1. Introduction

This document describes the quality control (QC) flags available for Release 3.0 (R3.0) 1662-2014 data stored in the International Maritime Meteorological Archive (IMMA1) format (Smith et al. 2016; hereafter *R3.0-imma1*), how those flags were set, and the criteria used to select:

a) The official release "Final" dataset from the superset of "Total" IMMA data—by excluding landlocked, "certain" and "uncertain" duplicates, and other suspect/erroneous reports.

b) "Enhanced" data: ships plus other selected platform types, using 4.5 standard deviation (σ) trimming limits; or "standard" data: ship only; 3.5σ trimming limits.

The enhanced/standard data selections are used in turn for: calculating trimmed year-month summary statistics boxes back to 1800 (and 1°×1° boxes since 1960); to create the enhanced-trimmed IMMA data served in-bulk from NCEI; and to select enhanced/standard (or other custom-trimmed) data on demand from NCAR (webpage interface available under: http://rda.ucar.edu/datasets/ds548.0/) into alternative user formats. In addition, these QC flags and data selection procedures are used (as applicable) for "preliminary" ICOADS data and monthly summary products for 2015-forward (updated monthly, and lagging the data month up to five days).

One goal in designing the QC flags was to provide the information necessary for a user to reproduce either the enhanced or standard data. Although this approach is more complex than having simple flags that indicate whether a given report or data element was used, it provides flexibility for users who might choose to make use of different combinations of flags. Or, for users who do not wish to make use of that flexibility, NCAR's webpage interface can apply pre-defined data deletions and selections, and Fortran software is available (from http://icoads.noaa.gov/software/), interfacing with the IMMA1 read/write program ({rwimma1} and {trimqc0.f, trimqc1.f, and trimqc2.f}).

Section 2 describes the specific QC flags available in the IMMA format, and how each was set for R3.0 (or in previous processing[1]). Section 3 documents the rules used for production of the Final IMMA dataset, from the Total dataset. Finally, Section 4 covers the data selection criteria used to create enhanced or standard trimmed IMMA data, or monthly summary statistics (MSG format), using some of those flags.

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[1] During R2.5 processing, QC flags on all the data were re-set, except that the adaptive QC flags for *SST* (*SQZ* and *SQA*) were carried forward into R3.0, as discussed in sec. 2. For R2.5.1 (i.e. the IMMA1 version of R2.5), all those data were not re-QC'd, except for when *N*=9 was recovered from IMMA supplemental data for some NCEP GTS data. We note further that R2.5.1 (i.e., marine reports that were already part of ICOADS, including some originating as far back as *Release 1*) provided the largest historical input ingredient for R3.0.

2. ICOADS-assigned QC flags available in the *Icoads* attm of IMMA

Table 1 lists the QC elements available (some presently obsolete or unused, as indicated) as part of the *Icoads* attm. Table 2 documents the simple "base36" numbering system used to encode some flags into one character, for space saving purposes, within the range 0, …, 9, A …, Z (i.e., basically an extended hexadecimal-type system).

Table 1. QC flags within the *Icoads* attm (see Table C1 in *R3.0-imma1*) of the IMMA format (fields 1-15 of that attm are described in Table C1). Grey-shaded flags are obsolete or unused.

No.	Len.	Abbr.	Element description	Scaled Min.	Scaled Max.	Units (Code)
			QC elements (38 characters):			
			Adaptive QC flags (12 characters; only *SQZ-SQA* in use):			
16	1	SQZ	*SST*: z flag	1	35	base36 (obsolete)
17	1	SQA	*SST*: alpha flag	1	21	base36 (obsolete)
18	1	AQZ	*AT*: z flag			(unused)
19	1	AQA	*AT*: alpha flag			(unused)
20	1	UQZ	U-wind: z flag			(unused)
21	1	UQA	U-wind: alpha flag			(unused)
22	1	VQZ	V-wind: z flag			(unused)
23	1	VQA	V-wind: alpha flag			(unused)
24	1	PQZ	SLP: z flag			(unused)
25	1	PQA	SLP: alpha flag			(unused)
26	1	DQZ	Humidity: z flag			(unused)
27	1	DQA	Humidity: alpha flag			(unused)
			Night/day flag (1 character):			
28	1	ND	night/day flag	1	2	
			Trimming flags (6 characters):			
29	1	SF	*SST* flag	1	15 [F]	base36
30	1	AF	*AT* flag	1	15 [F]	base36
31	1	UF	U-wind flag	1	15 [F]	base36
32	1	VF	V-wind flag	1	15 [F]	base36
33	1	PF	*SLP* flag	1	15 [F]	base36
34	1	RF	*RH* (& *WBT/DPT*) flag	1	15 [F]	base36
			NCDC-QC flags (14 characters):			
35	1	ZNC	report-status flag (ship position)	1	10 [A]	base36
36	1	WNC	wind flag	1	10 [A]	base36

