UNITED STATES MARINE CORPS
Marine Corps Air Facility
2100 Rowell Road
Quantico, Virginia 22134-5063

LOCAL AREA FORECASTERS HANDBOOK

Prepared By:
A. R. ABBOTT
SSGT USMC

Approved By:
W. W. HUBLER
GYSGT USMC

FOREWARD

This Forecasters Handbook was prepared in accordance with NAVMETOCCOMINST 3140.2E and is a revision of the June 1997 Forecasters Handbook prepared by MCAF Quantico, Virginia.

The Forecasters Handbook is an unclassified publication setting forth, in some detail, climatological summaries and local forecasting rules employed by the METOC section when forecasting local weather. However, due to the specific nature of some of the contents, the distribution of this Handbook should be of a **LIMITED** nature and for **OFFICIAL USE** only.

The specified purpose of the Forecasters Handbook is to provide newly assigned weather forecasters with guidelines on local area weather conditions associated with typical synoptic scale developments. The Handbook also serves as a ready reference and review for the seasoned forecaster in the Quantico area.

All recommendations concerning changes, additions or deletions to improve the effectiveness of this handbook are encouraged. Additional copies may be obtained, upon request, from Weather Service Chief, Marine Corps Air Facility, Quantico, Virginia 22134-5063 or via MCAF Quantico's website address: https://www.metocwx.quantico.usmc.mil

W. W. HUBLER
GYSGT USMC
WEATHER SERVICE CHIEF

RECORD OF CHANGES

Change #	Date of Change	Date Entered	Entered by:
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			

TABLE OF CONTENTS

Foreward	I
Record of Changes	II
Table of Contents	III
List of Figures and Tables	V
SECTION 1	
100.0 BASIC DESCRIPTION	1-1
100.1 GENERAL LOCATION and DESCRIPITON	1-1
100.2 TOPOGRAPHIC DESCRIPTION	1-2
100.3 OFFICE DESCRIPTION	1-2
100.4 LOCAL FORECAST AREA	1-3
100.5 RUNWAY DESCRIPTION	1-4
101.0 METEOROLOGICAL INSTRUMENTS	1-4
101.1 AUTOMATED SURFACE OBSERVATION SYSTEM (ASOS)	1-4
101.2 THERMOSCREEN (ML-217)	1-4
101.3 TEMPERATURE AND DEW POINT EQUIPMENT	1-4
101.4 WIND DIRECTION/SPEED MEASURING EQUIPMENT	1-4
101.5 VISIBILITY	1-4
101.6 PRESSURE	1-5
101.7 CLOUD HEIGHT MEASURING INSTRUMENTS	1-5
101.8 PRECIPITATION MEASURING EQUIPMENT	1-5
101.9 METEOROLOGICAL RADAR	1-5
101.10 LIGHTENING POSITION AND TRACKING SYSTEM (LPATS)	1-6
102.0 METEOROLOGCIAL COMMUNICATIONS	1-5
102.1 COMMUNICATOR	1-6
102.2 PILOT TO FORECASTER UHF RADIO	1-7
102.3 HOMEPAGE/INTERNET	1-8
103.0 SUPPORTED ACTIVITIES	1-8
104.0 METOC SUPPORT SERVICES	1-8
104.1 ROUTINE PRODUCTS	1-8
SECTION 2	
200.0 CLIMATOLOGY	2-1
200.1 GENERAL NARRATIVE	2-1
200.2 WINTER (DEC-FEB)	2-1
200.3 SPRING (MAR-MAY)	2-2
200.4 SUMMER (JUN-AUG)	2-2
200.5 AUTUMN (SEP-NOV)	2-3
201.0 WEATHER AT A GLANCE	2-4
202.0 SYNOPTIC CLIMATOLOGY	2-8
202.1 NORTH AMERICAN TYPE A	2-9
202.2 NORTH AMERICAN TYPE B (MERIDIONAL)	2-10
202.2a NORTH AMERICAN TYPE B-a	2-11
202.2b NORTH AMERICAN TYPE B-b	2-12
202.2c NORTH AMERICAN TYPE B-c	2-13
202.3 NORTH AMERICAN TYPE B (ZONAL)	2-14
202.4 NORTH AMERICAN TYPE D	2-15
202.5 NORTH AMERICAN TYPE C	2-16
202.5a NORTH AMERICAN TYPE Ch	2-16
202.5b NORTH AMERICAN TYPE Cl	2-17
202.6 NORTH AMERICAN TYPE E (ZONAL)	2-18
202.6a NORTH AMERICAN TYPE El	2-18
202.6b NORTH AMERICAN TYPE Em	2-19
202.7 EASTERN U.S. TYPES	2-20
202.7a EASTERN U.S. TYPE Ga	2-21
202.7b EASTERN U.S. TYPE Gb	2-22

202.7c EASTERN U.S. TYPE Ha	2-23
202.7d EASTERN U.S. TYPE Hb	2-23
202.8 HATTERAS LOWS	2-24
202.8a HATTERAS LOW TYPE A	2-25
202.8b HATTERAS LOW TYPE B	2-26
203.0 TROPICAL STORMS/HURRICANES	2-27
SECTION 3	
300.0 FORECASTING	3-1
301.0 THUNDERSTORMS	3-1
301.1 AIRMASS THUNDERSTORMS	3-1
301.2 FRONTS/TROUGHS	3-2
301.3 LEESIDE TROUGHS	3-2
301.4 STABILITY INDICES	3-2
301.4a LIFTED INDEX (LI)	3-3
301.4b SHOWALTERS INDEX (SI)	3-3
301.4c TOTAL TOTALS (TT)	3-3
301.4d K INDEX (KI)	3-4
301.4e SEVERE WEATHER THREAT (SWEAT)	3-4
301.5 TORNADOES	3-5
301.6 HAIL	3-5
302.0 PRECIPITATION TYPE/SNOW FORECASTING	3-8
302.1 SNOW	3-8
302.2 SNOW FORECASTING TECHNIQUES	3-10
302.3 FORECASTING SNOWFALL AMOUNTS	3-10
302.4 FREEZING PRECIPITION/SLEET	3-11
303.0 COLD AIR DAMMING (CAD)	3-11
304.0 FOG FORECASTING	3-12
304.1 RADIATION FOG	3-12
304.2 ADVECTION FOG	3-12
304.3 PRE-FRONTAL FOG	3-13
304.4 POST-FRONTAL FOG	3-13
304.5 SNOW FOG	3-13
305.0 LOCAL WINDS	3-14
306.0 TEMPERATURE FORECASTING GUIDELINES	3-15
307.0 LOW LEVEL WIND SHEAR (LLWS)	3-15
307.1 LLWS and THUNDERSTORMS	3-15
307.2 LLWS and FRONTS	3-16
307.3 LLWS and LOW LEVEL JETS	3-16
307.4 LLWS and STRONG SURFACE WINDS	3-17
308.0 TURBULENCE FORECASTING	3-17
SECTION 4	
400.0 SPECIALIZED SUPPORT	4-1
SECTION 5	
500.0 ENVIRONMENTAL EFFECTS	5-1
500.1 CEILING AND VISIBILTY	5-1
500.2 TEMPERATURE & ATMOSPHERIC DENSITY	5-1
500.3 SURFACE WINDS	5-1
500.4 THUNDERSTORMS & LIGHTNING	5-1
500.5 TURBULENCE	5-1
500.6 ICING	5-1
500.7 PRECIPITATION	5-2
501.0 WIND CHILL	5-2
SECTION 6	
REFERENCES	6-1
APPENDIX	

LIST OF FIGURES

FIGURE/DESCRITION	PAGE
1-1 OVERHEAD VIEW OF MCAF QUANTICO	1-1
1-2 VIRGINIA COUNTIES MAP	1-1
1-3 VIRGINIA TOPOGRAPHIC MAP	1-2
1-4 QUANTICO METOC OFFICE LAYOUT	1-3
1-5 BRIEFING AREA	1-3
1-6 FORECASTER'S DESK	1-3
1-7 SMART BOARD	1-3
1-8 WALL OF THUNDER/LPATS	1-3
1-9 OPUP	1-6
1-10 COMMUNICATOR	1-7
2-1 FAVORED AREAS OF CYCLOGENESIS	2-9
2-2 TABLE OF BOWIE and WEIGHTMAN TYPES WITH CIT COUNTERPARTS	2-9
2-3 NORTH AMERICAN TYPE A	2-10
2-4 NORTH AMERICAN TYPE B-a	2-11
2-5 NORTH AMERICAN TYPE B-b	2-12
2-6 NORTH AMERICAN TYPE B-c	2-14
2-7 NORTH AMERICAN TYPE D	2-15
2-8 NORTH AMERICAN TYPE Ch	2-17
2-9 NORTH AMERICAN TYPE Cl	2-18
2-10 NORTH AMERICAN TYPE El	2-19
2-11 NORTH AMERICAN TYPE Em	2-20
2-12 EASTERN U.S. TYPE Ga	2-21
2-13 EASTERN U.S. TYPE Gb	2-22
2-14 EASTERN U.S. TYPE Ha	2-23
2-15 EASTERN U.S. TYPE Hb	2-24
2-16 HATTERAS LOW TYPE A	2-26
2-17 HATTERAS LOW TYPE B	2-27
2-18 MCAF FLOOD PICTURE	2-28
2-19 MCAF FLOOD PICTURE	2-28
2-20 MCAF FLOOD PICTURE	2-29
2-21 MCAF FLOOD PICTURE	2-29
2-22 AUGUST TROPICAL CYCLONE TRACKS	2-29
2-23 SEPTEMBER TROPICAL CYCLONE TRACKS	2-30
2-24 OCTOBER TROPICAL CYCLONE TRACKS	2-30
3-1 FIGURING HAIL ON SKEW-T	3-6
3-2 FAWBUSH-MILLER DIAGRAM	3-7
3-3 HAIL CORRECTION FOR WBZ CHART	3-7
3-4 CRITICAL VALUES FOR THICKNESS	3-9
3-5 FRONTAL TEMPERATURE CONTRAST/SPEED AND LLWS	3-16
5-1 WIND CHILL CHART	5-2
APPENDIX	
AIRMASS THUNDERSTORM WORKSHEET	APPENDIX A
WINTER PRECIPITATION WORKSHEET	APPENDIX B

SECTION 1

100.0 BASIC DESCRIPTION

100.1 GENERAL LOCATION AND DESCRIPTION

Marine Corps Air Facility (MCAF) Quantico, designated Turner Field, is located approximately at 38°30′ north latitude and 77°18′ west longitude; the field elevation is 12 feet above mean sea level. MCAF Quantico is located 70 miles north of Richmond, Virginia and 35 miles south of Washington, D.C. MCAF is located on the southeastern flank of Marine Corps Base (MCB) Quantico, which is located in Prince William County and bordered by Stafford County to the south, Fauquier County to the west, and Fairfax County to the north. The airfield is situated on the west bank of the Potomac River with the Appalachian Mountains, oriented northeast to southwest, beginning 70 miles to the west.

FIGURE 1-1 (Overhead View of MCAF Quantico)

FIGURE 1-2 (Virginia Counties Map)

100.2 TOPOGRAPHIC DESCRIPTION

The general area around the facility is composed of small rolling hills, less than 400 feet in height, separated by marshes and small streams which drain into the Potomac River. The land slopes to the east. The Chopawamsic Creek borders the field to the south. This creek's marsh covers an area beginning ¼ mile to the west of the facility. A small line of hills, approximately 200 feet in elevation, is orientated southwest to northeast and passes one mile to the west of the facility. The Air Facility itself is set upon a man-made, flat, wide terrace which forms the west bank of the Potomac River.

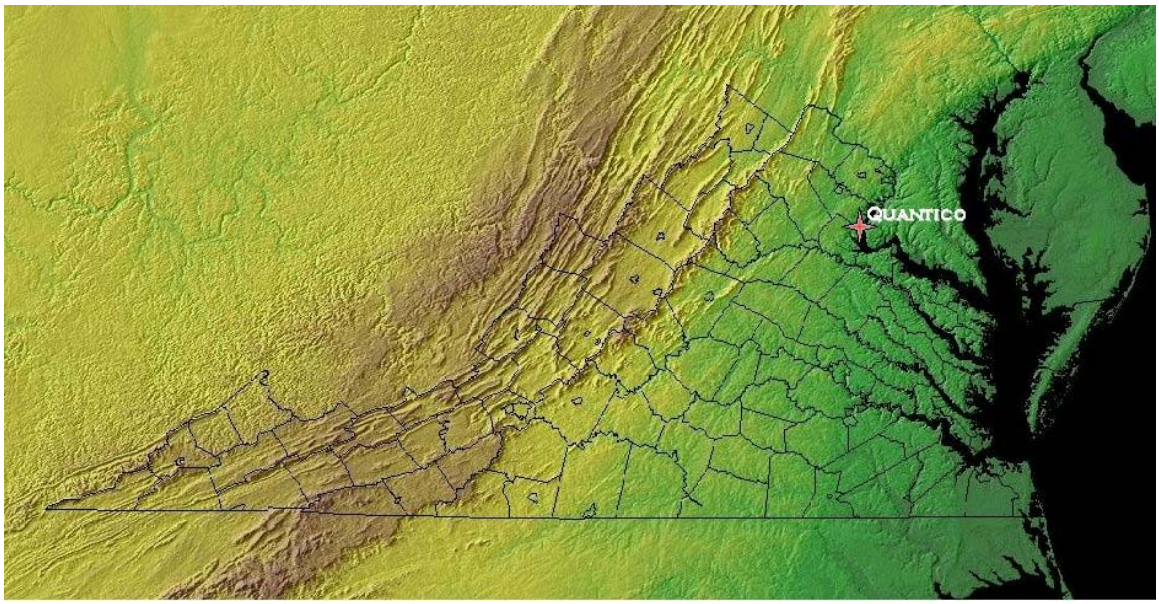


FIGURE 1-3 (Virginia Topographic Map)

100.3 OFFICE DESCRIPTION

The Weather operational and administrative sections are located in BLDG 2105 aboard MCAF Quantico. The administrative section is located on the west side of the hanger. This administrative office space consists of the NCOIC and the administrative clerk areas. The operational section is located on the eastern side (airfield side) of the building and consists of 3 areas. The largest area comprises the duty forecaster's work space/briefing area. The second area is comprised of the safe, weather section training SNCO's desk, rack-room, and ASOS Acquisition Control Unit. The last area consists of the observer's desk with crash phone. (See Figure 1-4)

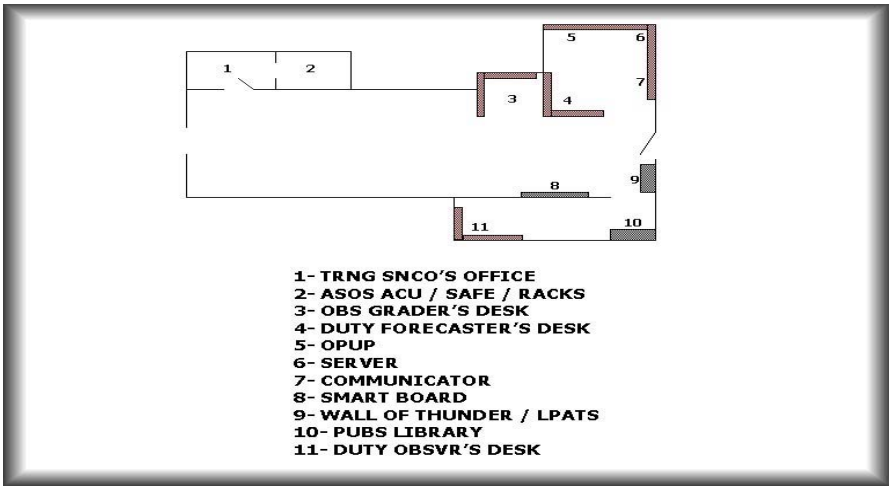


FIGURE 1-4 (Quantico METOC Office Layout)

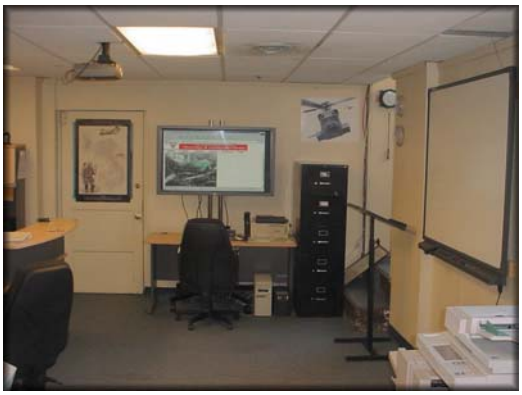


Figure 1-5 (Briefing Area)

Figure 1-6 (Forecaster's Desk)

Figure 1-7 (SMART Board)

Figure 1-8 (Wall of Thunder/LPATS)

100.4 LOCAL FORECAST AREA

The local forecast area for MCAF Quantico is defined as a 60 nautical mile (NM) radius around MCAF, to include the National Capital region. The local flying area is defined as a 250 NM radius around the air field.

100.5 RUNWAY DESCRIPTION

The air facility consists of one hard surface asphalt runway with the following dimensions (See Fig 1-1):

Runway	Dimensions
02/20	4236’ X 150’

The following are the weather minimums for MCAF Quantico (ref AFO P3700.1D):

VFR - Ceiling not less than 1,000 feet, and visibility not less than 3 statute miles(SM).

Special VFR - 1SM visibility, no ceiling.

101.0 METEOROLGICAL INSTRUMENTS

101.1 AUTOMATED SURFACE OBSERVATION SYSTEM (ASOS)

The ASOS is the primary means of gathering various weather data at MCAF Quantico. The ASOS Data Collection Package (DCP) consists of various sensors used in collecting measurements in wind speed/direction, sky condition, visibility, temperature/dew point, and pressure. It also provides the forecaster and observer with current readings of the previous mentioned elements as well as archived reading of past weather data, and a summary of the day which includes max/min temps, max wind speed, total rainfall, etc. The ASOS DCP is located 1,080FT east-southeast of Delta Taxiway/Runway 02/20 intersection.

101.2 THERMOSCREEN ML-42

The weather section maintains a thermoscreen which contains some of the observers back-up equipment such as sling psychrometer, ML-450 electric psychrometer, maximum and minimum thermometers. The thermoscreen is located approximately 18FT from the southwest corner of BLDG 2105 at 5FT above ground level (AGL).

101.3 TEMPERATURE AND DEW POINT MEASURING EQUIPMENT

The ASOS temperature/dew point sensor is the primary instrument used for temperature readings aboard MCAF. The sling psychrometer and electric psychrometer are the back-up to the ASOS and are located in the thermoscreen.

101.4 WIND DIRECTION/SPEED MEASURING EQUIPMENT

The ASOS is the primary sensor for wind speed/direction readings with the PMQ-3 Hand Held Wind Anometer being the back-up. One PMQ-3 is located in the weather section in the Observer’s area.

101.5 VISIBILITY

The primary means of obtaining current visibility readings is the duty weather observer utilizing the ASOS visibility sensor reading and the current visibility markers as set forth in the visibility marker folder maintained in the weather office publications library. The experienced

eye of the duty observer is the most valuable tool for taking visibilities. The Air Traffic Control Tower also takes tower visibility observations, when required, and passes them to the duty observer via the Tower phone located in the Observer's area. A current list of certified Tower Visibility Observers is maintained in the Observer's area next to the Tower phone.

101.6 PRESSURE

The ASOS is the primary sensor for current station pressure, sea level pressure, and altimeter setting readings used aboard MCAF. The ML-448 Aneroid Barometer, mounted on the wall in the Observer's area at approximately 7FT AGL, is the back-up to the ASOS. With a pressure reading taken from the aneroid barometer the duty observer, utilizing the Pressure Reduction Computer, can obtain current sea level pressure and altimeter settings.

101.7 CLOUD HEIGHT MEASURING INSTRUMENTS

The experienced eye of the duty weather observer is the primary means of obtaining cloud height measurements aboard MCAF. The Duty observer also has various methods at his/her disposal to aid in their determination of cloud height such as ASOS ceilometer, ceiling balloons, Skew-T, known heights of fixed objects, and different weather stations in the local area.

101.8 PRECIPITATION MEASURING EQUIPMENT

The ASOS rain gauge is the primary means of getting total **liquid** precipitation amounts. The ML-217, 4 inch rain gauge serves as a back-up to the ASOS and as the primary means of gathering water equivalents of solid types of precipitation such as hail/snow/ice pellets. It is located approximately 19FT from the southwest corner of BLDG 2105.

101.9 METEOROLOGICAL RADAR

The WSR-88D Radar Data Acquisition (RDA) Unit is maintained by the National Weather Service Forecast Office in Sterling, Virginia. It is located approximately 30 miles to the north-northwest of MCAF Quantico. The Open System Principle User Processor (OPUP) is located in the Forecaster's area. Other means of obtaining radar images are available via the internet; however, they limit the forecaster's ability to interpret products and should only be utilized to obtain visual reference of large scale features.

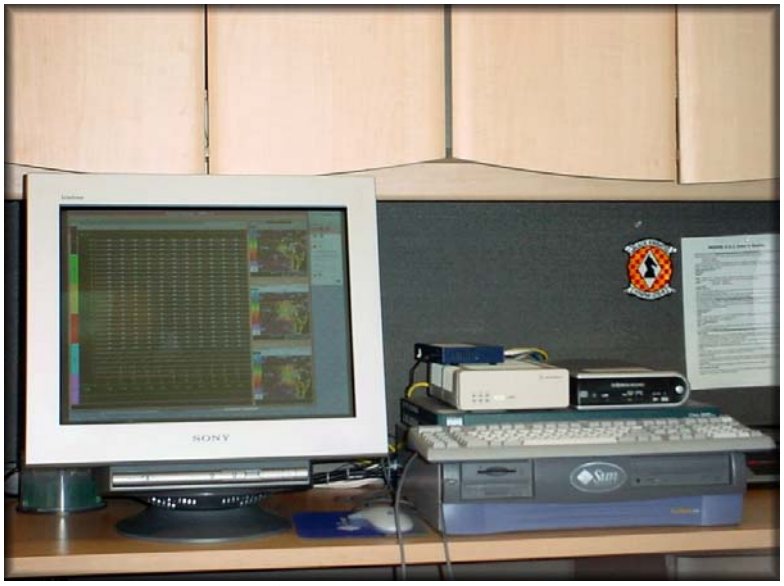


Figure 1-9 (OPUP)

101.10 LIGHTENING POSITION AND TRACKING SYSTEM (LPATS)

The LPATS consists of a computer that is connected via a phone line to a nationwide network of other LPATS systems to track all cloud to ground lightening strikes within the continental United States. Our LPATS is also equipped with an Electric Field Mill (EFM). The EFM measures the atmospheric electric field intensity in the local area. Accurate measurement of the electric field provides valuable information that helps to assess the probability of a lightening strike in the measured area. When the field mill reaches the established threshold, an audible alarm is sounded to alert personnel of the threat of lightening. When used with other sources of weather information, such as radar and satellite imagery, the EFM offers the best and most reliable information on predicting lightening strikes.

