# Training Objectives

## Meteorologist Operational Internship Program

Environment Canada

Meteorological Service of Canada

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# Introduction

The Meteorologist Operational Internship Program **(MOIP)** is an entry level training program delivered by the Meteorological Service of Canada Environment Canada to train new employees to carry out a multidisciplinary role as operational meteorologists for the various weather centres across Canada. The course is intended for individuals with an education in the physical and atmospheric sciences.

This document describes the training objectives of this training program.
Companion documents outline the program in more detail.

**Meteorologist Operational Internship Program Description** gives an overview of the program.

**MOIP Intern Evaluation Methodology**, describes how interns are evaluated to ensure the standards of the program are maintained.

The emphasis in internship is not in the theory of meteorology but rather in operational applications of that theory. There is also an emphasis on the acquisition of client service-oriented skills. This ensures that the techniques and procedures learned are operationally relevant. An important part of an operational meteorologist's duties require effective personal skills to ensure effective team work in the forecast production phase and effective interaction in the delivery of services to clients. These personal suitability criteria are an important aspect of the whole training program including both the course and the on the job training and are outlined in module 14.5.

In the documentation that follows, the material is divided into a hierarchical structure of topics and modules. Definitions of these terms are:

**Topic**: A major grouping of training activities consisting of a number of modules which are interdependent or which may be logically grouped together because of the nature of the subject area.

**Module**: A grouping of a relatively small number of closely related and dependent activities which would not normally be studied in isolation.

**Terminal Objective**: A statement describing a specific item that a student must be able to do (or know) in order to meet the module goal.

**Enabling Objective**: A statement which describes in more detail the skills required to accomplish the terminal objective.

# TOPIC 0: UTILISATION OF OPERATIONAL WORK TOOLS

This introductory topic gives the intern basic abilities and familiarity with the working tools of a meteorologist at his/her workstation, in order to facilitate their work on course and later when starting operations. Skills in these areas will improve gradually with time.

## Terminal Objective 0.1:

Develop basic skills in following data access types to accomplish various internship tasks.

Enabling Objectives

a) Alpha Manager (SAS, CIR, IDS, SFC, HUM, SHP, …)
b) Image Manager (selection masks, animation, navigation, etc)
c) GRIB Data Viewer (Met Manager)
d) Tephigram viewer
e) Lightning display software
f) Weather Alert
g) Severe Weather Watcher Network Data
h) Internet

## Terminal Objective 0.2:

Develop basic skills in the following Forecast Production Software types to accomplish various internship tasks.

Enabling Objectives

a) SCRIBE
b) Bull Prep
c) Edigraf

## Terminal Objective 0.3:

Intern must be aware of the following dissemination tools.

Enabling Objectives

a) AVIPADS
b) Weather Copy
c) Weather Radio
d) 1-900 service
e) Answering Systems (ATADS)
f) Autofax, FTP, Internet

# TOPIC 1: METEOROLOGICAL OBSERVATIONS

This topic introduces the intern to the various meteorological observing and monitoring systems.

## Module 1.1: Geography

Identify and locate significant geographical reference points and political subdivisions in North America.

**Terminal Objective 1.1.1**

Describe the characteristics and uses of polar stereographic and Mercator map projections.

Enabling Objectives:

a) Define great circle, small circle, map scale true at 60°N, latitude and longitude.
b) Find a distance of approximately 30nm between any two points on a map.

**Terminal Objective 1.1.2**

Locate and identify specified geographical features on a map.

Enabling Objectives:

a) Memorize 100% of Canadian provinces and their capitals; and 80% of the U.S. states
b) Describe in a general way the topography of Canada. Also according to a given list, memorize at least 80% of the mountain ranges and the principal North American topographical regions.

c) According to a given list, memorize at least 80% of the rivers, lakes, oceans, in North America.

**Terminal Objective 1.1.3**

Describe the various meteorological identifier systems. Memorize and decode the identifiers necessary to function effectively in internship operating area.

## Module 1.2: Surface and Upper Air Observations

Decode and interpret surface observations, upper air observations and map plots. Be aware of basic observing and reporting procedures and available reference material.

**Terminal Objective 1.2.1**

Describe the MSC environmental monitoring network and be aware of references and resources which provide information about the monitoring network.

**Terminal Objective 1.2.2**

Decode Canadian and U.S. hourly weather reports (in METAR code and secondarily in SA code), including all additional data groups transmitted and including hourly reports from automatic observing stations, buoys and ships.

Terminal Objective 1.2.3
Decode and interpret surface weather reports. Know where to find reference material for observing and reporting procedures. (e.g. MANOBS)

Enabling Objectives:

a) Wind
b) Visibility
c) Atmospheric Phenomena
d) Sky condition
e) Temperature
f) Humidity (Dew Point)
g) Atmospheric Pressure (Altimeter setting and MSL pressure)
h) General Remarks

**Terminal Objective 1.2.4**

Decode and interpret Automatic Weather Observing Systems (AWOS).

Enabling Objectives:

a) Describe the weather elements that can and cannot be observed by AWOS sensors.
b) Describe how the AWOS weather elements differ from or are similar to the weather elements reported in human observations.
    i i cloud amount, cloud opacity, cloud height
    ii visibility
    iii atmospheric phenomenon
    iv pressure
    v humidity
    vi wind
    vii icing
    viii total precipitation

c) Describe the limitations of the sensors for the above:
    i

**Terminal Objective 1.2.5**

Decode and interpret plotted synoptic reports.

Enabling Objectives:

a) Decode plots from surface and Automatic Weather Observing Stations (AWOS);
b) Decode plotted reports from buoys, and ships. .

**Terminal Objective 1.2.6Decode plotted upper air charts.**

Enabling Objectives:

a) Decode temperature, wind, dew point depression and geopotential height on the standard upper air charts;
b) Decode the 1000-500 hPa geopotential thickness on a 500 hPa chart;
c) State approximate standard atmosphere heights for the standard upper air surfaces.
d) Decode supplementary data plots and identify the source of the data.
e) Identify rejected data.

**Terminal Objective 1.2.7**

Decode and interpret pilot reports (PIREPs).

## Module 1.3: Satellite Systems

Describe the various types of data that are available from polar orbiting and geostationary weather satellites.

**Terminal Objective 1.3.1**

Describe the meteorological satellite systems presently supplying data for operational use.

Enabling Objectives:

a) Describe the network of geostationary satellites and their orbital characteristics;
b) Describe the scanning strategy used by the imager to view the earth;
c) Describe the network of polar-orbiting satellites (POES) and their orbital characteristics;
d) Describe the scanning strategy used by the imager to view the earth
e) Discuss the advantages and disadvantages of the polar and geostationary orbits.
f) Name and briefly describe the characteristics of the imaging and vertical sounder instruments aboard GOES and METEOSAT(in less detail) geostationary satellites and the NOAA polar orbiting satellites;
g) Describe the communication path followed by the satellite data from sensor to user for each satellite type;
h) Describe the image resolution characteristics for each satellite system.
i) Describe how the orbital characteristics of each satellite system, and the resolution of the sensors may affect the interpretation of targets (ground and clouds) and their apparent location with respect to the ground

**Terminal Objective 1.3.2**

Describe the principles by which radiation received at the satellite sensor are used to infer target albedo or temperature.

Enabling Objectives:

a) Describe Planck's Law and how it relates to radiation received at the satellite;
b) Describe some of the limitations and errors which arise when the principles learned in a) are applied to the atmosphere.

**Terminal Objective 1.3.3**

Describe the characteristics of the various sensing channels available and discuss the uses that are most applicable for each sensing wavelength.

Enabling Objectives:

a) Describe the characteristics of the VIS channel and list the uses made of data from this channel;
b) Describe the characteristics of the IR (4, 11 and 12 micron) channels and list the uses made of data from these channels;
c) Describe the characteristics of the NIR channel and list the uses made of data from this channel;
d) Describe the characteristics of the water vapour (6.7 micron) channel and list the uses made of data from this channel;

**Terminal Objective 1.3.4**

Interpret the basic information appearing on satellite imagery including the principles of image enhancement.

Enabling Objectives:

a) Decode the headers for both geostationary and polar orbiting satellites and discuss the implications of the information obtained from the header;
b) State why satellite images are enhanced;
c) Describe the principles of image enhancement (both infrared and visible);
d) Use enhancements to determine from infrared imagery the temperature of any point.

**Terminal Objective 1.3.5**

Describe the vertical sounding output from operational satellites highlighting their utility in a forecast office.

Enabling Objectives:

a) Explain the relationship between radiation reaching the satellite and the absorption characteristics of the atmosphere;
b) Explain the differences between the POES and GOES sounder instruments, especially in the choice of sensor receiving wavelengths;
c) Briefly describe the procedure by which profiles of temperature and moisture are produced from the sounder instruments;
d) Describe some of the derived products created from GOES and POES sounding data, and their application.

## Module 1.4: Radar Fundamentals

Demonstrate a basic understanding of the theory and major output of conventional and Doppler radar systems

**Terminal Objective 1.4.1**

Explain the basics of conventional radar systems providing data to Canadian Weather Offices.

Enabling Objectives:

1. Describe the distribution of radars in Canada and in U.S. border stations that provide data to Canada
2. Describe the main components of the radar systems used in Canada
3. State two advantages of using pulsed radar
4. State at least four assumptions used in the radar equation. See Module 2.4A notes
5. Describe the main characteristics of the radar beam in terms of
    - wavelength
    - pulse length
    - beamwidth
    - beam volume
    - range
    - resolution
6. Explain anomalous propagation including the atmospheric conditions which lead to
    - super-refraction
    - sub-refraction
    - ducting

    See Module 2.4A notes.
7. Describe other factors affecting the displayed intensity such as
    - attenuation
    - partial beam filling
    - beam blocking
    - beam spreading
    - overshooting of the radar beam

- multi-trip echoes
- side lobes

See Module 1.4A and 2.4A notes.

8. Describe the effects on the radar signal from the following non-meteorological targets
    - obstacles and obstructions (buildings, mountains)
    - biological (birds, insects, etc.) targets
    - miscellaneous targets such as chaff

**Terminal Objective 1.4.2 (Covered in Module 2.4B Notes)**

Explain the basics of Doppler radar systems providing data to Canadian weather offices.

Enabling Objectives:

1. Explain the Doppler effect
2. Explain why velocity folding occurs
3. Describe the limitations of Doppler radar including
    - unambiguous range
    - second trip echoes
    - maximum unambiguous velocity (Nyquist velocity)
4. Explain the Doppler dilemma
5. Describe how the Canadian radar system extends the range of the maximum unambiguous velocity

**Terminal Objective 1.4.3**

Describe the different radar products available in Canadian forecast offices and their use.

Enabling Objectives

2. Describe how a volume scan is taken in Canada
3. Be familiar with the Unified Radar Processor (URP) regional summer and winter composites (SUDDS and WIDDS) and multi-layer products for single radar (SERF)
4. Describe radar reflectivity products, such as
    - PPI (Plan Position Indicator)
    - CAPPI (Constant Altitude PPI)
    - PRECIP
    - Echo top
    - Vertical cross section
    - 3HR PA (precipitation accumulation)
5. Briefly describe summer severe weather products, such as SVR WX, Max R.
6. Be aware of radar products from the Doppler cycle, in particular radial velocities,

## Module 1.5: Lightning Sensing and Display Theory

**Terminal Objective 1.5.1**

Describe the lightning detection system of the CLDN.

Enabling objectives:

a) State lightning types detected;
b) Describe the two major sensing technologies;
c) Describe how the data is monitored;
d) State limitations of this sensing system; and
e) Describe the communications topology.

**Terminal Objective 1.5.2**

State uses of lightning information in met operations, and describe any operational research and correlation with significant weather events.

# TOPIC 2: ANALYSIS

This topic introduces the intern to various methods of interpreting meteorological data and organizing the data into patterns.

## Module 2.1: Surface Analysis

Analyze basic meteorological fields plotted on surface charts.

