NATIONAL VERIFICATION PROGRAM

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1. Purpose. The chapter states policy for the National Weather Service (NWS) verification program (NVP). The NVP provides data to gage the accuracy, skill, and timeliness of NWS warnings, watches and forecasts. This provides a baseline to assist NWS managers in setting goals for measuring performance as mandated by the Government Performance and Results Act.

Verification data provide feedback to forecasters and managers and help identify training needs with the goal of continuous improvement of products and services. Verification scores shall not be used to establish criteria for rating the forecasting performance element.

2. Organizational Responsibilities. The operation and maintenance of national verification programs shall include compiling statistics on a quarterly basis and making them available via World Wide Web site, server or electronic mail. Quarterly reporting periods shall be adjusted for seasonal events, including hurricanes, winter storms and non-convective high winds.

2.1 Weather Service Headquarters (WSH).

2.1.1 Office of Meteorology (OM). The Customer Service Core (OM11) shall provide direction and manage the implementation of verification programs for weather, hydrologic and climate warnings and forecasts. These include severe weather, public weather, aviation weather, marine weather, fire weather, quantitative precipitation and river flooding.

In addition, OM11 manages the operation and maintenance of the national watch/warning verification program.

2.1.2 Office of Systems Development (OSD). The OSD Techniques Development Laboratory (TDL) shall support the public and aviation verification programs by: (1) providing data/information collection and collation software to operate at Weather Forecast Offices (WFOs); (2) collecting and archiving basic data transmitted from the WFOs to the National Oceanic and Atmospheric Administration (NOAA) Central Computer Facility

(NCCF) in Suitland, Maryland; (3) performing all data processing of national verification statistics; and (4) providing the documentation of the structure and application of the verification software.

2.1.3 Office of Hydrology (OH). OH shall oversee (1) the verification of hydrologic/hydrometeorologic products issued by River Forecast Centers (RFC) and (2) site-specific river flood warnings issued by the WFOs.

2.2 National Centers for Environmental Prediction (NCEP).

2.2.1 Environmental Modeling Center (EMC). EMC shall operate and maintain the national marine verification program (NMVP). EMC shall verify quantitative precipitation forecasts (QPF) from the operational numerical models.

2.2.2 Hydrometeorological Prediction Center (HPC). HPC shall verify their QPF guidance.

2.2.3 Marine Prediction Center (MPC). MPC shall prepare coded marine forecasts for verification of their offshore forecast areas.

2.2.4 Climate Prediction Center (CPC). CPC shall verify all 6-10 day and seasonal outlooks.

2.2.5 Aviation Weather Center (AWC). AWC shall verify all AIRMETs (airman’s meteorological information), SIGMETs (significant meteorological information), and convective SIGMETs over domestic airspace.

2.2.6 Storm Prediction Center (SPC). SPC shall verify all tornado and severe thunderstorm watches.

2.2.7 National Hurricane Center (NHC). The NHC shall verify their hurricane watches and warnings.

2.3 Field Offices With National Center Responsibility.

2.3.1 Alaska Aviation Weather Unit (AAWU)/WFO Anchorage. WFO Anchorage shall prepare coded marine forecasts for verification of their coastal and offshore forecast areas. AAWU shall verify their AIRMETs and SIGMETs.

2.3.2 Central Pacific Hurricane Center (CPHC)/WFO Honolulu. CPHC shall verify their hurricane watches and warnings. WFO Honolulu shall prepare coded marine forecasts for verification of their offshore forecast areas. WFO Honolulu shall verify their SIGMETs.

2.4 Regional Headquarters. Regional headquarters shall (1) assist WSH with the implementation of national verification programs; (2) help WFOs, RFCs, and Center Weather Service Units (CWSUs) interpret policy and procedures for data collection; and (3) use verification output to assist field offices in service improvement. With direction from OM, the regional headquarters are responsible for the implementation and proper use of verification software provided by WSH.

2.5 Weather Forecast Offices. WFOs are responsible for running software in support of national verification, preparing coded marine forecasts for verification, performing quality control of the verification database and preparing Storm Data reports.

2.6 River Forecast Centers. RFCs shall verify hydrologic/hydrometeorologic products, including (1) river forecasts at representative points within their areas of responsibility and (2) QPFs issued by the RFC Hydrometeorological Analysis and Support function and WFOs.

2.7 Center Weather Service Units. NWS is coordinating with the Federal Aviation Administration to develop a suite of CWSU products. The products shall be verified.

3. Verification Procedures. Details on verification procedures are given in Appendices A through F.

WFO PUBLIC AND AVIATION FORECAST VERIFICATION PROCEDURES

1. Introduction. The WFOs use a software package called the Advanced Weather Interactive Processing System (AWIPS) verification program (AVP). AVP is maintained by TDL and automates the data collection process for public and aviation forecasts and observations. The procedures in this appendix apply to products issued by WFOs through AWIPS.

2. Verification Sites. National verification is performed at selected sites called the national network. Table 1 contains the national network. Each WFO has at least one verification site in the national network. For continuity, additional sites from the Automation of Field Office Services (AFOS) era are also included, giving some WFOs more than one verification site. Since snowfall is no longer reported in the aviation routine weather reports (METAR), the snowfall verification sites are the WFOs which report snowfall in the supplementary climate data (SCD). When a WFO which reports snowfall is not co-located with a national network verification site, the WFO is used for just snowfall verification and no other elements.

3. Data Input. Public and aviation forecasts are verified twice a day. This equates to once every 0000 coordinated universal time (UTC) model run (defined as a forecast cycle) and once every 1200 UTC forecast cycle. If the integrated computer worded forecast (ICWF) is used to prepare the public forecast, no manual data entries are required of the WFO forecaster unless database corrections are necessary. The public forecast elements, given in section 7.1 of this appendix, are automatically decoded from the station digital forecast matrices (DFM) twice a day when the forecaster runs the CCF formatter. Conversely, if the ICWF is not used for public forecast issuance, the forecaster shall use the verification editor to enter all public forecast elements into the database for each verification site (including the snowfall site, if applicable) no later than 2 hours after forecast issuance. The verification editor contains a detailed help file. Aviation forecast data, which

Table 1. Public/Aviation Forecast Verification Sites.