102.0 METEOROLOGICAL COMMUNICATIONS

102.1 COMMUNICATOR (AUTOMATED MASS NOTIFICATION SYSTEM)

The Communicator is an automated mass notification system. Quantico METOC obtained this system in the fall of 2003 in order to streamline the weather warning callout process, what used to take anywhere from 15-20 minutes to call out warning can now be done in 5-10 minutes. The other benefit of the system is that it is totally automated, just a few mouse clicks and the warning is transmitted. This frees up the duty observer, so he/she can keep more abreast of the weather conditions outside. The user has the option of using pre-recorded messages or recording their own messages containing information on weather warnings. The System Administrator can make multiple lists of contacts with primary and alternate phone numbers which are maintained in the computer; additions and updates to this list can be made at any time. The benefit of the ability to maintain multiple contact lists is so that a list can be maintained specifically for sections that need certain warnings (i.e. needing all weather warnings, or just lightening warning or WBGTI conditions). Once the duty forecaster determines that a weather warning needs to be set, he/she starts the program, selects

the message to be sent, or records their own message, selects which contact list is to be called, and the computer calls every number maintained in that list. The person receiving the call is notified that they are about to receive an important weather notification, presses any button on their phone and the weather warning is then played for them. Upon completion of the warning, the listener has the option to have the message repeated if they did not get all the information passed. The Communicator can utilize up to six phone lines simultaneously to transmit any warnings. If the primary number called is busy the computer automatically calls the alternate number for that contact (if available). If the computer reaches a busy line, answering machine, or no one picks up it will keep calling that number until someone answers or for a preset amount of time (ours is set for 10 minutes). Once all numbers have been reached, or the preset time has run out, the Communicator generates a list of every person called and says whether that person successfully got the message or whether it was a busy line or answering machine that was contacted. We maintain these sheets in lieu of the old warning call-out sheet as a record of the type of warning called out and which phones numbers were contacted or not contacted because of busy lines or answering machines.

Figure 1-10 (Communicator)

102.2 PILOT TO FORECASTER UHF RADIO

Designated "Quantico Metro", transmits on a frequency of 355.3 MHz. It provides air crews with in-flight contact with the duty forecaster. Reception range is dependant upon equipment, weather conditions, and line of sight obstructions. Optimum reception ranges are:

Altitude	Range (NM)
0-5000'	50
5-10,000'	100
10-15,000'	150
15-30,000'	200
30,000'+	200+

102.3 HOMEPAGE/INTERNET ACCESS

The Weather section maintains an internet web site at https://www.metocwx.quantico.usmc.mil. The website provides various local weather information as well as links to various weather products.

103.0 SUPPORTED ACTIVITIES

The units listed below are provided METOC support on a recurring basis. Quantico METOC also occasionally provides support for various Marine Corps, Navy, and Air Force assets.

- MARINE HELICOPTER SQUADRON ONE (HMX-1)

- HEADQUARTERS MARINE CORPS (ASL 37)

- MARINE CORPS AIR FACILITY (MCAF), QUANTICO

- MARINE CORPS BASE (MCB), QUANTICO

- MARINE CORPS COMBAT DEVELOPMENT COMMAND (MCCDC)

- THE BASIC SCHOOL (TBS)

- OFFICER'S CANDIDATE SCHOOL (OCS)

- MARINE DET, ANDREWS AIR FORCE BASE

- QUANTICO AERO CLUB

- EXPEDITIONARY WARFARE SCHOOL (EWS), QUANTICO

104.0 METOC SUPPORT SERVICES

104.1 ROUTINE PRODUCTS

The METOC section provides the following products on a recurring nature:

- HMX-1 Presidential Support Briefings

- Climatological Briefs/Packages

- Terminal Aerodrome Forecasts (TAF'S)

- Plain Language 96 hour Local Area Forecasts

- Drop Zone Forecast

- DD175-1 Flight Weather Briefings

- In-flight weather briefings via METRO

- Horizontal Weather Depictions (HWD)

- Cross-Country Weather Briefs

- Weather Warnings (per AFO 3121.1E)
- Astronomical & Tidal Data
- Surface Weather Observations

SECTION 2

200.0 CLIMATOLOGY

200.1 GENERAL NARRATIVE

The Potomac River, and the surrounding creeks that empty into the Potomac, play a couple of important roles in determining the general climate at Quantico. First, temperatures tend to be a couple of degrees cooler in the summer months and a couple of degrees warmer in the winter months than surrounding areas. Second, when conditions are right fog will develop in and around areas with water. Third, airmass thunderstorms will generally intensify when they reach the Potomac and follow its course. The Appalachian Mountain Range is an important obstruction to advancing fronts. Often cold fronts will become distorted and frontolysize over the mountains and under-go frontogenesis on the lee side.

The influence of the Cape Hatteras region is of great importance in the winter and transitional months. It is a region of sudden, vicious storms. Any frontal system moving into that area should be watched carefully as intense cyclogenesis can occur due to the marked temperature contrast of the warmer underlying water masses. Development of Hatteras Lows usually results in extended periods of inclement weather at Quantico.

200.2 WINTER (DEC-FEB)

During this period the Bermuda High has taken its southern most position in the southeastern Atlantic Ocean. High Pressure persists over Canada and the Polar Regions, with one or two outbreaks of cold air per week. The Icelandic Low has intensified and its associated trough acts as a steering mechanism for Low Pressure systems developing over the Gulf of Mexico and Texas. The polar front jet (PFJ) is the most influential factor in determining movement of lows. The worst weather occurs when the PFJ lies east of the Appalachians and is oriented SW-NE along the eastern seaboard. The PFJ is at its southern most point extending eastward across the Gulf of Mexico and northeastward toward the Mid-Atlantic States. The Polar front is also at its southern most point extending from southeastern Texas across northern Florida toward southeastern Georgia to Bermuda. Waves frequently develop along the polar front in the northwestern Gulf of Mexico and move northeastward toward the Cape Hatteras area where intensification occurs. Strong northeasterly winds typically accompany these storms.

Early in the season, the Bermuda High is still positioned fairly far north in relation to its winter position. This enables some weak to moderate continental polar (cP) airmasses to modify rapidly and results in unseasonably warm temperatures for the local area. A cold front that is oriented W-E will typically become quasi-stationary along the North Carolina/Virginia border, this usually happens once or twice a month. Waves developing along this boundary or a north/south oscillation of this boundary can cause flight conditions to fluctuate between IFR and VFR; with low ceilings, rain, and fog persisting from 48-96 hours. This type of situation is commonly referred to as Cold Air Damming (CAD), and will be discussed in detail in Section III.

It usually takes an outbreak of cP air to end the inclement weather and bring VFR conditions back to the local area.

The mean winds are from the northwest and occur with cold frontal passage. After frontal passage winds are typically gusty and can often range from 25-30 knots. During the winter months aviation operations can be impacted due to a number of factors including; but not limited to: fog, low stratus ceilings, freezing precipitation, icing conditions, low level turbulence associated with gusty surface winds, etc.

Snowfall is generally less frequent and less intense than inland due to the moderating effects of the Potomac River and surrounding creeks. Mean snowfall is typically between 2-6 inches per month. Snow events occur more frequently in January and February.

200.3 SPRING (MAR-MAY)

During this period the Bermuda/Azores High intensifies, moves northward, and builds to the west. The Icelandic low begins to weaken and the PFJ and polar front retreat northward and exist across the central U.S. through the Mid-Atlantic States. Late in the period there is often a sharp contrast in temperatures as polar air gives way to seasonal warming. Temperatures can fall 20-25 degrees F with cold frontal passage. Thunderstorms associated with these cold fronts are usually very strong and at times may become severe weather producers.

Convective activity increases throughout this transitional period. Fog and low stratus occur less frequent with the warming of the surrounding water masses. Haze also becomes more prevalent later in the period with the stagnation of High Pressure centers over the east coast.

Prevailing winds are out of the northwest early in the period and become southerly toward the end of the period. Wind speeds are generally moderate except when associated with thunderstorm activity or with cold frontal passage.

200.4 SUMMER (JUN-AUG)

The Bermuda High dominates the weather along the East Coast and western Atlantic. The Icelandic Low becomes so diffuse it almost disappears. High zonal flow dominates the eastern U.S., with the occasional shift to low zonal flow bringing polar air from eastern Canada once or twice a month.

Cold fronts are usually dry and diffuse, with the associated line of convection often splitting into two separate areas; one to the north of the station and one to the south of the station. Sometimes a pressure trough forms on the east side of the Appalachians in advance of the front. A squall line will typically develop ahead of and parallel to the front accompanied with a line of thunderstorms and gusty surface winds. Occasionally cold fronts with an E-W orientation will stall out south of the station. Little adverse weather is typically associated with this pattern, as compared to previous months.
Warm fronts are uncommon during this time of the year. Often the cold air ahead of the front is so shallow it can disappear with daytime

heating, usually depicting a rapid northward jump of the front during the daytime hours. In the rare occurrence of a warm front, expect an area of low ceilings, low visibilities, and rain to accompany the front.

Majority of the thunderstorm activity experienced during this part of the year is air mass or the occasional pre-frontal squall line. Air mass thunderstorms are typically associated with short periods of heavy rain and strong wind gusts from varying directions.

Visibilities are restricted to less than 7 miles in haze about 50% of the time during the summer. Fog is usually not a factor during this time of the year, although can develop due to radiational cooling or in advancement of a warm front.

Hurricane season begins on June 1 for the eastern U.S., although it is not until August when the threat of a hurricane becomes a concern for the Mid-Atlantic States.

200.5 AUTUMN (SEP-NOV)

During this period the transition from a maritime tropical air mass to a continental polar air mass occurs. The Bermuda High recedes to the southeast weakening the ridge over the southeastern U.S. The Icelandic Low intensifies and begins to attract low pressure systems developing off the east coast of the U.S. The Canadian High moves southward, bringing with it a marked sharpness in cold frontal passage and a prevailing northwesterly wind.

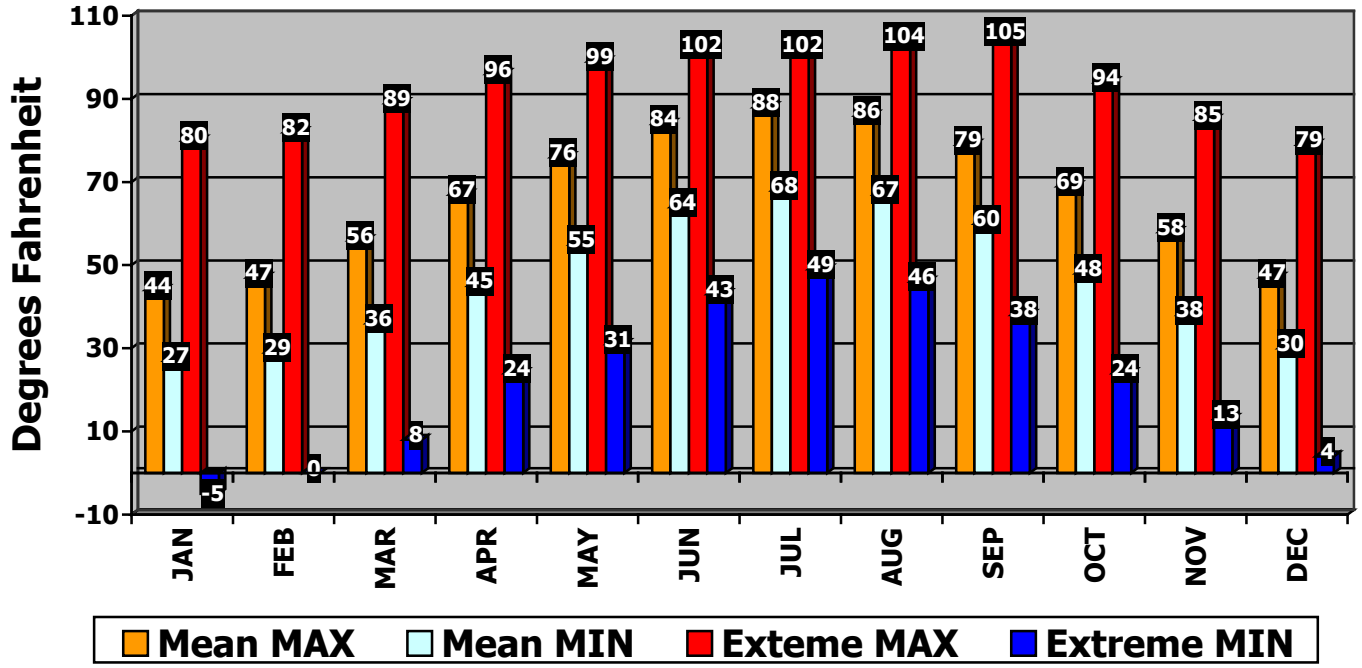
Lows form more frequently in Texas and the Gulf of Mexico and move northeastward on either side of the Appalachians. Those that move up west of the Appalachians bring with them prolonged periods of low ceilings, low visibilities, fog, and occasionally freezing precipitation or snow, particularly in late November. Lows moving east of the Appalachians typically get most of their energy and moisture from the warmer coastal waters so the development of any freezing precipitation is rare at best. They are generally more violent but usually are of shorter duration.

In September and October cold fronts move rapidly eastward and are usually associated with little weather and slight temperature contrasts. Fair weather and moderate temperatures with little humidity usually dominate for 3-4 days after passage of a cold front. Occasionally a maritime tropical air mass can move northward form the Gulf of Mexico or the Caribbean and will usually carry with it unseasonably warm and humid temperatures lasting typically for 1-2 days.

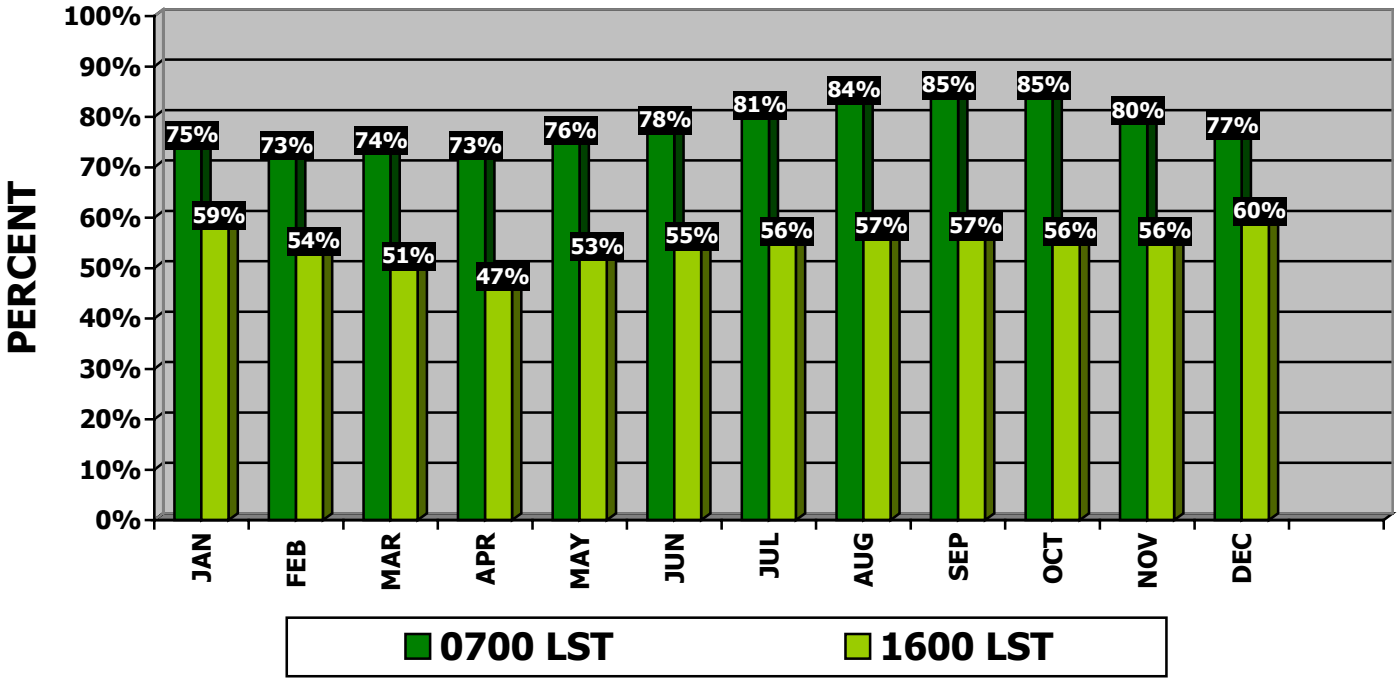
Hurricanes reach their maximum frequency early in the period due to the sea surface temperatures reaching their peak in the western Atlantic.

Fog generally occurs on average of about 10-12 days per month and usually poses an impact to aviation operations. Fog formation is dominated by advection fog and pre-frontal fog, with radiation fog becoming less frequent in occurrence and usually of little significance.

