P1.33 MESONET WIND QUALITY MONITORING ALLOWING ASSIMILATION IN THE RUC AND OTHER NCEP MODELS

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For the period 2007-05-01 18:30:00 to 2007-05-28 21:59:59
Only including 1800 - 2100 UTC
(Click on a column header to sort by that column)

network	N sites	N T	avg T	bias T	std T	N S	avg S	bias S	std S
.	.	.	.	.	.	.	.	V	.
28	140	9908	69.8	0.6	3.1	9908	8.9	-5.7	6.3
66	113	7449	71.7	1.0	5.6	7451	3.6	-4.8	4.9
64	53	701	67.8	2.6	4.9	705	8.2	-4.6	4.9
7	74	3482	71.2	0.7	6.3	3482	4.4	-4.5	5.4
5	3934	244910	72.0	1.7	6.0	244886	4.4	-4.5	7.1
42	7	208	58.1	7.1	9.4	405	8.0	-3.5	4.7
16	9	494	78.5	-1.6	11.4	489	4.3	-3.2	4.1
6	4080	271907	72.3	0.8	4.6	271907	5.6	-3.0	5.2
60	834	59074	73.1	1.0	5.3	59074	5.7	-2.8	4.7
51	164	11595	72.4	1.8	6.0	11519	5.4	-2.7	4.1
36	58	3829	73.4	1.3	5.4	3822	4.2	-2.7	3.9
61	35	2284	72.3	0.3	6.4	2291	4.6	-2.6	4.2
1	12	780	55.8	-2.5	4.6	780	9.3	-2.5	5.4
31	52	3560	72.7	1.1	10.2	3559	9.9	-2.4	5.9
37	6	440	60.6	0.7	4.2	366	5.6	-2.3	3.6
46	11	753	65.4	2.3	3.8	753	5.4	-2.2	4.1
RAWS	1707	121585	67.0	0.7	6.4	121546	7.2	-2.1	5.3
67	29	1805	56.3	-2.6	6.5	1805	12.6	2.0	6.7
30	13	681	54.1	-8.2	7.6	681	8.1	-1.9	6.9
65	52	3504	72.4	0.5	3.1	3504	11.9	1.9	4.5
17	11	746	72.4	1.8	3.9	673	11.0	-1.7	5.4
41	13	902	73.5	-0.1	3.0	902	8.2	-1.7	4.9
9	81	5170	61.6	0.1	6.1	5216	7.5	-1.7	6.2
Maritime	763	13629	60.9	0.8	4.6	13489	13.5	1.7	5.2
45	45	1709	70.1	2.7	5.9	1709	8.6	-1.7	5.2
4	5	341	72.4	3.2	3.1	341	7.0	1.6	2.3
15	33	2371	83.4	-0.1	2.9	2371	9.1	-1.5	4.2
50	71	3202	67.2	1.4	5.3	4458	10.9	1.4	4.6
38	2260	127912	60.2	-2.6	12.1	66027	8.2	-1.1	6.6
33	25	1609	80.6	-0.1	3.3	1609	7.2	-1.1	4.9
10	126	8954	64.3	1.7	4.5	1655	6.9	-1.1	4.0
32	35	1955	77.7	0.3	2.6	1955	5.0	-1.1	3.7
METAR	2195	157247	69.4	1.4	5.4	157330	10.7	1.0	5.8
29	22	1517	76.3	2.7	4.0	1515	7.0	-0.9	4.5
12	10	731	71.5	-1.6	2.5	731	7.7	0.9	3.8
11	8	380	65.7	1.4	3.8	380	8.9	-0.9	4.7
48	35	2212	72.4	1.1	3.9	2207	9.8	0.9	4.5

Figure 1. ESRL-OQM surface monitoring (ob-minus-RUC1h forecast) summary for period 1-28 May 2007 for 1800-2100 UTC. Ordered by *mean wind speed difference* (highlighted) between observations and RUC 1-h forecasts. Network data providers are identified in encoded GSD numbers for mesonet providers. See text in sections 1 and 3.3.

