Diff (K*10)	P Diff (mb)
273	273	0	0	0	0
299	298	1	0	0	0
349	348	1	0	0	0
356	356	0	0	0	0
355	355	0	0	0	0
363	363	0	0	0	0
362	363	-1	0	0	0
361	361	0	0	0	0
372	372	0	1	0	0
390	390	0	0	0	0
394	394	0	0	0	0
372	372	0	0	0	0
358	358	0	0	0	0
361	361	0	0	0	0
371	371	0	0	0	0
375	376	-1	0	0	0
376	376	0	0	0	0
378	378	0	0	0	0
379	378	1	0	0	0
378	377	1	0	0	0
371	371	0	0	10	0
362	362	0	0	0	0
353	353	0	0	0	0
354	353	1	0	0	0
357	357	0	0	0	0
355	355	0	0	0	0
347	347	0	0	0	0
332	332	0	0	0	0
230	233	-3	0	0	0
132	132	0	0	0	0
114	114	0	0	0	0
93	93	0	0	0	0

Table A-4. Summary statistics of difference data (CMD-B1) with assimilation of regional RAOBs.

	WD(mils)	WS(knots)	Tv(K*10)	P(mb)
RMSE:	**0.71**	**0.18**	**1.77**	**0.00**
MAE:	**0.31**	**0.03**	**0.31**	**0.00**

Table A-5. CMD vs. B1 METCMs: with and without regional RAOBs
CMD METCM without assimilation of regional RAOBs.

Zone	Wind Dir (Mils/10)	Wind Speed (Knots)	Virtual Temp (Deg K*10)	Air Pressure (mb)
0	283	8	2760	957
1	324	12	2760	946
2	371	18	2760	917
3	372	19	2730	872
4	369	19	2690	819
5	364	21	2660	768
6	369	23	2640	720
7	396	23	2630	675
8	423	21	2600	633
9	418	19	2570	592
10	411	18	2540	554
11	395	19	2510	518
12	365	22	2460	467
13	363	33	2380	405
14	369	38	2310	350
15	368	39	2240	301
16	366	38	2200	258
17	369	37	2190	221
18	377	32	2210	189
19	385	27	2230	162
20	380	23	2230	139
21	369	20	2230	119
22	358	18	2220	102
23	356	16	2210	88
24	358	14	2210	75
25	355	13	2210	64
26	347	10	2210	55
27	332	6	2220	44
28	230	2	2240	32
29	132	7	2240	24
30	114	11	2240	17
31	93	13	2270	13

Table A-6. CMD vs. B1 METCMs: with and without regional RAOBs
B1v2 METCM with assimilation of regional RAOBs.

Zone	Wind Dir (Mils/10)	Wind Speed (Knots)	Virtual Temp (Deg K*10)	Air Pressure (mb)
0	283	8	2760	957
1	324	12	2760	946
2	371	18	2760	917
3	372	19	2730	872
4	369	19	2690	819
5	364	21	2660	768
6	369	23	2640	720
7	396	23	2630	675
8	423	21	2600	633
9	418	19	2570	592
10	411	18	2540	554
11	395	19	2510	518
12	365	22	2460	467
13	363	33	2380	405
14	369	38	2310	350
15	368	39	2240	301
16	366	38	2200	258
17	369	37	2190	221
18	377	32	2210	189
19	385	27	2230	162
20	380	23	2230	139
21	369	20	2230	119
22	358	18	2220	102
23	356	16	2210	88
24	358	14	2210	75
25	355	13	2210	64
26	347	10	2210	55
27	332	6	2220	44
28	230	2	2240	32
29	132	7	2240	24
30	114	11	2240	17
31	93	13	2270	13

Table A-7. CMD vs. B1 METCMs: with and without regional RAOBs Difference Data (CMD without – B1v2 with assimilation of regional RAOBs).

WD New (mils/10)	**WD Old (mils/10)**	**WD Diff (mils/10)**	**WS Diff (knots)**	**Tv Diff (K*10)**	**P Diff (mb)**
283	273	10	-1	0	0
324	298	26	-1	0	0
371	348	23	1	10	0
372	356	16	-1	0	0
369	355	14	-1	-10	0
364	363	1	1	0	0
369	363	6	3	0	0
396	361	35	4	10	0
423	372	51	2	0	1
418	390	28	0	0	0
411	394	17	1	0	0
395	372	23	2	0	1
365	358	7	1	0	0
363	361	2	4	0	0
369	371	-2	3	0	0
368	376	-8	1	0	0
366	376	-10	-1	10	0
369	378	-9	-1	0	0
377	378	-1	-2	0	0
385	377	8	0	0	0
380	371	9	1	0	0
369	362	7	2	0	0
358	353	5	1	0	0
356	353	3	0	0	0
358	357	1	0	0	0
355	355	0	0	0	0
347	347	0	0	0	0
332	332	0	0	0	0
230	233	-3	0	0	0
132	132	0	0	0	0
114	114	0	0	0	0
93	93	0	0	0	0