**Terminal Objective 2.1.1**

Analyze and label, to specified standards, the following meteorological fields:

- mean sea level pressure
- pressure tendency
- temperature
- climatological data

Enabling objectives:

a) Position standard isopleths by interpolating between plotted data, and employing the use of modeling if necessary.
b) Use all the available data, including history, to locate features;
c) Infer physical fields from secondary information;
d) Learn the use of geostrophic wind scales and/or tables;
e) Recognize and correct, where possible, erroneous data.

**Terminal Objective 2.1.2**

Incorporate any relevant mesoscale effects into analysis charts.

Enabling objectives

a) Prepare analyses over a limited area with a fine map scale;
b) Accurately discriminate incorrect reported data from legitimate mesoscale effects;
c) Diagnose processes occurring on the mesoscale;
d) Incorporate other data sources such as significant remarks and radar data into the analysis.

## Module 2.2: Analysis of Standard Upper Levels

Analyze derived meteorological fields on upper air charts, and identify characteristic features of the mid-tropospheric circulation.

**Terminal Objective 2.2.1**

Identify and interpret the kinematic structure of mid-tropospheric circulation.

Enabling Objectives:

a) Describe the four types of kinematic flow (deformation, vorticity, divergence and translation), and recognize these flows on a 500 hPa chart;
b) Describe the three components of absolute vorticity (shear, curvature and planetary);
c) Analyze vorticity maxima and minima on a 500 hPa chart and provide history, using standard notation;
d) Relate deformation to the analyzed wind field and empirically relate deformation to the vorticity pattern;
e) Analyze deformation axes (zones) on a 500 hPa chart, using standard notation.

**Terminal Objective 2.2.2**

Given a sequence of 500 hPa analyses, describe the general evolution of the circulation in terms of long waves.

Enabling Objectives:

a) Identify main air streams;
b) Construct a control line chart;
c) Identify the positions of long wave troughs and ridges, using various techniques.

**Terminal Objective 2.2.3**

Given a sequence of 500 hPa vorticity analyses, describe the evolution of the mid level circulation in terms of short waves.

Enabling Objectives:

a) Analyze the position of short wave ridges and troughs and provide history, using standard notation;
b) Analyze areas of significant vorticity advection, and estimate approximate magnitudes of the advection;
c) Relate the evolution of short waves to the long wave pattern;
d) Evaluate the validity and impact of rejected data on the analysis and adjust accordingly.

**Terminal Objective 2.2.4**

Given appropriate upper level charts, analyze thermal advection fields.

Enabling Objectives

a) Analyze the position of zero thermal advection lines, using standard notation;
b) Analyze areas of significant thermal advection, and estimate approximate magnitudes of the advection.

**Terminal Objective 2.2.5**

Interpret mid-tropospheric trough and ridge patterns in terms of the evolution of the circulation.

Enabling Objectives:

a) Interpret the evolution of asymmetric trough and ridge patterns in terms of tilt, confluence and wind strength;
b) Recognize processes leading to the formation of cut-off centers, intensification of the zonal current, blocking patterns, etc.

## Module 2.3: Satellite Interpretation

Demonstrate an understanding of the principles of interpretation of the satellite data available in Canadian forecast offices.

**Terminal Objective 2.3.1**

Identify cloud types, terrain features and various atmospheric constituents using all available wavelengths and multi-spectral imagery.

Enabling Objectives:

a) Describe methods of distinguishing cloud areas from terrain features;
b) Describe the differences in texture, brightness and temperature for different types of cloud, relating these to sun angle, angle of view, contamination and attenuation;

c) Identify atmospheric constituents such as forest fires, smog and volcanic ash.

**Terminal Objective 2.3.2**

Locate, on satellite imagery, cloud patterns that indicate dynamic processes in the atmosphere.

Enabling Objectives:

a) Describe the indicators in satellite imagery which aid in the identification of upper-level features such as (but not limited to):
   - jet streams
   - vorticity maxima
   - upper ridge lines
   - upper trough lines
   - deformation axes
   - upper wind speed and direction
   - comma cloud systems;
b) Describe the indicators in satellite imagery which aid in the identification of low-level and meso-scale features such as (but not limited to):
   - low centres
   - fronts
   - low-level wind speed and direction;
c) Describe how satellite imagery may be used to aid in forecasting of the evolution of the features given in a) and b).

**Terminal Objective 2.3.3**

Locate, on satellite imagery, cloud patterns that indicate convective processes in the atmosphere.

Enabling Objectives:

a) Describe the indicators in satellite imagery which aid in the identification of the intensity of convection
b) Describe how satellite imagery may be used to aid in the long-range forecasting of the initiation area of convective activity
c) Describe how satellite imagery may be used to aid in the short-range forecasting of the evolution of convective activity

**Terminal Objective 2.3.4**

Locate, using satellite imagery, areas of interest that relate to a particular forecasting problem.

Enabling objectives:

a) Describe the use of satellite imagery to aid in detecting forecasting problems such as (but not limited to)
   - areas of turbulence
   - areas of possible aircraft icing
   - potential areas of heavy precipitation
b) Describe how satellite imagery may be used to aid in forecasting of the areas found in a).

**Terminal Objective 2.3.5**

Understand the principles used to combine satellite data and other data to create derived products useful for a specific meteorological application.

Enabling Objectives:

a) Be aware of the products that can be derived from sounding data and their application;

b) Be aware of the multispectral techniques of combining imagery data to highlight low cloud and fog, icing, and other features of interest;
c) Be aware of techniques used to derive atmospheric wind speeds using GOES imagery
d) Be aware of the satellites and techniques used to derive ocean surface wind speeds.

## Module 2.4: Radar Interpretation

Demonstrate an understanding of the principles of radar interpretation and a basic use of the Unified Radar Processor (URP) software.

**Terminal Objective 2.4.1**

Interpret radar data available in Canadian forecast offices in an operational setting and demonstrate an understanding of the principles of radar interpretation.

Enabling objectives

1. Explain the method of relating reflectivities to rain/snowfall rates (Z-R and Z-S relationships)
2. Explain the process which produces a bright band in radar reflectivities.
3. Given a standard display of radar reflectivities such as a CAPPI or PPI distinguish the following from precipitation signals
    - anomalous propagation
    - ground clutter
    - clear air echoes
4. Describe the interpretation problems caused by the following specific effects
    - fraction of a filled beam
    - precipitation gradient and beam volume
    - target distance from radar
    - second trip echoes
5. Describe the representation of true wind velocity by its radial component
6. Infer the vertical wind profile using Doppler radial velocity data
7. Identify or infer synoptic scale meteorological features or processes with radar such as but not limited to
    - warm and cold fronts
    - thermal advections
    - freezing levels
    - freezing precipitation
8. Identify or infer mesoscale meteorological features or processes with radar such as but not limited to
    - mesocyclones
    - convergence and divergence
    - gust fronts
    - microbursts
    - sea and land breeze fronts
    - low level jets
    - precipitation banding

**Terminal Objective 2.4.2 URP**

Effectively utilize the functionality of URP in the forecast process, such as the URP viewer, animations, and other tools.

## Module 2.5: Tephigram and Hodograph Analysis

Analyze tephigrams and hodographs for basic parameters, for the vertical distribution of moisture and for stability.

**Terminal Objective 2.5.1**

Be familiar with the operational implications of the properties of the radiosonde instruments used to measure temperature and humidity.

Enabling Objectives:

a) State the time constant of the thermistor at the surface and at 15 km;
b) Give two causes of error in temperature measurements and explain where these errors occur;

c) State the precision of the hygristor in terms of temperature;
d) Give the time constant of the hygristor for various temperatures;
e) State the relationship between temperature, dew point temperature and frost point temperature for cases where the air is saturated with respect to the ice in a cloud.

**Terminal Objective 2.5.2**

Describe the fundamental lines which appear on a tephigram and calculate basic thermodynamic quantities.

Enabling Objectives:

a) Identify the following lines on a tephigram:
    - Isobars
    - dry adiabats
    - saturated adiabats
    - isotherms
    - mixing ratio
b) Read from the tephigram the heights of the ICAO standard atmosphere pressure levels;
c) Define the following parameters and determine them from a tephigram:
    - potential temperature
    - potential wet bulb temperature
    - frost point temperature
    - mixing ratio
    - saturation mixing ratio
    - virtual temperature
    - wet bulb temperature
    - dew point temperature
    - relative humidity
d) Define the term “conservative property”. Describe the conditions in which the following properties are conserved:

- relative humidity
- vapour pressure
- mixing ratio
- temperature
- potential temperature
- potential wet bulb temperature

- dew point temperature

e) Calculate the layer mean value of the following parameters from a tephigram:

- mixing ratio
- temperature
- dew point temperature
- wet bulb temperature
- potential wet bulb temperature
- potential temperature

**Terminal Objective 2.5.3**

Use an atmospheric sounding to determine layers of latent and potential instability and to locate the freezing level, the tropopause, and inversions.

Enabling Objectives:

a) Define the following terms:
   - inversion
   - tropopause
   - absolute stability
   - absolute instability
   - convective temperature
   - static instability
   - pseudo-latent instability
   - conditional instability
   - lifting condensation level
   - convective condensation level
   - level of free convection
   - equilibrium level
   - latent instability
   - potential instability

b) From a plotted tephigram, determine the following:
   - lifting condensation level
   - convective condensation level
   - level of free convection
   - equilibrium level
   - convective temperature

c) From a plotted tephigram, determine layers of latent and potential instability;

d) From a plotted tephigram, locate the tropopause.

e) Differentiate between the following types of inversions (or stable layers):
   - frontal
   - radiation
   - continental arctic air
   - subsidence
   - local surface effects
   - tropopause

f) Locate on a plotted tephigram, the freezing level and any above or near freezing layers;

g) Relate stability of the air mass to air quality consideration

**Terminal Objective 2.5.4**

Use a hodograph to determine thermal advection and changes in stability.

Enabling Objectives:

a) Use a hodograph to determine the thermal wind and vertical wind shear between two levels;

b) Use a hodograph to determine the top of the boundary layer;

c) Define veering and backing and state the type of thermal advection which is associated with veering and backing;

d) From a hodograph, calculate the direction and magnitude of thermal advection;

e) Apply the stability tendency equation to the hodograph and tephigram to identify layers where stability is increasing or decreasing with time;

f) Relate hodograph and temperature profiles in the boundary layer to air pollution considerations.

**Terminal Objective 2.5.5**

Use an individual tephigram sounding to analyze the vertical atmospheric profile for cloud.

Enabling Objectives:

a) State the guidelines correlating cloud amount to dew point spread;
b) Determine cloud type (convective/stratiform) based on stability and moisture of a sounding;
c) State the guidelines for determining stratiform cloud bases and tops;
d) State the guidelines for determining convective cloud bases, average tops and maximum tops.

## Module 2.6: Airmass and Frontal Analysis

Given current meteorological analyses and satellite imagery, construct spatially and temporally consistent analyses of airmasses, fronts and jet streams.

**Terminal Objective 2.6.1**

Explain what airmasses are and be able to identify them given charts, tephigrams, and hodographs.

**Terminal Objective 2.6.2**

Analyze synoptic scale fronts.

Enabling Objectives:

a) Identify fronts at the surface and on upper air charts, using horizontal thermal gradients and the horizontal wind field;
b) Interpret the vorticity field (shear and curvature) in terms of fronts;
c) Understand and apply synoptic guidelines involving pressure tendency, cloud types, weather, etc. to determine surface frontal locations;
d) Identify upper level fronts, and indicate their position on surface charts;
e) Identify and analyze non-classical frontal structures;
f) Locate fronts using tephigrams and hodographs;
g) Locate fronts using satellite imagery.

**Terminal Objective 2.6.3**

Analyze jet axes and jet maximums.

Enabling Objectives:

a) Locate jet axes using satellite imagery and data plotted on upper air charts; and
b) Determine from temperature data whether the strongest winds are above or below the level at which the analysis is done.

## Module 2.7: Nephanalysis

On a surface map, using all available data, analyze clouds, weather and obstructions to visibility.

**Terminal Objective 2.7.1**

Given a surface map, and using all other available data, analyze areas of similar cloud masses (cloud types, bases, tops, vertical extent).