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1. Introduction

Operational NCEP model problems related to observational data quality have occurred during 2006-2007, and specifically related to erroneous observations not detected by existing quality control (QC) procedures. These undetected observation error events (UOEEs) have occurred over this period for aircraft, surface, profiler, rawinsonde, and GPS precipitable water observations. Since the Rapid Update Cycle (RUC) model is widely used for nowcast analyses and very short-range forecasts (1-3h) which are sensitive to observation errors, these UOEEs have been noted from RUC data, but certainly occur for other NCEP operational models, although with less prominence.

In this paper, we review three levels of observation quality monitoring (OQM) either developed or enhanced by NOAA/ESRL to detect otherwise UOEEs. In this context, the term "monitoring" is meant to convey collection of observed vs. independent values over some period of time from a 1-h to a multi-week period. The first of these has already been applied to the operational RUC, and the second is planned as part of a RUC upgrade package for later in 2007 (similar to mean wind speed bias performance as shown in Fig. 1). The third is planned to provide daily updated reject lists for mesonet stations to vastly increase the number of mesonet stations with data available for use in analyses at NCEP (RUC, NAM, Real-Time Mesoscale Analysis - RTMA) and other mesonet users.

2. History regarding mesonet wind errors

In 2005, mesonet observations (not including winds) began to be assimilated into the operational Rapid Update Cycle (RUC) running at NCEP. However, during pre-implementation testing for the 2005 RUC changes, it was discovered that mesonet winds had to be withheld since widespread poor siting of these observations frequently led to degraded surface wind analyses. An example from this 2005 test period is shown in Fig. 2, where RUC analyzed 10-m winds are shown with (bottom) and without (top) assimilation of mesonet winds for a case with strong post-frontal winds (8 May 2005). Much of the eastern US had METAR-observed winds of 10-20 kts, but most mesonet sites showed wind speeds less than 10 kts, as reflected in the RUC analysis assimilation those winds (Fig.2 - lower left). One-hour 10-m wind forecasts (upper/lower right) were in good agreement with METAR winds, a result of the 3-D dynamics/physics in the RUC model providing independence from initial conditions.