Eastern Region		
WFO Ids	**WFOs**	**Verification sites***
KAKQ	Wakefield, VA	KORF
KALY	Albany, NY	KALB
KBGM	Binghamton, NY	KBGM/KSYR/KAVP
KBOX	Boston, MA	KBOS/KPVD
KBTV	Burlington, VA	KBTV
KBUF	Buffalo, NY	KBUF
KCAE	Columbia, SC	KCAE
KCAR	Caribou, ME	KCAR
KCHS	Charleston, SC	KCHS/KSAV
KCLE	Cleveland, OH	KCLE/KERI
KCTP	State College, PA	KMDT
KGSP	Greenville/ Spartanburg, SC	KGSP/KCLT
KGYX	Portland, ME	KPWM/KCON
KILM	Wilmington, NC	KILM
KILN	Cincinnati, OH	KCVG/KCMH
KLWX	Baltimore, MD/ Washington, DC	KDCA
KMHX	Morehead City, NC	KEWN
KOKX	New York City, NY	KLGA/KEWR
KPBZ	Pittsburgh, PA	KPIT
KPHI	Philadelphia, PA	KPHL
KRAH	Raleigh/Durham, NC	KRDU
KRLX	Charleston, WV	KCRW/KBKW
KRNK	Roanoke, VA	KROA

Southern Region		
WFO IDs	**WFOs**	**Verification sites***
KABQ	Albuquerque, NM	KABQ/KTCC
KAMA	Amarillo, TX	KAMA
KBMX	Birmingham, AL	KBHM
KBRO	Brownsville, TX	KBRO
KCRP	Corpus Christi, TX	KCRP
KEPZ	El Paso, TX	KELP
KEWX	Austin/ San Antonio, TX	KSAT
KEYW	Key West, FL	KEYW
KFFC	Atlanta, GA	KATL
KFWD	Fort Worth, TX	KDFW
KHGX	Houston/ Galveston, TX	KIAH
KJAN	Jackson, MS	KJAN/KMEI
KJAX	Jacksonville, FL	KJAX
KLCH	Lake Charles, LA	KLCH
KLIX	New Orleans/ Baton Rouge, LA	KMSY
KLUB	Lubbock, TX	KLBB
KLZK	Little Rock, AR	KLIT
KMAF	Midland/Odessa, TX	KMAF
KMEG	Memphis, TN	KMEM
KMFL	Miami, FL	KMIA
KMLB	Melbourne, FL	KMLB
KMOB	Mobile, AL	KMOB
KMRX	Knoxville, TN	KTYS
KOHX	Nashville, TN	KBNA
KOUN	Oklahoma City, OK	KOKC
KSHV	Shreveport, LA	KSHV
KSJT	San Angelo, TX	KSJT/KABI
KSJU	San Juan, PR	KSJU
KTAE	Tallahassee, FL	KTLH
KTBW	Tampa Bay Area, FL	KTPA
KTSA	Tulsa, OK	KTUL/KFSM

Central Region		
WFO Ids	**WFOs**	**Verification sites***
KABR	Aberdeen, SD	KABR
KAPX	Gaylord, MI	KAPN
KARX	La Crosse, WI	KLSE
KBIS	Bismarck, ND	KBIS
KBOU	Denver/Boulder, CO	KDEN
KCYS	Cheyenne, WY	KCYS
KDDC	Dodge City, KS	KDDC
KDLH	Duluth, MN	KDLH
KDMX	Des Moines, IA	KDSM/KALO
KDTX	Detroit, MI	KDTW
KDVN	Quad Cities, IA	KMLI
KEAX	Kansas City/ Pleasant Hill, MO	KMCI
KFGF	Grand Forks, ND	KFAR
KFSD	Sioux Falls, SD	KFSD
KGID	Hastings, NE	KGRI
KGJT	Grand Junction, CO	KGJT
KGLD	Goodland, KS	KGLD
KGRB	Green Bay, WI	KGRB
KGRR	Grand Rapids, MI	KGRR
KICT	Wichita, KS	KICT
KILX	Lincoln, IL	KSPI
KIND	Indianapolis, IN	KIND
KIWX	North Webster, IN	KSBN
KJKL	Jackson, KY	KLOZ
KLBF	North Platte, NE	KLBF
KLMK	Louisville, KY	KSDF/KLEX
KLOT	Chicago, IL	KORD
KLSX	St. Louis, MO	KSTL
KMKX	Milwaukee, WI	KMKE/KMSN
KMPX	Minneapolis, MN	KMSP
KMQT	Marquette, MI	KSAW/KMQT**
KOAX	Omaha, NE	KOMA
KPAH	Paducah, KY	KPAH
KPUB	Pueblo, CO	KPUB

Central Region, continued		
WFO Ids	**WFOs**	**Verification sites***
KRIW	Riverton, WY	KRIW/KCPR
KSGF	Springfield, MO	KSGF
KTOP	Topeka, KS	KTOP
KUNR	Rapid City, SD	KRAP

Western Region		
WFO Ids	**WFOs**	**Verification sites***
KBOI	Boise, ID	KBOI
KBYZ	Billings, MT	KBIL
KEKA	Eureka, CA	KACV
KFGZ	Flagstaff, AZ	KFLG
KGGW	Glasgow, MT	KGGW
KHNX	San Joaquin Valley, CA	KFAT
KLKN	Elko, NV	KEKO
KLOX	Los Angeles, CA	KLAX/KCQT***
KMFR	Medford, OR	KMFR
KMSO	Missoula, MT	KMSO
KMTR	San Francisco Bay Area, CA	KSFO
KOTX	Spokane, WA	KGEG
KPDT	Pendleton, OR	KPDT
KPIH	Pocatello, ID	KPIH
KPQR	Portland, OR	KPDX
KPSR	Phoenix, AZ	KPHX
KREV	Reno, NV	KRNO
KSEW	Seattle/Tacoma, WA	KSEA
KSGX	San Diego, CA	KSAN
KSLC	Salt Lake City, UT	KSLC/KCDC
KSTO	Sacramento, CA	KSAC
KTFX	Great Falls, MT	KGTF
KTWC	Tucson, AZ	KTUS
KVEF	Las Vegas, NV	KLAS

Alaska and Pacific Regions		
WFO Ids	**WFOs**	**Verification sites***
PAFC	Anchorage, AK	PANC/PABE
PAFG	Fairbanks, AK	PAFA/PAOM
PAJK	Juneau, AK	PAJN/PAYA
PHFO	Honolulu, HI	PHNL
PGUM	Guam	PGUM

* Verification sites for all public and aviation elements except snowfall are listed. The snowfall verification sites are the WFOs which report snowfall in the Supplementary Climate Data.

** KSAW is used for aviation elements, and KMQT is used for public elements.

*** KLAX is used for aviation elements, and KCQT is used for public elements.

include the ceiling height, visibility, wind direction and wind speed, are automatically decoded from the 0600 and 1800 UTC terminal aerodrome forecasts (TAF).

When available, nested grid model (NGM) model output statistics (MOS) guidance elements (public and aviation) are automatically entered into the verification database. All verifying data taken from the METARs, Aviation Selected Special Weather Reports (SPECI), and SCDs are automatically entered into the verification database.

All data in the verification database may be viewed through the verification editor. The verification editor is also used for manually editing any elements in the verification database. Further details concerning the setup and running of the verification software at the WFO are given in Lufkin and Morris (1998) or subsequent AWIPS verification user manuals.

4. Quality Control. WFOs shall monitor the verification database through the AWIPS verification editor and enter any missing or incorrect values. Missing guidance values shall only be entered when the forecaster receives the guidance early enough for forecast preparation.

5. Data Transmission to the NCCF. Approximately 5 days after the start of a forecast cycle, all national network verification data for that cycle are automatically transmitted to the NCCF. Local site data are not transmitted to the NCCF but are retained in the WFO database.