Summary Statistics for CMD-P without and B1v2 with assimilation of Regional RAOBs

	WD(mils)	**WS(knots)**	**Tv(K*10))**	**P(mb)**
RMSE:	**15.58**	**1.57**	**3.54**	**0.25**
MAE:	**10.16**	**1.09**	**1.25**	**0.06**

Table A-8. CMD vs. CMD METCMs: with and without regional RAOBs CMD METCM with assimilation of regional RAOBs.

Zone	Wind Dir (Mils/10)	Wind Speed (Knots)	Virtual Temp (Deg K*10)	Air Pressure (mb)
0	273	9	2760	957
1	299	13	2760	946
2	349	17	2750	917
3	356	20	2730	872
4	355	20	2700	819
5	363	20	2660	768
6	362	20	2640	720
7	361	19	2620	675
8	372	20	2600	632
9	390	19	2570	592
10	394	17	2540	554
11	372	17	2510	517
12	358	21	2460	467
13	361	29	2380	405
14	371	35	2310	350
15	375	38	2240	301
16	376	39	2190	258
17	378	38	2190	221
18	379	34	2210	189
19	378	27	2230	162
20	371	22	2240	139
21	362	18	2230	119
22	353	17	2220	102
23	354	16	2210	88
24	357	14	2210	75
25	355	13	2210	64
26	347	10	2210	55
27	332	6	2220	44
28	230	2	2240	32
29	132	7	2240	24
30	114	11	2240	17
31	93	13	2270	13

Table A-9. CMD vs. CMD METCMs: with and without regional RAOBs CMD METCM without assimilation of regional RAOBs.

Height (m AGL)	Zone	Wind Direction (tens of mils)	Wind Speed (knots)	Virtual Temp (Deg K*10)	Air Pressure (mb)
0	0	283	8	2760	957
200	1	324	12	2760	946
500	2	371	18	2760	917
1000	3	372	19	2730	872
1500	4	369	19	2690	819
2000	5	364	21	2660	768
2500	6	369	23	2640	720
3000	7	396	23	2630	675
3500	8	423	21	2600	633
4000	9	418	19	2570	592
4500	10	411	18	2540	554
5000	11	395	19	2510	518
6000	12	365	22	2460	467
7000	13	363	33	2380	405
8000	14	369	38	2310	350
9000	15	368	39	2240	301
10000	16	366	38	2200	258
11000	17	369	37	2190	221
12000	18	377	32	2210	189
13000	19	385	27	2230	162
14000	20	380	23	2230	139
15000	21	369	20	2230	119
16000	22	358	18	2220	102
17000	23	356	16	2210	88
18000	24	358	14	2210	75
19000	25	355	13	2210	64
20000	26	347	10	2210	55
22000	27	332	6	2220	44
24000	28	230	2	2240	32
26000	29	132	7	2240	24
28000	30	114	11	2240	17
30000	31	93	13	2270	13

Table A-10. CMD vs. CMD METCMs: with and without regional RAOBs difference data CMDs with and without assimilation of regional RAOBs.

WD New (mils/10)	WD Old (mils/10)	WD Diff (mils/10)	WS Diff (knots)	Tv Diff (K*10)	P Diff (mb)
273	283	-10	1	0	0
299	324	-25	1	0	0
349	371	-22	-1	-10	0
356	372	-16	1	0	0
355	369	-14	1	10	0
363	364	-1	-1	0	0
362	369	-7	-3	0	0
361	396	-35	-4	-10	0
372	423	-51	-1	0	-1
390	418	-28	0	0	0
394	411	-17	-1	0	0
372	395	-23	-2	0	-1
358	365	-7	-1	0	0
361	363	-2	-4	0	0
371	369	2	-3	0	0
375	368	7	-1	0	0
376	366	10	1	-10	0
378	369	9	1	0	0
379	377	2	2	0	0
378	385	-7	0	0	0
371	380	-9	-1	10	0
362	369	-7	-2	0	0
353	358	-5	-1	0	0
354	356	-2	0	0	0
357	358	-1	0	0	0
355	355	0	0	0	0
347	347	0	0	0	0
332	332	0	0	0	0
230	230	0	0	0	0
132	132	0	0	0	0
114	114	0	0	0	0
93	93	0	0	0	0

Summary Statistics of Difference Data (CMD-P-CMD-P) with and without assimilation of Regional RAOBs

	WD(mils)	WS(knots)	Tv(K*10)	P(mb)
RMSE:	**15.45**	**1.54**	**3.95**	**0.25**
MAE:	**9.97**	**1.06**	**1.56**	**0.06**

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Appendix B. Special Processing of WMOs

As may be judged from this report and also considering the limitations, there was very little or no room for error in conducting this test. Without RW Hornbaker's (SERCO contractor) contribution, this part of the CMD-P DT testing would not have been successful.