Enabling Objectives:

a) Analyze surface data for areas of similar cloud masses, given specified values of cloud type, bases, tops or vertical extent;
b) Interpret satellite imagery for cloud types, tops and thickness, adjust analysis accordingly;
c) Interpret tephigram analyses for cloud types, bases, tops and vertical extent, and adjust analysis accordingly;

d) Access other sources of data (PIREPs, radar, etc.) and adjust analysis accordingly;
e) In data sparse areas, use knowledge of atmospheric structures and processes, and apply modeling techniques to modify and complete the analysis.

**Terminal Objective 2.7.2**

Given a map with plotted surface data, and using all other available data, analyze areas of continuous, intermittent and convective precipitation.

Enabling Objectives:

a) Analyze surface data for type, character and intensity of precipitation;
b) Interpret satellite imagery for cloud types and vertical extent, and adjust analysis accordingly;
c) Interpret tephigram analyses for cloud types and vertical extent, and adjust analysis accordingly;
d) Access other sources of data (PIREPs, radar, etc.) and adjust analysis accordingly;
e) In data sparse areas, use knowledge of atmospheric structures and processes, and apply modeling techniques to modify and complete the analysis.

**Terminal Objective 2.7.3**

Given a map with plotted surface data, and using all other available data, analyze areas of restricted visibility.

Enabling Objectives:

a) Analyze surface data for areas of restricted visibility;
b) Interpret satellite imagery for areas of restricted visibility, and adjust analysis accordingly;
c) Interpret tephigram analyses for the presence or absence of low level moisture or inversions, and adjust analysis accordingly;
d) Access other sources of data (PIREPs, radar, etc.) and adjust analysis accordingly;
e) In data sparse areas, use knowledge of atmospheric structures and processes, and apply modeling techniques to modify and complete the analysis.

**Terminal Objective 2.7.4**

Given a surface map, and using all other available data, construct a horizontal weather depiction (HWD) analysis including clouds, weather and visibility restrictions.

Enabling Objectives:

a) Determine representative bases and tops for major cloud subdivisions;
b) Determine areas of similar precipitation type and determine representative visibility ranges;
c) When appropriate incorporate local effects in the description of the weather pattern;
d) Model cloud and precipitation areas to appropriate synoptic features.

# TOPIC 3: DIAGNOSIS

This topic describes the factors and processes that contribute to the development of weather. This emphasis is on the intern being able to produce clear and concise explanations of the reasoning used and the physical process considered, while incorporating all analyzed data.

## Module 3.1: Diagnosis 1 - Cloud, Precipitation and Visibility

Explain the current and recent cloud, precipitation, and restrictions to visibility for a given location or area in terms of relevant physical processes.

**Terminal Objective 3.1.1**

Discuss the factors and processes contributing to observed synoptic scale cloud and precipitation.

Enabling Objectives:

a) Explain the large scale physical processes significant to synoptic scale clouds and precipitation (including its phase);
b) Explain typical fields which correlate well with synoptic scale cloud and precipitation (including its phase);
c) Given any meteorological situation, explain the amount and extent of synoptic scale cloud and its precipitation pattern in terms of forcing for large scale vertical motion;
d) Given any meteorological situation, explain the phase of the observed synoptic scale precipitation;
e) Transcribe organized areas of synoptic scale cloud and precipitation to chart format (horizontal weather depiction) according to specified standards.

**Terminal Objective 3.1.2**

Discuss (describe and explain) the factors and processes contributing to the observed boundary layer clouds, precipitation and obstructions to visibility.

Enabling Objectives:

a) Explain the physical and microphysical processes significant for boundary layer cloud and precipitation (including its phase);
b) Explain the physical and microphysical processes significant for restrictions to visibility (haze, fog, blowing snow, pollution, etc.);
c) Where relevant, relate boundary layer clouds, precipitation, and restrictions to visibility to the synoptic pattern and/or air quality;
d) Given any meteorological situation, explain the current boundary layer cloud, precipitation (including phase), and restrictions to visibility using all available data.
e) Transcribe organized areas of boundary layer cloud and precipitation to chart format (horizontal weather depiction) according to specified standards.

**Terminal Objective 3.1.3**

Discuss (describe and explain) the processes contributing to observed convective clouds and weather. Assess the type and intensity of the associated convective precipitation.

Enabling Objectives:

a) Given a sounding, determine convective parameters that are significant;
b) Interpret the following stability indices:
   - Showalter - SSI

- Lifted - Sweat
- Total Totals - Helicity
- George's K - CMC SVR WX Package

c) Given observed conditions, describe and identify the mechanisms which are affecting the convective instability;
d) Describe some typical synoptic situations associated with summer or winter convective weather (significant summer convection, snowsqualls, etc.);
e) Given any meteorological situation, explain the amount and intensity of convective clouds and precipitation (summer or winter);

## Module 3.2: Diagnosis 2 – Temperature, Wind, Icing and Turbulence

Explain the current and recent weather elements (temperature, surface wind, icing, turbulence) for a given location or area in terms of the relevant physical processes.

**Terminal Objective 3.2.1**

Discuss (describe and explain) the physical processes influencing the current **surface temperature** and state the importance of these processes for specific situations.

Enabling Objectives:

a) Relate the current surface temperature fields to synoptic scale features;
b) Discuss and explain the factors and physical processes which influence surface temperature;
c) Discuss and explain current temperatures, local trends, and areal temperature field characteristics in terms of other meteorological parameters, boundary layer processes, and climatological effects.

**Terminal Objective 3.2.2**

Discuss (describe and explain) the physical processes influencing the current **surface wind** and state the importance of these processes for specific situations.

Enabling Objectives:

a) Explain the relationships between geostrophic wind, gradient wind, and the observed wind;
b) Explain the influence of low level stability on the observed wind;
c) Explain the influence of friction on the observed wind;
d) Explain the influence of the isallobaric field on the observed wind;
e) Describe the impact of land and sea breezes on the observed wind;
f) Describe the impact of mountain and valley winds on the observed wind.

**Terminal Objective 3.2.3**

Discuss (describe and explain) the physical processes influencing the current **icing** type and intensity (for aviation purposes) and state the importance of these processes for specific situations.

Enabling Objectives:

a) Identify and describe the types and intensities of icing with reference to the impact on aviation;

b) Explain the physical factors (meteorological and aerodynamic) which influence the type and intensity of icing;
c) Describe typical icing correlations between cloud structures, synoptic features, airmasses and seasons;
d) Infer local icing conditions given any meteorological situation using data, analyses, and satellite imagery.

**Terminal Objective 3.2.4**

Discuss (describe and explain) the physical processes influencing the current atmospheric **turbulence** (for aviation purposes) and state the importance of these processes for specific situations.

Enabling Objectives:

a) Identify and describe the types and intensities of turbulence with reference to the impact on aviation;
b) Explain the physical factors (meteorological and aerodynamic) which influence the type and intensity of turbulence;
c) Describe typical synoptic situations where each type of turbulence may occur,
d) Infer local turbulence conditions given any meteorological situation using data, analyses, and satellite imagery.

# TOPIC 4: WEATHER PROGNOSIS

This topic deals with various techniques and procedures used to forecast surface features and weather elements on time scales out to 48 hours. Prognosis techniques in the short range rely heavily on diagnosis methods learned in the previous topic. As the forecast moves to longer time scales, an understanding of numerical prediction models is necessary in order to assess properly the objective guidance. At all time scales, the forecaster must keep user requirements in mind in order to increase the utility of forecast products.

## Module 4.1: Short-Range Forecasting of Weather Systems (0-12 hours)

Determine the short term evolution of weather systems (such as lows, highs and fronts), consistent with current and historical data, over a period of up to 12 hours. Data will be assessed and interpreted as appropriate, to ensure a logical and consistent evolution.

**Terminal Objective 4.1.1**

By accessing historical data, apply simple extrapolative techniques to predict the short term movement of identifiable weather features, both at the surface and aloft.

Enabling Objectives:

a) For any meteorological feature (surface/upper low or high, surface/upper ridge or trough, front), identify all relevant maps necessary as history for the required extrapolation;
b) Complete a thorough analysis of other data sources such as satellite and radar to ensure a proper diagnosis of the current location;
c) Reconstruct the past motion of the relevant feature, re-analyzing as necessary to ensure a consistent motion;
d) Calculate the velocity of any feature, and recognize any trends (acceleration, deceleration or development);
e) Estimate the forecast location of the feature for any time up to 12 hours;
f) Describe the limitations of extrapolative techniques.

**Terminal Objective 4.1.2**

Using current surface and upper air data (wind, pressure, pressure tendencies, geopotential heights, height tendencies, etc.), estimate the instantaneous velocity of any feature, and identify any short term trends (accelerating or decelerating, deepening or filling, intensifying or weakening).

Enabling Objectives:

a) Use the upper wind data to estimate the velocity of fronts and pressure centres;
b) Examine the pressure tendency field to predict any short term changes in the movement of fronts, the direction of motion of pressure centres and the development of new centres. Also predict the future pressure change at any point, and the future central pressure of any surface high or low;
c) Determine the instantaneous change in intensity of any surface or upper low, by determining the Laplacian of the pressure or height fields;
d) Examine 500 hPa advection and height tendency fields to predict any short term changes in the 500 hPa flow pattern, and its subsequent effect on the surface circulation;
e) Describe the limitations of these techniques.

**Terminal Objective 4.1.3**

Construct a final short range prognostic chart of surface features ensuring consistency with current and historical data.

Enabling Objectives:

a) Assimilate the diagnostic and historical data from the previous two objectives into a coherent picture of the short term evolution of atmospheric features;
b) Assess numerical short term forecasts, including those from previous model runs which are valid for the current time period;
c) Resolve any significant differences between objective and empirical guidance;
d) Estimate the forecast position of surface lows and highs (with central pressures), surface troughs and ridges, fronts;
e) Describe the local orientation and strength of the pressure gradient;
f) Ensure vertical and horizontal consistency of the surface prognosis;
g) Ensure consistency with current and historical data and analyses;
h) Incorporate local climatological effects;
i) Construct in chart form a short range forecast of relevant meteorological features;
j) Explain the reasoning used in preparing the prognosis emphasizing the techniques used and their validity for the situation.

## Module 4.2 Short Range Forecasting of Clouds, Precipitation and Restrictions to Visibility (0-12 hours)

Determine the short term evolution of the clouds, precipitation and restrictions to visibility for a given location or area using diagnostic techniques and other methods valid in the short time range.

**Terminal Objective 4.2.1**

Using all available data, apply short range techniques to predict the short term evolution of synoptic scale clouds and precipitation.

Enabling Objectives:

a) Apply simple extrapolative techniques (using data such as chart history, radar, satellite) to determine the short term changes in synoptic scale cloud and precipitation;
b) Use synoptic correlation techniques and consider identified trends in the synoptic forcing mechanisms to determine the evolution of synoptic scale cloud and precipitation;
c) Select and use a representative sounding to forecast the character and extent of synoptic scale cloud and its inferred precipitation for a location;
d) Apply synoptic correlation, knowledge of physical processes and any relevant objective techniques to determine short term changes in the phases of synoptic scale precipitation;
e) Apply synoptic correlation, history and short range techniques to quantitative forecasting of synoptic scale precipitation amounts;
f) Forecast organized areas of synoptic scale clouds and precipitation and transcribe to chart format according to specified standards.

**Terminal Objective 4.2.2**

Using all available data, apply short range techniques to predict the short term evolution of boundary layer clouds, precipitation and restrictions to visibility.

Enabling Objectives:

a) Based on identified trends in the significant physical processes, describe the expected evolution of boundary layer clouds and precipitation;
b) Based on identified trends of the significant physical processes, describe the expected evolution of restrictions to visibility;
c) Select and use a representative sounding to forecast the character and extent of boundary layer cloud and its inferred precipitation for a location;
d) Where relevant, apply synoptic correlation techniques and identified trends in the synoptic

forcing features to explain changes in boundary layer clouds and precipitation;
e) Where relevant, apply synoptic correlation techniques and identified trends in the synoptic forcing features to explain changes in restrictions to visibility;
f) Apply relevant short range techniques to determine short term changes in the phase of boundary layer precipitation, and to boundary layer precipitation amounts;
g) Incorporate the effects of diurnal changes on boundary layer cloud and weather;
h) Describe and apply nomograms and other objective techniques to forecast changes in boundary layer clouds, precipitation and restrictions to visibility;
i) Forecast organized regions of boundary layer clouds and precipitation and transcribe these onto charts according to standards.