6. Public/Aviation Verification Reports.

6.1 National Results. TDL computes verification scores quarterly for each verification point in the national network. A summary of verification scores is provided in Appendix G. The application of verification scores to individual forecast elements is discussed in Dagostaro (1985). Separate scores are computed for the cool (October through March) and warm (April through September) seasons. To enhance feedback, verification scores are also computed for the first 3 months of each cool and

warm season. Three- and 6-month score summaries may be accessed from the Office of Systems Operations (OSO) server with software managed and maintained by each regional headquarters. The data are organized by individual WFO, NWS region, and the entire Nation.

Periodically, OM11 computes and disseminates results from the national verification database focusing upon a particular scientific, management, or training issue. In particular, verification data help assess NWS capabilities in forecasting certain significant weather events.

6.2 Regional Results. The regional headquarters have the option to further process the national summaries described in section 6.1 of this appendix or request local summaries from the field offices.

7. Elements.

7.1 Public Elements. Projections for public elements are defined as the number of verifying hours elapsed since 0000 UTC for the early morning forecast and 1200 UTC for the late afternoon forecast.

If the ICWF is not used to issue the forecast, the public elements of the local forecast shall be entered manually through the verification editor. The verification editor contains a detailed help file.

7.1.1 Max/Min Temperatures.

Forecasts: Daytime maximum (max) and nighttime minimum (min) temperatures are forecast in whole degrees Fahrenheit. Daytime is defined as 7 a.m. to 7 p.m. Local Standard Time (LST). Nighttime is defined as 7 p.m. to 8 a.m. LST.

Projections: (approximate)

- 1st period (12-24 hours)
- 2nd period (24-36 hours)
- 3rd period (36-48 hours)
- 4th period (48-60 hours)

Observations: Daytime max and nighttime min temperatures are inferred from the METARs. An algorithm, described in Beasley (1995), uses the 6-hour max/min temperatures (1xxxx and 2xxxx groups) and hourly temperature readings to derive a daytime max and nighttime min.

7.1.2 Probability of Precipitation (PoP). Probability of 0.01 inch or greater liquid equivalent precipitation within a 12-hour period.

Forecasts: 12-hour PoPs are evaluated using the following percentages: {0, 10, 20, ..., 80, 90, 100}.

Projections:

- 1st period (12-24 hours)
- 2nd period (24-36 hours)
- 3rd period (36-48 hours)

Observations: From METAR, 12-hour precipitation amounts to the nearest hundredth of an inch are recorded.

7.1.3 Precipitation Type. Precipitation type is only verified September through May.

Forecasts: Entered by category, where:

1 = freezing precipitation (freezing drizzle and freezing rain).

2 = frozen precipitation (snow, snow grains, hail, ice pellets and ice crystals).

3 = liquid precipitation (drizzle and rain).

If the local forecaster expects mixed precipitation, the most critical element is entered. The order of priority for “most critical” is freezing, frozen and liquid. Thus, if freezing rain and snow are expected, a "1" is entered. MOS precipitation type is a single category.

Projections: 18, 30, and 42 hours.

Observations: From METARs and SPECIs, all precipitation types on the verification hour and within the period ± 1 hour of the verifying hour are recorded. Questionable observations are flagged at WSH by a quality control program and removed from the national computation sample. Table 2 gives a list of verification sites which have observations of freezing drizzle, freezing rain and ice pellets augmented by human observers.

For observations taken solely by ASOS, mixed states (e.g., mixed rain and snow) are often reported as snow. Ice pellets and snow pellets are often reported as rain. “Unknown precipitation” is reported when the precipitation is too light for ASOS to distinguish the type, usually at the onset of very light precipitation.

When computing national verification statistics for precipitation type, the most critical forecast precipitation type is compared to the most critical observed precipitation type within the period ±1 hour of the verifying hour.

7.1.4 Cloud Amount.

Forecasts: From the station DFM and MOS, each forecast at each verifying hour is recorded as a category:

- Clear (CLR), no sky coverage
- Scattered (SCT), greater than 0/8 to 4/8 sky coverage
- Broken (BKN), 5/8 to 7/8 sky coverage
- Overcast (OVC), Vertical Visibility (VV)

Table 2. Verification sites for which observations of freezing drizzle, freezing rain and ice pellets are augmented by human observers.

Eastern Region			
KALB	KCHS/KSAV	KDCA	KRDU
KBOS/KPVD	KCLE	KLGA/KEWR	KROA
KBTV	KCLT	KORF	KSYR
KBUF	KCRW	KPHL	
KCAE	KCVG/KCMH	KPIT	

Southern Region			
KABQ	KELP	KMEM	KTLH
KATL	KIAH	KMOB	KTUL
KBHM	KJAN	KMSY	KTYS
KBNA	KJAX	KOKC	
KCRP	KLBB	KSAT	
KDFW	KLIT	KSHV	

Central Region			
KDEN	KICT	KMSP	KSGF
KDLH	KIND	KOMA	KSTL
KDSM	KMCI	KORD	
KDTW	KMKE/KMSN	KSBN	
KGRR	KMQT	KSDF	

Western Region	
KBIL	KRNO
KGEG	KSEA
KPDX	KSLC
KPHX	

Alaska Region
PAFA/PAOM
PAJN/PAYA
PANC/PABE

Pacific Region
None

Projections: 12, 18, and 24 hours.

Observations: From METAR, the cloud amount at each verifying hour is recorded as a category. The METAR category “FEW” (defined as greater than 0/8 to 2/8 sky coverage) is defined as “SCT” for verification. ASOS only reports clouds below 12,000 feet above ground level (AGL). Table 3 gives a list of verification sites which have observations of clouds above 12,000 feet augmented by human observers. For verification sites not listed in Table 3, cloud observations are complemented with information from the Geostationary Operational Environmental Satellite (GOES) cloud product (Kluepfel et al., 1994) at WSH for national score generation.

7.1.5 Snowfall Amount. Snowfall is only verified September through May. Since snowfall is no longer reported in the METAR, the snowfall verification sites are the WFOs which report snowfall in the SCD.

Forecasts: From the station DFM and MOS, each forecast is recorded as a category:

- No snow
- Trace to less than 2 inches
- 2 to less than 4 inches
- 4 to less than 6 inches
- 6 or more inches

Projection: 1st period (12-24 hours).

Observations: Snowfall amounts are taken from the SCD and recorded as integers. For amounts above 1 inch, the decimal value is truncated (e.g., 2.7 inches is recorded as “2”). For values ranging from 0.1 to 0.9 inch, the snowfall is recorded as “1.”

Table 3. Verification sites for which observations of clouds above 12,000 feet are augmented by human observers.

Eastern Region			
KALB	KCLT	KLGA/KEWR	KSYR
KBOS/KPVD	KCRW	KPHL	
KBUF	KCVG/KCMH	KPIT	
KCLE	KDCA	KRDU	

Southern Region			
KABQ	KIAH	KMSY	KTPA
KATL	KJAX	KOKC	KTUL
KBNA	KMEM	KSAT	KTYS
KDFW	KMIA	KTLH	

Central Region			
KDEN	KICT	KMQT	KSTL
KDSM	KIND	KMSP	
KDTW	KMCI	KORD	
KGRR	KMKE	KSDF	

Western Region		
KFAT	KPDX	KSEA
KGEG	KPHX	KSFO
KLAS	KRNO	KSLC
KLAX	KSAN	

Alaska Region
PAFA/PAOM
PAJN/PAYA
PANC/PABE

Pacific Region
None

7.1.6 Wind Speed.

Forecasts: From the Station DFM and MOS, the wind speed at the verifying hour is recorded to the nearest knot. Forecasts are evaluated in two categories——less than 22 knots and 22 knots or greater.