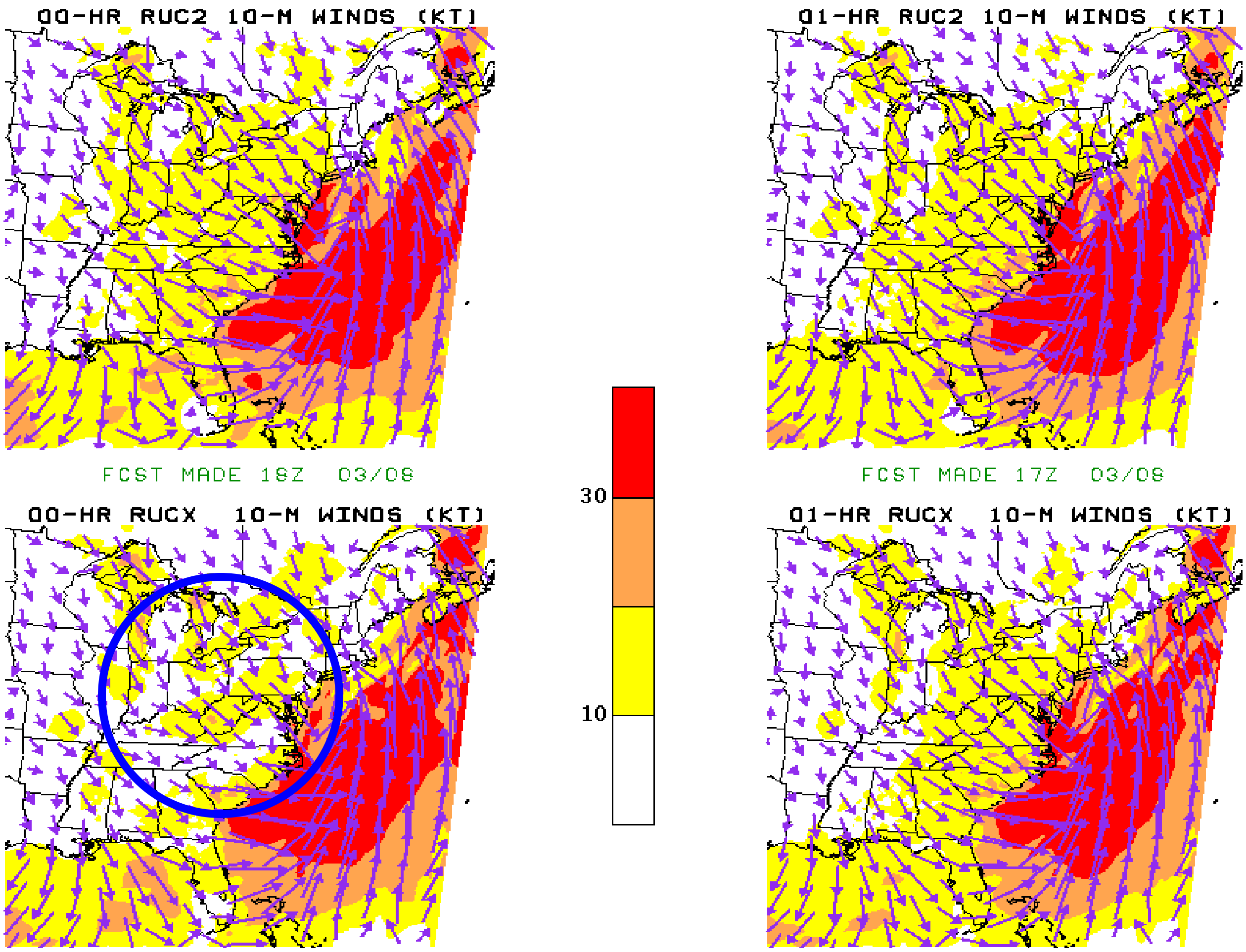


Figure 2. 10-m wind (kts) for RUC analyses without (top-left) and with (bottom-left) assimilation of mesonet data including winds. Valid 1800 UTC 8 March 2005. Also shown are the 1-h RUC forecasts of 10-m wind from cycles without (top-right) and with (bottom-right) mesonet assimilation.

This wind quality problem was not detected by existing National Centers for Environmental Prediction (NCEP) quality flags, including those set by the Meteorological Assimilation Data Ingest System (MADIS, Miller et al. 2007) used for collection of mesonet data for NOAA. Nor could this wind quality problem be addressed by the "buddy check" QC used in the RUC analysis (Benjamin et al. 2004a), even after first subtracting background RUC 1-h forecast values to improve the sensitivity of its buddy-check QC. The failure of the RUC buddy-check QC was because siting problems were so widespread with the numerous mesonet stations that these stations would corroborate each other. This problem was especially evident in strong wind speed events with 10-m winds stronger than 15 kts (knots). For the same problem, also evident with the similar variational QC method(e.g., Su et al. 2007), NCEP/EMC decided to not use mesonet wind observations in the NAM or RTMA analyses until improved QC techniques could be developed.

3. A hierarchy of Observation Quality Monitoring (OQM) procedures

To address observation QC problems (UOEEs) like these encountered not only for surface observations, but also in different “flavors” for aircraft, profiler, and rawinsonde observations, NOAA/ESRL has developed 3 tiers of observation quality monitoring (OQM), some of which are much-quicker-response versions of well-known OQM procedures (e.g., ECMWF 1984).

To develop these 3 tiers, we followed these principles:

- Collection of mean observation-minus-background (O-B) statistics for a given platform (or station) are much more sensitive for error detection than a single O-B value. This is not a new idea, since all major operational numerical weather prediction centers (e.g., NCEP, and the European Centre for Medium Range Weather Forecasts) keep reject lists based on station-by-station O-B differences. However, NCEP issues new reject lists on a monthly basis, but experience with the RUC showed what was needed: a much more immediate OQM procedure, sensitive within a single day or even a single hour for a station misbehavior.

- Use of a background value (B) from an independent model forecast is essential. A model forecast enforces physical consistency with local topography, soil moisture, terrain, land-water contrasts, vertical mixing, time of day, etc. The model forecast, even at only 1-h duration as shown in Fig. 2 (right side) then provides independence from local observation errors at the analysis time. In the case of mesonet wind observations, the use of the RUC 1-h surface forecasts for backgrounds has been found to be very effective in OQM since the RUC shows highest accuracy at 1-h forecasts (Benjamin et al. 2004a, Figs. 14-17).