**Terminal Objective 4.2.3**

Determine the most significant processes and factors influencing convective clouds and weather and describe expected short term changes in convective weather.

Enabling Objectives:

a) Identify the most significant processes and synoptic features affecting or likely to affect convective clouds and weather. Forecast trends in the convection based on changes in these forcing mechanisms;
b) Select and use a representative sounding to forecast the character and extent of convective clouds and weather for a location. Modify the sounding for relevant physical processes;
c) Using appropriate short range techniques, determine short range trends in significant convective parameters;
d) Incorporate the effects of diurnal and seasonal changes on convective clouds and weather;
e) Apply relevant short range techniques to the quantitative forecasting of convective precipitation amounts;
f) Describe and apply nomograms or other objective techniques to forecast changes in convective clouds and convective weather,
g) Forecast organized areas of convective clouds and weather and transcribe to chart format according to specified standards.

## Module 4.3: Short Range Forecasting of Weather Elements (0-12 hours)

Use diagnostic and short range techniques to forecast elements such as temperature, wind, icing and turbulence over the next twelve hours.

**Terminal Objective 4.3.1**

Determine the most significant physical processes and factors influencing the short term evolution of the surface temperature for any situation, and forecast quantitative temperature extremes and trends.

Enabling Objectives:

a) Correlate the current surface temperatures to synoptic features and forecast temperature extremes and trends based on the identified motions of these features;
b) Identify the most significant physical processes in the boundary layer affecting the surface temperature and forecast temperature extremes and trends based on the future evolution of these physical processes;
c) Explain diurnal and seasonal variations in the factors and physical processes which influence the surface temperature extremes and trends;
d) Describe and apply nomograms or objective techniques to the quantitative forecasting of temperature.

**Terminal Objective 4.3.2**

Determine the most significant physical processes and factors influencing the short term evolution of the surface wind for any situation, and forecast the velocity and trends of wind.

Enabling Objectives:

a) Identify trends in the pressure gradient and geostrophic winds;
b) Identify trends in stability, friction, and the isallobaric field, and indicate their potential impact on the short term evolution of the surface wind;
c) Identify significant local effects (including channelling, funnelling, orographic effects, etc.), influencing the surface wind;
d) Incorporate the effects of diurnal variations in land/sea breezes and mountain/valley winds into the forecast wind;
e) Use the isallobaric field to forecast short term changes in the pressure gradient, and assess the impact of these changes on the surface wind;
f) Assimilate all of this information into a scientifically sound forecast of the surface wind over the next twelve hours.

**Terminal Objective 4.3.3**

Determine the most significant physical processes and factors influencing the short term evolution of aircraft icing type and intensity for any situation, and forecast the intensity, type and trend of icing.

Enabling Objectives:

a) Identify significant meteorological parameters which must be forecast in order to arrive at a forecast of icing for aviation interests;
b) Select and use a representative tephigram to forecast atmospheric icing for a given location;
c) Identify significant local effects influencing icing and forecast the magnitude and trend of icing based on changes in these local effects;
d) Incorporate the effects of diurnal and seasonal changes in the processes and factors influencing icing into the icing forecast;
e) Identify circumstances under which icing may develop or change character at some future time;
f) Identify the factors influencing the height of the freezing level, and forecast the short term trend in the height of the freezing level;
g) Assess, and incorporate if appropriate, the icing forecast produced in the Aviation Package available from Canadian NWP models.

**Terminal Objective 4.3.4**

Determine the most significant physical processes and factors influencing short term evolution of the type and intensity of atmospheric turbulence (for aviation purposes) for a particular situation and forecast the intensity, type and trend in turbulence.

Enabling Objectives:

a) Identify significant meteorological parameters which must be forecast in order to arrive at a forecast of turbulence;
b) Select and use a representative tephigram or hodograph to forecast atmospheric turbulence for a given location;
c) Identify significant local effects influencing turbulence and forecast the magnitude and trend of turbulence based on changes in these local effects;
d) Incorporate the effect of diurnal and seasonal changes in the processes and factors influencing turbulence into the forecast;
e) Identify circumstances under which turbulence may develop or change character at some future time;

f) Assess, and incorporate if appropriate, the turbulence forecast produced in the Aviation Package available from Canadian NWP models.

## Module 4.4: Intermediate Range Forecasting (12-24 hours)

For forecasts in the 12 to 24 hour range, the forecaster must begin to incorporate numerical guidance into the forecast process. Forecasts in this time range represent a “blending” of short range techniques with the guidance provided by NWP products.

**Terminal Objective 4.4.1**

Use diagnostic techniques to asses the 12 to 24 hour validity of NWP model forecasts.

Enabling Objectives:

a) Use trends from data sources such as surface observations, satellite and radar to assess the current performance of numerical forecast products;
b) Assess NWP guidance in quantitative forecasting of synoptic scale precipitation amounts;
c) Use diagnostic techniques such as the energetics checklist to assess potential for development;
d) Apply empirical techniques such as George's technique of maritime deepening, Henry's rule for the motion of cold lows, and empirical rules associated with cold injection;
e) Adjust the numerical forecast output to agree with your diagnostic assessment.

**Terminal Objective 4.4.2**

Use diagnostic techniques to assess the 12 to 24 hour validity of statistical model output guidance.

Enabling Objectives

a) Diagnose recent trends in weather parameters which are forecast with statistical guidance;
b) Assess NWP and statistical guidance in quantitative forecasting of temperature;
c) Assess NWP and statistical guidance in quantitative forecasting of wind;
d) Use this diagnosis along with knowledge of how numerical and statistical guidance parameters are derived in order to adjust the forecast subjectively.

**Terminal Objective 4.4.3**

Use diagnostic techniques to forecast boundary layer and mesoscale weather phenomena using large scale model fields as guidance.

Enabling Objectives

a) Use large scale forecasts of stability and other fields to identify areas with potential for convective weather;
b) Assess NWP guidance such as the Summer Severe Weather package and HIMAP to forecast convective precipitation amounts and changes to convective clouds and weather,
c) Deduce boundary layer weather such as fog and stratus using numerical forecasts of relevant large scale fields;
d) Assess NWP guidance to forecast changes in boundary layer clouds, precipitation and restrictions to visibility;
e) Incorporate other relevant local effects, and adjust model forecasts for local forecast areas.

## Module 4.5: Medium-Range Forecasting (24-48 hours)

Forecasts beyond 24 hours need to be largely consistent with numerical guidance. This module describes the role that the operational forecaster can play in forecasts for this time frame.

**Terminal Objective 4.5.1**

Assess all available relevant NWP and objective guidance.

Enabling Objectives:

a) Identify all relevant NWP charts or GRIB output (model, level, valid time) and fields (including units) and determine the value of any field at any specified point;
b) Compare forecasts from a variety of NWP models and consult the various products available from ensemble forecasts to impart a level of confidence in the day two forecast, and thereby add utility to the forecast product;
c) Use knowledge of model characteristics such as resolution and convective parameterization to make decisions when models provide conflicting guidance for the second day;
d) Provide a measure of consistency in the forecast when models vary significantly from one run to the next, so that the forecast product maintains the confidence of the user.

**Terminal Objective 4.5.2**

Assess all available numerical model guidance and infer the extent and type of the cloud and precipitation patterns including the intensity, amount and phase of the associated precipitation.

Enabling Objectives:

a) Estimate the location of fronts using model output guidance;
b) Forecast synoptic scale cloud coverage using numerical guidance;
c) Assess the validity of model precipitation forecasts using knowledge of resolution and physical parameterization schemes;
d) Use diagnostic techniques to forecast boundary layer clouds and weather from the larger scale forecasts of the models;
e) Use diagnostic techniques to forecast convective clouds and weather from the larger scale forecasts of the models;
f) Use diagnostic techniques to forecast precipitation phase, given model guidance.

**Terminal Objective 4.5.3**

Determine the forecast for the surface temperature and wind using all available guidance and data.

Enabling Objectives:

a) Use knowledge of numerical models and statistical forecast methods to assess the validity of temperature and wind forecasts for the second day;
b) Assess forecast pressure gradients and atmospheric stability to provide an estimate of the forecast wind;
c) Recognize situations where it is useful to adjust the temperature and wind guidance for day two;
d) Incorporate significant local effects into the final forecast for temperature and wind.

## Module 4.6: Special Weather-Related Elements

There are many weather-related elements which are often important parameters, and which may need to be included in weather forecasts. It is important for the operational forecaster to understand how these elements are derived, and their utility for the forecast user.

**Terminal Objective 4.6.1**

Understand the derivation of a variety of weather-related factors and indices. Know how and when to use these factors to add to the usefulness of the weather forecast.

Enabling Objectives

a) Understand how wind chill is calculated and recognize situations when it should be mentioned in the forecast
b) Understand how Humidex is calculated and recognize situations when it should be mentioned in the forecast
c) Understand the meteorology used in calculating the UV (ultraviolet) index, and recognize the importance of this seasonal product.

**Terminal Objective 4.6.2**

Understand how volcanic ash impacts on aviation safety, how its trajectory is forecast, and how the forecast of volcanic ash is delivered to the aviation client.

# TOPIC 5: FORECAST PRODUCTION

This topic describes the production of forecasts in a semi automated environment with emphasis on the impact of environmental factors on client groups and the role of the forecaster in the production. This includes procedures to monitor and control automated production and to direct and prioritize the human focus on significant and hazardous weather and decisions to intervene.

## Module 5.1: Public Forecasts

Oversee the semi automated production of forecasts for a variety of public products.

**Terminal Objective 5.1.1**

Maintain the forecast weather element data base which can be used to create a variety of products that are relevant to a variety of public user groups including commercial products. Emphasis will be on procedures to maintain a public forecast data base.

Enabling Objectives:

a) Discuss the purpose of a forecast weather element data base;
b) Describe a variety of high impact weather events and derived indices and the impact on client groups. These events will be priority in maintaining the weather element data base;
c) Describe the purpose of standard operating procedures and its relevance in maintaining the public forecast data base;
d) Describe the format of a variety of routine and specialized public forecast products and the significance of the environmental elements for the client groups;
e) Maintain the forecast weather element data base so that needs of client groups are met, emphasis is on most critical elements, and standard operating procedures are followed;
f) Become familiar with derived public forecast indices such as, wind chill, humidex and UVB index;
g) Interpret and describe the meteorological scenarios of the public forecast data base for a variety of users such as supervisor, peers, and clients.

**Terminal Objective 5.1.2**

In response to a significant change in forecast scenario, amend the public forecast data base as necessary.

Enabling Objectives:

a) State the amendment requirements for the forecast weather element data base;
b) Describe the procedures to intervene in the semi automated production to amend public forecast product.

**Terminal Objective 5.1.3**

In response to impending hazardous weather create messages and products to warn the public of the expected event.

Enabling Objectives:

a) Describe the purpose of the Weather Watch, Weather Warning, and Special Weather Statement including differences;
b) List the elements and criteria which would require a Weather Watch or Weather Warning and what impact these elements have on the user;
c) Work with a team to provide warning and forecast information during hazardous events;
d) Describe the conditions under which a Special Weather Statement would be issued;

e) Describe the purpose of the status statement in the public forecast and its relationship to the Weather Warning.
f) Describe the procedures for creating Weather Watch, Weather Warning and a Special Weather Statements;
g) Describe procedures for managing the public forecast data base in response to Weather Watch, Weather Warning and a Special Weather Statements to ensure data base and warning messages are consistent;

## Module 5.2: Marine Forecasts

Given the required meteorological elements, encode marine forecasts consistent with MSC's national marine forecast standards.

**Terminal Objective 5.2.1**

Given the required meteorological elements, encode a marine area forecast.