No.	Len.	Abbr.	Element description	Scaled Min.	Scaled Max.	Units (Code)
37	1	BNC	visibility (*VV*) flag	1	10 [A]	base36
38	1	XNC	present weather (*WW*) flag	1	10 [A]	base36
39	1	YNC	past weather (*W1*) flag	1	10 [A]	base36
40	1	PNC	*SLP* flag	1	10 [A]	base36
41	1	ANC	*AT* flag	1	10 [A]	base36
42	1	GNC	*WBT* flag	1	10 [A]	base36
43	1	DNC	*DPT* flag	1	10 [A]	base36
44	1	SNC	*SST* flag	1	10 [A]	base36
45	1	CNC	cloud flag	1	10 [A]	base36
46	1	ENC	wave flag	1	10 [A]	base36
47	1	FNC	swell flag	1	10 [A]	base36
48	1	TNC	pressure tendency (*A* and *PPP*) flag	1	10 [A]	base36
49	2	QCE	**External flags (i.e., 2-char. *QCE* when decoded into six flags[1]):**	0	63	integer encoding (6 flags)
		ZE	report-status flag	1	1	1 = erroneous (based on NCDC quality control)
		SE	*SST* flag	1	1	"
		AE	*AT* flag	1	1	"
		WE	wind flag	1	1	"
		PE	*SLP* flag	1	1	"
		RE	*RH* (*WBT*/*DPT*) flag	1	1	(unused)
50	1	LZ	**Landlocked flag (1-character):** 2°×2° landlocked flag	1	1	
51	2	QCZ	**Source exclusion flags (i.e., 2-char. *QCZ* when decoded into five flags[1]):**	0	31	integer encoding (5 flags)
		SZ	*SST* flag	1	1	data excluded from enhanced- or standard-trimmed IMMA/MSG (in addition to other possible QC criteria, see Table 9)
		AZ	*AT* flag	1	1	"
		WZ	wind flag	1	1	"
		PZ	*SLP* flag	1	1	"
		RZ	*RH* (*WBT*/*DPT*) flag	1	1	"

1. Appendix A describes how to convert the coded (base36) values stored in these flags into true (floating-point) values. However, software along these lines to decode QCE/QCZ is not yet implemented within {rwimma1}, and thus presently *SZ-RZ* and *ZE-RE* are not defined variables within {rwimma1}).

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Table 2. Base36 encoding (note: Table 1 in *R3.0-imma1*). Decimal numbers and base36 equivalents. The complete set of 1-character encodings (0-35) is listed on the left, and examples of 2-character encodings (0-1295) are given on the right. Note that the subset 0-F of base36 is the same as hexadecimal.

1-character encoding:								E.g., 2-character encoding:	
dec.	*base36*	*dec.*	*base36*	*dec.*	*base36*	*dec.*	*base36*	*dec.*	*base36*
0	0	10	A	20	K	30	U	0	0
1	1	11	B	21	L	31	V	1	1
2	2	12	C	22	M	32	W	2	2
3	3	13	D	23	N	33	X	.	.
4	4	14	E	24	O	34	Y	.	.
5	5	15	F	25	P	35	Z	.	.
6	6	16	G	26	Q			1293	ZX
7	7	17	H	27	R			1294	ZY
8	8	18	I	28	S			1295	ZZ
9	9	19	J	29	T				

16) *SQZ*   adaptive QC: *SST*: z flag (obsolete)
17) *SQZ*   adaptive QC: *SST*: alpha flag (obsolete)
18) *AQZ* – 27) *DQA* (note: all unused)

As detailed in Table 3, *SQZ* indicates the relationship of *SST* to "adaptive" QC limits in 0.5σ (standard deviation) increments, and *SQZ* provides a measure of the reliability of the QC. The remaining flag positions were allocated in IMMA, but as yet remain unused.

> Background: These *SST* flags are not utilized for any of the usual ICOADS data selection processes, and, for most users, we would recommend that they be considered obsolete and not used. The *SST* flags were assigned experimentally in 2001 to Release 2.0 (R2.0) data. With subsequent ICOADS updates they have been carried forward as assigned, but not updated, thus it is important to note that they are only available on a subset of the currently available R3.0 data. Further information on the adaptive approach and how the *SST* flags were set is available at http://icoads.noaa.gov/aqc.html

Table 3. As listed in Table 1, a pair of adaptive QC flags has been allocated for selected primary variables, with abbreviations ending in *Z* and *A* (e.g., *SQZ* and *SQA* for *SST*; the only two of the adaptive flags currently in limited use as discussed above). These refer to the z* and alpha** values resulting from the comparison of the observation to adaptive QC limits. If an observation is missing, or exceeds physical limits (e.g., for *SST*: outside the range $-5.0°C$ to $40°C$), the flags are set to missing. This table (see also http://icoads.noaa.gov/aqc.html) describes how to convert the coded (base36) information as provided by {rwimma1} into true (floating-point) values.†

Value (flag 3rd letter):	True value:		Units	Base	Coded:	
	Min.	*Max.*			*Min.*	*Max.*
z (*Z*)	-8.5σ	8.5σ	0.5	-18	1	35
alpha (*A*)	0.0	1.0	0.05	-1	1	21

* z: indicates the relationship of an individual observation to the adaptive standard deviation (σ) limits in 0.5σ steps. The extremes are open-ended in that any values $< -8.5\sigma$ or $> 8.5\sigma$ are mapped to $\pm8.5\sigma$. Other σ values represent intervals of approximately $\pm0.25\sigma$ around the reported values because of rounding to the nearest 0.5σ. E.g., -3.5σ represents the approximate interval -3.75σ to -3.25σ.
** alpha: provides a measure of the reliability of the QC: it has a roughly inverse relationship with the number of observations available nearby (smaller alpha values indicate more data).
† A 2-stage encoding is applied: 1) The floating-point true value is divided by the "units" (the smallest increment of the data being encoded). Then the base is subtracted to produce, after rounding, a coded positive integer. 2) The integer is transformed into a base36 character. Decoding reverses this process by transforming the base36 value back into the coded value, and then the true value is reconstructed by:

true value = (coded + base) * units

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28) *ND*   night/day report flag
The night/day report flag was set to indicate whether the report fell in local nighttime or daytime, as determined according to Slutz et al. (1985) (hereafter *Release 1*), supp. A (http://icoads.noaa.gov/Release_1/suppA.html):
    1 = report time is local nighttime
    2 = report time is local daytime