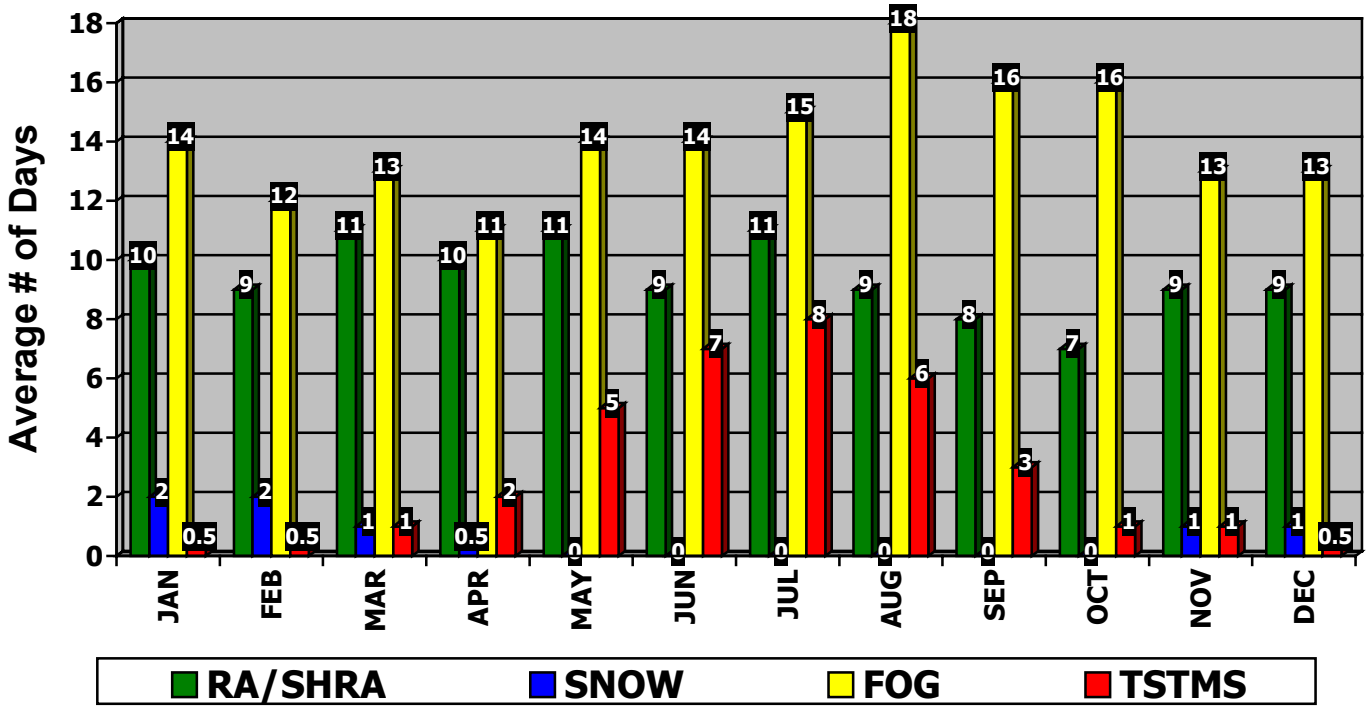
TEMPERATURE



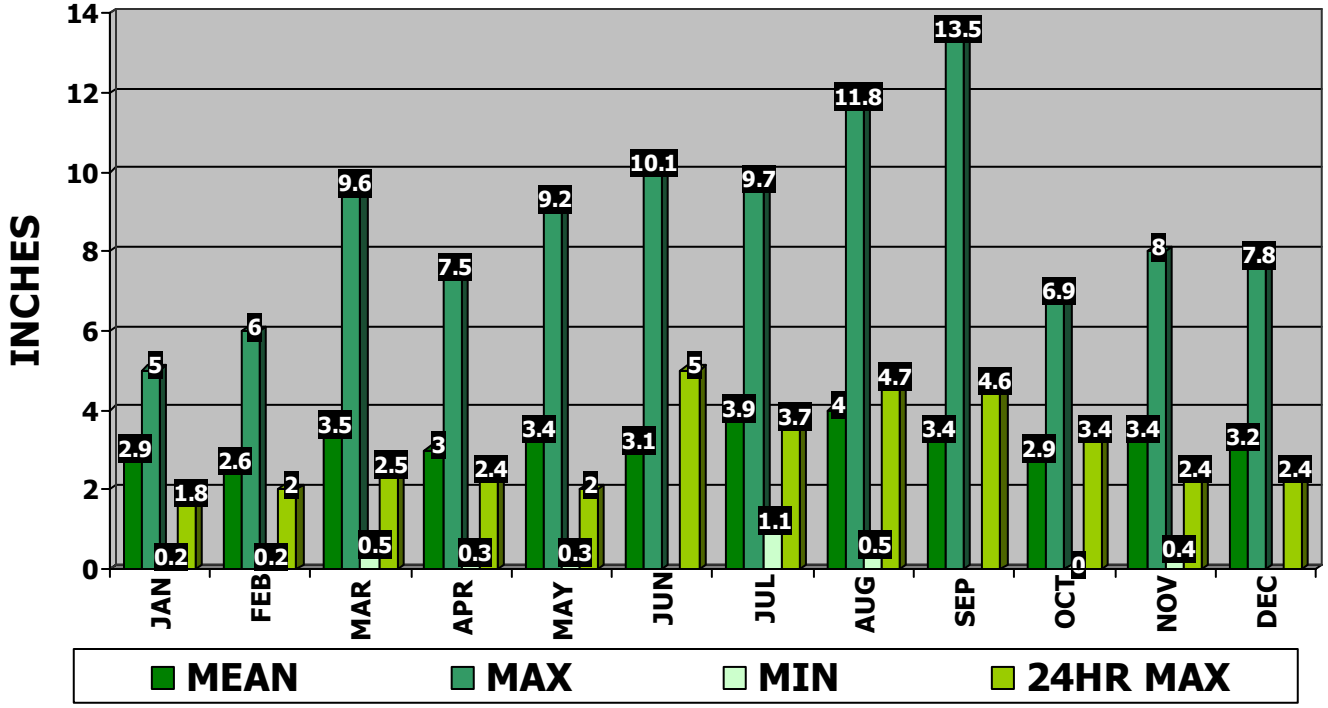
RELATIVE HUMIDITY



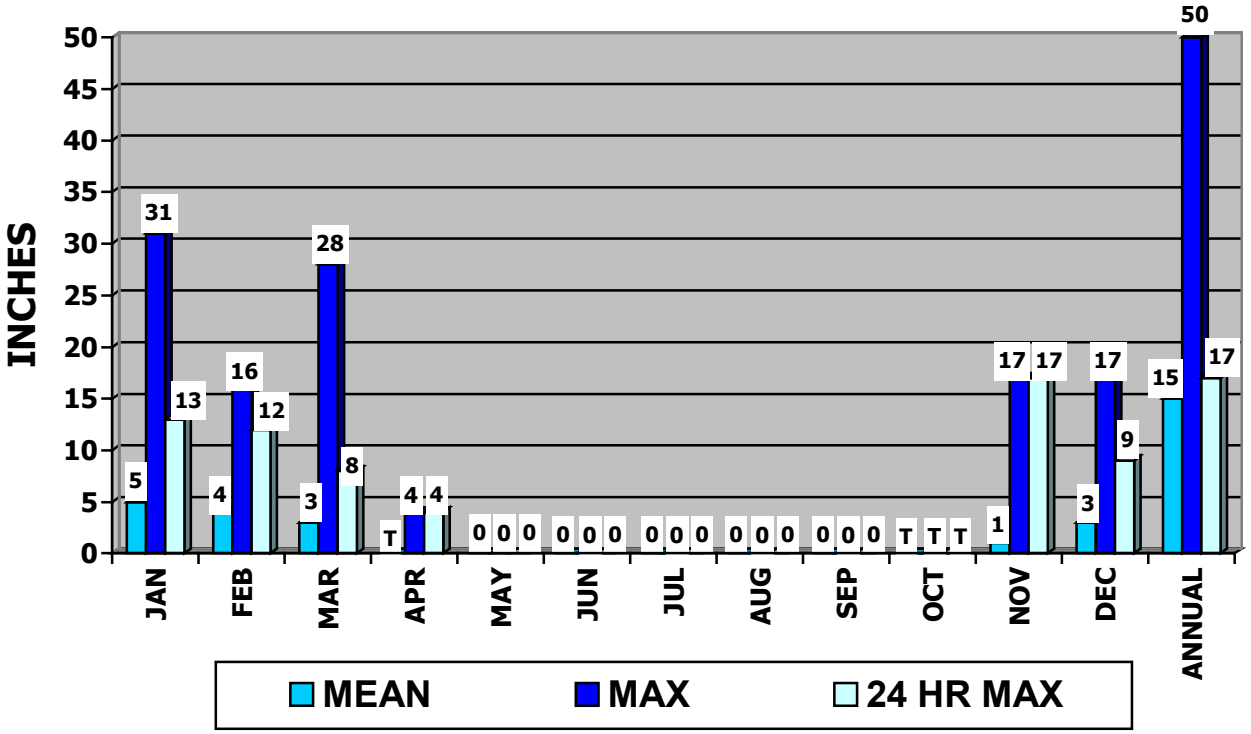
WEATHER TYPES



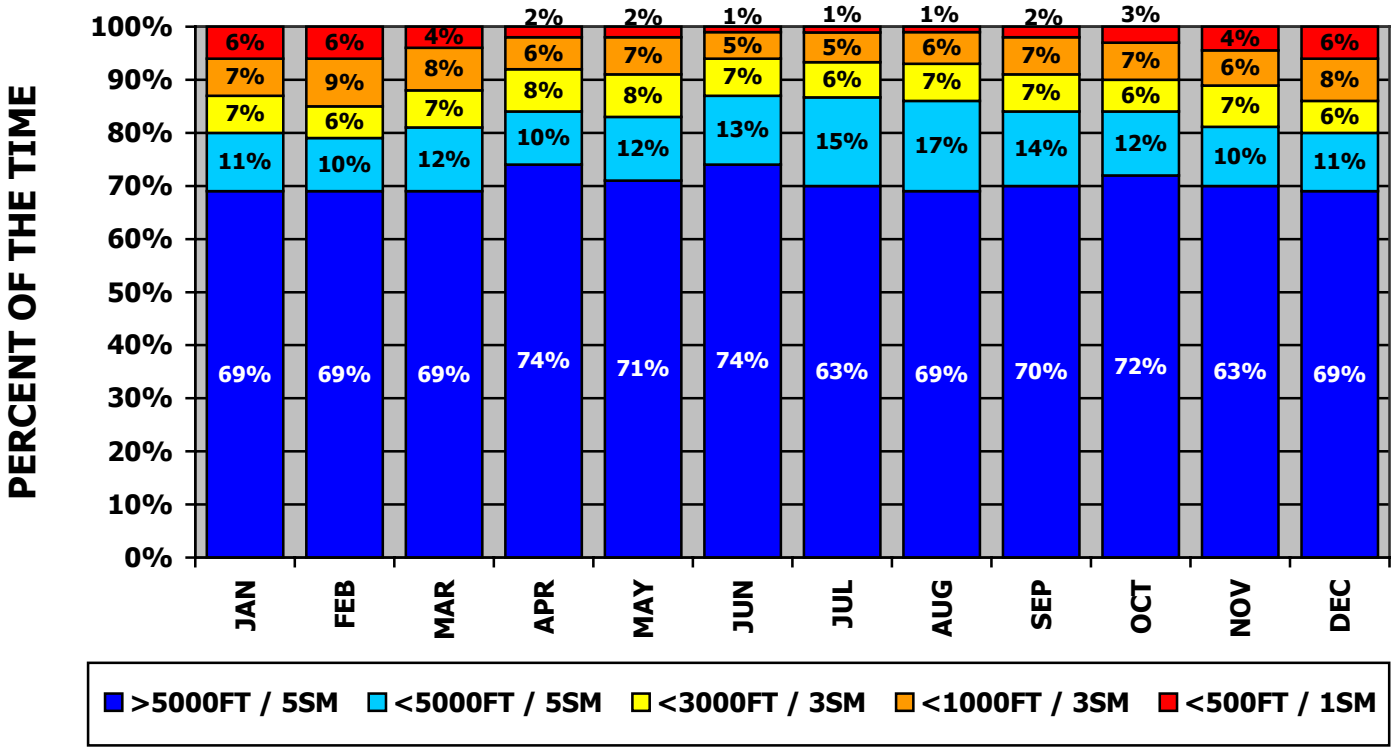
PRECIPITATION AMOUNTS



SNOWFALL AMOUNTS

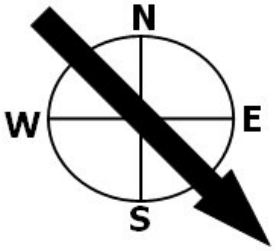


CEILINGS & VISIBILITIES



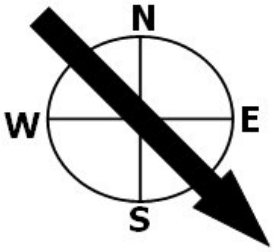
AVERAGE MONTHLY WIND DIRECTION/SPEEDS

JANUARY



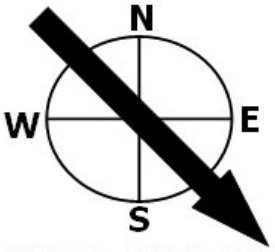
AVERAGE SPEED: 7 KT
MAX GUST: 53KT

FEBRUARY



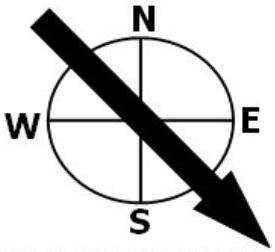
AVERAGE SPEED: 8 KT
MAX GUST: 54KT

MARCH



AVERAGE SPEED: 8 KT
MAX GUST: 50KT

APRIL

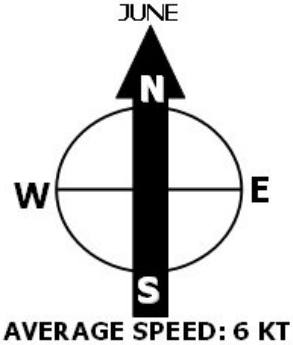


AVERAGE SPEED: 7 KT
MAX GUST: 64KT

MAY

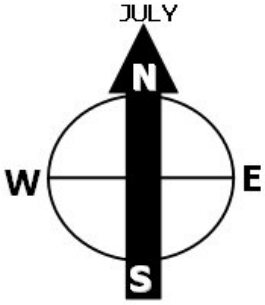
AVERAGE SPEED: 6 KT
MAX GUST: 65KT

JUNE



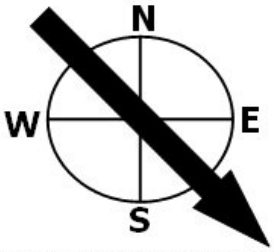
AVERAGE SPEED: 6 KT
MAX GUST: 55KT

JULY



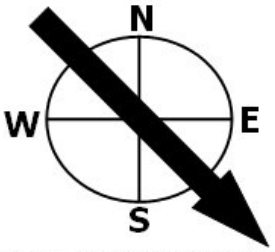
AVERAGE SPEED: 6 KT
MAX GUST: 63KT

AUGUST



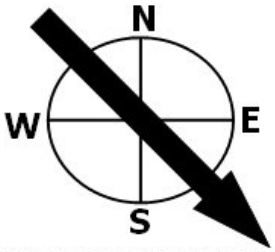
AVERAGE SPEED: 5 KT
MAX GUST: 66KT

SEPTEMBER



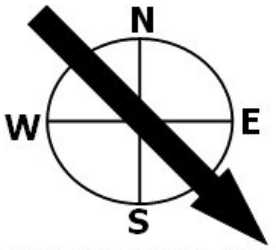
AVERAGE SPEED: 5 KT
MAX GUST: 48KT

OCTOBER



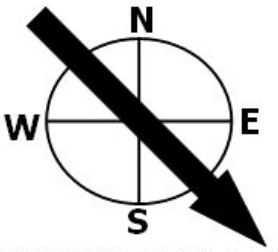
AVERAGE SPEED: 5 KT
MAX GUST: 62KT

NOVEMBER



AVERAGE SPEED: 6 KT
MAX GUST: 52KT

DECEMBER



AVERAGE SPEED: 6 KT
MAX GUST: 51KT

202.0 SYNOPTIC CLIMATOLOGY

Since it requires years of experience and a photographic memory to develop a mental catalogue of weather patterns, a weather type classification is extremely useful as a means of selecting analogous situations from the past for application to the present. Classification of weather patterns into types was originally developed by Bowie and Weightman, and was refined by R. D. Elliot of the California Institute of Technology (CIT).

The principle behind the CIT classification system is that each type is characterized by a certain typical sequence of broad scale features of pressure distribution. In this system the broad features of the upper westerlies are recognized as the steering mechanisms of migratory cyclones and anticyclones.

The atmosphere is one complete system and acts in an integrated manner. Although the CIT system is primarily a surface typing system, the upper air patterns should be given primary consideration at all times for variations from the ideal pattern. The actual tracks of surface lows can be more directly inferred from upper air patterns. When discussing normal storm tracks it must be remembered that with a low zonal index situation any storm may travel considerably south of its normal track resulting in an entirely different synoptic picture. The tendency is for the jetstream to shift to the south results in the southward shift of the steering current, forcing the paths of the migratory cyclones south of normal.

The average period between passages of successive major cyclones past a fixed point is about three days. One such system is always represented by a type, and two or more successive major systems are of the same type two thirds of the time. Occasionally, the same type may persist for almost a month. Ideally, a given type is expected to persist for three days, or a multiple of three days.

Types pertaining to the North American continent and of importance to the East Coast are presented in this handbook. Areas of persistent high pressure are delineated. The trajectories of major polar outbreaks are denoted. Successive daily positions of a single cyclone and its associated frontal system are shown in conventional fashion. Individual movements are idealized and there is some variation from case to case. There are certain types which do not occur at all in the summer; although all summer types occur, in slightly modified form, in winter. The seasonal differences are primarily in the frequencies of occurrence of the various types. Figure 2-1 displays the favored areas of cyclogenesis for the North American Continent. Figure 2-2 displays a table of the Bowie and Weightman types with their CIT counterparts.

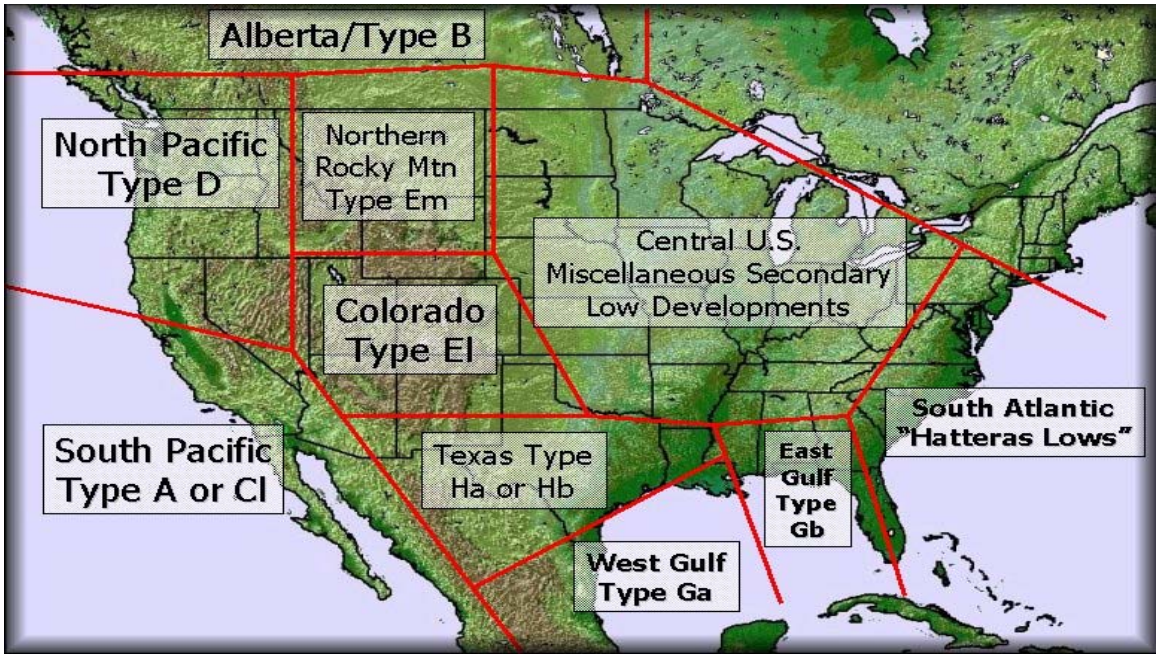


Figure 2-1 (Favored Areas of Cyclogenesis)

Bowie and Weightman Types	CIT Types
South Pacific	A, Cl
Alberta	B types
North Pacific	D
Colorado	El
Northern Rocky Mountain	Em
West Gulf	Ga
East Gulf	Gb
Texas	Ha, Hb
South Atlantic	Hatteras Lows

Figure 2-2

202.1 NORTH AMERICAN TYPE A

With the North American Type A system, the temperatures are well below normal west of the Rockies and above normal in the eastern United States. Copious precipitation occurs in the Mississippi and Ohio River valleys as the low moves northeastward towards the Hudson Bay. The anticyclone track for this regime is eastward across the northern border of the U.S., or they move up from the Four-Corners region before swinging eastward across the southern states.

CHARCTERISTICS:

1. Stationary long wave troughs are located near 105°W-115°W and 170°E-180°E.

2. A stationary long wave ridge is located about 145°W-150°W.

3. A northwesterly jet extends southeastward from the ridge in the vicinity of Ocean Station "P" off the west coast of North America through the southern plateau, then northeastward toward New England.

4. The Eastern Pacific Anticyclone is well to the northwest of its normal winter position of about 40°N and 145°W.

LOCAL EFFECTS:

Low pressure systems associated with this type of system, move well north of the Quantico area. Although heavy precipitation occurs with this system in the North Central U.S., the Mid Atlantic states will normally experience dry cold frontal passage with minimal precipitation.

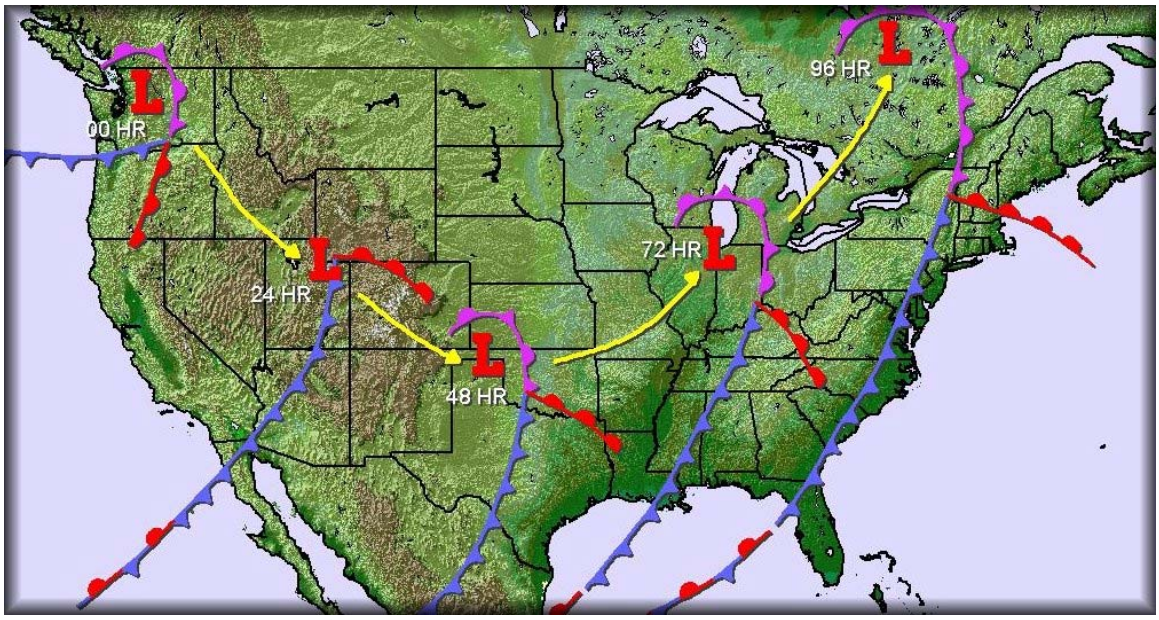


Figure 2-3 (North American Type A)

202.2 NORTH AMERICAN TYPE B (MERIDIONAL)

The type B lows generally do not penetrate the United States south of the Great Lakes and northern New England. The dominant feature associated with these types of systems, which keep the lows to the north, is persistent high pressure in the Great Basin. This Basin High is maintained by an upper level ridge in the west, while a trough aloft exists over the Ohio Valley. The mean upper flow is meridional in contrast to the zonal B types, resulting in strong polar outbreaks into the United States. The mean upper flow is sufficiently different in the four meridional B types that cP outbreaks of different characteristics are associated with each. The B-a type only has a minor outbreak, which affects eastern Canada and the northeastern United States. The B-b type is associated with a rather intense outbreak of cP air into the Great Plains, and a deeper upper level trough exists over the Ohio Valley than with the B-a type. The B-c type has an outbreak that moves down, both over and to the east of the Rockies. In this and other respects the B-c type is similar to the Type A system. Actually, the upper level ridge and trough are also farther west in the B-c types than in the other meridional B types.

202.2a NORTH AMERICAN TYPE B-a

CHARACTERISTICS:

1. A major ridge is located near 155° W and 120° W with a trough near 90° W, another major trough is located in the Pacific at 150° W and 160° W.

2. A strong surface high with associated fair weather persists in the Great Basin.

3. A semi permanent low exists in the Gulf of Alaska.

4. The surface low moves across Canada along the 6th parallel.

5. Weak mP fronts trail farther south into the United States.

6. Small polar outbreaks occur in eastern Canada and in the northeastern U.S.

7. This type is more frequent during the summer than during other seasons of the year.

LOCAL EFFECTS:

Occasionally cP air will reach as far south as Quantico. During the summer months this creates a very sharp contrast between the cold and dry air associated with the cP High and the warm, moist air of the Bermuda High. Strong thunderstorms are usually associated with this type.

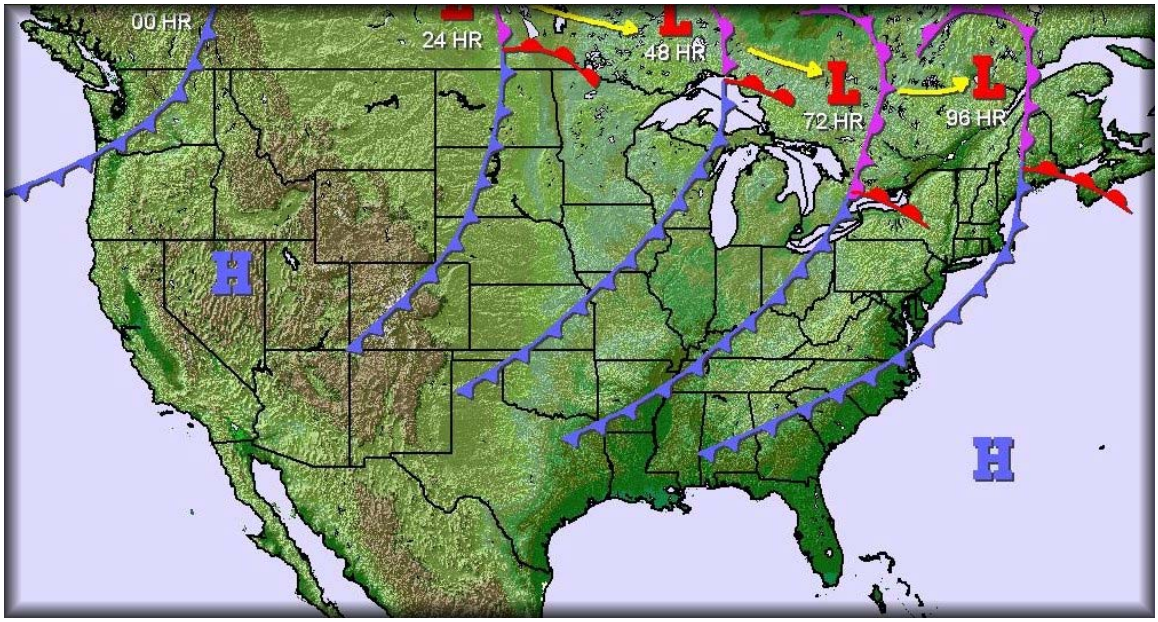


Figure 2-4 (North American Type B-a)

202.2b NORTH AMERICAN TYPE B-b

CHARACTERISTICS:

1. Major troughs and ridges are in the same location as they are in the B-a type.

2. A Great Basin High with fair weather exists.

3. Lows move southeastward from the Gulf of Alaska toward the Upper Great Lakes region.

4. A cP airmass develops over the prairie provinces of Canada, in the rear of the low.

5. A strong cP outbreak may move into the north central Plains when the low is near Lake Superior.

6. The cP outbreaks penetrate farther south into the Gulf of Mexico.

7. The first cold fronts of the fall season reach southern Texas and may also reach Florida.

8. The upper trough is deeper than in the B-a type and may produce considerable amounts of precipitation along the Atlantic seaboard.