Enabling objectives:

a) Discuss the purpose of a marine forecast, stating its user's needs and meteorological knowledge;
b) Describe the format of a marine forecast, including the heading with the issue and valid times, area of coverage and proper ordering of the required elements;
c) State the rules for describing weather elements in a marine forecast;
d) From the information supplied, extract the necessary data to compose a marine area forecast
e) Divide the area of responsibility of the marine forecast, combining regions of relatively similar weather.
f) Encode a marine area forecast using Marine SCRIBE

**Terminal Objective 5.2.2**

Given all relevant meteorological data and forecasts, write marine weather statements and synopses

Enabling Objectives:

a) State the purpose and contents of marine weather statements and technical synopses;
b) Describe the format of a marine weather statement, including the heading with issue times and accepted terminology;
c) Describe the format of a technical marine synopsis including the heading with issue times, acceptable terminology and abbreviations.

**Terminal Objective 5.2.3**

Given a sequence of observations amend marine forecasts as necessary.

Enabling Objectives:

a) List the amendment criteria for marine forecasts;
b) Describe the format of an amended marine forecast.

**Terminal Objective 5.2.4**

Given the present and forecast weather elements, assess the need for a marine warning.

Enabling Objectives:

a) Describe the criteria for marine warnings;
b) Describe the relationship between marine warnings and marine forecasts;

c) Given the necessary meteorological data, write a marine warning according to national standards.

## Module 5.3: Aviation Aerodrome Forecasts

Given the required meteorological elements, encode aviation terminal forecasts consistent with MANAIR specifications.

**Terminal Objective 5.3.1**

Given the required meteorological elements, write a TAF consistent with MANAIR specifications.

Enabling Objectives:

a) Discuss the purpose of a TAF, stating its users' needs and meteorological knowledge;
b) Define VFR, MVFR, IFR, airport alternate limits, NSW, SKC, VV, PROB, TEMPO, FM and BECMG
c) Describe the format of a TAF, including the header with issue and valid times, area of coverage, and elements;
d) State the allowed values for each element;
e) From information supplied, extract the elements necessary for a TAF (winds, visibility, weather, clouds);
f) Divide the valid time of the TAF into part periods, using FM or BECMG as appropriate, separating periods of significantly different weather.

**Terminal Objective 5.3.2**

Given a sequence of weather observations along with airport operational limits, amend terminal forecasts as necessary.

Enabling Objectives

a) List the MANAIR TAF amendment criteria;
b) Describe TAF amendment formats.

## Module 5.4: Aviation Area Forecasts

Given the required meteorological elements, encode aviation area forecasts and warnings (GFA, AIRMET and SIGMET) consistent with MANAIR specifications.

**Terminal Objective 5.4.1**

Given the required meteorological elements, discuss how each element would impact our VFR, Charter and Regional aviation clients.

Enabling Objectives:

a) Discuss the purpose of a GFA;
b) Discuss the difference between a VFR, Regional and Charter pilots;
c) Describe what meteorological information the VFR, Regional and Charter pilots would require from the GFA;
d) Discuss the impacts of certain meteorological elements our on different clients. Be sure to consider low cloud and visibility, icing in cloud, freezing precipitation, turbulence, and thunderstorms.

**Terminal Objective 5.4.2**

Given the required meteorological elements, create and merge GFAs consistent with MANAIR specifications.

Enabling Objectives:

b) Describe the format of a GFA including the heading, the issue and valid times of the Clouds and Weather Charts, and of the Icing, Turbulence and Freezing Level Charts, the areas of responsibility, and sections of each chart (Title Box; Legend Box; Comments Box; CLDS and WX; ICG, TURB and FZLVL);
c) Describe the different areas of responsibilities for GFA;
d) List the elements included in each section and their allowed values, formats, and appearance;

e) From the information supplied extract the necessary data to compose each section using MANAIR, GFA SOP, and MANAB abbreviations;
f) Organize and combine significantly similar weather to create reasonable depictions of the evolution of the weather within the area of responsibility;
g) Create depictions in a tool such as Edigraf using MANAIR, GFA SOP, and MANAB rules for appearance and abbreviations;
g) Co-ordinate with other forecasters to produce consistent depictions;
h) Merge GFAs following MANAIR specifications.

**Terminal Objective 5.4.3**

Given a sequence of weather observations, amend the GFA using AIRMETs as necessary.

Enabling Objectives:

a) State the purpose of an AIRMET, its relationship to the GFA, and its impact on the user;
b) Describe the format of an AIRMET, including issue and valid times;
c) Describe the different areas of responsibilities for AIRMET;
d) List the MANAIR criteria for the issue of an AIRMET;
e) List the elements of an AIRMET and their recommended order;
f) Co-ordinate with other forecasters to produce consistent products.

**Terminal Objective 5.4.4**

Given a sequence of weather observations, write a SIGMET, as necessary, consistent with MANAIR specifications.

Enabling Objectives:

a) State the purpose of a SIGMET, its relationship to the GFA and AIRMETs, and its impact on the user;
b) Describe the format of a SIGMET including its issue and valid times, how it is updated or cancelled, and its area of coverage;
c) Describe the different areas of responsibilities for SIGMET;
d) List the MANAIR criteria for the issue of a SIGMET;
e) List the elements of a SIGMET and their recommended order;
f) Co-ordinate with other forecasters to produce consistent products.

## Module 5.5: Special Users and Commercial Forecasts

Given the required meteorological elements, encode forecasts for special users and commercial interests.

**Terminal Objective 5.5.1**

Given the required meteorological elements, create a bulletin type forecast for other meteorologists or special users. For example, create a synopsis, a fire weather forecast, FX, a climate bulletin, etc.

**Terminal Objective 5.5.2**

a) Given the required meteorological elements, provide specialized forecast consultation for 1-900 callers.
b) Given the required meteorological elements, prepare a site-specific forecast for a specified commercial client.

# TOPIC 6: ATMOSPHERIC PATTERNS AND PROCESSES

This topic provides an overview of the physical and dynamical processes that form the cornerstone of our understanding of atmospheric behaviour.

## Module 6.1: Atmospheric Circulations

Discuss and explain the planetary and synoptic scale circulation controls operating in the atmosphere, showing how these processes determine the preferred location of cyclones and anticyclones.

**Terminal Objective 6.1.1**

Discuss the controls to atmospheric flow and weather patterns that exist on large space or time scales.

Enabling Objectives:

a) Compare and contrast the long-wave pattern for a summer mean flow and a winter mean flow discussing the role of thermal and orographic features in the maintenance of the typical long-wave pattern;
b) Describe the characteristics of blocking patterns, in terms of shape, scale, duration. geographical and seasonal frequency;
c) Explain how the location of the long-waves influence the location and movement of cyclones and anticyclones;
d) Discuss the dynamical factors that influence the formation of cyclones and anticyclones including the characteristics of two types of dynamical secondary circulations having a limited vertical extent;
e) Describe the thermally induced circulations, e.g., cold high, warm low, instability trough;
f) Indicate areas in North America favoured for cyclogenesis and anticyclogenesis for both summer and winter and discuss the dominant physical processes in each case;
g) Describe the general storm tracks over North America.

**Terminal Objective 6.1.2**

Describe the energy cycle of mid-latitude baroclinic disturbances, listing sources and sinks of the relevant types of energy and the conversion processes involved.

Enabling Objectives:

a) Describe the “energetics” approach;
b) Define APE (available potential energy), ZAPE (zonal available potential energy), EAPE (eddy available potential energy), ZKE (zonal kinetic energy) and EKE (eddy kinetic energy);
c) Describe the mean energy cycle for the northern Hemisphere;
d) Using meteorological charts, describe how to assess the amount of APE (in both ZAPE and EAPE forms), the processes affecting the amount of APE and the processes changing ZAPE into EAPE;
e) Using meteorological charts, describe the processes converting EAPE into EKE, and list the factors influencing the conversion rate;
f) Using meteorological charts, describe the processes converting EKE into ZKE and frictional losses, and list the factors influencing the conversion rates;
g) Describe the potential for development of a baroclinic wave, in terms of individual processes in the energy cycle;
h) Describe how satellite imagery may be used to assess the energetics of a system.

**Terminal Objective 6.1.3**

Describe the effect of the large scale flow on the three dimensional airflow in a mature baroclinic wave, including the relationship between surface and upper air flow patterns.

Enabling Objectives:

a) Indicate the relationship of a mature baroclinic wave to the following upper air fields:
   - 500 hPa contour ridge/trough
   - areas of significant upper level divergence/convergence
   - areas of significant low level divergence/convergence
b) Sketch diagrams showing the 3-dimensional trajectories of airflow through a mature baroclinic wave, including the warm and cold conveyor belts and the dry airstream;
c) Relate the characteristics of the airflows to various upper and surface features, and their influence on the large scale cloud and precipitation patterns associated with a baroclinic wave.

## Module 6.2: Structure and Evolution of Baroclinic Waves and Fronts

Discuss the life cycle and structure of baroclinic waves and associated fronts, explain them in terms of quasi-geostrophic theory and, using satellite imagery and meteorological charts, identify the patterns associated with each stage.

**Terminal Objective 6.2.1**

Given meteorological analyses and/or satellite imagery, identify and describe the evolution of any synoptic scale disturbances present.

Enabling Objectives:

a) Describe the evolution of a typical baroclinic wave from an incipient wave on a baroclinic zone, during intensification, through to final occlusion. Relate the development of the wave to changes in its associated fields and processes;
b) Sketch diagrams of a typical baroclinic wave at any stage of its development, including:
   - 1000-500 hPa thickness
   - vorticity patterns
   - surface fronts
   - surface isobars
   - relate to upper level features
c) Sketch diagrams of a typical comma cloud at any stage of its development, and relate it to various surface and upper level features and cloud patterns;
d) Define “self-development” and “self-limiting”;
e) Describe how a secondary circulation is set up over a surface low and high and 500 hPa ridge and trough;
f) Recognize cyclogenesis patterns on satellite imagery, and be able to identify the stage of development of the cyclone from the imagery.

**Terminal Objective 6.2.2**

Use quasi-geostrophic theory to explain the three dimensional structure and development of baroclinic waves.

Enabling Objectives:

a) State and explain the implications of the assumptions of the quasi-geostrophic approximation;

b) Identify and qualitatively explain the terms in the quasi-geostrophic vorticity, thermodynamic energy, omega and geopotential tendency equations;
c) Describe the effect of wavelength on the motion of upper level waves in terms of planetary

and relative vorticity;
d) Explain the effect of vorticity and thickness advection on the movement and amplification of upper waves, referring also to the influence of wavelength;
e) Explain the effect of vorticity and thickness advection on the vertical velocity fields, including the influence of airmass stability;
f) State and explain in physical terms the wavelength restrictions on baroclinic development derived from the two-level quasi-geostrophic mode (short wave cut-off and long wave damping);
g) Define isentropic potential vorticity and explain why it is a useful quantity in the study of atmospheric flow patterns;
h) Explain the invertibility principle of potential vorticity;
i) Explain the role of an isentropic potential vorticity anomaly in cyclogenesis.

**Terminal Objective 6.2.3**

Using standard meteorological analyses and prognoses identify areas of ascent and subsidence in the atmosphere and explain these areas in terms of the relevant physical processes.

Enabling Objectives:

a) Describe methods of estimating vertical velocity, including their limitations;
b) Describe situations in which the quasi-geostrophic omega equation is liable to be inaccurate;
c) List and describe the terms in the full omega equation which are important to consider when estimating vertical velocity in both the boundary layer and free atmosphere;
d) Explain the relationship between divergence and vertical velocity;
e) Given upper level and surface charts for idealized synoptic situations, describe the vertical velocity profile;
f) Use the Q-vector approach to estimate vertical motion;
g) Describe Zwack's diagnostic divergence method for calculating the vertical velocity profiles;
h) Construct qualitative vertical velocity profiles given standard upper and surface charts;
i) Identify physical processes that can contribute to vertical motion but which are not accounted for by the quasi-geostrophic omega equation.

**Terminal Objective 6.2.4**

Describe the idealized structure of a front and its relationship to jet streams, the tropopause and models of cyclone development.