29) *SF*   trimming: *SST* flag
30) *AF*   trimming: *AT* flag
31) *UF*   trimming: U-wind flag
32) *VF*   trimming: V-wind flag
33) *PF*   trimming: *SLP* flag
34) *RF*   trimming: *RH* (and *DPT/WBT*) flag
These flags indicate the relationship of a given observational data value to the legacy (*Release 1*, supp. C; http://icoads.noaa.gov/Release_1/suppC.html) trimming limits, or to indicate if those limits, which were calculated separately for three historical periods (1854-1909, 1910-49, and 1950-79; see also http://icoads.noaa.gov/dsul.html) are unavailable, or other conditions. Specifically, where $a1$ is the individual observation under scrutiny, g is the smoothed median, and $s1$ and $s5$ are the smoothed lower and upper median deviation, the trimming flags have the following defined values (values 8-10 are currently unused):
    1 = within 2.8σ limits (g – 2.8*$s1$ ≤ $a1$ ≤ g + 2.8*$s5$)
    2 = less than 2.8σ lower limit (g – 3.5*$s1$ ≤ $a1$ < g – 2.8*$s1$)
    3 = greater than 2.8σ upper limit (g + 2.8*$s5$ < $a1$ ≤ g + 3.5*$s5$)
    4 = less than 3.5σ lower limit (g – 4.5*$s1$ ≤ $a1$ < g – 3.5*$s1$)
    5 = greater than 3.5σ upper limit (g + 3.5*$s5$ < $a1$ ≤ g + 4.5*$s5$)
    6 = less than 4.5σ lower limit ($a1$ < g – 4.5*s1)
    7 = greater than 4.5σ upper limit ($a1$ > g + 4.5*$s5$)
    11 = limits missing (ocean/coastal box); OSD buoy data correct (*SF*/*PF* only)
    12 = limits missing (ocean/coastal box)
    13 = landlocked 2° box
    14 = data unusable (*SF*, *AF*, and *PF*, only; see Table 4)
    15 = data missing or not computable (see Table 4)
The flags for data missing or unusable (14-15) were set instead of the flags for limits missing or landlocked (11-13), if both were applicable (i.e., values 11-13 refer only to usable data). The numeric ordering of the flags allows computation of "untrimmed" summaries, for example, by testing for a flag value ≤ 12 (i.e. excluding only landlocked, unusable, or missing data).

> Background: As discussed on http://icoads.noaa.gov/dsul.html, we made an important procedural change starting at R2.5, such that the *RH* trimming limits for 1910-49 were also used for screening all *RH* (and thus indirectly *DPT*/*WBT*) data prior to 1910 (as discussed further in Woodruff et al. 2011). The configuration of the trimming flags now differs in several ways from what was used for *Release 1*, including an expansion in defined range, changes that were first established at R2.0 and implemented in the now obsolete LMR/LMRF observational formats (see http://icoads.noaa.gov/e-doc/stat_trim for further details). Trimming flag value 11 was set only for OSD (formerly ISDM/MEDS; deck 714) buoy *SST* or

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SLP data falling within an ocean/coastal box lacking trimming limits, for which the OSD QC flag (see Table 7) indicated that the data were checked and appeared correct. Note that any OSD *AT* or wind data appearing under these circumstances were instead flagged 12, because OSD applied a lower level of quality control to those elements.

Table 4. SST, *AT*, and *SLP* data were classified as "unusable" (trimming flag value 14) if the observation was outside the global physical limits given in this table.* Or, those variables were instead classified as missing (flag value 15), if the field in question was missing. Flag value 14 is not defined for *UF* or *VF* because those flags refer to computed data elements not available as fields in IMMA; similarly, flag value 14 is not defined for *RF*.** Flag value 15 is used to refer to data that were missing or not computable for wind*** and *RH*.**** [Note: Adapted from Table 2 in http://icoads.noaa.gov/e-doc/stat_trim.]

Variable	Physical limit minimum	Physical limit maximum
sea surface temperature (*SST*)	–5.0°C	40.0°C
air temperature (*AT*)	–88.0°C	58.0°C
sea level pressure (*SLP*)	870.0 hPa	1074.6 hPa

* Previously to R2.5, the definition of "unusable" also extended to if the relevant data element was stored in the error attachment in the now obsolete LMR format. The *SST* and *AT* limits were originally based on ranges established for Compressed Marine Reports (CMR4/CMR5) for *Release 1* (see supps. D-E); temperature values outside these ranges could not be stored in CMR, and thereby were indirectly omitted from statistics. For later Releases, in contrast, we calculated statistics directly from IMMA (or previously to R2.5 from the obsolete LMRF/LMR formats). Thus the global limits are checked when setting *SF* and *AF*, since *SST* or *AT* values outside these ranges may appear in IMMA. *SLP* values are limited to this range in CMR and LMR/LMRF formats, thus any *SLP* value outside this range was already omitted from CMR (or previously appeared in the LMR error attachment).
** Prior to IMMA1, it was not possible to store a reported (or computed) *RH* in IMMA0, or in the obsolete LMRF/LMR formats. While a field for reported (or computed) *RH* is now available in IMMA1, flag value 14 is still undefined for *RF*.
*** Wind was considered not computable if some wind data existed but computed *U* and *V* did not result after application of *Release 1*, supp. E, Table E2-1, including all cases where only wind speed resulted.
**** Relative humidity (*RH*) was considered not computable if *AT* was missing or unusable, if *DPT* was missing or unusable, or if the calculation of dew point depression (*DP*) yielded a value outside the range 0°C ≤ *DP* ≤ 70°C, such that the calculation of *DP* was changed to yield zero when –0.5°C ≤ *AT* – *DPT* < 0°C. In addition, for *Release 1*, *RH* was set to missing if *AT* fell outside the 3.5σ limits; for later Releases, the variable hierarchy for statistics (*Release 1*, supp. A, Figure A4-1) has served to implement this dependency at different trimming levels.