LOCAL EFFECTS:

This type occasionally produces waves off the southeastern U.S. in the form of Hatteras Lows (covered separately in the handbook). These systems occur most frequently in the spring and fall, resulting in the first and last outbreaks of polar air to the local area. Little weather except frontal thunderstorms can be expected, unless development of a Hatteras Low occurs.

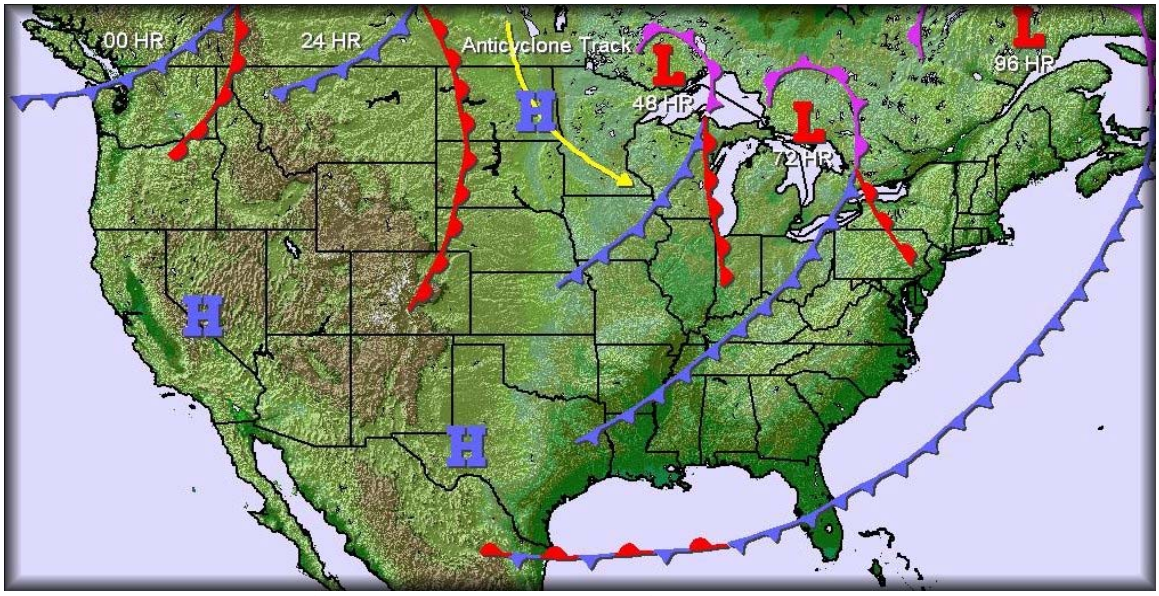


Figure 2-5 (North American Type B-b)

202.2c NORTH AMERICAN TYPE B-c

CHARACTERISTICS:

1. A major ridge aloft is located near 135° W, with a trough aloft near 100° W.

2. A surface high persists just off the coast of Washington and Oregon keeping the west coast free of storms.

3. Lows move from the Gulf of Alaska through the Great Lakes region toward northern New England.

4. Outbreaks of cP air move southeastward of their normal path, along the Continental Divide.

5. In many cases the low moves as much as ten degrees of latitude south of the path indicated; toward Nebraska or South Dakota.

6. Secondary lows of major importance sometimes develop in Colorado.

7. Behind the cold front, easterly upslope winds blow cold air toward the Divide and over into the Great Basin, bringing blizzard conditions to Wyoming and eastern Colorado.

8. Frequently a stationary low develops over the southern Great Basin while cP air continues to push southward east of the Divide into Texas. The cold low aloft is responsible for the persistence of inclement weather in the Great Basin. There is usually not much of a surface low associated with the upper cold low, and the pressure usually uniformly increases northeastward from New Mexico.

9. The B-c type is most frequent in August and September. In early September it often brings early season snow flurries and light snowfalls to the Rockies and the Great Plains area adjacent to the mountains.

LOCAL EFFECTS:

A late summer type, the B-c can also bring an early outbreak of cool air with strong convective activity into the local area. As with the B-b type, the B-c may also result in the development of Hatteras Lows as the cold front moves into the Atlantic.

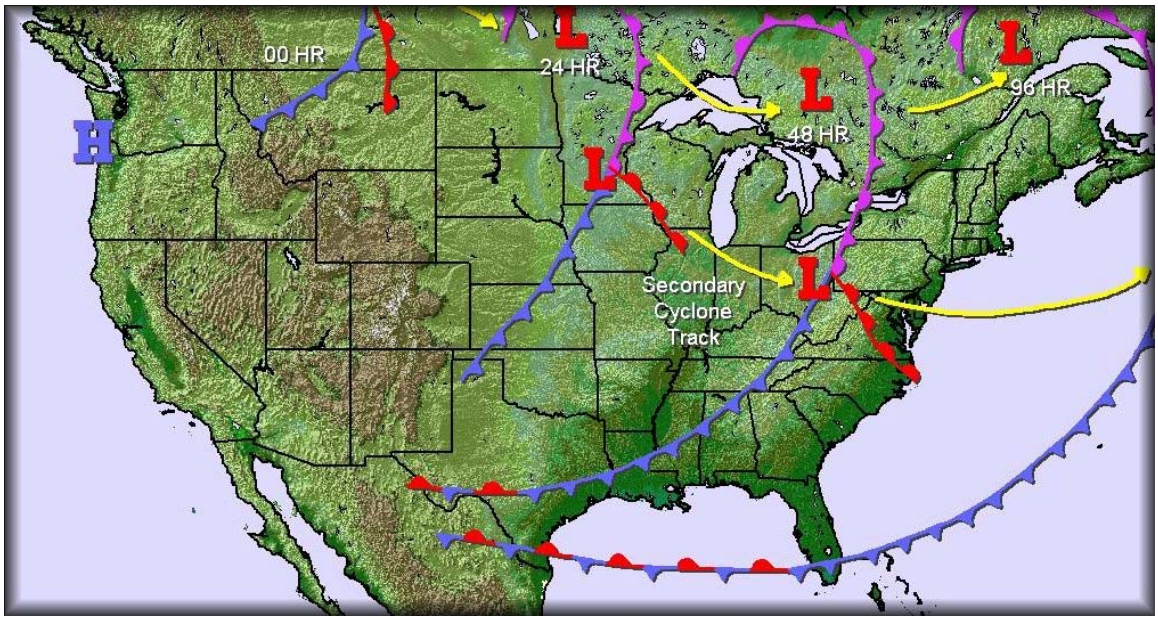


Figure 2-6 (North American Type B-c)

202.3 NORTH AMERICAN TYPE B (ZONAL)

CHARACTERISTICS:

1. This is the zonal-flow type of the systems discussed above, with the westerlies slightly north of normal latitudes. Pacific surface highs are found along the 30th parallel, with the eastern lobe of the high located near 135° W and the western lobe located near 175° W.

2. The upper flow is rather smooth from west to east with a slight trough off the west coast and one in the eastern U.S.

3. A surface low moves at about 15 degrees of longitude per day from the Sakhalin Islands to the Gulf of Alaska, where a weak stagnating low occurs. A separate low develops, and then moves through northern Canada with a southward trailing frontal zone.

4. These systems are followed by Pacific air masses except in eastern Canada, New England and the Mid-Atlantic states where a small amount of cP air moves down from the northern Canada.

5. The surface low intensifies as it reaches eastern Canada.

6. There are no cP intrusions from the Alberta area and only weak high pressure systems break-off from the semi-permanent high over the western U.S. plateau and move into the central Plains.

LOCAL EFFECTS:

Normally a summer type, the type B (zonal) is associated with high zonal index. The weather pattern moves rapidly eastward and produces relatively no inclement weather throughout the local area. The influx of a new air mass provides a welcomed change from the high humidities commonly found in the local area during the summer months.

202.4 NORTH AMERICAN TYPE D

CHARACTERISTICS:

1. There is a meridional flow with a major ridge aloft in the Pacific near 160° W and a trough near 130° W and 135° W with a minor ridge near 105° W and a minor trough near 80° W.

2. An unusual crescent shaped surface high is found over Alaska with one ridge extending southeastward toward Lake Superior and another extending southward from the Aleutian chain merging into the eastern lobe of the Pacific high.

3. A large semi-permanent low persists off the British Columbia coast.

4. Cyclonic "off-shots" move inland along the Washington and British Columbia border into Montana and then pass through the north central U.S.

5. A series of fronts crosses the west coast at the rate of about one per day bringing considerable amounts of precipitation and very cold air to the Pacific Northwest.

6. A polar outbreak into the central Plains follows each major low and frontal system as it passes eastward and intensifies in the Great Lakes region.

LOCAL EFFECTS:

The type D systems are more frequent during the winter months and produce another form of cold polar outbreak for the local area. Frontal passage produces periods of inclement weather, usually of short duration, in the Quantico area. These frontal passes are usually followed by clear, cold periods as the polar air mass moves over the area.

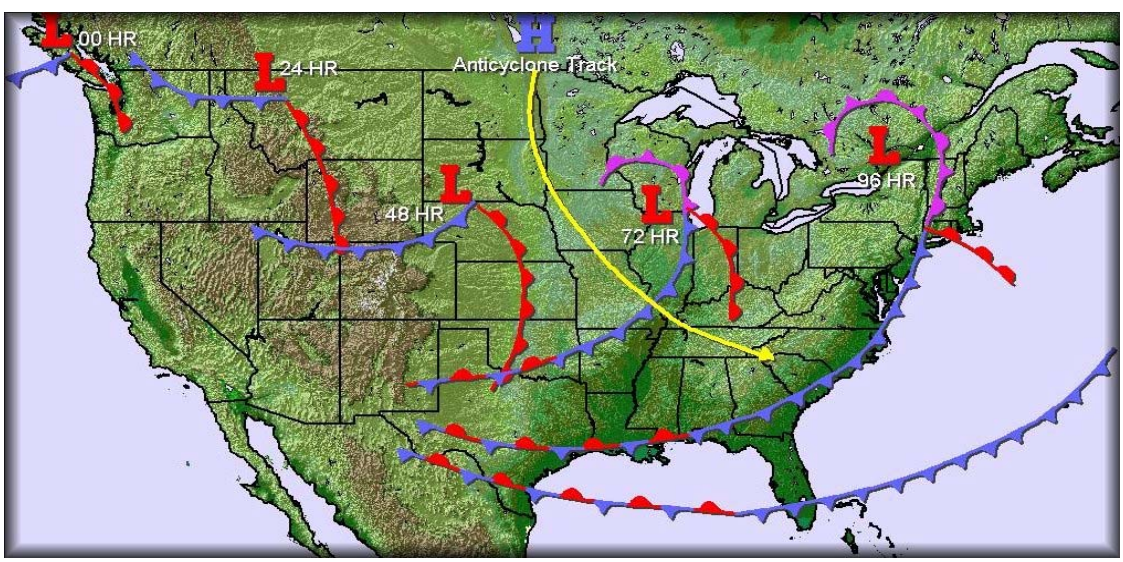


Figure 2-7 (North American Type D)

202.5 NORTH AMERICA TYPE C

The Great Basin High, so characteristic of the Type B systems, sometimes becomes displaced as far north as British Columbia. This permits storms to move across southern California and cause heavy rains and floods in the coastal plains. At this same time, Washington and Oregon have clear, dry weather; an unusual and infrequent occurrence. Simultaneously, filling lows enter Canada from the Gulf of Alaska and regenerate east of the Rockies. They then move as major storms across the lower Hudson Bay toward Labrador. There are two distinctive Type C setups; first a moderate high pressure system over the northern Basin and British Columbia, with storm tracks to the north and to the south is characteristic of the Cl type. Second, an exceptionally strong Basin High farther north over the Yukon characterizes the Ch type with northern storm tracks across the Arctic Ocean and another track in the south through southern California.

Both of these types are typical blocking patterns; i.e. high latitude highs of a persistent nature capped with warm ridges, or closed anticyclones aloft with split jets to the west and low latitude persistent troughs or cold lows aloft meridionally in phase with the warm ridges to the north.

202.5a NORTH AMERICAN TYPE Ch

1. A meridional flow type with a major ridge and closed high aloft exists near 130° W with a major trough near 75° W. Another low latitude trough exists near 115° W through 120° W, south of the major ridge.

2. A persistent surface high of at least 1040mb exists over northern British Columbia. Portions of this cold surface high move southeast and south as intense polar outbreaks along the Continental Divide. These block the eastward progression of southern California cyclones at New Mexico.

3. Persistent cyclonic activity occurs in the vicinity of northern Hudson Bay, northern Quebec, and the Maritime Provinces.

4. A cold front sweeps southward from Quebec across the eastern U.S. with a major polar outbreak spreading completely over the U.S. No cyclonic flow or frontal activity emanate from the Rockies with this type.

LOCAL EFFECTS:

A winter type, the Ch is rarely seen in other seasons. Because of the intensity of the polar outbreak, this type will cause the coldest weather in the Quantico area along with clear skies and windy conditions, as long as the surface flow is from the northwest.

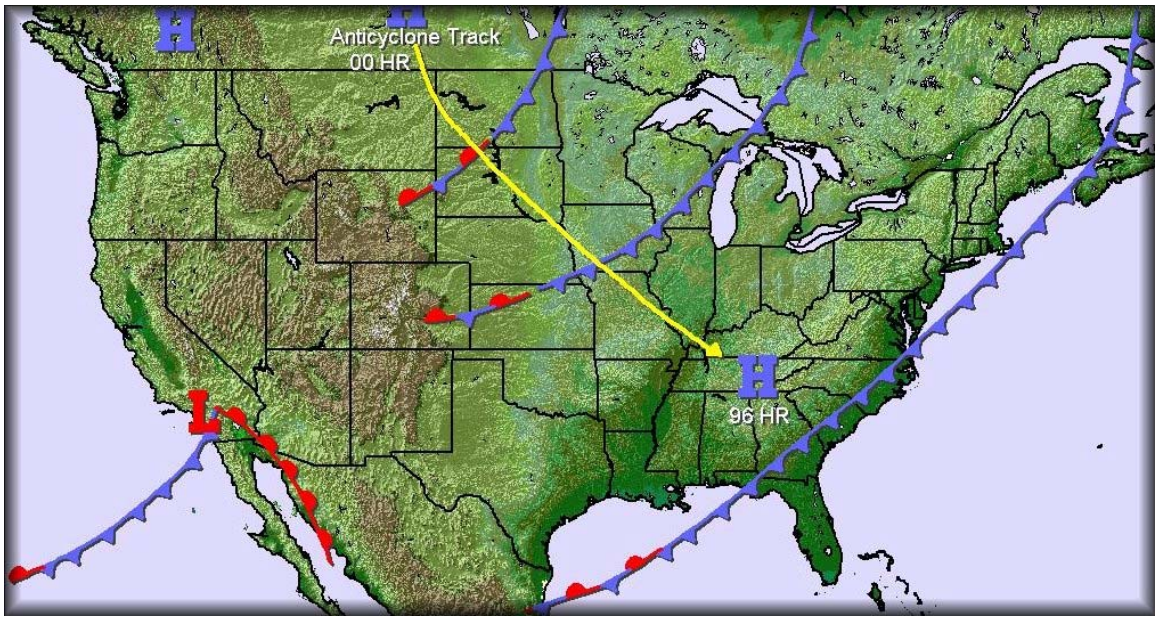


Figure 2-8 (North American Type Ch)

202.5b NORTH AMERICAN TYPE Cl

CHARACTERISTICS:

1. A major ridge aloft near 125° W and a trough aloft near 85° W exist. In the low latitudes a trough exists near 120°-125° W almost due south of the major ridge.

2. A Basin High persists over the Rockies in the northern U.S. The High migrates east-southeastward towards the Mid-Atlantic States and a new high immediately replacing it. No intense cP outbreaks occur with this type.

3. Two cyclone tracks are active, one from California across the Gulf States and another from southeastern Alaska across Canada. Canadian cyclones do not appreciably affect the weather pattern in the U.S. as the trailing fronts associated with this track are very diffuse. The southern cyclones produce the heaviest precipitation experienced in Southern California while the Pacific Northwest remains practically clear. The movement of cyclones on the southern track is very erratic.

LOCAL EFFECTS:

The Cl type is most frequent in winter and will cause copious amounts of precipitation, occasionally of the frozen variety in the Quantico area. Because the movement of the southern low is very erratic, particularly from the Gulf of Mexico, and eastward, the systems (especially their precipitation patterns) should be observed closely.

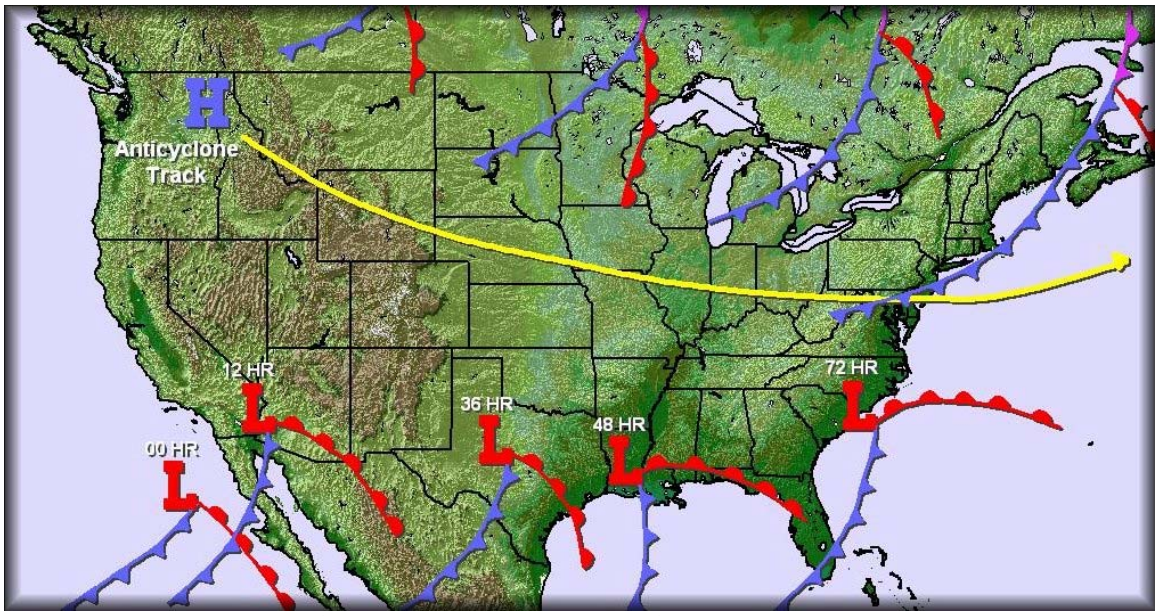


Figure 2-9 (North American Type Cl)

202.6 NORTH AMERICAN TYPE E (ZONAL)

In zonal flow types, there are no persistent large amplitude waves aloft and generally no pronounced outbreaks of cP air. Differences between zonal types are determined primarily by the mean latitude of the belt of strong westerlies. With the southward shift in the westerlies a band of extreme cold surface highs appear at higher latitudes. In the E types, the zonal flow is not stable and tends to break down into meridional flow patterns over North America. The El and Em types, when crossing the 105th meridian, are found respectively at 47° N and 40° N.

202.6a NORTH AMERICAN TYPE El

CHARACTERISTICS:

1. A weak, cold surface high persists over Alaska and northern California.

2. Lows enter the North American continent near Vancouver Island and the eastward track crosses the Continental Divide then dips southward through Nebraska.

3. As the system crosses the Rockies, cyclogenesis frequently occurs in the vicinity of the panhandle region of Texas with a new warm sector of mT air. This new storm moves northeastward to the Gulf of St. Lawrence.

4. Pacific air dominates the U.S. and cP air moves primarily eastward across southern Canada. When the air to the north of the storm track is exceptionally cold, the westerlies aloft are strong and the low moves eastward more rapidly than would be indicated. There is no cyclogenesis south of the low.

LOCAL EFFECTS:

This type typically occurs during early autumn and late spring. The type El systems and tracks are extremely significant to the local area when cyclogenesis occurs over the panhandle region. The high that moves across southern Canada typically slows down considerably, or "stalls" out over eastern Canada. The flow around this high brings cP air with northeasterly winds to the local area. This sets up a "damming" situation (discussed further in Section III/Cold Air Damming) ahead of the approaching warm front. Widespread IFR conditions and precipitation extend throughout the local area, and usually persist until passage of the cold front. The cold front tends to move slowly because the upper steering flow is relatively light and the belt of strong westerlies is farther north. Therefore the inclement weather can persist for up to three to four days. Skies begin to clear and temperatures cool off after cold frontal passage.

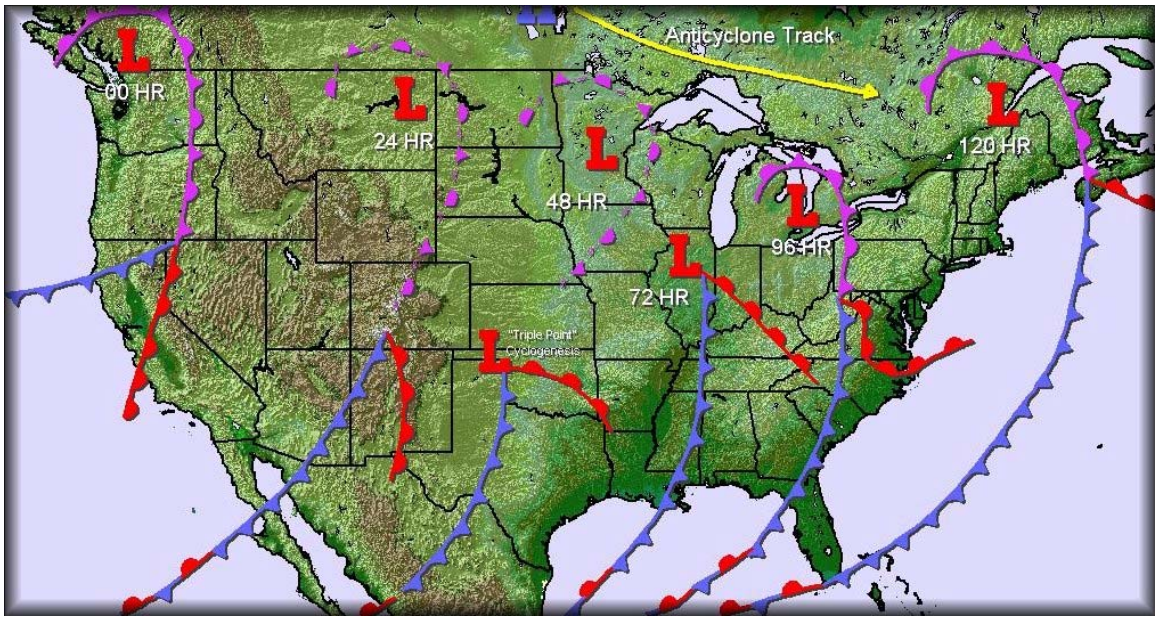


Figure 2-10 (North American Type El)

202.6b NORTH AMERICAN TYPE Em

CHARACTERISTICS:

1. The belt of westerlies aloft occurs farther south than with the El type, near the 35th parallel.

2. The storm track extends from Vancouver Island through the panhandle region and southern Missouri to New England.

3. A high of about 1035mb persists in northwestern Canada.

4. The low is continually pressed southward by the mass of cP air over Canada. A moderate cold outbreak follows the low into the Great Lakes region and New England.