Enabling Objectives:

a) Illustrate and explain the relationship between the temperature and wind fields based upon the geostrophic thermal wind equation;
b) Define a front dynamically in terms of temperature, wind, stability and vorticity;
c) Discuss the applicability of an idealized frontal model to actual fronts, indicating where and when the model is most successful and how observed fronts depart from the ideal;
d) Discuss the formation and evolution of a surface front including the processes of frontogenesis and frontolysis;
e) Discuss the contribution of the following processes to surface frontogenesis and frontolysis:
    - deformation
    - divergence
    - surface friction
    - diabatic processes
f) Explain the formation and structure of upper tropospheric fronts;
g) Define and describe the jet-stream and define the jet axis and core;
h) Based on the thermal wind relationship, explain the position and intensity of the jet with relation to the front and the tropopause;
i) Given a schematic cross-section with front(s) and tropopause, indicate the approximate jet-stream position(s);

j) Describe and explain the secondary circulations about jet maxima;
k) Explain the propagation of jet maxima in relation to the secondary circulations;
l) Explain the life cycle of a mid-latitude cyclone and its relationship to the polar front as described by the Bergen School;
m) Describe some of the modifications that have been proposed to the Bergen model, including split fronts, trowals and cold fronts aloft;
n) Explain the life cycle and potential applications of the marine cyclone model.

## Module 6.3: Mesoscale Processes I

Discuss processes occurring in the mesoscale that affect the weather elements for a local area.

**Terminal Objective 6.3.1**

List and describe the physical processes operating in the planetary boundary layer (PBL).

Enabling Objectives:

a) Define and describe the planetary boundary layer (PBL), including its primary layers and the effect of stability on the depth of these layers;
b) List and describe common heat sources and sinks within the PBL; describe as well as the associated physical processes affecting the thermal regime in the PBL;
c) List and describe common moisture sources and sinks within the PBL: describe as well as the associated physical processes affecting the moisture regime in the PBL;
d) List and describe the physical processes operating in the PBL which lead to vertical motion;
e) List and describe the sources of meteorological information relevant to thermal and moisture regimes as well as vertical motion in the PBL;
f) Explain factors that lead to the formation of low-level jets and their variation; Describe the operational relavance of low-level jets;
g) Explain the effect of stability on the surface wind field;
h) Relate PBL state to air quality and pollution dispersion.

**Terminal Objective 6.3.2**

Describe and explain mesoscale atmospheric phenomena associated with orography or the distribution of thermal sources and sinks. Explain how these phenomena may interact with larger scale features.

Enabling Objectives:

a) Describe and explain the land/sea breeze circulation and the associated weather;
b) Describe and explain mountain/valley winds and their associated weather;
c) Describe the effect of land/sea breezes and mountain/valley winds on pollutant concentration and dispersion;
d) Describe and explain the influence an urban area has on weather patterns;
e) Describe the effects of variations in surface heating on the local circulation and their effect on pollution dispersion;
f) Explain the factors that lead to the formation of polar lows and the variation in intensity, Describe the associated weather.

**Terminal Objective 6.3.3**

Describe and explain, using simple models, gravity waves in the atmosphere. Illustrate situations where gravity waves may be important to the forecast problem.

Enabling Objectives:

a) Using simple mathematical models, explain the existence of gravity waves;
b) Discuss the main forcing mechanisms for gravity waves;

c) Discuss the interaction of gravity waves with larger and smaller scales;
d) Describe and explain lee waves noting their importance in the free atmosphere;
e) Describe the physical processes influencing downslope windstorms;
f) Discuss the forcing mechanisms behind severe downslope windstorms such as Chinooks windstorms, Les Suêtes, and Wreckhouse winds.

**Terminal Objective 6.3.4**

Explain the structure, dynamics and life-cycle of tropical storms, including their post-tropical and extra-tropical phases.

Enabling Objectives:

a) Describe the favourable conditions for tropical cyclogenesis;
b) Describe the climatology of tropical cyclones, their genesis regions and preferred tracks;
c) Describe the life cycle of a tropical storm;
d) Describe the structure of a tropical storm, including its energy sources;
e) Discuss forecast techniques used in forecasting the motion, intensity and weather associated with systems of tropical origin;
f) Describe the formation of subtropical cyclones;
g) Describe the post tropical phase of tropical systems, including changes in structure and motion;
h) Discuss the transition of tropical systems to extra-tropical cyclones, including their contribution to extra-tropical redevelopment.

## Module 6.4: Mesoscale Processes II

## Terminal Objective 6.4.1

Using atmospheric soundings determine buoyancy estimates, wind shear parameters, and storm motion.

Enabling Objectives:

a) Describe and assess the stability of atmospheric soundings:
    - Local parcel stability
    - Latent instability
    - Potential instability
    - Differential advection causing changes in stability.
b) Describe and interpret the vertical wind shear properties of atmospheric soundings using the hodograph:
    - Vertical wind shear
    - Storm motion and storm relative winds
    - Hodograph curvature
c) Explain how convection is dependent on factors such as insolation, moisture, winds, stability and local geography;
d) State and distinguish between the mechanisms by which latent instability and potential instability are realized.
e) Explain latent and potential instability are important to convection.

**Terminal Objective 6.4.2**

Explain and assess the physical processes controlling storm evolution and structure.

Enabling Objectives:

a) Describe the buoyancy processes related to:

- Updrafts including
  - Bubble convection
  - CAPE
  - Estimate of updraft strength
  - CIN
  - Entrainment
- Downdrafts including
  - Evaporative cooling
  - Precipitation loading
  - Downdraft CAPE
  - Estimate of downdraft strength

b) Describe how cold pool and low level shear interactions control storm evolution and structure;
c) Describe how buoyancy and deep shear interactions control storm evolution and structure including:
   -Tilting
   -Hodograph curvature and storm evolution

**Terminal Objective 6.4.3**

Describe conceptual models used to explain various convective weather phenomena and how the basic physical processes are functioning within these models.

Enabling Objectives:

a) Describe the life cycle of a single cell thunderstorm, its characteristics, associated weather, and typical pre-storm environment;
b) Describe the life cycle of a multicell thunderstorm, its characteristics, associated weather, and typical pre-storm environment; differentiate it from a non-severe thunderstorm;
c) Briefly describe a squall line, a mesoscale convective system (MCS), and a mesoscale convective complex (MCC);

**Terminal Objective 6.4.4**

Explain the severe weather phenomena resulting from convective storms which cause hazardous weather.

Enabling Objectives:

a) Describe the characteristics of heavy rain events;
b) Describe briefly the characteristics of the following convective weather phenomena: tornado, cold air funnel, land spout, waterspout, and dust devil;
c) Describe the characteristics of hail producing thunderstorms;
d) Describe the characteristics of straight line wind events such as dry and wet microburst;
e) Describe the characteristics and climatology of lightning

**Terminal Objective 6.4.5**

Describe how the forecaster assesses the convective potential and threat of hazardous weather and determine both in any given situation.

Enabling Objectives:

a) Describe how an operational convective assessment is performed, what factors are important to look for, and why they are important:
   - Instability
   - Moisture
   - Vertical motion (trigger)
   - Wind shear
b) Describe how to locate a convective threat area;

**Terminal Objective 6.4.6**

Describe the organization of some other mesoscale convective and mesoscale non-convective precipitation systems.

Enabling Objectives:

a) Describe elevated convection patterns i.e. associated with upper troughs; dry lines, etc.;
b) Describe symmetric instability and Conditional Symmetric Instability, CSI;
c) Describe nocturnal thunderstorm processes.

# TOPIC 7: NUMERICAL GUIDANCE

With the advent of more sophisticated computer models and the development of automated forecast systems, it has become increasingly important for the operational forecaster to understand the intricacies of numerical models and their post-processing. This knowledge is essential so that the forecaster can recognize those situations where numerical guidance is likely to be in error, and to know when human intervention can be most beneficial.

## Module 7.1: NWP Models: Fundamentals, Structure and Dynamics

Discuss the characteristics, structure and dynamics of numerical weather prediction (NWP) models, particularly those used in Canadian weather offices, with reference to the basic concepts and numerical techniques used in these models.

**Terminal Objective 7.1.1**

Describe the overall strategy of numerical weather prediction, including the general structure of NWP models.

Enabling Objectives:

a) Describe the components of an NWP model and how the model fits into the forecast process;
b) Name the principal equations which are relevant to motions in the atmosphere;
c) Describe the impact of the hydrostatic approximation on numerical models;
d) Define the various vertical coordinates and discuss the advantages and disadvantages of each for NWP models;
e) Compare the methods for calculating spatial derivatives (e.g. spectral vs. grid point);
f) Describe grid point truncation and spectral truncation;
g) Describe the impact of horizontal resolution on computer resources and the resolution of meteorological features;
h) Describe the strategies used in vertical integration in NWP models;
i) Describe some of the strategies used in defining model domain and boundary conditions.

**Terminal Objective 7.1.2**

Describe how models produce precipitation and clouds, and explain the influence of physical parameterizations on NWP forecasts.

Enabling Objectives:

a) Define precipitation and cloud parameterization (PCP) and convective parameterization (CP);
b) Describe the relationship of large scale forcings of wind, temperature and moisture with model parameterizations;
c) Describe the impacts of inferred, simple and complex clouds on precipitation forecasts;
d) Describe how convection is formed in a model;
e) Describe the operational impacts of cloud schemes;
f) Explain what convective parameterization schemes are primarily designed to do;
g) Describe the characteristics of convective parameterization schemes;
h) Be familiar with the descriptions of of some of the operational convective parameterization schemes, most notably Kuo, Kain-Fritsch and explicit schemes;
i) Explain the effects of an overactive or underactive convective parameterization scheme;
j) Describe the impacts of convective parameterization and how to react to them operationally;
k) Understand the role of the parameterization of the following physical processes, as well as the interactions of these parameterization schemes:
    - atmospheric radiation (solar and infrared)
    - surface processes

- turbulence and vertical diffusion.

**Terminal Objective 7.1.3**

Identify the various forms of NWP model output available operationally in Canada and identify the major technical specifications for operational and research oriented Canadian models.

Enabling Objectives:

a) For each Canadian model, state the specifications of the model under the following headings and discuss, in general terms, how a particular formulation affects the results obtained from the model:
   - effective horizontal resolution;
   - type of vertical representation used and the number of levels;
   - horizontal and vertical domain of integration including the boundary conditions;
   - data cut-off time;
b) Discuss the characteristic features of Canadian models that can influence the quality of their forecasts;
c) Identify the various fields plotted on operational NWP chart output;
d) Describe the characteristics of, and identify appropriate uses for direct numerical point forecasts such as FOCN, FDCN.

**Terminal Objective 7.1.4**

Discuss the methods and possible benefits of ensemble techniques in numerical forecasting.

Enabling Objectives:

a) Discuss the purpose and value of ensemble prediction systems;
b) Describe the various methods of how ensemble prediction systems are made;
c) Interpret various ensemble products.

## Module 7.2: Data Assimilation

Describe the techniques and processes of data assimilation used by the operational models, with reference to how these procedures impact on the model output.

**Terminal Objective 7.2.1**

Explain the characteristics of data assimilation.

Enabling Objectives:

a) Explain why raw unmodified data may not be used in the model initialization process;
b) Describe some of the problems involved with the availability and use of data by NWP models;
c) Define data assimilation, and explain its role in NWP;
d) Explain the role of a trial field in the analysis of the actual field and in the initialization of operational models;
e) Describe, in simple terms, the statistical techniques used in data assimilation;
f) List the various data sources that are used, and briefly describe the quality control methods used on these data;
g) Define observation increments and analysis increments;
h) Discuss the impact of dynamical imbalances such as gravity waves on data assimilation, and proper ways to control them;
i) Identify situations in which the assimilation system is more likely than usual to fail.

**Terminal Objective 7.2.2**

Describe the data assimilation and forecast cycle in operation at CMC.

Enabling Objectives:

a) Describe the structural design constraints on the CMC production system;
b) Describe how CMC's operational runs are interdependent;
c) Describe the CMC data assimilation cycle;
d) Recognize rejected data on CMC upper air charts;
e) Recognize the benefits of ensemble filter methods for data assimilation.