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35) *ZNC* NCDC-QC: report-status flag (ship pos.) (*shipf*) [note: supp. J abbrev.])
36) *WNC* NCDC-QC: wind flag (*windf*)
37) *BNC* NCDC-QC: visibility (*VV*) flag (*visf*)
38) *XNC* NCDC-QC: present weather (*WW*) flag (*prswxf*)
39) *YNC* NCDC-QC: past weather (*W1*) flag (*pstwxf*)
40) *PNC* NCDC-QC: *SLP* flag (*pressf*)
41) *ANC* NCDC-QC: *AT* flag (*dryf*)
42) *GNC* NCDC-QC: *WBT* flag (*wetf*)
43) *DNC* NCDC-QC: *DPT* flag (*dewf*)
44) *SNC* NCDC-QC: *SST* flag (*seaf*)
45) *CNC* NCDC-QC: cloud flag (*cloudf*)
46) *ENC* NCDC-QC: wave flag (*seawvf*)

47) *FNC*   NCDC-QC: swell flag (*swlwvf*)
48) *TNC*   NCDC-QC: pressure tendency (*A* and *PPP*) flag (*ptendf*)

Release 1, supp J (http://icoads.noaa.gov/Release_1/suppJ.html) documents these 14 flags. The abbreviations employed in the detailed NCDC-QC flowchart in supp. J, and in Table J0-1 there, are also provided above (and in Table 5) for cross-reference. Table 5 reproduces some general information from Table J0-1 about the possible settings of each flag, and Table 6 reproduces information from Table J0-2 about each NCDC-QC flag value's alphabetic meaning.

> Background: For COADS *Release 1*, the NCDC-QC procedure (see supp. J) was adapted by NCDC from longstanding marine QC procedures used in Asheville. This complex procedure focused largely on the characteristics of ship (VOS) data, and therefore now believed to be considerably out-of-date in at least some of its details (e.g., as the SHIP/FM 13 GTS code has changed through the years). The procedure also relies in some of its tests on outdated monthly climatological fields (i.e., 5°x5° box long-term monthly means and standard deviations), derived from pre-COADS data held at NCDC many years ago. In addition to being one ingredient for enhanced (or standard) trimmed data filtering, as discussed in Section 4, the NCDC-QC flags are also currently important because they supply one criterion for selection of the best/preferable duplicate, during dupelim processing (see *R3.0-dupelim*).

Table 5. Possible NCDC-QC flag values, where "–" indicates an undefined flag value, or letters included in the table indicate a defined flag value. For the letters, lower-case "x" indicates a flag value not utilized, whereas upper-case flag values were utilized, in preparing enhanced or standard trimmed data (see also Table 9). In addition to correct "R" and missing "S", the NCDC-QC flags are divided up into those referring to correctable ("Mod."), Suspect, or Erroneous data. (Note: adapted from Table J0-1 in *Release 1*, supp. J, http://icoads.noaa.gov/Release_1/suppJ.html; and from Table 3 in http://icoads.noaa.gov/e-doc/stat_trim.)

IMMA abbrev.	Release 1 abbrev.	NCDC-QC flag description	R	Mod. A	Mod. B	Suspect J	Suspect K	Suspect L	Erroneous M	Erroneous N	Erroneous Q	S
35) *ZNC*	*shipf*	report-status flag	x	–	–	–	†	–	M*	–	–	–
36) *WNC*	*windf*	wind flag	x	x	–	x	–	–	x**	–	x	x
37) *BNC*	*visf*	*VV* flag	x	–	–	–	–	–	x	–	–	x
38) *XNC*	*prswxf*	*WW* flag	x	–	x	x	–	x	x	–	–	x
39) *YNC*	*pstwxf*	*W1* flag	x	–	–	x	–	–	x	–	–	x
40) *PNC*	*pressf*	*SLP* flag	x	–	–	–	†	x	x	–	Q	x
41) *ANC*	*dryf*	*AT* flag	x	–	–	x	†	x	x	N	Q	x
42) *GNC*	*wetf*	*WBT* flag	x	–	x	–	†	x	x	N	Q	x
43) *DNC*	*dewf*	*DPT* flag	x	–	x	–	†	x	x	N	Q	x
44) *SNC*	*seaf*	*SST* flag	x	–	–	–	†	x	x	–	Q	x
45) *CNC*	*cloudf*	cloud flag	x	†	x	x	–	–	–	x	–	x
46) *ENC*	*seawvf*	wave flag	x	x	x	x	–	–	x	x	x	x
47) *FNC*	*swlwvf*	swell flag	x	–	x	x	–	–	x	x	x	x
48) *TNC*	*ptendf*	*A* and *PPP* flag	x	–	–	–	x	–	x	–	–	x

† Additional possible flag values in the obsolete *Release 1* TD-1129 format for data in the period 1970-79 because of flag overlaying (see supp. J), but no longer applicable in the currently available R3.0 data, in which *ptendf* during 1970-79 is the only flag that still may be set to K.
* For *ZNC*, the NCDC-QC report-status flag M indicates, among other possibilities, a landlocked report based on a check using a 1°×1° land/sea grid. This is more stringent than the 2°×2° grid used to set the separate landlocked flag (*LZ*). Thus *LZ* may conflict with the setting of *ZNC*.
** This NCDC-QC flag is necessary to implement *Release 1*, supp. E (Table E2-1), however the flag information is not used for calculating the trimmed summaries, which are calculated using only the trimming flags *UF* and *VF*.