- Corollary to previous point: Use of the previous analysis as a persistence forecast for the background B greatly reduces the effectiveness of OQM with O-B statistics. Siting problems (or measurement error) results in temporally correlated errors.

We have found the following three OQM collection procedures to be useful. In each one of these proposed procedures, thresholds must be set for RMS and mean O-B differences for each variable type (e.g., temperature, wind speed, etc.) from which automated reject decisions or reject lists can be produced:

1) Mean O-B stats by individual *platforms at individual analysis time windows. – OQM#1*

This OQM technique, developed at ESRL’s Global Systems Division (GSD), has already been implemented in the operational RUC at NCEP as follows. Within a given 1-h time window, individual platforms from many observation types will each produce many hourly observations (when including multiple levels), e.g., aircraft, profilers, surface, rawinsondes, etc. For temperature, if mean O-B differences for over 12 reports within a 1-h time window exceed 2˚C, all reports from this station are rejected. Similarly, if mean O-B wind speed differences for a given platform (e.g., aircraft tail number or a specific wind profiler) for a 1-h window exceed 5 m/s, all reports from that station are rejected for this analysis time.

This OQM method #1 has been found to be very effective for the RUC over the last 2 years, and has prevented many previous UOEEs. Refinements to thresholds were developed during that period, adding wind speed thresholds that have identified otherwise UOEEs from profilers and aircraft. This refinement will allow introduction of boundary-layer profiler winds into the RUC in the planned 2007 upgrade.

Obviously, OQM method #1 is weak in that, by definition, it does not use a large number of reports over multiple time periods. Also, it can fail at some individual analysis times, even though most aircraft will report at least 12 times hourly. But OQM method #1 is easiest to implement and does not require a longer-term monitoring capability.

Pros:

- Prevents many UOEEs
- Easy to implement within analysis code
- Does not require long-term database for monitoring capability
- Suitable for detecting errors from platforms/stations that report many times per

hour or at many levels (including aircraft, profiler, rawinsonde).

Cons:

- Misses some significant UOEEs
- Incapable of detecting mesonet siting problems, especially for wind problems.

2) Mean O-B stats by *network providers – OQM#2*

This statistic has been used so far for aircraft (carriers, aircraft types (e.g., turboprop) for given carriers) and surface observations (e.g., mesonet providers such as OK Mesonet). In February 2007, an initial mesonet wind provider uselist was determined and implemented in the developmental RUC at ESRL/GSD. This uselist was based on only three daytime cases. OQM#2 assumes that siting is similar for all stations for a given network provider. The threshold chosen for these 1800 UTC (mid-day, daytime mixing) cases was an O-B mean (over all stations for a given mesonet provider) wind speed difference of 1.0 m/s (~2 mph).

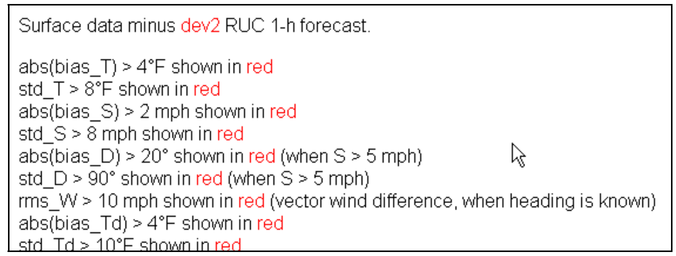
Similar results were shown in a provisional mesonet wind provider "do not use" list, a complement to a uselist. This OQM product (Fig. 1) was developed over a 28-day period in May, using the ESRL-OQM-surface database, showing all networks with mean wind speed O-B difference averaging at least 0.9 mph, with threshold-exceeding values at least 2.0 mph shaded in red.

Pros:

- Identifies reliable surface networks that provide winds without wind speed bias.
- Increases the number of reliable surface wind observations available (as now planned for the operational RUC in 2007).
- Can provide useful statistics from network provider summaries from a few analysis run times without requiring a full database accumulating data quality events over a longer time period. (However, OQM#2 works even better using such a database.)

Cons:

- Depends on assumption of similar siting for all stations for a given provider. Therefore, it is unable to exonerate well-sited stations within a network including many poorly sited stations. Similarly, it cannot identify the hypothetical few problematic stations within a network with few problems overall.