Projection: 42 hours.

Observations: From METARs and SPECIs, the wind speed at the verifying hour is recorded in knots. The highest sustained speed within the period ±3 hours of the verifying hour is also recorded.

7.2 Aviation Elements. Regularly scheduled TAFs beginning at 0600 and 1800 UTC are verified. Projection times for aviation elements are defined as the number of hours elapsed since the initial valid time of the TAF. The verification software evaluates the prevailing portion of the TAF and does not recognize TEMPO groups, PROB groups, or amended forecasts.

7.2.1 Ceiling Height.

Forecasts: The TAF ceiling height at each verifying hour is recorded in hundreds of feet AGL. Also, the following are recorded:

- Unlimited ceiling
- Ceiling above 9000 feet

The MOS forecast at the verifying hour is taken from the 0000 and 1200 UTC cycles and recorded as a category:

- Less than 200 feet AGL
- 200 to 400 feet AGL
- 500 to 900 feet AGL
- 1000 to 3000 feet AGL
- 3500 to 6000 feet AGL
- 7000 to 12,000 feet AGL
- Greater than 12,000 feet AGL

Projections: 3, 6, 9, and 15 hours.

Observations: From METAR, ceiling height at each verifying hour is recorded in hundreds of feet AGL. For ASOS observations with no augmented clouds above 12,000 feet: (1) unlimited ceiling implies no ceiling below 12,000 feet, and (2) ceiling above 9000 feet implies a ceiling above 9000 feet, up to and including 12,000 feet.

7.2.2 Visibility.

Forecasts: The TAF visibility at each verifying hour is recorded in miles and fractions thereof. The MOS forecast at each verifying hour is recorded as a category:

- Less than 0.5 mile
- 0.5 through 0.875 mile
- 1 through 2.75 miles
- 3 through 5 miles
- 6 or more miles

Projections: 3, 6, 9, and 15 hours.

Observations: From METAR, the visibility at each verifying hour is recorded in miles and fractions thereof. Visibilities above 7 miles are recorded as “8.”

7.2.3 Wind Direction and Speed.

Forecasts: From the TAFs and MOS at each verifying hour, the wind direction is recorded to the nearest ten degrees relative to true north and the sustained wind speed is recorded to the nearest knot.

Projections: 3, 9, and 15 hours.

Observations: From METARs and SPECIs, the wind direction and sustained speed at each verifying hour are recorded (same units as forecasts).

WATCH/WARNING VERIFICATION PROCEDURES

1. Introduction. The severe weather verification database managed by OM is comprised of events and warnings for tornadoes, severe thunderstorms, and flash floods. The warnings are collected and parsed at WSH, and event data are extracted from the Storm Data reports prepared by the WFOs using the personal computer program "StormDat." The information is used by OM to generate statistics for warnings issued by the WFOs.

For the contiguous United States (CONUS), the SPC maintains a database of tornado and severe thunderstorm watches they issue. Tornado and severe thunderstorm event data provided by OM are used by the SPC to generate verification statistics for the tornado and severe thunderstorm watches.

Winter storm and high wind warning and event data are collected at each WFO and forwarded to their regional headquarters. Each region provides WSH with separate statistical summaries for winter storm and high wind warnings and events.

2. Matching Warnings and Events. This section defines the methods for matching specific types of warnings and events in the severe weather database. The matching process determines whether or not a warning is verified and the warning lead time associated with each event.

2.1 Tornado and Severe Thunderstorm. The basic area for a tornado or severe thunderstorm warning is a county. Tornado and severe thunderstorm warnings are verified by any representative event meeting the appropriate Weather Service Operations Manual (WSOM) warning criteria and occurring within the valid time and area of the warning. Since each county specified in a warning represents a separate verification area, a warning covering three counties is counted as three "warned areas." At least one severe event occurring during the valid period of a warning in a warned county produces a "verified warning."

For verification purposes, severe thunderstorm wind and hail events separated by less than 10 miles or 15 minutes are

considered duplicates. Exceptions to this rule are reports of winds 65 knots or greater and hail size 2 inches or greater. Also, an event is not considered a duplicate if it is the only event verifying a warning. Events considered duplicates for verification purposes still appear in the publication Storm Data.

Statistics are computed for tornado and severe thunderstorm warnings and events by two methods. For the first method, all tornado and severe thunderstorm data are treated as a generic severe local storm. This means any tornado or severe thunderstorm warning may be verified by either a tornado or severe thunderstorm event. To verify, a warning must be issued prior to the ending time of the event. Likewise, any tornado or severe thunderstorm event may be covered by either a tornado or severe thunderstorm warning. To count as a hit, the event must occur during the valid time period of the warning and in the warning area. The second method only considers tornado warnings and events. A confirmed tornado is required to verify a tornado warning. Likewise, a tornado event must be covered by a tornado warning.

The computation of lead time for a tornado affecting a single county is based on the time the tornado is reported to touch down in the county. A tornado moving into a second county creates an additional tornado event. The lead time for the second tornado event is based on the time the tornado entered the second county. The process is similar for severe thunderstorm events. If an event occurs over a period of time, and a warning was issued after the initial onset of the event but prior to the end of the event, the lead time is zero. Any event occurring outside the valid time period or area covered by a warning counts as a missed event and is assigned a lead time of zero.

2.2 Winter Storm and High Wind. For winter storm, heavy snow, lake effect snow, blizzard, ice storm, and high wind warnings, each zone represents a separate verification area. Zones are defined in WSOM Chapter C-11. For verification purposes, winter storm, heavy snow, blizzard and ice storm warnings are treated generically as winter storms. This means any of these warnings may be verified by heavy snow, a blizzard

or an ice storm. Likewise, any heavy snow, blizzard or ice storm event may be covered by a winter storm, heavy snow or ice storm warning.

Warnings are often extended in time and/or area. Extensions of warnings to new areas are counted as new warnings. Extensions in time for any of the zones in the initial warning will not be verified as a separate warning.

The computation of lead time for winter storm and high wind events is based on when an event is first reported in a zone. The term “event” is defined as weather conditions meeting or exceeding the region-defined criteria for winter storm or high wind warnings (e.g., 4 inches of snow). If a warning is issued during the 2-hour period immediately following the time warning criteria are first met but prior to the end of the event, the warning is verified and the lead time for the event is zero. If a warning is issued more than 2 hours after the time warning criteria are first met but prior to the end of the event, the result is one missed event with zero lead time and one verified warning. Events with no warning at all are assigned a lead time of zero.

2.3 Flash Flood. Flash flood warning procedures are given in Appendix F.

3. Matching Watches and Events. The procedures given in this section explain how specific types of watches and events in the severe weather database are matched to determine whether or not a watch is verified and the lead time for each event.