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Table 6. NCDC-QC flag meaning (note: adapted from Table J0-2 in *Release 1*, supp. J). For dupelim processing, the quality code assigned to each report is the sum of the weights of the values associated with the 14 flags listed in Table 5.

*Value**	*IMMA***	*Weight*	*Meaning*	*Reason*
R	1	0	correct	–
A	2	1	correctable	legality
B	3	1	correctable	internal consistency
J	4	2	suspect	internal consistency
K	5	2	suspect	time
L	6	2	suspect	extreme (outside ± 4.8σ)
M	7	3	erroneous	legality
N	8	3	erroneous	internal consistency
Q	9	3	erroneous	extreme (outside ± 5.8σ)
S	10	3	missing	–

* Alphabetic representation used in the *Release 1*, supp. J to describe the flags.
** Corresponding numeric representation used in IMMA for storing the original documented flag values.
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49) *QCE*　　external flags (decoded from *QCE* into the following six flags):
　　　ZE　　　　external: report-status flag
　　　SE　　　　external: *SST* flag
　　　AE　　　　external: *AT* flag
　　　WE　　　　external: wind flag
　　　PE　　　　external: *SLP* flag
　　　RE　　　　external: *RH* (*WBT*/*DPT*) flag (unused)
The single extant value of the external flags is defined as follows:
　　　1 = erroneous (based on external OSD buoy quality control)
and set specifically according to Table 7.
　　　　　　Background: The external QC flags were designed to capture selected results from independent QC procedures, limited presently to OSD (formerly ISDM/MEDS; deck 714) drifting (and moored) buoy data.

Table 7. OSD flag values used for setting the external QC flags (*RE* is unused presently) to erroneous (1). An additional OSD flag for pressure tendency was not carried forward into the external QC flags, and while 3 or 4 can also be set by the OSD quality control for the report-status flag, *ZE* is always missing because all such erroneous reports were deleted during IMMA translation (for further information, see http://icoads.noaa.gov/e-doc/stat_trim). In addition, OSD elements associated with an external QC flag set to indicate erroneous were deleted during IMMA translation for the entire period-of-record.

Abbrev.	*External flag description*	*OSD input flags utilized to set external QC flag=1*
ZE	report-status flag	–
SE	*SST* flag	3 or 4
AE	*AT* flag	3 or 4
WE	wind flag	3 or 4 (speed and/or direction)
PE	*SLP* flag	3 or 4
RE	*RH* (*WBT*/*DPT*) flag	–

50) *LZ*   2°×2° landlocked flag

The single extant value of the landlocked flag (*LZ*) is defined as follows:

    1 = report over land

If *LZ* is missing, this indicates that the report falls over an ocean or coastal region as defined by a "landlocked" file at 2°×2° resolution (see *Release 1, supp. G*; http://icoads.noaa.gov/Release_1/suppG.html)*.*

> Background: As discussed in Table 5, the NCDC report-status flag *ZNQ* may conflict with the setting of *LZ* due to the use of a higher-resolution (1°×1°) check in the NCDC-QC procedure. For further information about both land/sea masks see http://icoads.noaa.gov/mask.html.

51) *QCZ*   source exclusion flags (decoded from *QCZ* into the following five flags):

SZ	source exclusion: *SST* flag
AZ	source exclusion: *AT* flag
WZ	source exclusion: wind flag
PZ	source exclusion: *SLP* flag
RZ	source exclusion: *RH* (*WBT*/*DPT*) flag

The single extant value of the source exclusion flags is defined as follows:

    1 = data automatically disqualified from statistics

The source exclusion flags are provided to indicate when certain sources or selections of data are automatically omitted from the enhanced or standard trimmed data for subjective reasons. These flags are set independently from the trimming and other QC flags, based only on data source, platform type (*PT*), or report time, and without testing for the presence or usability of data (see Table 4).

For 1980-2014 data, the source exclusion flags were set as follows:

    a) *SZ* through *RZ*: All coastal data (*PT*=13, 14, or 16).
    b) *WZ*: All wind measurements from drifting buoys (*PT*=7).
    c) *SZ* through *RZ*: All off–3-hourly NDBC (deck 883) moored buoy data (*PT*=6), i.e., any such moored buoy report at an hour other than 00, 03, 06, 09, 12, 15, 18, or 21 UTC. For the purpose of this test, hour to hundredths is first rounded to the nearest hour, except that reports at exactly half past the hour are automatically rejected (reports with a missing or erroneous hour are also automatically rejected).

For 1950-79 data, rule c) was modified and rule d) added:

    a) (Rule active, but not applicable to 1950-79 data.)
    b) (Rule active, but not applicable to 1950-79 data.)
    c) As for rule c) above, except applied instead to decks 876-882.
    d) *WZ*: Any wind measurements from IATTC data (SID=70 or SID=71).

For 1662-1949 data, none of the rules were applicable (no source exclusion flags were set).

> Background: See http://icoads.noaa.gov/e-doc/stat_trim for further information about the development and application of these rules previously to R3.0.

3. Rules for production of the Final IMMA dataset from the Total dataset

To construct the Final R3.0 IMMA dataset from the Total dataset (which mirrored the entire R3.0 input):

    (a) Reports with duplicate status *DUPS*>2 were eliminated (see Table 8).
    (b) Landlocked *LZ*=1 reports were eliminated.