Surface data minus dev2 RUC 1-h forecast.

abs(bias_T) > 4°F shown in red
std_T > 8°F shown in red
abs(bias_S) > 2 mph shown in red
std_S > 8 mph shown in red
abs(bias_D) > 20° shown in red (when S > 5 mph)
std_D > 90° shown in red (when S > 5 mph)
rms_W > 10 mph shown in red (vector wind difference, when heading is known)
abs(bias_Td) > 4°F shown in red
std_Td > 10°F shown in red

Figure 3. Preliminary thresholds for automated reject list for surface observations for longer-term O-B differences. These thresholds will be modified in the future.

3) Mean O-B stats by individual platforms over longer-term periods. – OQM#3

This OQM is the strongest QC tool among the three listed here, although we recommend retaining OQM #1 even when OQM #3 is available. OQM #3 is not a new idea, and has already been used for many years by operational NWP centers, including the NCEP Central Operations (NCEP/NCO).

NOAA/ESRL/GSD has taken an additional step in developing a *real-time automated* database for this OQM producing *automated daily reject lists* for aircraft and soon, for surface observations also.

Pros:

- Isolates siting problems for individual stations, allowing effective uselists (or conversely, reject lists) for data assimilation into multiple models (e.g., RUC, NAM, RTMA, etc.).
- Allows all well-sited stations within a mixed-quality mesonetwork to be identified, greatly increasing the number of reliable observations for data assimilation.
- Provides metadata for data providers to mitigate individual station/platform problems. This has been very effective as national NWP centers report such problems for individual rawinsonde or surface stations or individual aircraft tail numbers (Moninger et al. 2003).
- In a fully automated version, can be used to produce automated daily updated reject lists, as NOAA/ESRL/GSD already does for its aircraft database (used in NOAA/ESRL/GSD versions of the real-time RUC since early 2007).

- Can detect changes in data quality from individual stations on a daily basis.

Cons:

- An interactive database monitoring system must be developed and maintained, such as that at http://amdar.noaa.gov/ruc_acars .

4. Mesonet wind provider uselist (OQM #2)

A version of the RUC O-B statistics produced hourly at NOAA/ESRL/GSD has now been extended to distinguish observation quality for over 40 different mesonet wind providers, including the Oklahoma Mesonet, Automated Weather Source (AWS), RAWS, the Citizens Weather Observers Program, and many state-based networks. Differences between observations and 1-h RUC forecasts for temperature, wind speed, RH, and surface pressure are accumulated for each mesonet provider for each hour. From these accumulations, mean absolute differences and biases are calculated.

A preliminary mesonet wind do-not-use list can quickly be extracted from the statistics shown in Fig. 1, based on daytime 18-21z statistics from May 2007. Note that METAR and maritime wind observations show very good agreement with the RUC 1-h forecasts, with several mesonet providers indicating at least 2.0 mph (~1.0 m/s) wind bias, and some even exceeding 3.0 mph wind speed bia

For the period 2007-05-02 00:00:00 to 2007-05-08 19:29:22
(Click on a column header to sort by that column)

network	N sites	N T	avg T	bias T	std T	N S	avg S	bias S	std S	N DIR	bias D	std D	rms W	N Td	avg Td	bias Td	std Td
.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	3911	576324	60.9	0.8	3.7	576324	4.3	-3.4	5.0	150279	-1	43	6.1	576324	44.8	-2.5	8.6
5	3801	521437	60.5	1.4	4.8	521212	3.4	-4.7	7.5	99791	0	45	8.8	505339	44.5	-1.6	7.1
38	2300	279123	48.0	-1.5	11.6	137194	7.3	-1.6	6.5	54518	-8	52	6.5	113239	31.0	-2.9	8.2
METAR	2187	321792	59.2	1.4	4.3	321600	9.0	-0.1	5.4	186301	-1	30	5.4	318529	44.2	-1.3	5.5
RAWS	1654	251922	53.7	0.4	6.2	251965	6.0	-2.6	5.5	92392	-2	48	6.0	251009	36.9	-2.5	7.3
60	817	125360	62.7	1.7	3.9	125360	4.6	-3.2	4.5	34489	-7	41	5.5	125359	42.1	-1.8	5.7
Marit	647	27401	57.8	1.0	4.7	26598	13.4	1.1	6.7	19710	-3	29	6.7	12347	53.7	-0.6	6.6
51	164	25201	59.1	2.5	4.4	25045	4.5	-4.1	3.8	8656	-12	51	5.4	25201	40.0	-2.1	6.4
28	140	20709	60.7	1.1	2.4	20713	7.7	-6.5	5.8	12740	0	42	8.7	20175	52.5	1.4	12.0
10	126	19183	50.2	1.2	4.1	3511	5.0	-1.7	3.8	1041	1	27	4.1	0	0.0	0.0	0.0
13	116	17127	59.9	0.7	6.4	0	0.0	0.0	0.0	0	0	0	0.0	16166	46.4	-1.0	7.7
53	116	18474	69.3	0.4	2.4	18474	9.4	-0.1	4.2	10798	4	25	4.2	18471	63.8	-0.0	2.2