3.1 Tornado and Severe Thunderstorm. For the CONUS, tornado and severe thunderstorm watches are verified by the SPC. The area defined by a severe thunderstorm or tornado watch is defined as the verification area without regard to the number of counties affected. Weiss et al. (1980) give a description of how SPC accounts for variations in the size of convective watch areas. Similar to warnings (see section 2.1 of this appendix), statistics are stratified for tornado and severe thunderstorm watches combined and for tornado watches only.

QPF VERIFICATION PROCEDURES

Details on QPF verification at EMC and HPC are provided in section 11.2.1 of NWS (1999a).

A national QPF verification program is under development and is described in section 11.3 of NWS (1999a). A subset of the national program was implemented in support of the QPF Process Assessment Team and is documented in NWS (1999b). Currently, QPF verification at WFOs and RFCs are defined by each regional headquarters.

MARINE FORECAST VERIFICATION PROCEDURES

The MPC and the WFOs shall send coded marine verification forecasts (MVF) twice a day for each verification site in their individual forecast areas. The format for coding an MVF is given in Table 4. Any functioning buoy or C-MAN residing within the forecast area of a WFO or MPC shall be used as a verification site. Any buoy or C-MAN which becomes inactive (i.e., no data available for verification) should be removed from the MVF. The MVFs shall be consistent with the coastal or offshore forecasts and may be sent up to 2 hours after forecast issuance time. Table 5 gives a sample coastal forecast with the corresponding MVF. Table 6 contains the list of national marine verification sites.

EMC archives marine forecast/observation data at the NCCF in Suitland, Maryland, and computes quarterly verification scores, which are posted to the National Marine Verification Program Home Page:

http://polar.wwb.noaa.gov/omb/papers/nmvp/

Verification statistics are computed for warning category, wind direction, wind speed and significant wave height. These statistics are based on a series of 5 hourly buoy or C-MAN observations within the period ±2 hours of the 18- and 30-hour verification times (i.e., 18 and 30 hours since the 0000 or 1200 UTC model initialization). A summary of each element follows.

1. Advisories and Warnings. Advisories and warnings are verified against the highest of 5 hourly speed observations. The wind speed threshold is adjusted by 2 knots due to sensor accuracy.

- The lower threshold defining small craft advisories (SCA) is set locally or regionally, and these values are programmed into the marine verification software. Either the observed lower wave height threshold for an SCA or the observed lower wind threshold for an SCA minus 2 knots verifies the advisory. A 35-knot

observed wind is the upper threshold for verifying an SCA.

- A 32- to 49-knot wind verifies a gale warning.
- A 32- to 65-knot wind verifies a tropical storm warning.
- A wind exceeding 45 knots verifies a storm warning.
- A wind exceeding 61 knots verifies a hurricane warning. In Alaska Region, a wind exceeding 61 knots also verifies a warning for hurricane force winds in the absence of a hurricane.

Note it is possible for the verification forecast to include an advisory/warning category along with a wind speed less than the lower threshold (adjusted for the 2-knot sensor error). This is because the advisory/warning is verified against the highest of the 5 hourly wind speed observations whereas the forecast wind speed is verified against the average of the 5 hourly wind speed observations. An example would be expected increasing/decreasing winds during the 2-hour verification period warranting indication of an advisory/warning, yet the average wind speed is expected to be below threshold.

The advisory/warning status forecast in the MVF should reflect the worst conditions expected at the time the forecast is verified ±2 hours. For example, if a gale warning is issued due to winds increasing to above gale warning criteria in the second 12-hour forecast period (no advisory/warning criteria are expected in the first 12-hour period), the MVF should indicate “NO” advisory/warning at the 18-hour projection (first period) and “GL” at the 30-hour projection (second period).

2. Wind Speed. The coded forecast to the nearest knot at the verifying hour is verified against an average of the 5 hourly wind speed observations centered on the verifying hour.

3. Wind Direction. The coded forecast is stated to the nearest 10 degrees of the compass. The verifying observation is the vector resultant of the 5 hourly wind direction observations centered on the verifying hour. These five winds are converted to x- and y-components, averaged and converted to a wind direction. Forecasts and verifying observations are converted to categories (i.e., 8 points of the compass).

4. Wave Height. The coded forecast to the nearest foot at the verifying hour is verified against the average of the five significant wave height observations centered on the verifying hour.

5. Further Details. Further details on methodology are provided in Burroughs (1993), and software documentation appears in Burroughs and Nichols (1993).

Table 4. Explanation of code used for point verification forecasts in the MVF.

CODE FORMAT *%%F nn(space)xxxxx(space)*t_1t_1*/WW/ddff/*hh/t_2t_2/WW/ddff*/hh [LF][LF]$$*	
%%F	Code for NCEP computer and delimiter for operational forecast
nn	Forecaster number. Note: comparative verification will NOT be used as an individual performance measure. However, once statistics become available, individuals should review them for self-improvement and knowledge.
xxxxx	Buoy/C-MAN identifier
t_1t_1	Verification time 18 hours from NCEP model initialization (18 UTC today for 0000 UTC cycle today; 06 UTC tomorrow for 1200 UTC cycle today).
WW	Warning status NO: No advisory or warning SC: Small Craft Advisory (Coastal Marine Forecast only) GL: Gale Warning ST: Storm Warning TS: Tropical Storm Warning HR: Hurricane Warning HF: In Alaska Region, warning for Hurricane Force winds in the absence of a hurricane.
dd	Wind direction in tens of degrees. If wind direction is less than 100 degrees, place a zero in the tens digit, *e.g.,* 07. When wind speed equals 100 knots or more, add 50 to wind direction, *e.g.,* 57. Code 99 if wind is forecast to be variable based on regional guidelines.
ff	Wind speed to nearest knot, not to nearest 5 knots as expressed in the area forecast. If wind speed is less than 10 knots, place a zero in the tens digit place, e.g., 06. For 100 knots or more, subtract 100, *e.g.,* 110 knots entered as 10 and add 50 to *dd*.
hh	Significant wave height (combined wind waves and swell). If less than 10 feet, place a zero in the tens digit, e.g., 08.
t_2t_2	Verification time 30 hours from NCEP model initialization (06 UTC tomorrow for 0000 UTC cycle today; 18 UTC tomorrow for 1200 UTC cycle today).
[LF][LF]$$	End bulletin code (2 line feeds followed by turn off code)

Table 5. Examples of marine products.

Example of Coastal Waters Forecast:

```
FZUS56 KMTR 011030
CWFEKA

COASTAL MARINE FORECAST
NATIONAL WEATHER SERVICE EUREKA CA
230 AM PST FRI JAN 1 1999

POINT ST GEORGE TO POINT PIEDRAS BLANCAS AND OUT 60 NM
INCLUDING THE SAN FRANCISCO BAY AREA AND MONTEREY BAY

.SYNOPSIS...(Text)

PZZ450-011630-
POINT ST. GEORGE TO CAPE MENDOCINO OUT TO 20 NM
230 AM PST WED JAN 1 1999

...GALE WARNING...

.TODAY...NORTHWEST WINDS 40 KTS. SEAS 15 FT.
.TONIGHT...WINDS BECOMING NORTH DECREASING TO 25 KTS. SEAS
LOWERING TO 5 FT.
.THURSDAY...NORTH WINDS DECREASING TO 15 KTS. SEAS 5 FT.
```

Example of Corresponding Coded MVF (see table 6 for complete list of verification sites):

```
FXUS56 KEKA 011030
MVF002

%%F56 46014 18/GL/3235/15/06/SC/3620/05
%%F56 46022 18/GL/3238/15/06/SC/3623/05
```

Note: SC (Small Craft Advisory) is indicated in the coded forecast for the second verification period based on the wind speed exceeding the small craft threshold even though the corresponding coastal marine forecast has no “small craft advisory” header.