(c) Reports with the intermediate reject flag *IRF*=0 or *IRF*=2 were also eliminated. However, to allow for more detailed analysis of the processing results and possible adjustments, all those flagged reports were retained in the R3.0 Total dataset.

Background: The defined values of *IRF* (from *R3.0-imma1*) are:
0 – Retain in Intermediate data file, reject from final data file
1 – Retain in both Intermediate and final data files
2 – Reject from both Intermediate and final data files (placed in reject file)

Table 8 (note: Table D8 from *R3.0-imma1*). Duplicate status (*DUPS*) assignments. In previous Releases, "certain" (C) duplicates were eliminated from the LMR output, and then "uncertain" (U) duplicates were eliminated from LMRF. Prior to R3.0 processing, settings marked by footnotes apply only to pre-1980 data. For R3.0 processing, *DUPS*=3, 5, 6, and 7 were no longer used (indicated by grey shading).

DUPS	U/C	Description
0		unique
1		best duplicate
2		best duplicate with substitution
3	U	worse duplicate: uncertain weather element match with hour cross[1]
4	U	worse duplicate: uncertain weather element match with no cross
5	U	worse duplicate: uncertain weather element match with day cross[2]
6	U	worse duplicate: time/space match with *ID* mismatch (unused until 1950)
7	U	worse duplicate: certain weather element match with hour cross[1]
8	C	worse duplicate: certain weather element match with no cross
9	C	worse duplicate: combined *DUPS* 4 and 6
10	C	worse duplicate: combined *DUPS* 6 and 8
11	C	worse duplicate: time/space/ID match
12	C	worse duplicate: combined *DUPS* 4 and 11
13	C	worse duplicate: combined *DUPS* 8 and 11
14	C	automatic data rejection

1. For *Release 1*, applied to 1854-1979 data; for R2.0, applied to 1784-1979 data; for R2.5, applied to 1662-1979 data.

2. For *Release 1*, applied to 1854-1969 data; for R2.0, applied to 1784-1969 data; for R2.5, applied to 1662-1969 data.
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4. Rules for production of enhanced/standard IMMA/MSG

The Monthly Summary Group (MSG format) products are available back to 1800 using 2° latitude × 2° longitude boxes, and back to 1960 using 1°×1° boxes. Please refer to *R3.0-stat_doc* for a description of currently available statistics products and time periods of available products.

As introduced in Section 1, these MSG statistics are produce in two versions— "standard" (ship only; 3.5σ trimming) and "enhanced" (mixed platforms; 4.5σ trimming)— which were created by applying different quality control and data selection criteria, as documented in this section. Following is an overview of the rules used for creation of the enhanced and standard statistics:

a) Enhanced data: The 1950-79 trimming limits originally defined for *Release 1* were used, but expanded to 4.5σ for all trimmed variables. In addition, *SST* and *SLP* data from OSD drifting buoys were accepted in regions without trimming limits, provided the applicable OSD flag indicated that QC had been performed on that element. IATTC (tuna fishing fleet) wind data were excluded from enhanced statistics (due to

tendencies to seek out calm wind conditions for fishing activities), but *SST* and cloudiness data were included.

b) Standard data: The 1950-79 trimming limits were also used (for data before and after 1979), but at the original 3.5 sigma level used for Release 1 trimming. These statistics were limited as nearly as practical to ordinary ship data. Fishing fleet data (IATTC; *SID* = 70 or 71) were excluded from this set, as well as non-ship data that could be identified

Table 9 describes the specific rules used to filter data to create the enhanced (or standard) IMMA data, or the corresponding MSG monthly summaries. Tables 10 and 11 provide further details about the enhanced filtering, mainly relevant to how the IMMA reports are filtered to create enhanced data served either from NCAR or NCEI.

Table 9. QC flags and other IMMA fields used to prepare enhanced or standard data, such that data meeting the indicated criteria were not used. Tests were applied in the order listed, e.g., if an entire report was rejected, neither the report nor individual elements within it were further checked. Some field tests have been abbreviated, e.g., "*SZ-RZ*" indicates "SZ through RZ," and "*SF/PF*" indicates "*SF* or *PF*." [Note: Update for R3.0 of Tables 4a and 4b in http://icoads.noaa.gov/e-doc/stat_trim; greyed-out information no longer applies for R3.0 output data (i.e. was applied instead at IMMA translation), but has been carried forward for comparison with earlier procedures. For future Releases, consideration should be given to simplifying or replacing some of the special and other tests that are not presently flag-based (e.g. if still deemed appropriate, have tests implemented instead via source exclusion flag etc.).]

Enhanced IMMA Data and Monthly Summary Products:		
Report rejection:	Description of test	Field test
	a) Uncertain dups	*DUPS* > 2
	b) Landlocked*	(i) *LZ* = 1
		(ii) *ZNC* = M (only for MSG, and only applied ≥1950, since for earlier data M can also indicate hour missing)
Element rejection:		
	a) Source exclusion	*SZ-RZ* = 1
	b) NCDC-QC flags	*ZNC-TNC*: some flags are used selectively according to Table 5
	c) External QC flags	*ZE-RE = 1*
	d) Trimming flags	1 > *SF-RF* > 5 except *SF/PF* = 11 not rejected
	e) Special	*SID*=70/71 (IATTC tuna fishing data) wind data
Standard IMMA Data and Monthly Summary Products:		
Report rejection:	Description of test	Field test
	a) Uncertain dups	(same as Enhanced)
	b) Landlocked	(same as Enhanced)
	c) Non-ship data	not *PT* = 2/5 (1980-forward), except *PT* = missing accepted for deck 888 only;

				or *PT* > 5 and accept any *PT*=missing (pre-1980)
		d) Special		*SID*=70/71 (IATTC tuna fishing data)
Element rejection:				
		a) Source exclusion		(same as Enhanced)
		b) NCDC-QC flags		(same as Enhanced)
		~~c) External QC flags~~		~~(same as Enhanced)~~
		d) Trimming flags		1 > *SF-RF* > 3