LOCAL EFFECTS:

Frequently occurring in late winter and early spring, the Em type causes late snow events throughout the central U.S. Normally the storm track will remain far enough north of Quantico that it will have little, if any, effects upon the local area. However, with a more southerly track this type will cause widespread "wintry" precipitation throughout the Quantico area.

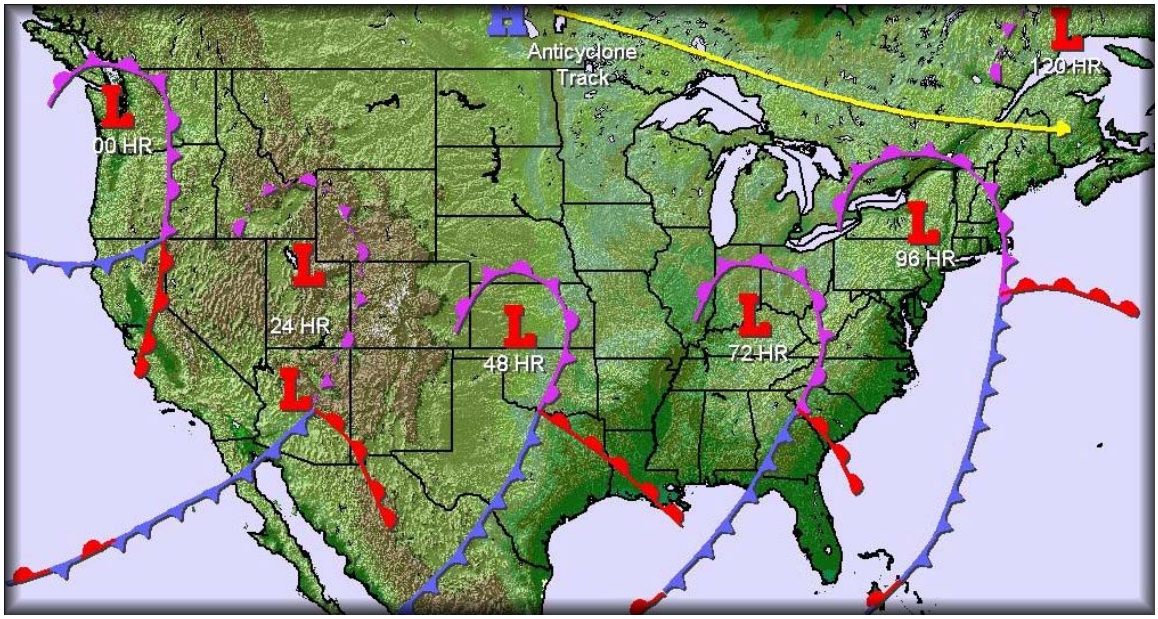


Figure 2-11 (North American Type Em)

202.7 EASTERN U.S. TYPES

It has been mentioned previously that waves, which develop in the Gulf and move northeasterly, seriously affect the weather along the Eastern Seaboard. Ga and Gb types fall into this category. One of the characteristic features of these types is that, after moving out of the Gulf area, they may leave a trailing frontal zone in the Gulf of Mexico, which lingers until the next system moves in. As the frontal trough of the next type moves eastward, the divergence aloft often causes cyclogenesis on the Gulf front. One of the basic differences between the two types is that the Ga’s track is to the west of the Appalachians and the Gb’s track is to the east of the mountains.

Occurring throughout the year, but most significant in the spring and early summer, are the stagnant highs over the Midwest and Northeastern States. They are produced by the cold waters of the Hudson Bay. Lows moving in from the west are shunted southward around the high. This characterizes the Ha systems. Weak to moderate outbreaks accompanying these highs often result in a stagnant front through the central U.S. During the summer the high, or a portion of it, moves almost due south along the East Coast and appears to merge to merge with the Bermuda High. This scenario characterizes the Hb type.

202.7a EASTERN U.S. TYPE Ga

CHARACTERISTICS:

1. An upper level trough is located off the Eastern Seaboard, which is usually progressive due to its short wave length. An upper level ridge exists between 110° and 130° W.

2. A wave forms on a quasi-stationary front near the Texas coast with the approach of a new frontal trough from the west. This new low deepens and moves northeastward on a path just west of the Appalachians and is accompanied by widespread precipitation to the north.

3. This type is most frequent in the winter and spring. The worst weather occurs to the north and west of the low center and generally includes mixed precipitation. Rain, drizzle, and fog dominate east of the Appalachians.

LOCAL EFFECTS:

This system must be closely observed for a possible, more easterly shift in its track and for secondary cyclogenesis to the south of the Appalachians. The introduction of cold air advection into the northeast sector of the low becomes a significant freezing rain and/or snow situation to the north of the warm front and a more easterly track would pose a significant threat to the Quantico area.

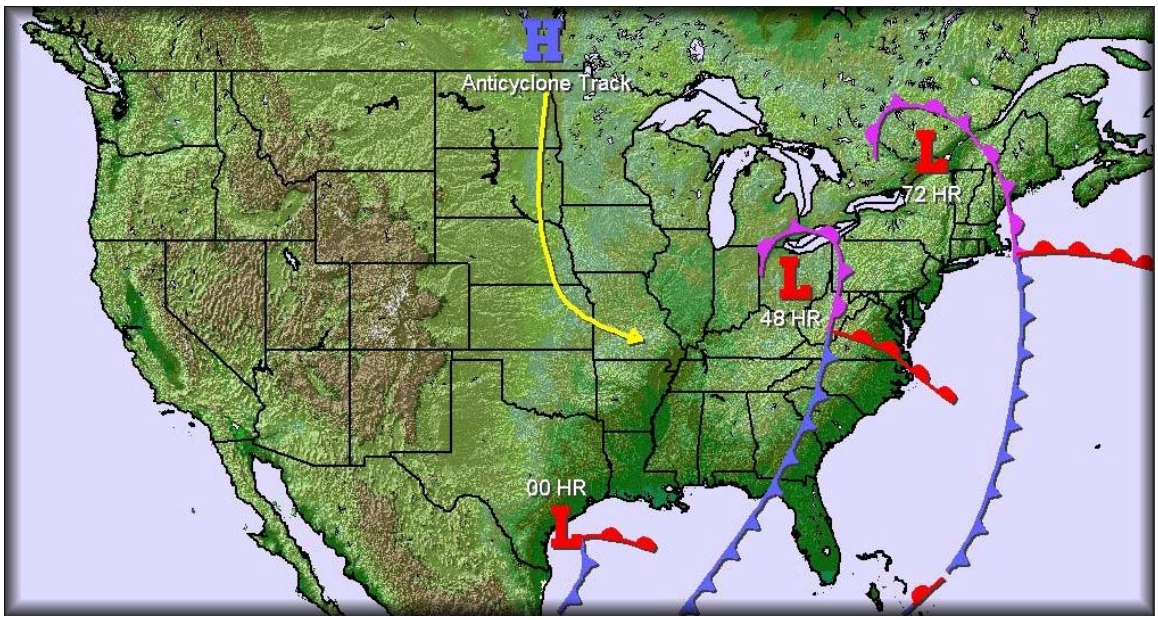


Figure 2-12 (Eastern US Type Ga)

202.7b EASTERN U.S. TYPE Gb

CHARACTERISTICS:

1. A sharp ridge is located near 100° W with a trough just east of the Appalachians, or along the East Coast. The exact location of the trough is extremely significant since a difference of a few hundred miles in location means the difference between a stable wave and a Hatteras Low.

2. A wave forms on a quasi-stationary front in the eastern Gulf of Mexico due to the approach of another upper trough from the west.

3. When the wave moves northeastward, maintaining a track over land, they generally remain stable. With an east-northeast track, new cyclogenesis will occur in the vicinity of Cape Hatteras. Immediately after this occurs the Hatteras Low becomes dominate, rapidly deepens and advances rapidly northeastward along the coast.

LOCAL EFFECTS:

This type is most frequent in the winter, and produces New England's "Nor'easters". It accounts for most of the snowfall which occurs over the local area and southward along the coastal plains. To the north it may or may not produce heavy snowstorms dependent upon the proximity of the low center to the coast. If the center remains over land as it moves northeastward it also derives more energy from the warm coastal waters. Of critical importance is the source and strength of the cold air advection to the north of the low. These types must be closely monitored as it can significantly affect the Quantico area.

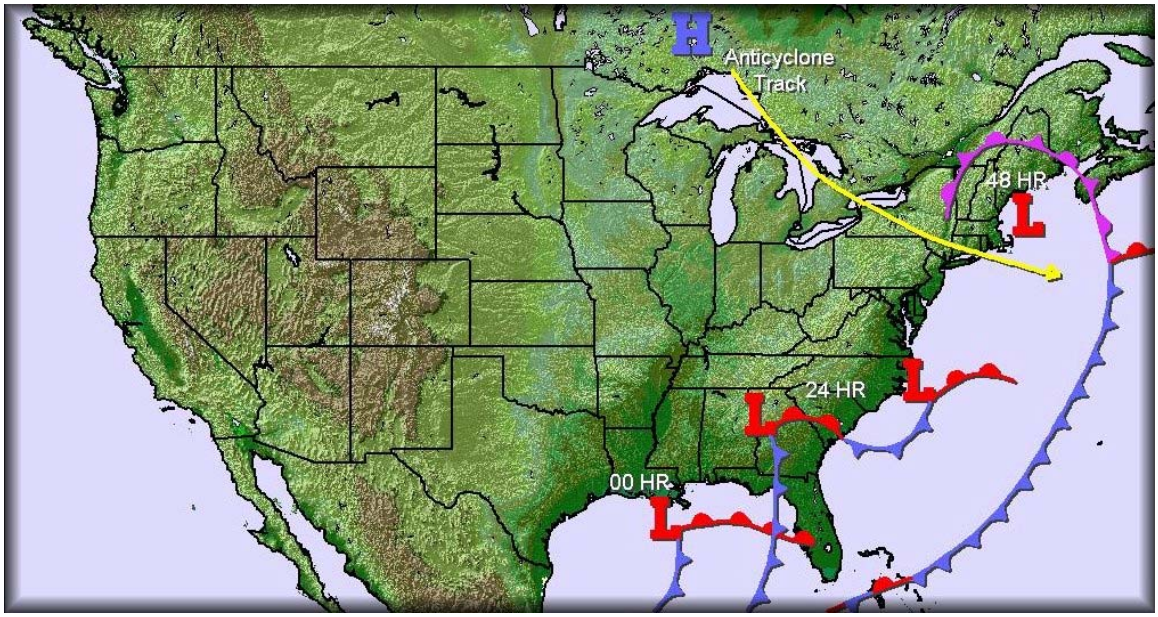


Figure 2-13 (Eastern US Type Gb)

202.7c EASTERN U.S. TYPE Ha

CHARACTERISTICS:

1. A slight ridge aloft is located near 95°-100° W. A weak trough exists along, or off the East Coast with a weak trough in the western U.S.

2. A persistent surface high over the Hudson Bay extends southward with a separate center over the Great Lakes.

3. Surface Low movements are quite erratic but are deflected by the stationary high extending from the Hudson Bay.

LOCAL EFFECTS:

This type is most frequent in the late winter and in spring. It usually causes poor flying conditions and inclement weather for extended periods as waves develop on the front and move from west to east. Another factor to pay close attention to with this system is that the High over the Great Lakes is a source of cold air advection down the Eastern Seaboard. The track of the low can provide significant warm, moist air overrunning this cold air at the surface. Such a combination can result in heavy snow or freezing rain.

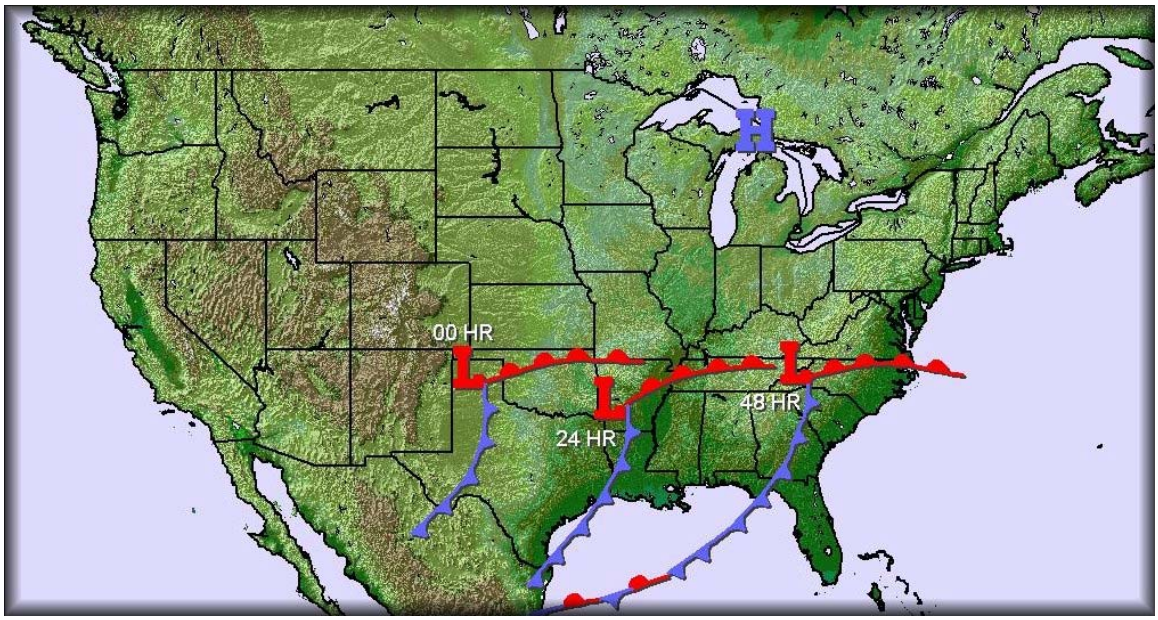


Figure 2-14 (Eastern US Type Ha)

202.7d EASTERN U.S. TYPE Hb

1. Anticyclonic circulation persists over most of the U.S.

2. The Bermuda High is quite strong and blocks frontal systems invading the southeastern U.S., which remains hot and humid.

3. An east-west quasi-stationary front exists in the Mid-Atlantic States with cool dry air to its north. A sharp temperature

contrast may exist across the front, producing numerous thunderstorms.

4. Warm fronts associated with this type are not very well defined and not very common. The layer of cold air to the north of the front is extremely shallow and may be wiped out by daytime surface heating. This gives the appearance of a rapid northward jump of the warm front during the day. The contrast existing between the air masses, across the warm front, is generally slight.

LOCAL EFFECTS:

The mean position of the quasi-stationary frontal system associated with the Hb type is between Washington D.C. and Norfolk. Forecasting the movement to the north or south of Quantico is extremely important because of the persistent inclement weather encountered in and to the north of the frontal zone. The Hb type falls into the category of the "East Coast Wedge Front" which is more commonly known as a "Back Door Cold Front".

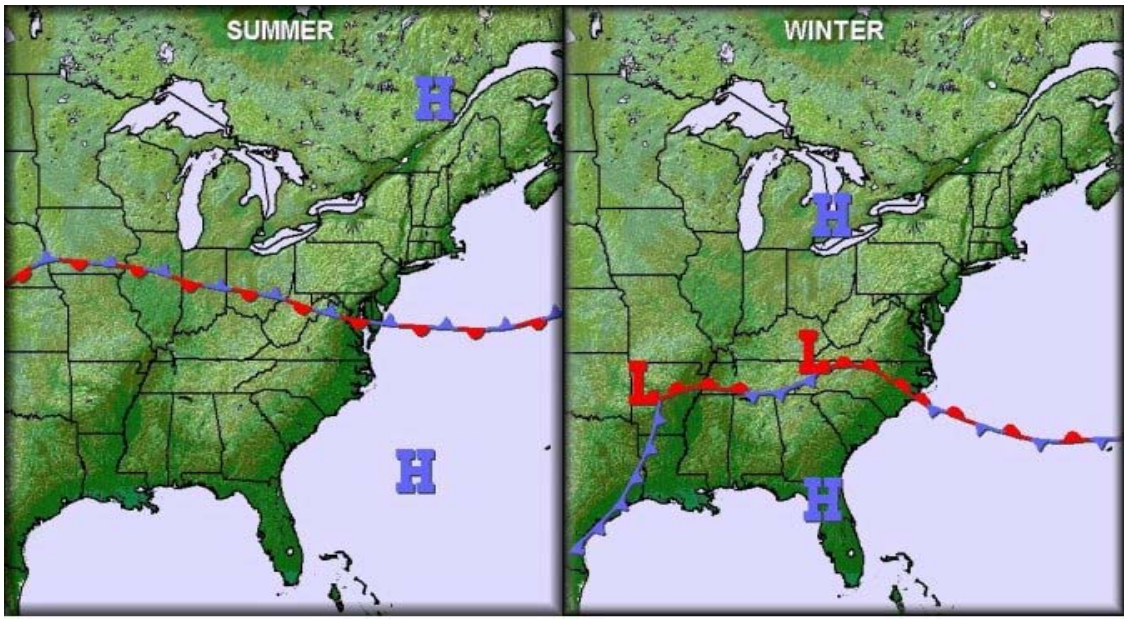


Figure 2-15 (Eastern US Type Hb Summer/Winter Scenarios)

202.8 HATTERAS LOWS

With the exception of tropical lows, which first appear in the Tropical Atlantic, practically all storms that form in the southwestern North Atlantic are of the Hatteras Low type, and usually form in one of the following ways:

1. When the Bermuda High is stationary and is well developed or intensifying, an approaching low pressure trough and associated cold front from the west will be blocked by the Bermuda High, giving rise to ideal conditions for the formation of a Hatteras Low, if the 700mb chart contours are parallel to the cold front.

2. The following factors are conducive to the formation of a secondary low on the warm front in the Hatteras area:

   A. A well developed Bermuda High existing over the Gulf of Mexico and the southeastern states.

   B. A quasi-stationary front oriented east-west across the waters near Cape Hatteras, becoming a warm front and extending westward to a low center. The following criteria are necessary for the formation of a Hatteras Low; mP or cP/mP air along the Eastern Seaboard north of the front, with a narrow wedge of high pressure east of the Appalachians.

3. Hatteras Lows also form on weak stationary fronts associated with the warm, moist air from the Bermuda High, which occasionally lies off the South Carolina coast.

202.8a HATTERAS LOW TYPE A

CHARACTERISTICS:

1. A cold anticyclone covers most of the U.S. east of the Rockies. The cold continental air mass is flowing off the continent. A current of warm maritime air is flowing from a southerly or southwesterly direction, opposed to the flow of the cold air.

2. A portion of the trailing cold front is retarded between these opposing surface air flows and is distorted into a wave form. The 700mb contours must be parallel to the front in order for this to occur. It has been noted that cyclonic development in the Hatteras region is generally accompanied by an upper level short wave trough over the area.

3. In many cases the Type A does not have much impact on the weather at coastal stations because they originate over the ocean and move northeastward.

4. Type A is most frequent in November, dropping to a minimum frequency in January, and reaching a second maximum in March.

5. The mean point of origin of the Type A is slightly east of the temperature axis of the Gulf Stream near 32° N latitude.

LOCAL EFFECTS:

The coastal region will have experienced a cold frontal passage within the past day or two before Type A cyclogenesis occurs. The presence of warm front type clouds and precipitation spreading north of the retarded portion of the cold front is a significant indication of Type A development. It has also been observed that with this and other coastal lows moving northward along the Atlantic coast that an inverted trough will frequently develop to the north, in advance of the low center. The inverted trough will distort the wind flow to a more northeasterly direction, which can change rain to snow due to increased cold air advection.

Figure 2-16 (Hatteras Low Type A)

202.8b HATTERAS LOW TYPE B

CHARCTERSTICS:

1. An occluding or occluded primary cyclone in the Great Lakes region is nearly stationary or moving northeastward. A shallow wedge of cold continental air lies between the Appalachians and the Gulf Stream from a cold anticyclone centered in eastern Canada or over the Grand Banks. Warm maritime air is overrunning this cold wedge.

2. The secondary low forms near the coastline to the southeast of the primary low and along the warm front, or what appears to be the warm front of the older storm. There is a spreading of precipitation and stable type clouds over the cold wedge, partially separated from the cloud and precipitation area of the primary low.

3. The Type B is not readily identifiable by the cloud sequence because the same sequence is expected to appear ahead of the approaching primary cyclone. Close attention must be paid to the synoptic pattern of middle clouds of the primary system and the developing secondary system. If the secondary system develops close to the primary system the separation of the cloud systems is not noticeable.

4. Sometimes there are two distinct precipitation areas when the Type B system is developing. Sometimes the two distinct precipitation areas are so vast or move so rapid over the coastal region that it could not be due solely to the movement of the primary system.
5. The isallobaric pattern should also be carefully studied in relation to the movement and development of the two systems. An area, or line, of maximum pressure falls not associated with the

moving center or trough of the primary cyclone is an indisputable sign of Type B development.

6. The Type B is most frequent in January, dropping to a minimum frequency in February, and reaching a secondary maximum in March.

7. The Type B shows two areas of favored development, the primary near Norfolk and the other south of Cape Cod.

LOCAL EFFECTS:

The Type B affects the weather along the coast more than the Type A. As the cold air at the surface is already present in the Quantico area with the Type B, the Hatteras Low will further enhance the cold air advection and warm air overrunning, and can cause very heavy snowfall.