Table 6. National Marine Verification Sites. Forecast areas are designated by C (coastal) or O (offshore). Only coastal forecasts require small craft advisory as a warning category.

Region	WFO or National Center	Point Identifier	Latitude	Longitude	Forecast Area
Eastern	Caribou, ME (CAR)	MDRM1	44.0 N	68.1 W	C
	Portland, ME (GYX)	MISM1	43.8 N	68.9 W	C
		44007	43.5 N	70.1 W	C
	Boston, MA (BOX)	44013	42.4 N	70.7 W	C
		BUZM3	41.4 N	71.0 W	C
	New York City, NY (OKX)	ALSN6	40.5 N	73.8 W	C
		44025	40.3 N	73.2 W	C
	Philadelphia, PA (PHI)	44009	38.5 N	74.7 W	C
	Wakefield, VA (AKQ)	CHLV2	36.9 N	75.7 W	C
		44014	36.6 N	74.8 W	C
		DUCN7	36.2 N	75.8 W	C
	Morehead City, NC (MHX)	DUCN7	36.2 N	75.8 W	C
		DSLN7	35.2 N	75.3 W	C
		CLKN7	34.6 N	76.5 W	C
	Wilmington, NC (ILM)	FPSN7	33.5 N	77.6 W	C
	Charleston, SC (CHS)	41004	32.5 N	79.1 W	C
		FBIS1	32.7 N	79.9 W	C
		41008	31.4 N	80.9 W	C

Region	WFO or National Center	Point Identifier	Latitude	Longitude	Forecast Area
Southern	Jacksonville, FL (JAX)	SAUF1	29.9 N	81.3 W	C
	Melbourne, FL (MLB)	41009	28.5 N	80.2 W	C
	Miami, FL (MFL)	FWYF1	25.6 N	80.1 W	C
	Key West, FL (EYW)	MLRF1	25.0 N	80.4 W	C
		LONF1	24.8 N	80.9 W	C
		SMKF1	24.6 N	81.1 W	C
		SANF1	24.5 N	81.9 W	C
		DRYF1	24.6 N	82.7 W	C
	Tampa Bay Area, FL (TBW)	VENF1	27.1 N	82.5 W	C
		42036	28.5 N	84.5 W	C
	Tallahassee, FL (TAE)	42039	28.8 N	86.0 W	C
		CSBF1	29.7 N	85.4 W	C
		KTNF1	29.8 W	83.6 W	C
	Mobile, AL (MOB)	DPIA1	30.3 N	88.1 W	C
		42040	29.2 N	88.3 W	C
		42039	28.8 N	86.0 W	C
	New Orleans/ Baton Rouge, LA (LIX)	42007	30.1 N	88.8 W	C
		BURL1	28.9 N	89.4 W	C
		GDIL1	29.3 N	90.0 W	C
	Lake Charles, LA (LCH)	SRST2	29.7 N	94.1 W	C
		42035	29.3 N	94.4 W	C
	Houston/Galveston, TX (HGX)	42035	29.3 N	94.4 W	C
	Corpus Christi, TX (CRP)	42019	27.9 N	95.4 W	C
	Brownsville, TX (BRO)	42020	26.9 N	96.7 W	C

Region	WFO or National Center	Point Identifier	Latitude	Longitude	Forecast Area
Western	Los Angeles, CA (LOX)	46025	33.8 N	119.1 W	C
		46054	34.3 N	120.5 W	C
		46011	34.9 N	120.9 W	C
	San Francisco, CA (MTR)	46042	36.8 N	122.4 W	C
		46012	37.4 N	122.7 W	C
		46026	37.8 N	122.8 W	C
		46013	38.2 N	123.3 W	C
	Eureka, CA (EKA)	46014	39.2 N	124.0 W	C
		46022	40.7 N	124.5 W	C
		PTAC1	39.0 N	123.7 W	C
		46030	40.4 N	124.5 W	C
	Medford, OR (MFR)	46027	41.9 N	124.4 W	C
		CARO3	43.3 N	124.4 W	C
	Portland, OR (PQR)	NWPO3	44.6 N	124.1 W	C
		46050	44.6 N	124.5 W	C
		46029	46.1 N	124.5 W	C
	Seattle, WA (SEW)	46041	47.4 N	124.5 W	C
		WPOW1	47.7 N	122.4 W	C
		SISW1	48.3 N	122.8 W	C
		TTIW1	48.4 N	124.7 W	C
		DESW1	47.7 N	124.5 W	C
Alaska	Juneau, AK (PAJK)	FFIA2	57.3 N	133.6 W	C
	Anchorage, AK (PAFC)	46001	56.3 N	148.2 W	O
		46061	60.2 N	146.8 W	C
		46060	60.6 N	146.8 W	C
		POTA2	61.06 N	146.70 W	C
		MRKA2	61.08 N	146.66 W	C
		BLIA1	60.8 N	146.9 W	C
		46035	56.9 N	177.8 W	O

Region	WFO or National Center	Point Identifier	Latitude	Longitude	Forecast Area
Pacific	Honolulu, HI (PHFO)	51001	23.4 N	162.3 W	O
		51002	17.2 N	157.8 W	O
		51003	19.1 N	160.8 W	O
		51004	17.4 N	152.5 W	O
NCEP Marine Prediction Center (MPC)		44005	42.9 N	68.9 W	O
		44011	41.1 N	66.6 W	O
		44008	40.5 N	69.4 W	O
		44004	38.5 N	70.7 W	O
		41001	34.7 N	72.6 W	O
		41002	32.3 N	75.2 W	O
		46059	38.0 N	130.0 W	O
		46002	42.5 N	130.3 W	O
		46005	46.1 N	131.0 W	O
NCEP Tropical Prediction Center (TPC)		41010	28.9 N	78.6 W	O
		42001	25.9 N	89.7 W	O
		42002	25.9 N	93.6 W	O
		42003	25.9 N	85.9 W	O

FIRE WEATHER FORECAST VERIFICATION PROCEDURES

There is no central data collection and verification score computation system for fire weather forecasts. Until such a system is developed, OM will work with the regions to ensure each office with fire weather responsibility maintains a local fire weather verification program.

Fire weather forecast products are produced in support of the Forest Service National Fire Danger Rating (NFDR) System. Forecast elements from the fire weather forecasts are processed by the Forest Service central computer, the Weather Information Management System (WIMS), to produce a daily NFDR outlook. Observational data are provided by the Forest Service via WIMS and by other land management agencies.