Figure 4. Summary of ESRL-OQM-surface O-B statistics ordered by number of sites for each network provider.

For the period 2007-05-01 18:30:00 to 2007-05-28 21:59:59
Only including 1800 - 2100 UTC
(Click on a column header to sort by that column)

network	N sites	N T	avg T	bias T	std T	N S	avg S	bias S	std S	N DIR	bias D	std D	rms W	N Td	avg Td	bias Td	std
.	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.
30	13	681	54.1	-8.2	7.6	681	8.1	-1.9	6.9	336	11	80	7.2	643	33.3	-5.6	7.
42	7	208	58.1	7.1	9.4	405	8.0	-3.5	4.7	259	-5	31	5.9	252	40.1	0.8	5.
56	2	123	74.1	5.4	5.0	0	0.0	0.0	0.0	0	0	0	0.0	123	50.3	-2.0	3.
SAO	66	2503	49.1	-5.0	18.9	2346	10.7	0.7	5.7	1614	2	45	5.8	2396	32.7	-8.1	16.
59	16	1107	59.4	-4.5	8.7	1061	9.1	-0.9	18.7	365	5	75	18.5	1107	37.1	-3.7	6.
21	53	3087	65.1	4.3	11.3	1476	11.0	0.1	5.8	1033	1	41	5.8	63	55.7	-2.8	3.
4	5	341	72.4	3.2	3.1	341	7.0	1.6	2.3	136	17	30	2.8	341	49.0	-1.9	5.
29	22	1517	76.3	2.7	4.0	1515	7.0	-0.9	4.5	722	5	45	4.6	1517	54.5	0.3	4.
45	45	1709	70.1	2.7	5.9	1709	8.6	-1.7	5.2	1075	2	44	5.5	1709	52.7	-1.5	4.
38	2260	127912	60.2	-2.6	12.1	66027	8.2	-1.1	6.6	31344	-6	55	6.6	53937	32.2	-3.3	9.
67	29	1805	56.3	-2.6	6.5	1805	12.6	2.0	6.7	1201	-7	55	7.0	1805	30.6	-3.3	7.
64	53	701	67.8	2.6	4.9	705	8.2	-4.6	4.9	496	-5	36	6.7	701	42.8	-1.7	5.
1	12	780	55.8	-2.5	4.6	780	9.3	-2.5	5.4	572	2	60	6.0	780	35.8	-9.4	5.
46	11	753	65.4	2.3	3.8	753	5.4	-2.2	4.1	263	2	37	4.7	753	34.0	-9.6	7.
47	42	2921	69.9	2.2	4.3	2078	6.7	-0.6	4.3	888	13	45	3.6	2196	43.9	-3.2	6.
40	81	5364	65.6	1.9	7.0	4684	13.5	-0.5	5.7	3906	-2	26	5.7	5221	47.4	0.8	7.
51	164	11595	72.4	1.8	6.0	11519	5.4	-2.7	4.1	4517	-10	56	4.9	11595	46.7	-2.8	6.
17	11	746	72.4	1.8	3.9	673	11.0	-1.7	5.4	503	-3	31	5.6	289	47.7	-1.3	4.
10	126	8954	64.3	1.7	4.5	1655	6.9	-1.1	4.0	786	1	29	4.1	0	0.0	0.0	0.
5	3934	244910	72.0	1.7	6.0	244886	4.4	-4.5	7.1	62282	1	48	8.4	237320	47.5	-1.5	7.
16	9	494	78.5	-1.6	11.4	489	4.3	-3.2	4.1	124	-5	32	5.4	495	46.8	-5.9	10.
12	10	731	71.5	-1.6	2.5	731	7.7	0.9	3.8	324	9	35	3.9	731	45.0	-1.0	4.
34	4	291	70.6	-1.5	6.1	291	8.1	-0.6	4.1	144	12	31	4.2	288	41.3	-0.5	5.
11	8	380	65.7	1.4	3.8	380	8.9	-0.9	4.7	224	-15	54	4.8	380	37.3	-2.3	9.
METAR	2195	157247	69.4	1.4	5.4	157330	10.7	1.0	5.8	105653	0	34	6.0	155673	46.1	-2.1	6.
50	71	3202	67.2	1.4	5.3	4458	10.9	1.4	4.6	3209	-1	37	4.8	0	0.0	0.0	0.
36	58	3829	73.4	1.3	5.4	3822	4.2	-2.7	3.9	981	-6	65	4.7	3829	48.7	1.0	10.