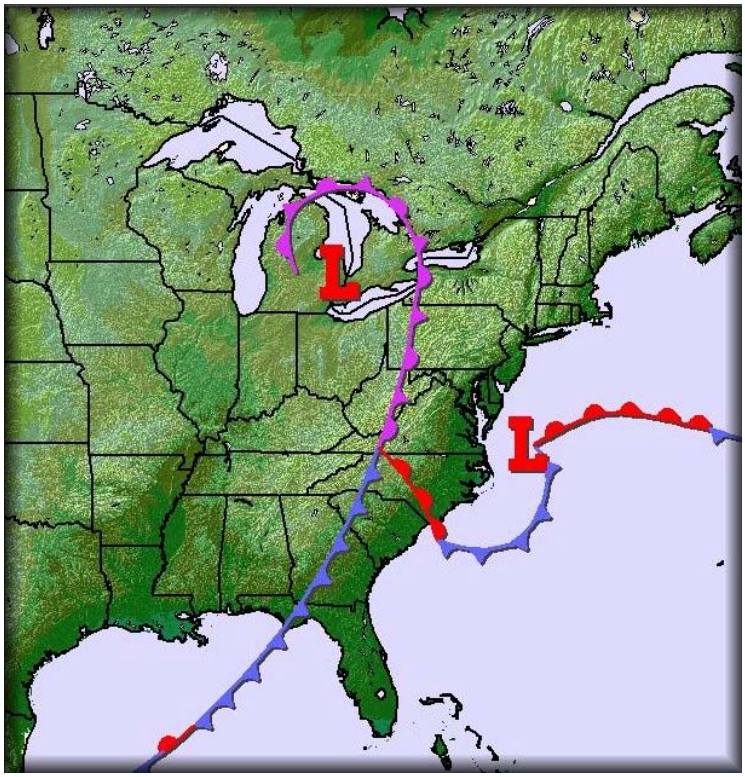


Figure 2-17 (Hatteras Low Type B)

203.0 TROPICAL STORMS AND HURRICANES

Tropical storms/hurricanes occasionally pose a threat to the Quantico area. Several factors, however, reduce the risk of a head on strike from these types of storms. First is the fact that Quantico is situated at such a high latitude. Second is the fact that Quantico is located so far inland from the Atlantic coastline. Tropical systems that approach the Quantico area usually fall under two categories; first a lot of storms that approach the area follow a typical track that re-curves out to sea. Second, a lot of storms that approach the area have already made land fall and begin to weaken immediately, as the storm weakens so does the chance for large scale damage. Nevertheless, the occurrence of these storms should never be taken lightly. Strong winds

and torrential rains associated with these systems can pose a significant threat to the Air Facility. First, the Air Facility sits on relatively flat land and there is little in the way of terrain that offers shielding from strong winds. All structures aboard the Air Facility are subject to wind damage. As with winds, torrential rain associated with these systems poses isolated, local flooding threat to areas on the Air Facility. The rest of MCB Quantico lies well above sea-level, so the risk of flooding is reduced. The Air Facility, however, is surrounded by water, and sits at just 11 feet above MSL. The torrential rains accompanying these storms can and will accumulate and flood in isolated areas. Storm surge does not typically pose a threat to the Air Facility, mainly due to the fact that it sits so far inland from the main coastline. There is, however, another phenomenon that can cause massive flooding aboard the Air Facility. Storms that have a center, which upon its closest approach to Quantico is located to the west of the Air Facility, should be watched closely. Several factors contribute to the threat of severe flooding aboard the Air Facility. First, with the closest point of approach being to the west, the winds experienced in the local area will become primarily southeasterly. This southeasterly flows "drags" with it water and funnels it up the Chesapeake Bay and into surrounding rivers, including the Potomac. This can cause rivers to rise close to flood stages. Second, close attention should be paid to the tides. The occurrence of high tide during the time of this type of scenario can greatly add to the threat of severe flooding. Coupled with torrential rains, if all these factors are in place, the chance for flooding aboard the Air Facility is greatly increased. The pictures below are evidence of the effects of this scenario and how it can impact the Air Facility. Images 2-22 - 2-24 show the average tropical cyclone tracks from 1945 through 1997 for August through October.

Figure 2-18

Figure 2-19

Figure 2-20

Figure 2-21

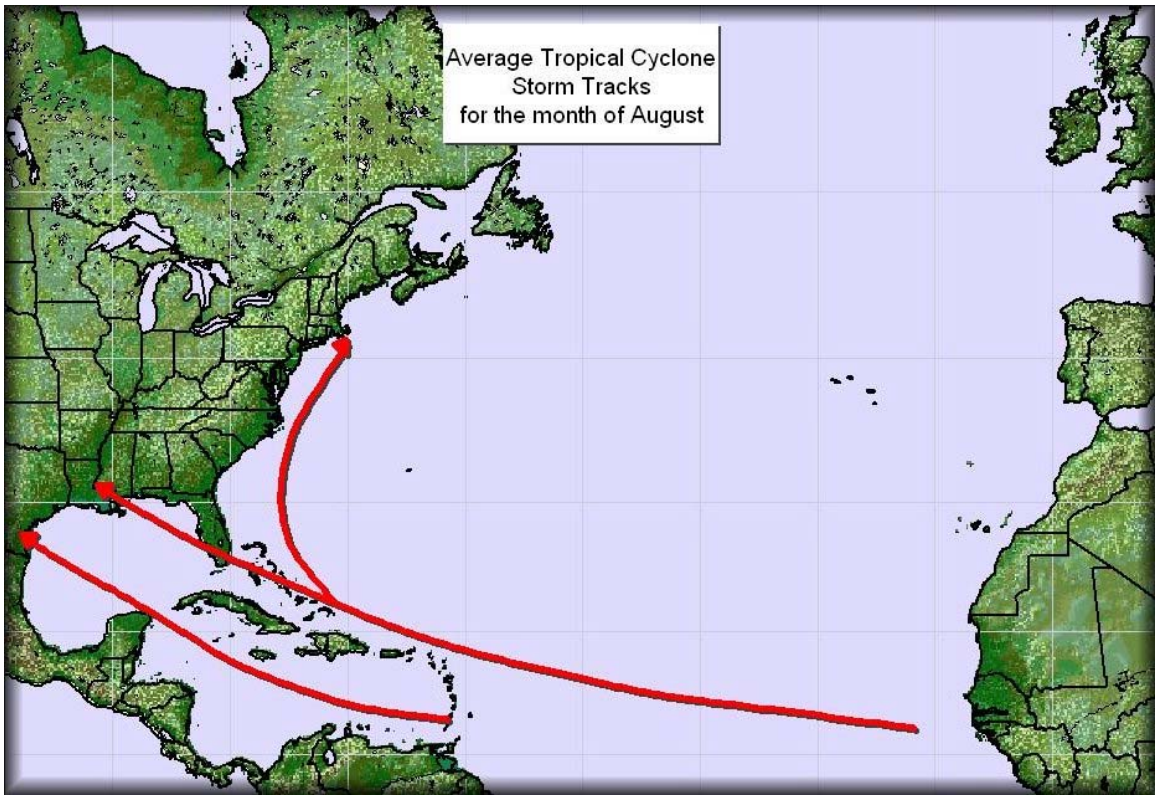


Figure 2-22 (August Tropical Cyclone Tracks)

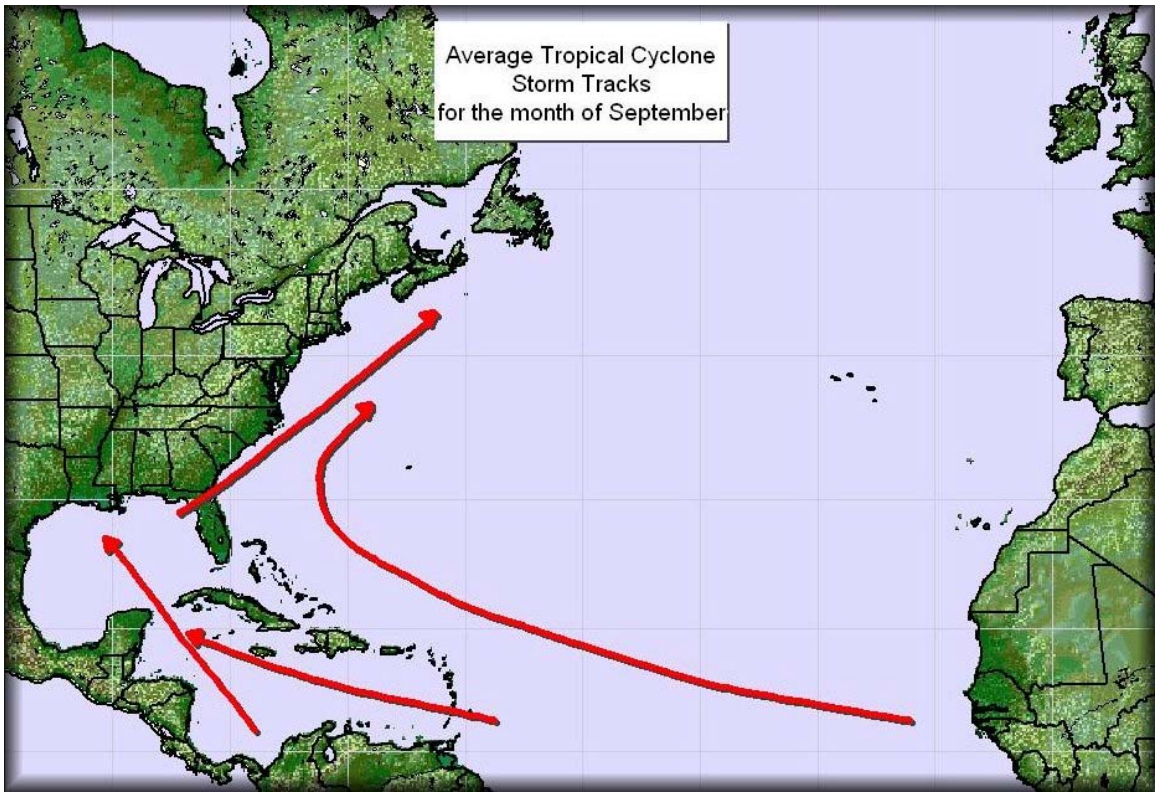


Figure 2-23 (September Tropical Cyclone Tracks)

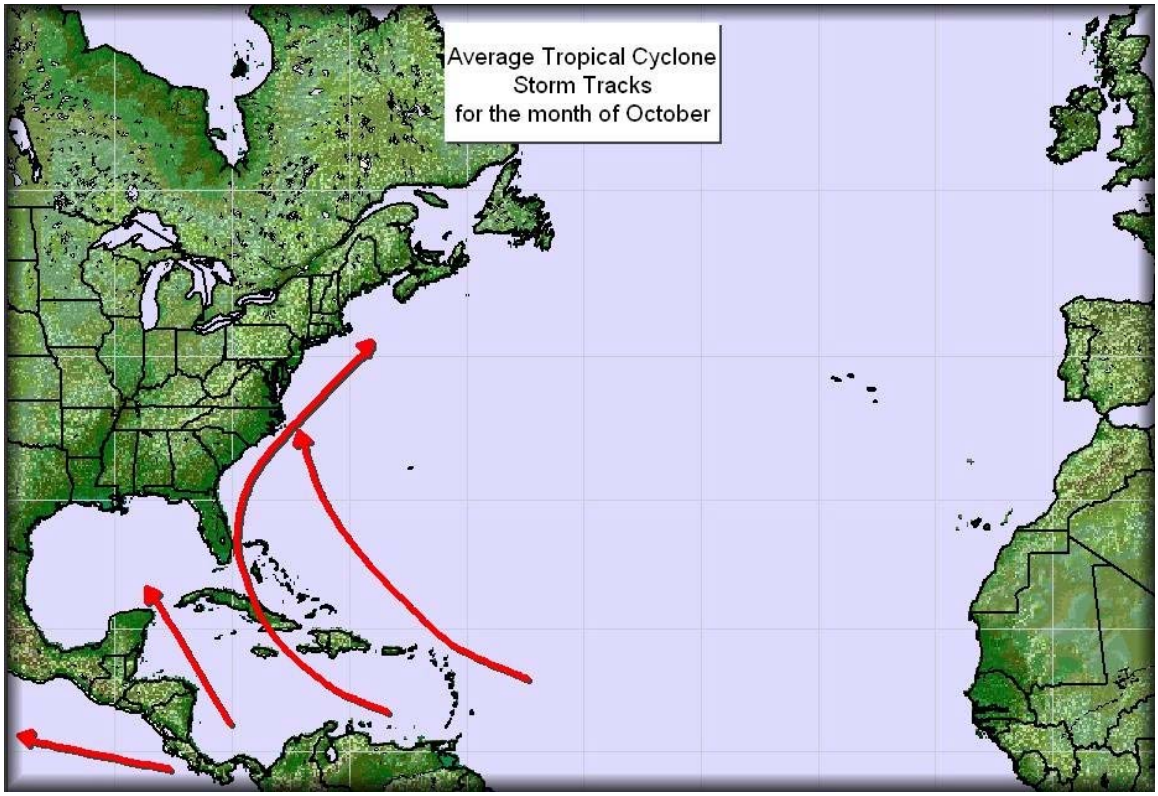


Figure 2-24 (October Tropical Cyclone Tracks)

SECTION 3

300.0 FORECASTING

The skills required for forecasting and analysis come from intensive initial training and grow by experience and practice. In order to better one's skills, a forecaster must always be willing to learn by doing, and by evaluating past forecasts. It is inevitable that at one point or another in a forecaster's career that one or more of his/her forecast(s) will not materialize as expected. The desire to learn from these shortcomings is what separates good forecasters from great forecasters.

The best forecasters use every product at their disposal. Every forecaster's process in developing their own opinions should begin with a review of the weather over the past 24 hours. This should then be followed up by an analysis of all current data and an interpretation of all forecast products. A constant watch of all available data must be observed; including but not limited to: Current observations, satellite and radar imagery, upper air soundings, etc. All data must be monitored on a continuous basis; forecasting is an ever-changing process and the forecaster's process should change to adapt to the current trend of the weather pattern. If these guidelines are followed, the result will be a well-rounded forecast with the forecaster increasing his own knowledge and gaining invaluable experience.

The following parts in this section describe some of the various weather events that occur in the Quantico area and some techniques used to aid in the forecasting of them. These techniques should only be used as a guideline.

301.0 THUNDERSTORMS

301.1 AIR MASS THUNDERSTORMS

The most predominate type of thunderstorms that occur in the Quantico area. The season for air mass thunderstorms begins in late April and runs through early October, with the greatest frequency occurring from late May through early September. During this period, the Bermuda High frequently ridges westward and creates extended period of hot and humid conditions to the Mid-Atlantic region. If the Bermuda High ridges to far westward, then moisture from the Gulf of Mexico will be transported across the Central CONUS, and the moisture along the eastern seaboard will generally be insufficient to sustain thunderstorm development. If, however, the Bermuda High does no ridge that far west, or weakens and shifts eastward, moisture from the Gulf of Mexico will then be transported along the Eastern CONUS and into the local area. In general, for air mass thunderstorms to occur there must be a moist layer from the surface to about 700mb.

These thunderstorms will typically form along the slopes of the Blue Ridge Mountains during the late afternoon hours at the time of maximum surface heating, when dew points are greater than 70°F. As a general rule of thumb, these storms will move in an east-northeast direction, following the general flow pattern of the steering level. The steering level found to be most useful is the mean wind vector between 10,000ft

and 20,000ft when the average velocity is greater than 10 knots. These storms have a tendency to increase in intensity as they move across the warmer waters of the Potomac River during the summer, and generally dissipate between the hours of 2300 and 0100 local standard time. Refer to Appendix A for an Airmass Thunderstorm Worksheet.

301.2 FRONTS AND TROUGHS

During the summer, the occurrence of thunderstorms in conjunction with the passage of a cold front or short wave trough should be assumed until some other reason is determined as to why they should not occur. A cold front need not have any temperature difference across it in order for its mechanical lifting of warm, moist air to trigger thunderstorm development. Likewise, a short wave trough will also induce the additional vertical lifting to increase instability to the thunderstorm threshold. Generally, the factors that inhibit thunderstorm development with summer cold fronts and short wave troughs are insufficient vertical moisture or abnormally cool surface temperatures.

The prerequisite for winter thunderstorm development is a strong temperature contrast between two adjoining masses of air. Therefore, the development of winter thunderstorms is very rare.

301.3 LEESIDE TROUGH

A leeside trough may develop at any time of the year when conditions are right. Ideal conditions exist with westerly flow aloft (particularly 850-700mb) across the mountains. However, during the summer months when the atmosphere is warm, moist, and primed for convection, some of the most severe thunderstorms experienced in the Quantico area can develop due to the existence of a leeside trough. The first indication that a leeside trough has developed is cyclonic turning of the surface winds on the leeside of the Blue Ridge Mountains. Any convection that develops along the Appalachian Mountains should be watched carefully when a leeside trough is present. The greatest chance for severe weather development in a leeside trough situation is during the late afternoon hours, when temperatures are at their warmest and surface dew points are above 70°F. Forecasters should also monitor the upper levels for a cold pocket (preferably at 500mb); considering all other parameters are in place for convection, a cold pocket at 500mb will only steepen lapse rates and further destabilize the atmosphere. With all these factors in place severe thunderstorm development is highly likely.

301.4 STABILITY INDICIES

There are many stability indices that attempt to numerically state the stability of the atmosphere and the probability of thunderstorms. Most of these values are calculated by using the most current upper air data. Therefore, risk should be taken when basing a forecast off of these values as the current data may not be representative of the atmosphere when thunderstorms are expected to occur. Recently, forecast Skew-T soundings have been developed that incorporate model data into them; as the models improve, so does the accuracy of the forecasts. When using the values shown in the various tables below, you should not base your forecast off of just one or two of the

different indexes. Sound forecasting techniques should be applied when determining whether or not to rely on this data for forecasted thunderstorm development.

301.4a LIFTED INDEX (LI)

This is an index used to determine the stability of the lower half of the troposphere. An air parcel is lifted from the surface with temperature and mixing ratios representative of the mean layer values of the lowest 100mb of the atmosphere. This is done in order to capture low level boundary layer temperature and moisture conditions while reducing diurnal effects. This hypothetical parcel is then lifted dry adiabatically to the LCL and pseudo-adiabatically to 500mb. The value of this index is the temperature of the environment subtracted from the temperature of the parcel at 500mb. The risk of thunderstorms and severe weather activity is defined as follows:

LIFTED INDEX (LI) VALUE	**EXPECTED CONVECTIVE ACTIVITY**
LI > 2	NO SIGNIFICANT ACTIVITY
2 > LI > 0	SHOWERS/TSTMS POSS W/ OTHER SOURCE OF LIFT
0 > LI > -2	THUNDERSTORMS POSSIBLE
-2 > LI > -4	TSTMS MORE PROBABLE BUT FEW, IF ANY, SEVERE
-4 > LI	SEVERE THUNDERSTORMS POSSIBLE

301.4b SHOWALTER INDEX (SI)

This is an index used to determine the stability of the lower half of the troposphere. An air parcel is lifted from an initial position at 850mb where localized low level influences are greatly reduced. It is lifted dry adiabatically to its LCL and then pseudo-adiabatically to 500mb. The environmental temperature is then subtracted from the parcel temperature to obtain the value of the Showalter index. The risk of severe weather activity is defined as follows:

SHOWALTER INDEX (SI) VALUE	**EXPECTED CONVECTIVE ACTIVITY**
SI > 3	NO SIGNIFICANT ACTIVITY
3 > SI > 1	SHOWERS POSSIBLE W/ OTHER SOURCE OF LIFT
1 > SI > -2	THUNDERSTORMS POSSIBLE (GENERALLY WEAK)
-2 > SI > -3	THUNDERSTORMS MORE PROBABLE (POSSIBLY STRONG)
-3 > SI > -6	STRONG OR SEVERE THUNDERSTORMS POSSIBLE
-6 > SI	STRONG OR SEVERE THUNDERSTORMS LIKELY

301.4c TOTAL TOTALS INDEX (TT)

The Total-Totals index (TT) is an index of atmospheric instability composed of two indices: the Cross Total (CT) and the Vertical Total (VT). The CT is a measure of how buoyant the air parcel is due to less dense, moist air in the lower levels. It is defined as the difference between the 850mb dew point temperature and the 500mb temperature. The

VT is a measure of how buoyant the air parcel is due to warm air at lower levels. It is defined as the difference between the 850mb temperature and the 500mb temperature. The sum of the CT and VT is the TT index. The VT deals with the thermal difference while the CT takes into account the amount of moisture present. Hence, the three main factors in obtaining high TT index values are the following: a high 850mb temperature, a high 850mb dew point temperature, and a low 500mb temperature. The risk of severe weather activity is defined as follows:

TOTAL TOTALS INDEX (TT) VALUE	**CONVECTIVE ACTIVITY EXPECTED**
44 – 45	ISOLATED MODERATE THUNDERSTORMS
46 – 47	SCATTERED MODERATE/A FEW HEAVY THUNDERSTORMS
48 – 49	SCATTERED MODERATE/A FEW HEAVY/ ISOLATED SEVERE THUNDERSTORMS
50 – 51	SCATTERED HEAVY/A FEW SEVERE THUNDERSTORMS AND ISOLATED TORNADOES
52 – 55	SCATTERED TO NUMEROUS HEAVY/ FEW TO SCATTERED SEVERE THUNDERSTORMS/ FEW TORNADOES
> 55	NUMEROUS HEAVY/SCATTERED SEVERE THUNDERSTORMS AND SCATTERED TORNADOES

301.4d K INDEX (KI)

The K index is similar to Total Totals index except that it takes into account moist air at 700mb contributing to air mass thunderstorm development. The K index is defined as follows:

KI = T850 - T500 + Td850 - (T700 - Td700)

Where T850 is the 850mb temperature, Td850 is the 850mb dew point temperature, T700 is the 700mb temperature, Td700 is the 700mb dew point temperature, and T500 is the 500mb temperature.

The risk of air mass thunderstorms is defined as follows:

K INDEX (KI) VALUE	**AIR MASS THUNDERSTORM PROBABILITY**
< 15	0%
15 – 20	< 20%
21 – 25	20 – 40%
26 – 30	40 – 60%
31 – 35	60 – 80%
36 – 40	80 – 90%
> 40	> 90%

301.4e SWEAT (***S***EVERE ***W***EATHER THR***EAT***) INDEX

This is a United States Air Force index that takes into account thermal instability, low level moisture content, vertical wind shear and horizontal wind speeds. The risk of severe weather activity is defined as follows:

SWEAT INDEX VALUE	CONVECTIVE ACTIVITY EXPECTED
SWEAT < 300	NONE
300 < SW < 400	ISOLATED MODERATE TO HEAVY THUNDERSTORMS
400 < SWEAT < 500	SEVER THUNDERSTORMS AND TORNADOES PROBABLE
SW > 500	SEVERE THUNDERSTORMS AND TORNADOES LIKELY

301.5 TORNADOES

The occurrence of tornadoes in the Quantico area is rare, however, there have been several observed in the local area. Forecasting for tornado development is extremely difficult so the forecaster must be ever vigilant in convective weather, paying close attention to current surface observations, vertical wind shear profiles, and weather radar interpretation. Any severe thunderstorm is capable of producing a tornado, but not all severe thunderstorms will develop a tornado. An in-depth knowledge of weather radar interpretation will greatly aid in the forecasting of tornado development and the dissemination of appropriate weather warnings.