The forecast area of responsibility of WFOs for fire weather forecasts may differ from the normal areas covered by other forecast programs. A WFO may be designated as a “hub” for purposes of fire weather forecasting. WFO hubs may be responsible for both their normal area of responsibility as well as all or parts of the areas of responsibility of one or more surrounding WFOs. Accordingly, not all WFOs in regions covered by fire weather forecasts will produce fire weather forecasts.

Those elements best suited to a viable verification program are:

- Temperature
- Relative humidity
- Wind speed.

Fire weather forecast locations consist of individual fire weather zones, with the zones usually defined as areas of homogeneous terrain and/or vegetation types. However, fire weather forecasts are verified on a point-by-point basis at individual observation sites (i.e., Forest Service ranger stations) where verifying observations are taken. Forecasts may be issued for specific stations in the zones or as a trend for the entire zone. Forecast element values are normally expressed in terms of forecast trend. Trend forecast values are computed

as the difference of the actual forecast values minus the previous observed value of the element.

Verification scores applicable to fire weather forecasts include mean absolute error of the individual elements, biases, and percent correct based on an established range of forecast error.

HYDROLOGIC VERIFICATION PROCEDURES

WFOs provide information used in the verification of flash flood warnings and also perform verification of locally-issued hydrologic forecast products according to office and regional guidelines. RFCs provide information used in the verification of hydrologic forecasts and also conduct verification activities for other products such as water supply forecasts according to local office and regional guidelines.

1. Flash Flood Warnings. WFOs shall support verification of flash flood warnings through submission of reports on flash flooding to the Storm Data publication. The flash flood warnings to be verified are county based and issued under the product category “FFW.” At the discretion of the WFO forecaster, the terms “flash flood warning” or “flood warning” are used in the mass media header of an FFW product. Flood warnings issued under the FFW category should not be confused with flood warnings issued under the FLW category for longer term events on main-stem rivers, incorporating river stage heights. For verification purposes, all warnings issued under the FFW category are considered flash flood warnings. Storm Data reports entered into “StormDat” under the event type “flash flood” or “flood/flash flood” will verify an FFW regardless of whether the FFW mass media header states “flash flood warning” or “flood warning.” Information about the severe weather verification database is found in Appendix B.

The computation of lead time for a flash flood event is based on beginning time of the event in a county. If the event occurs over a period of time, and a warning was issued after the onset of the event but prior to the end of the event, the warning is verified and the lead time is zero. Any event occurring outside the valid time period or area covered by a warning counts as a missed event and is assigned a lead time of zero.

2. River Forecasts. The initial phase of river forecast verification is conducted using products issued by RFCs. For a selected set of locations, both stream level observations (stage) and stage forecasts issued by RFCs are posted to a database. Forecast values are matched with concurrent observations. From

these pairs, metrics assessing the performance of the forecast system are determined. The initial phase of river forecast verification is based on calculations of average and root-mean-square differences between observed and forecast values for each verification location. Verification statistics for locations are grouped together by forecast lead time as well as hydrologic characteristics, i.e., (1) locations responding rapidly to rainfall, (2) locations with intermediate responses, and (3) locations with slow responses.

In selecting river locations for verification purposes, locations not strongly affected by upstream regulation should be used. Streamflow at locations downstream from water control structures can be dominated by operations of the upstream structure. Verification statistics at these locations would be unrepresentative and show anomalously high forecast accuracy because the forecast discharge can often be all but specified based on knowledge of the structure’s operations.

VERIFICATION SCORES

1. Introduction. Verification scores are applied at the local, regional, and national levels. Different scores may be applied to the same data. The type of score selected for use depends upon the objective. Frequently used scores are given in this appendix and presented within the context of specific elements and events subject to verification. An excellent reference for verification scores is Wilks (1995).

In general terms, the scores are measures of accuracy and skill. **Accuracy** is a measure of how much a forecast agrees with the event or element being forecast. The smaller the difference between the forecast and observation, the greater the accuracy. **Skill** is a measure of improvement of a forecast over an established standard. Examples of standards often used for comparison include the climatological frequency (or value), persistence, or forecasts made by another process (e.g., model output statistics). The greater the improvement, the greater the skill.

2. Generalized Contingency Table. A forecast/observation contingency table is often developed to summarize all variables by category. The following generalized contingency table has m mutually exclusive and exhaustive categories. The element X_{ij} gives the number of times the observation was in the ith category and the forecast was in the jth category. The row and column totals have the subscript p. Various scores can be computed from the elements in a contingency table such as:

	Forecast Category				
Observed Category	1	2	...	m	Total
1	X_{11}	X_{12}	...	X_{1m}	X_{1p}
2	X_{21}	X_{22}	...	X_{2m}	X_{2p}
...	...	...	...	...	...
m	X_{m1}	X_{m2}	...	X_{mm}	X_{mp}
Total	X_{p1}	X_{p2}	...	X_{pm}	X_{pp}

a. Percent Correct *(PC)* is the percentage of time a correct forecast was made *(j=I)* regardless of the category.

$$PC = \frac{\sum_{i=1}^{m} X_{ii}}{X_{pp}} \times 100$$

b. Bias by Category *(BIAS)* measures the tendency to overforecast (*BIAS* > 1) or underforecast (*BIAS* < 1) a particular category, *I*. For each contingency table, *m* values of bias exist.

$$BIAS_i = \frac{X_{pi}}{X_{ip}}$$

c. Skill Score *(SS)* measures the fraction of possible improvement of the forecasts over some standard or test set of forecasts. When the test forecasts are the values expected by chance *(E)*, computed from the marginal totals of the contingency table, the score is known as the Heidke skill score.

$$SS = \frac{NC - E}{T - E}, \text{ where:}$$

$$NC \text{ (number correct)} = \sum_{i=1}^{m} X_{ii}; \quad T = X_{pp}; \quad E = \sum_{i=1}^{m} \frac{X_{ip}X_{pi}}{T}$$

3. Specialized Contingency Table. The following contingency table applies when there are only two outcomes (yes or no) for a specific event or forecast. The number of correct forecasts for the specific event is given by *A*, and the number of events observed but not forecast is given by *B*. The number of forecasts which did not verify is represented by *C*. The number of times the specific event was neither forecast nor observed is represented by *X*.

		Forecasts	
		Yes	No
Events	Yes	*A*	*B*
	No	*C*	*X*

The scores most frequently computed from this table are:

a. Probability of Detection *(POD)* is the fraction of actual events *(A+B)* correctly forecast *(A)*. The more often an event is correctly forecast, the better the score. The best possible score is 1, the worst possible score is 0.

$$POD = \frac{A}{A + B}$$

b. False Alarm Ratio *(FAR)* is the fraction of all forecasts *(A+C)* which were incorrect *(C)*. The more often an event is forecast and does not occur, the worse the score. The best possible score is 0, the worst possible score is 1.

$$FAR = \frac{C}{A + C}$$

The *POD* and *FAR* are most often used in the verification of watches and warnings. However, it is possible to apply the *POD* and *FAR* to many events and forecasts related to the elements listed in Appendix A. Two examples are the *POD* for ceilings below 1000 feet and the *FAR* for forecasts of freezing rain.