In order to compare the assimilation of regional WMO data between the CMD-P and the Block-1 systems, and thereby verify that the CMD-P system essentially replicates the Block-1 WMO assimilation process, it was necessary to transfer the WMO data from the Block-1 to the CMD-P. The Block-1 receives the data via a satellite receiver that is connected to a TVSAT; TVSAT data transmission is unclassified. On the other hand, the CMD-P exclusively uses the GBS for such data transfer and the GBS is a classified system. A CMD-P connected to GBS must operate in a classified environment and all its output messages and analyses thereof are similarly classified. Therefore, by far the most desirable option was to operate in an unclassified environment in which the received WMO data are transferred to CMD-P from the Block 1. Mr. Hornbaker investigated whether the transfer could be accomplished using universal serial bus (USB) drives as both systems are standalone. He was able to format and mount the USB memory stick on the Block 1. Then he wrote a script to save the actual data file name in a numerically indexed file, where the numbers will be the new filename on the memory stick. This was necessary because the memory stick has to be formatted as a FAT16. Unfortunately, this did not work because the CMD-P "REDHAT SIDE" had disabled the USB ports. There are CD/DVD drives on both systems but there was not a way to write the WMO data onto a CD on the Block-1. Mr. Hornbaker had to research thoroughly the protocol for writing CDs on a Solaris 8 system, which is also a dated system since it has not been supported since 2010. He wrote a script, "***burnIt***" to write the WMO files to a CD on his computer and copied it and the USB vfstab entry to the USB stick. We had to re-image the Block-1 Solaris 8 system and got the model working and he restored the ***burnIt*** script and vfstab entry.

In order to move the files on the CDROM to the CMD-P, Mr. Hornbaker wrote a second script, ***dtrans***, to automatically copy the data to a user-specified directory on the CMD-P. It was also found that when our account on the CMD-P, arltest, was set up, a number of environment values used to specify directory paths for data transfers during WMO data assimilation did not get set preventing subsequent system data transfers. Without the properly set environmental variables, the data exchange scripts that transfer data between various directories on the CMD-P did not work and the data were not used by the CMD-P. Mr. Hornbaker was able to diagnose the deficiency, and, in addition, made the ***dtrans*** script accessible via a taskbar button. Further adjustments to the ***burnIt*** and ***dtran***s scripts were required on the Solaris 8 side, after debugging the ***burnIt*** script, to set it up to run from a root alias called burn.

Finally, it was found that the CD/DVD reader/writers differ in the Block-1 systems. During the course of testing, ARL had to return two Block-1 systems to PM MATIC, and the CD/DVD reader/writer did change on the later Block-1 systems involved in the test contributing extra complexity to what was necessary to accomplish this work.

List of Symbols, Abbreviations, and Acronyms

3-D	three-dimensional
AFWA	Air Force Weather Agency
AGL	above ground level
ARL	U.S. Army Research Laboratory
BER	Bergen
CHS	common hardware system
CMD-P	Computer, Meteorological Data – Profiler
DT	Developmental Test
GBS	Global Broadcast System
MAE	mean absolute error
MEI	Meiningen
MET	meteorology
METCM	Computer Meteorological Message
MM5	Mesoscale Model – Generation 5
MMS-P	Meteorological Measuring Set – Profiler
NOPGAPS	Navy Operational Global Atmospheric Prediction System
OBE	Idar-Oberstein
PM-MaTIC	Product Manager for Meteorological and Target Identification Capabilities
PVM	Profiler Virtual Module
RAOBs	radiosonde observations
RMSE	root mean square error
TVSAT	Tactical VSAT
UPPS	Unified Post Processing System

USB	imoversa; seroa; bus
WMO	World Meteorological Organization

1 (PDF only)	DEFENSE TECHNICAL INFORMATION CTR DTIC OCA 8725 JOHN J KINGMAN RD STE 0944 FORT BELVOIR VA 22060-6218
2	US ARMY RSRCH LAB ATTN RDRL CIE M P HAINES ATTN RDRL CIE M T JAMESON BLDG 1622 WHITE SANDS MISSILE RANGE NM 88002-5513
4	US ARMY RSRCH LAB ATTN RDRL CIE J COGAN ATTN IMAL HRA MAIL & RECORDS MGMT ATTN RDRL CIO LL TECHL LIB ATTN RDRL CIO LT TECHL PUB ADELPHI MD 20783-1197

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