## Module 7.3: Model Derived Products

Describe the operational characteristics of post processing techniques and statistical forecast guidance, and describe in general terms the statistical techniques used in developing this guidance.

**Terminal Objective 7.3.1**

Describe statistical procedures employed by the Canadian Meteorological Centre, including the operational characteristics of the guidance.

Enabling Objectives:

a) Define post processing and explain why it is needed;
b) Explain what is done during post processing and how post processing interacts with the model;
c) Compare post processing with direct model output;
d) Explain why derived parameters are needed and how derived fields are created;
e) Describe and compare the following techniques of statistical prediction, and know the strengths and weaknesses of each:
    - Perfect Prog
    - MOS
    - UMOS
f) Briefly explain the multiple linear regression (MLR) method used in developing the statistical models;
g) Describe the implementation methods of statistical guidance;
h) Be aware of some of the issues and trends involved in the use of statistical guidance (e.g. MOS vs. UMOS).

**Terminal Objective 7.3.2**

Describe the various statistical forecast products issued by CMC, including the statistical procedures employed and the operational characteristics of the guidance.

Enabling Objectives:

a) Describe the statistical techniques used and discuss the major sources of error in the following operational products:
    - Probability of precipitation (PoP)
    - Cloud opacity
    - Spot temperatures
    - Maximum/minimum temperatures (FM)
    - Surface winds;
b) Discuss the characteristics and quality of the 3-4-5 day forecasts;
c) Describe each element that is forecast in the FXCN05 and FXCN09 forecasts issued by CMC, including the statistical procedures employed.

**Terminal Objective 7.3.3**

Describe the methods used in SCRIBE to obtain the weather elements forecasts.

Enabling Objectives:

a) Describe the philosophy behind Scribe;
b) Describe how the weather element matrices are prepared by Scribe;
c) Briefly describe how the space and time combination system works;
d) Describe the function of the concepts generator;
e) Describe the function of the interface;
f) Describe the quality control module and the text generator.

## Module 7.4: Forecast Verification Techniques

Understand and interpret various forecast verification statistics.

**Terminal Objective 7.4.1**

Describe the requirements for a good verification system.

Enabling Objectives:

a) Explain the major reasons MSC is involved in forecast verification;

**Terminal Objective 7.4.2**

Describe statistics used for the verification of weather element forecasts.

Enabling Objectives:

a) Identify and interpret a weather element contingency table:
    - Number of events successfully forecast
    - Number of false alarms
    - Number of missed forecasts
    - Number of non-events successfully forecast
    - Total number of forecast events
    - Total number of observed events
    - Total number of successful forecasts
    - Total number of observations
    - Total number of forecasts
b) Identify and interpret various verification indices:
    - Frequency
    - Skill Score
    - False Alarm Ratio
    - Probability of Detection
    - Bias
    - Critical Success Index
    - Heidke Skill Score

# TOPIC 8: WEATHER OFFICE SIMULATORS

The purpose of the weather office simulators is to develop operational skills in a situation closely resembling that of an actual weather office. This gives the intern the opportunity to synthesize and apply the knowledge learned during internship, and to develop speed and confidence in producing operational products.

Interns perform a subset of the duties associated with a major weather office, with an instructor available to provide guidance and support. The simulation can normally be carried out on day shifts, Monday to Friday.

Initially, emphasis is on analysis and diagnosis skills, and on the encoding of forecasts. The area of responsibility is small, and the time allotted for each product is generous. As time goes on, the duties are steadily increased and the time shortened. Near the end of simulator, most of the duties of a typical weather office are simulated and deadlines are becoming operationally realistic. When simulator is complete, interns will be capable of handling about 80% of a typical operational workload and will be ready, after a period of regional orientation, to move into rotating shifts in a double-banked situation in a weather office.

The following Terminal Objectives outline the major categories considered in the simulator. Each of these aspects is critical in an operational environment.

## Module 8.1: Simulator I

**Terminal Objective 8.11**

Produce the required analyses, prognoses, forecasts and briefings to specified standards of scientific validity and consistency.

**Terminal Objective 8.1.2**

Produce required analyses, prognoses, forecasts and briefings to specified standards of presentability.

**Terminal Objective 8.1.3**

Produce required analyses, prognoses, forecasts and briefings within specified deadlines demonstrating an effective forecaster work routine.

Enabling Objectives

a) Be able to produce a complete surface analysis for an area approximately equal to the Prairie Provinces, southern Quebec, or Atlantic Provinces within 60 minutes;
b) Be able to produce required prognosis charts to support forecast preparation as listed below;

Examples:
GFA panels for an area of responsibility, either hand drawn or with Edigraf

c) Be able to produce a limited number of forecast products.

Examples:
4 hand written TAFS, not to standard over either the Maritime Provinces, western Quebec, or 1 Prairie Province
Weather elements forecasts for 4 Public Regions for Nova Scotia and PEI, western Quebec, or 1 prairie province

d) To start developing weather watch strategies for the above forecast volume.;

**Terminal Objective 8.1.4**

Work effectively in the team.

**Terminal Objective 8.1.5**

Communicate effectively with peers and clients.

Enabling Objectives

a) Give effective shift change briefings;
b) Respond to client consultation.

## Module 8.2: Simulator II

**Terminal Objective 8.2.1**

Produce the required analyses, diagnoses, prognoses, forecast database, and briefings to specified standards of scientific validity and consistency.

Enabling Objectives

a) Recognize patterns and trends and make infererences about meteorological processes important to the forecast problems;
b) Investigate meteorological processes and explain analysis, diagnosis and prognosis;
c) Use a scientific systematic approach to typical forecast problems;
d) Make forecast decisions based on sound meteorological principles;
e) Justify decisions by relating to relevant meteorological principles;
f) Maintain consistency in products, across borders, and from one shift to another;
g) Maintain and scientifically respond to a weather watch; Make and justify forecast decisions in response to changing or unexpected situations.

**Terminal Objective 8.2.2**

Produce required analyses, diagnoses, prognoses, forecast database, and briefings to specified standards of presentability. Produce on an average weather day the required analyses, prognoses, forecasts and briefings in the proper format.

Enabling Objectives

a) Present a professional manner in ones work, approach to work, and in communications such as briefings;
b) Consult relevant Standard Operating Procedures and incorporate standards into work.

**Terminal Objective 8.2.3**

Produce required analyses, diagnosis, prognoses, forecast database and briefings within specified deadlines demonstrating an effective forecaster work routine.

Enabling Objectives

a) Demonstrate a priority setting approach to work by focusing effort on high impact weather;
b) Take decisions at any stage of work based on information available at the time;
c) Adjust decisions quickly when faced with new or changing situation;
d) Demonstrate an organized routine for analysis/diagnosis prognosis, and decision making by taking a systematic approach to solving forecast problems;
e) Adjust routine based on forecast problem or situation;
f) Be able to produce a Horizontal Weather Depiction or complete surface analysis for an area approximately equal to the Prairie Provinces, southern Quebec, or Atlantic Provinces within

45 minutes;

c) Be able to produce required prognosis charts to support forecast preparation as listed below;

Examples:

GFA panels for an area of responsibility

g) Be able to produce forecast volume approaching that of a typical weather centre (approximately 80%). Forecasts would typically have deadlines within 4 hours of beginning of shift;

Examples:

10 TAFS over the Maritime Provinces, western Quebec, or 1 prairie province

Public forecasts for Nova Scotia and PEI, western Quebec, or 1 prairie province

h) Be able to maintain weather watch and amendments for the above forecast volume;

i) Be able to perform a rapid spin up at the beginning of the shift (within 30 minutes) enabling effective client consultation, maintenance of amendment and warning production.

**Terminal Objective 8.2.4**

Work effectively in the team.

Enabling Objectives

a) Get along with team members and treat them with respect;
b) Discuss forecast issues and share ideas with team members;
c) Cooperate with others to achieve consistency in products, across borders, and from one shift to another;
d) Collaborate with others to make decisions.

**Terminal Objective 8.2.5**

Communicate effectively with peers and clients.

Enabling Objectives

e) Give effective shift change briefings;
c) Respond effectively to client consultation.

**Terminal Objective 8.2.6**

Learn effective strategies for coping with shift work.

Enabling Objectives:

a) Learn about circadian rhythms and the “biological clock”;
b) Learn about the health effects of shift work and strategies to deal with minimizing any adverse effects, such as avoiding fatigue and obtaining proper nutrition.

# TOPIC 9: FORMAL COMMUNICATION

An operational forecaster must communicate well to perform effectively. While on shift, the meteorologist must interact with the other members of the team and other forecast offices to produce consistent products, and at shift change briefing, must be able to pass information and guidance to the following shift. Within the Weather Services Offices, the meteorologist will communicate with clients, and therefore should develop effective product dissemination and delivery skills.

This topic applies the principles of good verbal and written communication to all forms of communication in the classroom and workplace, and to some specific forms of communication used routinely in an operational environment.

During the course, the effective communication skills outlined will be practised in the classroom during ad hoc discussions, current weather discussions, and shift briefings. Written communication will be evaluated using exercises, assignments, exams, and internal communications.

## Module 9.1: Weather Services

Communicate effectively orally and in writing during the provision of weather services to clients.

**Terminal Objective 9.1.1**

Present ideas orally and in writing in a clear concise manner, that are logically developed and presented in a manner easily understood by the audience.

Enabling Objectives:

a) Clarity, conciseness, logic, accuracy, usage, expression

**Terminal Objective 9.1.2**

Prepare effective written forecast products and deliver effective oral presentations, in both scheduled and ad hoc situations, to a range of **clients** such as

- General Public
- Media
- Aviation
- Marine

Enabling Objectives:

a) Determine the client's specific requirement;
b) Use appropriate terminology and vocabulary;
c) Emphasize the appropriate meteorological parameters;
d) Demonstrate knowledge of user requirements for the above listed clients;
e) Include appropriate informational content such as historical perspective, warnings in effect;
f) Supply the information in accordance with established formats and guidelines.

**Terminal Objective 9.1.3**

Given a complaint against MSC services, products, personnel or policies, record the details of the complaint, attempt to defuse the situation, and/or refer the matter to an appropriate authority.

Enabling Objectives:

a) Be familiar with the role and responsibility of the operational forecaster in receiving and

responding to complaints;
b) Recognize situations when it is appropriate to defer the complaint to a supervisor or designated Environment Canada spokesperson;
c) Be aware of current weather issues or topics which might be an issue with the media or clients.

## Module 9.2: Internal Communication / Co-ordination

Communicate effectively orally and in writing while co-ordinating within the forecast team.

**Terminal Objective 9.2.1**

Coordinate effectively with peers to produce oral and written forecasts that are consistent between the varied forecast products within the area of responsibility and consistent with products in bordering regions.

Enabling Objectives:

a) Initiate and actively participate in decision making;
b) Work out acceptable solutions to divergent view points in group decisions;
c) Deliver and/or prepare consistent products.

**Terminal Objective 9.2.2**

Effectively communicate with classmates, instructors, and guests by giving, listening to and participating in current weather discussions and shift change briefings.

Enabling Objectives:

a) Describe the general format and content of the following shift change briefings: Aviation , Public, and Marine;
b) Explain the roles of the forecasters involved in giving and receiving change briefings;
c) Deliver effective current weather discussions and shift change briefings;
d) Communicate effectively while answering ad hoc questions during current weather discussions and shift change briefings.

**Terminal Objective 9.2.3**

Enabling Objectives:

Given all sources of weather information, maintain a comprehensive weather watch.
a) Notice changes in weather parameters from a variety of sources;
b) Communicate significant changes to the forecast team and clients;
c) Incorporate significant changes into products appropriately and in a timely manner.

**Terminal Objective 9.2.4**

Communicate effectively in writing in a variety of situations.

Enabling Objectives:

a) Through email with peers, supervisors and managers.
b) In examinations and assignments.

# TOPIC 10: SKILLS DEVELOPMENT

Operational meteorology is more than simply the sum of the individual module skills. Rather, the scientific problem solving requires a synthesis of these skills: the ability to put together information from several sources into a single coherent package, and translate it into useful forecasts.