301.6 HAIL

Like tornadoes, the occurrence of hail in the local area is rare but not unimaginable. And, like tornadoes, it is difficult to forecast for the exact location and size of hail. Any thunderstorm is capable of producing hail; however, hail is most common with super cell thunderstorms. There are a couple of methods that have proven to work quite well in aiding in the determination of hail size. First is by utilizing the height of the wet bulb zero (WBZ) from the Skew-T. The WBZ height is the freezing level that will result due to evaporational cooling. WBZ heights between 5,000 - 12,000FT AGL are generally associated with hail that reaches the surface. The best potential for large hail (≥3/4") is with a WBZ height from 7,000 - 10,000FT AGL. The size of hail rapidly diminishes with WBZ heights of less than 6,000FT and greater than 11,000FT. With WBZ heights of less than 6,00FT the warm layer in which rain drops form (rain drops eventually form hail) is very shallow. The shallow warm layer inhibits the amount of collision-coalescence that occurs between liquid water and hail necessary to increase hail size. With WBZ heights greater than 11,000FT the cold layer in which hail is to form is very small and any hail that does form may melt completely from falling through such a large warm layer.

Another reliable method for determining hail size is the Fawbush-Miller method utilizing the Skew-T diagram as described below.

1. Determine the Convective Condensation Level (CCL).

2. The moist adiabat that intersects the CCL is then traced up to the pressure level where the dry bulb air temperature is -5°C.

3. This pressure level, the dry bulb temperature curve, and the moist adiabat intersecting with the CCL form a triangle which outlines a positive area.

4. The base of the triangle is then used to determine the horizontal and vertical coordinates needed to determine hail size.

a. The horizontal coordinate is equivalent to the length of the horizontal side of the triangle in °C. (example, 5°C = a horizontal coordinate of 5)

b. The vertical coordinate is equivalent to the length of the dry adiabat, in °C, through the triangle measured from the pressure level at the base of the triangle to the pressure level of the CCL.

5. These values are then used to determine the expected hail size by utilizing the Fawbush-Miller graph in image 3-2. If the WBZ height is above 10,500FT, utilize the graph in image 3-3. Refer to figure 3-?? for a visual reference of the steps described above.

It is important to note that when using a current Skew-T, the data used is current data and may not be representative of the future state of the atmosphere.

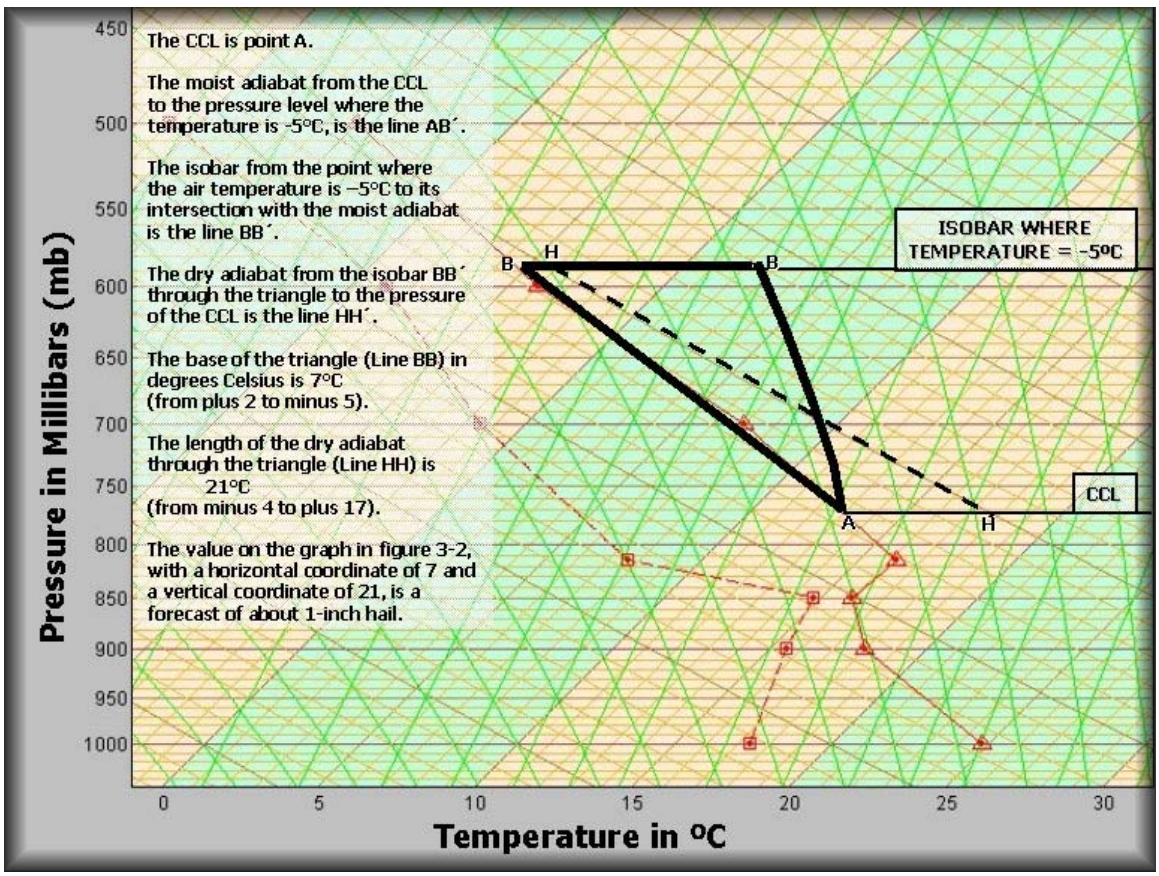


Figure 3-1 (Figuring Hail on a Skew-T)

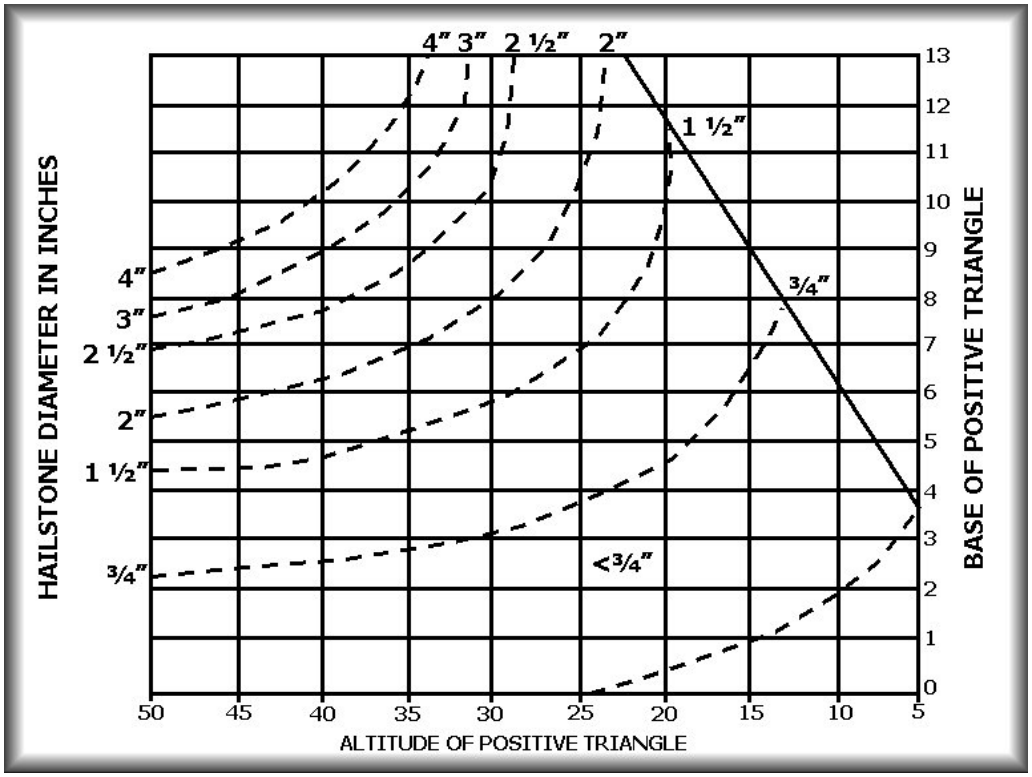


Figure 3-2 (Fawbush-Miller Graph)

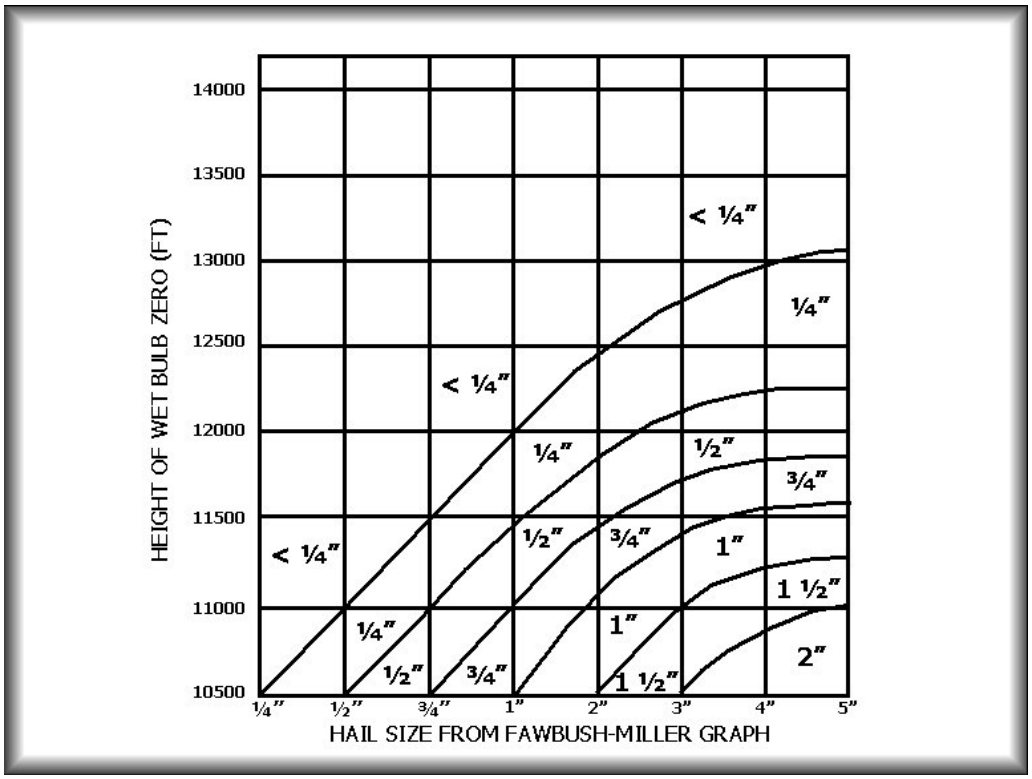


Figure 3-3 (Hail Correction for WBZ Chart)

302.0 PRECIPITATION TYPE AND SNOW FORECASTING

During the winter and transitional months, the occurrence of snow/freezing precipitation and how much will actually fall is critical to base operations. However, it is probably one of the most challenging feats a forecaster may encounter in his/her career. The Quantico area regularly lies right on the rain/snow belt. An all rain event may be experienced here at Quantico, but 30-60 miles north can see an all snow event.

The primary importance of forecasting the amount of snowfall is the decision whether or not to conduct snow removal operations. Snowfall of less than 1", or 1-2" that is expected to melt rapidly, will not usually require removal. Accumulation of 2" or greater that is not expected to melt rapidly will require a great deal of removal preparation and operations, usually at great financial liability to the base. Forecasting snowfall amounts also aids the Commander, MCB Quantico and the Commanding Officer, MCAF Quantico in their decision to cease operations. The Base Commander will require regular updates on snowfall amounts when deciding whether to keep the base open or to keep it closed. Likewise, the Commanding Officer of MCAF will need to make the decision on whether to open the airfield or to keep it closed. Most of the time, these decisions are made based off of your forecast. The most difficult removal situation, and probably the most significant impact to airfield operations, is when one or more inches of any form of freezing precipitation accompanies snowfall.

The techniques described in the following sections are designed to help you, the forecaster, in the determination of what type(s) of precipitation will occur and how much. Refer to Appendix B for a Winter Precipitation Forecasting Worksheet.

302.1 SNOW

When determining whether snow will occur or not, no one factor can simply be relied on. Several factors, such as surface temperatures, upper level temperatures, thickness, freezing levels, and evaporational cooling should be looked at forecasting for snow. Each one has its own critical value that has been determined from numerous climatological studies. As a rule of thumb, these values can be applied when forecasting for Quantico and the immediate surrounding area.

Considered by itself, surface temperature does not offer an effective means of forecasting for snow. With a surface temperature of 34°F, it has been found that snow and rain will occur with equal frequency. 34°F should therefore be considered the local critical value. Snow very rarely occurs at temperatures of greater than 39°F. It is likely to see a mixture of rain/snow/sleet with surface temperatures ranging from 35°F-39°F.

The 850mb temperature is considered one of the most significant parameters when forecasting for snow. The 850mb critical value for temperature at Quantico is -2°C. With 850mb temperatures of -2°C or less, snow should be expected. 850mb temperatures greater than -2°C through 0°C typically yield a mixture of rain/snow/sleet, and 850mb temperatures greater than 0°C will produce rain. It is important to note that although temperatures at 850mb, or any level for that matter,

may be cold enough for snow; an inversion, particularly around the 850mb-700mb level, can create problems in your forecast. Because of this, forecaster's should use caution when using standard level charts (SFC, 850mb, 700mb, 500mb, etc.). The Skew-T diagram is very useful when looking for inversions. The only drawback to using Skew-T's is that, at best, they are only produced twice per day (12Z & 00Z). Many things can change in 12 hours that could have an affect on the precipitation type. However, with advances in Numerical Weather Prediction (NWP), forecast Skew-T soundings based on the model data have been developed.

Thickness values represent the mean virtual temperature of a layer of the atmosphere. Higher thickness values are generally associated with warmer air, and lower thickness values are associated with colder temperatures. If lower thickness values replace higher thickness values then cold air advection (CAA) is occurring. And vice versa, if higher values are replacing lower values, then warm air advection (WAA) is occurring. The 1000mb-500mb thickness values are the most common ones used. However, thickness values can be obtained between any to levels in the atmosphere. For our purposes we will be using the 1000mb-500mb, 1000mb-850mb, 1000mb-700mb, and the 850mb-700mb thickness values. The following table illustrates the critical thickness values applicable to the local area:

LEVELS	**CRITICAL VALUE**
1000mb-500mb	< 540 decameters (dam) for snow
	540 - 542 dam for mix
1000mb-700mb	≤ 283 dam for snow
	283 - 286 dam for mix
1000mb-850mb	≤ 130 dam for snow
850mb-700mb	< 153 dam for snow
	153 - 156 for mix

FIGURE 3-4 (Critical Values for Thickness)

As with the 850mb temperature, the freezing level is one of the most critical parameters for snow forecasting. In the Quantico area, the critical value for freezing levels is 1,200FT. A freezing level greater than 1,200FT would be sufficient enough to melt any snow falling to rain. With a freezing level 1,200FT or less, any frozen precipitation that would fall would not have sufficient time to melt completely. The Skew-T will depict the height of any freezing level(s). Again, the Skew-T is limited to two per day and may not represent the actual conditions expected when precipitation occurs. Numerous NWP models can be used for forecast freezing level heights.

As precipitation falls through a dry (unsaturated) layer of air, it evaporates. The evaporation of the precipitation causes the atmosphere to cool. Evaporational cooling of the layer will be pronounced, typically 5°F - 10°F within 2 hours of the onset of precipitation, if the layer is initially unsaturated. Once saturation is reached, evaporational cooling ceases. This can be important to factor in when a couple of the factors described above, such as surface temperature and freezing level, are close to their critical value. Freezing levels slightly greater than 1,200FT and surface temperatures slightly above 34°F can be lowered due to evaporational cooling. This can cause precipitation that starts as rain to change to snow or prevent snow

from changing to rain. Generally ceilings of 3,000FT AGL at the onset of precipitation can maximize evaporational cooling.

302.2 SNOW FORECASTING TECHNIQUES

With the numerous variables that impact precipitation types, forecast for snow will no doubt be one of your greatest challenges while stationed at Quantico. Numerous NWP models are available to aid you in your decision. However, no single model or parameter has proven to be a determining variable by itself. The use of sound forecasting techniques applied to the various critical values can greatly improve the accuracy of your forecast. The below chart can be used to aid you in rain versus snow forecasting.

302.3 FORECASTING SNOWFALL AMOUNTS

Once the determination has been made that snow will occur, determining how much will actually fall will prove to be just as hard. Several methods can be used. The first one we will discuss is a subjective technique based off of historical synoptic patterns.

(1) If the low pressure center's past movement, present location, and future movement based on an isallobaric analysis, indicates that it will move west of the station, initially forecast less than 1" of snow due to the long trajectory of moisture over land vice directly onshore into the local area.

(2) If the low pressure center is forecast to move along and over the coastline initially forecast 1-3" of snow due to the short direct trajectory of moisture into the local area. Increase the forecasted amount to greater than 3" if the low center intensifies in the vicinity of Cape Hatteras.

(3) If the low pressure center is forecast to move northeastward along and over the Gulf Stream, forecast less than 1" of snow or none at all based on the possibility that the local area will not be within the radius of the low's precipitation shield.

Another method for forecasting snow amounts is to use NWP models. Most models have precipitation products that predict max precipitation totals. The two models used most frequently at Quantico are the ETA and the MM5. Both are regional models, thus forecast accuracy is increased but the length of the forecast decreased. They only forecast out to 72 hours. Both these models have proven to be quite accurate on precipitation types; however, for snowfall accumulations both tend to over-forecast by about 1".

The forecaster should not rely solely on the previously discussed methods. Several factors can increase the risk of greater accumulations. Low pressure intensification, increased CAA, and decreased speed of the low all favor greater snowfall amounts. A constant watch on the system is needed in order to fine tune and tweak your forecast.

302.4 FREEZING PRECIPITATION AND SLEET

The best conditions for snow to occur are when below freezing temperatures exist at all levels. A warm, shallow surface layer with upper level temperatures below freezing will produce a rain snow mix. A deep, warm surface layer will melt all snow over to rain. If the warm layer exists aloft, and temperatures above and below the warm layer are sub-freezing, a freezing rain and/or sleet event may incur.

Freezing rain/drizzle can occur in two different synoptic weather scenarios. First, freezing rain/drizzle can occur when a snow flake falls through a warm layer and melts completely, then it falls through another subfreezing layer near the surface. However, this freezing layer is not deep enough to freeze the rain drops completely; they are termed "super-cooled" and freeze on contact. The second scenario is similar to the first with one exception; precipitation begins as rain not snow. Ice pellets develop in the same manner; however, the sub-freezing layer near the surface is deep enough to completely re-freeze the rain drops.

If the warm layer aloft is greater than 1,200FT thick and the sub-freezing level closest to the surface is 1,500FT or less, then forecast freezing rain/drizzle. If the sub-freezing level near the surface is greater than 1,500FT, then forecast ice pellets.

303.0 COLD AIR DAMMING (CAD)

CAD generally occurs during the winter and transitional months. The synoptic situation with this scenario is as follows: Quantico usually experiences cold frontal passage a couple days prior to CAD setting up, cP air from a high centered over the Great Lakes region is advected into the area behind the cold front, the high then moves into eastern Canada, a stationary frontal boundary (remnants of the cold front that passed through couple days earlier) exists or a warm frontal boundary approaches from the southwest. As the high moves into eastern Canada, cP air becomes wedged up against the Appalachian Mountains; typically this is represented by a cold thermal tongue and a pressure ridge east of the Appalachians. The eastward progression of the high shifts the winds to a more northeasterly component, and the cP air associated with the high becomes slightly modified as it moves over the warmer waters of the Atlantic. This slightly modified cP air then begins to over-run the cP air wedged up against the Appalachians. This causes a moist, stable environment with a cold layer at the surface and a warmer, moist layer above it. Dissipation of this scenario occurs either when the wind flow changes from a northeasterly component to a southeasterly component, or when the next cold frontal system passes through the area.

The scenario described above is the typical synoptic pattern associated with CAD. However, the conditions listed below are also necessary for CAD to occur:

(1) The layer of air below 850mb must have a lapse rate less than the moist adiabatic lapse rate (3°F/1,000FT).

(2) The wind flow from the near-surface to 850mb must have a directional component that is perpendicular to the terrain contours. This typically occurs when the 850mb winds are northeasterly. The southern limits of CAD are when the 850mb winds change from northeasterly to southeasterly.

The effects of CAD are as follows:

(1) Extended period of low ceilings and visibilities lasting for up to 3-4 days.

(2) A lower maximum and minimum temperature than might otherwise be expected.

(3) Higher sea level pressures than expected.

(4) Lighter surface winds due to stability.

(5) Depending on the strength of the wind flow and lifting aloft, the amount of moisture aloft, and the depth and temperature of the cold air near the surface, the possibility of freezing rain/drizzle, rain/snow mix, or rain changing over to snow occurring exists.

304.0 FOG FORECASTING

The following information is presented on the different types of fog expected in the local area, and techniques to aid in forecasting for them.

304.1 RADIATION FOG

Radiation fog is fog that occurs when the radiational cooling of the Earth's surface reduces temperatures to saturation. The main occurrence is during the late fall/early summer when the local area is under influence from the Bermuda High. Conditions that are most favorable for radiation fog development are when, overnight, the skies are expected to remain mostly clear and winds are expected to be light and variable. The clear skies allow for maximum radiational cooling which creates an inversion, and the light winds prevent low-level mixing of the atmosphere. Fog will persist until the surface temperature reaches the maximum temperature of the inversion. To forecast the time of dissipation, determine the temperature at the top of the inversion, and then determine when the surface temperature will reach that temperature. As a general rule of thumb, by 0900-1000L there is sufficient warming of the surface to "break" the inversion and dissipate the fog.

304.2 ADVECTION FOG

Advection fog occurs when warm, moist air moves over a colder surface. The ideal time frame for this type of fog to form is late autumn through winter. Also, this type of fog typically occurs in the Quantico area when a CAD scenario is in place. However, any time there is sufficient land/water temperature contrast, with an easterly wind, advection fog can occur. If the land/water temperature contrast is weak, then the warm air modifies more quickly and fog is not likely to

move into the local area. Dissipation of the fog usually occurs when the warm advection weakens or ceases and/or the warm air is modified by cooling from below.