Figure 5. Top temperature-bias problems identified by ESRL-OQM-surface system by mesonet providers for 1800-2100 UTC (daytime) observations during May 2007.

Based on this new hourly monitoring of mesonet wind biases, an objectively based mesonet wind provider uselist has been established and is now being used to safely allow assimilation of mesonet wind obsevations from specified providers in an experimental version of the RUC run at NOAA/ESRL/GSD. Assimilation of wind observations from the mesonet uselist providers is planned to begin with the operational RUC at NCEP later in 2007 as part of a larger RUC change package (Benjamin et al. 2007a). This change will also improve the quality of the NWS/NCEP Real-Time Mesoscale Analysis by improving the RUC-RTMA background data described in Benjamin et al. (2007b).

5. Initial results from ESRL's surface OQM database (OQM #3)

ESRL has developed The interactive OQM database developed by NOAA/ESRL and interactive web page allows more specific *station-specific* uselists . In the associated MySQL database, ESRL records events for all hourly surface observations for all variables and for accompanying RUC 1-h forecast values providing independent estimates of those 2-m temperature and dewpoint and 10-m winds. Station-specific lists for mean wind speed difference from the RUC 1-h forecast, for instance, similar to Fig. 1, can be produced but are not shown in this paper.

To demonstrate the utility of the ESRL-OQM surface capability, we also include a summary of results by providers (encoded for mesonet providers) in order of the number of stations by provider (Fig. 4). Although there are 67 providers in the current ESRL-OQM-surface database, we show in Fig. 4 the 12 most numerous station providers. Fig. 4 allows comparison between METAR vs. RUC O-B differences compared to the O-B differences for other surface data providers.

We also show a list of the providers with the largest mean O-B differences for 2-m temperatures in Fig. 5. Here, the mean METAR differences are only 1.4 deg F, whereas there are several network providers with mean temperature differences of over 4 deg F. Note that these differences do not necessarily imply a problem with the observing network, but they highlight areas for further investigations. For instance, it could be that a network of coastal stations might correspond to RUC grid points treated as water, leading to a large mean O-B temperature difference showing up as a "bias". Alternatively, stations from a given surface data provider might have inadequate shading or ventilation, exaggerating daytime temperature. The ESRL-OQM surface capability will allow these questions to be investigated.

We note again that comparison of O-B statistics between different surface providers is invaluable for potential usage of the data, especially using METAR O-B statistics as a baseline.

The ESRL-OQM-surface database and interactive capability is being made available to NOAA assimilation groups including those at NCEP and within ESRL.

6. Conclusions

Improved OQM (observation quality monitoring) using differences with an independent model forecast (such as the RUC 1-h forecast) is necessary for improved data assimilation for many observation types. ESRL has developed such capabilities for aircraft data, and now in a preliminary version for surface observations as well, as described in this paper.

The ESRL-OQM-surface capability will provide

- Fuller and more reliable assimilation of surface mesonet data.
- Quicker detection of station/platform errors after they start.
- A full OQM interactive web site allowing human interaction now exists in experimental version at ESRL/GSD.

7. Acknowledgments

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