Overforecasting an event will achieve a high *POD* but at the expense of a high *FAR*. Overall success can be expressed by the critical success index (CSI).

c. Critical Success Index is the ratio of correct forecasts *(A)* to the number of events *(A+B)* plus the number of incorrect forecasts *(C)*.

$$CSI = \frac{A}{A + B + C}$$

The best possible score is 1, the worst is 0. The relationship among *POD*, *FAR*, and *CSI* can be expressed as follows:

$$CSI = [(POD)^{-1} + (1 - FAR)^{-1} - 1]^{-1}$$

In the case of severe thunderstorm watches and warnings, the value of *A* varies depending upon whether it is taken from the warning or the event database. This is true because multiple events within a single county are sometimes counted as separate events in the event database, whereas only one warning can be in effect for a particular county at the same time. For this reason, the number of warned events in the event database, denoted below as A_e, may exceed the number of verified warnings in the warning database, denoted below as A_w. Using these conventions, the definitions of *POD* and *FAR* are

$$POD = \frac{A_e}{A_e + B}$$

$$FAR = \frac{C}{A_w + C}$$

Given these expressions for *POD* and *FAR* and the *CSI* formula, expressed in terms of *POD* and *FAR*, the *CSI* becomes:

$$CSI = \frac{A_w A_e}{A_w A_e + A_w B + A_e C}$$

4. Scores Computed for Specific Forecast Elements. Other scores may be computed, where N = number of cases; f_i = the *ith* forecast, and o_i = the *ith* observation (matching the forecast).

4.1 Temperature, Wind Speed and Direction, and Wave Height. Scores frequently computed for forecasts of temperature, wind speed and direction, and wave height include:

a. Mean Error *(ME)* indicates whether collective forecast values were too high or too low.

$$ME = \frac{1}{N}\sum_{i=1}^{N} (f_i - o_i)$$

b. Mean Absolute Error *(MAE)* measures error without regard to the sign (whether positive or negative).

$$MAE = \frac{1}{N}\sum_{i=1}^{N} |f_i - o_i|$$

c. Root Mean Square Error *(RMSE)* weights large errors more than the MAE.

$$RMSE = \sqrt{\frac{1}{N}\left[\sum_{i=1}^{N}(f_i - o_i)^2\right]}$$

The above measures of accuracy *(ME, MAE, RMSE)* may also be computed for some forecast standard, such as *MOS* guidance, climatology *(CLI)*, or persistence *(PER).* For example, the *MAE* for *MOS* guidance forecasts (m_i) is

$$MAE_{MOS} = \frac{1}{N}\sum_{i=1}^{N}|m_i - o_i|$$

Forecast skill is determined by measuring the improvement of local forecasts over a forecast standard. For example, the *MAE* may be used to compute the percent improvement of local forecasts over *MOS*, $I(MAE)_{MOS}$.

$$I(MAE)_{MOS} = \frac{MAE_{MOS} - MAE}{MAE_{MOS}} \times 100$$

Other examples include $I(RMSE)_{MOS}$, $I(MAE)_{CLI}$, and $I(RMSE)_{PER}$.

4.2 Precipitation. Scores typically computed for precipitation verification include:

a. Brier Score *(BS)* measures the mean square error of all PoP intervals forecast. The standard NWS Brier score, defined below, is one-half the original score defined by Brier (1950).

$$BS = \frac{1}{N}\sum_{i=1}^{N}(f_i - o_i)^2$$

For PoP verification, assuming 10 percent probability intervals, f_i = forecast probability (0, 0.1, 0.2, ... , 0.8, 0.9, 1.0) for the *ith* case, o_i = observed precipitation occurrence (0 or 1), and N = the number of cases.

b. Climatological Brier Score *(BS_{CLI})* is an application of the Brier score to forecasts, c_i, consisting of climatic relative frequencies, *RF* (see below).

$$BS_{CLI} = \frac{1}{N}\sum_{i=1}^{N}(c_i - o_i)^2$$

c. Improvement over Climate Based on Brier Score *($I(BS)_{CLI}$)* measures the improvement gained from actual forecasts versus climatological values.

$$I(BS)_{CLI} = \frac{BS_{CLI} - BS}{BS_{CLI}} \times 100$$

The MOS guidance Brier score is analogous to BS_{CLI}, but for MOS guidance forecasts. Likewise, the improvement over MOS guidance based on Brier score is analogous to $I(BS)_{CLI}$.

d. Relative Frequency of the Event *(RF)* is the fraction of the time the event occurred.

$$RF = \frac{1}{N}\sum_{i=1}^{N} o_i$$

e. Reliability, a measure of bias, compares the average forecast of the event with the relative frequency of the event. The reliability may be determined overall or by forecast interval, e.g., 10 percent PoP intervals.

$$\frac{1}{N}\sum_{i=1}^{N} f_i \quad \textit{compared with} \quad \frac{1}{N}\sum_{i=1}^{N} o_i \ ,$$

Where *N* is the total number of events or the number of events in the interval. If the average forecast of the event is larger (smaller) than the relative frequency of the event, the event was overforecast (underforecast).

4.3 Ceiling Height and Visibility. The following score is used for verifying ceiling height and visibility forecasts:

<u>Log score *(LS)*</u> emphasizes accuracy in the more critical lower ceiling height and visibility ranges.

$$LS = \frac{50}{N}\sum_{i=1}^{N} \left| Log_{10}\left(\frac{f_i}{o_i}\right) \right|$$

Where f_i is the category of the *ith* forecast and o_i is the category of the *ith* observation. Note, f_i and o_i may also be used to represent the actual respective forecast and observed values of the element (i.e., ceiling height in feet, visibility in statute miles). Persistence is often used as the reference standard for evaluating ceiling height and visibility forecasts. The last hourly observation available to the forecaster before dissemination of the TAF defines the persistence forecasts of ceiling height and visibility to which the local forecasts are compared.

USE OF VERIFICATION INFORMATION

1. Introduction. Verification is a useful tool at all levels. It helps delineate strengths and weaknesses in NWS forecast programs and implicitly suggest priorities for the allocation of resources and training requirements. Local application programs provide rapid feedback to forecasters. Individual forecasters are encouraged to evaluate their performance for systematic biases and errors. Verification data may be used by management and individual forecasters to isolate troublesome weather situations, forecast elements, forecast periods, forecast areas, etc., for more detailed study, leading to greater understanding of the science and improved forecasts.

2. Forecaster Evaluation. Verification scores shall not be used to directly establish criteria for rating the forecasting and warning performance element. Such direct use of the verification program is not considered suitable because objectively derived verification scores by themselves seldom fully measure the quality of a set of forecasts. A forecaster demonstrates overall skill through his or her ability to analyze data, interpret guidance, and generate forecasts of maximum utility. Individual forecaster verification data shall be a private matter between management and employee and safeguarded accordingly.

A proper way of utilizing forecast verification scores in the performance evaluation process is as an indicator of excellence or of need for improvement. For example, a skill score which is “clearly above average” may be used, in part, to recognize excellence via the awards system. However, NWS managers at all echelons should be aware no two forecasters, offices, or management areas face the same series of weather events. Factors which must be taken into account include the number of forecasts produced, availability and quality of guidance, local climatology, and increased level of difficulty associated with rare events. There is no substitute for sound supervisory judgment in accounting for these influences.

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