Skills development sessions are used to provide a break from continuous self study modules and exam writing. They may be informal sessions of map analysis, or more structured labs on diagnosis or prognosis. During these sessions one or more instructors are available to assist and provide feedback.

## Module 10.1: Analysis and Prognosis Practice

These sessions are reserved for practising the analytical and prognostic skills introduced in Topics 2-4. The skills taught in current class sessions are practised to allow the intern to develop speed and confidence. In addition, skills which were introduced earlier are reviewed to maintain competence.

Nephanalysis and the analysis of basic and derived fields, tephigrams and hodographs are the first skills to be practised. The emphasis near the end of the course shifts to more complex analyses (frontal, jet stream) and to the production of complete motion and weather system prognostic charts.

When practical, the current weather situation is used as the basis for this activity. Occasionally case studies are presented, usually to illustrate a particular point.

## Module 10.2: Forecast Writing Practice

The emphasis during these practice sessions is on developing and maintaining the intern's ability to compose forecasts.

When practical, the current weather situation is used as a basis for this activity. This has two definite advantages – first the instructor does not know what actually will happen (and thus the feedback will be unbiased) and second, the intern has a greater interest in current weather than in a "canned" exercise.

## Module 10.3: Study Periods

There is a requirement for considerable self-study to successfully complete the requirements of the course. When possible, a number of hours during the course have been set aside as study periods. These sessions may be used as the intern sees fit; for assignments, skills practice, consulting instructors, preparation for exams or supplementals. Study during the evenings and weekends will also be required for success. It is the responsibility of each intern to keep up with assigned reading, practice skills, work on identified deficiencies, and review concepts prior to classroom practical exercises and examinations.

# TOPIC 11: METEOROLOGICAL APPLICATIONS AND ATMOSPHERIC SCIENCE ISSUES

The science of meteorology has much broader implications beyond the operational forecasting that is emphasized in internship. This topic provides an introduction to some of the other activities in which the Meteorological Service of Canada is involved.

## Module 11.1: Climate

**Terminal Objective 11.1.1**

Describe the physical processes which drive the earth's climate system

Enabling Objectives:

a) Describe the physical processes responsible for the earth's climate in terms of energy balance, atmospheric moisture, topography, water balance and ocean-biosphere-cryosphere interactions;
b) Describe the following climatological phenomena which occur periodically: teleconnections, El Nino southern oscillation, omega blocks, etc.;
c) Describe the characteristics of various climate regions of Canada;

**Terminal Objective 11.1.2**

Describe how climate data is accessed, displayed, and used in routine forecast production.
a) Discuss methods for accessing and displaying climate date;
b) Discuss applications of climate data in forecast production including such topics as prediction techniques in the short, medium and extended range

**Terminal Objective 11.1.3**

Explain the processes responsible for climate change, and explain the implications of climate change on ecosystems and Canadian society.

Enabling Objectives:

a) Become familiar with the terminology of Climate change including:
    - variability
    - fluctuations
    - climate change
    - global change
b) Describe the difference between climate change and climate variability;
c) Discuss the natural and human processes responsible for climate change including:
    - astronomical, geophysical (volcanoes, El Nino)
    - greenhouse gases (natural and human produced)
    - stratospheric ozone
d) Discuss the scientific evidence for the presence of global change including historical data, experimental and modeling results, and the relative levels of confidence in each;
e) Describe the general aspects of climate prediction such as prediction techniques, verification, value of climate forecasts;
f) Describe general characteristics of climate simulation models;
g) Discuss the implications of global change to Canada and to Canada's ecosystems;;:

## Module 11.2: Atmospheric Issues

**Terminal Objective 11.2.1**

Understand the air pollution transportation cycle and diagnose the meteorological conditions which control the dispersion of pollutants.

Enabling Objectives:

a) Describe the observing instruments and networks that measure the amount of pollution the atmosphere;
b) Describe the air pollution transportation cycle;
c) Describe the dispersion characteristics of gases and particulates;
d) Describe the impact of meteorological parameters on dispersion;
e) Describe in general 3 numerical dispersion models and their advantages and limits;
f) Describe the Meteorological Service of Canada's role in Environmental Emergency Response;
g) Describe the basic air quality observational systems, measurement techniques and data availability.

**Terminal Objective 11.2.2**

Assess and describe the atmospheric chemistry important to pollutant transport and transformations through the atmosphere.

Enabling Objectives:

a) Describe the atmospheric gases that compose the atmosphere and their atomic structure and chemical bonds;
b) Describe the chemical and physical process of the atmospheric gases and their chemical reactions;
c) Describe physical and chemical properties of aerosols;
d) Describe chemical and physical characteristics of pollutants;
e) Describe the reactions of major pollutants.

**Terminal Objective 11.2.3**

Describe the current situation on various atmospheric issues.

Enabling Objectives:

a) Describe the main issues in the following areas with emphasis on the current status, extent of the problem, and policy:
    - Acidic deposition
    - Ozone layer depletion
    - Climate change
    - Smog
    - Mercury deposition

## Module 11.3 Hydrology / Hydrometeorology

Interest only. Not required for this internship.

**Terminal Objective 11.3.1**

Understand the basic characteristics of the hydrologic cycle and the feedback to and from meteorology.

Enabling Objectives

a) Describe the time scales and apportionment of the basic processes of evaporation, atmospheric transport, precipitation and surface transport;
b) Describe the sources and sinks of water in terms of glaciers, ground water, lakes and rivers;
c) Describe the feedback mechanisms of soil moisture surplus and deficits.

**Terminal Objective 11.3.2**

Understand the basic applications of meteorological data to regional hydrology.

Enabling Objectives

a) Describe the concepts of watersheds and catchment basins;
b) Describe the meteorological inputs into streamflow modelling.

**Terminal Objective 11.3.3 (Optional not required)**

Understand the surface water data collection program.

Enabling Objectives

a) Describe the type of water monitoring that is done by Environment Canada.
b) Describe areas where co-operation between meteorologists and water people could leverage their respective expertise.

# TOPIC 12: FEDERAL CIVIL SERVICE

This topic deals with the organizational structure of Environment Canada and also covers those policies and procedures that have an impact on career planning and progression of the employee.

## Module 12.1: Organization and Departmental Perspective Orientation

Demonstrate a basic knowledge of the organization of Environment Canada, its components and important programs.

**Terminal Objective 12.1.1**

Describe the organizational structure of Environment Canada.

**Terminal Objective 12.1.2**

Describe the structure of the Meteorological Service of Canada.

**Terminal Objective 12.1.3**

Describe the business plan of Environment Canada, its component tables, and the role of the Meteorological Service of Canada.

## Module 12.2: Environment Canada Regional Structures

Demonstrate a basic knowledge of the structure and organization of Environment Canada, and its important priorities.

**Terminal Objective 12.2.1**

Describe the organizational and reporting structure of Environment Canada.

**Terminal Objective 12.2.2**

Demonstrate a knowledge of the components of Environment Canada, its branches and programs, and locations of offices throughout the region.

**Terminal Objective 12.2.3**

Demonstrate a knowledge of the important issues currently facing the region, and be able to discuss these issues.

# TOPIC 13: OPERATIONAL DUTIES

This topic marks the beginning of the intern's double banking in an operational weather office. Performance in the following modules is evaluated by operational meteorologists on shift with the intern.

## Module 13.1: Office Role

Knows office mandate.

## Module 13.2: Schedules

Can interpret and use the office shift schedule.
Can complete administrative forms such as Monthly Leave Reporting and Extra Duty Reporting.
Can use the office duty schedules.

## Module 13.3: Standing Orders

Is aware of office procedures, policies and guidelines and knows where to find documentation.
Is aware of MSC policies and guidelines and knows where to find documentation.

## Module 13.4: User Orientation

Knows the major client groups for the office.
Knows the basic client requirements of these major client groups.

## Module 13.5: Services Orientation

Knows where to find reference material such as case studies, climatology, topography, relevant web sites, etc.
Is aware of office dissemination technologies.
Has been introduced to dissemination procedures and is beginning to apply them.

# TOPIC 14: OPERATIONAL SKILLS AND SERVICE DELIVERY

## Module 14.1: Data and Analysis

Knows identifiers and official place name for each site.
Uses a variety of tools to access required data (surface obs., PIREPs, upper air data, satellite, radar, lightning, etc.).
Accesses and uses climatological data.
Organizes data in a timely and accurate fashion.
Interprets the accuracy and relevance of the data.
Incorporates data in a weather watch.

## Module 14.2: Diagnosis

Interprets surface and upper air data, PIREPs, etc.
Interprets tephigrams and hodographs to diagnose stability, cloud, weather, icing turbulence, etc.
Interprets satellite, radar and lightning data to infer synoptic, and mesoscale processes.
Uses sound scientific reasoning in the diagnosis of relevant physical processes causing the current weather.
Incorporates local and larger scale effects of topography.
Integrates all factors including conflicting information to form a reasonable diagnosis of synoptic and mesoscale processes.
Maintains a weather watch and revises diagnosis as necessary to reconcile with new data.

## Module 14.3: Prognosis

Uses short range and medium forecast techniques as appropriate.
Uses NWP output as appropriate and uses a wide variety of NWP output (uses Grib viewer).
Assesses accuracy of NWP fields.
Modifies NWP products and derived fields.
Recognizes and interprets parameters that affect the motion and development of synoptic scale systems.
Employs critical diagnosis techniques in assessing the quality of numerical guidance.
Recognizes and understands the formation and behaviour of meso-scale weather systems such as thunderstorms.
Creates a realistic evolution of weather systems.
Creates a realistic evolution of weather elements.
Coordinates with colleagues to produce consistent products.

## Module 14.4: Forecast Service

Knows the areas & regions covered in the forecast products and can determine appropriate grouping of regions.
Creates forecasts and products based on sound scientific methodologies and reasoning.
Incorporates climatology and local effects into forecast products.
Maintains a close weather watch of all data including surface reports, PIREPs, satellite, radar, lightning, etc.
Ensures that a physical consistency (temporal and spatial) is maintained.
Issues amendments and warnings within the established criteria.
Creates warnings of hazardous weather within the established criteria.
Uses proper format and terminology to create useable products.
Ensures consistency with other forecasts in the offices and with adjacent forecast offices.

Carries out a thorough analysis, diagnosis and prognosis of the weather situation before encoding forecasts.
Complete forecast production actives within specified time constraints.
Knows client requirements and incorporates them into products and consultations for maximum utility.
Communicates in a clear & concise professional manner with clients and colleagues (i.e.: client consultations, weather discussions and shift change briefings).
Responds to and initiates discussions with clients and colleagues.
Participates effectively in professional decision making processes in the forecast team.

## Module 14.5: Interpersonal Skills

### 14.5.1 Judgement

The ability to perceive a situation correctly; to reach reasonable conclusions; to display appropriate behaviour; to exercise discretion in completing tasks and dealing with people; to assess situation before acting.

### 14.5.2 Motivation and Initiative

The ability to use personal resources and energies with determination and to achieve positive results through self-direction, conscientiousness, persistent effort and diligence.

### 14.5.3 Adaptability

The ability to work effectively in a variety of situations; the willingness to accept new methods and procedures, to adapt to the needs and changes in one's environment and to modify behaviour taking into account the opinions of others and the needs of the organization.

### 14.5.4 Effective Interpersonal Relationships

The ability to produce good results through interaction with other individuals including peers, supervisor, and clients; to be pleasant, cooperative, respectful, diplomatic, responsive, and to make a positive contribution to the team.

### 14.5.5 Work Under Pressure

The ability to maintain a smooth workflow, focus, control and effectiveness under stress; under trying circumstances to remain well-mannered and professional with peers, supervisor, and clients.

### 14.5.6 Reliability

The ability to be trustworthy; to be punctual in attending to work; to minimize absences from work; to complete assigned work in a timely manner and to an acceptable standard.

### 14.5.7 Effective Communication

The ability to express oneself to peers, supervisor and clients in a clear, concise manner using appropriate vocabulary and good grammar; to present ideas that are logically developed and in a logical sequence; to demonstrate good listening skills.