* Reports with *LZ* = 1 (landlocked according to a 2° check) were deleted from the Final IMMA product, and also thereby from MSG. Reports which were landlocked according to the 1° NCDC-QC check, or otherwise suspect according to NCDC-QC, were retained in IMMA, but deleted from MSG. Thus a more stringent landlocked check was applied to MSG (at both 2° and 1° resolution) than to IMMA.
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Table 10. Selected *Core* IMMA1 (see Table C1 in *R3.0-imma1*) fields, cross-referenced against the trimming and other QC flags (see Table 1). If any of these flags are set as indicated in Table 9, the given field(s) is rejected from the enhanced (or standard) IMMA output data. [Note: Besides those listed, additional NCDC-QC element flags also remain unused (i.e., wave/swells, and cloud elements besides *N*; see Tables 1 and 5). As shown in this table ("–'), indicators associated with the primary fields are not eliminated in the IMMA1 enhanced data [note: this information remains to be confirmed as accurate for all ICOADS software/user interfaces filtering the data].

No.	*Len.*	*Abbr.*	*Element description*	*Trimming flags*	*NCDC-QC flags*	*Source excl. flags*
17	1	*DI*	wind dir. indic.	–	–	–
18	3	*D*	wind dir. (true)	*WF*	*WNC*	*WZ*
19	1	*WI*	wind speed indic.	–	–	–
20	3	*W*	wind speed	*WF*	*WNC*	*WZ*
21	1	*VI*	*VV* indic.		(*BNC* not used)	
22	2	*VV*	visibility		(*BNC* not used)	
23	2	*WW*	present weather		(*XNC* not used)	
24	1	*W1*	past weather		(*YNC* not used)	
25	5	*SLP*	sea level pressure	*PF*	*PNC*	*PZ*
26	1	*A*	characteristic of *PPP*		(*TNC* not used)	
27	3	*PPP*	amt. pressure tend.		(*TNC* not used)	
28	1	*IT*	indic. for temps.	–	–	–
29	4	*AT*	air temperature	*AF*	*ANC*	*AZ*
30	1	*WBTI*	*WBT* indic.	–	–	–
31	4	*WBT*	wet-bulb temp.	*RF*	*GNC*	*RZ*
32	1	*DPTI*	*DPT* indic.	–	–	–
33	4	*DPT*	dew-point temp.	*RF*	*DNC*	*RZ*
34	2	*SI*	*SST* meas. method	–	–	–
35	4	*SST*	sea surface temp.	*SF*	*SQ*	*SZ*
36	1	*N*	total cloud amount		(*CNC* not used)	

Table 11. Platform type (*PT*; the type of observing platform) field in IMMA, versus report utilization in Standard ("S") and Enhanced—or only in Enhanced ("E")—data and in monthly summary products, for R2.5 (left) compared to R3.0 (right). Data reported from some *PT*s are also subject to report rejections and individual data element exclusions based on source exclusion flags etc. (see Section 2) as indicated by "X."

PT	*Description*	*R2.5**	*R3.0***
0	US Navy or "deck" log, or unknown	S	S
1	merchant ship or foreign military	S	S
2	ocean station vessel—off station or station proximity unknown	S	S
3	ocean station vessel—on station	S	S
4	lightship	S	S
5	ship	S	S
6	moored buoy	E	E
7	drifting buoy	X	X
8	ice buoy [note: currently unused]	E	E
9	ice station (manned, including ships overwintering in ice)	E	E
10	oceanographic station data (bottle and low-resolution CTD/XCTD data)	E	E
11	mechanical/digital/micro bathythermograph (MBT)	E	E
12	expendable bathythermograph (XBT)	E	E
13	Coastal-Marine Automated Network (C-MAN) (NDBC operated)	X	X
14	other coastal/island station	E†	X
15	fixed ocean platform (plat, rig)	E	E
16	tide gauge	E††	X
17	high-resolution Conductivity-Temp.-Depth (CTD)/Expendable CTD (XCTD)	E	E
18	profiling float	E	E
19	undulating oceanographic recorder	E	E
20	autonomous pinneped bathythermograph	E	E
21	glider	E	E

* Also applicable for 2008-forward to the NCEP-based GTS preliminary NRT data and products.
** Also applicable for 2015-forward to the GTS blend (NCEP- & NCEI-based) preliminary NRT data and products.
† Applicable only to 6,205 R2.5 (deck 145) reports with *PT*=14.
†† Implemented, but did not apply to any R2.5 data since there were no reports with *PT*=16.
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References

Freeman, E., S.D. Woodruff, S.J. Worley, S.J. Lubker, E.C. Kent, W.E. Angel, D.I . Berry, P. Brohan, R. Eastman, L. Gates, W. Gloeden, Z. Ji, J. Lawrimore, N.A. Rayner, G. Rosenhagen, and S.R. Smith, 2016: ICOADS Release 3.0: A major update to the historical marine climate record. *Int. J. Climatol*. (doi:10.1002/joc.4775).

Slutz, R.J., S.J. Lubker, J.D. Hiscox, S.D. Woodruff, R.L. Jenne, D.H. Joseph, P.M. Steurer, and J.D. Elms, 1985: *Comprehensive Ocean-Atmosphere Data Set; Release 1*. NOAA Environmental Research Laboratories, Climate Research Program, Boulder, Colo., 268 pp. [Available online at http://icoads.noaa.gov/Release_1/coads.html].

Smith S.R., E. Freeman, S.J. Lubker, S.D. Woodruff, S.J. Worley, W.E. Angel, D.I. Berry, P. Brohan P, Z. Ji, E.C. Kent, et al., 2016: The International Maritime Meteorological Archive (IMMA) Format [http://icoads.noaa.gov/e-doc/imma/R3.0-imma1.pdf or an abbreviated version is available at: http://icoads.noaa.gov/e-doc/imma/R3.0-imma1_short.pdf].

Woodruff, S.D., S.J. Worley, S.J. Lubker, Z. Ji, J.E. Freeman, D.I. Berry, P. Brohan, E.C. Kent, R.W. Reynolds, S.R. Smith, and C. Wilkinson, 2011: ICOADS Release 2.5: Extensions and enhancements to the surface marine meteorological archive. *Int. J. Climatol*., **31**, 951-967 (doi:10.1002/joc.2103).

Appendix A

Table A1. As indicated in Table 1, the *QCE* (external) and *QCZ* (source exclusion) flags are each handled only as a single element by the {rwimma1} program, but each actually holds a set of flags, i.e., those stored in *QCE* are: *ZE*, *SE*, *AE*, *WE*, *PE*, *RE* (note: flag *RE*, presently unused, has been set aside for possible future use); and those in *QCZ* are: *SZ*, *AZ*, *WZ*, *PZ*, *RZ*. The individual flags are each stored effectively using a single bit (0=missing, or 1=reject data) as detailed in this table (which lists all the *QCE* flag combinations, while the shaded subset applies only to the smaller set of *QCZ* flags).*

n		SZ	AZ	WZ	PZ	RZ	n		SZ	AZ	WZ	PZ	RZ	n						
n	ZE	SE	AE	WE	PE	RE	n	ZE	SE	AE	WE	PE	RE	n	ZE	SE	AE	WE	PE	RE
1	0	0	0	0	0	1	22	0	1	0	1	1	0	43	1	0	1	0	1	1
2	0	0	0	0	1	0	23	0	1	0	1	1	1	44	1	0	1	1	0	0
3	0	0	0	0	1	1	24	0	1	1	0	0	0	45	1	0	1	1	0	1
4	0	0	0	1	0	0	25	0	1	1	0	0	1	46	1	0	1	1	1	0
5	0	0	0	1	0	1	26	0	1	1	0	1	0	47	1	0	1	1	1	1
6	0	0	0	1	1	0	27	0	1	1	0	1	1	48	1	1	0	0	0	0
7	0	0	0	1	1	1	28	0	1	1	1	0	0	49	1	1	0	0	0	1
8	0	0	1	0	0	0	29	0	1	1	1	0	1	50	1	1	0	0	1	0
9	0	0	1	0	0	1	30	0	1	1	1	1	0	51	1	1	0	0	1	1
10	0	0	1	0	1	0	31	0	1	1	1	1	1	52	1	1	0	1	0	0
11	0	0	1	0	1	1	32	1	0	0	0	0	0	53	1	1	0	1	0	1
12	0	0	1	1	0	0	33	1	0	0	0	0	1	54	1	1	0	1	1	0
13	0	0	1	1	0	1	34	1	0	0	0	1	0	55	1	1	0	1	1	1
14	0	0	1	1	1	0	35	1	0	0	0	1	1	56	1	1	1	0	0	0
15	0	0	1	1	1	1	36	1	0	0	1	0	0	57	1	1	1	0	0	1
16	0	1	0	0	0	0	37	1	0	0	1	0	1	58	1	1	1	0	1	0
17	0	1	0	0	0	1	38	1	0	0	1	1	0	59	1	1	1	0	1	1
18	0	1	0	0	1	0	39	1	0	0	1	1	1	60	1	1	1	1	0	0
19	0	1	0	0	1	1	40	1	0	1	0	0	0	61	1	1	1	1	0	1
20	0	1	0	1	0	0	41	1	0	1	0	0	1	62	1	1	1	1	1	0
21	0	1	0	1	0	1	42	1	0	1	0	1	0	63	1	1	1	1	1	1

* Specifically, only the lowest-order six bits in *QCE*, or the lowest-order five bits in *QCZ*, are set (note that the actual physical location depends on whether the computer storage architecture is little-endian versus big-endian), with the individual six/five flags set in order as listed above from left to right. Following are pseudo-Fortran codes (architecture independent, since the operations are handled using integer arithmetic), where *QCE* and *QCZ* are the integer values (*n* in the table above) made available from {rwimma1}, and MISS is the missing data value (blank in IMMA), to decode the individual flags stored within those elements:

```
IF (QCE.NE.MISS) THEN                    IF (QCZ.NE.MISS) THEN
    ZE=MOD(QCE/2/2/2/2/2,2)                  SZ=MOD(QCZ/2/2/2/2,2)
    SE=MOD(QCE/2/2/2/2,2)                    AZ=MOD(QCZ/2/2/2,2)
    AE=MOD(QCE/2/2/2,2)                      WZ=MOD(QCZ/2/2,2)
    WE=MOD(QCE/2/2,2)                        PZ=MOD(QCZ/2,2)
    PE=MOD(QCE/2,2)                          RZ=MOD(QCZ,2)
    RE=MOD(QCE,2)                        ENDIF
ENDIF
```

Note that software along these lines to decode *QCE*/*QCZ* is not yet implemented within {rwimma1}.

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