304.3 PRE-FRONTAL FOG

Pre-Frontal fog is a phenomenon that occurs when a warm fronts approaches from the south. It is caused by the evaporational cooling of a warm rain that falls through a cool, dry layer near the surface. As the evaporational cooling increases the dry layer begins to saturate. This causes ceilings to drop and fog can form as a result. It typically occurs in the shallow cold layer ahead of warm fronts or stationary fronts where rain will not cool to the air temperature before reaching the surface. Weak temperature contrast across the front and/or strong winds will likely inhibit the development of fog and the evaporation will likely form a stratus deck in lieu of fog. Once the atmosphere becomes completely saturated, evaporational cooling stops. Factors that may sustain the fog are as follows:

(1) Cold air advection from northeast can sustain the fog by replacing the saturated air with unsaturated air, by maintaining the horizontal and vertical temperature contrast, and by advecting fog into the area from different locations.

(2) After the rains stops, fog can be sustained from nocturnal radiational cooling.

Dissipation of the fog occurs when a heating process, which will occur with passage of the warm front, replaces the cooling process maintaining the condensation.

304.4 POST-FRONTAL FOG

The occurrence of post-frontal fog in the Quantico area is rare, but not unheard of. In the rare chance it does occur, dense fog can develop and last for a short period of time. Stable conditions are needed following a moderate to heavy rain with frontal passage. It results from the evaporation of water into cold, dry air. The stable conditions are rather easily forecast from the gradient behind the front, i.e. the weaker the gradient, the denser the fog. Any increase in the wind speed due to a tightening pressure gradient generally breaks up the fog due to an increase of mixing in the low levels. Although rare in occurrence, post-frontal fog can be quite dense with zero visibility for a short period of time.

304.5 SNOW FOG

Like pre-frontal fog, snow fog forms from the evaporational cooling from melting snowflakes. After snow stops falling, if the air temperature rises well above freezing, fog can not be maintained due to the fact that heat in the air is drawn to the surface to aid in the melting process. With temperatures well below freezing after snow ceases, water vapor in the air is sublimated to the snow and fog dissipates or does not form due to lack of moisture. However, conditions are favorable for fog sustainment/development when temperatures hover right around freezing after snow stops due to warm air advection.

305.0 LOCAL WINDS

The Air Facility is located on the western shore of the Potomac River, which is 2 ½ miles wide in this area. The orientation of the river gives an open expanse of water extending some twelve miles to the south of the station. The Potomac is generally not a large enough body of water to play a significant role in the formation of a sea breeze. Between the months of May and September, however, when the local area is under influence of the western lobe of the Bermuda High and the pressure gradient is very weak, the formation of a sea breeze is not uncommon. Again, due to the fact that the Potomac is not a large body of water, any sea breeze that does form is typically not as pronounced as it would be at a station on the main Atlantic coastline. Another terrain induced wind that affects the Quantico area is a land/mountain breeze. Quantico lies in between the Appalachian Mountains and the Potomac River. They both play a role in the development of this land/mountain breeze. The breeze is not confined to any one season, but exists in some form year round. As with sea breezes, the land/mountain breeze will generally only develop under a weak pressure gradient. During the evening when radiational cooling begins, the air along the mountains begins to cool. As the air begins to cool it descends the mountain slopes, thus a westerly wind is induced. Likewise, the Potomac has a similar effect on the wind, mainly during the summer and late autumn, when the land/water temperature gradient is at its peak. As with the mountain breeze, during the evening, land cools more rapidly than the waters of the Potomac. A breeze from the cooler land to the warmer waters is induced. As stated earlier, the land breeze is more prevalent during the summer and late autumn; the effects of the mountain breeze during this time only enhances the land breeze. The effects of the mountain breeze are generally experienced year round. The table below shows the basic effects seen with the sea breeze and the land/mountain breeze.

	Average Wind Direction	**Average Wind Speed**	**Time Span**
Land/Mountain Breeze	280°	4-6 Knots	0200-0800
Sea Breeze	150°	8-12 Knots	1400-1800

As a general rule of thumb, the sea breeze experienced in the Quantico area is not sufficient enough to induce convection, although it definitely can enhance any airmass thunderstorms in the area. Some special notes concerning sea breezes and land/mountain breezes are:

(1) During the summer time, when the sea breeze is most prevalent, emphasis should be directed as to whether the existence of a sea breeze is forecasted to occur. A sea breeze can lower the expected maximum temperature 1-2°C.

(2) The effects of the sea breeze and land/mountain breeze will only be experienced under a weak pressure gradient.

(3) While the sea breeze and land breeze are most prevalent during the summer and late autumn, the mountain breeze can generally

occur year round.

306.0 TEMPERATURE FORECASTING GUIDELINES

Generally, NWP models prove to be fairly accurate when forecasting for the maximum and minimum temperatures. There are, however, some trends that should be noted. Through the 48 hour forecast, accuracy tends to be within 1-2°C. From the 72-96 hour forecast, accuracy lies between 3-4°C. Some factors that can affect the forecasted temperatures are greater amount of cloud cover than expected and lower maximum temperatures and increase minimum temperatures a few degrees. An error in the forecasted time of frontal passage can also play a part in affecting temperatures. Forecasters should use model guidance subjectively and apply sound forecast reasoning to temperature forecasts.

307.0 LOW LEVEL WIND SHEAR (LLWS)

Wind shear is a change in wind speed and/or direction over a short distance, which results in a tearing or shearing action. Although wind shear can occur at any altitude, it is particularly hazardous when it happens over a short period of time and within 2,000 feet of the ground, during takeoff or landing. During this phase of flight, the aircraft operates only slightly above stall speed, and a major change in wind velocity can lead to a loss of lift. If the loss is great enough that power response is inadequate, it results in a steep descent. The altitude at which the encounter occurs, pilot reaction time, and airplane response capability determine if the descent can be altered in time to prevent an accident.

Several types of weather phenomena are conducive for the development of LLWS; the most common observed in the Quantico area are associated with thunderstorms, fast moving fronts, low-level jets, and strong surface winds.

307.1 LLWS AND THUNDERSTOMS

The winds around a thunderstorm are complex. Downdrafts or micro-bursts exiting the base of a thunderstorm spread outward in all directions upon approaching the surface and form an area of gustiness near the thunderstorm. The outer limit of this gusty area is referred to as the "gust front".

The thunderstorm downdraft may produce the most dangerous shear conditions associated with the outflow of a thunderstorm. The gust front frequently extends 10 to 15 miles away from the thunderstorm. Extreme wind shears of 10 knots per 100 feet of altitude have been measured immediately behind the gust front, while horizontal wind shears of 40 knots per mile have been recorded across the gust front. In addition to the tremendous speed shears reached, the most severe thunderstorms produce directional shears of 90° to 180°.

Wind shear associated with thunderstorms is by far the most hazardous, because of the complexity and multiplicity of the shears produced. Prevailing low-level winds are forced up over the gust front; currents that feed into the storm are present; and more than one gust front may be encountered, because of multiple down-drafts.

307.2 LLWS AND FRONTS

Winds can be significantly different in two air masses forming a front. Fronts that are most conducive to significant wind shear are fast moving (30 knots or more) and/or have at least a 5°C (10°F) temperature differential. Figure 3-5 may be used as a general guideline to determine if a front will have wind shear and/or turbulence associated with it.

Low-level wind shear occurs with a cold front after the front passes. Because cold fronts have a greater slope and normally move faster than warm fronts, low-level wind shear usually lasts less than 2 hours. The wind shear associated with a warm front is more dangerous to airport operations. Strong winds aloft, associated with the warm front may cause a rapid change in wind direction and speed where the warm air overrides the cold, dense air near the surface. Warm-frontal wind shear may persist 6 hours or more ahead of the front because of the front's shallow slope and slow movement.

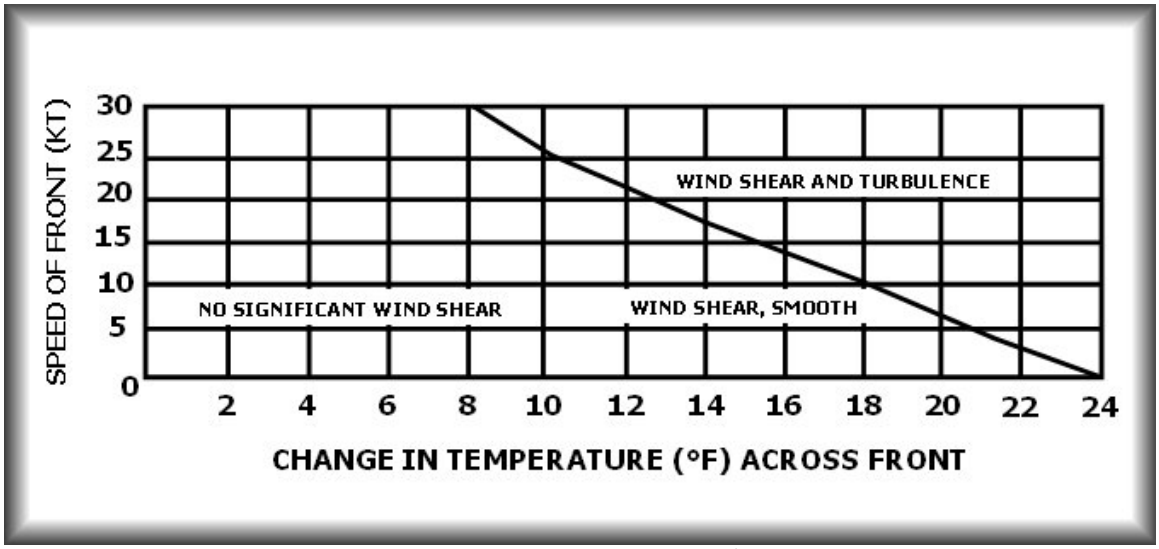


FIGURE 3-5 (Frontal Temperature Contrast/Speed and LLWS Chart)

307.3 LLWS AND LOW-LEVEL JETS

A low-level jet often forms just above a radiation inversion. It starts to form at sundown, reaches maximum intensity just before sunrise, and is destroyed by daytime heating (usually by 10 a.m. local time). The low-level jet is observed in all parts of the world at all times of the year. In the United States it is common in the Great Plains and the Central states. Radiational cooling creates a calm, stable dome of cold air 300 to 1,000 feet thick, termed an inversion layer. The low-level jet occurs just above the top of the inversion layer, and while speeds of 30 knots are common, wind speeds in excess of 65 knots have been reported. Any time a radiation inversion is present, the possibility of low-level wind shear exists.

307.4 LLWS AND STRONG SURFACE WINDS

Strong winds at the surface imply speed shear aloft unaffected by friction. Turbulent mixing increases this contrast between the surface and aloft. Gustiness, descending air with excess speed, and turbulence creates updrafts and downdrafts of horizontal shear of vertical winds. Thus, any time the surface winds are strong, solicit aircraft flying in the local area for a PIREP on wind shear conditions.

308.0 TURBULENCE FORECASTING

The fundamental rules applied when forecasting for turbulence offer the forecaster a good starting point in determining the type, intensity, and levels of turbulence at and around Quantico. Typically, in the strong winds that sometimes accompany the passage of cold fronts, light to moderate turbulence from the surface to about 12,000FT AGL can be expected. Another factor that promotes turbulence in the local area is any time there is a strong westerly wind component over the Appalachians. Ideal wind directions are from 270°-300° at all levels. Ideal wind speeds range from about 30-40 knots at 1,500FT - 2,000FT, and increase significantly as you go aloft. In this scenario it is not uncommon to experience severe turbulence. Therefore, a forecast for severe turbulence from the surface to about 8,000FT AGL would be called for. While altocumulus standing lenticular (ACSL) clouds are not a prerequisite, they usually indicate the presence severe turbulence, and your forecast should reflect this.

SECTION 4

400.0 SPECIALIZED SUPPORT

Quantico METOC does not currently produce any specialized forecasts on a recurring basis. However, requests for specialized support can come in at any time. Marine Helicopter Squadron One supports one of this Nation's most significant operations, Presidential Support. Quantico METOC receives its fair share of requests for METOC support of the Presidential Support Mission. All forecasters stationed aboard Quantico should be cognizant of this and always be prepared to provide whatever METOC support is needed.

SECTION 5

500.0 ENVIRONMENTAL EFFECTS

METOC support plays a vital role in the Marine Corps mission. Although not dependent on the weather, the success of most military operations is highly impacted by it, especially aviation operations. Operations at MCAF Quantico are affected by the general weather conditions described below.

500.1 CEILING AND VISIBILITY

VFR conditions, although not mandatory, greatly increase the success of aviation operations aboard MCAF. Special VFR (SVFR) operations can be conducted, although the number of aircraft allowed to operate in SVFR conditions is at the discretion of the local air traffic controller. SVFR minima are defined as 1 SM visibility and no ceiling.

500.2 TEMPERATURE AND ATMOSPHERIC DENSITY

Marine Helicopter Squadron One is comprised entirely of rotary wing aircraft. Rotary wing aircraft must have accurate readings of temperature, pressure altitude, and density altitude for optimum aircraft operations. Transient vertical take-off and landing (VTOL) aircraft occasionally operate at MCAF, and also require these readings for optimum operation.

500.3 SURFACE WINDS

The tower makes a change in the duty runway, when a predominant change in the wind direction is forecasted.

500.4 THUNDERSTORMS AND LIGHTENING

Due to the high importance of Marine Helicopter Squadron One’s mission, operations around thunderstorms may be necessary. For the safety of personnel and equipment, typically only high priority missions will be conducted around thunderstorms. All fueling operations will cease as soon as lightning has been detected or observed within 10NM of the Air Facility.

500.5 TURBULENCE

Severe and extreme turbulence pose a significant threat to all aircraft. Thus the occurrence of any severe or extreme turbulence will typically halt all aircraft operations aboard MCAF.

500.6 ICING

Moderate icing can pose a significant threat to aircraft when they are exposed to it for extended periods of time. Therefore, aircraft operations can be limited in moderate icing. Severe icing conditions will typically halt all aircraft operations.

500.7 PRECIPITATION

The occurrence of any freezing precipitation causes a severe icing hazard. Therefore freezing precipitation will halt aircraft operations.

501.0 WIND CHILL

The wind chill temperature is how cold people and animals feel when outside. Wind chill is based on the rate of heat loss from exposed skin caused by wind and cold. As the wind increases, it draws heat from the body, driving down skin temperature and eventually the internal body temperature. Therefore, the wind makes it FEEL much colder. If the temperature is 0 degrees Fahrenheit and the wind is blowing at 15 mph, the wind chill is -19 degrees Fahrenheit. At this wind chill temperature, exposed skin can freeze in 30 minutes. During the winter months, wind chill temperatures can pose a significant impact to personnel aboard Quantico.

WIND CHILL CHART

WIND SPEED (MPH) \ TEMPERATURE (°F)	CALM	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5		36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10		34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15		32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20		30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25		29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30		28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35		28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40		27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45		26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50		26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55		25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60		25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

FROSTBITE TIMES: 30 MIN, 10 MIN, 5 MIN

$$\text{WIND CHILL (°F)} = 35.74 + 0.6215T - 35.75\,(V^{0.16}) + 0.4275T(V^{0.16})$$

WHERE, T = AIR TEMPERATURE (°F) & V = WIND SPEED (MPH)

Figure 5-1 (Wind Chill Chart)

SECTION 6

REFERENCES:

FLEET NUMERICAL METOC DETACHMENT Asheville, NC. International Station Meteorological Climate Summary, 1996.

U.S. NAVY. Aerographer's Mate 1 & C (NAVEDTRA 14010), September 1995.

AIR FORCE COMBAT CLIMATOLOGY CENTER (AFCCC). Summer Regimes (AFWA/TN-01/001), 15 March 2001.

AIR FORCE COMBAT CLIMATOLOGY CENTER (AFCCC). Winter Regimes (AFWA/TN-01/002), 1 December 2001.

NATIONAL WEATHER SERVICE (NWS), Office of Climate, Water, and Weather Services (http://www.nws.noaa.gov/om/services.shtml), 9 September 2003.

METOC DIVISION, MCAF Quantico, VA. Local Area Forecaster's Handbook, Revised June 1997.

NAVAL ATLANTIC METEOROLOGY AND OCEANOGRAPHY DETACHMENT, Patuxent River, MD. Local Area Forecaster's Handbook.

AIRMASS THUNDERSTORM WORKSHEET

A	CONVECTIVE CONDENSATION LEVEL (CCL) HEIGHT:	
B	TEMPERATURE NECESSARY FOR CONVECTION:	
C	MAXIMUM TEMPERATURE FORECAST:	
D	IS TEMPERATURE FOR CONVECTION EXPECTED TO BE REACHED:	YES / NO
E	BASED OFF OF ANSWERS FROM A-D, IS CONVECTIVE DEVELOPMENT LIKELY, IF YES PROCEED TO SECTION F.	YES / NO

F	INVERSION(S) PRESENT:			
	CIRCLE	NONE		
		WEAK / MODERATE / STRONG	HEIGHT:	
		WEAK / MODERATE / STRONG	HEIGHT:	
		WEAK / MODERATE / STRONG	HEIGHT:	

G	INVERSION(S) FCSTD TO LAST THROUGHOUT THE PERIOD AND EXPECTED TO BE STRONG ENOUGH TO PREVENT OR INHIBIT CONVECTIVE ACTIVITY. IF YES DO NOT FCST FOR TSTM'S. IF NO, PROCEED TO SECTION H:	YES / NO
H	IS THERE SUFFICIENT MOISTURE AVALIABLE FROM THE SFC - 10,000FT	YES / NO
I	IF NO, WILL SUFFICIENT MOISTURE BE AVALIABLE AT TIME CONVECTION IS EXPECTED TO BEGIN?	YES / NO
J	IF ANSWERED NO FOR BOTH SECTIONS H & I, DO NOT FCST FOR TSTM'S. IF ANSWERED NO FOR SECTION H, BUT YES FOR SECTION I PROCEED TO SECTION K.	
K	GENERAL STABILITY OF ATMOSPHERE	STABLE / UNSTABLE / CONDITIONALLY UNSTABLE

L	STABILITY INDICES	ANAL	SI	
			LI	
			KI	
			TT	
		FCST	SI	
			LI	
			KI	
			TT	

M	WERE THUNDERSTORMS OR CLOUDS OF VERTICAL EXTENT PRESENT THE PREVIOUS DAY?	YES / NO
	IF SO, HAS THERE BEEN ANY CHANGE IN THE LOWER LEVELS THAT WILL FURTHER INHIBIT DEVELOPMENT TODAY?	YES / NO

BASED OFF OF ALL THE CONSIDERATIONS ABOVE; FORMULATE A FORECAST AND DISCUSS YOUR DECISION IN THE FORECAST RATIONALE SECTION.

FORECAST RATIONALE:

FCSTD TIME OF TSTM DEVELOPMENT	MAXIMUM FCSTD CONVECTIVE GUSTS	HAIL: YES / NO	MAX HAIL SIZE EXPECTED

WINTER PRECIP WORKSHEET

A	DETERMINE THICKNESS OF 1000MB(SFC) THROUGH 500MB, 1000MB(SFC) THROUGH 700MB, 1000MB(SFC) THROUGH 850MB, AND 850MB-700MB THICKNESS.	1000-500MB	
		1000-700MB	
		1000-850MB	
		850-700MB	

	SNOW	MIX	RAIN
1000-500MB	< 540	540 - 542	> 542
1000-700MB	≤ 283	283 - 286	> 286
1000-850MB	≤ 130		> 130
850-700MB	< 153	153 - 156	> 156

B	WHAT IS THE TEMPERATURE AT 850MB?	850MB TEMP =

	SNOW	MIX	RAIN
850MB TEMP	≤ -2°C	> -2°C, BUT ≤ 0°C	> 0°C

CONSIDERING THE THICKNESS VALUES FROM SECTION A AND THE 850MB TEMP FROM SECTION B, WHICH OF THE FOLLOWING IS MOST LIKELY	SNOW / MIX/ RAIN

IF SNOW IS LIKELY PROCEED TO SECTION D. IF A MIX IS LIKELY, PROCEED TO SECTION C. IF RAIN IS LIKELY PROCEED TO SECTION D.

			LEVELS	TEMP AT TOP OF INVERSION.
C	ARE THERE ANY INVERSIONS PRESENT? IF NOT PROCEED TO SECTIONS D-F.	YES / NO		

IF THERE ARE INVERSIONS PRESENT, ARE ANY OF THEM ABOVE FREEZING? IF NOT PROCEED TO SECTION D.	YES / NO
IF SO, WHAT IS THE DEPTH OF THE MELTING LAYER?	
IS THERE A SUB-FREEZING LAYER BELOW THE MELTING LAYER THAT EXTENDS TO THE SURFACE?	YES / NO
WHAT IS THE DEPTH OF THE SUB-FREEZING LAYER?	

TAKE THE VALUES FOR THE DEPTH OF THE MELTING & SUB-FREEZING LAYER AND COMPARE THEM WITH THE CHART BELOW TO DETERMINE THE PROBABLE TYPE OF PRECIPITATION. DISCUSS COMMENTS IN THE FORECAST RATIONALE SECTION.

	FZRA	PL	FZRA/PL	FZRA/PL	SN/SG/PL	SN/SG/PL
DEPTH OF MELTING LAYER/ DEPTH OF SUB-FREEZING LEVEL CLOSEST TO THE SURFACE	> 1200FT / ≤ 1500FT	> 1200FT / >1500FT	600-1200FT / ≤ 1500FT	600-1200FT / > 1500FT	< 600FT / ≤ 1500FT	< 600FT / > 1500FT

D	HEIGHT OF FREEZING LEVEL? COMPARE WITH THE CHART BELOW AND PROCEED TO SECTION E.	

	SNOW	MIX	RAIN
HEIGHT OF FREEZING LEVEL	≤ 600FT	601-1199FT	≥ 1200FT

E	WHAT IS THE SURFACE TEMPERATURE? COMPARE WITH CHART BELOW AND PROCEED TO SECTION F.	

	SNOW	MIX	RAIN
SFC TEMP	≤ 34°F	35°F - 39°F	> 39°F

F	IS WARM AIR ADVECTION EXPECTED WITH THE PRECIPITATION EVENT?	YES / NO

IF SO, IS THE WAA EXPECTED TO BE SUFFICIENT TO WARM UPPER LEVEL TEMPERATURES ENOUGH TO CHANGE PRECIPITATION. DISCUSS YOUR ANSWERS IN THE FORECAST RATIONALE SECTION.

BASED OFF OF ALL THE CONSIDERATIONS ABOVE AND FUTURE CONSIDERATIONS THAT MAY AFFECT THE ATMOSPHERE (i.e. WAA/CAA); FORMULATE A FORECAST AND DISCUSS YOUR DECISION IN THE FORECAST RATIONALE SECTION BELOW. **NOTE** THIS WORKSHEET IS DESIGNED TO ASSIST IN DEVELOPING A SOUND FORECAST, THEREFORE IT IS BEST TO USE DATA THAT WILL BE REPRESENTATIVE OF THE ATMOSPHERE THROUGHOUT THE PRECIPITATION EVENT.

FORECAST RATIONALE:

FINAL FORECAST: